Status of the CMS Silicon Strip Tracker and Commissioning Results

PSD8 – Glasgow, 1-5 September 2008

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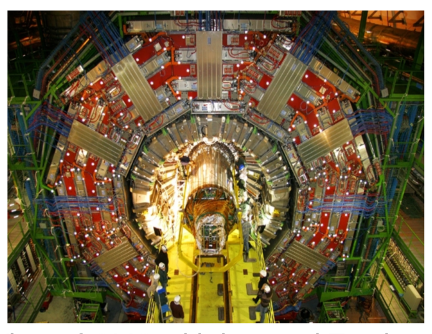
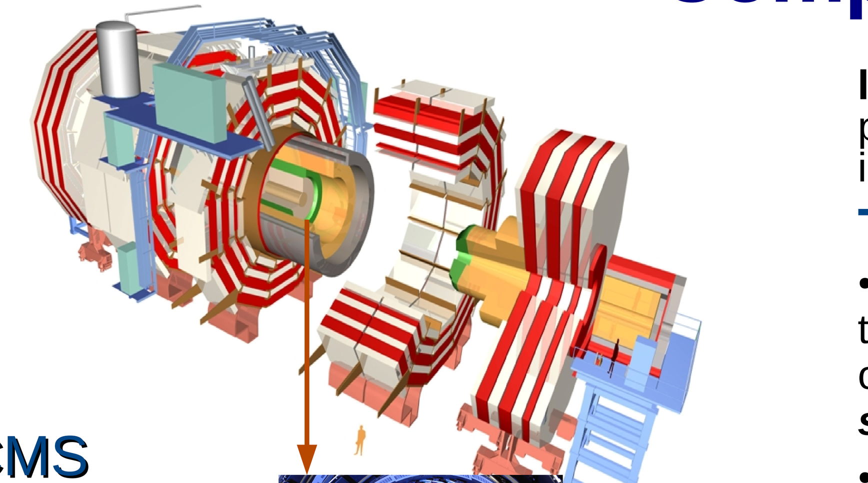
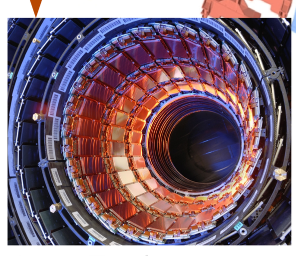
Compact Muon Solenoid - Tracker



View of CMS with inserted Tracker





Inner Tracker
(barrel-TIB, disks-TID)

Length = 5.8 m
Diameter = 2.5 m
Running temp = -25° C
(In order to **reduce radiation damage**, operation at low temperature is required)

Physics Goals at CMS

- Discovery of **Higgs boson**
- Elucidation of the electroweak symmetry breaking mechanism
- Search for physics beyond the standard model
- To achieve these physics goals, all detector subsystems are required to be at their best performance

With about 200 m² of active silicon area the SST is the **largest silicon strip tracker** ever built for high energy physics experiments. It surrounds the LHC beam interaction point.

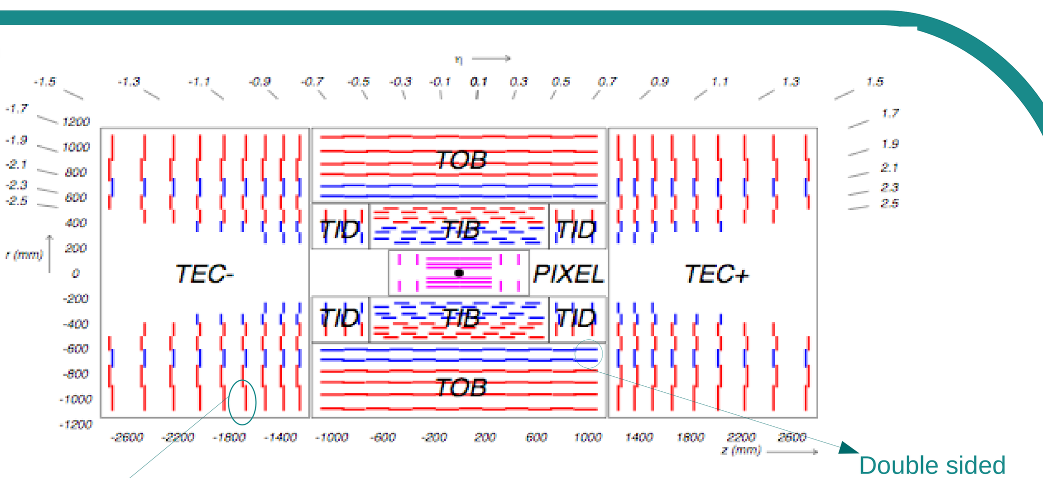
Tracker is designed to offer :

