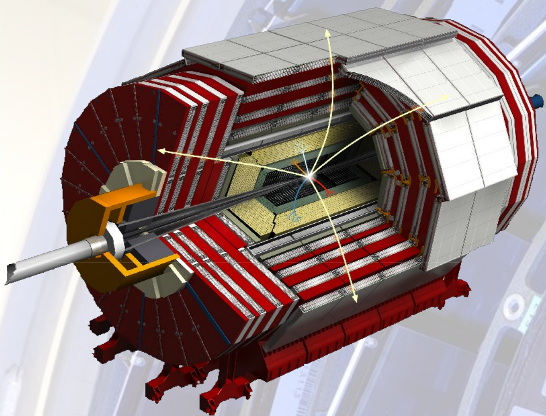


CMS Tracker commissioning and first operation experience

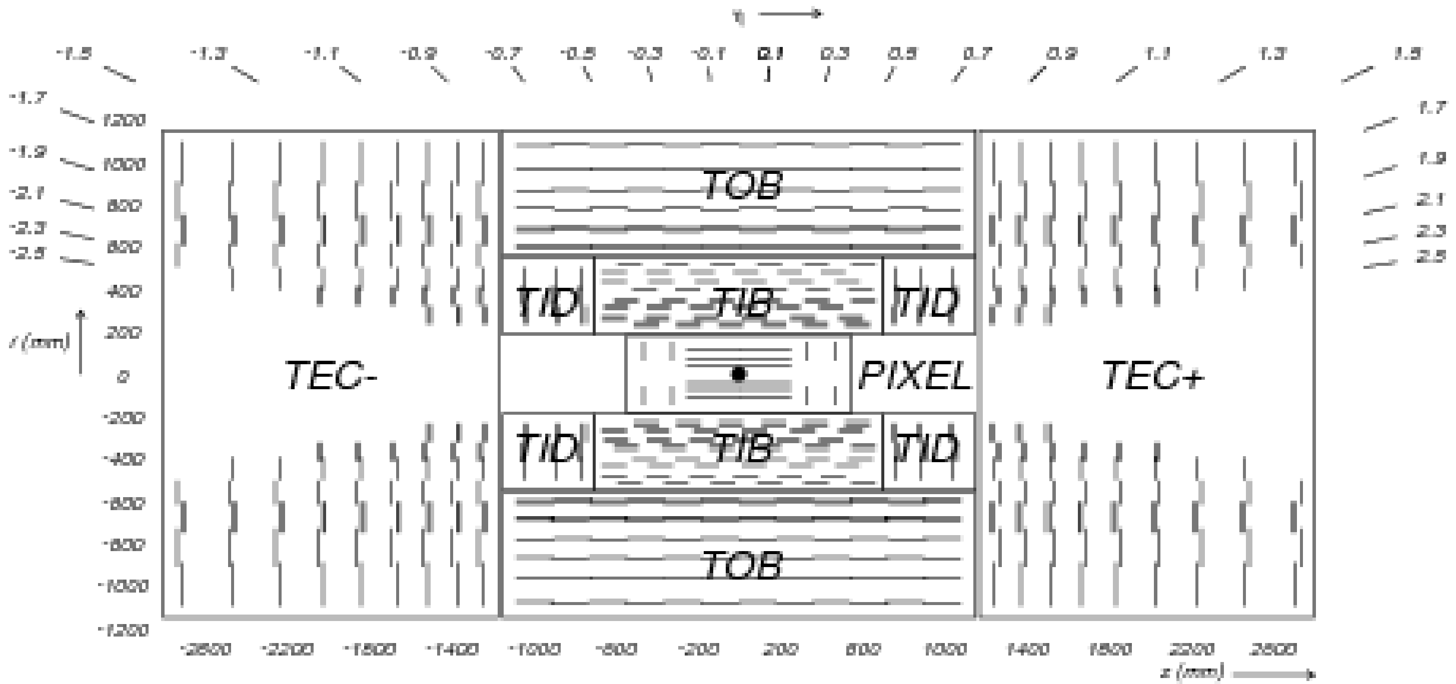
16th International Workshop on Vertex detectors
September 23-28, 2007
Lake Placid, NY, USA

C. Delaere · CERN
on behalf of the CMS collaboration

Plan

- Short introduction on the tracker
- Description of the program at TIF
- Strategy and results from the commissioning
  - Trigger
  - DAQ system
  - Commissioning procedure
- Results on "low-level detector performance"
  - Noise and S/N
  - Efficiency
  - ...
- General experience on operating the Tracker at different temperatures.
  - Tracker
  - Services
  - Collaboration

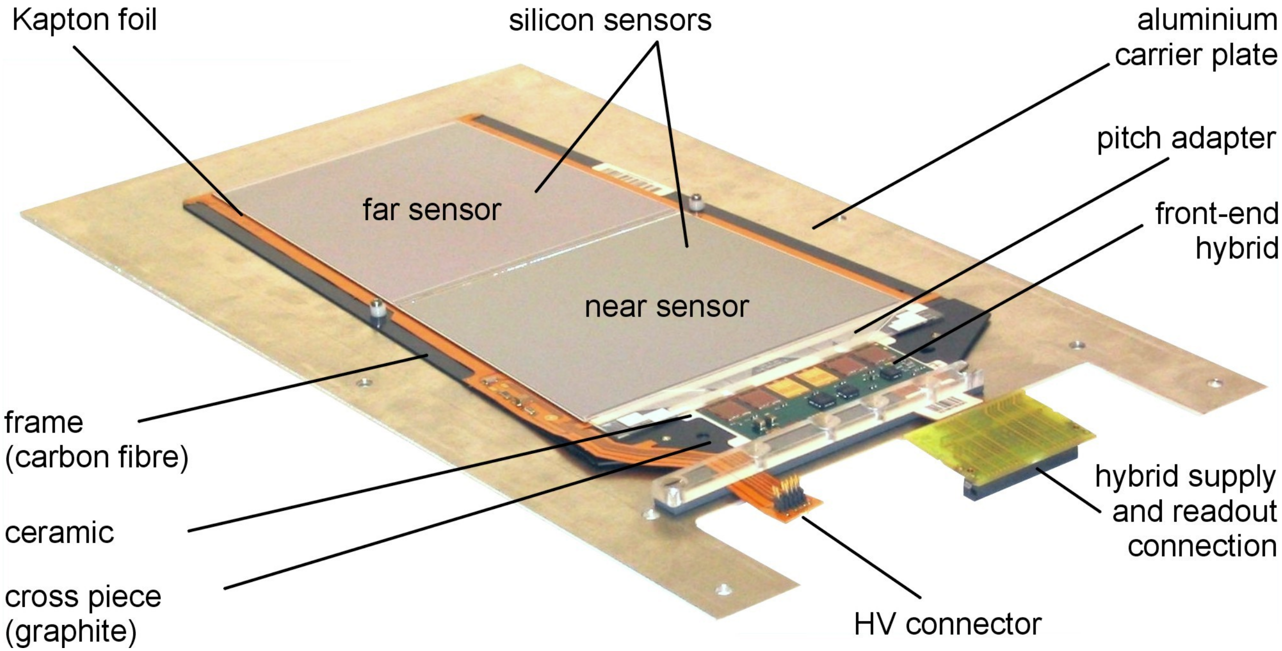
General Layout



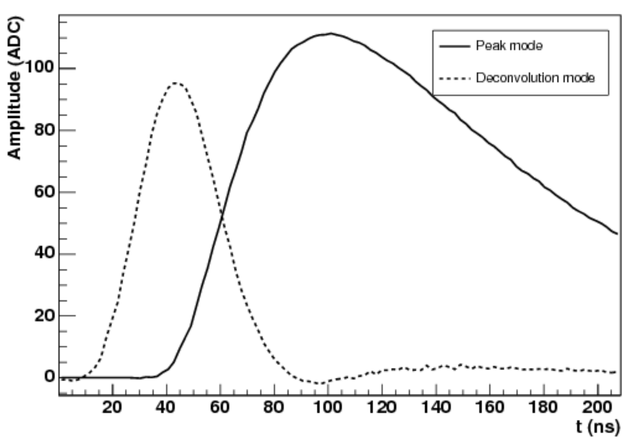
Considering only the silicon strip tracker:

- 200 m² of silicon
- 24244 sensors (i.e. 15148 modules)
- 11'059'200 channels
- 4 subdetectors (+pixel), covers pseudorapidities $|\eta|<2.5$
- 100 kHz readout (on L1 accept)

