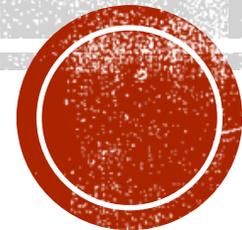# Exclusive Meeting – Deuteron Tagging

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02/23/2026

OVERVIEW

- Last time:
  - Verified updated TDIS framework with true MC on BeAGLE output

- New today:
  - Implemented updated TDIS in EICRecon framework
    - Both MC and RC
  - Simple acceptance+efficiency correction
    - Associated systematic uncertainty
 - First extraction of corrected RC spectator reduced cross section

DEUTERON REDUCED CROSS SECTION

- (left) Deuteron reduced cross section in EICRecon calculated using **tagged protons**

- (left) Deuteron reduced cross section in EICRecon calculated using **tagged neutrons**

- Example plots for one α_p, x_{bj}, and Q^2

- Original simulation sample
  - 500k events
  - Waiting for new production
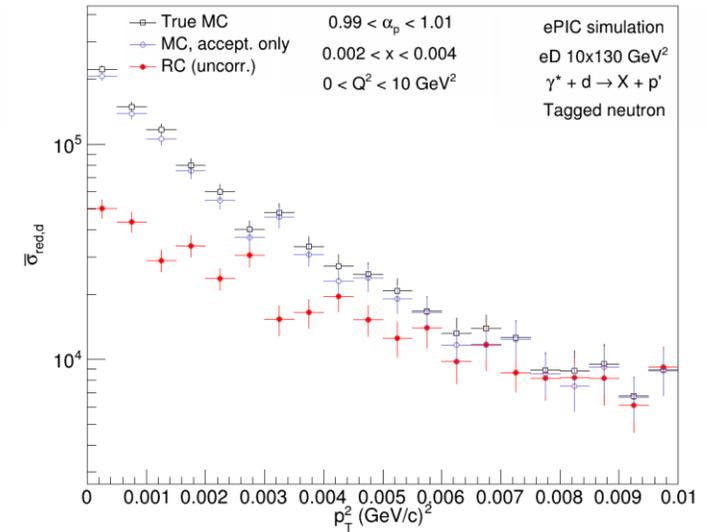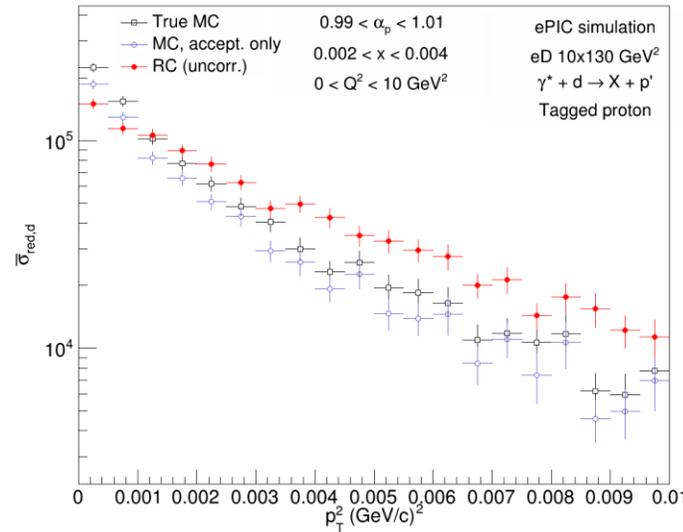
NUCLEON REDUCED CROSS SECTION — UNCORRECTED

