Neutron Spin from Double-Spectator Tagging at the EIC

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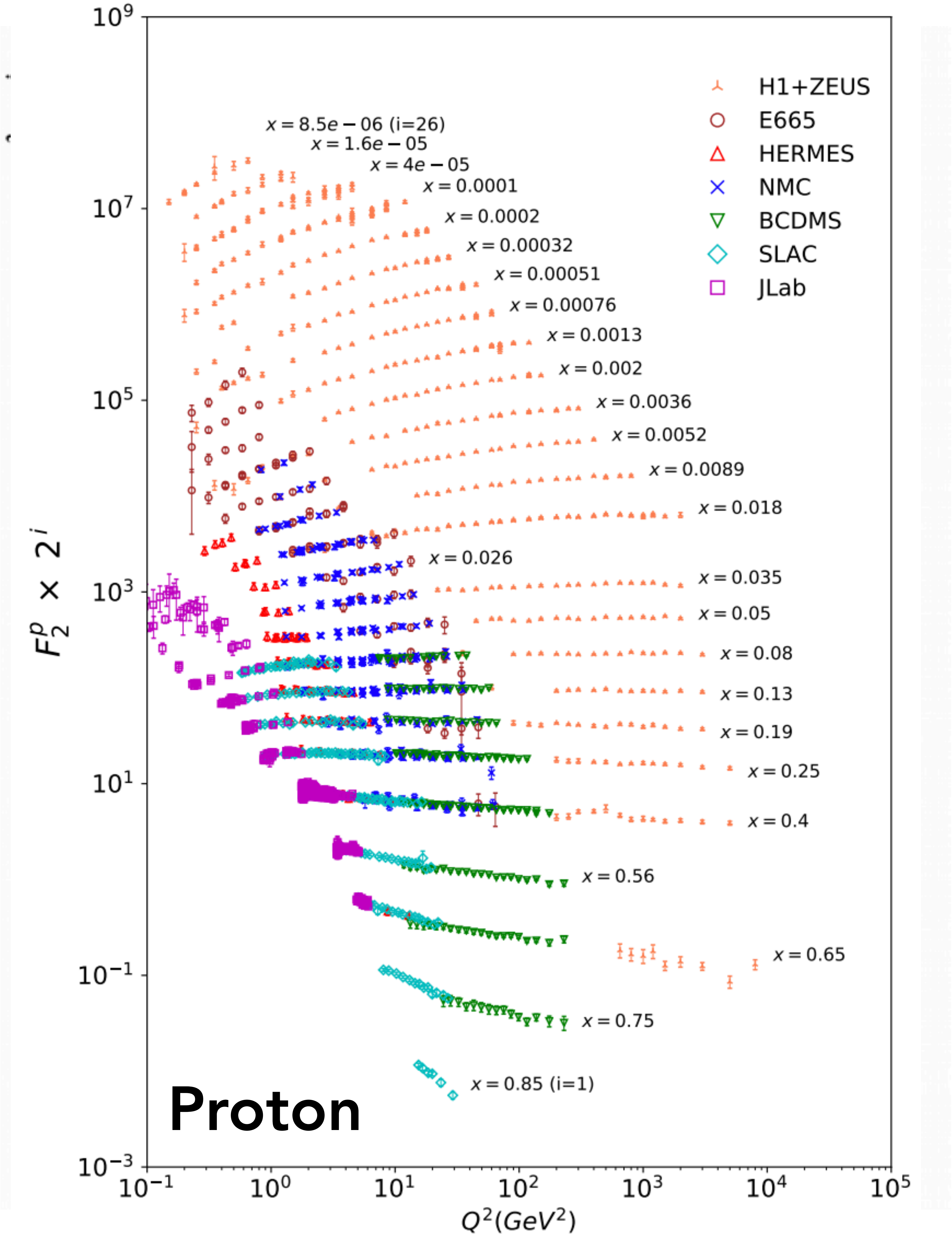
Nucleon Structure Measurements

Measuring nucleon structure fundamental for understanding QCD

Proton:

- Well measured
- Wide coverage in x_B, Q^2
- High precision



Nucleon Structure Measurements

Measuring nucleon structure fundamental for understanding QCD

Proton:

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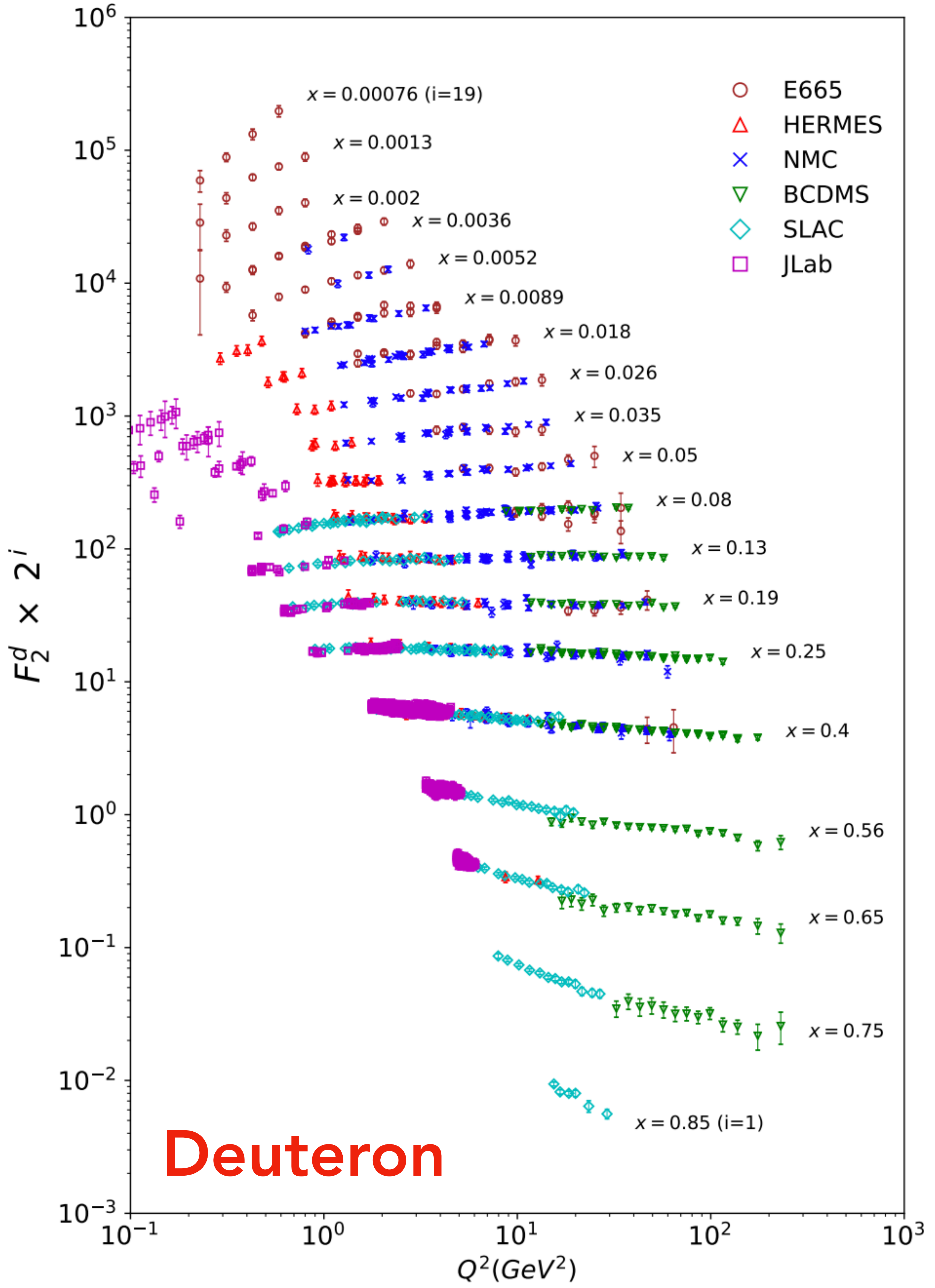
Neutron:

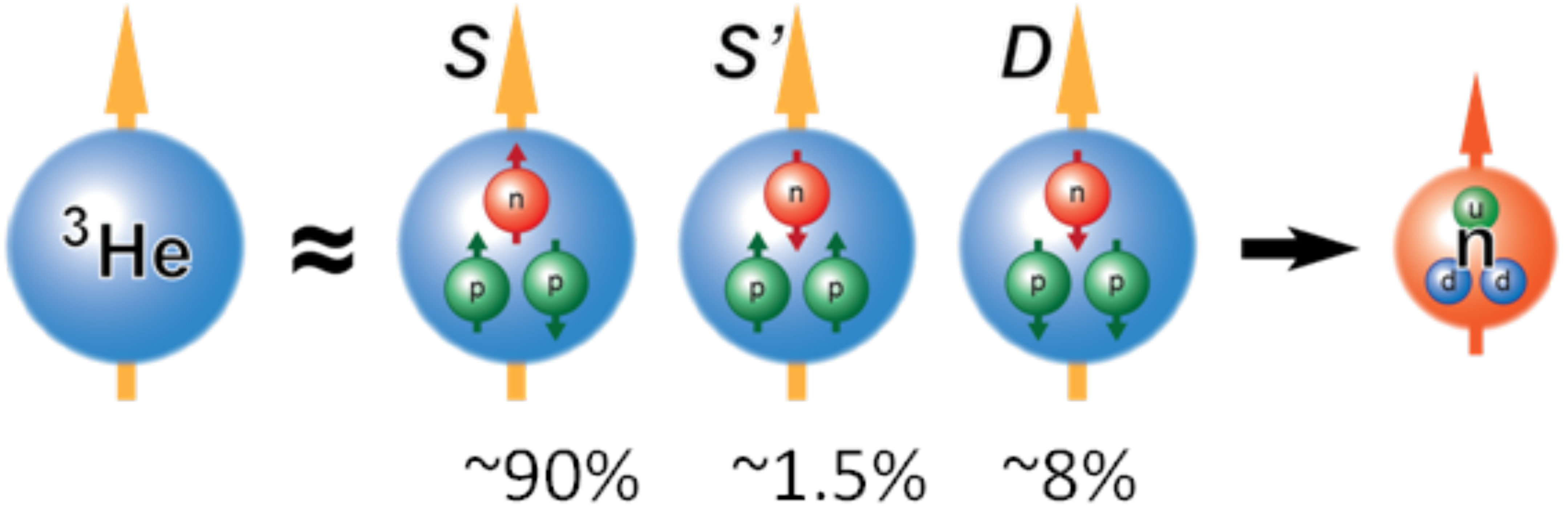
- No free neutron target
- Using light nuclei to probe the neutron
- Large model dependence



Polarized Neutrons in ^{3}He

- Neutron carries most of the spin in polarized ^{3}He
- Extracting A_1^n from inclusive $A_1^{^3He}$:

$$A_1^n \approx \frac{1}{P_n}\frac{F_2^{^3He}}{F_2^n}(A_1^{^3He} - 2P_p\frac{F_2^p}{F_2^{^3He}}A_1^p)$$



