Developing a general eA tagging program in ePIC – beginning with Deuterium

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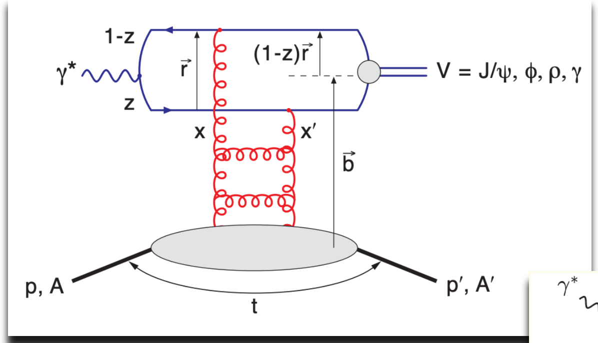
September 22, 2023

*In collaboration with members in the eA study group

Motivation

- A general question: what are the [capability/limit/acceptance] of the ePIC detector in terms of selecting *e*A exclusive events?



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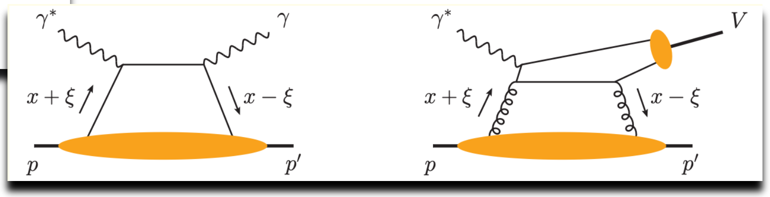

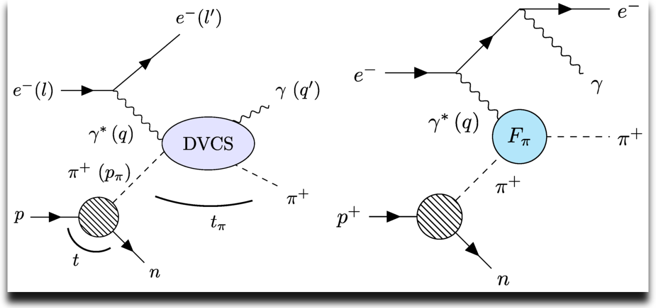

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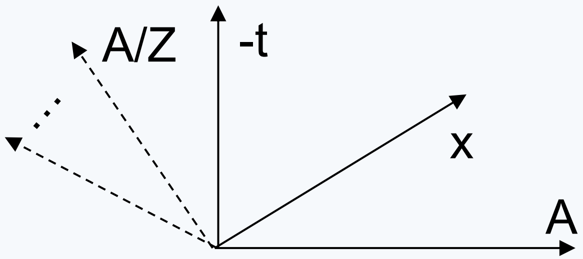
Motivation

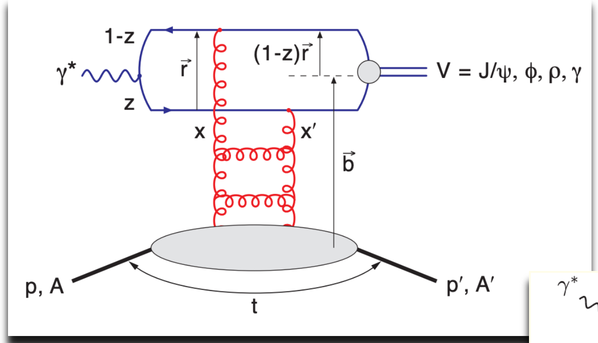
- A general question: what are the [capability/limit/acceptance] of the ePIC detector in terms of selecting *eA* exclusive events?

➢ Specifically, what is the acceptance of coherent and incoherent eA reactions for a given [Q^2, x, -t, A, A/Z, coh/incoh] ?



[a multi-dimensional acceptance plot]

➢ This will be essential for all exclusive reactions that extends from ep to eA.



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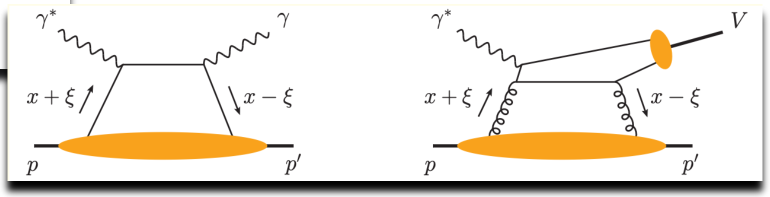

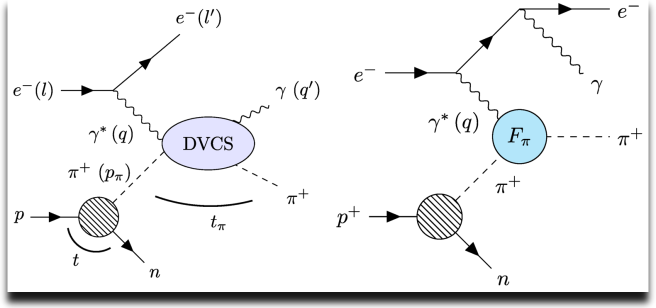

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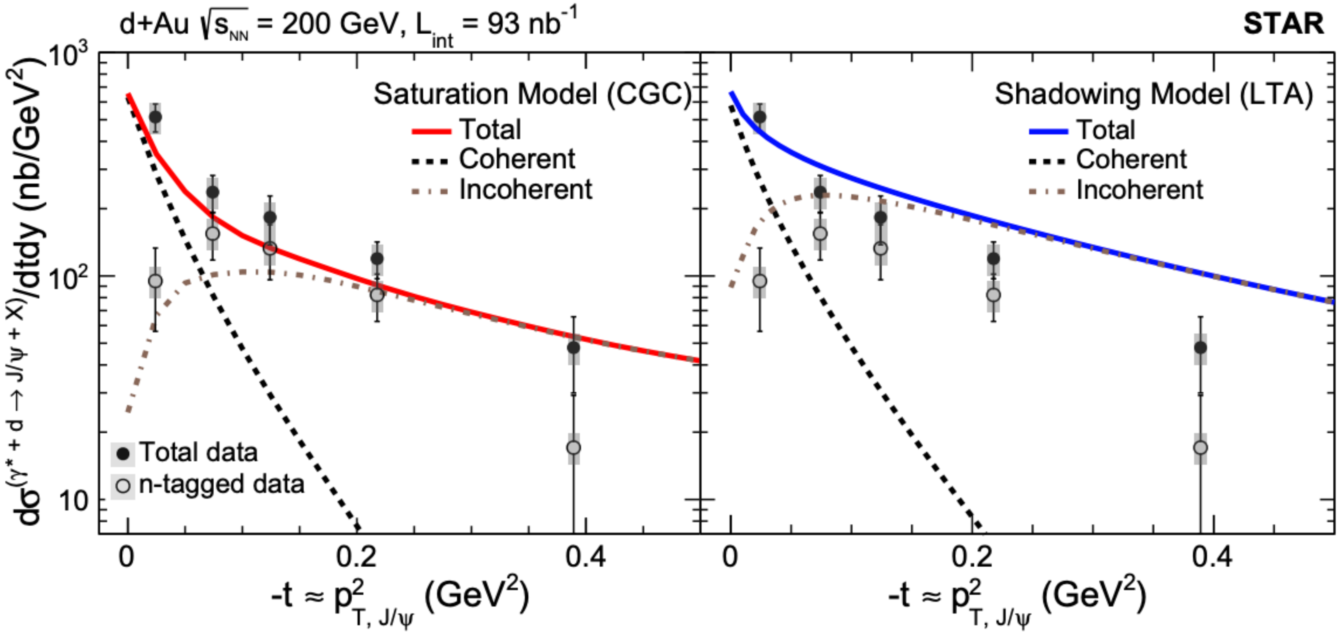
Starting from the Deuterium – simplest nuclear system



