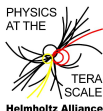


# Integration of Alignment into Overall CMS Calibration Workflow

Gero Flucke  
DESY

(on behalf of the CMS Collaboration)

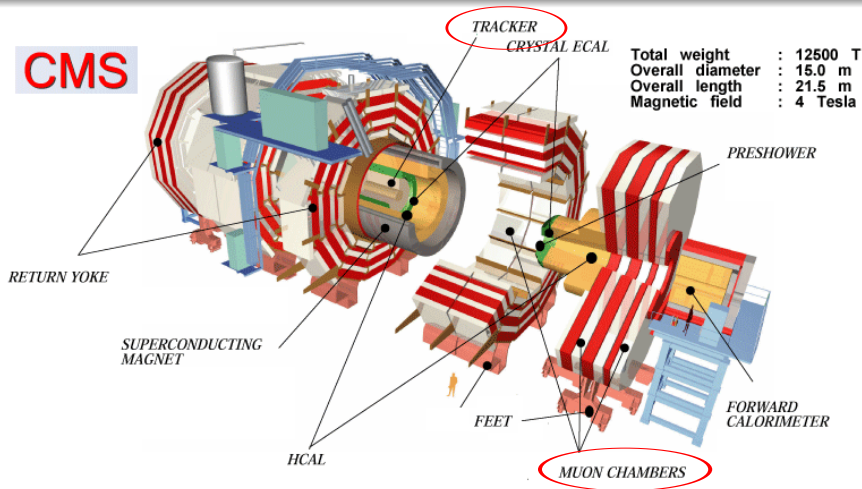


3rd LHC Detector Alignment Workshop  
June 15-16, 2009  
CERN, Geneva (Switzerland)

- **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)

**CMS**



- Full Silicon Tracker.
- Large Solenoid:  
 $B = 3.8 \text{ T}$ .

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

## Complex Reconstruction of LHC Events.

- **Ambitious goals in terms of resolution:**
    - ⇒ Require **excellent alignment and calibration**.
  - **Large data rate:**
    - ⇒ **Robust framework** to handle alignment/calibration.
  - **Aiming for fast turn around for physics results:**
    - ⇒ Essential alignment and calibration for **prompt reconstruction**.
- ⇒ Short timescale to derive rapidly changing detector conditions.
- Special data formats to minimise I/O-overhead: **AICaReco**.
  - **Which constants** will be subject to **frequent changes**?
    - Analysis of LHC data will show.
    - **Alignment framework prepared.**

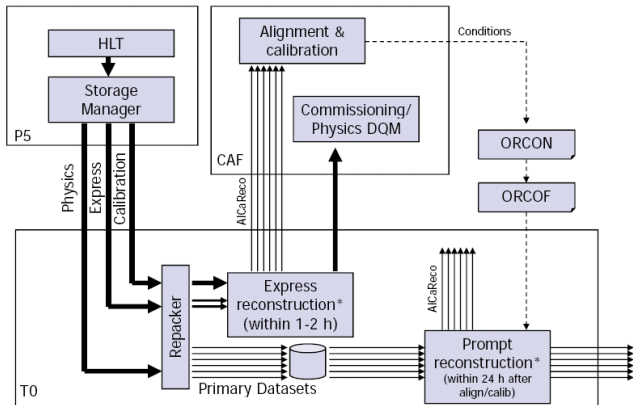
## Alignment Most Relevant for Tracking Detectors

- 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:

