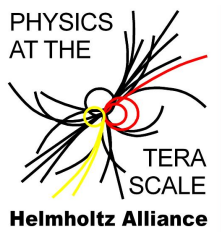
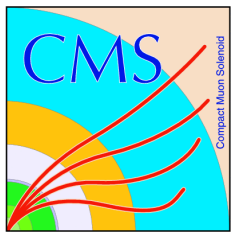
Integration of Alignment into Overall CMS Calibration Workflow

Gero Flucke
DESY
(on behalf of the CMS Collaboration)



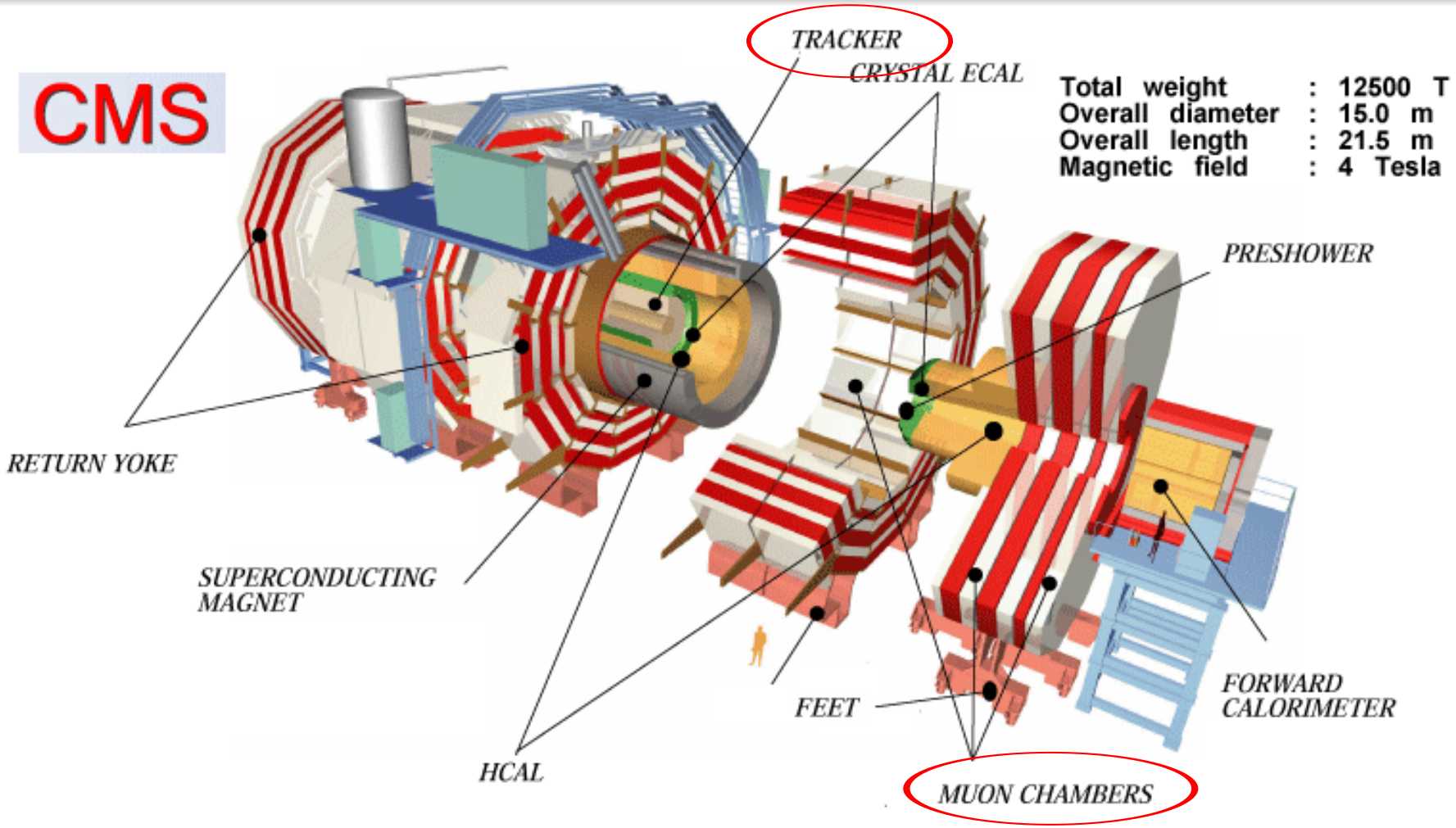


3rd LHC Detector Alignment Workshop
June 15-16, 2009
CERN, Geneva (Switzerland)

Outline

- Scope of the CMS Alignment Framework
- Alignment within the CMS Calibration Dataflow
- Alignment Constants in the Databases
- Simulation Exercise:
  - Computing, Software and Analysis Challenge 2008.
- Real Data Experience:
  - Data Taking with Cosmic Muons.
- Summary

The CMS Detector at LHC Point 5 (P5)



- Full Silicon Tracker.
- Large Solenoid: $B = 3.8$ T.

- Muon System in Return Yoke:
  - Drift Tube Chambers (DT).
  - Cathode Strip Ch. (CSC).

CMS Alignment and Calibration Challenge

Complex Reconstruction of LHC Events.

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

$\Rightarrow$ Short timescale to derive rapidly changing detector conditions.

- Special data formats to minimise I/O-overhead: AlCaReco.
- Which constants will be subject to frequent changes?
  - Analysis of LHC data will show.
  - **Alignment framework prepared.**

CMS Alignment Scope

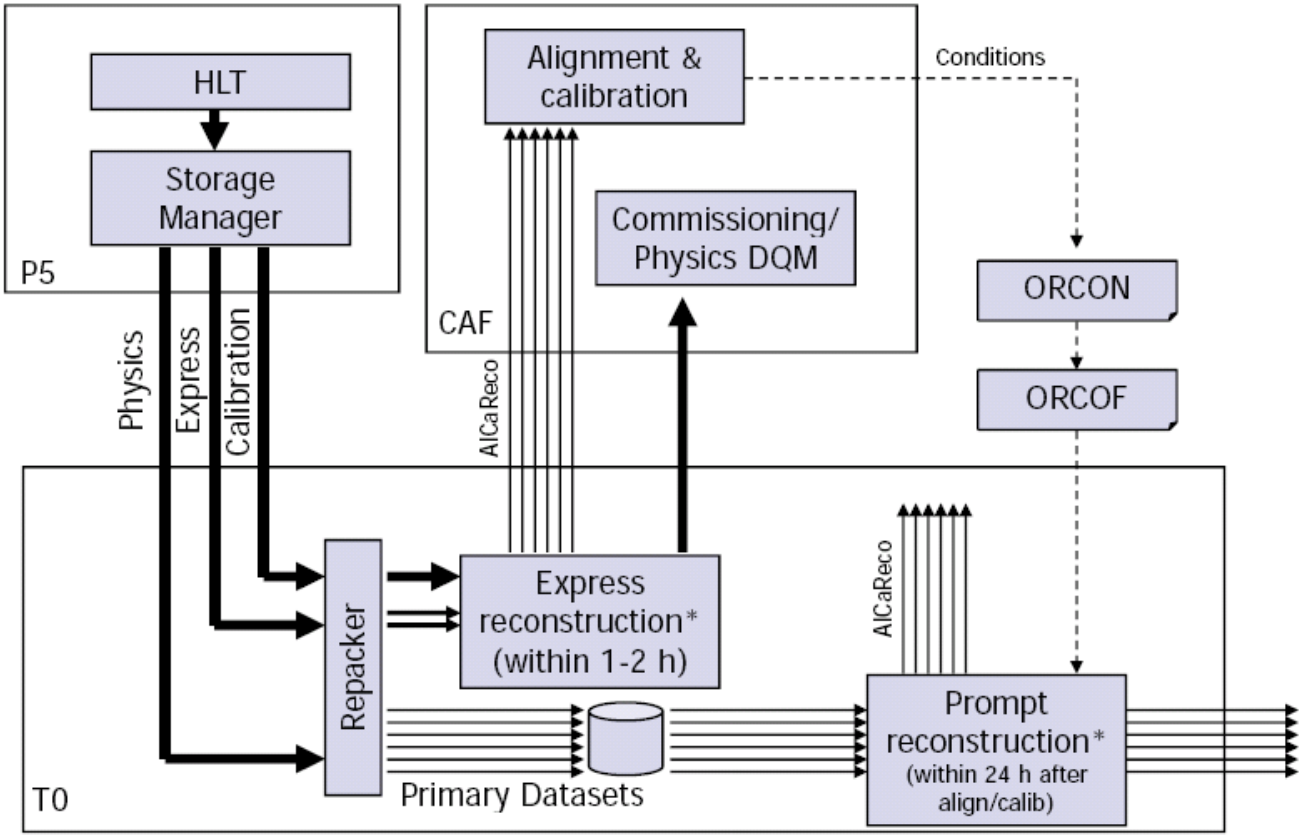
Alignment Most Relevant for Tracking Detectors

- Calorimeters:
  - Software capable to apply corrections to design geometry. . . .
- Silicon Tracker:
  - Input during LHC running:
    Laser Alignment System (LAS), tracks.
- Muon System:
  - DT (Barrel), CSC (Endcaps), RPC (coarse for trigger).
  - Input during LHC running:
    Hardware system, tracks.

