CMS Performance in Run2

di-photon event with $m_{\gamma\gamma}$ = 745 GeV

Federico De Guio (CERN)
on behalf of the CMS collaboration

XXII Cracow Epiphany Conference on the Physics in LHC Run2
7 - 9 January 2016

Activity ongoing on three fronts

- Complete Run1 analysis

- 2015 data taking and Run2 analysis

- Upgrade activities

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See P. Srimanobhas talk

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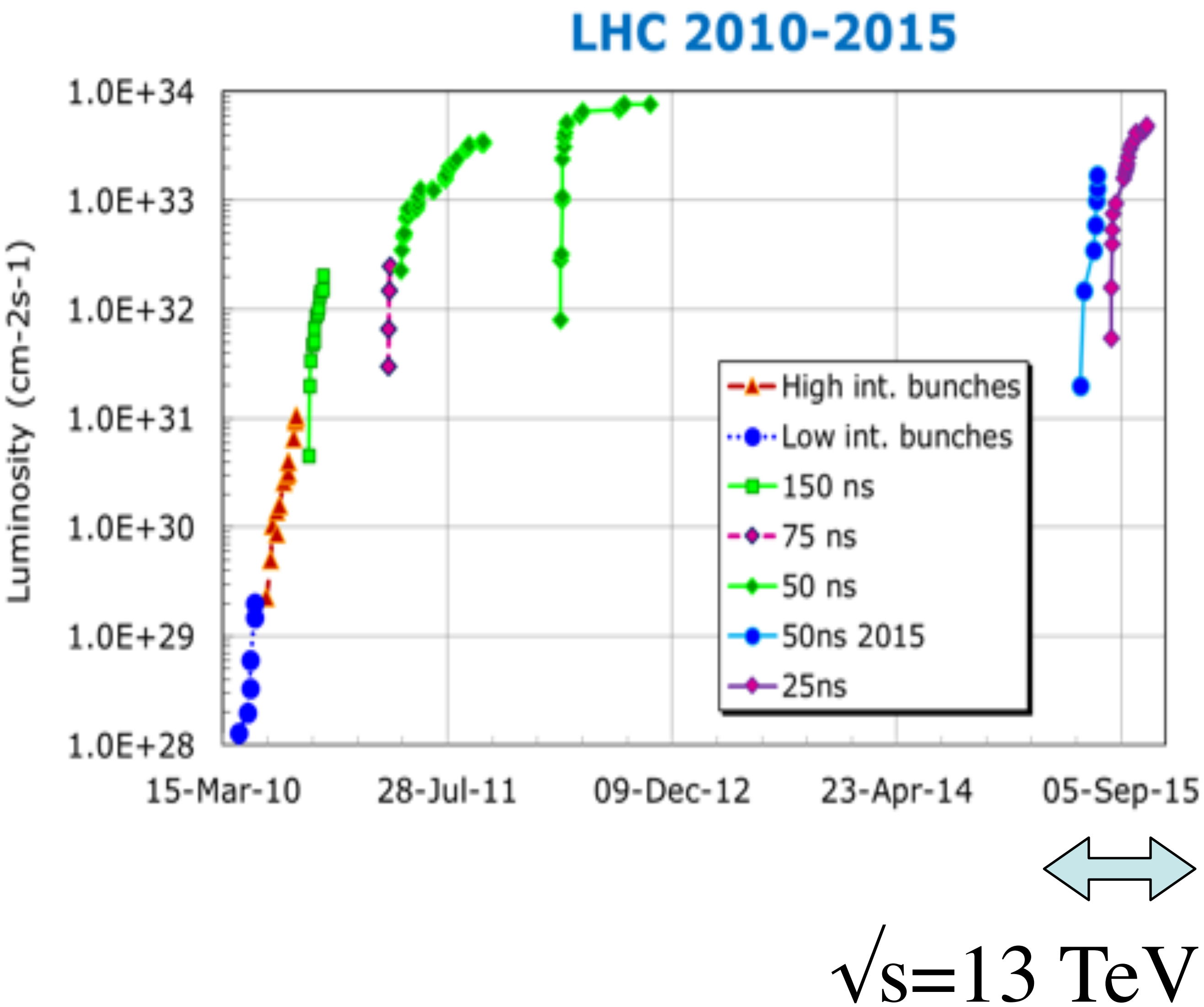
Many specific talks at this conference

See Phat’s talk

A successful recommissioning run for LHC: 25 ns + √s=13 TeV

- **More than 4/fb** pp collisions delivered to CMS and ATLAS
- Up to **1.2×10^{11} ppb and 2244 bunches**
- Peak lumi: **> $5 \times 10^{33} cm^{-2}s^{-1}$**
- **4 weeks HI running** completed before Christmas break

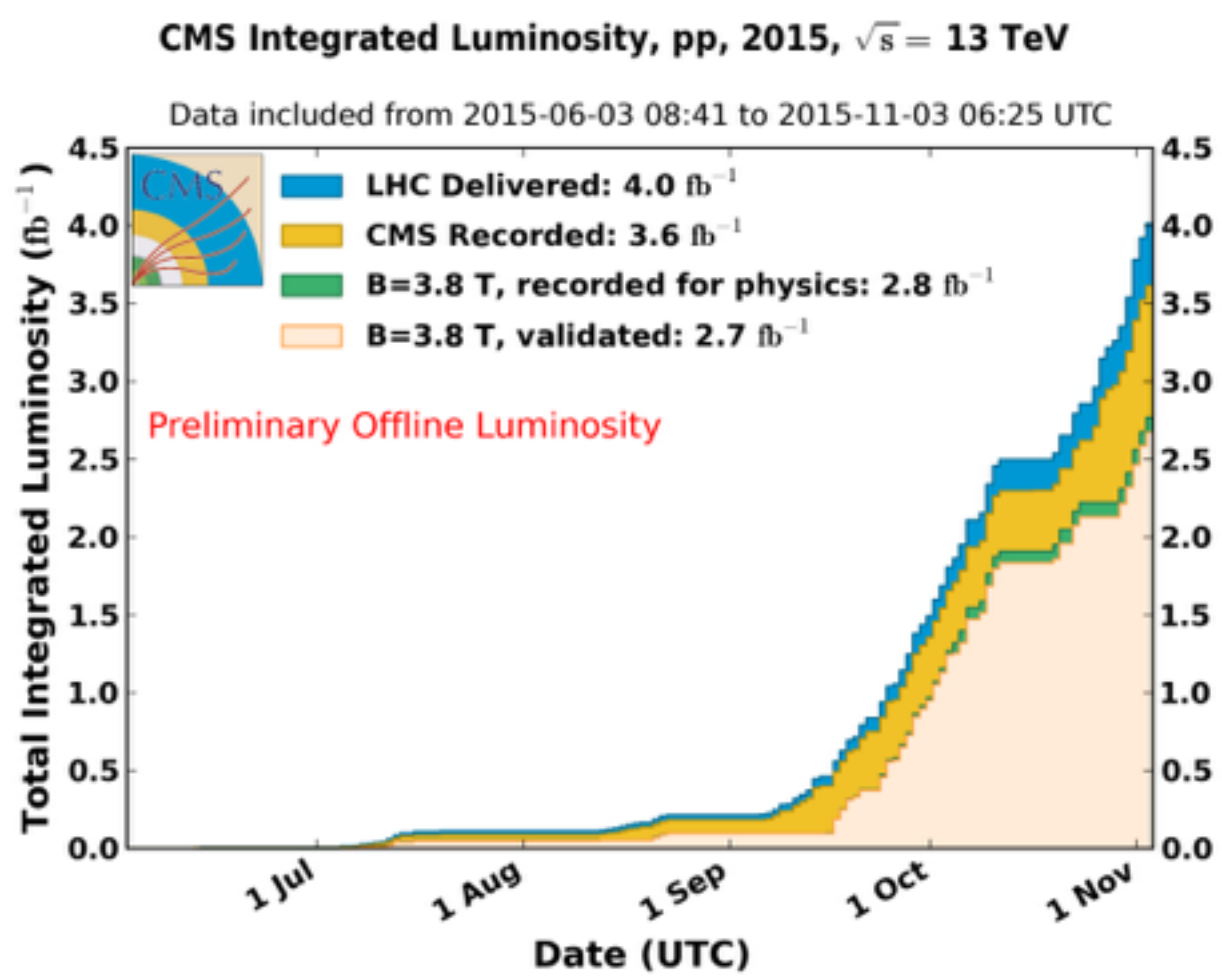


Large fraction of good data despite the erratic behaviour of the CMS magnet

- Build up of **contaminants** in the magnet **cryogenic system**. Deep cleaning operations currently ongoing.

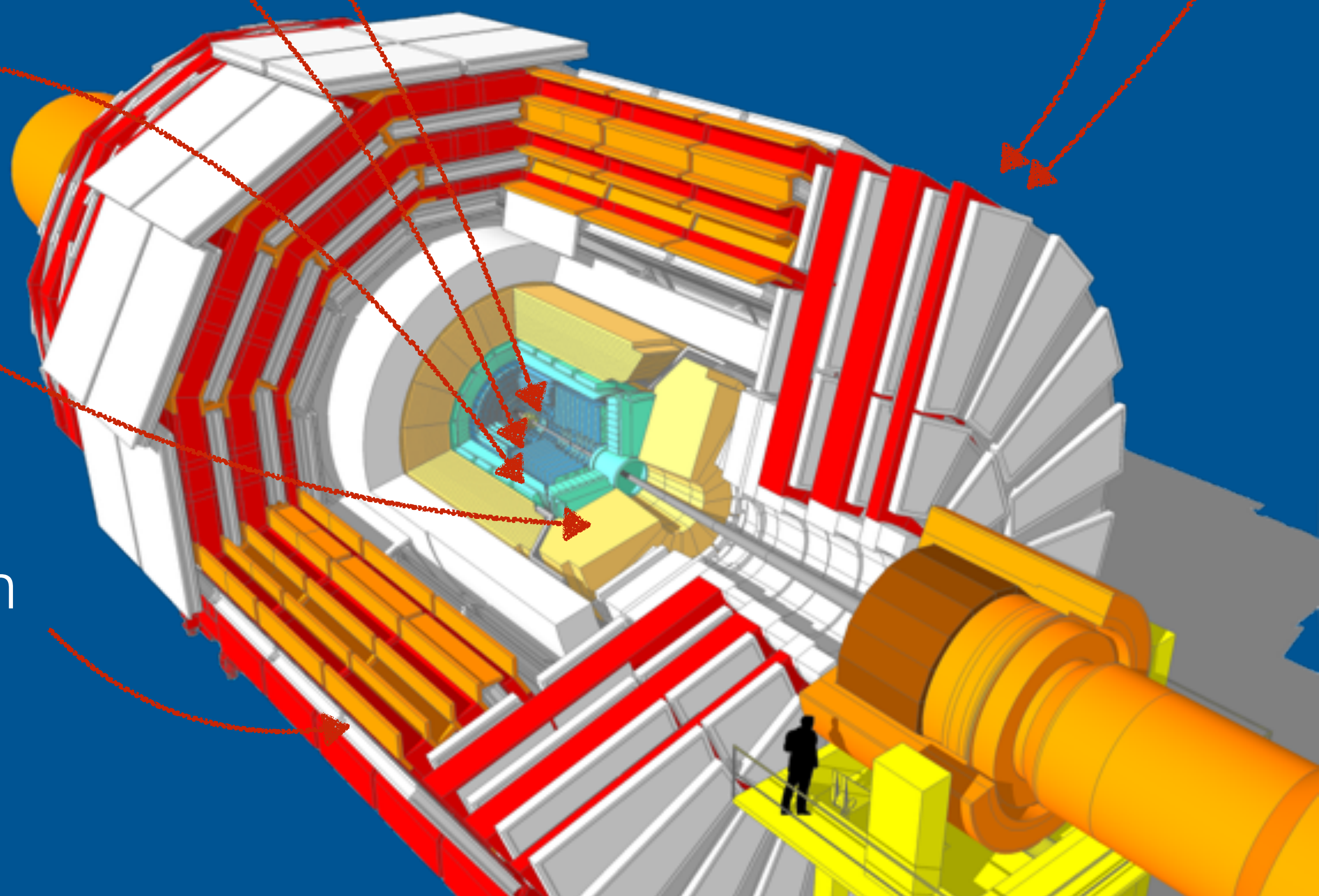
- **2.7fb^{-1} validated for physics @13TeV with B=3.8T**

- Huge transversal effort to provide optimized reconstruction algorithms+Calibrations+MC for **0T data taking**

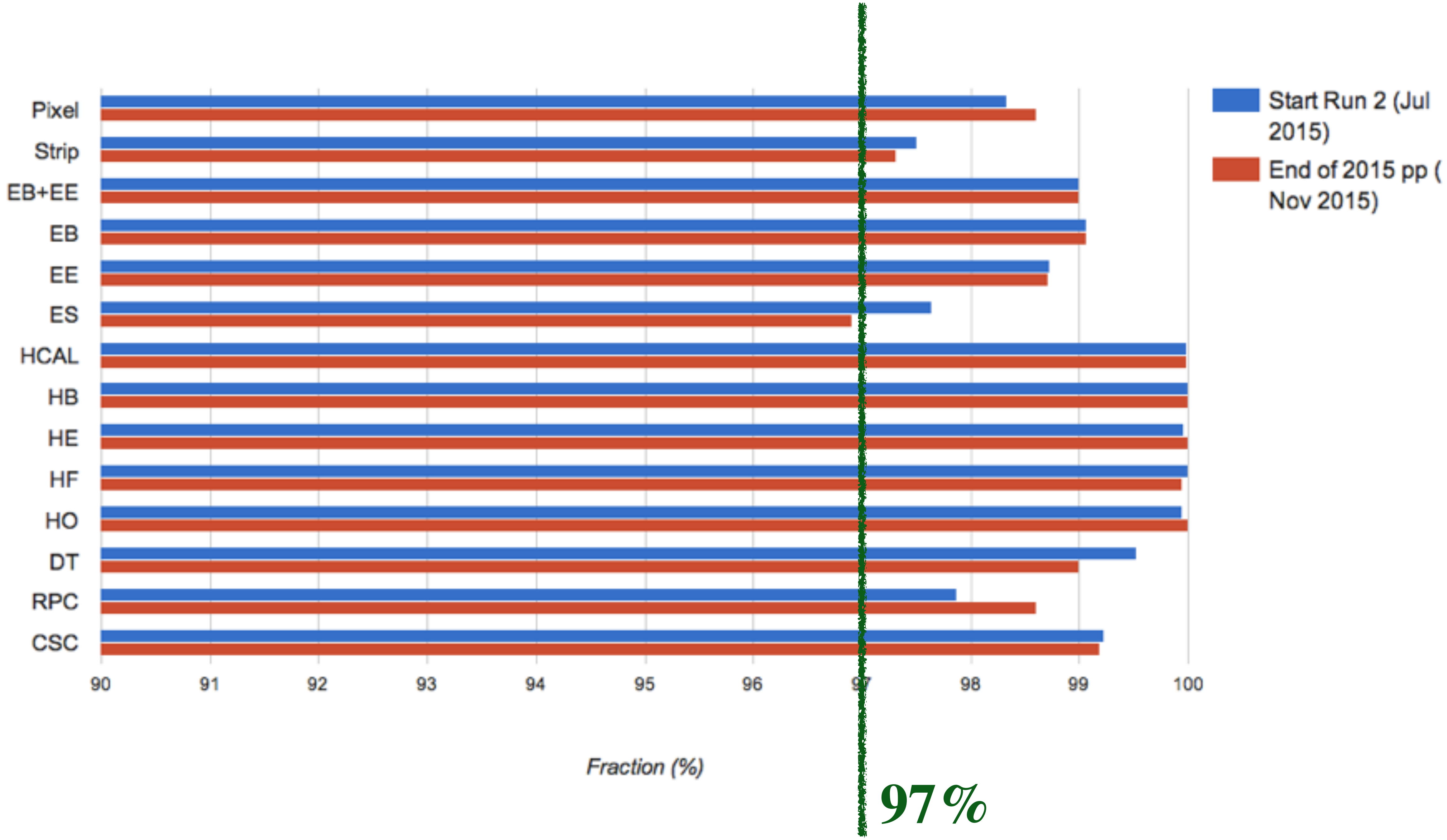


The 25 ns challenge: many detector updates since Run1

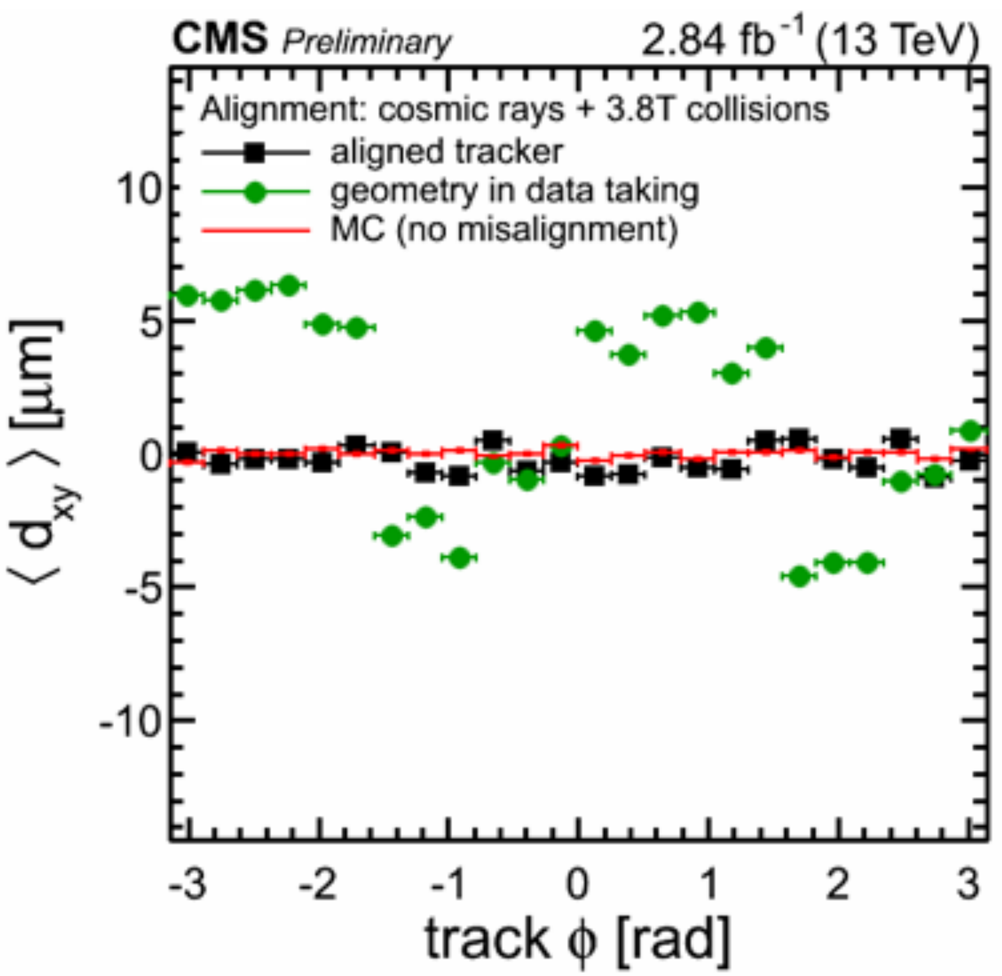
- Silicon pixels: replaced modules
- Silicon tracker: operated at lower temperature (–15ºC)
- Electromagnetic calorimeter: new trigger optical links
- Hadronic calo: new photodetectors on HO, new Back-End on HF
- Drift Tube chambers: relocation of trigger electronics in the service cavern
- Resistive Plate Chambers: new chambers
- Cathode Strip Chambers: new chambers & electronics

