CMS Silicon Strip Tracker Performance

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On behalf of the CMS collaboration

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CMS Silicon Strip Tracker

- 2.4m diameter, 5.5m long, 198m^2, 15148 modules, 9.3 million channels, in a 3.8T solenoïd
- must provide low occupancy, fast readout, high precision, radiation hardness
- double sided layers : stereo angle of 100 mrad (5.7 deg)

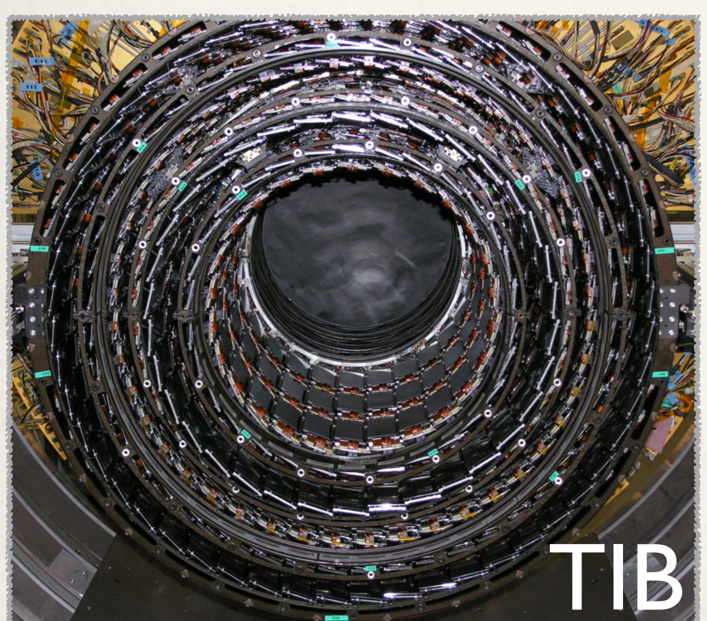
GLOSSARY

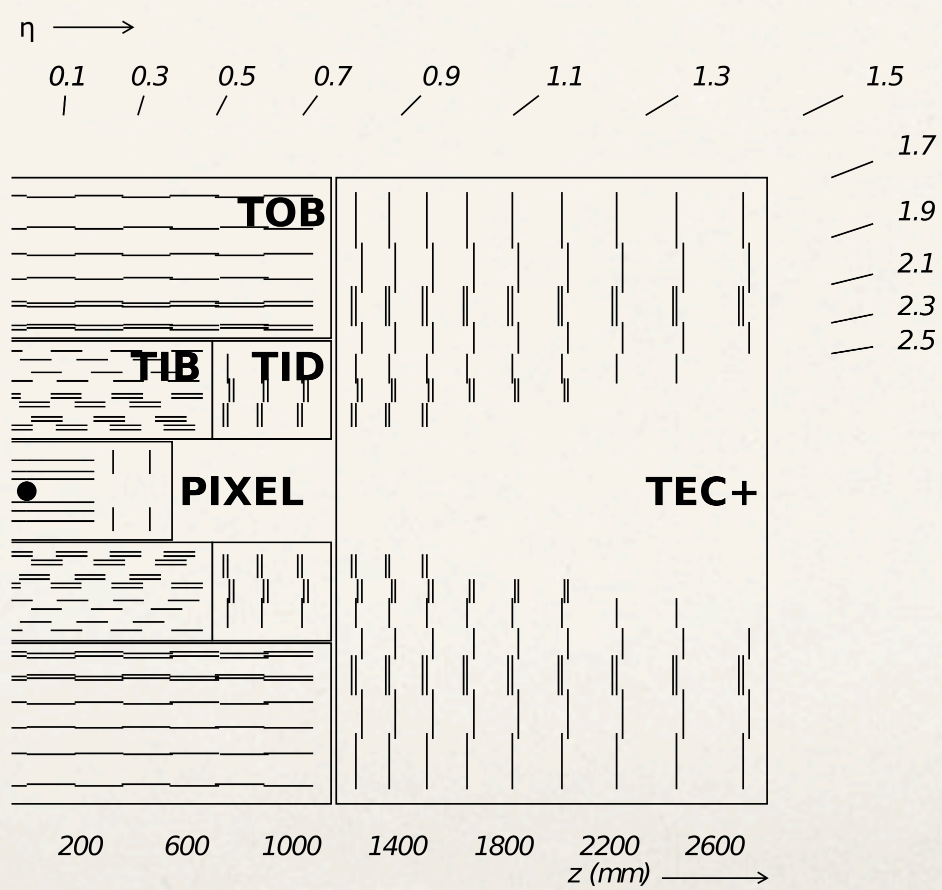
TIB : Tracker Inner Barrel

