Investigations of coherent J/ψ production background at the EIC

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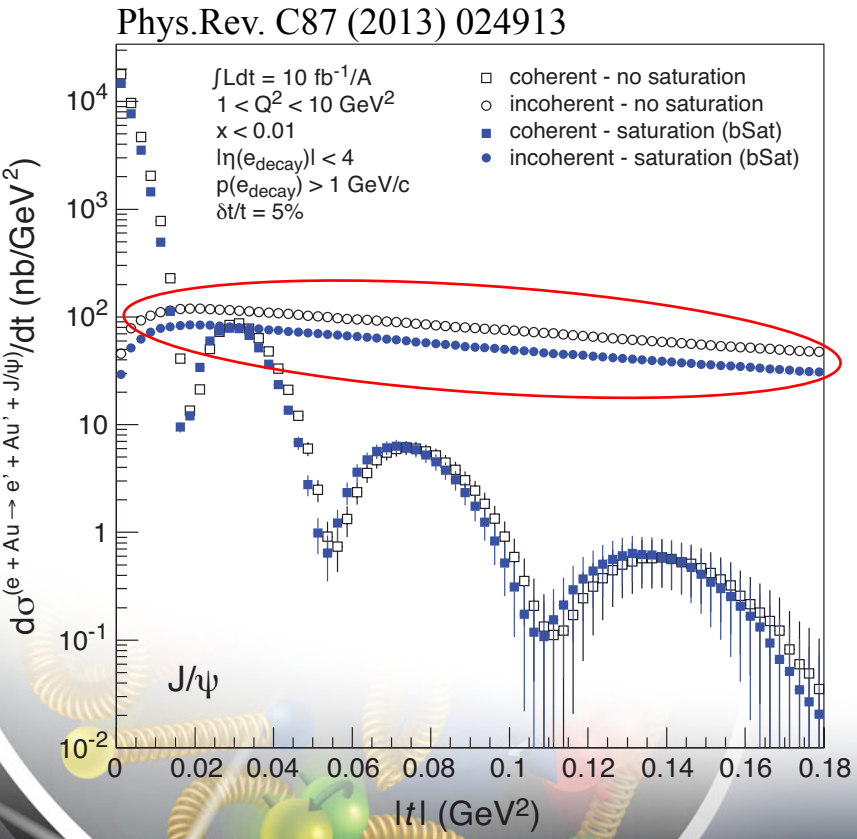
Incoherent diffractive events vetoing

Exclusive coherent vector meson production e + A → 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 → 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

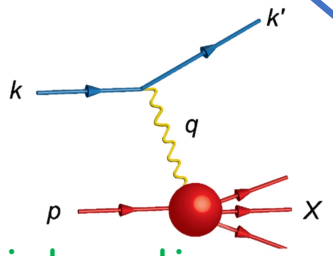


- The goal is to remove all the incoherent diffractive events
- Veto on forward neutrons, protons and photons.

Events	ratio
Only neutron(s)	7.659%
Only proton(s)	0%
Only photon(s)	3.254%
Neutron(s) and proton(s)	3.194%
Neutron(s) and photon(s)	44.238%
Proton(s) and photon(s)	2.265%
Neutron(s), proton(s) and photon(s)	39.390%

BeAGLE simulation framework

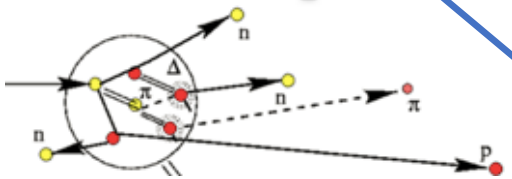
We are using BeAGLE (**B**enchmark **eA** **G**enerator for **LE**ptoproduction) package for the event simulation.



Primary interaction

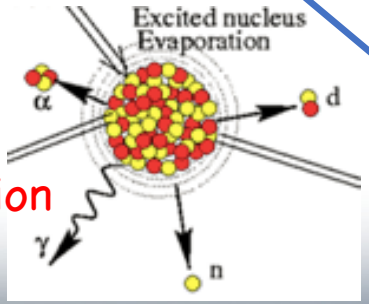
Primary interaction treated by **PYTHIA** hard collision.

Cascade process handled by **DPMJET**.



Intra-nuclear cascade

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



Nuclear remnant evaporation

PYTHIA tune for ZEUS e+p

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

Cuts on Event level:

