Update on IR-8 DD4hep Simulation

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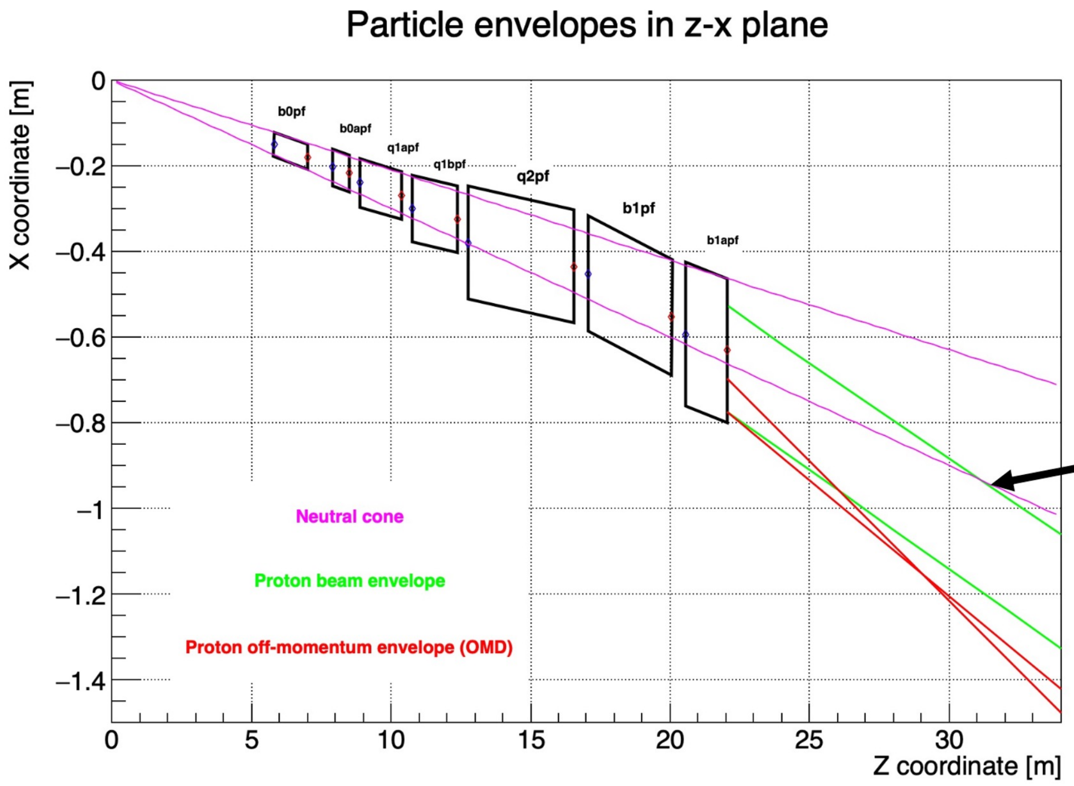
Approach – Beam Pipe Impact

- Evaluate beam pipe impact on tagging by far-forward detectors
  - Exit window to ZDC: material and location
  - Expected neutron tagging efficiency at ZDC being reduced, but nuclear fragment tagging efficiency at RPSF being same
  - Therefore, expected total vetoing efficiency stays the same
- ✓ Find optimal location for exit window to ZDC
- ✓ Implement simplified box-shaped beampipe between BXDS01A and ZDC including exit window
- ✓ Single particle simulation to check detector acceptance
- ✓ Run with same BeAGLE sample
- ✓ Evaluate vetoing efficiency and Compare number of surviving events at each veto selection

Find Optimal Location for Exit Window

IR-6 Simulation Example

Particle envelope geometry



Proton and neutron cone interference ends here (between Z = 31 and 32 meters).

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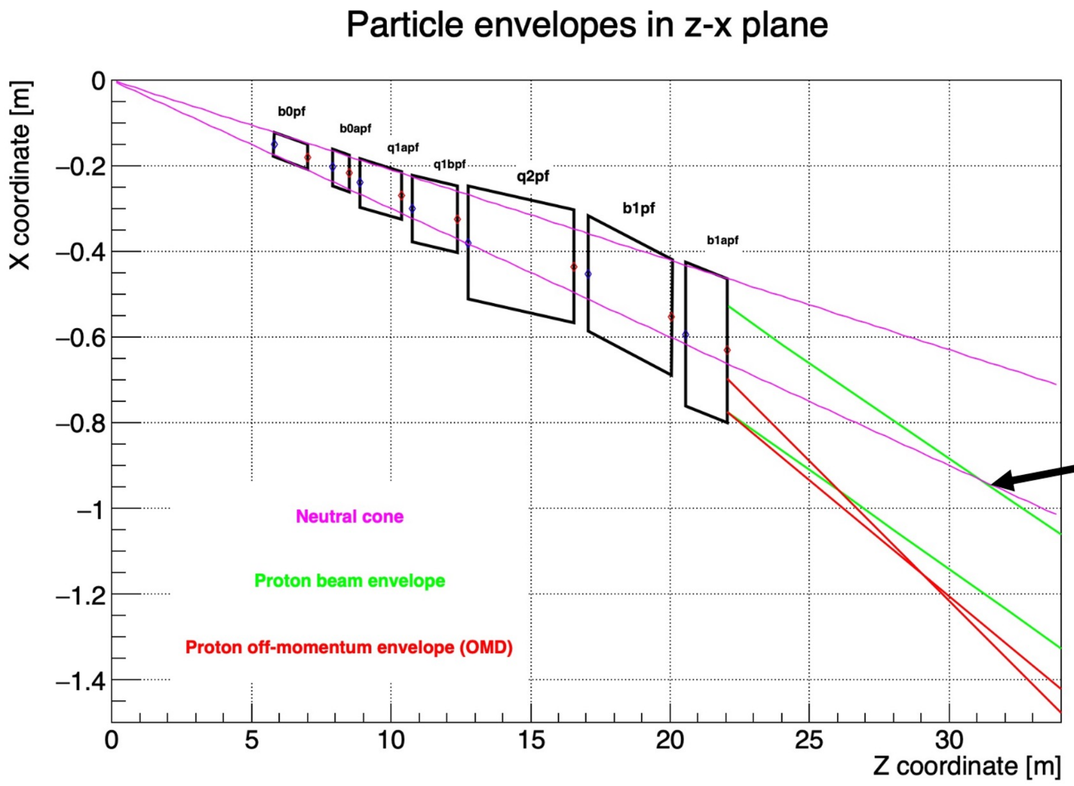
From Alex Jentsch

