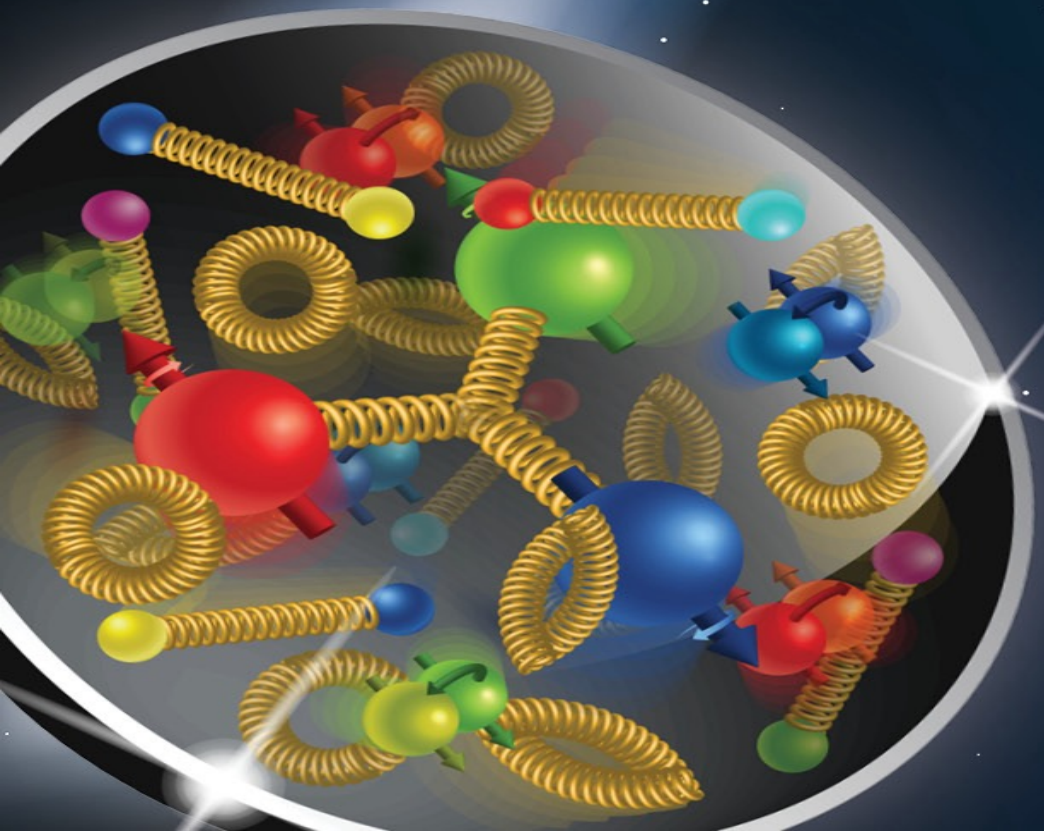

Overview of ZDC Requirements for the EIC

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ePIC TIC Meeting
October 9th, 2023

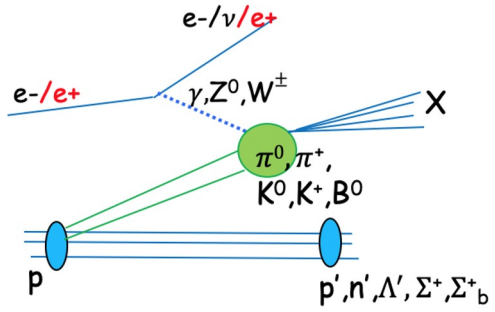
BROOKHAVEN NATIONAL LABORATORY
Jefferson Lab
U.S. DEPARTMENT OF ENERGY | Office of Science

Basic “Requirements”

