CMS Silicon strips operations and performance

Erik Butz
Massachusetts Institute of Technology

for the CMS collaboration

Vertex 2010

8/6/2010

Introduction

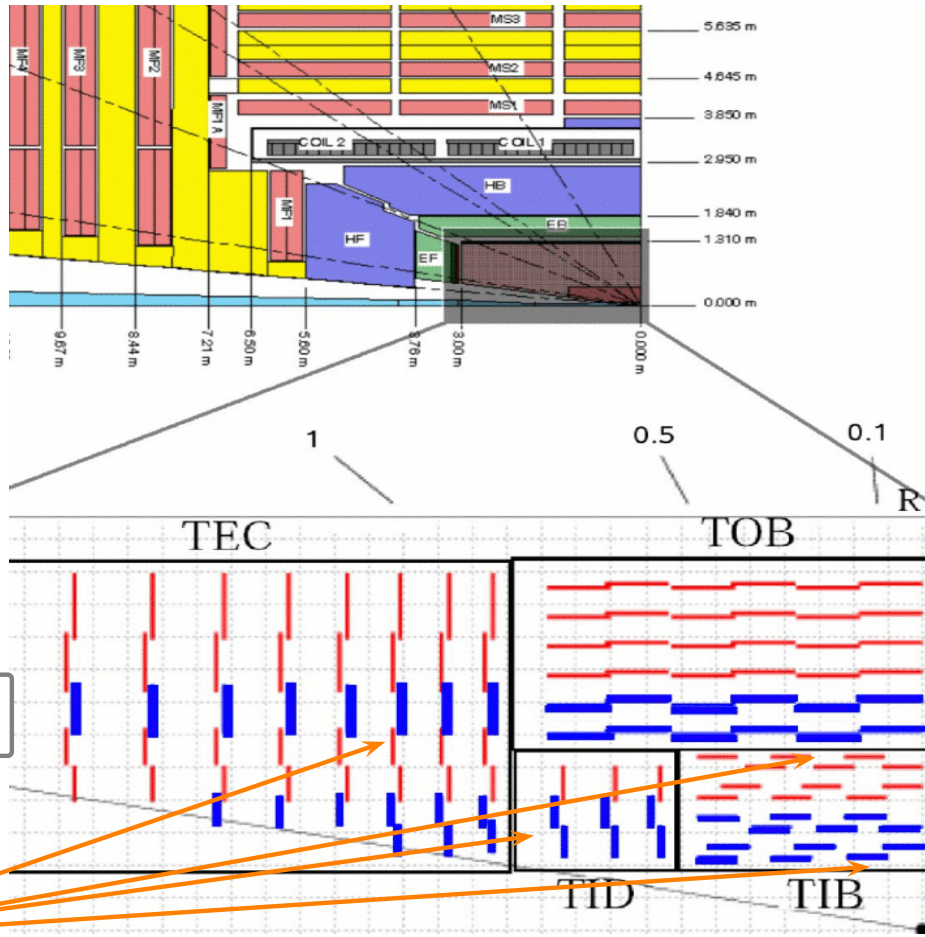
Will focus here on low-level results from the silicon strip tracker only, covering all aspects needed to get the system to work

- For results on the operation of the CMS pixel detector
  $\rightarrow$ K.Ecklund
- For results on the tracking performance of the CMS tracking system
  $\rightarrow$ A.Venturi
- For studies of beam-backgrounds in the CMS pixel detector
  $\rightarrow$ H.Snoek

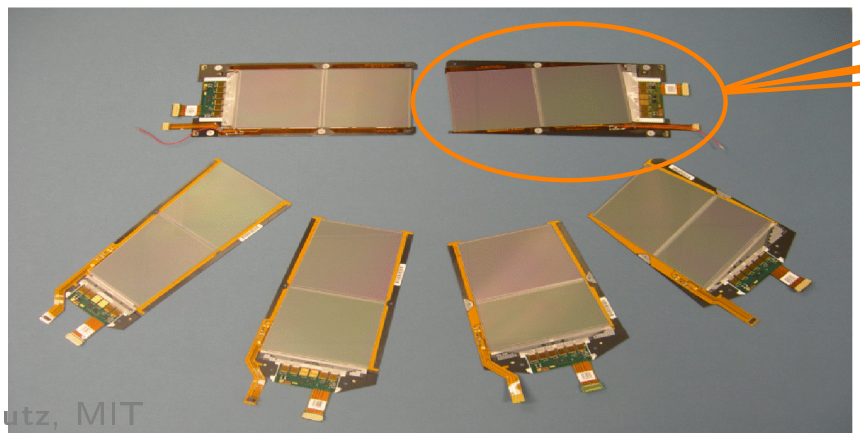
Introduction – The CMS Silicon Strip Tracker

- Largest silicon tracker ever built (active area $\sim$200 m^2)
- 5 m long, 2.5 m diameter
- Approx. 9.6 million electronic channels 10 layers in barrel region (4 Inner Barrel (TIB), 6 Outer Barrel (TOB)) and 9 discs in the endcaps (up to 14 Hits per track)
- Analog readout
- First "all-silicon" central tracker

+ Pixel detector (>60 Mio channels (not covered))

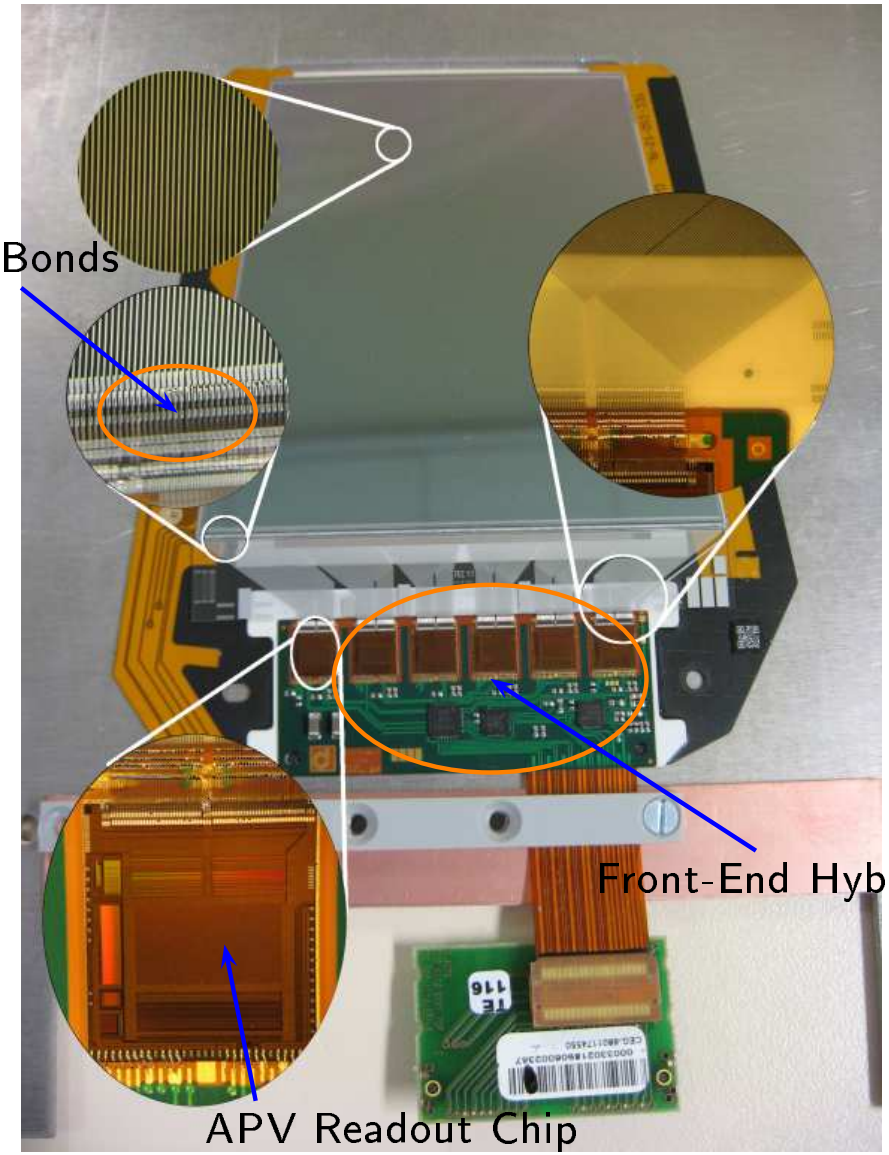


Stereomodule



- Angular coverage down to 9° to the beam-pipe ($|\eta| < 2.5$)
- 4 layers (3 rings) contain stereo modules for 2-D hit reconstruction

The Modules of the CMS Silicon Strip Tracker



Sensors

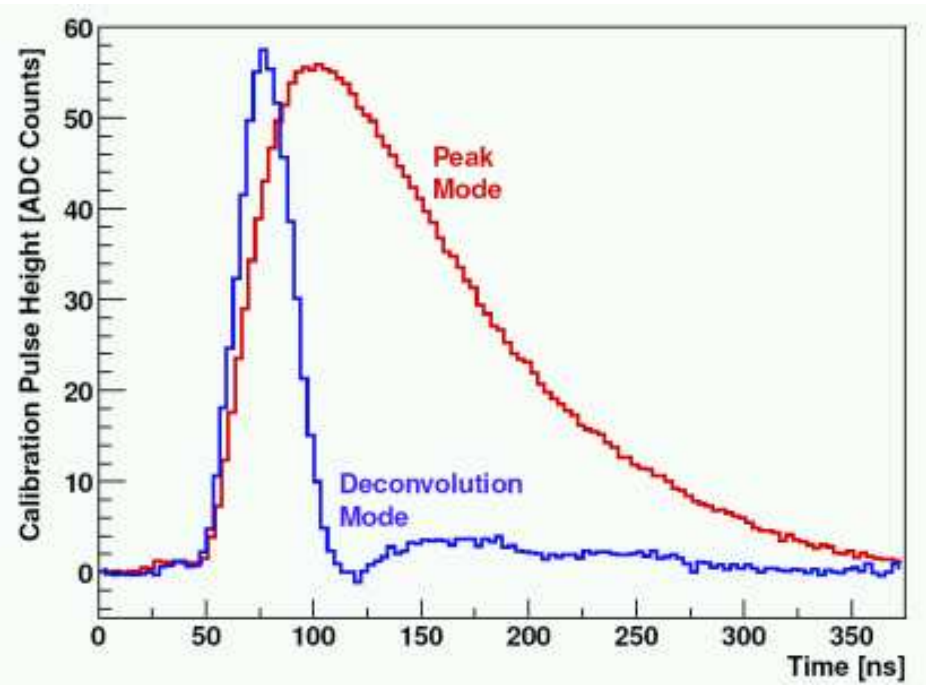
- p^+-implants in n-type silicon bulk, n^+-backplane for ohmic contact
- 320 μm and 500 μm thick sensors used
- Strip pitch 83 μm– 205 μm
- AC-coupled Readout

Modules

- Analog readout: APV25 readout chip, 128 channels $\times$ 192 cell pipeline buffer (4.8 μs latency for Level 1 trigger decision)
- Readout in Peak- or Deconvolution Mode
- Data transfer from tracker volume via Optical link

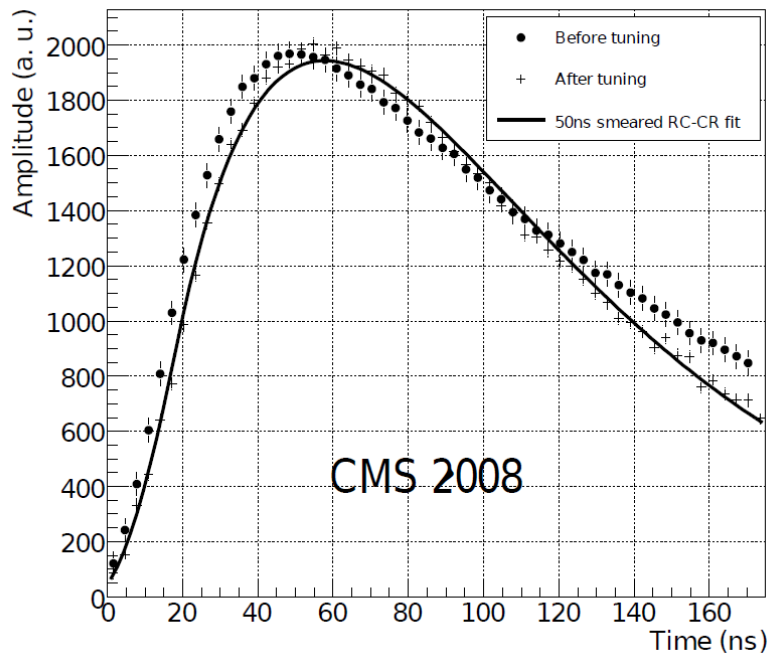
Readout Modes of CMS Silicon Strip Tracker

Strip Tracker can be read out in peak- or deconvolution mode (sampled every 25 ns)



signal for bucket k in deconvolution mode:
$d_k = w_3 p_{k-2} + w_2 p_{k-1} + w_1 p_k$
3-sample FIR filter

- Peak mode: read out single point from shaper
- Used at low luminosity
- More robust to possible timing misalignment
- Deconvolution mode: combine signal from three readout buckets to shorten pulse duration to $<$50 ns (removes pile-up from subsequent events)
- Deconvolution mode suitable for high luminosity (25 ns bunch spacing)
- Comes at the cost of higher noise compared to peak mode