- (left) **Neutron** reduced cross section in EICRecon

- (left) **Proton** reduced cross section in EICRecon

- Example plots for one: α_p, x_{bj}, and Q^2
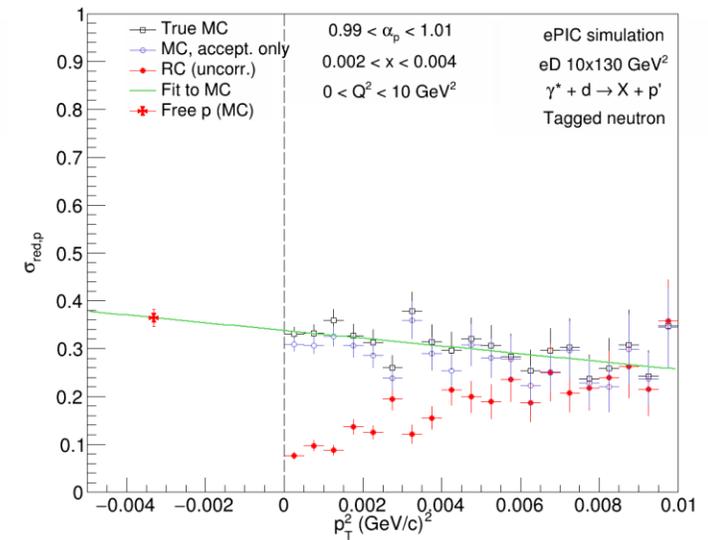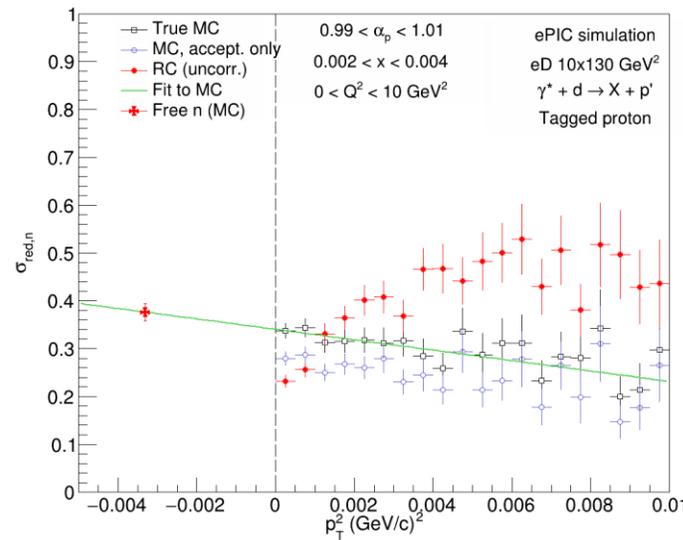
NUCLEON REDUCED CROSS SECTION — UNCORRECTED

- (top) My results

- (bottom) Original paper

- The tagged proton RC seems to be qualitatively consistent with original paper

- Tagged neutron RC appears to be different
  - Systematic shift down

- Example plots for one: α_p, x_{bj}, and Q^2
  - Different for my and original paper

A. Jentsch, Z. Tu, C. Weiss: Phys. Rev. C **104**, 065205.

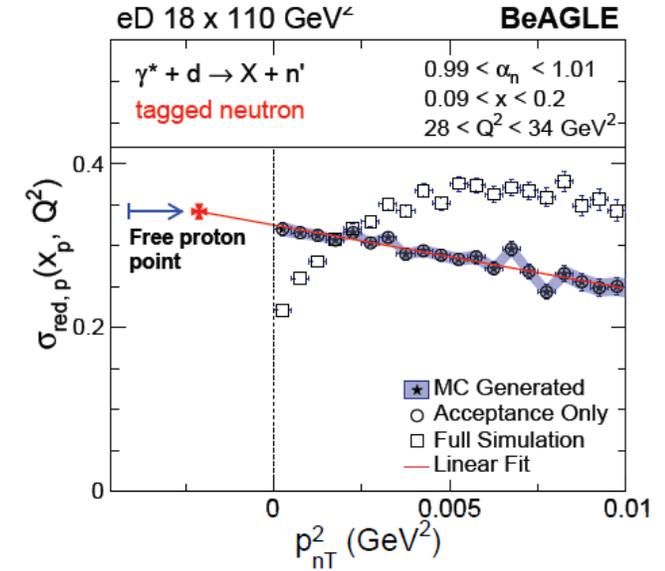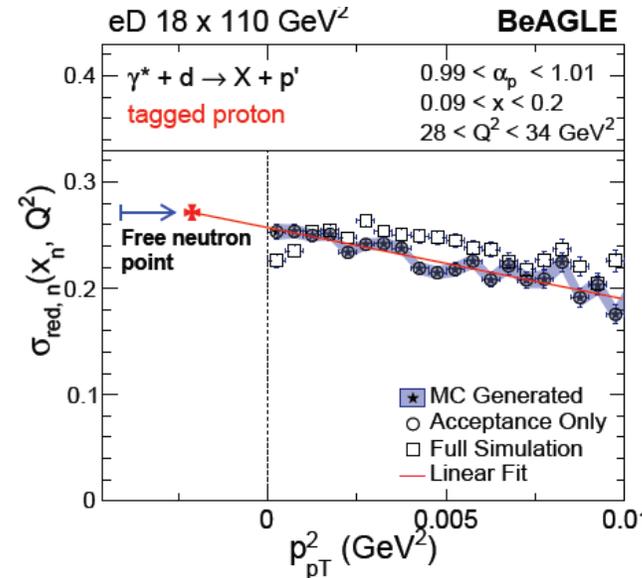# EFFICIENCY AND ACCEPTANCE

