The CMS Framework for Alignment and Calibration

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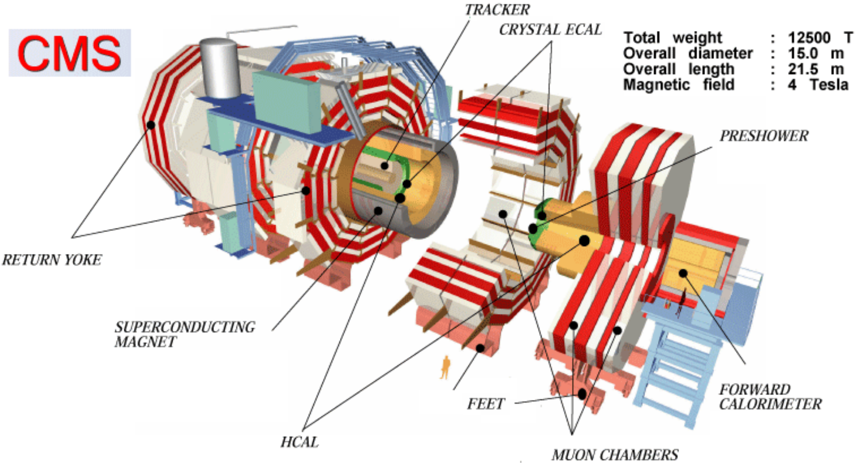
Outline

- The CMS Detector: Alignment and Calibration Challenge
- The Alignment and Calibration Workflow:
  - “Scene”, “Actors” and “Language”.
- Simulation Exercise:
  - Computing, Software and Analysis Challenge 2008.
- Real Data Experience:
  - Cosmic Data Taking.
- Conclusions

The CMS Detector at LHC Point 5 (P5)



- Onion Structured Detector.
- Large Solenoid: $B = 3.8$ T.
- Complete since August.

- Seen LHC Beam Halo in September.
- Now Large Cosmics Run.

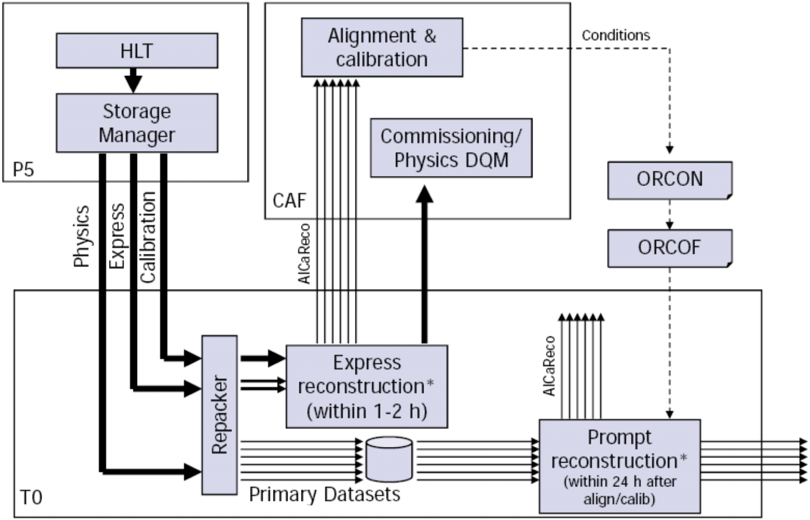
CMS Alignment and Calibration Challenge

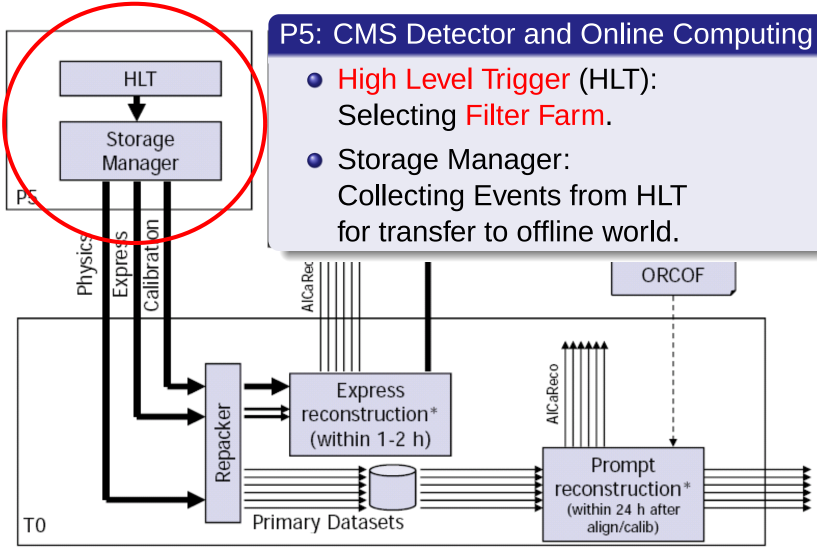
Complex Reconstruction of LHC Events.

