Operation of the CMS Silicon Tracker

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on behalf of the CMS Collaboration

July 6, 2011

RD11: 10th International Conference on Large Scale Applications and Radiation Hardness of Semiconductor Detectors

Florence, Italy

Introduction

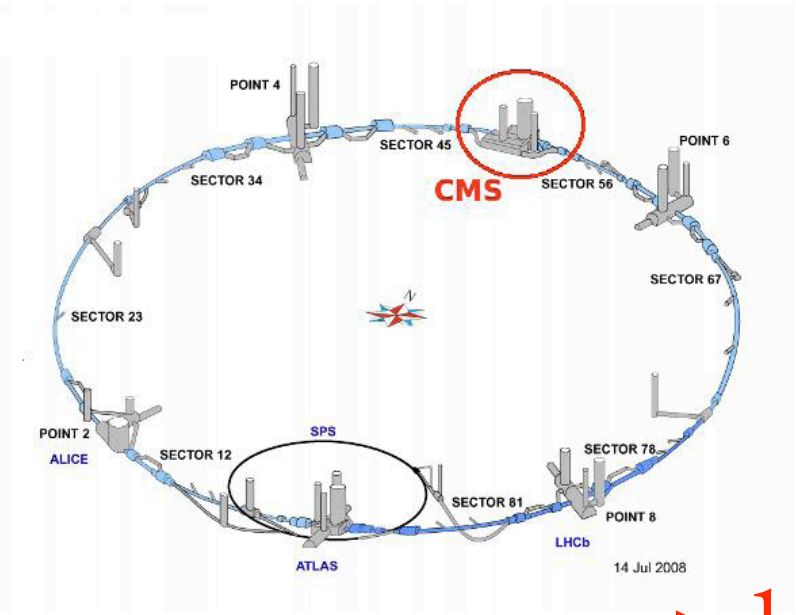
Operations (this talk)

- CMS Silicon Tracker at the LHC
- Status and Operation of the Tracker
- Calibration
- Lorentz Angle
- Radiation damage effects
- Conclusion

Performance (Matthew's talk)

- Tracking efficiency
- Momentum resolution
- Primary Vertex reconstruction
- Impact parameter
- Performance on physics

The CMS detector at the LHC

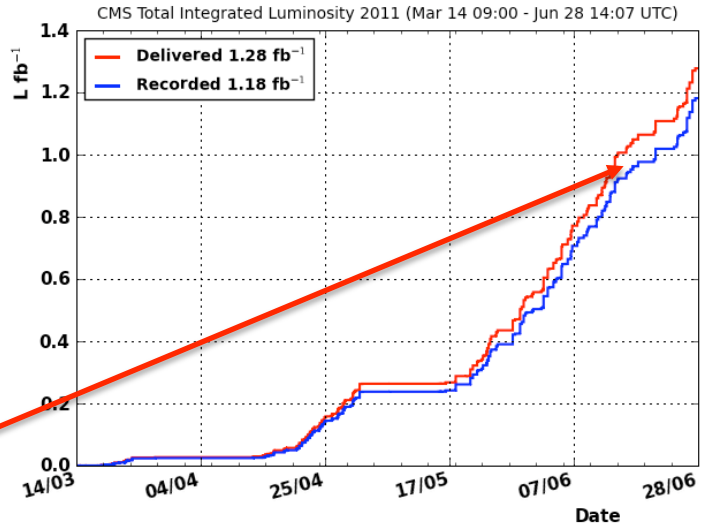


LHC

Circumference = 27 km

p – p collider @ $\sqrt{s}$ = 7 TeV

Inst. Lumi. = 10^{34} cm^{-2} s^{-1}



> 1 fb^{-1} data collected!

up to 5 fb^{-1} expected by end of 2011

CMS

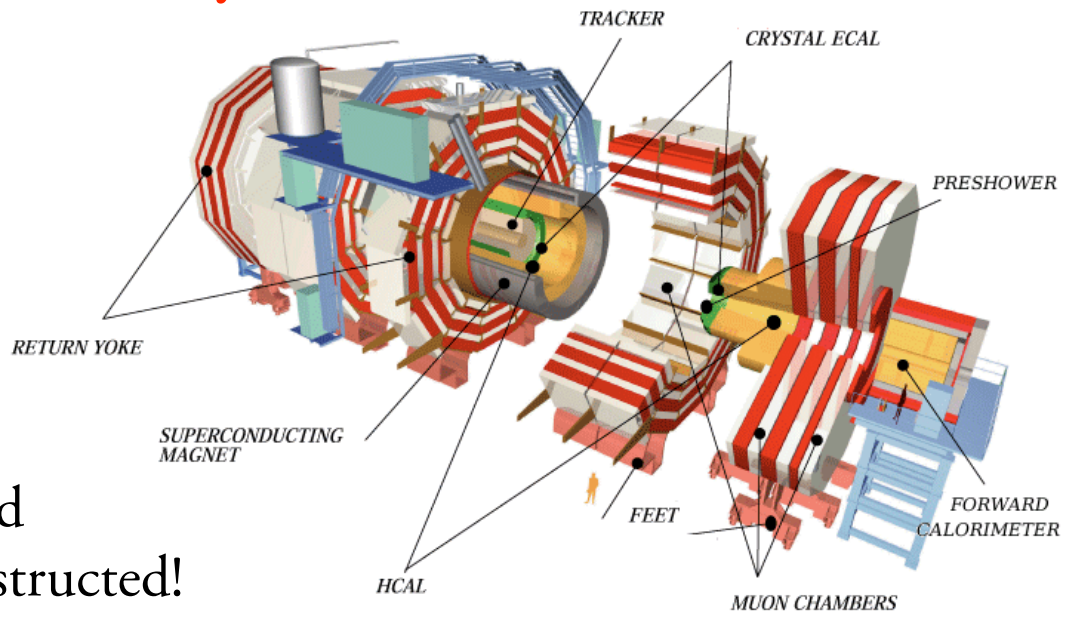
Length = 22 m

Diameter 15 m

Magnetic field = 3.8 T

Tracker + Calorimeter inside solenoid

The largest Silicon detector ever constructed!



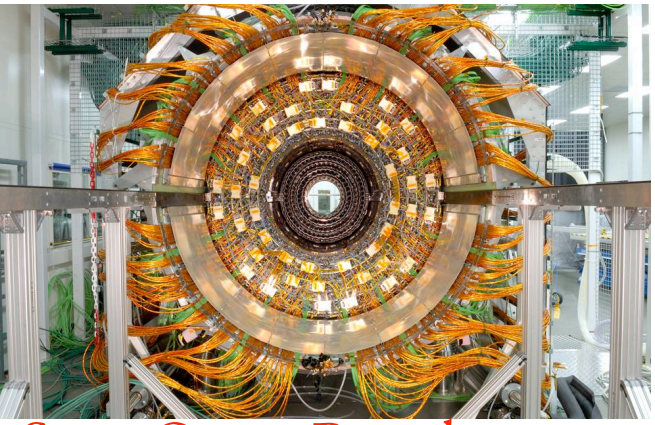
The CMS Silicon Tracker

Silicon Strips + Pixels = Tracker

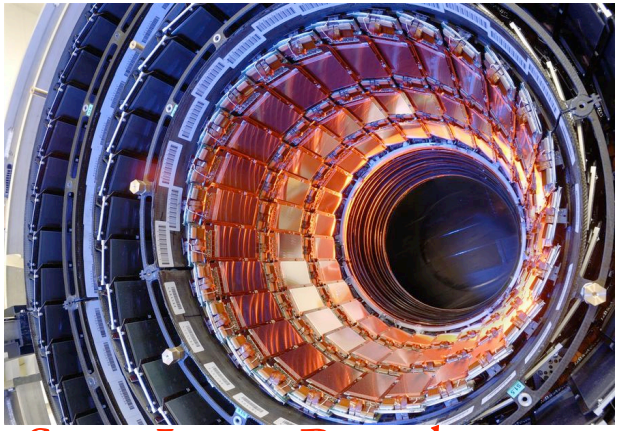
9 million channels
200 m^2 silicon area
Length = 5.8 m
Diameter = 2.5 m

66 million channels
1.1 m^2 silicon area
Barrel length = 53 cm
Layers @ R = 4.2, 7.3, 11 cm
FD @ z = 34.5, 46.5 cm

Main tracking detector
dp/p = 10% for 1TeV particles
High efficiency
Good 2 track separation
Radiation hardness
Light as possible



