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The LHCb trigger in 2011 and 2012

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Contents

1 Introduction

The LHCb trigger has performed very well during the LHC Run I [1], showing a remarkable capacity to adapt to the changing running conditions. One of the key points of this adaptability is the capacity for performing very fast changes in the selection requirements in the software algorithms run in the HLT. While most of the trigger selections were quite stable during Run I, small changes were unavoidable due to changes in the running conditions, *e.g.*, between 2011 and 2012, and the need of adjusting the trigger rates. This fact, combined with the large number of lines included in the HLT, caused frequent changes of trigger configuration during the data taking period. The aim of this document is to provide a detailed record of the various LHCb trigger configurations used for *pp* collisions during Run I, including the luminosity collected with each of them*.

The LHCb trigger is configured via a unique key—the *Trigger Configuration Key* or TCK—which defines the software version, the sequence of algorithms and the selection requirements applied in each trigger line. A TCK is identified by a 32-bit value, the lower 16 bits of which define the L0 configuration, and in this document—and as a general rule in the LHCb software—are represented as an hexadecimal number. A given TCK can only be run with a given version of the Moore software—the application within the LHCb software framework in charge of running the HLT—so any changes in the underlying code imply the creation of a new configuration key. This ensures the *a posteriori* reproducibility of any trigger run during data taking.

In Chapter 2 of this document, the software versions used by each TCK—including the versions of the LHCb stack and the specific trigger packages—as well as the luminosity collected with each of them, are summarized. Additionally, finer detail is given by including the DB tags used in each run.

A general, non-detailed, description of the tracking and reconstruction procedures is given in Chapter 3, putting special emphasis on the variations in the applied requirements throughout the data taking.

* While this document intends to provide detailed references to make it understandable to the widest possible audience, documentation of some of the software packages or algorithms is not available publicly and therefore cannot be cited here.

Chapters 4 and 5 present the TCKs used in 2011 and 2012, respectively. In each chapter—that is, each year—the TCK with more luminosity is chosen as a reference, and for it all trigger lines are described in detail, including the physics context, design, prescales and selection requirements. The rest of the TCKs of each year are then presented as a comparison to the reference. To support these chapters, Appendix A includes a small introduction of the LHCb software frameworks used in the HLT and the definitions and conventions necessary to understand the selections included in it.

Finally, in order to make the use of this document easier, an index of all trigger lines, separated by trigger level, is included at the end. In it, **bold** numbers are used for references to the text, while *italic* numbers are used for referencing tables.

2

TCK and software overview

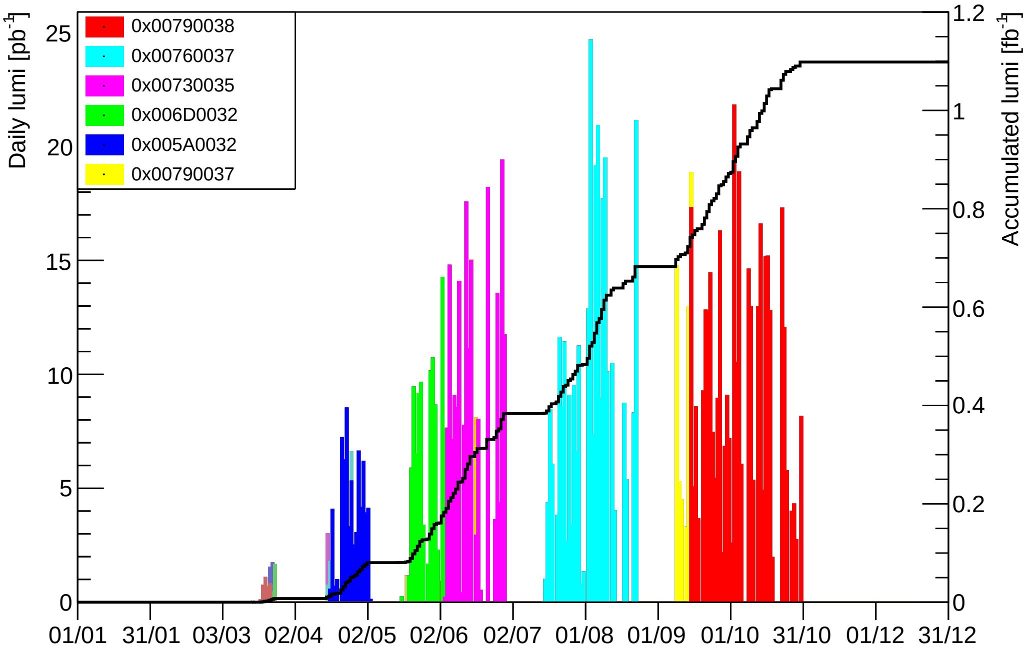
Throughout this document, TCKs are only considered if the integrated luminosity taken with them is above $10\,\mathrm{pb}^{-1}$; this allows to remove the testing or faulty ones without affecting any physics study. In this chapter, the software versions used by each TCK are described, and a run-by-run overview of the database tags used in 2011 and 2012 are given.

2.1 TCK overview

The TCKs used in 2011 and 2012—that is, those with an integrated luminosity above $10\,\mathrm{pb}^{-1}$—are listed with their respective luminosities (total and split by magnet polarity) and Moore versions in Tables 2.1.1 and 2.1.2. The chronological representation of their use thoroughout the year can be found in Figure 2.1.

TABLE 2.1.1. *Summary of TCKs used in 2011 with luminosity above $10\,pb^{-1}$ grouped by Moore version. The subscripts* up *and* down *refer to the two polarities of the LHCb magnet [2].*

	$\mathcal{L}_{\mathrm{up}}$ [pb^{-1}]	$\mathcal{L}_{\mathrm{down}}$ [pb^{-1}]	$\mathcal{L}_{\mathrm{total}}$ [pb^{-1}]	Moore version
`0x005A0032`	35.9	28.4	64.4	v12r5
`0x006D0032`	0.0	61.7	61.7	v12r6p1
`0x00730035`	133.7	61.8	195.5	
`0x00760037`	105.9	191.6	297.6	v12r8
`0x00790037`	42.3	0.0	42.3	v12r9p1
`0x00790038`	144.3	179.9	324.2	



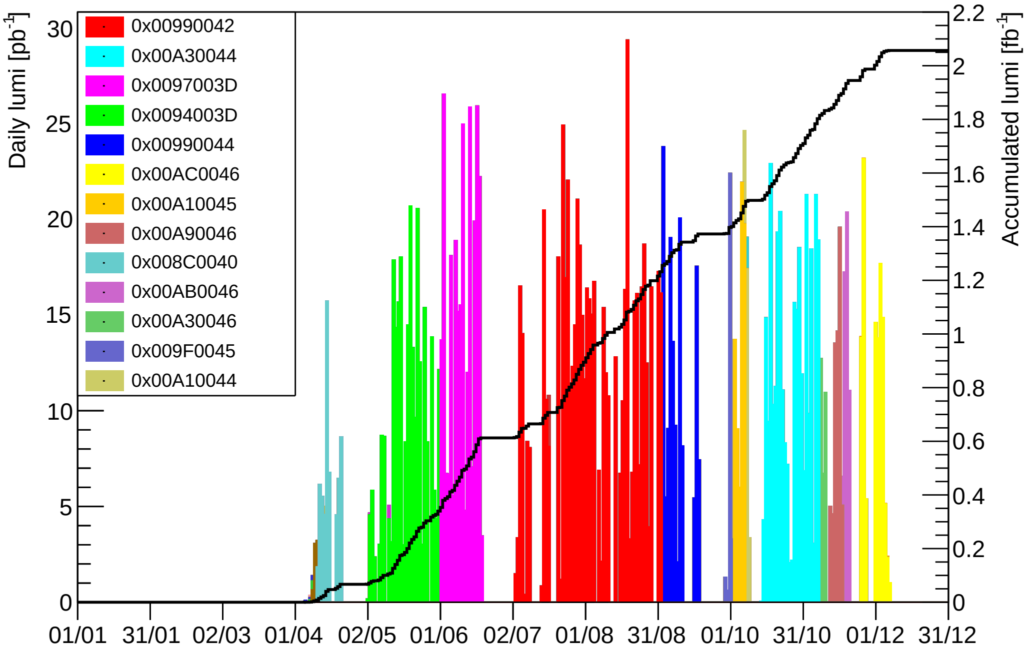


FIGURE 2.1. *Chronological use of the TCKs used in (top) 2011 and (bottom) 2012 with luminosity above 10 pb^{-1}. Each TCK is represented with one color-filled box (see legend) and the black solid line represents the accumulated luminosity.*

TABLE 2.1.2. *Summary of TCKs used in 2012 with luminosity above 10 pb^{-1} grouped by* MOORE *version. The subscripts* up *and* down *refer to the two polarities of the LHCb magnet. Two TCKs,* `0x0094003D` *and* `0x0097003D`*, were used in collision data taking with two different* MOORE *versions each, v14r2 and v14r2dev, but the amount of luminosity taken with the latter version is negligible.*

	$\mathcal{L}_{\text{up}}$ [pb^{-1}]	$\mathcal{L}_{\text{down}}$ [pb^{-1}]	$\mathcal{L}_{\text{total}}$ [pb^{-1}]	MOORE version
0x008C0040	0.0	55.4	55.4	v13r3
0x0094003D	158.1	103.2	261.3	v14r2
0x0097003D	121.0	151.8	272.8	
0x00990042	352.1	203.2	555.3	v14r6
0x00990044	30.4	110.5	140.9	
0x00A10044	25.6	0.0	25.6	v14r8
0x00A10045	70.4	0.0	70.4	
0x009F0045	27.6	0.0	27.6	
0x00A30044	163.5	124.5	288.0	v14r9
0x00A30046	19.4	10.9	30.4	
0x00A90046	0.0	35.2	35.2	v14r11
0x00AC0046	8.5	103.3	111.7	
0x00AB0046	0.0	50.1	50.1	

TABLE 2.2.1. *LHCb software stack for the* MOORE *versions used in 2011 (first section) and 2012 (second section).*

	HLT	REC	PHYS	LHCB	LBCOM	GAUDI
v12r5	v13r4	v11r3	v12r2	v32r2	v10r2	v22r1
v12r6p1	v13r5p1	v11r4	v12r4	v32r3	v10r3	v22r2
v12r8	v13r9	v11r5	v12r5	v32r4	v10r4	v22r2
v12r9p1	v13r10p1	v11r6	v12r6	v32r5	v10r5	v22r2
v13r3	v14r3	v13r2	v14r2	v34r2	v12r2	v23r2
v14r2	v15r1	v13r2	v14r2	v34r2	v12r2	v23r2
v14r6	v15r3	v13r3	v14r3	v34r3	v12r3	v23r2
v14r8	v15r5	v13r3	v14r3	v34r3	v12r3	v23r2
v14r9	v15r5	v13r3	v14r3	v34r3	v12r3	v23r2
v14r11	v15r5	v13r3	v14r3	v34r3	v12r3	v23r2

2.2 LHCb software stack version changes

The version of the projects in the LHCb software stack for all MOORE versions in Tables 2.1.1 and 2.1.2 is shown in Table 2.2.1. In addition, the version tags corresponding to the HLT packages required explicitly by each version of the `HLT` project are detailed in Tables 2.2.2 and 2.2.3.

TABLE 2.2.2. *Version of the packages explicitly required by the* HLT *project for the versions used in the 2011 TCKs, as detailed in Table 2.2.1. Packages not explicitly required by the given version of the* HLT *project are marked with an en-dash.*

	v13r4	v13r5p1	v13r9	v13r10p1
Hlt/Hlt1Lines	v6r9	v6r10p1	v6r12	v6r12
Hlt/Hlt1Muons	v1r3	v1r3	v1r3	v1r3
Hlt/Hlt2Lines	v8r4	v8r5p1	v8r7	v8r8
Hlt/Hlt2SharedParticles	v6r1	v6r2	v6r3p1	v6r3p1
Hlt/HltBase	v12r1	v12r1	v12r1p1	v12r1p1
Hlt/HltBeamGasAlley	v3r0	v3r0	v3r0	v3r0
Hlt/HltCommon	v8r1	v8r1	v8r2	v8r2
Hlt/HltConf	v9r8	v9r9p1	v9r10p1	v9r11
Hlt/HltCosmics	v1r0p2	v1r0p2	v1r0p2	v1r0p2
Hlt/HltDisplVertices	v3r3p1	v3r3p2	v3r4	v3r4
Hlt/HltGlobalMonitor	v3r8	v3r8	v3r8	v3r8
Hlt/HltL0Conf	v3r0	v3r0	v3r0p1	v3r0p1
Hlt/HltLine	v5r1p5	v5r1p5	v5r1p6	v5r1p7
Hlt/HltLuminosity	v2r18	v2r18	v2r18	v2r18
Hlt/HltMonitor	–	v1r0	v1r0p1	v1r0p1
Hlt/HltMuon	v4r0	–	–	–
Hlt/HltRawData	v2r10p3	v2r10p3	v2r11	v2r11
Hlt/HltRecChecker	v1r13	v1r13	v1r13	v1r13
Hlt/HltSelChecker	v12r0	v12r0	v12r1	v12r1
Hlt/HltSettings	v5r11	v5r12	v5r14	v5r15
Hlt/HltTisTosTobbing	v1r1	v1r1	v1r1	v1r1
Hlt/HltTracking	v9r7	v9r8p1	v9r9p1	v9r9p2
Hlt/TCKUtils	v1r8	v1r8p1	v1r9	v1r9p1
L0/L0Calo	–	–	–	–
Phys/BBDecTreeTool	v1r2	v1r2	v1r2	–
Phys/KalmanFilter	–	–	–	–
Phys/LoKiPhys	–	–	–	–
Phys/LoKiTracks	v2r1	v2r1	v2r1p1	–
Phys/LoKiTrigger	v12r1	v12r2	v12r3	v12r4
Phys/LoKiUtils	–	–	–	–
Tf/FastVelo	–	–	–	–
Tf/PatAlgorithms	–	–	–	–

TABLE 2.2.3. *Version of the packages explicitly required by the* HLT *project for the versions used in the 2012 TCKs, as detailed in Table 2.2.1. Packages not explicitly required by the given version of the* HLT *project are marked with an en-dash.*

	v14r3	v15r1	v15r3	v15r5
`Hlt/Hlt1Lines`	v6r20	v6r23	v6r25	v6r28
`Hlt/Hlt1Muons`	v1r5	v1r5	v1r5	v1r5
`Hlt/Hlt2Lines`	v8r18	v8r20	v8r23	v8r27
`Hlt/Hlt2SharedParticles`	v6r7	v6r9	v6r11	v6r12
`Hlt/HltBase`	v12r3	v12r3	v12r3	v12r3
`Hlt/HltBeamGasAlley`	v3r0	v3r0	v3r0	v3r0
`Hlt/HltCommon`	v8r4	v8r5	v8r5	v8r7
`Hlt/HltConf`	v9r15	v9r17	v9r20	v9r21
`Hlt/HltCosmics`	v1r0p2	v1r0p2	v1r0p2	v1r0p2
`Hlt/HltDisplVertices`	v3r9	v3r9	v3r11	v3r11
`Hlt/HltGlobalMonitor`	v3r9	v3r9	v3r9	v3r9
`Hlt/HltL0Conf`	v3r0p1	v3r0p1	v3r0p1	v3r0p1
`Hlt/HltLine`	v5r1p7	v5r1p7	v5r1p7	v5r1p7
`Hlt/HltLuminosity`	v2r19	v2r19	v2r19	v2r19
`Hlt/HltMonitor`	v1r1	v1r1	v1r1	v1r1
`Hlt/HltMuon`	–	–	–	–
`Hlt/HltRawData`	v2r11	v2r11	v2r11	v2r11
`Hlt/HltRecChecker`	v1r13	v1r13	v1r14	v1r14
`Hlt/HltSelChecker`	v12r1p1	v12r1p1	v12r1p1	v12r1p1
`Hlt/HltSettings`	v5r27	v5r31	v5r41	v5r54
`Hlt/HltTisTosTobbing`	v1r1	v1r1	v1r1	v1r1
`Hlt/HltTracking`	v9r16	v9r19	v9r24	v9r25
`Hlt/TCKUtils`	v1r10	v1r10	v1r11	v1r11
`L0/L0Calo`	–	–	–	v11r8
`Phys/BBDecTreeTool`	–	–	–	–
`Phys/KalmanFilter`	–	v1r4	–	–
`Phys/LoKiPhys`	–	v10r9	–	–
`Phys/LoKiTracks`	–	v2r6	–	–
`Phys/LoKiTrigger`	v12r7	v12r8	v12r8	v12r8
`Phys/LoKiUtils`	–	v1r2	–	–
`Tf/FastVelo`	–	v1r8	–	–
`Tf/PatAlgorithms`	–	v4r23	v4r24	v4r24

2.3 DB tags

Conditions and detector database tag information is detailed, at the start of each run, in the corresponding log in the LHCb Online System. This information was afterwards collected and can be found in the LHCb bookkeeping. The used tags in 2011 and 2012, along with their corresponding runs, are detailed in Tables 2.3.1 and 2.3.2, respectively.

TABLE 2.3.1. *Summary of DB tag combinations (and corresponding runs) used in 2011 in TCKs with luminosity above* $10\,pb^{-1}$.

	CONDDB tag	DDDB tag	Run range
`0x005A0032`	`head-20110331`	`head-20110302`	89489 – 89717 89956 – 89964 89975 – 89989 90002 – 90014 90029 – 90037 90045 – 90059 90070 – 90104 90123 90137 – 90139 90154 – 90165 90182 – 90207 90257 – 90273 90315 – 90328 90374 – 90375 90397 – 90574 90614 – 90618 90639 – 90651 90763
`0x006D0032`	`head-20110512`	`head-20110302`	91657 – 91658 91919 – 92315
	`head-20110524`		92525 – 92735 92838 – 92906
`0x00730035`	`head-20110524`	`head-20110302`	92929 – 93557 93559 – 93704 93775 – 94011
	`head-20110622-Reco10`		94170 – 94385
`0x00760037`	`head-20110622`	`head-20110302`	95946 – 100256
`0x00790037`	`head-20110901`	`head-20110722`	101373 – 101761
`0x00790038`	`head-20110901`	`head-20110722`	101762 – 104414

TABLE 2.3.2. *Summary of DB tag combinations used in 2012 in TCKs with luminosity above 10 pb^{-1}.*

	CONDDB tag	DDDB tag	Run range
0x008C0040	cond-20120831	dddb-20120831	111955 – 112298
	head-20120316	head-20120316	112495 – 112795
	head-20120413	head-20120413	113013 – 113146
0x0094003D	cond-20120831	dddb-20120831	117098
	head-20120420	head-20120413	114205 – 117103
0x0097003D	cond-20120831	dddb-20120831	117850
	head-20120420	head-20120413	117192 – 118880
0x00990042	cond-20120628	head-20120413	119956 – 120794
	cond-20120710	head-20120413	121713 – 124231
	cond-20120730	head-20120413	124272 – 126680
	head-20120316	head-20120316	126389 – 126403
	cond-20120829	head-20120413	126824 – 126940
0x00990044	cond-20120829	head-20120413	126972 – 128492
0x009F0045	cond-20120831	dddb-20120831	129534 – 129644
0x00A10045	cond-20120831	dddb-20120831	129693 – 129905
0x00A10044	cond-20120831	dddb-20120831	129922 – 129978
0x00A30044	cond-20120831	dddb-20120831	130316 – 131798
0x00A30046	cond-20120831	dddb-20120831	131883 – 131983
0x00A90046	cond-20120831	dddb-20120831	132104 – 133511
0x00AB0046	cond-20120831	dddb-20120831	132409 – 132633
0x00AC0046	cond-20120831	dddb-20120831	133059 – 133785

3

Reconstruction overview

Since the reconstruction and tracking configuration is not something intrinsically linked to a TCK—but linked to a given version of `Hlt/HltTracking`—the tracking and PV finding sequences and their changes throughout the year will be discussed in this section*. In fact, only 8 different versions of the package were used throughout 2011 and 2012 (Tables 2.2.2 and 2.2.3) and the changes between them are small.

3.1 HLT1 tracking

The tracking sequence configuration for HLT1 tracks is roughly as follows†:

1. VELO tracks are built using the `FastVeloTracking` algorithm with the `HLT1Only` flag [4].
2. Optionally, VELO tracks may be matched to the muon stations with x and y windows of 200 mm to identify them as muon candidates, with a minimum momentum requirement of 6 GeV/c.
3. Optionally, before upgrading to forward tracks, a validation with the TT may be performed by making use of the `FastTTValidationTool`. When discussing HLT1 lines, it will be explicitly specified if the TT validation is used.
4. VELO tracks are upgraded to forward tracks with a direct use of the `PatForwardTool` [5] and its `tracksFromTrack` method, using either the `TightForward` or `LooseForward` configurations. The specific cuts for these configurations are given in Table 3.1.1, but in all cases either (a) the number of

* Only `Hlt/HltTracking` will be discussed, so any changes coming from other parts of the LHCb stack will not be included in this discussion. These can be followed up by checking the corresponding versions for each stack, shown in Table 2.2.1. The aim of this section is not to describe the tracking and PV finding algorithms in detail—this is documented elsewhere—but to give a good idea of the configuration options used for each of the included algorithm.

† More details on the differences between offline and online tracking can be found in Ref. [3].

TABLE 3.1.1. *Requirements on the VELO tracks to be upgraded to forward/long tracks for the `TightForward` and `LooseForward` upgrade configurations for each version (or version range) of the `Hlt/HltTracking` package. The first column corresponds to 2011, while the other three correspond to the versions used in 2012.*

			v9r7→v9r9p2	v9r16	v9r19	v9r24→v9r25
`TightForward`	p	GeV/c	> 10.0	> 10.0	> 10.0	> 3.0
	p_{T}	GeV/c	> 1.25	> 1.6	> 1.25	> 1.25
`LooseForward`	p	GeV/c	> 6.0	> 6.0	> 6.0	> 3.0
	p_{T}	GeV/c	> 0.5	> 0.5	> 0.5	> 0.5

hits of the track needs to be above 12 or (b) for OT-only tracks, the number of OT hits needs to be above 14.

5. Track is fitted using a Kalman filter based fitter (`TrackMasterFitter`).
6. Optionally, a long track may be upgraded to a muon candidate with further identification requirements; this step requires decoding the muon stations.

In addition, a simpler, VELO-only track fit was added in 2012. This tracking method essentially performs a straight line fit using the `ConfiguredForwardStraightLineFitter` fitter, and is used in a few—very specific—lines.

3.2 HLT2 tracking

The tracking sequence in HLT2 is closer to the offline version than the HLT1 one. In 2011, forward tracks were reconstructed, while in 2012 long (L) and downstream (D) tracks were built*. In both cases, the reconstruction steps are as roughly as follows:

1. VELO tracking is performed with `FastVeloTracking` algorithm with the `HLT2Complement` flag. This flag, combined with the configuration with `HLT1Only` used in HLT1, results in a sequence almost identical to running `FastVeloTracking` only once completely.
2. Forward tracking is performed and VELO tracks are upgraded to forward tracks with the full `PatForward` algorithm [5], which performs extra steps to prepare the hits and perform ghost killing. Two configurations can be used in the forward tracking procedure—*first loop* and *second loop*—with requirements summarized in Table 3.2.1; in both cases it is required again that either (a) the number of hits of the track is above 12 or (b) for OT-only tracks, the number of OT hits is above 14. Second loop reconstruction is typically executed after some preselection process that lowers the rate and its designed to recover lower momentum particles that were not picked up in first instance due to timing limitations; even though the configuration existed in both 2011 and 2012, it was not used in 2012, since first loop tracks in 2012 were equivalent to second loop ones in 2011.
3. Only in the 2012 reconstruction, seeding on unused hits in the T-stations, matching of the VELO and seed tracks and clone killing are performed with the `PatSeeding` [6], `PatMatch` and

* Long and forward tracks cross the full tracking system from the VELO to the T-stations, while downsteam tracks only transverse the TT and T-stations.

TABLE 3.2.1. *Forward/long track reconstruction requirements in HLT2 for each version (or version range) of the* `Hlt/HltTracking` *package. The first column corresponds to 2011, while the other two correspond to the versions used in 2012.*

		v9r7→v9r9p2		v9r16		v9r19→v9r25	
		1st	2nd	1st	2nd	1st	2nd
p	GeV/c	> 5.0	> 3.0	> 1.0	> 1.0	> 3.0	> 1.0
p_T	GeV/c	> 0.5	> 0.3	> 0.3	> 0.15	> 0.3	> 0.15

`TrackEventCloneKiller` [7] algorithms, respectively; this allows to obtain long tracks. Additionally, the seed tracks can be used to build downstream tracks using the `PatDownstream` algorithm.

4. A Kalman fit is performed using the `TrackMasterFitter`, .

5. Particles are made from the Kalman-fitted tracks. In the case of muons, the muon ID information—which is determined, when needed, by running the `MuonIDAlg` algorithm—is added to the ProtoParticle prior to building the particle object.

3.3 PV reconstruction

Primary vertex finding and reconstruction is performed from the VELO tracks (reconstructed by the `FastVeloTracking` algorithm) by making use of the `PatPV3D` algorithm with the `PVSeedTool` and `LSAdaptPV3DFitter` fitter.

The only change in configuration throughout 2011 and 2012 is the size of the PV search window, from beamspot $\rho < 0.5$ mm to beamspot $\rho < 0.3$ mm. More precisely, the 0.5 mm cut was used in `Hlt/HltTracking` versions v9r7 and v9r8p1, corresponding to the first three studied 2011 TCK, up to the 2011 June technical stop (see Fig. 2.1). For the rest of the year, and in 2012, the 0.3 mm cut was used.

3.4 Calorimeter reconstruction

The calorimeter is used for the reconstruction of neutral electromagnetic particles, that is, γ and π^0. Neutral clusters in the ECAL are associated with photons, which are distinguished using SPD information by analyzing the number of hits in the SPD cells in front of the ECAL cluster. Neutral pions decay into a pair of photons. Below a transverse energy of 2.5 GeV, π^0 are mostly reconstructed as a resolved pair of separated photons, and thus are called *resolved* π^0. However, a large fraction of photon pairs coming from high energy π^0 cannot be resolved as a separate pair of clusters given the ECAL granularity. These are called *merged* π^0 and are not distinguished from photons at trigger level. In HLT2, merged π^0 are built from a single calorimeter deposition with a mass window of 60 MeV/c^2 around the π^0 mass, while resolved π^0 are built from two calorimeter depositions of $E_T > 200$ MeV with a mass window of 30 MeV/c^2 around the nominal π^0 mass.

Calorimeter reconstruction in the HLT underwent a large change during 2011. In `Hlt/HltTracking` versions v9r7 and v9r8p1—up to the 2011 June technical stop—an almost-offline calorimeter reconstruction was performed, which resulted in slow timing in lines making use of calorimetric particles due to (a) the clusterization process and (b) the track matching for CaloPID. With the introduction of the

HLT2 radiative topological lines, after the 2011 June technical stop a new HLT calorimeter reconstruction was introduced [8], in which `L0CaloCandidates` over a certain E_T threshold are used as seeds for clusterization and their CaloPID is assigned based on the type of the `L0CaloCandidate`. This saves time, and therefore all lines making use of calorimetric particles—π^0, γ or electrons—eventually changed to this type of calorimeter reconstruction, replacing, *e.g.*, the use of `Hlt2BiKalmanFittedElectrons` by `Hlt2BiKalmanFittedElectronsFromL0`.

4

2011 TCKs

The reference TCK for 2011, `0x00790038`, is described in §4.1 and then compared to the rest of 2011 TCKs in the following subsections.

4.1 Reference TCK: `0x00790038`

The reference TCK `0x00790038` was the last relevant one used in 2011 and also the one used to collect most luminosity, as detailed in Table 2.1.1. In this section this TCK will be described in detail, so it can be compared with the rest of TCKs used in 2011 in the following sections. The main reconstruction features of this TCK are summarized in Chapter 3.

4.1.1 L0

The L0 lines (called *channels* due to their hardware nature) active in this TCK, along with their cut configuration and prescales, can be found in Table 4.1.1. More detailed information can be found elsewhere [2, 9]. Note that the beam gas channels, `L0B1gas` and `L0B2gas`, are only triggered in beam 1-empty and empty-beam 2 crossings, respectively. In addition, `L0NoPVFlag` uses the PU unit to trigger on events with zero reconstructed vertices in the region $z \in [-150, 150]$ mm.

4.1.2 HLT1

In this TCK, the PV is reconstructed in the HLT with the requirement that the radial distance with respect to the middle of the VELO (ρ) is below 0.3 mm, as discussed in §3.3. The tracking sequence configuration for HLT1 forward tracks is described in §3.1, with the main tracking requirements summarized in Table 3.1.1.

In addition, most lines include the use of Global Event Cuts (GEC). These GEC require that the number of hits in the IT is below 3000 and the number of hits in the OT is below 15000. In addition, the maximum number of hits in the VELO defines two different GEC:

- Loose GEC, which require the number of VELO hits to be below 10000.
- Tight GEC, which require the number of VELO hits below 3000.

The HLT1 non-technical (physics) lines included in the `0x00790038` TCK are shown with their prescales in Table 4.1.2 and detailed in the next subsections.

Beam gas lines

The beam gas lines—`Hlt1BeamGas(CrossingEnhanced|NoBeam)?Beam(1|2)`, `Hlt1BeamGasCrossingForcedReco` and `Hlt1BeamGasCrossingParasitic`†—run on the output of the corresponding L0 beam gas channels and make use of the tight GEC. They also require that the PV has a beamspot ρ smaller than 4 mm and the presence of more than 9 tracks. Further requirements on the ODIN—the LHCb Readout Supervisor [11]—crossing and trigger types, and on the z position and number of tracks of the PV are applied, as shown in Table 4.1.3.

Dimuon lines

The dimuon lines—`Hlt1DiMuon(Low|High)Mass`—as well as their performance, are described in detail in Ref. [3]. In them, pairs of muons are combined with requirements summarized in Table 4.1.4; both lines use the loose GEC.

Diproton lines

The diproton lines—`Hlt1DiProton($|LowMult)`—run on lower multiplicity events with no GEC and build two-track vertices consistent with (prompt) $J/\psi \to p\bar{p}$. As can be seen in Table 4.1.5, the low multiplicity line applies much looser selection criteria, but only runs in very low multiplicity events.

Passthrough lines

The any-L0 lines—`Hlt1L0Any($|NoSPD|NoSPDRateLimited|RateLimited)`—and the `Hlt1L0HighSumETJet` line ran as rate-limited passthrough of the output of specific L0 lines with no GEC. In particular,

- `Hlt1L0Any` and `Hlt1L0AnyRateLimited` are pre- and post-scaled passthrough lines running on any of the L0 physics (non-beam-gas) channels, respectively;
- `Hlt1L0AnyNoSPD` and `Hlt1L0AnyNoSPDRateLimited` did the same thing but on the output of the `L0*NoSPD` channels; and
- `Hlt1L0HighSumETJet` ran on the output of `L0HighSumETJet`.

† Throughout the document, regular expressions following the Python implementation [10] are used to refer to sets of lines of similar names in order to keep the text as compact as possible and to help highlight the similarities and differences amongst them.

No- and micro-bias lines

The no bias lines ran, prescaled, on events with `LumiTrigger` ODIN trigger type and `BeamCrossing` ODIN bunch crossing type. The `Hlt1MBNoBias` line was scaled to 11 Hz with a random phase periodic limiter, while the `Hlt1CharmCalibrationNoBias` line output was simply scaled to 500 Hz, as summarized in Table 4.1.2. The `Hlt1VeloClosingMicroBias` line ran on events with the VELO not in its final closed position, performing the VELO reconstruction and accepting the events with tracks at the rate shown in Table 4.1.2.

Single muon and electron lines

The single muon and electron lines without IP requirement—`Hlt1Single(Electron|Muon)NoIP`—and the electroweak muon trigger—`Hlt1SingleMuonHighPT`—are summarized in Table 4.1.6. In the case of the muon lines, the muon matching with VELO tracks, as well as the muon candidate upgrade, is performed, while in the case of electrons the candidate track is built starting from an energy deposition in the ECAL.

Single track lines

The single track lines—`Hlt1Track(AllL0|Muon|Photon)`—are described in detail in [12]. In them, a single detached high momentum track is used to identify decays coming from B, D and τ meson decays, applying different requirements in momentum and p_{T} depending on the L0 channels they run on, in all cases using the loose GEC configuration; applied requirements are summarized in Table 4.1.7. Additionally, the muon line applies the optional muon identification steps in the tracking configuration.

No-PV line

The no PV pass-through line—`Hlt1NoPVPassThrough`—runs on those events that pass the low multiplicity L0 channels (`L0.*,lowMult`).

Luminosity lines

The lumi lines were used for triggering events for luminosity studies:

- `Hlt1Lumi` ran on events with `LumiTrigger` ODIN trigger type scaled to 997 Hz with a random phase periodic limiter.
- `Hlt1LumiMidBeamCrossing` ran on events with `BeamCrossing` ODIN bunch-crossing type which had fired the `L0MUON,minbias` L0 channel.

Technical lines

The HLT1 technical lines are

- `Hlt1ErrorEvent`, which fires in case there is an error in any HLT1 line; and
- `Hlt1Global`, which is in charge of joining the HLT1 trigger decisions and managing the events needed for luminosity studies.

4.1.3 HLT2

The tracking features of this TCK are summarized in §3.2 and the key requirements of the forward track reconstruction in HLT2 can be found in the first column of Table 3.2.1. Note that no seeding or track matching is performed in the track reconstruction. The HLT2 lines included in TCK `0x00790038` can be divided in several groups, which are discussed in the next subsections. Note that the nomenclature used for describing these lines is discussed in Appendix A.

$B^0_{(s)} \to h^+h^-$ lines

The $B^0_{(s)} \to h^+h^-$ lines*, including the lifetime-unbiased ones, ran on the output of HLT1 physics, *i.e.*, `Hlt1(?!Lumi)(?!Velo)(?!NoPV).*Decision`, with prescales summarized in Table 4.1.8. The main difference between the biased and unbiased lines (see selection in Table 4.1.9) is that the latter don't make use of IP requirements and apply a HLT1 TIS filter on the tracks; to compensate, they apply soft cuts on the kaon PID (thus building $B^0_s \to K^+K^-$) and make use of a NeuroBayes MVA approach to further filter the events. In order to decrease the timing, a preselection is performed without RICH information, which is then calculated only on those events accepted in this first pass.

$B^0 \to h^+h^-\pi^0$ line

The `Hlt2B2HHPi0_Merged` line runs on the output of the `L0Photon` or `L0Electron` and the HLT*1* physics lines with prescales equal to 1. In it, candidates are built from `Hlt2BiKalmanFittedPions` and `Hlt2MergedPi0s` according to the decay descriptor `B0 -> (rho(770)0 -> pi+ pi-) pi0` using only merged π^0—that is, $\pi^0 \to \gamma\gamma$ in which the two photons are seen as one calorimeter cluster—with requirements summarized in Table 4.1.10.

Topological lines

The topological lines, listed in Table 4.1.11 and described in [13,14], ran with unit prescale. These topological lines can be divided in four groups:

- The regular lines—`Hlt2Topo[2-4].*`—which take as input:
  - Kaons obtained by filtering `BiKalmanFittedKaonsWithMuonID` with the requirements from Table 4.1.12, and
  - Long K^0_S and Λ^0—that is, made from two long tracks—built from `BiKalmanFittedPions` and `BiKalmanFittedProtons`—in the case of Λ^0—with $\chi^2_{\text{IP}} > 9$, $p > 3000$ MeV/c and $p_{\text{T}} > 300$ MeV/c. The requirements applied on these flying particles, referred to as V^0 from now on, are shown in Table 4.1.13.
- The muon lines—`Hlt2TopoMu[2-4].*`—which also take as input the same filtered kaons as the regular lines with an extra `ISMUON` required for at least one of the tracks (Table 4.1.12), and the long V^0 from Table 4.1.13.
- The electron lines—`Hlt2TopoE[2-4].*`—which take as input the filtered kaons from the regular lines with an extra PIDe requirement for at least one of the tracks (Table 4.1.12). Additionally, it is required

* From now on it will be assumed that $h = K, \pi$, unless explicitly stated. Charge conjugation is also implied throughout the document.

that the events have passed the `L0Electron` channel and any of the `Hlt1(Track|.*Electron)` HLT1 lines.

- The radiative lines—`Hlt2TopoRad.*`—which combine the filtered kaons from the regular lines with `BiKalmanFittedPhotonsFromL0` with the requirement that the event has been triggered in L0 by either `L0Photon` or `L0Electron`.

As can be seen in Table 4.1.11, each of the first three cases is subdivided in 2-, 3- and 4-body lines, with the regular lines having both a cut-based and a multivariate-based variant (BBDT, see [14]). In the case of the radiative lines, there is only BBDT-based 2- and 3-body lines, being one of the bodies a photon.

The input variables for the BBDT are: $\sum |p_{\mathrm{T}}|$, $p_{\mathrm{T}}^{\mathrm{min}}$, mass, corrected mass, DOCA, candidate χ^2_{IP} and flight distance χ^2. For each of the n-body combinations, a different BBDT training (and thus configuration file) is used (see in Table 4.1.14). In the case of cut-based lines, requirements are not simple cuts but consist on a series of cut combinations, each of which is called a *tree*, that are evaluated sequentially; if the candidate passes any of them, it is accepted.

In all cases, the candidates for the topological lines are built as follows:

1. For building the 2-body line, two tracks*, are combined.

2. The resulting 2-track combinations are forwarded as input for the 3-body line. They are also required to be TOS [15] in `Hlt1TrackAllL0`, `Hlt1TrackMuon` or `Hlt1TrackPhoton` and further filtered to obtain the 2-body line.

3. The 3-body line takes the 2-track objects prior to applying the TOS requirement and the filtering and uses them to build 3-track combinations with the same cuts as the 2-track objects. In the same way as before, these 3-track combinations are, on one side, TOSsed and further filtered to build the 3-body line and, on the other side, forwarded as input for the 4-body line.

4. The 4-body line takes as input the 3-track combinations and applies TOS and further filtering.

Selection criteria applied when building the n-body objects are shown in Table 4.1.15. Final cuts on the BBDT for each of the relevant lines are shown in Table 4.1.16, while Table 4.1.17 contains the cut trees for the `Simple` lines.

Radiative topological lines

The radiative topological lines [8]—`Hlt2RadiativeTopoPhotonL0` and `Hlt2RadiativeTopoTrackTOS`—are built with the same inclusiveness idea as the regular topological lines, and were also run with unit prescales. However, in this case, only 2-track + photon combinations are built and requirements are set keeping in mind the presence of a high-E_{T} neutral particle. In a first step, right- and wrong-sign 2-track objects are built from `Hlt2BiKalmanFittedKaons` with selection criteria detailed in Table 4.1.18. Afterwards, these tracks are combined with one high-E_{T} `Hlt2BiKalmanFittedPhotonsFromL0` to build an object with decay descriptor `[B0 -> K*(892)0 gamma]cc`, always taking into account the possibility of missing tracks, as shown in Table 4.1.19. The `Hlt2RadiativeTopoPhotonL0` line applies explicitly runs on those events that passed `L0Photon` or `L0Electron`, while the `Hlt2RadiativeTopoTrackTOS` drops this condition by requiring that one of the tracks is responsible for firing any the `Hlt1Track` HLT1 lines.

* From now on, and for the sake of simplicity, we will consider the photon and the V^0 as “tracks”.

Exclusive radiative lines

The exclusive radiative lines for $B^0 \to K^{*0}(\to K^{\pm}\pi^{\mp})\gamma$ and $B^0_s \to \phi(\to K^+K^-)\gamma$ [16] include several prescaled monitoring lines with wider mass ranges for the vector meson and the B candidate, as detailed in Table 4.1.20. In them, straightforward combinations of `BiKalmanFittedPions` and `BiKalmanFittedKaons` with `Hlt2BiKalmanFittedPhotonsFromL0` are performed according to the `[B0 -> K*(892)0 gamma]cc` and `B_s0 -> gamma phi(1020)` decay descriptors. Selection criteria applied for each channel are shown in Table 4.1.21.

$D^0 \to h^{\pm}h^{\mp}h^{\pm}h^{\mp}$ lines

The $D^0 \to h^{\pm}h^{\mp}h^{\pm}h^{\mp}$ line and its wide D^0 mass monitoring one—`Hlt2CharmHadD02HHHH` and `Hlt2-CharmHadD02HHHHWideMass`—were run with prescales shown in Table 4.1.22. In these lines, charge-0 and ±2 $K^* \to hh$ combinations are built with the `Hlt2CharmHadTwoBodyForMultiBody` configurable (see cuts in Table 4.1.23) and are further combined with two extra particles to build a D^0 (effectively building $D^0 \to K^*hh$). These extra hadrons, which are a combination of regular `BiKalmanFitted` particles (confusingly called "low IP") and low-p_{T} second-loop particles, are selected according to the requirements from Table 4.1.24. The D^0 candidate is built with an HLT1 track TOS filter and is tagged by reconstructing $D^* \to D^0\pi$ decay with a slow pion, as summarized in Table 4.1.25.

$D^0 \to h^{\pm}h^{\mp}$ lines

The $D^0 \to h^{\pm}h^{\mp}$ lines and their corresponding wide mass lines were run with prescales detailed in Table 4.1.26. They make use of a GEC on the number of forward tracks and apply an HLT1 TOS cut on the input tracks. In them, the three possible $D^0 \to h^{\pm}h^{\mp}$ combinations (and the corresponding wide-mass monitoring lines) are built in a straightforward way, with requirements shown in Table 4.1.27.

$D^{\pm} \to h^{\pm}h^{\mp}h^{\pm}$ lines

The $D^{\pm} \to h^{\pm}h^{\mp}h^{\pm}$ lines—`Hlt2CharmHadD2HHH` and `Hlt2CharmHadD2HHHWideMass`—ran with the prescales detailed in Table 4.1.28. These lines apply the same two-stage principle as the $D^0 \to h^{\pm}h^{\mp}h^{\pm}h^{\mp}$ HLT2 line, and hence they also make use of the `Hlt2CharmHadTwoBodyForMultiBody` configurable (see Table 4.1.23), to which an extra particle (dubbed h_3) is added—either a first-loop "low IP" or a second-loop low p_{T} particle. Requirements applied to this extra particle, as well as to the three-particle system are detailed in Table 4.1.29.

$D^{\pm} \to K^0_{\mathrm{S}}h^{\pm}$ lines

The $D^{\pm} \to K^0_{\mathrm{S}}h^{\pm}$ lines, one for each flavor of the hadron—`Hlt2CharmHadD2KS0H_D2KS0K` and `Hlt2-CharmHadD2KS0H_D2KS0Pi`—ran with unit prescales. These lines use as input long K^0_{S} coming from `Hlt2SharedParticles` (see first column in Table 4.1.30); no downstream K^0_{S} are used. Further requirements applied on these K^0_{S}, along with the ones applied on the bachelor h and their combination, can be found in Table 4.1.31.

$D^0 \to K^0_{\mathrm{S}}h^{\pm}h^{\mp}$ line

The $D^0 \to K^0_{\mathrm{S}}h^{\pm}h^{\mp}$ line—`Hlt2CharmHadD02HHKsLL`—ran with unit prescales. Contrary to the previous line, in this case long K^0_{S} are built within the line—not taken from `Hlt2SharedSharedParticles`—by combining pairs of Hlt2BiKalmanFittedPions with requirements shown in Table 4.1.32*. Two-hadron objects are then built taking into account the four possible hadron and sign combinations and are selected according to criteria from Table 4.1.33. The K_S^0 and two-hadron objects are combined to build the D^0 according to the selection from Table 4.1.34.

$\Lambda_c^\pm \to K^\mp p^\pm \pi^\pm$ line

The Hlt2CharmHadLambdaC2KPPi line, which was run with unit prescales, applies the RICH PID on the protons using a 2-step technique: first, $\Lambda_c^\pm$ candidates are built without PID information, and after a sizeable amount of events have been filtered by this first selection the RICH reconstruction is triggered. The selection criteria applied in this final selection are detailed in Table 4.1.35.

Charm minimum bias lines

The five charm minimum bias lines—Hlt2CharmHadMinBiasD02(KK|Kpi), Hlt2CharmHadMinBias-Dplus2hhh, Hlt2CharmHadMinBiasLambdaC2KPPi and Hlt2CharmHadMinBiasLambdaC2LambdaPi—are used to provide samples of minimally selected lifetime unbiased charm and were run, with unit prescales and without GEC, on the output of the Hlt1CharmCalibrationNoBias HLT1 line. They make use of BiKalmanFitted particles as input with the addition, in the Hlt2CharmHadMinBiasLambdaC2LambdaPi case, of second loop particles (defined in Table 3.2.1). The decay descriptors for each line can be found in Table 4.1.36. The summary of the selection criteria used in the 2- and 3-h lines can be found in Table 4.1.37, while the selection applied to Hlt2CharmHadMinBiasLambdaC2LambdaPi, with an intermediate flying particle, is detailed in Table 4.1.38.