$P_n \approx 87\,\%$

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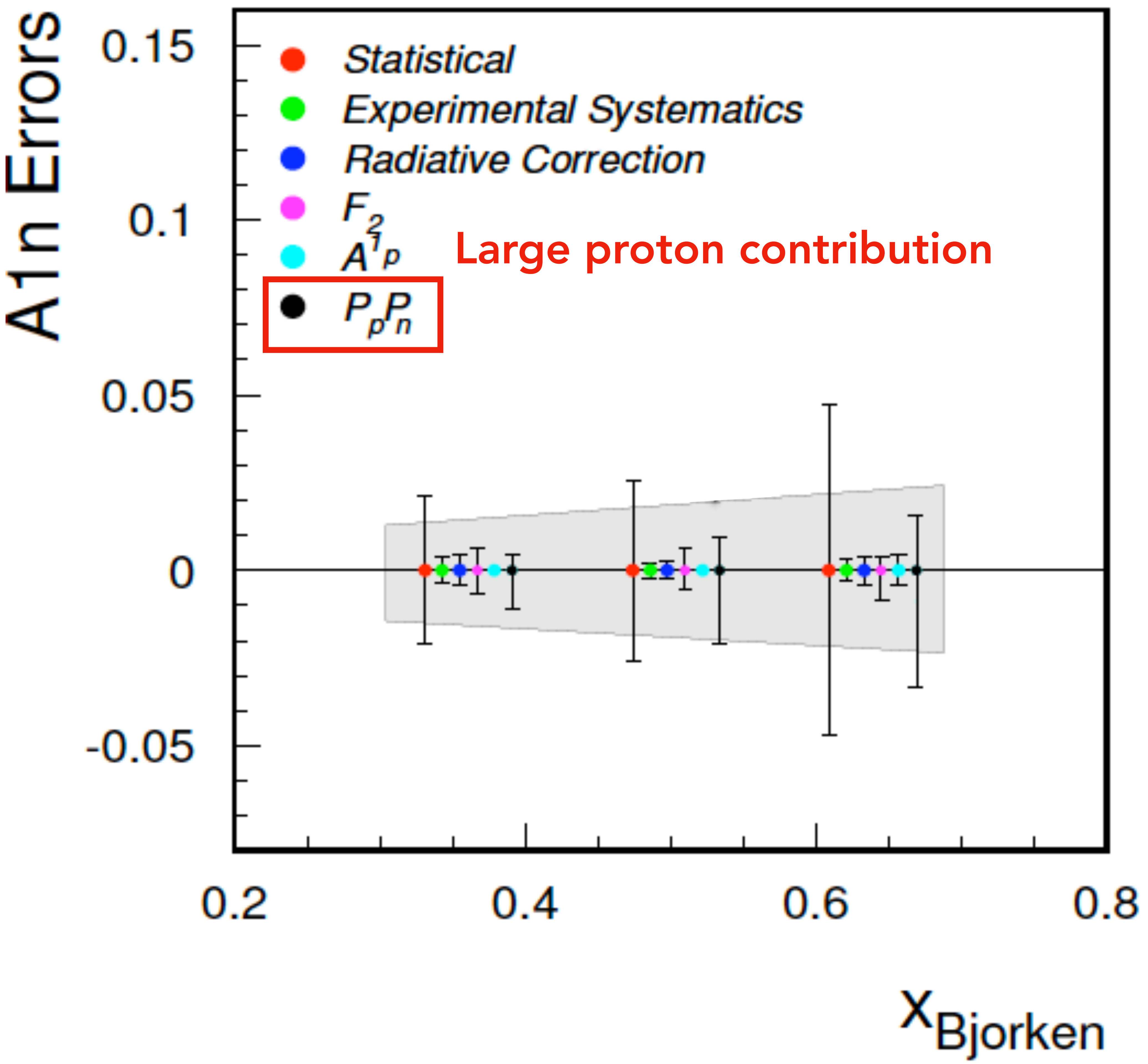
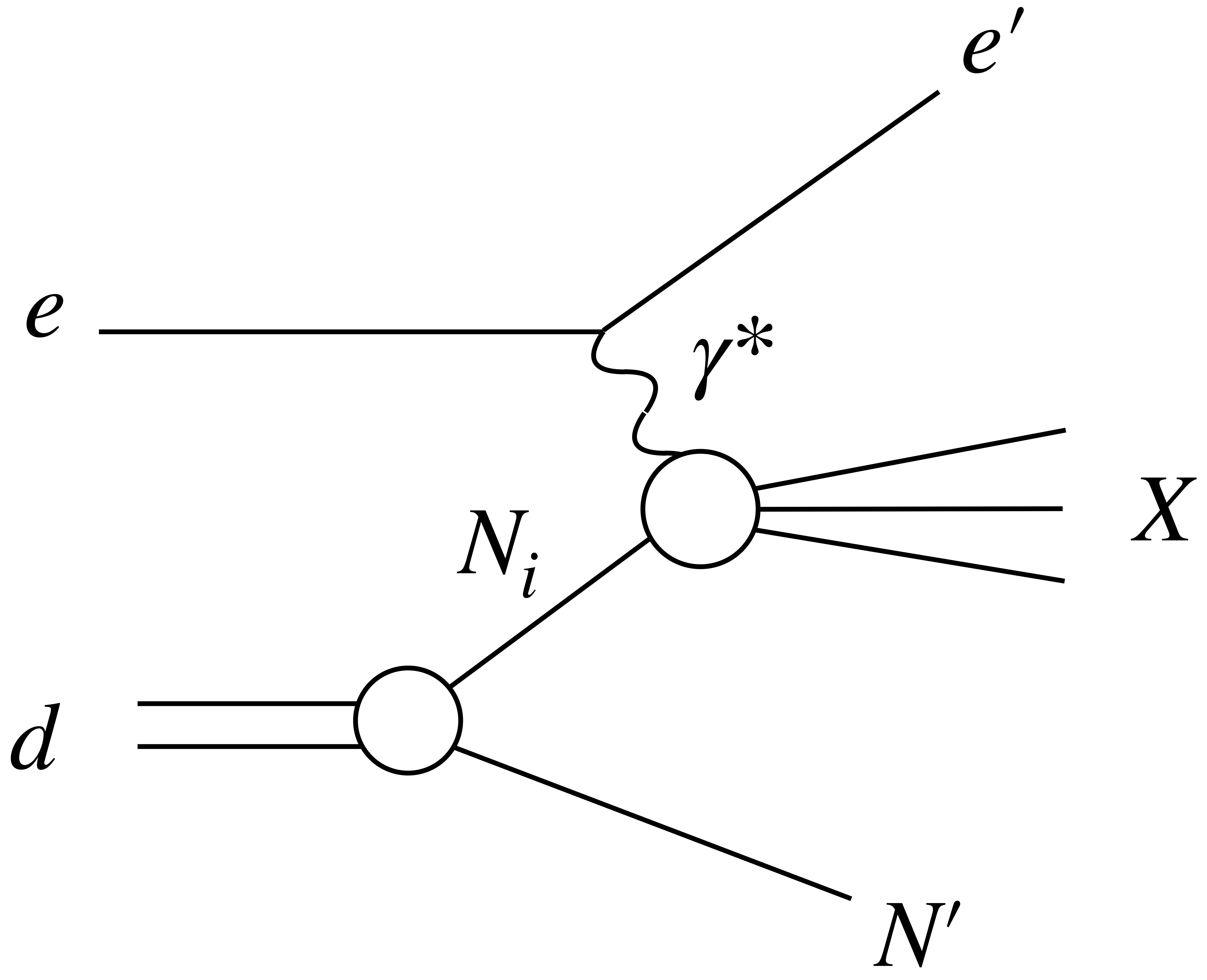
- **Corrections introduce large uncertainties**

