Update on IP8 DD4hep Simulation: Far-Forward Acceptance and Tagging Efficiency

Jihee Kim (jkim11@bnl.gov)

2023/11/20

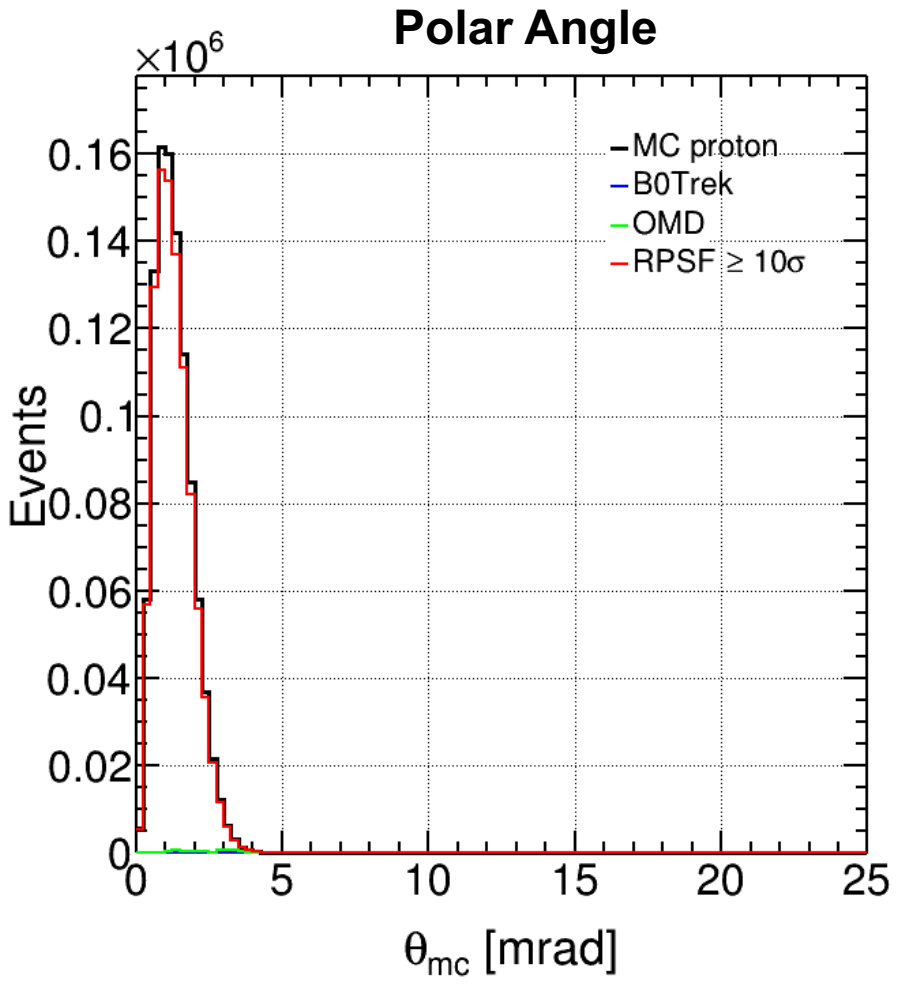
Approach – pT Acceptance

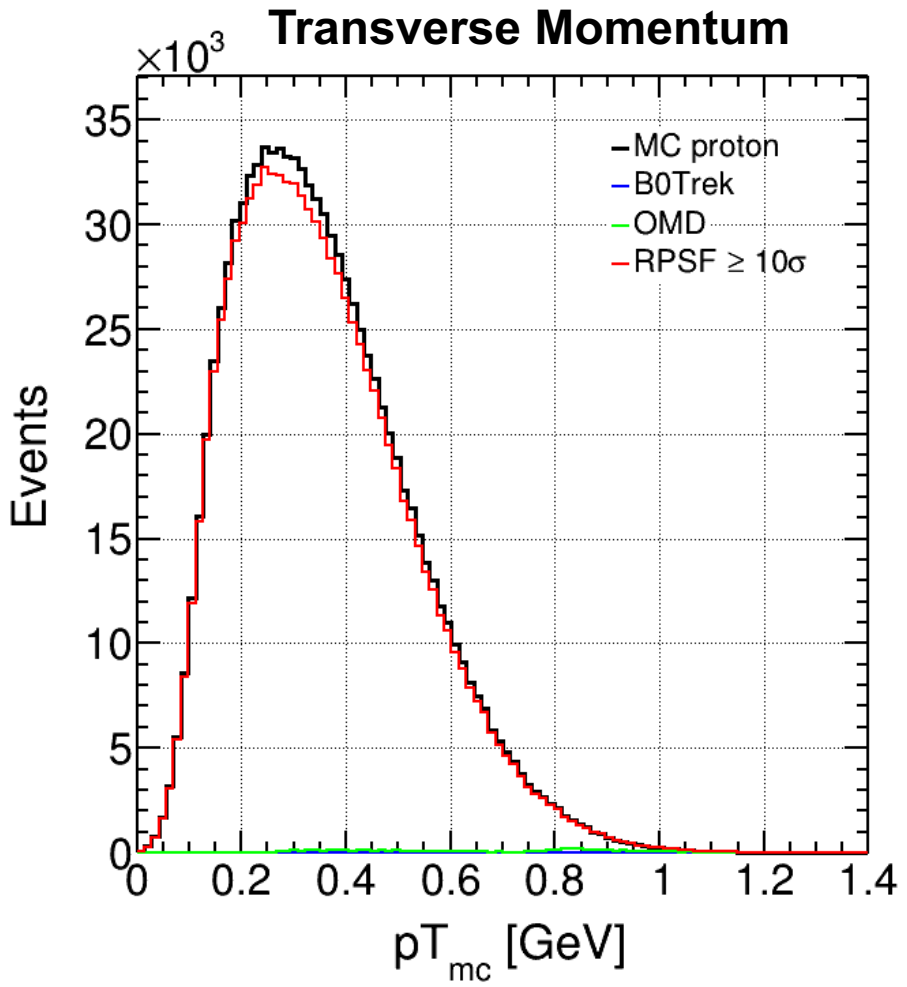
- By **tagging final-state proton**, it directly connects to **momentum transfer, t, measurement**
  - Investigate **low pT acceptance cutoffs**
- Used simulated **ep DVCS 1M** events each
  - Three beam energy combinations: ep 18×275, 10×100, and 5×41 GeV^2
    - S3/eictest/EPIC/EVGEN/EXCLUSIVE/DVCS/18x275/DVCS.3.18x275.hepmc
    - S3/eictest/EPIC/EVGEN/EXCLUSIVE/DVCS/10x100/DVCS.1.10x100.hepmc
    - S3/eictest/EPIC/EVGEN/EXCLUSIVE/DVCS/5x41/DVCS.2.5x41.hepmc
- Passed through **afterburner IP8 ep high divergence** configuration
  - IP8 crossing angle (35 mrad) and IP6 ep high divergence beam effects based on **EIC CDR table 3.3**
- **Accepted events for scattered protons *reconstruction purpose***
  - B0 tracker: **all four layers** have hits
  - OMD: **two layers** (actual four layers as redundancy) have hits
  - RPSF: **two layers** have hits > 10σ safe distance based on ***ep β @ IP6***

DVCS 18 GeV on 275 GeV (1/2)

Linear Scale

*Each histogram fills separately





MC
B0
OMD
RPSF

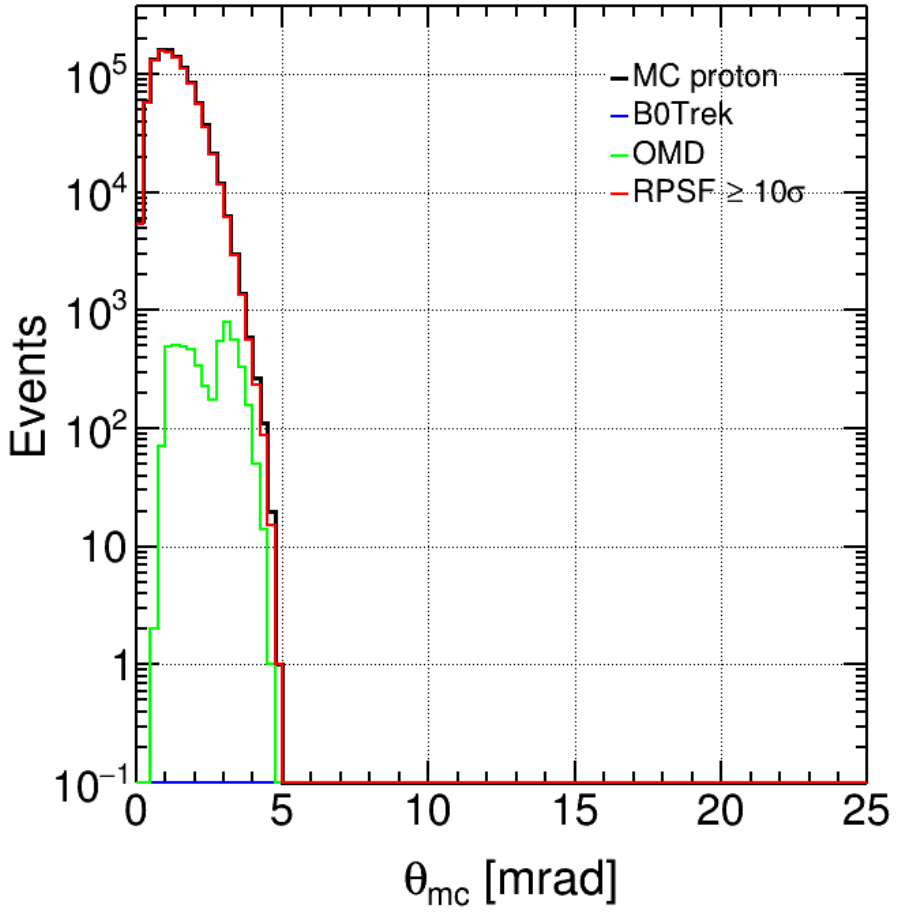
Scattered protons are very forward (< 5 mrad), measured in **Roman Pot at secondary focus**
(**96.77 % events accepted** with 10σ safe distance cut based on **ep β @ IP6**)

DVCS 18 GeV on 275 GeV (2/2)

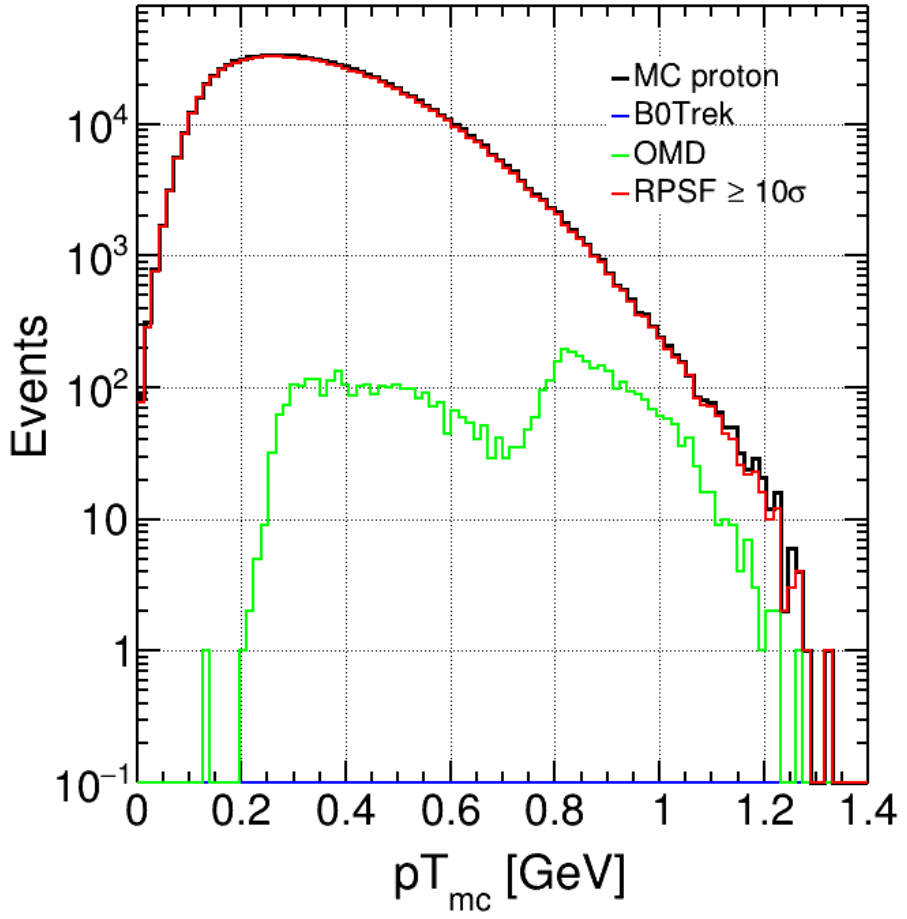
Log Scale

*Each histogram fills separately

Polar Angle



Transverse Momentum



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OMD
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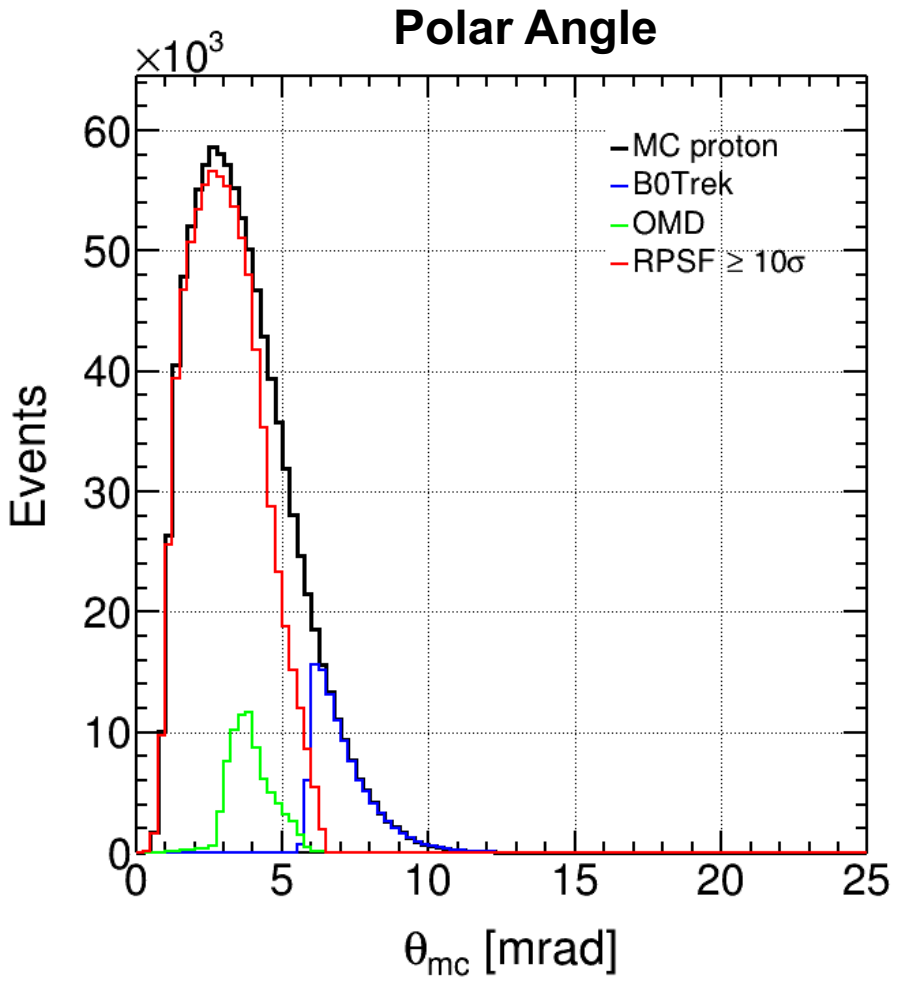
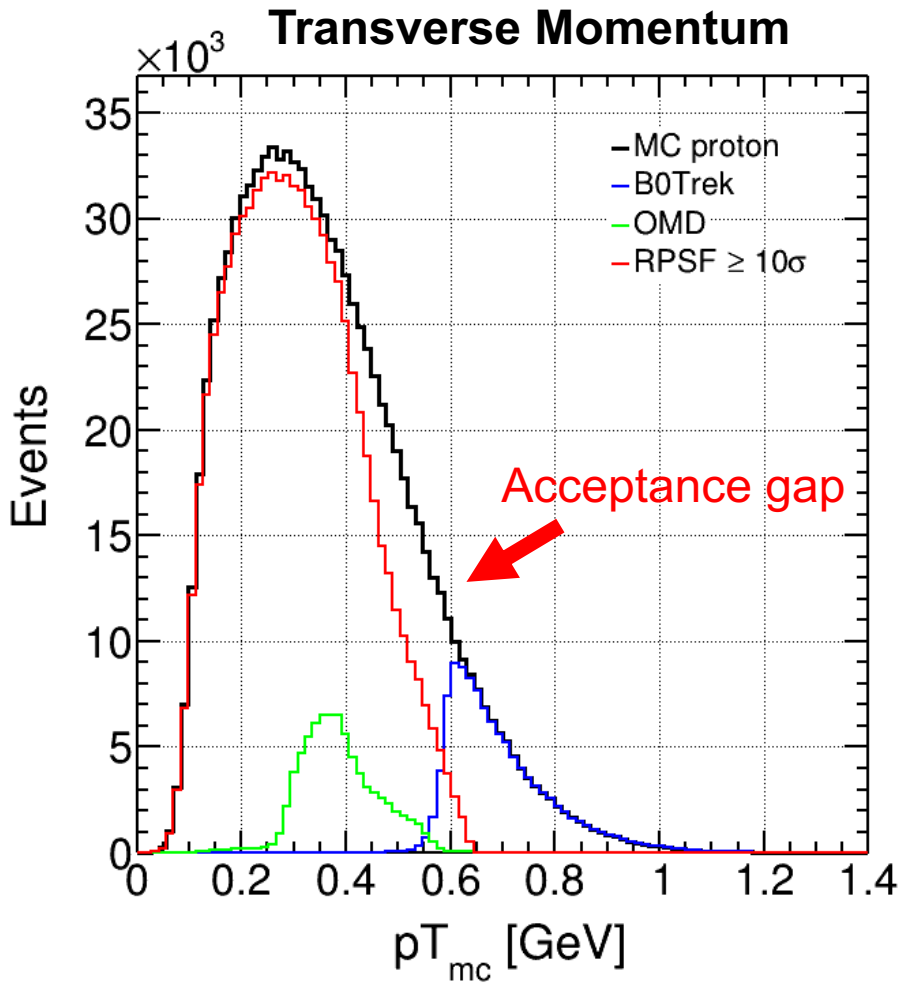
Scattered protons are very forward (< 5 mrad), measured in **Roman Pot at secondary focus**
(**96.77 % events accepted** with 10σ safe distance cut based on **ep β @ IP6**)

