MILO VERMEULEN — 12/09/2019

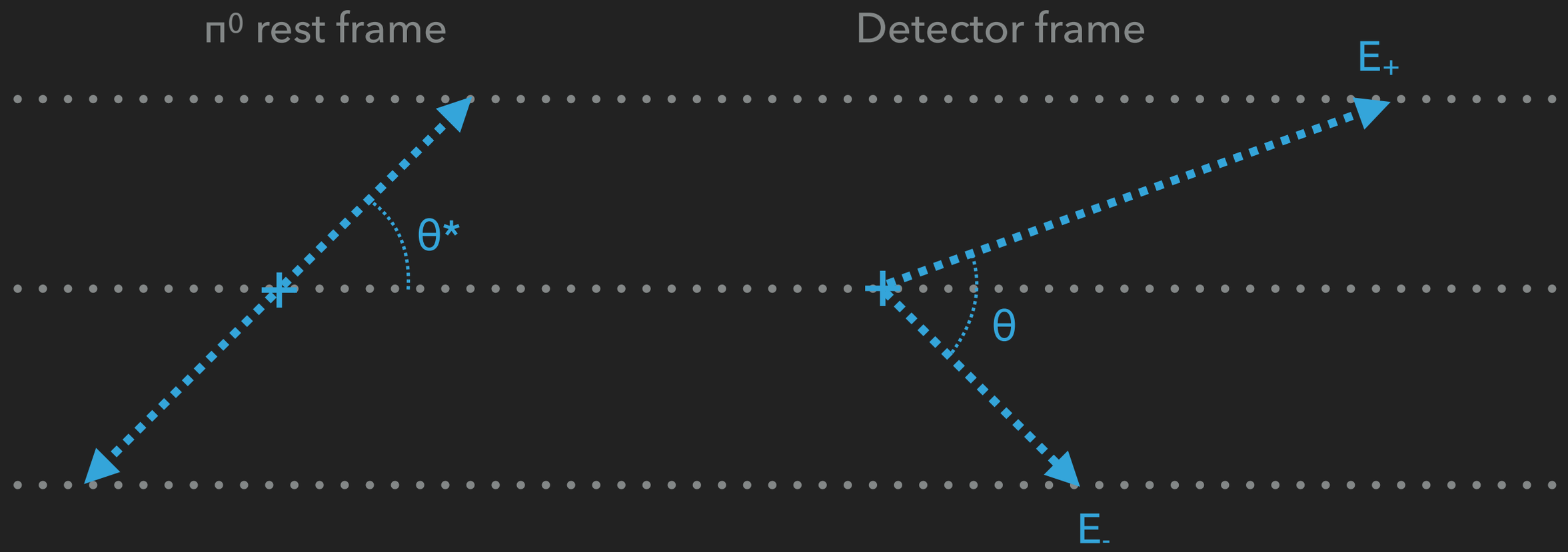
OVERLAPPING Π^0 SHOWERS

BACKGROUND

- π^0 are produced in hadronic interactions, decay π^0 -> $\gamma\gamma$
- Potential to look like electron shower if:
  - Only one γ shower is reconstructed
  - The shower occurs close to the π^0 vertex
- How good is Pandora at distinguishing the two γ showers?

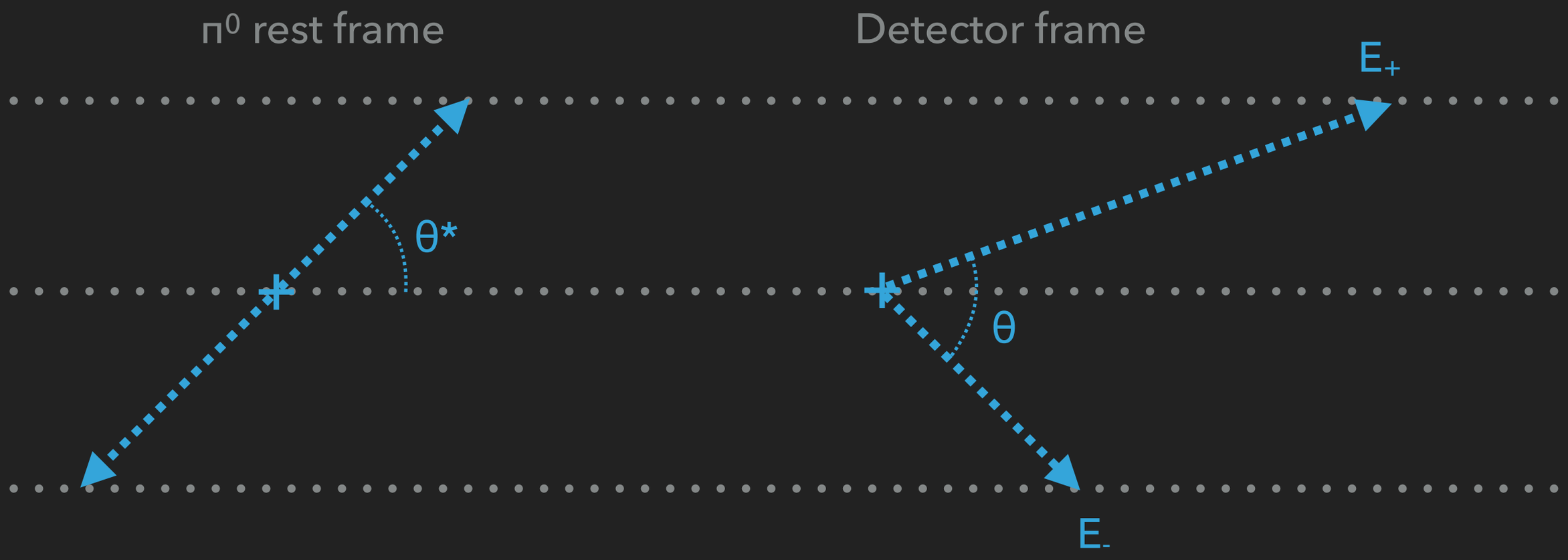
OPENING ANGLE

- Opening angle: the angle between π⁰ photons θ



OPENING ANGLE — PARAMETERS

- Opening angle $\cos\theta = 1 - \frac{2m_{\pi^0}^2}{E_{\pi^0}^2(1-\alpha^2)} = 1 - \frac{2m_{\pi^0}^2}{4E_+E_-}$
- Asymmetry $\alpha = \frac{E_+ - E_-}{E_+ + E_-}$



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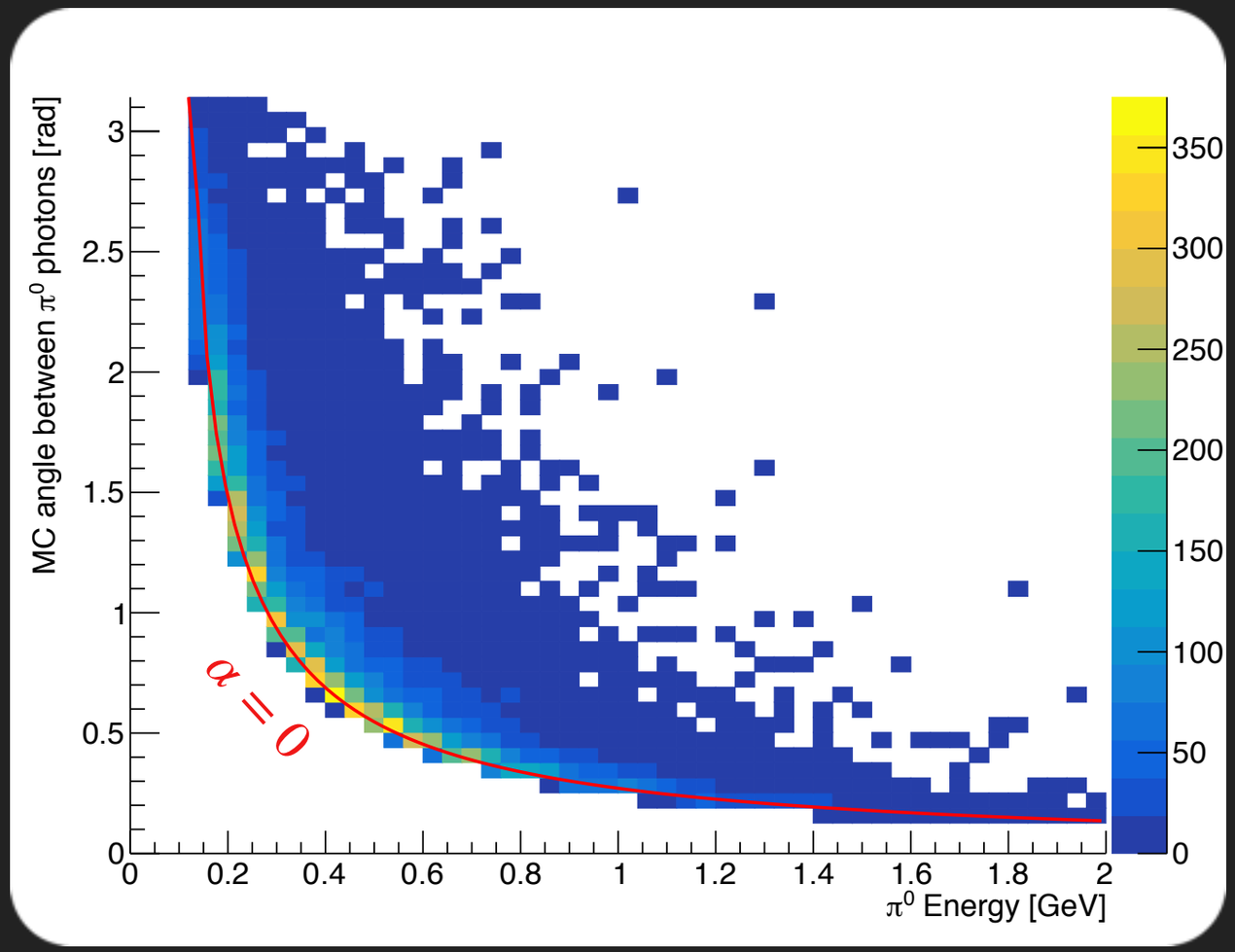
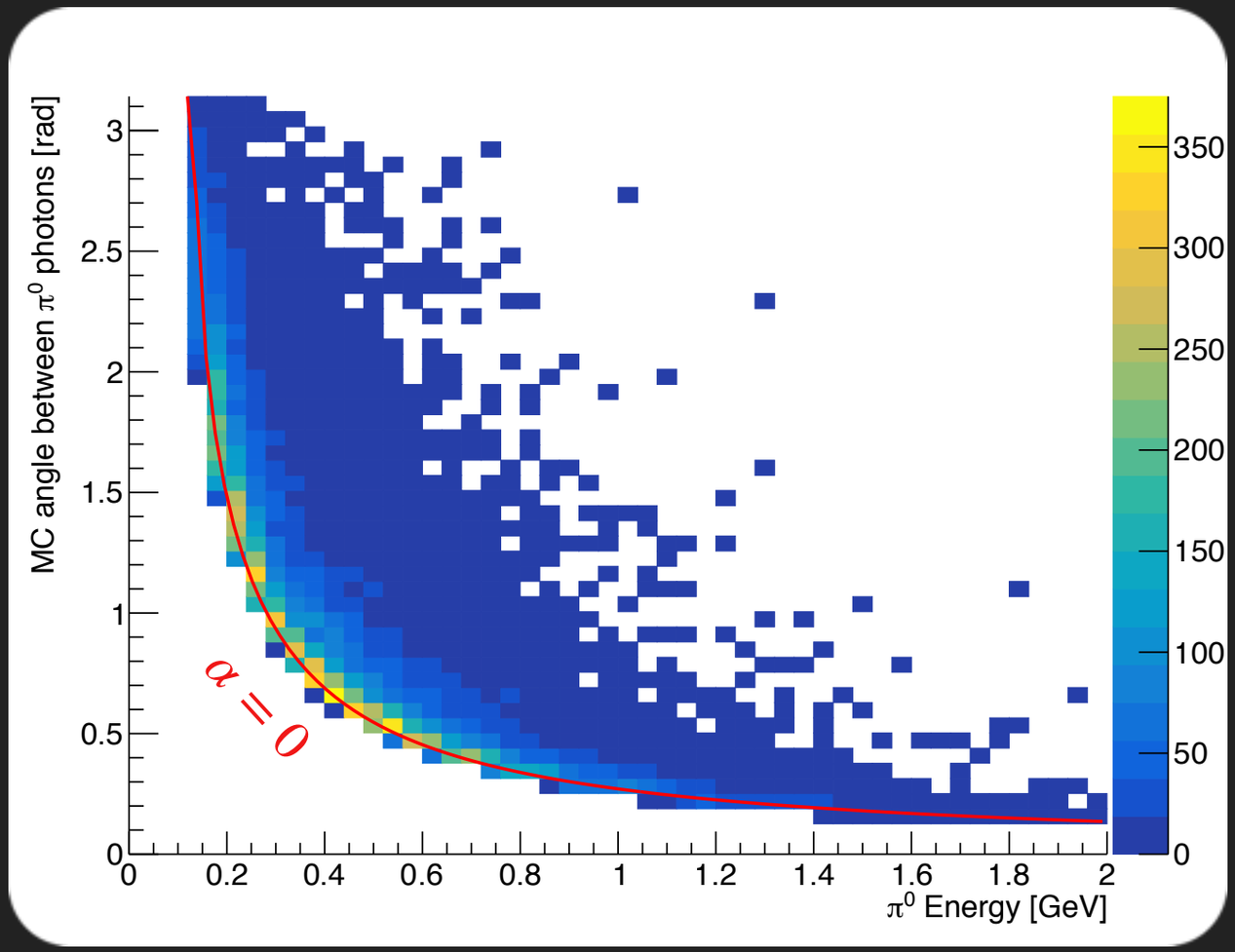


