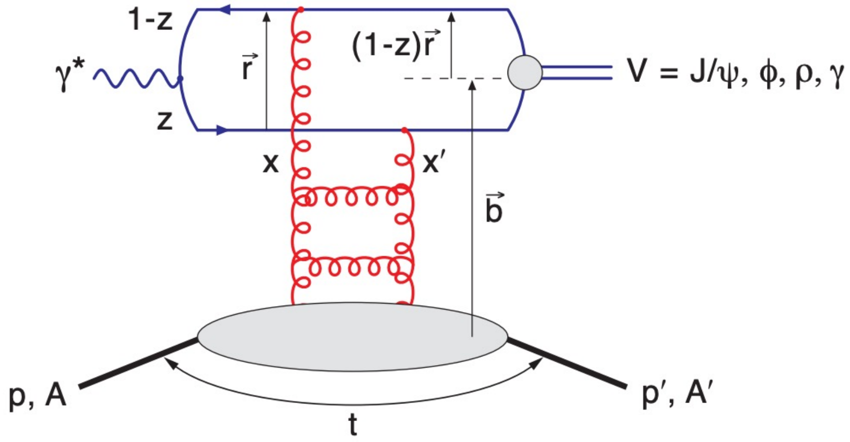
Diffractive Vector Meson production at the Electron-Ion Collider

Introduction:

Measure the process of eA → e'+V+A'



Physics goals:

Gluon spatial distribution, saturation dynamics, etc.

Kong Tu

BNL

06.27.2022

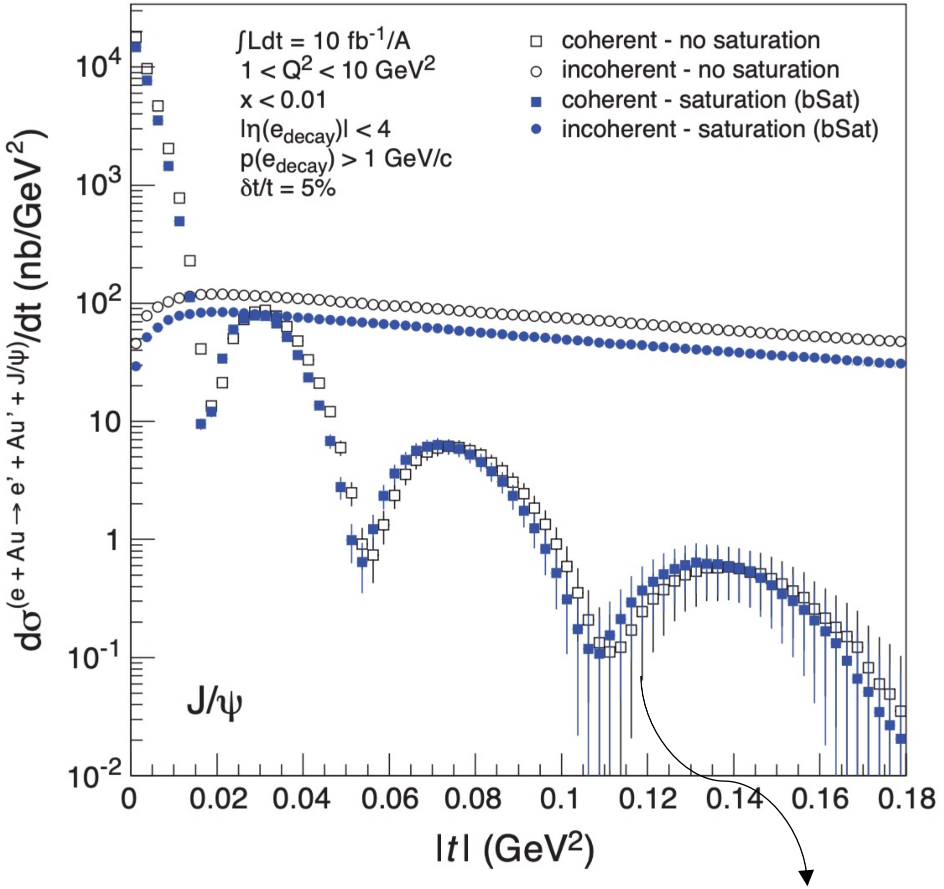
Disclaimer: this is the ATHENA approach and has been presented before

Challenges and Opportunities

Two major challenges:

1. Incoherent background dominates most of the $-t$ *regime. How to veto/suppress this background?*
2. Excellent momentum resolution to resolve the structure of the coherent diffractive peaks/dips.

(EIC White Paper)



Assumed Woods-Saxon distribution.