$D^0 \to \mu^+\mu^-$ line

The non-prescaled Hlt2CharmRareDecayD02MuMu line builds $D^0 \to \mu^+\mu^-$ decays from Hlt2BiKalmanFittedMuons with the requirements shown in Table 4.1.39.

$D^\pm \to \mu\mu h$ lines

The semileptonic $D^\pm \to \mu\mu h$ line—Hlt2CharmSemilepD2HMuMu—and its corresponding monitoring line—Hlt2CharmSemilepD2HMuMuWideMass—run with prescales shown in Table 4.1.40, work analogously to the $D^+ \to h^+h^-h^+$ ones, replacing two hadrons by two muons: the Hlt2CharmHadTwoBodyForMultiBody configurable is substituted by the Hlt2CharmSemilepTwoMuonForMuMuHadConf configurable, which build a $\mu\mu$ pairs (including same-sign ones) from Hlt2BiKalmanFittedMuons (see Table 4.1.41), prior to a second-loop track reconstruction. No GEC are applied in any case and the individual selection criteria for each of the lines are shown in Table 4.1.42.

$D^0 \to \mu^+\mu^-h^+h^-$ lines

The semileptonic $D^0 \to \mu^+\mu^-h^+h^-$ lines—Hlt2CharmSemilepD02HHMuMu, Hlt2CharmSemilepD02HH-MuMuHardHadronsAndMuons and Hlt2CharmSemilepD02HHMuMuHardHadronsSoftMuons—where both hadrons are of the same type, and their corresponding wide-mass monitoring lines, were run with prescales shown in Table. 4.1.43. Depending on how the D^0 candidate is built, three cases can be distinguished:

* Note that the LL part in the line name refers to "long-long" and hence refers to the use of two long tracks to build the K_S^0. This convention is often used in line names, along with DD for downstream flying particles, such as K_S^0 or Λ^0.

- In `Hlt2CharmSemilepD02HHMuMu`), D^0 are built as $D^0 \to J/\psi h^+ h^-$, analogously to the previously discussed $D^\pm \to \mu\mu h^\pm$, in which the `Hlt2CharmSemilepTwoMuonForMuMuHadConf` configurable is used.
- In `Hlt2CharmSemilepD02HHMuMuHardHadronsAndMuons`, D^0 are built as $D^0 \to K^{*0}\mu^+\mu^-$ by combining `BiKalmanFittedMuons` with K^{*0} built with the `Hlt2CharmSemilepTwoHadForMuMuHH` configurable; the requirements for this configurable can be found in Table 4.1.44.
- In `Hlt2CharmSemilepD02HHMuMuHardHadronsSoftMuons`, D^0 are built as $D^0 \to D^+(\to K^{*0}\mu^+)\mu^-$ by combining the `Hlt2CharmSemilep2Had1MuForHHMuMu` configurable with softer, low IP muons. The `Hlt2CharmSemilep2Had1MuForHHMuMu` configurable constructs $D^\pm$ candidates making use of the `Hlt2CharmSemilepTwoHadForMuMuHH` configurable (see Table 4.1.44) for building the $K^{*0} \to h^+h^-$ system and afterwards adding a muon, with criteria shown in Table 4.1.45.

In all cases, no GEC are used, and the requirements applied, including the wide-mass monitoring lines, can be found in Table 4.1.46.

$D^0 \to \mu^+ h^- \nu$ lines

The different charm semileptonic $D^0 \to \mu^+ h^- \nu$ lines, run with prescales shown in Table 4.1.47 build D^0 decays with the same requirements (see Table 4.1.48) but with different decay descriptors to take into account right- and wrong-sign decays and the fact that $h^\pm$ can be either a π or a K. In addition, there is a tight line for $D^0 \to \mu^+ K^- \nu$—`Hlt2CharmSemilepD02HMuNu_D02KMuNuTight`—in which slow, second-loop pions are introduced to build $D^{*\pm} \to D^0(\to \mu^+ K^- \nu)\pi^\pm$ with requirements detailed in Table 4.1.49; this is the only line which is not prescaled.

$D^0 \to h_1^+ h_2^-$ lines

The $D^0 \to h_1 h_2$ lines, run with prescales shown in Table 4.1.50, cover the following $h_1^+ h_2^-$ combinations: $K^-\mu^+$, $K^-\pi^+$, $\mu^+\mu^-$ and $\pi^+\pi^-$. While it was originally intended that these lines would build a D^{*+} candidate from a D^0 and a slow pion—hence their names in Table 4.1.50—this configuration was not used in any of the 2011 TCKs included in this document. Thus, D^0 candidates are built from `BiKalmanFittedKaons`, `BiKalmanFittedPions` and `BiKalmanFittedMuons`, with all lines sharing the same selection criteria (except the D^0 mass window for the $D^0 \to \mu^+\mu^-$ line), as shown in Table 4.1.51. The differences amongst lines are the input particles and the decay descriptors, detailed in Table 4.1.52.

Dielectron lines

The dielectron lines, which were run with unit prescales, are designed for triggering decays such as $\Upsilon \to e^+e^-$. They both make use of `Hlt2SharedTrackFittedDiElectron` objects, built with the `J/psi -> e+ e-` decay descriptor from two `BiKalmanFittedElectrons` with $p_T > 1.0$ GeV/c and a vertex with a χ^2/ndf lower than 25. The soft p_T line—`Hlt2DiElectronB`—makes use of PIDe for identifying the electrons, while the high p_T line—`Hlt2DiElectronHighMass`—directly applies requirements on calorimeter quantities stored in the ProtoParticle; all selection criteria applied in these lines are shown in Table 4.1.53.

Unbiased dimuon lines

The unbiased dimuon lines, run with prescales detailed in Table 4.1.54, include:

- The J/ψ and $\psi(2S)$ lines—`Hlt2DiMuon(JPsi|Psi2S)($|HighPT)`—which include non-prescaled high-p_{T} versions, are documented in Ref. [3]. They mainly differ with each other in the mass window and the p_{T} requirements of the dimuon combination.
- The $B \to \mu\mu$ line—`Hlt2DiMuonB`.
- The high-mass dimuon lines—`Hlt2DiMuonDY[1-4]` and `Hlt2DiMuonZ`—designed for triggering on Drell-Yan and $Z \to \mu\mu$ processes.

These inclusive lines start from `TrackFittedDiMuon` objects, built from `BiKalmanFittedMuons` with the decay descriptor `J/psi(1S) -> mu+ mu-` and with only the requirement that the dimuon vertex χ^2 is below 25. These dimuon objects are then filtered according to the criteria detailed in Table 4.1.55.

Detached dimuon lines

The detached dimuon lines—`Hlt2DiMuonDetached`, `Hlt2DiMuonDetachedHeavy` and `Hlt2DiMuonDetachedJPsi`—which correspond to three different dimuon mass ranges, were run with unit prescales. They also make use of `TrackFittedDiMuon` objects, described above, on top of which a biased selection is applied (see [3] for further details); specific requirements for each line are shown in Table 4.1.56.

Trimuon lines

The non-prescaled trimuon lines—`Hlt2TriMuonDetached` and `Hlt2TriMuonTau`—were run with unit prescales with the aim of triggering B_c^+ and τ decays, respectively. The B_c^+ line requires three `TightMuons`, defined in Table 4.1.57, and builds a three-muon `[B_c+ -> mu+ mu+ mu-]cc` vertex with no extra requirements. The τ line requires three `GoodMuons`, also defined in Table 4.1.57, to build a `[tau+ -> mu+ mu+ mu-]cc` vertex, which is then filtered using the criteria in Table 4.1.58.

Dimuon + charm lines

The dimuon + charm lines—`Hlt2DiMuonAndD0`, `Hlt2DiMuonAndDp`, `Hlt2DiMuonAndDs` and `Hlt2DiMuonAndLc`—all run with unit prescales, start from a `DiMuon` object, built by filtering the already described `TrackFittedDiMuon` objects with criteria shown in Table 4.1.59. The selected `DiMuon` objects are then combined with a charm object built from the `Good` particles defined in Table 4.1.57 with the corresponding selection from Table 4.1.60 and decay descriptor from Table 4.1.61. Note that the D_s^+ and Λ_c^+ have a bug in the mass window that mde them unusable for their design purpose.

Dimuon + muon line

In the `Hlt2DiMuonAndMuon` line, run with unit prescales, a `TightMuon` is combined with a `DiMuon` object (Table 4.1.59) with vertex χ^2 larger than 10 and decay length significance above 6 using the decay descriptor `[B_c+ -> J/psi(1S) mu+]cc`.

Double dimuon line

The `Hlt2DoubleDiMuon` line, which was with unit prescales, simply combines two `DiMuon` objects (Table 4.1.59) with the decay descriptor `chi_b0(2P) -> J/psi(1S) J/psi(1S)` and no further requirements.

Diproton lines

The diproton lines—`Hlt2DiProton` and `Hlt2DiProtonLowMult`—ran, with unit prescales, on the output of specific HLT1 lines imposing requirements on the SPD multiplicity. They select diproton candidates using a two-stage approach: first, a preselection is performed on `Hlt2BiKalmanFittedProtons`, and then, when the rate is low enough, RICH reconstruction is triggered to apply PID requirements on the remaining events and build the final `J/psi(1S) -> p+ p~-` objects. The final set of selection criteria is shown in Table 4.1.62.

Displaced vertices lines

The displaced vertices lines, with prescales shown in Table 4.1.63, perform their selection in three steps (see [17] for further details):

1. All vertices with more than four tracks are reconstructed with `PatPV3D`, applying optimized cuts for vertices smaller than PVs (shown in Table 4.1.64).
2. Two instances of the `Hlt2PreSelDV` algorithm loop on all reconstructed vertices (RV) to preselect Long Lived Particles in the event, matching the VELO tracks with forward tracks in order to obtain momentum information; one instance of the algorithm uses `BiKalmanFittedPions` and the other `BiKalmanFittedDownstreamPions`. The main features of this preselection are:
    - The RV with lowest z position is considered as a PV and is skipped.
    - RVs with at least one backward track are removed.
    - RVs closer than 0.4 (2) mm to the beam line and further than 5 m are rejected in the long (downstream) instance.
    - Candidates originating from regions with detector material are not rejected.
    - The reconstructed mass of the candidate is requested to be in the $3 - 14000\ \text{GeV}/c^2$.
3. Specialized instances of the `Hlt2SelDV` algorithm are created for each line. This algorithm adds a wide range of kinematical and geometrical requirements to apply on the candidates selected in the previous stage, such as cuts on the sum of the children p_T, the position of decay vertices, radial and z estimated errors on the decay vertex positions (σ_r and σ_z) and the presence of a high p_T muon; it is also possible to require a minimum number of successful candidates per event. Two kind of selections are applied: one RV (*prey*) passing tight selection criteria, used when hunting for single long-lived particles, or two preys with looser criteria, used when looking for two particles coming from a common parent; selection critera applied in each case are detailed in Tables 4.1.65 and 4.1.66.

Express lines

The HLT2 express lines were run rate-limited, as shown in Table 4.1.67. These are a collection of lines covering a wide variety of alignment and calibration cases and are defined as follows:

- The `Hlt2ExpressBeamHalo` line is used for VELO sensor and module alignment. It makes use of the `PatVeloAlignTrackFilter` algorithm to select beam halo tracks parallel to $z = 0$ with the criteria summarized in Table 4.1.68.
- The `Hlt2ExpressJPsi` line is used for alignment and for muon ID calibration. It selects unbiased J/ψ from `BiKalmanFittedMuons` with very simple requirements, shown in Table 4.1.69.

- The `Hlt2ExpressJPsiTagProbe` line is used for muon ID calibration using the *tag and probe* method, in which one no PID `TagAndProbePion` is combined with a `TagAndProbeMuon` with `IsMuon` to build a `[J/psi(1S) -> mu+ pi-]cc` candidate. Selection criteria from Table 4.1.70 are applied only to one of the two particles, which is flagged as the *tag*.
- The `Hlt2ExpressLambda` line is used muon ID and PID calibration and ran on the output of the HLT1 Physics lines (`Hlt1(?!Lumi)(?!Velo)(?!NoPV).*Decision`). Candidates matching the `[Lambda0 -> p+ pi-]cc` decay descriptor are built, without the use of PID, from the `Hlt2BiKalmanFittedPions` and `Hlt2BiKalmanFittedProtons` containers with requirements detailed in Table 4.1.71.
- The `Hlt2ExpressDs2PhiPi` line is also used for PID calibration. Candidates are built combining `Hlt2BiKalmanFittedPions` and `Hlt2BiKalmanFittedKaons` (no second loop) using the decay descriptors `phi(1020) -> K+ K-` and `[D_s+ -> pi+ phi(1020)]cc` with the criteria shown in Table 4.1.72.
- The `Hlt2ExpressDStar2D0Pi` line is also used for PID calibration. Candidates are built from `Hlt2BiKalmanFittedPions` and `Hlt2BiKalmanFittedKaons` (no second loop) using the decay descriptors `[D0 -> K- pi+]cc` and `[D*(2010)+ -> D0 pi+]cc` with the cuts shown in Table 4.1.73.
- The `Hlt2ExpressKS` line is also used for PID calibration. In it, K_S^0 are built from long tracks with requirements shown in Table 4.1.74.

Inclusive ϕ lines

The inclusive ϕ lines—`Hlt2IncPhi` and `Hlt2IncPhiSidebands`—run with prescales shown in Table 4.1.75, are documented in Refs. [18]. In them, $\phi \to K^+K^-$ candidates are built with two mass windows, corresponding to the nominal line and a wider, prescaled, monitoring line, in two steps: first, geometric cuts on the tracks are applied, and afterwards RICH PID is calculated to provide further filtering. The final set of requirements is summarized in Table 4.1.76.

Low multiplicity lines

The low multiplicity lines, mainly designed for diffractive physics, ran on the output of the low multiplicity L0 channels and the `Hlt1NoPVPassThroughDecision` HLT1 line with prescales shown in Table 4.1.77. They can be split in four groups:

- The non-filtered 2-track lines for muons, electrons and hadrons—`Hlt2diPhotonDiMuon`, `Hlt2LowMultElectron_nofilter` and `Hlt2LowMultHadron_nofilter`—build right- and wrong-sign objects (as `J/psi(1S)`) from the corresponding `BiKalmanFitted` particles, requiring tracks with p_T larger than 400, 250 and 1000 MeV/c, respectively. The L0 requirement in each of these lines is shown in Table 4.1.78.
- The filtered 2-track lines—`Hlt2LowMultElectron` and `Hlt2LowMultHadron`—require less than 8 VELO tracks and no backward tracks, and afterwards build the `J/psi(1S)` objects the same way as the non-filtered lines—that is, with the L0 requirements in Table 4.1.78 and with a requirement on the track p_T of > 250 and > 1000 MeV/c, respectively.

- The filtered single muon line—Hlt2LowMultMuon—ran on the output of the L0Muon,lowMult and L0DiMuon,lowMult channels, requiring less than 4 VELO tracks, no backward tracks and a BiKalmanFittedMuon with p_{T} larger than 400 MeV/c.
- The diphoton (π^0) line—Hlt2LowMultPhoton—which runs on the output of L0Photon,lowMult or L0DiEM,lowMult, gets π^0 from the MergedPi0s and ResolvedPi0s containers, and applies a further cut of $p_{\mathrm{T}} > 250$ MeV/c to the parent.

$B_c \to J/\psi\, \mu X$ lines

The $B_c \to J/\psi\, \mu X$ lines—Hlt2TFBc2JpsiMuX and Hlt2TFBc2JpsiMuXSignal—were run with unit prescales. In these lines, [B_c+ -> J/psi(1S) mu+]cc decays are built by filtering TrackFittedDiMuon objects (described in Page 23) and then combining them with one BiKalmanFittedMuon. Inclusiveness is maintained by avoiding strict mass requirements and the usage of pointing variables. The full set of selection criteria is shown in Table 4.1.79. It can be seen from the table that the Hlt2TFBc2JpsiMuXSignal line, with the prescales used in this TCK, is not needed.

Single muon lines

The inclusive single muon lines, which were run with prescales shown in Table 4.1.80, are documented in Ref. [3]. Of these lines, Hlt2SingleMuon selects detached single Hlt2BiKalmanFittedMuons passing the Hlt1TrackMuon line, while the rest are built to select prompt single muons, analogously to the corresponding HLT1 line; applied requirements are shown in Table 4.1.81.

Single electron lines

The single electron lines ran on the output of the L0Electron channel and the Hlt1(Track|.*Electron) lines with the prescales shown in Table 4.1.82. They trigger on a single BiKalmanFittedElectron with p_{T}, IP and PID requirements, as detailed Table 4.1.83.

Technical lines

The technical lines ran with prescales shown in Table 4.1.84 and are described as follows:

- The Hlt2DebugEvent selects a fraction of the events passing non-lumi HLT1 lines—corresponding to the regular expression ^Hlt1(?!Lumi).*Decision$')—and stores debug information about them.
- The Hlt2ErrorEvent fires if there is an error in any line matching the Hlt2.* pattern.
- The Hlt2Forward runs the forward tracking on events passing the HLT1 lines selected by the Hlt1(?!Lumi)(?!Velo)(?!NoPV).*Decision expression.
- The Hlt2Global line is in charge of putting together the trigger decisions, writing the trigger reports in the event and writing and stripping the luminosity information. Therefore, it accepts all events coming from lines matching the Hlt2.* pattern.
- The Hlt2Lumi line accepts lumi events triggered by Hlt1Lumi.* lines.
- The Hlt2PassThrough line accepts—with a prescale—all events passing non-lumi HLT1 lines.

- The `Hlt2Transparent` line is designed to accept all the events passing the HLT1 non-physics lines with the use of a regular expression filter: `^Hlt1(ODIN.*|L0.*|MB.*|BeamGas.*|Velo.*|NZS.*|Incident|Tell1Error|ErrorEvent)Decision$`.

TABLE 4.1.1. *Basic L0 configuration, with thresholds and prescales, for the reference TCK `0x00790038`. All energy values are measured in* MeV *and transverse momenta in* MeV/*c*.

	SPD mult	PU mult	$\sum E_T$	Hadron E_T	Electron E_T	Photon E_T	$p_{T\,\mathrm{largest}}$	$p_{T\,\mathrm{2nd\ largest}}$	$\sqrt{p_{T\,\mathrm{largest}} \times p_{T\,\mathrm{2nd\ largest}}}$	Prescale
`L0B1gas`		< 30	> 5000							1.0
`L0B2gas`		> 9	< 1000							1.0
`L0CALO`	> 2			> 240						10^{-6}
`L0DiEM,lowMult`	< 10				> 240	> 240				1.0
`L0DiHadron,lowMult`	< 10		> 2000	> 1000						0.1
`L0DiMuon`	< 900								> 1296	1.0
`L0DiMuon,lowMult`	< 10						> 80	> 80		1.0
`L0DiMuonNoSPD`									> 1296	10^{-4}
`L0Electron`	< 600				> 2500					1.0
`L0Electron,lowMult`	< 10				> 1000					1.0
`L0ElectronHi`	< 600				> 4200					1.0
`L0ElectronNoSPD`					> 2500					10^{-4}
`L0Hadron`	< 600			> 3500						1.0
`L0HadronNoSPD`				> 3500						10^{-4}
`L0HighSumETJet`			> 30000							10^{-6}
`L0MUON,minbias`							> 240			10^{-5}
`L0Muon`	< 600						> 1480			1.0
`L0Muon,lowMult`	< 10						> 200			1.0
`L0MuonNoSPD`							> 1480			10^{-4}
`L0Photon`	< 600					> 2500				1.0
`L0Photon,lowMult`	< 10					> 1000				1.0
`L0PhotonHi`	< 600					> 4200				1.0
`L0PhotonNoSPD`						> 2500				10^{-4}
`L0NoPVFlag`						> 2500				1

TABLE 4.1.2. *HLT1 lines and their pre- and postscales in the reference TCK* `0x00790038`.

	Prescale	Postscale
`Hlt1BeamGasBeam1`	1	2 Hz
`Hlt1BeamGasBeam2`	1	2 Hz
`Hlt1BeamGasCrossingEnhancedBeam1`	1	2 Hz
`Hlt1BeamGasCrossingEnhancedBeam2`	1	2 Hz
`Hlt1BeamGasCrossingForcedReco`	1	0.5 Hz
`Hlt1BeamGasCrossingParasitic`	1	0.5 Hz
`Hlt1BeamGasNoBeamBeam1`	1	0.5 Hz
`Hlt1BeamGasNoBeamBeam2`	1	0.5 Hz
`Hlt1DiMuonHighMass`	1	1
`Hlt1DiMuonLowMass`	1	1
`Hlt1DiProtonLowMult`	1	1
`Hlt1DiProton`	1	1
`Hlt1L0AnyNoSPDRateLimited`	1	1 Hz
`Hlt1L0AnyNoSPD`	0.01	1
`Hlt1L0AnyRateLimited`	1	1 Hz
`Hlt1L0Any`	10^{-6}	1
`Hlt1L0HighSumETJet`	1	1
`Hlt1MBNoBias`	1	1
`Hlt1CharmCalibrationNoBias`	1	500 Hz
`Hlt1VeloClosingMicroBias`	1	500 Hz
`Hlt1SingleElectronNoIP`	1	1
`Hlt1SingleMuonHighPT`	1	1
`Hlt1SingleMuonNoIP`	0.01	1
`Hlt1TrackAllL0`	1	1
`Hlt1TrackMuon`	1	1
`Hlt1TrackPhoton`	1	1
`Hlt1NoPVPassThrough`	1	1
`Hlt1Lumi`	1	1
`Hlt1LumiMidBeamCrossing`	1	1
`Hlt1ErrorEvent`	1	0.01 Hz
`Hlt1Global`	1	1

TABLE 4.1.3. *Selection requirements applied in the HLT1 beam gas lines in TCK 0x00790038.*

	L0	ODIN crossing type	ODIN trigger type	PV z position [mm]
Hlt1BeamGasBeam1	L0B1gas at 5 kHz	Beam1	–	$[-1200.0, 400.0]$
Hlt1BeamGasBeam2	L0B2gas at 5 kHz	Beam2	–	$[0.0, 1200.0]$
Hlt1BeamGasCrossingEnhancedBeam1	L0B1gas at 5 kHz	BeamCrossing	BeamGasTrigger	$[-1200.0, -300.0] \cup [300.0, 400.0]$
Hlt1BeamGasCrossingEnhancedBeam2	L0B2gas at 5 kHz	BeamCrossing	BeamGasTrigger	$[300.0, 1200.0]$
Hlt1BeamGasCrossingForcedReco	(SpdMult > 5 or PUHits > 5) at 1 kHZ	BeamCrossing	–	$[-1200.0, -300.0] \cup [300.0, 1200.0]$
Hlt1BeamGasCrossingParasitic	(SpdMult > 5 or PUHits > 5) and has VELO tracks	BeamCrossing	–	$[-1200.0, -300.0] \cup [300.0, 1200.0]$
Hlt1BeamGasNoBeamBeam1	L0B1gas at 10 kHz	NoBeam	–	$[-1200.0, 400.0]$
Hlt1BeamGasNoBeamBeam2	L0B2gas at 10 kHz	NoBeam	–	$[0.0, 1200.0]$

TABLE 4.1.4. *Requirements applied on the dimuon HLT1 lines in TCK* `0x00790038`.

			`Hlt1DiMuonHighMass`	`Hlt1DiMuonLowMass`
Muons	Track χ^2/ndf		< 4	
	p_{T}	MeV/c	> 500	
	p	MeV/c	> 6000	
	χ^2_{IP}		–	> 3
Dimuon	DOCA	mm	< 0.2	
	χ^2_{vtx}		< 25	
	M	MeV/c^2	> 2700	> 1000

TABLE 4.1.5. *Requirements applied on the tracks and the 2-track object in the diproton HLT1 lines in TCK `0x00790038`.*

			`Hlt1DiProton`	`Hlt1DiProtonLowMult`
Trigger requirements	L0		`L0Hadron` and `SPDMult` < 300	`SPDMult` < 20
Tracks	VELO hits		> 9	–
	VELO missing hits		< 3	–
	Track upgrade		Tight	Loose
	Track hits		> 15	–
	p_{T}	MeV/c	> 1900	> 500
	p	MeV/c	> 10000	> 6000
2-track object	DOCA	mm	< 0.1	< 0.3
	χ^2_{vtx}		< 4	< 25
	p_{T}	MeV/c	> 6500	–
	M	MeV/c^2	$[2800, 4000]$	> 2800

TABLE 4.1.6. *Requirements applied on the track candidate in the HLT1 single muon and electron lines in TCK 0x00790038.*

	L0	VELO hits	VELO missing hits	track upgrade	hits	χ^2/ndf	p [GeV/c]	p_{T} [GeV/c]
Hlt1SingleMuonNoIP	L0Muon	> 9	< 3	Loose	> 16	< 4	> 6.0	> 1.3
Hlt1SingleElectronNoIP	L0Electron	> 0	< 999	Tight	> 0	< 4	> 20.0	> 10.0
Hlt1SingleMuonHighPT	L0Muon	> 0	< 999	Tight	> 0	< 4	> 8.0	> 4.8

TABLE 4.1.7. *Requirements applied on the track in the HLT1 track lines in TCK 0x00790038.*

	L0	VELO hits	VELO missing hits	track upgrade	hits	χ^2/ndf	p [GeV/c]	p_{T} [GeV/c]	χ^2_{IP}
Hlt1TrackAllL0	L0_DECISION_PHYSICS	> 9	< 3	Tight	> 16	< 2	> 10.0	> 1.7	> 16
Hlt1TrackPhoton	L0PhotonHi or L0ElectronHi	> 9	< 4	Loose	> 15	< 2	> 6.0	> 1.2	> 16
Hlt1TrackMuon	L0Muon or L0DiMuon	> 0	< 999	Loose	> 0	< 2	> 8.0	> 1.0	> 16

TABLE 4.1.8. *Pre- and postscales of the $B^0_{(s)} \to h^+h^-$ HLT2 lines in TCK* `0x00790038`.

	Prescale	Postscale
`Hlt2B2HH`	1	1
`Hlt2B2HHLTUnbiased`	0.1	1
`Hlt2B2HHLTUnbiasedDetached`	1	1

TABLE 4.1.9. *Selection requirements applied in the $B^0_{(s)} \to h^+h^-$ HLT2 lines in TCK* `0x00790038`.

			Hlt2B2HH	Hlt2B2HHLTUnbiased	Hlt2B2HHLTUnbiasedDetached
Decay descriptor			B0 -> pi+ pi-	B_s0 -> K+ K-	
Input particles			Hlt2BiKalmanFittedPions	Hlt2BiKalmanFittedRichKaons	
$h^\pm$	Track χ^2/ndf		< 5		
	p	MeV/c^2	–	> 10000	
	p_T	MeV/c^2	> 1000		
	IP	mm	> 0.12	–	–
	TIS		–	Hlt1.*	
	PIDK		–	> 0.1	
h^+h^- combination	$M(p_h^\mu)$	MeV/c^2	$[4700, 5900]$	$[5000, 5900]$	
	DOCA	mm	< 0.1		
	Largest p_T	MeV/c	–	> 1500	
	Largest PIDK		–	–	> 0.1
B meson	χ^2_vtx/ndf		–	< 10	
	p_T	MeV/c	> 1200	–	–
	p	MeV/c	–	> 10000	
	τ	ps	> 0.0006	–	> 0.1
	IP	mm	< 0.12	–	–
	Decay angle		–	< 0.9	

TABLE 4.1.10. *Selection requirements applied in the `Hlt2B2HHPi0_Merged` line in TCK `0x00790038`.*

$\pi^\pm$	Track χ^2/ndf		< 4.0
	p	MeV/c	> 5000
	p_T	MeV/c	> 500
	χ^2_IP		> 9
$\pi^+\pi^-$ combination	DOCA	mm	< 0.2
	Smallest track χ^2/ndf		< 2.4
ρ	χ^2_vtx		< 10
	χ^2_VS		> 100
π^0	E_T	MeV	> 2500
B^0	$M(p^\mu_\rho + p^\mu_{\pi^0})$	MeV/c^2	$[3700, 6900]$
	p_T	MeV/c	> 3000
	χ^2_IP		< 25
	DIRA		> 0.99987
	M	MeV/c^2	$[4200, 6400]$

TABLE 4.1.11. *List of topological lines in TCK `0x00790038`.*

`Hlt2Topo2BodyBBDT`
`Hlt2Topo2BodySimple`
`Hlt2Topo3BodyBBDT`
`Hlt2Topo3BodySimple`
`Hlt2Topo4BodyBBDT`
`Hlt2Topo4BodySimple`
`Hlt2TopoE2BodyBBDT`
`Hlt2TopoE3BodyBBDT`
`Hlt2TopoE4BodyBBDT`
`Hlt2TopoMu2BodyBBDT`
`Hlt2TopoMu3BodyBBDT`
`Hlt2TopoMu4BodyBBDT`
`Hlt2TopoRad2BodyBBDT`
`Hlt2TopoRad2plus1BodyBBDT`

TABLE 4.1.12. *Requirements applied on the input kaons for the topological HLT2 lines in TCK `0x00790038`.*

Common requirements	p_T	MeV/c	> 500
	p	MeV/c	> 5000
	χ^2_IP		> 4
Regular and muon lines	Track χ^2/ndf		< 3 or (`ISMUON` and < 4)
Electron lines	Track χ^2/ndf		< 3 or (PIDe> -2.0 and < 5)

TABLE 4.1.13. *Requirements applied on V^0 mesons in the topological HLT2 lines in TCK* `0x00790038`.

			K_S^0	Λ^0
$\pi^\pm, p^\pm$	Track χ^2/ndf		< 3	
	p_T	MeV/c	> 500	
	p	MeV/c	> 5000	
	χ^2_{IP}		> 16	
V^0 meson	χ^2_{vtx}		< 10	
	p_T	MeV/c	> 500	
	p	MeV/c	> 5000	
	χ^2_{IP}		> 4	
	DIRA		> 0	
	χ^2_{VS}		> 1000	
	M	MeV/c^2	$[452.648, 542.648]$	$[1085.683, 1145.683]$

TABLE 4.1.14. *File names of the BDT parameters used in the BBDT-based topological lines in TCK* `0x00790038`. *The version of* `ParamFiles` *corresponding to this TCK is* `v8r10`.

2-body	`Hlt2Topo3Body_BDTParams_v1r0.txt`
3-body	`Hlt3Topo3Body_BDTParams_v1r0.txt`
4-body	`Hlt4Topo3Body_BDTParams_v1r0.txt`

TABLE 4.1.15. *Requirements applied on the n-track objects in the topological HLT2 lines in TCK* `0x00790038`. *The selection criteria in the last section are only applied when building the n-body line and therefore are not passed as input of the $(n+1)$-body line.*

			$n = 2$	$n = 3$	$n = 4$
Input $(n-1)$-track object	χ^2_{vtx}		–	< 10	–
	M	MeV/c^2	–	< 6000	< 6000
n-track object	$M(\sum p^\mu)$	MeV/c^2		< 7000	
	Max DOCA	mm		< 0.2	
	DIRA			> 0	
	χ^2_{VS}			> 100	
n-body line	Smallest track χ^2/ndf			< 2.4	
	$\sum p_T$	MeV/c	> 3000	> 4000	> 4000

TABLE 4.1.16. *Cut applied on the BBDT for each of the topological* `BBDT` *HLT2 lines in TCK* `0x00790038`.

	$n = 2$	$n = 3$	$n = 4$
Regular	> 0.4	> 0.4	> 0.3
Muon	> 0.1	> 0.1	> 0.1
Electron	> 0.1	> 0.1	> 0.1
Radiative	> 0.1	> 0.1	–

TABLE 4.1.17. *Selection trees applied in the `Simple` topological HLT2 lines in TCK `0x00790038`. A candidate is accepted if it passes any set of requirements (row) fora given n.*

	χ^2_{VS}	$\sum_{\mathrm{children}} p_{\mathrm{T}}$ [MeV/c]	Min p_{T} [MeV/c]	DOCA [mm]	M [MeV/c^2]	$M_{\mathrm{corrected}}$ [MeV/c^2]
$n = 2$	> 100	> 3000	> 3000	< 0.2	< 7000	$[4000, 7000]$
	> 100	> 10000	–	< 0.2	< 7000	$[4000, 7000]$
	> 1000	> 5000	> 750	< 0.2	< 7000	$[2000, 7000]$
	> 300	> 5500	> 1000	< 0.2	< 7000	$[2000, 7000]$
$n = 3$	> 100	> 4000	> 3000	< 0.1	< 7000	$[4000, 7000]$
	> 100	> 15000	–	< 0.1	< 7000	$[4000, 7000]$
	> 300	> 4000	> 2000	< 0.1	$[3000, 7000]$	$[4500, 6500]$
	> 300	> 6000	> 1000	< 0.1	$[3000, 7000]$	$[4500, 6500]$
	> 300	> 7500	> 750	< 0.1	$[3000, 7000]$	$[4500, 6500]$
	> 1000	> 4000	> 1500	< 0.1	$[3000, 7000]$	$[4500, 6500]$
	> 1000	> 7000	> 600	< 0.1	$[3000, 7000]$	$[4500, 6500]$
$n = 4$	> 100	> 4000	> 2000	< 0.1	< 7000	$[4000, 7000]$
	> 100	> 15000	–	< 0.1	< 7000	$[4000, 7000]$
	> 300	> 4000	> 1750	< 0.1	$[3500, 7000]$	$[4000, 7000]$
	> 300	> 8000	> 600	< 0.1	$[3500, 7000]$	$[4000, 7000]$
	> 1000	> 4000	> 1250	< 0.1	$[3500, 7000]$	$[4000, 7000]$
	> 1000	> 7500	> 550	< 0.1	$[3500, 7000]$	$[4000, 7000]$

TABLE 4.1.18. *Selection requirements applied on the 2-track objects in the radiative topological HLT2 lines in TCK `0x00790038`.*

GEC	Forward tracks		< 120
Tracks	Track χ^2/ndf		< 5
	χ^2_{IP}		> 10
	p	MeV/c	> 5000
	p_{T}	MeV/c	> 700
2-track object	χ^2_{vtx}		< 10
	DOCA	mm	< 0.15
	Smallest track χ^2/ndf		< 3
	DIRA		> 0
	p_{T}	MeV/c	> 1500
	M	MeV/c^2	< 2000

TABLE 4.1.19. *Requirements applied on the 2-track + photon combinations in the radiative topological HLT2 lines in TCK `0x00790038`.*

Photon	E_{T}	MeV	> 2500
2-track + photon object	p_{T}	MeV/c	> 1000
	$p_{\mathrm{T},K_1} + p_{\mathrm{T},K_2} + E_{\mathrm{T},\gamma}$	MeV/c	> 5000
	VS		> 0
	χ^2_{VS}		> 64
	$M_{\mathrm{corrected}}$	MeV/c^2	$[4000, 7000]$

TABLE 4.1.20. *Pre- and postscales of the exclusive radiative lines in TCK `0x00790038`.*

	Prescale	Postscale
`Hlt2Bd2KstGamma`	1	1
`Hlt2Bd2KstGammaWideBMass`	0.05	1
`Hlt2Bd2KstGammaWideKMass`	0.05	1
`Hlt2Bs2PhiGamma`	1	1
`Hlt2Bs2PhiGammaWideBMass`	0.1	1

TABLE 4.1.21. *Selection requirements applied in the exclusive radiative HLT2 lines in TCK 0x00790038. The values corresponding to the monitoring lines (wide K^{*0} and B meson mass) are shown in parentheses.*

			$B \to K^{*0}\gamma$	$B_s^0 \to \phi\gamma$
Trigger	L0		`L0Photon` or `L0Electron`	
	HLT1		HLT1 Physics	
$h^{\pm}$	Track χ^2/ndf		< 5	
	χ^2_{IP}		> 10	
Vector meson	χ^2_{vtx}		< 10	
	$\lvert M - m_V \rvert$	MeV/c^2	< 20	$< 100(125)$
Photon	E_{T}	MeV	> 2600	
B meson	χ^2_{IP}		< 25	
	DIRA		$> \cos(0.045)$	$> \cos(0.063)$
	$\lvert M - m_B \rvert$	MeV/c^2	$< 1000(2000)$	

TABLE 4.1.22. *Pre- and postscales of the $D^0 \to h^{\pm}h^{\mp}h^{\pm}h^{\mp}$ lines in TCK 0x00790038.*

	Prescale	Postscale
`Hlt2CharmHadD02HHHH`	1	1
`Hlt2CharmHadD02HHHHWideMass`	0.1	1

TABLE 4.1.23. *Selection requirements applied in the `Hlt2CharmHadTwoBodyForMultiBody` configurable in TCK `0x00790038`.*

Decay descriptors	`K*(892)+ -> pi+ pi+`
	`K*(892)0 -> pi+ pi-`
	`K*(892)- -> pi- pi-`
	`K*(892)+ -> K+ K+`
	`K*(892)0 -> K+ K-`
	`K*(892)- -> K- K-`
	`K*(892)0 -> K+ pi-`
	`K*(892)0 -> K- pi+`
	`K*(892)+ -> K+ pi+`
	`K*(892)- -> K- pi-`		

$h^{\pm}$	Track χ^2/ndf		< 3
	p	MeV/c	> 5000
	p_{T}	MeV/c	> 500
	χ^2_{IP}		> 10
$h_1 h_2$ combination	$\sum_h p_{\mathrm{T}}$	MeV/c	> 2000
	DOCA	mm	< 0.1
	$M(p^{\mu}_{h_1} + p^{\mu}_{h_2})$	MeV/c^2	< 2100
K^* meson	VS	mm	> 3.0
	χ^2_{VS}		> 40.0
	$M_{\mathrm{corrected}}$	MeV/c^2	< 3500

TABLE 4.1.24. *Requirements applied on the two particles that are combined with the 2-body objects obtained from the `Hlt2CharmHadTwoBodyForD02HHHH` configurable in the $D^0 \to h^{\pm}h^{\mp}h^{\pm}h^{\mp}$ lines in TCK `0x00790038`.*

		"Low IP" tracks	Low p_{T} tracks
Track type		First loop	Second loop
Track χ^2/ndf		< 3	< 5
p_{T}	MeV/c	–	> 250
p	MeV/c	–	2000
χ^2_{IP}		> 1.7	

TABLE 4.1.25. *Selection requirements applied in the $D^0 \to h^\pm h^\mp h^\pm h^\mp$ HLT2 line in TCK `0x00790038`. Selection requirements applied in the monitoring line (when needed) are shown in parentheses.*

GEC	Forward tracks		< 110
$K^* hh$ combination	$\sum p_\mathrm{T}$	MeV/c	> 3000
	$M(\sum p^\mu)$	MeV/c^2	< 2100
	Min DOCA	mm	< 0.1
	Max DOCA	mm	< 0.5
	PV		all from same
D^0	χ^2_vtx/ndf		< 20
	χ^2_IP		< 25
	DIRA		> 0.9995
	χ^2_VS		> 100
	$M_\mathrm{corrected}$	MeV/c^2	< 3500
	M	MeV/c^2	$[1800, 1900]$ ($[1700, 2100]$)
	HLT1 TOS		`Hlt1Track.*`
Slow π	Track χ^2/ndf		< 100
	p	MeV/c	> 3000
	p_T	MeV/c	> 300
$D^{*\pm}$	DOCA	mm	< 100
	$M_{D^*} - M_{D^0}$	MeV/c^2	$[0, 180]$

TABLE 4.1.26. *Pre- and postscales of the $D \to h^\pm h^\mp$ HLT2 lines in TCK `0x00790038`.*

	Prescale	Postscale
`Hlt2CharmHadD02HH_D02KK`	1	1
`Hlt2CharmHadD02HH_D02KKWideMass`	1	0.1
`Hlt2CharmHadD02HH_D02KPi`	1	1
`Hlt2CharmHadD02HH_D02KPiWideMass`	1	0.1
`Hlt2CharmHadD02HH_D02PiPi`	1	1
`Hlt2CharmHadD02HH_D02PiPiWideMass`	1	0.1

TABLE 4.1.27. *Selection requirements applied in the $D^0 \to h^\pm h^\mp$ HLT2 lines in TCK `0x00790038`. Selection requirements applied in the monitoring lines (when needed) are shown in parentheses.*

GEC	Forward tracks		< 110
$h^\pm$	Track χ^2/ndf		< 3
	p	MeV/c	> 5000
	p_T	MeV/c	> 800
	χ^2_{IP}		> 9
h^+h^- combination	p_T	MeV/c	> 2000
	DOCA	mm	< 0.1
	Largest h p_T	MeV/c	> 1500
	$M(\sum p^\mu)$	MeV/c^2	$[1715, 2065]$
D^0	χ^2_{vtx}/ndf		< 10
	DIRA		> 0.99985
	χ^2_{VS}		> 40
	HLT1 TOS		`Hlt1Track.*`
	M	MeV/c^2	$[1815, 1915]$ ($[1715, 2065]$)

TABLE 4.1.28. *Pre- and postscales of the $D^\pm \to h^\pm h^\mp h^\pm$ HLT2 lines in TCK `0x00790038`.*

	Prescale	Postscale
`Hlt2CharmHadD2HHH`	1	1
`Hlt2CharmHadD2HHHWideMass`	0.1	1

TABLE 4.1.29. *Selection requirements applied in the $D^\pm \to h^\pm h^\mp h^\pm$ HLT2 lines in TCK `0x00790038`. Selection requirements applied in the monitoring line (when needed) are shown in parentheses.*

			low IP tracks	low p_T tracks
GEC	Forward tracks		< 110	
$h_3^\pm$	Track type		First loop	Second loop
	Track χ^2/ndf		< 3	
	χ^2_{IP}		> 5	
$K^* h_3^\pm$ combination	$\sum_{h_1}^{h_3} p_T$	MeV/c	> 2500	
	Min DOCA	mm	< 0.08	
	$M(\sum_{h_1}^{h_3} p^\mu)$	MeV/c^2	< 2100	
$D^\pm$	χ^2_{vtx}/ndf		< 20	
	χ^2_{IP}		< 15	
	χ^2_{VS}		> 150	
	$M_{corrected}$	MeV/c^2	< 3500	
	M	MeV/c^2	$[1800, 2040]$ ($[1700, 2100]$)	
	HLT1 TOS		`Hlt1Track.*`	

TABLE 4.1.30. *Requirements applied on the K_S^0 built by `Hlt2SharedParticles` in TCK `0x00790038`.*

			Long	Downstream
$\pi^{\pm}$	Track χ^2/ndf			< 20
K_S^0	χ^2_{vtx}			< 30
	$\lvert M - m_{K_S^0}\rvert$	MeV/c^2	< 35	< 64

TABLE 4.1.31. *Selection requirements applied in the $D^{\pm} \to K_S^0 h^{\pm}$ HLT2 lines in TCK `0x00790038`.*

K_S^0	$\pi^{\mp}$ track χ^2/ndf		< 5
	$\pi^{\pm}$ χ^2_{IP}		> 45
	χ^2_{vtx}/ndf		< 12
	p_{T}	MeV/c	> 700
	χ^2_{IP}		> 7
Bachelor $h^{\pm}$	Track χ^2/ndf		< 4
	p	MeV/c	> 4500
	p_{T}	MeV/c	> 450
	χ^2_{IP}		> 10
$D^{\pm}$	χ^2_{vtx}/ndf		< 12
	p_{T}	MeV/c	> 1000
	χ^2_{IP}		< 20
	$\Delta z(K_S^0, D^{\pm})$	mm	> 10
	HLT1 TOS		`Hlt1Track.*`
	M	MeV/c^2	$[1770, 2070]$

TABLE 4.1.32. *Requirements for building $K_S^0 \to \pi^+\pi^-$ for the $D^0 \to K_S^0 h^{\pm} h^{\mp}$ HLT2 line in TCK `0x00790038`.*

$\pi^{\pm}$	Track χ^2/ndf		< 20
	p	MeV/c	> 2000
	χ^2_{IP}		> 9
K_S^0	χ^2_{vtx}/ndf		< 30
	VS$_z$	mm	$[-1000, 650]$
	χ^2_{VS}		> 100
	$\lvert M - m_{K_S^0}\rvert$	MeV/c^2	< 11.4

TABLE 4.1.33. *Requirements for building the 2-hadron K^{*0} objects for the $D^0 \to K^0_S h^\pm h^\mp$ line in TCK* `0x00790038`.

$h^\pm$	Track χ^2/ndf		< 5
	p	MeV/c	> 1500
$h_1^+ h_2^-$ combination	$p_T(p^\mu_{h_1} + p^\mu_{h_2})$	MeV/c	> 1000
	$M(p^\mu_{h_1} + p^\mu_{h_2})$	MeV/c^2	< 1450
	PV		all from same
K^{*0}	χ^2_{vtx}/ndf		< 10
	VS	mm	> 2

TABLE 4.1.34. *Final selection applied in the $D^0 \to K^0_S h^\pm h^\mp$ line in TCK* `0x00790038`.

