The CMS Strip Tracker Calibration, Methods and Experience with Cosmic Ray Data

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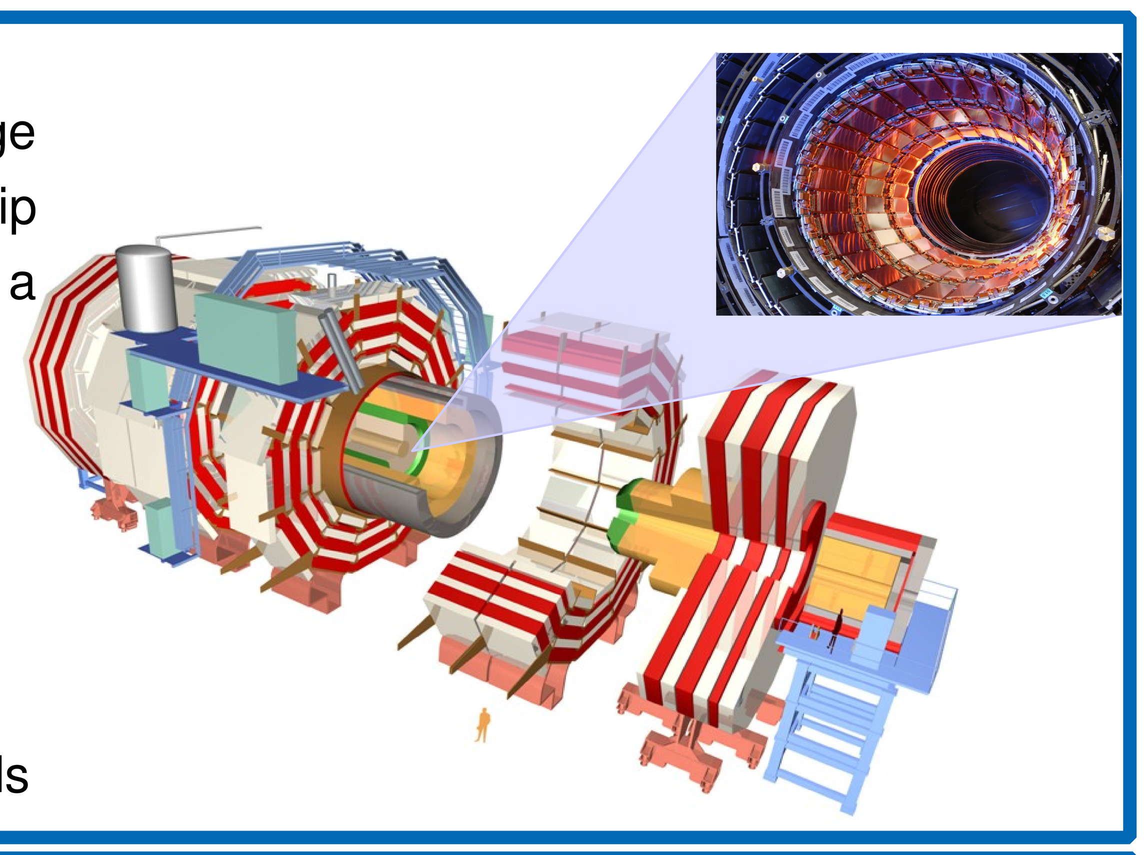
Introduction

The Compact Muon Solenoid (CMS) detector is one of the four experiments operated at the Large Hadron Collider (LHC) at CERN. It is a multi-purpose detector composed of a Pixel detector, a Strip Tracker, Electromagnetic and Hadronic Calorimeters, a superconducting Solenoid Magnet providing a magnetic field of 3.8T and a Muon System.