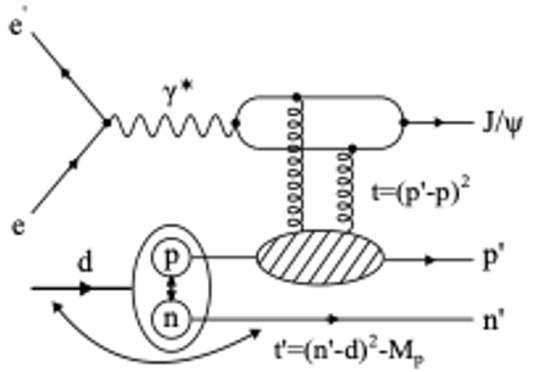
- ZDC requirements were put together prior to the Yellow Report, and before any comprehensive study of the physics was really put together.
  - Hadronic energy resolution: $\frac{\sigma_E}{E} \leq \frac{50\%}{\sqrt{E}} \oplus 5\%$
  - EM energy resolution: $\frac{\sigma_E}{E} \leq \frac{25\%}{\sqrt{E}} \oplus 2\%$
  - Soft photon sensitivity for $E \sim 100$ MeV
  - Sufficient dynamic range for energy deposits from breakup of heavy nuclei (several neutrons with $E \sim 110$ GeV
  - Sufficient granularity to provide angular resolution for pT reconstruction: $\frac{\sigma_\theta}{\theta} \leq \frac{3\,mrad}{\sqrt{E}}$
- ZDC acceptance: θ < 5mrad (not ϕ-symmetric) – driven by aperture, not detector.

(some) Physics channels relying on ZDC

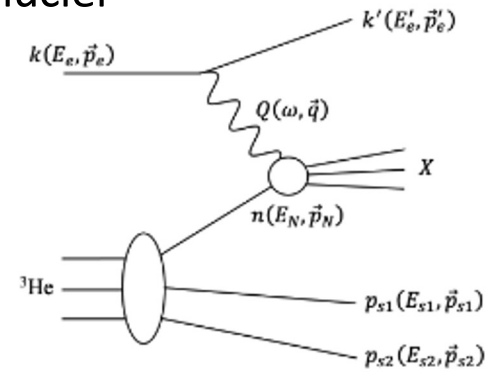
Sullivan process



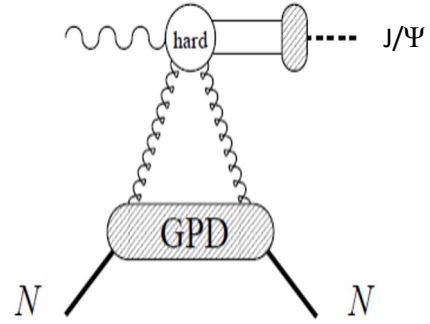
e+d exclusive J/Psi with p/n tagging



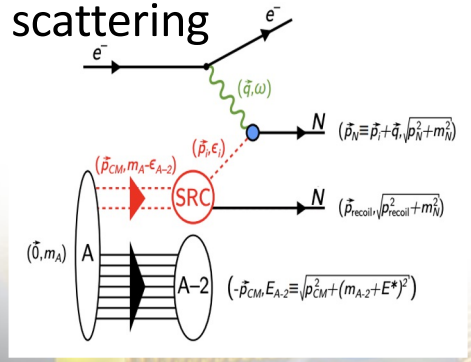
spectator tagging in light nuclei



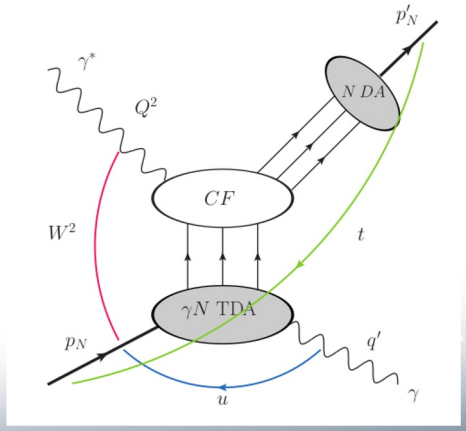
coherent/incoherent J/ψ production in e+A