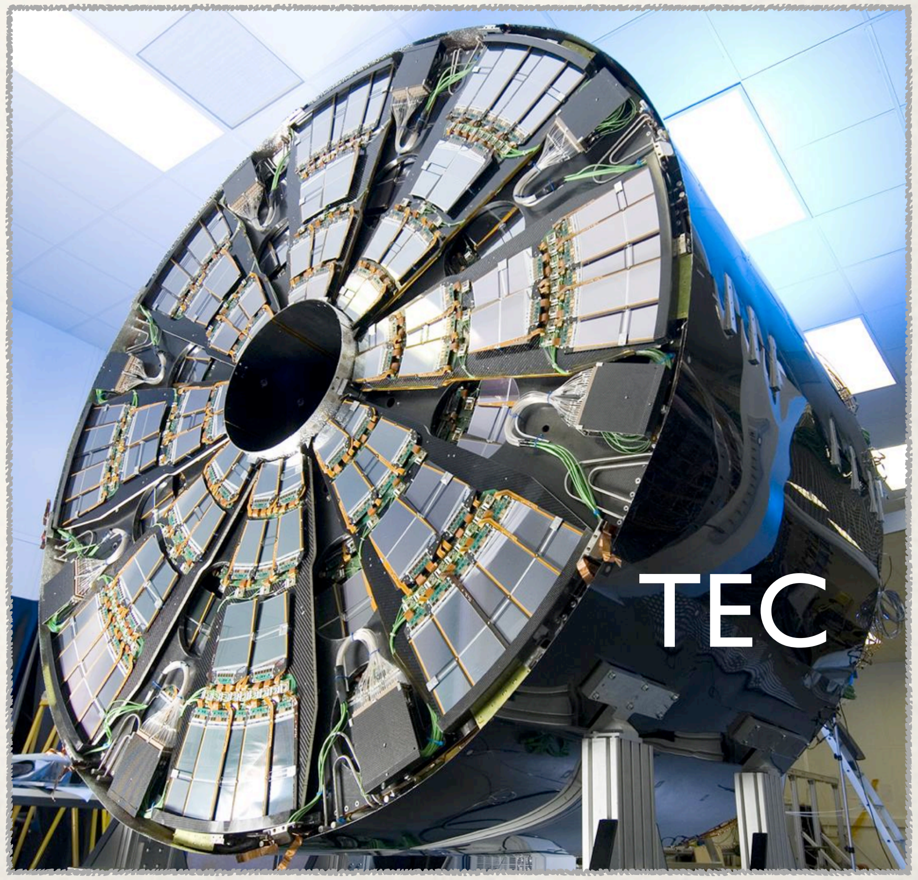
TOB : Traker Outer Barrel

TID : Tracker Inner Disks

TEC : Tracker End Cap

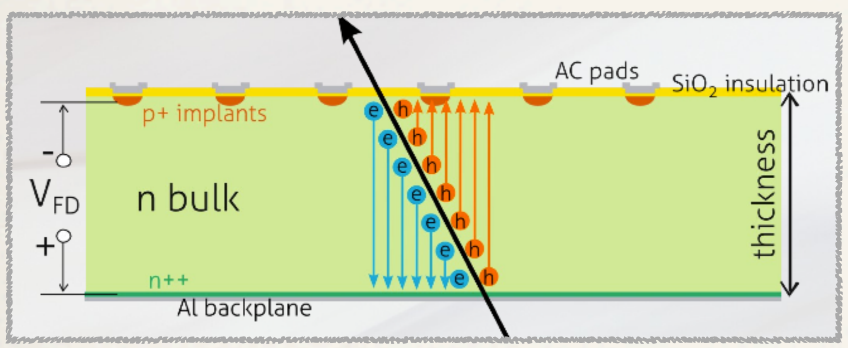


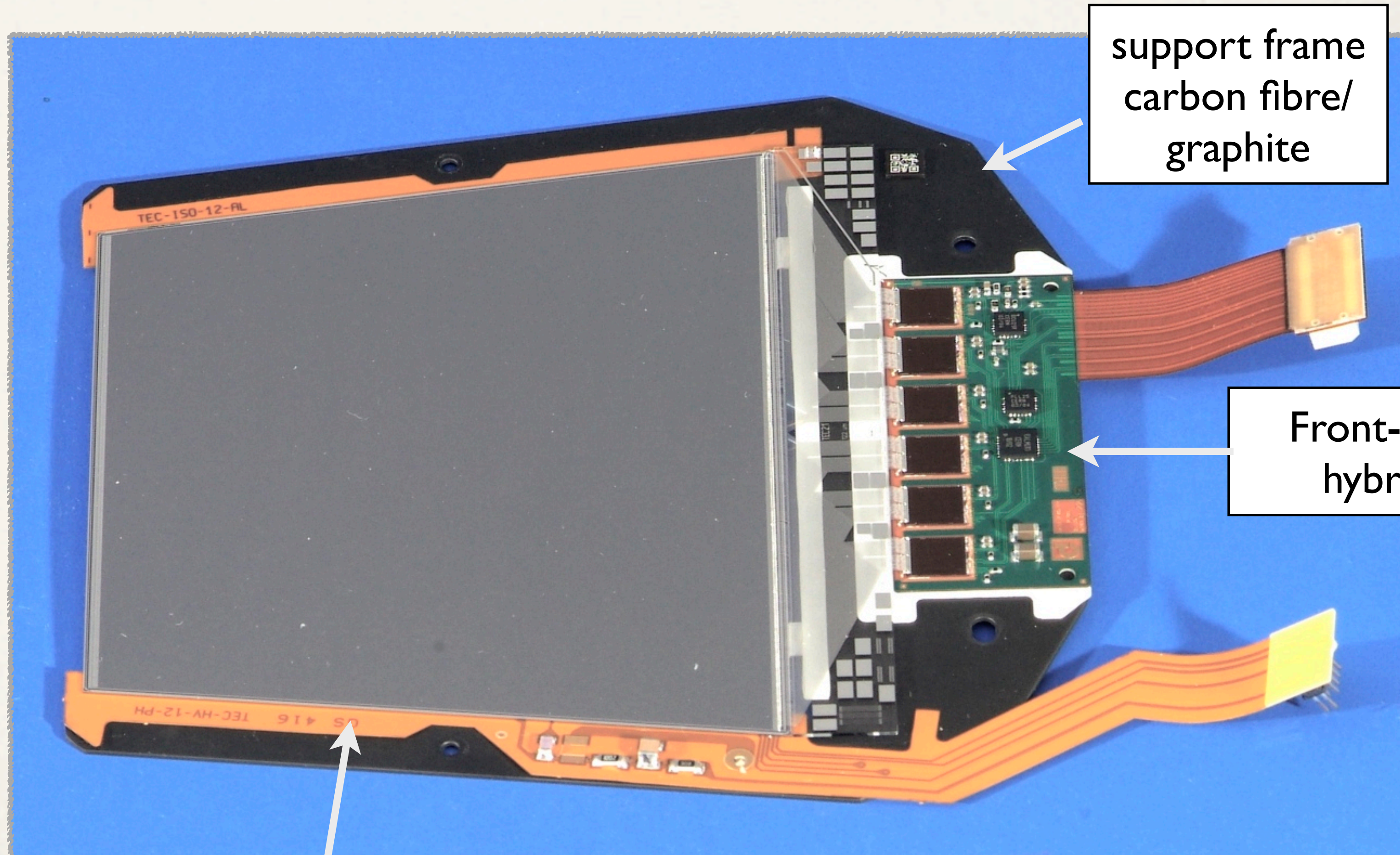




Modules

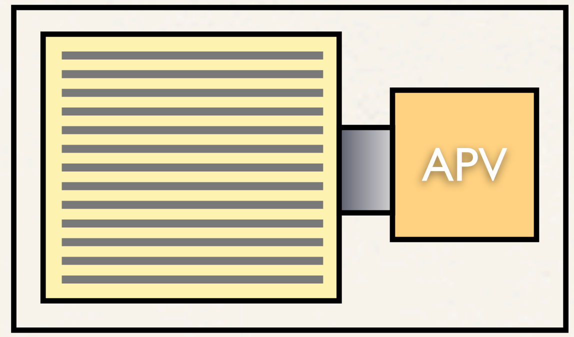
- sensors of p+ strips on n-bulk, thickness of 320 and 500 μm
- 15 types of sensors, 512 or 768 strips, pitch 80-205 μm
- pitch depend of R : keep low occupancy and good resolution
- analogue readout



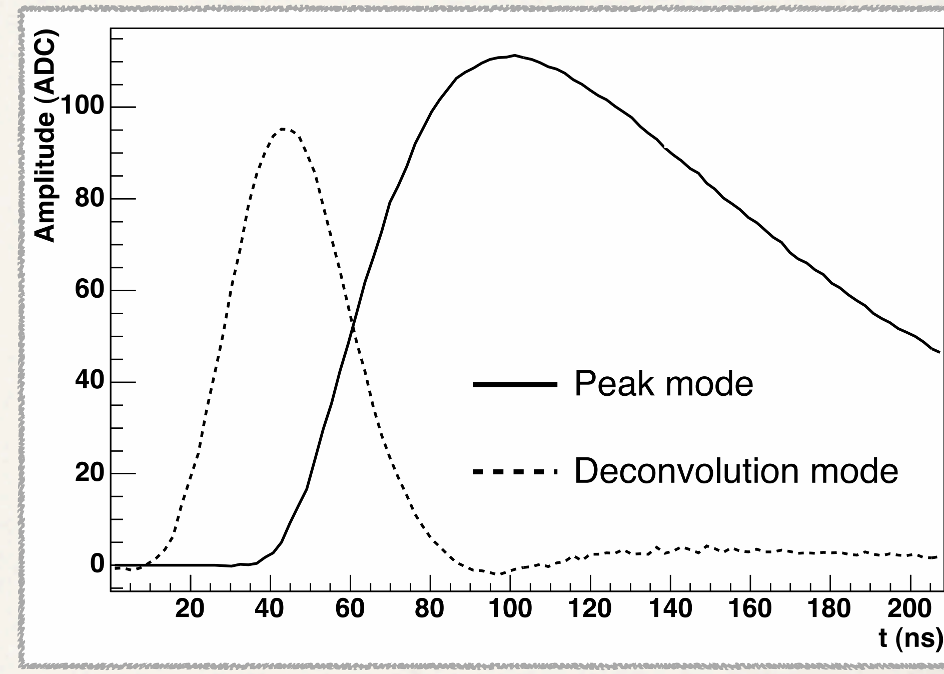


Readout

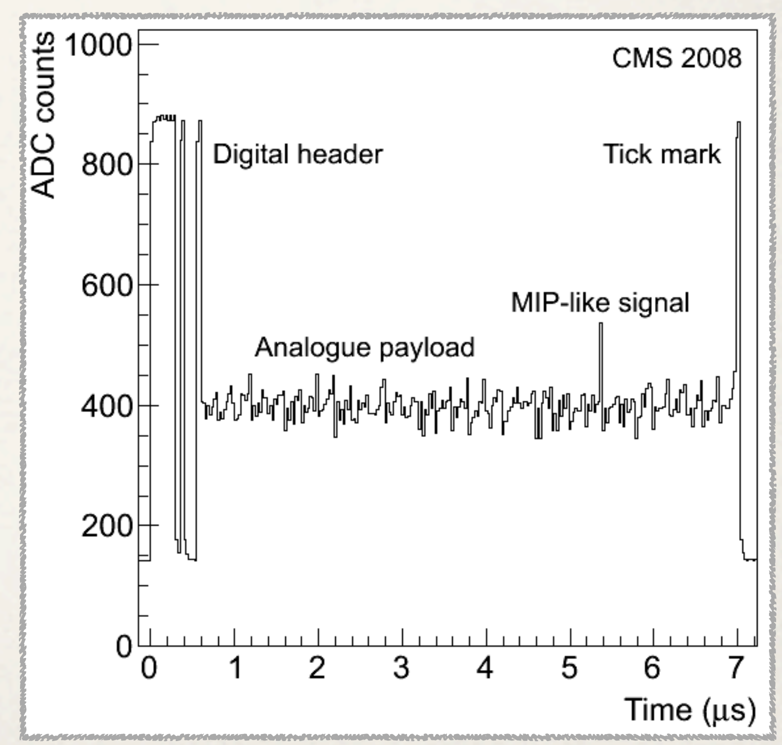
APV25 chip :