Focus on:

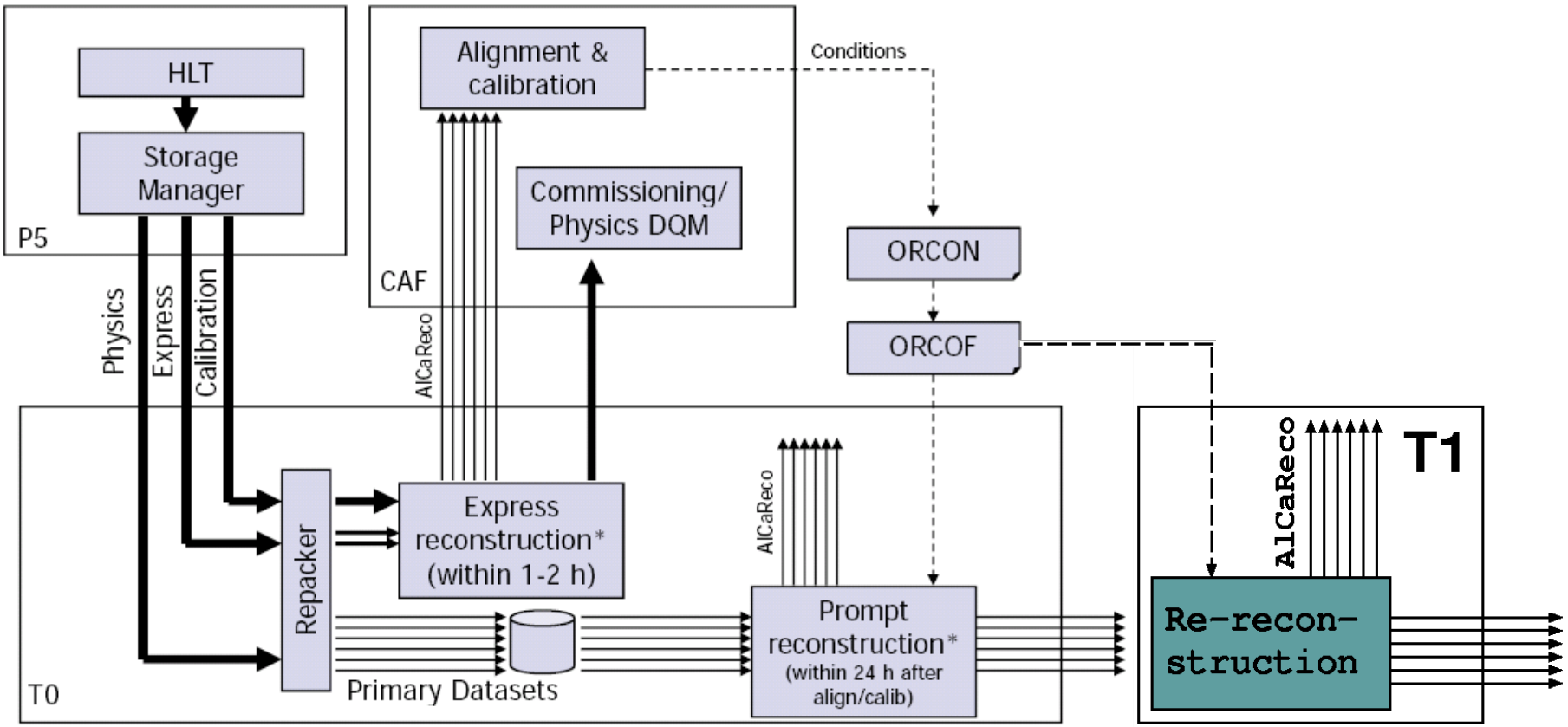
- Track-based Alignment.
- Tracker, DT and CSC.

Alignment/Calibration Workflow: Overview



- Here:
  for constants in prompt reconstruction workflow.
- Long-time constants:
  to be picked up in later re-reconstruction cycles.

Alignment/Calibration Workflow: Overview

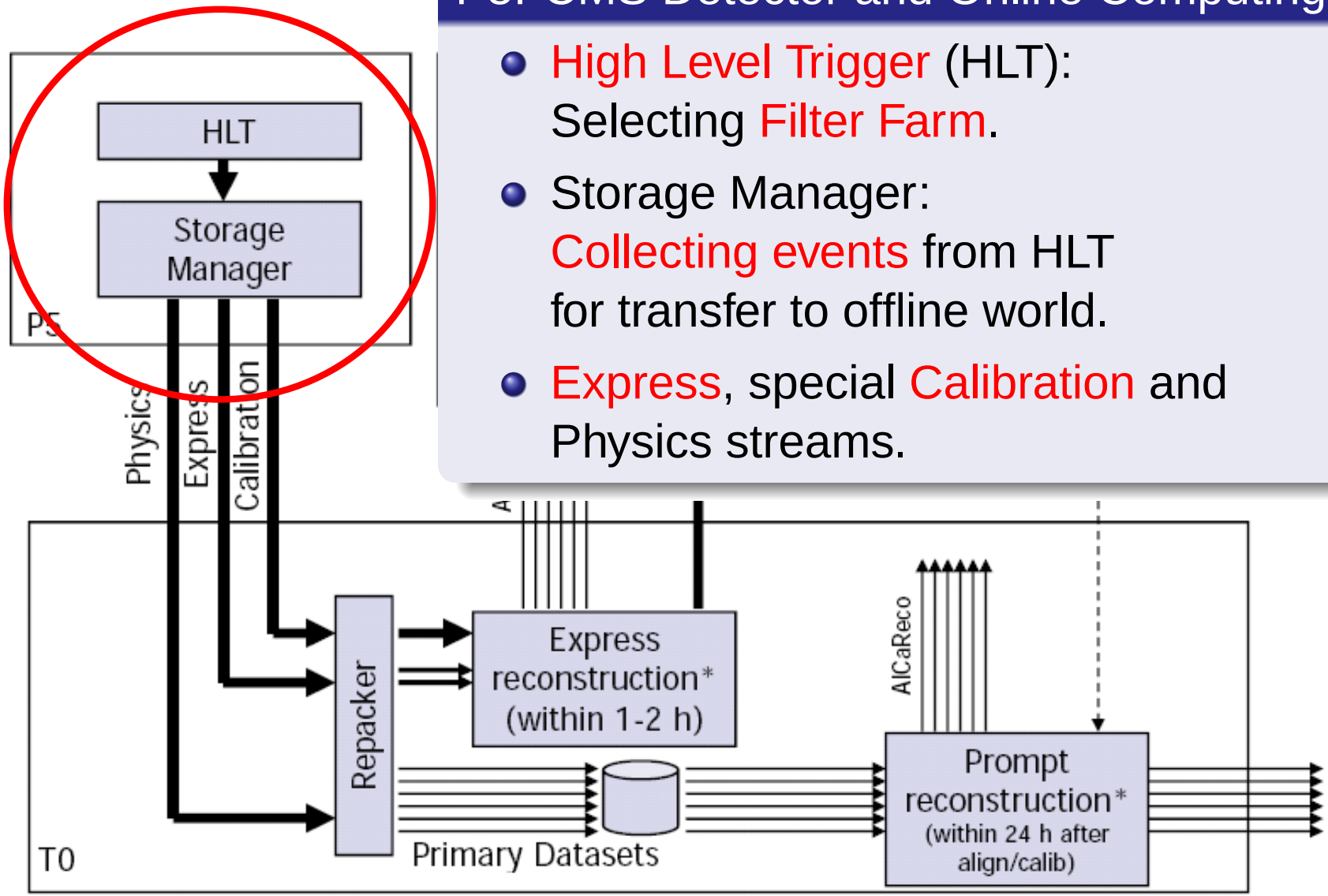


- Here:
  for constants in prompt reconstruction workflow.
- Long-time constants:
  to be picked up in later re-reconstruction cycles.

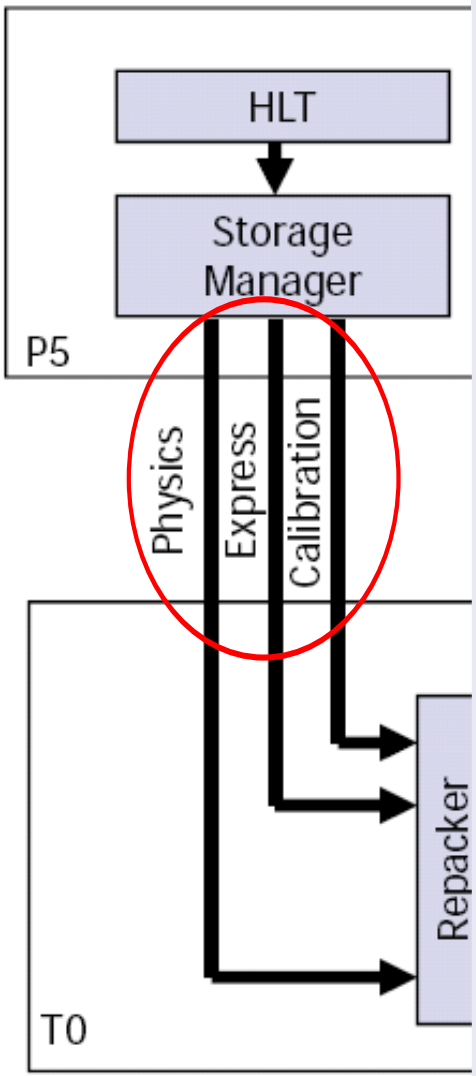
Prompt Alignment/Calibration Workflow: Point 5

P5: CMS Detector and Online Computing

- High Level Trigger (HLT): Selecting Filter Farm.
- Storage Manager: Collecting events from HLT for transfer to offline world.
- Express, special Calibration and Physics streams.