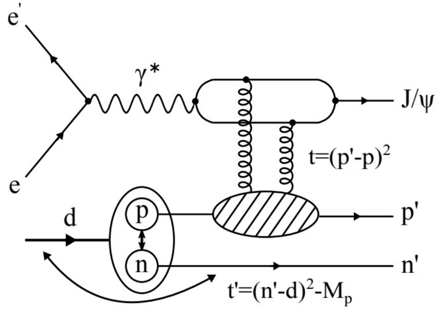
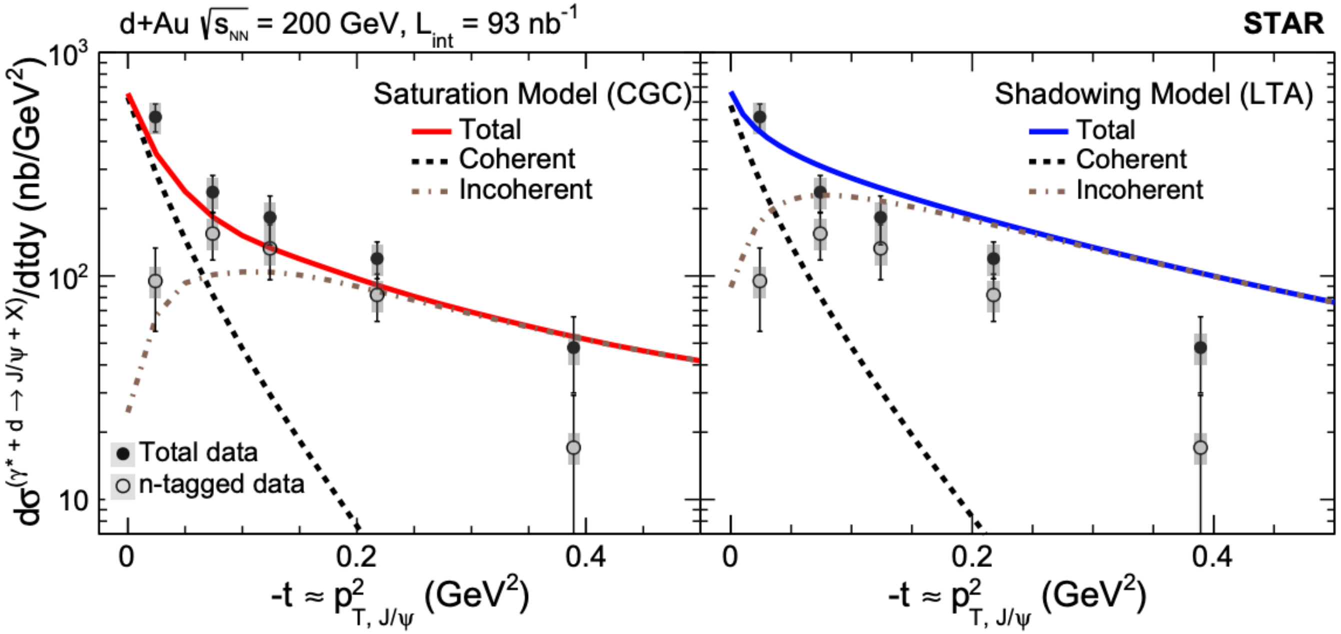


Figure 1: Diagram of incoherent diffractive J/ψ productions in electron-deuteron scattering

STAR UPC data provided the first data constraints on coherent and incoherent eD scattering.
[Phys. Rev. Lett. 128 (2022) 12, 122303]

Starting from the Deuterium – simplest nuclear system



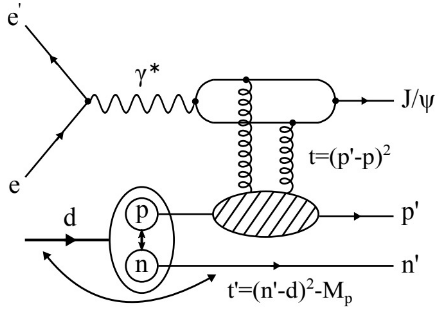


Figure 1: Diagram of incoherent diffractive J/ψ productions in electron-deuteron scattering

STAR UPC data provided the first data constraints on coherent and incoherent eD scattering.
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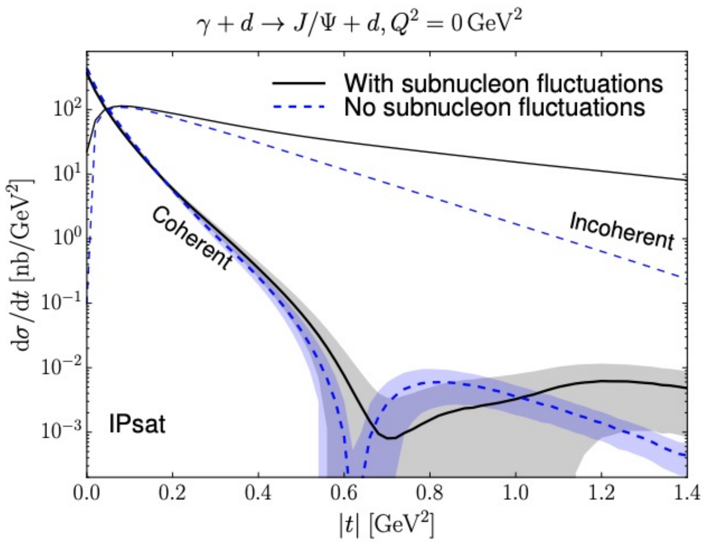
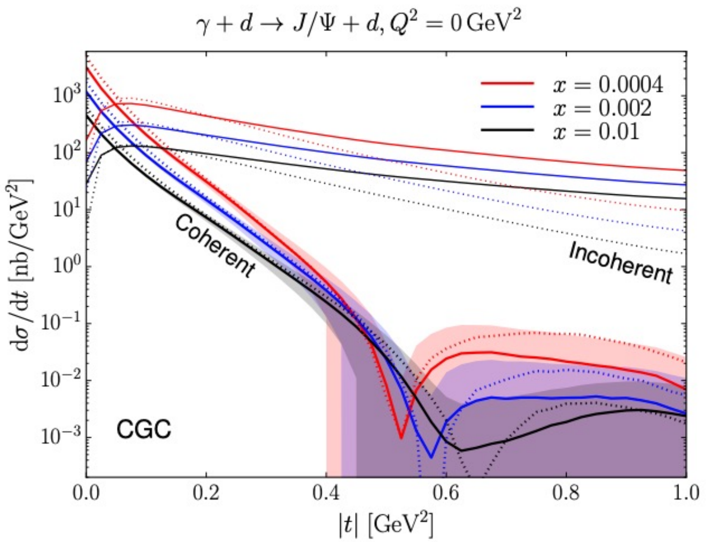
What we learned:

i) incoherent and coherent are well described by theory, which is based on the nuclear wavefunction with small nuclear effects.

ii) Low-t, ~ 0.1 GeV^2, coherent is dominated, and incoherent takes over after that.

Starting from the Deuterium – simplest nuclear system

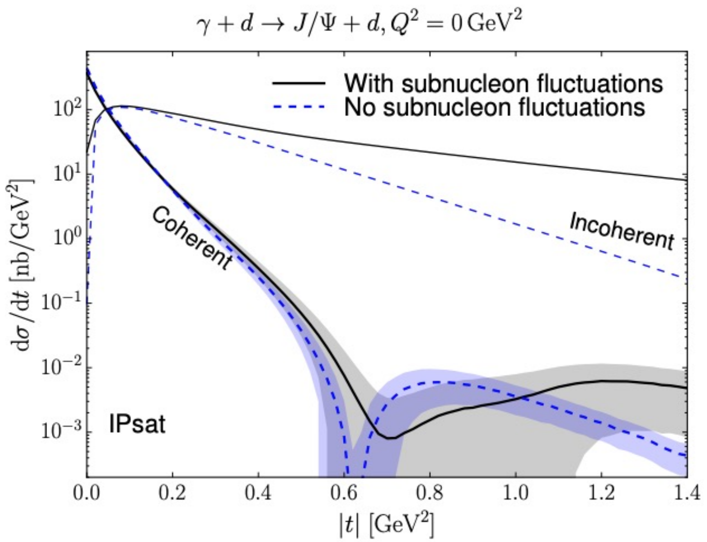


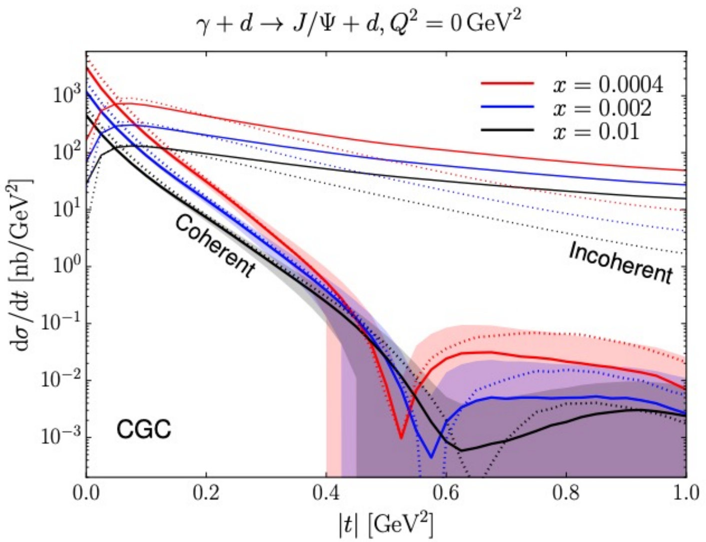


EIC prediction for eD photoproduction based on Saturation models by [Mäntysaari, Schenke]

Coherent: average density.
Incoherent: density fluctuation.

Starting from the Deuterium – simplest nuclear system





EIC prediction for eD photoproduction based on Saturation models by [Mäntysaari, Schenke]

Coherent: average density.
Incoherent: density fluctuation.

What we NEED:

i) Separate coherent and incoherent, because they present different physics!
ii) Low-t, ~ 0.1 GeV^2, coherent deuteron is difficult to be tagged, we can only achieve via **incoherent veto** method. Like the heavy nuclei case.

(coherent eA tagging, qualitatively, is harder when goes to low-t and low-x)

Veto analysis on deuteron breakups using the BeAGLE model

- BeAGLE has implemented the Light-cone wavefunction of deuteron based on the Ciofi. et al parametrization. Many publications are available [Tu et al (2020), Jentsch et al (2021), …]

- **BeAGLE eD simulation 18x110 GeV, simulated through full ePIC detector.** We can simulate rho, phi, and Jpsi (no Upsilon). Here we specify BeAGLE to produce phi only.

- BeAGLE events are “burned” with the crossing angle and beam effects. Far-Forward detectors are all included (B0, OMD, RP, and ZDC), to veto on their activities. The current algorithm: if any of the following requirement is met, the event is vetoed:
  - **B0, at least one hit per layer.**
  - **ZDC EM, one hit is required to be vetoed**
  - **OMD, a track is required to be vetoed.**
  - **RP, a track is required to be vetoed**

- Because of the magnet setting in current software, we need to apply the FieldScaleFactor = 220/275.

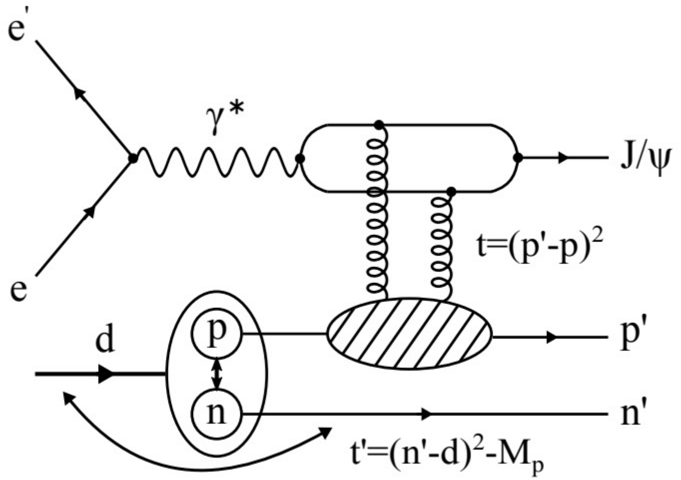
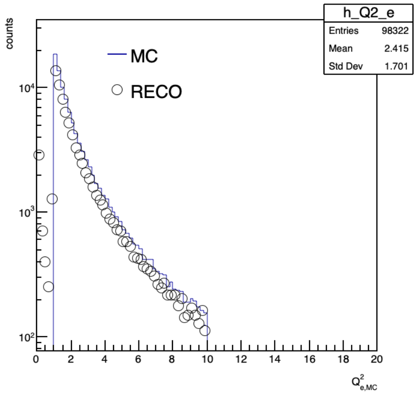