Power system

983 PS Modules

29 Crates

29 Branch Controllers

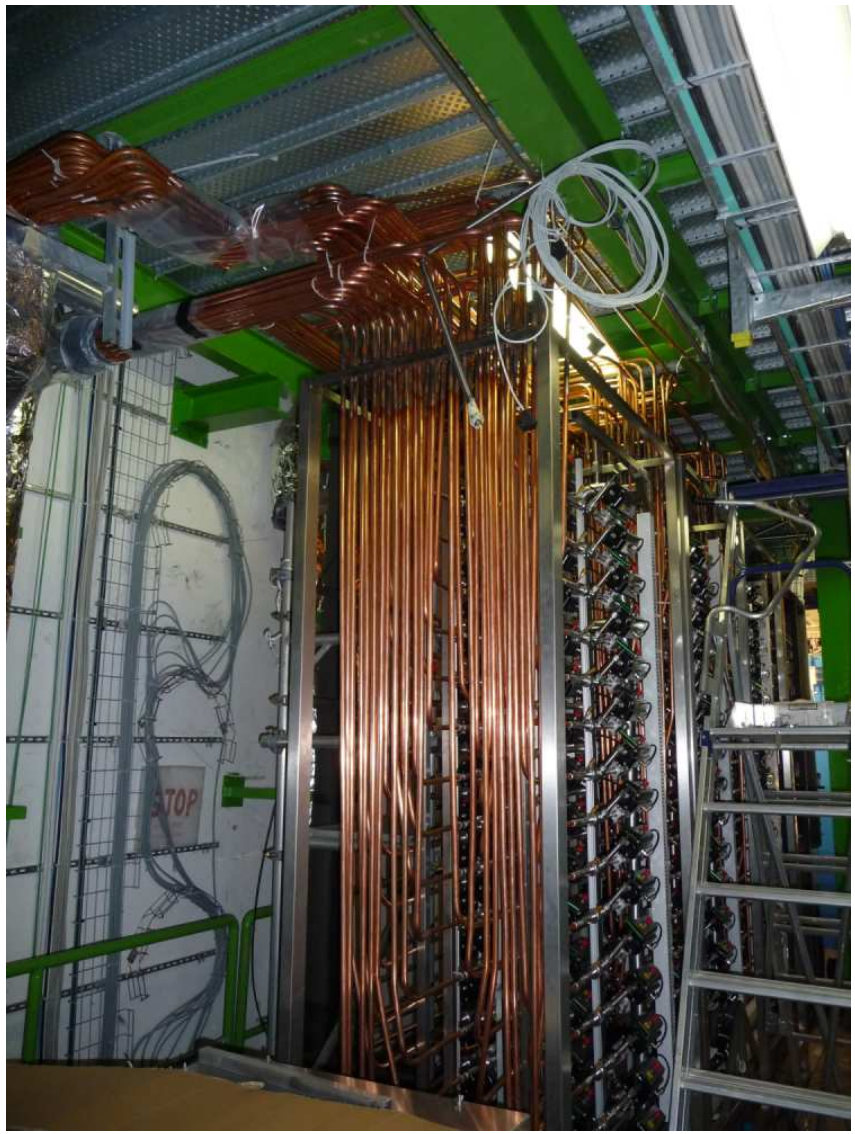
8 Main Frames

- PS system provides 1.25 and 2.5 V low voltage and between 20 and 500 V of high voltage to modules
- 356 control groups, 1944 power groups, 3888 HV channels
- Tracker can do transition from HV OFF to HV ON in about 75 seconds
- Power to tracker 36 – 49 kW

Power system is working reliably with low PS exchange rate and stable performance

Cooling the CMS tracker

- An efficient cooling of the silicon tracker is essential for the operation of the tracker, especially to mitigate the effects of irradiation
- Thermal screen around tracker volume ensures stable temperature of $18^{\circ}\mathrm{C}$ for ECAL
- C_6F_{14} used as coolant
- Tracker is cooled by two plants:
  - 1st plant: leak rate that is close to zero
  - 2nd plant: two line closed due to high leak rate; leak rate is low when a few lines (5) are excluded
- Operational temperatures: -20°C to +15°C, $4^{\circ}\mathrm{C}$ currently
- Plan is to lower temperature after the 2011/12 LHC shutdown

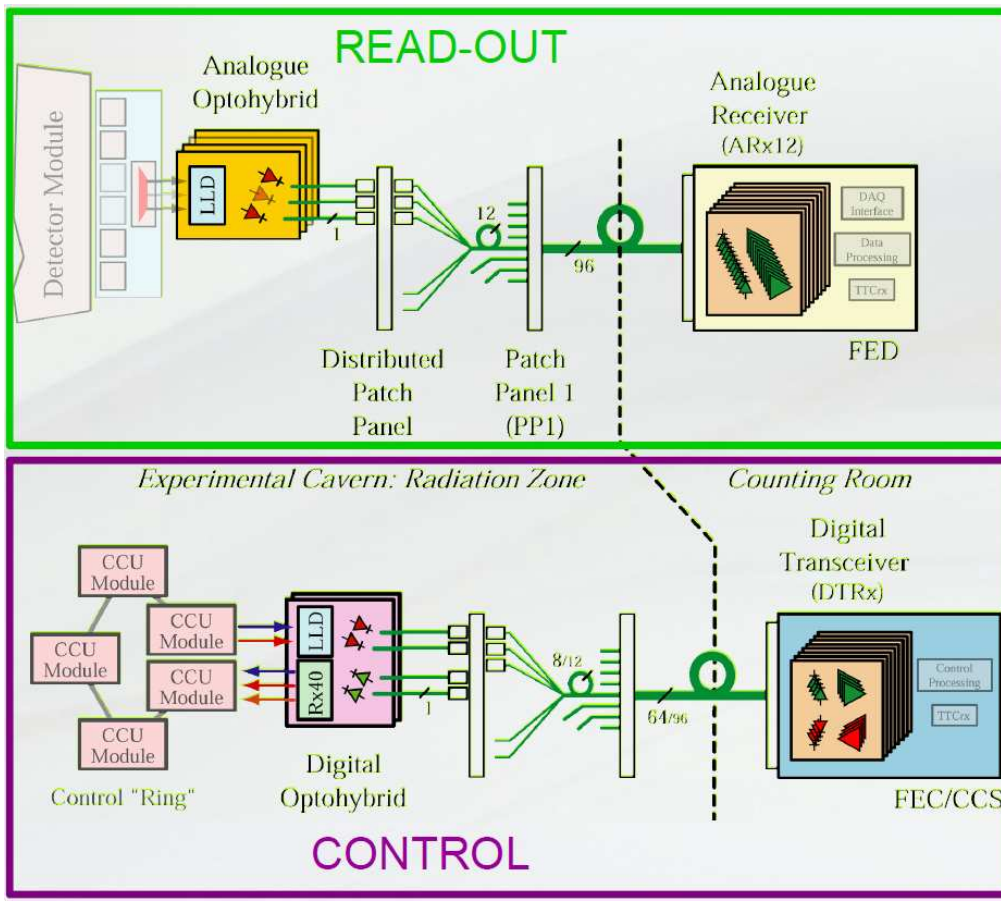


Commissioning Procedures

- Strip tracker has analog readout
- digitization only done in the Front End Drivers

Need to:

- Internally time align
  → Synchronization of channels
- Tune laser gain
- Optimize chip parameters
- Optimize pulse shape to ideal
-
- Determine Noise and Pedestals
  → For FED data reduction
- Synchronize with CMS
  → Align sampling with physics events

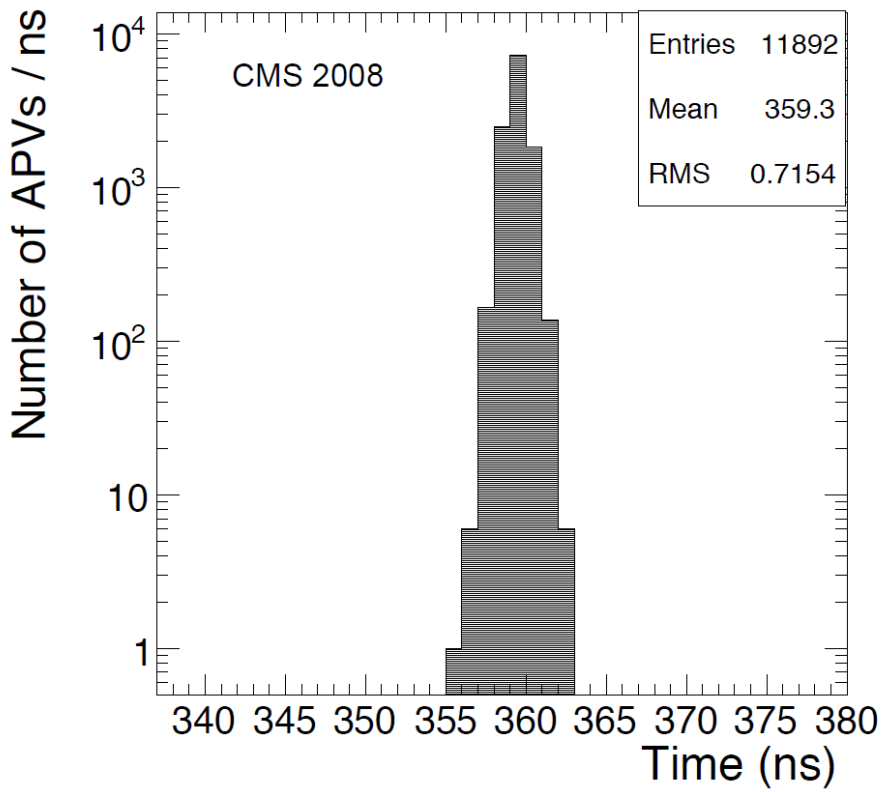


Commissioning Procedures

- Strip tracker has analog readout
- digitization only done in the Front End Drivers

Need to:

- Internally time align
  → Synchronization of channels
- Tune laser gain
- Optimize chip parameters
- Optimize pulse shape to ideal
-
- Determine Noise and Pedestals
  → For FED data reduction
- Synchronize with CMS
  → Align sampling with physics events

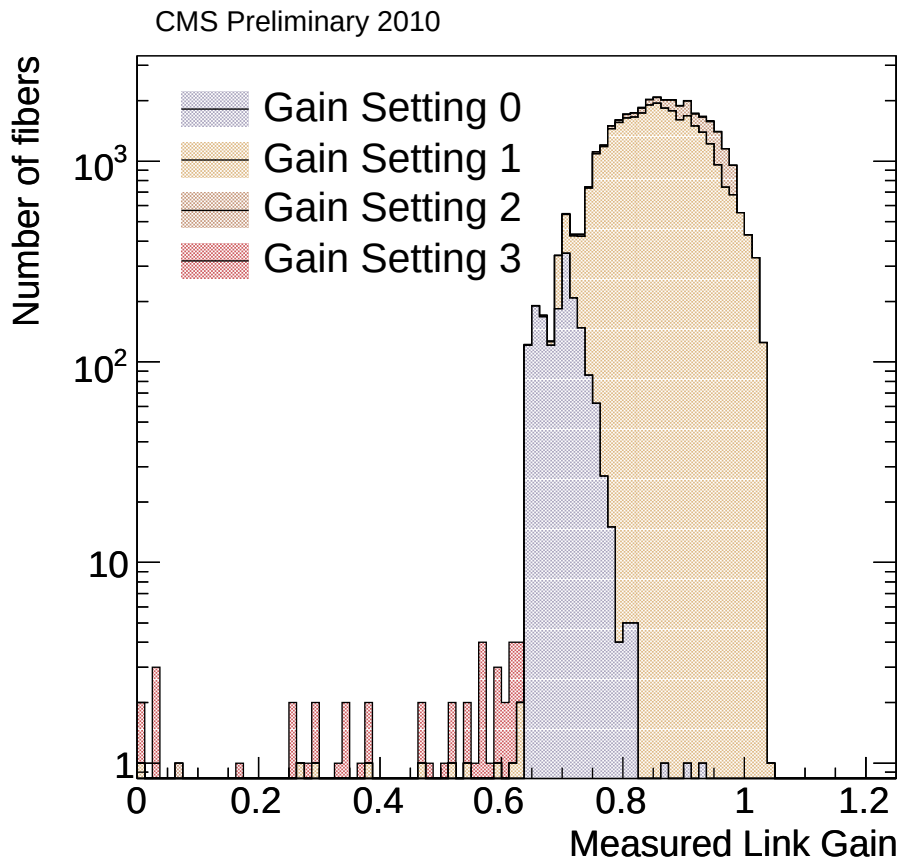


Commissioning Procedures

- Strip tracker has analog readout
- digitization only done in the Front End Drivers

Need to:

- Internally time align
  $\rightarrow$ Synchronization of channels
- Tune laser gain
- Optimize chip parameters
- Optimize pulse shape to ideal
-
- Determine Noise and Pedestals
  $\rightarrow$ For FED data reduction
- Synchronize with CMS
  $\rightarrow$ Align sampling with physics events

