Physics at LHC and beyond
10-17 August 2014, Quy-Nhon, Vietnam

Part2: challenges of CMS operations during LHC Run 1

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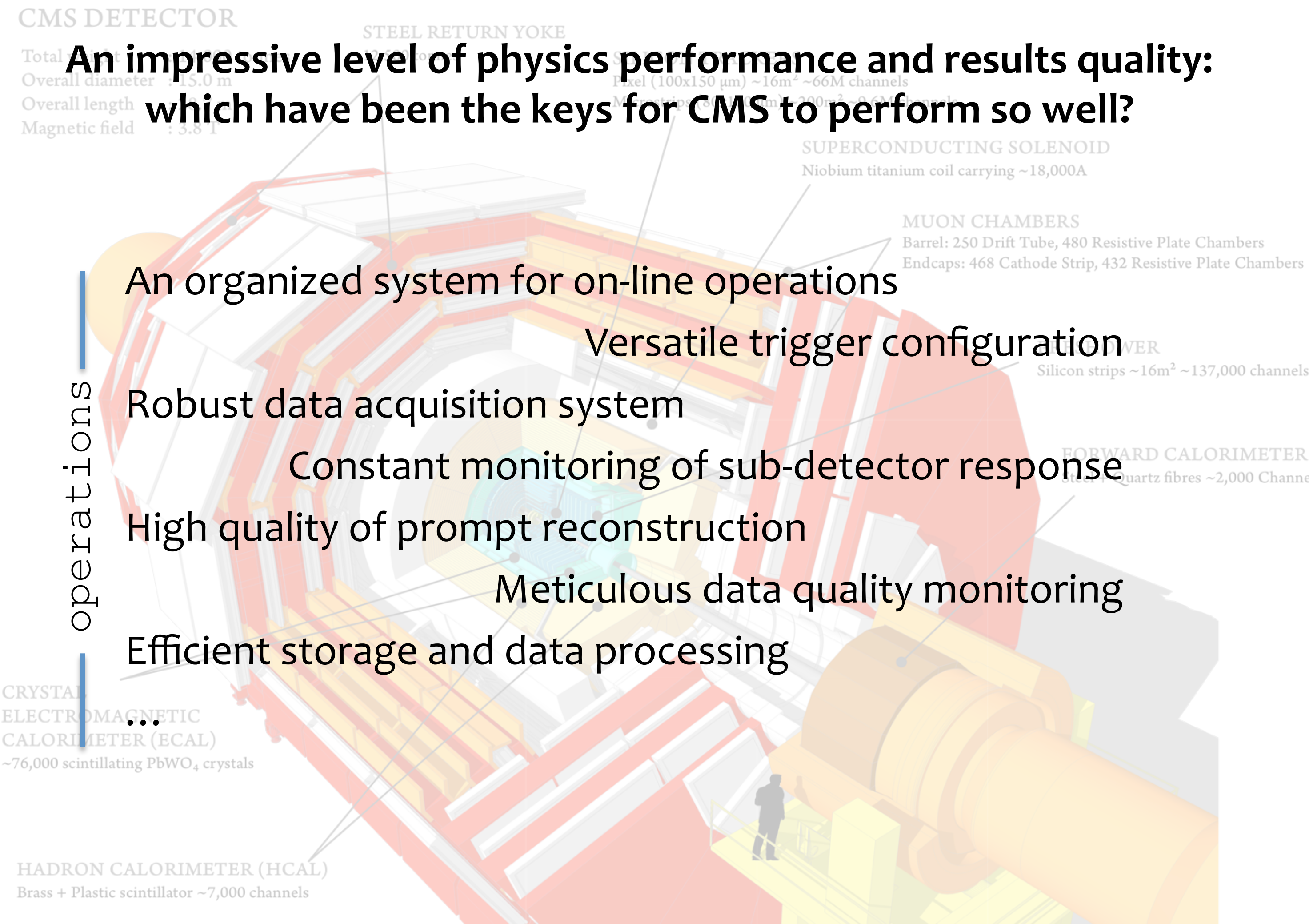
on behalf of CMS collaboration



An impressive level of physics performance and results quality: which have been the keys for CMS to perform so well?

