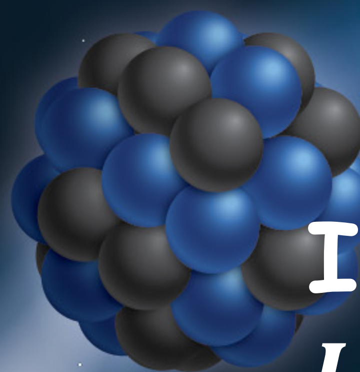
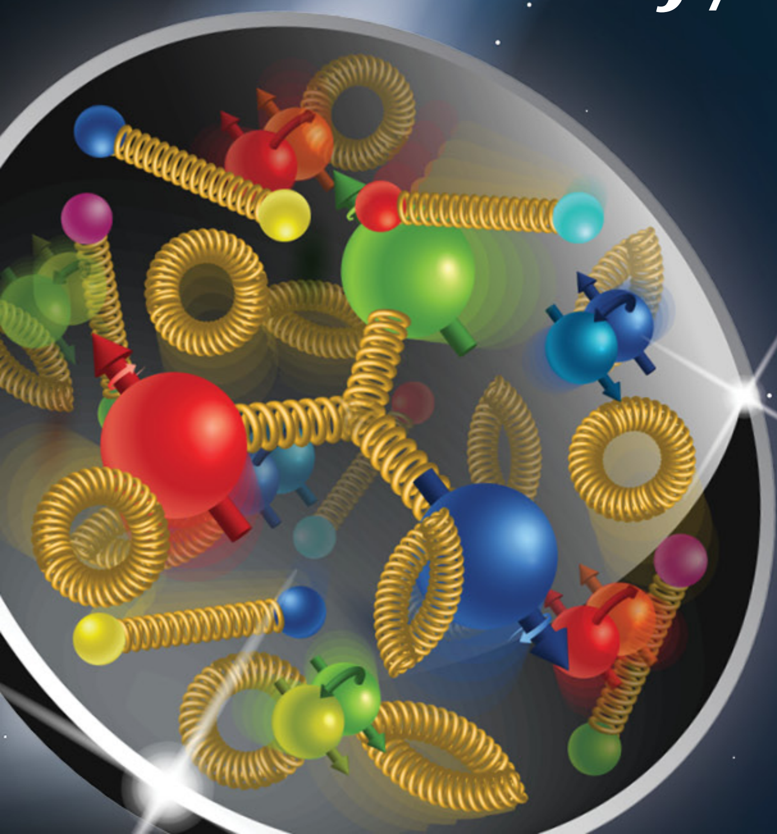
Investigations of coherent J/ψ production background at the EIC





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Open Questions in Photon-induced Interactions from Relativistic Nuclear Collisions to the future Electron-Ion Collider

Incoherent diffractive events vetoing

Exclusive coherent vector meson production $e + A \rightarrow e' + V + A$ where the nucleus remains intact is expected to be one of the important measurements at the EIC. The incoherent production $e + A \rightarrow e' + V + X$ swamps the coherent production, and we need to be able to veto the incoherent case in order to measure the coherent production.

$e + Pb \rightarrow e' + J/\psi + X(p, n, \gamma)$ 18x110 GeV

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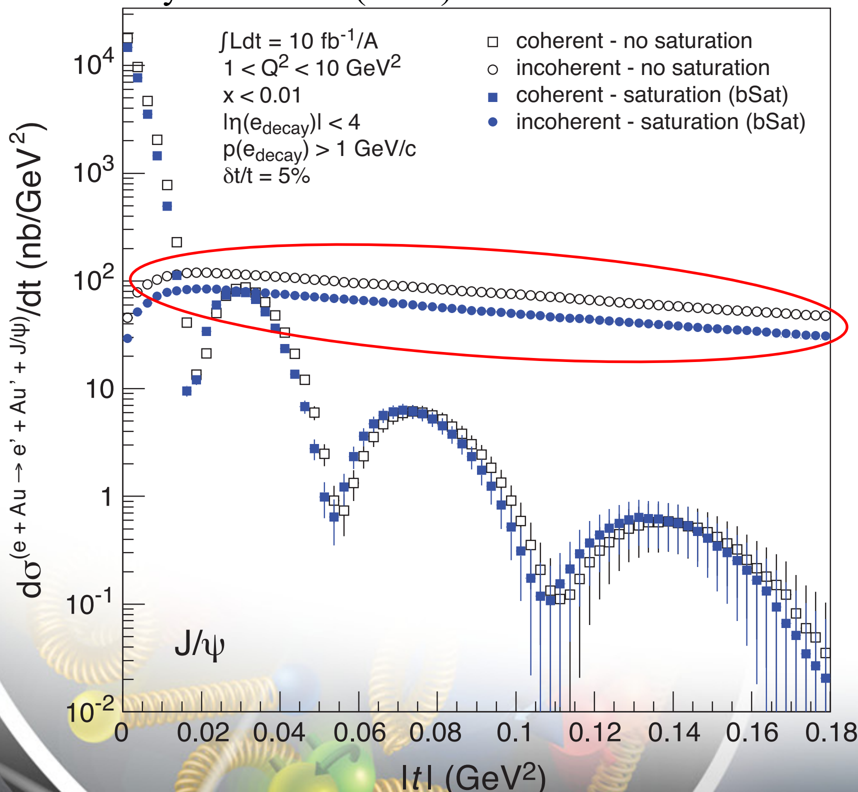
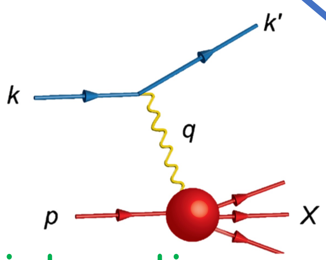


- The goal is to remove all the incoherent diffractive events
- Veto on forward neutrons, protons and photons.

Events	ratio
Only neutron(s)	8.1%
Only proton(s)	0%
Only photon(s)	7.66%
Neutron(s) and proton(s)	3.19%
Neutron(s) and photon(s)	40.94%
Proton(s) and photon(s)	5.82%
Neutron(s), proton(s) and photon(s)	35.03%

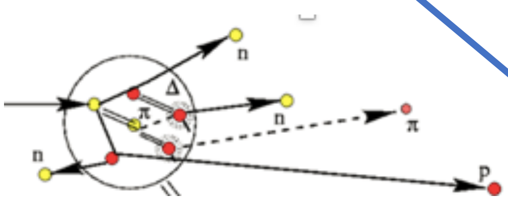
BeAGLE simulation framework

We are using BeAGLE (**B**enchmark **eA** **G**enerator for **LE**ptoproduction) package for the event simulation.



