IP8 DD4Hep Simulation

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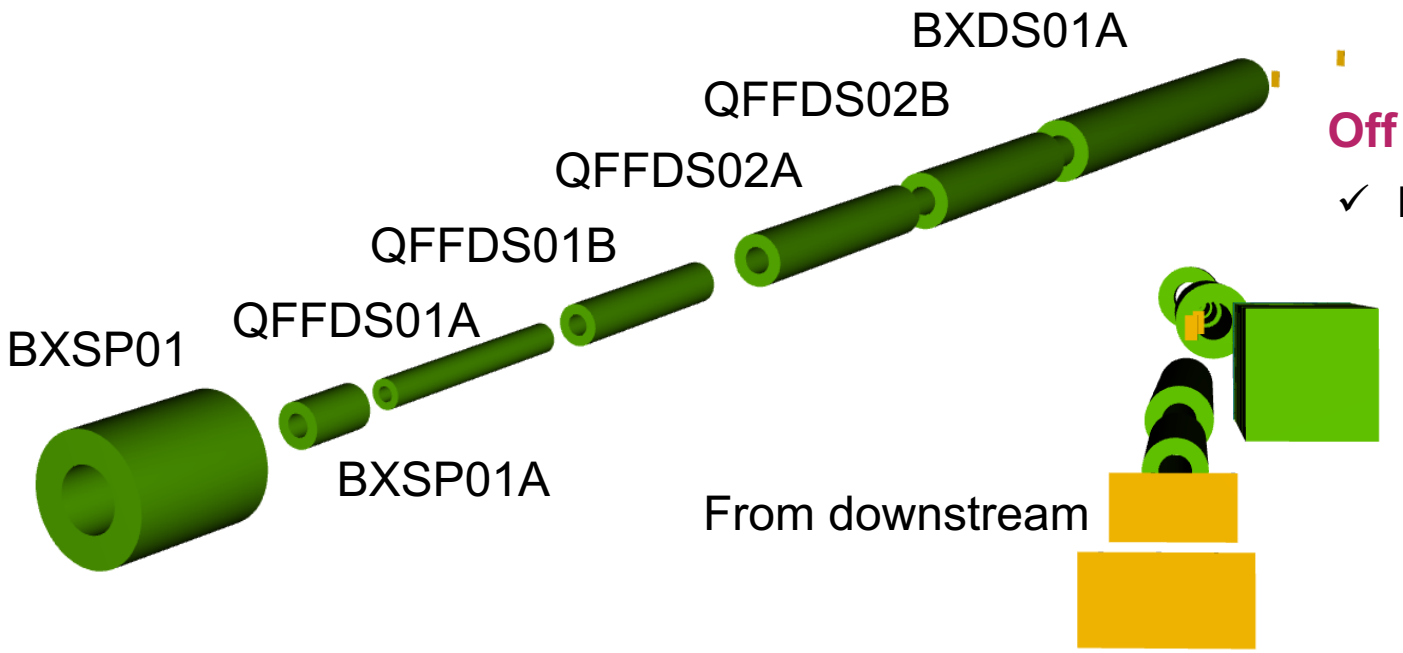
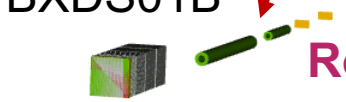
IP8 Far-Forward Layout

- World Volume filled with **Vacuum**
- **Origin (0 cm, 0 cm, 0 cm)**
- Crossing angles
  - **Ion crossing angle = +0.035 rad**
- No beam pipe implemented yet



QDS01
One additional quadrupole magnet before 2nd focus



Roman Pots at 2nd focus (RPSF)

Zero Degree Calorimeter (ZDC)

Off Momentum Detectors (OMD)

✓ Implemented far-forward detectors in IP6 configuration
- OMD assumed **20 cm tall and 10 cm wide** placed at (x,z) = (0.723133m, 25.9359m) & (0.702435m, 27.9363m)
- ZDC assumed **2 meter-long and 60 × 60 cm²** placed at (x,z) = (1.3798m, 35.4293m(front))
- RPSF assumed **14 cm tall and 26 cm wide** placed at (x,z) = (1.00603m, 43.9339m) & (1.03788m, 45.4337m)

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

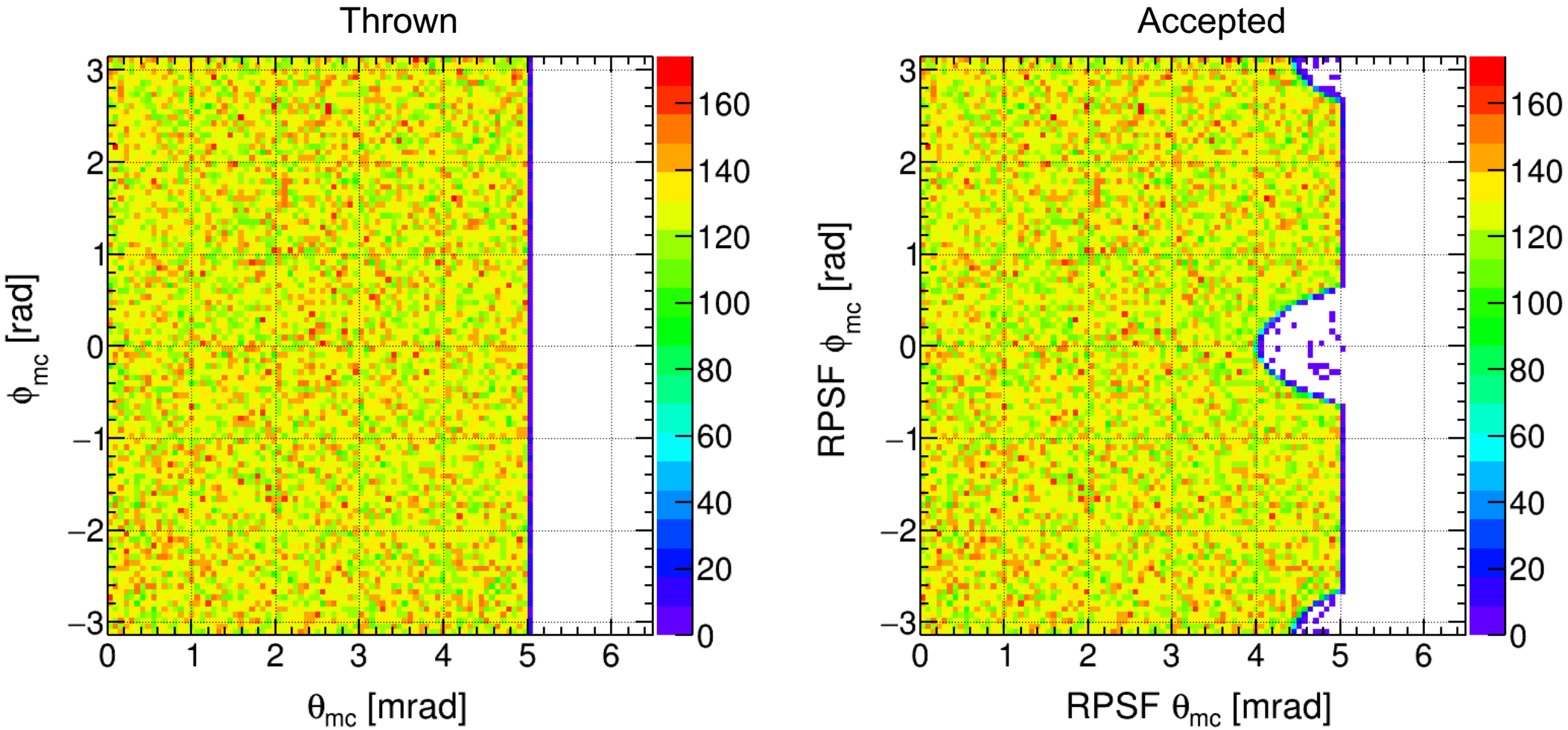
Far-Forward Acceptance

Method

- **Far-Forward region**
  - Particles with $\boldsymbol{\theta}$ **< ~ 37 mrad (2.1°)**
  - **Tag charged hadrons** (protons, pions) or **neutral particles** (neutrons, photons)
- **Single particle simulation** focusing on scattering angle **0 <** $\boldsymbol{\theta_{MC}}$ **< 5 mrad**
  - **Roman Pot at Secondary Focus** for detecting charged particles from nuclear breakup
    - Proton energy: E_p = 275 GeV
  - **Zero Degree Calorimeter** for detecting photons and neutrons
    - Neutron energy: E_n = 275 GeV (***$\boldsymbol{\theta_{MC}}$** **< 10 mrad**)
  - **Off-Momentum Detector** for detecting protons from nuclear breakup
    - Proton energy: 123.75 GeV (45%) < E_p < 151.25 GeV (55%)

Roman Pots at Secondary Focus

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



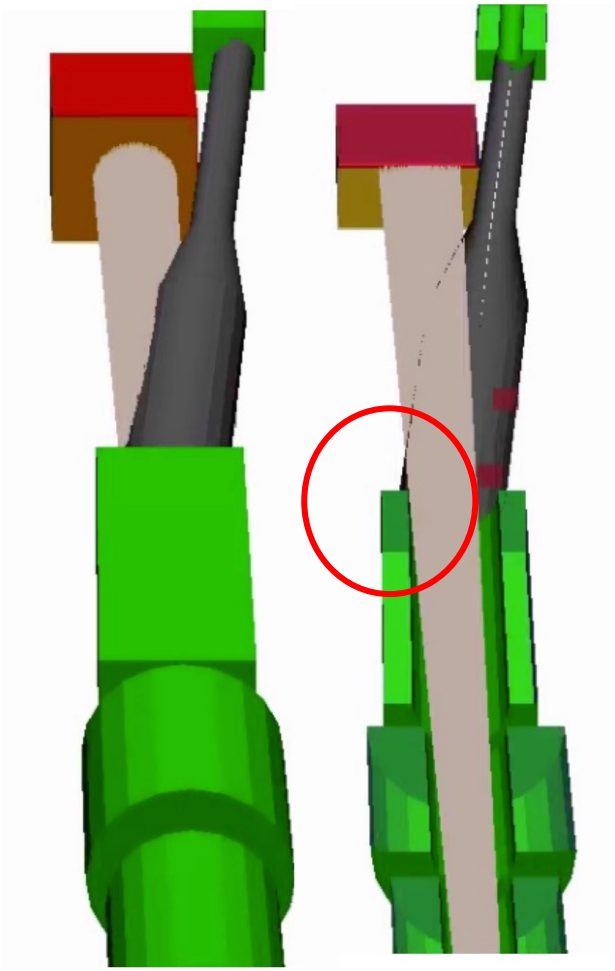
About 95.4 % events were accepted and observed losses at higher theta (polar angle)

