Status of CMS

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On behalf of the
CMS Collaboration

Presented at
IPRD10: 12^{th} Topical Seminar on Innovative Particle and Radiation Detectors

June 7, 2010

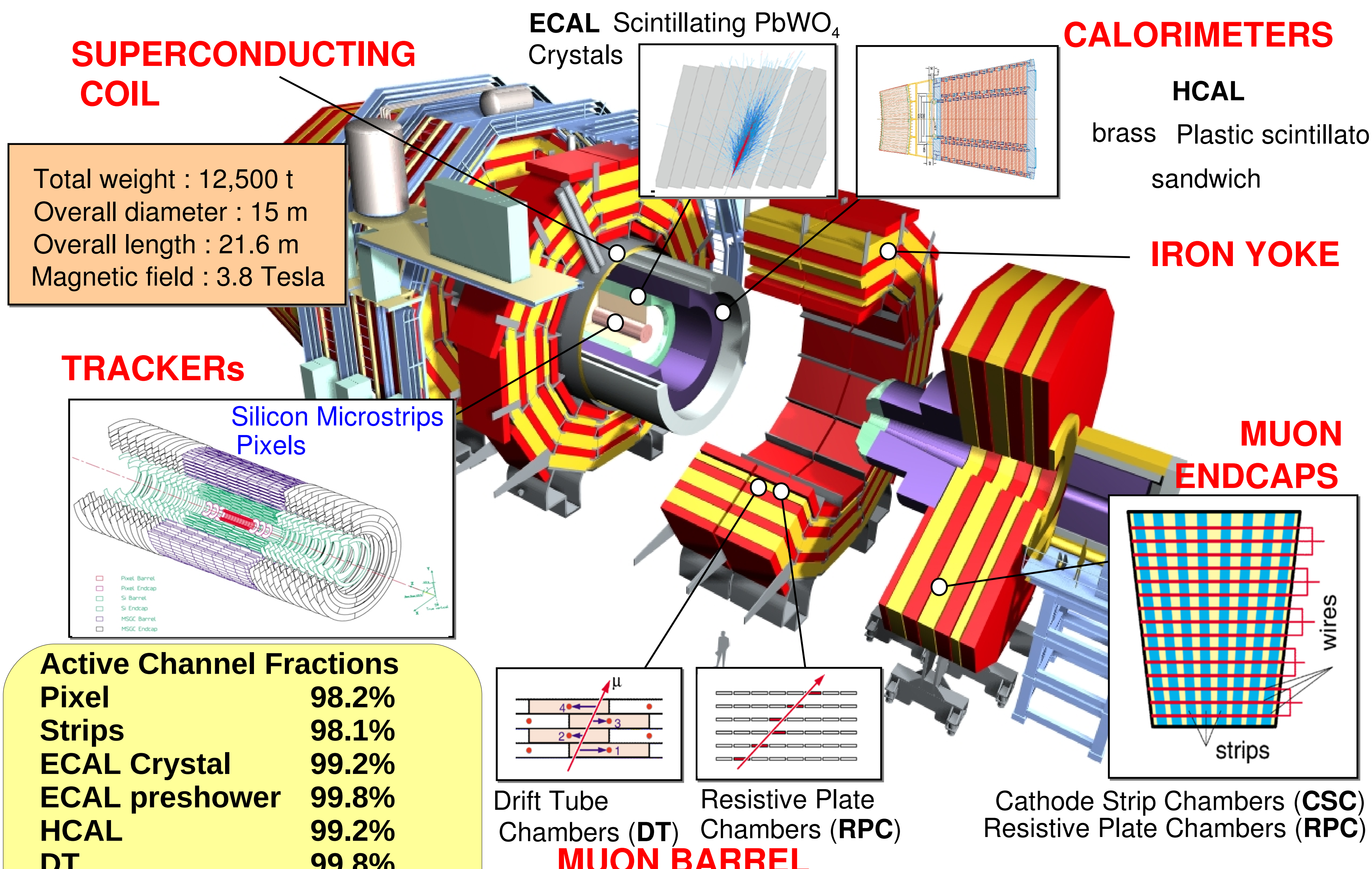
Outline

- Overview of CMS
- First 7 TeV collisions
- Detector performance
- Some issues:
  - Events with large pixel occupancy
  - Anomalous calorimeter energies
- Summary

Related Talks and Posters at this Conference:

D. C. Contardo: “First CMS results at 7 TeV”
J. Thompson: “Operational experience with the CMS pixel detector”
D. Bonacorsi: “From commission to collisions: Preparation and execution of CMS computing”
N. M. Wickramage: “An investigation of the dependence of CMS RPC operation on environmental parameters”
F. De Guio : “Measurement of the muon stopping power in lead tungstate with the CMS detector”
J. Bernardini: “Track reconstruction with first collision data in CMS”
L. Quertenmont: “Particle identification with ionization energy loss in the CMS silicon strip tracker”
E. A. Chivite: “The alignment of the CMS silicon tracker”
L. Borrello: “CMS silicon strip tracker operation”
S. M. E. De Visscher: “Evaluation of the CMS pixel detector data from the first LHC collisions”
A. Martelli: “Experience with the electron reconstruction with the first CMS data”
M. M. Obertino: “Calibration of the CMS electromagnetic calorimeter with first LHC data”
R.-S. Lu: “Performance, calibration and alignment of CMS preshower detector”
T. Orimoto: “Commissioning of the CMS electromagnetic calorimeter with first collisions”
R. Dell'Orso: “Design and development of micro-strip stacked module prototypes to measure flying particle directions
D. Spiga: “Running the CMS computing for the analysis of the first data”
S.-K. Park: “CMS muon detector and and trigger performance”
J. Veverka: “Monitoring the stability of the CMS electromagnetic calorimeter”
A. Cimmino: “Data quality monitoring for the CMS resistive plate chamber detector”
N. Beni: “S4CMS: A combined monitoring of sensors in CMS experimental site”

The Compact Muon Solenoid Detector



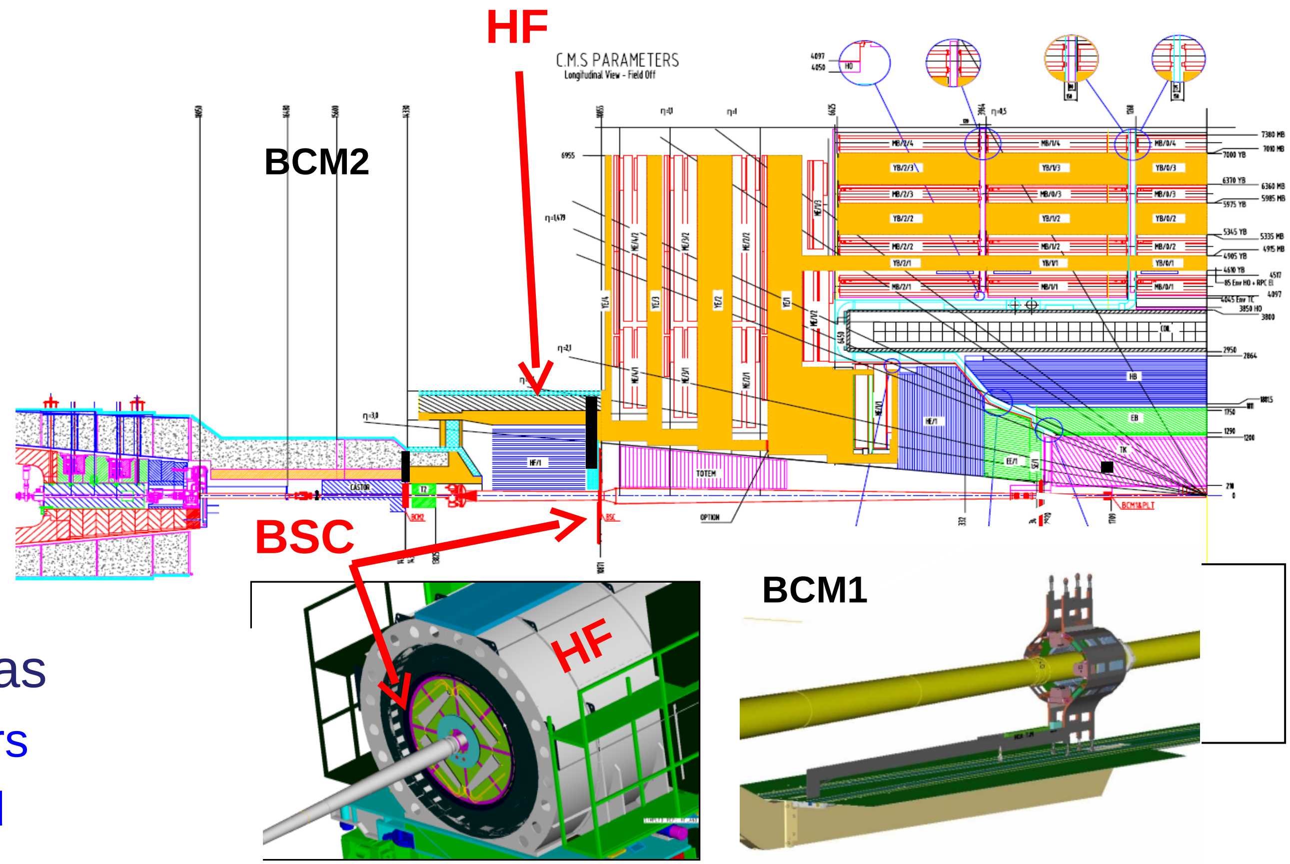
Active Channel Fractions	
Pixel	98.2%
Strips	98.1%
ECAL Crystal	99.2%
ECAL preshower	99.8%
HCAL	99.2%
DT	99.8%
RPC	98.8%
CSC	98.5%

Commissioning Triggers

7 TeV Start up:

Minimum bias triggers

- Hadronic Forward
  - HF: $2.5 < |\eta| < 5.0$
- Beam Scintillator Counter
  - BSC: 10.5 m from IP
- Beam Pick-up Timing
  - BPTX: 175 m from IP



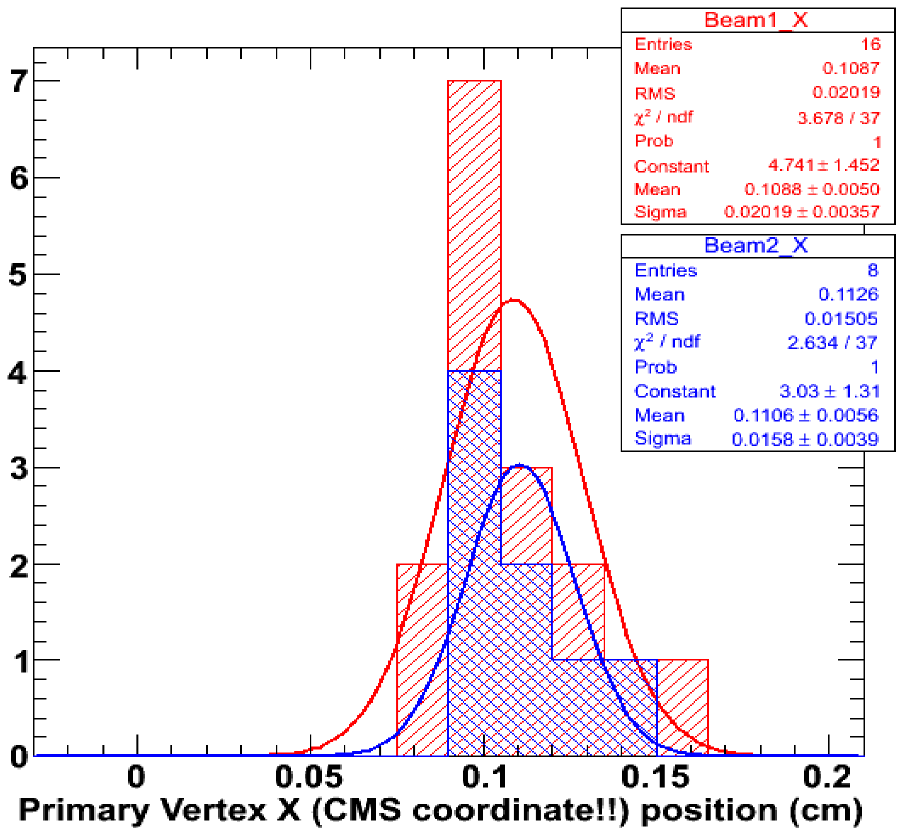
- Trigger: Min Bias & Zero Bias
  - L1 Beam Scintillator Counters
  - L1 Trigger “BPTX” prescaled
- Minimum Bias selection:
  - BSC (OR 2 planes): $\epsilon \sim 90\%$
  - HF (E > 3 GeV both sides): $\epsilon \sim 90\%$
    - Combined high efficiency

