CMS Alignment and Calibration Framework

Setup and First Experiences with Data

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Outline

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Challenges and Requirements

- Event reconstruction at the LHC will be a complex task

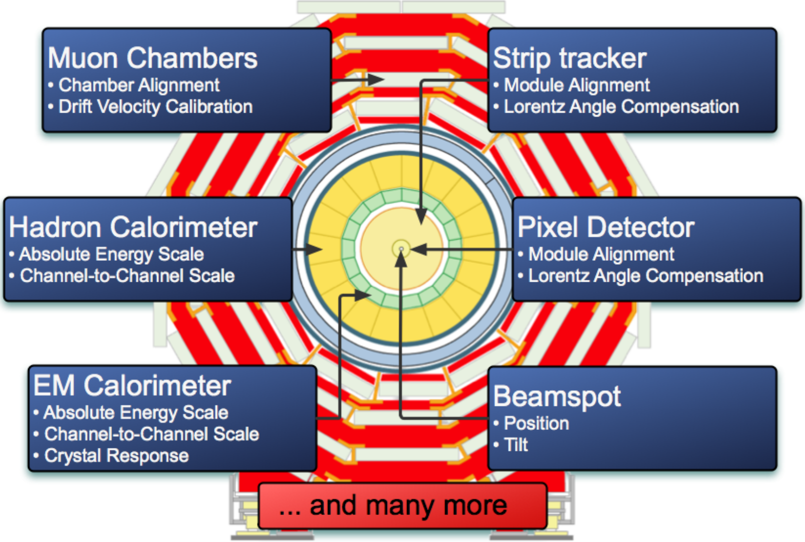
Challenges

- Design performance of CMS detector requires high precision alignment and calibration
- Fast turnaround for physics studies
- High data rates at LHC $\Rightarrow$ stress on computing infrastructure

Requirements to the Framework

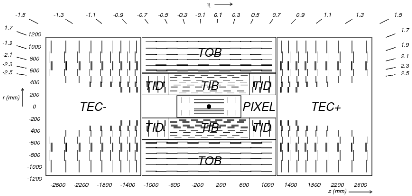
- Provide fast flow of specific data needed for alignment/calibration
- Provide fast turnaround for alignment/calibration tasks
- Ability to handle many tasks in parallel
- Database infrastructure for handling of alignment/calibration conditions

The CMS Detector and some Example Alignment and Calibration Tasks



Example Alignment and Calibration Task

Track-based Alignment



The Challenge

- 1440 pixel +15148 strip modules ×6 degrees of freedom
- High measurement precision $\mathcal{O}(10\ \mu\text{m})$
- Sensitive to small changes

The Solution

- Use tracks to measure the module position and orientation
- Minimize $\chi^2 = \sum \frac{(x_{meas} - x_{reco})^2}{\sigma^2_{meas}}$ for all hits on all tracks
- Need many $\mathcal{O}(10^6)$ tracks

- Large computational problem
- Streamlined process required (e.g. I/O)

Outline

Alignment & Calibration Skims (AlCaReco) - Selection

Many algorithms need to run (even iterate) on a large number of events (e.g. track-based alignment).

Definition of AlCaReco

- Reduced event rate and size
  ⇒ Efficient use of computing resources (i.e. fast turnaround, minimize I/O overhead, maximize storage efficiency)
- Filter events (exploiting HLT and reconstructed information) and event content
  ⇒ Only necessary information is stored
- HLT selection read from database
  ⇒ Flexibility to react on changes in HLT menus

Alignment & Calibration Skims (AlCaReco) Content

- Diverse tasks and subsystems
  $\Rightarrow$ Input to alignment and calibration tasks differs widely
- Event content according to specific alignment/calibration purpose (e.g. reconstructed data, data not available after reconstruction or non collision data)
- Multiple AlCaReco skims are foreseen, used by ≥ 1 task (e.g 9 during cosmic ray data-taking)
- Contain Data Quality Monitoring (DQM) histograms

