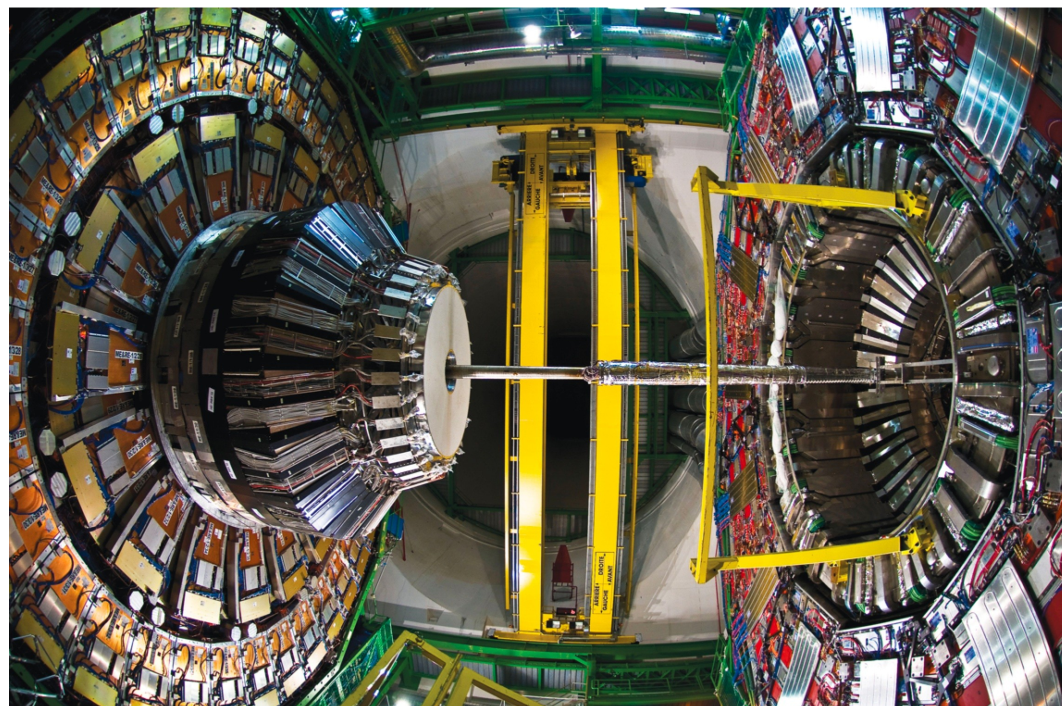
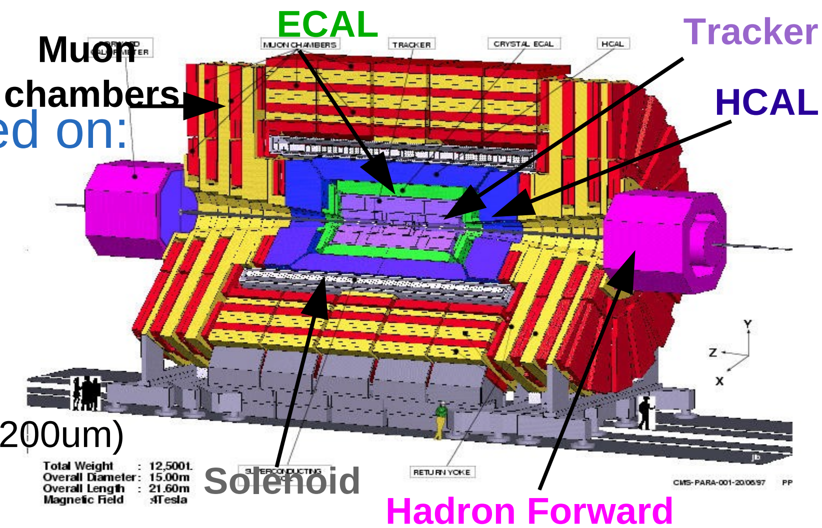
Operation of the CMS detector with first collisions at 7 TeV at the LHC