Strip Outer Barrel



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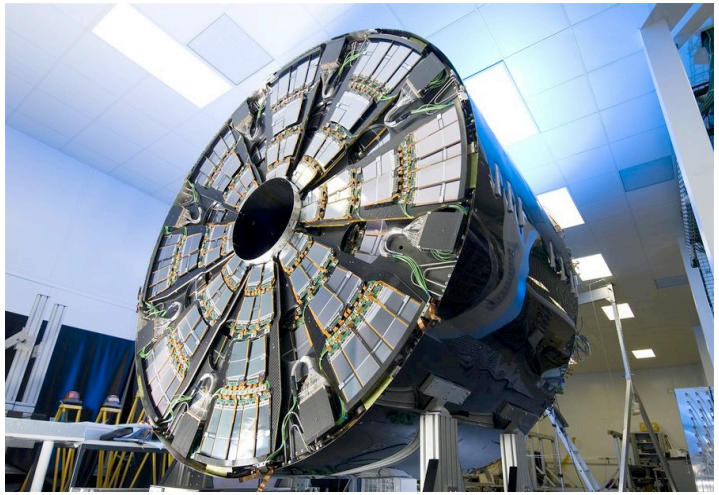
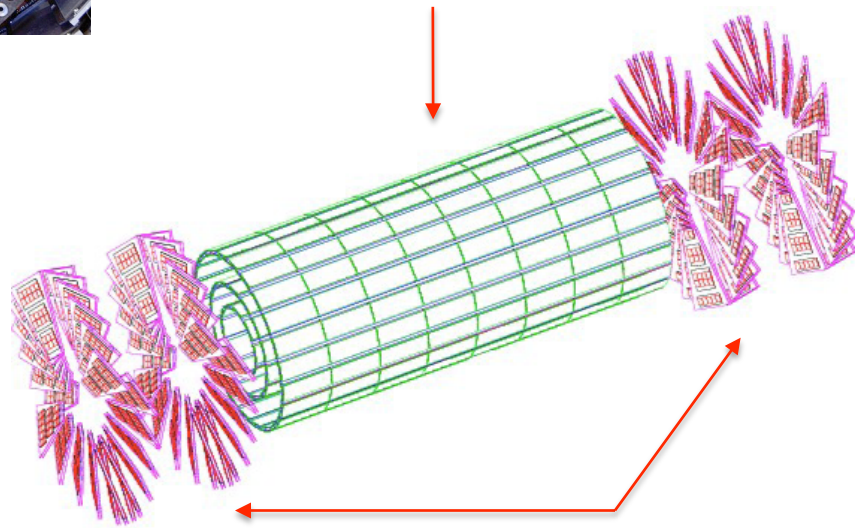


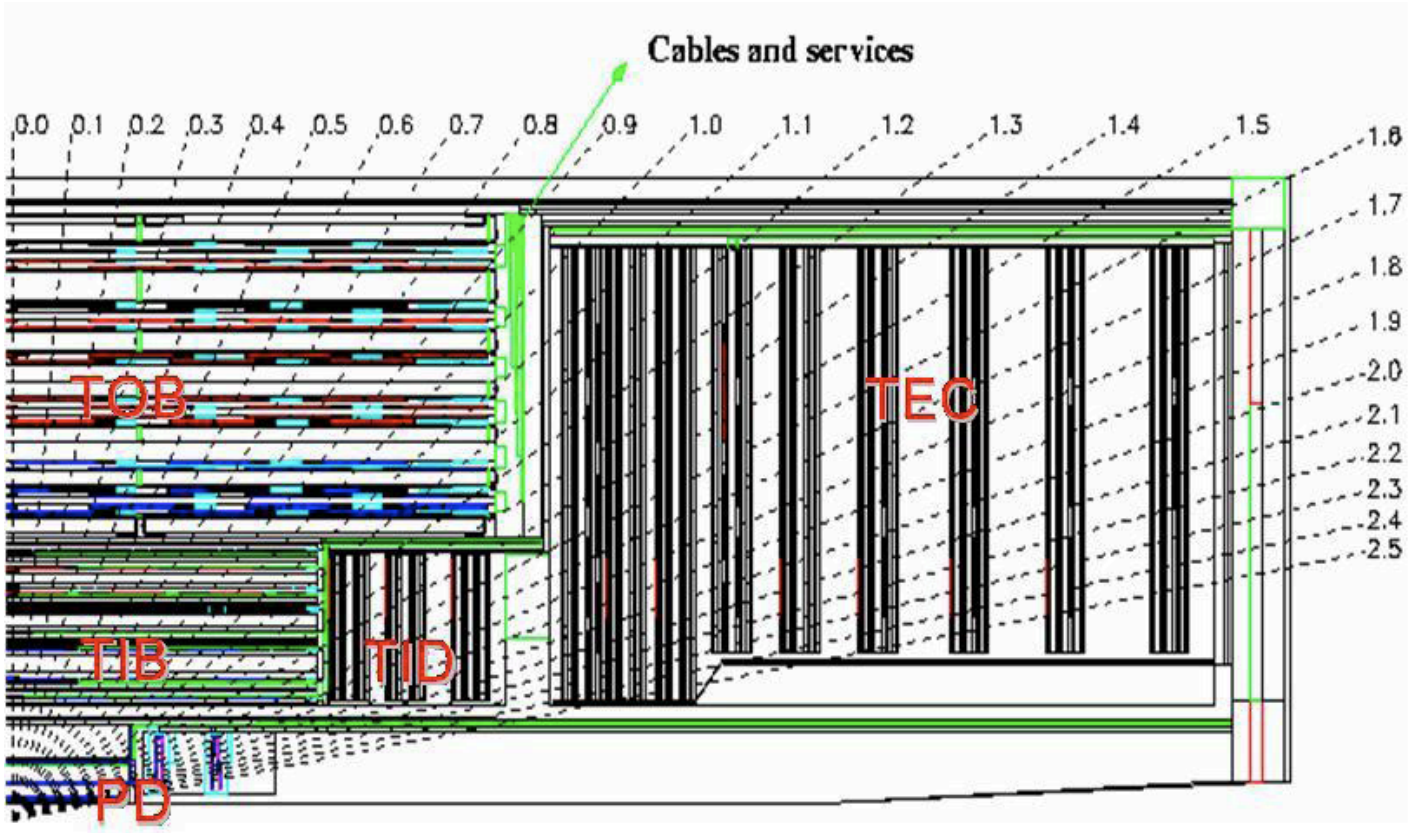
2 × Strip End Cap

Pixel Barrel



Pixel Forward disks

Silicon Strip Detector



Modules
Thin: 6136 3112(ss) + 3024(ds)
Thick: 9096 5496(ss) + 3600(ds)

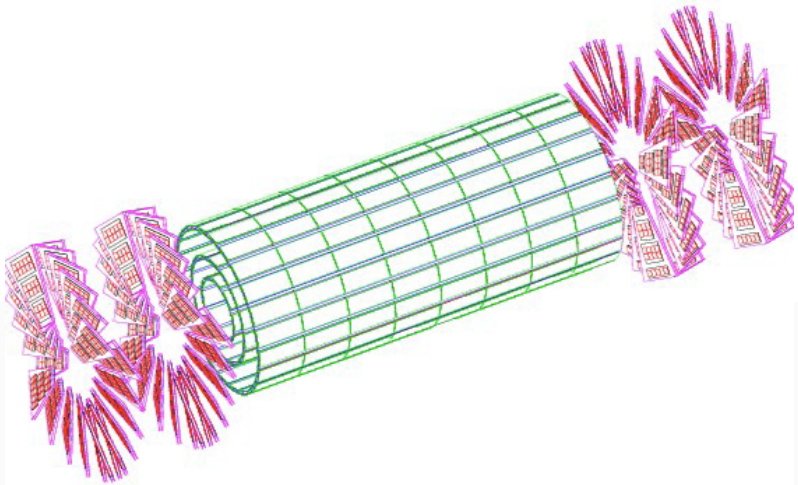
75,376 APV chips
9,648,128 strips

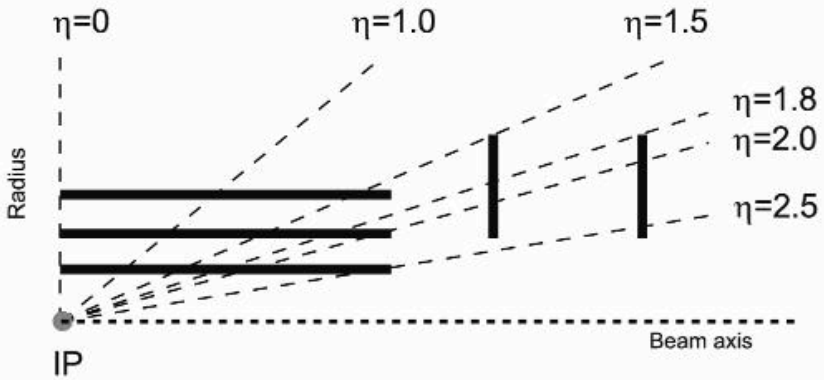
Tracker Inner Barrel (TIB): 4 layers
Tracker Outer Barrel (TOB): 6 layers
Tracker Inner Disks (TID): 3*2 disks
Tracker End Cap (TEC): 9*2 disks

