UNIVERSITY OF BRISTOL / LAL ORSAY

Assessments

Renato Quagliani

June 7, 2015

1 OVERVIEW OF WORK DONE

A description of the work done up to now will be described. It consists in two major blocks. The first one is related to the analysis work and it has been done from June 2014 to October 2014 , period in which i was finishing the master degree in Ferrara Unviersity and i get the NPAC master 2 at Paris Sud University. The second one is related to the work done in the context of the Upgrade of the LHCb detector consisting in the improvements of the *Seeding* tracking algorithm which actually becomes the development of new algorithm , the *Hybrid Seeding*.

1.1 SOFTWARE DEVELOPMENT PROJECT : SEEDING ALGORITHM FOR THE LHCB UPGRADE

Before discuss about the work done in this domain a small introduction about the tracking and the upgrade of the *LHCb* detector is mandatory.

1.1.1 INDTRODUCTION TO LHCB AND TO THE UPGRADE SCINTILLATING FIBRE TRACKER (SCIFI).

The *LHCb* detector [1] aims to search indirect signatures of New Physics through quantum loop induced processes through the measurements of strongly suppressed Standard Model processes and studying very rare decays. In this context precision and statistics play a fundamental role. Up to now, in *LHCb* and *LHC*, no deviations from the Standard Model (SM) have been observed and even if *LHCb* has provided the world's best measurements in some channels, it is still limited from improving them by statistics rather than systematics. Due to this the upgrade of the *LHCb* forward spectrometer is mandatory in order to collect *O(100)* times more data and reduce the statistics uncertainty of a factor 10 in order to be comparable with the theoretical one [2][3].

The *LHCb* detector is designed to be a single-arm forward spectrometer aiming to detect of particles and their decay products, and as the *b* in the name of the detector suggests, it is designed to study particles containing *b* and *c* quarks which are produced strongly boosted in the forward and backward (lost) directions for symmetric energies of colliding protons.[1]

The detailed description of the *LHCb* detector can be found in [1].

The data taking at *LHCb* during 2011 and 2012 at LHCb are mainly determined by few steps:

- Interesting events are selected by the *L0 Trigger* which is implemented at the hardware level aiming to reduce the 40 *MHz* bunch crossing rate to 1*MHz* making use of estimation and measurements of the signature of particles having high E_T, p_T through the Muon stations and the calorimeter. The main reason why this is done is because the read-out system for Run-I and Run-II cannot afford an incoming rate of 40*MHz*. In the upgrade infact, all the read-out will be substituted and the *L0* trigger will be replaced by a software one.

- *High Level Trigger*: It consists in an *Online* software trigger where the full reconstruction of tracks is performed. It's at this level that the tracking algorithms are run. After this step , data are stored and an *Offline* reconstruction is also performed before providing usable object for data analysis. [2]

- *LHCb* luminosity is kept constant and it'reduced wrt other *LHC* experiments of 2 orders of magnitudes. This reduction in luminosity is achieved thanks to the *Luminosity Levelling* mechanism which avoid head-on collisions separating beams perpendicularly to the collision plane. This decrease of luminosity is mandatory since the main studies on *b* and *c* hadrons requires an extraordinary precise reconstruction of the production vertex of the $b\bar{b}$ pairs, so, the VErtex LOcator (*VELO*) can be placed at very small distance from the interaction point limiting problems coming from radiation damages. [3]

[1] The relevant process infact is the quark-gluon fusion which can be obtained in proton proton collisions only with strongly asymmetric PDFs.

[2] During the Run-I, the seeding algorithm (called *PatSeeding*) in the *HLT* was run making use of the left-over hits coming from the *Forward* algorithm. During Run-I the *Seeding* was used in the online reconstruction in tandem with the *Forward* as described before while in the offline reconstruction it was run as a *Standalone* algorithm. For the Run-II ...to complete.

[3] The decrease from the maximal designed luminosity of *LHC* of $10^{34} cm^{-2} s^{-1}$ to the *LHCb* one $10^{32} cm^{-2} s^{-1}$ permit to reduce the average number of inelastic collisions from 27 to 0.53 and it allows to reconstruct with extraordinary precision the primary vertices.

The track reconstruction at *LHCb* is decompose in different steps. The idea is to provide different containers containing different category of tracks. The track classification at *LHCb* is done depending on the path the track goes through, so it's based on the datector's hit content as shown in Fig. 1.1.

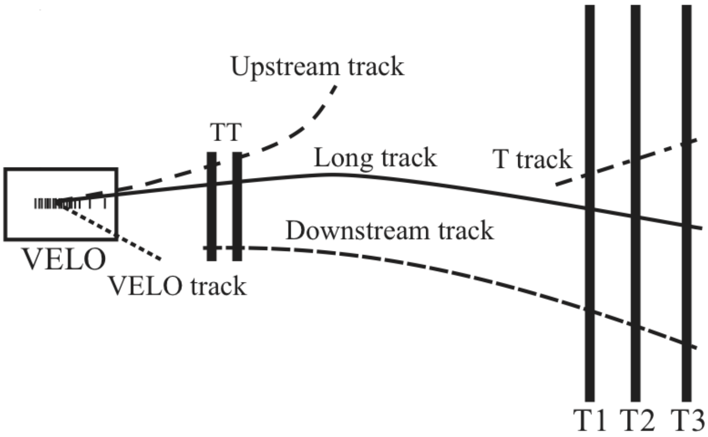

Figure 1.1: Track type at *LHCb*. Velo tracks are basically straight lines since the magnetic field is almost 0 in that region. Tracks are mainly bended in the x-z [4]plane between the Tracker Turicensis (Upstream Tracker for the upgrade) and the T-Stations which is composed by the Inner Tracker(IT) and the Outer Tracker(OT) (Run-I and Run-II), while for the upgrade the stations will be replaced by the Scintillating Fibre tracker (SCIFI).

