Update on IP8 DD4hep Simulation

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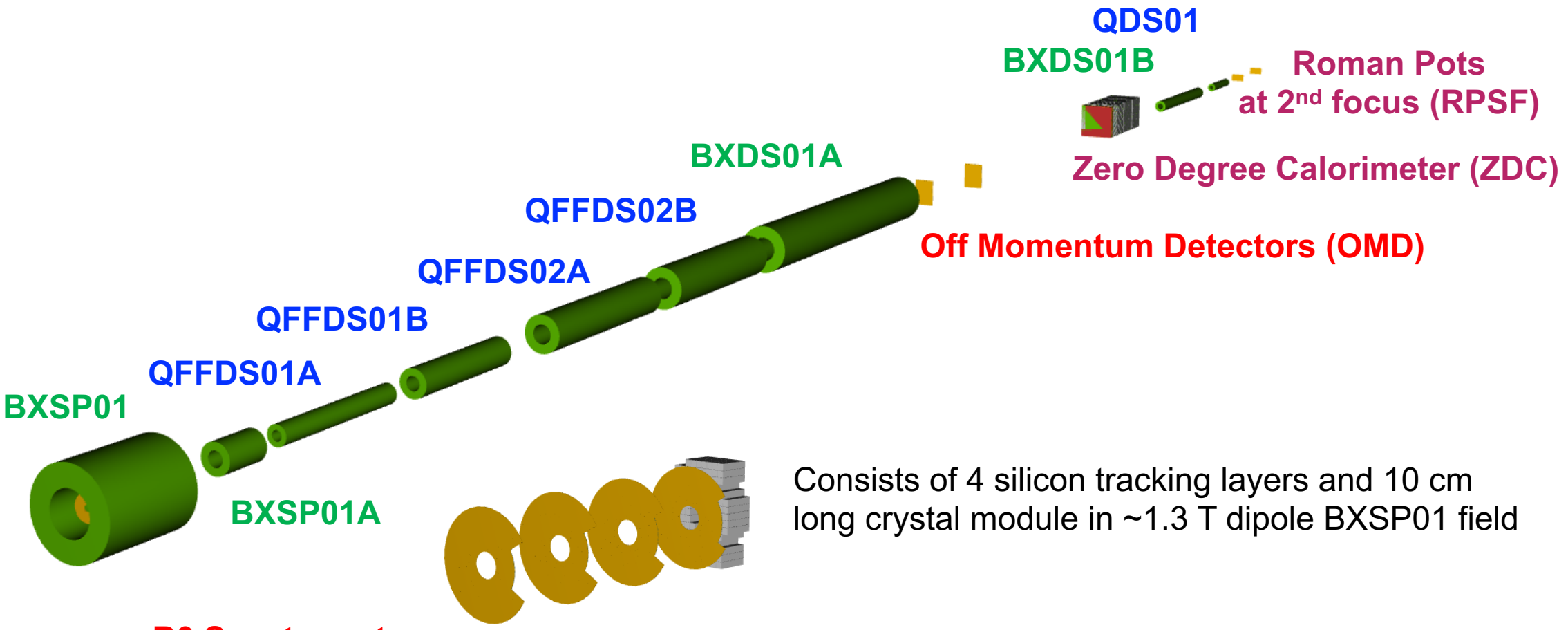
What's New

- Updated Far-Forward layout
  - Added **B0 spectrometer** (tracker + electromagnetic calorimeter) to tag nuclear breakups such as protons and photons
  - Made **OMD** a bit larger to get better acceptance assuming they are sitting regardless of beampipe design
- Updated incoherent tagging power
  - Included B0 spectrometer and (a bit larger) OMD

IP8 Far-Forward Layout

Implemented in **IP6 detector configuration**

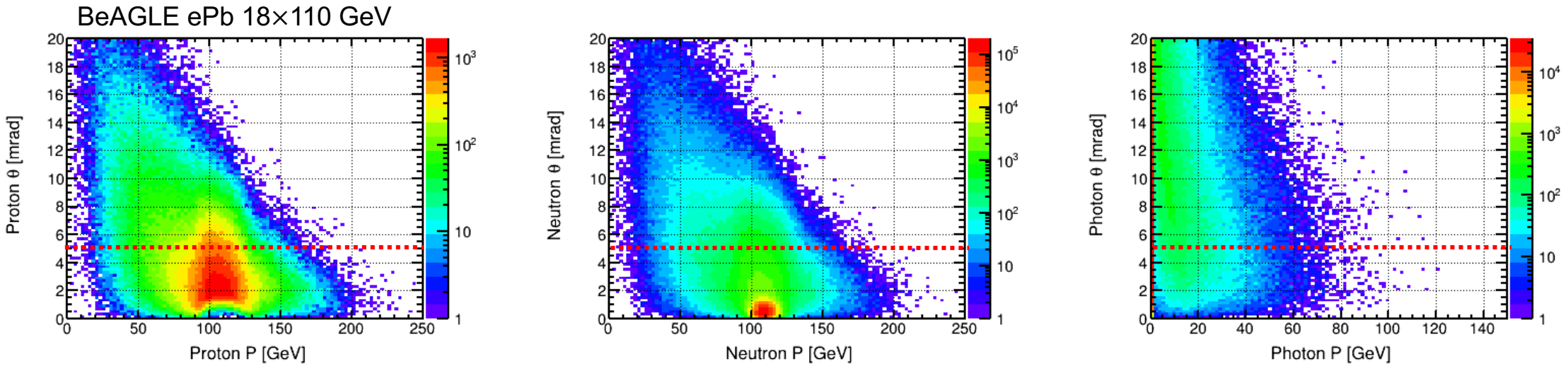


Consists of 4 silicon tracking layers and 10 cm long crystal module in ~1.3 T dipole BXSP01 field

References from https://wiki.bnl.gov/eic-detector-2/images/d/de/IR8_magnet_layout_12052022.xlsx
https://wiki.bnl.gov/eic-detector-2/images/8/86/IP8_HSR_lattice_performance_10_13_22_v3.pdf

Approach – Acceptance

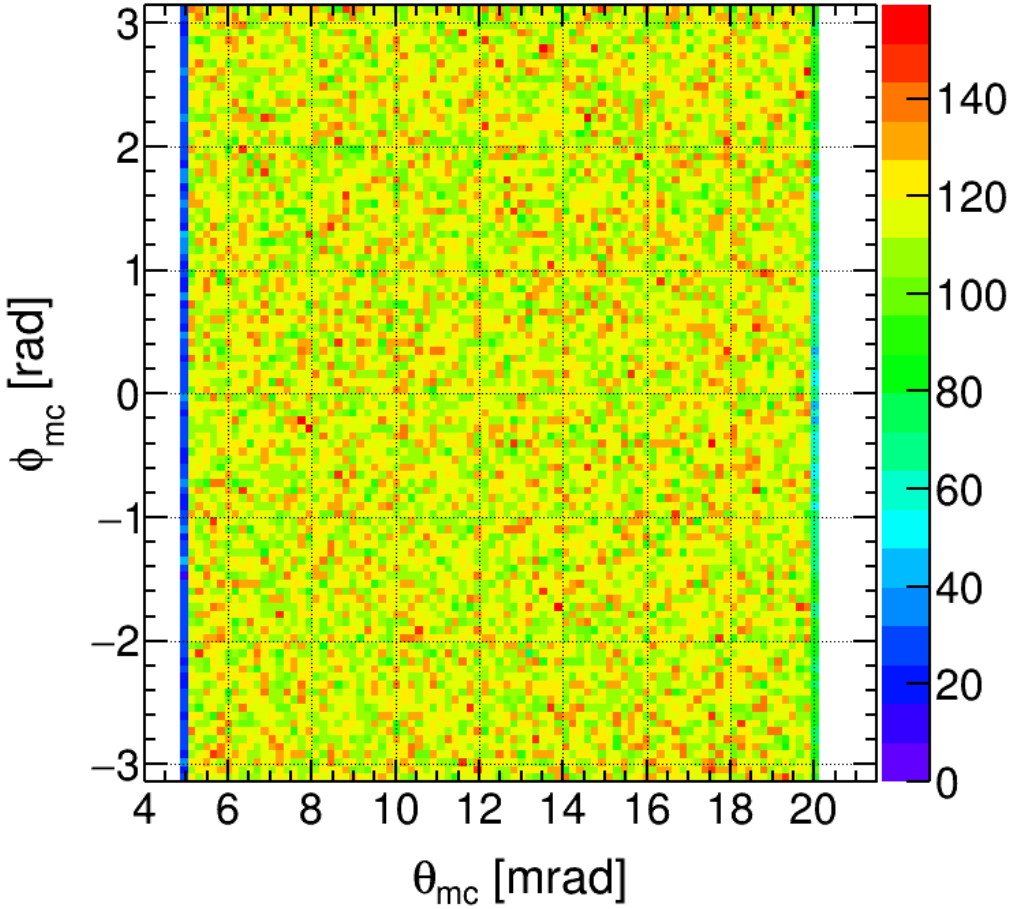
- **Single particle simulation**
  - **B0 Spectrometer (Tracker + Calorimeter)** focusing **$5 < \theta_{MC} < 20$ mrad**
    - Proton energy: 80 GeV < E_p < 120 GeV
    - Photon energy: 1 GeV < E_γ < 40 GeV ***running***
  - **Off-Momentum Detector** focusing **$0 < \theta_{MC} < 5$ mrad**
    - Proton energy: 123.75 GeV (45%) < E_p < 151.25 GeV (55%)



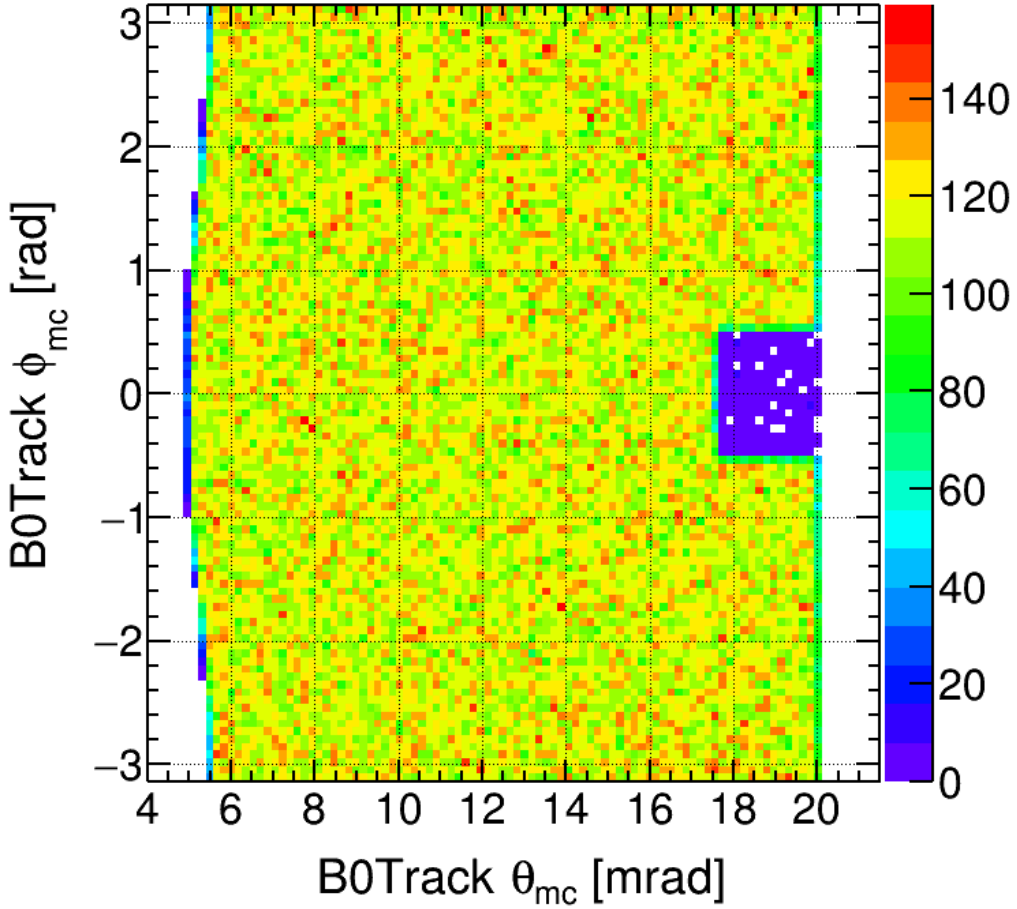
B0 Tracker

Single Proton
80 GeV < E < 120 GeV
5 < θ_{MC} < 20 mrad

Generated



Accepted

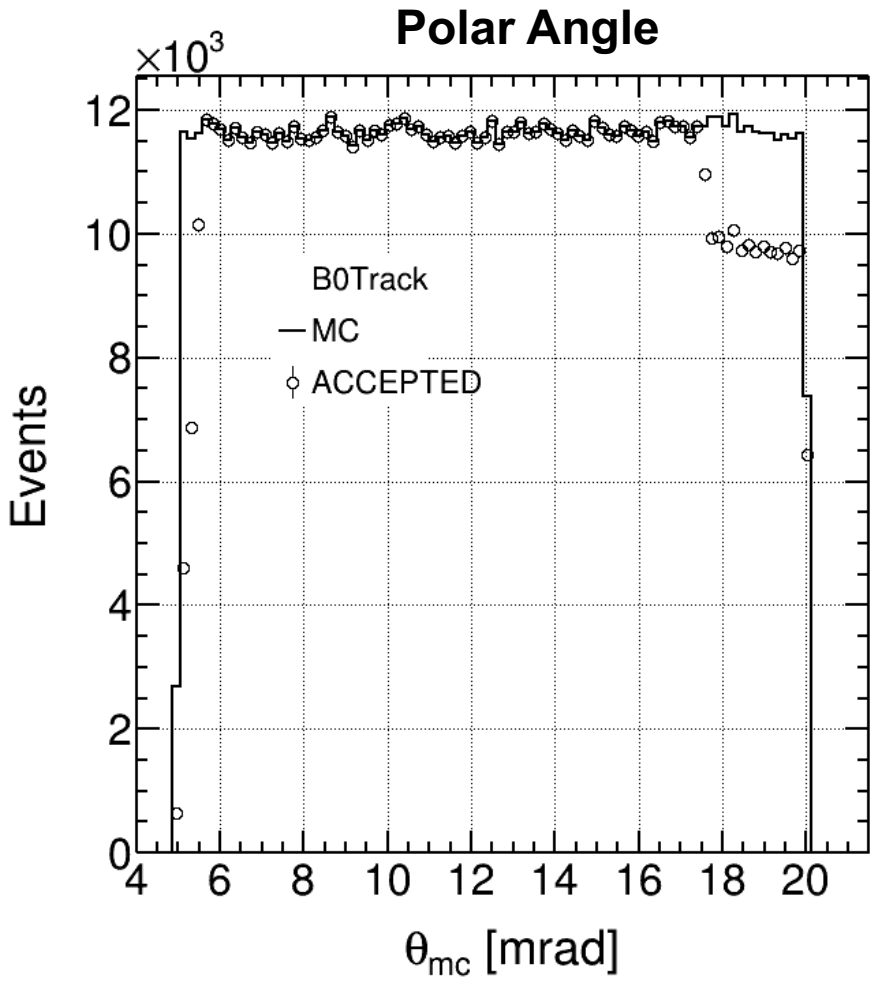


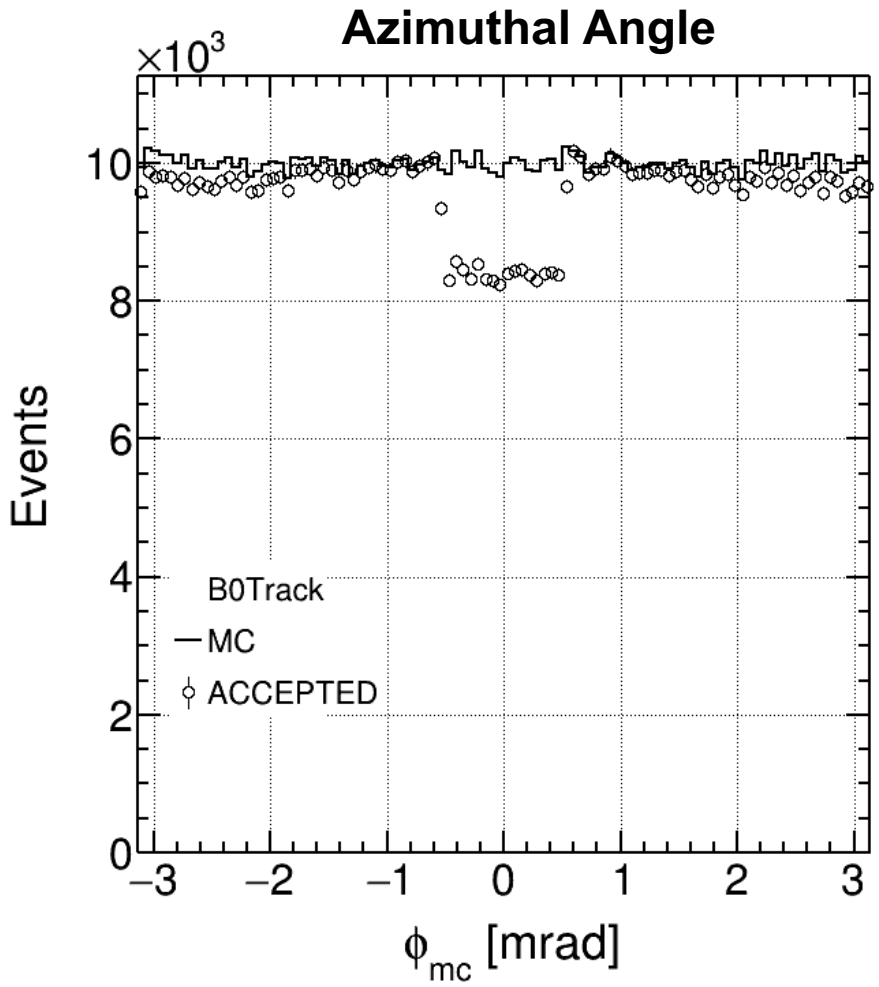
About **95.83 %** events were **accepted**

