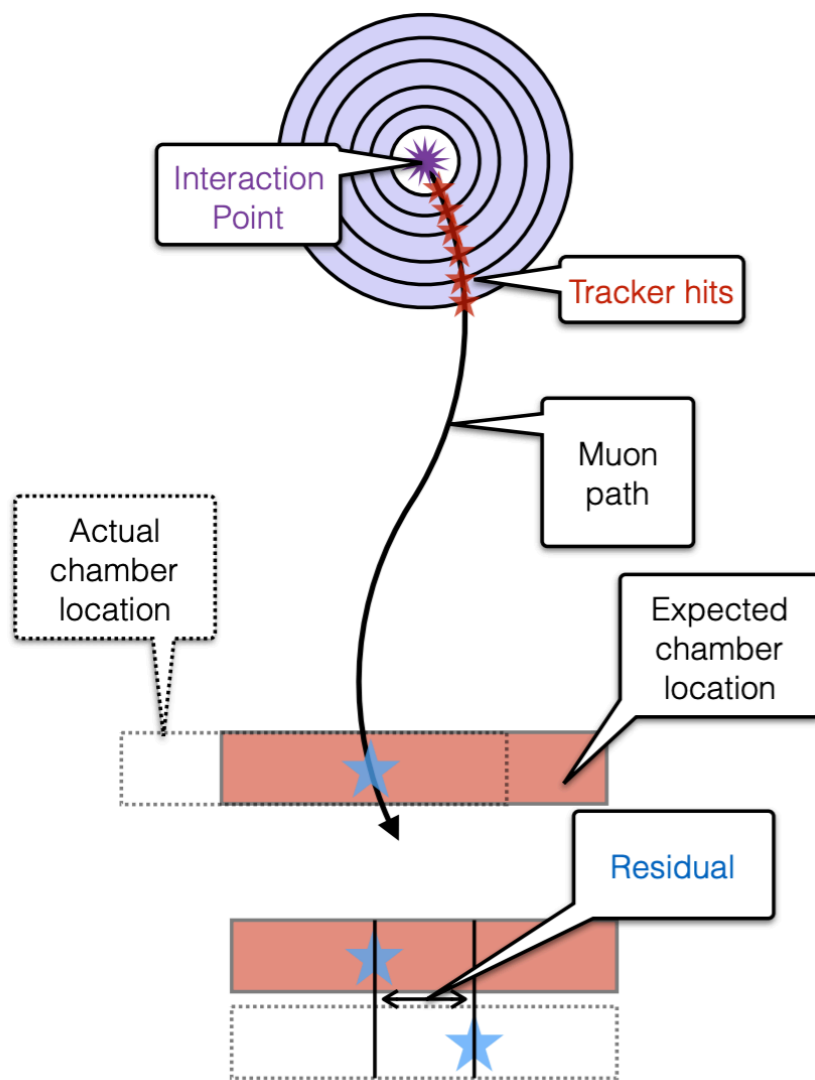


# Study of the muon alignment effect on momentum scale of high $p_T$ muons

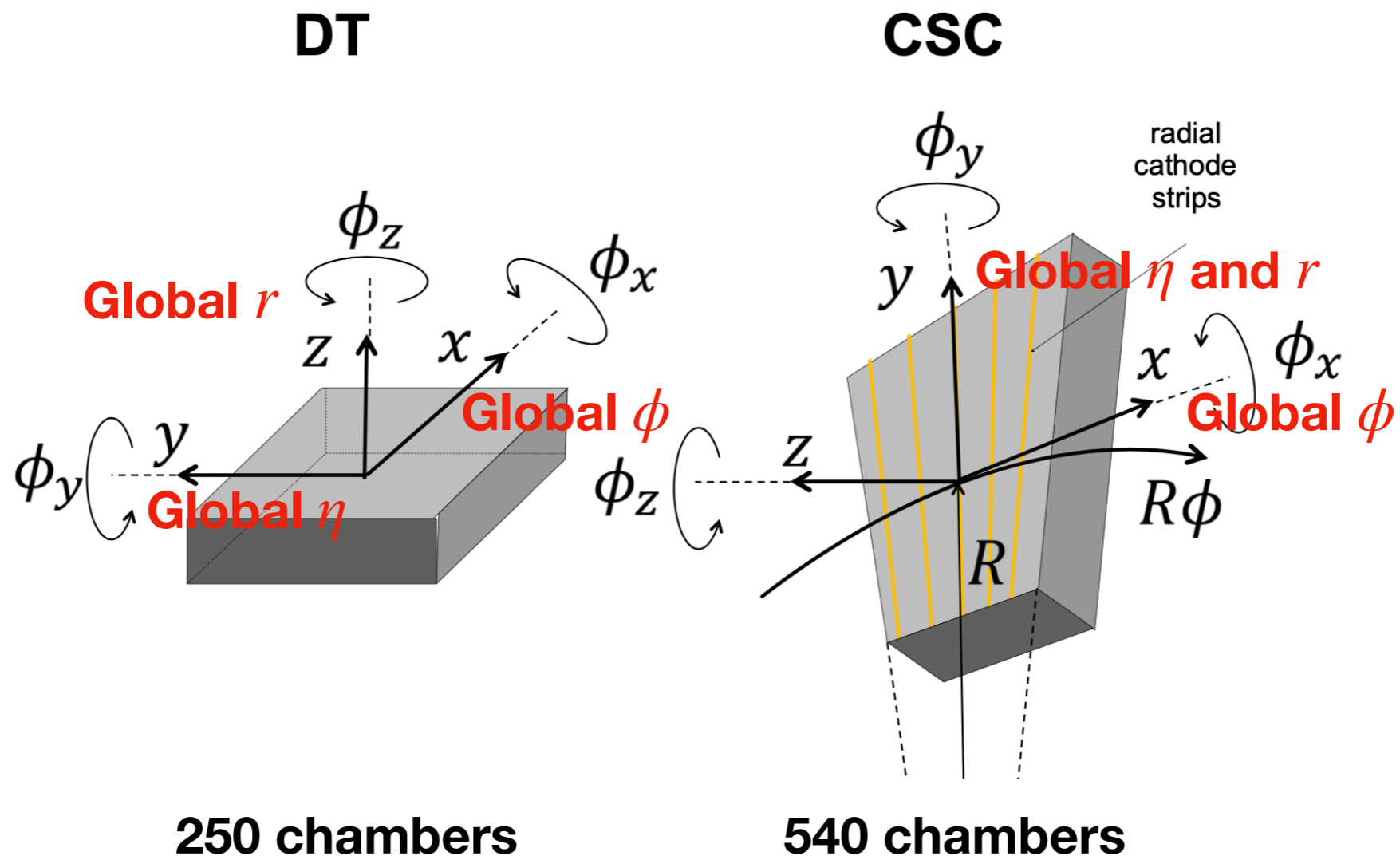
Hyunyoung Kim on behalf of muon alignment group  
**Texas A & M University**

# Track-Based Muon Alignment



- **Track-based muon alignment (TBMA)**
  - propagate the tracker part of muons to the muon system
  - Muon residual: difference between the reconstructed position and the predicted position on the muon chamber
- The TBMA technique is proven to be efficient, robust, and stable in Run1 and Run2
- The algorithm is developed and integrated into CMSSW framework
- Sources of possible systematic uncertainties have been investigated and various improvements to reduce their effect are being developed
- **Muon system alignment is very important for muon reconstruction and TBMA has good accuracy on the order of  $100 \mu\text{m}$  (depend on chamber type, position, and integrated luminosity)**

# Degree of Freedom

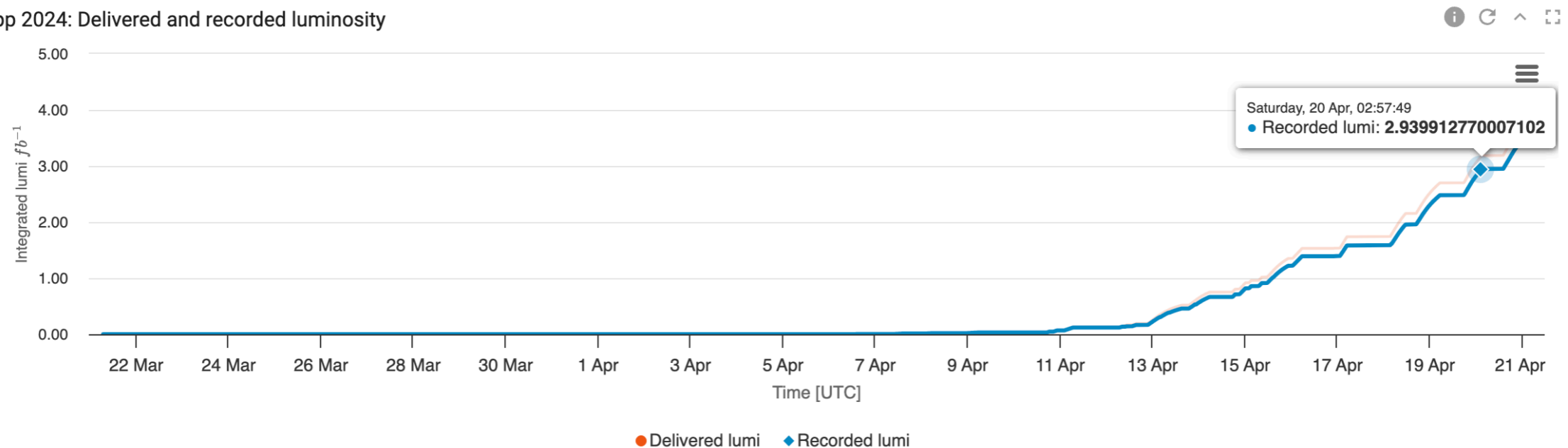


**DT alignment uses 6 DOF but CSC alignment uses 3 DOF (x, y, and  $\phi_z$ )**

*\*GEM alignment uses 3 DOF (x, y, and  $\phi_z$ ) with 144 GE1/1 chambers for Run 3*

