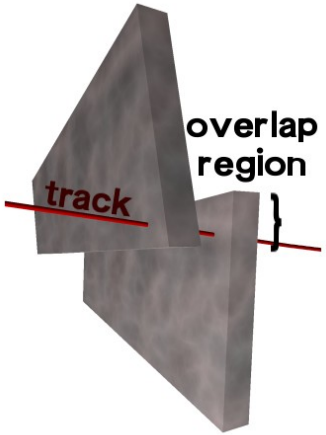
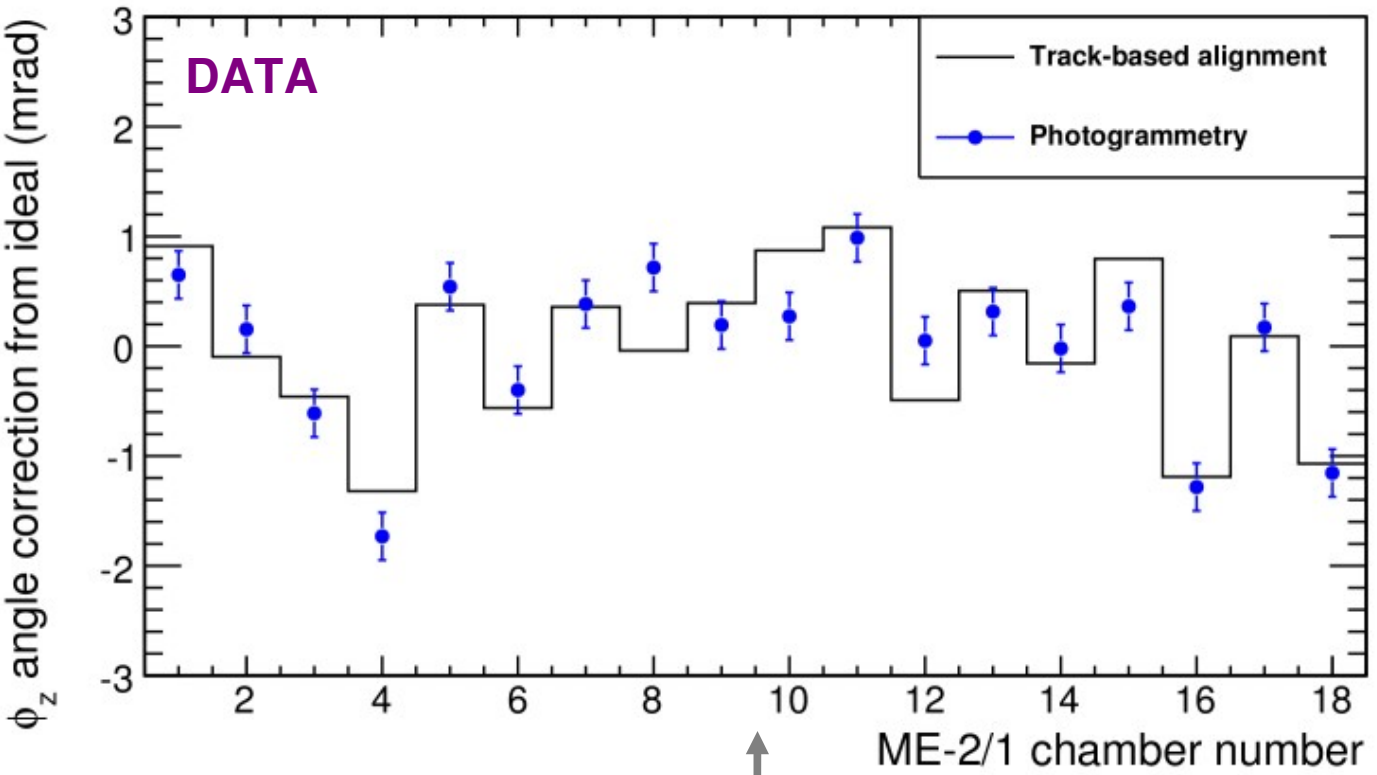
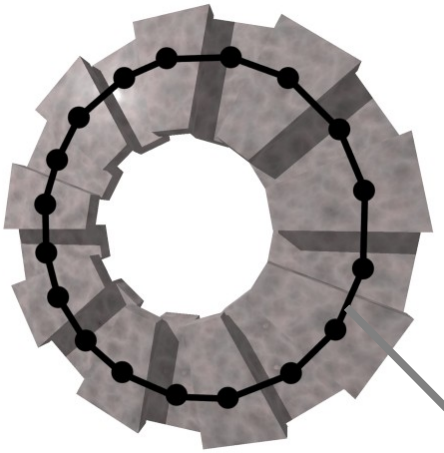
CSC Alignment with beam-halo muons



