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U.S. DEPARTMENT OF ENERGY
Office of Science

ZDC Acceptance Studies

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Outline

- ZDC Studies for neutron tagging of e+p->e+n+pi$^+$
  - Investigation of low acceptance in 5x41 GeV events
  - First a look at angular acceptance
  - A look at energy acceptance
- A brief look at backwards pi^0 production (slides courtesy of Zachary Sweger)
  - pi^0 goes to 2 photons to be detected in the ZDC
  - Acceptance Studies

Part 1
First Study
Neutrons generated according to $e+p \rightarrow e+n+\pi^+$ kinematics

Generator Properties

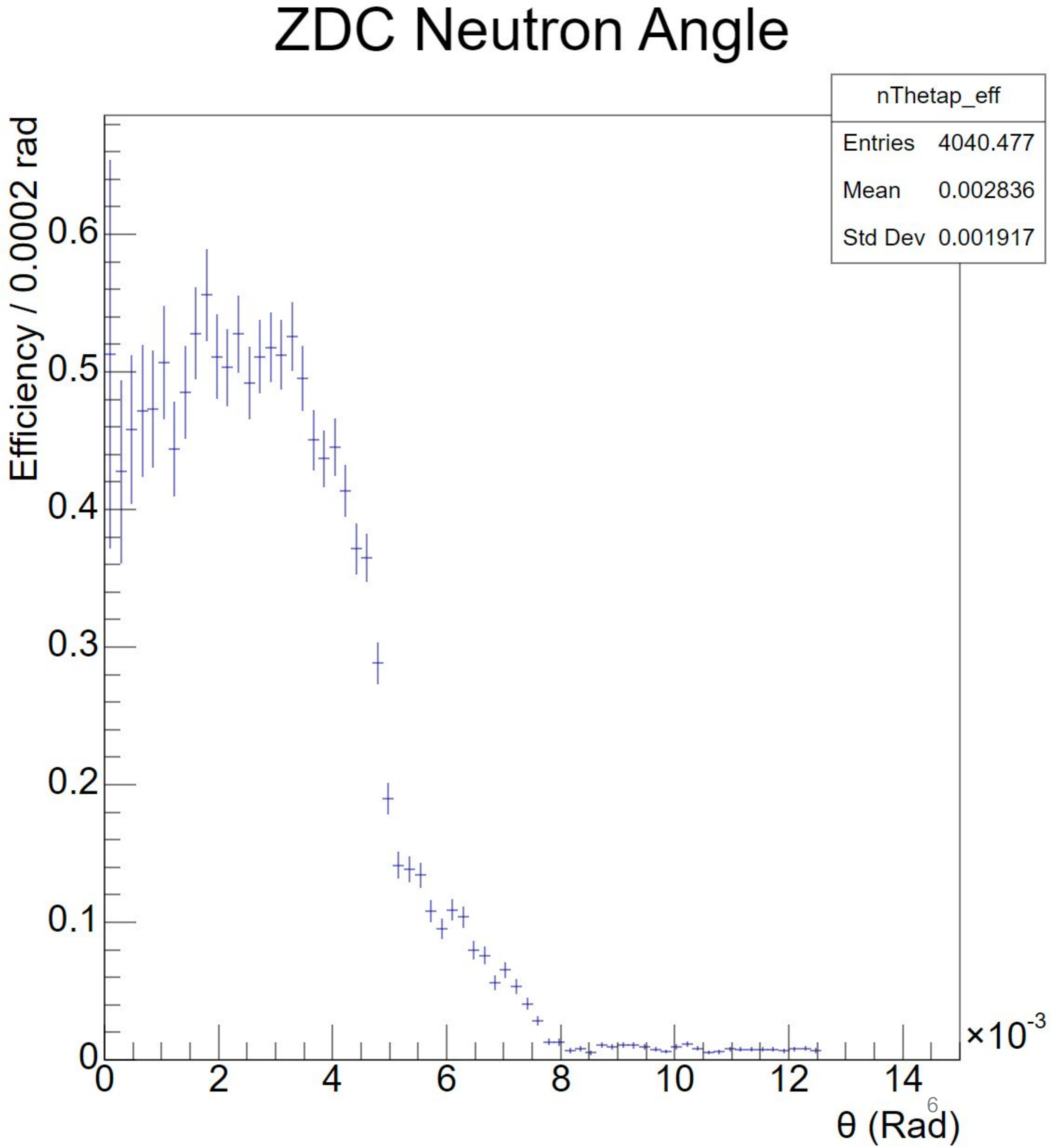
- Only throws the neutron, ensures it matches physical kinematics
  - No cross-section weighting
- Cuts
  - $0 < -t < 1$ GeV^2
  - 0 < theta < 13.5 mrad (later reduced to 8.5 mrad)
    - Defined with respect to proton beam axis (center of ZDC)

I wrote a generator that only produces the neutrons in order to investigate the neutron acceptance since I noticed lower acceptance than expected. Single particle simulations run faster ;)

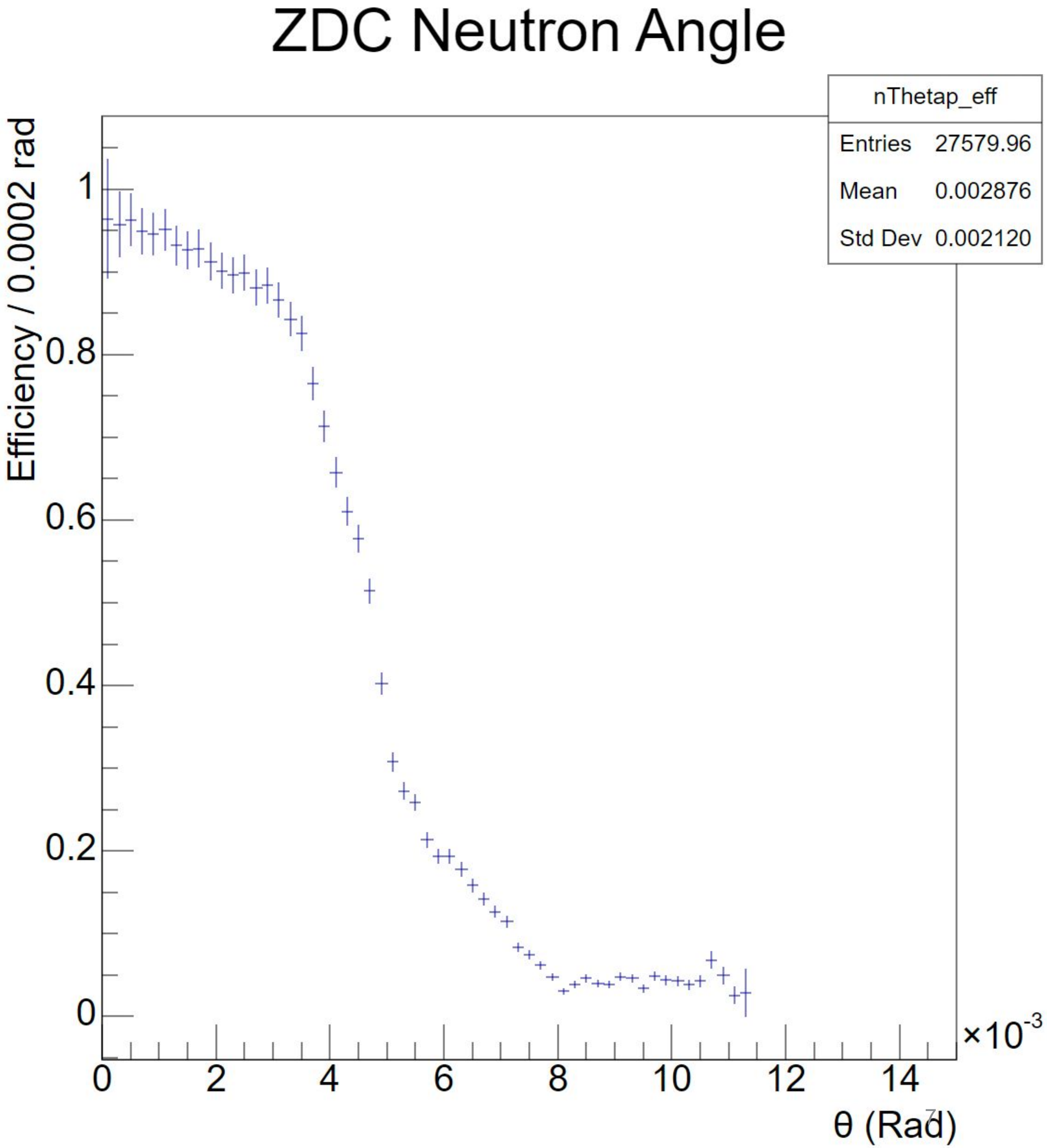
Definition of "Acceptance"

- Loop through all hits in ZDC and to check if the thrown neutron is associated with any hit
  - In this situation, a rescattered neutron that hits the ZDC is not accepted
  - Does not currently look at any daughter particles
- Binned according to thrown kinematics, does not take into account anything from the ZDC other than "did it make it there?"

