Extracting PMT efficiency and angular response from cosmic muons

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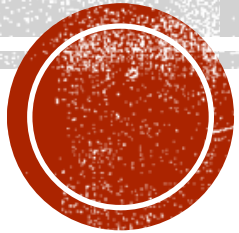
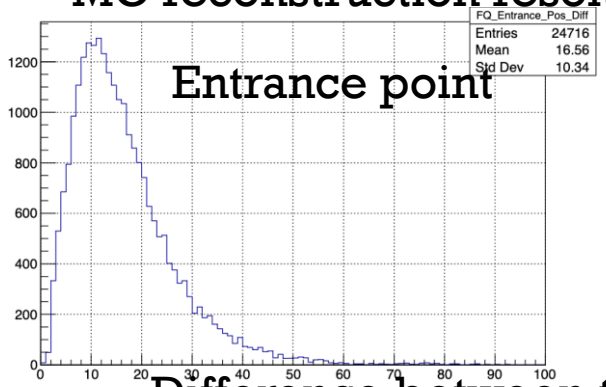
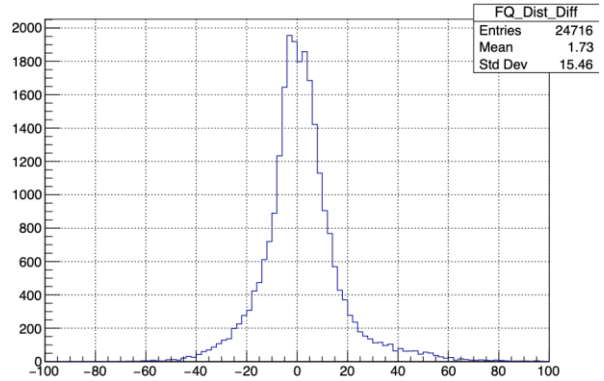


Reminder

- Selection of top-down detector crossing cosmic muons explained here
  - MC reconstruction resolution quite good (~mPMT radius)

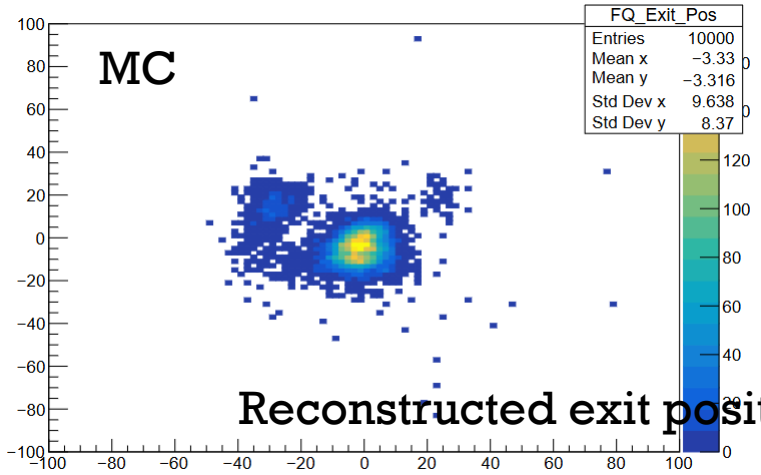


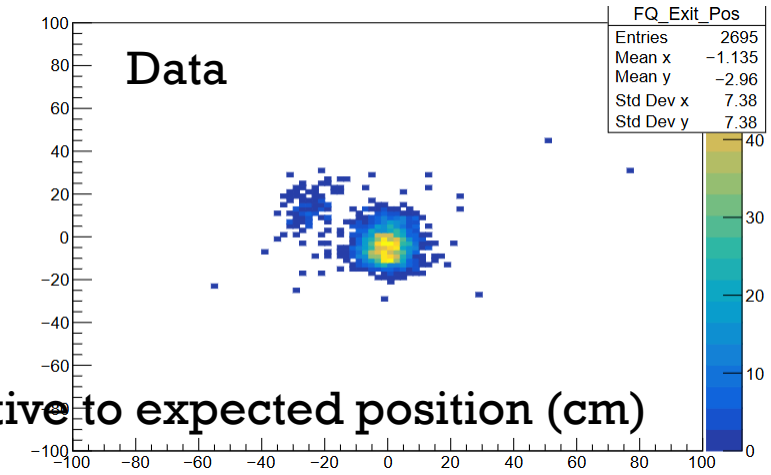
Difference between truth and reco points (cm)



Truth – Reco track length (cm)

