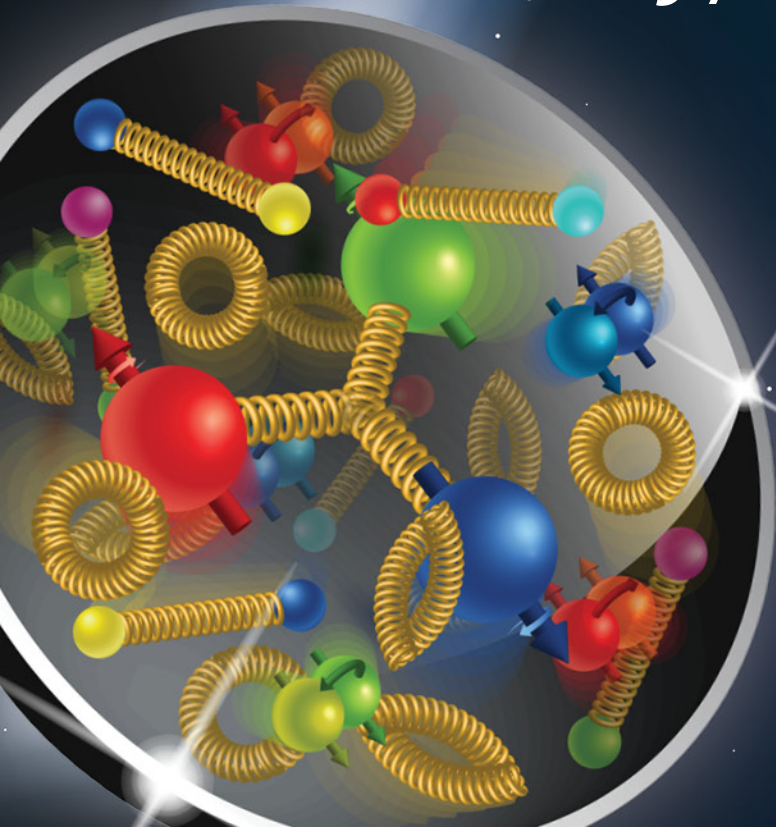# Investigations of coherent J/ψ production background at the EIC

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BNL & CCNU

Virtual Quarkonia As Tools 2021

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

Phys.Rev. C87 (2013) 024913
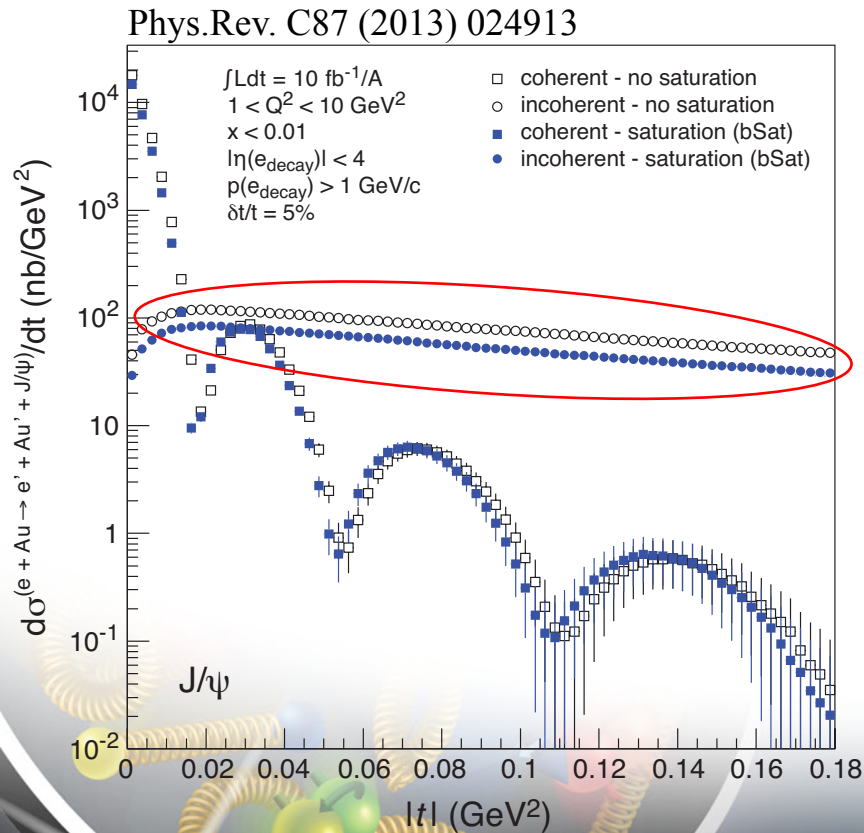

- The goal is to remove all the incoherent diffractive events
- Veto on forward neutrons, protons and photons.