Prompt Alignment/Calibration Workflow: Data Streams



Data Streams

Physics

- Events selected for physics analysis (and longterm calibrations).

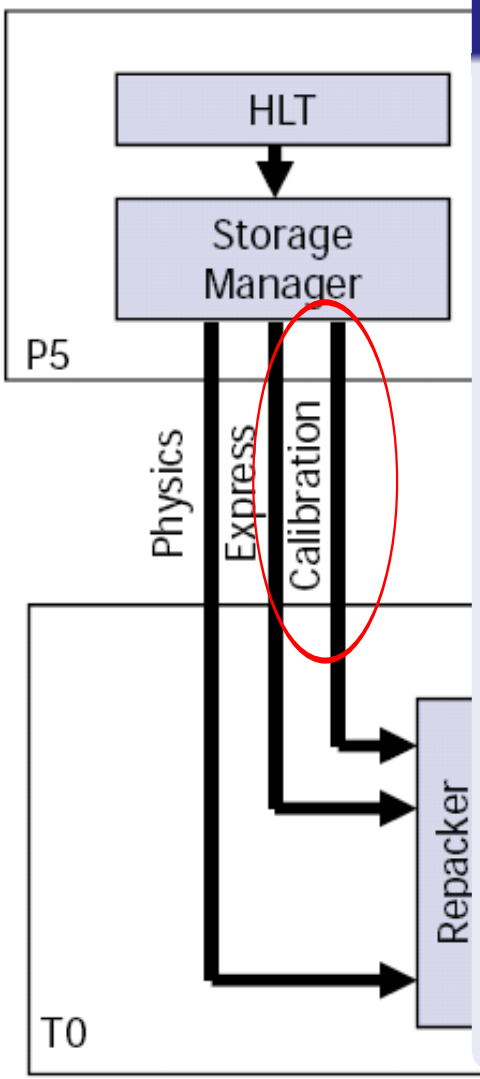
Express

- $\mathcal{O}$(10-20%) subset (defined by HLT): fast calibration, (physics) validation.

Calibration

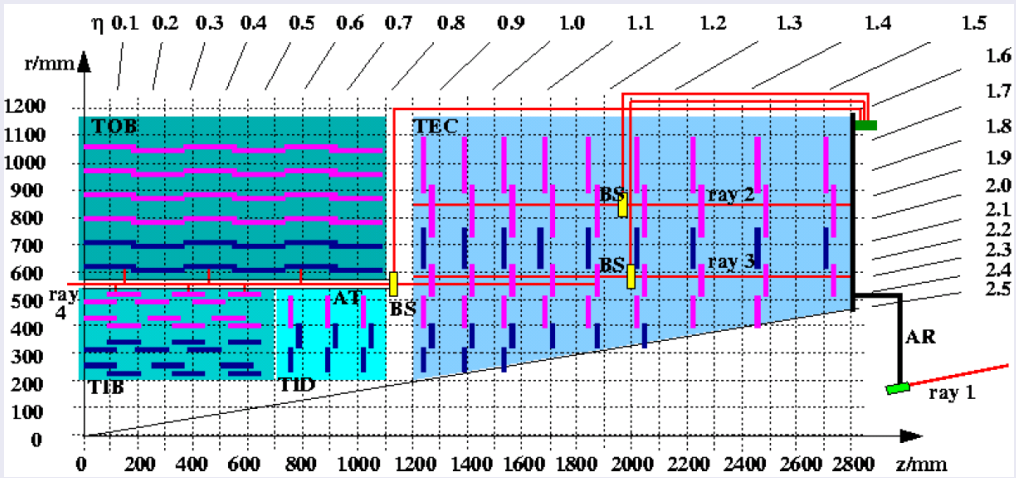
- Dedicated Datasets (AlCaRaw).
  - Special HLT output, reduced content: minimal information needed.
  - For procedures with very high event rate, otherwise saturating bandwidth.
  - e.g. for ECAL: $\pi^0 \rightarrow \gamma\gamma$ events.
- LHC abort gap events.

Prompt Alignment/Calibration Workflow: LAS



Abort gap events needed for alignment:

Tracker Laser Alignment System (LAS)

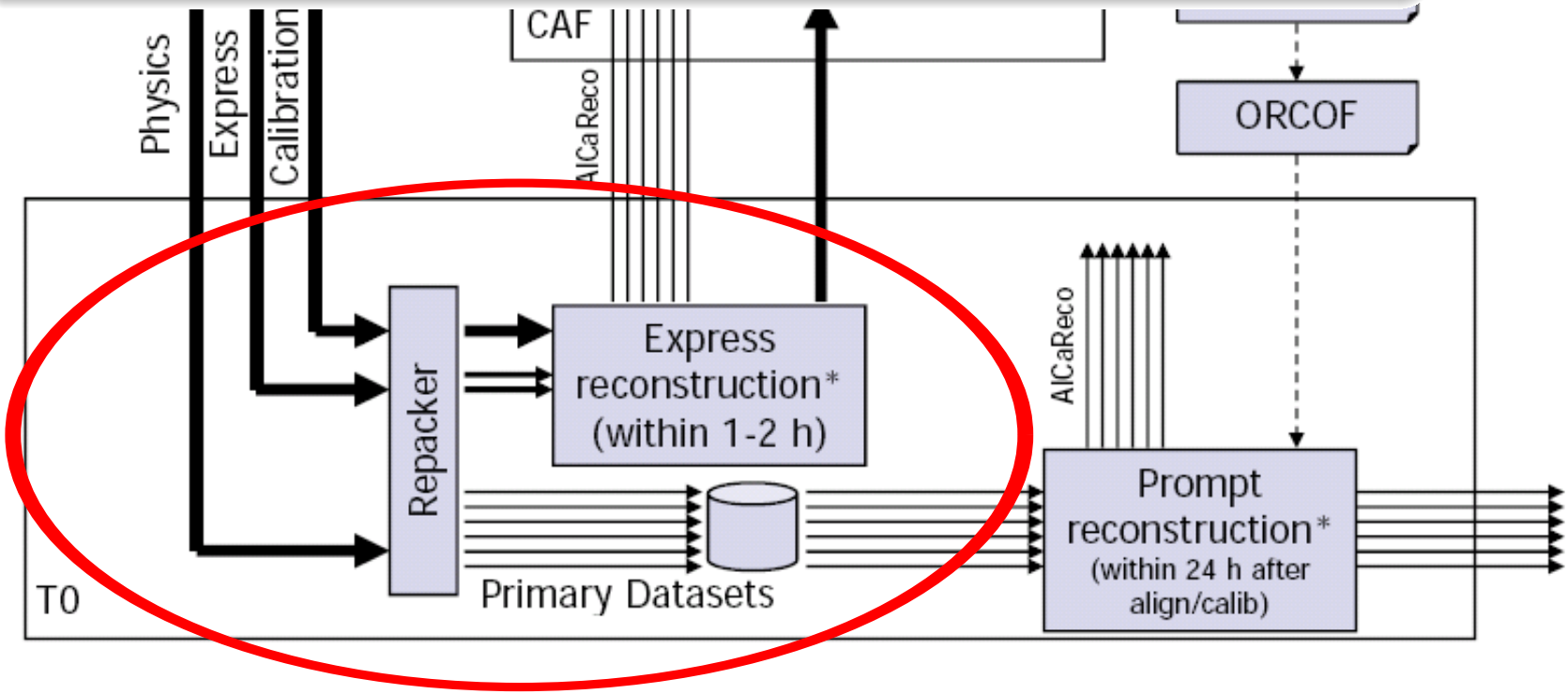


- About 2000 laser beam “shots”.
- 434 silicon strip modules hit.
- Operated ~once per hour.