DVCS 10 GeV on 100 GeV (1/2)

Linear Scale

*Each histogram fills separately





MC
B0
OMD
RPSF

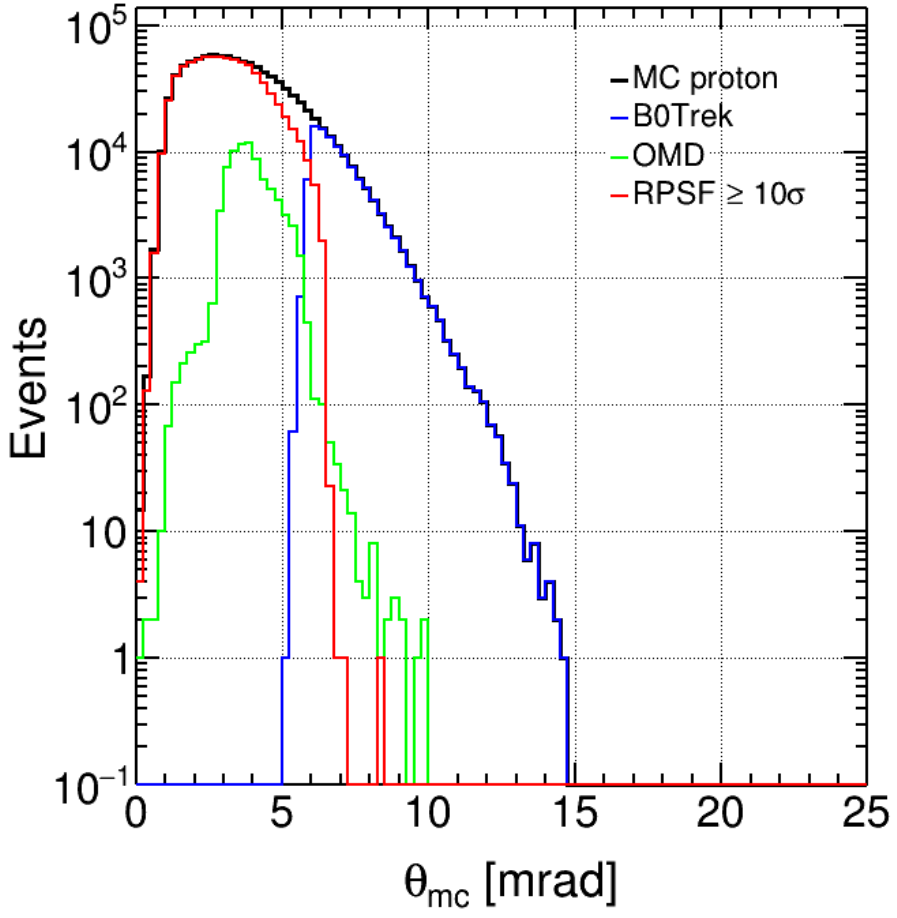
Scattered protons measured in **both B0 and *Roman Pot at secondary focus**
(**10.89 % and 79.46 % events accepted** with 10σ safe distance cut based on **ep β @ IP6**)

DVCS 10 GeV on 100 GeV (2/2)

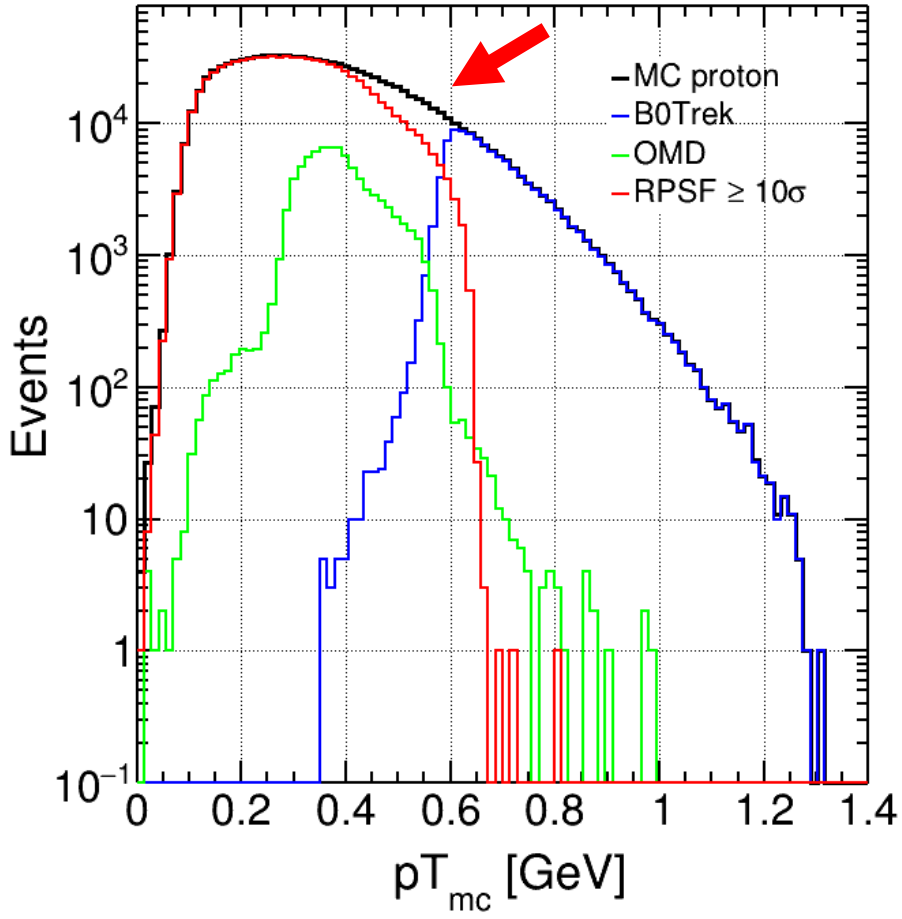
Log Scale

*Each histogram fills separately

Polar Angle



Transverse Momentum



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Scattered protons measured in **both B0 and *Roman Pot at secondary focus**
(**10.89 % and 79.46 % events accepted** with 10σ safe distance cut based on **ep β @ IP6**)

DVCS 5 GeV on 41 GeV (1/2)

Linear Scale

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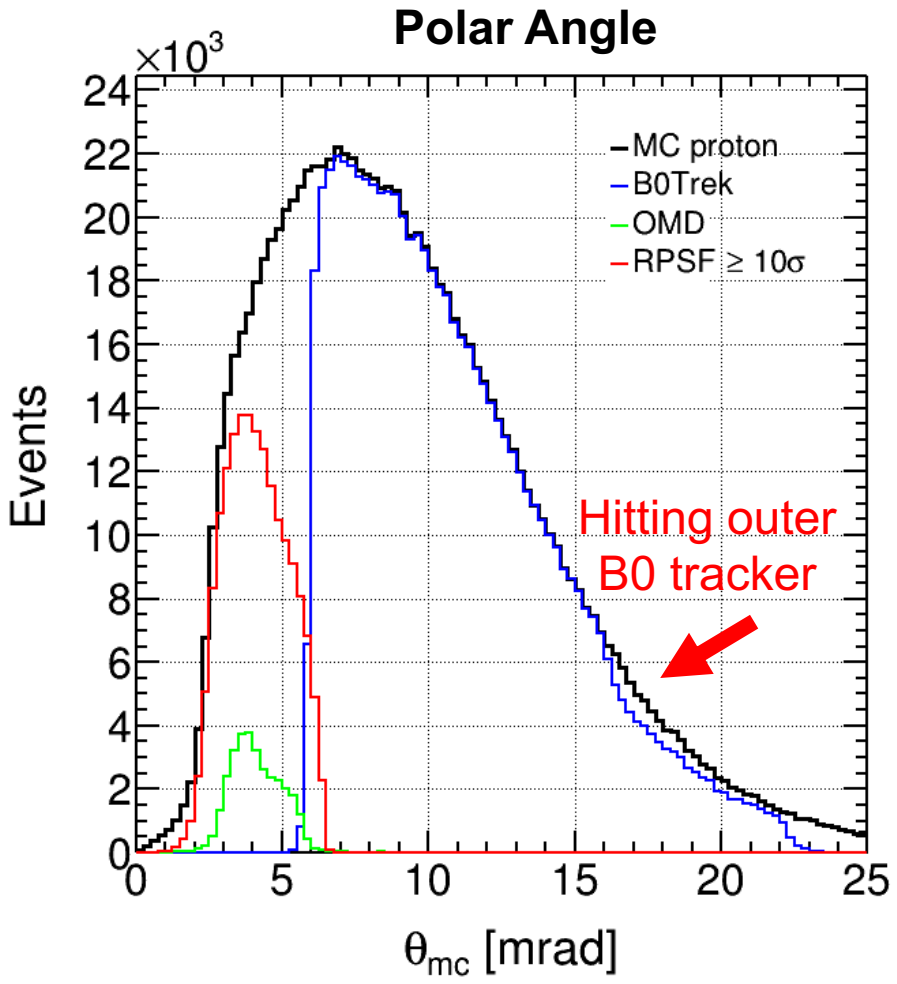
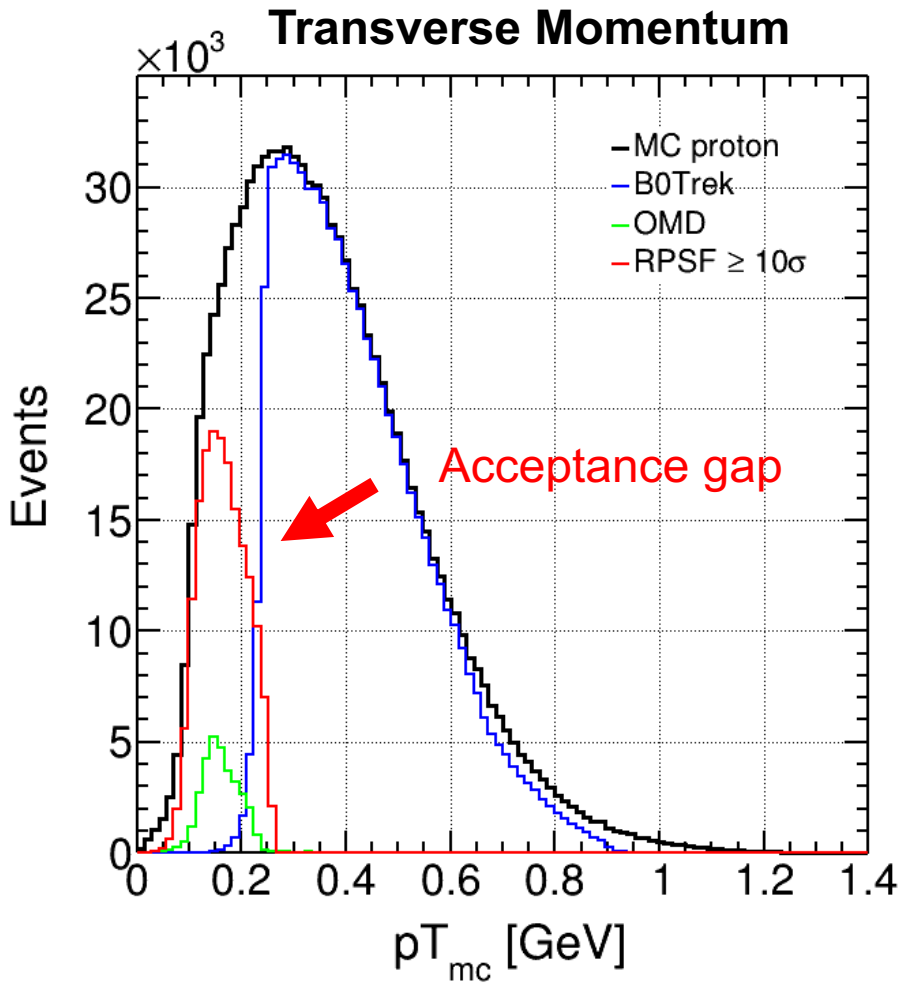




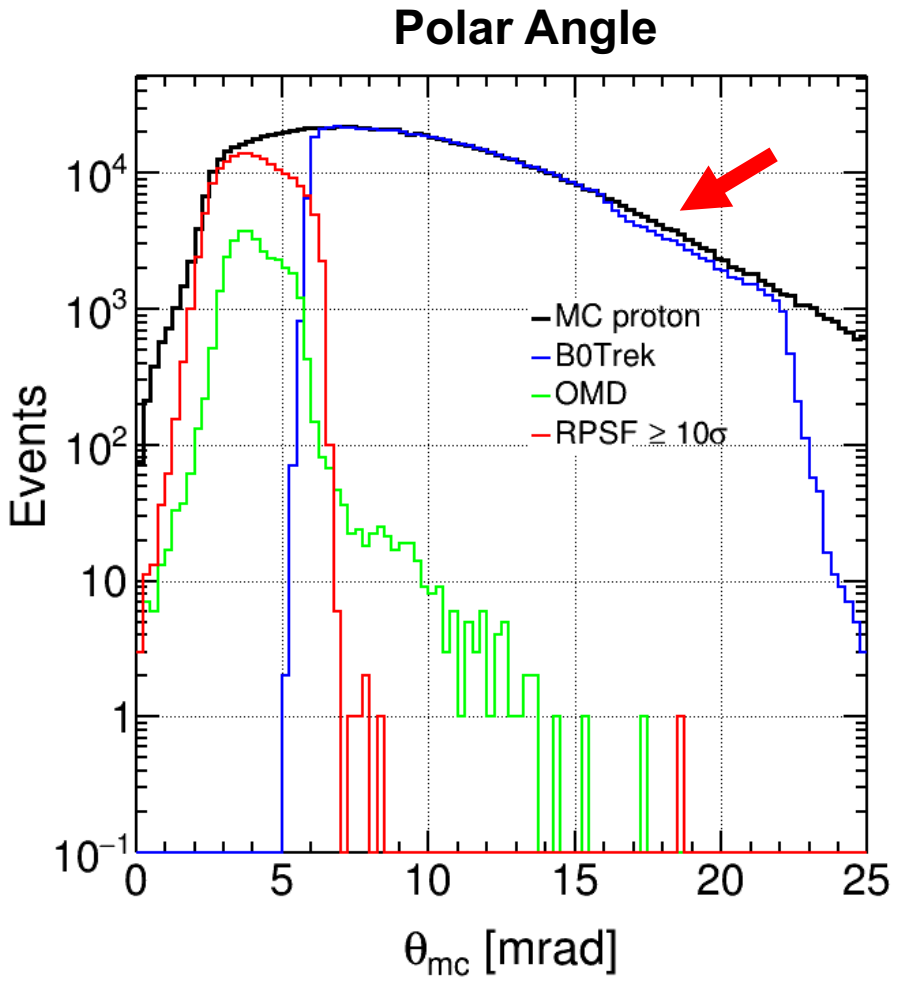
MC
B0
OMD
RPSF

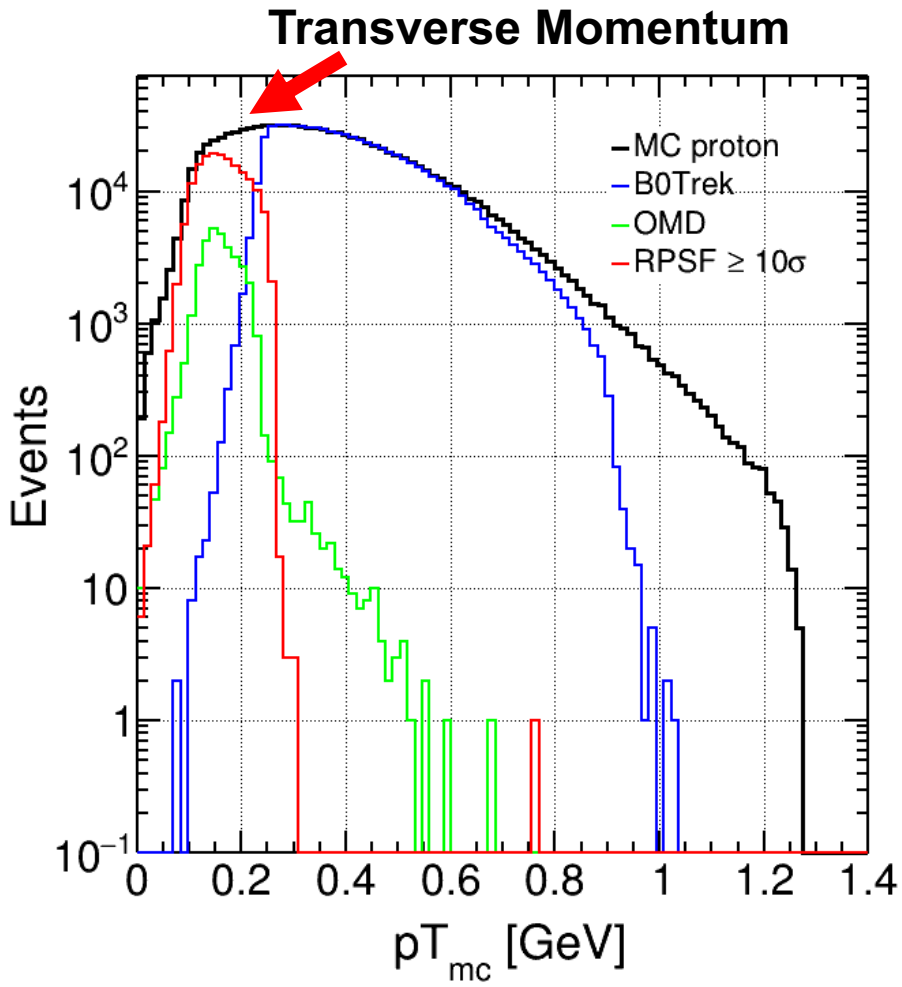
Scattered protons measured in **both *B0 and Roman Pot at secondary focus**
(**70.62 % and 17.00 % events accepted** with 10σ safe distance cut based on **ep β @ IP6**)