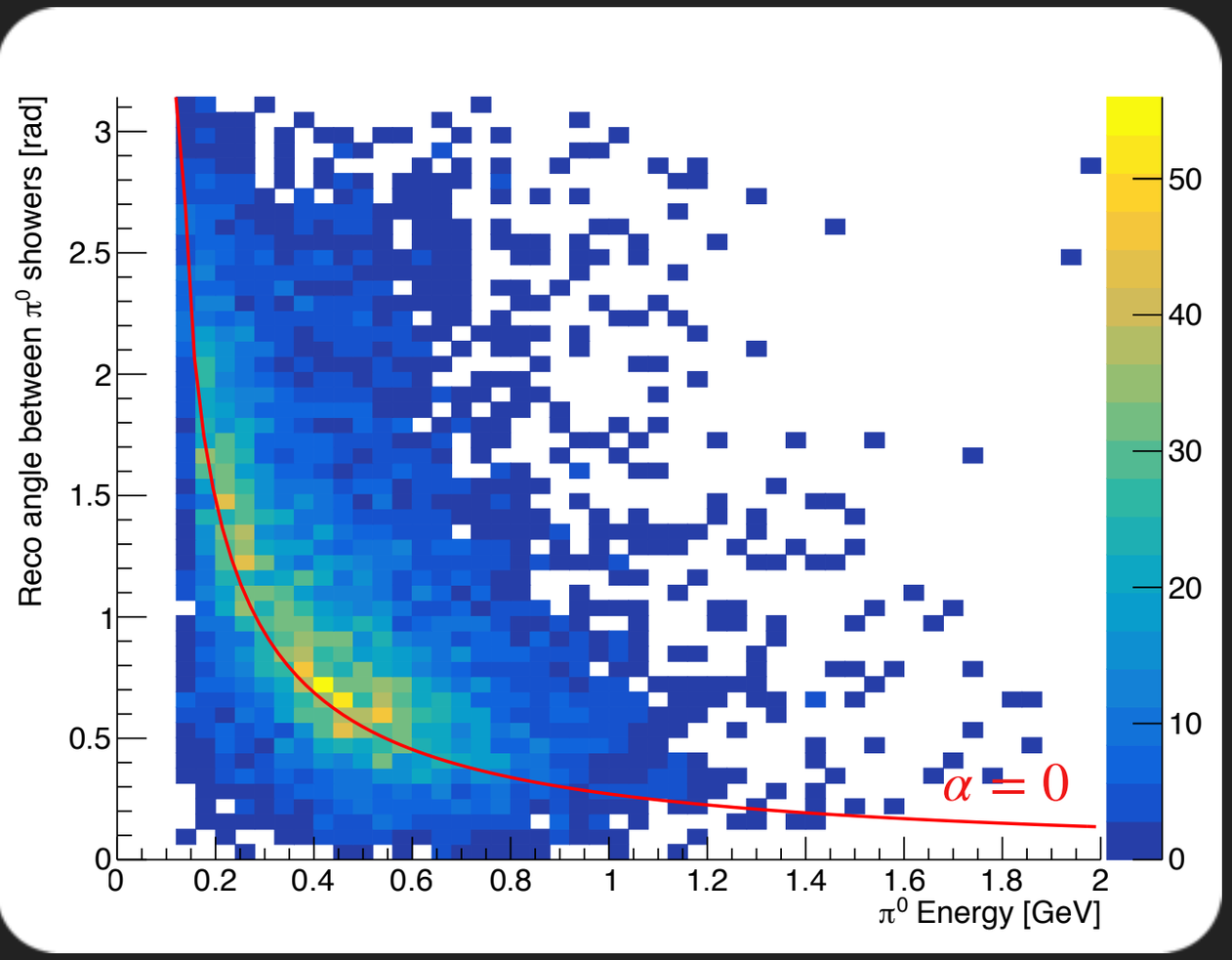
Data: 30,000 single 2 GeV π⁺ in ProtoDUNE, standard beam position (~20,000 π⁰)

OPENING ANGLE — PARAMETERS

- Very few double showers reconstructed at $E_{\pi} > 1$ GeV?



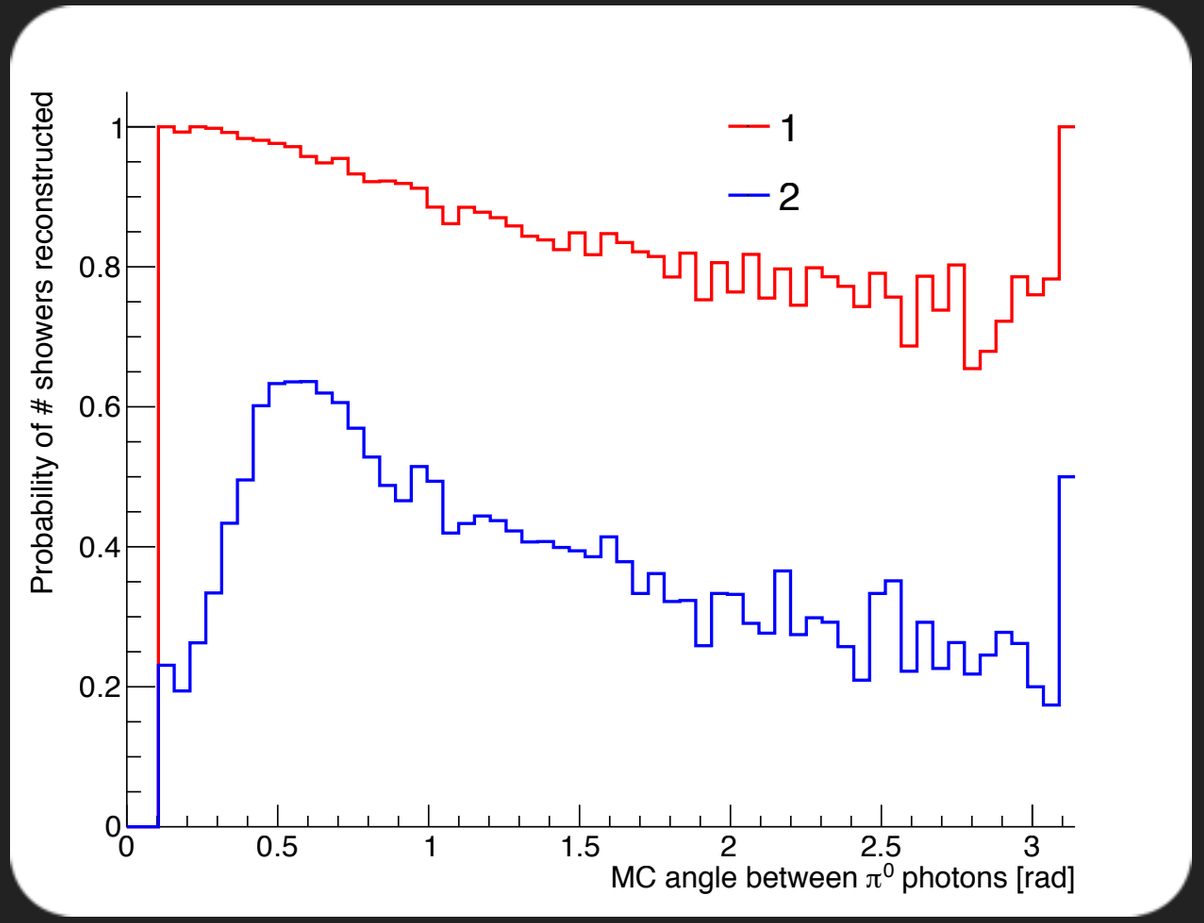
Monte Carlo



Reconstruction

RECONSTRUCTION EFFICIENCY

- Number of showers reconstructed per π^0
- Drop at $\theta < 0.5$ for 2 showers suggests overlap