Find Optimal Location for Exit Window

IR-6 Simulation Example

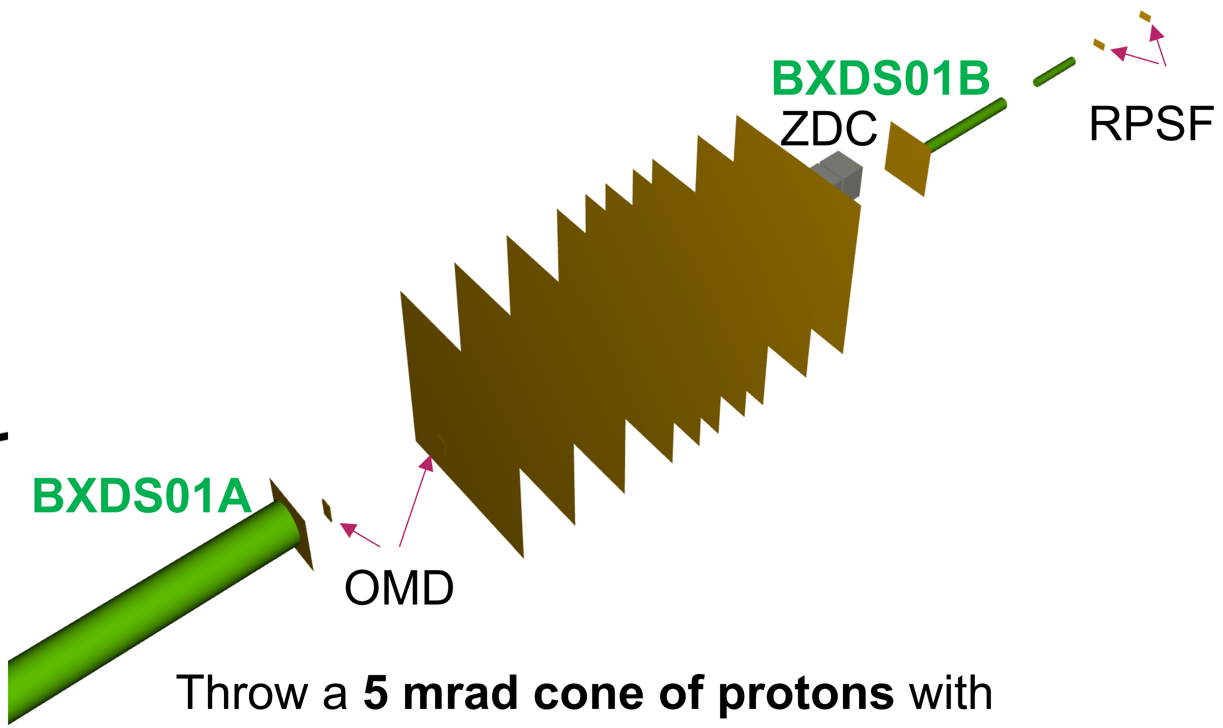
Particle envelope geometry



From Alex Jentsch

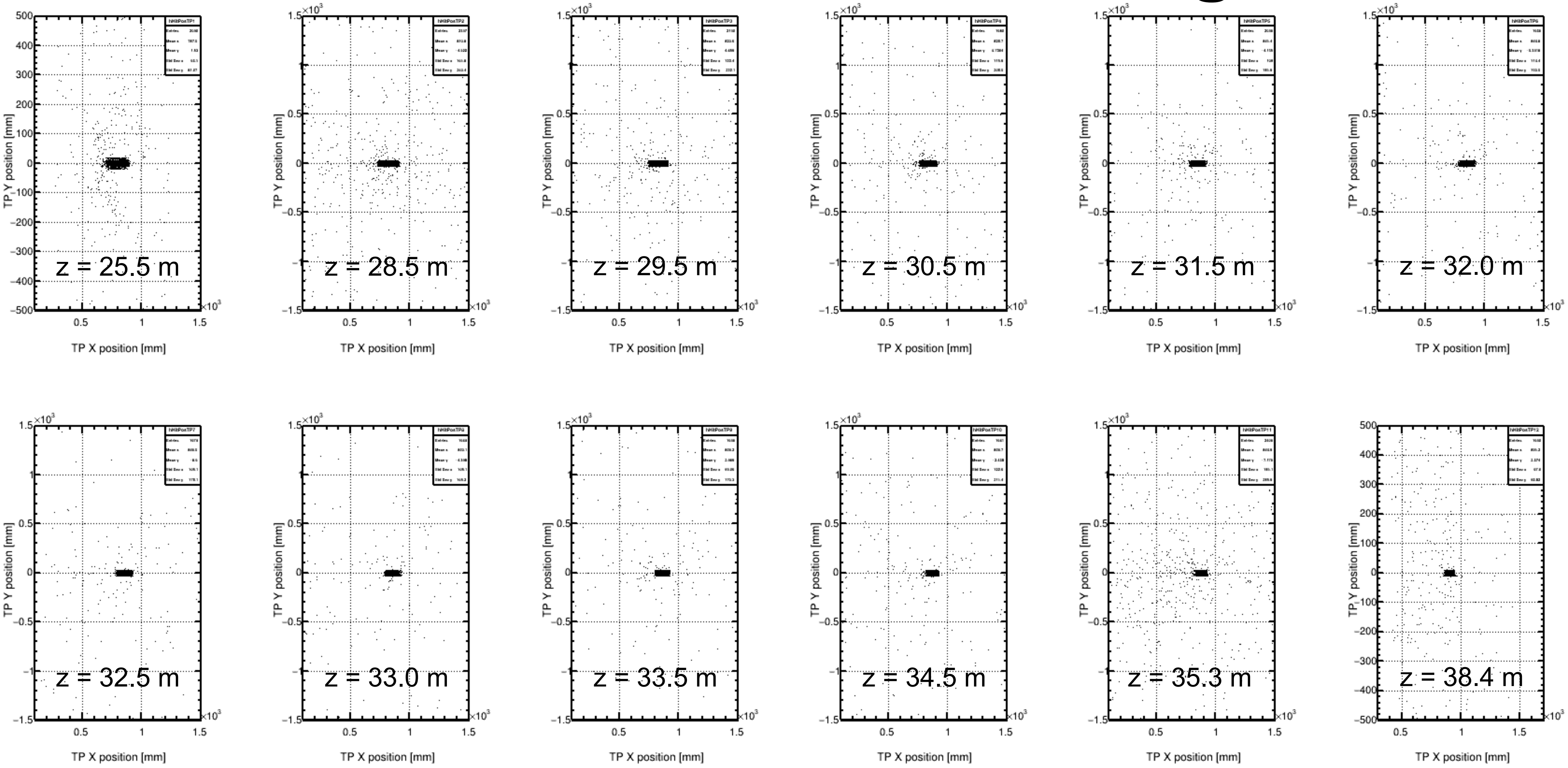
IR-8 Simulation

Insert **12 very thin silicon planes** between magnets

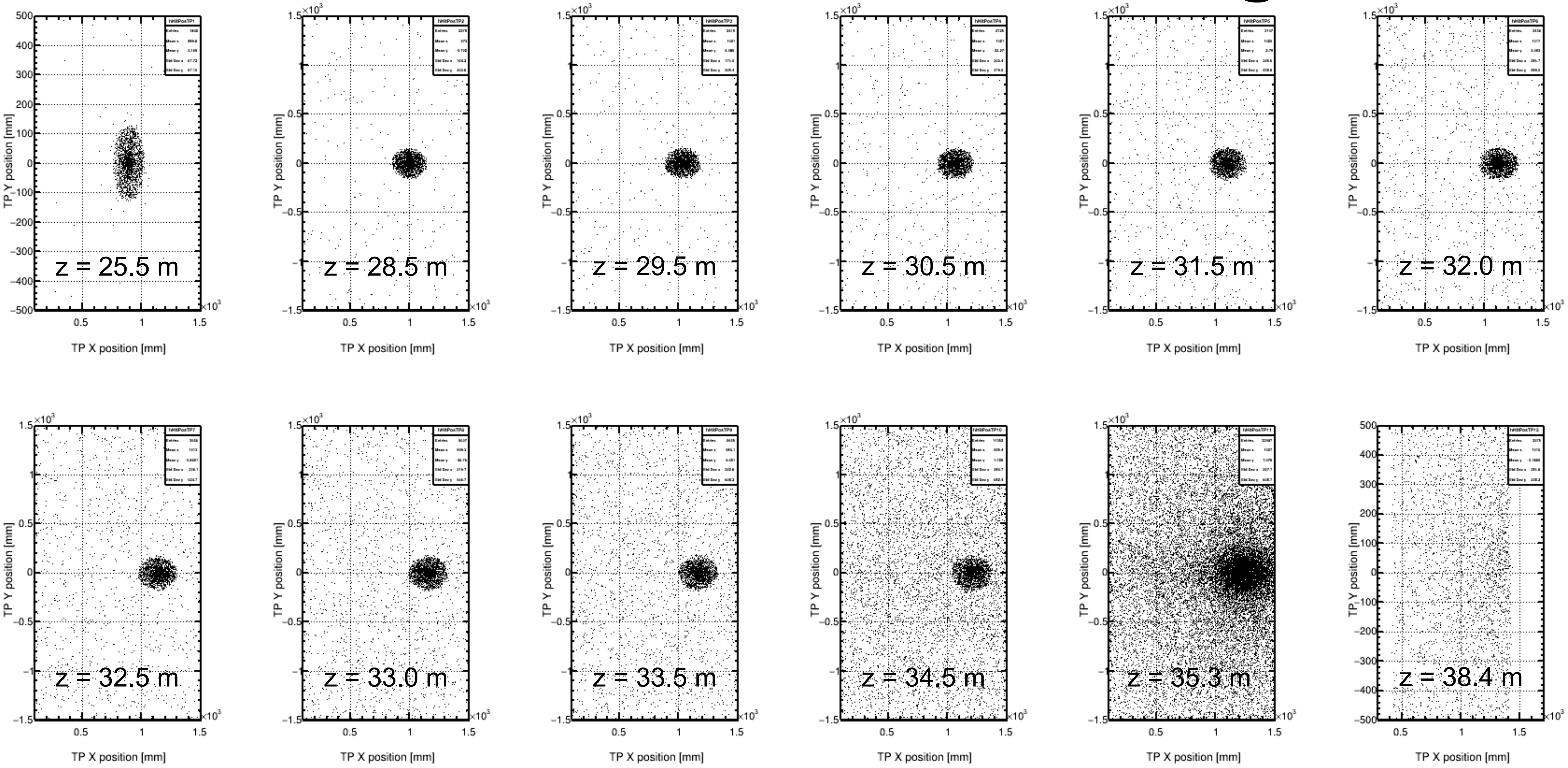


Throw a **5 mrad cone of protons** with
magnets ON (treated as nominal protons)
magnets OFF (treated as neutrons*)