- accurate measurement of the charged particles trajectories in 4T magnetic field emerging from ~20 overlapping p-p interactions (provided by the 10 layers of ***silicon microstrip detectors***)
- precise reconstruction of the secondary vertices – 3 layers of ***silicon pixel detectors*** improve the measurement of the impact parameter of charged-particle tracks

Physics Environment	Design Requirements
High particle fluency	Radiation hardness
High track density	High granularity
25 ns between interactions	Fast read-out

Silicon Detectors were chosen because :

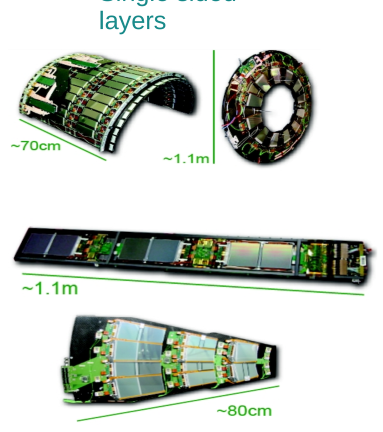
- Good energy resolution
- Fast charge collection
- Low multiple scattering



CMS Tracker Layout

Single sided layers

Double sided layers (provide measurements in both r-Φ and r-z coordinates)



TIB : 16 half cylinder shells
TID : 18 rings

TOB :688 rods

TEC : 2x144 petals

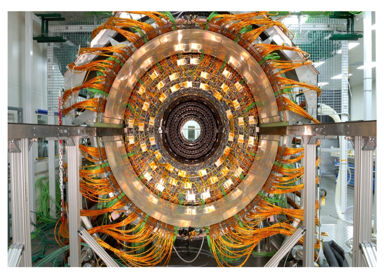
In order to maintain a good S/N ratio for longer strip length, different geometries, there were used thick silicon sensors (500 μm instead of 300 μm for TOB and TEC)

Tracker Integration Facility

TIF at CERN was constructed as a large clean room for both the assembly and the test operation of a substantial part of the Tracker.

The Tracker assembly was completed in March 2007 and 15% of the detector(on the +Z side) was connected to services (cooling, power, control, readout) intended for the final system.

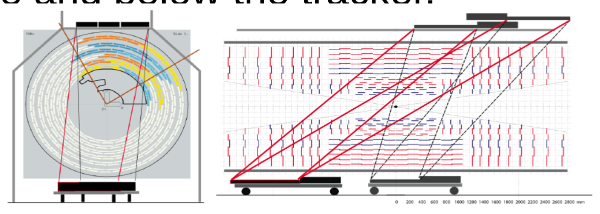
In order to understand the efficiency and alignment of the Tracker modules, a *cosmic ray* trigger was implemented in the TIF. From March through July about 5 million Cosmic Ray Events were recorded. This period, referred to as the **Sector Test**, provided practical experience of the operation of the systems (Data Acquisition, Data Quality Monitoring, Control, Safety, Cooling etc.)



TOB at TIF

The cooling plant used for the Sector Test was simpler than the final system and its cooling power was limited. A minimum operating temperature of -10°C was obtained, compared to -25°C in the final system. The temperatures measured at the cooling tubes proved to be very stable with variations of less than 0.1°C

The cosmic trigger configuration was designed to allow useful studies of tracking performance and the alignment of the detector. The trigger design was constrained by space above and below the tracker.



The trigger had a frequency of about 6Hz.