Clipping occurs in Quadrupoles for protons

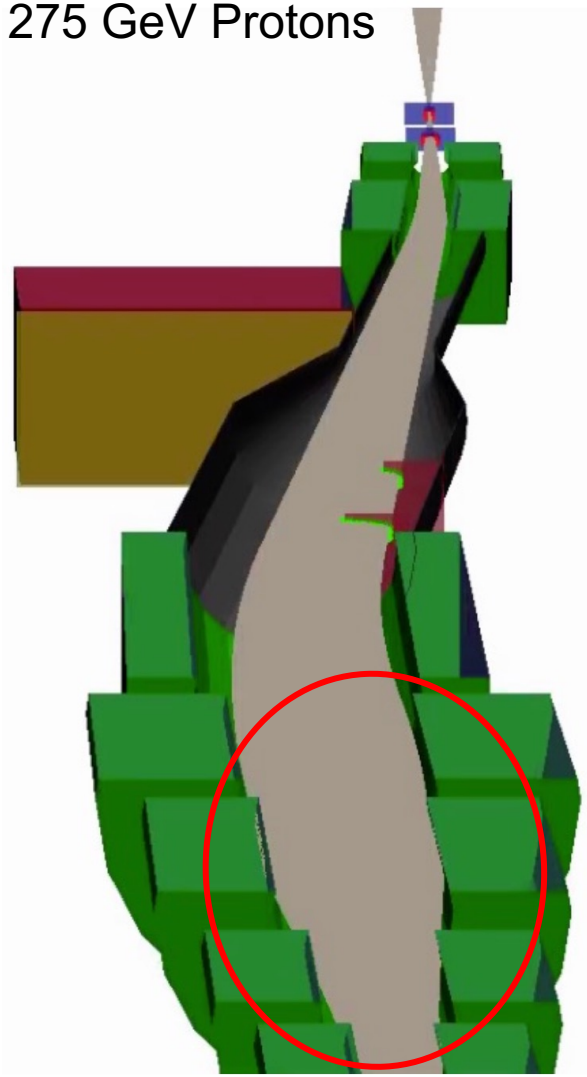
Kindly Provided by Alex Jentsch using EicRoot Simulation Event Display
Reference from https://wiki.bnl.gov/eic-detector-2/images/8/86/IP8_HSR_lattice_performance_10_13_22_v3.pdf

Clipping on Acceptance of Far-Forward

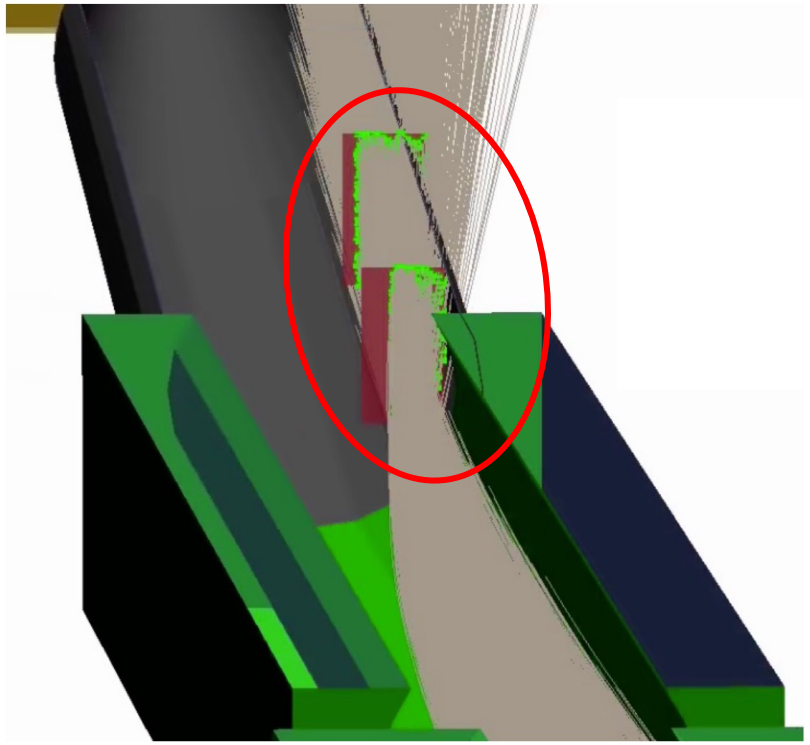
275 GeV Neutrons



275 GeV Protons



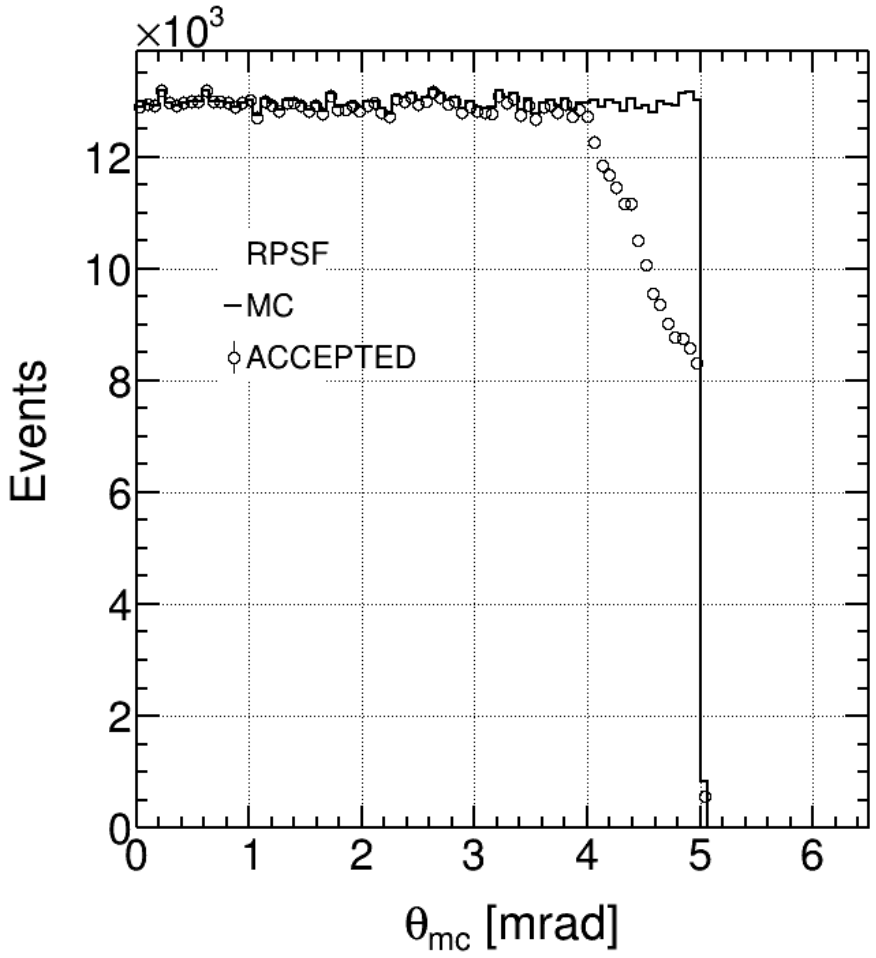
123.75 – 151.25 GeV Protons

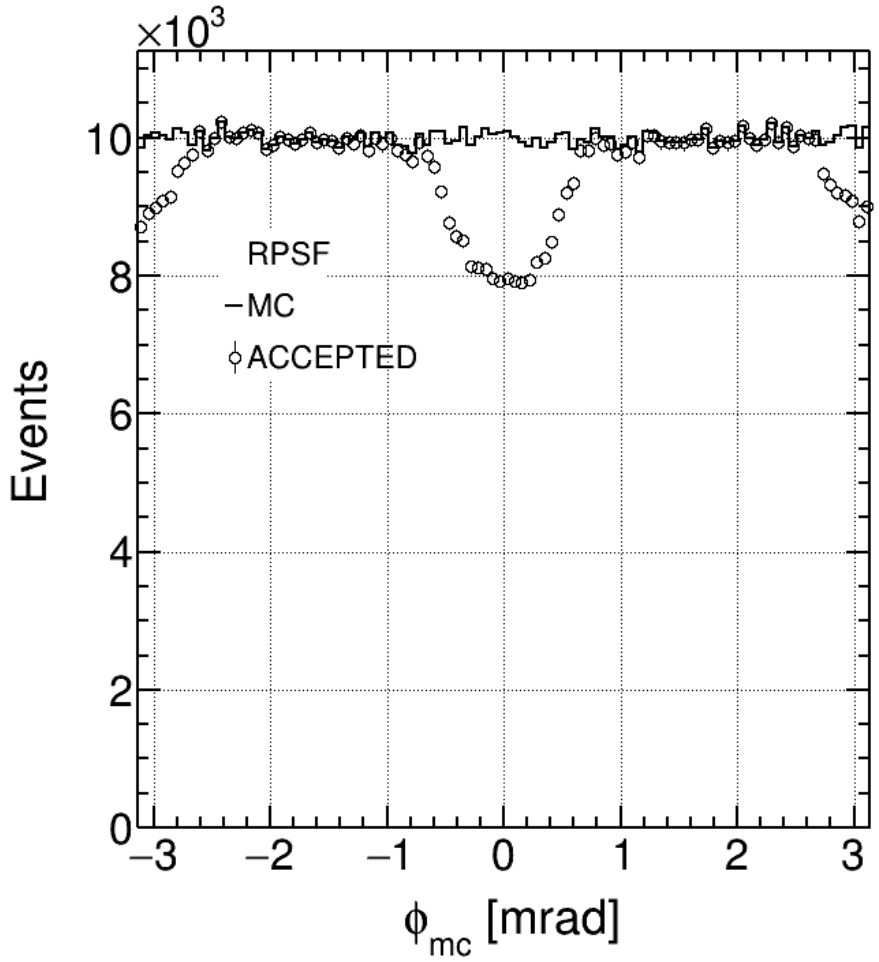


DD4hep simulation event display was not successful…

Roman Pots at Secondary Focus

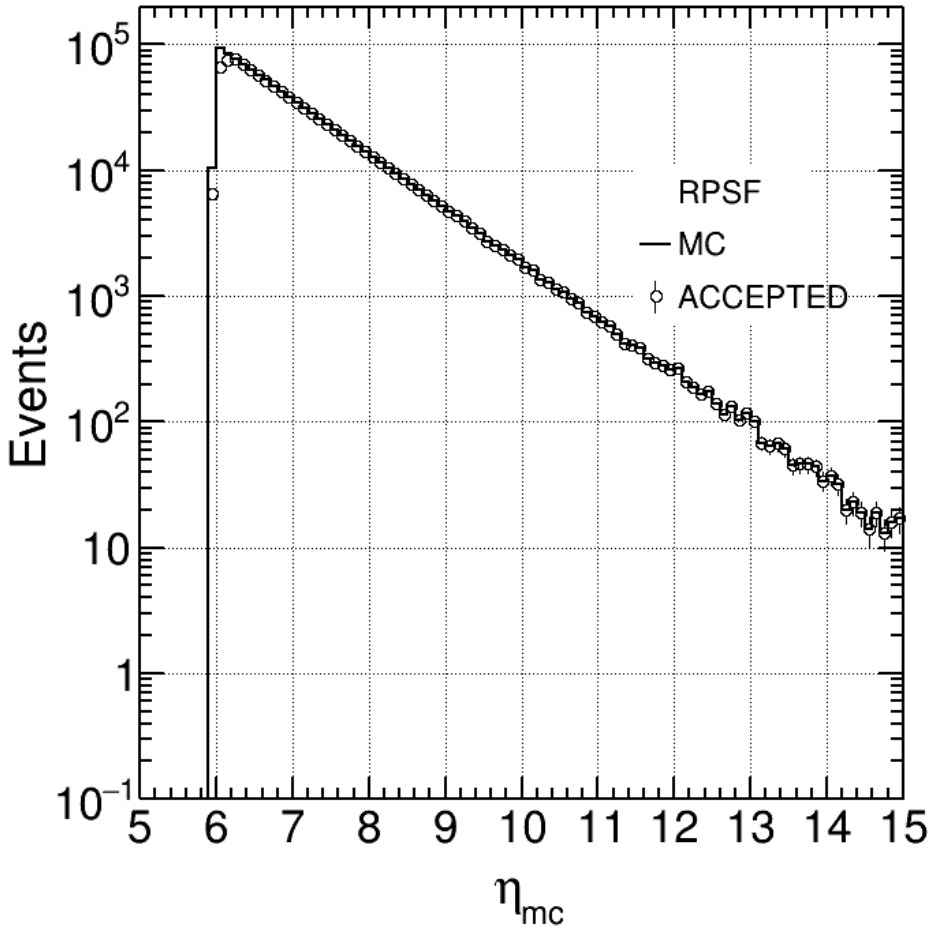
Single Proton
E = 275 GeV
$0 < \theta_{MC} < 5$ mrad