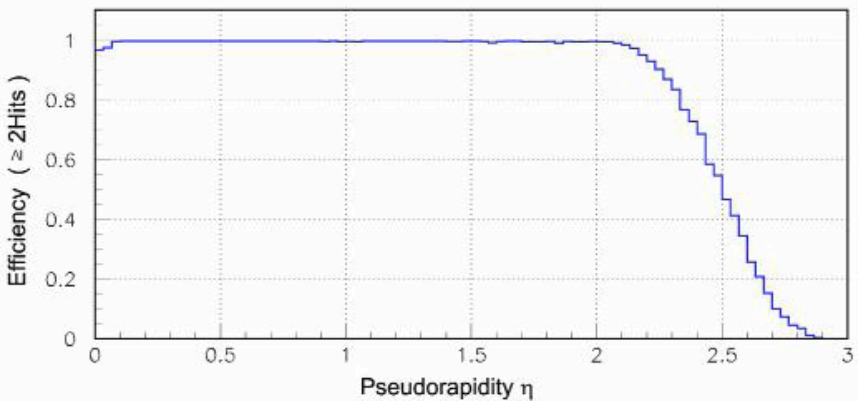
Coverage: $|\eta| < 2.5$

Each track has at least 10 high precision measurements

Pixel Detector







Modules

Bpix (Barrel Pixel)
768 modules, 11520 ROCs
48 Mpixels

Fpix (Forward Pixel)
192 panels, 4320 ROCs
18 Mpixels

Coverage: $|\eta| = 2.1$ with 3 pixel hits
$2.1 < |\eta| < 2.5$ with 2 pixel hits

Tracker Infrastructure

Service	Strips	Pixels
Cooling	- Coolant T = +4°C -Two cooling plants: SS1, SS2 - 91 cooling loops - SS1 **stable** during 2010/2011, leak 0.1 kg/day - SS2 developed leak, now controlled (0.5 kg/day)	- Coolant T = +7.4°C - **Stable** during 2010/2011
Power	- **Stable** running in 2010/2011 - 2010: 1% PSU failure rate - 2011: <1% PSU failure rate	- **Stable** running in 2010/2011
Electronics	- Hardware very **stable** in 2010/2011 - Firmware adjustments to cope with *out-of-synch* from extra frame events	-Hardware very **stable** in 2010/2011 - Firmware adjustments to handle high multiplicity and internal noise
Detector Control Systems (DCS)	- Monitor power (LV and HV), Temperature, and Relative Humidity - **Stable** functionality - New calibration of humidity and dew-points made at the beginning of 2011	
Data Quality Monitoring (DQM)	-Monitoring continues to improve with added data taking experience - **Stable** functionality	
Online Software	-Tracker software is very well written and **requires little maintenance** - Calibrations work very reliably - Long term support of experts always as concern	

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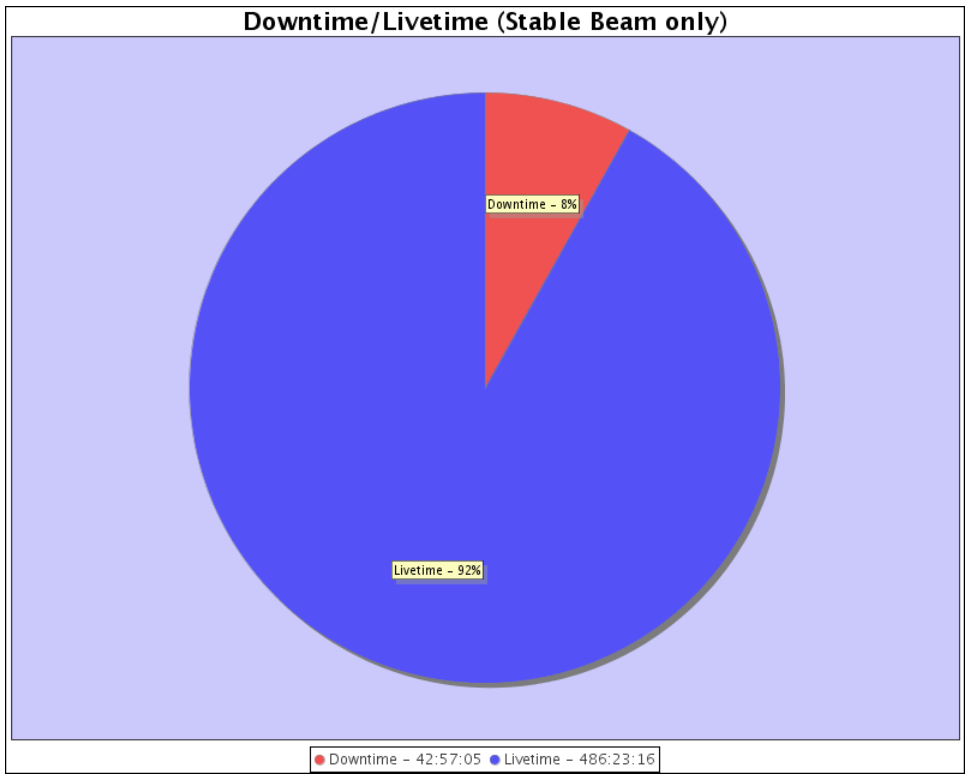
The Tracker is stable during 2010 and 2011 Running