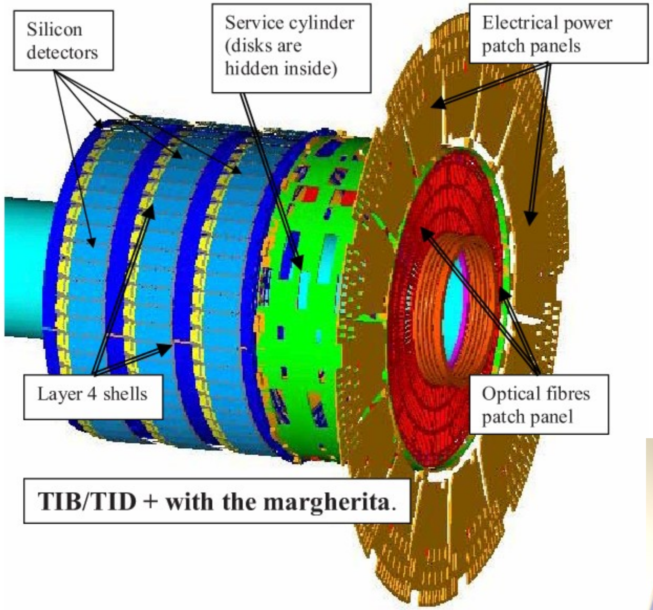
TEC module on its transport plate:

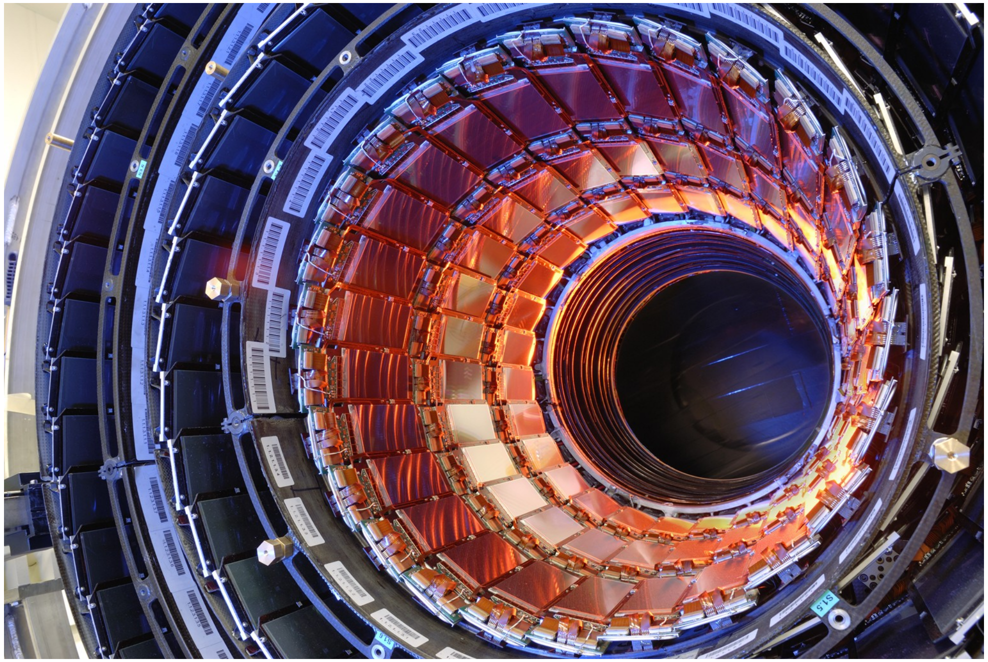


- Each module embed analog readout chips (APV25).
- It can be operated in two modes:
  - Peak mode : signal lasts for >100ns
  - Deconvolution mode: signal lasts for 25ns

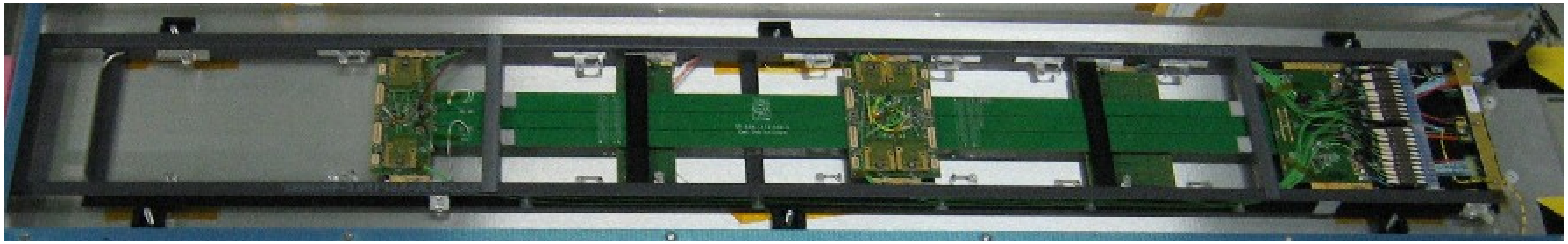


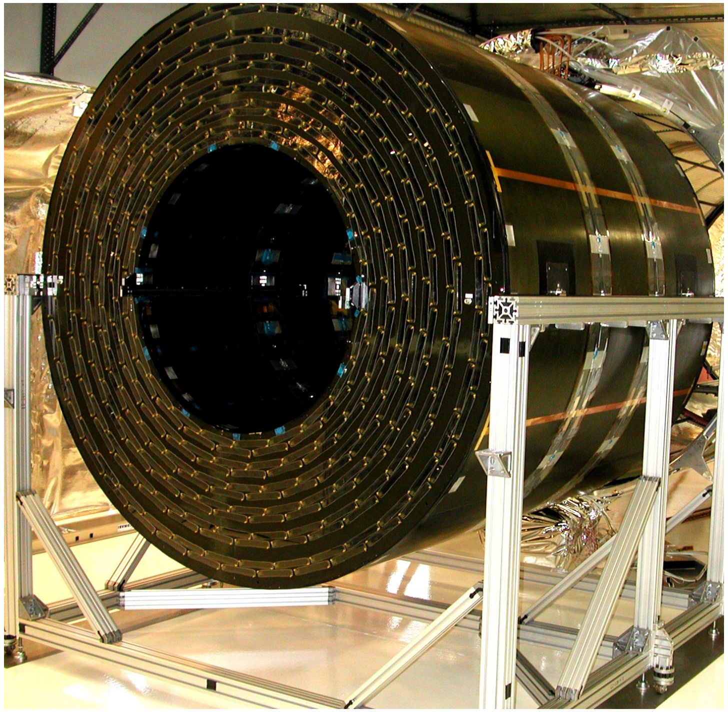
TIB/TID

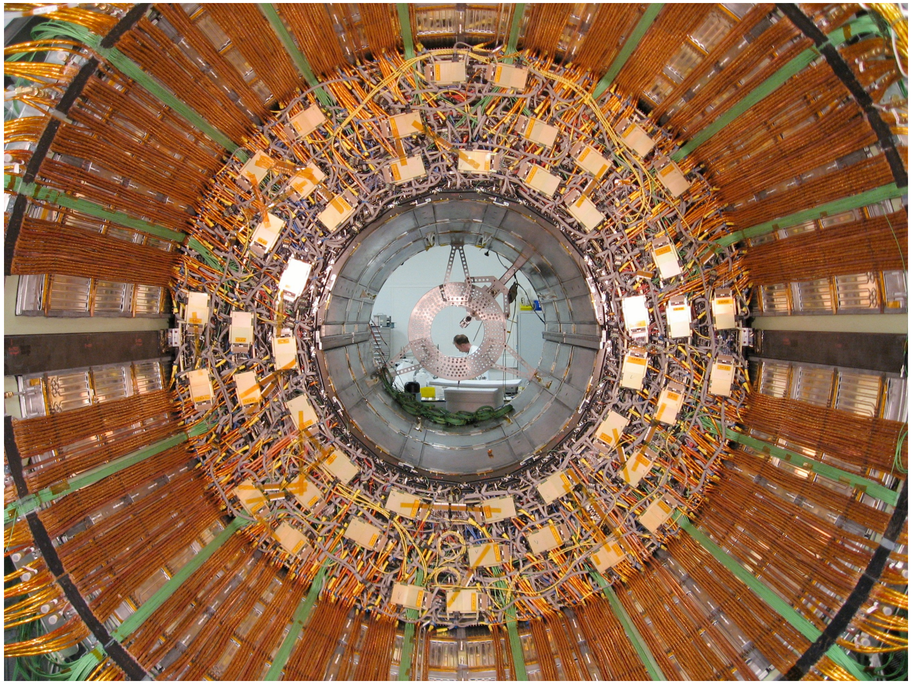

Silicon detectors
Service cylinder (disks are hidden inside)
Electrical power patch panels
Layer 4 shells
Optical fibres patch panel
TIB/TID + with the margherita.