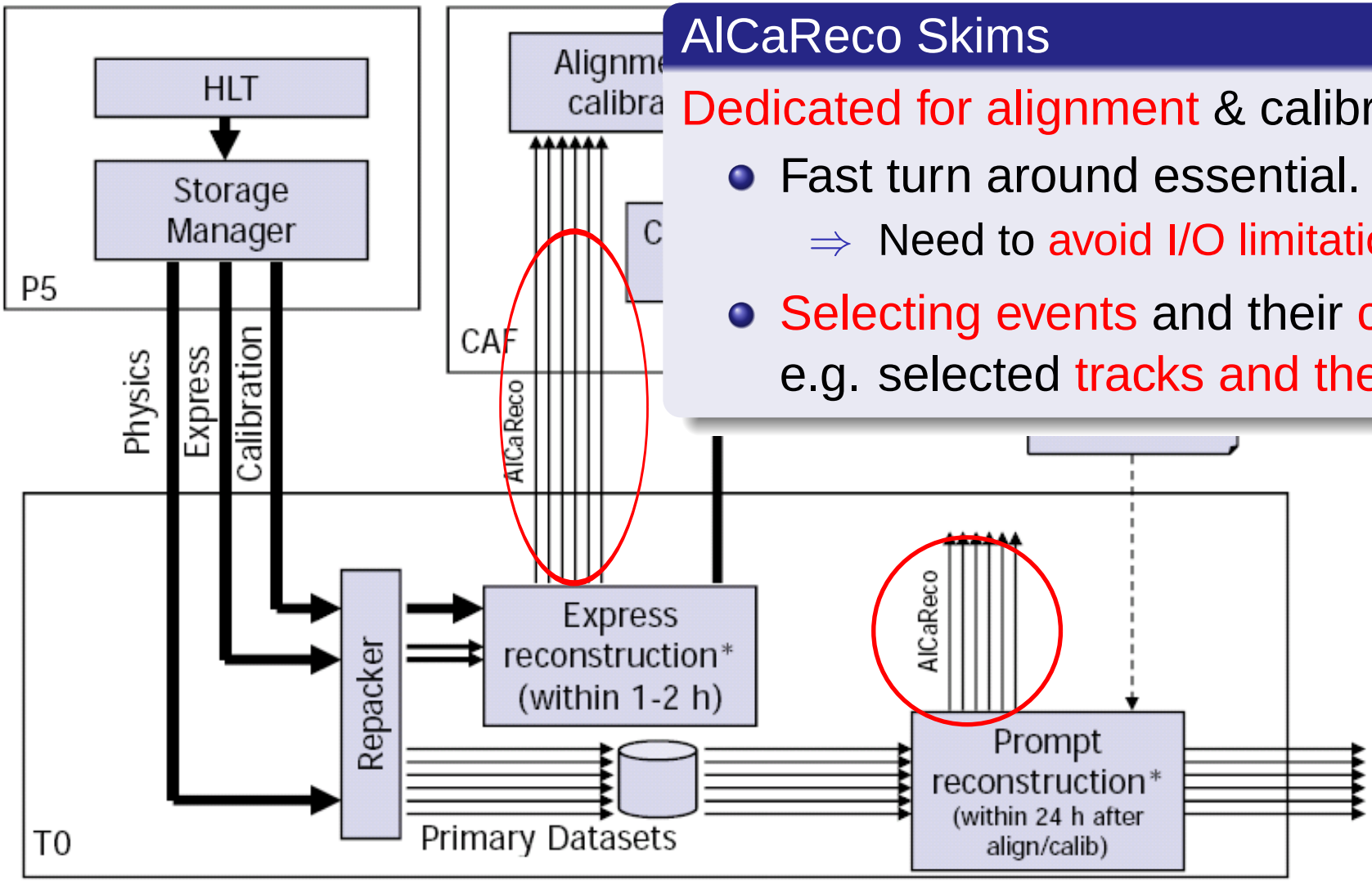
Prompt Alignment/Calibration Workflow: Expr. Reco

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

- Repack streams into Event Data Model format.
- Buffer bulk physics data on disk.
- Reconstruct express and calibration streams.
  - ⇒ Alignment and Calibration Skims (AlCaReco) for Monitoring and Short Latency Calibration.



Prompt Alignment/Calibration Workflow: AlCaReco

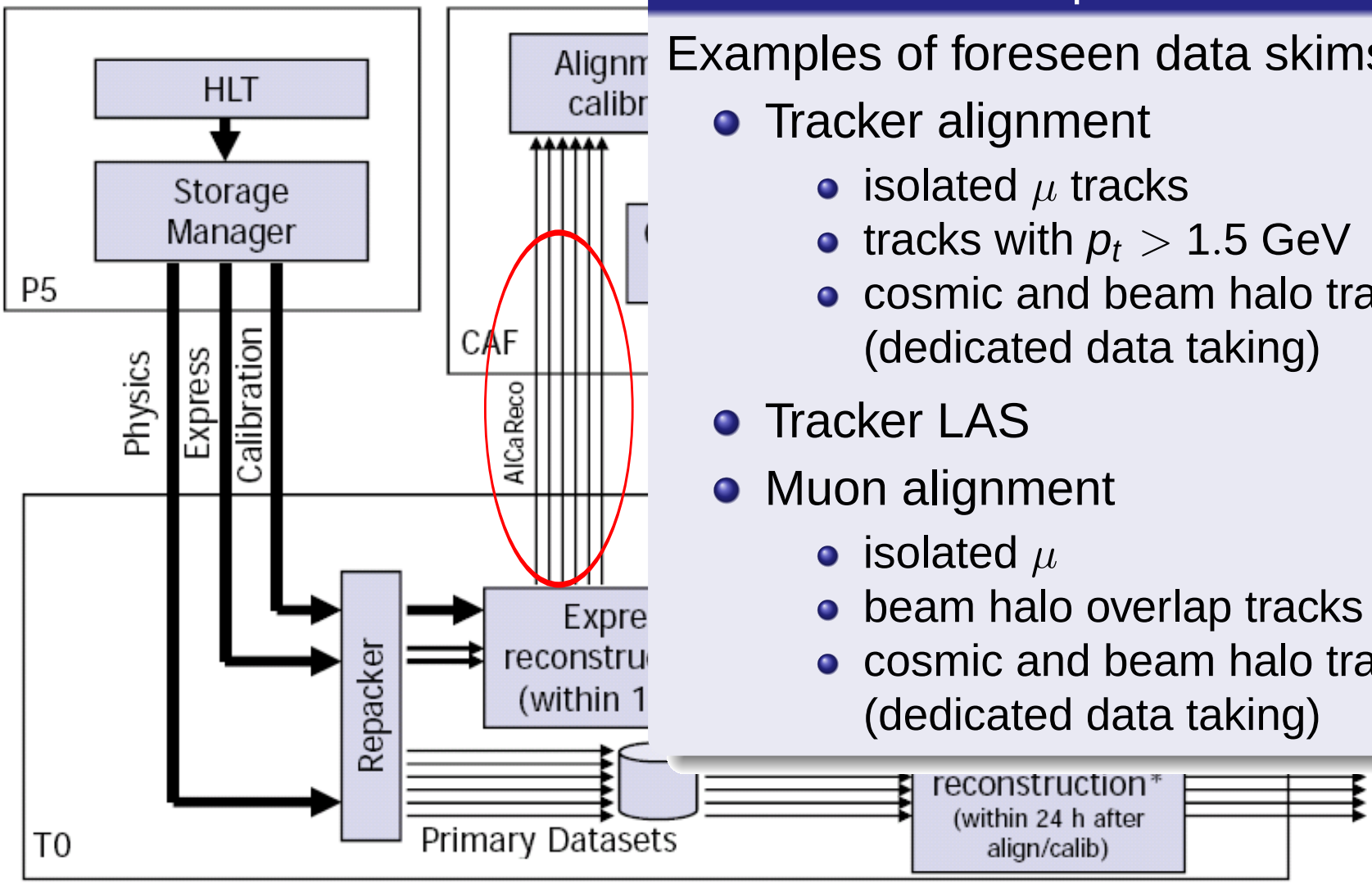


AlCaReco Skims

Dedicated for alignment & calibration.

- Fast turn around essential.
  - $\Rightarrow$ Need to avoid I/O limitations!
- Selecting events and their content e.g. selected tracks and their hits

Prompt Alignment/Calibration Workflow: AlCaReco

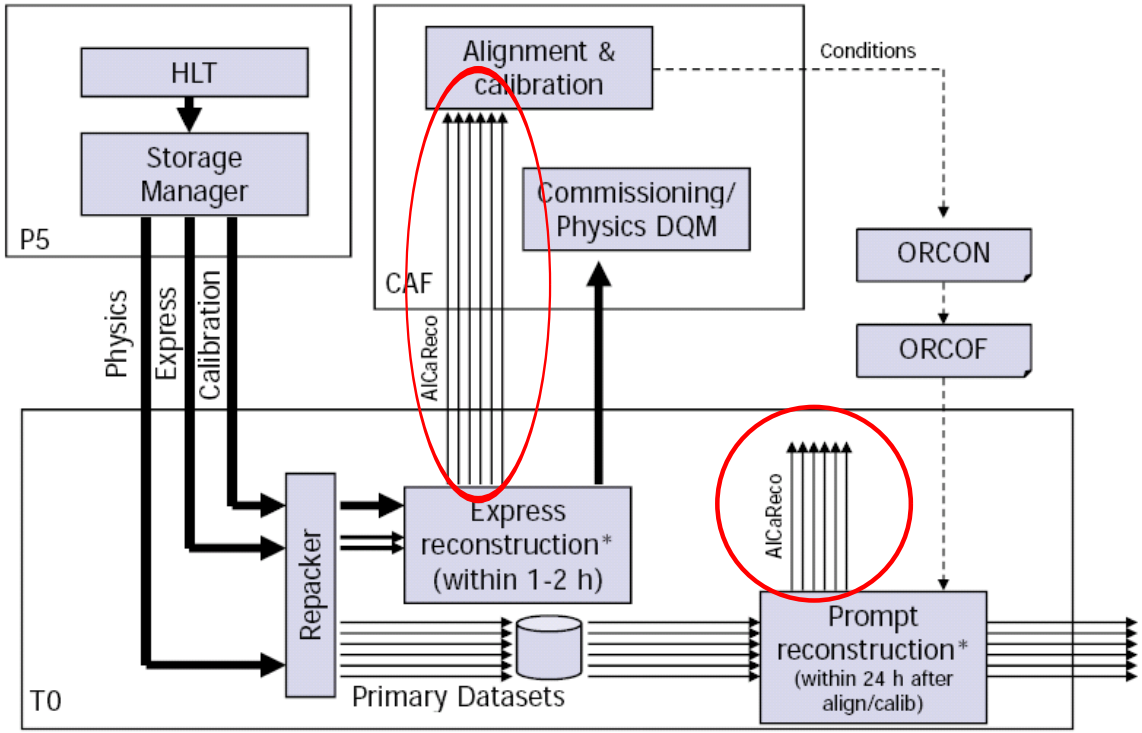


AlCaReco from Express Reconstruction

Examples of foreseen data skims:

