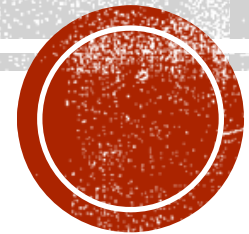


Exclusive Meeting — Deuteron Tagging

Jan Vanek

University of New Hampshire

11/24/2025

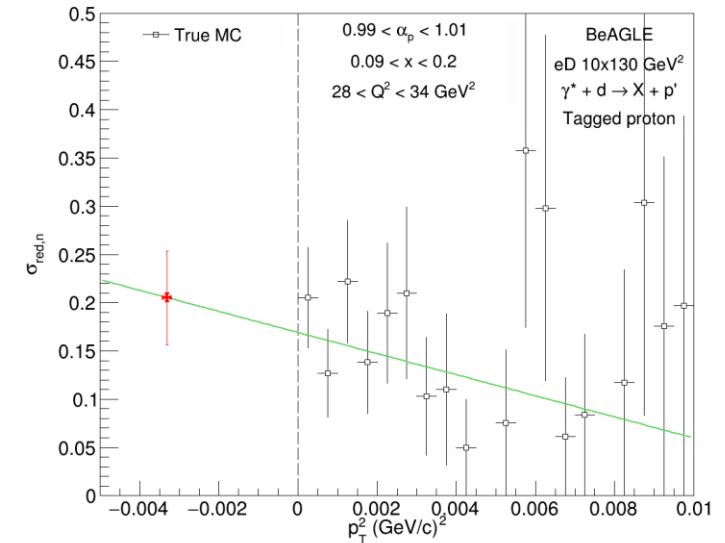
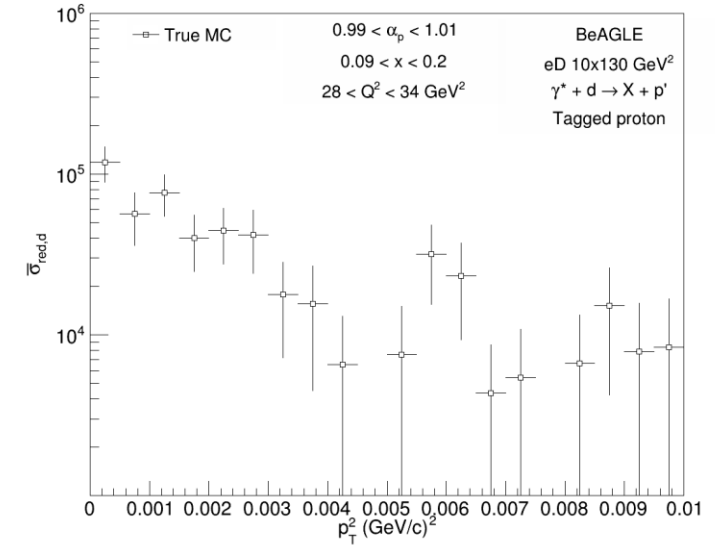


OVERVIEW

- Extraction of deuteron and neutron reduced cross section from HepMC and **EICRecon** simulation output
 - True MC information, without any beam or detector effects
 - Simulation setup:
 - eD DIS events at $10 \times 130 \text{ GeV}^2$ (simulation by Alex)
 - Scattering on neutron, tagging of protons
 - Goal:
 - Reproduction of deuteron reduced cross section from A. Jentsch, Z. Tu, C. Weiss: [Phys. Rev. C 104, 065205](#)
- Today:
 - Fixed x calculation
 - Fixed typo in the code with swapped x_{deuteron} and x_{nucleon}
 - New kinematic binning
 - Optimization for the new simulation
 - Added framework that uses MC information from EICRecon