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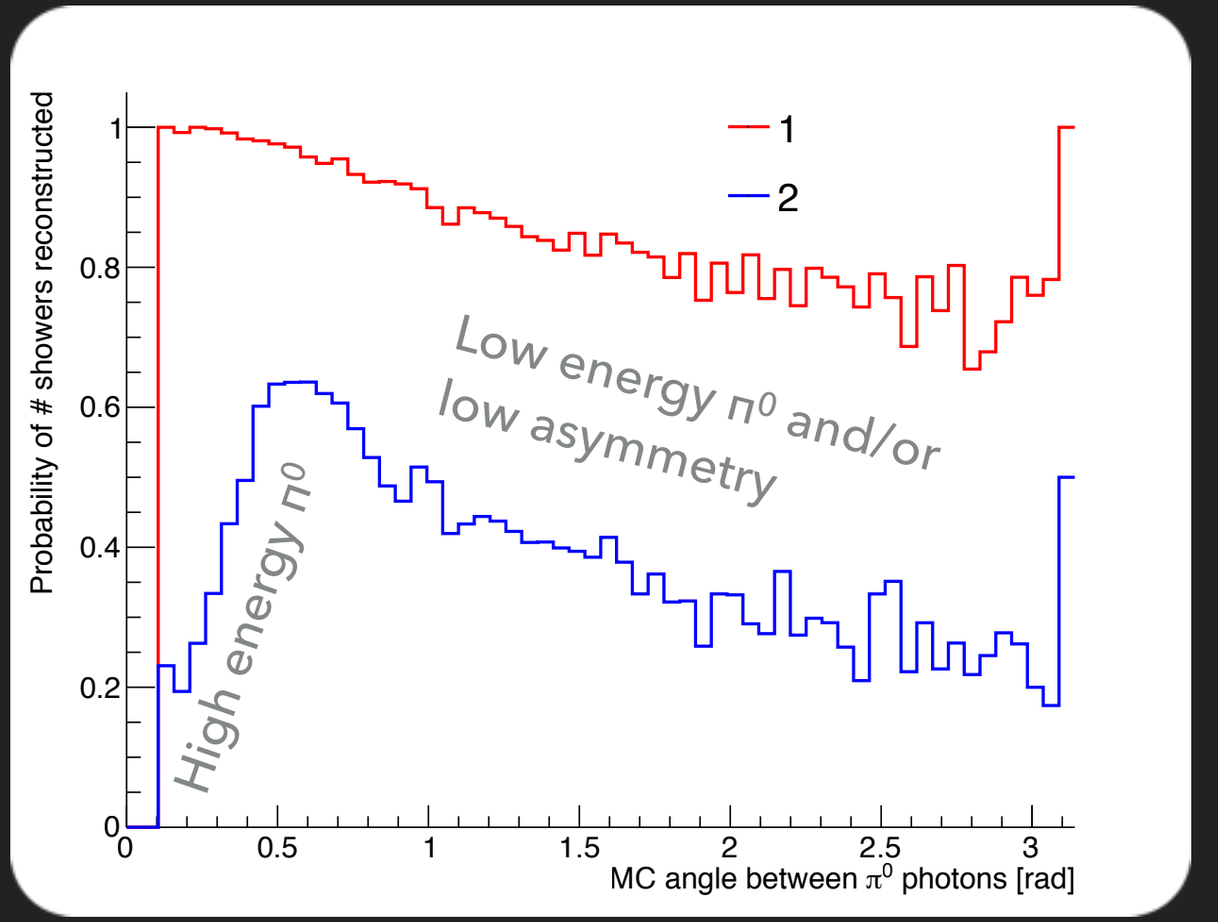
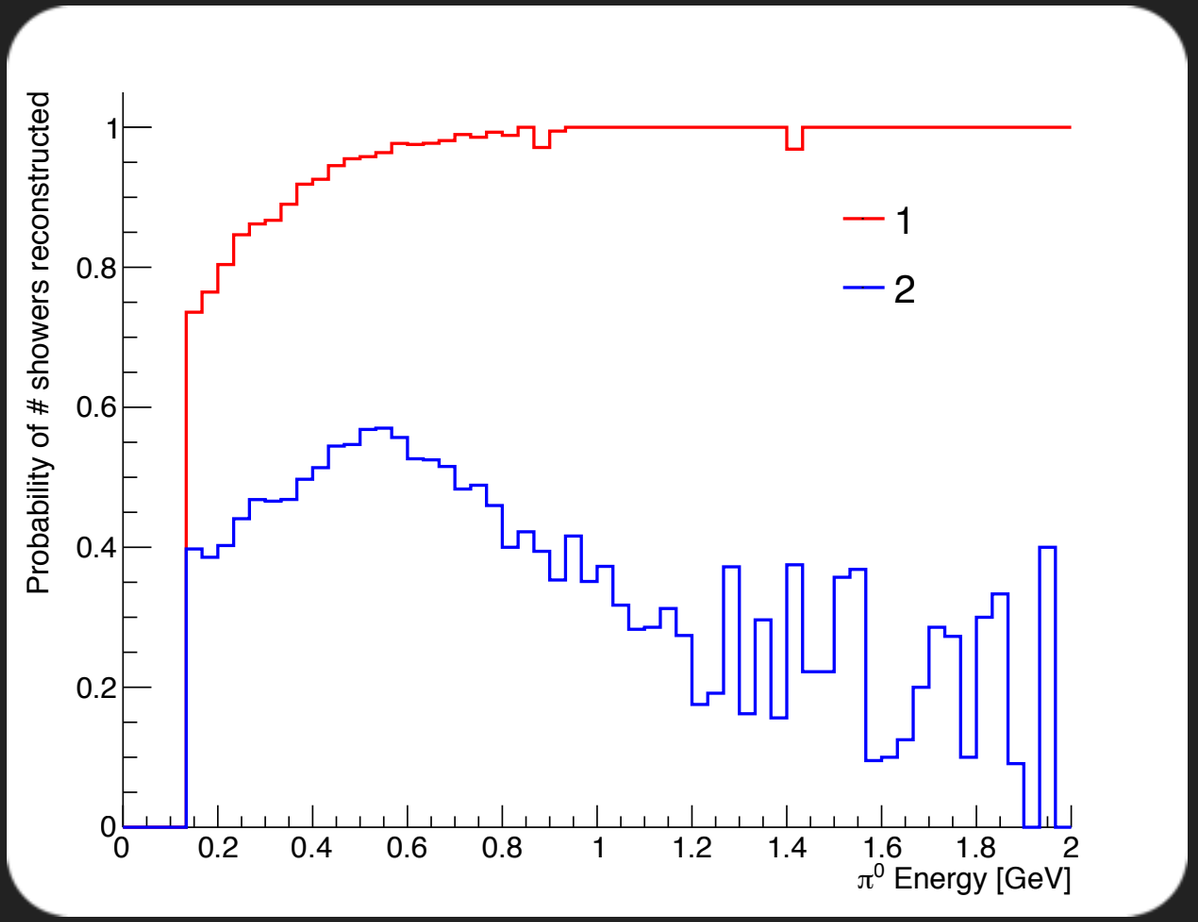
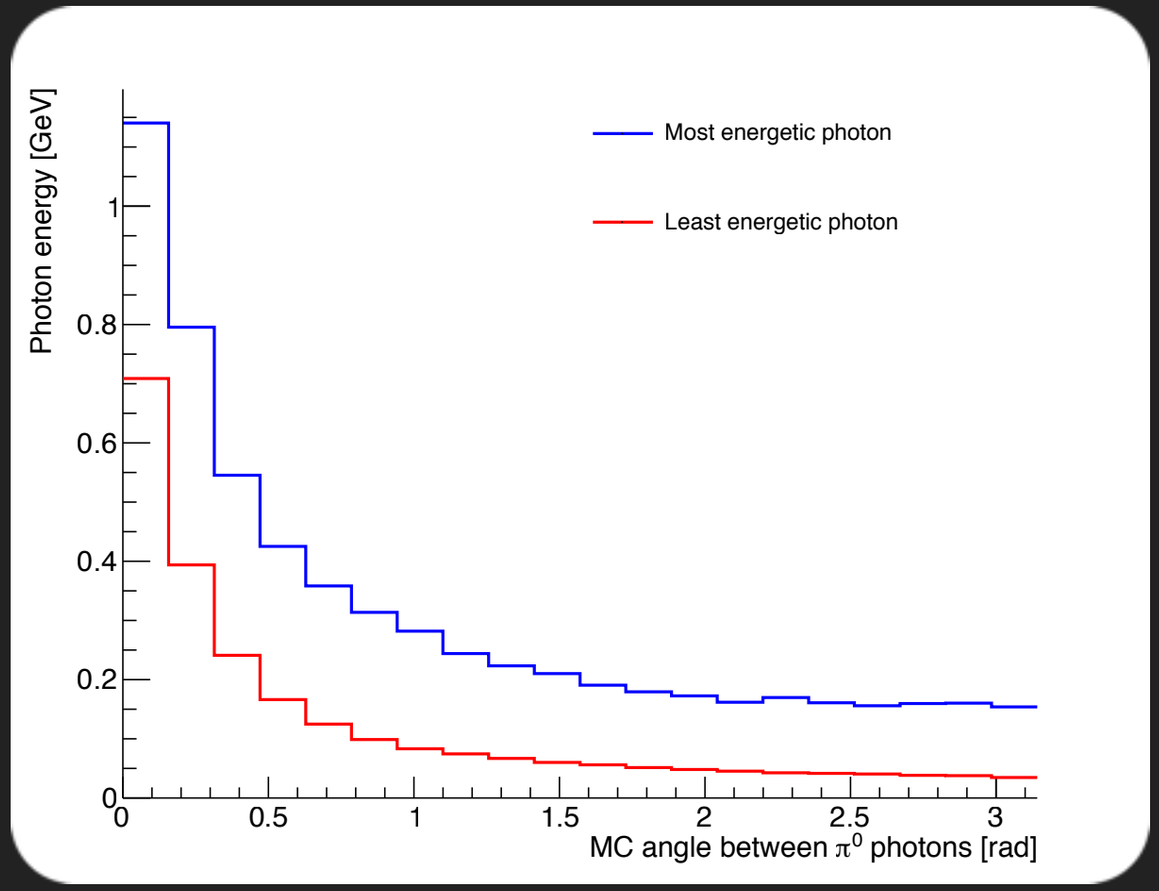
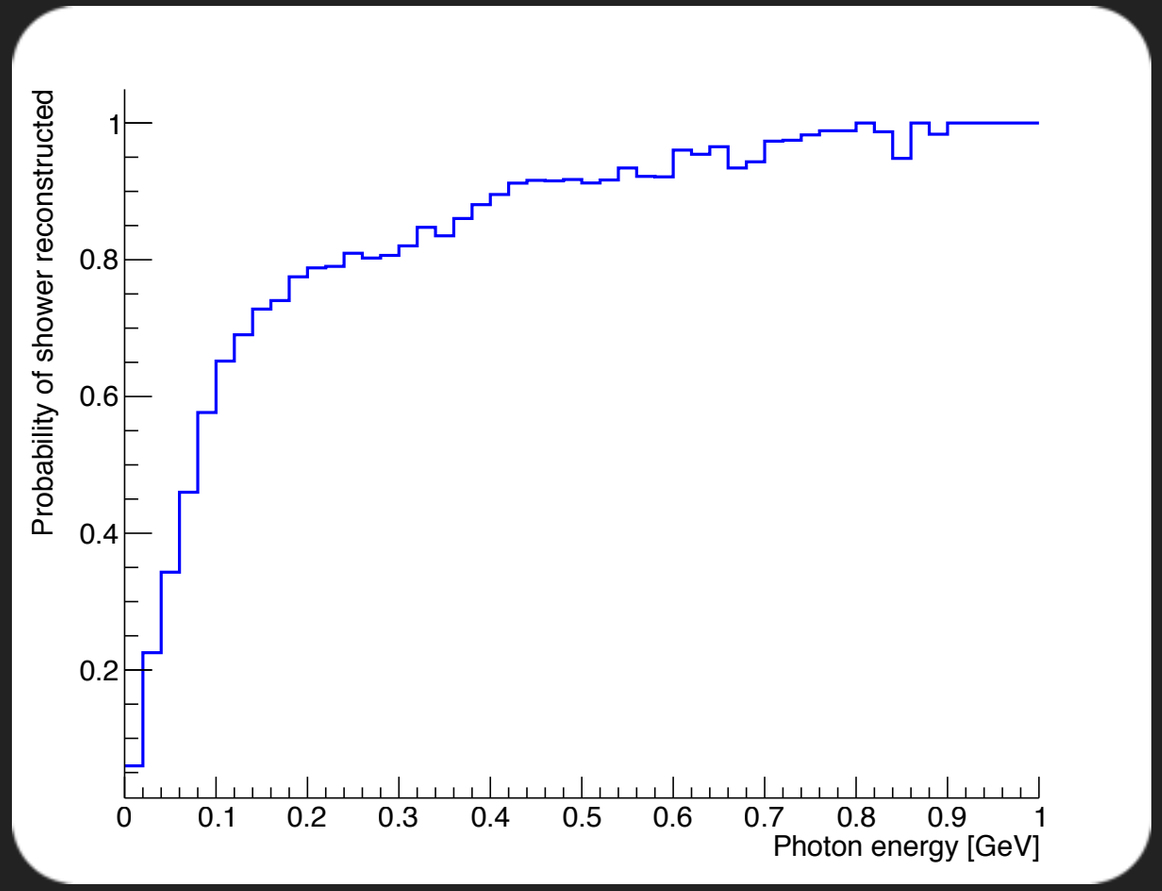