- Ambitious goals in terms of resolution:
  - $\Rightarrow$ Require excellent alignment and calibration.
- Aiming for fast turn around for physics results:
  - $\Rightarrow$ Essential alignment and calibration for prompt reconstruction.
- Large data rate:
  - $\Rightarrow$ Robust framework to handle alignment/calibration.

$\Rightarrow$ Proof-of-principle in simulation and cosmic data taking.

Prompt Alignment/Calibration Workflow: The Scene



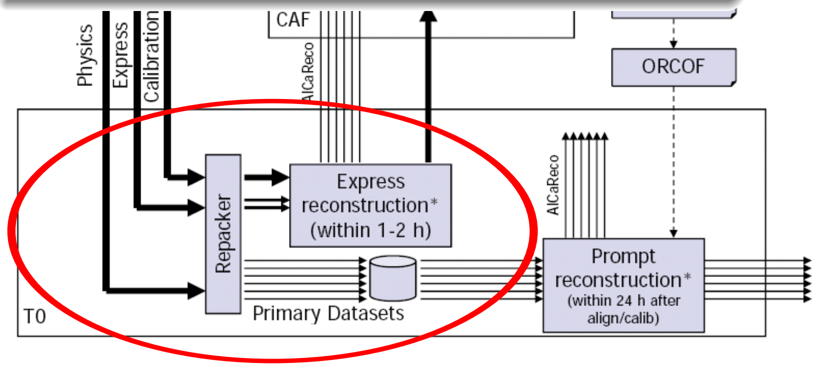


P5: CMS Detector and Online Computing

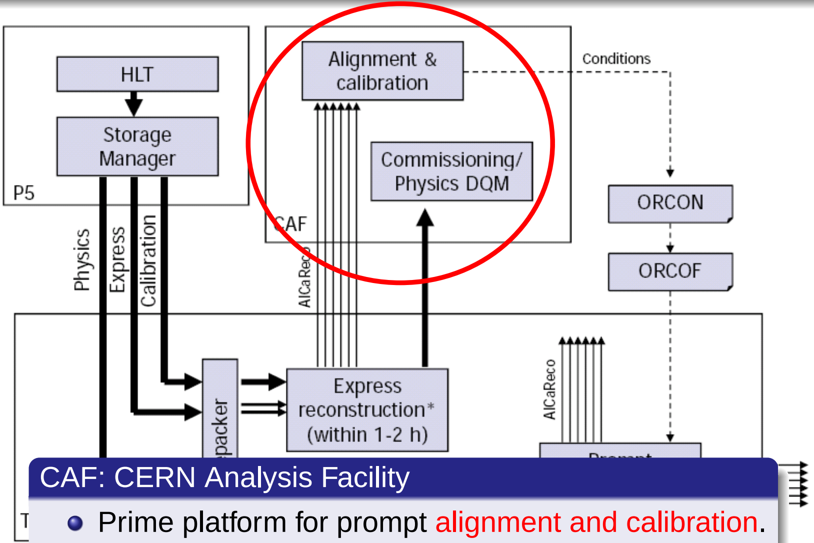
- High Level Trigger (HLT): Selecting Filter Farm.
- Storage Manager: Collecting Events from HLT for transfer to offline world.

Tier-0 (T0): Offline Production at CERN (Meyrin)

- Repack into Datasets according to HLT.
- $\mathcal{O}$(10-20%) Express Reconstruction.
  - ⇒ Alignment and Calibration Streams (AlCaReco) for Monitoring and Short Latency Calibration.
- Buffer bulk of data on disk.