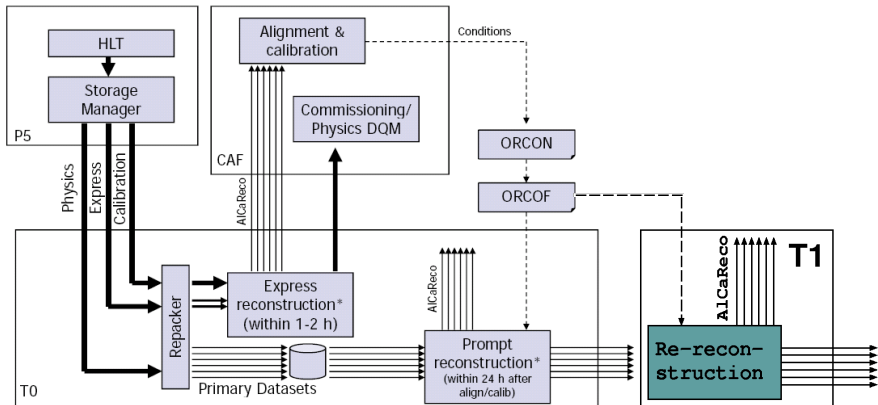
- Track-based Alignment.
- Tracker, DT and CSC.

# 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

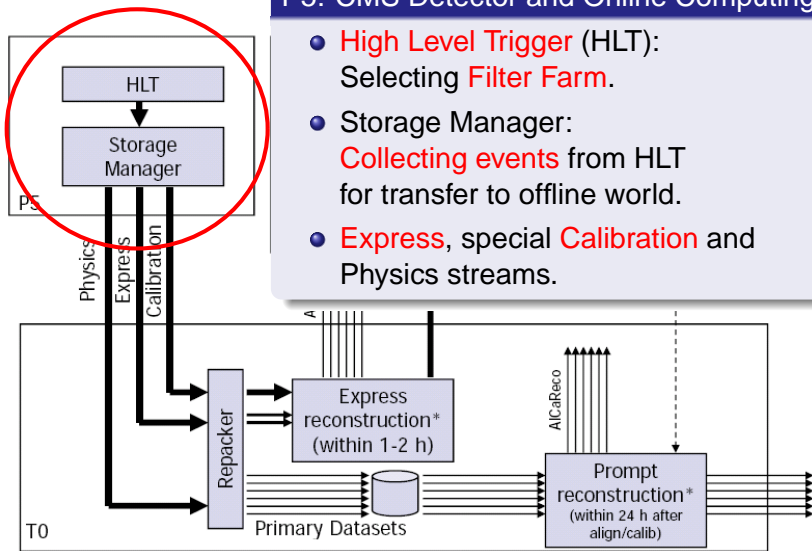


- Here: for constants in **prompt reconstruction workflow**.
- Long-time constants: to be picked up in **later re-reconstruction cycles**.

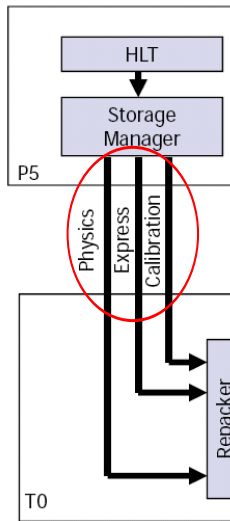
# Prompt Alignment/Calibration Workflow: Point 5

## 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.







## Data Streams

### Physics

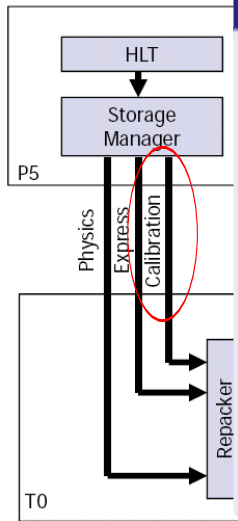
- Events selected for physics analysis (and longterm calibrations).

### Express

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

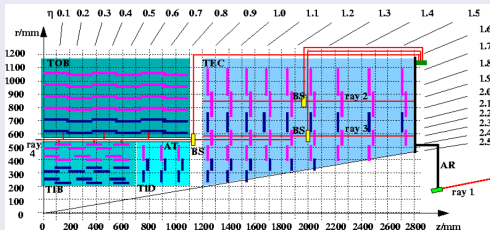
### Calibration

- Dedicated Datasets (AICaRaw).
  - **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.