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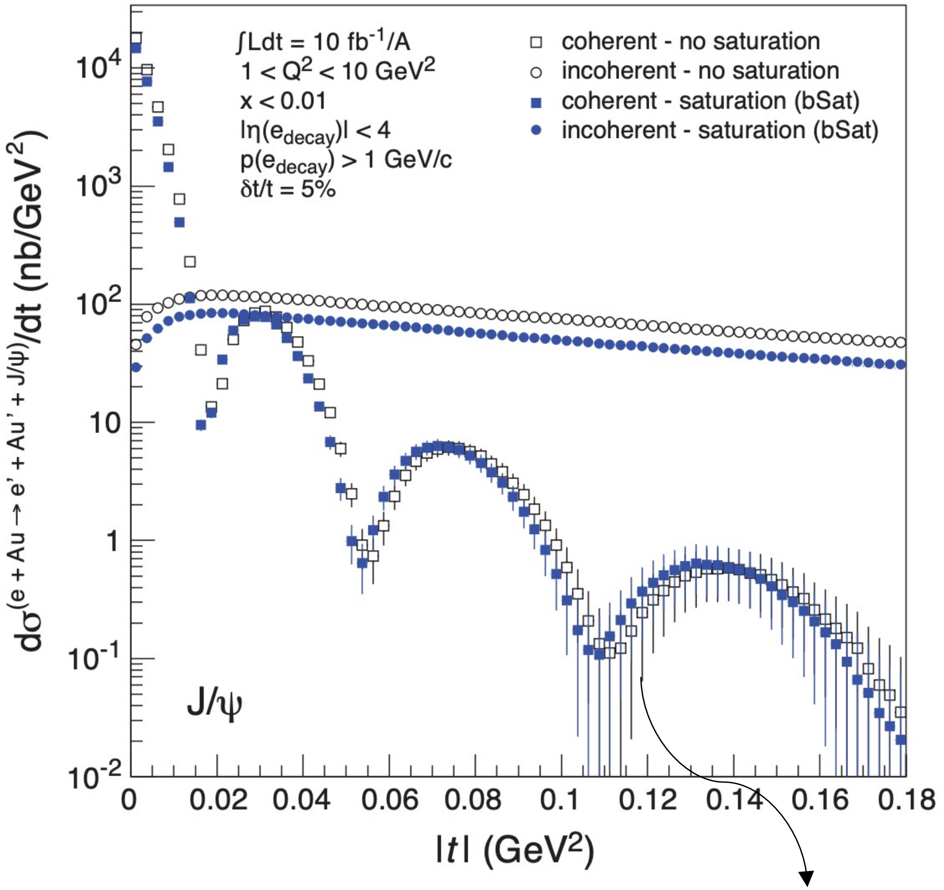
Electron-Ion Collider: a high-energy high-luminosity electron-nucleus collider.

Advantages:

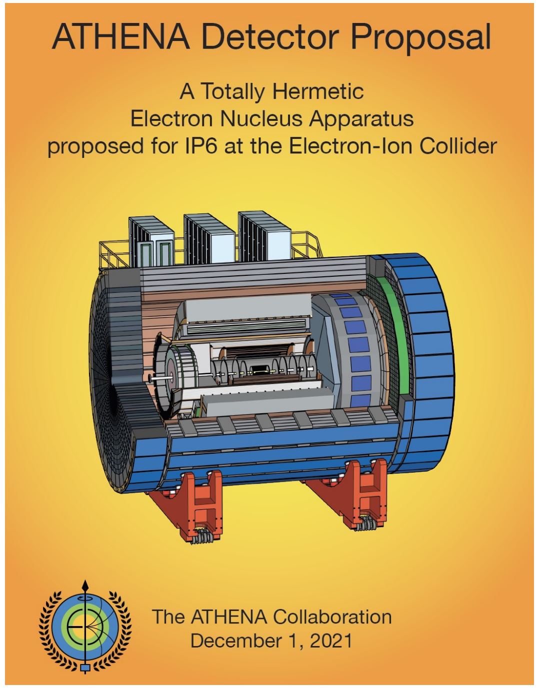
- Excellent detectors (tracking, calorimetry, etc.)
- Forward detectors to suppress incoherent backgrounds.
- Wide range of Q^2 instead of only photoproductions

(EIC White Paper)



Assumed Woods-Saxon distribution.

ATHENA proposal



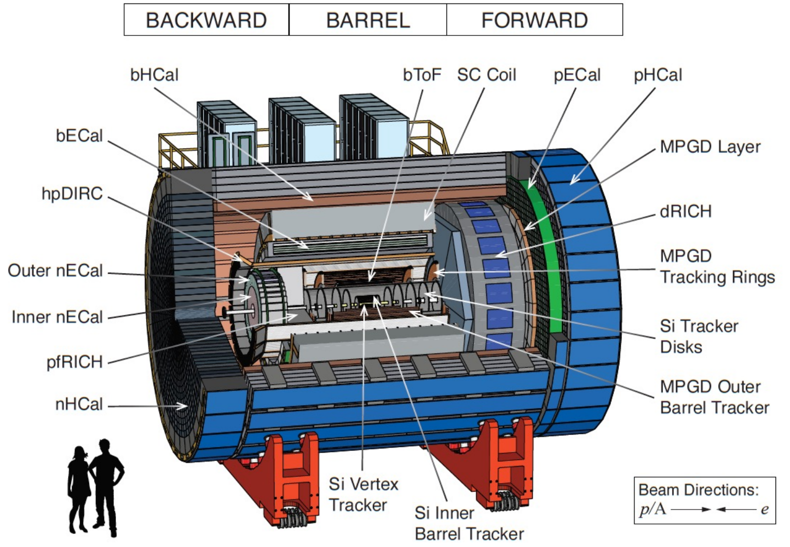
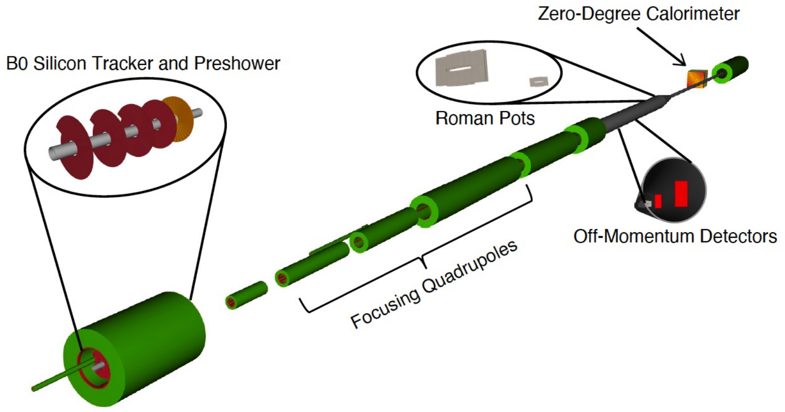


Figure 1.1: Crosscut view of the ATHENA central detector. The detector acronyms are defined in the text and are summarised in the Glossary.