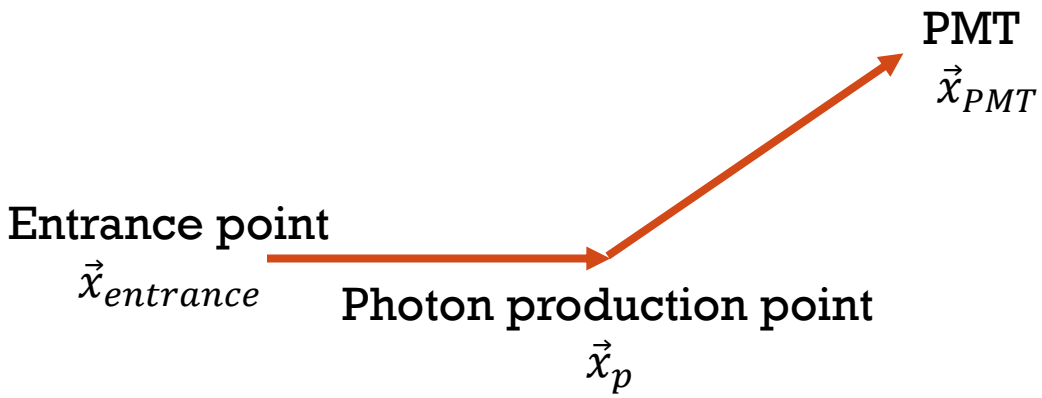
- Cross-checks with beam crossing muon: looks reasonably good





Reconstructed exit position relative to expected position (cm)