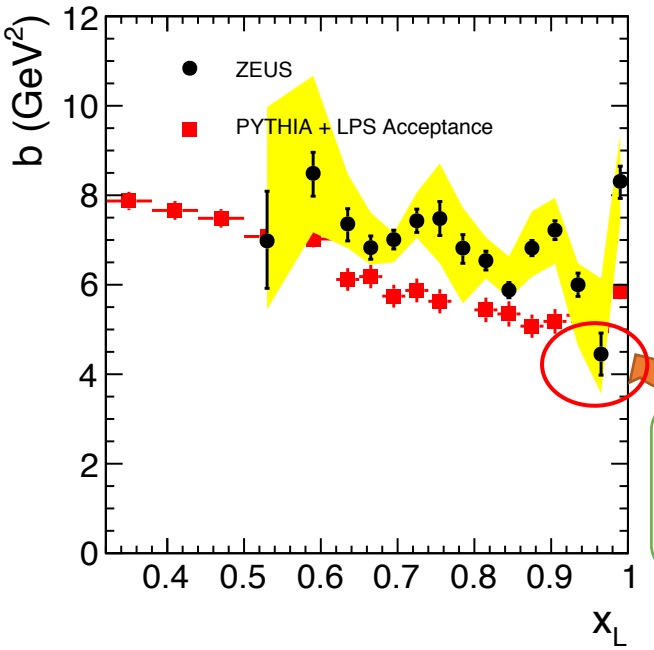
$x_L > 0.32$

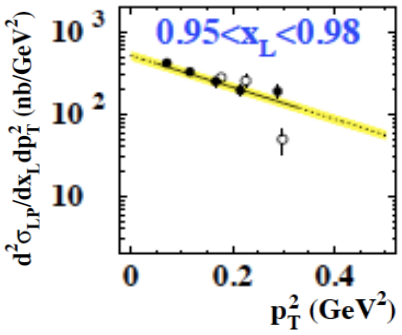
$p_T^2 < 0.5\ \mathrm{GeV}^2$

$Q^2 > 3\ \mathrm{GeV}^2$

$45 < W < 225\ GeV$

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

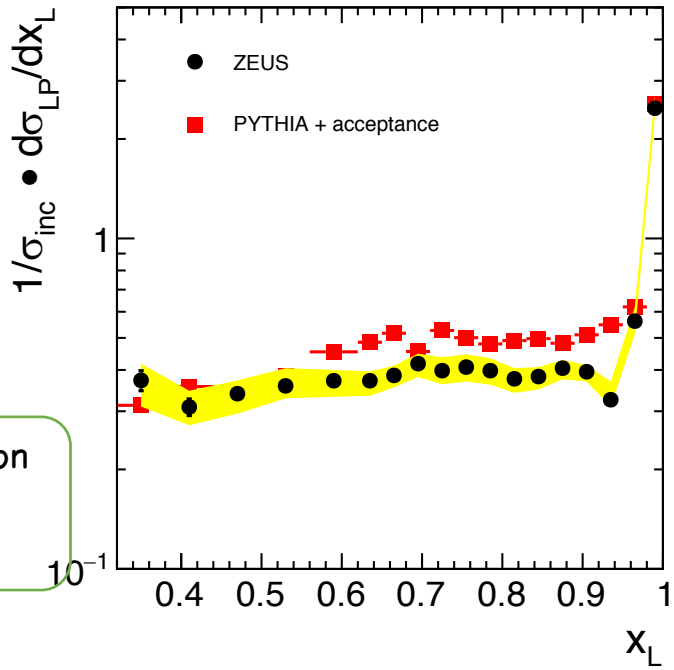




x_L is the momentum fraction carried by the outgoing leading proton.

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 ?

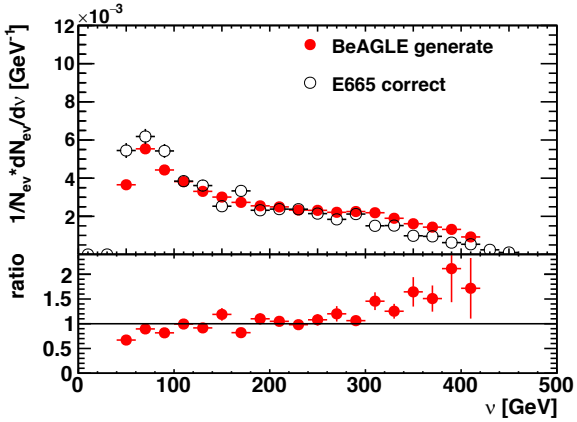
Z. Phys. C 61, 179-198(1994)

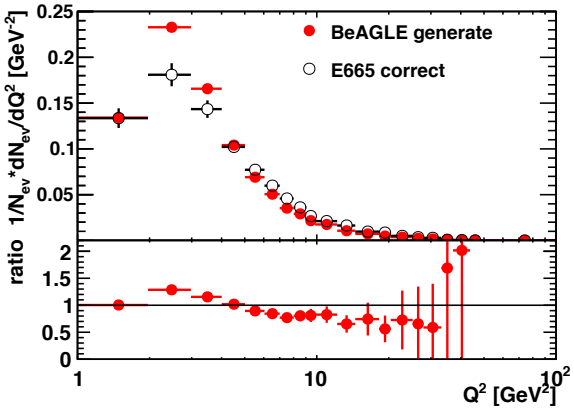
Data sample:

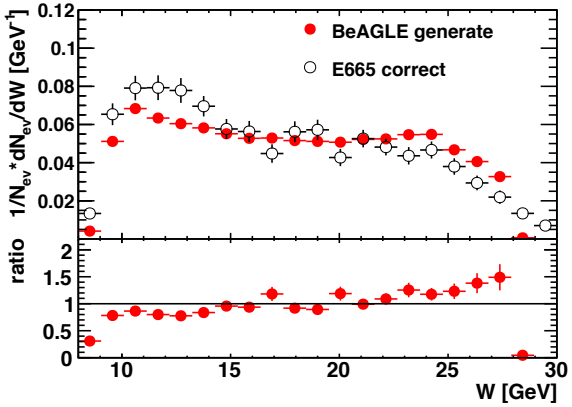
μ^++Xe
Beam momentum:
490 GeV × 0GeV

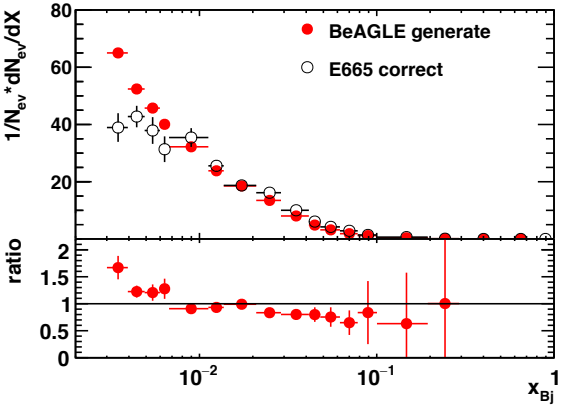
$0.1 < y < 0.85$
$1.0 < Q^2 < 100$
$0.0035 \text{ rad} < \theta < 6.29 \text{ rad}$
8<W<30 GeV
X>0.002