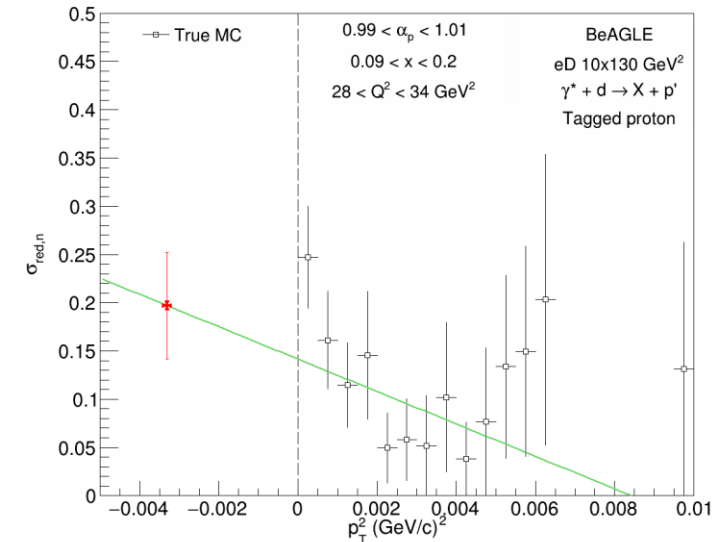
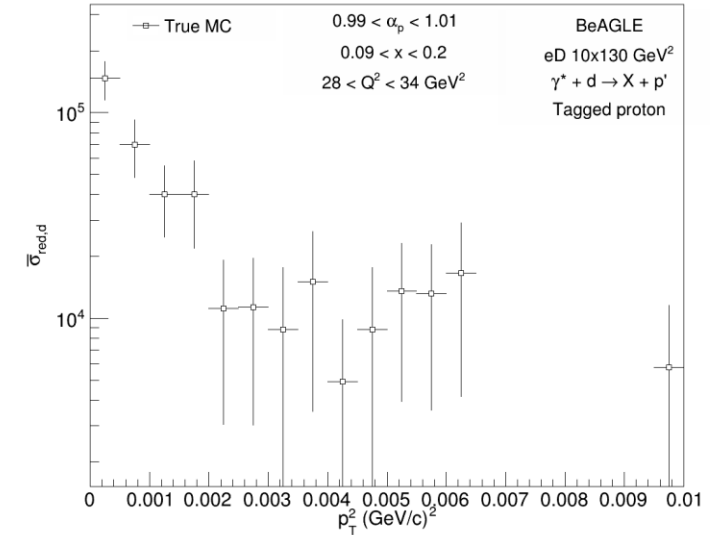
ORIGINAL VERSION WITH NUCLEON χ

- (top) Deuteron reduced cross section using tagged protons
- (bottom) Neutron reduced cross section using tagged protons
- Original version, with typo in the code
 - Using nucleon χ