RECONSTRUCTION EFFICIENCY — LARGE ANGLE, LOW ENERGY

- Photon energy is lower for larger opening angles
- Shower reconstruction efficiency drops off at low energy





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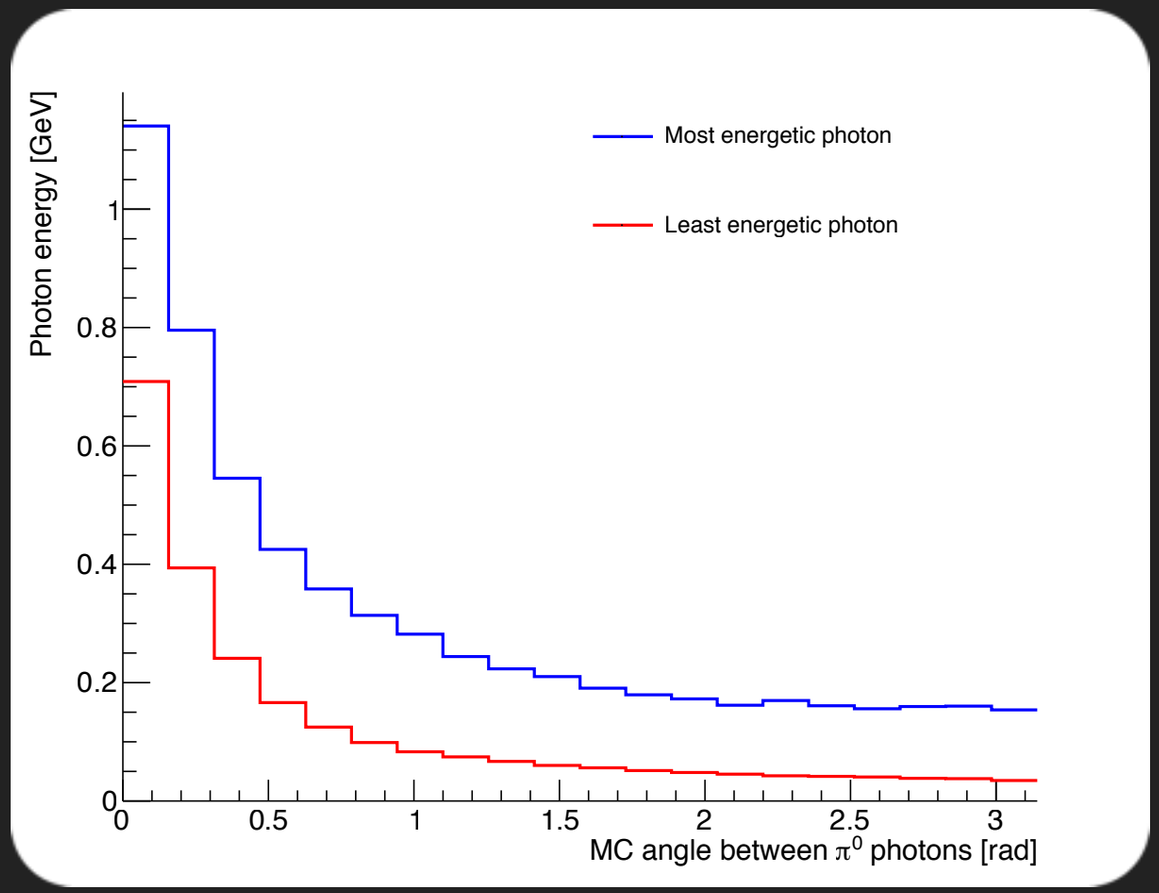