Abort gap events needed for alignment:

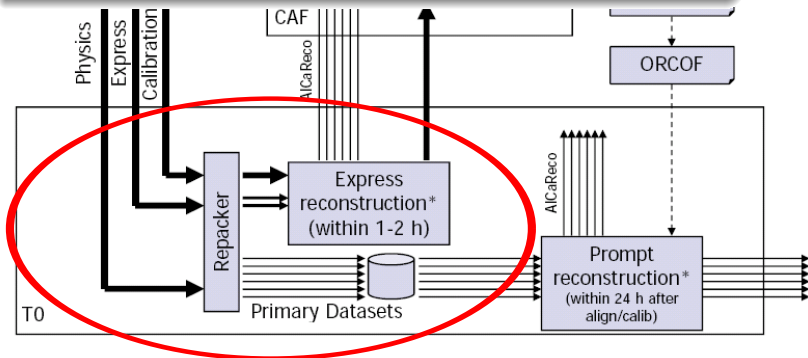
## Tracker Laser Alignment System (LAS)



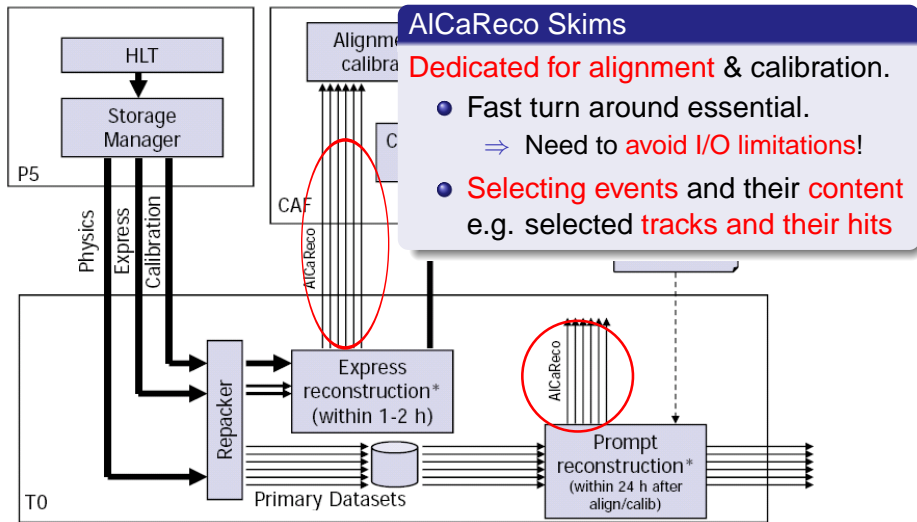
- About 2000 laser beam “shots”.
- 434 silicon strip modules hit.
- Operated ~once per hour.

