Coherent Vector-Meson electroproduction in electron-deuteron collisions in ePIC

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Motivation

- Coherent Vector-Meson, photon, etc. production on light nuclei are sensitive to GPDs and gluonic form factors.
- Light-ions are also interesting because we could polarize them (He3 for ePIC in the baseline design)
- There are certain advantages and disadvantages of deuteron, He3, He4:
    - He3 or He4 and their diffractive 'dips' are sensitive to nuclear shadowing. See recent studies by Guzey et al [**Phys.Rev.Lett. 129 (2022) 24, 242503**]
    - Deuteron, however, is **easy to model and the spectator is by now well understood** in terms of how to tag and access the initial-state physics, and some final-state physics too.
    - Deuteron is **much harder to be polarized** than He3, and we are unlikely to have polarized deuteron on day 1.
- Detecting **coherent scattered light-ion is challenging**, and harder for higher energy configuration, for low-x kinematics.
- One possible way to study coherent, is to **veto the incoherent production** from light-ion breakup.

Model - BeAGLE

- 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), …]

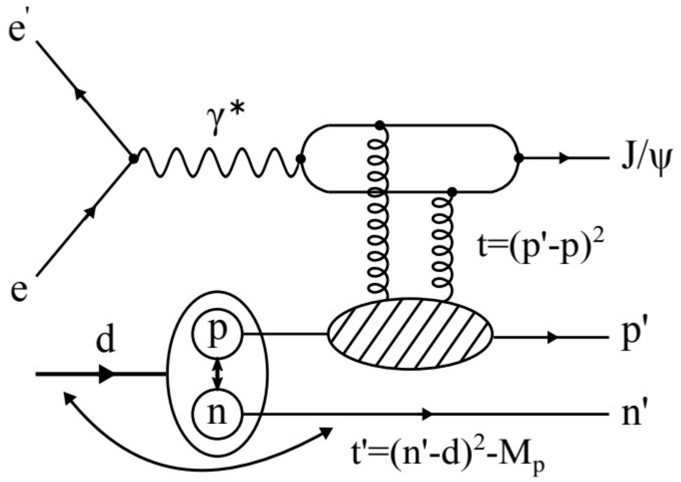
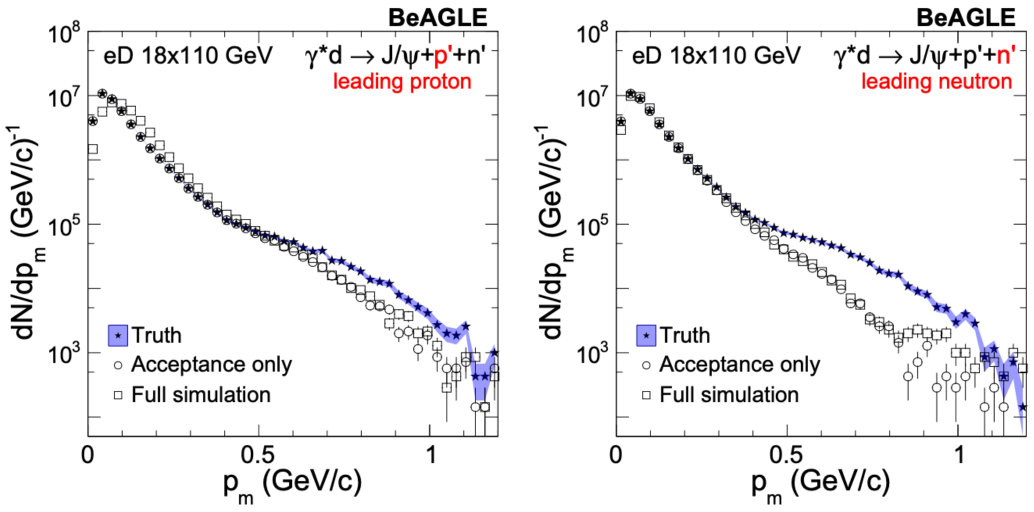


Figure 1: Diagram of incoherent diffractive J/ψ productions in electron-deuteron scattering

