CMS Tracker Early Run II Performance

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On behalf of the CMS collaboration

EUROPEAN PHYSICAL SOCIETY HEP2015

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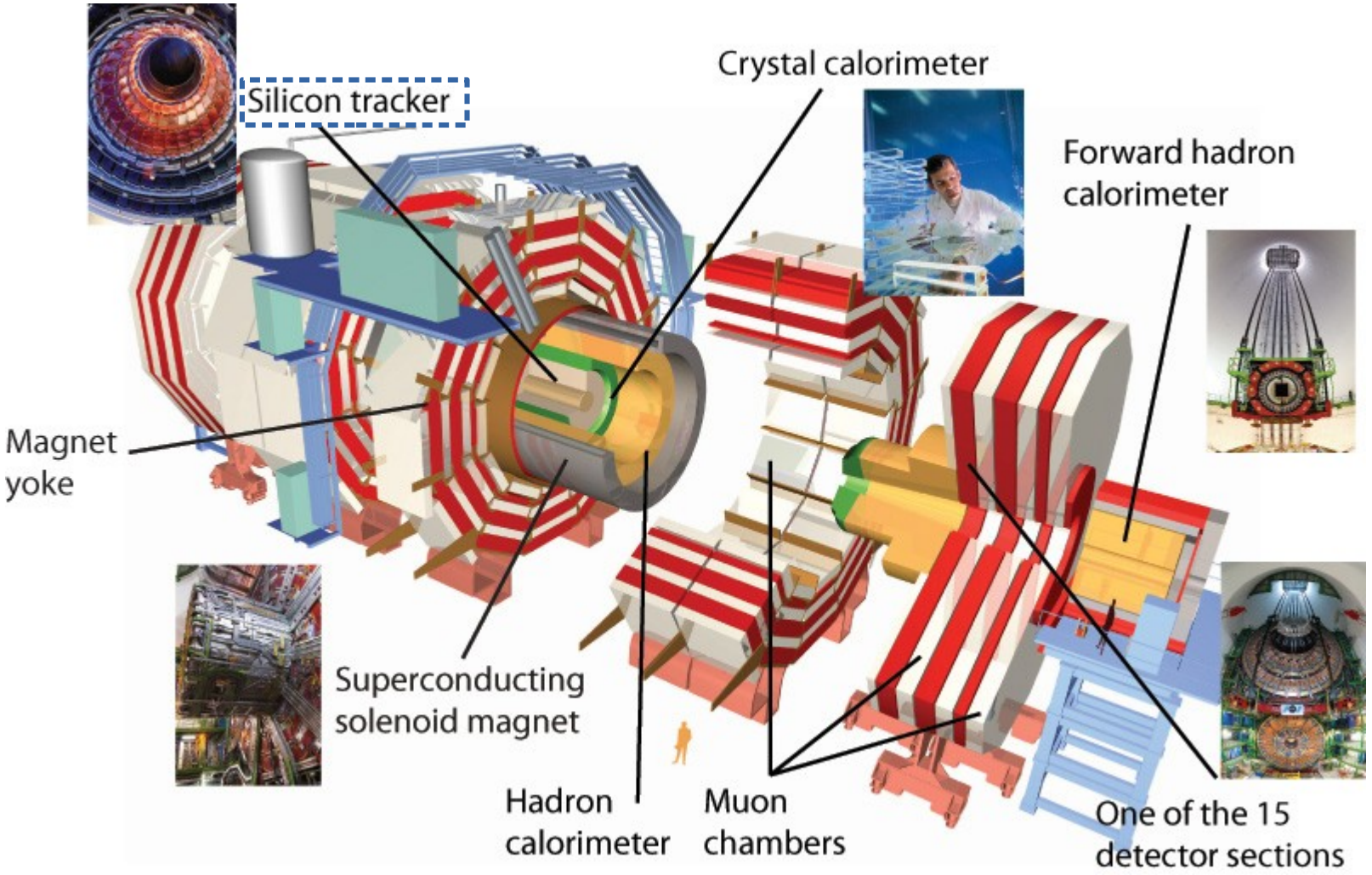
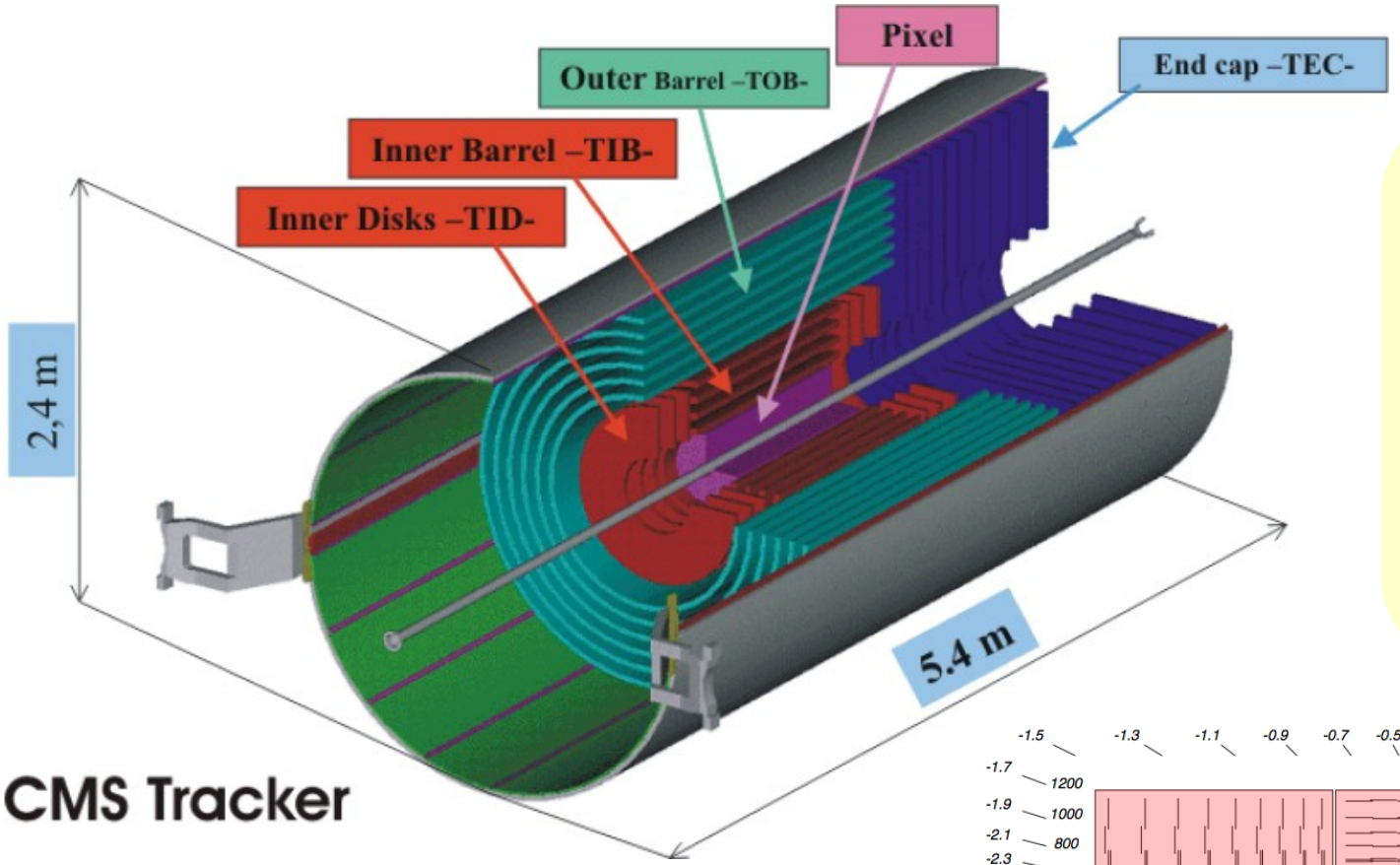
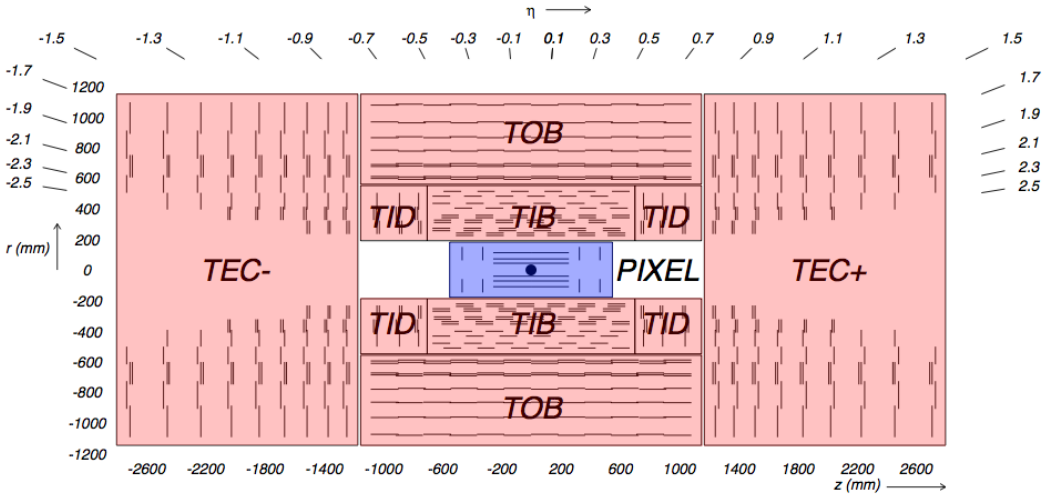
The CMS Detector



The CMS Tracker (1)