DVCS 5 GeV on 41 GeV (2/2)

Log Scale

*Each histogram fills separately





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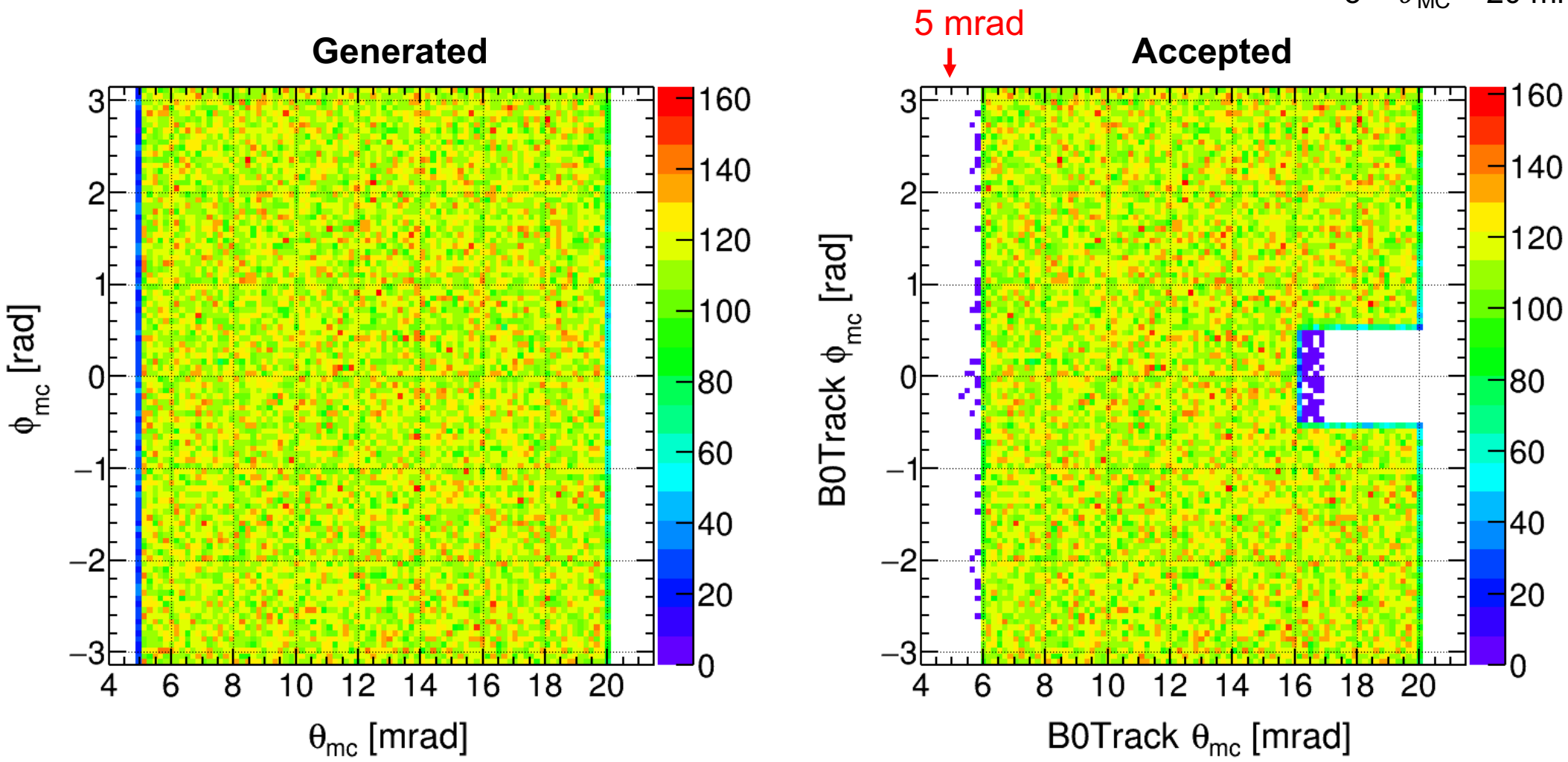
Scattered protons measured in **both *B0 and Roman Pot at secondary focus**
(**70.62 % and 17.00 % events accepted** with 10σ safe distance cut based on **ep β @ IP6**)

B0 Tracker

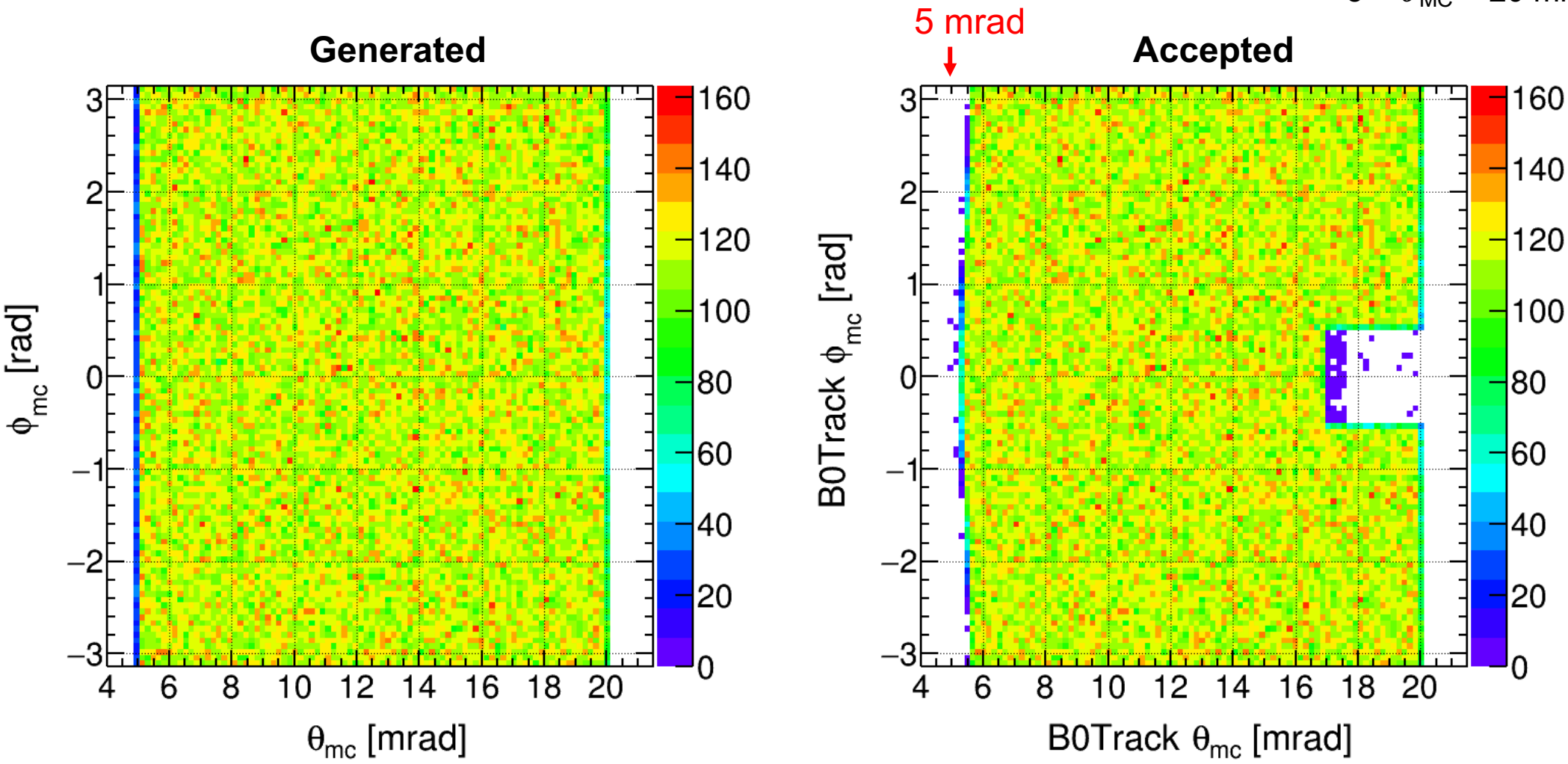
Single Proton
80 GeV < E < 120 GeV
5 < θ_{MC} < 20 mrad



About **88.94 %** events were **accepted with requiring all 4 tracker layers**

B0 Tracker

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



About **93.6 %** events were **accepted with requiring more than 2 tracker layers**

Approach – pT Acceptance

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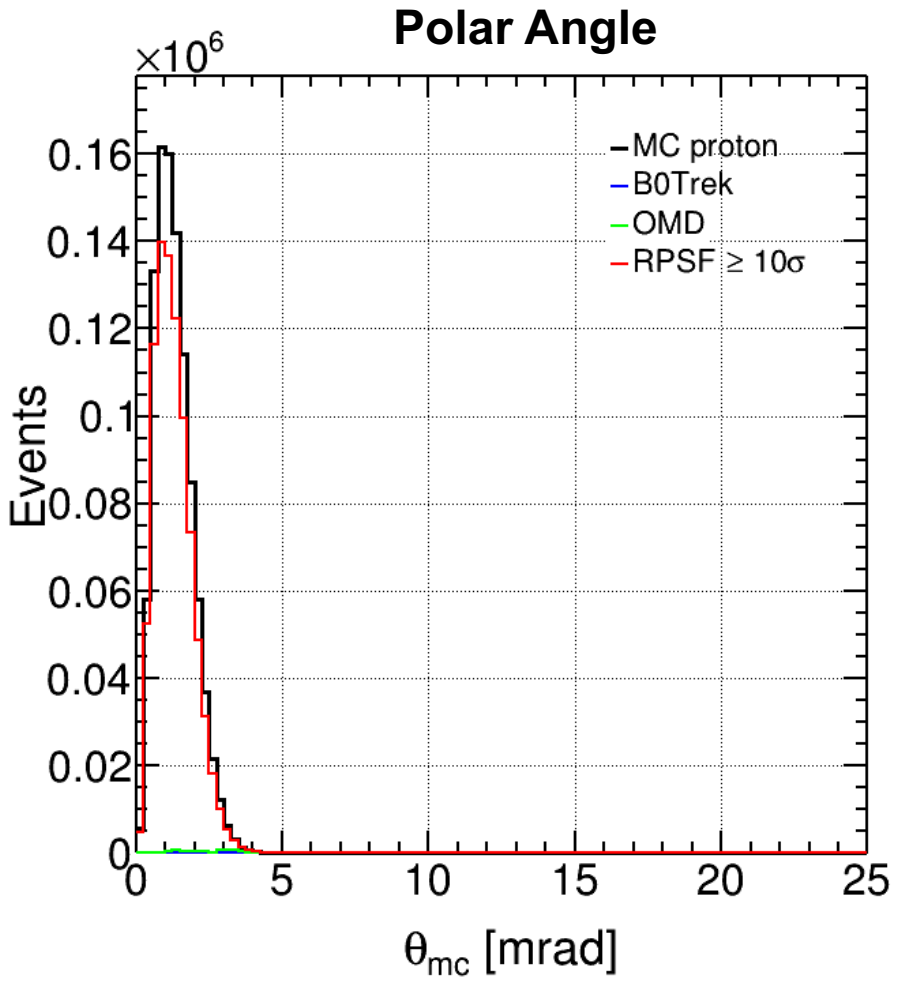
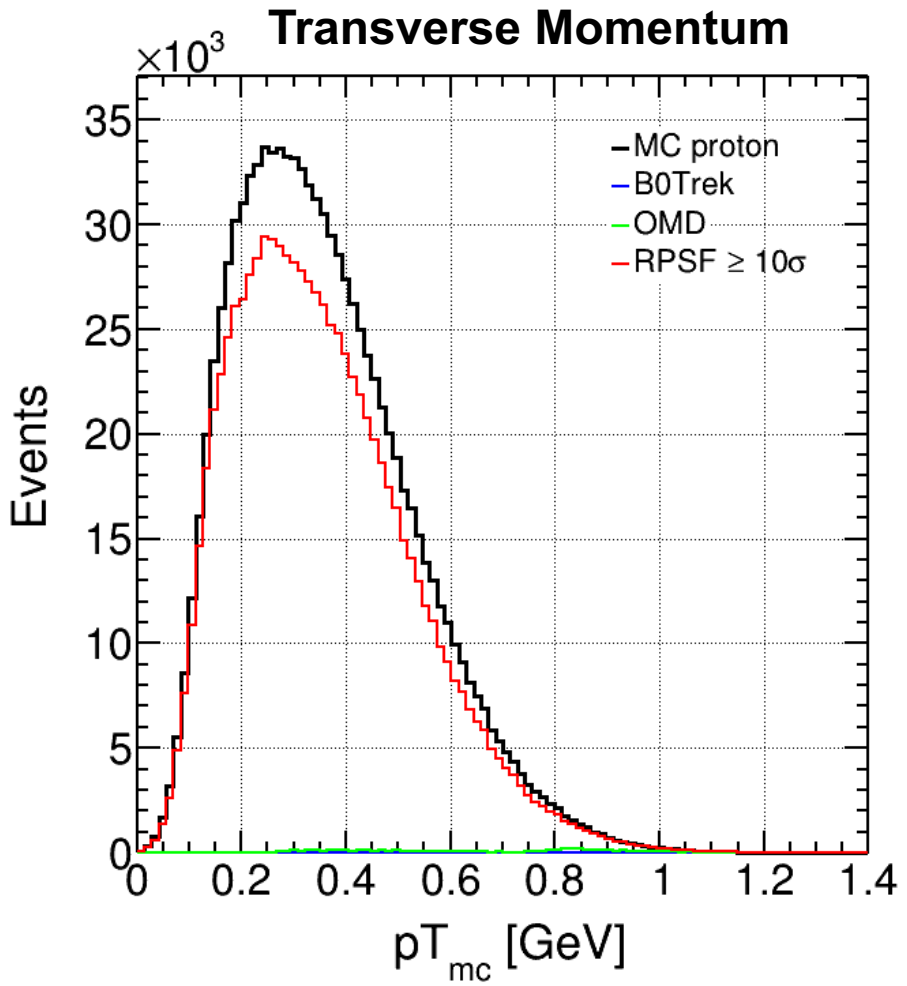
** Do it properly
β is defined as a function of z

DVCS 18 GeV on 275 GeV (1/2)

Linear Scale

*Each histogram fills separately





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OMD
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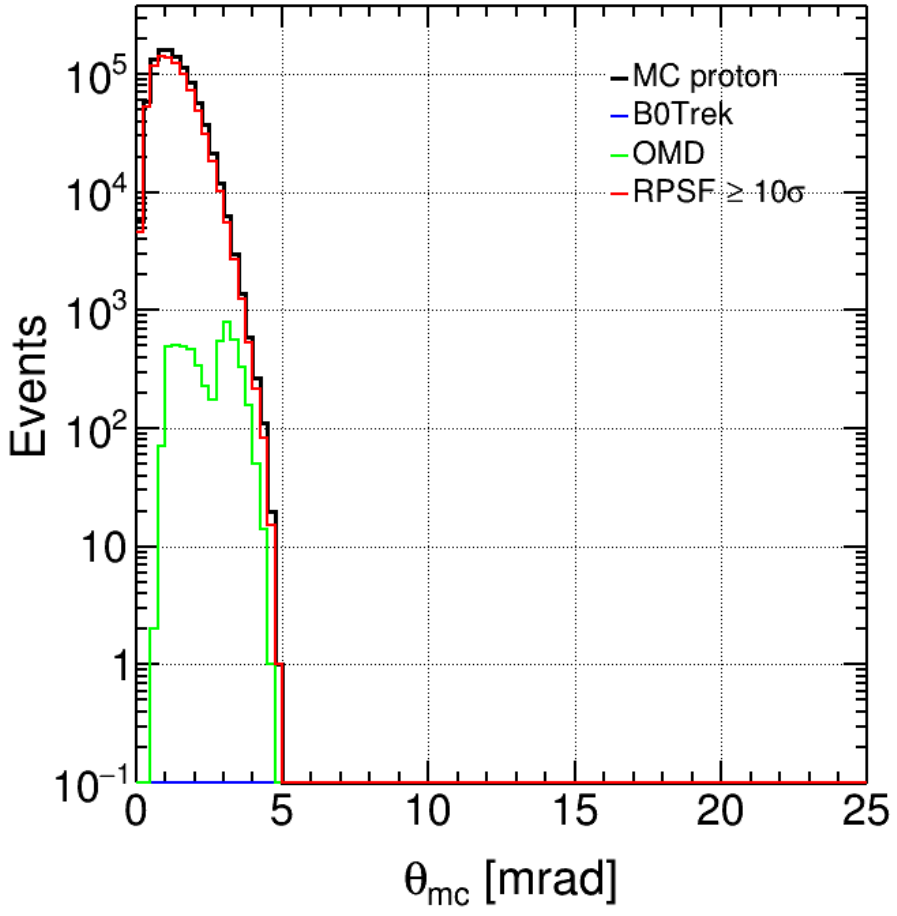
Scattered protons are very forward (< 5 mrad), measured in **Roman Pot at secondary focus**
(**86.33 % events accepted** with 10σ safe distance cut based on **ep β @ IP8 RPSF**)

DVCS 18 GeV on 275 GeV (2/2)