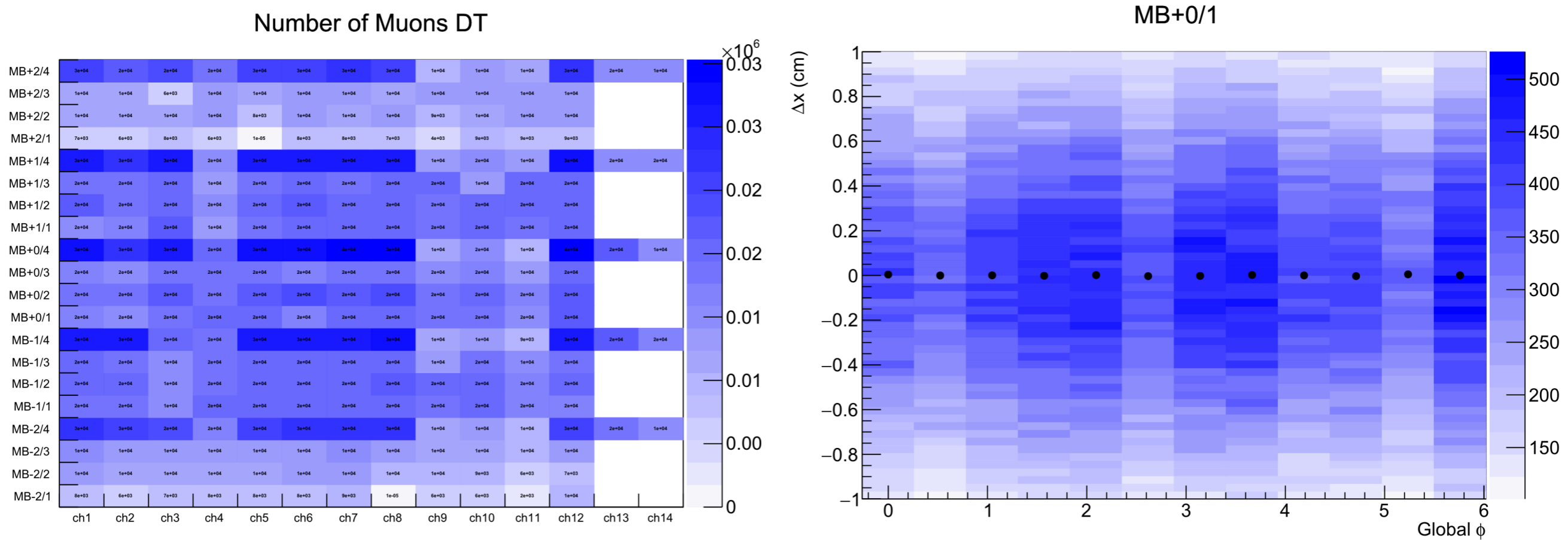
# 2024 TBMA

pp 2024: Delivered and recorded luminosity



- About 3/fb dataset
- All subsystems (DT, CSC, and GEM) have been updated with the new alignment conditions.
- Zero GPR based
- Physics validation looks good
- The new tags have been appended to online GTs on May 14th

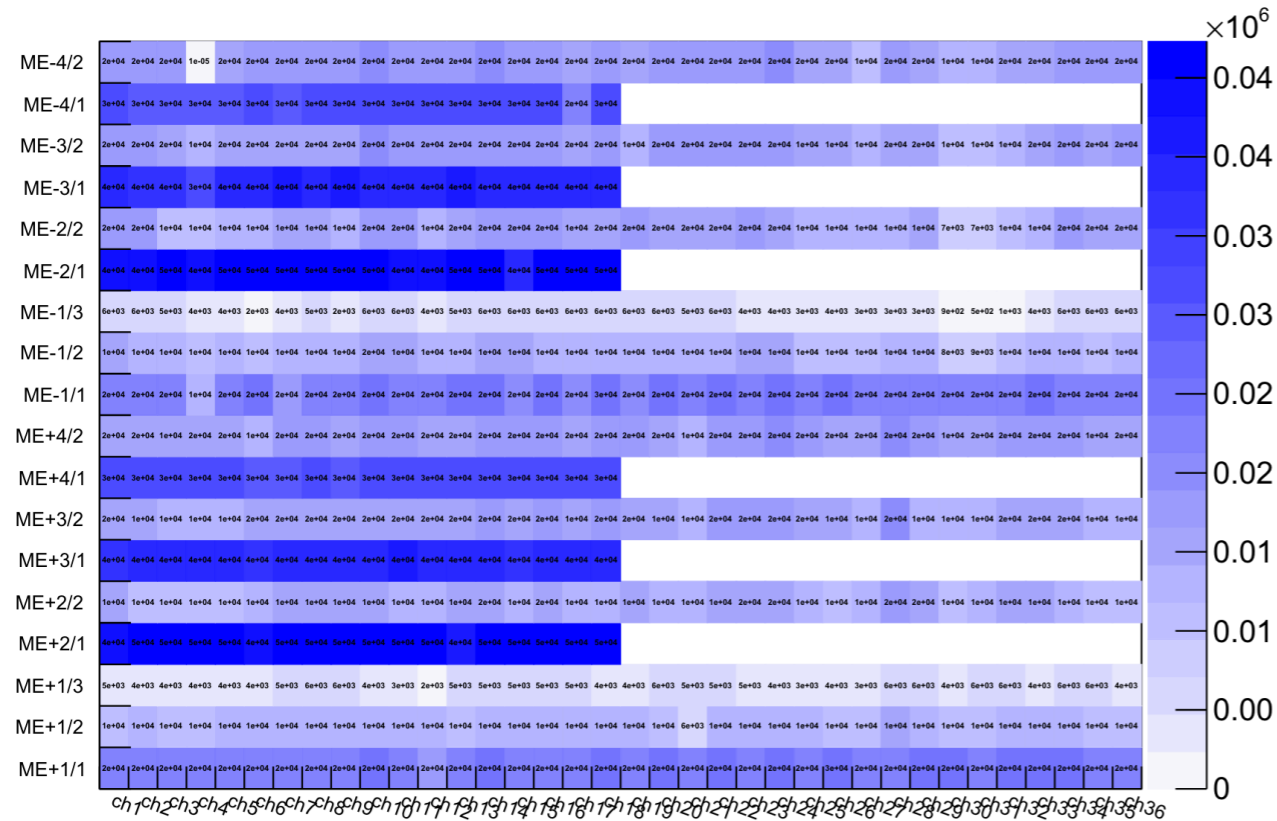
# DT



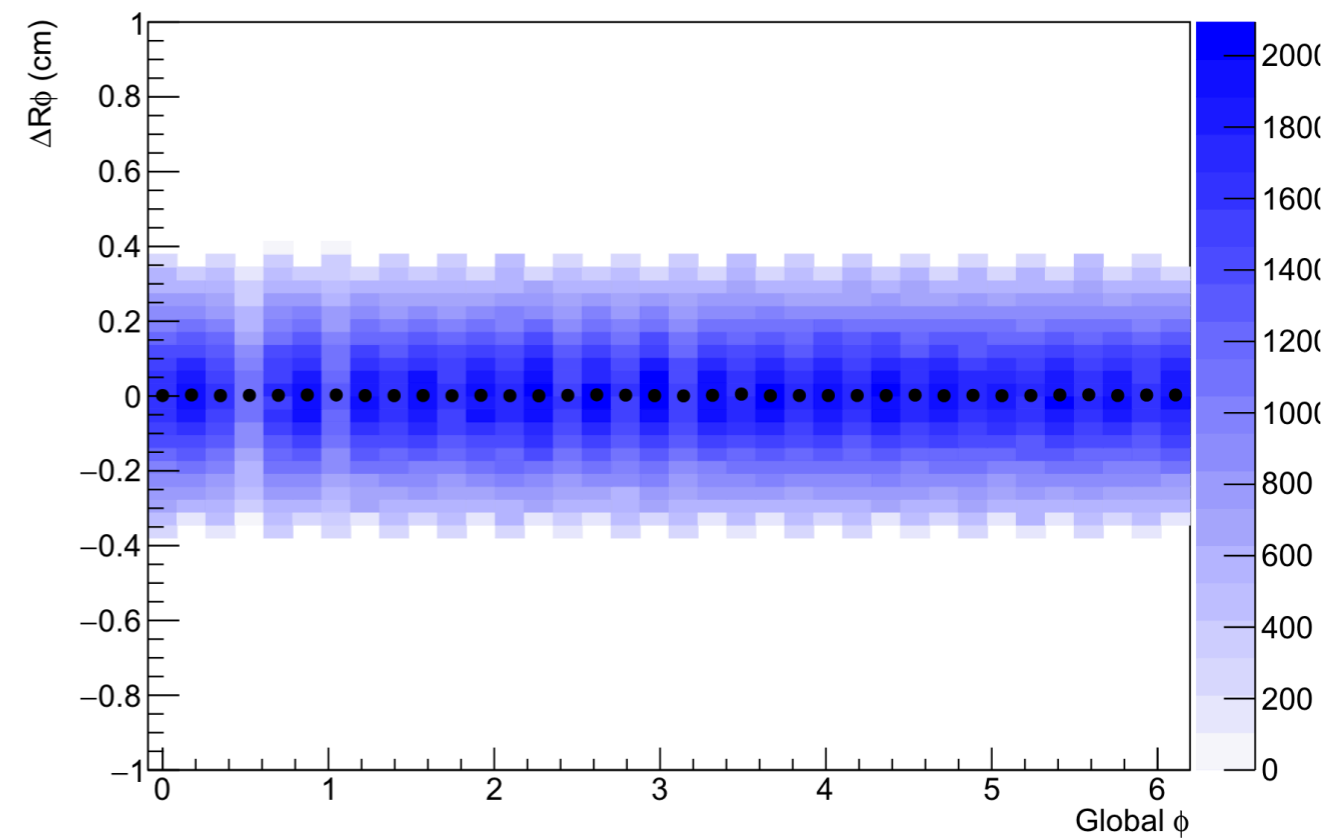
- Two chambers (MB+2/1/5 and MB-2/1/8) don't have any entries
- Overall residual distributions look fine