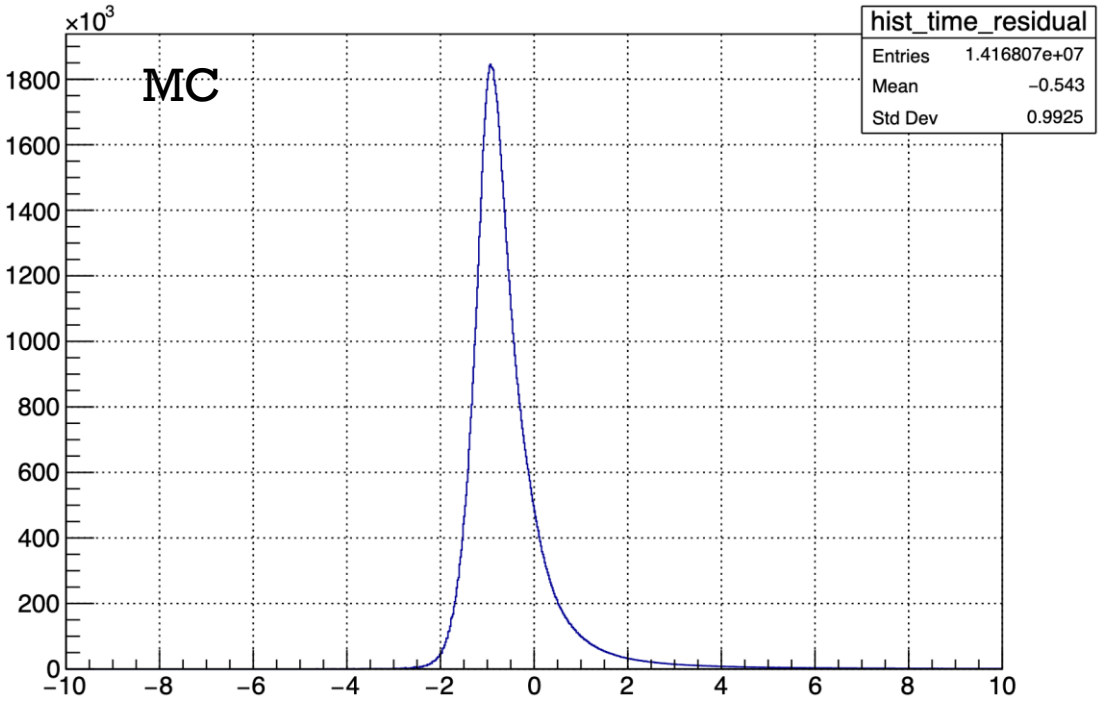
Time residuals

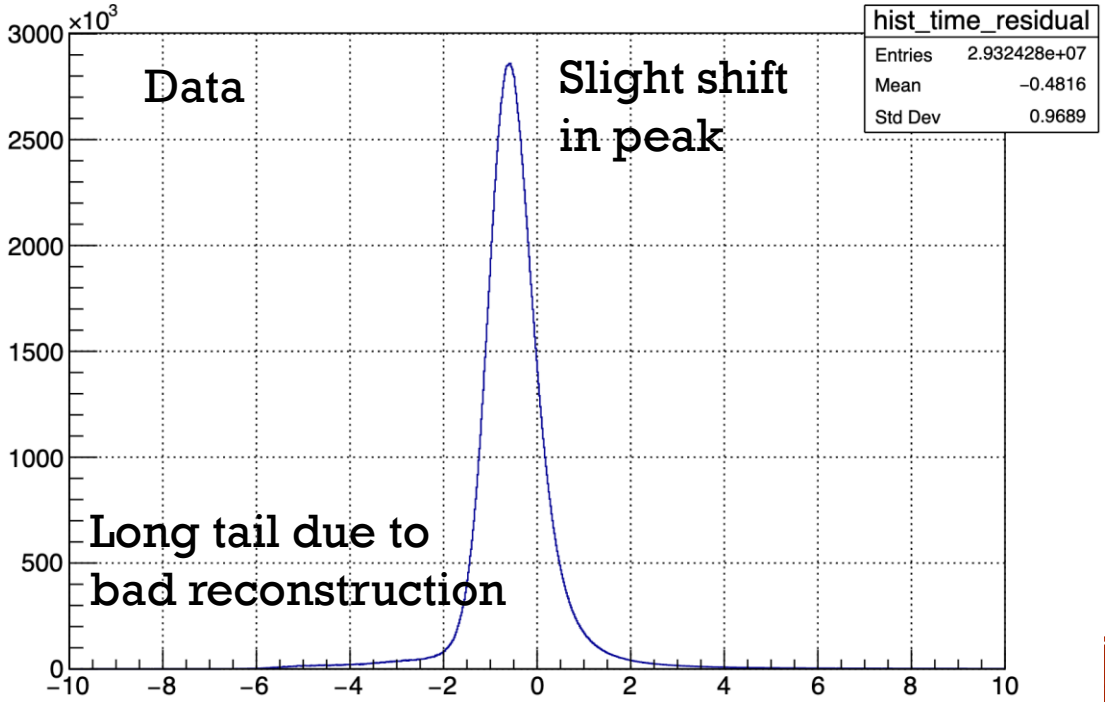


- Use fiTQun reconstructed vertex, time and direction to calculate

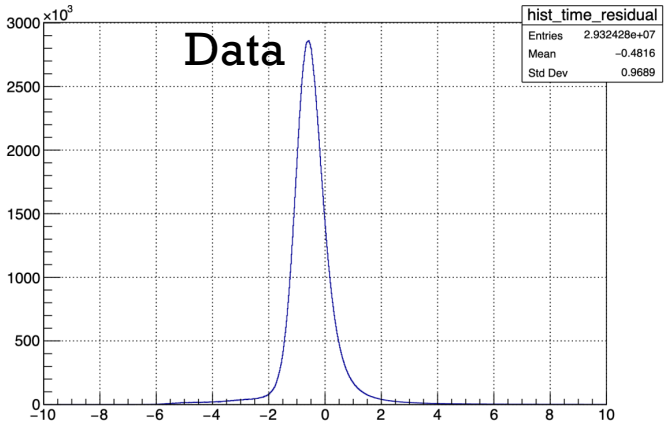
$$t_{res} = t_{PMT} - t_{entrance} - \left|\vec{x}_p - \vec{x}_{entrance}\right|/c - \left|\vec{x}_{PMT} - \vec{x}_p\right| \cdot n/c$$