Physics triggers are now deployed based on calorimetry and muons

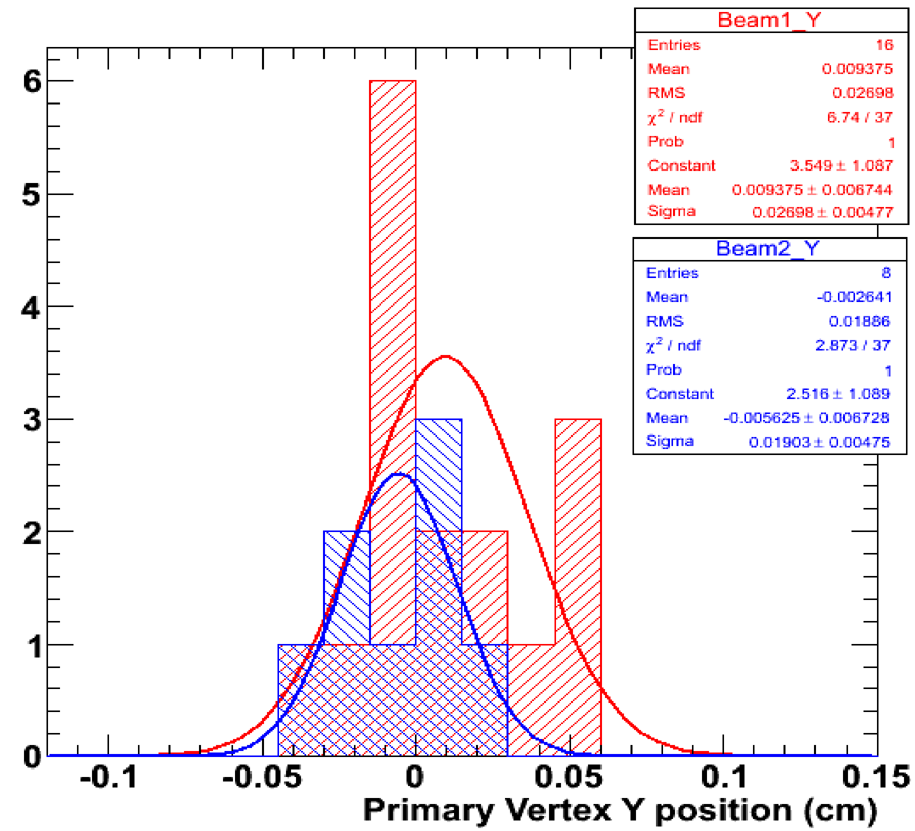
Beam Gas in non-Colliding Beams

- Before the first 7 TeV stable beams for the 'The CERN Media Event', we took data with non-colliding beams to reconstruct beam-gas interactions to determine the beam positions to verify that we would have collisions in CMS.

Horizontal

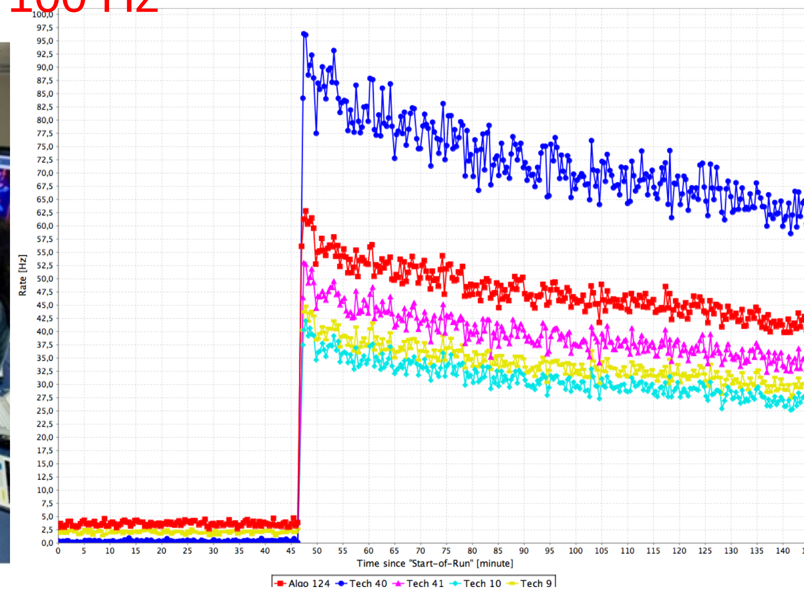


Vertical



March 30: First 7 TeV Collisions

100 Hz



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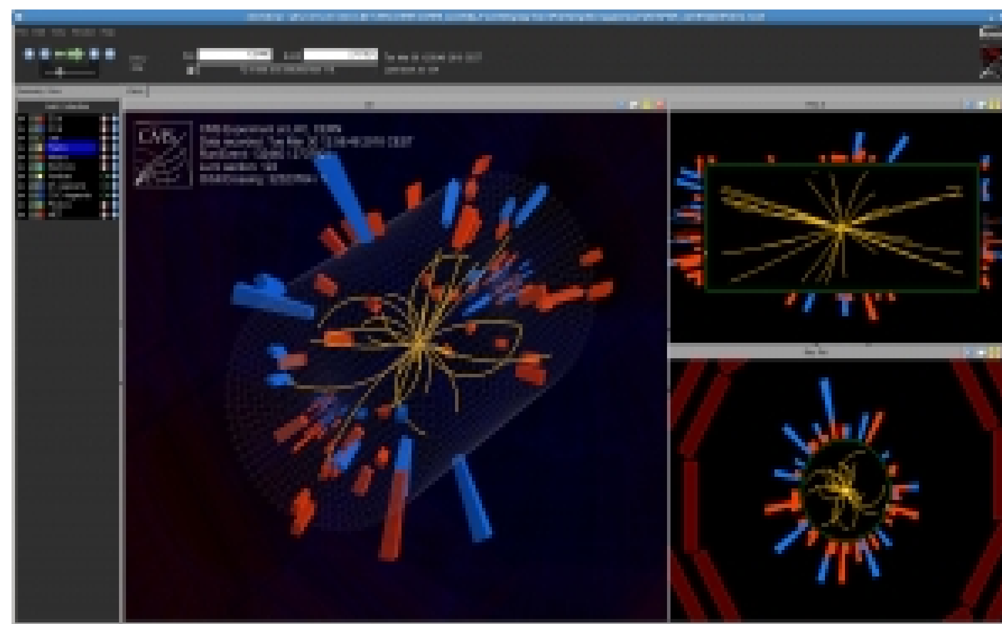
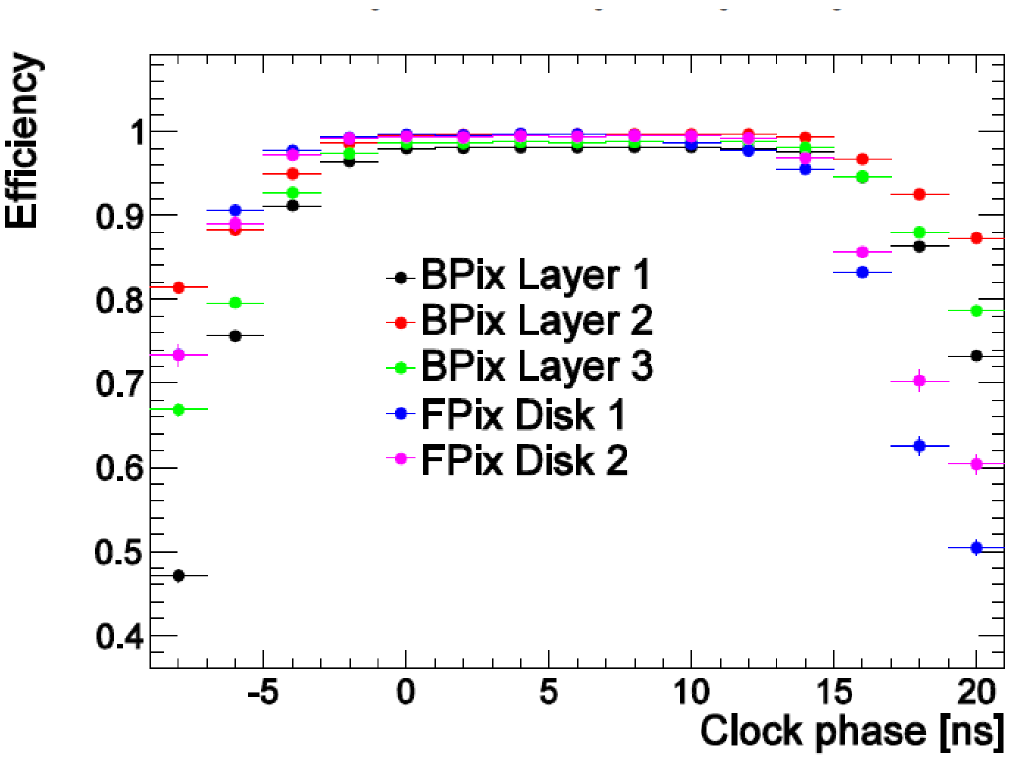


Beyond the Media Event

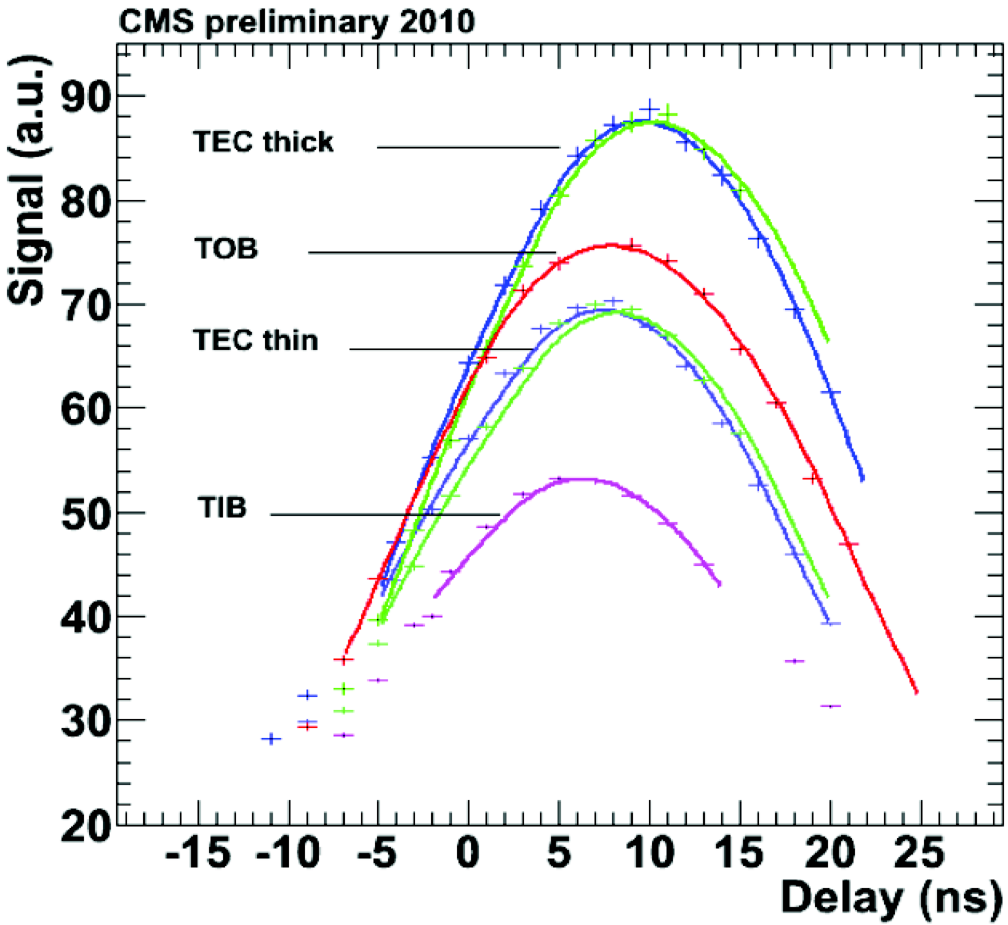
- Within two hours after the first collisions we started our program of delay scans:
  - We had collected several hundred thousand min bias events, enough for the dN/dη analysis at 7 TeV.
  - Pixels and strips (in the deconvolution mode) are read out only for one 25 ns clock cycle. Important to adjust the timing with respect to the LHC clock and the time of collisions.
  - Calorimeters and muon systems need to be timed properly in order to deploy the physics triggers.
    - Only the CSC from the muon subsystems had enough statistics at this early stage to perform a delay scan.
- This program was carried out in the first ~two weeks.
  - Some results from these scans are shown next.