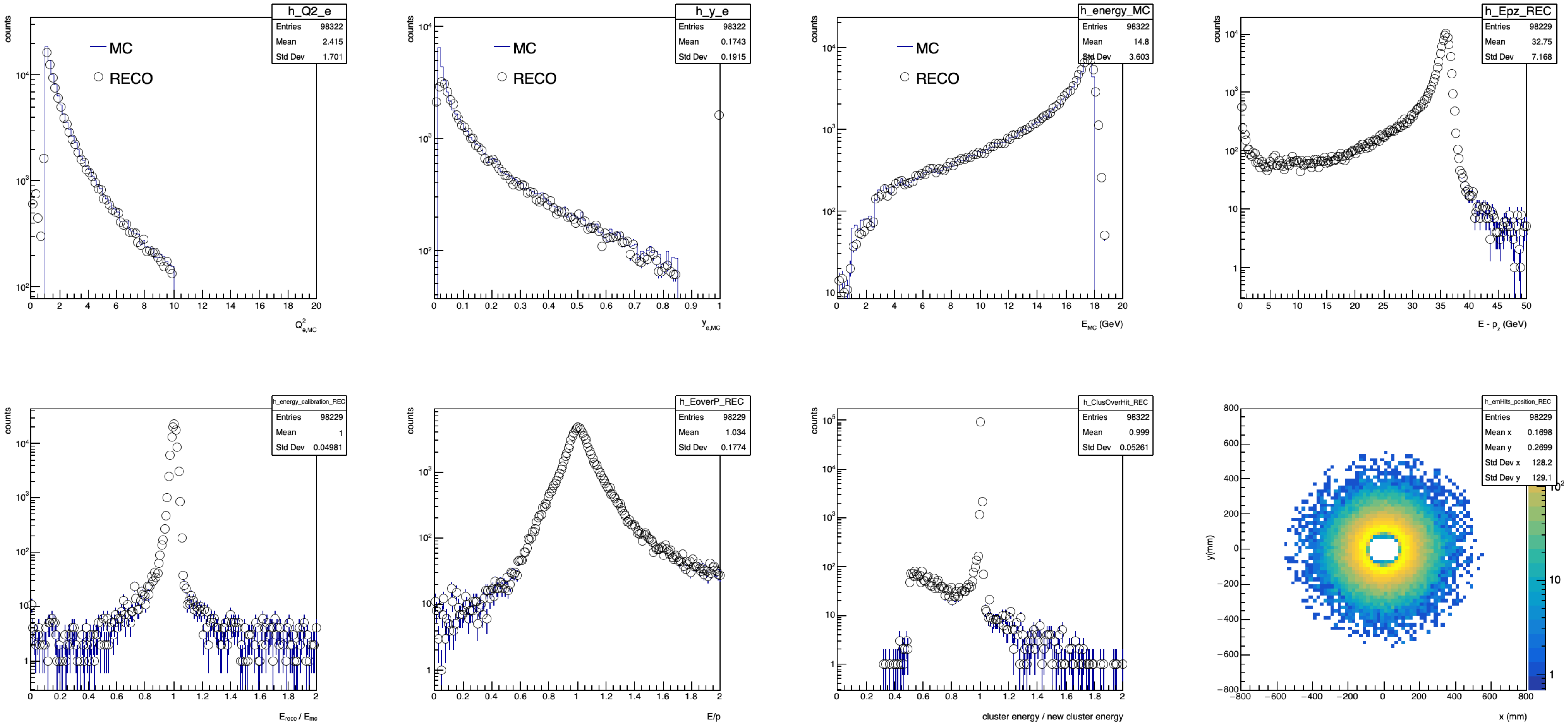


- The question is: how to access the coherent *ed* scattering?

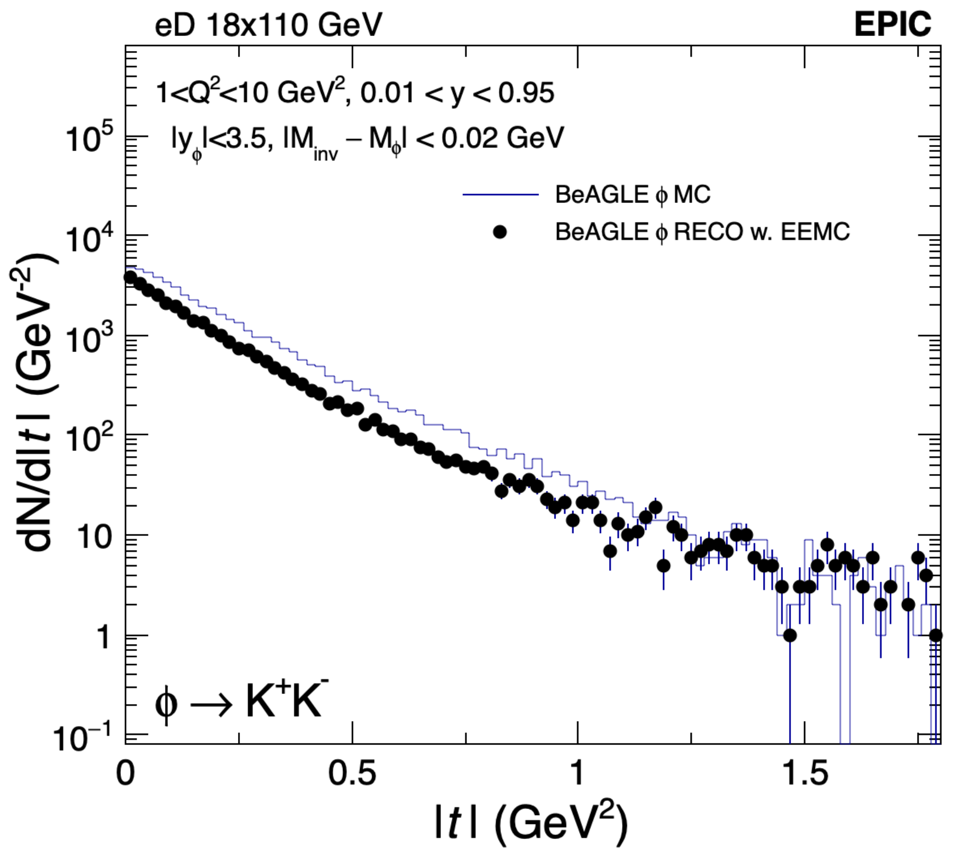
Veto exercise on deuteron breakup

- BeAGLE ed simulation 18x110 GeV, simulated through ePIC.
- We can simulate rho, phi, and Jpsi. Here we specify BeAGLE to produce phi only. (Cross section will be slightly wrong, but we don't care about the absolute cross section now)
- BeAGLE events are "burned" with the crossing angle, beam effects after-burner.
- FF detectors are all included (B0, OMD, RP, and ZDC), to veto on their hits. The current algorithm is simple, **if there's more than zero hit, this event is vetoed.**
- Because of the magnet setting, we have to apply the FieldScaleFactor = 220/275.