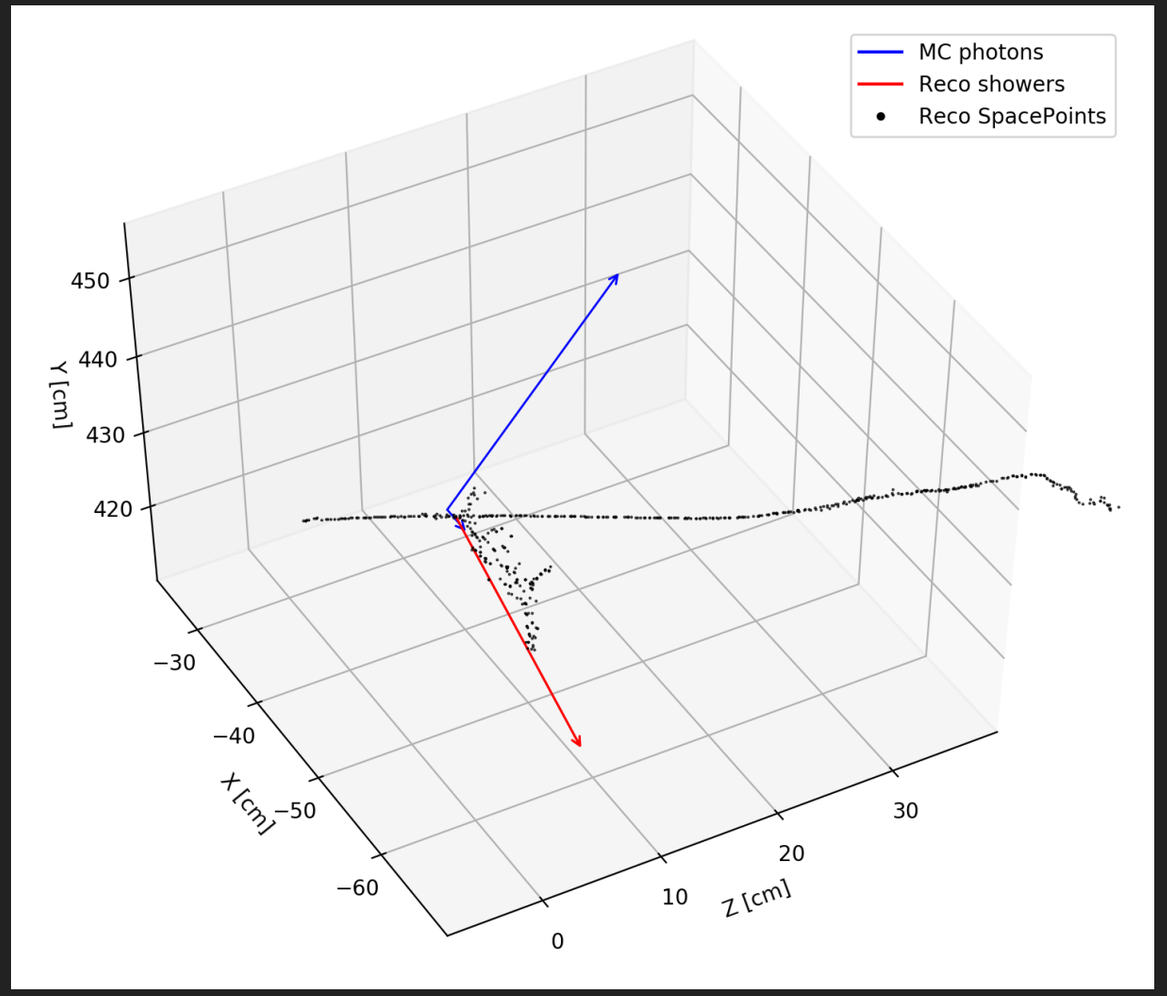
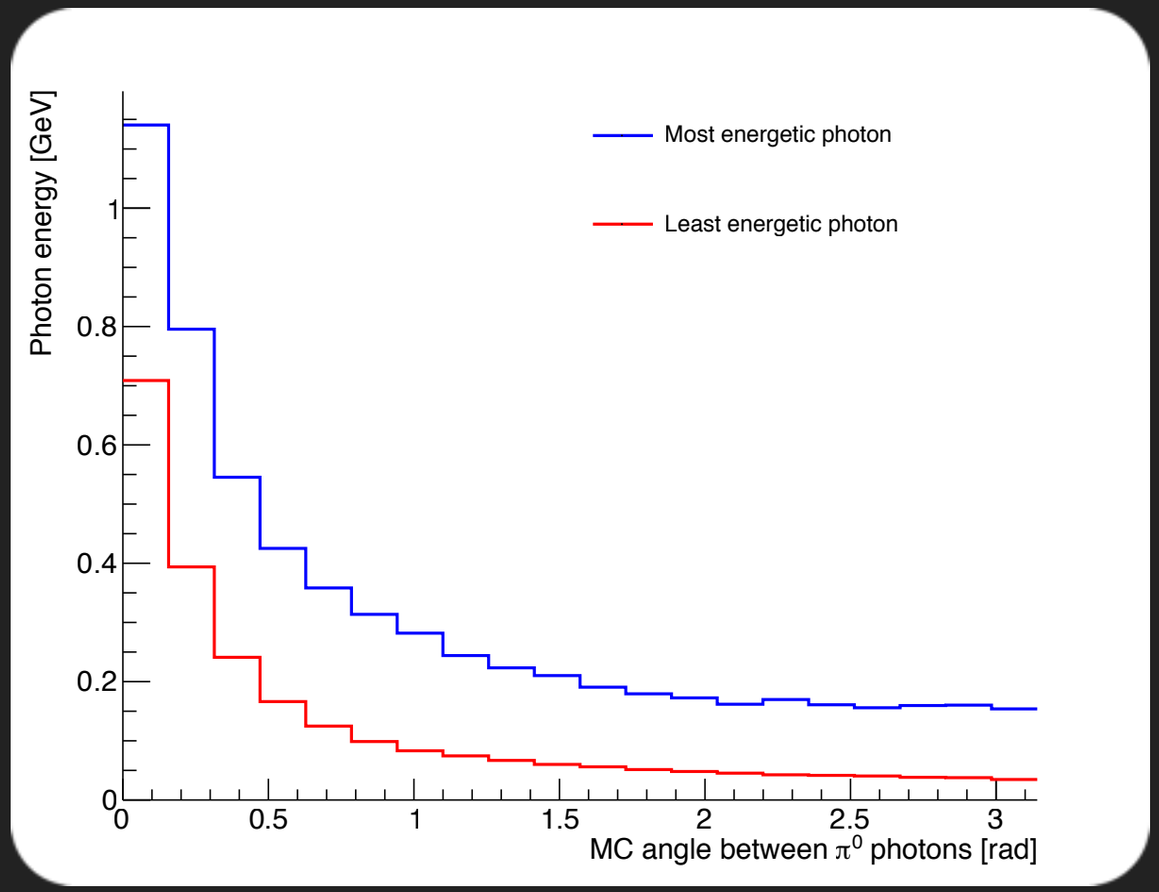
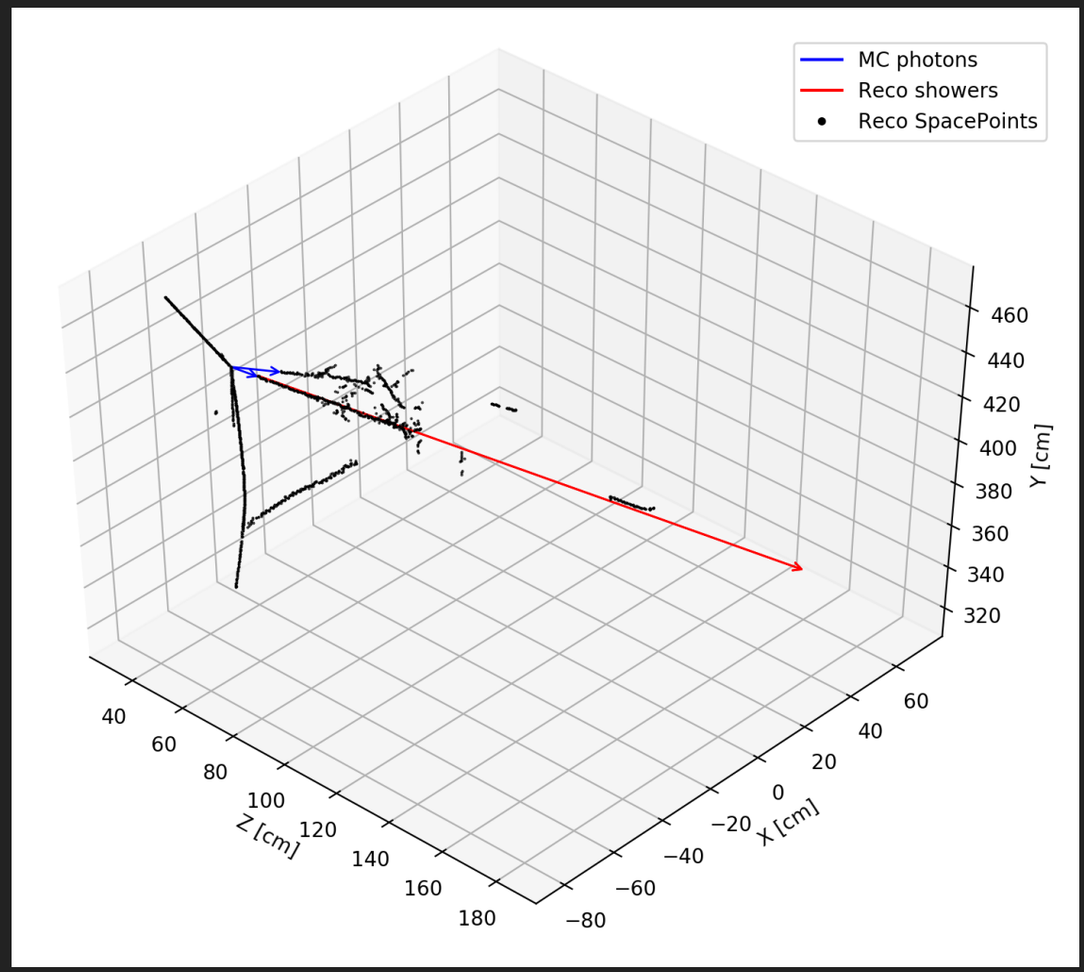




RECONSTRUCTION EFFICIENCY — SMALL ANGLE, HIGH ENERGY

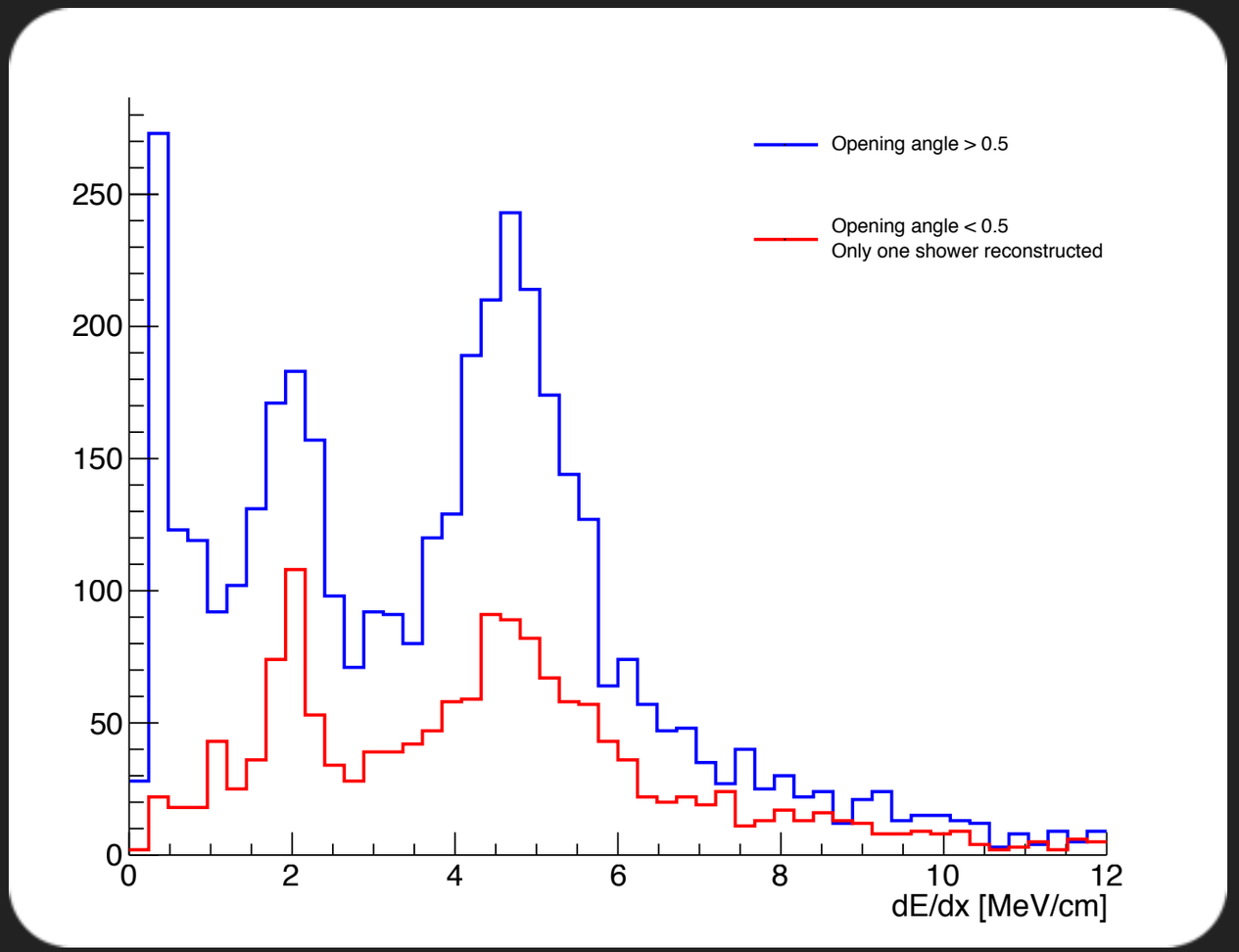
- High energy π⁰ cause overlapping high energy photons