- Only include PMTs within the 42 deg Cherenkov cone from entrance point

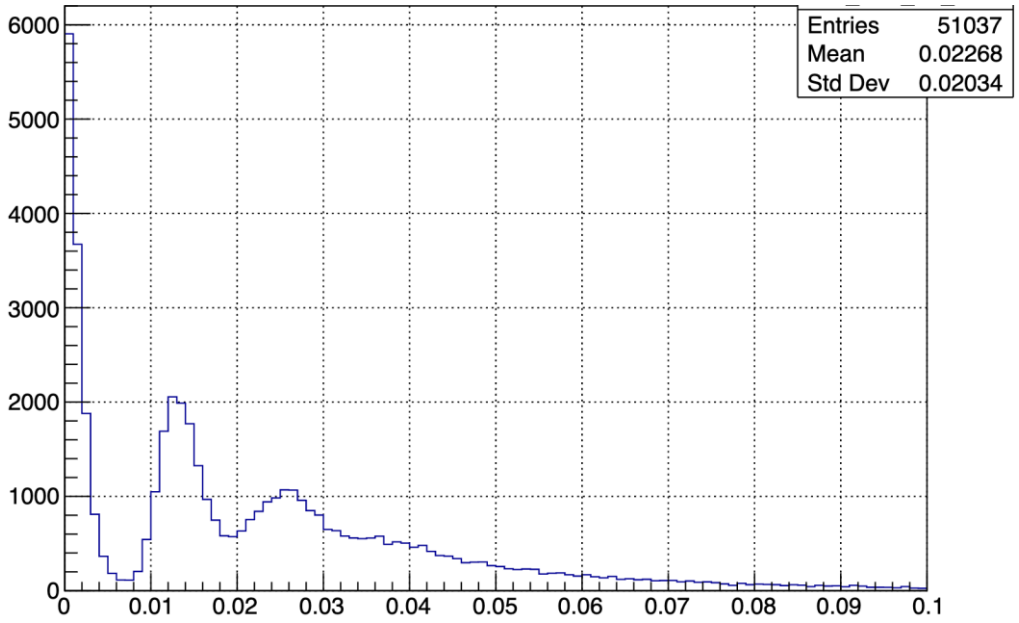




Time residuals



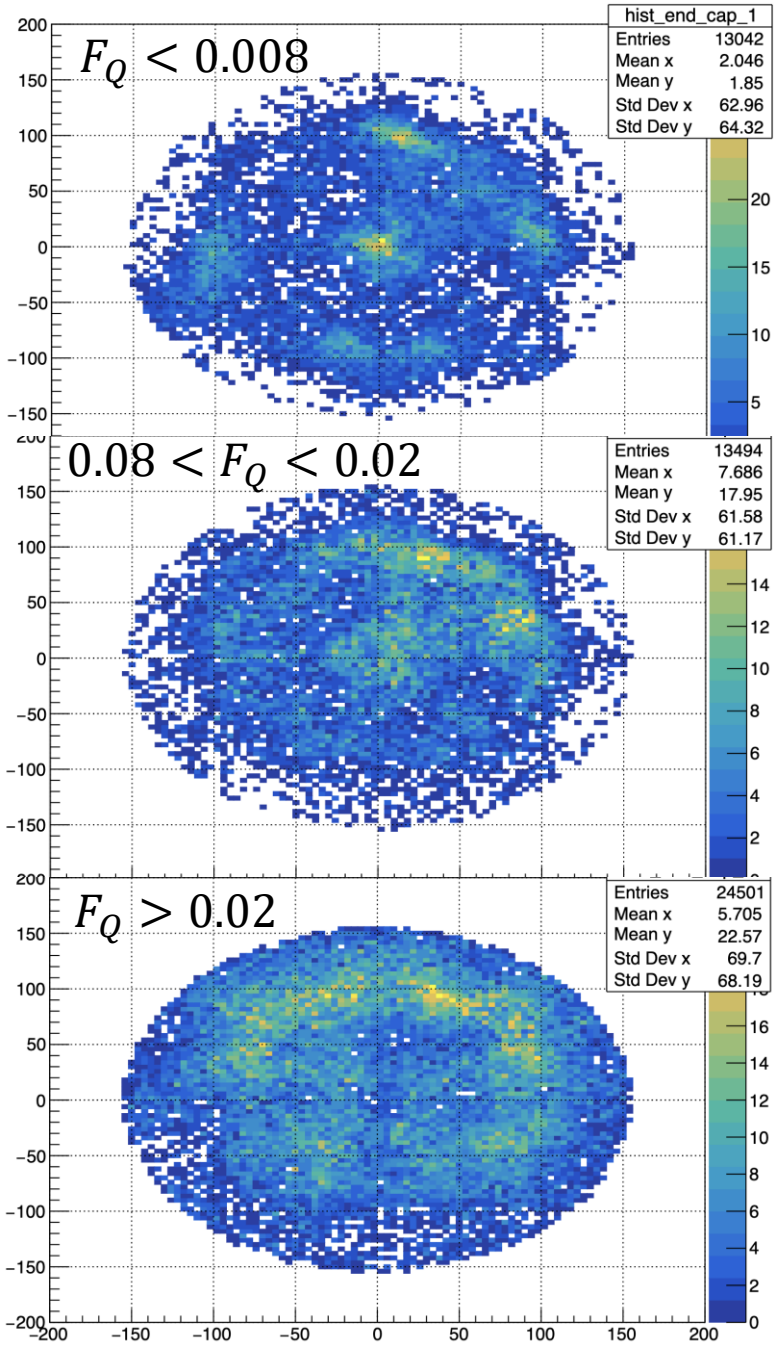
- Fraction of charges with t_{res}< -2ns in data



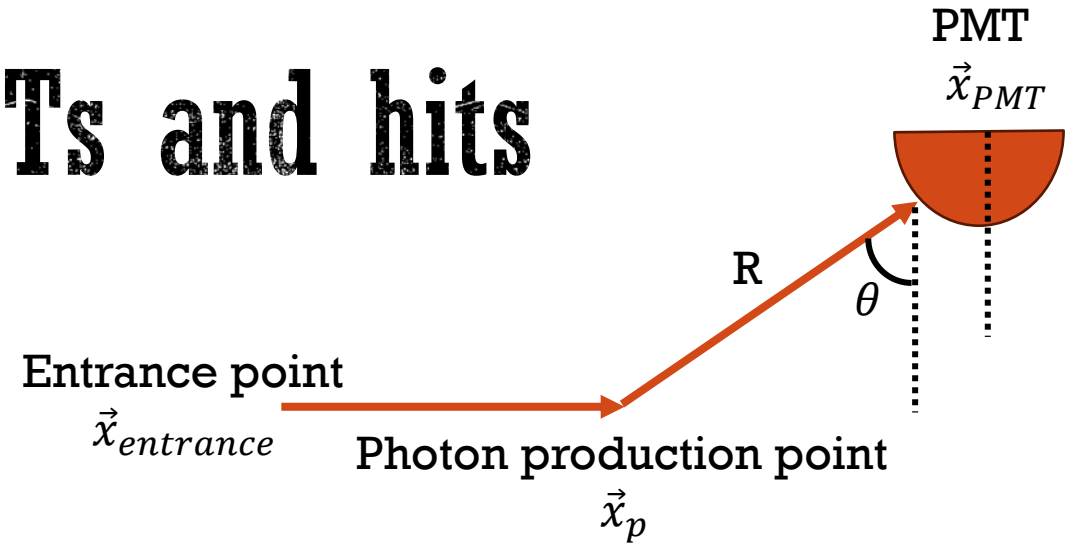
Fraction of charges F_Q

- Events with small F_Q are with exit points on empty/low eff mPMT slots → less likely to overflow PMT (causing 0 hit)

