Study of the muon alignment effect on momentum scale of high pT muons

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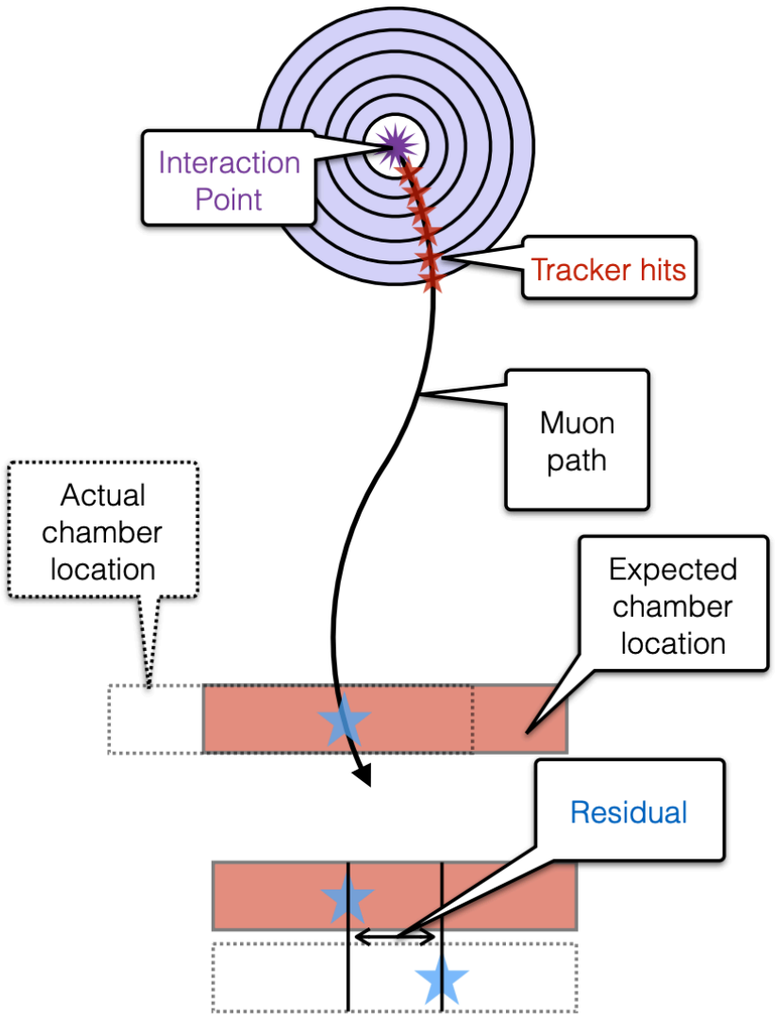
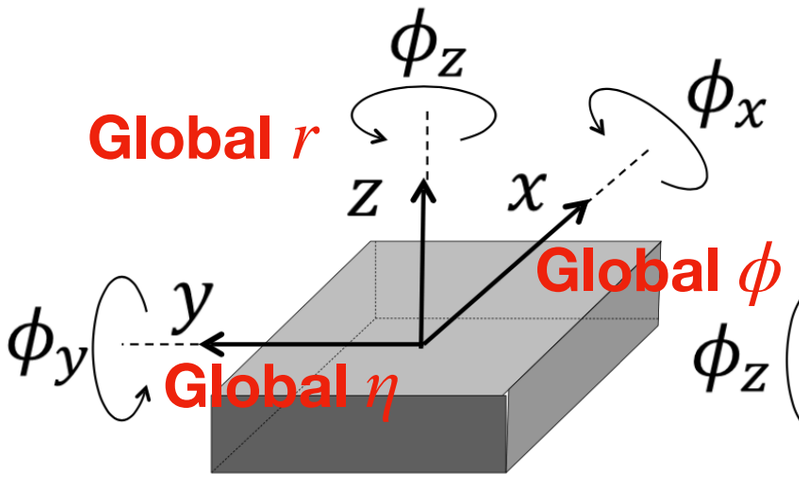
Track-Based Muon Alignment



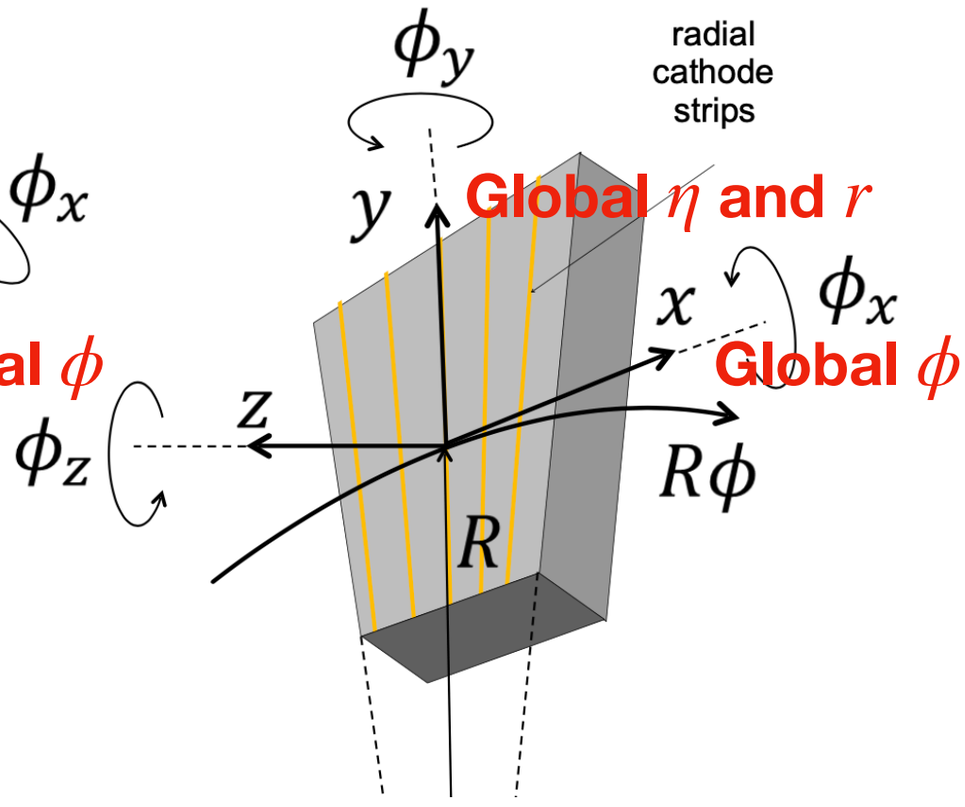
- **Track-based muon alignment (TBMA)**
  - propagate the tracker part of muons to the muon system
  - Muon residual: difference between the reconstructed position and the predicted position on the muon chamber
- The TBMA technique is proven to be efficient, robust, and stable in Run1 and Run2
- The 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 μm (depend on chamber type, position, and integrated luminosity)**

Degree of Freedom

DT



CSC

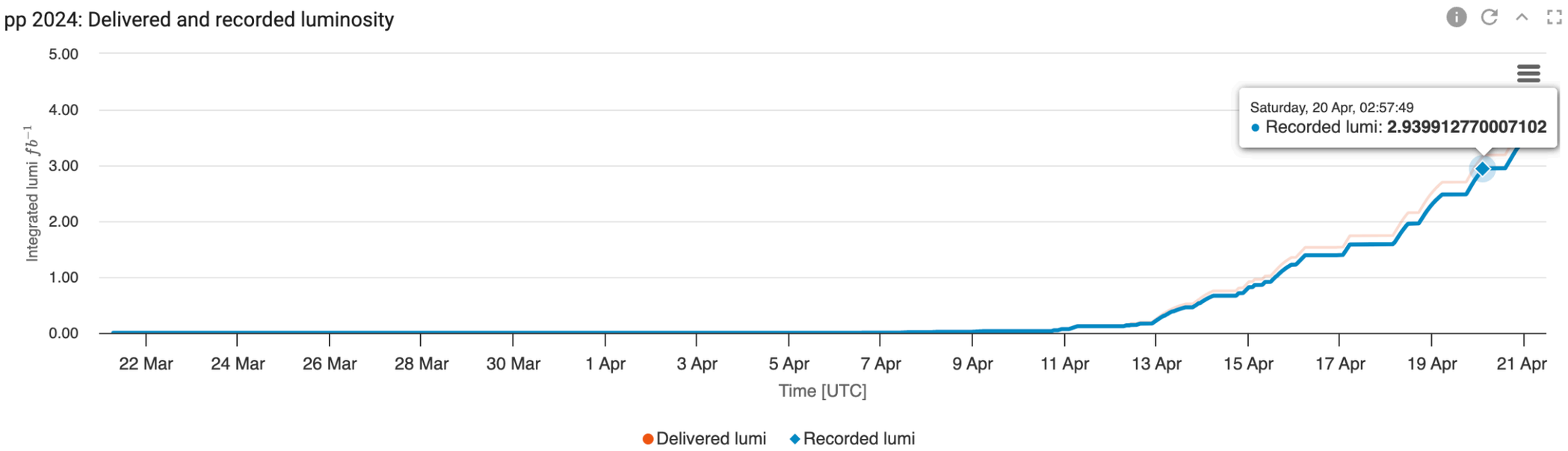


250 chambers **540 chambers**

DT alignment uses 6 DOF but CSC alignment uses 3 DOF (x, y, and ϕ_z)