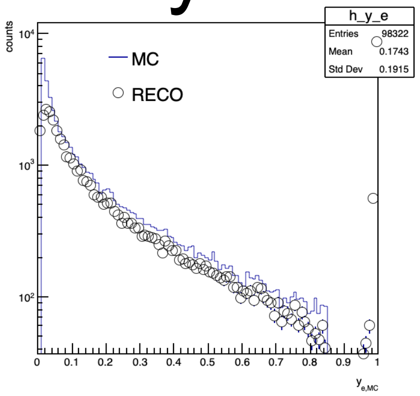
Figure 1: Diagram of incoherent diffractive J/ψ productions in electron-deuteron scattering

Some DIS control plots [Sep 11]

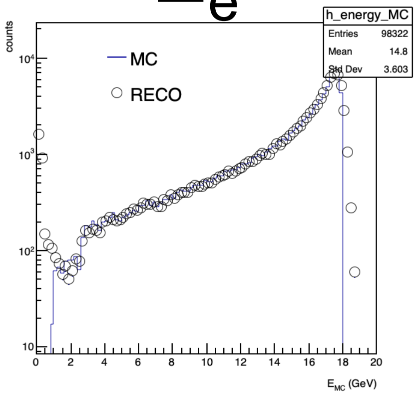
Q^2



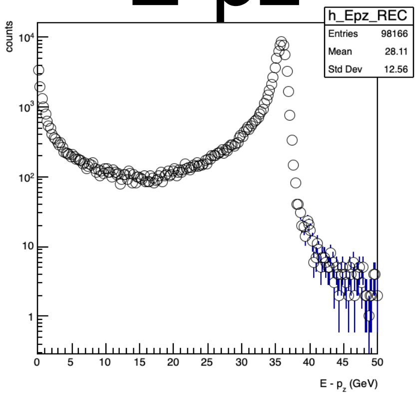
y

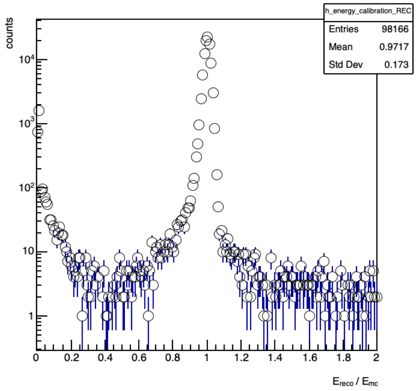


$E_{e'}$

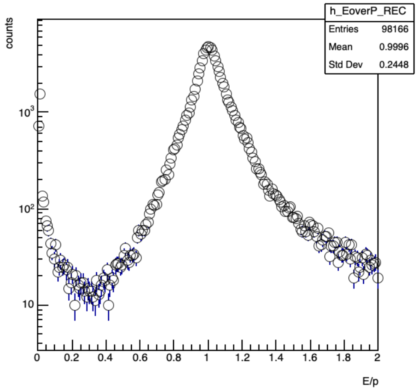


E-pz

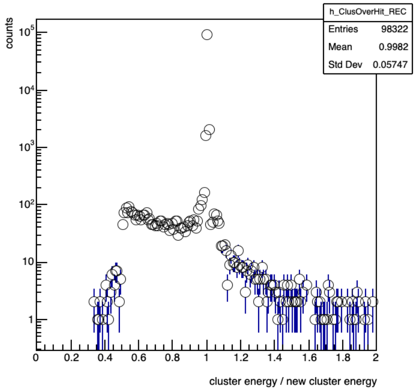




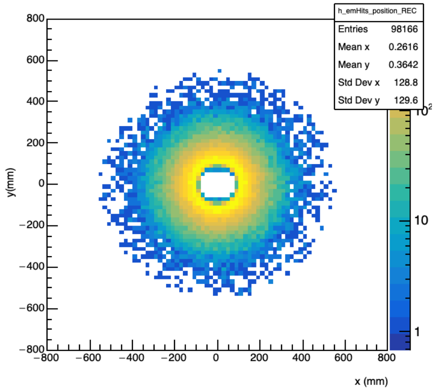
$E_{rec,\ e'}/E_{mc,\ e'}$



E/p (e')