> 98% uptime

Tracker Operation in 2011

- CMS is 93% efficient since the March 2011 restart



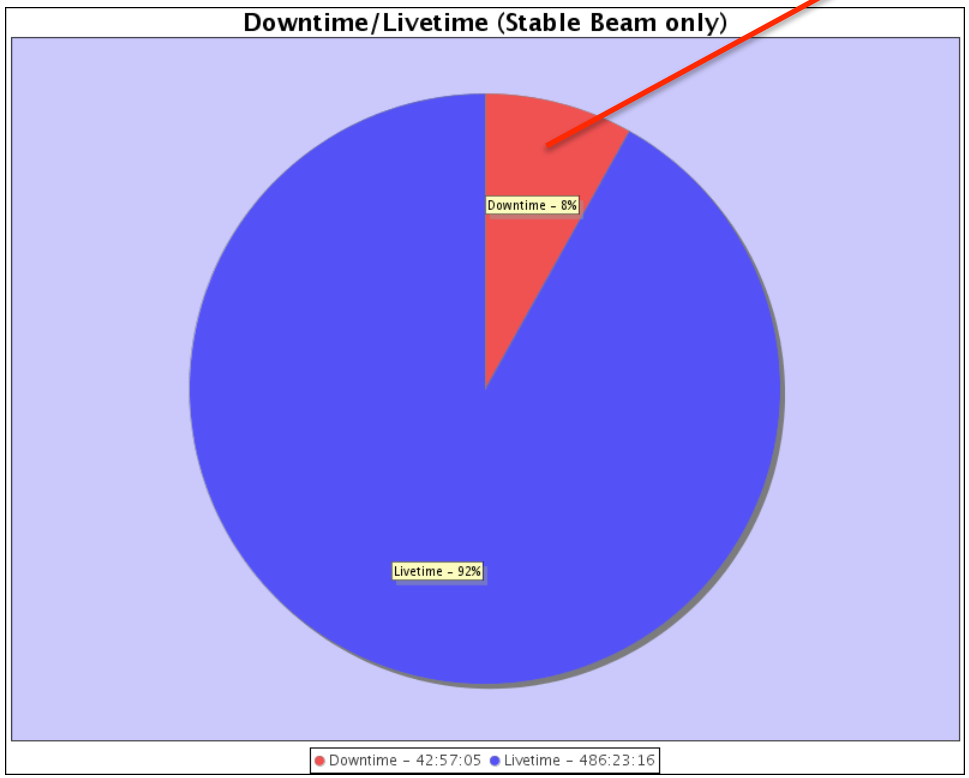
Tracker Operation in 2011

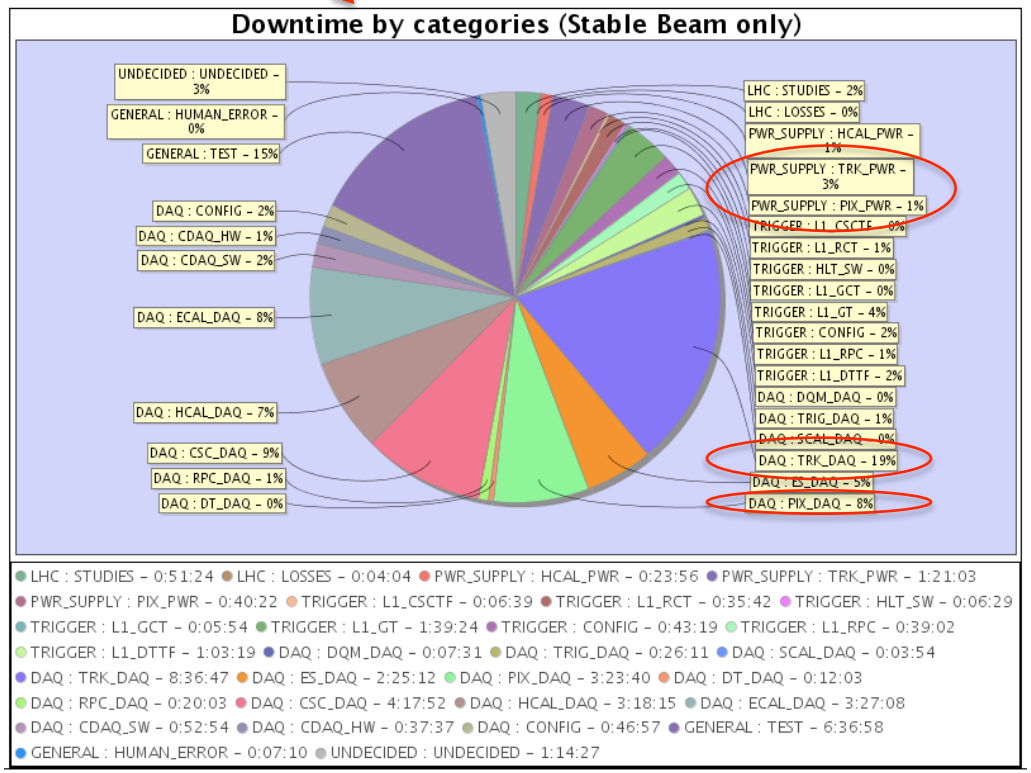
- CMS is 93% efficient since the March 2011 restart

Downtime by Tracker category

- 31% Tracker downtime
- Strips DAQ (60% CMS DAQ) = 19%
- Strips Power = 3%
- Pixel DAQ = 8%
- Pixel Power = 1%

7% CMS downtime by detector category





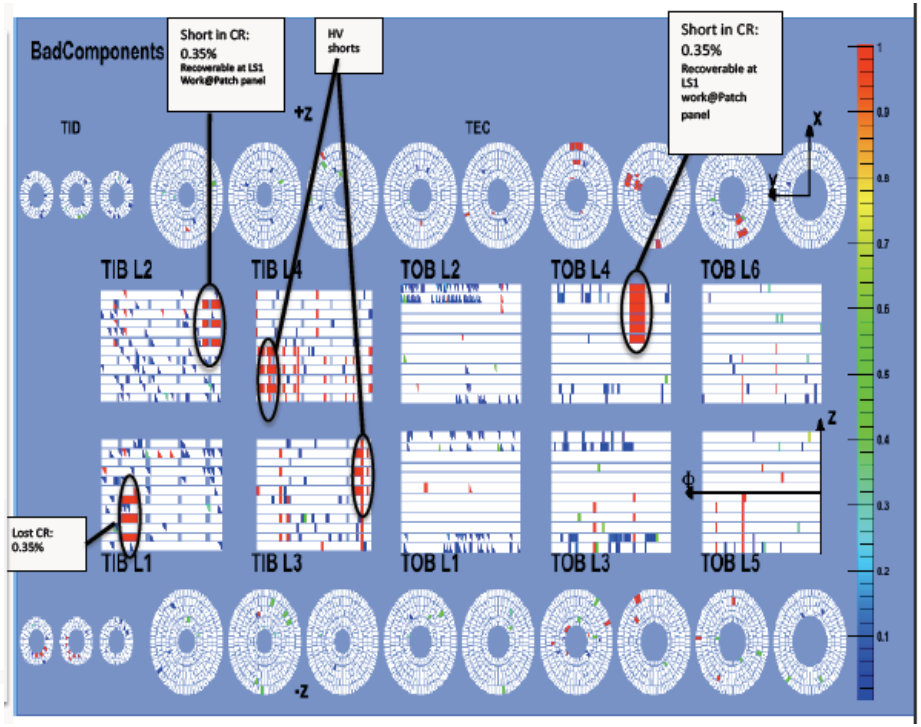
Tracker Organization

- Since 2010 there are no permanent Tracker shifters
- Detector On-call (DOC) responsible for daily operations
  - One DOC each for Strips and Pixels
  - Serves as single point contact for all Strip or Pixel related issues
  - One week shift duration
- Team of on-call experts also available
  - DCS, DAQ, DQM, Power, Safety

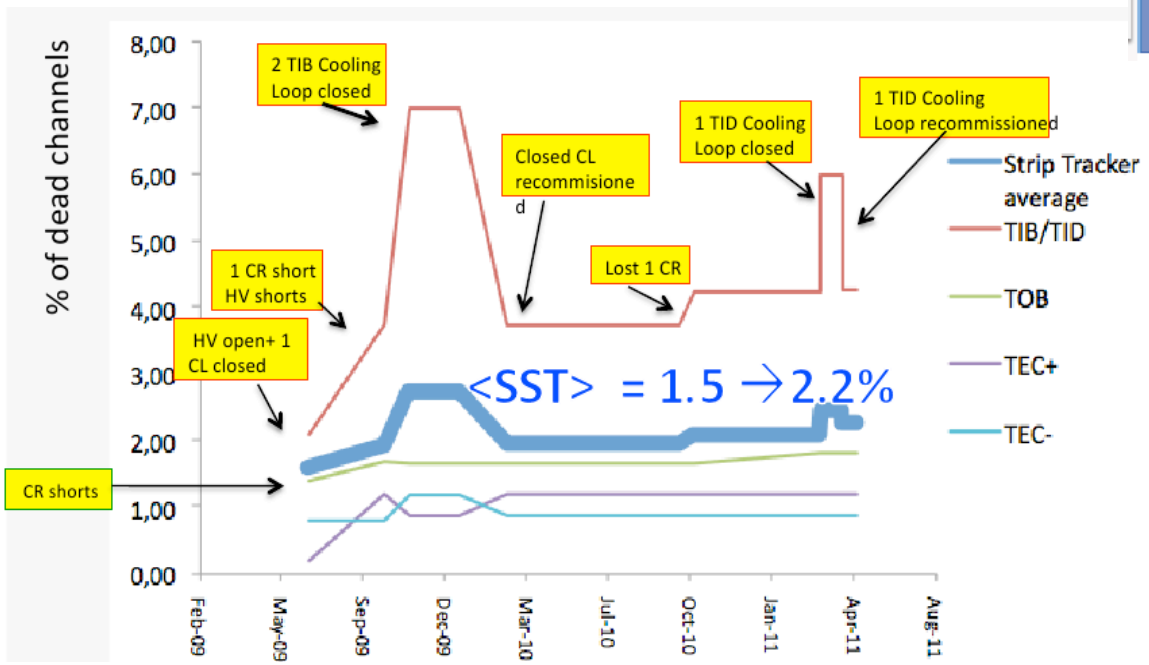
Strip Detector Status

- Strip Tracker: 97.75%
  - TIB/TID: 94.3%
  - TOB: 98.1%
  - TEC+: 98.2%
  - TEC-: 98.9%

