UNIVERSITA
DEGLI STUDI
DI TORINO

Summary of MTD DPG activities post-TDR

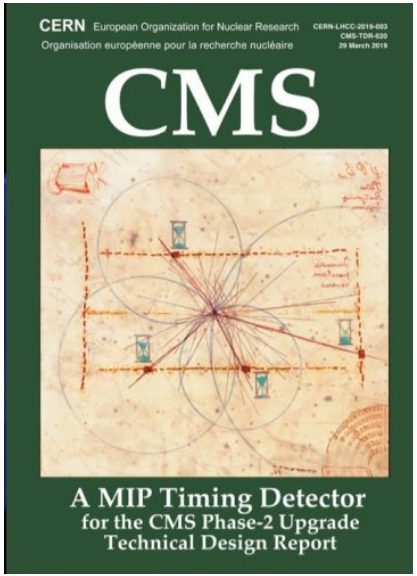
UPSG workshop 9.22.2021

Federico Siviero on behalf of the MTD collaboration

INFN / University of Torino

MIP Timing Detector (MTD)

MTD TDR



- Several studies have been performed using the TDR description of MTD → MTD performances reported to be sub-optimal

However...

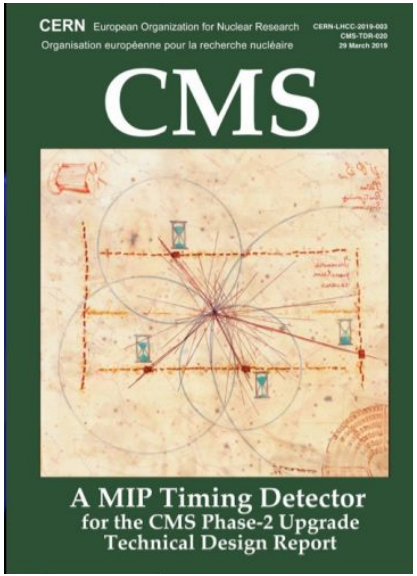
- Reconstruction code at TDR time was still in an early stage
- Moreover, ETL description was far from the final one

- **Several improvements have come in the last year: they are the subject of this presentation**

MTD is divided in Barrel (BTL) and Endcap (ETL)

MIP Timing Detector (MTD)

MTD TDR



- Several studies have been performed using the TDR description of MTD → MTD performances reported to be sub-optimal

However...

- Reconstruction code at TDR time was still in an early stage
- Moreover, ETL description was far from the final one

- **Several improvements have come in the last year: they are the subject of this presentation**

➔ **any claim about the use of MTD should be rebased on the most recent version of the code**

MTD is divided in Barrel (BTL) and Endcap (ETL)

Outline

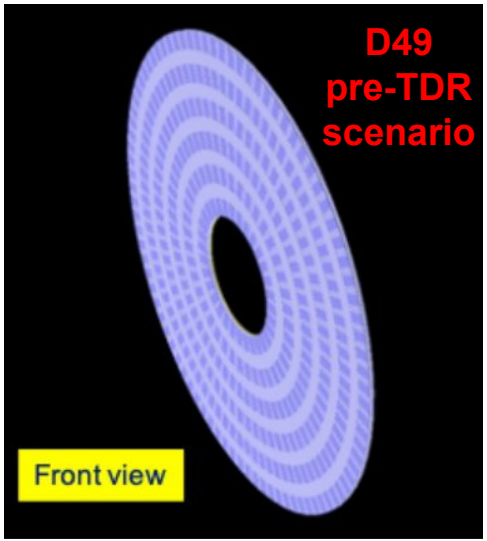
- New geometry scenarios
- Development in ETL Digitization
- The issue of time uncertainties and 4D-vertexing
- MTD within the CMS tracking system
- An MTD study: VBF HH → 4b

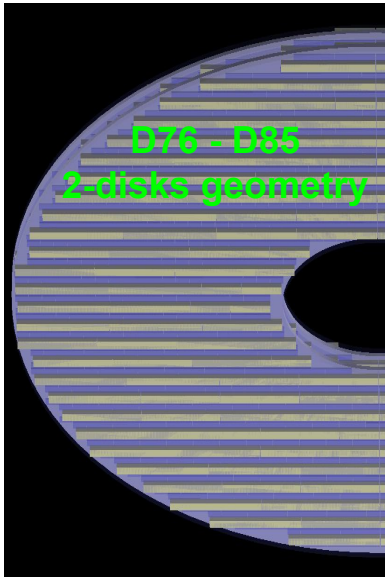
Outline

- New geometry scenarios
- Development in ETL Digitization
- The issue of time uncertainties and 4D-vertexing
- MTD within the CMS tracking system
- An MTD study: VBF HH → 4b

New ETL geometry description

- Migration to DD4hep completed at the end of 2020 (F.Cossutti presentation)
- Most recent scenarios available in CMSSW: D76, D85
- 2 main advances with respect to the old ETL scenario (D49)
  - **2-disks** instead of a single one
  - From a ring-oriented geometry to a **sector-based** one

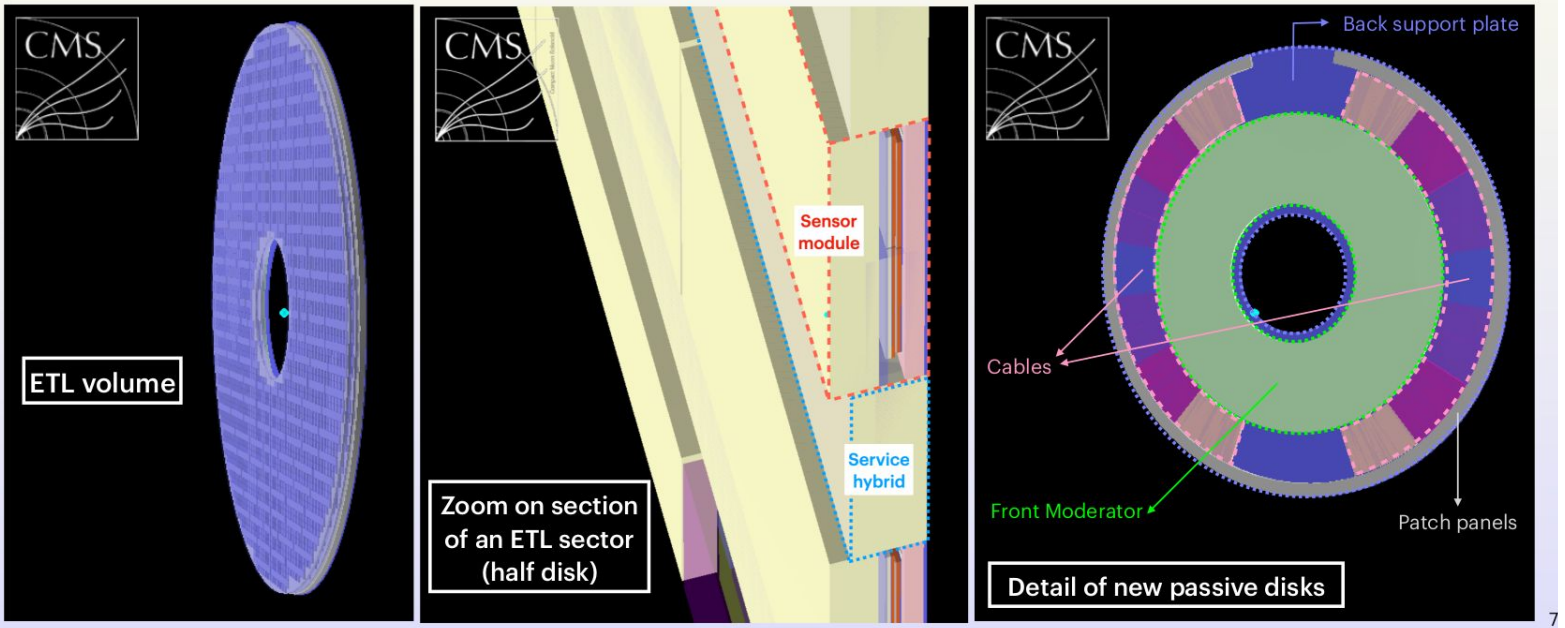




New ETL geometry description

- Migration to DD4hep completed at the end of 2020 (F.Cossutti presentation)
- Most recent scenarios available in CMSSW: D76, D85

Update of **ETL z layout for v6** (Geometry D85): images of the implemented geometry from Fireworks



D85 adds passive materials and a different sensor module, compared to D76

ETL navigation

- Key issue: **identify LGADs compatible with a particle trajectory**
  - old navigation code based on ring-oriented geometry cannot work with new scenario

- A new navigation algorithm (M.Tornago) has been developed to operate in the 2-disk, sector-based geometry → fully tested and implemented in CMSSW
- Once the LGAD with minimum distance is found, move left/right and check whether compatible modules are present
- Then, move to the upper/lower row and repeat, until no compatible modules are found

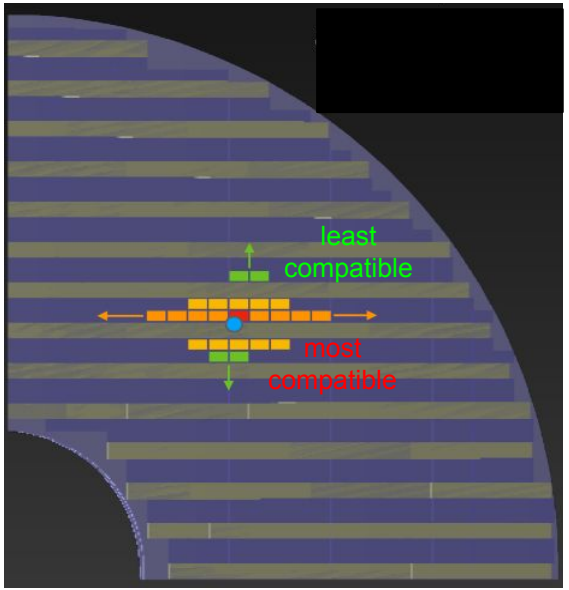


Illustration of the new navigation algorithm

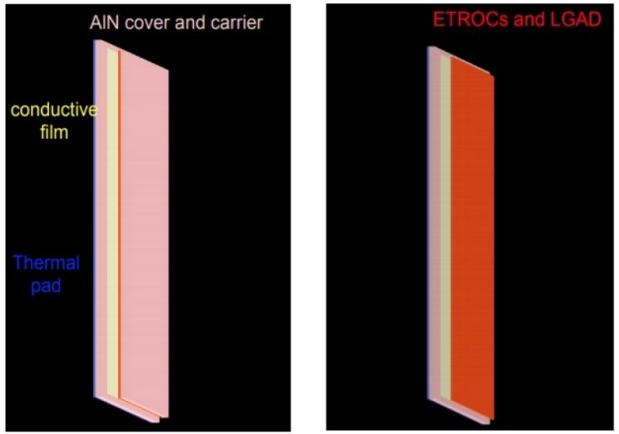
Outline

- New geometry scenarios
- Development in ETL Digitization
- The issue of time uncertainties and 4D-vertexing
- MTD within the CMS tracking system
- An MTD study: VBF HH → 4b