Pixel and Strip Time Alignment

Pixel



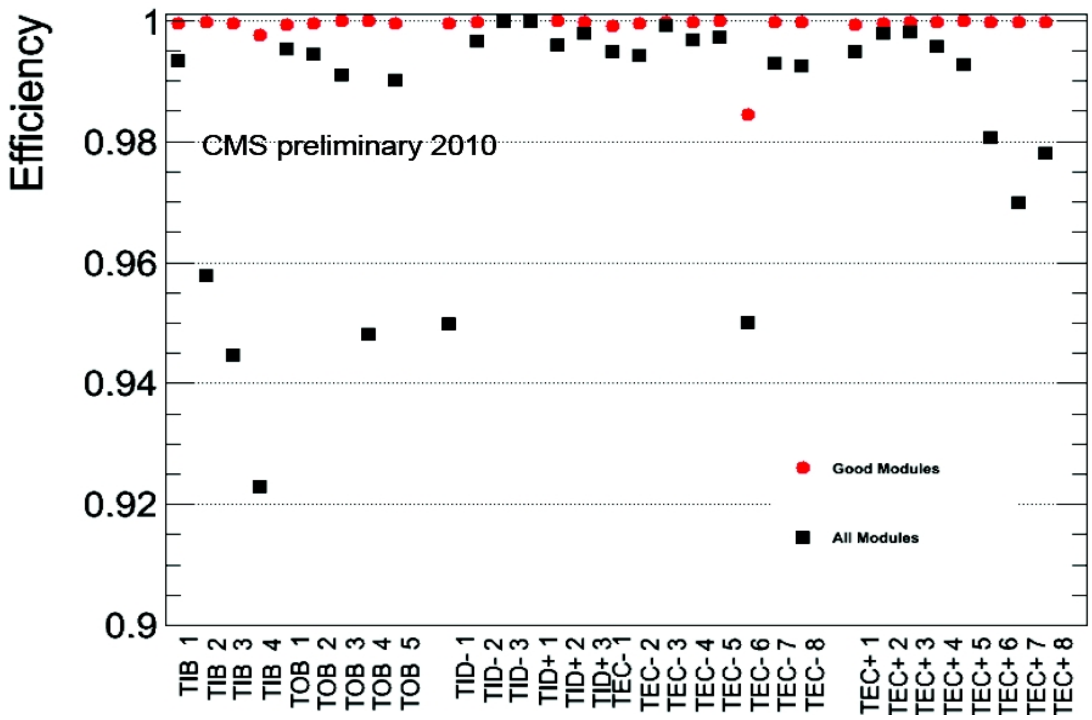
Strips



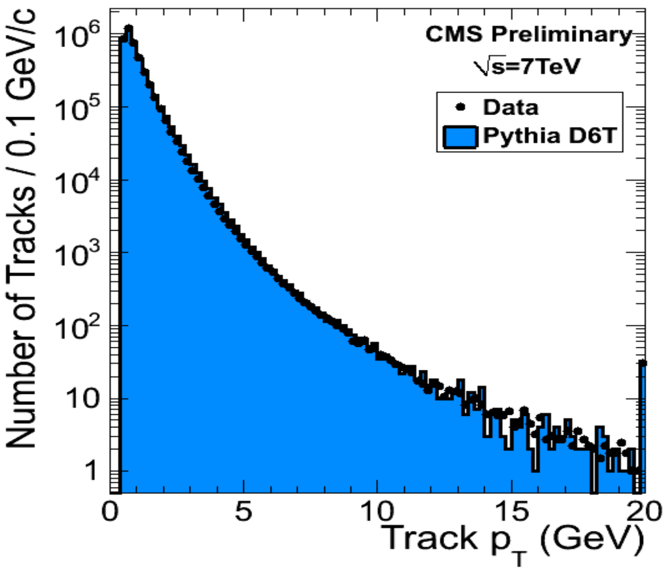
- Fine delay scans – in steps of ~2ns – taken to time align tracking detectors with respect to the LHC beam.
- Optimal time alignment important to measure small charge deposits – important for positions resolutions in pixels via charge sharing.

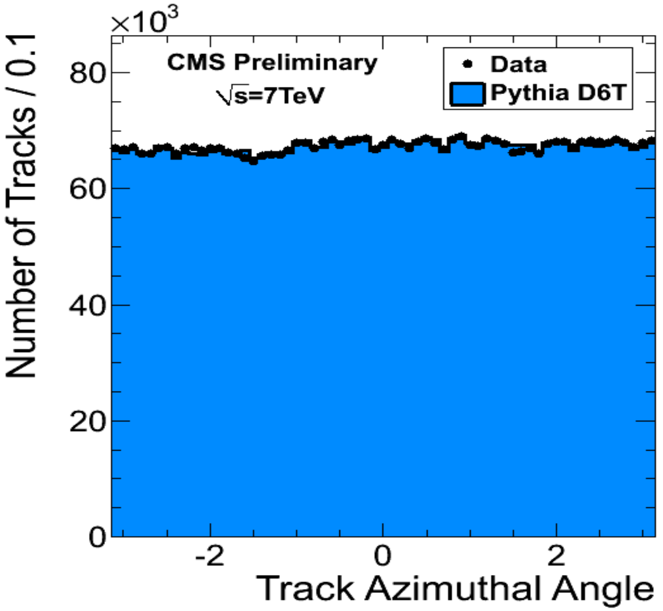
Tracking Performance

Strip Tracker Hit Efficiency



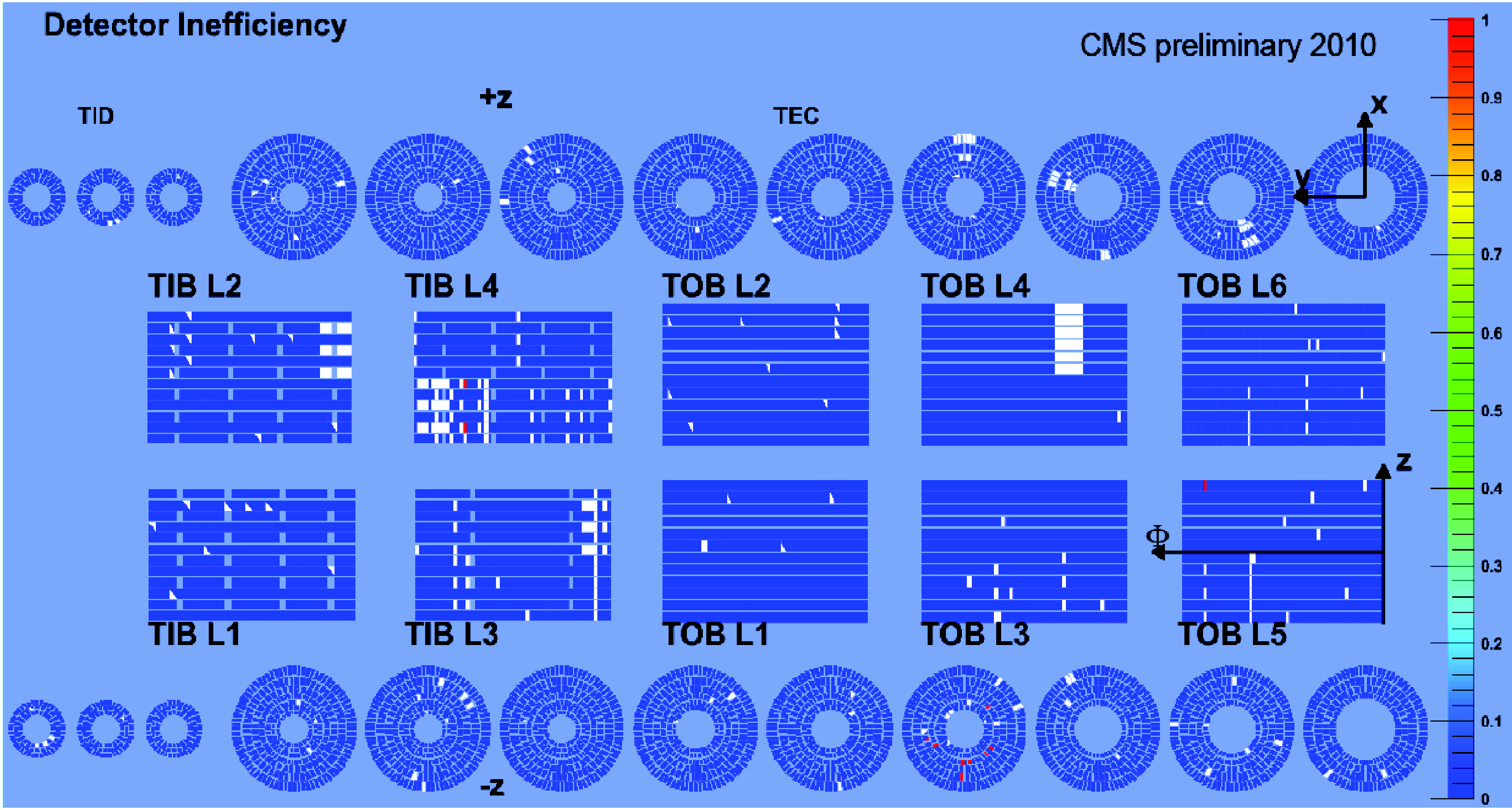
Track Distributions





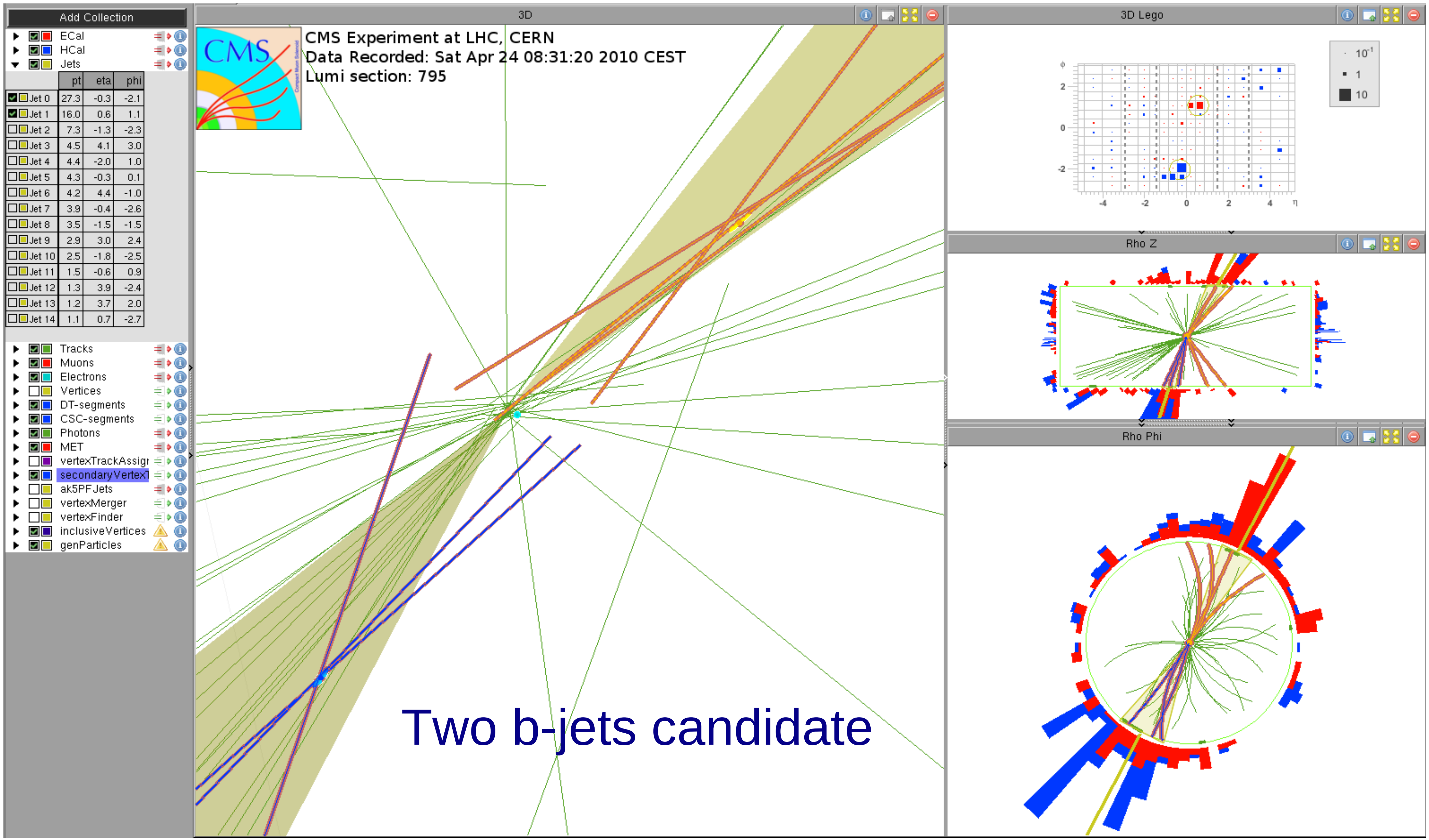
- With 98.1% of channels active in the strips and 98.2% active in the pixels the tracking performance is excellent.