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





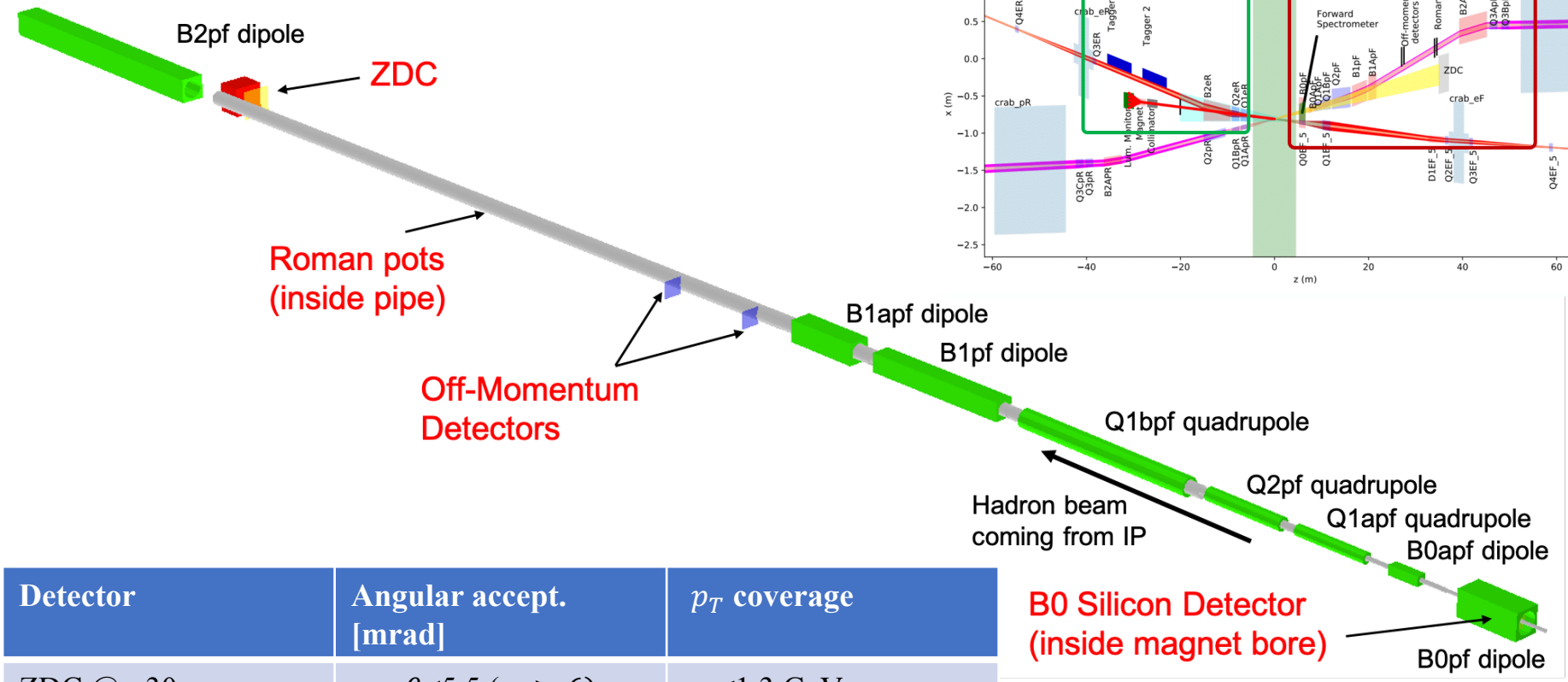




The comparison shows that BeAGLE does reasonably describe lepton-nucleus interactions at the Electron-Ion collider.