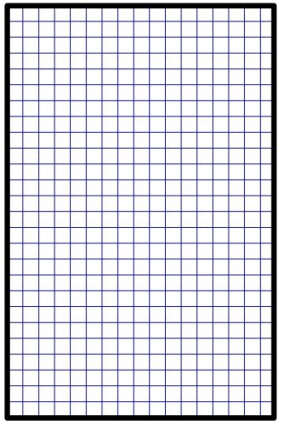
ETL Digitization

- Improvements towards a more sophisticated model of the digitization process
- **Radiation-dependent gain** (gain is function of absorbed dose) has been introduced
- Add periphery and interpixel **no-gain areas**
  - Previously LGAD was a compact block and a matrix existed only at logical level, with no no-gain zones

GEANT4



LOGIC

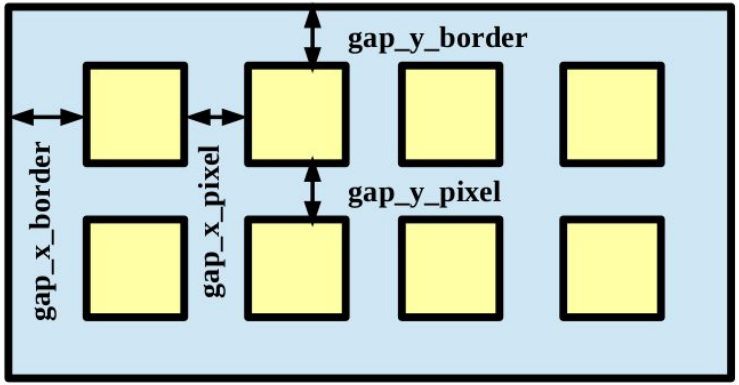


see P.Martinez [presentation]

ETL Digitization

- Improvements towards a more sophisticated model of the digitization process
- **Radiation-dependent gain** (gain is function of absorbed dose) has been introduced
- Add periphery and interpixel **no-gain areas**
  - Previously LGAD was a compact block and a matrix existed only at logical level, without no-gain areas

- A *pixel* function receives the SimHit and returns the (n,m) pixel coordinate + a boolean (false=no-gain region hit)



...next step: parametrization of the ETL signal shape

Outline

- New geometry scenarios
- Development in ETL Digitization
- The issue of time uncertainties and 4D-vertexing
- MTD within the CMS tracking system
- An MTD study: VBF HH → 4b

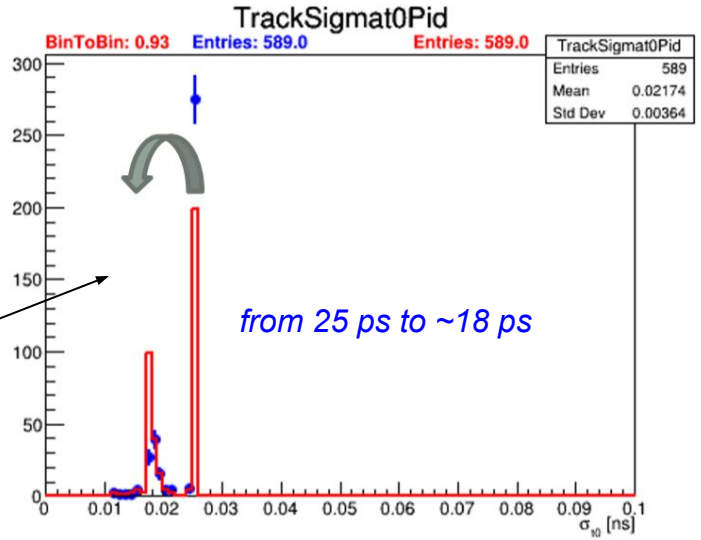
ETL time from both disks

- **With the new, 2-disks geometry, ETL time is given by 2 timestamps**
- Hit time from disk 2 is projected onto disk 1, assuming pion TOF between the disks
  - $t'_{disk2} = t_{disk2} - TOF_{\pi}$

➢ New ETL time implemented in CMSSW

➢ ***TrackExtenderWithMTD* now uses both ETL disks to associate a time**

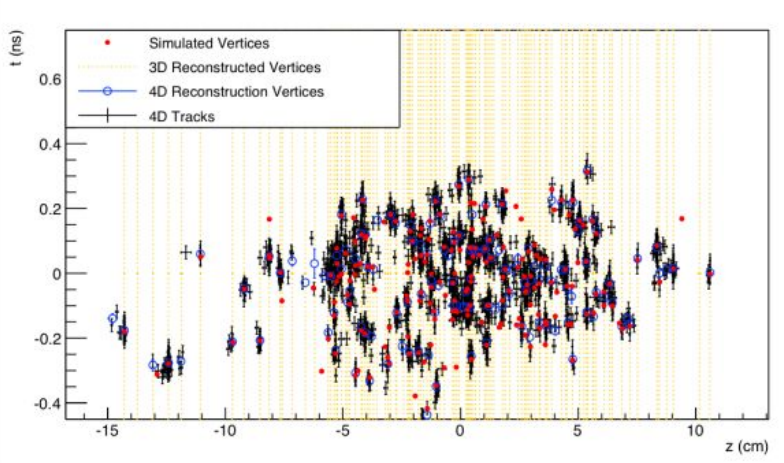
➢ Uncertainties are reduced, due to the combination of the 2 disks



F.Cossutti presentation at June CMS week

4D-vertices

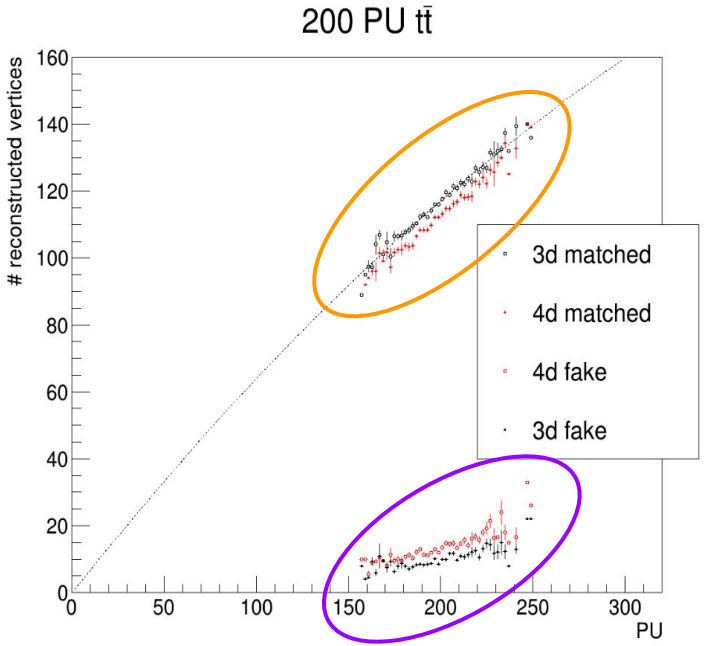
- A key purpose of MTD is Pile-Up (PU) rejection → add time coordinate to distinguish vertices overlapping in space, but not in time
- Key point is, therefore, 4D vertexing : reconstruct not only the vertices spatial coordinates (3D vertexing) but add also their timing



Vertices overlapping in z can be disentagled adding temporal dimension

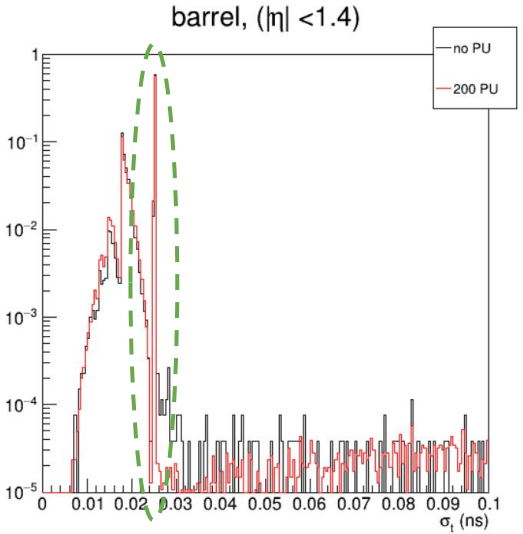
4D-vertices

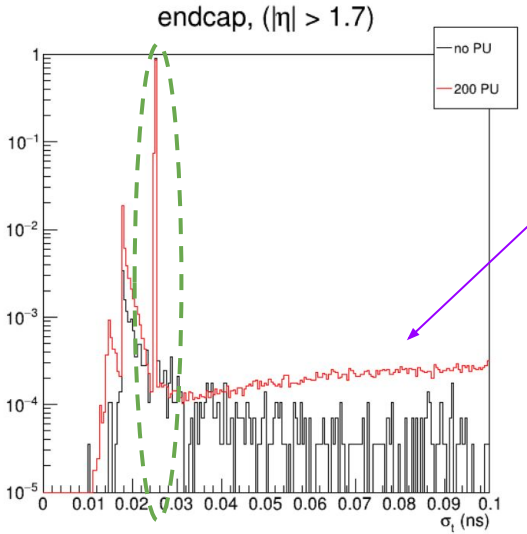
- A key purpose of MTD is Pile-Up (PU) rejection → add time coordinate to distinguish vertices overlapping in space, but not in time
- Key point is, therefore, 4D vertexing : reconstruct not only the vertices spatial coordinates (3D vertexing) but add also their timing
- Issue raised by W. Erdmann (presentation at tracking POG, June 2020) : 4D vertices are not optimal
- **4D** are less efficient and with higher fake rate than 3D vertices



Vertex truth-matching based on truth-matched tracks

MTD timing uncertainties



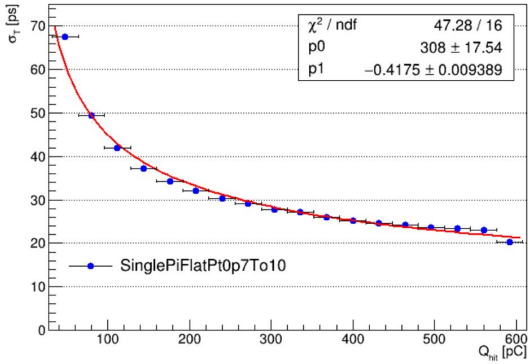


- **A part of 4D vertices poor performance is related to timing uncertainties**
- Tail with high uncert. in the endcap are residual of mass-hypothesis disambiguation (work to fix this ongoing)
- 25 ps spike: it was an hardcoded value related to single-hit clusters → does not correspond to the observed resolution and has been fixed

see F.Cossutti presentation during the CMS week for more details

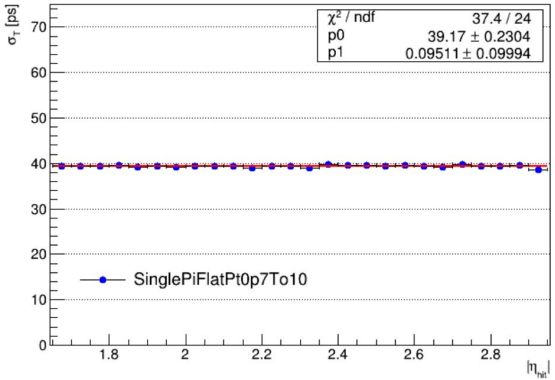
25 ps spike → fixed

- The resolution on the barrel region depends upon E_{hit} but not upon η
  - BTL parametization: ***σ(Q) = a*Q^b*** expressed as a function of the hit charge Q



