


CMS: Alignment work and data flow

Jim Pivarski, Alexei Safonov

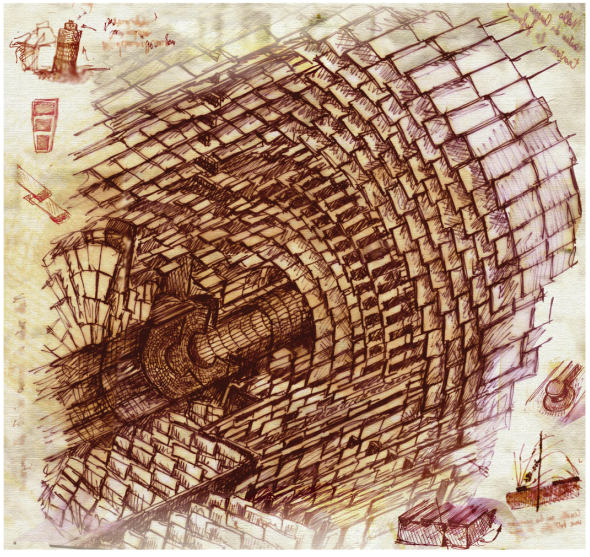
Texas A&M University

26 June, 2007

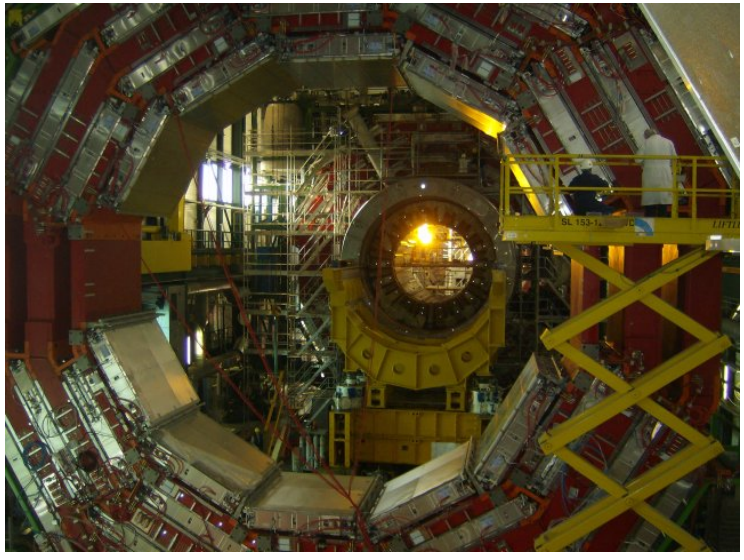
General direction of this talk

- Physical data flow: from raw data to alignment corrections
- Software architecture
- Monitoring alignment output
- Alignment exercises in Monte Carlo and data

Tracking systems at CMS

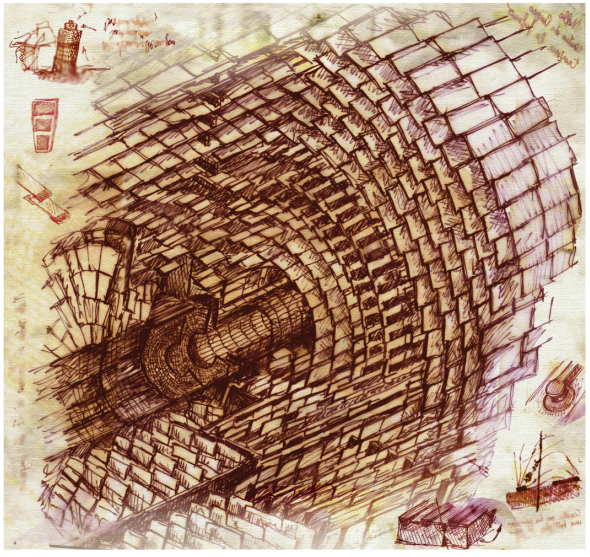


Silicon tracker and pixel detector: 15,000 modules

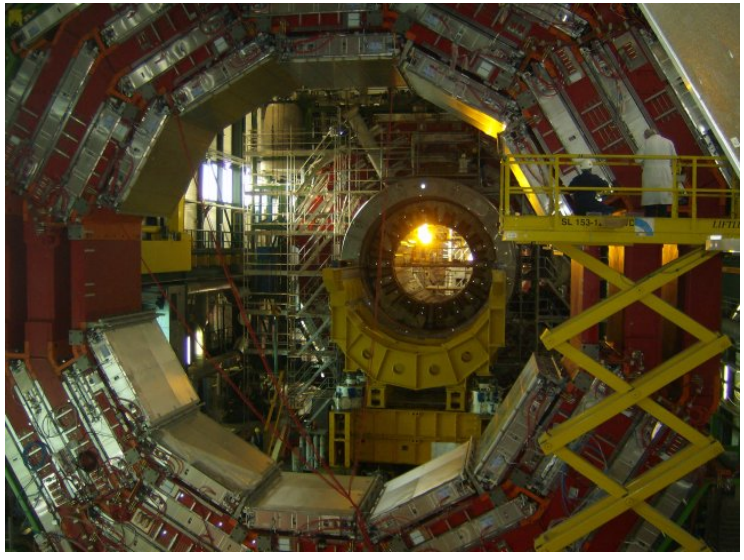


Muon detector: track sees 18–45 layers: an independent tracking system in its own right

Tracking systems at CMS



Silicon tracker and pixel detector: 15,000 modules



Muon detector: track sees 18–45 layers: an independent tracking system in its own right