Some DIS control plots [July-17]



t-distribution in BeAGLE



This is without the FF veto, comparing with the true MC.
The difference is because the selections were applied:

- Good electron selections:
  - Leading cluster (new algorithm).
  - Energy calibration is ~ 4.5%
  - Select 150 mm < 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 L on the t reco. (e.g., $-t = -(\boldsymbol{p}_{A',corr} - \boldsymbol{p}_A)^2$)

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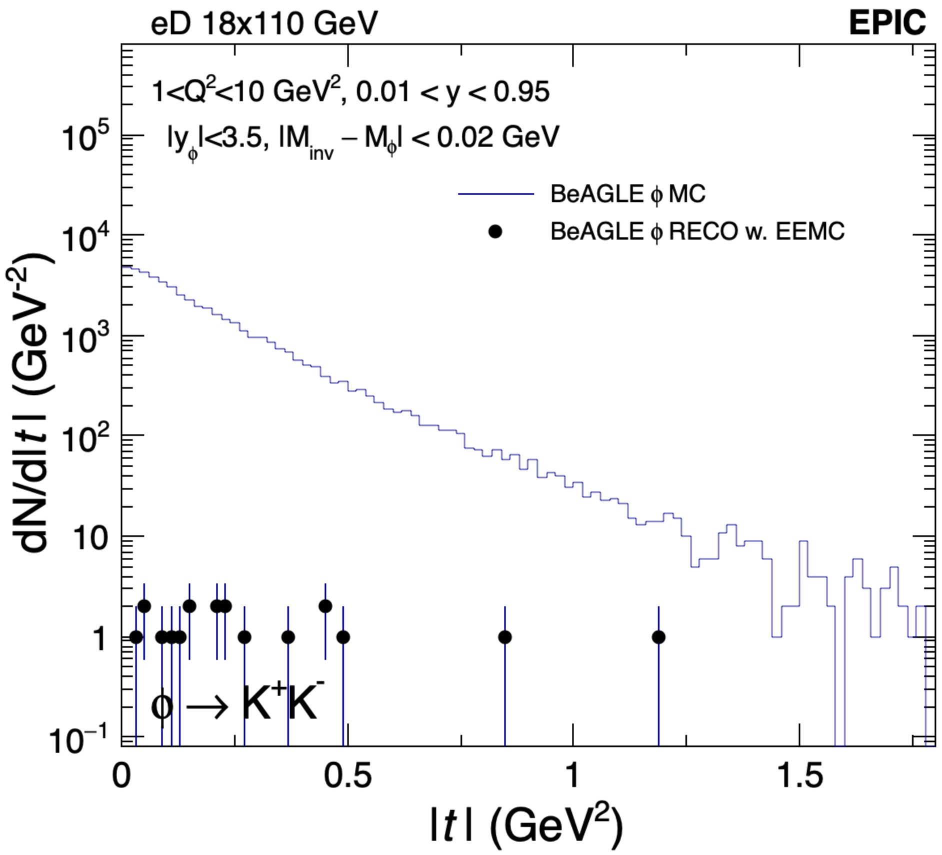

We found the problem of too much vetoing… and Alex has found that it may relate the world material = "Air"

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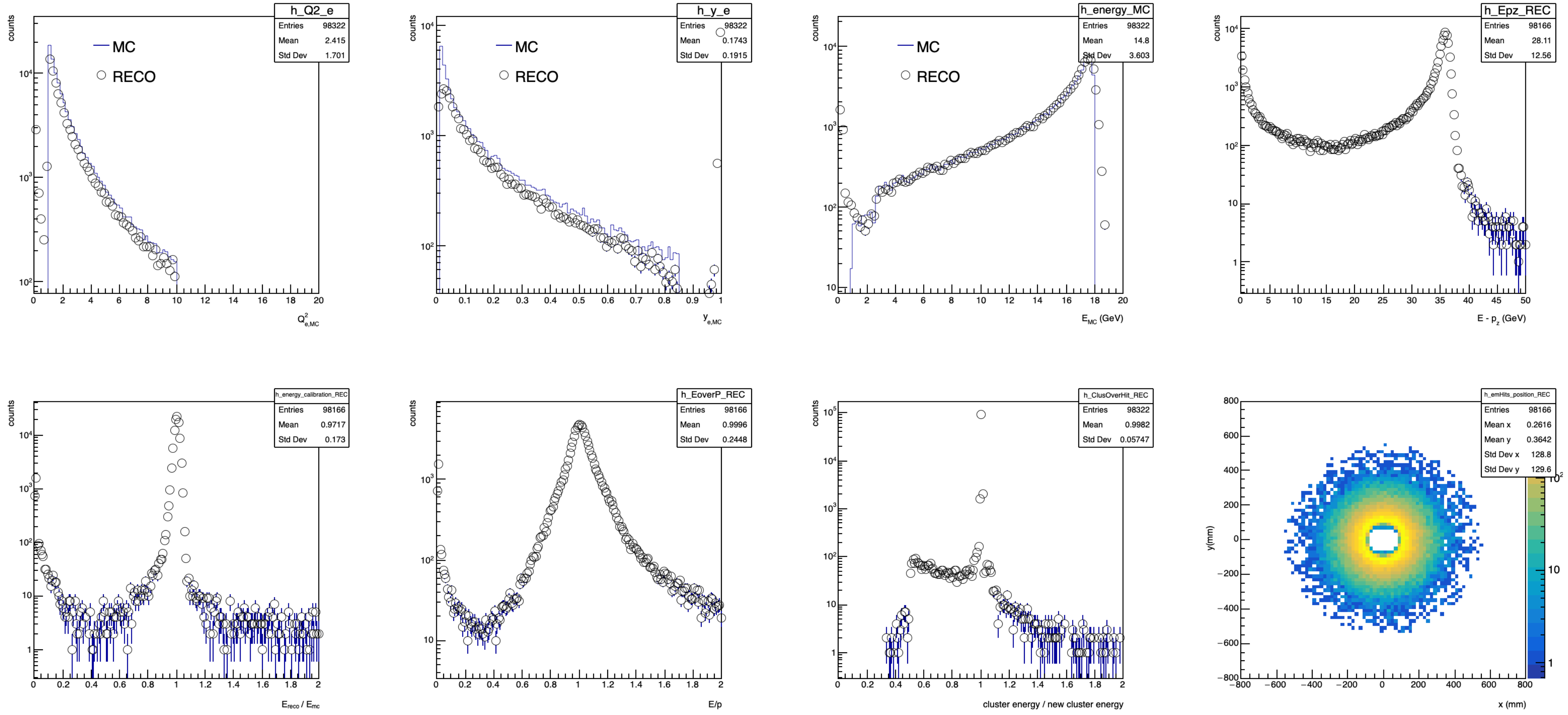
ePIC full simulation [Aug 17-Sep 11, 2023]