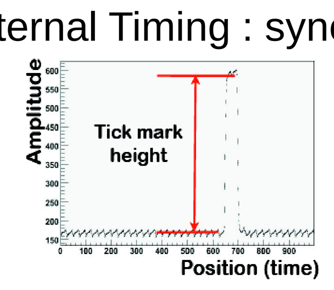
Layout of one trigger scintillator configuration used at TIF - xy view (left) and rz view (right). The straight lines connecting the active area of the top and bottom scintillator counters indicate the acceptance region

Commissioning Procedure

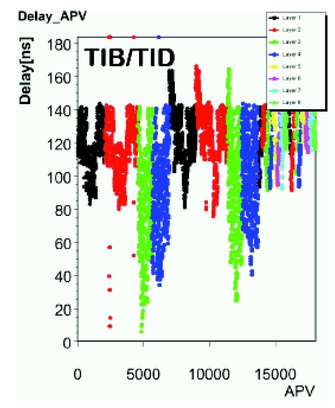
The fully assembled Tracker was moved from TIF to p5 at the end of 2008. Cables connection was completed in March 2008, and the first round of commissioning started immediately with a temporary cooling plant. After installing the final cooling plant, the second round of checkout and commissioning started in June.

The commissioning procedure consists of:

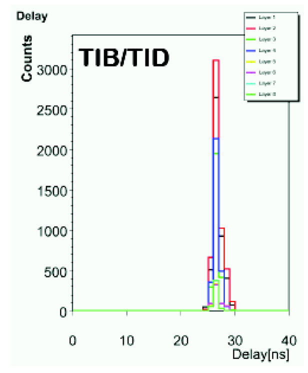
- Control – PSU/readout map : identify connections between control and power supply/readout systems.
- Internal Timing : synchronization of all channels



Tick marks (APV synchronization pulses) were used to synchronize the SST internally

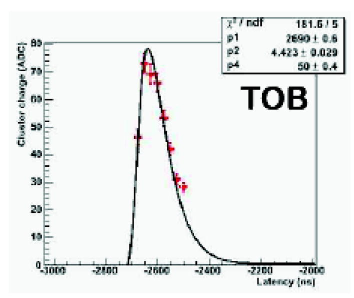


Before synchronization
(Cable structure clearly visible)

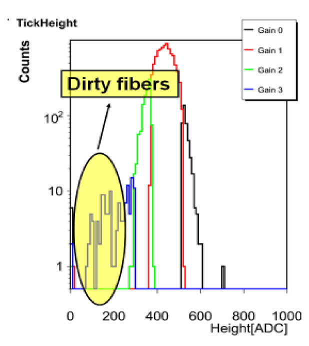


After synchronization
(All channels aligned)

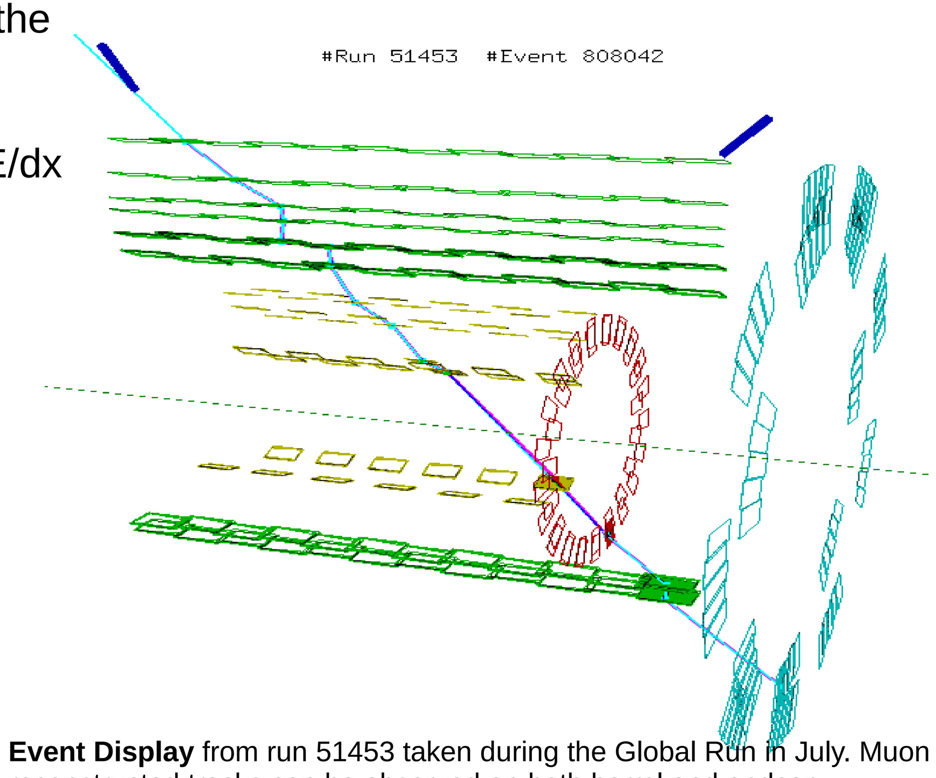
- Optical Gain Scan : tune the amplitude of the signal. It determines the gain settings for Laser bias, input signal
- Tuning APV pulse shape to assure: homogeneity of the tracker response, performances over time, reducing of the systematics in dE/dx studies the tracker response
- Pedestal and Noise
- APV Latency Scan : synchronize tracker with LHC clock