module

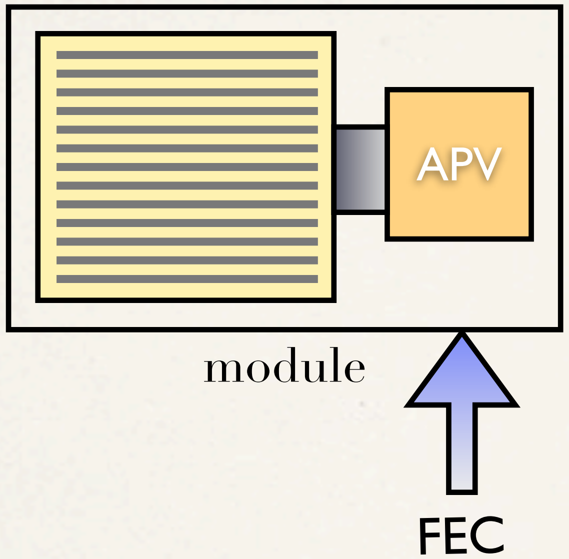


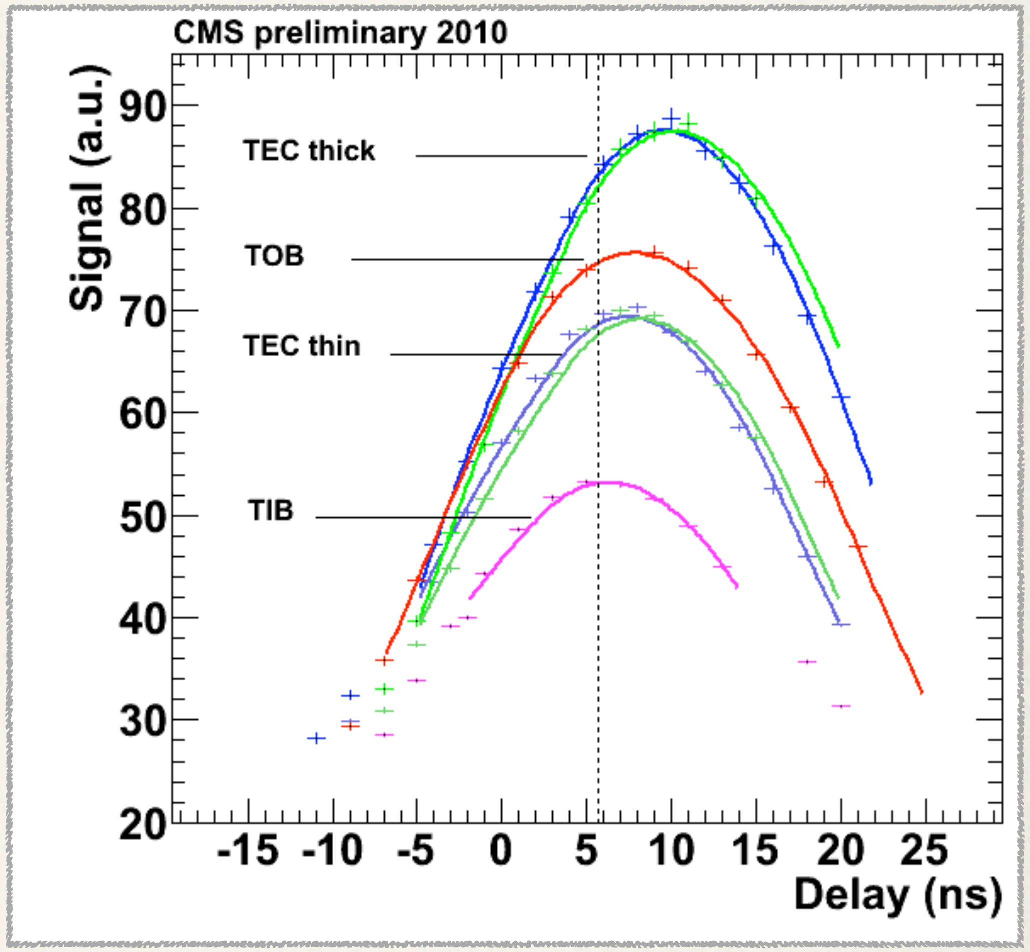
- pre-amplification
- fast shapping :
  - Peak mode : rise time of 50 ns, 1 sample
  - Deconvolution mode :
    - standard mode in collision
    - combine 3 samples, shorter pulse
    - needed but more sensitive to timing and reduced S/N
  - 2 shaper parameters tuned to give expected rise time and shape close to ideal RC-CR curve



- Send information of 128 strips in an analogue frame

Timing

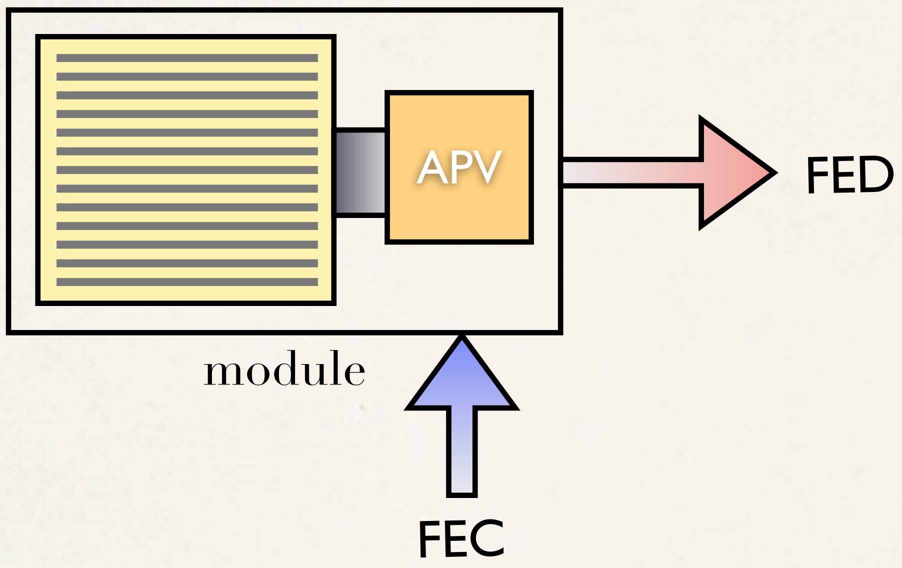




Off-detector Front-End Controller (FEC)

- send clock, L1 triggers, slow control commands
- time adjustement
  - Synchronization of all modules to each other, looking at tick mark sent every 35 LHC clock
  - global latency scan by steps of 25ns, synchronize tracker to central trigger
  - fine delay scan by steps of 1ns
    - per detector layer
    - delay corrected for time of flight
  - mis-timing of 5 ns would give ~6% less signal in TOB