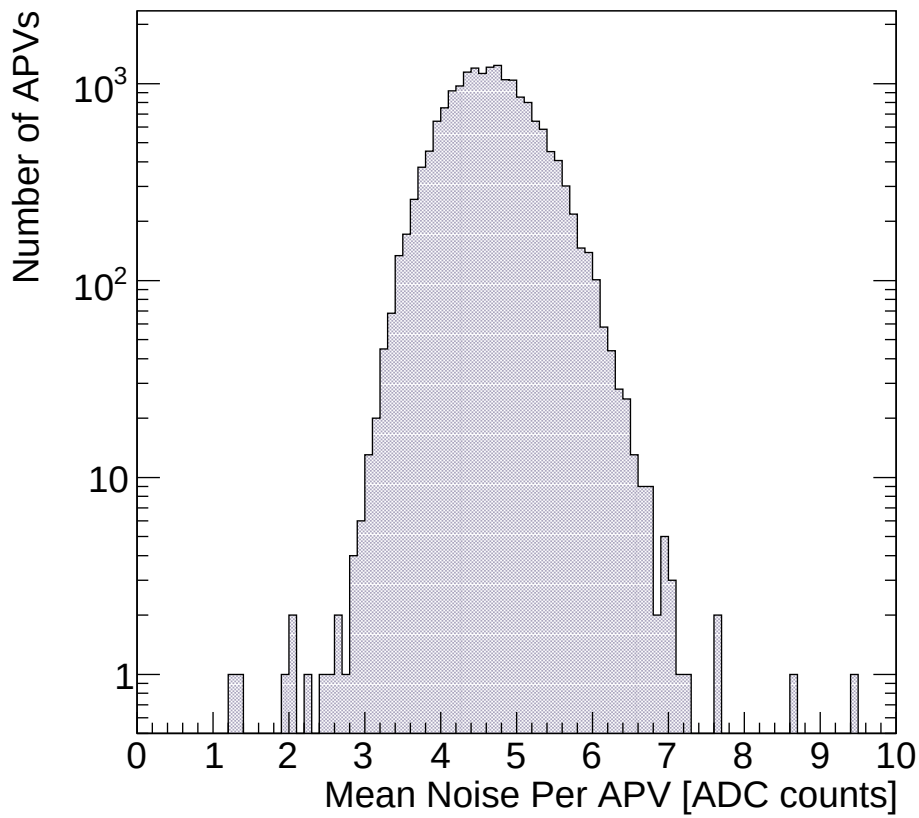


Commissioning Procedures

- Strip tracker has analog readout
- digitization only done in the Front End Drivers

Need to:

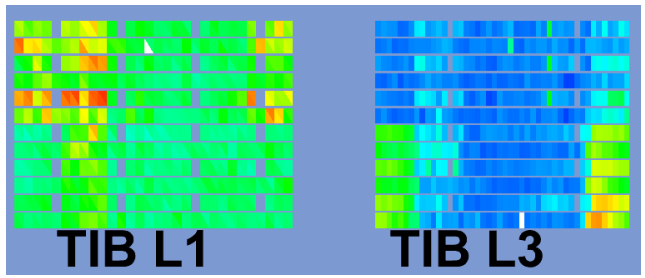
- Internally time align
  $\rightarrow$ Synchronization of channels
- Tune laser gain
- Optimize chip parameters
- Optimize pulse shape to ideal
-
- Determine Noise and Pedestals
  $\rightarrow$ For FED data reduction
- Synchronize with CMS
  $\rightarrow$ Align sampling with physics events



Status of Active Channels

Channels in readout

	Percentage	Modules total
TIB/TID	96.25	3540
TOB	98.33	5208
TEC-	99.13	3200
TEC+	98.81	3200
Tracker	98.1	15148



Temperature in TIB Layer 1 and 3

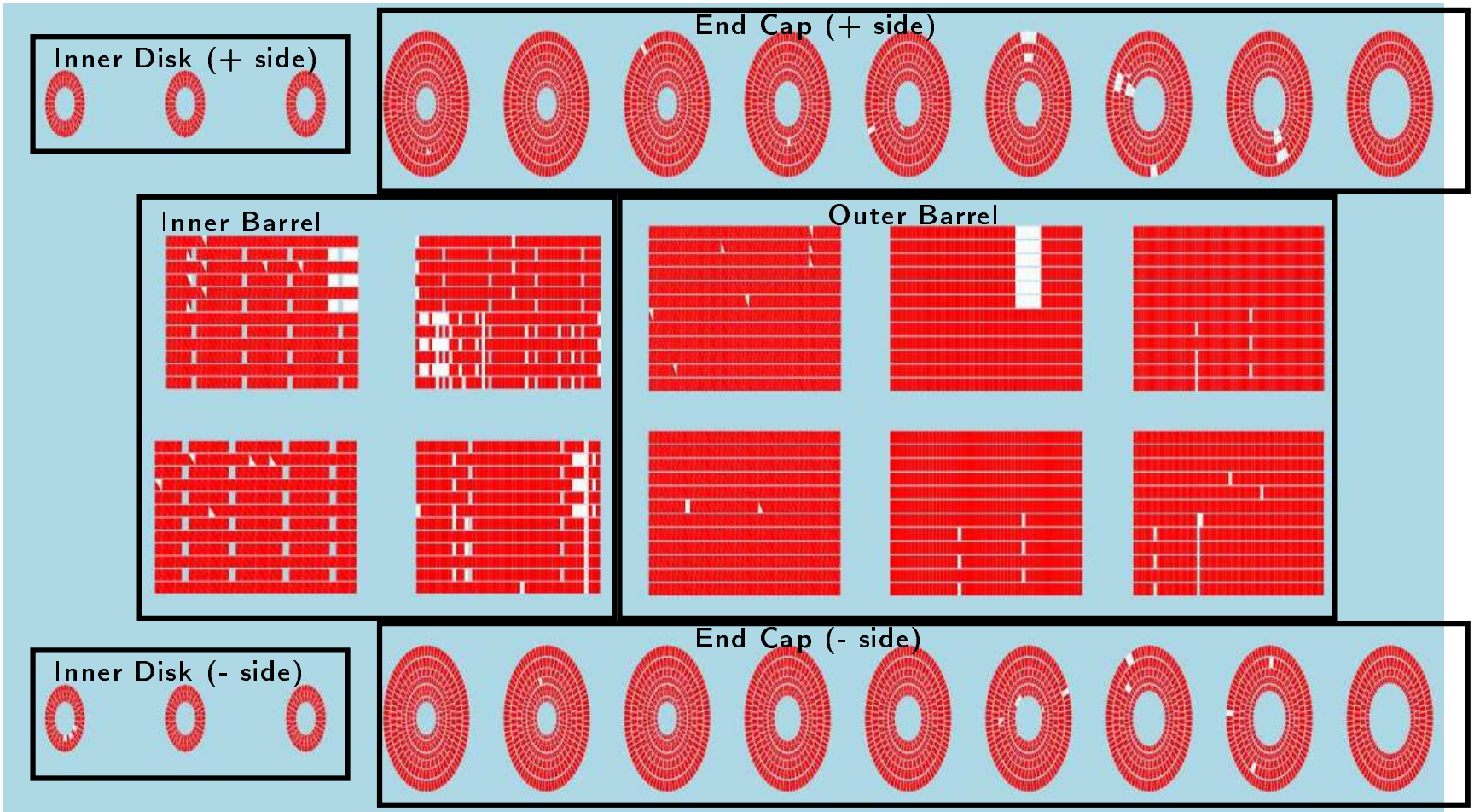
- TIB/TID: 92.9 % operational in 2009

→ could be increased to 96.25 % in 2010

→ possible by inclusion of modules which rely on passive cooling from neighboring cooling loops for the time being

