Investigations of coherent J/ψ production background at the EIC

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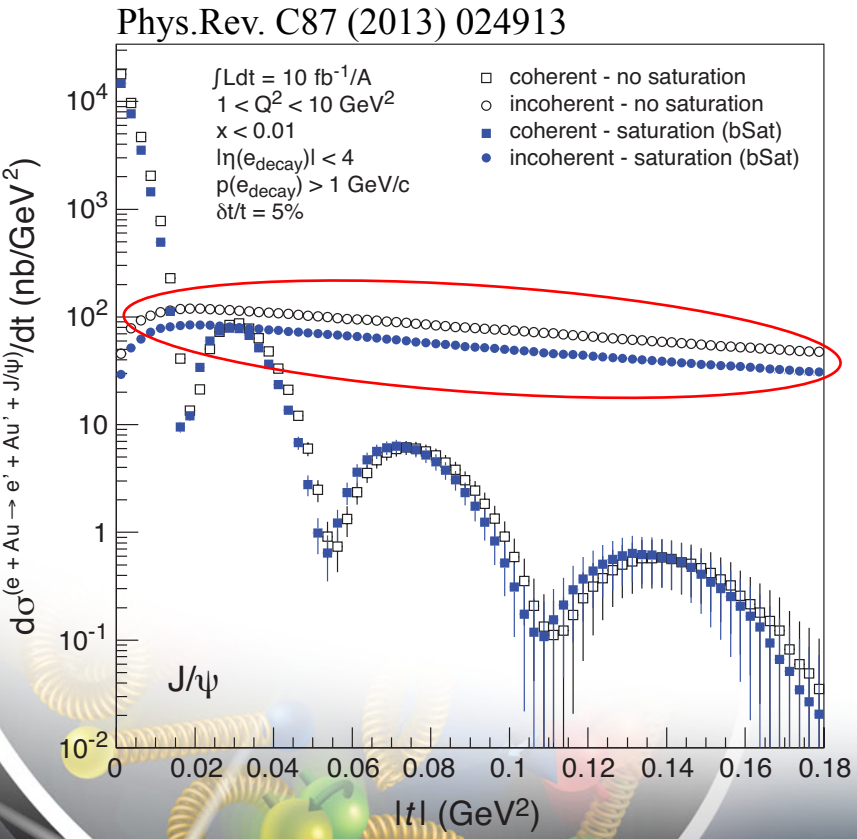
Incoherent diffractive events vetoing

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

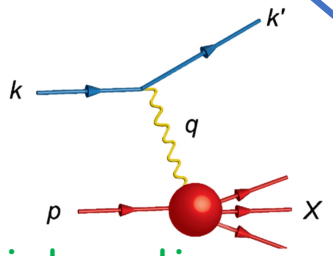


- The goal is to remove all the incoherent diffractive events
- Veto on forward neutrons, protons and photons.

Events	ratio
Only neutron(s)	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

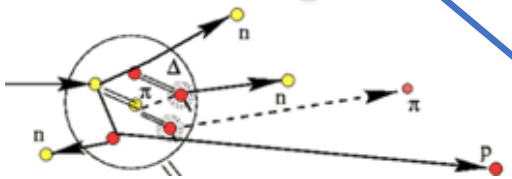
We are using BeAGLE (**B**enchmark **eA** **G**enerator for **LE**ptoproduction) package for the event simulation.



Primary interaction

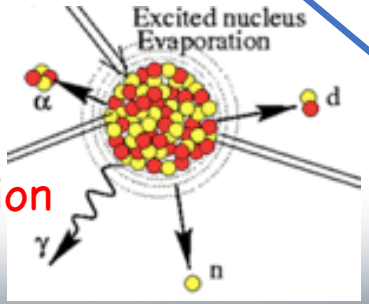
Primary interaction treated by **PYTHIA** hard collision.