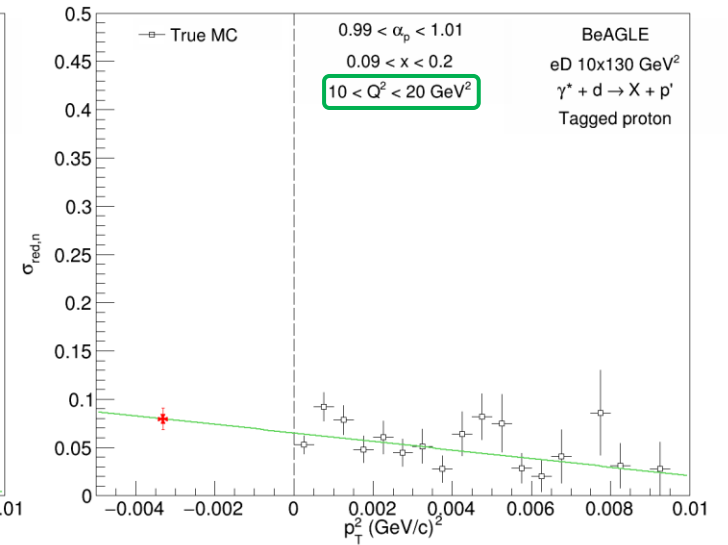
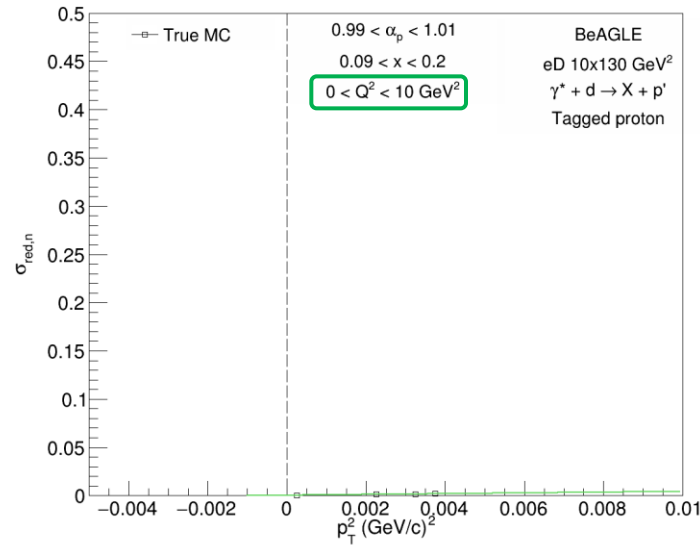
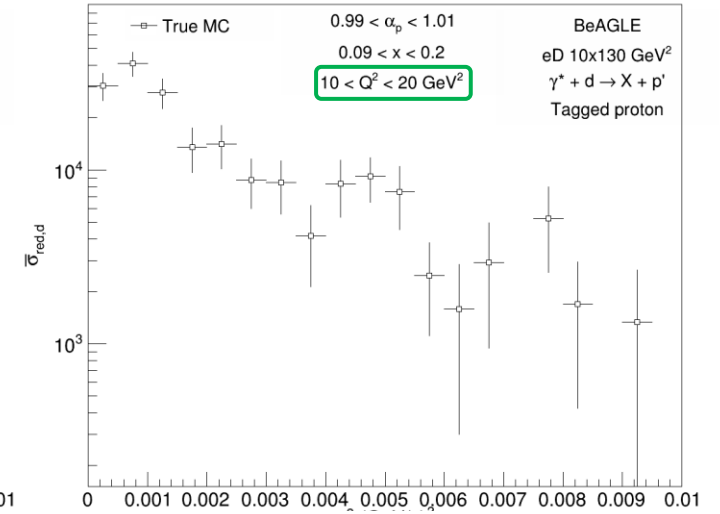
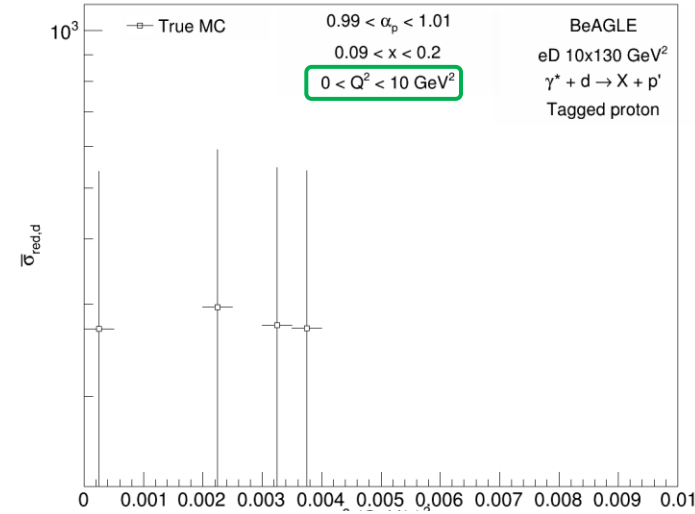
ORIGINAL VERSION WITH DEUTERON x

- (top) Deuteron reduced cross section using tagged protons
- (bottom) Neutron reduced cross section using tagged protons
- New version, with fixed typo
 - Using deuteron x
- Framework still appears to work
 - Within errors with the limited statistics