Reconstructed exit point at bottom cap



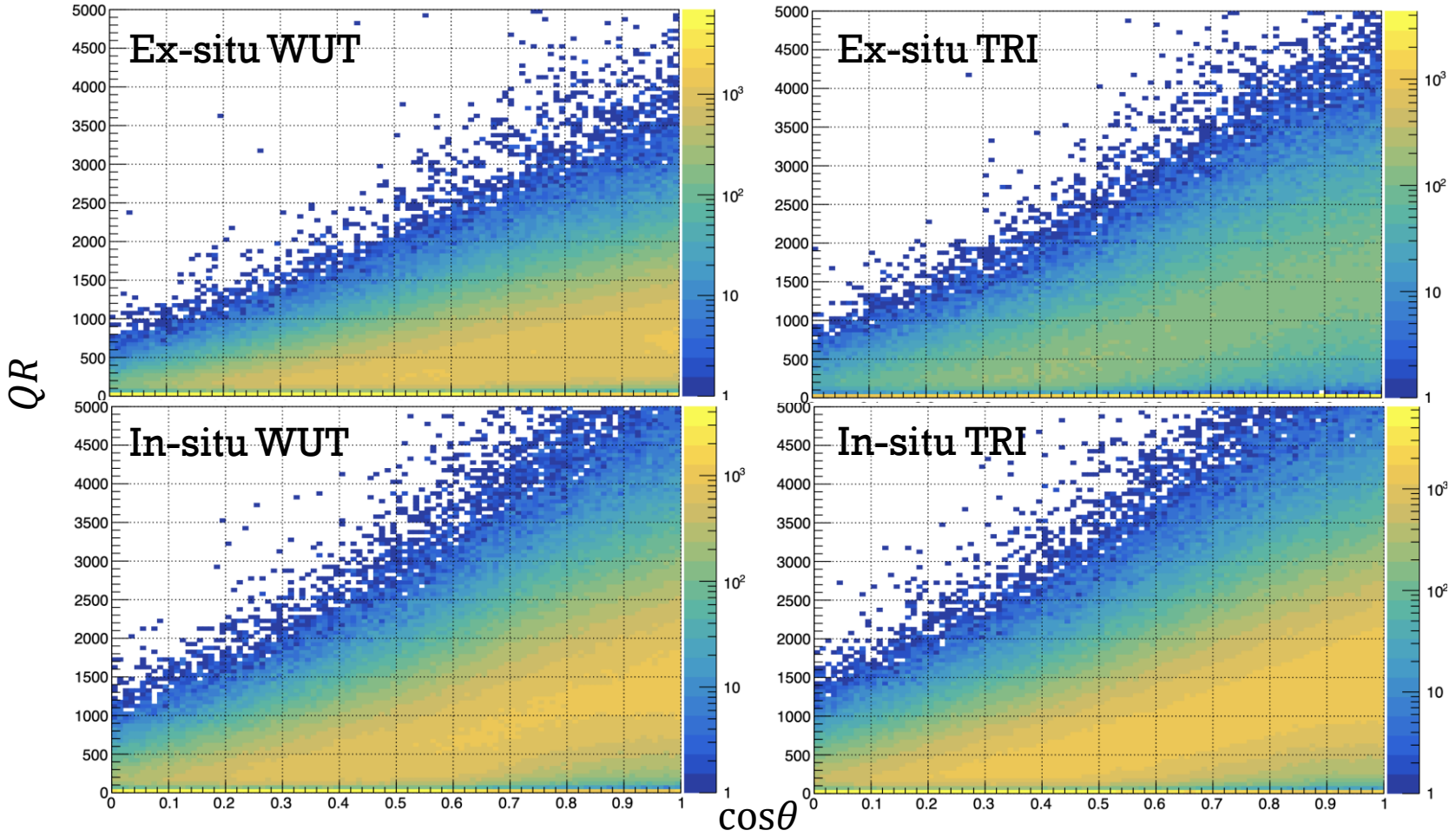
Selection of events, PMTs and hits



- Event level
  - $F_Q < 0.08$
- PMT level
  - located within 42 deg Cherenkov cone from entrance point
  - Both hit and unhit PMTs (excluding bad channels)
- Hit level
  - $-2 < t_{res}/ns < 2$
  - Photon distance R > 100 cm, to select hits with small reco. uncertainties
- Since $Q \propto A(\theta)/R$, fill a 2D histogram of $(\cos\theta, QR)$