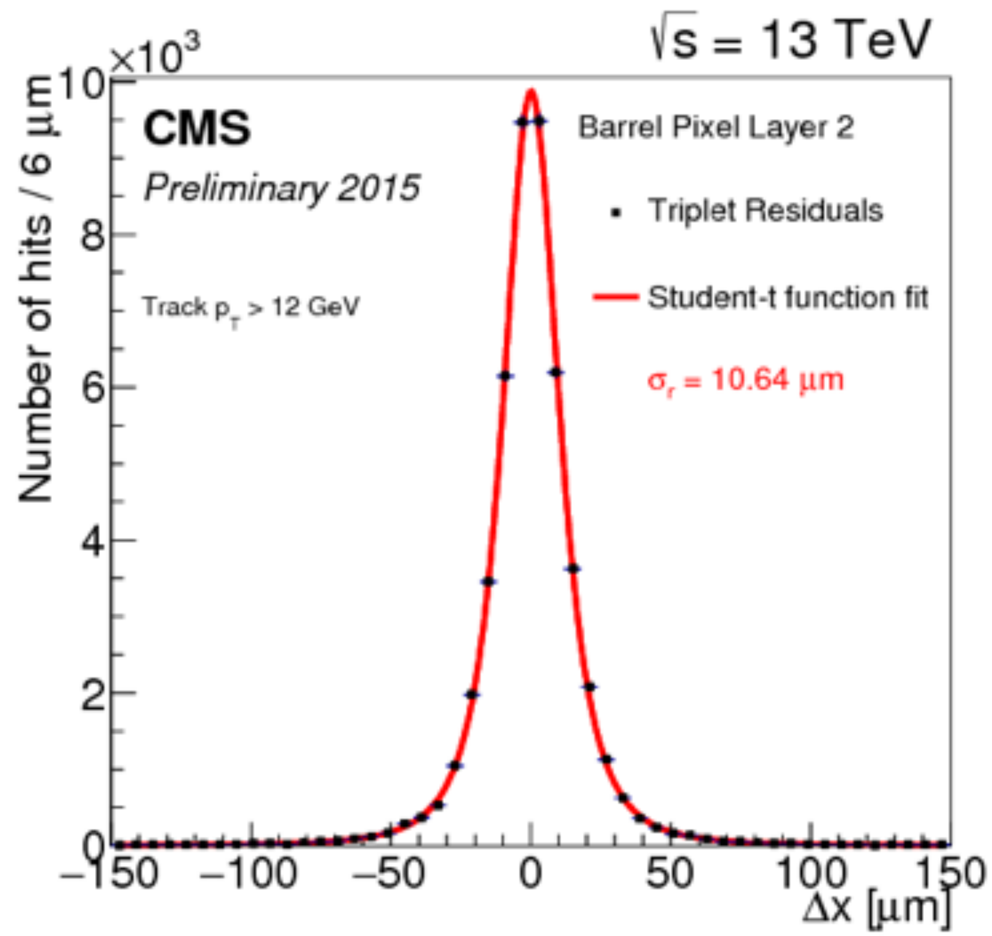


Excellent availability of the CMS detector



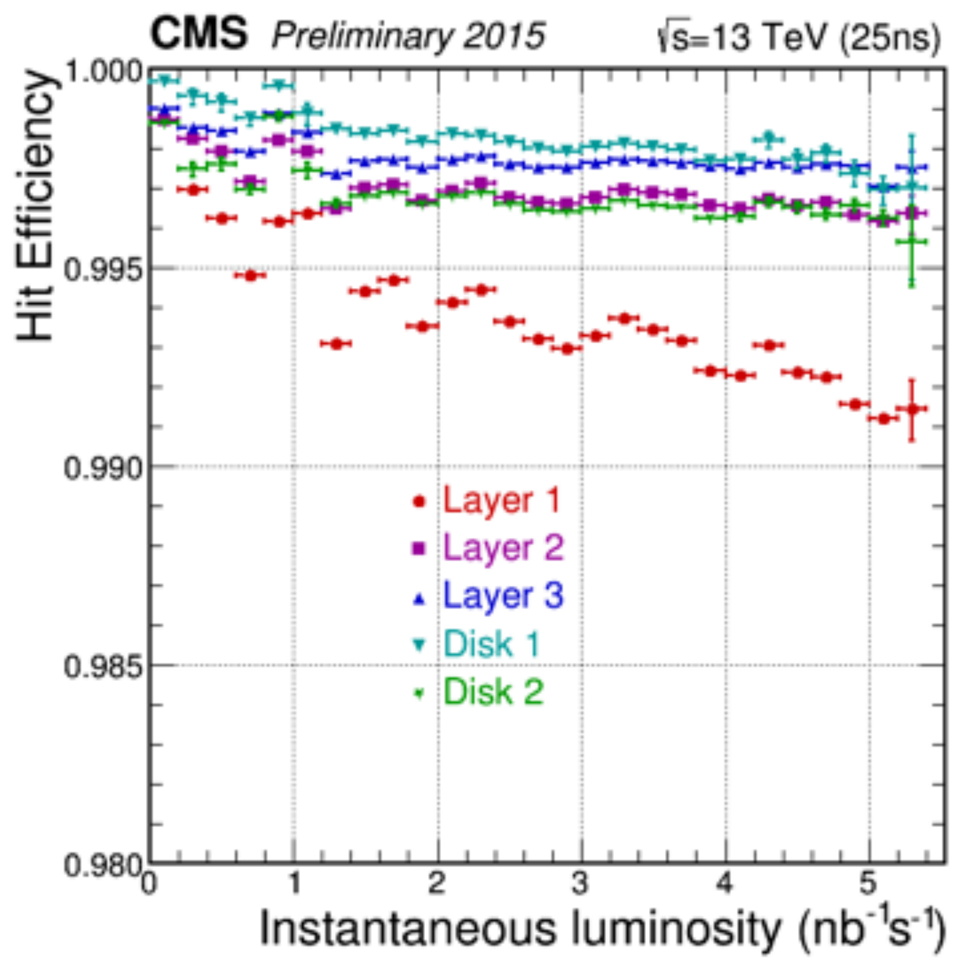
Tracker alignment & resolution: as good as in Run1

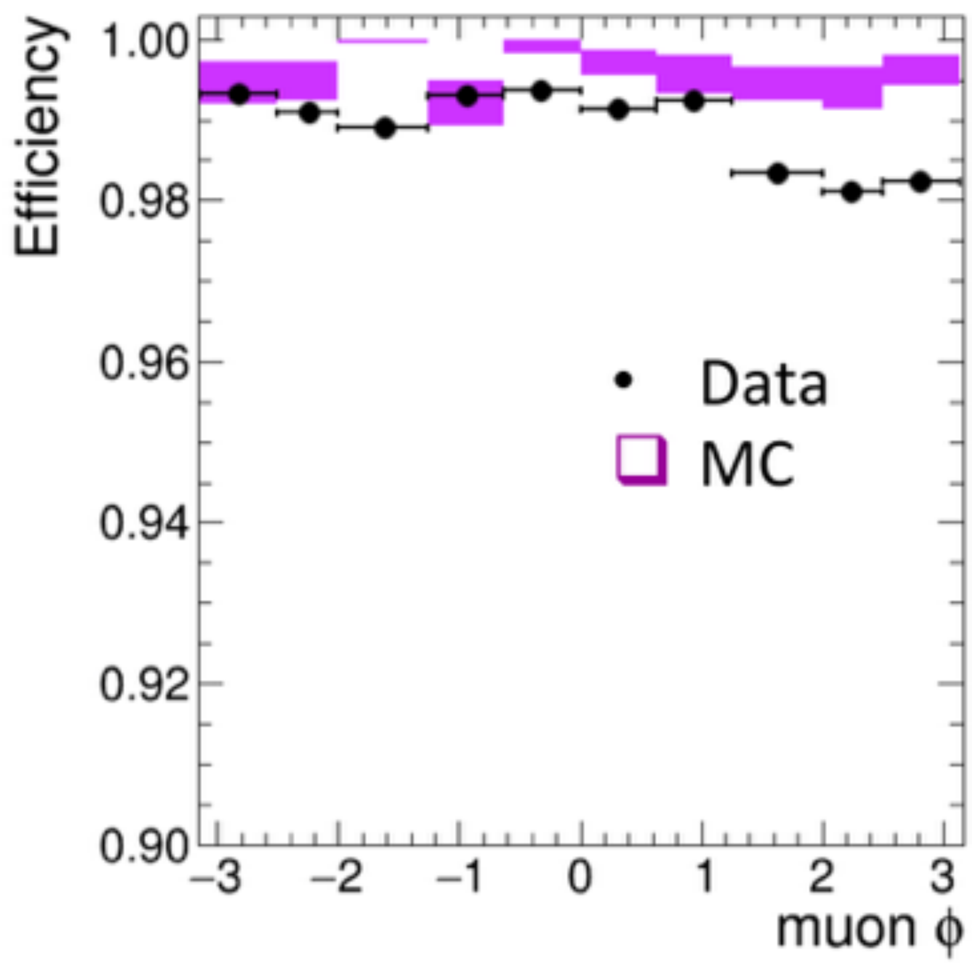




- Optimal conditions for **re-reco**:
  - Compensate for effect of magnet cycles+final modules alignment at the **µm level**
- Pixel Detector Resolution:
  - transverse to the beam: **σ_R=10.64 µm**
  - parallel to the beam: **σ_Z=29.09 µm**

Improved pixel hit efficiency (left) and tracking efficiency (right)



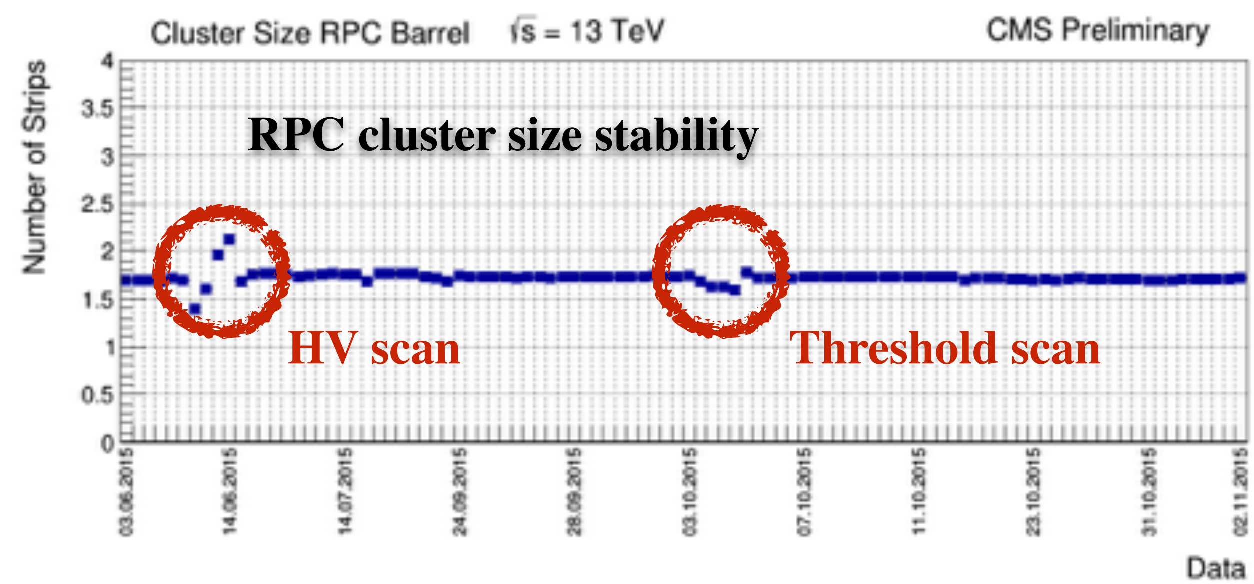


- Dynamic inefficiency most visible on layer 1
- **Efficiency above 99%** on all layers/disks

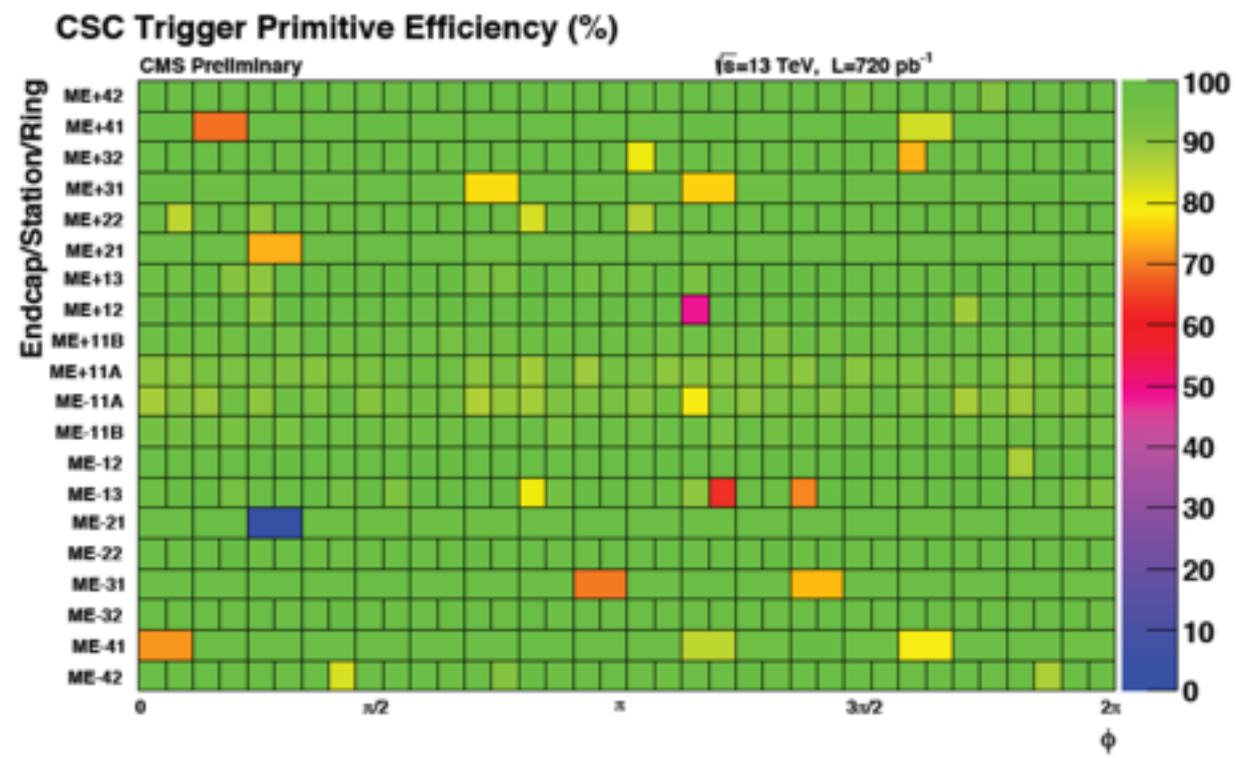
- Small inefficiency in $1 < \Phi < 3$ due to missing strip module in layer 2
- Included in **new MC simulation**

Muon Detectors: new CSC and RPC chambers and read-out commissioned

- New chambers **reduce** the muon **trigger rate** in the endcaps significantly

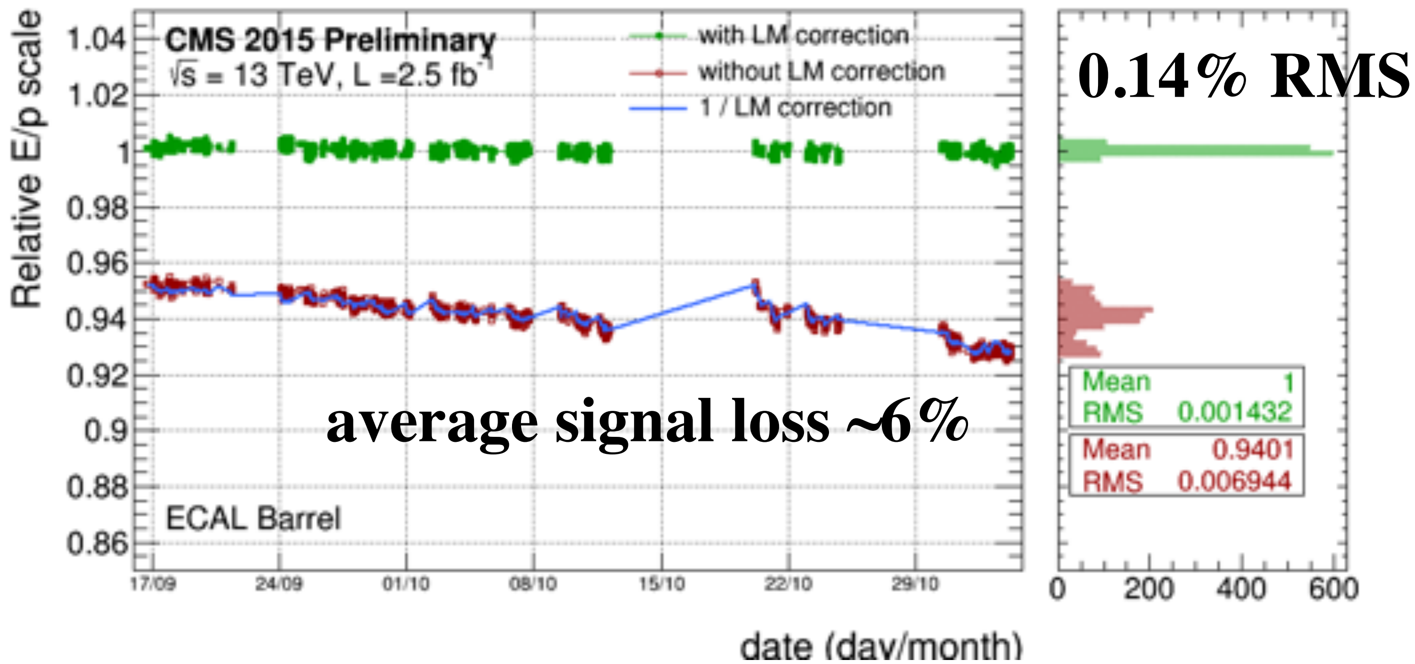


- Good **stability** of RPC cluster size
  - good stability of RPC triggers
  - important for L1 pT assignment

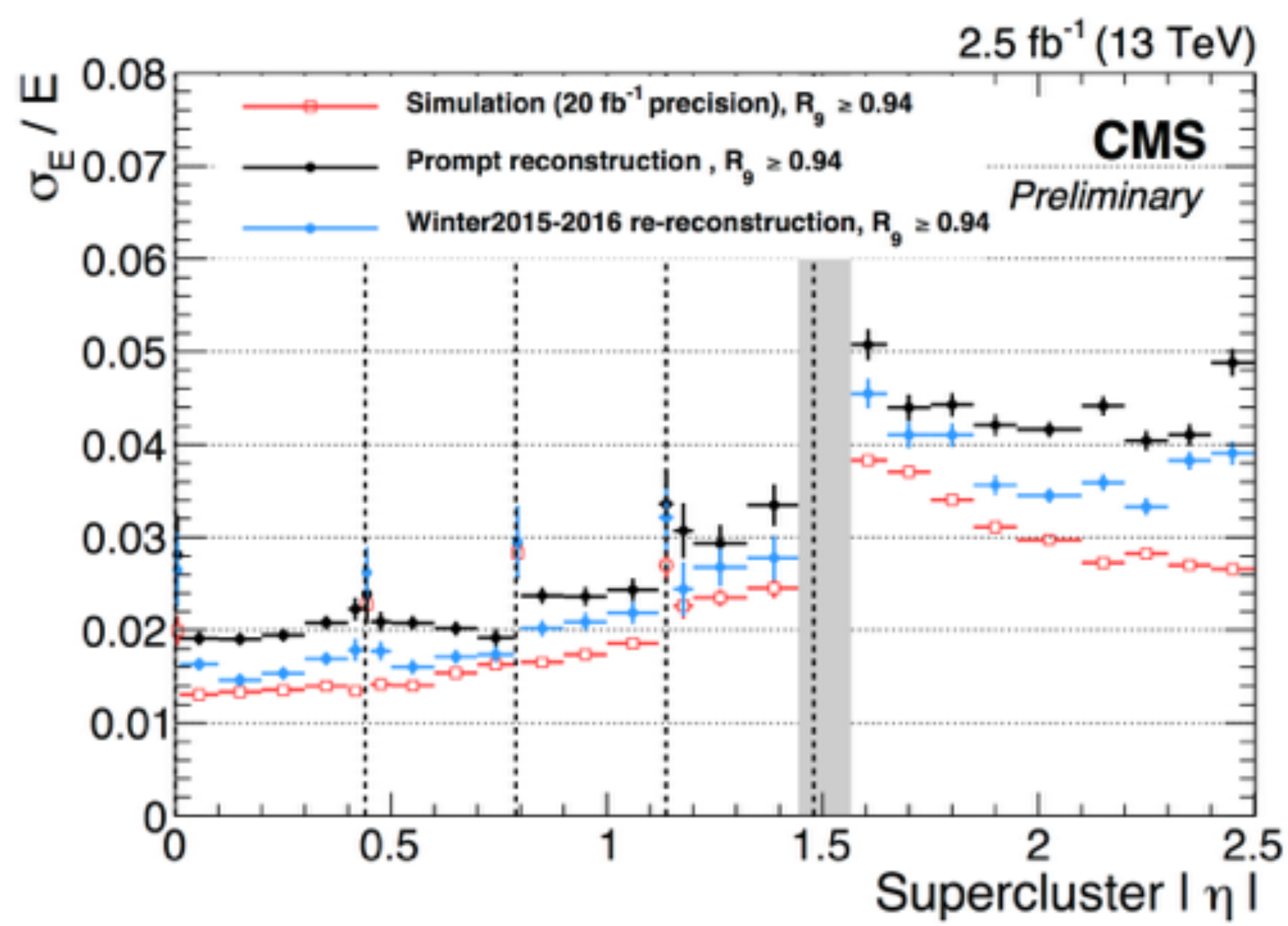


- Upgrades to forward inner CSC readout electronics
  - 48 strips —> 48 channels
  - **hit resolutions improves by 20% wrt Run I**

ECAL: excellent performance and stability



- Excellent **stability** of the response
  - energy compared to track momentum
  - electrons from Z→ee and W→eν



- Comparable energy resolution with respect to 2012 for low brem electrons:
  - **~1,5% resolution in central barrel**
  - new reconstruction algorithm to improve the **out of time pile up rejection** also at HLT

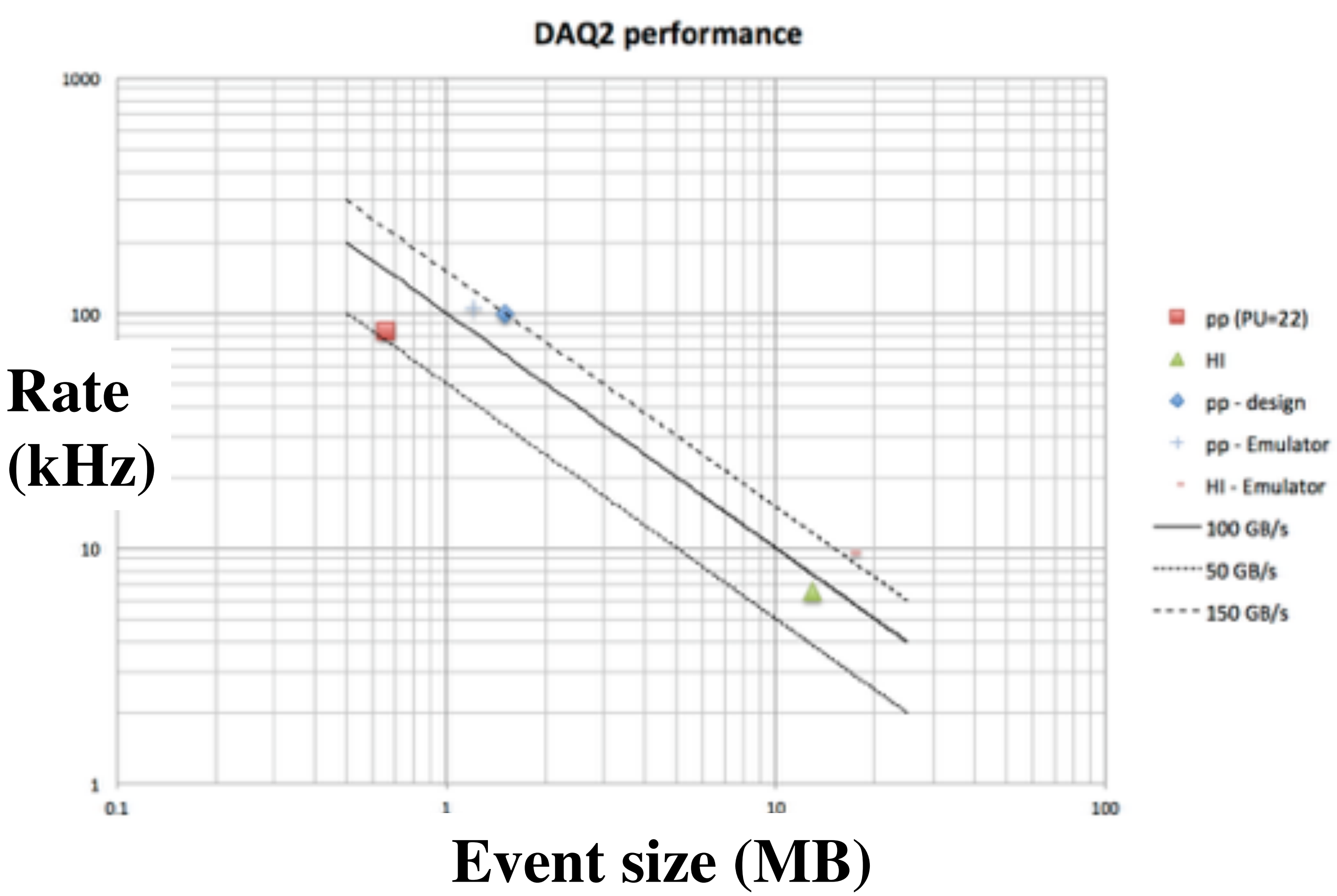
Consolidation & Upgrade for DAQ, Trigger, Monitoring and Computing systems