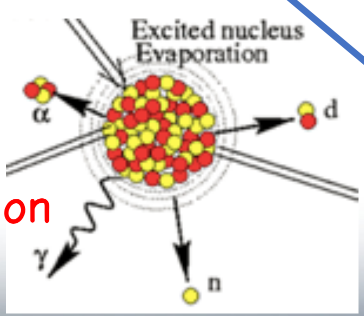
Primary interaction

Primary interaction treated by **PYTHIA** hard collision.



Intra-nuclear cascade

Cascade process handled by **DPMJET**.



Nuclear remnant evaporation

Target remnant evaporation and break up included by **FLUKA**.

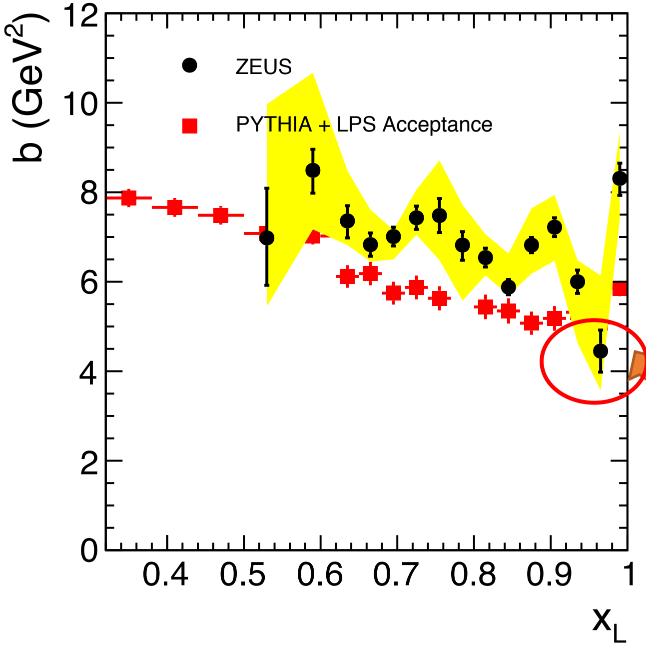
PYTHIA tune for ZEUS e+p

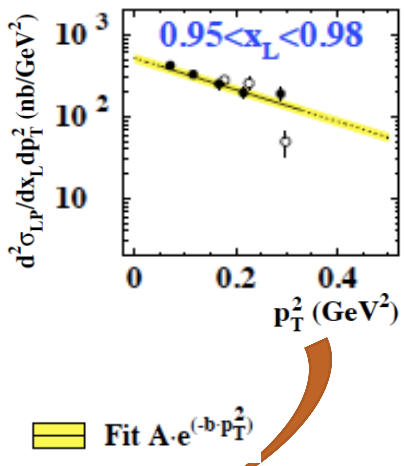
Cuts on Event level:

$$x_L > 0.32$$
$$p_T^2 < 0.5 \text{ GeV}^2$$
$$Q^2 > 3 \text{ GeV}^2$$
$$45 < W < 225 \; GeV$$

$e^+p \rightarrow e^+Xp$ (27.5 GeV x 820 GeV)

LPS trigger conditions and acceptance were required, dropped tracks very close to beamline or the edge of LPS detectors.

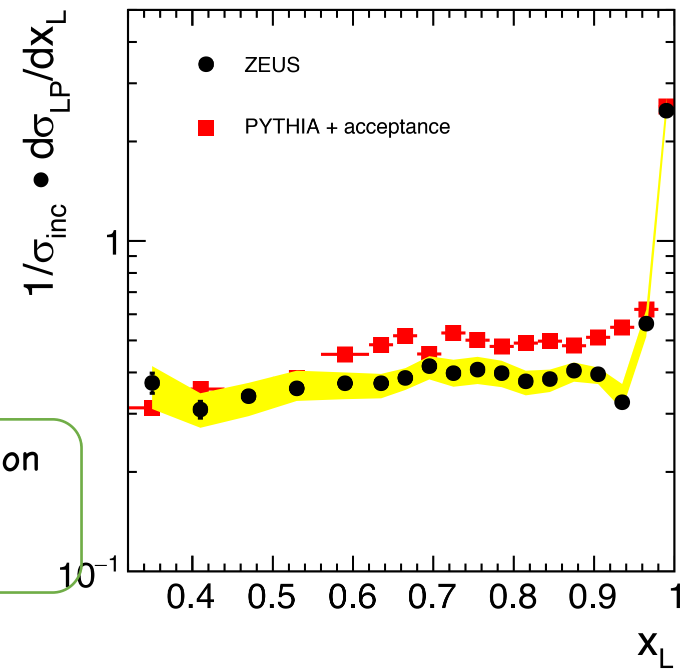




x_L is the momentum fraction carried by the outgoing leading proton.

JHEP 0906:074,2009

The leading proton production rate:



We have a good PYTHIA tune for target fragmentation for ep.

Remaining improvement would require a full GEANT simulation for the Hera Interaction Region

How well have we validated the Beagle results ?

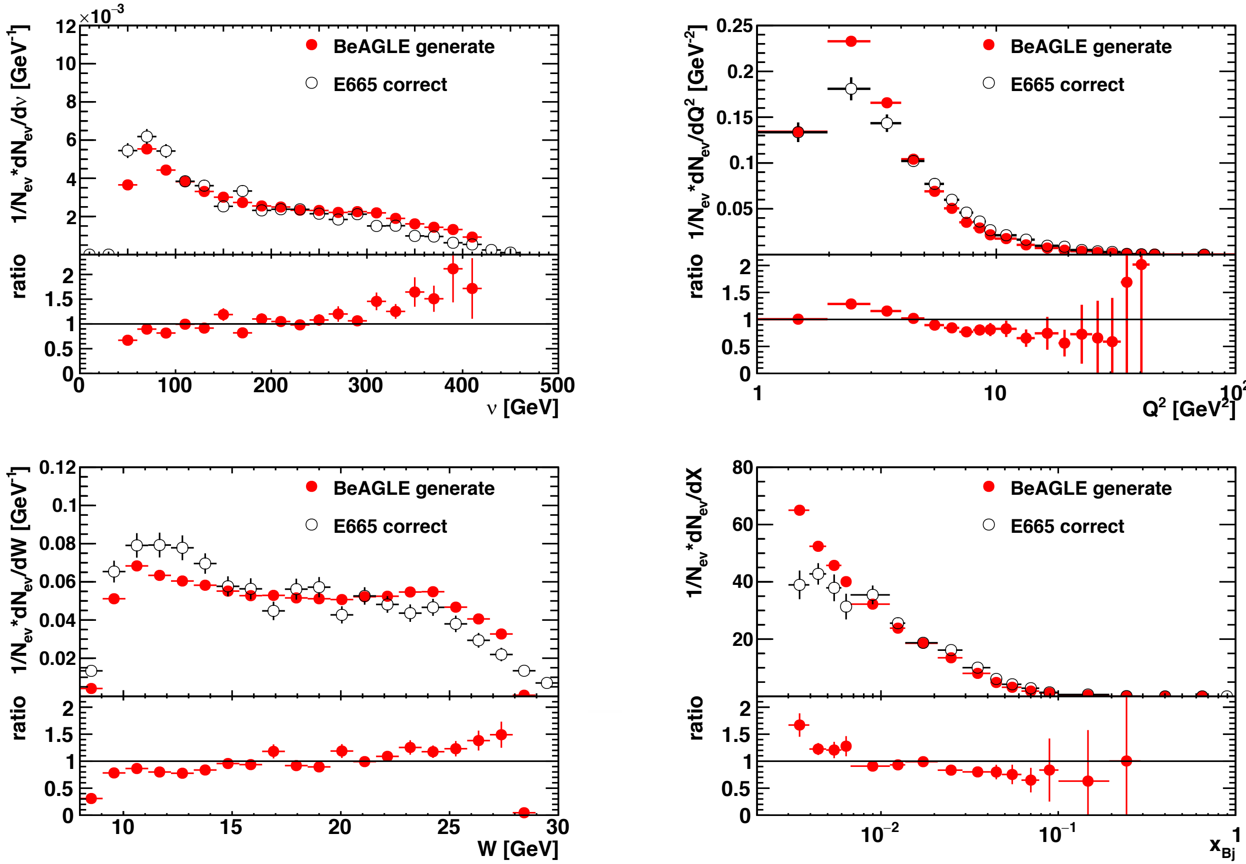
Z. Phys. C 61, 179-198(1994)

