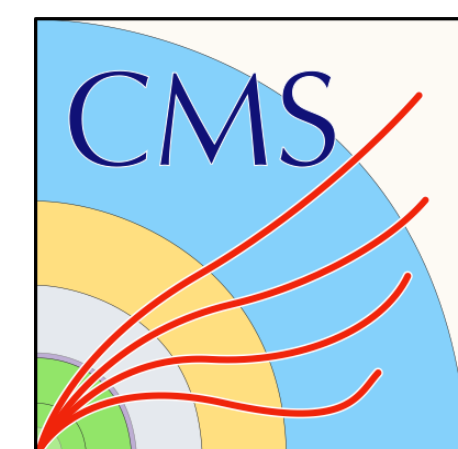


First Simulation Study of iRPC Two-End Hit Reconstruction in CMS Phase-2

Juhee Song^{1,2}, Boris Pavlov³, Michael Tytgat² on behalf of the CMS Collaboration

¹Hanyang University, ²Vrije Universiteit Brussel, ³University of Sofia "St. Kliment Ohridski"

juhee.song@cern.ch

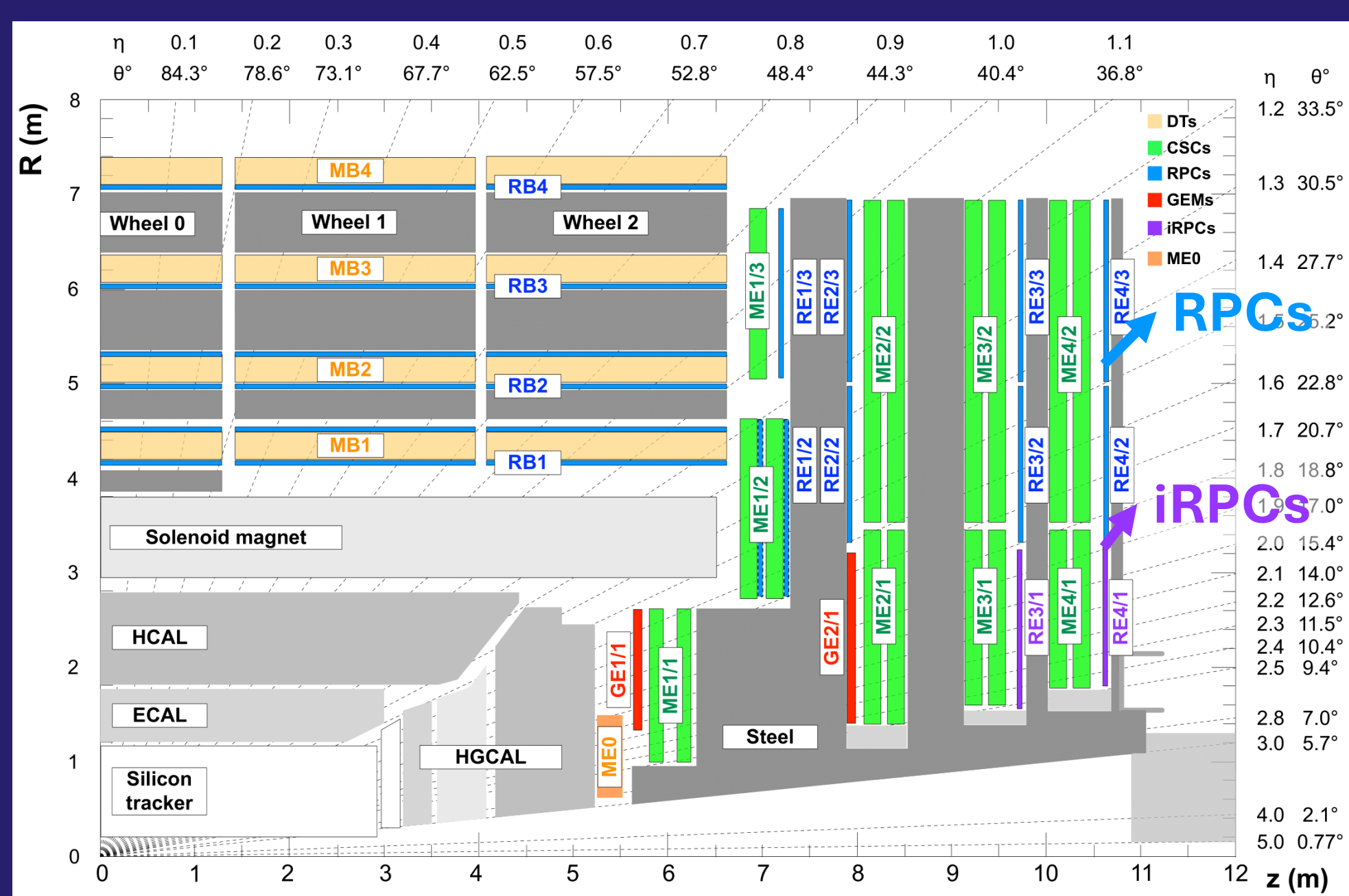


iRPCs for the HL-LHC CMS Muon System

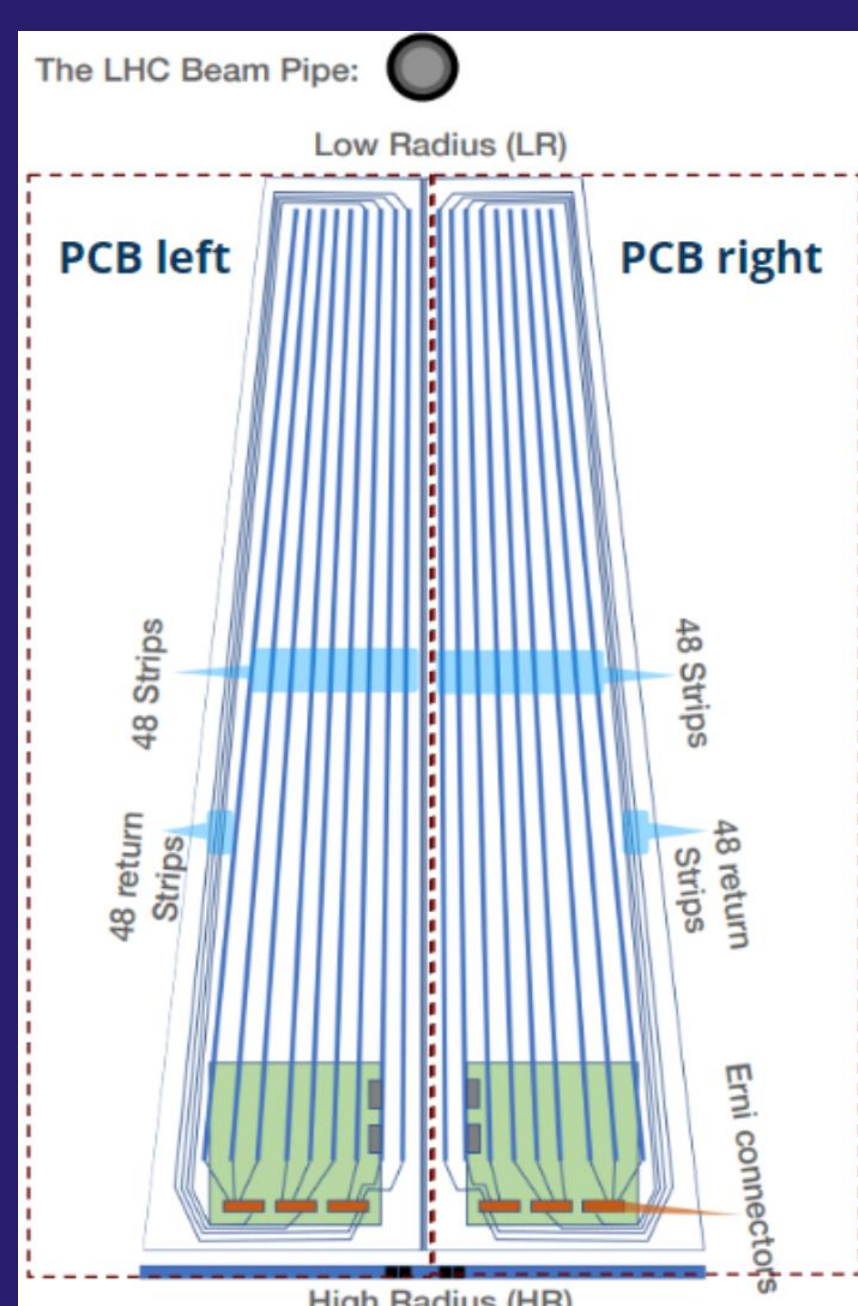
- HL-LHC: about 5x higher luminosity and 3-4x higher pileup; CMS is upgraded (Phase-2) to keep triggering and reconstruction robust in that environment
- For muons, the upgrade extends coverage to forward regions, adds redundancy and provides a sustainable trigger rate
- iRPC chambers go in RE3/1 and RE4/1: thinner gaps, slightly lower-resistivity bakelite and more sensitive electronics for high rate; two-end strip readout
- Two-end readout plus timing information is crucial: a reconstructed hit gives (x, y, t)

