PROCEEDINGS OF SCIENCE

CMS Cathode Strip Chamber Calibration Constants and Validation Using the 2022 Calibration Run data

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The reconstruction of data from the Cathode Strip Chambers (CSCs) relies on calibration data, including electronic constants such as gains, pedestals, timing constants for triggering, and complete chamber validity information. These calibration parameters, referred to as conditions data, are generated through dedicated calibration runs or studies conducted between data-taking periods. This proceeding outlines the procedures for measuring, validating, and storing these constants. Additionally, it describes the creation and storage of bad chamber files.

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1. Introduction

The CMS experiment features 540 Cathode Strip Chambers (CSCs) installed in its endcap region. The CSCs are cylindrical detectors surrounding the beamline, with positions typically described in cylindrical coordinates. The wires run radially (along the r-direction) to measure the ϕ-coordinate, while the strips, oriented perpendicularly, determine the z-position. By combining the z-position from the strips and the ϕ-position from the wires, a complete 3D hit position is reconstructed. Fig. 1 shows the geometry of strip and wire planes in a CSC chamber and illustrates how we detect muons using the CSCs. Conditions data for the CSCs include parameters essential for reconstructing muon hits, enabling their use in the High-Level Trigger (HLT), offline reconstruction, and Monte Carlo (MC) simulations. Conditions data are sets of run- or time-dependent information stored in a central database system. Table 1 presents the various types of condition data, detailing their purpose, usage scenarios, and update intervals.

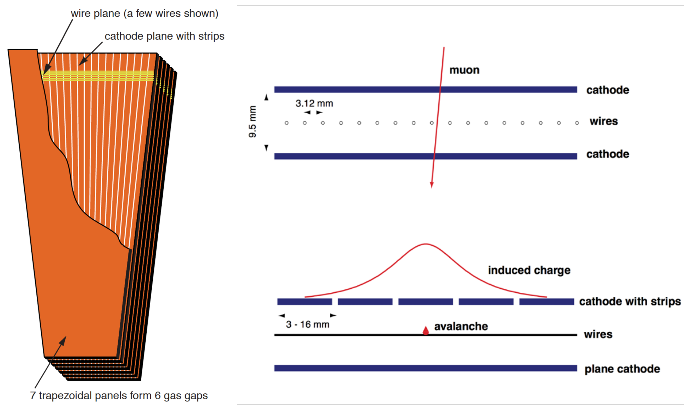

Figure 1: (Left) CSC chamber showing wire plane and cathode strips and (Right) Muon detection in CSCs

2. Calibration

Calibration constants for the CSC electronics are derived from dedicated pulser runs conducted in non-beam conditions. Each of the 270,000 strips in the CSC system is assigned a linear integer index, facilitating efficient database storage and rapid retrieval of associated values. For instance, pedestal values are measured with the pulser amplitude set to zero. In Fig. 2 a point is plotted for each of the 270k strips in the system, where the ordinate is the strip channel index, and the abscissa is the relative change in the pedestal value, defined as the difference between the new and old values divided by the old value. The large differences in pedestal values correspond to chambers with newly-installed upgraded electronics.

3. Validation

When a muon passes through a CMS muon detector, it produces hits that are used to reconstruct its kinematics. To achieve precise values for reconstructed hits (rechits), calibration constants must

Conditions data	**What are they?**	**Where are they used?**	**When are they updated?**
CSCBadChambers CSCBadStrips CSCBadWires	Flags for chambers/channels not providing data	Simulation: for best match with an existing real dataset	When best simulation of existing data is required
CSCChambersTimeCorrections CSCDBChipSpeedCorrections	Offline adjustments to center rechit times on t=0 for IP muons	Real data and Simulation: for best offline rechit times	When online timing is changed (rarely)
CSCDBCrosstalk CSCDBGains CSCDBNoiseMatrix CSCDBPedestals	Electronics parameters of strip channels	Real data: precise values of minor importance Simulation: need values to convert hits to signal	When CSC Operations provides calibration data from dedicated CSC local runs
CSCCrateMap CSCChamberMap CSCDDUMap	Electronics cable mappings	Real data: hardware labels to geometric values	'Never' change
CSCRecoGeometry	C++ CSC strip and wire geometry in db format	Simulation: Digitization Real data: Local reco	'Never' change
CSCRecoDigiParameters	Chamber parameters associated with strip and wire geometry	Simulation: Digitization Real data: Local reco	'Never' change
CSCDBGasGainCorrections	Precise corrections to system gas gain derived from detailed Run I analysis	Precision CSC studies in run 1 only	No plans to update
CSCDBL1TPParameters	Basic pieces of information used by the trigger system obtained from CSC detector	To make decisions about whether to retain or discard collision events (Muon selection)	'Never' change

Table 1: Conditions Data Summary Table.