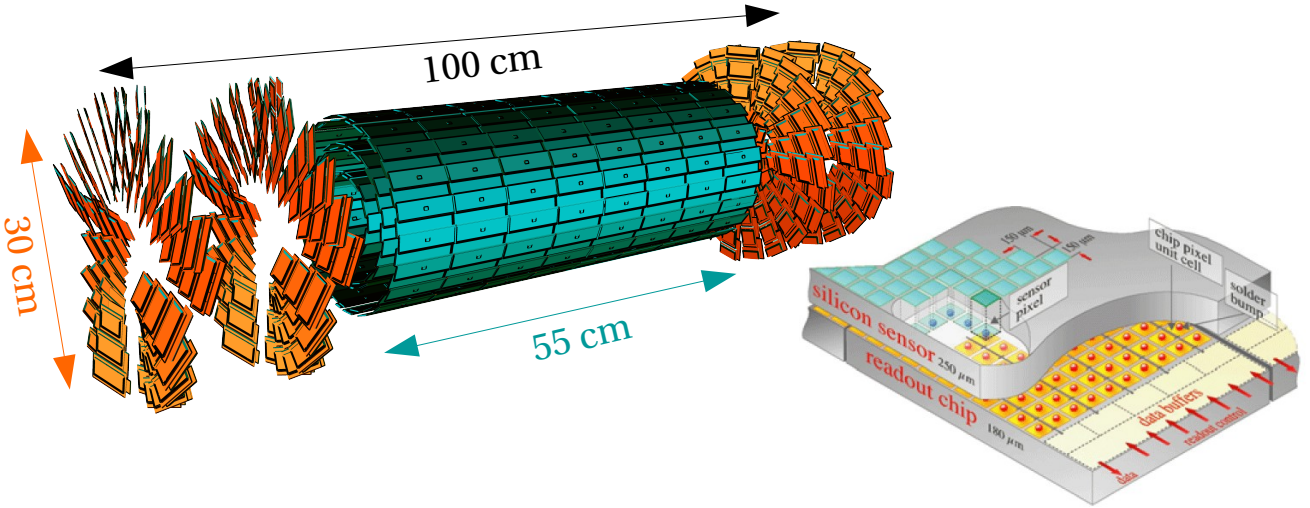


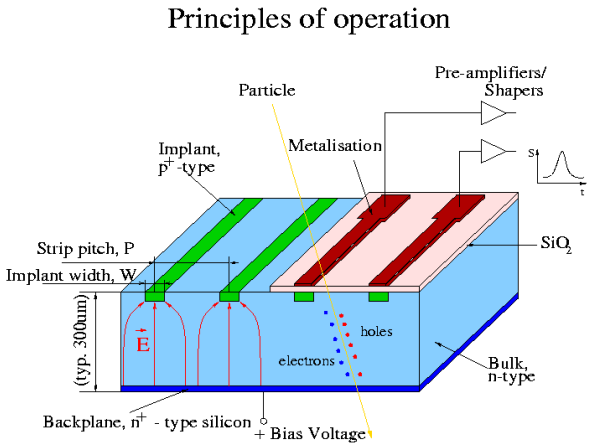
- All Silicon
- Analogue readout
- Sensitive area : 200 m²
- Pseudo-rapidity : $|\eta| < 2.5$
- T°: -15° C/-10° C ✶ New !
- Composed of Strip and Pixel

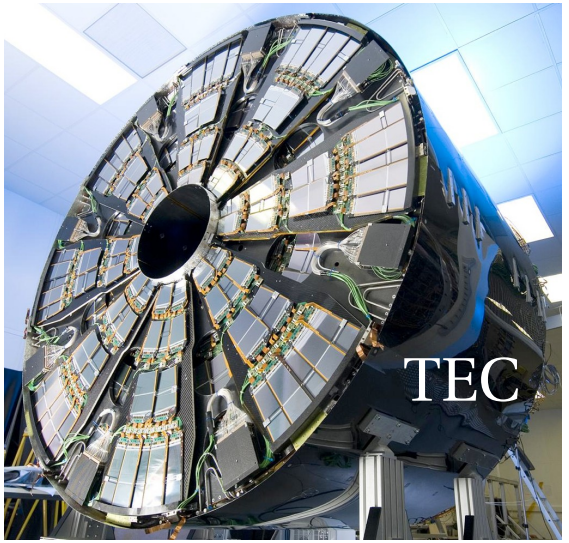


The CMS Tracker (2)

- Pixel detector
  - 3 barrel layers (BPix)
    R : 4.4, 7.3 and 10.2 cm
  - 2x2 forward disks (FPix)
    z : ± 34.5 and ± 46.5 cm
  - 1 440 Modules
  - 66 M Pixels
  - Pixel size : 100 x 150 µm



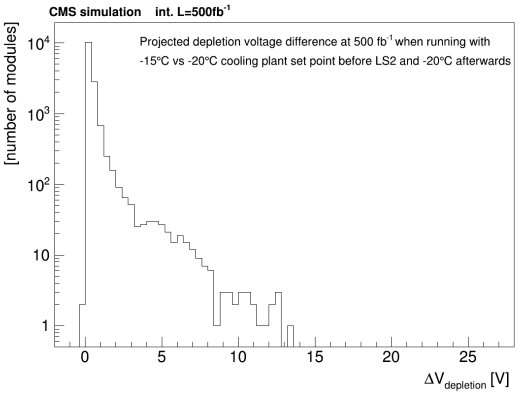


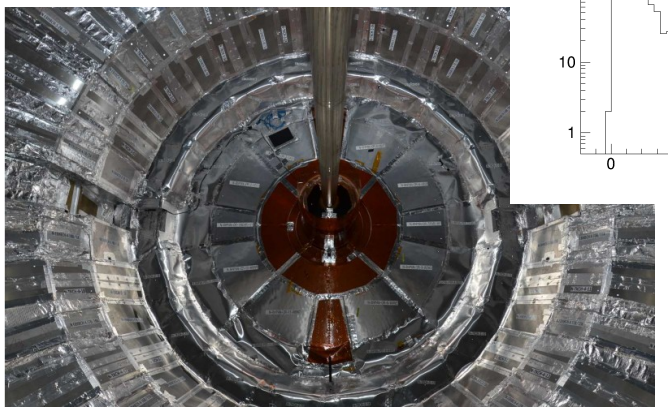


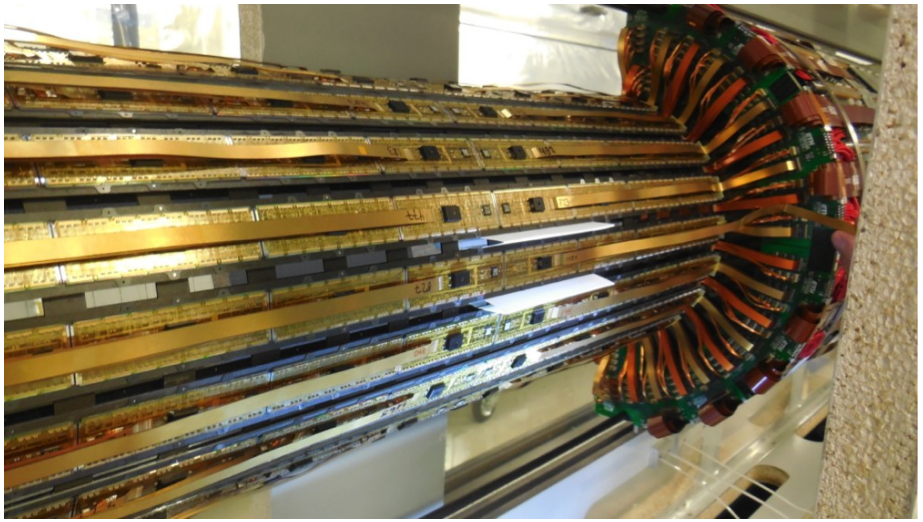
- Strip detector
  - 15 148 Modules
  - 9.6 M strips
  - p+ strips on n bulk
  - Pitch : 80 – 205 µm

First LHC Long Shut Down

- Tracker at +4°C during run I : $\mathcal{L}$ ~ 30 fb^{-1}
- At the end of Run II : $\mathcal{L}$ ~ 150 fb^{-1}
- Operating colder : -15°$_{Strip}$/-10°$_{Pix}$
  - C_6F_{14} cooling plants refurbished
  - Improve dry gas system
  - Improve sealing and insulation



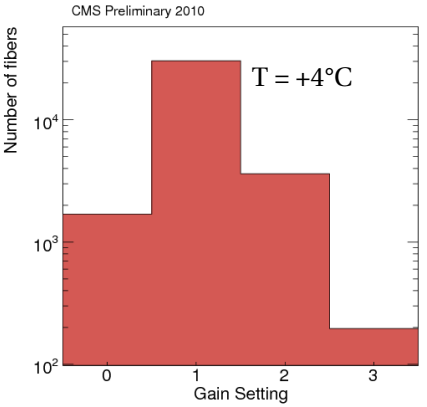


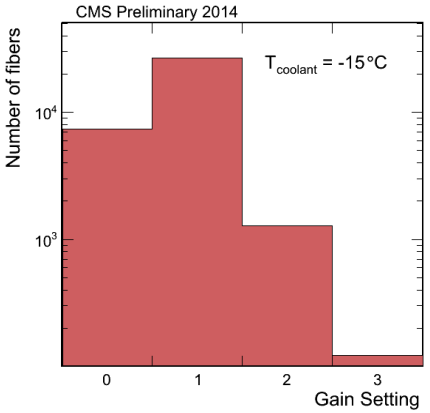


- Pixel faulty channels after run I
  - BPix ~ 2.3 %
  - FPix ~ 7.8 %
- Extraction from CMS in summer 2013 to repair most of them
- Reinsertion in CMS on 8th December 2014