Status of Active Channels

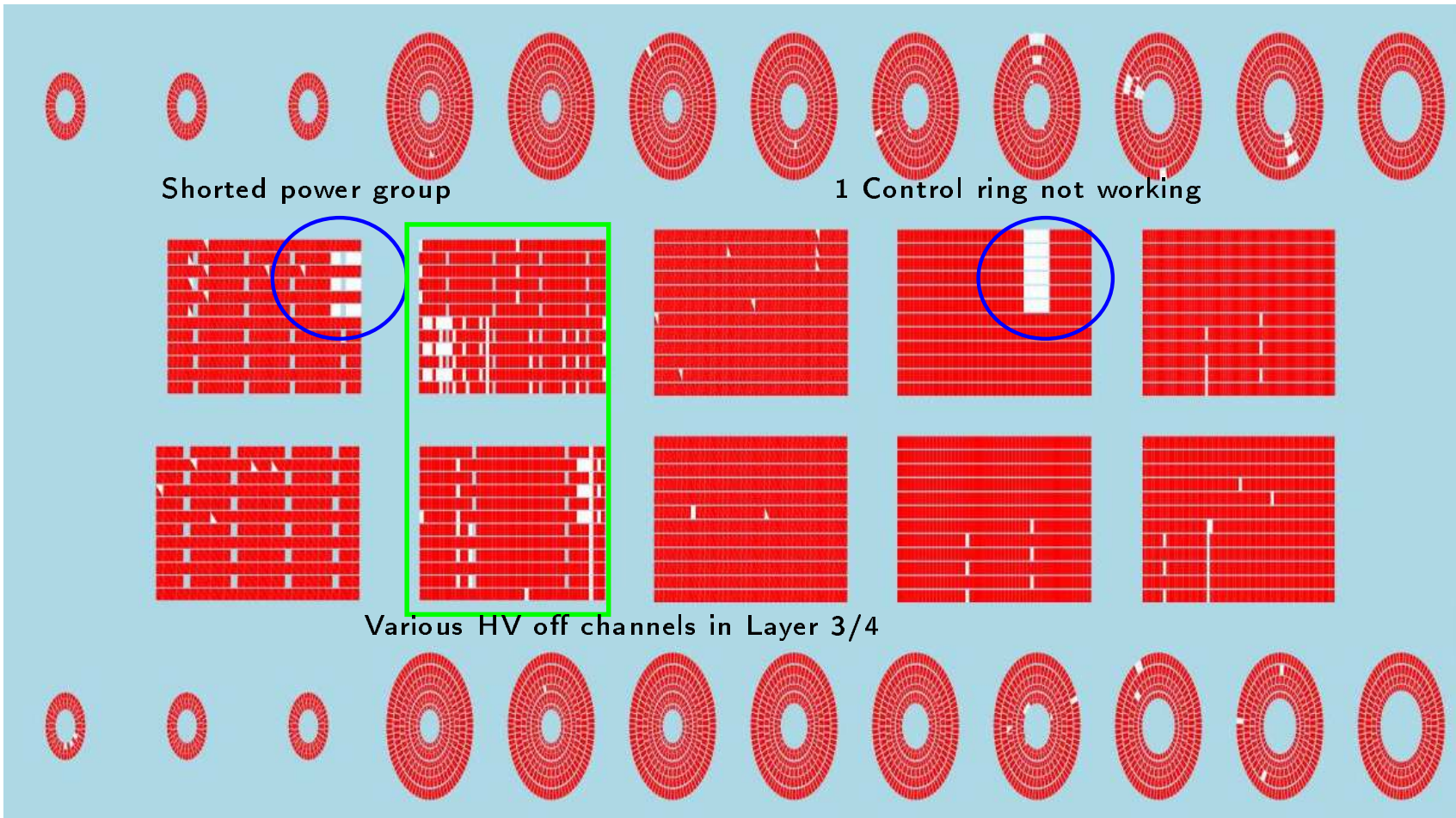
Channels in readout – graphically



Situation of the strip tracker in June 2010

Status of Active Channels

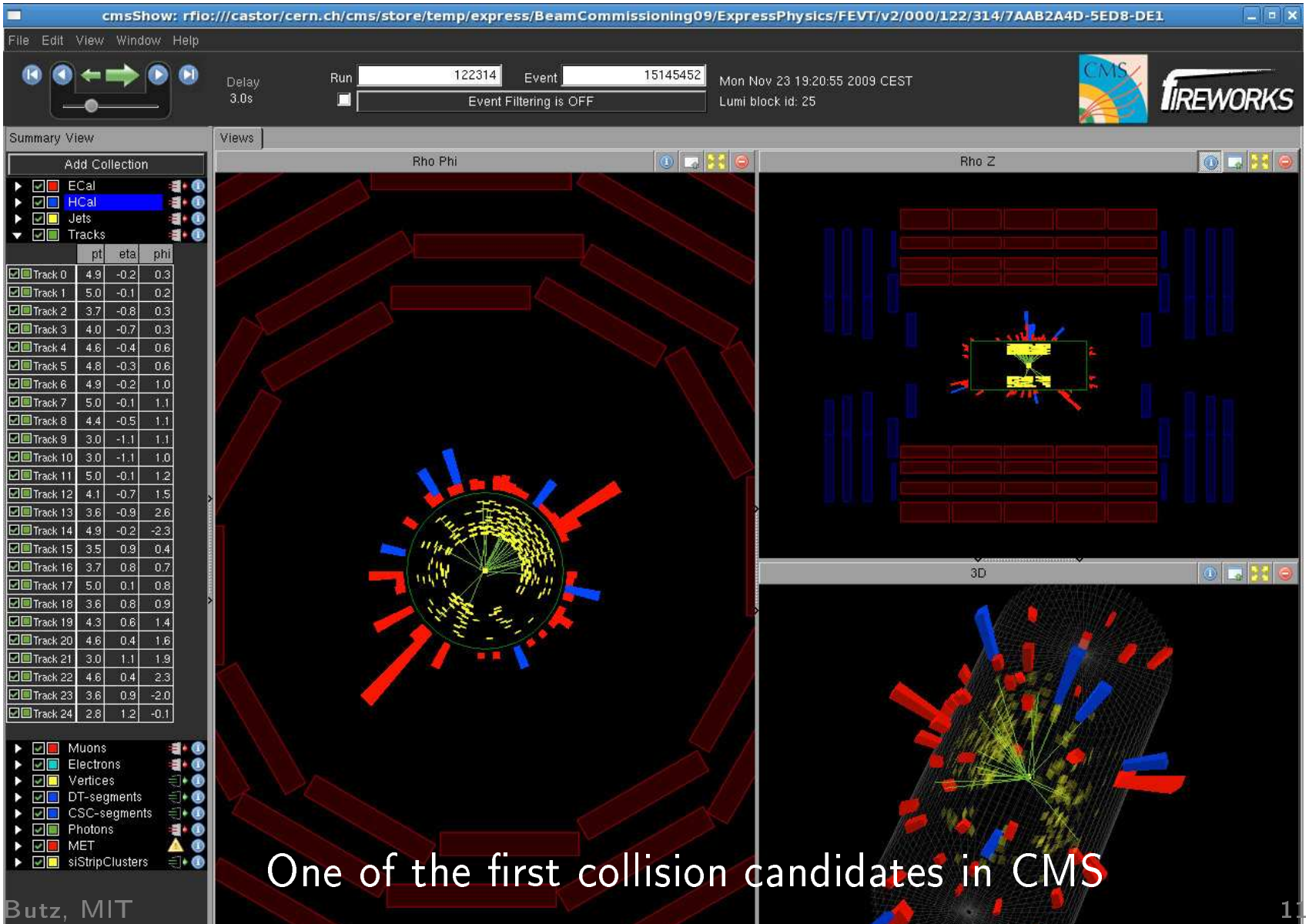
Channels in readout – graphically



Situation of the strip tracker in June 2010

Operation

First collisions in 2009

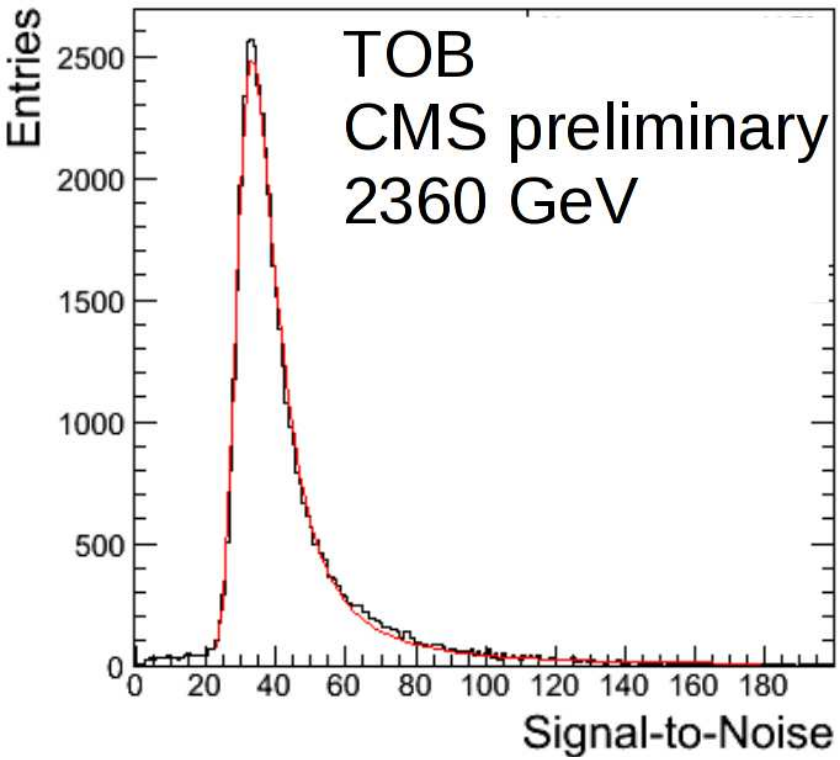


One of the first collision candidates in CMS

Operation

First collisions in 2009

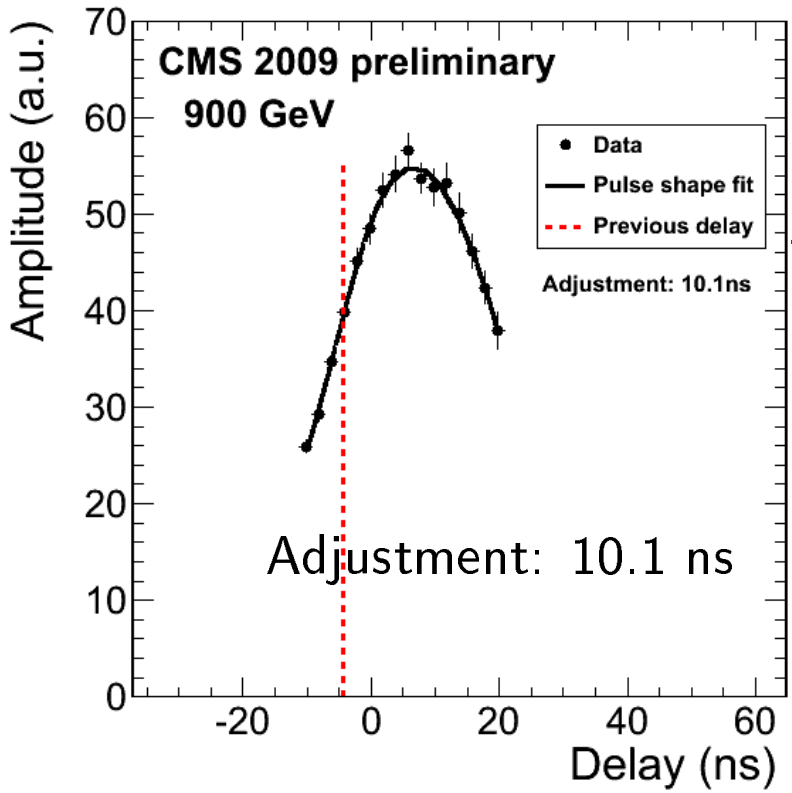
- CMS tracker has been operated successfully from the first collisions in November 2009
- Cautious operation during LHC machine development (also in 2010), but tracker fully on with HV at nominal operation voltages for first collisions
- Operated in peak mode for most 2009 runs



Operation

First collisions in 2009

- CMS tracker has been operated successfully from the first collisions in November 2009
- Cautious operation during LHC machine development (also in 2010), but tracker fully on with HV at nominal operation voltages for first collisions
- Operated in peak mode for most 2009 runs

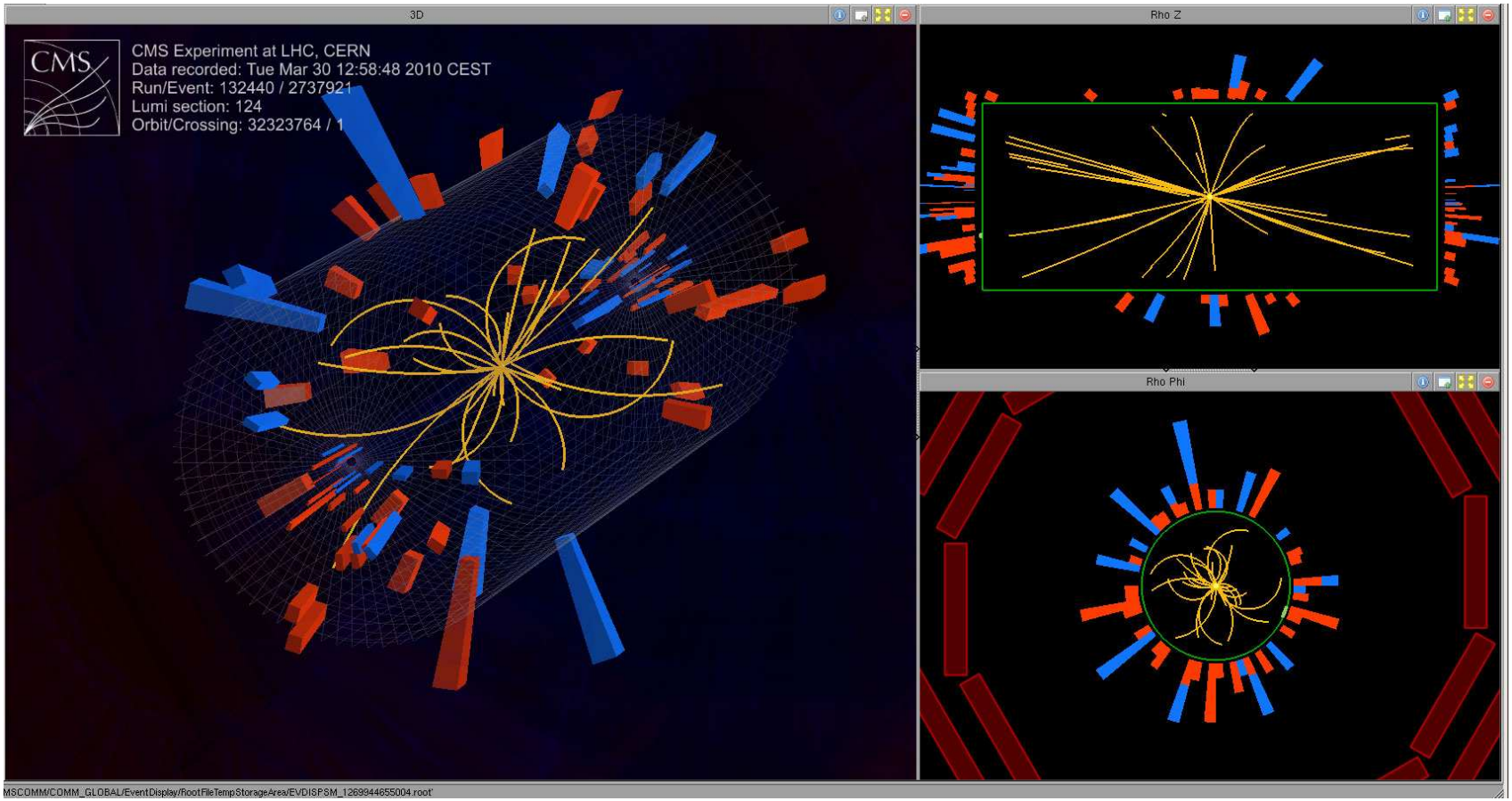


Trigger Fine Timing

- first trigger fine timing performed
- starting with TOB only
- provided useful input for correction of timing for operation in deconvolution mode

Operation

Collisions in 2010



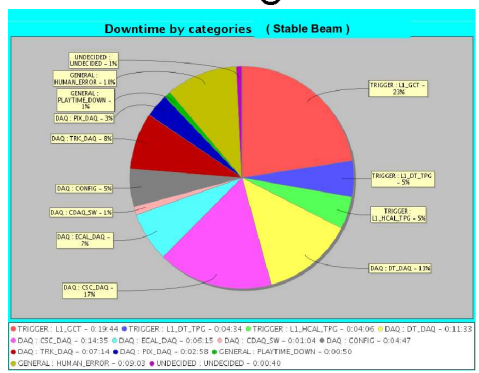
High energy collision candidate during media event 30th March

Collisions in 2010

- Following the first successful trigger fine timing, strip tracker was operated in deconvolution mode during all of 2010
- Uptime $>$ 90 % (including inefficiencies due to time alignment runs at very low luminosities)
- Efforts ongoing to eliminate or mitigate problems
- Items:
  - DAQ software/driver crashes (only fatal at state transitions)
  - Efforts to reduce configuration time
  - PS system was improved a lot from 2009 to 2010

  $\rightarrow$ much less time needed for HV HV OFF$\rightarrow$ON transistions

CMS overall efficiency 91 %, including time for various timing scans

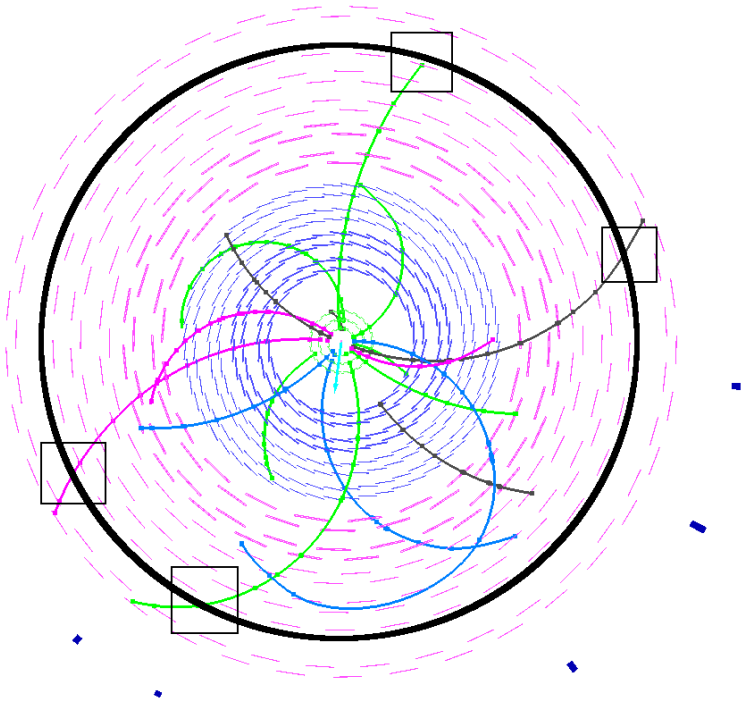


Example:

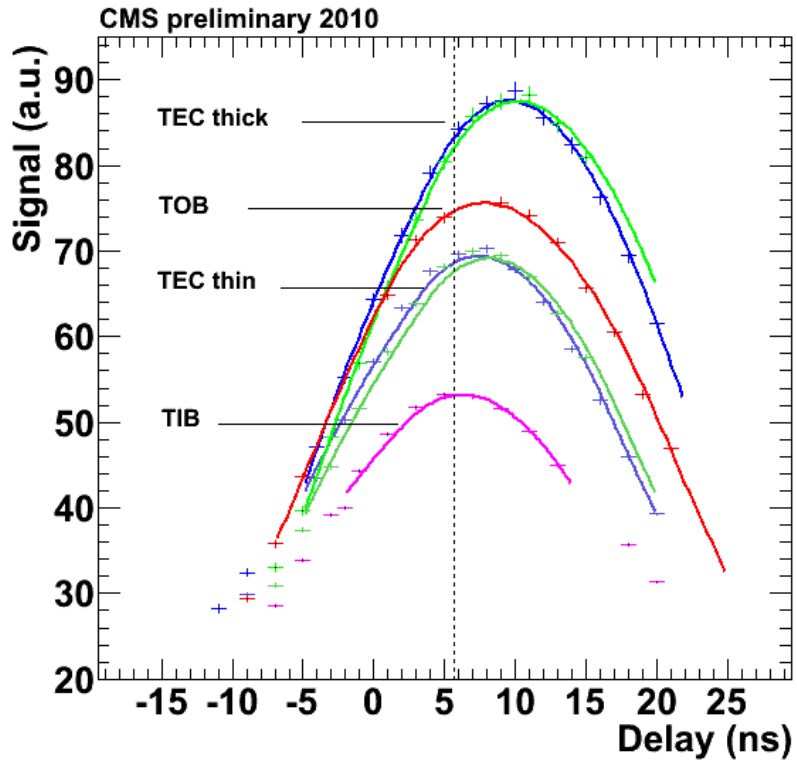
- Strip Tracker caused 8% of total CMS downtime between LHC fill 1101 and 1119
- Overall CMS efficiency in this period: 95 %

Trigger Fine Timing – Part II

- For each subdetector, one layer is put into deconvolution mode while the rest is kept in peak mode.
- Sampling point is determined per subdetector



2009



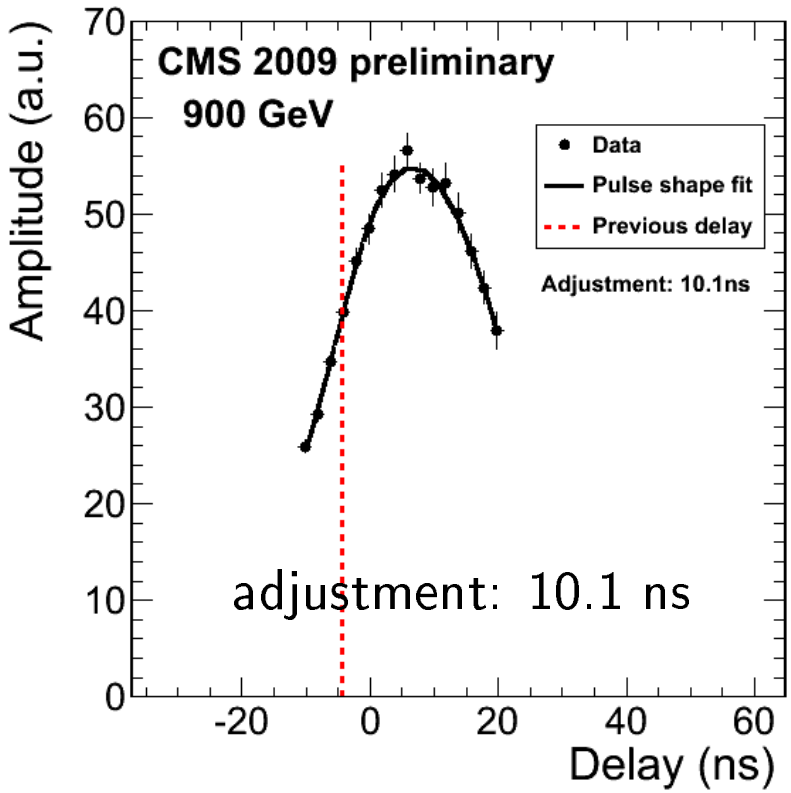
2010

- small (2.5 ns) additional shift observed

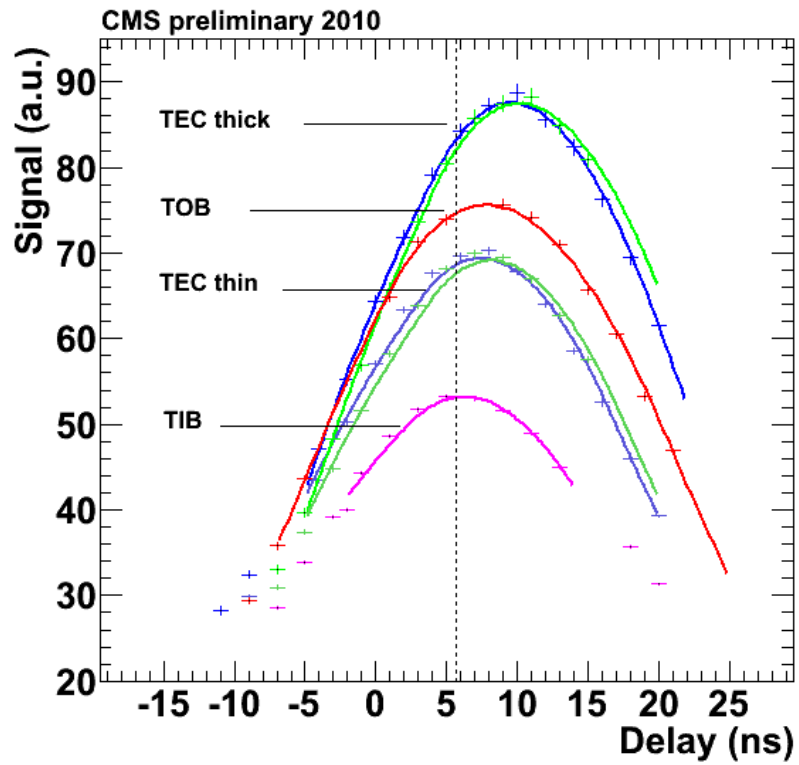
Fine timing adjustments on all components provides optimal charge collection

Trigger Fine Timing – Part II

- For each subdetector, one layer is put into deconvolution mode while the rest is kept in peak mode.
- Sampling point is determined per subdetector



2009



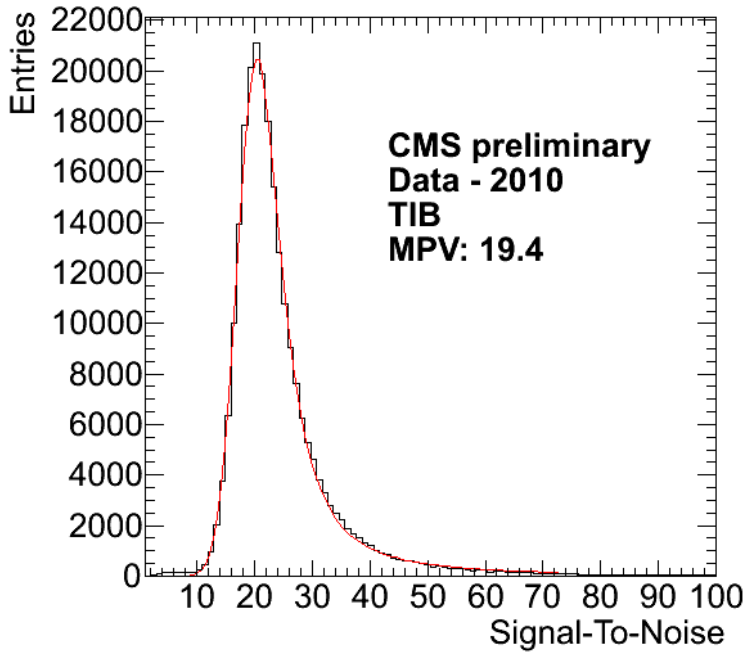
2010

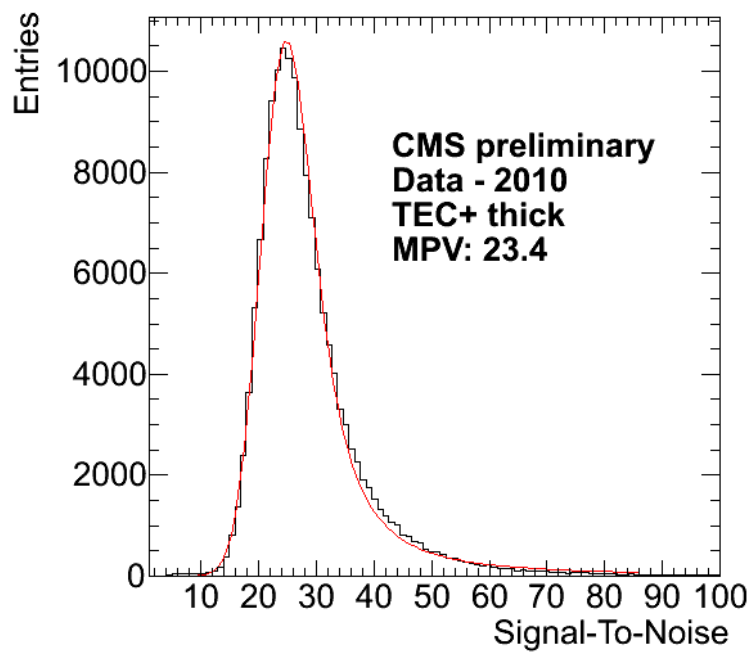
- small (2.5 ns) additional shift observed

Fine timing adjustments on all components provides optimal charge collection

Signal-to-Noise Performance with 7 TeV Beams

Examples (all other subdetectors in backup)



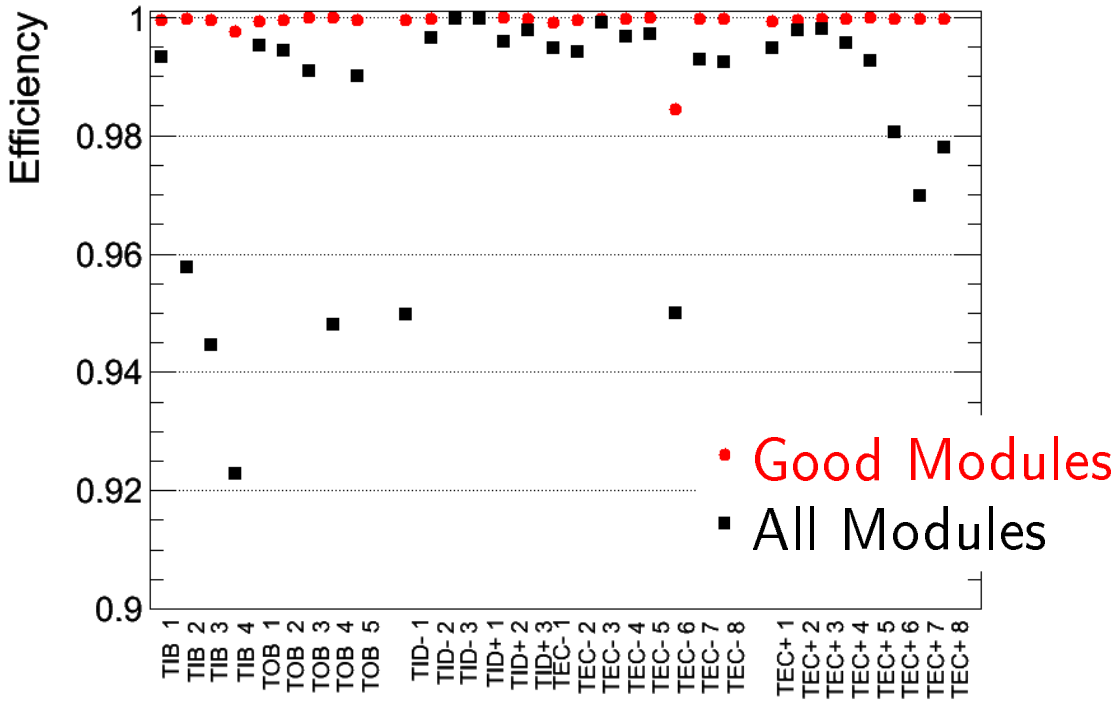


- Corrected for track angle
- obtained during collisions, tracker operating in deconvolution mode