Example: Content of Track-based Alignment AlCaRecos

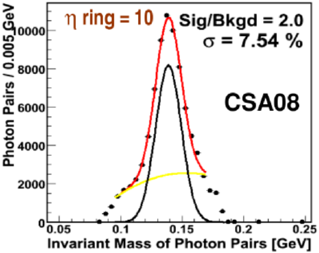
- Only tracks and clusters are needed to refit tracks
- Special AlCaReco skims containing:
  - Minimum bias tracks
  - Isolated muon tracks
  - Tracks from resonances decaying into muons (Z, J/ψ,Υ)
  - Cosmic ray muon tracks
  - Beam halo muon tracks

Reduced Data Format for Transport (AlCaRaw)

Some (currently calorimetry) calibrations need very high event rates
$\Rightarrow$ If limited by Point5 $\longrightarrow$ Tier0 bandwidth, reduce data format at Point5

Idea

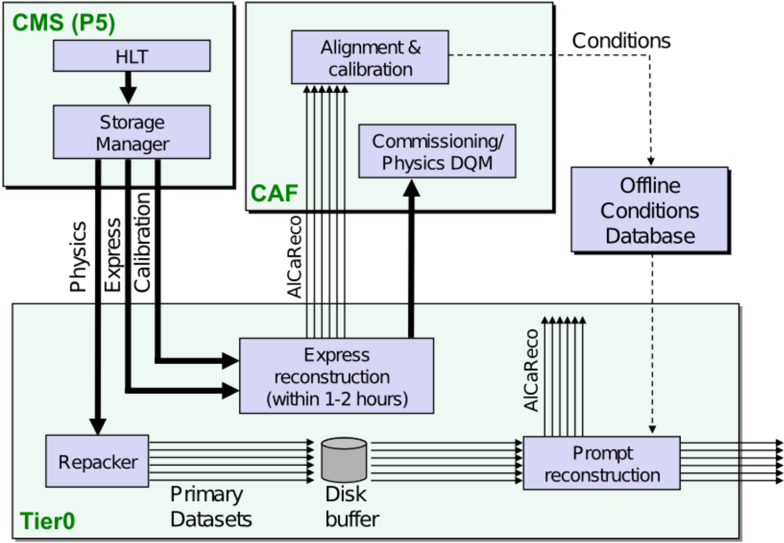
reduce RAW event size
$\longrightarrow$ higher rate Point5 to Tier0 possible
$\longrightarrow$ partial reconstruction to AlCaReco



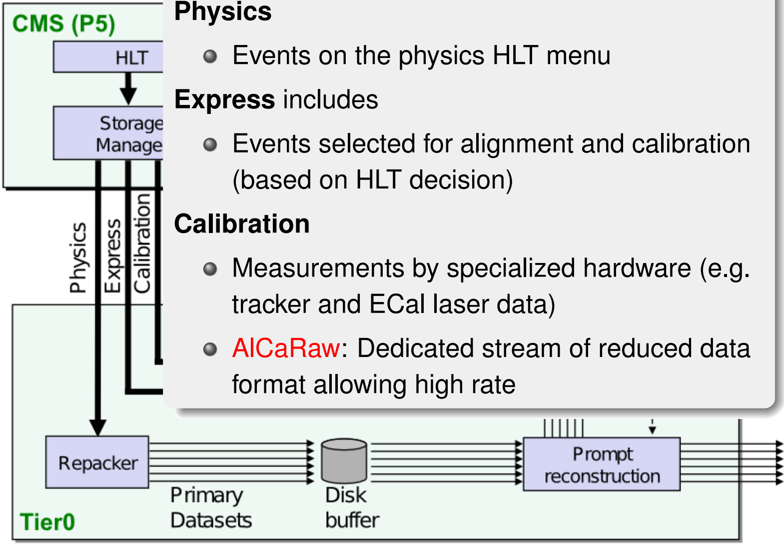
Example:
ECal channel-to-channel calibration