DOUBLE SHOWER FEATURES

- Different dE/dx (first 5 cm) for overlapping showers?
- Not really

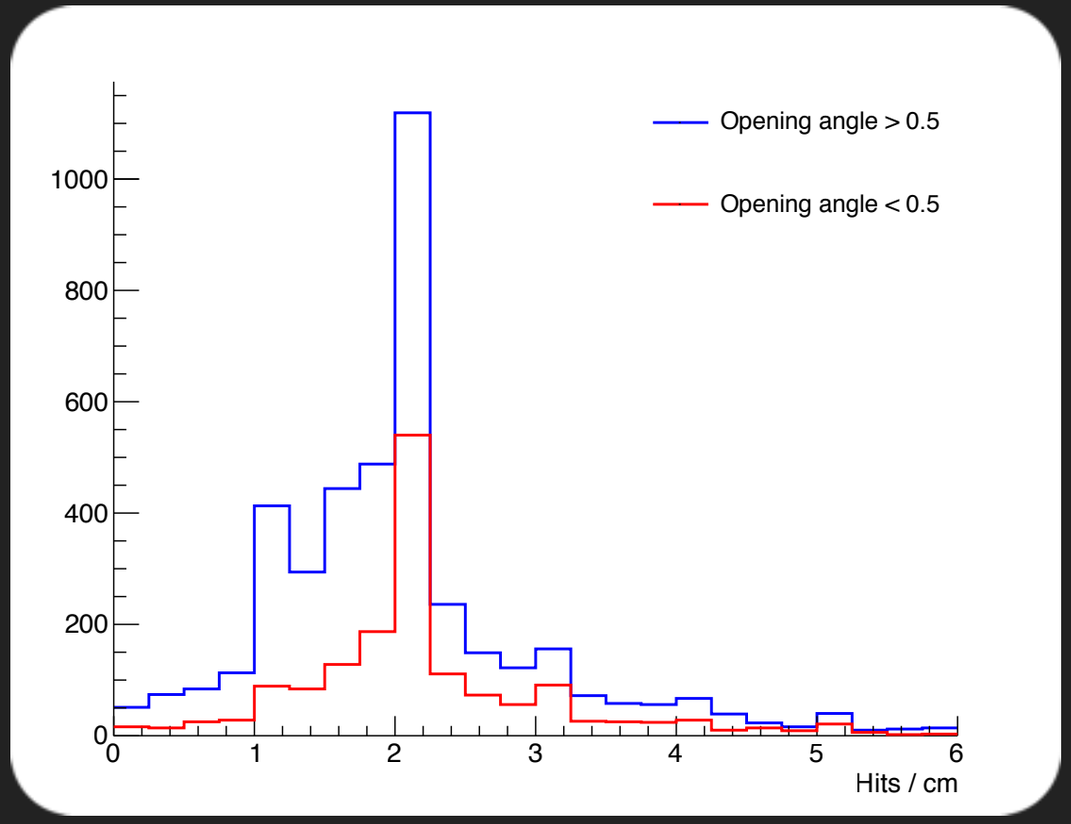


Number of shower hits > 400

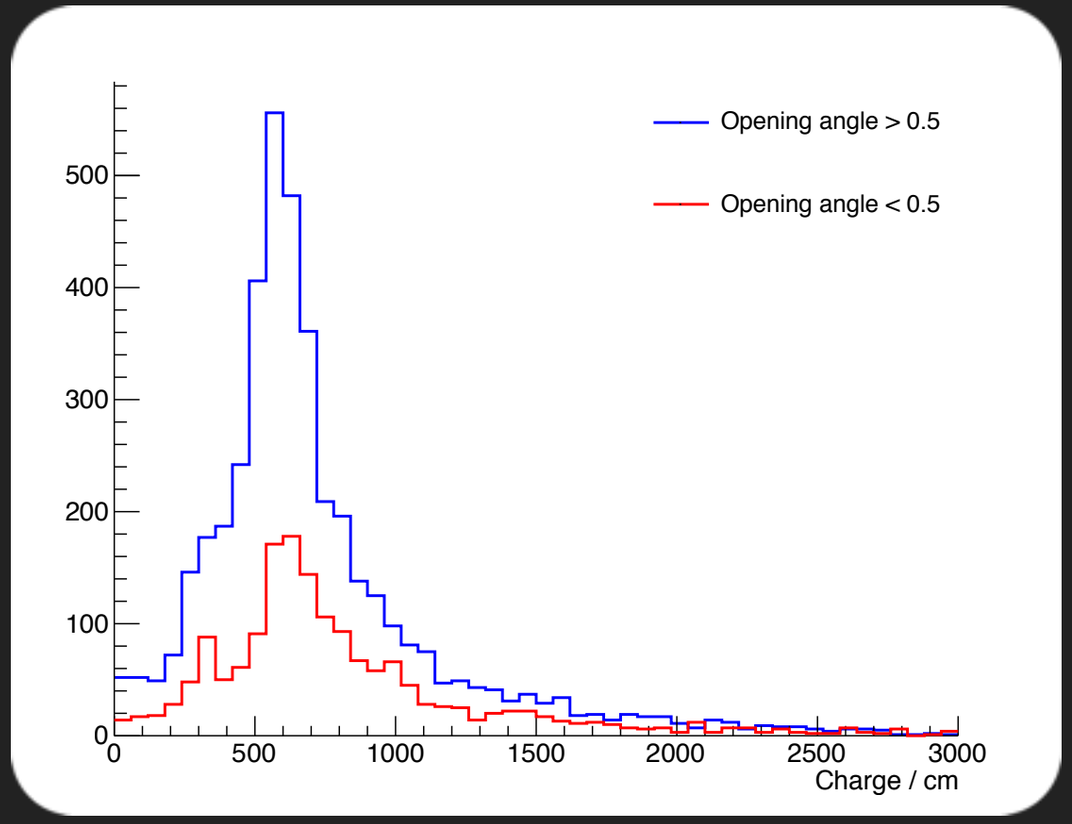
DOUBLE SHOWER FEATURES

- Different number of initial hits for overlapping showers?