Strip Tracker Efficiency Map



- Overall 98.2% of detector is working

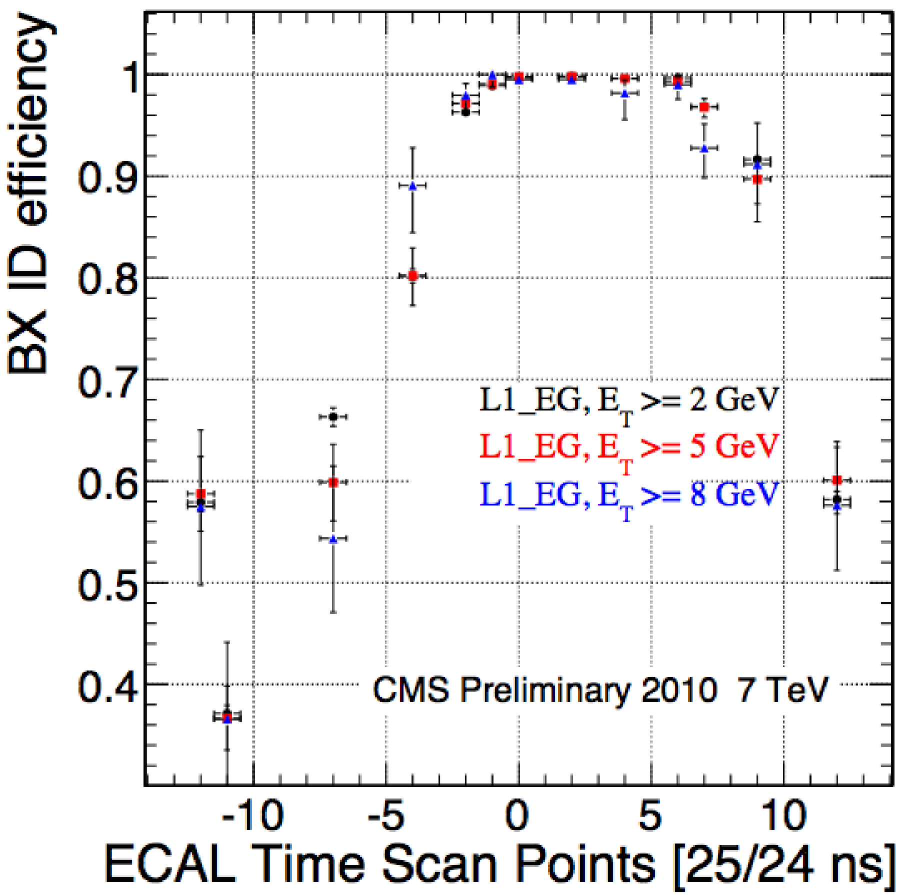
Vertexing: b-tagging



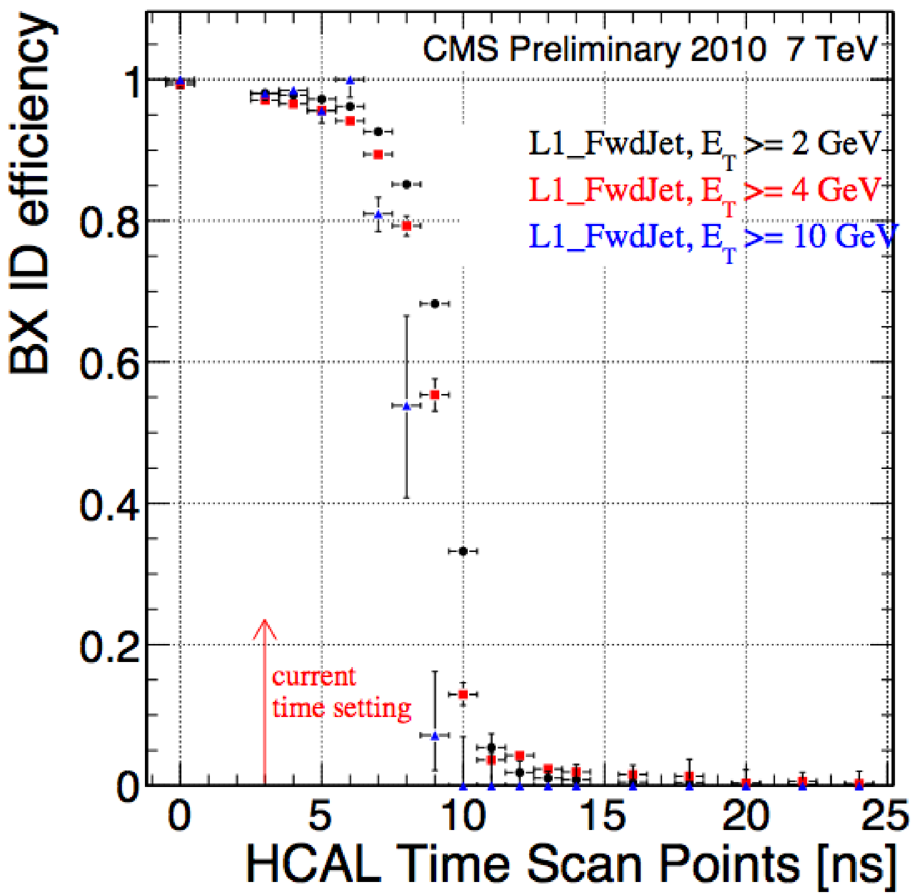
Two b-jets candidate

ECAL and HCAL Time Alignment

ECAL

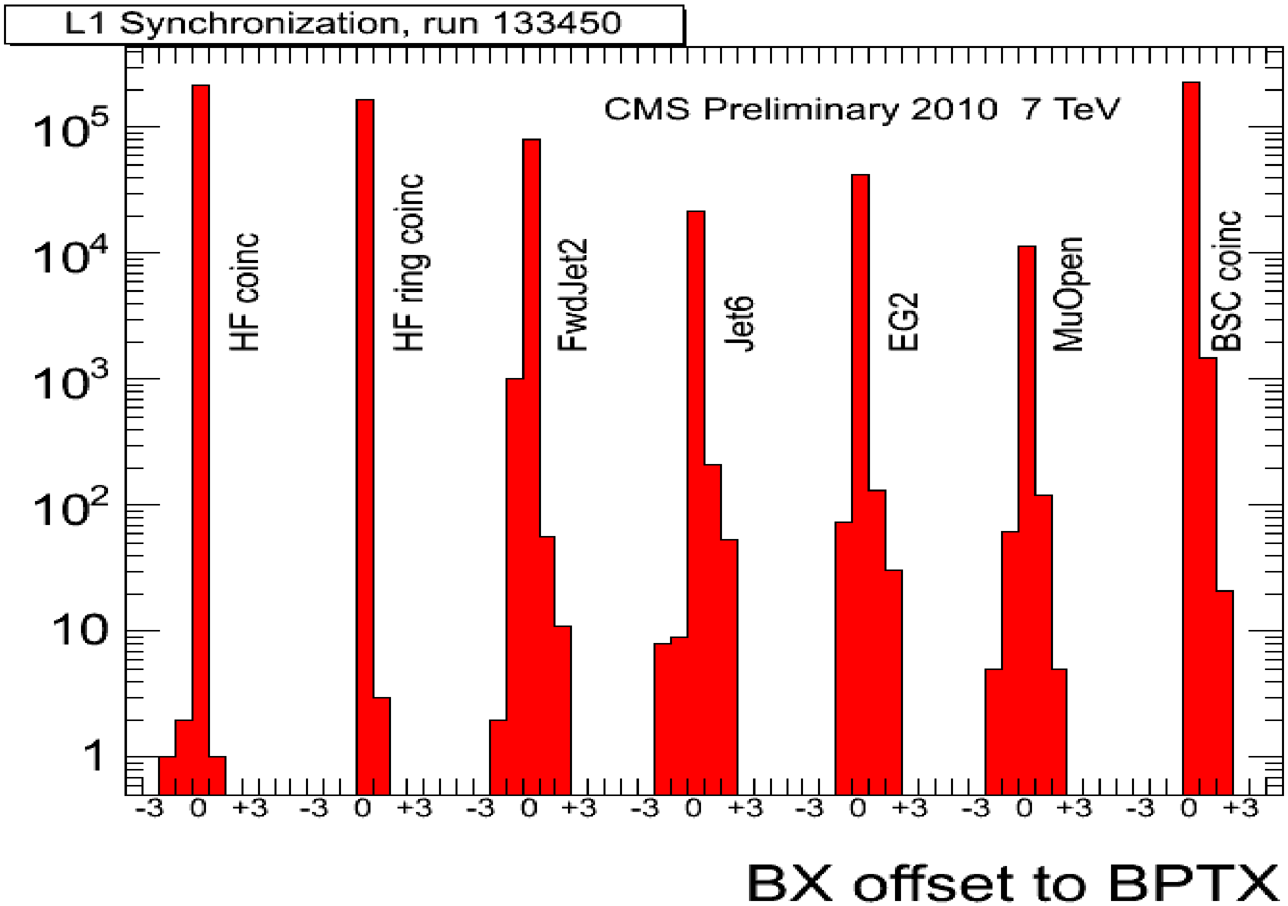


HCAL



- Fine phase adjusted to ensure precise timing of L1 trigger

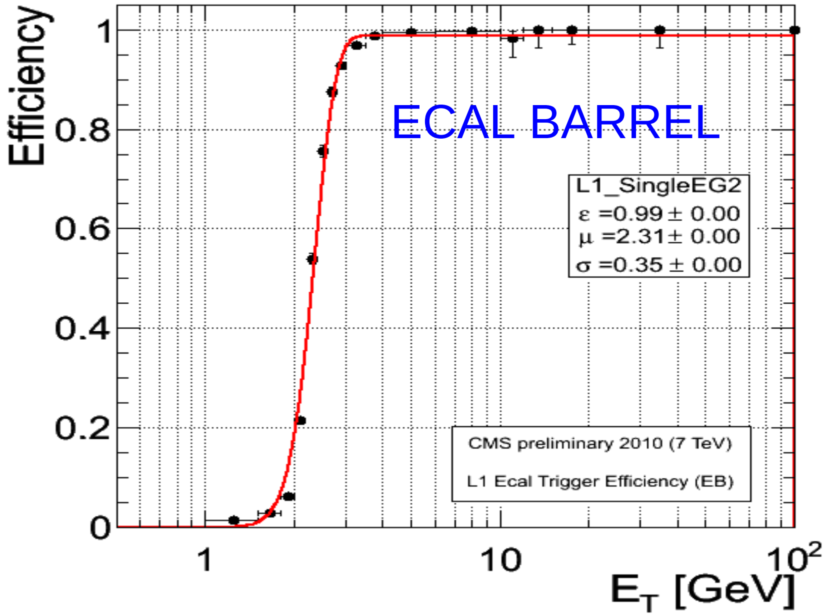
L1 Time Alignment

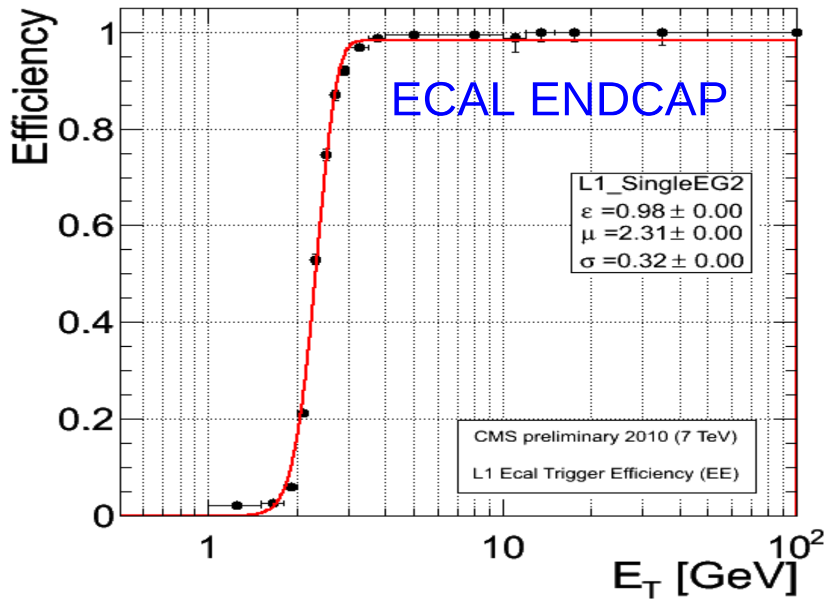


- With timed in L1 algorithms we have not deployed them in the trigger.
- Still, at the highest luminosity seen so far, 2×10^{29} $cm^{-2}s^{-1}$, we have passed the full minbias rate to the HLT and reduced the logging rate in the HLT.