operations

An organized system for on-line operations

Versatile trigger configuration

Robust data acquisition system

Constant monitoring of sub-detector response

High quality of prompt reconstruction

Meticulous data quality monitoring

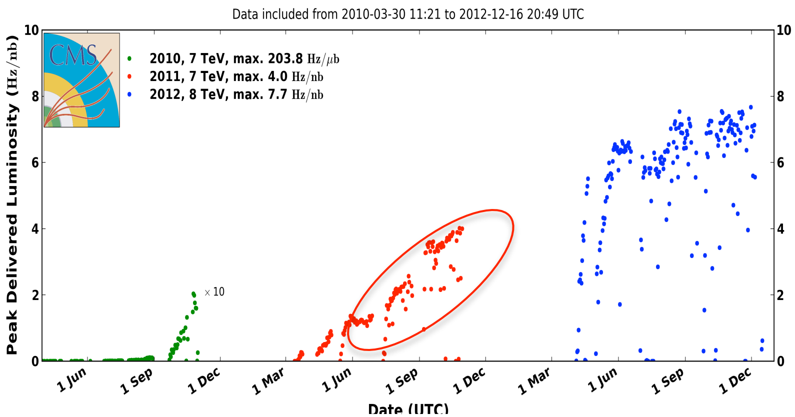
Efficient storage and data processing

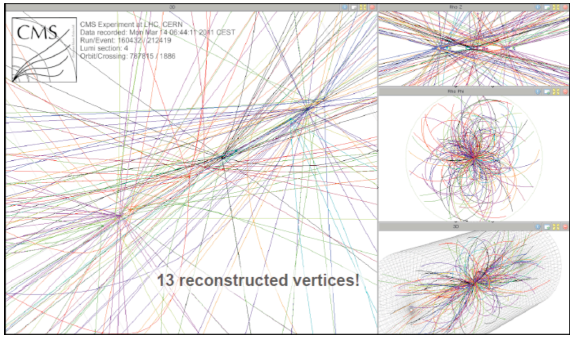
…

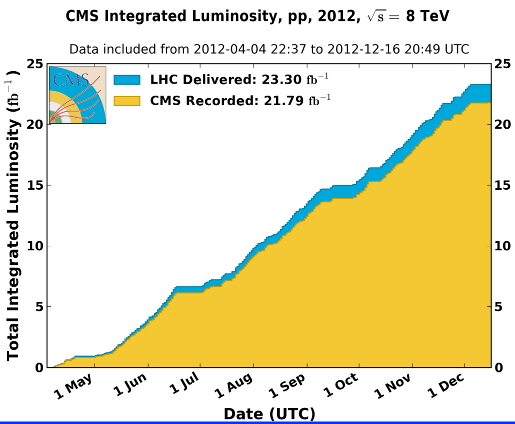
Challenges during LHC Run 1

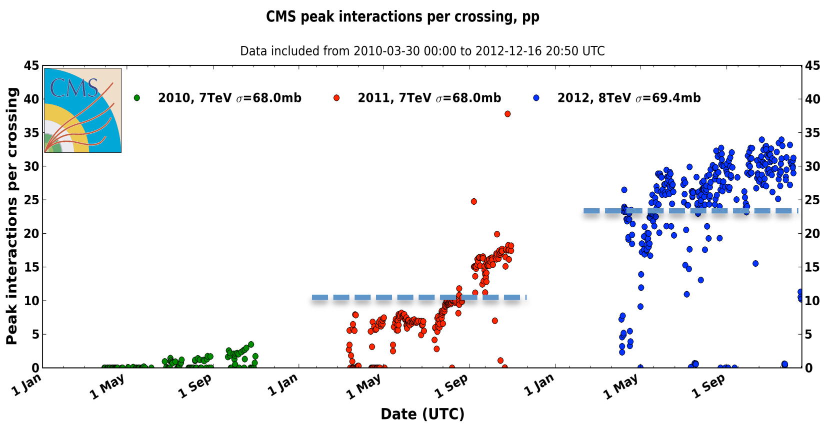
Increasing of peak lumi →
need revisiting of trigger paths

Increasing of pile-up (#proton/bunch) →
need tuning of reconstruction and triggers







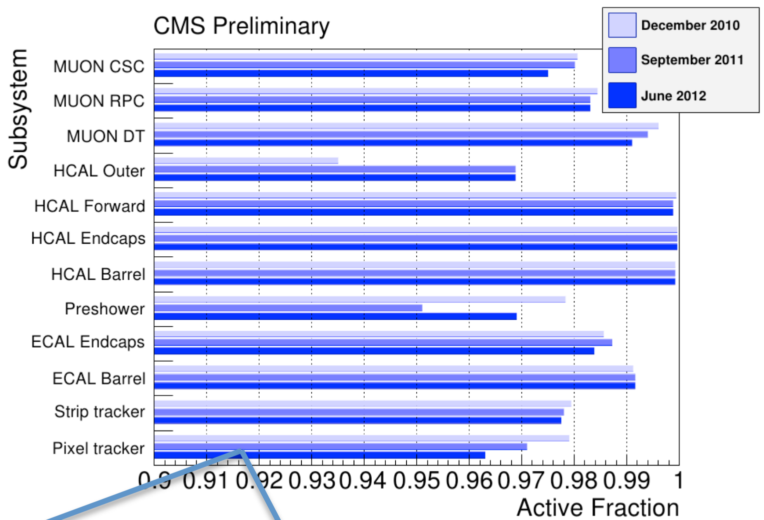


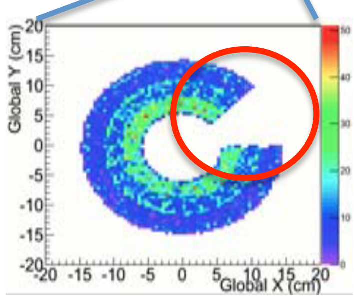
Detector downtime → need automation of data acquisition