Number of hits / cm in the first 5 cm



Charge / cm in the first 5 cm

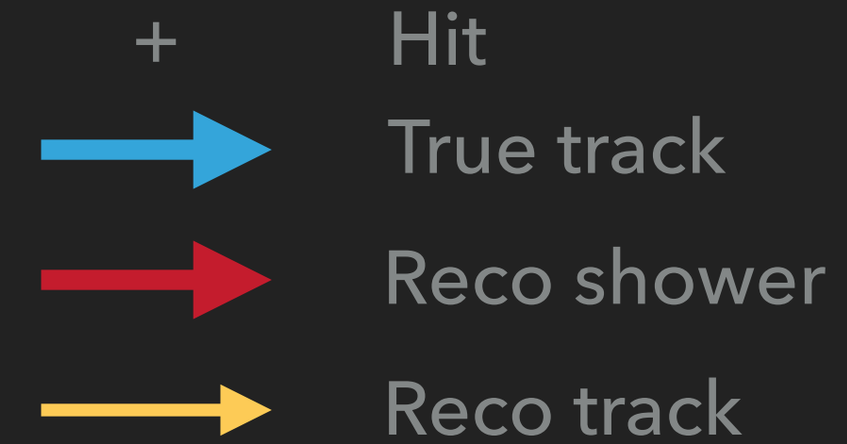


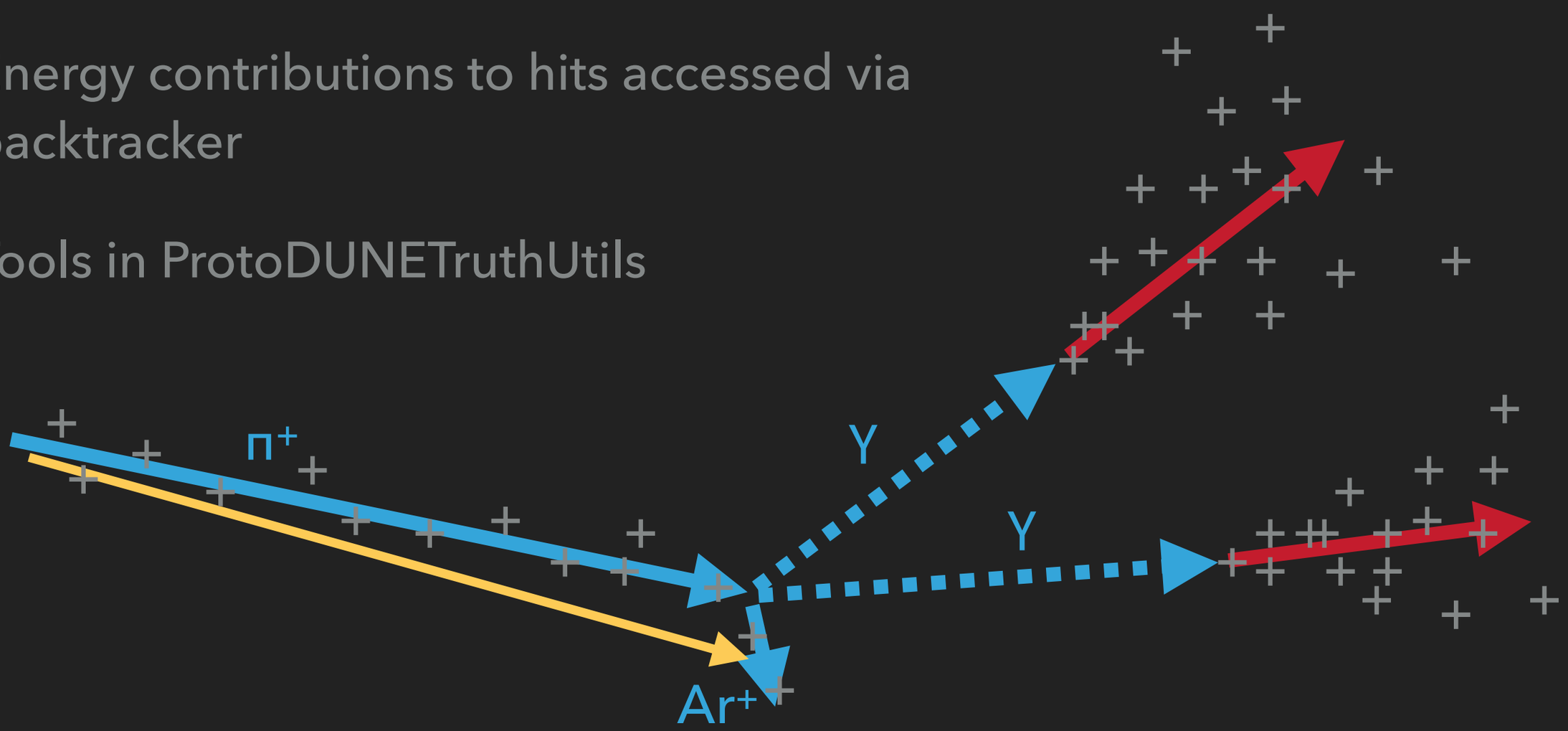
SUMMARY

- π^0 showers seem to be overlapping at $E_\pi > 1$ GeV
- So far no luck untangling these
- Effects other than overlap?
- Should gather more statistics in small angle region
  → more energetic π^0s

BACKUP — MC-RECO MATCHING

- Photons can be considered reconstructed if they are the primary energy contributor to a shower object
- Energy contributions to hits accessed via backtracker
- Tools in ProtoDUNETruthUtils

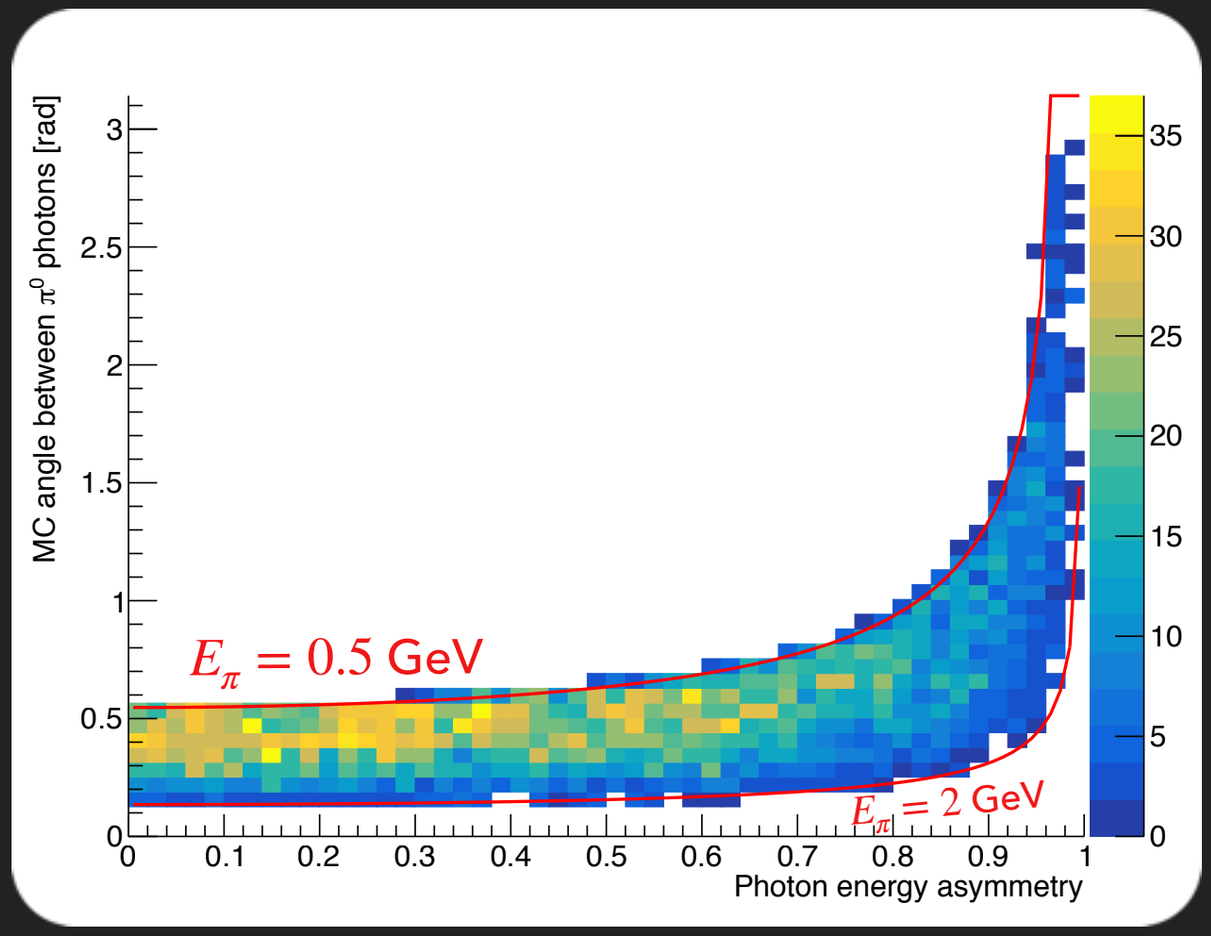




BACKUP — ASYMMETRY

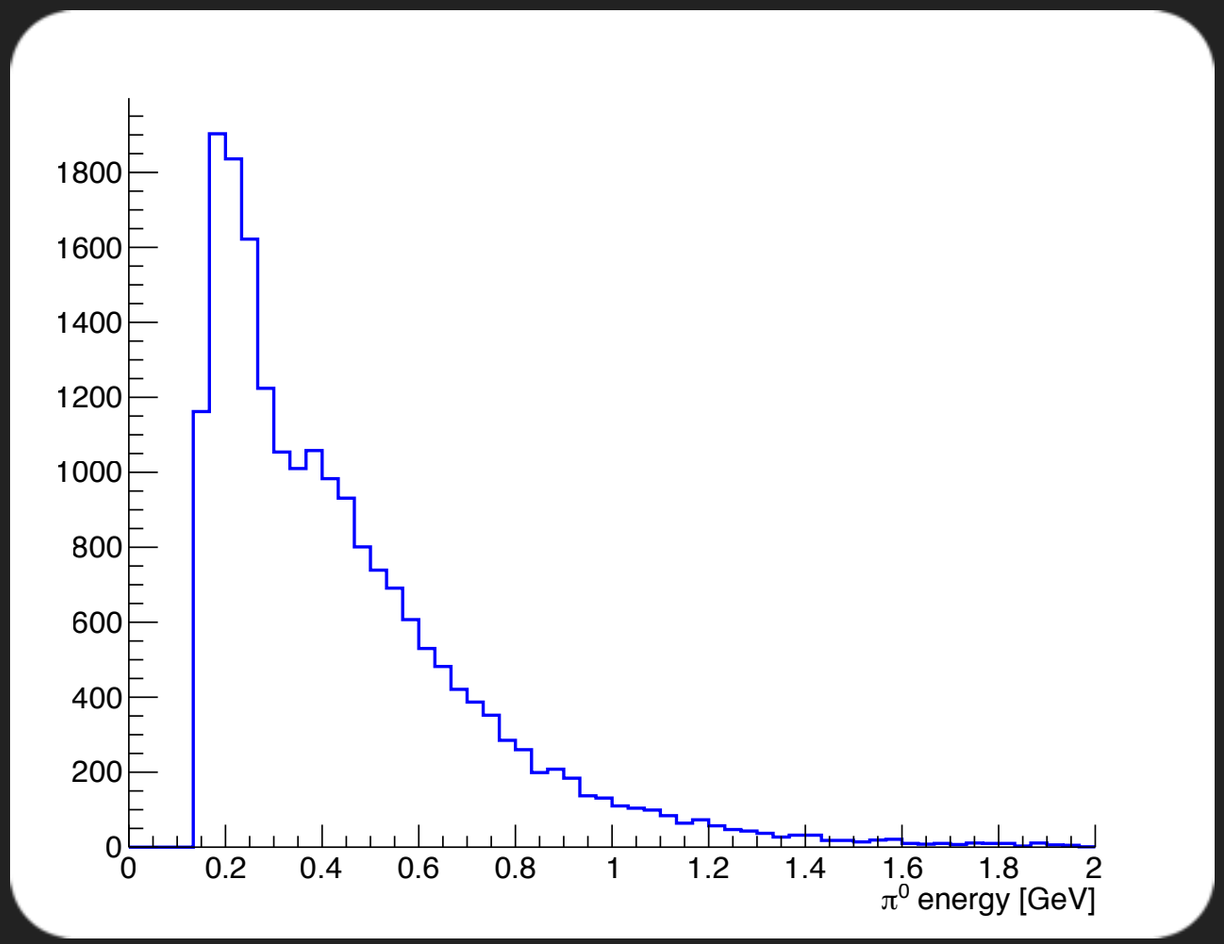
- $\alpha = \dfrac{E_+ - E_-}{E_+ + E_-}$
- $\alpha = \beta \cos\theta^* = \dfrac{E_\pi^2 - m_\pi^2 c^4}{E_\pi^2} \cos\theta^*$
- $\cos\theta = 1 - \dfrac{2m_\pi^2}{E_\pi^2(1-\alpha^2)}$