Quasi-elastic electron scattering

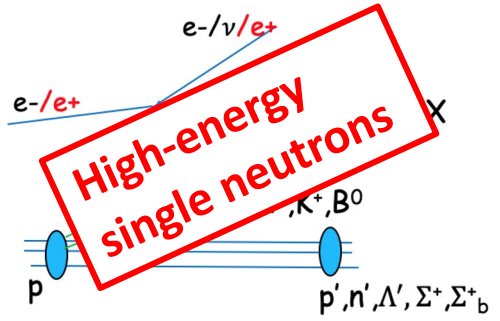


u-channel backward exclusive electroproduction



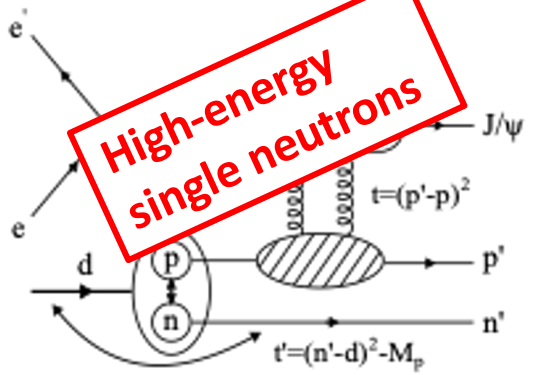
(some) Physics channels relying on ZDC

Sullivan process



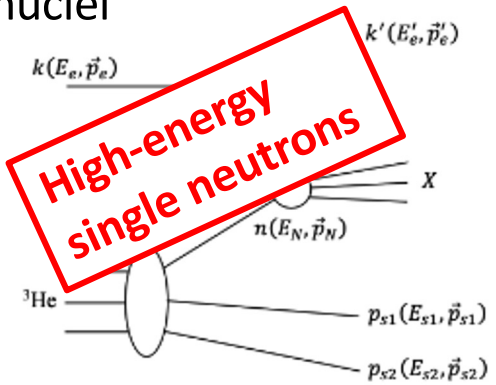
High-energy single neutrons

e+d exclusive J/Psi with p/n tagging



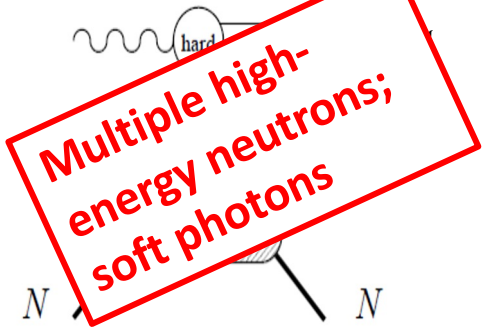
High-energy single neutrons

spectator tagging in light nuclei



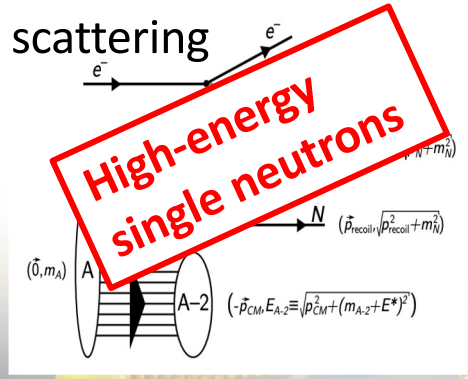
High-energy single neutrons

coherent/incoherent J/ψ production in e+A



Multiple high-energy neutrons; soft photons

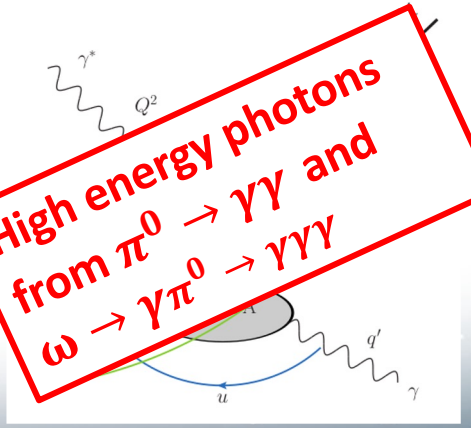
Quasi-elastic electron scattering



High-energy single neutrons

- In every case, we will only have *one* of the possible final state options (e.g. either neutrons or photons, not both).

u-channel backward exclusive electroproduction



High energy photons from $\pi^0 \rightarrow \gamma\gamma$ and $\omega \rightarrow \gamma\pi^0 \rightarrow \gamma\gamma\gamma$

Some examples

- Soft photon tagging important for vetoing of incoherent e+A events (about 3.25% of events produce *only* soft photon).