GEC	Forward tracks		< 110
D^0	χ^2_{vtx}/ndf		< 20
	p_T	MeV/c	> 2000
	τ	ps	> 0.2
	DIRA		> 0
	$\lvert M(p^\mu_{K^0_S} + p^\mu_{K^{*0}}) - M_{D^0}\rvert$	MeV/c^2	< 100
	HLT1 TOS		`Hlt1Track.*`

TABLE 4.1.35. *Selection requirements applied in the $\Lambda_c^\pm \to K^\mp p^\pm \pi^\pm$ HLT2 line in TCK* `0x00790038`.

GEC	Forward tracks		< 120
$K^\mp, p^\pm, \pi^\pm$	Track χ^2/ndf		< 3
	p_T	MeV/c	> 500
	χ^2_{IP}		> 9
$p^\pm$ only	p	MeV/c	> 10000
	PIDp		> 0
	PIDp − PIDK		> 0
$\Lambda_c^\pm$	χ^2_{vtx}/ndf		< 15
	p_T	MeV/c	> 2500
	χ^2_{VS}		> 16
	DIRA		> 0.99985
	$M(\sum p^\mu)$	MeV/c^2	$[2150, 2430]$
	HLT1 TOS		`Hlt1Track.*`

TABLE 4.1.36. *Decay descriptors in the charm minimum bias HLT2 lines in TCK `0x00790038`.*

`Hlt2CharmHadMinBiasD02KK`	`[D0 -> K- K+]cc`
`Hlt2CharmHadMinBiasD02KPi`	`[D0 -> K- pi+]cc`

`Hlt2CharmHadMinBiasDplus2hhh`	`[D+ -> pi- pi+ pi+]cc`
	`[D+ -> K- K+ pi+]cc`
	`[D+ -> K- pi+ pi+]cc`
	`[D+ -> K+ pi+ pi-]cc`

`Hlt2CharmHadMinBiasLambdaC2KPPi`	`[Lambda_c+ -> K- p+ pi+]cc`
`Hlt2CharmHadMinBiasLambdaC2LambdaPi`	`[Lambda_c+ -> Lambda0 pi+]cc`

TABLE 4.1.37. *Selection requirements applied in the 2- and 3-hadron charm minimum bias HLT2 lines in TCK `0x00790038`. The mass cut from the `Hlt2CharmHadMinBiasLambdaC2KPPi` line is shown in parentheses.*

			2-h	3-h
$h^{\pm}$	Track χ^2/ndf		< 3	< 4
	χ^2_{IP}		–	> 4
	p_{T}	MeV/c	> 800	> 300
c-hadron	χ^2_{vtx}/ndf		< 15	< 20
	p_{T}	MeV/c	> 2000	> 2500
	DIRA		> 0.9998	> 0.9999
	χ^2_{VS}		–	> 16
	τ	ps	> 0.15	–
	$M(\sum p^{\mu})$	MeV/c^2	$[1715, 2015]$	$[1765, 2065]$ ($[2150, 2430]$)

TABLE 4.1.38. *Selection requirements applied in the `Hlt2CharmHadMinBiasLambdaC2LambdaPi` HLT2 line in TCK `0x00790038`.*

Λ^0 children	Track χ^2/ndf		< 5
	χ^2_{IP}		> 36
	p_{T}	MeV/c	> 500
Λ^0	χ^2_{vtx}/ndf		< 20
	$\lvert M - m_{\Lambda^0}\rvert$	MeV/c^2	< 20
Bachelor π	Track χ^2/ndf		< 4
	p_{T}	MeV/c	> 300
	χ^2_{IP}		> 4
$\Lambda_c^\pm$	χ^2_{vtx}/ndf		< 20
	p_{T}	MeV/c	> 2500
	DIRA		> 0.9999
	χ^2_{VS}		> 16
	$M(p^\mu_{\pi^\pm} + p^\mu_{\Lambda^0})$	MeV/c^2	$[2150, 2430]$

TABLE 4.1.39. *Selection requirements applied in the $D^0 \to \mu^+\mu^-$ HLT2 line in TCK `0x00790038`.*

$\mu^\pm$	Track `IsMuon`		True
	p_{T}	MeV/c	> 1000
	χ^2_{IP}		> 4
D^0	χ^2_{vtx}/ndf		< 25
	τ	ps	> 0.1
	$\lvert M(\sum p^\mu) - m_{D^0}\rvert$	MeV/c^2	< 100

TABLE 4.1.40. *Pre- and postscales of the $D^\pm \to \mu^+\mu^- h$ HLT2 lines in TCK `0x00790038`.*

	Prescale	Postscale
`Hlt2CharmSemilepD2HMuMu`	1	1
`Hlt2CharmSemilepD2HMuMuWideMass`	0.1	1

TABLE 4.1.41. *Selection requirements applied in the `Hlt2CharmSemilepTwoMuonForMuMuHad` configurable in TCK `0x00790038`.*

Decay descriptors	`J/psi(1S) -> mu+ mu-`
	`phi(1020) -> mu+ mu+`
	`rho(770)0 -> mu- mu-`		

$\mu^{\pm}$	Track χ^2/ndf		< 5
	p_{T}	MeV/c	> 500
	p	MeV/c	> 5000
	χ^2_{IP}		> 2
$\mu^+\mu^-$ combination	DOCA	mm	< 0.1
	$\sum p_{\mathrm{T}}$	MeV/c	> 0
	$M(\sum p^{\mu})$	MeV/c^2	< 2100
	PV		all from same
Dimuon object	VS	mm	> 0
	χ^2_{VS}		> 20
	$M_{\mathrm{corrected}}$	MeV/c	< 3500

TABLE 4.1.42. *Selection requirements applied in the $D^{\pm} \to \mu\mu h$ HLT2 lines in TCK `0x00790038`. Selection requirements applied in the monitoring lines (when needed) are shown in parentheses.*

Decay descriptors			`D+ -> J/psi(1S) pi+`
			`D- -> J/psi(1S) pi-`
			`D+ -> J/psi(1S) K+`
			`D- -> J/psi(1S) K-`
			`D+ -> phi(1020) pi-`
			`D- -> rho(770)0 pi+`
			`D+ -> phi(1020) K-`
			`D- -> rho(770)0 K+`

$h^{\pm}$	Track χ^2/ndf		< 5
	p_{T}	MeV/c	> 300
	p	MeV/c	> 2500
	χ^2_{IP}		> 0
$(2\text{-}\mu)h^{\pm}$ combination	Min DOCA	mm	< 0.1
	Max DOCA	mm	< 0.25
	$\sum p_{\mathrm{T}}$	MeV/c	> 1500
	Largest child p_{T}	MeV/c	> 0
	$\sum \sqrt{\chi^2_{\mathrm{IP}}}$		> 15
	Largest child χ^2_{IP}		> 9
	PV		all from same
$D^{\pm}$	χ^2_{vtx}/ndf		< 20
	χ^2_{IP}		< 36
	DIRA		> 0.9998
	χ^2_{VS}		> 20
	$M_{\mathrm{corrected}}$	MeV/c^2	< 3500
	M	MeV/c^2	$[1800, 2050]$ $([1700, 2100])$

TABLE 4.1.43. *Pre- and postscales of the $D^0 \to \mu^+\mu^-h^+h^-$ HLT2 lines in TCK `0x00790038`.*

	Prescale	Postscale
`Hlt2CharmSemilepD02HHMuMu`	1	1
`Hlt2CharmSemilepD02HHMuMuWideMass`	0.1	1
`Hlt2CharmSemilepD02HHMuMuHardHadronsAndMuons`	1	1
`Hlt2CharmSemilepD02HHMuMuHardHadronsAndMuonsWideMass`	0.1	1
`Hlt2CharmSemilepD02HHMuMuHardHadronsSoftMuons`	1	1
`Hlt2CharmSemilepD02HHMuMuHardHadronsSoftMuonsWideMass`	0.1	1

TABLE 4.1.44. *Selection requirements applied in the* `Hlt2CharmSemilepTwoHadForMuMuHH` *configurable in TCK* `0x00790038`.

Decay descriptors	`K*(892)0 -> pi+ pi-` `K*(892)0 -> K+ K-`		
$h^{\pm}$	Track χ^2/ndf		< 5
	p_{T}	MeV/c	> 500
	p	MeV/c	> 5000
	χ^2_{IP}		> 4
$h^{+}h^{-}$ combination	DOCA	mm	< 0.12
	$\sum p_{\mathrm{T}}$	MeV/c	> 0
	$M(\sum p^{\mu})$	MeV/c^2	< 2100
K^{*0}	VS		> 0
	χ^2_{VS}		> 20
	$M_{\mathrm{corrected}}$	MeV/c^2	< 3500

TABLE 4.1.45. *Selection requirements applied in the* `Hlt2CharmSemilep2Had1MuForHHMuMu` *configurable in TCK* `0x00790038`.

Decay descriptors	`D+ -> K*(892)0 mu+` `D- -> K*(892)0 mu-`		
$\mu^{\pm}$	Track χ^2/ndf		< 8
	p_{T}	MeV/c	> 500
	p	MeV/c	> 5000
	χ^2_{IP}		> 0
$K^{*0}\mu^{\pm}$ combination	Largest child p_{T}	MeV/c	> 0
	$\sum p_{\mathrm{T}}$	MeV/c	> 0
	Min DOCA	mm	< 0.12
	Max DOCA	mm	< 0.25
	PV		all from same
$D^{\pm}$	χ^2_{vtx}/ndf		< 30
	χ^2_{VS}		> 20
	$\sum_{K,\pi,\mu}\sqrt{\chi^2_{\mathrm{IP}}}$		> 10
	$M_{\mathrm{corrected}}$	MeV/c^2	< 3500
	M	MeV/c^2	$[0, 1950]$

TABLE 4.1.46. *Selection requirements applied in the $D^0 \to \mu^+\mu^-h^+h^-$ HLT2 lines in TCK `0x00790038`, where* bachelor particle(s) *refers to those particles that have not been used to build an intermediate resonance, i.e., two hadrons (`Hlt2BiKalmanFitted(SecondLoop|)(Kaons|Pions)`), two muons (`Hlt2BiKalmanFittedMuons`) and one muon (`Hlt2BiKalmanFitted(SecondLoop|)Muons`). Selection requirements applied in the monitoring lines (when needed) are shown in parentheses.*

			$D^0 \to J/\psi\, h^+h^-$	$D^0 \to K^{*0}\mu^+\mu^-$	$D^0 \to D^+\mu^-$
Bachelor particle(s)	Track χ^2/ndf		< 5	< 5	< 10
	p_{T}	MeV/c	> 300	> 500	> 250
	p	MeV/c	> 2500	> 5000	> 2500
	χ^2_{IP}			> 0	
D^0 combination	Largest child p_{T}	MeV/c		> 0	
	$\sum p_{\text{T}}$	MeV/c	> 2500	> 0	> 0
	Min DOCA	mm	< 0.1	< 0.15	< 0.5
	Max DOCA	mm	< 0.2	< 0.25	< 0.5
	$\sum \sqrt{\chi^2_{\text{IP}}}$		> 12	> 10	> 10
	$M(\sum p^{\mu})$	MeV/c^2		< 2100	
D^0	χ^2_{vtx}/ndf		< 20	< 20	< 50
	χ^2_{IP}		< 36	< 36	< 50
	DIRA		> 0.9998	> 0.9996	> 0.9996
	χ^2_{VS}		> 25	> 20	> 20
	$M_{\text{corrected}}$	MeV/c^2		< 3500	
	M	MeV/c^2		$[1800, 1950]$ $([1700, 2100])$	

TABLE 4.1.47. *Pre- and postscales of the $D^0 \to \mu^+ h^- \nu$ HLT2 lines in TCK* `0x00790038`.

	Prescale	Postscale
`Hlt2CharmSemilepD02HMuNu_D02KMuNu`	0.05	1
`Hlt2CharmSemilepD02HMuNu_D02KMuNuTight`	1	1
`Hlt2CharmSemilepD02HMuNu_D02KMuNuWS`	0.01	1
`Hlt2CharmSemilepD02HMuNu_D02PiMuNu`	0.05	1
`Hlt2CharmSemilepD02HMuNu_D02PiMuNuWS`	0.01	1

TABLE 4.1.48. *Selection requirements applied in the $D^0 \to \mu^+ h^- \nu$ (non-tight) HLT2 lines in TCK* `0x00790038`.

Trigger requirements	L0 filter		`L0Muon` or `L0Hadron`
$\mu^\pm$	Track χ^2/ndf		< 3
	p_{T}	MeV/c	> 800
$h^\mp$	Track χ^2/ndf		< 3
	p_{T}	MeV/c	> 600
$\mu^+ h^-$ combination	DOCA	mm	< 0.07
	$\sum p_{\mathrm{T}}$	MeV/c	> 2800
	$p(\sum p^\mu)$	MeV/c	> 20000
	$M(\sum p^\mu)$	MeV/c^2	< 1900
	PV		all from same
D^0	χ^2_{vtx}/ndf		< 10
	VS$_z$	mm	> 0
	VS	mm	> 4
	$M_{\mathrm{corrected}}$	MeV/c^2	$[1400, 2700]$
	HLT1 TOS		`Hlt1TrackMuon`

TABLE 4.1.49. *Selection requirements applied in the `Hlt2CharmSemilepD02HMuNu_D02KMuNuTight` HLT2 line in TCK `0x00790038`.*

Trigger requirements	L0 filter		`L0Muon` or `L0Hadron`
$\mu^{\pm}$	Track χ^2/ndf		< 3
	p_{T}	MeV/c	> 800
$K^{\mp}$	Track χ^2/ndf		< 3
	p_{T}	MeV/c	> 600
$\mu^{+}K^{-}$ combination	DOCA	mm	< 0.07
	$\sum p_{\mathrm{T}}$	MeV/c	> 1500
	$p(\sum p^{\mu})$	MeV/c	> 20000
	$M(\sum p^{\mu})$	MeV/c^2	< 1900
	PV		all from same
D^0	χ^2_{vtx}/ndf		< 10
	VS$_z$	mm	> 0
	VS	mm	> 10
	$M_{\mathrm{corrected}}$	MeV/c^2	$[1400, 2700]$
	HLT1 TOS		`Hlt1TrackMuon`
Slow π	Track χ^2/ndf		< 100
	p_{T}	MeV/c	> 300
	p	MeV/c	> 3000
$D^0\pi^{\pm}$ combination	DOCA	mm	< 120
	PV		all from same
$D^{*\pm}$	$M_{D^{*\pm}} - M_{D^0}$	MeV/c^2	$[0, 250]$

TABLE 4.1.50. *Pre- and postscales of the $D^{*+} \to \pi^+ D^0(\to h_1^+ h_2^-)$ HLT2 lines in TCK `0x00790038`.*

	Prescale	Postscale
`Hlt2Dst2PiD02KMu`	0.15	1
`Hlt2Dst2PiD02KPi`	0.01	1
`Hlt2Dst2PiD02MuMu`	1	1
`Hlt2Dst2PiD02PiPi`	0.03	1

TABLE 4.1.51. *Selection requirements applied in the $D^{*+} \to \pi^+ D^0(\to h_1 h_2)$ HLT2 lines in TCK* `0x00790038`. *The different mass cut applied for the $D^0 \to \mu^+\mu^-$ line is shown in a parentheses.*

$h^\pm$	Track χ^2/ndf		< 5
	p	MeV/c	> 4000
	p_T	MeV/c	> 750
	χ^2_{IP}		> 3
$h_1^+ h_2^-$ combination	DOCA	mm	< 1
	Largest child p_T	MeV/c	> 1100
	Largest child χ^2_{IP}		> 8
	$\sum p_T$	MeV/c	> 1800
	$\lvert M(\sum p^\mu) - m_{D^0}\rvert$	MeV/c^2	< 70 (< 300)
D^0	χ^2_{vtx}/ndf		< 10
	χ^2_{IP}		< 15
	DIRA		> 0.9997
	χ^2_{VS}		> 20

TABLE 4.1.52. *Decay descriptors used for building the different $D^0 \to h_1 h_2$ candidates in the $D^{*+} \to \pi^+(D^0 \to h_1 h_2)$ HLT2 lines in TCK* `0x00790038`.

`Hlt2Dst2PiD02KMu`	`D0 -> K- mu+` `D0 -> K+ mu-`
`Hlt2Dst2PiD02KPi`	`D0 -> K- pi+` `D0 -> K+ pi-`
`Hlt2Dst2PiD02MuMu`	`D0 -> mu+ mu-`
`Hlt2Dst2PiD02PiPi`	`D0 -> pi+ pi-`

TABLE 4.1.53. *Selection requirements applied in the dielectron HLT2 lines (denoted without the* `Hlt2DiElectron` *prefix) in TCK* `0x00790038`.

			`B`	`HighMass`
Trigger	L0 filter		`L0Electron`	
	HLT1 filter		`Hlt1(Track|.*Electron)`	
Electron	Track χ^2/ndf		< 10	
	p_T	MeV/c	> 1000	> 10000
	PID cuts		PIDe> 1.5	$E_{PS} > 50$ MeV $E_{ECAL}/p > 0.1$ $E_{HCAL}/p < 0.05$
Dielectron	χ^2_{vtx}/ndf		< 25	
	p_T	MeV/c	> -999	
	M	GeV/c^2	$[10, 10^7]$	> 20

TABLE 4.1.54. *Pre- and postscales of the unbiased dimuon HLT2 lines in TCK `0x00790038`.*

	Prescale	Postscale
`Hlt2DiMuonJPsi`	0.2	1
`Hlt2DiMuonJPsiHighPT`	1	1
`Hlt2DiMuonPsi2S`	0.1	1
`Hlt2DiMuonPsi2SHighPT`	1	1
`Hlt2DiMuonB`	1	1
`Hlt2DiMuonDY1`	0.005	1
`Hlt2DiMuonDY2`	0.03	1
`Hlt2DiMuonDY3`	1	1
`Hlt2DiMuonDY4`	1	1
`Hlt2DiMuonZ`	1	1

TABLE 4.1.55. *Selection requirements applied in the unbiased dimuon HLT2 lines (denoted with the `Hlt2DiMuon` prefix for clarity) in TCK `0x00790038`.*

	Muon		Dimuon		
	Track χ^2/ndf	p_{T} [MeV/c]	χ^2_{vtx}/dof	p_{T} [MeV/c]	M [MeV/c^2]
`JPsi`	< 5	> 0	< 25	> 0	$[m_{J/\psi} - 120, m_{J/\psi} + 120]$
`JPsiHighPT`				> 2000	$[m_{J/\psi} - 100, m_{J/\psi} + 100]$
`Psi2S`	< 5	> 2000	< 25	> 0	$[m_{\psi(2S)} - 100, m_{\psi(2S)} + 100]$
`Psi2SHighPT`				> 3500	
`B`	< 5	–	< 10	–	> 4700
`DY1`	< 10	> 800	–	–	> 2500 and $\notin [3000, 3200]$
`DY2`	< 10	> 1000	–	–	> 5000
`DY3`	< 10	–	–	–	> 10000
`DY4`	< 10	–	–	–	> 20000
`Z`	–	–	–	–	> 40000

TABLE 4.1.56. *Selection requirements applied in the detached dimuon HLT2 lines in TCK `0x00790038`.*

<table>
<tr><th></th><th></th><th></th><th><code>Hlt2DiMuonDetached</code></th><th><code>Hlt2DiMuonDetachedHeavy</code></th><th><code>Hlt2DiMuonDetachedJPsi</code></th></tr>
<tr><td rowspan="3">Muon</td><td>Track χ^2/ndf</td><td></td><td colspan="3">< 5</td></tr>
<tr><td>χ^2_{IP}</td><td></td><td>> 9</td><td>–</td><td>–</td></tr>
<tr><td>p_{T}</td><td>MeV/c</td><td colspan="2">> 500</td><td>–</td></tr>
<tr><td rowspan="4">Dimuon</td><td>χ^2_{vtx}/ndf</td><td></td><td colspan="3">< 25</td></tr>
<tr><td>p_{T}</td><td>MeV/c</td><td>> 1500</td><td>> 0</td><td>–</td></tr>
<tr><td>VS/σ_{VS}</td><td></td><td>> 7</td><td>> 5</td><td>> 3</td></tr>
<tr><td>M</td><td>MeV/c^2</td><td>> 1000</td><td>> 2950</td><td>$[m_{J/\psi} - 120, m_{J/\psi} + 120]$</td></tr>
</table>

TABLE 4.1.57. *Requirements applied on the particle objects used in the multimuon HLT2 lines in TCK `0x00790038`.*

	Track type	Track χ^2/ndf	χ^2_{IP}	p_{T} [MeV/c]
`GoodMuon`	`BiKalmanFittedMuons`	< 6	> 16	–
`TightMuon`	`BiKalmanFittedMuons`	< 6	> 36	> 1400
`GoodKaon`	`BiKalmanFittedKaons`	< 6	> 9	–
`GoodPion`	`BiKalmanFittedPions`	< 6	> 9	–
`GoodProton`	`BiKalmanFittedProtons`	< 6	> 9	–

TABLE 4.1.58. *Selection requirements applied in the `Hlt2TriMuonTau` HLT2 line in TCK `0x00790038`.*

$\mu^+\mu^+\mu^-$ combination	Largest muon p_{T}	MeV/c	> 1000
	$M(p^{\alpha}_{\mu^+_1} + p^{\alpha}_{\mu^+_2})$	MeV/c^2	$> 2m_{\mu} + 3$
	$\lvert M(\sum p^{\mu}) - m_{\tau}\rvert$	MeV/c^2	< 300
Trimuon object	χ^2_{vtx}		< 25
	$c\tau$	μm	> 45

TABLE 4.1.59. *Requirements applied when building a `DiMuon` object from `TrackFittedDiMuon` in the dimuon + charm HLT2 lines in TCK `0x00790038`.*

χ^2_{vtx}		< 12
p_{T}	MeV/c	> 1200
M	MeV/c^2	$[m_{J/\psi} - 110, m_{J/\psi} + 110] \cup [m_{\psi(2S)} - 110, m_{\psi(2S)} + 110] \cup [5000, \infty]$

TABLE 4.1.60. *Requirements applied when building the good (up) and buggy (down) charm objects for the dimuon + charm HLT2 lines in TCK* `0x00790038`*. Entries marked in red are suspected bugs.*

			D^0	D^+
Decay descriptor			`[D0 -> K- pi+]cc`	`[D+ -> K- pi+ pi+]cc`
D combination	$p_T(\sum p^\mu)$	MeV/c	> 2500	
	$\lvert M(\sum p^\mu) - m_D \rvert$	MeV/c^2	< 65	
D meson	χ^2_{vtx}		< 30	
	$c\tau$	µm	> 100	

			D_s^+	Λ_c^+
Decay descriptor			`[D_s+ -> K- K+ pi+]cc`	`[Lambda_c+ -> p+ K- pi+]cc`
c-hadron combination	$p_T(\sum_{children} p^\mu)$	MeV/c	> 2500	
	$M(p^\mu_{K^+} + p^\mu_{K^-})$	MeV/c	< 1040	–
	$M(\sum p^\mu)$	MeV/c^2	$[m_{D^+} - 65, m_{D_s^+} - 65]$	$[m_{D^+} - 65, m_{D^+} + 65]$
c-hadron	χ^2_{vtx}		< 30	
	$c\tau$	µm	> 100	

TABLE 4.1.61. *Decay descriptors used in the dimuon + charm HLT2 lines in TCK* `0x00790038`.

`Hlt2DiMuonAndD0`	`[chi_b2(1P) -> J/psi(1S) D0]cc`
`Hlt2DiMuonAndDp`	`[chi_b2(2P) -> J/psi(1S) D+]cc`
`Hlt2DiMuonAndDs`	`[chi_b2(2P) -> J/psi(1S) D_s+]cc`
`Hlt2DiMuonAndLc`	`[chi_b2(2P) -> J/psi(1S) Lambda_c+]cc`

TABLE 4.1.62. *Selection requirements applied in the diproton HLT2 lines in TCK* `0x00790038`.

			`Hlt2DiProton`	`Hlt2DiProtonLowMult`
Trigger	L0 `SPDMult`		< 300	< 20
	HLT1 line		`Hlt1DiProton`	`Hlt1DiProtonLowMult`
$p^{\pm}$	Track χ^2/ndf		< 4	< 5
	p_{T}	MeV/c	> 1900	> 500
	PIDp		> 20.0	> 10.0
	PIDp-PIDK		> 10.0	–
$p^{+}p^{-}$ combination	$\sum p_{\mathrm{T}}$	MeV/c	> 6300	–
	$M(\sum p^{\mu})$	MeV/c^2	$[2750, 4100]$	> 2800
Diproton	χ^2_{vtx}/ndf		< 9	
	p_{T}	MeV/c	> 6500	–
	M	MeV/c^2	$[2800, 4000]$	> 2800

TABLE 4.1.63. *Pre- and postscales of the displaced vertices HLT2 lines in TCK* `0x00790038`.

	Prescale	Postscale
`Hlt2DisplVerticesDouble`	1	1
`Hlt2DisplVerticesDoublePostScaled`	1	0.01
`Hlt2DisplVerticesHighVSSingle`	1	1
`Hlt2DisplVerticesHighMassSingle`	1	1
`Hlt2DisplVerticesSingle`	1	1
`Hlt2DisplVerticesSingleDown`	1	1
`Hlt2DisplVerticesSingleHighFDPostScaled`	1	1
`Hlt2DisplVerticesSingleHighMassPostScaled`	1	1
`Hlt2DisplVerticesSingleMVPostScaled`	1	0.0006
`Hlt2DisplVerticesSinglePostScaled`	1	0.0001

TABLE 4.1.64. *Configuration of `PatPV3D` for the displaced vertices HLT2 lines in TCK `0x00790038`.*

`PVSeed3DTool`	DOCA with any other track	mm	< 0.2
	Seed radius	mm	< 1
	Number of tracks per seed		≥ 3
`LSAdaptPV3DFitter`	Track IP to seed	mm	< 2
	Number of tracks per vertex		≥ 4

TABLE 4.1.65. *Requirements applied on the `Hlt2SelDV` selection for the one-prey displaced vertices HLT2 lines (denoted without the `Hlt2DisplVertices` prefix for legibility reasons) in TCK `0x00790038`.*

<table>
<tr><th></th><th></th><th>HighVSSingle</th><th>HighMassSingle</th><th>Single</th><th>SingleDown</th></tr>
<tr><td>Number of candidates</td><td></td><td colspan="4">≥ 1</td></tr>
<tr><td>Number of RV children</td><td></td><td>≥ 5</td><td>≥ 6</td><td>≥ 5</td><td>≥ 4</td></tr>
<tr><td>Prey mass</td><td>GeV/c^2</td><td>$[4.5, 14000.0]$</td><td>$[10.0, 14000.0]$</td><td>$[7.0, 14000.0]$</td><td>$[3.0, 14000.0]$</td></tr>
<tr><td>Mass of heaviest prey</td><td>GeV/c^2</td><td colspan="4">> 0.0</td></tr>
<tr><td>$\sum_{\text{children}} p_{\mathrm{T}}$</td><td>$\mathrm{GeV}/c^2$</td><td colspan="4">$[3.0, 14000.0]$</td></tr>
<tr><td>Prey angle wrt PV</td><td>rad</td><td colspan="4">> 0</td></tr>
<tr><td>Prey z</td><td>mm</td><td>$[-10000.0, 100000.0]$</td><td>$[-10000.0, 100000.0]$</td><td>$[-10000.0, 100000.0]$</td><td>$[200.0, 100000.0]$</td></tr>
<tr><td>Prey VS</td><td>mm</td><td colspan="4">> 0</td></tr>
<tr><td>Radial distance to PV</td><td>mm</td><td>$[4.0, 10000.0]$</td><td>$[0.4, 10000.0]$</td><td>$[2.5, 10000.0]$</td><td>$[2.0, 10000.0]$</td></tr>
<tr><td>σ_z</td><td></td><td colspan="4">> 1000</td></tr>
<tr><td>σ_r</td><td></td><td colspan="4">> 1000</td></tr>
</table>

<table>
<tr><th></th><th></th><th>SingleHighFDPostScaled</th><th>SingleHighMassPostScaled</th><th>SingleMVPostScaled</th><th>SinglePostScaled</th></tr>
<tr><td>Number of candidates</td><td></td><td colspan="4">≥ 1</td></tr>
<tr><td>Number of RV children</td><td></td><td>≥ 5</td><td>≥ 4</td><td>≥ 4</td><td>≥ 4</td></tr>
<tr><td>Prey mass</td><td>GeV/c^2</td><td>$[4.5, 14000.0]$</td><td>$[10.0, 14000.0]$</td><td>$[3.0, 14000.0]$</td><td>$[3.0, 14000.0]$</td></tr>
<tr><td>Mass of heaviest prey</td><td>GeV/c^2</td><td colspan="4">> 0.0</td></tr>
<tr><td>$\sum_{\text{children}} p_{\mathrm{T}}$</td><td>$\mathrm{GeV}/c^2$</td><td colspan="4">$> 14000.0$</td></tr>
<tr><td>Prey angle wrt PV</td><td>rad</td><td colspan="4">> 0</td></tr>
<tr><td>Prey z</td><td>mm</td><td>$[-10000.0, 100000.0]$</td><td>$[-10000.0, 100000.0]$</td><td>$[-10000.0, 100000.0]$</td><td>$[-10000.0, 100000.0]$</td></tr>
<tr><td>Prey VS</td><td>mm</td><td colspan="4">> 0</td></tr>
<tr><td>Radial distance to PV</td><td>mm</td><td>$[2.0, 10000.0]$</td><td>$[0.4, 10000.0]$</td><td>$[0.4, 10000.0]$</td><td>$[0.4, 10000.0]$</td></tr>
<tr><td>σ_z</td><td></td><td colspan="4">> 1000</td></tr>
<tr><td>σ_r</td><td></td><td colspan="4">> 1000</td></tr>
</table>

TABLE 4.1.66. *Requirements applied on the `Hlt2SelDV` selection for the two-prey displaced vertices HLT2 lines (denoted without the `Hlt2DisplVertices` prefix for legibility reasons) in TCK `0x00790038`.*

		`Double`	`DoublePostScaled`
Number of candidates		≥ 2	
Prey mass	GeV/c^2	$[3.0, 14000.0]$	
Mass of heaviest prey	GeV/c^2	> 4.5	> 0.0
$\sum_{\text{children}} p_{\text{T}}$	GeV/c^2	> 14000.0	
Prey angle wrt PV	rad	> 0	
Prey z	mm	$[-10000.0, 100000.0]$	
Prey VS	mm	> 0	
Radial distance to PV	mm	$[0.4, 10000.0]$	
σ_z		> 1000	
σ_r		> 1000	

TABLE 4.1.67. *Pre- and postscales of the Express HLT2 lines in TCK `0x00790038`.*

	Prescale	Postscale
`Hlt2ExpressBeamHalo`	1	1 Hz
`Hlt2ExpressJPsi`	1	5 Hz
`Hlt2ExpressJPsiTagProbe`	1	5 Hz
`Hlt2ExpressLambda`	1	1 Hz
`Hlt2ExpressDStar2D0Pi`	1	1 Hz
`Hlt2ExpressDs2PhiPi`	1	1 Hz
`Hlt2ExpressKS`	1	1 Hz

TABLE 4.1.68. *Configuration of the `PatVeloAlignTrackFilter` algorithm for the `Hlt2ExpressBeamHalo` line in TCK `0x00790038`.*

Number of hits	$[20, 5000]$
Number of hits per cell	$[10, 100]$
Number of bins in r	36
Number of bins in ϕ	36
Minimum hits per r slice	10
Maximum number of hits per sensor	25

TABLE 4.1.69. *Requirements applied in building $J/\psi \to \mu^+\mu^-$ candidates in the `Hlt2ExpressJPsi` line in TCK `0x00790038`.*

$\mu^+\mu^-$ combination	Smallest μ p_{T}	MeV/c	> 500
J/ψ	$\chi^2_{\text{vtx}}/\text{ndf}$		< 25
	p_{T}	MeV/c	> 1000
	$\lvert M - m_{J/\psi}\rvert$	MeV/c^2	< 120

TABLE 4.1.70. *Selection requirements applied in the `Hlt2ExpressJPsiTagProbe` line in TCK `0x00790038`.*

$\mu^\pm, \pi^\mp$	Track χ^2/ndf		< 3
	χ^2_{IP}		> 15
	p	MeV/c	> 3000
	p_{T}	MeV/c	> 800
Tag particle	χ^2_{IP}		> 25
	p	MeV/c	> 6000
	p_{T}	MeV/c	> 1500
J/ψ	χ^2_{vtx}/ndf		< 5
	χ^2_{VS}		> 225
	$\lvert M(\sum p^\mu) - m_{J/\psi}\rvert$	MeV/c^2	< 200

TABLE 4.1.71. *Selection requirements applied in the `Hlt2ExpressLambda` line in TCK `0x00790038`.*

$p^\pm, \pi^\mp$	Track χ^2/ndf		< 5
	Track type		Long
	χ^2_{IP}		> 25
	p	MeV/c	> 2000
Λ^0	χ^2_{vtx}		< 9
	Vertex z	mm	< 2200
	χ^2 of lifetime fit		< 36
	$c\tau$	mm	> 5
	$\lvert M(p \text{ as } \pi) - m_{K^0_{\text{S}}}\rvert$	MeV/c^2	> 20
	$\lvert M - m_{\Lambda^0}\rvert$	MeV/c^2	< 25

TABLE 4.1.72. *Selection requirements applied in the `Hlt2ExpressDs2PhiPi` line in TCK `0x00790038`.*

$K^\pm$	χ^2_{IP}		> 1
	p	MeV/c	> 1000
	p_{T}	MeV/c	> 300
ϕ	χ^2_{IP}		> 2.28
	DOCA	mm	< 10
	$\lvert M - m_\phi\rvert$	MeV/c^2	< 50
π^+	χ^2_{IP}		> 12.18
	p	MeV/c	> 1000
	p_{T}	MeV/c	> 300
D_s^+	χ^2_{vtx}		< 12.18
	DIRA		> 0.999
	χ^2_{IP}		< 12.18
	IP	mm	< 0.05
	$\lvert M - m_{D_s^+}\rvert$	MeV/c^2	< 50

TABLE 4.1.73. *Selection requirements applied in the `Hlt2ExpressDStar2D0Pi` line in TCK `0x00790038`.*

D^0 children	χ^2_{IP}		> 6
	p	MeV/c	> 2000
	p_{T}	MeV/c	> 400
D^0	χ^2_{vtx}/ndf		< 10
	p_{T}	MeV/c	> 1000
	DIRA		> 0.9999
	χ^2_{VS}		> 12
	$M - m_{D^0}\|$	MeV/c^2	< 50
Slow π	χ^2_{IP}		> 2
	p_{T}	MeV/c	> 110
D^*	χ^2_{vtx}/ndf		< 15
	p_{T}	MeV/c	> 2200
	$\|M - m_{D^*}\|$	MeV/c^2	< 50
	$M_{D^*} - M_{D^0}$	MeV/c^2	< 155.5

TABLE 4.1.74. *Selection requirements applied in the* `Hlt2ExpressKS` *line in TCK* `0x00790038`.

$\pi^{\pm}$	Track χ^2/ndf		< 5
	p	MeV/c	> 2000
	χ^2_{IP}		> 25
K^0_S	Vertex z	mm	< 2200
	χ^2 of lifetime fit		< 36
	$c\tau$	mm	> 1
	$\lvert M(\pi \text{ as } p) - m_{\Lambda^0}\rvert$	MeV/c^2	> 9
	$\lvert M - m_{K^0_\text{S}}\rvert$	MeV/c^2	< 50

TABLE 4.1.75. *Pre- and postscales of the inclusive ϕ HLT2 lines in TCK* `0x00790038`.

	Prescale	Postscale
`Hlt2IncPhi`	1	1
`Hlt2IncPhiSidebands`	1	0.05

TABLE 4.1.76. *Selection requirements applied in the inclusive ϕ lines in TCK* `0x00790038`. *The cuts corresponding to the monitoring line are shown in parentheses.*

GEC	Forward tracks		< 120
$K^{\pm}$	Track χ^2/ndf		< 5
	χ^2_{IP}		> 6
	p_T	MeV/c	> 800
	PIDK		> 0
ϕ	χ^2_{vtx}/ndf		< 20
	DOCA	mm	< 0.2
	p_T	MeV/c	> 1800
	$\lvert M - m_\phi\rvert$	MeV/c^2	$< 20\,(30)$

TABLE 4.1.77. *Pre- and postscales of the low multiplicity HLT2 lines in TCK* `0x00790038`.

	Prescale	Postscale
`Hlt2diPhotonDiMuon`	1	1
`Hlt2LowMultElectron`	1	1
`Hlt2LowMultElectron_nofilter`	0.05	1
`Hlt2LowMultHadron`	1	1
`Hlt2LowMultHadron_nofilter`	0.01	1
`Hlt2LowMultMuon`	0.1	1
`Hlt2LowMultPhoton`	0.001	1

TABLE 4.1.78. *L0 requirements applied on the 2-track low multiplicity lines in TCK `0x00790038`.*

	L0 requirement
`Hlt2diPhotonDiMuon`	`L0Muon,lowMult` or `L0DiMuon,lowMult`
`Hlt2LowMultElectron.*`	`L0Electron,lowMult` or `L0DiEM,lowMult`
`Hlt2LowMultHadron.*`	`L0DiHadron,lowMult`

TABLE 4.1.79. *Selection requirements applied in the $B_c \to (J/\psi \to \mu^+\mu^-)\mu X$ lines in TCK `0x00790038`. The cut corresponding to the wide J/ψ mass line (`Hlt2TFBc2JpsiMuX`) is shown in parentheses.*

J/ψ	Children p_{T}	MeV/c	> 1200
	$\chi^2_{\mathrm{vtx}}/\mathrm{ndf}$		< 20
	$\lvert M - m_{J/\psi}\rvert$	MeV/c^2	100 (220)
Bachelor μ	p_{T}	MeV/c	> 2000
B_c^+	$\chi^2_{\mathrm{vtx}}/\mathrm{ndf}$		< 25
	p_{T}	MeV/c	> 5000
	$M(p^{\alpha}_{J/\psi} + p^{\alpha}_{\mu})$	MeV/c^2	[3200, 6400]

TABLE 4.1.80. *Pre- and postscales of the inclusive single muon HLT2 lines in TCK `0x00790038`.*

	Prescale	Postscale
`Hlt2SingleMuon`	0.5	1
`Hlt2SingleMuonHighPT`	1	1
`Hlt2SingleMuonLowPT`	0.002	1
`Hlt2SingleMuonVHighPT`	1	1

TABLE 4.1.81. *Selection requirements applied in the inclusive single muon lines (denoted without the `Hlt2Single` prefix for legibility reasons) in TCK `0x00790038`.*

		`Muon`	`MuonLowPT`	`MuonHighPT`	`MuonVHighPT`
p_{T}	MeV/c	> 1300	> 4800	> 10000	> 15000
Track χ^2/ndf		< 2	< 10	–	–
IP	mm	> 0.5	–	–	–
χ^2_{IP}		> 200	–	–	–

TABLE 4.1.82. *Pre- and postscales of the inclusive single electron HLT2 lines in TCK `0x00790038`.*

	Prescale	Postscale
`Hlt2SingleTFElectron`	1	1
`Hlt2SingleElectronTFHighPt`	0.01	1
`Hlt2SingleElectronTFLowPt`	0.001	1
`Hlt2SingleTFVHighPtElectron`	1	1

TABLE 4.1.83. *Selection requirements applied in the inclusive single electron lines (denoted without the `Hlt2Single` prefix for legibility reasons) in TCK `0x00790038`.*

		`TFElectron`	`ElectronTFLowPt`	`ElectronTFHighPt`	`TFVHighPtElectron`
Track χ^2/ndf		< 5	< 5	< 20	< 20
IP	mm	> 0.05	–	–	–
χ^2_{IP}		> -1	–	–	–
p_{T}	MeV/c	> 10000	> 4800	> 10000	> 15000
PID		$\mathrm{PID}_e > 4$		$E_{\mathrm{PS}} > 50$ MeV $E_{\mathrm{ECAL}}/p > 0.1$ $E_{\mathrm{HCAL}}/p < 0.05$	

TABLE 4.1.84. *Pre- and postscales of the technical HLT2 lines in TCK `0x00790038`.*

	Prescale	Postscale
`Hlt2DebugEvent`	0.0001	1.0
`Hlt2ErrorEvent`	1.0	0.01 Hz
`Hlt2Forward`	0.0001	1.0
`Hlt2Global`	1.0	1.0
`Hlt2Lumi`	1.0	1.0
`Hlt2PassThrough`	0.0001	1.0
`Hlt2Transparent`	1.0	1.0

4.2 `0x005A0032`

The `0x005A0032` TCK used a loser requirement in the beamspot ρ in the PV reconstruction, namely $\rho < 0.5$ mm, as discussed in §3.3.

4.2.1 *Line content*

This TCK lacks many of the HLT2 lines that were going to be used later in the year, including charm, dimuon, displaced vertices, low multiplicity and radiative topological, as summarized in Table 4.2.1.

4.2.2 *Prescales*

From the lines present in both TCKs, we can see in Table 4.2.2 that

- in L0, the `NoSPD` channels were less prescaled with respect to the reference;
- in HLT1, the beam gas lines were prescaled to a rate 10 times larger with respect to the reference, while the `NoSPD` lines were even less rate-limited;
- in HLT2, mainly the dimuon and semileptonic charm lines were less prescaled than the reference.

4.2.3 *HLT1 lines*

The differences in HLT1 lines with respect to the reference TCK concern

- the beam gas lines, in which virtually no requirement in PV position was applied in `0x005A0032`; and
- the lack of GEC in all HLT1 lines.

4.2.4 *HLT2 lines*

When comparing the design of the HLT2 lines included in this TCK, several considerations need to be made:

- While all the topological lines—cut- and BBDT-based—are already present in `0x005A0032`, in this TCK V_0 particles are not used as inputs.
- The inclusive ϕ lines in `0x005A0032` lack track HLT1 TOSing as well as GEC, which were added later in order to keep the rate under control.
- In the exclusive radiative lines, the 2010 calorimeter reconstruction is used in `0x005A0032`, in constrast with the reference TCK, where the calorimeter reconstruction based on the L0 objects is included.
- In `0x005A0032`, the `Hlt2CharmHadD02HHHH($|WideMass)` lines were simply building $D^0 \to K^* hh$, while in the reference TCK a $D^{*+} \to D^0\pi^+$ filter, including a slow pion, was added, as explained in Page 20.

The differences in selection criteria for the different HLT2 lines are mainly caused by much looser selections with respect to the reference, and concern

- the $B^0 \to h^+h^-\pi^0$ line, in which a cut on the combination mass was replaced by a cut in the vertexed mass, shown in Table 4.2.3;
- the exclusive radiative lines for $B^0 \to K^{*0}\gamma$ and $B_s^0 \to \phi\gamma$, shown in Table 4.2.4, included a too tight mass window before the vertex fits;
- the $D^0 \to h^+h^-h^+h^-$ lines, looser in `0x005A0032` as shown in Table 4.2.5;
- the $D^0 \to h^+h^-$ lines, as shown in Table 4.2.6;
- the $D \to K_S^0 h$ lines, with $h = K, \pi$ (Table 4.2.7);
- the `Hlt2CharmSemilepTwoMuonForMuMuHadConf` configurable (Table 4.2.8), which is shared by the semileptonic $D^+ \to h^+\mu^+\mu^-$ and $D^0 \to h^+h^-\mu^+\mu^-$ lines (Tables 4.2.9 and 4.2.10);
- the semileptonic $D^0 \to \mu^\pm h^\mp \nu$ lines, shown in Table 4.2.11;
- the `Hlt2DiElectronB` line, where the mass requirement on the dielectron pair is lower with respect to the reference TCK (see Table 4.2.12), allowing to also trigger $B \to e^+e^-$;
- the unbiased dimuon high-p_{T} J/ψ line and $\psi(2S)$ line, where p_{T} and mass windows were adjusted, as shown in Table 4.2.13;
- the unbiased high-mass dimuon lines, summarized in Table 4.2.14; and
- the $\tau^+ \to \mu^+\mu^-\mu^+$ line, with looser cuts detailed in Table 4.2.15.
- the diproton lines, the PID requirements of which were changed (see Table 4.2.16);
- the J/ψ tag and probe line, with differences listed in Table 4.2.17;
- the $B_c^+ \to J/\psi\,\mu X$ lines, which include loose and tight (`Signal`) J/ψ's, shown in Table 4.2.18;

Additionally, there are several lines present in this TCK that are not included in the reference one (or were prescaled to zero):

- The `Hlt2DiMuon` and `Hlt2DiMuonLowMass` lines ran heavily prescaled (see Table 4.2.2), building `J/psi(1S) -> mu+ mu-` from `Hlt2BiKalmanFittedMuons` with requirements shown in Table 4.2.19.
- The `Hlt2DiMuonNoPV` line ran with unit prescales on events passing the `Hlt1NoPVPassThrough` HLT1 line and builds `J/psi(1S) -> mu+ mu-` from `Hlt2BiKalmanFittedMuons` with requirements detailed in Table 4.2.20.
- The diproton track-fitted lines—`Hlt2DiProtonLowMultTF` and `Hlt2DiProtonTF`—were run with a prescale of 0.005, building `J/psi(1S) -> p+p~-` candidates from `Hlt2BiKalmanFittedProtons` on low multiplicity events that have fired the `Hlt1DiProtonLowMult` line; the applied requirements are shown in Table 4.2.21.
- The displaced vertices `Hlt2DisplVerticesLowMassSingle` line ran with unit prescales and configuration detailed in Table 4.2.22.
- The `Hlt2ExpressHLT1Physics` line ran on the output of HLT1 physics lines, `Hlt1(?!Lumi).*`, and was postscaled to a rate of 1 Hz.