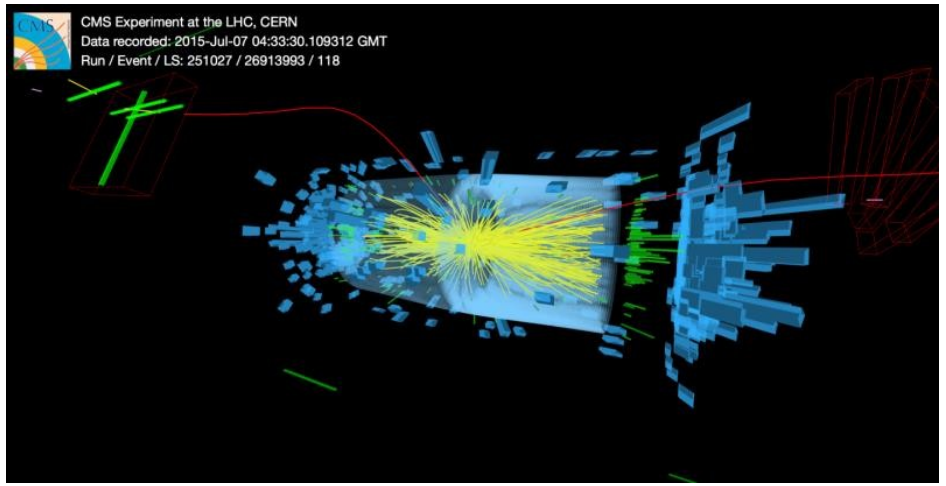
2015 Commissioning

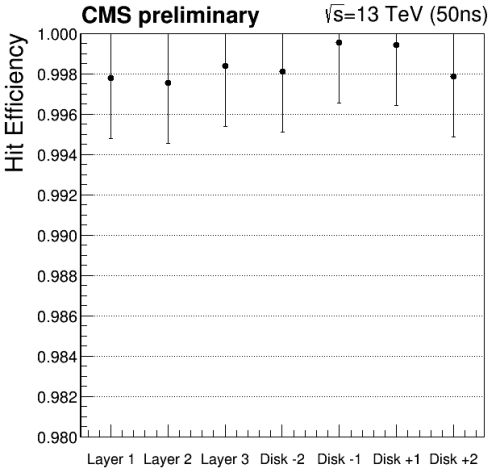
- Calibration to account for the signal loss in the readout chain
  - Lower signal amplification needed at lower temperature
  - Ample room to compensate for radiation damages
- Cosmic runs before pp collisions
  - 0 T (early 2015), 3.8 T (~March)
  - First alignment and timing scan
  - Noisy pixel mask (<0.1%)

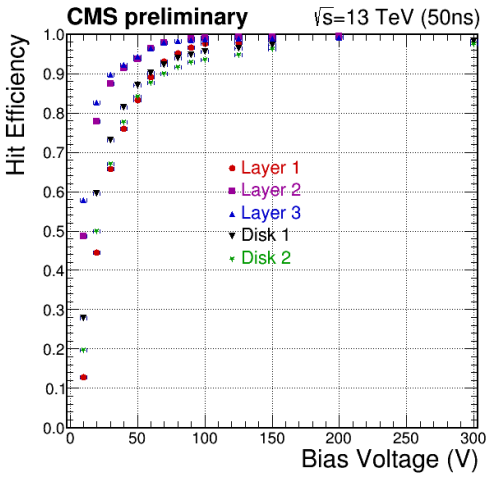




- Proton collisions with 13 TeV centre of mass energy started on 20th May
  - 0 T at the very beginning
  - 3.8 T since the 6th of July

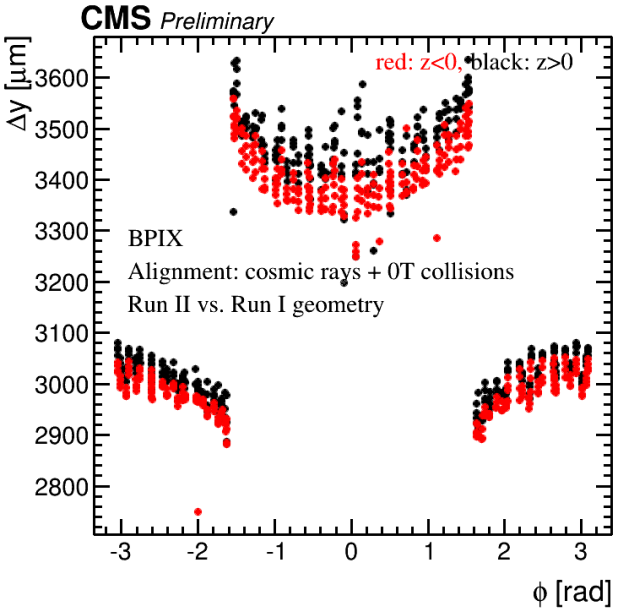


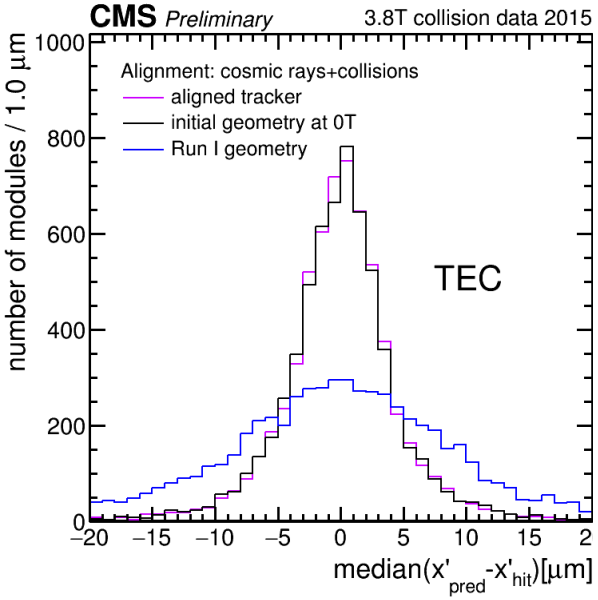


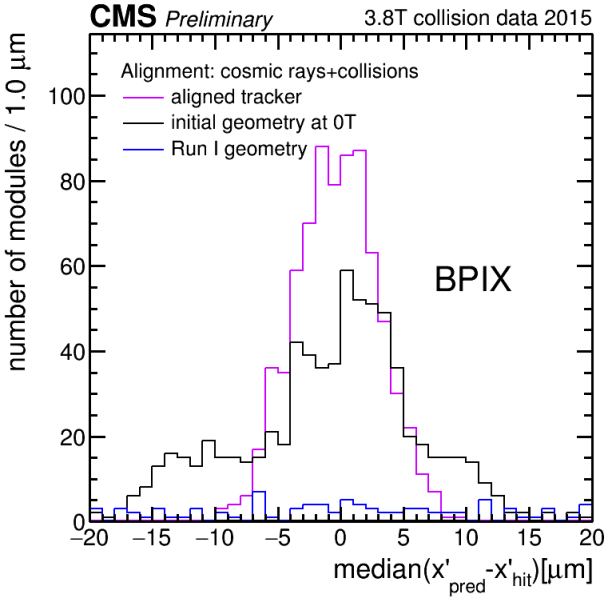


Detector Alignment

- Determine geometry parameters for each module (~200k parameters to fit)
  - Several alignments in different conditons
  - Each time starting with the previous alignment parameters
- Pixel has been displaced w.r.t. run I geometry (extraction/replacement + BPix recentering)



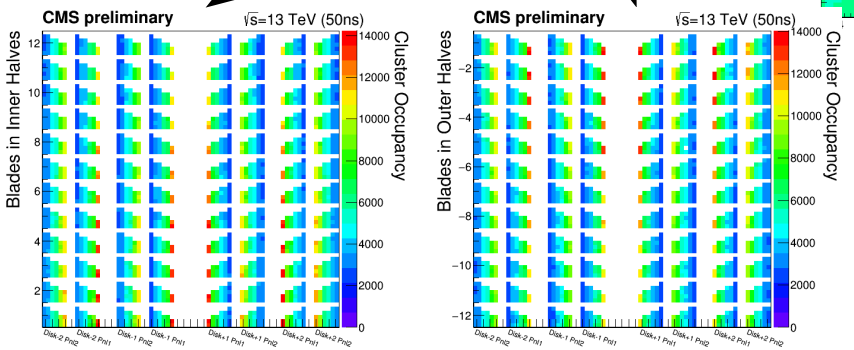


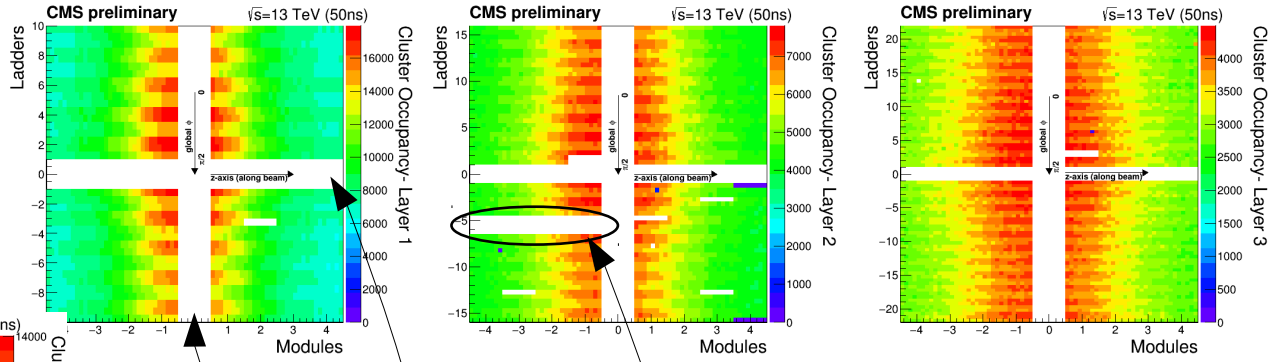


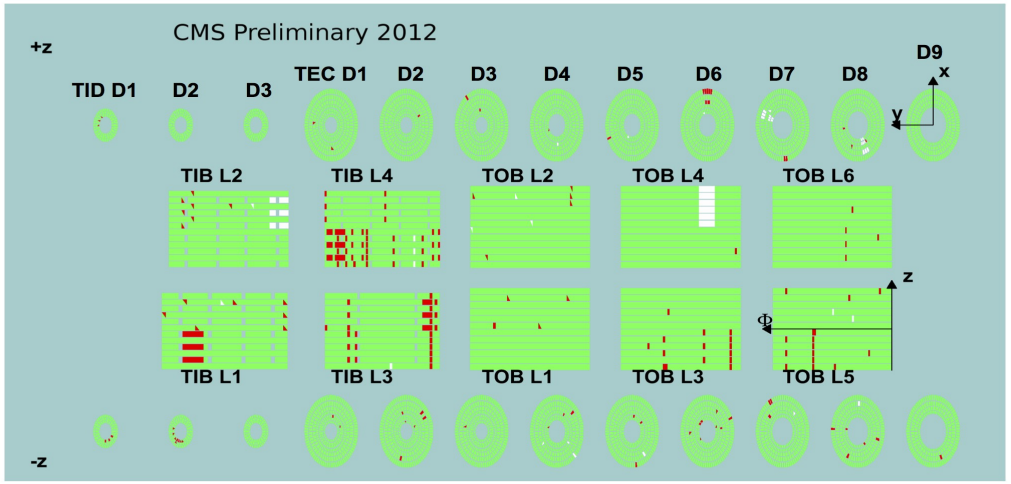
- Validation : refit the track with new parameters and obtain hit prediction from the other hits
- Pixel mooves when magnetic field is switched on
- Relative movement of Pixel w.r.t Strip impacts also Strip distribution
- Performance limited by statistics