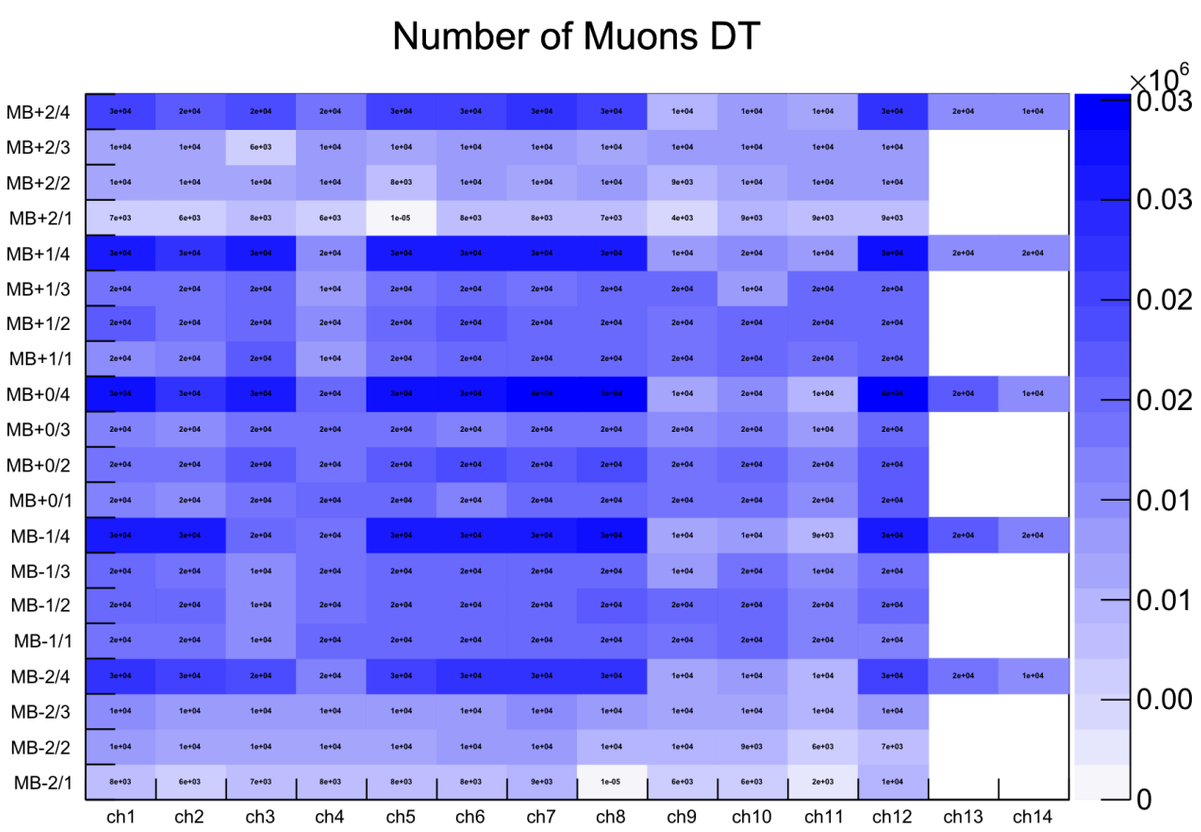
GEM alignment uses 3 DOF (x, y, and ϕ_z) with 144 GE1/1 chambers for Run 3