- Tracker alignment
  - isolated μ tracks
  - tracks with $p_t > 1.5$ GeV
  - cosmic and beam halo tracks (dedicated data taking)
- Tracker LAS
- Muon alignment
  - isolated μ
  - beam halo overlap tracks in CSC
  - cosmic and beam halo tracks (dedicated data taking)

Prompt Alignment/Calibration Workflow: AlCaReco

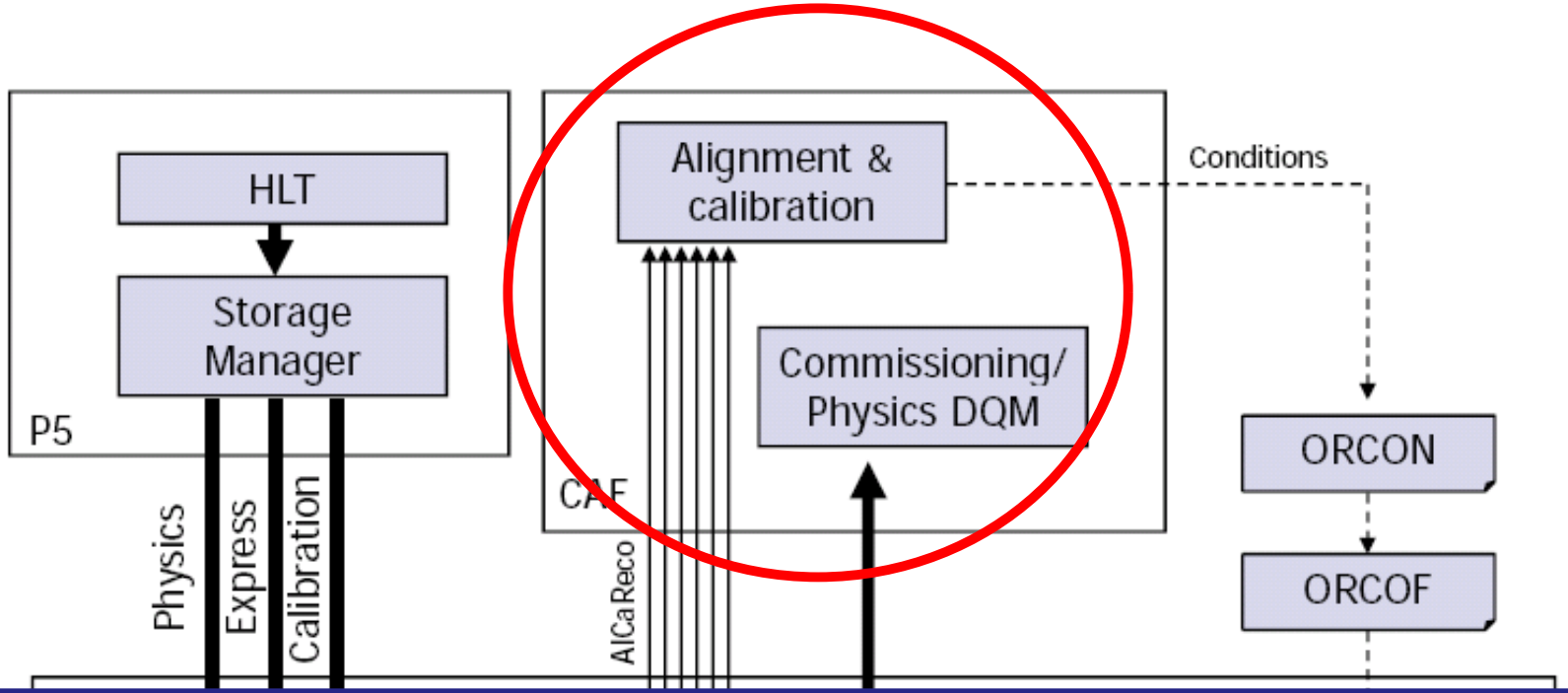


AlCaReco Skims: HLT Selection

- First AlCaReco selection step: choose HLT paths.
- Need flexible configuration:
  adjustable to changing HLT menus.

$\Rightarrow$ Selected paths read from DB (like calibration constants $\Rightarrow$).

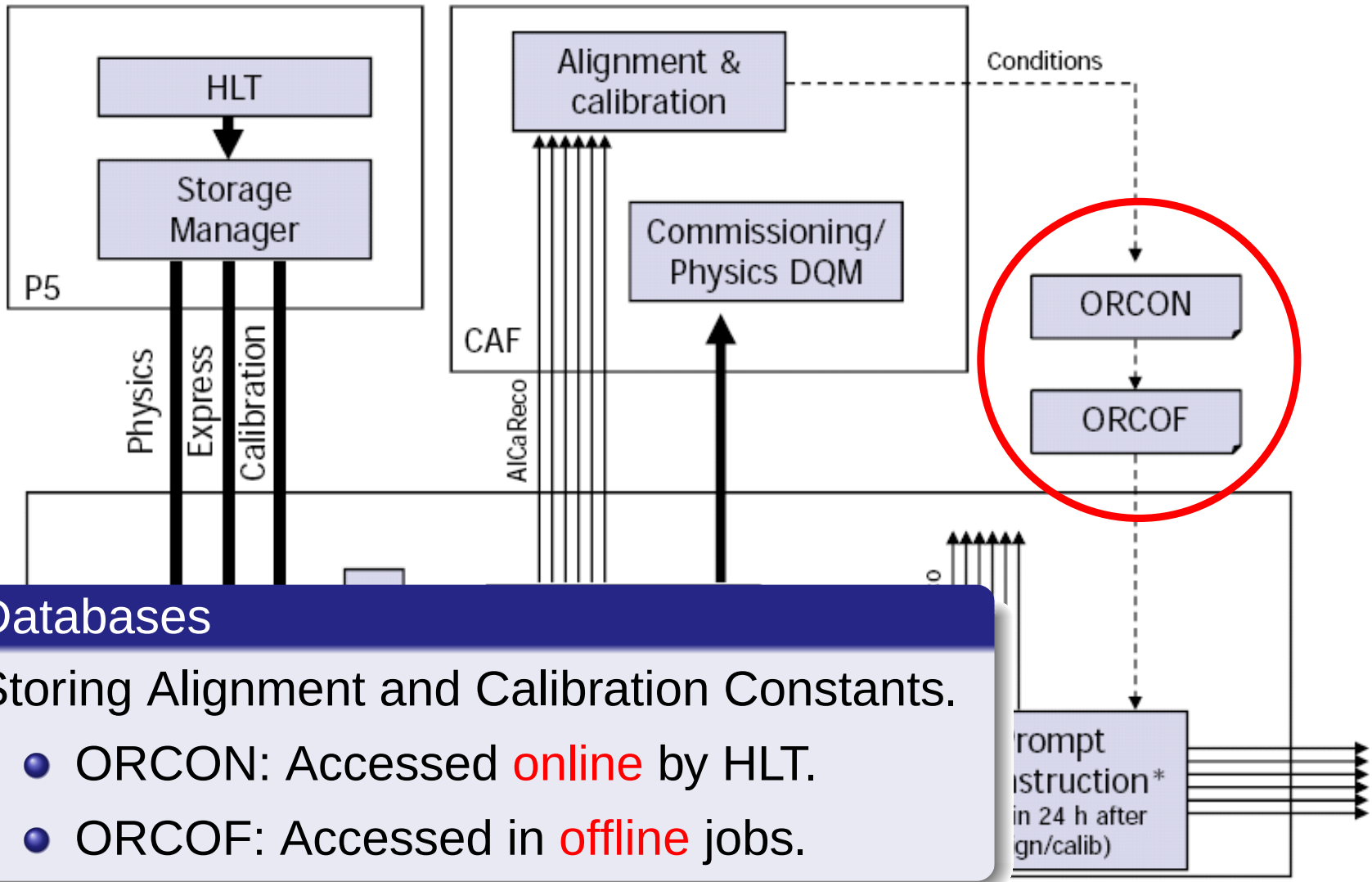
Prompt Alignment/Calibration Workflow: CAF



CAF: CERN Analysis Facility

- Prime platform to run alignment and calibration algorithms (including monitoring and validation).
- Batch farm (also interactive access).
- Fast access to data due to disk storage of
  - AlCaReco,
  - intermediate files of individual workflows.