Angular response

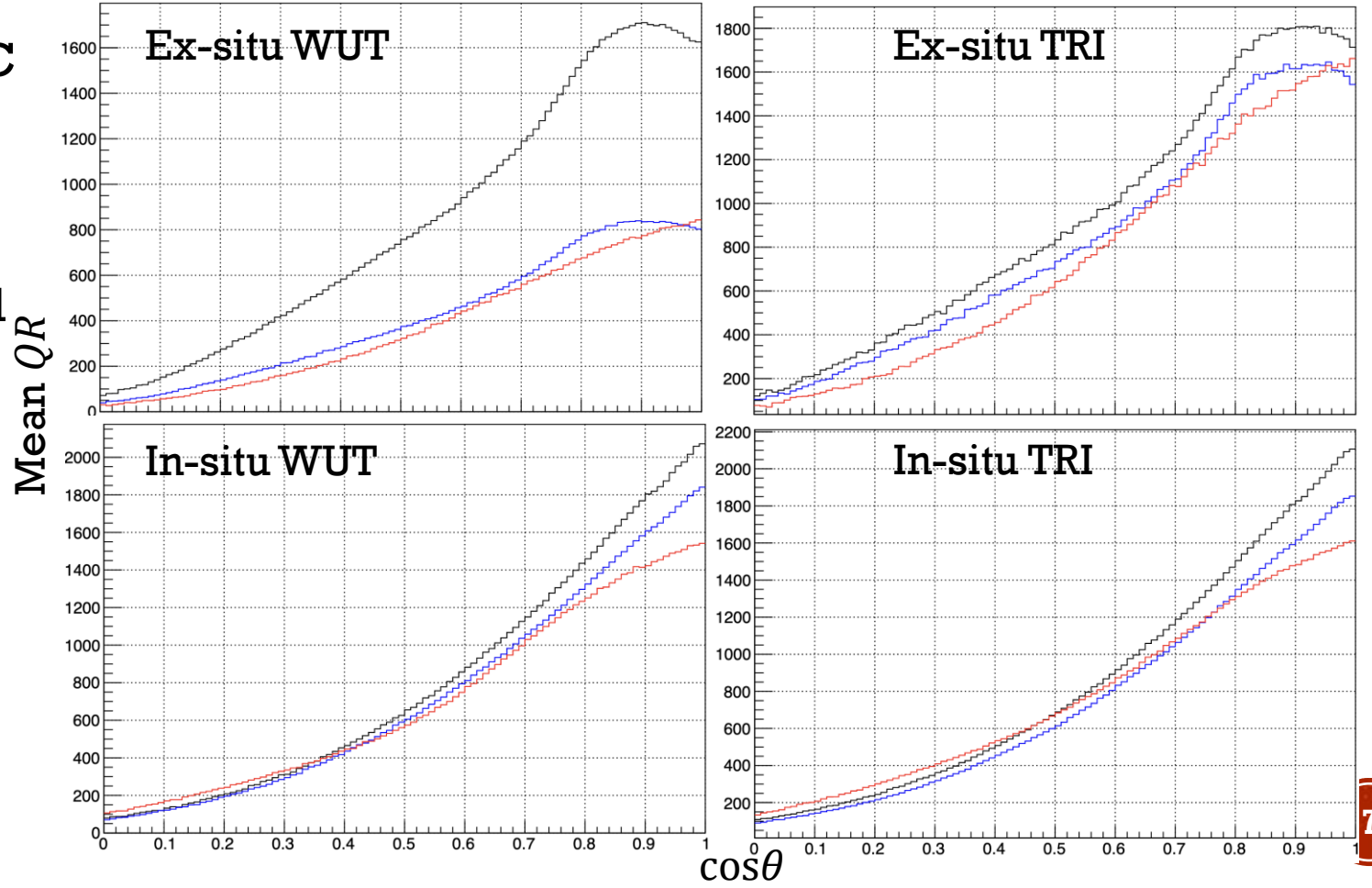
- Different responses between ex-situ and in-situ mPMTs in data