Challenges during LHC Run 1

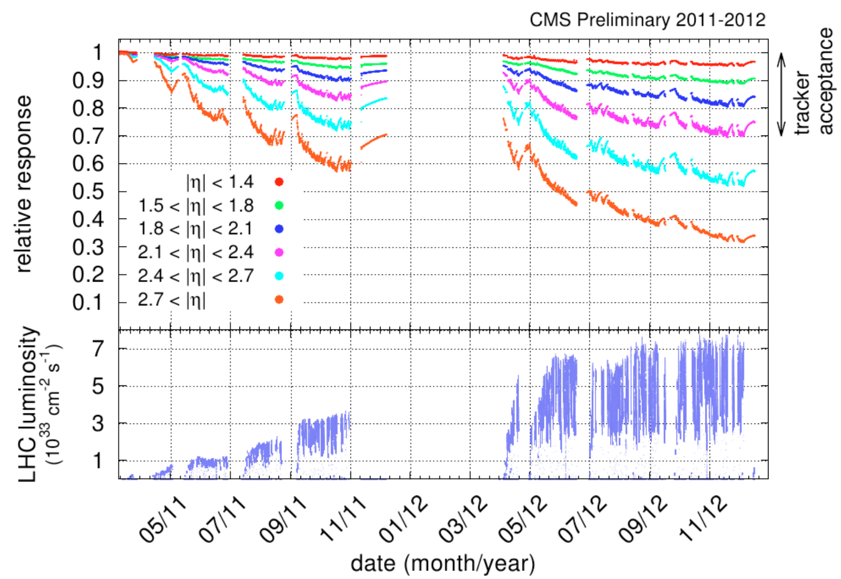
Detector inactive module/channels →
most of the losses addressed during shutdown

Misalignment and miscalibration →
A fast workflow already during prompt reco





Pixel disk region masked due optical connections



ECAL transparency loss used to correct physics data promptly

How did we tackle all this?

An organized system for on-line operations

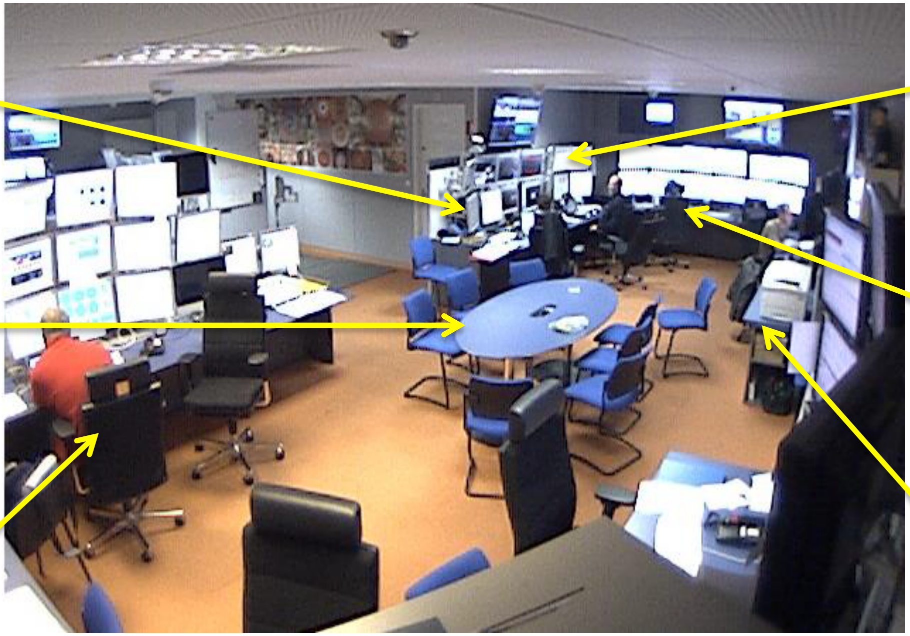
CMS control room: core of the operations at LHC Point 5

- **Most far of LHC points** from Meyrin site (where main experts reside)
- Built up an easy-to-access system for allowing key expert interventions **from remote**

CMS shift leader

Run Field manager

Detector Control System (DCS) shifter



Data Quality Monitor (DQM) shifter

On-line trigger shifter

Data AcQuisition (DAQ) shifter

+ *Offline* shifter: run certifications, offline DQM, Operation Release Managers, etc..