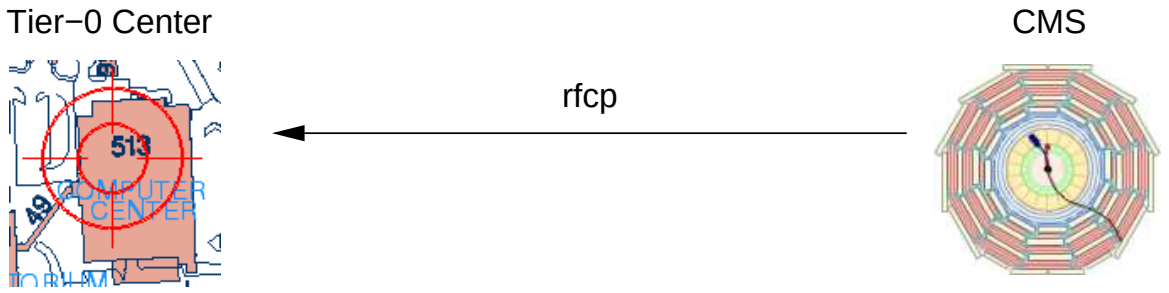
- This talk will be both about alignment of both


Physical data flow

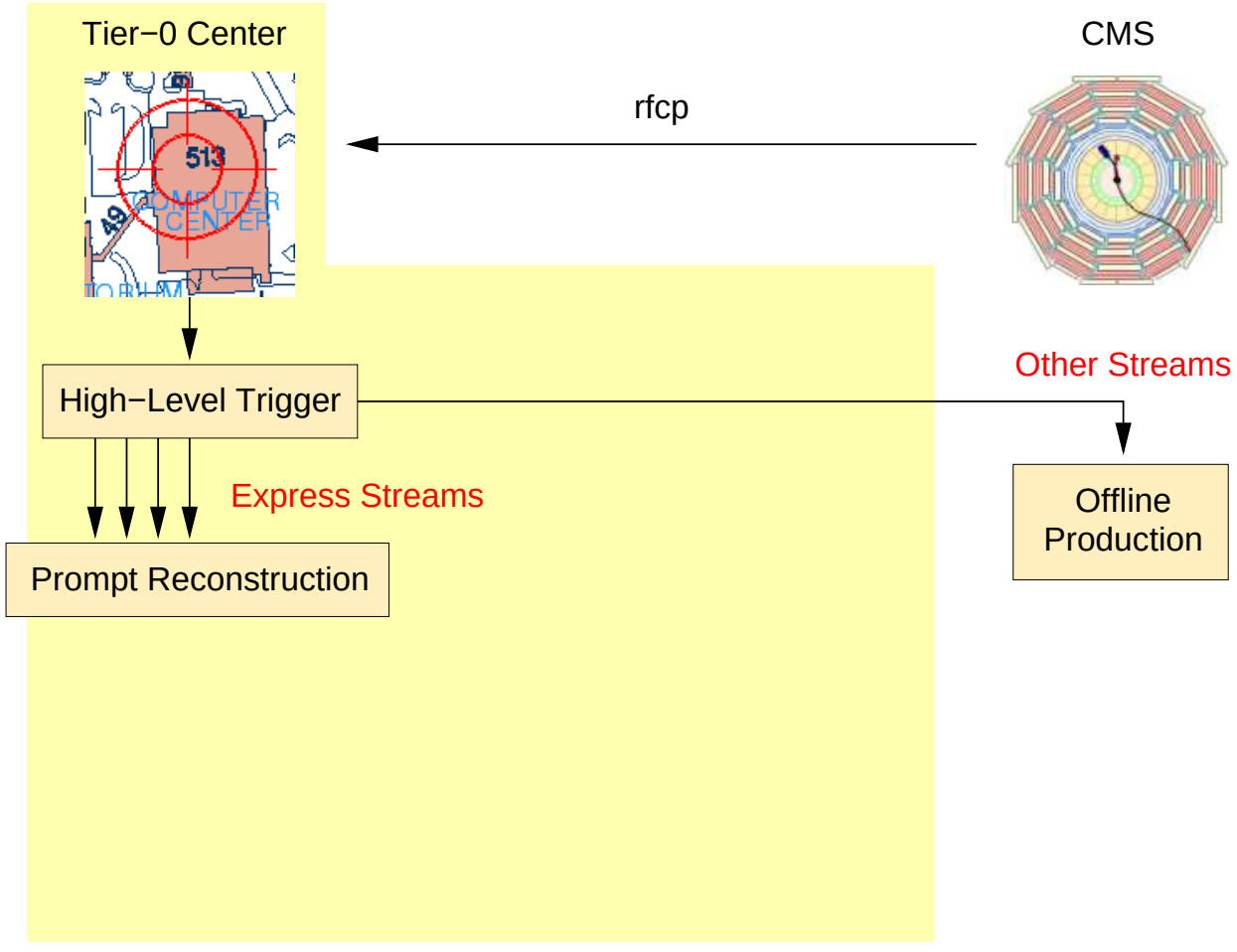
Motivation for prompt alignment

- CMS High-Level Trigger uses the same reconstruction software as offline, including alignment corrections
- Alignment results improve the performance of our trigger
- We want an infrastructure to immediately align on tracks, as they are read out of the detector