Hadron lattice in simulation set to be 275 GeV proton

B0 Tracker

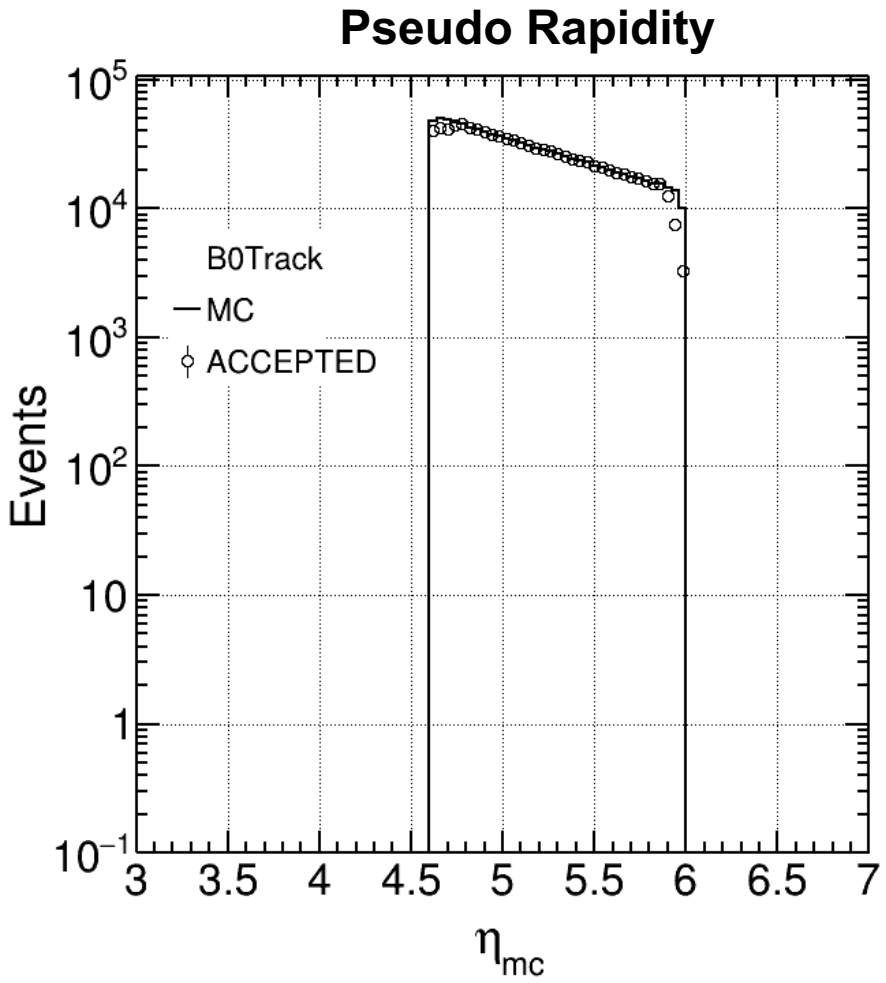
Single Proton
80 GeV < E < 120 GeV
5 < θ_{MC} < 20 mrad

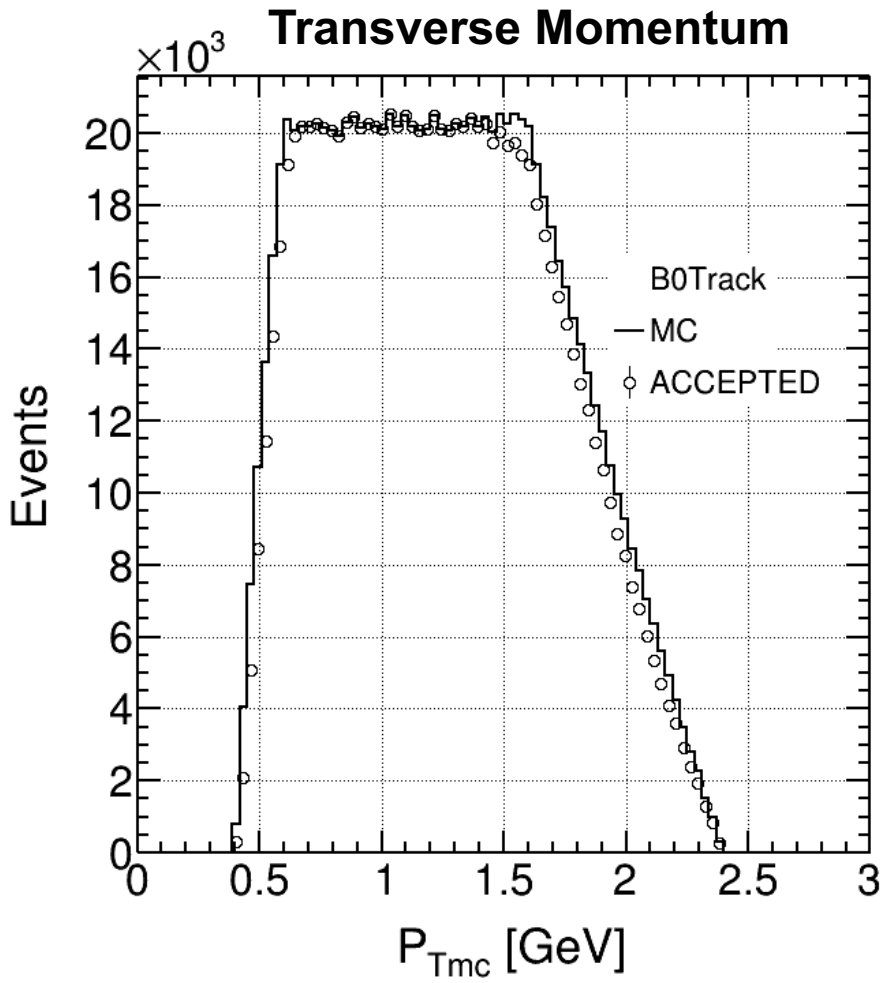




B0 Tracker

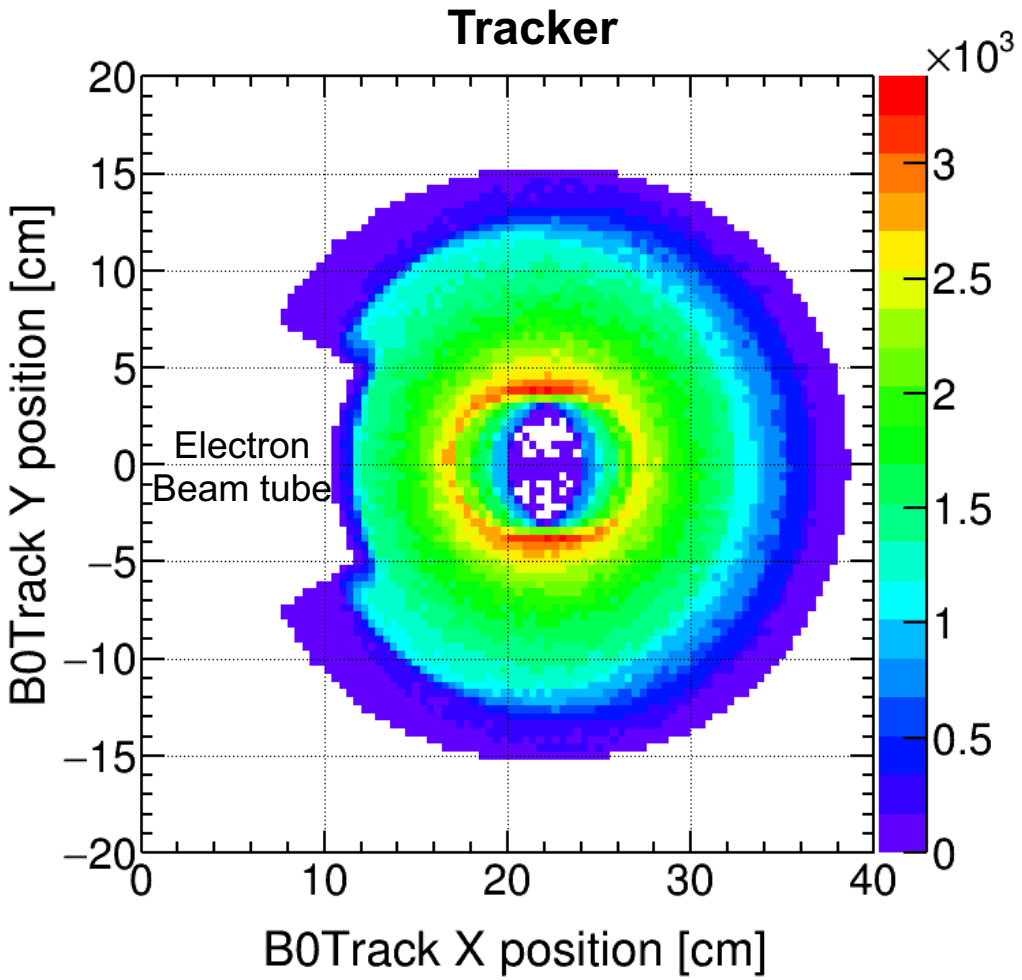
Single Proton
80 GeV < E < 120 GeV
5 < θ_{MC} < 20 mrad

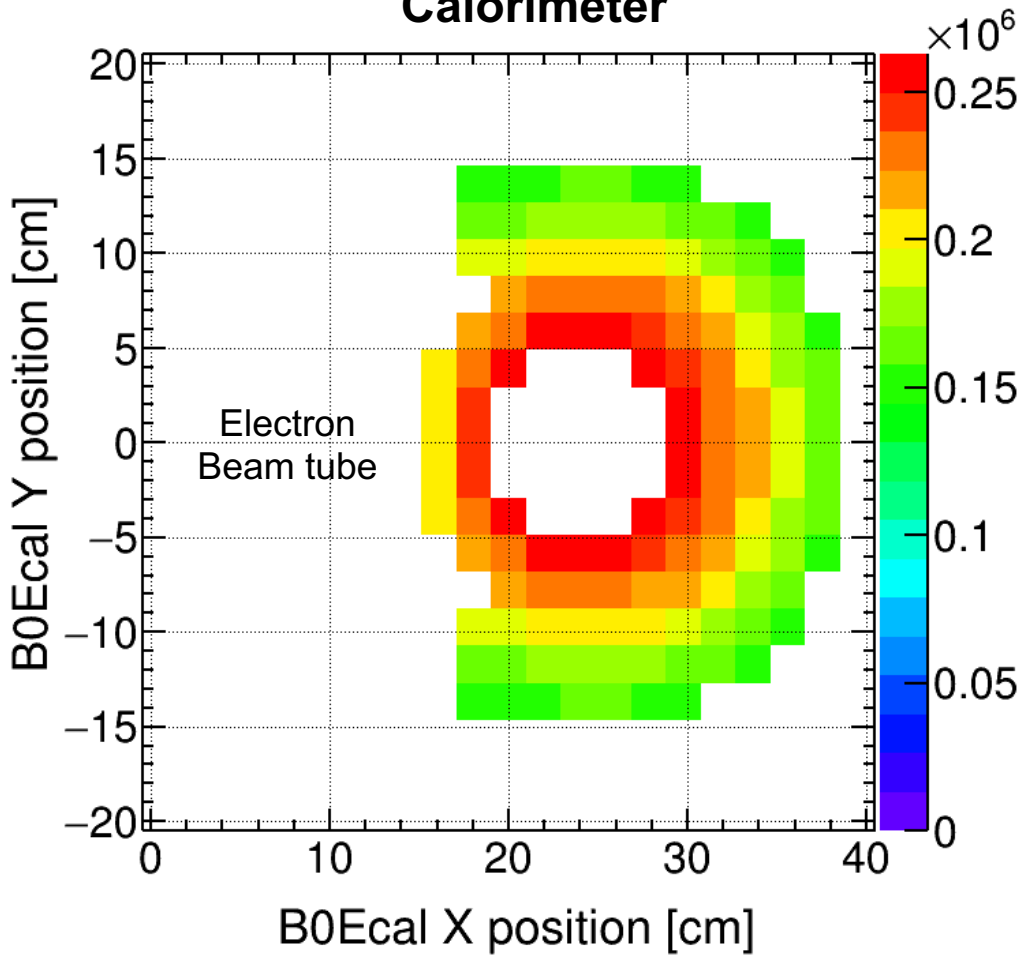




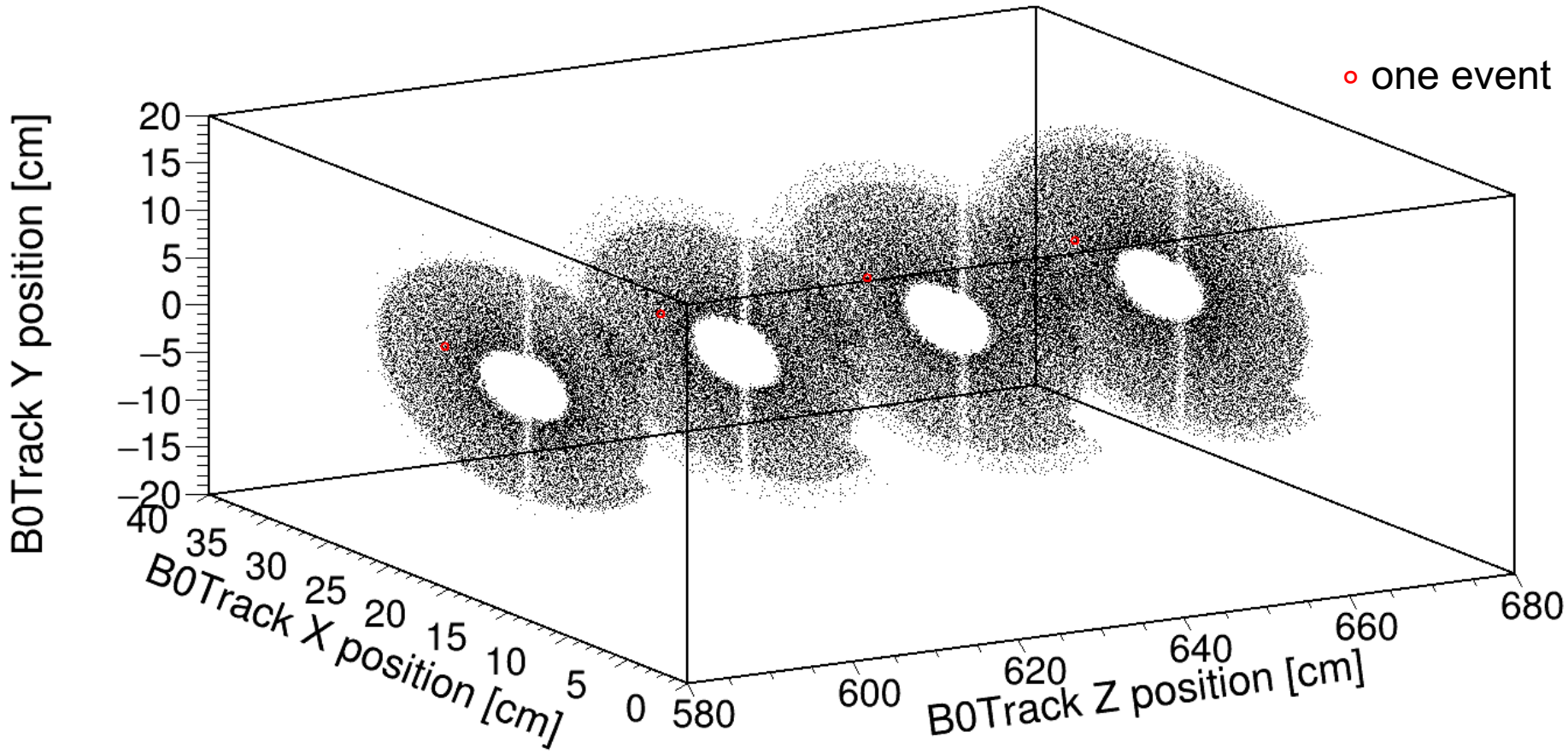
B0 Tracker + Calorimeter

Single Proton
80 GeV < E < 120 GeV
5 < θ_{MC} < 20 mrad



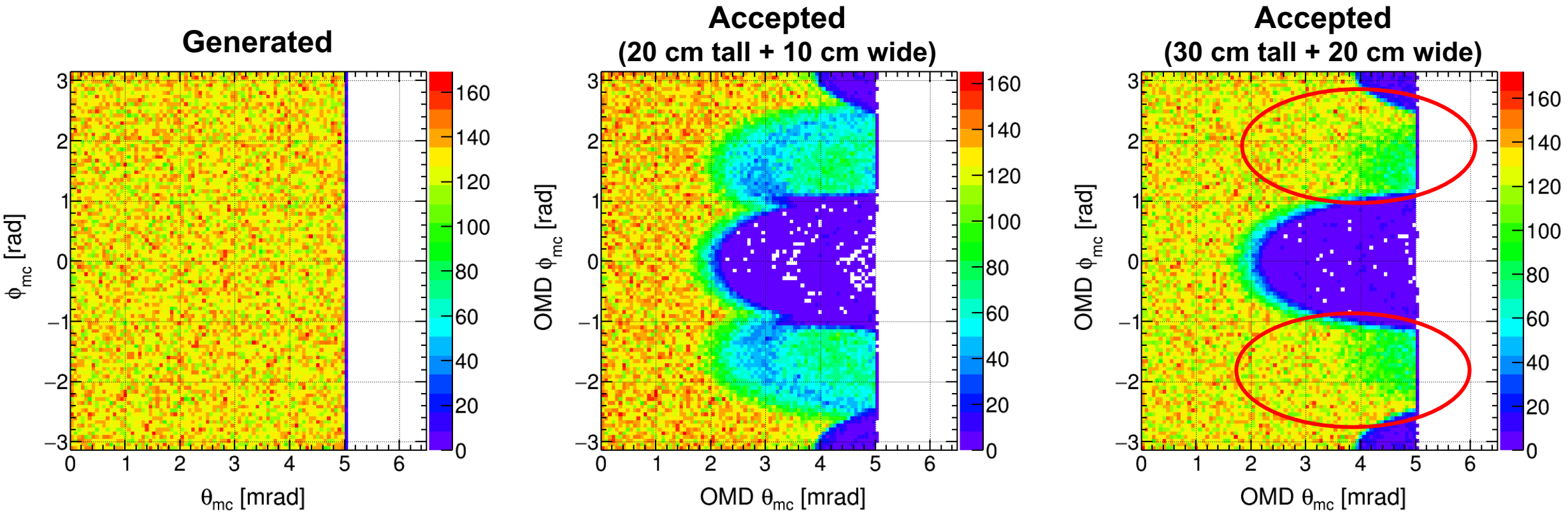


B0 Tracker


one event
B0Track Y position [cm]
20
15
10
5
0
−5
−10
−15
−20
B0Track X position [cm]
40
35
30
25
20
15
10
5
0
B0Track Z position [cm]
580
600
620
640
660
680