Far-Forward region (A-going direction)



(See A. Jentsch's talk for details, **5/4/22, 11:50 AM, WG6)**

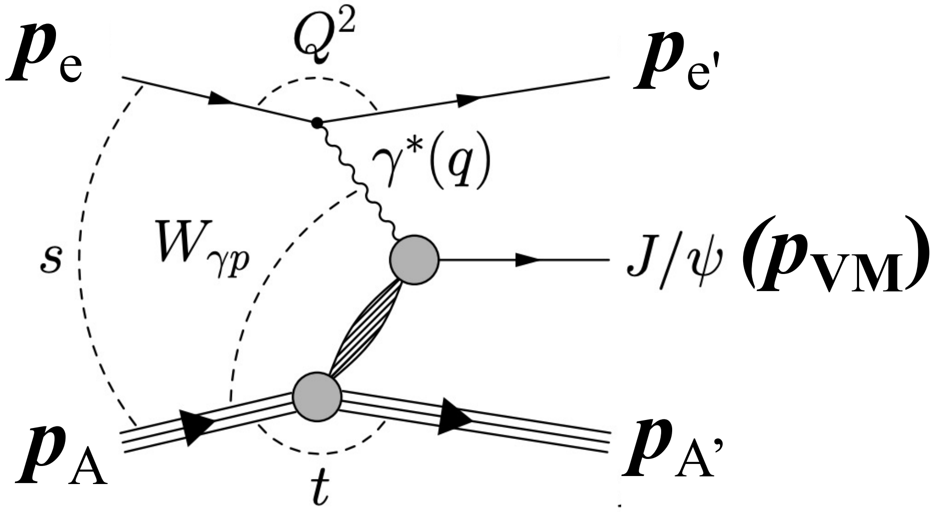
Highlights:

1. 3T magnetic field for tracking, great momentum resolution for VM decays.
2. nECal with excellent energy resolution for low Q^2 scattered electron.
3. Wide coverage of far-forward detectors for incoherent background suppression.

Reconstruction method of *-t*

- Method Exact (E): $-t = -(\boldsymbol{p}_{e} - \boldsymbol{p}_{e'} - \boldsymbol{p}_{VM})^2 = -(\boldsymbol{p}_{A'} - \boldsymbol{p}_{A})^2$
- Method Approximate (A) (UPCs) $-t = (\vec{p}_{T,e'} + \vec{p}_{T,VM})^2$
- Improved Method E: Method L $-t = -(\boldsymbol{p}_{A',corr} - \boldsymbol{p}_{A})^2$,

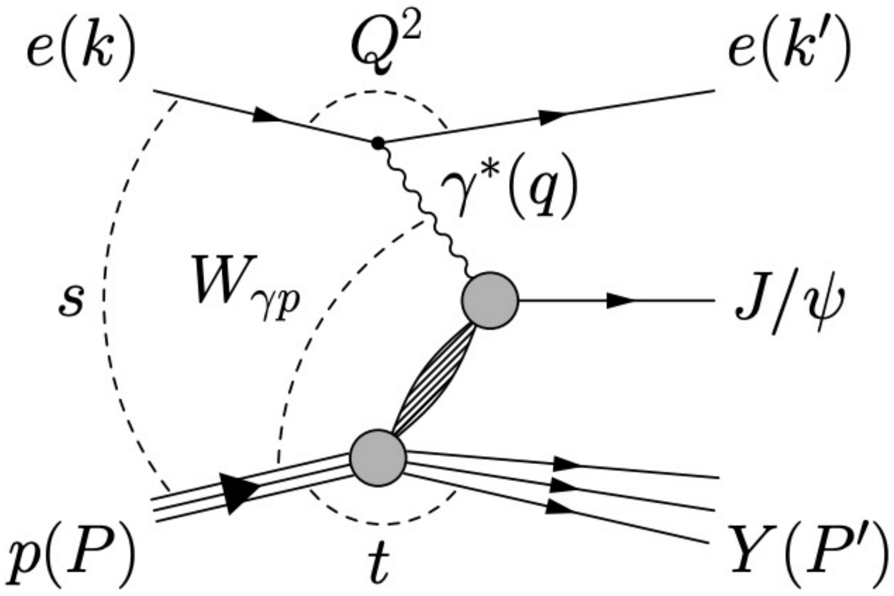
where $\boldsymbol{p}_{A',corr}$ is constrained by exclusive reaction.