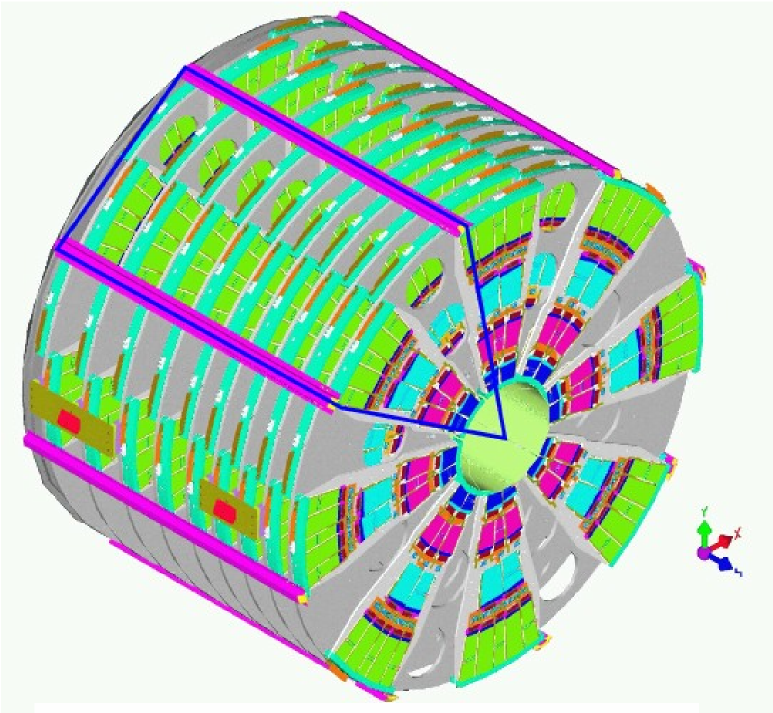
TOB

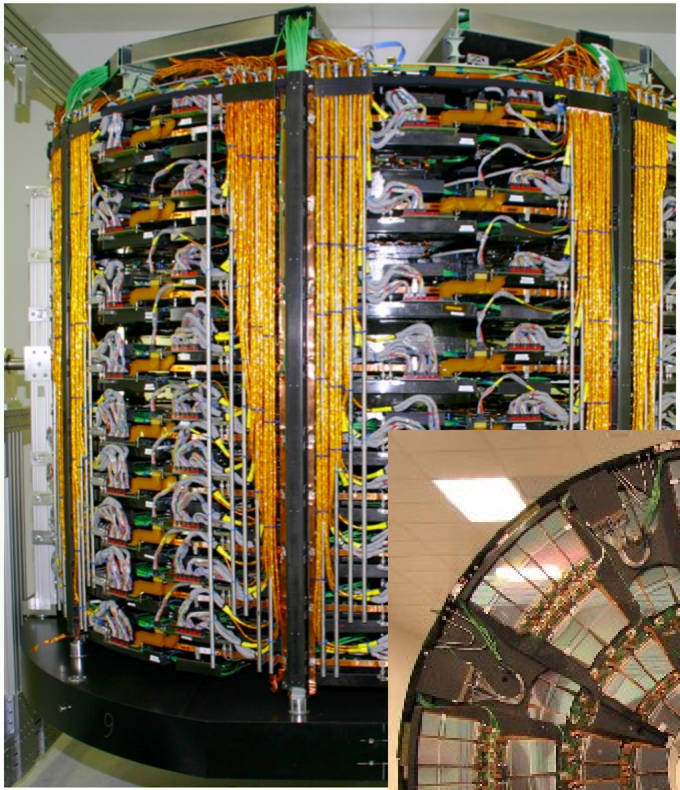


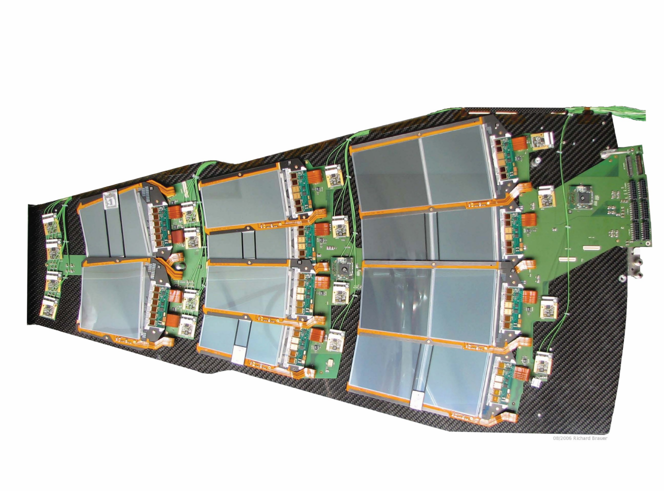


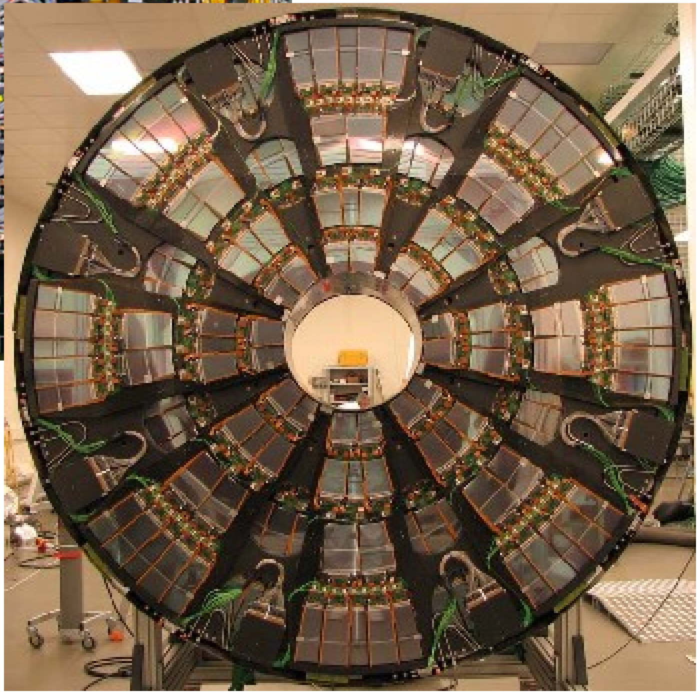


TEC





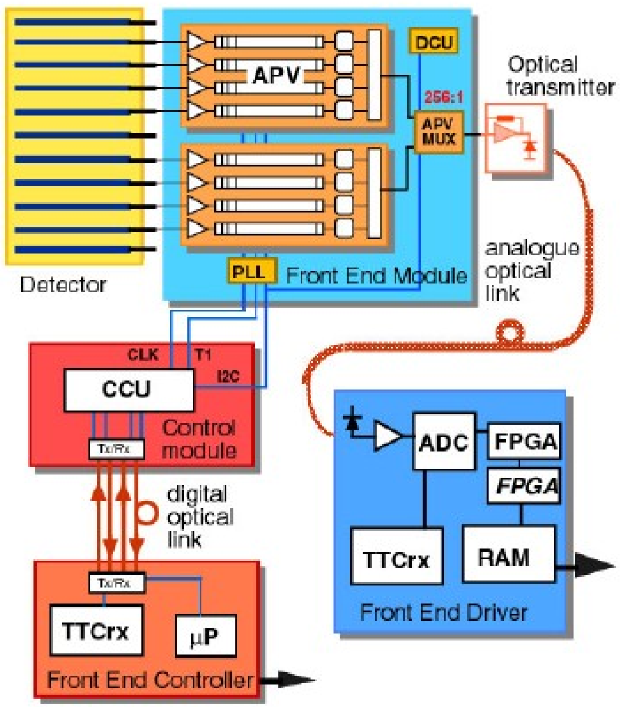




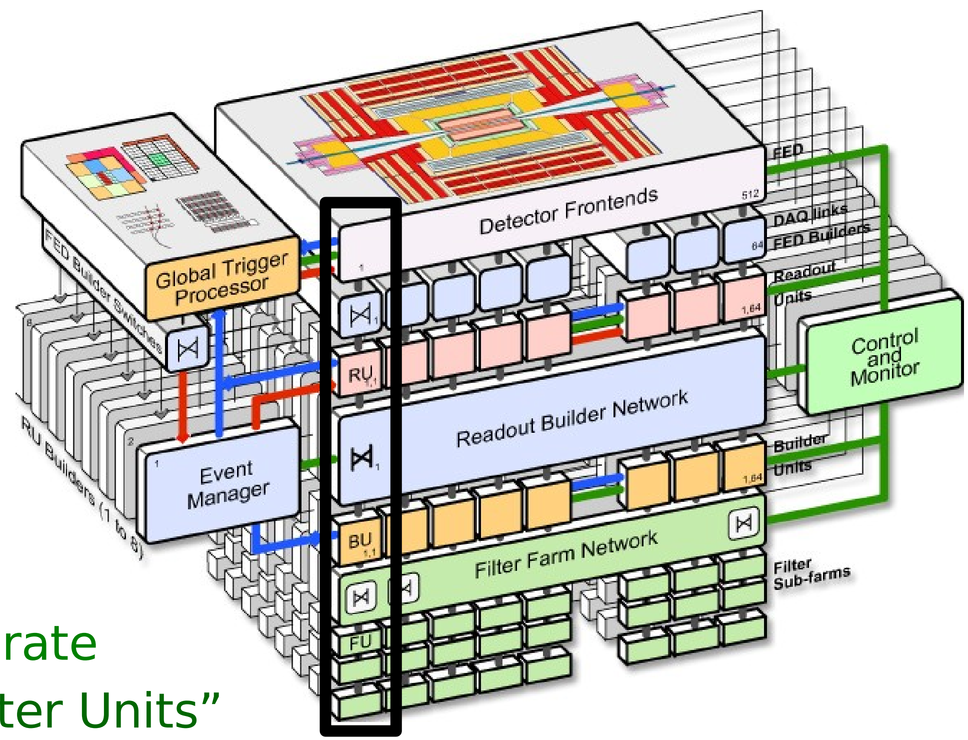
Program at the TIF

- TIF stands for “Tracker Integration Facility”
- TIF was tremendous opportunity to gain experience with all aspects of detector operations before installation.
- Part I : Integration (from November to March)
  - ❑ At each integration step, pre-tests, survey, mechanical integration, connection, post-tests.
  - ❑ Installation of services (LV, HV, Detector safety, Dry air, Cooling,...)
- Part II : Warm developments (from March to May)
  - ❑ Weekdays: development of subsystems
    => Operate 12.5% of the tracker
    - o DAQ procedures – Commissioning
    - o Detector tests, noise studies, hardware fixes
  - ❑ Weekend: Cosmics
    - o Data for tracking and alignment studies
- Part III : Cold operation (from May to July)
  - ❑ Operation at 10°C, 0°C, -10°C and -15°C (coolant temperature)
    - o Performances and safety, temperature-dependent defaults, ...
  - ❑ Cosmic data and Laser Alignment at various temperatures