Data sample:

μ^{+}+Xe
Beam momentum:
490 GeV × 0GeV

$0.1 < y < 0.85$
$1.0 < Q^2 < 100$
0.0035 rad $< \theta < 6.29$ rad
8<W<30 GeV
X>0.002

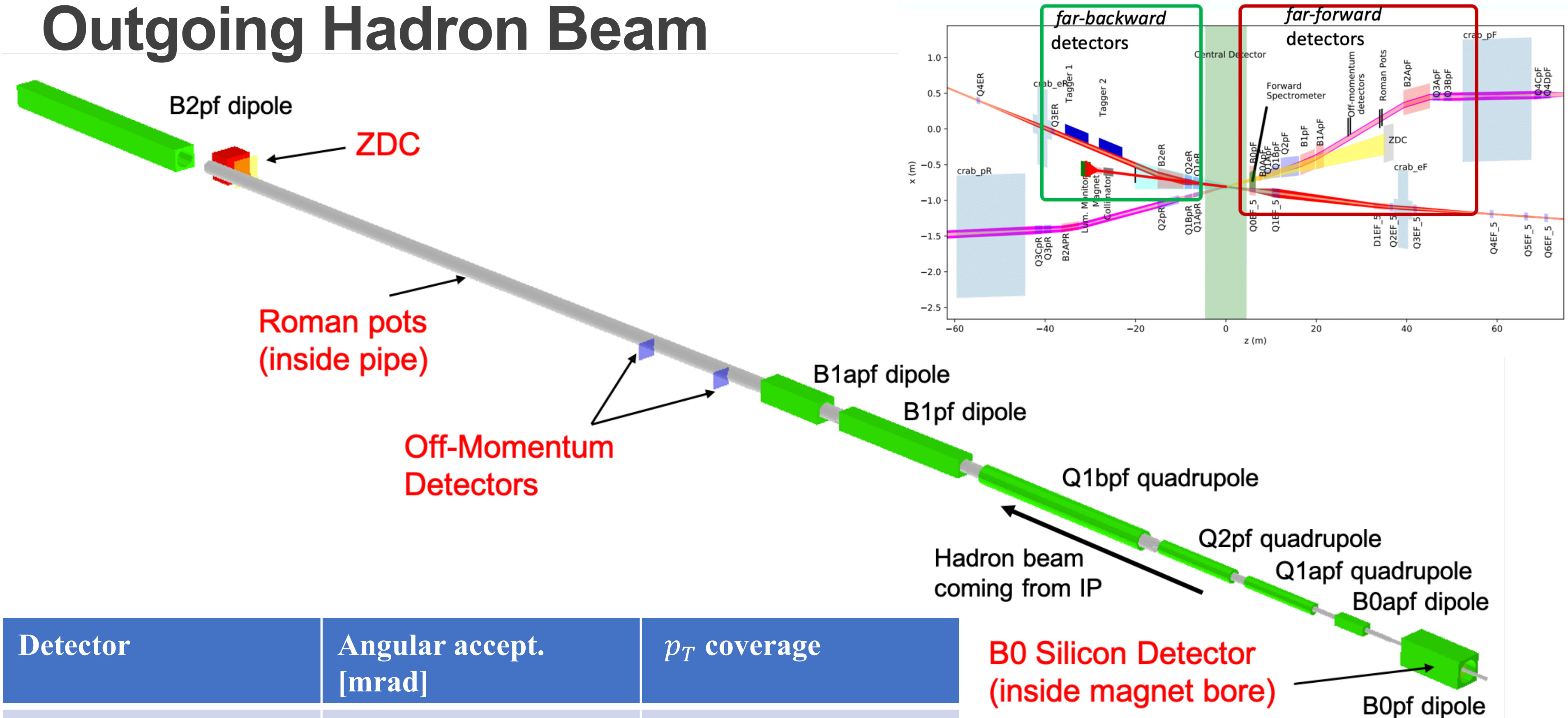
These plots are for inclusive variables only, so they do not verify the nuclear cascade part.



The comparison shows that BeAGLE does reasonably describe lepton-nucleus interactions at the Electron-Ion collider.