Detector Status

- Pixel active fraction
  - BPix : 98.01 %
  - FPix : 99.98 %



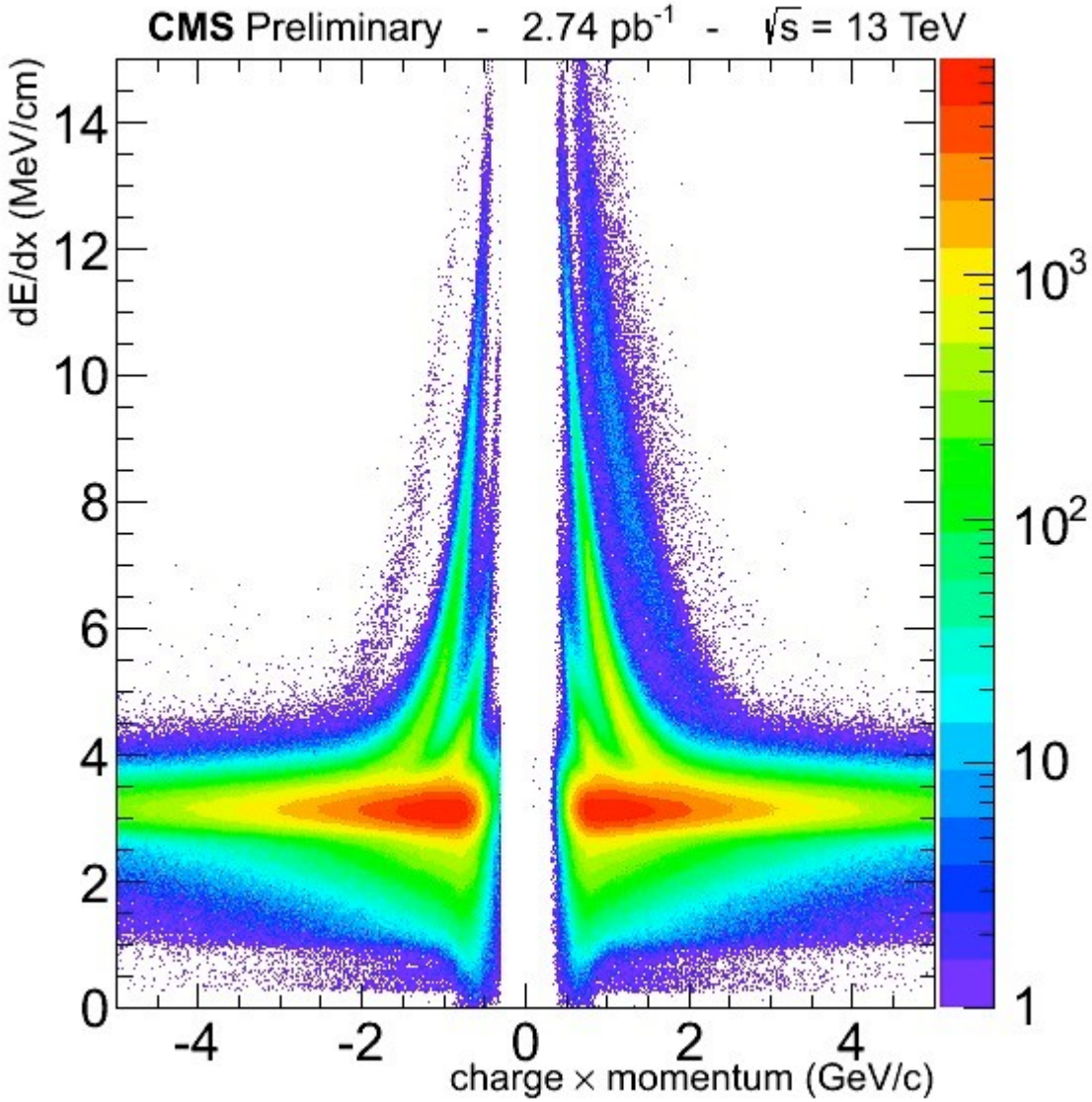




- Strip active fraction is stable w.r.t. time. 2008 : 98. 5 %, 2013 : 97.48 %, 2015 : 97.5 %
- Faulty channels mainly due to
  - Control rings
  - HV channels
  - LV channels
- No impact on tracking efficiency

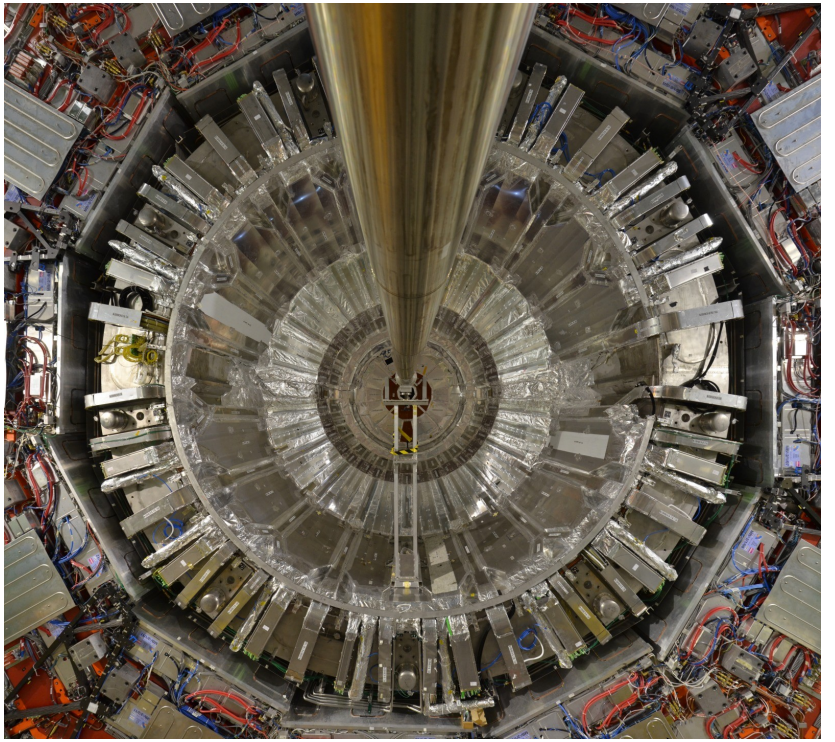
Tracker is ready for physics

- With a proper calibration, the collected signal can be translated into an energy deposit (dE)
- Accounting for the particle trajectory through the sensor, we can reconstruct its dE/dx which depends on its mass and momentum
- From right to left (positive x axis) we can see the Deuteron, Proton and Kaon bands
- Expected asymmetry between positive and negative charges (pp collisions)



Summary

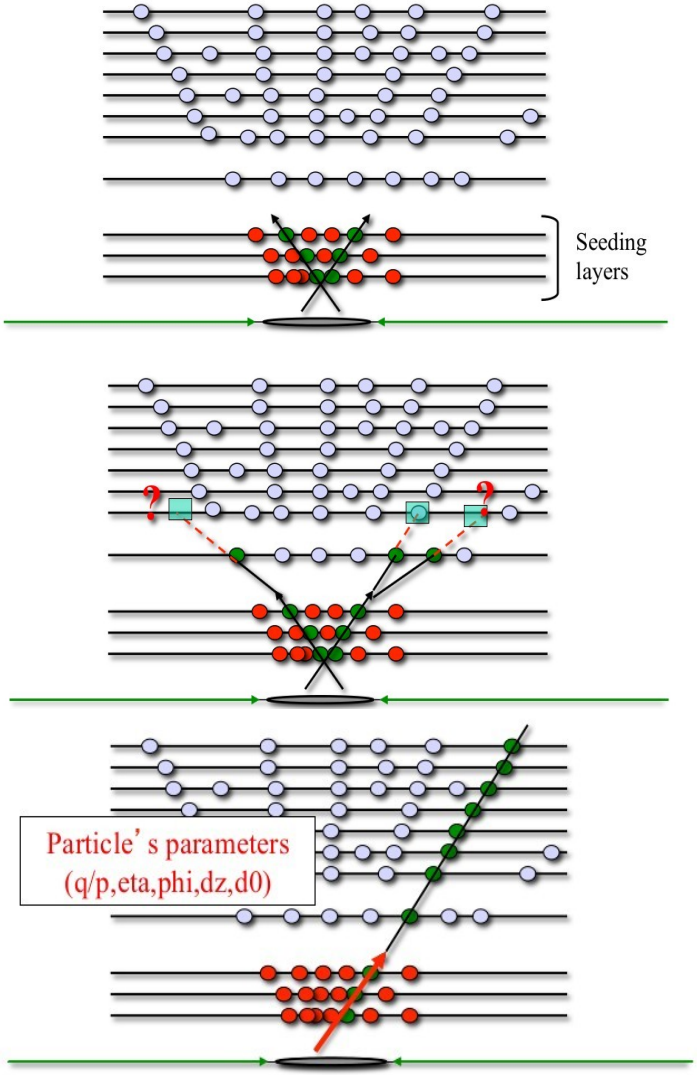
- Tremendous work has been done during LS1
  - Operate colder ($\mathcal{L}_{\text{run II}} \sim 150\ \text{fb}^{-1}$)
    - Cooling plants
    - Dry gas system
    - Sealing
  - Repair of Pixel broken channels
- Detector commisssioned and aligned
- CMS Tracker is ready for physics at 13 TeV !