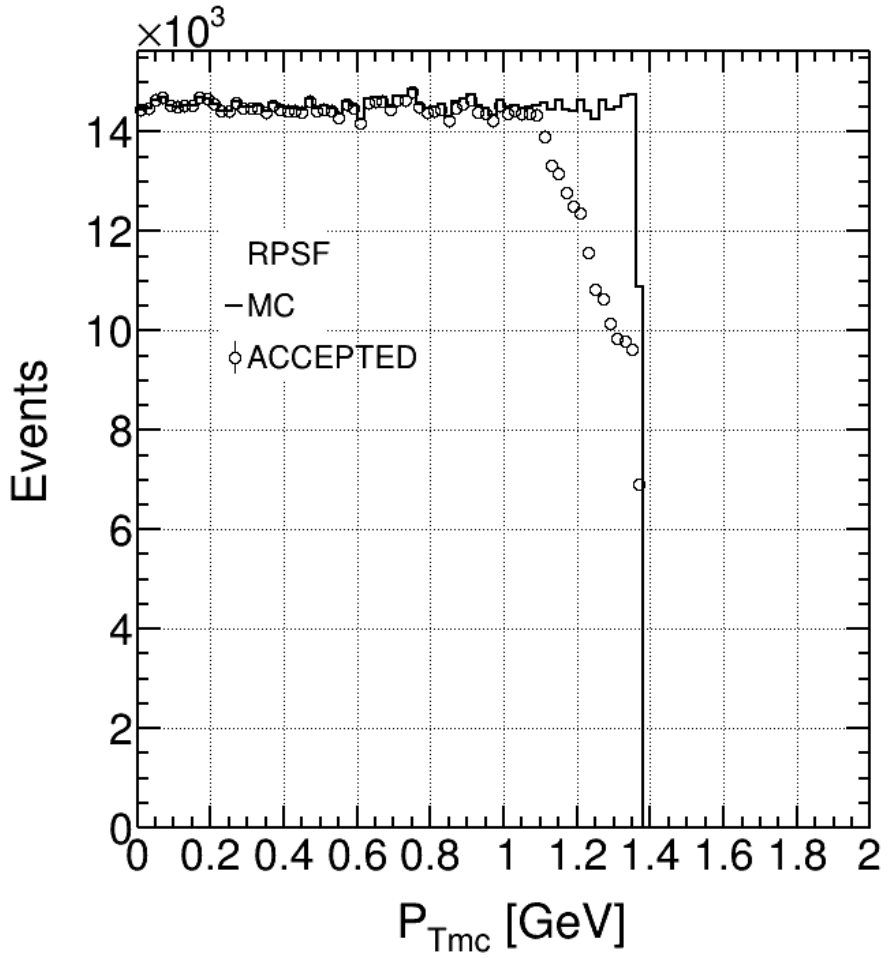




Roman Pots at Secondary Focus

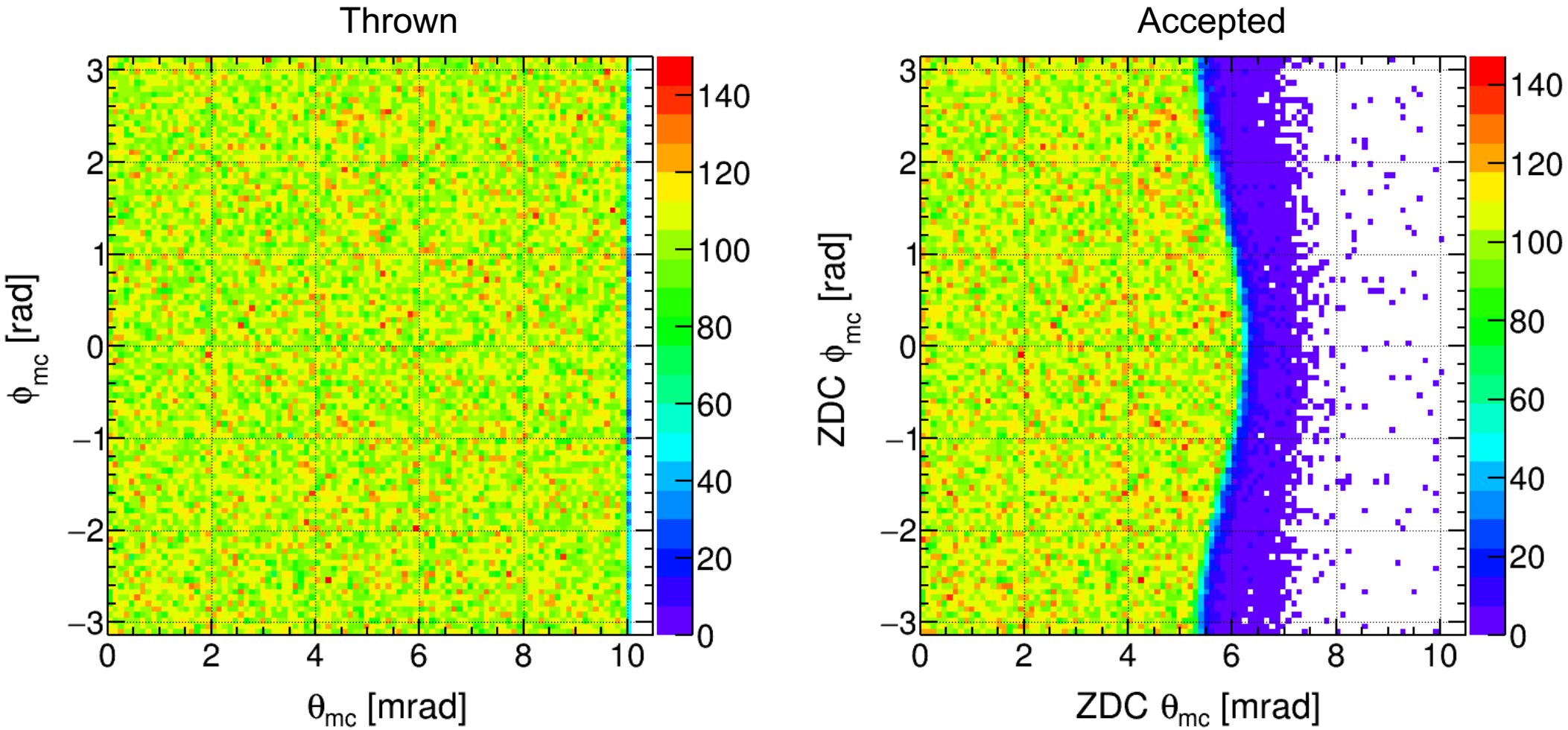
Single Proton
E = 275 GeV
$0 < \theta_{MC} < 5$ mrad





Zero Degree Calorimeter

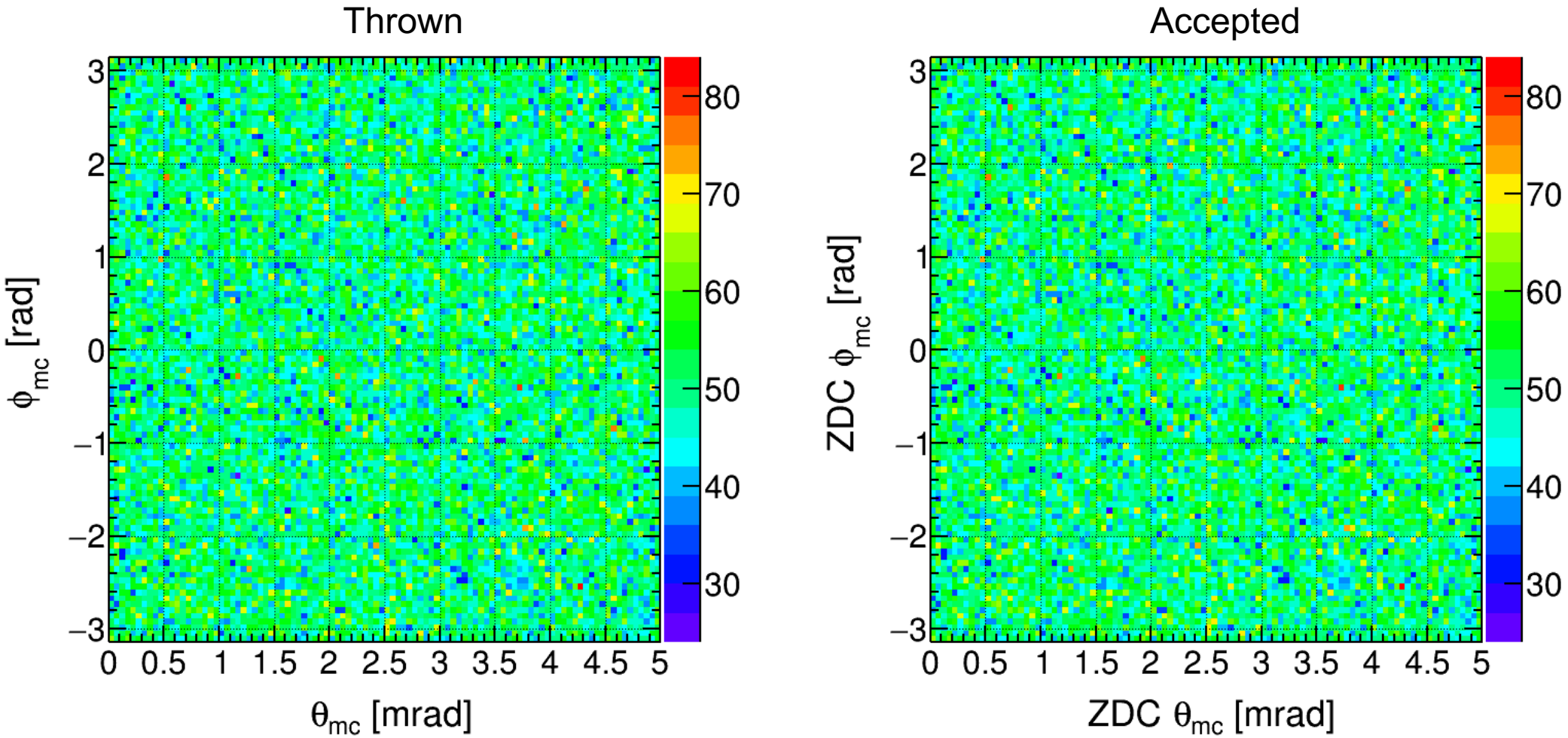
Single Neutron
E = 275 GeV
$0 < \theta_{MC} < 10$ mrad