Results very good and in agreement with expectations

Detector efficiency

Hit finding efficiency

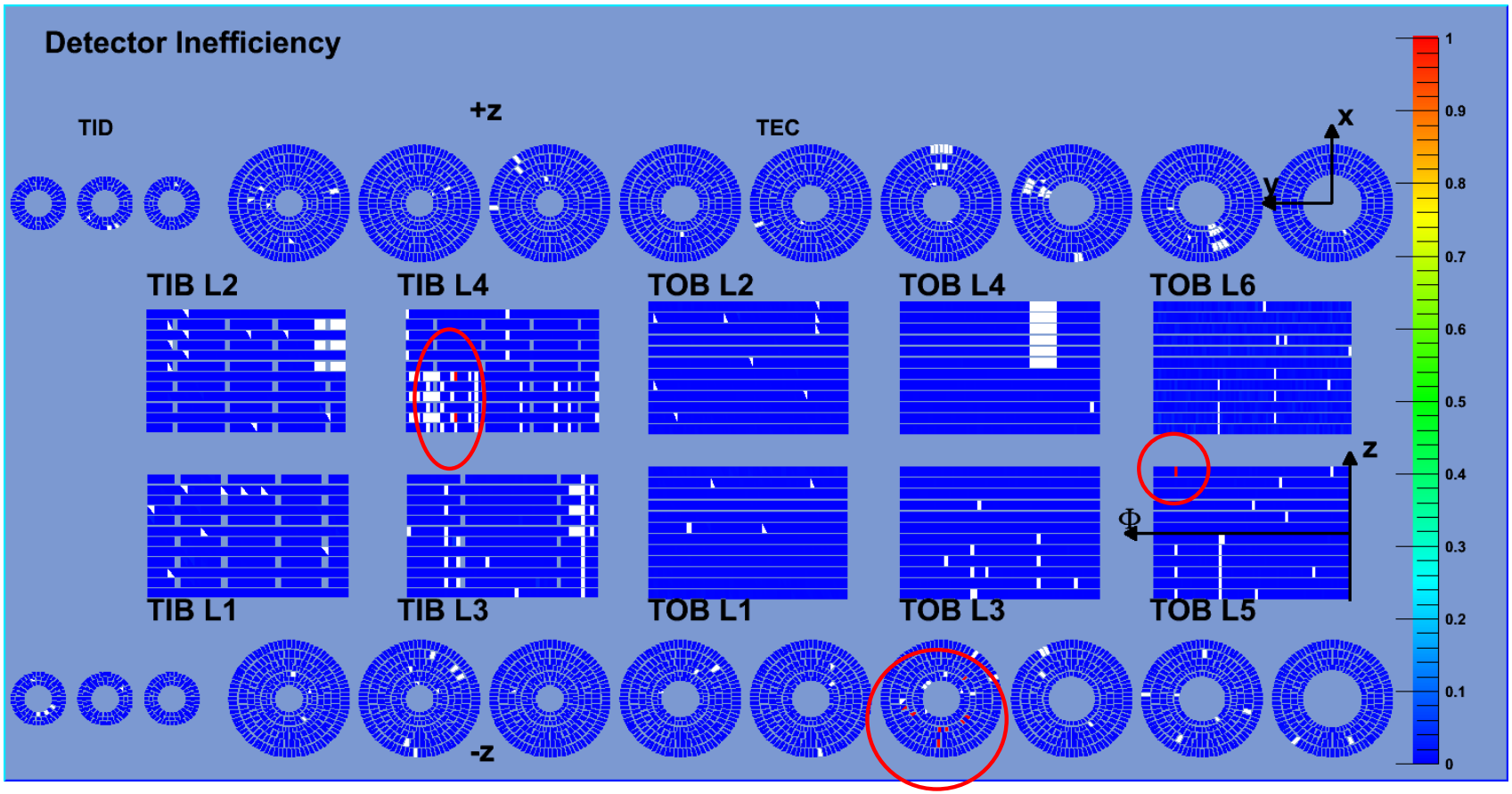


- Overall efficiency: 99.9 %
- Parts with lower efficiency are due to localized problems

$\rightarrow$ Can be reliably identified

Detector efficiency

Inefficiency

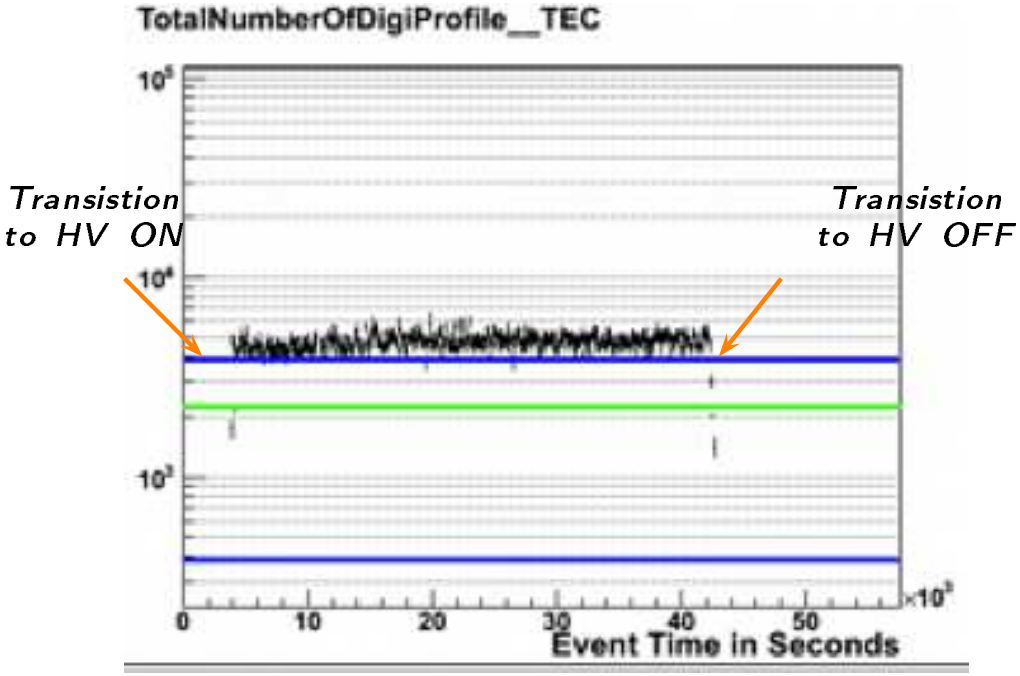


only about 11 out of almost 15000 active modules inefficient

Streamlining Operations

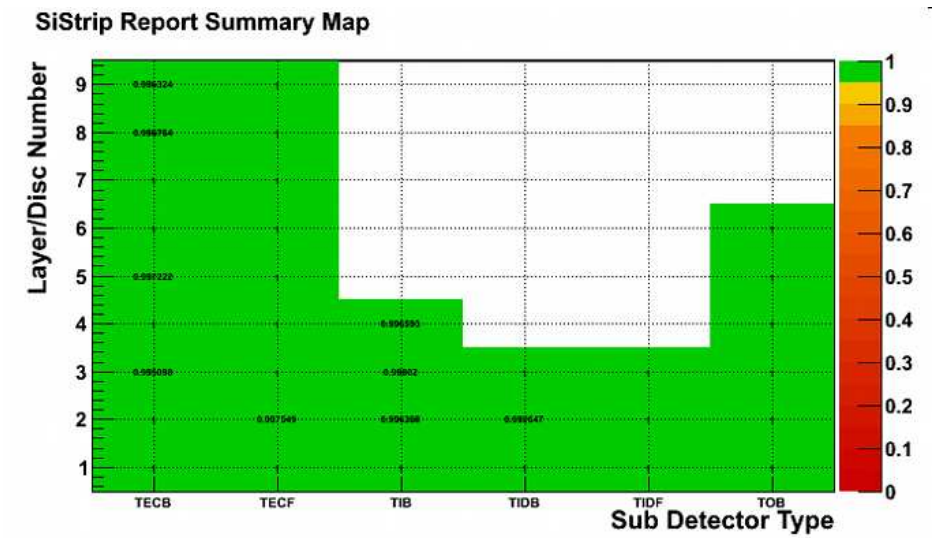
Data suppression in HV off periods

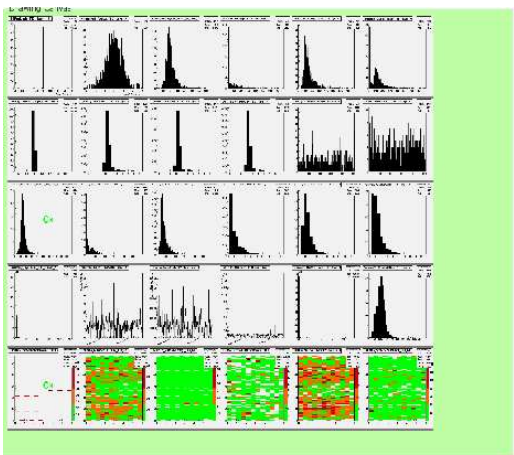
- when change of LHC beam conditions mode requires tracker to be on standby (LV on/HV off), the data is suppressed at FEDs to reduce bandwidth load

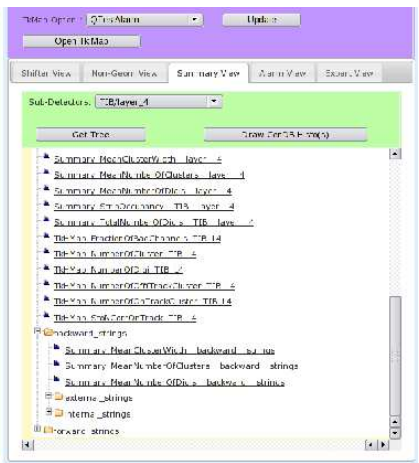


Reduction of data volume for HV off periods working successfully

Data Quality Monitoring

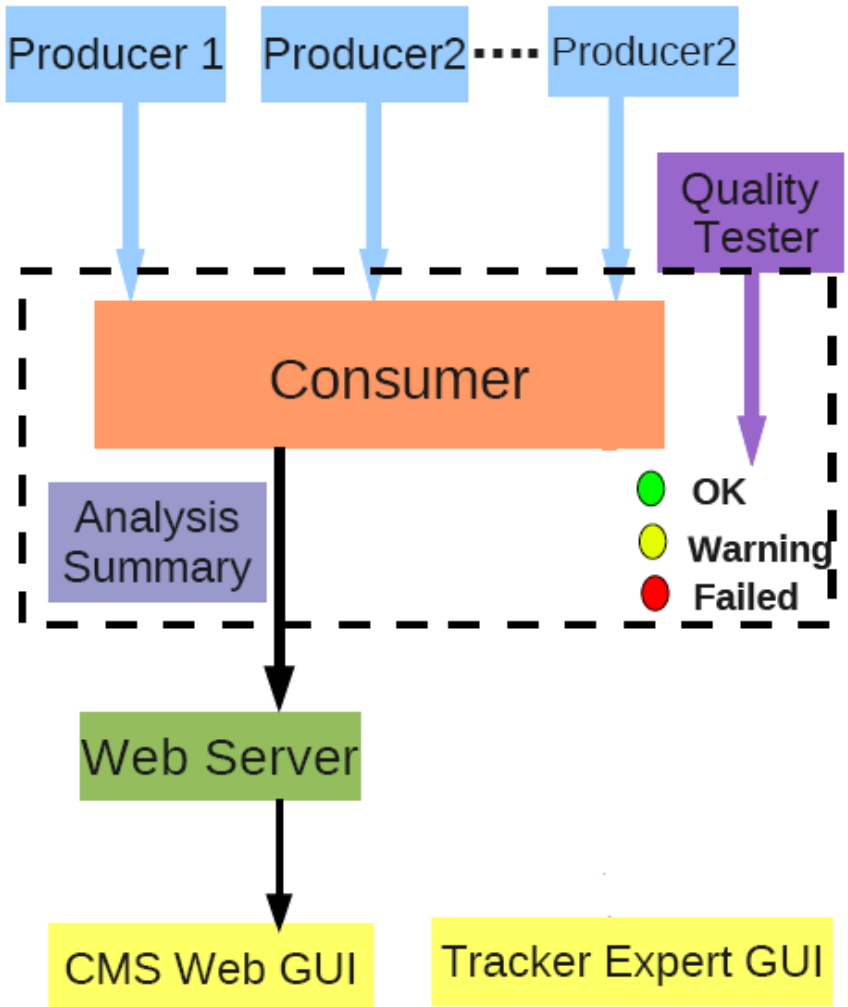






- Detector performance are monitored using the DQM system
  - online to give prompt feedback during data taking
  - offline to analyse the full statistics and certify data
- The full tracker reconstruction chain is monitored through histograms on
  - Status of Feds , Occupancy, Clusters, Track parameters
- Module level histograms are further processed to
  - Create summary histograms
  - Perform Quality Test
  - Produce global DQM flags

Data Quality Monitoring



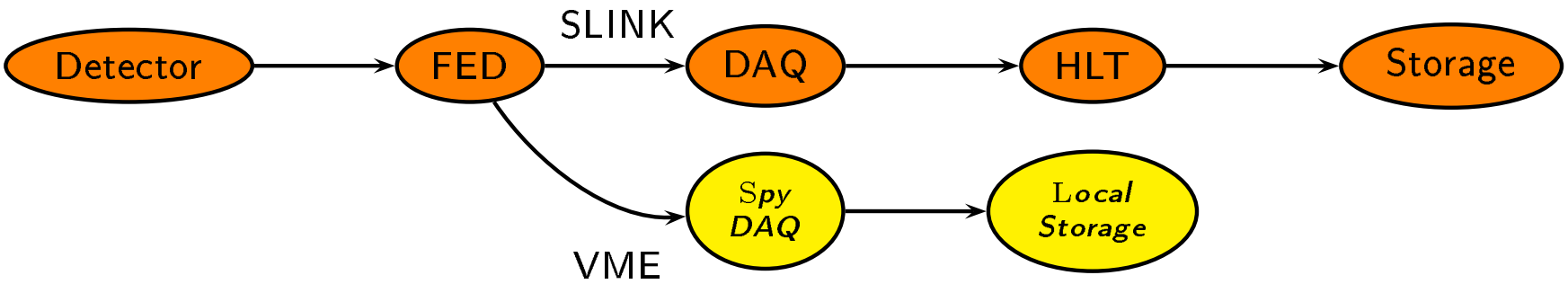
Quality Monitoring of the data happening both centrally from CMS and locally from subdetector shifters/experts