Prompt Alignment/Calibration Workflow: The Actors III

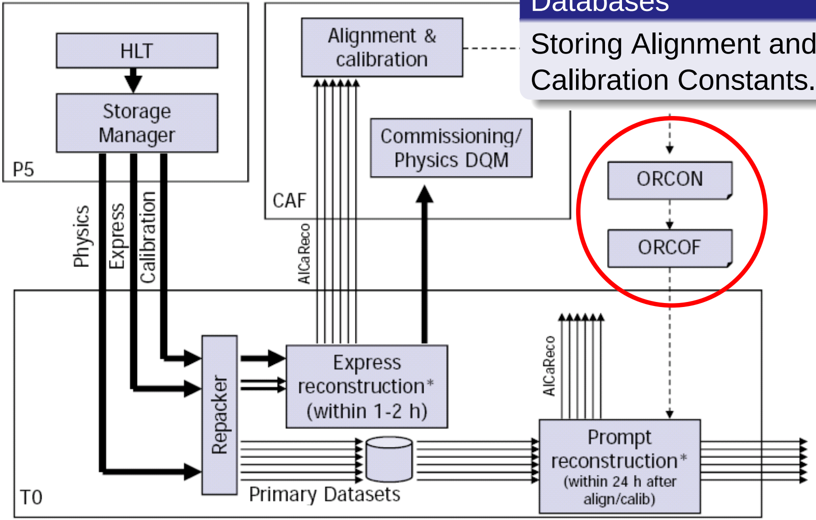


CAF: CERN Analysis Facility

- Prime platform for prompt alignment and calibration.
- Batch farm.
- Fast access to data: Disk storage.

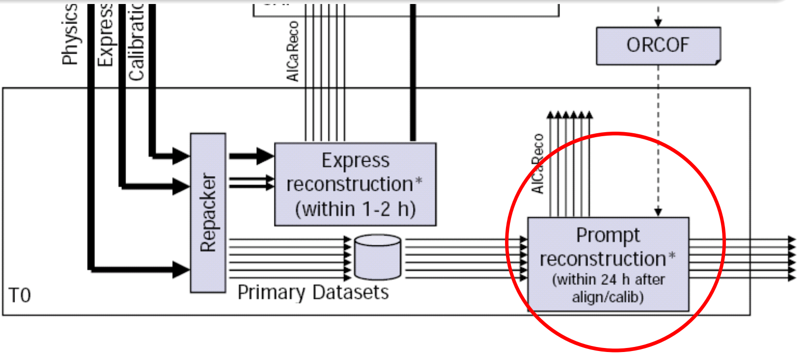
Databases

Storing Alignment and Calibration Constants.

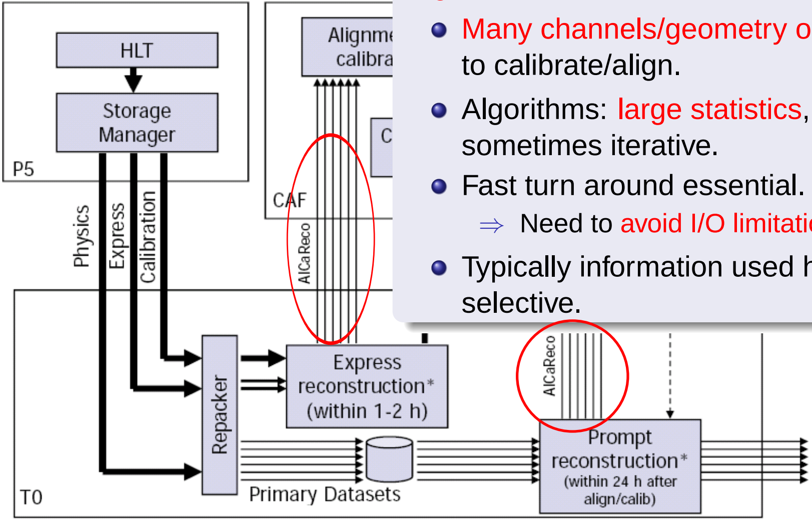


Tier-0 (T0): Offline Production at CERN (Meyrin)

- Prompt Reconstruction, $\mathcal{O}$(24 h) delay:
  - picking up updated constants,
  - sets time limit to achieve short term constants.
- Create Alignment and Calibration Streams (AlCaReco) for longer latency workflows.