## 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: AICaReco

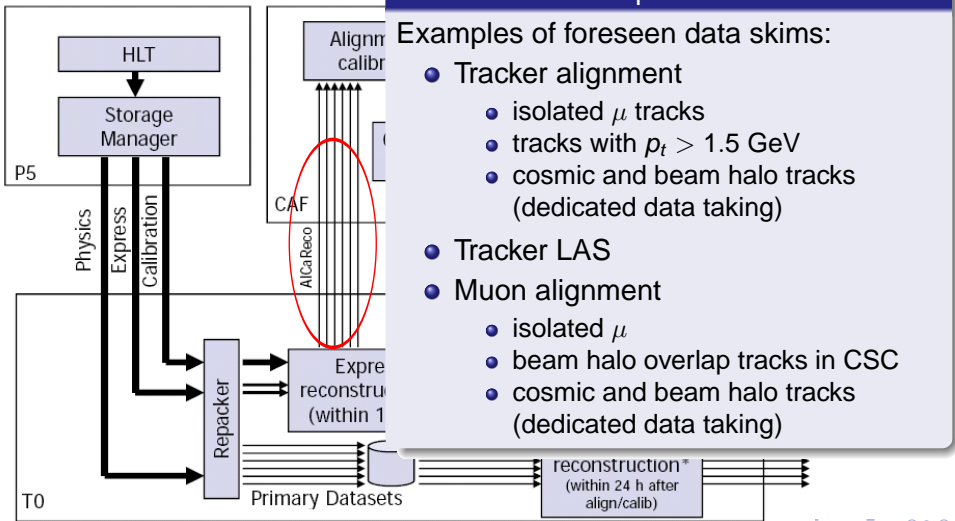


# Prompt Alignment/Calibration Workflow: AICaReco

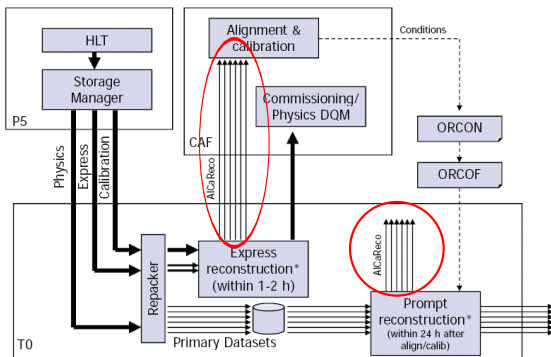
## AICaReco from Express Reconstruction

Examples of foreseen data skims:

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



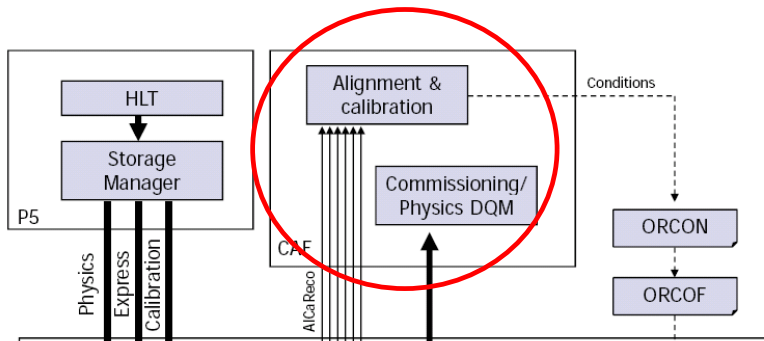
# Prompt Alignment/Calibration Workflow: AICaReco



## AICaReco Skims: HLT Selection

- First AICaReco selection step: choose HLT paths.
  - Need **flexible** configuration: adjustable to **changing HLT menus**.
- ⇒ Selected paths read from DB (like calibration constants ⇒).

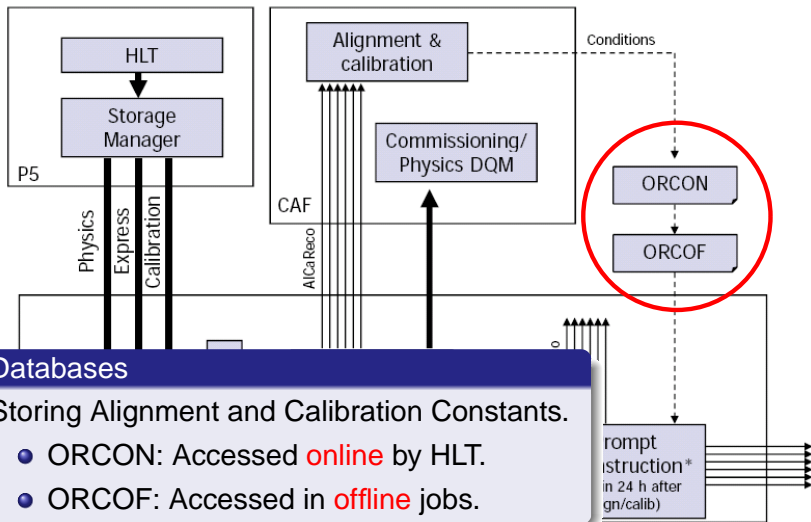
# Prompt Alignment/Calibration Workflow: CAF



## 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.

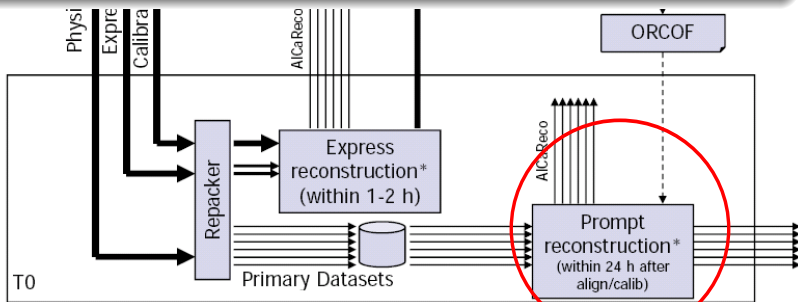
- ORCON: Accessed **online** by HLT.
- ORCOF: Accessed in **offline** jobs.