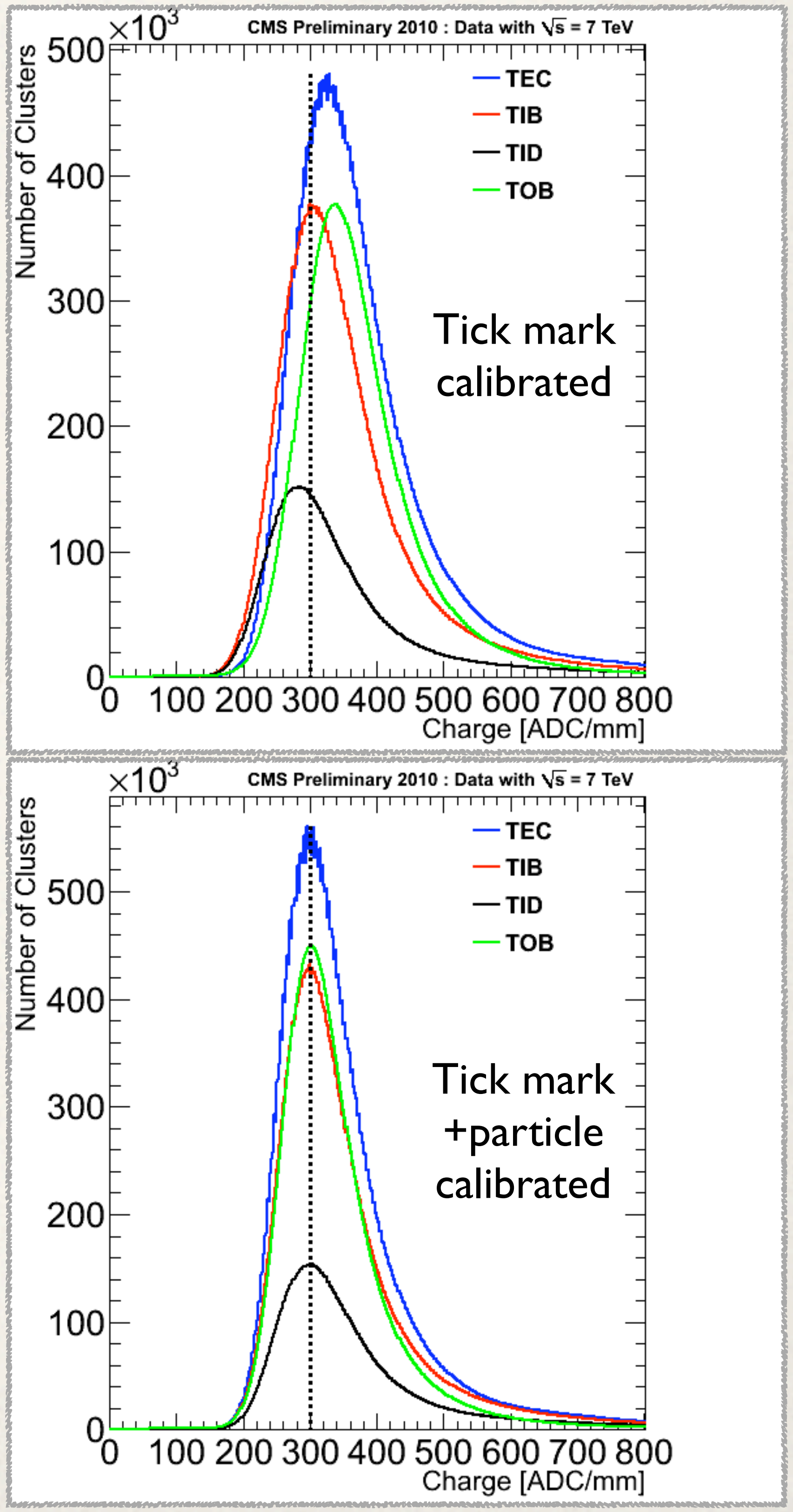
Signal treatment



- Data sent via optic link to Front End Driver (FED) processing board
  - laser tuned to optimize ADC range
- FED digitize signal and apply Zero Suppression
  - analogue baseline level tuned for a MIP signal at 1/3 of ADC range
  - special runs in absence of signal to measure pedestal and noise for each strip
  - Noise depends on strip length, temperature
  - calibration each times conditions have changed (hardware, temperature)

Gain calibration

- tick mark calibration
  - First calibration using tick mark height and tuning it to 640 ADC counts
    - does not take into account differences at the sensor level
- particle calibration
  - use path length corrected on-track cluster charge
  - normalize to 300 ADC counts/mm : expected value for MIP with calibration of 270e-/ADC count

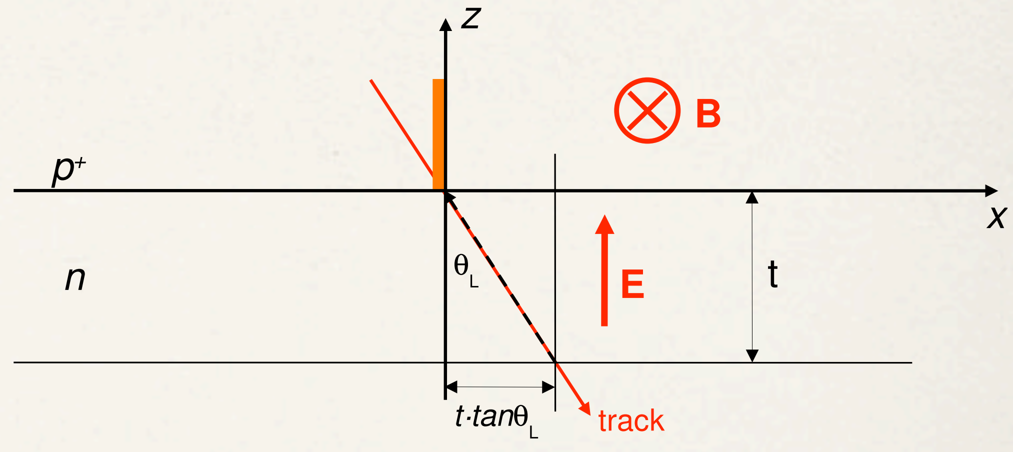


Clusters and hits

- Cluster from 3 thresholds algorithm :
  - seeded from strips with charge > 3 times the strip noise
  - add neighbours with charge > 2 times the strip noise
  - cluster kept if charge > 5 times cluster noise (quad. sum of strips noise)
  - need of strip noise value
- Hit : cluster with associated position and errors
  - position from centroid of strips signal height
  - corrected from magnetic field effect

Lorentz Angle

- Due to magnetic field, drift direction of charge carriers is tilted by the Lorentz angle

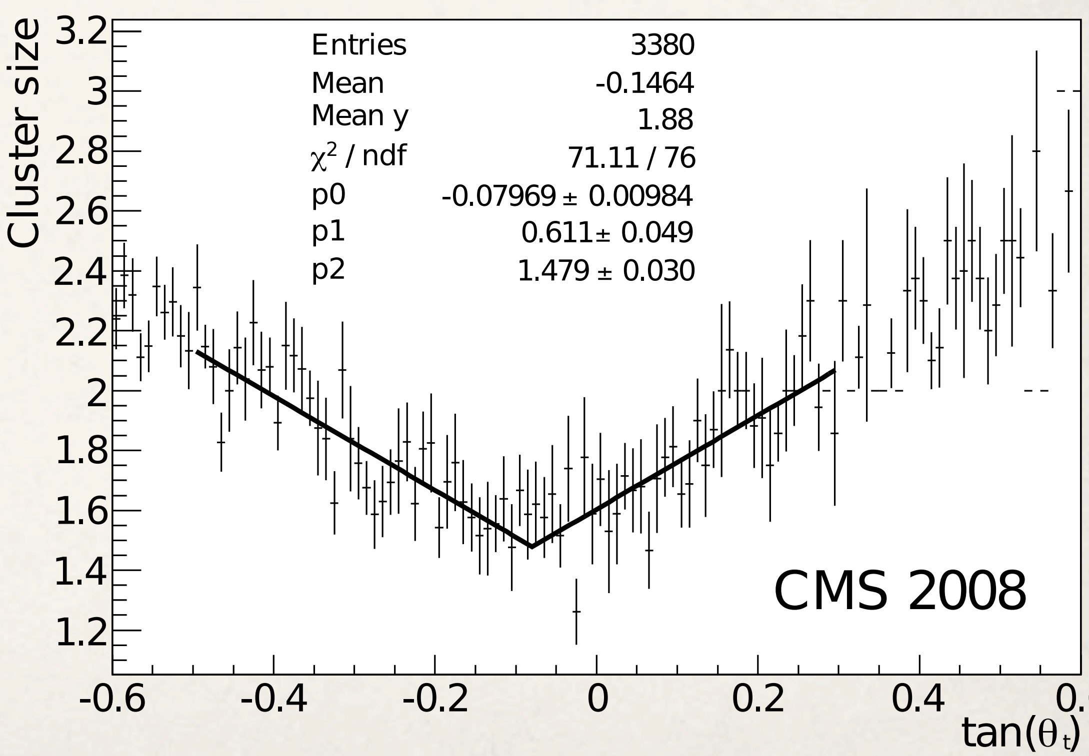


- maximal effect in barrel : B ⊥ E

- Systematic shift in cluster position : $\delta x_{\text{cluster}} = \frac{t}{2} \cdot \tan \Theta_L$