IR Layout and Acceptances

Outgoing Hadron Beam

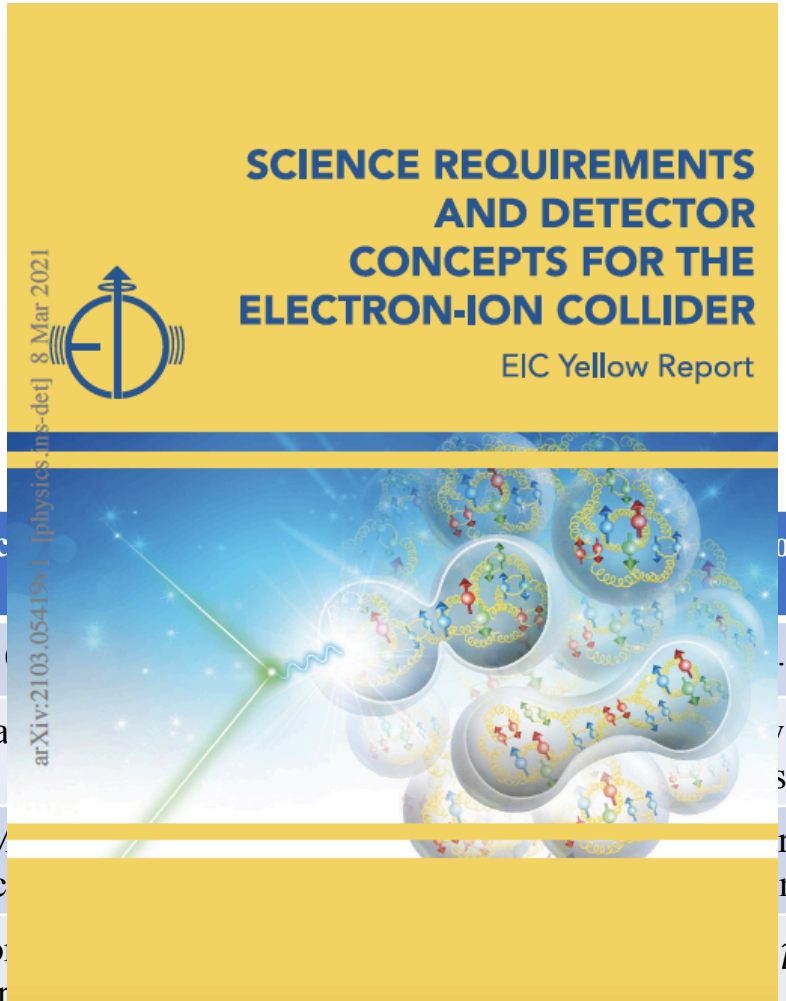


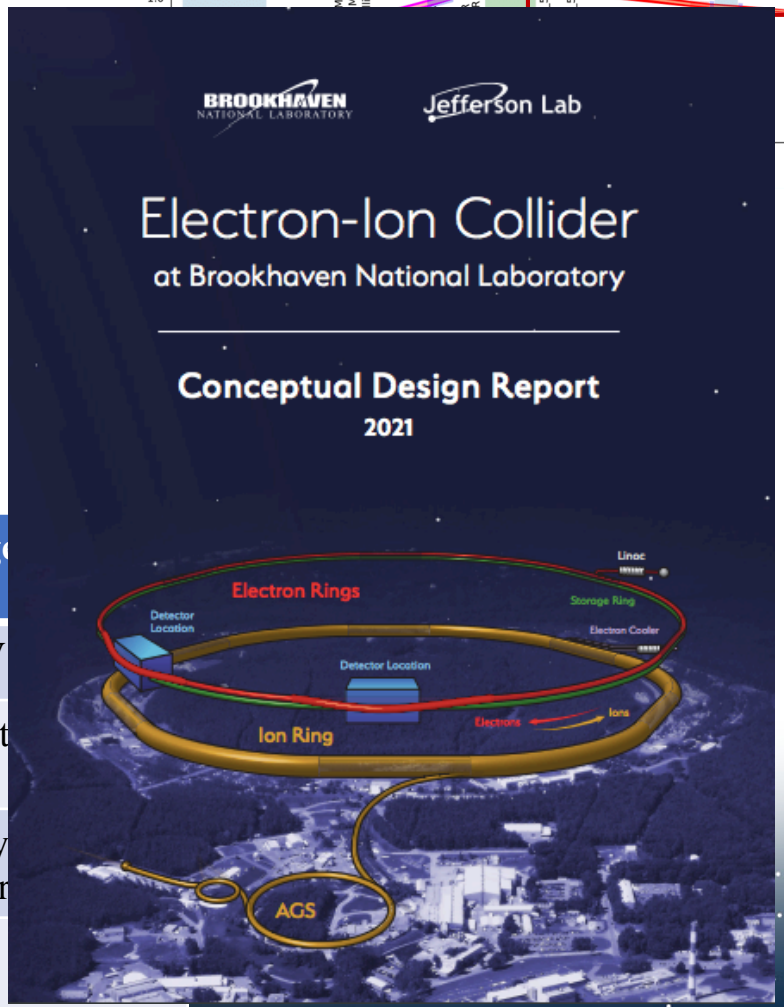
Detector	Angular accept. [mrad]	p_T coverage
ZDC @ ~30m	θ<5.5 ($\eta > 6$)	p_T<1.3 GeV
Roman Pots	0*<θ<5.0 ($\eta > 6$)	*Low p_T cutoff (beam optics)
Off-Momentum Detectors	0.0< θ < 5.0 ($\eta > 6$)	Low-rigidity particles from nuclear breakups
B0 forward spectrometer	5.5 < θ < 20.0 (4.6< η < 5.9)	High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



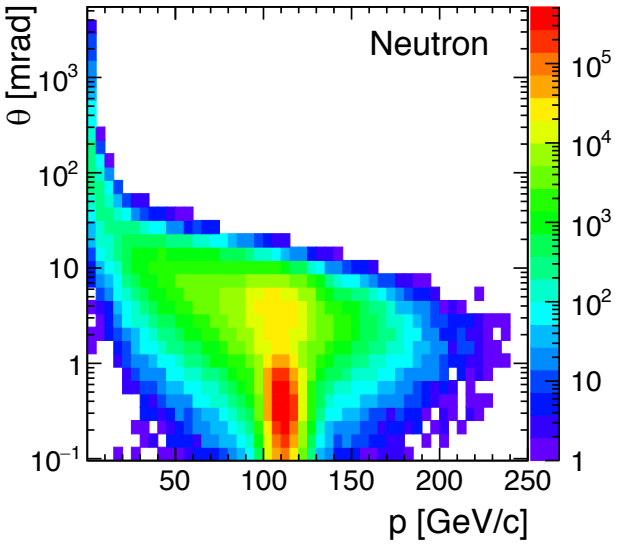


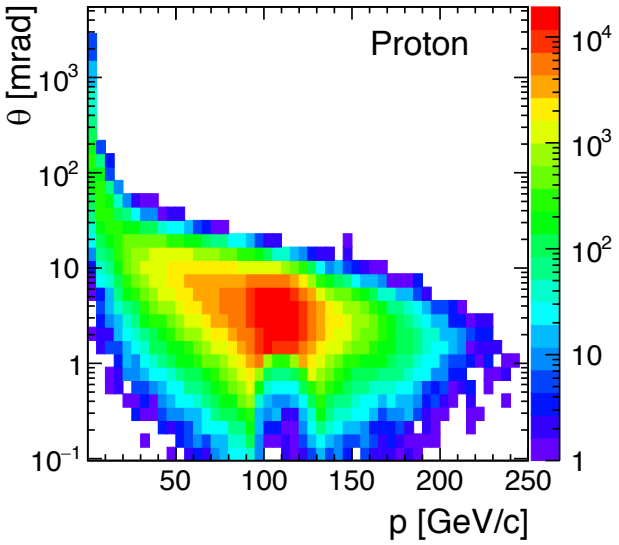
Detec		overag
ZDC (		.3 GeV
Roma		p_T cut s)
Off-M Detec		rigidity nuclear
B0 fo spectr		p_T

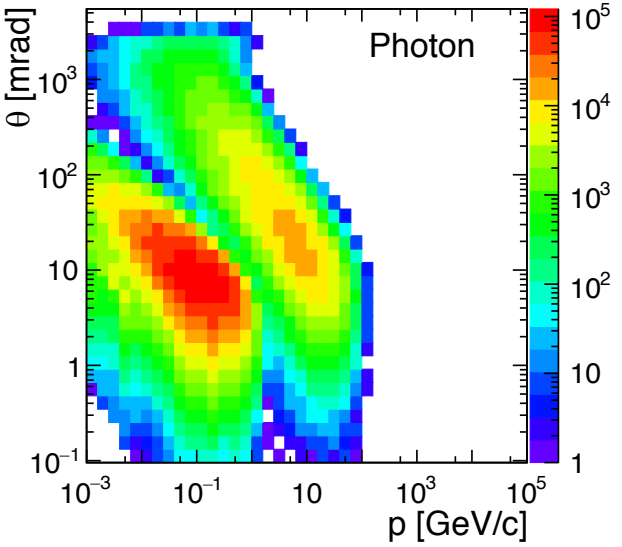
Protons, neutrons and photons θ vs. p distribution

The scattering angle as fct. of the total momentum for photons, protons, neutrons in BeAGLE generator.

Note: Every particle from the nucleus decay is shown → events can appear several times
For vetoing the incoherent events, only one of the particles that's detected by the detectors is sufficient.





