Detector performance challenges in Run2

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On behalf of
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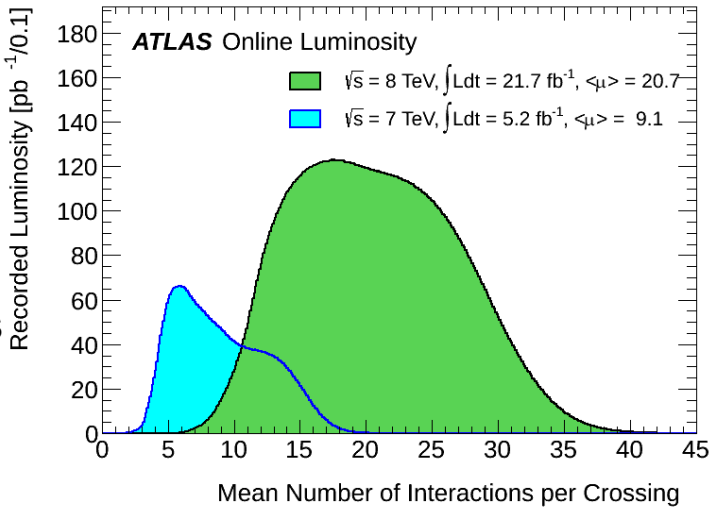
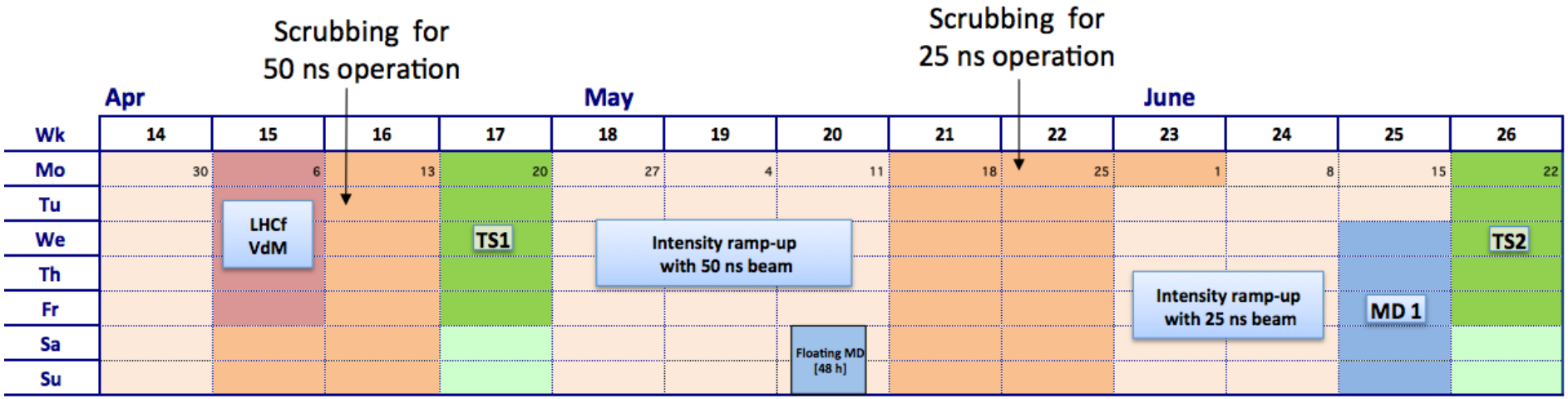
Challenges

- During run 2, detectors will face unprecedented conditions
  - 25ns **bunch spacing** (instead of 50ns)
  - Higher **luminosity** (1.3E34cm^{-2}s^{-1} in 2015, up to 1.7E34cm^{-2}s^{-1} by LS2)
  - Higher **energy** (13TeV, compared to 8TeV so far)
    - Heavier resonances
    - More boosted objects

} up to <m> ~ 50 (factor ~2 higher than Run 1)



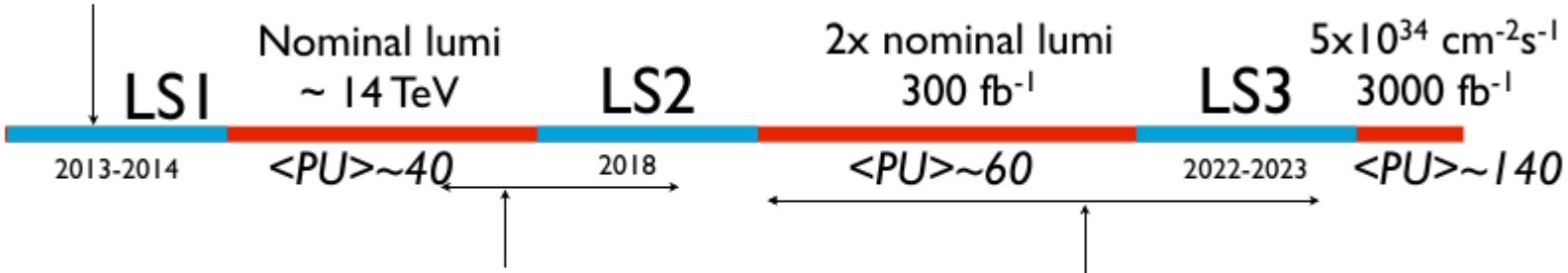
- The **early days** of run 2 will be challenging in many ways
  - Recommissioning of the detectors after (more than) two years
  - Machine conditions will change on a daily basis
  - Physics expectations will be high



Challenges

- In the case of CMS, several hardware changes are foreseen **during** Run 2
  - L1 Trigger upgrade (see next presentation)
  - HCAL upgrade (photo-detectors, electronics)
  - Pixel upgrade (EYETS 2016-2017)

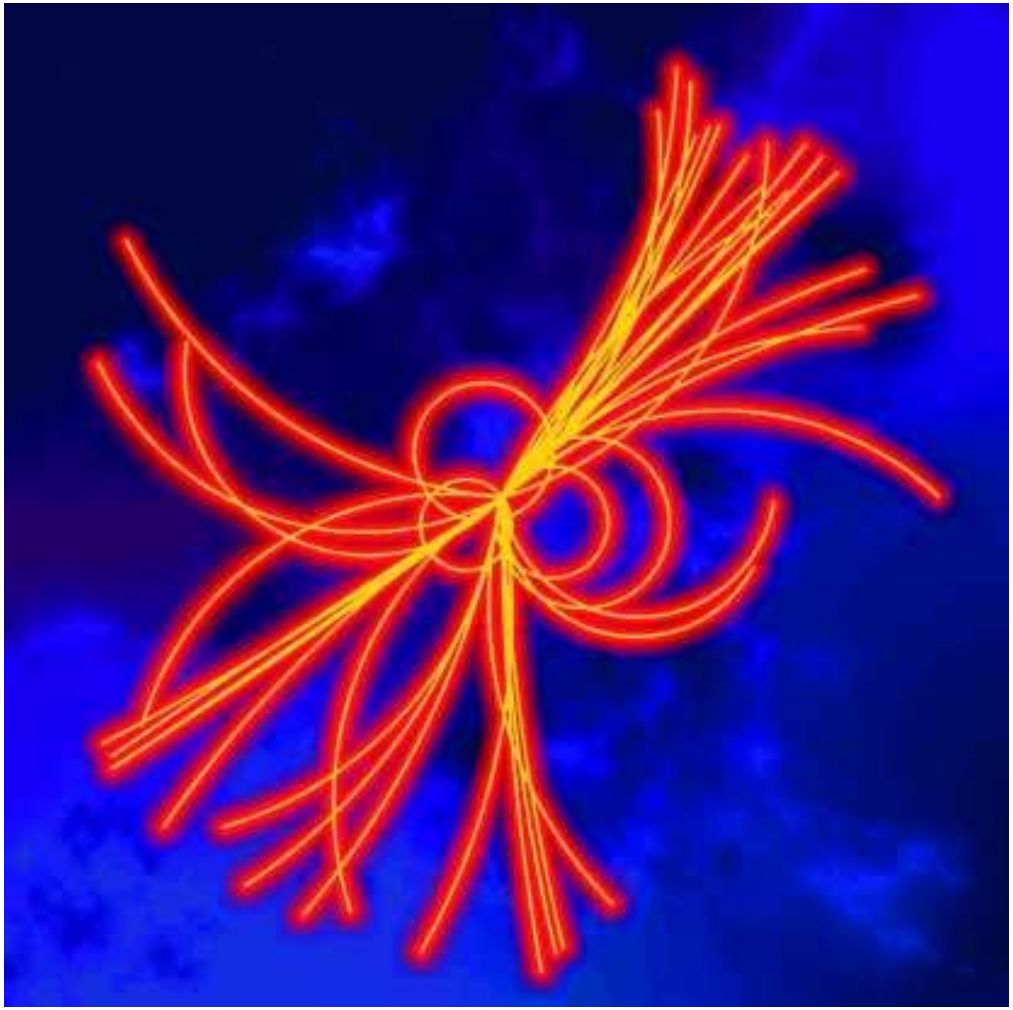
Reparations and LS1 projects: in production
- **Completion of muon coverage (ME4)**
- **Improve muon operations: ME1, DT electronics**
- Replace HF (PMTs) and HO (SiPM) photodetectors



Phase 1: production
- Pixel detector replacement
- HCAL electronics upgrade
- **L1-Trigger upgrade**

Phase 2: Tecnical Proposal 2014
- Tracker replacement, **Track Trigger**
- Forward region: Calorimetry, **Muons**, Pixels
  - **GEMs in first two endcap stations**
  - **New RPCs in 3rd and 4th station**
  - **|η|>2.4: "ME0" GEM, up to η=4?**
  - **New CSC and DT electronics**
- Further Trigger and DAQ upgrade: **10us, 1MHz**

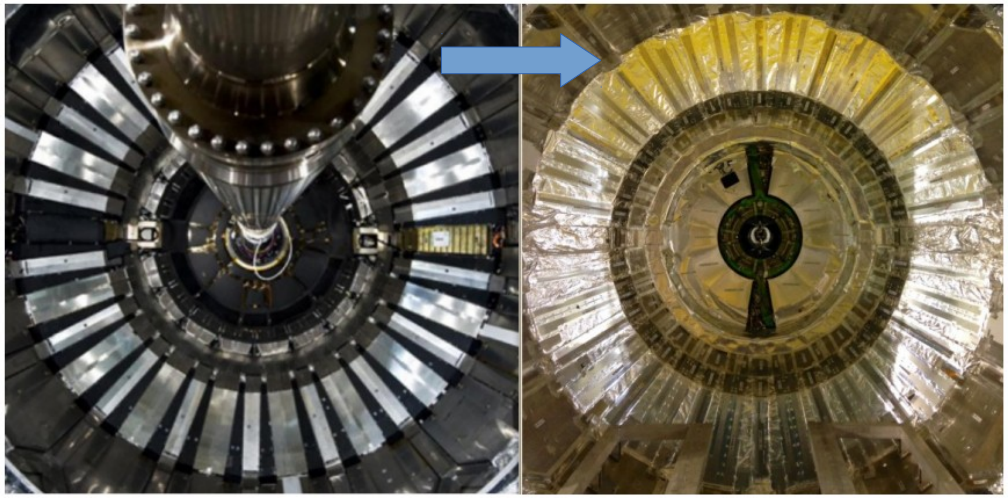
CMS Tracker & tracking

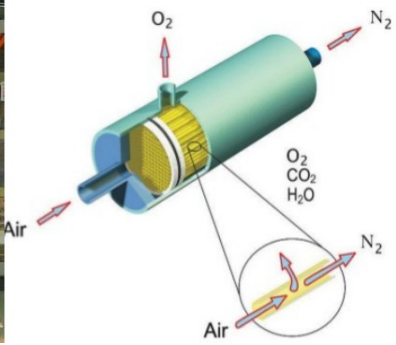


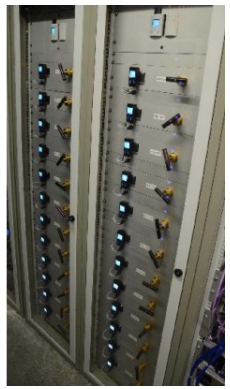
CMS Tracker

- In order to sustain the increased radiation levels in run 2, the tracker has to be operated at lower temperatures.
  - Run 1 operating point: +4°C
  - Run 2 operating point: -15°C
- This implied an effort to prevent humidity in the “bulkhead” region in between the tracker volume and the ECAL endcap.