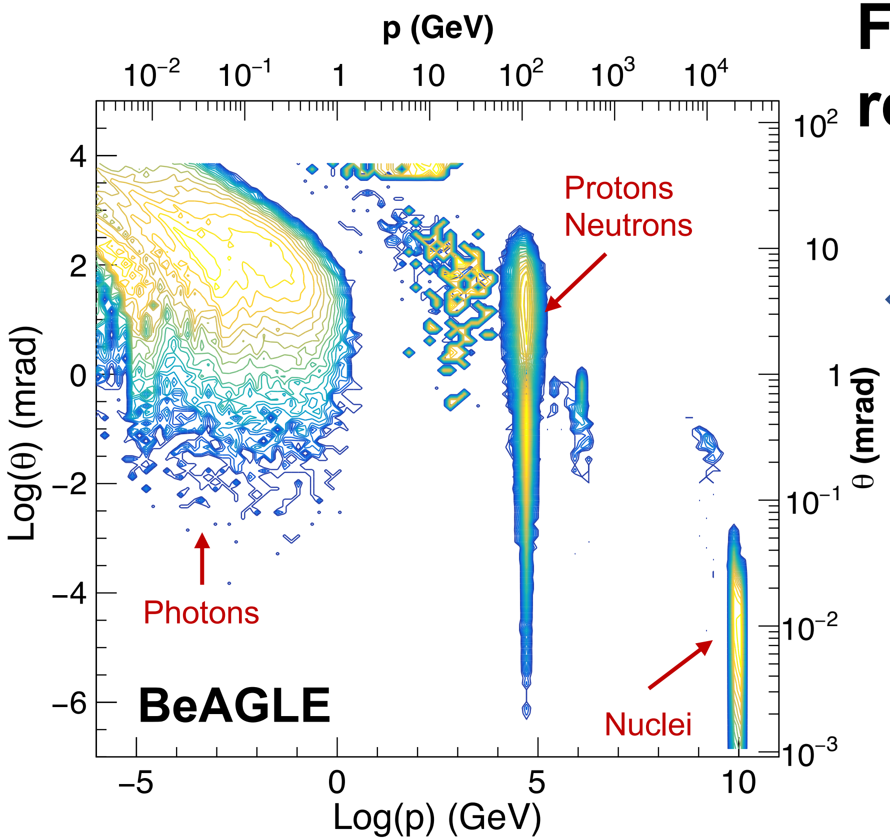
Best method concluded from the EIC Yellow Report – **Method L**

- Insensitive to beam effects, e.g., angular divergence and momentum spread.
- More precise than Method A for electroproduction

Incoherent background



Proton or nucleus dissociation



Far-forward region

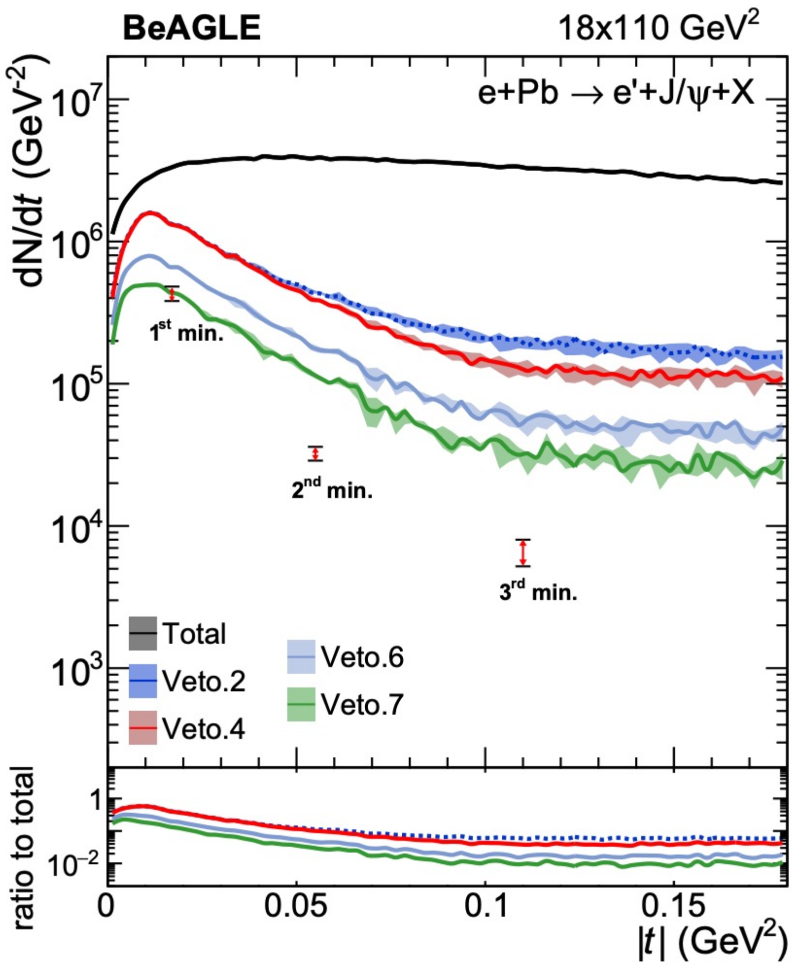
- ➢ *Incoherent itself is a great interest*, but it is the major background to the coherent case.
- ➢ Far-forward region is busy! Many breakup particles, e.g., protons, neutrons, photons, and nuclei
- ➢ BeAGLE – general-purpose eA MC, see https://eic.github.io/software/beagle.html

Performance of background suppressions

- No neutrons in ZDC (veto 2)
- No proton in any forward detectors (veto 3-5)
- No photon > 50 MeV in B0 or ZDC (veto 6-7)
- Minima (1st min. 2nd min. 3rd min.) are from *Sartre* MC generator (slide 4-5). Only 5% resolution assumed.

➢ Vetoing all of them is impossible. The question is how much is needed.