| 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%

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BeAGLE simulation framework

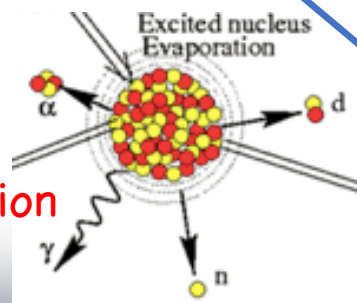We are using BeAGLE (**B**enchmark **eA G**enerator for **LE**ptoproduction) package for the event simulation.
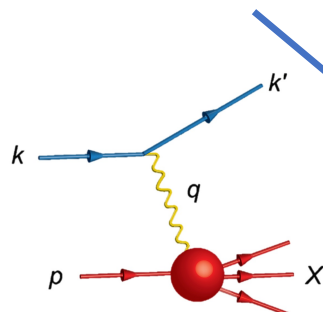
Primary interaction

Primary interaction treated by **PYTHIA** hard collision.
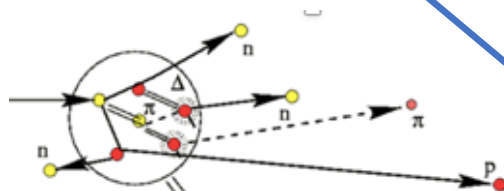
Intra-nuclear cascade

Cascade process handled by **DPMJET**.

Nuclear remnant evaporation

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

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PYTHIA tune for ZEUS e+p

$e^+ p \rightarrow e^+ X p$ (27.5 GeV x 820 GeV)
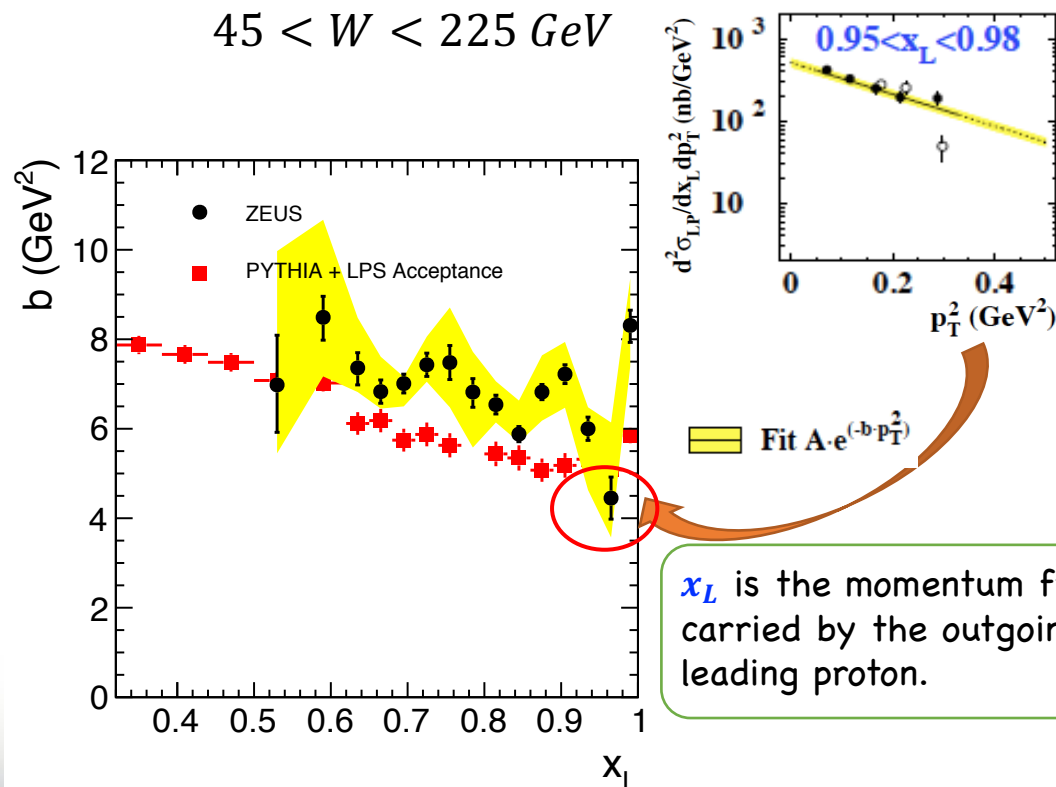
Cuts on Event level:

