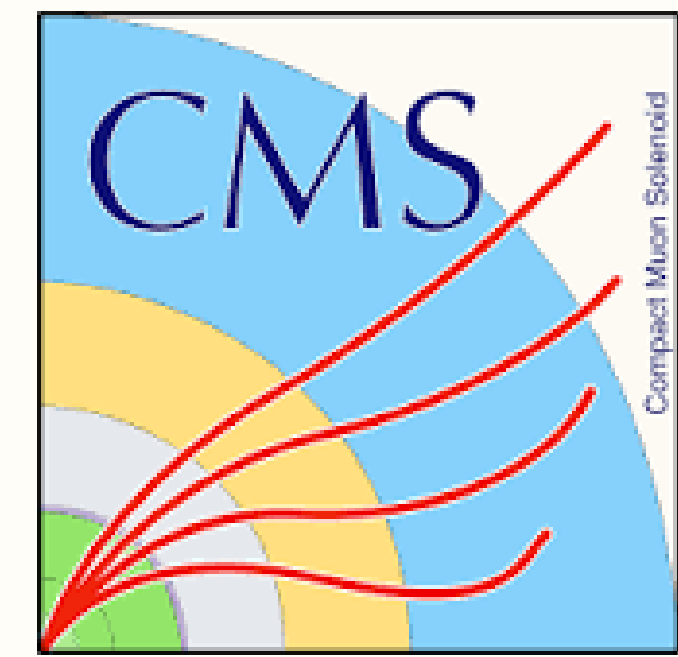


An Optimized Algorithm for Determining RPC HV Channel Working Points

Mihaela Pehlivanova on behalf of the CMS Muon group

Sofia University, Bulgaria

Correspondence to: mihaela.pehlivanova@cern.ch



1 Introduction

The CMS Resistive Plate Chambers (RPCs) provide fast and precise muon detection, with their performance strongly dependent on the applied High Voltage (HV). Optimal operation requires both **high detection efficiency** and **low cluster size**.

A **HV Scan** is performed during each data-taking year to characterize the efficiency and cluster size as a function of the effective HV for each double gap. The chamber is divided into **pseudorapidity partitions** (“rolls”), and several rolls can share the same HV supply channel. Individual roll working points are first determined from the efficiency curves and then used to establish a common working point for each HV channel. The traditional procedure primarily targets the **lowest possible operating voltage** that maintains the required detector performance. This minimizes the long-term effects of radiation-induced aging, since such effects accumulate primarily during operation with high voltage applied. However, when multiple rolls share an HV channel, this can result in a compromise in efficiency or cluster size for some of the rolls in the channel. This motivates the development of a **new approach** to determine the channel working points.

This work introduces a new algorithm to determine the HV channel working point by simultaneously considering the performance of **all rolls connected to the same HV channel**. The goal is to ensure efficient and stable long term detector operation while maintaining good spatial resolution.

2 Optimization of the channel Working Point algorithm

The standard algorithm used to determine the operating voltage of the HV channels is illustrated in Figure 1. When the working points (WPs) of rolls connected to the same channel differed significantly, the channel voltage was set according to the roll with the lowest WP, with an additional 100 V applied. This approach therefore avoided applying unnecessarily high voltage to the roll with the lowest WP, as could occur when using the average WP.

The proposed algorithm goes beyond minimizing the operating voltage. It simultaneously considers the performance of all rolls connected to the same channel, aiming to achieve high efficiency for all rolls while keeping the cluster size below 3. A smaller cluster size improves the spatial resolution of the RPC hit, allowing for a more precise determination of the muon trajectory and bending angle, which in turn improves the accuracy of the muon momentum estimation in the CMS muon trigger. [1]