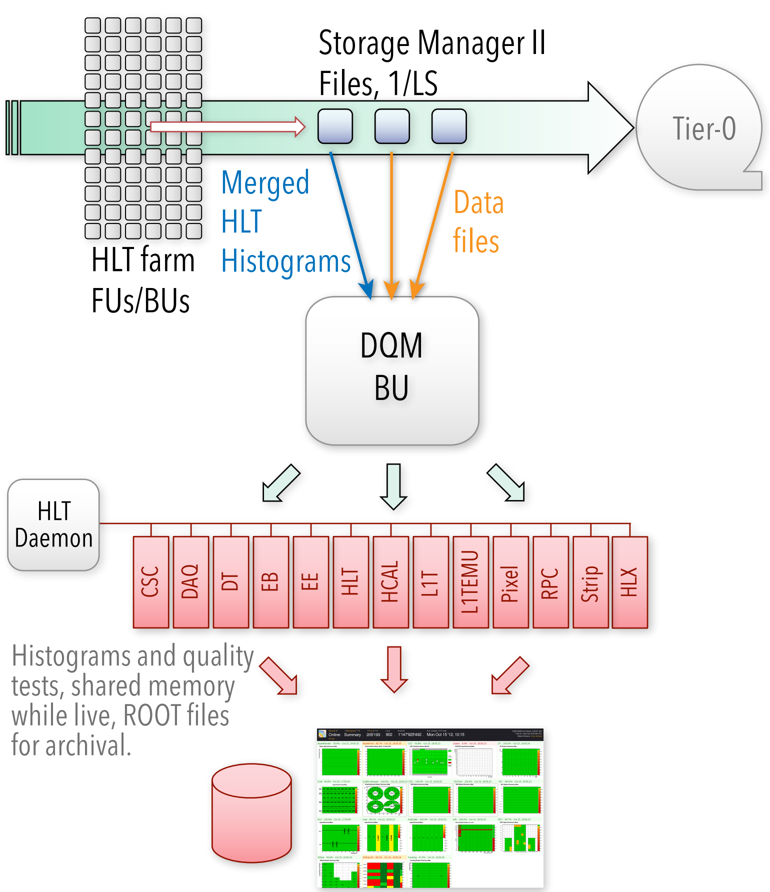
- Data acquisition (DAQ): new architecture, hardware, software
- Trigger Control and Distribution System (TCDS)
- New online data quality monitoring (DQM) system
- Level-1 trigger: new calorimeter trigger
- New online luminometers

Brand new DAQ and DQM systems are performing flawlessly

- New layout for DAQ2
  - increased **bandwidth** (200 GB/s)
  - new **machines** for filter farm
    - processing capacity of 200 ms/evt
  - **file based** approach
  - new **storage** system (350 TB)

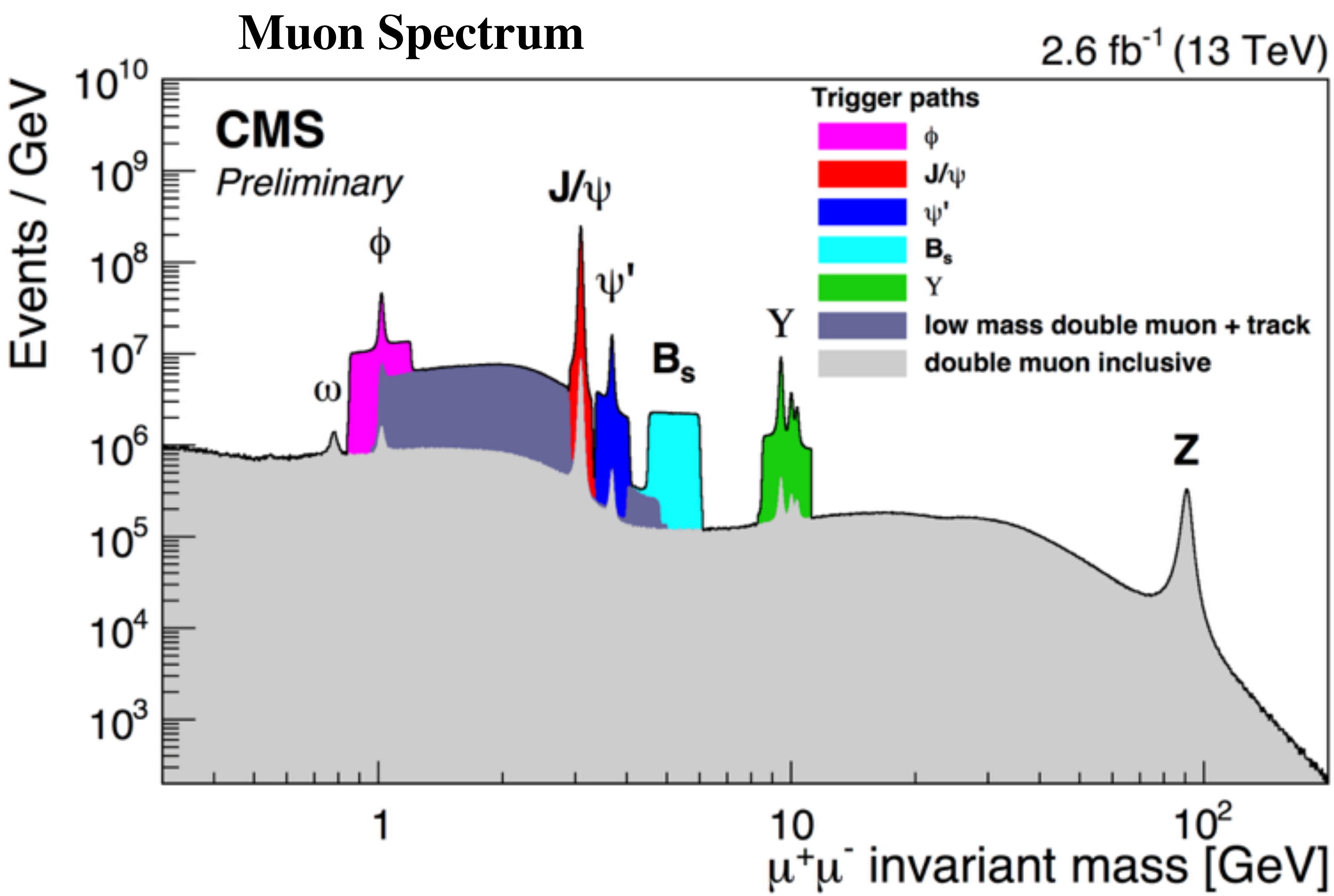
- Updated DQM framework
  - as effective as in Run1
  - **live monitoring** with little latency (~50s)
  - **high flexibility** for different applications





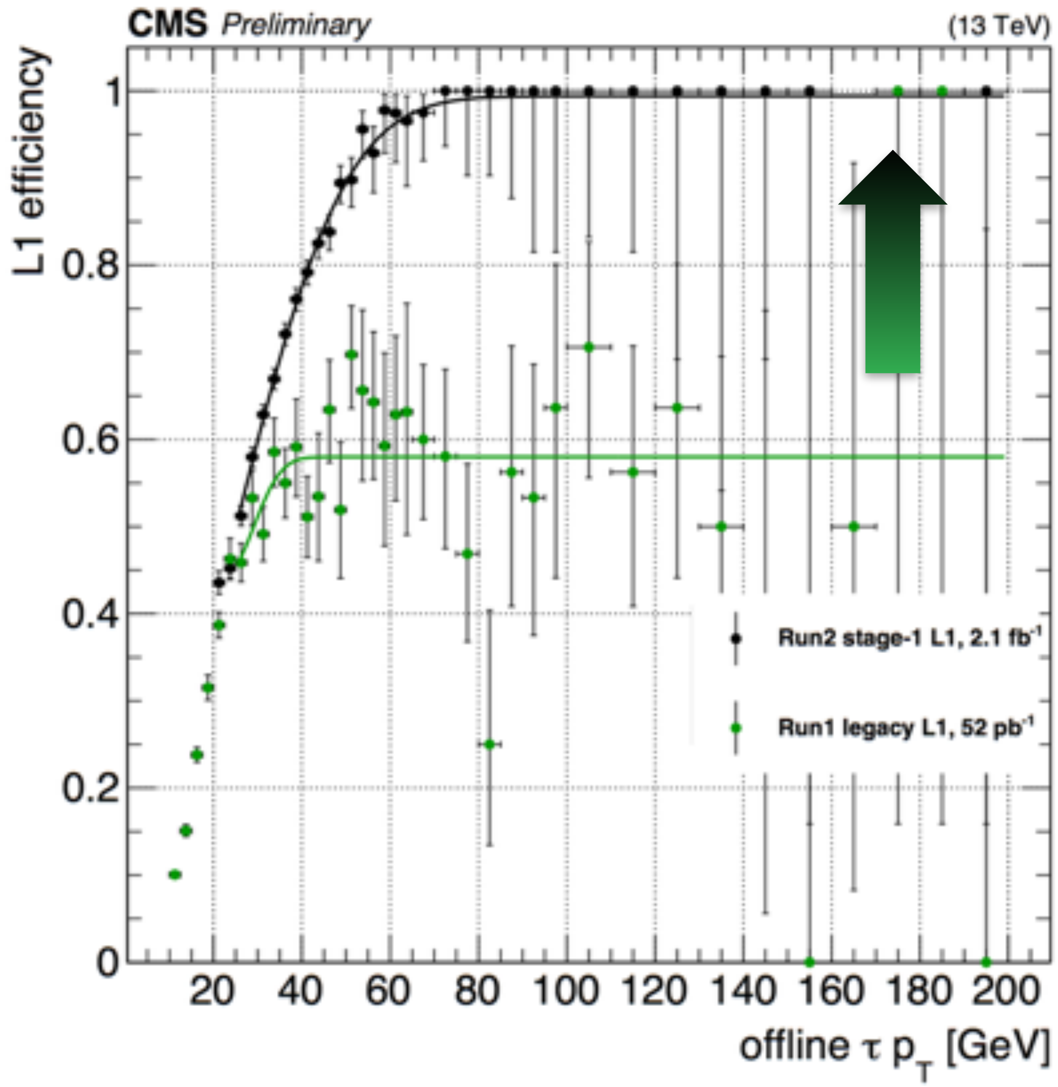
Trigger: what CMS can do exploiting 1kHz output rate

- **Flexible menu** with dedicated triggers capable of probing different regimes



Level 1 trigger: better tau trigger, PU subtraction for jets, isolation, energy sums

- L1 trigger upgrade for Run2 will complete in 2016
- Goal: control rates by **rejecting PU** and **keep low thresholds** at the same time
- New L1 single isolated Tau hadronic trigger efficiency pT > 28GeV compared to Run1 setup



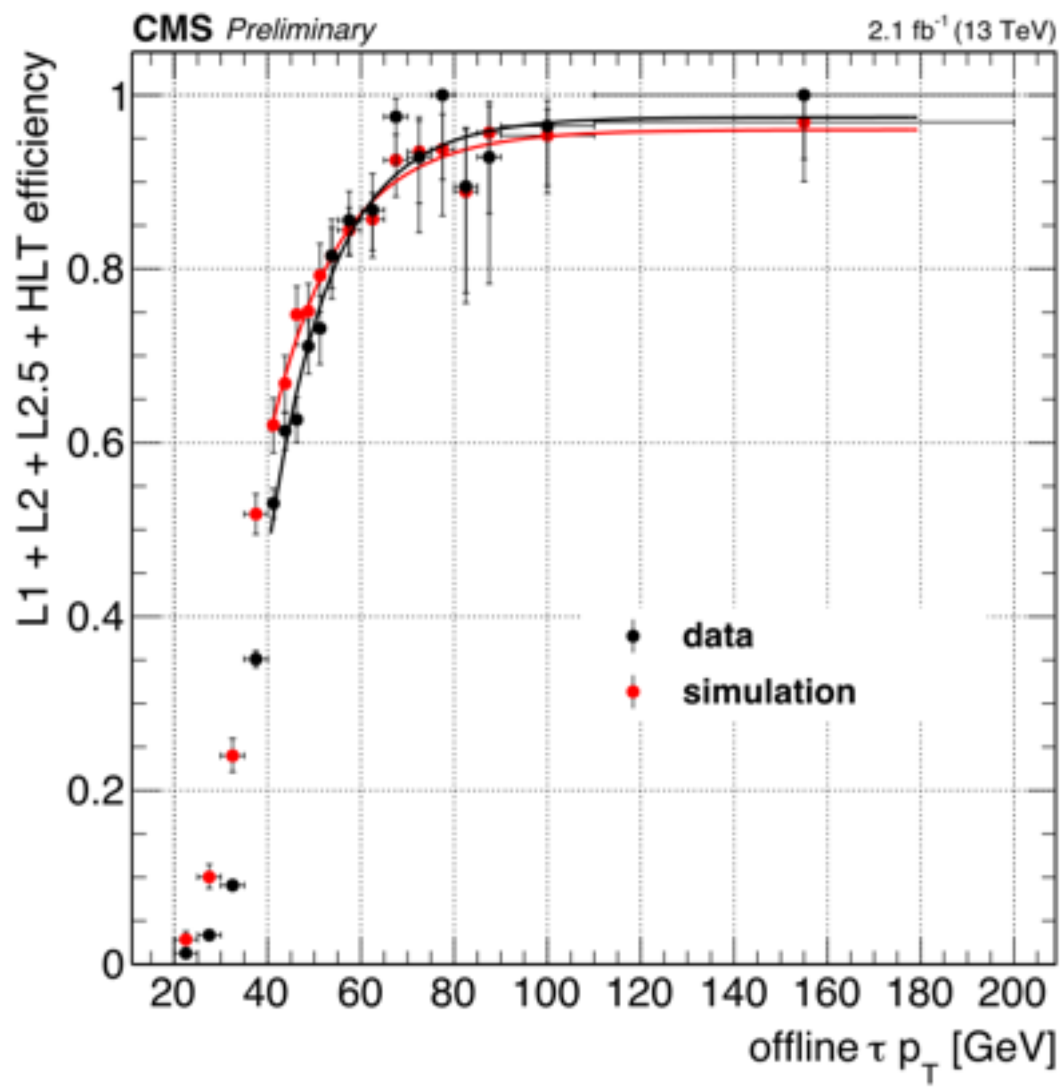
High Level Trigger: many different scenarios (50ns, 25ns, VdM, PbPb, pp-ref, …)

- Significant improvements in the **trigger algorithms** to handle increase in rate and PU

- **Multithread** validated and deployed online
  - offline like software on commercial CPUs is run

- Dedicated triggers for calibration/alignment and commissioning in general

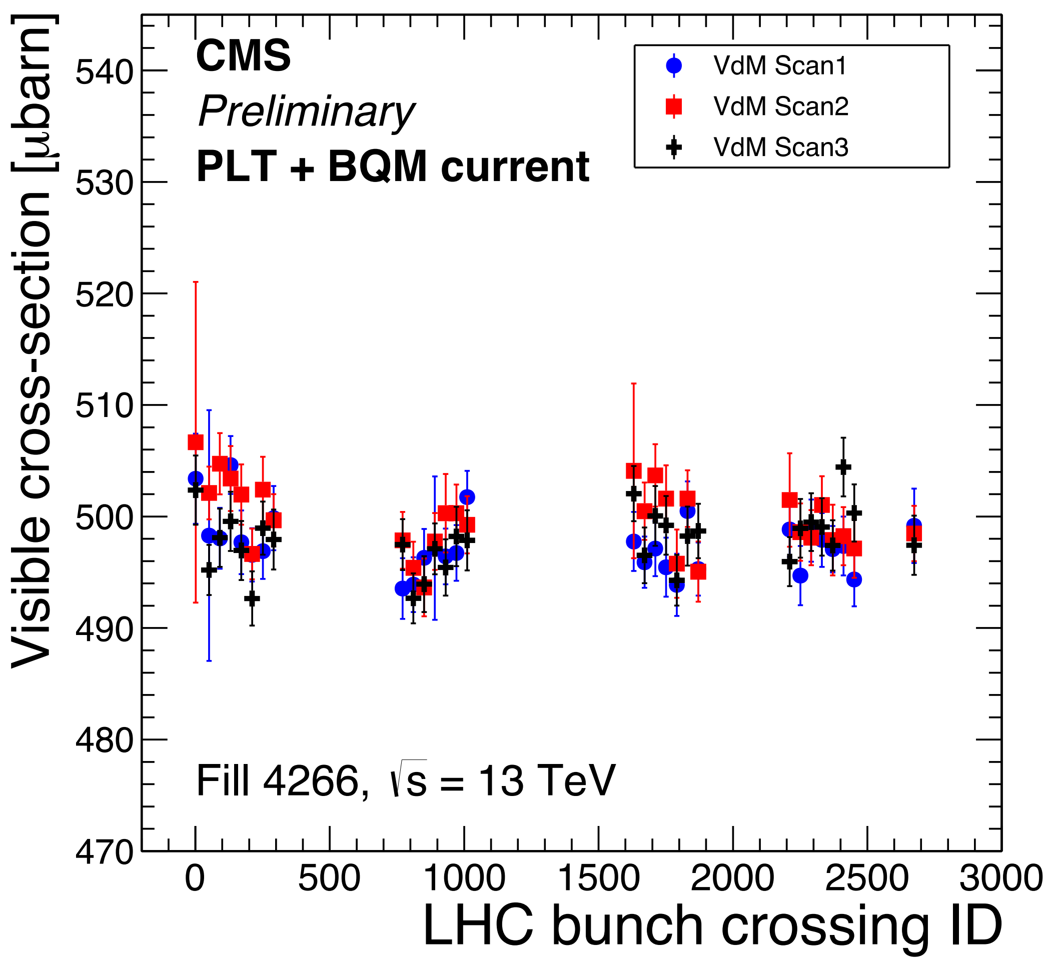
- **Accurate description** of the trigger **in MC** simulation



L1+HLT efficiency as a function of offline tau p_T for isolated double tau hadronic trigger with p_T > 35 GeV

Beam Monitor and Luminosity calibration: response of multiple detectors is used

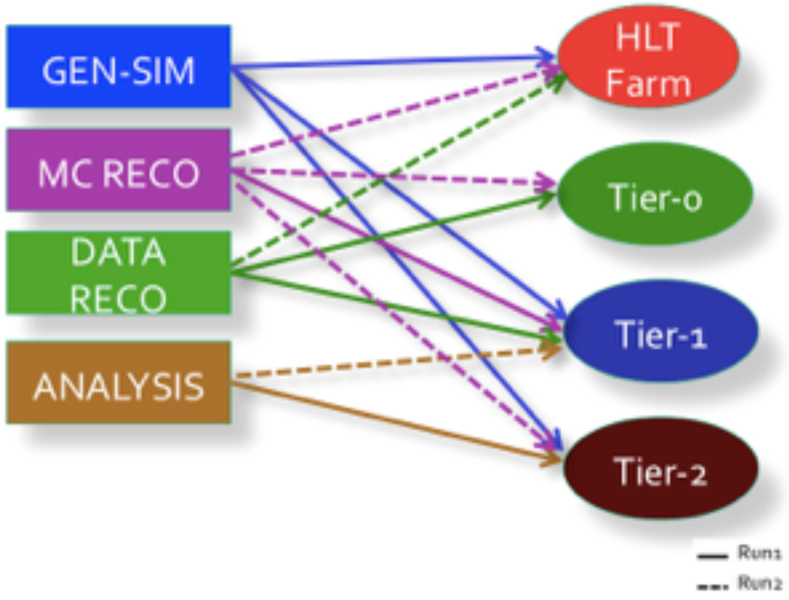
- CMS luminometers calibrated independently using the **Van der Meer** (VdM) scan technique
- **Multiple detectors** very useful to understand beam and detector systematics



Source	Uncertainty [%]
VDM calibration using fill 4266	
Uncertainty from VDM	2.6
PLT Related Systematics during 25 ns	
PLT Corrections, Deadtime etc.	2.4
Detector behavior during 25 ns	
Linearity and stability	3.0
TOTAL uncertainty (for 25 ns)	**4.6**