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:

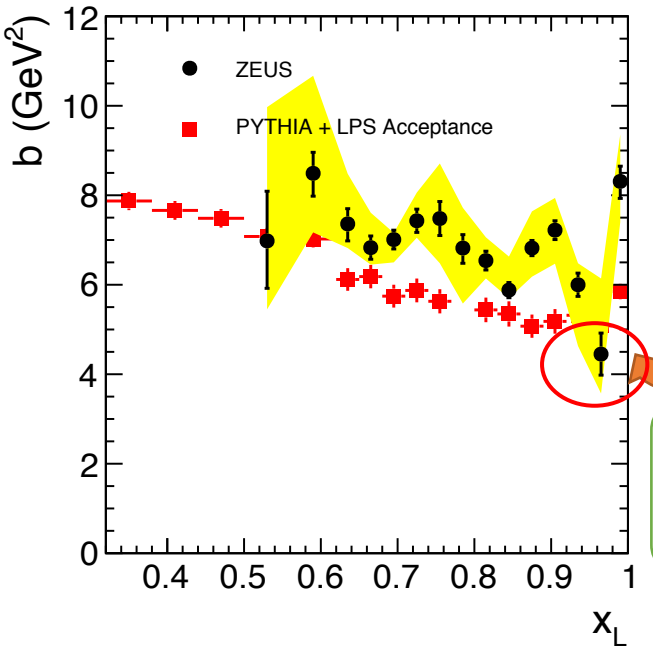
$x_L > 0.32$

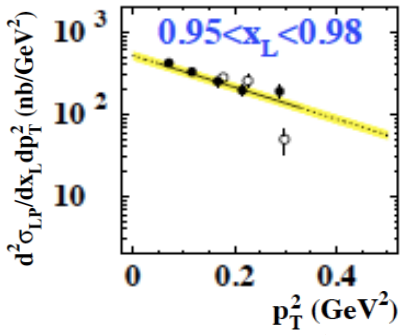
$p_T^2 < 0.5\ \mathrm{GeV}^2$

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

$45 < W < 225\ GeV$

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

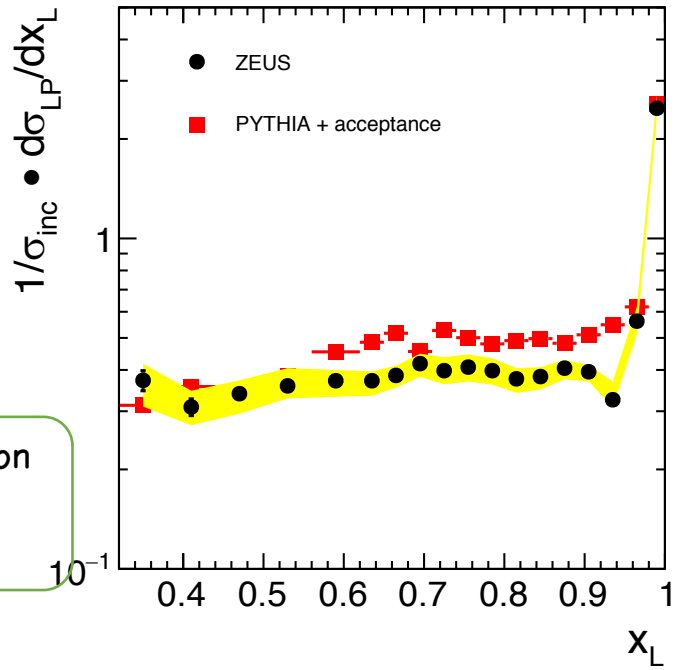




x_L is the momentum fraction carried by the outgoing leading proton.

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 ?