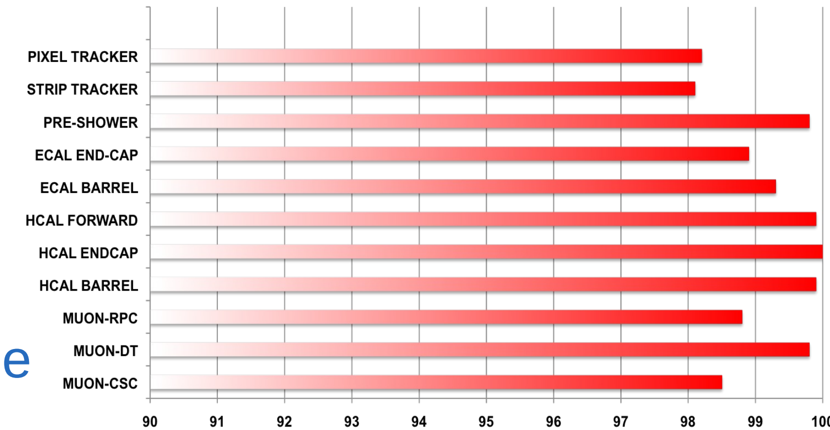
Gianluca Cerminara (CERN)
on behalf of the CMS Collaboration

The CMS Detector @ the LHC

- Compact Muon Solenoid (CMS):
  - compact 4π experiment → design based on:
    - high intensity B field
      (3.8T superconducting solenoid)
    - redundant muon spectrometer
    - high precision silicon tracker (σ_x = 15-200um)
      - ~ 76M channels (Pixel + SiStrip)
    - high precision homogeneous EM calorimeter (ECAL)
      - ~ 76k $PbWO_4$ scintillating crystals
    - hermetic calorimeter



- High level of complexity →
  very demanding in terms of operation:
  - Very careful preparation of online/offline infrastructure prior to first data
    - CMS is presenting results obtained with data acquired up to last Monday!



	MUON-CSC	MUON-DT	MUON-RPC	HCAL BARREL	HCAL ENDCAP	HCAL FORWARD	ECAL BARREL	ECAL END-CAP	PRE-SHOWER	STRIP TRACKER	PIXEL TRACKER
Series1	98.5	99.8	98.8	99.9	100	99.9	99.3	98.9	99.8	98.1	98.2

Channel Status

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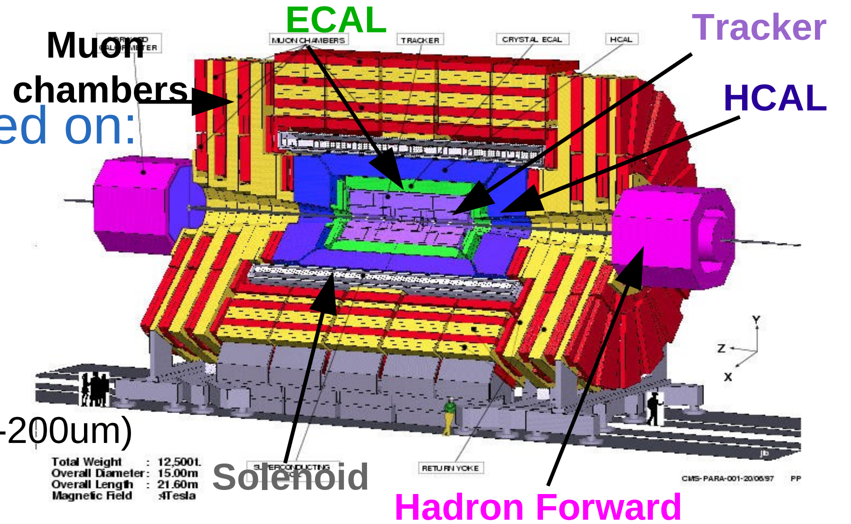