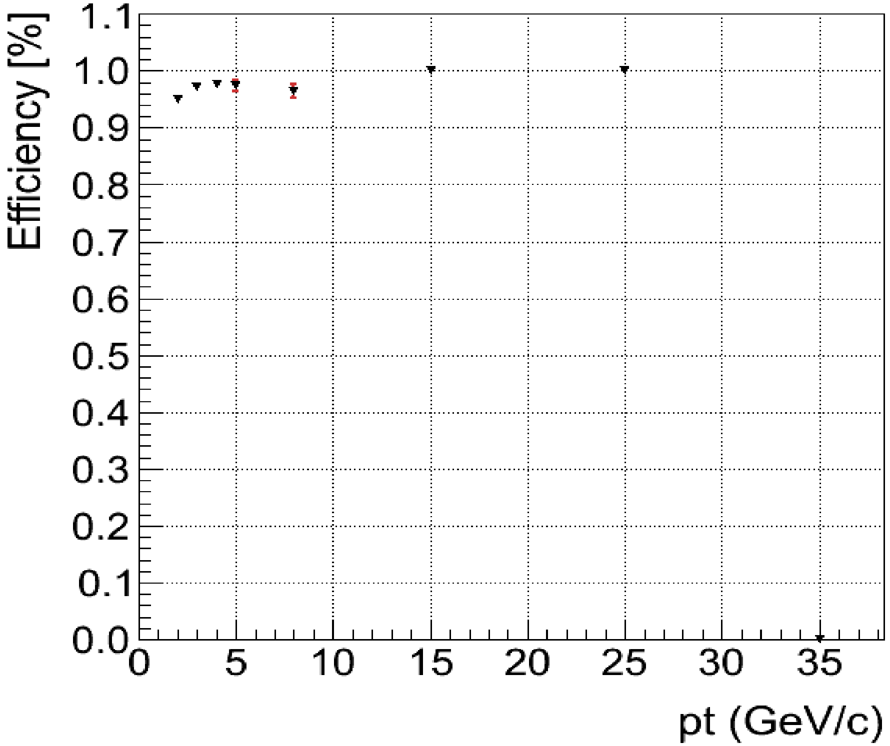
Examples of Trigger Performance

Turn-on curves for 2 GeV threshold



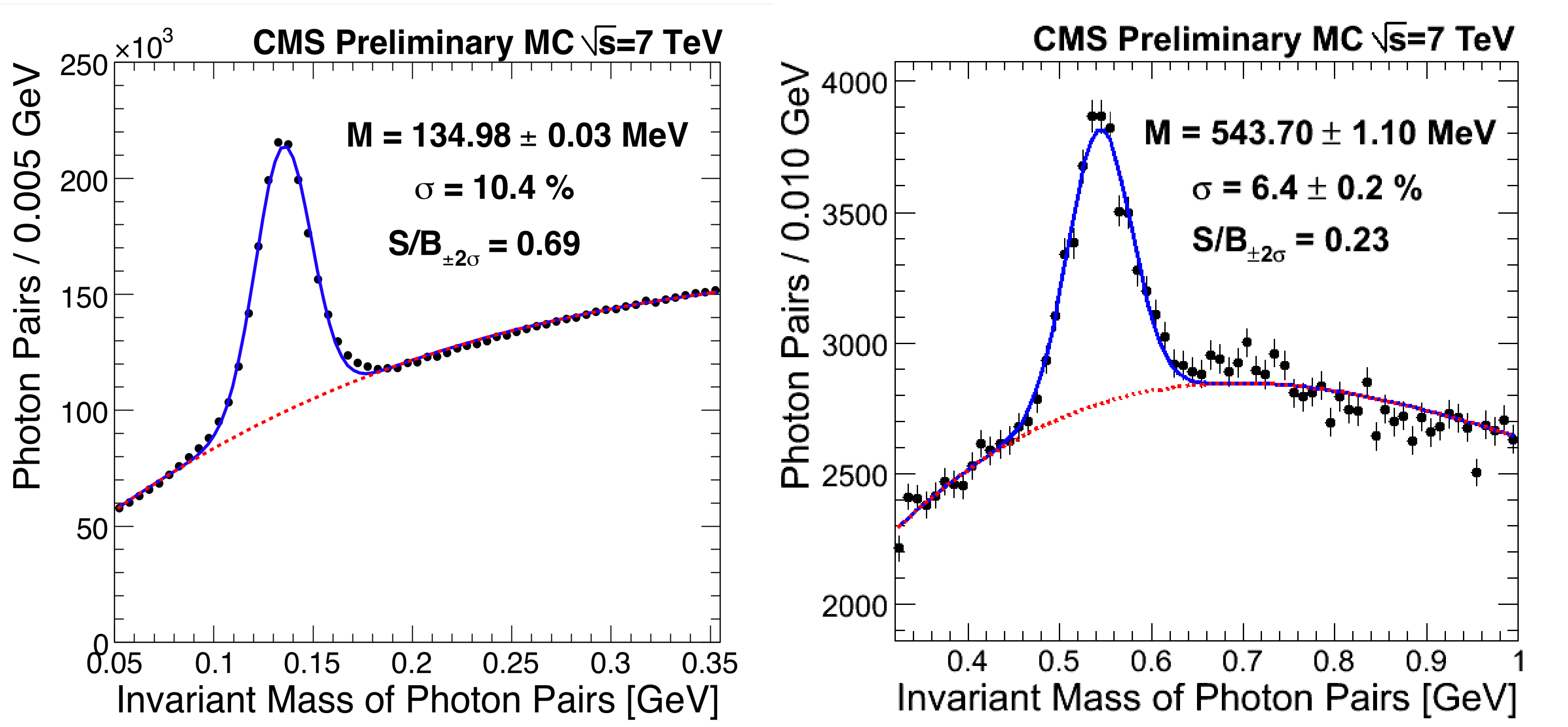


CSC Forward Muon Trigger Efficiency



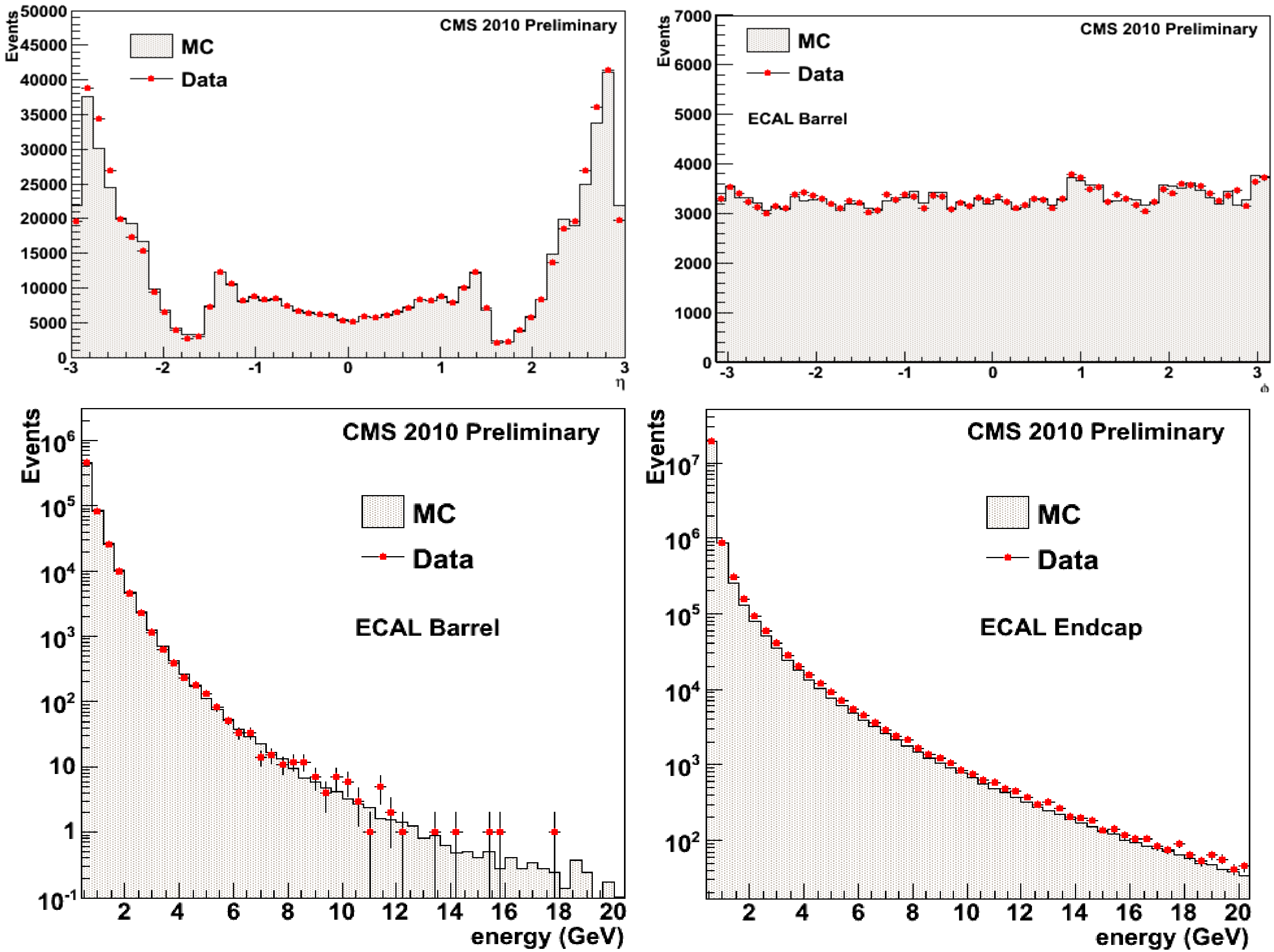
- Triggers first deployed in flagging mode; after validating timing to ensure low pre-firing the triggers are now deployed.

π^0 and η Reconstruction



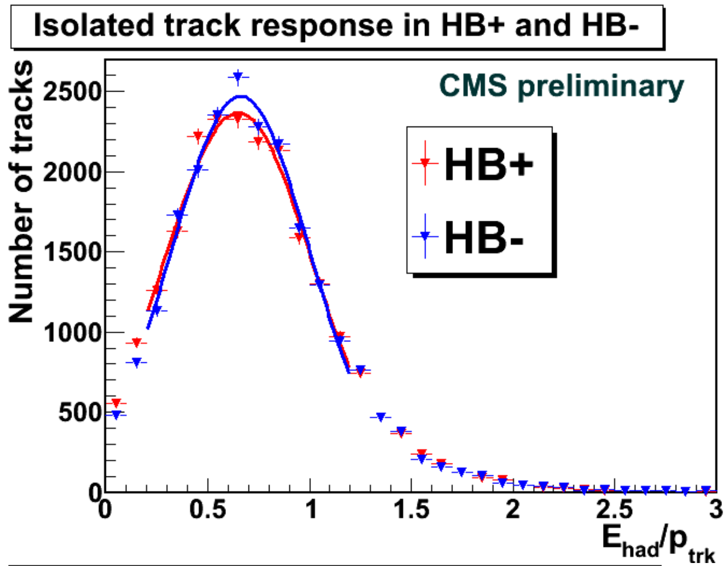
- The excellent ECAL performance allow the clean reconstruction of π^0 and η signals

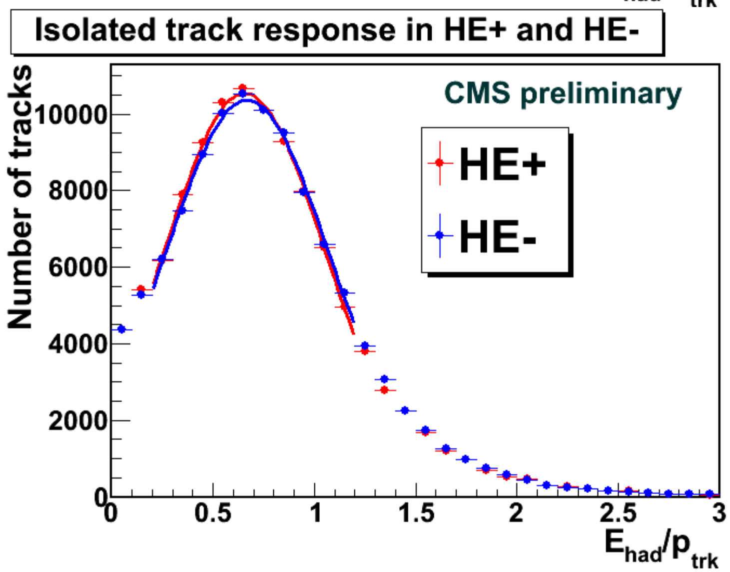
MC vs. Data Distributions for ECAL



Overall very good agreement between data and MC

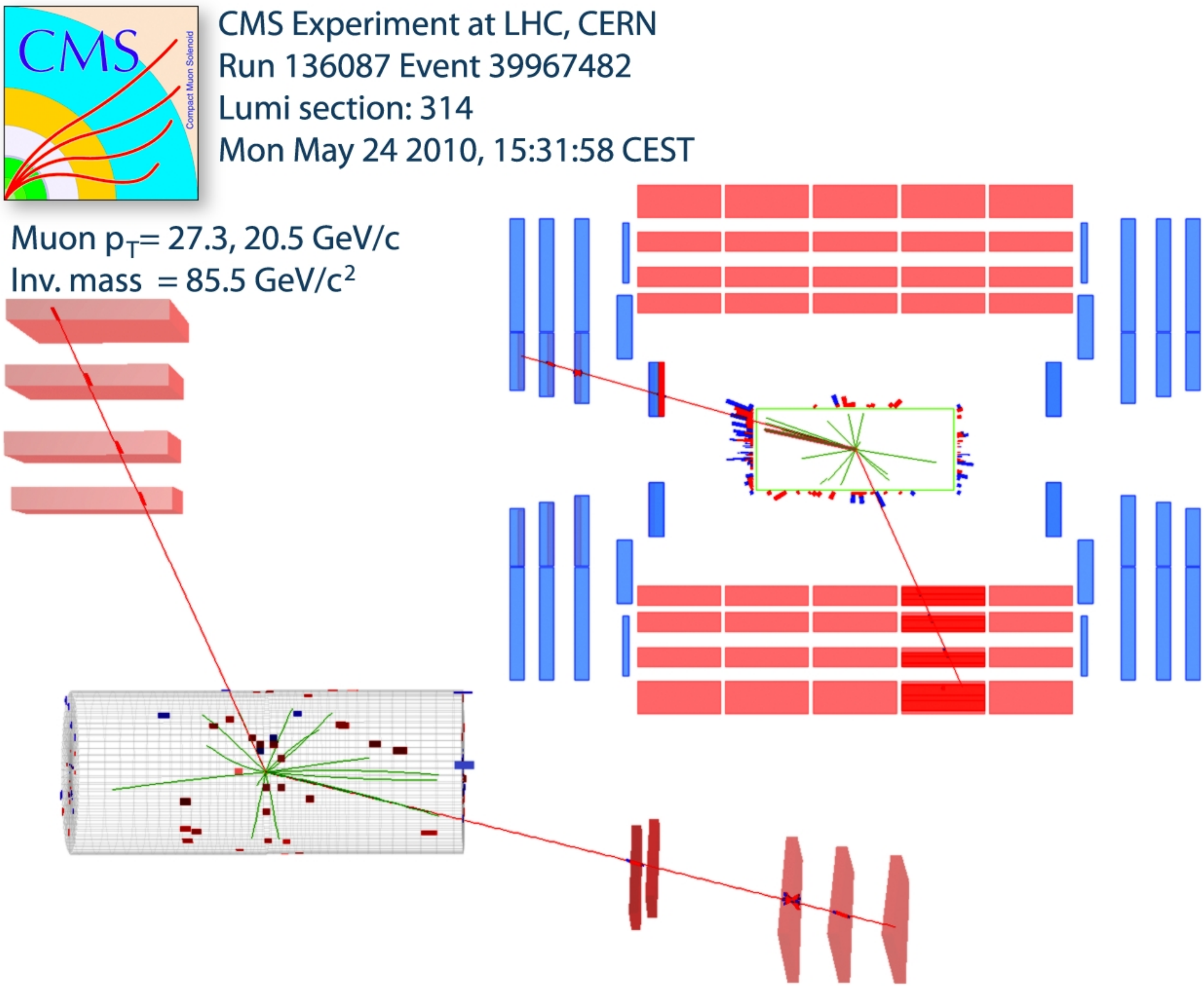
HCAL Calibration with Isolated Tracks





- An important calibration of the HCAL will be done with high pT (pT>60 GeV) isolated tracks.
- At this point we don't have enough statistics at high pT to carry out the procedure.
- Isolated tracks with pT>5 GeV has been used to study the algorithm.
- Good agreement is seen between the plus and minus side of the detector.