➢ This result was used in ATHENA proposal



*Phys. Rev. D **104**, 114030*

Result – ATHENA Tracker only

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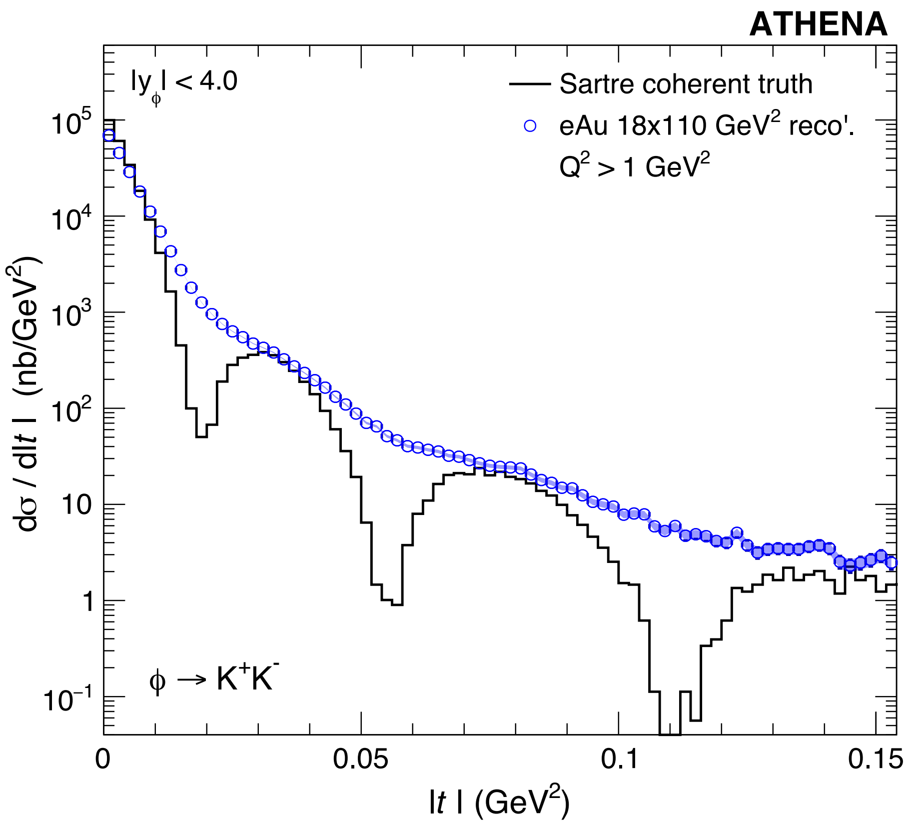

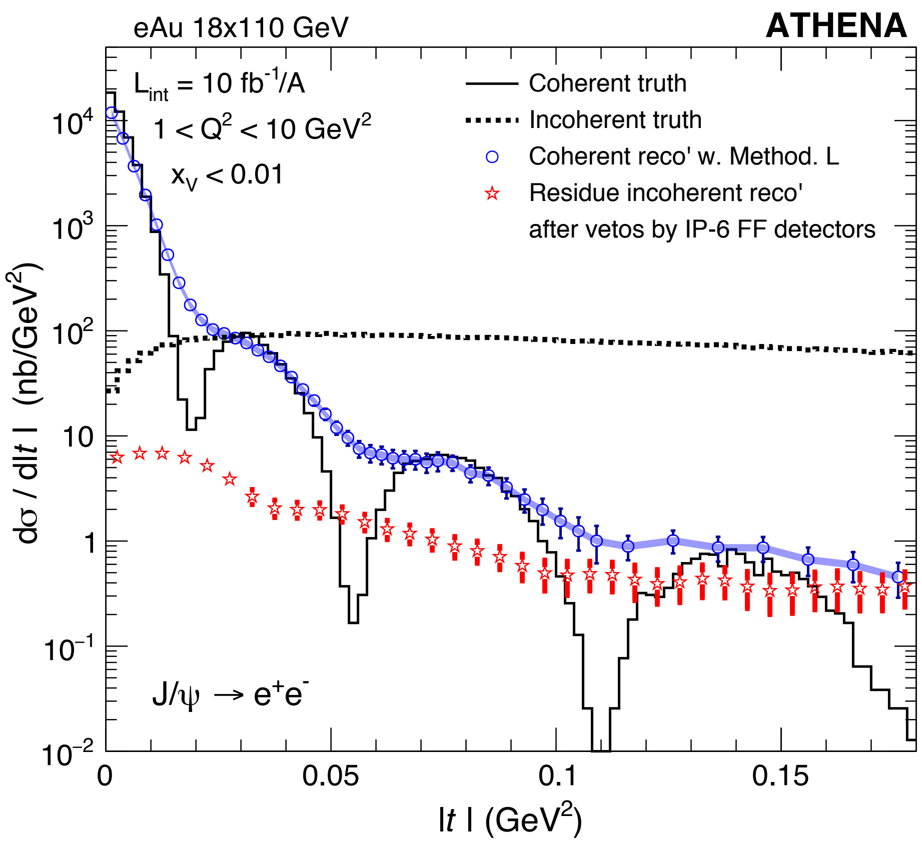

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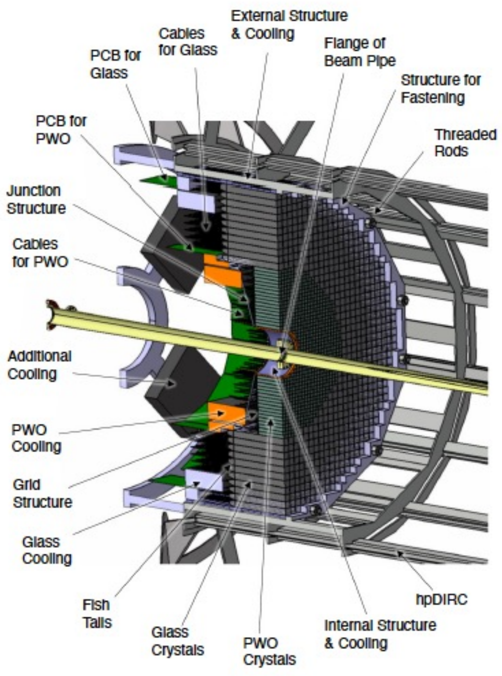
- ➢ Challenge 1: Incoherent background, but it only becomes an issue at high *–t;*
- ➢ Challenge 2: *Momentum resolution is not enough. Bottleneck - p_T resolution of the scattered electron.*