Latency is determined by reconstructing pulse shape. The working point is chosen closest to the maximum



Low tick mark height usually correspond to dirty fibers



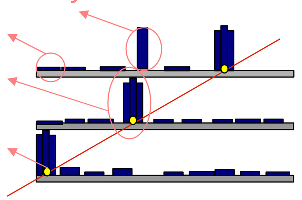
Event Display from run 51453 taken during the Global Run in July. Muon reconstructed tracks can be observed on both barrel and endcap.

Noise Performance

The noise of a Tracker module is almost completely determined by the input capacitance to the readout chip, which is dominated by the capacitance of the silicon strips.

The pedestal and noise studies are part of the calibration of the detector.

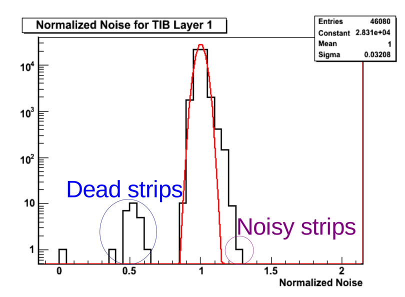
Dead or noisy channels can contribute to a bad reconstruction of the particle trajectory.



Tracker Noise Performance

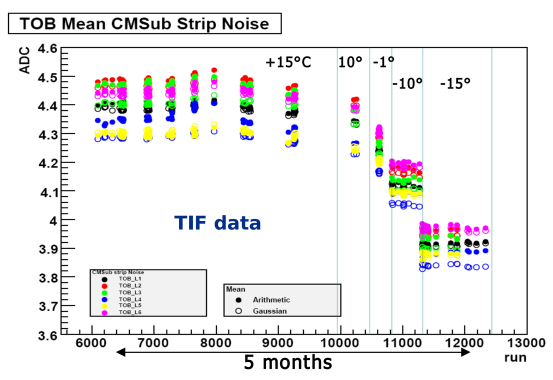
- The fraction of strips identified as noisy/dead is very small

Detector type	Fraction of Dead Strips (%)	Fraction of Noisy Strips (%)
TIB	0.05	0.04
TID	0.05	0.2
TOB	0.04	0.3
TEC	0.08	0.02



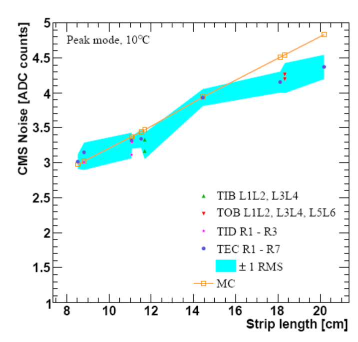
The algorithms used to identify the bad strips have to deal with the correction of the gain. The normalization of the noise is one way to avoid the gain differences.

- During the Sector Test, runs at different temperatures were taken (from +15°C to -15°C). Even though the mean of the noise increases with temperature, it is lower than 5 ADC counts and stable at the level of 0.5% for constant temperature.



The Mean Noise for TOB layers for the runs taken during the operation at TIF.

- As expected, the noise is proportional to the strip length, within the statistical uncertainty. The mean of the noise show differences for the same strip length, but different module geometries. The results are in good agreement with Monte Carlo predictions.



Hit Reconstruction

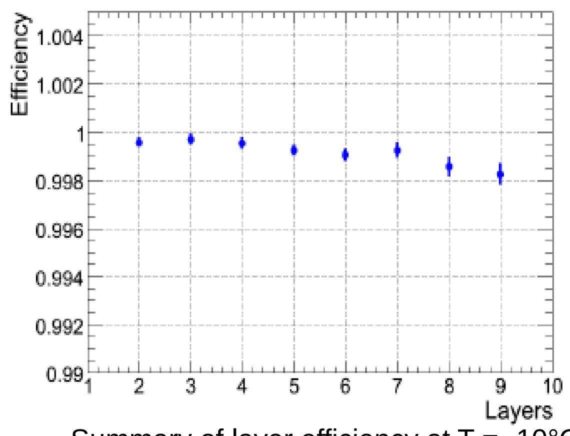
The efficiency of a Tracker module to produce a hit when transversed by a particle, is one of the most important characteristics of the detector performance. It depends on the losses in the silicon, electronic chain or data acquisition.