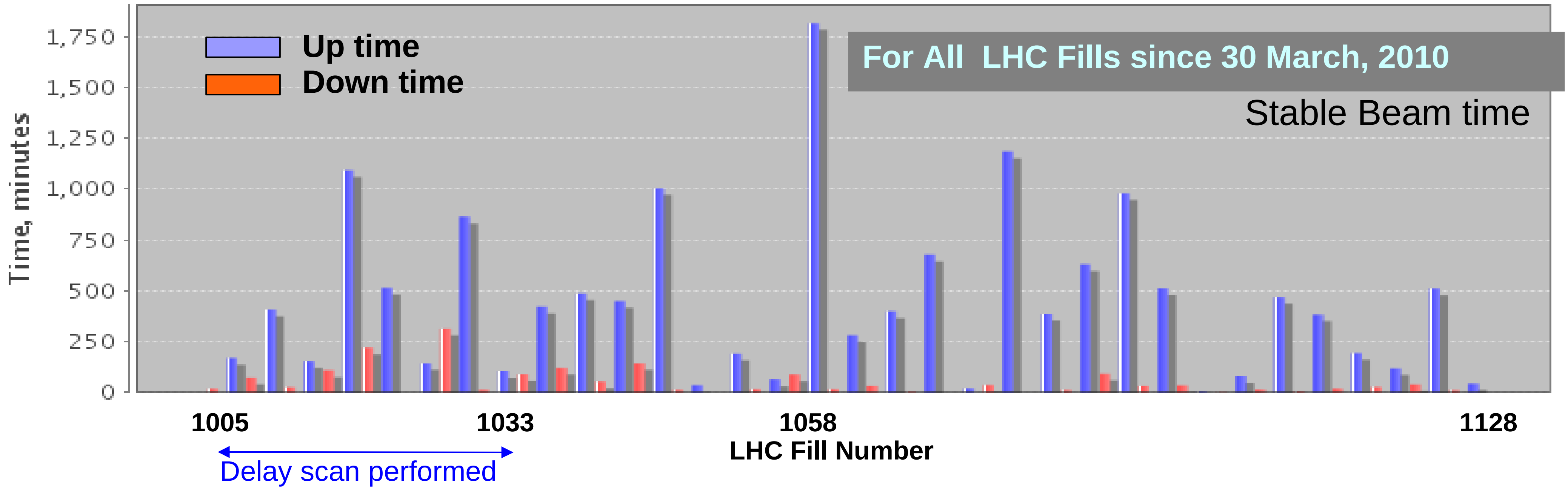
Muon Reconstruction: $Z \to \mu\mu$



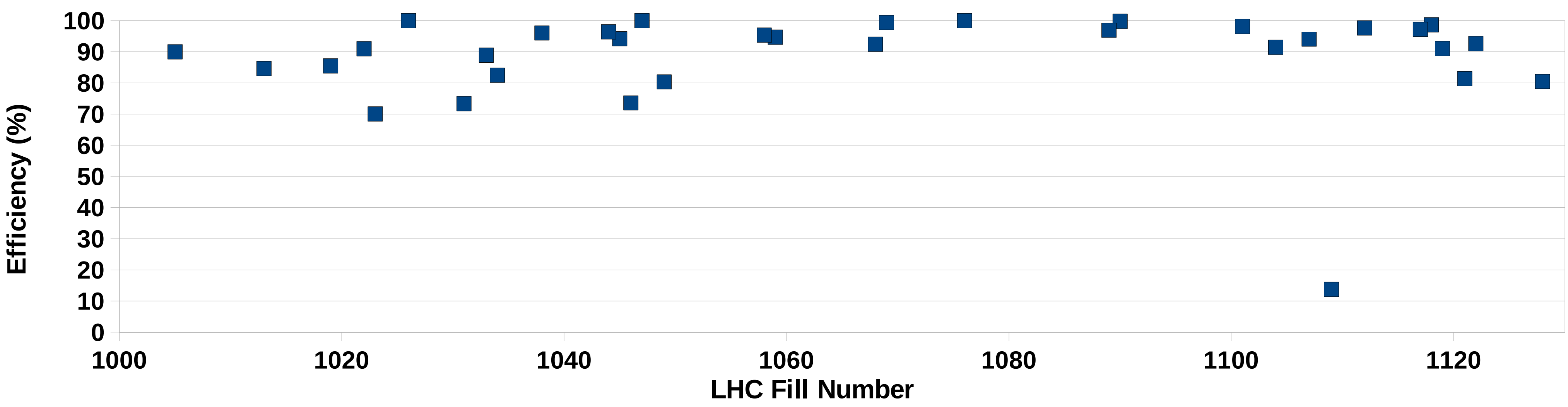
Run Time Logger

- The run time logger is our main tool for tracking data taking inefficiencies.
  - Any stops to the data taking is automatically registered and the shift leader enters the reason for the stop.
- The tool automatically generates summaries of the outages per fill, per run, or over a given time interval.
  - Some examples from the summaries on the next slides.

CMS Up Time



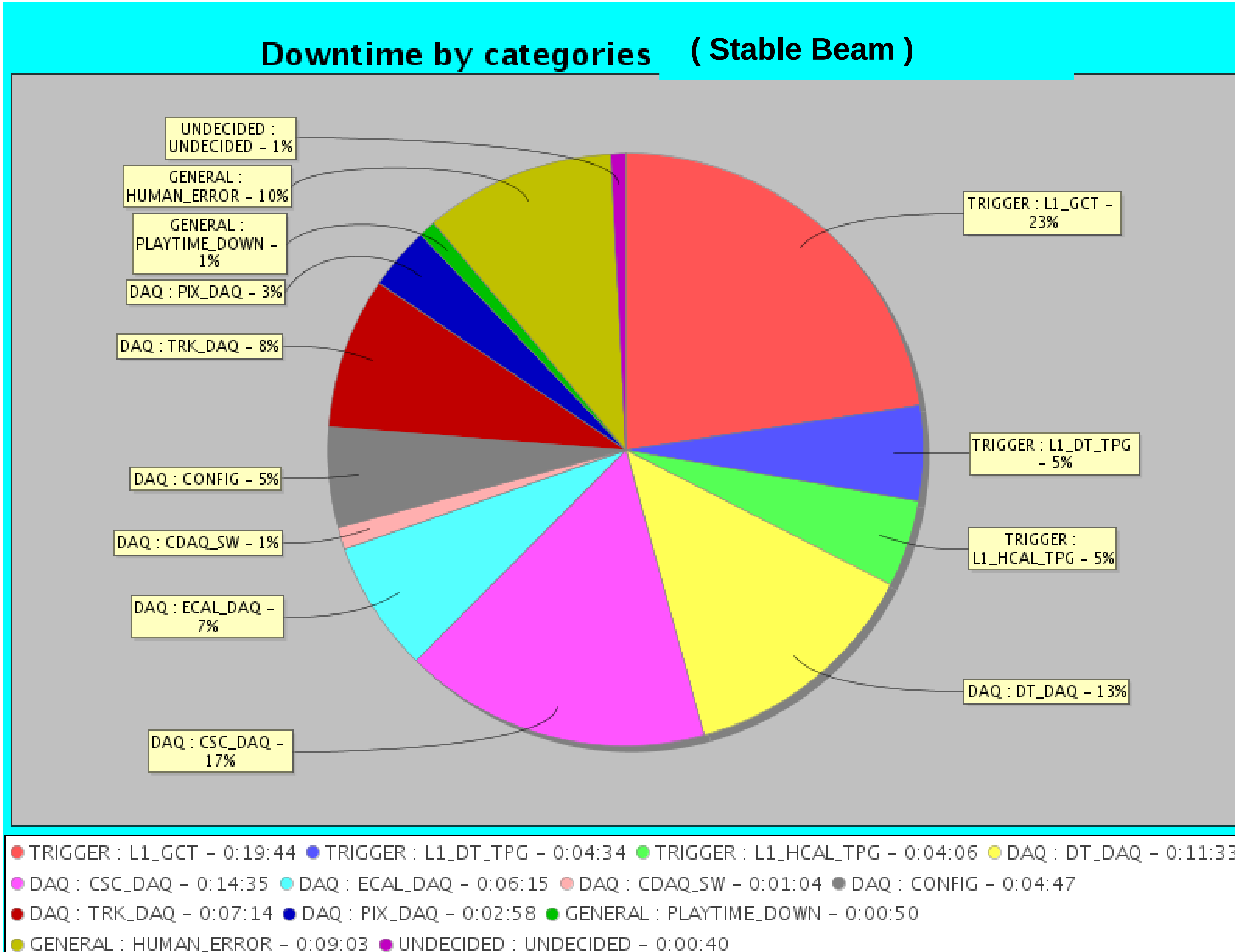
Up time
Down time
For All LHC Fills since 30 March, 2010
Stable Beam time
Time, minutes
1,750
1,500
1,250
1,000
750
500
250
0
1005
1033
1058
1128
LHC Fill Number
Delay scan performed



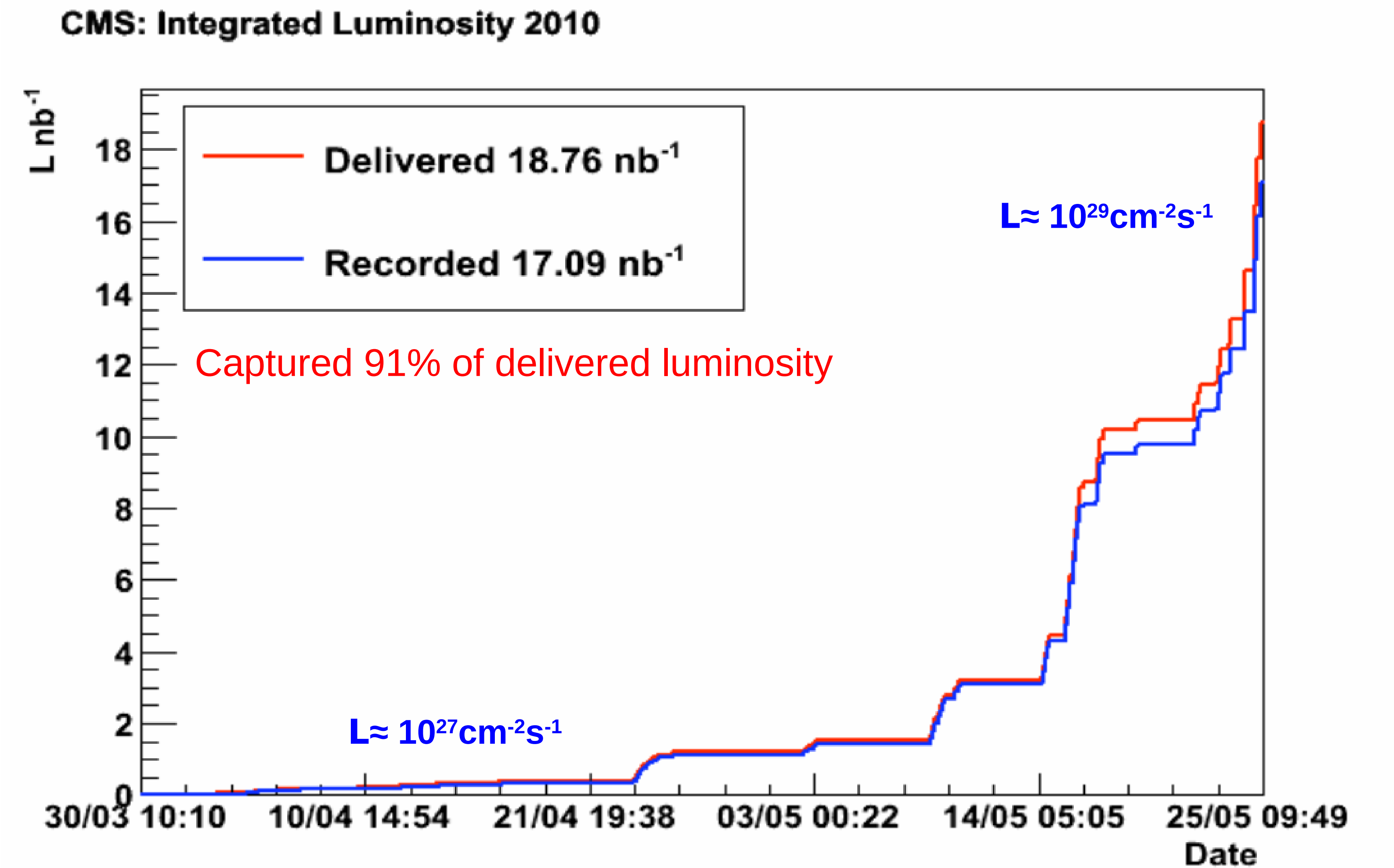
Efficiency (%)
100
90
80
70
60
50
40
30
20
10
0
1000
1020
1040
1060
1080
1100
1120
LHC Fill Number