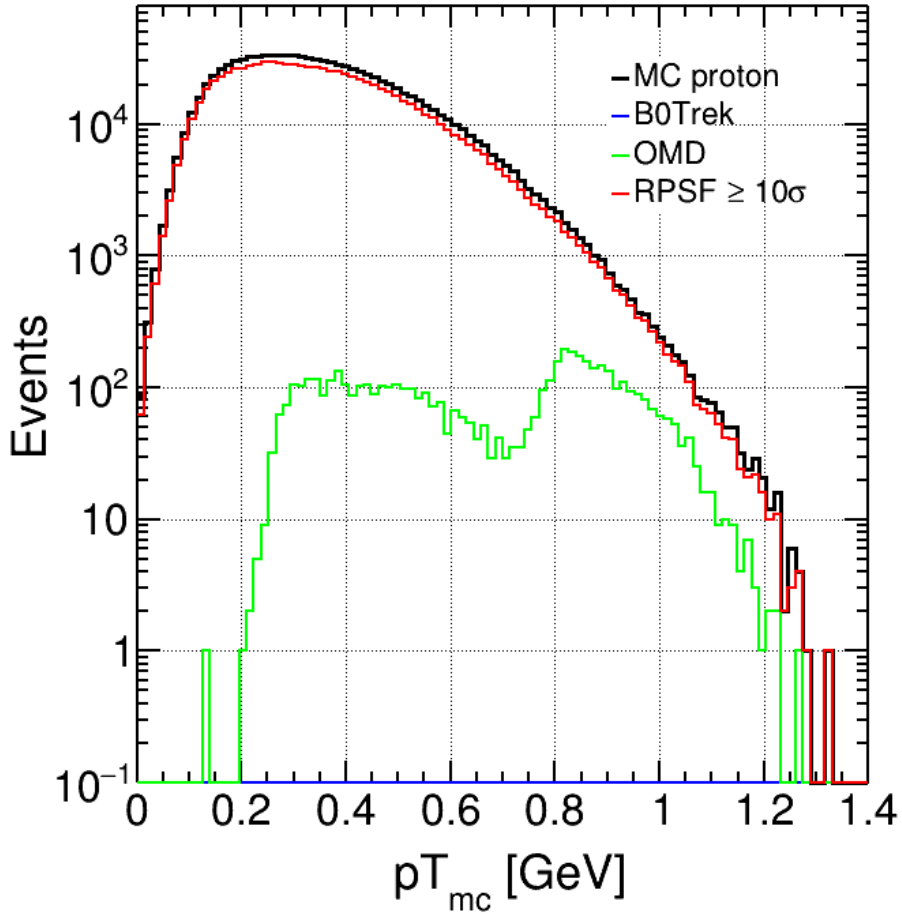
Log Scale

*Each histogram fills separately

Polar Angle



Transverse Momentum



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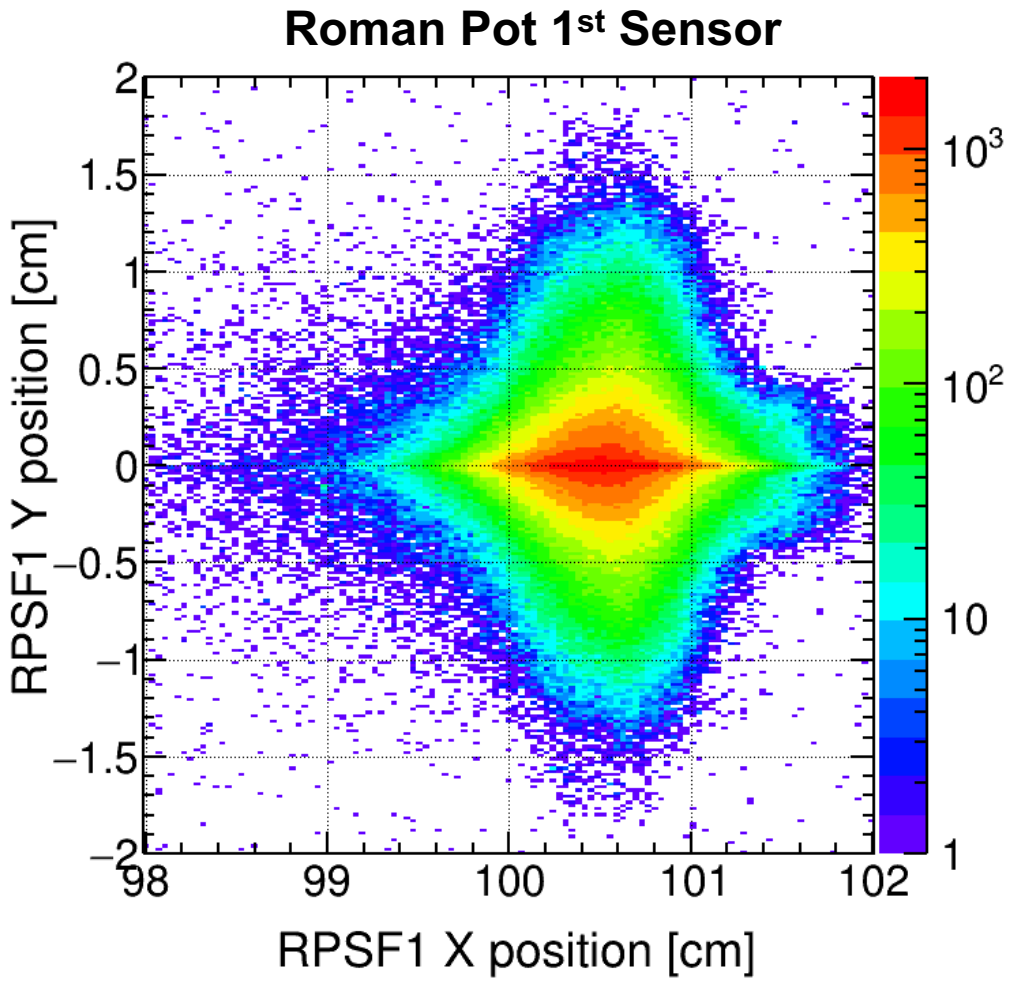
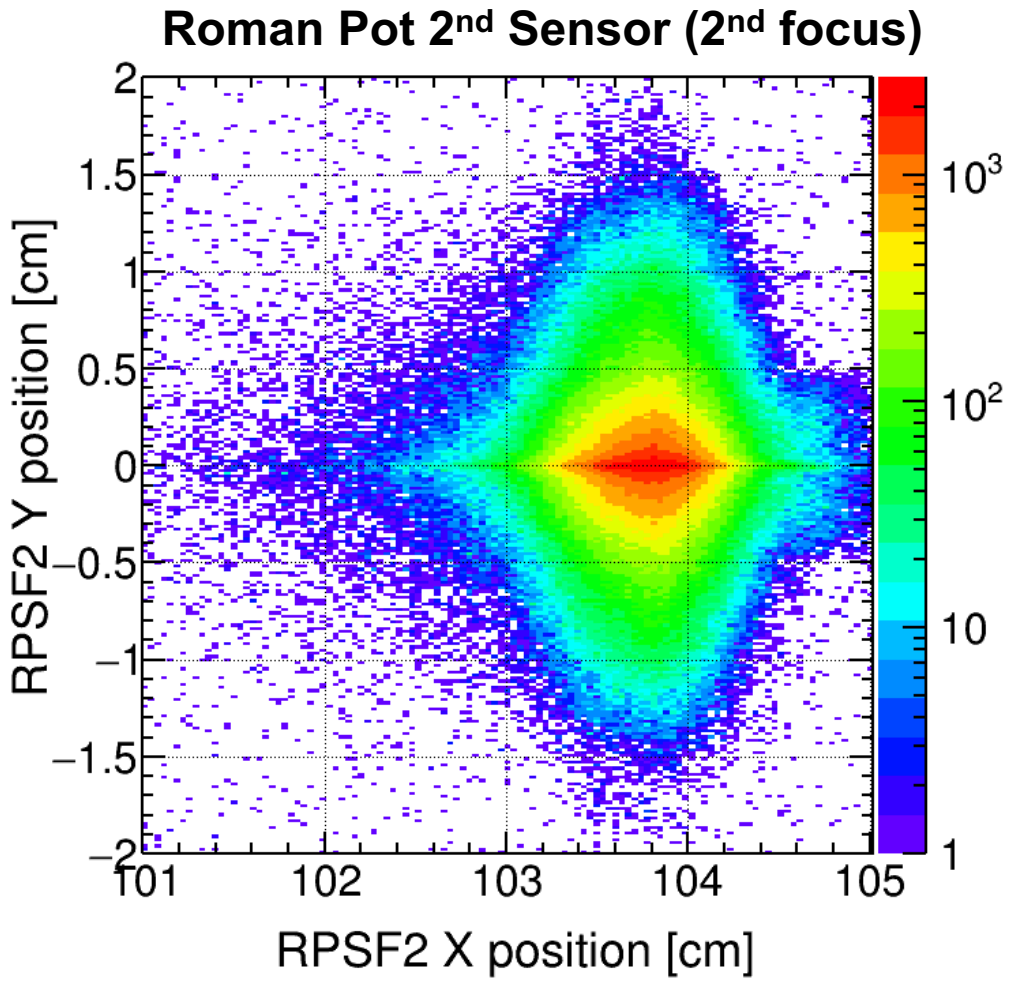
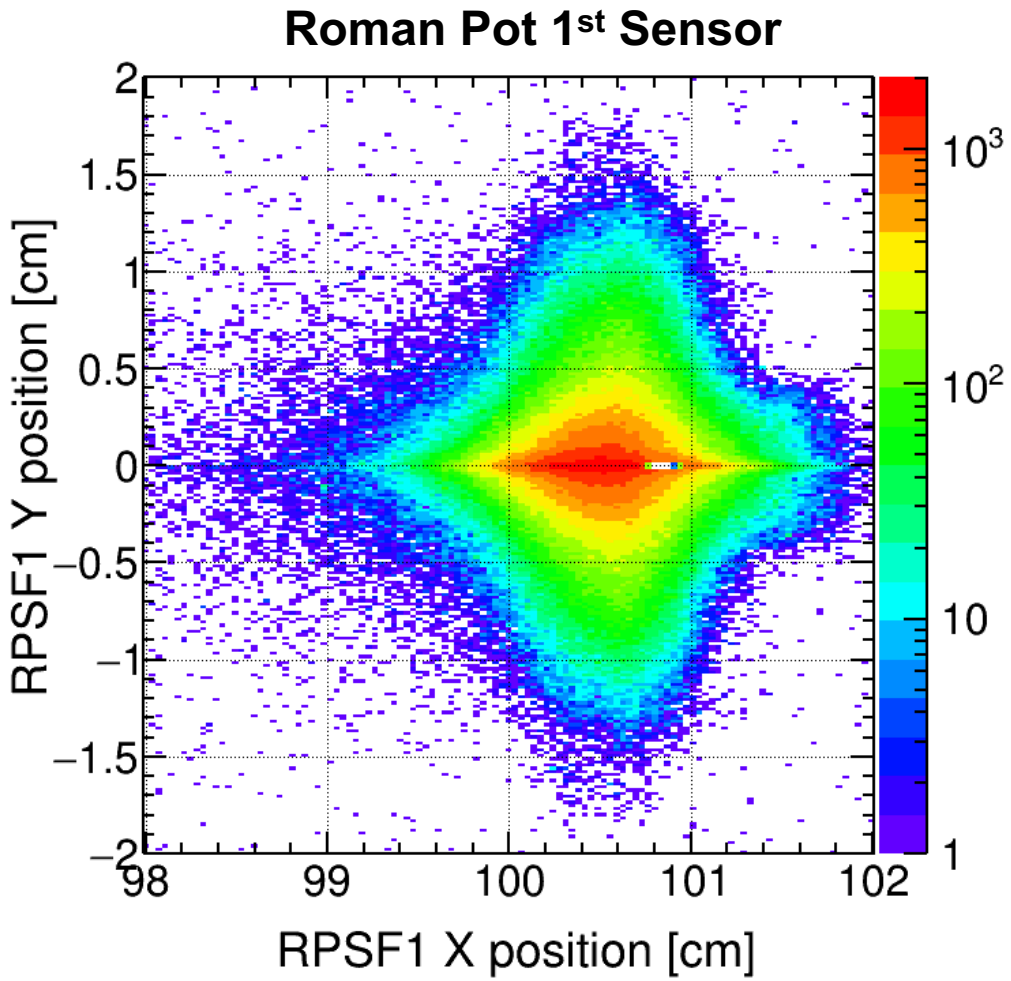
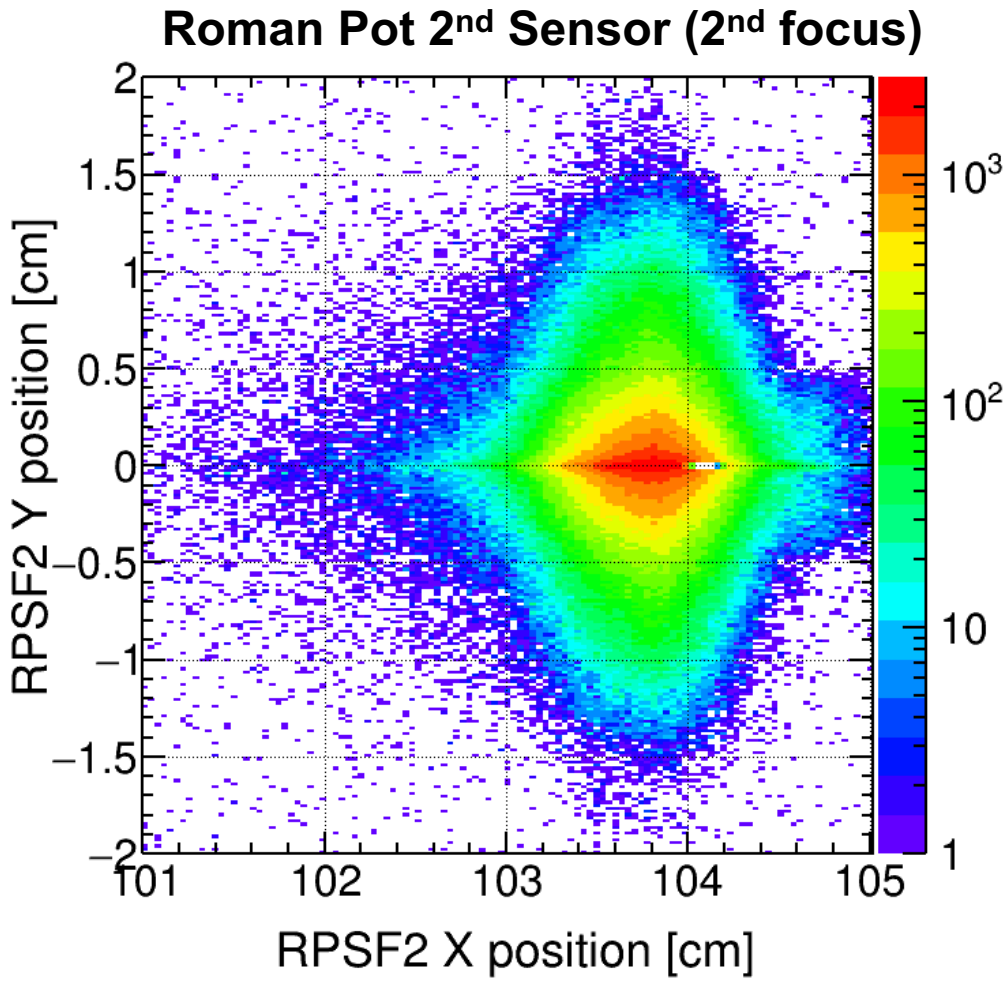