- Select tracks that pass through overlap of two chambers
- Determine relative position by requiring consistency between the two track segments:
  - $r\phi$ position (most important for momentum resolution)
  - ϕ_z: rotation in layer's plane (second most important)
  - ϕ_y: rotation around alignment pin axis



- Solve system of 18-36 relative corrections

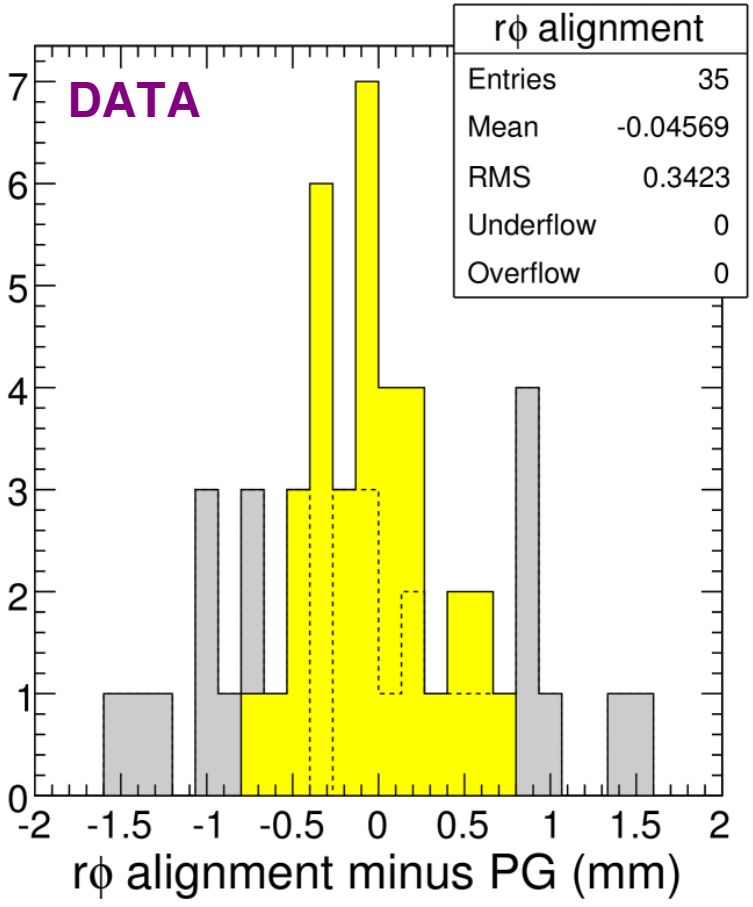


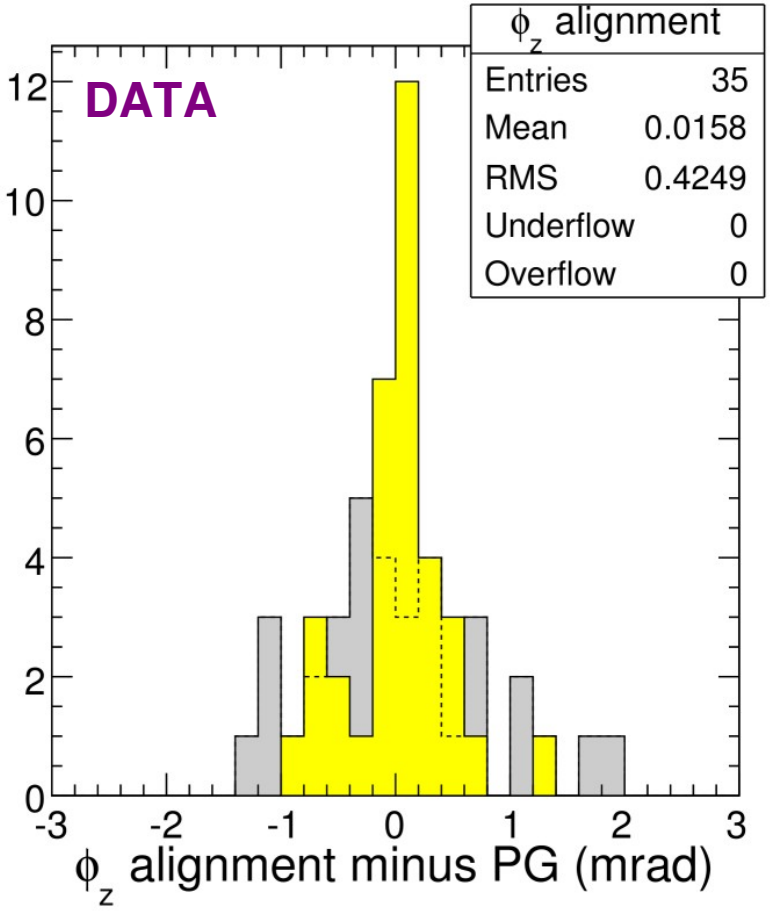
- Cross-check against photogrammetry

Accuracy determined from photogrammetry (PG)