- Simple efficiency correction using ratio of MC and RC nucleon reduced cross section
  - RC/MC

- Associated relative systematic uncertainty:
  - $|RC - MC|/MC$
  - Added in quadrature to statistical uncertainty for final results (shown later)

- Example plots for one: α_p, x_{bj}, and Q^2
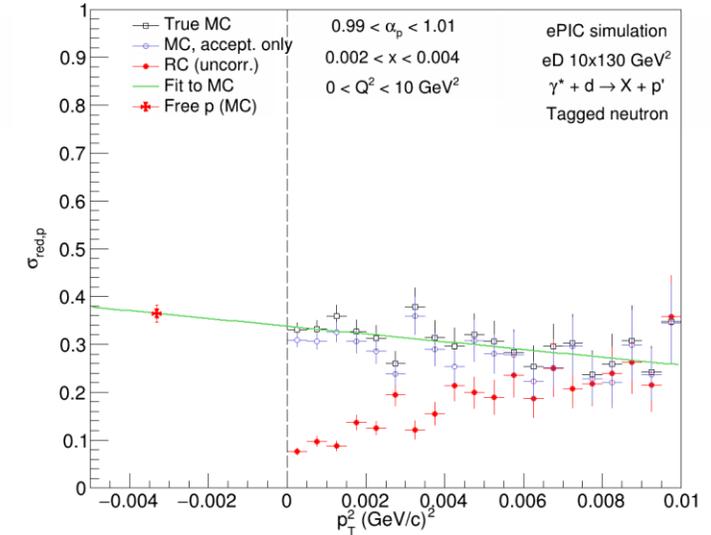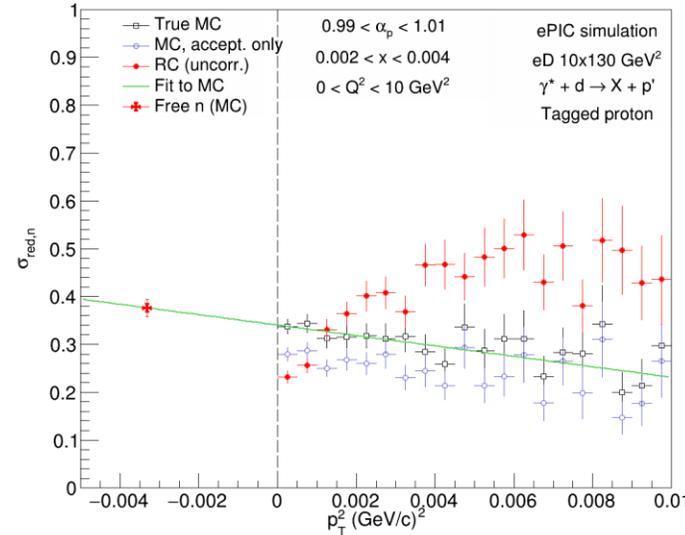
Tagged proton