Prompt Alignment/Calibration Workflow: Databases



Databases

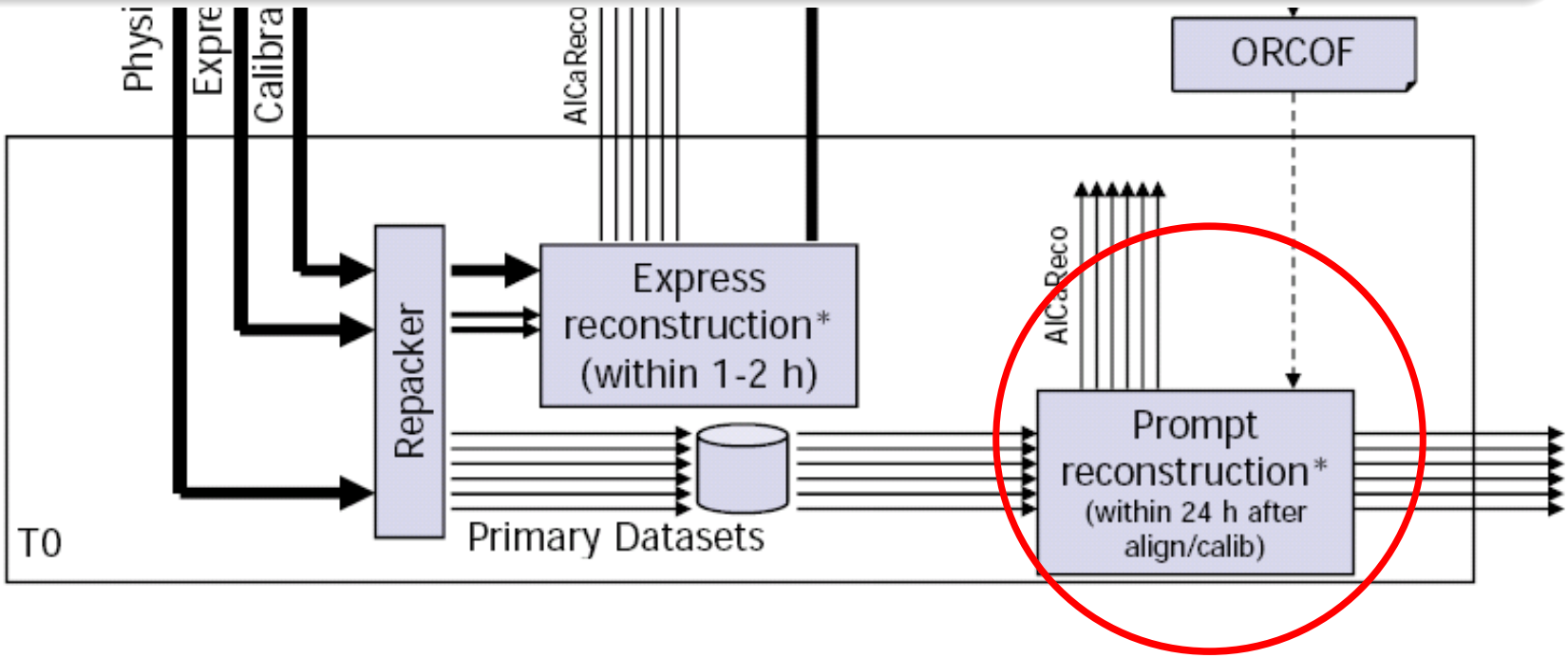
Storing Alignment and Calibration Constants.

- ORCON: Accessed online by HLT.
- ORCOF: Accessed in offline jobs.

Prompt Alignment/Calibration Workflow: Prompt Reco

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

- Prompt Reconstruction, within $\mathcal{O}(24\ \mathrm{h})$:
  - picking up updated constants,
  - sets time limit to achieve short term constants.
- Create Alignment and Calibration Skims (AlCaReco) for longer latency workflows.
- Later reconstructions cycles can pick up refined alignment.

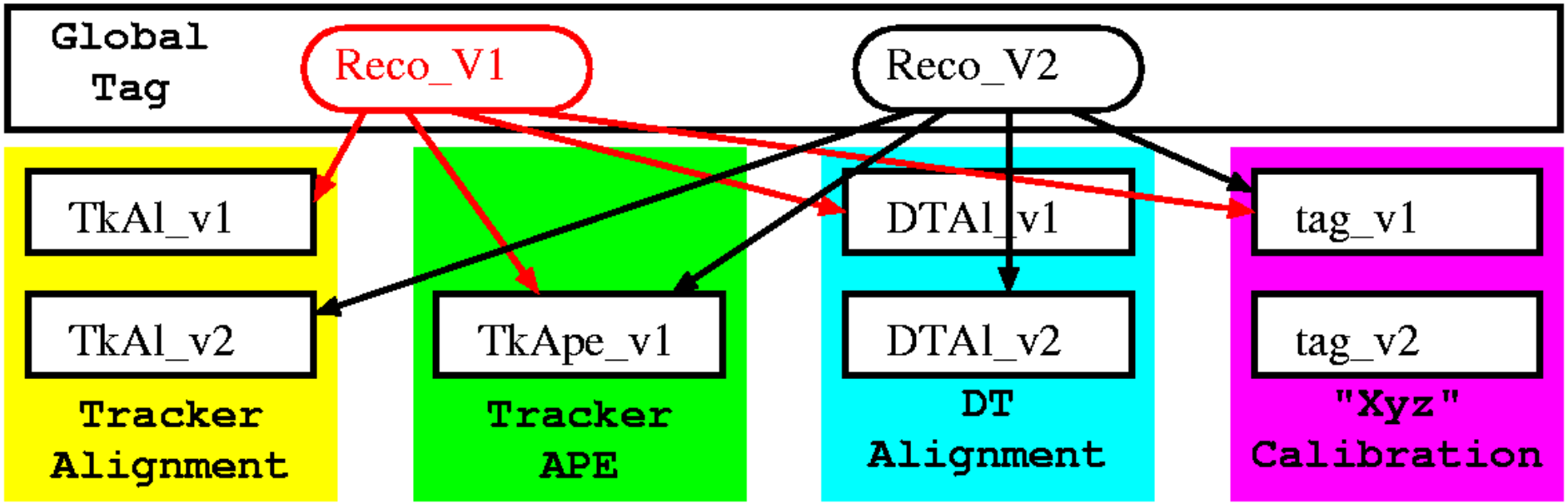


Alignment Constants

Content

- Storing absolute positions and orientations:
  - per each module/chamber/etc. used in reconstruction,
  - one set for each: tracker, DT, CSC.
- Alignment Position Errors (APE) in parallel:
  - reflecting uncertainties of alignment constants,
  - added to local measurements in reconstruction:
    - $\Rightarrow$ pattern recognition,
    - $\Rightarrow$ down-weighting of imprecisely aligned components.
- Global shifts and rotation for each major detector:
  - tracker, muon system, ECAL, HCAL,
  - applied on top of global positions per module/chamber/etc.

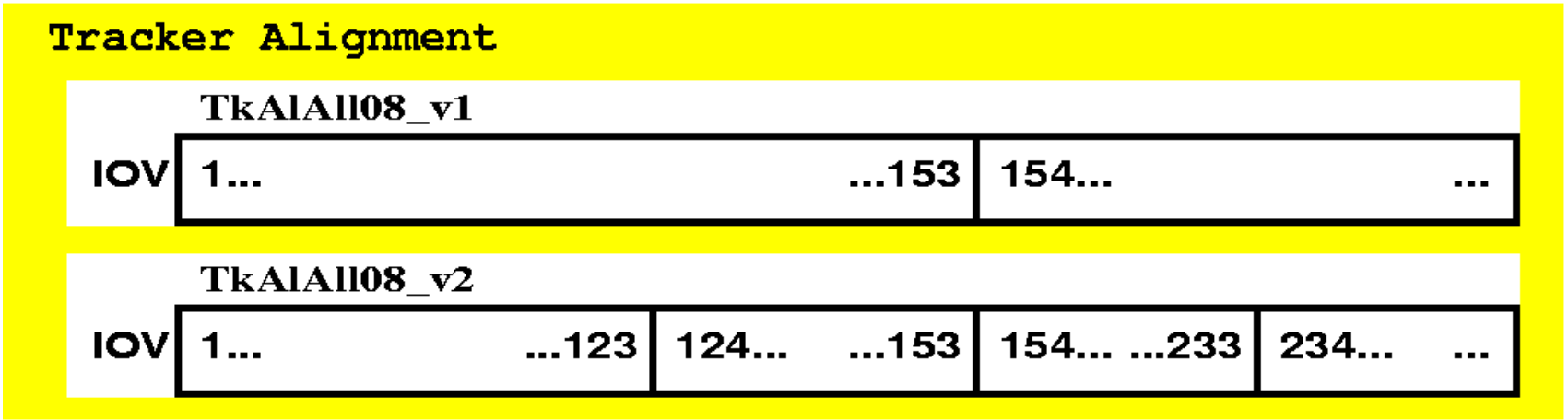
Alignment Constants



Database Access

- Constants are identified via “tag”:
  e.g. “Tracker_Geometry_v3_offline”.
- Summarising GlobalTag:
  - set of calibration, alignment and detector conditions,
  - complete and consistent as needed for reconstruction,
  - simple access for non-experts,
  - experts can customise their constants (alignment, APE,. . .).

