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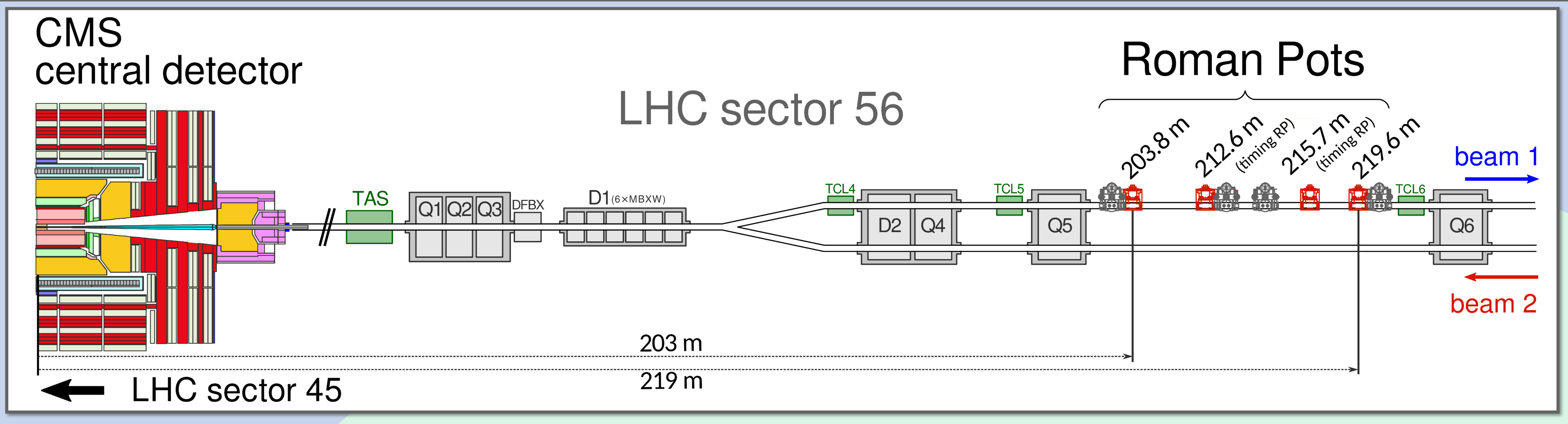
Authors: A. Bellora[1], T. Ostafin[1] on behalf of the CMS Collaborations
Contacts: andrea.bellora@cern.ch

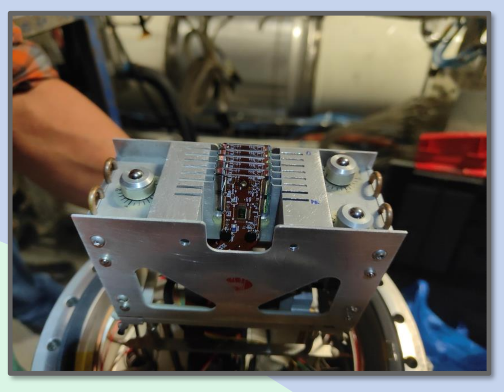
[1]AGH University of Kraków, Poland

An automation framework for the calibration of the CMS Precision Proton Spectrometer