- → central DQM run continuously and always in collision mode
- → local instance with more quantities monitored, higher granularity (300 k histograms)

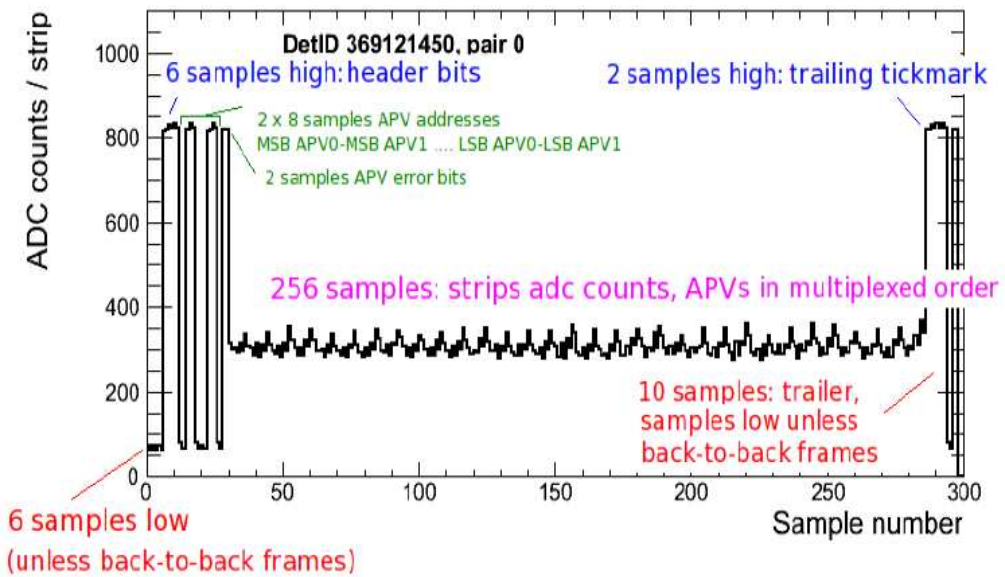
DQM working smoothly since very first collisions with rapid feedback to data taking

DAQ Tools

- Operation very smooth, so focus moves to upgraded monitoring
- The so-called 'spy-channel' Separate data stream in parallel to normal data taking via S-LINK64



Captures full raw-data frame



- Provides complete non-zero suppressed data including error bits, etc. . .
- Read at low rate (max 0.3 Hz)

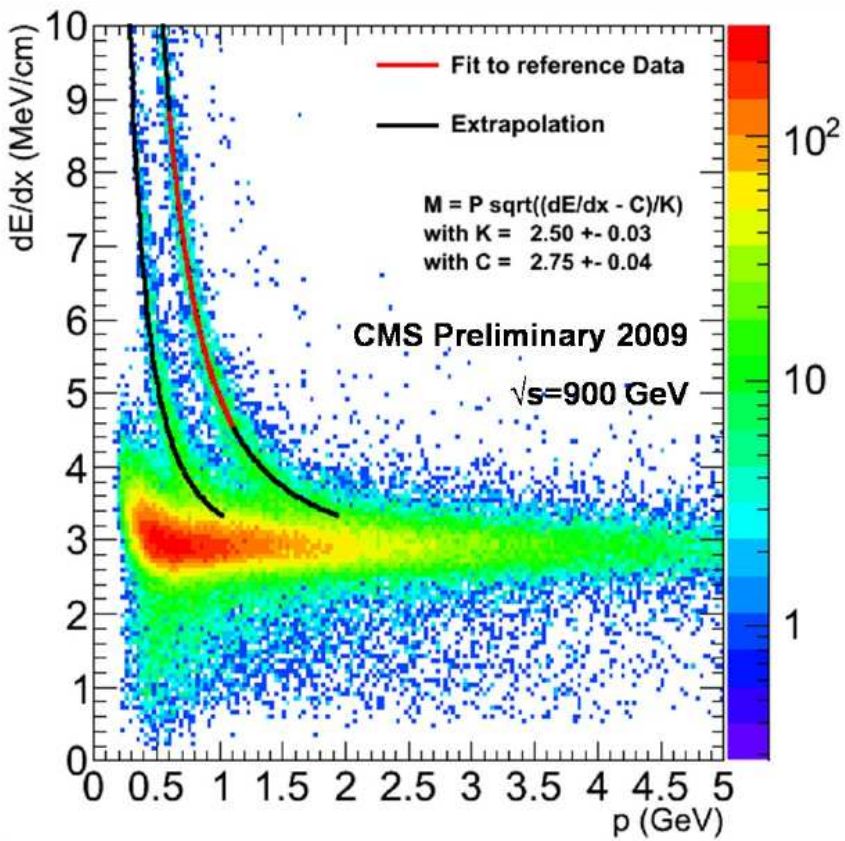
Spy Channel Applications

- Calculation of noise thresholds taken during physics data-taking (no need for separate calibration runs)
- Stability of readout
- Monitoring of
  - FED hardware
  - FED zero-suppression
  - Detector efficiencies
  - ...

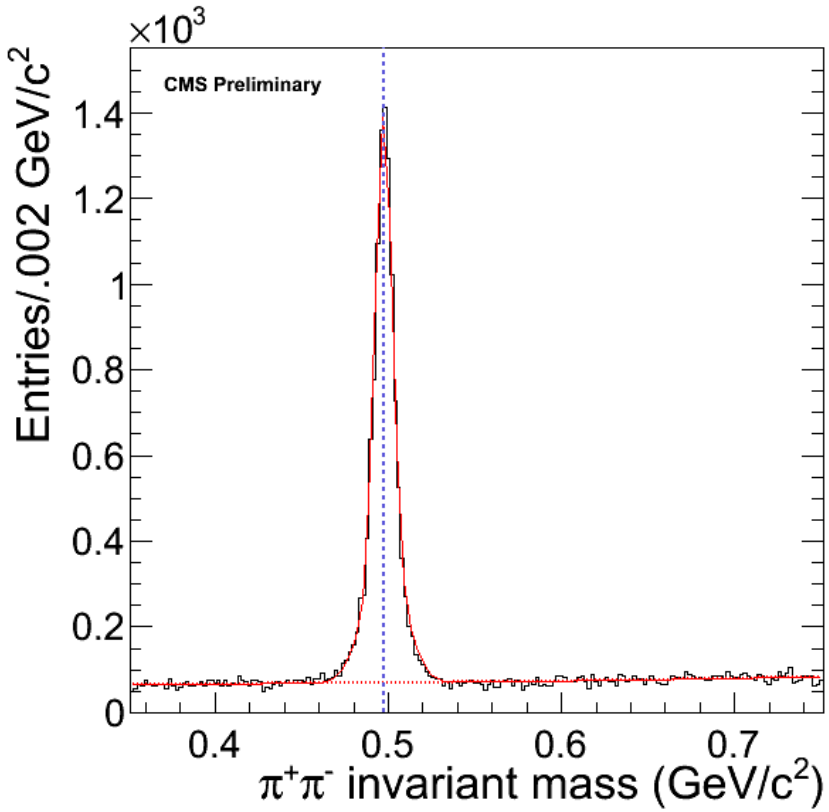
Spy channel is a powerful tool which will provide crucial information about the low-level performance of the detector during running

Outlook

Strip tracker is performing very well, providing high quality data for physics analysis



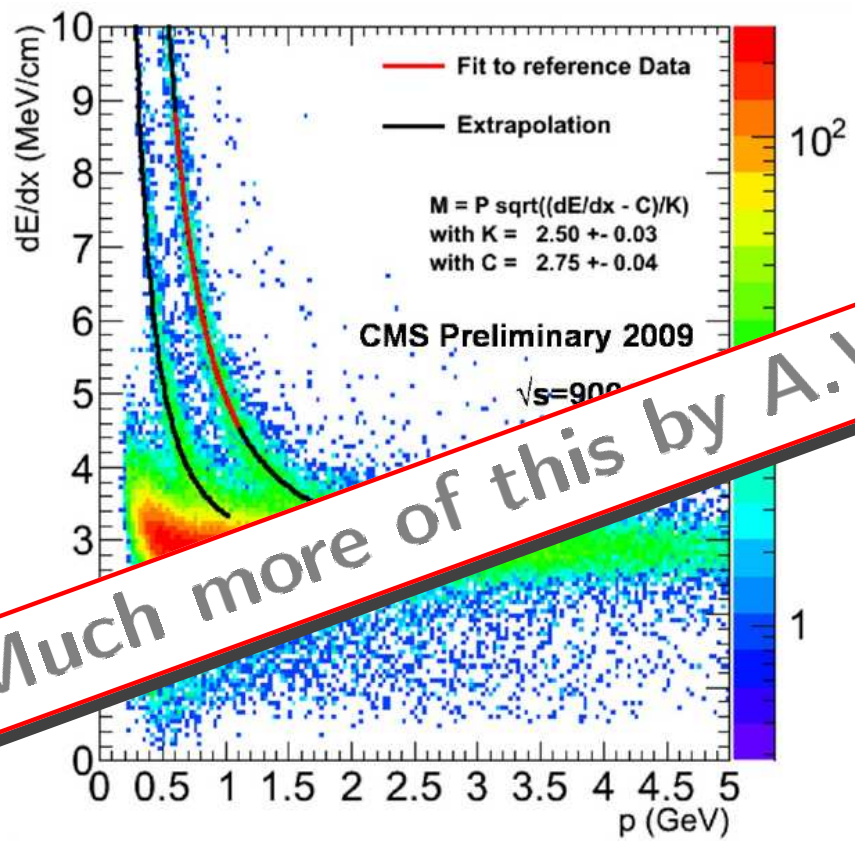
Specific energy loss



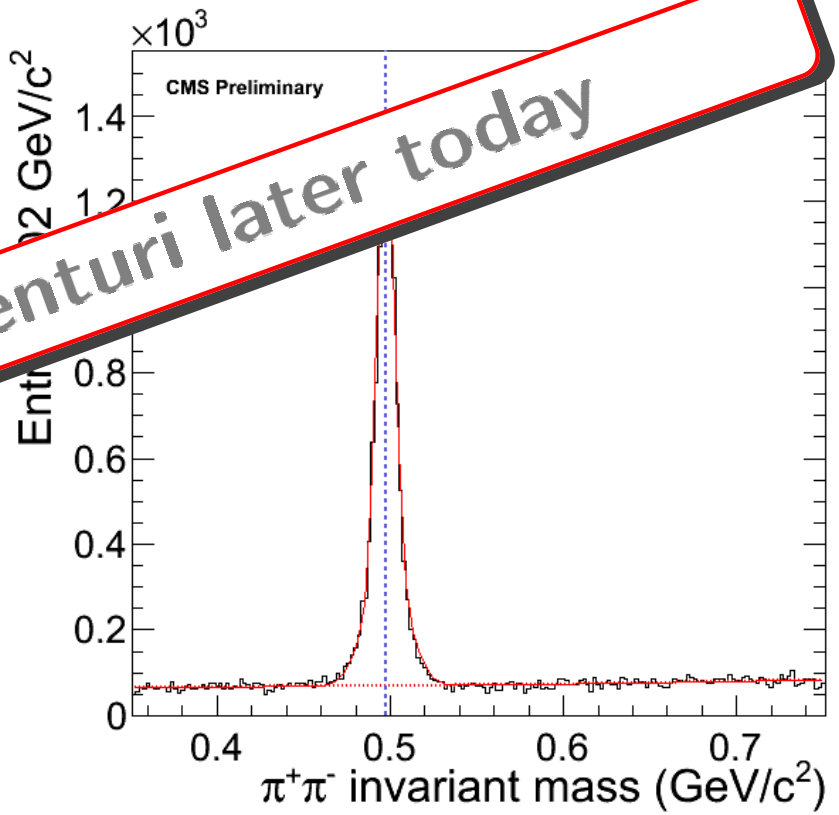
K^0_s mass plot

Outlook

Strip tracker is performing very well, providing high quality data for physics analysis