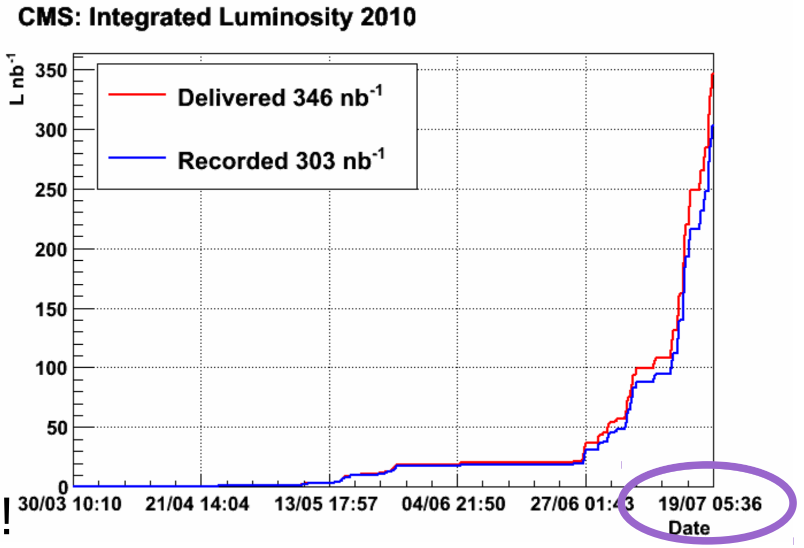

Offline Operations: Outline

Offline workflows:
deliver validated & calibrated data for physics analysis

Need to fulfil several requirements:

- offline reconstruction must provide both:
  - prompt feedback on detector status and data quality
  - sample for physics analysis
- provide up-to-date alignment & calibration (AlCa)
  - calibration workflows with short latency
  - provide samples for calibration purposes: AlCa streams
  - consistent set of conditions for data and MC
- data validation and certification for analysis
  - data quality monitoring (DQM)

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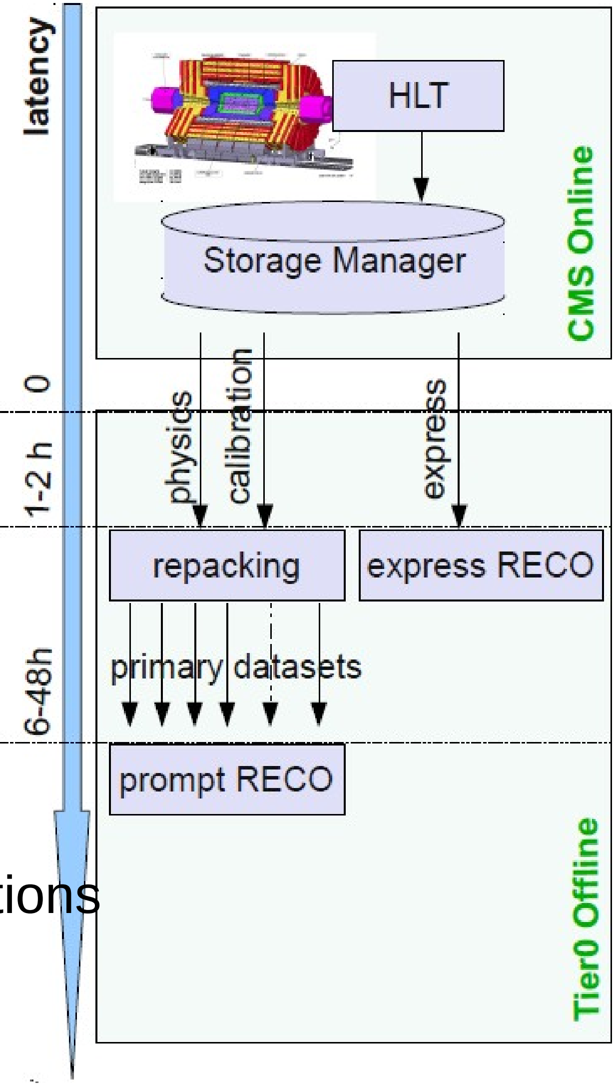
Data Streams & Tier0 processing

- Data streams & Tier0 workflows → specialized for different tasks
- Depending on the latency
  - express → prompt feedback & calibrations
    - short latency: 1-2 hours
    - ~40Hz bandwidth shared by:
      - calibration (½)
      - detector monitoring (¼)
      - physics monitoring (¼)
  - Alignment & Calibration (AlCa) streams
  - bulk data → sample for physics analysis (prompt reconstruction)
    - split in Primary Datasets (using High Level Trigger (HLT) decision)
    - will be delayed of 48h → get latest calibrations
    - writing ~300Hz