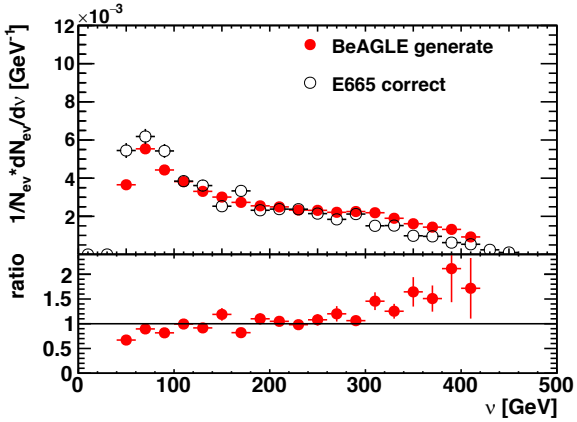
Z. Phys. C 61, 179-198(1994)

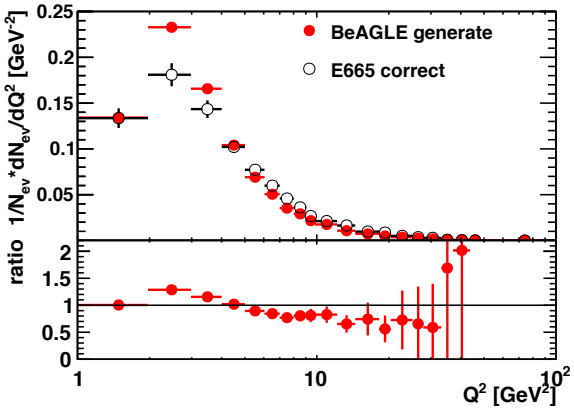
Data sample:

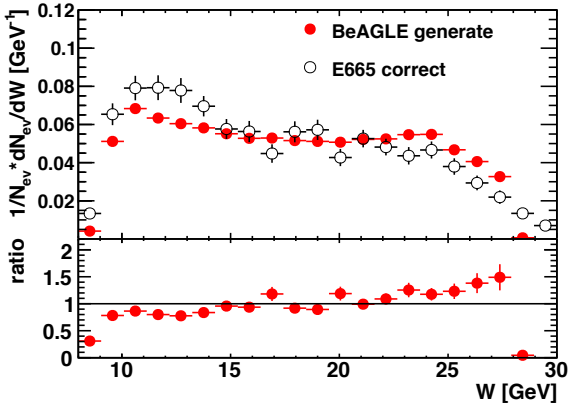
μ^++Xe
Beam momentum:
490 GeV × 0GeV

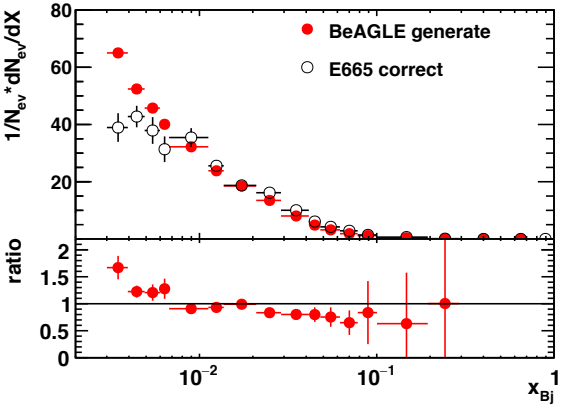
$0.1 < y < 0.85$
$1.0 < Q^2 < 100$
$0.0035 \text{ rad} < \theta < 6.29 \text{ rad}$
8<W<30 GeV
X>0.002

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





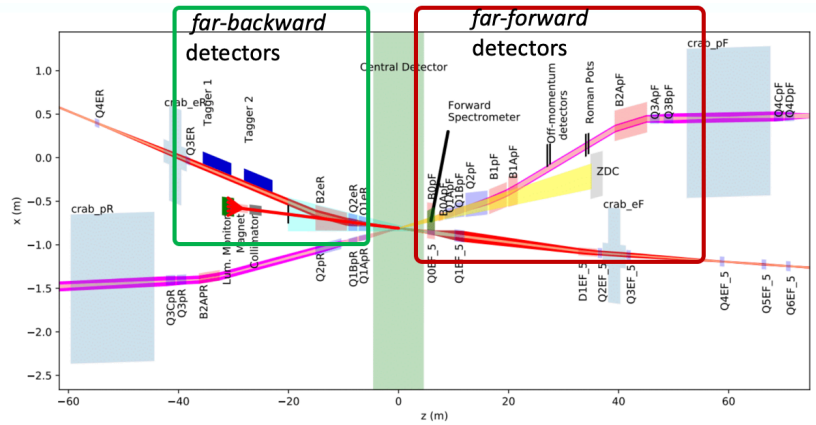




The comparison shows that BeAGLE does reasonably describes lepton-nucleus interactions at the Electron-Ion collider.