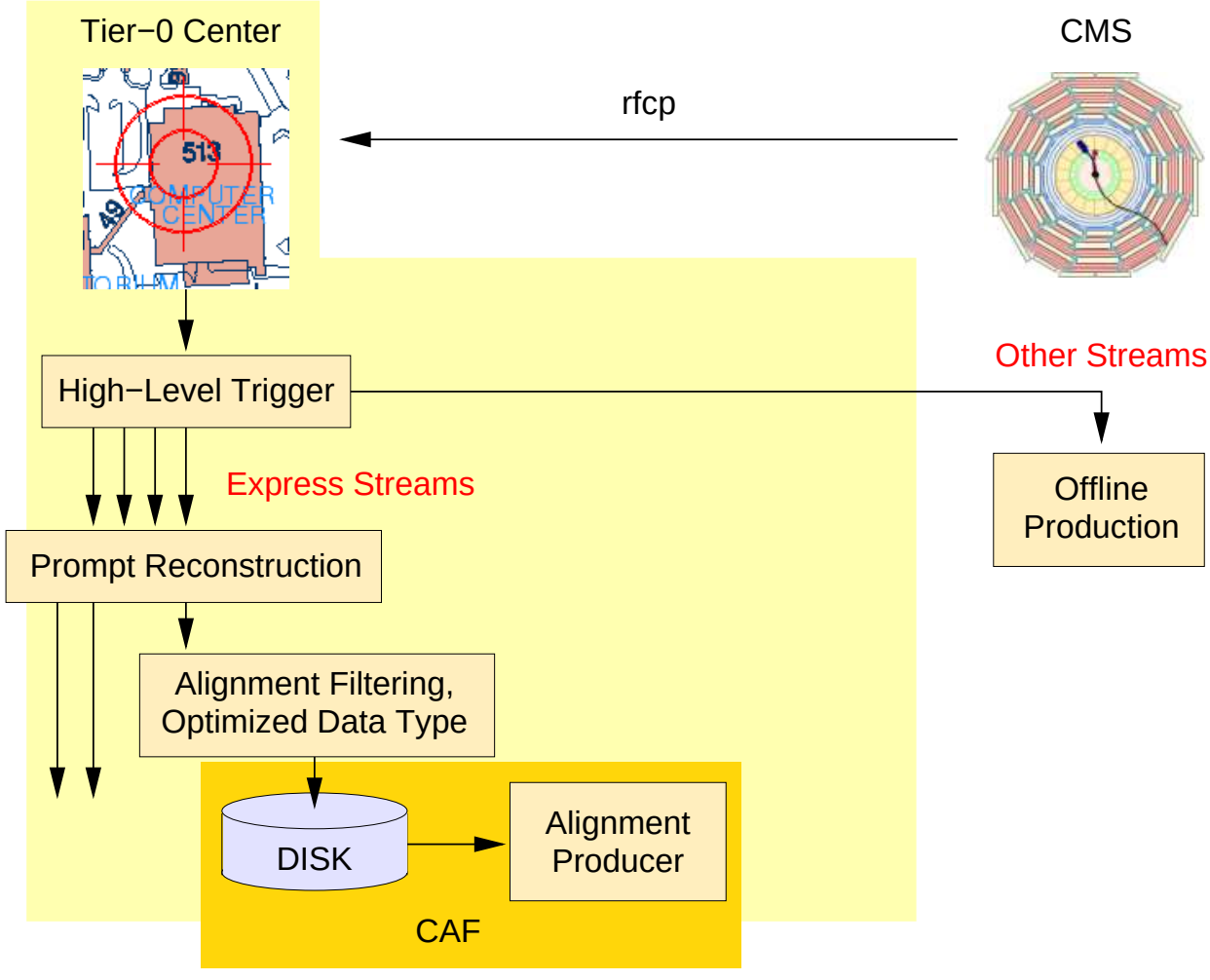
From CMS read-out to alignment to corrected data