# Prompt Alignment/Calibration Workflow: Prompt Reco

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

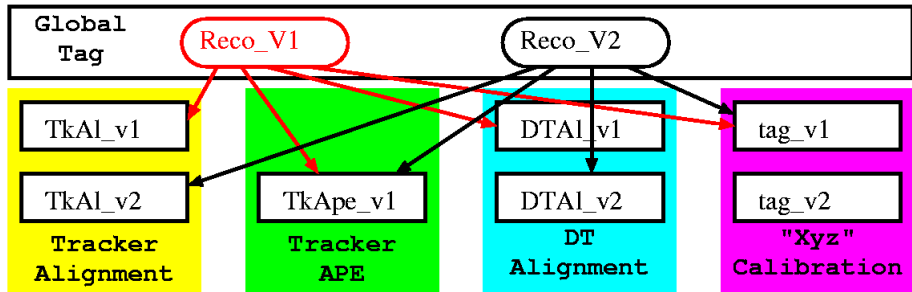
- **Prompt Reconstruction**, within  $\mathcal{O}(24\text{ h})$ :
  - picking up updated constants,
  - sets time limit to achieve short term constants.
- Create **Alignment and Calibration Skims** (AlCaReco) for longer latency workflows.
- Later reconstructions cycles can pick up refined alignment.



## 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:
    - ⇒ pattern recognition,
    - ⇒ 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,...).

## Tracker Alignment

TkAlAll08_v1							
IOV	1...	...	...	...153	154...	...	...

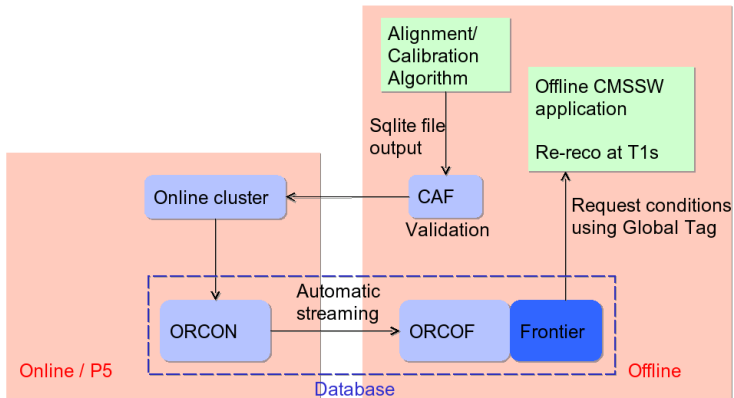
TkAlAll08_v2									
IOV	1...	...	...123	124...	...	...153	154... ...233	234...	...

## 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**:  $(\text{current run} + 1) \rightarrow \infty$
  - 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  $1 \rightarrow \infty$

⇒ **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 AICaReco 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	$2 \cdot 10^{30} \text{ cm}^{-2}\text{s}^{-1}$	6 days	$1 \text{ pb}^{-1}$	300 Hz	150 M
S156	156x156	$2 \cdot 10^{31} \text{ cm}^{-2}\text{s}^{-1}$	6 days	$10 \text{ pb}^{-1}$	300 Hz	150 M

**Tight schedule:**

S43 and S156 alignment and calibration tasks in **consecutive weeks**.