IR Layout and Acceptances

Outgoing Hadron Beam

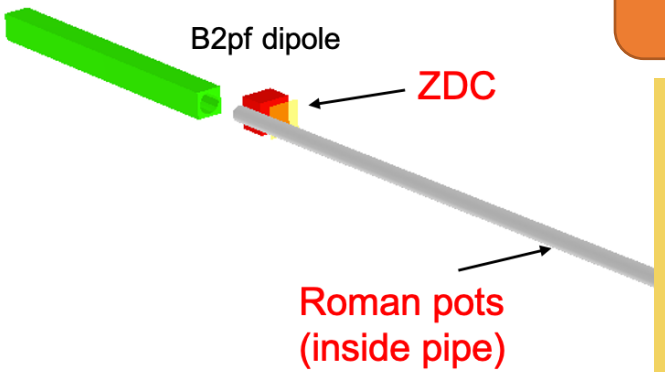


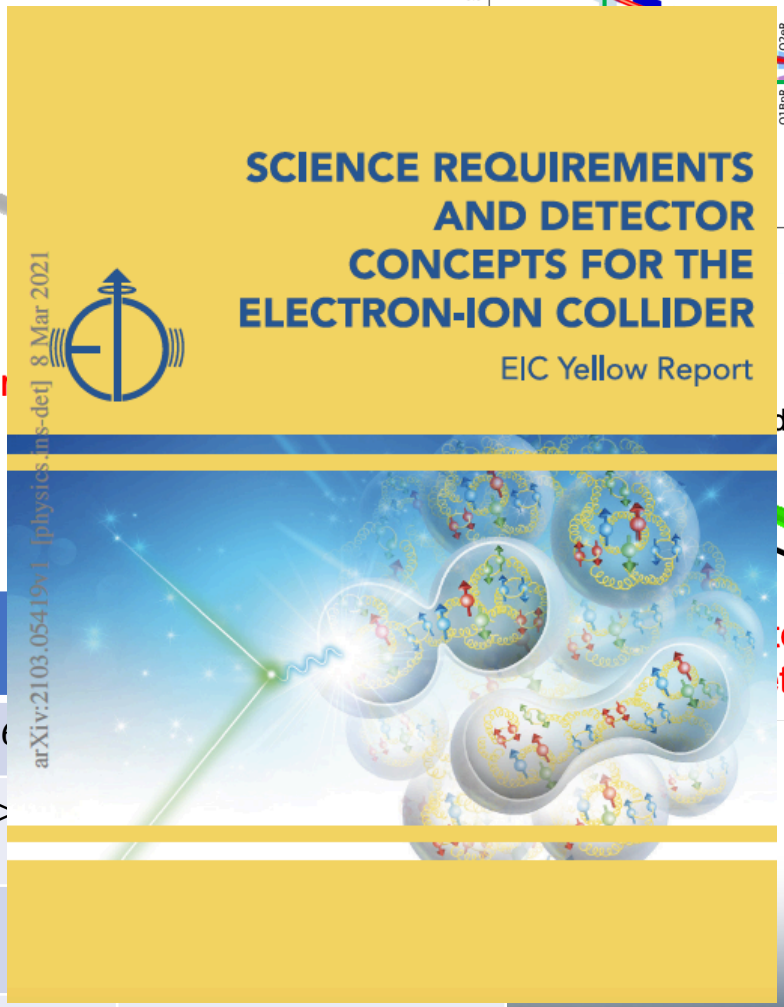
Detector	Angular accept. [mrad]	p_T coverage
ZDC @ ~30m	θ<5.5 ($\eta > 6$)	p_T<1.3 GeV
Roman Pots	0*<θ<5.0 ($\eta > 6$)	*Low p_T cutoff (beam optics)
Off-Momentum Detectors	0.0< θ < 5.0 ($\eta > 6$)	Low-rigidity particles from nuclear breakups
B0 forward spectrometer	5.5 < θ < 20.0 (4.6< η < 5.9)	High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