Back-up

Track Reconstruction

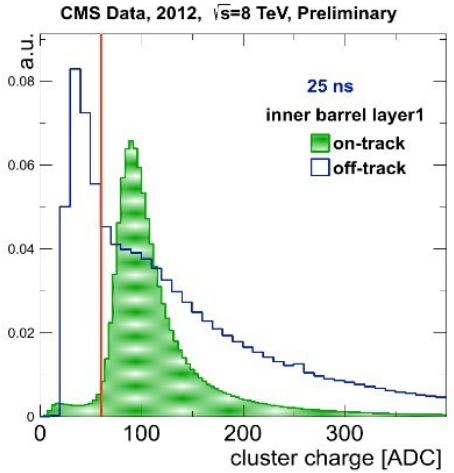
- Seed generation
  - Initial track candidates with 2 or 3 hits
  - Estimate trajectory parameters + uncertainties
- Track finding
  - Extrapolate seed trajectory searching for additional hits
  - Update track parameters
- Track fitting
  - Provide the best possible estimate of the track parameters
- Track selection + hit removal
  - Quality criteria (χ^2, N_{layers}, dz, …)

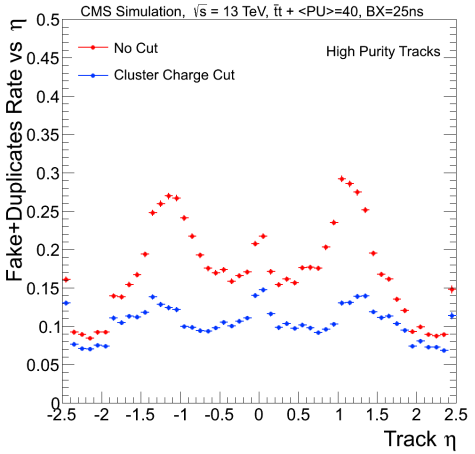


These four steps are done iteratively with different seeds and selections

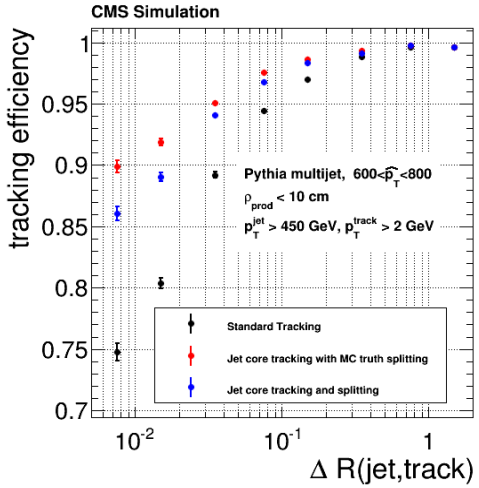
Tracking Improvement

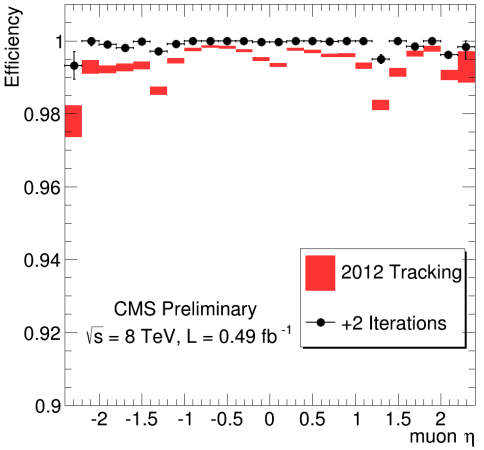
- Strip cluster charge cut to suppress out-of-time pile-up