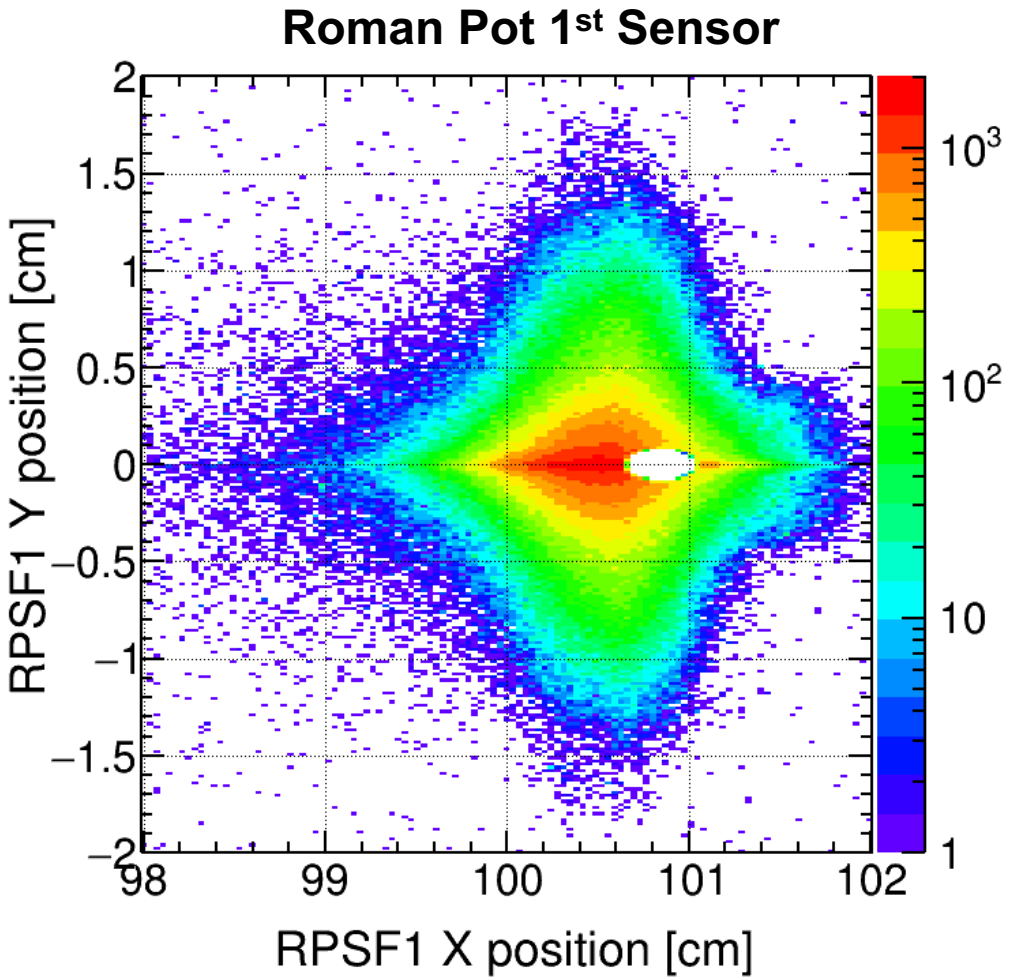
DVCS 18 GeV on 275 GeV

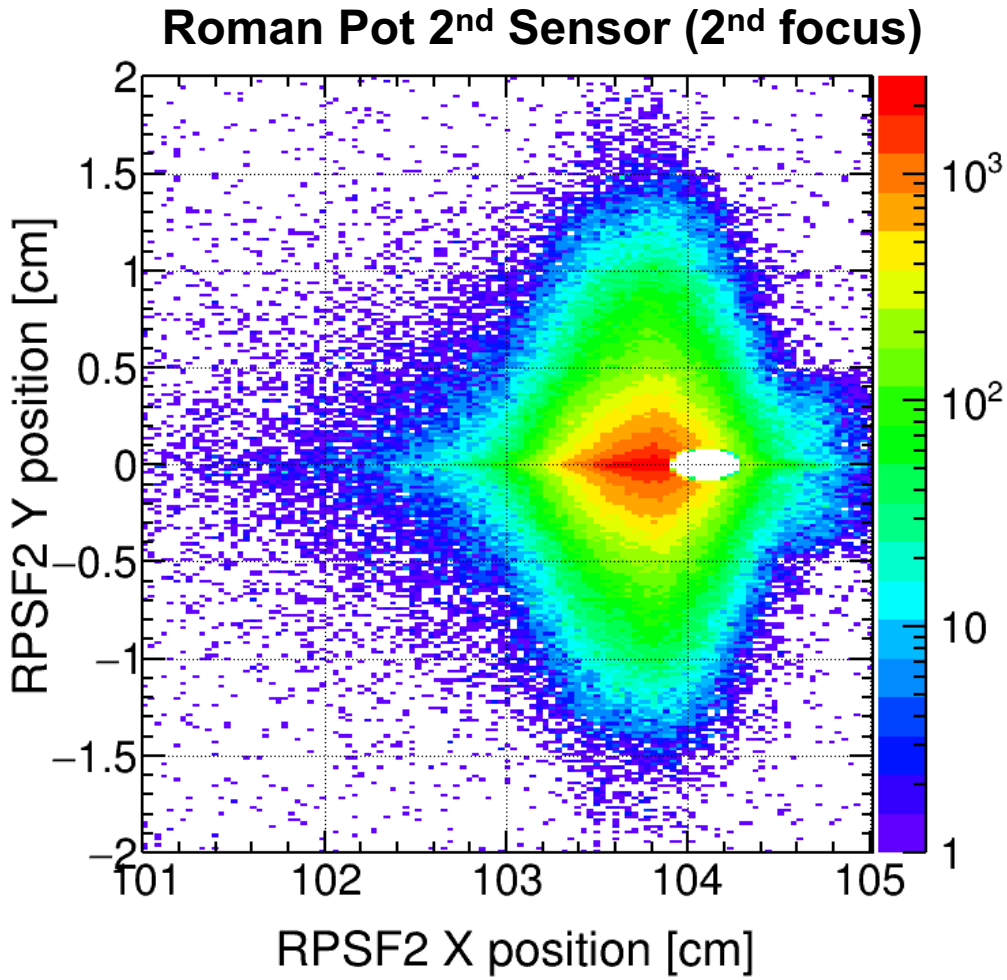




96.77 % events accepted with 10σ safe distance cut based on **ep β @ IP6**

DVCS 18 GeV on 275 GeV





86.33 % events accepted with 10σ safe distance cut based on **ep β @ IP8 RPSF**

DVCS 10 GeV on 100 GeV (1/2)

Linear Scale

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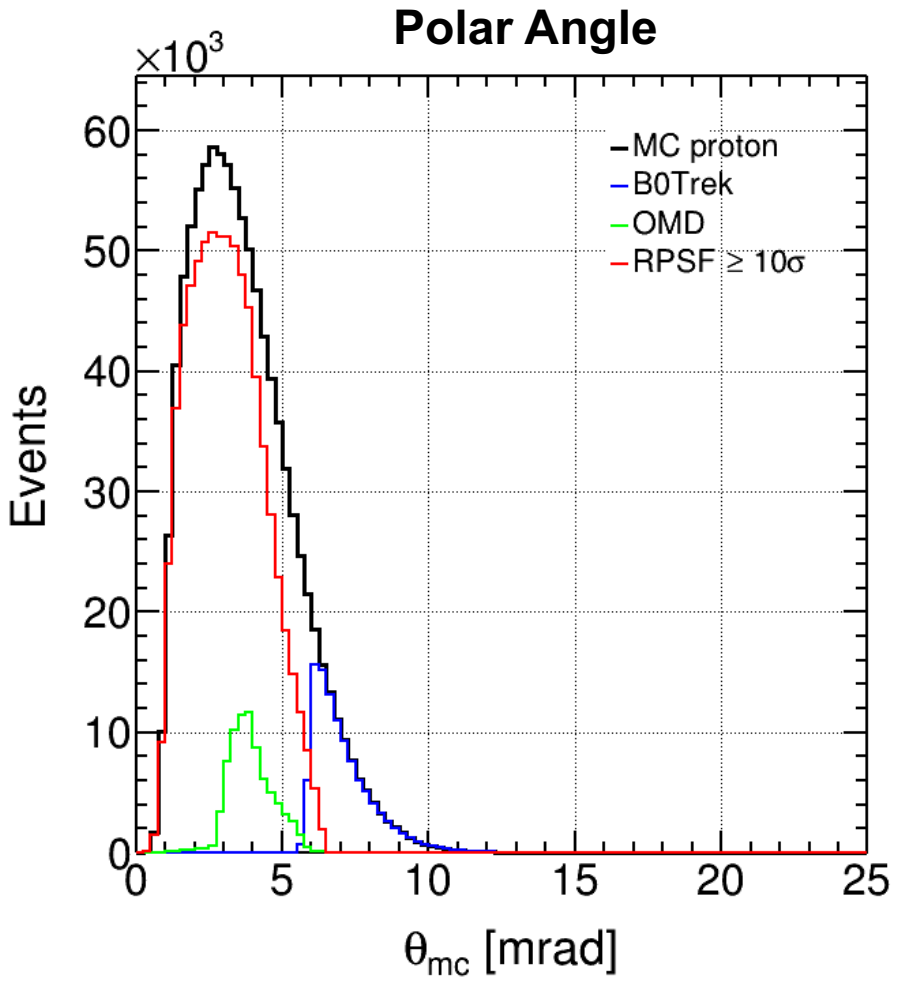
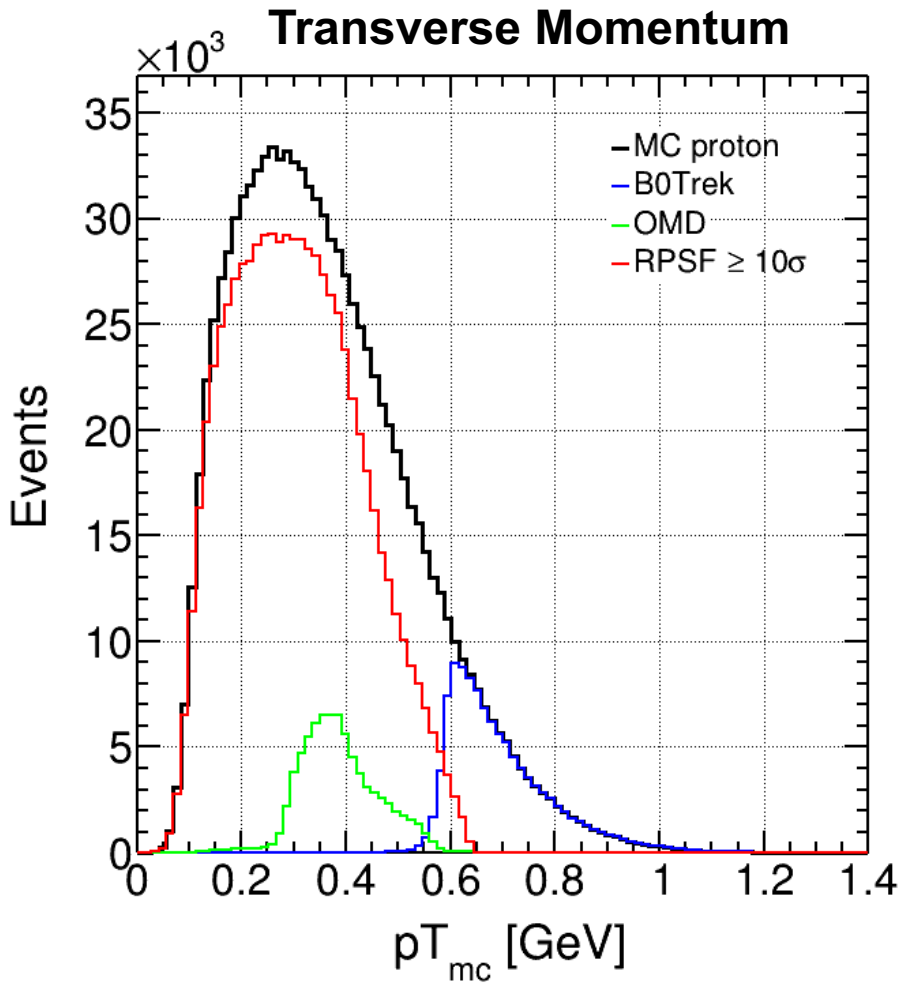




MC
B0
OMD
RPSF

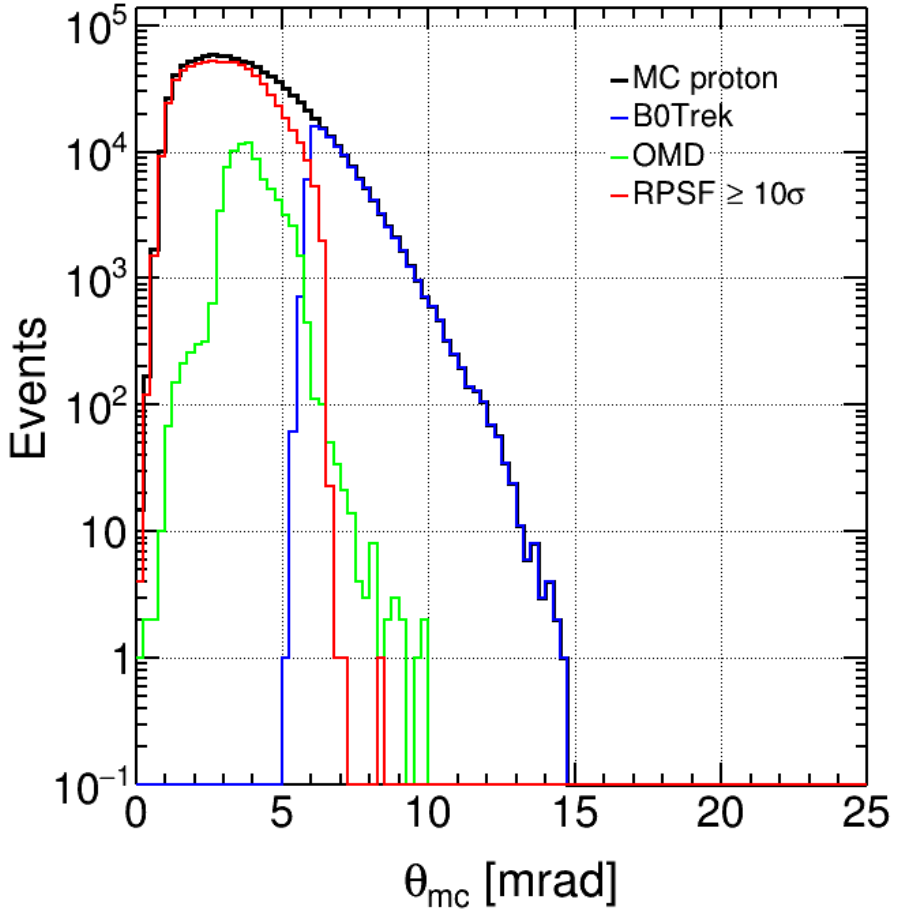
Scattered protons measured in **both B0 and *Roman Pot at secondary focus** (**10.89 %** and **74.49 % events accepted** with 10σ safe distance cut based on **ep β @ IP8 RPSF**)

DVCS 10 GeV on 100 GeV (2/2)

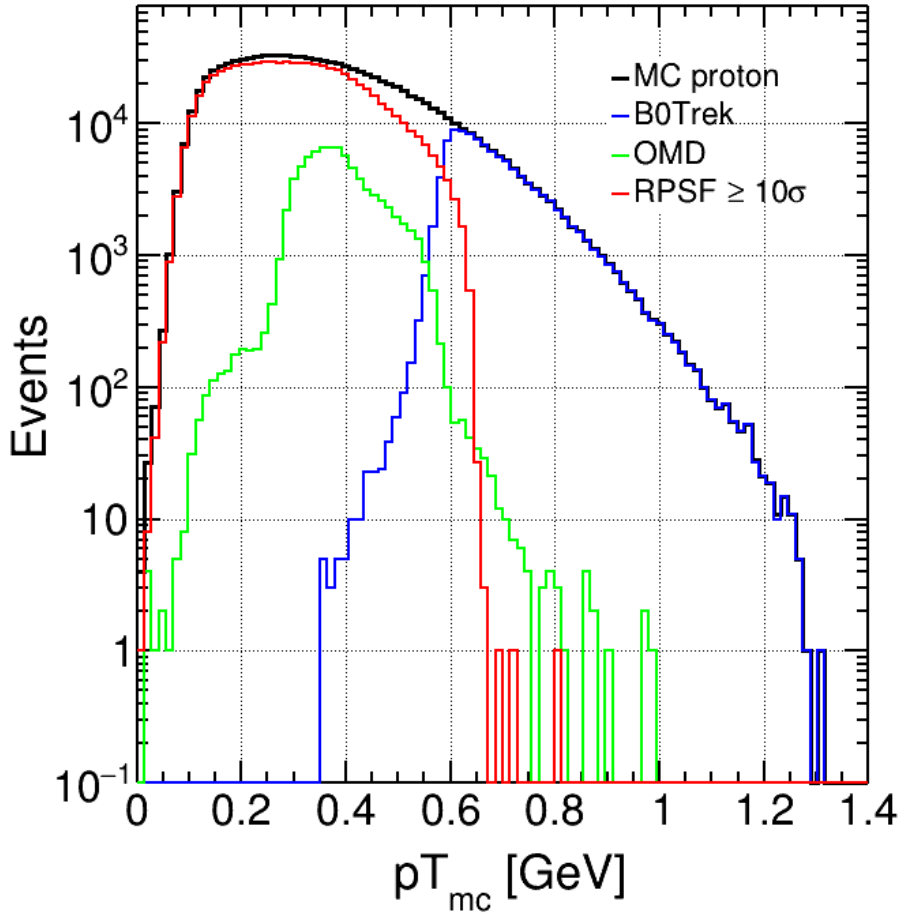
Log Scale

*Each histogram fills separately

Polar Angle



Transverse Momentum



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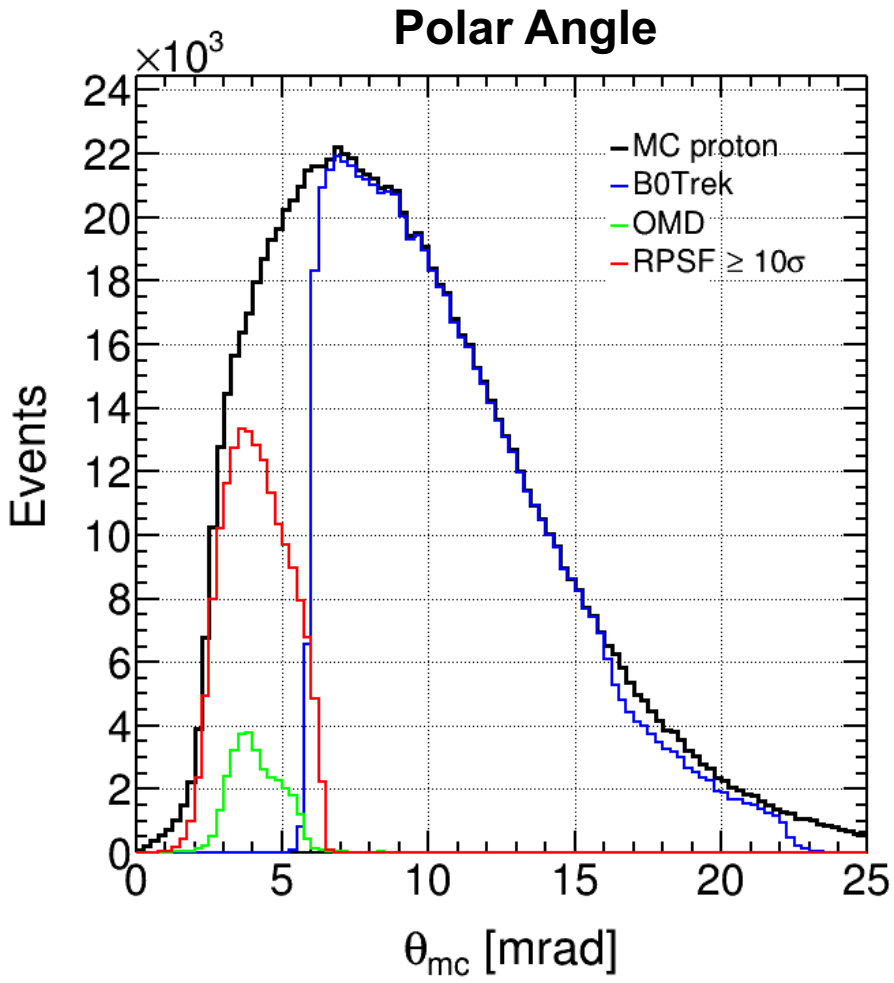
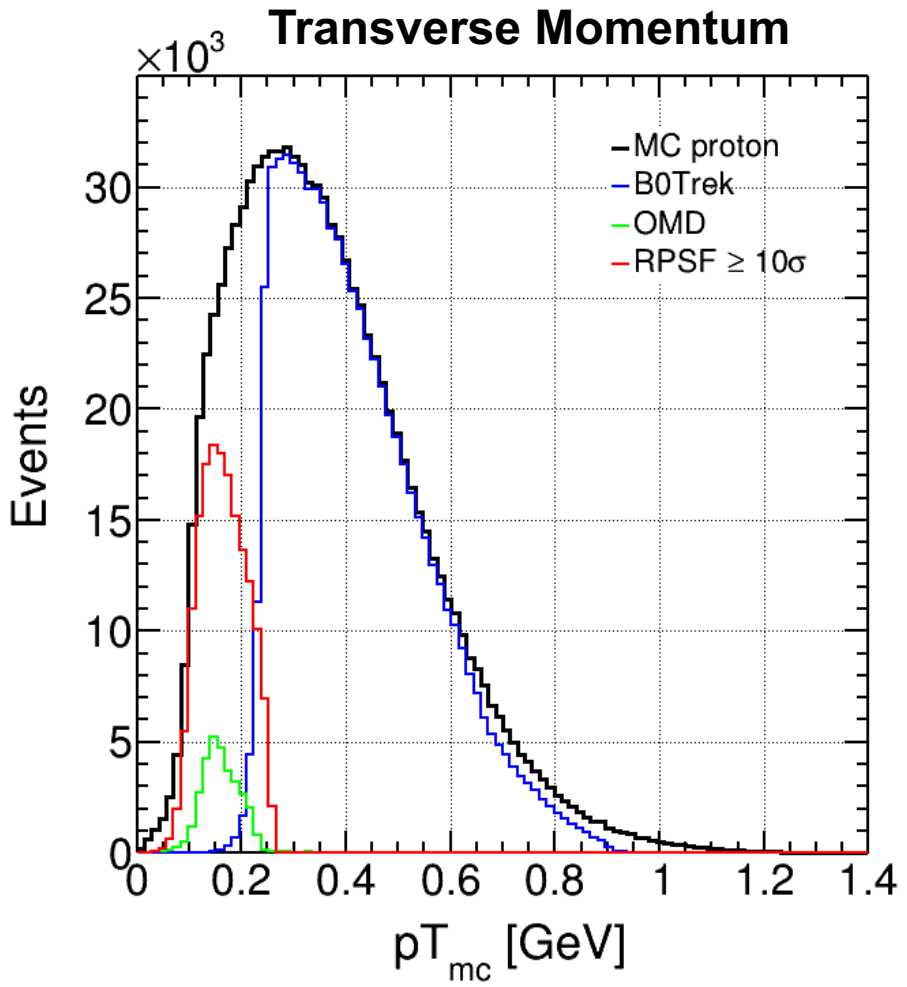
DVCS 5 GeV on 41 GeV (1/2)