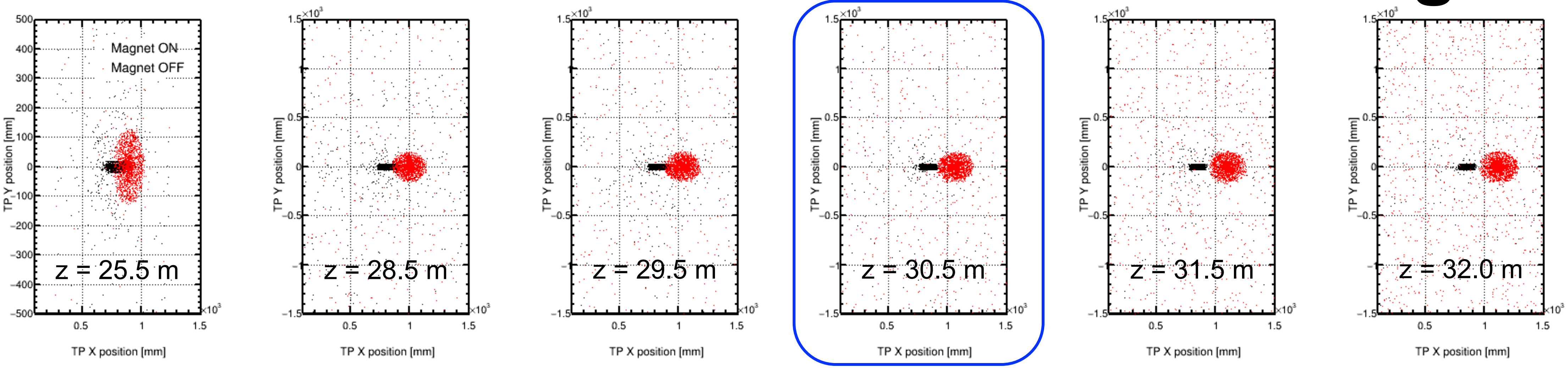
Hit Positions of Protons w/ Magnets



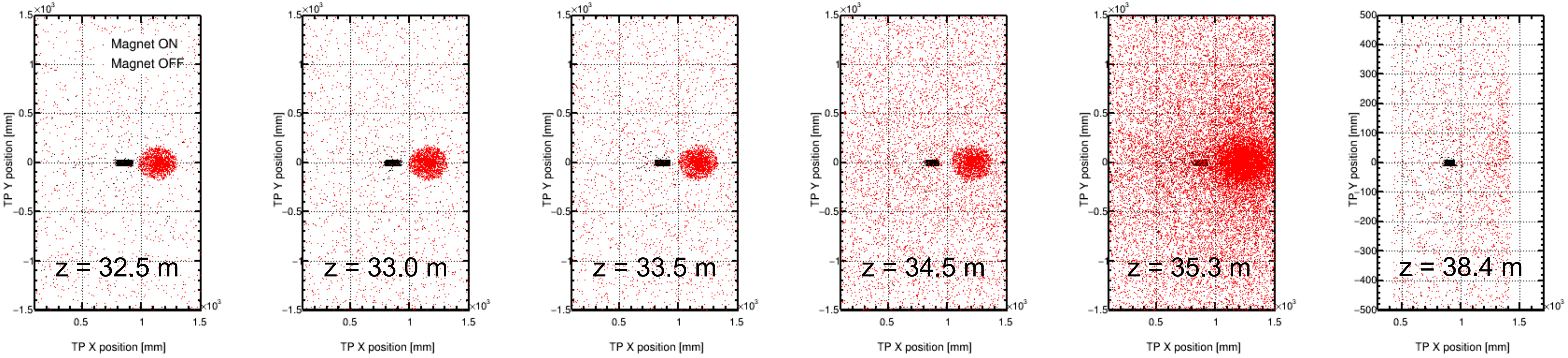
Hit Positions of Protons w/o Magnets



Hit Positions of Protons w/ & w/o Magnets

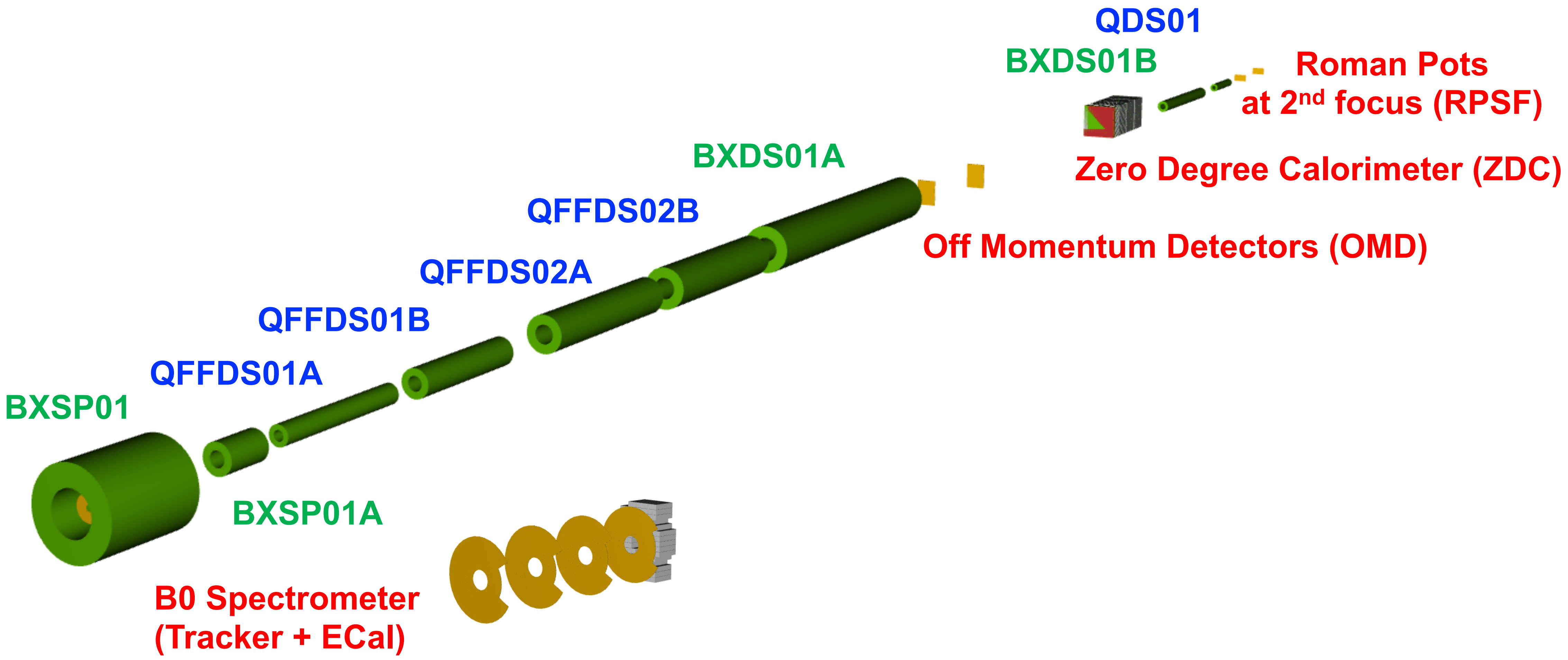


Neutrons* are separable from Protons



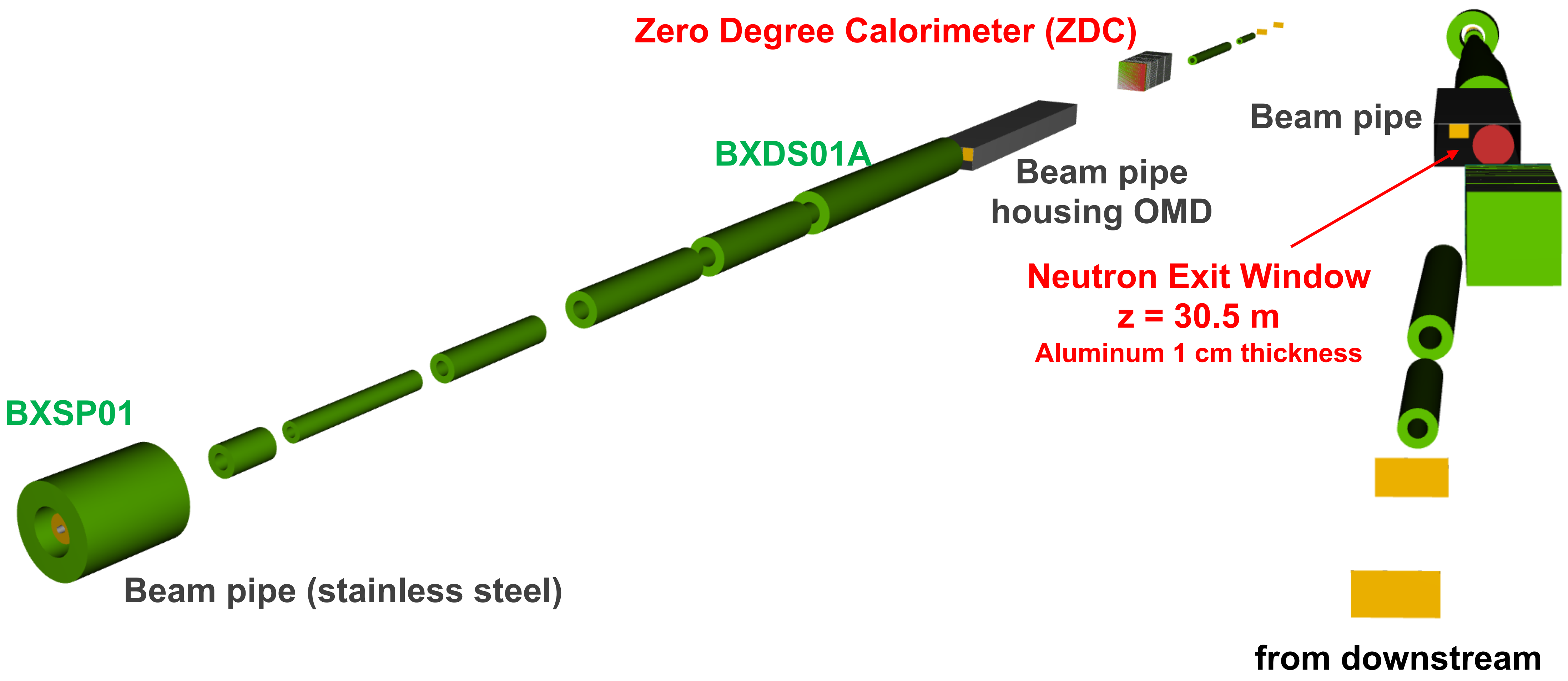
IR-8 Layout in DD4hep Simulation