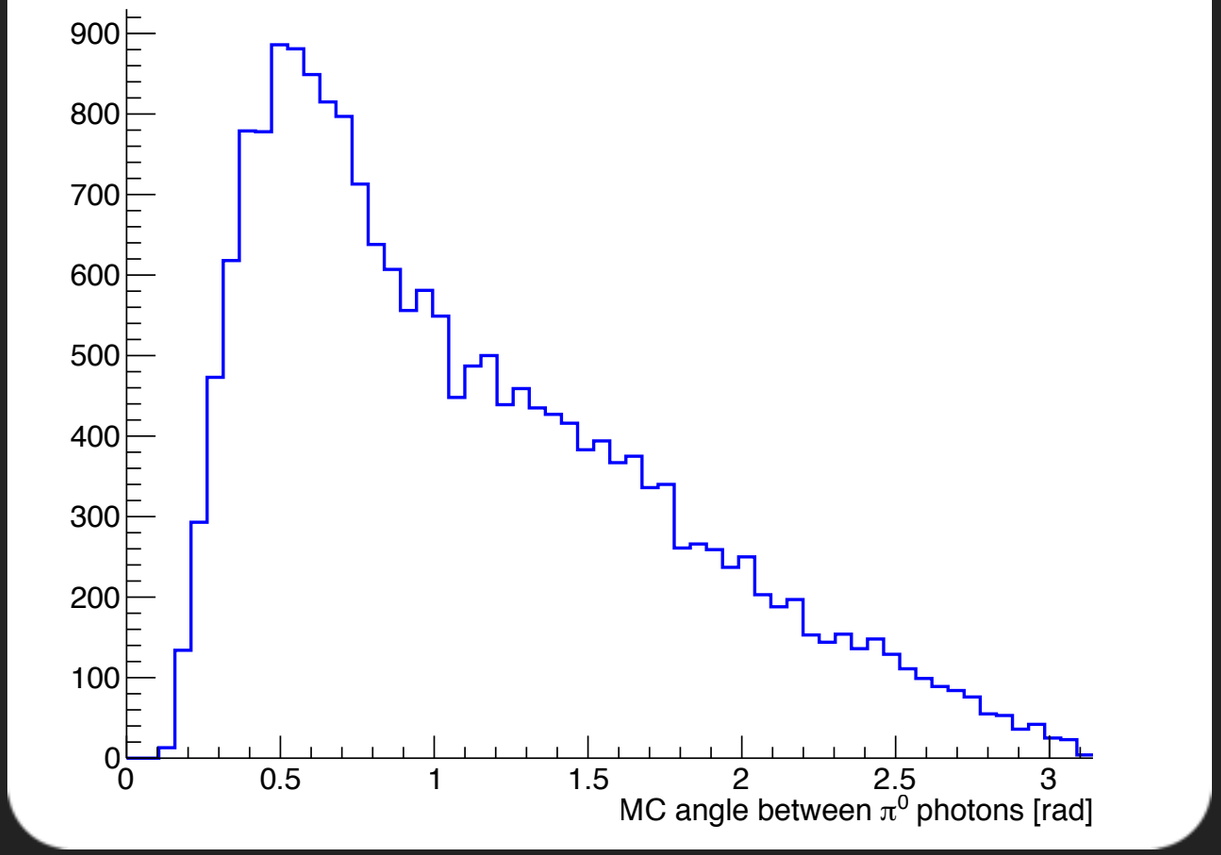
Shown here: MC points for $E_\pi > 0.5$



BACKUP — Π⁰ SAMPLE

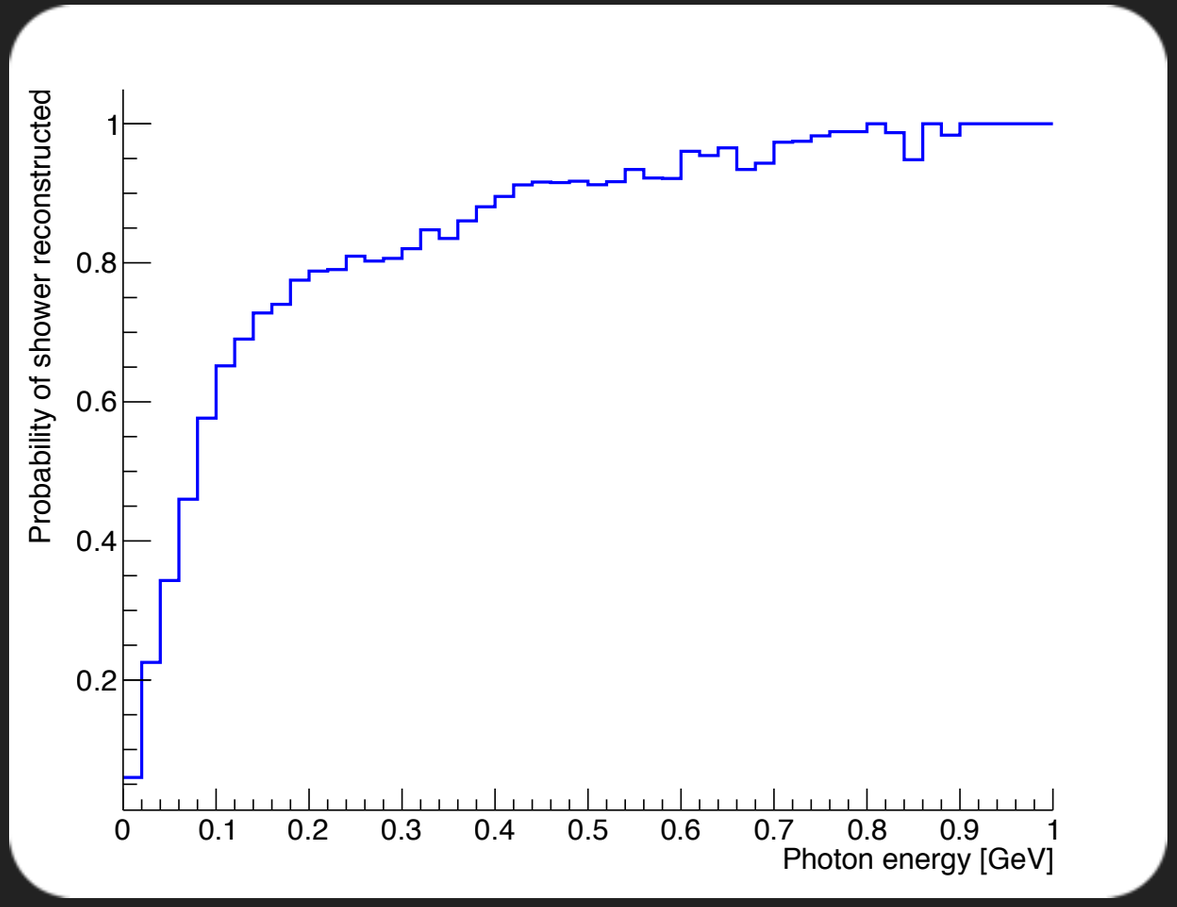
- ~ 20,000 π^0s in 30,000 2 GeV π^+ events

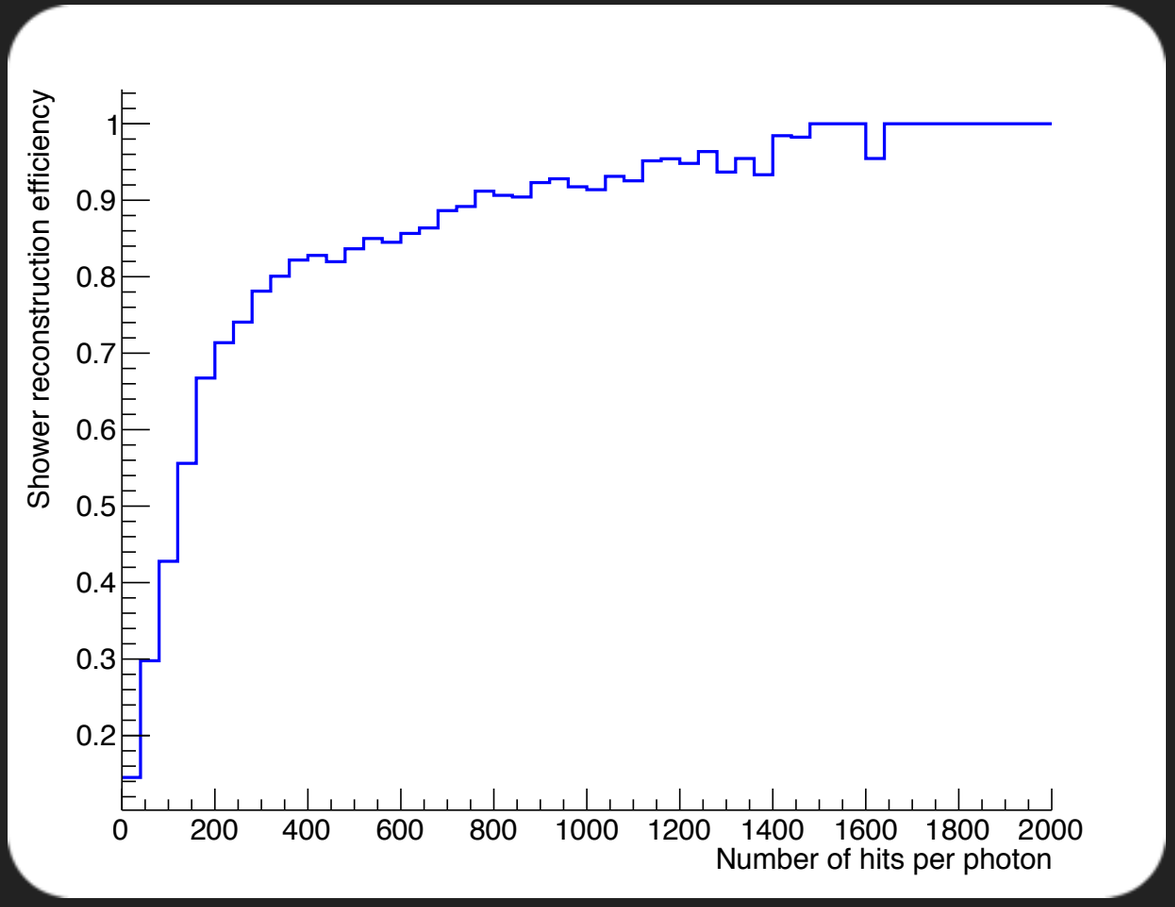




BACKUP — PHOTON RECONSTRUCTION EFFICIENCIES

- Graphs look to be in close agreement with TDR, if a little lower
- Might be caused by close proximity to other showers





BACKUP — DE/DX

- The dE/dx of each hit is determined in a cylinder at the start of a shower
- The median of this distribution gives an indication for the shower's dE/dx