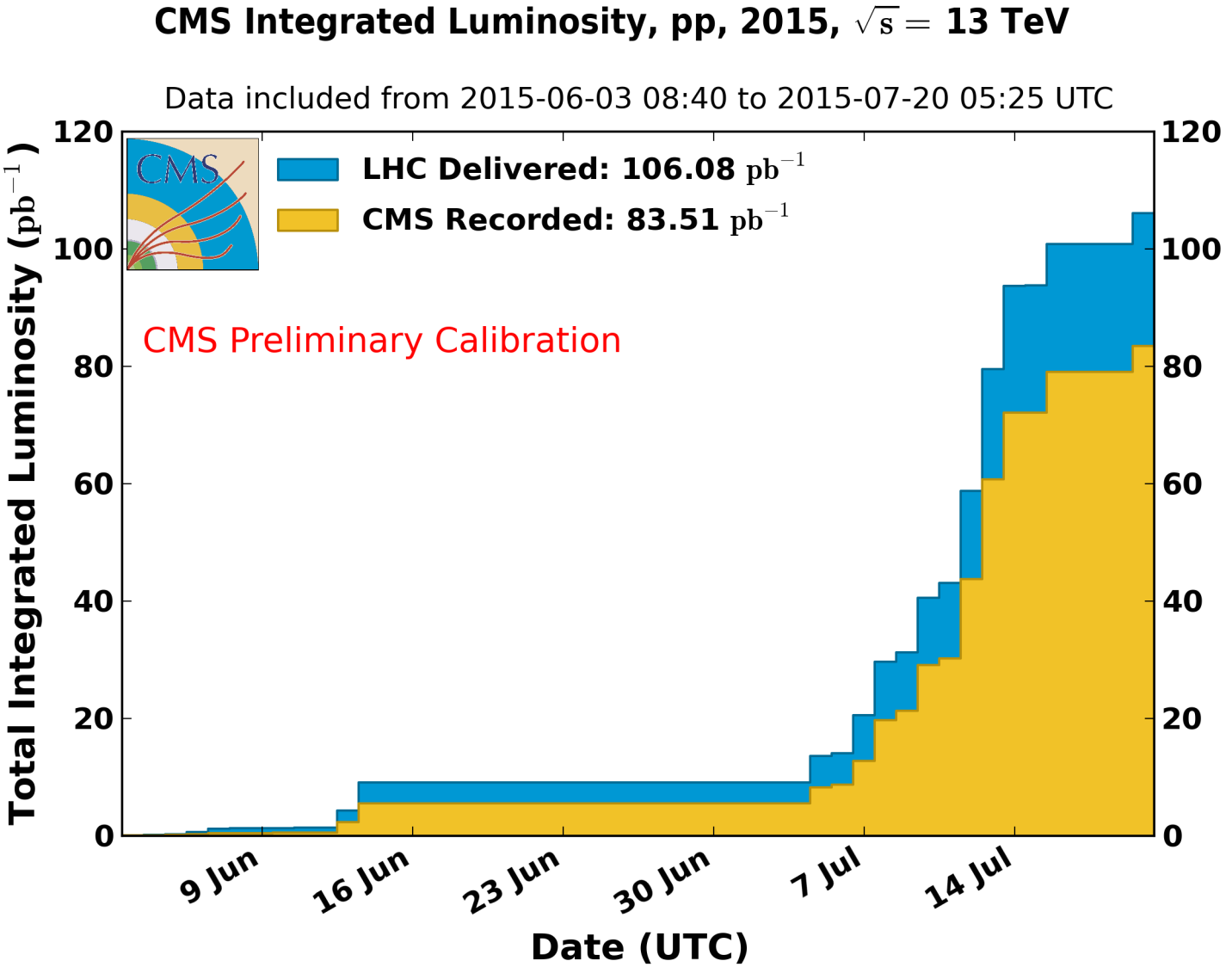


- Add tracking iteration for high pt jet and muons

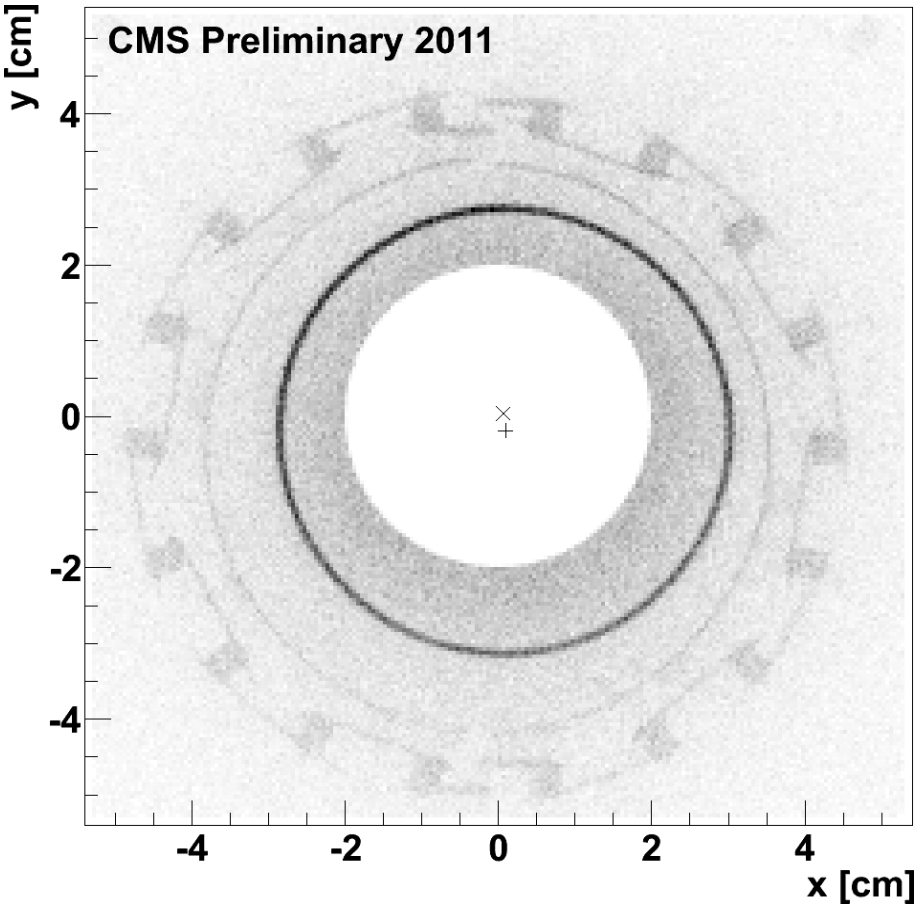


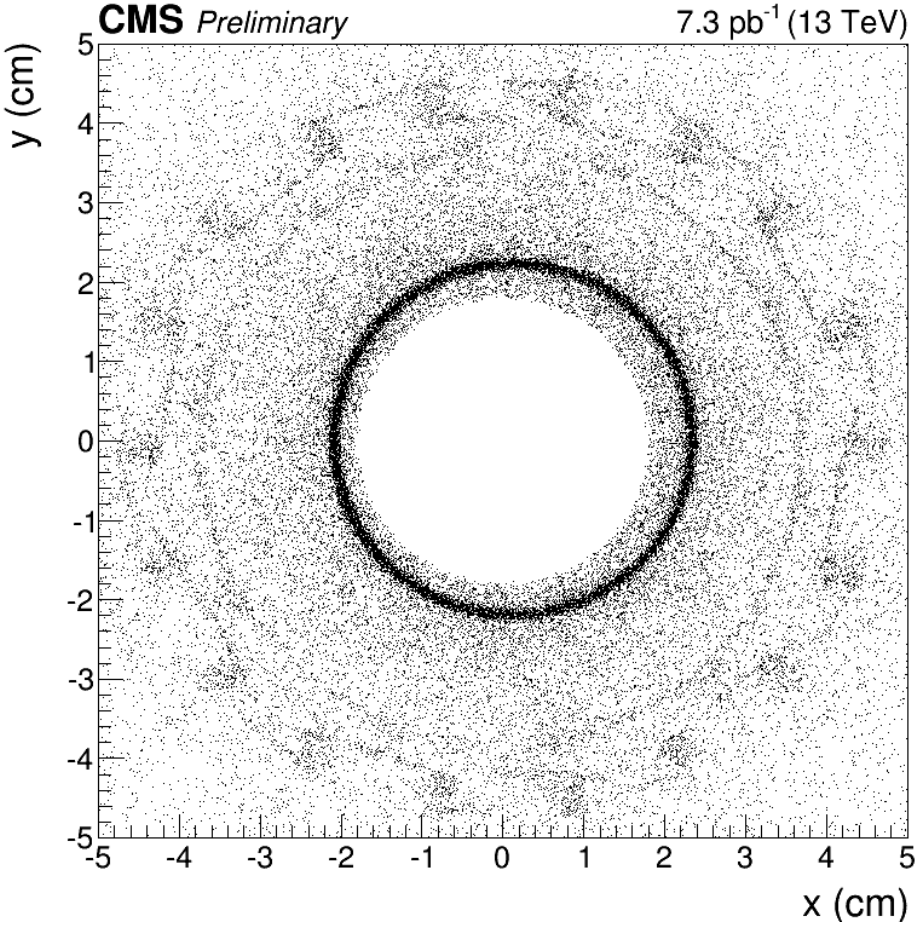


Luminosity


CMS Integrated Luminosity, pp, 2015, $\sqrt{s} = 13$ TeV
Data included from 2015-06-03 08:40 to 2015-07-20 05:25 UTC
CMS
LHC Delivered: 106.08 pb^{-1}
CMS Recorded: 83.51 pb^{-1}
CMS Preliminary Calibration
Total Integrated Luminosity (pb^{-1})
0
20
40
60
80
100
120
9 Jun
16 Jun
23 Jun
30 Jun
7 Jul
14 Jul
Date (UTC)

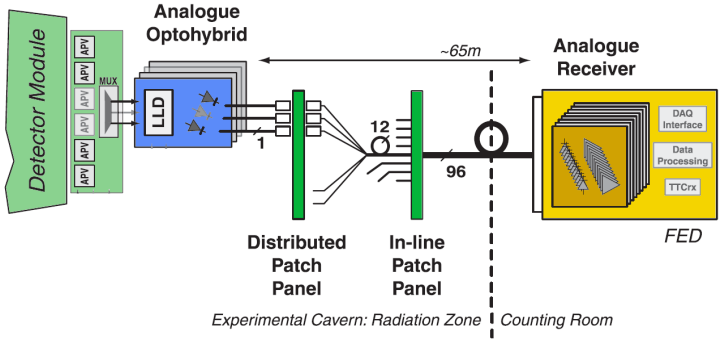
Beam Pipe Position



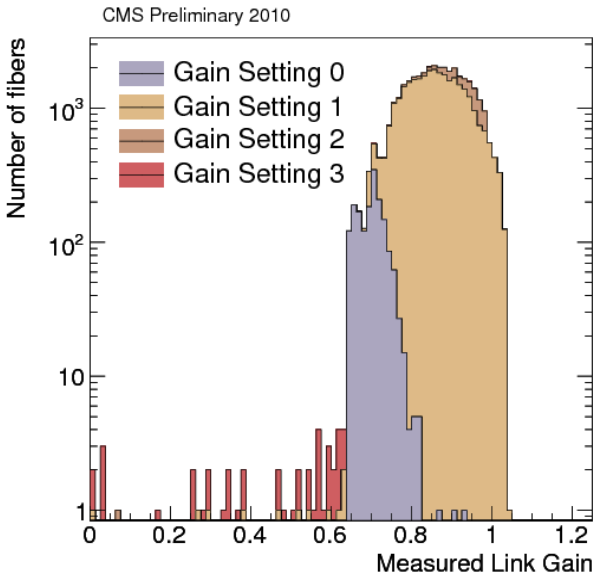


Strips Calibration at -15°C

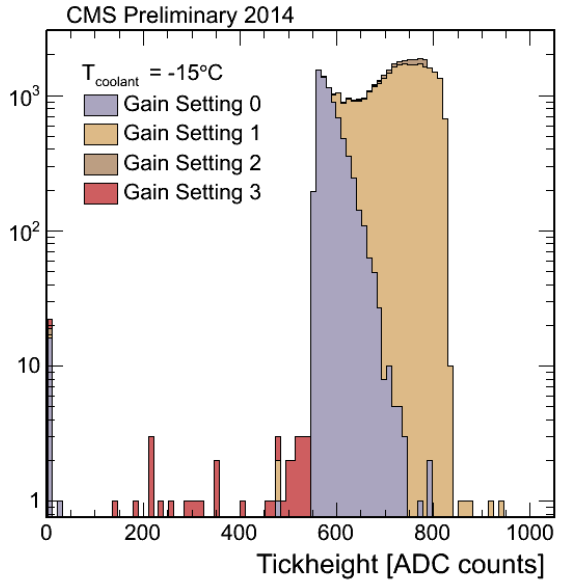
- APV's send data to the Front End Drivers through optical fibers
- Differences among the readout chain (temperature and radiation) generate non-uniform signal yield for a same amount of collected charges → **Gain parameter**

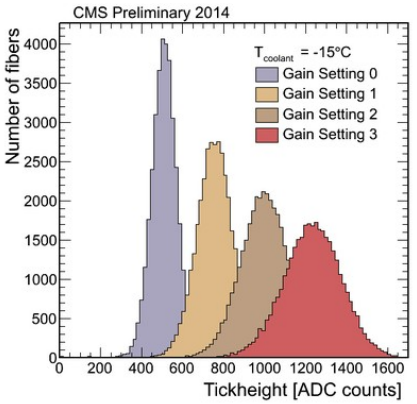


Run 1, +4°C



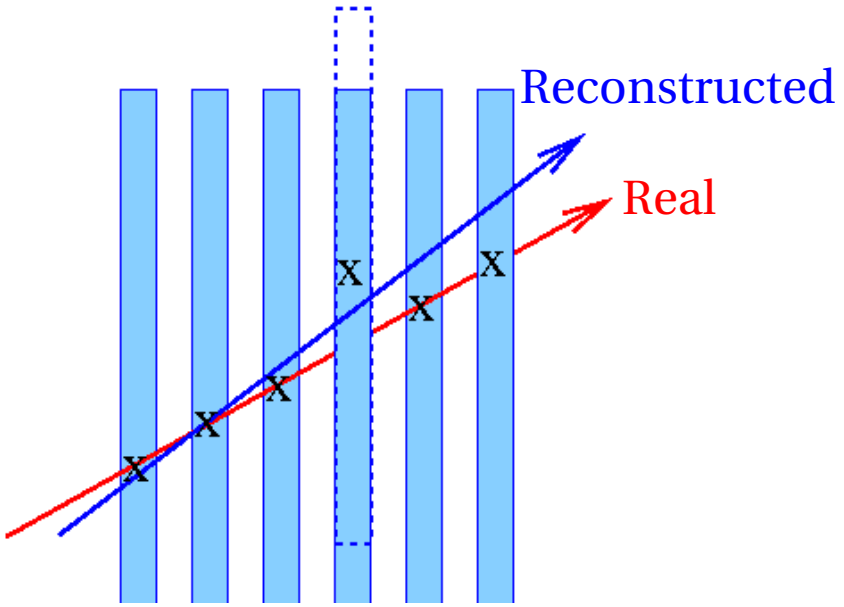
Run 2, -15°C



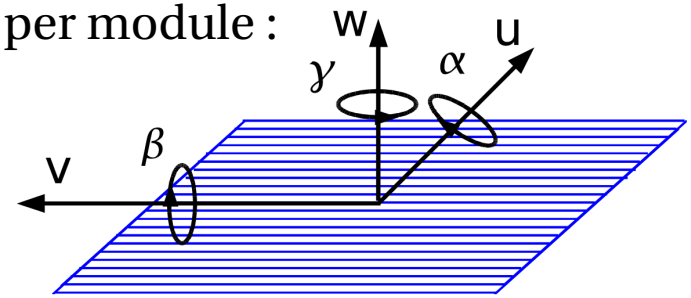


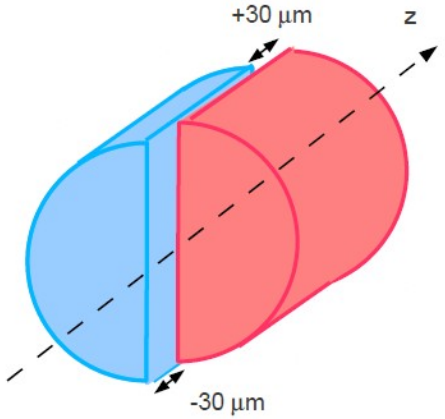
- 'Tick height' is the difference between digital 0 and 1 issued by APV's as seen by the FED
- Lasers on AOH are designed with four gain settings (0, 1, 2, 3)
- Choose the gain setting in order to have homogeneous gain parameters