The CMS Precision Proton Spectrometer

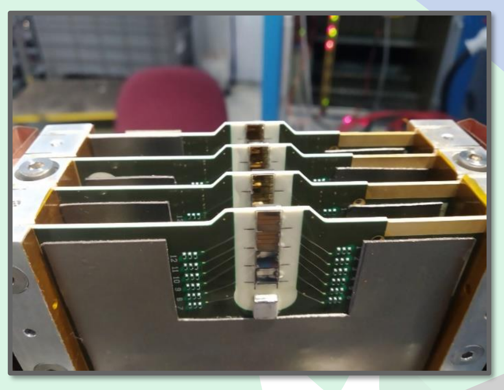


The **Precision Proton Spectrometer** is a system of **near-beam tracking and timing detectors**, **located in Roman pots (RPs)** at about **200m from the CMS interaction point (IP)** [1]. The Roman Pots are movable mechanical devices that allow the detectors to be brought very close (within a few mm) to the beam, to measure the 4-momentum of the scattered protons, along with their time-of-flight from the IP. PPS is taking data during the LHC Run 3 with its upgraded detector system [2].
The **PPS physics program is focused on Central Exclusive Production (CEP)**, a family of processes in which the protons survive the interaction at the IP. Information on the proton kinematic properties can be correlated with the decay products measured by the CMS central detectors, providing a **strong background suppression,** and **cleanly tagging CEP events.**



Tracking detectors

- 3D silicon pixel sensors
- PROC600 readout chip
- 150 μm thickness
- 150 × 100 μm^2 pitch
- 1.56 × 1.6 cm^2 active area
- 2 stations per sector
- 6 planes per station

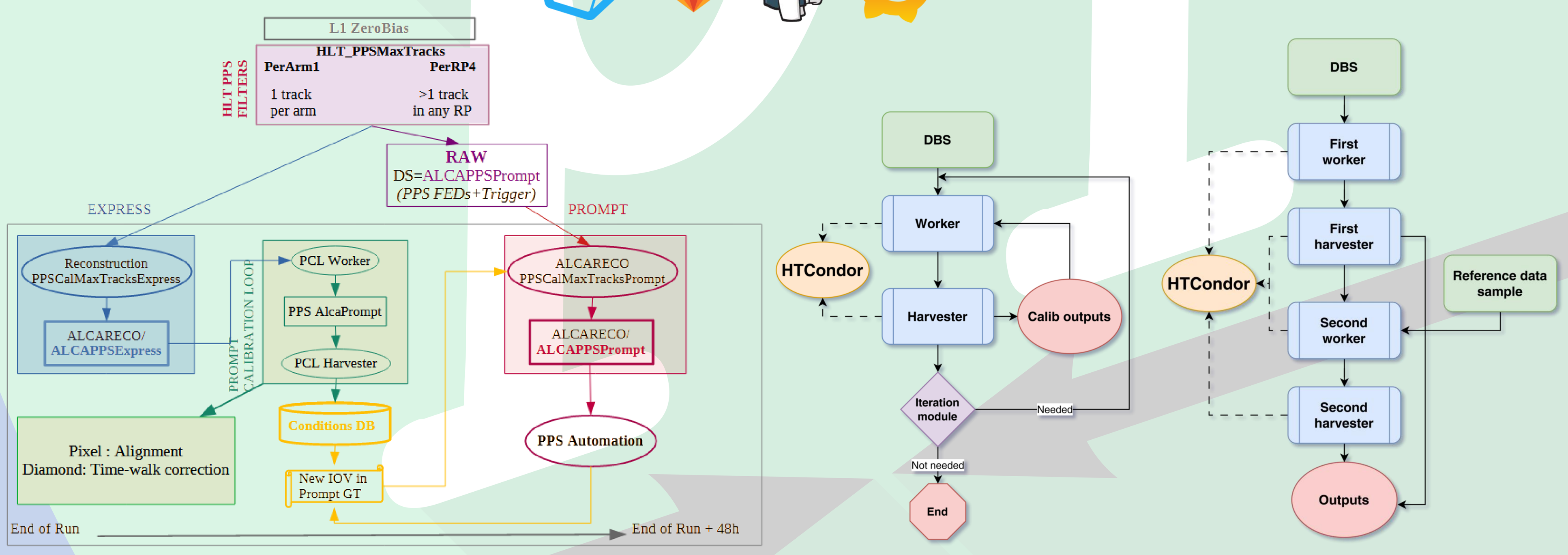


Timing detectors

- Diamond sensors
- NINO+HPTDC readout
- Double-diamond layout
- 500 μm thickness
- 2 stations per sector
- 4 planes per station
- 10-12 channels per plane