➔ This poster presents the validation of iRPC hit reconstruction in Phase-2 simulation

	Existing RPC [1]	Improved-RPC (iRPC) [2]
η coverage	$ \eta < 1.9$	$ \eta < 2.4$
Readout	one-end	two-end
Time granularity	25 ns	0.2 ns
Hit information	x only	$time, x, y$



The CMS muon system with Phase-2 upgrade [3]



The iRPC readout system overview [4]

iRPC Clustering Algorithm

- When a muon crosses the gas gap, an avalanche induces a signal
- A dedicated clustering algorithm is implemented to combine information from both ends of the strips (HR: High-radius, LR: Low-radius) [4]

1. Paired signals

keep only strips with a signal on both ends

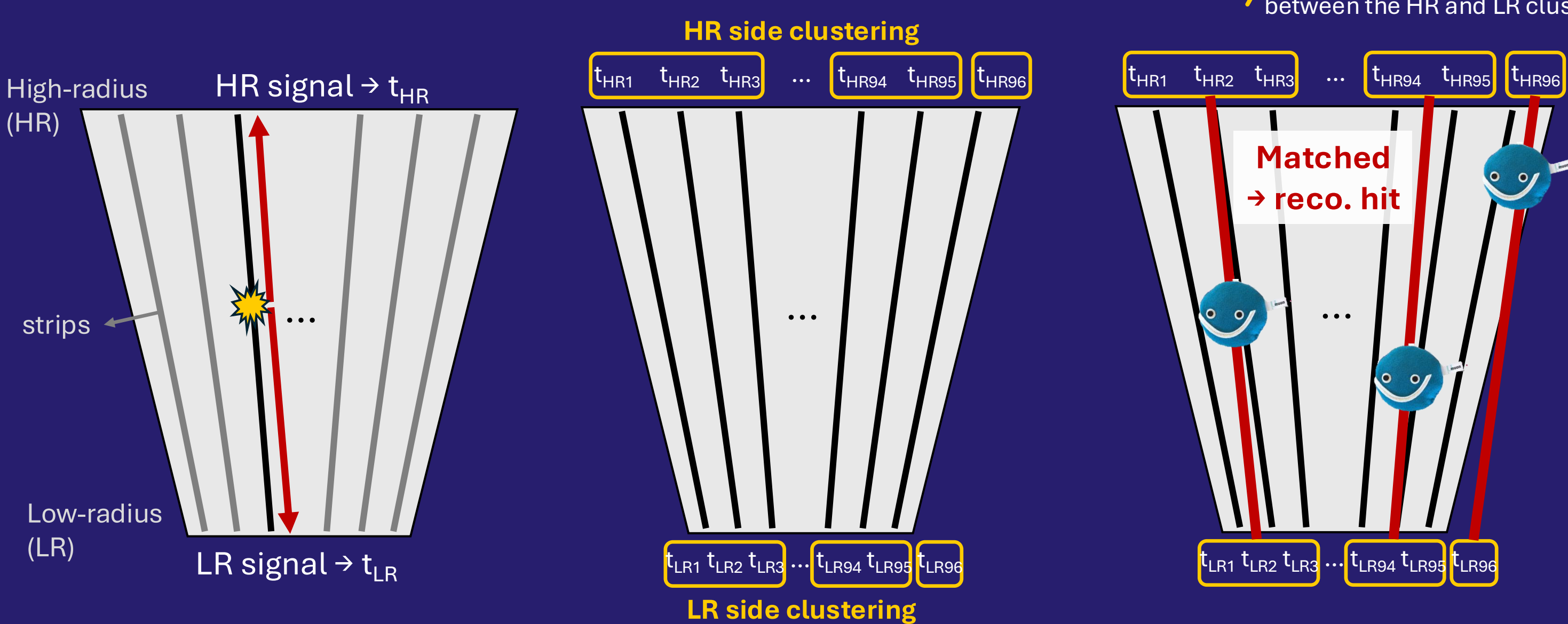
2. Cluster each end

neighbour strips if $|\Delta t| < 3$ ns

3. Two-end matching

if $|\Delta \text{strip}| < 1 \rightarrow \text{hit}^{\text{reco}}(x, y, t)$

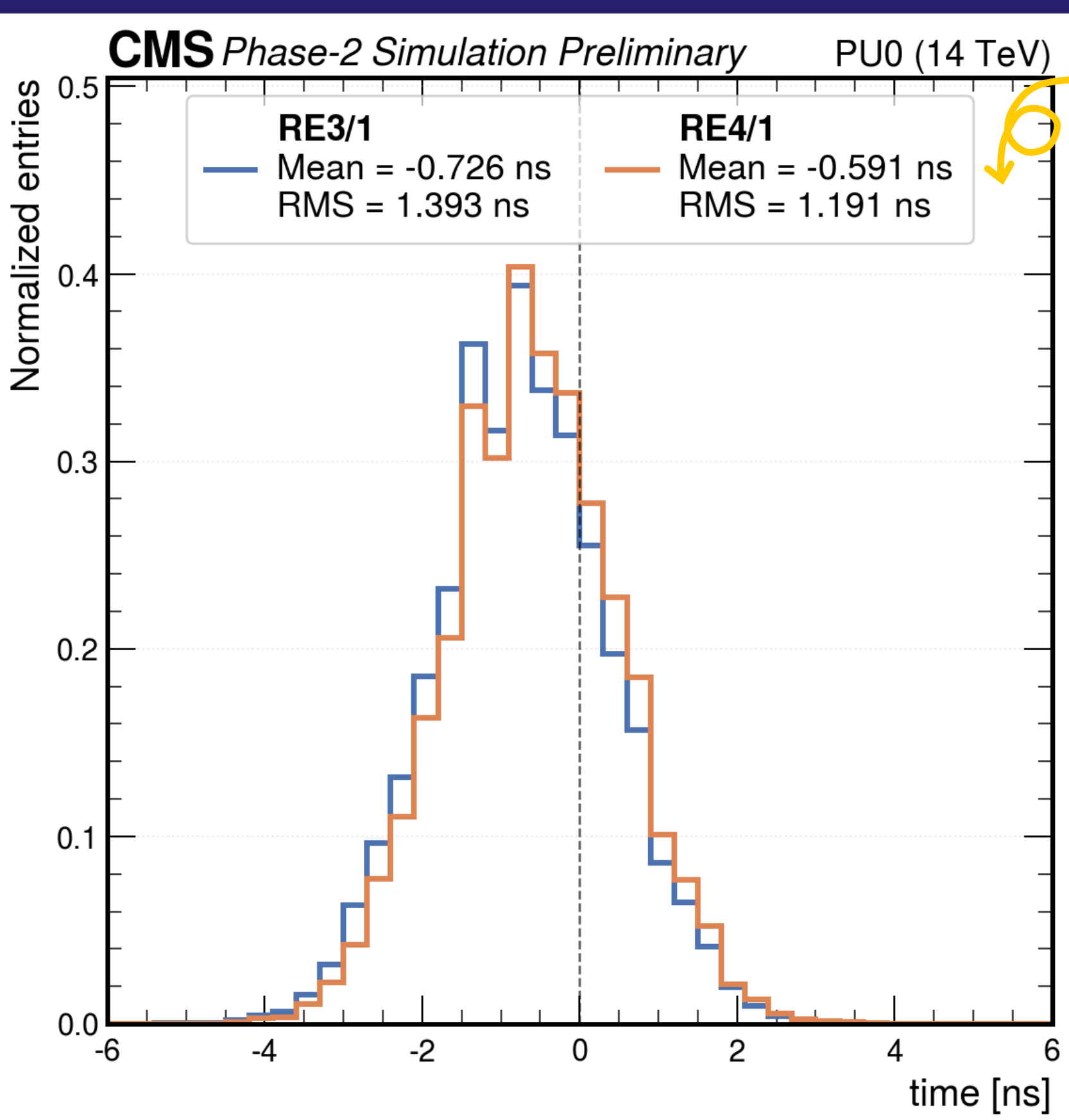
difference in strip number between the HR and LR clusters