Readout and DAQ architecture



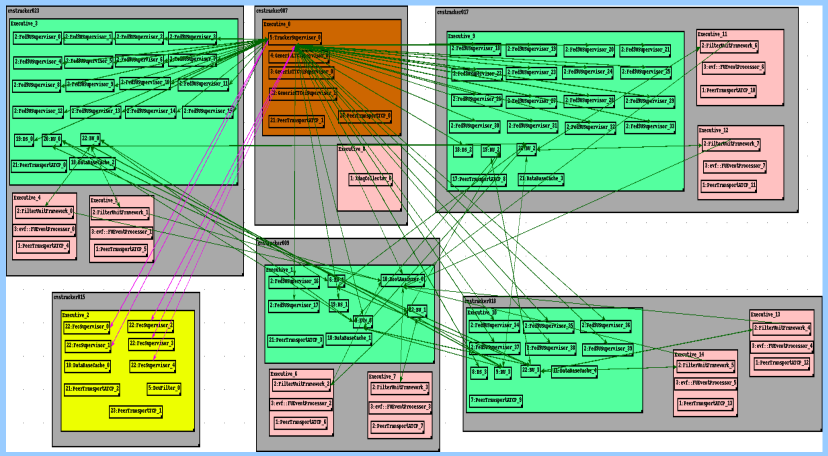
- The CMS tracker readout consist of :
  - The front-end that does **analog** pulse-shaping and **optical** transmission.
  - The **FED** that houses ADCs.
  - The **FEC** for clock/trigger distribution + front-end control.



- The CMS tracker DAQ for the TIF operation mimics the final CMS DAQ
  - Distributed architecture
  - Two “Readout Units” per VME crate
  - Several “Builder Units” and “Filter Units”

12.5% test configuration

- The 12.5% system consist of:
  - 65 FEDs (5188 FED channels)
  - 8 FECs (2161 modules)
  - 6 RU
  - 6 BU
  - 12FU
  - 1 LTC + 3 TTCci
  - 1 StorageManager



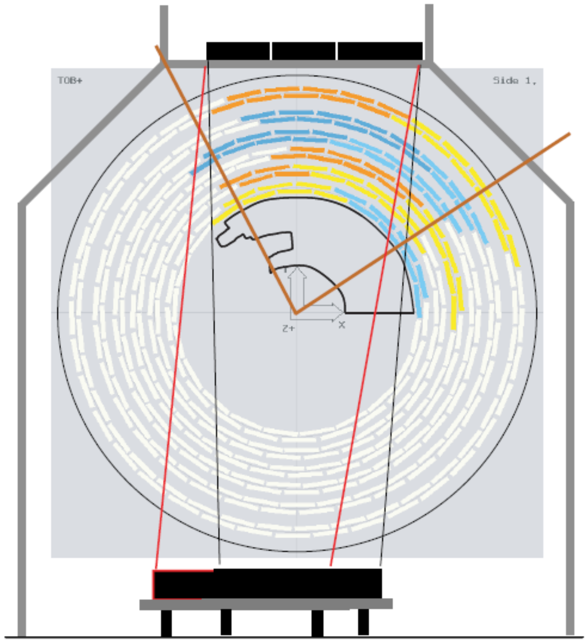
Example configuration for the 4% test.
Running on 6 PCs
Each box represents a process. Lines are network connections.

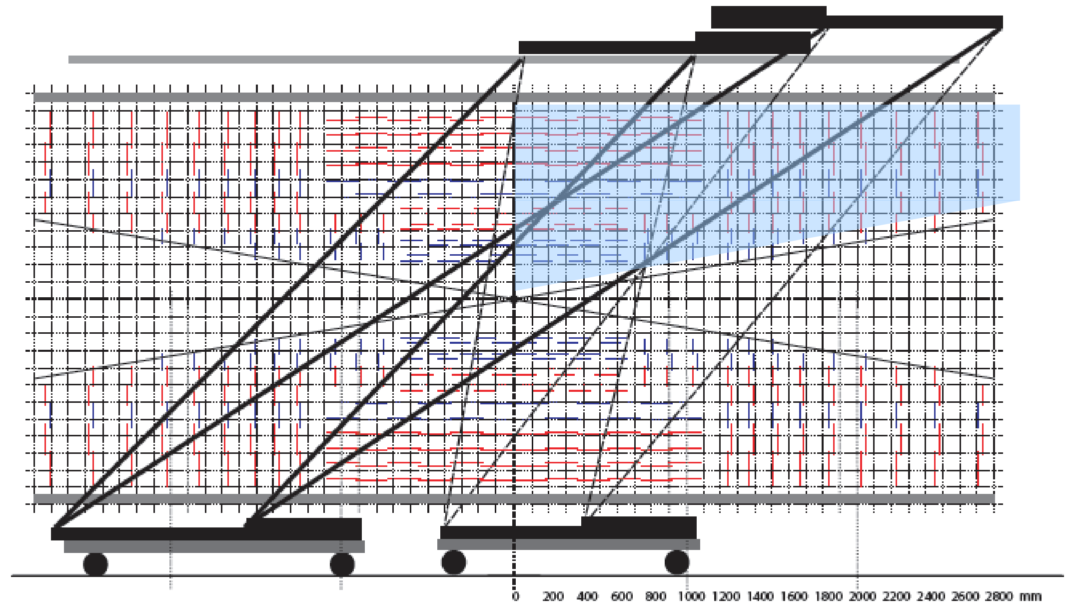
- It corresponds to slightly more than ½ DAQ slice (aka partition) in the final setup.
- Scales well and runs smoothly at up to 5Hz (limited by the disk write speed).

Trigger configuration

The CMS tracker requires an external trigger.

- Most of the commissioning is performed using a cyclic trigger.
- A scintillator-based cosmic trigger has been installed.





The CMS tracker requires an external trigger.

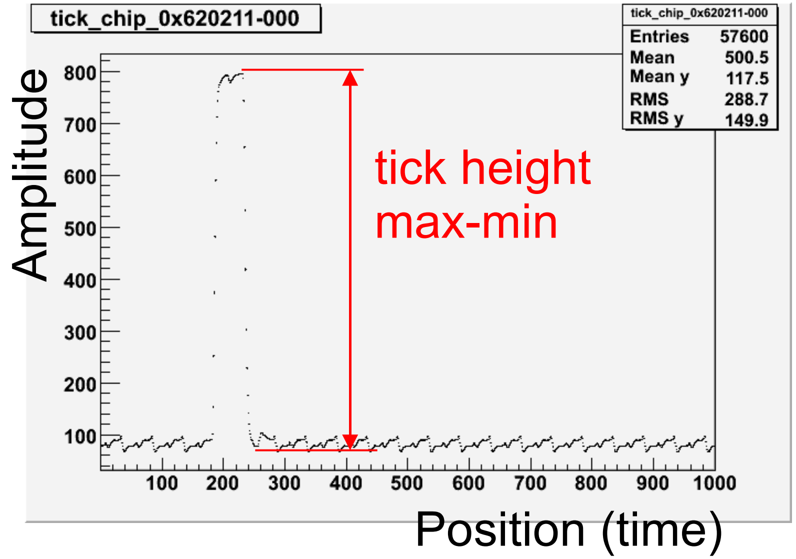
- Coincidence between scintillators above and below the tracker
- 5cm of lead installed to cut the low-energy tail.