TABLE 4.2.1. *Differences in line contents between `0x00790038` and `0x005A0032`. Lines included are marked with a check mark (✓).*

	0x00790038	0x005A0032
L0HighSumETJet	✓	
L0NoPVFlag	✓	
Hlt1CharmCalibrationNoBias	✓	
Hlt1L0HighSumETJet	✓	
Hlt1SingleElectronNoIP	✓	
Hlt1TrackForwardPassThrough	✓	
Hlt1TrackForwardPassThroughLoose	✓	
Hlt2B2HHLTUnbiasedDetached	✓	
Hlt2CharmHadLambdaC2KPPi	✓	
Hlt2CharmHadMinBiasD02KK	✓	
Hlt2CharmHadMinBiasD02KPi	✓	
Hlt2CharmHadMinBiasDplus2hhh	✓	
Hlt2CharmHadMinBiasLambdaC2KPPi	✓	
Hlt2CharmHadMinBiasLambdaC2LambdaPi	✓	
Hlt2CharmSemilepD02HHMuMuHardHadronsAndMuons	✓	
Hlt2CharmSemilepD02HHMuMuHardHadronsAndMuonsWideMass	✓	
Hlt2CharmSemilepD02HHMuMuHardHadronsSoftMuons	✓	
Hlt2CharmSemilepD02HHMuMuHardHadronsSoftMuonsWideMass	✓	
Hlt2CharmSemilepD02HMuNu_D02KMuNuTight	✓	
Hlt2DiMuonAndD0	✓	
Hlt2DiMuonAndDp	✓	
Hlt2DiMuonAndDs	✓	
Hlt2DiMuonAndGamma	✓	
Hlt2DiMuonAndLc	✓	
Hlt2DiMuonAndMuon	✓	
Hlt2DiMuonNoPV		✓
Hlt2DiMuonPsi2SHighPT	✓	
Hlt2DiProtonLowMultTF		✓
Hlt2DiProtonTF		✓
Hlt2DisplVerticesDoublePostScaled	✓	
Hlt2DisplVerticesLowMassSingle		✓
Hlt2DisplVerticesSingle	✓	
Hlt2DisplVerticesSingleHighFDPostScaled	✓	
Hlt2DisplVerticesSingleHighMassPostScaled	✓	
Hlt2DisplVerticesSingleMVPostScaled	✓	
Hlt2DoubleDiMuon	✓	
Hlt2ExpressHLT1Physics		✓
Hlt2LowMultElectron	✓	
Hlt2LowMultElectron_nofilter	✓	
Hlt2LowMultHadron	✓	
Hlt2LowMultHadron_nofilter	✓	
Hlt2LowMultMuon	✓	
Hlt2LowMultPhoton	✓	
Hlt2Lumi	✓	
Hlt2RadiativeTopoPhotonL0	✓	
Hlt2RadiativeTopoTrackTOS	✓	
Hlt2SingleMuonVHighPT	✓	
Hlt2SingleTFElectron	✓	
Hlt2SingleTFVHighPtElectron	✓	
Hlt2TopoRad2BodyBBDT	✓	
Hlt2TopoRad2plus1BodyBBDT	✓	
Hlt2diPhotonDiMuon	✓	

TABLE 4.2.2. *Differences in prescales between `0x00790038` and `0x005A0032`.*

	0x00790038	0x005A0032
L0PhotonNoSPD	0.0001	0.001
L0MuonNoSPD	0.0001	0.001
L0ElectronNoSPD	0.0001	0.001
L0HadronNoSPD	0.0001	0.001
L0DiHadron,lowMult	0.1	1.0
L0DiMuonNoSPD	0.0001	0.001
Hlt1BeamGasBeam1	2 Hz	20 Hz
Hlt1BeamGasBeam2	2 Hz	20 Hz
Hlt1BeamGasCrossingEnhancedBeam1	2 Hz	20 Hz
Hlt1BeamGasCrossingEnhancedBeam2	2 Hz	20 Hz
Hlt1BeamGasCrossingForcedReco	0.5 Hz	5 Hz
Hlt1BeamGasCrossingParasitic	0.5 Hz	5 Hz
Hlt1BeamGasNoBeamBeam1	0.5 Hz	5 Hz
Hlt1BeamGasNoBeamBeam2	0.5 Hz	5 Hz
Hlt1ErrorEvent	0.01 Hz	1 Hz
Hlt1L0AnyNoSPD	0.01	0.001
Hlt1L0AnyNoSPDRateLimited	1 Hz	100 Hz
Hlt1L0AnyRateLimited	1 Hz	100 Hz
Hlt2B2HHLTUnbiased	0.1	1
Hlt2CharmSemilepD02HMuNu_D02KMuNu	0.05	1
Hlt2CharmSemilepD02HMuNu_D02KMuNuWS	0.01	0.1
Hlt2CharmSemilepD02HMuNu_D02PiMuNu	0.05	1
Hlt2CharmSemilepD02HMuNu_D02PiMuNuWS	0.01	0.1
Hlt2DiMuon	0	0.01
Hlt2DiMuonDY1	0.005	0.05
Hlt2DiMuonDY2	0.03	0.2
Hlt2DiMuonJPsi	0.2	1
Hlt2DiMuonLowMass	0	0.002
Hlt2DiMuonPsi2S	0.1	1
Hlt2DisplVerticesSinglePostScaled	0.0001	0.0006
Hlt2Dst2PiD02KMu	0.15	0.03
Hlt2Dst2PiD02KPi	0.01	0.002
Hlt2Dst2PiD02PiPi	0.03	0.006
Hlt2ErrorEvent	0.01 Hz	1 Hz
Hlt2SingleElectronTFHighPt	0.01	1
Hlt2SingleElectronTFLowPt	0.001	1
Hlt2SingleMuonLowPT	0.002	0.02

TABLE 4.2.3. *Differences in selection requirements in the $B^0 \to h^+h^-\pi^0$ `Hlt2B2HHPi0_Merged` line between `0x00790038` (Table 4.1.10) and `0x005A0032`.*

			0x00790038	0x005A0032
B^0	$M(p^\mu_\rho + p^\mu_{\pi^0})$	MeV/c^2	$[3700, 6900]$	$[4200, 6400]$
	M	MeV/c^2	$[4200, 6400]$	–

TABLE 4.2.4. *Differences in selection requirements in the `Hlt2B(s2Phi|d2Kst)Gamma($|Wide(B|K)Mass)` lines between `0x00790038` (Table 4.1.21) and `0x005A0032`.*

			0x00790038	0x005A0032
Wide K^{*0}	$\lvert M(\sum p^\mu) - m_{K^{*0}}\rvert$	MeV/c^2	< 187.5	< 125
	$\lvert M_{K^{*0}} - m_{K^{*0}}\rvert$	MeV/c^2	< 125	< 100
B meson	$\lvert M(p^\mu_V + p^\mu_\gamma) - m_B\rvert$	MeV/c^2	$< 1500\,(3000)$	$< 1000\,(2000)$
	$\lvert M_B - m_B\rvert$	MeV/c^2	$< 1000\,(2000)$	–

TABLE 4.2.5. *Differences in selection requirements in the `Hlt2CharmHadD02HHHH($|WideMass)` lines between `0x00790038` (Tables 4.1.23 and 4.1.25) and `0x005A0032`.*

			0x00790038	0x005A0032
h_1h_2 combination	$\sum p_{\mathrm{T}}$	MeV/c	> 3000	> 2000
	DOCA	mm	< 0.5	–
D^0	DIRA		> 0.9995	–

TABLE 4.2.6. *Differences in selection requirements in the `Hlt2CharmHadD02HH_D02(PiPi|KK|KPi)($|WideMass)` lines between `0x00790038` (Table 4.1.27) and `0x005A0032`.*

			0x00790038	0x005A0032
$h^\pm$	Track χ^2_{IP}		> 9.0	> 2.0
h^+h^- combination	$M(\sum p^\mu)$	MeV/c^2	$[1715.0, 2065.0]$	$[1715.0, 2015.0]$
D^0	χ^2_{VS}		> 40	> 25
	M in `WideMass`	MeV/c^2	$[1715.0, 2065.0]$	$[1715.0, 2015.0]$

TABLE 4.2.7. *Differences in selection requirements in the `Hlt2CharmHadD2KS0H_D2KS0(Pi|K)` lines between `0x00790038` (Table 4.1.31) and `0x005A0032`.*

			0x00790038	0x005A0032
K_S^0	$\pi^\pm$ track χ^2/ndf		< 5	< 3
	$\pi^\pm$ χ^2_{IP}		> 45	> 90
	$\chi^2_{\mathrm{vtx}}/\mathrm{ndf}$		< 12	< 15
	p_{T}	MeV/c	> 700	> 800
Bachelor $h^\pm$	Track χ^2/ndf		< 4	< 5
	χ^2_{IP}		> 10	> 30
$D^\pm$	$\chi^2_{\mathrm{vtx}}/\mathrm{ndf}$		< 12	< 15
	χ^2_{IP}		< 20	< 25
	$\Delta z(K_S^0, D^\pm)$	mm	> 10	–

TABLE 4.2.8. *Differences in selection requirements in the `Hlt2CharmSemilepTwoMuonForMuMuHadConf` configurable for the $D^+ \to h^+\mu^+\mu^-$ and $D^0 \to h^+h^-\mu^+\mu^-$ lines between `0x00790038` (Table 4.1.41) and `0x005A0032`.*

			0x00790038	0x005A0032
$\mu^\pm$	χ^2_{IP}		> 2	> 4
Dimuon object	VS	mm	> 0.0	> 1.0
	χ^2_{VS}		> 20	> 25

TABLE 4.2.9. *Differences in selection requirements in the `Hlt2CharmSemilepD2HMuMu($|WideMass)` lines between `0x00790038` (Table 4.1.42) and `0x005A0032`. Requirements on the monitoring line are show in parentheses (when needed).*

			`0x00790038`	`0x005A0032`
$h^{\pm}$	p_{T}	MeV/c	> 300	> 350
$(2\text{-}\mu)h^{\pm}$ combination	Max DOCA	mm	< 0.25	< 0.2
	$\sum p_{\mathrm{T}}$	MeV/c	> 1500	> 2000
	Largest child p_{T}	MeV/c	> 0	> 1000
	Children χ^2_{IP}		$\sum \sqrt{\chi^2_{\mathrm{IP}}} > 15.0$	Largest $\chi^2_{\mathrm{IP}} > 9.0$
$D^{\pm}$	$\chi^2_{\mathrm{vtx}}/\mathrm{ndf}$		< 20	< 15
	DIRA		> 0.9998	> 0.9996
	χ^2_{VS}		> 20	> 4
	M	MeV/c^2	$[1800, 2050]$ $([1700, 2100])$	$[1800, 2000]$ $([1700, 2100])$

TABLE 4.2.10. *Differences in selection requirements in the `Hlt2CharmSemilepD02HHMuMu($|WideMass)` lines between `0x00790038` (Table 4.1.46) and `0x005A0032`.*

			0x00790038	0x005A0032
Bachelor particles cuts	p_{T}	MeV/c	> 300	> 350
D^0 combination	Largest child p_{T}	MeV/c	> 0	> 1400
	Children χ^2_{IP}		$\sum\sqrt{\chi^2_{\mathrm{IP}}} > 12.0$	Largest $\chi^2_{\mathrm{IP}} > 9.0$
D^0	$\chi^2_{\mathrm{vtx}}/\mathrm{ndf}$		< 20	< 15
	DIRA		> 0.9998	> 0.9996
	M	MeV/c^2	$[1800, 1950]$ ($[1700, 2100]$)	$[1800, 2000]$ ($[1700, 2100]$)

TABLE 4.2.11. *Differences in selection requirements in the `Hlt2CharmSemilepD02HMuNu_D02(K|Pi)MuNu($|WS)` lines between `0x00790038` (Table 4.1.48) and `0x005A0032`.*

			0x00790038	0x005A0032
$\mu^{\pm}$	p_{T}	MeV/c^2	> 800	> 600
	p	MeV/c^2	–	> 3600
	χ^2_{IP}		–	> 5
$h^{\mp}$	χ^2_{IP}		–	> 5
$\mu \pm h^{\mp}$ combination	DOCA	mm	< 0.07	< 0.08
	$\sum p_{\mathrm{T}}$	MeV/c	> 2800	> 2000
	$p(\sum p^{\mu})$	MeV/c	> 20000	> 18000
	$M(\sum p^{\mu})$	MeV/c^2	< 1900	< 2000
D^0	VS$_z$	mm	> 4.0	> 0.0
	IP	mm	–	> 0.2
	DIRA		–	> 0.9995

TABLE 4.2.12. *Differences in selection requirements in the `Hlt2DiElectronB` line between `0x00790038` (Table 4.1.53) and `0x005A0032`.*

			0x00790038	0x005A0032
Dielectron	M	GeV/c^2	$[10, 10^7]$	$[4.8, 10^7]$

TABLE 4.2.13. *Differences in selection requirements in the `Hlt2DiMuonJPsiHighPT` and `Hlt2DiMuonPsi2S` lines between `0x00790038` (Table 4.1.55) and `0x005A0032`.*

			0x00790038	0x005A0032
`Hlt2DiMuonJPsiHighPT`	Dimuon p_{T}	MeV/c	> 2000	> 3000
	$\lvert M - m_{J/\psi}\rvert$	MeV/c^2	< 100	< 150
`Hlt2DiMuonPsi2S`	Dimuon p_{T}	MeV/c	> 2000	> 0
	$\lvert M - m_{\psi(2S)}\rvert$	MeV/c^2	< 100	< 120

TABLE 4.2.14. *Differences in selection requirements in the `Hlt2DiMuonDY[1-4]` and `Hlt2DiMuonZ` lines between `0x00790038` (Table 4.1.55) and `0x005A0032`.*

			0x00790038	0x005A0032
`Hlt2DiMuonDY[1-4]`	Dimuon p_{T}	MeV/c	–	> 0
`Hlt2DiMuonDY1`	μ track χ^2/ndf		< 10	–
	μ p_{T}	MeV/c	> 800	–
	Dimuon M	MeV/c^2	> 2500 and $\notin [3000, 3200]$	> 2500
`Hlt2DiMuonDY2`	μ p_{T}	MeV/c	> 1000	–

TABLE 4.2.15. *Differences in selection requirements in the `Hlt2TriMuonTau` line between `0x00790038` (Table 4.1.58) and `0x005A0032`.*

			0x00790038	0x005A0032
$\mu^+\mu^+\mu^-$ combination	$\lvert M(\sum p^\mu) - m_\tau \rvert$	MeV/c^2	< 300	< 350
τ	χ^2_{vtx}		< 25	< 30
	$c\tau$	µm	> 45	> 40

TABLE 4.2.16. *Differences in selection requirements in the `Hlt2DiProton($|LowMult)` lines, corresponding to the regular and low multiplicity case, between `0x00790038` (Table 4.1.62) and `0x005A0032`.*

		0x00790038		0x005A0032	
		Regular	`LowMult`	Regular	`LowMult`
$p^\pm$	PIDp	> 20.0	> 10.0	> 10.0	> 10.0
	PIDp-PIDK	> 10.0	–	> 5.0	> 0.0

TABLE 4.2.17. *Differences in selection requirements in the `Hlt2ExpressJPsiTagProbe` line between `0x00790038` (Table 4.1.70) and `0x005A0032`.*

			0x00790038	0x005A0032
$\mu^\pm, \pi^\mp$	Track χ^2/ndf		< 3	–
	χ^2_{IP}		> 15	–
Tag particle	χ^2_{IP}		> 25	–
	ProtoParticle E_{ECAL}	MeV	–	$[-10, 1000]$
	ProtoParticle E_{HCAL}	MeV	–	$[1000, 4000]$
J/ψ	χ^2_{vtx}/ndf		< 20	< 5
	χ^2_{VS}		> 225	–
	$\lvert M(\sum p^\mu) - m_{J/\psi} \rvert$	MeV	< 200	< 300

TABLE 4.2.18. *Differences in selection requirements in the `Hlt2TFBc2JpsiMuX` and `Hlt2TFBc2JpsiMuXSignal` lines between `0x00790038` (Table 4.1.79) and `0x005A0032`. Requirements on the wide mass line are show in parentheses (when needed).*

			0x00790038	0x005A0032
J/ψ	Children p_{T}	MeV/c	> 1200	> 1000
	$\lvert M - m_{J/\psi} \rvert$	MeV/c^2	100 (220)	100 (250)
Bachelor μ	p_{T}	MeV/c	> 2000	> 1200
B_c^+	$M(p^\alpha_{J/\psi} + p^\alpha_\mu)$	MeV/c^2	$[3200, 6400]$	$[3000, 7000]$
	p_{T}	MeV/c	> 5000	> 4000

TABLE 4.2.19. *Selection requirements applied in the prescaled `Hlt2DiMuon` and `Hlt2DiMuonLowMass` lines in TCK `0x005A0032`.*

			Hlt2DiMuon	Hlt2DiMuonLowMass
$\mu^{\pm}$	Track χ^2/ndf		–	< 5
	p_{T}	MeV/c	> 0	
J/ψ	χ^2_{vtx}/ndf		< 25	
	p_{T}	MeV/c	> 0	
	M	MeV/c^2	> 2900	> 500

TABLE 4.2.20. *Selection requirements applied in the `Hlt2DiMuonNoPV` line in TCK `0x005A0032`.*

$\mu^{\pm}$	p_{T}	MeV/c	> 400
$\mu^+\mu^-$ combination	$p_{\mathrm{T}}(\sum p^{\mu})$	MeV/c	< 1500
	$M(\sum p^{\mu})$	MeV/c^2	> 1000

TABLE 4.2.21. *Selection requirements applied in the `Hlt2DiProtonLowMultTF` `Hlt2DiProtonTF` (first column) and `Hlt2DiProtonLowMultTF` (second column) lines in TCK `0x005A0032`.*

			Regular	Low multiplicity
L0	SPD multiplicity		< 300	< 20
$p^{\pm}$	Track χ^2/ndf		< 4	< 5
	p_{T}	MeV/c	> 1900	> 500
J/ψ	χ^2_{vtx}/ndf		< 9	
	p_{T}	MeV/c	> 6500	–
	M	MeV/c^2	$[2800, 4000]$	> 2800

TABLE 4.2.22. *Requirements applied on the `Hlt2SelDV` selection for the `Hlt2DisplVerticesLowMassSingle` in TCK `0x005A0032`.*

Number of candidates		≥ 1
Number of RV children		≥ 6
Prey mass	GeV/c^2	$[4.5, 9.0]$
Mass of heaviest prey	GeV/c^2	> 0.0
$\sum_{\mathrm{children}} p_{\mathrm{T}}$	GeV/c^2	$[3.0, 10.0]$
Prey angle wrt PV	rad	> 0
Prey z	mm	$[-10000.0, 100000.0]$
Prey VS	mm	> 0
Radial distance to PV	mm	$[0.3, 10000.0]$
σ_z		> 1000
σ_r		> 1000

4.3 `0x006D0032`

This TCK is the first to incorporate the GEC used in the reference TCK, but the difference in the beamspot ρ cut in the 3D PV reconstruction still remains (< 0.5 mm versus the < 0.3 mm in `0x00790038`)

4.3.1 Line content

This TCK still lacks many of the lines that would be run in the reference TCK, with a comparison found in Table 4.3.1. With respect to the previous TCK (`0x005A0032`), the HLT1 `Hlt1SingleElectronNoIP` and `Hlt1TrackForwardPassThrough($|Loose)`, and the HLT2 `Hlt2diPhotonDiMuon` and low multiplicity `Hlt2LowMult(Muon|Hadron|Photon|Electron)` lines were introduced, while `Hlt2DiMuonNoPV` was removed.

4.3.2 Prescales

Differences in prescales of the lines present both in this TCK and in the reference TCK are summarized in Table 4.3.2. It can be seen that the prescales of some of the newly introduced lines are different with respect to the reference TCK. With respect to `0x005A0032`, only the $D^* \to \pi D^0$ lines prescales were changed to agree with the reference TCK.

4.3.3 HLT1 lines

The differences in cuts in the HLT1 lines with respect to the reference TCK concern uniquely the beamspot ρ, as stated above.

4.3.4 HLT2 lines

Considerations about the code of the HLT2 lines addressed for `0x005A0032`, *i.e.*, the lack of V_0 in the topological lines, the refinements in the inclusive ϕ , the usage of the old calorimeter reconstruction in the radiative linesand the lack of a $D^{*+} \to D^0\pi^+$ filter for $D^0 \to hhhh$ lines, are still valid. In addition, several considerations need to be made for the newly introduced low multiplicity lines when comparing them to the reference TCK:

- For all of them—`Hlt2LowMult(Muon|Hadron|Photon|Electron)`—the `0x006D0032` TCK lacks the filter for backward tracks.
- The `Hadron`, `Photon` and `Electron` lines also lack the filter on number of VELO tracks.
- The `Photon` line lacks merged and resolved π^0 as input, which were included in the reference TCK.

Differences in HLT2 selection criteria with respect to the reference TCK are the same as in the previous TCK, and are summarized starting in Page 71 and in Tables 4.2.12–4.2.15 (replacing `0x005A0032` by `0x006D0032`). The lines present in this TCK that are not included in the reference one are described in §4.2.4.

TABLE 4.3.1. *Differences in line contents between `0x00790038` and `0x006D0032`. Lines included are marked with a check mark (✓).*

	0x00790038	0x006D0032
L0HighSumETJet	✓	
L0NoPVFlag	✓	
Hlt1CharmCalibrationNoBias	✓	
Hlt1L0HighSumETJet	✓	
Hlt2B2HHLTUnbiasedDetached	✓	
Hlt2CharmHadLambdaC2KPPi	✓	
Hlt2CharmHadMinBiasD02KK	✓	
Hlt2CharmHadMinBiasD02KPi	✓	
Hlt2CharmHadMinBiasDplus2hhh	✓	
Hlt2CharmHadMinBiasLambdaC2KPPi	✓	
Hlt2CharmHadMinBiasLambdaC2LambdaPi	✓	
Hlt2CharmSemilepD02HHMuMuHardHadronsAndMuonsWideMass	✓	
Hlt2CharmSemilepD02HHMuMuHardHadronsAndMuons	✓	
Hlt2CharmSemilepD02HHMuMuHardHadronsSoftMuonsWideMass	✓	
Hlt2CharmSemilepD02HHMuMuHardHadronsSoftMuons	✓	
Hlt2CharmSemilepD02HMuNu_D02KMuNuTight	✓	
Hlt2DiMuonAndD0	✓	
Hlt2DiMuonAndDp	✓	
Hlt2DiMuonAndDs	✓	
Hlt2DiMuonAndGamma	✓	
Hlt2DiMuonAndLc	✓	
Hlt2DiMuonAndMuon	✓	
Hlt2DiMuonPsi2SHighPT	✓	
Hlt2DiProtonLowMultTF		✓
Hlt2DiProtonTF		✓
Hlt2DisplVerticesDoublePostScaled	✓	
Hlt2DisplVerticesLowMassSingle		✓
Hlt2DisplVerticesSingleHighFDPostScaled	✓	
Hlt2DisplVerticesSingleHighMassPostScaled	✓	
Hlt2DisplVerticesSingleMVPostScaled	✓	
Hlt2DisplVerticesSingle	✓	
Hlt2DoubleDiMuon	✓	
Hlt2ExpressHLT1Physics		✓
Hlt2LowMultElectron_nofilter	✓	
Hlt2LowMultHadron_nofilter	✓	
Hlt2Lumi	✓	
Hlt2RadiativeTopoPhotonL0	✓	
Hlt2RadiativeTopoTrackTOS	✓	
Hlt2SingleMuonVHighPT	✓	
Hlt2SingleTFElectron	✓	
Hlt2SingleTFVHighPtElectron	✓	
Hlt2TopoRad2BodyBBDT	✓	
Hlt2TopoRad2plus1BodyBBDT	✓	

TABLE 4.3.2. *Differences in prescales between* `0x00790038` *and* `0x006D0032`.

	0x00790038	0x006D0032
L0PhotonNoSPD	0.0001	0.0001
L0MuonNoSPD	0.0001	0.0001
L0ElectronNoSPD	0.0001	0.0001
L0HadronNoSPD	0.0001	0.0001
L0DiHadron,lowMult	0.1	0.1
L0DiMuonNoSPD	0.0001	0.0001
Hlt1L0AnyRateLimited	1 Hz	100 Hz
Hlt1L0AnyNoSPD	0.01	0.001
Hlt1L0AnyNoSPDRateLimited	1 Hz	100 Hz
Hlt1BeamGasNoBeamBeam1	0.5 Hz	5 Hz
Hlt1BeamGasNoBeamBeam2	0.5 Hz	5 Hz
Hlt1BeamGasBeam1	2 Hz	20 Hz
Hlt1BeamGasBeam2	2 Hz	20 Hz
Hlt1BeamGasCrossingEnhancedBeam1	2 Hz	20 Hz
Hlt1BeamGasCrossingEnhancedBeam2	2 Hz	20 Hz
Hlt1BeamGasCrossingForcedReco	0.5 Hz	5 Hz
Hlt1BeamGasCrossingParasitic	0.5 Hz	5 Hz
Hlt1ErrorEvent	0.01 Hz	1 Hz
Hlt2SingleElectronTFLowPt	0.001	1
Hlt2SingleElectronTFHighPt	0.01	1
Hlt2B2HHLTUnbiased	0.1	1
Hlt2SingleMuonLowPT	0.002	0.02
Hlt2CharmSemilepD02HMuNu_D02KMuNuWS	0.01	0.1
Hlt2CharmSemilepD02HMuNu_D02PiMuNuWS	0.01	0.1
Hlt2CharmSemilepD02HMuNu_D02KMuNu	0.05	1
Hlt2CharmSemilepD02HMuNu_D02PiMuNu	0.05	1
Hlt2LowMultHadron	1	0.1
Hlt2LowMultPhoton	0.001	1
Hlt2DisplVerticesSinglePostScaled	0.0001	0.0006
Hlt2DiMuon	0	0.01
Hlt2DiMuonLowMass	0	0.002
Hlt2DiMuonJPsi	0.2	1
Hlt2DiMuonPsi2S	0.1	1
Hlt2DiMuonDY1	0.005	0.05
Hlt2DiMuonDY2	0.03	0.2
Hlt2ErrorEvent	0.01 Hz	1 Hz

4.4 0x00730035

This TCK is very similar to 0x006D0032, with only a few differences, mainly regarding the diproton lines.

4.4.1 Line content

This TCK has the same line content than 0x006D0032, so its differences with the reference TCK are summarized in Table 4.3.1, replacing 0x006D0032 with 0x00730035.

4.4.2 Prescales

Changes in prescales of the lines present both in this TCK and in the reference TCK are summarized in Table 4.4.1. The diproton lines, both in HLT1 (Hlt1DiProton) and HLT2 (Hlt2DiProton), were effectively turned off by a 0 prescale, and the prescale of the Hlt2LowMultHadron line was set to 1, in contrast to the previous TCK 0x006D0032 and the reference TCK.

4.4.3 HLT1 lines

The differences in cuts in the HLT1 lines with respect to the reference TCK concern uniquely the beamspot ρ (< 0.5 mm in 0x00730035 versus < 0.3 mm in 0x00790038). This is analogous to the case of the previous TCK.

4.4.4 HLT2 lines

Like 0x006D0032, in HLT2 this TCK lacks

- V_0 as inputs in the topological lines;
- the refinements in the inclusive ϕ lines;
- the $D^{*+} \to D^0\pi^+$ filter for $D^0 \to hhhh$ lines;
- the filter for backward tracks in the low multiplicity lines;
- the filter on the number of VELO tracks in the Hadron, Photon and Electron low multiplicity lines; and
- merged and resolved π^0 in the input of the Photon low multiplicity line.

In addition, the old calorimeter reconstruction is still used in the radiative lines.

Differences in cuts in HLT2 with respect to the reference TCK are the same as in the previous TCKs, and are summarized starting in Page 71 and in Tables 4.2.12–4.2.15 (replacing 0x005A0032 by 0x00730035)

TABLE 4.4.1. *Differences in prescales between 0x00790038 and 0x00730035.*

	0x00790038	0x00730035
L0PhotonNoSPD	0.0001	0.0001
L0MuonNoSPD	0.0001	0.0001
L0ElectronNoSPD	0.0001	0.0001
L0HadronNoSPD	0.0001	0.0001
L0DiMuonNoSPD	0.0001	0.0001
Hlt1L0AnyRateLimited	1 Hz	100 Hz
Hlt1L0AnyNoSPD	0.01	0.001
Hlt1L0AnyNoSPDRateLimited	1 Hz	100 Hz
Hlt1DiProton	1	0
Hlt1BeamGasNoBeamBeam1	0.5 Hz	5 Hz
Hlt1BeamGasNoBeamBeam2	0.5 Hz	5 Hz
Hlt1BeamGasBeam1	2 Hz	20 Hz
Hlt1BeamGasBeam2	2 Hz	20 Hz
Hlt1BeamGasCrossingEnhancedBeam1	2 Hz	20 Hz
Hlt1BeamGasCrossingEnhancedBeam2	2 Hz	20 Hz
Hlt1BeamGasCrossingForcedReco	0.5 Hz	5 Hz
Hlt1BeamGasCrossingParasitic	0.5 Hz	5 Hz
Hlt1ErrorEvent	0.01 Hz	1 Hz
Hlt2SingleElectronTFLowPt	0.001	1
Hlt2SingleElectronTFHighPt	0.01	1
Hlt2B2HHLTUnbiased	0.1	1
Hlt2SingleMuonLowPT	0.002	0.02
Hlt2DiProton	1	0
Hlt2CharmSemilepD02HMuNu_D02KMuNuWS	0.01	0.1
Hlt2CharmSemilepD02HMuNu_D02PiMuNuWS	0.01	0.1
Hlt2CharmSemilepD02HMuNu_D02KMuNu	0.05	1
Hlt2CharmSemilepD02HMuNu_D02PiMuNu	0.05	1
Hlt2LowMultPhoton	0.001	1
Hlt2DisplVerticesSinglePostScaled	0.0001	0.0006
Hlt2DiMuon	0	0.01
Hlt2DiMuonLowMass	0	0.002
Hlt2DiMuonJPsi	0.2	1
Hlt2DiMuonPsi2S	0.1	1
Hlt2DiMuonDY1	0.005	0.05
Hlt2DiMuonDY2	0.03	0.2
Hlt2ErrorEvent	0.01 Hz	1 Hz

4.5 `0x00760037`

This TCK, which was put into place after the June 2011 technical stop, represents a great change with respect to previous TCKs and it is much closer to the reference TCK. Many new lines were introduced, the PV beamspot ρ cut was also changed to the same value as in the reference TCK (beamspot $\rho < 0.3$ mm) and the new calorimeter reconstruction was used, as discussed in Chapter 3.

4.5.1 *Line content*

This TCK has a very similar line content with respect to the reference TCK, as can be seen in Table 4.5.1; the main differences concern the BBDT radiative topological and the low multiplicity HLT2 lines.

With respect to the previous TCK, the non-biased HLT1 charm calibration line was included; in HLT2, new lines include

- $B \to hh$ lifetime unbiased detached;
- charm hadronic $\Lambda_c \to Kp\pi$ and minimum bias for D^0, D^+ and Λ_c;
- charm semileptonic $D^0 \to hh\mu\mu$ with hard hadrons;
- charm semileptonic $D^0 \to h\mu\nu$ with very displaced D meson;
- dimuon for high-$p_{\mathrm{T}}\,\psi(2S)$;
- dimuon + X, where X can be a D meson, a photon, a Λ_c or another muon;
- double dimuon;
- displaced vertices;
- cut-based radiative topological; and
- single muon and electrons.

4.5.2 *Prescales*

Prescales are the same as in the reference TCK, so the differences with respect to the previous TCK can be obtained from Table 4.4.1 (replacing `0x00790038` by `0x00760037`).

4.5.3 *HLT1 lines*

The HLT1 line requirements were the same as in the reference TCK, once the adjustment of the PV beamspot ρ is considered.

4.5.4 *HLT2 lines*

Few differences remain with respect to the reference TCK. However, when comparing the HLT2 lines in this TCK with the ones in the reference one, several considerations still need to be made:

- Like in previous TCKs, all the topological lines—cut- and BBDT-based—are already present in `0x00730035` but V_0 particles are not used as inputs.

- The Hlt2LowMult(Muon|Hadron|Electron) low multiplicity lines lack the backward tracks killer, and the Hadron and Electron lines lack the filter in number of VELO tracks, as well.
- The newly added charm semileptonic $D^0 \to h\mu\nu$ Hlt2CharmSemilepD02HMuNu_D02KMuNuTight line does not apply the D^* filter, in contrast to the reference TCK.

With respect to the previous TCK, this TCK has the addition of

- the refinements in the inclusive ϕ lines, including track TOS cut and GEC;
- the new calorimeter reconstruction, based on L0 candidates;
- the usage of merged and resolved π^0 in the input of the Hlt2LowMultPhoton low multiplicity line; and
- the $D^{*+} \to D^0\pi^+$ filter for $D^0 \to hhhh$ lines;

In terms of selection criteria, differences with the reference TCK can be found in several lines:

- In the $D^0 \to h^+h^-$ lines, the track $\chi^2_{\rm IP}$ and D^0 $\chi^2_{\rm VS}$ were made equal to the reference TCK, with the only remaining difference being the mass cut, as shown in Tablee 4.5.2.
- The newly introduced tight $D^0 \to h\mu\nu$ line presents different cuts to the reference TCK, summarized in Table 4.5.3.
- The $D \to K^0_{\rm S}h$ lines keep the same differences as in previous TCKs (see Table 4.2.7, replacing 0x005A0032 by 0x00760037).
- In the J/ψ tag and probe line, differences are also the same as in previous TCKs, and are listed in Table 4.2.17 (replacing 0x005A0032 by 0x00760037).
- In the diproton lines, the PID requirements differences were the same as those reported in Table 4.2.16, replacing 0x005A0032 by 0x00760037.

TABLE 4.5.1. *Differences in line contents between `0x00790038` and `0x00760037`. Lines included are marked with a check mark (✓).*

	0x00790038	0x00760037
L0NoPVFlag	✓	
Hlt2ExpressHLT1Physics		✓
Hlt2DiProtonTF		✓
Hlt2DiProtonLowMultTF		✓
Hlt2TopoRad2BodyBBDT	✓	
Hlt2TopoRad2plus1BodyBBDT	✓	
Hlt2Lumi	✓	
Hlt2LowMultHadron_nofilter	✓	
Hlt2LowMultElectron_nofilter	✓	

TABLE 4.5.2. *Differences in selection requirements in the `Hlt2CharmHadD02HH_D02(PiPi|KK|KPi)($,WideMass)` lines between `0x00790038` (Table 4.1.27) and `0x00760037`.*

			0x00790038	0x00760037
h^+h^- combination	$M(\sum p^\mu)$	MeV/c^2	$[1715.0, 2065.0]$	$[1715.0, 2015.0]$
D^0	M in `WideMass`	MeV/c^2	$[1715.0, 2065.0]$	$[1715.0, 2015.0]$

TABLE 4.5.3. *Differences in selection requirements in the `Hlt2CharmSemilepD02HMuNu_D02KMuNuTight` line between `0x00790038` (Table 4.1.49) and `0x00760037`.*

			0x00790038	0x00760037
μ^+K^- combination	$\sum p_{\mathrm{T}}$	MeV/c	> 1500	> 2800
D^0	χ^2_{VS}		> 10	> 20

4.6 `0x00790037`

This line is the same as the reference line in terms of HLT. The only difference between the two lines comes from the L0, where the `L0NoPVFlag` channel is absent in `0x00790037`.

5

2012 TCKs

The reference TCK for 2012 is `0x00990042`, the one with which most luminosity was collected throughout the year (see Table 2.1.2). It will be described in §5.1 and then compared to the rest of 2012 TCKs in the following subsections.

5.1 Reference TCK: `0x00990042`

In this section, `0x00990042`, the most used TCK of 2012, is described in detail so it can be compared with the other TCKs of the year afterwards. Whenever relevant, comparison with the 2011 TCK, described in §4.1, will also be highlighted.

5.1.1 L0

The list of L0 channels active in this TCK, along with their cut configuration and prescales, can be found in Table 5.1.1. The included channels are the same as in the reference TCK of 2011 (Table 4.1.1) except for the `L0NoPVFlag`, which has been removed. As in the 2011 case, note that the beam gas channels, `L0B1gas` and `L0B2gas`, are only triggered in beam 1-empty and empty-beam 2 crossings, respectively.

5.1.2 HLT1

In this TCK, like the 2011 reference TCK discussed in §4.1.2, the PV is reconstructed with the requirement that the beamspot ρ distance is below 0.3 mm, as discussed in §3.3.

The tracking configuration is discussed in §3.1, and is very similar to that of the 2011 reference TCK, except for some looser selection requirements. It is also worth noting the addition of the VELO-only track fit, used by the displaced vertices lines.

As for GECs, in TCK 0x00990042 only one GEC is configured*, which requires that the number of hits in the IT is below 3000, the number of hits in the OT is below 15000 and the number of hits in the VELO is below 6000. Therefore, it sits in between of the Loose and Tight GEC of 2011, with a maximum number of hits in the VELO of 3000 and 10000, respectively.

The HLT1 non-technical lines included in the 0x00990042 TCK and their prescales are shown in Table 5.1.2 and detailed in the next subsections. Note that the Hlt1BeamGasCrossingEnhancedBeam(1|2) were postscaled to 0, but not prescaled.

Beam gas lines

The beam gas lines—Hlt1BeamGasBeam(1|2), Hlt1BeamGas(CrossingEnhanced|NoBeam)Beam(1|2), Hlt1BeamGasCrossingForcedReco($|FullZ) and Hlt1BeamGasCrossingParasitic—ran on the output of the corresponding L0 beam gas channels, requiring the presence of more than 9 tracks and making use of the GEC. On top of this, the Hlt1BeamGas(CrossingEnhanced|NoBeam)?Beam(1|2), Hlt1BeamGasCrossingForcedReco($|FullZ) and Hlt1BeamGasCrossingParasitic require that the PV has a beamspot ρ smaller than 4 mm, while Hlt1BeamGasHighRhovertex applies the opposite cut, *i.e.*, beamspot ρ larger than 4 mm. Further requirements on the ODIN crossing and trigger types, and on the z position and number of tracks of the PV are applied, as shown in Table 5.1.3.

Dimuon lines

The dimuon lines—Hlt1DiMuon(Low|High)Mass—as well as their performance, are described in detail in Ref. [3] and on Page 16. Requirements on the muons and on their vertex in the 2012 reference TCK, quite different to their 2011 counterparts, are summarized in Table 5.1.4; both lines use the GEC.

Diproton lines

The diproton lines—Hlt1DiProton($|LowMult)—ran on low multiplicity events with no GEC and build two-track vertex consistent with (prompt) $J/\psi \to p\bar{p}$. As can be seen in Table 5.1.5, the values of the requirements applied in these lines remain almost unchanged with respect to the 2011 reference TCK.

Passthrough lines

The any-L0 lines—Hlt1L0Any($|NoSPD)—and the Hlt1L0HighSumETJet line ran as rate-limited passthrough of the output of specific L0 lines with no GEC. In particular, Hlt1L0Any is a pre-scaled passthrough line running on L0_DECISION_PHYSICS, while Hlt1L0AnyNoSPD does the same thing but on the output of the L0 *NoSPD channels. The Hlt1L0HighSumETJet line runs on the output of L0HighSumETJet. The Hlt1L0AnyNoSPDRateLimited and Hlt1L0AnyRateLimited lines, included in the 2011 reference TCK, were not used in this TCK.

No- and micro-bias lines

The no-bias lines ran, prescaled, on ODIN no-bias events—as given by the second bit of the ODIN EVTTYPE field. The Hlt1MBNoBias line is prescaled to 0.1, while the Hlt1CharmCalibrationNoBias line was postscaled to 500 Hz, as shown in Table 5.1.2. The Hlt1VeloClosingMicroBias line ran on events

* This GEC is defined as LooseGECs in the code, but we will refer to it simply as GEC.

with the VELO not in its final closed position, performing the VELO reconstruction and accepting the events with tracks at the rate shown in Table 5.1.2.

Single muon and electron lines

The requirements of the "no-IP" single muon and electron lines—`Hlt1Single(Electron|Muon)NoIP`—and the electroweak muon trigger—`Hlt1SingleMuonHighPT`—are summarized in Table 5.1.6. In the case of the muon lines, the muon matching with VELO tracks and the muon candidate upgrade are performed, while in the case of electrons the candidate track is built starting from an energy deposition in the ECAL. In all cases, the GEC is applied.

Single track lines

The track lines are described in detail in [12]. In 2012, the `Hlt1TrackAllL0Tight` line was added to the previously discussed `Hlt1Track(AllL0|Muon|Photon)` lines and all lines except the muon one added the TT validation discussed in §3.1. In all these lines, a single detached high momentum track is used to identify decays coming from B, D and τ meson decays, applying different requirements in momentum and p_{T} depending on the L0 channels they ran on, in all cases using the GEC configuration; these selection criteria are summarized in Table 5.1.7. In addition, the muon line applies the muon identification steps in the tracking configuration.

No-PV line

The no PV pass-through line—`Hlt1NoPVPassThrough`—ran on those events that pass the low multiplicity L0 channels (`L0.*,lowMult`).

Displaced vertices line

The displaced vertices line—`Hlt1VertexDisplVertex`—was added for the 2012 run and is where of the newly introduced VELO-only tracks were used.

First, these VELO-only tracks are filtered by requiring that they have more than 2 consecutive VELO space points, more than 3 VELO space points and that their DOCA with respect to the beamline larger than 2 mm. Then, those events in which an excess of 49 tracks remain are discarded.

With this track selection, a displaced vertices is built requiring that these tracks have a DOCA smaller than 0.3 mm and that the fitted vertex has a beamspot ρ above 12 mm. Track upgrade is then performed using the loose forward tracking configuration and it is required to have at least one track with $p_{\mathrm{T}} > 1.7$ GeV/c, $p > 10$ GeV/c and a track fit $\chi^2 < 2.5$.

Luminosity lines

Similarly to 2011, the lumi lines were used for triggering events for luminosity studies:

- `Hlt1Lumi` ran on events with `LumiTrigger` ODIN trigger type.
- `Hlt1LumiMidBeamCrossing` ran on events with `BeamCrossing` ODIN bunch-crossing type which had fired the `L0MUON,minbias` L0 channel.

Technical lines

The HLT1 technical lines are

- `Hlt1ErrorEvent`, which fires in case there is an error in any HLT1 line; and
- `Hlt1Global`, which is in charge of joining the HLT1 trigger decisions and managing the events needed for luminosity studies.

5.1.3 HLT2

The key cuts of the forward track reconstruction in HLT2 in TCK `0x00990042` are discussed in §3.2, where it can be seen that the momentum cuts are more relaxed than their 2011 counterparts (Table 3.2.1). Additionally, in 2012 the seeding and clone killing are also performed for the forward tracking.

As was done for the reference TCK for 2011, the non-technical HLT2 lines in TCK `0x00990042` have been divided in several groups in order to characterize them.

$B^0_{(s)} \to h^+h^-$ lines

The $B^0_{(s)} \to h^+h^-$ lines, including the lifetime-unbiased ones, are very similar to the ones used in 2011 (see Page 18). Both `Hlt2B2HH` and `Hlt2B2HHLTUnbiasedDetached` were run with unit prescales, while `Hlt2B2HHLTUnbiasedDetached` was prescaled to zero. Also, the selection criteria are very similar to the 2011 ones, as can be seen in Table 5.1.8*.

$B^0 \to h^+h^-\pi^0$ line

The `Hlt2B2HHPi0_Merged` line ran on the output of the `L0Photon` and `L0Electron` L0 channels and the HLT1 physics lines with prescales equal to 1. In it, candidates are built according to the decay descriptor `B0 -> (rho(770)0 -> pi+ pi-) pi0` using only merged π^0, with cuts summarized in Table 5.1.9.