IR Layout and Acceptances

Outgoing Hadron Beam

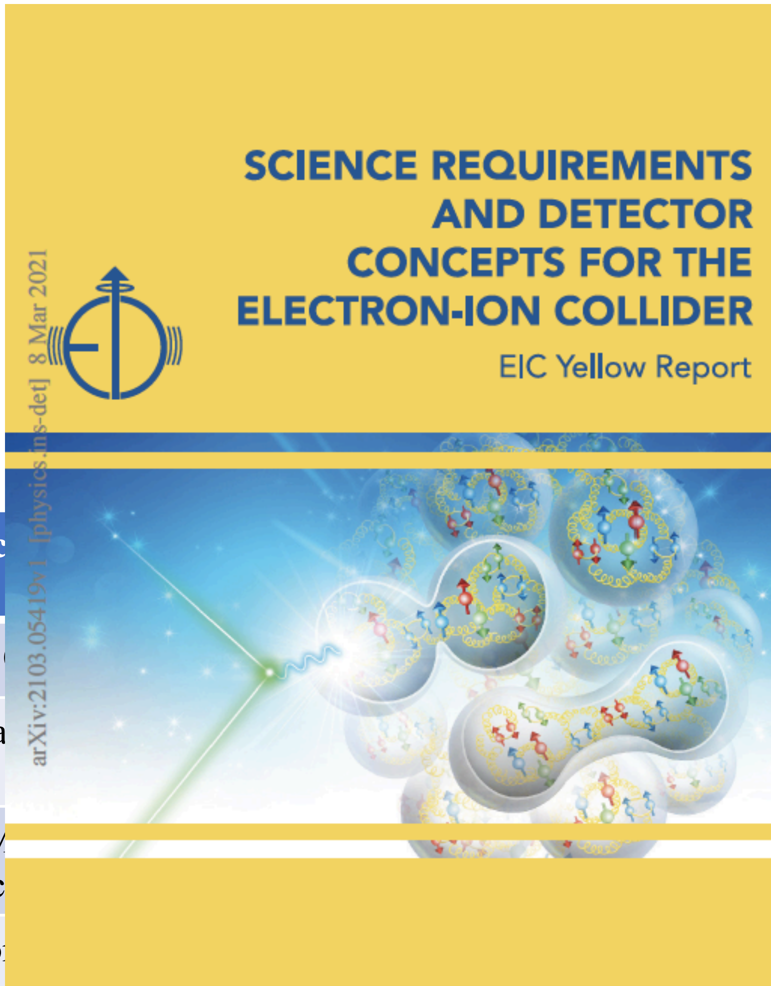


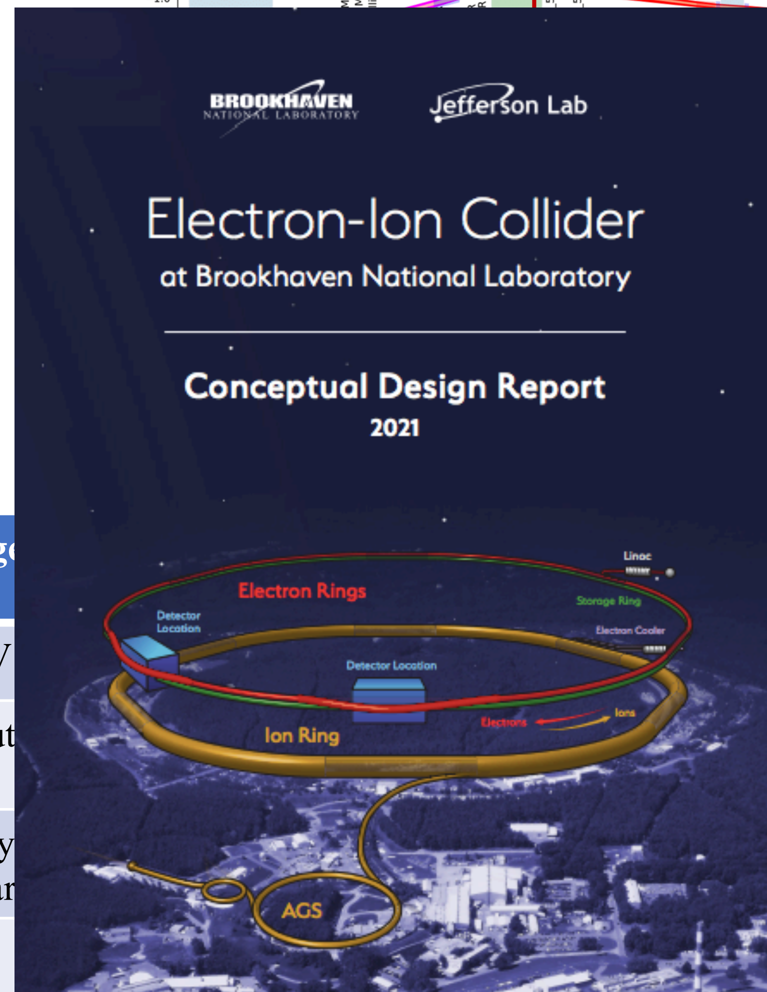
Detector	Angular accept. [mrad]	p_T coverage
ZDC @ ~30m	θ<5.5 ($\eta > 6$)	p_T<1.3 GeV
Roman Pots	0*<θ<5.0 ($\eta > 6$)	*Low p_T cutoff (beam optics)
Off-Momentum Detectors	0.0< θ < 5.0 ($\eta > 6$)	Low-rigidity particles from nuclear breakups
B0 forward spectrometer	5.5 < θ < 20.0 (4.6< η < 5.9)	High p_T

IR Layout and Acceptances

Outgoing Ha

Details are published in the Yellow Report,
arXiv https://arxiv.org/abs/2103.05419
and CDR
https://www.bnl.gov/ec/files/EIC_CDR_Final.pdf



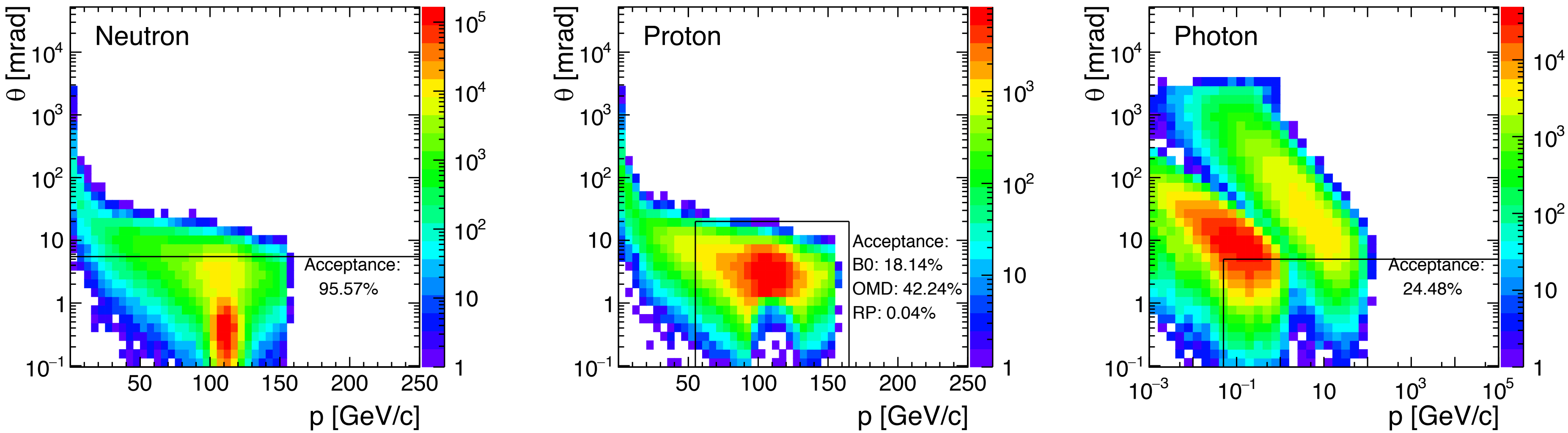


Detec…		…overage
ZDC …		…3 GeV
Roma…		… p_T cut … s)
Off-M… Detec…		…rigidity … nuclear…
B0 fo… spectrometer	(4.0 < η < 5.9)	… p_T

Protons, neutrons and photons θ $vs.p$ distribution

The scattering angle as fct. of the total momentum for photons, protons, neutrons in BeAGLE generator. The guided lines are the approximate acceptance for detecting each particles.