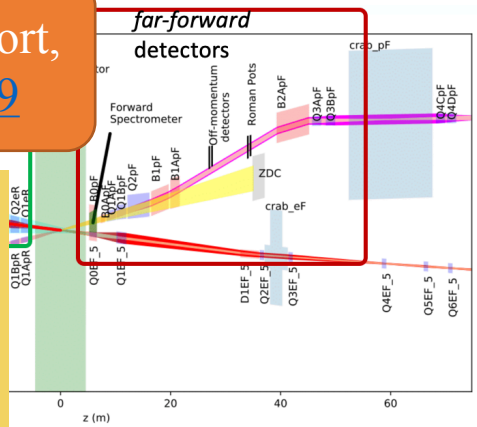
IR Layout and Acceptances

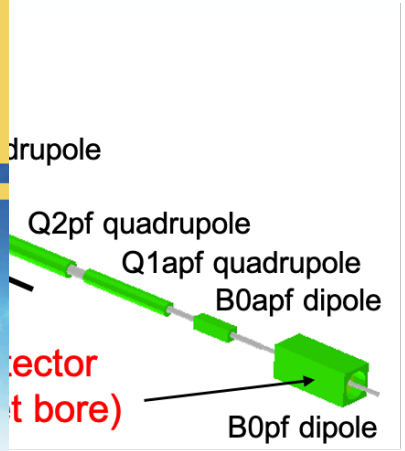
Outgoing Hadron

Details are published in the Yellow Report, arXiv https://arxiv.org/abs/2103.05419









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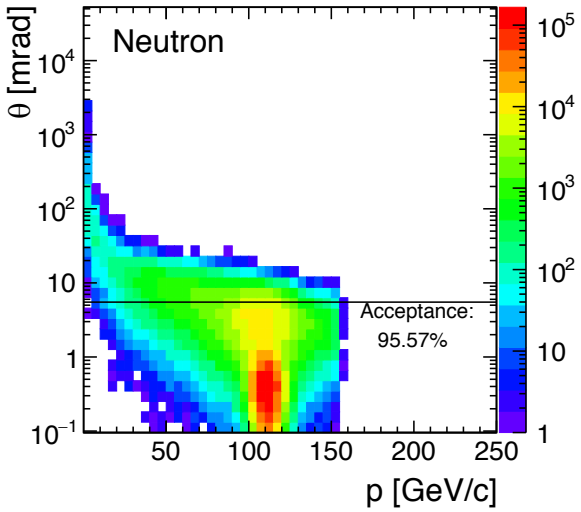
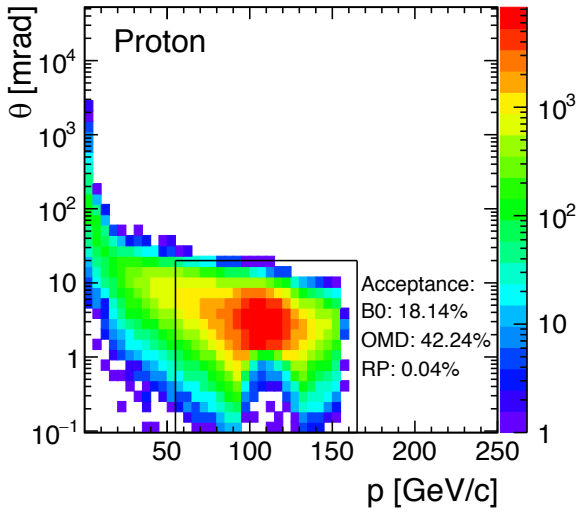
Roman Pots	0*<θ<5.0 ($\eta >$	
Off-Momentum Detectors	0.0< θ < 5.0 (η	
B0 forward spectrometer	$5.5 < \theta < 20.0$ ($4.6 < \eta < 5.9$)	High p_T