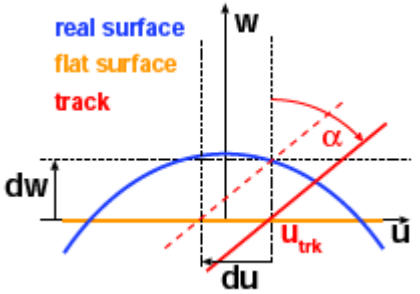
Track Based Alignment

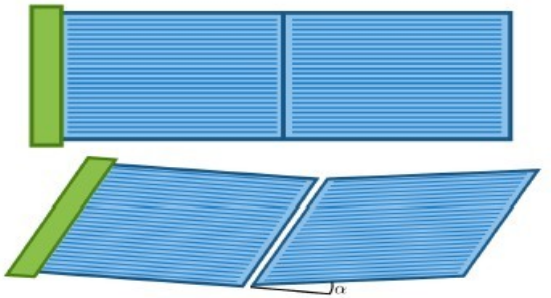


- Determine the module geometry parameters from a large sample of reconstructed charged particles trajectories
- Principle : minimize residuals (x_{hit} - x_{track})
- Alignment parameters per module :
  - 3 positions
  - 3 rotations
  - 2 bows
  - 1 kink (for TOB and outer TEC)





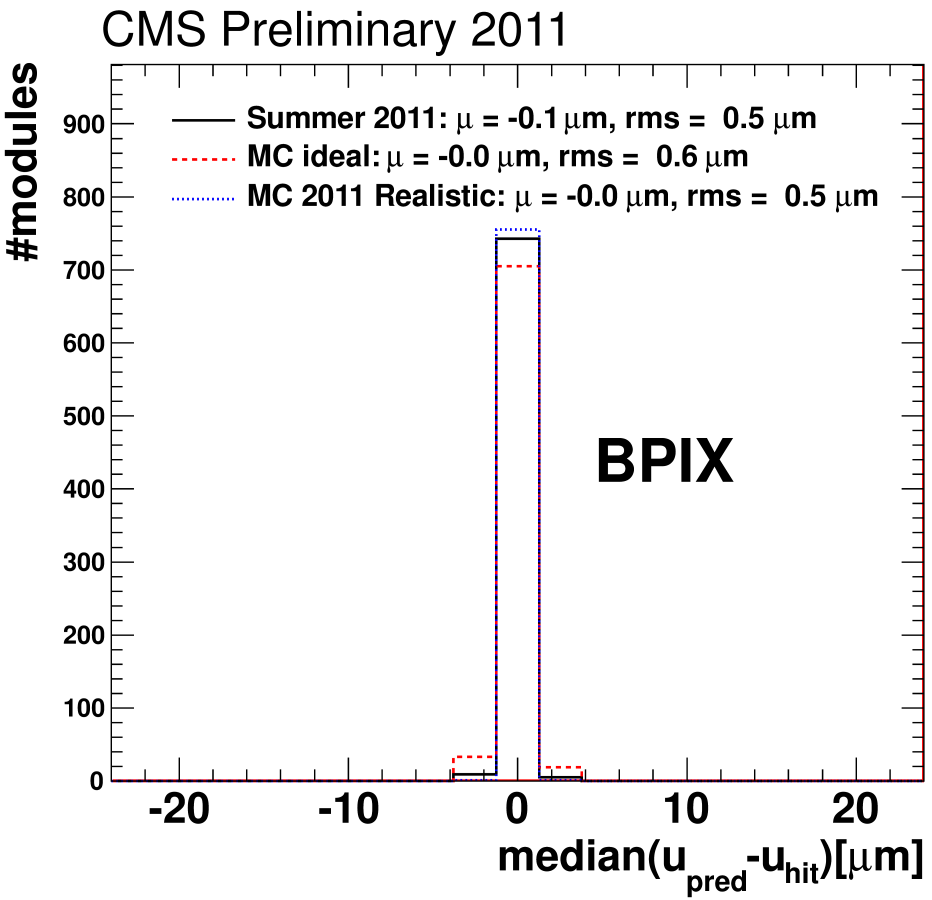




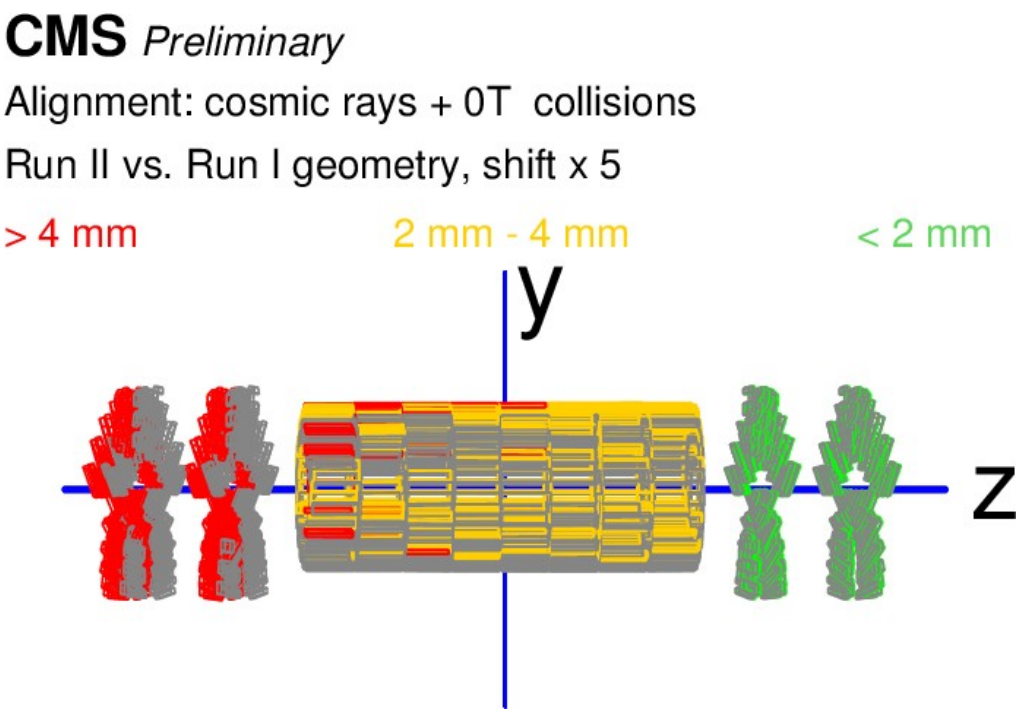
Big challenge : determine simultaneously ~ 200k parameters with high precision