$$\sigma_T(Q) = p_0\, Q^{p_1}$$

- ETL resolution is flat both in E_{hit} and η
  - ***σ = 39 ps***



$$\sigma_T = 39\ ps$$

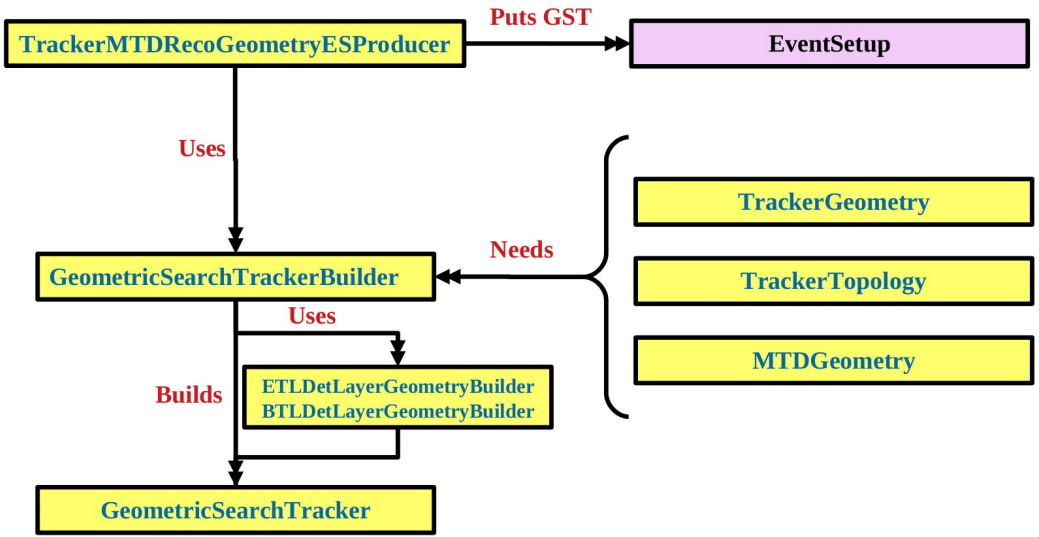
more detail in [M.Casarsa's presentation at MTD DPG]

Outline

- New geometry scenarios
- Development in ETL Digitization
- The issue of time uncertainties and 4D-vertexing
- MTD within the CMS tracking system
- An MTD study: VBF HH → 4b

MTD in the CMS tracking system

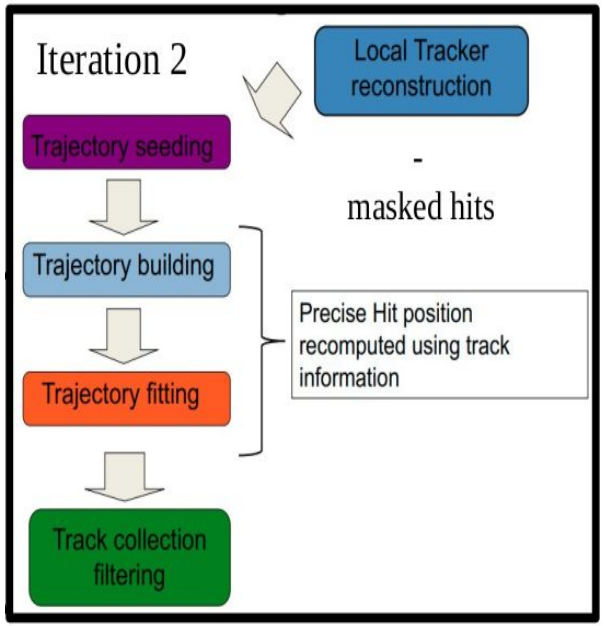
- MTD adds 2 layers to the CMS tracker → if MTD hits are added a posteriori, no benefit from a tracking point of view → need to include MTD in the tracker standard navigation



- First step: joint Tracker-MTD navigation successfully completed in Spring 2020 (presentation by P.Martinez)
- This update allows the tracker navigation to automatically find and link the MTD system → **from a logical point of view, MTD and tracker are now unified**

MTD in the CMS “iterative tracking”

- **Addition of MTD in the iterative structure of the CMS tracking algorithm** → Possible benefits in the hit-track association
- Trajectory seeding (1st step of the algorithm) code works fine with the new Tracker + MTD Navigation → no change needed if no MTD seeds are added
- Trajectory building (2nd step) is fundamental in the iterative tracking and naturally involves MTD → work ongoing and some proposals are ready to be discussed with experts
- Trajectory fitting (not yet covered) : time back-propagation belongs here + problem of mass disambiguation
- Trajectory filtering: not yet covered, likely the simplest part



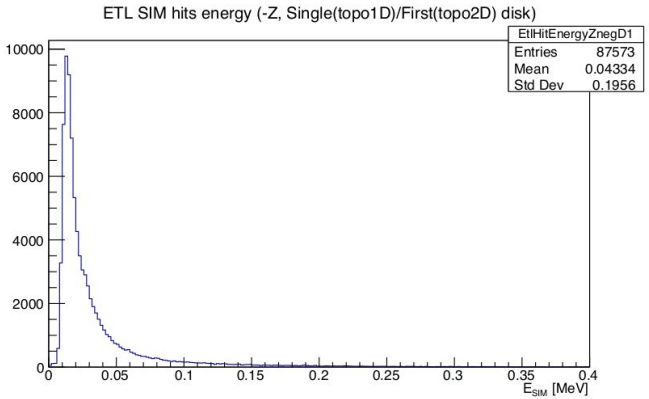
from P.Martinez presentation, MTD DPG July 2021

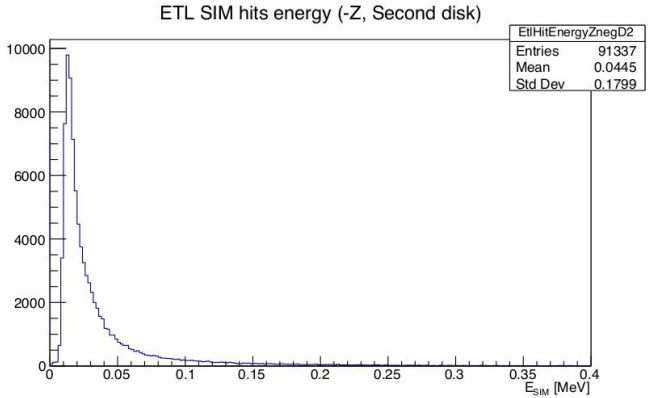
MTD Validation Code

- **Validation Code updated at SIM, DIGI, RECO** level accordingly to the new geometry scenario, available in CMSSW
- Work ongoing to implement a **validation code for the 4D-vertex quality** (re-implementing code by W. Erdmann)
- Next: **validation code to study the impact of timing on PUPPI jets**

SIM Hits validation

1000 TTbar PU=0 events
33424.0_2026D73+TTbar_13TeV_TuneCUETP8M1_GenSim
HLBeamSpot+DigiTrigger+RecoGlobal+HARVESTGlobal





presentation by G.Sorrentino

4D Vertexing - Jets

- Key issue: at the moment any study is biased by **jet collection being based on 3D input vertices**
  - In touch with PUPPI experts (A. Benecke, A. Hinzmann) to recompute PUPPI jets with 4D vertices
- **How should we use timing in the track-vertex association?**
  - It can be used in the 4D-vertexing, with the PUPPI algorithm that remains unchanged
  - Or one can move to a dz-dt selection, i.e. timing is used as an additional PU rejection tool inside PUPPI
  - Both paths are being studied, there is no clear answer presently → working on a validation code

more in presentation by A. Benecke, MTD DPG June 2021

Cleaning of MTD-related event content

- MTD used to contribute for ~ ⅓ to AODSIM (!) → main reason: (re-)tuning of MVA quality flag for MTD hit-track association (*trackExtenderWithMTD*)
- *trackExtenderWithMTD* has to be re-run and return MVA quality variable on AODSIM
  - But the needed information is available in RECOSIM, if this is available on demand, no need to inflate AODSIM
- Cleaning of MTD-related AODSIM is now completed → check PR by F.Cossutti https://github.com/cms-sw/cmssw/pull/34195

presentation by F.Cossutti, June 2021

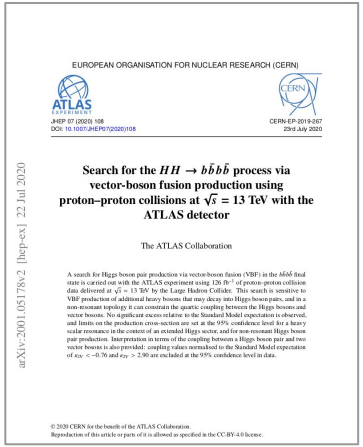
Outline

- New geometry scenarios
- Development in ETL Digitization
- The issue of time uncertainties and 4D-vertexing
- MTD within the CMS tracking system
- An MTD study: VBF HH → 4b

VBF HH → 4b

- Aim of this study is the impact of MTD timing in removing pile-up (PU) candidates from jets, considering a 200 PU scenario
- We chose VBF HH→4b as benchmark channel
  - Can benefit from the enhanced b-tagging related to timing
  - ETL can be very useful in VBF tagging
- Sample: /VBF_HHTo4B_CV_1_C2V_1_C3_1_TuneCP5_PSWeights_14TeV-madgraph-pythia8/ Phase2HLTTDRWinter20RECOMiniAOD-PU200_110X_mcRun4_realistic_v3-v2/MINIAODSIM
- Setup: CMSSW_11_1_5
  - globaltag = "111X_mcRun4_realistic_T15_v1"
  - era = Phase2C9
  - Geometry scenario D49
  - Reco jets from ‘slimmedJetsPuppi’
- Based on a study by ATLAS with Run2 data

see presentation at MTD DPG


EUROPEAN ORGANISATION FOR NUCLEAR RESEARCH (CERN)

ATLAS EXPERIMENT

JHEP 07 (2020) 108
DOI: 10.1007/JHEP07(2020)108

CERN-EP-2019-267
29-d July 2020

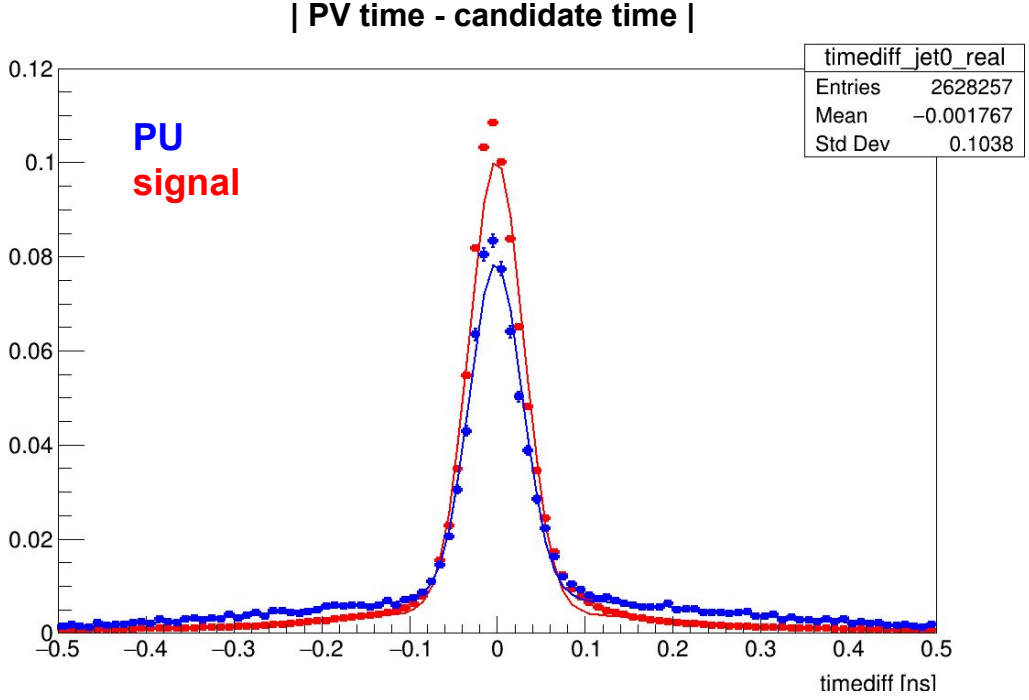
arXiv:2001.05178v2 [hep-ex] 22 Jul 2020

Search for the $HH \to b\bar{b}b\bar{b}$ process via vector-boson fusion production using proton–proton collisions at $\sqrt{s}$ = 13 TeV with the ATLAS detector