Complete sealing of the region



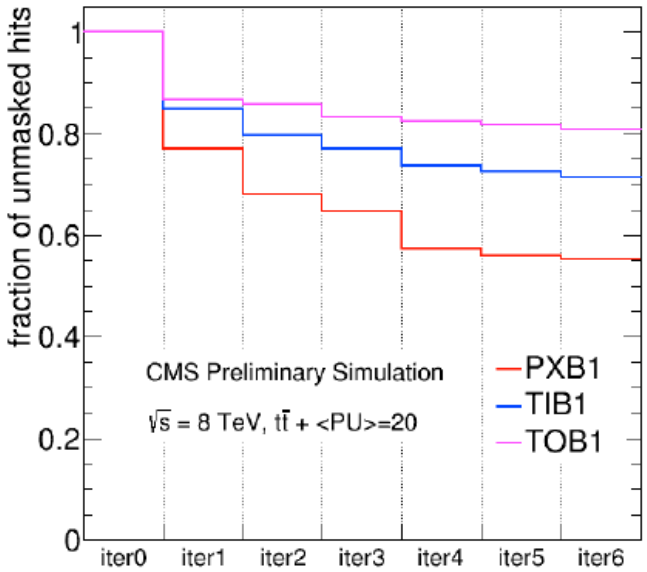


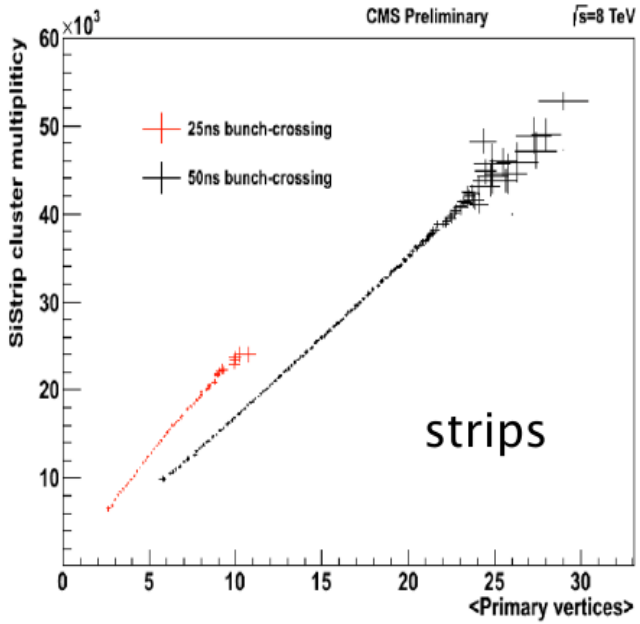


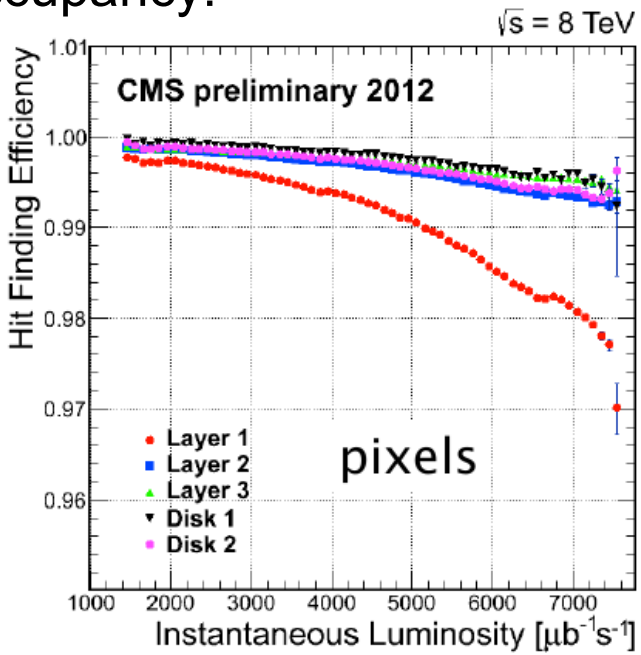
Brand new dry gas (membrane) plant

Tracking challenges at high pile-up

Tracking in run 2 is a challenge due to increasing tracker occupancy:







- Pixels are affected by a dynamic inefficiency, mainly due to saturation of chip readout buffers.
- Out of time pile-up increases the occupancy of the strip detector by ~45% (only ~5% for pixels)
- Iterative tracking is not the definitive solution, tracker is far from being empty after all iterations

Tracking challenges at high pile-up

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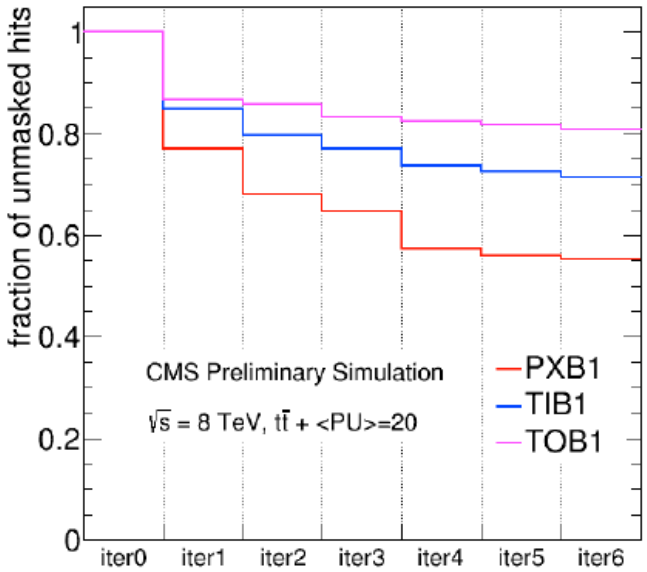

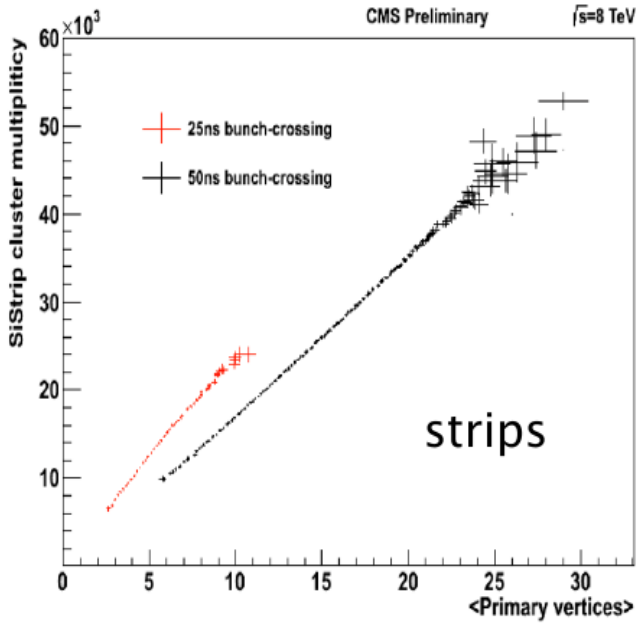

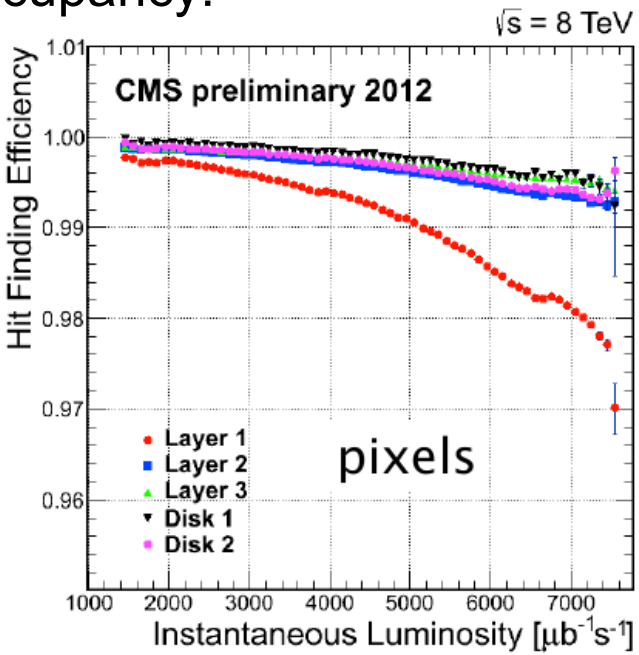

New Pixel detector by the end of 2016

- Out of time pile-up increases the occupancy of the strip detector by ~45% (only ~5% for pixels)

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Tracking challenges at high pile-up

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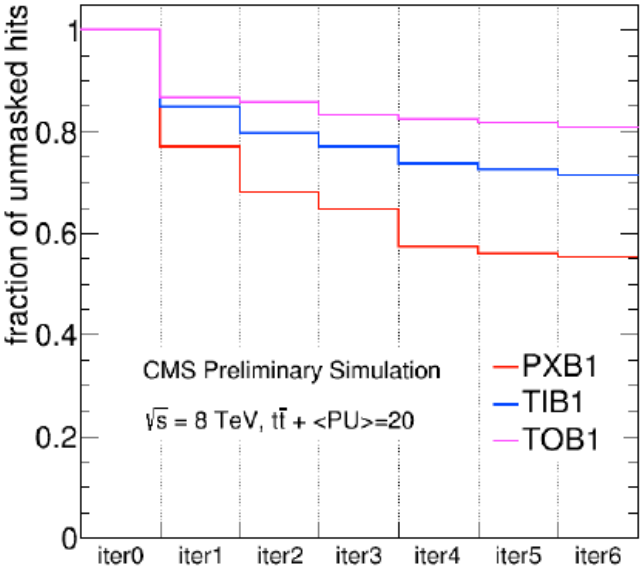
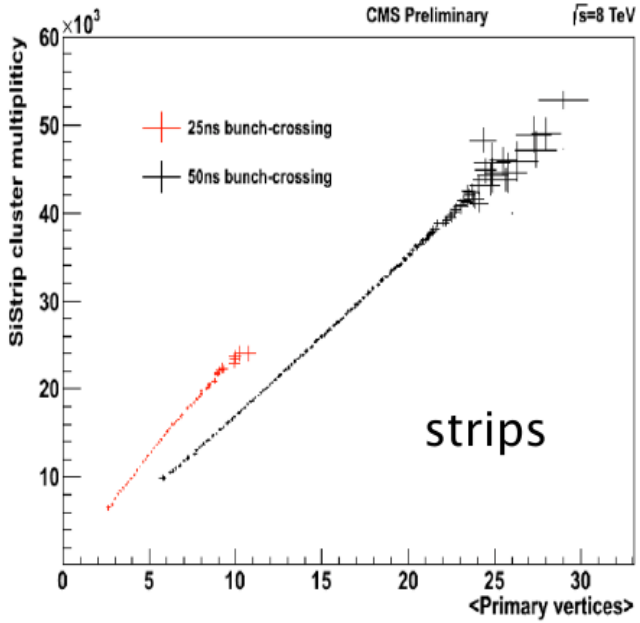
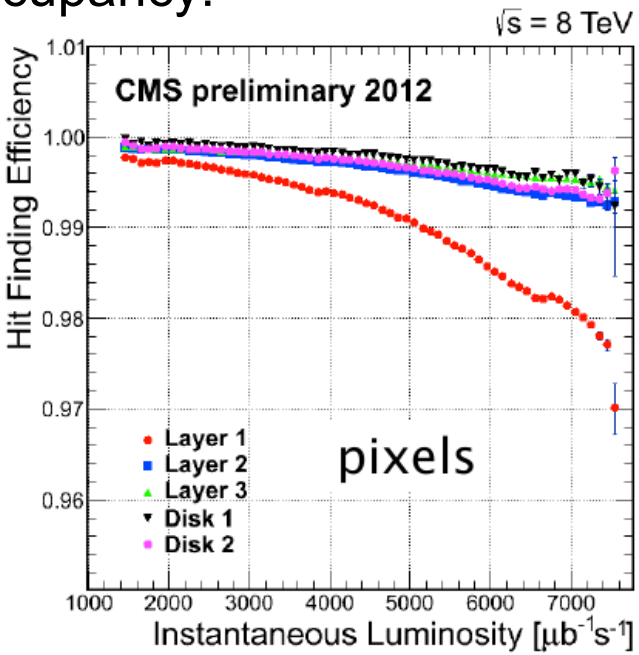






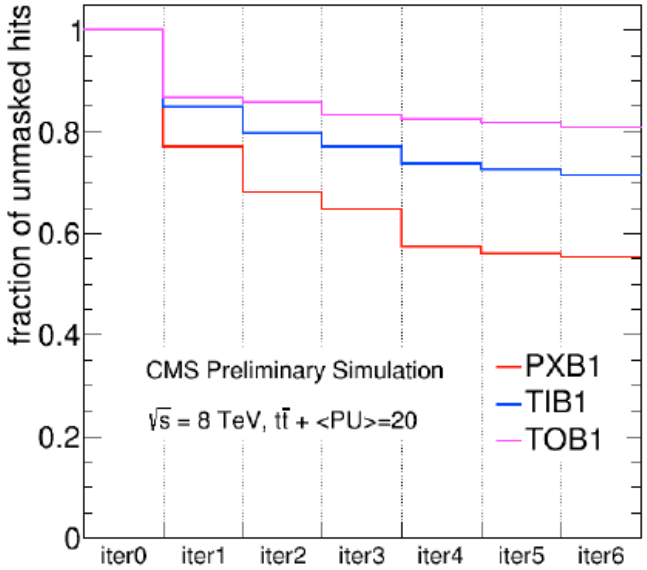
New Pixel detector by the end of 2016

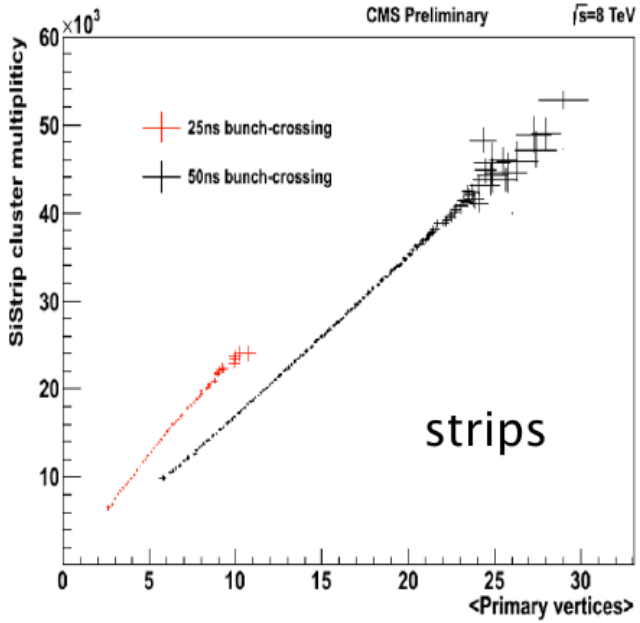
Introduction of a cluster charge cut

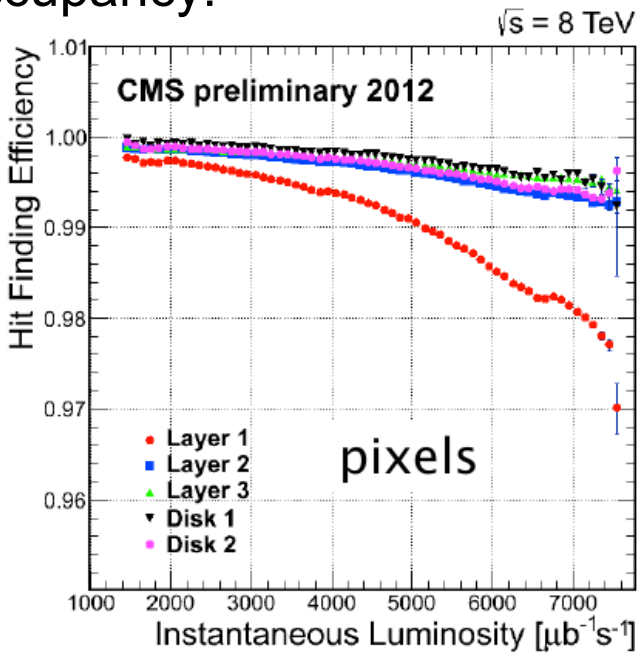
- Iterative tracking is not the definitive solution, tracker is far from being empty after all iterations