Efficiency has been measured by modifying the track reconstruction algorithm to skip the layer under study during the pattern recognition phase.

A sample of high quality events was selected with the following requirements:

- one and only one track reconstructed
- one hit in the first TIB layer
- one hit in the two outermost TOB layers
- at least four reconstructed hits (of which at least three matched from stereo layers)
- select only tracks almost perpendicular to the modules

In order to avoid genuine inefficiencies present at the edge of the sensor and in the bonded region between two sensors, additional cuts have been applied to restrict the regions in which efficiency is measured.

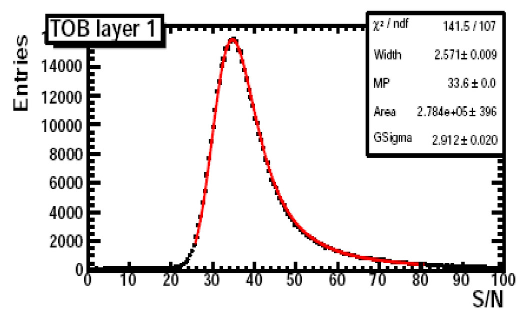


Summary of layer efficiency at T = -10°C

The hit reconstruction efficiency exceeds 99.8% for all measured layers.

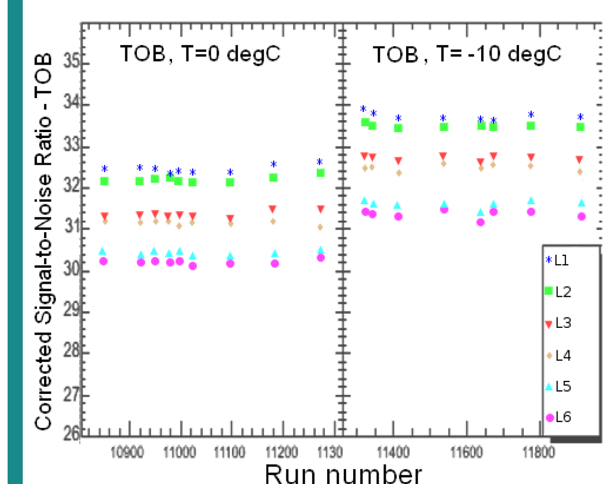
Signal Characterization

The Signal-to-Noise quantity normalized to the sensor thickness is an ideal parameter for measuring the stability of the Tracker because this ratio is largely independent of gain corrections. It allows an accurate comparison of the performance of the modules in the same layer or at different temperatures or from run to run.



S/N for TOB, layer1, at -10°C. The charge is corrected for the angle of the track.

S/N ratio is calculated for all clusters from one layer. If the noise is constant for all strips in the cluster, then the cluster noise is independent of the cluster size and equal to the strip noise. All Tracker layers show a large S/N, in all cases > 26.



The most probable values of the landau of S/N corrected for the angle of the track vs the run number at different temperatures. The values for all TOB layers are shown.

S/N shows a very stable behavior for TIB and TOB with variations less than 0.3% when compared the runs taken at the same temperature. S/N increases with decreasing temperature, as expected from the noise temperature dependence. Similar results were obtained for TID and TEC, but the lower statistics per run gives rise to a higher statistical errors in the measurements.

Conclusions

- The Silicon Strip Tracker construction was finished in March 2007 at the TIF.
- Noise results are excellent. The noise shows a very stable behavior of all subdetectors.
- The signal-to-noise is larger than 26 for all layers/rings and the hit reconstruction efficiency is above 99.8 %.
- The level of bad strips is below 0.1%.
- The commissioning at TIF demonstrated that the Tracker fully meets the experiment requirements and it has an excellent quality.
- The most part of the detector is already fully commissioned.
- In July 2008, TIB, TOB, TID and TEC- participated for the first time in a Global Run and the first look at the SST performance looks really good.