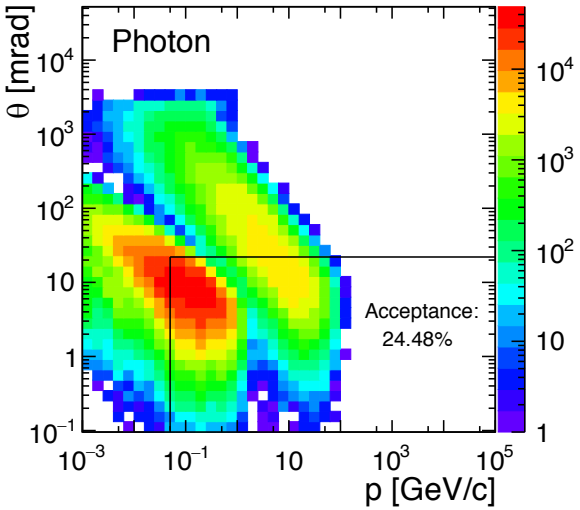
Protons, neutrons and photons θ vs. p distribution

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





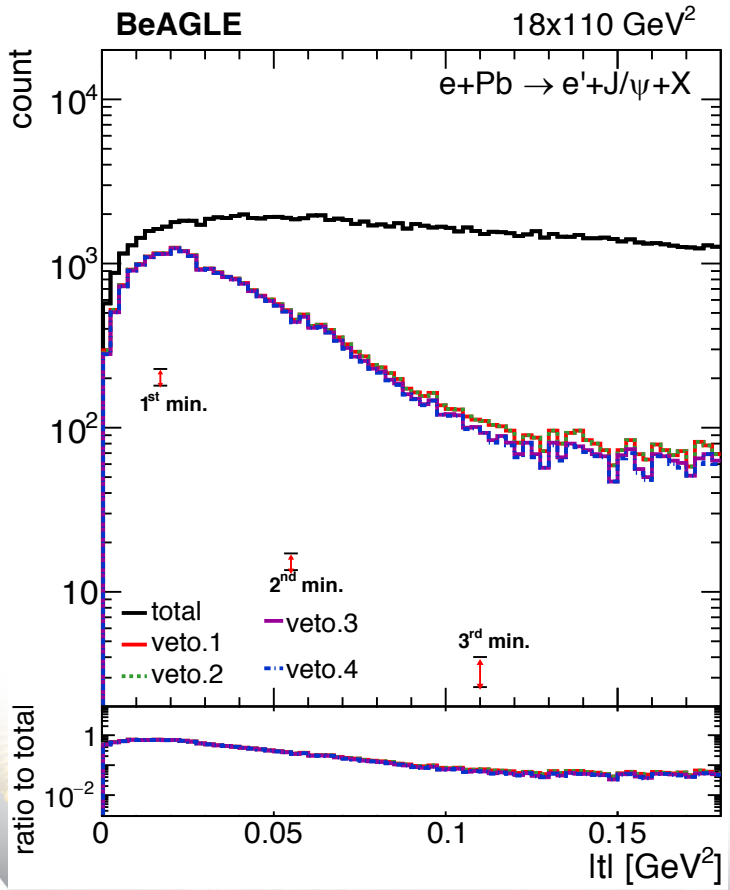


- Neutrons have a good acceptance with close to 95%.
- Protons acceptance is generally very good except at very large scattering angle and at very low momentum.
- Only 24% photons are within the ZDC angular acceptance. Most of the photons are currently outside of the ZDC → Integrate photon detection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