Downtime Statistics Example: between fill # 1101 and 1119

Live time: 29:24:12, Down time:01:27:23, Efficiency: 95%



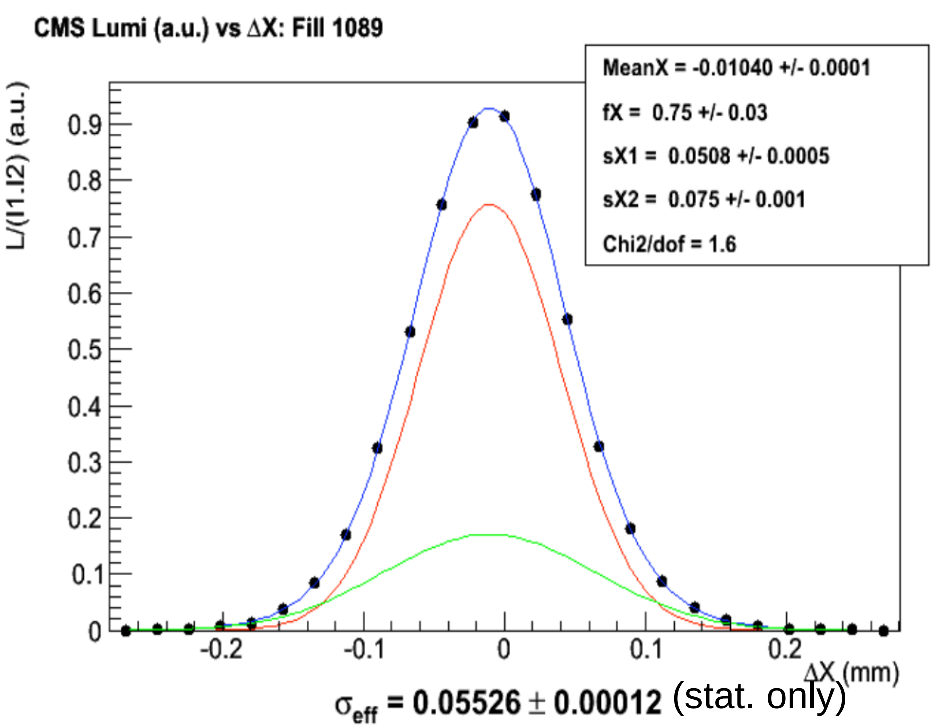
CMS Recorded Luminosity

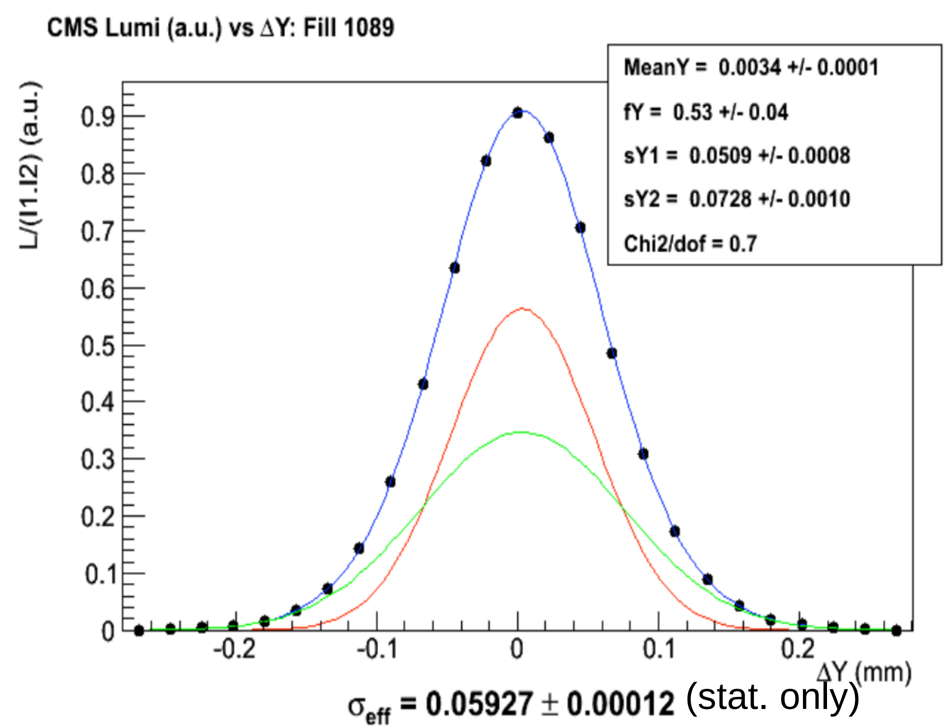


Seen inst. luminosity increase by more than two orders of magnitude.
Waiting for the LHC to take the next step.

van der Meer Scans

- At the start of each fill – and sometime during the fills – the LHC performs a scan of the beams to optimize the luminosity.
- CMS has also performed full van der Meer scans to measure the beam size and combined with the measured bunch currents allow us to determine the absolute luminosity.
  - Will then update the absolute normalization for the CMS luminosity – currently determined from Monte Carlo simulation



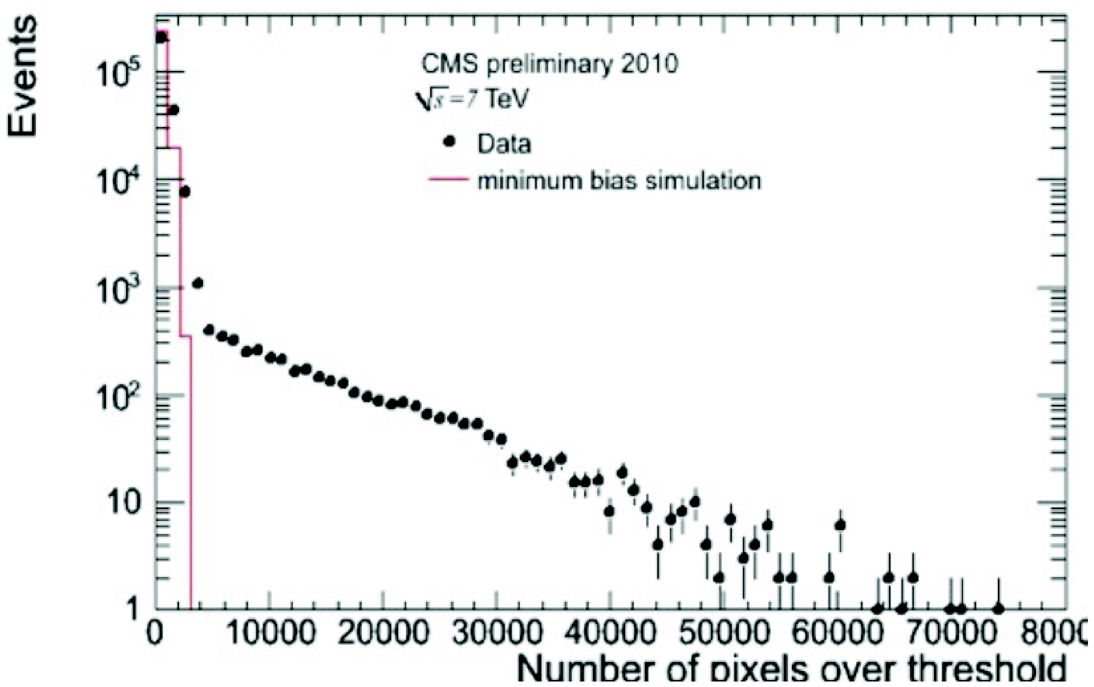


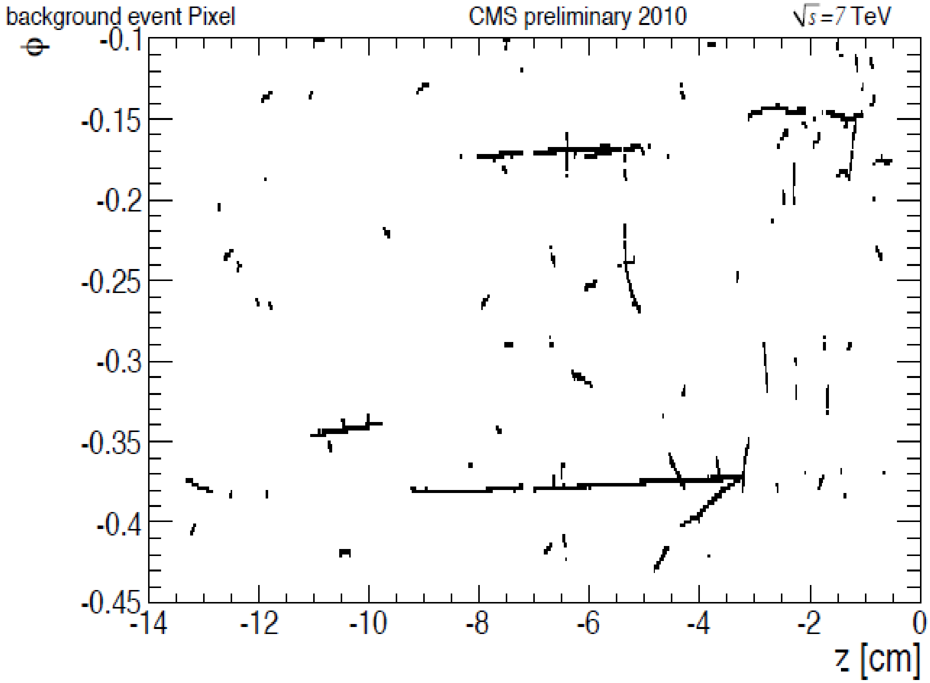
Some Unexpected Features

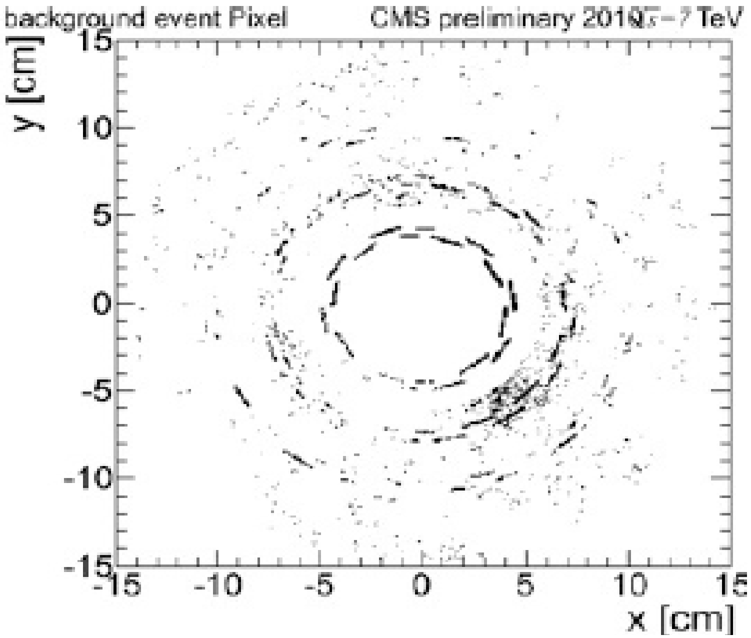
- Though the CMS detector has performed remarkably well during the first few months of operation there are a few issues that has required special attention.
  - Very large occupancy events in the pixel detector
  - Anomalous energy deposits in the ECAL and HCAL

- I will briefly describe these problems and the solutions that we have deployed to address them.