Topological lines

The topological lines, described in detail in Page 18 and Refs. [13,14], present minimal changes with respect to the reference TCK for 2011. As can be inferred from comparing Tables 4.1.11 and 5.1.10, the `Simple` and the radiative lines were prescaled to 0†.

The main change of the topological lines with respect to the reference 2011 TCK is the addition of downstream K^0_S and Λ^0 as input for the n-body combinations and the requirement that the event has a maximum of 500 long tracks. These K^0_S and Λ^0 are taken from `Hlt2SharedParticles`—and not built explicitly in the lines—according to the selections in Tables 5.1.11 and 5.1.12, respectively, with an additional requirement of $\tau > 20$ ps. The requirements on the input kaons are also slightly changed, as can be seen in Table 5.1.13.

The candidate-building procedure is the same way as in 2011, with just minor changes in selection criteria and the application of the PIDe requirement in the electron lines just before the BBDT filtering: first,

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* The configured requirements for `Hlt2B2HHLTUnbiased` are also shown for reference, since the line wasn't prescaled to zero all year.

† These lines were used in some TCKs at the beginning of the year, so it's worth remembering that most of their configuration is common with the regular, non-prescaled, BBDT lines. Additionally, specific requirements to these lines are discussed in this section.

2-body objects are built from the input particles (kaons, K_S^0 and Λ^0) and a TOS requirement on the HLT1 Track lines (`Hlt1TrackAllL0`, `Hlt1TrackAllL0Tight`, `Hlt1TrackMuon` or `Hlt1TrackPhoton`) is applied; these 2-body objects are then forwarded to the 3-body line and, at the same time, further filtered to obtain the 2-body line candidates; subsequently, a 3-body object is built from combining the forwarded 2-body object and the input particles and the TOS requirement is applied, with the result being further filtered to obtain the 3-body lines and also forwarded to the 4-body line; the operation is repeated to build the candidates for the 4-body line.

The requirements applied to the n-body objects are summarized in Table 5.1.14 and the extra preselection criteria applied on the candidates for each of the n-body lines are shown in Table 5.1.15. These preselected n-body lines are finally filtered with the BBDT thresholds shown in Table 5.1.16 or with the selection trees from Table 5.1.17 in case of the `Simple` lines (prescaled to 0 in this TCK).

Radiative topological lines

The radiative topological lines were largely rewritten with respect to those included in the 2011 reference TCK and described in [8], but their basic idea remained unchanged. The main changes were:

- The addition of long K_S^0 as inputs for the 2-track object.
- The application of an explicit TOS on the non-muon HLT1 Track lines—`Hlt1TrackAllL0`, `Hlt1TrackAllL0Tight` and `Hlt1TrackPhoton`.
- The proper alignment of photon and track requirements with respect to the L0 and HLT1 thresholds.

These large changes came with a change in name of the two lines, from `Hlt2RadiativeTopoPhotonL0` and `Hlt2RadiativeTopoTrackTOS` to `Hlt2RadiativeTopoPhoton` and `Hlt2RadiativeTopoTrack`.

Both lines select 2-track + photon combinations using topological criteria (avoiding cuts on variables such as mass or B χ^2_{IP}), with `Hlt2RadiativeTopoPhoton` selecting candidates with a hard photon and softer tracks, and `Hlt2RadiativeTopoTrack` accessing a region of the phase space with a softer photon and harder tracks. This idea is reinforced by the specific filters on L0 applied in each of the lines.

2-track objects are built from `Hlt2BiKalmanFittedKaons` filtered according to the criteria in Table 5.1.18 and K_S^0 built from `Hlt2BiKalmanFittedPions` with requirements summarized in Table 5.1.19. The 2-track objects, selected according to Table 5.1.20, are combined with photons with $E_T > 2500$ MeV and further filtered to obtain the final candidates, as shown in Table 5.1.21.

Exclusive radiative lines

The exclusive radiative lines for $B^0 \to K^{*0}(\to K^\pm\pi^\mp)\gamma$ and $B_s^0 \to \phi(\to K^+K^-)\gamma$ [16] ran with the same prescales as in 2011 (Table 4.1.20). Selections were tightened with respect to the 2011 version, as shown in Table 5.1.22, and, as discussed previously, the used photons are built from `L0CaloCandidates` instead of using the full calorimeter reconstruction.

$D^0 \to h^\pm h^\mp h^\pm h^\mp$ lines

The amount of $D^0 \to h^\pm h^\pm h^\pm h^\pm$ lines increased from 2 in 2011 to 20 due to a splitting by final state and the inclusion of a prescaled non-D^* line for each of the final states; additionally, for each line there is a corresponding wide-mass monitoring line. Detailed prescale information can be found in Table 5.1.23.

Despite the change in number of lines, the way these lines work is very similar to that of the two lines from 2011: charge-0 and ±2 combinations —namely $K^{*0} \to \pi^+\pi^-$, $K^{*+} \to K^+K^+$ and $K^{*-} \to K^-K^-$— are built using the twoBodySequence of the Hlt2CharmHadTwoBodyForD02HHHH configurable (see selection in Table 5.1.24). Two further tracks, selected according to the criteria in Table 5.1.25, are added to the K^* to build a D^0, with requirements detailed in Table 5.1.26; the particle combinations corresponding to each of the lines can be found in Table 5.1.27. In order to tag events, a final step is performed in the Dst lines, in which the $D^{*\mp} \to D^0\pi^\mp$ decay is reconstructed by adding a slow pion, with cuts detailed in the last section of Table 5.1.26.

$D^0 \to h^\pm h^\mp$ lines

The $D^0 \to h^\pm h^\mp$ lines and their corresponding wide mass lines were run with the same prescales as in 2011 (see Table 4.1.26). The strategy and requirements in these lines are very similar to those from the 2011 reference TCK (described in Page 20), as can be seen in Table 5.1.28.

$D^\pm \to h^\pm h^\mp h^\pm$ lines

The $D^\pm \to h^\pm h^\mp h^\pm$ lines—Hlt2CharmHadD2HHH and the wide mass Hlt2CharmHadD2HHHWideMass—ran with the same prescales used in 2011 (Table 4.1.28). However, these lines differ quite significantly with respect to the 2011 reference in the way candidates are built: in this case the decay of the $D^\pm$ meson is not built through an intermediate 2-body state, but directly as a 3-body decay, taking into account all the possible combinations of Hlt2BiKalmanFittedPions and Hlt2BiKalmanFittedKaons, with requirements detailed in Table 5.1.29.

$D^0 \to h^\pm h^\mp X$ lines

The $D^0 \to h^\pm h^\mp X$ line—Hlt2CharmHadD02HHXDst_hhX—and its corresponding monitoring line—Hlt2CharmHadD02HHXDst_hhXWideMass—were introduced in 2012 and were run with prescales shown in Table 5.1.30. They build $D^{*\pm}$ candidates by combining a two-body K^{*0} object, built using the twoBodyHHXSequence of the Hlt2CharmHadTwoBodyForD02HHHH configurable, with a slow pion; the twoBodyHHXSequence has the same requirements as the twoBodySequence used in the $D^0 \to h^\pm h^\mp h^\pm h^\mp$ lines (see Table 5.1.24), simply changing the decay descriptor to resolve the four possible neutral two-hadron combinations, `K*(892)0 -> (pi|K)+ (pi|K)-`. The final selection for the $D^{*\pm}$ candidates are shown in Table 5.1.31.

$D^\pm \to K^0_S h^\pm$ lines

The $D^\pm \to K^0_S h^\pm$ lines—Hlt2CharmHadD2KS0H_D2KS0K, Hlt2CharmHadD2KS0H_D2KS0Pi, Hlt2CharmHad-D2KS0H_D2KS0DDK and Hlt2CharmHadD2KS0H_D2KS0DDPi—were run with unit prescales. As can be inferred from the line names, the main difference with respect to the 2011 lines described in Page 20 is the addition of downstream K^0_S. These K^0_S are provided by Hlt2SharedParticles, built from Hlt2BiKalmanFittedPions with requirements shown in Table 5.1.11). Afterwards, $D^\pm$ candidates are build according to the criteria from Table 5.1.32.

$D^0 \to K^0_S h^\pm h^\mp$ lines

The $D^0 \to K^0_S h^\pm h^\mp$ lines—Hlt2CharmHadD02HHKsLL and Hlt2CharmHadD02HHKsDD—ran with unit prescales. It works in the same way as the one run in 2011, only this time using long and downstream K^0_S from Hlt2SharedParticles (Table 5.1.11) with a further filtering detailed in Table 5.1.33. Two 2-hadron objects are built in the same way (see requirements in Table 4.1.33), but in the case of downstream K_S^0 a tigher filter is applied, leaving the final requirements as detailed in Table 5.1.34 (note how, unlike its 2011 counterpart, this line only applies the TOS requirement on the tracks of the two-hadron object).

$D^0 \to K_S^0 K_S^0$ line

The $D^0 \to K_S^0 K_S^0$ lines—`Hlt2CharmHadD2KS0KS0` and the wide mass `Hlt2CharmHadD2KS0KS0WideMass`—ran with prescales shown in Table 5.1.36. In these lines, two long K_S^0 from `Hlt2SharedParticles` (see requirements in Table 5.1.11) are combined to build a D^0 with the criteria detailed in Table. 5.1.37.

$\Lambda_c^\pm \to h^\mp p^\pm h^\pm$ lines

The $\Lambda_c^\pm \to h^\mp p^\pm h^\pm$ lines, an extended version of the `Hlt2CharmHadLambdaC2KPPi` line from 2011, were run with prescales shown in Table 5.1.38. Similarly to their 2011 counterpart, these lines apply the RICH PID on the protons using a 2-step technique:

1. Signal $\Lambda_c^\pm$ candidates are built from `BiKalmanFitted` particles (without PID information) and filtering is applied.
2. After a sizeable amount of events have been filtered by the first selection, the RICH reconstruction is triggered.
3. New $\Lambda_c^\pm$ candidates are then built according to the selection in Table 5.1.39.

The decay descriptor that corresponds to each line—which is the only things that sets them apart—can be extracted from the line name by knowing that the last hadron in the line name has the same sign as the $\Lambda_c^\pm$ candidate, *e.g.*, the `Hlt2CharmHadLambdaC2PiPK` line corresponds to $\Lambda_c^\pm \to \pi^\mp p^\pm K^\pm$.

Charm minimum bias lines

The list of charm minimum bias lines is the same as in the 2011 reference TCK—the two- and three-body `Hlt2CharmHadMinBiasD02(KK|Kpi)`, `Hlt2CharmHadMinBiasDplus2hhh` and `Hlt2CharmHad-MinBiasLambdaC2KPPi`, and the Λ^0 + pion `Hlt2CharmHadMinBiasLambdaC2LambdaPi`—described in Page 21. The 2- and 3-body lines have the same selection requirements as their 2011 counterparts (see Table 4.1.37) and the only difference is that in 2012 no second loop particles are used. The `Hlt2CharmHadMinBiasLambdaC2LambdaPi` line is also very similar to the 2011 one, with updated requirements—mainly coming from changes in `Hlt2SharedLambdaLLTrackFitted`—as shown in Table 5.1.40.

$D^0 \to \mu^+\mu^-$ line

The non-prescaled `Hlt2CharmRareDecayD02MuMu` line, run with unit prescales, builds its candidates in the same way and with the same requirements as in its 2011 counterpart, described in Page 21 and Table 4.1.39.

$c \to \mu\mu h^\pm$ lines

The charm semileptonic lines, included in the 2011 reference TCK as a single line, were split in 2012 according to the flavor of the hadron and the relative sign of the two muons:

- The Hlt2CharmSemilep3bodyD2KMuMu($|SS) lines use BiKalmanFittedKaons as input for the kaon, Hlt2CharmSemilep3bodyD2PiMuMu($|SS) use BiKalmanFittedPions for the pion, and Hlt2CharmSemilep3bodyLambdac2PMuMu($|SS) use Hlt2BiKalmanFittedProtons for the proton.
- The Hlt2CharmSemilep3body(D2K|D2Pi|Lambdac2P)MuMu lines have opposite-sign muon pairs, built as J/psi(1S) -> mu+ mu-, while Hlt2CharmSemilep3body(D2K|D2Pi|Lambdac2P)MuMuSS lines use same-sign muon pairs, built as phi(1020) -> mu+ mu+ and rho(770)0 -> mu- mu-.

These lines, along with their corresponding prescales, are shown in Table 5.1.41.

All lines make use of the Hlt2CharmSemilepTwoMuonForMuMuHad configurable for building the dimuon objects from Hlt2BiKalmanFittedMuons, with requirements shown in Table 5.1.42. These two-body objects are afterwards combined with the suitable hadron to build all the lines with decay descriptors shown in Table 5.1.43. The selection criteria are shown in Table 5.1.44.

$D^0 \to \mu^+\mu^-h^+h^-$ lines

The $D^0 \to \mu^+\mu^-h^+h^-$ lines were simplified compared to their 2011 counterparts by splitting them according to the flavor of the hadrons (which in this case can be different). The three resulting lines—Hlt2CharmSemilepD02KKMuMu, Hlt2CharmSemilepD02KPiMuMu and Hlt2CharmSemilepD02PiPiMuMu—were run with unit prescales.

Dimuon objects are built using the Hlt2CharmSemilepTwoMuonForMuMuHad configurable (Table 5.1.42) in the same way as the $c \to \mu\mu h^\pm$ lines, but only the opposite-sign muon combinations are used. These objects are then combined with pairs of opposite-sign hadrons and filtered with criteria detailed in Table 5.1.45.

$D^0 \to \mu^+h^-\nu$ lines

The charm semileptonic $D^0 \to \mu^+h^-\nu$ lines are very similar to their 2011 counterparts, which were discussed in Page 22, including their prescales (shown in Table 4.1.47). The four non-tight lines—Hlt2CharmSemilepD02HMuNu_D02(K|Pi)MuNu($|WS)—have the same requirements as in 2011 (see Table 4.1.48). Differences appear in the Hlt2CharmSemilepD02HMuNu_D02KMuNuTight line, where slow pions are not built using second loop particles but from BiKalmanFittedPions, applying a tighter requirement on their track χ^2/ndf, as shown in Table 5.1.46.

$D^{*+} \to \pi^+D^0(\to h_1h_2)$ lines

The $D^{*+} \to \pi^+D^0(\to h_1h_2)$ lines—Hlt2Dst2PiD02KMu, Hlt2Dst2PiD02KPi, Hlt2Dst2PiD02MuMu and Hlt2Dst2PiD02PiPi—are identical to those in the 2011 reference TCK and are described in Page 22, with prescales in Table 4.1.50, selection in Table 4.1.51 and decay descriptors in Table 4.1.52.

Dielectron lines

The dielectron lines—Hlt2DiElectronB and Hlt2DiElectronHighMass—work similarly to those in the 2011 reference TCK, described in Page 22, and ran with unit prescales. Differences with respect to 2011 concern the electron-building procedure, which also caused the removal of the PIDe requirements from the Hlt2DiElectronB line; more precisely, as already discussed, the Hlt2SharedTrackFittedDiElectron objects are replaced by Hlt2SharedFromL0TrackFittedDiElectronFromL0 objects, built from two

Hlt2BiKalmanFittedElectronsFromL0. With this change, the PID requirements of the two lines are unified, as shown in Table 5.1.47.

Unbiased dimuon lines

The unbiased dimuon lines, described in Page 22, ran with the same prescales as in 2011 (shown in Table 4.1.54). There are small differences with respect to the selection requirements applied in 2011 reference TCK, mainly regarding the track χ^2/ndf of the muons, as shown in Table 5.1.48.

Detached dimuon lines

Similarly to their 2011 counterparts, described in Page 23, the detached dimuon lines correspond to different dimuon mass ranges and ran with unit prescales. In this case, however, four (instead of three) mass ranges are considered, correspondig to four different lines—Hlt2DiMuonDetached, Hlt2DiMuonDetachedHeavy, Hlt2DiMuonDetachedJPsi and Hlt2DiMuonDetachedPsi2S. The behavior of these four lines is the same: starting from TrackFittedDiMuon objects, filtering is applied:w according to the criteria shown in Table 5.1.49.

Trimuon lines

The non-prescaled trimuon lines—Hlt2TriMuonDetached and Hlt2TriMuonTau—are quite similar to their 2011 counterparts, discussed in Page 23. They still require three TightMuons and three GoodMuons, respectively, as input for a three-muon vertex, but the definition of these objects is slightly changed, as detailed in Table 5.1.50. The three-muon vertex in Hlt2TriMuonTau, corresponding to [tau+ -> mu+ mu+ mu-]cc, is then filtered according to the criteria in Table 5.1.51; the three-muon vertex in Hlt2TriMuonDetached, corresponding to [B_c+ -> mu+ mu+ mu-]cc, is not subject to any further filtering.

Dimuon + charm lines

The idea behind the dimuon + charm lines—Hlt2DiMuonAndD0, Hlt2DiMuonAndDp, Hlt2DiMuonAndDs and Hlt2DiMuonAndLc—is the same as in 2011 (see Page 23) and the differences between the two TCKs are due to the small changes in the construction of the Good objects, as discussed in the previous subsection and in Table 5.1.50.

Therefore, in these lines a DiMuon object, built by filtering TrackFittedDiMuon objects with requirements shown in Table 4.1.59, is combined with a charm object built from Good particles (defined in Table 5.1.50) according to the corresponding selection from Table 4.1.60*; the used decay descriptors are detailed in Table 4.1.61.

Dimuon + muon line

The Hlt2DiMuonAndMuon line, run with unit prescale, is exactly the same as its 2011 counterpart—described in Page 23—except for the definition of the TightMuon, as shown in Table 5.1.50. Thus, candidates are built by combining a DiMuon object (Table 4.1.59) with extra vertex quality and detachment requirements—namely, vertex $\chi^2/\mathrm{ndf} > 10$ and decay length significance above 6—with a TightMuon with the decay descriptor [B_c+ -> J/psi(1S) mu+]cc.

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* Note that the suspected bugs in the 2011 TCK are still present in the reference 2012 TCK.

Double dimuon line

The Hlt2DoubleDiMuon line, run with unit prescales, is also exactly the same as its 2011 counterpart.It simply combines two DiMuon objects from Table 4.1.59 with the decay descriptor chi_b0(2P) -> J/psi(1S) J/psi(1S), without any further requirements.

Diproton lines

The diproton lines—Hlt2DiProton and Hlt2DiProtonLowMult—ran, with unit prescale, on the output of specific HLT1 lines, also imposing requirements on the SPD multiplicity. Their working principle is the same as their 2011 counterparts—discussed in Page 24—so candidates are selected using a two-stage approach: first, a preselection is performed, and, when the rate is low enough, RICH reconstruction is triggered to apply PID requirements on the remaining tracks. The final set of selection criteria, extremely similar to that in the 2011 reference TCK, is shown in Table 5.1.52.

Displaced vertices lines

The displaced vertices lines, with prescales shown in Table 5.1.53, were largely rewritten with respect to their 2011 counterparts, mainly to improve speed and performance. In the 0x00990042 TCK, the selection is performed in four (or five) steps:

1. VELO tracks not originating from a PV are selected by requiring they have an IP> 0.1 mm. Backward tracks are removed.

2. Vertex reconstruction is performed using these tracks by running PatPV3D with special settings for low-multiplicity vertex, detailed in Table 4.1.64.

3. The LLParticlesFromRecvertex algorithm converts these vertex into long-lived particles—with particle ID corresponding to ~chi_10—applying the common requirements from the first column of Table 5.1.54 in order to reduce CPU usage.

4. (Only in Hlt2DisplvertexSingleDown) The long-lived particles coming from the previous step are preselected according to the criteria in Table 5.1.55. In those events with at least one preselected VELO candidate, downstream tracking is executed and vertexing is performed with cuts shown in Table 5.1.56. Finally, the LLParticlesFromRecvertex algorithm is run again with requirements found in the second column of Table 5.1.54 to build a long-lived ~chi_10 particle.

5. In the case of the Single lines, the resulting ~chi_10 particle is filtered according to the criteria in Table 5.1.57. In the case of the Double lines, a H_10 -> ~chi_10 ~chi_10 decay is built with requirements summarized in Table 5.1.58. In both cases, each line is optimized to cover a different part of the phase space.

Express lines

The HLT2 lines for the EXPRESS stream were run rate-limited, as shown in Table 5.1.59. With respect to the 2011 reference TCK (Table 4.1.67), several prescales changed, the Hlt2ExpressD02KPi line was added and the Hlt2ExpressJPsiTagProbe line was prescaled to zero.

This collection of lines covers a wide variety of alignment and calibration cases and is defined very similarly to 2011:

- The Hlt2ExpressBeamHalo line is used for VELO sensor and module alignment, making use of the PatVeloAlignTrackFilter algorithm to select beam halo tracks parallel to $z = 0$. The selection requirements are the same as in 2011 and are summarized in Table 4.1.68.
- The Hlt2ExpressJPsi line is used for alignment and for muonID calibration. It selects unbiased J/ψ from BiKalmanFittedMuons with very simple requirements, shown in Table 5.1.60.
- The Hlt2ExpressLambda line is used for muonID and PID calibration and, contrary to its 2011 counterpart, ran on the output of any HLT1 line. Candidates are built according to the [Lambda0 -> p+ pi-]cc decay descriptor, without the use of PID, from the Hlt2BiKalmanFittedPions and Hlt2BiKalmanFittedProtons containers with the same selection criteria as in 2011 (Table 4.1.71).
- The Hlt2ExpressDs2PhiPi line is used for PID calibration. Candidates are built in the same way as in 2011, that is, combining Hlt2BiKalmanFittedPions and Hlt2BiKalmanFittedKaons using the decay descriptors phi(1020) -> K+ K- and [D_s+ -> pi+ phi(1020)]cc. Selection requirements are however different, as shown in Table 5.1.61.
- The Hlt2ExpressDStar2D0Pi and Hlt2ExpressD02KPi lines are also used for PID calibration. Candidates are built starting from Hlt2BiKalmanFittedPions and Hlt2BiKalmanFittedKaons with the decay descriptors [D0 -> K- pi+]cc (in both lines) and [D*(2010)+ -> D0 pi+]cc (in Hlt2ExpressDStar2D0Pi) with the selection shown in Tables 5.1.62 and 5.1.63.
- The Hlt2ExpressKS line, in which K_S^0 are built from long tracks with the same requirements as in 2011 (Table 4.1.74), is also used for PID calibration. Contrary to its 2011 counterpart, this line ran on the output of any HLT1 line, and not only physics lines (Hlt1(?!Lumi)(?!Velo)(?!NoPV).*Decision).

Inclusive ϕ lines

The inclusive ϕ lines—Hlt2IncPhi and Hlt2IncPhiSidebands—ran with prescales shown in Table 4.1.75, building $\phi \to K^+K^-$ candidates in two steps: first, geometric requirements on the tracks are applied, and afterwards RICH PID is calculated to provide further filtering power. They are very similar to their 2011 counterparts, the only difference being the GEC, as shown in Table 5.1.64.

Di-ϕ line

The Hlt2DiPhi line, run with unit prescales, was not present in 2011 and it is intended for the study of charmonium decays to two ϕ resonances, which in turn decay into two kaons each. These decays are built with the decay descriptor J/psi(1S) -> (phi(1020) -> K+ K-) (phi(1020) -> K+ K-). Similarly to the inclusive ϕ line, the selection is performed in two steps, in the second of which the RICH PID is calculated to provide further selection power over the BiKalmanFittedKaons. The final selection requirements are shown in Table 5.1.65.

Low multiplicity lines

The low multiplicity lines, mainly designed for diffractive physics, ran on the output of the low multiplicity L0 channels from Table 5.1.66 and the Hlt1NoPVPassThroughDecision HLT1 line with prescales shown in Table 5.1.67. As can be seen on the table, a few new low multiplicity lines—corresponding to charm—where introduced with respect to the 2011 reference TCK.

As in the case of the 2011, the low multiplicity lines can be split in several groups:

- The non-filtered 2-track lines—Hlt2diPhotonDiMuon, Hlt2LowMultHadron_nofilter and Hlt2LowMultElectron_nofilter—build right- and wrong-sign two-track objects (as J/psi(1S)) from the corresponding BiKalmanFitted tracks, requiring the track to have a p_{T} in excess of 400, 250 and 1000 MeV/c, respectively. The main difference of these lines with respect to their 2011 counterparts is that the electrons are built with the new HLT calorimeter reconstruction.

- The filtered 2-track lines—Hlt2LowMultElectron and Hlt2LowMultHadron—require less than 8 VELO tracks and no backward tracks, and afterwards build the J/psi(1S) objects the same way as the non-filtered lines, that is, with p_{T} requirements of 250 and 1000 MeV/c, respectively.

- The filtered single muon line—Hlt2LowMultMuon—ran, exactly as in 2011, on the output of L0Muon,lowMult or L0DiMuon,lowMult, requiring less than 4 VELO tracks, no backward tracks and a BiKalmanFittedMuon with p_{T} larger than 400 MeV/c.

- The diphoton (π^0) line—Hlt2LowMultPhoton—gets π^0 from both the MergedPi0sFromL0 and ResolvedPi0sFromL0 containers and requires them to have $p_{\mathrm{T}} > 250$ MeV/c. Similarly to the electron lines discussed above, the only difference with respect to the 2011 line is the use of the new calorimeter reconstruction based on L0CaloCandidates.

- The χ_c lines—Hlt2LowMultChiC2HH($|HH) and the wrong-sign Hlt2LowMultChiC2HH($|HH)WS—build signal candidates from Hlt2BiKalmanFittedRichLowPTKaons (BiKalmanFittedKaons with RICH information) and Hlt2BiKalmanFittedPions with decay descriptors and selection shown in Table 5.1.68.

- The D meson lines—Hlt2LowMultD2K(Pi|PiPi|3Pi) and Hlt2LowMultD2K(Pi|PiPi|3Pi)WS—build candidates from Hlt2BiKalmanFittedRichLowPTKaons and Hlt2BiKalmanFittedPions with the decay descriptors and requirements from Table 5.1.69.

- The inclusive two-kaon line—Hlt2LowMultDDInc—builds right- and wrong-sign combinations from Hlt2BiKalmanFittedRichLowPTKaons by requiring less than 8 VELO tracks, no backward tracks and the fulfillment of the selection criteria in Table 5.1.70.

$B_c \to (J/\psi \to \mu^+\mu^-)\mu X$ lines

The $B_c \to (J/\psi \to \mu^+\mu^-)\mu X$ lines—Hlt2TFBc2JpsiMuX and Hlt2TFBc2JpsiMuXSignal—are described in Page 26. In the 2012 reference TCK these lines also ran with unit prescales and have the same requirements as in 2011, found in Table 4.1.79.

$\Lambda_c^\pm \to \Lambda^0 h^\pm$ lines

The $\Lambda_c^\pm \to \Lambda^0 h^\pm$ lines, introduced in 2012, are split according to all the possible combinations of the type of hadron ($\pi^\pm$ or $K^\pm$) and of the Λ^0 (long or downstream). The resulting four lines—Hlt2LambdaC_LambdaC2Lambda0DDK, Hlt2LambdaC_LambdaC2Lambda0DDPi, Hlt2LambdaC_LambdaC2Lambda0LLK and Hlt2LambdaC_LambdaC2Lambda0LLPi—were run with unit prescales. They make use of Λ^0 from Hlt2SharedParticles (Table 5.1.12), which are further filtered and combined with a bachelor hadron—$\pi^\pm$ or $K^\pm$—to build the $\Lambda_c^\pm$ candidates, with requirements shown in Table 5.1.71.

Single electron lines

The single electron lines—`Hlt2SingleTFElectron`, `Hlt2SingleElectronTFHighPt`, `Hlt2SingleElectronTFLowPt` and `Hlt2SingleTFVHighPtElectron`—similarly to their 2011 counterparts, run on the output of the `L0Electron` channel and the `Hlt1(Track|.*Electron)` lines with prescales shown in Table 4.1.82. As with other calorimeter-related lines, in these lines the `Hlt2BiKalmanFittedElectrons` used in 2011 were replaced by the `Hlt2BiKalmanFittedElectronsFromL0`, and therefore PIDe is not available for selection. This can be seen in the cuts summarized in Table 5.1.72.

Single muon lines

The inclusive single muon lines—`Hlt2SingleMuon`, `Hlt2SingleMuonHighPT`, `Hlt2SingleMuonLowPT` and `Hlt2SingleMuonVHighPT`—ran with prescales shown in Table 4.1.80, are detailed in Page 26. The 2012 version, including the requirements in Table 4.1.81, is exactly the same as in the 2011 reference TCK, excluding the already discussed changes in tracking and PV reconstruction.

Technical lines

The technical lines ran with slightly different prescales with respect to the 2011 reference TCK, as shown in Table 5.1.73. Besides these small changes, they work similarly to their 2011 counterparts, the description of which can be found in Page 26.

TABLE 5.1.1. *Basic L0 configuration, with cuts and prescales, for the reference TCK `0x00990042`. All energy values are measured in* MeV *and transverse momenta in* MeV/c. *Threshold values that have changed with respect to the 2011 reference TCK (Table 4.1.1) are highlighted in* ***bold***.

	SPD mult	PU mult	$\sum E_T$	Hadron E_T	Electron E_T	Photon E_T	p_T^{largest}	$p_T^{\text{2nd largest}}$	$\sqrt{p_T^{\text{largest}} \times p_T^{\text{2nd largest}}}$	Prescale
`L0B1gas`		< 30	> 5000							1.0
`L0B2gas`		> 9	**< 4000**							1.0
`L0CALO`	> 2			> 240						10^{-6}
`L0DiEM,lowMult`	< 10				**> 480**	**> 480**				1.0
`L0DiHadron,lowMult`	< 10	**< 3**	**–**	**> 500**						**0.25**
`L0DiMuon`	< 900								**> 1600**	1.0
`L0DiMuon,lowMult`	< 10						> 80	> 80		1.0
`L0DiMuonNoSPD`									**> 1600**	10^{-4}
`L0Electron`	< 600				**> 2720**					1.0
`L0Electron,lowMult`	< 10				> 1000					1.0
`L0ElectronHi`	< 600				> 4200					1.0
`L0ElectronNoSPD`					**> 2720**					10^{-4}
`L0Hadron`	< 600			**> 3620**						1.0
`L0HadronNoSPD`				**> 3620**						10^{-4}
`L0HighSumETJet`			**> 50000**							$\mathbf{10^{-4}}$
`L0MUON,minbias`							> 240			10^{-5}
`L0Muon`	< 600						**> 1760**			1.0
`L0Muon,lowMult`	< 10						> 200			1.0
`L0MuonNoSPD`							**> 1760**			10^{-4}
`L0Photon`	< 600					**> 2720**				1.0
`L0Photon,lowMult`	< 10					> 1000				1.0
`L0PhotonHi`	< 600					> 4200				1.0
`L0PhotonNoSPD`						**> 2720**				10^{-4}

TABLE 5.1.2. *HLT1 lines and their pre- and postscales of the reference TCK `0x00990042`. Differences with the 2011 reference TCK (Table 4.1.2) are highlighted in **bold**.*

	Prescale	Postscale
`Hlt1BeamGasBeam1`	1	2 Hz
`Hlt1BeamGasBeam2`	1	2 Hz
`Hlt1BeamGasCrossingEnhancedBeam1`	1	**0**
`Hlt1BeamGasCrossingEnhancedBeam2`	1	**0**
`Hlt1BeamGasCrossingForcedReco`	1	0.5 Hz
`Hlt1BeamGasCrossingForcedRecoFullZ`	0.001	0.5 Hz
`Hlt1BeamGasCrossingParasitic`	1	**1 Hz**
`Hlt1BeamGasHighRhovertex`	**1.0**	**4 Hz**
`Hlt1BeamGasNoBeamBeam1`	1	0.5 Hz
`Hlt1BeamGasNoBeamBeam2`	1	0.5 Hz
`Hlt1DiMuonHighMass`	1	1
`Hlt1DiMuonLowMass`	1	1
`Hlt1DiProtonLowMult`	1	1
`Hlt1DiProton`	1	1
`Hlt1L0AnyNoSPD`	0.01	1
`Hlt1L0Any`	10^{-6}	1
`Hlt1L0HighSumETJet`	1	1
`Hlt1MBNoBias`	**0.1**	1
`Hlt1CharmCalibrationNoBias`	1	500 Hz
`Hlt1VeloClosingMicroBias`	1	500 Hz
`Hlt1SingleElectronNoIP`	1	1
`Hlt1SingleMuonHighPT`	1	1
`Hlt1SingleMuonNoIP`	0.01	1
`Hlt1TrackAllL0`	1	1
`Hlt1TrackAllL0Tight`	**1**	**1**
`Hlt1TrackMuon`	1	1
`Hlt1TrackPhoton`	1	1
`Hlt1NoPVPassThrough`	1	1
`Hlt1VertexDisplVertex`	**1.0**	**1.0**
`Hlt1Lumi`	1	1
`Hlt1LumiMidBeamCrossing`	1	1
`Hlt1ErrorEvent`	1	0.01 Hz
`Hlt1Global`	1	1

TABLE 5.1.3. *Requirements applied on the ODIN crossing and trigger types, and on the z position and number of tracks of the PV in the HLT1 beam gas lines in TCK `0x00990042`.*

	L0	ODIN crossing type	ODIN trigger type	PV z position [mm]
Hlt1BeamGasBeam1	L0B1gas at 5 kHZ	Beam1	–	$[-2000.0, 400.0]$
Hlt1BeamGasBeam2	L0B2gas at 5 kHZ	Beam2	–	$[0.0, 2000.0]$
Hlt1BeamGasCrossingEnhancedBeam1	L0B1gas at 5 kHZ	BeamCrossing	BeamGasTrigger	$[-2000.0, -300.0] \cup [300.0, 400.0]$
Hlt1BeamGasCrossingEnhancedBeam2	L0B2gas at 5 kHZ	BeamCrossing	BeamGasTrigger	$[300.0, 2000.0]$
Hlt1BeamGasCrossingForcedReco	(SpdMult > 5 or PUHits > 5) at 1 kHZ	BeamCrossing	–	$[-2000.0, -300.0] \cup [300.0, 2000.0]$
Hlt1BeamGasCrossingForcedRecoFullZ	(SpdMult > 5 or PUHits > 5) at 1 kHZ	BeamCrossing	not LumiTrigger	$[-2000.0, 2000.0]$
Hlt1BeamGasCrossingParasitic	(SpdMult > 5 or PUHits > 5) at 50 kHZ	BeamCrossing	–	$[-2000.0, -300.0] \cup [300.0, 2000.0]$
Hlt1BeamGasHighRhovertex	(SpdMult > 5 or PUHits > 5)	Beam1 or Beam2	–	$[-2000.0, 2000.0]$
Hlt1BeamGasNoBeamBeam1	L0B1gas at 10 kHZ	NoBeam	–	$[-2000.0, 400.0]$
Hlt1BeamGasNoBeamBeam2	L0B2gas at 10 kHZ	NoBeam	–	$[0.0, 2000.0]$

TABLE 5.1.4. *Requirements applied on the muon tracks and dimuon vertex in the dimuon HLT1 lines in TCK `0x00990042`. Differences with respect to the 2011 reference TCK (Table 4.1.4) are highlighted in* ***bold****.*

			`Hlt1DiMuonHighMass`	`Hlt1DiMuonLowMass`
$\mu^{\pm}$	Track χ^2/ndf		**< 3**	
	p_{T}	MeV/c	> 500	**> 0**
	p	MeV/c	> 3000	**> 0**
	χ^2_{IP}		–	**> 6**
Dimuon	DOCA	mm	< 0.2	
	χ^2_{vtx}		< 25	
	M	MeV/c^2	> 2700	**> 0**

TABLE 5.1.5. *Requirements applied on the tracks and 2-track vertex in the DiProton HLT1 lines in TCK `0x00990042`. Differences with respect to the 2011 reference TCK (Table 4.1.5) are highlighted in **bold**.*

			`Hlt1DiProton`	`Hlt1DiProtonLowMult`
Trigger requirements	L0		`L0Hadron` and `SPDMult` < 300	`SPDMult` $<$ **10**
	VELO hits		> 9	–
	VELO missing hits		< 3	–
Track	Track upgrade		Tight	Loose
	Track hits		> 15	–
	p_T	MeV/c	> 1900	> 500
	p	MeV/c	> 10000	> 6000
2-track object	DOCA	mm	< 0.1	< 0.3
	χ^2_{vtx}		< 4	< 25
	p_T	MeV/c	> 6500	–
	M	MeV/c^2	$[2800, 4000]$	> 2800

TABLE 5.1.6. *Requirements applied on the track candidate in the HLT1 single muon and electron lines in TCK `0x00990042`. Differences with respect to the 2011 reference TCK (Table 4.1.6) are highlighted in* ***bold***.

	L0	VELO hits	VELO missing hits	track upgrade	hits	χ^2/ndf	p [GeV/c]	p_{T} [GeV/c]
`Hlt1SingleMuonNoIP`	`L0Muon` or **`L0MuonNoSPD`**	> 9	< 3	Loose	> 16		**> 3.0**	> 1.3
`Hlt1ElectronMuonNoIP`	`L0Electron`	> 0	< 999	Tight	> 0	**< 3**	> 20.0	> 10.0
`Hlt1SingleMuonHighPT`	`L0Muon` or **`L0MuonNoSPD`**						**> 3.0**	> 4.8

TABLE 5.1.7. *Requirements applied on the track in the HLT1 track lines in TCK `0x00990042`. Differences with respect to the 2011 reference TCK (Table 4.1.7) are highlighted in* ***bold***.

	L0	VELO hits	VELO missing hits	track upgrade	hits	χ^2/ndf	p [GeV/c]	p_{T} [GeV/c]	**IP** [mm]	χ^2_{IP}
`Hlt1TrackAllL0(Tight)`	`L0_DECISION_PHYSICS`	> 9	< 3	Tight	> 16	< 2 (**1.5**)		**> 1.6** (1.7)		
`Hlt1TrackPhoton`	`L0PhotonHi` or `L0ElectronHi`		< 4	Loose	> 15	< 2	**> 3.0**	> 1.2	**> 0.1**	> 16
`Hlt1TrackMuon`	`L0Muon` or `L0DiMuon`	> 0	< 999		> 0	**< 2.5**		> 1.0		

TABLE 5.1.8. *Selection requirements applied in the $B^0_{(s)} \to h^+h^-$ HLT2 lines in TCK `0x00990042`. Note that the `Hlt2B2HHLTUnbiased` line is prescaled to zero in this TCK. Differences with respect to 2011 reference TCK (Table 4.1.9) are highlighted in **bold**.*

			Hlt2B2HH	Hlt2B2HHLTUnbiased	Hlt2B2HHLTUnbiasedDetached
$h^\pm$	Track χ^2/ndf		**< 3**		
	p	MeV/c^2	–	> 10000	
	p_T	MeV/c^2	> 1000		
	IP	mm	> 0.12	–	–
	TIS		–	`Hlt1.*`	
	PIDK		–	> 0.1	
h^+h^- combination	$M(p_h^\mu)$	MeV/c^2	[4700, 5900]	[5000, 5900]	
	DOCA	mm	< 0.1		
	Largest p_T	MeV/c	–	> 1500	
	Largest PIDK		–	–	> 0.1
$B^0_{(s)}$	χ^2_vtx/ndf		–	< 10	
	p_T	MeV/c	> 1200	–	–
	p	MeV/c	–	> 10000	
	τ	ps	> 0.0006	–	**> 0.3**
	IP	mm	< 0.12	–	–
	Decay angle		–	< 0.9	

TABLE 5.1.9. *Selection requirements applied in the `Hlt2B2HHPi0_Merged` line in TCK `0x00990042`. Differences with respect to 2011 reference TCK (Table 4.1.10) are highlighted in* **bold**.

$\pi^\pm$	Track χ^2/ndf		**< 3.0**
	p	MeV/c	> 5000
	p_T	MeV/c	> 500
	χ^2_IP		> 9
$\pi^+\pi^-$ combination	DOCA	mm	< 0.2
	Smallest track χ^2/ndf		**< 2.0**
	χ^2_VS		> 100
	$M(p^\mu_\rho + p^\mu_{\pi^0})$	MeV/c^2	$[3700, 6900]$
π^0	E_T	MeV	> 2500
B^0	χ^2_vtx/ndf		< 10
	p_T	MeV/c	> 3000
	χ^2_IP		< 25
	DIRA		> 0.99987
	M	MeV/c^2	$[4200, 6400]$

TABLE 5.1.10. *List of topological lines in TCK `0x00990042`.*

`Hlt2Topo2BodyBBDT`
`Hlt2Topo3BodyBBDT`
`Hlt2Topo4BodyBBDT`
`Hlt2TopoE2BodyBBDT`
`Hlt2TopoE3BodyBBDT`
`Hlt2TopoE4BodyBBDT`
`Hlt2TopoMu2BodyBBDT`
`Hlt2TopoMu3BodyBBDT`
`Hlt2TopoMu4BodyBBDT`

TABLE 5.1.11. *Requirements applied on the K^0_S built by `Hlt2SharedParticles` in TCK `0x00990042`.*

			Long	Downstream
$\pi^\pm$	Track χ^2/ndf		< 3	< 4
	χ^2_IP		> 36	—
	p	MeV/c	—	> 3000
	p_T	MeV/c	—	> 175
K^0_S	χ^2_vtx/ndf		< 30	
	τ	ps	> 2	—
	VS_z	mm	—	> 400
	$\lvert M - m_{K^0_\mathrm{S}}\rvert$	MeV/c^2	< 35	< 64

TABLE 5.1.12. *Requirements applied on the Λ^0 built by `Hlt2SharedParticles` in TCK `0x00990042`.*

			Long	Downstream
$p^{\pm}, \pi^{\mp}$	Track χ^2/ndf		< 4	
	χ^2_{IP}		> 36	–
	p	MeV/c	–	> 3000
	p_{T}	MeV/c	–	> 175
Λ^0	$\chi^2_{\mathrm{vtx}}/\mathrm{ndf}$		< 30	
	τ	ps	> 2	–
	VS_z	mm	–	> 400
	$\lvert M - m_{\Lambda^0}\rvert$	MeV/c^2	< 20	< 64

TABLE 5.1.13. *Requirements applied on the input tracks for the topological HLT2 lines in TCK `0x00990042`. Changes with respect to TCK `0x00790038` (Table 4.1.12) are highlighted in **bold**.*

Track χ^2/ndf		**< 2.5**
p_{T}	MeV/c	> 500
p	MeV/c	> 5000
χ^2_{IP}		> 4

TABLE 5.1.14. *Requirements applied on the n-track objects in the topological HLT2 lines in TCK `0x00990042`.*

			$n = 2$	$n = 3$	$n = 4$
Input $(n-1)$-track object	$\chi^2_{\mathrm{vtx}}/\mathrm{ndf}$		–	< 10	–
	M	MeV/c^2	–	< 6000	< 6000
n-track object	$M(\sum p^{\mu})$	MeV/c^2		< 7000	
	Max DOCA	mm		< 0.2	
	Smallest child χ^2_{IP}			> 16 or at least one V^0	
	DIRA			> 0	
	χ^2_{VS}			> 100	

TABLE 5.1.15. *Preselection requirements on the n-body candidates, applied on top of those in Table 5.1.14, in the topological HLT2 lines in TCK `0x00990042`.*

		$n = 2$	$n = 3$	$n = 4$
Number of V^0		≤ 2	≤ 1	≤ 0
$\sum_{\text{children}} p_T$	MeV/c	> 3000	> 4000	> 4000
Smallest track χ^2/ndf			< 2	
At least one track with			$\chi^2_{\text{IP}} > 16$ and $p_T > 1500$ MeV/c or muon with $p_T > 1000$ MeV/c	
PIDe in `E` lines			> -2.0	

TABLE 5.1.16. *Cut applied on the BDT for each of the topological `BBDT` HLT2 lines in TCK `0x00790038`.*

	$n = 2$	$n = 3$	$n = 4$
Regular	> 0.4	> 0.4	> 0.3
Muon	> 0.1	> 0.1	> 0.1
Electron	> 0.1	> 0.1	> 0.1

TABLE 5.1.17. *Selection requirements applied in the `Simple` topological HLT2 lines in TCK `0x00790038`.*

		$n = 2$	$n = 3$	$n = 4$
$\sum_{\text{children}} p_T$	MeV/c	> 7000	> 8000	> 9000
DOCA	mm		< 0.2	
χ^2_{VS}			> 1000	
M	MeV/c^2	$[2500, 7000]$	$[3000, 7000]$	$[3500, 7000]$

TABLE 5.1.18. *Requirements applied on input kaons in the radiative topological HLT2 lines in TCK `0x00990042`.*

Track χ^2/ndf		< 5
χ^2_{IP}		> 10
p	MeV/c	> 5000
p_T	MeV/c	> 500

TABLE 5.1.19. *Requirements applied for building K_S^0 in the radiative topological HLT2 lines in TCK* `0x00990042`.