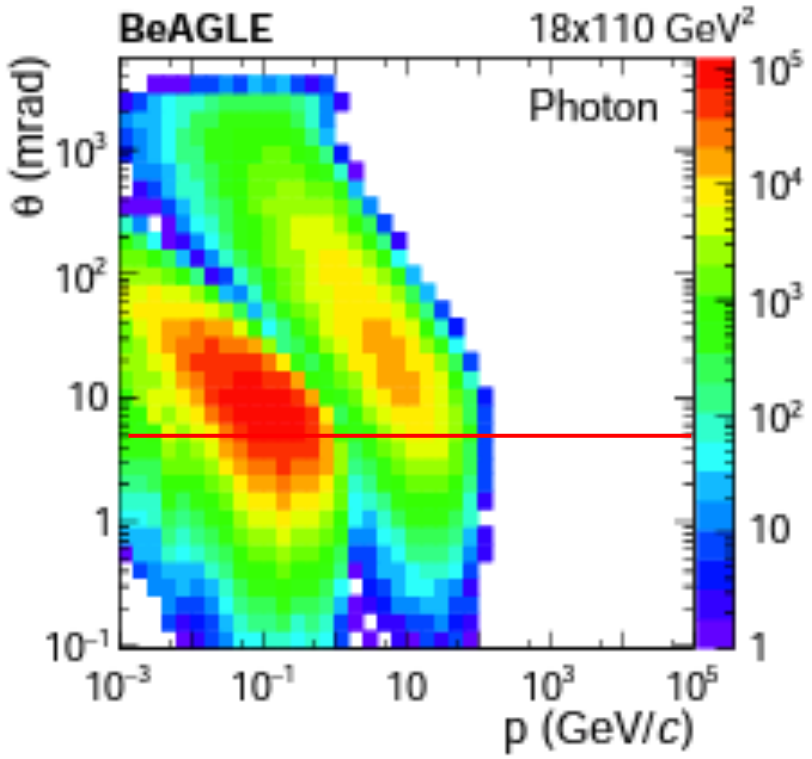
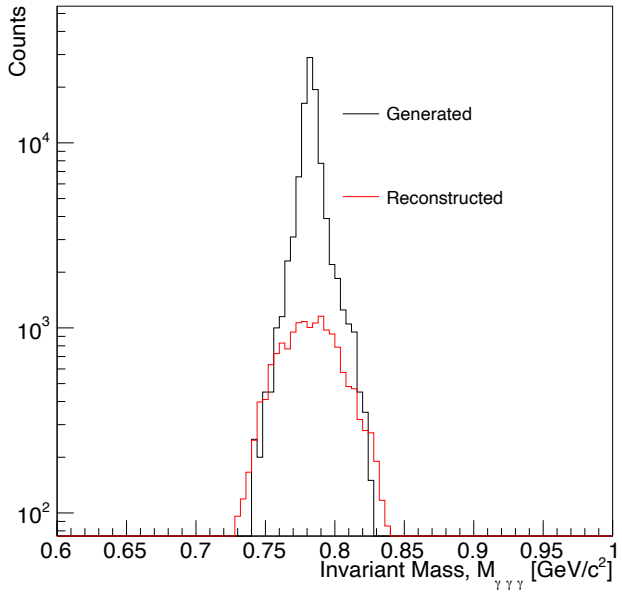
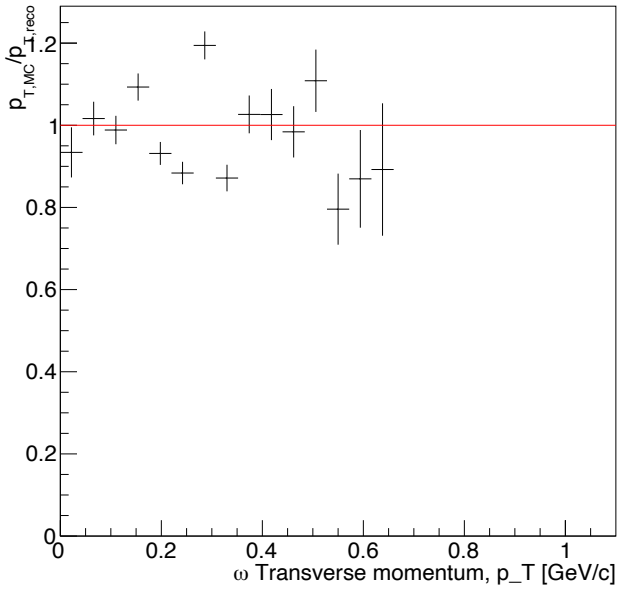