Tagged neutron
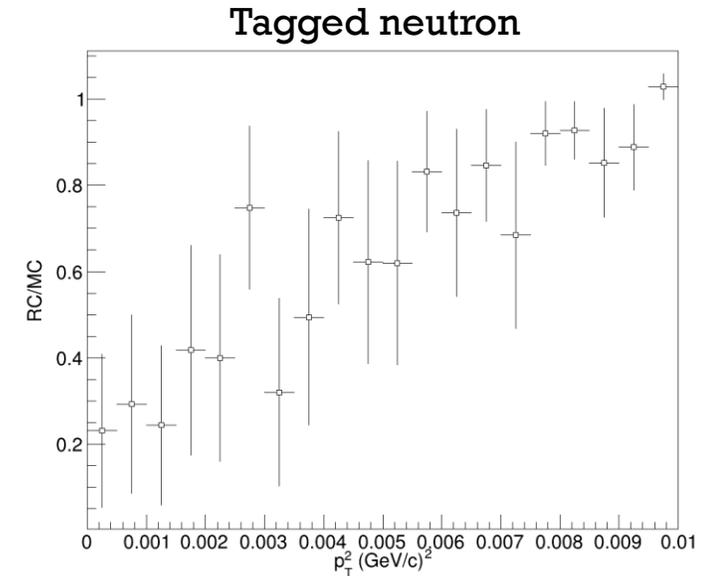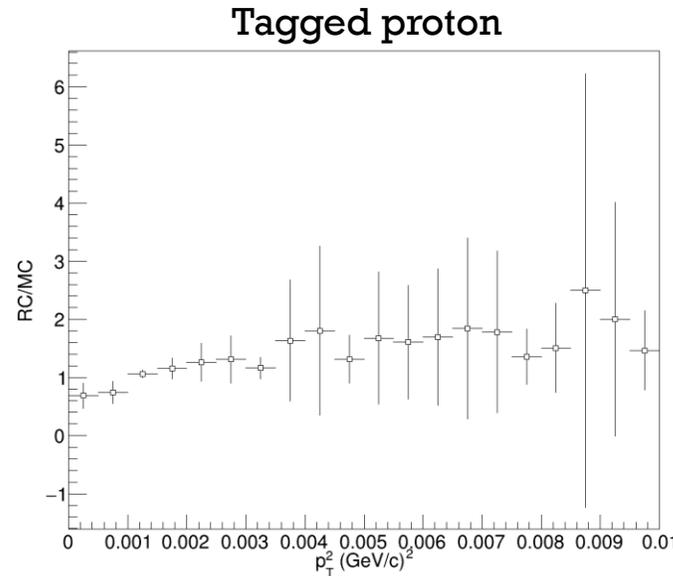
NUCLEON REDUCED CROSS SECTION – CORRECTED

- (left) **Neutron** reduced cross section in EICRecon
  - Corrected

- (left) **Proton** reduced cross section in EICRecon
  - Corrected

- Example plots for one: α_p, x_{bj}, and Q^2
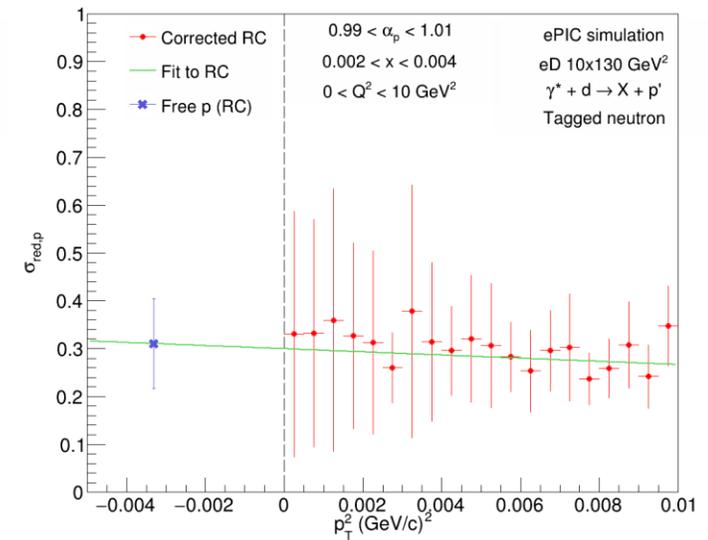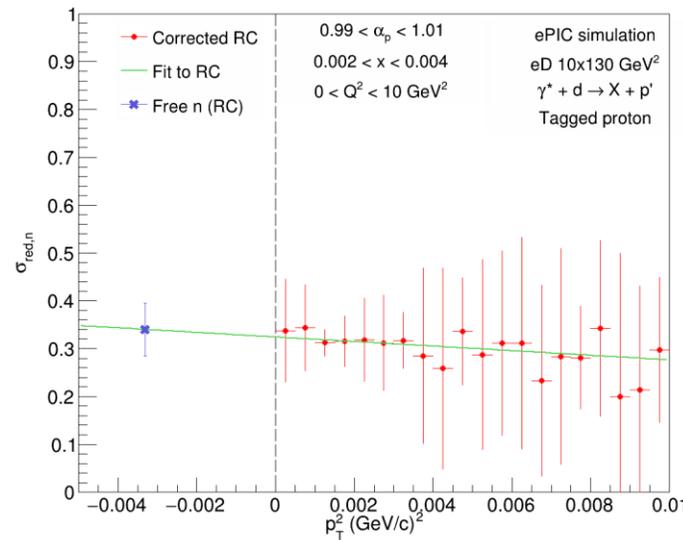
REDUCED CROSS SECTION VS. x_{bj} (eN)