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

Some DIS control plots [Sep 11]



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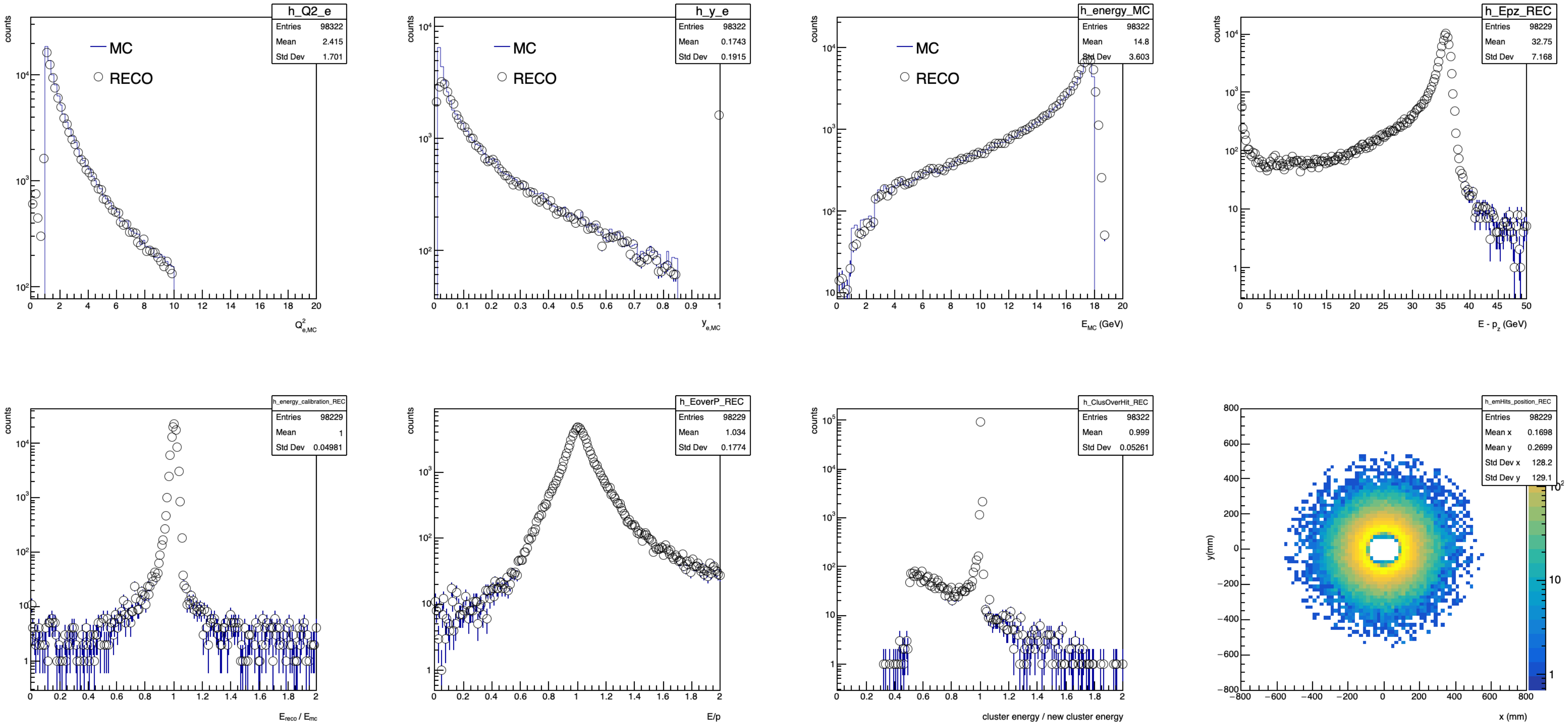
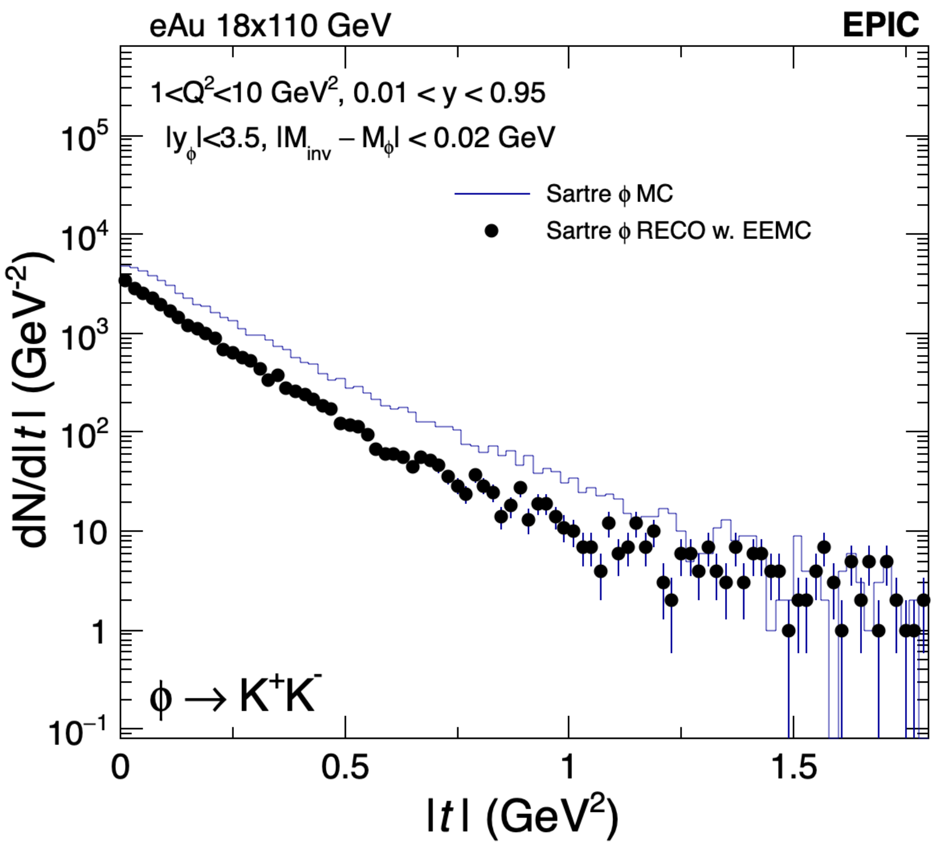
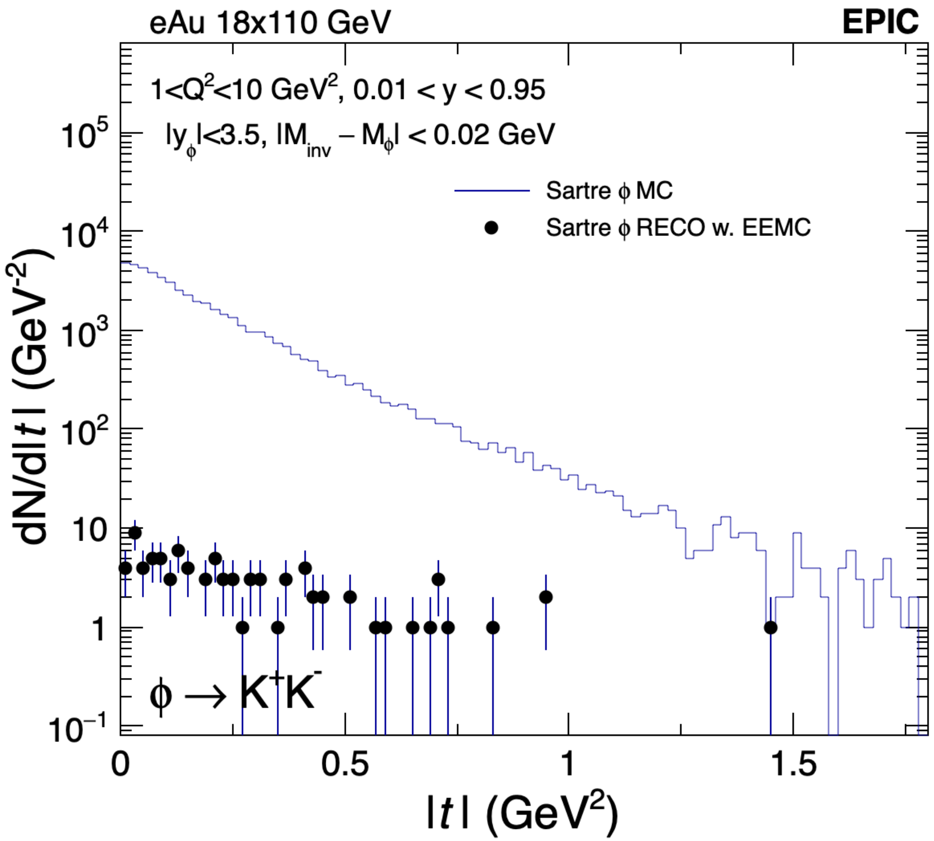