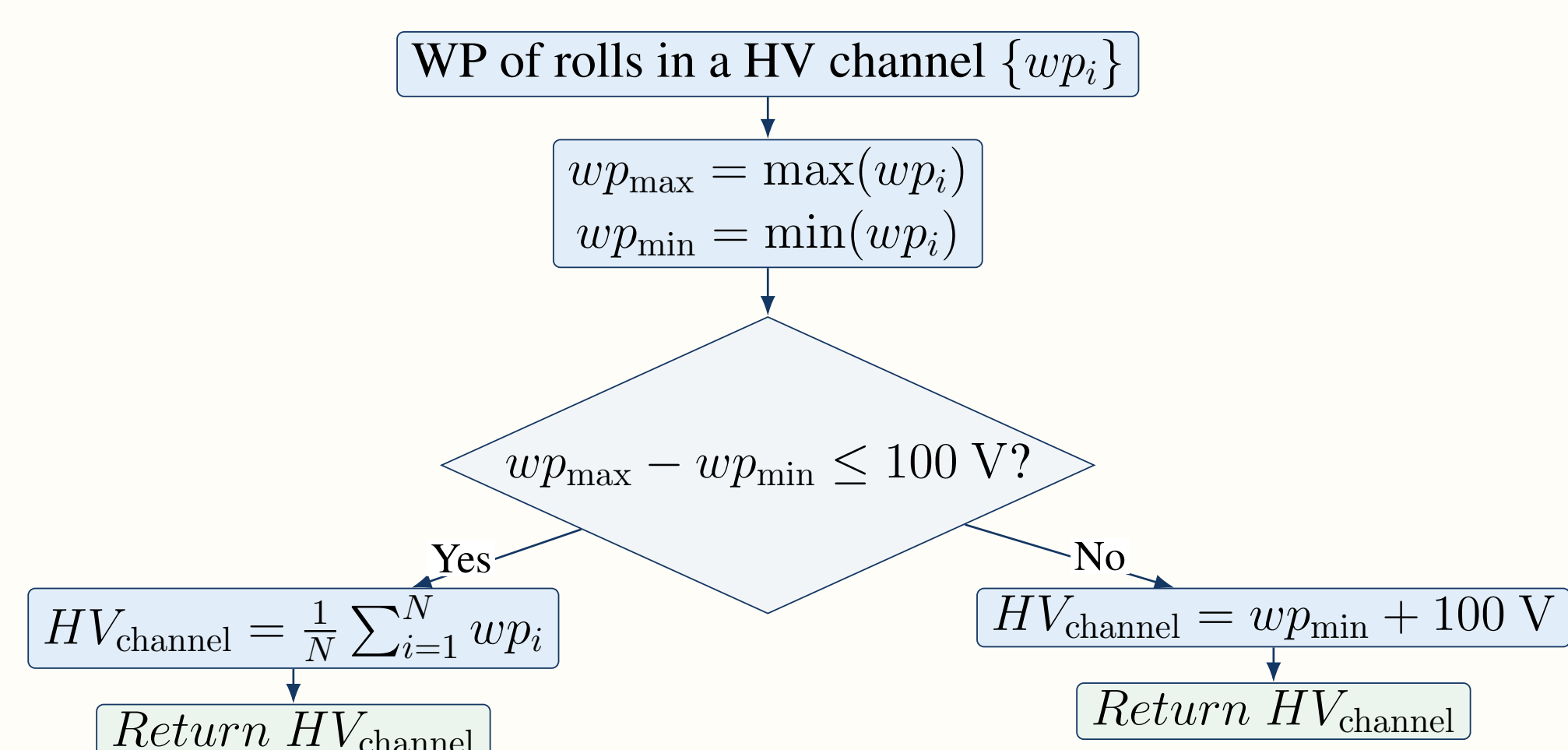


Figure 1: Standard [2] algorithm for determining the HV channel working point.