Hall A Experiment E12-06-112

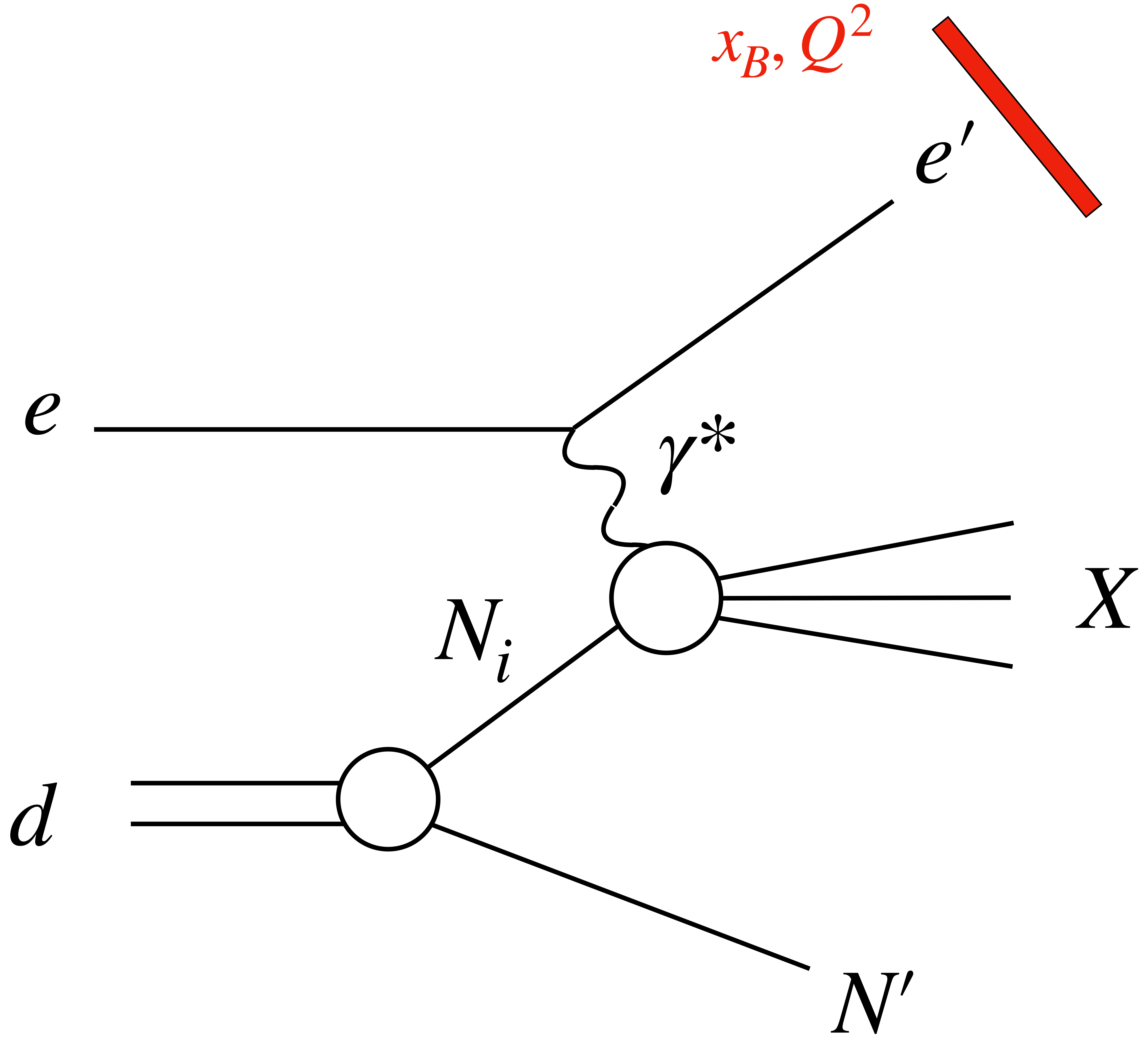


Spectator-Tagged DIS



Spectator tagging facilitates effective targets not readily found in nature

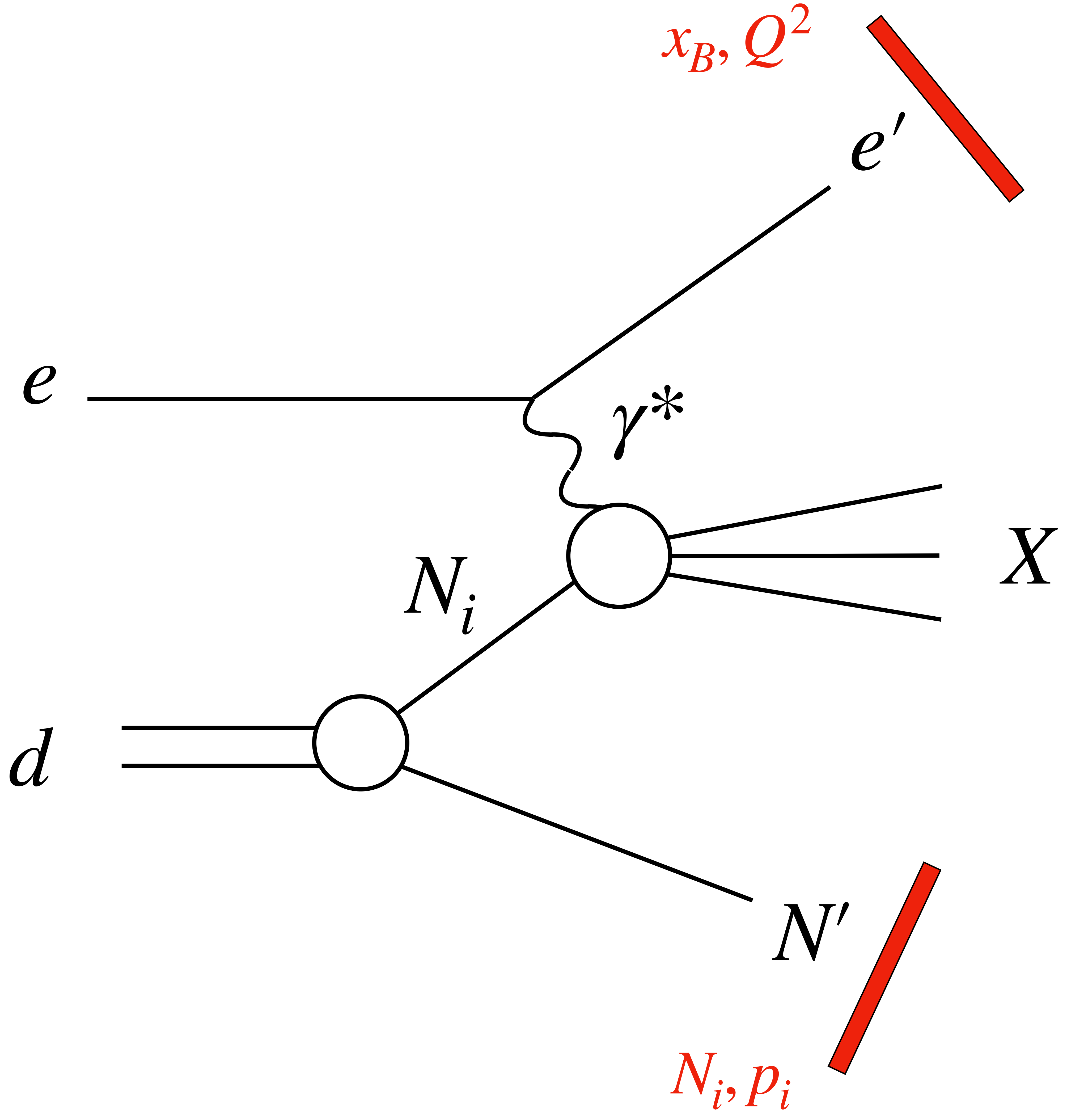
Spectator-Tagged DIS



Spectator tagging facilitates effective targets not readily found in nature

- Measure scattered electron for DIS variables: x_B, Q^2

Spectator-Tagged DIS

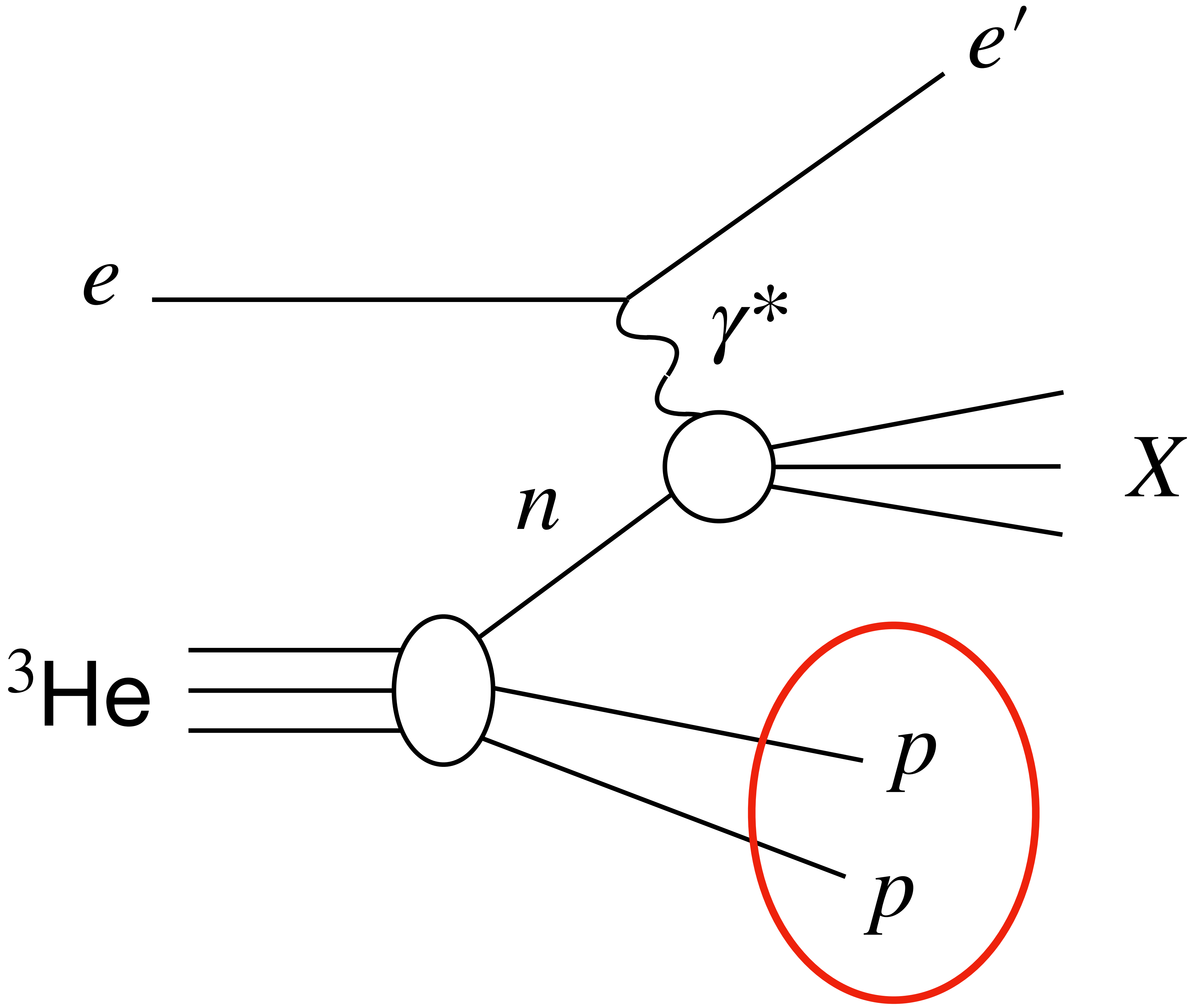


Spectator tagging facilitates effective targets not readily found in nature

- Measure scattered electron for DIS variables: x_B, Q^2
- Measure spectator system for initial nuclear state: p_i, isospin

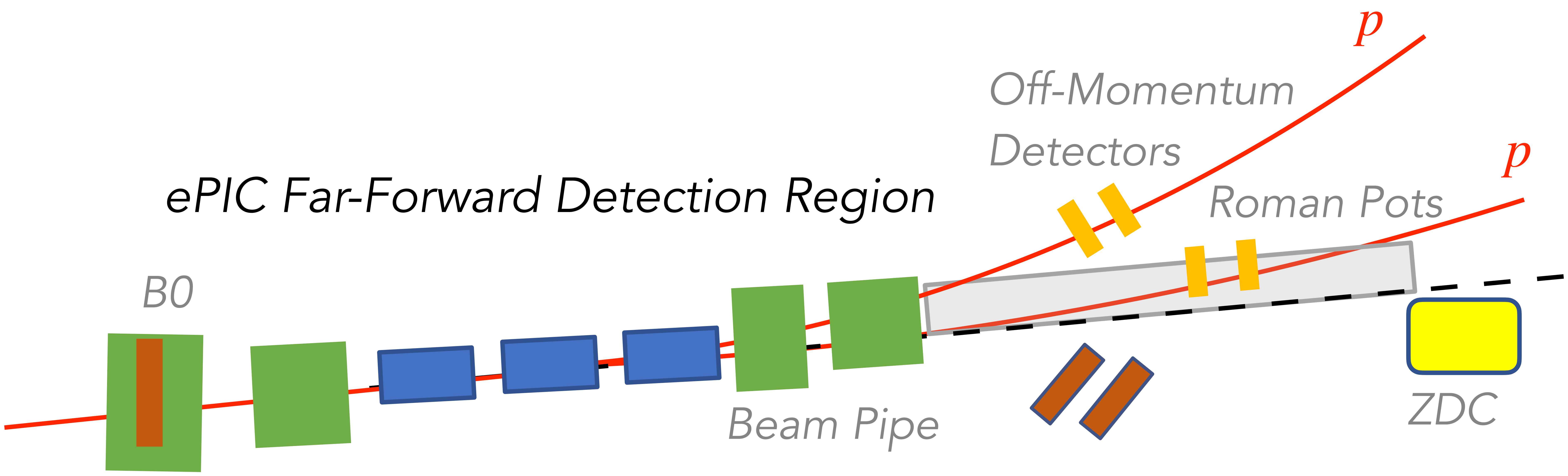
A_1^n from Double-Spectator Tagging

- Measure two spectator protons → active neutron
- Reduced model-dependency
- Require low momentum for quasi-free neutron