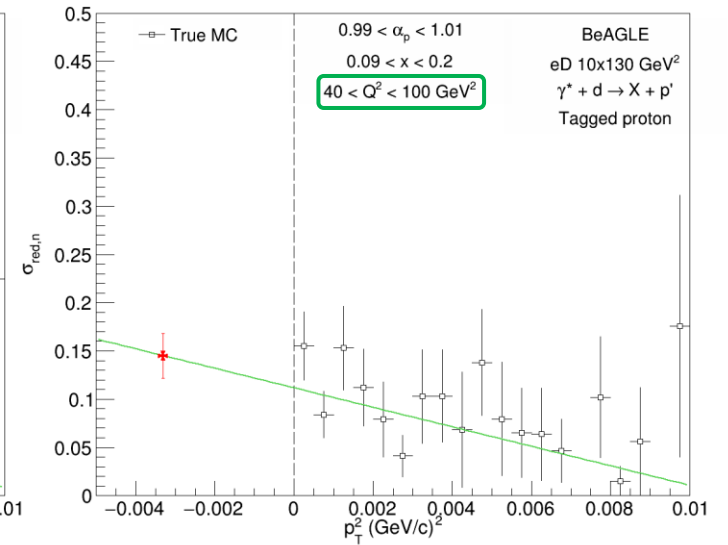
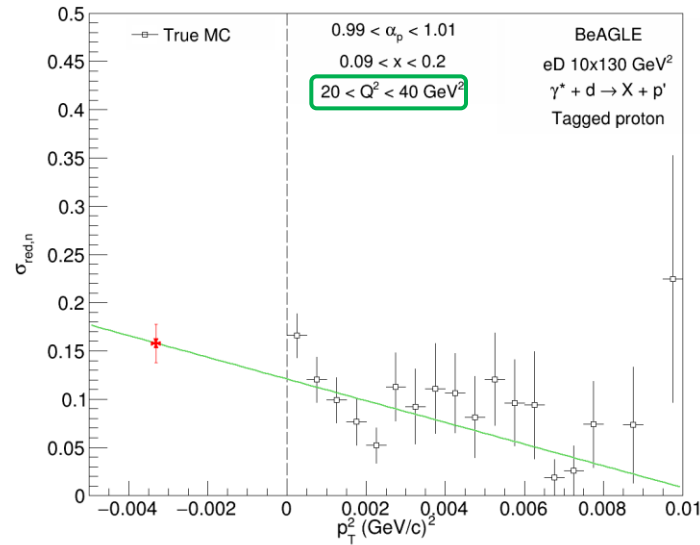
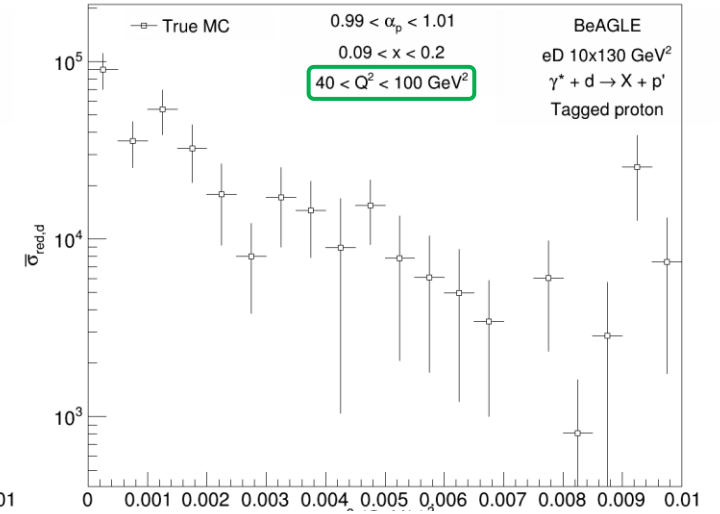
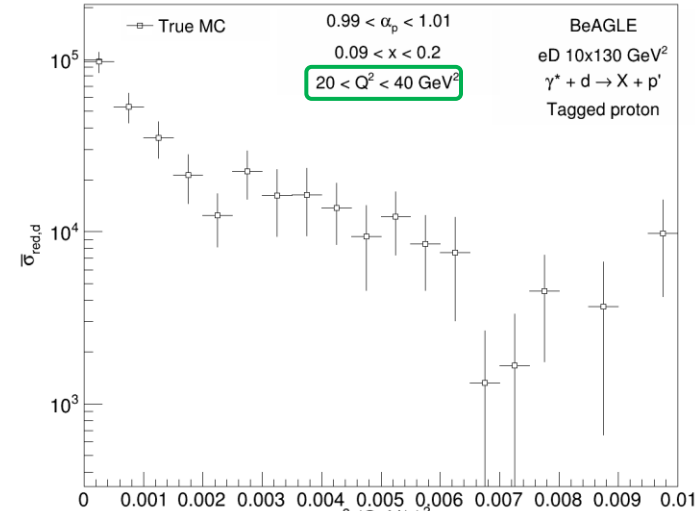
NEW BINNING