A versatile trigger system

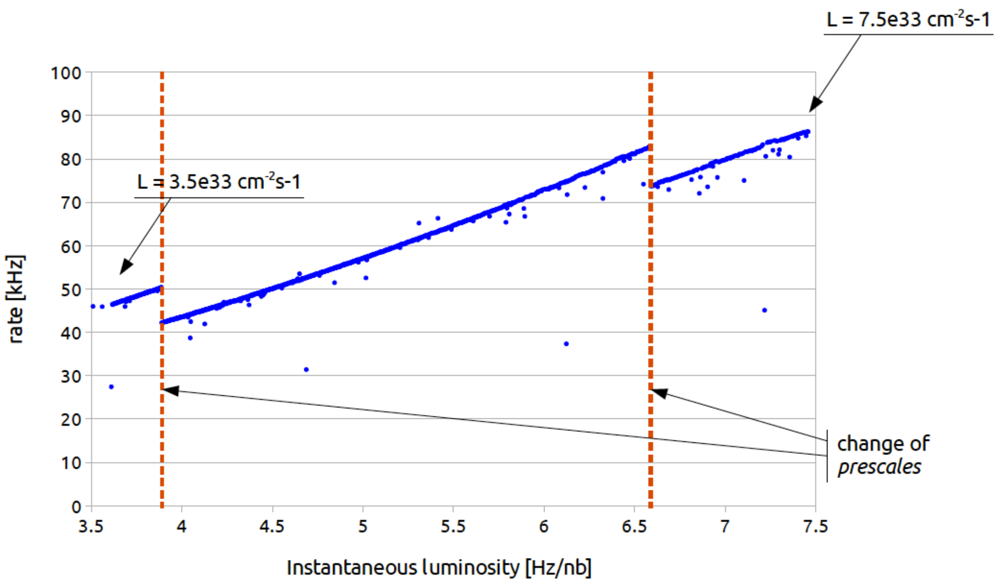
Level 1

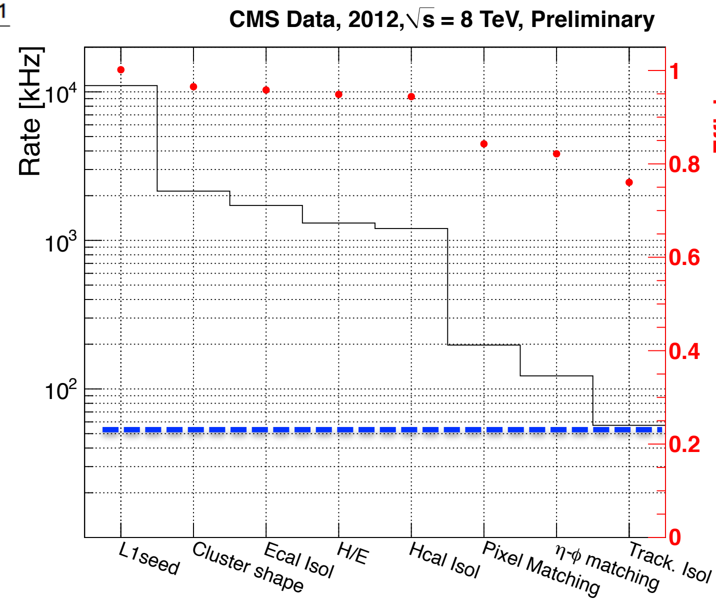
- hardware based : **4 µs** decision time
- 20-MHz bunch-crossing rate to **100 kHz**

+

High Level Trigger (HLT)

- Software based: **50-200 ms** decision time
- Reduce to **400 Hz** *(core)* + **600 Hz** *(parked)*





strategy

- ✓ **Re-tuning** of trigger paths and seeds, **rather than prescaling physics paths**
- ✓ **"parking"** of loose HLT path dataset (processed during LS1)
- ✓ Improving tracking and **speeding up reconstruction**

Detector downtime:

- Periodic re-synchronization of sub-detectors during data taking
- Stand-by needed also **during LHC dump warning** (kicker at point 6)
- **Require Heavy automation** of DCS and DAQ

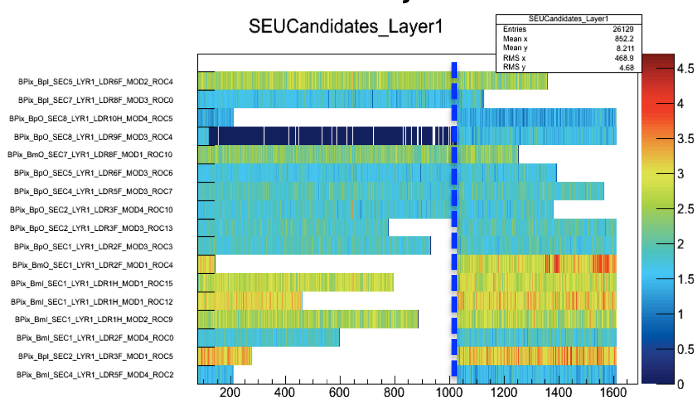
Downtime episodes during Run1

Tracker HV turn-on, need to be in stand-by until stable beam declared

→

- **Automatic ramping of HV at DAQ**
- Provided beam conditions met criteria in the **30 s** prior to the declaration of stable beam

1.5 bit flip / LHC fill in Pixel electronics caused by ionization



→

- Out Of Sync (OOS) errors
- Implemented at DAQ level
- **O(seconds)** to reconfigure

Constant monitoring of sub-detectors

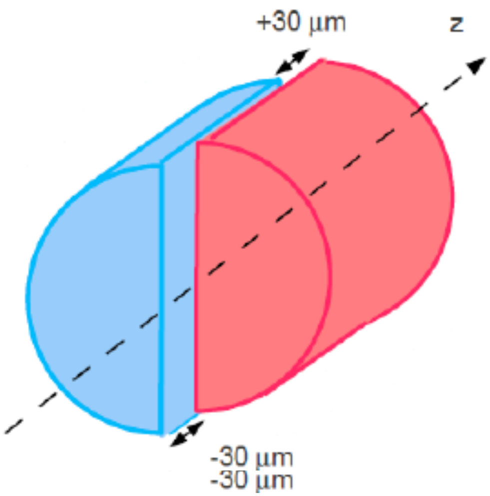
Example: detector control system for CMS solenoid (B=3.8T, kept at T=-268.5°C)