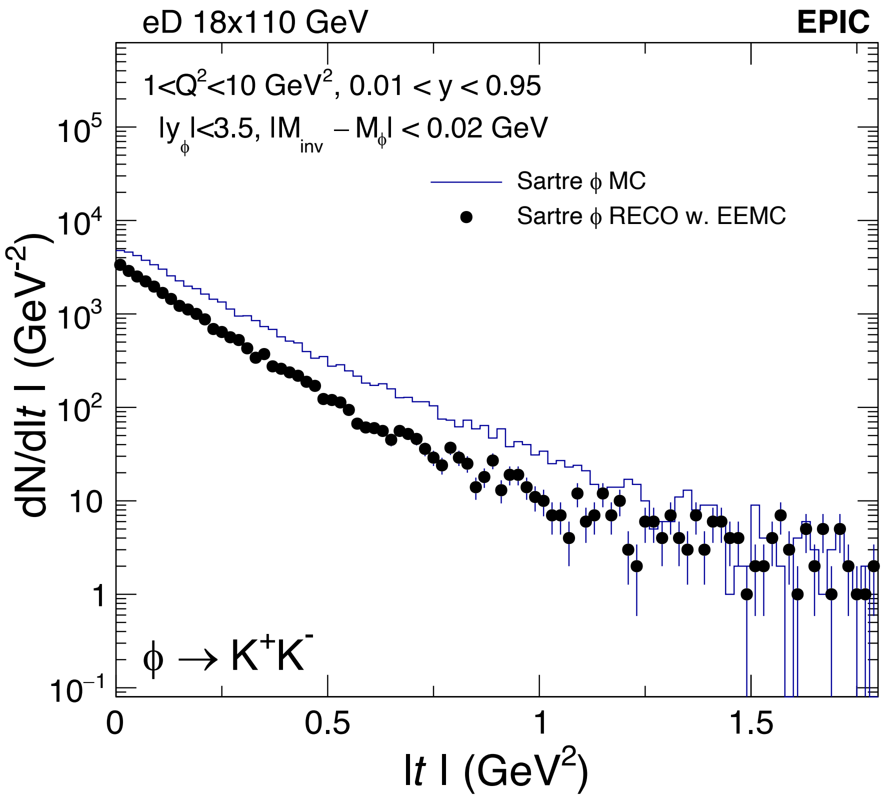


Default/test cluster energy



EEMCal cluster in x-y

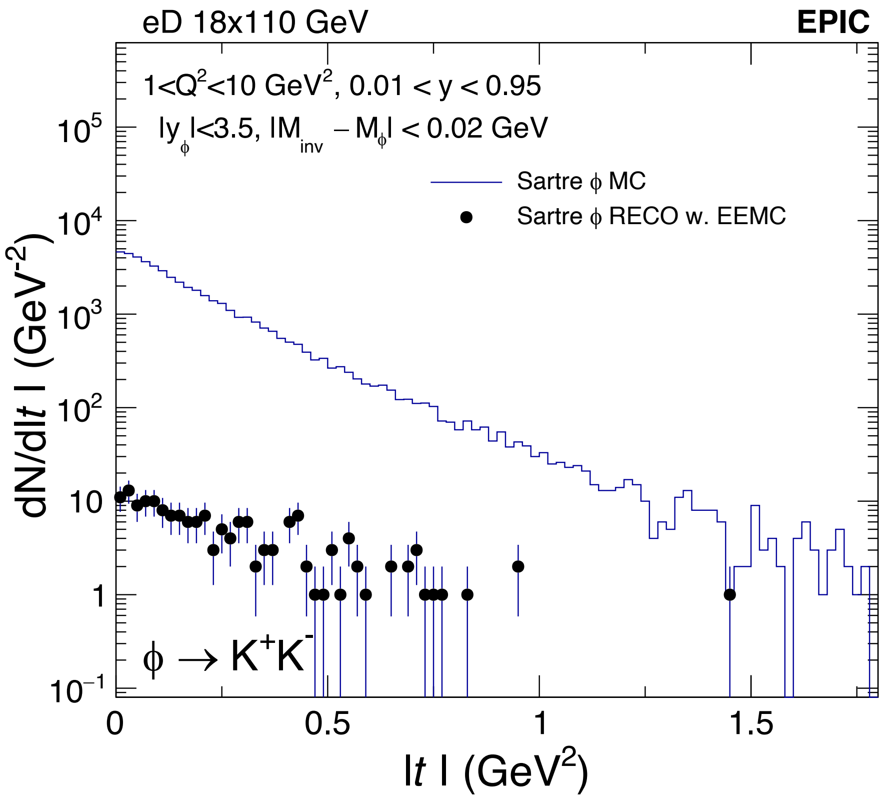
t-distribution with ePIC_full [Sep 11 version]



This is without the FF veto, comparing with the true MC.

- Good electron selections:
  - Leading cluster (new algorithm).
  - Energy calibration is ~ 4.5%
  - Select clusterRadius < 550 mm
  - Electron track (leading p_T, charge < 0, !association to K^-)
  - **0.8 < E/p < 1.18**
- DIS event selection:
  - **27 < E – Pz < 40 GeV**
- ϕ phase space:
  - daughter K |pseudorapidity| < 3.0;
  - Within 0.02 GeV of ϕ mass.
- Method A on the t reco. (e.g., $-t = (\boldsymbol{p}_{T,e'}+\boldsymbol{p}_{T,VM})^2$)

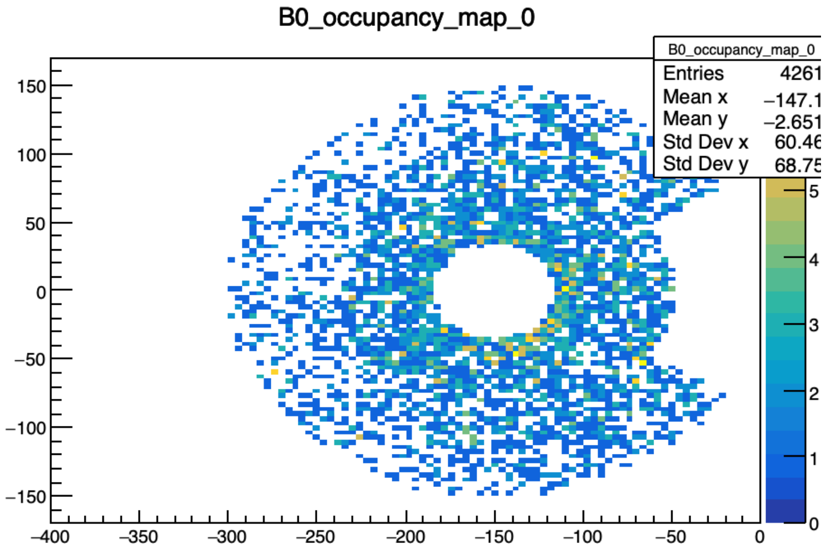
t-distribution with ePIC_full [Sep 11 version]



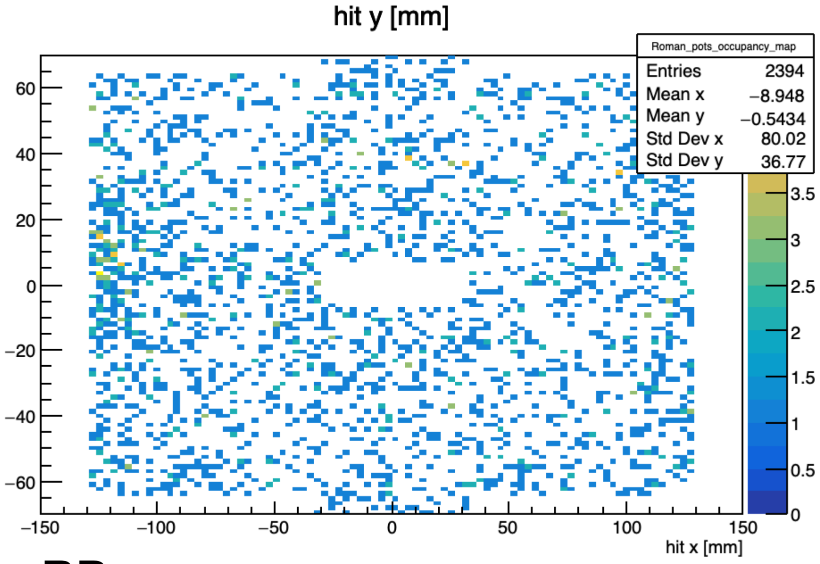
- All cuts are the same as previous slide.
  This is with veto.
- Finally, the vetoing performance seems to make (**more**) sense now.*
- Vetoing power ranges from 300 to 15, starting from low to high t. (vetoing power = residue/before)

* we discovered a **handful of simulation issues** during this analysis.. but thanks to the FF group (e.g., A. Jentsch) and S&C, those were fixed. (this is one of the reasons why analyses at this stage are important - a feedback system for detector and software developments)