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

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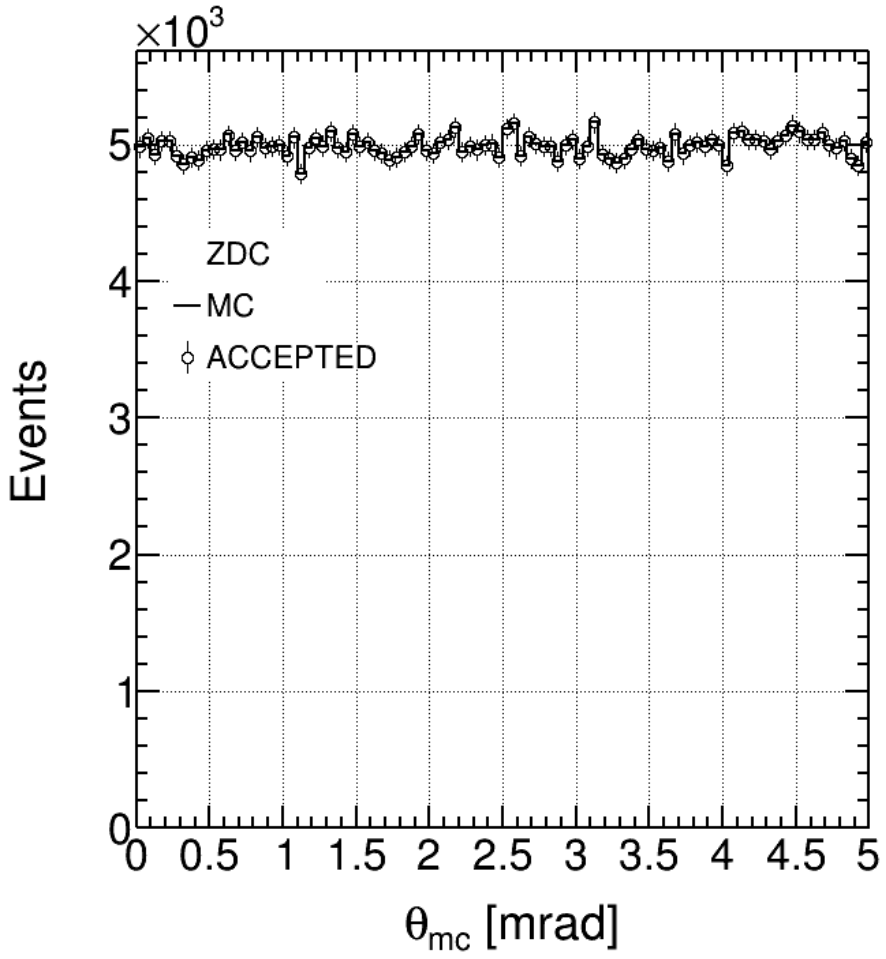

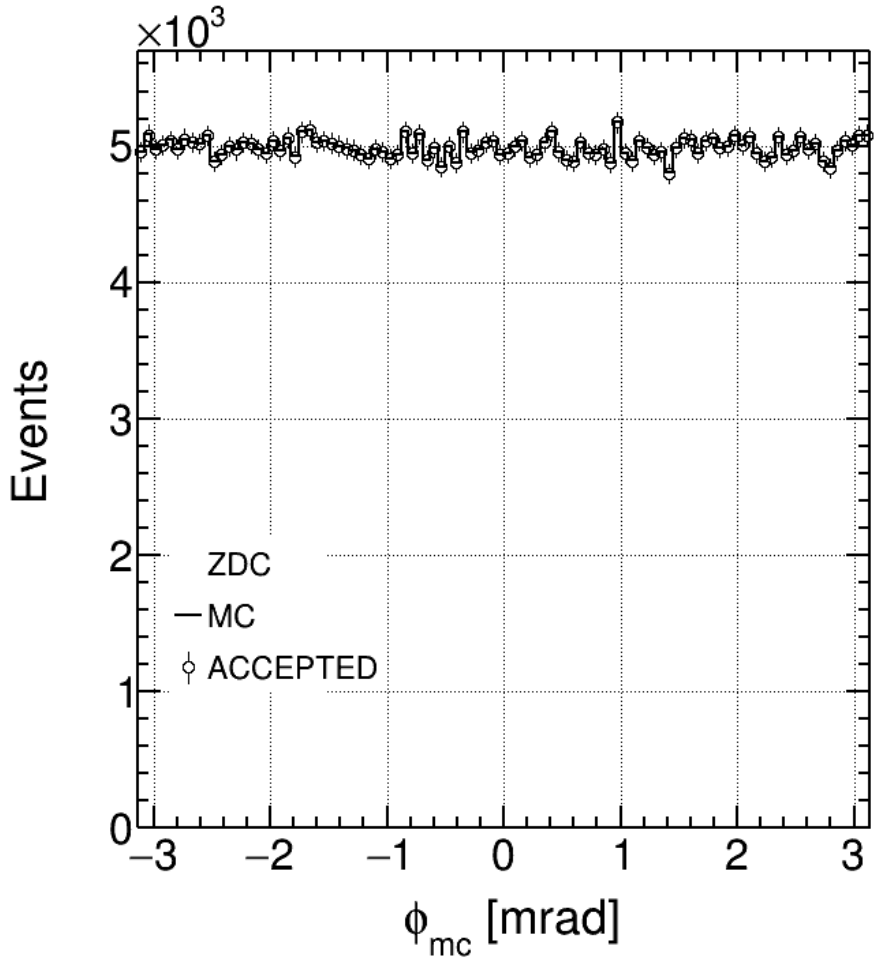

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E = 275 GeV
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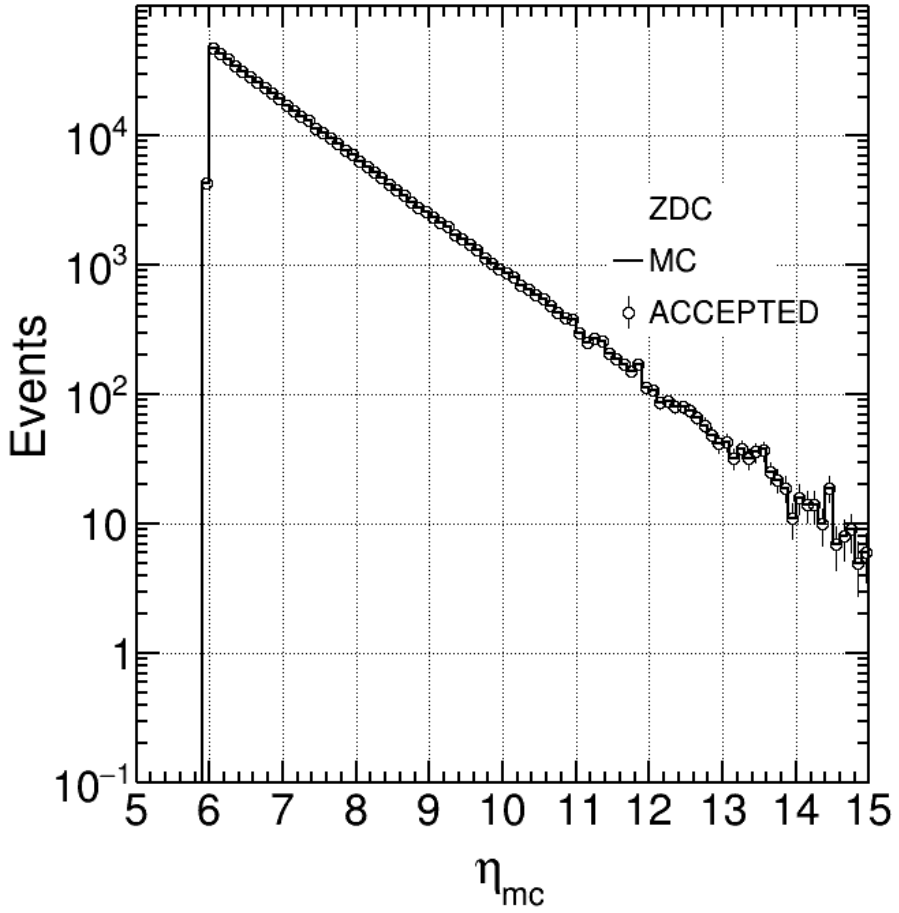
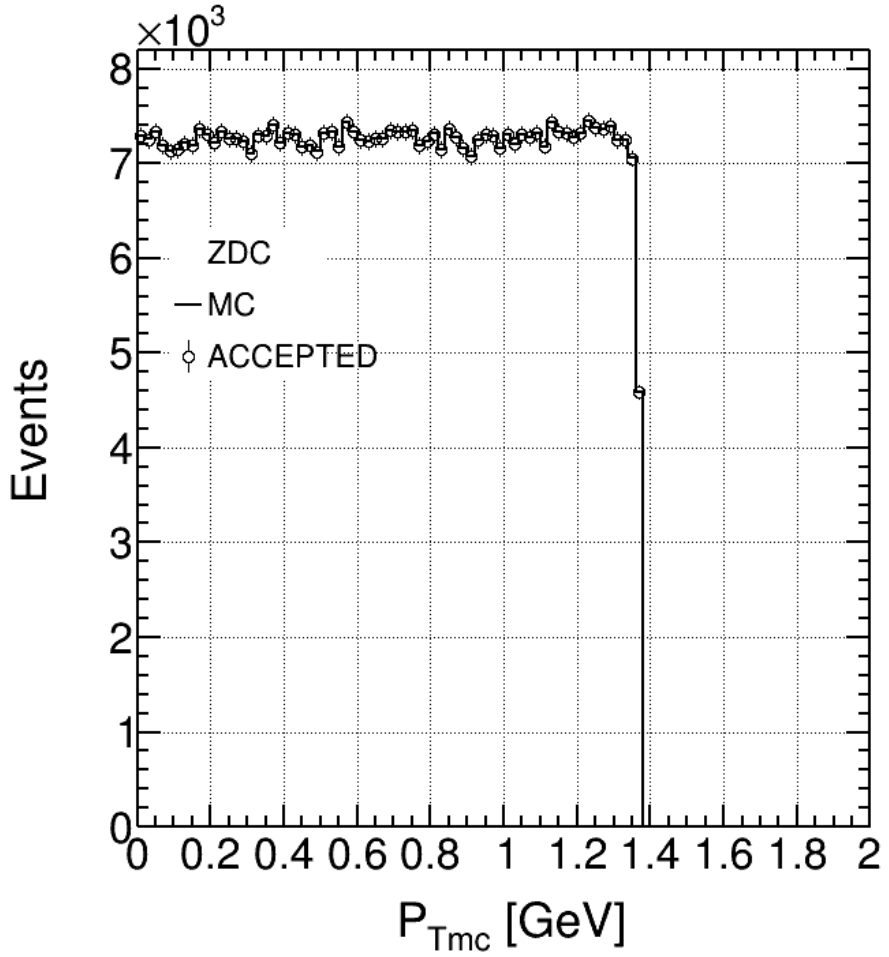
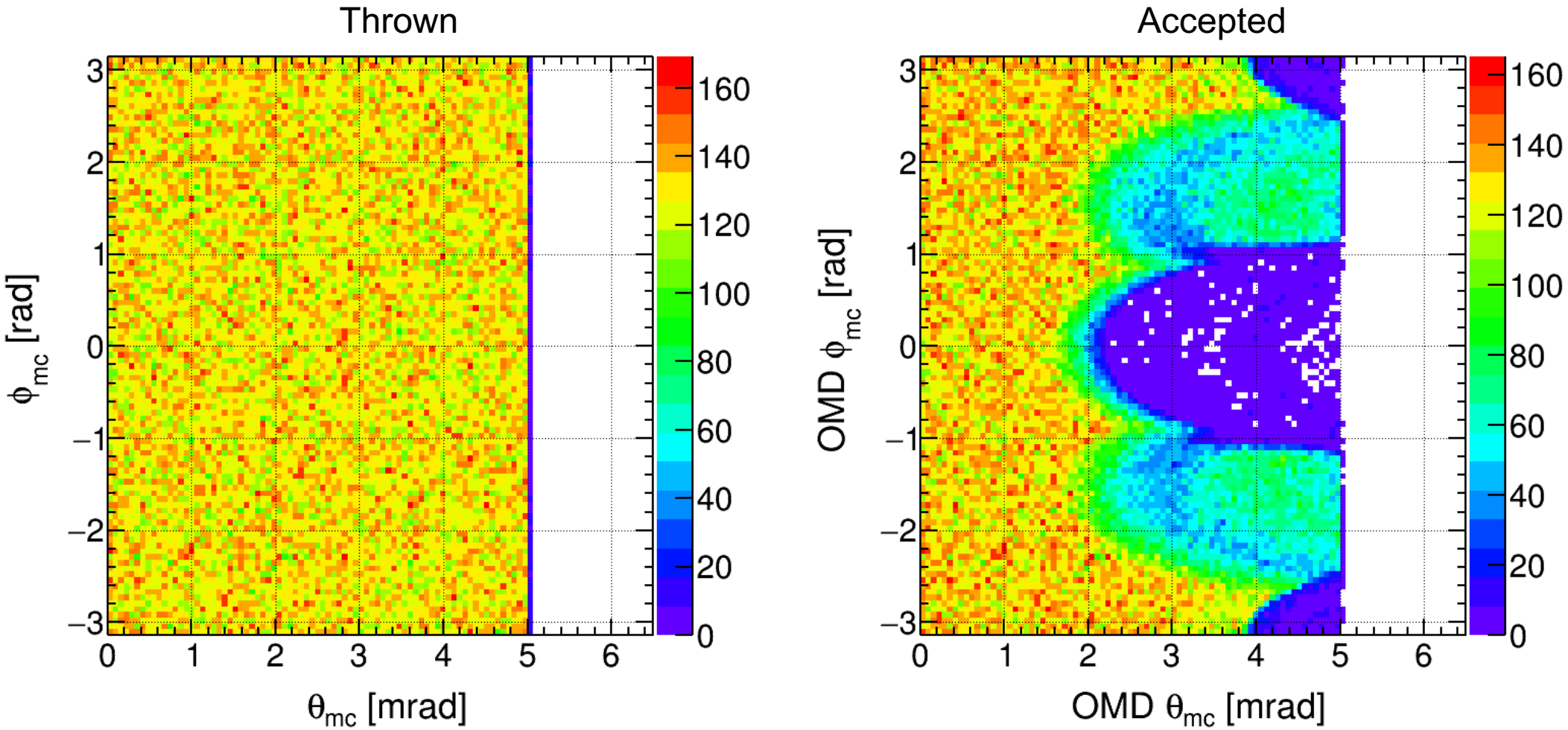