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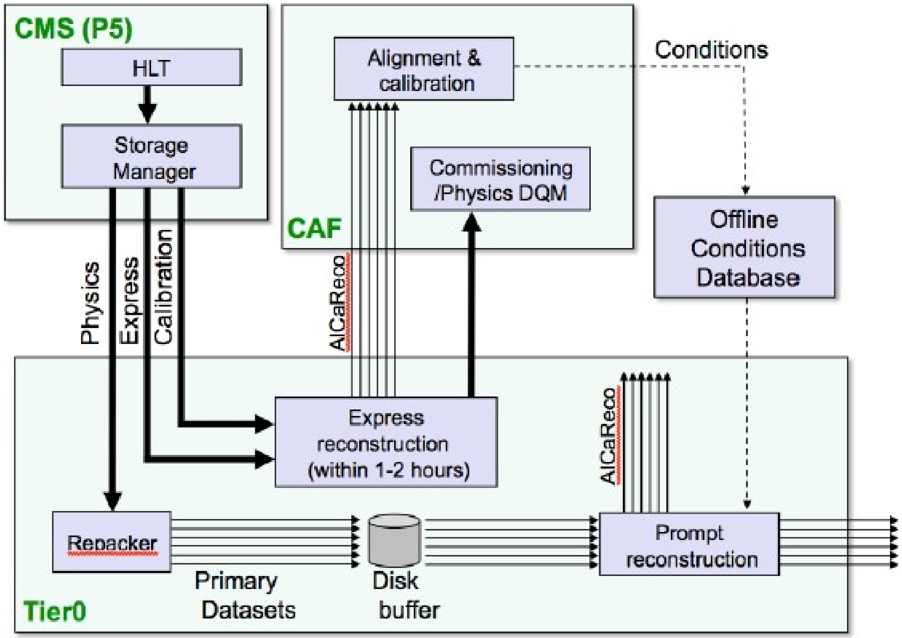
Calibration Workflows

- Provide most up-to-date conditions @ all stages of the data processing
- Different workflows depending on the time scale of updates:
  - quasi-online calibrations for HLT and express:
    - e.g. beam-spot → quick determination online
  - prompt calibrations: monitor/update conditions expected to vary run-by-run (or even more frequently):
    - updated conditions must be ready before prompt-reconstruction
  - offline re-reco workflows:
    - more stable conditions
    - workflows which need higher statistics:
      run on AlCa streams produced during prompt-reco or offline re-reco