Reconstructed iRPC Hit: time, x, and y

- After clustering: the reconstructed hit gives $time$, local position x , and y
- These quantities are built from the two-end times (t_{LR} and t_{HR})
- Simulation sample: generated single μ events with Pythia8
 - p_T 2-100 GeV, $|\eta| < 2.85$, zero pileup

Quantity	Idea
$time$	average of the two ends: $(t_{LR} + t_{HR})/2$
x	which strip fired (strip position)
y	$\propto (t_{LR} - t_{HR})$

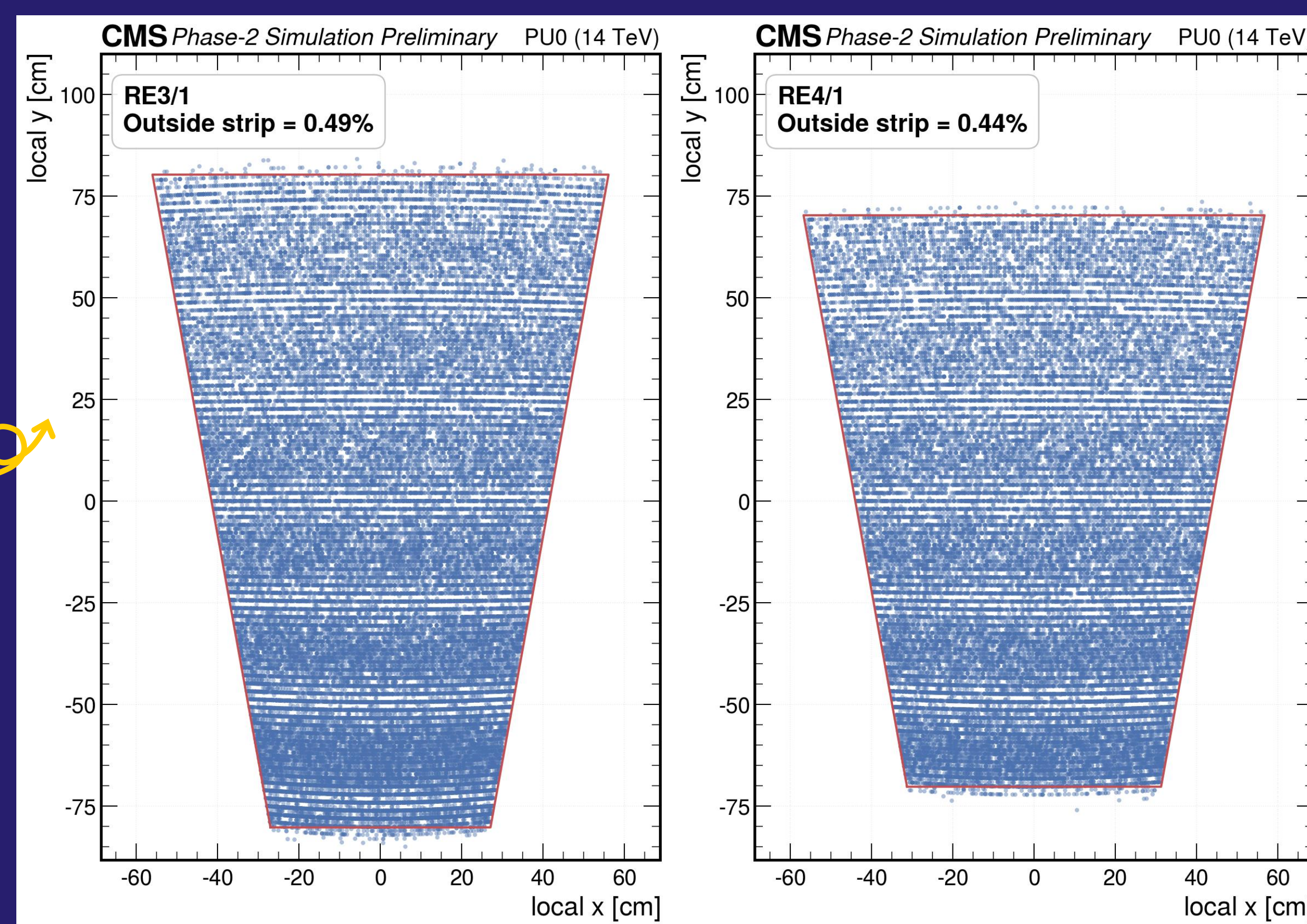


Normalized iRPC reconstructed hit time distributions

- Time is shown relative to the expected muon arrival at the chamber, so the peak sits near 0
- RMS is consistent with the time smearing (~ 1 ns) used in the digitizer

Local positions of iRPC reconstructed hits in RE3/1 (left) and RE4/1 (right)

- Reconstructed hit positions fill the chambers as expected
- The y banding from discrete TDC time steps
- A few hits ($< 0.5\%$) reconstruct beyond the strip ends: y is from Δt , so time jitter/TDC can overshoot the physical length (they are kept in all plots)



Performance in Phase-2 Simulation

- Matching:** pair a true muon hit with a reconstructed hit in the same chamber
- Efficiency of the iRPC hit reconstruction algorithm:** fraction of true muon hits that produce a reconstructed hit

$$E = \frac{N_{\text{true muon with reco. hit}}}{N_{\text{true muon}}} \approx 93.4\%$$

- The loss is in the digitization step – once a signal exists, almost all become reconstructed hits ($\sim 99.8\%$)