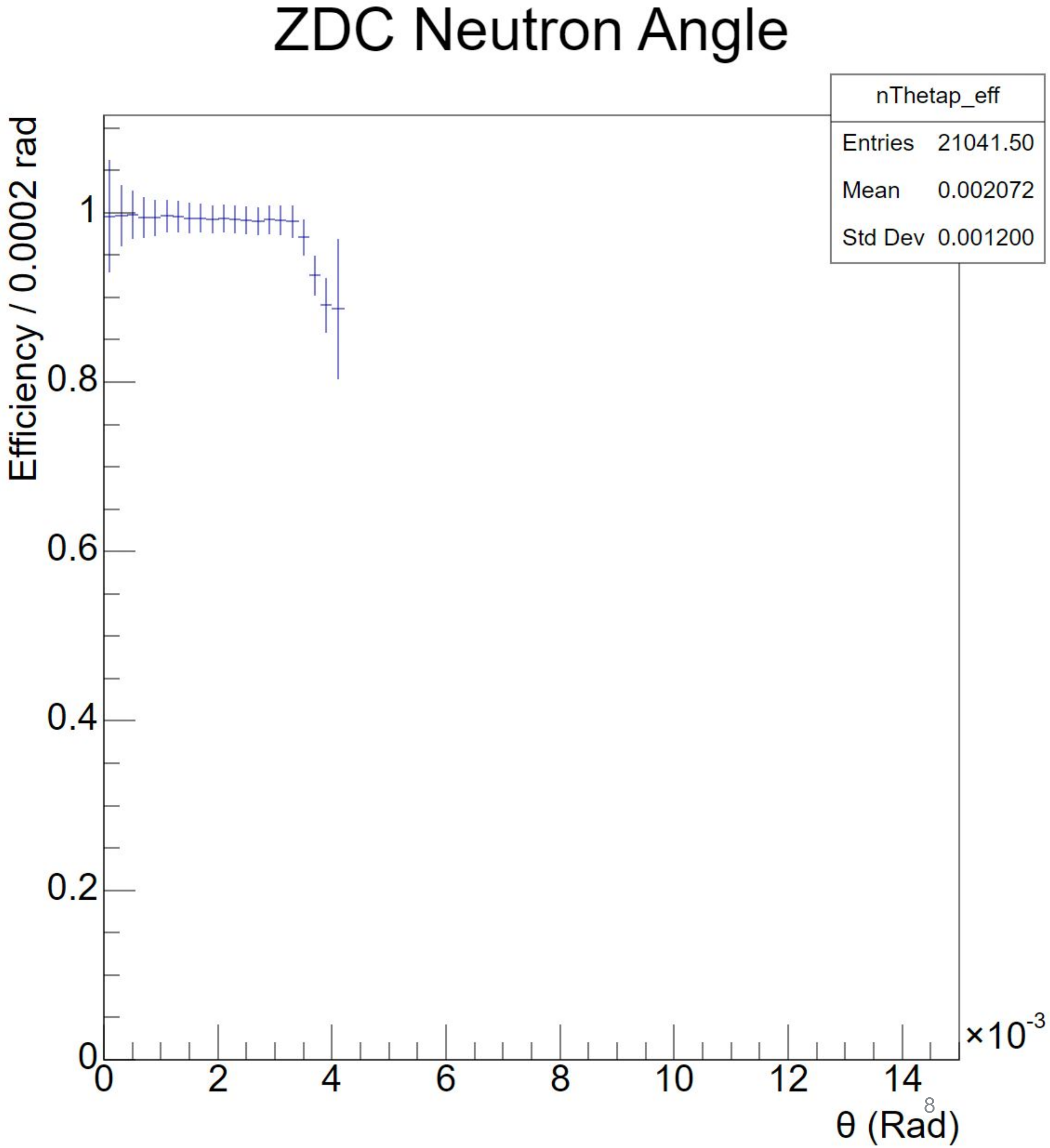
41 GeV proton beam
BryceCanyon geometry



100 GeV proton beam
BryceCanyon geometry

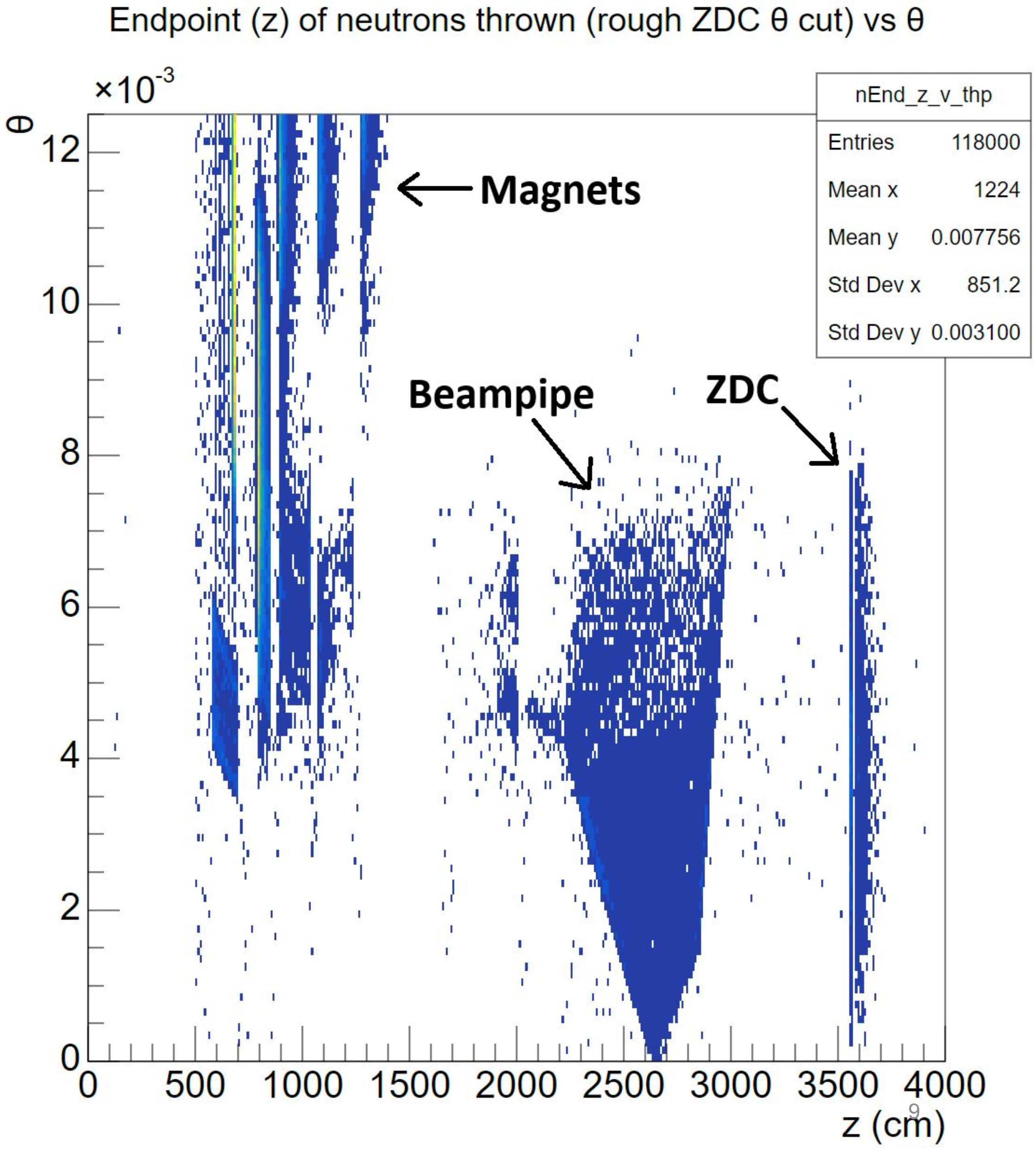


275 GeV proton beam
BryceCanyon geometry



Where are we losing events?