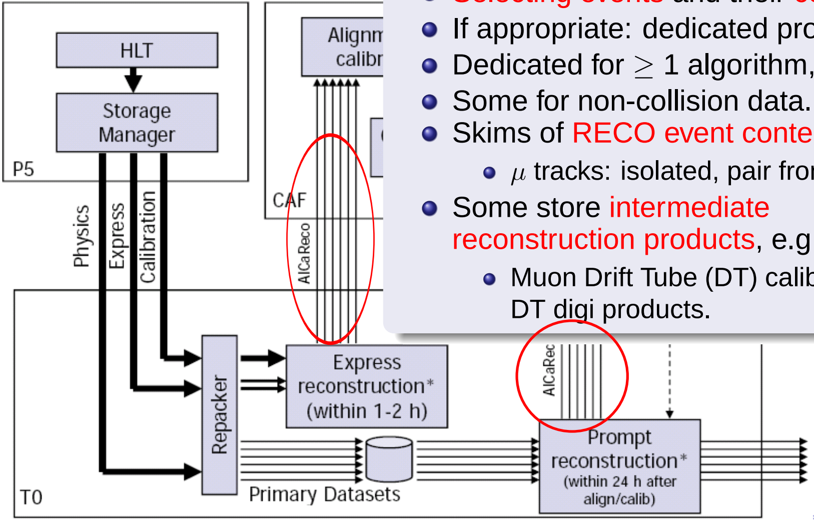
Prompt Alignment/Calibration Workflow: Languages I



AlCaReco Streams

Small data skims dedicated for alignment/calibration.

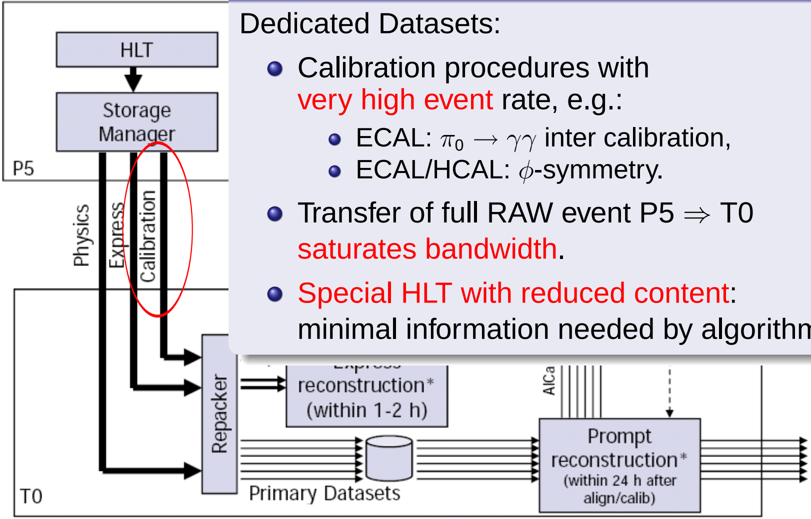
- Many channels/geometry objects to calibrate/align.
- Algorithms: large statistics, sometimes iterative.
- Fast turn around essential.
  - ⇒ Need to avoid I/O limitations!
- Typically information used highly selective.



AlCaReco Streams

Currently about 20:

- Selecting events and their content.
- If appropriate: dedicated products.
- Dedicated for $\geq$ 1 algorithm,
- Some for non-collision data.
- Skims of RECO event content, e.g.
  - μ tracks: isolated, pair from J/Ψ, Z
- Some store intermediate reconstruction products, e.g.
  - Muon Drift Tube (DT) calibration with DT digi products.