- Comparison of the MC and RC **neutron** reduced cross sections

- Reasonably consistent result

- Uncertainties dominated by systematics
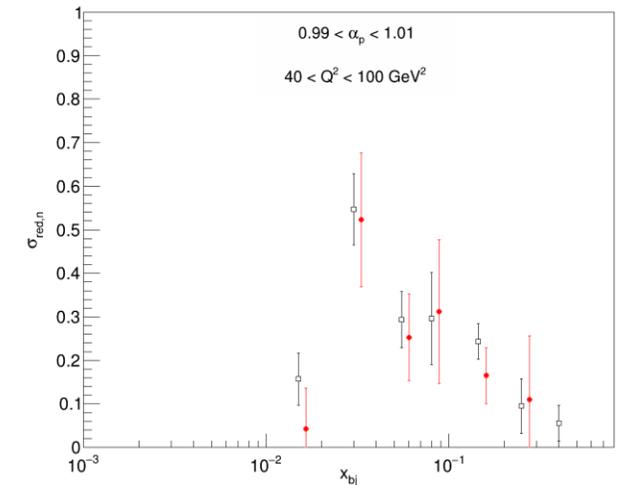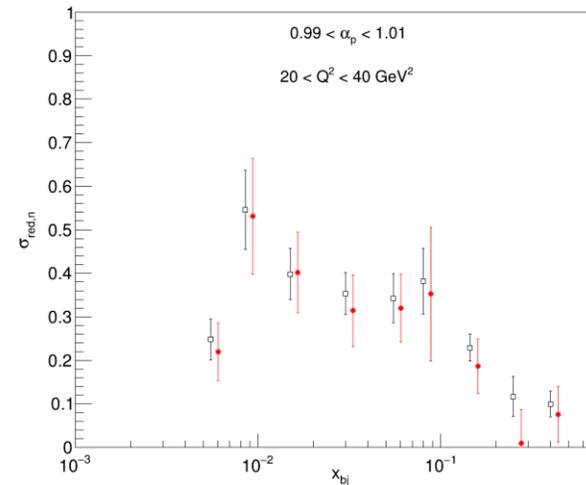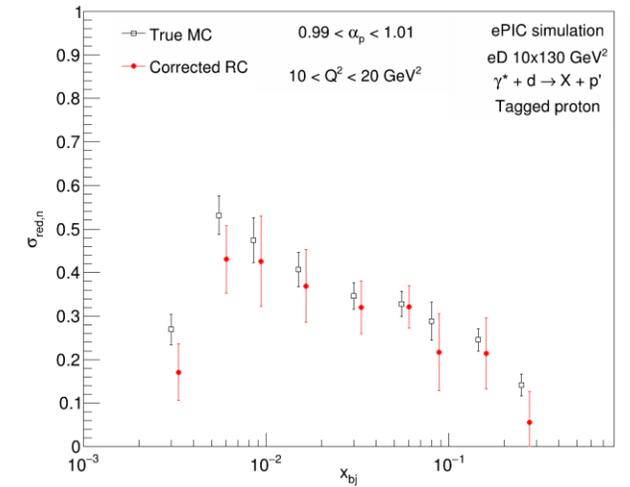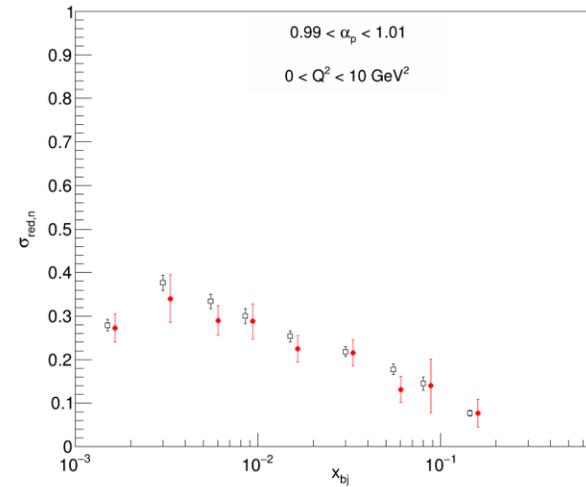
REDUCED CROSS SECTION VS. x_{bj} (eP)