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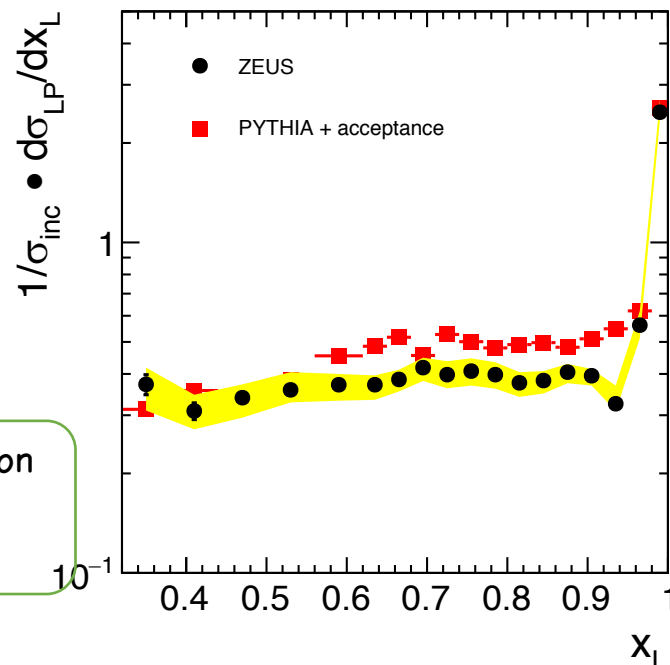$45 < W < 225 \; GeV$

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

JHEP 0906:074,2009

The leading proton production rate:

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

Fit $A \cdot e^{(-b \cdot p_T^2)}$

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 ?

Data sample:

$\mu^+ + Xe$
Beam momentum:
490 GeV × 0GeV

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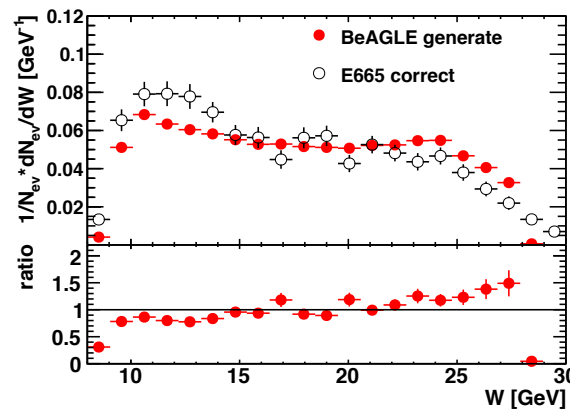$0.0035 \text{ rad} < \theta < 6.29 \text{ rad}$
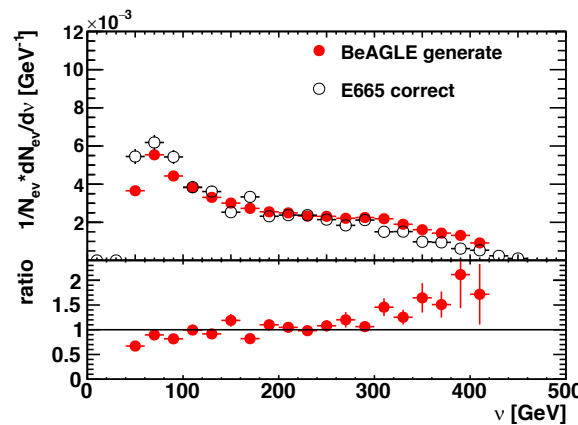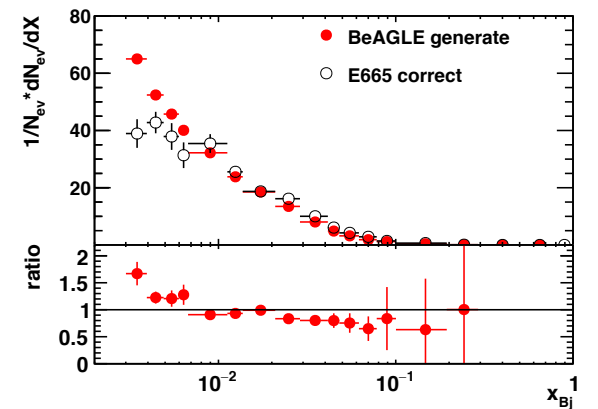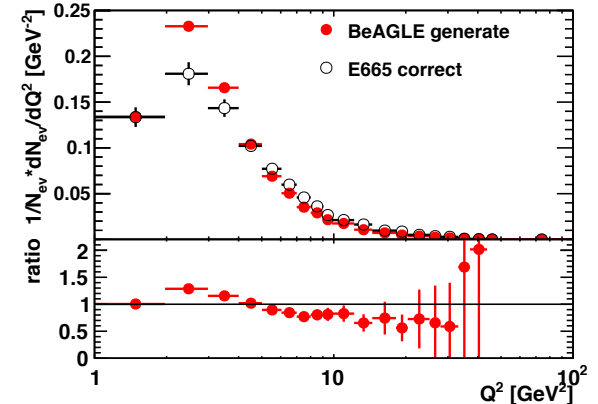$8 < W < 30 \text{ GeV}$
$X > 0.002$