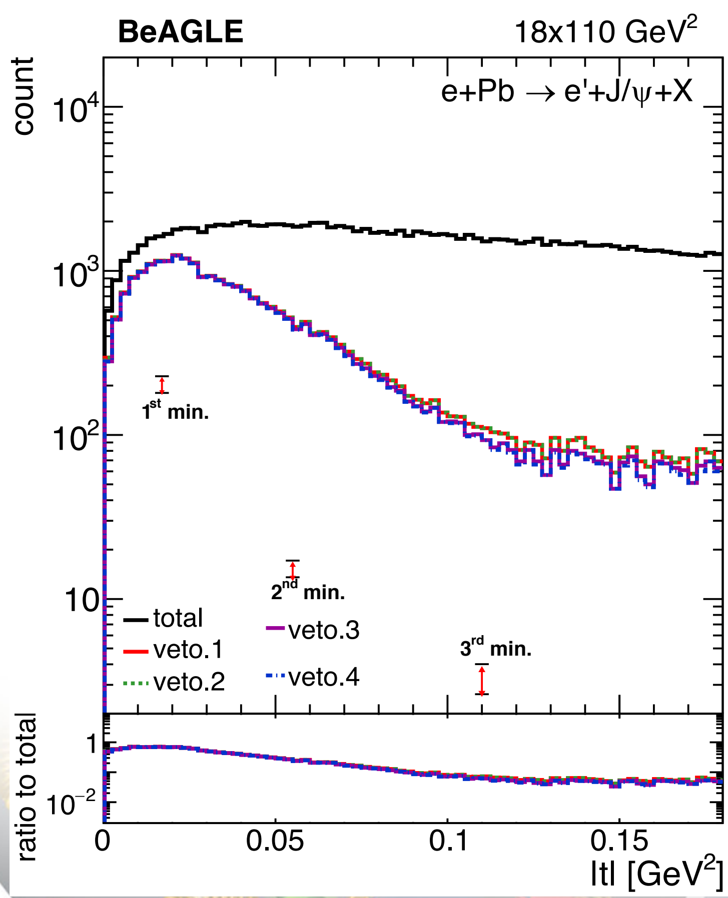
Note: Every particle from the nucleus decay is shown → events can appear several times



- Neutrons have a good acceptance with close to 95%.
- Protons acceptance is generally very good except at very large scattering angle and at very low momentum.
- Only 24% photons are within the ZDC angular acceptance. Most of the photons are currently outside of the ZDC → Integrate photon detection in B0 → preshower within B0.

Vetoing Incoherent Events: Protons and Neutrons

The beam pipe is broken into sections to make it a bit easier to turn pieces on and off in the simulation.
→ the beam pipe design/material is critical



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Beam pipe material:

beamPipeQuads: **aluminum (thickness 1-2mm)**
beamPipeB0: **aluminum (thickness 1.5mm)**
beamPipeRP: **aluminum (thickness 2mm)**
beamPipeZDC: **aluminum (thickness 2mm)**

The impact of the different detectors is studied by adding one requirement / cut after the other.

Veto.1:
- no neutron in ZDC

Veto.2:
- Veto1 + no proton in Roman Pots

Veto.3:
- Veto2 + no proton in off-momentum detector

Veto.4:
- Veto3 + no proton in B0

Survived event count	
Total events	100%
Cut1	16.81%
Cut2	16.81%
Cut3	16.29%
Cut4	15.77%

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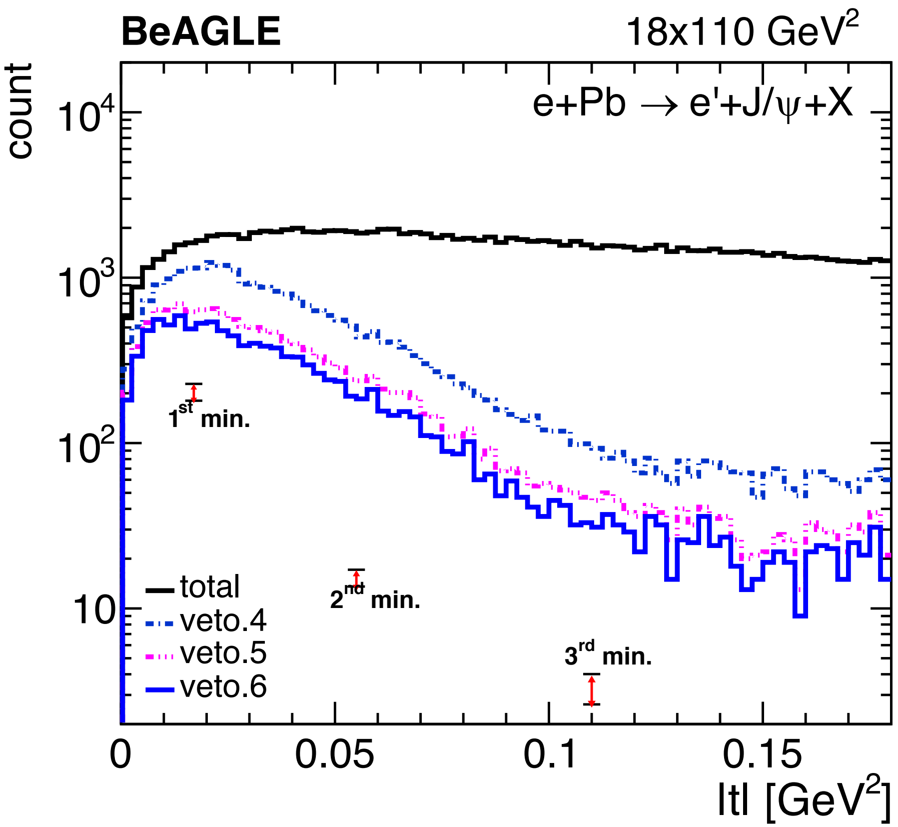
Vetoing Incoherent Events: Photons