- New binning in Q^2 optimized for the new simulation
 - True MC from HepMC output



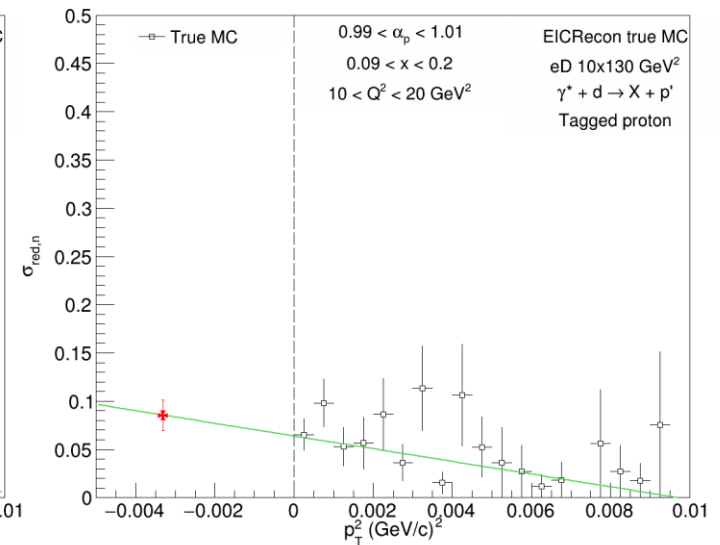
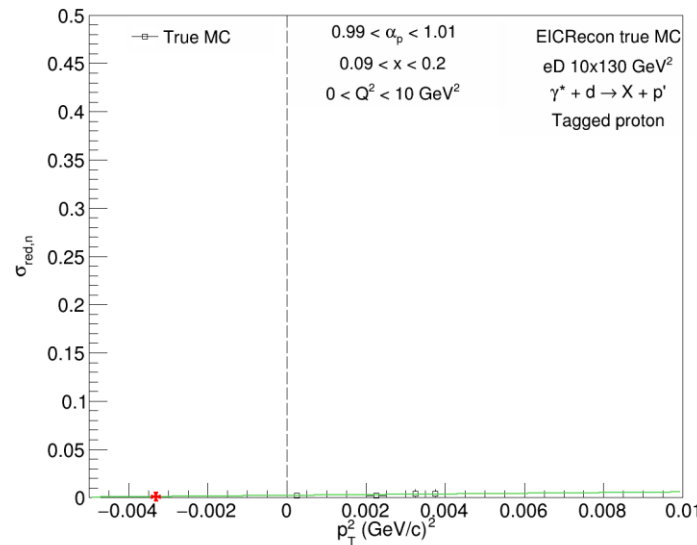