Result – ATHENA nECal+Tracker

ATHENA backward nECal
(-4 < η < -1.5)



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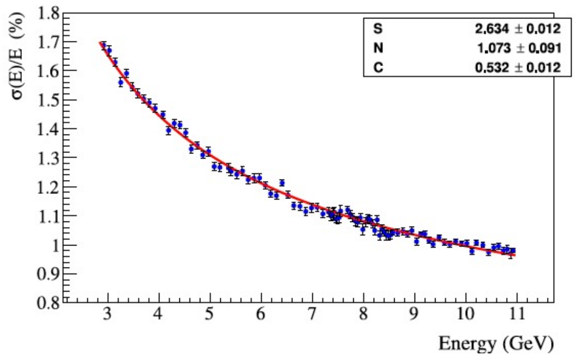

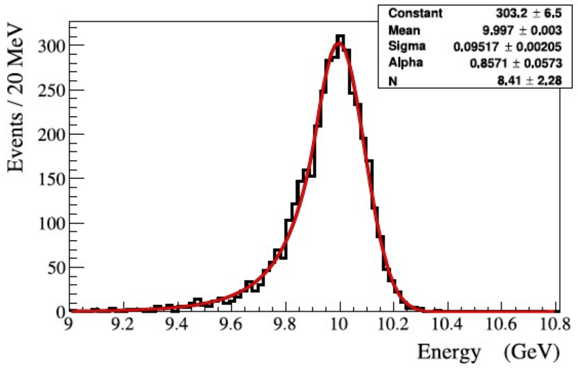

Results on $PbWO_4$ scintillating crystals for Jlab experiments. ~ 1% energy resolution

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ATHENA backward nECal *Nucl.Instrum.Meth.A* 1013 (2021) 165683

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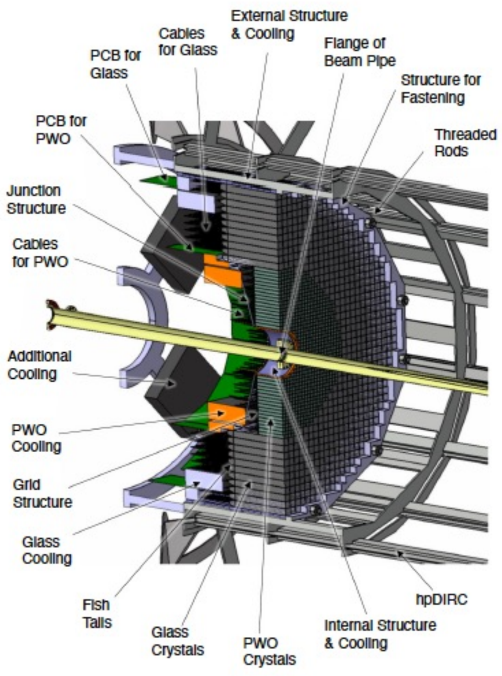
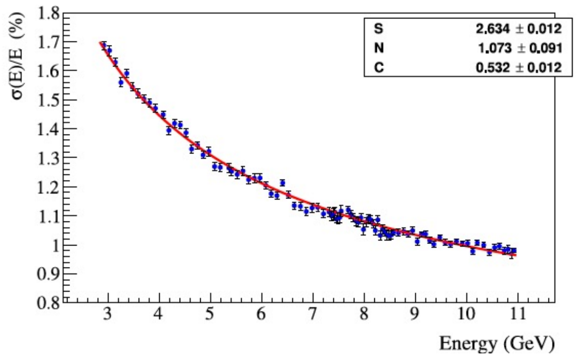
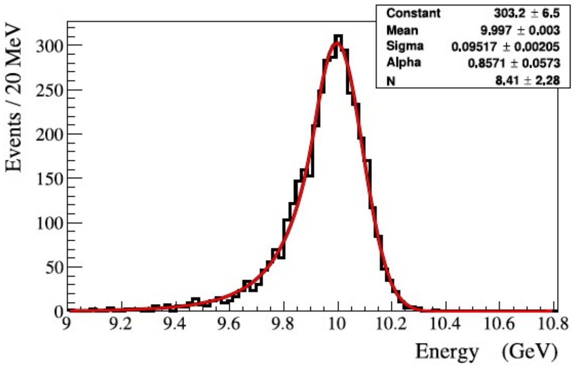
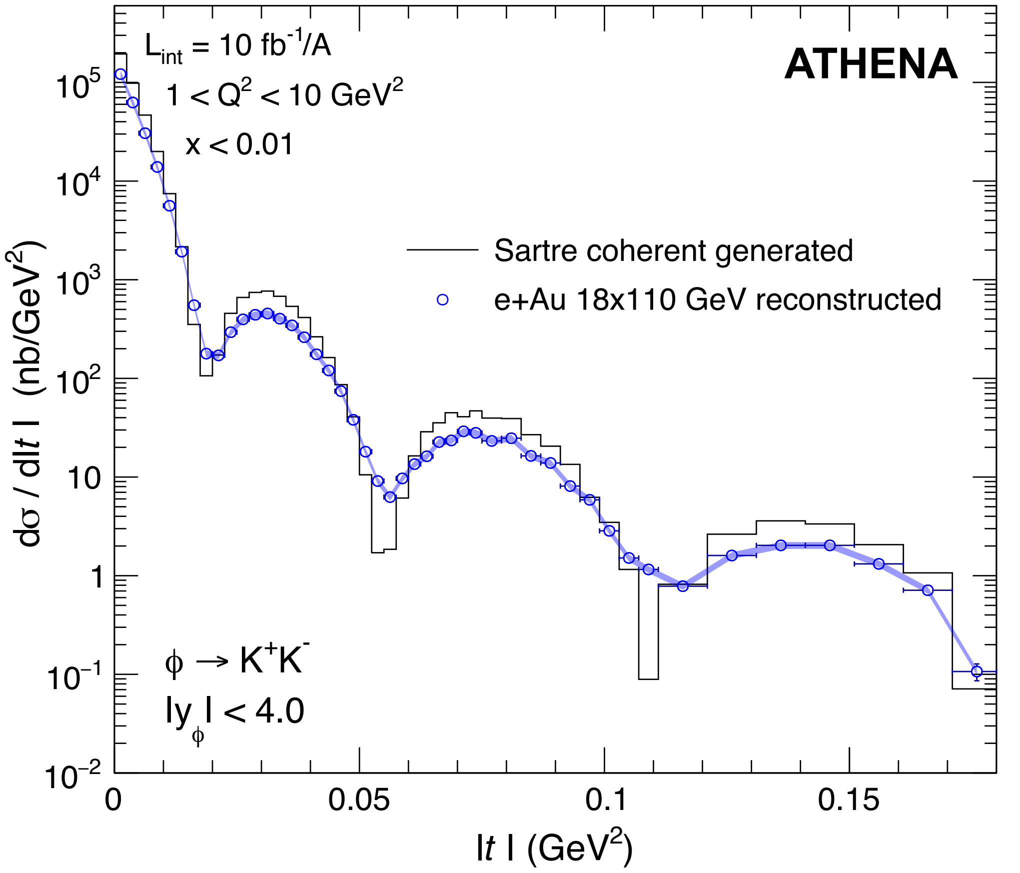