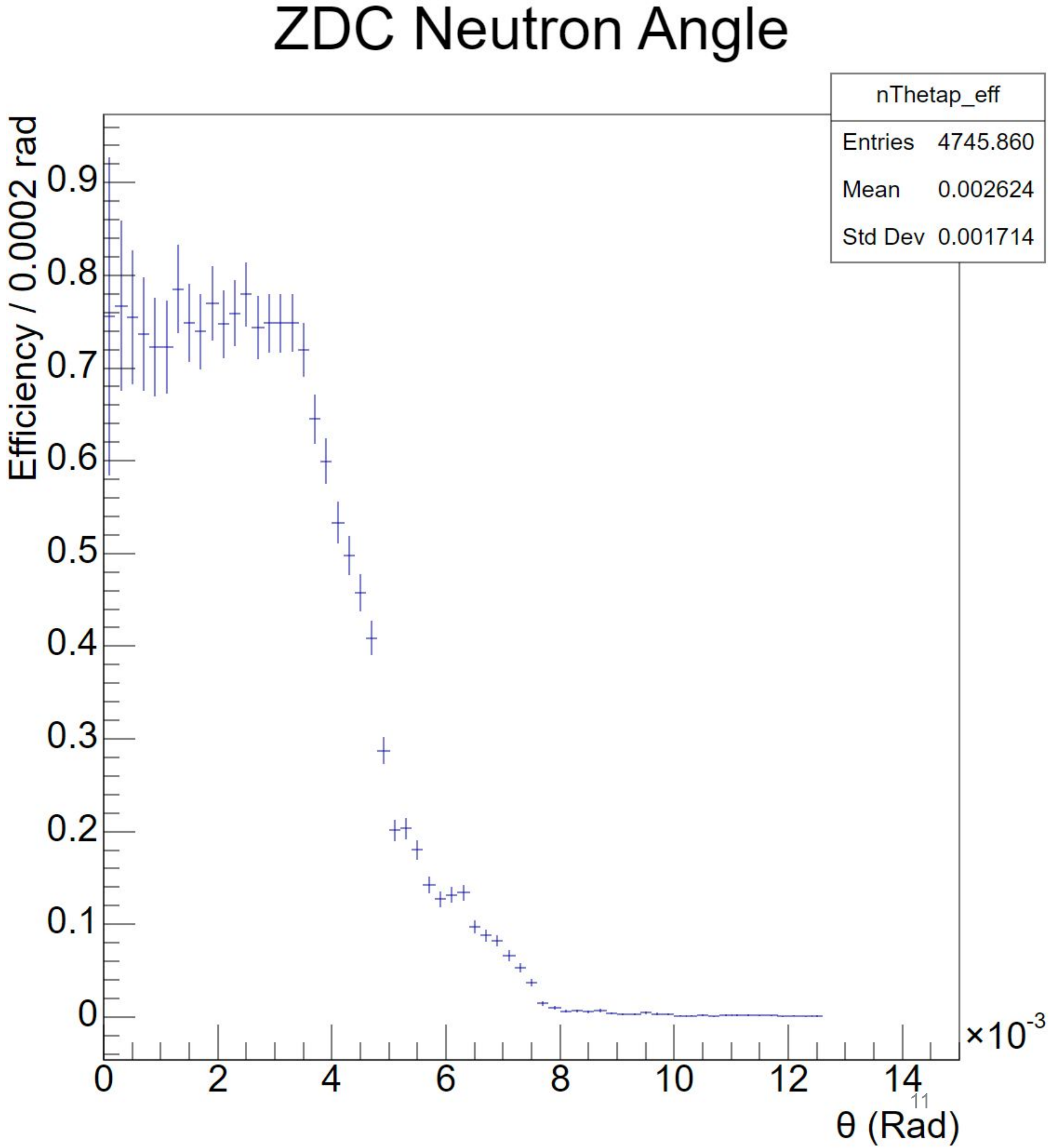
- Biggest problem in 5 on 41
- Plotting stopping location of the MC Particle vs thrown angle (since some are thrown outside of nominal acceptance)



Next Test:
Set beamline material to aluminum
(to verify that it is the beampipe)