The Silicon Strip Tracker consists of:

- ~198m^2 of sensitive silicon
- 10 barrel layers, 3 inner disks and 9 endcap disks at each barrel end
- 15148 silicon modules with ~10 M readout channels
- 40MHz readout system comprising modules, analogue optical links and analogue receiver boards

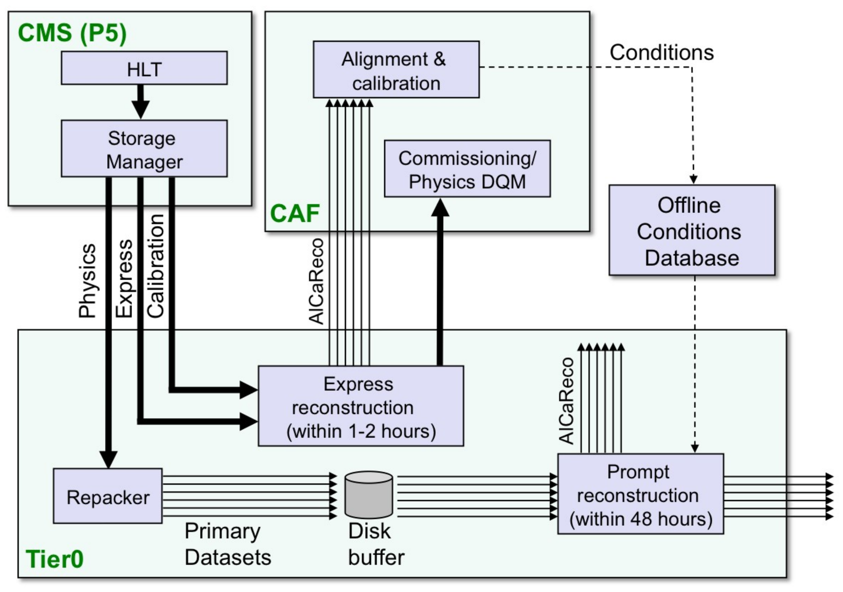


Calibration Workflow

In 2008 and 2009 CMS was operated in Cosmic Runs with full magnetic field (CRAFT) for several month. About 270M (480M) muon events were collected including about 6M (12M) tracks reconstructed in the Strip Tracker in CRAFT08 (CRAFT09).

These events were used to exercise the calibration workflows requested for the low level reconstruction, mainly the *Channel Status*, *Lorentz Angle* and *Gain* calibration.

The procedures are based on Express Stream datasets dedicated to each calibration task and reconstructed within 1-2 hours after data taking to have a fast calibration feedback for the reconstruction of the full statistics [1].

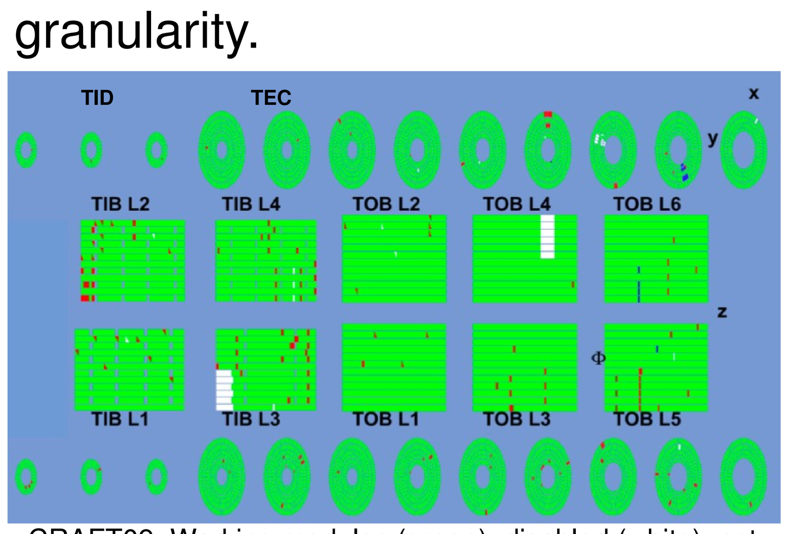


The up-to-date constants are then uploaded to a database and provided for the prompt reconstruction, which has a delay of 24-48 hours to allow the calibration procedures to finish.

Channel Status Calibration

To achieve a high quality hit and track reconstruction and to avoid fake hits and inefficiencies, a good knowledge of the readout channel status is vital.