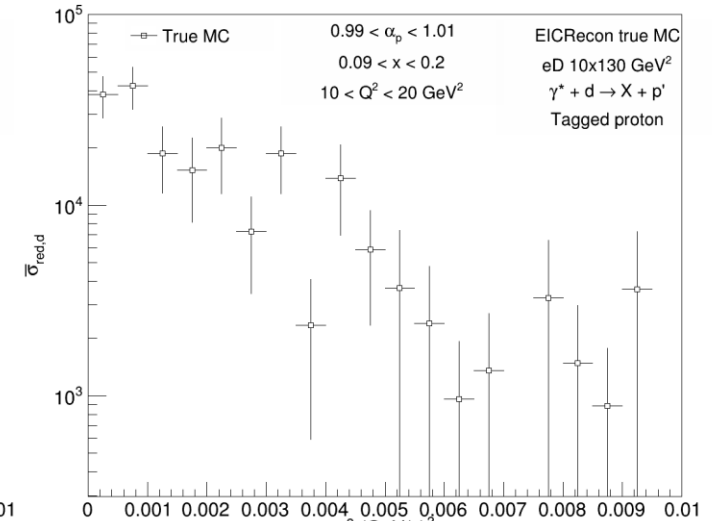
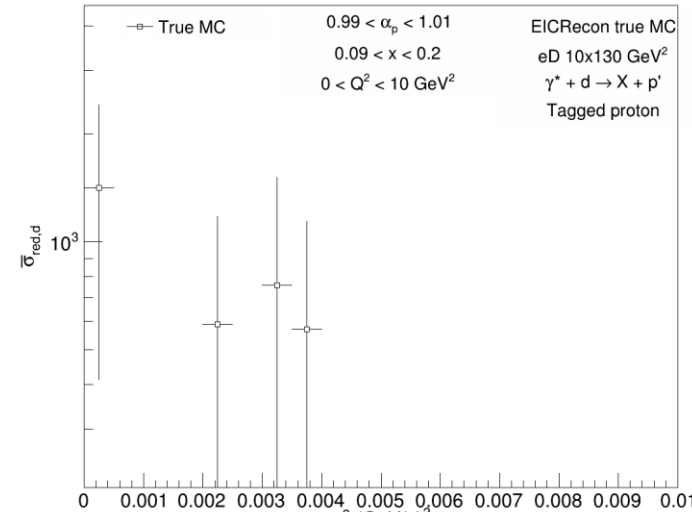
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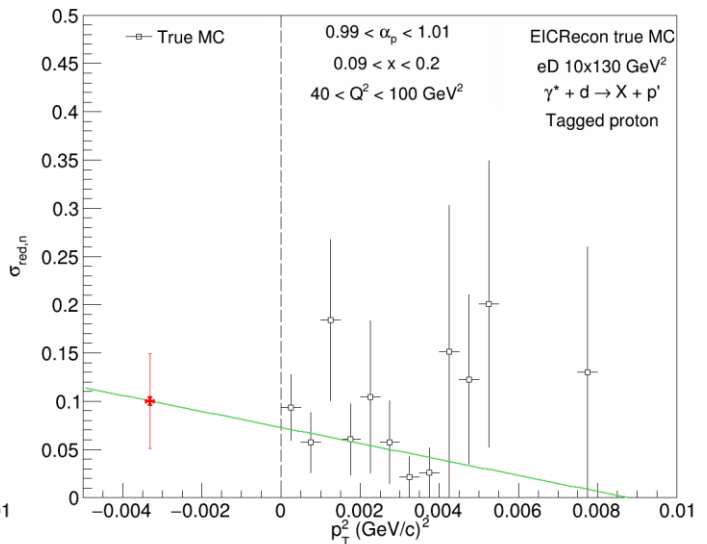