Proposed pre-conceptual design of IR-8 Forward Hadron Lattice



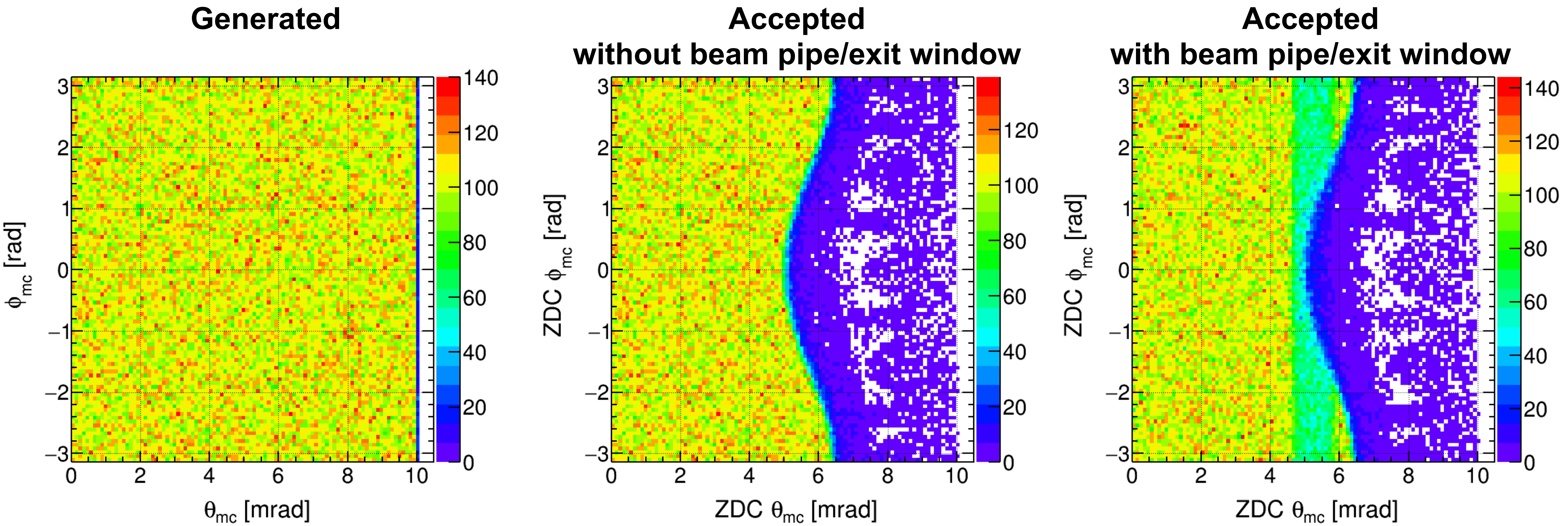
Simplified Beam Pipe Implementation

Proposed pre-conceptual design of IR-8 Forward Hadron Lattice



Detector Acceptance Comparison: ZDC

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



In total, about **99.96 % (97.2 % with beam pipe/exit window)** events were accepted.