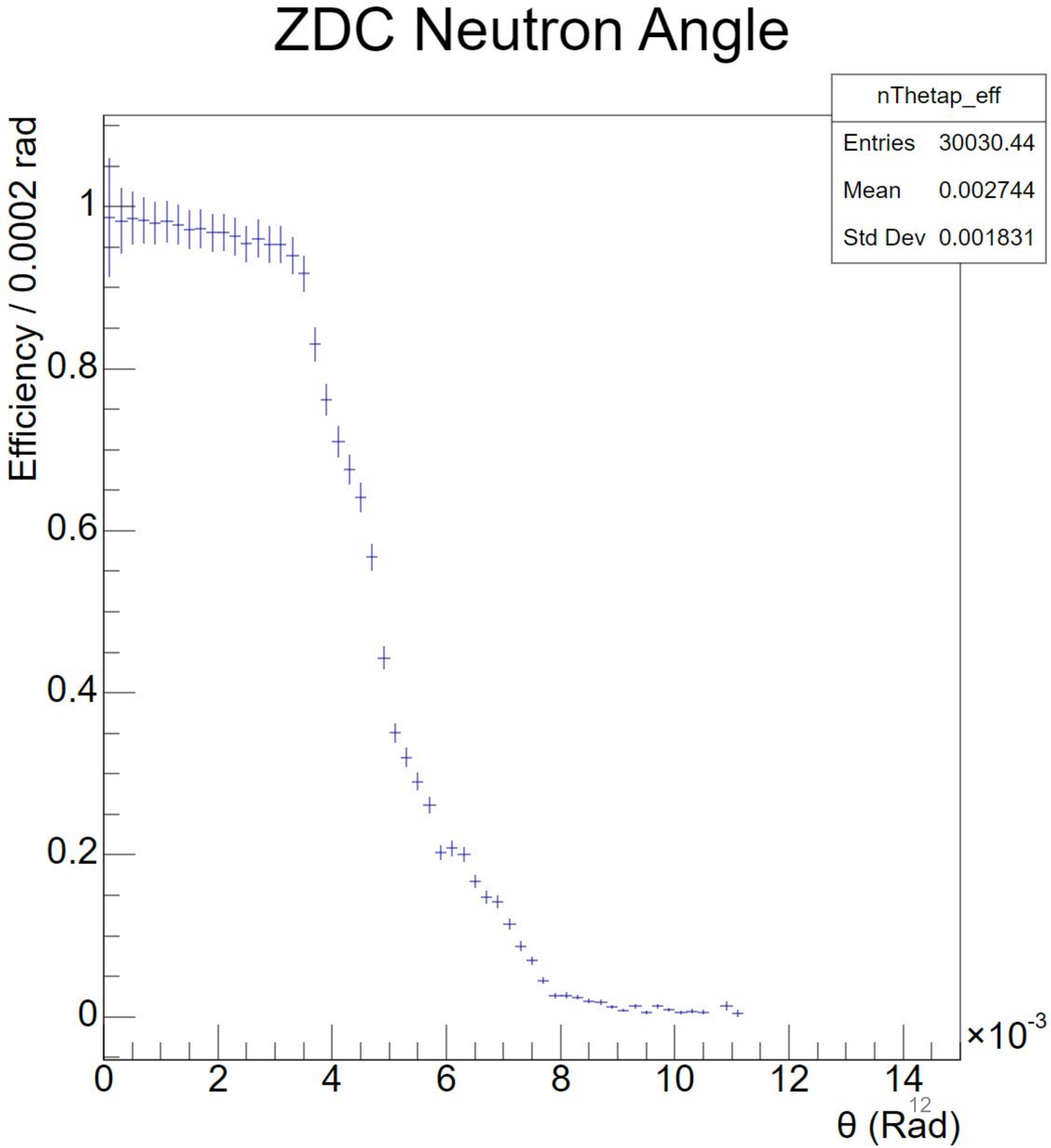
41 GeV proton beam
BryceCanyon geometry

- **+ World set to vacuum**
- **+ Aluminum beampipe**



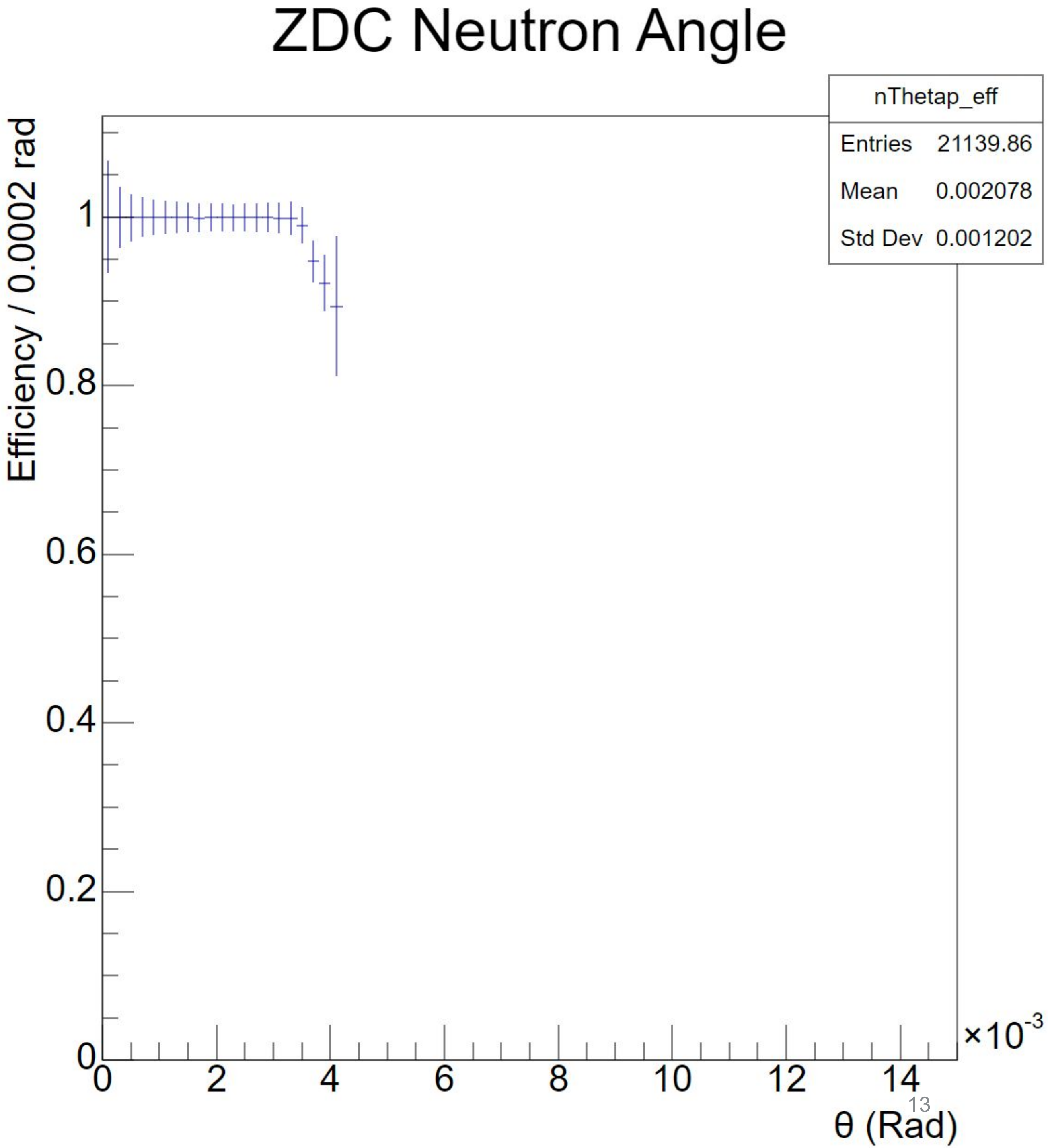
100 GeV proton beam
BryceCanyon geometry

- **World set to vacuum**
- **Aluminum beampipe**



275 GeV proton beam
BryceCanyon geometry

- + World set to vacuum
- + Aluminum beampipe

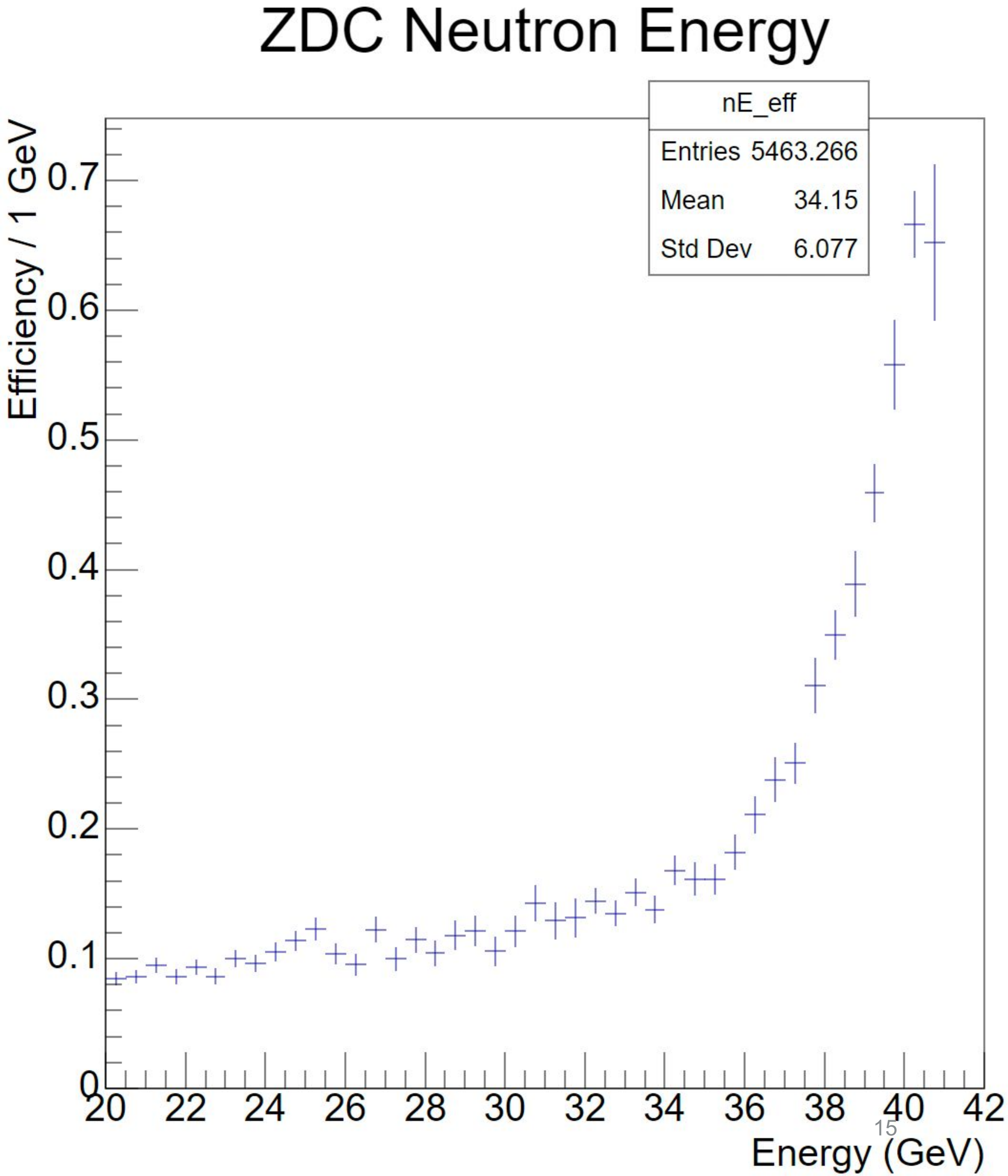


What does the energy acceptance look like?
(since 5x41 seems to have the worst problem)