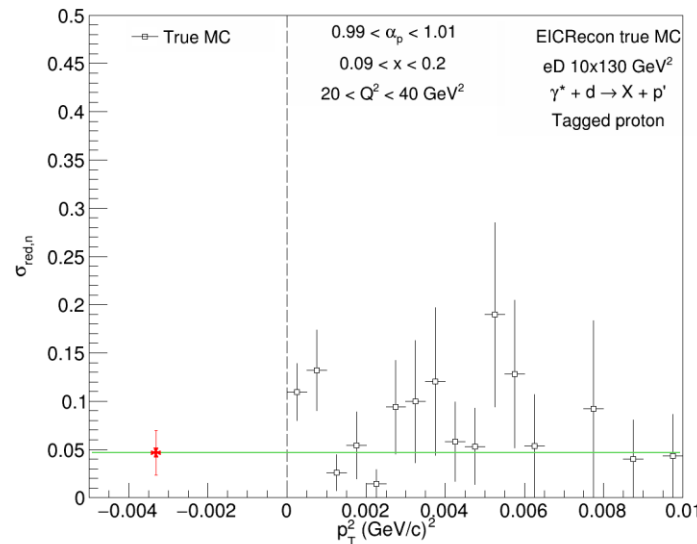
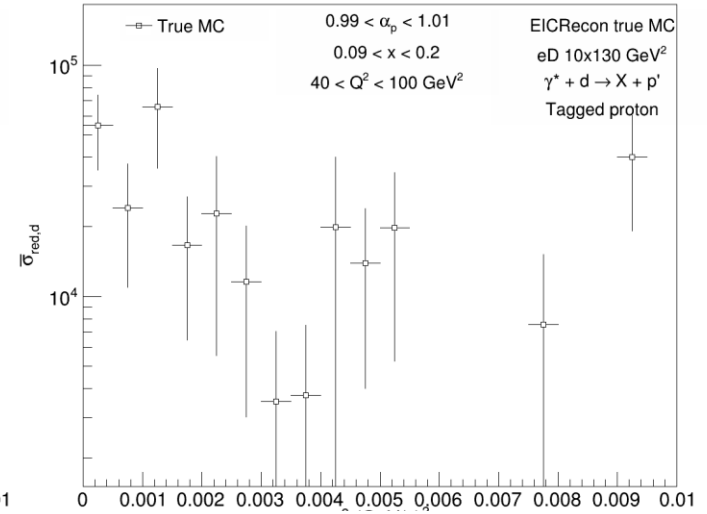
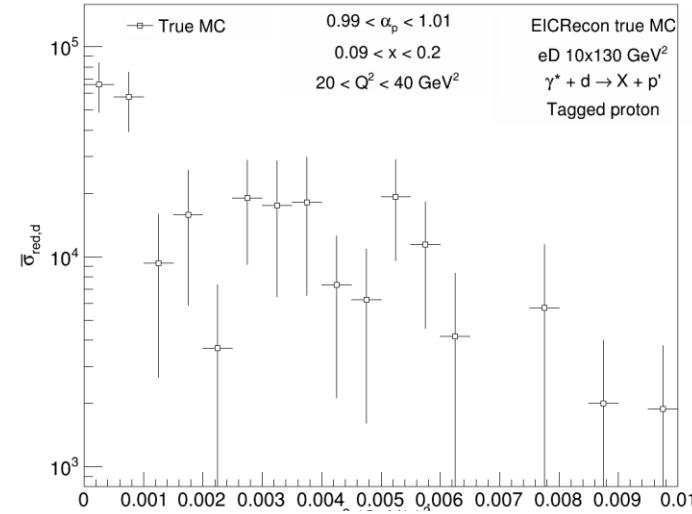
MC IN EICrecon