Off Momentum Detectors

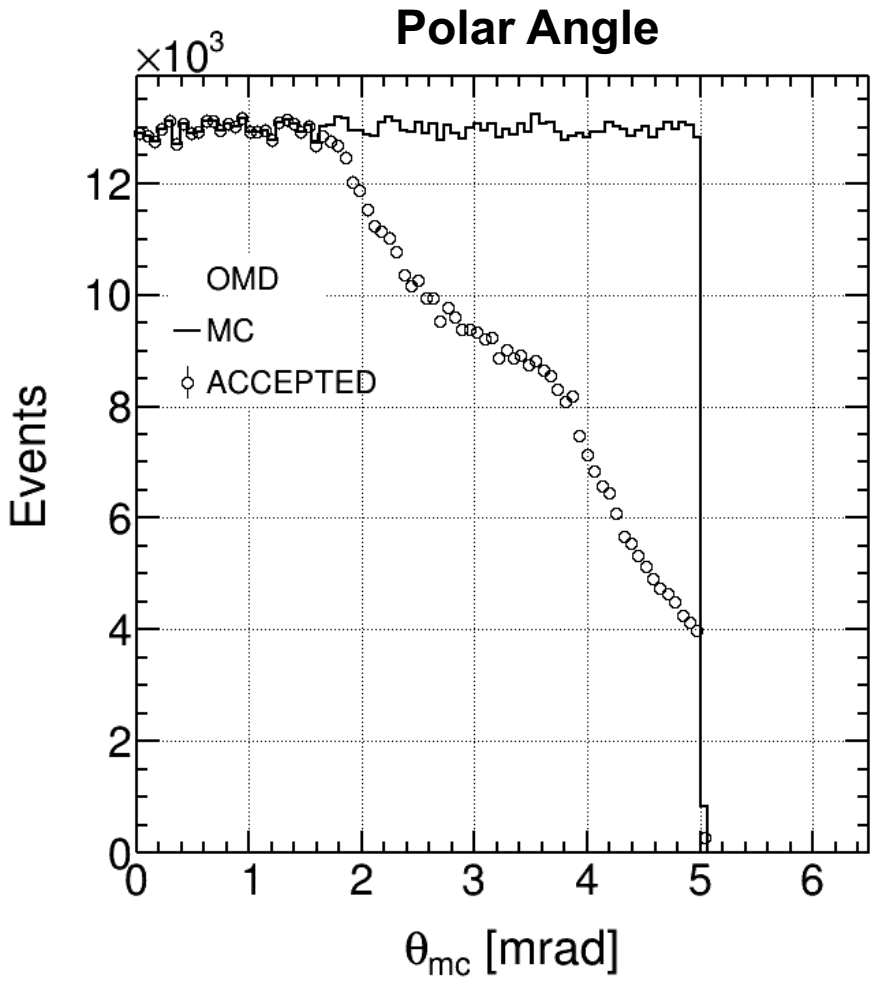
Single Proton
123.75 GeV (45%) < E < 151.25 GeV (55%)
$0 < \theta_{MC} < 5$ mrad

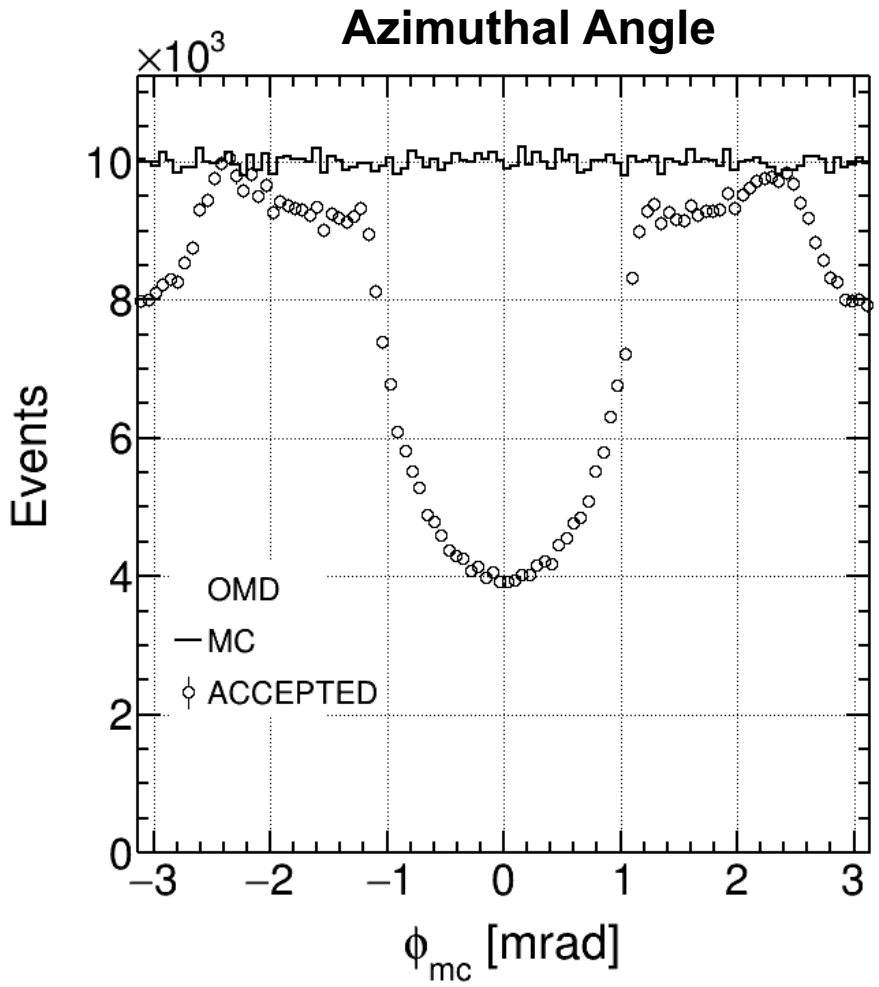


About **64.7 %** to **76.92 %** events were **accepted by stretched plane**
Hadron lattice in simulation set to be 275 GeV proton (Clipping occurs in Quadrupoles for protons)

Off Momentum Detectors

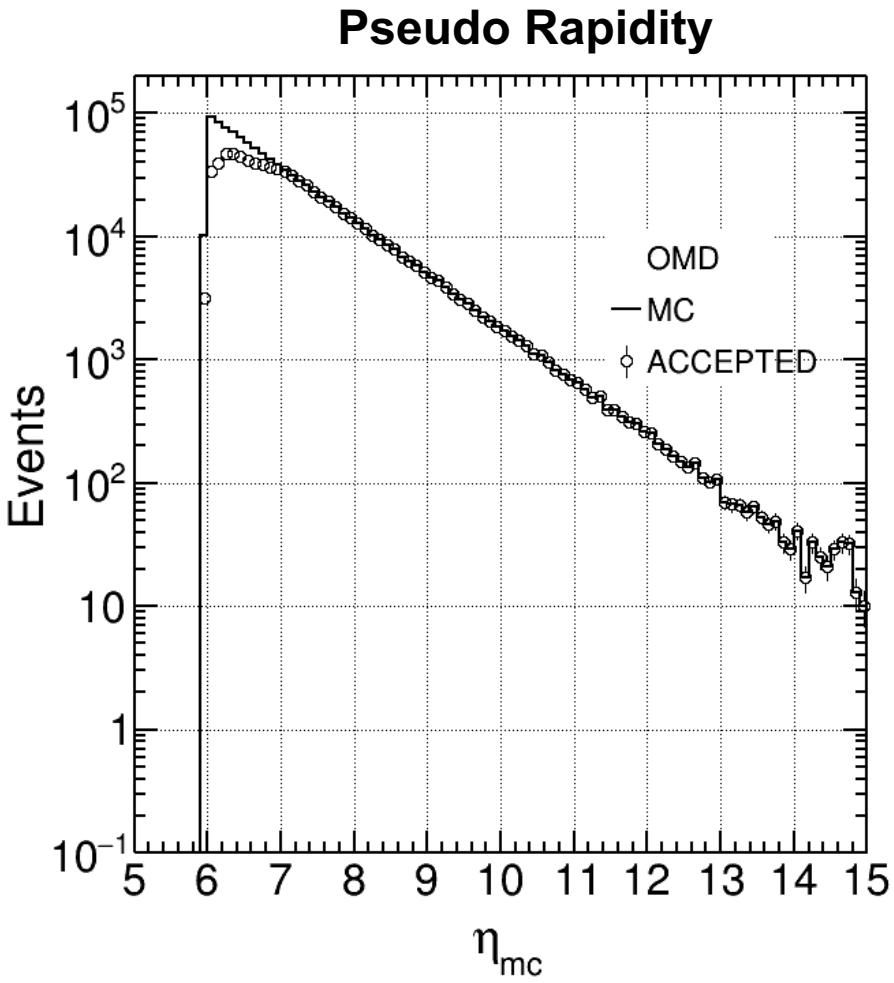
Single Proton
123.75 GeV (45%) < E < 151.25 GeV (55%)
$0 < \theta_{MC} < 5$ mrad

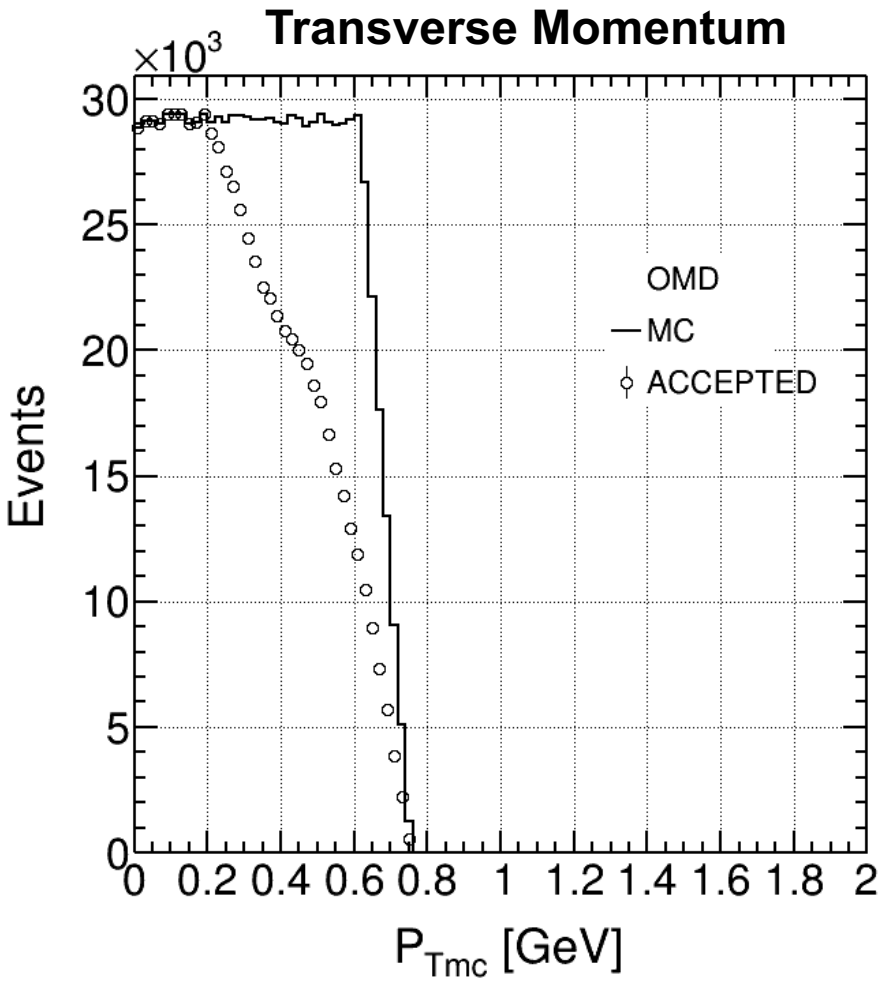




Off Momentum Detectors

Single Proton
123.75 GeV (45%) < E < 151.25 GeV (55%)
$0 < \theta_{MC} < 5$ mrad





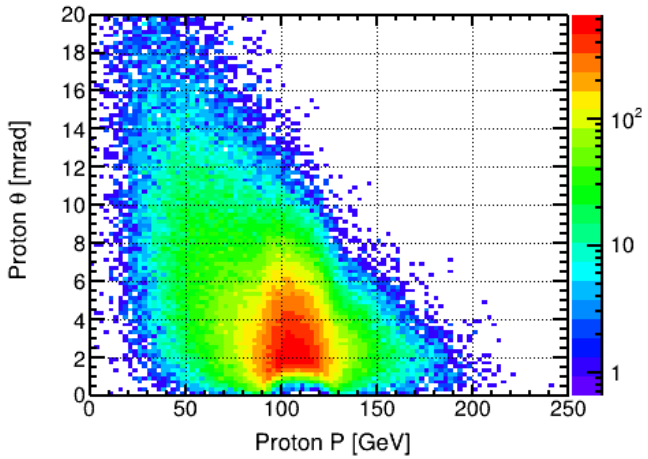
Approach – Incoherent Tagging Power

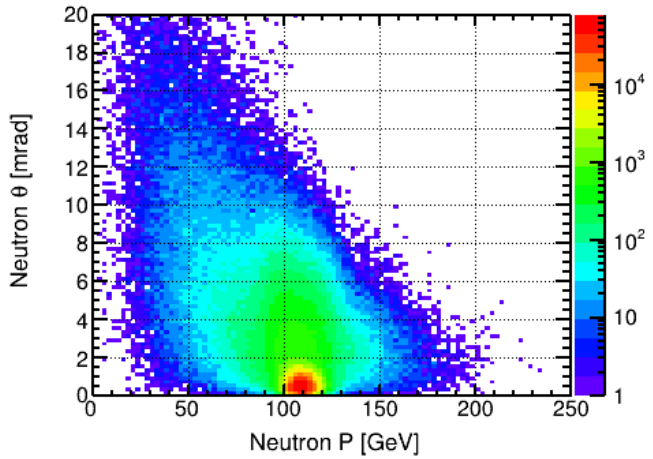
- Used **BeAGLE** 350k events with **$1 < Q^2 < 10$**
  - **ePb 18×110 GeV incoherent diffractive $J/\psi(\mu\mu)$ events** $ePb \rightarrow e' + J/\psi(\mu\mu) + X$ (S3/eictest/EPIC/EVGEN/EXCLUSIVE/DIFFRACTIVE_JPSI_ABCONV/BeAGLE/ePb_18x108.41_tau10_B1.1_Jpsi_highstats/ePb_18x108.41_tune3_tau10_B1.1_extracted_Jmu_1-9.hepmc)
  - Through **afterburner** : applied **crossing angle 35 mrad** and beam parameters as in **IP6 eAu from EIC CDR table 3.5**
- Discarded events having **more than one electrons in final state within η < -1**
- Calculated **10σ radial cut** based on **IP6 eAu** from **EIC CDR table 3.5**
  - $R_{10\sigma}$ ~ 3.89526 mm
- **Tagging power *no central detector yet***
  - B0 Tracker at least two out of four layers have registered RAW hits
  - OMD all four layers have registered RAW hits
  - ZDC any registered RAW hits in either ECAL and HCAL
  - RPSF one layer (closet to 2nd focus) has registered RAW hits outside **10σ**