t-distribution with ePIC_full [Sep 11 version]



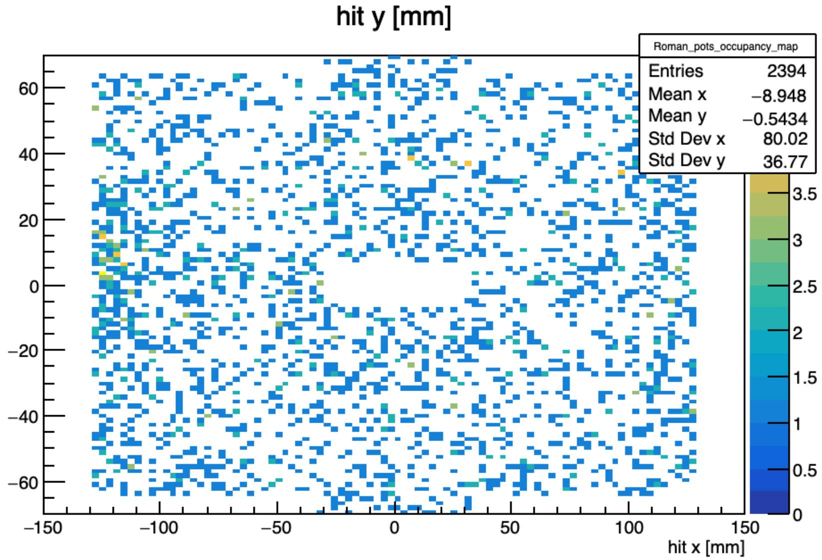
- All cuts are the same as previous slide.
- This is before veto.
- The reco part seems to be shifted a little lower, which should be related to our E-pz cut.

t-distribution with ePIC_full [Sep 11 version]