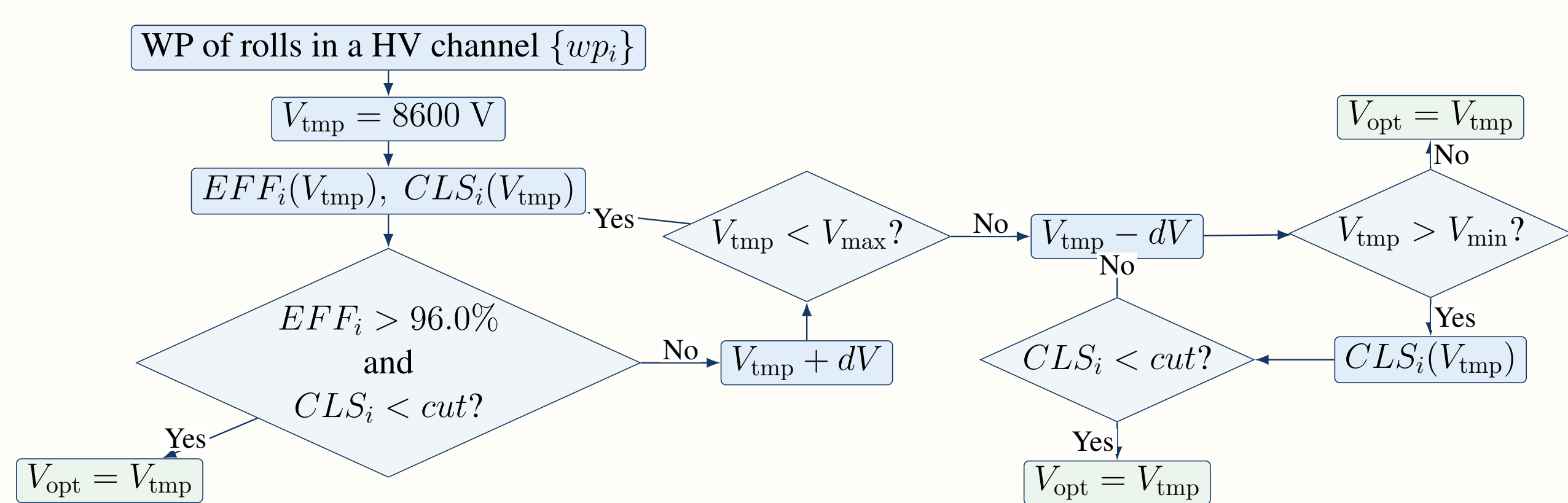


Figure 2: Proposed algorithm for determining the HV channel working point.

The cluster size cut was chosen in the range 2.1–2.6, with chamber-type-dependent values selected for RB1, RB2, RB3, RB4, RE1/2/3, and RE4. For each region, the cut was chosen to achieve a mean efficiency above 96% while minimizing the mean cluster size.