Off Momentum Detectors

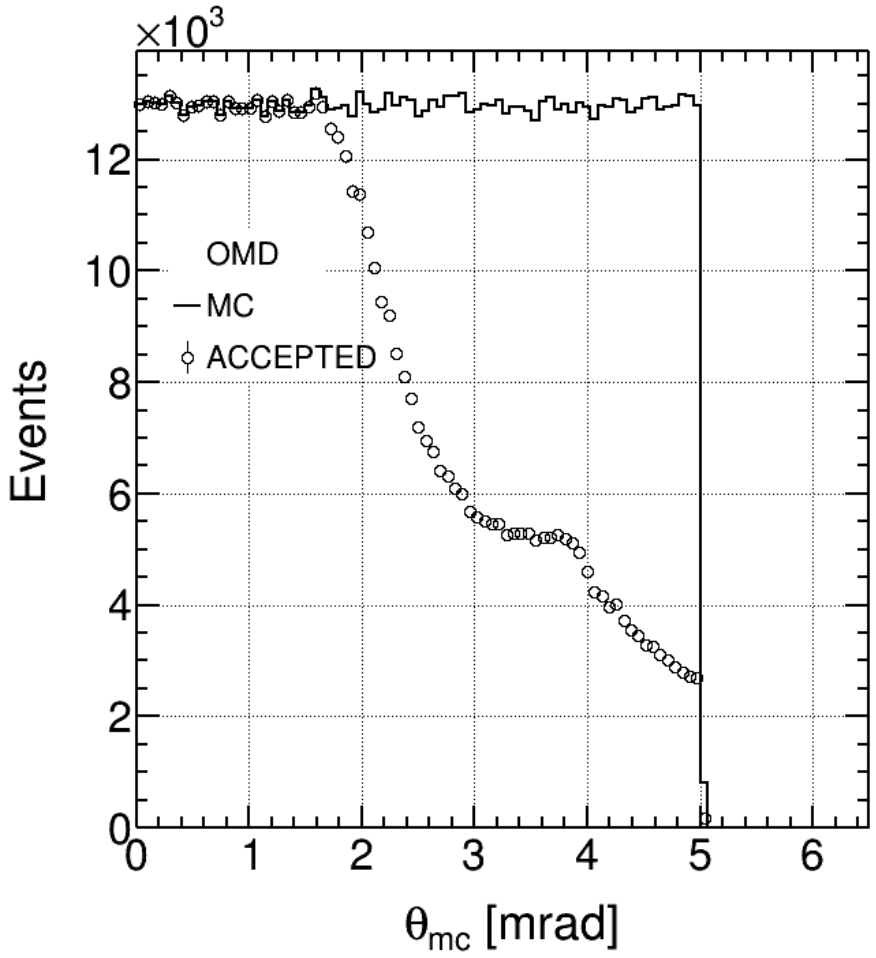
Single Proton
123.75 GeV (45%) < E < 151.25 GeV (55%)
$0 < \theta_{MC} < 5$ mrad

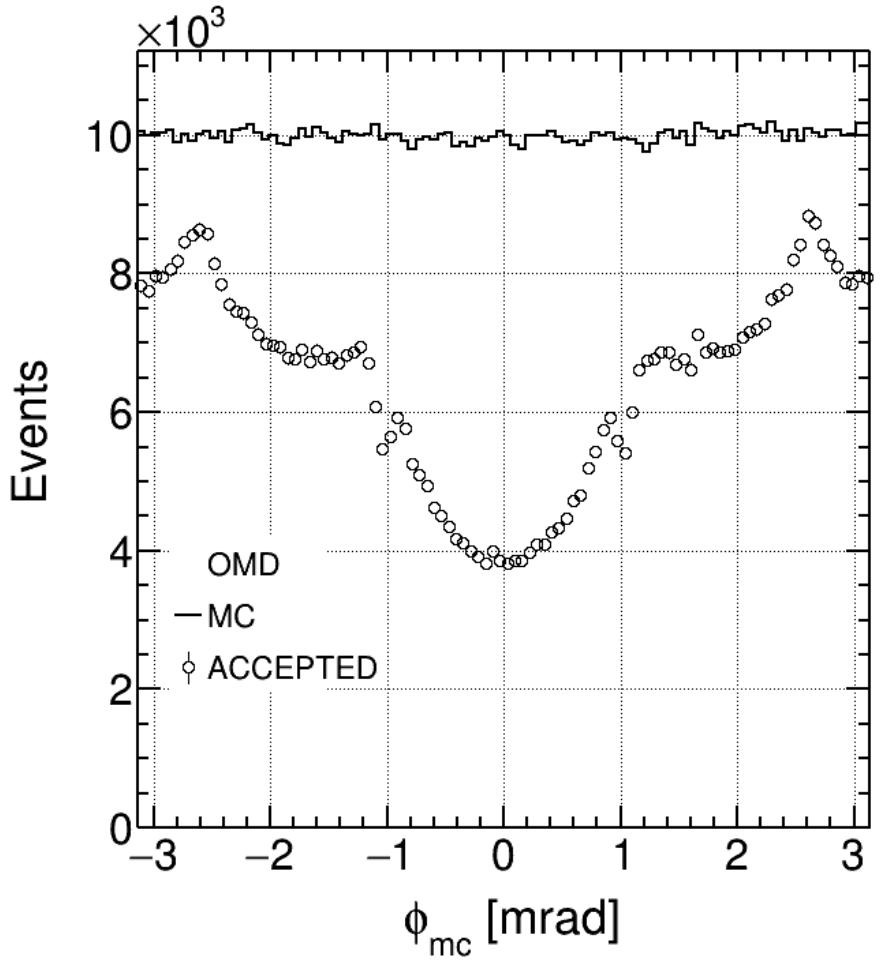


About 64.7 % events were accepted where scattering angle stretched upto 2 mrad
Hadron lattice in simulation set to be 275 GeV proton

Off Momentum Detectors

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





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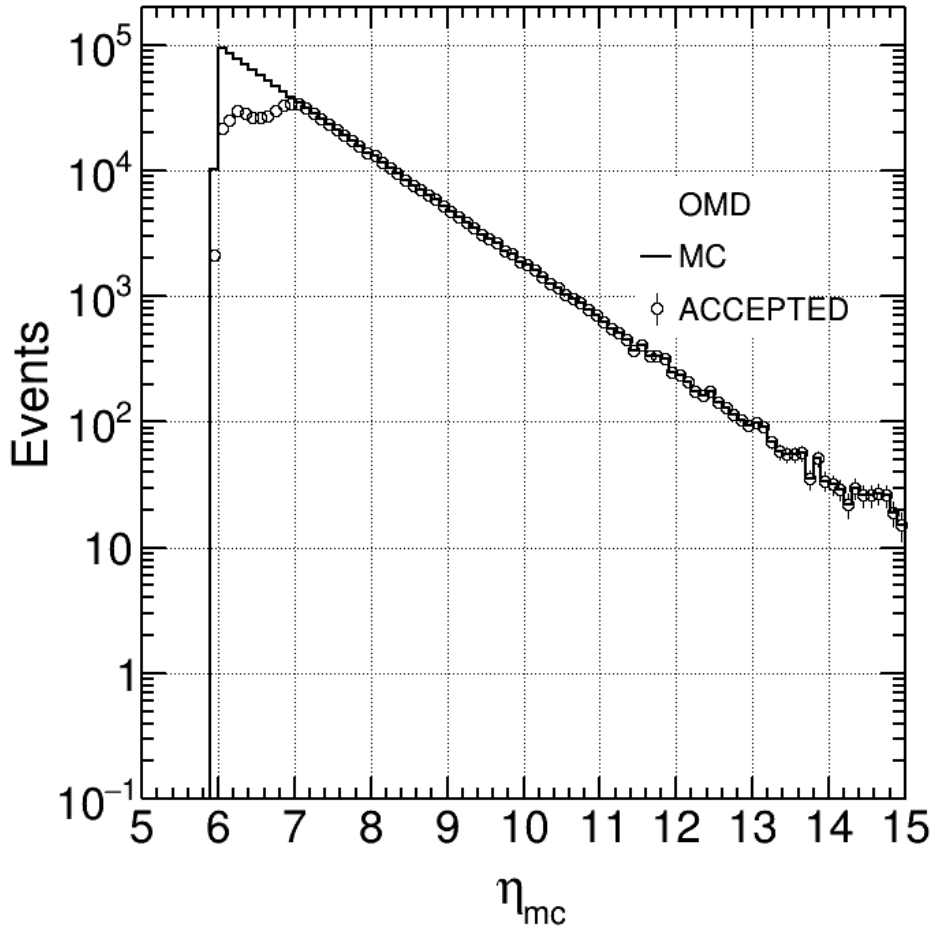
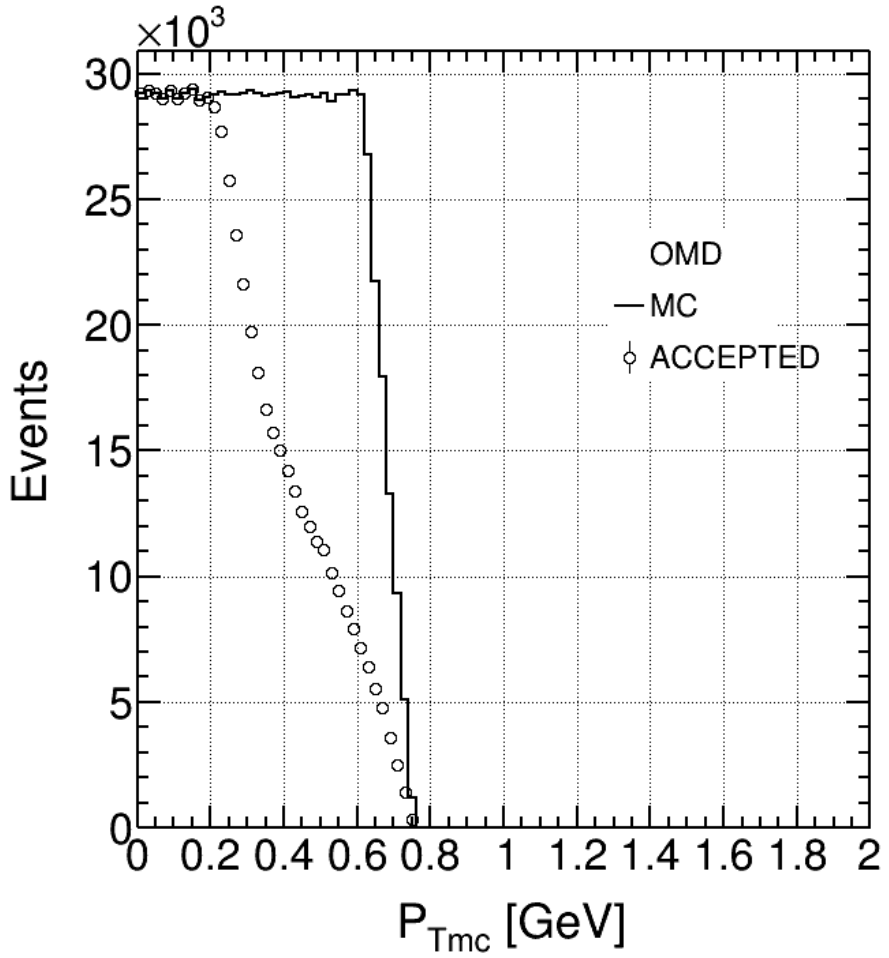