Mapping of dead strips



Evolution of Strips excluded from DAQ

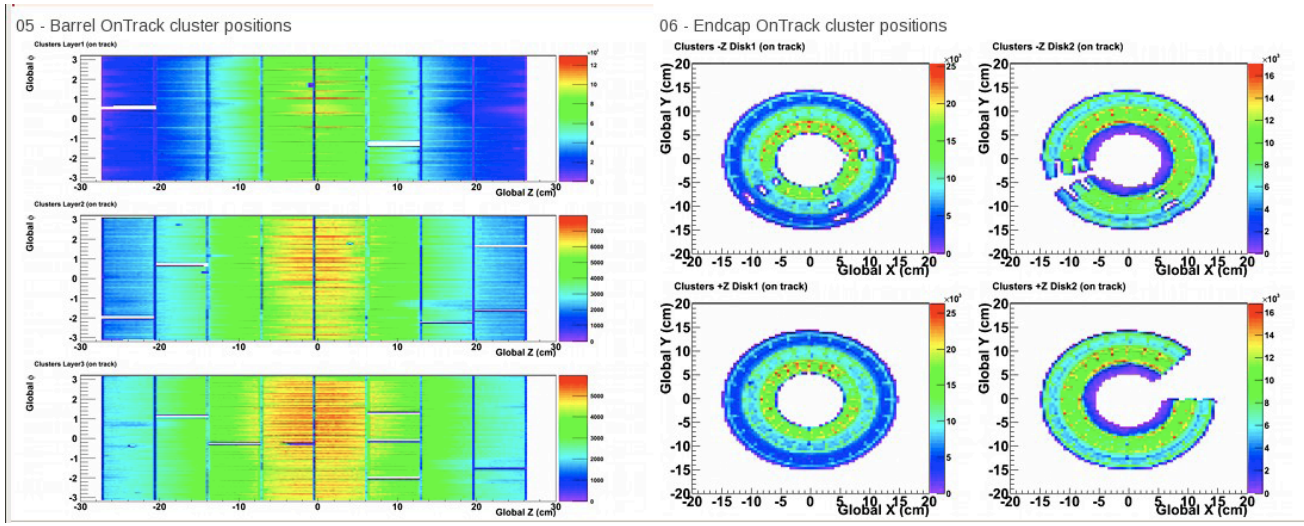


3 categories of failures

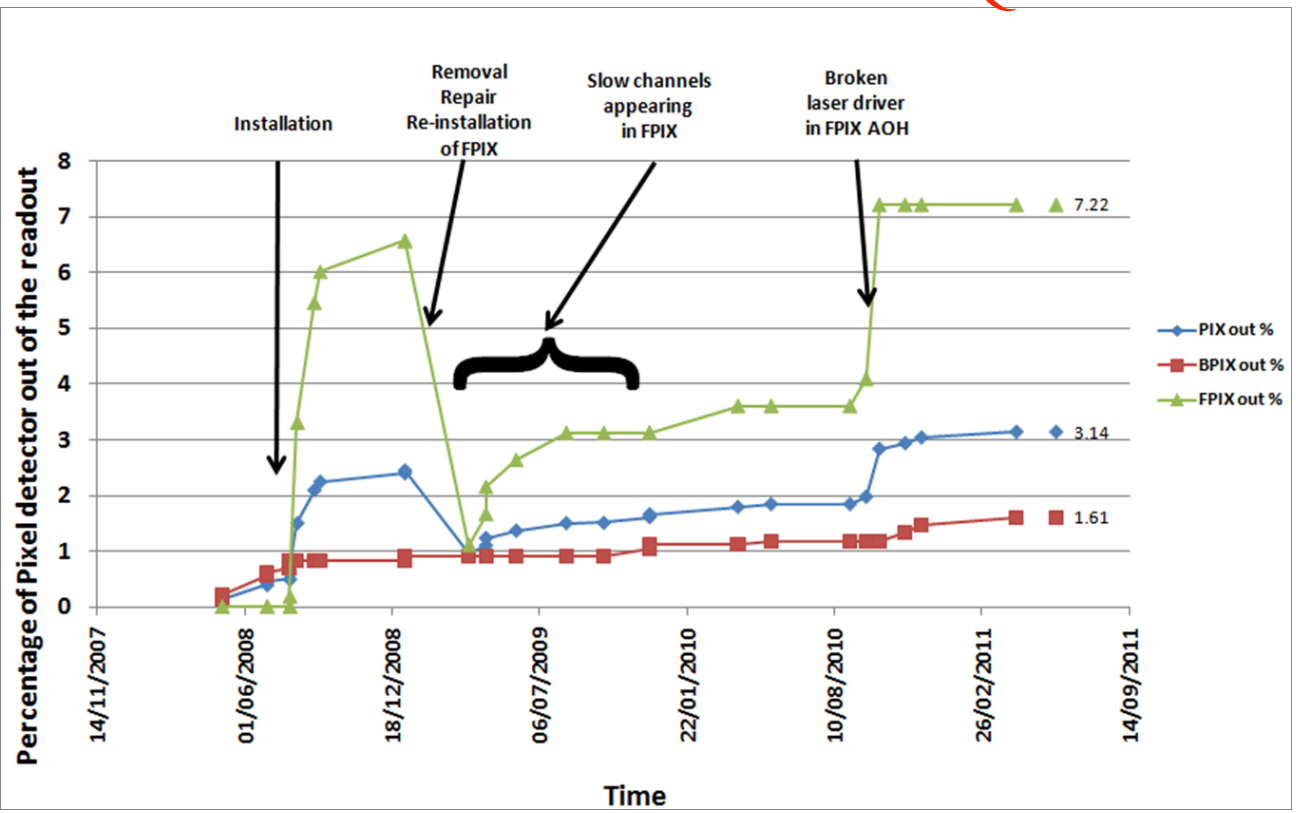
- "Dead" – permanently damage
- "Excluded" – occasional failure
- Shows readout errors

Pixel Detector Status

- Pixel detector: 96.9%
  - FPix: 92.8%
  - BPix: 98.4%
- 'Dead' Pixels: 3.1%



Evolution of Pixels excluded from DAQ



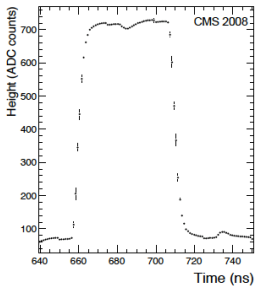
BPix loss at ~0.5%/year
-Problems consistent with failing wire bonds

FPix – single point loss in service electronics

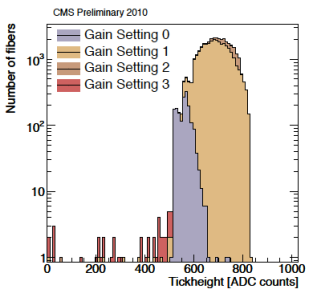
Online Calibrations

- Proper readout defined by several groups of (e.g. Strip) settings:

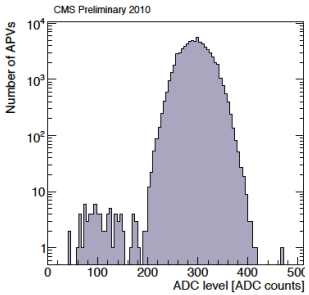
Internal synchonization



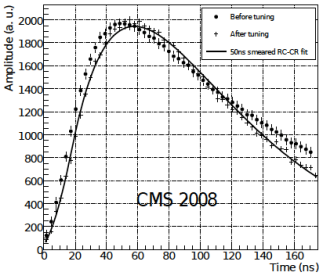
Gain calibration



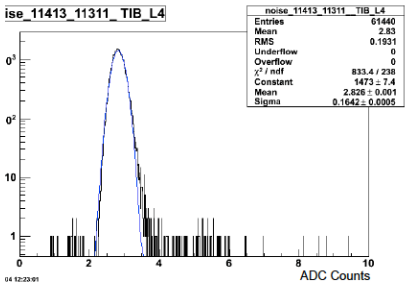
Base line adjustment



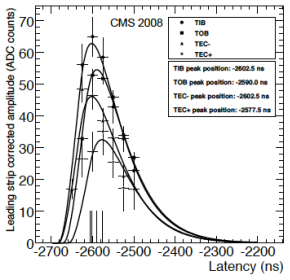
Pulse shape tuning



Pedestal and Noise



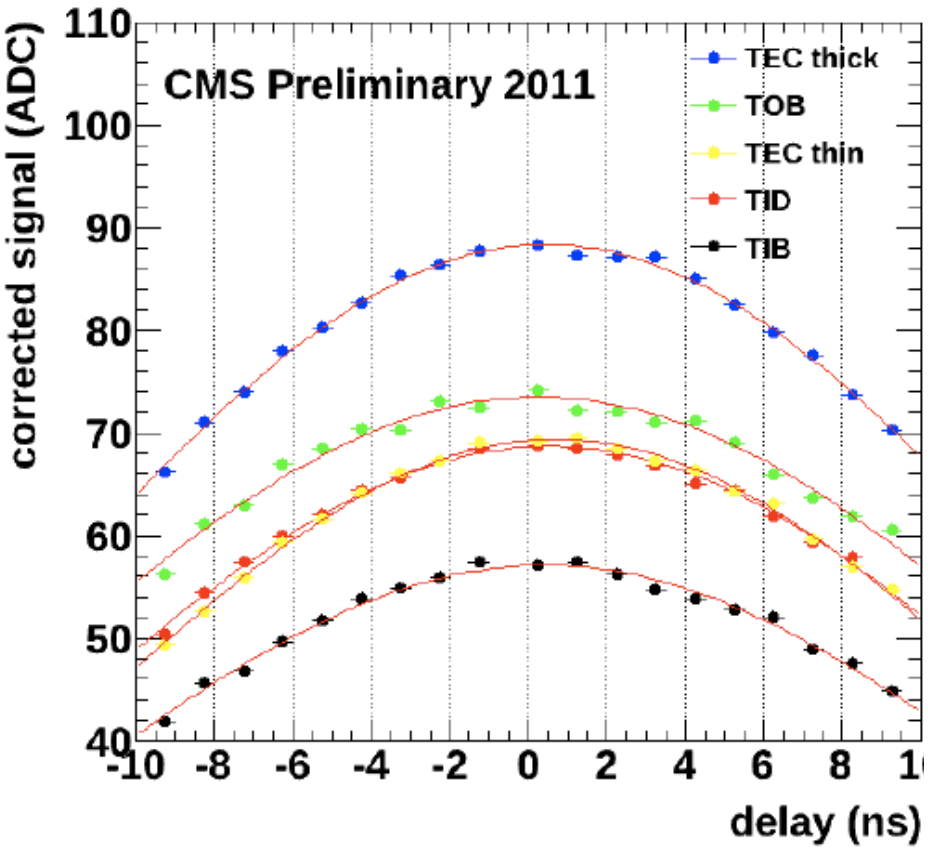
Latency scan



- Majority of settings remain unchanged until:
  - Change in detector hardware (e.g. Front End Driver replacement)
  - Change in detector operating temperature
  - Significant radiation accumulated
- Some parameters re-calibrated regularly:
  - Pedestals and noise
  - Offset in optical receivers to keep signal within ADC range

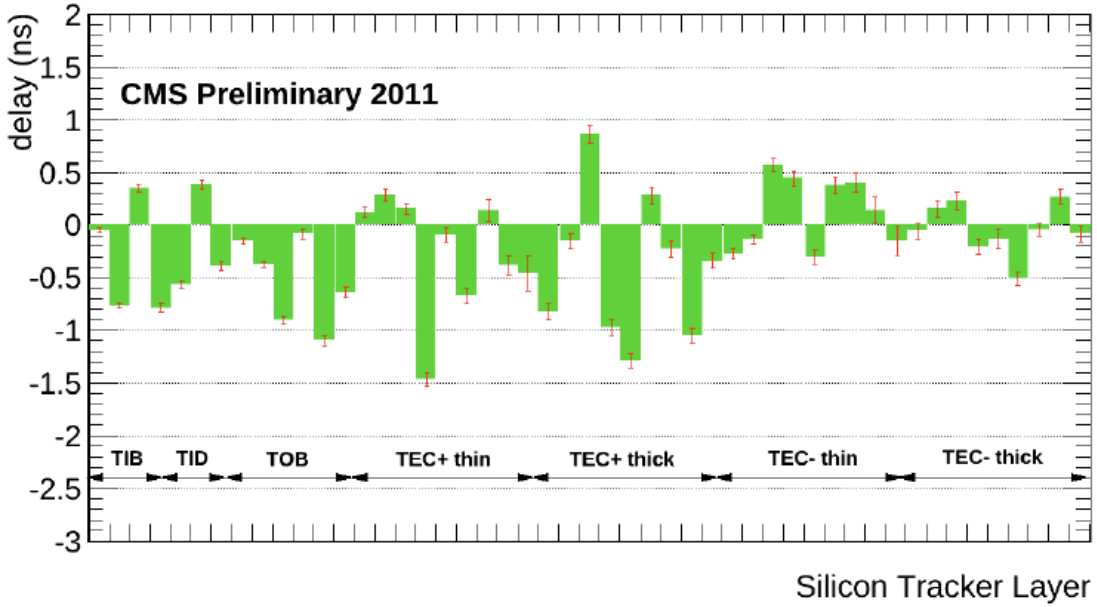
Time Signal Profile

- Profile of the signal for difference parts of the Strip Tracker shows expected 12 ns width



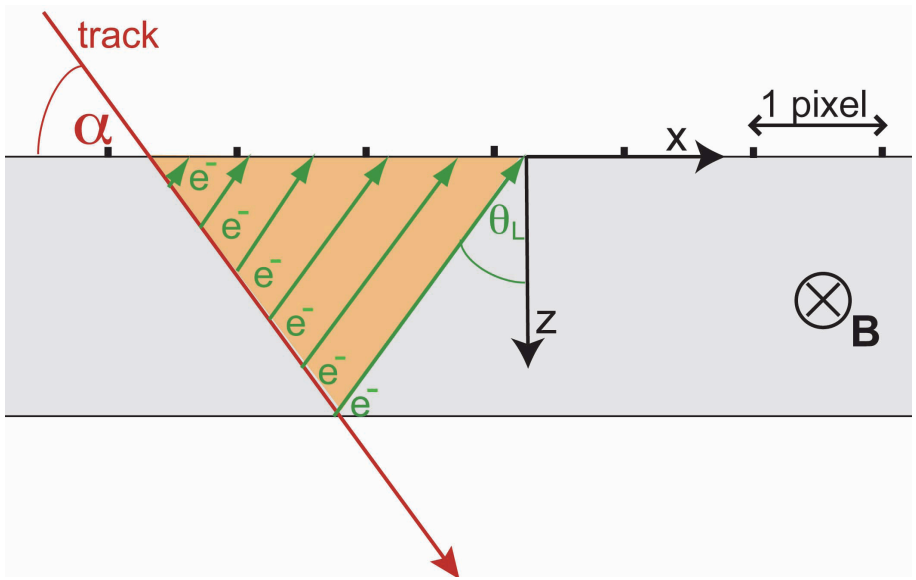
Random time delay scan

- The measured position of signal w.r.t. the nominal sampling point
- Deviation is within ~1 ns.



Lorentz Angle Measurements

- Electrons and holes move under the influence of the electric field to the implants where they are collected. In the 3.8 T CMS magnetic field, the Lorentz force tilts the drift direction and displaces the reconstructed position.