$\pi^{\pm}$	Track χ^2/ndf		< 5
	χ^2_{IP}		> 16
	p	MeV/c	> 3000
	p_{T}	MeV/c	> 300
K_S^0	χ^2_{vtx}/ndf		< 10
	DIRA		> 0
	χ^2_{VS}		> 1000
	M	MeV/c^2	$[467.648, 527.648]$

TABLE 5.1.20. *Requirements applied on the 2-track objects in the radiative topological HLT2 lines in TCK* `0x00990042`.

GEC	Number of forward tracks		< 120
Tracks	Track χ^2/ndf		< 5
	χ^2_{IP}		> 10
	p	MeV/c	> 5000
	p_{T}	MeV/c	> 500
2-track object	χ^2_{vtx}/ndf		< 10
	Smallest track χ^2/ndf		< 3
	Smallest track χ^2_{IP}		> 16 or all from same PV
	DOCA	mm	< 0.15
	DIRA		> 0
	p_{T}	MeV/c	> 1500
	M	MeV/c^2	< 2000

TABLE 5.1.21. *Requirements applied on the 2-track + photon combinations in the radiative topological HLT2 lines in TCK `0x00990042`. Differences with respect to the 2011 reference TCK (Table 4.1.19) are highlighted in **bold**.*

			`Hlt2RadiativeTopoPhoton`	`Hlt2RadiativeTopoTrack`
GEC	Number of long tracks		< 120	< 120
Trigger	L0		`L0Photon` or `L0Electron`	`L0Hadron`
	HLT1		HLT1 Physics	HLT1 Physics
Photon	E_{T}	MeV	**> 2500**	**> 2000**
2-track object	Largest track p_{T}	MeV/c	**> 1200**	**> 3000**
2-track + photon object	p_{T}	MeV/c	**> 2000**	**> 2000**
	$\sum p_{\mathrm{T}}$	MeV/c	> 5000	> 5000
	VS	mm	> 0	> 0
	χ^2_{VS}		> 64	> 64
	$M_{\mathrm{corrected}}$	MeV/c^2	$[4000, 7000]$	$[4000, 7000]$

TABLE 5.1.22. *Selection requirements applied in the exclusive radiative HLT2 lines in TCK 0x00790038. The values corresponding to the monitoring lines (wide K^{*0} and B meson mass) are shown in parentheses. Differences with respect to the 2011 reference TCK (Table 4.1.21) are highlighted in **bold**.*

			$B \to K^{*0}\gamma$	$B_s^0 \to \phi\gamma$
Trigger	L0		L0Photon or L0Electron	
	HLT1		HLT1 Physics	
$h^{\pm}$	Track χ^2/ndf		< 5	
	p_{T}	MeV/c	**> 500**	
	χ^2_{IP}		**> 20**	
Vector meson	χ^2_{vtx}		< 10	
	$\lvert M - m_V \rvert$	MeV/c^2	< 20	< 100(125)
Photon	E_{T}	MeV	> 2600	
B meson	χ^2_{IP}		**< 12**	
	p_{T}	MeV/c	**> 2000**	
	DIRA		> cos(0.045)	> cos(0.063)
	$\lvert M - m_B \rvert$	MeV/c^2	< 1000(2000)	

TABLE 5.1.23. *Pre- and postscales of the $D^0 \to h^{\pm}h^{\mp}h^{\pm}h^{\mp}$ lines in TCK 0x00990042.*

	Prescale	Postscale
Hlt2CharmHadD02HHHHDst_4pi	1.0	1.0
Hlt2CharmHadD02HHHHDst_4piWideMass	0.1	1.0
Hlt2CharmHadD02HHHH_4pi	0.1	1.0
Hlt2CharmHadD02HHHH_4piWideMass	0.05	1.0
Hlt2CharmHadD02HHHHDst_K3pi	1.0	1.0
Hlt2CharmHadD02HHHHDst_K3piWideMass	0.1	1.0
Hlt2CharmHadD02HHHH_K3pi	0.1	1.0
Hlt2CharmHadD02HHHH_K3piWideMass	0.05	1.0
Hlt2CharmHadD02HHHHDst_2K2pi	1.0	1.0
Hlt2CharmHadD02HHHHDst_2K2piWideMass	0.1	1.0
Hlt2CharmHadD02HHHH_2K2pi	0.1	1.0
Hlt2CharmHadD02HHHH_2K2piWideMass	0.05	1.0
Hlt2CharmHadD02HHHHDst_KKpipi	1.0	1.0
Hlt2CharmHadD02HHHHDst_KKpipiWideMass	0.1	1.0
Hlt2CharmHadD02HHHH_KKpipi	0.1	1.0
Hlt2CharmHadD02HHHH_KKpipiWideMass	0.05	1.0
Hlt2CharmHadD02HHHHDst_3Kpi	1.0	1.0
Hlt2CharmHadD02HHHHDst_3KpiWideMass	0.1	1.0
Hlt2CharmHadD02HHHH_3Kpi	0.1	1.0
Hlt2CharmHadD02HHHH_3KpiWideMass	0.05	1.0

TABLE 5.1.24. *Selection requirements applied in the `twoBodySequence` of the `Hlt2CharmHadTwoBodyForD02HHHH` configurable in TCK `0x00990042`.*

Decay descriptors	`K*(892)0 -> pi+ pi-`
	`K*(892)+ -> K+ K+`
	`K*(892)- -> K- K-`		

$h^{\pm}$	Track χ^2/ndf		< 3
	p	MeV/c	> 3000
	p_{T}	MeV/c	> 300
	χ^2_{IP}		> 6
$h_1 h_2$ combination	$\sum p_{\mathrm{T}}$	MeV/c	> 0
	DOCA	mm	< 0.1
	PV		all from same
	$M(\sum p^{\mu})$	MeV/c^2	< 2100
K^* meson	VS	mm	> 0
	χ^2_{VS}		> 20.0
	$M_{\mathrm{corrected}}$	MeV/c^2	< 3500

TABLE 5.1.25. *Requirements applied on the particles that are combined with the 2-body objects coming from the `Hlt2CharmHadTwoBodyForD02HHHH` configurable in the $D^0 \to h^{\pm}h^{\pm}h^{\pm}h^{\pm}$ lines in TCK `0x00990042`.*

Track χ^2/ndf		< 3
p_{T}	MeV/c	> 300
p	MeV/c	> 3000
χ^2_{IP}		> 1.8

TABLE 5.1.26. *Selection requirements applied in the $D^0 \to h^\pm h^\mp h^\pm h^\mp$ HLT2 lines in TCK* `0x00990042`. *Requirements applied in the monitoring line (when needed) are shown in parentheses.*

$K^* hh$ combination	$\sum p_\mathrm{T}$	MeV/c	> 1500
	$M(\sum p^\mu)$	MeV/c^2	< 2100
	Min DOCA	mm	< 0.1
	Max DOCA	mm	< 0.25
	PV		all from same
D^0	χ^2_vtx/ndf		< 15
	χ^2_IP		< 42
	DIRA		> 0.9999
	χ^2_VS		> 36
	VS_ρ	mm	> 0
	$M_\mathrm{corrected}$	MeV/c^2	< 3500
	M	MeV/c^2	$[1790, 1940]$ ($[1700, 2100]$)
	HLT1 TOS		`Hlt1Track.*`
Slow π	Track χ^2/ndf		< 3
	p	MeV/c	> 3000
	p_T	MeV/c	> 300
$D^{*\mp}$	DOCA	mm	< 100
	$M_{D^{*\mp}} - M_{D^0}$	MeV/c^2	$[0, 170]$

TABLE 5.1.27. *Decay descriptors corresponding to each of the $D^0 \to h^\pm h^\pm h^\pm h^\pm$ lines in TCK* `0x00990042`.

<table>
<tr><td>Hlt2CharmHadD02HHHH(|Dst)_4pi($|WideMass)</td><td>D0 -> (K*(892)0 -> pi+ pi-) pi+ pi-</td></tr>
<tr><td>Hlt2CharmHadD02HHHH(|Dst)_K3pi($|WideMass)</td><td>D0 -> (K*(892)0 -> pi+ pi-) K- pi+
D0 -> (K*(892)0 -> pi+ pi-) K+ pi-</td></tr>
<tr><td>Hlt2CharmHadD02HHHH(|Dst)_2K2pi($|WideMass)</td><td>D0 -> (K*(892)- -> K- K-) pi+ pi+
D0 -> (K*(892)+ -> K+ K+) pi- pi-</td></tr>
<tr><td>Hlt2CharmHadD02HHHH(|Dst)_KKpipi($|WideMass)</td><td>D0 -> (K*(892)0 -> pi+ pi-) K+ K-</td></tr>
<tr><td>Hlt2CharmHadD02HHHH(|Dst)_3Kpi($|WideMass)</td><td>D0 -> (K*(892)- -> K- K-) pi+ K+
D0 -> (K*(892)+ -> K+ K+) pi- K-</td></tr>
</table>

TABLE 5.1.28. *Selection requirements applied in the $D^0 \to h^{\pm}h^{\mp}$ HLT2 line in TCK `0x00990042`. Requirements applied in the monitoring lines (when needed) are shown in parentheses and changes with respect to the 2011 reference TCK (Table 4.1.27) are highlighted in* **bold**.

GEC	**Long tracks**		**< 180**
$h^{\pm}$	Track χ^2/ndf		< 3
	p	MeV/c	> 5000
	p_{T}	MeV/c	> 800
	χ^2_{IP}		> 9
h^+h^- combination	p_{T}	MeV/c	> 2000
	DOCA	mm	< 0.1
	Largest h p_{T}	MeV/c	> 1500
	$M(\sum p^{\mu})$	MeV/c^2	$[1715, 2065]$
D^0	χ^2_{vtx}/ndf		< 10
	DIRA		> 0.99985
	χ^2_{VS}		> 40
	HLT1 TOS		`Hlt1Track.*`
	M	MeV/c^2	$\mathbf{[1790, 1930]}$ ($[1715, 2065]$)

TABLE 5.1.29. *Selection requirements applied in the $D^{\pm} \to h^{\pm}h^{\mp}h^{\pm}$ HLT2 line in TCK `0x00990042`. Requirements applied in the monitoring lines (when needed) are shown in parentheses.*

Decay descriptors			`[D+ -> pi+ pi+ K-]cc`
			`[D+ -> pi+ K+ K-]cc`
			`[D+ -> K+ K+ K-]cc`
			`[D+ -> K+ K+ pi-]cc`
			`[D+ -> pi+ pi+ pi-]cc`
			`[D+ -> pi+ pi- K+]cc`

GEC	Long tracks		< 180
$h^{\pm}$	Track χ^2/ndf		< 3
	p	MeV/c	> 3000
	p_{T}	MeV/c	> 300
	χ^2_{IP}		> 6
$h^+h^-h^+$ combination	$\sum p_{\mathrm{T}}$	MeV/c	> 2800
	Min DOCA	mm	< 0.08
	$(M \sum_h p^{\mu})$	MeV/c^2	< 2100
	PV		all from same
$D^{\pm}$	χ^2_{vtx}/ndf		< 15
	χ^2_{IP}		< 12
	χ^2_{VS}		> 175
	HLT1 TOS		`Hlt1Track.*`
	M	MeV/c^2	$[1800, 2040]$ ($[1700, 2100]$)

TABLE 5.1.30. *Pre- and postscales of the $D^0 \to h^\pm h^\mp X$ HLT2 lines in TCK* `0x00990042`.

	Prescale	Postscale
`Hlt2CharmHadD02HHXDst_hhX`	1.0	1.0
`Hlt2CharmHadD02HHXDst_hhXWideMass`	0.05	1.0

TABLE 5.1.31. *Selection requirements applied in the $D^0 \to h^\pm h^\mp X$ HLT2 lines in TCK* `0x00990042`*. Requirements applied in the monitoring line (when needed) are shown in parentheses.*

GEC	Long tracks		< 180
K^{*0} object	Children track χ^2/ndf		< 2.25
	Largest track χ^2_{IP}		> 36
	χ^2_{vtx}/ndf		< 10
	χ^2_{VS}		> 100
	DIRA		> 0.99
	M	MeV/c^2	< 1900
	HLT1 TOS		`Hlt1Track.*`
Slow π	Track χ^2/ndf		< 2.25
	p	MeV/c	> 3000
	p_{T}	MeV/c	> 300
	χ^2_{IP}		< 9
K^{*0} + slow π combination	DOCA	mm	< 100
	PV		all from same
$D^{*\pm}$	p_{T}	MeV/c	> 3750
	$M_{D^{*\pm}} - M_{K^{*0}}$	MeV/c^2	$[0, 250]$ ($[0, 500]$)

TABLE 5.1.32. *Selection requirements applied in the $D^{\pm} \to K_S^0 h^{\pm}$ HLT2 lines in TCK* `0x00790038`.

			Long K_S^0	Downstream K_S^0
K_S^0	Child track χ^2/ndf		< 3	< 4
	Child χ^2_{IP}		> 36	
	χ^2_{vtx}/ndf		< 12	
	χ^2_{IP}		> 6	—
	χ^2_{VS}		> 300	> 200
	p_T	MeV/c	> 800	
Bachelor $h^{\pm}$	Track χ^2/ndf		< 3	
	p	MeV/c	> 2000	
	p_T	MeV/c	> 200	
	χ^2_{IP}		> 12	
$D^{\pm}$	χ^2_{vtx}/ndf		< 12	
	p_T	MeV/c	> 800	
	χ^2_{IP}		< 17	
	$\Delta z(K_S^0, D^{\pm})$	mm	> 10	
	HLT1 TOS		`Hlt1Track.*`	
	M	MeV/c^2	$[1760, 2080]$	

TABLE 5.1.33. *Filtering applied on top of the K_S^0 built by* `Hlt2SharedParticles` *for the $D^0 \to K_S^0 h^{\pm} h^{\mp}$ lines in TCK* `0x00990042`*. Note that some of the requirements are actually softer or the same than those applied on the input K_S^0, detailed in Table 5.1.11.*

			Long K_S^0	Downstream K_S^0
$\pi^{\pm}$	Track χ^2/ndf		< 2.5	—
	χ^2_{IP}		> 9	—
	p_T	MeV/c	> 200	
K_S^0	χ^2_{vtx}		< 20	
	τ	ps	> 2	—
	χ^2_{VS}		> 400	
	Track TOS		`Hlt1Track.*`	
	$\lvert M - m_{K_S^0}\rvert$	MeV/c^2	< 30	< 40

TABLE 5.1.34. *Requirements for building the two-hadron objects for the $D^0 \to K^0_S h^\pm h^\mp$ lines in TCK* `0x00990042`.

			Long K^0_S	Downstream K^0_S
$h^\pm$	Track χ^2/ndf		< 5	< 2
	p	MeV/c	> 1500	
$h_1 h_2$ combination	$M(\sum p^\mu)$	MeV/c^2	< 1450	
	Largest χ^2_{IP}		—	> 12.5
	$\sum p_{\text{T}}$	MeV/c	> 1000	
	PV		all from same	
K^{*0}	χ^2_{vtx}/ndf		< 10	< 5
	p_{T}	MeV/c	—	> 1000
	VS	mm	> 2	> 4

TABLE 5.1.35. *Requirements applied on the D^0 candidates for the $D^0 \to K^0_S h^\pm h^\mp$ lines in TCK* `0x00990042`.

GEC	Long tracks		< 180
D^0	χ^2_{vtx}/ndf		< 20
	p_{T}	MeV/c	> 2000
	τ	ps	> 0.3
	DIRA		> 0.999
	χ^2_{IP}		< 20
	M	MeV/c^2	[1795, 1935]

TABLE 5.1.36. *Pre- and postscales of the $D^0 \to K^0_S K^0_S$ HLT2 lines in TCK* `0x00990042`.

	Prescale	Postscale
`Hlt2CharmHadD2KS0KS0`	1.0	1.0
`Hlt2CharmHadD2KS0KS0WideMass`	0.1	1.0

TABLE 5.1.37. *Requirements applied on the D^0 candidates for the $D^0 \to K^0_S K^0_S$ HLT2 lines in TCK* `0x00990042`. *Values corresponding to the monitoring line are shown in parentheses.*

GEC	Long tracks		< 180
K^0_S	p_T	MeV/c	> 750
	p	MeV/c	> 5000
	χ^2_{IP}		> 9
$K^0_S K^0_S$ combination	$M(\sum p^\mu)$	MeV/c^2	< 2100
	$\sum p_T$	MeV/c	> 2500
D^0	χ^2_{vtx}/ndf		< 20
	DIRA		> 0.99985
	χ^2_{VS}		> 36
	χ^2_{IP}		< 30
	M	MeV/c^2	$[1800, 2040]$ ($[1700, 2100]$)

TABLE 5.1.38. *Pre- and postscales of the $\Lambda_c^{\pm} \to h^{\mp} p^{\pm} h^{\pm}$ HLT2 lines in TCK* `0x00990042`.

	Prescale	Postscale
`Hlt2CharmHadLambdaC2KPK`	1.0	1.0
`Hlt2CharmHadLambdaC2KPKWideMass`	1.0	0.1
`Hlt2CharmHadLambdaC2PiPK`	1.0	1.0
`Hlt2CharmHadLambdaC2PiPKWideMass`	1.0	0.1
`Hlt2CharmHadLambdaC2PiPPi`	1.0	1.0
`Hlt2CharmHadLambdaC2PiPPiWideMass`	1.0	0.1
`Hlt2CharmHadLambdaC2KPPi`	1.0	1.0
`Hlt2CharmHadLambdaC2KPPiWideMass`	1.0	0.1

TABLE 5.1.39. *Selection requirements applied in the $\Lambda_c^{\pm} \to h^{\mp} p^{\pm} h^{\pm}$ HLT2 lines in TCK* `0x00990042`. *The mass window of the* `WideMass` *lines is shown in parentheses.*

GEC	Long tracks		< 180
$K^{\pm}, \pi^{\pm}$	Track χ^2/ndf		< 3
	p_{T}	MeV/c	> 500
	χ^2_{IP}		> 9
$p^{\pm}$	Track χ^2/ndf		< 3
	p	MeV/c	> 10000
	p_{T}	MeV/c	> 1500
	χ^2_{IP}		> 9
	PIDp		> 0
$h^- p^+ h^+$ combination	$\sum p_{\mathrm{T}}$	MeV/c	> 2500
	Largest child χ^2_{IP}		> 15
	$M(\sum p^{\mu})$	MeV/c^2	$[2211, 2361]$ ($[2136, 2436]$)
$\Lambda_c^{\pm}$	$\chi^2_{\mathrm{vtx}}/\mathrm{ndf}$		< 15
	χ^2_{VS}		> 49
	VS_{ρ}	mm	< 4
	DIRA		> 0.99985
	τ	ps	< 0.02
	HLT1 TOS		`Hlt1Track.*`

TABLE 5.1.40. *Selection requirements applied in the* `Hlt2CharmHadMinBiasLambdaC2LambdaPi` *HLT2 line in TCK* `0x00990042`*. Differences with respect to the 2011 line (Table 4.1.38) are highlighted in* ***bold****.*

$p^{\pm}, \pi^{\mp}$	Track χ^2/ndf		$\mathbf{< 4}$
	χ^2_{IP}		> 36
	p_{T}	MeV/c	–
Λ^0	χ^2_{vtx}/ndf		< 30
	$\boldsymbol{\tau}$	**ps**	$\mathbf{> 2}$
	$\lvert M - m_{\Lambda^0}\rvert$	MeV/c^2	< 20
Bachelor π	Track χ^2/ndf		< 4
	p_{T}	MeV/c	> 300
	χ^2_{IP}		> 4
$\Lambda_c^{\pm}$	χ^2_{vtx}/ndf		< 20
	p_{T}	MeV/c	> 2500
	DIRA		> 0.9999
	χ^2_{VS}		> 16
	$M(p^{\mu})$	MeV/c^2	$[2150, 2430]$

TABLE 5.1.41. *Pre- and postscales of the $c \to \mu\mu h^{\pm}$ HLT2 lines in TCK* `0x00990042`*.*

	Prescale	Postscale
`Hlt2CharmSemilep3bodyD2KMuMu`	1.0	1.0
`Hlt2CharmSemilep3bodyD2KMuMuSS`	1.0	1.0
`Hlt2CharmSemilep3bodyD2PiMuMu`	1.0	1.0
`Hlt2CharmSemilep3bodyD2PiMuMuSS`	1.0	1.0
`Hlt2CharmSemilep3bodyLambdac2PMuMu`	1.0	1.0
`Hlt2CharmSemilep3bodyLambdac2PMuMuSS`	1.0	1.0

TABLE 5.1.42. *Selection requirements applied in the `Hlt2CharmSemilepTwoMuonForMuMuHad` configurable in TCK `0x00990042`. Differences with respect to the 2011 version (Table 4.1.41), mainly following changes in the tracking reconstruction, are highlighted in **bold**.*

Decay descriptors	`J/psi(1S) -> mu+ mu-`
	`phi(1020) -> mu+ mu+`
	`rho(770)0 -> mu- mu-`		

$\mu^{\pm}$	Track χ^2/ndf		**< 5**
	p_{T}	MeV/c	**> 300**
	p	MeV/c	**> 3000**
	χ^2_{IP}		> 2
$\mu^+\mu^-$ combination	DOCA	mm	< 0.1
	$\sum p_{\mathrm{T}}$	MeV/c	> 0
	$M(\sum p^{\mu})$	MeV/c^2	< 2100
	PV		all from same
Dimuon object	VS		> 0
	χ^2_{VS}		**> 9**
	$M_{\mathrm{corrected}}$	MeV/c	< 3500

TABLE 5.1.43. *Decay descriptor used in each of the $c \to \mu\mu h^{\pm}$ HLT2 lines in TCK `0x00990042`. The definition of the dimuon objects (`J/psi(1S)`, `phi(1020)` and `rho(770)0`) can be found in Table 5.1.42.*

`Hlt2CharmSemilep3bodyD2PiMuMu`	`D+ -> J/psi(1S) pi+` `D- -> J/psi(1S) pi-`
`Hlt2CharmSemilep3bodyD2KMuMu`	`D+ -> J/psi(1S) K+` `D- -> J/psi(1S) K-`
`Hlt2CharmSemilep3bodyLambdac2PMuMu`	`Lambda_c+ -> J/psi(1S) p+` `Lambda_c - -> J/psi(1S) p~-`
`Hlt2CharmSemilep3bodyD2PiMuMuSS`	`D+ -> phi(1020) pi-` `D- -> rho(770)0 pi+`
`Hlt2CharmSemilep3bodyD2KMuMuSS`	`D+ -> phi(1020) K-` `D- -> rho(770)0 K+`
`Hlt2CharmSemilep3bodyLambdac2PMuMuSS`	`Lambda_c+ -> phi(1020) p~-` `Lambda_c - -> rho(770)0 p+`

TABLE 5.1.44. *Selection requirements applied in the $c \rightarrow \mu^+\mu^-h^\pm$ HLT2 lines in TCK `0x00990042`. The mass window corresponding to the Λ_c lines is shown in parentheses. Differences with respect to the 2011 version (Table 4.1.42) are highlighted in **bold**.*

$h^\pm$	Track χ^2/ndf		**< 5**
	p_{T}	MeV/c	> 300
	p	MeV/c	**> 3000**
	χ^2_{IP}		> 0
$(2\text{-}\mu)h^\pm$ combination	Min DOCA	mm	< 0.1
	Max DOCA	mm	< 0.25
	$\sum p_{\mathrm{T}}$	MeV/c	**> 500**
	$\sum \sqrt{\chi^2_{\mathrm{IP}}}$		**> 17**
	PV		all from same
c-hadron	χ^2_{vtx}/ndf		< 20
	χ^2_{IP}		< 36
	DIRA		**> 0.9999**
	χ^2_{VS}		> 20
	$M_{\mathrm{corrected}}$	MeV/c^2	< 3500
	M	MeV/c^2	$[1800, 2050]$ ($[2200, 2370]$)

TABLE 5.1.45. *Selection requirements applied in the $D^0 \rightarrow \mu^+\mu^-h^+h^-$ HLT2 lines in TCK `0x00990042`.*

$h^\pm$	Track χ^2/ndf		< 5
	p_{T}	MeV/c	> 300
	p	MeV/c	> 3000
	χ^2_{IP}		> 0
$(\mu^+\mu^-)h^+h^-$ combination	Min DOCA	mm	< 0.1
	Max DOCA	mm	< 0.2
	$\sum p_{\mathrm{T}}$	MeV/c	> 3000
	$\sum \sqrt{\chi^2_{\mathrm{IP}}}$		> 12
	PV		all from same
D^0	χ^2_{vtx}/ndf		< 15
	χ^2_{IP}		< 25
	DIRA		> 0.9999
	χ^2_{VS}		> 36
	$M_{\mathrm{corrected}}$	MeV/c^2	< 3500
	M	MeV/c^2	$[1800, 1950]$

TABLE 5.1.46. *Selection requirements applied in the `Hlt2CharmSemilepD02HMuNu_D02KMuNuTight` HLT2 line in TCK `0x00990042`. Differences with respect to the 2011 reference TCK (Table 4.1.49) are highlighted in **bold**.*

Trigger requirements	L0 filter		`L0Muon` or `L0Hadron`
$\mu^{\pm}$	Track χ^2/ndf		< 3
	p_{T}	MeV/c	> 800
$h^{\mp}$	Track χ^2/ndf		< 3
	p_{T}	MeV/c	> 600
$\mu^{+}h^{-}$ combination	DOCA	mm	< 0.07
	$\sum p_{\mathrm{T}}$	MeV/c	> 1500
	$p(\sum p^{\mu})$	MeV/c	> 20000
	$M(\sum p^{\mu})$	MeV/c^2	< 1900
	PV		all from same
D^0	χ^2_{vtx}/ndf		< 10
	VS$_z$	mm	> 0
	VS	mm	> 10
	$M_{\mathrm{corrected}}$	MeV/c^2	$[1400, 2700]$
	HLT1 TOS		`Hlt1TrackMuon`
Slow π	Track χ^2/ndf		**< 3**
	p_{T}	MeV/c	> 300
	p	MeV/c	> 3000
$D^0\pi^{\pm}$ combination	DOCA	mm	< 120
	PV		all from same
$D^{*\pm}$	$M_{D^{*\pm}} - M_{D^0}$	MeV/c^2	$[0, 250]$

TABLE 5.1.47. *Selection requirements applied in the dielectron HLT2 lines (denoted without the `Hlt2DiElectron` prefix) in TCK `0x00990042`. Differences in the PID requirements with respect to the 2011 reference TCK (Table 4.1.53) are highlighted in **bold**.*

			`B`	`HighMass`
Trigger	L0 filter		`L0Electron`	
	HLT1 filter		`Hlt1(Track|.*Electron).*`	
$e^{\pm}$	Track χ^2/ndf		< 10	
	p_{T}	MeV/c	> 1000	> 10000
	E_{PS}	MeV	**> 50**	
	E_{ECAL}/p		**> 0.1**	
	E_{HCAL}/p		**< 0.05**	
Dielectron	χ^2_{vtx}/ndf		< 25	
	p_{T}	MeV/c	> -999	
	M	MeV/c^2	$[10^4, 10^{10}]$	$> 2\times10^4$

TABLE 5.1.48. *Selection requirements applied in the unbiased dimuon HLT2 lines (denoted with the `Hlt2DiMuon` prefix for clarity) in TCK `0x00990042`. Differences with respect to the 2011 reference TCK (Table 4.1.55) are highlighted in **bold**.*

	Muon		Dimuon		
	Track χ^2/ndf	p_{T} [MeV/c]	χ^2_{vtx}/ndf	p_{T} [MeV/c]	M [MeV/c^2]
JPsi	**< 4**	> 0	< 25	> 0	$[m_{J/\psi} - 120, m_{J/\psi} + 120]$
JPsiHighPT				> 2000	$[m_{J/\psi} - 100, m_{J/\psi} + 100]$
Psi2S	**< 4**	> 2000	< 25	> 0	$[m_{\psi(2S)} - \mathbf{120}, m_{\psi(2S)} + \mathbf{120}]$
Psi2SHighPT				> 3500	
B	**< 4**	–	< 10	–	> 4700
DY1	< 10	> 800	–	–	> 2500 and $\notin [3000, 3200]$
DY2		> 1000	–	–	> 5000
DY3		–	–	–	> 10000
DY4		–	–	–	> 20000
Z	–	–	–	–	> 40000

TABLE 5.1.49. *Selection requirements applied in the detached dimuon HLT2 lines (denoted with the `Hlt2DiMuon` prefix for clarity) in TCK `0x00990042`. Differences of the first three columns with respect to the 2011 reference TCK (Table 4.1.56) are highlighted in **bold**.*

			`Detached`	`DetachedHeavy`	`DetachedJPsi`	`DetachedPsi2S`
Muon	Track χ^2/ndf				**< 4**	
	χ^2_{IP}		> 9	–	–	–
	p_{T}	MeV/c	**> 300**		–	–
Dimuon	χ^2_{vtx}/ndf		**< 8**		< 25	
	p_{T}	MeV/c	**> 600**	> 0	–	–
	VS/σ_{VS}		> 7	> 5	> 3	
	M	MeV/c^2	**> 0**	> 2950	$[m_{J/\psi} - 120, m_{J/\psi} + 120]$	$[m_{\psi(2S)} - 120, m_{\psi(2S)} + 120]$

TABLE 5.1.50. *Requirements applied on the particle objects used in the multimuon HLT2 lines in TCK `0x00990042`. Differences with respect to the 2011 reference TCK (Table 4.1.57) are highlighted in **bold**.*

	Track type	Track χ^2/ndf	χ^2_{IP}	p_{T} [MeV/c]
`GoodMuon`	`BiKalmanFittedMuons`		**> 9**	–
`TightMuon`			> 36	> 1400
`GoodKaon`	`BiKalmanFittedKaons`	**< 4**		–
`GoodPion`	`BiKalmanFittedPions`		> 9	–
`GoodProton`	`BiKalmanFittedProtons`			–

TABLE 5.1.51. *Selection requirements applied in the `Hlt2TriMuonTau` HLT2 line in TCK `0x00990042`. Differences with respect to the 2011 reference TCK (Table 4.1.58) are highlighted in **bold**.*

$\mu^+\mu^+\mu^-$ combination	Largest muon p_{T}	MeV/c	**> 0**
	$M(p^{\alpha}_{\mu^+_1} + p^{\alpha}_{\mu^+_2})$	MeV/c^2	$> 2m_{\mu,\text{PDG}} + 3$
	$\lvert M(\sum p^{\mu}) - m_{\tau}\rvert$	MeV/c^2	< 300
τ	χ^2_{vtx}		< 25
	$c\tau$	µm	**> 75**

TABLE 5.1.52. *Selection requirements applied in the diproton HLT2 lines in TCK `0x00990042`. Differences with respect to the 2011 reference TCK (Table 4.1.62) are highlighted in **bold**.*

			`Hlt2DiProton`	`Hlt2DiProtonLowMult`
Decay descriptor			`J/psi(1S) -> p+ p~-`	
Trigger	L0 `SPDMult`		< 300	**< 10**
	HLT1 line		`Hlt1DiProton`	`Hlt1DiProtonLowMult`
$p^{\pm}$	Track χ^2/ndf		< 4	< 5
	p_{T}	MeV/c	> 1900	> 500
	PIDp		> 20.0	> 10.0
	PIDp-PIDK		> 10.0	–
p^+p^- combination	$\sum p_{\text{T}}$	MeV/c	> 6300	–
	$M(\sum p^{\mu})$	MeV/c^2	[2750, 4100]	> 2800
Diproton	χ^2_{vtx}/ndf		< 9	
	p_{T}	MeV/c	> 6500	–
	M	MeV/c^2	[2800, 4000]	> 2800

TABLE 5.1.53. *Pre- and postscales of the displaced vertices HLT2 lines in TCK `0x00990042`.*

	Prescale	Postscale
`Hlt2DisplvertexSingle`	1.0	1.0
`Hlt2DisplvertexSingleDown`	1.0	1.0
`Hlt2DisplvertexSingleHighFD`	1.0	1.0
`Hlt2DisplvertexSingleVeryHighFD`	1.0	1.0
`Hlt2DisplvertexSingleHighMass`	1.0	1.0
`Hlt2DisplvertexSinglePS`	0.01	1.0
`Hlt2DisplvertexSingleLoosePS`	0.001	1.0
`Hlt2DisplvertexDouble`	1.0	1.0
`Hlt2DisplvertexDoublePS`	0.01	1.0

TABLE 5.1.54. *Configuration of the `LLParticlesFromRecvertex` algorithm of the displaced vertices HLT2 lines in TCK `0x00990042`.*

<table>
<tr><th></th><th></th><th>Long</th><th>Downstream</th></tr>
<tr><td>Number of tracks of the “most upstream” PV</td><td></td><td colspan="2">> 10</td></tr>
<tr><td>Reconstructed mass</td><td>MeV/c^2</td><td>> 0</td><td>> 2800</td></tr>
<tr><td>ρ distance to the beam line</td><td>mm</td><td colspan="2">> 0.3</td></tr>
<tr><td>Number of children</td><td></td><td>> 4</td><td>> 5</td></tr>
<tr><td>Track χ^2/ndf for children that are not VELO-only</td><td></td><td colspan="2">< 5</td></tr>
<tr><td>Fraction of the energy contributed by one child</td><td></td><td colspan="2">< 0.9</td></tr>
<tr><td>Fraction of children with a hit upstream of the vertex</td><td></td><td colspan="2">< 0.49</td></tr>
</table>

TABLE 5.1.55. *Preselection of long-lived particles applied prior to executing the downstream tracking reconstruction in the `Hlt2DisplvertexSingleDown` HLT2 line in TCK `0x00990042`.*

Vertex in matter veto		True
Reconstructed mass	MeV/c^2	> 2800
ρ distance to the beam line	mm	> 0.4
Number of children		≥ 5
Fraction of the energy contributed by one child		< 0.9
Fraction of children with a hit upstream of the vertex		< 0.49

TABLE 5.1.56. *Configuration of the non-default settings of the `PatPV3D` algorithm for the downstream vertexing in the `Hlt2DisplvertexSingleDown` HLT2 line in TCK `0x00990042`.*

`PVSeed3DTool`	DOCA with any other track	mm	< 2.0
	Seed radius	mm	< 20.0
	Number of tracks per seed		≥ 3
`LSAdaptPV3DFitter`	Track IP to seed	mm	< 2
	Number of tracks per vertex		≥ 3
	χ^2/ndf of tracks removed from next PV search		< 64
	Δz condition for convergence	mm	< 0.0005

TABLE 5.1.57. *Requirements applied on the long-lived candidates in the `Single` displaced vertices HLT2 lines in TCK `0x00990042`.*

	Vertex in matter veto	# of children	ρ distance [mm]	M [GeV/c^2]
`Hlt2DisplvertexSingle`	Yes	≥ 4	> 1.5	> 5.0
`Hlt2DisplvertexSingleDown`	No	≥ 5	> 2.0	> 3.0
`Hlt2DisplvertexSingleHighFD`	Yes	≥ 5	> 3.0	> 2.8
`Hlt2DisplvertexSingleVeryHighFD`	Yes	≥ 4	> 5.0	> 2.0
`Hlt2DisplvertexSingleHighMass`	Yes	≥ 5	> 0.5	> 8.0
`Hlt2DisplvertexSingleLoosePS`	No	≥ 4	> 0.4	> 0.0
`Hlt2DisplvertexSinglePS`	Yes	≥ 4	> 1.5	> 2.5

TABLE 5.1.58. *Requirements applied on the long-lived candidates in the `Double` displaced vertices HLT2 lines in TCK `0x00990042`.*

			`Hlt2DisplvertexDouble`	`Hlt2DisplvertexDoublePS`
`~chi_10`	Number of children		≥ 4	
	ρ distance	mm	> 0.4	
`H_10`	*Vertex in matter* veto		At least 1 child	No
	Smallest child M	GeV/c^2	> 2.0	
	Largest child M	GeV/c^2	> 2.8	> 2.0

TABLE 5.1.59. *Pre- and postscales of the Express HLT2 lines in TCK `0x00990042`.*

	Prescale	Postscale
`Hlt2ExpressBeamHalo`	0.001	2 Hz
`Hlt2ExpressJPsi`	1.0	5 Hz
`Hlt2ExpressD02KPi`	0.1	5 Hz
`Hlt2ExpressDStar2D0Pi`	0.1	5 Hz
`Hlt2ExpressDs2PhiPi`	1.0	1 Hz
`Hlt2ExpressKS`	0.001	1 Hz
`Hlt2ExpressLambda`	0.01	1 Hz

TABLE 5.1.60. *Requirements applied in building J/ψ candidates in the `Hlt2ExpressJPsi` line in TCK `0x00990042`. Differences with respect to the 2011 reference TCK (Table 4.1.69) are highlighted in **bold**.*

$\mu^{\pm}$	**Track** $\boldsymbol{\chi^2}$**/ndf**		**< 4**
$\mu^+\mu^-$ combination	Smallest μ p_{T}	MeV/c	> 500
J/ψ	χ^2_{vtx}/ndf		**< 7**
	p_{T}	MeV/c	> 1000
	$\lvert M - m_{J/\psi}\rvert$	MeV/c^2	**< 80**

TABLE 5.1.61. *Selection requirements applied in the `Hlt2ExpressDs2PhiPi` line in TCK `0x00990042`. Differences with respect to the 2011 reference TCK (Table 4.1.72) are highlighted in **bold**.*

$K^{\pm}$	**Track** $\boldsymbol{\chi^2}$**/ndf**		**< 4**
	χ^2_{IP}		**> 16**
	p	MeV/c	> 1000
	p_{T}	MeV/c	**> 500**
ϕ	χ^2_{IP}		**> 16**
	DOCA	mm	**< 0.3**
	$\lvert M - m_{\phi}\rvert$	MeV/c^2	< 50
$\pi^{\pm}$	χ^2_{IP}		**> 16**
	p	MeV/c	> 1000
	p_{T}	MeV/c	**> 500**
D_s^+	χ^2_{vtx}		**< 9**
	DIRA		> 0.999
	χ^2_{IP}		**< 9**
	IP	mm	< 0.05
	$\lvert M - m_{D_s^+}\rvert$	MeV/c^2	< 50

TABLE 5.1.62. *Selection requirements applied in the D^0 candidates in the `Hlt2ExpressD02KPi` lines in TCK `0x00990042`.*

D^0 children	Track χ^2/ndf		< 3
	p	MeV/c	> 5000
	p_T	MeV/c	> 800
	χ^2_IP		> 2
$K^-\pi^+$ combination	Largest child p_T	MeV/c	> 1500
	$p_\mathrm{T}(\sum p^\mu)$	MeV/c	> 2000
	DOCA	mm	< 0.1
D^0	χ^2_vtx/ndf		< 10
	DIRA		> 0.99985
	χ^2_VS		> 25
	$\lvert M - m_{D^0}\rvert$	MeV/c^2	< 50

TABLE 5.1.63. *Selection requirements applied in the `Hlt2ExpressDStar2D0Pi` line in TCK `0x00990042`. Differences with respect to the 2011 reference TCK (Table 4.1.73) are highlighted in **bold**.*

D^0 children	χ^2_IP		**> 5**
	p	MeV/c	**> 3000**
	p_T	MeV/c	**> 600**
D^0	χ^2_vtx/ndf		< 10
	p_T	MeV/c	> 1000
	DIRA		> 0.9999
	χ^2_VS		**> 10**
	$\lvert M - m_{D^0}\rvert$	MeV/c^2	< 50
Slow π	χ^2_IP		> 2
	p_T	MeV/c	> 110
D^*	χ^2_vtx/ndf		< 15
	p_T	MeV/c	> 2200
	$\lvert$Mass $- m_{D^*}\rvert$	MeV/c^2	< 50
	Mass $- D^0$ Mass	MeV/c^2	< 155.5

TABLE 5.1.64. *Selection requirements applied in the inclusive ϕ lines in TCK 0x00990042. The values corresponding to the monitoring line are shown in parentheses and changes with respect to the 2011 reference TCK (Table 4.1.76) are highlighted in **bold**.*

GEC	**Long** tracks		**< 180**
$K^{\pm}$	Track χ^2/ndf		< 5
	χ^2_{IP}		> 6
	p_{T}	MeV/c	> 800
	PID		PIDK > 0
ϕ	χ^2_{vtx}/ndf		< 20
	DOCA	mm	< 0.2
	p_{T}	MeV/c	> 1800
	$\lvert M - m_{\phi}\rvert$	MeV/c^2	20 (30)

TABLE 5.1.65. *Selection requirements applied in the di-ϕ HLT2 line in TCK 0x00990042.*

$K^{\pm}$	Track χ^2/ndf		< 4
	p	MeV/c	> 3000
	p_{T}	MeV/c	> 650
	PIDK		> 0
ϕ	χ^2_{vtx}/ndf		< 9
	p_{T}	MeV/c	> 800
	$\lvert M - m_{\phi}\rvert$	MeV/c^2	< 20
J/ψ	χ^2_{vtx}/ndf		< 9
	p_{T}	MeV/c	> 2000
	M	MeV/c^2	$[2800, 4800]$

TABLE 5.1.66. *L0 requirement in the low multiplicity HLT2 lines in TCK* `0x00990042`.

	L0 requirement
`Hlt2diPhotonDiMuon`	`L0Muon,lowMult` or `L0DiMuon,lowMult`
`Hlt2LowMultElectron` `Hlt2LowMultElectron_nofilter`	`L0Electron,lowMult` or `L0DiEM,lowMult`
`Hlt2LowMultHadron` `Hlt2LowMultHadron_nofilter`	`L0DiHadron,lowMult`
`Hlt2LowMultMuon`	`L0Muon,lowMult` or `L0DiMuon,lowMult`
`Hlt2LowMultPhoton`	`L0Photon,lowMult` or `L0DiEM,lowMult`

`Hlt2LowMultChiC2HH`
`Hlt2LowMultChiC2HHWS`
`Hlt2LowMultChiC2HHHH`
`Hlt2LowMultChiC2HHHHWS`
`Hlt2LowMultD2KPi`
`Hlt2LowMultD2KPiWS`
`Hlt2LowMultD2KPiPi`
`Hlt2LowMultD2KPiPiWS`
`Hlt2LowMultD2K3Pi`
`Hlt2LowMultD2K3PiWS`
`Hlt2LowMultDDInc`
	`L0DiHadron,lowMult`

TABLE 5.1.67. *Pre- and postscales of the low multiplicity HLT2 lines in TCK `0x00990042`. In the first section, differences with respect to the 2011 reference TCK (Table 4.1.77) are highlighted in **bold**; the lines on the second section are new in 2012.*

	Prescale	Postscale
`Hlt2diPhotonDiMuon`	1.0	1.0
`Hlt2LowMultElectron`	1.0	1.0
`Hlt2LowMultElectron_nofilter`	0.05	1.0
`Hlt2LowMultHadron`	1.0	1.0
`Hlt2LowMultHadron_nofilter`	0.01	1.0
`Hlt2LowMultMuon`	0.1	1.0
`Hlt2LowMultPhoton`	**0.01**	1.0
`Hlt2LowMultChiC2HH`	1.0	1.0
`Hlt2LowMultChiC2HHWS`	0.1	1.0
`Hlt2LowMultChiC2HHHH`	1.0	1.0
`Hlt2LowMultChiC2HHHHWS`	0.1	1.0
`Hlt2LowMultD2KPi`	1.0	1.0
`Hlt2LowMultD2KPiWS`	0.1	1.0
`Hlt2LowMultD2KPiPi`	1.0	1.0
`Hlt2LowMultD2KPiPiWS`	0.1	1.0
`Hlt2LowMultD2K3Pi`	1.0	1.0
`Hlt2LowMultD2K3PiWS`	0.1	1.0
`Hlt2LowMultDDInc`	1.0	1.0

TABLE 5.1.68. *Selection requirements applied in the low multiplicity χ_c HLT2 lines in TCK 0x00990042.*

			$\chi_c \to hh$	$\chi_c \to hhhh$

Decay descriptors	Right-sign		`chi_c1(1P) -> pi+ pi-`
			`chi_c1(1P) -> K+ K-`
				`[chi_c1(1P) -> K+ K+ pi- pi-]cc`
				`chi_c1(1P) -> K+ K- pi+ pi-`
				`chi_c1(1P) -> K+ K+ K- K-`
				`chi_c1(1P) -> pi+ pi+ pi- pi-`

	Wrong-sign		`[chi_c1(1P) -> K+ K+ pi- pi-]cc`
			`chi_c1(1P) -> K+ K- pi+ pi-`
			`chi_c1(1P) -> K+ K+ K- K-`
			`chi_c1(1P) -> pi+ pi+ pi- pi-`
				`[chi_c1(1P) -> K+ K+ pi+ pi+]cc`
				`[chi_c1(1P) -> K+ K+ pi+ pi-]cc`
				`[chi_c1(1P) -> K+ K- pi+ pi+]cc`
				`[chi_c1(1P) -> K+ K+ K+ K+]cc`
				`[chi_c1(1P) -> K+ K+ K+ K-]cc`
				`[chi_c1(1P) -> pi+ pi+ pi+ pi+]cc`
				`[chi_c1(1P) -> pi+ pi+ pi+ pi-]cc`

GEC	VELO tracks		< 6	
	Backward tracks		0	
$h^{\pm}$	Track χ^2/ndf		< 3	
	p	MeV/c	> 5000	
	p_{T}	MeV/c	> 100	
	Kaon PIDK		> 0	
n-h combination	p	MeV/c	> 10000	
	p_{T}	MeV/c	$[0, 5000]$	
	Max DOCA	mm	< 0.5	< 0.7
	$\sum p_{\mathrm{T}}$	MeV/c	> 200	> 400
	$M(\sum p^{\mu})$	MeV/c^2	$[3300, 3600]$	$[2850, 4500]$
χ_c	χ^2_{vtx}/ndf		< 15	

TABLE 5.1.69. *Selection requirements applied in the low multiplicity D meson HLT2 lines in TCK* `0x00990042`.