Angular response

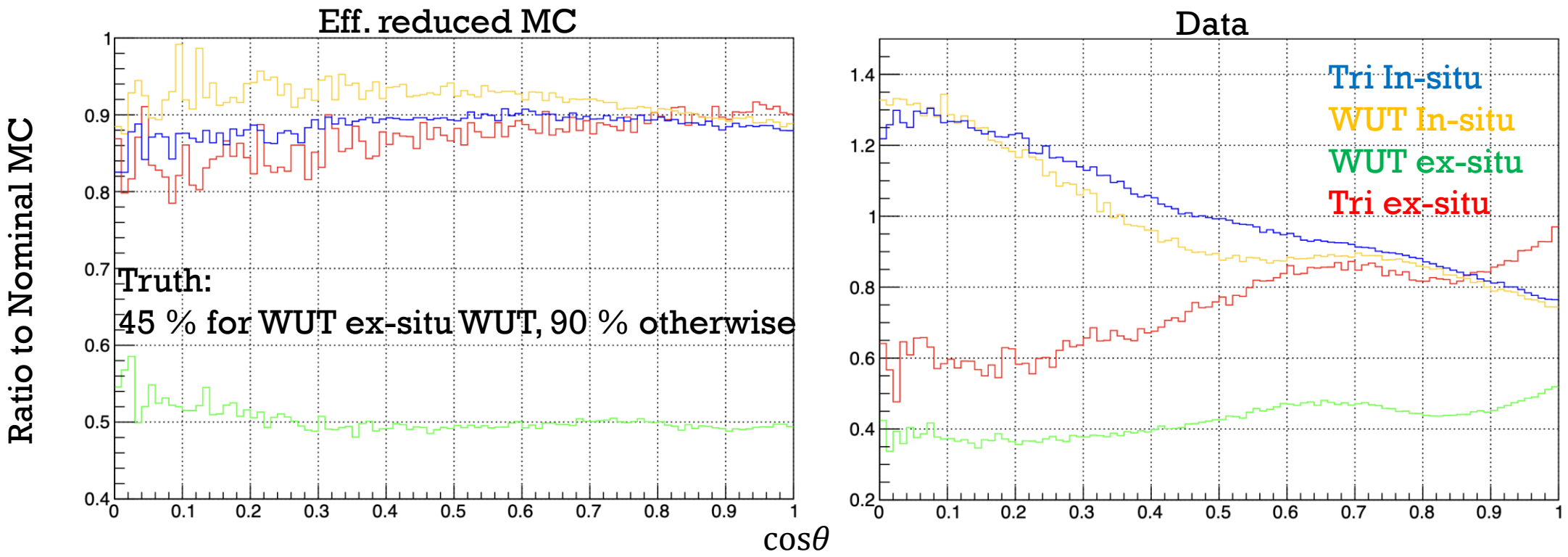
- Taking the mean of each slide of $\cos\theta$
- Both Nominal and Eff. reduced MC are reprocessed with MDT
  - Eff. reduced: 45 % for Ex-situ WUT, 90 % otherwise
- Different shapes between MC and Data