→ Beam pipe design/material is critical



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

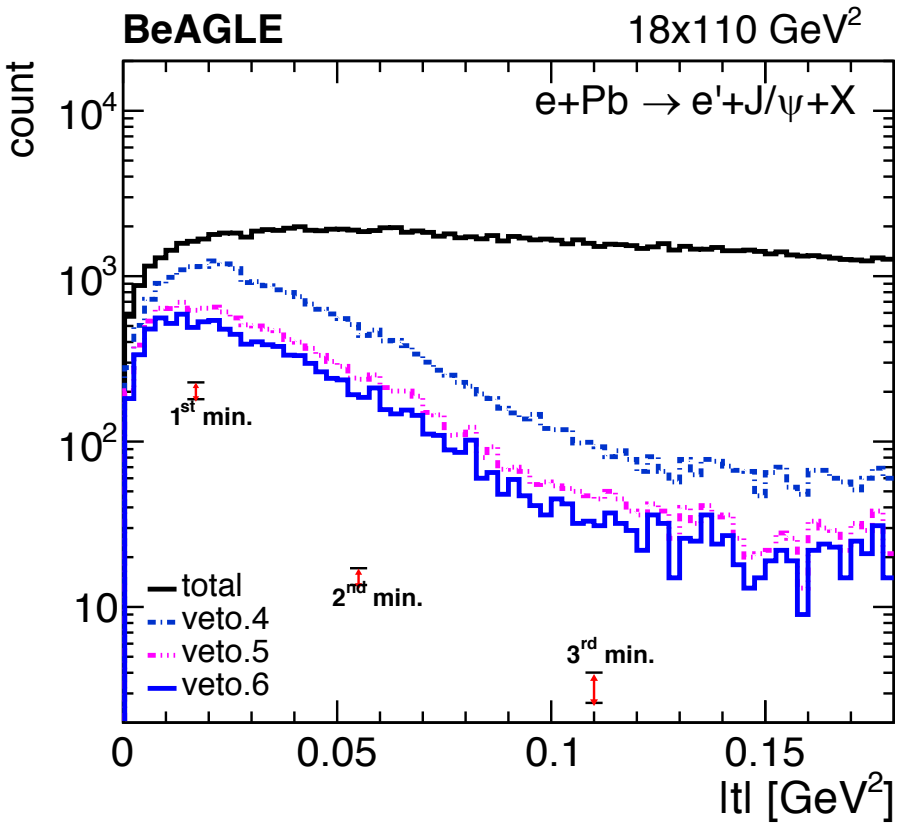
Veto.3:
- Veto2 + no proton in off-momentum detector

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%

Phys.Rev. C87 (2013) 024913

Vetoing Incoherent Events: Photons



Veto.5:

- Veto4 + no anything in preshower

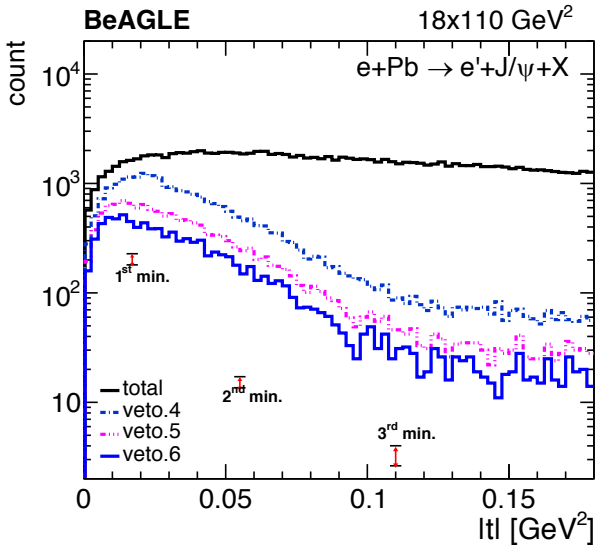
Veto.6:

- 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%

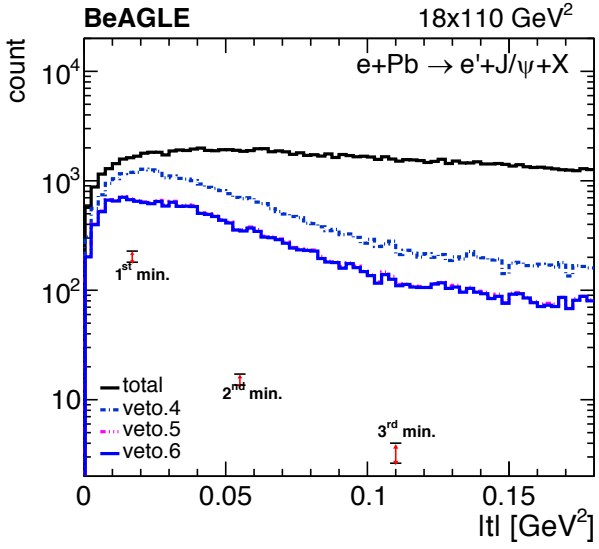
Vetoing Incoherent Events

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%

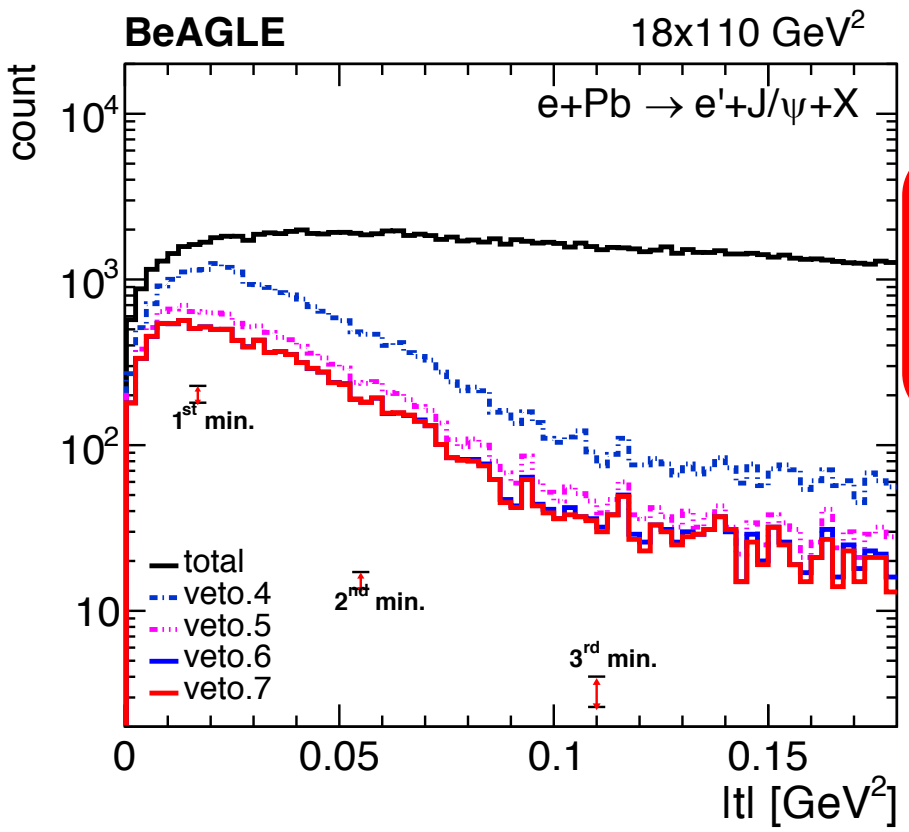
Beam pipe material:
- beamPipeQuads: **aluminum**
- beamPipeB0: **aluminum**
- beamPipeRP: **stainless steel**
- beamPipeZDC: **stainless steel**



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 ($|\eta| < 4.0$ & $p_T > 100\ \mathrm{MeV/c}$ & $E > 50\ \mathrm{MeV}$) other than e- and J/ψ in the main detector (generator level)

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.

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
    - 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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