These plots are for inclusive variables only, so they do not verify the nuclear cascade part.
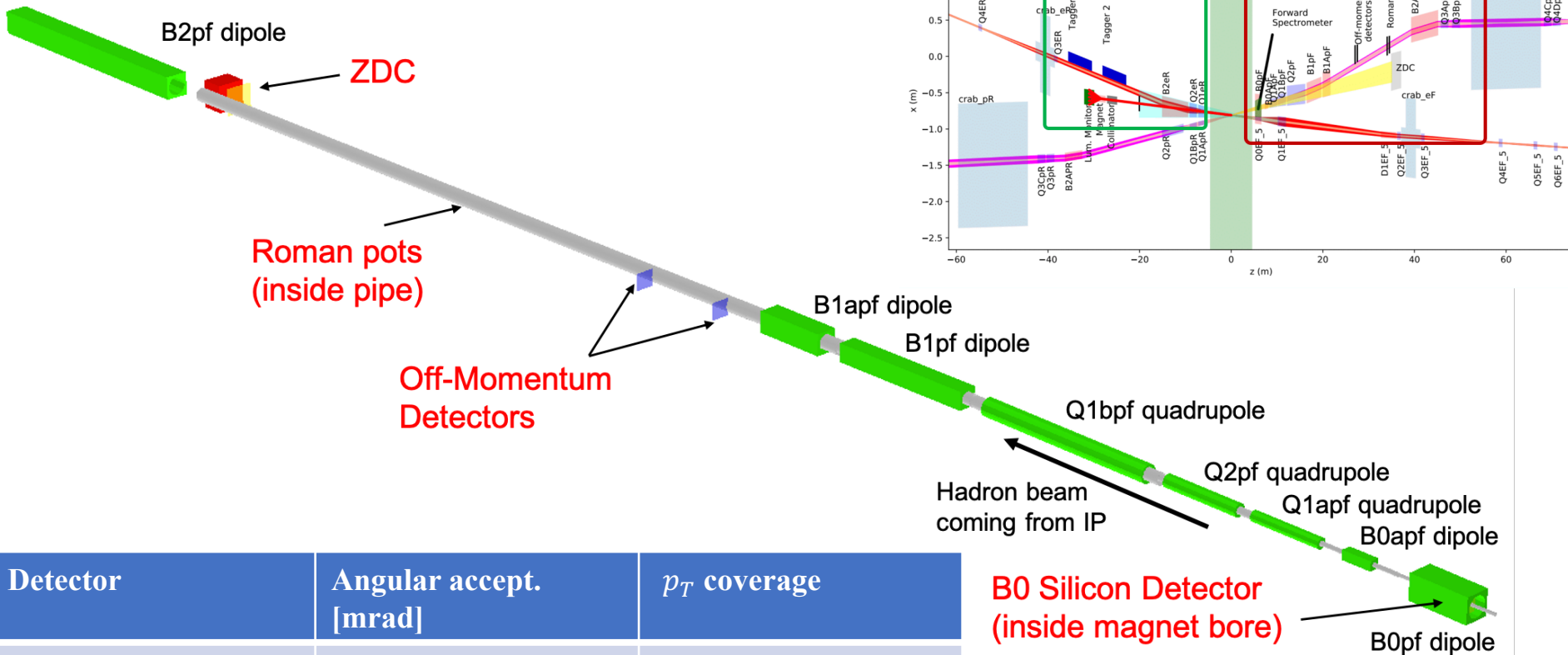
Z. Phys. C 61, 179-198(1994)