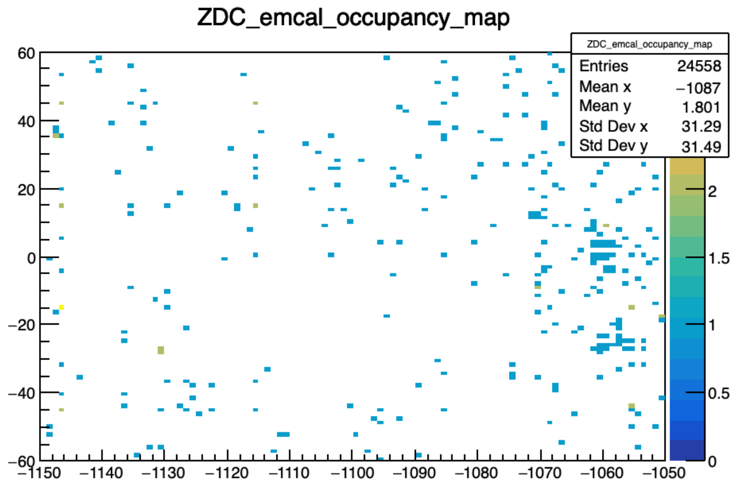


- All cuts are the same as previous slide.
- This is with veto.
- Finally, the vetoing performance seems to make **more** sense now, BUT realistically, it may be worse than this.
- We have about 100 to 15 times of reduction power, starting from low to high t.

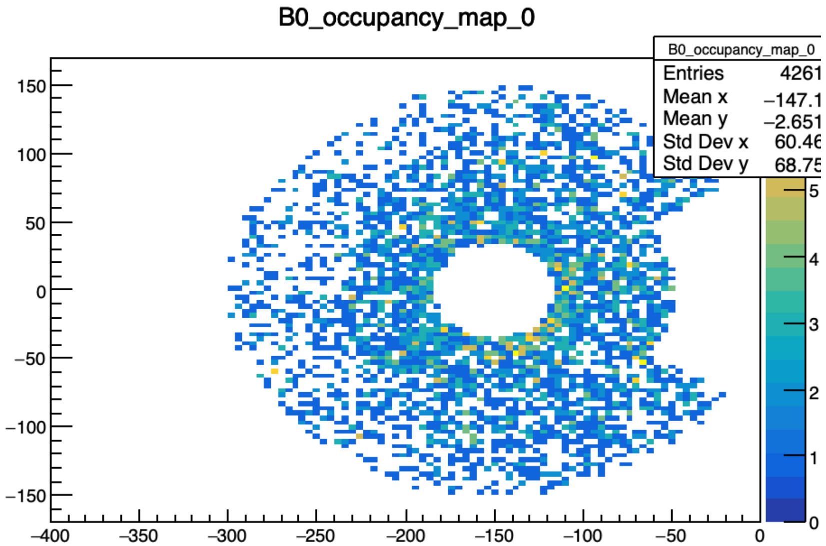
Some technical details - Every FF detector has hits.



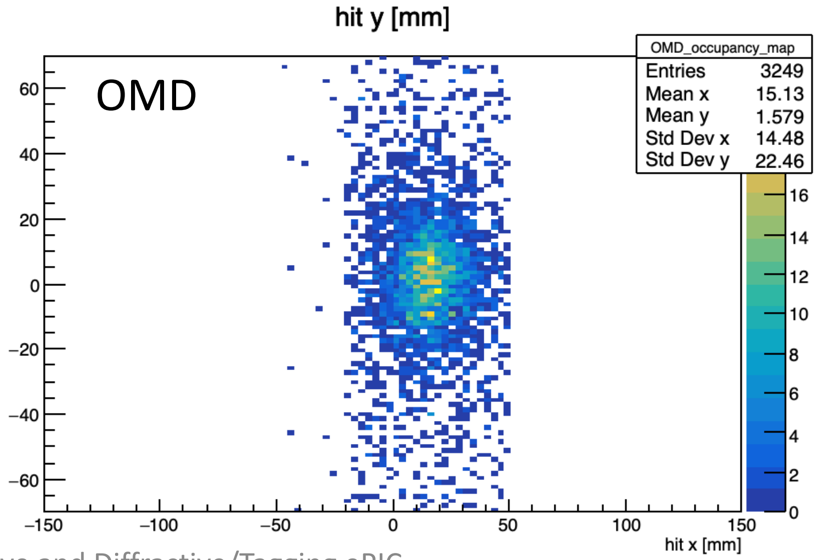
RP



ZDC



(B0, there are 4 layers)



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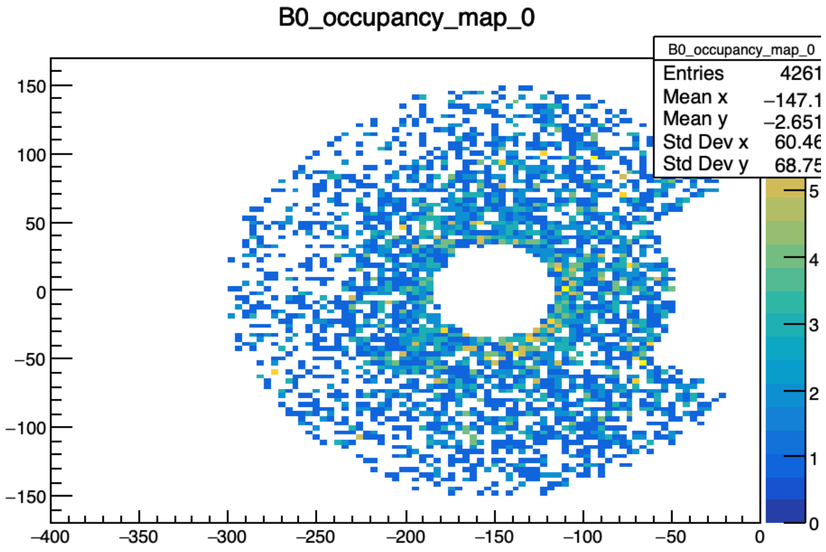