Linear Scale

*Each histogram fills separately





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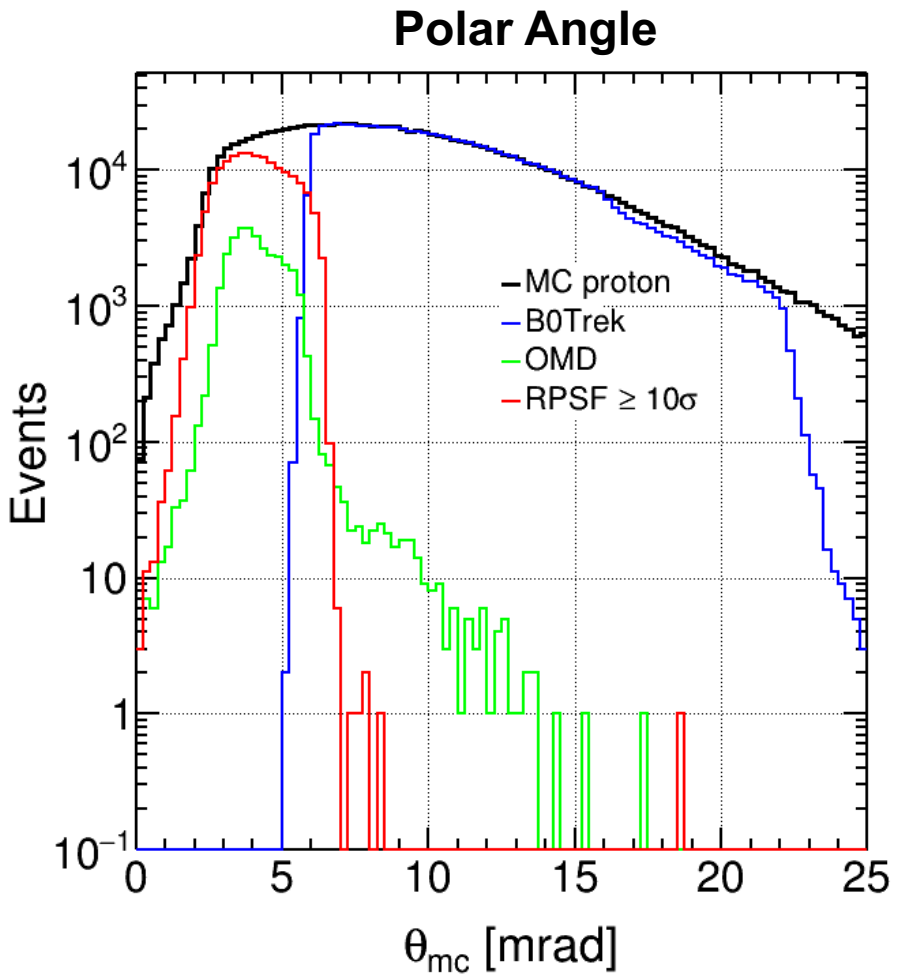
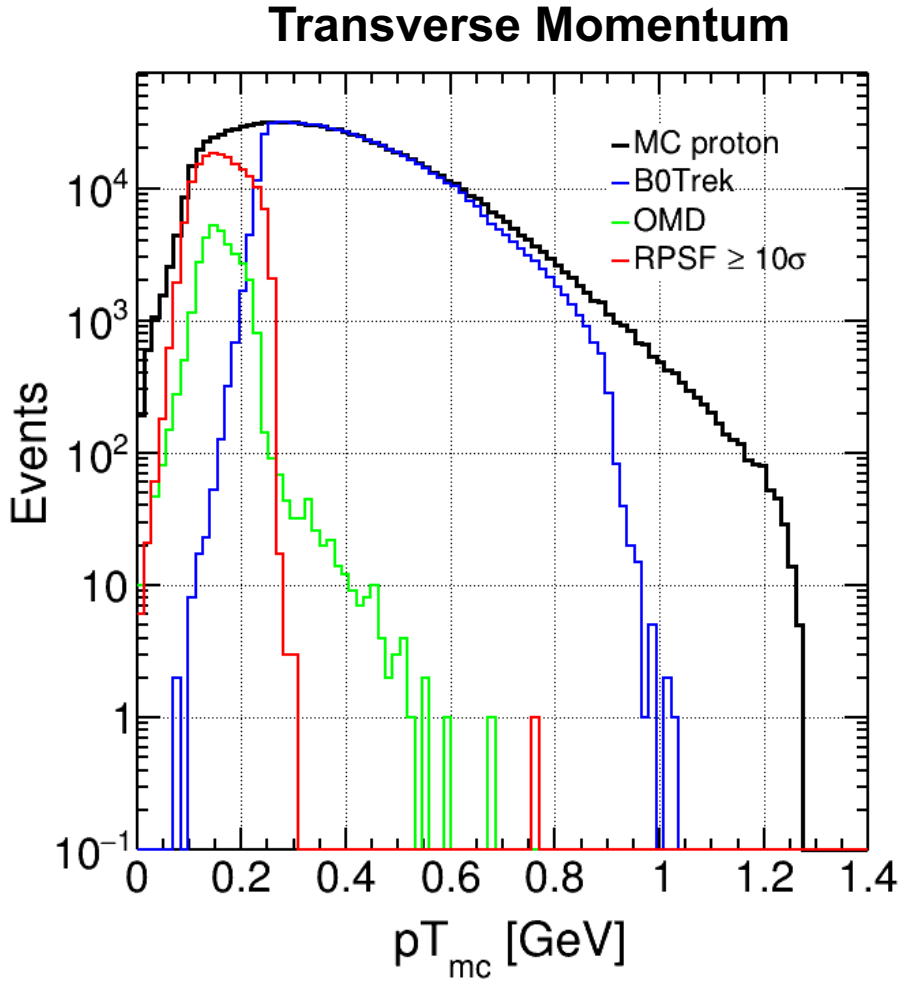
Scattered protons measured in **both *B0 and Roman Pot at secondary focus** (**70.62 %** and **16.55 % events accepted** with 10σ safe distance cut based on **ep β @ IP8 RPSF**)

DVCS 5 GeV on 41 GeV (2/2)

Log Scale

*Each histogram fills separately





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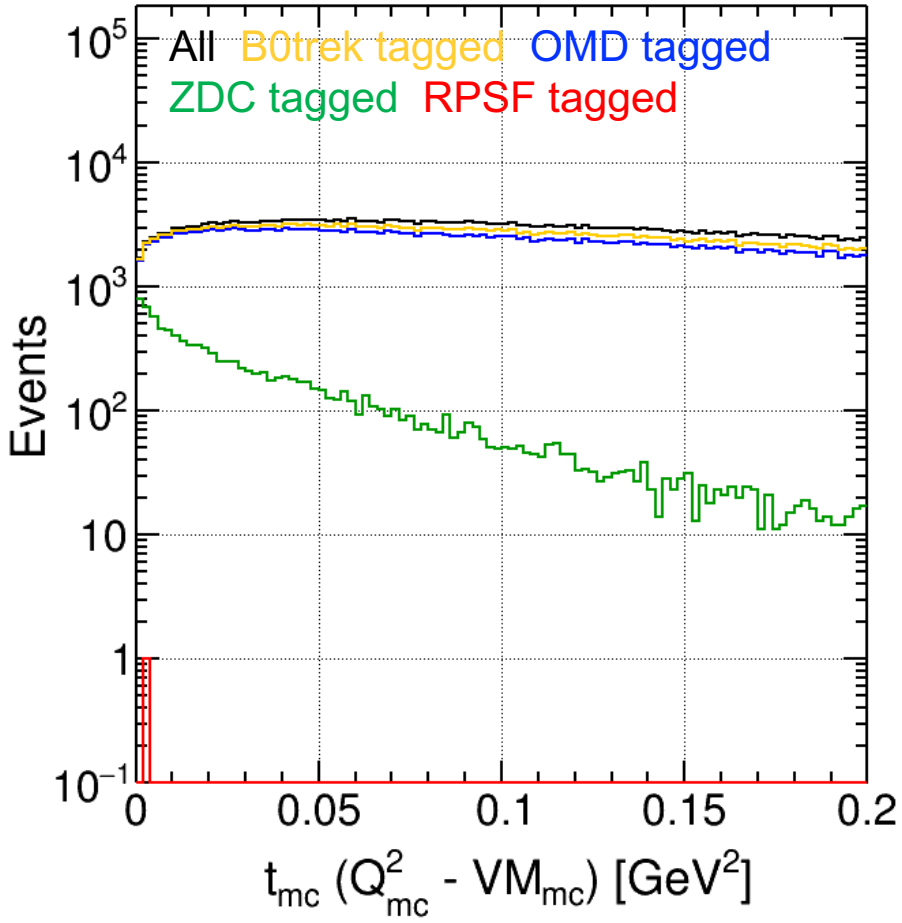
Approach – Incoherent Tagging Efficiency

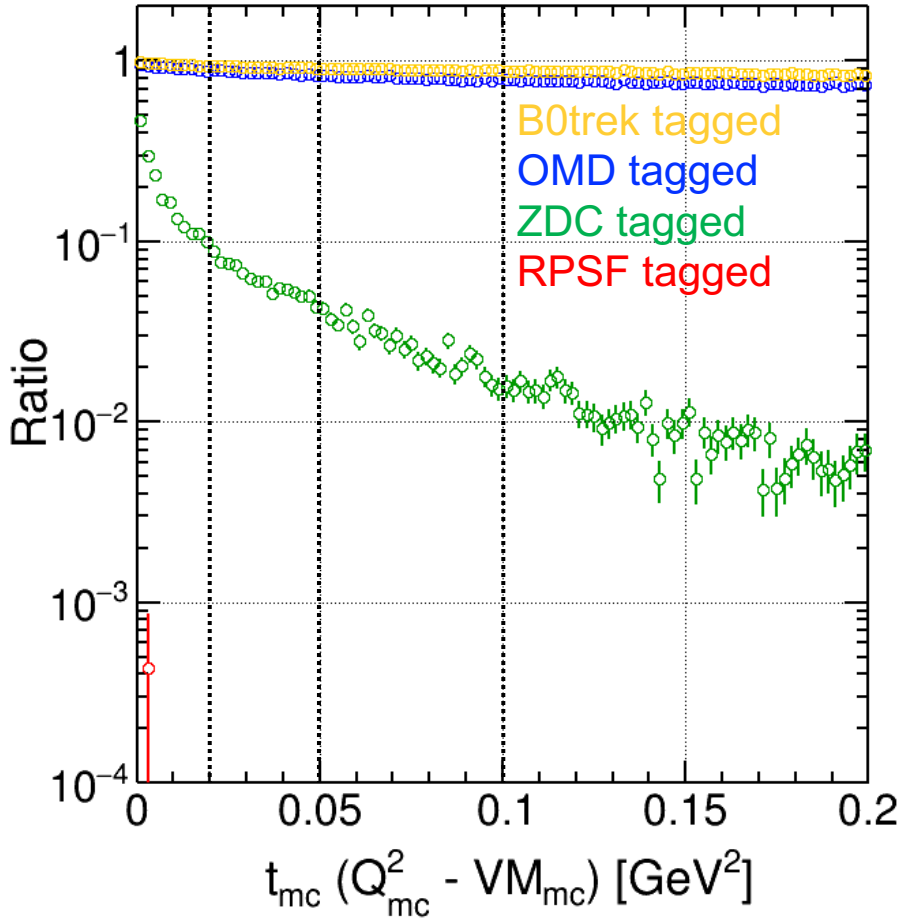
- Used simulated **BeAGLE** 801k events with **$1 < Q^2 < 10$**
  - **ePb 18×110 GeV incoherent $J/\psi(\mu\mu)$ events** $ePb \rightarrow e' + J/\psi(\mu\mu) + X$ (S3/eictest/EPIC/EVGEN/EXCLUSIVE/DIFFRACTIVE_JPSI_ABCONV/BeAGLE/ePb_18x108.41_tau10_B1.1_Jpsi_highstats/ePb_18x108.41_tune3_tau10_B1.1_extracted_Jmu_1.hepmc)
- Passed through **afterburner IP8 eAu** configuration
  - IP8 crossing angle (35 mrad) and IP6 eAu beam effects based on **EIC CDR table 3.5**
- Discarded events having **more than one electron in final state with η < -1**
- Calculated **10σ safe distance cut** based on ***eAu β @ IP6 and @ IP8 RPSF***
  - @ IP6: $X_{1\sigma}$ ~ 0.198869 [mm] and $Y_{1\sigma}$ ~ 0.0216527 [mm]
  - @ IP6 RPSF: $X_{1\sigma}$ ~ 0.314867 [mm] and $Y_{1\sigma}$ ~ 0.1629770 [mm]
- **Tagged events for nuclear breakups *tagging purpose***
  - B0 Tracker: **at least two out of four layers** have registered RAW hits
  - OMD: **two layers** (actual four layers as redundancy) 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** safe distance