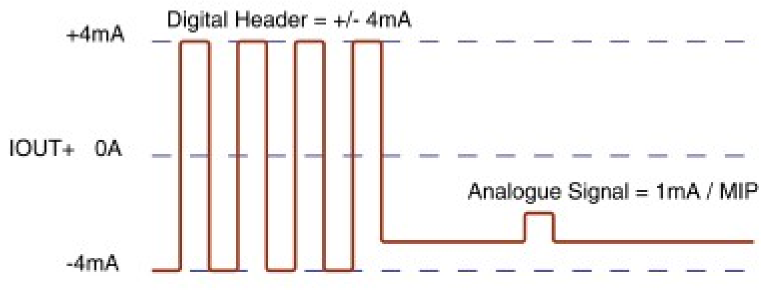
Trigger rate : 6.5+-0.1 Hz

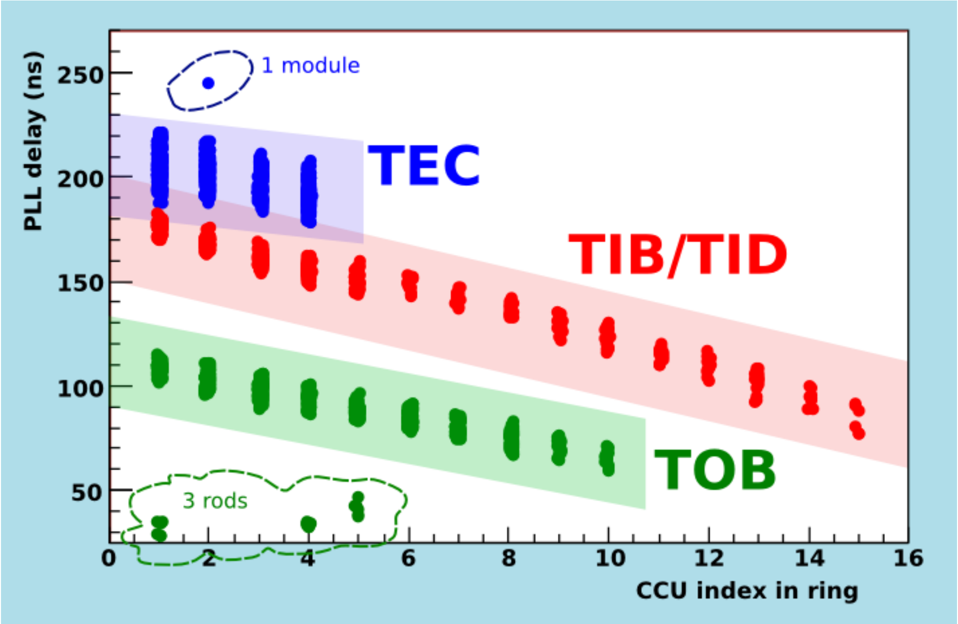
Commissioning sequence

- The commissioning of the tracker is subdivided is various steps:
  - ❑ Control-PSM map
    - o Control the electric cabling
  - ❑ Control-Readout map
    - o Control the optical cabling
  - ❑ Internal Timing
    - o Synchronize the readout
  - ❑ Optical Gain
    - o Tune the amplitude of the signal
  - ❑ Analog baseline tune
  - ❑ Tuning the APV pulse shape
  - ❑ Pedestal and noise
    - o to be stored in the online database for later reference
  - ❑ APV latency scan
    - o find the right bunch-crossing (25ns)
  - ❑ Fine tuning of the pulse shape sampling
    - o tune to 1ns taking into account effects from TOF, etc.
- Lots of data has been obtained. In the following slides, I will give some selected results.

Synchronization



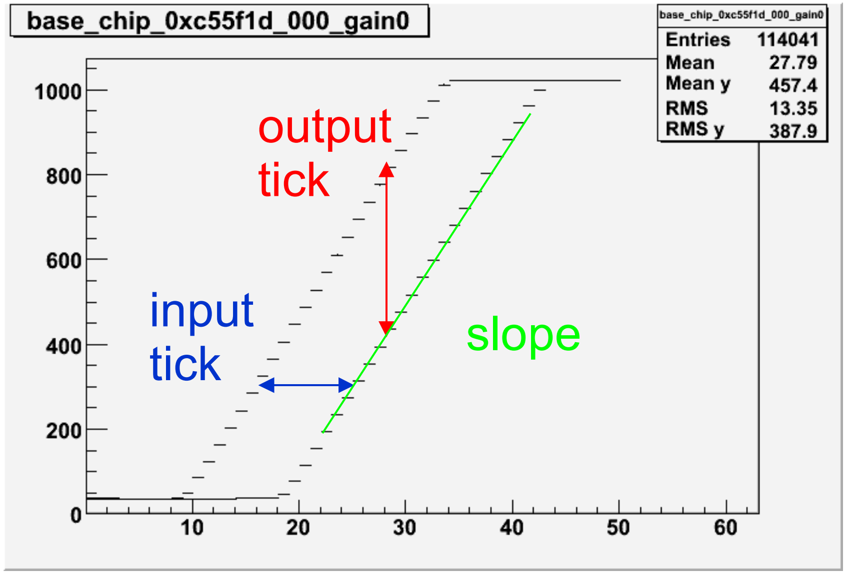


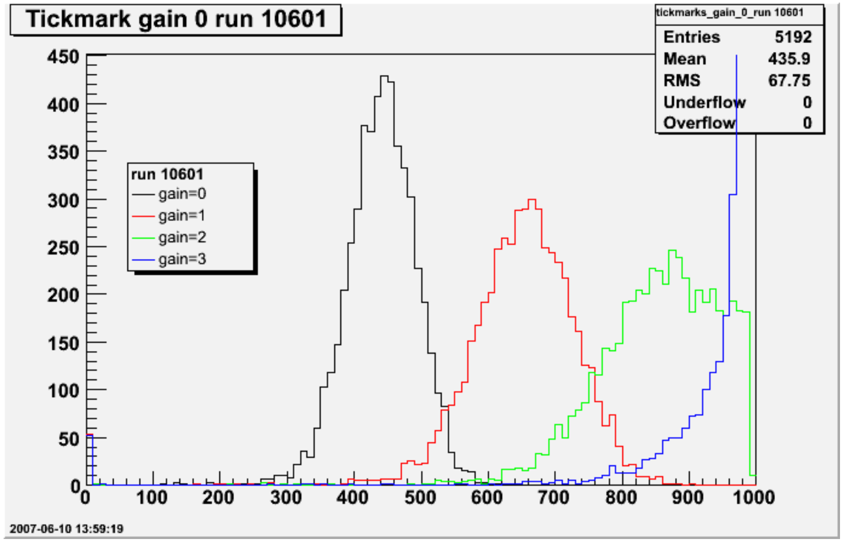


- The first data-related commissioning step deals with the internal synchronization of the tracker.
  - One programmable "phase-locked loop" delay chip on each module.
  - Accommodates for the different fiber length / electrical datapath.

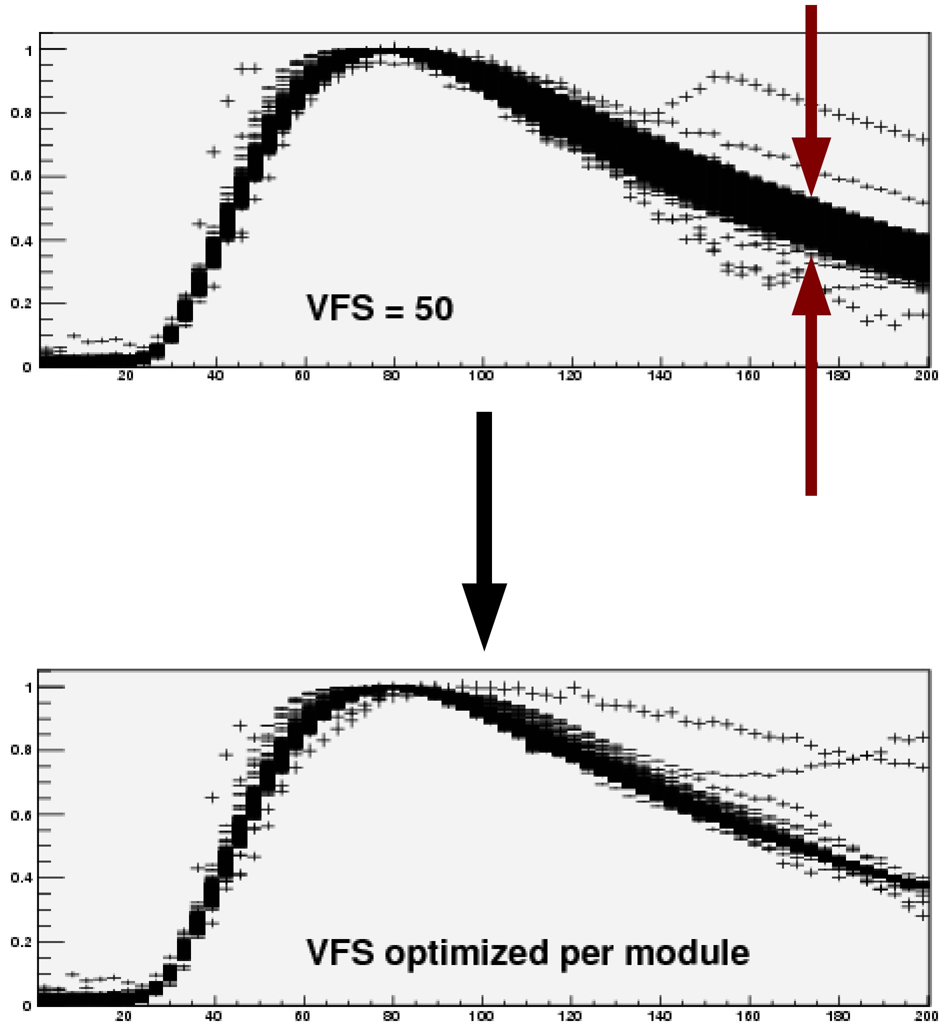
Gain scans

- Used to set the proper AOH (analog opto-hybrid) settings :
  - Laser bias,
  - Input signal scale factor.
- What is monitored :
  - Output tickmark height,
  - “Slope”,
  - Estimated input tickmark,
- Optimal parameters are automatically determined for each AOH.
  - Depends on the temperature.
  - Depends on the integrated fluency.