Alignment Constants

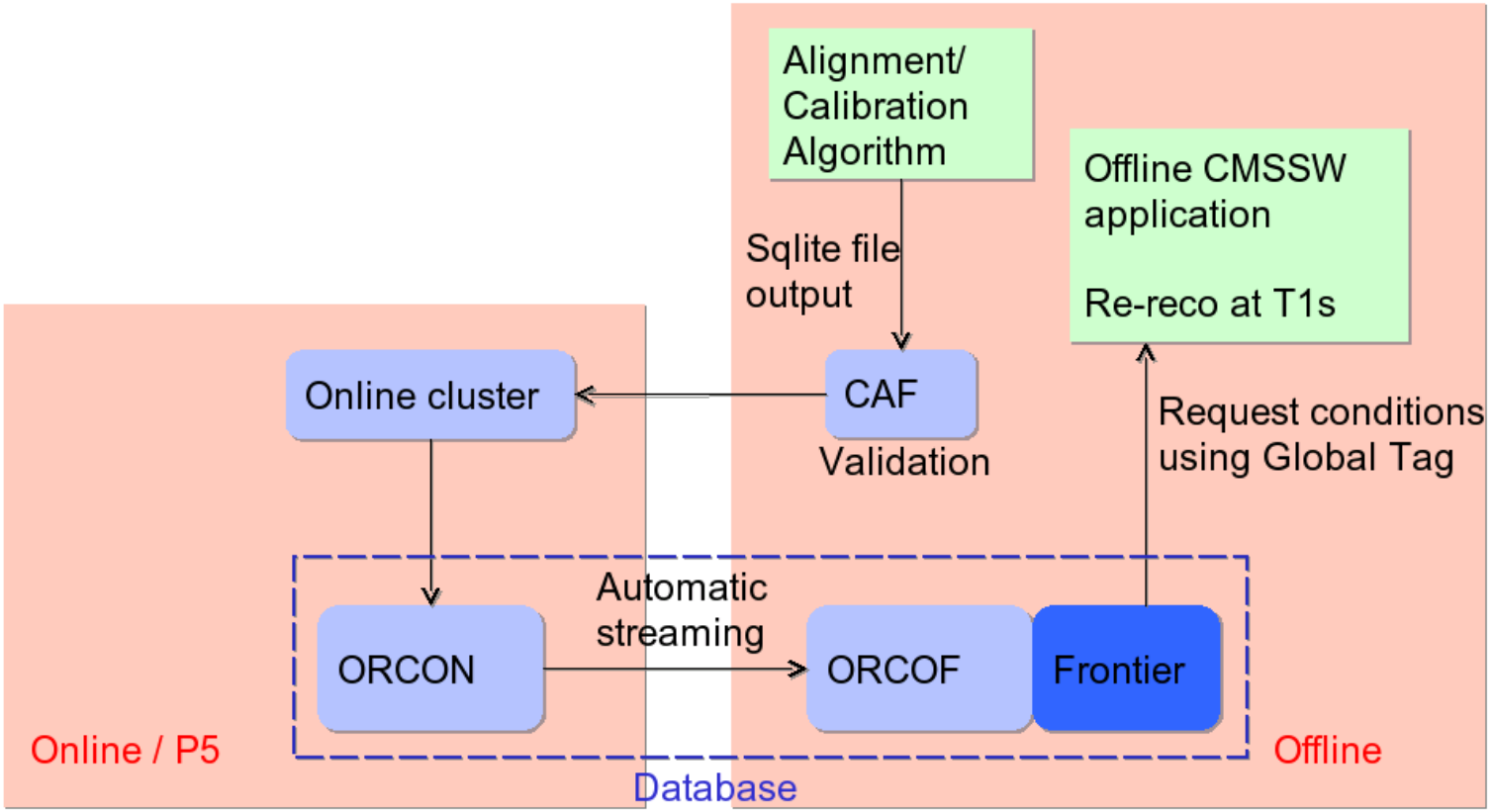


Data Taking Time Dependence

- Within a tag, constants can vary from run to run: defined by Intervals of Validity (IOV).
- Tags for different IOV conventions:
  1. for use in HLT (only in online database): can update constants for future IOV: (current run $+ 1) \rightarrow \infty$
  2. for prompt reconstruction: can update for data before its prompt reconstruction starts
  3. for data (re-)reprocessing: IOV fixed, no updates
  4. for simulation (misalignment): IOV fixed, usually $1 \rightarrow \infty$

$\Rightarrow$ **Ensures reproducibility.**

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).

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 expected startup conditions.

Two Scenarios from LHC Commissioning Schedule

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

Tight schedule:
S43 and S156 alignment and calibration tasks in consecutive weeks.

Calibration and Alignment Tasks

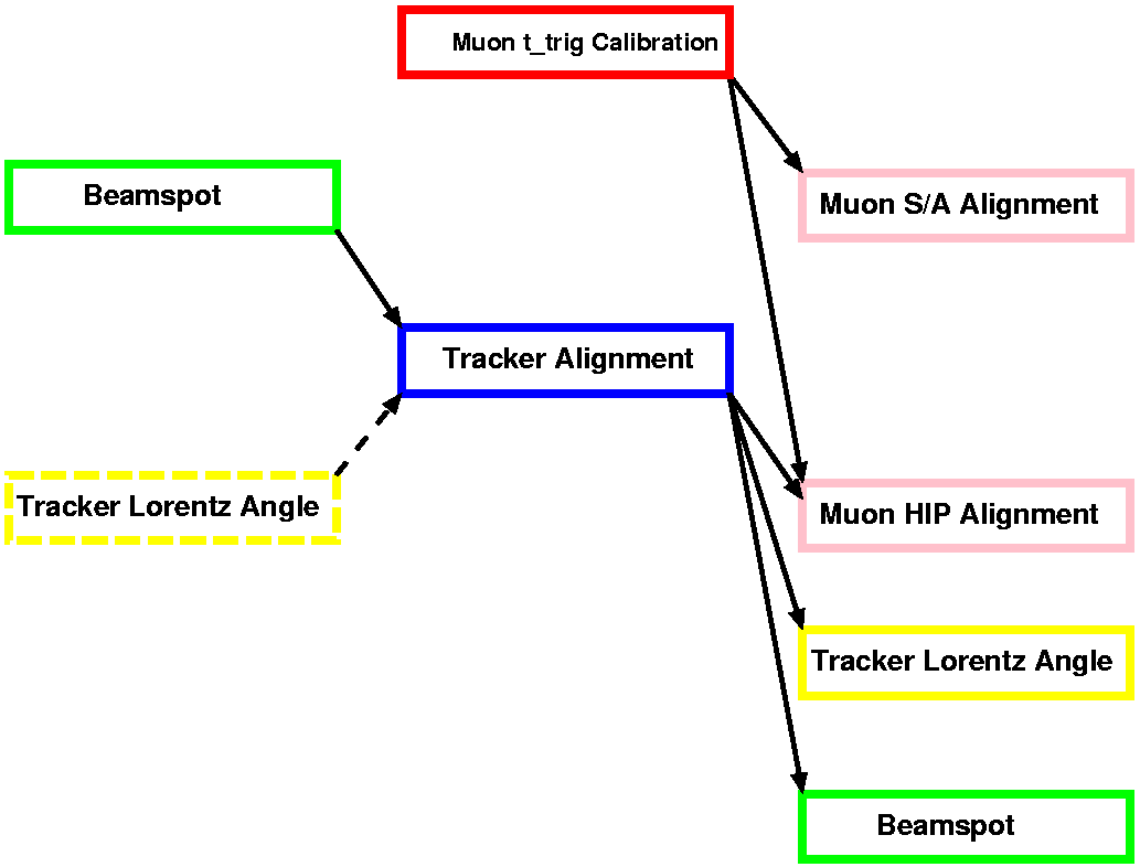
- Tracker Alignment:
  - Millepede algorithm.
  - HIP algorithm.
  - Kalman algorithm.
- Muon System Alignment:
  - HIP algorithm.
  - Standalone algorithm.
- ECAL Calibration:
  - ϕ-symmetry.
  - Use of $\pi^0 \rightarrow \gamma\gamma$.
  - Use of $Z \rightarrow e^+e^-$.
- HCAL Calibration:
  - ϕ-symmetry.
  - Use of isolated tracks.
  - Di-jet balancing.
- Tracker Calibration:
  - Pixel Lorentz angle.
  - Strip Lorentz angle.
  - Strip charge response.
- Muon DT Calibration:
  - Time pedestal.
  - Drift velocity.
- Muon 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 t_{trig} calibration.



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

$\Rightarrow$ Conditions exchange before being official.

- (Tracker Lorentz angle $\Leftrightarrow$ alignment: real data experience reversed order.)

CSA08 Results: Tracker Alignment with Millepede II

Datasets: $>$ 4 M Tracks

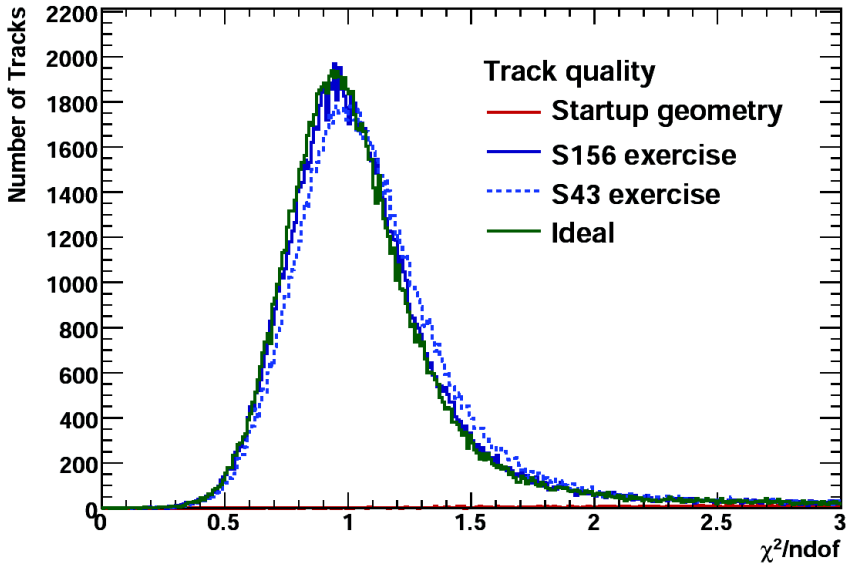
AlCaReco streams selecting:

- Minimum bias tracks ($p_t > 1.5$ GeV).
- Isolated muons.
- $Z \rightarrow \mu\mu$ decays.
- $J/\Psi \rightarrow \mu\mu$ decays.
- Cosmic muons (S156 only).