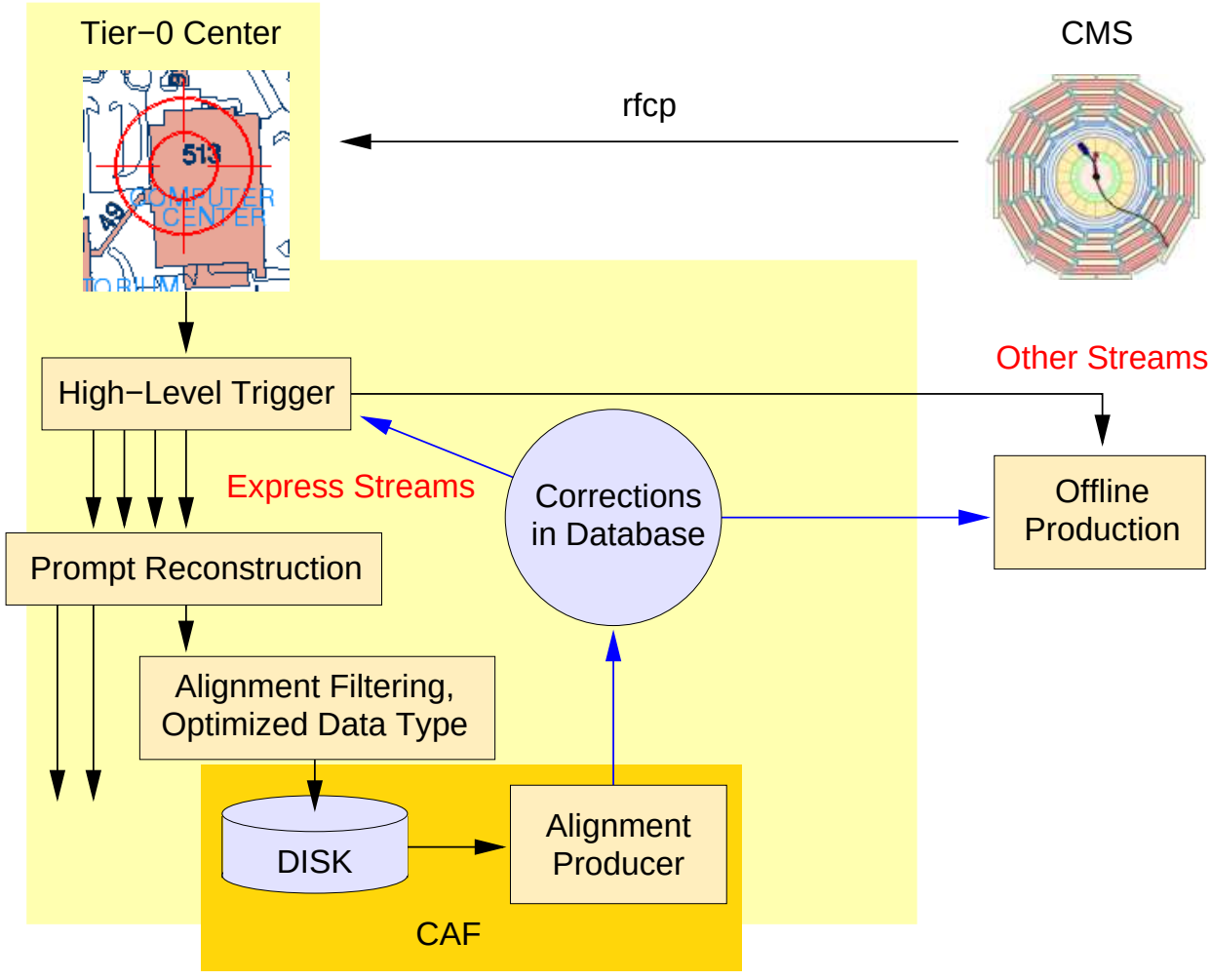
From CMS read-out to alignment to corrected data



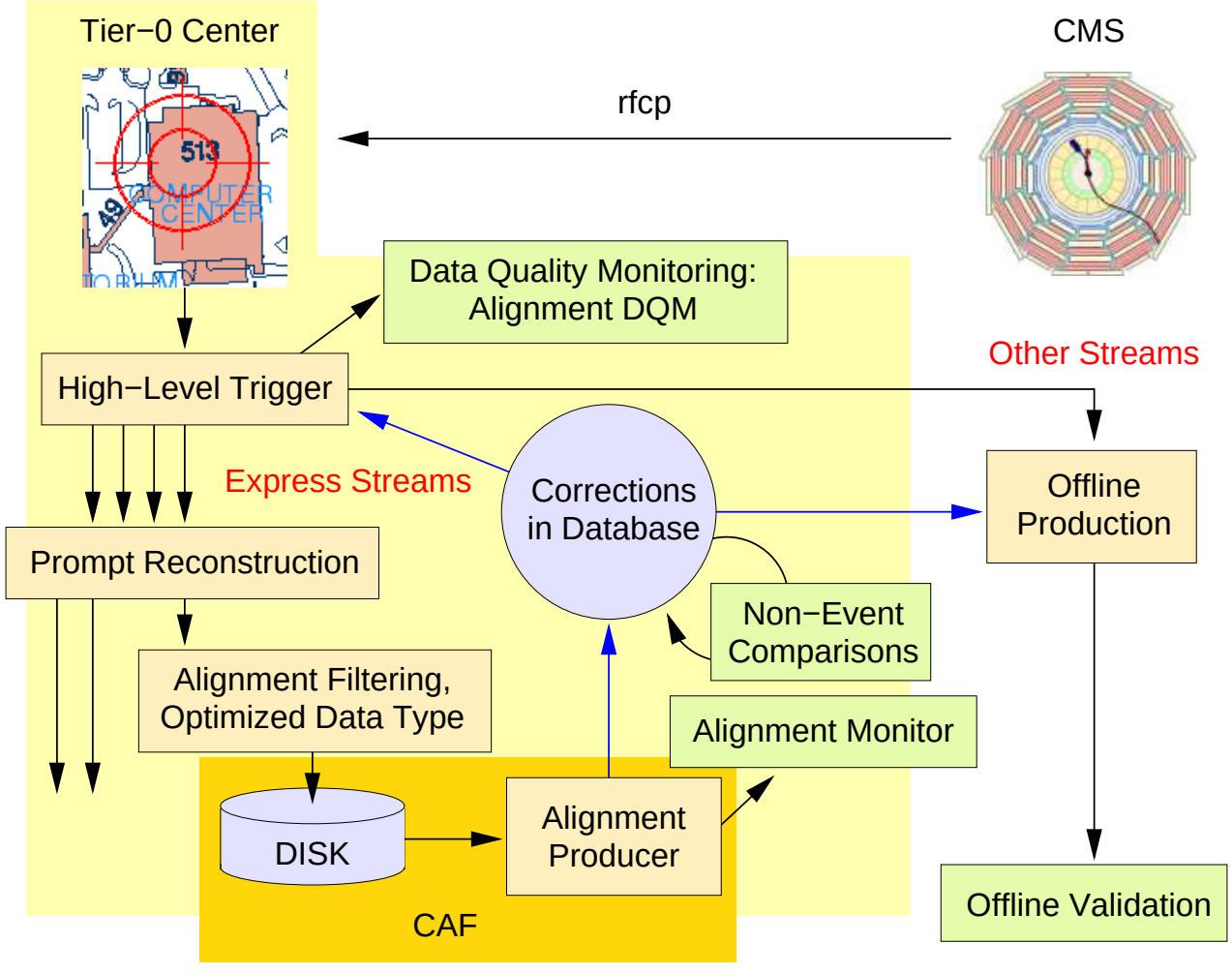
From CMS read-out to alignment to corrected data