This information is accessed from different sources: During commissioning a list of active detectors included in the readout is provided; the Detector Control System (DCS) delivers the high and low voltage status of each strip module; and the offline calibration compiles a list of unusual high occupancy components down to single strip granularity.



CRAFT09: Working modules (green), disabled (white), not read-out (red), other (mainly missing HV) (blue)

The offline calibration is performed in two consecutive steps:

- Identification of "hot" readout chips (APVs)
- Identification of single "hot" strips by comparing the respective hit occupancy with the average.

All channel status information are stored into the database and the bad components are removed from the reconstruction chain.

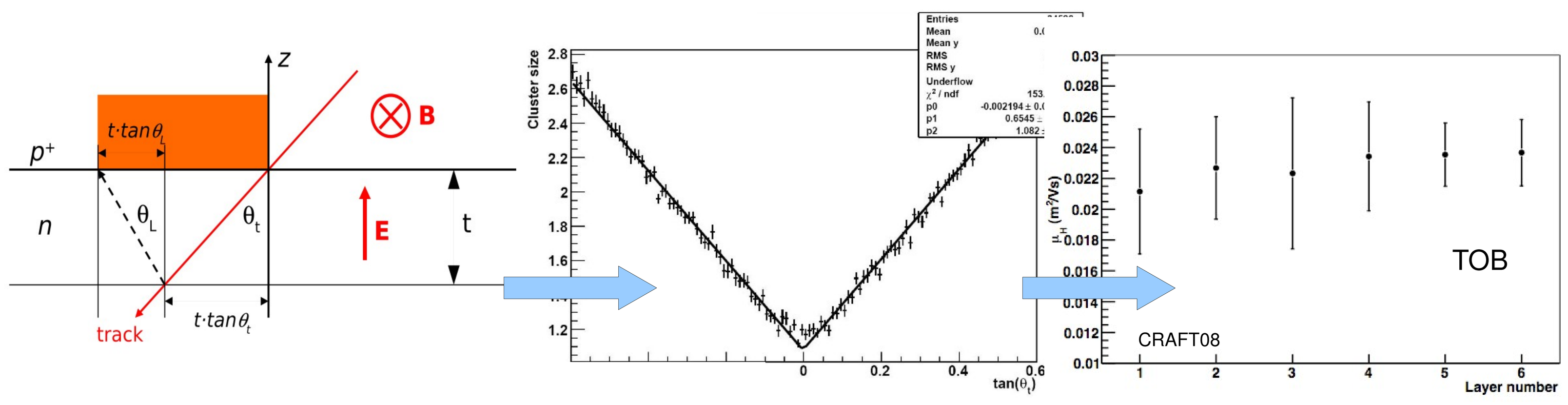
In CRAFT09 the operational fraction of the Strip Tracker was 98.1%.

Lorentz Angle Calibration

Since the strip tracker is operated in a 3.8T magnetic field, the charge carriers produced in the silicon undergo a Lorentz force while drifting to the readout strips deflecting their drift direction by the so-called "Lorentz angle". This causes a shift of the measured cluster position of about 15-25µm with respect to the real impact point.

To correct for this shift in the hit reconstruction, the Lorentz angle which depends on the electric and magnetic fields, the temperature and the absorbed radiation dose, has to be measured.