Full acceptance in θ_{MC} changed from up to 5 mrad to 4.5 mrad

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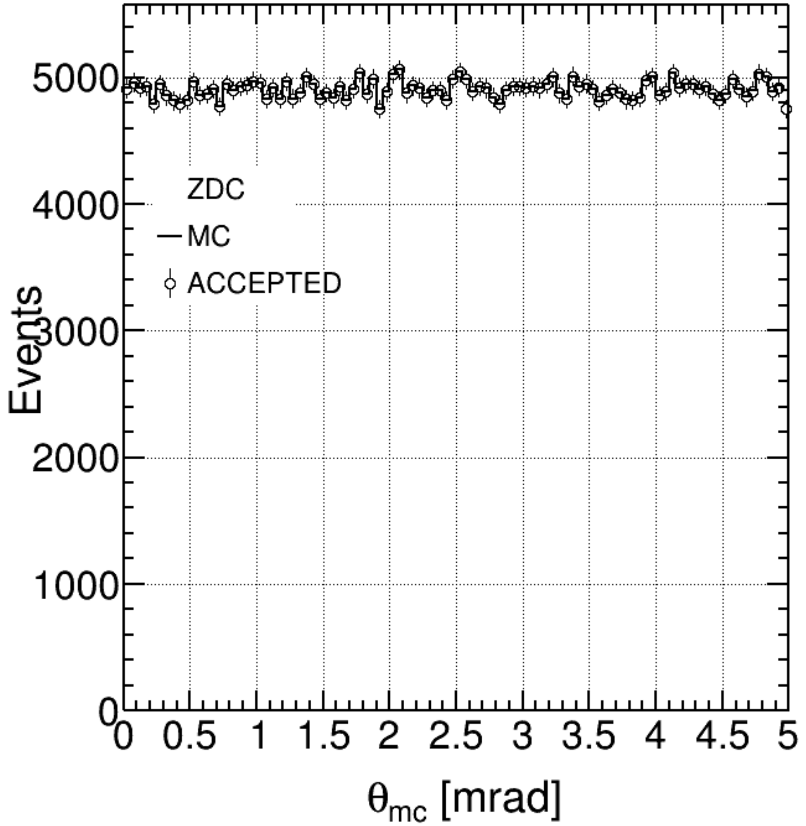
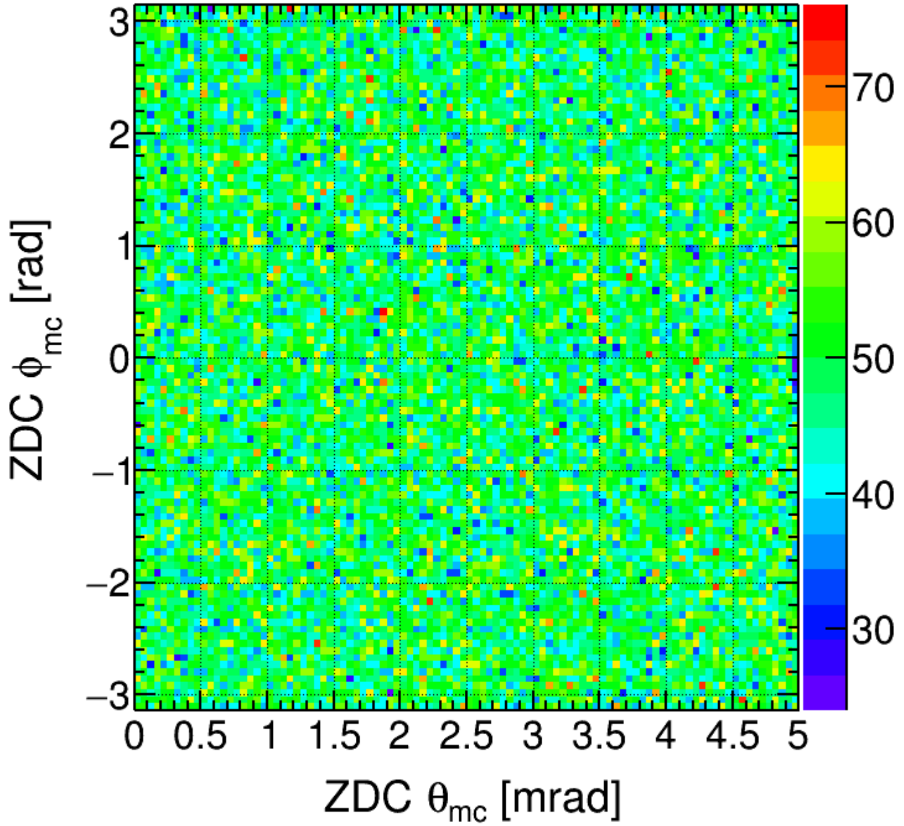


Accepted
without beam pipe/exit window



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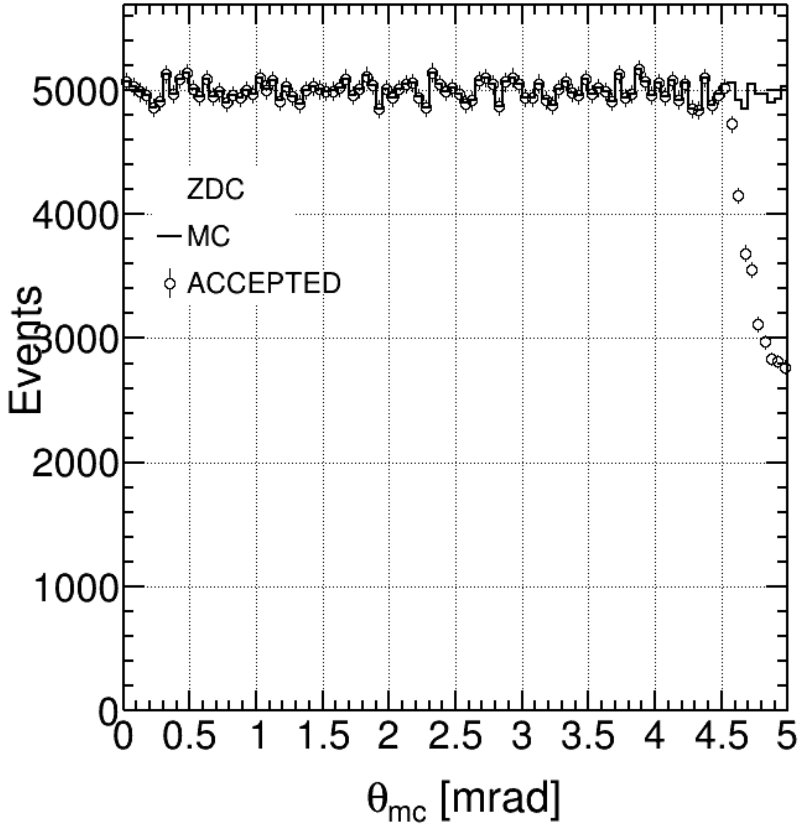

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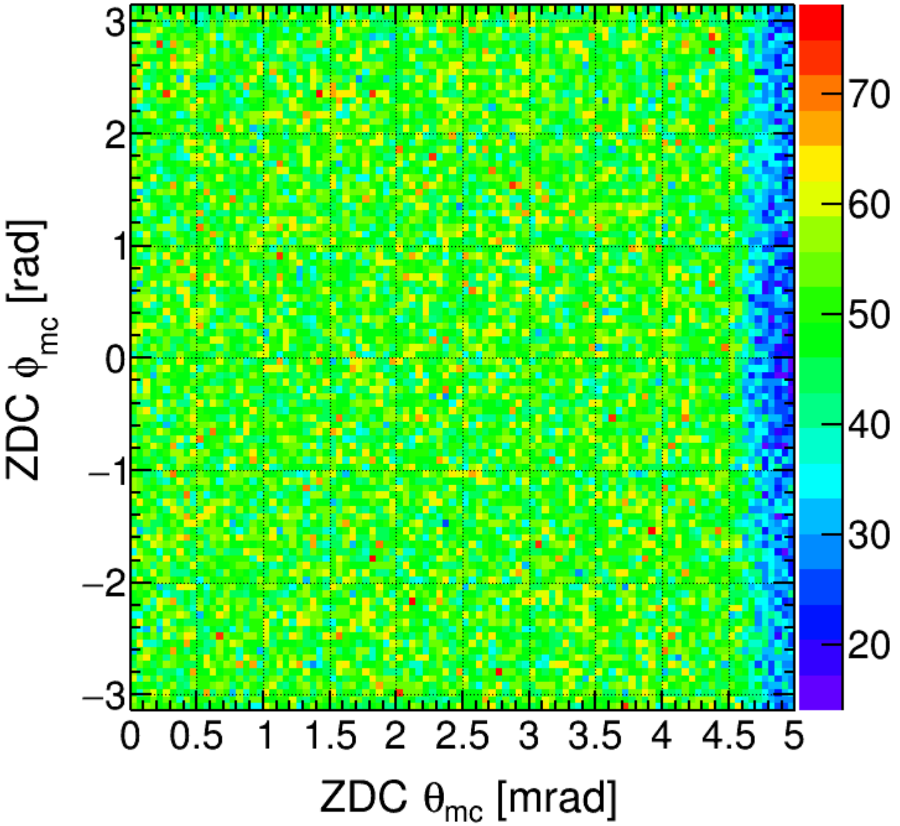