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

IR Layout and Acceptances

Outgoing Hadron Beam

B2pf dipole

ZDC

Roman pots (inside pipe)

Off-Momentum Detectors

B1apf dipole

B1pf dipole

Q1bpf quadrupole

Hadron beam coming from IP

Q2pf quadrupole

Q1apf quadrupole

B0apf dipole

B0 Silicon Detector (inside magnet bore)

B0pf dipole

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

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IR Layout and Acceptances

Outgoing Hadron

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

B2pf dipole

ZDC

Roman pots
(inside pipe)

Off-Momentum
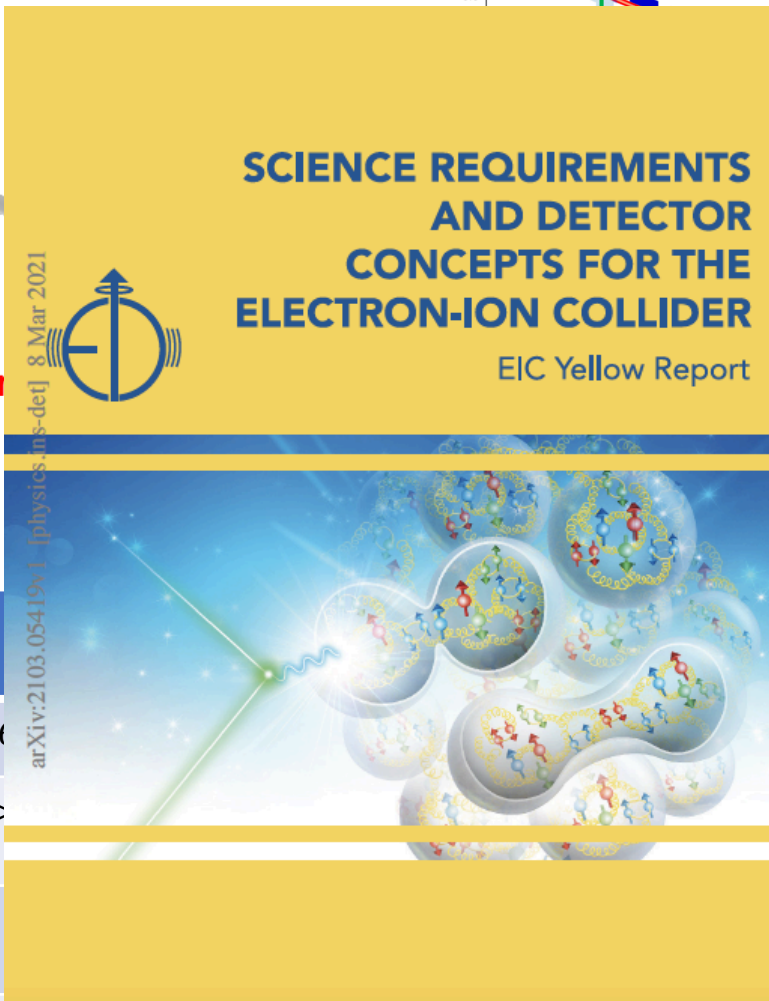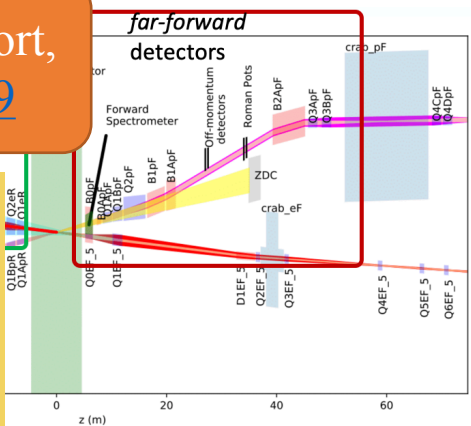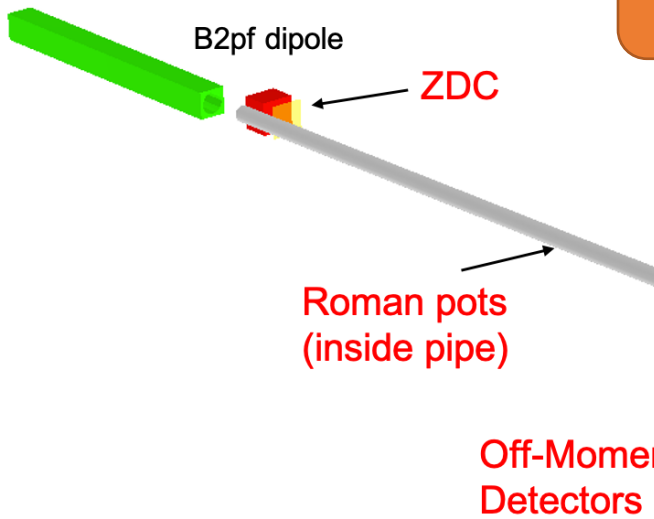Detectors