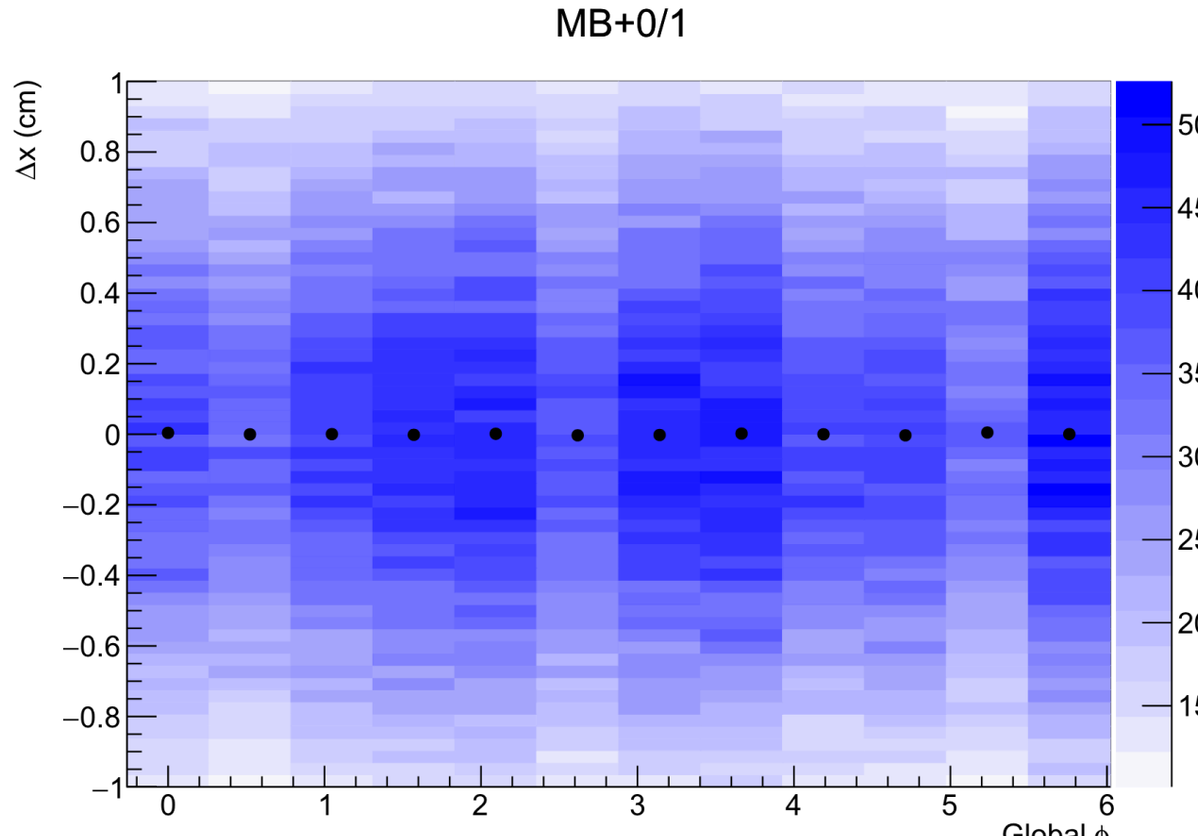
2024 TBMA



- 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

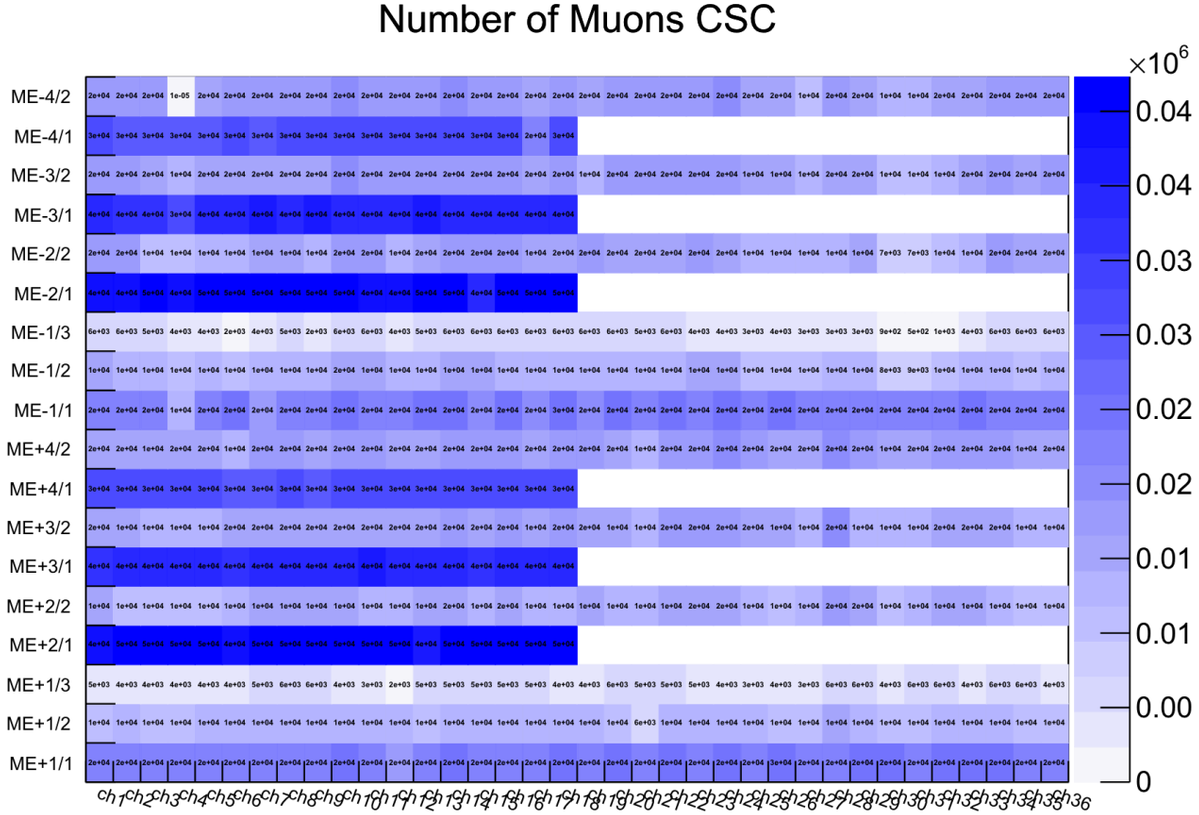
DT

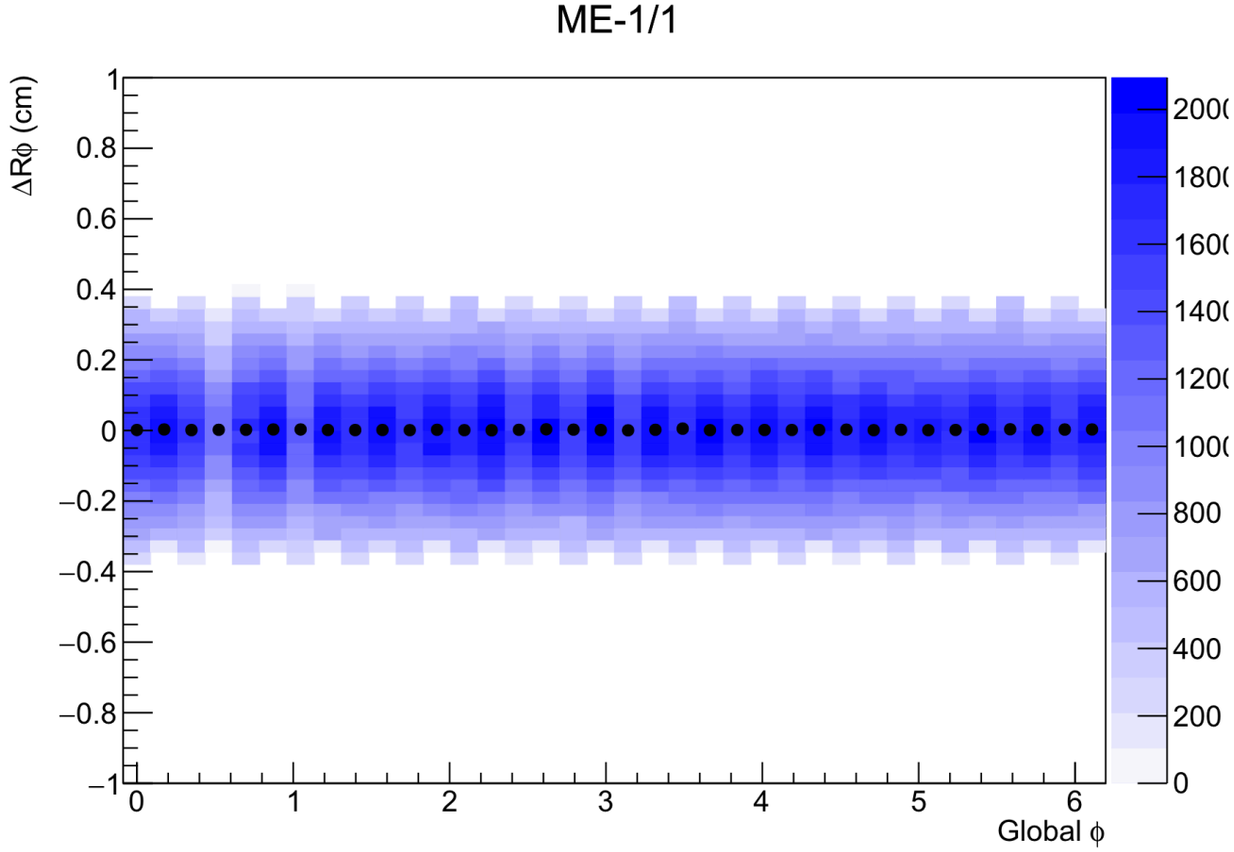




- **Two chambers (MB+2/1/5 and MB-2/1/8) don't have any entries**
- **Overall residual distributions look fine**

CSC

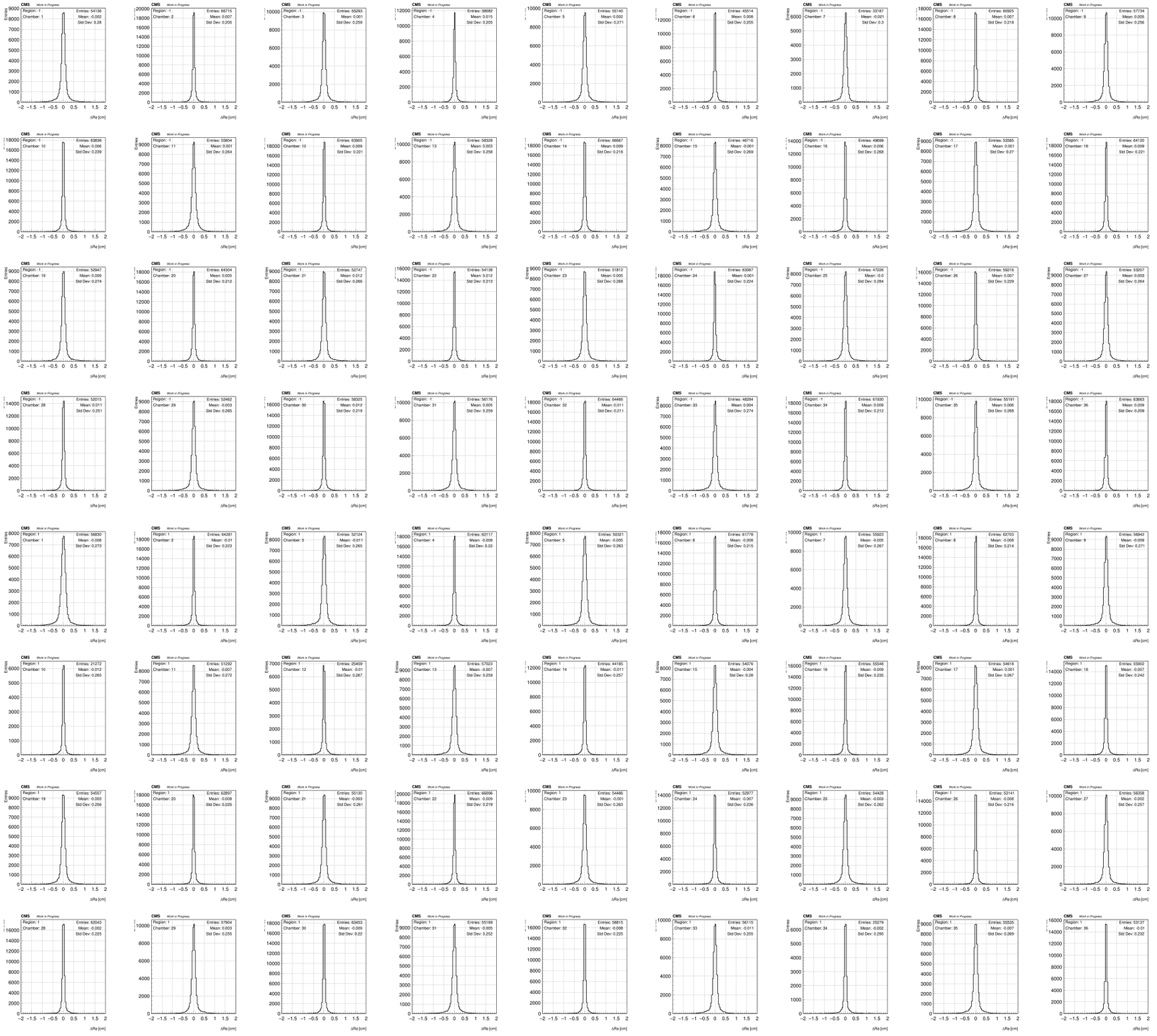




- **ME-4/2/4 doesn’t have any entries.**
- **Overall residual distributions look fine**
- **CSC had a z position issue; alignment starts from an ideal CSC geometry**
  - **we don’t align dz parameter but CSC chambers have unrealistic z shifts**