Figure from: W. Chang, E.C. Aschenauer, M. D. Baker, A. Jentsch, J.H. Lee, Z. Tu, Z. Yin, and L.Zheng, Phys. Rev. D **104**, 114030 (2021)

- Backward u-channel ω production.



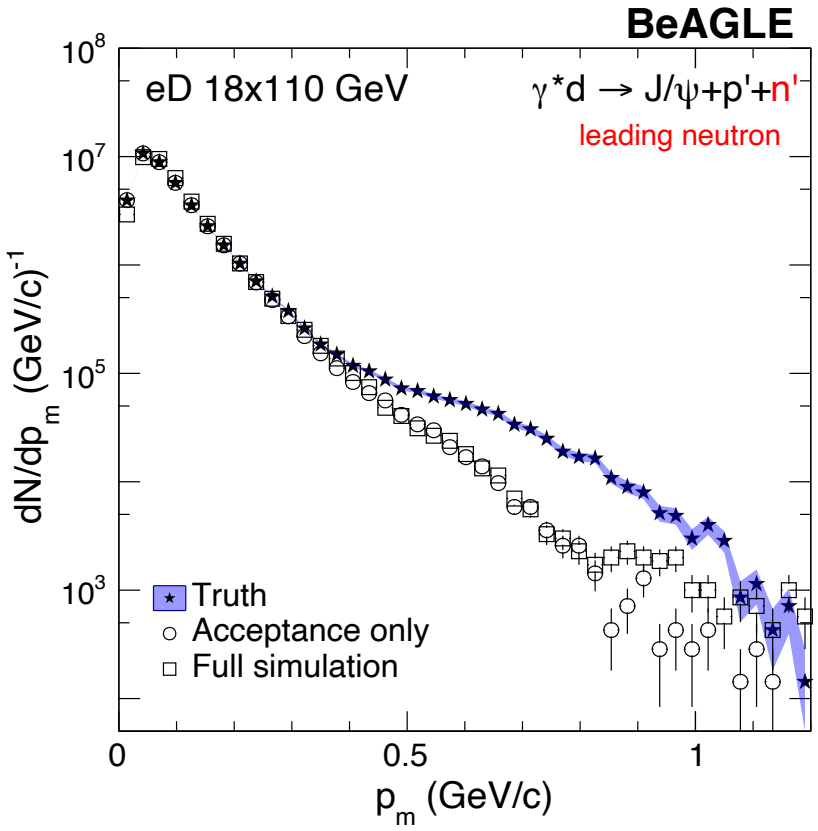


- Study performed with STARLIGHT events using EICROOT.
- Final state: $\omega \rightarrow \gamma\pi^0 \rightarrow \gamma\gamma\gamma$ (ZDC acceptance ~ 16%)
- Study assumed $\frac{\sigma_E}{E} \leq \frac{10\%}{\sqrt{E}} \oplus 3\%$ and $\frac{\sigma_\theta}{\theta} \leq \frac{1\,mrad}{\sqrt{E}}$