41 GeV Energy Acceptance

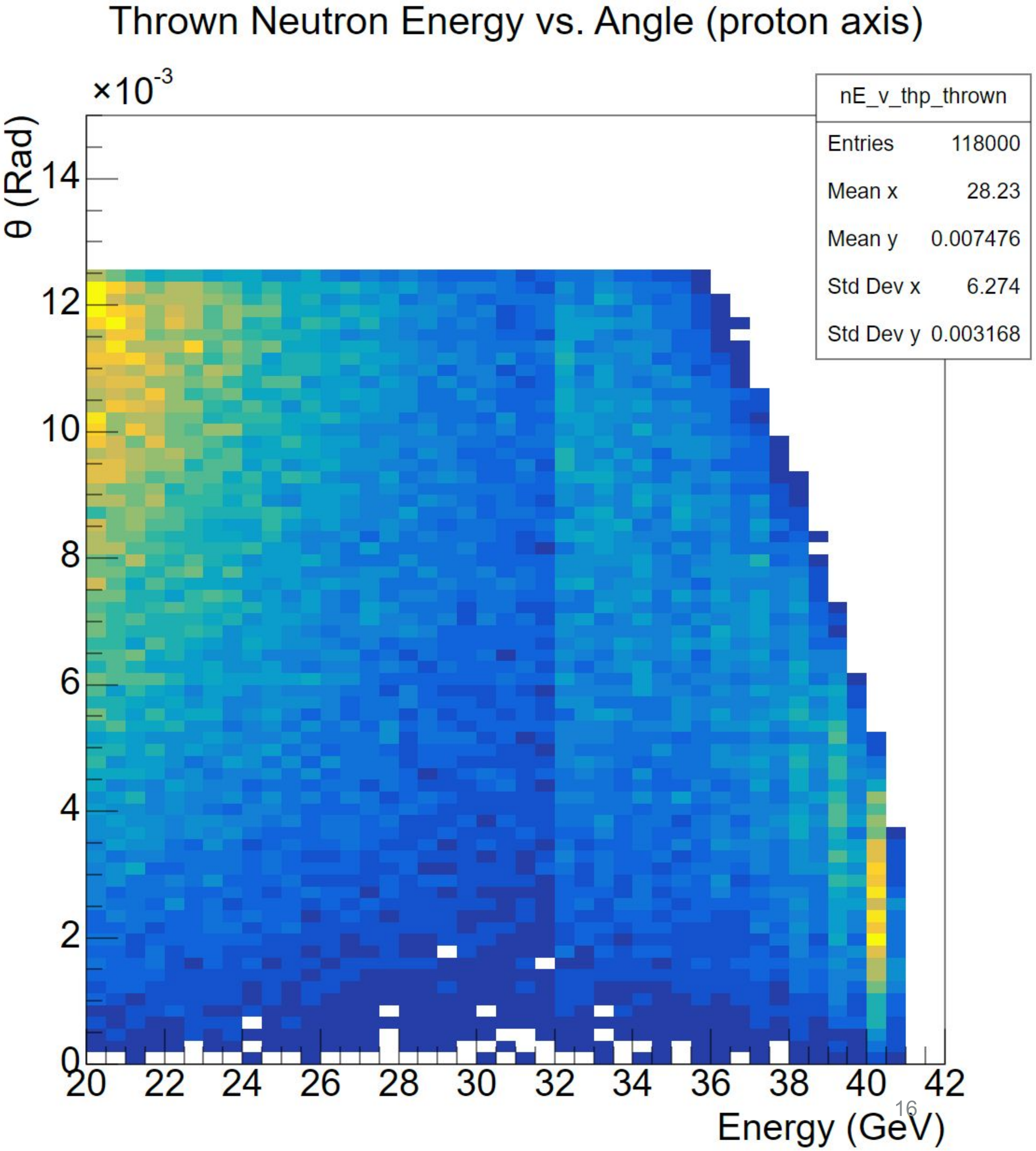
Is the angular acceptance dragged down by the low low-energy acceptance?

Plot to the right uses stock Bryce Canyon geometry (SS beampipe)



A look at the Energy Distribution (41 GeV)

- My generator has a *lot* of low energy neutrons thrown
  - Important caveat: I have begun a preliminary comparison of this to a cross section weighted set of simulated events. While the kinematics *should* be good, the distribution seems to be rather different than a realistic distribution.
  - In the future I will be using the realistic events, but the simple “neutron only” simulation runs substantially faster
- What happens if we ignore the kinematics and just throw 41 GeV neutrons?
  - Presumably the lower energy neutrons won’t be as prominent when weighted by cross section

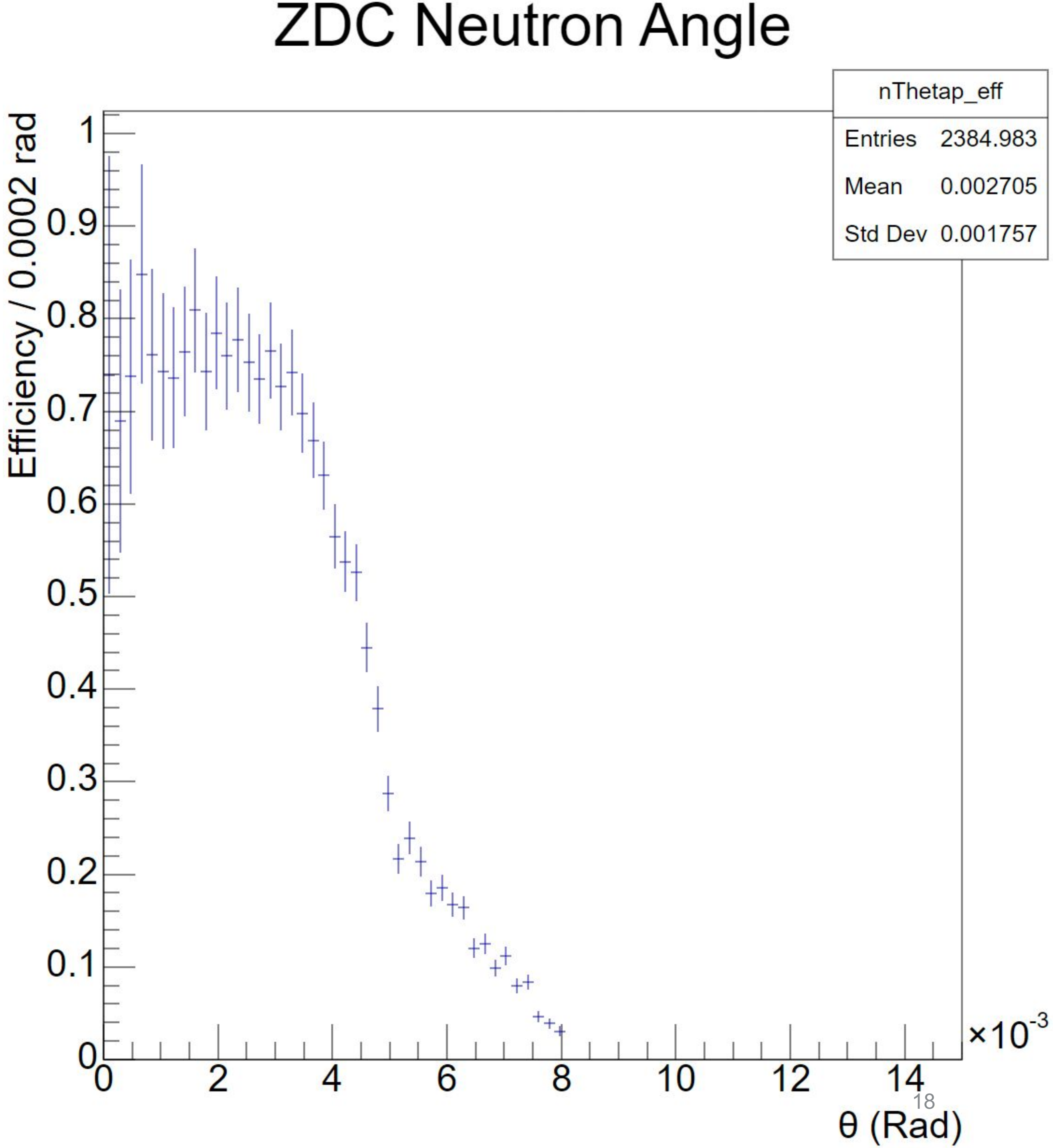


Single Energy Neutron Generator

- Throws neutrons of a single energy (41 GeV here)
- 0 < theta < 8 mrad (defined w.r.t. proton axis)
- No physics or cross sections

41 GeV neutrons
Stock BryceCanyon
(SS beampipe restored)

The acceptance looks a lot better



Part 1 Summary

- The beamline, as is in the simulation geometry, causes problems detecting “low” energy neutrons
  - More than 50% stopped when energy is below ~39 GeV
- With the beampipe curving off, the neutrons see a very large amount of material in the path to the ZDC
  - The plot on slide 9 seems to suggest that the most material is seen around 4 mrad, with neutrons stopping in material over approximately 9 meters (I still need to look up the exact geometry to verify this measurement)
- The current beampipe design is a limiting factor in studying physics processes that rely on the ZDC

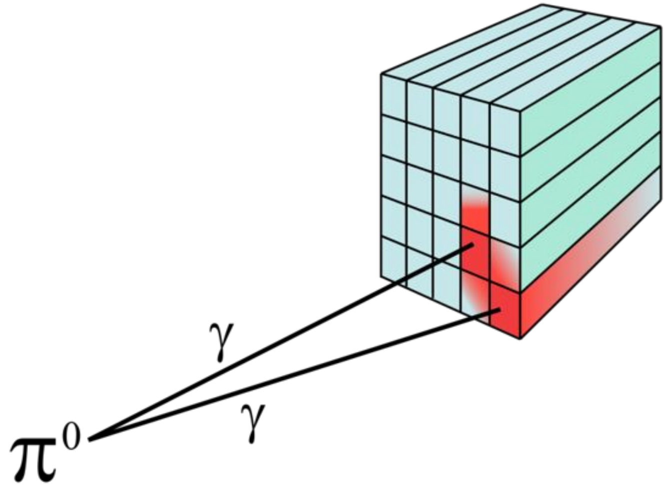
Part 2
Backward pi^0 production
(slides courtesy of Z. Sweger)

Backward π^0 at Generator-Level

- Backward π^0 events simulated with eSTARlight
- 18×275 GeV is best
- Generated 100k events of exclusive u-channel π^0 production at 18×275GeV with Q^2 from 1e-7 to 10 GeV^2
- Afterburned with the high-divergence configuration
- Ran 1000 test events through the ePIC simulation and reconstruction framework
- Many thanks to Kong Tu and Tyler Hague for teaching me how to process these!