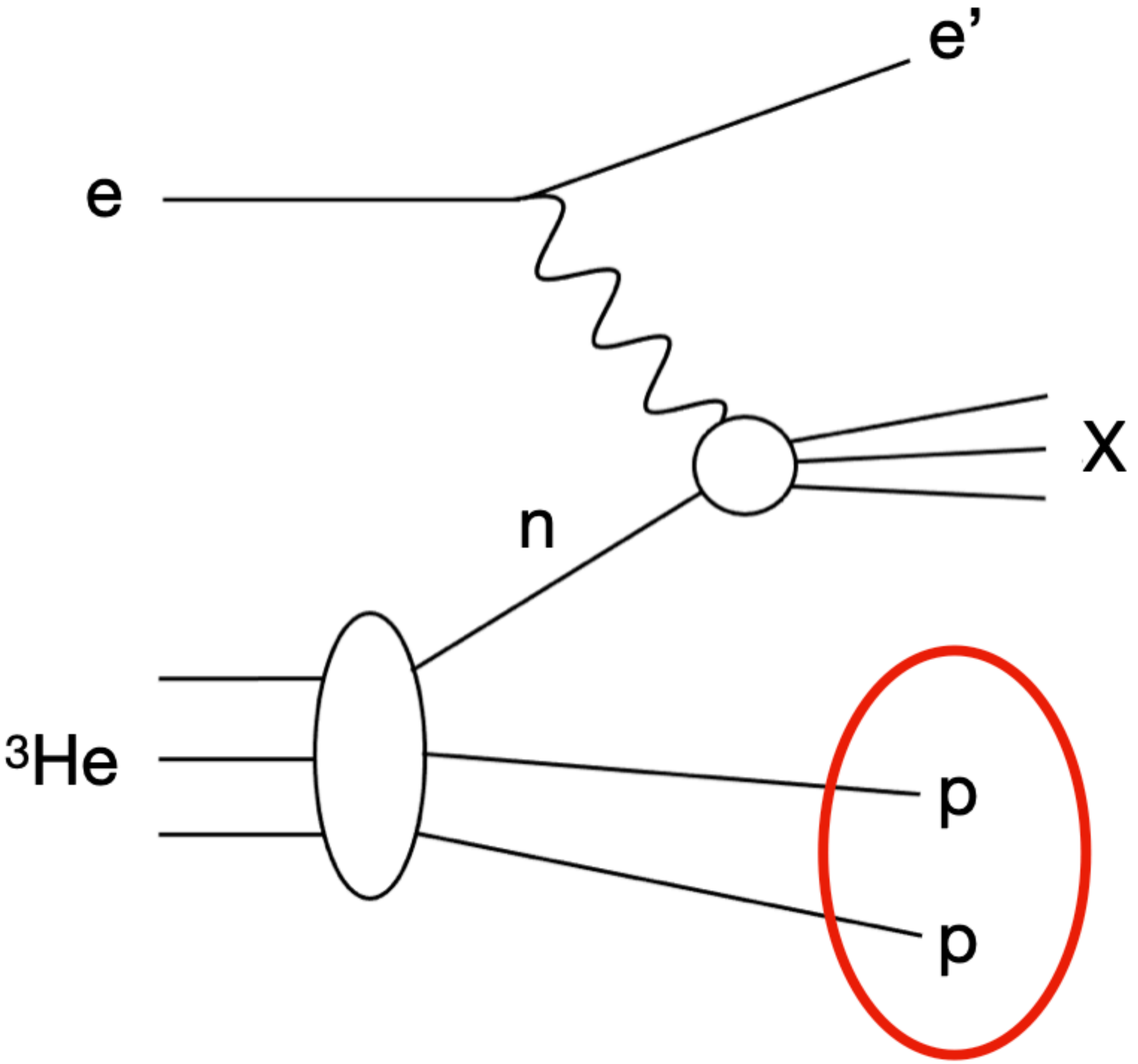
Spectator Tagging at the EIC

- Far-forward detection allows measuring particles with high rapidity
- Protons, neutrons, ions separate cleanly in magnetic field
- Low-momentum spectators detected with high efficiency



Physics Event Modelling

- Generate neutron DIS events
- Sample initial nuclear state from ^{3}He model
- Combine for full event $^3\mathrm{He}(e, e'p_{s1}p_{s2})X$



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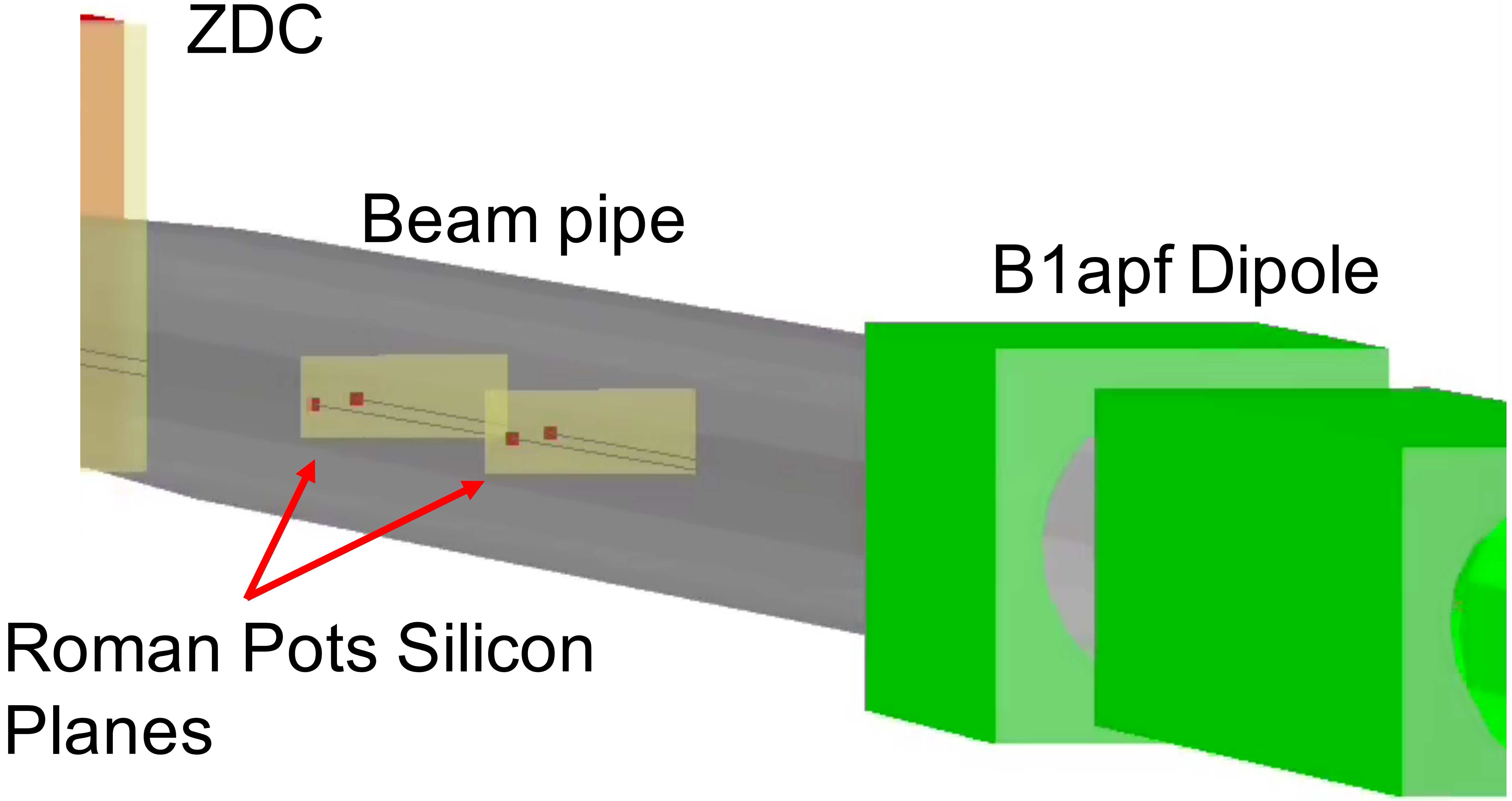
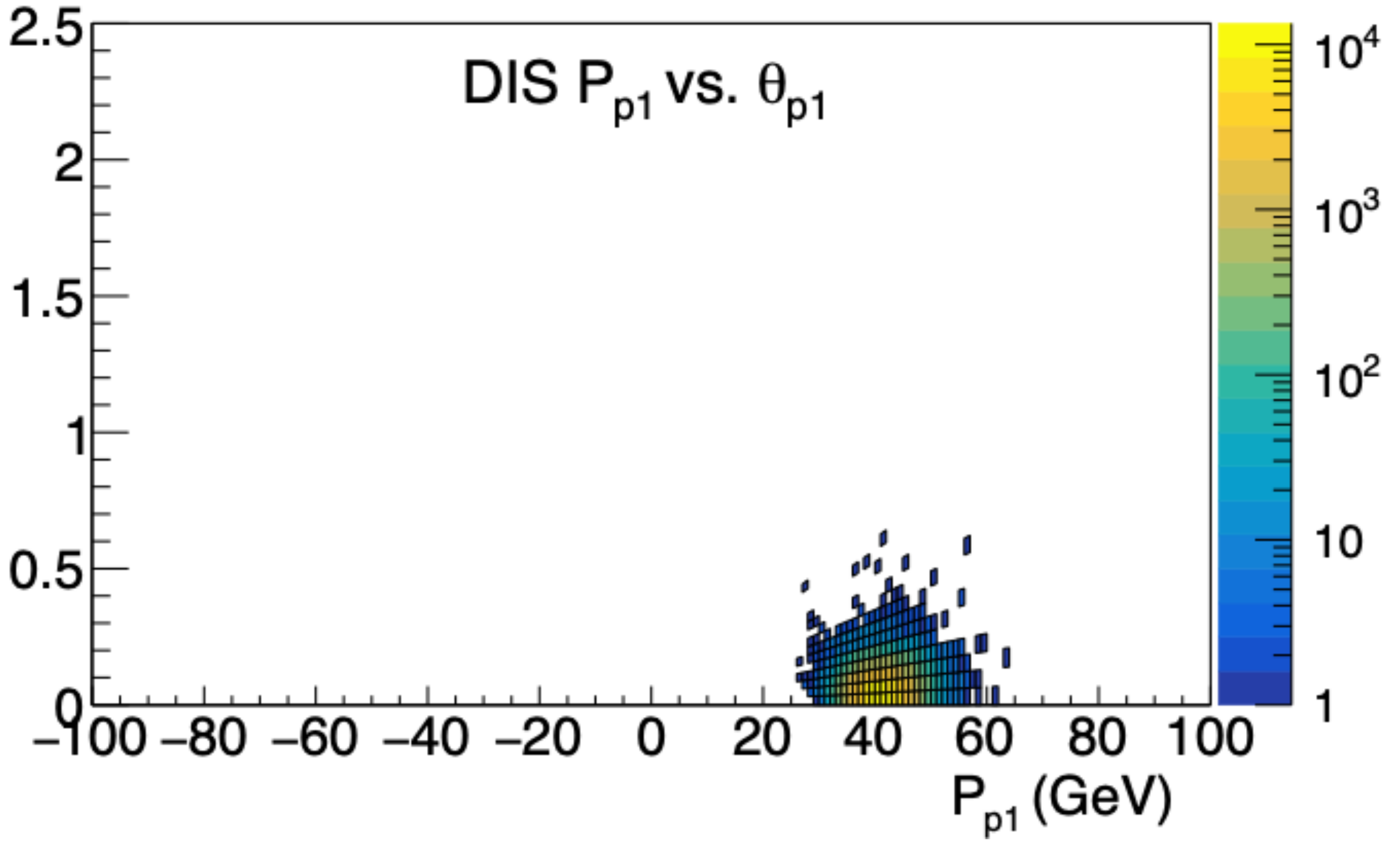
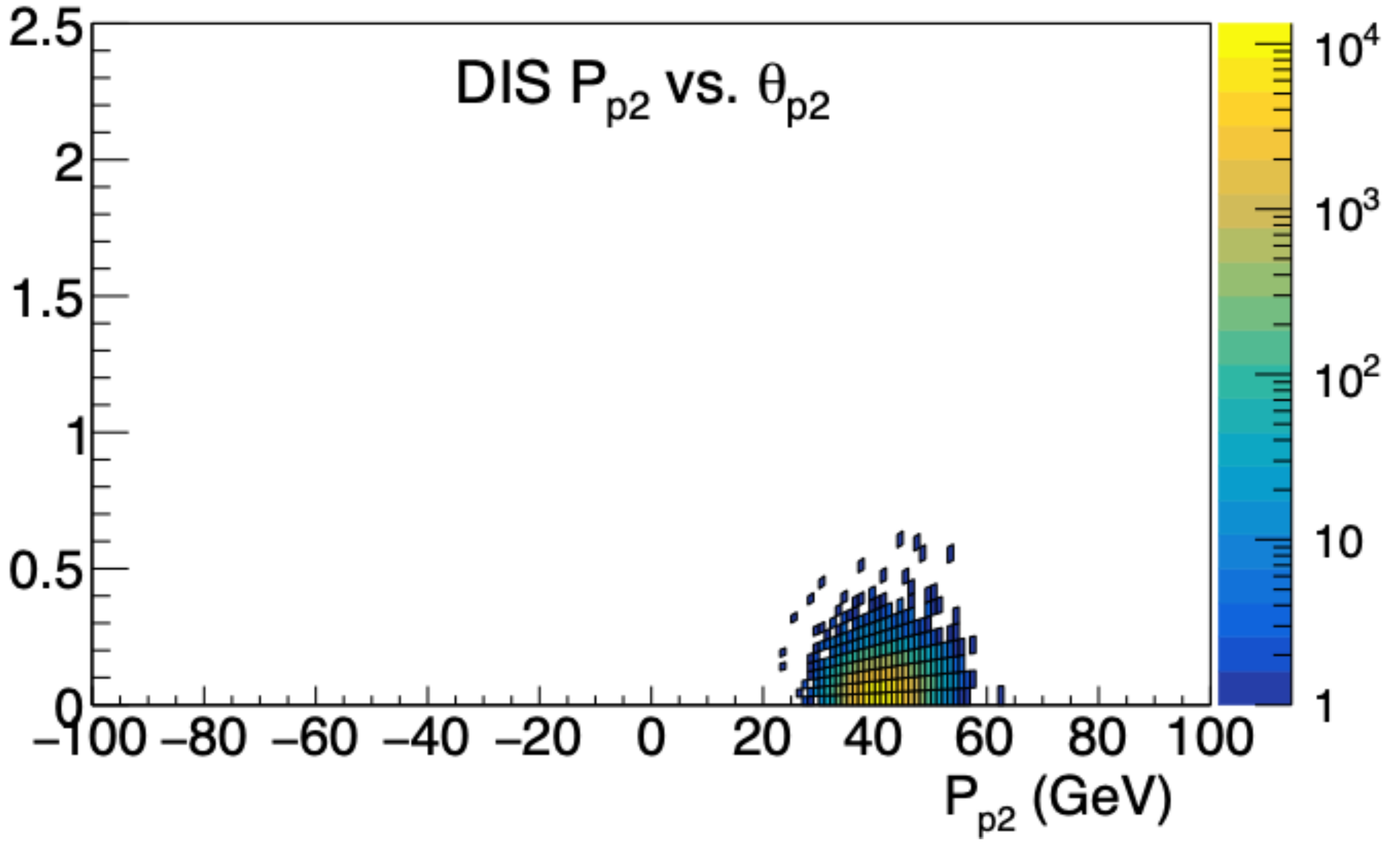
Simulate detector response to final-state particles