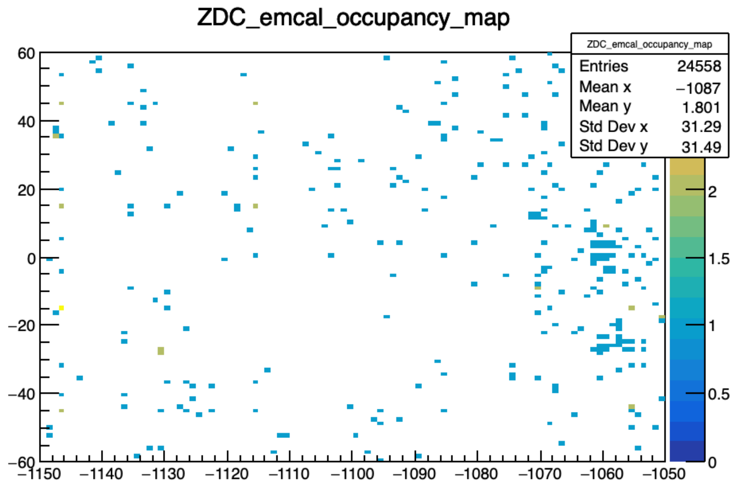
Some technical details - Every FF detector has hits.



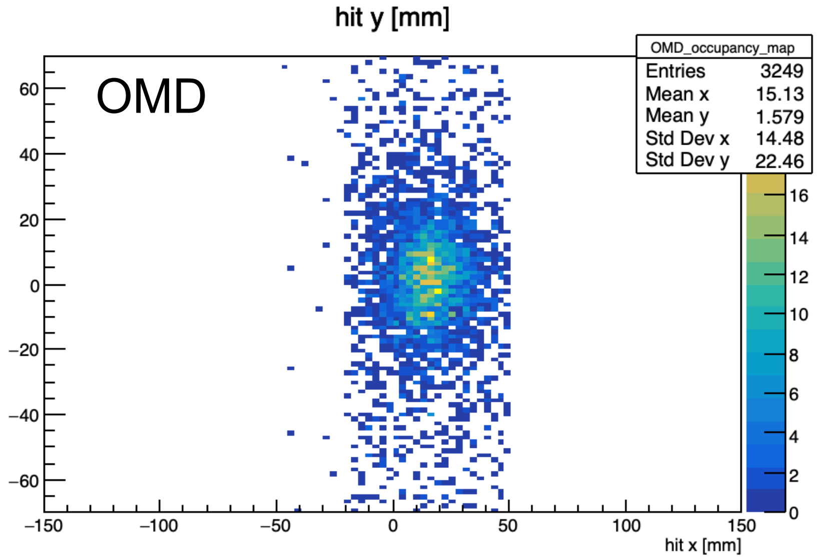
(B0, there are 4 layers)



RP



ZDC



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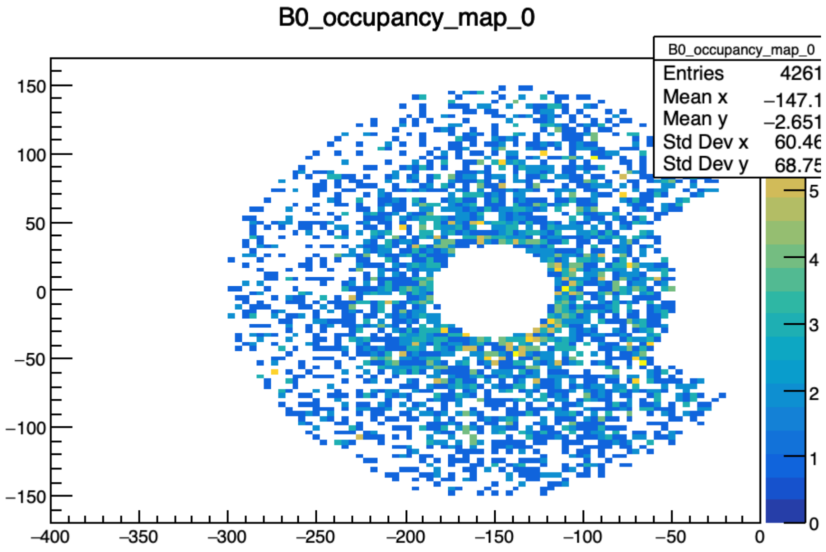

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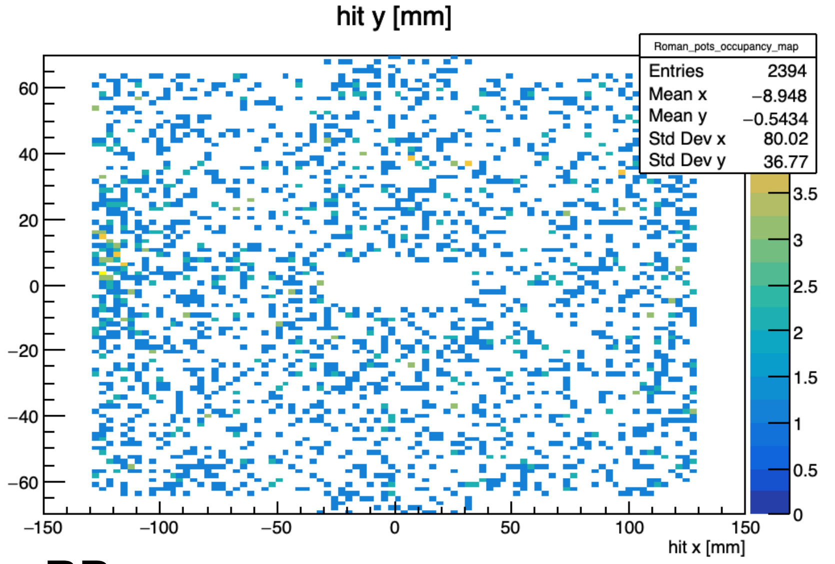
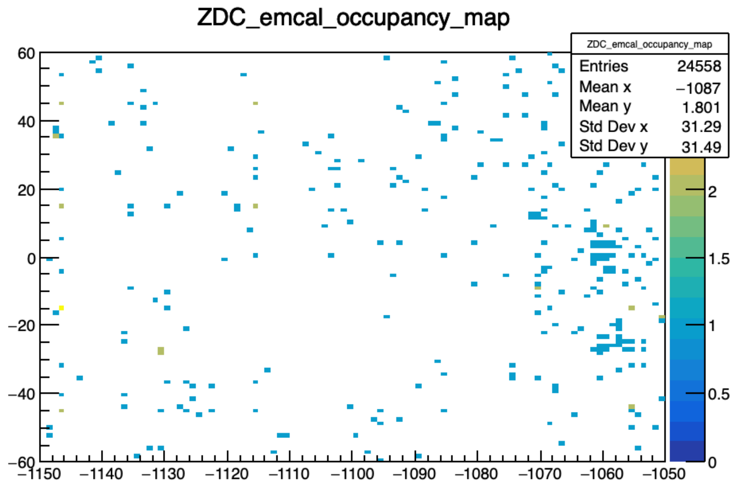
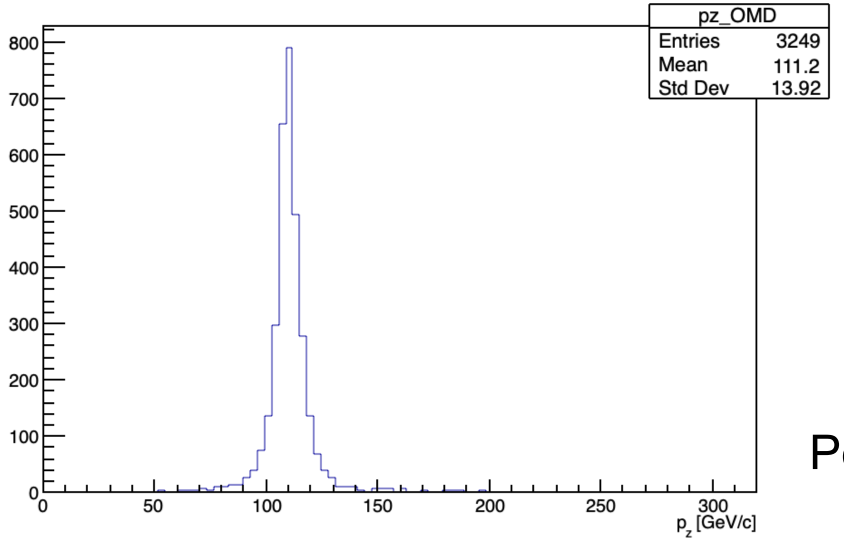