The ATLAS Collaboration

A search for Higgs boson pair production via vector-boson fusion (VBF) in the $b\bar{b}b\bar{b}$ final state is carried out with the ATLAS experiment using 126 fb^{-1} of proton–proton collision data delivered at $\sqrt{s}$ = 13 TeV by the Large Hadron Collider. This search is sensitive to VBF production of additional heavy bosons that may decay into Higgs boson pairs, and in a non-resonant topology it can constrain the quartic coupling between the Higgs bosons and vector bosons. No significant excess relative to the Standard Model expectation is observed, and limits on the production cross-section are set at the 95% confidence level for a heavy scalar resonance in the context of an extended Higgs sector, and for non-resonant Higgs boson pair production. Interpretation in terms of the coupling between a Higgs boson pair and two vector bosons is also provided: coupling values normalised to the Standard Model expectation of $\kappa_{2V} < -0.76$ and $\kappa_{2V} > 2.90$ are excluded at the 95% confidence level in data.

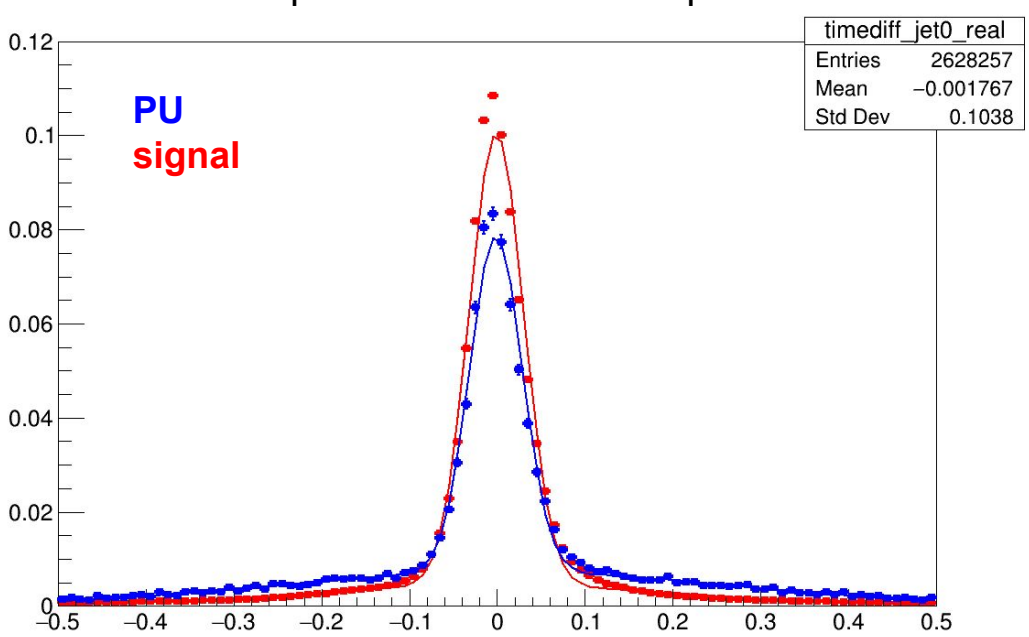
VBF HH → 4b



normalized to integral

- Signal and PU jets are determined on a dr-matching basis
- **Key observable is the time difference between the leading vtx time and jet candidates time**
- Considering a beamspot spread of ~ 180 ps:
  - we would expect the PU candidates to have σ = sqrt(2)*180 ps ~ 250 ps (PV and candidate time uncorrelated)
  - whereas the signal candidates should have σ ~ 40 ps (detector resolution, PV and candidate times are correlated)

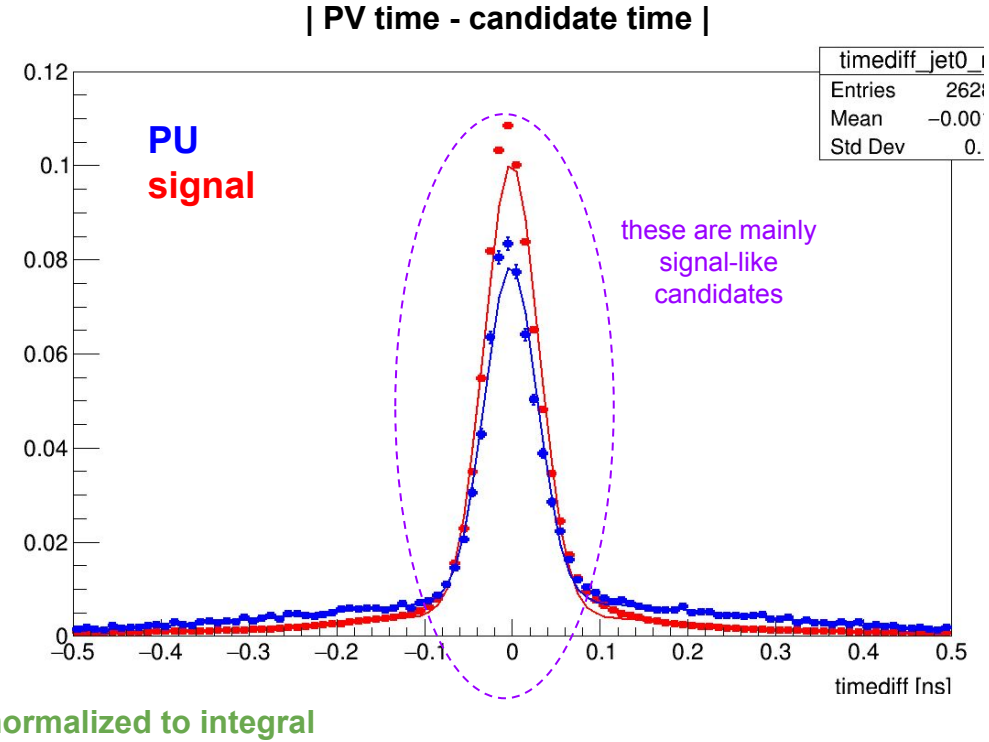
VBF HH → 4b



An appropriate timing cut on the time difference should reject a major fraction of PU candidates → the timing cut could be an important PU rejection tool

- Signal and PU jets are determined on a dr-matching basis
- **Key observable is the time difference between the leading vtx time and jet candidates time**
- Considering a beamspot spread of ~ 180 ps:
  - we would expect the PU candidates to have σ = sqrt(2)*180 ps = 250 ps (PV and candidate time uncorrelated)
  - whereas the signal candidates should have σ ~ 40 ps (detector resolution, PV and candidate times are correlated)

VBF HH → 4b



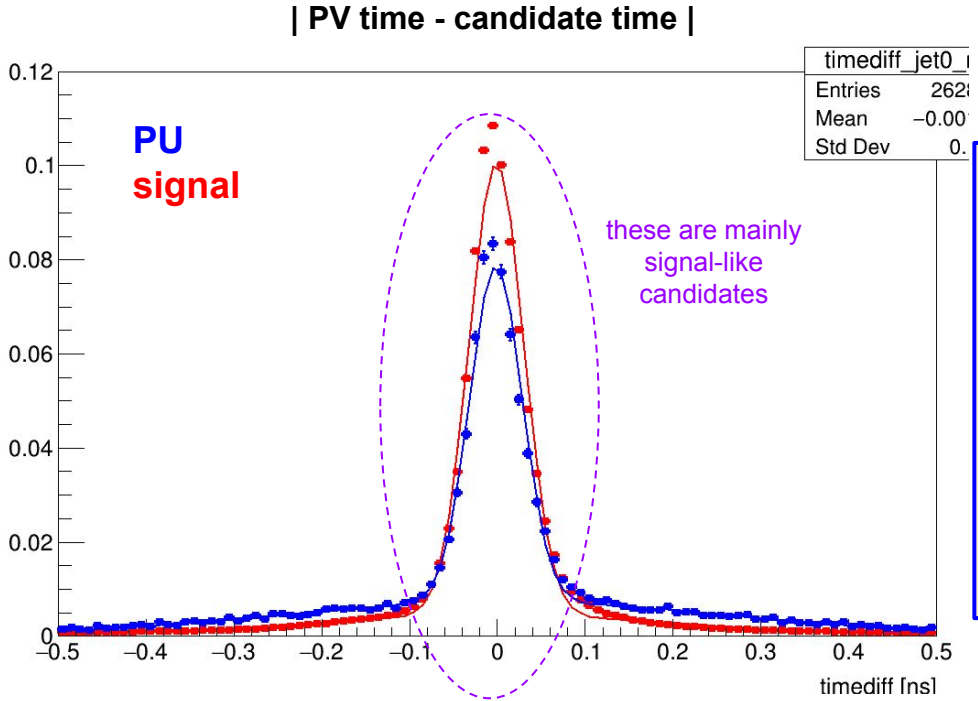
normalized to integral

- Key issue: distributions are similar, dominated by signal-like candidates

2 main causes identified:

- The reconstructed primary vertex does not match the simulated one in ~ 15% of the events (backup for more details)
- At 200 PU, the PU-rejection algorithm (PUPPI) is removing too many tracks from the signal jets, even those associated with real signal candidates
- Hence **timing is not useful**, since any timing cut would rule out basically the same (small) fraction of candidates from signal and PU jets, with no improvement in the rejection power

VBF HH → 4b



normalized to integral

- Key issue: distributions are similar, dominated by signal-like candidates

- Work ongoing to check a possible improvement in the primary vertex tagging, related to the latest developments in the MTD uncertainties
- In contact with PUPPI group to develop a new version of the algorithm, exploiting the MTD timing in the most fruitful way

timing cut would rule out basically the same (small) fraction of candidates from signal and PU jets, with no improvement in the rejection power

Code to get timing variables

- process.MyJetAnalysis.pvCollName = cms.string('offlineSlimmedPrimaryVertices4D')
- process.MyJetAnalysis.patJetCollName = cms.string('slimmedJetsPuppi')
- process.MyJetAnalysis.genJetCollName = cms.string('slimmedGenJets')

python config file

- tok_PATJet_ = consumes<std::vector<pat::Jet>>(patJetCollName_);
- tok_GenJet_ = consumes<std::vector<reco::GenJet>>(genJetCollName_);
- tok_PV_ = consumes<std::vector<reco::Vertex>>(pvCollName_);

- edm::Handle<std::vector<reco::Vertex>> pv;
- iEvent.getByToken(tok_PV_, pv);

- edm::Handle<std::vector<reco::GenJet>> genjets;
- iEvent.getByToken(tok_GenJet_, genjets);