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Event Selection

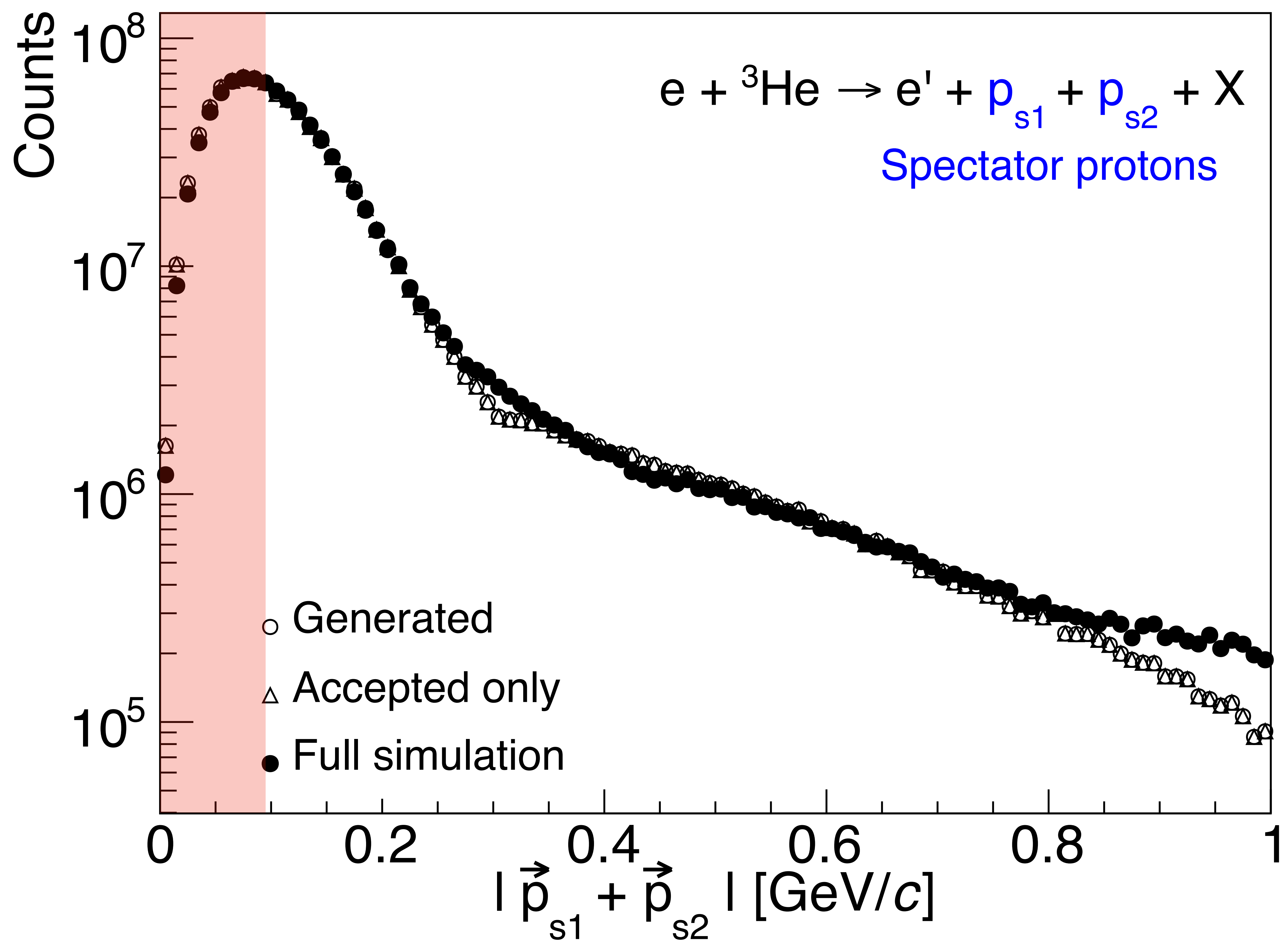
DIS Cuts:

- $Q^2 > 2$ GeV^2
- $W^2 > 4$ GeV^2
- $0.05 < y < 0.95$

Tagging Cuts:

- Both spectator protons detected
- $|\vec{p}_{s1} + \vec{p}_{s2}| < 0.1$ GeV

Bin in x_B, Q^2, scale to 100 fb^{-1}



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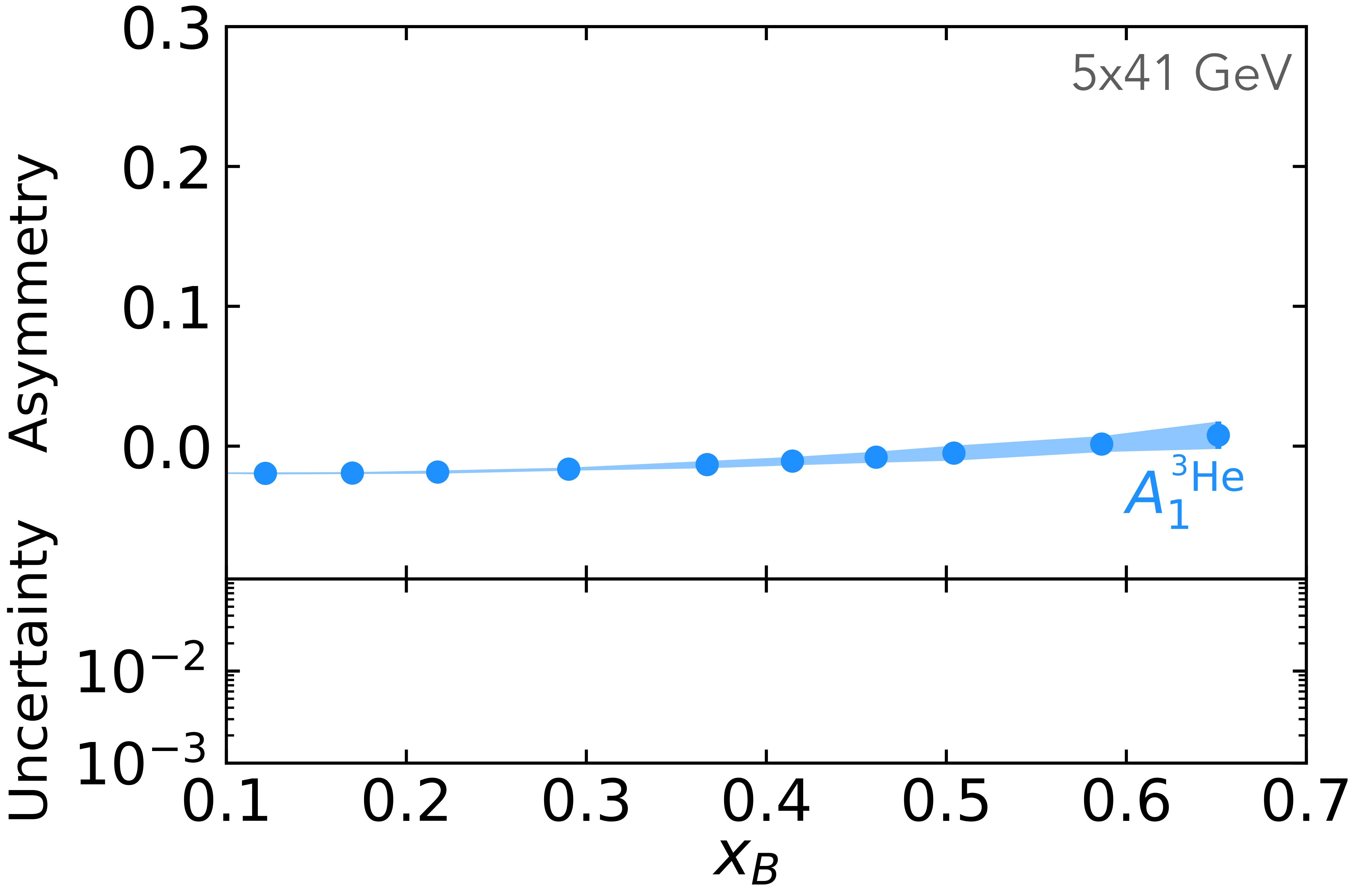
A_1^n from inclusive ^{3}He(e, e')