Run I Alignement

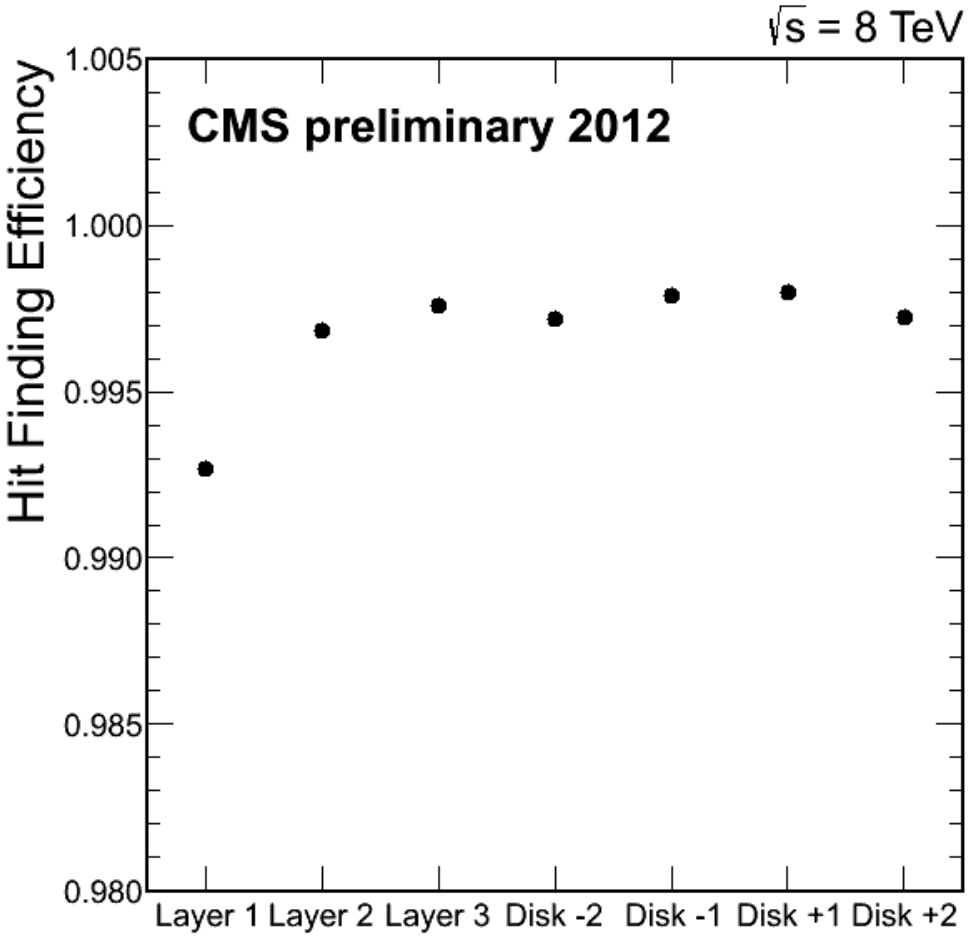
Benefits from more statistics

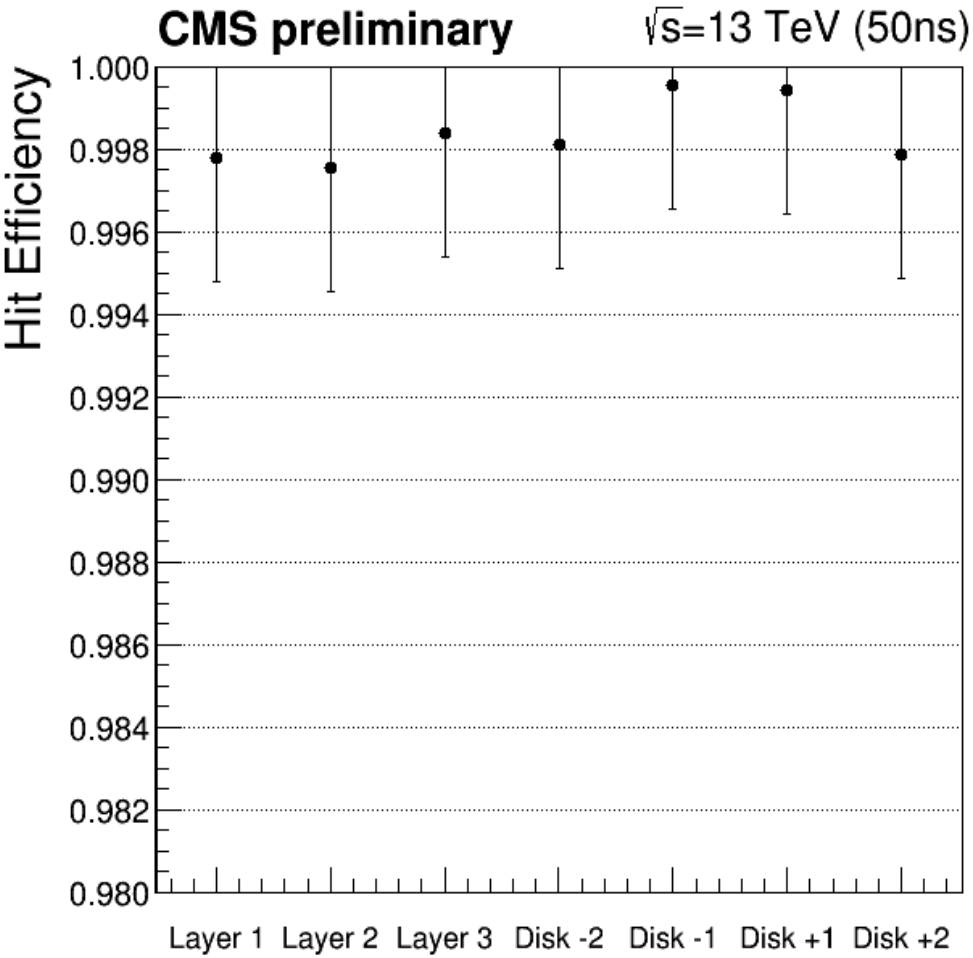


Pixel run I vs run II



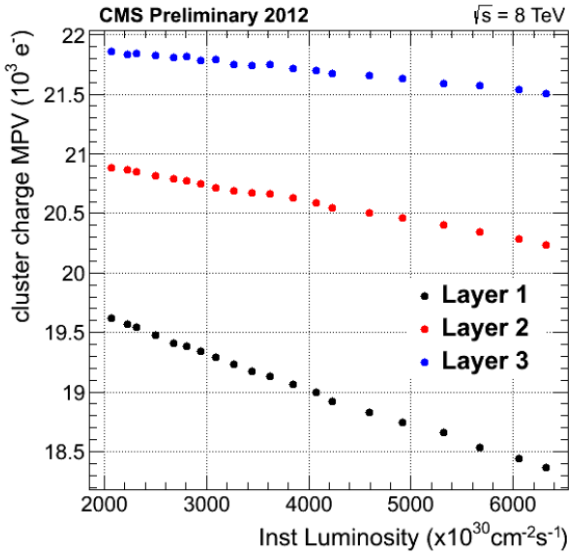
Pixel Hit Efficiency

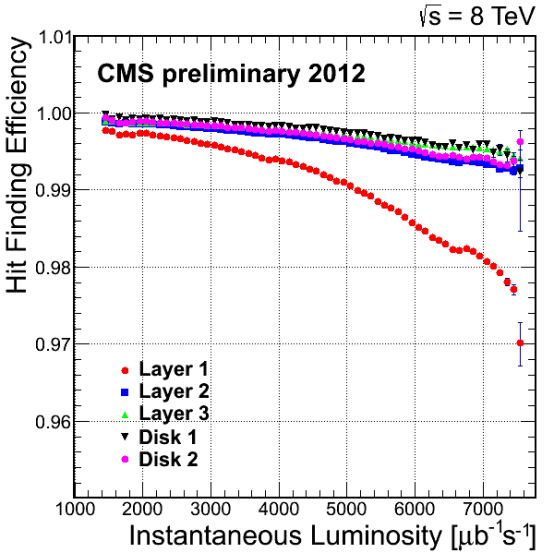




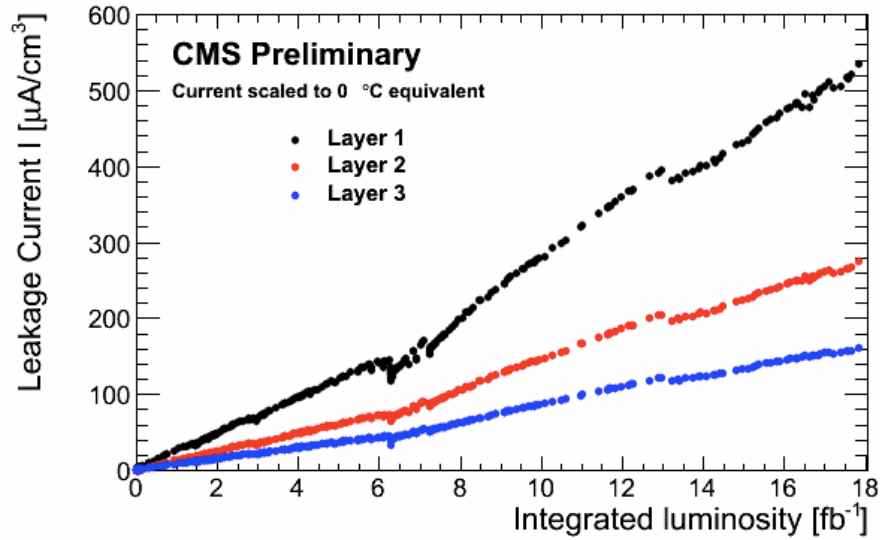
Pixel and Luminosity

- Pixel hit finding efficiency drops with increasing instantaneous luminosity

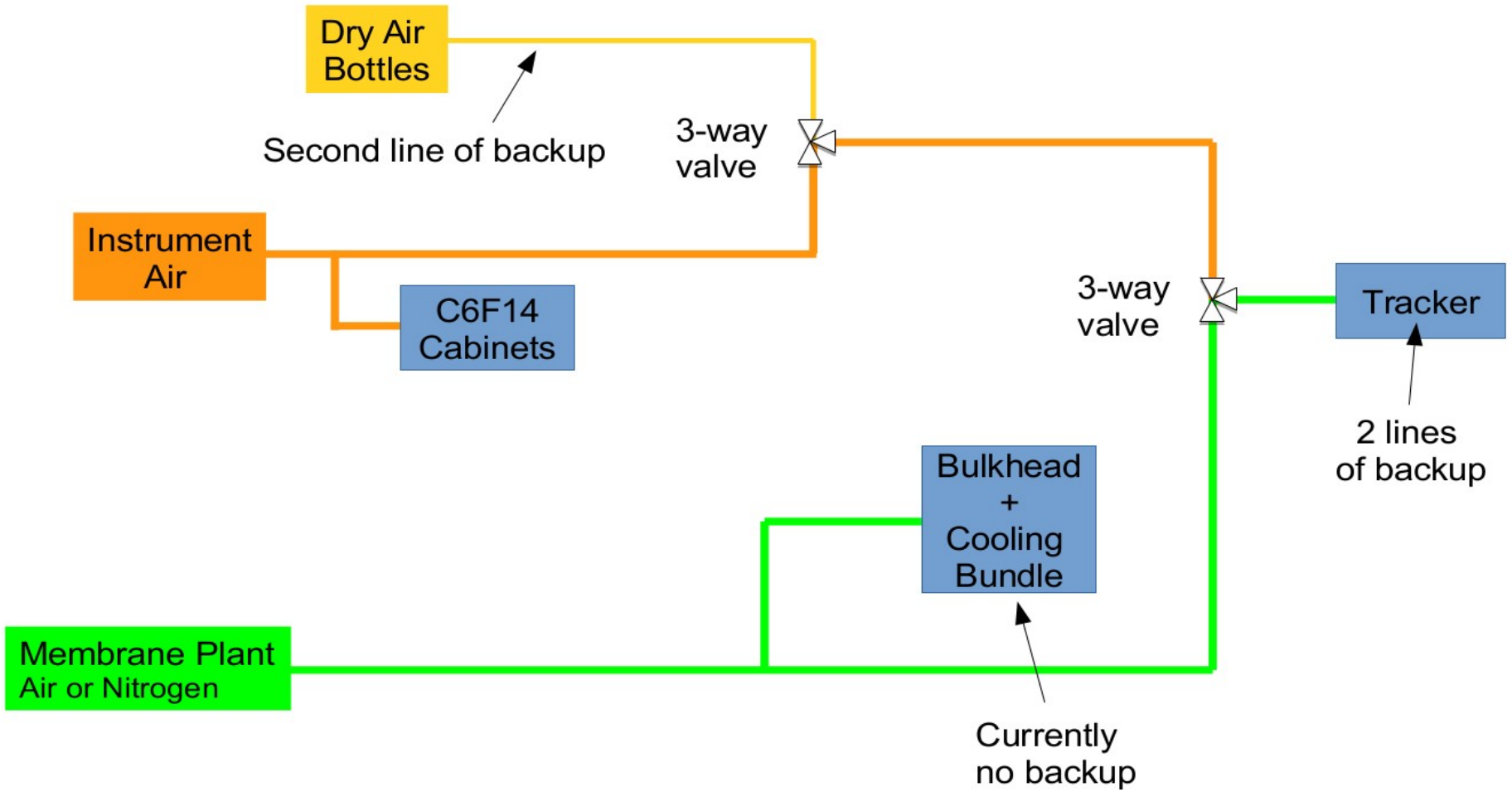




- Leakage current increases with intergated luminosity



Old Dry Gas System



New Dry Gas System