GEM

Endcap-1

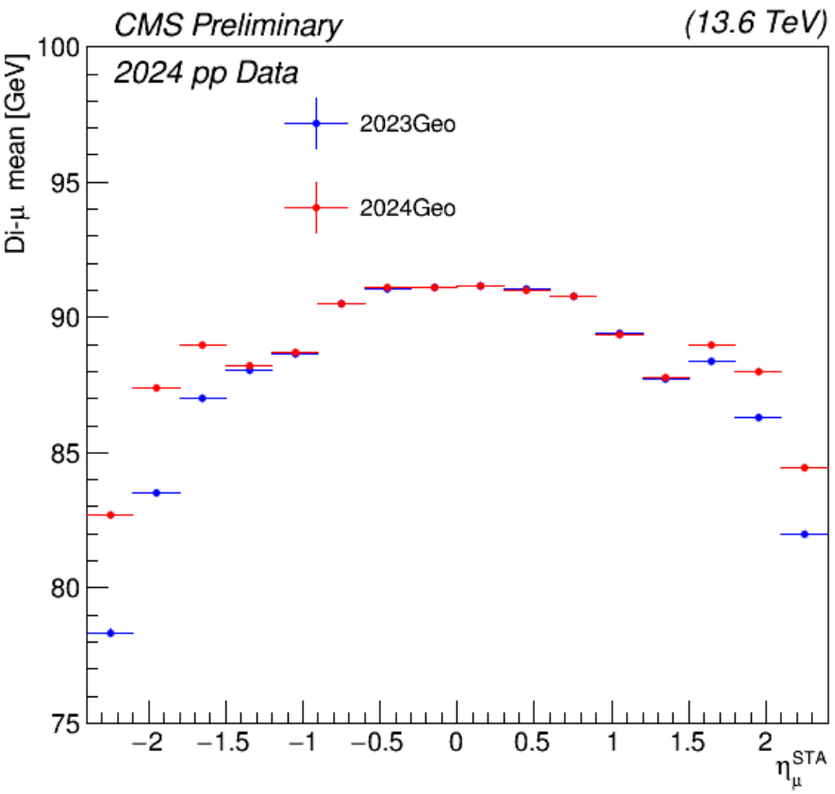


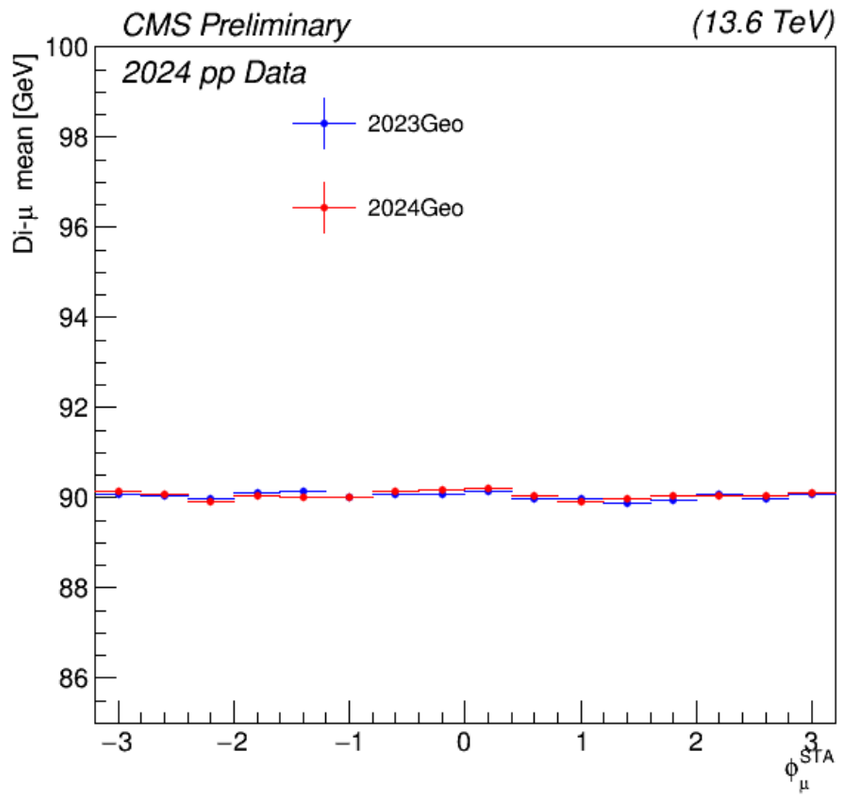
Endcap+1

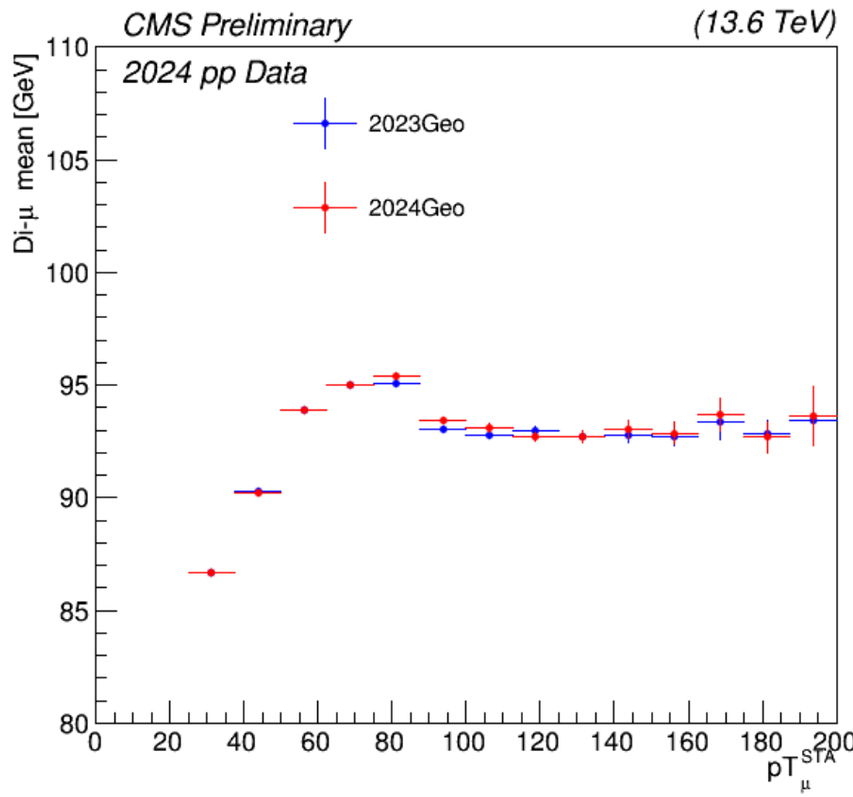
Physics Validation

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

Dimuon Mass



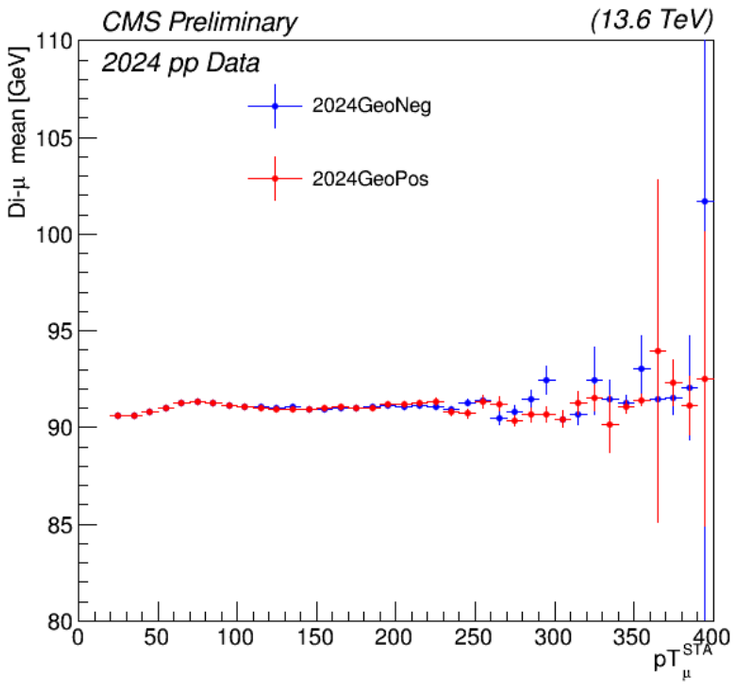


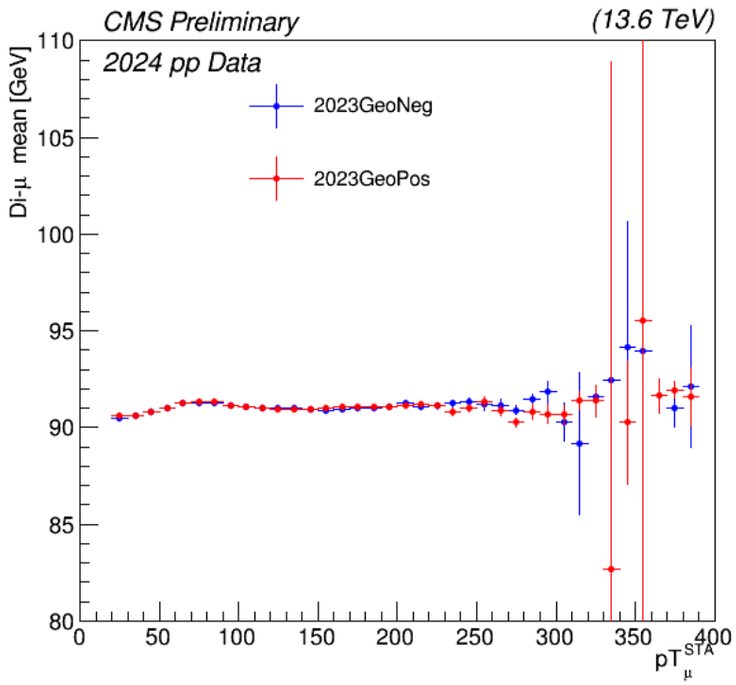


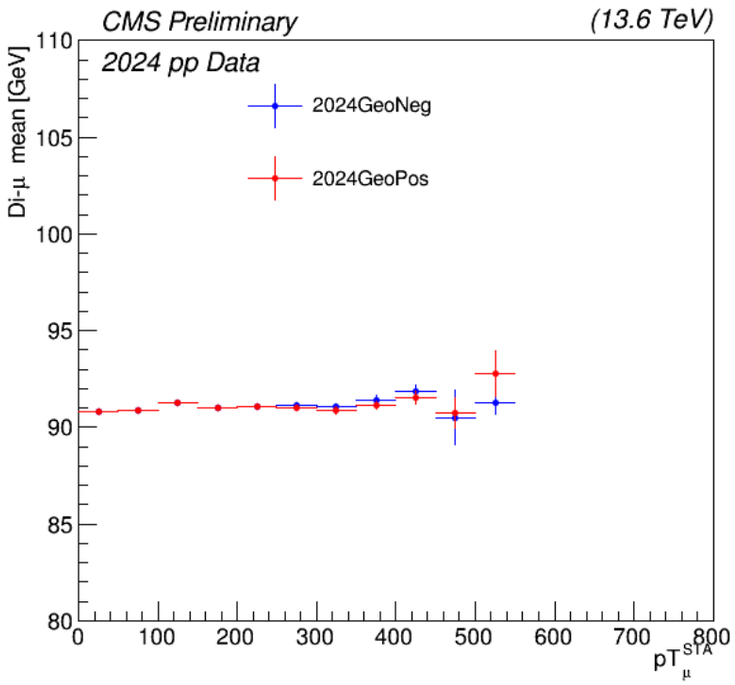
- **Dimuon mass distributions by η, ϕ, and p_T**
- **One leg is a global muon and the other leg is a STA muon**