- edm::Handle<std::vector<pat::Jet>> patjets;
- iEvent.getByToken(tok_PATJet_, patjets);

lines to be inserted in the .cc script

Code to get timing variables

- vtx_time = pv->t();
- vtx_time_error = pv->tError();

primary vertex time and error

- for(pat::JetCollection::const_iterator it_patjet = patjets->begin(); it_patjet != patjets->end(); ++it_patjet){

```
        for (unsigned int id = 0, nd = pjet->numberOfDaughters(); id < nd; ++id) {

            const pat::PackedCandidate &packedC = dynamic_cast<const pat::PackedCandidate
            &>(*pjet->daughter(id));

           float candidate_time = packedC.time();
           float candidate_time_error = packedC.timeError();

        }
}
```

to get candidate times and errors in reco jet (exactly the same with Gen Jets)

- presently, MVA quality flag not accessible in MINIAOD
- It is used as an hardcoded cut (>0.5) for the filling of time info when building PFCandidates

Summary

- Many advances in the MTD reconstruction code since TDR
- Post-TDR Geometry scenario D76, D85 have been successfully tested and are available in CMSSW
- ETL Digitization has been developed to consider LGAD interpixel and periphery no-gain areas
- Problem of the hardcoded 25 ps in the time uncertainties has been solved, the uncertainty is now parametrized in a more realistic way → still have to assess the impact on 4D vertexing
- MTD and Tracker are now unified from a logical point of view → work ongoing to fully insert MTD in the CMS tracking system
- MTD validation code available in CMSSW
- Future plans:
  - full insertion of MTD in the tracking system, use of time back-propagation
  - ReReco of PUPPI jets with 4D vertices
- VBF HH → 4b interesting process for MTD: timing not useful for PU rejection as of now, closely collaborating with PUPPI experts to improve that

Summary

- Many advances in the MTD reconstruction code since TDR
- Post-TDR Geometry scenario D76, D85 have been successfully tested and are available in CMSSW
- ETL Digitization has been developed to consider LGAD interpixel and periphery no-gain areas
- Problem of the hardcoded 25 ps in the time uncertainties has been solved, the uncertainty is now parametrized in a more realistic way → still have to assess the impact on 4D vertexing
- MTD and Tracker are now unified from a logical point of view → work ongoing to fully insert MTD in the CMS tracking system
- MTD validation code available in CMSSW
- Future plans:
  - full insertion of MTD in the tracking system, use of time back-propagation
  - ReReco of PUPPI jets with 4D vertices
- VBF HH → 4b interesting process for MTD: ti
  with PUPPI experts to improve that

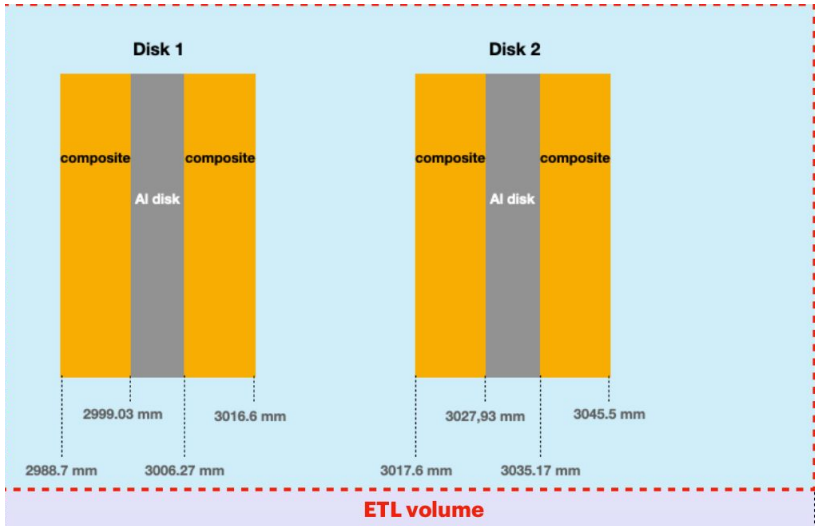
Given such advances in the reconstrcution code, any study performed months ago is obselete and should be redone considering the most recent updates

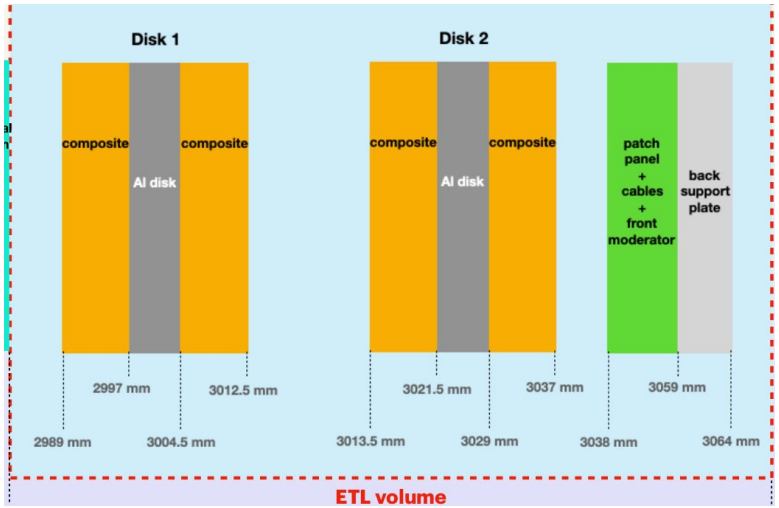
Thank You!

BACKUP

New ETL geometry scenario

- Summer 2021: latest etl version (etl v6) → goes into scenario D85



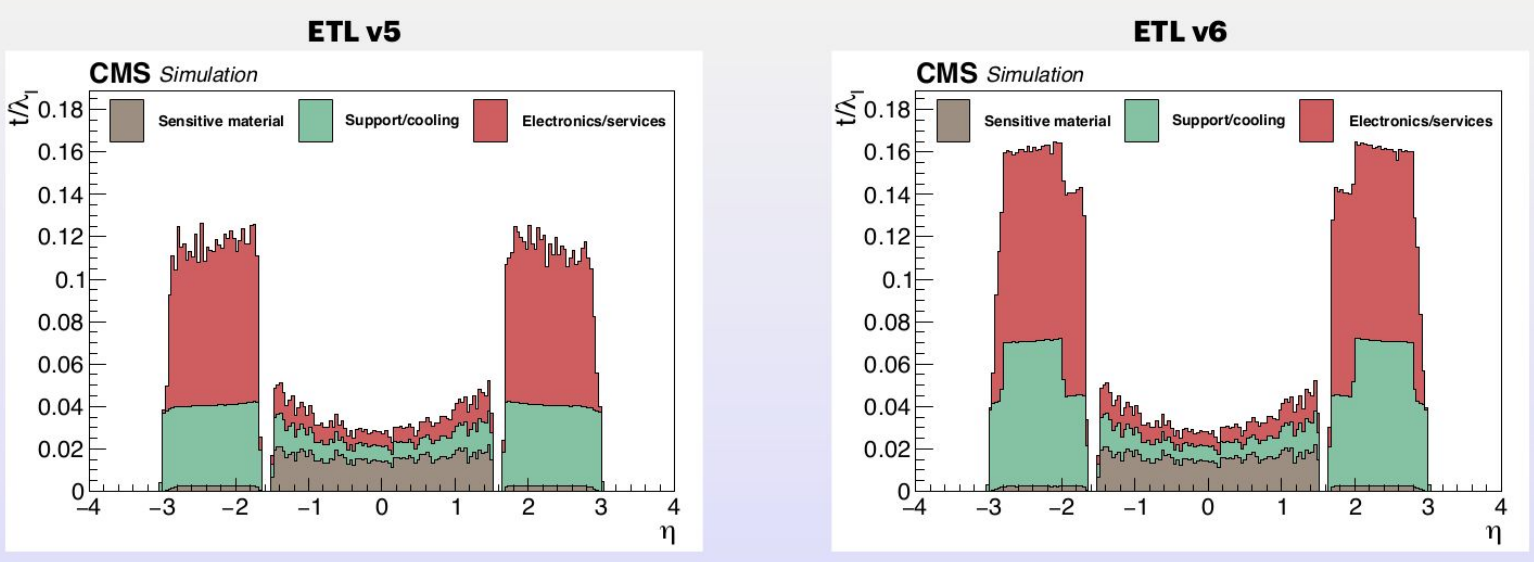


new passive layers added, according to latest geometry description by N.Koss

New ETL geometry scenario

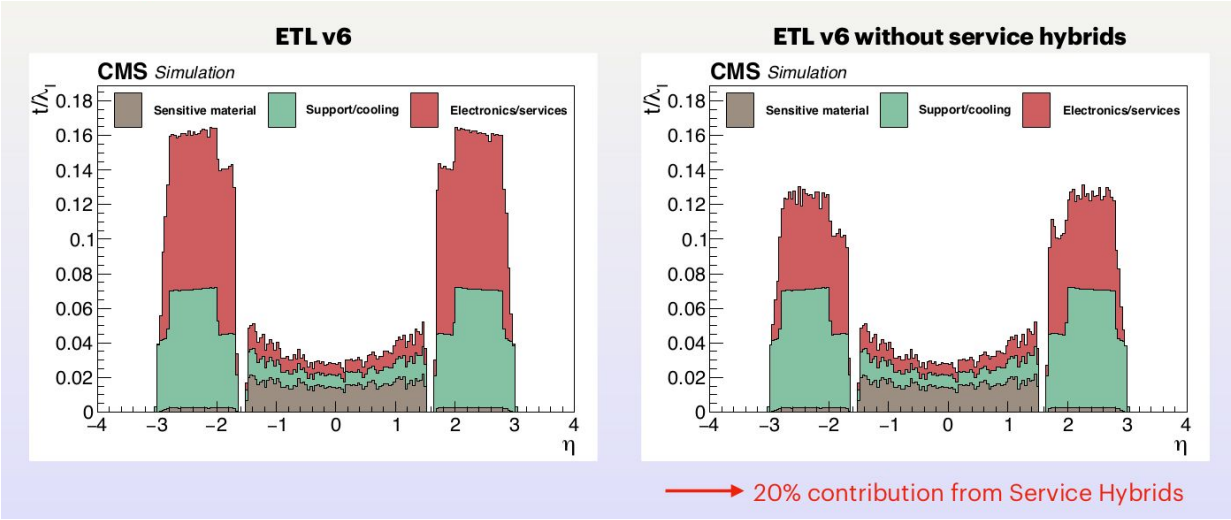
- A comparative study of the material budget of etl v5 and v6 has been performed
- 100k neutrinos simulated to sample the detector without interactions
- Plotted as t/X_0 or t/λ as a function of η and φ

Increased contribution by passive materials in v6, as expected



New ETL geometry scenario

- The contribution of the single elements has been assessed too (v6 only)