High Pixel Occupancy Events



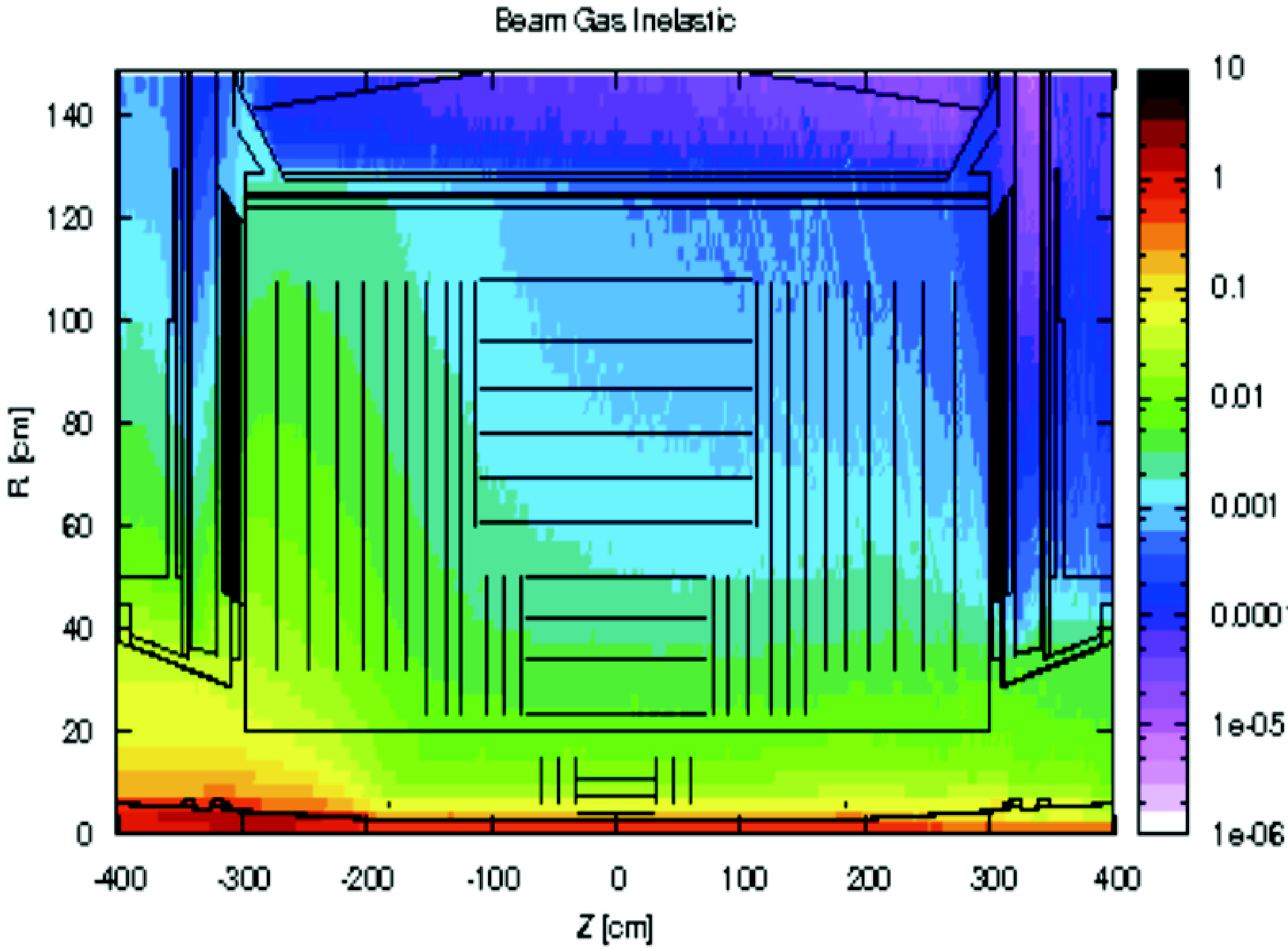




- Events with occupancy much larger than expected from minbias events seen in the pixel detector.
  - Tracks parallel to the barrel pixel modules – source along beam line.
- Readout of these high occupancy events in the pixels takes long time.
  - Readout and recovery modified in frontend readout firmware.

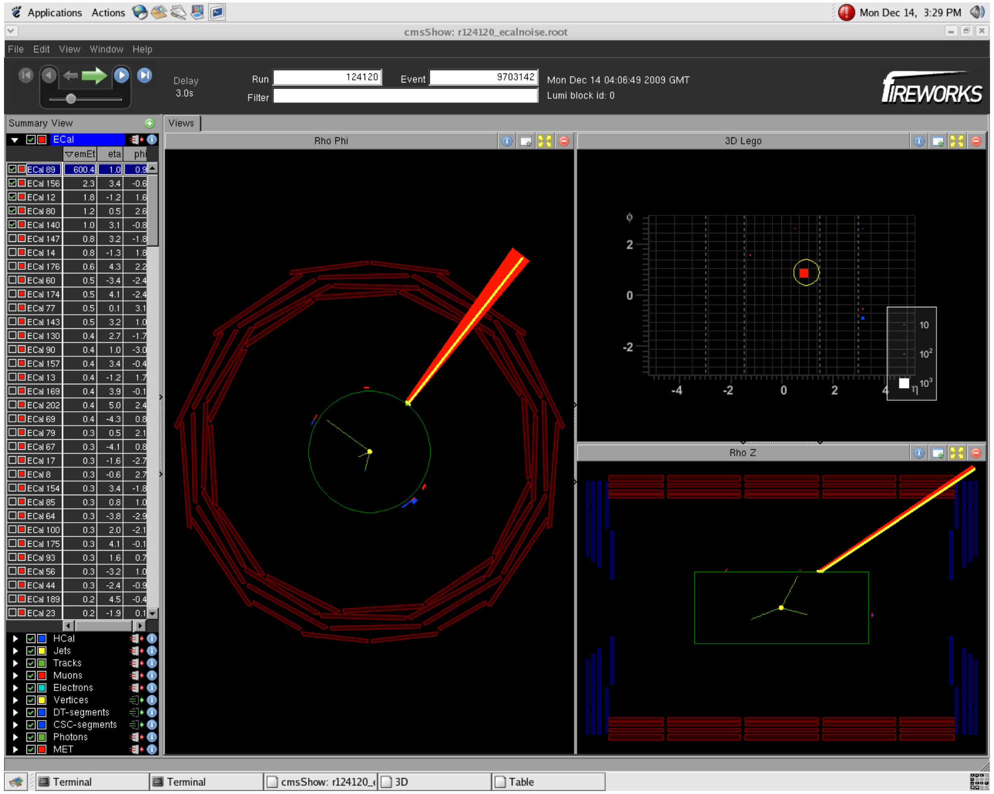
Beam-Gas Interactions

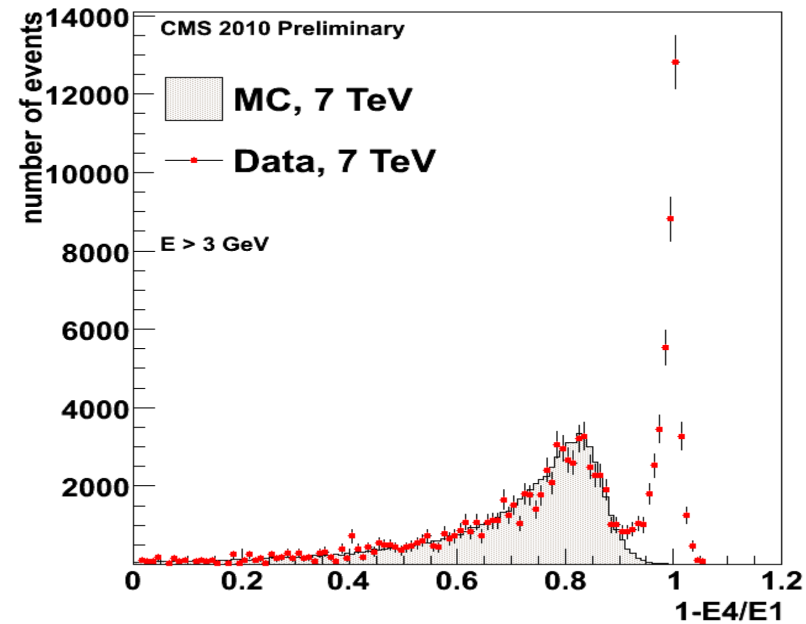
- The source of these large pixel events is beam-gas interaction outside detector area.

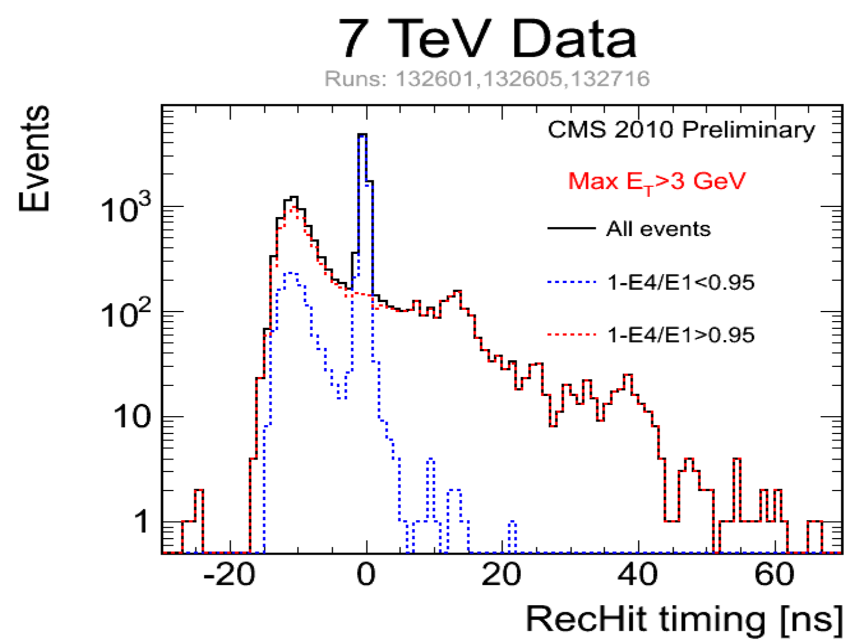


- Simulation of beam-gas interactions shows that the rate and radial distributions of particles are qualitatively in agreement with the observations.
- More detailed studies are underway.

ECAL Anomalous Energy Deposits



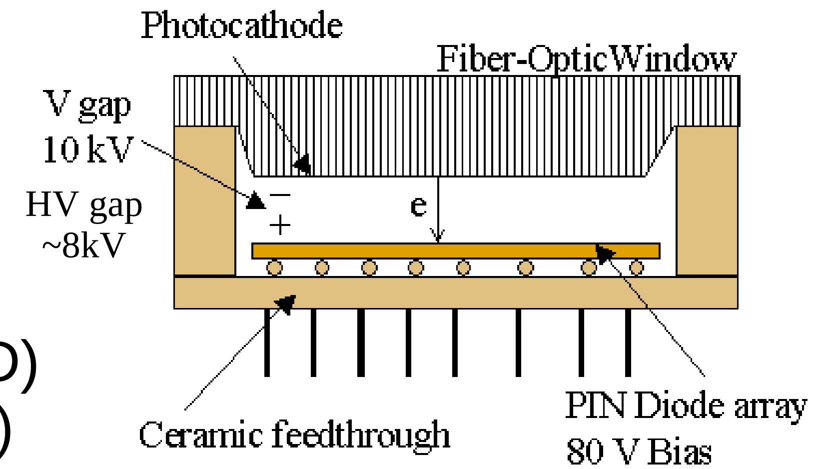


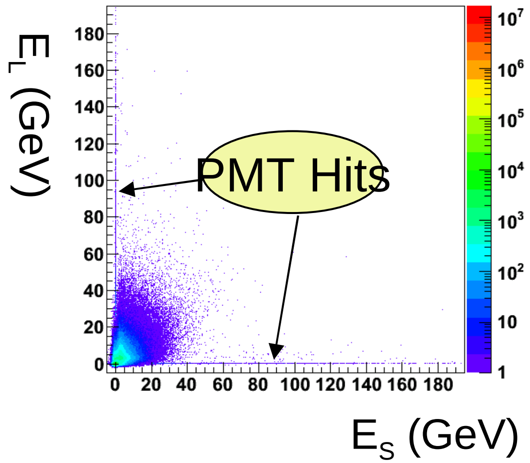


- Large energy deposits in single crystal in barrel. Barrel uses avalanche photodiodes (APD). Not seen in endcap which use vacuum phototriodes (VPT).
- Source: Energy deposited in APD by heavy ionizing particles.
- Can be rejected based on 'shower shape' and timing.

HCAL Anomalous Signals

- Electronic noise from Hybrid Photo Diodes (HPD), used in Barrel, Endcap, and Outer HCAL
  - HPD Ion Feedback (1 channel)
  - HPD Discharge (up to 18 channels = 1 HPD)
  - Readout Box Noise (up to 72 ch. = 4 HPDs)
- 10-20 Hz for E>20 GeV from all 288 barrel and endcap HPDs.
- Noise is random and very small overlap with physics.
- Filters developed to remove this noise based on timing, pulse shape, and EM fraction. (*JINST 5 T03014*)
- Cherenkov light produced by interactions in the window of the Forward Calorimeter PMTs, can also be filtered out based on energy asymmetry in long vs. short fibers. (*Eur. Phys. J. C53, 139-166, 2008*)





Conclusions

- CMS has operated with high efficiency since the start of 7 TeV operations on March 30, 2010.
  - We have recorded 91% of the luminosity delivered by the LHC in stable beam conditions.
- All subdetectors operating with an active channel fraction greater than 98%.
- The detectors have been timed in to the LHC beam
  - L1 physics triggers have been deployed.
  - The high level trigger is now actively selecting events for storage.
- We have performed van der Meer scans for absolute luminosity determination.
- Some smaller problems have come up, and has been promptly understood and addressed.
- Looking forward to the next step in luminosity from the LHC.