- Use $\pi^0 \longrightarrow \gamma\gamma$ decay at expected rate of 1 kHz (special HLT trigger)
- Constrain photon energies to π^0 mass to calibrate
- Allows precise and fast calibration
- Transfer of full data format would saturate bandwidth
- Store 3×3 crystals around photon seed only in AlCaRaw

Steps of the Alignment and Calibration Workflow



At Point 5



Transferred to Tier0

Physics

- Events on the physics HLT menu

Express includes

- Events selected for alignment and calibration (based on HLT decision)

Calibration

- Measurements by specialized hardware (e.g. tracker and ECal laser data)
- AlCaRaw: Dedicated stream of reduced data format allowing high rate

At the Tier0

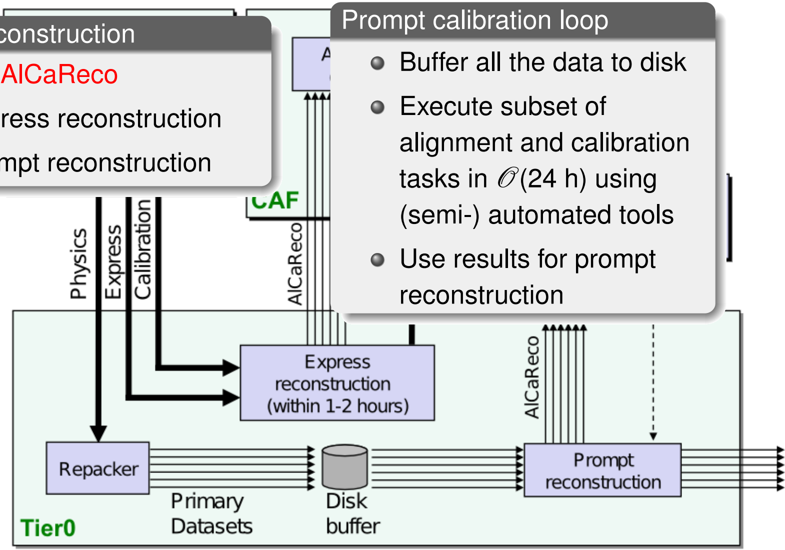
Event reconstruction

includes AlCaReco

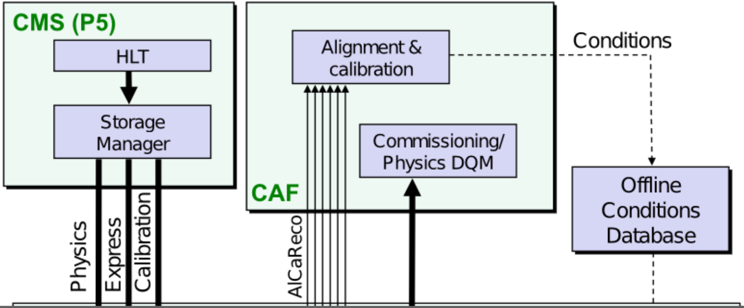
- Express reconstruction
- Prompt reconstruction

Prompt calibration loop

- Buffer all the data to disk
- Execute subset of alignment and calibration tasks in $\mathcal{O}(24\text{ h})$ using (semi-) automated tools
- Use results for prompt reconstruction



At the CERN Analysis Facility (CAF)

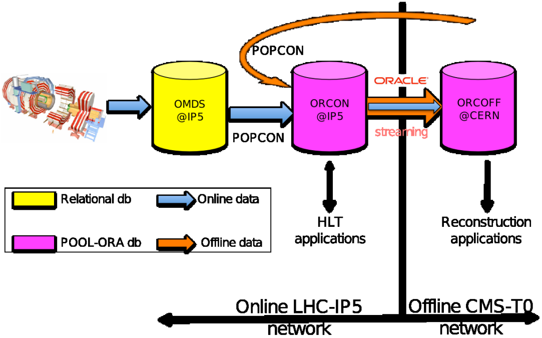


CERN Analysis Facility (CAF)