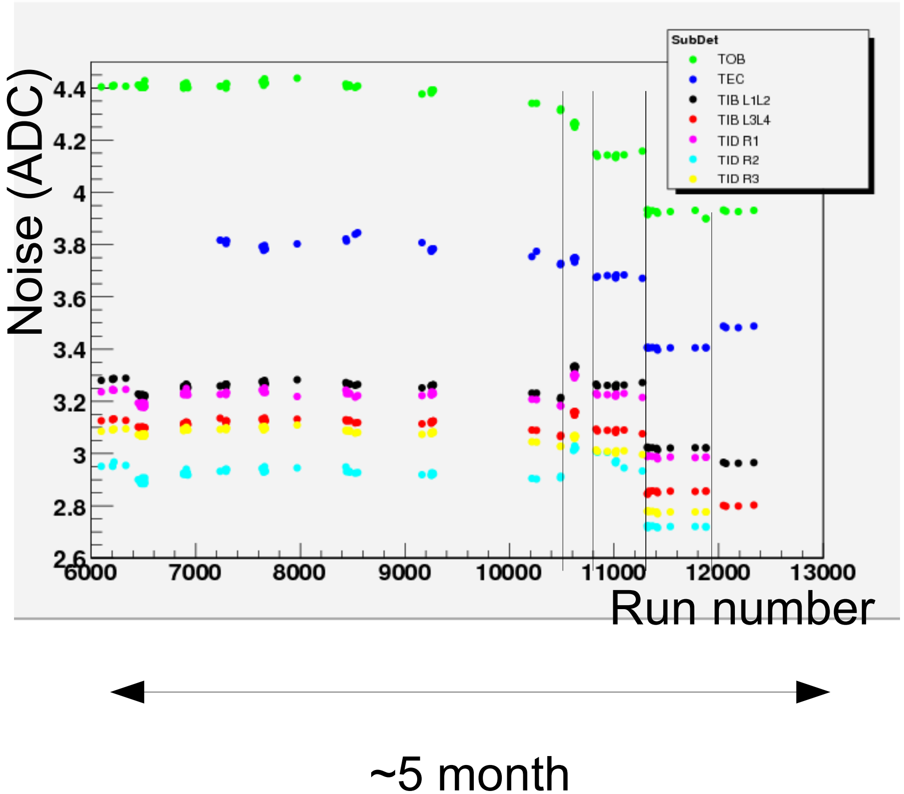


Pulse shape tune



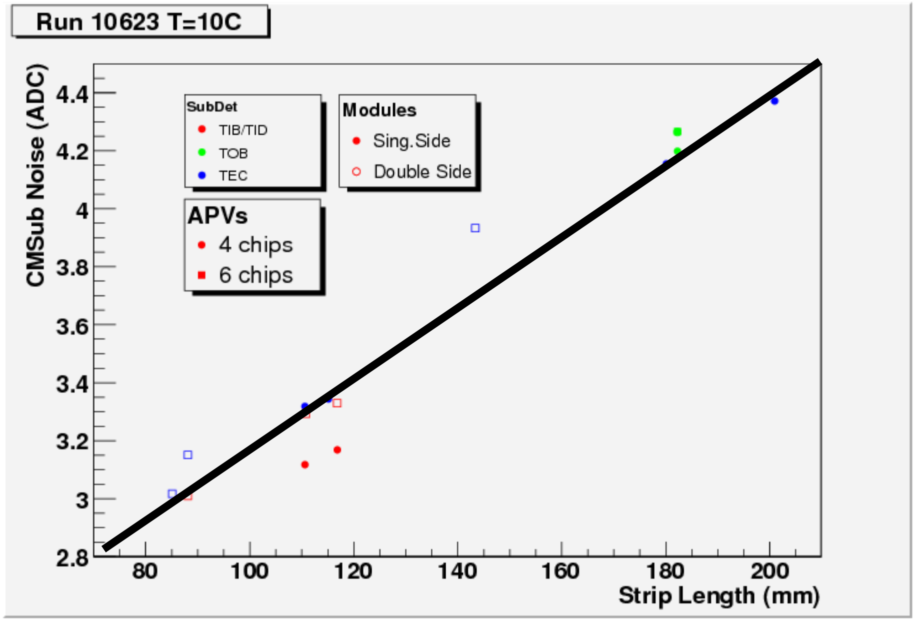
- The APV pulse shape has to be tuned for each chip:
  - ❑ Homogeneity of the tracker response
  - ❑ Guarantee performances over time
  - ❑ Reduce the systematics in dE/dx studies
  - ❑ Impact on the offline absolute calibration
  - ❑ Impact on the response to off-time particles (e.g. Stable heavy particles).
- Here one example: “VFS tune” (the shaper feedback voltage bias).

Noise study



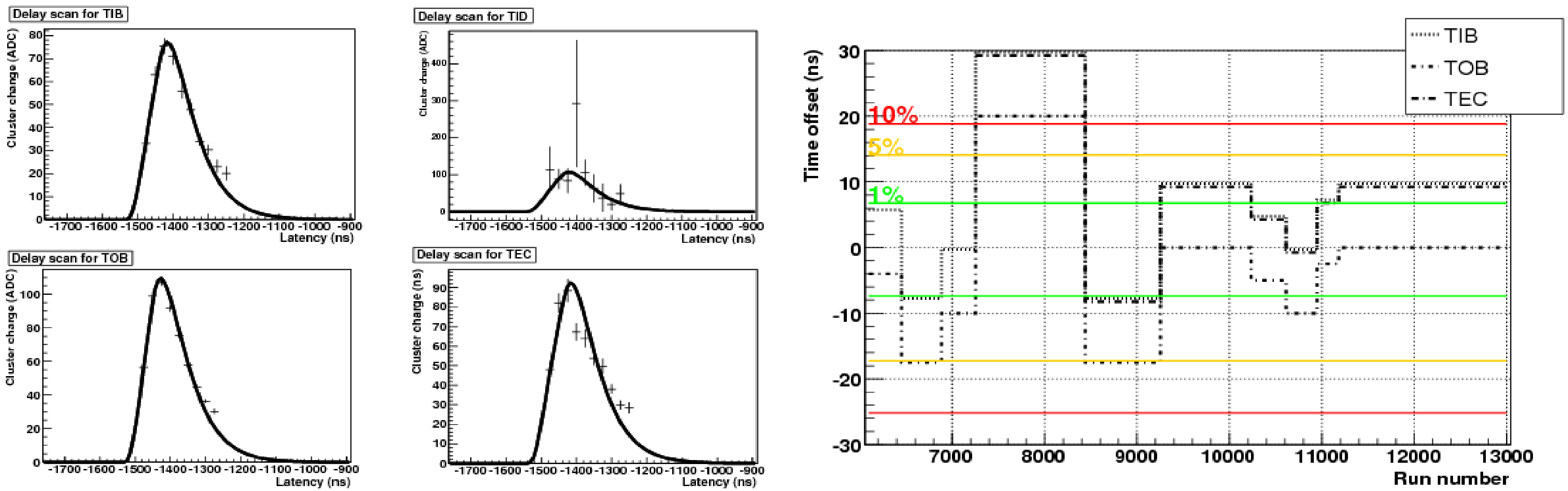
- The noise is stable over time.
- Changes correspond to different temperature phases.
- Lower than 5 ADC in peak mode.

- As expected, the noise scales with the strip length.
- Other effects (like the number of chips/module) are small.



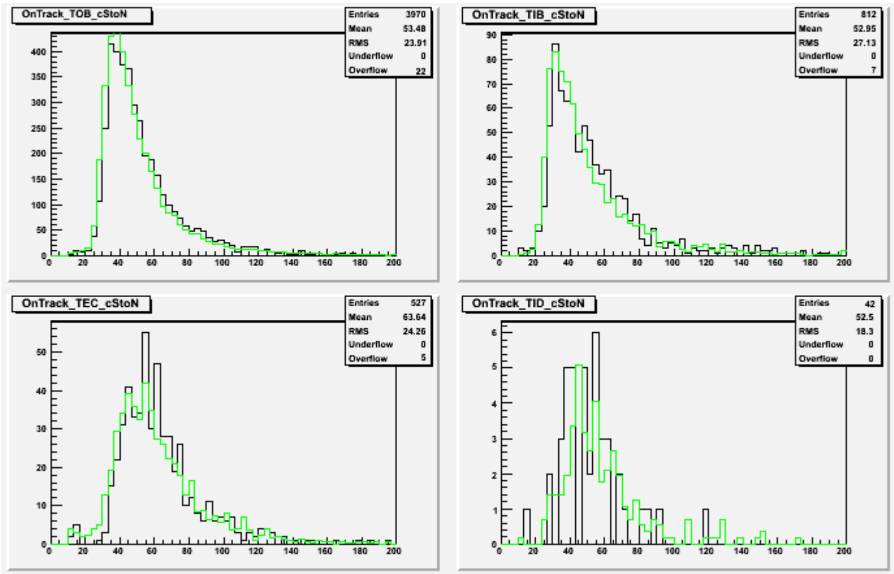
Latency

- The aim of latency scans is to be synchronized with the external trigger, i.e. to find the right bunch-crossing.
- The APV latency can be set by steps of 25ns.
- The best latency is set by reconstructing the pulse shape and by choosing the working point closest to the maximum.