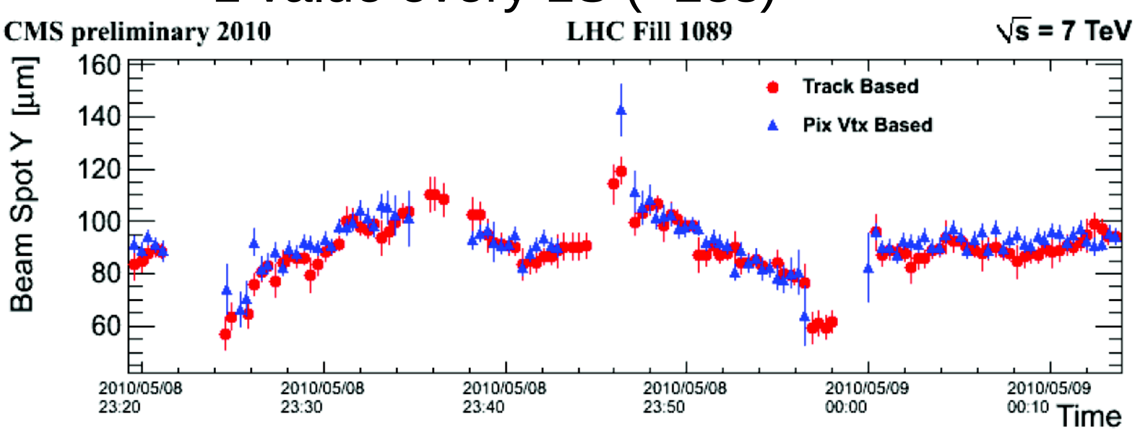
Prompt-Calibration Loop

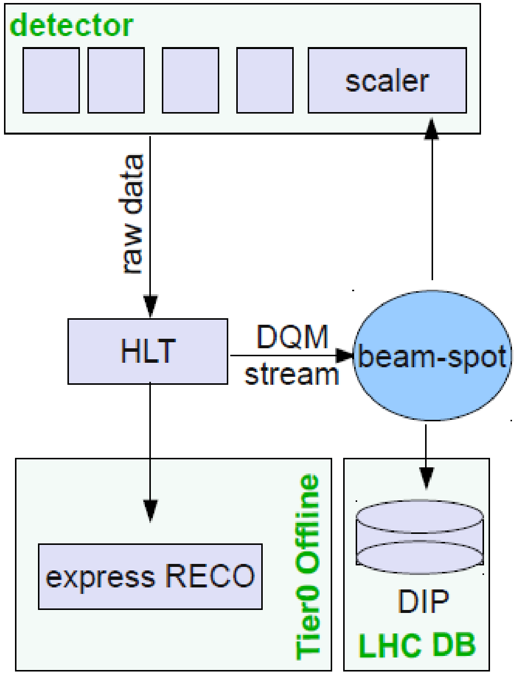
- Prompt calibration workflows:
  - conditions which need continuous updates:
    - beam-spot position → measured every 23s (= 1 Lumi Section)
    - tracker problematic channels → respond to HV trips/noise
  - conditions which need monitoring
    - calorimeter problematic channels → mask hot channels
    - tracker alignment → monitor movements of large structures
- Update strategy based on delay between express and prompt reco
  - AlCa streams out of express used for calibration
    - compute conditions in time for prompt-reco
      → start 48h later
- Reduce need for offline re-reco
- Dedicated resources @ CERN: CMS Analysis Facility (CAF)



Example: Beam-Spot Measurement

- Track beam-spot 3D position and width as a function of time:
  - track based → correlation of impact parameter and azimuthal angle (d_0-ϕ)
  - vertex based → 3D fit to distribution of primary-vertexes
- Quasi-online workflow for express (and HLT) reconstruction
  - using DQM-dedicated stream (sampling @ ~ 100Hz max)
  - using track based and pixel-only vertexing → very fast
    - 1 value every 5 Lumi-Section (~2 min)
- Runs also in prompt-calibration loop
  - full statistics and tracking capabilities
    - 1 value every LS (=23s)