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Detector Acceptance Comparison: RPSF

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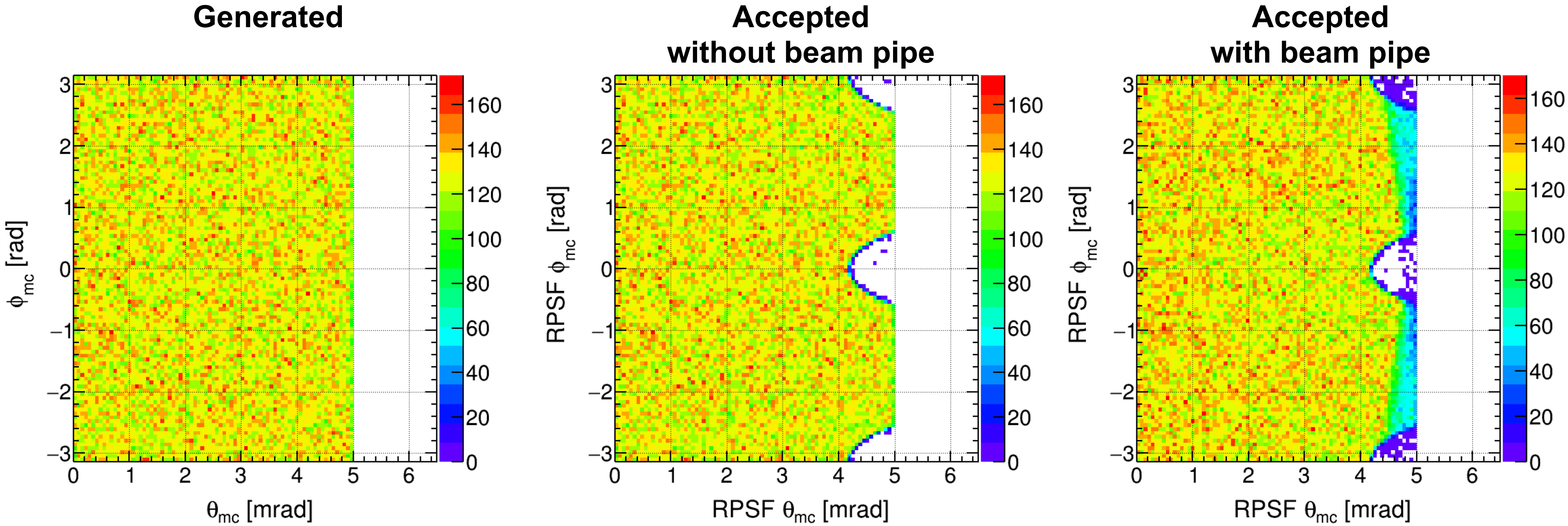

In total, about **95.3 % (91.7 % with beam pipe)** events were accepted.
However, **full acceptance up to 4.2 mrad stays the same**

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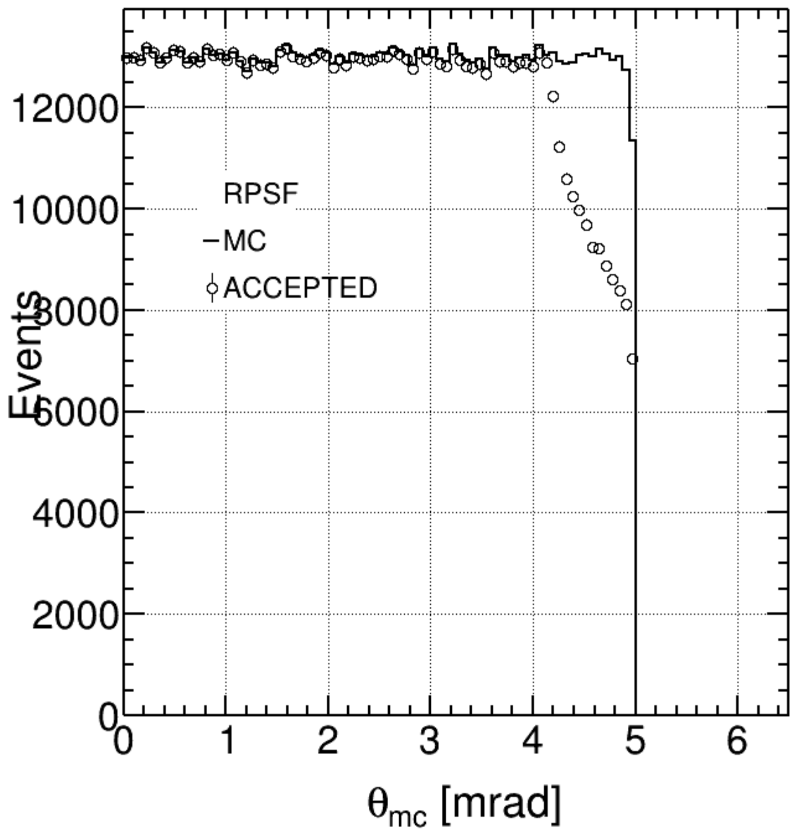
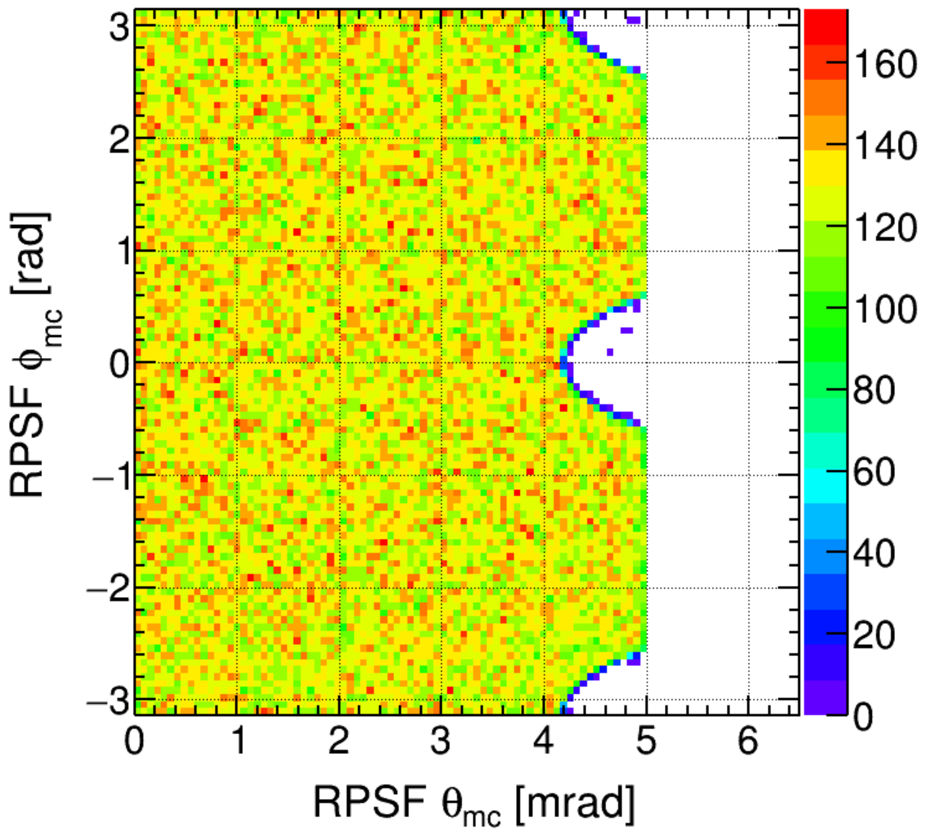