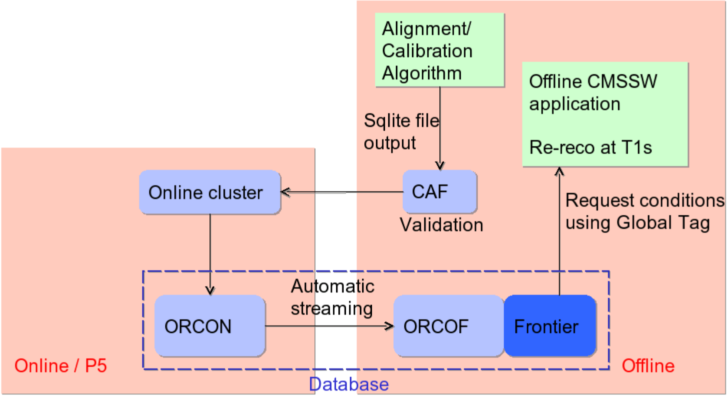


AlCaRaw Streams

Dedicated Datasets:

- Calibration procedures with very high event rate, e.g.:
  - ECAL: $\pi_0 \rightarrow \gamma\gamma$ inter calibration,
  - ECAL/HCAL: ϕ-symmetry.
- Transfer of full RAW event P5 $\Rightarrow$ T0 saturates bandwidth.
- Special HLT with reduced content: minimal information needed by algorithms.

Offline Alignment and Calibration Constants Flow



- Constants derived offline on CAF.
- Validated on CAF.
- Transferred to P5/online.

- Upload to online DB (ORCON).
- Automatic streaming to ORCOF.
- Accessed offline via dedicated cache (Frontier).

Computing Software and Analysis Challenge (CSA08)

Testing Offline Data Handling at Full Scope (May 2008)

Realistic exercise on simulated data:

- Prompt reconstruction at T0 (no Express stream).
- Produce AlCaReco skim at T0.
- Quasi Real-Time Calibration & Alignment at CAF.
- Re-reconstruction at Tier-1 with new constants.
- Starting from startup conditions.

Two Scenarios from LHC Commissioning Schedule

Name	Bunch schema	Luminosity	Duration [effective]	Integrated Luminosity	HLT Output	Events
S43	43x43	$2 \cdot 10^{30}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$	6 days	$1\ \mathrm{pb}^{-1}$	300 Hz	150 M
S156	156x156	$2 \cdot 10^{31}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$	6 days	$10\ \mathrm{pb}^{-1}$	300 Hz	150 M

Tight schedule:

S43 and S156 alignment and calibration tasks in consecutive weeks.

Calibration and Alignment Tasks

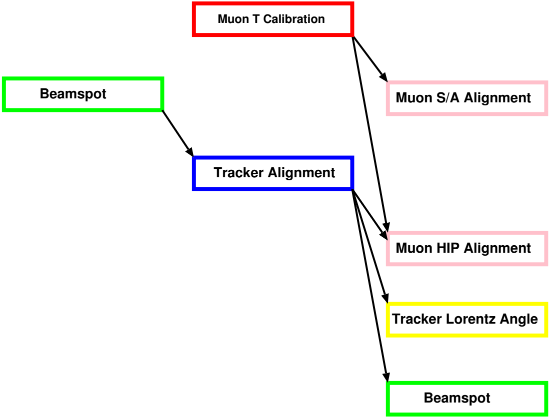
- Tracker Alignment:
  - Millepede algorithm,
  - HIP algorithm,
  - Kalman algorithm.
- Muon System Alignment:
  - HIP algorithm,
  - Standalone algorithm.
- ECAL Calibration:
  - ϕ-symmetry,
  - use of $\pi_0 \to \gamma\gamma$,
  - use of $Z \to e^+e^-$.
- HCAL Calibration:
  - ϕ-symmetry,
  - use of isolated tracks,
  - di-jet balancing.
- Tracker Calibration:
  - Pixel Lorentz angle,
  - Strip Lorentz angle,
  - Strip charge response.
- Muon Drift Tube (DT) Calib.:
  - time pedestal,
  - drift velocity.
- Muon Resistive Plate Chambers (RPC) Monitoring

$\Rightarrow$ Many parallel tasks as for real data.