CMS Automation Framework

Originally developed for the calibration of the CMS Electromagnetic Calorimeter, the Automation Framework is now being adopted by many sub-detectors. The main objective is to **reduce repetitive time-consuming tasks** that were previously performed by scientists, and **turn them into automatic workflows**.
This also comes with the benefit of making the results available more promptly, thus ensuring a quick response in case of anomalies.
The automation processes is **extremely versatile**, but, in its basic usage, it takes the data that are produced at the *Prompt reconstruction* level. These already include some fast calibrations that are executed by analysing small sets of data (after the *Express reconstruction*), and allow the automation to **leverage the full statistics** and perform calibration routines that can only be executed offline.
The framework was developed using **industry-grade tools**, such as GitLab, InfluxDB, Jenkins, HTCondor, and Grafana, hosted by the OKD PaaS platform that is available at CERN.
Calibration workflows, which consist in a sequence of **tasks**, are implemented as simple Python scripts, and call CMSSW framework plugins that would previously be executed manually. Each task can submit **multiple jobs** via HTCondor, profiting from the available computing clusters. Data can be aggregated following user-defined logics, e.g., PPS calibrations group data by data-taking run.
The **status** of each task and job, for each run is made **persistent using InfluxDB** and Jenkins acts as a steering wheel for the submission and execution of the analysis jobs. A Grafana **monitoring dashboard** was developed in order to spot any failures and allow users to intervene when needed.



PPS Calibration Workflows

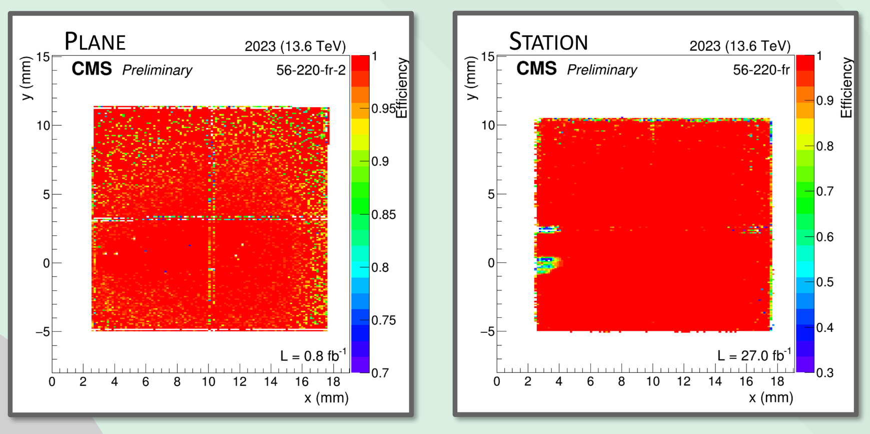
Tracking workflows

The **main calibration workflow** for tracking detectors consists in the computation of their **efficiency** [3], which evolves over time because of radiation damage:

- Compute the efficiency of each detector plane
- Convolve the per-plane results in a tracking station efficiency

Main features:

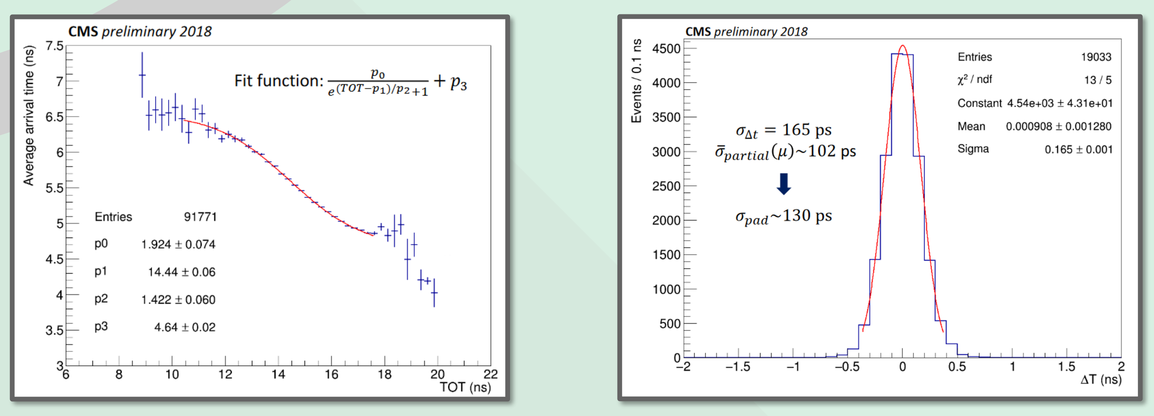
- Multiple input data sources
- Computationally intensive