- Comparison of the MC and RC **proton** reduced cross sections

- Tagged neutron analysis requires more attention
  - Much worse performance of RC
  - Large difference between MC and RC at low p_T^2
  - Different behavior than in original paper
  - Under investigation

- Uncertainties dominated by systematics
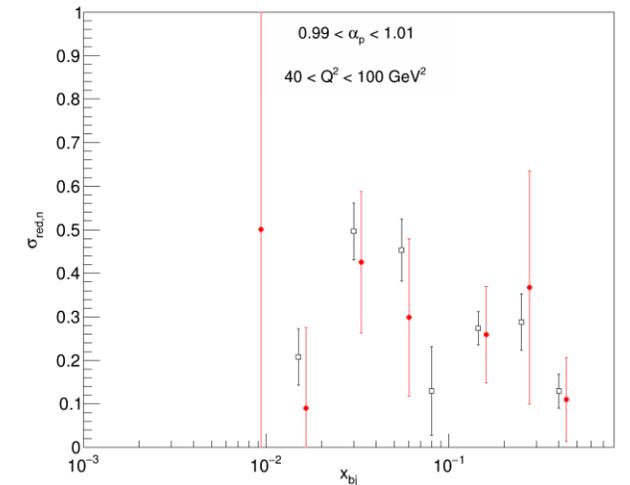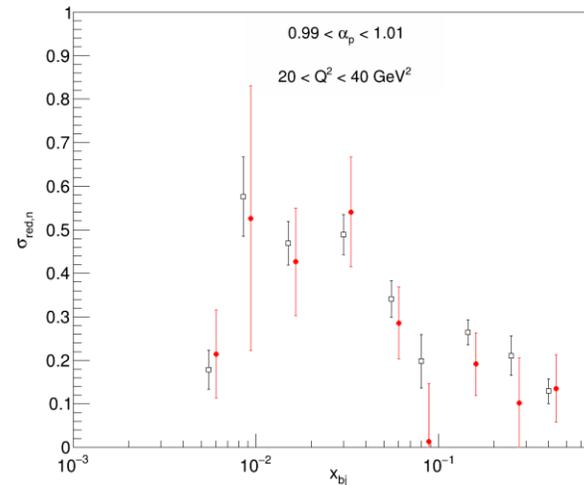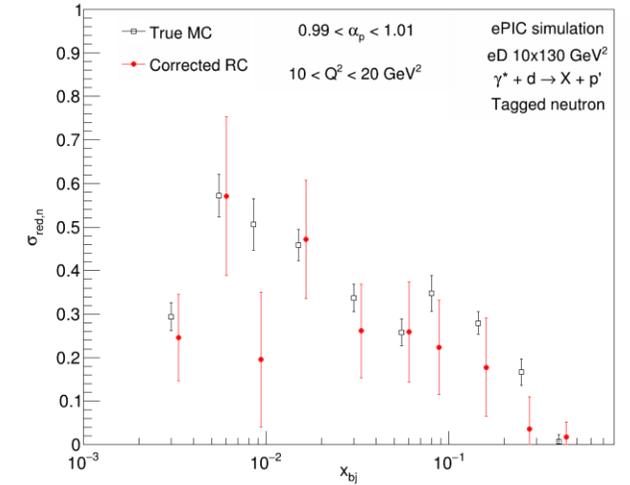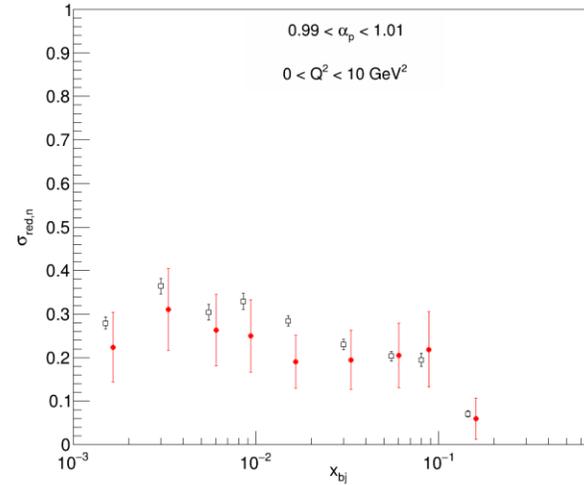
SUMMARY AND OUTLOOK