			$D^0 \to K^\pm\pi^\mp$	$D^\pm \to K^\pm\pi^\mp\pi^\pm$	$D^0 \to K^\pm\pi^\mp\pi^\pm\pi^\mp$
Decay descriptors	Right-sign		`[D0 -> K- pi+]cc`	`[D+ -> K+ pi+ pi-]cc`	`[D0 -> K- pi+ pi- pi+]cc`

	Wrong-sign		`[D0 -> K+ pi+]cc`	`[D+ -> K+ pi+ pi+]cc`	`[D0 -> K+ pi+ pi+ pi+]cc`
					`[D0 -> K+ pi+ pi+ pi-]cc`
					`[D0 -> K+ pi- pi- pi-]cc`

GEC	VELO tracks			< 8	
	Backward tracks			0	
$h^\pm$	Track χ^2/ndf			< 3	
	p	MeV/c		> 5000	
	p_{T}	MeV/c		> 100	
	Kaon PIDK			> 0	
n-h combination	p	MeV/c		> 10000	
	p_{T}	MeV/c		$[0, 5000]$	
	Max DOCA	mm	< 0.5	< 0.5	< 0.7
	$\sum_{\mathrm{children}} p_{\mathrm{T}}$	MeV/c	> 200	> 300	> 400
	$\lvert M(\sum_{\mathrm{children}} p^\mu) - m_D \rvert$	MeV/c		< 80	
D meson	χ^2_{vtx}/ndf			< 15	

TABLE 5.1.70. *Selection requirements applied in the low multiplicity KK HLT2 line in TCK* `0x00990042`. *No extra requirements are applied on the KK combination.*

Decay descriptors	`D0 -> K+ K-` `[D0 -> K+ K+]cc`		
GECs	VELO tracks		< 8
	Backward tracks		0
$K^{\pm}$	Track χ^2/ndf		< 3
	p	MeV/c	> 10000
	p_{T}	MeV/c	> 100
	PIDK		> 5

TABLE 5.1.71. *Selection requirements applied in the* $\Lambda_c^{\pm} \to \Lambda^0 h^{\pm}$ *HLT2 lines in TCK* `0x00990042`.

			Downstream Λ^0	Long Λ^0
Λ^0	Child track χ^2/ndf		< 4	< 3
	Child χ^2_{IP}		> 10	> 36
	χ^2_{vtx}/ndf		< 20	
	p_{T}	MeV/c	> 500	
	χ^2_{IP}		> 0	> 4
Bachelor $h^{\pm}$	Track χ^2/ndf		< 3	
	p	MeV/c	> 2500	
	p_{T}	MeV/c	> 350	
	χ^2_{IP}		> 9	
$\Lambda_c^{\pm}$	χ^2_{vtx}/ndf		< 15	
	p_{T}	MeV/c	> 1500	
	χ^2_{IP}		< 15	
	$\Delta z(\Lambda_c^{\pm}, \Lambda^0)$	mm	> 10	
	HLT1 TOS		`Hlt1Track.*`	
	M	MeV/c^2	$[2175, 2395]$	

TABLE 5.1.72. *Selection requirements applied in the inclusive single electron HLT2 lines (denoted without the `Hlt2Single` prefix for legibility reasons) in TCK `0x00990042`.*

		`TFElectron`	`ElectronTFLowPt`	`ElectronTFHighPt`	`TFVHighPtElectron`
Track χ^2/ndf		< 5	< 5	< 20	< 20
IP	mm	> 0.05	–	–	–
IP χ^2		> -1	–	–	–
p_{T}	MeV/c	> 10000	> 4800	> 10000	> 15000
E_{PS}	MeV	> 50			
E_{ECAL}/p		> 0.1			
E_{HCAL}/p		< 0.05			

TABLE 5.1.73. *Pre- and postscales of the technical HLT2 lines in TCK `0x00990042`. Differences with respect to the 2011 reference TCK (Table 4.1.84) are highlighted in **bold**.*

	Prescale	Postscale
`Hlt2DebugEvent`	$\mathbf{10^{-6}}$	1.0
`Hlt2ErrorEvent`	1.0	0.01 Hz
`Hlt2Forward`	$\mathbf{10^{-5}}$	1.0
`Hlt2Global`	1.0	1.0
`Hlt2Lumi`	1.0	1.0
`Hlt2PassThrough`	0.0001	1.0
`Hlt2Transparent`	1.0	1.0

5.2 0x008C0040

There are sizeable differences between 0x008C0040 and the 2012 reference TCK, since most of the new lines introduced in 2012 were still not included in this early TCK. Therefore, selection requirements are quite different to 0x00990042 and closer to 0x00790038.

5.2.1 *Line content*

The differences between this TCK and the 2012 reference TCK are shown in Table 5.2.1. Some lines present in the 2011 reference TCK (namely, the displaced vertices ones) were still used in this TCK, and the applied selection criteria are discussed in the following sections.

5.2.2 *Prescales*

The differences in prescales of the lines present in both TCKs are shown in Table 5.2.2. A few considerations can be made:

- In L0, L0DiHadron,lowMult was more prescaled than in the reference TCK.
- In HLT1, the Hlt1VertexDisplVertex line was disabled and Hlt1MBNoBias was heavily prescaled.
- In HLT2, the Express lines were prescaled to unity—with Hlt2ExpressJPsiTagProbe enabled—in the same way as the non-detached DiMuon lines. The Hlt2B2HHLTUnbiased line, and the BBDT-based radiative and Simple topological lines were disabled in the reference TCK.

5.2.3 *L0 thresholds*

Several L0 thresholds differ with respect to the reference TCK; these are detailed in Table 5.2.3.

5.2.4 *HLT1 lines*

In the GEC used in this TCK the number of hits in the VELO is required to be below 10000, contrary to the 6000 cut of the reference TCK.

The HLT1 lines present in 0x008C0040 and not present in the reference TCK are the passthrough lines—Hlt1L0AnyNoSPDRateLimited and Hlt1L0AnyRateLimited—described in Page 16, which ran with the same prescales as in the 2011 reference TCK.

The differences between the HLT1 lines present in both 0x008C0040 and the reference TCK concern

- the dimuon lines—Hlt1DiMuon(Low|High)Mass—as shown in Table 5.2.4;
- the single muon and electron lines, in which, comparing with Table 5.1.6, (a) Hlt1SingleMuonNoIP requires $p > 6$ GeV/c instead of the 3 GeV/c of the reference TCK, (b) Hlt1SingleMuonHighPT requires $p > 8$ GeV/c instead of the 3 GeV/c, and (c) Hlt1SingleElectronNoIP requires a track χ^2/ndf below 5 instead of 3;
- the single track lines, in which TT validation was not applied, and track χ^2/ndf, p and p_{T} requirements were changed according to the values shown in Table 5.2.5;
- the Hlt1CharmCalibrationNoBias line, in which explicit requirements on the ODIN trigger and bunch-crossing types are applied to select no-bias events instead of looking at the second bit in ODIN event type ; and

- the Hlt1BeamGasCrossingForcedRecoFullZ line, which doesn't require the event ODIN trigger type not to be LumiTrigger, contrary to the reference TCK (Table 5.1.3).

5.2.5 HLT2 lines

As shown in Table 5.2.1, the HLT2 lines present in 0x008C0040 and not present in the reference TCK are:

- The no-HLT1 $D^0 \to h^\pm h^\mp h^\pm h^\mp$ lines—Hlt2CharmHadD02HHHHDstNoHltOne.*—which ran with prescales shown in Table 5.2.6 and are just a copy of the regular $D^0 \to h^\pm h^\mp h^\pm h^\mp$ lines (discussed afterwards) with the HLT1 TOS requirement removed.

- The $D^0 \to h^\pm h^\mp h^\mp h^\mp$ lines—Hlt2CharmHadD02HHHH(Dst|DstNoHltOne)?_Ch2($|WideMass)—which ran with prescales shown in Table 5.2.6. They work analogously to the already discussed $D^0 \to h^\pm h^\mp h^\pm h^\mp$, lines, but building charge-2 candidates with the D0 -> K*(892)0 pi- K- and D0 -> K*(892)0 pi+ K+ decay descriptors.

It is worth noting thatthe displaced vertices lines, run with prescales shown in Table 5.2.7, still used in this TCK the base 2011 algorithms (Page 24). However, some of the changes applied afterwards—and discussed in Page 100—had already been introduced at this stage:

- Before the Hlt2PreSelDV algorithm is run, a VELO track filtering is applied: first, the used VELO tracks are required to have have IP> 0.1 mm and to be forward; second, it is required to have at more than 3 of these displaced VELO tracks.

- The *vertex in matter* veto tool, used in the 2012 lines, is introduced.

- The Hlt2PreSelDV and Hlt2SelDV are simplified with respect to their 2011 counterparts in order to improve speed and delay as much as possible particle building.
  - Radial cut of the displaced vertices with respect to the beam line and isolation requirement on the RV with respect to other RV's are removed.
  - Requirements on the fraction of energy carried by a single particle (< 0.9 for all long lines, < 0.85 for the Down line), the fraction of track having first hit upstream the vertex (< 0.49 for all lines) and the χ^2/ndf of long and dowstream tracks (< 5 and < 10, respectively) are added.

- Changes in requirements in the Hlt2SelDV algorithm with respect to the 2011 reference TCK are shown in Table 5.2.8.

Additionally, the TISTOSing in all the topological lines—including the radiative ones—doesn't include the Hlt1TrackAllL0Tight line, which was not present in this TCK.

Differences in selection requirements in the HLT2 lines, mainly due to the influence of the 2011 reference TCK, concern

- the Hlt2B2HHPi0_Merged line, as shown in Table 5.2.9;

- the Hlt2DiMuonPsi2S line, in which the p_T requirement on the dimuon object is > 0 instead of > 2000 MeV/c used in TCK 0x00990042;

- the particle objects used in the multimuon lines, as shown in Table 5.2.10;

- the Hlt2TriMuonTau line, in which it required that $c\tau > 45$ μm, in contrast with the $c\tau > 75$ μm cut of the reference TCK;

- the $B \to hh$ lines, as shown in Table 5.2.11;
- the K_S^0 and Λ^0 from `Hlt2SharedParticles`, as shown in Table 5.2.12;
- the topological lines, which lack the $\tau > 20$ ps cut on the V^0 and present changes in (a) the K_S^0 and Λ^0 from `Hlt2SharedParticles`, (b) the input track requirements (Table 5.2.13) and (c) the preselection of the n-body candidates (Table 5.2.14);
- the $D^0 \to K_S^0 h^\pm h^\mp$ lines—`Hlt2CharmHadD02HHKsLL` and `Hlt2CharmHadD02HHKsDD`—with the already mentioned changes in `Hlt2SharedParticles` K_S^0 (Table 5.2.12) and few modifications of the selection criteria, shown in Table 5.2.15;
- the $D^\pm \to K_S^0 h^\pm$ lines—`Hlt2CharmHadD2KS0H_D2KS0(DD)?(K|Pi)`—with the already mentioned changes in `Hlt2SharedParticles` K_S^0 (Table 5.2.12) and the requirement that both pions in long K_S^0 and the bachelor h have a track χ^2/ndf below 4 instead of 3 (Table 5.1.32);
- the non-monitoring $D^0 \to h^\pm h^\mp$ lines—`Hlt2CharmHadD02HH_D02KK`, `Hlt2CharmHadD02HH_D02KPi` and `Hlt2CharmHadD02HH_D02PiPi`—which require a D^0 mass of $[1815, 1915]$ MeV/c^2 instead of $[1790, 1930]$ MeV/c^2 (Table 5.1.28);
- the `Hlt2ExpressJPsi` line, as shown in Table 5.2.16;
- the `Hlt2ExpressDs2PhiPi` line, with difference summarized in Table 5.2.17;
- the $D^0 \to h^\pm h^\mp h^\pm h^\mp$ lines, with differences in the requirements applied in the `twoBodySequence` of the `Hlt2CharmHadTwoBodyForD02HHHH` configurable (Table 5.2.18) and in the 4-body selection, as summarized in Table 5.2.19;
- the $D^\pm \to h^\pm h^\mp h^\pm$ lines—`Hlt2CharmHadD2HHH` and `Hlt2CharmHadD2HHHWideMass`—with changes summarized in Table 5.2.20;
- the slow pion in the `Hlt2CharmSemilepD02HMuNu_D02KMuNuTight` line, with a track χ^2/ndf requirement of < 100 instead of the < 3 value from the reference TCK (Table 5.1.46); and
- the $\Lambda_c^\pm \to \Lambda^0 h^\pm$ lines—`Hlt2LambdaC_LambdaC2Lambda0(LL|DD)(K|Pi)`—with the already mentioned differences in the downstream `Hlt2SharedParticles` Λ^0 (Table 5.2.12) and changes in selection requirements summarized in Table 5.2.21;

TABLE 5.2.1. *Differences in line contents between* `0x00990042` *and* `0x008C0040`*. Lines included are marked with a check mark (✓).*

	0x00990042	0x008C0040
Hlt1L0AnyNoSPDRateLimited		✓
Hlt1L0AnyRateLimited		✓
Hlt1TrackAllL0Tight	✓	
Hlt2CharmHadD02HHHHDstNoHltOne_2K2piWideMass		✓
Hlt2CharmHadD02HHHHDstNoHltOne_2K2pi		✓
Hlt2CharmHadD02HHHHDstNoHltOne_3KpiWideMass		✓
Hlt2CharmHadD02HHHHDstNoHltOne_3Kpi		✓
Hlt2CharmHadD02HHHHDstNoHltOne_4piWideMass		✓
Hlt2CharmHadD02HHHHDstNoHltOne_4pi		✓
Hlt2CharmHadD02HHHHDstNoHltOne_Ch2WideMass		✓
Hlt2CharmHadD02HHHHDstNoHltOne_Ch2		✓
Hlt2CharmHadD02HHHHDstNoHltOne_K3piWideMass		✓
Hlt2CharmHadD02HHHHDstNoHltOne_K3pi		✓
Hlt2CharmHadD02HHHHDstNoHltOne_KKpipiWideMass		✓
Hlt2CharmHadD02HHHHDstNoHltOne_KKpipi		✓
Hlt2CharmHadD02HHHHDst_Ch2WideMass		✓
Hlt2CharmHadD02HHHHDst_Ch2		✓
Hlt2CharmHadD02HHHH_Ch2WideMass		✓
Hlt2CharmHadD02HHXDst_hhXWideMass	✓	
Hlt2CharmHadD02HHXDst_hhX	✓	
Hlt2DiMuonDetachedPsi2S	✓	
Hlt2DisplVerticesDoublePS	✓	
Hlt2DisplVerticesSingleHighFD	✓	
Hlt2DisplVerticesSingleHighMass	✓	
Hlt2DisplVerticesSingleLoosePS	✓	
Hlt2DisplVerticesSinglePS	✓	
Hlt2DisplVerticesSingleVeryHighFD	✓	
Hlt2DisplVerticesDoublePostScaled		✓
Hlt2DisplVerticesHighVSSingle		✓
Hlt2DisplVerticesHighMassSingle		✓
Hlt2DisplVerticesSingleHighFDPostScaled		✓
Hlt2DisplVerticesSingleHighMassPostScaled		✓
Hlt2DisplVerticesSingleMVPostScaled		✓
Hlt2DisplVerticesSinglePostScaled		✓
Hlt2LowMultChiC2HHHHWS	✓	
Hlt2LowMultChiC2HHHH	✓	
Hlt2LowMultChiC2HHWS	✓	
Hlt2LowMultChiC2HH	✓	
Hlt2LowMultD2K3PiWS	✓	
Hlt2LowMultD2K3Pi	✓	
Hlt2LowMultD2KPiPiWS	✓	
Hlt2LowMultD2KPiPi	✓	
Hlt2LowMultD2KPiWS	✓	
Hlt2LowMultD2KPi	✓	
Hlt2LowMultDDInc	✓	

TABLE 5.2.2. *Differences in prescales between 0x00990042 and 0x008C0040.*

	0x00990042	0x008C0040
L0DiHadron,lowMult	0.25	0.1
Hlt1BeamGasCrossingForcedRecoFullZ	0.001	1.0
Hlt1MBNoBias	0.1	1.0
Hlt1VertexDisplVertex	1.0	0.0
Hlt2B2HHLTUnbiased	0.0	0.1
Hlt2DebugEvent	10^{-6}	0.0001
Hlt2DiMuonJPsi	0.2	1.0
Hlt2DiMuonPsi2S	0.1	1.0
Hlt2ExpressBeamHalo	0.001	1.0
Hlt2ExpressD02KPi	0.1	1.0
Hlt2ExpressDStar2D0Pi	0.1	1.0
Hlt2ExpressJPsiTagProbe	0.0	1.0
Hlt2ExpressKS	0.001	1.0
Hlt2ExpressLambda	0.01	1.0
Hlt2Forward	10^{-5}	0.0001
Hlt2SingleMuon	0.5	1.0
Hlt2Topo2BodySimple	0	1.0
Hlt2Topo3BodySimple	0	1.0
Hlt2Topo4BodySimple	0	1.0
Hlt2TopoRad2BodyBBDT	0	1.0
Hlt2TopoRad2plus1BodyBBDT	0	1.0

TABLE 5.2.3. *Changes in the L0 thresholds between `0x00990042` (Table 5.1.1) and `0x008C0040`.*

			0x00990042	0x008C0040
L0DiEM,lowMult	Electron E_T	MeV	> 480	> 240
	Photon E_T	MeV	> 480	> 240
L0DiHadron,lowMult	Hadron E_T	MeV	> 500	> 1000
	PU mult		< 3	–
	$\sum E_T$		–	> 2000
L0DiMuon	$\sqrt{p_T^{\text{largest}} \times p_T^{\text{2nd largest}}}$	MeV/c	> 1600	> 1296
L0DiMuonNoSPD	$\sqrt{p_T^{\text{largest}} \times p_T^{\text{2nd largest}}}$	MeV/c	> 1600	> 1296
L0Electron	Electron E_T	MeV	> 2720	> 2500
L0ElectronNoSPD	Electron E_T	MeV	> 2720	> 2500
L0Hadron	Hadron E_T	MeV	> 3620	> 3500
L0HadronNoSPD	Hadron E_T	MeV	> 3620	> 3500
L0Muon	p_T^{largest}	MeV/c	> 1760	> 1480
L0MuonNoSPD	p_T^{largest}	MeV/c	> 1760	> 1480
L0Photon	Photon E_T	MeV	> 2720	> 2500
L0PhotonNoSPD	Photon E_T	MeV	> 2720	> 2500

TABLE 5.2.4. *Differences in selection requirements in the `Hlt1DiMuonHighMass` (top) and `Hlt1DiMuonLowMass` (bottom) dimuon HLT1 lines between `0x00990042` (Table 5.1.4) and `0x008C0040`.*

			0x00990042	0x008C0040
$\mu^\pm$	p	MeV/c	> 3000	> 6000

			0x00990042	0x008C0040
$\mu^\pm$	p_T	MeV/c	> 0	> 500
	p	MeV/c	> 0	> 6000
	χ^2_{IP}		> 6	> 3
Dimuon	M	MeV/c^2	> 0	> 1000

TABLE 5.2.5. *Changes in the single track lines HLT1 lines between `0x00990042` (Table 5.1.7) and `0x008C0040`.*

			0x00990042	0x008C0040
Hlt1TrackAllL0	p_T	MeV/c	> 1600	> 1700
	p	MeV/c	> 3000	> 10000
Hlt1TrackPhoton	p	MeV/c	> 3000	> 6000
Hlt1TrackMuon	Track χ^2/ndf		< 2.5	< 3
	p	MeV/c	> 3000	> 6000

TABLE 5.2.6. *Pre- and postscales of the $D^0 \to h^\pm h^\mp h^\pm h^\mp$ lines that are present in TCK `0x008C0040` and not in TCK `0x00990042`.*

	Prescale	Postscale
Hlt2CharmHadD02HHHHDstNoHltOne_4pi	1.0	1.0
Hlt2CharmHadD02HHHHDstNoHltOne_4piWideMass	0.1	1.0
Hlt2CharmHadD02HHHHDstNoHltOne_K3pi	1.0	1.0
Hlt2CharmHadD02HHHHDstNoHltOne_K3piWideMass	0.1	1.0
Hlt2CharmHadD02HHHHDstNoHltOne_KKpipi	1.0	1.0
Hlt2CharmHadD02HHHHDstNoHltOne_KKpipiWideMass	0.1	1.0
Hlt2CharmHadD02HHHHDstNoHltOne_2K2pi	1.0	1.0
Hlt2CharmHadD02HHHHDstNoHltOne_2K2piWideMass	0.1	1.0
Hlt2CharmHadD02HHHHDstNoHltOne_3Kpi	1.0	1.0
Hlt2CharmHadD02HHHHDstNoHltOne_3KpiWideMass	0.1	1.0
Hlt2CharmHadD02HHHHDstNoHltOne_Ch2	0.1	1.0
Hlt2CharmHadD02HHHHDstNoHltOne_Ch2WideMass	0.1	1.0
Hlt2CharmHadD02HHHHDst_Ch2	0.0	1.0
Hlt2CharmHadD02HHHHDst_Ch2WideMass	0.1	1.0
Hlt2CharmHadD02HHHH_Ch2	0.0	1.0
Hlt2CharmHadD02HHHH_Ch2WideMass	0.1	1.0

TABLE 5.2.7. *Pre- and postscales of the displaced vertices lines that are in TCK `0x008C0040` and not in TCK `0x00990042`.*

	Prescale	Postscale
Hlt2DisplVerticesDoublePostScaled	1.0	0.01
Hlt2DisplVerticesDouble	1.0	1.0
Hlt2DisplVerticesHighVSSingle	1.0	1.0
Hlt2DisplVerticesHighMassSingle	1.0	1.0
Hlt2DisplVerticesSingleDown	1.0	1.0
Hlt2DisplVerticesSingleHighFDPostScaled	1.0	1.0
Hlt2DisplVerticesSingleHighMassPostScaled	1.0	1.0
Hlt2DisplVerticesSingleMVPostScaled	1.0	0.001
Hlt2DisplVerticesSinglePostScaled	1.0	0.0005
Hlt2DisplVerticesSingle	1.0	1.0

TABLE 5.2.8. *Changes in the `Hlt2SelDV` algorithm in the displaced vertices HLT2 lines (denoted without the `Hlt2DisplVertices` prefix for legibility reasons) between `0x00790038`(Tables 4.1.65 and 4.1.66) and `0x008C0040`.*

			0x00790038	0x008C0040
DoublePostScaled	Prey mass	GeV/c^2	$[3.0, 14000.0]$	$[2.0, 14000.0]$
Double	Prey mass	GeV/c^2	$[3.0, 14000.0]$	$[2.0, 14000.0]$
	$\sum_{\text{children}} p_{\text{T}}$	GeV/c^2	$[3.0, 14000.0]$	$[1.0, 14000.0]$
	Mass of heaviest prey	GeV/c^2	> 4.5	> 2.8
HighVSSingle	Number of RV children		≥ 5	≥ 6
	Prey mass	GeV/c^2	$[4.5, 14000.0]$	$[3.2, 14000.0]$
	$\sum_{\text{children}} p_{\text{T}}$	GeV/c^2	$[3.0, 14000.0]$	$[1.0, 14000.0]$
MassSingle	Radial distance to PV	mm	$[0.4, 10000.0]$	$[0.5, 10000.0]$
	Prey mass	GeV/c^2	$[10.0, 14000.0]$	$[8.0, 14000.0]$
	$\sum_{\text{children}} p_{\text{T}}$	GeV/c^2	$[3.0, 14000.0]$	$[1.0, 14000.0]$
Down	Prey mass pre-seeding	GeV/c^2	$[3.0, 14000.0]$	$[2.8, 14000.0]$
	$\sum_{\text{children}} p_{\text{T}}$	GeV/c^2	$[3.0, 14000.0]$	$[1.0, 14000.0]$
HighFDPostScaled	Radial distance to PV	mm	$[2.0, 10000.0]$	$[3.0, 10000.0]$
	Prey mass	GeV/c^2	$[4.5, 14000.0]$	$[3.2, 14000.0]$
HighMassPostScaled	Number of RV children		≥ 4	≥ 5
	Radial distance to PV	mm	$[0.4, 10000.0]$	$[0.5, 10000.0]$
	Prey mass	GeV/c^2	$[10.0, 14000.0]$	$[8.0, 14000.0]$
MVPostScaled	Prey mass	GeV/c^2	$[3.0, 14000.0]$	$[0.0, 14000.0]$
SinglePostScaled	Prey mass	GeV/c^2	$[3.0, 14000.0]$	$[0.0, 14000.0]$
	$\sum_{\text{children}} p_{\text{T}}$	GeV/c^2	$[3.0, 14000.0]$	$[0.0, 14000.0]$
Single	Number of RV children		≥ 5	≥ 4
	Radial distance to PV	mm	$[2.5, 10000.0]$	$[1.7, 10000.0]$
	Prey mass	GeV/c^2	$[7.0, 14000.0]$	$[5.5, 14000.0]$
	$\sum_{\text{children}} p_{\text{T}}$	GeV/c^2	$[3.0, 14000.0]$	$[1.0, 14000.0]$

TABLE 5.2.9. *Differences in selection requirements in the `Hlt2B2HHPi0_Merged` line between TCK `0x00990042` (Table 5.1.9) and `0x008C0040`.*

		0x00990042	0x008C0040
$\pi^\pm$	Track χ^2/ndf	< 3.0	< 4.0
$\pi^+\pi^-$ combination	Smallest track χ^2/ndf	< 2.0	< 2.4

TABLE 5.2.10. *Differences in selection requirements in the particle objects used in the multimuon HLT2 lines between TCK `0x00990042` (Table 5.1.50) and `0x008C0040`.*

		`0x00990042`	`0x008C0040`
All	Track χ^2/ndf	< 4.0	< 6.0
`GoodMuon`	χ^2_{IP}	> 9	> 4

TABLE 5.2.11. *Differences in selection requirements in the $B \to hh$ HLT2 lines between TCK `0x00990042` (Table 5.1.8) and `0x008C0040`. Note that `Hlt2B2HHLTUnbiased` was disabled.*

			`0x00990042`	`0x008C0040`
`Hlt2B2HHLT.*`	Child track χ^2/ndf		< 3	< 5
`Hlt2B2HHLTUnbiasedDetached`	B meson τ	ps	> 0.3	> 0.1

TABLE 5.2.12. *Differences in selection requirements in the K^0_s and Λ^0 from `Hlt2SharedParticles` between TCK `0x00990042` (Tables 5.1.11 and 5.1.12) and `0x008C0040`.*

			`0x00990042`	`0x008C0040`
Long K^0_s	Child track χ^2/ndf		< 3	< 4
Downstream V^0	Child p_T	MeV/c	> 175	–
	Child χ^2_{IP}		–	> 9

TABLE 5.2.13. *Differences in selection requirements in the input tracks for the HLT2 topological lines between TCK `0x00990042` (Table 5.1.13) and `0x008C0040`.*

		`0x00990042`	`0x008C0040`
Regular and `Mu` lines	Track χ^2/ndf	< 2.5	< 3.0
`E` lines	Track χ^2/ndf	< 2.5	(< 4.0 and PIDe > −2.0) or < 3.0

TABLE 5.2.14. *Changes in the preselection requirements on the n-body candidates, applied on top of those in Table 5.1.14, in the HLT2 topological lines between TCK `0x00990042` (Table 5.1.15) and `0x008C0040`.*

	`0x00990042`	`0x008C0040`
Number of V^0 for $n = 3$	≤ 1	≤ 2
Number of V^0 for $n = 4$	≤ 0	≤ 1
At least one track with	$\chi^2_{\mathrm{IP}} > 16$ and $p_\mathrm{T} > 1500$ MeV/c or or muon with $p_\mathrm{T} > 1000$ MeV/c	$\chi^2_{\mathrm{IP}} > 9$ and $p_\mathrm{T} > 1350$ MeV/c

TABLE 5.2.15. *Differences in selection requirements in the $D^0 \to K_S^0 h^\pm h^\mp$ lines between TCK `0x00990042` (Tables 5.1.33 and 5.1.35) and `0x008C0040`.*

			0x00990042	0x008C0040
Downstream K_S^0	π χ^2_{IP}		–	> 9.0
GEC	Long tracks		< 180	< 120
D^0	τ	ps	> 0.3	> 0.2

TABLE 5.2.16. *Differences in selection requirements in the `Hlt2ExpressJPsi` line between TCK `0x00990042` (Table 5.1.60) and `0x008C0040`.*

		0x00990042	0x008C0040
$\mu^\pm$	Track χ^2/ndf	< 4	–
$\mu^+\mu^-$ combination	Smallest track χ^2/ndf	< 4	< 5
J/ψ	χ^2_{vtx}/ndf	< 7	< 10

TABLE 5.2.17. *Differences in selection requirements in the `Hlt2ExpressDs2PhiPi` line between TCK `0x00990042` (Table 5.1.61) and `0x008C0040`.*

			0x00990042	0x008C0040
$K^\pm$	Track χ^2/ndf		< 4	–
	χ^2_{IP}		> 16	> 1.0
	p_T	MeV/c	> 500	> 300
ϕ	χ^2_{IP}		> 16	> 2.18
	DOCA	mm	< 0.3	< 10.0
$\pi^\pm$	χ^2_{IP}		> 16	> 12.18
	p_T	MeV/c	> 500	> 300
D_s^+	χ^2_{vtx}/ndf		< 9	< 12.18
	χ^2_{IP}		< 9	< 12.18

TABLE 5.2.18. *Differences in selection requirements performed in the `twoBodySequence` of the `Hlt2CharmHadTwoBodyForD02HHHH` configurable between TCK `0x00990042` (Table 5.1.24) and `0x008C0040`.*

		0x00990042	0x008C0040
$h^\pm$	χ^2_{IP}	> 6	> 1.8
K^* meson	χ^2_{VS}	> 20.0	> 15

TABLE 5.2.19. *Differences in selection requirements in $D^0 \to h^\pm h^\mp h^\pm h^\mp$ lines between TCK `0x00990042` (Table 5.1.26) and `0x008C0040`. The mass cuts correspond to the non-monitoring (signal) lines.*

			0x00990042	0x008C0040
D^0	χ^2_{IP}		< 42	< 50
	M	MeV/c^2	$[1790, 1940]$	$[1800.0, 1930.0]$
Slow π	Track χ^2/ndf		< 3	< 100

TABLE 5.2.20. *Differences in selection requirements in the `Hlt2CharmHadD2HHH` and `Hlt2CharmHadD2HHHWideMass` lines between TCK `0x00990042` (Table 5.1.29) and `0x008C0040`.*

			0x00990042	0x008C0040
$h^\pm$	p	MeV/c	> 3000	> 2000
	p_{T}	MeV/c	> 300	> 200
	χ^2_{IP}		> 6	> 5
$h^+h^-h^+$ combination	$\sum p_{\mathrm{T}}$	MeV/c	> 2800	> 2500
$D^\pm$	χ^2_{vtx}/ndf		< 15	< 20
	χ^2_{IP}		< 12	< 15
	χ^2_{VS}		> 175	> 150

TABLE 5.2.21. *Differences in selection requirements in the $\Lambda_c^\pm \to \Lambda^0 h^\pm$ lines between TCK `0x00990042` (Table 5.1.71) and `0x008C0040`. Requirements corresponding to the long Λ^0 lines are shown in parentheses whenever necessary.*

			0x00990042	0x008C0040
Λ^0	Child track χ^2/ndf		$< 4\,(3)$	$< 5\,(5)$
Bachelor $h^\pm$	Track χ^2/ndf		< 3	< 5
	p_{T}	MeV/c	> 350	< 250
	χ^2_{IP}		> 9	> 4
$\Lambda_c^\pm$	p_{T}	MeV/c	> 1500	> 800
	χ^2_{IP}		< 15	< 25

5.3 0x0094003D

The main feature of this TCK is the fact that the HLT2 displaced vertices lines, still configured similarly to their 2011 counterparts (see the discussion in the previous section), were disabled through a 0 prescale factor.

5.3.1 Line content

There are still sizeable differences in line content between `0x0094003D` and the 2012 reference TCK, as shown in Table 5.3.1. Comparing to `0x008C0040`:

- the HLT1 passthrough lines—`Hlt1L0AnyNoSPDRateLimited` and `Hlt1L0AnyRateLimited`—were removed;
- the `Hlt2DiMuonDetachedPsi2S` line was introduced;
- the $D^0 \to h^{\pm}h^{\mp}X$ lines—`Hlt2CharmHadD02HHXDst_hhX($|WideMass)`—were also introduced; and
- the no-HLT1 and charge-2 $D^0 \to h^{\pm}h^{\mp}h^{\pm}h^{\mp}$ lines were removed;

From Table 5.3.1, one can see that the main remaining differences are the `Hlt1TrackAllL0Tight` line and low multiplicity HLT2 lines. Additionally, the displaced vertices lines were disabled through their prescale.

5.3.2 Prescales

The differences in prescales of the lines present in both TCKs are shown in Table 5.3.2. A few considerations can be made:

- In L0, `L0DiHadron,lowMult` was more prescaled than the reference.
- In HLT1, the `Hlt1BeamGasCrossingForcedRecoFullZ` was not prescaled.
- In HLT2, the `Hlt2DiMuonJPsi` line was less prescaled than in the reference TCK. The `Simple` topological lines and the `Hlt2B2HHLTUnbiased` line were active, contrary to the reference TCK.

Comparing to the previous TCK, in HLT1 `Hlt1VertexDisplVertex` line was activated, while in HLT2 the BBDT-based radiative topological lines were not even configured and—as already mentioned—the displaced vertices were disabled.

5.3.3 L0 thresholds

Several L0 thresholds differ with respect to the reference TCK, but much less than the previous TCK. As can be seen in Table 5.3.3, only differences in the low multiplicity channels remain.

5.3.4 HLT1 lines

The differences between the HLT1 lines present in both `0x0094003D` and the reference TCK concern

- the `Hlt1DiMuonHighMass`, shown in Table 5.3.4;

- the single muon lines, in which, comparing with Table 5.1.6, (a) `Hlt1SingleMuonNoIP` requires $p > 6$ GeV/c instead of the 3 GeV/c of the reference TCK and (b) `Hlt1SingleMuonHighPT` requires $p > 8$ GeV/c instead of the 3 GeV/c;
- the single track lines, in which TT validation was not applied, and track χ^2/ndf, p and p_T cuts were changed according to Table 5.3.5; and
- the `Hlt1BeamGasCrossingForcedRecoFullZ` line, which doesn't require the event ODIN trigger type not to be `LumiTrigger`, contrary to the reference TCK (Table 5.1.3).

5.3.5 HLT2 lines

Smilarly to the previous TCK, the TISTOSing in all the topological lines—including the radiative ones—doesn't include the `Hlt1TrackAllL0Tight` line, which was not present in this TCK.

Differences in selections in the HLT2 lines concern

- the `Hlt2B2HHLTUnbiasedDetached` line, which requires a B^0 meson τ above 0.1 ps, in contrast with the $\tau > 0.3$ ps requirement in the reference TCK;
- the K_S^0 and Λ^0 from `Hlt2SharedParticles`, as shown in Table 5.3.6;
- the topological lines, with the removal of the $\tau > 20$ ps cut on the V^0 and changes in (a) the downstream Λ^0 from `Hlt2SharedParticles` (Table 5.3.6) and (b) the preselection requirements on the n-body candidates (Table 5.3.7);
- the `Hlt2ExpressJPsi` line, as shown in Table 5.3.8;
- the $D^\pm \to h^\pm h^\mp h^\pm$ lines, which still were the same as in 2011, with changes summarized in Table 5.2.20;
- the $\Lambda_c^\pm \to \Lambda^0 h^\pm$ lines, with the already mentioned differences in the downstream Λ^0 (Table 5.3.6) and changes in selection criteria summarized in Table 5.3.9; and
- the $D^0 \to h^\pm h^\mp X$ lines, with differences summarized in Table 5.3.10.

TABLE 5.3.1. *Differences in line contents between* `0x00990042` *and* `0x0094003D`*. Lines included are marked with a check mark (✓). The displaced vertices lines present in* `0x0094003D` *were configured but prescaled to* 0.

	0x00990042	0x0094003D
Hlt1TrackAllL0Tight	✓	
Hlt2DisplVerticesHighMassSingle		✓
Hlt2DisplVerticesHighVSSingle		✓
Hlt2DisplVerticesSinglePostScaled		✓
Hlt2DisplVerticesDoublePostScaled		✓
Hlt2DisplVerticesSingleHighMassPostScaled		✓
Hlt2DisplVerticesSingleHighFDPostScaled		✓
Hlt2DisplVerticesSingleMVPostScaled		✓
Hlt2LowMultD2KPi	✓	
Hlt2LowMultD2KPiPi	✓	
Hlt2LowMultD2K3Pi	✓	
Hlt2LowMultChiC2HH	✓	
Hlt2LowMultChiC2HHHH	✓	
Hlt2LowMultD2KPiWS	✓	
Hlt2LowMultD2KPiPiWS	✓	
Hlt2LowMultD2K3PiWS	✓	
Hlt2LowMultChiC2HHWS	✓	
Hlt2LowMultChiC2HHHHWS	✓	
Hlt2LowMultDDInc	✓	
Hlt2DisplVerticesSingleLoosePS	✓	
Hlt2DisplVerticesSingleHighFD	✓	
Hlt2DisplVerticesSingleVeryHighFD	✓	
Hlt2DisplVerticesSingleHighMass	✓	
Hlt2DisplVerticesSinglePS	✓	
Hlt2DisplVerticesDoublePS	✓	

TABLE 5.3.2. *Differences in prescales between `0x00990042` and `0x0094003D`.*

	0x00990042	0x0094003D
`L0DiHadron,lowMult`	0.25	0.1
`Hlt1BeamGasCrossingForcedRecoFullZ`	0.001	1
`Hlt2DiMuonJPsi`	0.2	1
`Hlt2B2HHLTUnbiased`	0	0.1
`Hlt2Topo2BodySimple`	0	1
`Hlt2Topo3BodySimple`	0	1
`Hlt2Topo4BodySimple`	0	1
`Hlt2Forward`	10^{-5}	0.0001
`Hlt2DebugEvent`	10^{-6}	0.0001
`Hlt2DisplVerticesDouble`	1	0
`Hlt2DisplVerticesSingle`	1	0
`Hlt2DisplVerticesSingleDown`	1	0

TABLE 5.3.3. *Changes in the L0 thresholds between `0x00990042` (Table 5.1.1) and `0x0094003D`.*

			0x00990042	0x0094003D
`L0DiEM,lowMult`	Electron E_T	MeV	> 480	> 240
	Photon E_T	MeV	> 480	> 240
`L0DiHadron,lowMult`	Hadron E_T	MeV	> 500	> 1000
	PU mult		< 3	–
	$\sum E_T$		–	> 2000

TABLE 5.3.4. *Differences in selection requirements in the `Hlt1DiMuonHighMass` line between `0x00990042` (Table 5.1.4) and `0x0094003D`.*

			0x00990042	0x0094003D
$\mu^\pm$	p	MeV/c	> 3000	> 6000

TABLE 5.3.5. *Changes in the single track lines HLT1 lines between `0x00990042` (Table 5.1.7) and `0x0094003D`.*

			0x00990042	0x0094003D
`Hlt1TrackAllL0`	Track χ^2/ndf		< 2.0	< 1.5
	p_T	MeV/c	> 1600	> 1700
	p	MeV/c	> 3000	> 10000
`Hlt1TrackPhoton`	Track χ^2/ndf		< 2.0	< 1.5
	p	MeV/c	> 3000	> 6000
`Hlt1TrackMuon`	p	MeV/c	> 3000	> 6000

TABLE 5.3.6. *Differences in selection requirements in downstream Λ^0 from `Hlt2SharedParticles` between TCK `0x00990042` (Tables 5.1.11 and 5.1.12) and `0x0094003D`.*

			0x00990042	0x0094003D
Downstream Λ^0	Child p_T	MeV/c	> 175	–
	Child χ^2_{IP}		–	> 9

TABLE 5.3.7. *Changes in the preselection cuts on the n-body candidates, applied on top of those in Table 5.1.14, in the HLT2 topological lines between TCK `0x00990042` (Table 5.1.15) and `0x0094003D`.*

	0x00990042	0x0094003D
Number of V^0 for $n = 3$	≤ 1	≤ 2
Number of V^0 for $n = 4$	≤ 0	≤ 1
At least one track with	$\chi^2_{IP} > 16$ and $p_T > 1500$ MeV/c or or muon with $p_T > 1000$ MeV/c	$\chi^2_{IP} > 16$ and $p_T > 1700$ MeV/c

TABLE 5.3.8. *Differences in selection requirements in the `Hlt2ExpressJPsi` line between TCK `0x00990042` (Table 5.1.60) and `0x0094003D`.*

		0x00990042	0x0094003D
$\mu^\pm$	Track χ^2/ndf	< 4	–
$\mu^+\mu^-$ combination	Smallest track χ^2/ndf	< 4	< 5
	Smallest child χ^2_{IP}	–	> 5
J/ψ	χ^2_{vtx}/ndf	< 7	< 10

TABLE 5.3.9. *Differences in selection requirements in the $\Lambda_c^\pm \to \Lambda^0 h^\pm$ lines between TCK `0x00990042` (Table 5.1.71) and `0x0094003D`.*

			0x00990042	0x0094003D
Bachelor $h^\pm$	p_T	MeV/c	> 350	< 250
	χ^2_{IP}		> 9	> 4
$\Lambda_c^\pm$	p_T	MeV/c	> 1500	> 800
	χ^2_{IP}		< 15	< 25

TABLE 5.3.10. *Differences in selection requirements in the $D^0 \to h^\pm h^\mp X$ HLT2 lines between TCK `0x00990042` (Table 5.1.31) and `0x0094003D`.*

			`0x00990042`	`0x0094003D`
GEC	Long tracks		< 180	> -1
K^{*0} object	Children track χ^2/ndf		< 2.25	< 2.0
	Largest track χ^2_{IP}		> 36	> 25
Slow π	Track χ^2/ndf		< 2.25	< 2.5
$D^{*\pm}$	p_{T}	MeV/c	> 3750	> 3500

5.4 0x0097003D

This TCK is almost equal to the previous one, 0x0094003D, except for two differences:

- The Hlt1BeamGasCrossingForcedRecoFullZ line requires the event ODIN trigger type not to be LumiTrigger, like the reference TCK, and its prescale is also set to the reference TCK value (Table 5.1.2), 0.001.
- The displaced vertices lines, disabled in 0x0094003D, were enabled again.

5.5 `0x00990044`

This TCK is very similar to the reference one, `0x00990042` and therefore is very different to the TCKs up to `0x0097003D`. As the TCK name indicates, the only differences with respect to `0x00990042` concern the L0 thresholds, as detailed in Table 5.5.1.

TABLE 5.5.1. *Changes in the L0 thresholds between `0x00990042` (Table 5.1.1) and `0x00990044`.*

			0x00990042	0x00990044
`L0Electron` `L0ElectronNoSPD`	Electron E_T	MeV	> 2720	> 2960
`L0Hadron` `L0HadronNoSPD`	Hadron E_T	MeV	> 3620	> 3680
`L0Photon` `L0PhotonNoSPD`	Photon E_T	MeV	> 2720	> 2960

5.6 `0x00A10044`

5.6.1 *Line content*

Differences between `0x00A10044` and the reference TCK are summarized in Table 5.6.1. In it, it can be seen that they concern

- the addition of a high-p_{T} jets lines, both in HLT1 and HLT2;
- the addition of charged hyperon, $D^{\pm} \to h^{\pm}h^{\mp}h^{\pm}K^0_{\mathrm{S}}$, $K^0_{\mathrm{S}} \to \mu\mu\pi\pi$ and several low multiplicity lines in HLT2;
- the extension of the $D^0 \to h^{\pm}h^{\mp}X$ HLT2 lines;

These new lines are described in their corresponding subsection.

5.6.2 *Prescales*

The prescales of the lines included in this TCK and the reference TCK are the same, and thus they can be found throughout §5.1.