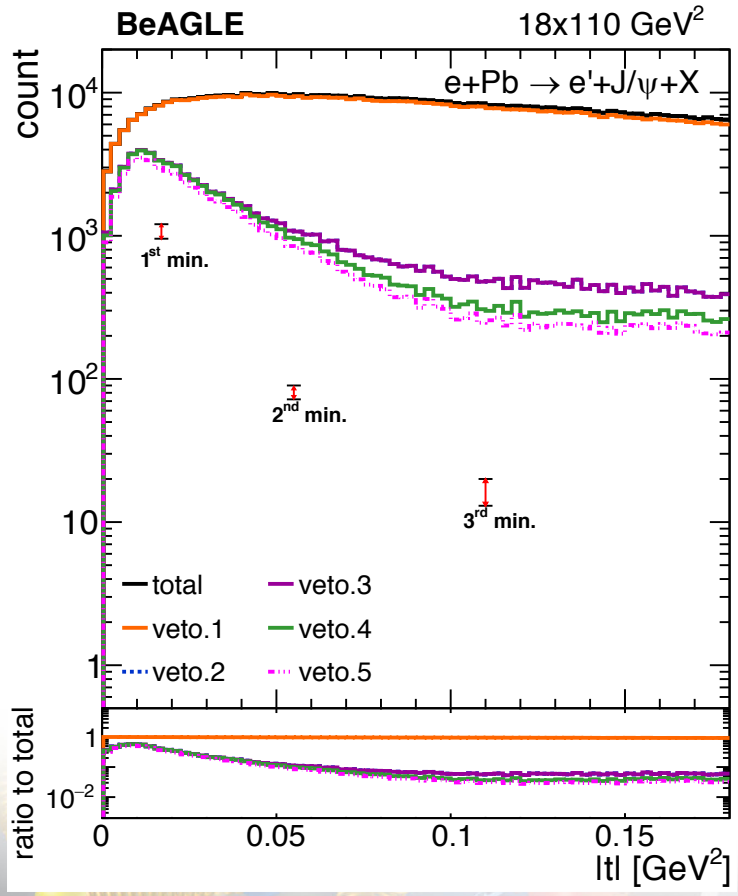


- Neutrons have a good acceptance with close to 95%.
- Protons acceptance is generally very good except at very large scattering angle and at very low momentum.
- Only 24% photons are within the ZDC angular acceptance. Most of the photons are currently outside of the ZDC → Integrate photon detection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



Phys.Rev. C87 (2013) 024913

Beam pipe material:

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

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

Veto.1:

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

Veto.2:

- **veto.1 and no neutron in ZDC;**

Veto.3:

- **veto.2 and no proton in RP;**

Veto.4:

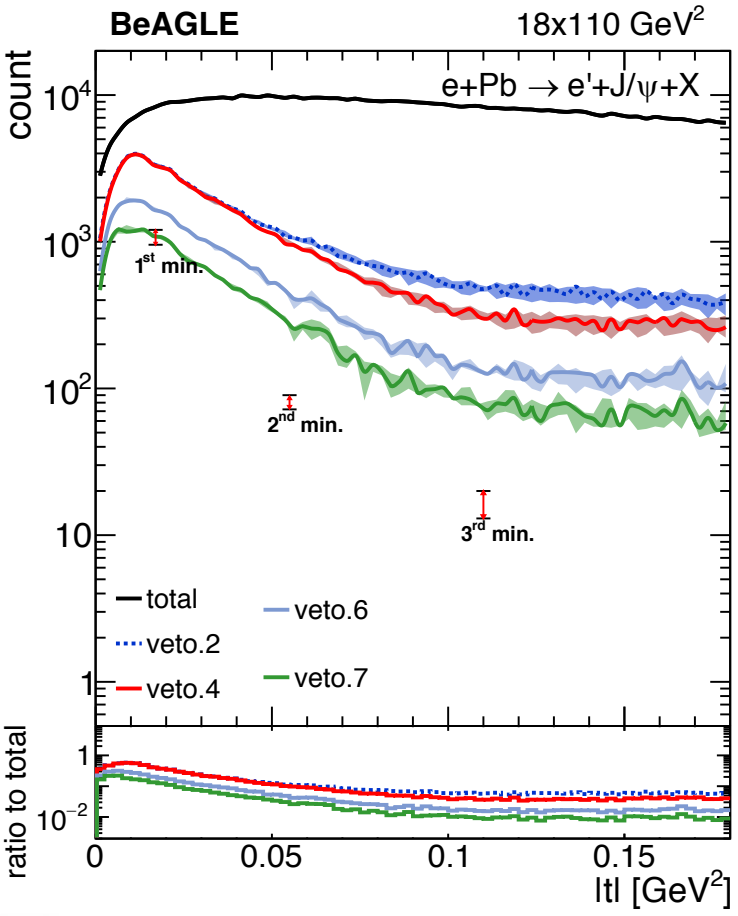
- **veto.3 and no proton in OMD;**

Veto.5:

- Veto.4 and no charge particles in B0

Survived event count	
Total events	100%
Veto.1	86.9%
Veto.2	9.73%
Veto.3	9.73%
Veto.4	8.73%
Veto.5	6.2%

Vetoing Incoherent Events: Photons



Veto.6:

- Veto4 + no anything in preshower

Veto.7:

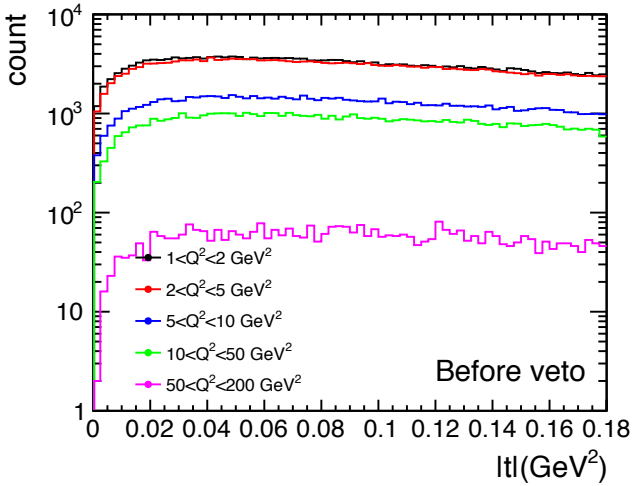
- Veto5 + no photon ***E>50MeV*** in ZDC