- Study cluster width versus particle crossing angle

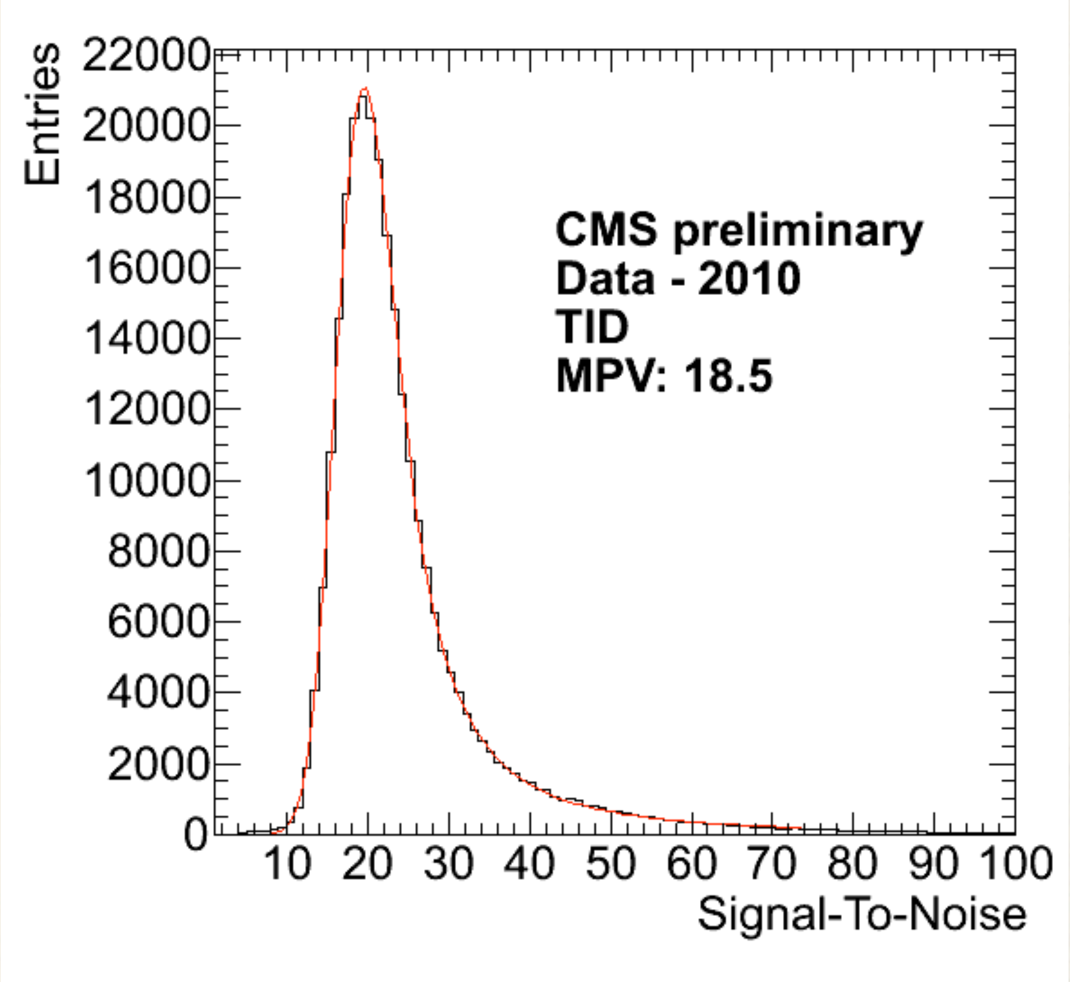
- Minimum cluster width for Lorentz angle



	$\tan \Theta_L$	δx
TIB	0.07±0.02	~10μm
TOB	0.09±0.01	~20μm

Charge collection

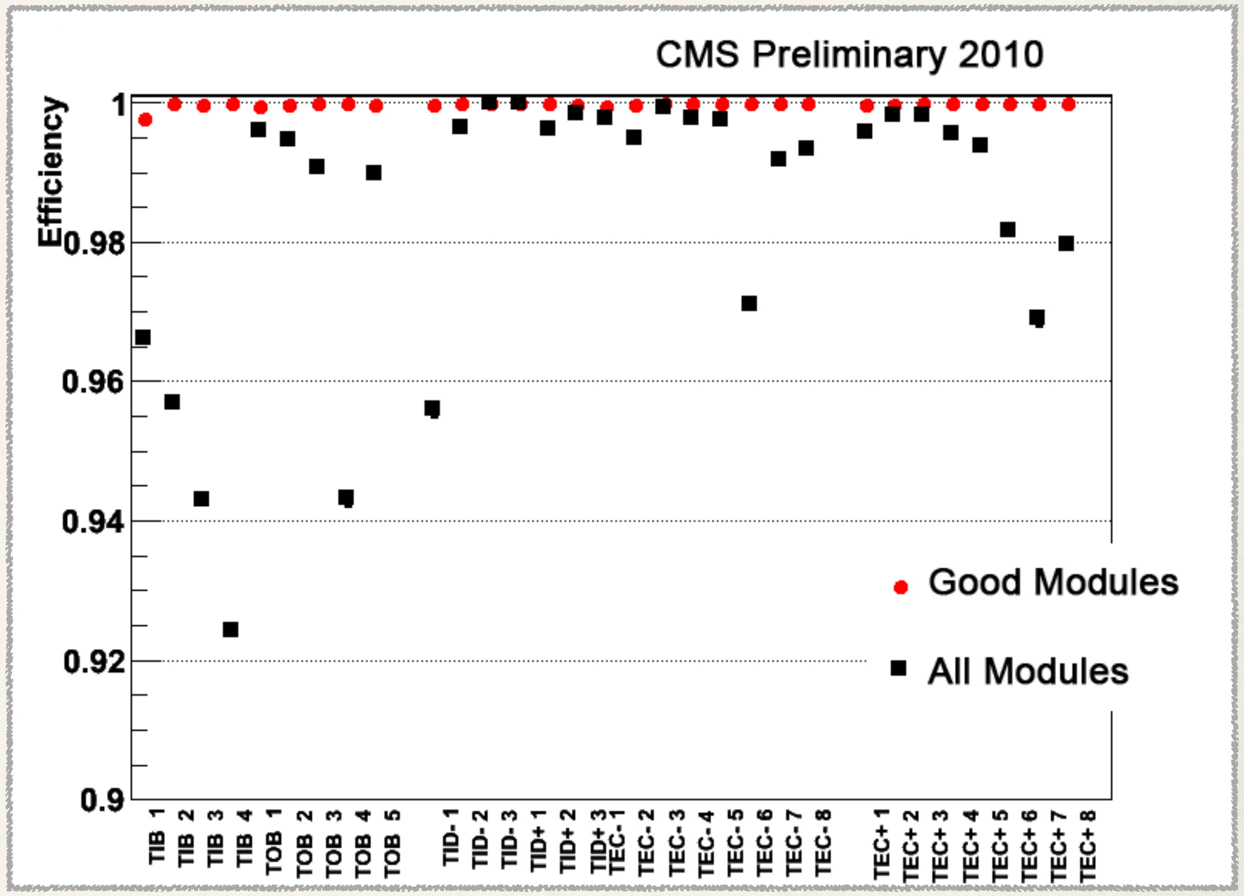
- S/N : important variable for monitoring of tracker, done run by run
- computed from on-track clusters corrected for path lenght
- thick sensors collect more than thin