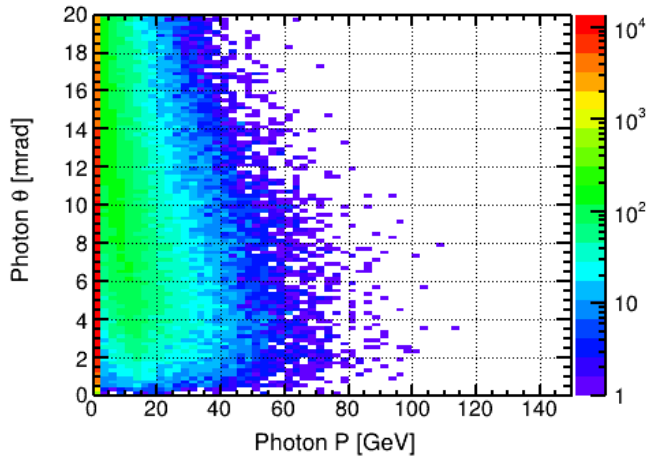
Nuclear Breakups Distribution

BeAGLE 18x110 GeV^2
Incoherent events
$ePb \rightarrow e' + J/\psi(\mu\mu) + X$

Generated Level	Nuclear Breakups at Final State	Number of Events
	Only Neutrons	7.55 %
	Only Protons	0.0 %
	Only Photons	3.23 %
	Neutrons + Protons	3.28 %
	Neutrons + Photons	43.97 %
	Protons + Photons	2.24 %
	Neutrons + Protons + Photons	39.73 %