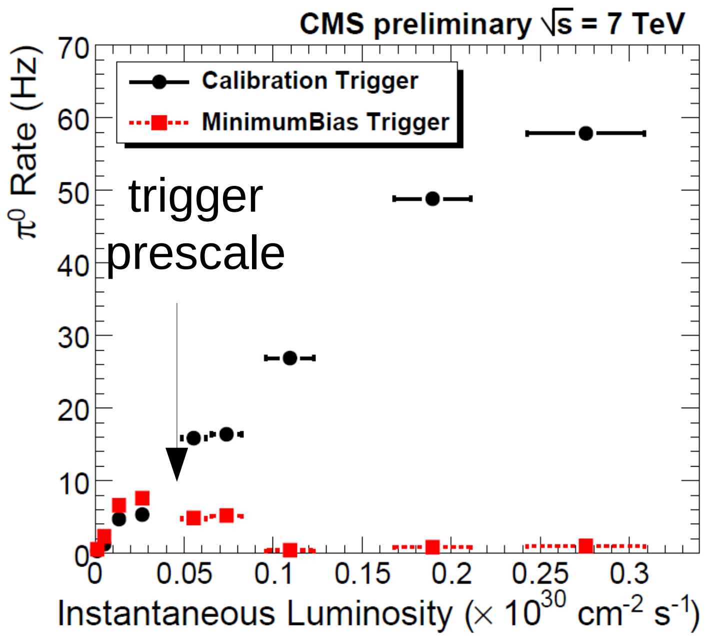
Alignment & Calibration Streams

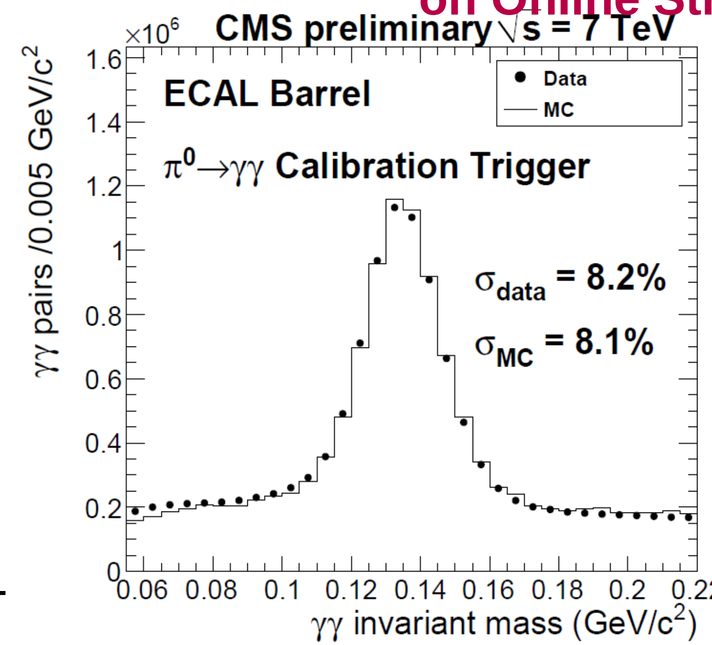
- All workflows fed using dedicated skims or datasets:
  - event selection tuned on the needs of the workflow
  - event content reduced to optimize bandwidth/disk space usage
- 2 kind of calibration streams:
  - produced directly @ HLT level
    - workflows statistically limited or requiring dedicated selection:
      - e.g. ECAL π^0 stream and ϕ-symmetry....
    - profit from High Level Trigger flexibility $\rightarrow$ software based
  - produced offline during express and prompt reconstruction (and offline re-processing)
    - just skimming events dedicated to calibrations

Example: ECAL Calibration

- Calibration stream produced @ HLT level: π^0 and η calibration events
- Stream optimized for:
  - low CPU usage @ HLT:
    - seeded by Level1 single-e/γ or single-Jet triggers
    - regional unpacking ($\Delta\eta \times \Delta\phi = 0.25 \times 0.4$ around the seed)
    - event selection based on info @ crystal-level only
  - low bandwidth
    - store data only for interesting crystals (ROI)