Accepted without beam pipe



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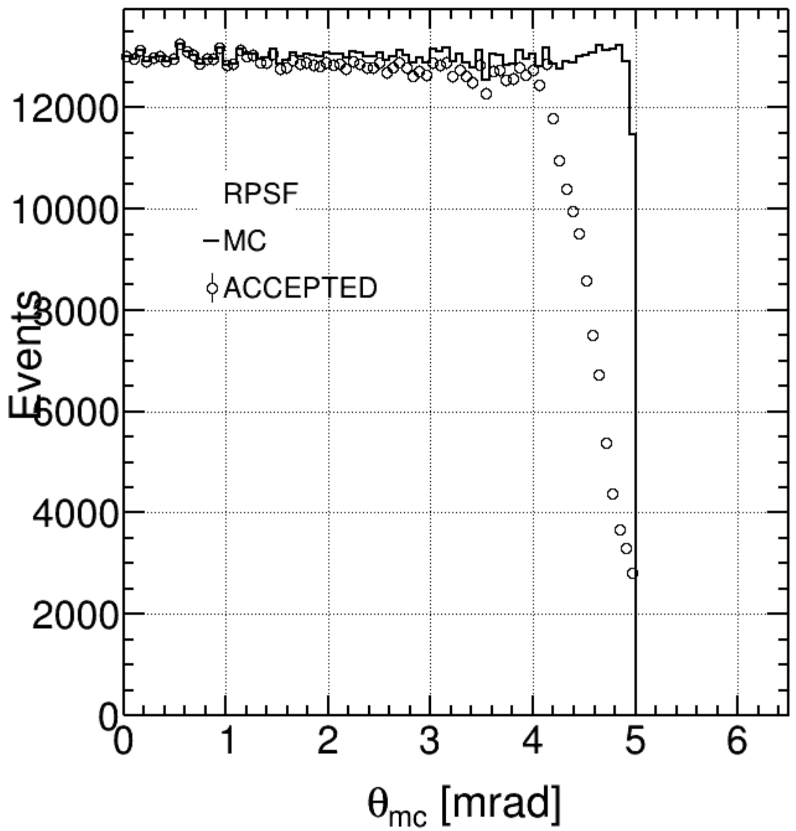
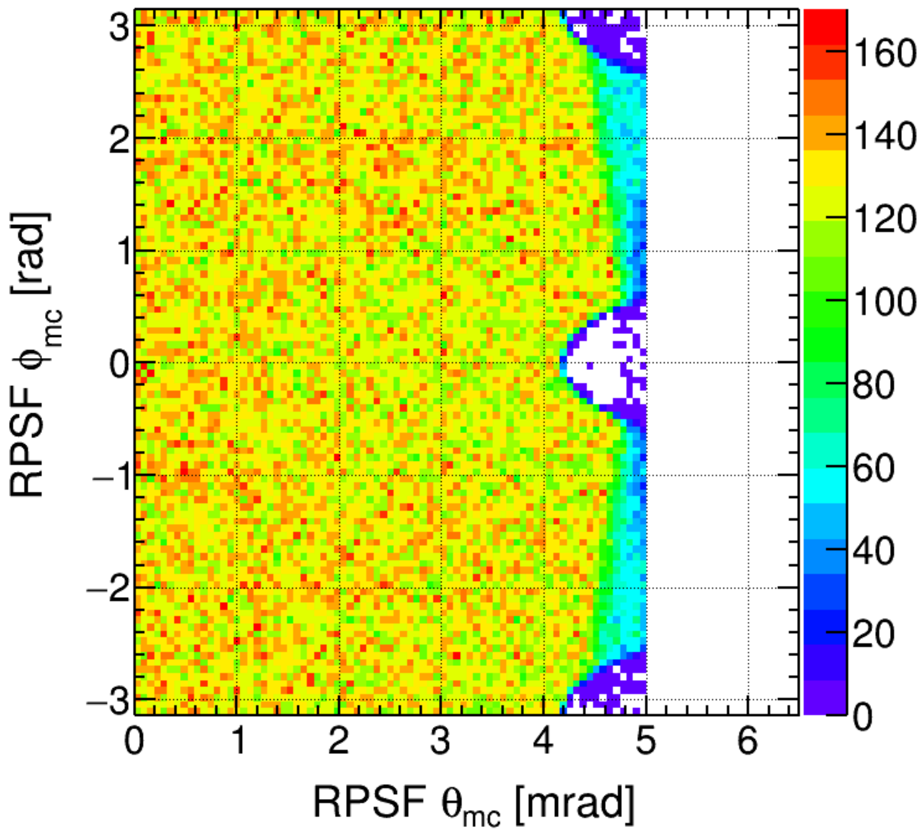


Accepted with beam pipe



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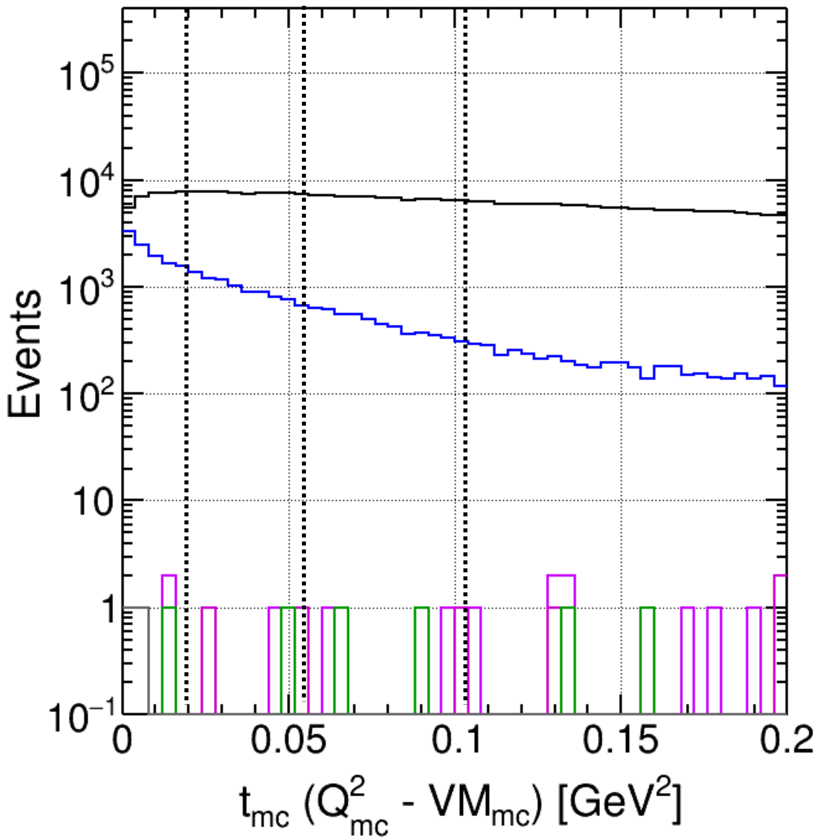
(Same) Sample and Event Selection

- Used **BeAGLE** v1.03.02 ePb 18×110 GeV^2 J/ψ production (**1 < Q^2 < 10**)
  Incoherent events $\boldsymbol{ePb \rightarrow e' + J/\psi(ee/\mu\mu) + X}$
- Passed through "**afterburner**" with **eAu** configuration **EIC CDR table 3.5**
  Beam effects (35 mrad crossing angle, angular divergence, and momentum spread)
- Applied **10σ safe distance cut** based on **eAu @ IR-8 Roman Pot at 2nd focus**
- **Event selection for nuclear breakups** – **tagging purpose**
  - ZDC Hcal: **any registered RAW hits**
  - RPSF: **one layer (closet to 2nd focus)** has registered RAW hits outside **10σ** safe distance
  - OMD: **two layers** (actual four layers as redundancy) have registered RAW hits
  - B0 Tracker: **at least two out of four layers** have registered RAW hits
  - B0 Ecal: **energy** of all hits greater than **100 MeV**
  - ZDC Ecal**: energy** of all hits greater than **100 MeV**