Tracking challenges at high pile-up

Tracking in run 2 is a challenge due to increasing tracker occupancy:







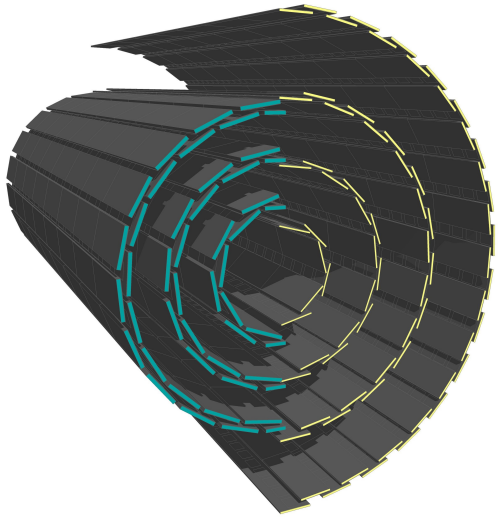
New Pixel detector by the end of 2016

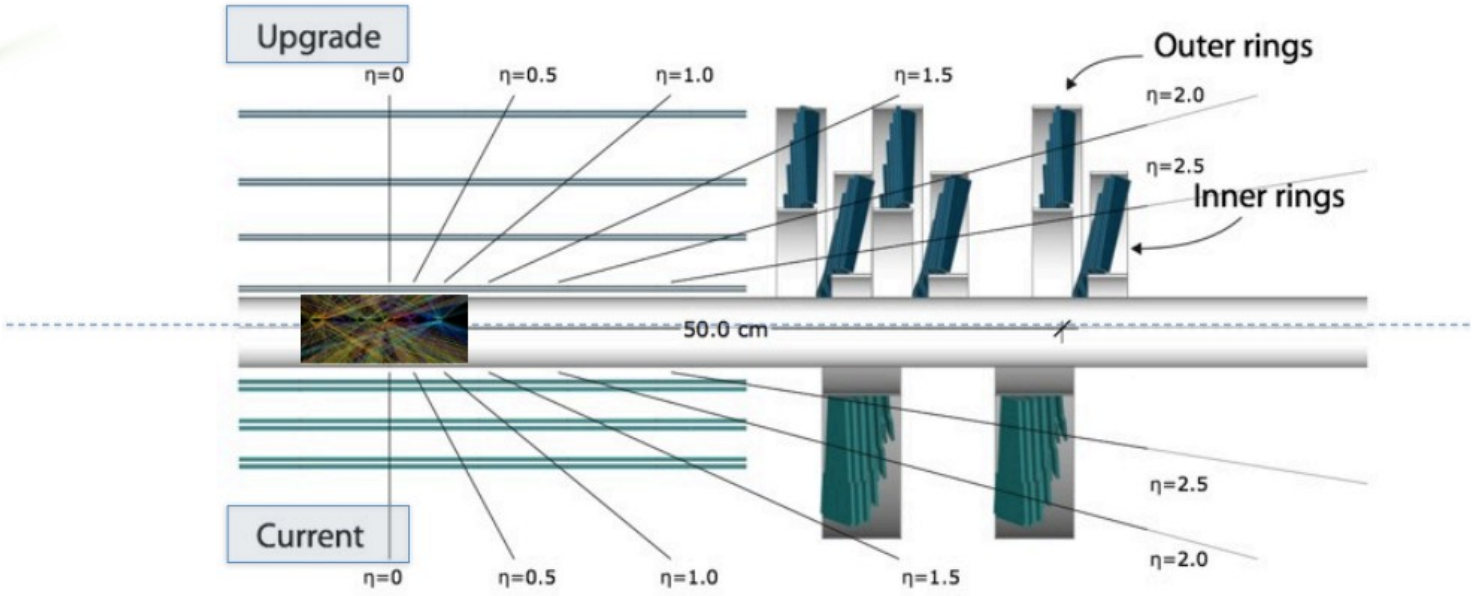
Introduction of a cluster charge cut

Global re-optimization of the tracking sequence

From 2017: pixel phase 1 upgrade

Depends on the installation of a new beam pipe during LS1





Pixel Upgrade

Baseline L = $2x10^{34}$ $cm^{-2}s^{-1}$ & 25ns **(50PU)**
Tolerate L = $2x10^{34}$ $cm^{-2}s^{-1}$ & 50ns **(100PU)**
Survive Integrated Luminosity of $500fb^{-1}$
(Evolutionary upgrade with) **minimal disruption of data taking**
Same detector concept: higher rate readout, data link & DAQ w/ less material forward
Robust tracking: 4 hit coverage

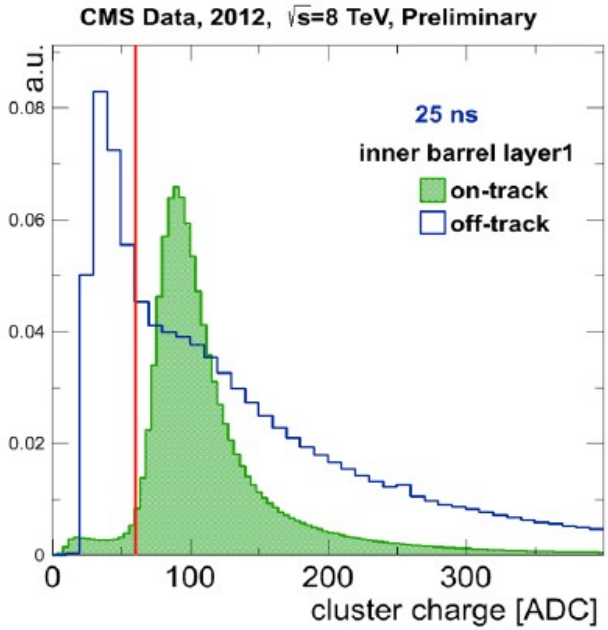
Cluster charge cut for OOTPU mitigation

- Clusters from out of time pile-up are characterized by low collected charge
  - Looping particles arrive at random time with respect with the primary particles

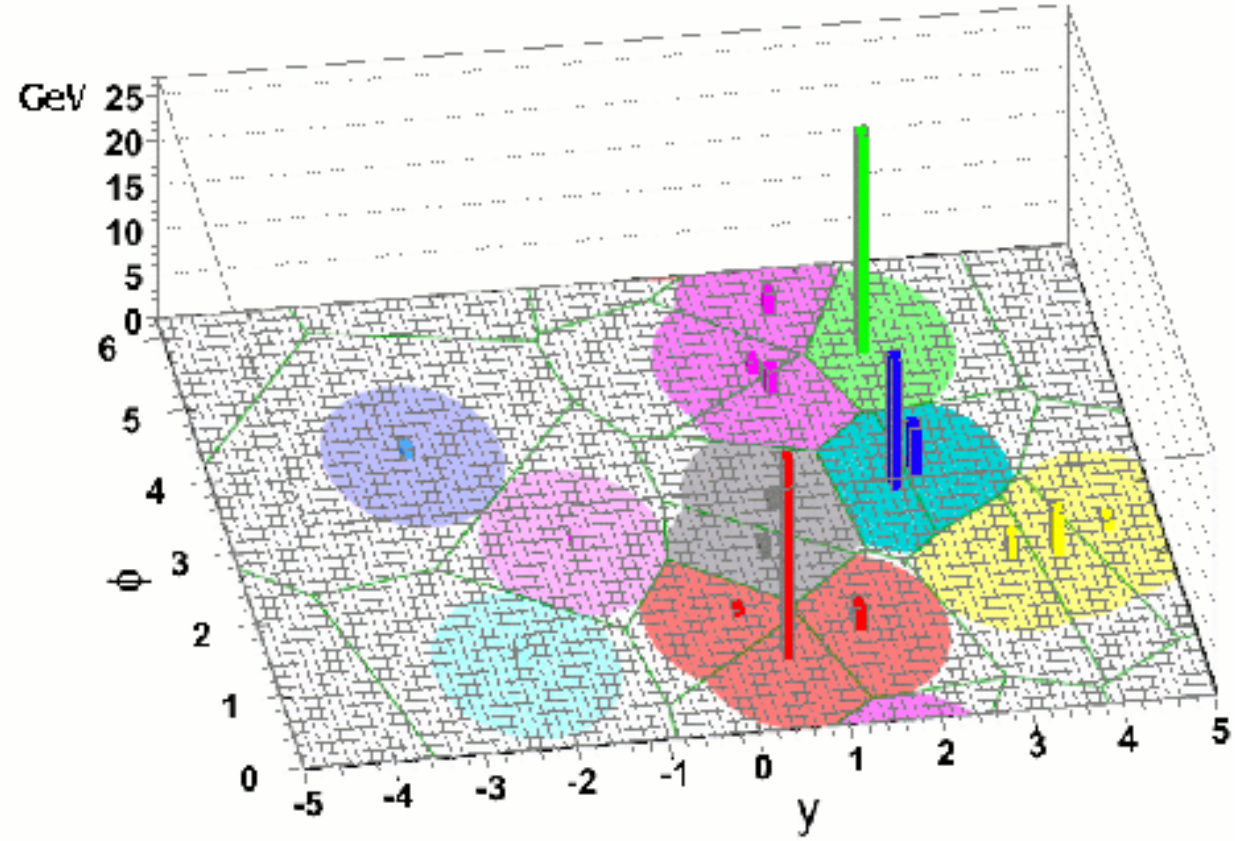
Due to out-of-time PU, there is a factor of 2 increase
- in fake rate
- in timing

The cluster charge cut effectively restores Run 1 performance.

- Cutting on the cluster charge suppresses the effect
  - accounts for sensor thickness and trajectory crossing angle
  - pT dependent cut to preserve potential signal from fractional charge particles
- Stable performance ensured by gain calibration in quasi-real time
  - The regular gain monitoring will be critical



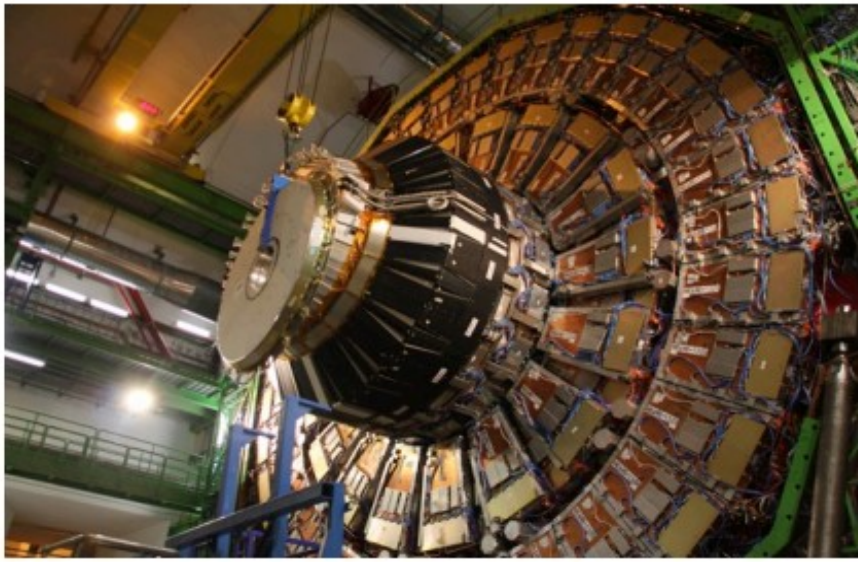
CMS Calorimeters



Preshower repairs during LS1

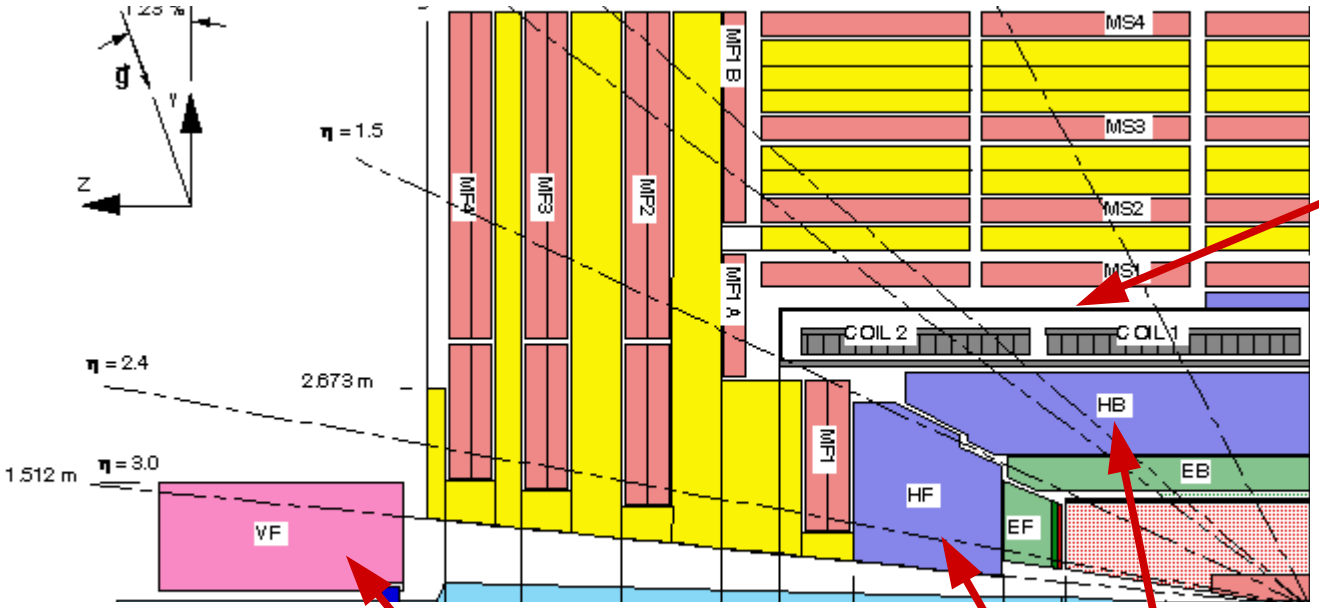
- In November 2013 a problem was detected with connectors at the exterior of the ES− disc. It was promptly decided to replace the four connectors of this type.