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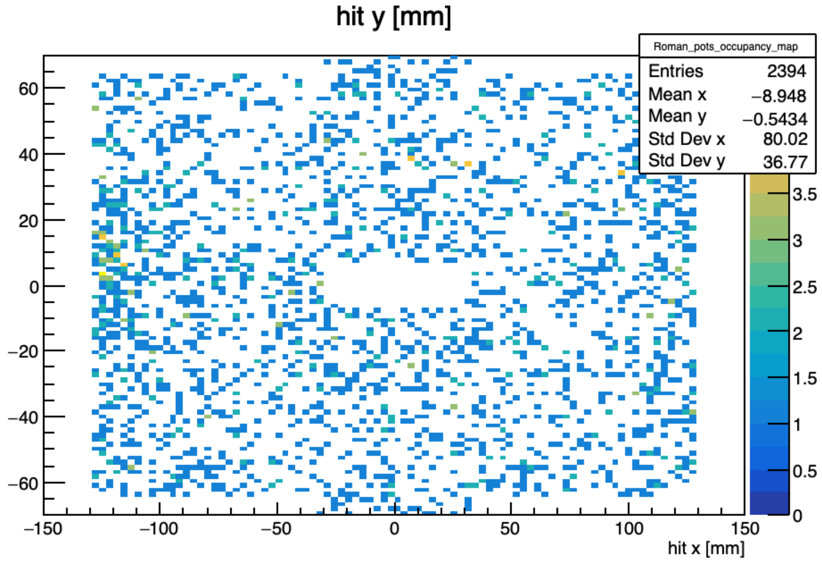
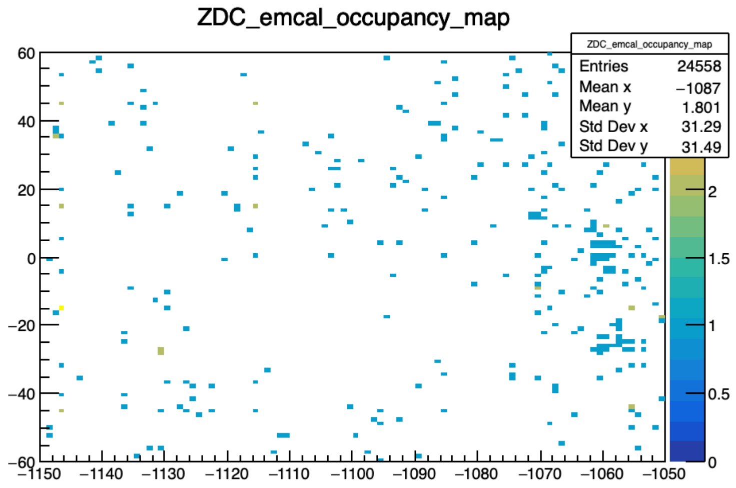


RP



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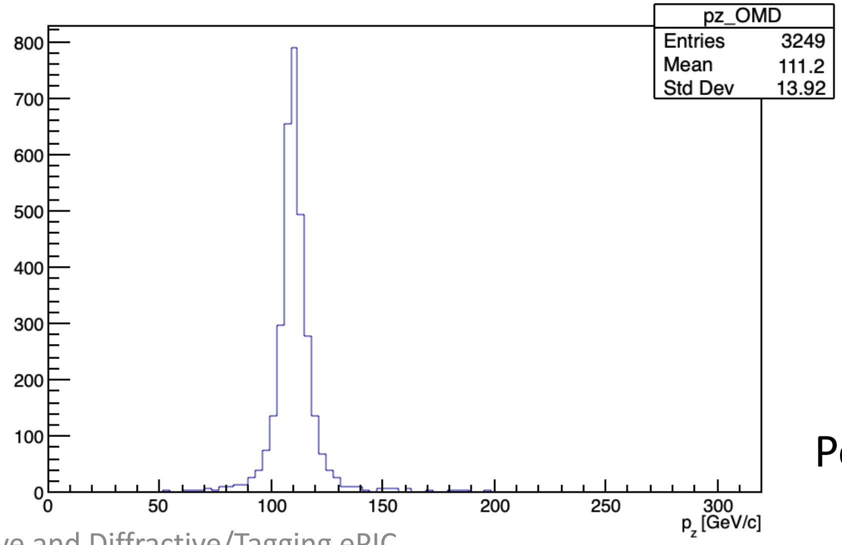
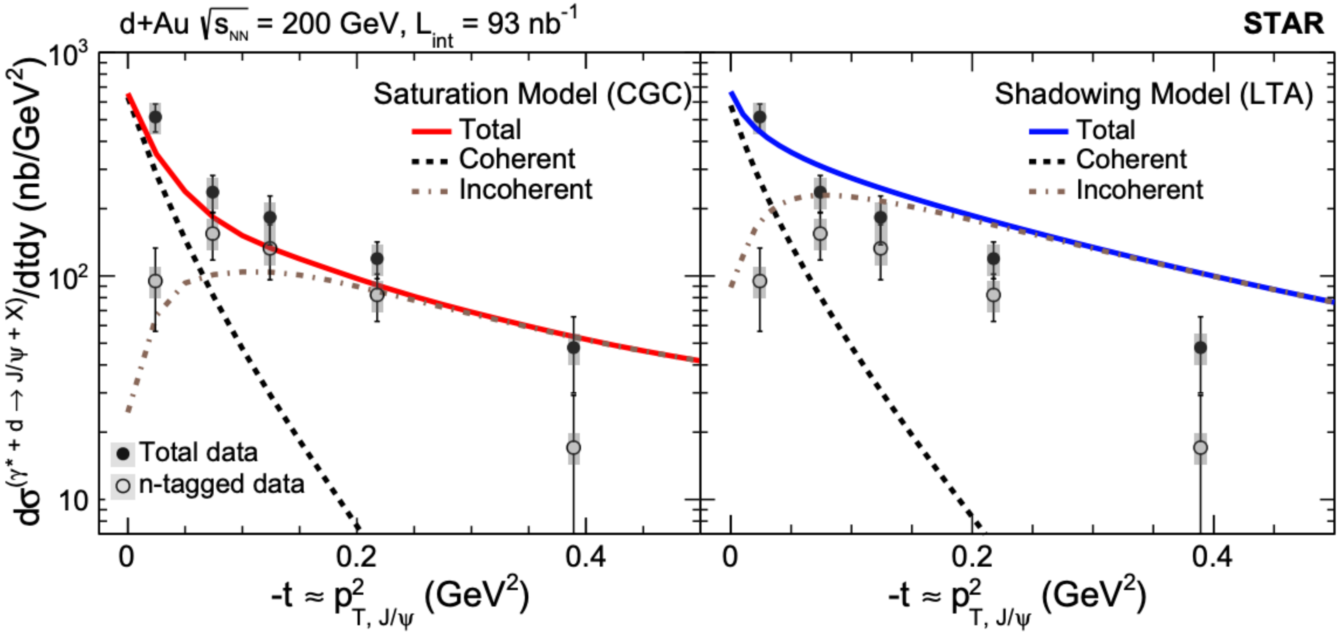