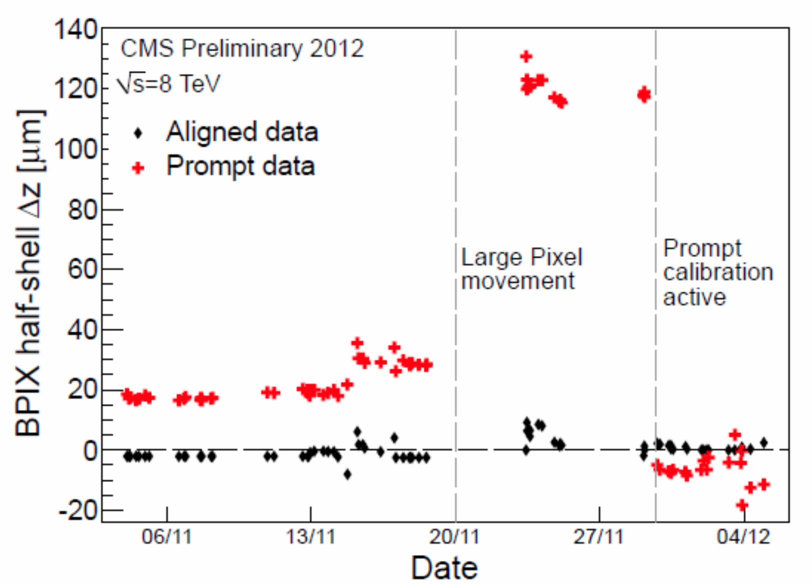
In general avoiding magnet recycling..

- Important downtime**: 2-3 days for ramping up** (critical if around LHC fills**)**

..if anyway needed

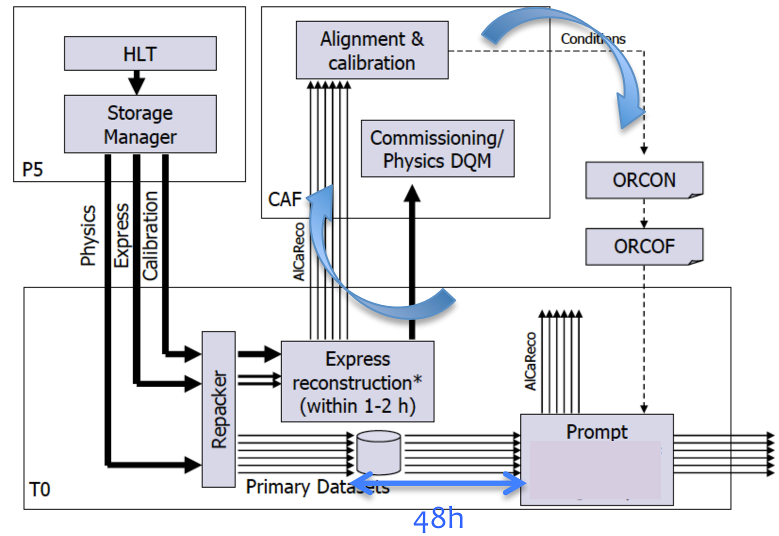
- at least controlling non-negligible mechanical effects on the rest of sub-detectors:
  - Longitudinal **100 μm** shift of the 2 halves of Pixel detector by magnet thermal cycle
  - **Recovered** by quasi-prompt alignment → **fully automated since Run2**





A prompt calibration *loop* in reconstruction

- Update-strategy based on delay between *express* and *prompt* reco (48h)
- Successfully used **during Run1** :
  - **beam-spot position** measured every Lumi Sections (LS= 23s of run)
  - **ECAL transparency corrections** measured with laser pulses