RP



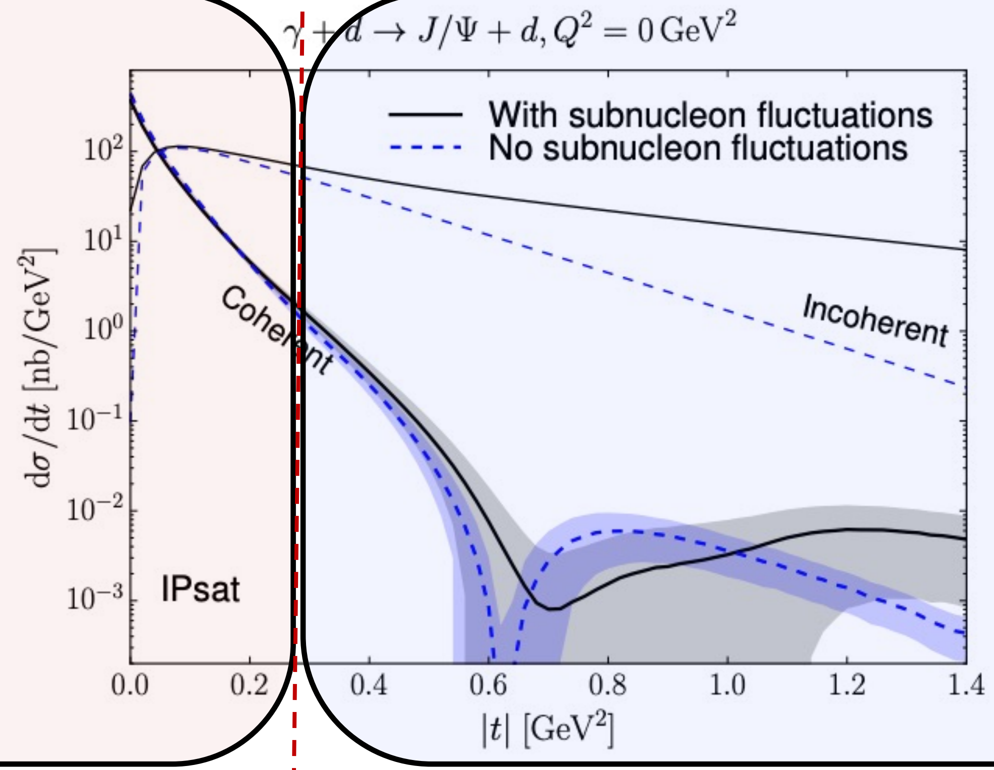
ZDC



Peaked at 110 GeV/c

What's next?

Incoherent veto:



Coherent tagging

The goal is to find this line →

- Low-t coherent via incoherent veto
- High-t coherent via tagging

This structure ('dip') moves to the left as A increases, so the requirement of incoherent veto and coherent tagging changes. It strongly depends on x and A.

A reminder of our "process"

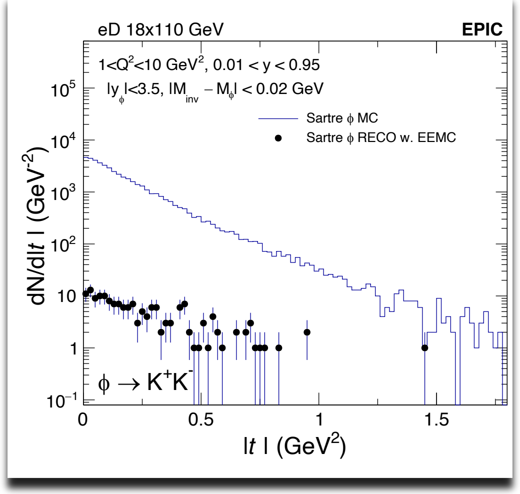
Phase 1:
Physics process identified.
Generator available.

Phase 2:
Physics events passed thru ePIC software simulation.

Phase 3:
Physics benchmark made.
Codes/scripts submitted.

- BeAGLE is our primary model;
- We simulated D^2, and Au^{197} so far;

- I propose to simulate He^3, C^{12},Ca^{40}, Zr^{90}, Xe^{131}, Pb^{208} for studying the full A-dependence