5.6.3 *L0 thresholds*

This TCK includes the same L0 configuration as TCK `0x00990044`, and therefore differences with respect to the reference TCK are summarized in Table 5.5.1 replacing `0x00990044` by `0x00A10044`.

5.6.4 *HLT1 lines*

In this TCK, GECs were modified to also include a minimum number of hits cut, therefore leaving the configuration detailed in Table 5.6.2.

Besides this change, there are two differences between this TCK and the reference one:

- The addition of a filter on the ODIN event type in `Hlt1NoPVPassThrough`, which rejects those events where the 0-bit is activated.
- The addition of the `Hlt1HighPtJetsSinglePV` line, albeit prescaled to 0. This line runs on events passing the `L0HighSumETJet` L0 line, builds PVs using `PatPV3D` and selects those events with only one of them.

5.6.5 *HLT2 lines*

The differences in selection criteria between TCK `0x00A10044` and the reference TCK concern

- the $D^0 \to h^{\pm}h^{\mp}h^{\pm}h^{\mp}$ lines, with relaxed mass windows (Table 5.6.3);
- the $D^0 \to h^{\pm}h^{\mp}X$ lines, as shown in Table 5.6.4; and
- the low-multiplicity D meson and χ_c lines, with the removal of the $\sum p_{\mathrm{T}}$ requirement in the n-h combination cuts (Tables 5.1.69 and 5.1.68).

In addition to these changes, several new lines were included and are discussed below.

Extended $D^0 \to h^\pm h^\mp X$ lines

These lines are an extension to the $D^0 \to h^\pm h^\mp X$ lines described in Page 96 by allowing $h = \mu^\pm, p^\pm, K_S^0, \Lambda^0$ besides the usual $h = K^\pm, \pi^\pm$. They were run with prescales shown in Table 5.6.5. In them, D^0 candidates are built by introducing extra two-body combinations to the `Hlt2CharmHadTwoBodyForD02HHHH` configurable (Table 5.1.24), described in Table 5.6.6 and which can be trivially matched to the line names. These sequences use `BiKalmanFitted` particles and Λ^0 and K_S^0 (both long and downstream) from `Hlt2SharedParticles` (Tables 5.1.11 and 5.1.12). Requirements applied on the tag $D^{*\pm}$ mesons are the same as in the other $D^0 \to h^\pm h^\mp X$, and are summarized in Tables 5.1.31 and 5.6.4.

Charged hyperon lines

The charged hyperon lines for the $\Omega^\pm \to \Lambda^0 K^\pm$, $\Xi^\pm \to \Lambda^0 \mu^\pm$ and $\Xi^\pm \to \Lambda^0 \pi^\pm$ decays are built very similarly to the $\Lambda_c^\pm \to \Lambda^0 h^\pm$ lines in the reference TCK—described in Page 102—and are split according to the type of Λ^0 (long or downstream). The resulting six lines—`Hlt2ChargedHyperon_Omega2Lambda0(DD|LL)K` and `Hlt2ChargedHyperon_Xi2Lambda0(DD|LL)(Mu|Pi)`—were run with unit prescales. In them, Λ^0 from `Hlt2SharedLambda(DD|LL)TrackFitted` (built with as in Table 5.1.12) are filtered according to Table 5.6.7 and afterwards combined with the corresponding bachelor particle with requirements shown in Table 5.6.8.

$D^\pm \to h^\pm h^\mp h^\pm K_S^0$ lines

The $D^\pm \to h^\pm h^\mp h^\pm K_S^0$ lines—`Hlt2CharmHadD2HHHKsDD` and `Hlt2CharmHadD2HHHKsLL`—ran with unit prescales. In them, $D^\pm$ candidates are built by combining a "$K^{*\pm}$ object" (made from three `BiKalmanFitted` particles) with either downstream or long K_S^0 filtered from `Hlt2SharedParticles` K_S^0. The applied requirements are shown in Table 5.6.9.

High-p_T jets line

The `Hlt2HighPtJets` line ran on the output of the `Hlt1HighPtJetsSinglePV` HLT1 line—prescaled to zero in this TCK—with unit prescales. It looks for track clusters (jets) by means of the `TrackClusterFinder` algorithm:

1. Events with a number of PV larger than n_{PV} are rejected.

2. The refined $\sum p_T$ of the event ($\sum p_{T,\mathrm{ref}}$) is calculated from `BiKalmanFitted` tracks with $p_T > 100$ MeV/c using

$$\sum p_{T,\mathrm{ref}} = \sqrt{\left(\sum_i \frac{p_i \sin\phi_i}{\cosh\eta_i}\right)^2 + \left(\sum_i \frac{p_i \cos\phi_i}{\cosh\eta_i}\right)^2}, \tag{5.1}$$

   where p_i, ϕ_i and η_i are the momentum, ϕ angle and pseudorapidity of the i-th track, respectively. Events with low $\sum p_{T,\mathrm{refined}}$ are rejected.

3. These `BiKalmanFitted` tracks with $p_T > 100$ MeV/c are further filtered by requiring that their track χ^2/ndf is below 5 units. From this point on, only these tracks are used in the algorithm.

4. For each track, the number of other tracks in the event (weight) that fall within the defined $|\Delta\eta|$ and $|\Delta\phi|$ windows are counted.

5. The track with the largest weight is used as a seed for a jet, which is built by adding all the tracks within the $|f\Delta\eta|$ and $|f\Delta\phi|$ windows, where f is an expansion factor. Tracks used for building this jet are not reused further.

6. Jets are built repeating the procedure from the previous step, using the remaining track with the largest weight as seed until the this weight is below a given threshold.

7. The p_{T} of each jet is computed as the scalar sum of the p_{T} of the included tracks.

8. The event is accepted if the largest jet has a p_{T} above $p_{\mathrm{T}}^{\mathrm{largest}}$ and if there are a minimum of n_{jets} (including the largest one) with a p_{T} above $p_{\mathrm{T}}^{\mathrm{min}}$.

$K^0_{\mathrm{S}} \to \mu\mu\pi\pi$ line

The `Hlt2KshortToMuMuPiPi` line, run with unit prescales, builds K^0_{S} by combining opposite- and same-sign muon pairs (built from `BiKalmanFittedMuons` with the `Hlt2TwoMuonForKshortToMuMuPiPi` configurable from Table 5.6.11) with pairs of `BiKalmanFittedPions` with requirements detailed in Table 5.6.12. It can be seen from the Table that there is a mismatch in the mass selection applied at combination and parent level, resulting in a final effective mass window of roughly $[490, 550]$ MeV/c^2.

Extended low multiplicity lines

Several new multiplicity lines—`Hlt2LowMultChiC2PP`, `Hlt2LowMultLMR2HH`, `Hlt2LowMultDDIncCP` and `Hlt2LowMultDDIncVF`—were introduced in this TCK, the last two replacing the `Hlt2LowMultDDInc` line. These lines have the same philosophy and design as the other low multiplicity lines, described in Page 101, and consequently they ran on the output of the `L0DiHadron,lowMult` low multiplicity L0 channel and of the `Hlt1NoPVPassThroughDecision` HLT1 line with prescales shown in Table 5.6.13.

These new low multiplicity lines can also be split in groups:

- The $\chi_c \to p^+ p^-$ line—`Hlt2LowMultChiC2PP`—which extends the low multiplicity χ_c lines and makes use of `Hlt2BiKalmanFittedRichLowPTProtons` to build candidates with the requirements in Table 5.6.14.

- The inclusive two-kaon lines—`Hlt2LowMultDDIncCP` and `Hlt2LowMultDDIncVF`—which ran with unit prescales. The `Hlt2LowMultDDIncCP` line replaces `Hlt2LowMultDDInc`, building candidates in the same way and with the differences in selection requirements shown in Table 5.6.15. The `Hlt2LowMultDDIncVF` line takes a different approach, replacing the use of `CombineParticles` with a simple filter requiring at least two kaons to pass the track requirements in those events accepted by the GEC; these track requirements are the same as thos in the `Hlt2LowMultDDIncCP` line, and can be found in Tables 5.1.70 and 5.6.15.

- The low-mass resonance line—`Hlt2LowMultLMR2HH`—which builds two-hadron resonances from `Hlt2BiKalmanFittedRichLowPTKaons` and `Hlt2BiKalmanFittedPions` with selection criteria shown in Table 5.6.16.

TABLE 5.6.1. *Differences in line contents between* `0x00990042` *and* `0x00A10044`*. Lines included are marked with a check mark (✓).*

	0x00990042	0x00A10044
Hlt1HighPtJetsSinglePV		✓
Hlt2ChargedHyperon_Omega2Lambda0DDK		✓
Hlt2ChargedHyperon_Omega2Lambda0LLK		✓
Hlt2ChargedHyperon_Xi2Lambda0DDMu		✓
Hlt2ChargedHyperon_Xi2Lambda0DDPi		✓
Hlt2ChargedHyperon_Xi2Lambda0LLMu		✓
Hlt2ChargedHyperon_Xi2Lambda0LLPi		✓
Hlt2CharmHadD02HHXDst_BaryonhhX		✓
Hlt2CharmHadD02HHXDst_BaryonhhXWideMass		✓
Hlt2CharmHadD02HHXDst_BaryonhhXWithKSDD		✓
Hlt2CharmHadD02HHXDst_BaryonhhXWithKSDDWideMass		✓
Hlt2CharmHadD02HHXDst_BaryonhhXWithKSLL		✓
Hlt2CharmHadD02HHXDst_BaryonhhXWithKSLLWideMass		✓
Hlt2CharmHadD02HHXDst_BaryonhhXWithLambda0DD		✓
Hlt2CharmHadD02HHXDst_BaryonhhXWithLambda0DDWideMass		✓
Hlt2CharmHadD02HHXDst_BaryonhhXWithLambda0LL		✓
Hlt2CharmHadD02HHXDst_BaryonhhXWithLambda0LLWideMass		✓
Hlt2CharmHadD02HHXDst_LeptonhhX		✓
Hlt2CharmHadD02HHXDst_LeptonhhXWideMass		✓
Hlt2CharmHadD02HHXDst_LeptonhhXWithKSDD		✓
Hlt2CharmHadD02HHXDst_LeptonhhXWithKSDDWideMass		✓
Hlt2CharmHadD02HHXDst_LeptonhhXWithKSLL		✓
Hlt2CharmHadD02HHXDst_LeptonhhXWithKSLLWideMass		✓
Hlt2CharmHadD02HHXDst_LeptonhhXWithLambda0DD		✓
Hlt2CharmHadD02HHXDst_LeptonhhXWithLambda0DDWideMass		✓
Hlt2CharmHadD02HHXDst_LeptonhhXWithLambda0LL		✓
Hlt2CharmHadD02HHXDst_LeptonhhXWithLambda0LLWideMass		✓
Hlt2CharmHadD2HHHKsDD		✓
Hlt2CharmHadD2HHHKsLL		✓
Hlt2HighPtJets		✓
Hlt2KshortToMuMuPiPi		✓
Hlt2LowMultChiC2PP		✓
Hlt2LowMultDDIncCP		✓
Hlt2LowMultDDIncVF		✓
Hlt2LowMultDDInc	✓	
Hlt2LowMultLMR2HH		✓

TABLE 5.6.2. *Differences in GECs between `0x00990042` and `0x00A10044`.*

	`0x00990042`	`0x00A10044`
Number of VELO hits	< 6000	$[50, 6000]$
Number of IT hits	< 3000	$[50, 3000]$
Number of OT hits	< 15000	$[50, 15000]$

TABLE 5.6.3. *Differences in selection requirements in the $D^0 \to h^\pm h^\mp$ HLT2 lines between TCK `0x00990042` (Table 5.1.28) and `0x00A10044`.*

			`0x00990042`	`0x00A10044`
h^+h^- combination	$M(\sum p^\mu)$	MeV/c^2	$[1715, 2065]$	$[1665, 2085]$
D^0	M	MeV/c^2	$[1790, 1930]$	$[1740, 1950]$
	M wide mass	MeV/c^2	$[1715, 2065]$	$[1665, 2085]$

TABLE 5.6.4. *Differences in selection requirements in the particle objects used in the in the $D^0 \to h^\pm h^\mp X$ HLT2 lines between TCK `0x00990042` (Table 5.1.31) and `0x00A10044`. Requirements applied in the monitoring line (when needed) are shown in parentheses.*

			`0x00990042`	`0x00A10044`
K^{*0} object	M	MeV/c^2	< 1900	< 2500
$D^{*\pm}$	$M_{D^{*\pm}} - M_{K^{*0}}$	MeV/c^2	$[0, 250]$ ($[0, 500]$)	$[0, 285]$ ($[0, 570]$)

TABLE 5.6.5. *Pre- and postscales of the extended $D^0 \rightarrow h^{\pm}h^{\mp}X$ HLT2 lines in TCK `0x00A10044`.*

	Prescale	Postscale
`Hlt2CharmHadD02HHXDst_BaryonhhX`	1	1
`Hlt2CharmHadD02HHXDst_BaryonhhXWideMass`	0.05	1
`Hlt2CharmHadD02HHXDst_BaryonhhXWithKSLL`	1	1
`Hlt2CharmHadD02HHXDst_BaryonhhXWithKSLLWideMass`	0.05	1
`Hlt2CharmHadD02HHXDst_BaryonhhXWithLambda0LL`	1	1
`Hlt2CharmHadD02HHXDst_BaryonhhXWithLambda0LLWideMass`	0.05	1
`Hlt2CharmHadD02HHXDst_BaryonhhXWithKSDD`	1	1
`Hlt2CharmHadD02HHXDst_BaryonhhXWithKSDDWideMass`	0.05	1
`Hlt2CharmHadD02HHXDst_BaryonhhXWithLambda0DD`	1	1
`Hlt2CharmHadD02HHXDst_BaryonhhXWithLambda0DDWideMass`	0.05	1
`Hlt2CharmHadD02HHXDst_LeptonhhX`	1	1
`Hlt2CharmHadD02HHXDst_LeptonhhXWideMass`	0.05	1
`Hlt2CharmHadD02HHXDst_LeptonhhXWithKSLL`	1	1
`Hlt2CharmHadD02HHXDst_LeptonhhXWithKSLLWideMass`	0.05	1
`Hlt2CharmHadD02HHXDst_LeptonhhXWithLambda0LL`	1	1
`Hlt2CharmHadD02HHXDst_LeptonhhXWithLambda0LLWideMass`	0.05	1
`Hlt2CharmHadD02HHXDst_LeptonhhXWithKSDD`	1	1
`Hlt2CharmHadD02HHXDst_LeptonhhXWithKSDDWideMass`	0.05	1
`Hlt2CharmHadD02HHXDst_LeptonhhXWithLambda0DD`	1	1
`Hlt2CharmHadD02HHXDst_LeptonhhXWithLambda0DDWideMass`	0.05	1

TABLE 5.6.6. *Decay descriptors used by the different sequences available in the* `Hlt2CharmHadTwoBodyForD02HHHH` *configurable in TCK* `0x00A10044`.

twoBodyBaryonHHXSequence	K*(892)0 -> p+ K- K*(892)0 -> p~- pi+ K*(892)0 -> p~- K+ K*(892)0 -> p+ p~- K*(892)0 -> p+ p+ K*(892)0 -> p~- p~-
twoBodyBaryonHHXWithKS(LL|DD)Sequence	K*(892)0 -> p~- KS0 K*(892)0 -> p+ KS0
twoBodyBaryonHHXWithLambda0(LL|DD)Sequence	K*(892)0 -> Lambda0 pi- K*(892)0 -> Lambda0 K- K*(892)0 -> Lambda0 pi+ K*(892)0 -> Lambda0 K+ K*(892)0 -> Lambda~0 pi- K*(892)0 -> Lambda~0 K- K*(892)0 -> Lambda~0 pi+ K*(892)0 -> Lambda~0 K+
twoBodyLeptonHHXSequence	K*(892)0 -> mu+ pi- K*(892)0 -> mu+ K- K*(892)0 -> mu+ p~- K*(892)0 -> mu- pi+ K*(892)0 -> mu- K+ K*(892)0 -> mu- p+ K*(892)0 -> mu+ mu- K*(892)0 -> mu+ mu+ K*(892)0 -> mu- mu-
twoBodyLeptonHHXWithKS(LL|DD)Sequence	K*(892)0 -> mu- KS0 K*(892)0 -> mu+ KS0
twoBodyBaryonHHXWithLambda0(LL|DD)Sequence	K*(892)0 -> Lambda0 pi- K*(892)0 -> Lambda0 mu+ K*(892)0 -> Lambda~0 mu- K*(892)0 -> Lambda~0 mu+

TABLE 5.6.7. *Requirements applied on the Λ^0 in the charged hyperon lines in TCK* `0x00A10044`.

<table>
<tr><th></th><th></th><th></th><th>Downstream Λ^0</th><th>Long Λ^0</th></tr>
<tr><td rowspan="2">$p^{\pm}, \pi^{\mp}$</td><td>Track χ^2/ndf</td><td></td><td>< 4</td><td>< 3</td></tr>
<tr><td>χ^2_{IP}</td><td></td><td>> 10</td><td>> 36</td></tr>
<tr><td rowspan="3">Λ^0</td><td>χ^2_{vtx}/ndf</td><td></td><td colspan="2">< 20</td></tr>
<tr><td>p_{T}</td><td>MeV/c</td><td colspan="2">> 500</td></tr>
<tr><td>χ^2_{IP}</td><td></td><td>> 0</td><td>> 25</td></tr>
</table>

TABLE 5.6.8. *Selection requirements applied in the charged hyperon lines in TCK `0x00A10044`. Requirements corresponding to the downstream lines (if different from the long ones) are shown in parentheses.*

			$\Omega^{\pm} \to \Lambda^0 K^{\pm}$	$\Xi^{\pm} \to \Lambda^0 \mu^{\pm}$	$\Xi^{\pm} \to \Lambda^0 \pi^{\pm}$
Decay descriptor			`[Omega- -> Lambda0 K-]cc`	`[Xi- -> Lambda0 mu-]cc`	`[Xi- -> Lambda0 pi-]cc`
	Track χ^2/ndf			< 3	
	χ^2_{IP}			> 25	
Bachelor $h^{\pm}$	p_{T}	MeV/c	> 350	> 250	> 350
	p	MeV/c	> 2500	> 5000	> 2500
	χ^2_{vtx}/ndf			< 15	
	p_{T}	MeV/c		> 1500	
	χ^2_{IP}			< 100	
Hyperon	τ	ps		> 2.0	
	$\Delta z(\Lambda^0, \text{hyperon})$	mm		$> 20\,(400)$	
	HLT1 TOS			`Hlt1Track.*`	
	M	MeV/c^2	$[1625, 1725]$	< 1350	$[1300, 1350]$

TABLE 5.6.9. *Selection requirements applied in the* `Hlt2CharmHadD2HHHKsDD` *and* `Hlt2CharmHadD2HHHKsLL` *lines in TCK* `0x00A10044`*. Note that the requirement on the $K^{*\pm}K^0_S$ combination mass, highlighted in red, selects a window around the D^0 mass—instead of the $D^\pm$ one—and that this (slightly asymmetrical) selection is tighter than the $D^\pm$ mass one.*

			Long K^0_S	Downstream K^0_S
	Decay descriptor		`[K*(892)+ -> pi- pi+ pi-]cc` `[K*(892)+ -> K+ K- pi+]cc` `[K*(892)+ -> K- pi+ pi+]cc` `[K*(892)+ -> K+ pi- pi+]cc`	
$K^{*\pm}$	Child track χ^2/ndf		< 5	< 2
	Child p_T	MeV/c	> 300	
	Child p	MeV/c	> 3000	
	Child χ^2_{IP}		> 5	
	Largest child χ^2_{IP}		–	> 12.5
	χ^2_{vtx}/ndf		< 11	< 9
	$p_T(\sum p^\mu)$	MeV/c	> 1300	
	p_T	MeV/c	–	> 1300
	$M(\sum p^\mu)$	MeV/c^2	< 1530	
	VS	mm	> 2.0	> 4.0
	PV		all from same	
K^0_S	Child track χ^2/ndf		< 2.5	–
	Child χ^2_{IP}		> 9	–
	Largest child p_T	MeV/c	> 200	
	χ^2_{vtx}		< 20	
	τ	ps	> 4.0	–
	χ^2_{VS}		> 400	
	$\lvert M - m_{K^0_S}\rvert$	MeV/c^2	< 30	< 40
$D^\pm$	χ^2_{vtx}/ndf		< 20	
	p_T	MeV/c	> 2000	
	DIRA		> 0.999	
	χ^2_{IP}		< 20	
	τ	ps	> 0.3	
	$\lvert M(\sum p^\mu) - m_{D^0}\rvert$	MeV/c^2	< 100	< 120
	M	MeV/c^2	$[1795, 2035]$	
	TOS		`Hlt1Track.*`	–

TABLE 5.6.10. *Configuration of the `TrackClusterFinder` algorithm in the `Hlt2HighPtJets` HLT2 line in TCK `0x00A10044`.*

n_{PV}		≤ 1
$\sum p_{\mathrm{T,ref}}$	GeV/c	≥ 17
$\lvert\Delta\eta\rvert$		< 0.35
$\lvert\Delta\phi\rvert$	rad	< 0.1134464
Expansion factor f		4
Seed track weight		≥ 6
$p_{\mathrm{T}}^{\mathrm{largest}}$	GeV/c	> 10
$p_{\mathrm{T}}^{\mathrm{min}}$	GeV/c	> 0
n_{jets}		≤ 1

TABLE 5.6.11. *Selection requirements applied in the `Hlt2TwoMuonForKshortToMuMuPiPi` configurable used in the `Hlt2KshortToMuMuPiPi` HLT2 line in TCK `0x00A10044`.*

Decay descriptor	`rho(770)0 -> mu+ mu-`
	`rho(770)+ -> mu+ mu+`
	`rho(770)- -> mu- mu-`		

$\mu^{\pm}$	Track χ^2/ndf		< 4
	p_{T}	MeV/c	> 300
	p	MeV/c	> 3000
	χ^2_{IP}		> 2
$\mu^+\mu^-$ combination	$\sum p_{\mathrm{T}}$	MeV/c	> 0
	DOCA	mm	< 0.1
	PV		all from same
ρ	VS	mm	> 0
	χ^2_{VS}		> 4
	M	MeV/c^2	< 240

TABLE 5.6.12. *Selection requirements applied in the `Hlt2KshortToMuMuPiPi` HLT2 line in TCK `0x00A10044`.*

Decay descriptor	`KS0 -> rho(770)0 pi+ pi-`
	`KS0 -> rho(770)+ pi- pi-`
	`KS0 -> rho(770)- pi+ pi+`		

$\pi^{\pm}$	Track χ^2/ndf		< 4
	p_{T}	MeV/c	> 300
	p	MeV/c	> 3000
	χ^2_{IP}		> 0
$\rho\pi\pi$ combination	$\sum p_{\mathrm{T}}$	MeV/c	> 1500
	Min DOCA	mm	< 0.1
	Max DOCA	mm	< 0.2
	Largest child p_{T}	MeV/c	> 0
	$M(\sum p^{\mu})$	MeV/c^2	< 550
	PV		all from same
K^0_{S}	χ^2_{vtx}/ndf		< 15
	DIRA		> 0.9999
	χ^2_{VS}		> 9
	$\sum_{\pi,\mu}\sqrt{\chi^2_{\mathrm{IP}}}$		> 12
	χ^2_{IP}		< 16
	M	MeV/c^2	$[490, 560]$

TABLE 5.6.13. *Pre- and postscales of the new low multiplicity HLT2 lines in TCK `0x00A10044`.*

	Prescale	Postscale
`Hlt2LowMultChiC2PP`	1	1
`Hlt2LowMultDDIncCP`	1	1
`Hlt2LowMultDDIncVF`	1	1
`Hlt2LowMultLMR2HH`	0.05	1

TABLE 5.6.14. *Selection requirements applied in the low multiplicity `Hlt2LowMultChiC2PP` line in TCK `0x00A10044`.*

Decay Descriptor			`chi_c1(1P) -> p+ p~-`
GEC	VELO tracks		< 6
	Backward tracks		0
$p^{\pm}$	Track χ^2/ndf		< 3
	p	MeV/c	> 5000
	p_{T}	MeV/c	> 100
	PIDp		> 0
p^+p^- combination	p	MeV/c	> 10000
	p_{T}	MeV/c	$[0, 5000]$
	Largest DOCA	mm	< 0.5
	$M(\sum p^{\mu})$	MeV/c^2	$[2850, 3600]$
χ_c	χ^2_{vtx}/ndf		< 15

TABLE 5.6.15. *Changes in requirements applied low multiplicity K^+K^- line between TCK `0x00990042` (Table 5.1.70) and `0x00A10044`.*

		`0x00990042`	`0x00A10044`
Line name		`Hlt2LowMultDDInc`	`Hlt2LowMultDDIncCP`
GECs	VELO tracks	< 8	< 11

TABLE 5.6.16. *Selection requirements applied in the low-mass resonance line in TCK `0x00A10044`.*

Decay descriptors	`phi(1020) -> K+ K-`
	`[phi(1020) -> K+ pi-]cc`
	`phi(1020) -> pi+ pi-`		

GECs	VELO tracks		< 6
	Backward tracks		0
$h^{\pm}$	Track χ^2/ndf		< 3
	p	MeV/c	> 5000
	p_{T}	MeV/c	> 100
$K^{\pm}$ only	PIDK		> 0
h^+h^- combination	DOCA	mm	< 0.2
	$p(\sum p^{\mu})$	MeV/c	> 15000
	$p_{\mathrm{T}}(\sum p^{\mu})$	MeV/c	$[0, 5000]$
	$M(\sum p^{\mu})$	MeV/c^2	$[400, 1600]$
ϕ	χ^2_{vtx}/ndf		< 4

5.7 `0x00A10045`

This TCK is practically identical to the previous one and therefore all differences with respect to the reference TCK can be found in §5.6.

5.7.1 Line content

The line content in this TCK is identical to that in TCK `0x00A10044`, with the differences with respect to the reference TCK detailed in Table 5.6.1.

5.7.2 Prescales

The prescales of the lines included in this TCK and the reference TCK are the same, and thus they can be found throughout §5.1. The prescales of the lines introduced in `0x00A10044` can be found throughout §5.6.

5.7.3 L0 thresholds

The only difference with respect to TCK `0x00A10044` regards the L0 configuration, with differences with respect to the reference TCK detailed in Table 5.7.1.

5.7.4 HLT

The HLT configuration in this TCK is exactly the same as in the previous one, `0x00A10044`, so differences with respect to the reference TCK can be obtained from §5.6.4 and §5.6.5.

TABLE 5.7.1. *Changes in the L0 thresholds between `0x00990042` (Table 5.1.1) and `0x00A10045`. Differences with `0x00A10044` and `0x00990044` are highlighted in **bold**.*

			0x00990042	0x00A10045
L0Electron L0ElectronNoSPD	Electron E_T	MeV	> 2720	> 2960
L0Hadron L0HadronNoSPD	Hadron E_T	MeV	> 3620	**> 3740**
L0Photon L0PhotonNoSPD	Photon E_T	MeV	> 2720	> 2960

5.8 **0x009F0045**

5.8.1 Line content

The line content in this TCK is identical to that in TCK 0x00A10044, with differences with respect to the reference TCK detailed in Table 5.6.1.

5.8.2 Prescales

The prescales of the lines included in this TCK and the reference TCK are the same, and thus they can be found throughout §5.1. The prescales of the lines introduced in 0x00A10044 can be found throughout §5.6.

5.8.3 L0 and HLT

This TCK is practically identical to the previous one, and therefore

- differences in L0 with respect to the reference TCK are summarized in Table 5.7.1; and
- differences in the HLT lines with respect to the reference TCK are detailed in §5.6.

The only difference with respect to the configuration of the HLT in 0x00A10044 is the prescale of the Hlt1HighPtJetsSinglePV line, which goes from 0 to 1. The activation of this line, described in Page 166, also means that the Hlt2HighPtJets line (Page 167) gets events in this TCK.

5.9 `0x00A30044`

5.9.1 *Line content*

The line content in this TCK is identical to that in TCK `0x00A10044`, with differences with respect to the reference TCK detailed in Table 5.6.1.

5.9.2 *Prescales*

The prescales of the lines included in this TCK and the reference TCK are the same, and thus they can be found throughout §5.1. The prescales of the lines introduced in `0x00A10044` can be found throughout §5.6.

5.9.3 *L0 thresholds*

This TCK goes back to the `0x0044` L0 configuration, the differences of which with respect to the reference TCK are detailed in Table 5.5.1 replacing `0x00990044` by `0x00A30044`.

5.9.4 *HLT1 lines*

The only change with respect to the previous TCK regards the `Hlt1HighPtJetsSinglePV` line—prescaled to 1 since TCK `0x009F0045`—where the code was changed to use the same `HltPV3D` algorithm as other HLT1 lines, avoiding an extra PV reconstruction step. Similarly to other TCKs, this line ran on events passing the `L0HighSumETJet` L0 line, selecting those events with only one PV. The rest of differences in HLT1 with respect to the reference TCK are discussed in §5.6.4.

5.9.5 *HLT2 lines*

The HLT2 configuration in this TCK is very similar to that in the previous ones. The differences in selection requirements between TCK `0x00A30044` and the reference TCK concern

- the $D^0 \to h^\pm h^\mp h^\pm h^\mp$ lines, discussed in Table 5.9.1;
- the $D^0 \to h^\pm h^\mp X$ hadron lines as shown in Table 5.9.2;
- the low-multiplicity D meson and χ_c lines, with the aforementioned removal of the $\sum p_\mathrm{T}$ requirement on the n-h combination (Tables 5.1.69 and 5.1.68); and
- the new lines introduced in `0x00A10044`, discussed in §5.6.5. In the case of the extended $D^0 \to h^\pm h^\mp X$ lines, this TCK presents some differences with respect to TCK `0x00A10044`, summarized in Table 5.9.3, with the final values being the same as in the $D^0 \to h^\pm h^\mp X$ hadron lines, discussed in the previous point.

TABLE 5.9.1. *Differences in selection requirements in the $D^0 \to h^\pm h^\mp$ HLT2 lines between TCK `0x00990042` (Table 5.1.28) and `0x00A30044`.*

			0x00990042	0x00A30044
h^+h^- combination	$M(\sum p^\mu)$	MeV/c^2	$[1715, 2065]$	$[1715, 2085]$
D^0	M	MeV/c^2	$[1790, 1930]$	$[1790, 1950]$
	M wide mass	MeV/c^2	$[1715, 2065]$	$[1715, 2085]$

TABLE 5.9.2. *Differences in selection requirements in the $D^0 \to h^\pm h^\mp X$ hadron HLT2 lines between TCK `0x00990042` (Table 5.1.31) and `0x00A30044`.*

			0x00990042	0x00A30044
K^{*0} object	M	MeV/c^2	< 1900	< 2500
$D^{*\pm}$	p_{T}	MeV/c	> 3750	> 3850

TABLE 5.9.3. *Differences in selection requirements in the extended $D^0 \to h^\pm h^\mp X$ HLT2 lines between TCK `0x00A10044` (Tables 5.1.31 and 5.6.4) and `0x00A30044`.*

			0x00A10044	0x00A30044
$D^{*\pm}$	p_{T}	MeV/c	> 3750	> 3850
	$M_{D^{*\pm}} - M_{K^{*0}}$	MeV/c^2	$[0, 285]$ $([0, 570])$	$[0, 250]$ $([0, 500])$

5.10 `0x00A30046`

This TCK is practically identical to the previous one and therefore all differences with respect to the reference TCK can be found in §5.10.

5.10.1 Line content

The line content in this TCK is identical to that in TCK `0x00A10044`, with the differences with respect to the reference TCK detailed in Table 5.6.1.

5.10.2 Prescales

The prescales of the lines included in this TCK and the reference TCK are the same, and thus they can be found throughout §5.1. The prescales of the lines introduced in `0x00A10044` can be found throughout §5.6.

5.10.3 L0 thresholds

The only difference with respect to TCK `0x00A30044` concerns the L0 configuration, with differences with respect to the reference TCK detailed in Table 5.10.1.

5.10.4 HLT

The HLT configuration in this TCK is exactly the same as in the previous one, `0x00A30044`, so differences with respect to the reference TCK can be obtained from §5.9.4 and §5.9.5.

TABLE 5.10.1. *Changes in the L0 thresholds between `0x00990042` (Table 5.1.1) and `0x00A30046`. Differences with respect to the `0x0044` L0 TCK are highlighted in **bold**.*

			`0x00990042`	`0x00A10045`
`L0Electron` `L0ElectronNoSPD`	Electron E_T	MeV	> 2720	**> 2860**
`L0Hadron` `L0HadronNoSPD`	Hadron E_T	MeV	> 3620	**> 3740**
`L0Photon` `L0PhotonNoSPD`	Photon E_T	MeV	> 2720	**> 2860**

5.11 0x00A90046

5.11.1 Line content

The line content in this TCK is identical to that in TCK 0x00A10044, with the differences with respect to the reference TCK detailed in Table 5.6.1.

5.11.2 Prescales

The prescales of the lines included in this TCK and the reference TCK are the same, and thus they can be found throughout §5.1. The prescales of the lines introduced in 0x00A10044 can be found throughout §5.6.

5.11.3 L0 thresholds

This TCK uses the 0x0046 L0 configuration, exactly the same as the TCK 0x00A30046. The differences with respect to the reference TCK are therefore detailed in Table 5.10.1 replacing 0x00A30046 by 0x00A90046.

5.11.4 HLT1 lines

The HLT1 line configuration is the same as in the previous TCK, 0x00A30044, so differences with respect to the reference TCK can be obtained from §5.9.4.

5.11.5 HLT2 lines

The HLT2 configuration in this TCK is very similar to that of the previous TCK, so the differences with respect to the reference TCK can be found in §5.9.5. Additionally, the configuration of one of the lines introduced in TCK 0x00A10044, Hlt2HighPtJets, was different due to changes in the requirements applied in the TrackClusterFinder, as shown in Table 5.11.1.

TABLE 5.11.1. *Changes in the configuration of the TrackClusterFinder algorithm in the Hlt2HighPtJets HLT2 line between 0x00A10044 (Table 5.6.10) and 0x00A90046.*

		0x00A10044	0x00A90046
$\sum p_{\mathrm{T,ref}}$	GeV/c	≥ 17	≥ 0
$\lvert\Delta\phi\rvert$	rad	< 0.1134464	< 0.26179939

5.12 0x00AC0046

5.12.1 Line content

The line content in this TCK is identical to that in TCK 0x00A10044, with the differences with respect to the reference TCK detailed in Table 5.6.1.

5.12.2 Prescales

The main difference of this TCK with respect to the previous one is the prescales of the HLT1 beam gas lines:

- Most lines were disabled, as shown in the list found in Table 5.12.1.
- In the Hlt1BeamGasBeam1 and Hlt1BeamGasBeam2 lines, the internal scaler of the L0B(1|2)Gas to 5 MHz was removed and the postscaler was changed from a limitation to 2 Hz to an accept-all mode, corresponding to the FALL LoKi functor.

Besides the beam gas lines, the prescales of the lines included in this TCK and the reference TCK were the same, and thus they can be found throughout §5.1. The prescales of the lines introduced in 0x00A10044 can be found throughout §5.6.

5.12.3 L0 thresholds

This TCK uses the 0x0046 L0 configuration, exactly the same as the TCK 0x00A30046. The differences with respect to the reference TCK are detailed in Table 5.10.1 replacing 0x00A30046 by 0x00AC0046.

5.12.4 HLT1 lines

The HLT1 line configuration is the same as in the previous TCK, 0x00A30044, except for the already mentioned changes in the beam gas lines. Differences with the reference TCK can be found in §5.9.4.

5.12.5 HLT2 lines

The HLT2 line configuration in this TCK is the same as the previous TCK, so the differences with respect to the references TCK can be found in §5.9.5.

TABLE 5.12.1. *Disabled BeamGas lines in 0x00AC0046 with respect to the reference TCK 0x00990042.*

Hlt1BeamGasNoBeamBeam1
Hlt1BeamGasNoBeamBeam2
Hlt1BeamGasCrossingEnhancedBeam1
Hlt1BeamGasCrossingEnhancedBeam2
Hlt1BeamGasCrossingForcedReco
Hlt1BeamGasCrossingForcedRecoFullZ
Hlt1BeamGasHighRhoVertices
Hlt1BeamGasCrossingParasitic

5.13 `0x00AB0046`

5.13.1 *Line content*

The line content in this TCK is identical to that in TCK `0x00A10044`, with the differences with respect to the reference TCK detailed in Table 5.6.1.

5.13.2 *Prescales*

This TCK undoes some of the changes regarding the beam gas lines introduced in the previous TCK, `0x00AC0046`: the previously disabled lines, listed in Table 5.12.1, were restored to the prescales from Table 5.1.2—including the 0-postscaled `Hlt1BeamGasCrossingEnhancedBeam(1|2)`. However, in the case of the `Hlt1BeamGasBeam1` and `Hlt1BeamGasBeam2` lines the changes are maintained, *i.e.*, the internal scaler of the `L0B(1|2)Gas` to 5 MHz was removed and the postscaler was changed from a limitation to 2 Hz to an accept-all mode.

Besides the beam gas lines, the prescales of the lines included in this TCK and the reference TCK are the same, and thus they can be found throughout §5.1. The prescales of the lines introduced in `0x00A10044` can be found throughout §5.6.

5.13.3 *L0 thresholds*

This TCK uses the `0x0046` L0 configuration, exactly the same as the TCK `0x00A30046`. The differences with respect to the reference TCK are detailed in Table 5.10.1 replacing `0x00A30046` by `0x00AC0046`.

5.13.4 *HLT1 lines*

The HLT1 line configuration is the same as in the previous TCK, `0x00AC0046`, except for the already mentioned differences in the beam gas lines. Differences with respect to the reference TCK can be found in §5.9.4.

5.13.5 *HLT2 lines*

The HLT2 line configuration in this TCK is the same as the previous TCK, so the differences with respect to the reference TCK can be found in §5.9.5.

A
Nomenclature

Several conventions are used in this document in order to present the selection criteria for the different lines in a compact and consistent fashion. These conventions, detailed below, concern the way the selection requirements are applied and the specific symbols used to express several of these requirements. Specifically, only those requirements for which no standard LHCb symbol exists are included, as the rest may be found elsewhere, *e.g.*, in many LHCb papers.

Particle selection

In most trigger lines, a particle decay is reconstructed and a *candidate* is built according to a given *decay descriptor*, a programmatic way of describing the decay chain. If this candidate passes a given set of selection criteria, it is accepted and therefore the line is fired. Candidates are built using specialized GAUDI algorithms, the most usual being `CombineParticles`, in charge of combining several children particles to build a single parent, and `FilterDesktop`, in charge of filtering arrays of particles according to some requirements. All these algorithms are chained and glued together using the LHCb Particle Selection Toolkit, which is intended to simplify both the writing and use of particle selections within the LHCb software framework. Additionally, lines can be *prescaled* or *postscaled*, meaning that only a fraction of (random) events are used as input or accepted as output, respectively.

Individual selection requirements, *e.g.*, p_{T}, mass, etc, are applied through the use of the *functors* provided by the LoKi framework, a data analysis software package based on the GAUDI architecture. These functors are function objects that take an input type `input` and provide a return value of type `output`, which can be either a `double`, `boolean` or a `std::vector` of, *e.g.*, particles or vertices (this latter type is extensively used in HLT1). The most used `input` types are vertices, particles, particle arrays and tracks.

Selection requirements classification

When specifying selection requirements for lines or configurables, selection requirements are split in different sections, separated by an horizontal rule, according to how they are applied in the `CombineParticles` algorithm:

Children requirements Applied to all the children of the given decay, unless explicitly stated, these cuts correspond to the `DaughterCuts` property in `CombineParticles`.

Combination requirements Applied to the array of the children of the given decay before vertex fitting, these cuts correspond to the `CombinationCut` property in `CombineParticles`. In this case, any cuts on combination variables such as mass or momentum (p) are applied to the sum of 4-momenta of the daughter particles; even if it's clear by the context, special symbols are employed to better signify this fact, *i.e.*, cuts applied on the combination mass are not written as M, but as $M(\sum p^{\mu})$. With this in mind, whenever a $\sum$ symbol is encountered in the combination cuts, it has to be considered as a sum over all children. Additionally, some selection requirements are defined as *largest* or *smallest*, which means the given selection threshold is applied on the child particle that has the largest or smallest value for that variable. Finally, as a general rule, combination cuts that are applied in order to reduce CPU time and are superseeded by cuts on the vertexed particle are not included in the tables.

Parent particle requirements Applied to the particle resulting of the vertex fit, these cuts correspond to the `MotherCut` property in `CombineParticles`. In some cases, if the only mass cut that is applied corresponds to a combination cut, it may be shown as a parent particle cut to simplify the tables; in these cases, a very clear notation is used.

Symbols used

In this section, the notation used for specifying some of the HLT selection requirements is clarified, giving their LoKi functor equivalence as used in most of the HLT lines.

Beamspot ρ Radial distance (ρ) with respect to the middle of VELO as measured by the X and Y resolvers, given by the `VX_BEAMSPOTRHO` LoKi functor.

Decay angle Cosine of the angle between the child's momentum and the parent's flight direction in the rest system of the parent particle, corresponding to the LoKi functors `LV[1-4]`. For two-body decays it corresponds to the polarization angle of the parent particle.

$\Delta z(X, Y)$ Distance in z between the end vertices of particles X and Y, both determined with the `VFASPF(VZ)` LoKi functor

DIRA Cosine of the angle between the momentum of the particle and the direction of flight from the associated PV to the decay vertex, given by the `BPVDIRA` LoKi functor.

DOCA Distance Of Closest Approach between two tracks/particles. When the parent particle has more than two children, the *max DOCA* and *min DOCA* notation is employed, meaning the combination of track pairs with the largest DOCA and the combination of track pairs with the smallest DOCA, respectively; this corresponds to the `AMAXDOCA` and `AMINDOCA` LoKi functors. It is sometimes introduced as a parent particle cut, but only if it helps simplifying the table; in this case, the cut needs to be understood as applied on the array of children particles.

E_X Energy deposited by a particle in the calorimeter subdetector X, with X being PS, ECAL or HCAL. It's usually used for particle identification purposes.

VS Separation of a vertex with respect to its associated PV (unless especifically stated), corresponding to the LoKi functor `BPVVD`.

VS/σ_{VS} Vertex separation significance, or decay length significance, of a vertex with respect to its associated PV, determined using the `BPVDLS` LoKi functor.

VS$_\rho$ (VS$_z$) Radial (z) distance from the end vertex of the particle to its associated PV, corresponding to the `BPVVDR` (`BPVVDZ`) LoKi functor.

χ^2_{VS} χ^2 separation of a vertex from its associated PV, corresponding to the LoKi functor `BPVVDCHI2`.

Mass cuts Whenever specifying mass cuts, M is used for the measured mass—with the $M(\sum p^\mu)$ notation in case of a combination cut—while m_X is used to specify the PDG mass of particle X. Following this notation, a mass window cut for particle X, expressed by the `ADMASS` LoKi functor, would be defined as $|M - m_X|$. If needed, the M notation has a subscript specifying the particle it refers to, *e.g.*, for Δm in $D^* \to D^0\pi$ would be expressed as $M_{D^*} - M_{D^0}$. In some cases, a mass is computed taking into account a possible misidentification of one of its daughters, *i.e.*, a wrong particle ID assignment; these are expressed as $M(x \text{ as } y)$, where x is the nominal ID assignment and y the alternate.

$M_{\text{corrected}}$ Corrected mass of the particle with respect to its flight direction, corresponding to the `BPVCORRM` LoKi functor, given by [19]

$$M_{\text{corrected}} = \sqrt{M^2 + |p'_{\text{T,missing}}|^2} + |p'_{\text{T,missing}}|,$$

where $|p'_{\text{T,missing}}|$ is the missing transverse momentum to the direction of flight of the particle.

PV all from same Requirement that the associated PV of all particles is the same, as given by the `AALLSAMEBPV` LoKi functor.

Proper time Proper time is expressed as τ when given in units of time, as given by the `BPVLTIME` LoKi functor, and as $c\tau$ when given in length units, as given by `BPVLTIME()*c_light`.

TIS cuts Trigger Independent of Signal (TIS) of the full decay chain of the signal particle. An event is considered TIS when the event minus the signal and its associated detector hits is sufficient to generate a positive trigger decision [15]. The TIS cut has to be interpreted as the value of the `TisTosSpecs` property of the `TisTosParticleTagger` algorithm—a package designed for the determination of the TISTOS properties of a given decay chain—without the `Decision%TIS` part of the string.

TOS cuts Trigger On Signal (TOS) of the full decay chain of the signal particle. An event is considered TOS when the presence of the signal is sufficient to generate a positive trigger decision [15]. The TOS cut has to be interpreted as the value of the `TisTosSpecs` property of the `TisTosParticleTagger` algorithm without the `Decision%TOS` part of the string.

List of L0 channels

List of HLT1 lines

2011

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List of HLT2 lines

2011

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