Veto.5:

- Veto4 + nothing in preshower

Veto.6:

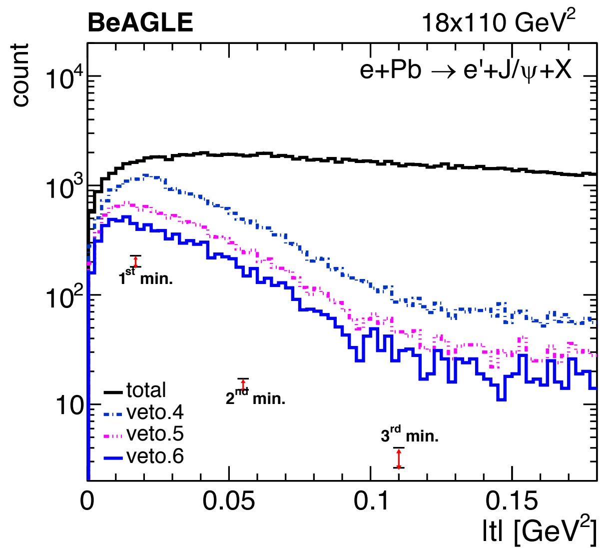
- Veto5 + no photon ***E>50MeV*** in ZDC

Survived event count	
Total events	100%
Cut1	16.81%
Cut2	16.81%
Cut3	16.29%
Cut4	15.77%
Cut5	7.33%
Cut6	5.82%

Veto on photon, ~10% events are further removed.

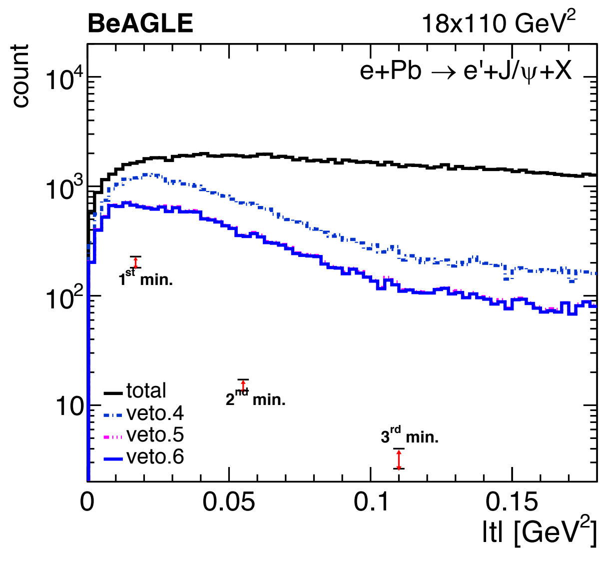
Vetoing Incoherent Events

Beam pipe material:
- beamPipeQuads: **aluminum**
- beamPipeB0: **aluminum**
- beamPipeRP: **beryllium**
- beamPipeZDC: **beryllium**



Survived event count	
Total events	100%
Cut1	16.7%
Cut2	16.7%
Cut3	16.18%
Cut4	15.66%
Cut5	7.3%
Cut6	4.96%

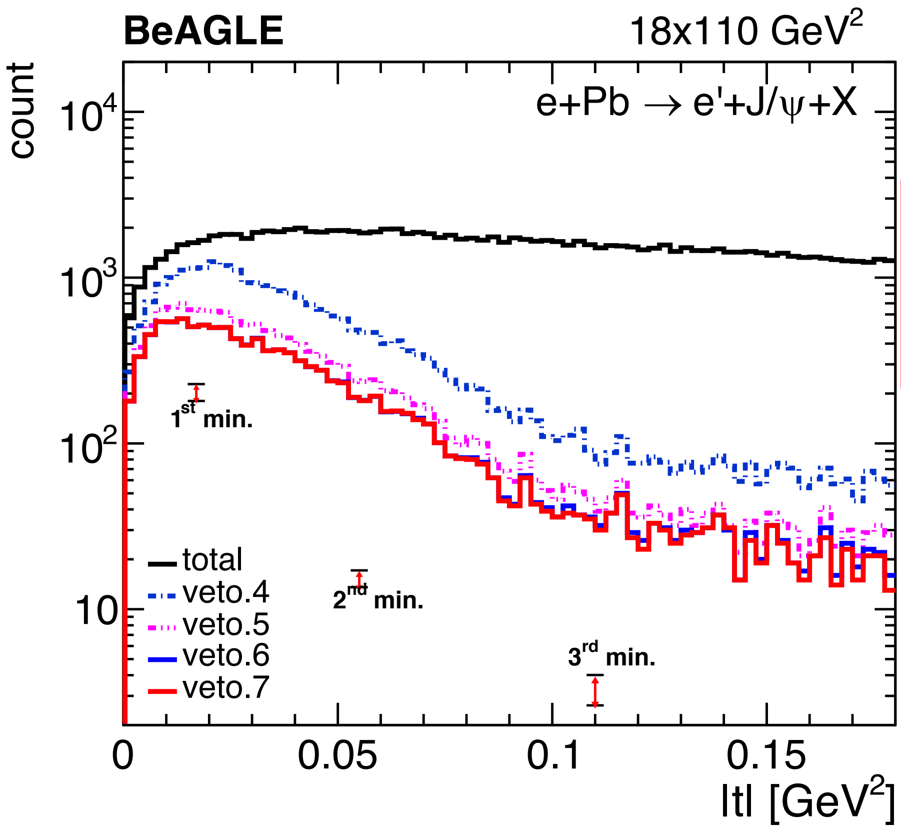
Beam pipe material:
- beamPipeQuads: **aluminum**
- beamPipeB0: **aluminum**
- beamPipeRP: **stainless steel**
- beamPipeZDC: **stainless steel**



Survived event count	
Total events	100%
Cut1	25.7%
Cut2	25.7%
Cut3	24.77%
Cut4	23.97%
Cut5	11.31%
Cut6	11.09%

Beam pipe material is critical to have good vetoing power

Vetoing Incoherent Events: Main detectors



Veto.5:

- Veto4 + no anything in preshower

Veto.6:

- Veto5 + no photon ***E>50MeV*** in ZDC

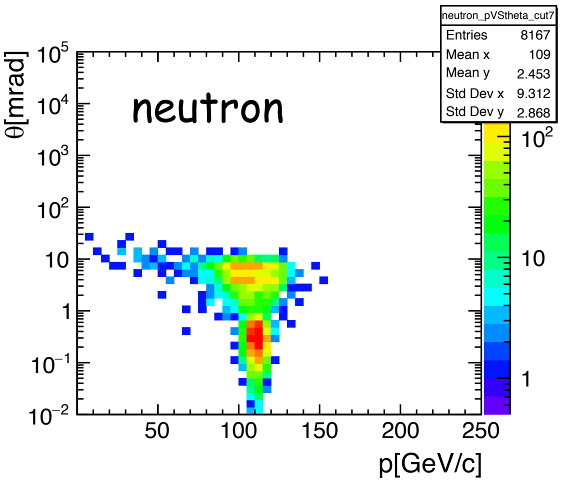
Veto.7:

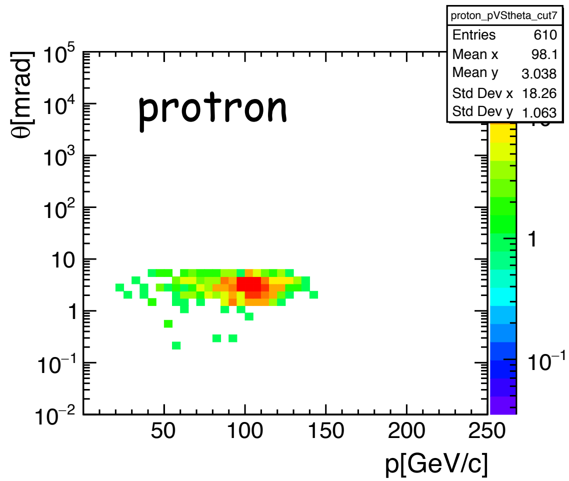
- Veto6 + no activities ($|\boldsymbol{\eta}| < \mathbf{4.0}$ & $\boldsymbol{p_T} > \mathbf{100\,MeV/c}$ & $\boldsymbol{E} > \mathbf{50\,MeV}$) other than e- and J/ψ in the main detector (generator level)

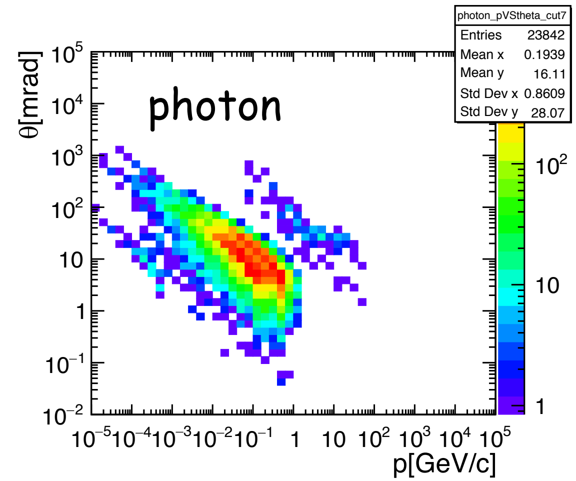
Survived event count		
Total events	250000	100%
Cut1	42026	16.81%
Cut2	42026	16.81%
Cut3	40734	16.29%
Cut4	39415	15.77%
Cut5	18324	7.33%
Cut6	14551	5.82%
Cut7	14203	5.68%

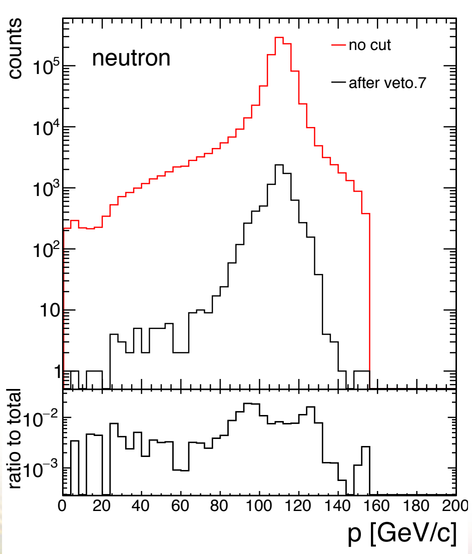
With these requirements, the rejection power is found to be not enough to reach the three minimum positions.

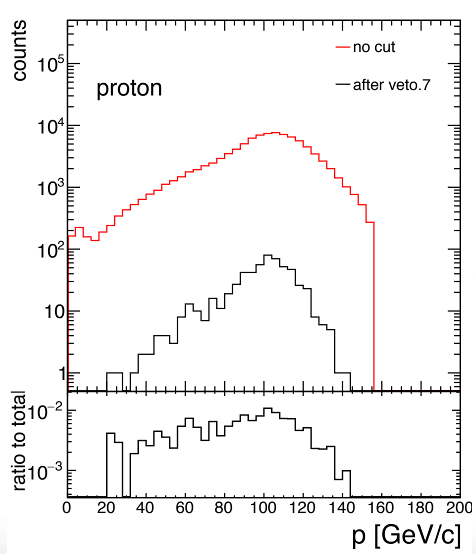
Protons, neutrons and photons distribution in survived events