## Calibration and Alignment Tasks

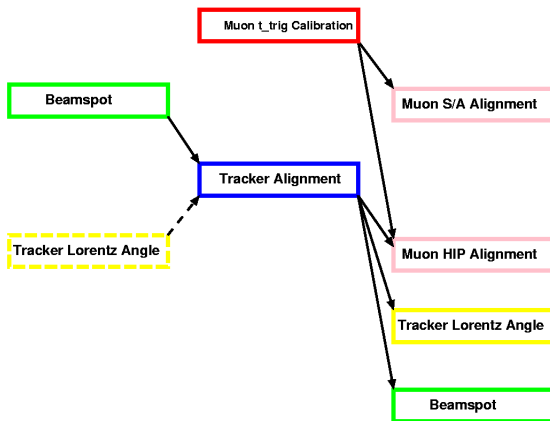
- **Tracker Alignment:**
  - Millepede algorithm.
  - HIP algorithm.
  - Kalman algorithm.
- **Muon System Alignment:**
  - HIP algorithm.
  - Standalone algorithm.
- **ECAL Calibration:**
  - $\phi$ -symmetry.
  - Use of  $\pi^0 \rightarrow \gamma\gamma$ .
  - Use of  $Z \rightarrow e^+e^-$ .
- **HCAL Calibration:**
  - $\phi$ -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

⇒ 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:**

⇒ Conditions exchange before being official.

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



Datasets: > 4 M Tracks

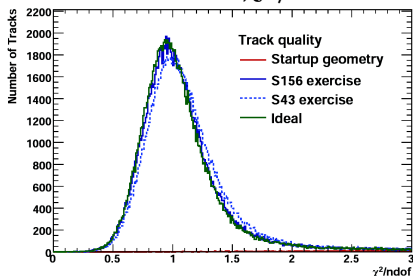
AICaReco streams selecting:

- 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).

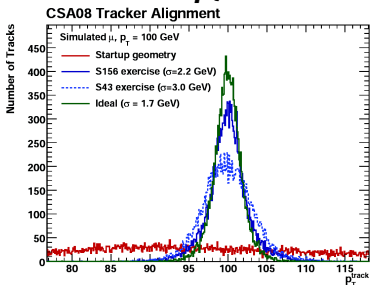
Results (S156)

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

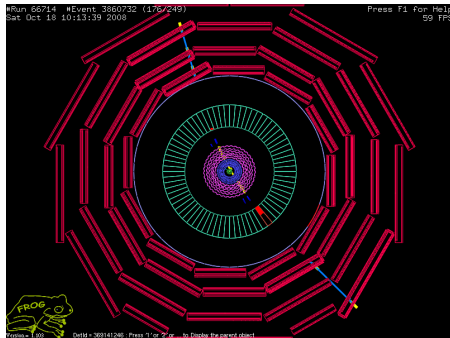
Data Driven:  $\chi^2/ndof$



Monte Carlo:  $p_t$  resolution



# Real Data Taking: Cosmic Muon Data



## CRUZET and CRAFT

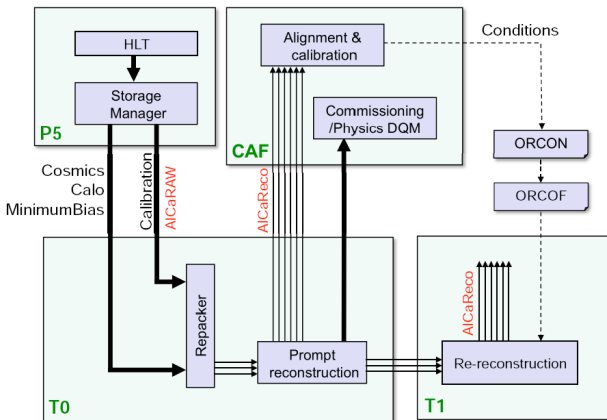
- Global Run of complete CMS.
- Around the clock.
- **Cosmic RUN at ZERo Tesla** .
- **Cosmic Run at Almost Four Tesla**

**Alignment results extensively covered in previous talks.**

## AICaReco 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.

- Elaborate calibration framework setup.
- Serving short-term constants already for **prompt reconstruction** ( $\mathcal{O}(24\text{ h})$  delay).
- Key ingredients:
  - **AICaReco** 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.