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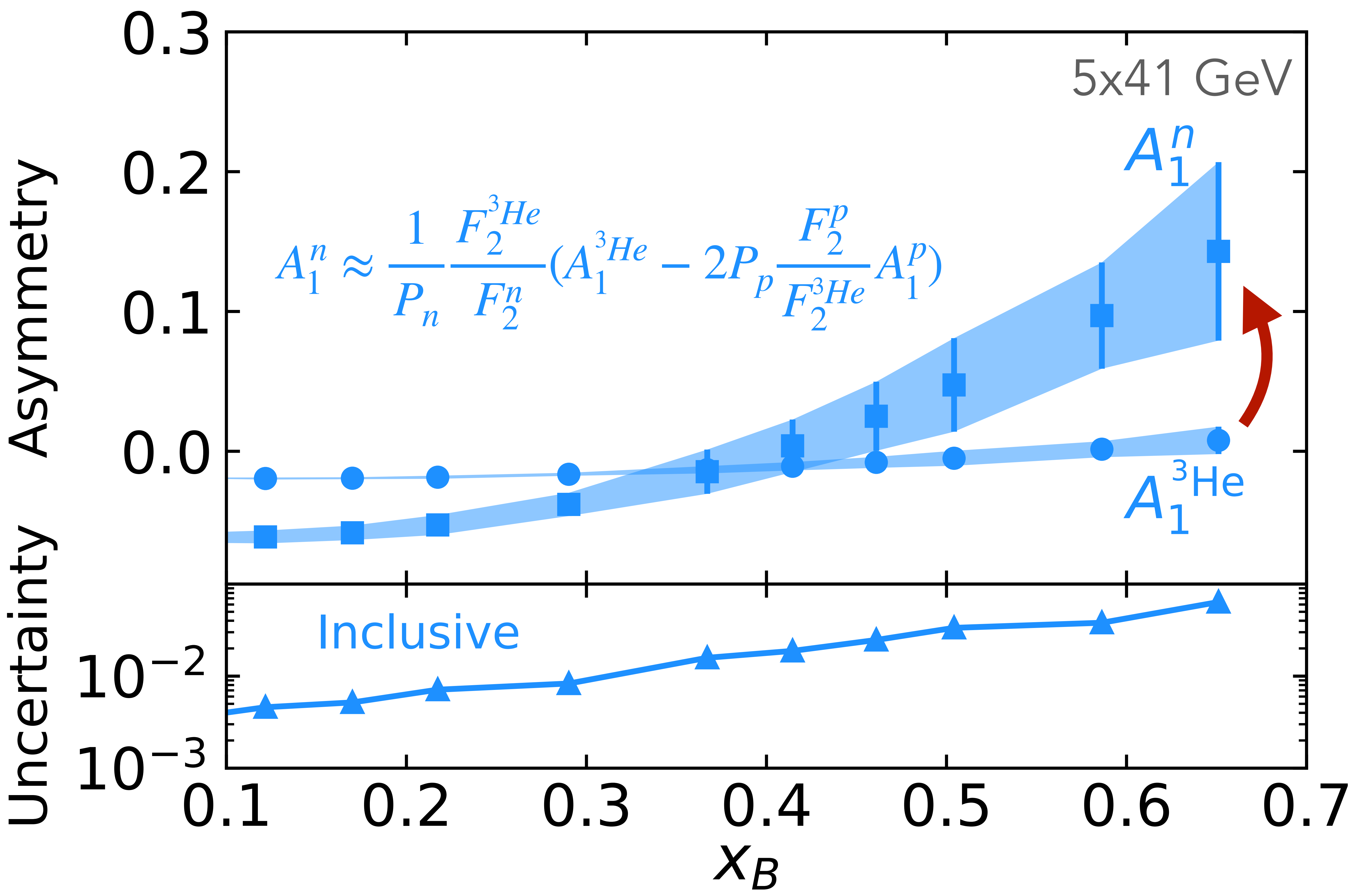

Extraction introduces large systematic uncertainties

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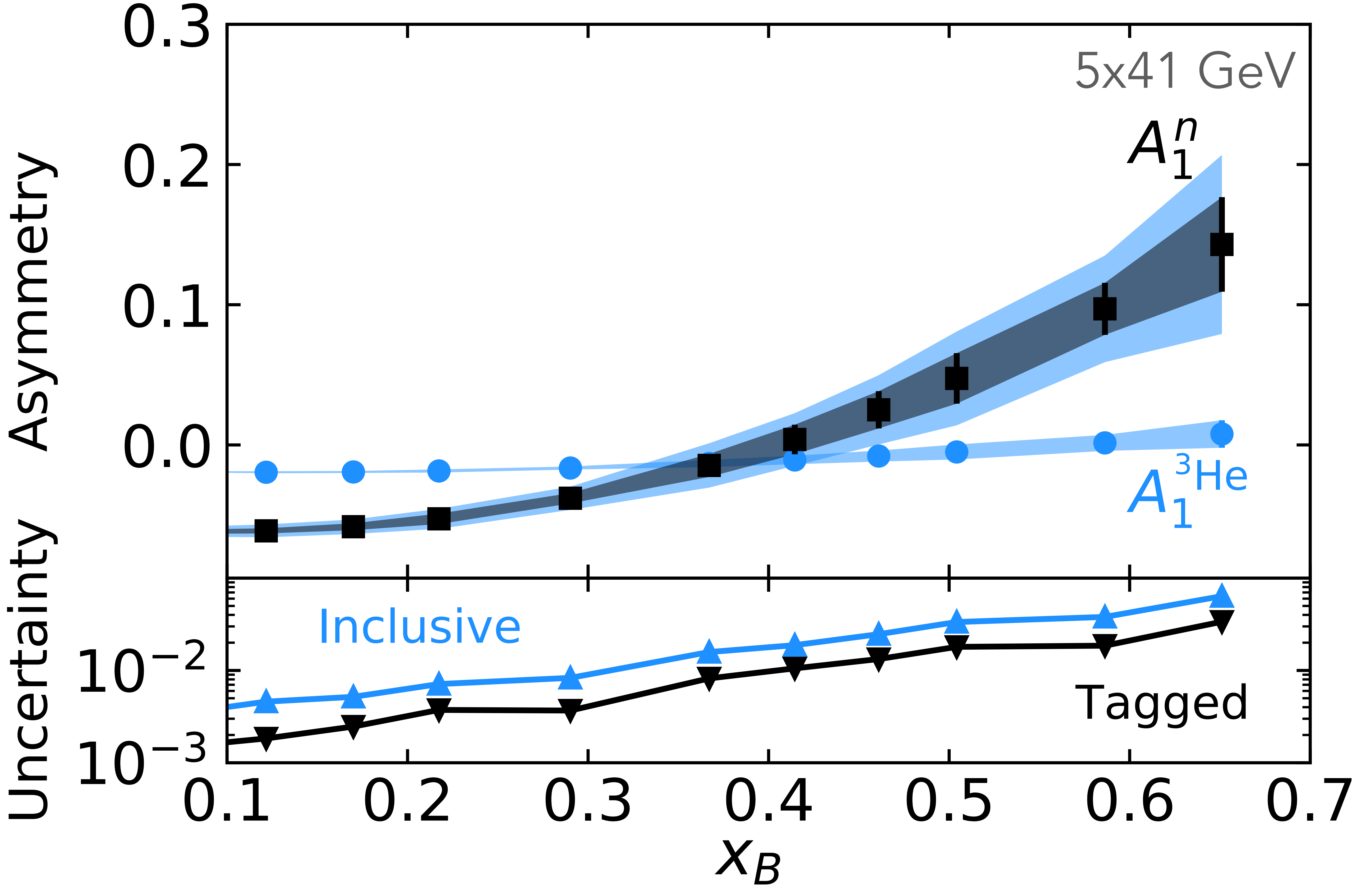
A_1^n from tagged $^3\text{He}(e, e'pp)$



Tagging improves precision

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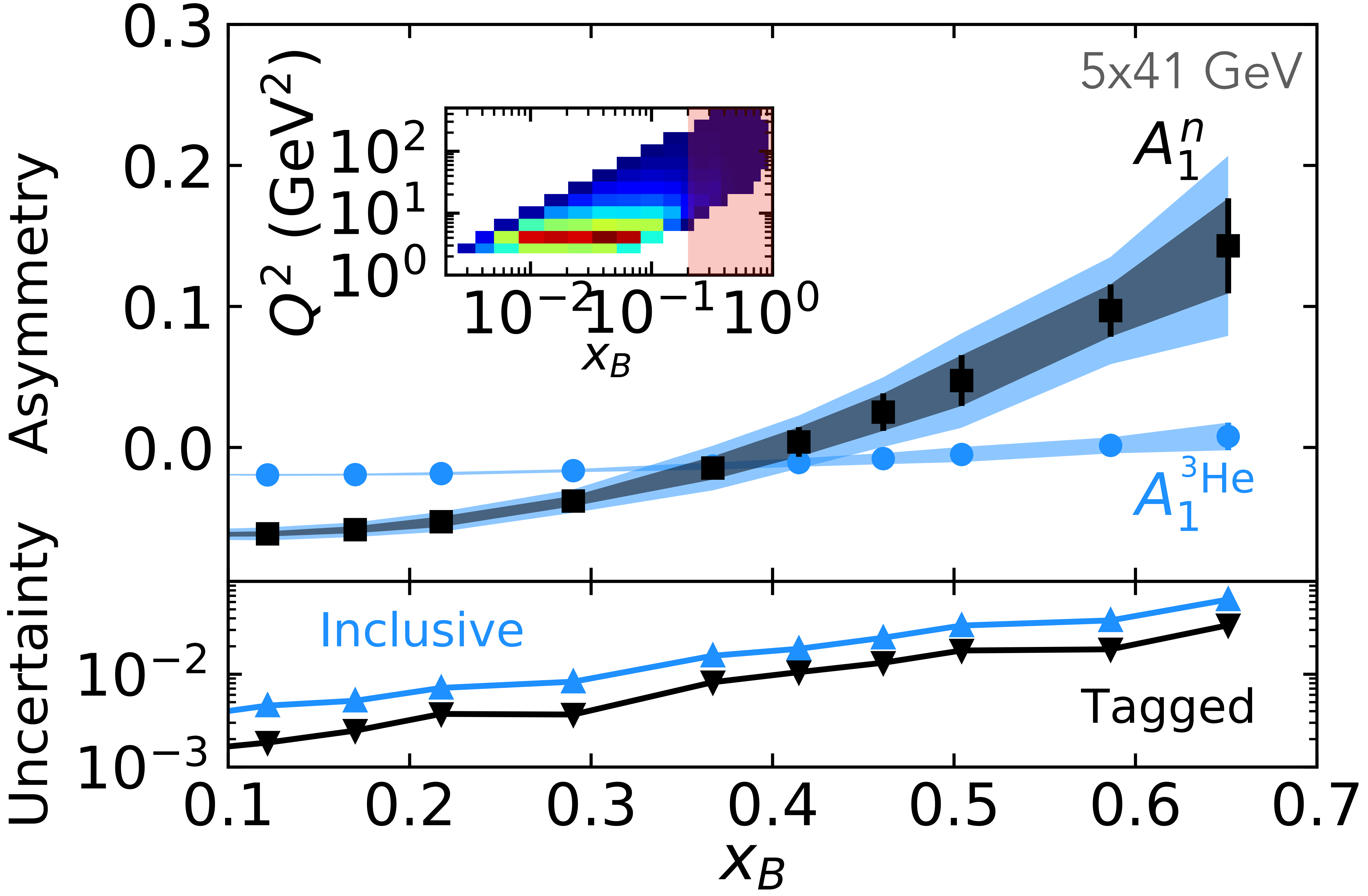
A_1^n Coverage at EIC