Workflow Interdependence

Example Workflows Depending on Results of Other Workflows

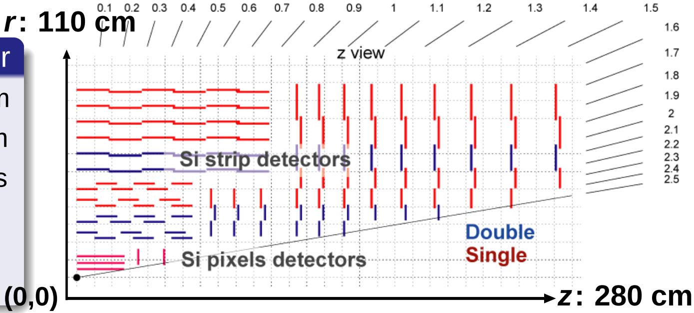
- Muon alignment with extrapolated tracks (HIP): Tracker Alignment.
- Muon standalone alignment: DT timing calibration.



- Taken into account for the first time.
- Established communication between teams:

⇒ Conditions exchange before being official.

CSA08 Results: Tracker Alignment



Full Silicon Tracker

- Pixel $r < 11$ cm
- Strip $r > 20$ cm
- $\approx 16k$ modules

$\Rightarrow$ up to 100k rigid body parameters

Three track based algorithms

- Common framework:
  - parameters,
  - database formats,
  - derivatives,
  - even including muon alignment.

$\Rightarrow$ Showing results from Millepede II algorithm (global fit approach, using 44k parameters).

CSA08 Results: Tracker Alignment

Datasets: $>$ 4 M Tracks

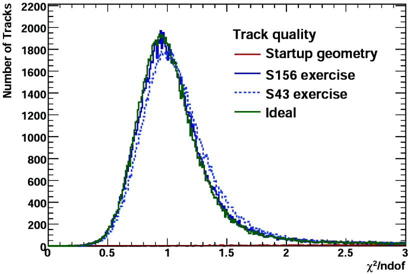
AlCaReco streams selecting:

- Minimum bias tracks ($p_t > 1.5$ GeV).
- Isolated muons.
- $Z \to \mu\mu$ decays.
- $J/\Psi \to \mu\mu$ decays.
- Cosmic muons.

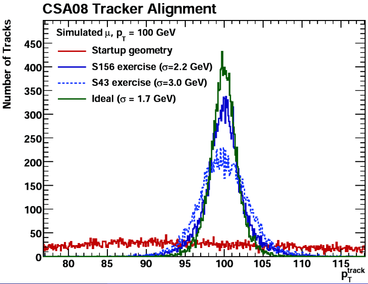
Results (S156)

- In time for muon alignment:
  - 50x 30 minutes CPU,
  - 1x 5h CPU.
- p_t^{rec} of $p_t^{gen} = 100$ GeV (μ)
  - $\sigma = 2.2$ GeV
  - ideal: 1.7 GeV

Data Driven: $\chi^2/ndof$



Monte Carlo: p_t resolution

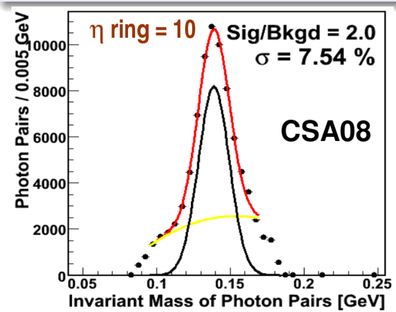


$\pi_0 \longrightarrow \gamma\gamma$ Method

- Constraining energies of unconverted photon pairs to π_0 mass.
- Target precision in Barrel using 2k π_0 per crystal with $E_t(\pi_0) \approx$ 5 GeV: 0.5% channel-to-channel.
- High rate up to 1 kHz expected at LHC:

$\Rightarrow$ AlCaRaw stream to keep data rate acceptable:

Only 3x3 crystal around candidates stored.

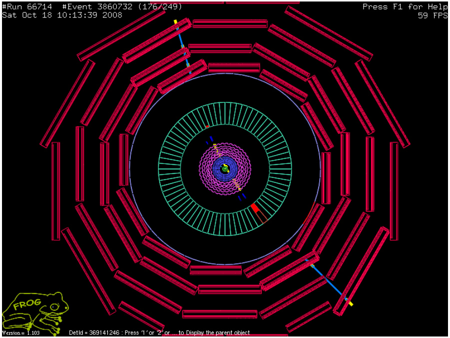


Results

First and successful test of end-to-end offline workflow:

- Channel-to-channel precision of 1% achievable in barrel within a few days of data taking.