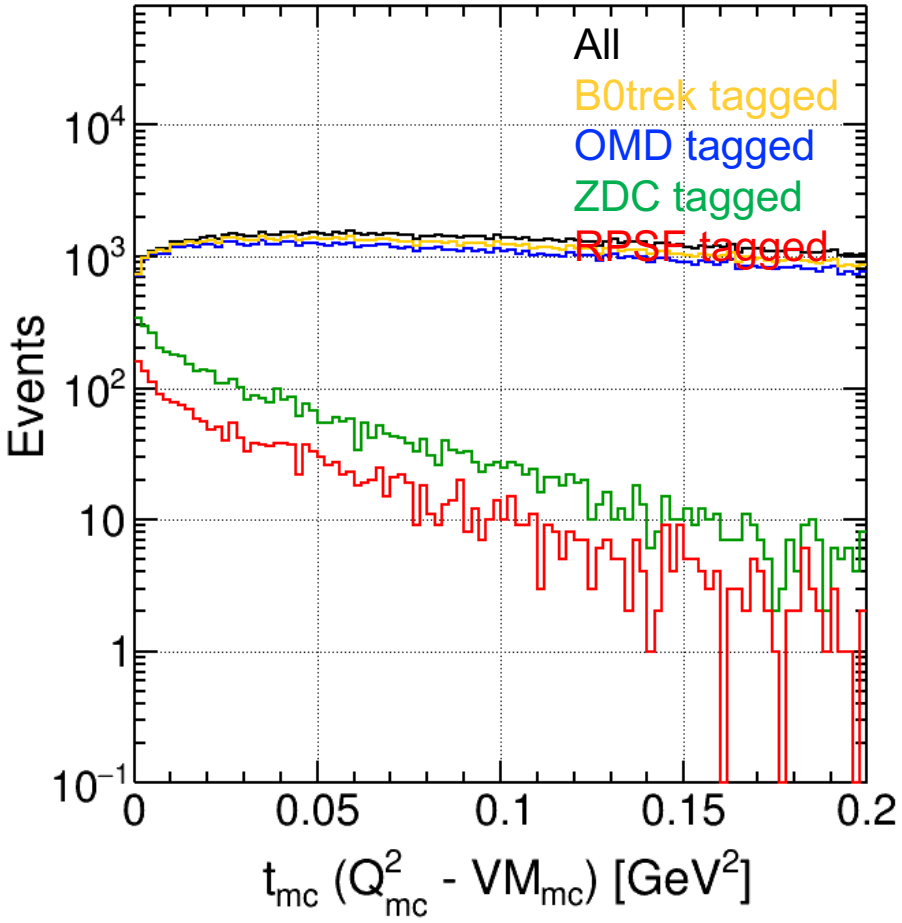




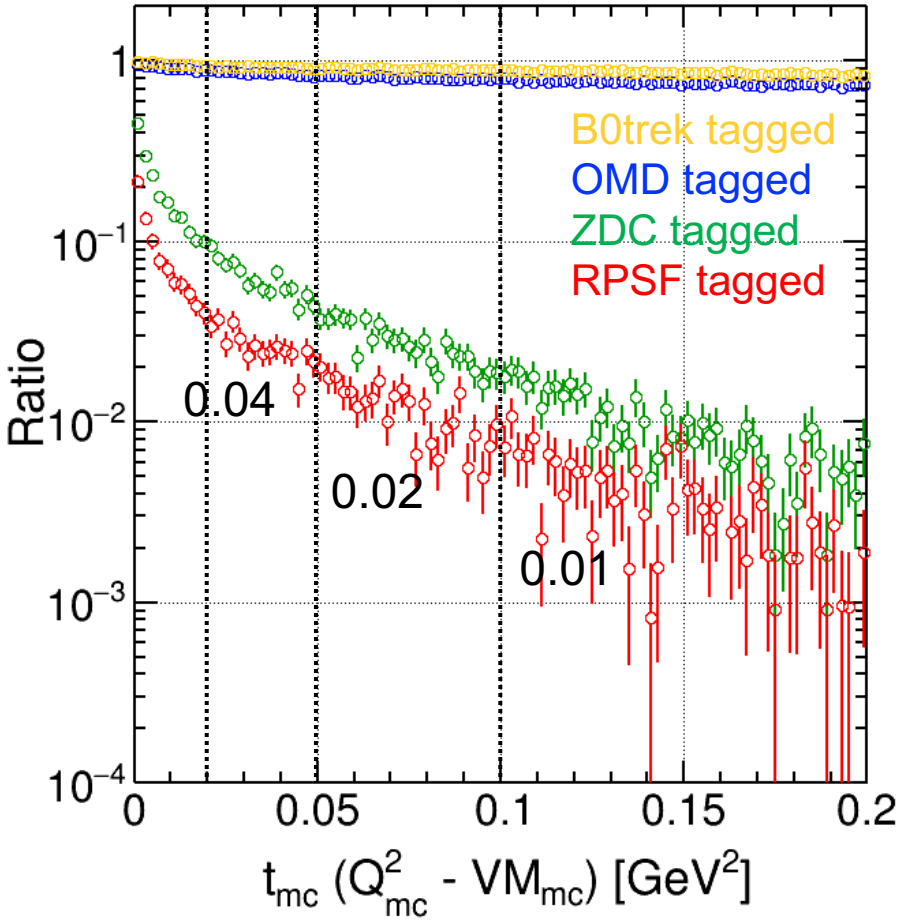


t distribution

BeAGLE 18x110 GeV^2
Incoherent events
$ePb \rightarrow e' + J/\psi(\mu\mu) + X$



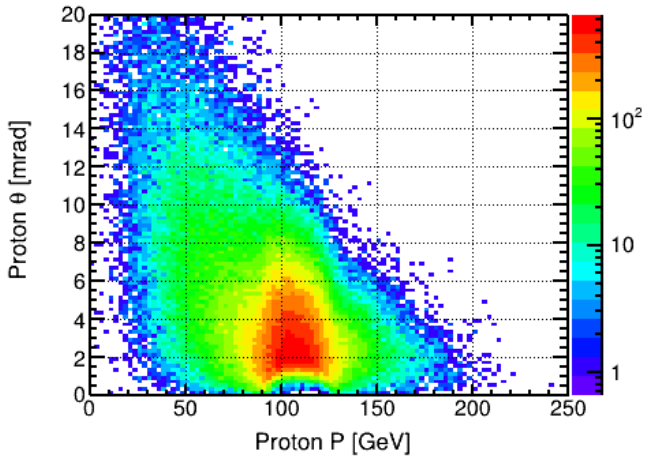
Coherent diffractive minima

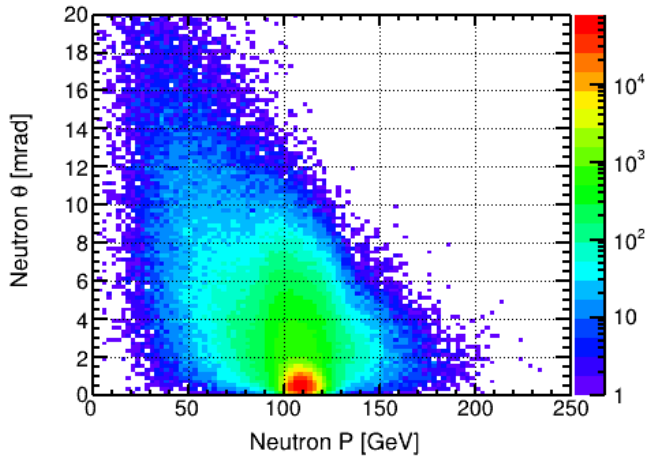


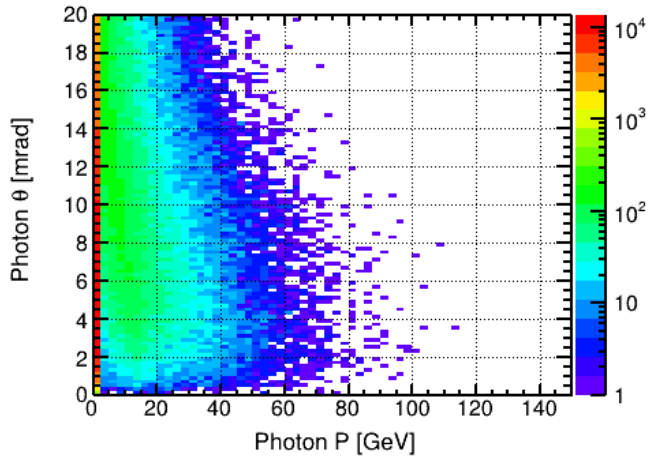
Nuclear Breakups Distribution

BeAGLE 18x110 GeV^2
Incoherent events
$ePb \rightarrow e' + J/\psi(\mu\mu) + X$

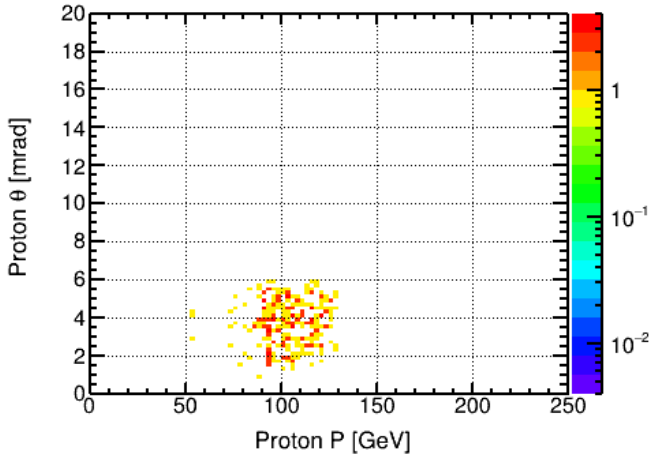
Generated Level

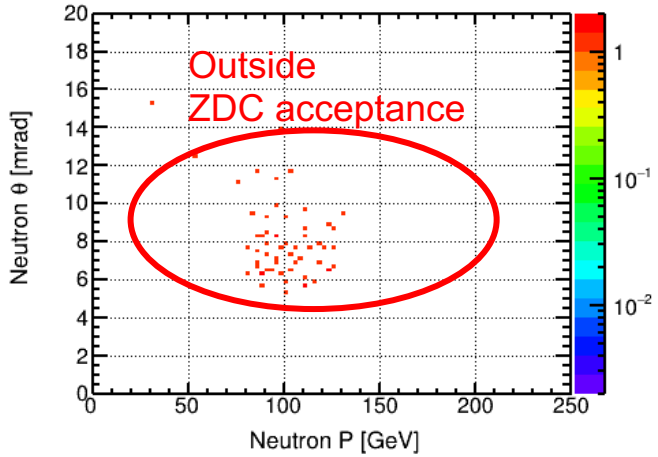


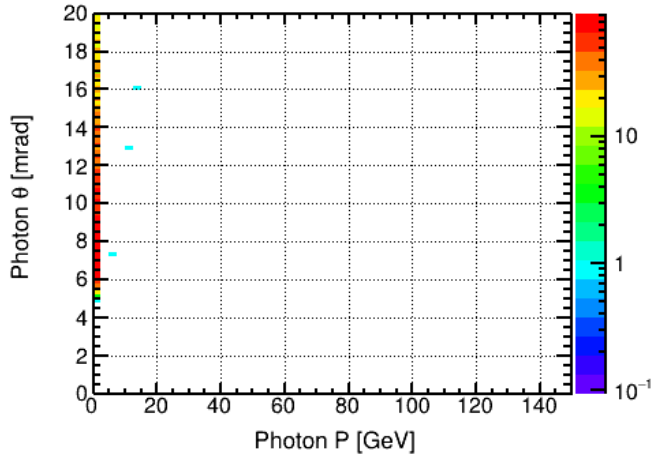




Remained Level

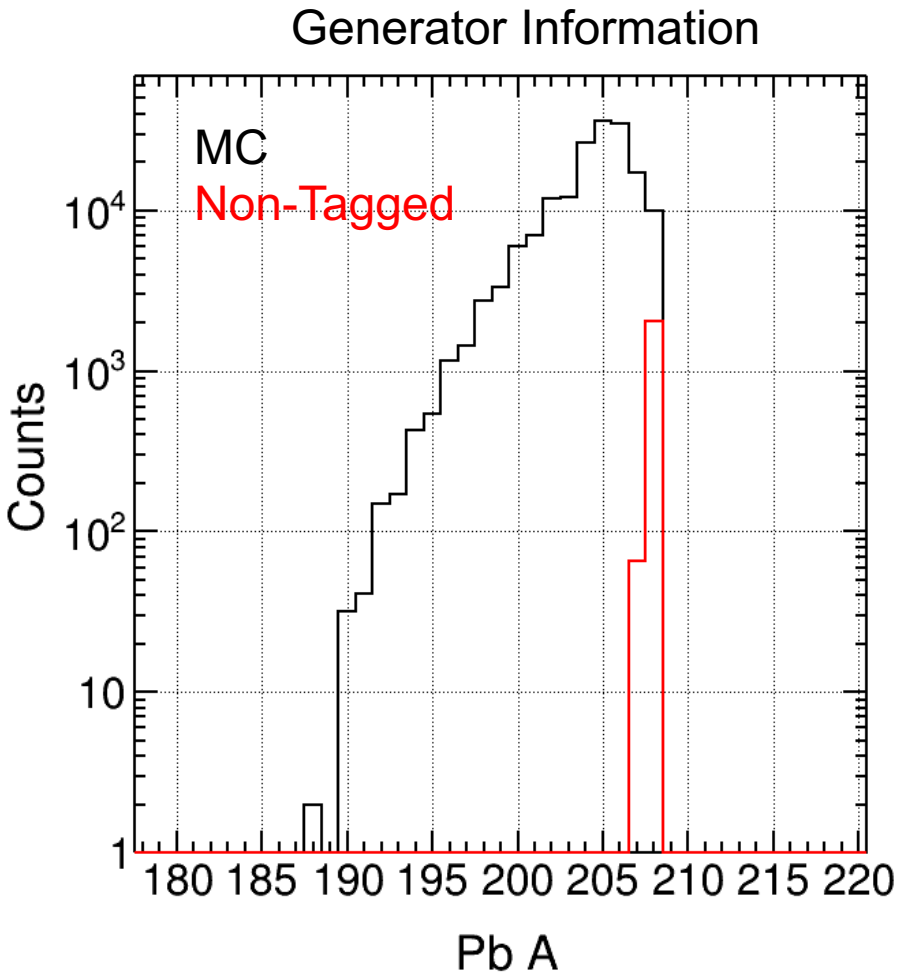


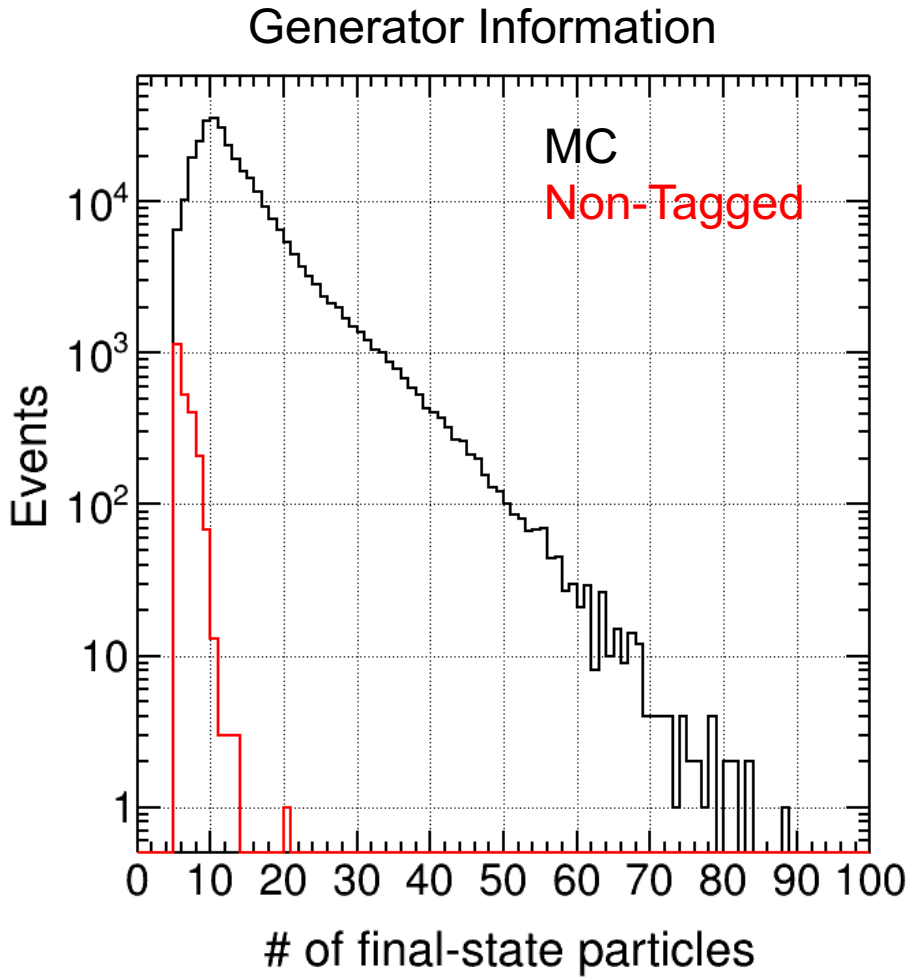




Remaining Events

BeAGLE 18x110 GeV^2
Incoherent events
$ePb \rightarrow e' + J/\psi(\mu\mu) + X$

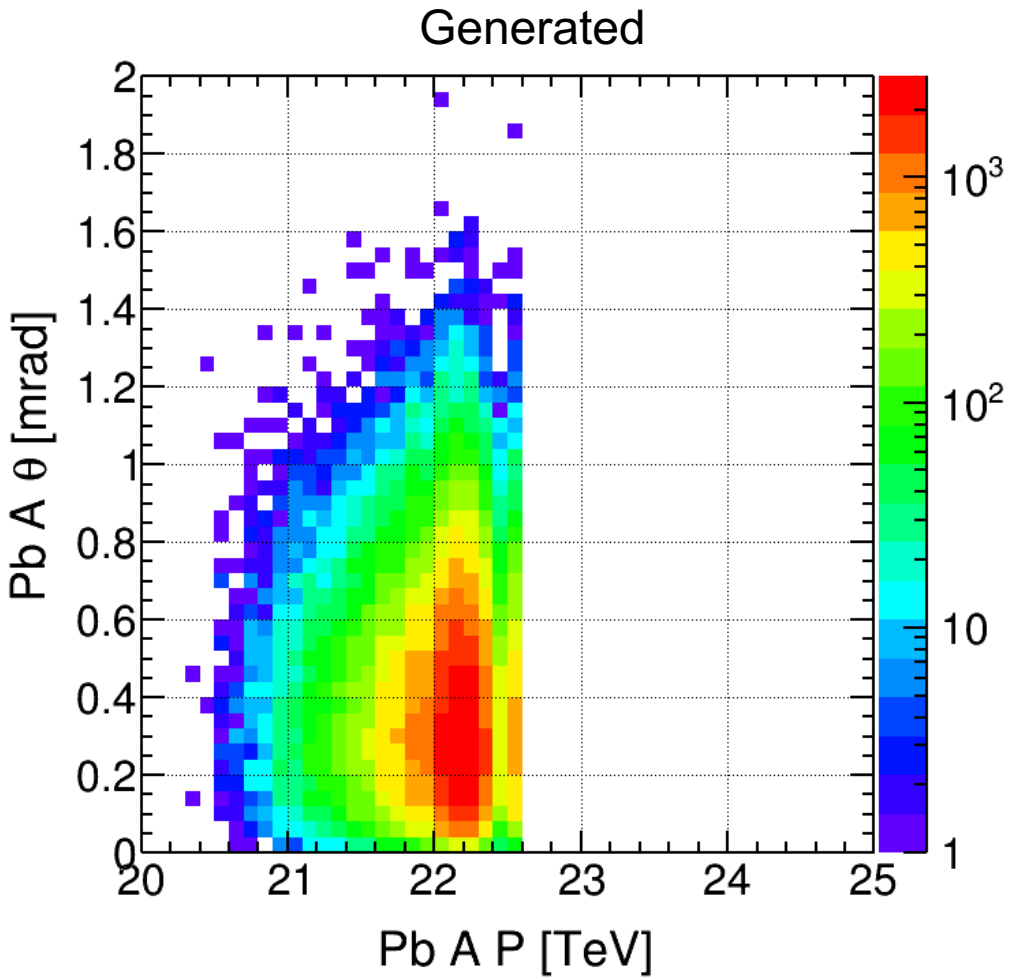


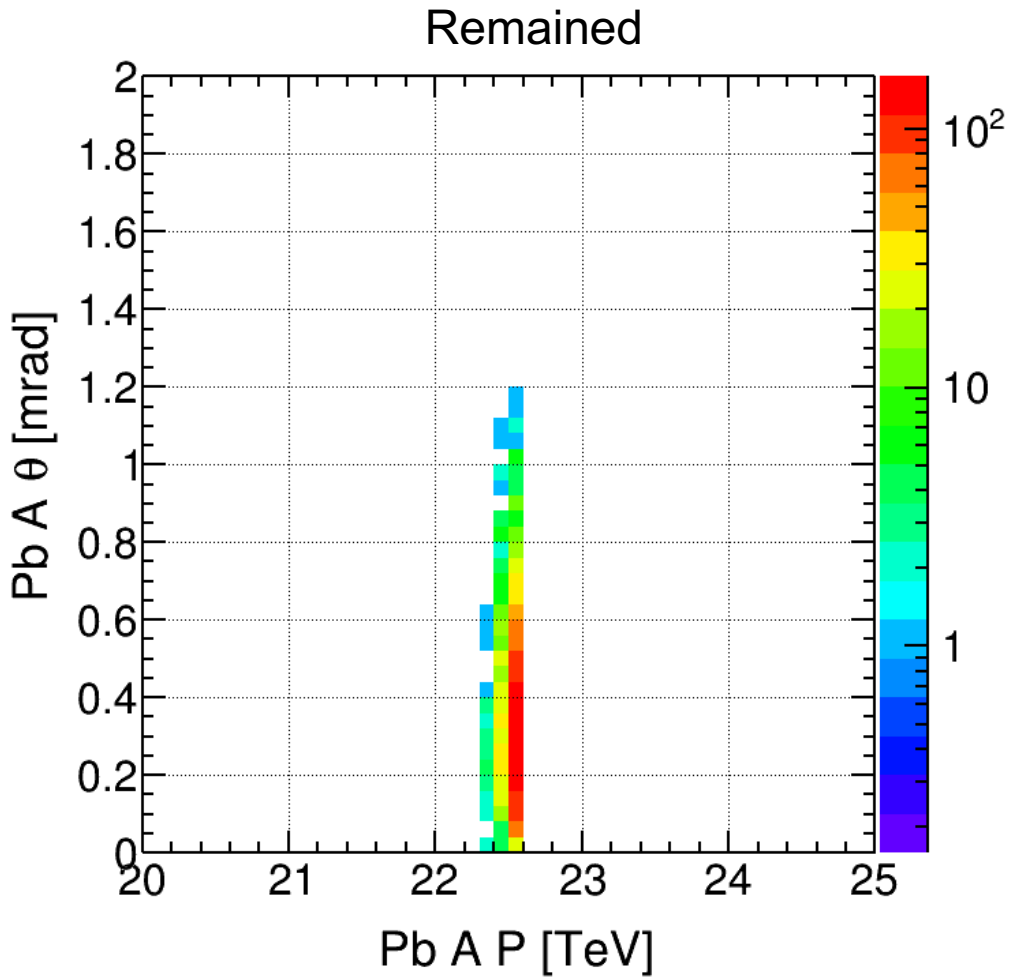


Remaining events have higher mass nuclear remnants and low number of particles in final state

Remaining Events

BeAGLE 18x110 GeV^2
Incoherent events
$ePb \rightarrow e' + J/\psi(\mu\mu) + X$

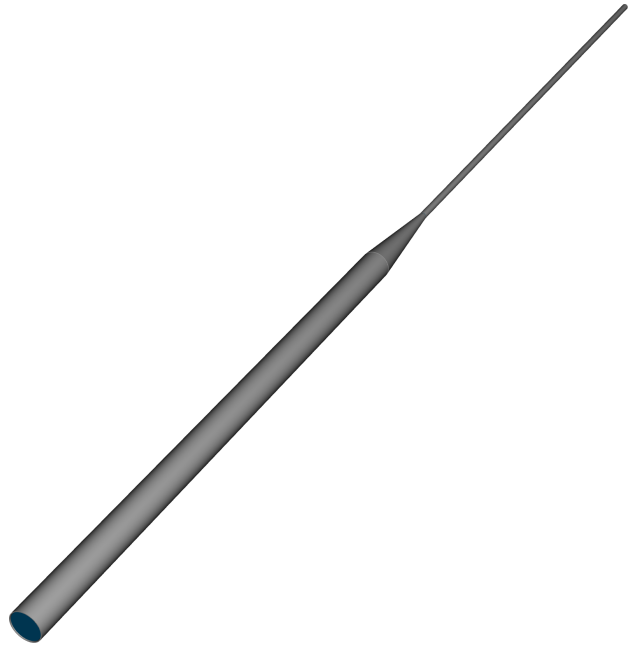




Remaining events have very small scattering angle

Summary and What Are Next Steps

- Added B0 spectrometer (tracker) to tag protons ***Need to look deeper***
- Given current layout, looked at incoherent event on tagging power with $1 < Q^2 < 10$ and $t < 0.2$
  - Tagging power ~ 96%, 98%, and 99% at t ~ 0.02, 0.05, and 0.1



- ❑ **Keep looking carefully in B0 and RPSF**
- ❑ **Look at B0 photon acceptance/tagging**
- ❑ **Add simplified beampipe in DD4hep** to quantify impact on acceptance/efficiency
- ❑ ***Access true particle ID** to cluster raw hits

BackUp Slide

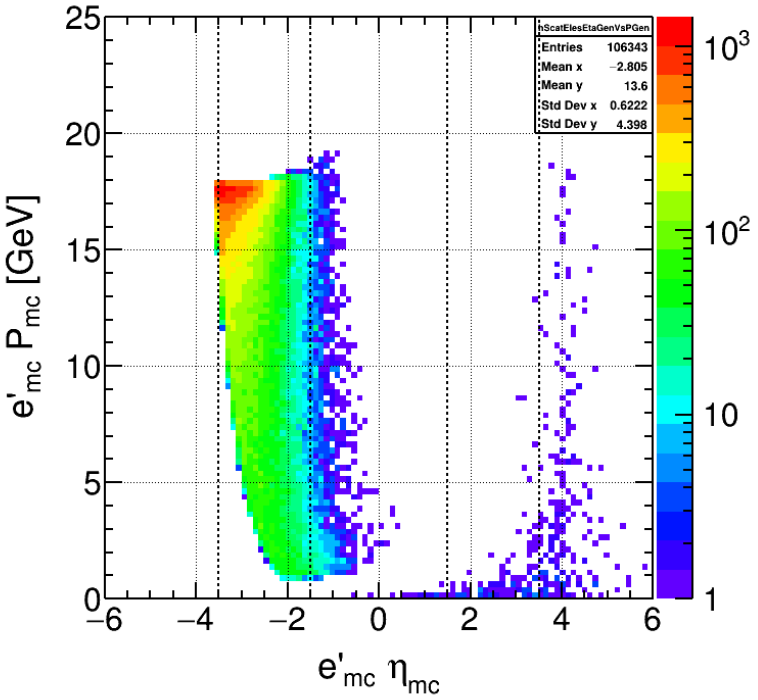
Candidates for e’

Final-state Electrons

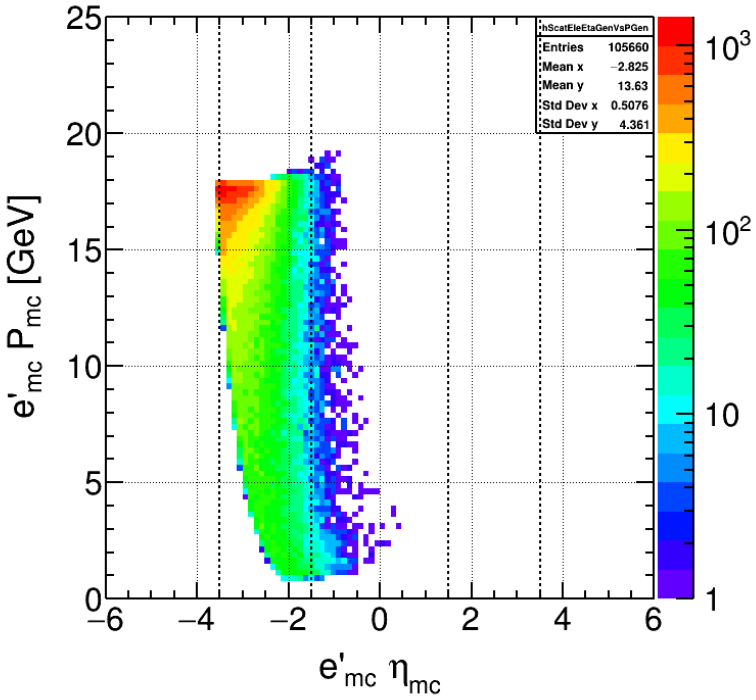
BeAGLE 18x110 GeV^2
Incoherent events
$ePb \rightarrow e' + J/\psi(\mu\mu) + X$

Within BeAGLE incoherent J/ψ events, there can be multiple electrons in final-state
If there are multiple electrons, take electron having less than -1 in rapidity
However, more than one electron heading backward (η < -1), then discard for now

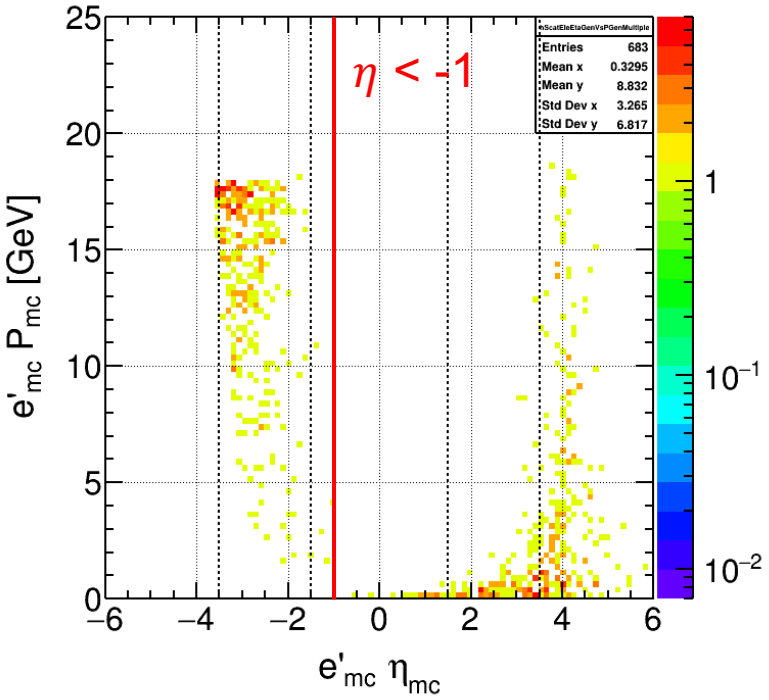
All Electrons



Only One Electron



More than One Electron

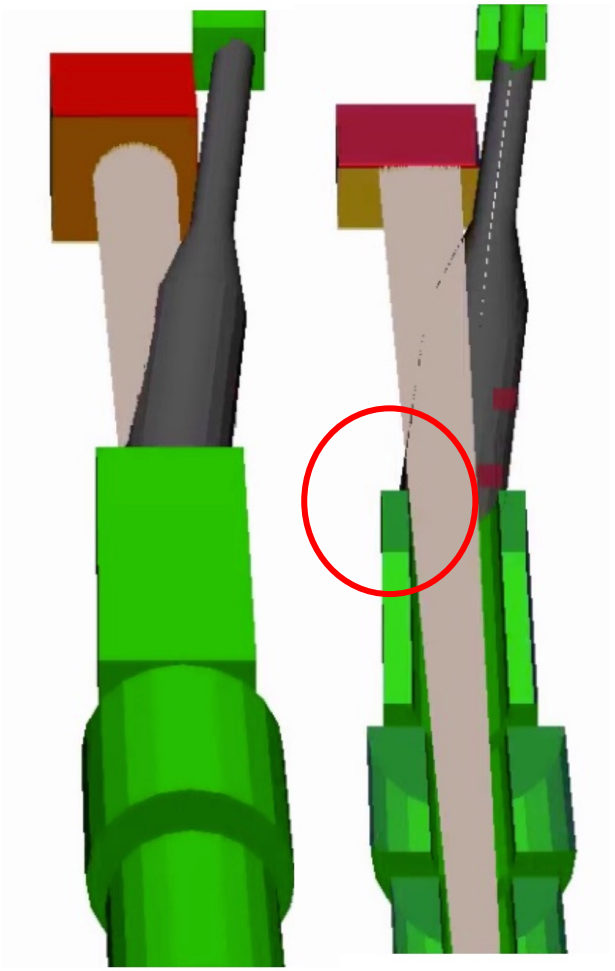


Clipping on Acceptance of Far-Forward

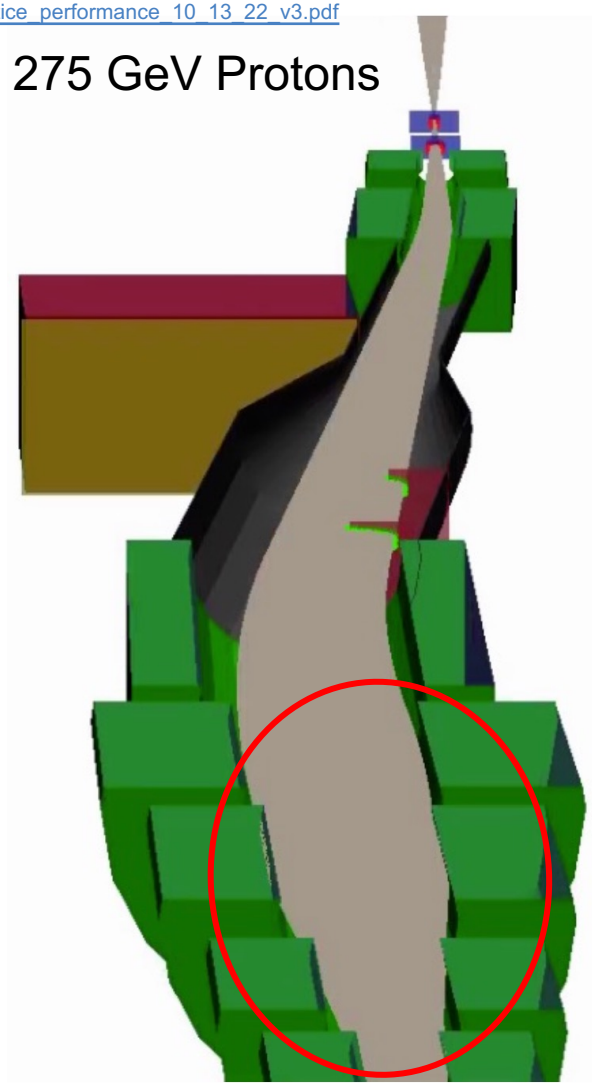
Kindly Provided by Alex Jentsch using EicRoot Simulation Event Display