  - This implied the removal of preshower for repair on the surface



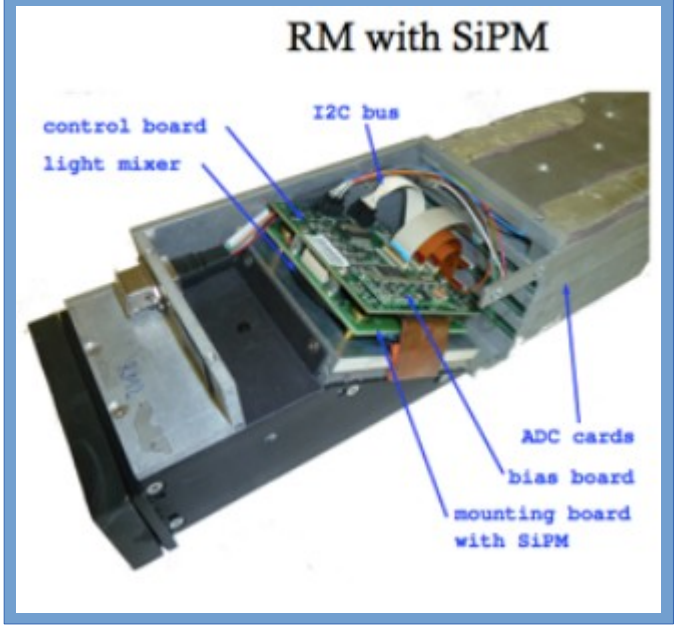
  - At the same time, we recovered non-operational channels
    - **96.8% operational in 2012 → 99.95% in 2014**
- Both disks were already re-installed and recommissioned.

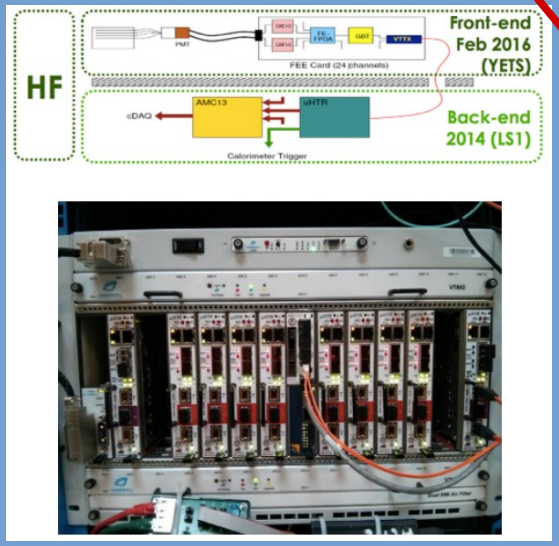
Interventions on HCAL during LS1



HO: replacement of HPDs by SiPMs

(HPDs were not behaving well because of the magnetic field)





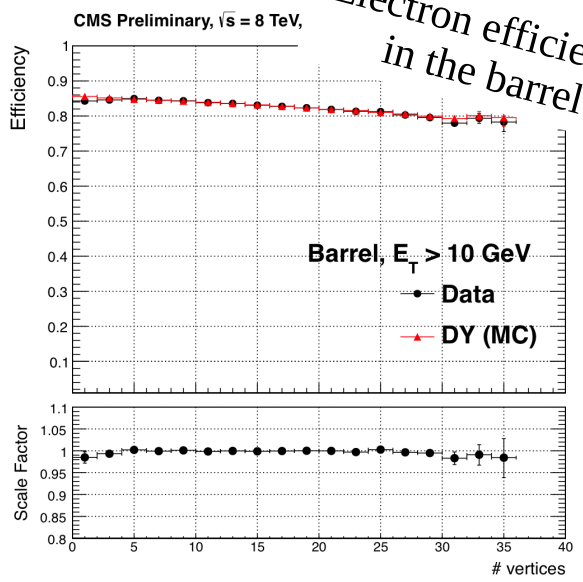
HF: switch to multi-anode PMTs and uTCA BE electronics

HBHE:
control modules replacement
and misc. repairs

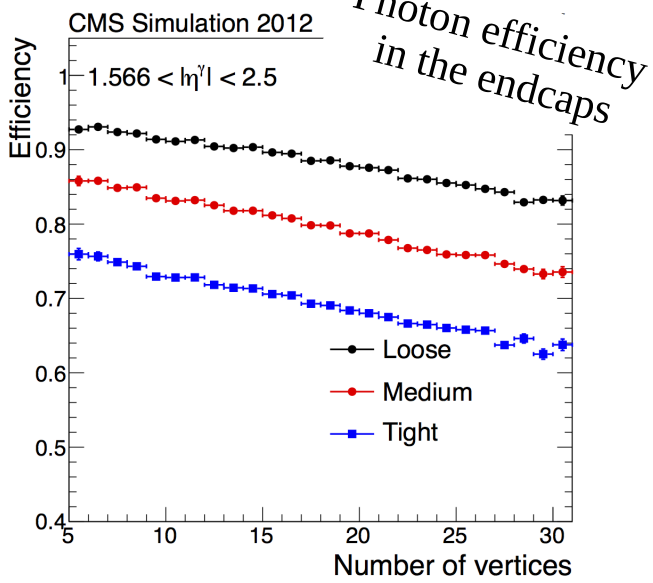
Electrons/photons reconstruction: PU effect

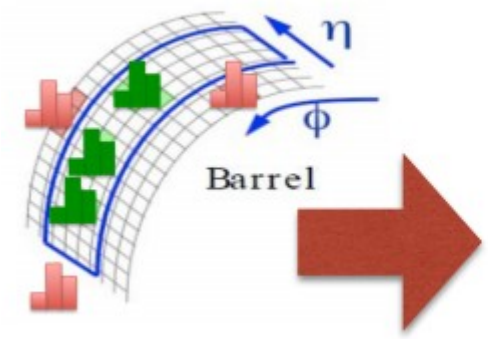
Electron and photon reconstruction is moderately affected by pileup.

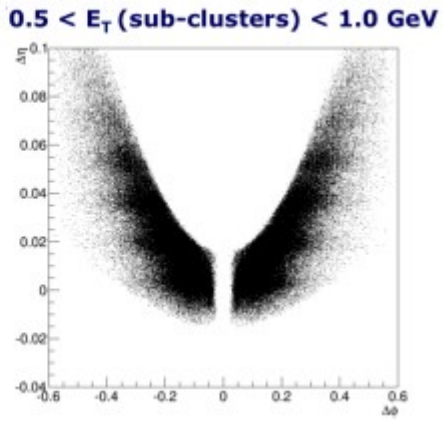
Electron efficiency in the barrel



Photon efficiency in the endcaps







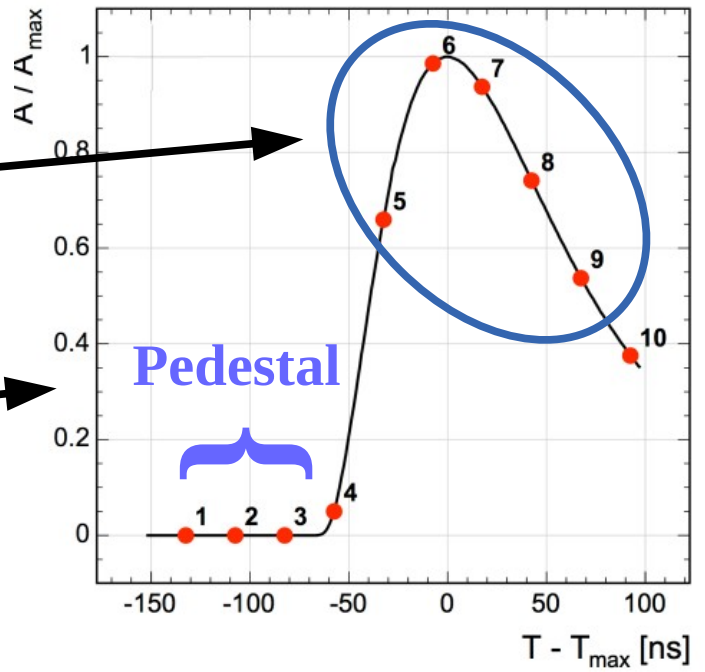
New clustering method using the precise shape of the expected deposit from photons from bremstrahlung.

Allows to maintain the established performance for electron reconstruction

Electrons/photons reconstruction: OOTPU

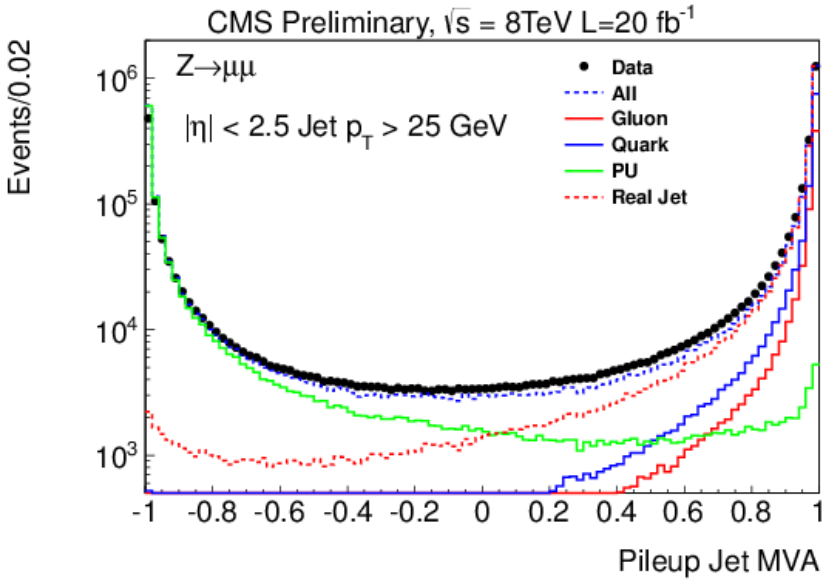
- Lead tungstate has fast scintillation response.
  - about 80% of the light emitted in 25 ns
  - **excellent time resolution** maintained through the signal processing
  - Each pulse shape made of 10 samples

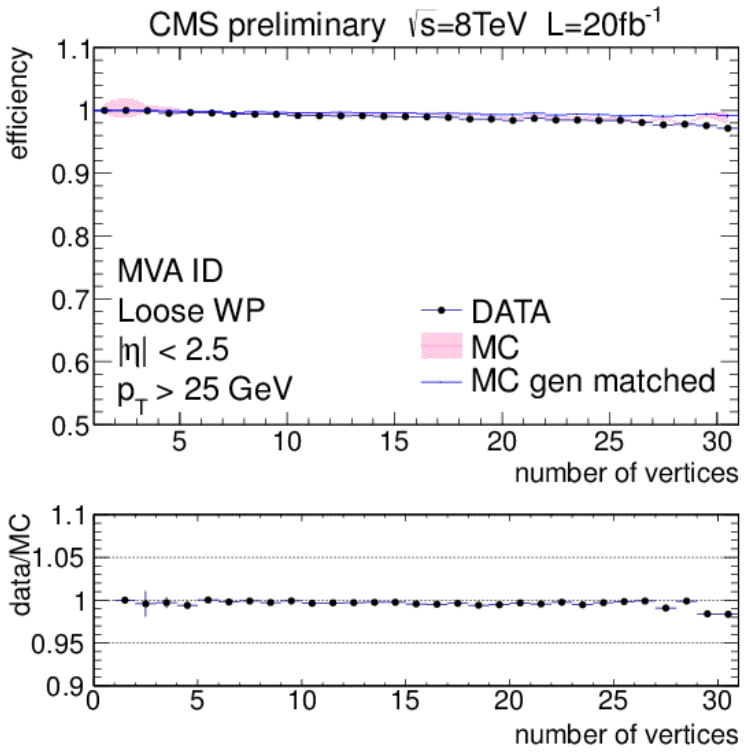
- **CMS is developing reconstruction methods resilient to out-of-time pileup.**
  - Different set of samples
    - Either shift by one sample
    - Either go from 5 to 1 sample
  - Alternative determination of the pedestal



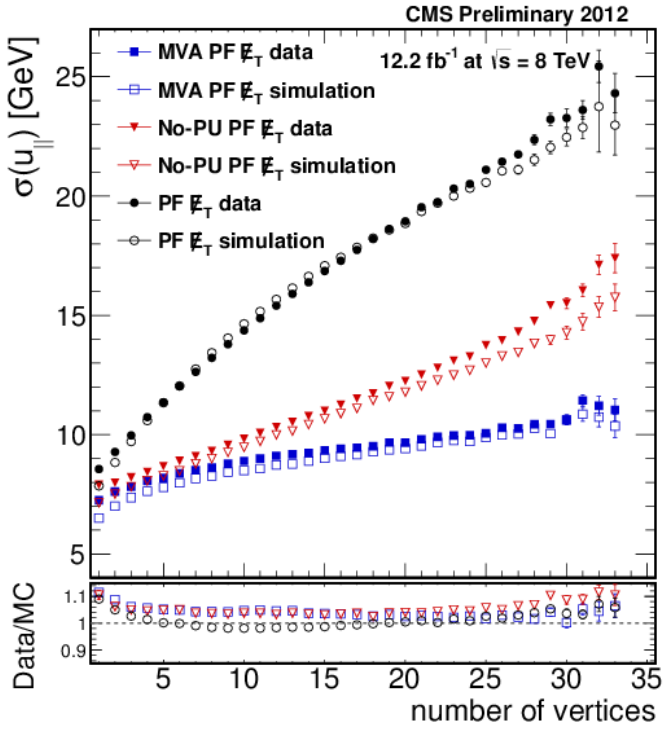
- Situation of HCAL is similar.