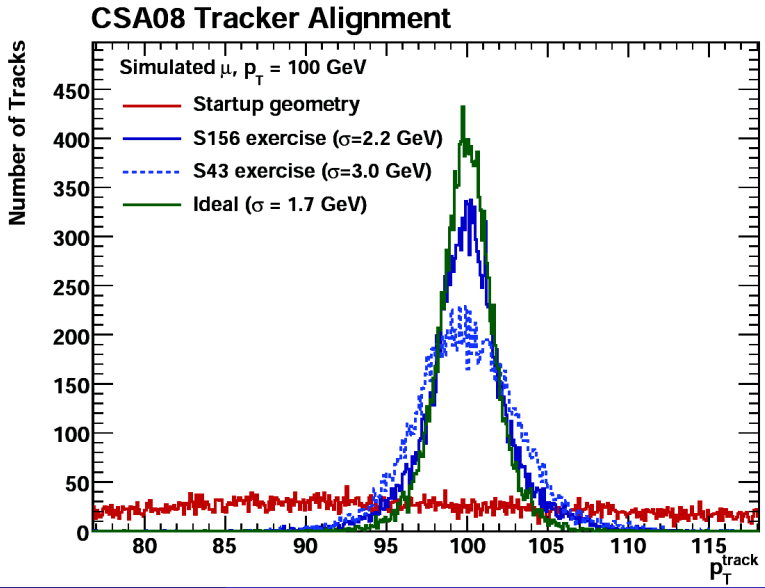
Results (S156)

- 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

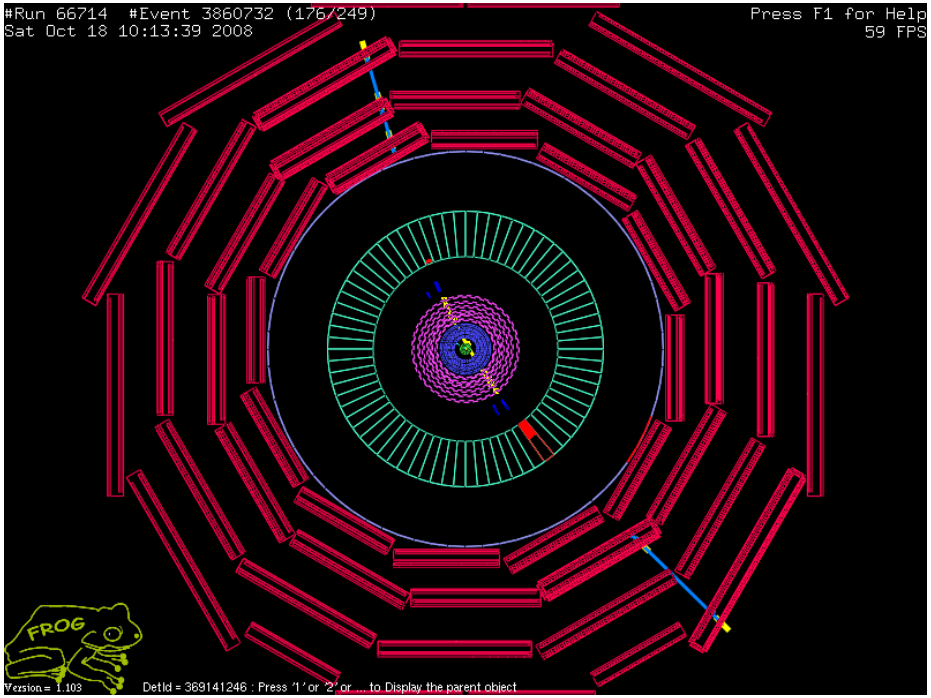
Data Driven: $\chi^2/ndof$



Monte Carlo: p_t resolution



Real Data Taking: Cosmic Muon Data



CRUZET and CRAFT

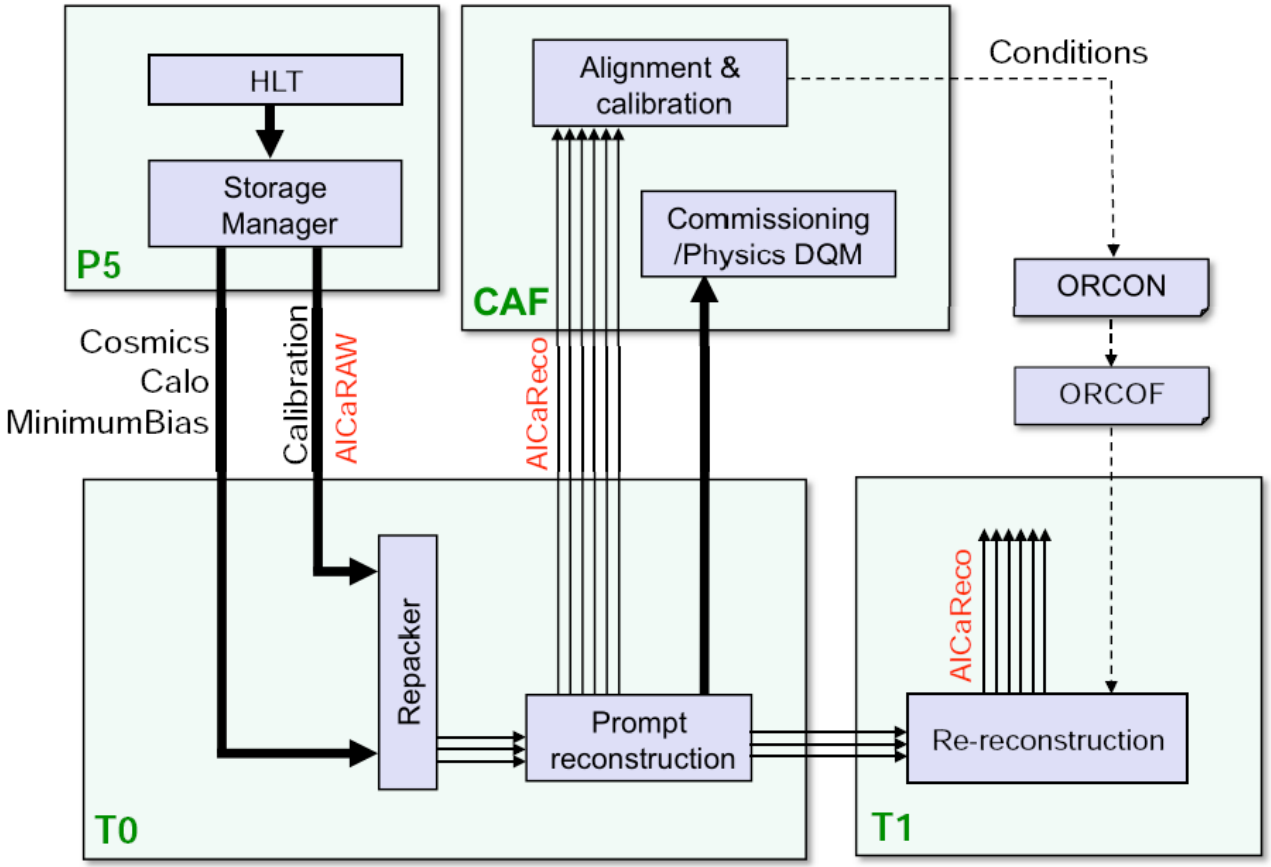
- Global Run of complete CMS.
- Around the clock.
- **C**osmic **RU**n at **ZE**ro **T**esla .
- **C**osmic **R**un at **A**lmost **F**our **T**esla

Alignment results extensively covered in previous talks.

AlCaReco Skims

- Run centrally by Data Operation (full automatising being implemented).
- 9 skims during CRAFT08, e.g.
  - tracker: cosmics skim, $4.9 \cdot 10^6$ events.
  - muon system: isolated muon skim, $51.8 \cdot 10^6$ events.

Alignment/Calibration Workflow During CRAFT '08



- Abort gap event stream with LAS data.
- No express stream/reconstruction yet.
- Prompt reconstruction:
  - constants update on-the-fly for "next run".
- 5 (partial) reprocessing cycles (T1) with condition updates.

Summary

- Elaborate calibration framework setup.
- Serving short-term constants already for prompt reconstruction ($\mathcal{O}$(24 h) delay).
- Key ingredients:
  - AlCaReco skims,
  - algorithms running on CAF,
  - storing constants in databases, accessible via GlobalTag.
- Long-term constants for later reprocessing cycles.
- Tested extensively, meeting challenges:
  - Simulation exercise CSA08,
  - cosmic data taking,
  - express processing being implemented.

Looking forward to:

- Large cosmics data taking scheduled July 2009.
- Beam halo and collision events in autumn/winter.