- Alignment and calibration tasks are executed on CAF
- Batch farm with interactive access
- Data and intermediate output stored on disk

$\Rightarrow$ Fast task execution, validation and debugging

Storage and Distribution of Alignment/Calibration Conditions



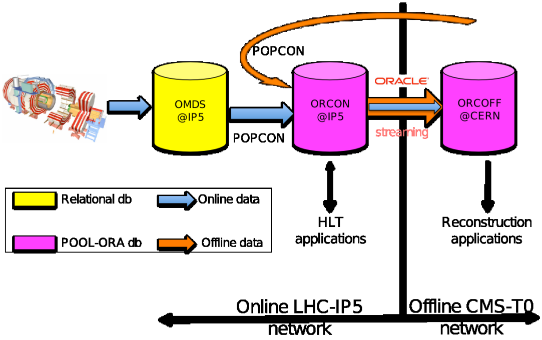
Goals

- Independence of off-site networks
- Robust access to offline conditions

accomplish different aspects using 3 databases

OMDS	Central registry for online conditions
ORCON	For offline conditions read by the online network
ORCOFF	For offline conditions read by the offline network
POPCON	Service to populate ORCON from various sources

Storage and Distribution of Alignment/Calibration Conditions



Goals

- Independence of off-site networks
- Robust access to offline conditions

accomplish different aspects using 3 databases

- Offline conditions are updated after sign-off
- Interval of validity (IOV) is stored with every set of conditions
- High level trigger can benefit from updated offline conditions
- Through ORCOFF and a hierarchy of proxies (Frontier) conditions are propagated other sites

Outline

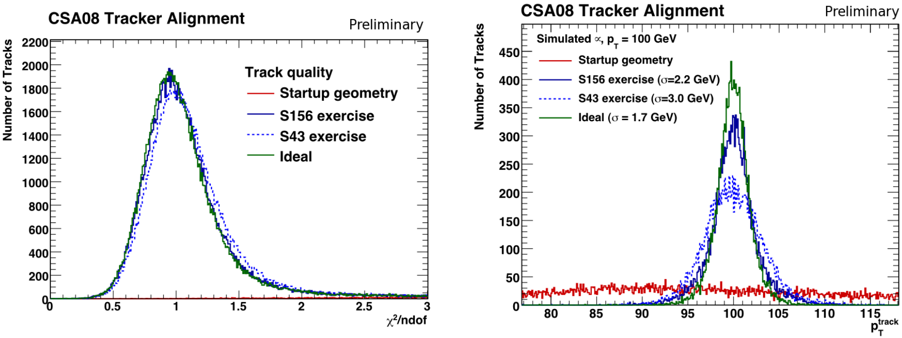
Computing, Software and Analysis Challenge in 2008 (CSA08)

- Simulating two start-up scenarios: 43×43 and 156×156 bunches
- For each scenario the equivalent of one week continuous data taking

Goals

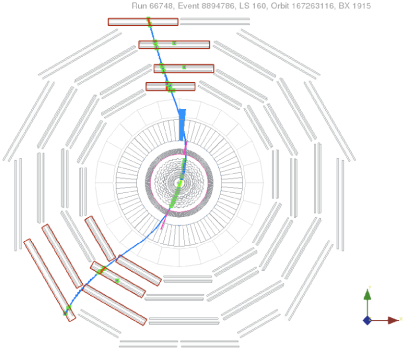
- Large scale Monte-Carlo exercise of all components
- Similar conditions as expected for first data in 2008
- Special emphasis on schedule: The workflow was exercised in the given week, including inter-dependencies of tasks

Track Based Alignment Results



- Track χ^2/ndof of aligned geometry nearly ideal
- Reconstruction of transverse momentum show improvements with statistics and used data sets