Nominal MC
Eff. reduced MC
Data



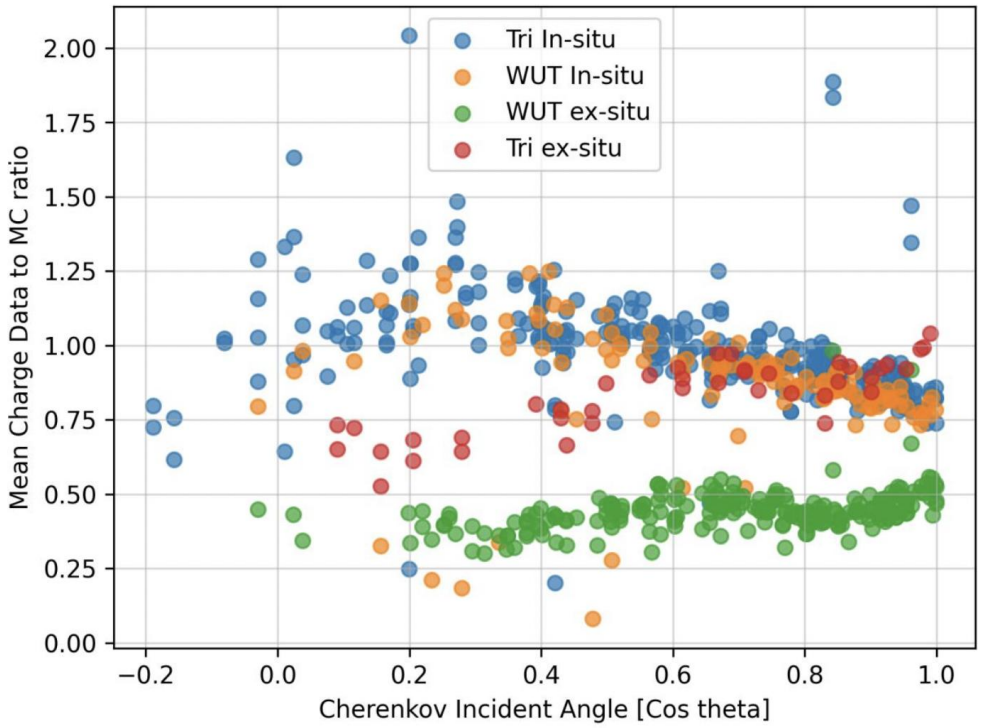
Angular response

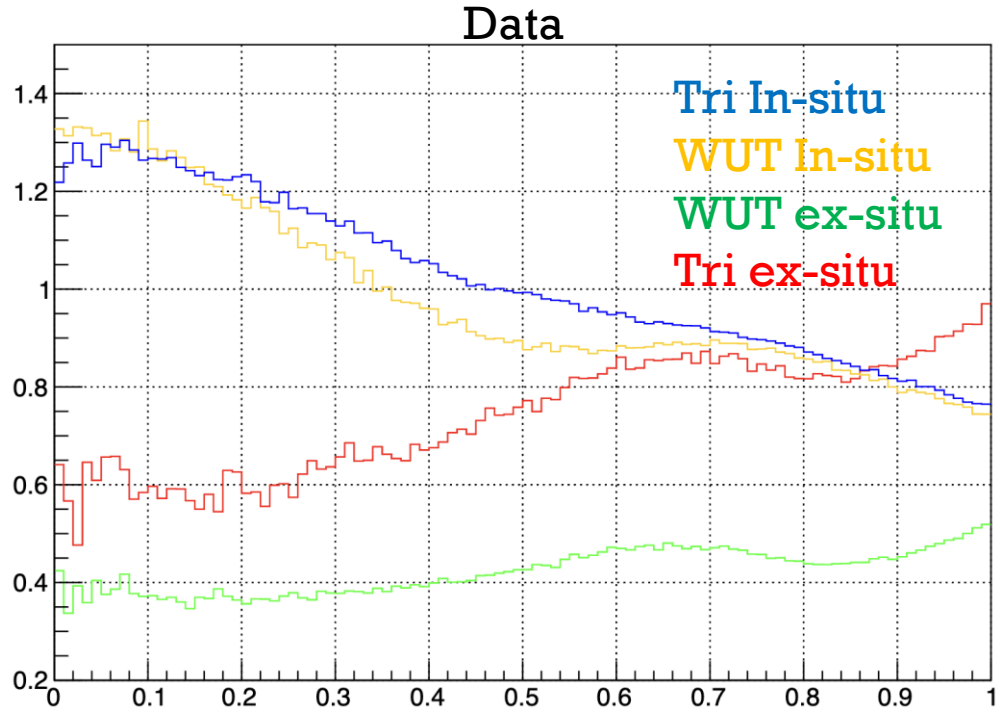
- MC suggested that the extracted ratio is accurate up to ~5%



Angular response

- MC suggested that the extracted ratio is accurate up to ~ 5%
- Consistent with Laurence's beam crossing muon results

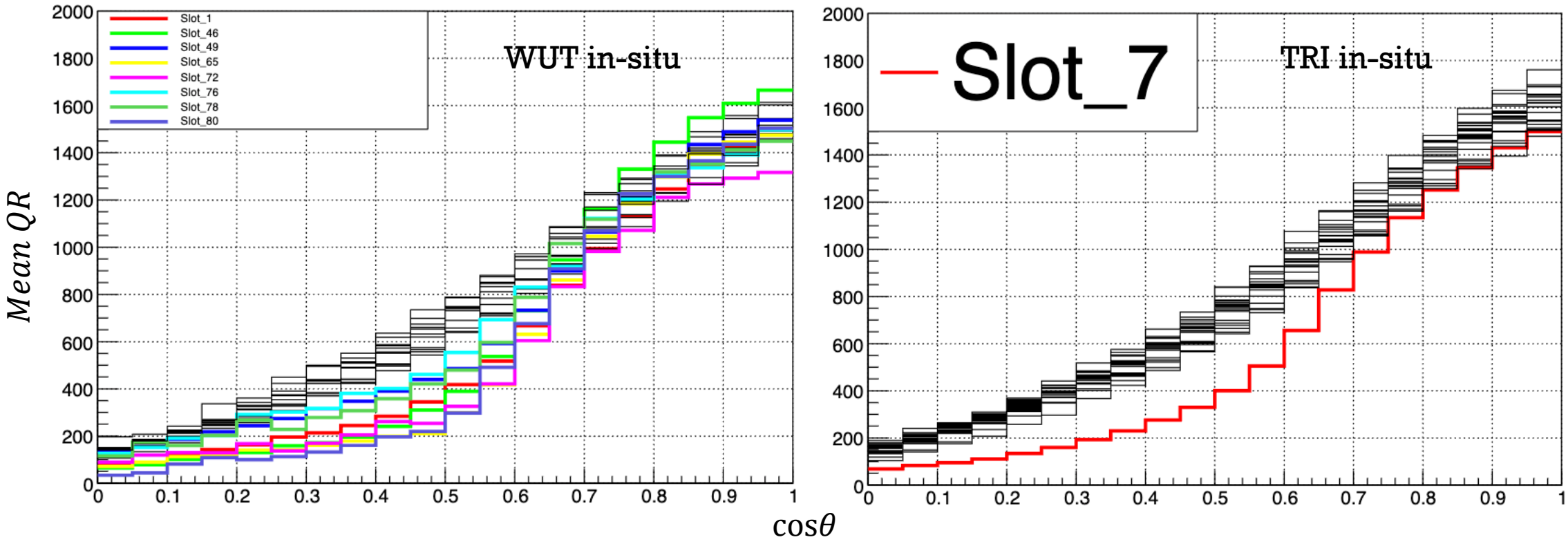




$\cos\theta$

Angular response

- Bonus: in-situ mPMT slot ID
  - Delamination?



Summary

- Top-down crossing cosmic muon sample (Run 1766 on Apr 24) is available
- Event, PMT and Hit level cuts are applied to measure angular response
  - 5% accuracy accroding to MC
  - Significant shape difference between MC and data
  - Consistent with beam muon observation
  - Individual mPMT response sensitive to e.g. delamination
- Next
  - Expand cosmic selection to include top cap mPMTs ? Expect worse vertex resolution
  - Properly implement angular response change into MDT

- Github repo here

Angular response

- Bonus: in-situ mPMT slot ID
  - Delamination?