far-forward detectors

Forward Spectrometer

Off-momentum detectors

Roman Pots

ZDC

crab_pF

crab_eF

z (m)

SCIENCE REQUIREMENTS
AND DETECTOR
CONCEPTS FOR THE
ELECTRON-ION COLLIDER

EIC Yellow Report

arXiv:2103.05419v1 [physics.ins-det] 8 Mar 2021

Q2pf quadrupole
Q1apf quadrupole
B0apf dipole

B0pf dipole

Detector	Angular accept. [mrad]	
ZDC @ ~30m	$\theta < 5.5$ ($\eta >$	
Roman Pots	$0^* < \theta < 5.0$ ($\eta >$	
Off-Momentum Detectors	$0.0 < \theta < 5.0$ (η	
B0 forward spectrometer	$5.5 < \theta < 20.0$ ($4.6 < \eta < 5.9$)	High p_T

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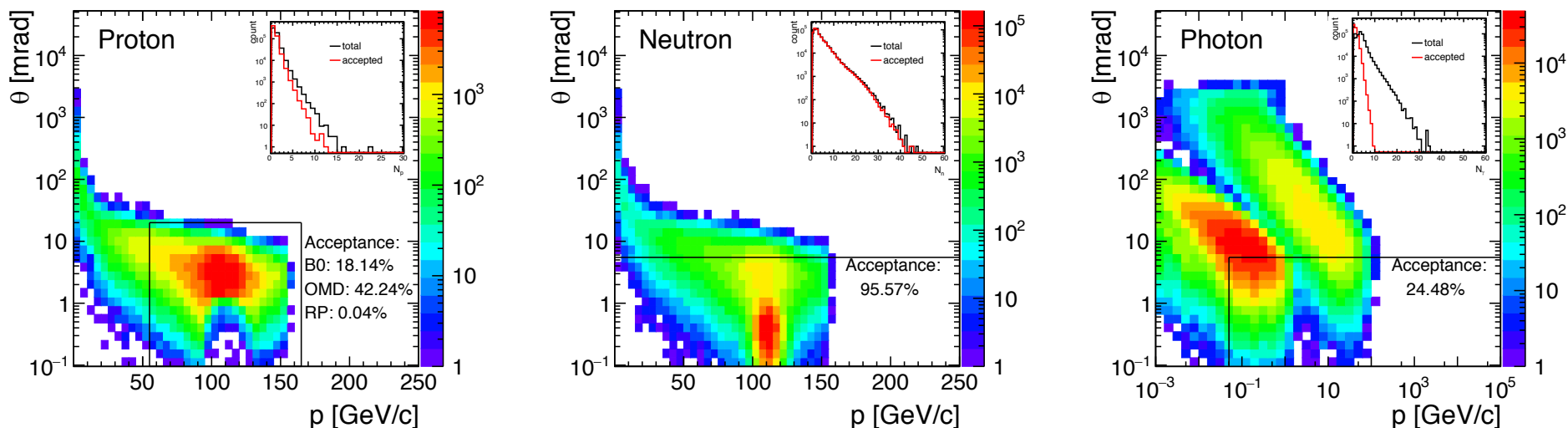
➤ Neutrons have a good acceptance with close to 95%.
➤ Protons acceptance is generally very good except at very large scattering angle and at very low momentum.
➤ Only 24% photons are within the ZDC angular acceptance. Most of the photons are currently outside of the ZDC → Integrate photon detection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