EIC allows measurement in valence region at high-Q^2

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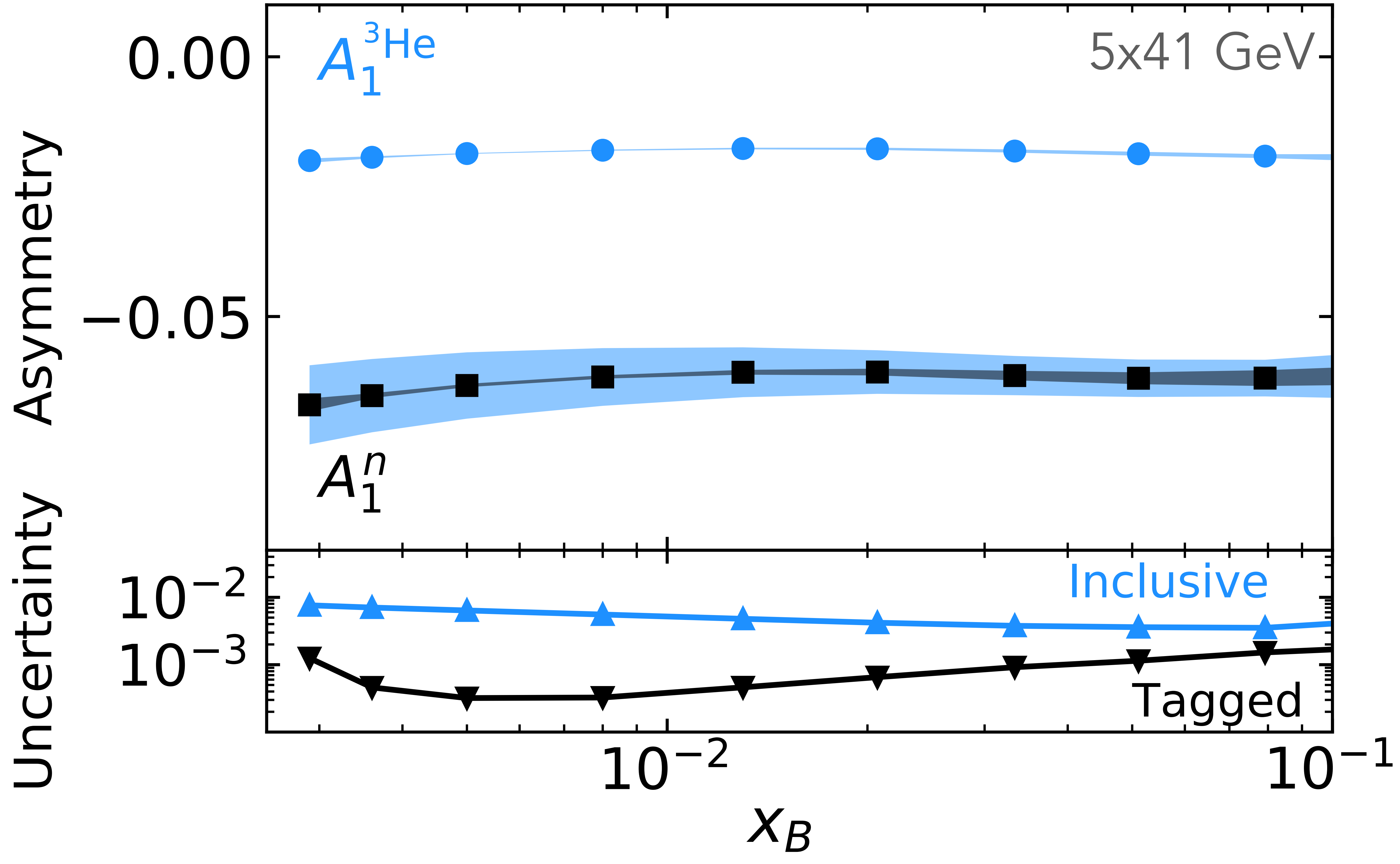

Coverage also extends to low-x_B even at low-energy setting

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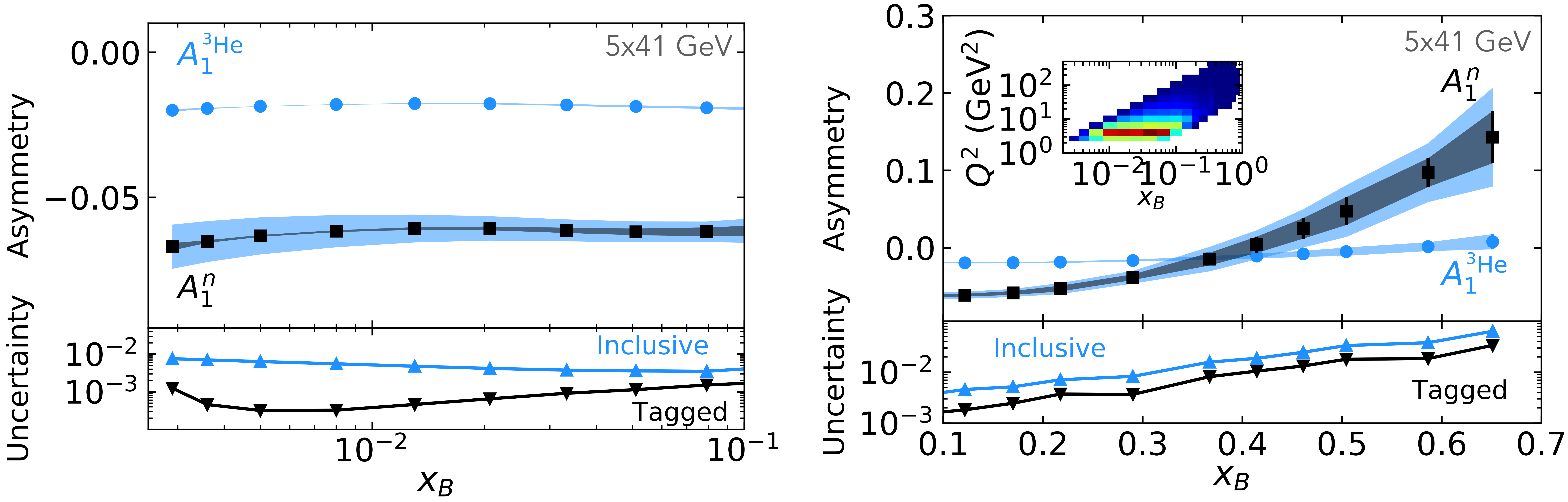
Inclusive vs. Tagged A_1^n



Spectator tagging reduces uncertainty in A_1^n by a factor of >10 at low-x, factor of >2 everywhere

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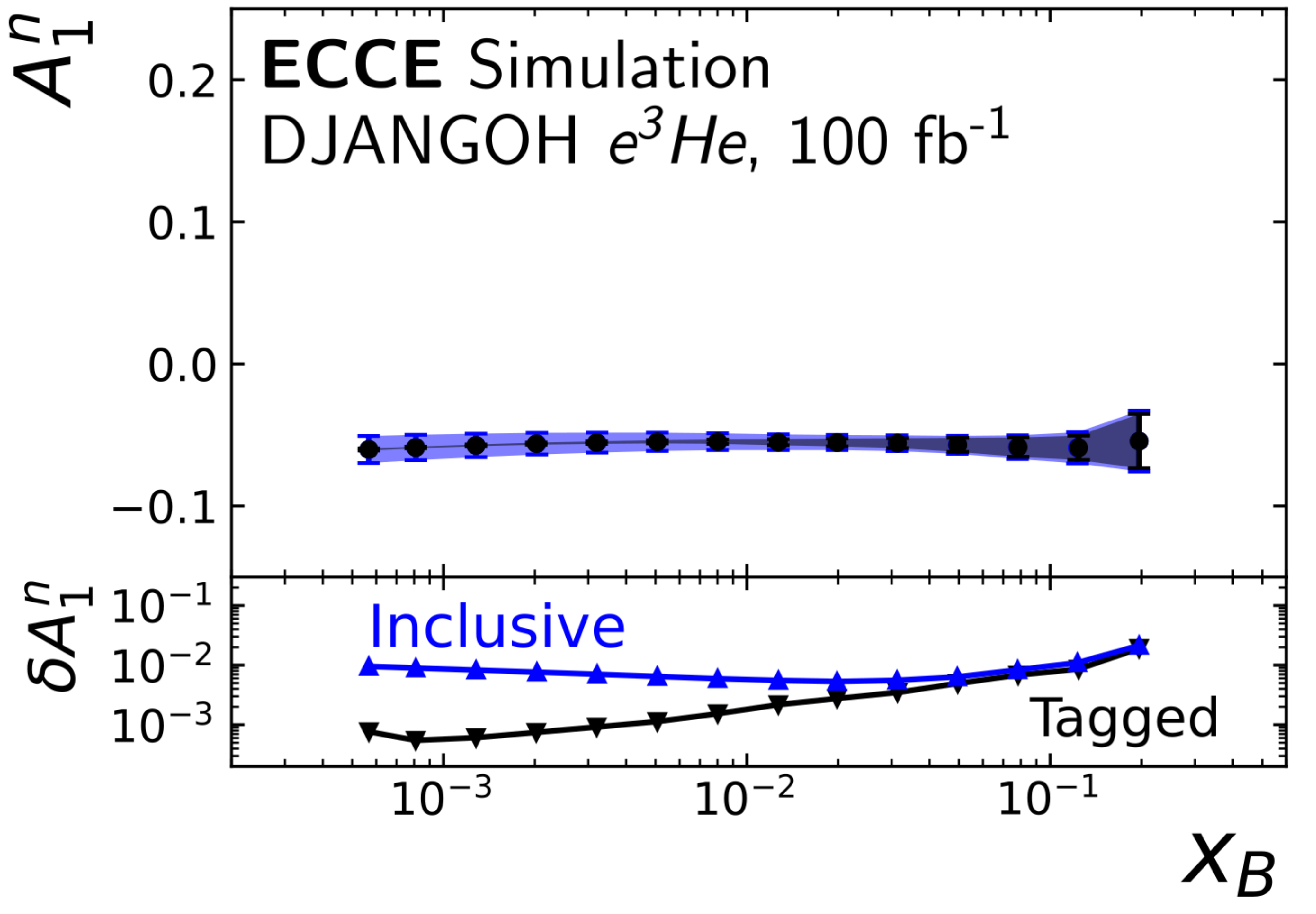
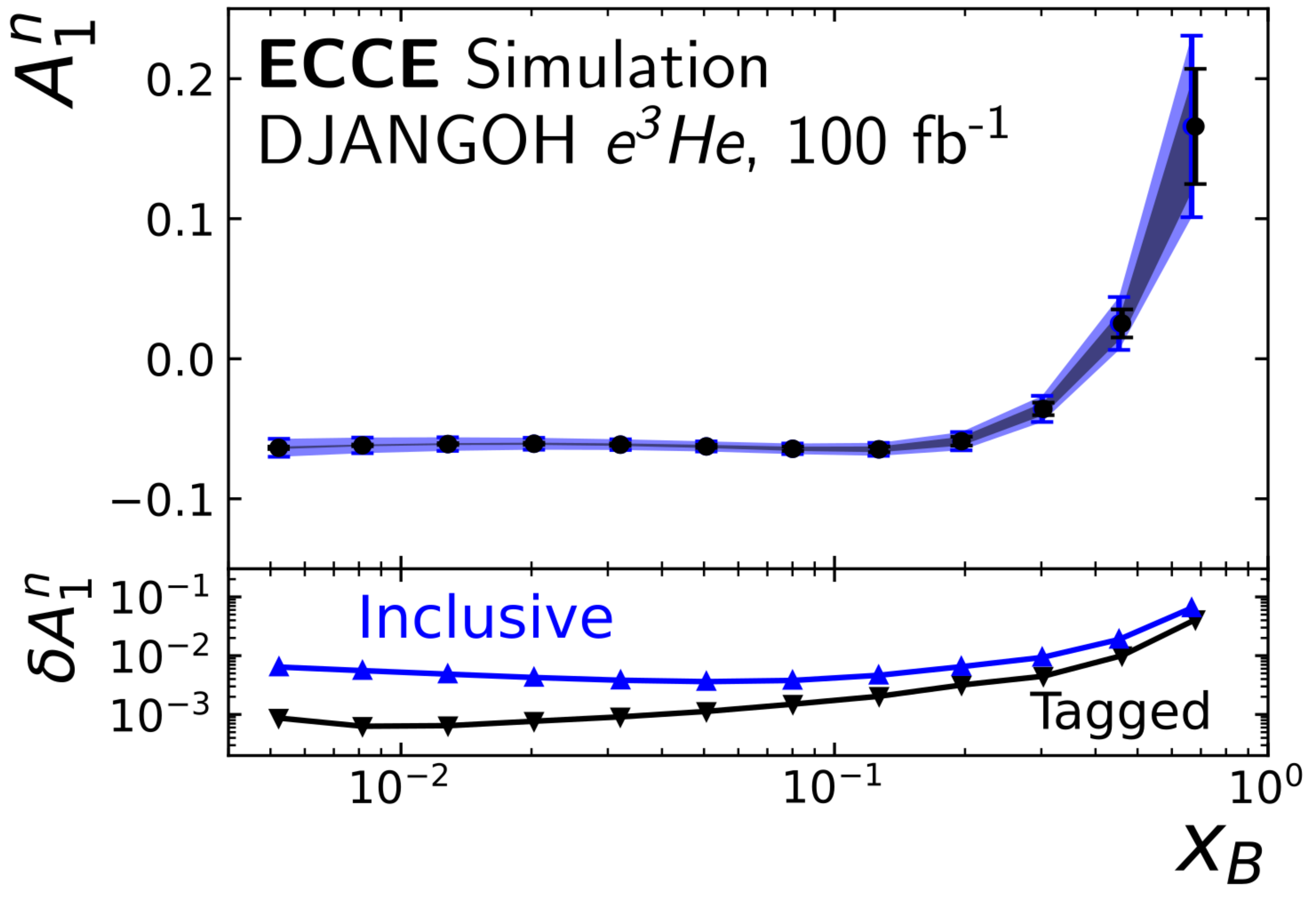
More detailed studies done with ePIC