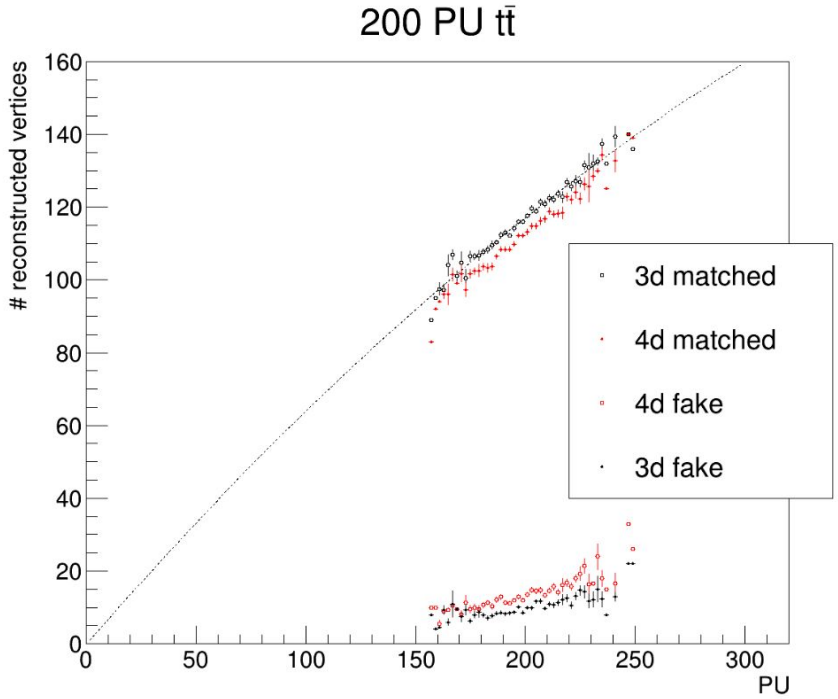
	X_0 (%)	λ (%)
Service hybrid	20	20
AlN plate	8	8
Front moderator	16	16
Read-out board	6	6
Sensor module services	16	16

MTD after TDR

- The performances of the MTD TDR reconstruction code were reported to be sub-optimal
- As a consequence, the introduction of timing in the reconstruction process was found to be almost negligible
- In this presentation, we will illustrate several post-TDR improvements
- any claim about the use of MTD should be based on the most recent developments shown in the following slides

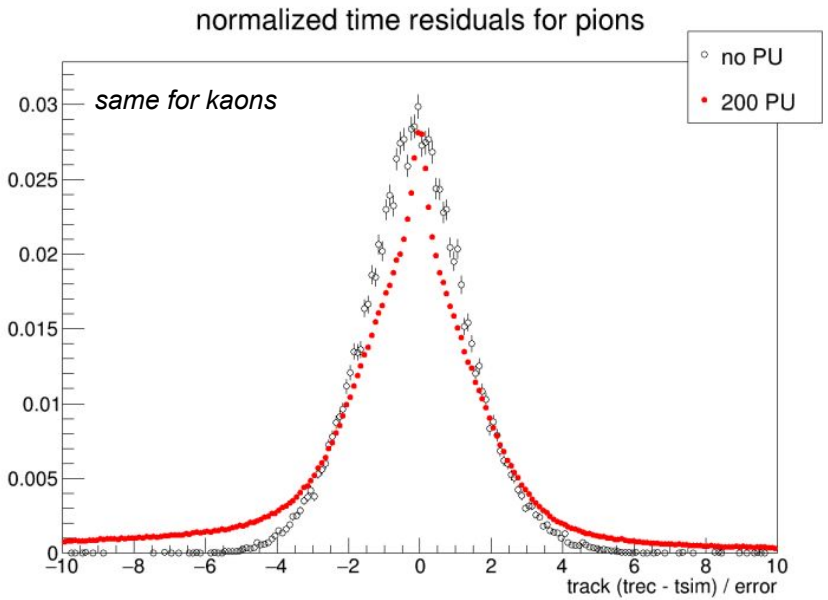
4D Vertexing

- 4D vertexing not yet optimal within CMSSW
- 4D are less efficient and with higher fake rate than 3D vertices
- tracks fed into clustering do not have proper tracks → might be related to mass ambiguities
- CMSSW_12_X milestone is to check the impact of 11_3 developments (retuning of uncertainties in particular) on the 4D vertexing
  - A validation code for 4D vertex, for a quick assessment of impact of MTD low-level reconstruction improvements is needed→ in contact with W. Erdmann



W. Erdmann, tracking POG meeting June 2020

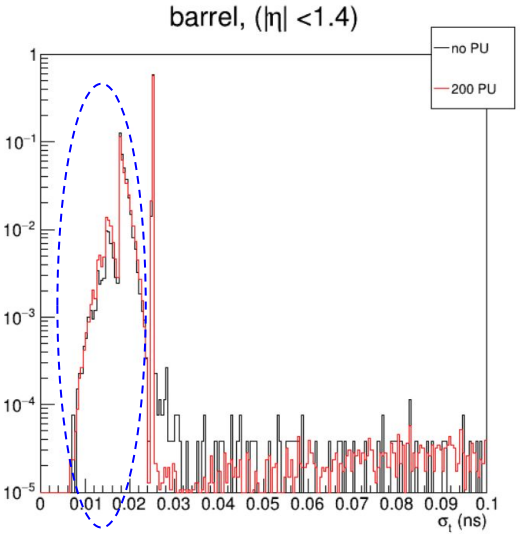
Uncertainty of single-hit clusters

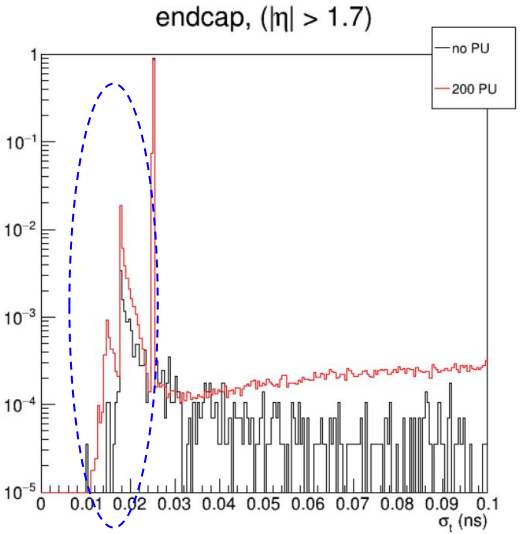


- Known issue with MTD tracks uncertainties: most tracks have fixed 25 ps uncertainty
- In addition, ETL features tails with poor resolution
  - Consequently, track-time pulls are not gaussian (spike at 0 due to tail with large uncertainties)
  - Pulls develop tails with PU

W. Erdmann, tracking POG meeting June 2020

Uncertainty of single-hit clusters



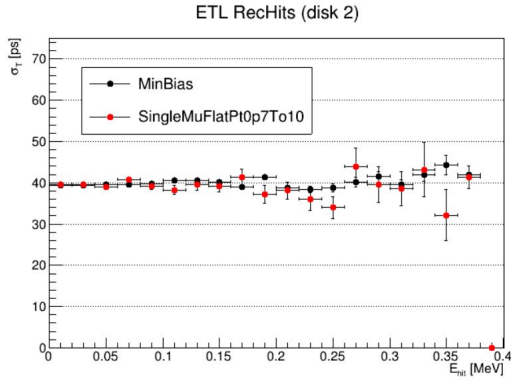


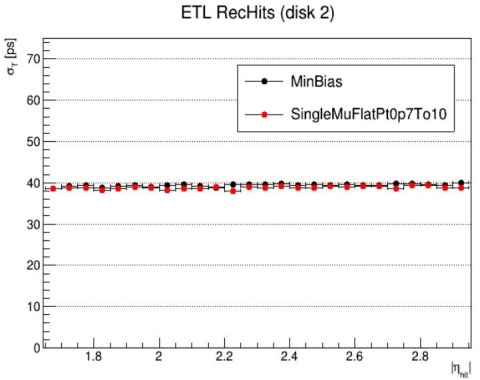
- 4D vertices poor performance related to timing uncertainties
- 25 ps is an hardcoded value related to single-hit clusters
- Tail with poor resolution in the endcap are residual of mass-hypothesis disambiguation in TOFPIDProducer
  - TrackExtenderWithMTD adds $(t_p - t_\pi)$ to MTD uncertainty
  - TOFPIDProducer assigns correct mass hyp. and removes $(t_p - t_\pi)$ uncertainty , but fails sometimes

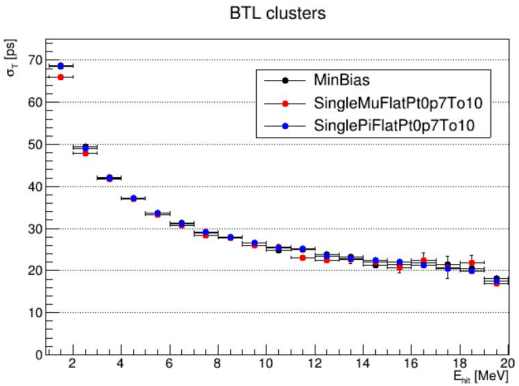
see F.Cossutti presentation during the CMS week for more details

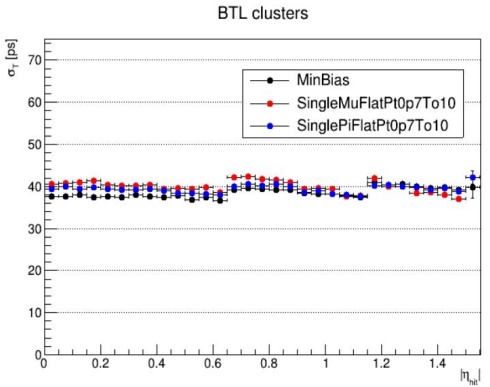
25 ps spike → fixed

- The problem of the hardcoded 25ps spike has been firstly addressed
- Using the D73 scenario (see next slides), histograms have been filled with the uncalibrated RecHits (t_{Reco} - t_{Sim}) residuals in E_{hit} and $|\eta_{hit}|$ bins, then fitted to a gaussian
- 3 different samples considered:
  - 10k MinBias events
  - 1M SingleMuFlatPt0p7To10 events
  - 1M SinglePiFlatPt0p7To10 events







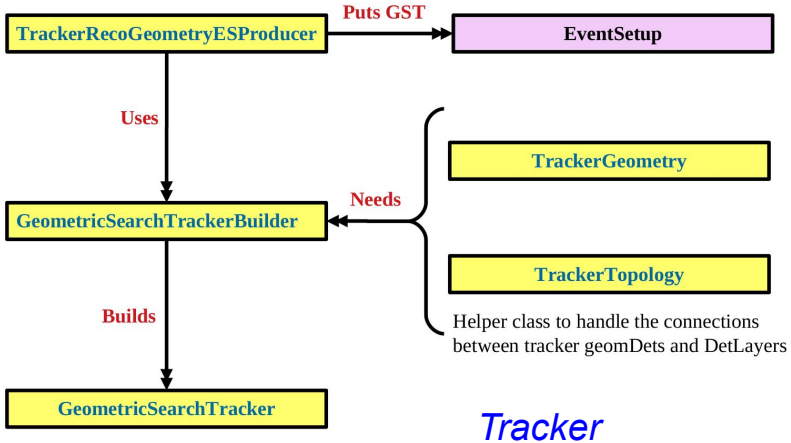


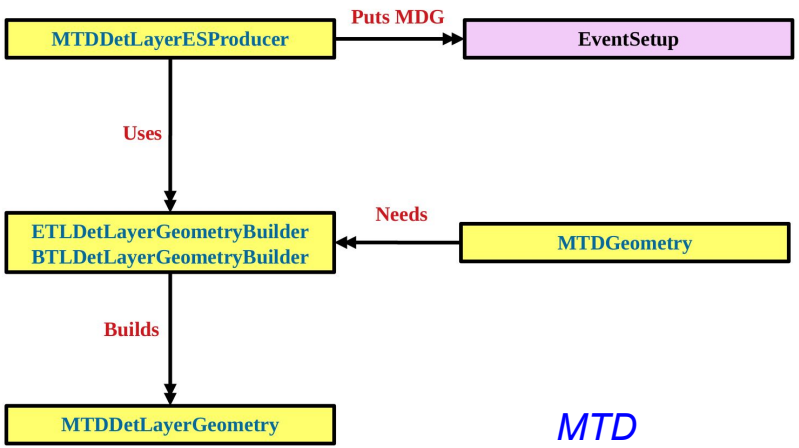
more detail in [M.Casarsa's presentation at MTD DPG]