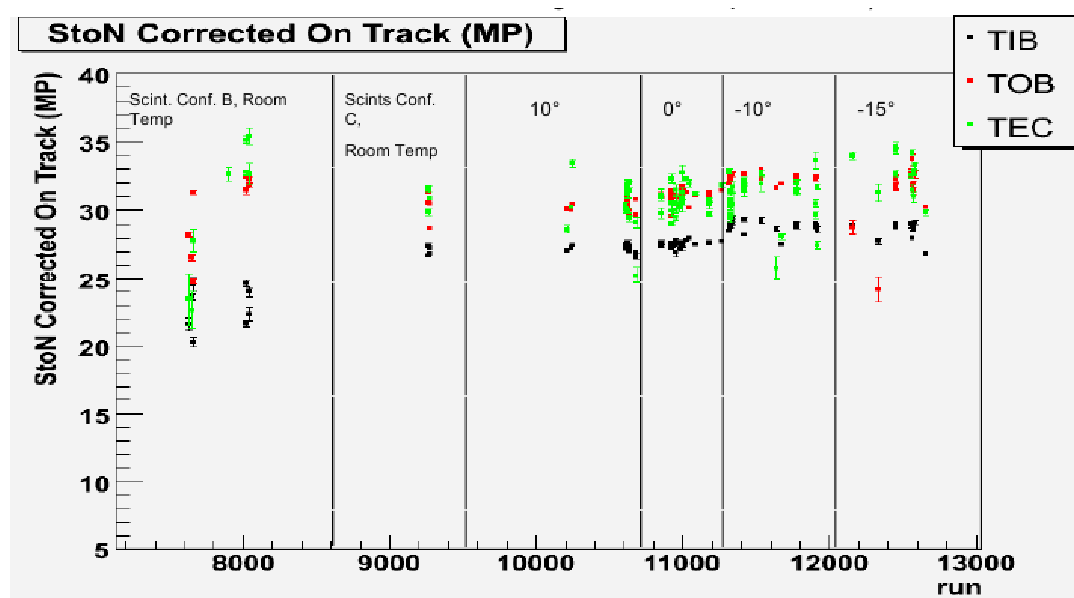
- The remaining uncertainty on S/N from synchronization on cosmics is better than 3%, after that rough preliminary tune.
- In CMS, there will be an additional “finedelay tune” to achieve a precision of 1ns.

Signal to noise

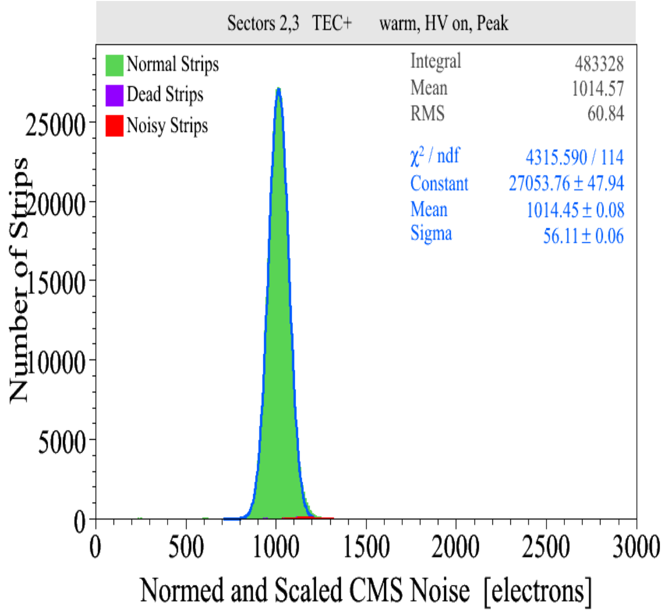


- Very good S/N values are achieved:
  - ~27 for TIB,
  - ~31 for TOB,
  - ~31 for TEC.
- Very low amount of noise clusters.
- Nice Landau shape.

- The S/N is stable with time.
- Care has to be taken about:
  - Temperature
  - Front-end configuration
- The behavior is well understood.

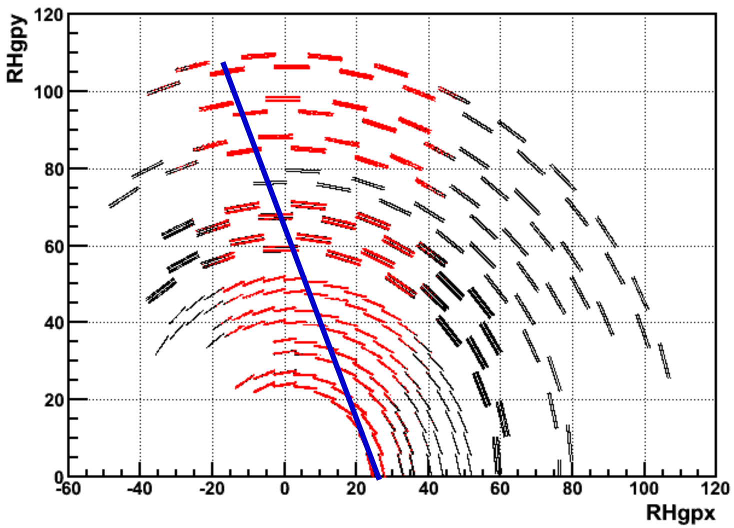


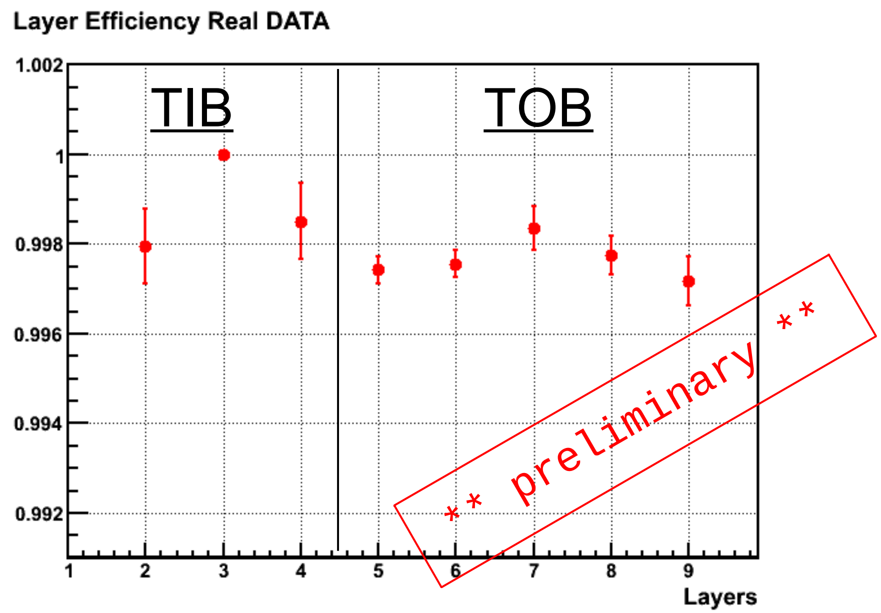
Efficiency from data



- The number of bad (dead or noisy) strips determined during integration is 0.2%
- The tracker efficiency has been cross-checked from data using single track events.
- Results are excellent:
  - Efficiency >99.7% everywhere.

Selected Region





Experience gained

- Completed tracker maintaining high quality of production.
- Developed "Standard" DAQ/Detector Control /Data Quality tools.
- Substantial dataset to evaluate TK performance at various temperatures.
- Important "engineering" tests
  - Grounding scheme for all subdetectors
  - Many permutations of interference (noise) tests
    - TIB/TOB/TEC/FPIX, Plus versus Minus,...
  - Thermal performance at various temperatures
  - Laser Alignment at various temperatures
  - Zero Suppression vs Virgin Raw data
  - Stability of Noise, Gain, etc over time
- Cosmic Data Taking
  - 5,025,043 events taken
  - Are used for tracking and alignment studies
    - Will be presented in talks by Carten Noeding and Gero Flucke

Experience gained (2)

- Developed Bookkeeping/Communication tools
  - Run Summary, Elog, Snapshot server
  - Run Quality flags, Data Tx and Access procedures
- Gained experience in various fields:
  - DAQ Operations, Calibration, Bookkeeping
  - Database management
  - Detector Control System performance, monitoring, archiving
  - Interlock operations, validation
  - Power Supplies System behavior, quirks
  - Data Quality Monitoring
  - Shifts and Operations
- Got the confidence that we can run the TK safely and effectively.
- New Experts!