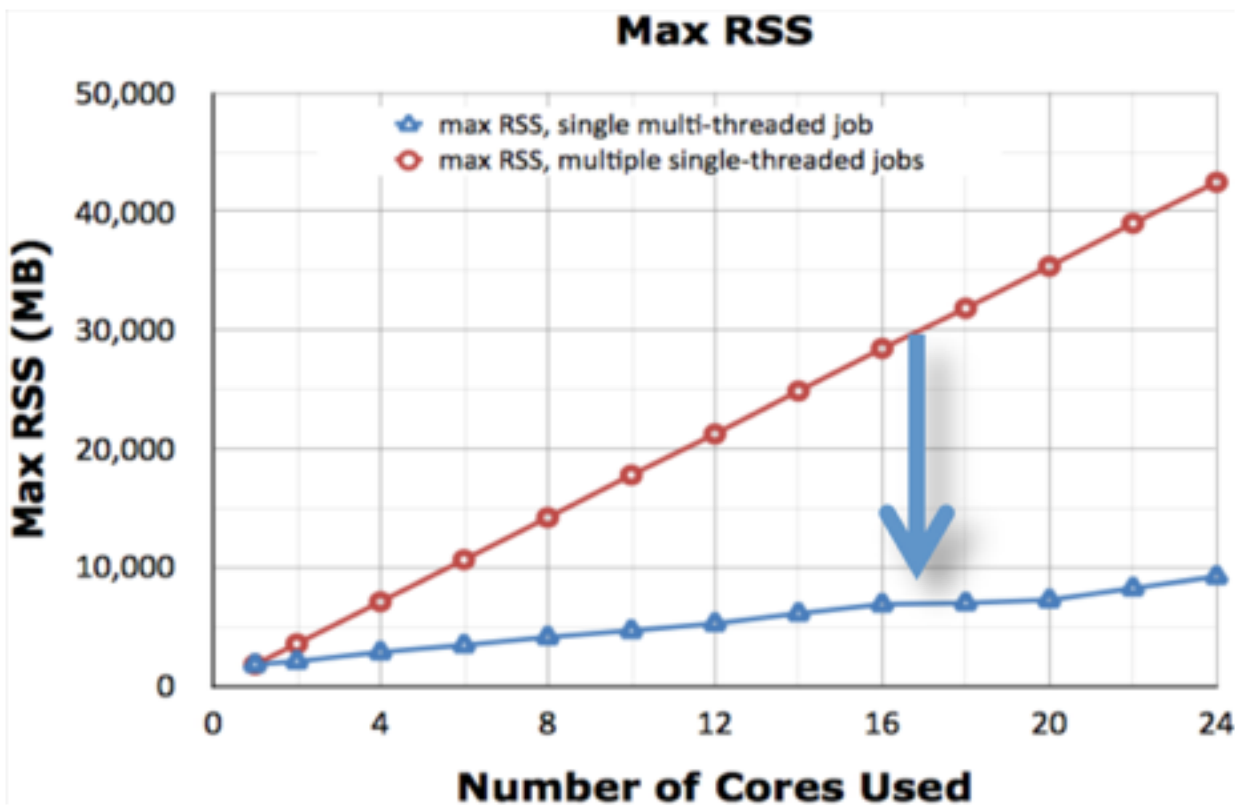
Offline and Computing: major improvements on multiple aspects

- **Global Pool** for resources provisioning
  - **Less Tier boundaries** in the Computing Model
  - Can operate all T1/T2/opportunistic resources in a single pool
  - **150kJobs** in parallel



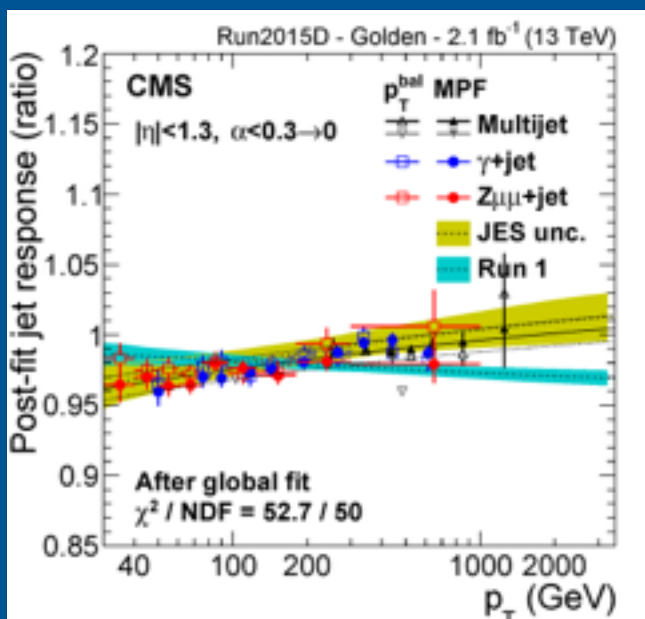
- **Multithread** deployed in prod
  - memory saving

- **Simulation improvements**
  - factor 2 speed up

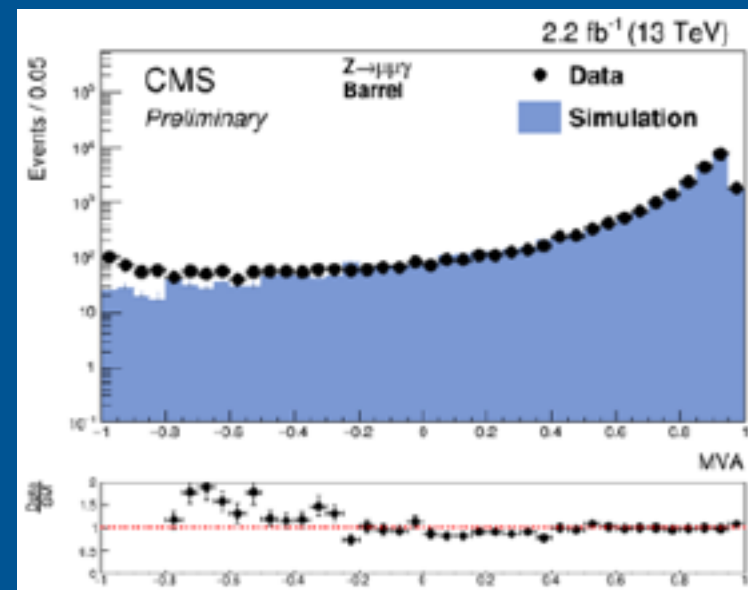


Physics objects @25ns: under control over many orders of magnitude

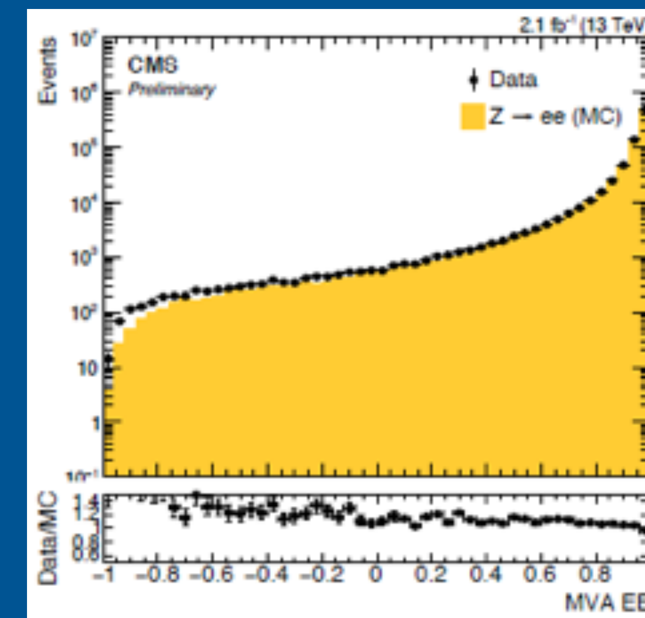
JES



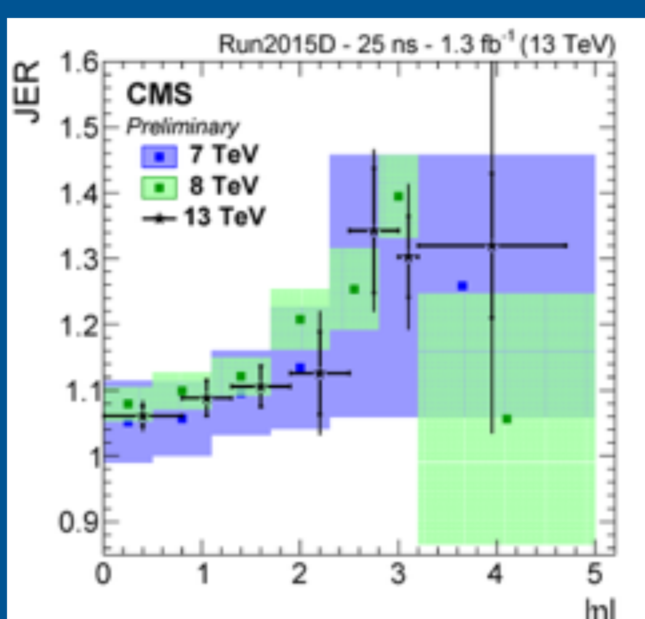
Photon



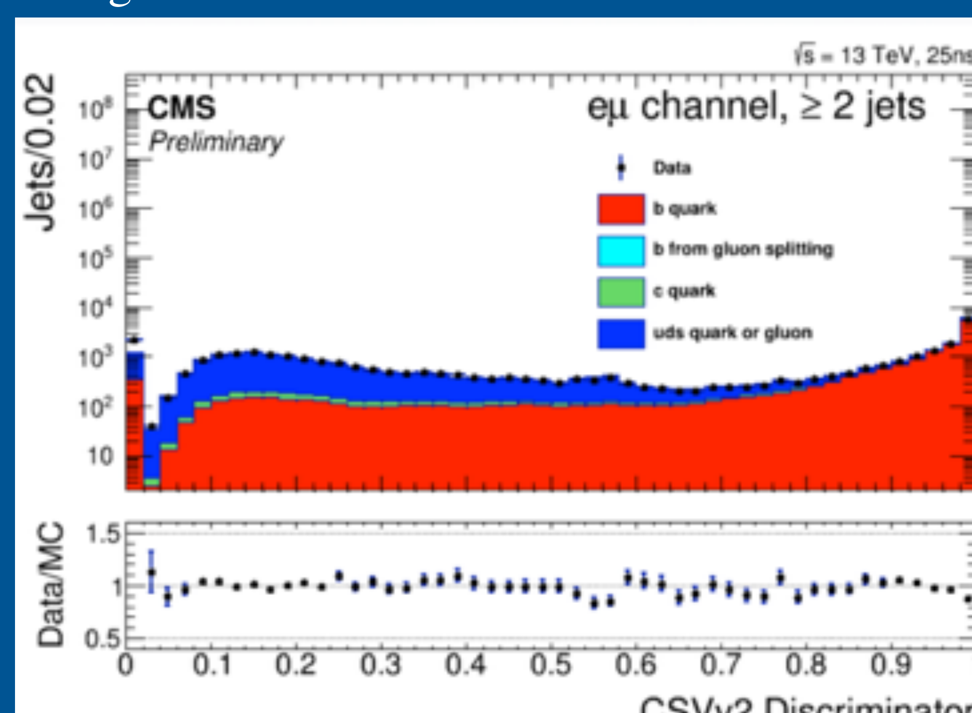
Electron



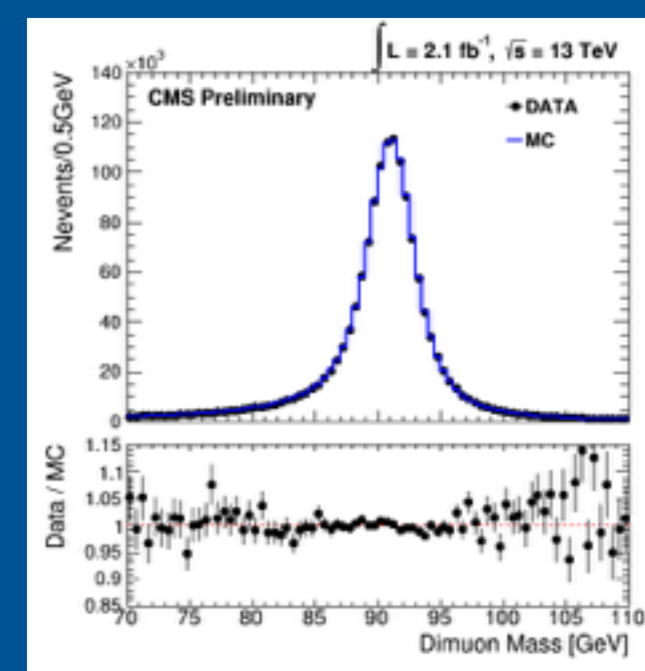
JER



b-tag

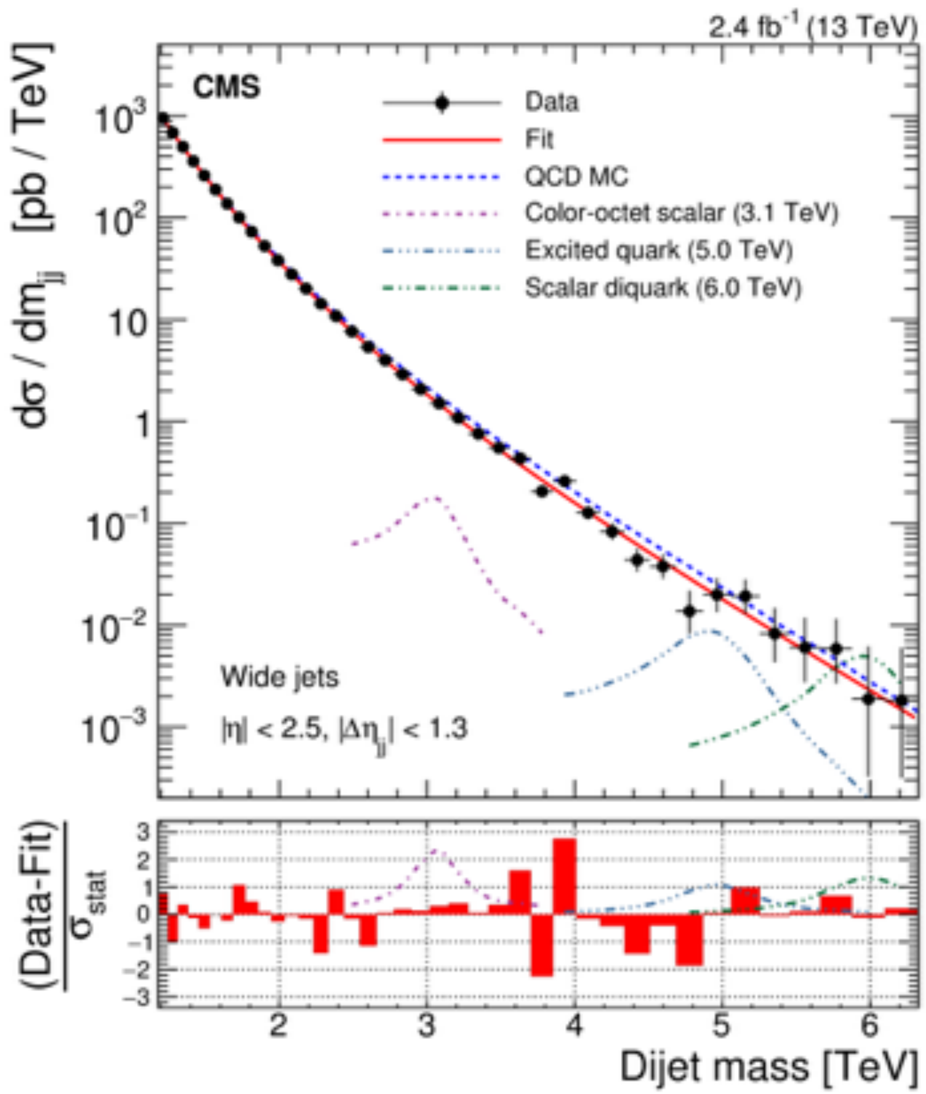


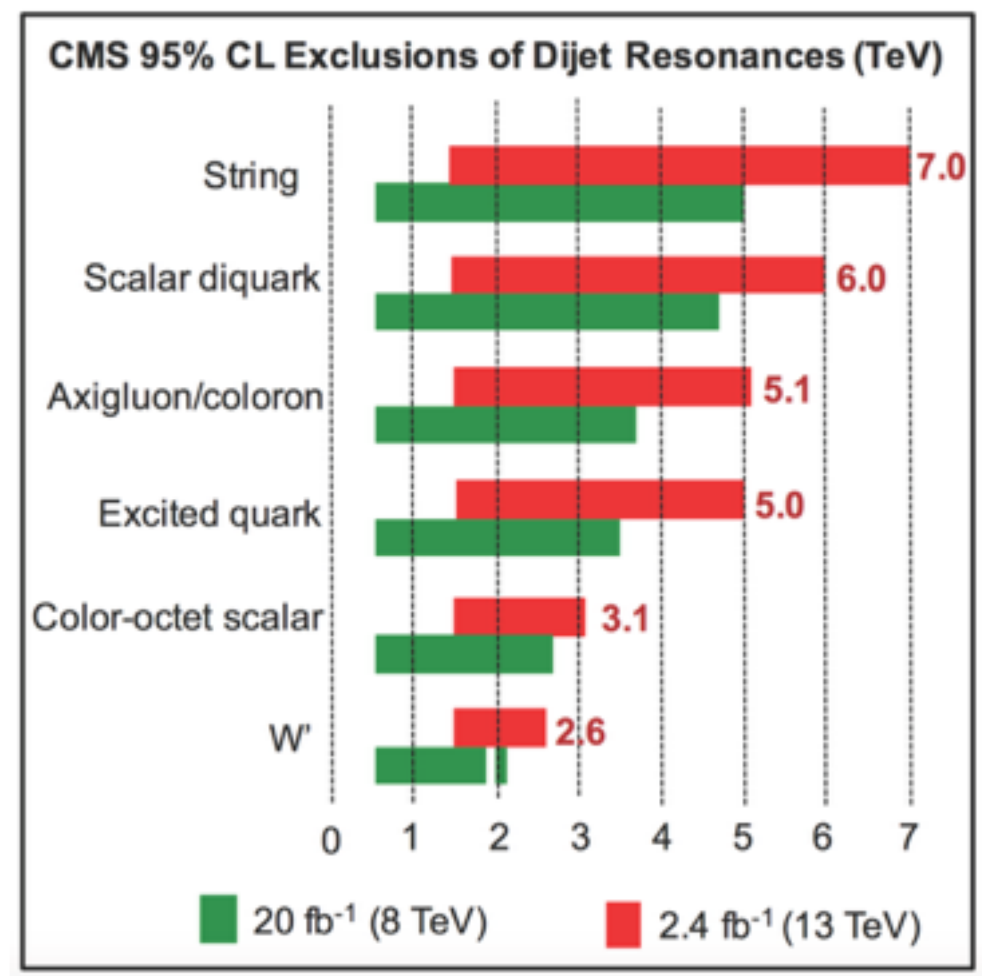
Z peak



One physics case: di-jet searches in Run2

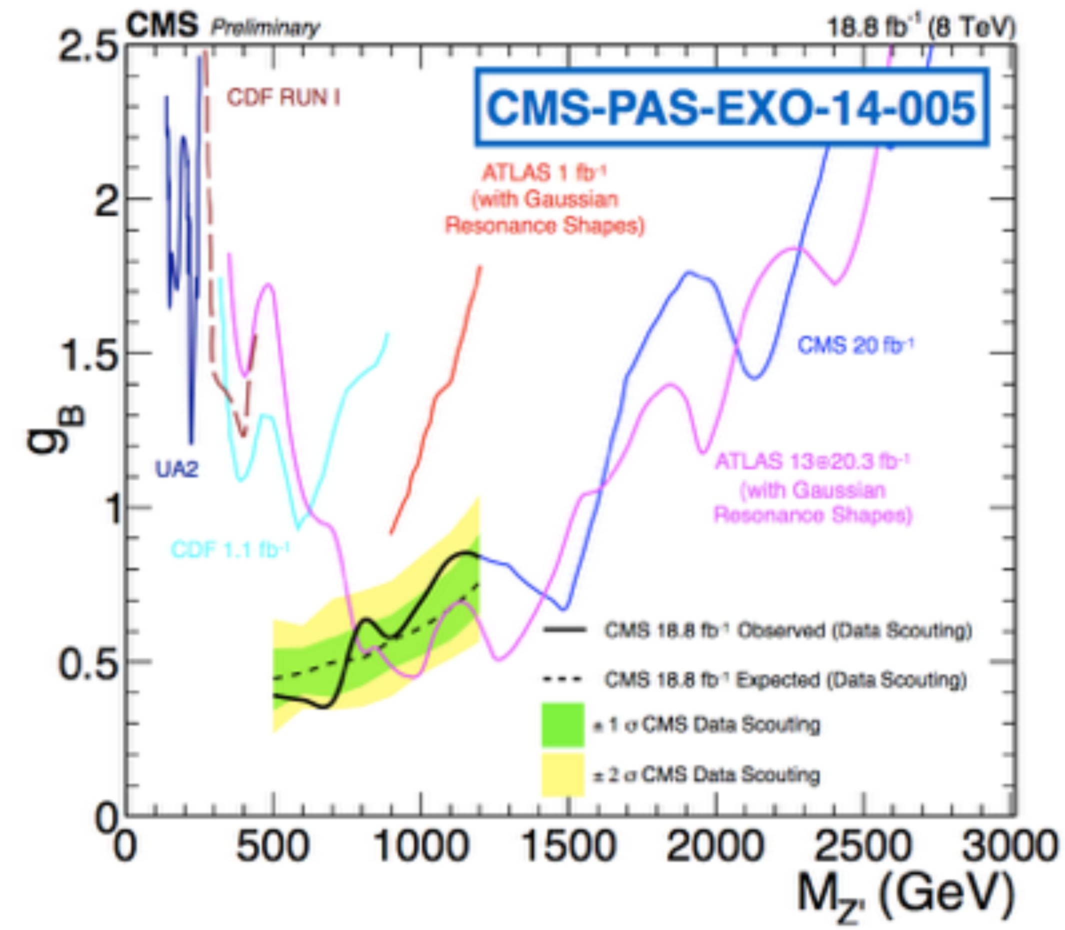
- No significant signals observed, **limits extend well beyond Run1** with 2.4/fb
- Benefits from **data scouting** at low masses (500-1200 GeV)