Timing workflows

Two calibration workflows are vital for the timing detectors [4]:

- **Alignment and time-walk correction**
  → correct the time of arrival as a function of the signal time-over-threshold and subtract constant time offsets
- Per-channel **time resolution** measurement
  → essential to weight properly every channel hit when combining the time information from multiple channels



Main features:

- High inter-dependency between workflows
- The computation of the channel resolution requires iterative steps

Results

The automation of calibration procedures, albeit with some overhead, has proven to **hugely decrease the person-time required by calibration tasks**

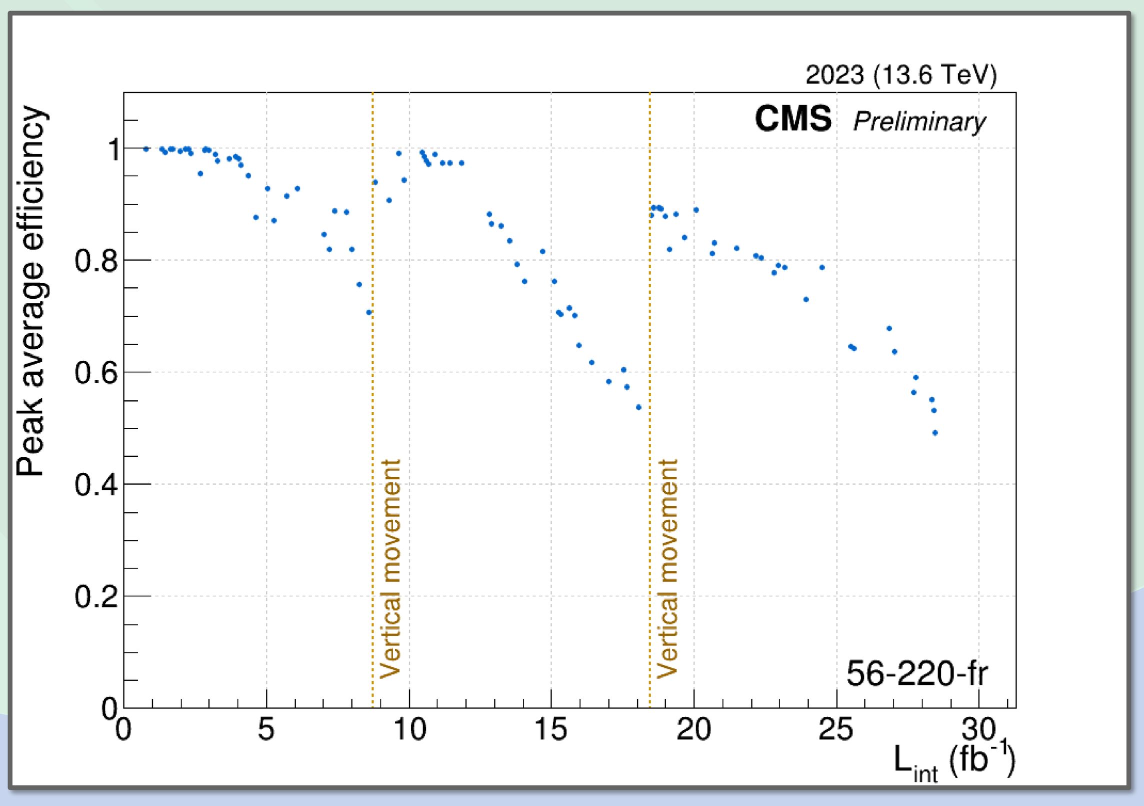
- Calibration procedures that previously took 1-2 months of user-time, now require a few days in total