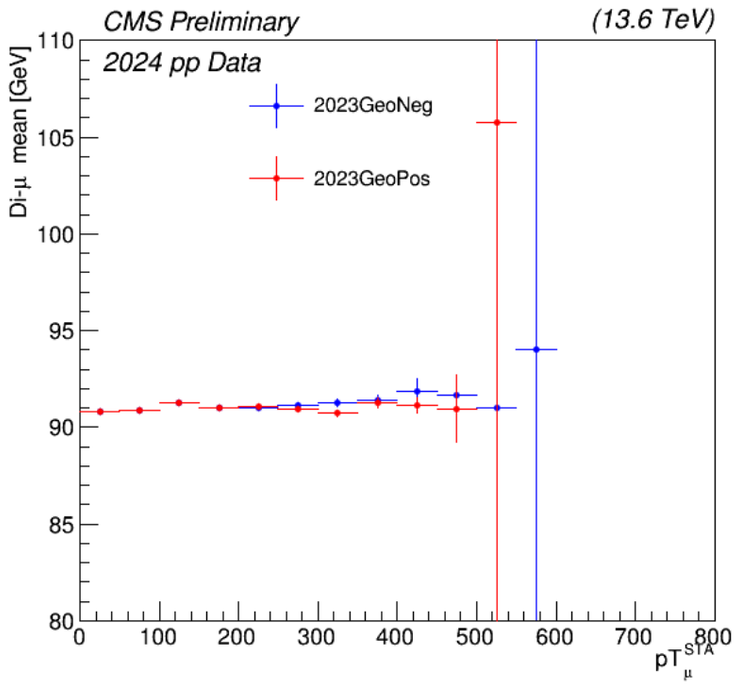
High pT Muon

- Run2024C + D (D is not the full dataset)
- Two global muons for the dimuon mass, not STA-GLB
- μ^- and μ^+ 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.

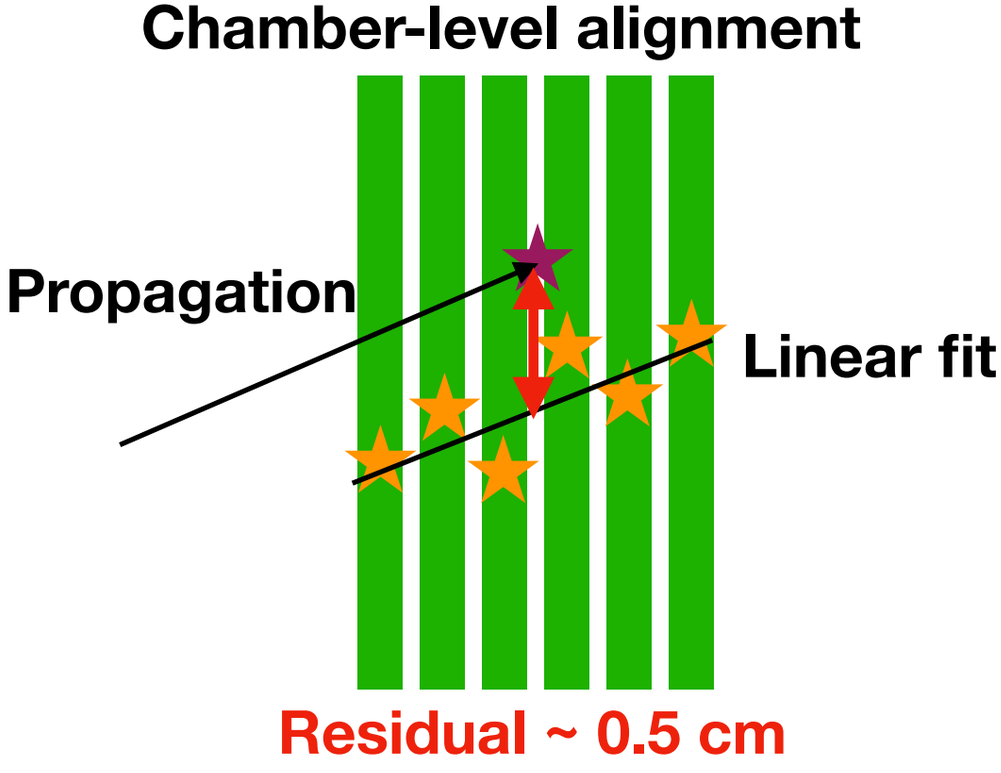
- The physics validation results look fine, especially the dimuon mass distribution by eta, which shows improvement in the high eta region.

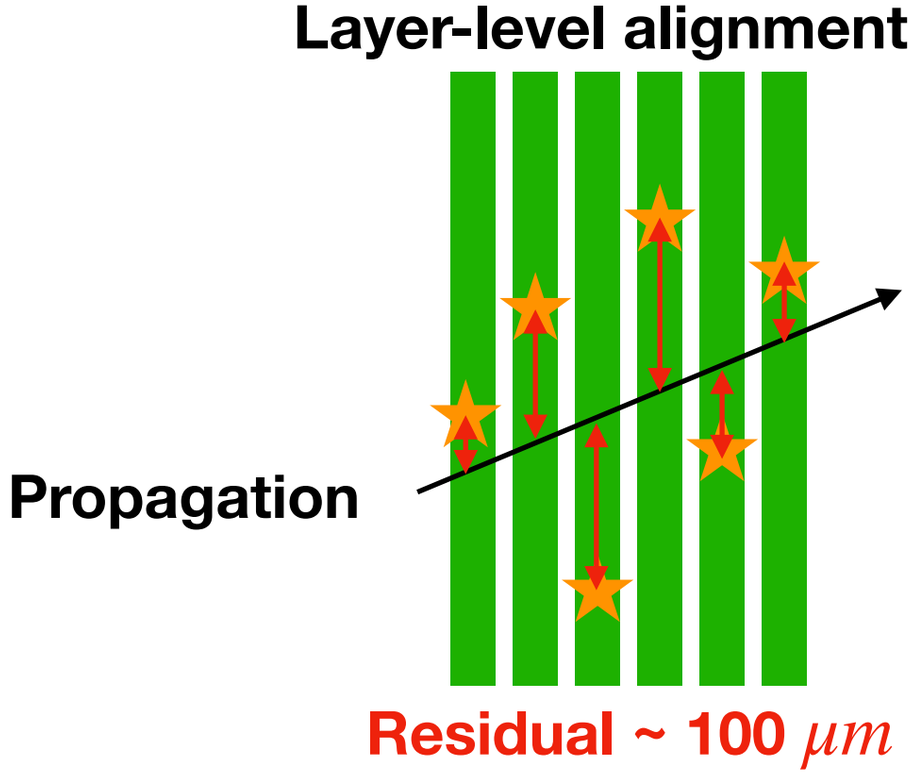
- The new tags have been appended to online GTs on May 14th.