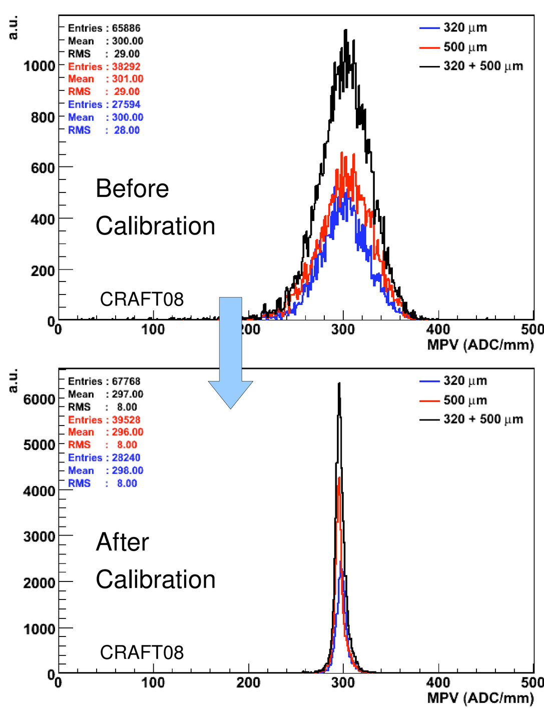
It can be measured by determining the track incident angle for which the minimum cluster width is achieved [2]. In this case the charge carriers drift parallel to the track direction and the incident angle is equal to the Lorentz angle. This calibration is only performed for barrel detectors since in the endcaps **E** and **B** are parallel and there is no Lorentz drift.



In CRAFT08 an average layer value for $\mu = \tan(\theta)/B$ of 0.018 was measured in TIB and 0.023 in TOB.

Gain Calibration

Due to different gains in the readout chain, the charge response of all tracker modules has to be equalized. The ultimate calibration, to be used by Particle ID techniques, takes the signal produced by particles and evaluates for each module the MPV of the Landau charge distribution (normalized for the path length).



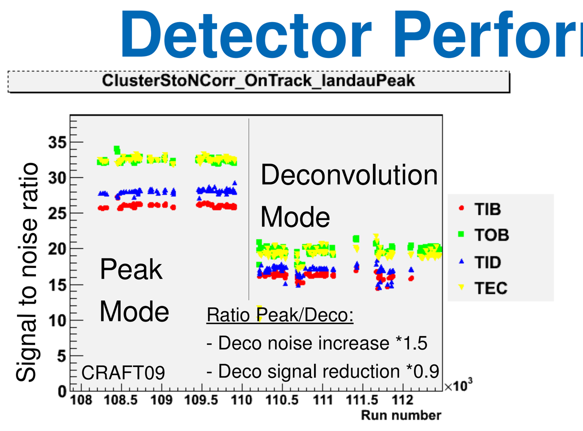
The gain factor is then defined as the ratio between the MPV and a reference value.

Using about 1M cosmic events, the gain factor could be measured for 90% of the strip modules in CRAFT08 [2]. The residual spread of the MPV distribution after calibration is about 3% and is dominated by the error on the MPV fit.

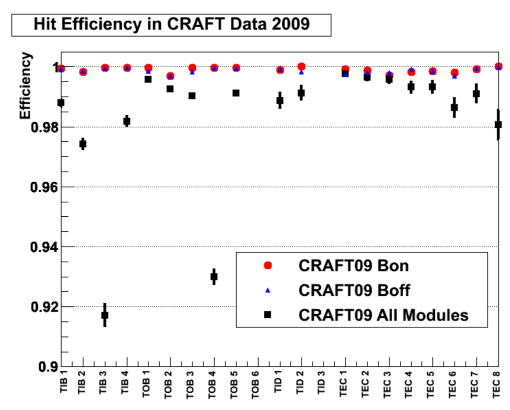
In addition to the calibration based on particles, a second gain equalization based on the APV digital signal (tick mark) is used since CRAFT09. It corrects only for the different response of the readout electronics chain.

Detector Performance

The single strip noise is stable along the runs (variation O(2%)). The cluster signal is Landau distributed with high S/N ratio. As expected, the APV Deconvolution Mode, which will be used in p-p collisions, has a reduced S/N (factor ~1.7).



The study of the module hit efficiency is another useful method to identify bad components. Excluding the known problematic modules, most tracker layers have a hit efficiency > 99.5%.



[1] D. Futyan, *Commissioning the CMS Alignment and Calibration Framework*, Proceedings for Computing in High-Energy Physics (CHEP09), Prague, Czech Republic
[2] The CMS Collaboration, *The CMS Silicon Strip Tracker Operation and Performance with Cosmic Rays in 3.8T Magnetic Field*, CMS Paper, Submitted to JINST