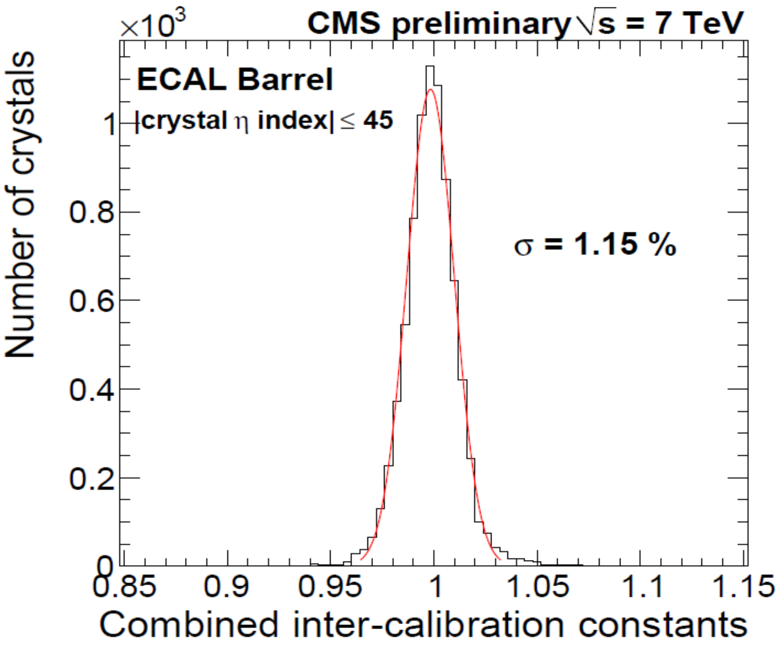
Produced directly on Online Stream





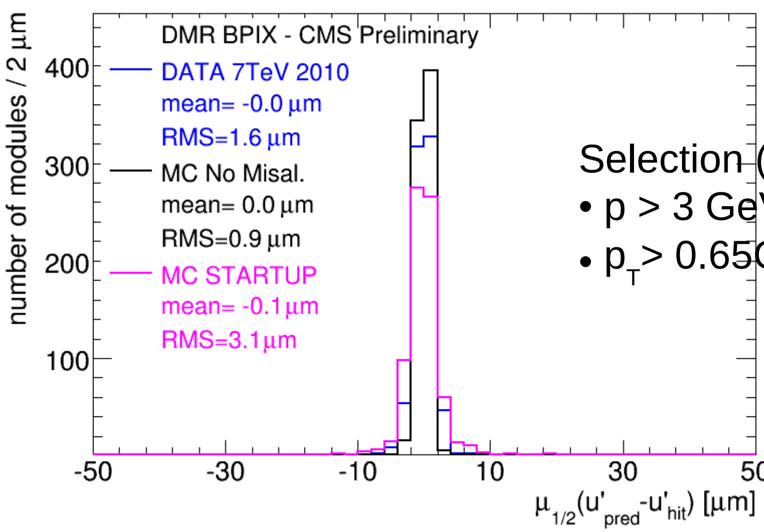
Example: ECAL Calibration

- Inter-calibration based on several (complementary) techniques:
  - ϕ-symmetry → ϕ invariance of energy flow @ fixed pseudo-rapidity
    - dedicated stream (@ HLT) of Minimum-Bias events
    - already ~ asymptotic in terms of performance
  - π^0 and η calibration → photon pairs $\pi^0(\eta) \to \gamma\gamma$
  - isolated electrons and di-electron resonances (larger dataset O(fb^{-1}))
  - monitoring of crystal transparency and light yield (only @ higher lumi)
- Combination allows to reach 1.15% precision in the barrel (design goal for $H \to \gamma\gamma$ is 0.5%)
  - estimated comparing in-situ calib. against test-beam values (1/4 of the barrel crystals)

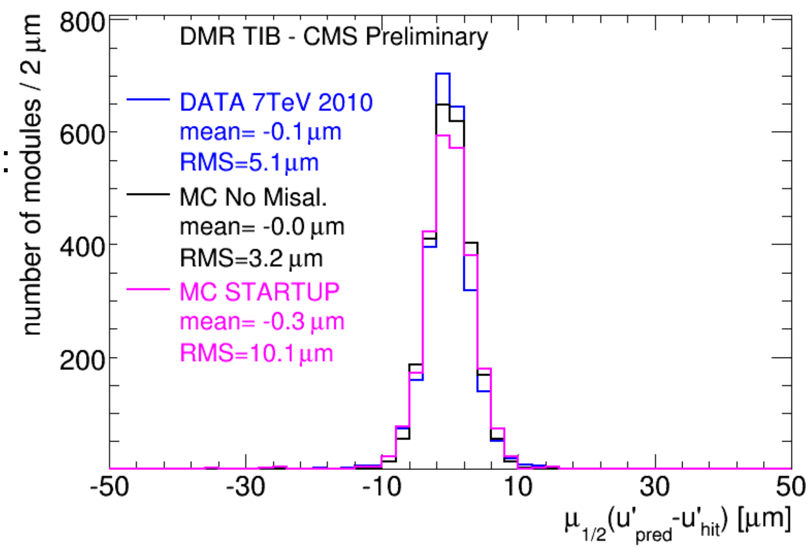


Different MC scenarios: e.g. alignment

- Different scenarios for conditions in Monte-Carlo
  - IDEAL → asymptotic reach of calibration and performance
  - STARTUP → realistic calibrations and problematic channels
- Example: different scenarios for tracker alignment
  - median of residual distribution (DMR) for all modules with > 200 entries
    - ideally (perfect alignment and infinite statistics) spikes at zero
    - RMS → estimate of alignment accuracy
- Alignment performance → already close to systematic limit