π^0 Both Photons in ZDC Acceptance

	5×41	10×100	18×275
$0<Q^2<1$ GeV^2	13%	72%	99%
$1<Q^2<10$ GeV^2	11%	69%	98%
$10<Q^2<20$ GeV^2	15%	79%	99%



Backward π^0 in ePIC Simulations

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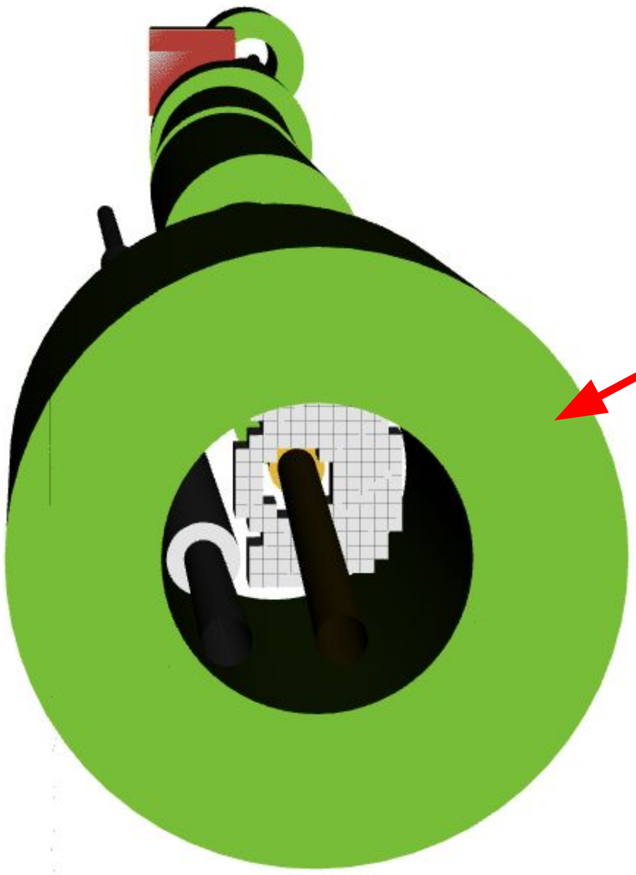
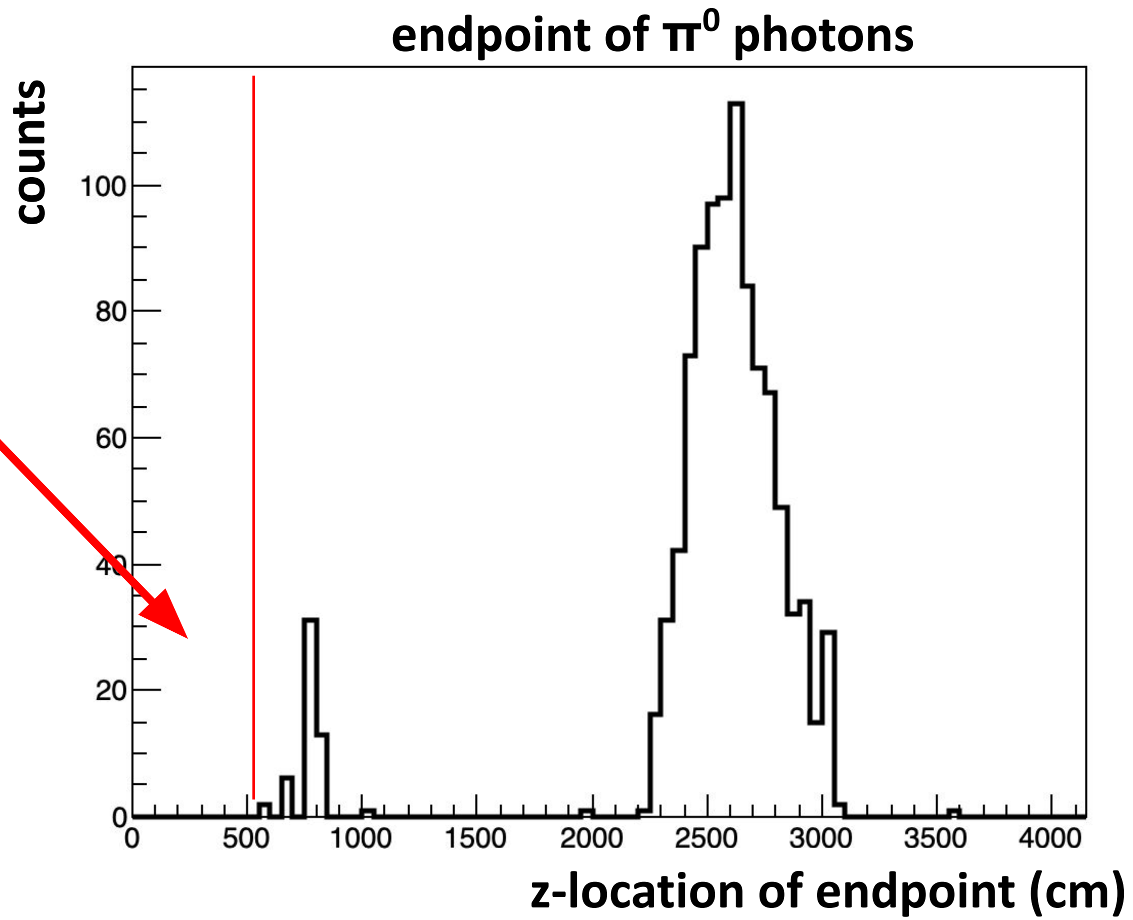
Before 500 cm, photon hasn't had a chance to hit B0