Jet/MET Performance

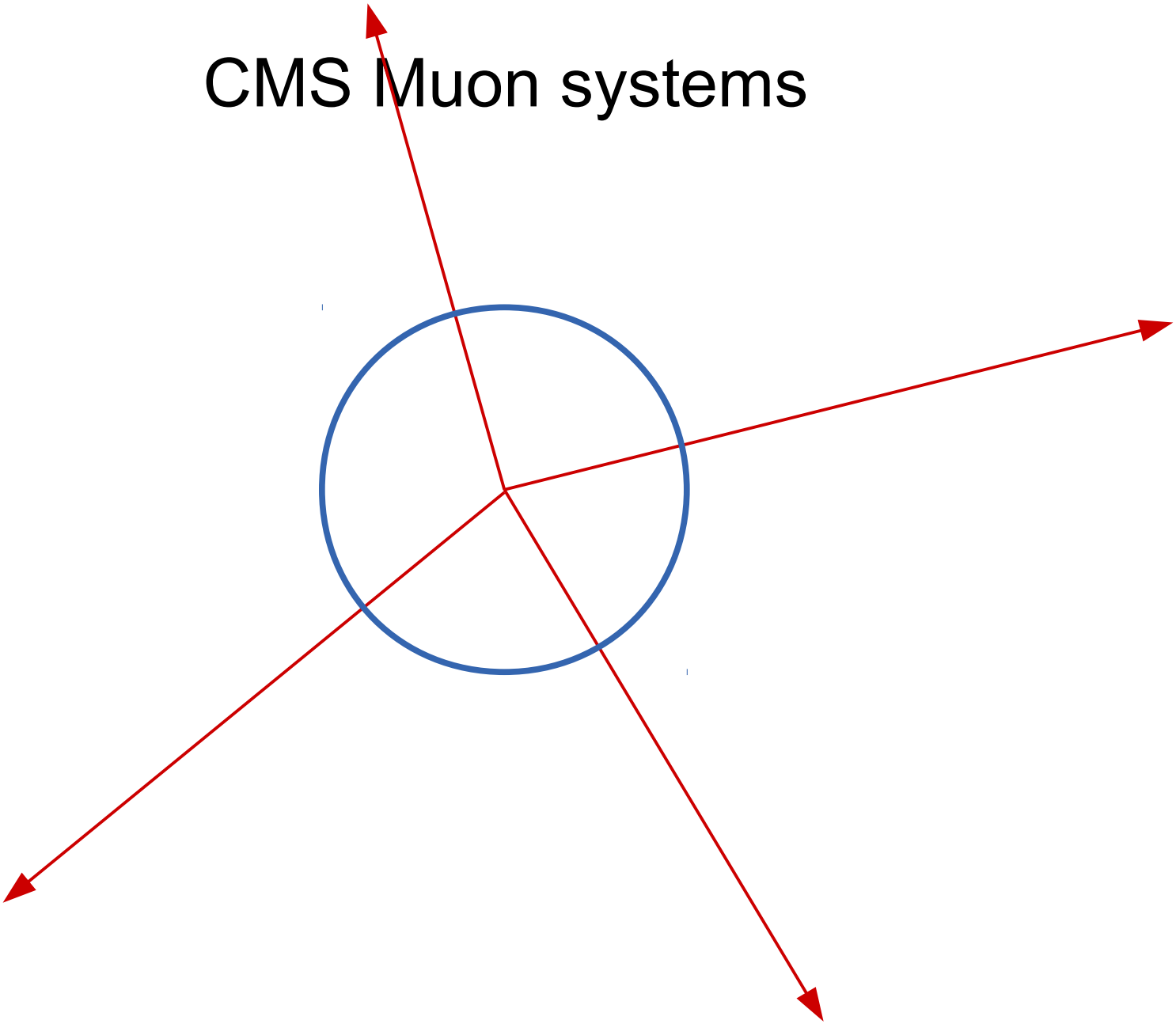




- Pileup identification is based on a MVA method already used during run 1
- Pileup-jet identification efficiency remains constant at high pileup
- MET resolution is only slightly affected by pileup when using the most advanced reconstruction method.

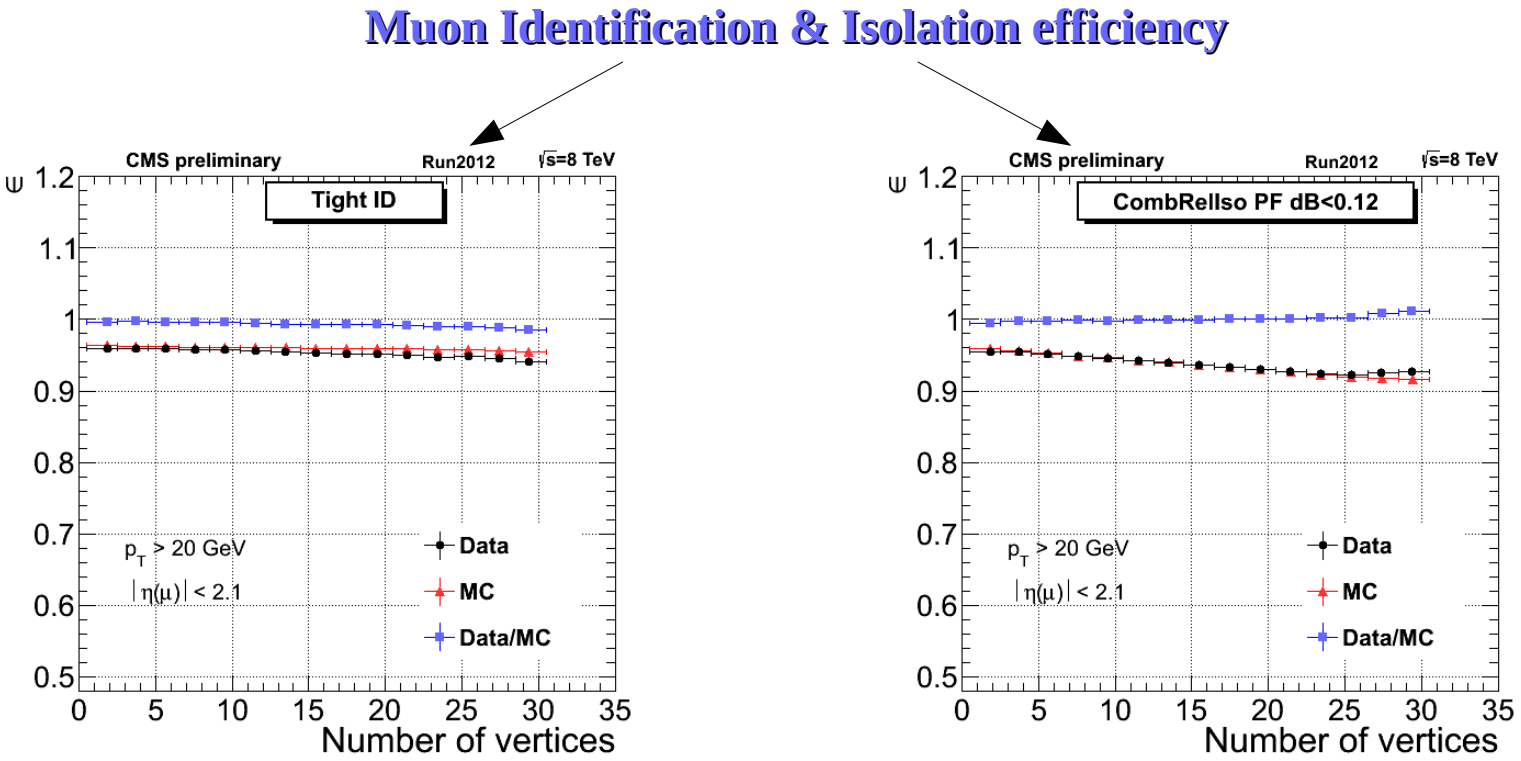


CMS Muon systems



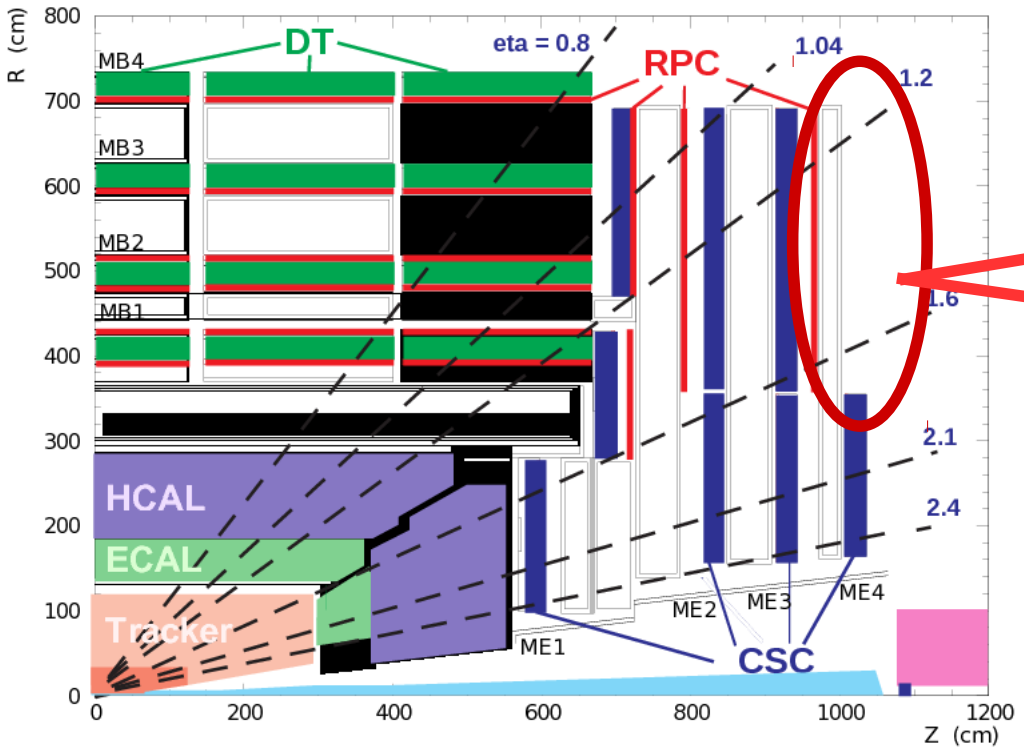
Pileup and muon efficiency

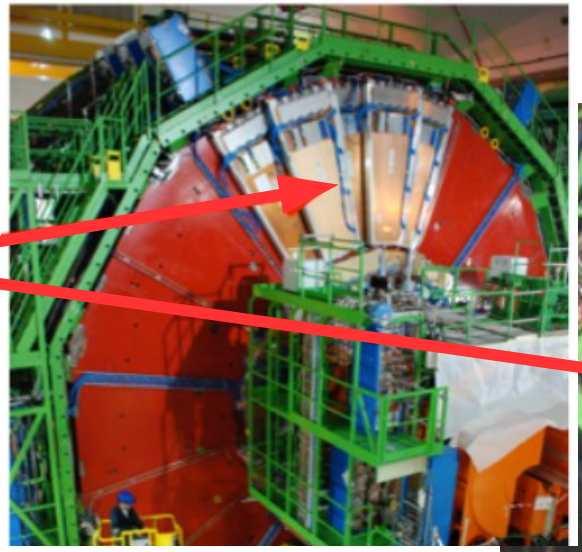
- Muon efficiency does not suffer significantly from pile-up

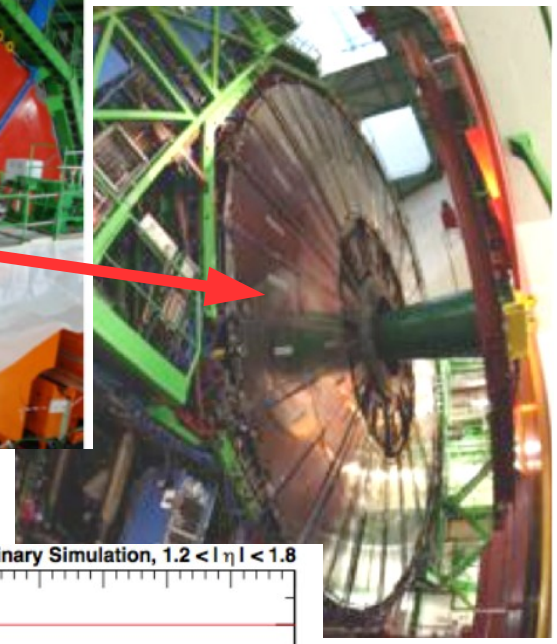


- Instead, the focus during LS1 has been on repairs to improve performance
  - Improvements targeting the trigger system (see next talk)
    - Implies a full recommissioning of the system in early 2015.