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
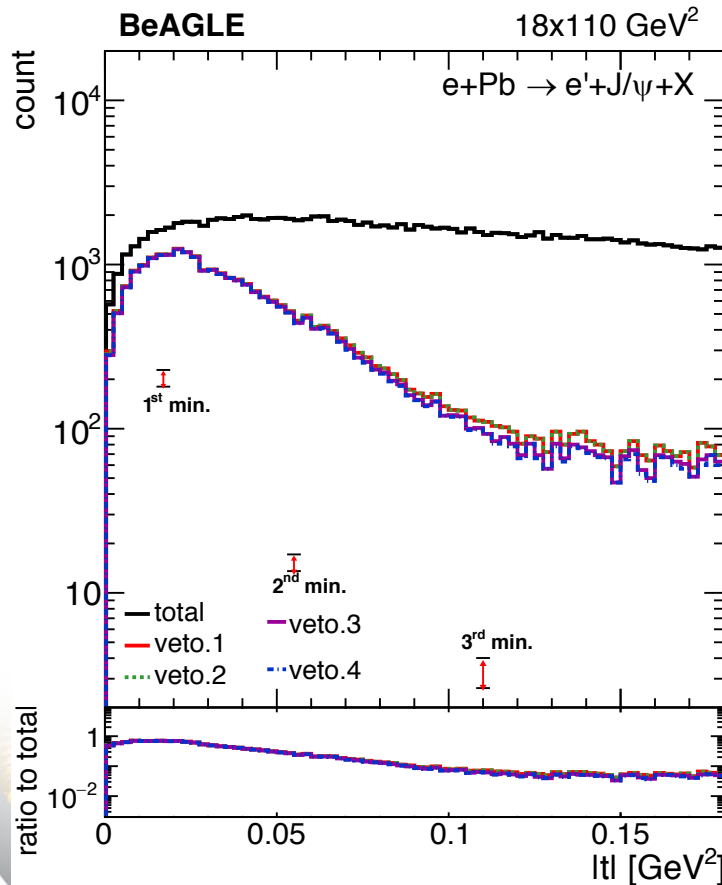
Beam pipe material:

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

BeAGLE 18x110 GeV^2

$e+Pb \rightarrow e'+J/\psi+X$

count

1st min.

2nd min.

3rd min.

total veto.3
veto.1 veto.4
veto.2

ratio to total

|t| [GeV^2]

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Vetoing Incoherent Events: Photons
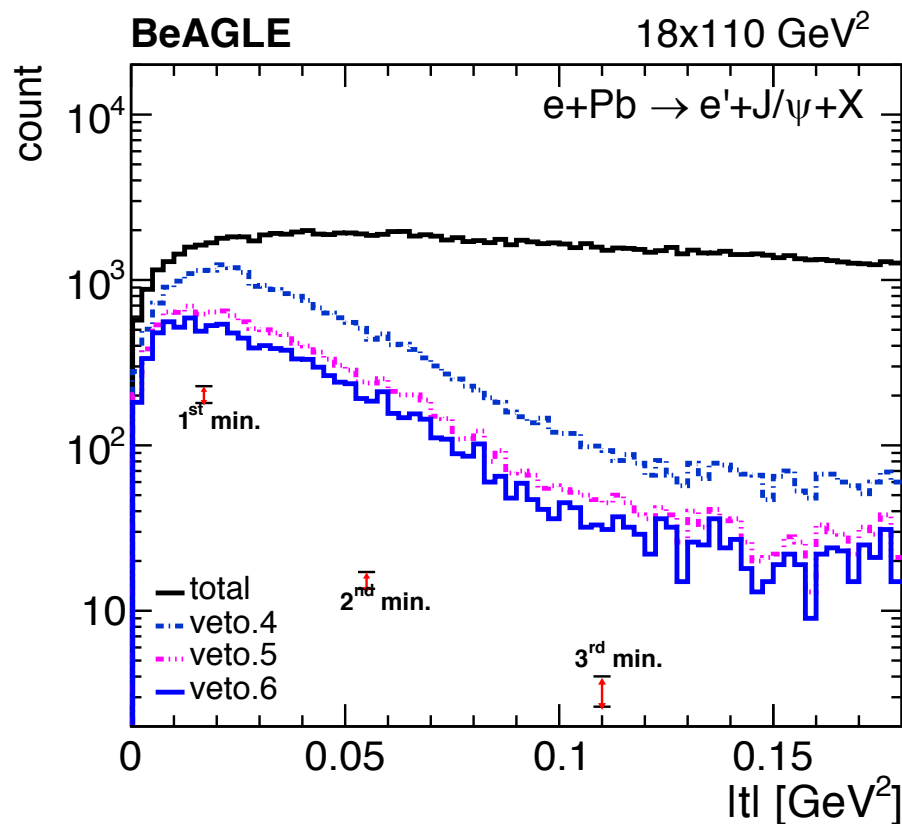
Veto.5:
- ➢ Veto4 + no anything in preshower