Backup

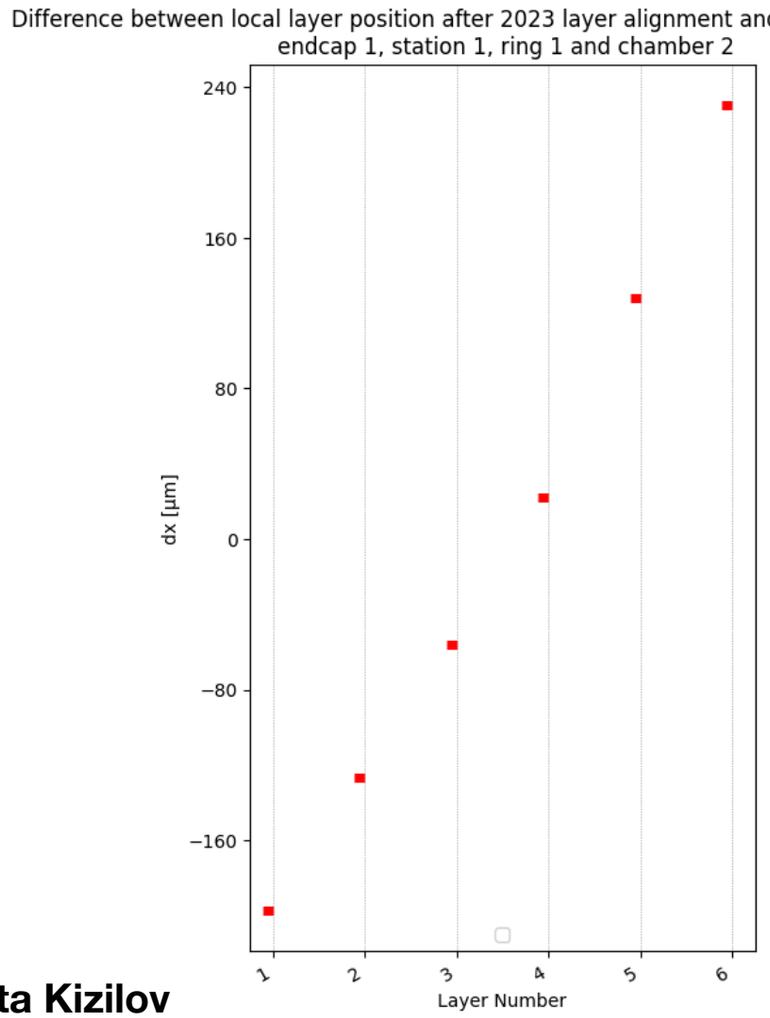
CSC Layer-level Residual

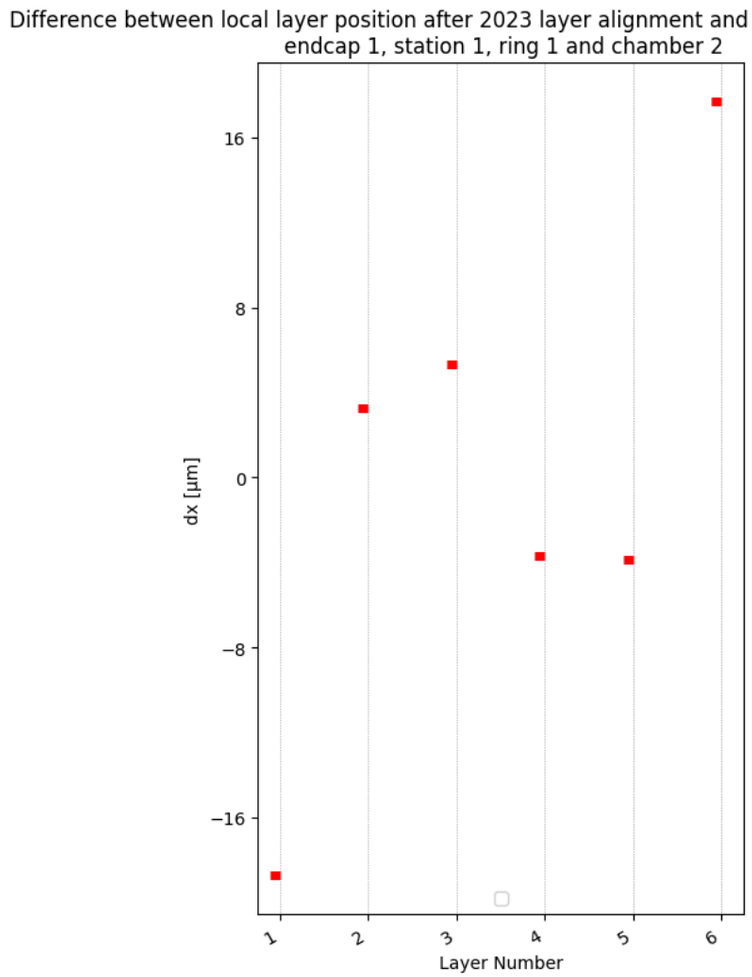
- After the chamber-level alignment, which involves linear fitting of the 6-layer's recHits, we calculate the layer-level residual for further alignment.