- Photogrammetry is alignment from a literal photograph of the detector: completely independent from tracks, 210 μm rϕ and 0.23 mrad ϕ_z resolution
- Chamber-by-chamber difference with respect to PG before (gray) and after (yellow) alignment with tracks shows improvement (35 chambers below)
- Track-based alignment accuracy: 270 μm rϕ and 0.35 mrad ϕ_z

(from RMS of difference minus PG resolution in quadrature; no PG data for ϕ_y)

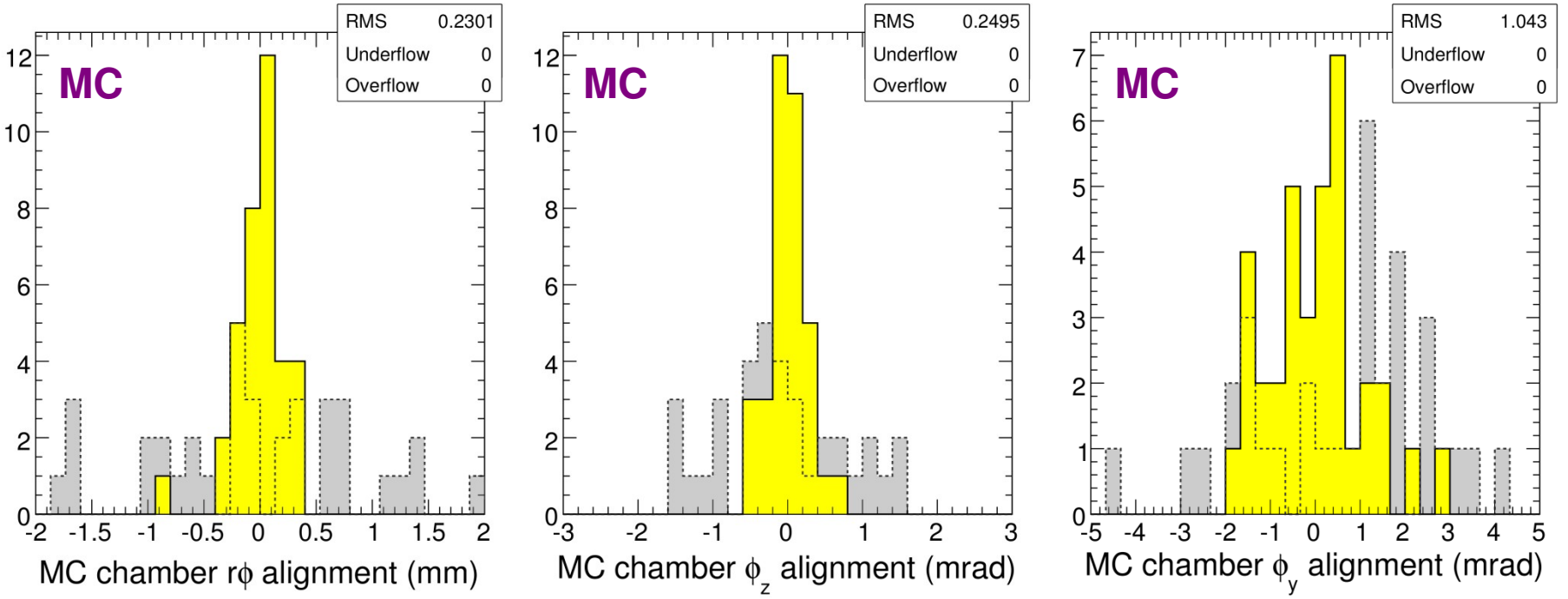




Achieved alignment resolution goal in 9 minutes of LHC beam-halo data!

Simulation of procedure in beam-halo Monte Carlo

- Roughly the same statistics, observe roughly the same resolutions



Consistency of residuals

- Sum of residuals around ring must be zero (must form a consistent circle)
  - always zero in MC (for rϕ, ϕz, and ϕy)
  - offset of rϕ residuals in data led to quantitative prediction and discovery of 10 μm chamber description error