	TIB	TID	TOB	TEC+ thin	TEC+ thick
MPV	19.4	18.5	22.5	19.4	23.9

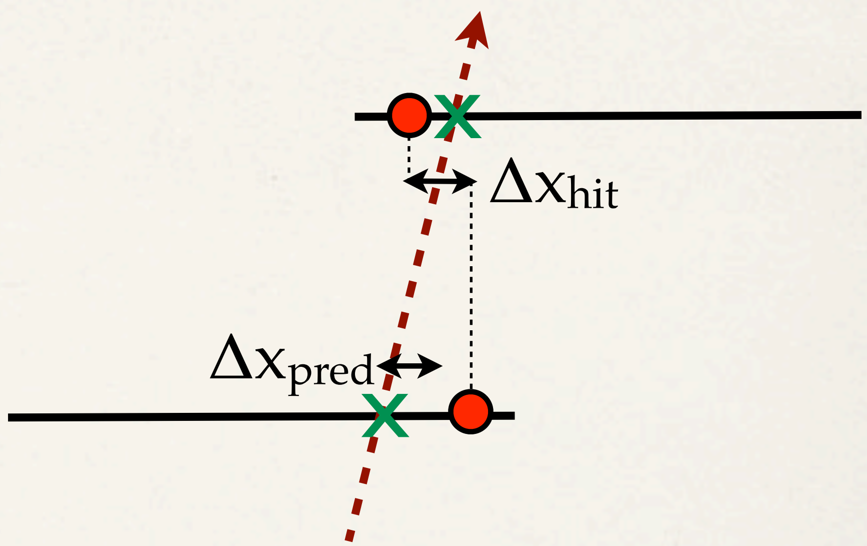
Module efficiency

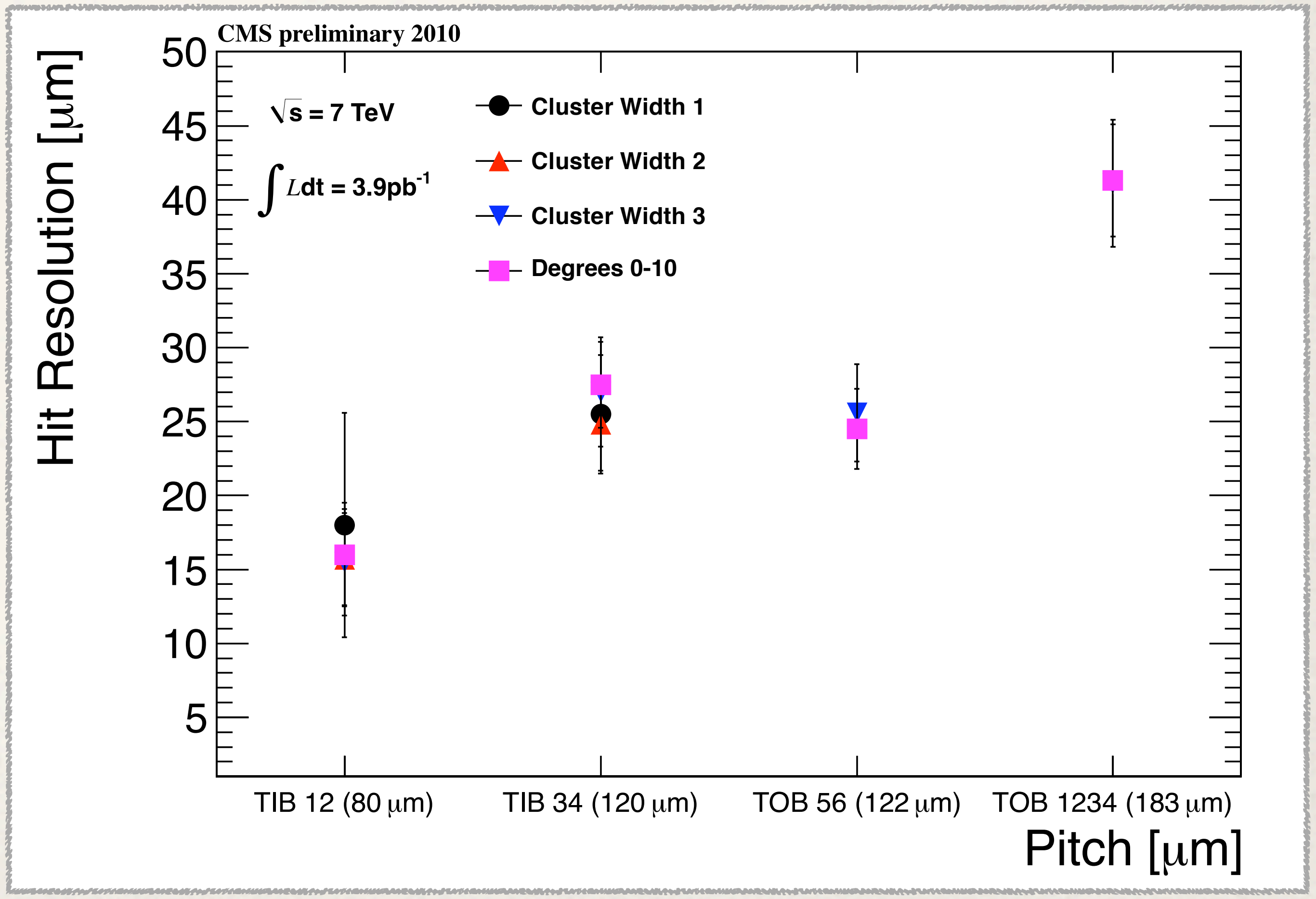
- 98.1% of channels in operation
- For active channels :
  99.8% efficiency
  - measured from high purity tracks
  - tracking without the layer studied
  - module crossed should contain a hit
- Done at module level, once per week, useful to spot problems



Hit resolution

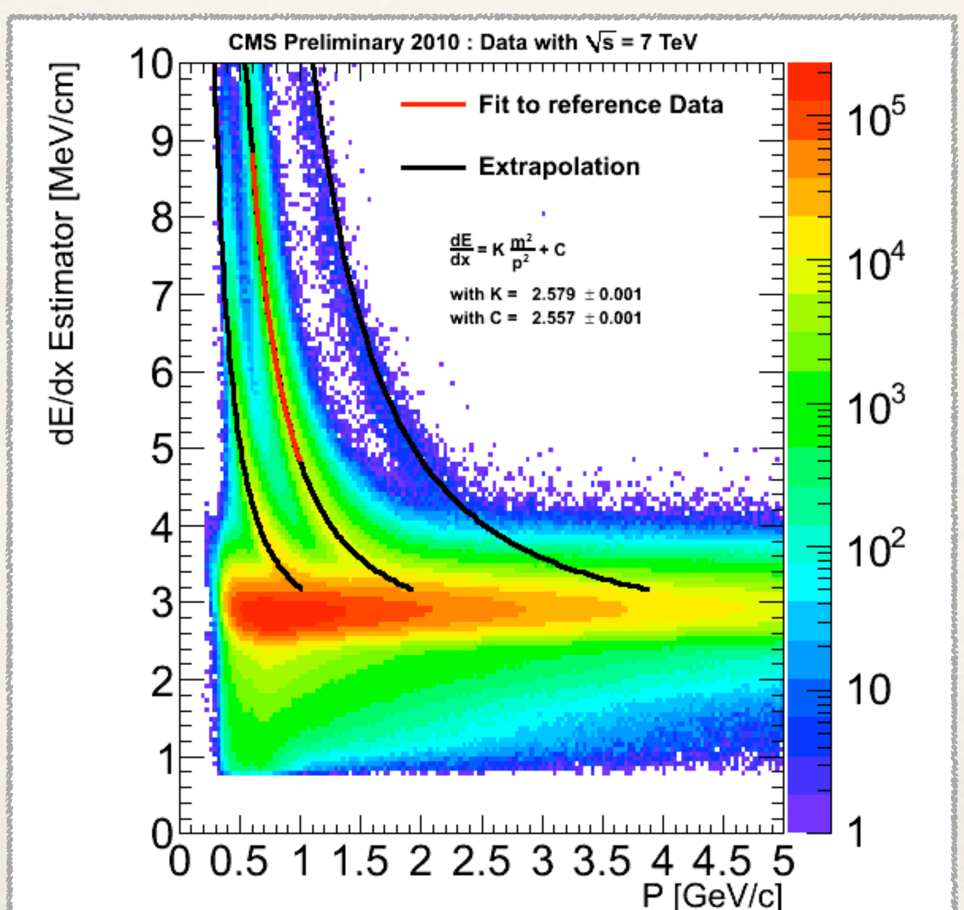
- reconstruct track without the layer considered
- Use overlapping modules
- Distance between 2 hits less sensitive to track extrapolation, interactions with material
- Compare Δx_{hit} to Δx_{pred}
- Resolution depends of strip length, pitch, particle incidence angle