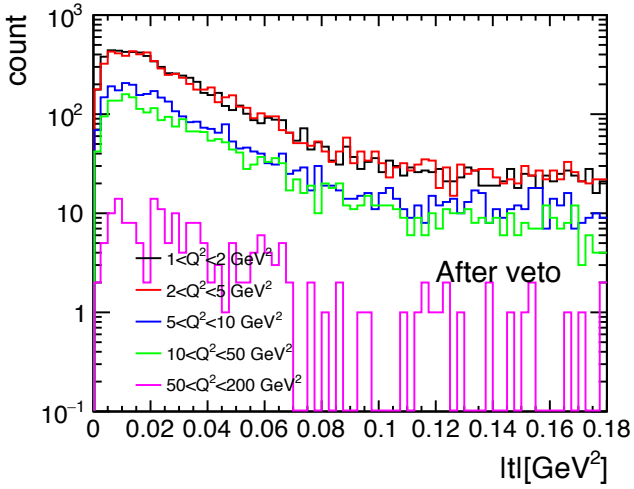
Survived event count		
Total events	1322778	100%
Veto.1	1149549	86.9%
Veto.2	128662	9.73%
Veto.3	128662	9.73%
Veto.4	115500	8.73%
Veto.5	81944	6.2%
Veto.6	43414	3.28%
Veto.7	26950	2.037%

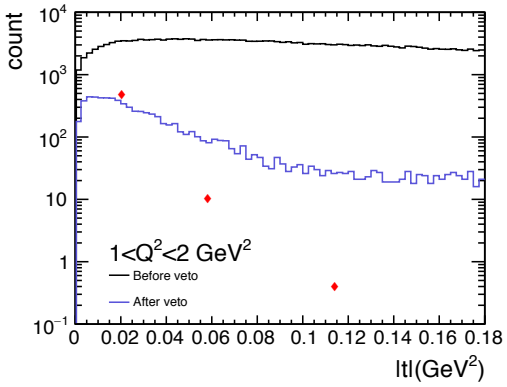
Veto on photon, ~4.2% events are further removed.

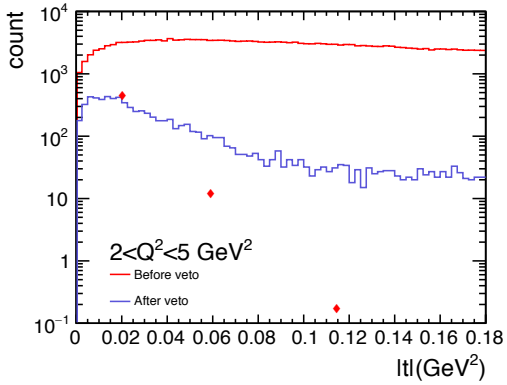
- With these requirements, the rejection power is found to be just enough to reach the first minimum position.
- ✓ The uncertainty bands bracket the difference in vetoing capability varying τ_0 from 6 fm to 14 fm with 10 fm as central value

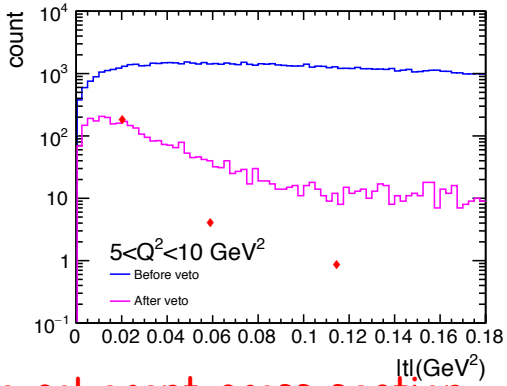
Q^2 dependence







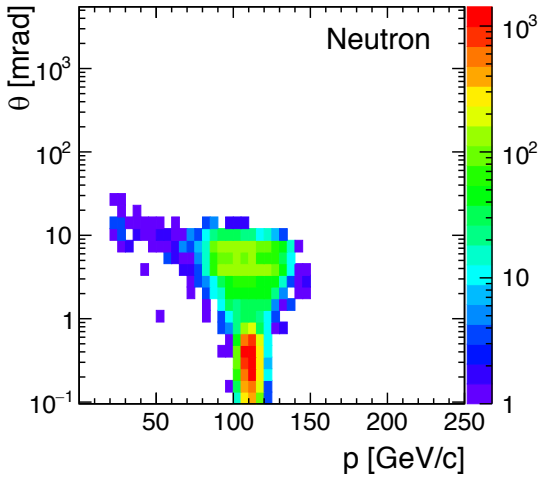


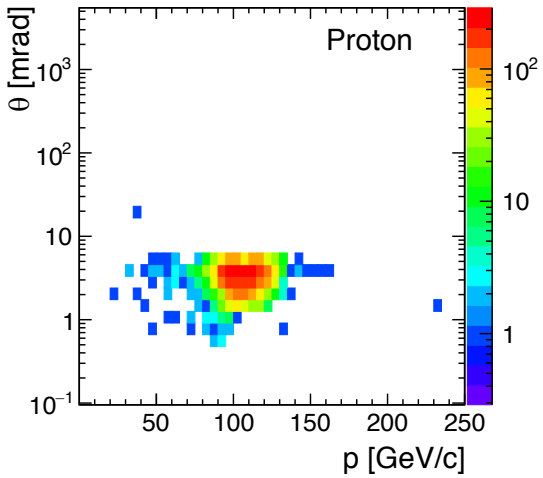


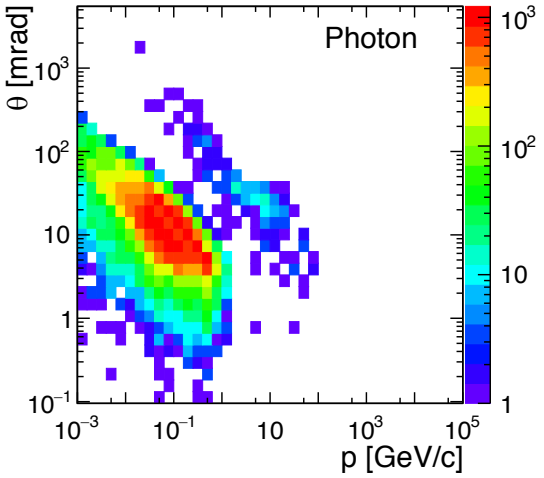
- The red diamonds in each plot represent the minima in the coherent cross section they are based on the ratio of incoherent to coherent in the corresponding Q^2 bin using the model implemented in *Sartre (without smearing)*.
- The vetoing power in different Q^2 bins is almost identical, for all bins, after veto.7 one just reaches the first minima.