# CSC

Number of Muons CSC



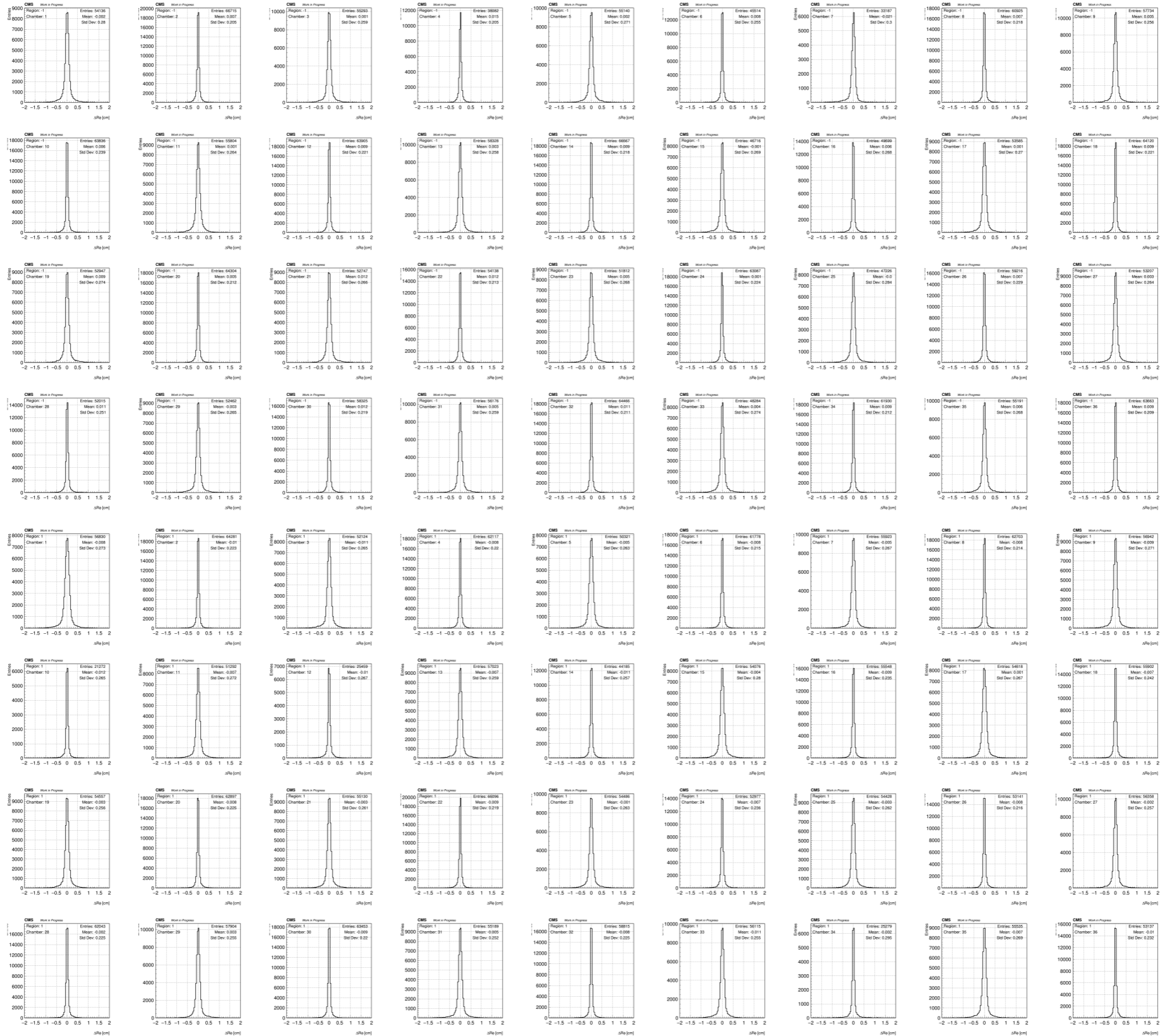
ME-1/1



- **ME-4/2/4 doesn't have any entries.**
- **Overall residual distributions look fine**
- **CSC had a z position issue; alignment starts from an ideal CSC geometry**
  - **we don't align dz parameter but CSC chambers have unrealistic z shifts**

# GEM

Endcap-1



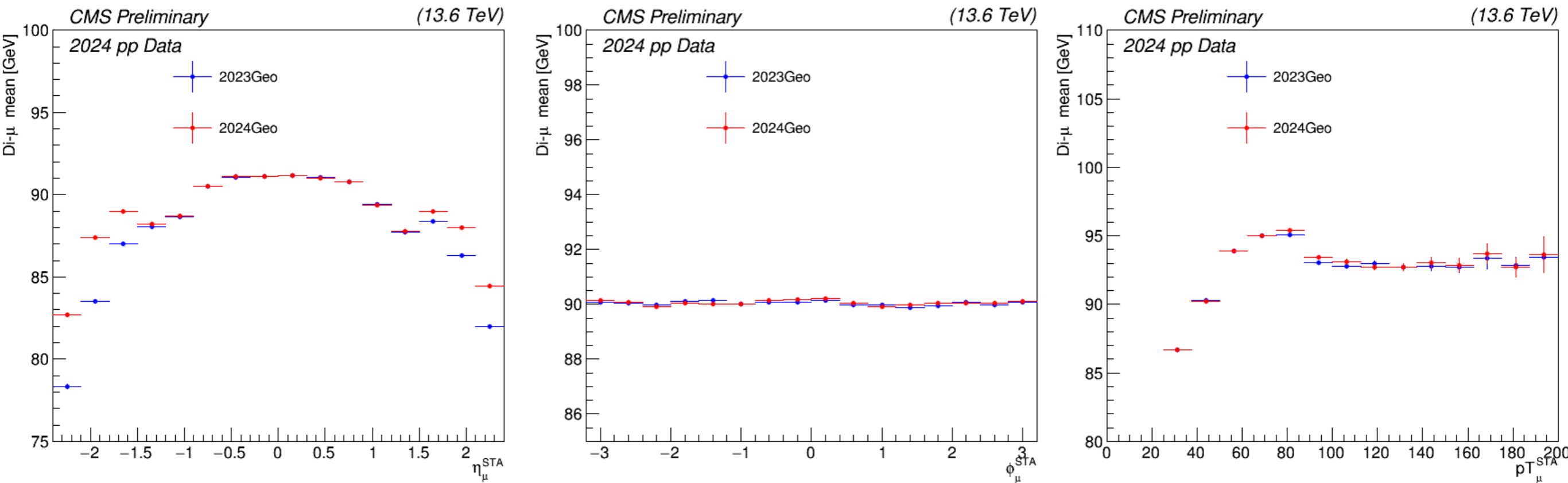
Endcap+1

# Physics Validation

- Run2024C dataset
  - 2023 Geometry: geometry in GT (updated tracker geometry)
  - 2024 Geometry: updated geometry with TBMA



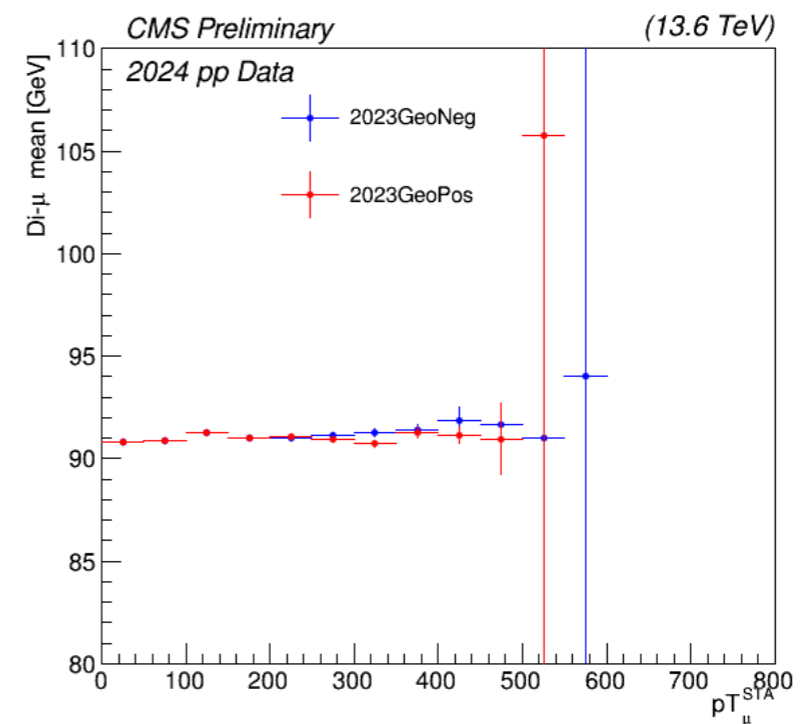
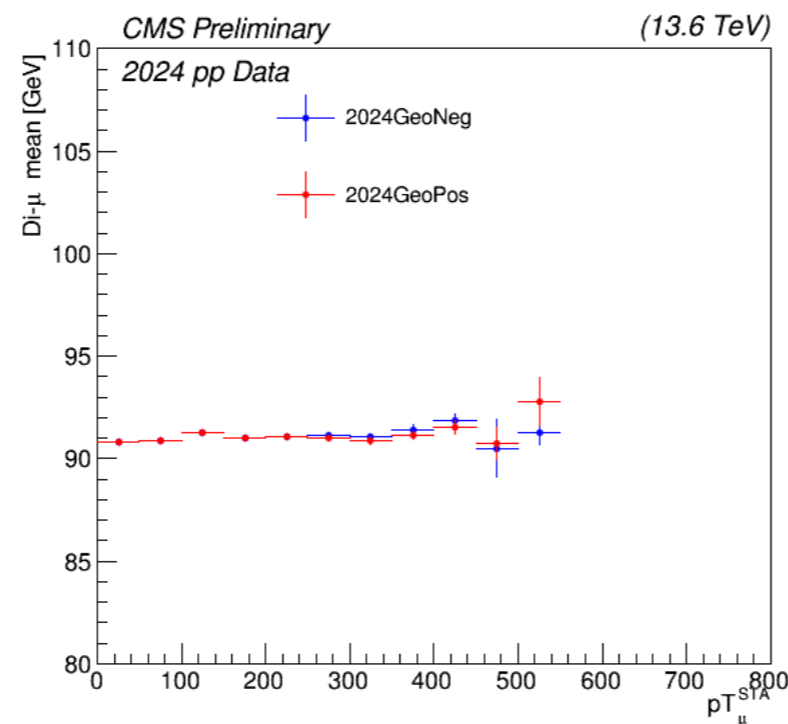
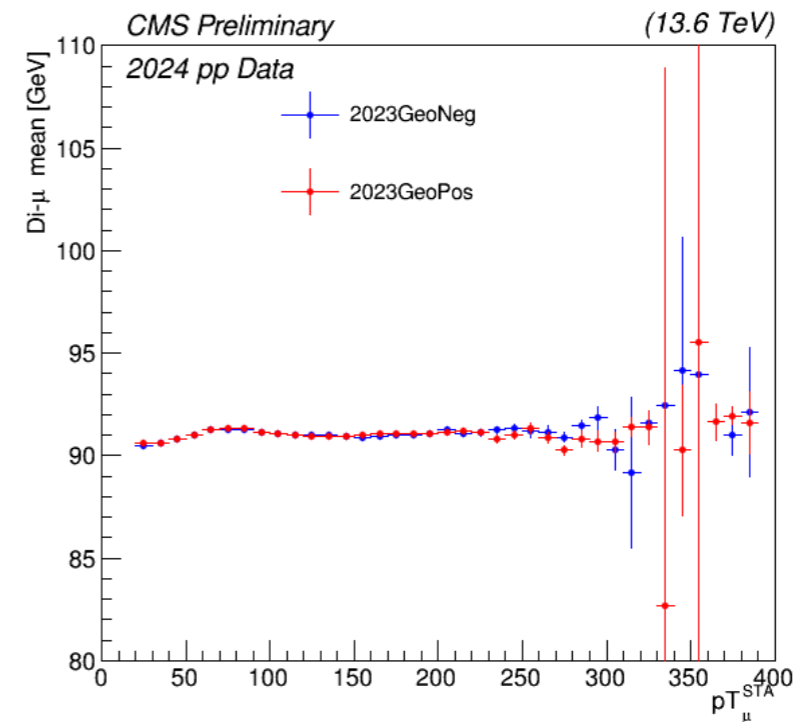
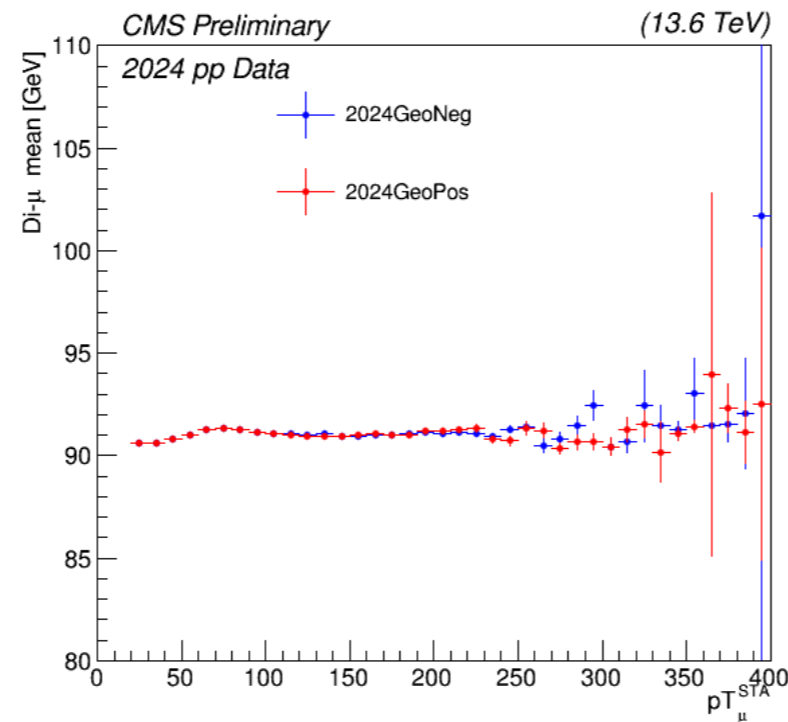
# Dimuon Mass