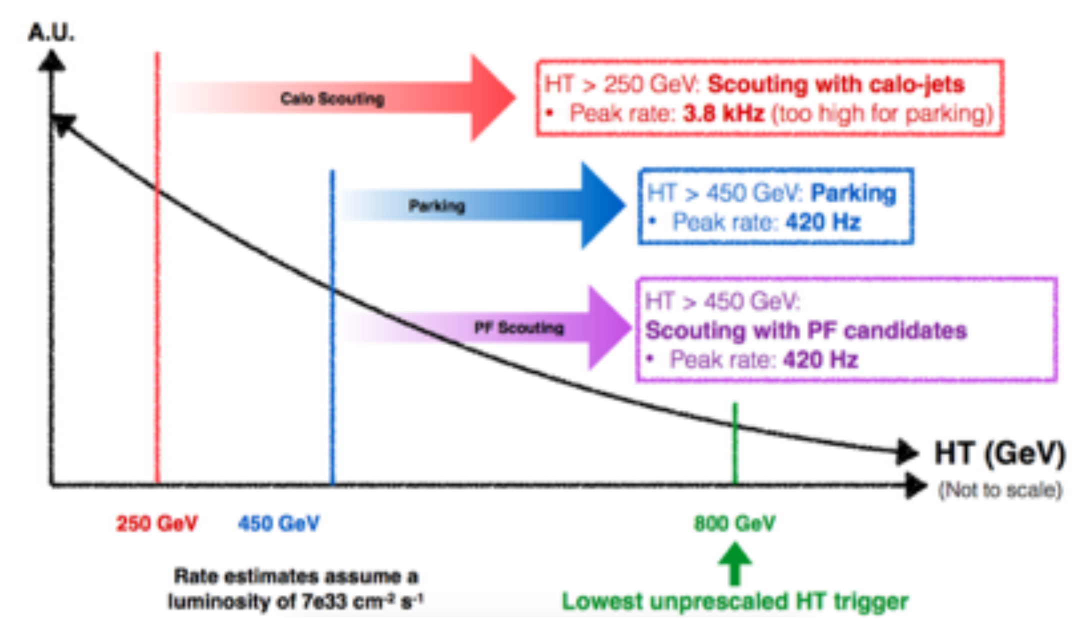


Data scouting: expanded strategy for Run2

- Data scouting in a nutshell
  - Physics objects reconstructed **online** at the HLT
  - HLT objects are saved in a minimal format: **small size, high rate**
  - No offline reco performed



- Expanded strategy for Run2
  - Run **Particle Flow Reco** online
  - **Parking** (on demand reco):
    - same events as PF scouting
    - full event information (~600 Hz available)



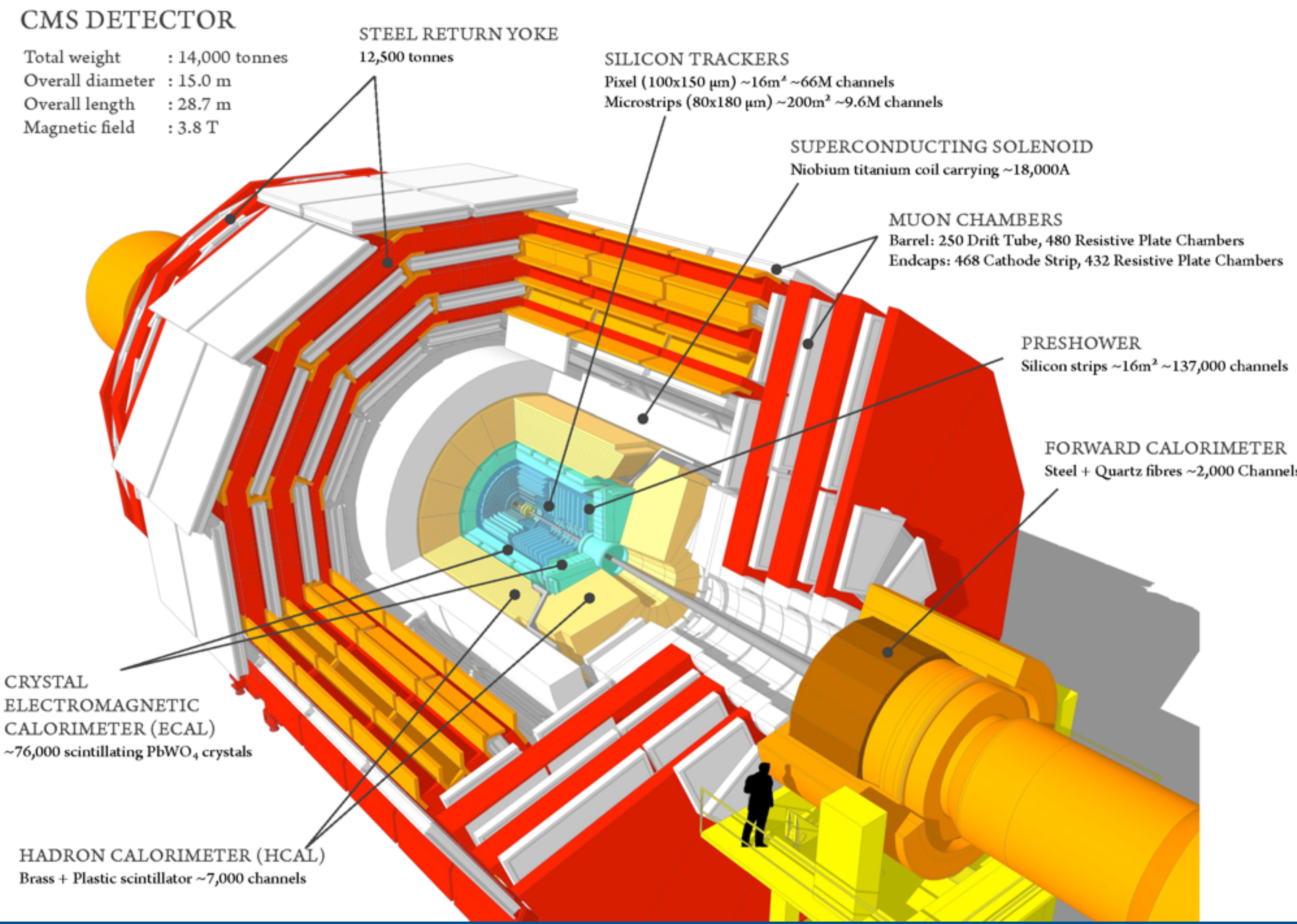
In summary: a successful recommissioning at all levels of a ~new detector

- A new exciting data taking period has just started not without surprises

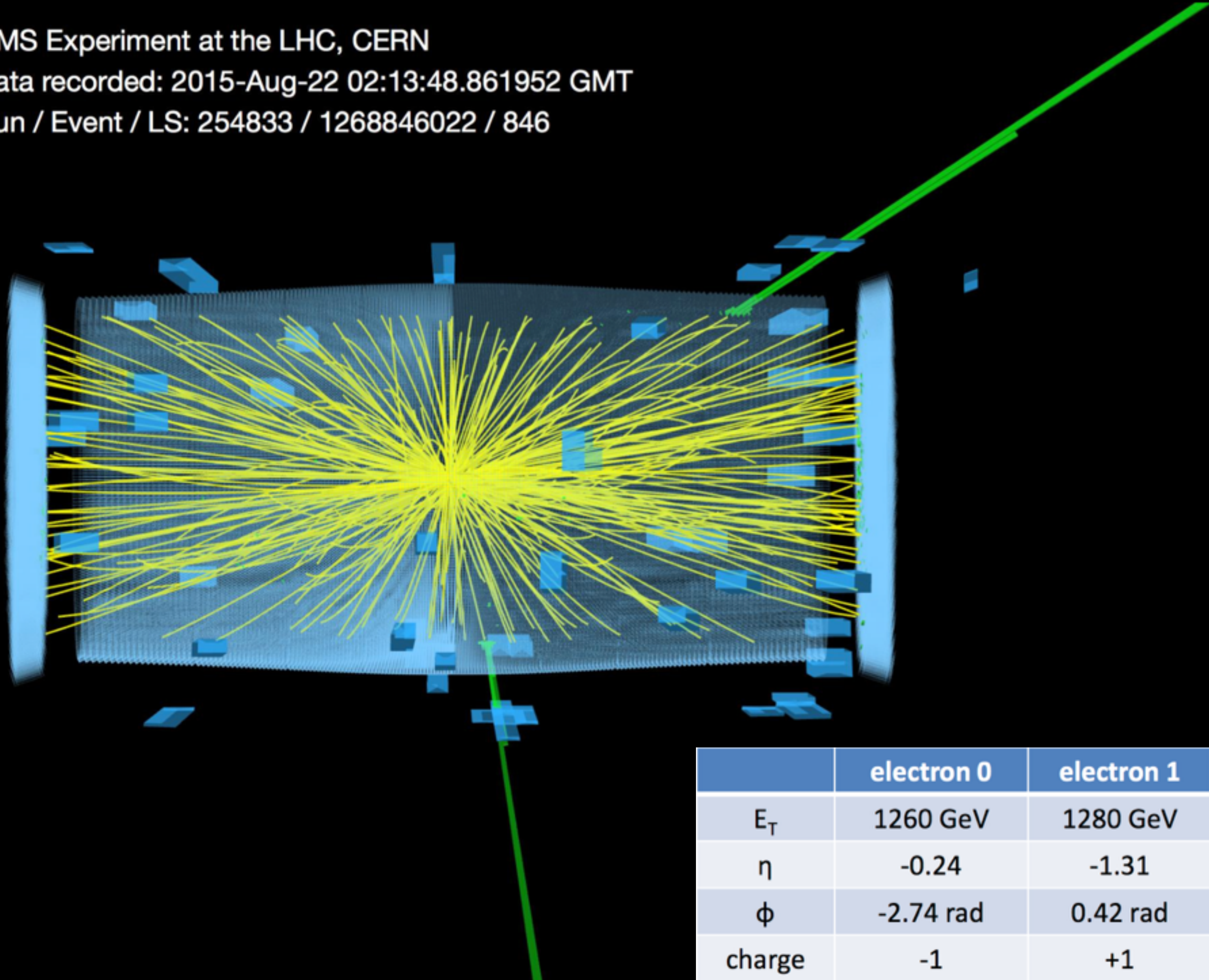
- Up-time of the CMS magnet was the main limitation in 2015, but didn't prevent the publication of many physics results
  - 33 public results from Run2

- Many improvements in place to cope with new conditions:
  - able to acquire data at higher rates
  - event reconstruction robust against 25 ns pipe-up conditions

Additional material

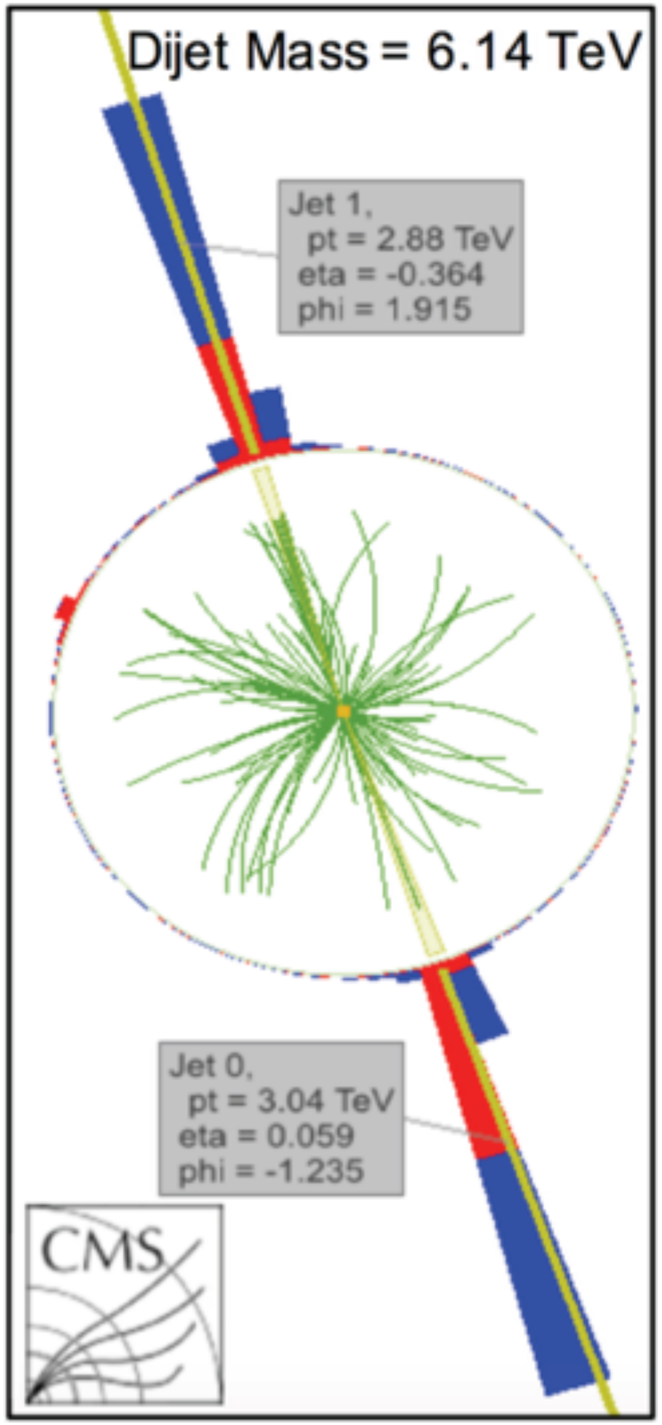

CMS DETECTOR
Total weight : 14,000 tonnes
Overall diameter : 15.0 m
Overall length : 28.7 m
Magnetic field : 3.8 T
STEEL RETURN YOKE
12,500 tonnes
SILICON TRACKERS
Pixel (100x150 μm) ~16m² ~66M channels
Microstrips (80x180 μm) ~200m² ~9.6M channels
SUPERCONDUCTING SOLENOID
Niobium titanium coil carrying ~18,000A
MUON CHAMBERS
Barrel: 250 Drift Tube, 480 Resistive Plate Chambers
Endcaps: 468 Cathode Strip, 432 Resistive Plate Chambers
PRESHOWER
Silicon strips ~16m² ~137,000 channels
FORWARD CALORIMETER
Steel + Quartz fibres ~2,000 Channels
CRYSTAL ELECTROMAGNETIC CALORIMETER (ECAL)
~76,000 scintillating PbWO4 crystals
HADRON CALORIMETER (HCAL)
Brass + Plastic scintillator ~7,000 channels

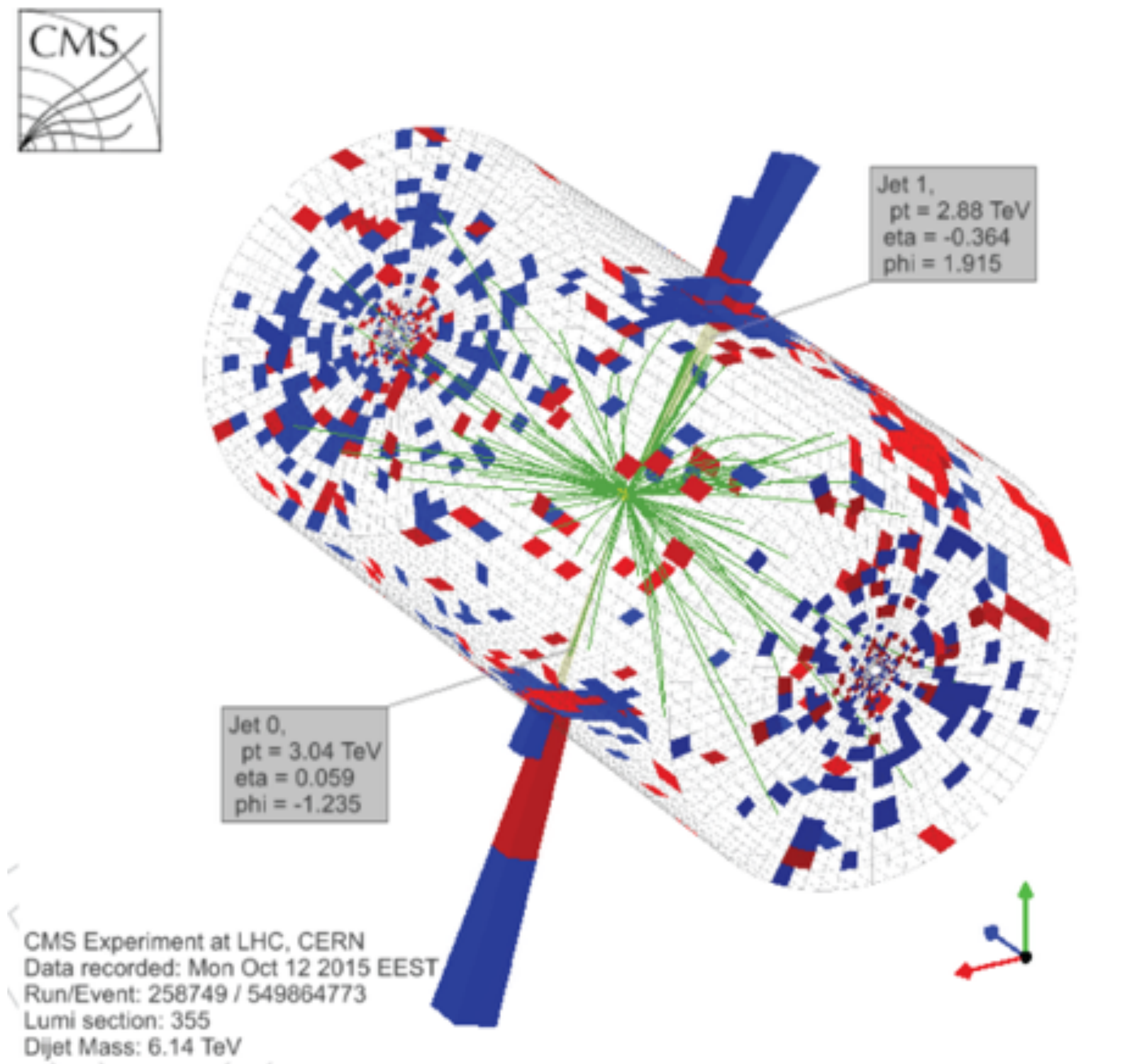
CMS Experiment at the LHC, CERN
Data recorded: 2015-Aug-22 02:13:48.861952 GMT
Run / Event / LS: 254833 / 1268846022 / 846



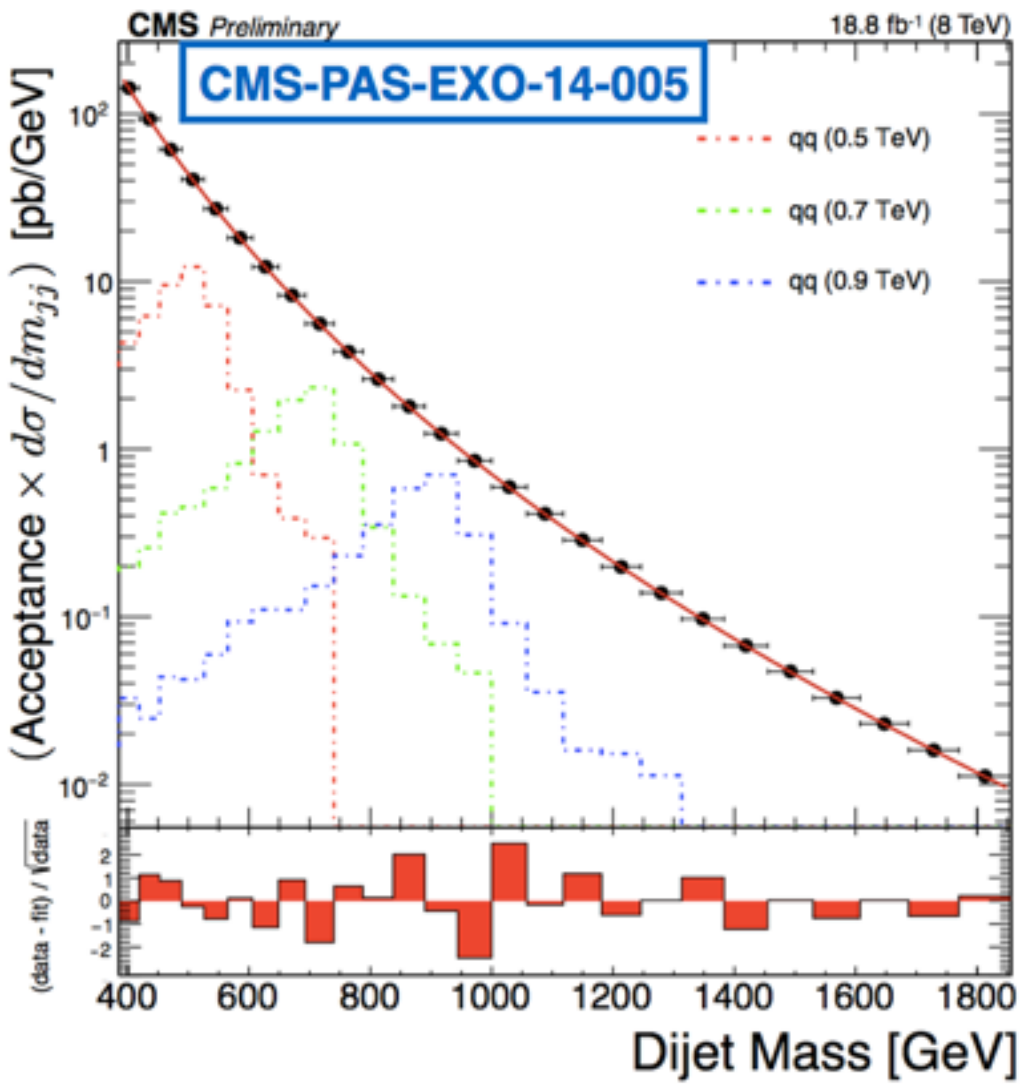
	electron 0	electron 1
E_T	1260 GeV	1280 GeV
η	-0.24	-1.31
ϕ	-2.74 rad	0.42 rad
charge	-1	+1
mass	2.91 TeV	