From CMS read-out to alignment to corrected data



From CMS read-out to alignment to corrected data



Triggers and Express Stream

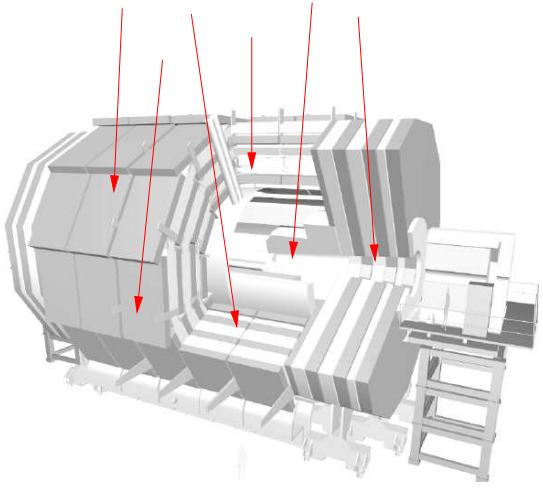
- Both tracking systems use muons for alignment
- Accept events from any trigger providing muons:
  single μ, di-μ, J/ψ, Υ, $Z \to \mu\mu$, μ with jets...
- Also include commissioning streams which select only on the basis of hardware trigger or partial High Level Trigger decisions

Triggers and Express Stream

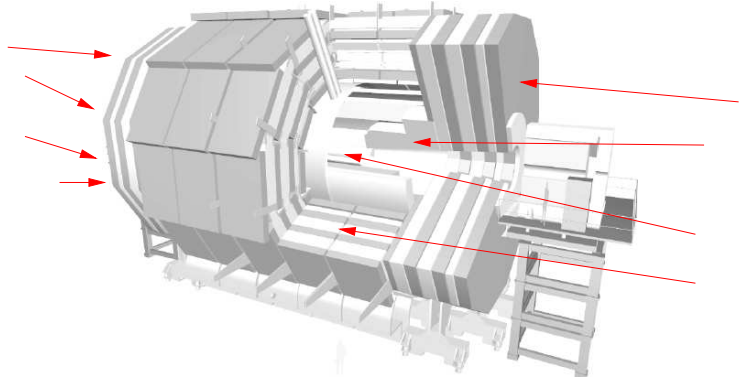
- Both tracking systems use muons for alignment
- Accept events from any trigger providing muons: single μ, di-μ, J/ψ, Υ, $Z \rightarrow \mu\mu$, μ with jets...
- Also include commissioning streams which select only on the basis of hardware trigger or partial High Level Trigger decisions

- Express Stream for alignment, calibration, monitoring, discovery channels (5–10% in normal running, 25% at first)
- Alignment stream is filtered to include only tracks/hits used for alignment (3k/event tracker, 10k/event muon)

Before first collisions



Cosmic rays, especially for barrels



Beam-halo, especially for endcaps

- A special pair of scintillator paddles added to extend η range of beam-halo trigger for tracker

Software

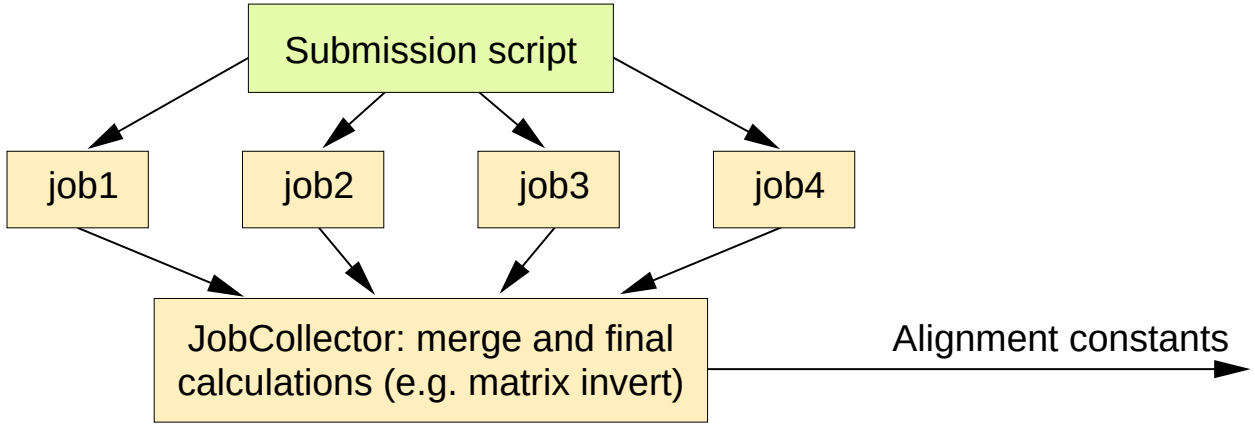
Common framework

- Common framework for
  - (a) all subdetectors
    - Muon system and Si-tracker use the same tracking data-formats and fitting algorithms
  - (b) all algorithms
    - HIP, MillePede II, and Kalman are plug-in modules

- Centrally manages
  - hierarchical geometry description with uncertainties and correlations at each level
  - coordinate transformations and derivatives
  - fixing/floating components and parameters
  - application of survey constraints
  - database access