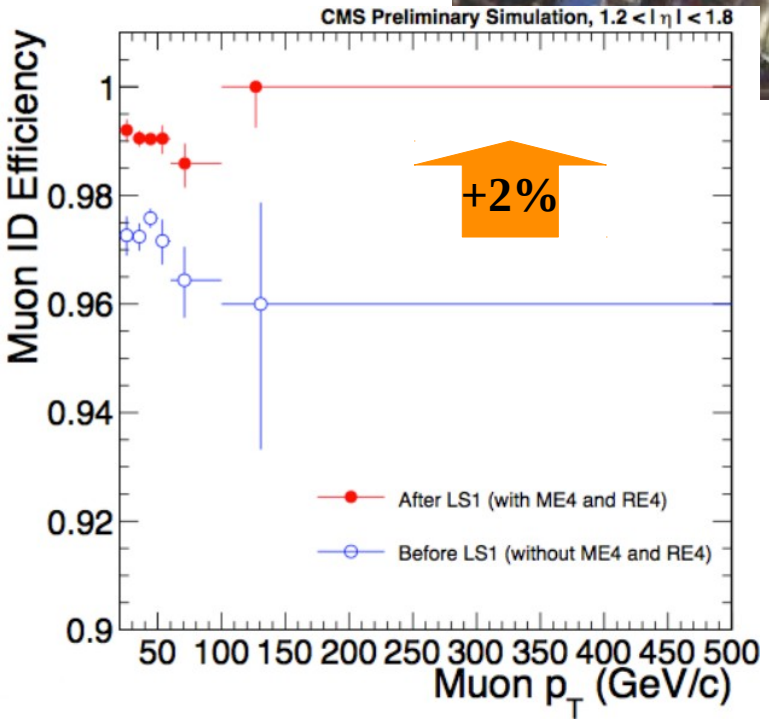
Completion of the forward muon system





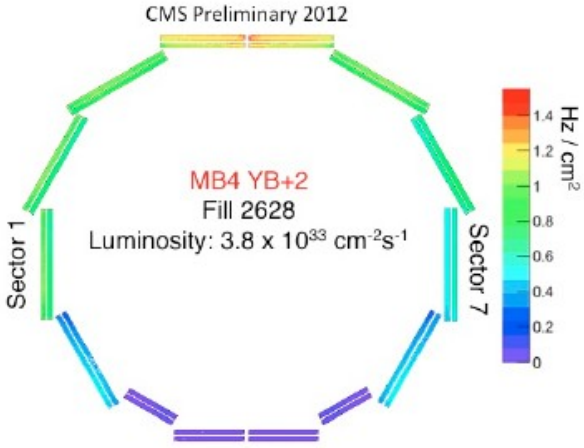


- The completion of the muon system in the forward region increases the muon id efficiency by ~2%.
- Redundancy also improves the fake rate.
- **Performance in run 2 will be better than in run 1.**

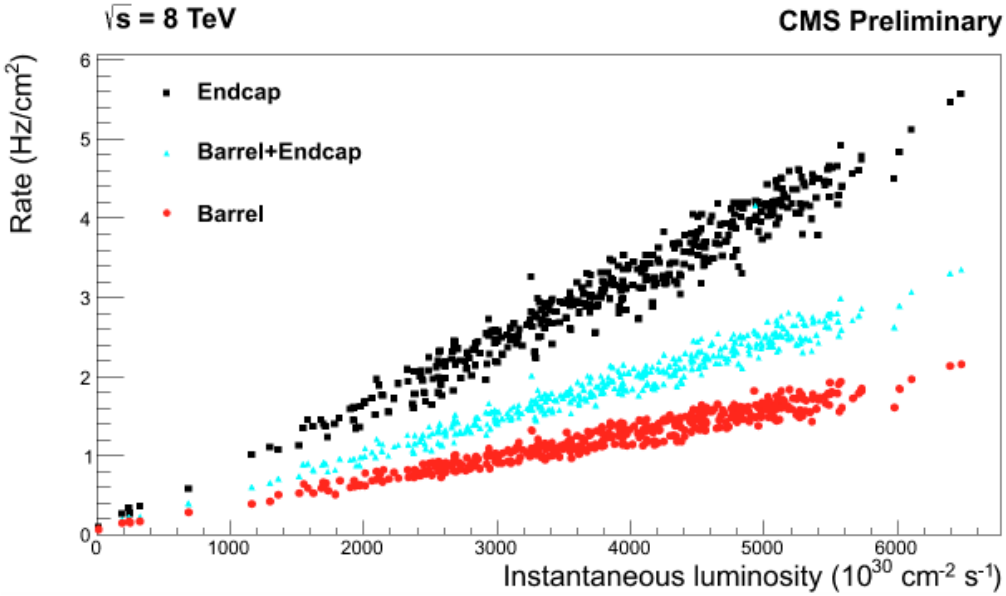


Background in the muon system

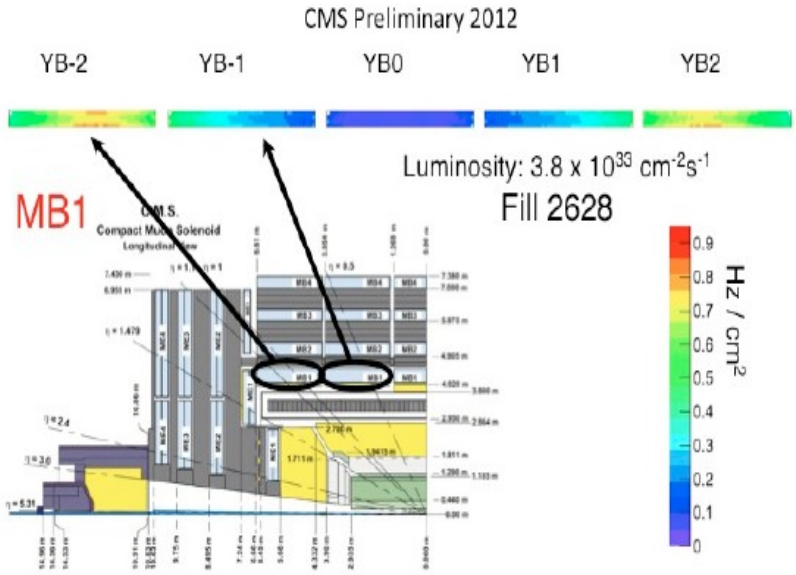
- The main sources of background in the muon system are:
  - **Photon-like background (neutron capture)**: neutrons populating the caverns
    - Highest rates in outer chambers and in top sectors (no shielding, far from the concrete floor)
  - **Prompt background**: mostly punchthrough/flythrough
    - Inner chambers, forward region
- Rate measurements in 2011 and 2012 show linear behavior
  - Extrapolation + safety factor + cross-check with simulations to prepare for higher luminosity runs

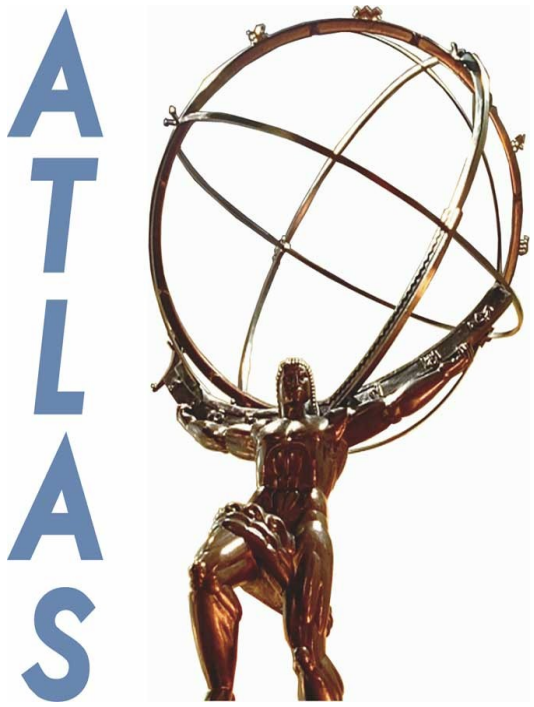


DT background rates



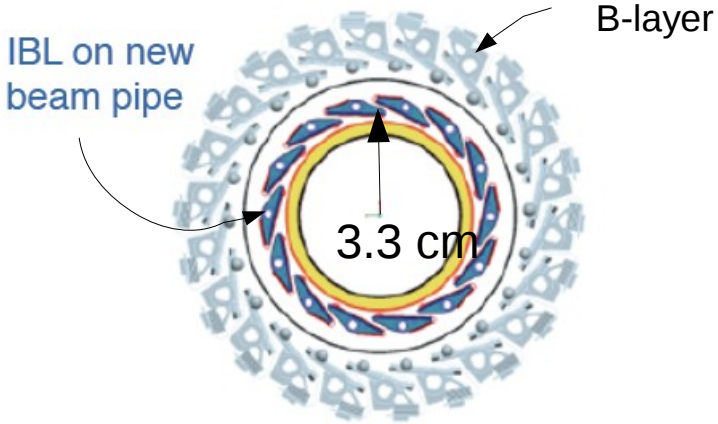
RPC backgroound rates vs luminosity

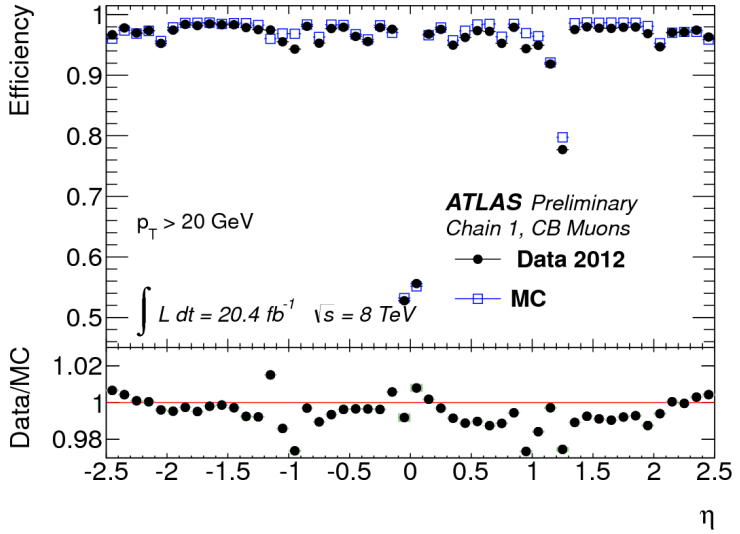



ATLAS

Hardware Upgrades & Consolidation

- Fourth (innermost) Pixel detector layer (“IBL”) being installed during current shutdown
- Will improve tracking, vertexing and b-tagging performance



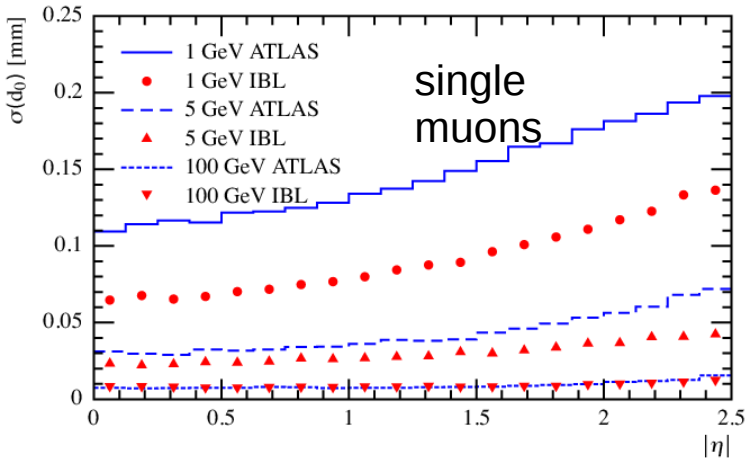


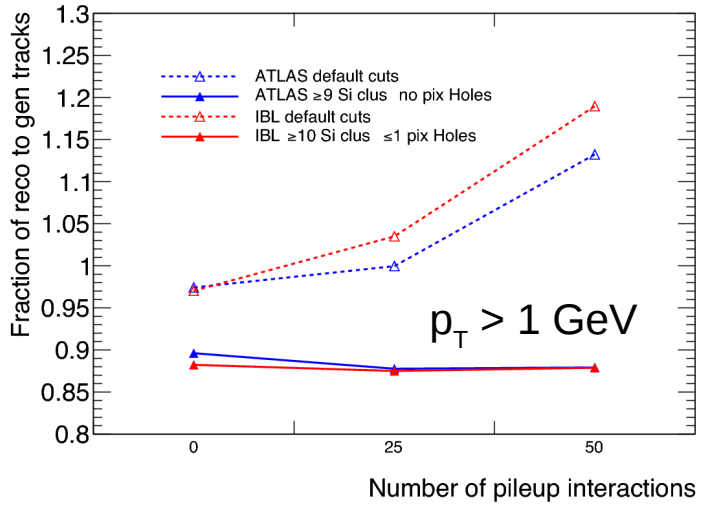
ATLAS Upgrade talk @ LHCP

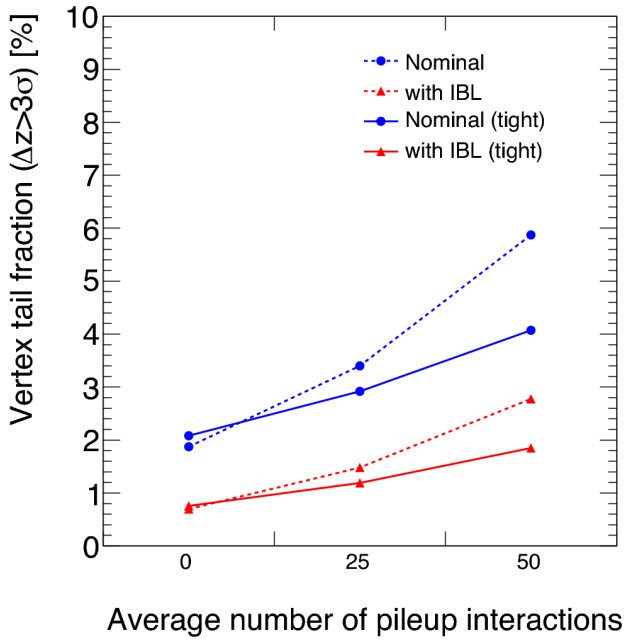
- Installation of muon chambers at 1.0 < |η| < 1.3 to recover lower efficiency
- New hardware-trigger component for Run 2: “Fast Tracker”
- Other trigger & software upgrades shown in upcoming talks

Tracking Performance

- IBL improves esp. track position measurement at vertex → improves fake track rejection and vertexing performance
- Need to retune track quality cuts and re-commission Inner Detector alignment
- Working on new vertexing algorithm to improve reconstruction of nearby vertices
- Probe heavier resonances ⇒ higher-p_T decay particles: Work ongoing to improve tracking efficiency in dense environments (high-p_T jets, b- and τ-decays)
- More pile-up ⇒ more tracks: Need to watch CPU timing of reconstruction and event data size



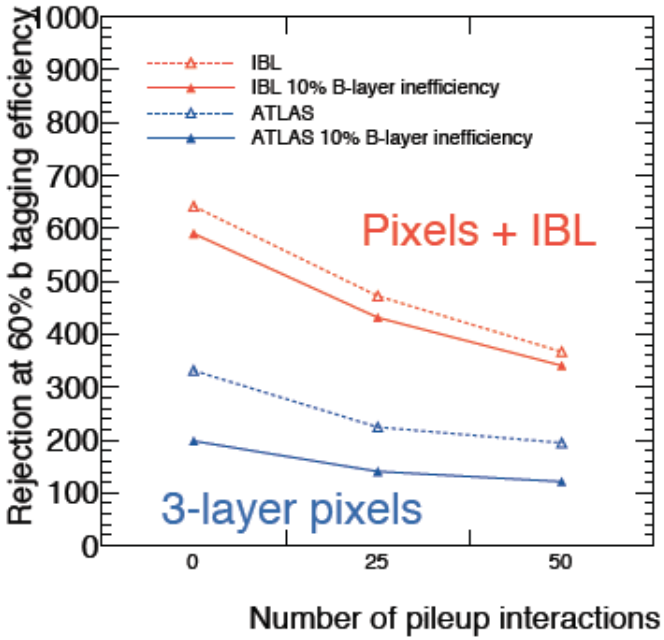




CERN-LHCC-2010-013

Flavor Tagging Performance

- IBL improves b-tagging performance
- Re-optimization of b-tagging algorithms for inclusion of IBL and higher pile-up
- Improve high-p_T tagging in close coordination with tracking group: optimizing algorithms for decays before and after first pixel layer
- New “Fast Track” trigger:
  - Improves b-tagging performance at trigger level
  - Permits tagging at much larger trigger rate ⇒ can lower jet p_T requirement