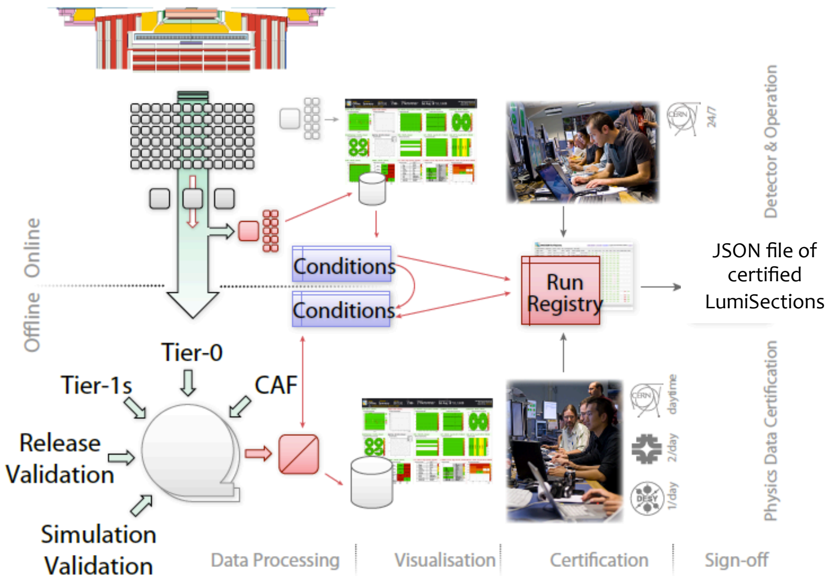


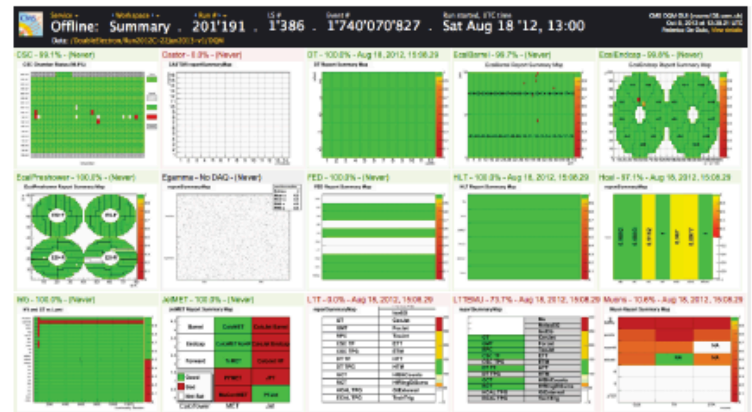
- Also conditions which need to be monitored (and updated if necessary):
  - **Tracker problematic channels** → HV trips/noise
  - **Calorimeter problematic channels** → mask hot channels
  - **Pixel alignment (since Run2)** → monitoring large structure shifts using tracks

CMS published physics measurements and discoveries out of prompt reco!

Monitoring of data quality (DQM)

- **Online :** live monitoring of detector performance during data taking
- **Offline :** reliable certification of the recorded data and release validation



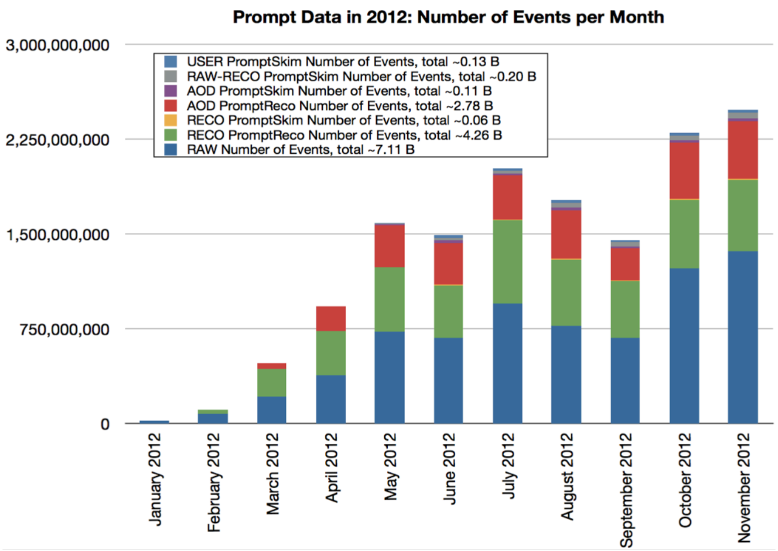


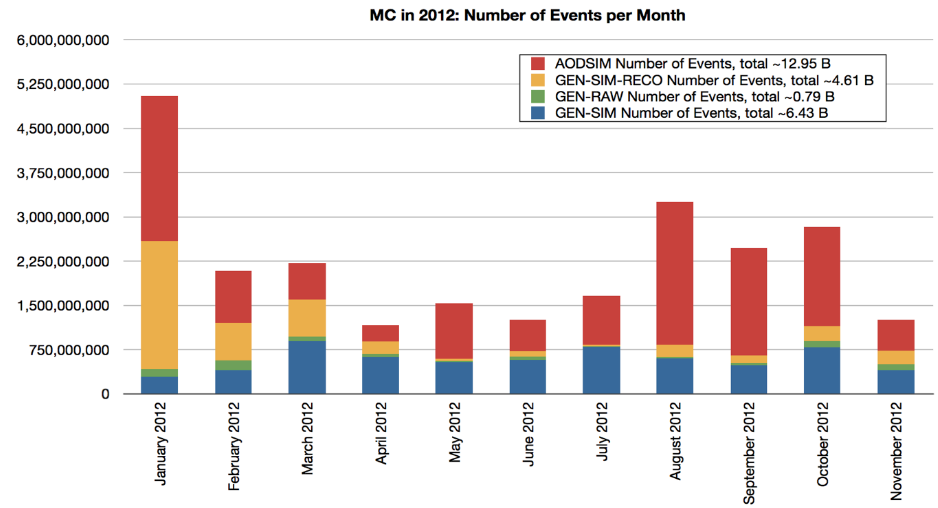
A snapshot of DQM GUI

- Web site (GUI) for browsing data quality histograms for a given dataset/run
- **Selection of LS** considered for physics performed **weekly** by offline detector experts and shifters
- Final list distribute in **JSON format** to use for filtering in the analysis jobs

An efficient storage and data flow

- 2012 was the busiest of the Run I years in terms of data collection and storage
  - **7 B physics events** were collected: 4 B prompt-reco + parked data
  - All 2012 data was reprocessed later in 2013:
    - Only few re-reco, thanks to timely **release validations** and **prompt calibration**
  - **13 B MonteCarlo simulated** events have been produced





Computing was used at 100% , no large problems which required recovering

Run 1: a success for CMS operations (and LHC machine)