MTD in the CMS tracking system

- MTD adds 2 layers to the CMS tracker → if MTD hits are added a posteriori, no benefit from a tracking point of view → need to include MTD in the tracker standard navigation
- Tracker navigation provides links between Detector Logical Layers (DetLayers) through a GeometricSearchTracker (GST) → key issue has been the extension of GST to MTD

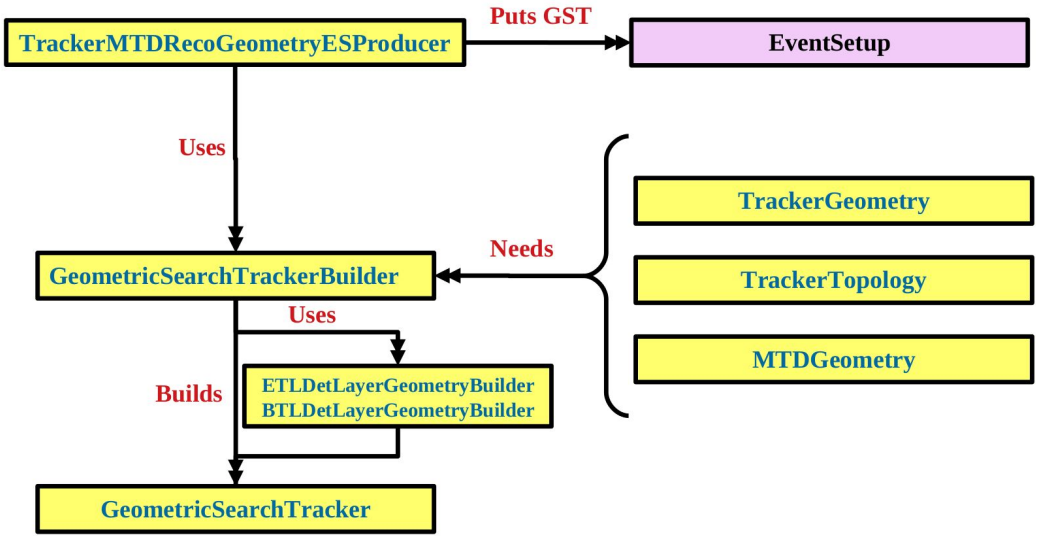
MTD has a very similar but independent structure than the tracker





MTD in the CMS tracking system

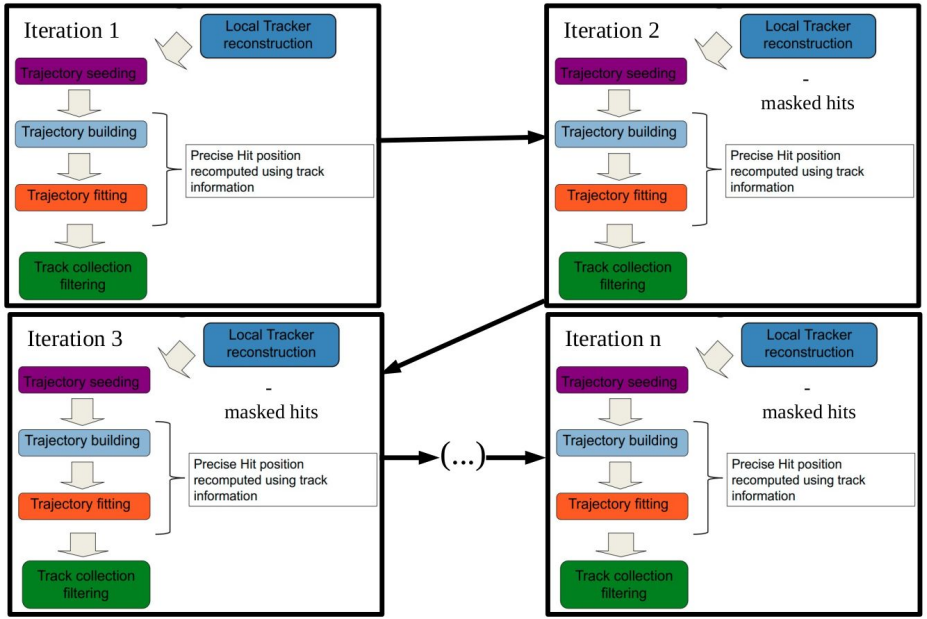
- MTD adds 2 layers to the CMS tracker → if MTD hits are added a posteriori, no benefit from a tracking point of view → need to include MTD in the tracker standard navigation
- Tracker navigation provides links between Detector Logical Layers (DetLayers) through a GeometricSearchTracker (GST) → key issue has been the extension of GST to MTD



- Two different constructor: Tracker only (standard) or Tracker + MTD,
  - easy to switch to the standard constructor, so that its logic is unaffected

MTD in the CMS tracking system

- Addition of MTD should be transparent in the iterative structure of the CMS tracking algorithm
  - Possible benefits in the hit-track association when adding MTD in the iterative tracking



from P.Martinez presentation, MTD DPG July 2021

CMS iterative tracking

MTD in the CMS tracking system

- Addition of MTD should be transparent in the iterative structure of the CMS tracking algorithm
  - Possible benefits in the hit-track association when adding MTD in the iterative tracking
- The CMS seeding (1st step of the algorithm) code works fine with the new Tracker + MTD Navigation → no change needed if no MTD seed are added
  - MTD seeds should be possibly added in /RecoTracker/TkSeedingLayers/python/PixelLayerTriplets_cfi.py

```
_layersForPhase2 = [ 'BPix1+BPix2+BPix3', 'BPix2+BPix3+BPix4',
                     'BPix2+BPix3+FPix1_pos', 'BPix2+BPix3+FPix1_neg',
                     'BPix1+BPix2+FPix1_pos', 'BPix1+BPix2+FPix1_neg',
                     'BPix2+FPix1_pos+FPix2_pos', 'BPix2+FPix1_neg+FPix2_neg',
                     'BPix1+FPix1_pos+FPix2_pos', 'BPix1+FPix1_neg+FPix2_neg',
                     'BPix1+FPix2_pos+FPix3_pos', 'BPix1+FPix2_neg+FPix3_neg',
                     'FPix1_pos+FPix2_pos+FPix3_pos', 'FPix1_neg+FPix2_neg+FPix3_neg',
                     'FPix2_pos+FPix3_pos+FPix4_pos', 'FPix2_neg+FPix3_neg+FPix4_neg',
                     'FPix3_pos+FPix4_pos+FPix5_pos', 'FPix3_neg+FPix4_neg+FPix5_neg',
                     'FPix4_pos+FPix5_pos+FPix6_pos', 'FPix4_neg+FPix5_neg+FPix6_neg',
                     'FPix5_pos+FPix6_pos+FPix7_pos', 'FPix5_neg+FPix6_neg+FPix7_neg',
                     'FPix6_pos+FPix7_pos+FPix8_pos', 'FPix6_neg+FPix7_neg+FPix8_neg',
                     'FPix6_pos+FPix7_pos+FPix9_pos', 'FPix6_neg+FPix7_neg+FPix9_neg'
```

Details about the specification of seeding layers

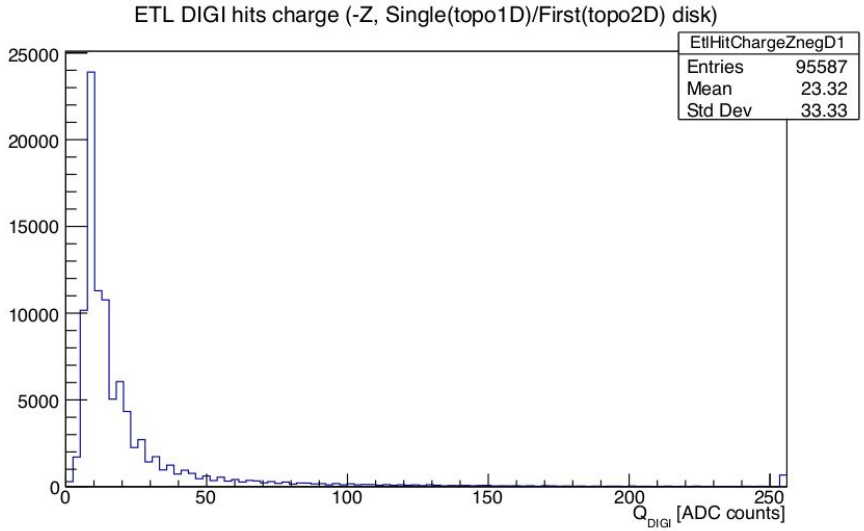
MTD in the CMS tracking system

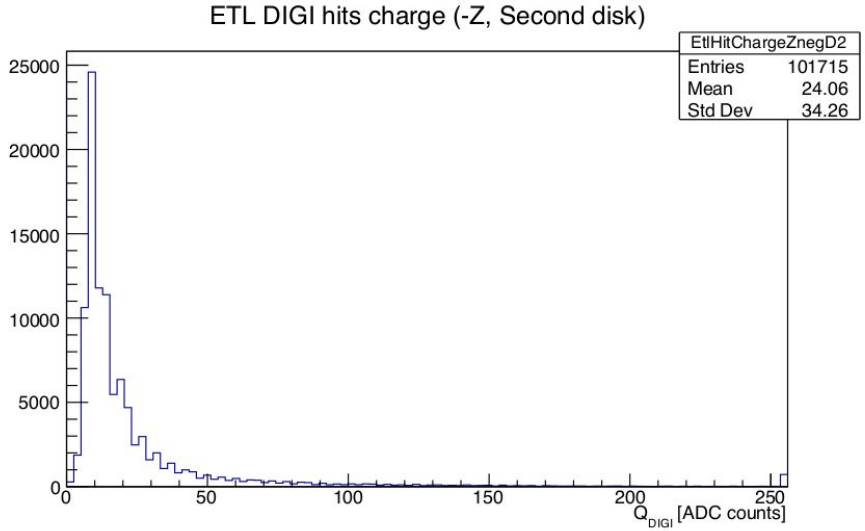
- Addition of MTD should be transparent in the iterative structure of the CMS tracking algorithm
  - Possible benefits in the hit-track association when adding MTD in the iterative tracking
- The CMS seeding (1st step of the algorithm) code works fine with the new Tracker + MTD Navigation → no change needed if no MTD seed are added
  - MTD seeds should be possibly added in /RecoTracker/TkSeedingLayers/python/PixelLayerTriplets_cfi.py
- Trajectory building (2nd step) is fundamental in the iterative tracking and naturally involves MTD
  - code crashes because MTD DetLayers are present but MTD is not in the MeasurementTracker class
  - Possible solution: override MeasurementTracker constructor to contain MTD info
  - Then make a dedicated object builder calling this constructor instead the standard (no MTD) one → similar to what is done for the GeometricSearchTracker (ongoing)

MTD Validation Code

- Code updated at SIM, DIGI, RECO level accordingly to the new geometry scenario (D72-73), LGAD thickness reduced to 50 μm instead of 300 μm
  - Only ETL affected by the new scenario → 2 disks + sector-based geometry