Reference from https://wiki.bnl.gov/eic-detector-2/images/8/86/IP8_HSR_lattice_performance_10_13_22_v3.pdf

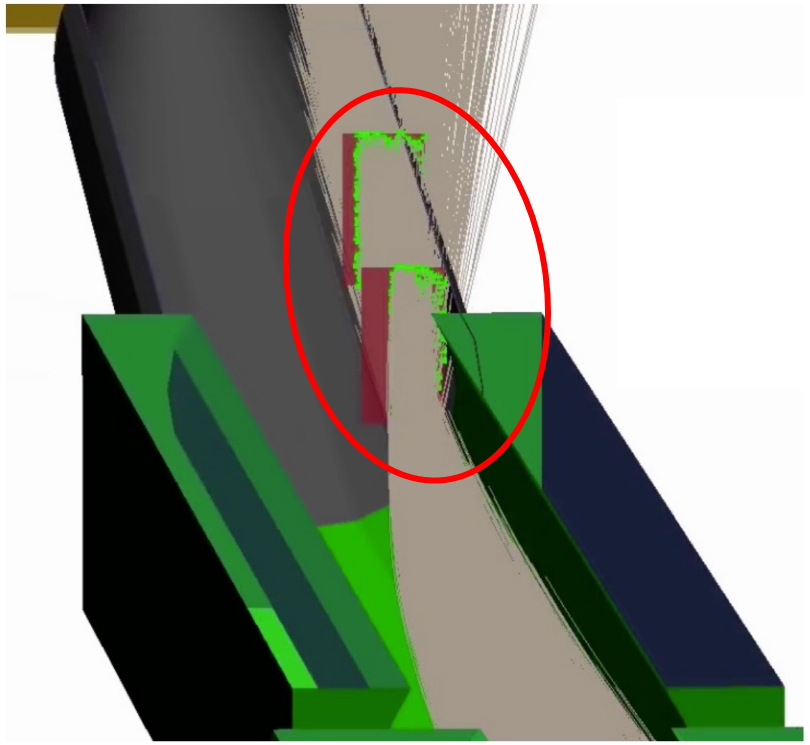
275 GeV Neutrons



275 GeV Protons



123.75 – 151.25 GeV Protons

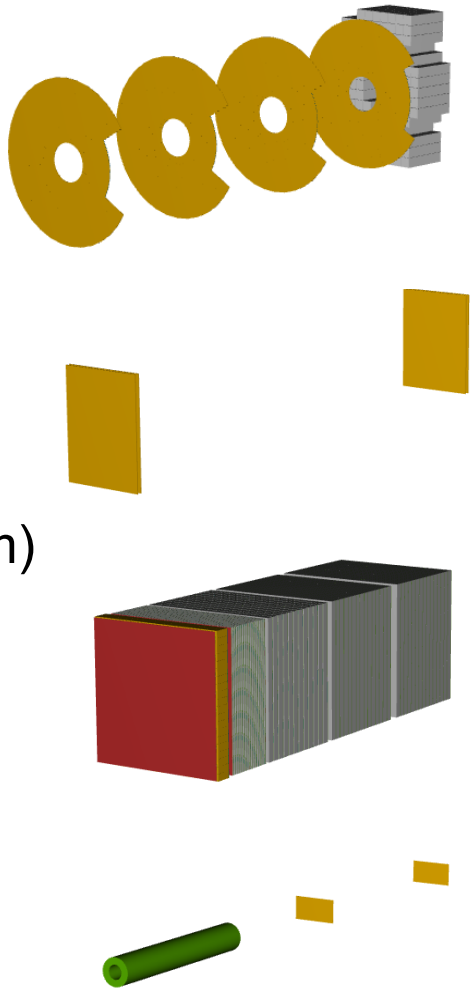


DD4hep simulation event display was not successful…

IP8 Far-Forward Detectors

Implemented in **IP6 detector configuration**

- **B0 Spectrometer (Tracker + Calorimeter)** ***flipped***
  - 4 tracker planes and 10 cm long crystal module
  - Placed at z = 0.06 m
- **Off Momentum Detector (OMD)**
  - 40 cm tall and 30 cm wide
  - Placed at (x, z) = (0.723133 m, 25.9359 m) and (0.702435 m, 27.9363 m)
- **Zero Degree Calorimeter (ZDC)**
  - 2 meter-long and 60 × 60 cm^2
  - Placed at (x, z) = (1.3798 m, 35.4293 m front)
- **Roman Pot at Secondary Focus (RPSF)**
  - 14 cam tall and 26 cm wide
  - Placed at (x, z) = (1.00603 m, 43.9339 m) and (1.03788 m, 45.4337 m)

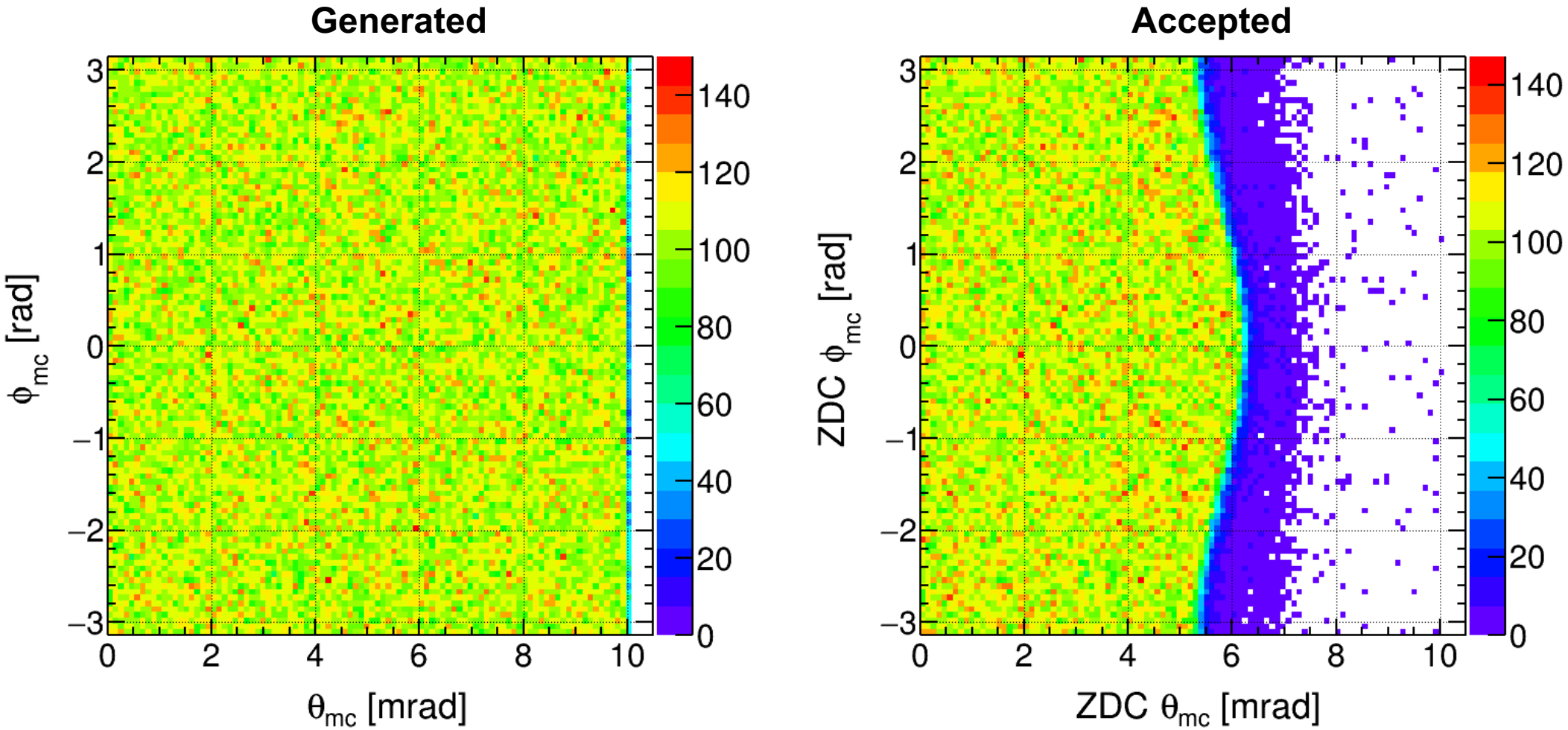


Approach – Acceptance

- **Far-Forward region**
  - Particles with θ **< ~ 37 mrad (2.1°)**
  - **Tag charged hadrons** (protons) or **neutral particles** (neutrons, photons)
- **Single particle simulation**
  - **B0 Tracker + Calorimeter**
    - Proton energy: 25 GeV < E_p < 55 GeV and **5 < θ_{MC} < 20 mrad**
    - Proton energy: 80 GeV < E_p < 120 GeV and **5 < θ_{MC} < 20 mrad**
    - Photon energy: GeV < E_γ < GeV and **5 < θ_{MC} < 20 mrad**
  - **Off-Momentum Detector** for detecting protons from nuclear breakup
    - Proton energy: 123.75 GeV (45%) < E_p < 151.25 GeV (55%) and **0 < θ_{MC} < 5 mrad**
  - **Zero Degree Calorimeter** for detecting photons and neutrons
    - Neutron energy: E_n = 275 GeV (***θ_{MC} < 10 mrad**)
  - **Roman Pot at Secondary Focus** for detecting charged particles from nuclear breakup
    - Proton energy: E_p = 275 GeV and **0 < θ_{MC} < 5 mrad**

Zero Degree Calorimeter

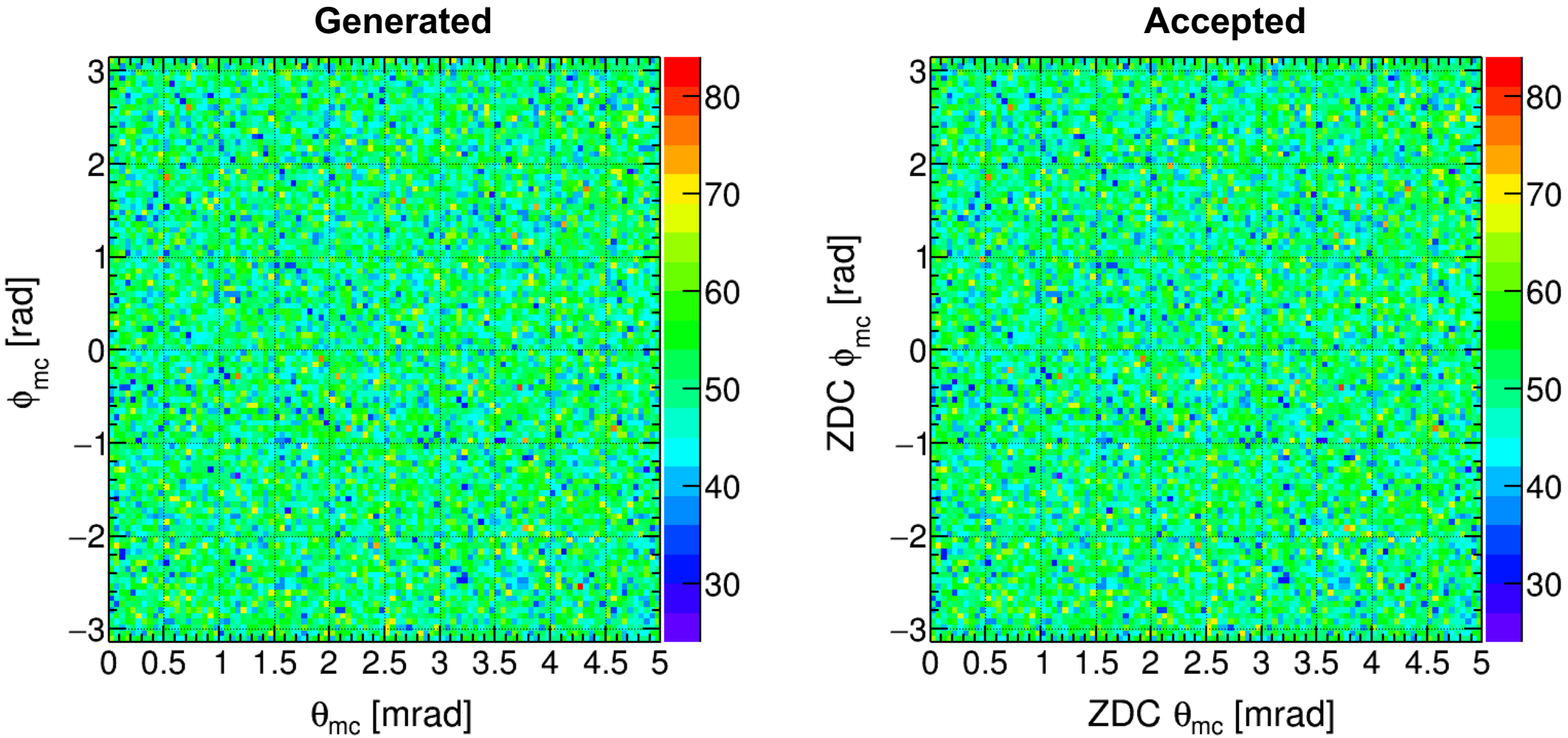
Single Neutron
E = 275 GeV
$0 < \theta_{MC} < 10$ mrad



About 99.98 % events were accepted (θ_{MC} < 5 mrad)
Clipping occurs in dipole before ZDC for neutrons