- MC information from EICRecon for the same underlying HepMC simulation
 - True MC information, without and beam effects and crossing angle
 - MCParticlesHeadOnFrameNoBeamFX
- Framework in EICRecon seems to be working
- See difference compared to HepMC output
 - Lower number of accepted events with EICRecon
 - Origin of difference currently being investigated
- New binning in Q^2 optimized for the new simulation
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SUMMARY AND OUTLOOK

- Fixed x calculation
- New binning in Q^2 optimized for the new simulation
- Implemented full framework for output from EICRecon
 - True MC only for now
- Result appears consistent with previously published result
 - Published result from A. Jentsch, Z. Tu, C. Weiss: [Phys. Rev. C 104, 065205.](#)
 - Notes:
 - This study and published results at different energy
 - Statistics of current MC is low
- To-do/outlook:
 - Cross-checks of framework with EICRecon output
 - Understanding of difference between reading HepMC directly and accessing MC information from EICRecon
 - Adding RC level information
 - Later, as it likely requires full efficiency and acceptance correction



BACKUP

DEUTERON REDUCED CROSS SECTION

- Differential cross section on d can be written in terms of deuteron reduced cross ($\sigma_{red,d}$) section and photon flux:

$$d\sigma_d = Flux(x, Q^2) \times \sigma_{red,d} \times \frac{dx}{2} dQ^2 \frac{d\phi_{e'}}{2\pi} [2(2\pi)^3]^{-1} \frac{d\alpha_p}{\alpha_p} \frac{dp_{T,p}^2}{2} d\phi_p$$

- Photon flux:

$$Flux(x, Q^2) = \frac{2\pi\alpha_{em}^2 y^2}{Q^4(1-\epsilon)x} = \frac{2\pi\alpha_{em}^2 [1+(1-y)^2]}{Q^4 x}$$

- Deuteron reduced cross section

$$\sigma_{red,d} = \frac{1}{Flux} \frac{d\sigma_d}{dx dQ^2 (d\phi_{e'}/2\pi) d\Gamma_p}, \text{ where } d\Gamma_p = [2(2\pi)^3]^{-1} \frac{d\alpha_p}{\alpha_p} \frac{dp_{T,p}^2}{2} d\phi_p$$

- Measured reduced cross section (integrated over $d\phi_p$)

$$\bar{\sigma}_{red,d} = \left(\frac{2.568}{L_{int}} \right) \frac{Q^4 x}{2\pi\alpha_{em}^2 [1+(1-y)^2]} \frac{[4(2\pi)^3] \alpha_p}{\Delta\alpha_p} \frac{dN}{\Delta x \Delta Q^2 \Delta p_{T,p}^2}$$

- $\Delta x, \Delta Q^2, \Delta p_{T,p}^2, \Delta\alpha_p$ are bin widths

- Scattered electron
- Spectator proton + struck deuteron
- Photon flux

A. Jentsch, Z. Tu, C. Weiss: [Phys. Rev. C **104**, 065205.](#)
 M. Strikman and C. Weiss: [Phys. Rev. C **97**, 035209.](#)
 C. Weiss and W. Cosyn: [Phys. Rev. C **102**, 065204.](#)

- Full azimuthal coverage for electron
 - $(\Delta\phi_{e'}/2\pi) = 2\pi/2\pi = 1$
- Full azimuthal coverage for spectator
 - $\Delta\phi_p = 2\pi$
 - We are also integrating over full 2π

POLE EXTRAPOLATION METHOD

- $\sigma_{red,n} = \frac{\bar{\sigma}_{red,d}(x, Q^2)}{[2(2\pi)^3]S_d(p_{pT}, \alpha_p)[pole]}$
- $\bar{\sigma}_{red,n}$ at the pole corresponds to a free n
 - $p_{pT}^2 \rightarrow -a_T^2$ which means negative (unphysical) p_{pT}^2
- Solution is to experimentally measure $\sigma_{red,n}$ as a function of p_{pT}^2 for small positive values and extrapolate to the pole
 - We are using DIS on bound n to extract F_2 of free n
- Same measurement can be done for p
 - Cross check with proton F_2 extracted with traditional method
 - Can be used to select optimal deuteron spectral function
- We can measure/calculate this
- External input from model/experiment
- Deuteron spectral function
 - $S_d(p_{pT}, \alpha_p)[pole] = \frac{R}{(p_{pT}^2 + a_T^2)^2}$
 - Position of pole
 - $a_T^2 = m_N^2 - \alpha_p(2 - \alpha_p)\frac{M_d^2}{4}$
 - Extrapolation done for $\alpha_p = 1$
 - Residue of spectral function
 - $R = 2\alpha_p^2 m_N \Gamma^2 (2 - \alpha_p)$
 - $\Gamma^2 = 0.007885 \text{ GeV}$

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