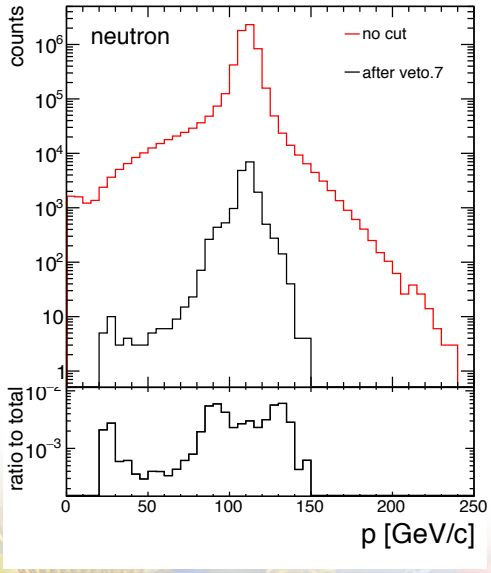
T. Ullrich provided the incoherent and coherent cross section in three different Q^2 bins using the model implemented in *Sartre*.

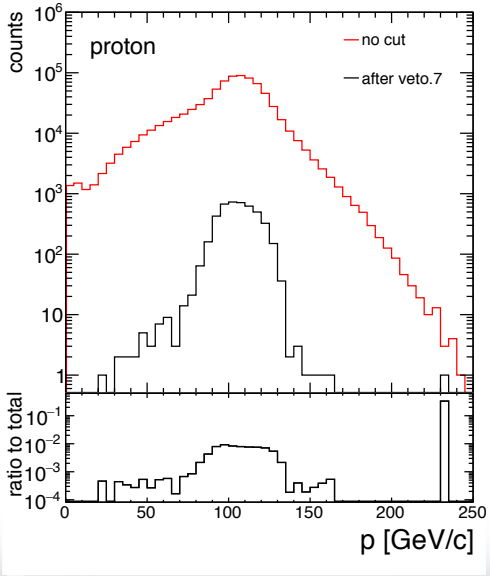
Protons, neutrons and photons distribution in survived events