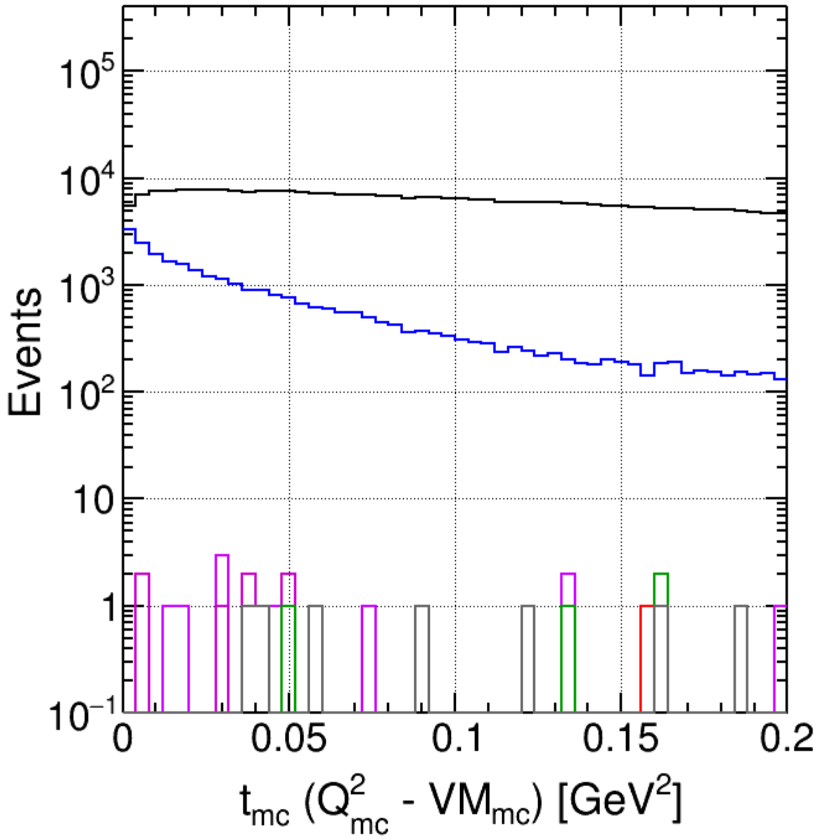
Vetoing Efficiency Comparison

Before beampipe and exit window



ZDC hcal tagged
(neutrons)
RPSF tagged
(protons, nuclear fragments)
OMD tagged
(charged particles)
B0 tracker tagged
(charged particles)
B0 ecal tagged
(photons)
ZDC ecal tagged
(photons)

After beampipe and exit window



Vetoing Efficiency Comparison

Veto Selections	Surviving Events	
	Before Beam Pipe/Exit Window	After Beam Pipe/Exit Window
All events	997,820	998,161
Events with one scattered electron identified and $\lvert\eta_{J/\psi}\rvert < 4$ and 1 < Q^2 < 10	732,455 (100 %)	732,707 (100 %)
ZDC HCAL tagged	41,848 (**5.71339 %**)	42,476 (**5.79713 %**)
+ RPSF tagged	71 (**0.00969343 %**)	66 (**0.00900769 %**)
+ OMD tagged	71 (0.00969343 %)	64 (0.00873473 %)
+ B0 tracker tagged	30 (0.00409581 %)	30 (0.00409441 %)
+ B0 ecal tagged	17 (0.00232096 %)	19 (0.00259312 %)
+ ZDC ECAL tagged	4 (**0.000546109 %**)	10 (**0.0013648 %**)

Summary

- Implemented partial beam pipe and neutron exit window to study impact of vetoing efficiency
  - ZDC neutron acceptance reduced by 0.5 mrad, evaluated by single particle simulation
  - Vetoing efficiency doesn't change much since each event has multiple neutrons and nuclear fragments can be captured at roman pot at secondary focus.

- Find the first draft of IR-8 vetoing efficiency (https://www.overleaf.com/2944235672dssxkvbwbwmy#ec4057)

Backup Slides

IP-8 Beam Parameters and 10σ Cut

From EIC CDR table 3.5 and Randy's eAu study

☺ RPSF: Roman Pot at Secondary Focus

eAu 18 GeV on 110 GeV	Momentum Dispersion ($D_{secondary\ focus}$)	Emittance X (ϵ_x*) [mm]	Emittance Y(ϵ_y*) [mm]	Beta function X (β_x secondary focus) [mm]	Beta function Y (β_y secondary focus) [mm]	Momentum spread ($\Delta p/p$)*
Old ep 18 on 275 GeV^2	0.382	43.2e-6	5.8e-6	2289.454596	4538.713168	6.2e-4
New ep 18 on 275 GeV^2	**0.465446718**	43.2e-6	5.8e-6	**498.013008**	**3392.376638**	6.2e-4
New eAu 18 on 110 GeV^2	**0.467582853**	43.2e-6	5.8e-6	**565.292559**	**1870.555797**	6.2e-4

$$\sigma_{x,y} = \sqrt{\epsilon_{x,y}\beta(z)_{x,y} + (D_{x,y}\frac{\Delta p}{p})^2}$$

where

ϵ : Emittance at z=0

β : Beta function at z=RPSF

D : Momentum dispersion at z=RPSF

$\frac{\Delta p}{p}$: Momentum spread at z=0

1σ calculation	$1\sigma_x$	$1\sigma_y$
ep β @ IR-8 RPSF (Old)	0.314867	0.1629770
ep β @ IR-8 RPSF (new)	**0.146677**	**0.140271**
eAu β @ IR-8 RPSF (new)	**0.156271**	**0.104160**

Nuclear Breakups Distribution

BeAGLE **v1.01.01**

Phys. Rev. D 104, 114030

produced particle	rate
only neutron	7.66%
only proton	0%
only photon	3.25%
neutron and proton	3.19 %
neutron and photon	44.24 %
proton and photon	2.27 %
neutron, proton and photon	39.39 %

TABLE II. Summary of particles produced in incoherent J/ψ production in BeAGLE.

BeAGLE **v1.03.02**

Nuclear Breakups at Final State	Number of Events
Only Neutrons	7.86 %
Only Protons	0.0001 %
Only Photons	3.45 %
Neutrons + Protons	3.18 %
Neutrons + Photons	45.41 %
Protons + Photons	1.85 %
Neutrons + Protons + Photons	38.25 %

About **95 %** of events have **neutrons**

Remaining (Non-Vetoed) Events

Phys. Rev. D 104, 114030

- Veto.1: no activity other than e^- and J/ψ in the main detector ($|\eta| < 4.0$ and $p_T > 100$ MeV/c) ;
- Veto.2: Veto.1 and no neutron in ZDC;
- Veto.3: Veto.2 and no proton in RP;
- Veto.4: Veto.3 and no proton in OMDs;
- Veto.5: Veto.4 and no proton in B0;
- Veto.6: Veto.5 and no photon in B0;
- Veto.7: Veto.6 and no photon with $E > 50$ MeV in ZDC.

Survived Event Ratio				
Material	Without beam pipe	Beryllium	Aluminum	Stainless Steel
Total events	100 %	100 %	100%	100%
Veto.1	86.9%	86.9%	86.9%	86.9 %
Veto.2	5.81%	9.73%	9.85%	17.2%
Veto.3	5.81%	9.73 %	9.85%	17.2%
Veto.4	5.09%	8.77%	8.89%	15.73%
Veto.5	4.32%	6.22%	5.97%	10.18%
Veto.6	2.29%	3.32%	3.18%	5.68%
Veto.7 ($E_{\text{photon}} > 50$ MeV)	1.06%	2.05%	2.46%	5.58%
Veto.7 ($E_{\text{photon}} > 100$ MeV)	-	2.18%	-	-

TABLE III. Summary of the percentage of events surviving the different vetoing steps for incoherent events assuming no beam pipe and different beam pipe materials of beryllium, aluminum, and stainless steel.

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	eAu β @ IR-8 RPSF
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