- **Dimuon mass distributions by  $\eta$ ,  $\phi$ , and  $p_{\text{T}}$**
- **One leg is a global muon and the other leg is a STA muon**

# High pT Muon

- Run2024C + D (D is not the full dataset)
- Two global muons for the dimuon mass, not STA-GLB
- $\mu^-$  and  $\mu^+$  probes
- The new 2024 geometry (left) and the 2024 tracker geometry + 2023 muon geometry (right)



# Online GTs

- Prompt  
DTAlignment\_2009\_v1\_express 1: 380726  
CSCAlignment\_2009\_v2\_express 1: 380726  
GEMAlignment\_prompt\_v2: 380644  
GlobalAlignment\_2009\_v2\_express: 380726
- HLT  
DTAlignment\_2009\_v1\_hlt 1: 380726  
CSCAlignment\_2009\_v1\_hlt 1: 380726  
GEMAlignment\_hlt\_v2: 380728  
GlobalAlignment\_2009\_v1\_hlt: 380728
- Express  
DTAlignment\_2009\_v1\_express 1: 380726  
CSCAlignment\_2009\_v2\_express 1: 380726  
GEMAlignment\_express\_v2: 380726  
GlobalAlignment\_2009\_v2\_express: 380726

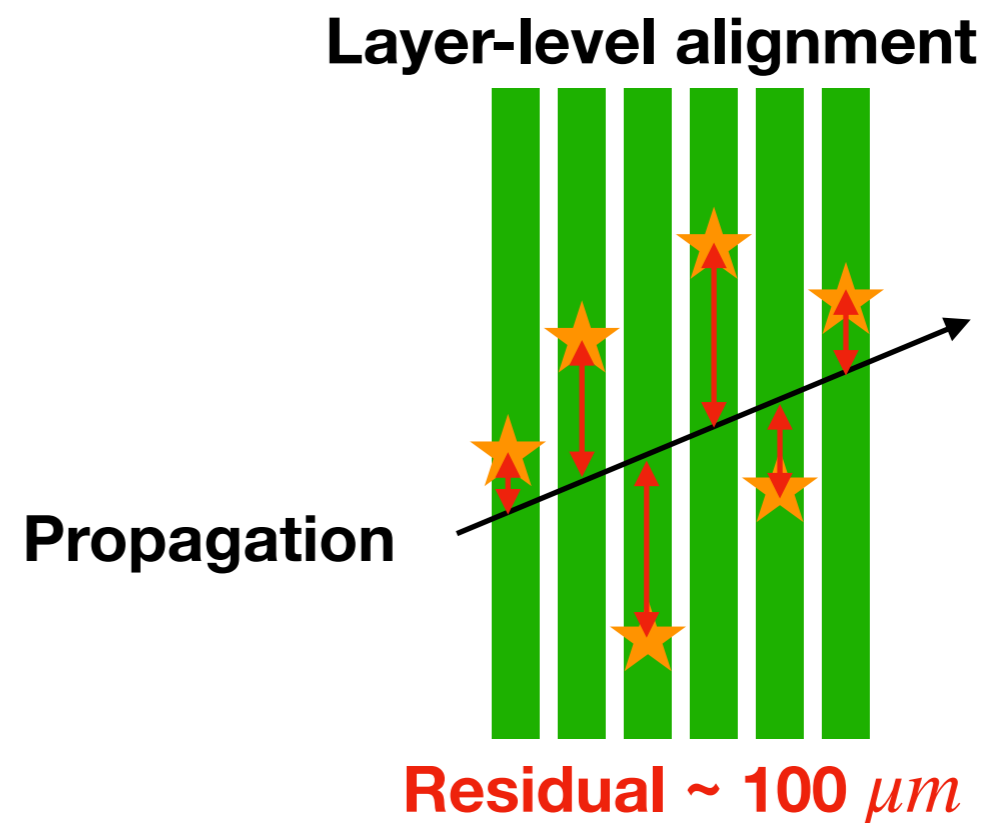
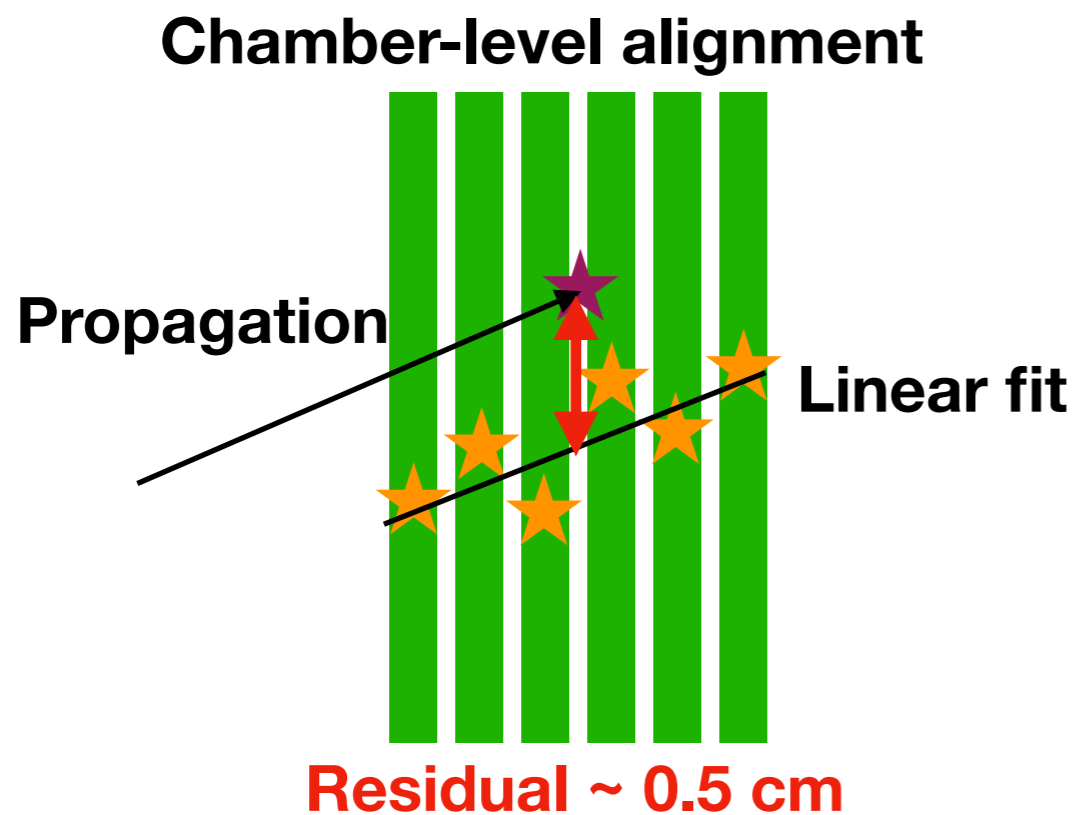
# Summary

- The 2024 muon alignment has been conducted with about 3/fb of dataset.
- All subsystems show minimal residuals after the alignment.
- The physics validation results look fine, especially the dimuon mass distribution by eta, which shows improvement in the high eta region.
- The new tags have been appended to online GTs on May 14th.