- Implemented full RC reconstruction into TDIS in eD framework
  - Basic acceptance and efficiency correction using MC and RC nucleon reduced cross sections
  - Conservative estimate of systematic uncertainty from difference of MC and RC nucleon reduced cross sections

- Uncertainties in the analysis are systematics dominated
  - Systematic uncertainty of acceptance and efficiency correction will likely dominate

- Tagged proton RC results appear consistent with original paper, while tagged neutron appear to behave differently

- Outlook:
  - Basic QA of RC spectator and scattered electron kinematics
    - Mainly to understand tagged neutron
  - Write analysis note

THANK YOU FOR ATTENTION

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12 BACKUP

NEW SIMULATION PRODUCTION

- Generated in BeAGLE

- Standard post-processing for simulation campaign
  - BrEGLE to HepMC conversion
  - Afterburner
  - Generate HepMC trees

- Main simulation production:
  - 20M events of eD 10x130 GeV^2
    - 10M of en and 10M of ep
  - 10M total (5M+5M) submitted for official simulation campaign

- Test production for framework validation:
  - 2M events of eD 18x110 GeV^2
  - Same energy as in original paper   A. Jentsch, Z. Tu, C. Weiss: Phys. Rev. C **104**, 065205.

VARIABLES

- Scattered electron

  - $Q^2 = -q^2 = -\left(p_{e,beam} - p_{e,scat}\right)^2$

  - $x = \dfrac{Q^2}{P \cdot q}$

  - $x_{nucleon} = \dfrac{Q^2}{2P_{nucl} \cdot q} = \dfrac{x}{2 - \alpha_p}$

- Kinematic variables

  - $y = \dfrac{p_d \cdot q}{p_d \cdot p_{e,beam}}$

  - $1 - \epsilon = \dfrac{y^2}{1 + (1-y)^2}$

- Light-cone momentum fraction:

  - $\alpha_p \equiv \dfrac{2p_p^+}{p_d^+} = \dfrac{2(E_p + p_{z,p})}{E_d + p_{z,d}}$

- Proton transfer momentum

  - $p_{T,p} = \sqrt{p_{x,p}^2 + p_{y,p}^2}$

- Fine structure constant

  - $\alpha_{em} = \dfrac{1}{137}$

- Luminosity and cross section

  - $L_{int} = \dfrac{N_{events}}{\sigma_{tot}}$

    - $mb = 2.568\ \text{GeV}^{-2}$

    - Results from paper: A. Jentsch, Z. Tu, C. Weiss: Phys. Rev. C **104**, 065205.

      - $\sigma_{tot} = 4.5 \cdot 10^{-5} \text{mb}$

    - For new simulation production (10x130 GeV^2):
      - $\sigma_{tot} = 3.538 \cdot 10^{-4} \text{mb}\ (en)$
      - $\sigma_{tot} = 3.707 \cdot 10^{-4} \text{mb}\ (ep)$
    - Test sample (18x110 GeV^2):
      - $\sigma_{tot} = 3.869 \cdot 10^{-4} \text{mb}\ (en)$

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:

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

- Photon flux:

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

- Deuteron reduced cross section

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

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

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

    - $\Delta x,\ \Delta Q^2,\ \Delta p^2_{T,p}, \Delta\alpha_p$ 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
  - $\Delta\phi_p = 2\pi$

POLE EXTRAPOLATION METHOD

- $\sigma_{red,n} = \dfrac{\bar{\sigma}_{red,d}(x,Q^2)}{[2(2\pi)^3]S_d(p_{pT},\alpha_p)[pole]}$

- $\bar{\sigma}_{red,n}$ at the pole corresponds to a free n
  - $p_{pT}^2 \to -a_T^2$ 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

- Deuteron spectral function
  - $S_d(p_{pT},\alpha_p)[pole] = \dfrac{R}{\left(p_{pT}^2+a_T^2\right)^2}$

- Position of pole
  - $a_T^2 = m_N^2 - \alpha_p(2-\alpha_p)\dfrac{M_d^2}{4}$

- Extrapolation done for $\alpha_p = 1$

- Residue of spectral function
  - $R = \alpha_p^2 m_N \Gamma^2(2-\alpha_p)$
  - $\Gamma^2 = 0.007885\ \mathrm{GeV}$

A. Jentsch, Z. Tu, C. Weiss: Phys. Rev. C **104**, 065205.
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