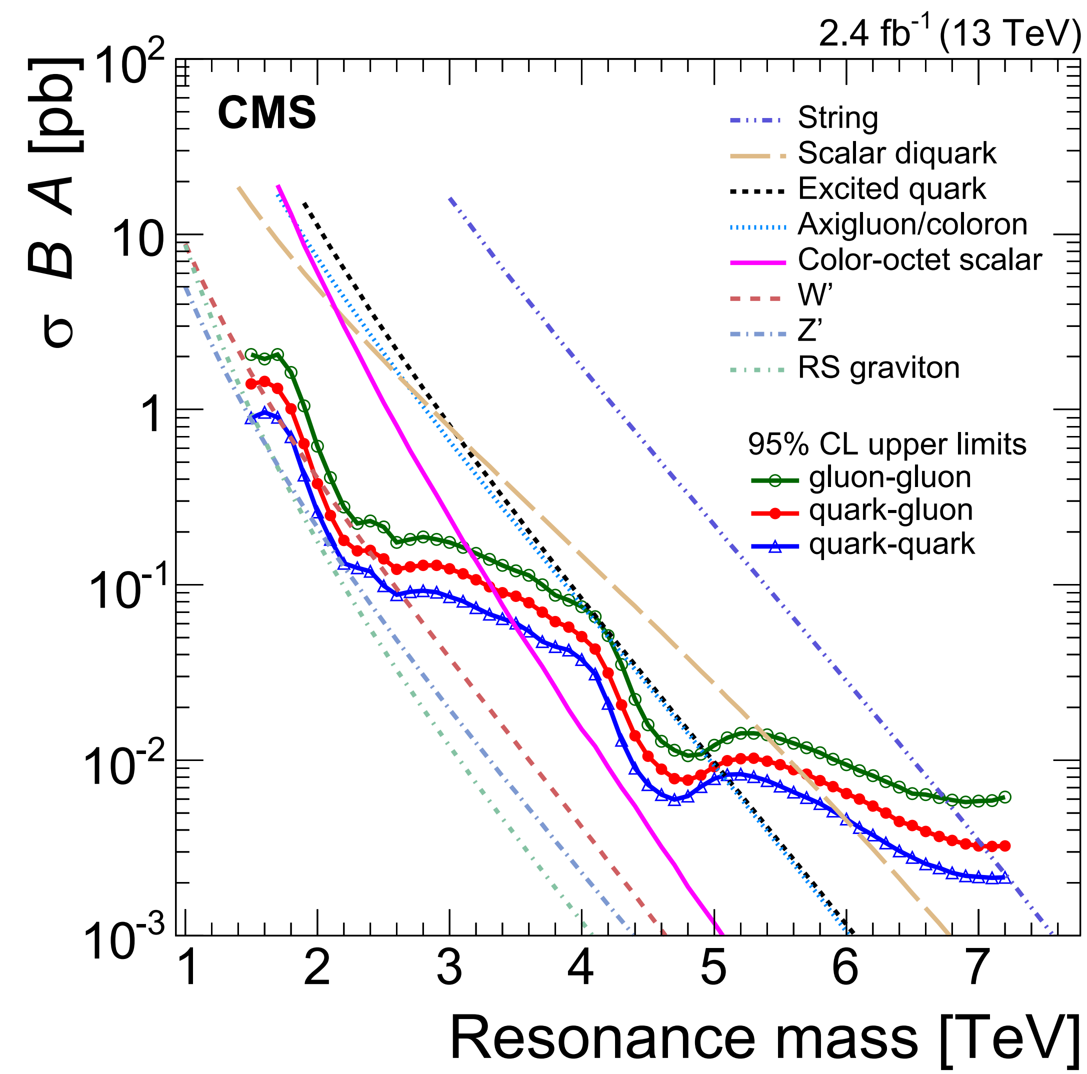
Highest mass di-jet event: 6.14 TeV



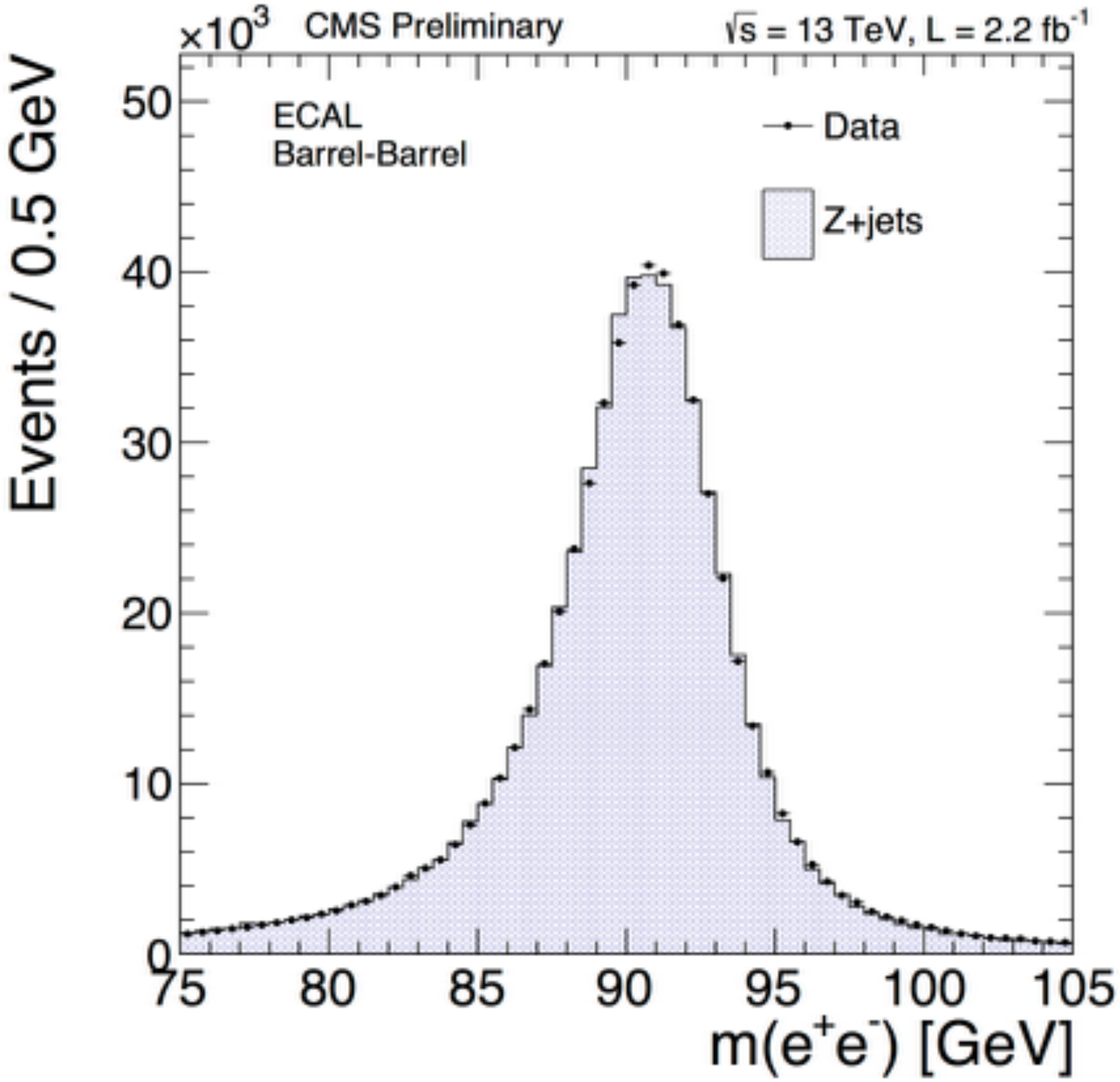


Di-jet run1 results

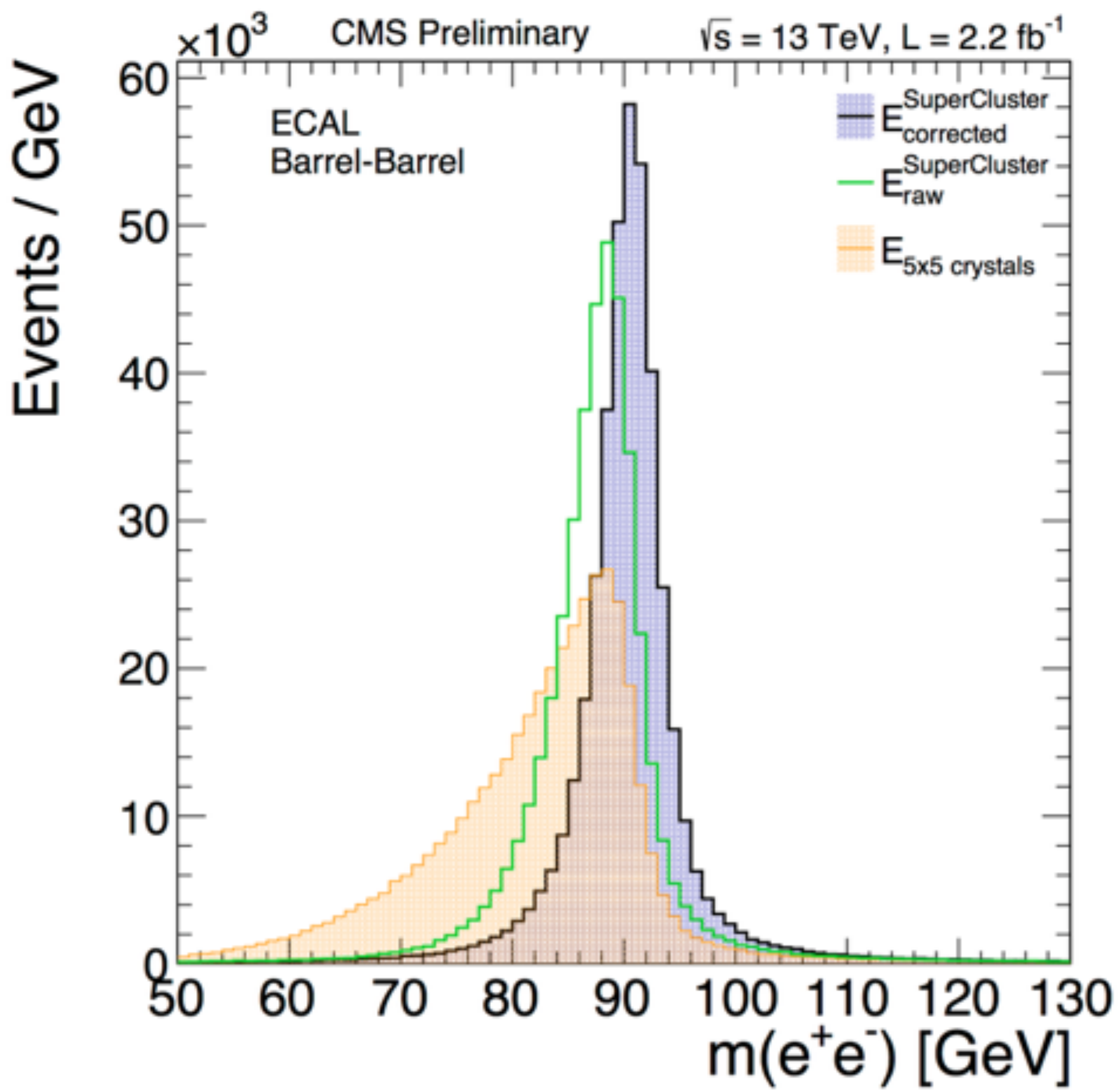




ECAL



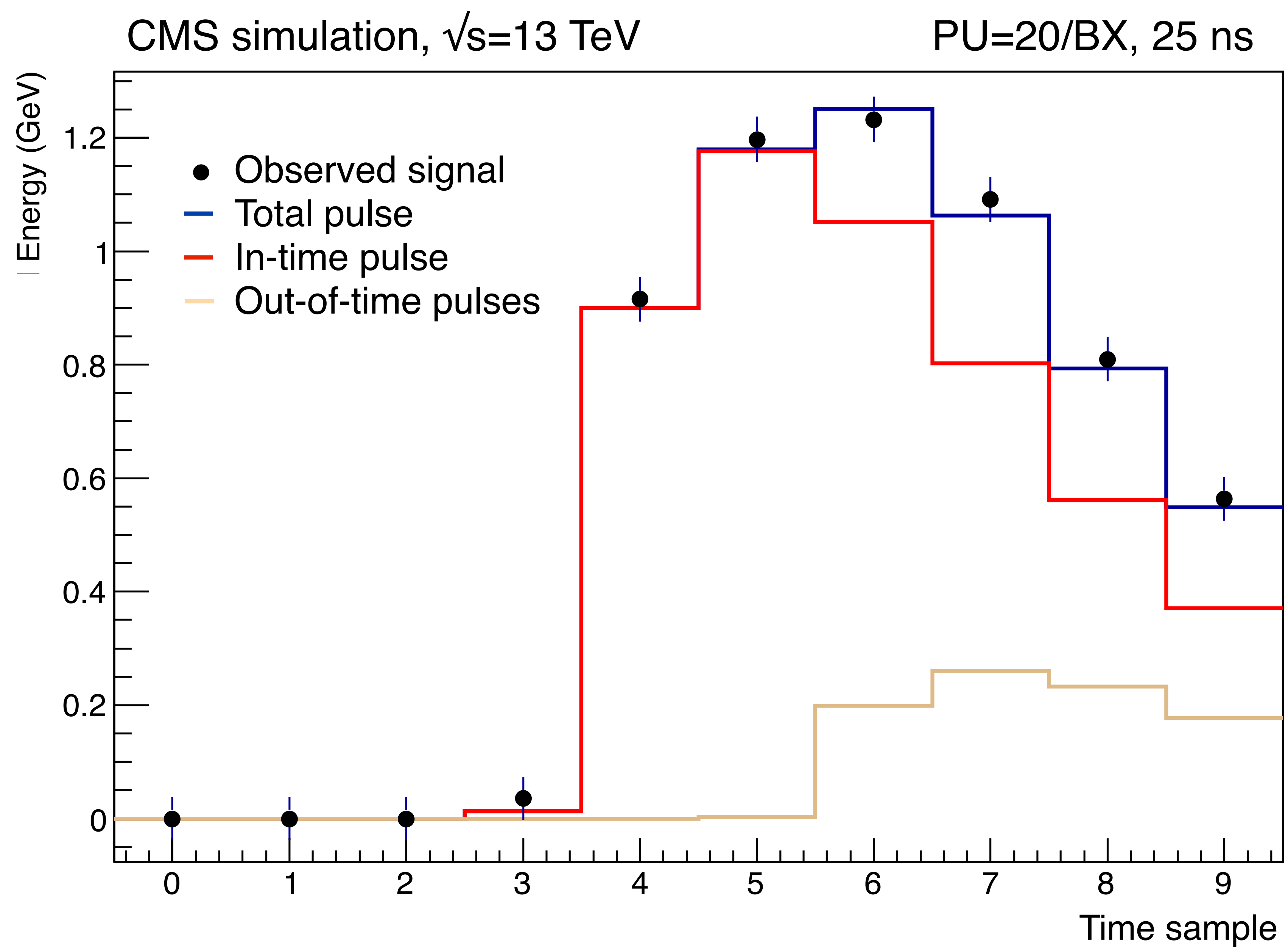
- Data-MC comparison on the Z peak



- Effect of clustering and cluster correction algos on the Z peak

ECAL

- Ecal Multi-fit algorithm very effective for OOT PU mitigation



HCAL new systems

- new HF PhotoMultiplier Tubes PMTs
  - in Run 1 we had R7525 Hamamatsu PMTs. Now we have R7600 PMTs, replaced during LS1. They have doubled QE and have a thinner window. Thinner window allows to have decrease the pre-firing rate from Cherenkov Hits. Muons producing Cherenkov when passing thru the cathode window.
  - HPD -> SiPMs for Hadron Outer. SiPMs don’t care about B field and have smaller size.

- HF Back End VME -> uTCA
  - http://cmsdoc.cern.ch/cms/HCAL/document/uTCA/uHTR/
  - http://cmsdoc.cern.ch/cms/HCAL/document/uTCA/
  - In short: more speed, more throughput, increased the #channels + optical readout + read out time information.

Recall of L1 legacy trigger (Run1)

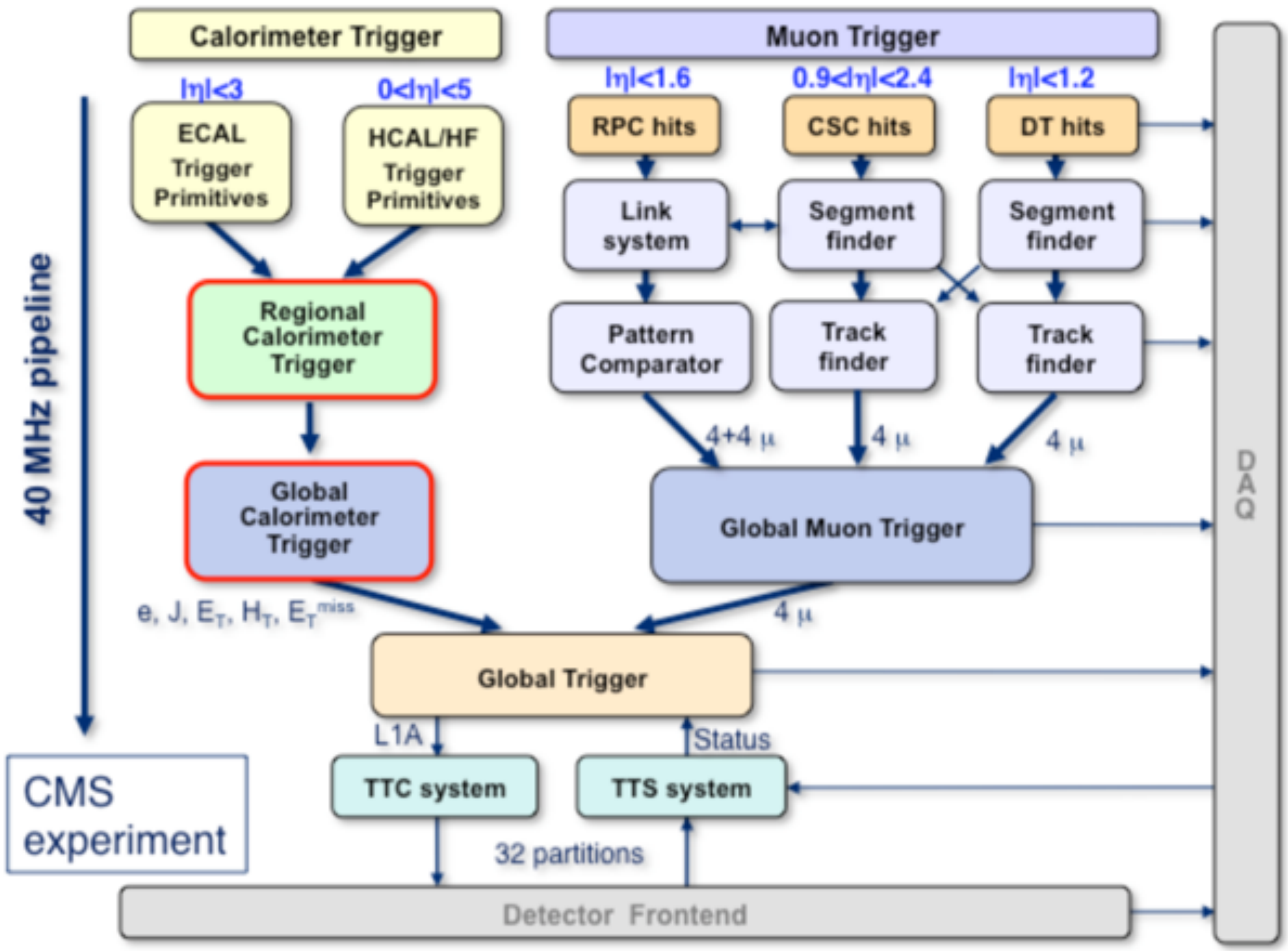
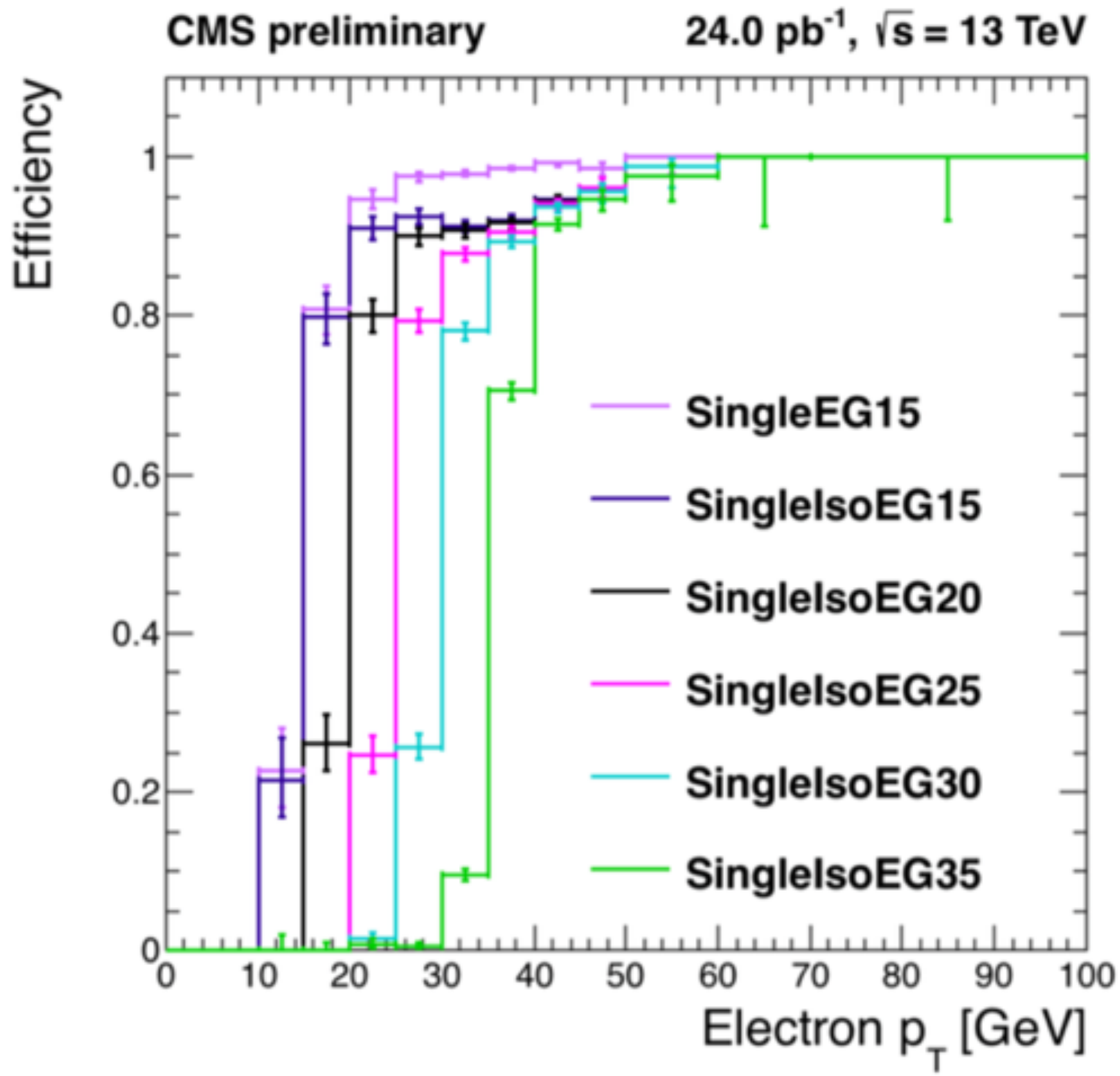


Fig. 1. A block diagram of the CMS Trigger used during LHC Run 1. Calorimeter, muon, and beam monitoring (not shown) are part of the decision making tree. Upgrades to all the trigger sub-systems are underway. The calorimeter portion is on the left hand side of the diagram.