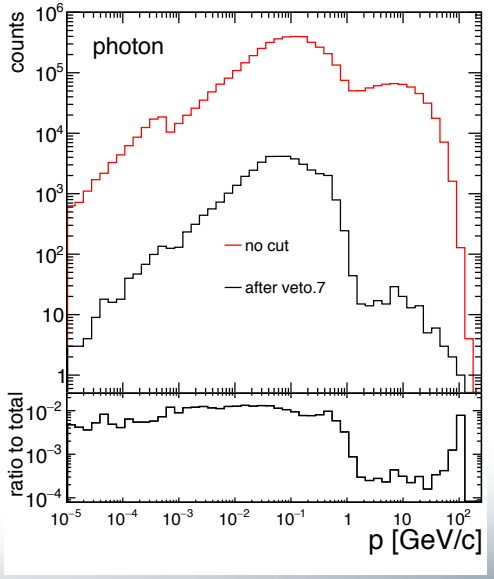






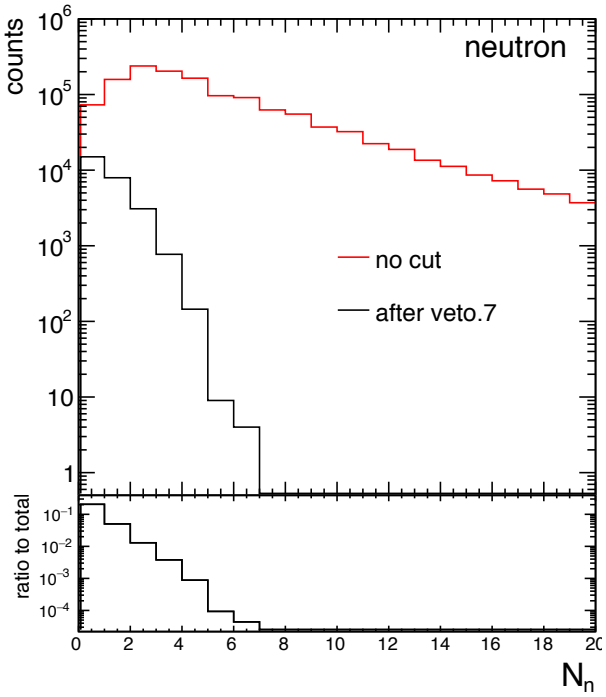


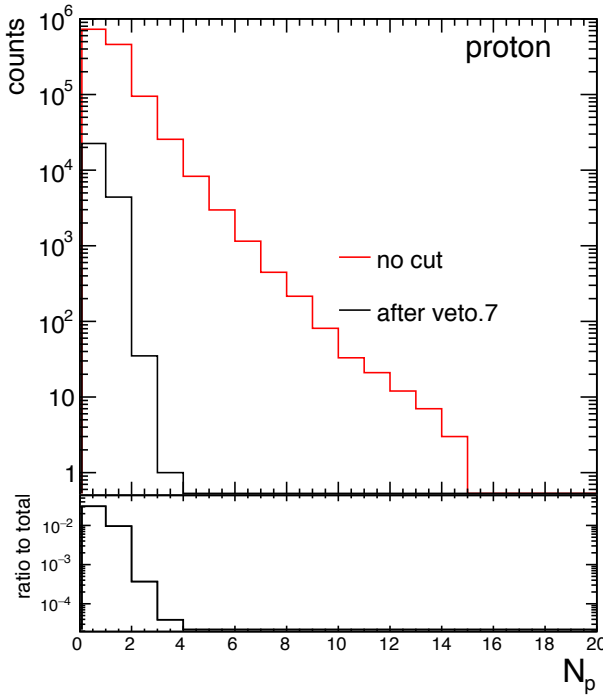


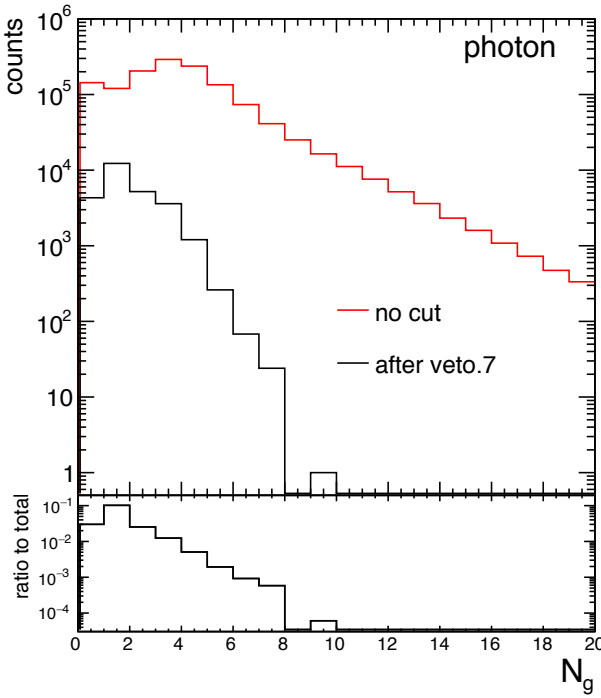


The vetoing efficiency for particles is >99%.

Protons, neutrons and photons multiplicity distribution



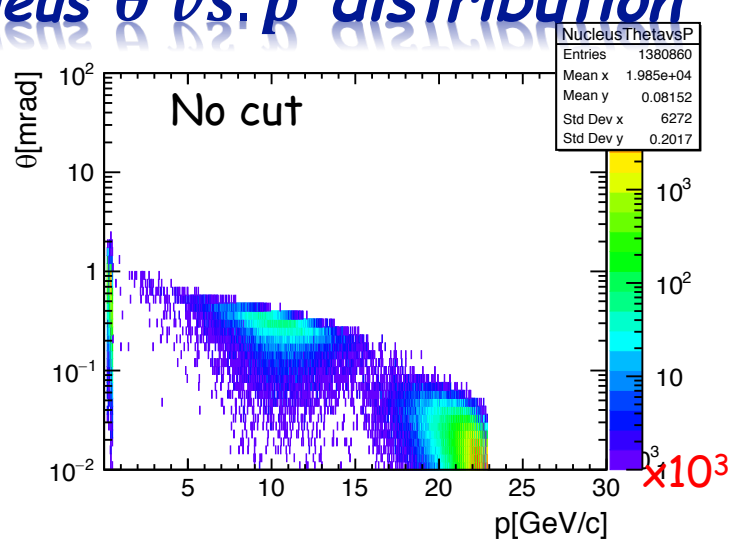


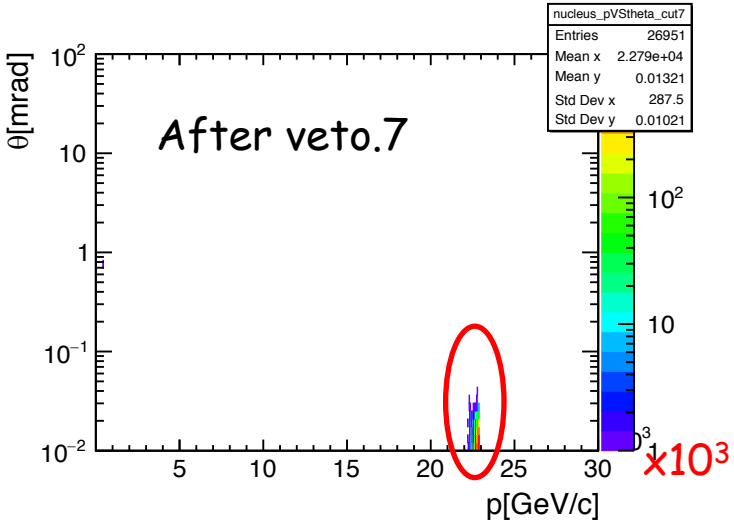


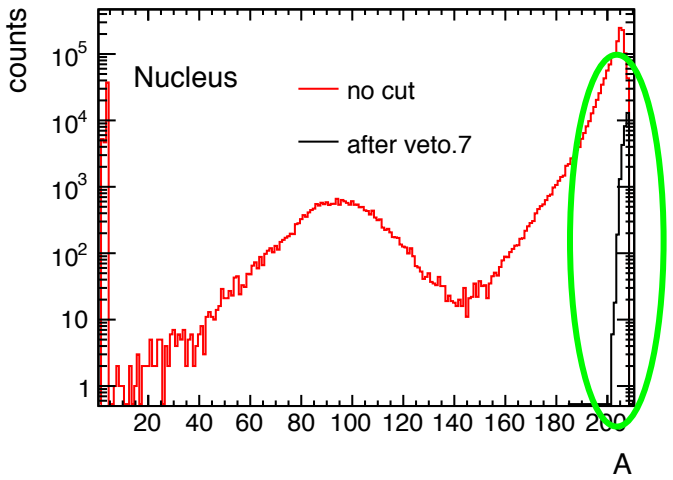
Multiplicity for non-vetoed events are peaked at lower multiplicity.

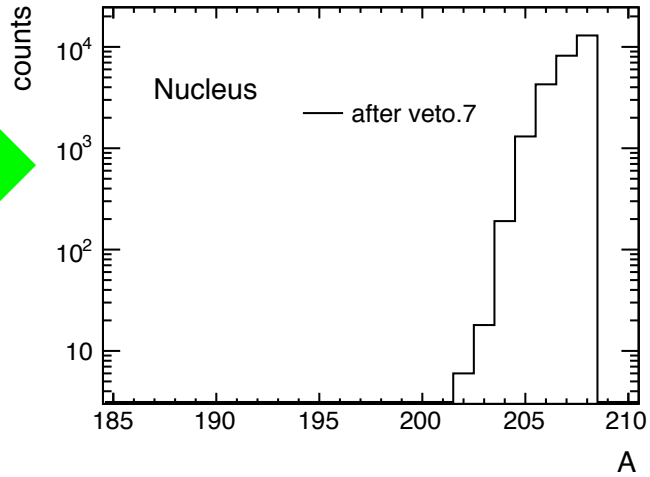
Events with more particles, the easier to veto.

Nucleus θ vs. p distribution









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

Summary

- coherent vector meson production $e + A \rightarrow e' + V + A$ is 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

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Thank you!