DIGI Hits validation

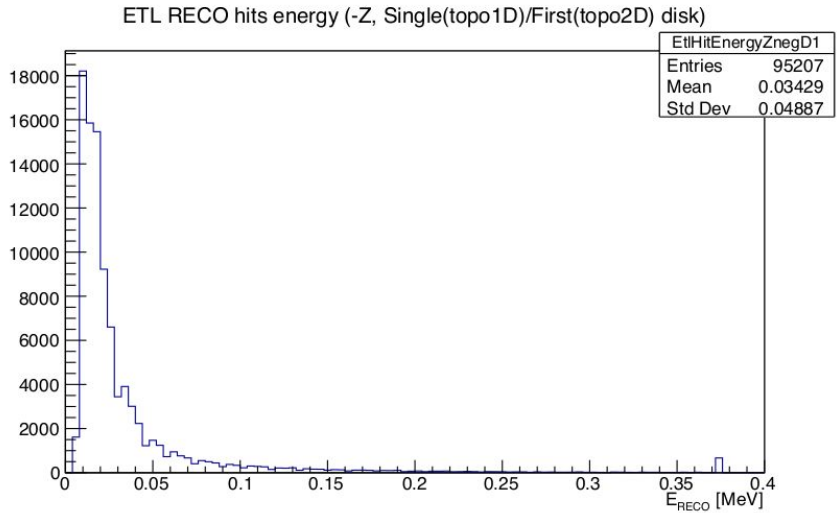


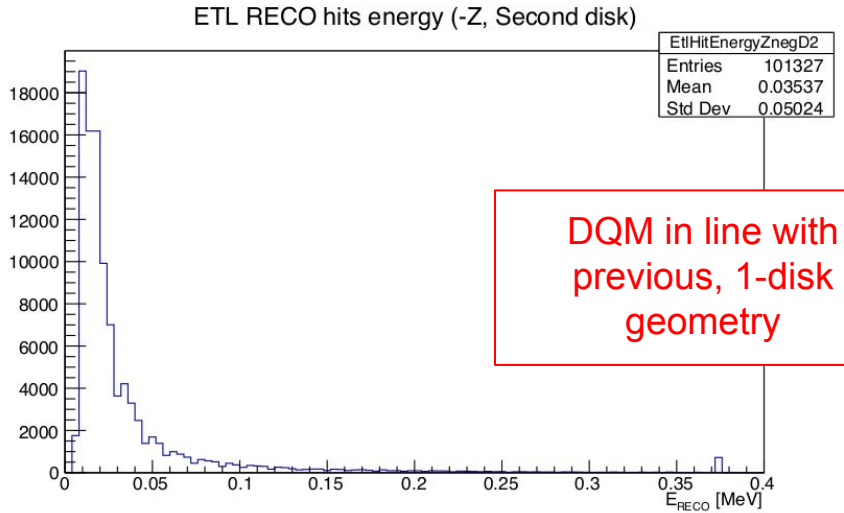


MTD Validation Code

- Code updated at SIM, DIGI, RECO level accordingly to the new geometry scenario (D72-73), LGAD thickness reduced to 50 μm instead of 300 μm
  - Only ETL affected by the new scenario → 2 disks + sector-based geometry

RECO Hits validation





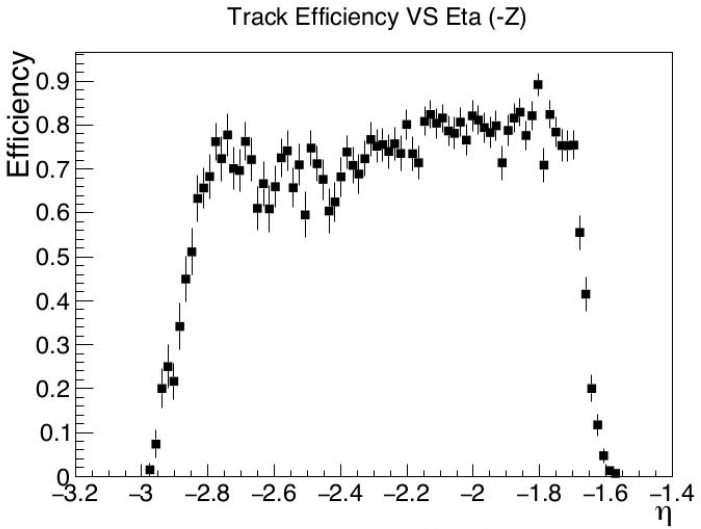
DQM in line with previous, 1-disk geometry

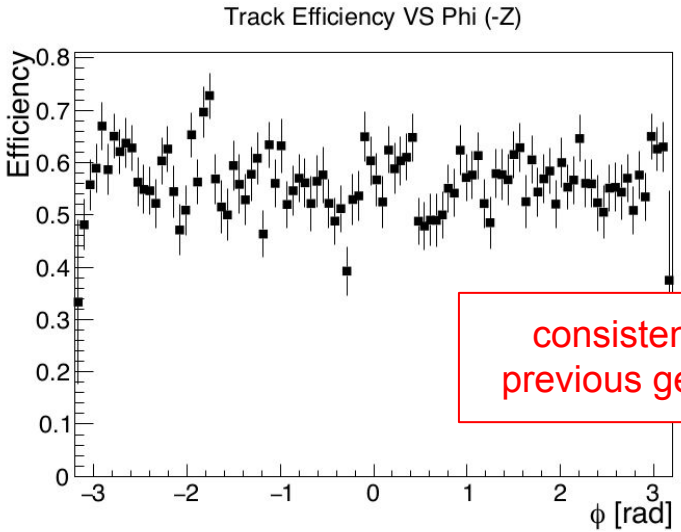
MTD Validation Code

- Code updated at SIM, DIGI, RECO level accordingly to the new geometry scenario (D72-73), LGAD thickness reduced to 50 μm instead of 300 μm
  - Only ETL affected by the new scenario → 2 disks + sector-based geometry

track-cluster association efficiency:

$$\frac{\text{Tracks with an associated deposit in ETL MTD}}{\text{All tracks with associated } \eta \text{ between -1.5 and -3.2}}$$



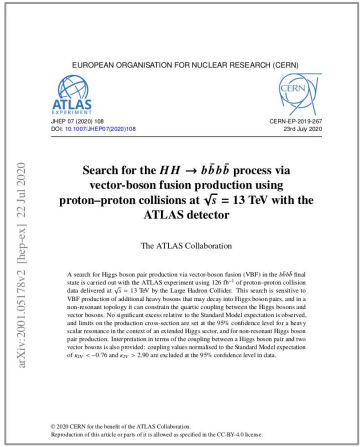


consistent with previous geometry

VBF HH → 4b

- Aim of this private study is the impact of MTD timing in removing pile-up (PU) candidates from jets, considering a 200 PU scenario
- We chose VBF HH→4b as benchmark channel
  - Can benefit from the enhanced b-tagging related to timing → any improvement is ^4
  - ETL can be very useful in VBF tagging
- Sample: /VBF_HHTo4B_CV_1_C2V_1_C3_1_TuneCP5_PSWeights_14TeV-madgraph-pythia8/ Phase2HLTTDRWinter20RECOMiniAOD-PU200_110X_mcRun4_realistic_v3-v2/MINIAODSIM
- Setup: CMSSW_11_1_5
  - globaltag = "111X_mcRun4_realistic_T15_v1"
  - eras.Phase2C9
  - Configuration.Geometry.GeometryExtended2026D49_cff
  - Reco jets from 'slimmedJetsPuppi'
- Based on a study by ATLAS with Run2 data

Studies with new samples and more updated setup are ongoing



EUROPEAN ORGANISATION FOR NUCLEAR RESEARCH (CERN)

ATLAS EXPERIMENT

JHEP 07 (2020) 108
DOI: 10.1007/JHEP07(2020)108

CERN-EP-2019-267
29-th July 2020

Search for the $HH \to b\bar{b}b\bar{b}$ process via vector-boson fusion production using proton–proton collisions at $\sqrt{s}$ = 13 TeV with the ATLAS detector

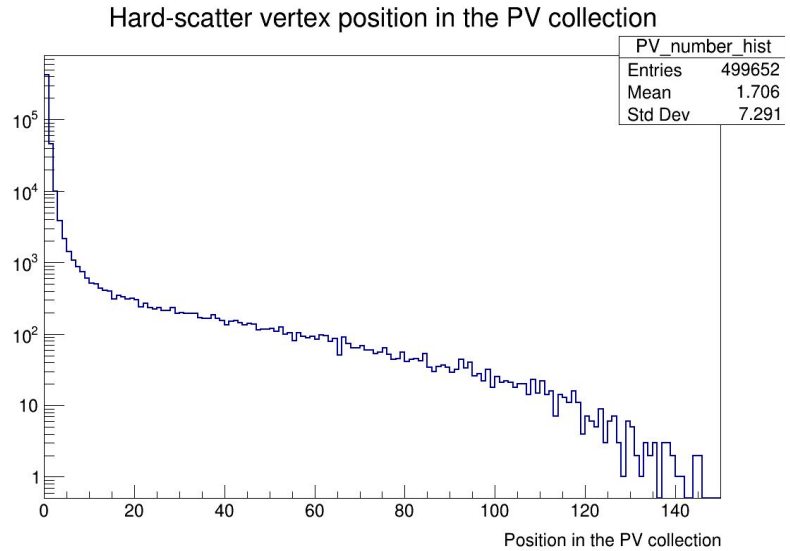
The ATLAS Collaboration

A search for Higgs boson pair production via vector-boson fusion (VBF) in the $b\bar{b}b\bar{b}$ final state is carried out with the ATLAS experiment using 126 fb^{-1} of proton–proton collision data delivered at $\sqrt{s}$ = 13 TeV by the Large Hadron Collider. This search is sensitive to VBF production of additional heavy bosons that may decay into Higgs boson pairs, and in a non-resonant topology it can constrain the quartic coupling between the Higgs bosons and vector bosons. No significant excess relative to the Standard Model expectation is observed, and limits on the production cross-section are set at the 95% confidence level for a heavy scalar resonance in the context of an extended Higgs sector, and for non-resonant Higgs boson pair production. Interpretation in terms of the coupling between a Higgs boson pair and two vector bosons is also provided: coupling values normalised to the Standard Model expectation of $\kappa_{2V} < -0.76$ and $\kappa_{2V} > 2.90$ are excluded at the 95% confidence level in data.

VBF HH → 4b

- Key issue: the reconstructed leading vertex does not match the simulated one in the 16% of the events
- PUPPI relies on a correct PV ranking → optionally exclude those 16% of the events
- Vertex collection in this study is 4D, known to be sub-optimal
- Need to check with the most recent updates (retuning of uncertainties) if the PV mistag rate is lowered
- Alternatively, working on a “pointing method” that uses the peculiar topology of this process (4 displaced vertices) to recover the correct PV

position in the reco PV collection of the vertex with the closest dz to the simulated leading vertex



Future plans (12_X and beyond)

- Continue integration of MTD in the CMS tracking system
- Use time back-propagation in the iterative tracking
- Use MTD for 3D vertex cleaning (vertexing experts interested)
- A code for 4D-vertex quality monitoring, to assess impact of MTD improvements on low-level reconstruction (short-term, in touch with vertexing experts)
- Rerun of PUPPI jets using 4D vertices (work ongoing with PUPPI experts, ~Fall 2021)

PUPPI