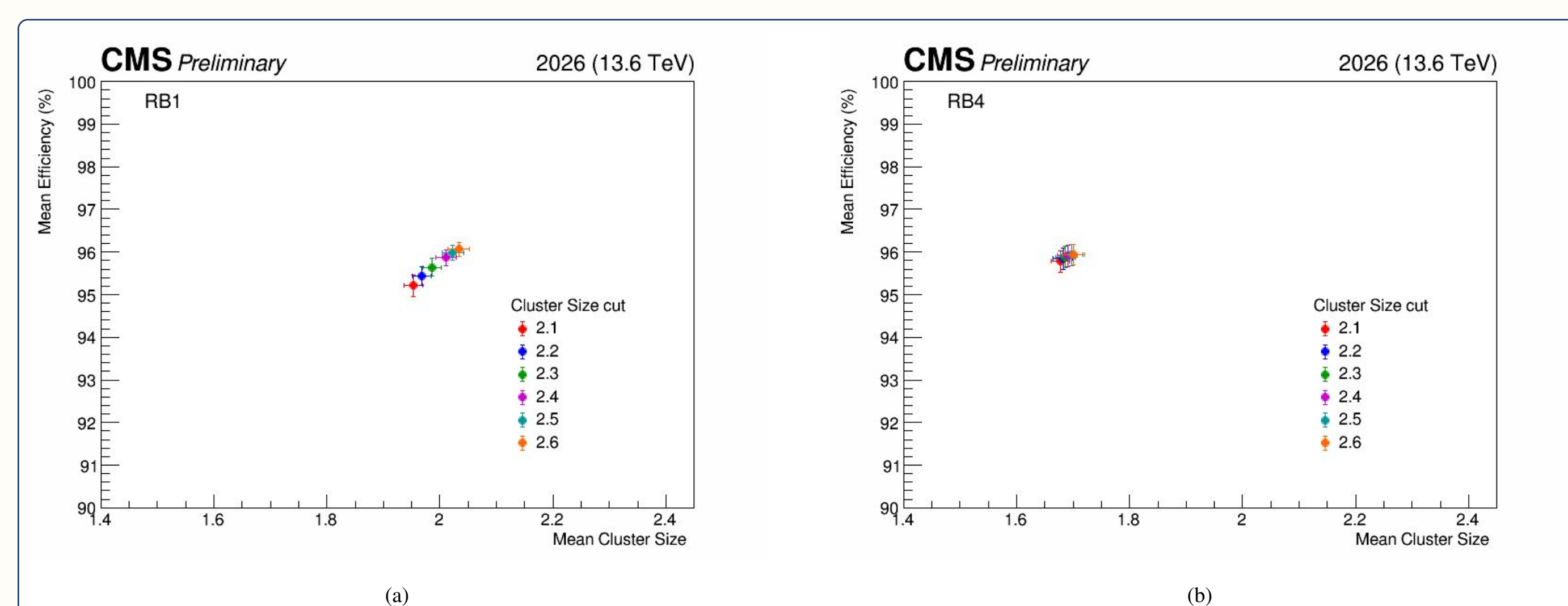


Figure 3: Mean efficiency versus mean cluster size for RPC rolls in the first RB1 (a) and fourth RB4 (b) barrel stations obtained with the proposed channel working point determination algorithm for different cluster size cut values. The markers indicate the mean values of the distributions, while the horizontal and vertical error bars represent the standard error of the mean. This study is used to determine the optimal cluster size cut. The results were obtained on 2026 HV scan data.

Conclusion

A new algorithm for determining RPC HV channel working points was developed, providing a more robust approach than the standard method. By scanning a range of voltages in small steps and simultaneously evaluating the efficiency and cluster size of all rolls connected to the same channel, the method determines a suitable channel working point while satisfying the required performance criteria. The comparison using the 2026 HV Scan data shows that the proposed approach achieves the targeted reduction in cluster size, while maintaining nearly equivalent efficiency to the standard method and avoiding excessive voltage on the individual rolls.

References

- [1] M.A. Shah and Samalan *et al.* Experiences from the RPC data taking during the CMS RUN-2. *Journal of Instrumentation*, **15**(C10027), 2020.
- [2] R. Reyes-Almanza *et al.* High voltage calibration method for the CMS RPC detector. *Journal of Instrumentation*, **14**(C09046), 2019.

3 Results

The proposed and standard algorithms were compared using the 2026 HV Scan data. The HV channel working point was calculated with both algorithms, and the efficiency and cluster size were evaluated for each roll at the corresponding working point. The differences are calculated as **proposed** – **standard** for the efficiency, cluster size and working point, respectively.

A left tail is observed in the distributions shown in Figure 4, corresponding to reduced working points and cluster sizes for some channels, together with a decrease in efficiency. While previous methods prioritized maintaining high efficiency, the method presented here achieves nearly equivalent efficiency while reducing the size of the cluster substantially in many cases, providing improved spatial resolution.