***Backup***

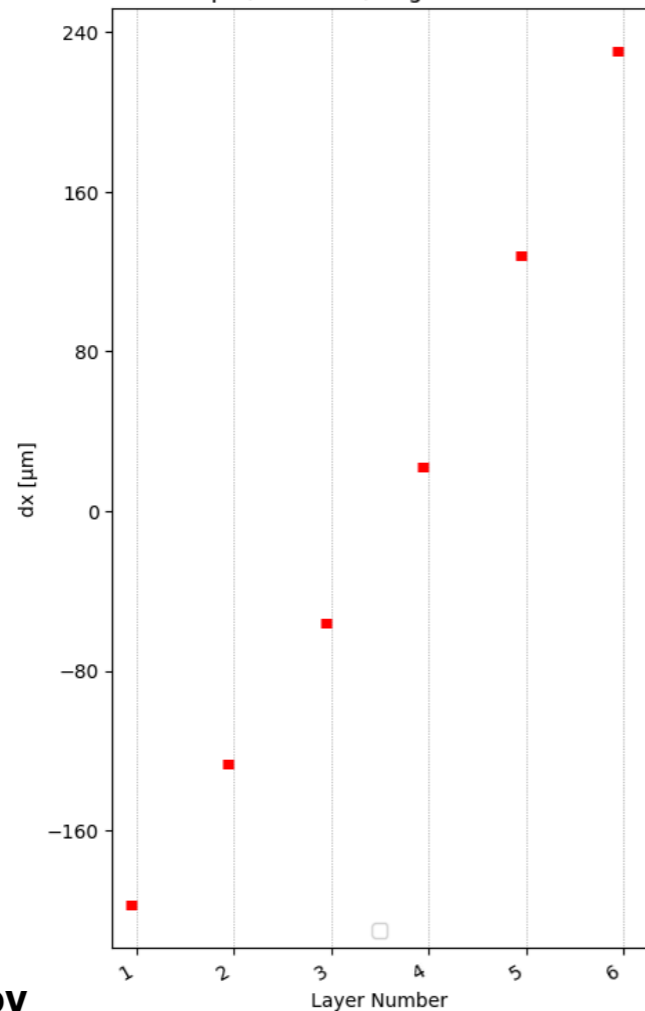
# CSC Layer-level Residual

- After the chamber-level alignment, which involves linear fitting of the 6-layer's recHits, we calculate the layer-level residual for further alignment.

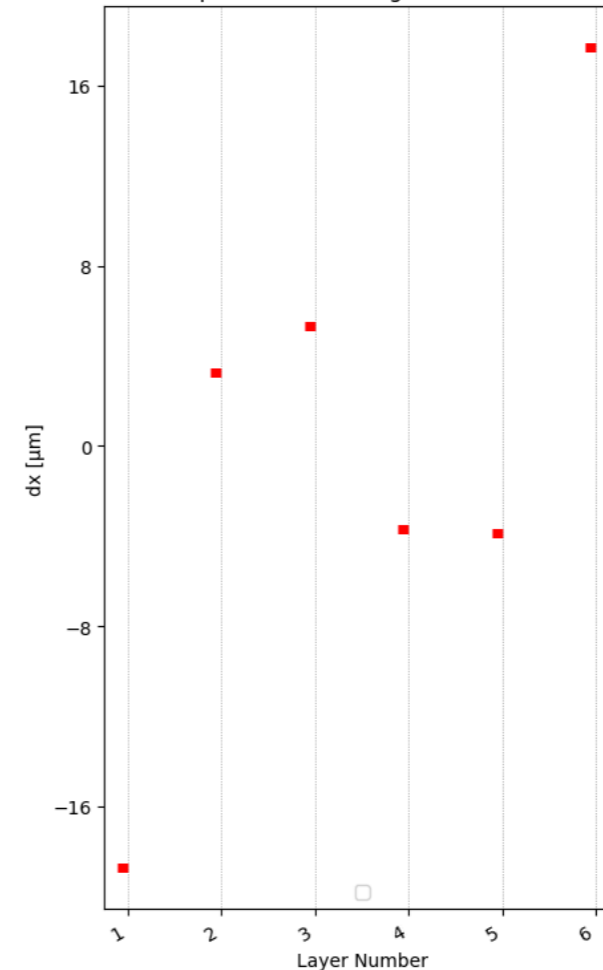


# CSC Layer Alignment Validation

Difference between local layer position after 2023 layer alignment and Run3\_IOV-352319 endcap 1, station 1, ring 1 and chamber 2



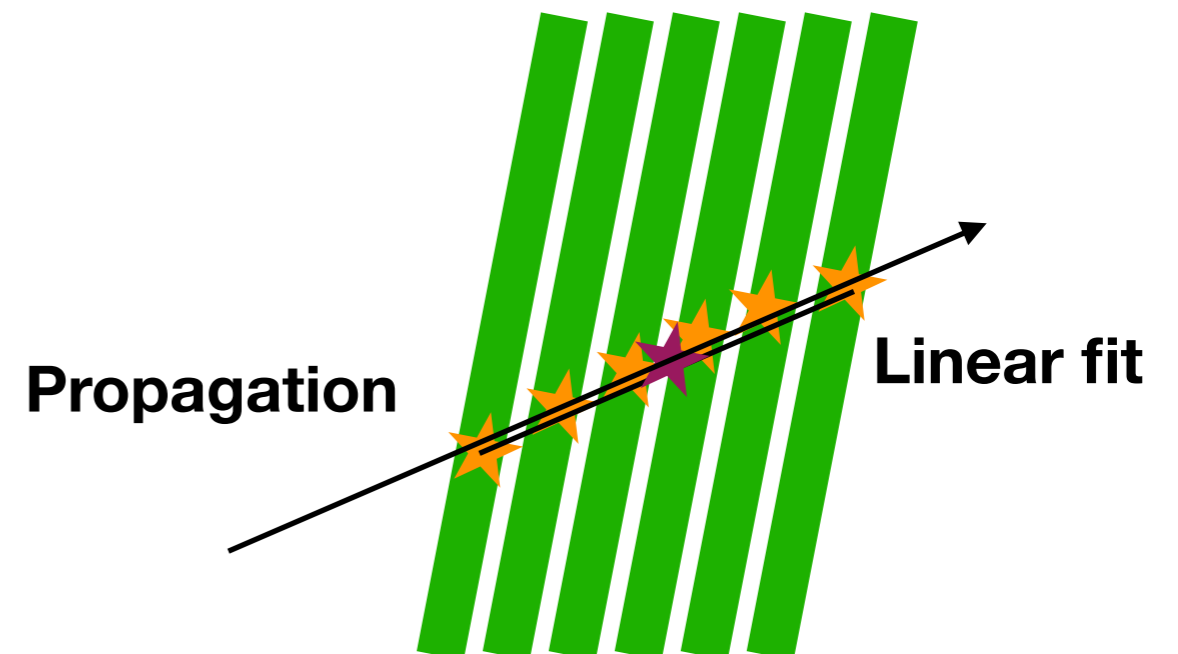
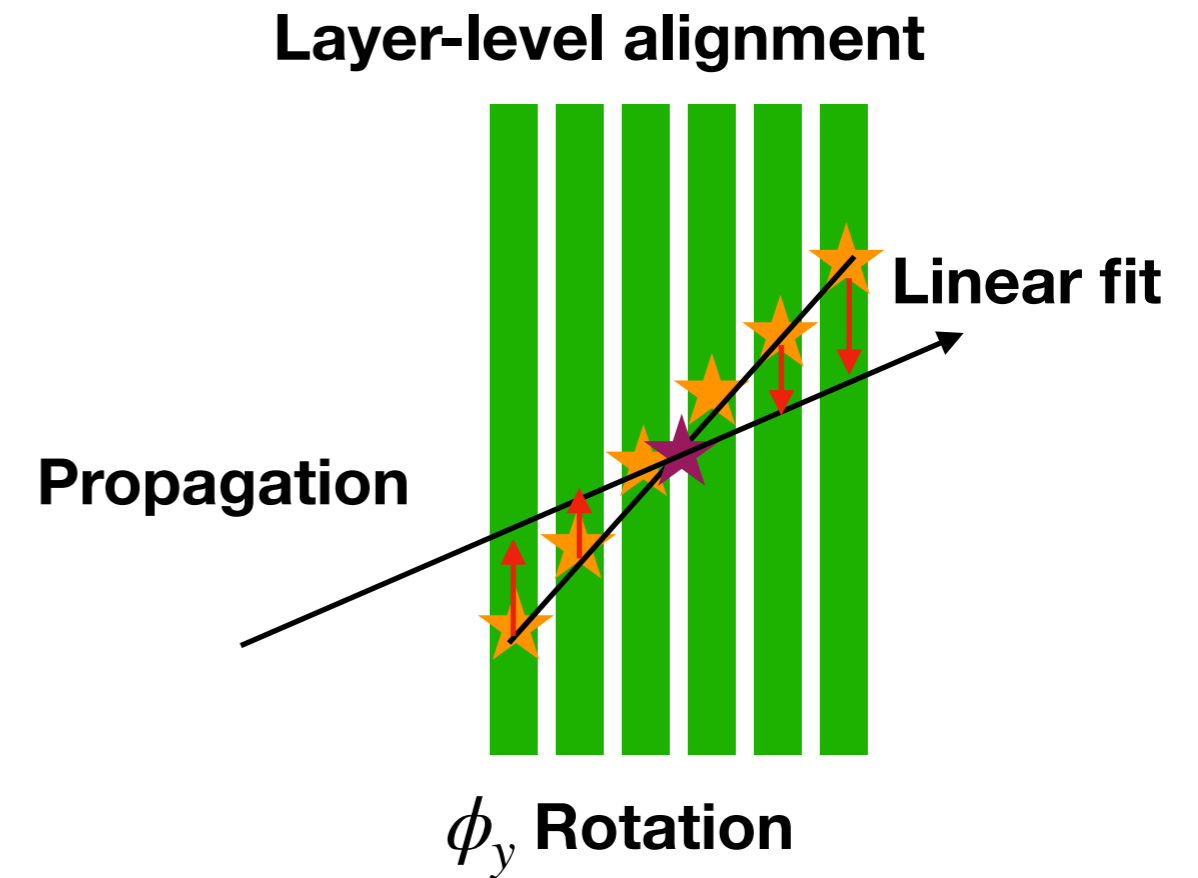
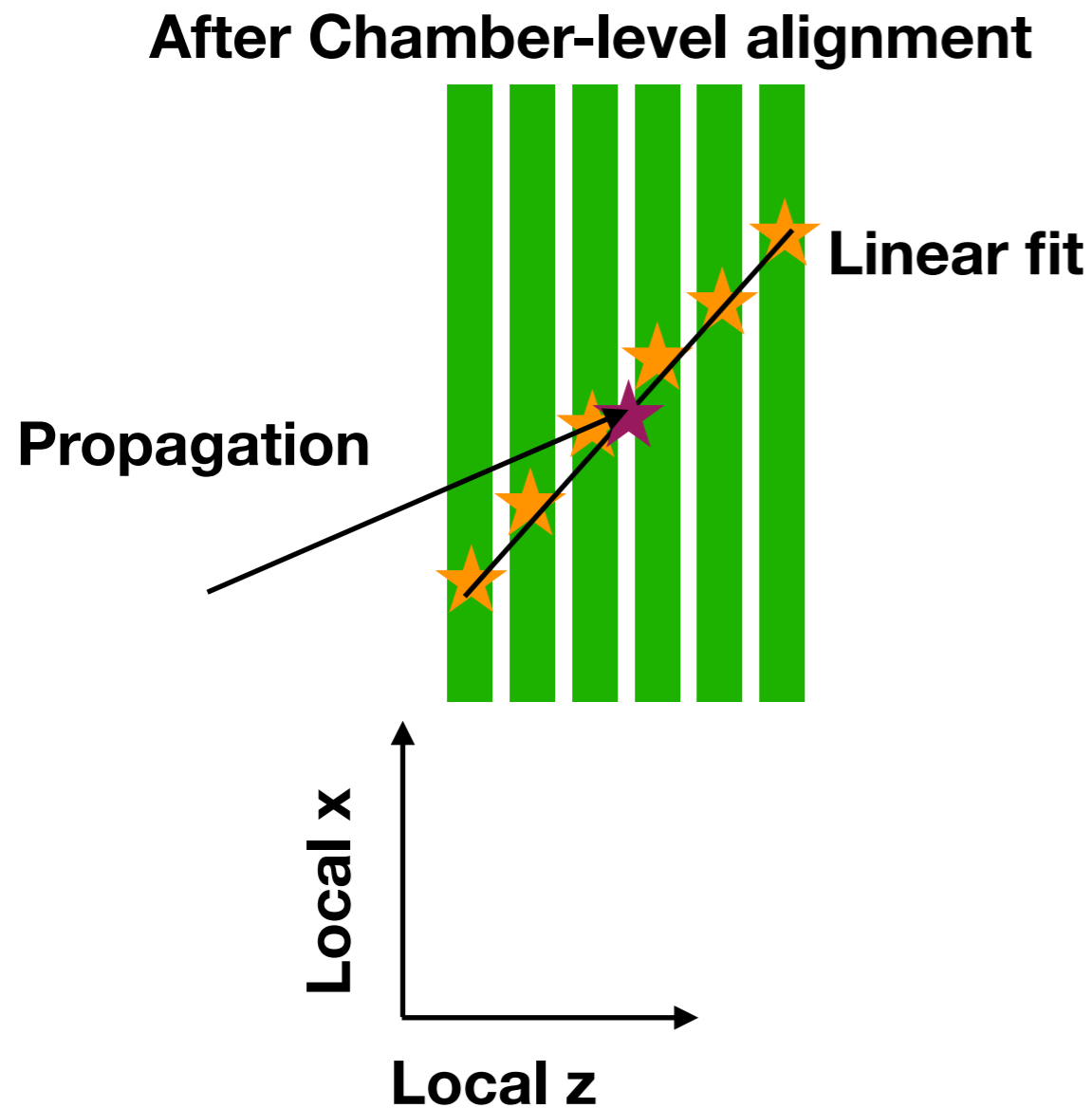
Difference between local layer position after 2023 layer alignment and 2022 layer alignment endcap 1, station 1, ring 1 and chamber 2