Incoherent Tagging Power

Method

- Used **BeAGLE** 791k 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**
  - Checked if **any registered RAW hits** exist in any of far-forward detectors, then be tagged ***no central detector yet***
  - For **RPSF**, if any registered RAW hits exist less than 10σ cut, ***not be tagged***

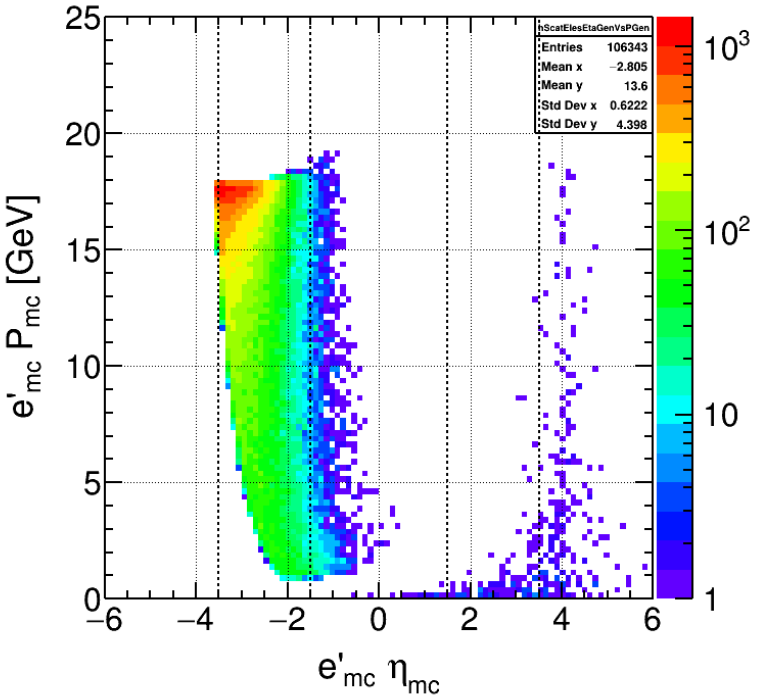
Candidates for e’

Final-state Electrons

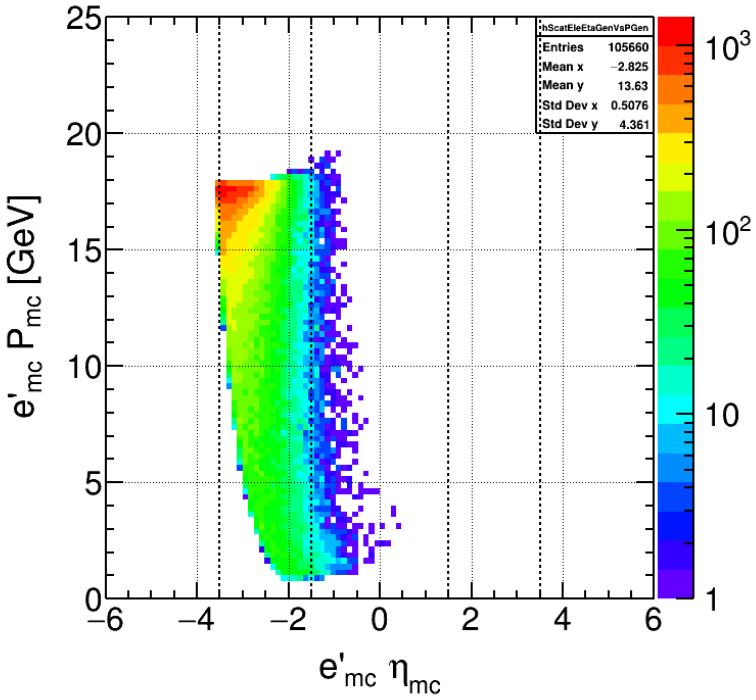
BeAGLE 18x110 GeV^2
Incoherent events
$ePb \rightarrow e' + J/\psi(\mu\mu) + X$