Built-in parallel-processing

- Large alignment job can be split into sub-jobs
- Sub-jobs store partial calculations in temporary ROOT files
- JobCollector merges partial results, performs final calculation
- Monitoring histograms are merged in the same way



- Total time is determined by the last sub-job to finish, so alignment requires a dedicated farm

Monitoring

Four stages of monitoring

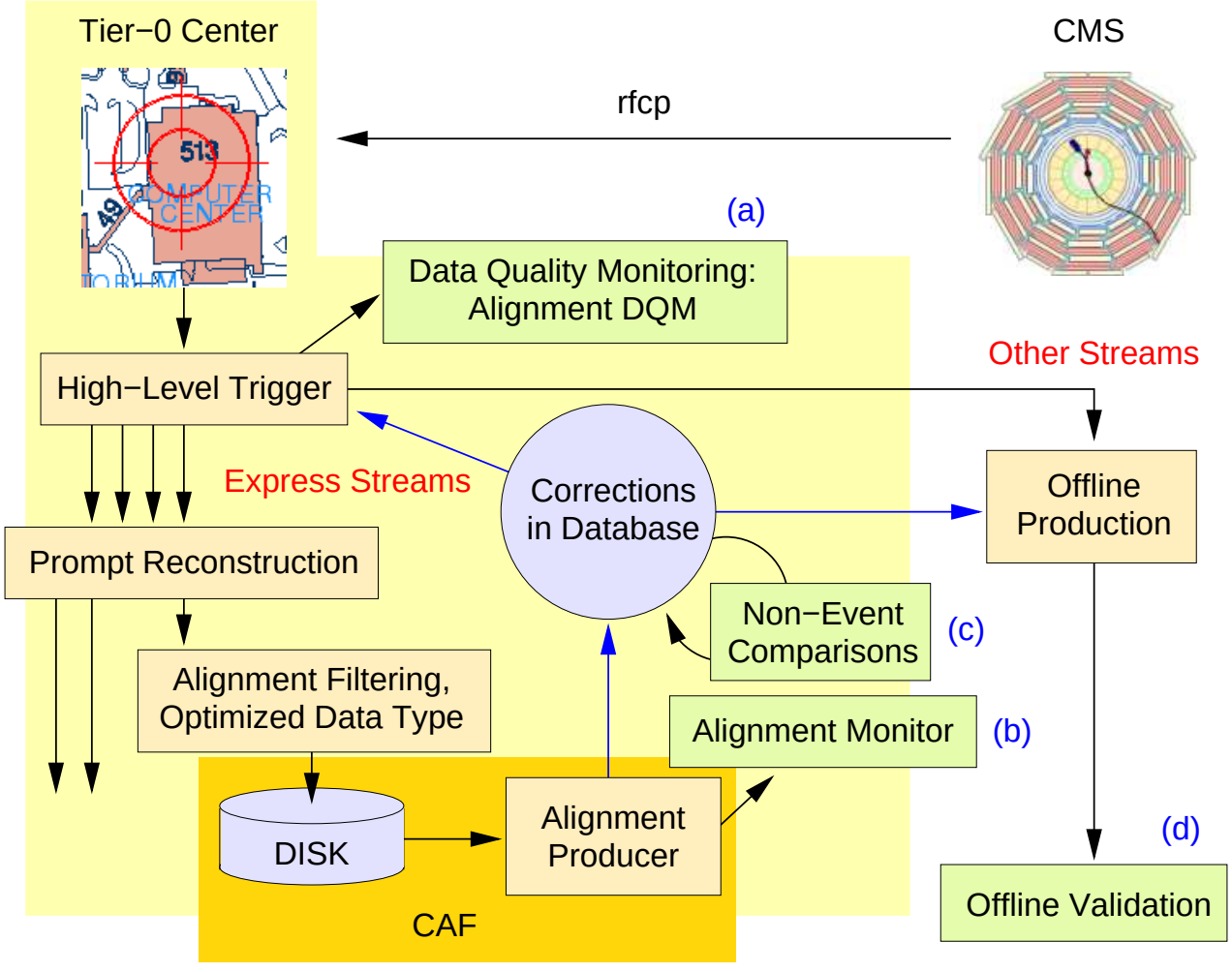
(a) Specialized plots for shifters in Data Quality Monitor (e.g. Z peak, agreement between overlapping chambers)

(b) Monitoring plots built into the alignment process

(c) Non-event level comparison of alignment geometries ("how different are these geometries?"), comparison with hardware/survey, and as a function of time