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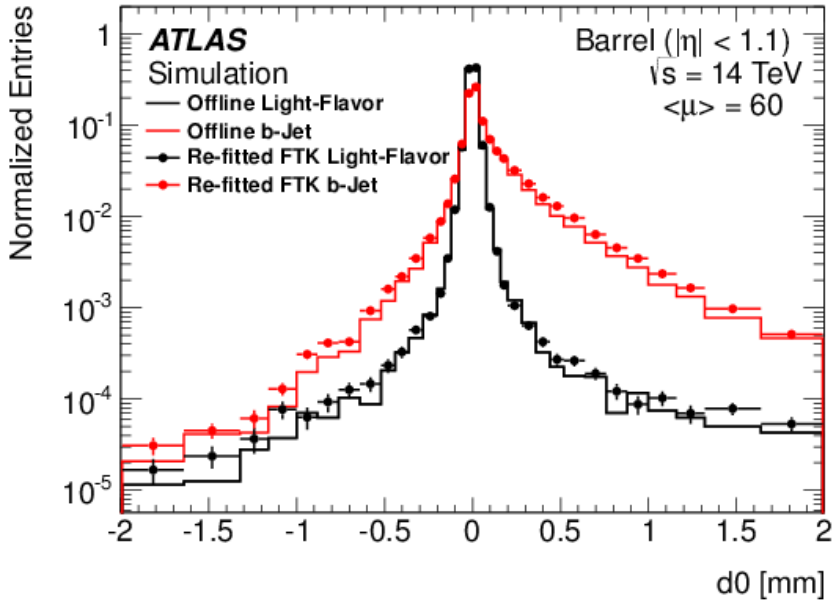
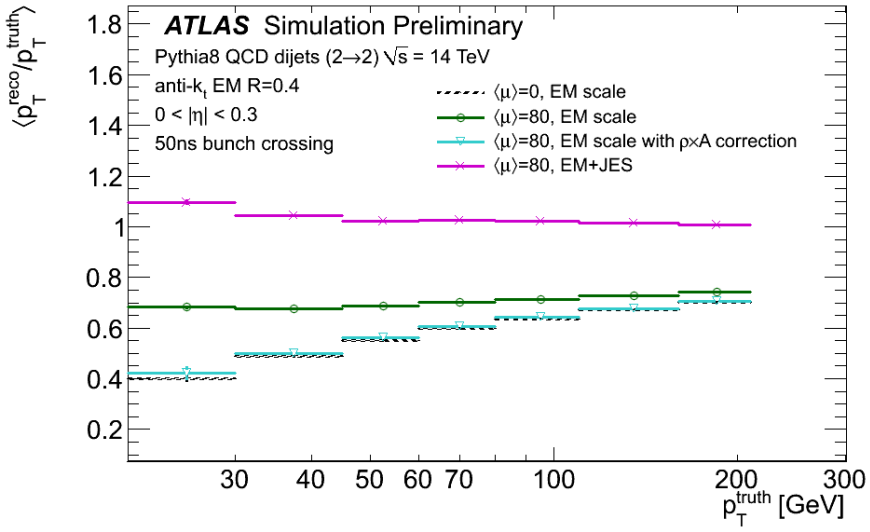


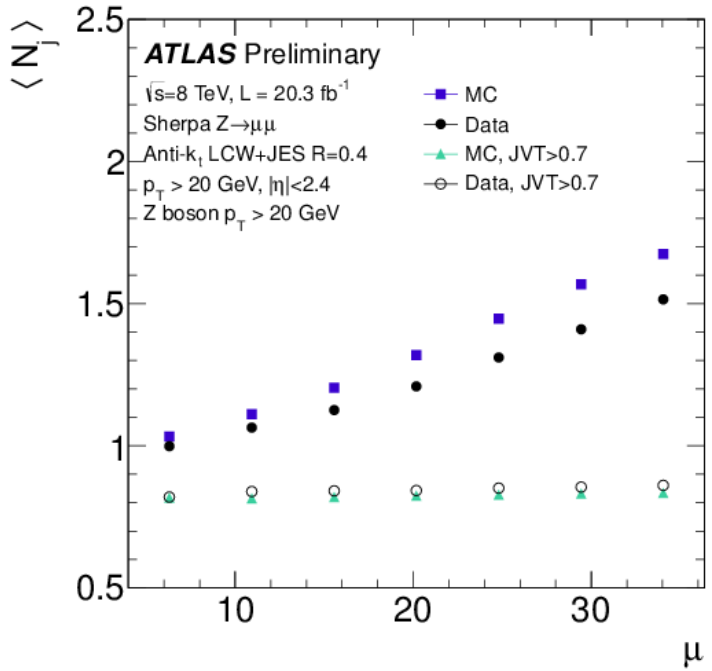
FTKPublicResults twiki

Jets and Missing-E_T Performance

- Jet response without pile-up largely restored with higher noise thresholds and pile-up subtraction based on jet area
- Reject pile-up jets using an MVA with track and vertex information, e.g. requiring minimum track-p_T fraction to come from hard-scatter vertex
- Also being studied: particle flow jet reconstruction → less sensitive to local pile-up fluctuations



JetEtmissApproved2013HighMuPileup twiki



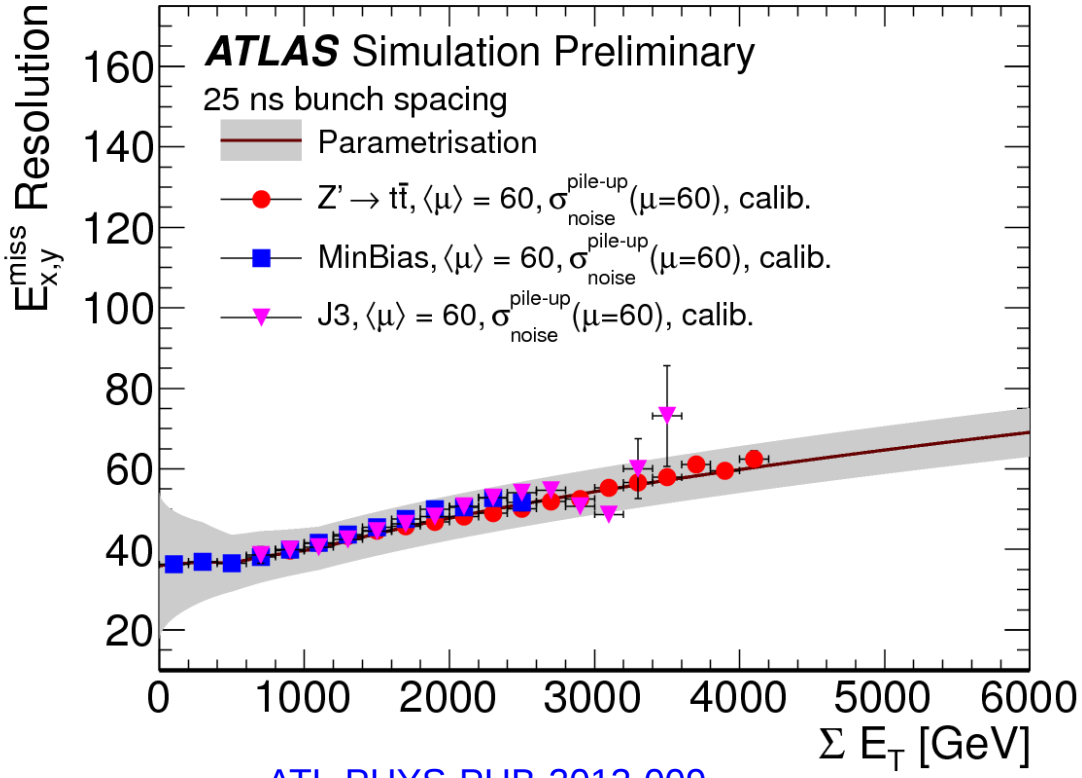
ATLAS-CONF-2014-018

Jets and Missing-E_T Performance

EtMiss = calibrated physics objects + tracks and clusters not associated to objects

- Pile-up suppression using tracks: Use only tracks for unmatched objects

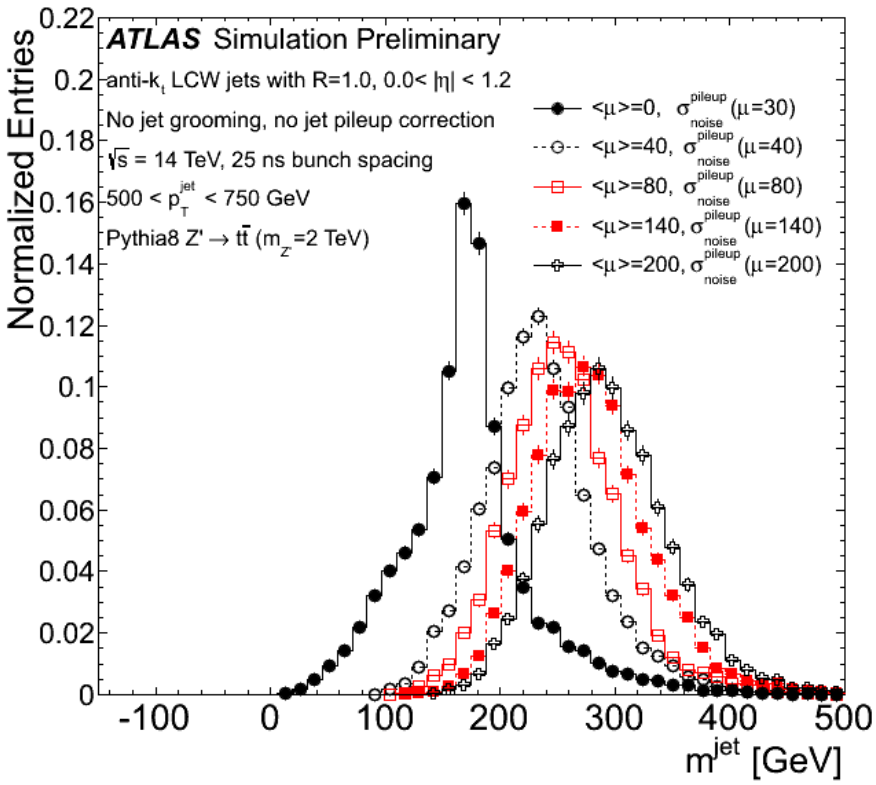
Note: Plot uses calorimeter clusters for unmatched objects

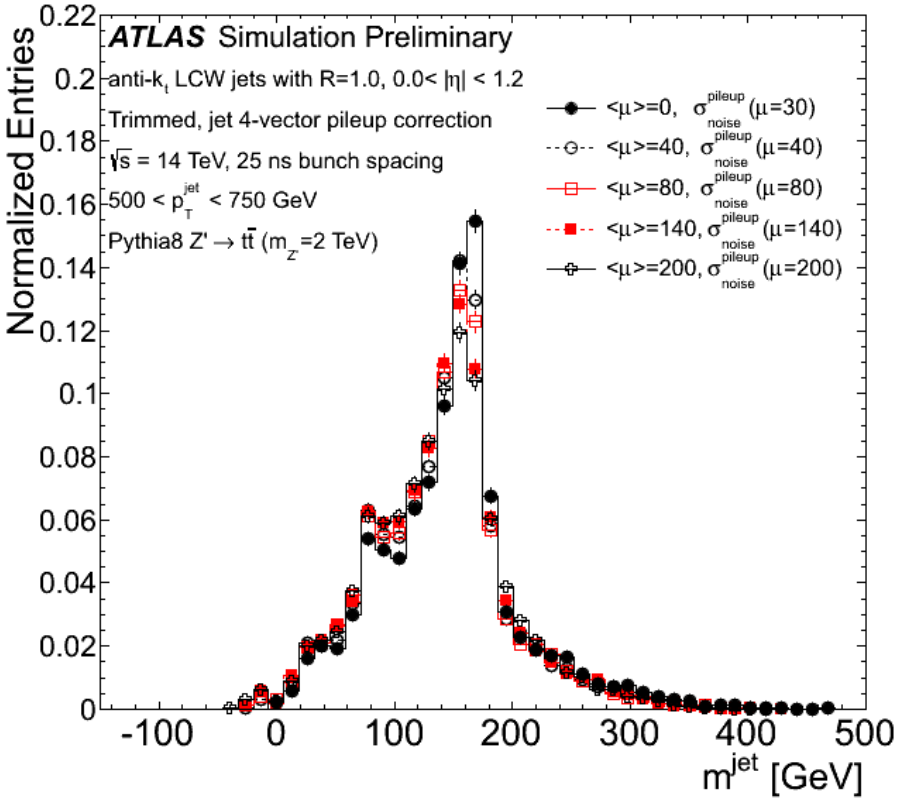


ATL-PHYS-PUB-2013-009

Jets and Missing-E_T Performance

Jet substructure: Jet mass shape retained at high <μ> after rejecting subjets with low-p_T fraction (“trimming”) and pileup correction