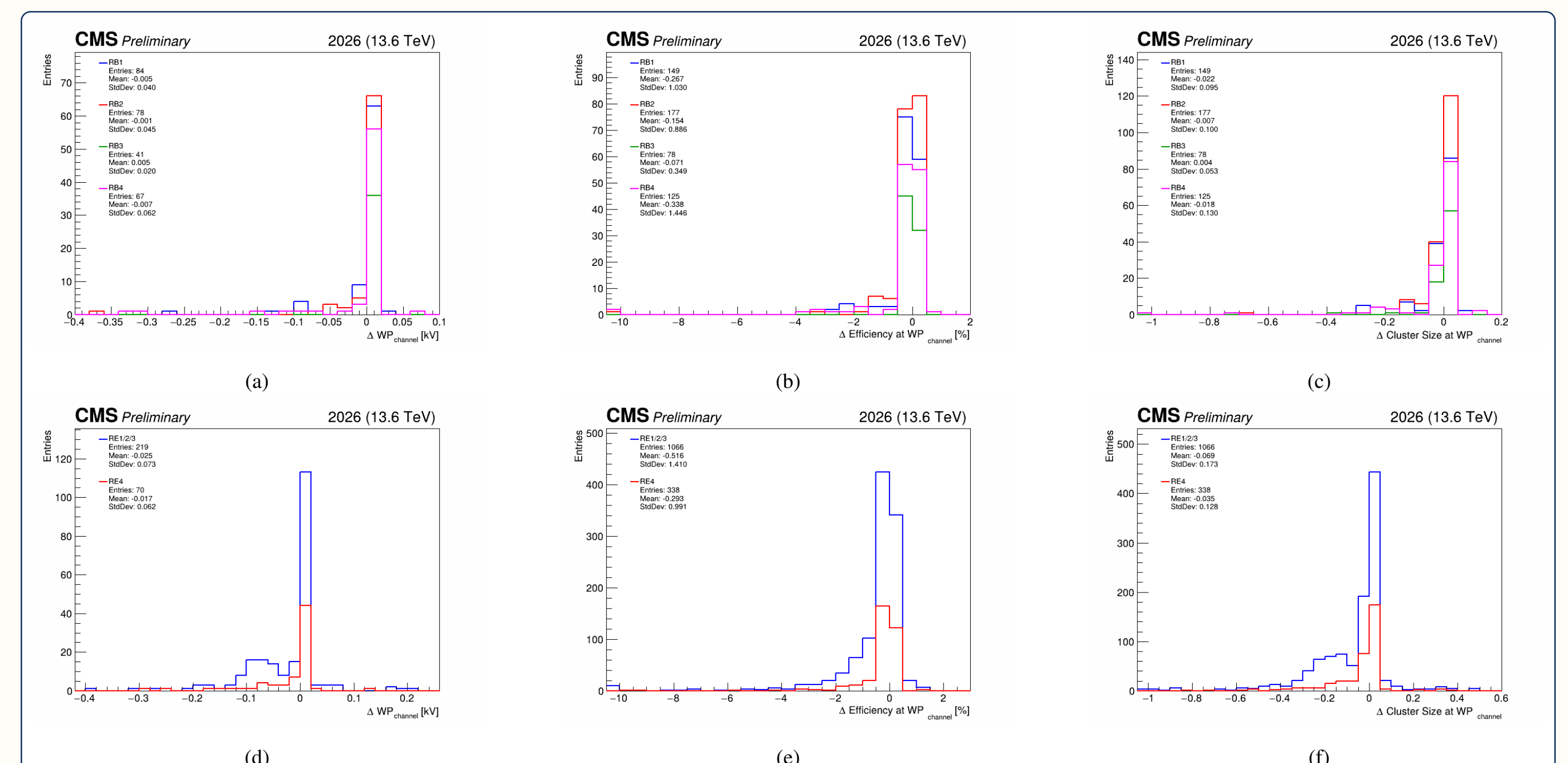


Figure 4: Comparison between the proposed and standard [2] working point determination algorithms for RPC HV channels, using the 2026 HV scan data. The distributions show the differences in HV channel working points (a,d), efficiency at the channel working point per roll (b,e), and cluster size at the channel working point per roll (c,f) for the barrel and endcap regions, respectively.