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%

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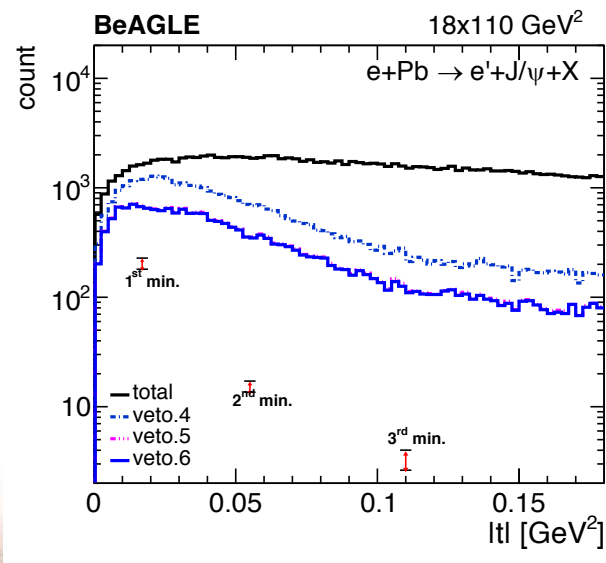
Vetoing Incoherent Events

Beam pipe material:
- beamPipeQuads: **aluminum**
- beamPipeB0: **aluminum**
- beamPipeRP: **beryllium**
- beamPipeZDC: **beryllium**
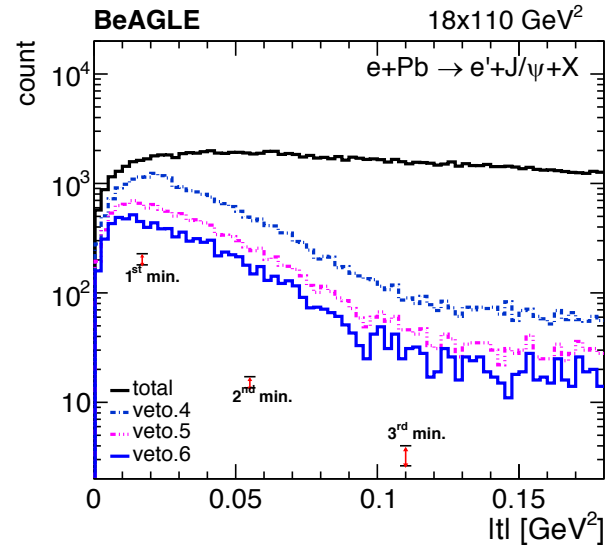
Survived event count	
Total events	100%
Cut1	16.7%
Cut2	16.7%
Cut3	16.18%
Cut4	15.66%
Cut5	7.3%
Cut6	4.96%

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

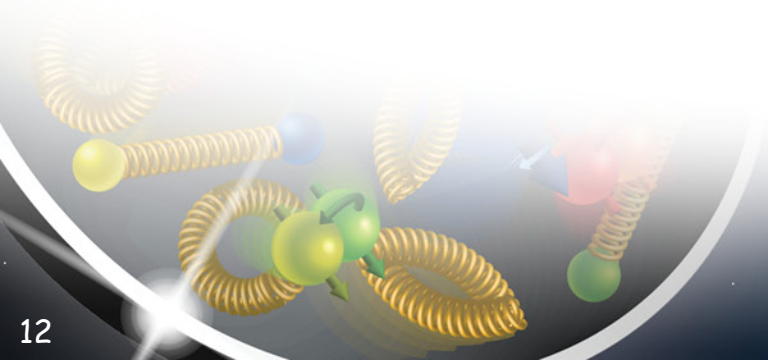| Survived event count	
Total events	100%
Cut1	25.7%
Cut2	25.7%
Cut3	24.77%
Cut4	23.97%
Cut5	11.31%
Cut6	11.09%

Beam pipe material is critical to have good vetoing power

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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
- ❑ Next steps
  - ➢ integrate central detector in vetoing
  - ➢ investigate other possible avenues to increasing the vetoing power
    - • tagging of heavier fragments

Summary

❑ **coherent** vector meson production $e + A \rightarrow e' + V + A$ very challenging measurement

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❑ 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
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❑ Next steps

  ➢ integrate central detector in vetoing
  ➢ investigate other possible avenues to increasing the vetoing power
    • tagging of heavier fragments

Thank you!