Conclusion and Next Steps

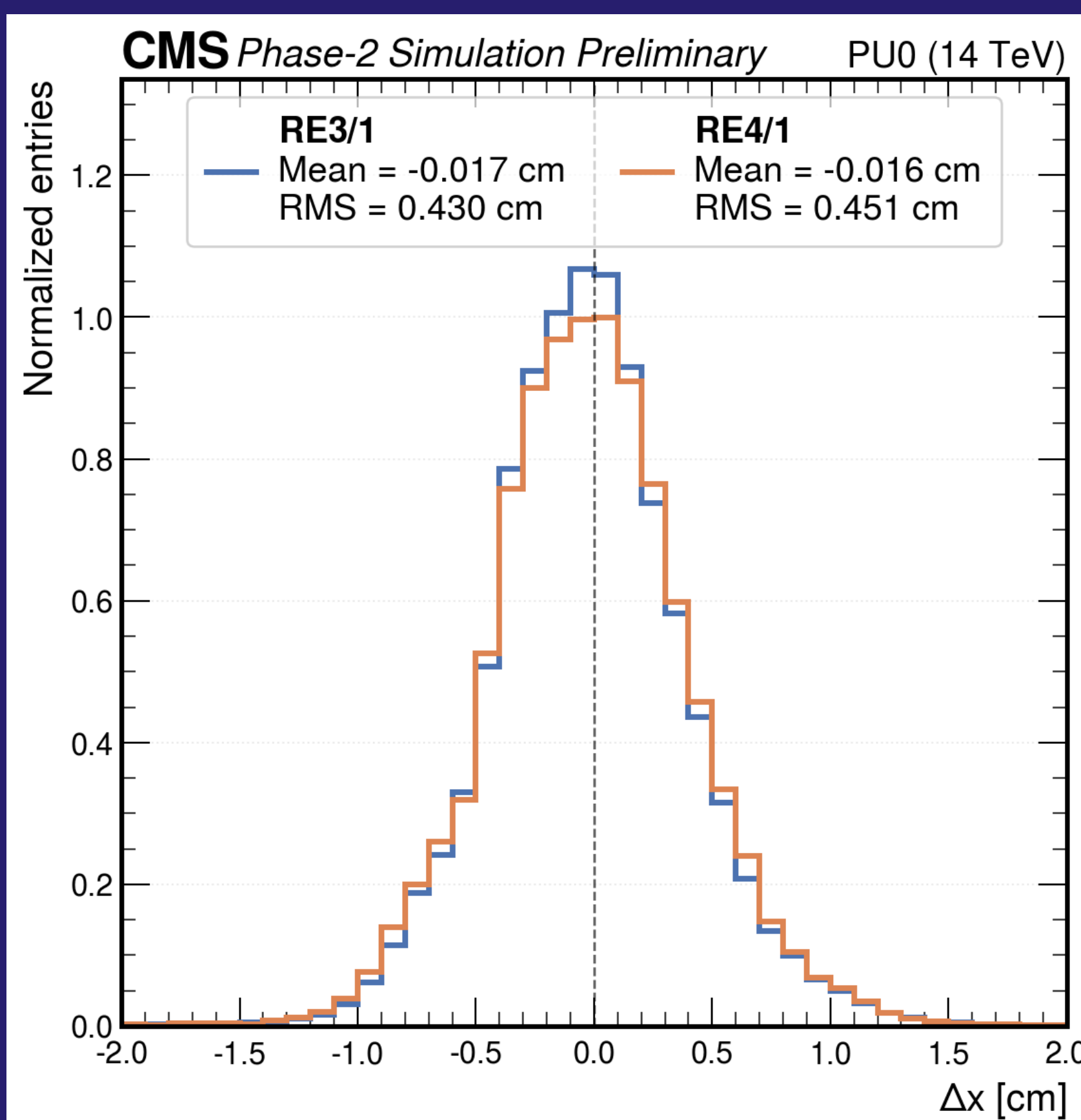
- First Phase-2 simulation study of iRPC reconstructed hits
- Clustering algorithm reconstructs $time, x$, and y as expected
- Spatial residuals match expectations for x and y

➔ Takeaway: given a signal, the clustering algorithm keeps 99.8% of hits; Δy is at the ~ 1.5 cm design scale

- This study is done with zero pileup; next is the algorithm performance tests with realistic pileup, and then including iRPC hits in muon tracking