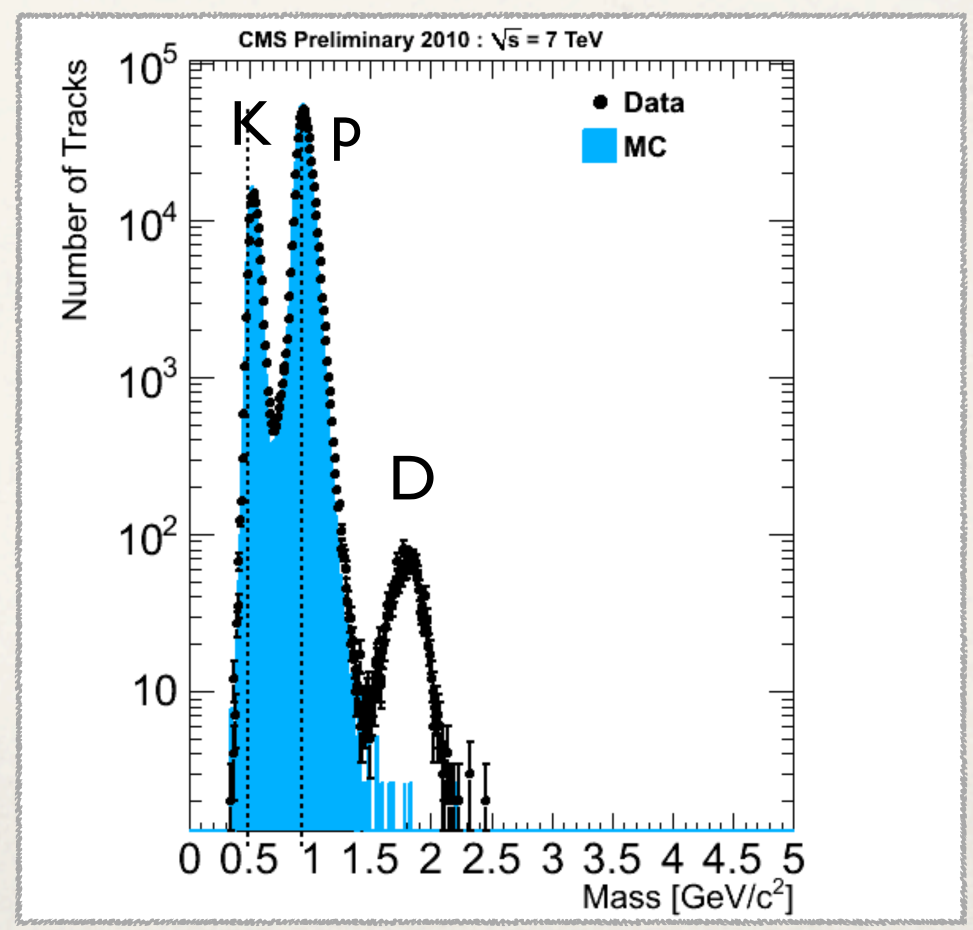




dE/dx

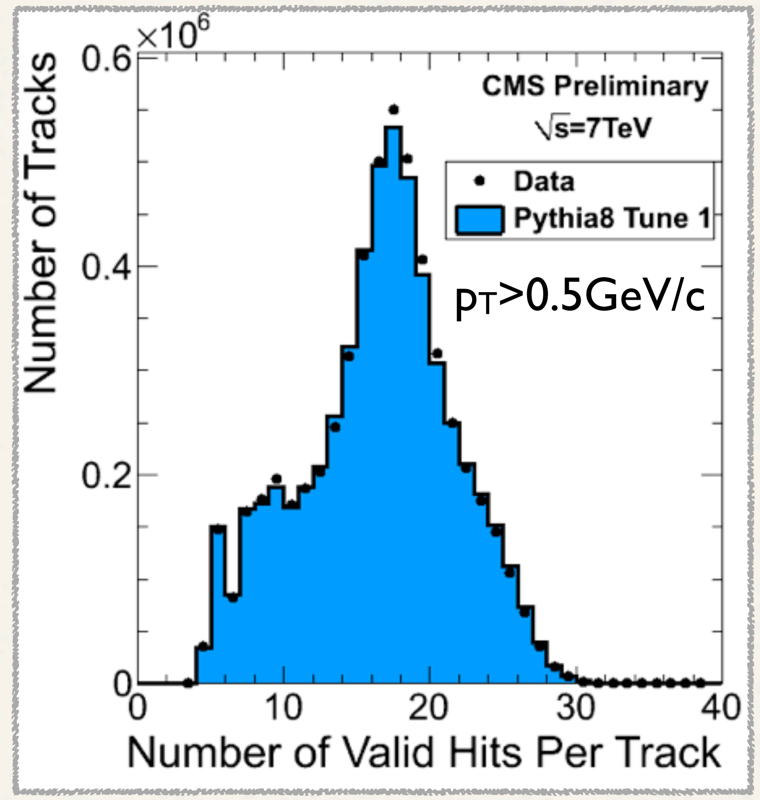
- Wide linear range that provide energy loss measurement
- use protons in 0.7-1.0 GeV/c range to fit : $\frac{dE}{dx} = K\frac{m^2}{p^2} + C$
- From parameters can extract mass spectrum : D peak visible (not in Pythia)
- used for search of heavy stable charged particles, reconstruction of low mass resonnances giving charge hadrons ($\Phi \rightarrow K^+K^-$)