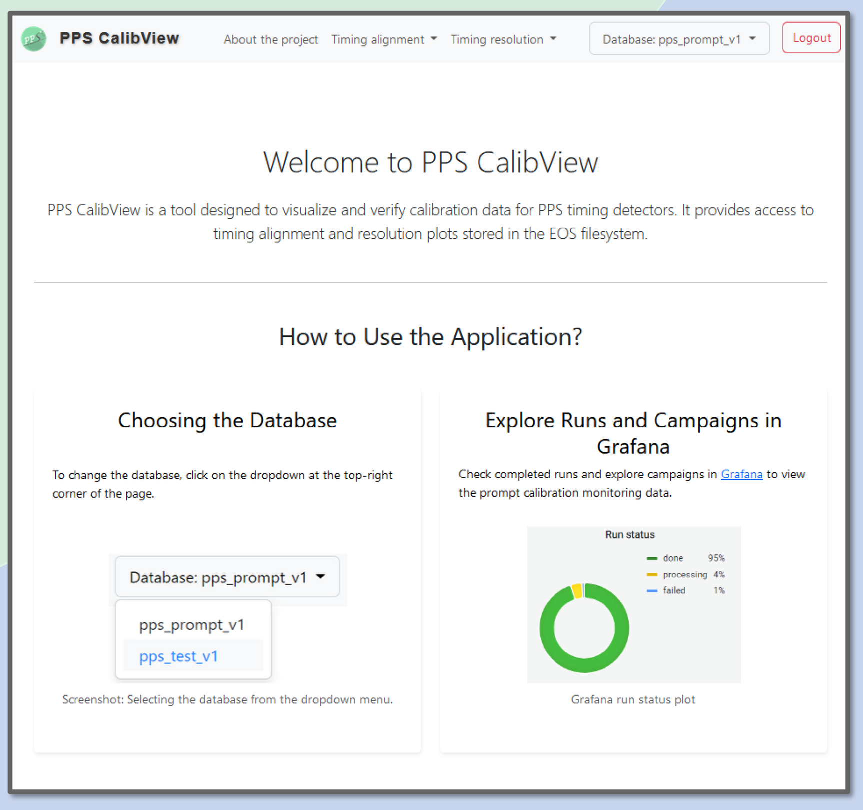
The PPS calibrations are **very efficient and fast**, even when requiring the re-reconstruction of entire datasets:

- The entire **PPS 2024 calibration dataset (~13 TB) was processed in ~36 hours**
- Finer optimizations are now possible, as an easy turn-around time can be achieved

Automatic calibrations also allow for **better monitoring**:

- **Dedicated applications** are being developed
- **Long-time trends** can be observed and used to improve the detector operation in view of better performance [5]





References

[1] CMS and TOTEM Collaborations, *CMS-TOTEM Precision Proton Spectrometer*, CERN-LHCC-2014-021, TOTEM-TDR-003, CMS-TDR-13
[2] CMS Collaboration, *Development of the CMS detector for the CERN LHC Run 3*, JINST 19 (2024) P05064
[3] CMS Collaboration, *Efficiency of the Pixel sensors used in the Precision Proton Spectrometer: radiation damage*, CMS-DP-2019-036
[4] CMS Collaboration, *Time resolution of the diamond sensors used in the Precision Proton Spectrometer*, CMS-DP-2019-034
[5] CMS Collaboration, *PPS: performance in Run 3 and efficiency of the pixel detector*, CMS-DP-2024-008

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