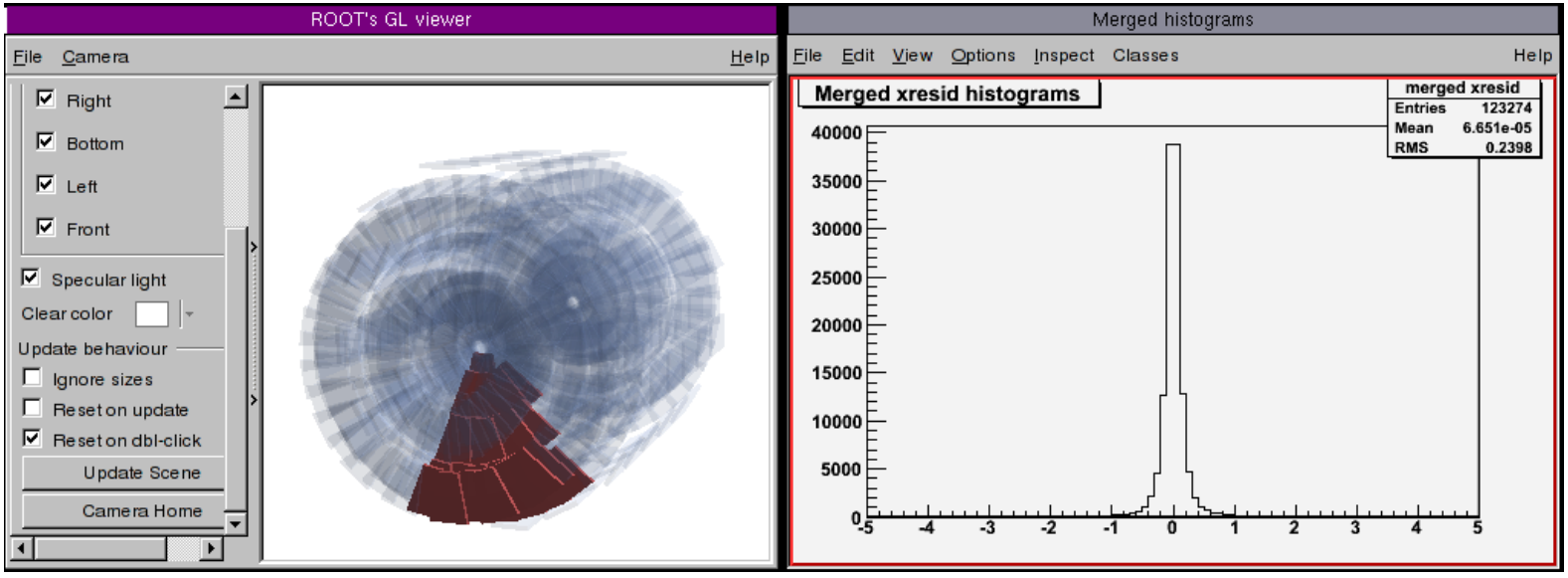
(d) Last check that we put the right thing into the database (same plots as (a))

Four stages of monitoring



Expert systems and routine plots

- Expert systems
  - Discover and zoom into problem areas
  - Manually read alignment corrections off of profiles

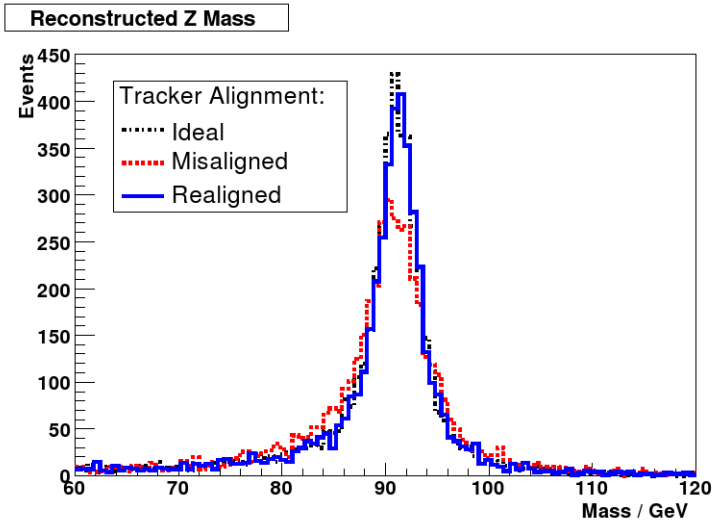


- Routine plots
  - Concise set of powerful alignment indicators
  - Will be derived from experience with expert systems

Alignment Exercises

CSA06: Computing Software Analysis 2006

- $\frac{1}{4}$ of anticipated 2008 data
- Emphasis on computing and work-flow, rather than alignment quality

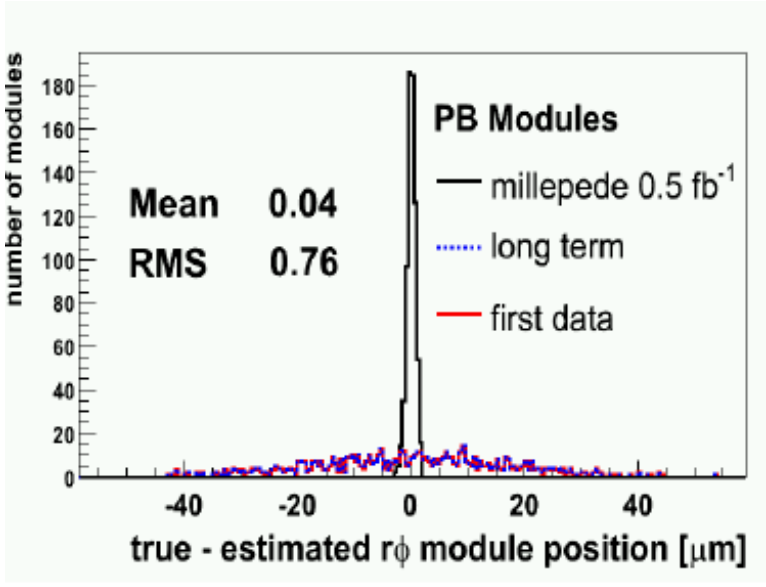


  - Full simulation of Si-tracker alignment
    - 2 million misaligned $Z \rightarrow \mu\mu$
    - HIP algorithm on a prototype of the alignemnt farm
    - Read/wrote geometry from database on-the-fly
    - Event sample re-reconstructed with corrections
  - Muon alignment tested the possibility of aligning at a remote Tier-2 site, with a simplified MillePede II algorithm