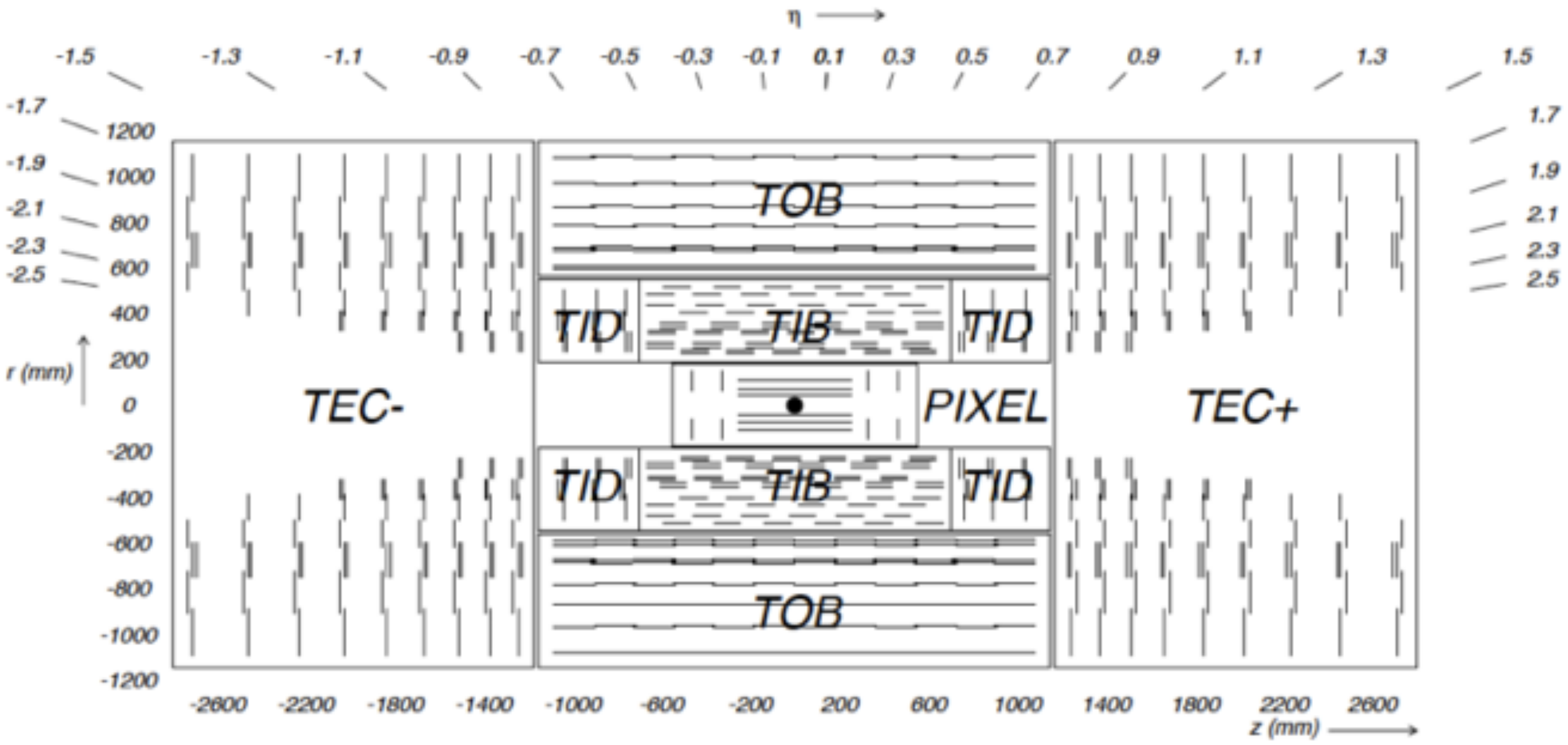
L1 e/gamma trigger efficiency VS reconstructed Pt

- Isolation reduces the rates significantly with only a small drop in efficiency

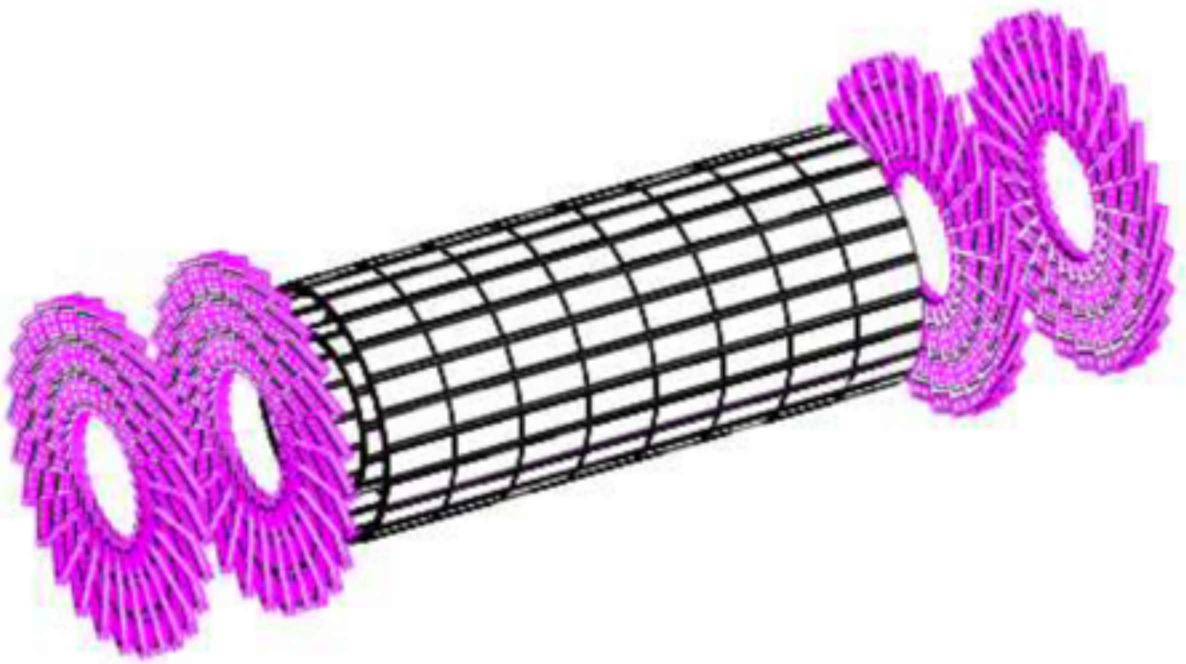
Isolated and non-isolated EGamma trigger efficiency as a function of offline p_T, for a range of thresholds, estimated from a sample of $Z \rightarrow ee$ events.



Tracker layout



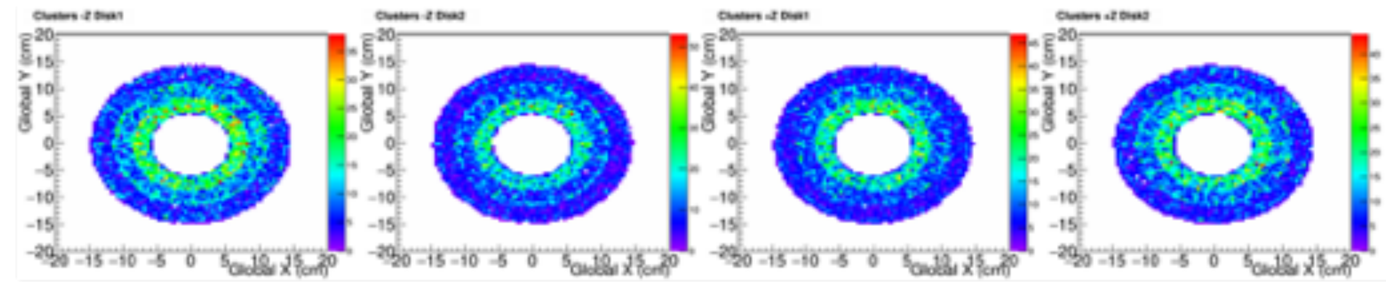
- Pixel + SiStrip

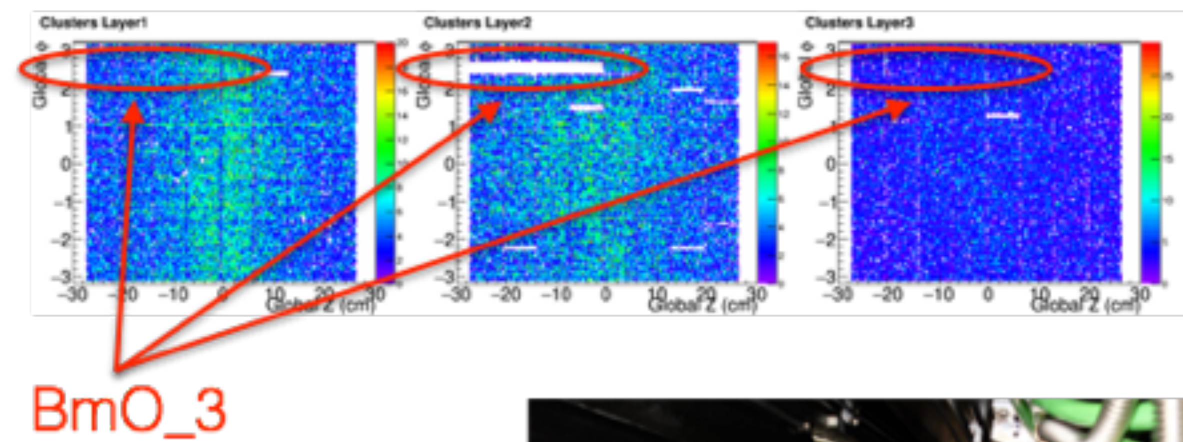


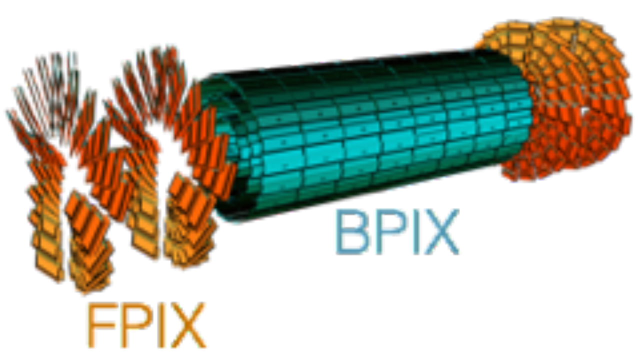
- Pixel

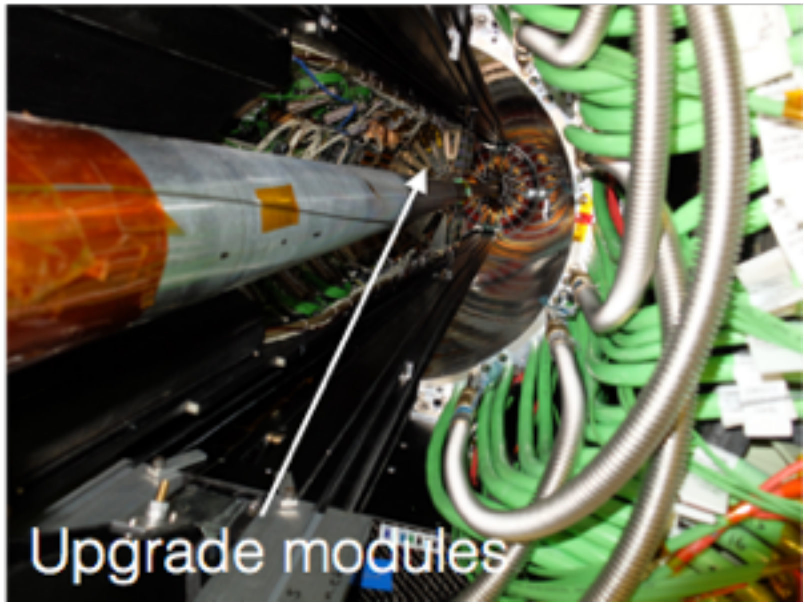
Pixel Tracker Operations

- Excellent performance at -10 degrees throughout 2015
- Pixel sector problem limited to only 1 layer out of 3
  - Small effect on track seeding and b-tagging and will be taken into account in MC
- Exercise of reading out prototype Phase I upgrade modules installed in FPIX has contributed to upgrade firmware development



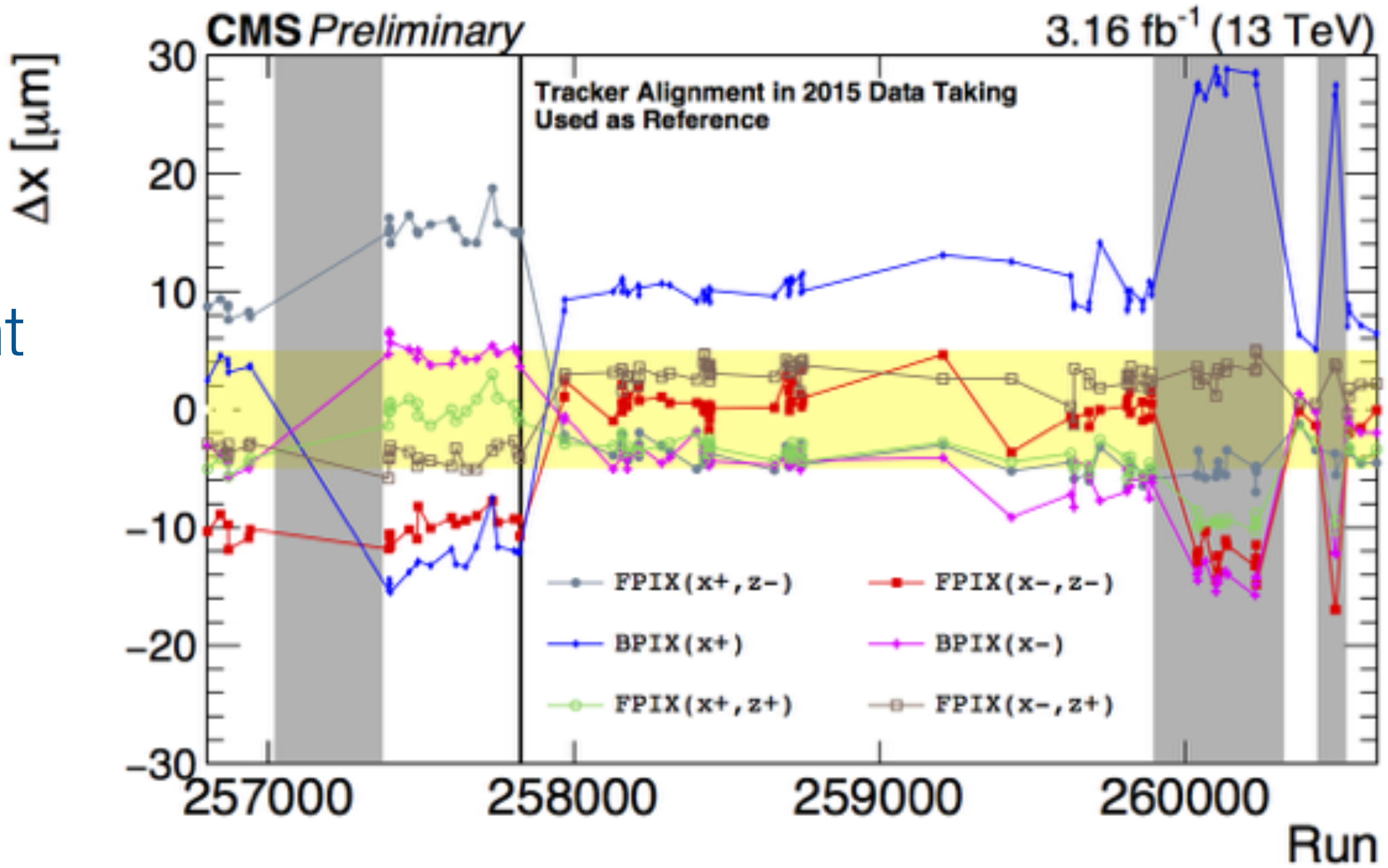






Interplay between magnet and tracker alignment

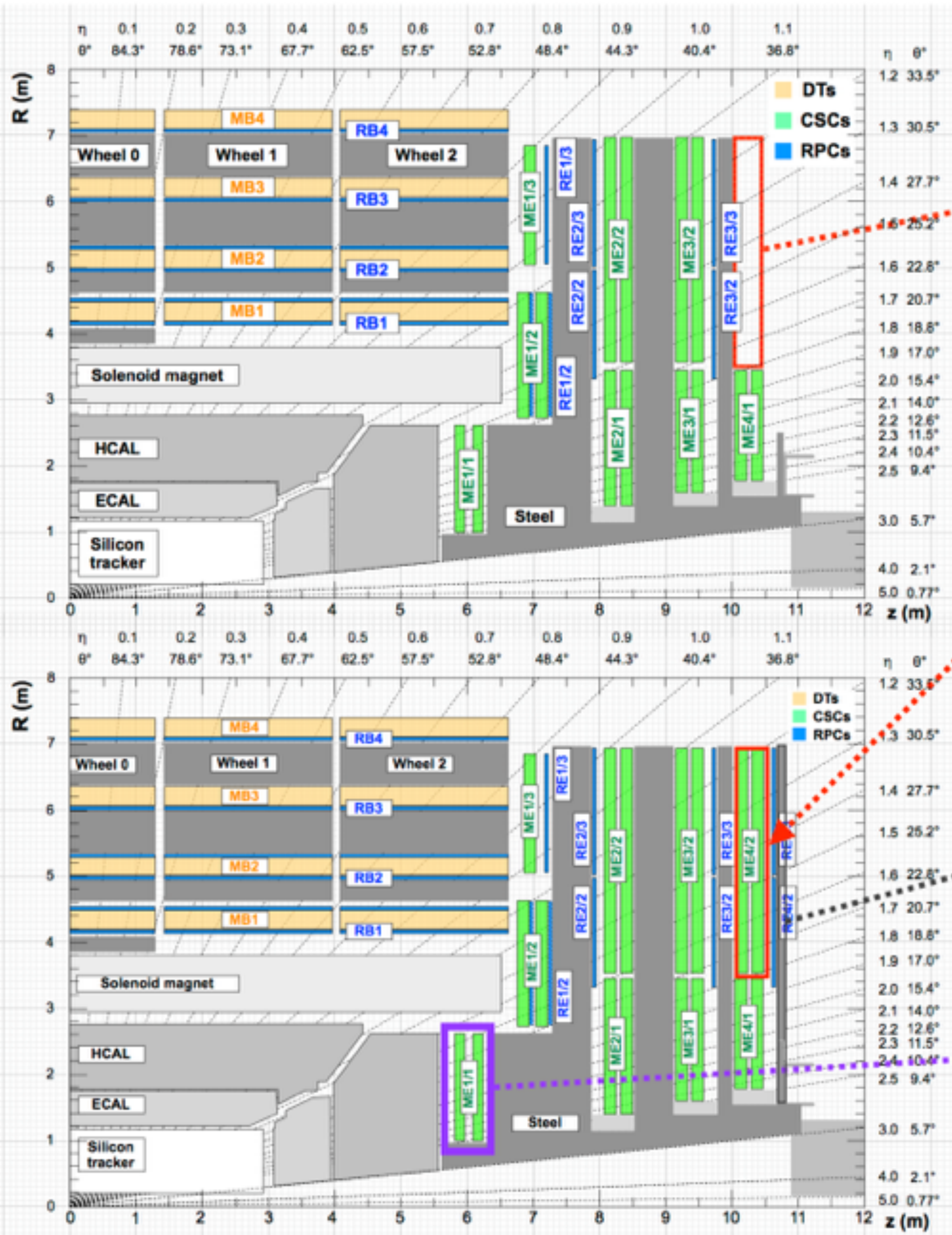
- Movements of pixel-detector large structures due to magnet cycles (grey area) monitored
- Several updates of the alignment used in data taking (initial geometry)
- Final alignment in several intervals of 2015 (10 IOVs) has been prepared at the module level for data reprocessing
- validation plot samples all intervals



Muon system layout in Run2

CMS - RUN I

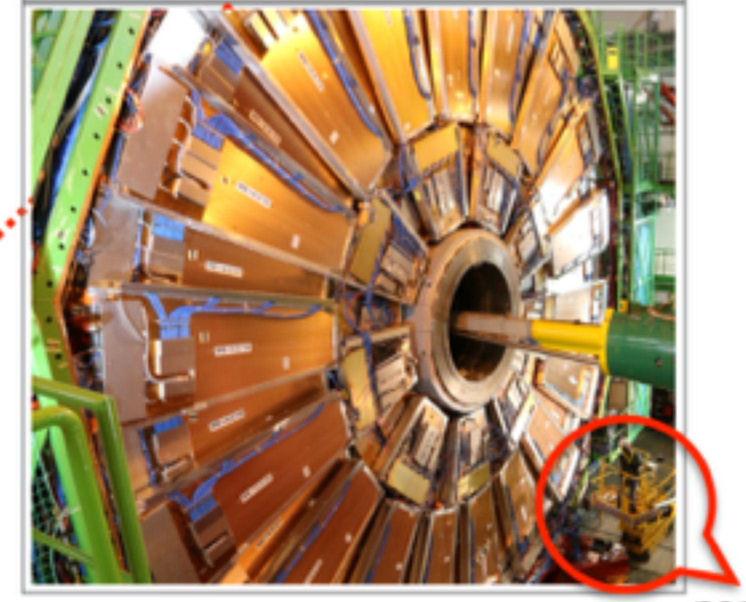
CMS - RUN II



Complete ME4/2

PreLSI: only 5 CSCs in +z

Now: ***36 CSCs per endcap***



person (set scale!)