Results on $PbWO_4$ scintillating crystals for Jlab experiments. ~ 1% energy resolution

Gaussian smearing = 1% energy resolution



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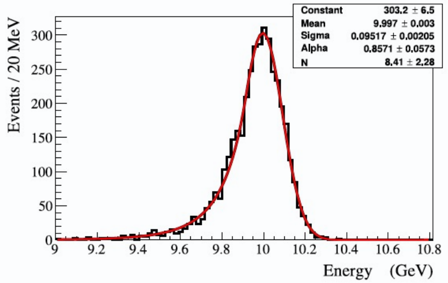
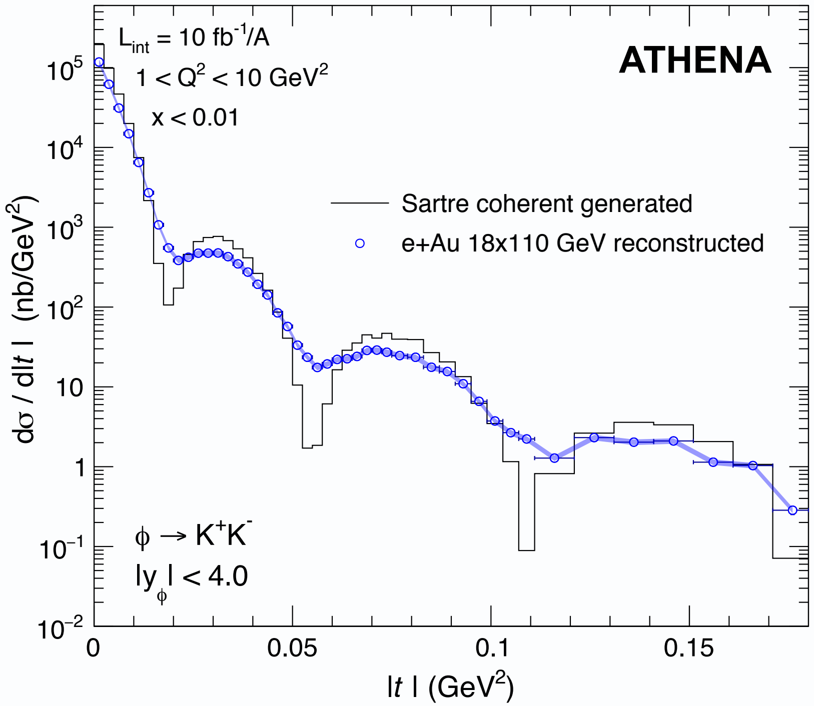
Huge improvement. Resolution of scattered electron dominated by nECal energy resolution

Result – ATHENA's further "*improvement*"