Mykyta Kizilov

**CSC layer-level residual before the layer-level alignment (left) and after layer-level alignment (right). The layer-level alignment shows an improvement of the residual. However, in this particular case, we expect the CSC chamber rotation of  $\phi_y$ .**

# CSC $\phi_y$ Rotation

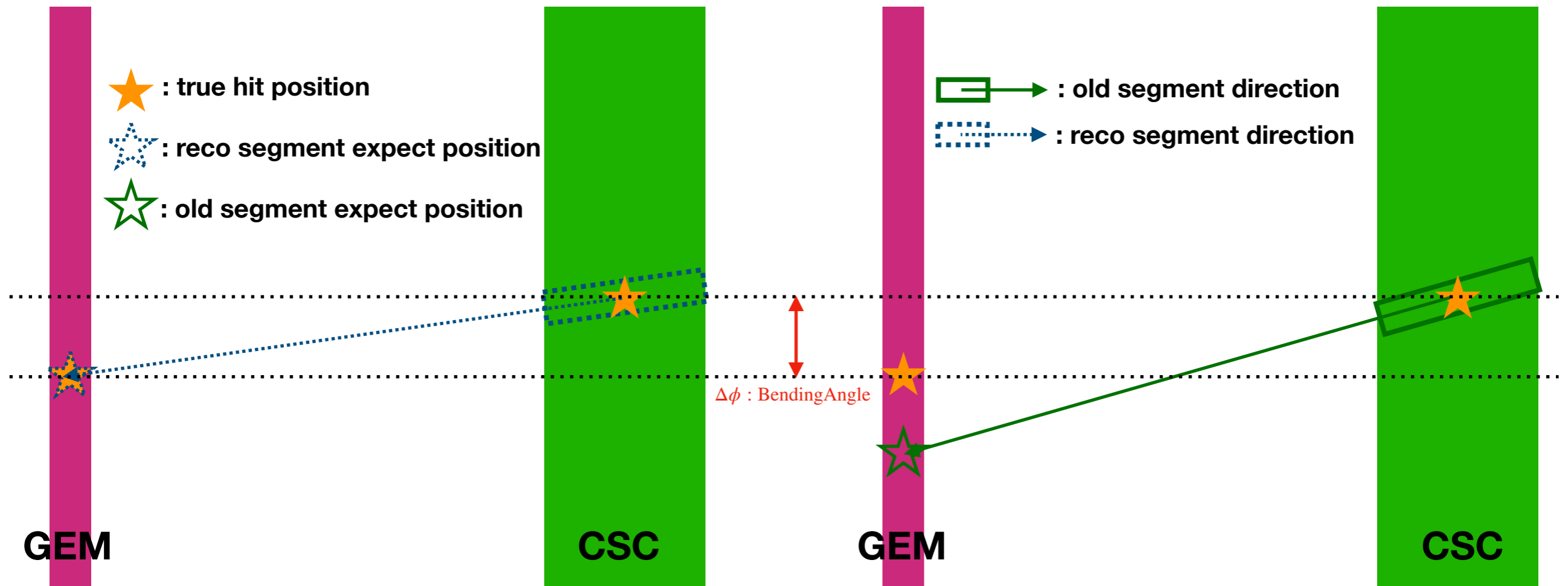




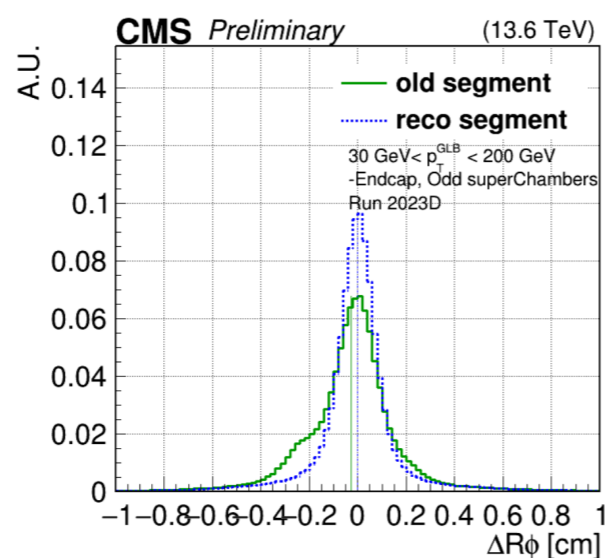
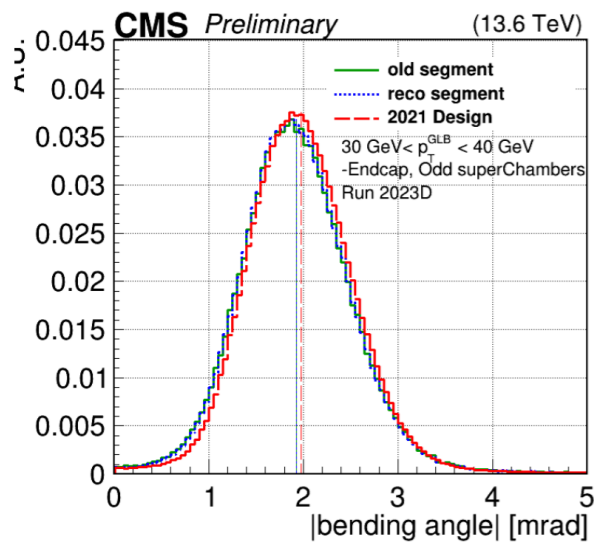
# GEM-CSC Alignment

- The CSC layer-level alignment shows an improvement of the GEM-CSC bending angle distribution because the layer-level alignment corrects the CSC segment direction.
- The unrealistic large layer-level residuals are due to the chamber  $\phi_y$  rotation.
  - We will correct the layer-level misalignment with the chamber  $\phi_y$  rotation but it requires further study.
  - To avoid the unexpected issue of the CSC segment performance, we would like to keep the ideal layer positions.
- However, GEM alignment will use the updated CSC segment of the CSC layer-level alignment.
  - It already proves the improvement in GEM-CSC bending angle performance.