Zero Degree Calorimeter

Single Neutron
E = 275 GeV
$0 < \theta_{MC} < 5$ mrad



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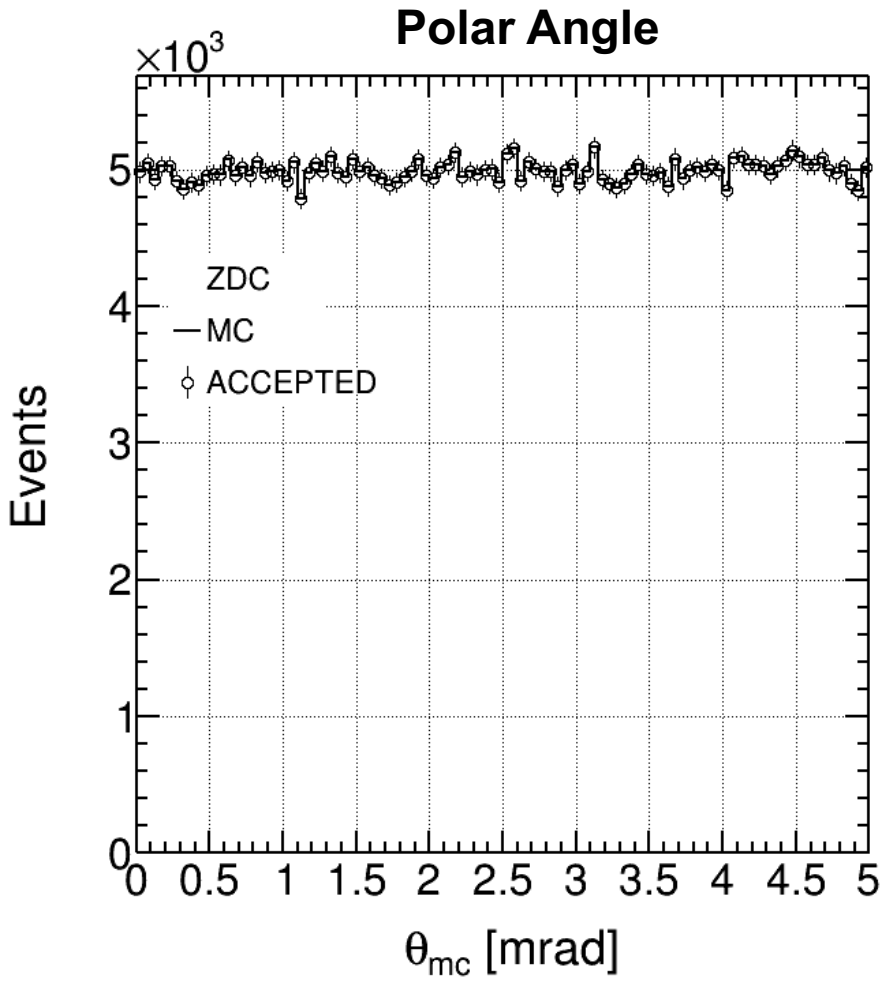
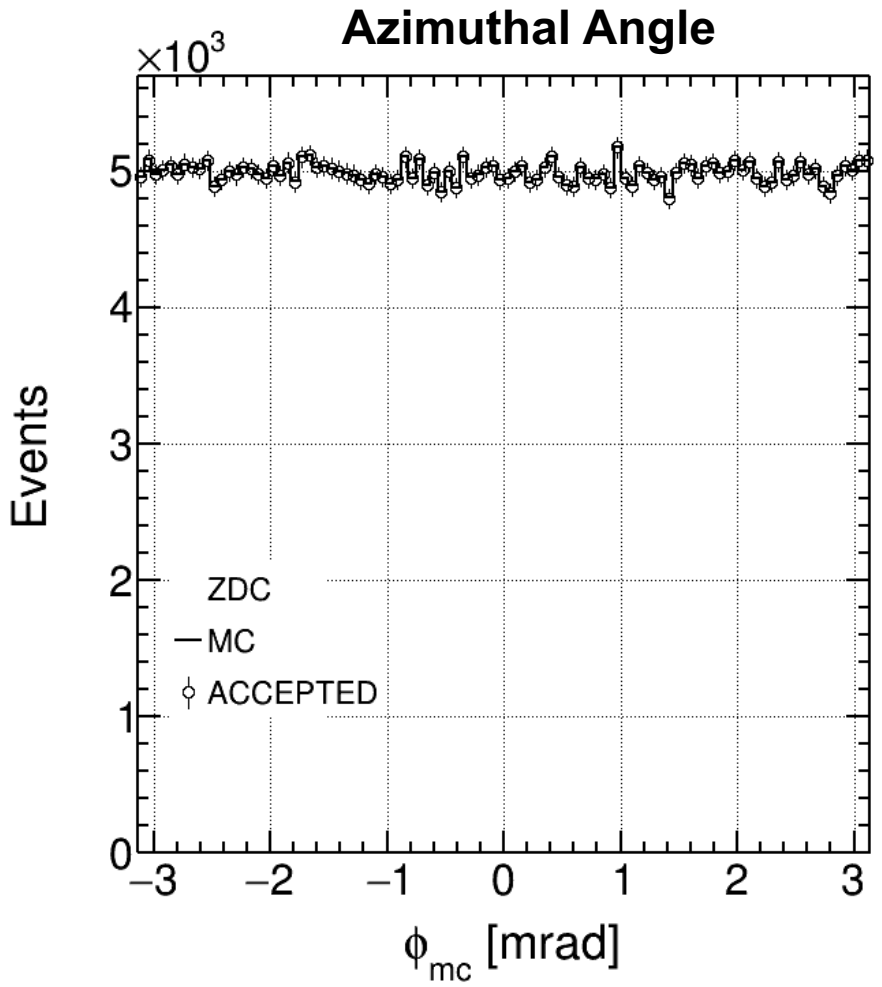
Zero Degree Calorimeter

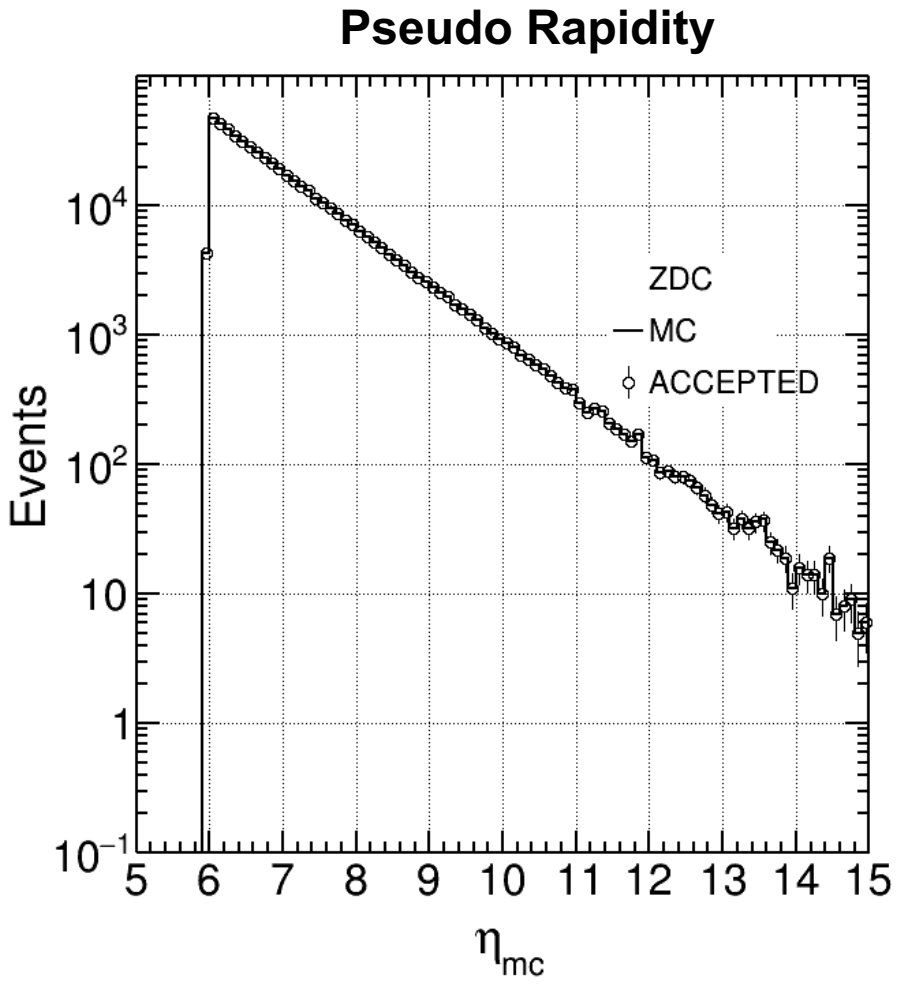
Single Neutron
E = 275 GeV
$0 < \theta_{MC} < 5$ mrad

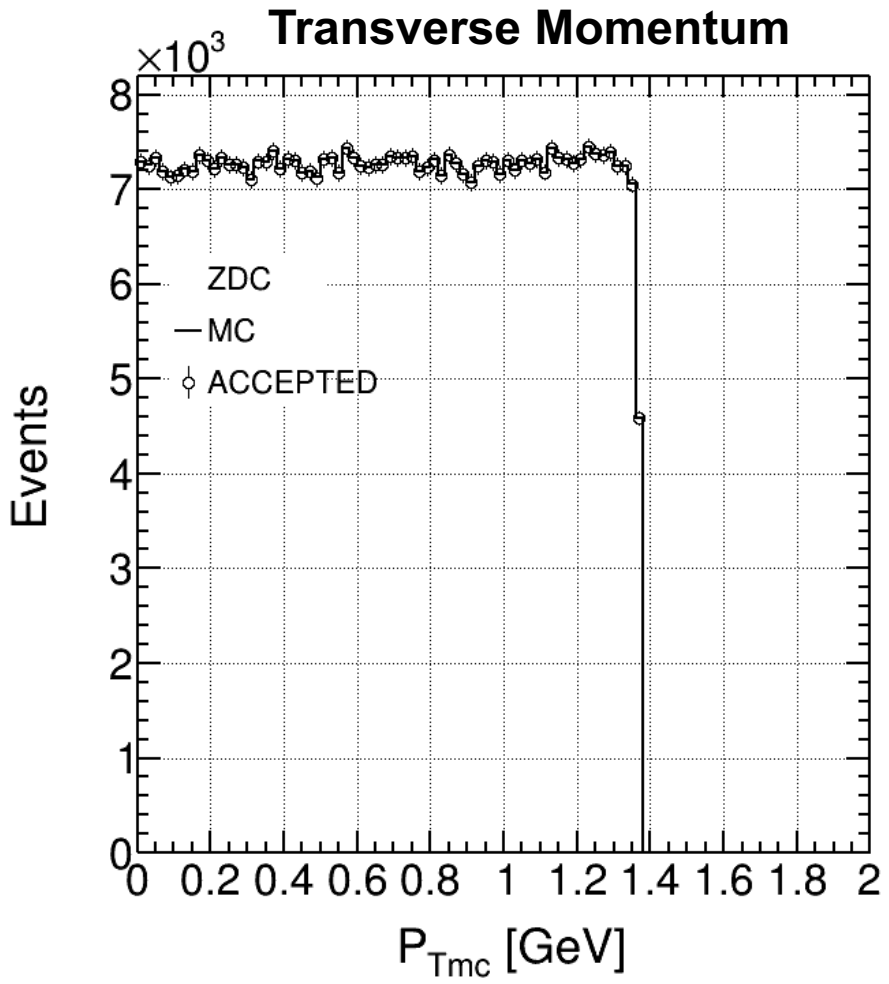




Zero Degree Calorimeter

Single Neutron
E = 275 GeV
$0 < \theta_{MC} < 5$ mrad





Zero Degree Calorimeter

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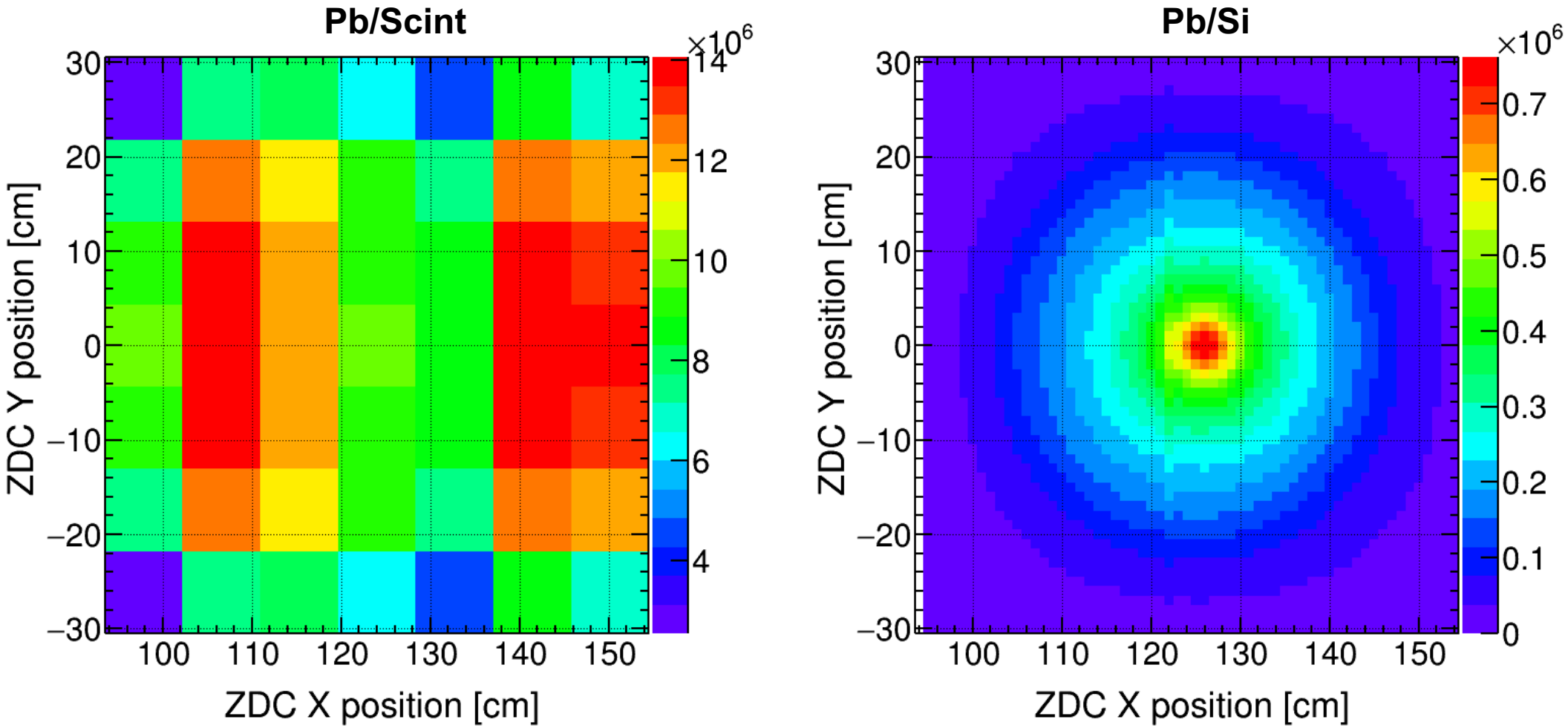
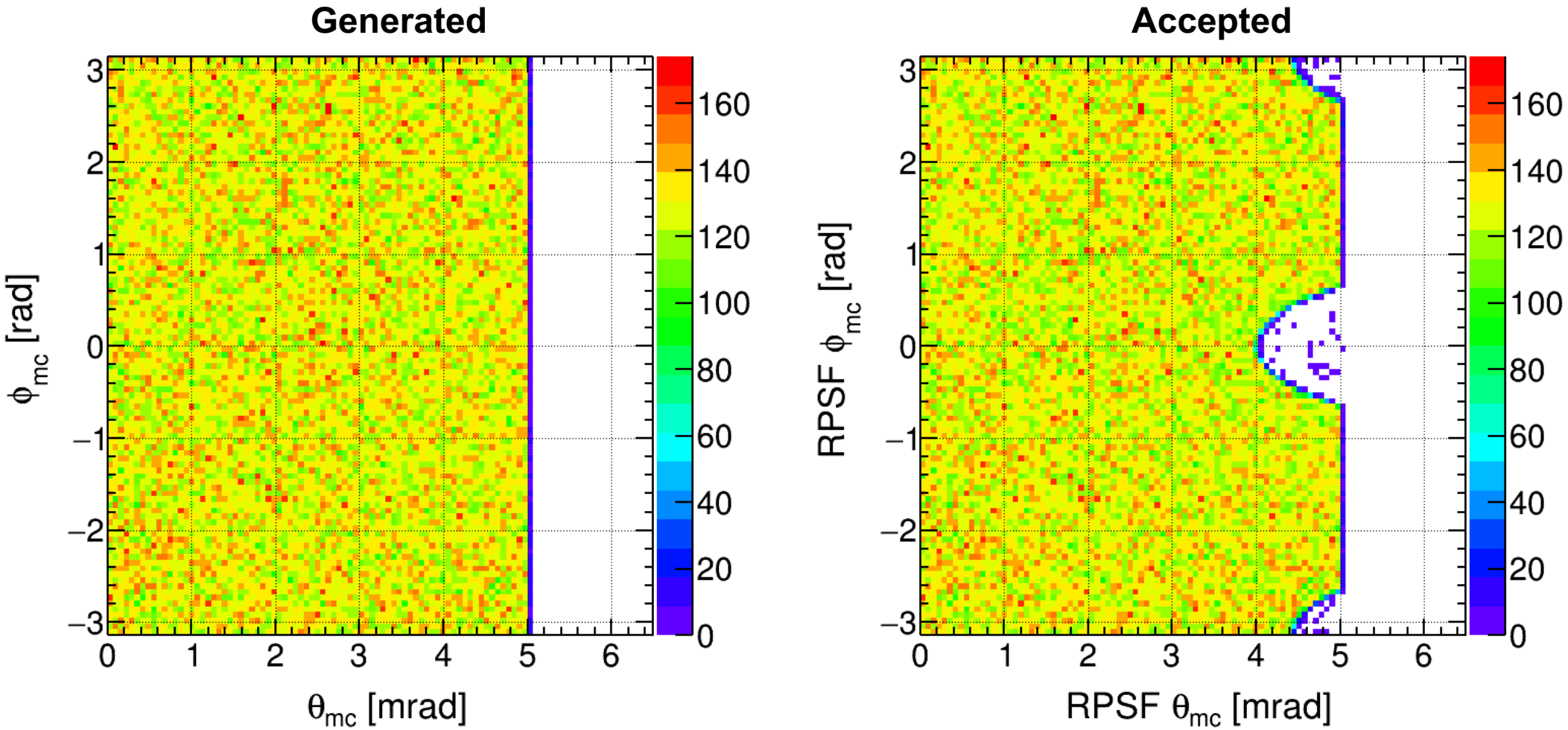


Pb/Scint and Pb/Si have 10 cm amd 1 cm segmentation respectively
Neutron penetrate a few interaction lengths before shower develops *Raw Hits*