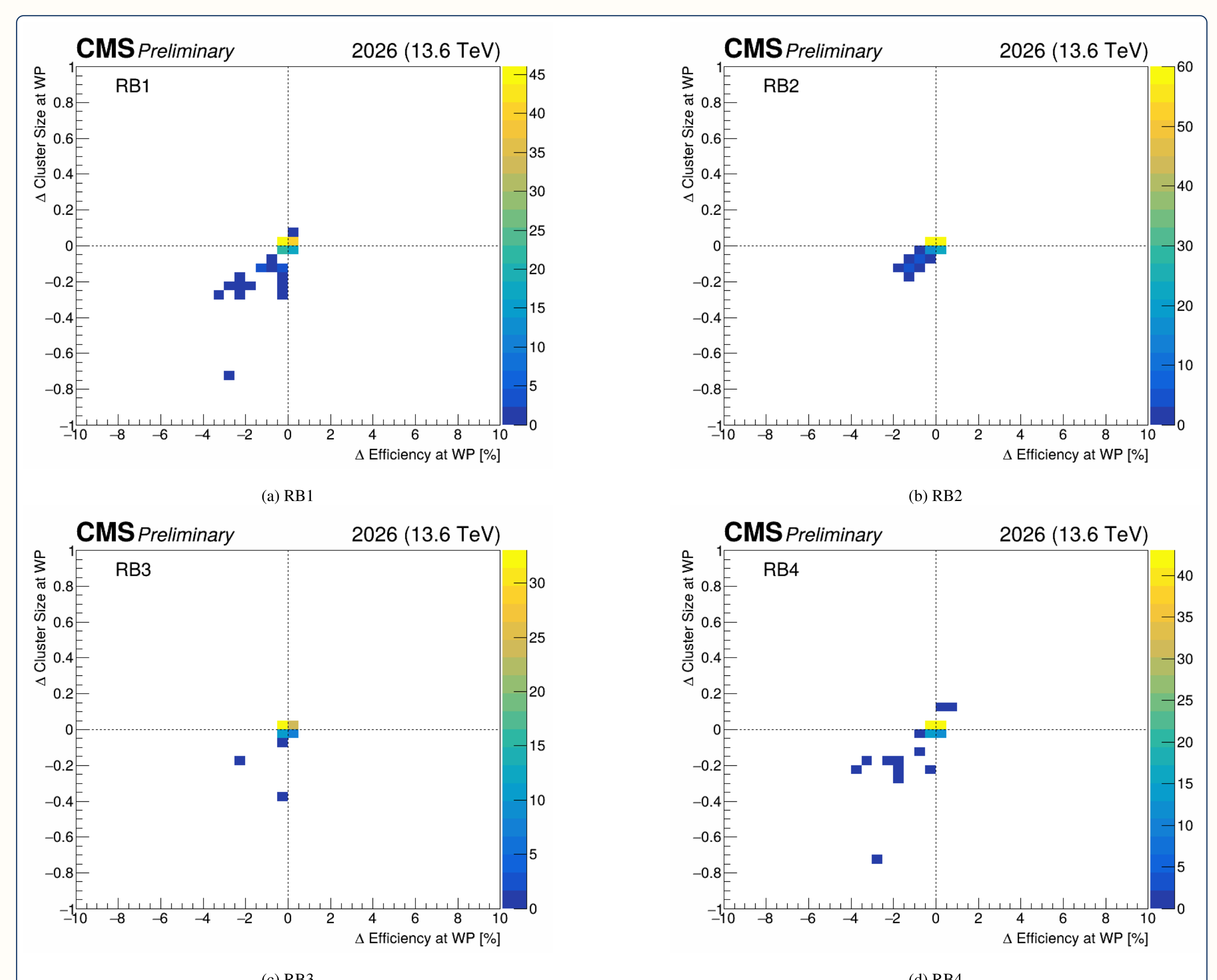


Figure 5: Two-dimensional distribution of the differences in efficiency and cluster size at the working point channel per roll for RPC HV channels in the four barrel stations, using the 2026 HV scan data: (a) RB1, (b) RB2, (c) RB3, and (d) RB4. The plots illustrate the relationship between changes in efficiency and cluster size at the channel working point.