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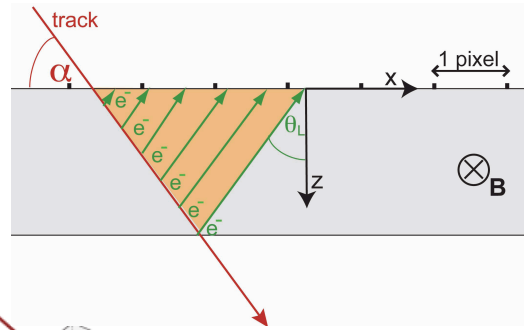
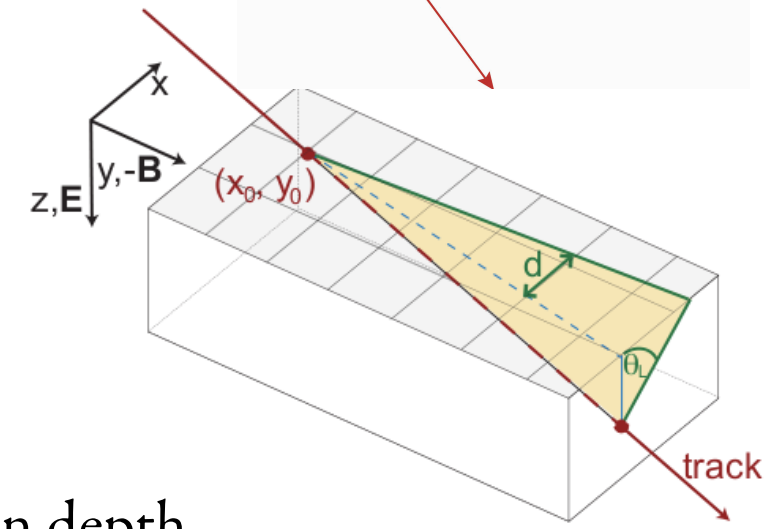


- Lorentz shift makes clusters wider
  - Better hit position resolution
  - Must be known for data and MC

1. Minimum cluster size in cosmic data
   - Measure cluster width vs. incident angle
2. 'Grazing angle' in collision data
   - Measure electron drift length vs. production depth



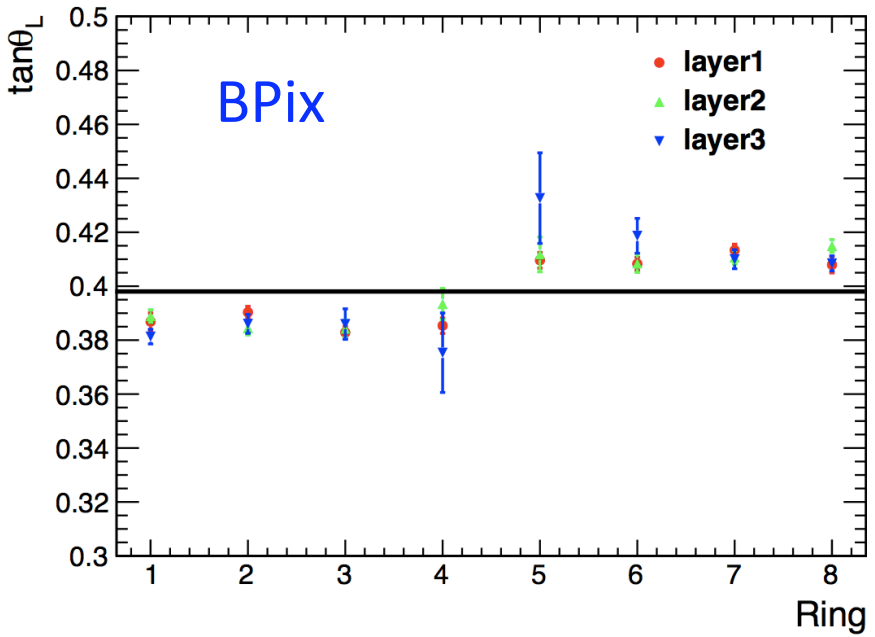
Results are consistent in different methods and with MC

BPix: cotα=-0.462(452)±0.003(2)

FPix: cotα=-0.074(74)±0.005(4)

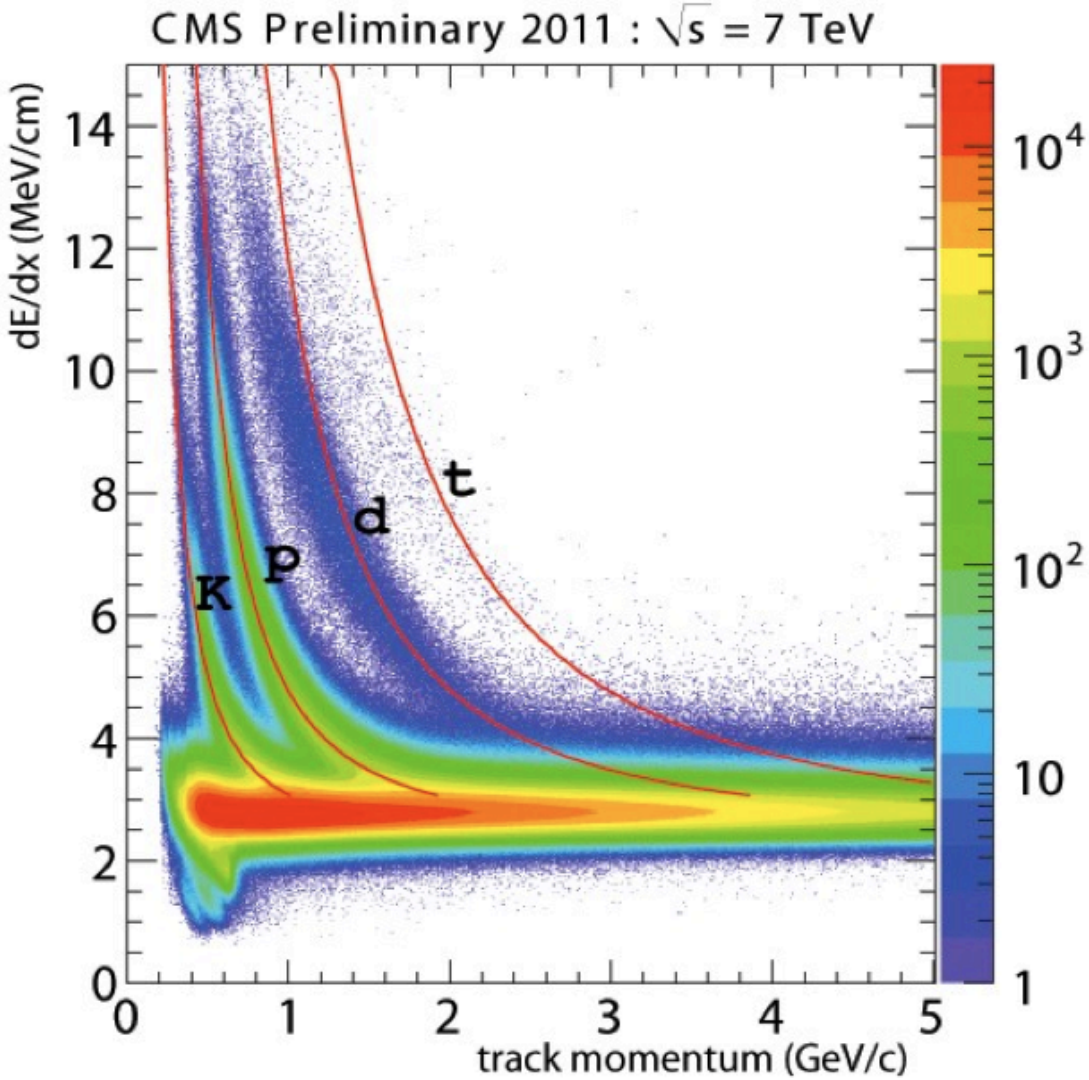
TIB : $\tan(\theta_L) = 0.07 \pm 0.02$

TOB: $\tan(\theta_L) = 0.09 \pm 0.01$



dE/dx vs. Momentum

- Energy deposited in silicon is measured from all values of the hits (~10 points)
- Kaons, protons, deuterons, and tritium are visible
- Bethe-bloch expectations are in red: extrapolated from a fit to the proton line



HV Scan

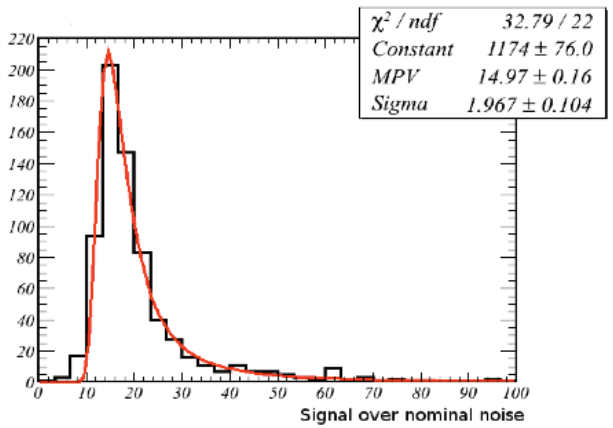
- High Voltage scan is performed by both Strips and Pixels separately