CSC Layer Alignment Validation

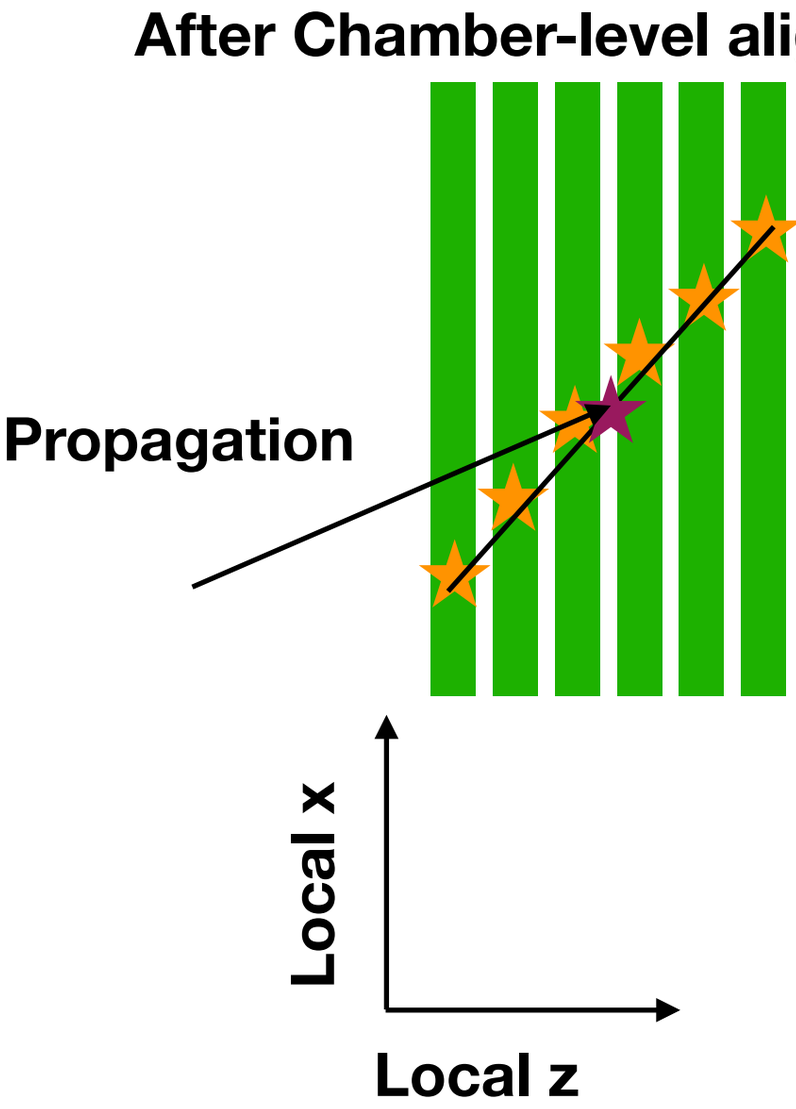


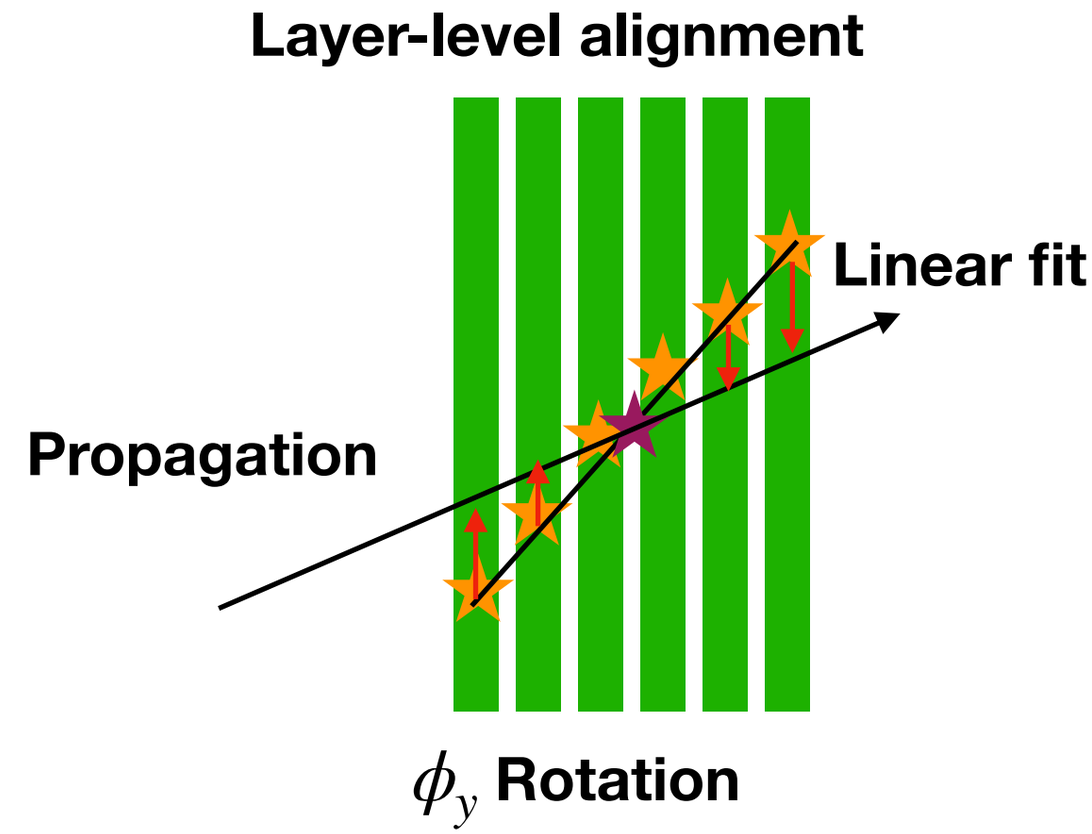


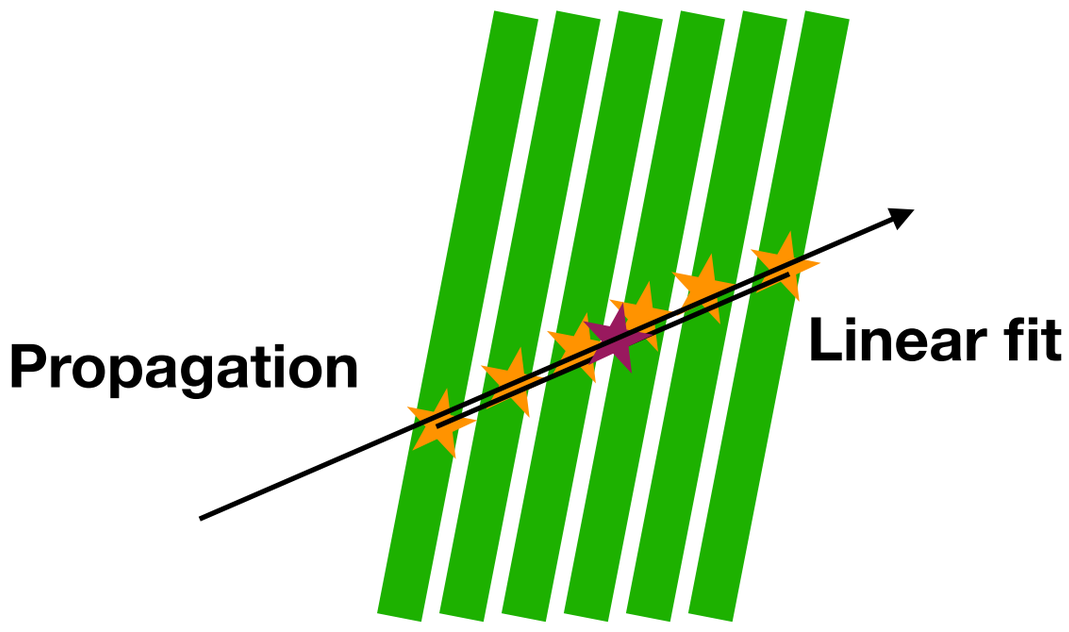
Mykyta Kizilov

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 ϕ_y.

CSC ϕ_y Rotation



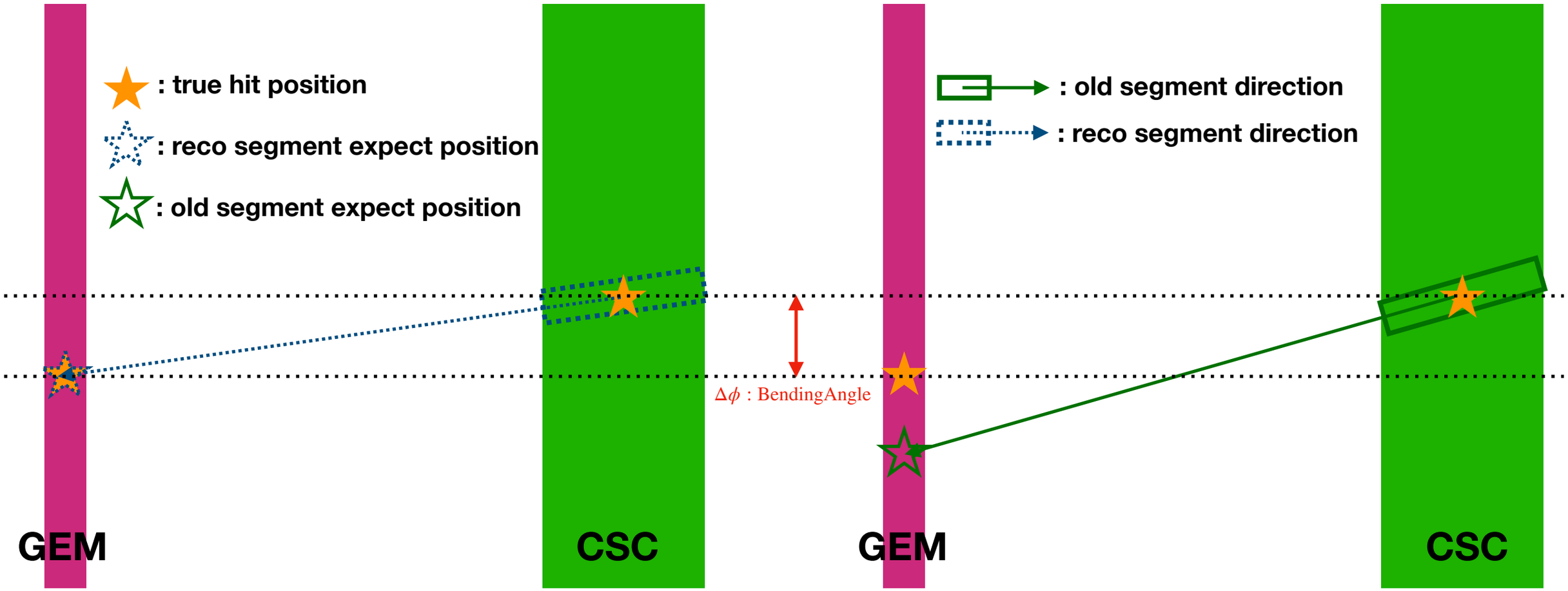




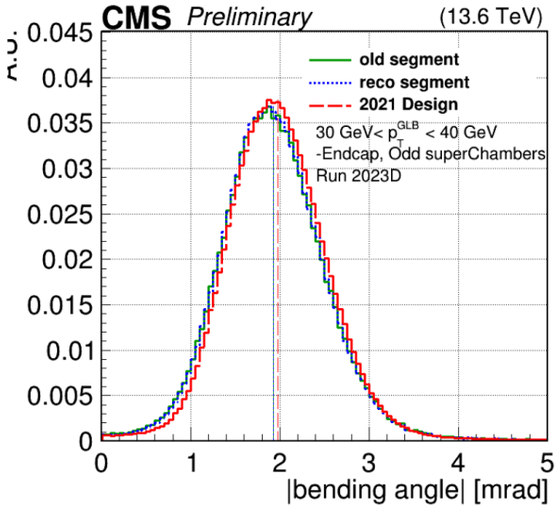
GEM-CSC Alignment

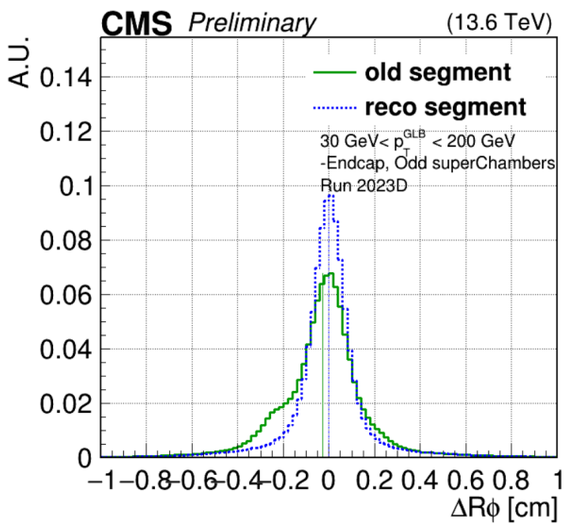
- The CSC layer-level alignment shows an improvement of the GEM-CSC bending angle distribution because the layer-level alignment corrects the CSC segment direction.
- The unrealistic large layer-level residuals are due to the chamber ϕ_y rotation.
  - We will correct the layer-level misalignment with the chamber ϕ_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