Real Data Taking: Cosmic Muon Data



CRUZET and CRAFT

Cosmic **RU**n at **ZE**ro **T**esla

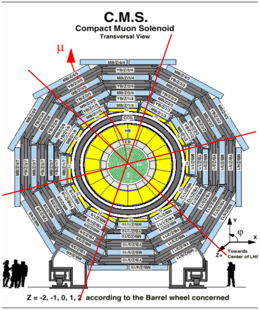
- Global Run of complete CMS.
- Around the clock.
- Since July with silicon tracker.

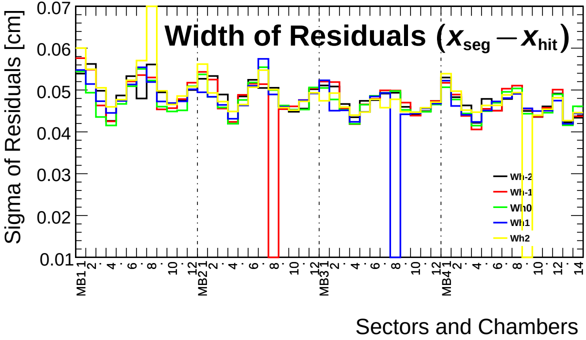
Since mid October magnet 3.8 T:
Cosmic **R**un at **A**lmost **F**our **T**esla

AlCaReco Streams

- Dedicated for cosmic data.
- Run centrally by Data Operation since July.
- First RECO based streams.
- Steadily ramped up to nine streams.
- Added AlCaRaw recently.

Muon Drift Tube Calibration with Real Cosmic Data





Muon DT Chambers

- Drift tube detectors.
- Within iron yoke of barrel.
- Three superlayers each: 2x ϕ, 1x θ.

Calibration with CRAFT Data

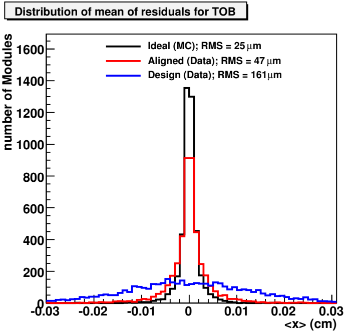
- Time pedestal: fit to digi time distribution.
- Validation: width of residuals $x_{segment} - x_{hit}$.
- Full workflow, but cosmics results limited:
  - Cosmic muons arbitrary in time.
  - Low statistics in horizontal chambers.
  - Known hardware problems.

Tracker Alignment with Real Cosmic Muon Data

CRUZET

- $B = 0$ T $\Rightarrow$ no momentum measurement.
  $\Rightarrow$ unknown multiple scattering.
- First results within a week!
- Accumulated coherent set of 345k AlCaReco events.

Mean Residuals per Module



Results

- Mean track hit residuals ($>$ 100 hits):
  - **Data Design Geometry.**
  - **Aligned Data.**
  - **Monte Carlo (no misalignment).**

$\Rightarrow$ Precision reached order of magnitude of simulation.

- Mainly barrel region covered so far.

Current Data Taking

CRAFT

- Collecting Data with B-Field until November 11th.
- $> 2.5 \cdot 10^6$ tracker cosmic AlCaReco events (until 31.10.)

$\Rightarrow$ First pixel tracker alignment within reach.

Conclusions

- CMS Alignment and Calibration Faces Big Challenges.
- Framework for Prompt Alignment and Calibration Set up.
- Very Successful Commissioning:
  - Simulation challenges (CSA08),
  - Cosmic Data Taking with $B = 0$ T and 3.8 T (CRUZET/CRAFT).
- Special Data Streams for Alignment and Calibration (AlCaReco and AlCaRaw):
  - Enable fast response of algorithms.
  - Production almost routine.
- Encouraging Results from Alignment and Calibration Workflows.

Framework in shape, exercised and confronted with real data:

CMS is well prepared for alignment and calibration challenges during collision data taking.