CSA07

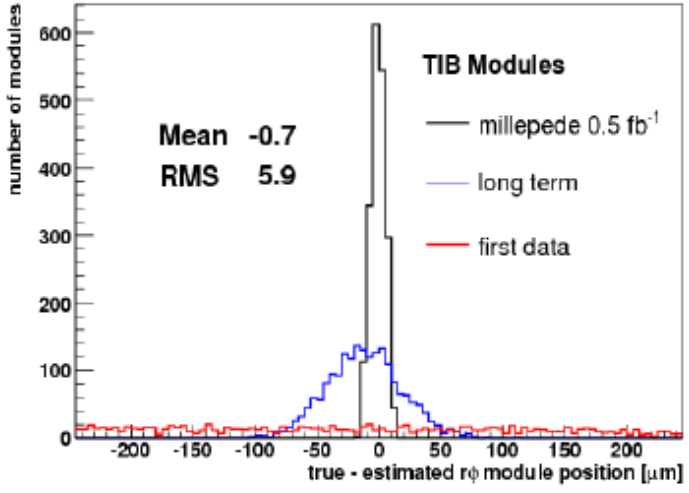
- Twice the data
- Mixed sample selected by High Level Trigger for realism
- Filter using simple p_T cut and using di-μ mass
- Tracker alignment will use the full MillePede II algorithm
- Muon alignment will do a full simulation with HIP (analogous to tracker in CSA06)
- Full exercise starts September 15

Demonstration of complete MillePede II tracker alignment



Pixel barrel RMS < 1 μm

Pixel barrel alignment an **order of magnitude** better than in the long term scenario.



TIB RMS = 6 μm

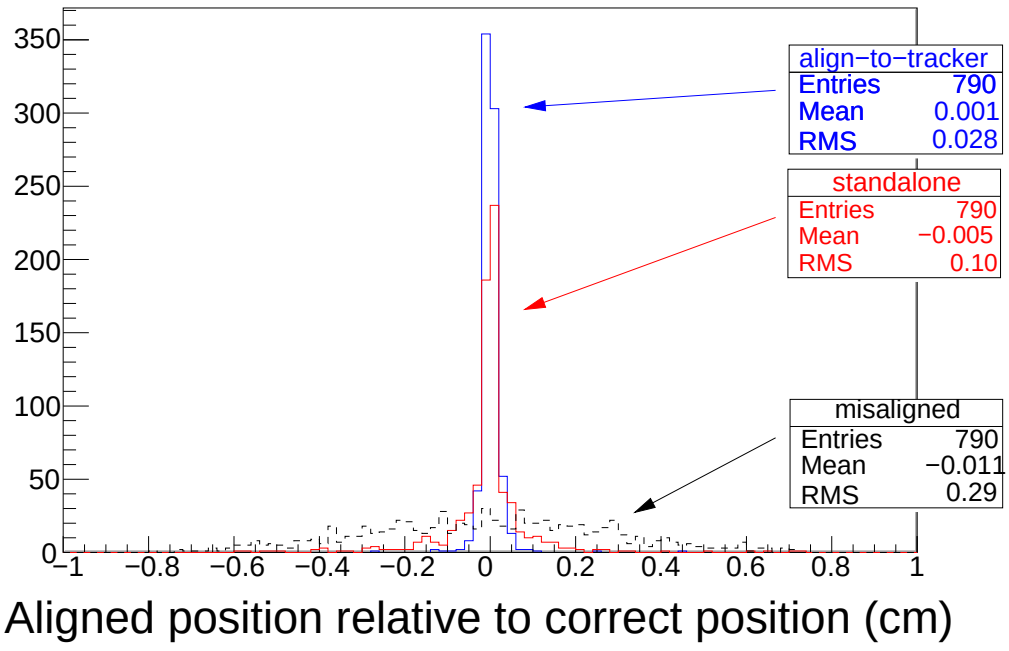
The inner barrel modules are well aligned in the r coordinate.

- 2 GB RAM, 1 h 40 min CPU (10 min matrix inversion)
- 3.5 million muon tracks

Demonstration of muon chamber alignment

(a) align muon system to tracker

(b) align standalone muon system without external reference



- 6 degrees of freedom, realistic initial misalignment
- 30 min per iteration (only standalone requires iterations)
- 16,000 muon tracks

Analysis of cosmic ray data underway

- 25% of Si-tracker is taking data in the Tracker Integration Facility (bât 186)
- 2 million cosmic rays (2 months)
- All three algorithms are currently being applied

Analysis of cosmic ray data underway

- 25% of Si-tracker is taking data in the Tracker Integration Facility (bât 186)
- 2 million cosmic rays (2 months)
- All three algorithms are currently being applied

- 21 muon chambers collected data in last September's Magnet Test Cosmics Challenge
- HIP and MillePede II are currently being applied

Analysis of cosmic ray data underway

- 25% of Si-tracker is taking data in the Tracker Integration Facility (bât 186)
- 2 million cosmic rays (2 months)
- All three algorithms are currently being applied

- 21 muon chambers collected data in last September's Magnet Test Cosmics Challenge
- HIP and MillePede II are currently being applied

- Real-data alignment efforts will continue with cosmic rays from upcoming Slice Tests, Global-Running-at-End-of-Months, local cosmic runs, and beam-halo from beam commissioning

Conclusions

- Infrastructure (farms, data streams) under development for prompt alignment
- Opportunities for human monitoring
- Proof-of-principle with full-scale exercises
- Cosmic ray alignments are happening right now