Add YE4 & RE4

Ungang ME1/1A

(inner strip ring of ME1/1)

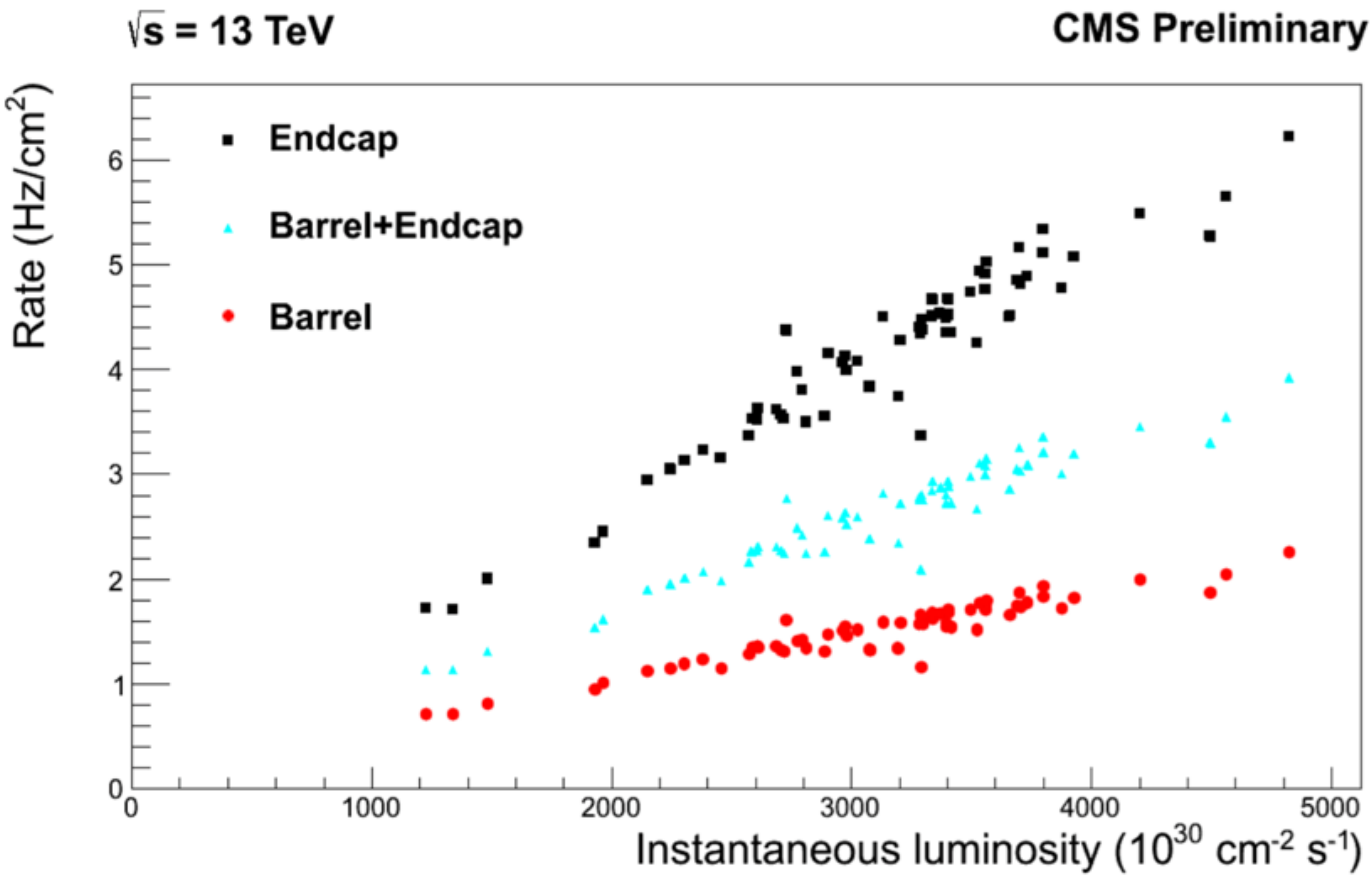
PreLS1: ME1/1A ganged

48 strips → 16 channels

The one CFEB per ME1/1A on each ME1/1 CSC is replaced by 3 new Digital CFEBs. Now:

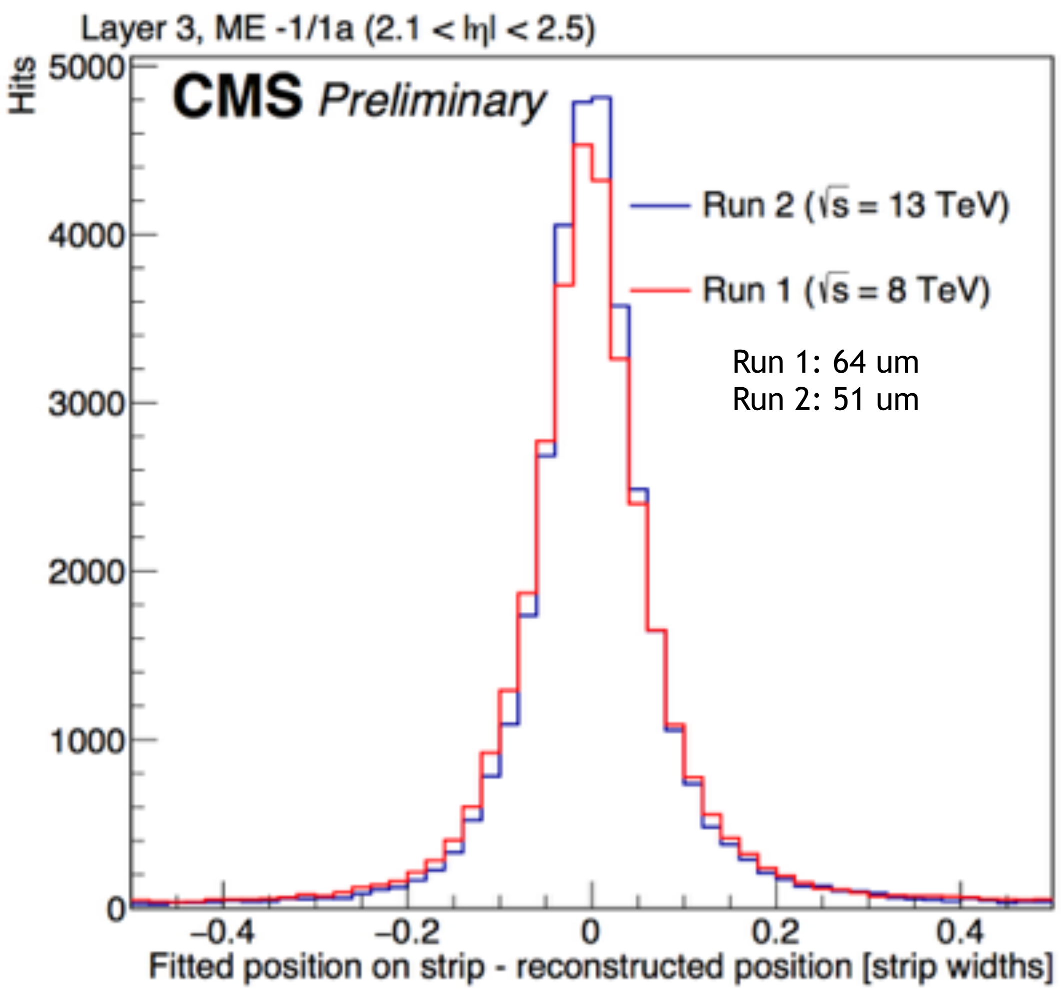
48 strips → 48 channels

RPC rate vs Ins. lumi at 13 TeV in 2015

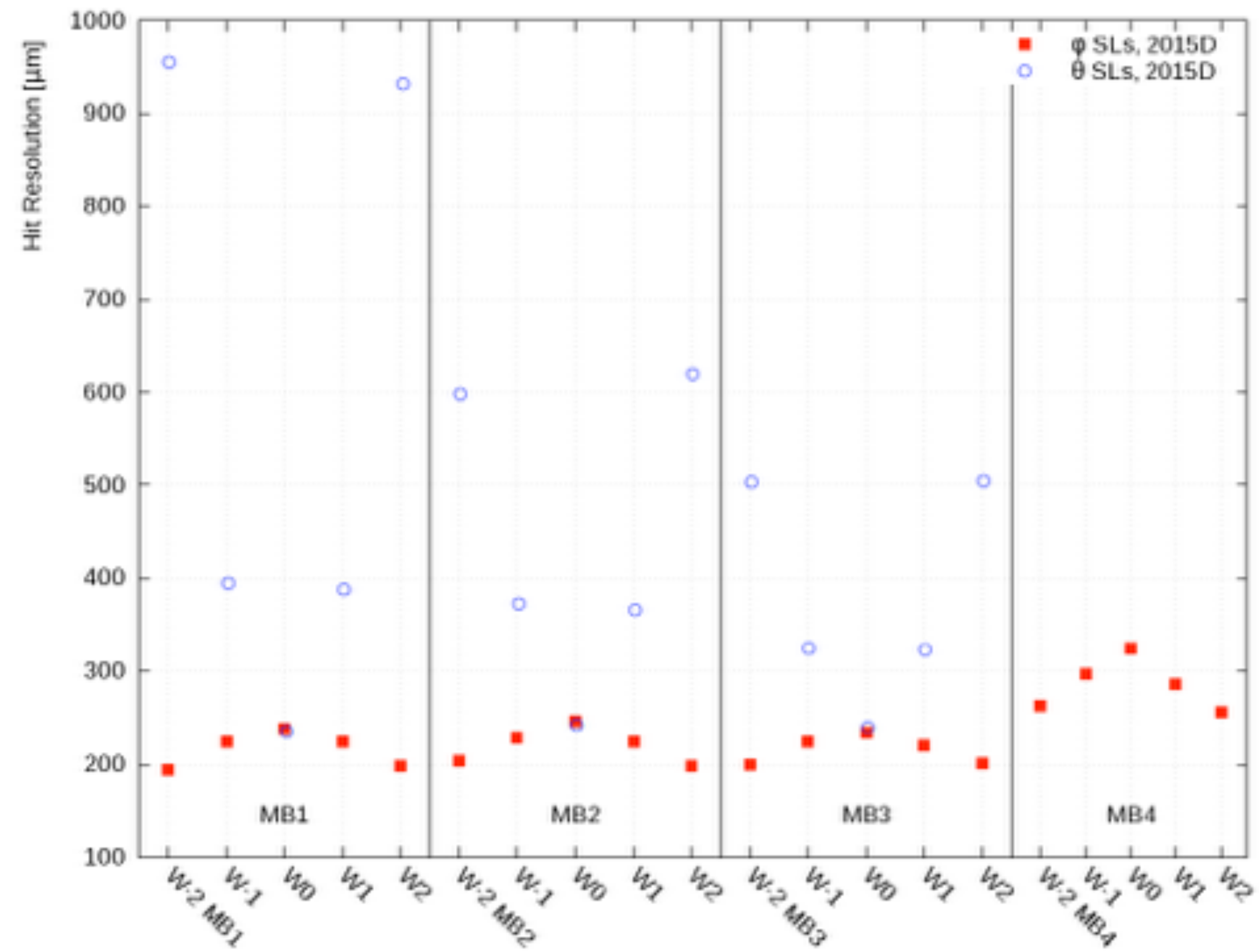


Improvements in DT and CSC spatial resolution

CSC hit position resolution

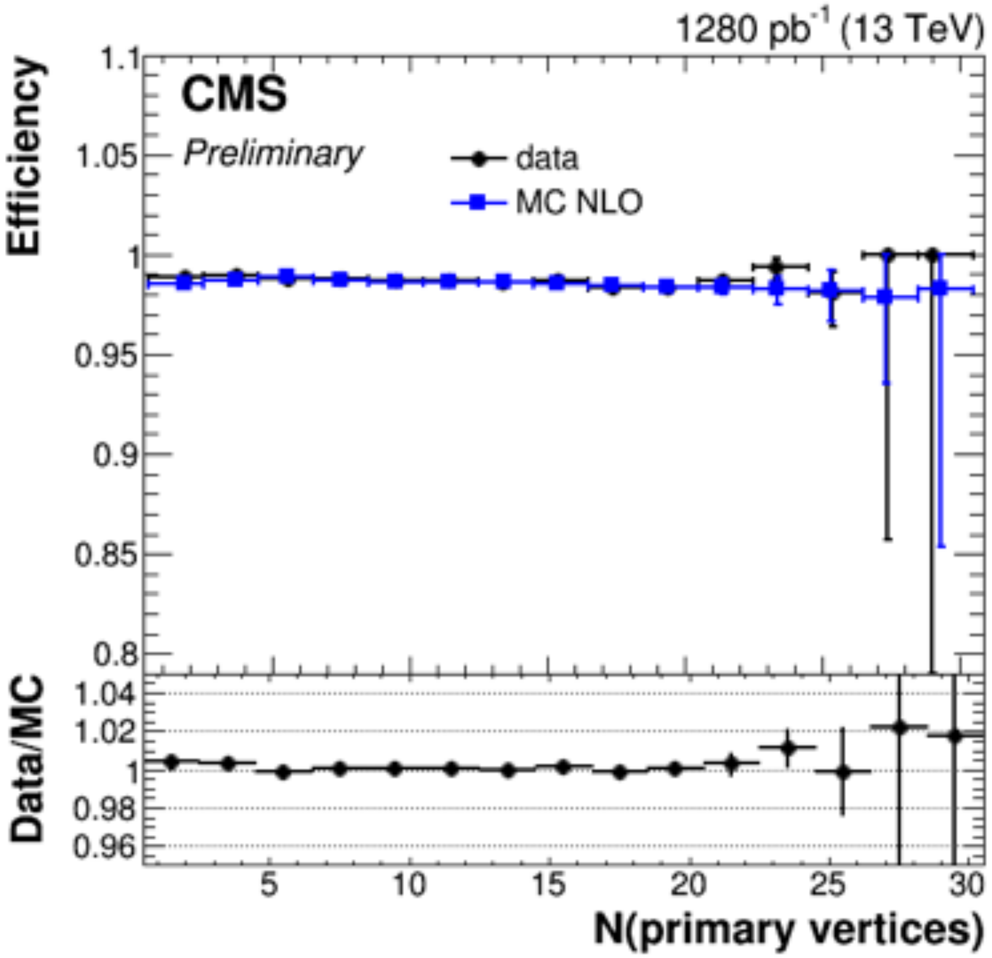


DT resolution



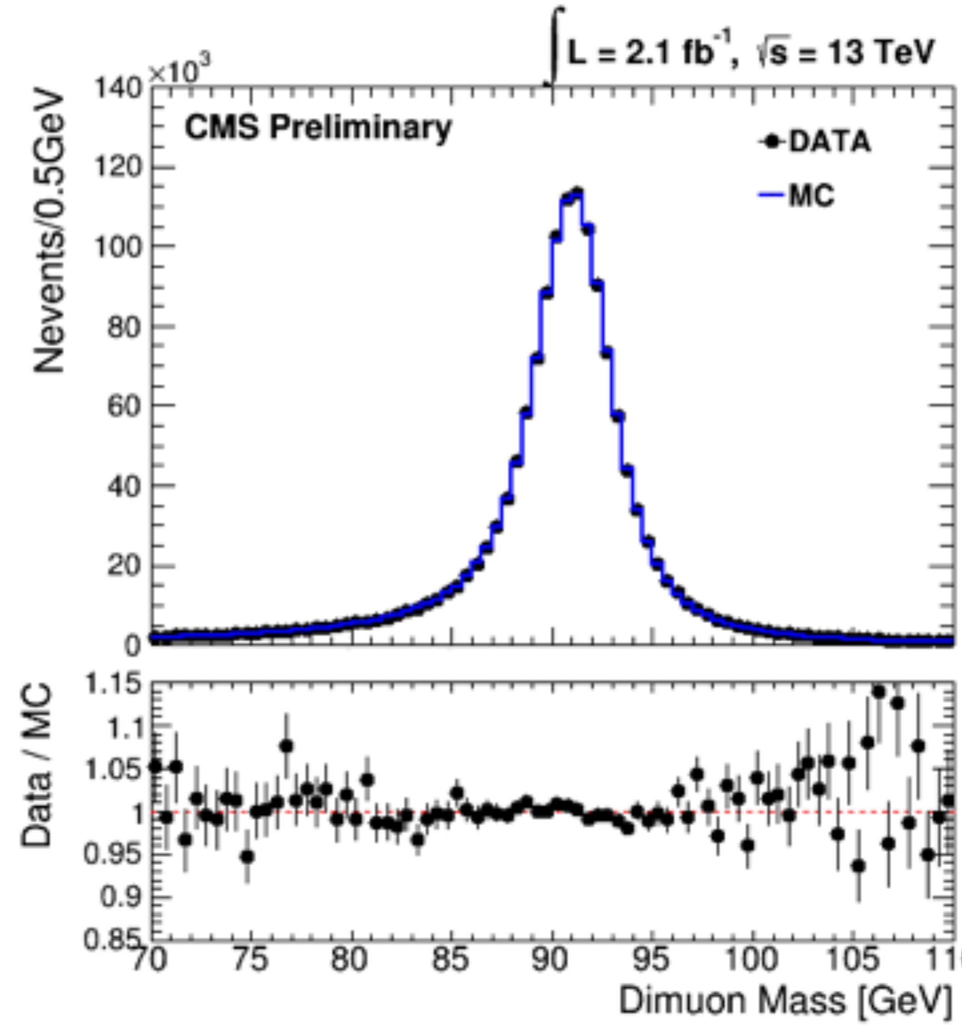
Muon ID robust against pileup and in good agreement with MC

Muon ID with loose isolation vs number of primary vertices



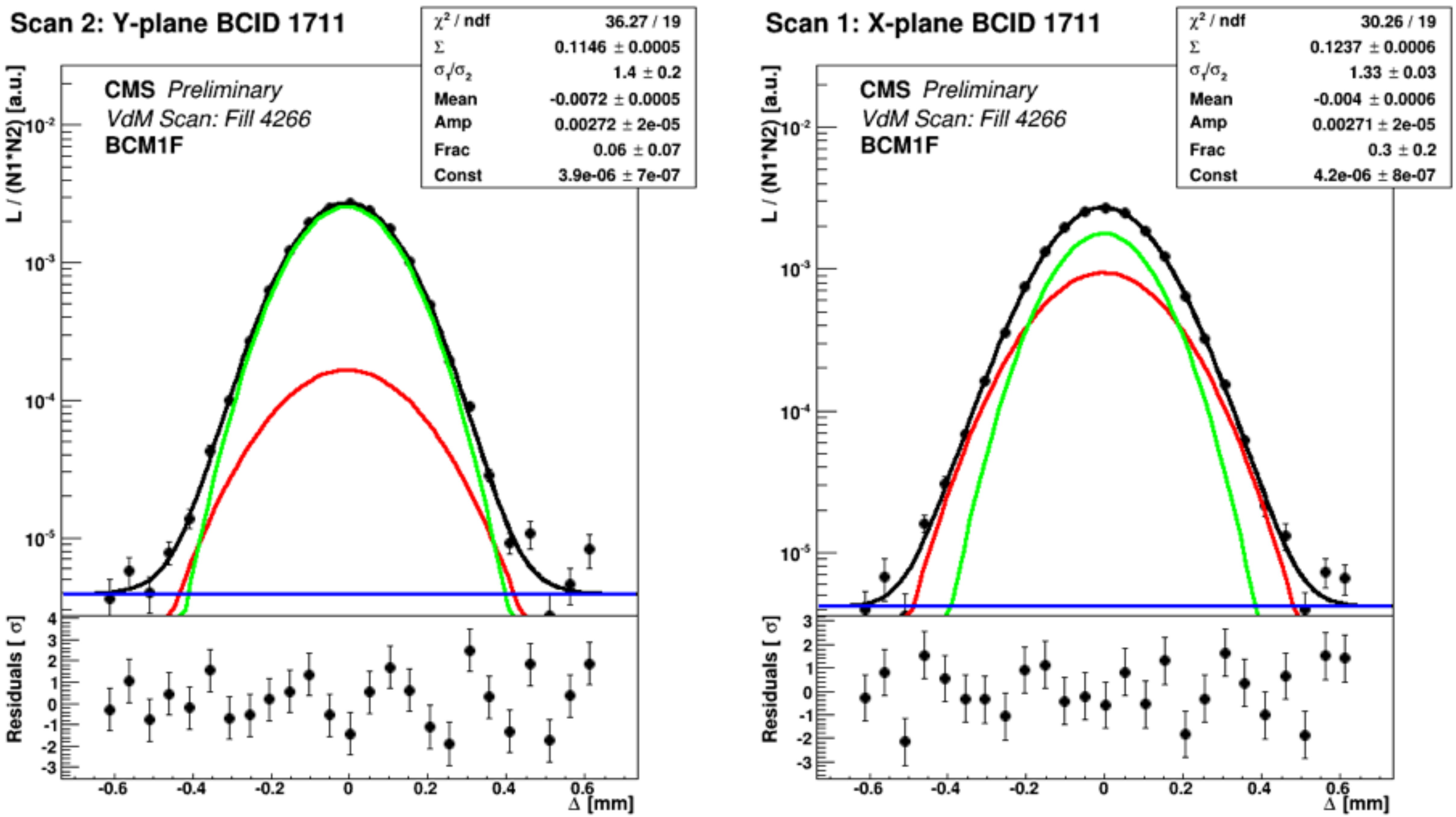
$P_T > 20$ GeV $|\eta| < 2.4$

Z line shape in data and MC



After data driven P_T calibration correction

Luminosity – detector performance



After the data taking: frenetic work to prepare for conferences

- New software release
  - data VS MC validation
- MC production campaigns
  - 3-4 billion events being produced
- Provide conditions for 2015 data reprocessing
  - optimal alignment and calibration used for the final data reco