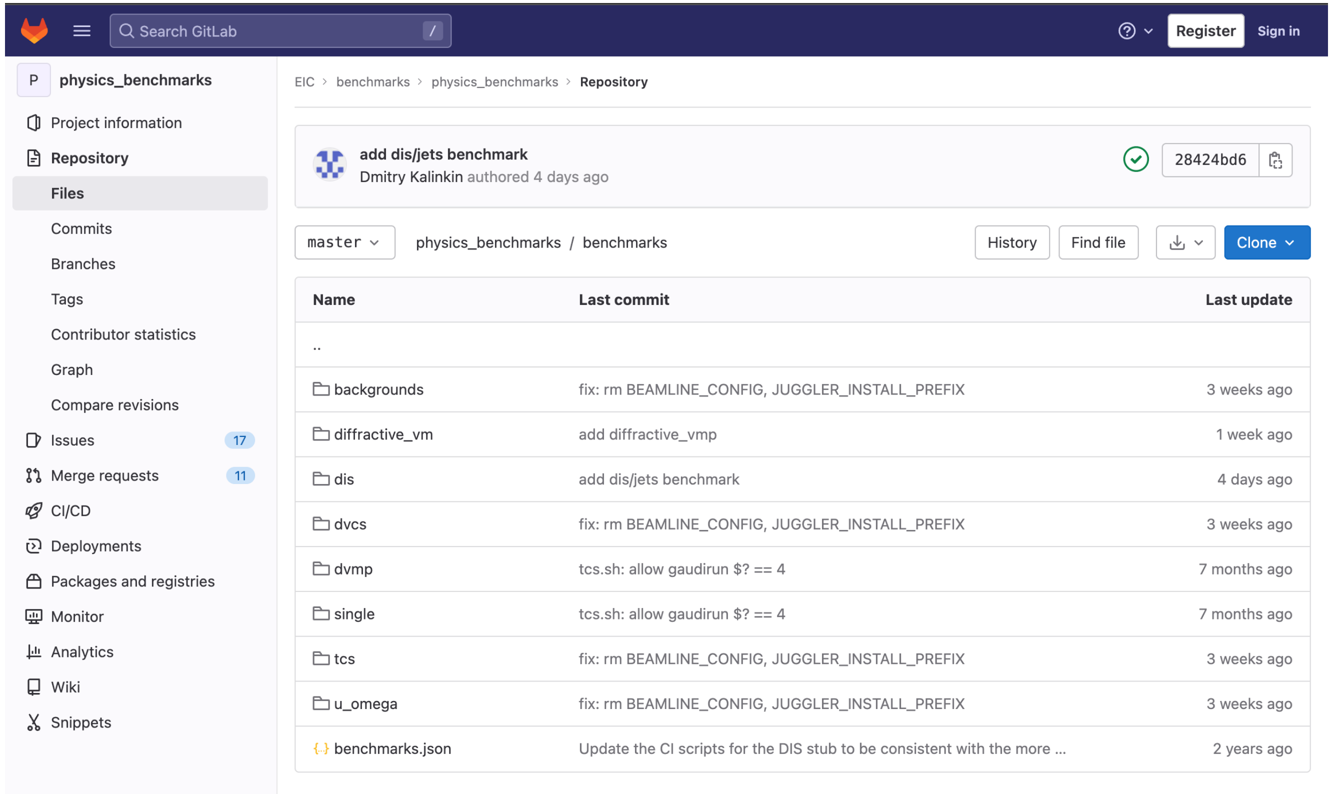


Not yet to the benchmark.

But we do have a benchmark for eAu coherent phi production.

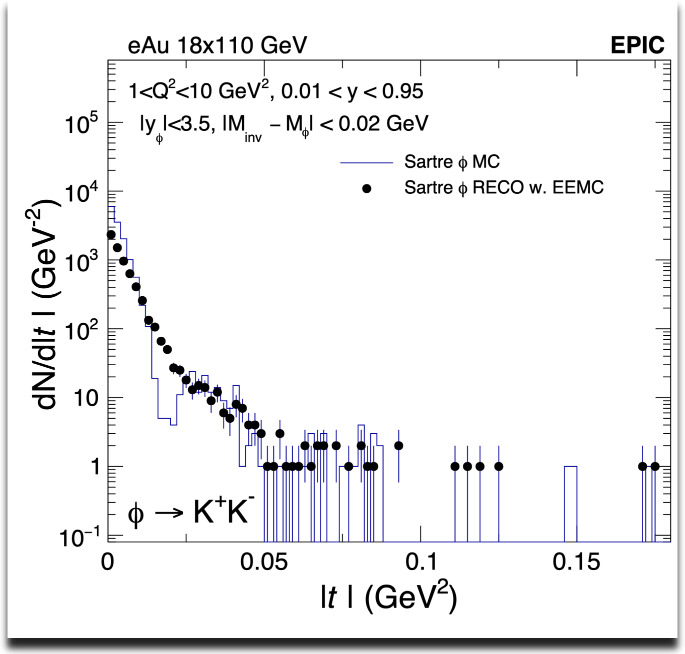
Phase 3 analysis – eAu diffractive Phi benchmark

https://eicweb.phy.anl.gov/EIC/benchmarks/physics_benchmarks/-/tree/master/benchmarks/diffractive_vm

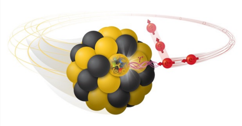


From now on, every campaign we can quickly make the same plot and check for updates/issues. For example, the August campaign, this benchmark returned empty, which indicated a problem in the Calorimeter (npsim issue on the calorimeter thresholds)

Thanks to S&C and especially **Dmitry Kalinkin** for making this benchmark official!



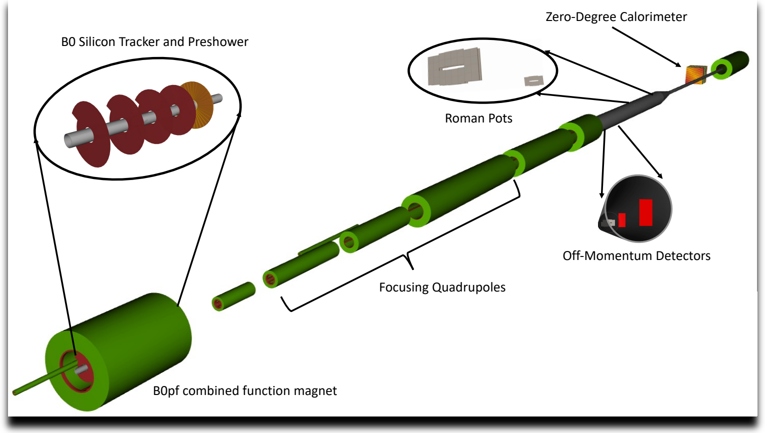
A test sample ran in July Campaign.



Summary

- In this study, we have a first look at how deuteron breakup can be vetoed using the ePIC detector.

  - This is a starting point to understand the general performance of eA exclusive program in ePIC.



- Similar studies are being done by [*Michael Pitt, Eden Mautner, et al.*] on heavy nuclei Pb^{208}. We will be performing light and medium A nuclei in the future, e.g., He^{3}, C^{12}, Ca^{40}, Zr^{90}, Xe^{131}.

- This is not only limited to Vector-Meson production, but also applies to DVCS on nuclear targets, or other exclusive processes.

This study came out of the "eA study group**", among many other interesting studies. [Join us, we meet weekly Tuesday 1pm. Send me an email to sign up.]*

Backup

ePIC full simulation [Aug 17-Sep 11, 2023]

Number of Issues discovered:

- OMD was not merged in EICrecon.
- World Material was “Air”.
- Container has issues due to some major changes in DD4HEP and GEANT 4.
- EICrecon issue related to matrix reconstruction.
- npsim Calorimeter threshold issues.
- Beam information not propagated from HEPMC file to EICrecon.

As of now, these issues were fixed or temporarily fixed