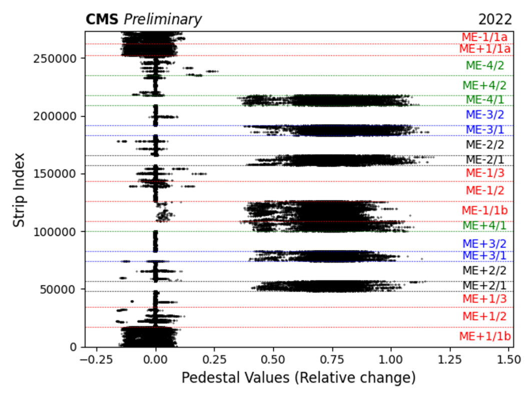

Figure 2: The relative change in pedestal values taken in 2016 and 2022 for each CSC strip channel. The labels on the right indicate the different rings of chambers in the CSC system. For example, ME+1/1 refers to station 1, ring 1 on the plus endcap side.

be applied to the raw CSC data. We then generate plots of the rechit residual distribution for each chamber. The width of the rechit position residual distribution indicates the precision with which hit positions in the CSC detector are determined. The residual is defined as the difference between the position of a rechit on layer 3 of a CSC and the expected position, which is derived from a segment fit to hits on all 6 layers of a CSC. The residuals are measured in units of the width of the strips. Validation plots such as Fig. 3, are reviewed for each chamber to evaluate the effects of updated constants compared to the previous ones. This plot is based on crosstalk, gain, pedestal and noise matrix values. There is typically little difference between old and new rechit position residuals because of the robustness of rechit builder algorithm but we need to ensure that the new constants maintain the good resolution. These constants play an important role in data taking and simulation to convert hits into spatial positions, times, and charge amplitudes.

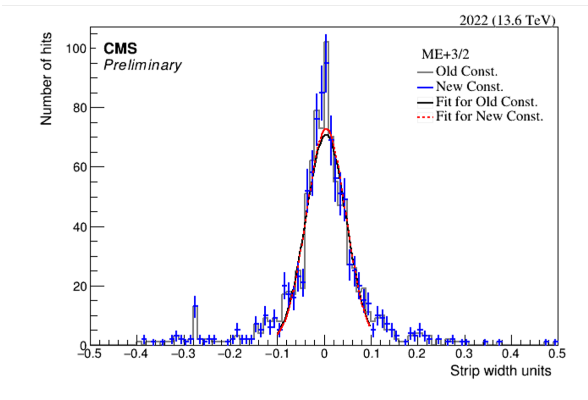

Figure 3: Rechit residual distribution for ME+3/2 chamber.

4. Bad Chambers

During CSC operations, some chambers may cease functioning and remain inactive until repairs are performed during short technical stops, held approximately every 10 weeks, or during extended year-end stops. On average, two to three chambers become inoperative per running period. There are many reasons why a chamber might not provide rechits, e.g., failed HV, LV, electronics boards, etc. Chambers that are non-functional during a specific period are designated as "bad chambers." We update the list of bad chambers in the central database to avoid digitization of such chambers in MC production in order to have the best match to the real dataset. Fig. 4 shows an example of how a bad chamber appears in data quality monitoring (DQM) plots.

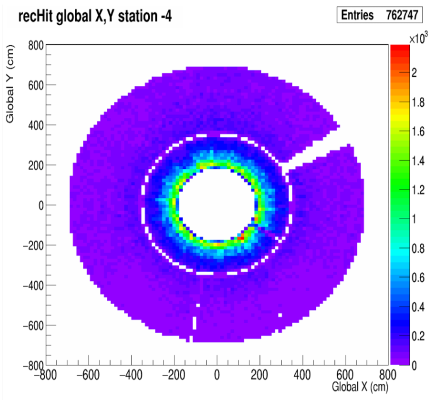

Figure 4: DQM plot showing a bad chamber in 2023.

5. Conclusion

The conditions data for CSC chambers are obtained from dedicated electronics calibration runs. After systematic validation, the constants are uploaded to the conditions database for use in data reconstruction and Monte Carlo simulations. In addition, chambers that are bad during each major data period are flagged in the database so that the simulation accurately reproduces the effect of the dead chambers.

References

[1] CMS Collaboration, “Development of the CMS detector for the CERN LHC Run 3”,arXiv:2309.05466.

[2] O. Boeriu, “Endcap Muon Chamber Calibration and Monitoring Procedures in CMS”, technical report, Northeastern Univ., Boston, MA USA, Jun, 2009, CMS-CR-2009-157