Selection (4M events):
- p > 3 GeV/c
- p_T > 0.65GeV/c



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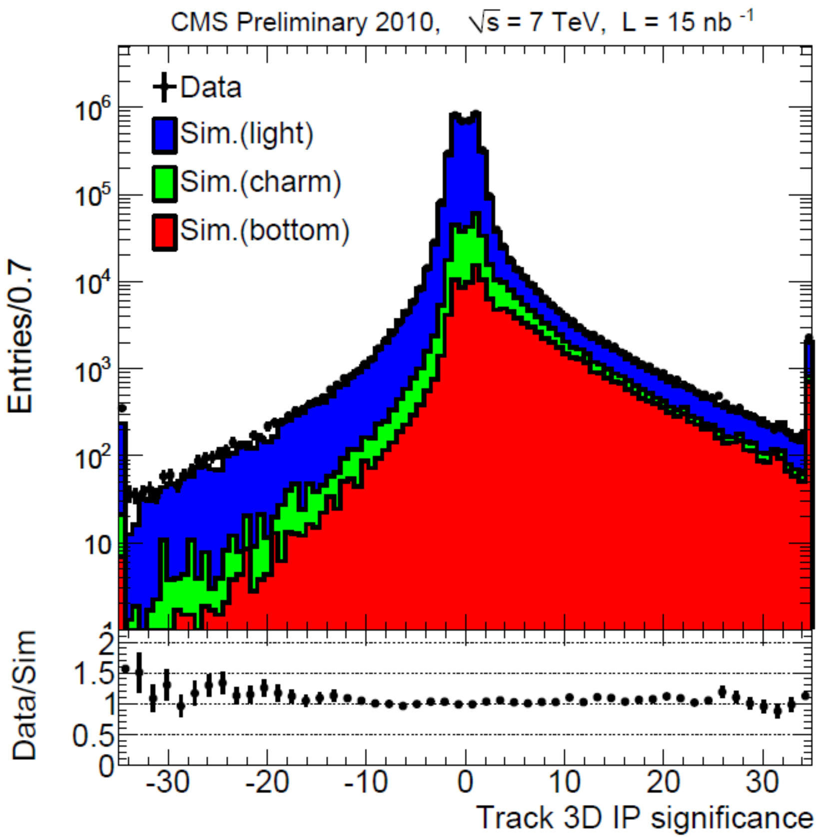
Data Certification

- The complexity of the offline workflows requires robust validation
- Several stages of Data Quality Monitoring (DQM):
  - online DQM → monitor detector performance during data-taking
    - dedicate event stream (sampling)
  - offline DQM → monitor performance of physics objects
    - runs on full statistics available for analysis:
      - express reco → fast feedback
      - prompt-reco → continuous monitor
      - offline re-reco → validation of software and condition updates
- Physics Validation Team → coordinates the validation activity. Feedback from:
  - groups responsible for physics objects
  - detector performance groups
  - analysis group

Performance

- Offline workflows demonstrated needed robustness and flexibility:
  - can tune latency depending on needs
  - produce physics results very quickly: plots like this one →

    out of prompt-reconstruction
    (few hours after the data acquisition)
- Quality of prompt-reco → minimize need for offline re-reco
  - by design 3 re-reco per year
- Key ingredients:
  performance of reconstruction code:
  - on minimum bias events:
    - timing: 0.6 seconds per event
    - event size:
      - 400kB RECO
      - 150kB AOD



Outlook

- ICHEP2010 → great stress-test of the whole analysis chain
  - acquired/calibrated/aligned/validated and analyzed all data up to last Monday
- Offline workflows → key ingredient for analysis capabilities
  - tools for fast calibration and feedback on detector performance
  - reliable validation strategy
  - produce and distribute data “analysis-ready”
- So far: performance of the system fully satisfactory
  - present commitment → optimize and consolidate all steps
    - getting ready the challenge of higher luminosity