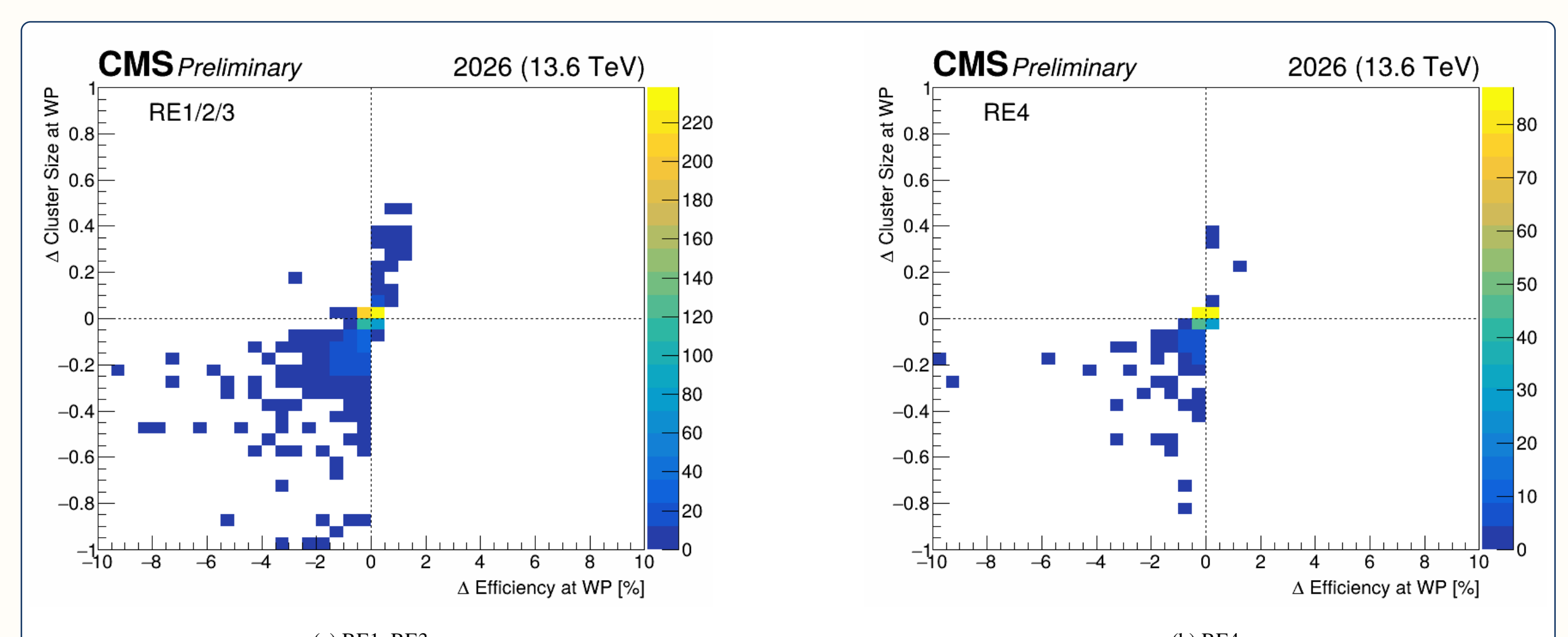


Figure 6: Two-dimensional distribution of the differences in efficiency and cluster size at the working point channel per roll for RPC HV channels in the endcap region, using the 2026 HV scan data: (a) RE1/2/3 and (b) RE4. The plots illustrate the relationship between changes in efficiency and cluster size at the channel working point.