# CSC Segment Direction

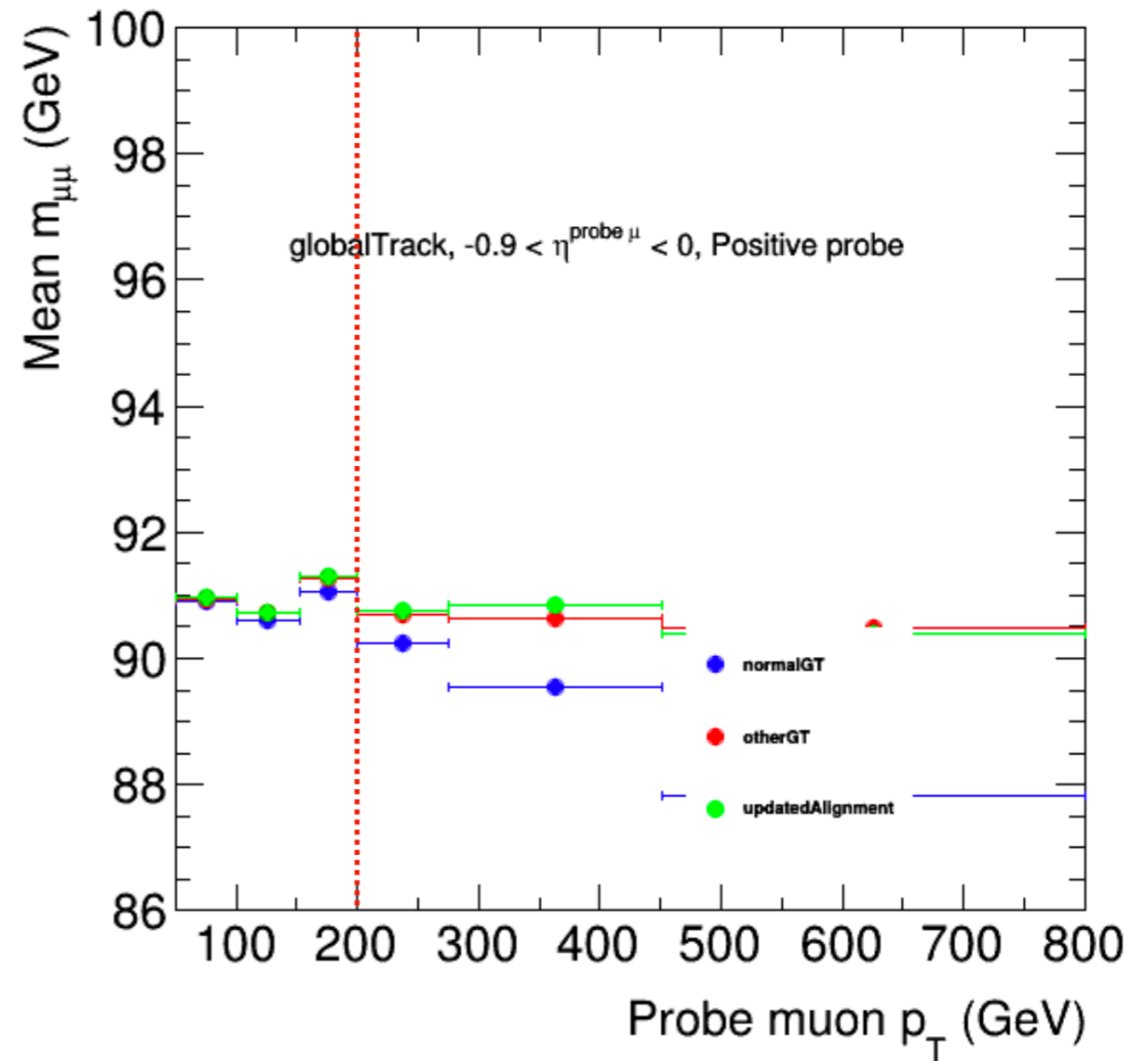
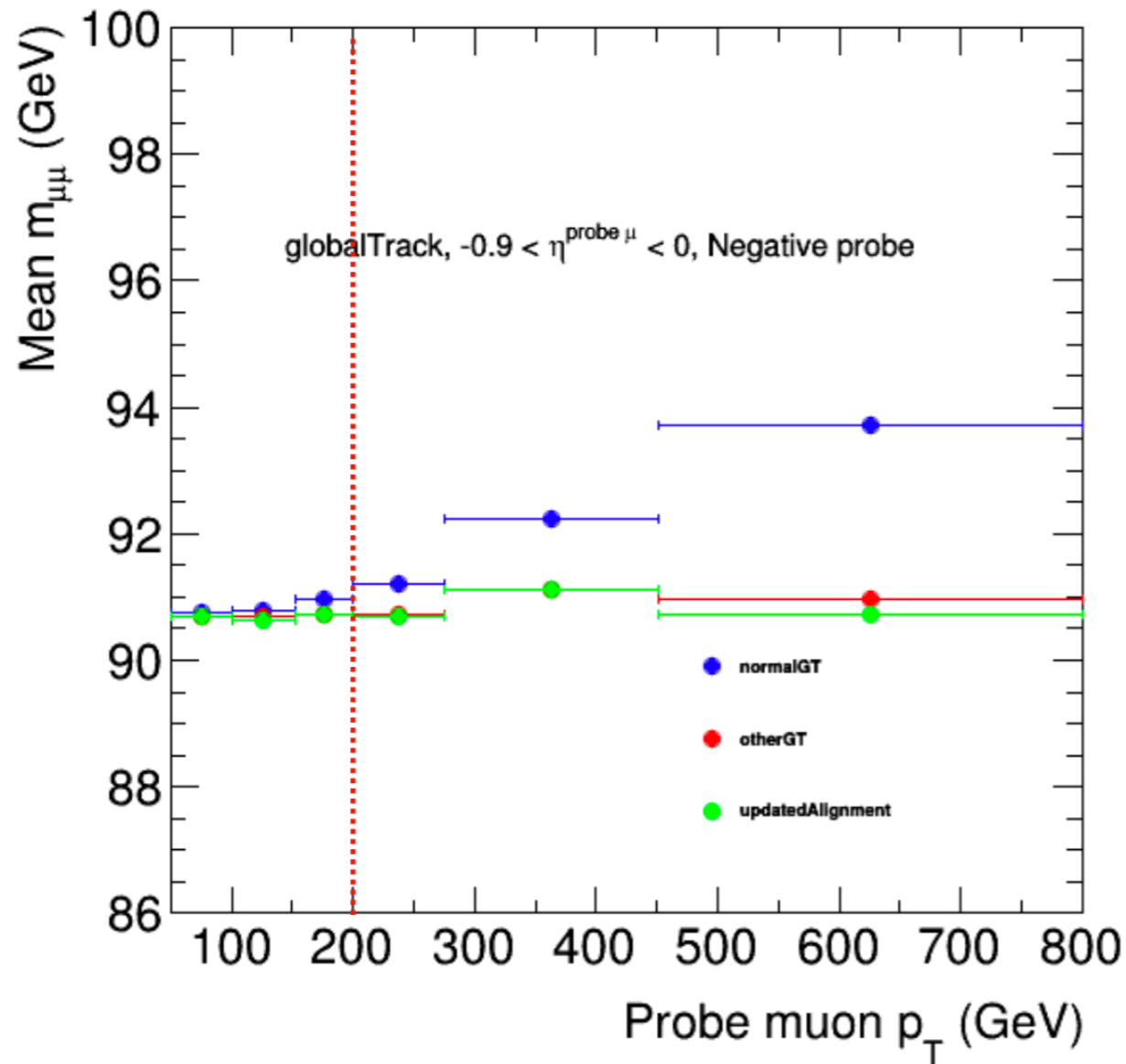


Towsifa



The top illustration shows the direction of old and reco (reconstruction with CSC layer-level alignment) CSC segments. **The bending angle remains unchanged for both old and reco segments (bottom left and illustration)**, but the residual can vary (bottom right). However, the old segment direction is incorrect, leading to an incorrect residual calculation for the old segment case (top left).

# Dimuon Mass by $p_T$



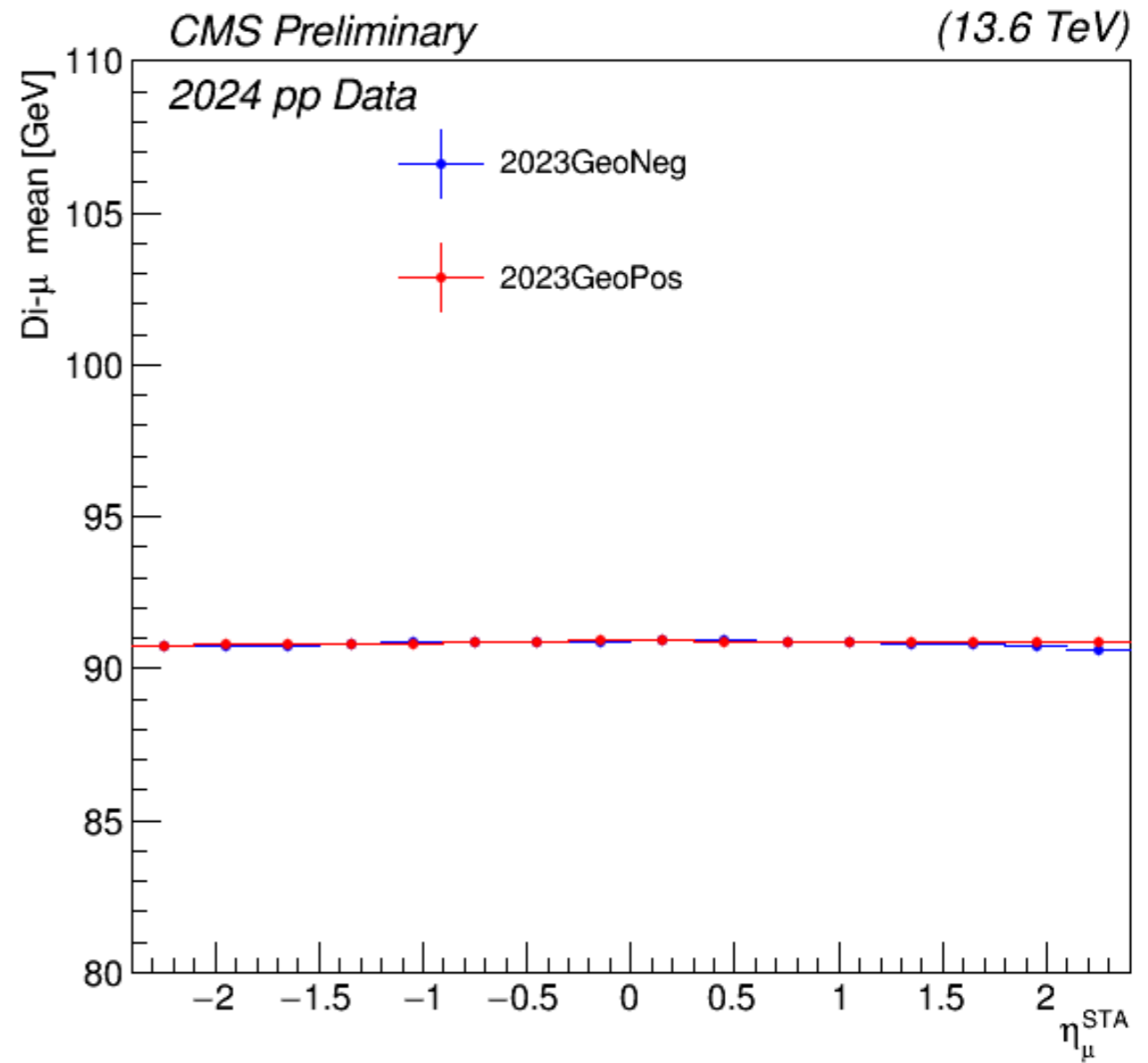
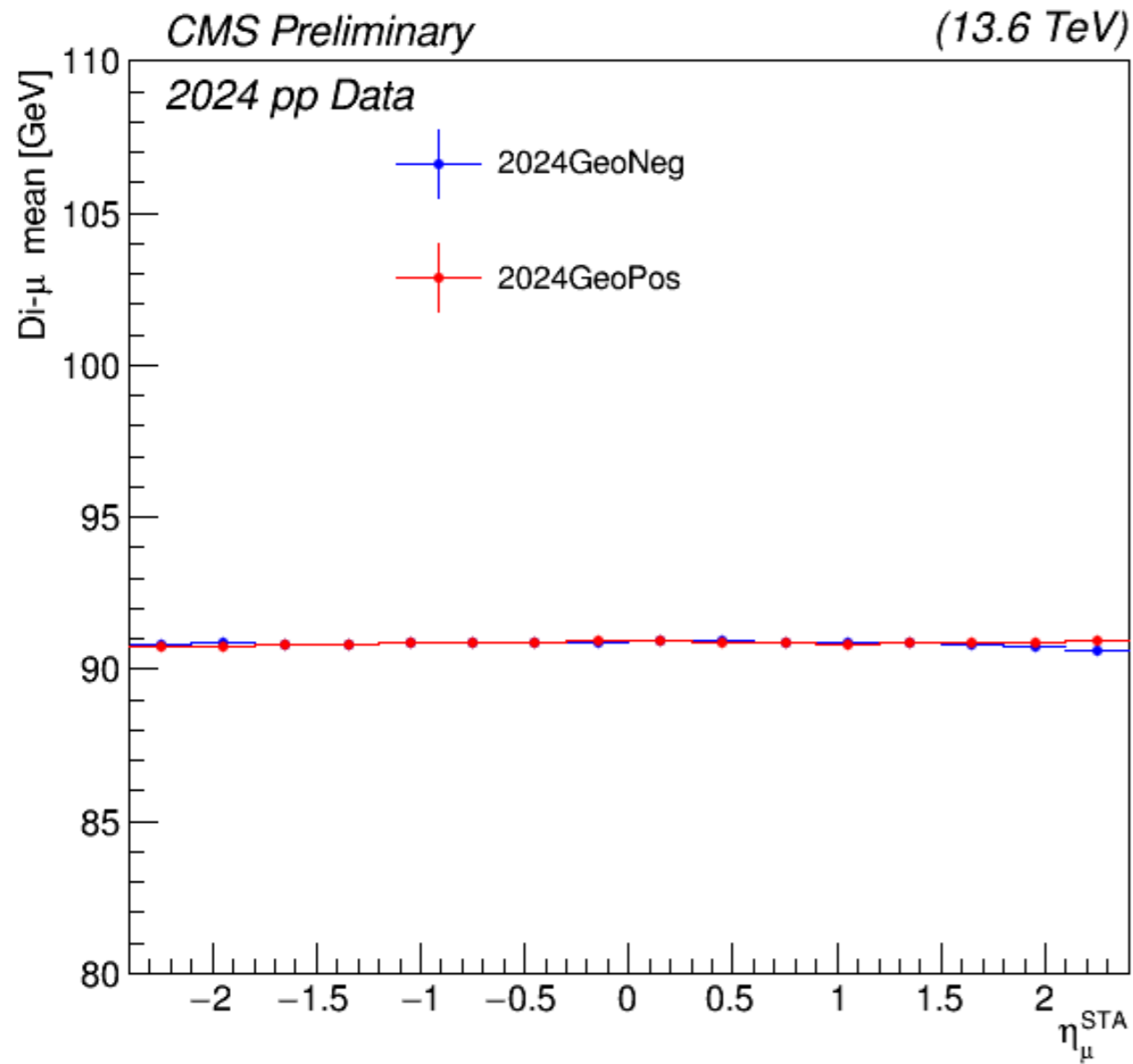
The dimuon mass has charge bias above 200 GeV