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

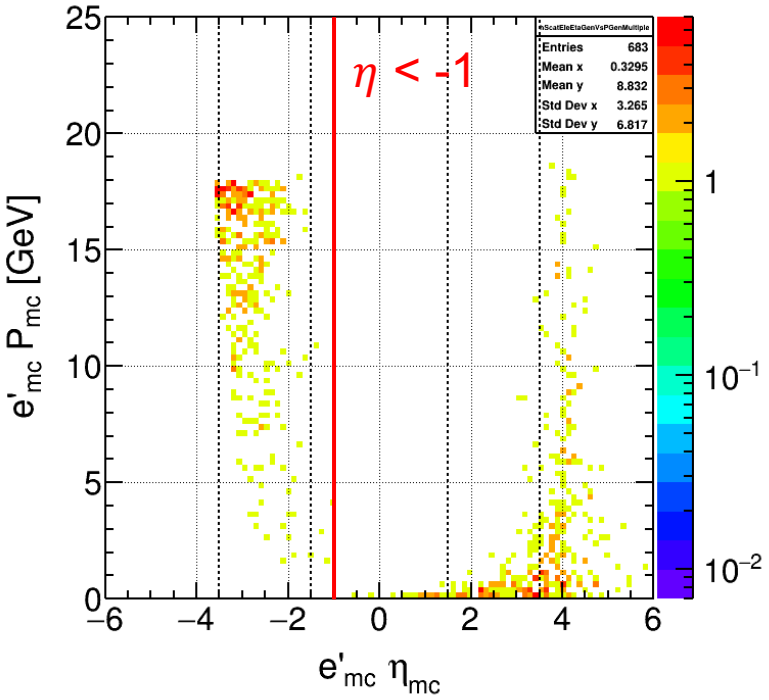
All Electrons



Only One Electron



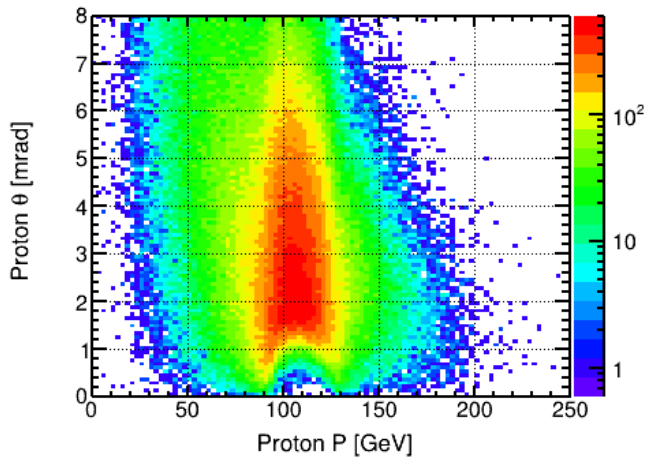
More than One Electron

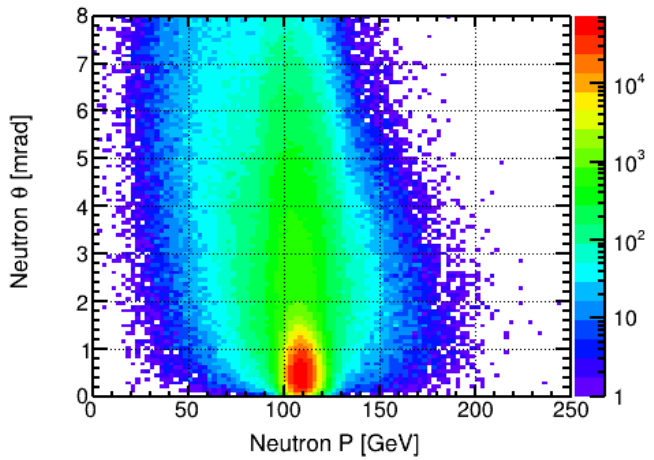


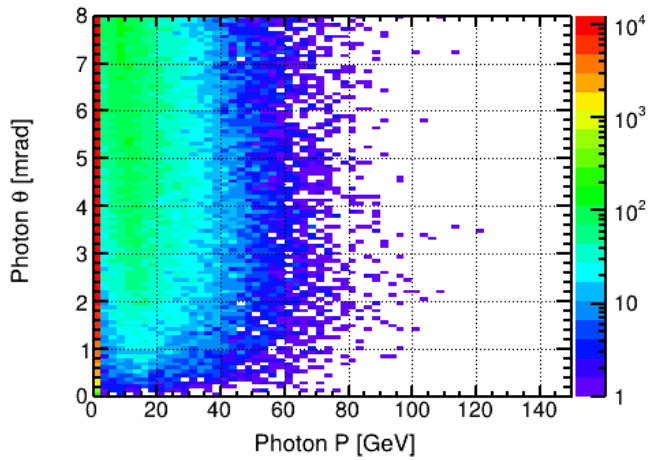
Nuclear Breakups Distribution

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 %

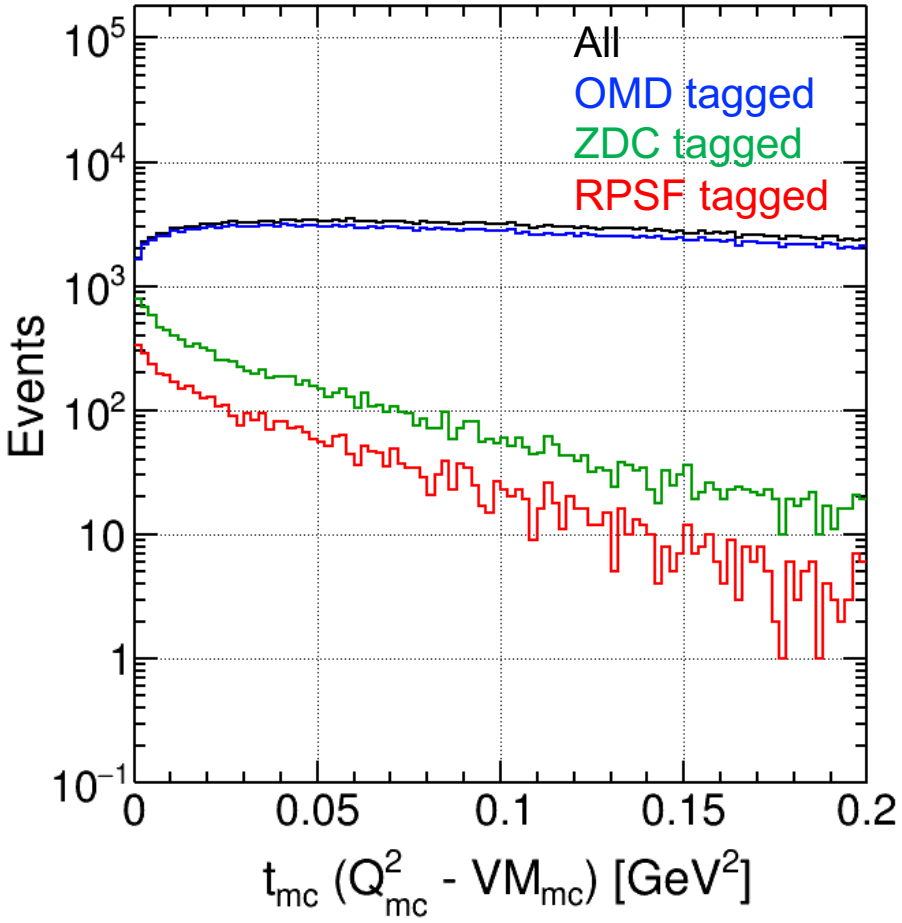


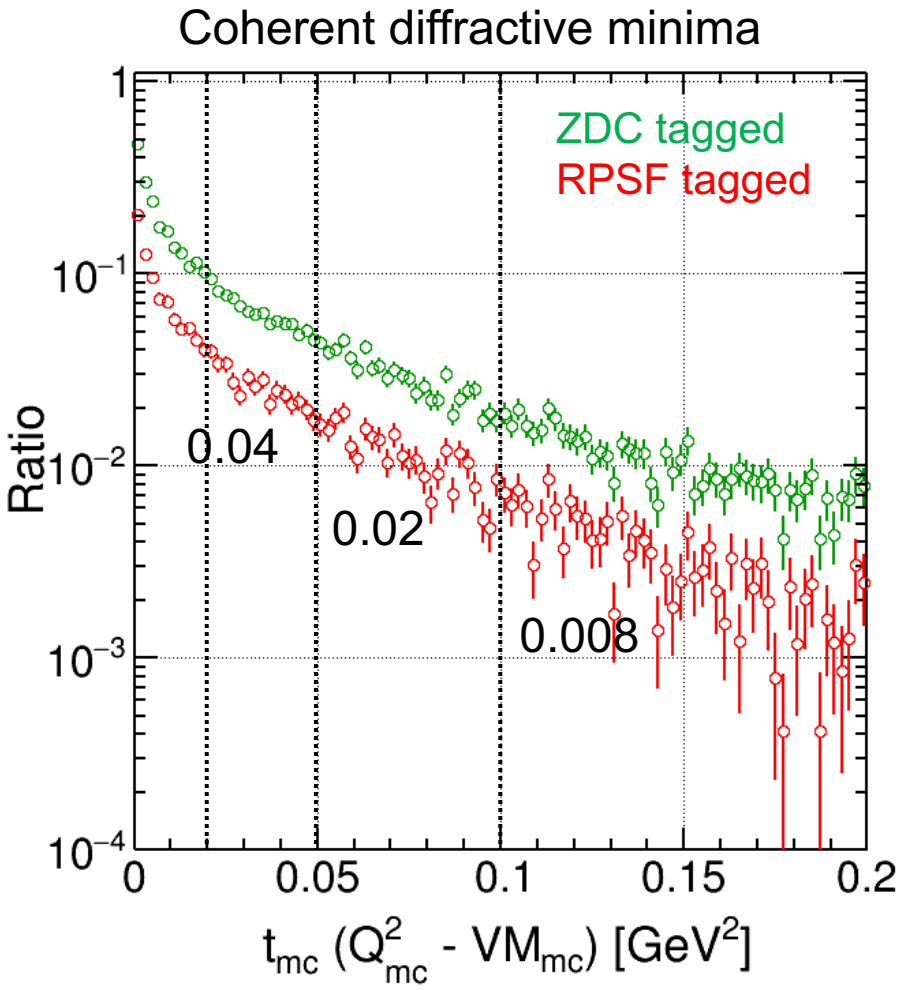




t distribution

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





Nuclear Breakups Distribution

BeAGLE 18x110 GeV^2
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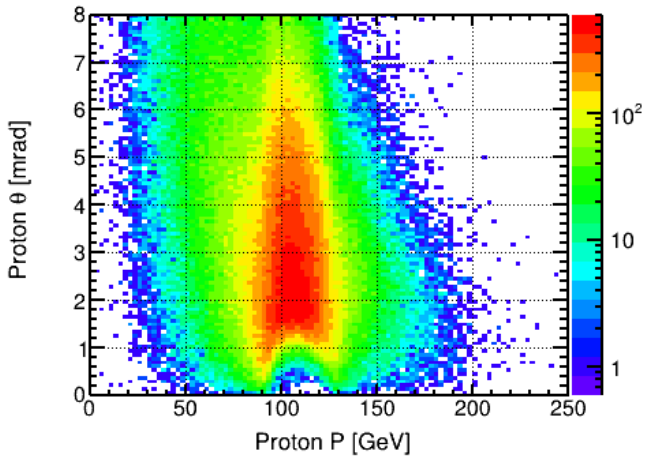
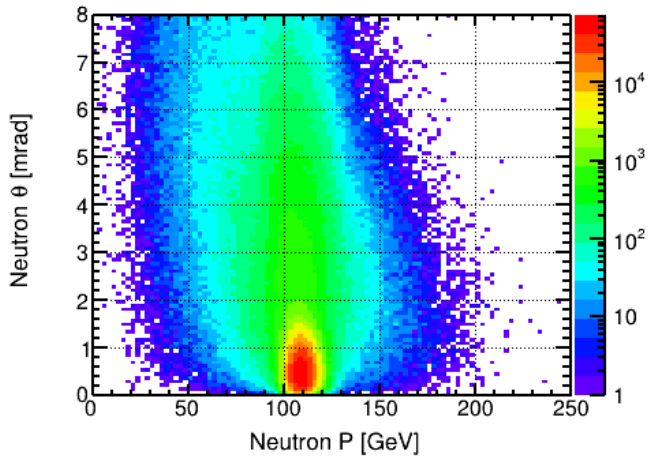
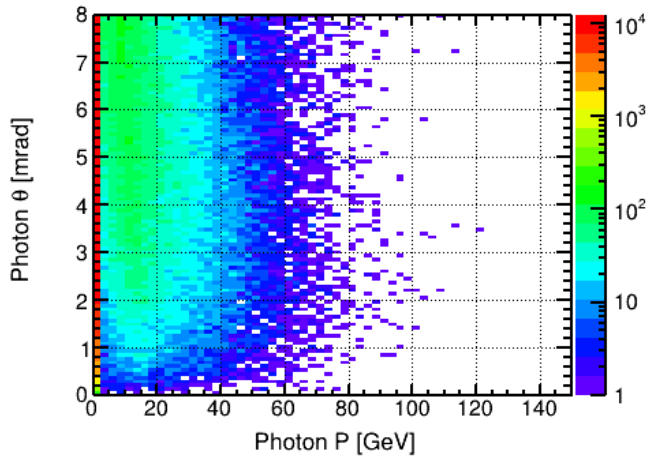
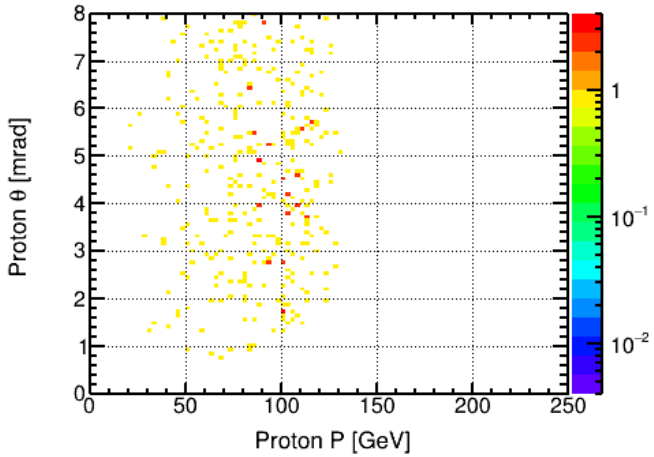
Generated Level