Roman Pots at Secondary Focus

Single Proton
E = 275 GeV
$0 < \theta_{MC} < 5$ mrad

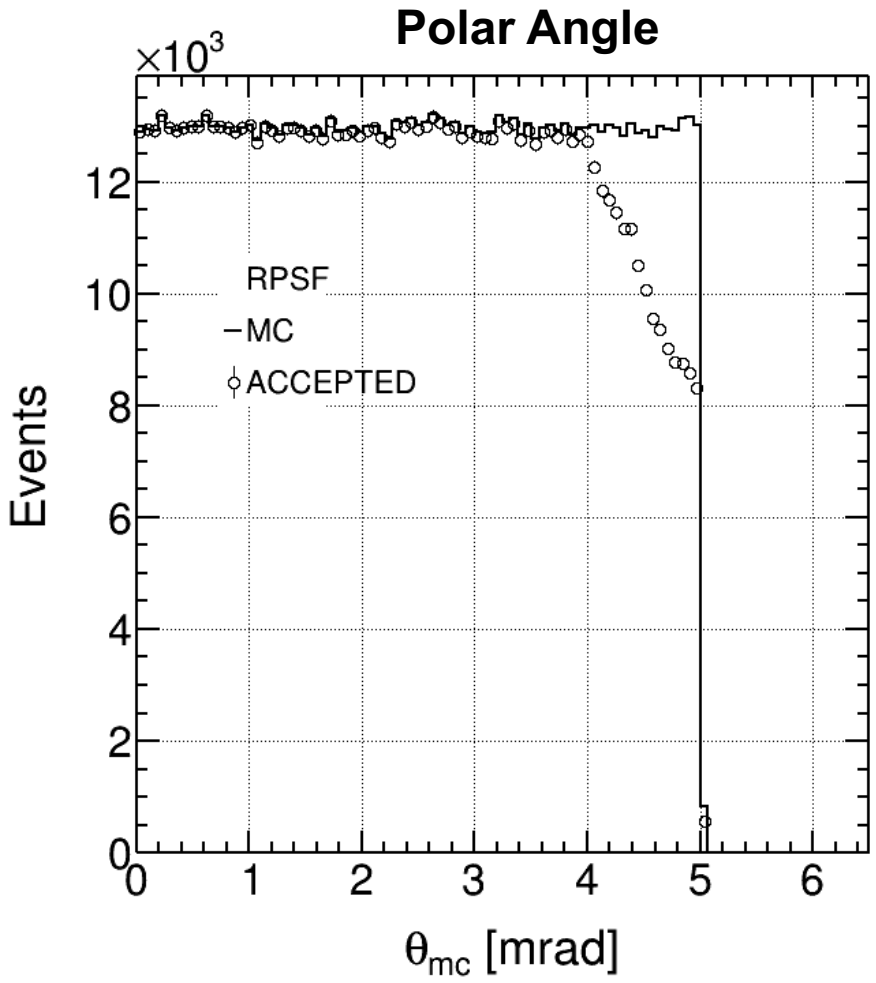


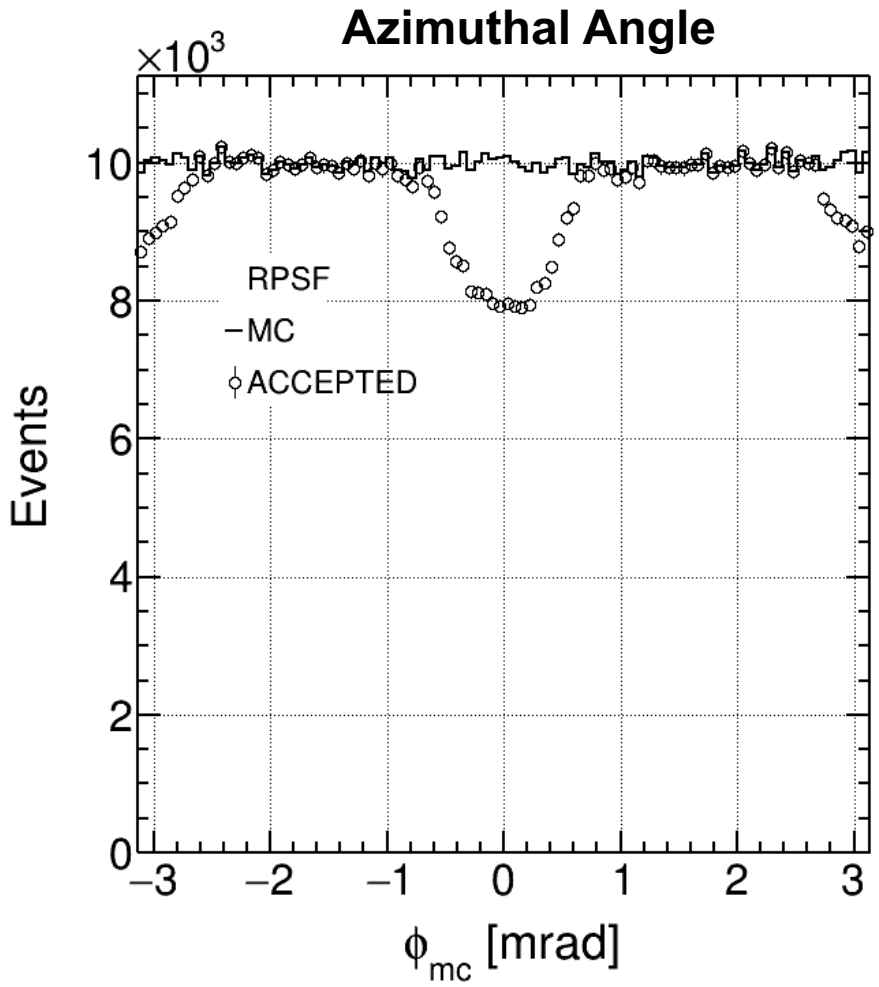
About 95.4 % events were accepted and observed losses at higher theta (polar angle)

Clipping occurs in Quadrupoles for protons

Roman Pots at Secondary Focus

Single Proton
E = 275 GeV
$0 < \theta_{MC} < 5$ mrad





Roman Pots at Secondary Focus

Single Proton
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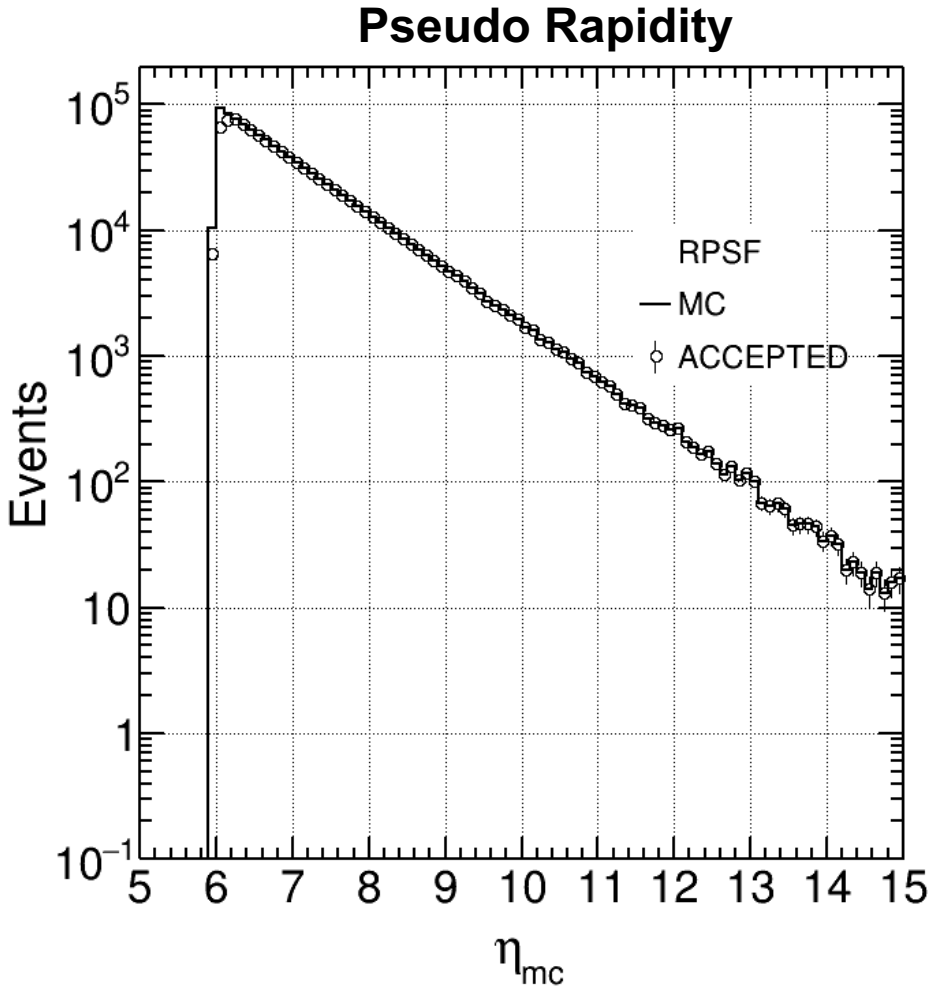

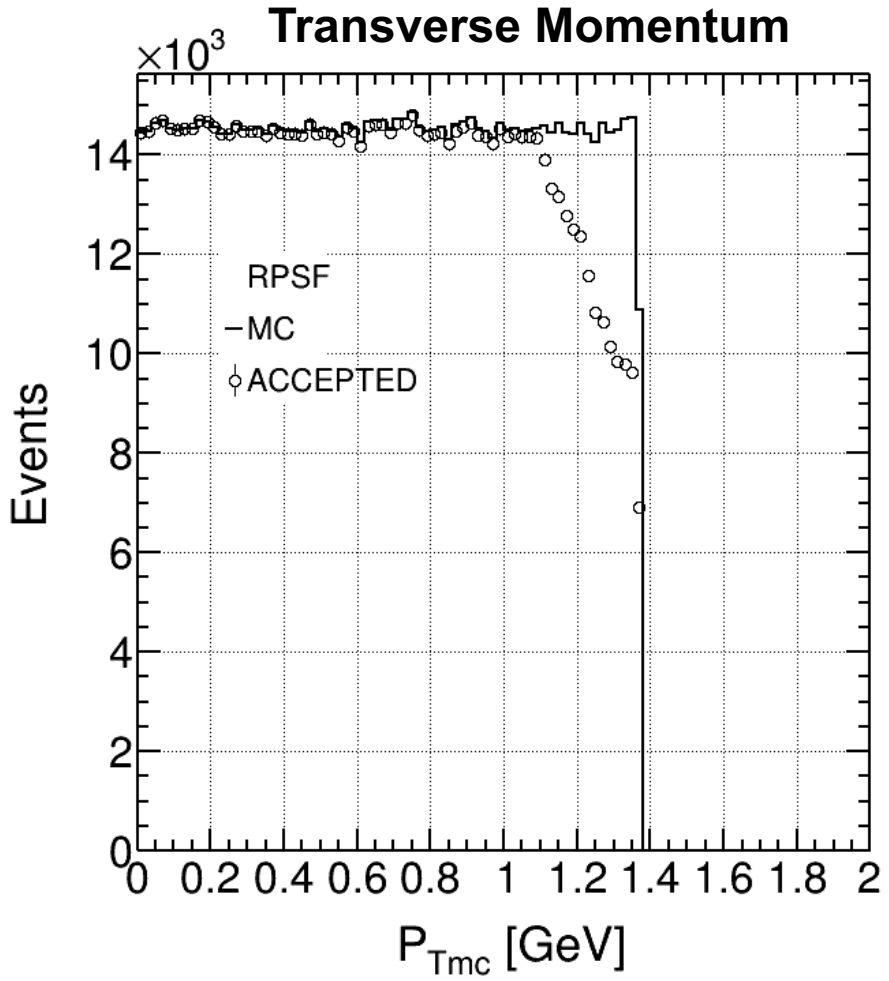

Roman Pots at Secondary Focus

Single Proton
E = 275 GeV
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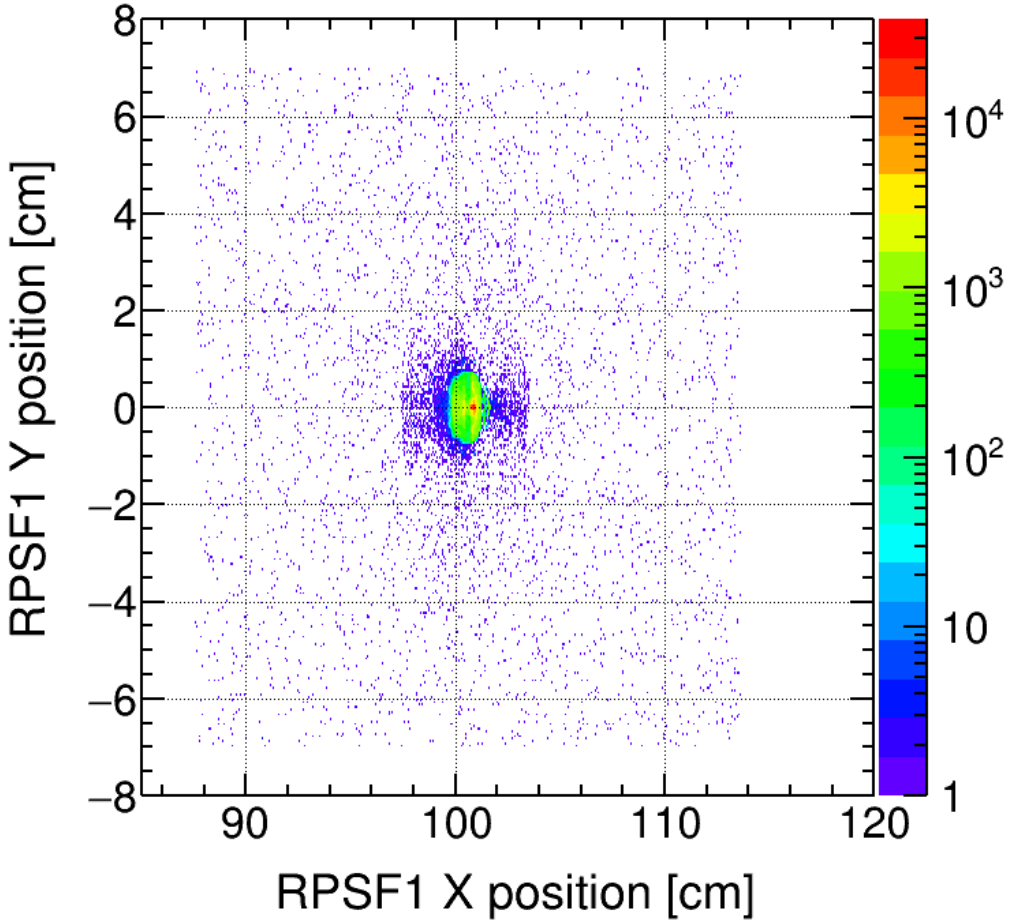

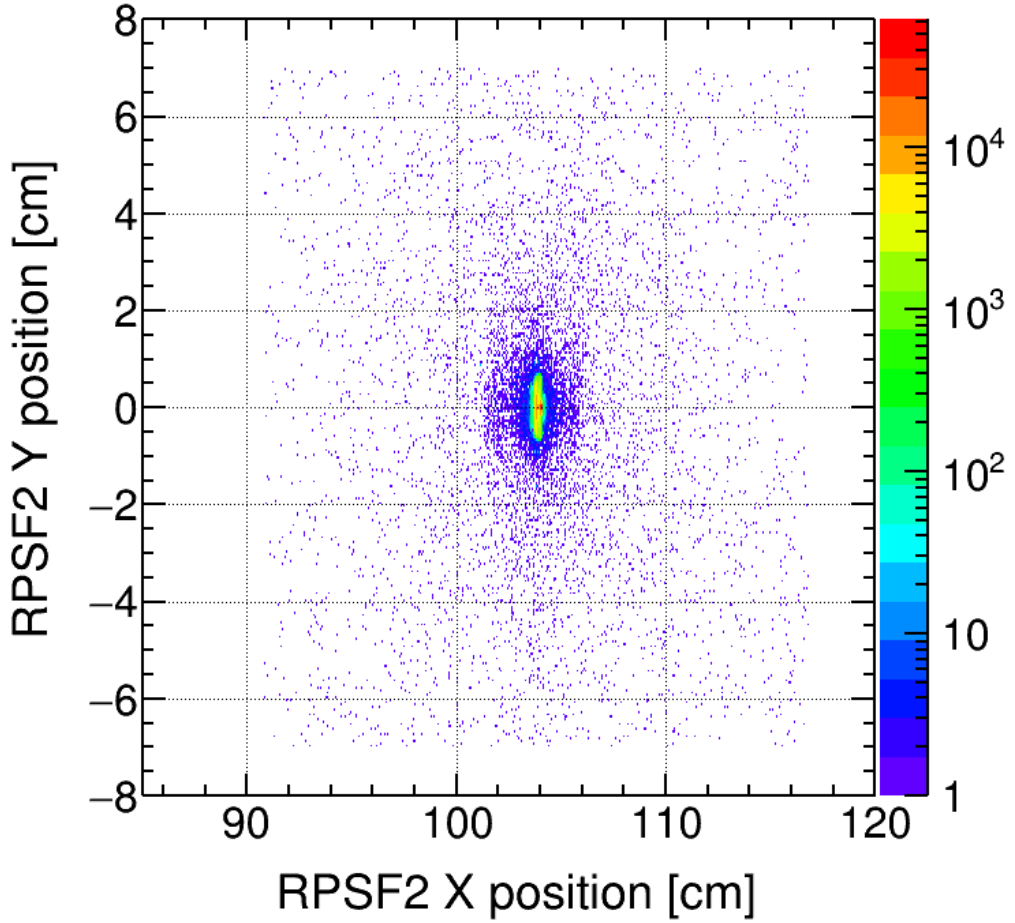

Roman Pots at Secondary Focus

Single Proton
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