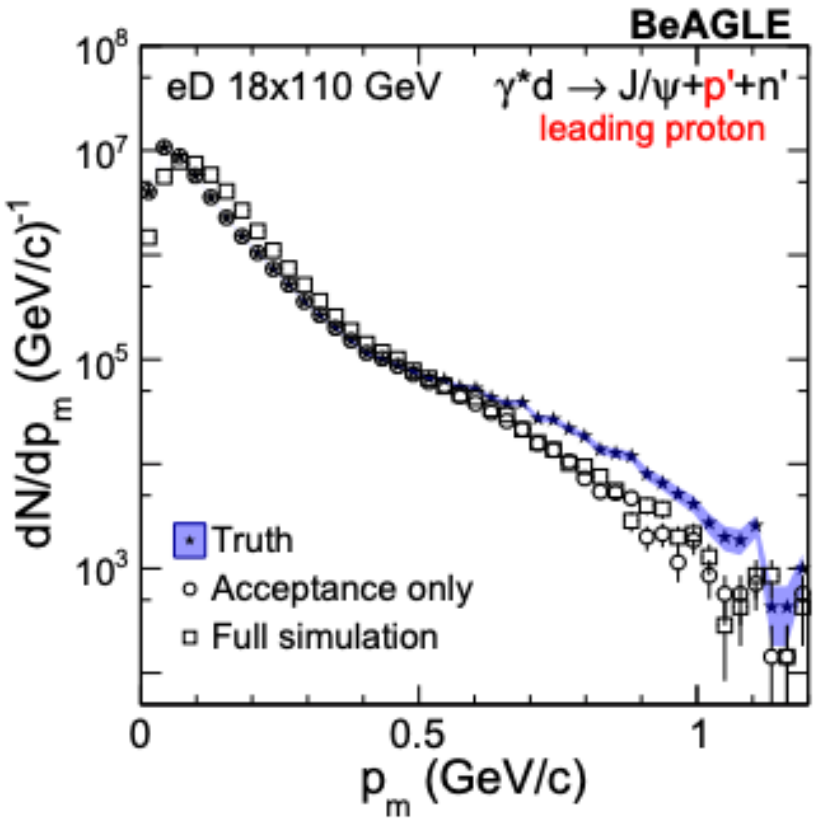
Some examples

From: Z. Tu, A. Jentsch *et al.*, Phys. Lett. B, **811** (2020)

- e+d spectator tagging to study short-range correlations.



Proton spectator from OMD.



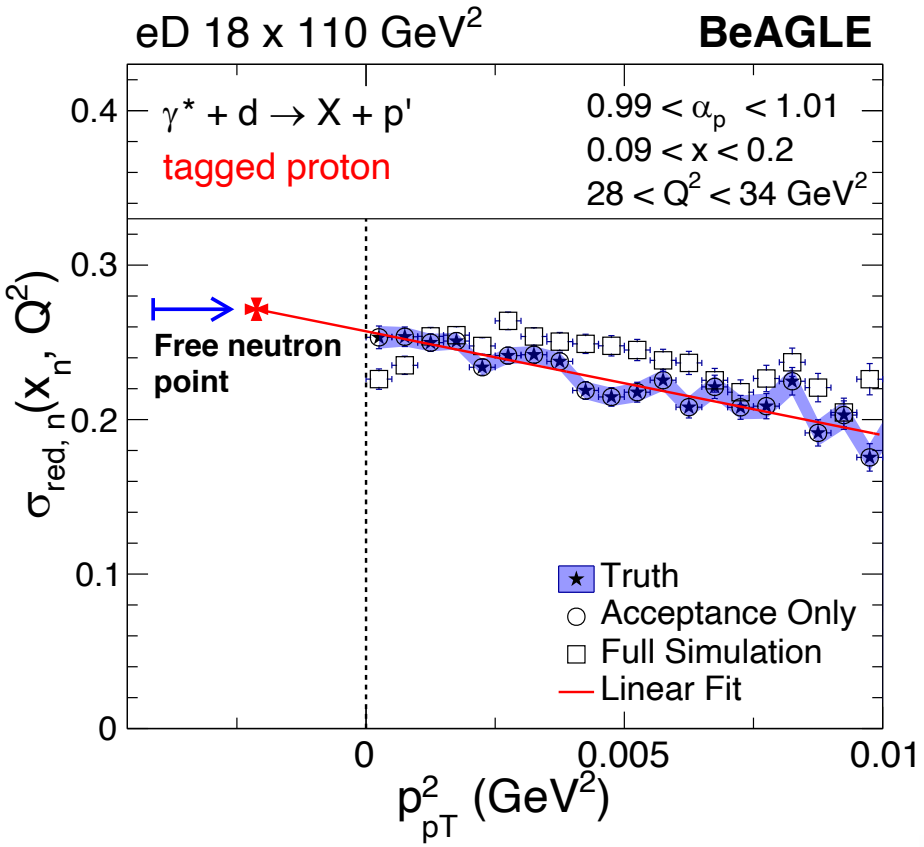
Neutron spectator from ZDC.