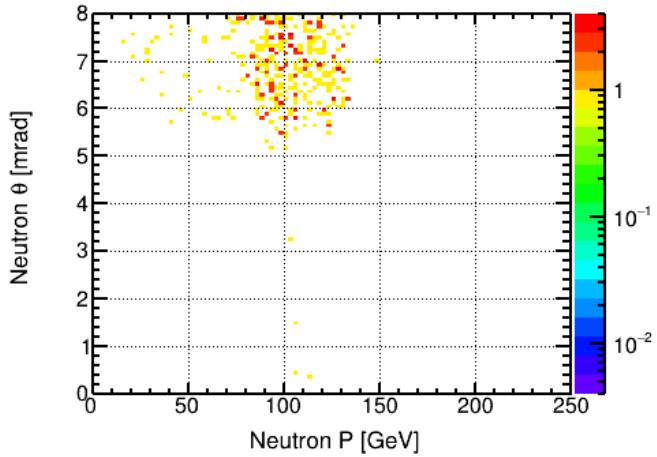


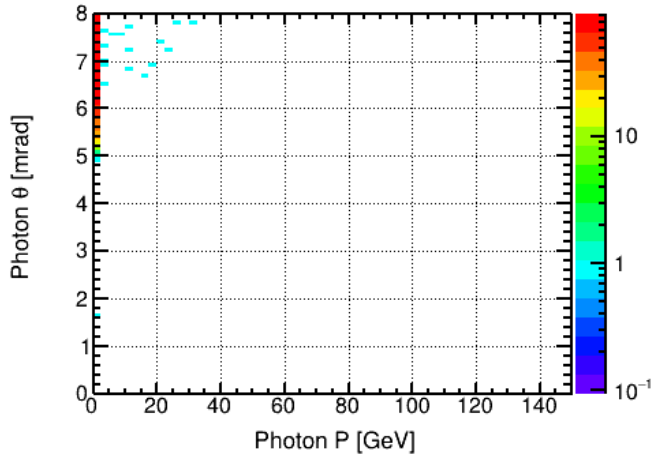




Remained Level

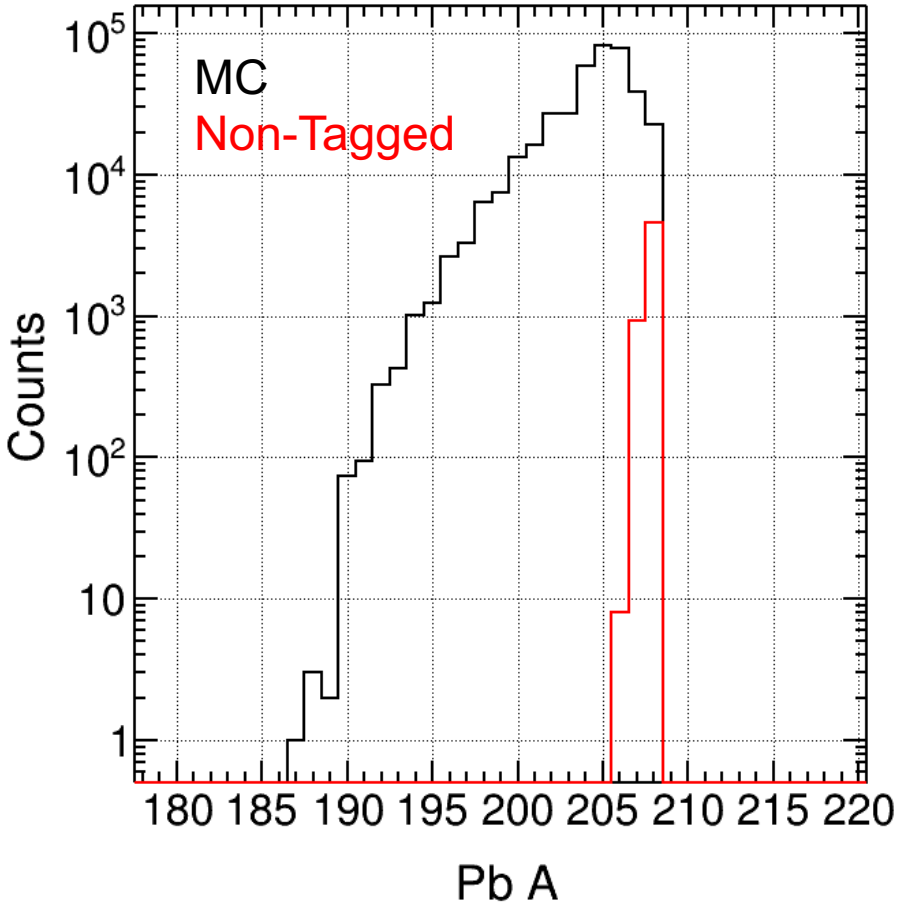


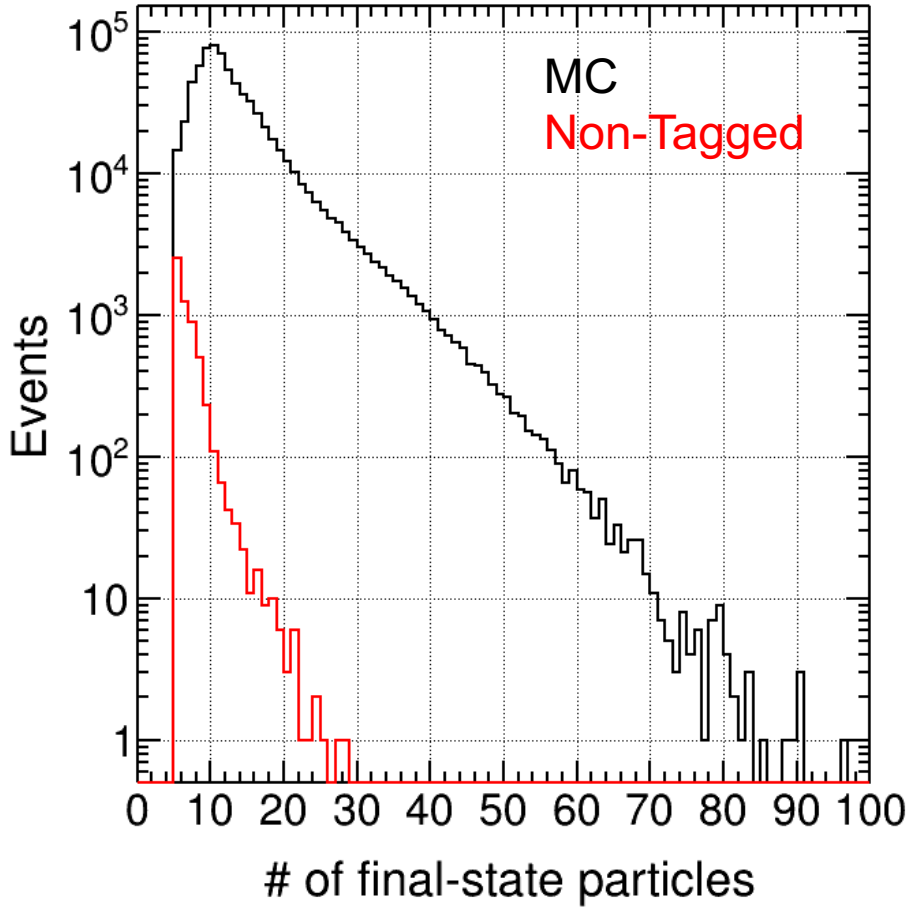




Remaining Events

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

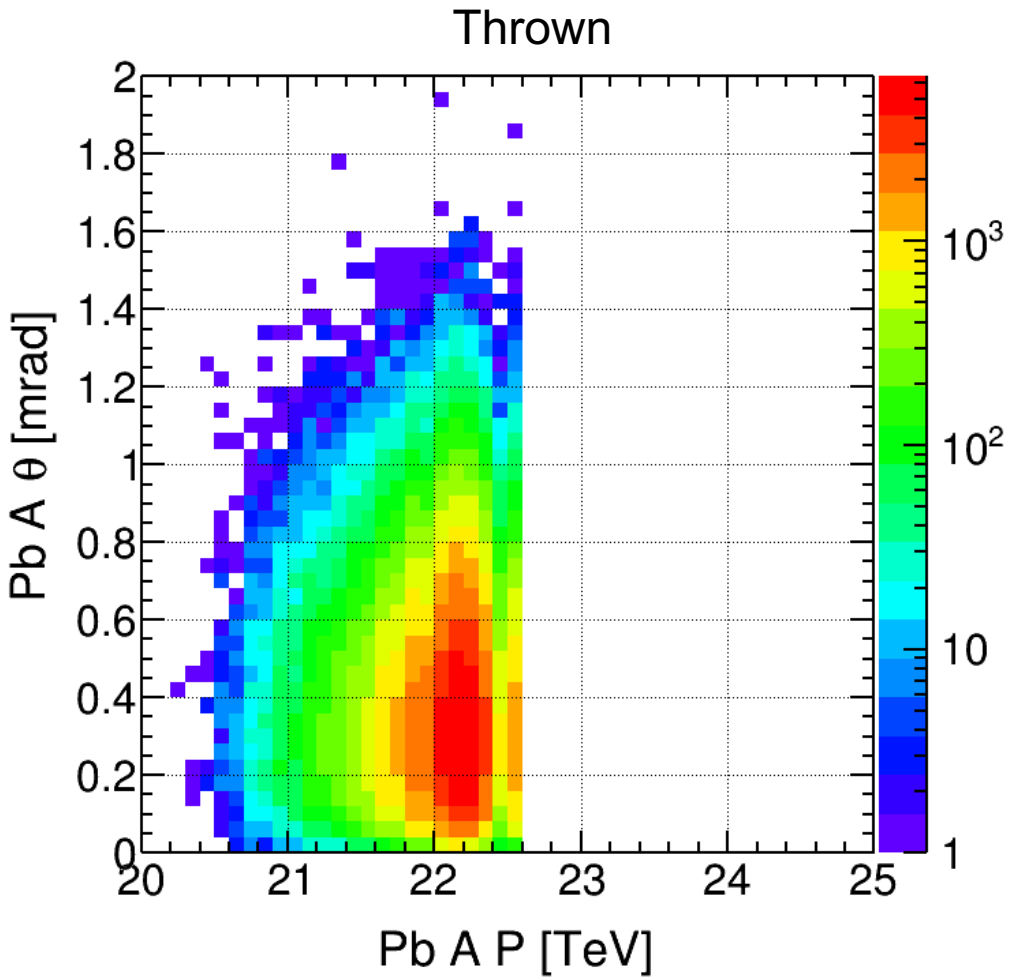


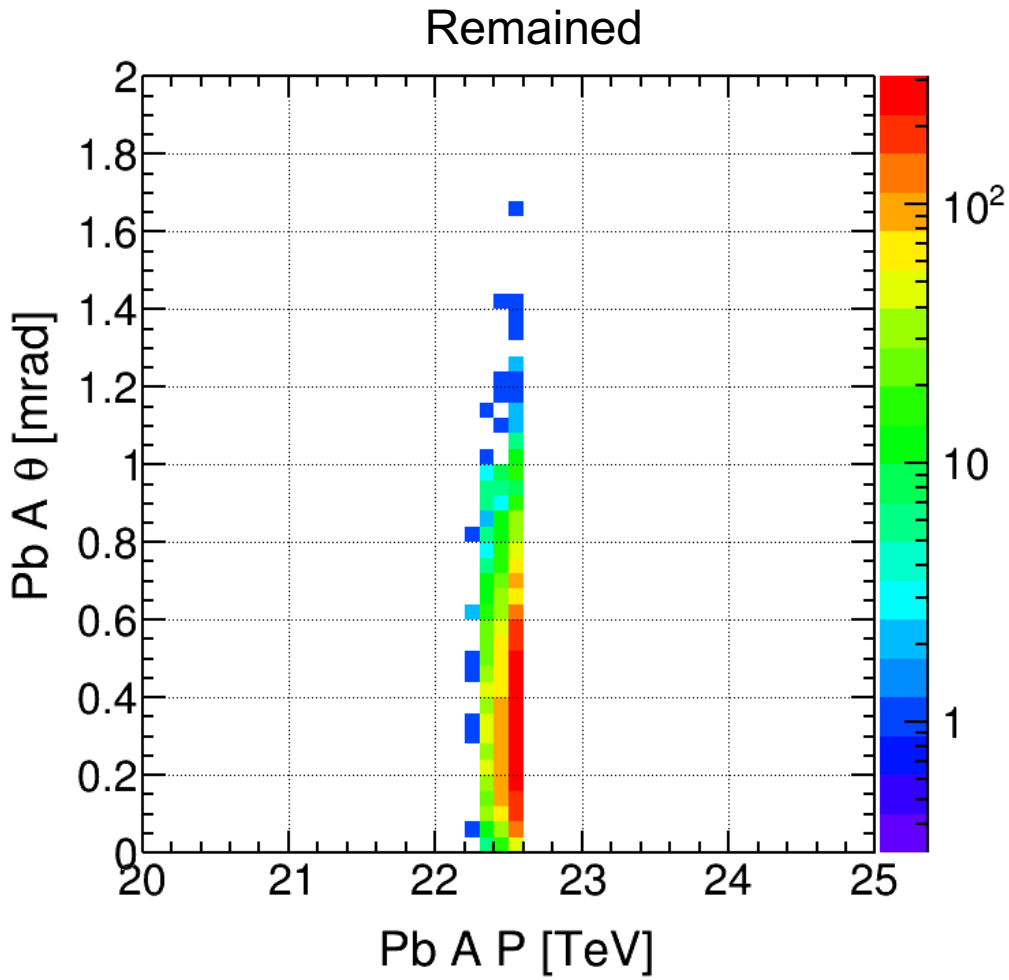


Remaining events have higher mass nuclear remnants and low number of particles in final state

Remaining Events

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





Remaining events have higher mass nuclear remnants and very small scattering angle

Summary

- Converted coordinate system in IP8 far-forward lattice and detectors in DD4hep simulation
  - From machine coordinate to electron beamline reference + origin (0,0,0)
  - Expect to make easier to add central detector with IP8 FF
- With basic components are in-place, looked at acceptance on each FF detector which makes sense
  - **Some further optimizations needed**
- Given current layout, looked at incoherent event on tagging power with $1 < Q^2 < 10$ and $t < 0.2$
  - Checked on coherent diffractive minima at t ~ 0.02, 0.05, and 0.1
  - Tagging power ~ 96%, 98%, and 99% at t ~ 0.02, 0.05, and 0.1
  - Regarding remaining events, it has low number of particles in final state and high mass nuclear remnants

Next Steps

- **Add simplified beampipe in DD4hep** to quantify impact on acceptance/efficiency
- **Add central tracker only** to reconstruct vector meson (J/ψ) in mid-rapidity
- **Optimize detector layout** and **find possible technologies and required energy/spatial resolution**
  - Add threshold in terms of hit reconstruction
- Find link to connect **hit-level info to true particle ID**

BackUp Slide

Q^2 and t Distribution

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