Blue: 2018UL (muon geometries have a momentum bias)

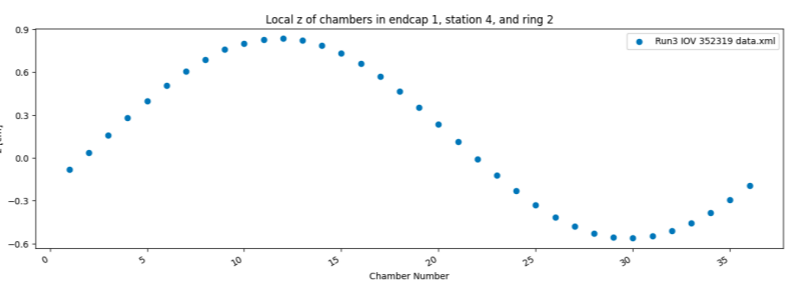
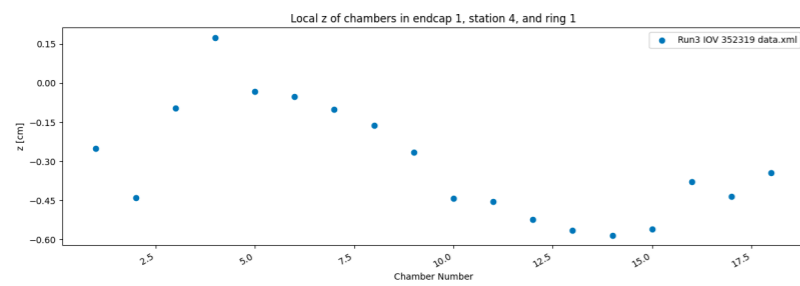
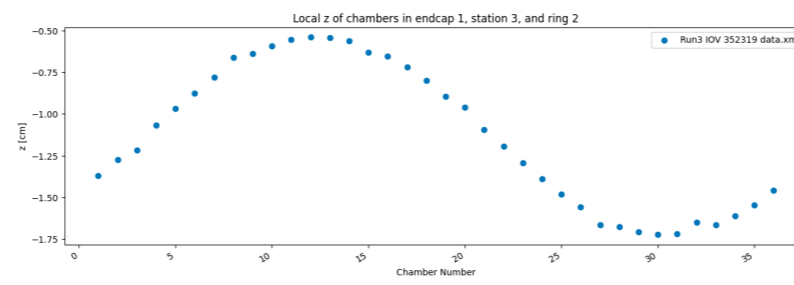
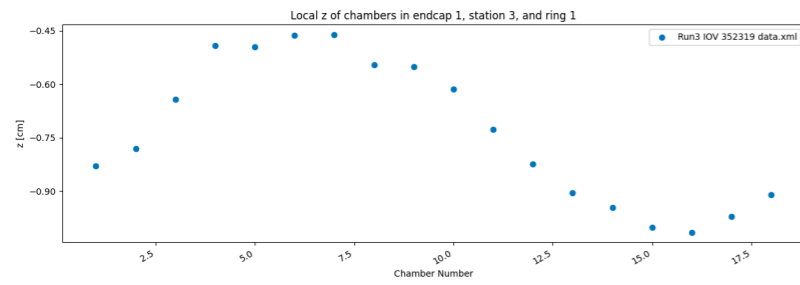
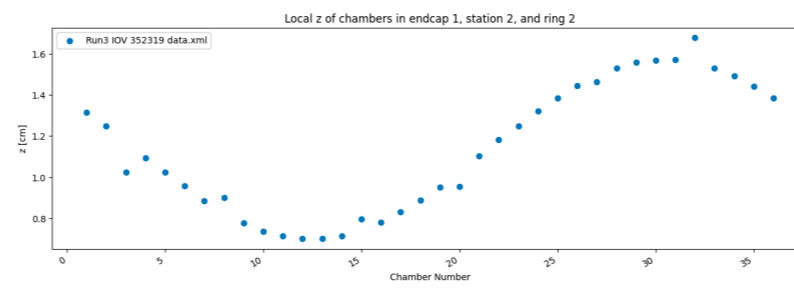
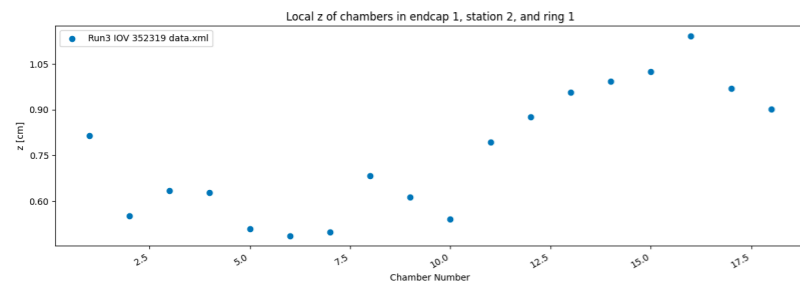
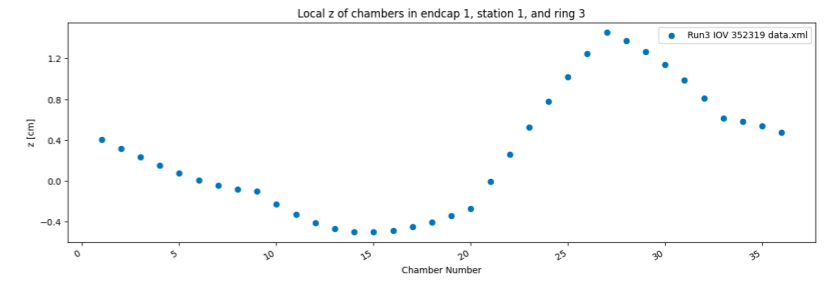
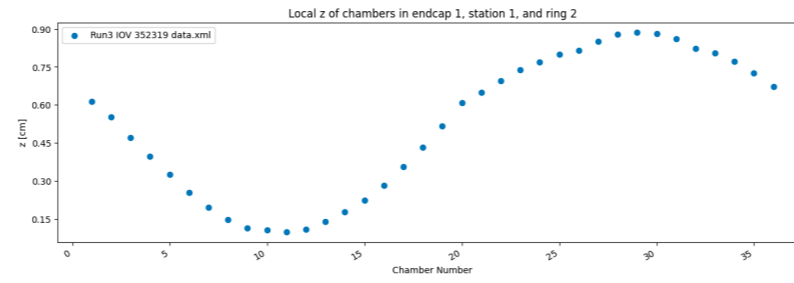
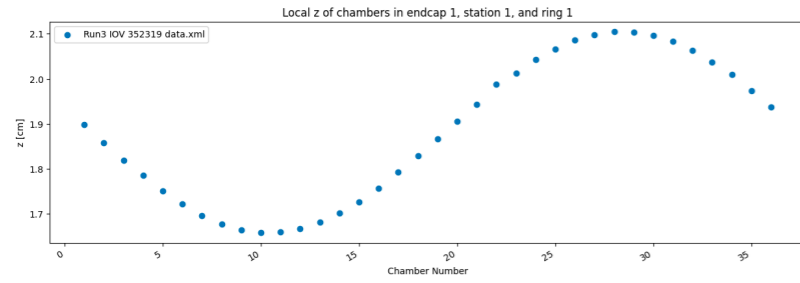
Red: current tracker geometry + 2018-preUL

Green: current tracker geometry + updated muon geometry

# Muon Charge Bias by $\eta$



# Endcap 1



# Endcap 2