In the tracking system of *LHCb* each track type is reconstructed by a proper algorithm and a schematic layout of how things work is given in table **??**.

Track Type	Used Detector	Algorithm(s)	Input	Output
Velo Tracks or Velo-Segment	Velo	Velo algorithm	/	Velo
Seed Tracks or T-Tracks	T-Stations (SciFi in upgrade)	Seeding algorithm	Allow the possible usage of the leftover hits of forward. If Not: Standalone Algorithm	Seed
Long Tracks (1)	Velo + TT + T-Stations (TT → UT T-Stations → SciFi in upgrade)	1) Forward tracking: Search in T-Stations knowing Velo-Segment (adding also TT) 2)Matching algorithm: Merge T-Tracks with Velo-Segment 3)BestSelector= Forward+Matching	Velo Container Velo and Seed Containers	Long
Downstream Tracks	T-Stations and TT (SciFi and UT)	Downstream algorithm: Use T-Tracks and add TT (UT upgrade) hits	Seed Container	Downstream
Upstream Track	Velo and TT	Upstream algorithm: Use Velo segment and add TT(UT upgrade) hits	Velo Container	Upstream

All the tracks produced by the algorithms provided before will be reprocessed by the Kalman Filter which will reprocess the tracks assigning a sort of *univoque* χ^2 to the track and will refit them taking into account the magnetic field map and the material budget of the tracks to multiscattering correction. From a more technical point of view, each track is defined by a vector of track state $\left(x, y, t_x, t_y, \frac{q}{p}\right)_z^T$ which is then propagated by a $5X5$ matrix through the detector considering the interactions and the B-Field map. At the level of the track search done by the algorithms the main goal is to provide for each track a set of compatible hits and only at the end of the algotithm they are converted into track state.

Going back to the upgrade, a brief description on what it consists is mandatory. A small recap is given in table **??** The reason why

	Current *LHCb*	Upgrade *LHCb*
Luminosity	$4 \cdot 10^{32} cm^{-2} s^{-1}$	$2 \cdot 10^{33} cm^{-2} s^{-1}$
$\mu = < \frac{Visible \quad Interactions}{BunchCrossing} >$	1.7	5.2
Hardware trigger	40 *MHz* to 1*MHz*	40 *MHz* Full software trigger for every 25 ns bunch crossing

the *L0* trigger will be removed in the upgrade is mainly because lot of analysis looking for deviations from Standard Model at *LHCb* are limited by statistics and a fixed 1 *MHz* readout at the upgrade running condition will be too limiting. In order to reach the physics goals the *LHCb* detector will be upgraded and the installation of the new detectors and read out is expected to happen during the long shutdown 2 in 2018/2019.

[4]z- is the beam axis direction and the y axis is the B field line direction.

First of all the actual velo will be replaced by a lightweight hybrid pixel detector capable of 40 MHz readout at the upgrade luminosity which is 5 times greater than the actual one. Regarding the *PID* detectors (*RICH1 and RICH2*), the aerogel from *RICH1* will be removed and the opitcal system will be modified, and , of course , new photon detectors and read-out system will be implemented. Since the *L0* trigger will not be present in the upgrade, so the Scintillating Pad detector and the pre-shower which basically initiate the electromagentic and hadronic shower and applies some vetoes to the events will be removed. The calorimeters will remain the same apart of the implementation of a new read-out. The muon system also will remain the same apart of a new read out and the removal of the first station (*M1*). The trackers downstream and upstream the magnet will be insteads completely replaced. In particular the tracker downstream the magnet which is now made by the so-called Inner tracker *IT* and the Outer Tracker*OT* will be replaced by the scintillating fibre (*SciFi*) detector to cope for the higher luminosity, higher occupancy and the 40 *MHz* read-out. For the current tracker system downstream the magnet two technologies are used: the Outer Tracker system is based on gaseous straw tube detector for a global resolution on the bending plane (*x*-*z*) of around 200 μm. The main reason why it's necessary to replace the Inner and Outer tracker is related to the Ocuupancy being too high in upgrade conditions and the fact that the electronics for them was designed for a 1MHz read-out rate. On top of that, the upgrade phase of LHCb is designed to collect an integrated luminosity of 50 fb^{-1} and the detector itself is required to be resistent to the corresponding radiation damages. The adopted solution for the upgrade is the Scintillating Fibre Tracker which is basically a tracker where the active material is actually the same of the transport one. The produced light is transported (and shifted in wavelenght to be not absorbed by the material itself) and collected by arrays of Silicon photomultipliers and the pitch of a single channel is designed to be equal to 250 μm. The detector will be placed in substitution to the actual one and its design is given in **??**.

1.1.2 Analysis Work : $B^0 \to D^0\overline{D}^0 K^{*0}$ analysis

2 Choice of Thesis Topic

3 Timetable for future

References

[1] LHCb Collaboration , *The LHCb Detector at the LHC, JINST 3(2008) S08005*

[2] LHCb collaboration, *Letter of Intent for the LHCb Upgrade*, CERN-LHCC-2011-001, March 2011.

[3] LHCb collaboration, *Framework TDR for the LHCb Upgrade*, CERN-LHCC-2012-007, May 2012.

[4] LHCb collaboration, *LHCb Scintillating Fibre Tracker Technical Design Report*, CERN-LHCC-2014-001; LHCb TDR 15.