500 cm



Backward π^0 in ePIC Simulations

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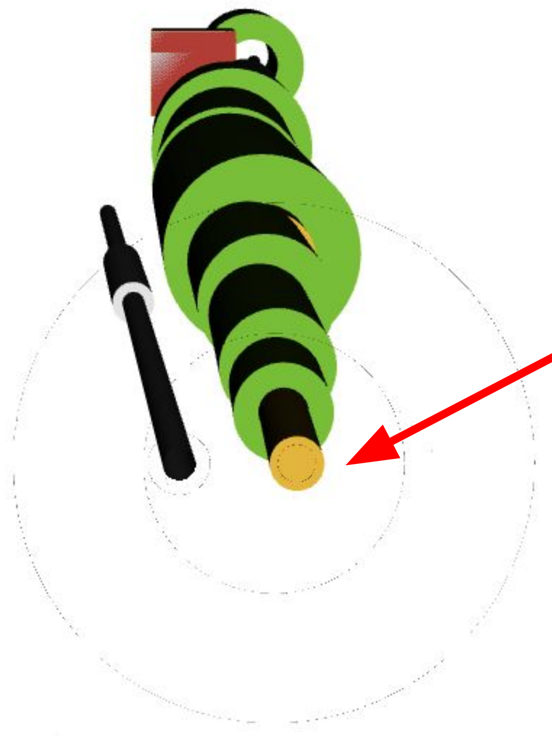
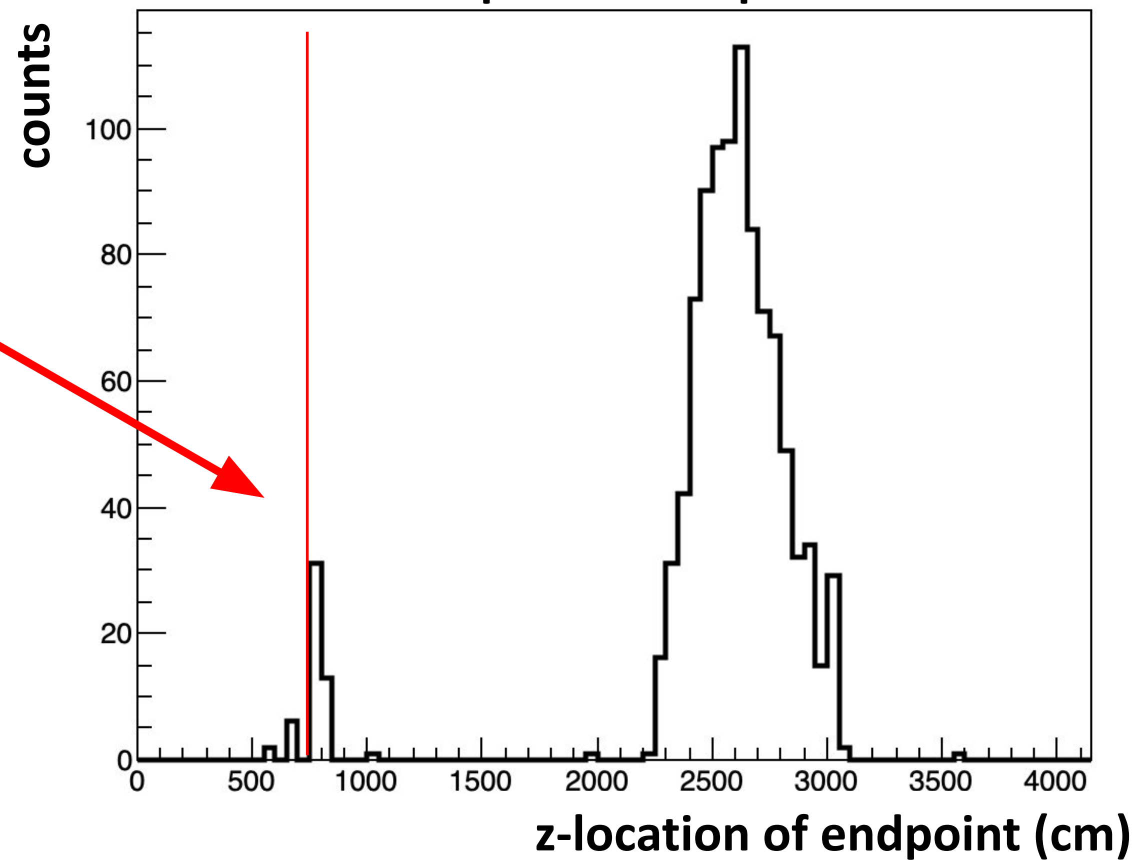
By 700 cm, we passed the B0 and only a few photons hit it



700 cm

endpoint of π^0 photons

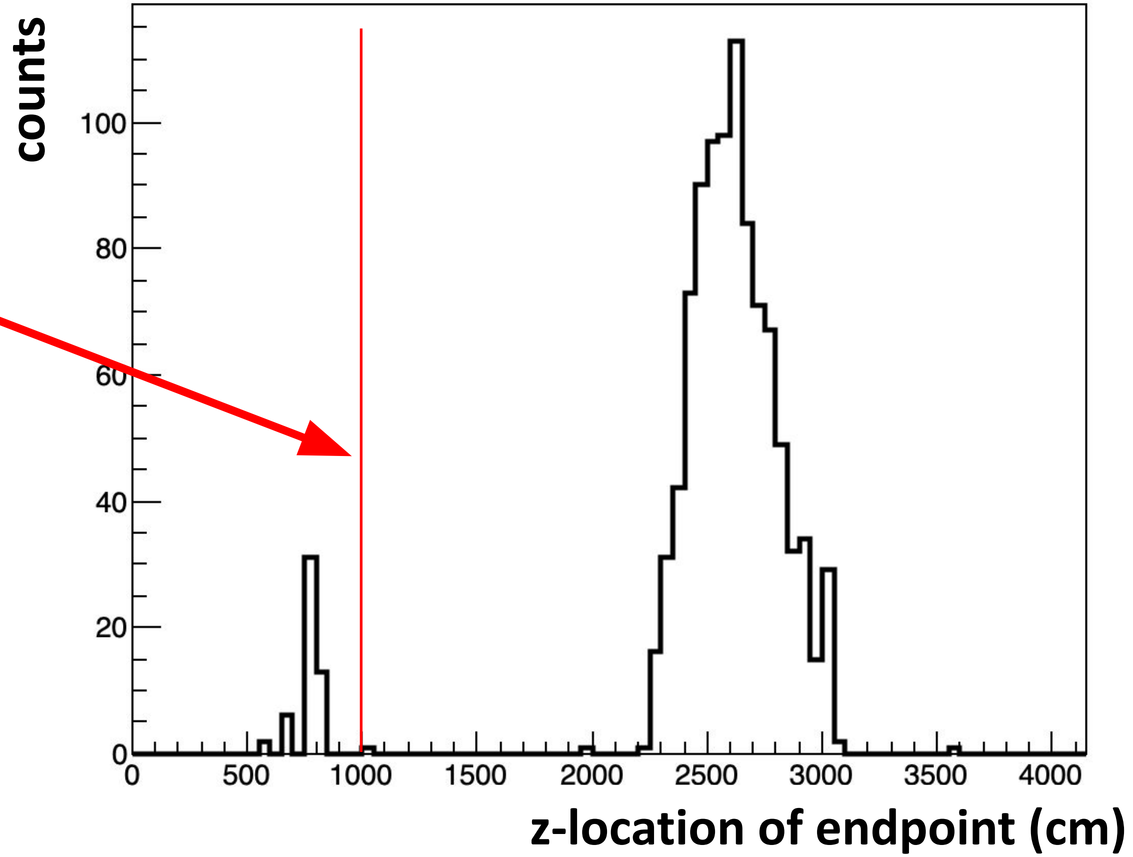


Backward π^0 in ePIC Simulations

By 1000 cm a few photons strike beam pipe and magnets

1000 cm

endpoint of π^0 photons



Backward π^0 in ePIC Simulations

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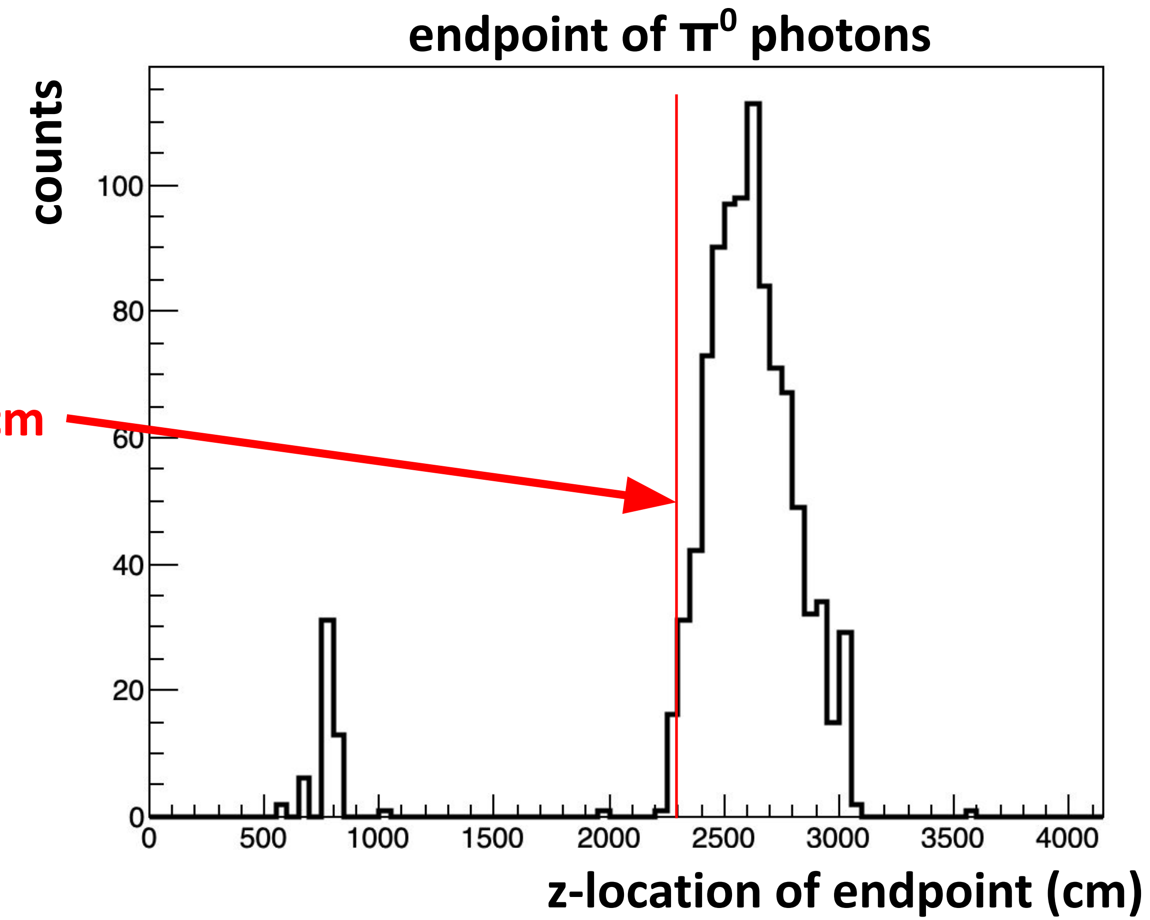
Not much interaction before 2300 cm