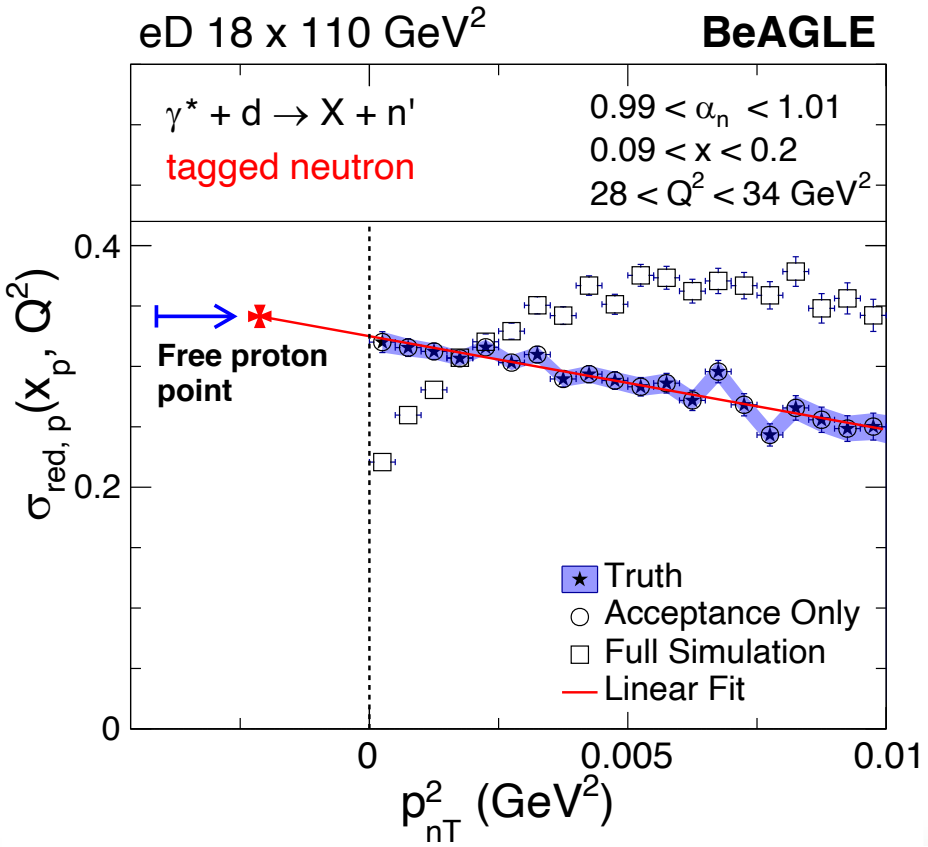
Assuming $\frac{\sigma_E}{E} \leq \frac{50\%}{\sqrt{E}} \oplus 5\%$ and $\frac{\sigma_\theta}{\theta} \leq \frac{3\ mrad}{\sqrt{E}}$

Some examples

From: A. Jentsch, Z. Tu, and C. Weiss, Phys. Rev. C **104,** 065205, (2021)

- e+d spectator tagging to study neutron structure functions.





Baseline ZDC assumption is problematic here – would benefit from improved neutron energy and angular resolution.

Proton spectator from OMD.

Neutron spectator from ZDC.

Assuming $\frac{\sigma_E}{E} \leq \frac{50\%}{\sqrt{E}} \oplus 5\%$ and $\frac{\sigma_\theta}{\theta} \leq \frac{3\ mrad}{\sqrt{E}}$

To summarize

- Original ZDC assumptions were put in-place prior to the YR with a less well-developed physics program.
  - Studies simply assumed that baseline performance.
  - They represent the bare-minimum of what we need to study exclusive EIC physics channels with neutral final-states.
- This is the time to look at our technology for this subsystem and do a final optimization of the performance to ensure maximum physics capability for the money.
  - This includes the EMCAL and HCAL technologies, longitudinal layout to maximize energy compensation via hardware (can also be improved in software), and granularity.