Peak instantaneous luminosity	**7.67 10^{33} cm^{-2} s^{-1}**
Max interactions per bunch crossing (PU)	**34.55**
Maximum colliding bunches	**1380**
Best recording efficiency by lumi for one fill	**98.93% [171.20 pb^{-1}]**
Maximum Recorded lumi in one day	**280.07 pb^{-1}**
L1 trigger output rate	**100 kHz**
HLT physics stream output rate	**400 Hz**
HLT physics stream output rate (for parked data)	**600 Hz**

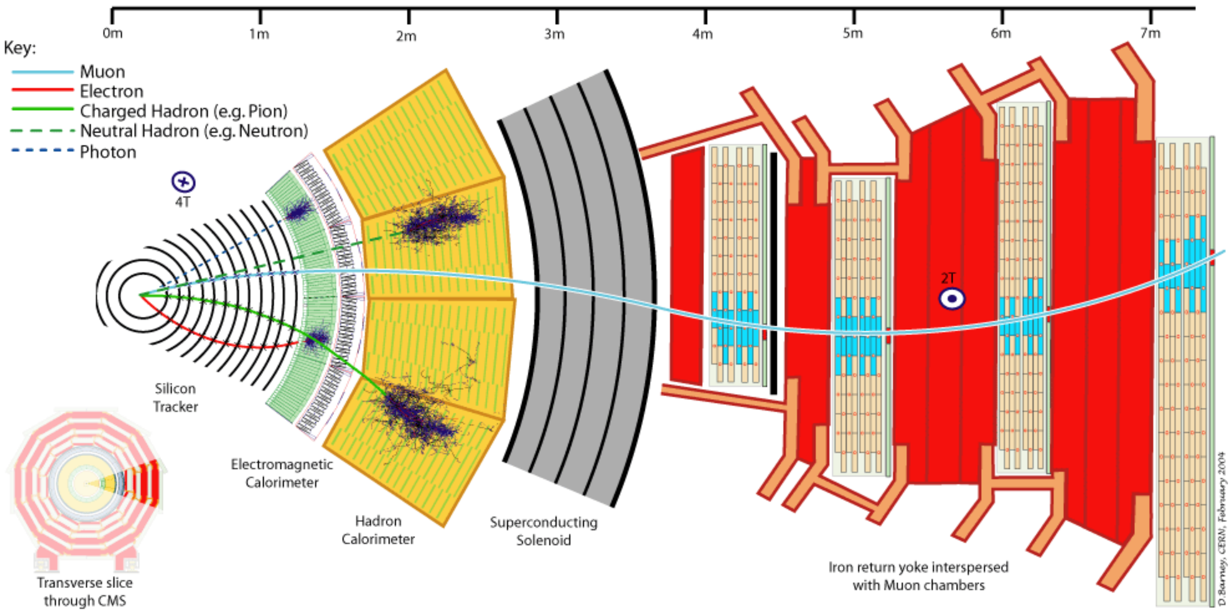
- Major improvements and challenges foreseen:
  - **Trigger, Tracking** : facing higher PU and ou-of-time PU (operations at 25ns)
  - **Prompt calibration** workflows: more automatized
  - **Computing:** the scale of the problem will increase by factor 6 in 2015 (x 2.5 evt reco time)

Many lessons from Run1 and CMS is working to keep the standard high for Run2

BACKUP

The tool: a Compact Muon Solenoid

- From particle reconstruction: muons, electrons, hadrons (charged and neutral), photons



… to physics objects: muons, electrons, jets, photons

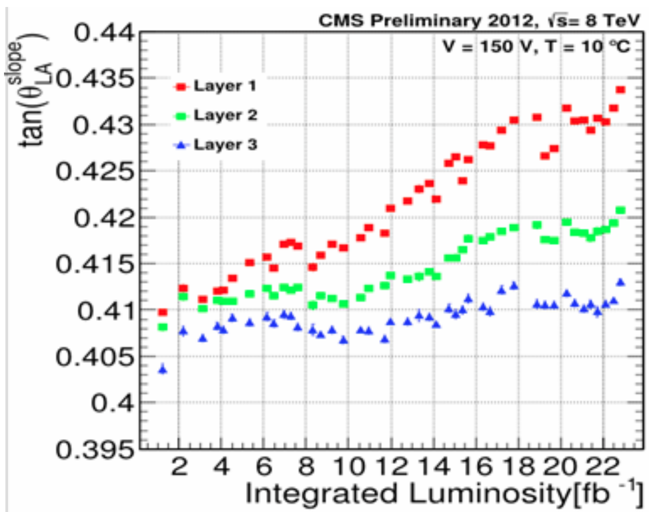
- Excellent detector performance:
  - Track-finding efficiency is more than 99%
  - Transverse momentum resolution: $\sigma(p_T)/p_T$= 1.5 - 3% for tracks of p_T ~ 100 GeV
  - Energy resolution for electrons and photons: $\sigma(E)/E$~ 1 %