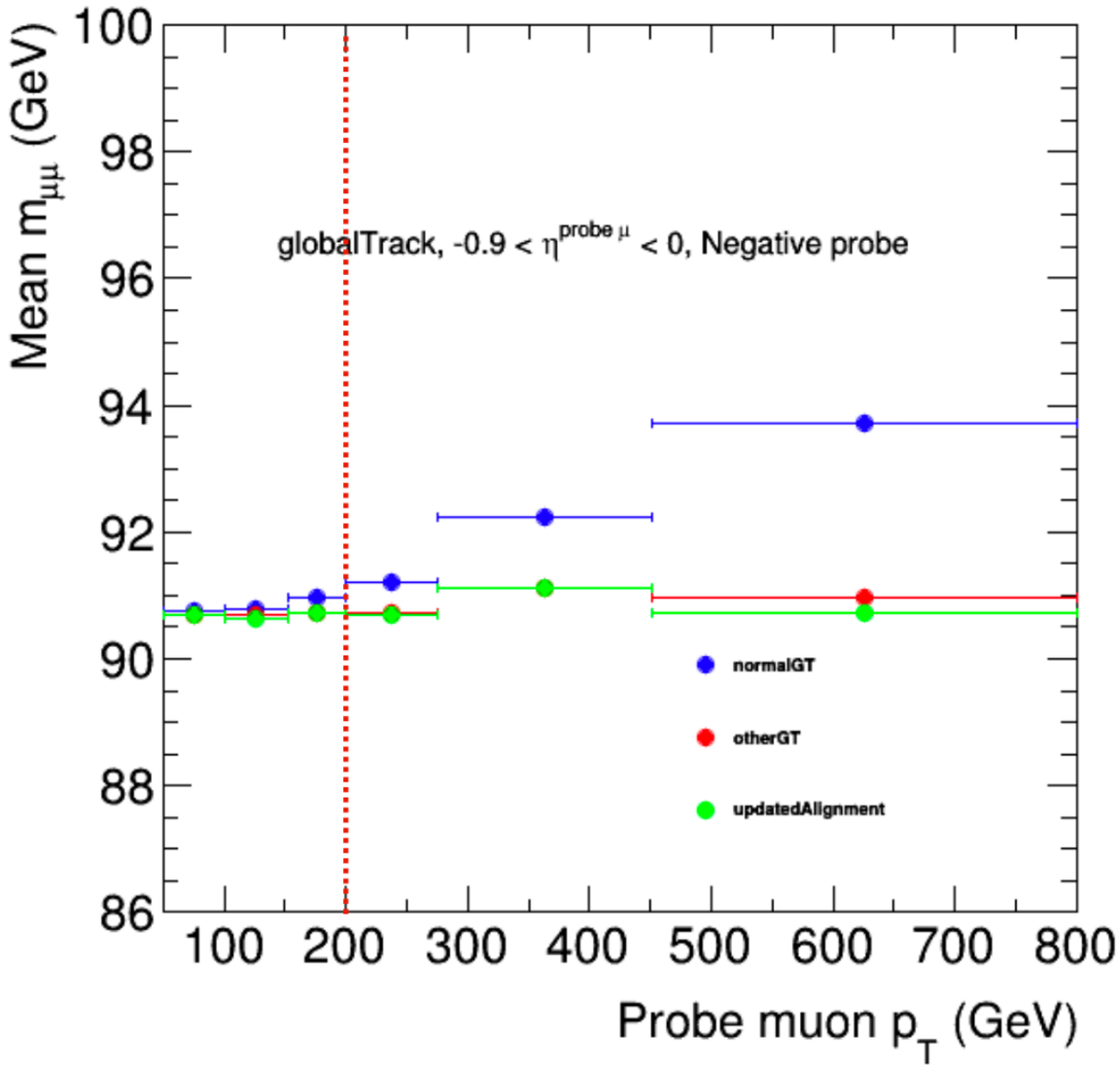
Towsifa

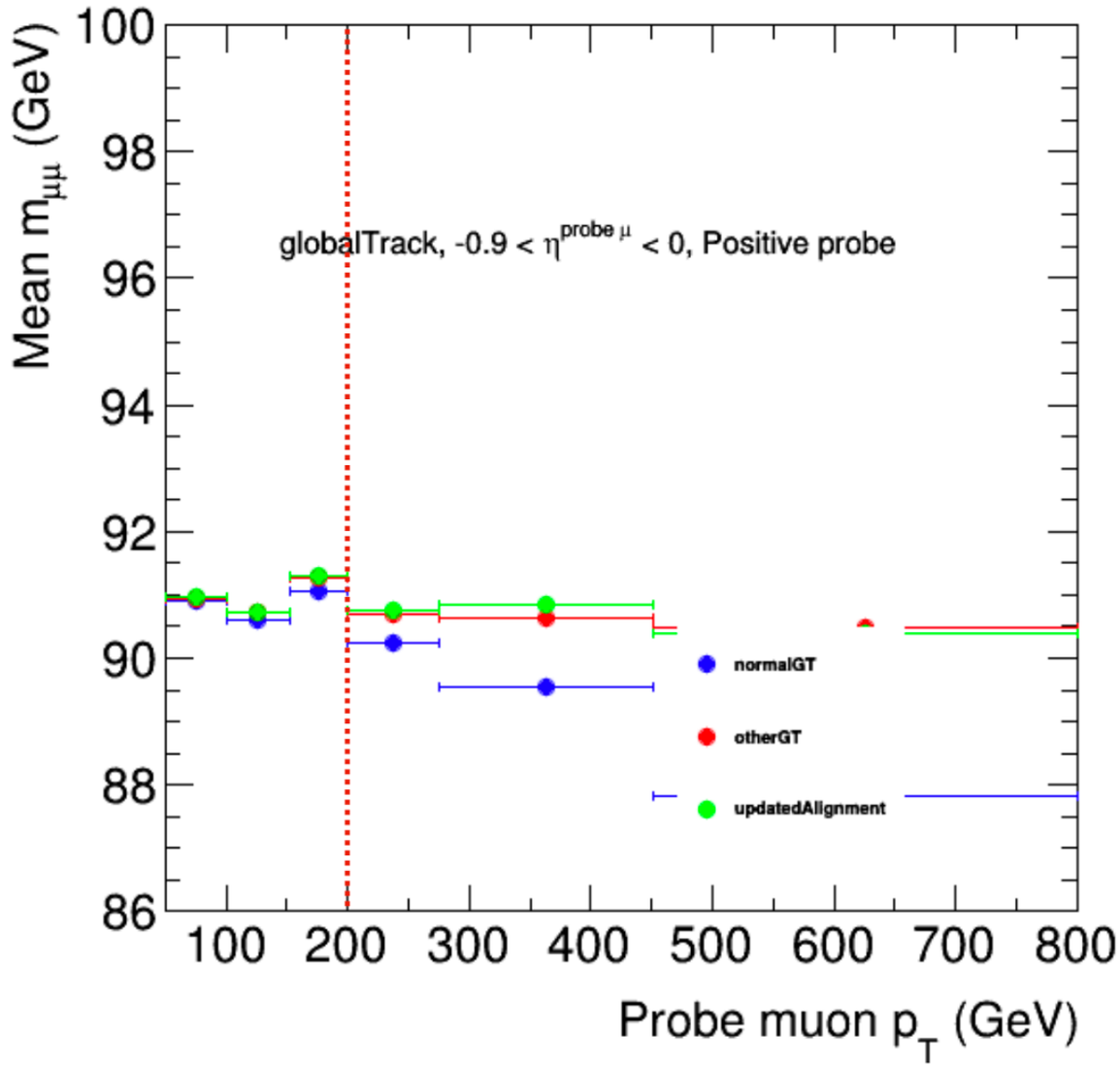




The top illustration shows the direction of old and reco (reconstruction with CSC layer-level alignment) CSC segments. The bending angle remains unchanged for both old and reco segments (bottom left and illustration), but the residual can vary (bottom right). However, the old segment direction is incorrect,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