After discussion with ECCE in our first joint meeting

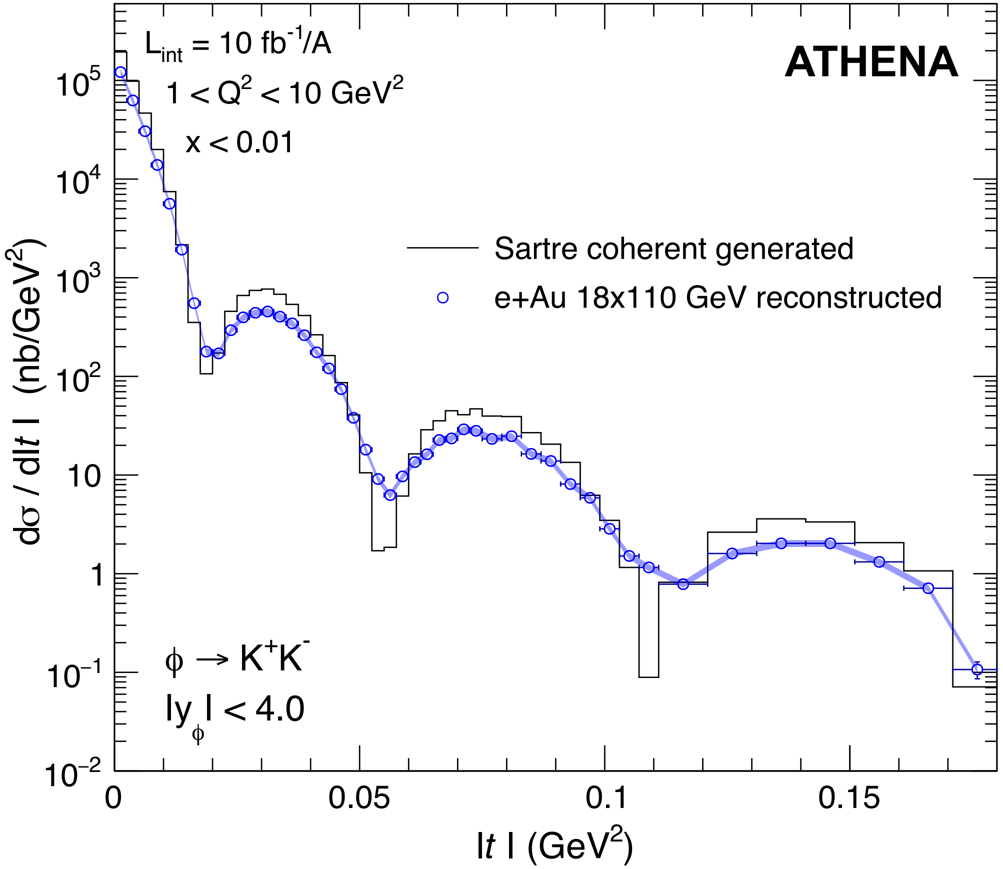


Non-Gaussian tail ~ Crystal Ball



The reconstructed –t distribution has an impact from Non-Gaussian tail

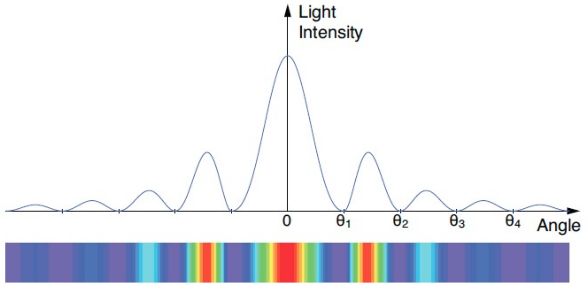
Gaussian smearing = 1% energy resolution

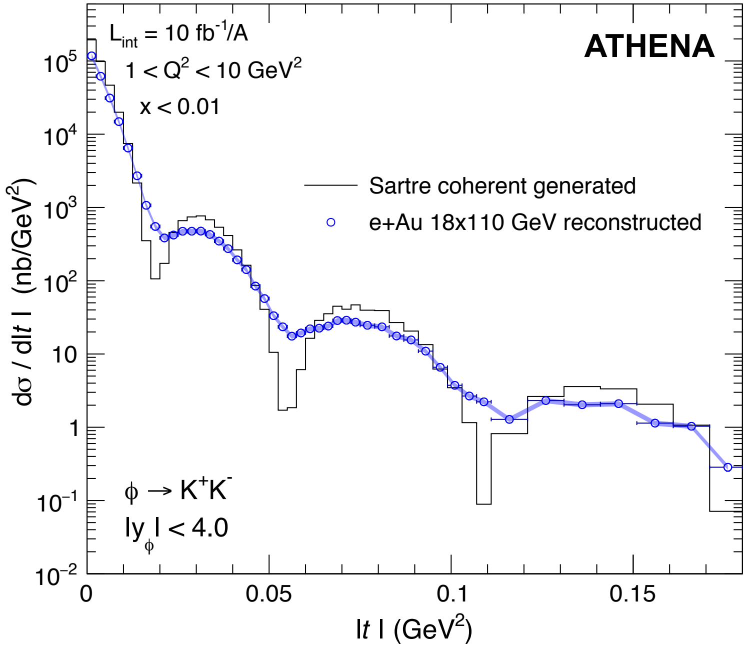


ATHENA and ECCE are working together in benchmarking this process with the EIC "Detector 1"

Summary

- Diffractive Vector-Meson is a powerful experimental tool to study the nucleon and nuclear structure, e.g., gluon spatial distributions.
- One of the most difficult, if not the most, measurements at the EIC.
- In order to achieve this measurement, we need to overcome:
    1) Incoherent background, where the nucleus breaks up. Veto on far-forward particles.
    2) Excellent energy resolution (~1%) to reconstruct the scattered electron.
- Will be working jointly from now on between the two proto-collaborations.





The next steps

- The remaining difference between ATHENA proposal and the ECCE proposal, despite differences in t reco method (*need confirmation/cross checks*), can only be narrowed down when we have a single software framework simulation sample (e.g., geometry, tracking, calorimetry, etc).
- **This doesn’t need to be the ultimate ``single software” that will be decided; we just need to pick one to study with > 2 independent analysis teams/persons to compare.**

- Currently, *simqa* team is going to produce the 1st simulation campaign in fun4all with all requested samples; however, we reserve some finite/limited resources to simulate in DD4HEP for opportunistic runs. (For example, if this study (diffractive VM) is necessary to be checked in DD4HEP, we could.)

- Benefit of this process - sensitive to detector performance and so on. For example, shall we explore this process with background studies (synchrotron radiation, e and hadron beam-gas)

Back up

Crystal Ball smearing