Cosmic Ray Data-Taking in 2008

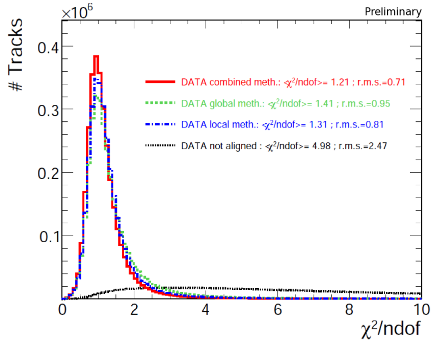


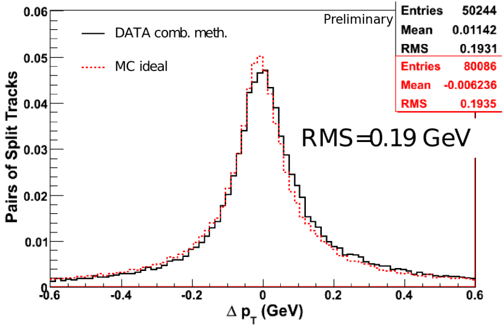
- 23 days of data-taking with magnet, strip tracker and drift tube muon system at nominal operation
- Triggered 270 M Events
- Executed a great variety of alignment and calibration tasks
- Opportunity to study real detector effects

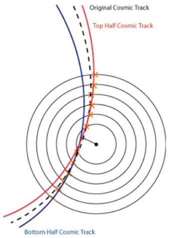
- Data has been studied to great detail
- Many paper drafts in their final stages

Track Based Alignment Results

Using Cosmic Data from 2008





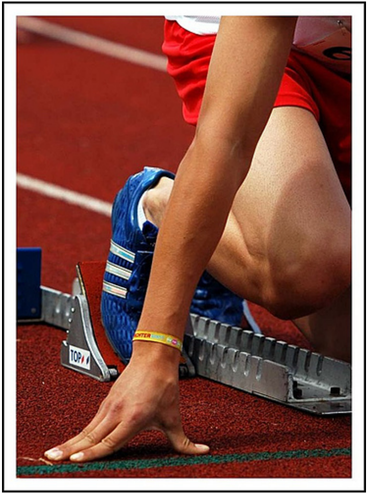


- Track χ^2/ndof greatly improved using cosmic ray data
- Split long track, use two halves to estimate Δp_T
  - Transverse momentum resolution measured from data shows large improvement, too.

Toward LHC Start-up in 2009

- Cosmic ray data were taken again in 2009
- Prompt alignment and calibration workflow of 3 tasks exercised for the first time
- Conditions were written to the databases in time for prompt reconstruction
- Longer term studies on their way to validate 2008 studies
- Results of cosmic run alignment and calibration to be used with first data
- Further tests of improved software with simulated collision data during fall 2009

Summary



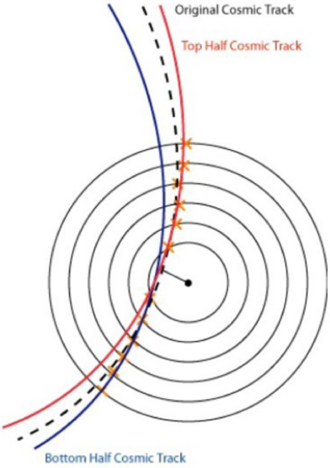
- Detector alignment and calibration is a challenging task at the LHC
- CMS has developed and commissioned a powerful framework for alignment & calibration
  - dedicated skims (AlCaReco)
  - algorithms performed at the CAF
  - prompt calibration concept
  - distributed conditions database
- The framework has been tested extensively on simulated and real data

Conclusion

Results show that the alignment and calibration framework is well prepared for collision data

The End

Measuring Track p_T Resolution from Data



- Only use tracks going through the pixel detector
- Split each track at the point of closest approach
- Refit both half on their own
- Compare transverse momentum measurements of both halves