Conclusions

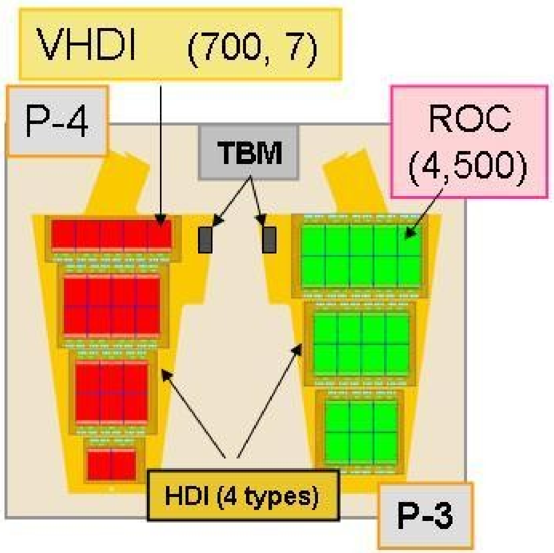
- The CMS tracker has been (pre)commissioned during 6 months.
- The acquisition and commissioning software has been heavily developed/tested/extended.
- Tracker performances are excellent:
  - Typical S/N ~30
  - 0.2% Bad strips
  - Module efficiency >99.7%
- A large set of cosmic events has been recorded for further study.

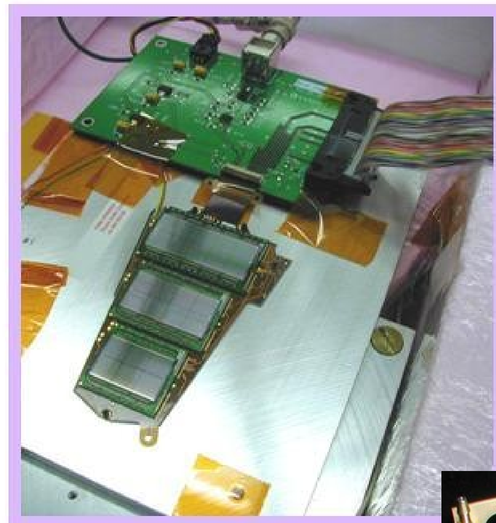
See the talks by Carsten Noeding and Gero Flucke

- A lot of experience has been gained in operating the tracker safely and efficiently.
- Looking forward to have data as part of CMS.

Backup slides

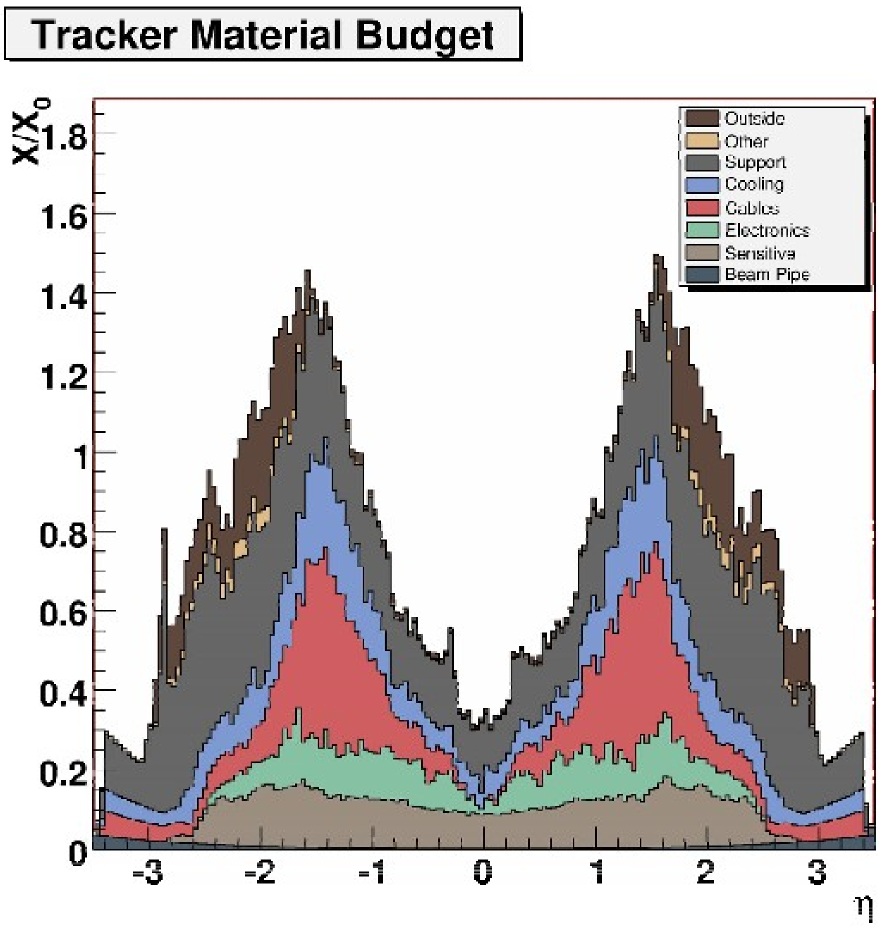
Pixel



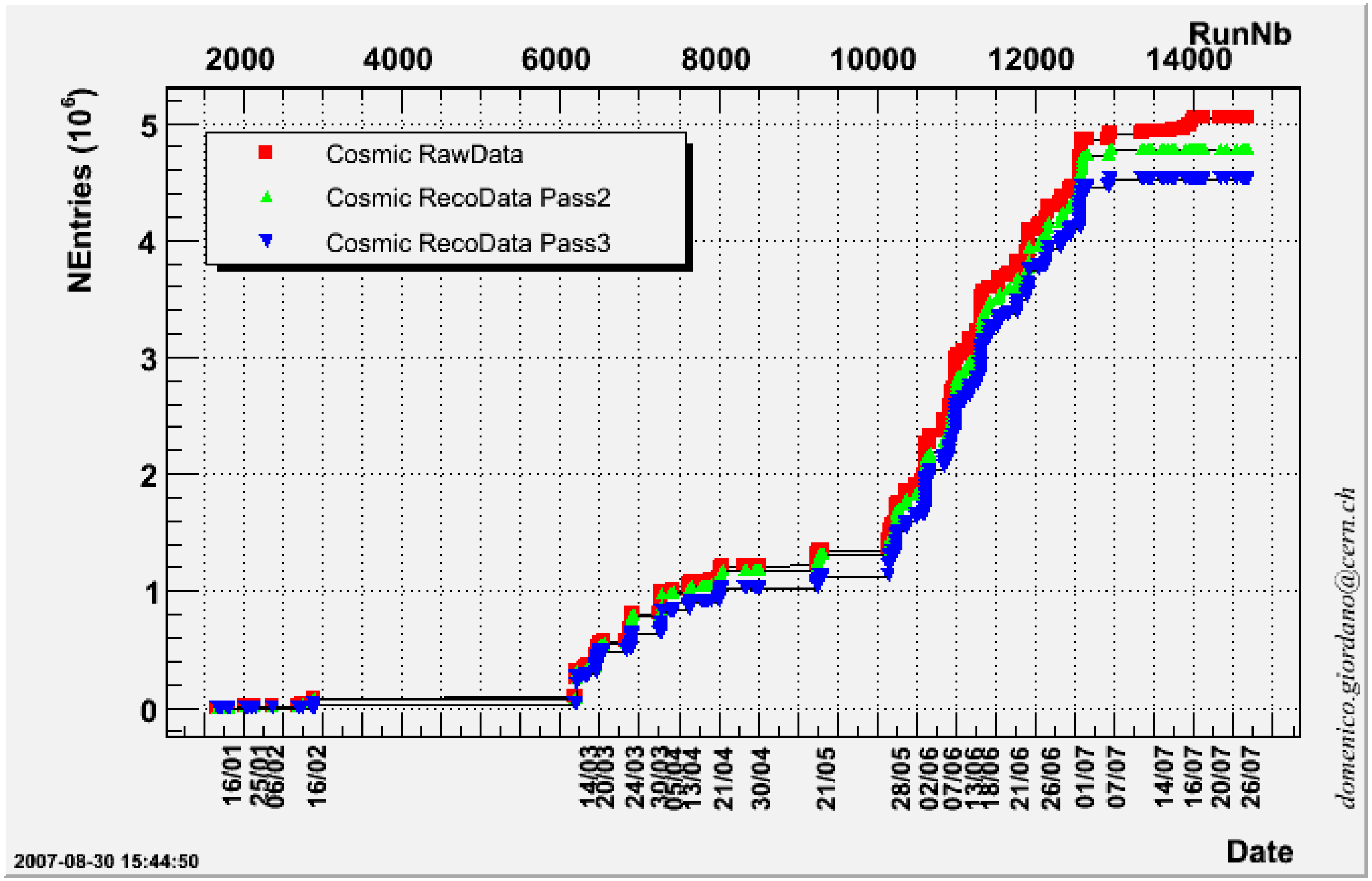


Will be covered by Mauro Dinardo.

Material budget



Distributed data processing



Fine delay scan

- A precision of 1ns on the detector synchronization is obtained:
  - ❑ By running the detector in deconvolution mode
  - ❑ By scanning PLL (on the detector front-end)
- It requires many corrections for time-of-flight, length of the readout fibers, etc.
- Will be crucial at high luminosity