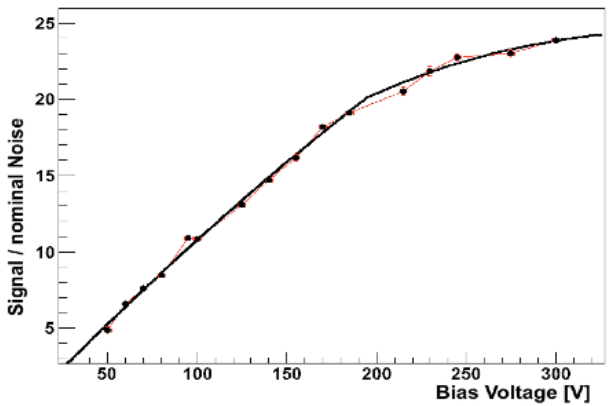
Strips

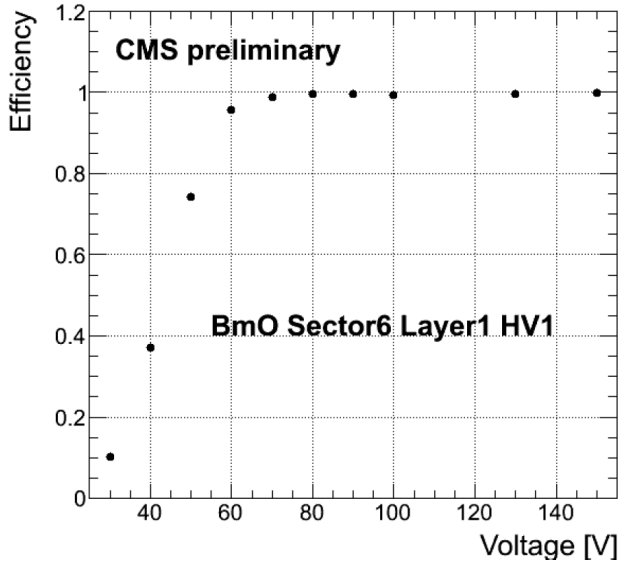
- Each module measured
- Fit to the signal over the nominal noise of the depletion voltage
- Measurement performed twice per year

Pixels

- Few modules in Bpix and Fpix measured
- No change in the depletion voltage observed
- Measurement performed once per year



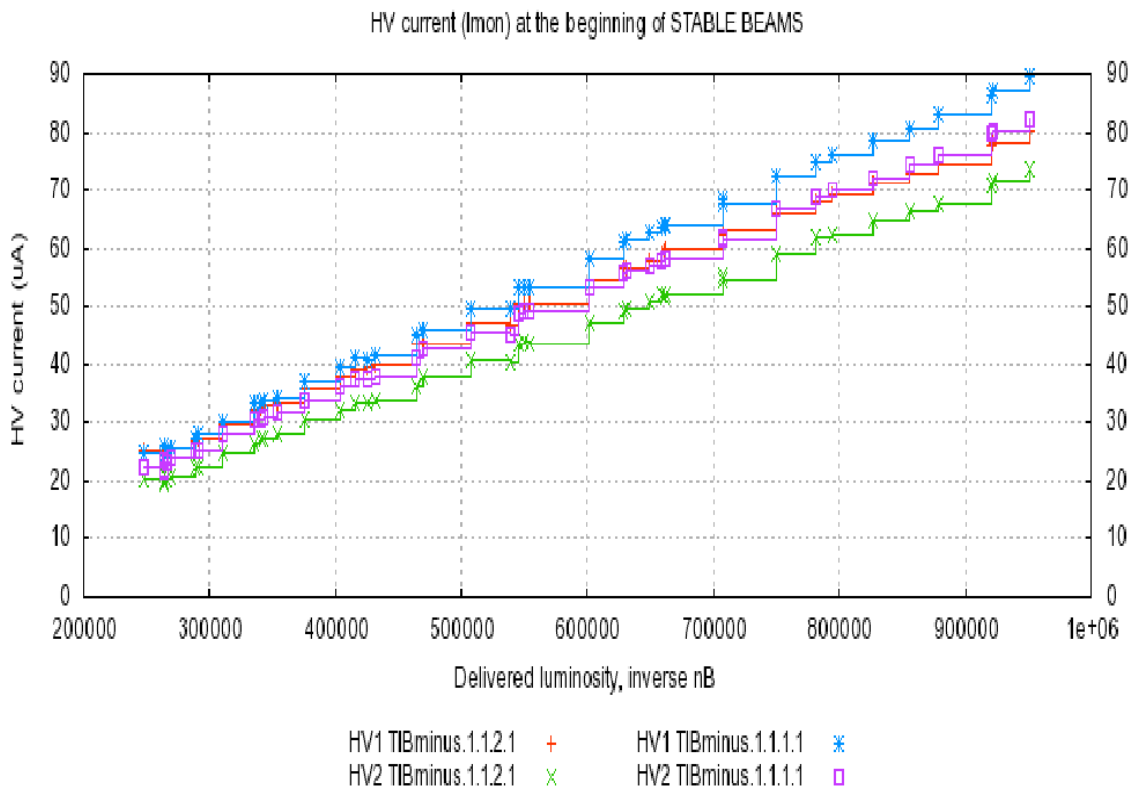




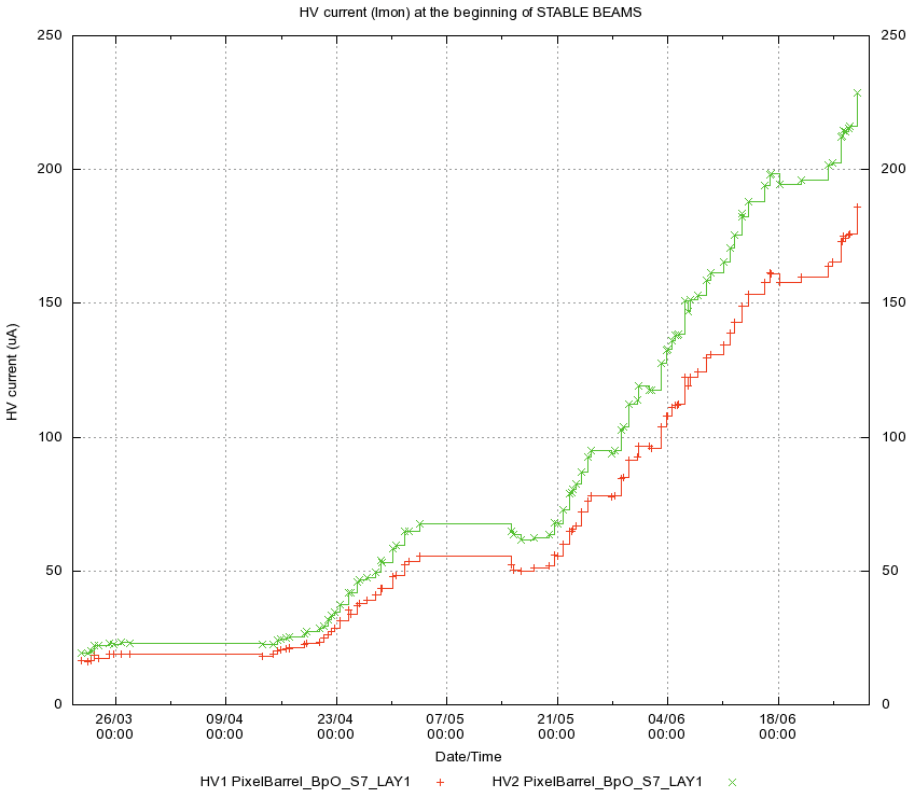
Detector Leakage Currents

- Leakage current increasing with integrated luminosity
- Effects of radiation on silicon are already visible
- At present temperatures good to run up to ~10 fb^{-1}

Strips



Pixels



Conclusion

- The CMS Silicon Tracker has operated very smoothly with minimal maintenance in 2011 resulting in > 98% running
- Both the Strip and Pixel detectors have healthy alive fractions @ ~97%
- CMS has collected it's first 1 fb^{-1} of data and the Tracker is not showing any sign of problems with an increase in instantaneous luminosity
- The operation and performance of the detector is well under control… please see more on the Tracker performance in Matthew Chan's talk
- dE/dx measurements show a nice separation of particles
- The first observed effects of radiation damage are matching expectations
- The Tracker is providing high quality data used in various physics analysis

Backup Slides

Going Colder

- Present temperatures
  - Strips: +4°C
  - Pixels: +7.4°C
- Plan for 2011/2012
  - Strips: stay at +4°C through 2012, no problems foreseen
  - Pixels: go to 0°C in 2012, factor of 2 reduction in leakage current