Peaked at 110 GeV/c

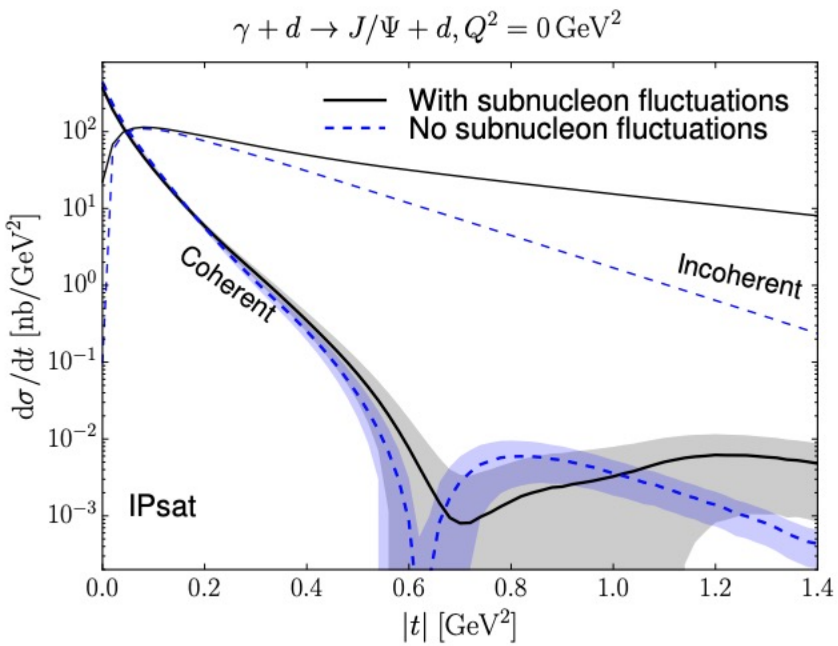
How much do we need?

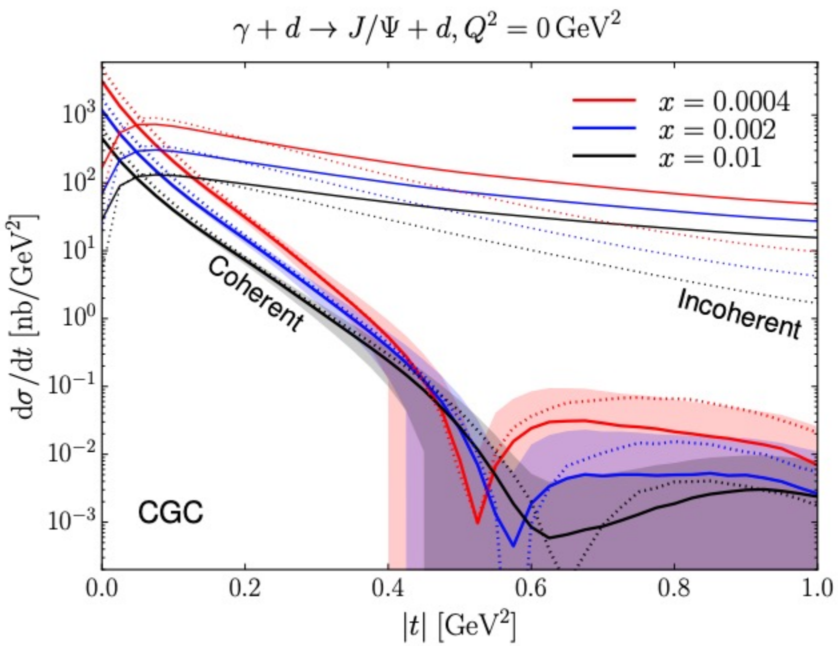


Phys. Rev. Lett. 128 (2022) 12, 122303

- At about -t ~ 0.2 GeV^2 , one needs about > 10 in reduction power.
- It seems like we can cover the low-t part of the coherent measurement via incoherent vetoing?

Predictions at the EIC





For the smallest and simplest nuclei - deuteron:

- t = [0 - 0.25] GeV^2, incoherent vetoing
- t = [0.25, 1.0] GeV^2, coherent tagging?

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

Summary

- In this study, We have done a first look at how deuteron breakup can be vetoed using the ePIC detector.
- Similar studies are being done by [Michael, Eden, et al.] on the heavy nuclei, and maybe there are other studies.
- We can have people who want to do some other nuclear species, e.g., medium A to see the performance.
- A few of us are trying to study – "*A general veto program at ePIC for exclusive physics*"

Physics Benchmark – eAu diffractive Phi

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