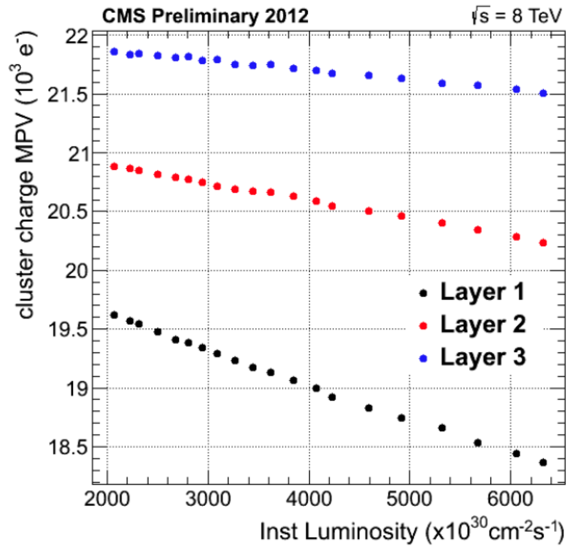
Effects of pile-up and luminosity increase in Pixels

A Short term effect:

- Higher occupancy increases the power consumption and therefore the temperature in the ROCs

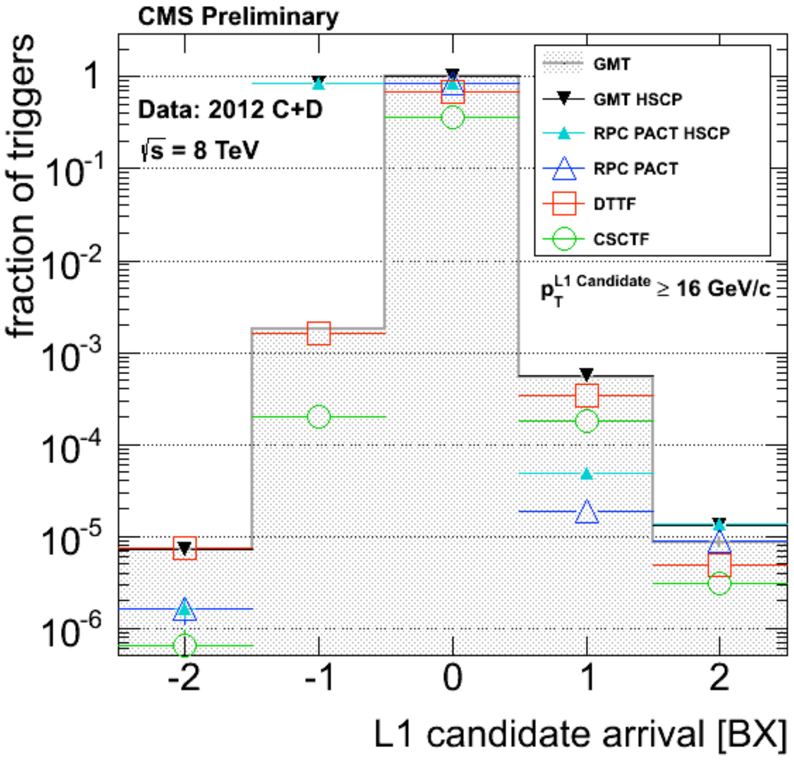
  →pixel charge gain calibration is temperature dependent

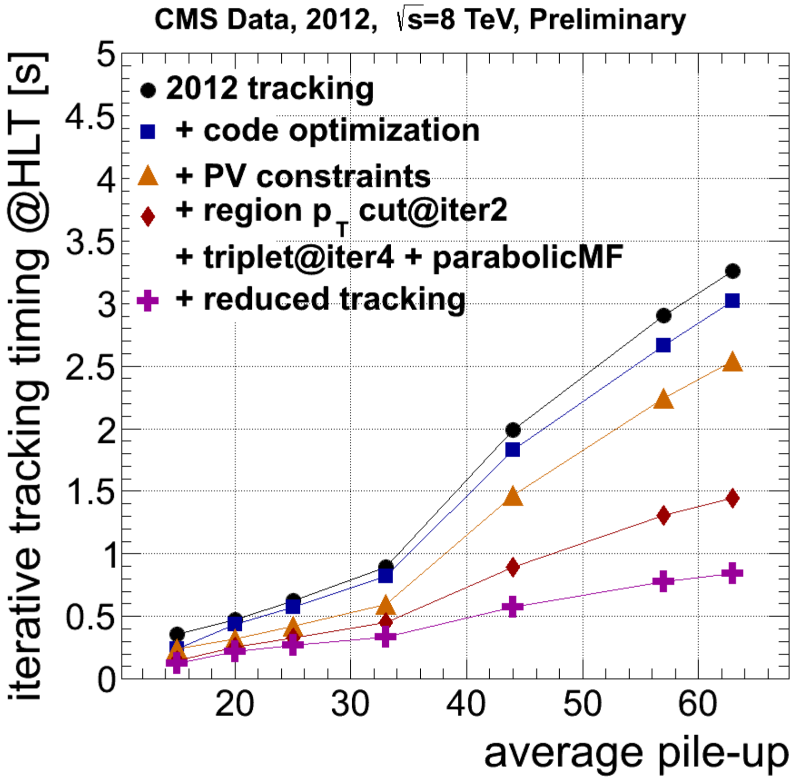




A long term-effect:

- Lorentz-angle measurement :
  - Also depends on integrated luminosity
  - Highly depends on bias voltage
  - Influences charge-sharing among pixels





L1: fraction of L1 muon triggers in the different bunch crosses

HLT: many studies and improvements have been developed during LS1 in order to mitigate the track reconstruction timing