Specific energy loss



K^0_s mass plot

Much more of this by A.Venturi later today

Summary

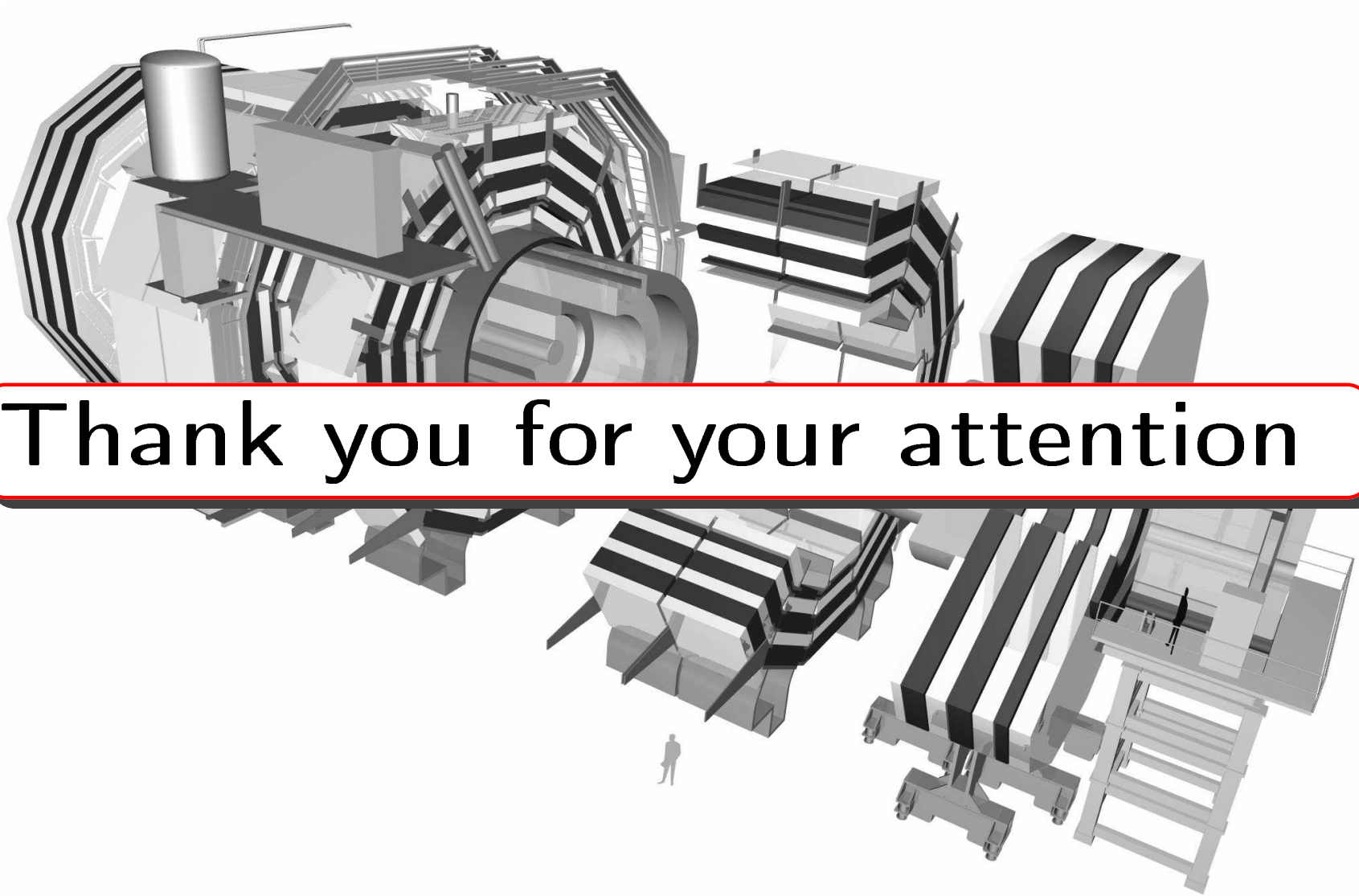
- CMS silicon strips tracker has been operated successfully during 2009 and 2010, recording high quality data from the very beginning
- The Signal-to-noise ratio is constantly high and in agreement with expectations in both peak and deconvolution readout mode
- The hit finding efficiency is close to 100 %
- A thorough data quality monitoring is in place
- The power and cooling systems are working reliably
- Spy channel will provide handles to monitor and possibly further improve the performance of the system

Outlook on Operations

- Improve monitoring of the system
  - spy channel
  - improved DAQ monitoring
- Wire bond protection being deployed
- Keep up reliability of the PS system
- Prepare for LHC long technical stop
  - lowering of temperature:

  $\rightarrow$ poses demands on
    - cooling and
    - humidity
- . . . many more . . . .
- First and most importantly:

  Deliver high quality physics data

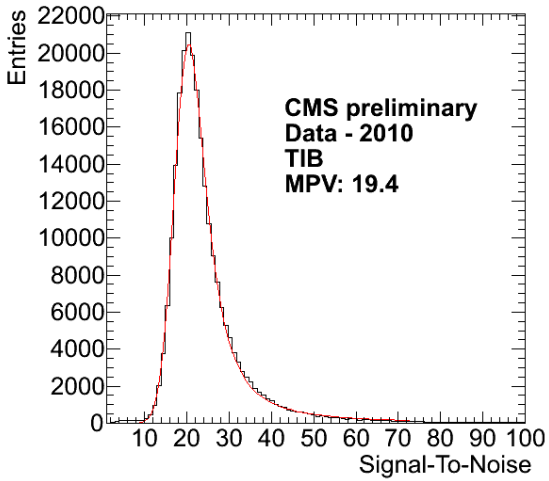


Thank you for your attention

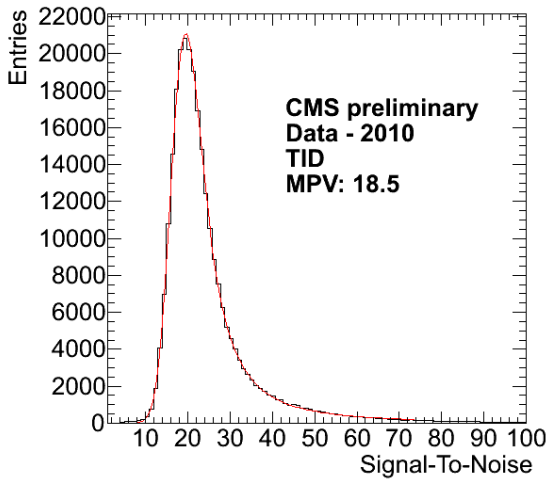
Backup

Signal-to-Noise Performance with 7 TeV Beams

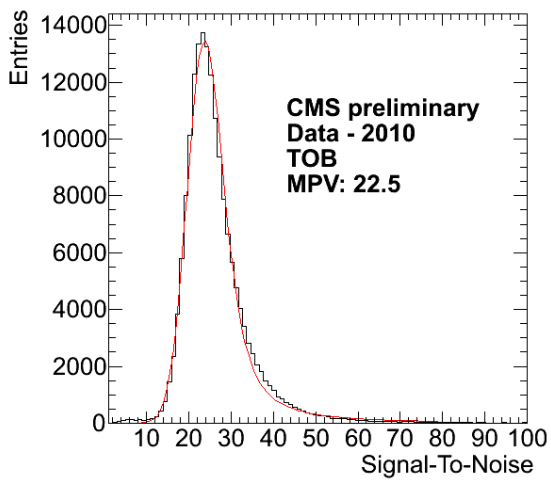
Inner Barrel/Disks Outer Barrel



TIB



TID



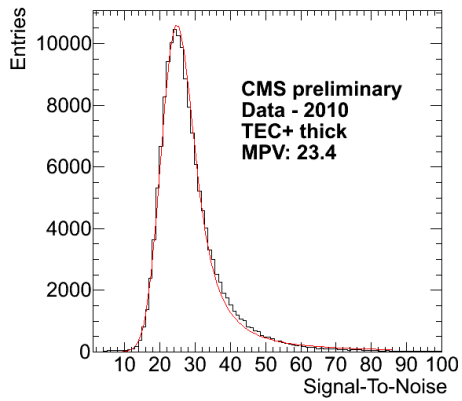
TOB

- Corrected for track angle
- Inner Barrel and inner disk have thin sensors (320 μm) outer barrel has thick sensors (500 μm)
- obtained during collisions, tracker operating in deconvolution mode

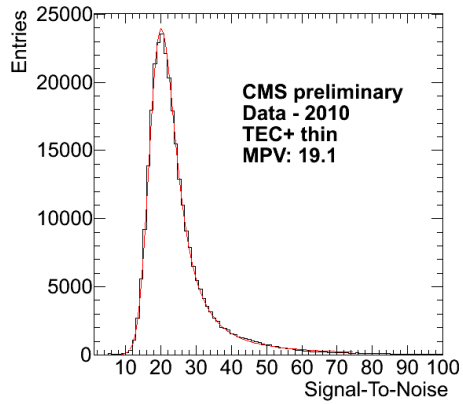
Results very good and in agreement with expectations

Signal-to-Noise Performance with 7 TeV Beams

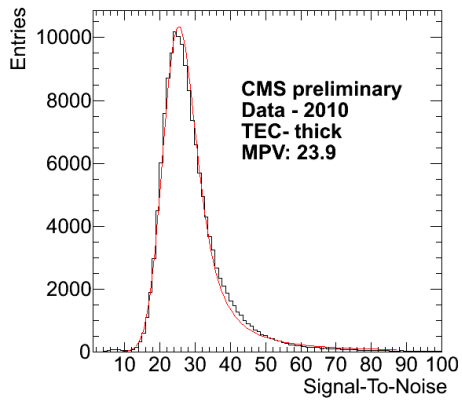
Endcaps



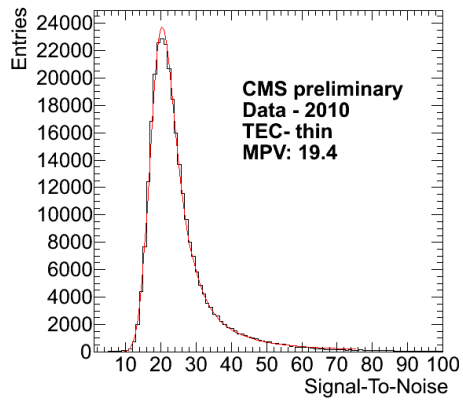
TEC+ thick



TEC+ thin



TEC- thick

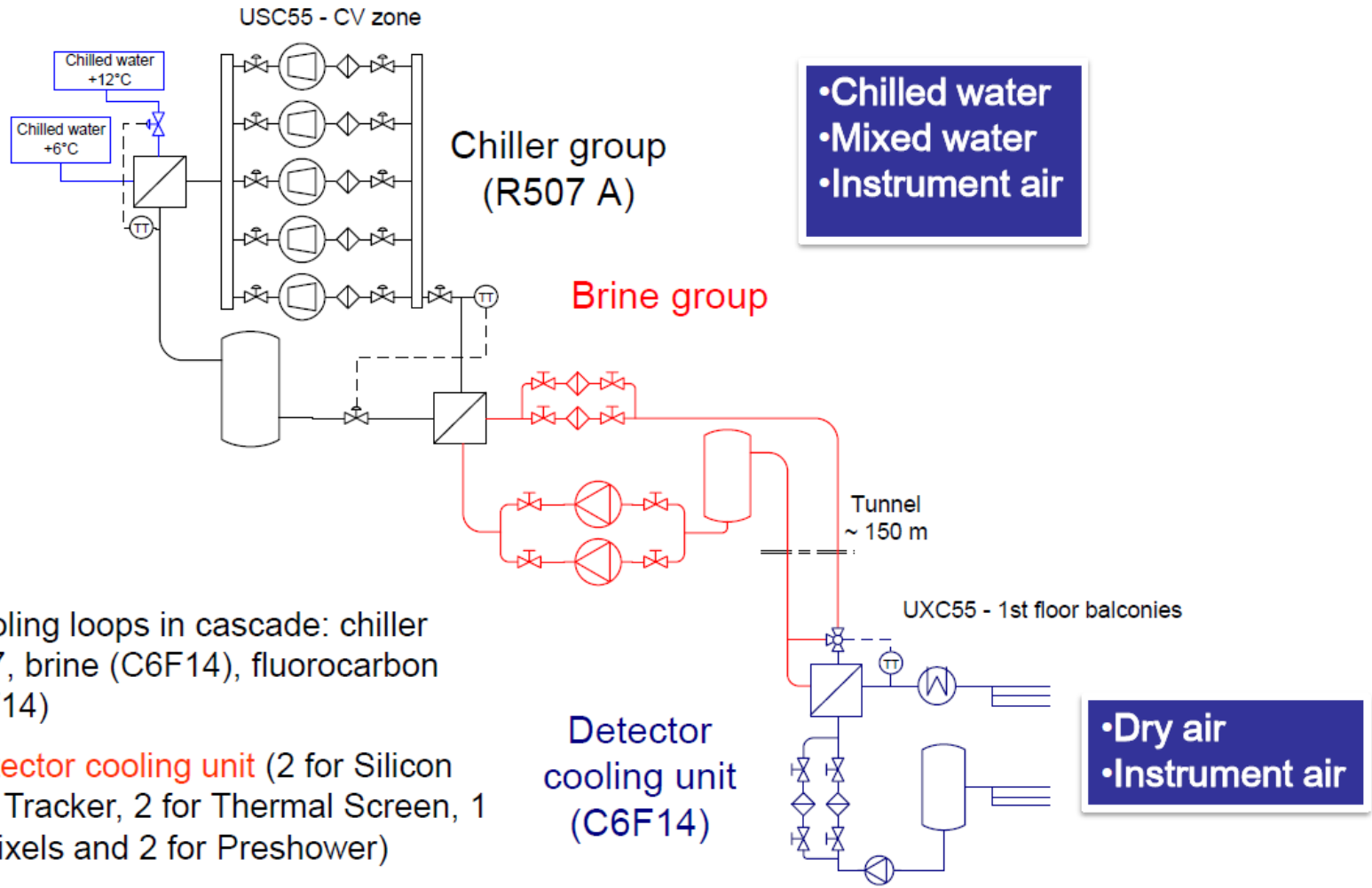


TEC- thin

- Endcaps have both thin and thick sensors

Results completely compatible with results from barrel detectors

Layout of Cooling Plan



- 3 cooling loops in cascade: chiller R507, brine (C6F14), fluorocarbon (C6F14)
- 7 detector cooling unit (2 for Silicon Strip Tracker, 2 for Thermal Screen, 1 for Pixels and 2 for Preshower)