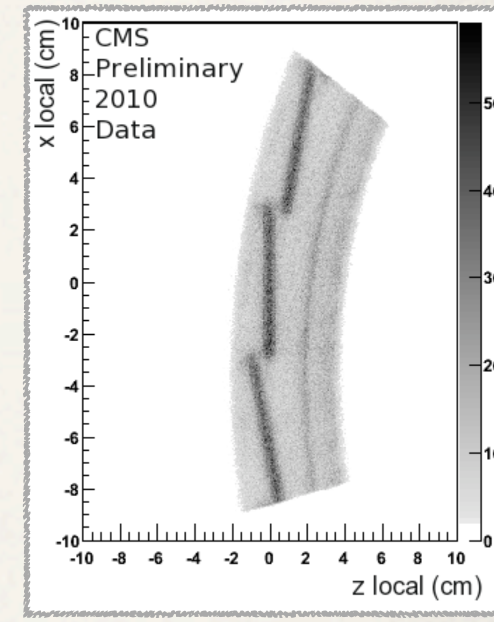


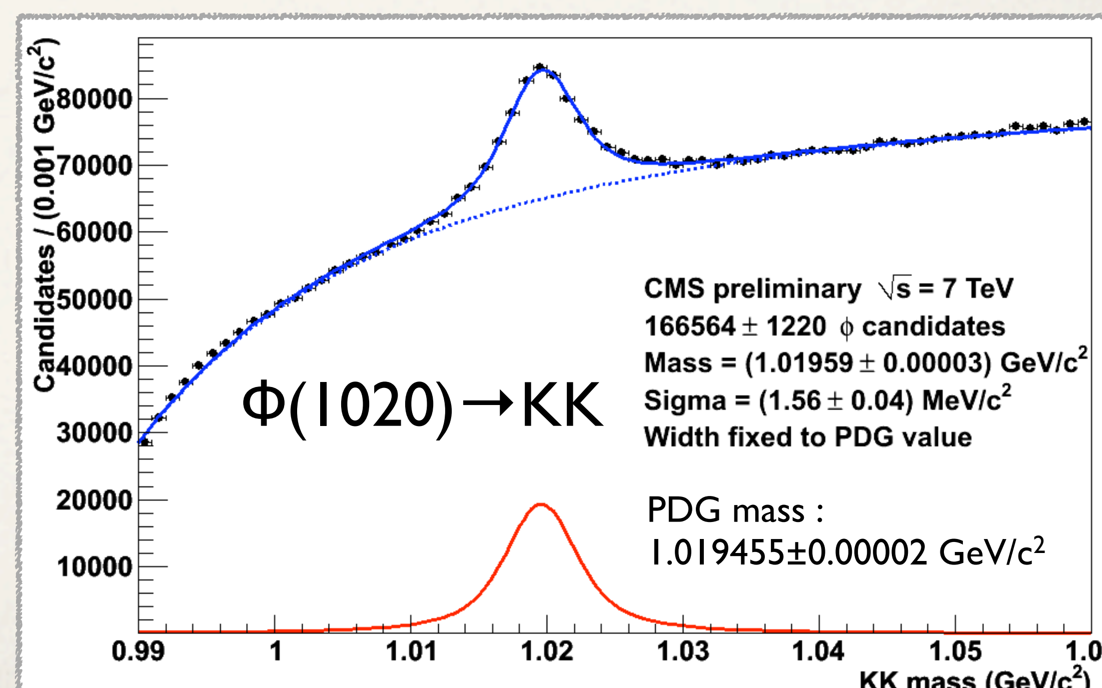


Tracking performance

- Basic track distributions : good data / simulation agreement
- Reconstruction of resonnances with good precision :
  - $K^0_S \rightarrow \pi\pi$, $\Lambda^0 \rightarrow p\pi$, $K^*(892)^\pm \rightarrow K^0_S\pi$, $\Xi^\pm \rightarrow \Lambda^0\pi$, $\Sigma(1385)^\pm \rightarrow \Lambda^0\pi$, $\Xi(1530)^0 \rightarrow \Xi\pi$
  - $\Phi(1020) \rightarrow KK$, $D^0 \rightarrow K\pi$, $D^* \rightarrow D^0\pi$, $D^+ \rightarrow K\pi\pi$, $\Omega^- \rightarrow \Lambda^0 K$
- Reconstruction of conversion and nuclear interactions







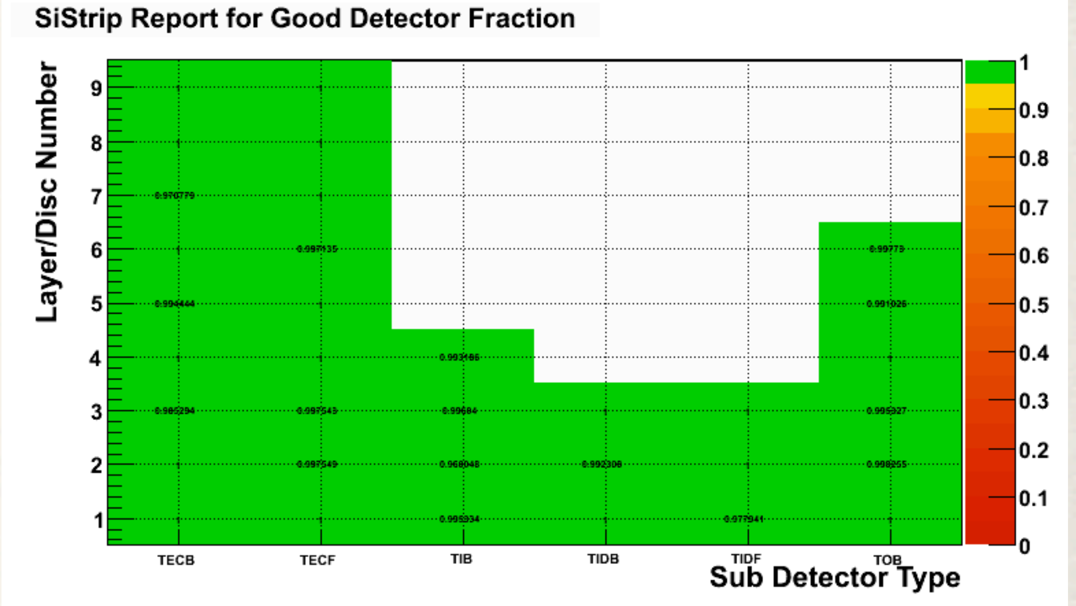
Conclusion

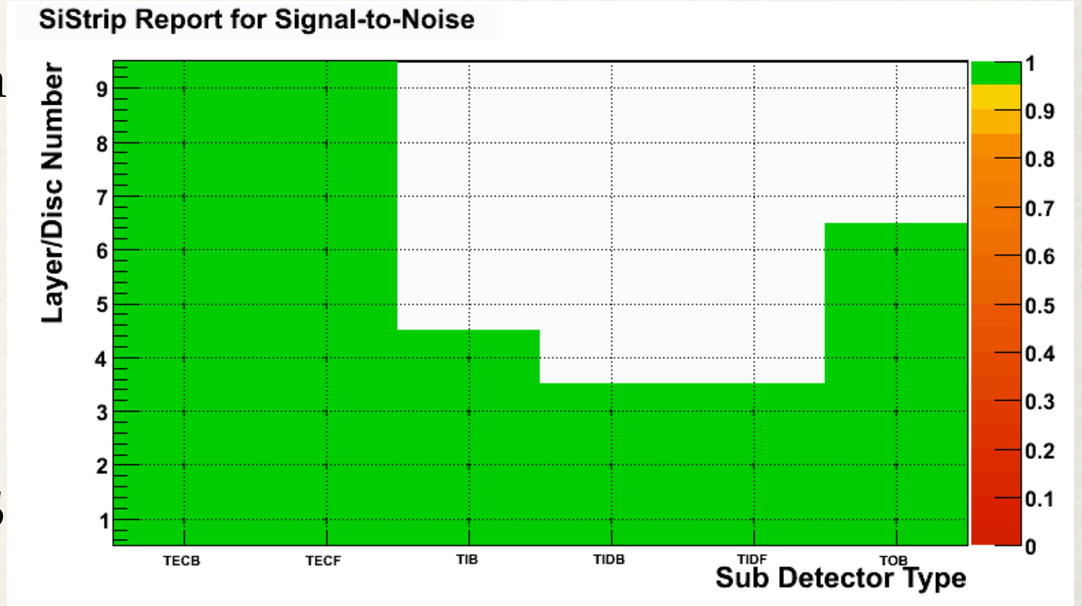
- Largest silicon tracker ever build
- Well calibrated and understood
- Efficient operation and excellent performance
- Allows good tracking, vertexing and physics analyses

Back-up

Detector monitoring

- Express Stream
  - First reco of data, within 2 hours after run end
    - a part of triggers only
    - used for online and first offline DQM
    - use masks taking into account hardware cabling
- Prompt Reco
  - First reco of all data, within 48 hours
  - Delay allows to use masking of strips and modules from a noisy channel analysis on run by run basis
  - Used for runs certification
- Other checks on regular basis :
  - spy channels : possibility to read data from FED before ZS
  - bias HV scan : to study evolution with radiation dose





Alignment

- track-based algorithms
    - Millepede II : global method, simultaneous fit of alignment parameters
    - Hit and Impact Point (HIP) : local approach, look at each module separately, large number of iterations for big misalignment
    - Used both in sequence
    - use cosmics (vertical tracks well suited for barrel) and collision events
- Validation looking at χ^2 of tracks, track-to-hits and track-to-vertex residuals
- Start to take into account bowing of sensors, kink between 2 sensors on same module

Distribution of Median of Residuals from hits