Backward π^0 in ePIC Simulations

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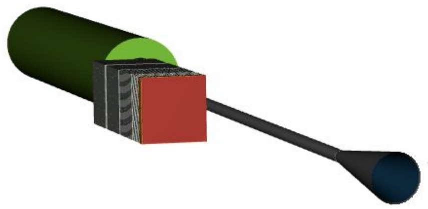
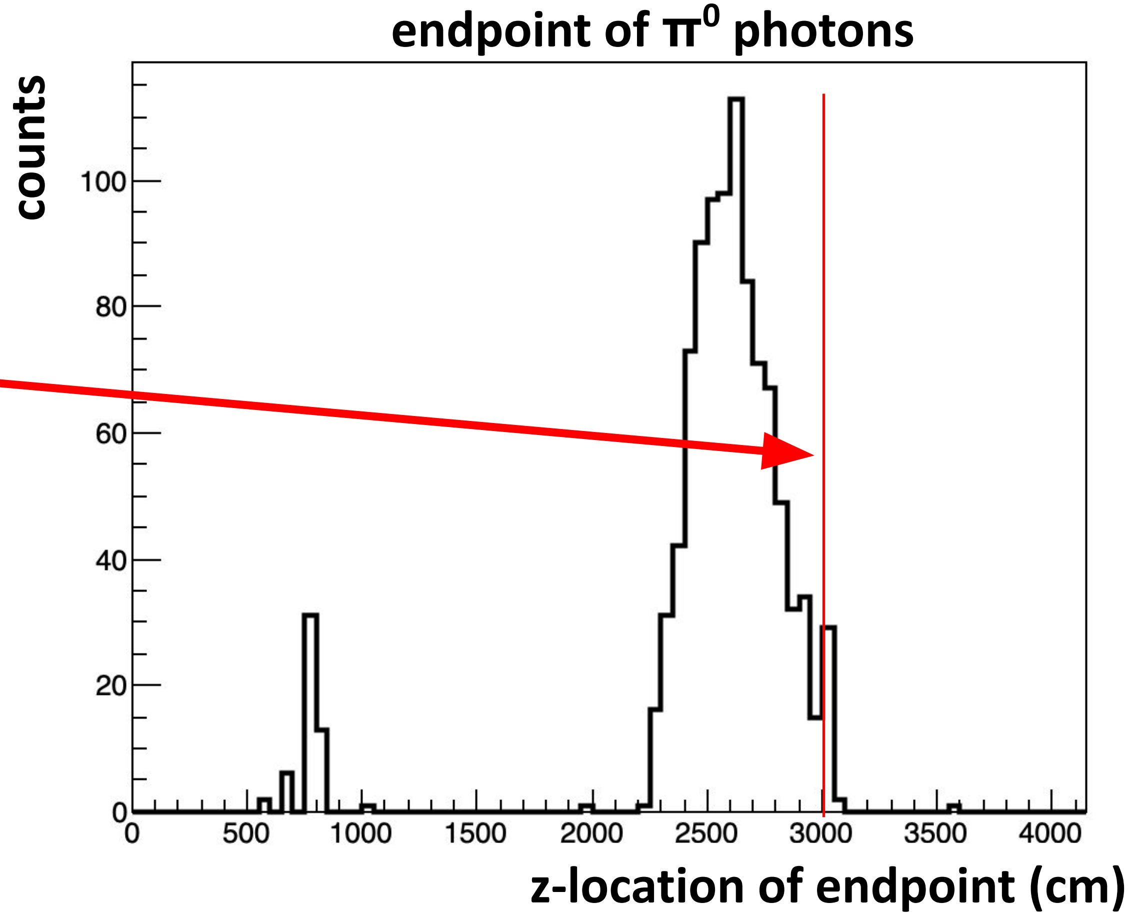
The majority of photons hit the beam pipe between 2300 and 3000 cm



3000 cm



Backward π^0 in ePIC Simulations

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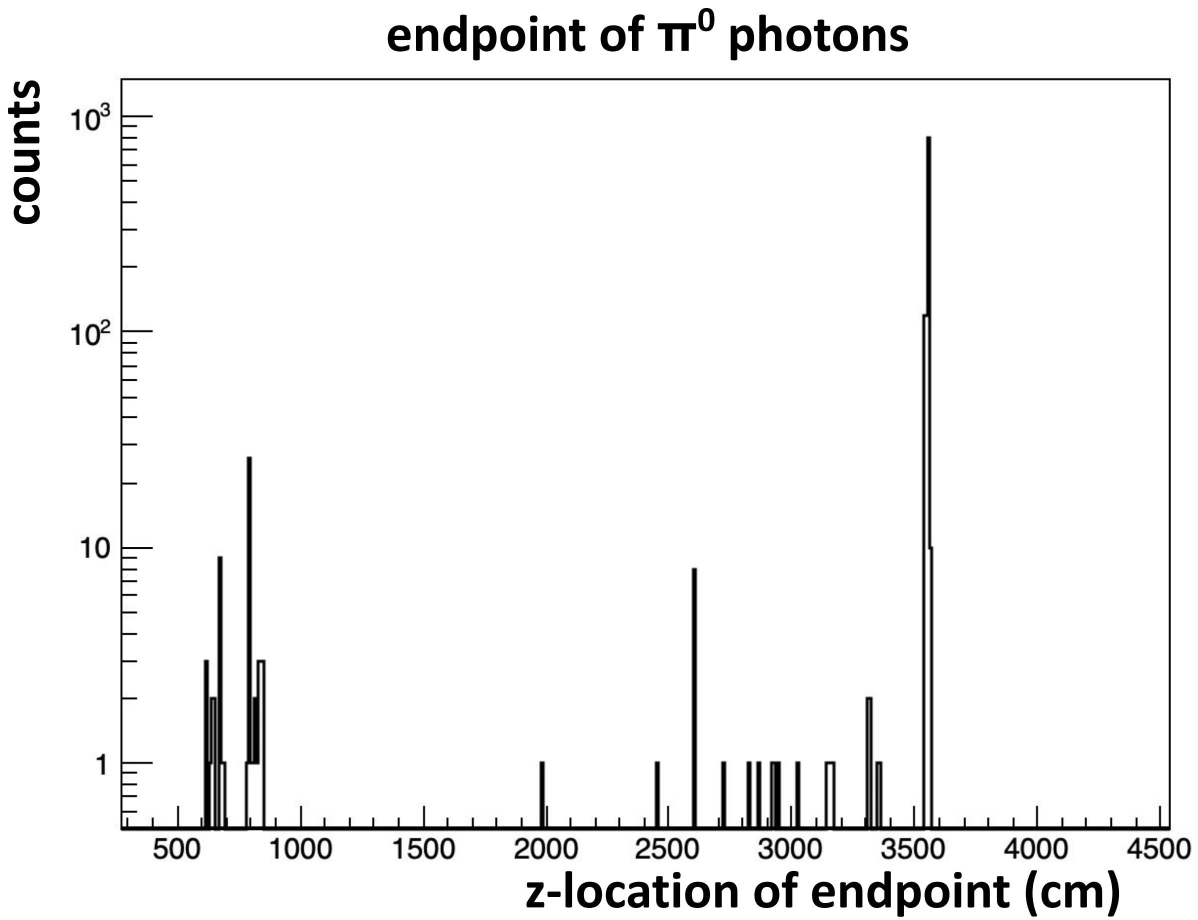
I next turned the beam pipe into vacuum.
Now the photons scatter first in the ZDC



Part 2 Summary

- The beampipe also causes issues (expectedly) for detecting photons
- Using an 18x275 GeV simulation of backward pi^0 production, Zachary Sweger found that nearly all photons are stopped by the beampipe before they can reach the ZDC
- These simulations are in agreement with my neutron study that the current beampipe design limits the study of physics that depends on the ZDC

Thank You!