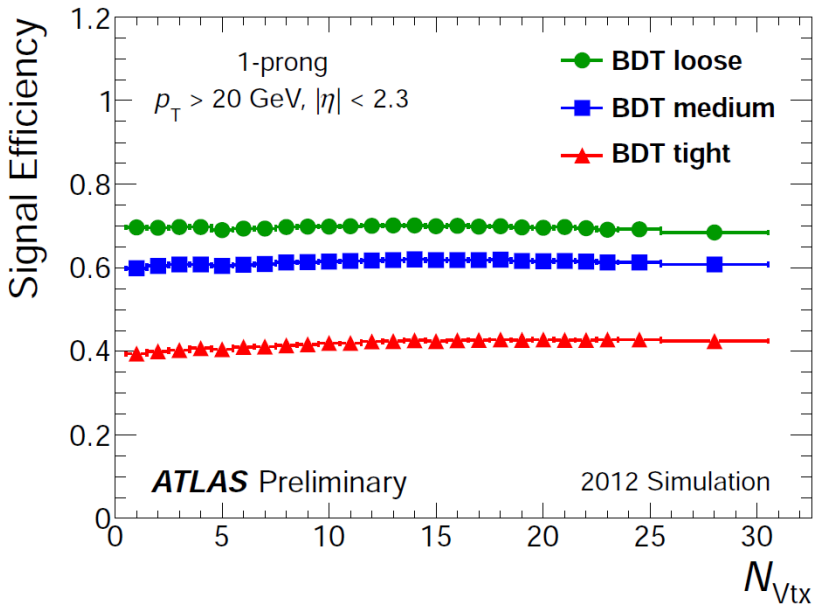


JetEtmissApproved2013HighMuSubstructure twiki

Tau Performance

Run 2 preparation:

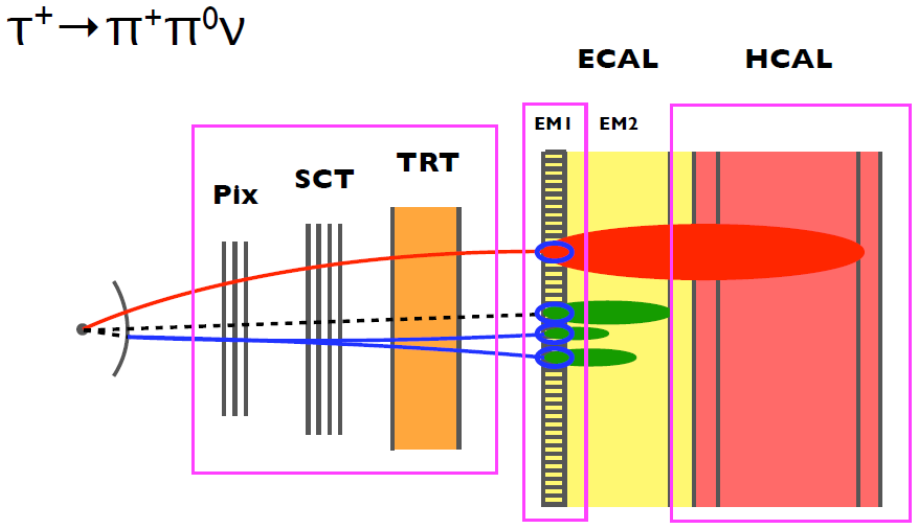
- Reconstruction efficiency depends on tracking
  → don't expect performance degradation
- Identification efficiency stable
- Energy resolution expected to be stable
- Optimize track and vertex quality criteria in high pile-up environment
- Fast Tracker improves tau selection at trigger



ATLAS-CONF-2013-064

New for Run 2: Substructure reconstruction

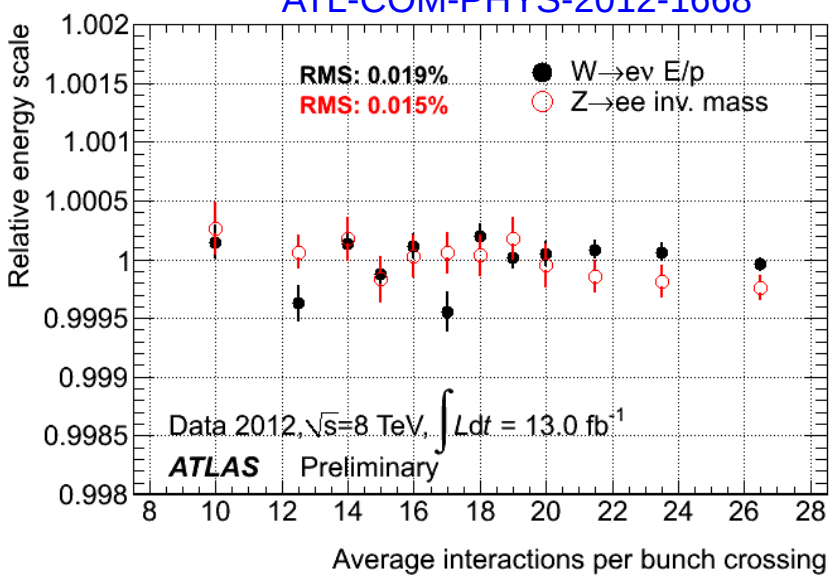
- Use track measurement for charged particles
- Reconstruct neutral pions from calorimeter
- Large improvement in tau energy resolution
- Access to tau spin through decay kinematics

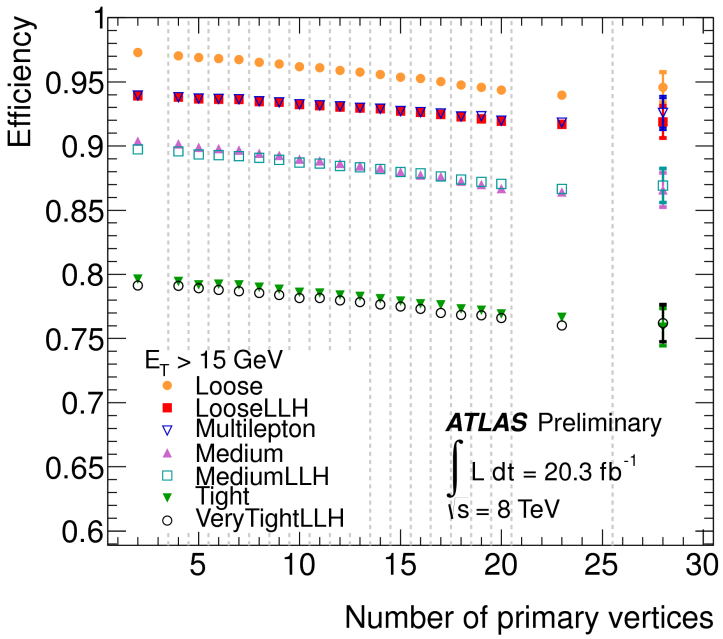


Electron/Photon Performance

- Improve e & γ identification at high pile-up e.g. isolated shower shapes look more background-like vs. pile-up → relax cuts or develop correction
- Good stability of electron energy scale vs. pile-up
- Studying pile-up robust methods to estimate energy isolation and to tag conversions

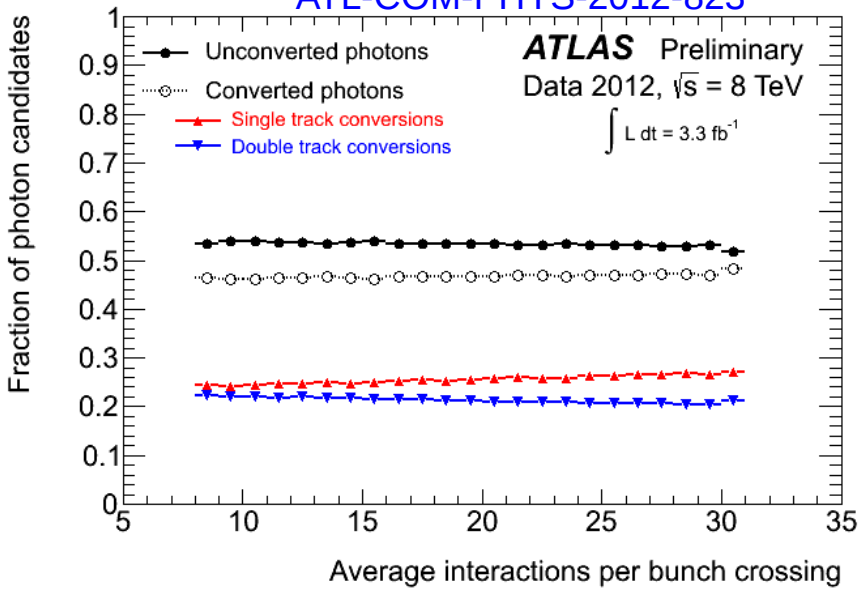
ATL-COM-PHYS-2012-1668





ATLAS-CONF-2014-032

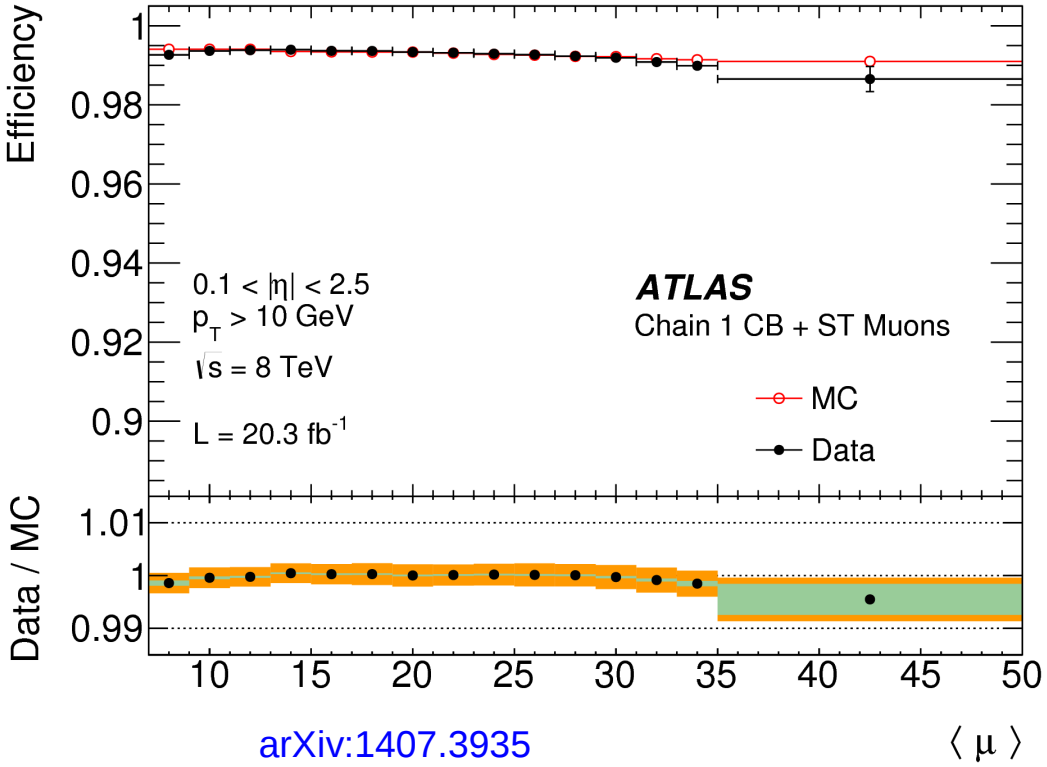
ATL-COM-PHYS-2012-823



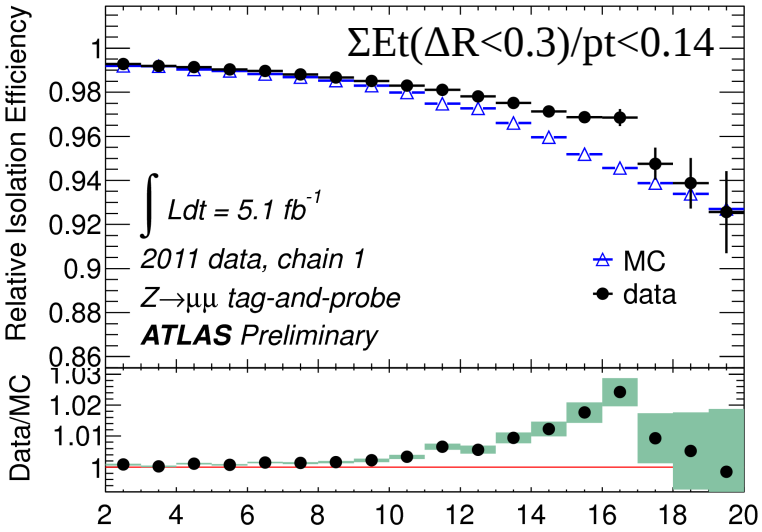
Muon Performance

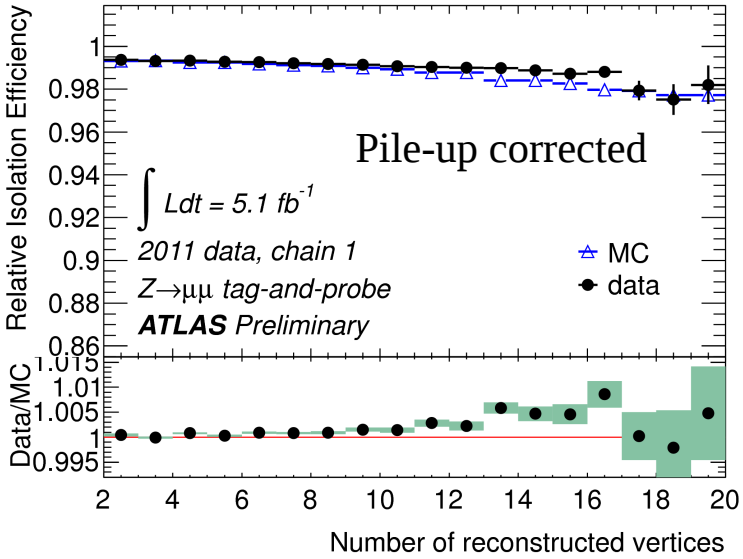
- Stable reconstruction efficiency vs. pileup, well reproduced in MC
- Studying corrections to muon isolation in context of VH analyses

Muon Public Plots



arXiv:1407.3935





Conclusions

- Presented a selection ongoing activities and results
- Detectors will face unprecedented conditions: higher pileup, higher integrated dose, higher energy
- New detector hardware is being installed and commissioned → will have impact on various physics objects
- ATLAS and CMS performance in Run 2 expected to be equal (even surpass) Run 1