t distribution

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



Coherent diffractive minima

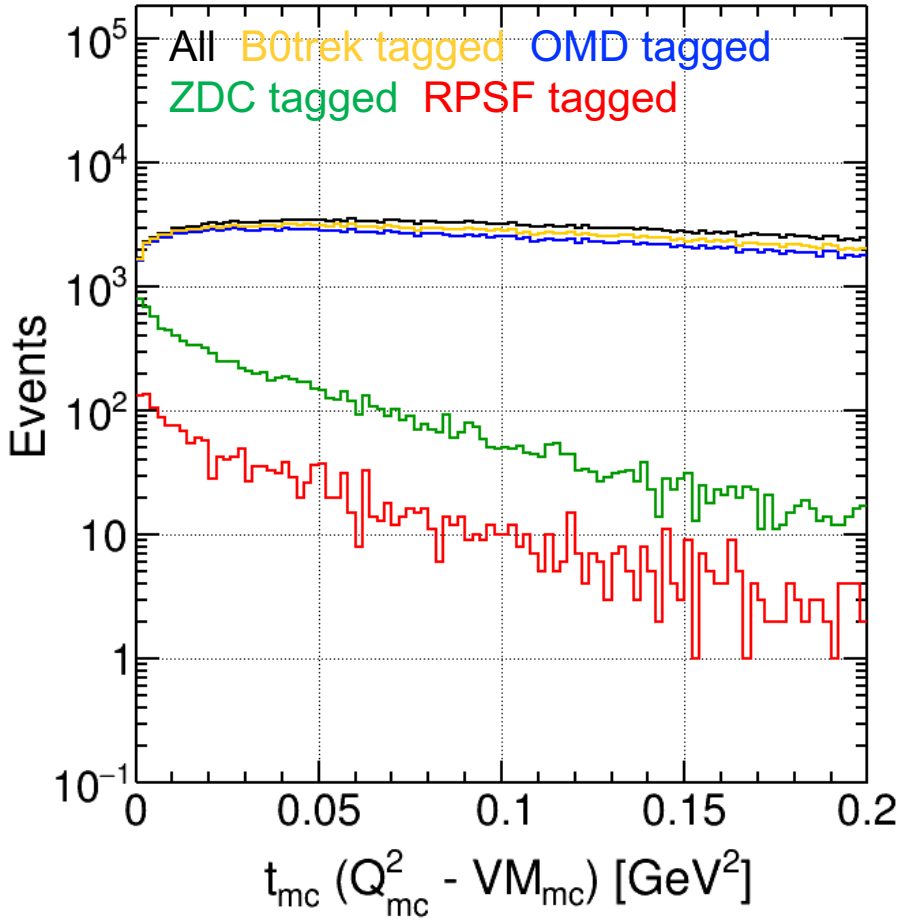


With 10σ safe distance cut based on ***ep β @ IP6***

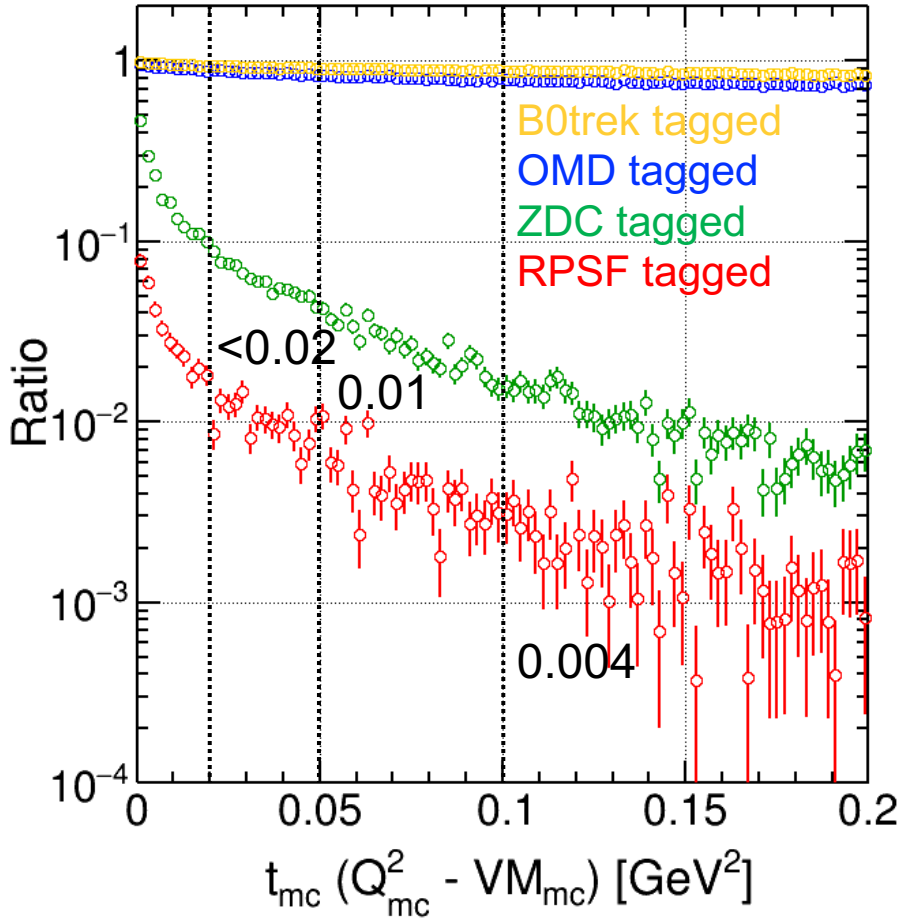
1 of 800,964 events were NOT tagged

t distribution

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



Coherent diffractive minima

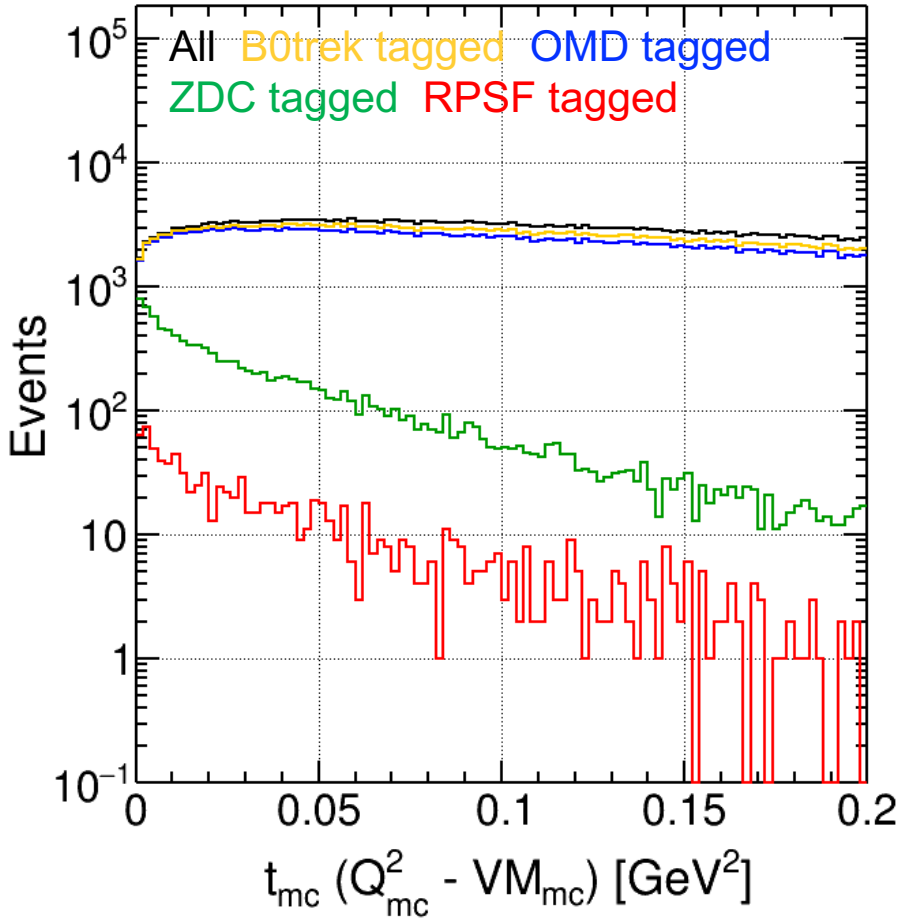


With 10σ safe distance cut based on ***ep β @ IP8 RPSF***

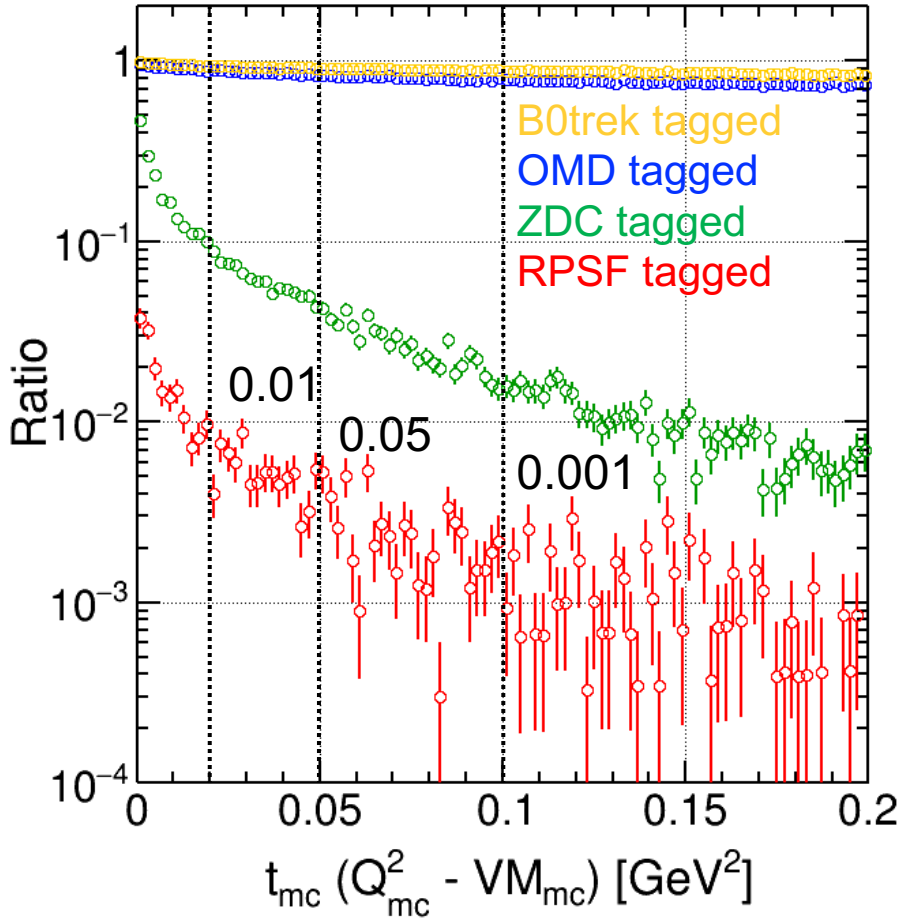
2,250 of 800,964 events were NOT tagged

t distribution

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



Coherent diffractive minima



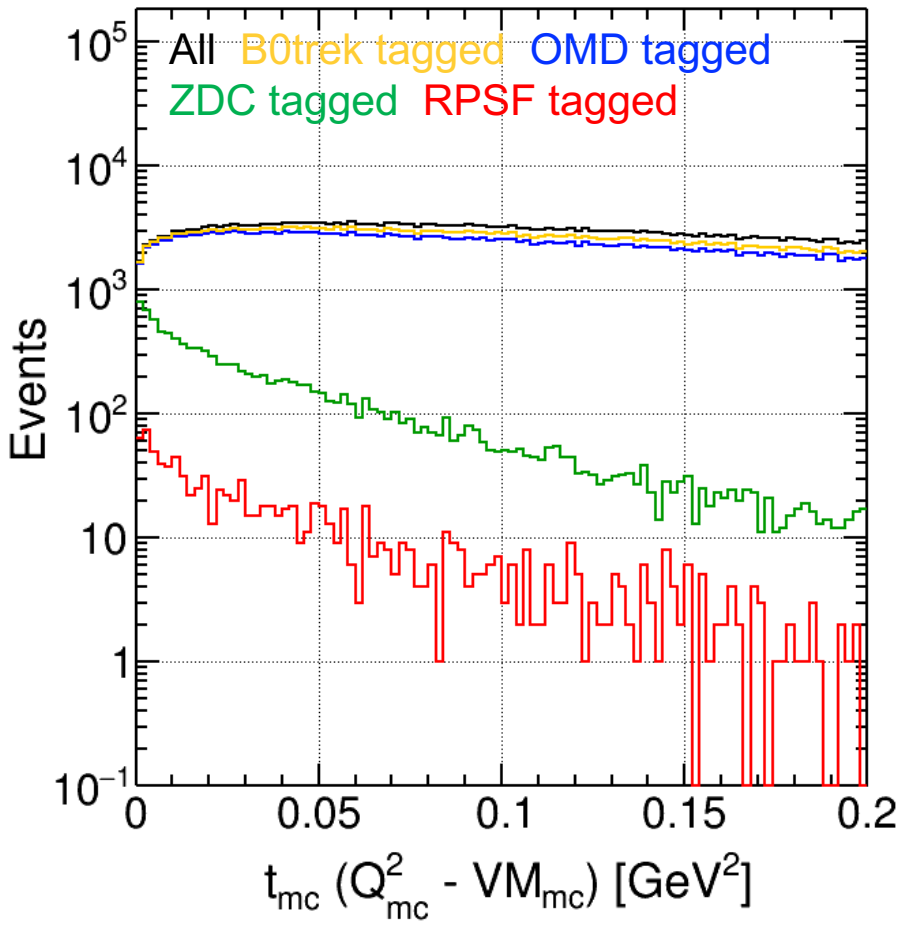
With 10σ safe distance cut based on ***exact same value Wan used***

1,131 of 800,964 events were NOT tagged

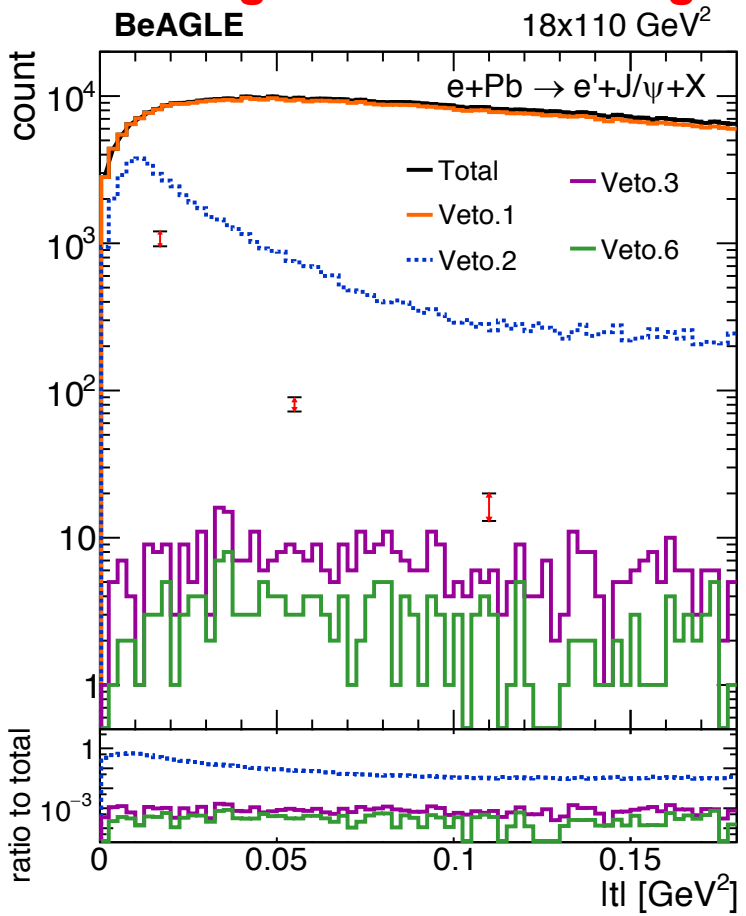
t distribution

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

***Not Apple-to-Apple Comparison* - beam effects/smearing included from beginning**



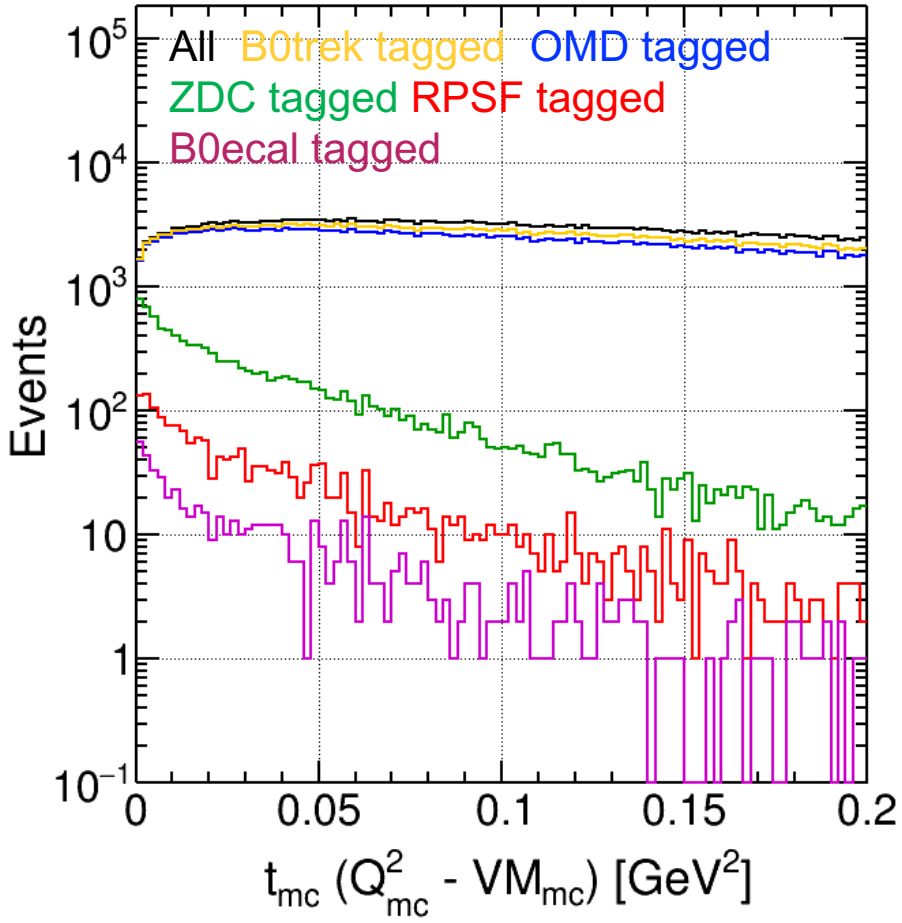
Used **Wan's sigma values**



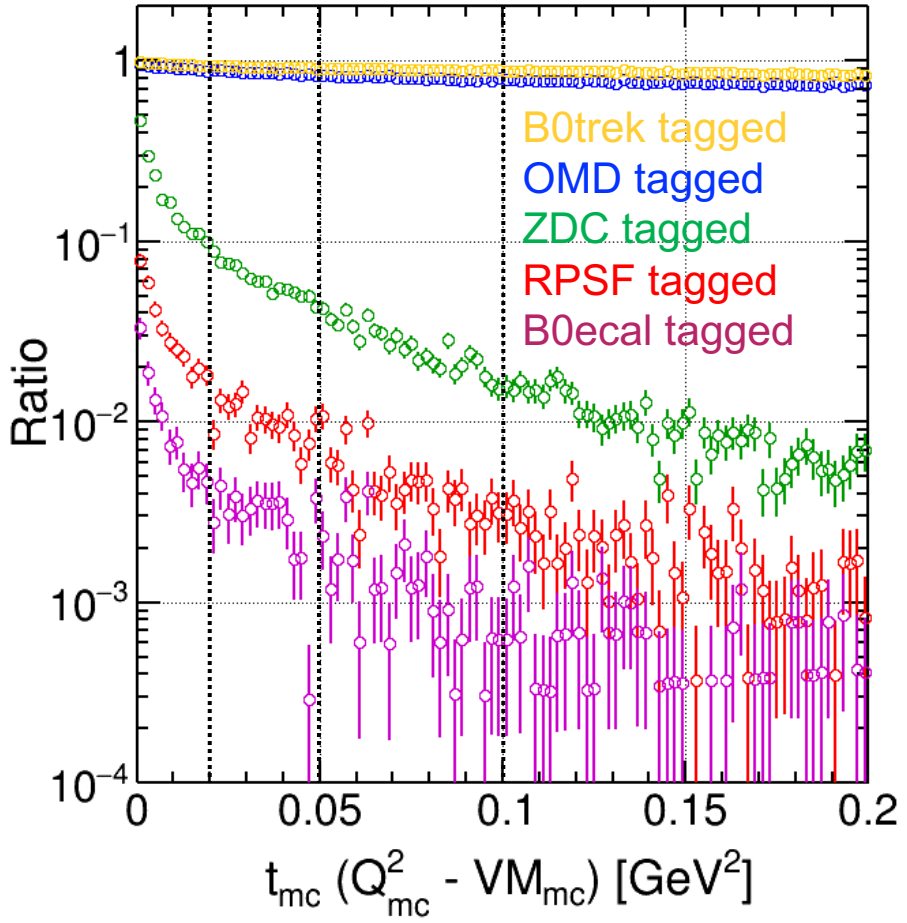
From Wan's presentation IP8 study

t distribution

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



Coherent diffractive minima



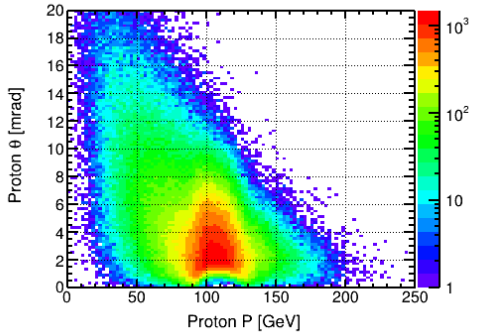
With 10σ safe distance cut based on ***ep β @ IP8 RPSF* + B0 Ecal tagged (any raw hits)**