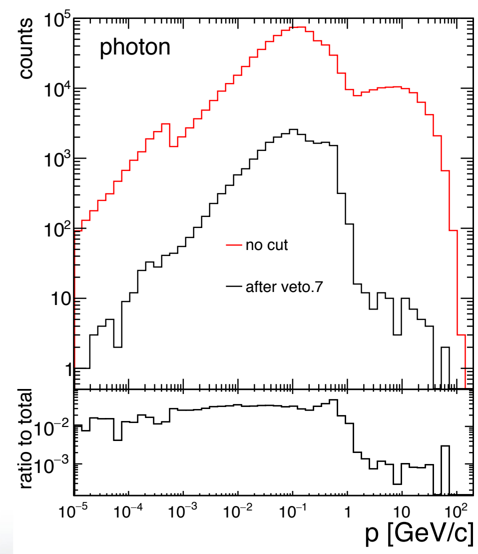






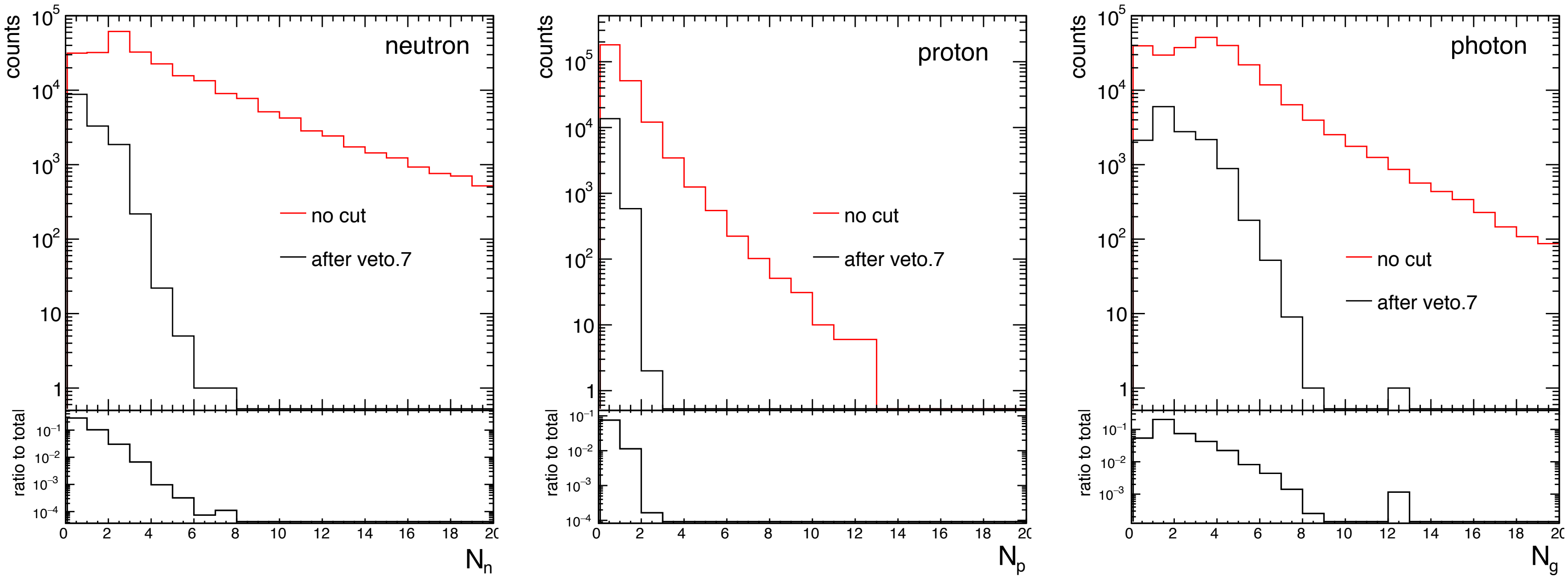






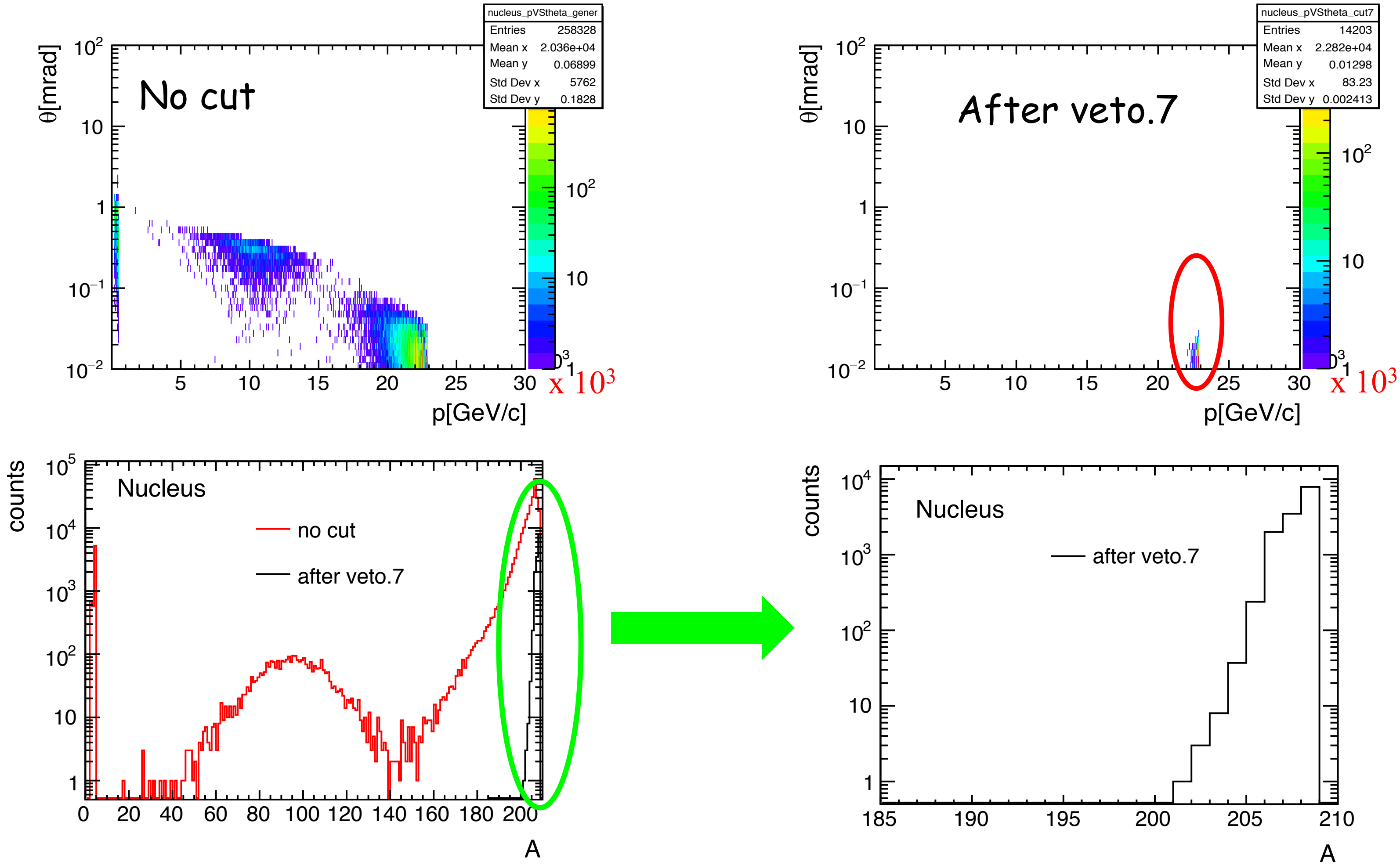
The vetoing efficiency for particles is >99%.

Protons, neutrons and photons multiplicity distribution



Multiplicity for non-vetoed events are peaked at lower multiplicity.
Events with more particles, the more likely it can be vetoed.

Nucleus θ vs. p distribution



- The survived events not only have low forward-going particle multiplicity, and high nucleus momentum.
- Nuclei, which evaporate less particles tend to have closer to the original beam momentum.
- Looking at the residual events, they are A>200 and peaked at 208, coming from events with photon emission. Detecting these nucleus will be extremely difficult if not impossible.

Summary

- coherent vector meson production $e + A \rightarrow e' + V + A$ very challenging measurement
- BeAGLE has been tuned successfully to several different measurements
- Vetoing power of incoherent $e + A \rightarrow e' + V + X$ events depends critically on
  - overall far forward acceptance for photons, neutron and protons
  - beam pipe design and material impacts the vetoing power
    - further careful optimization obeying all the constraints from the accelerator is under way
    - Iteration with engineers on more up-to-date beam pipe design with input from the results of these simulations is under way

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Thank you!