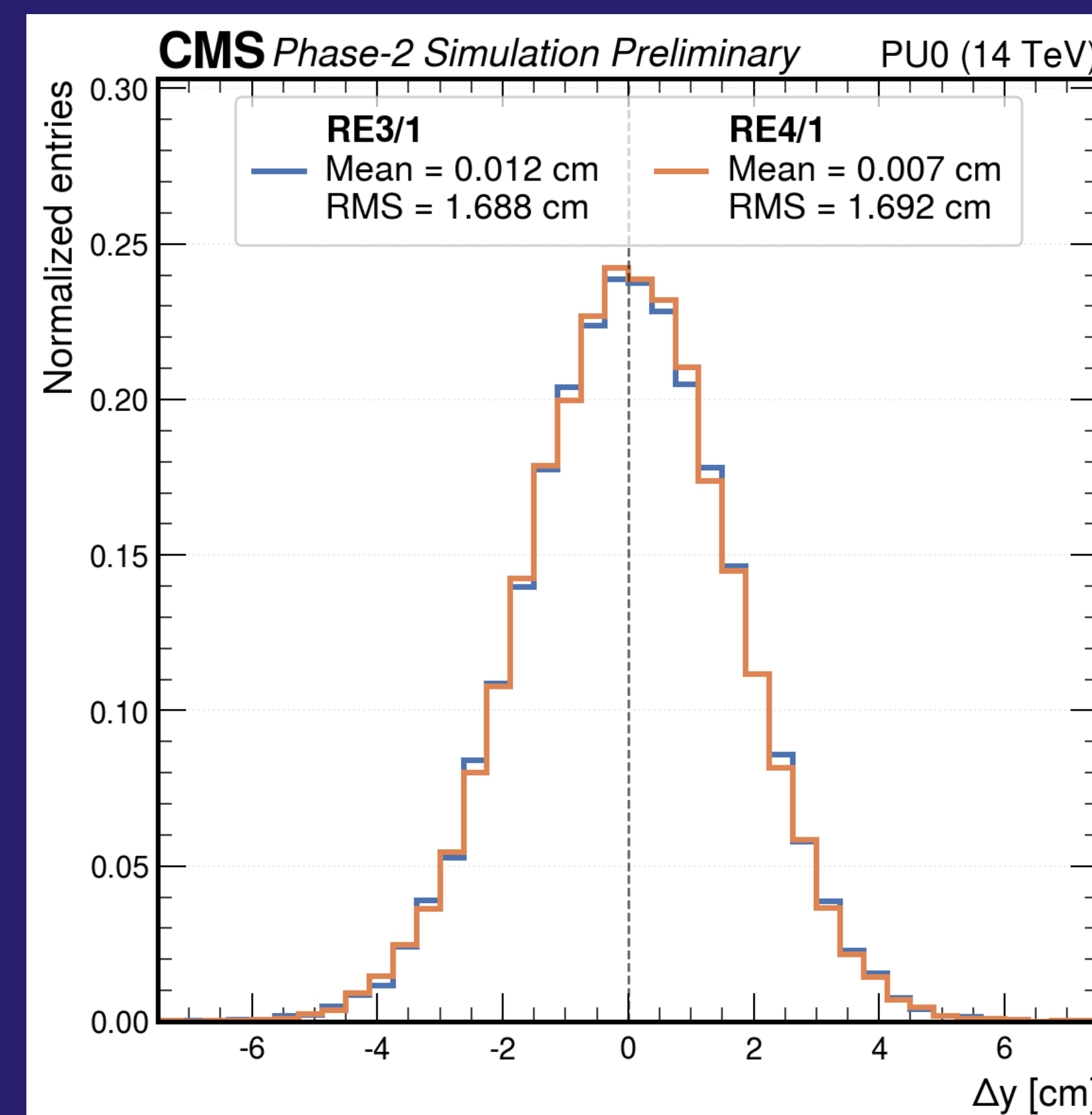
References

- [1] CMS Collaboration, CMS RPC Geometry Layout, CMS-DP-2017-053
- [2] A. Samalan et al., Improved RPC (iRPC) detector for CMS data taking in HL-LHC, PoS(ICHEP2024)888
- [3] CMS Collaboration, The Phase-2 Upgrade of the CMS Muon Detectors, CERN-LHCC-2017-012, CMS-TDR-016 (2017)
- [4] CMS Collaboration, CMS iRPC clustering algorithm and hit reconstruction, NIM A 1080 (2025) 170579
- [5] A. Samalan et al., Improved resistive plate chambers for HL-LHC upgrade of CMS, NIM A 1060 (2024) 169075



Normalized local-x residual distributions

- $\Delta x = x_{\text{reco}} - x_{\text{sim}}$ for muon-matched hits
- Both stations have distributions centered at 0 with expected RMS for strip-based x reconstruction



Normalized local-y residual distributions

- $\Delta y = y_{\text{reco}} - y_{\text{sim}}$ for matched hits
- Both stations have distributions centered at 0, and RMS is close to the ~ 1.5 cm along-strip resolution from test beam [5]
- Expected from the simulated electronics jitter and TDC time steps used in the digitizer