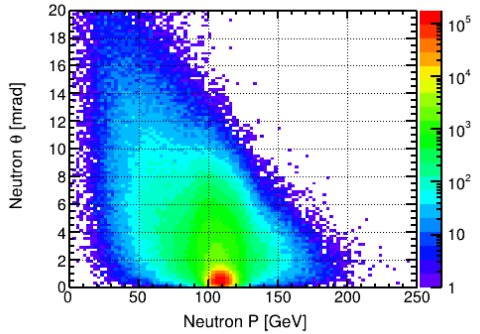
638 of 800,964 events were NOT tagged

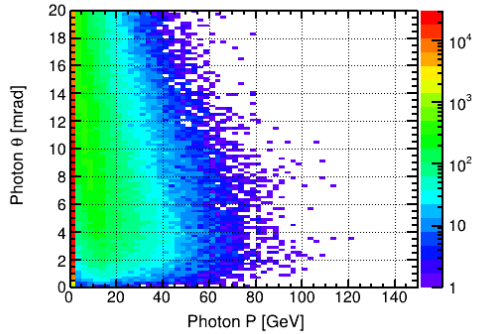
Remaining Events

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

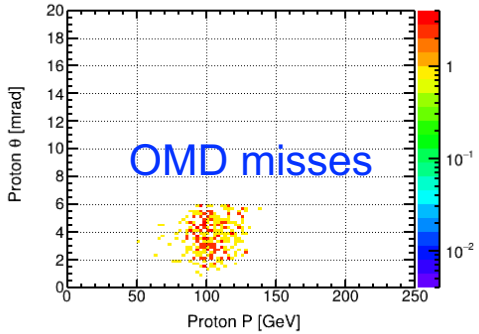
Generated level

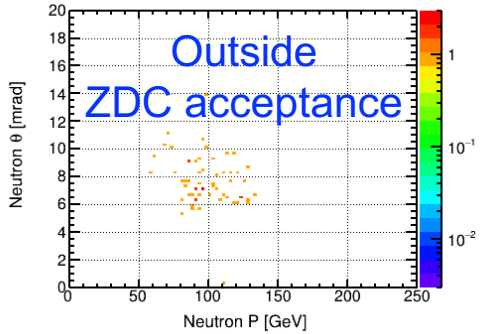


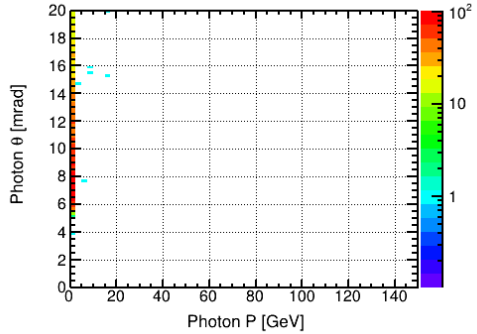




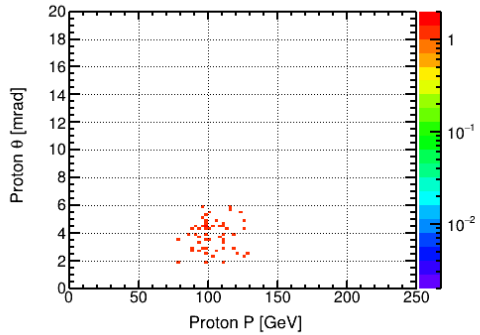
ep
β @ IP8 RPSF

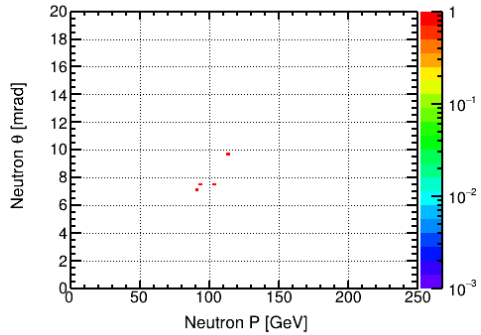


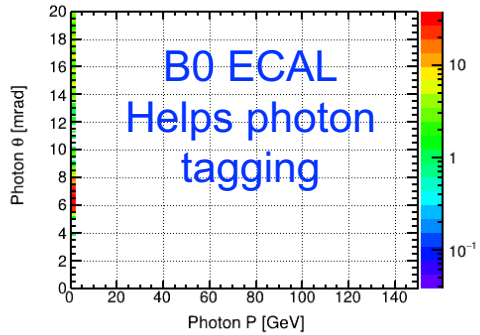




ep
β @ IP8 RPSF
+
B0 Ecal tagged
(any raw hits)

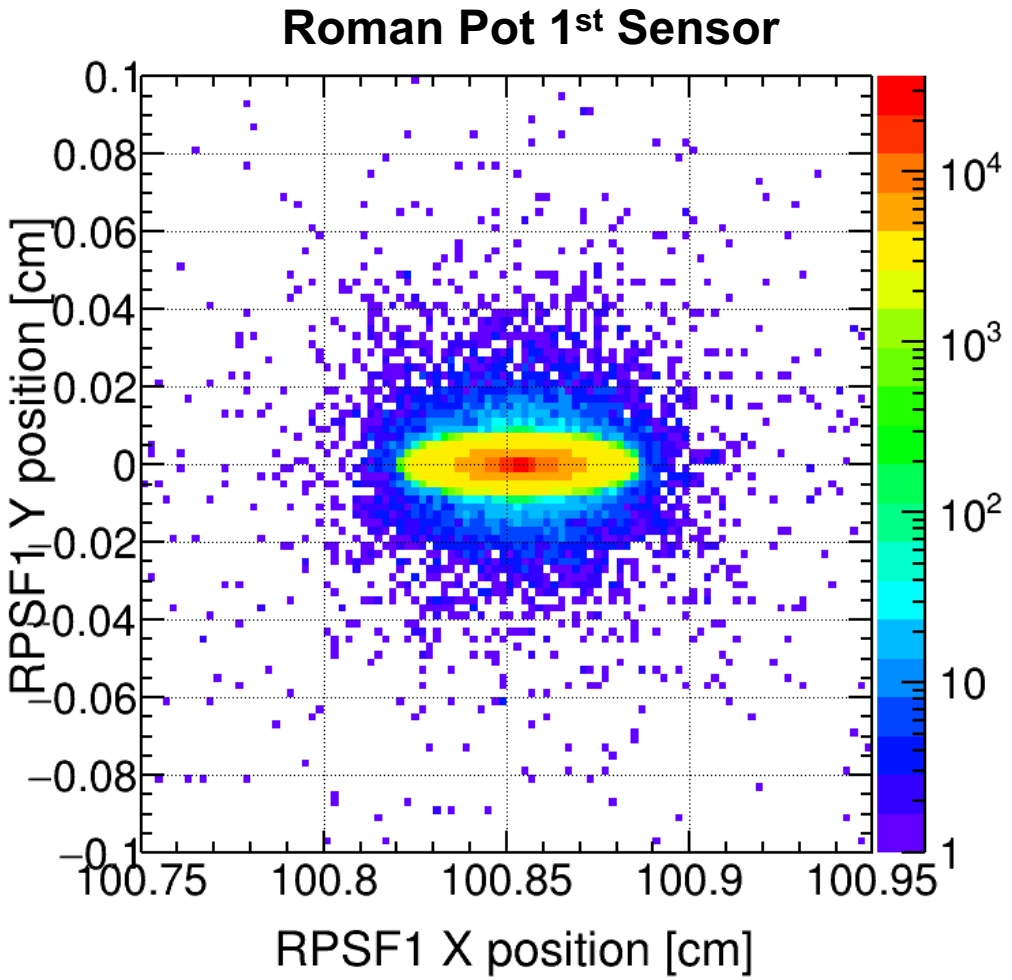


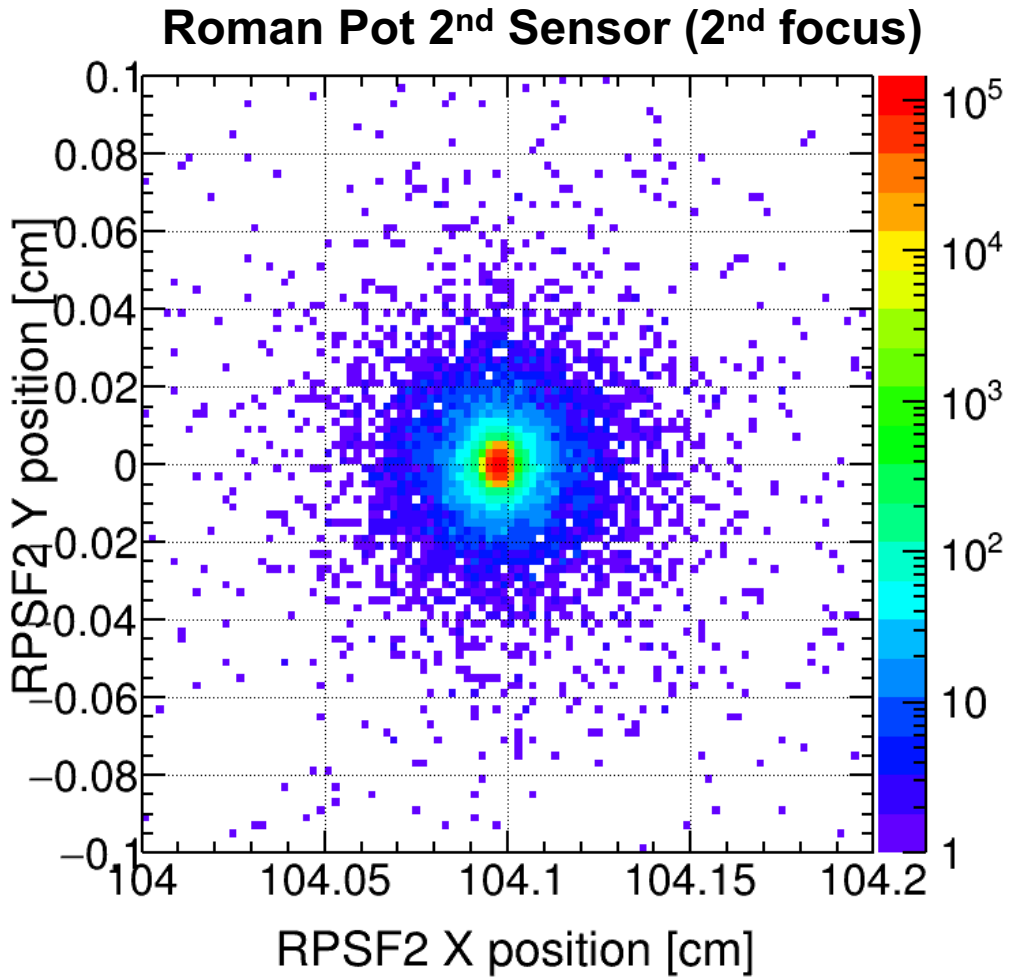




Beam Spot Study

Single Proton
E = 275 GeV
$0 < \theta_{MC} < 0.15$ mrad





Used **IP6 ep high divergence beam RMS** $\Delta\theta$ h/v [μrad] = 150/150 (EIC CDR table 3.3)
Ran single particle gun and Mimic **"1σ beam profile" to take a look**

Summary

- 10σ safe distance calculations
  - IP6 beam effects
  - Different β values

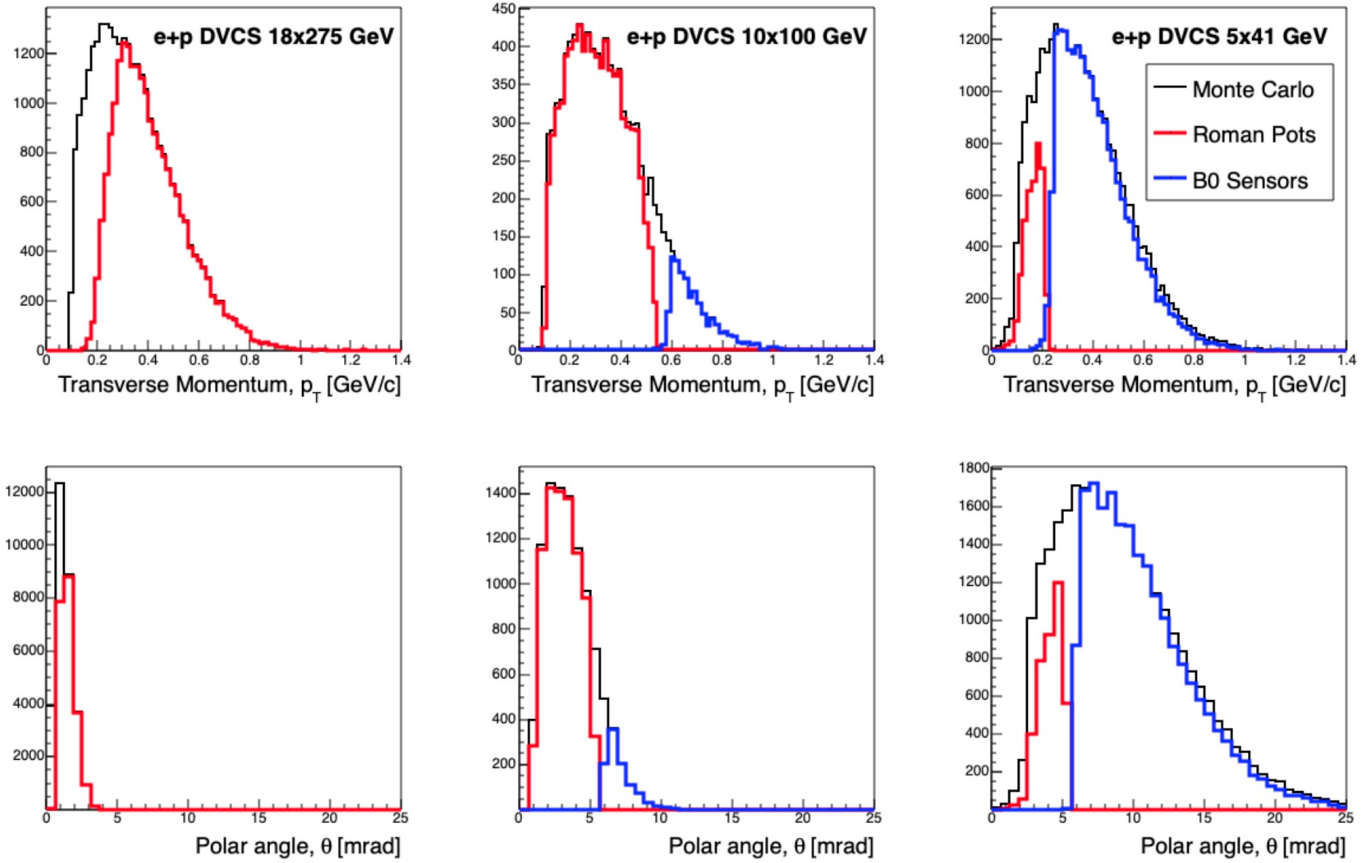
	σ_{1x}	σ_{1y}
ep β @ IP6	0.121077	0.0193225
ep β @ IP8 RPSF	0.203642	0.0867277
eAu β @ IP6	0.198869	0.0216527
eAu β @ IP8 RPSF	0.314867	0.1629770
Wan's	0.328283	0.085217

- Using exclusive DVCS events, understanding acceptance gap in pT between B0 and RPSF
  - ~250 MeV for 5 GeV on 41 GeV and ~550 MeV for 10 GeV on 100 GeV
  - It is limited on aperture due to beam pipe in particular
- Using BeAGLE incoherent events, understanding tagging power to understand background to coherent events with $1 < Q^2 < 10$ and $t < 0.2$
  - Tagging efficiency ~ 99% at t ~ 0.02, 0.05, and 0.1 coherent diffractive minima
  - It depends on 10σ safe distance is used significantly

Next Steps

- pT Acceptance
  - May make having different pT acceptance cutoffs between IP6 and IP8 so that covering pT acceptance for scattered protons would be good
  - Again, it is limited on aperture due to beam pipe in particular
  - Adjust beam pipe size (B0 hole size) to quantify impact on low pT cutoffs
  - Play with a bit smaller beam pipe size (B0 hole size) and w/ and w/o beam pipe
    - Current B0 tracker inner radius set to 3.5 cm ***current simulation only hole no beampipe***
- Beta function $\beta(z)_{x,y}$
  - 10σ safe distance cut at secondary focus depends on $\beta(z)_{x,y}$ largely
  - To get a better idea on tagging efficiency, need to evaluate more realistic $\beta(z)_{x,y}$ especially for at secondary focus
- In mean time, acceptance/tagging efficiency can still change according to beam effects/optics (currently all results are based on IP6 beam effects)

pT Acceptance from EIC YR



From EIC YR p.564

Figure 11.98: p_T (top row) and polar angle (bottom row) acceptance for three different beam energy configurations: 18x275 GeV (left), 10x100 GeV (middle), and 5x41 GeV (right). The black data in each figure represent the MC information from MILOU, the red lines are the accepted particles in the Roman Pots, and the blue lines are particles accepted in the B0 sensors.