18×166 GeV



5×41 GeV



Highest-energy setting pushes to $x_B < 10^{-3}$, where tagging is critical

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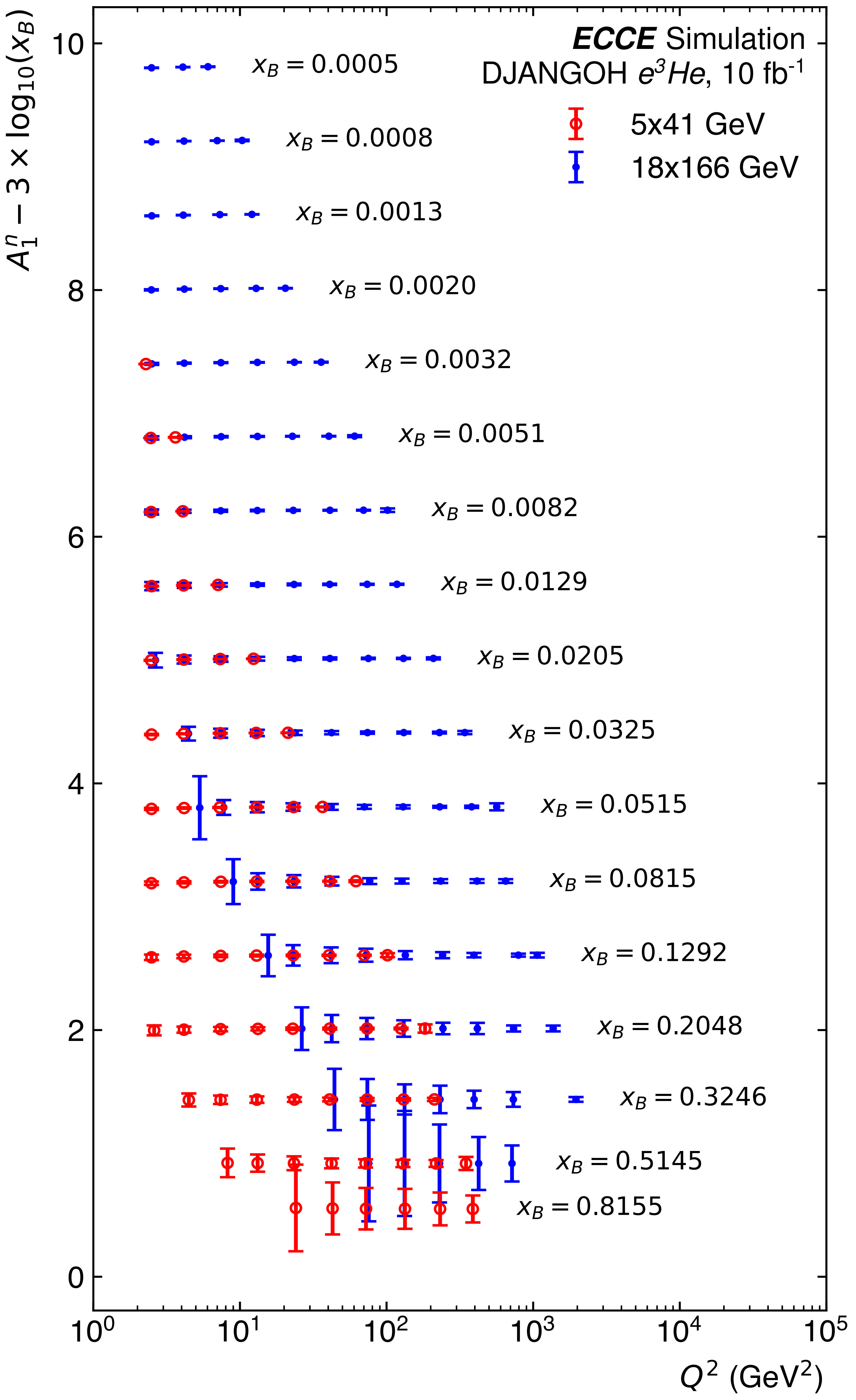
Combining EIC settings gives substantial kinematic coverage

Q^2-evolution of neutron spin structure still poorly known!



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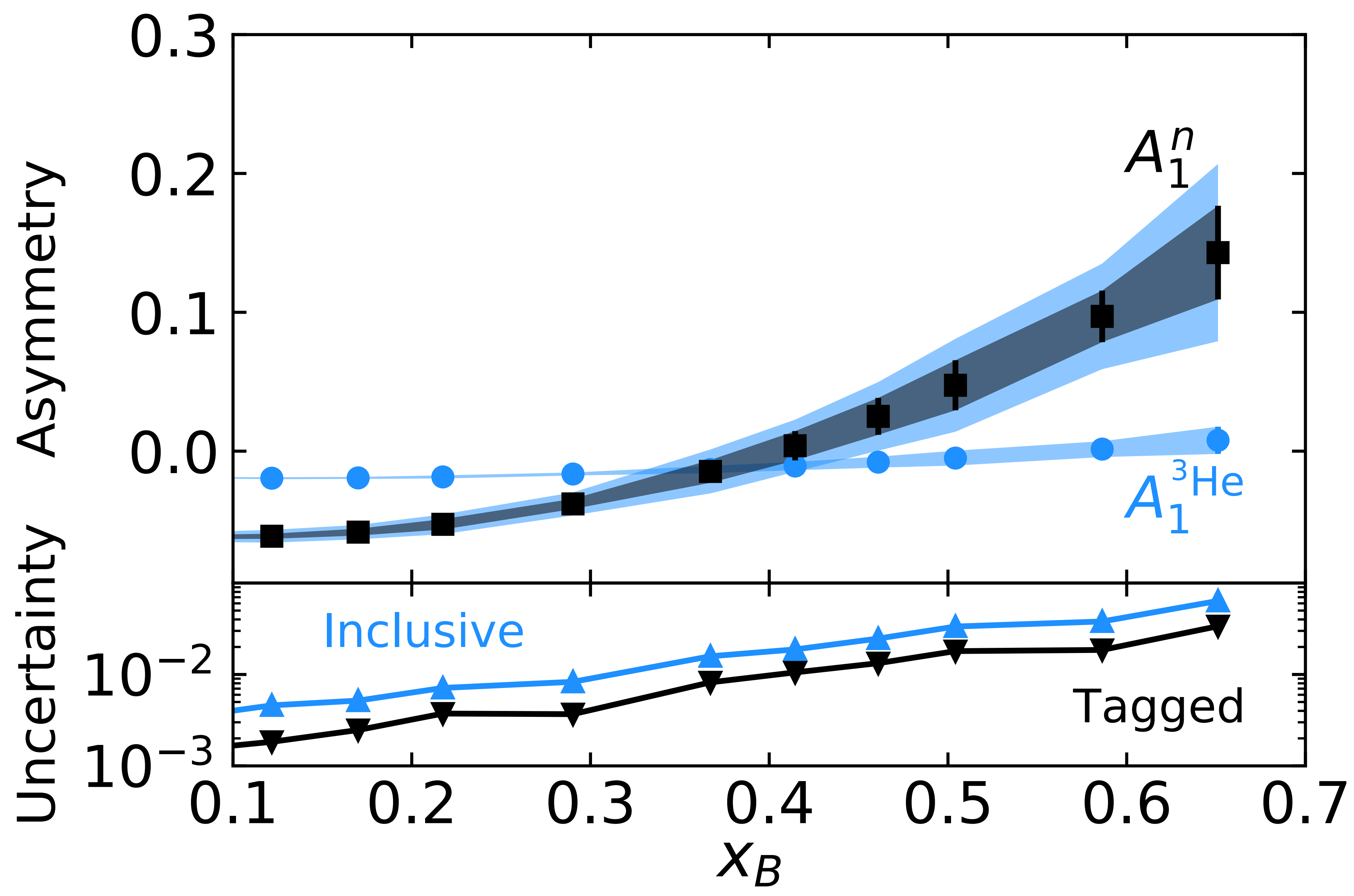
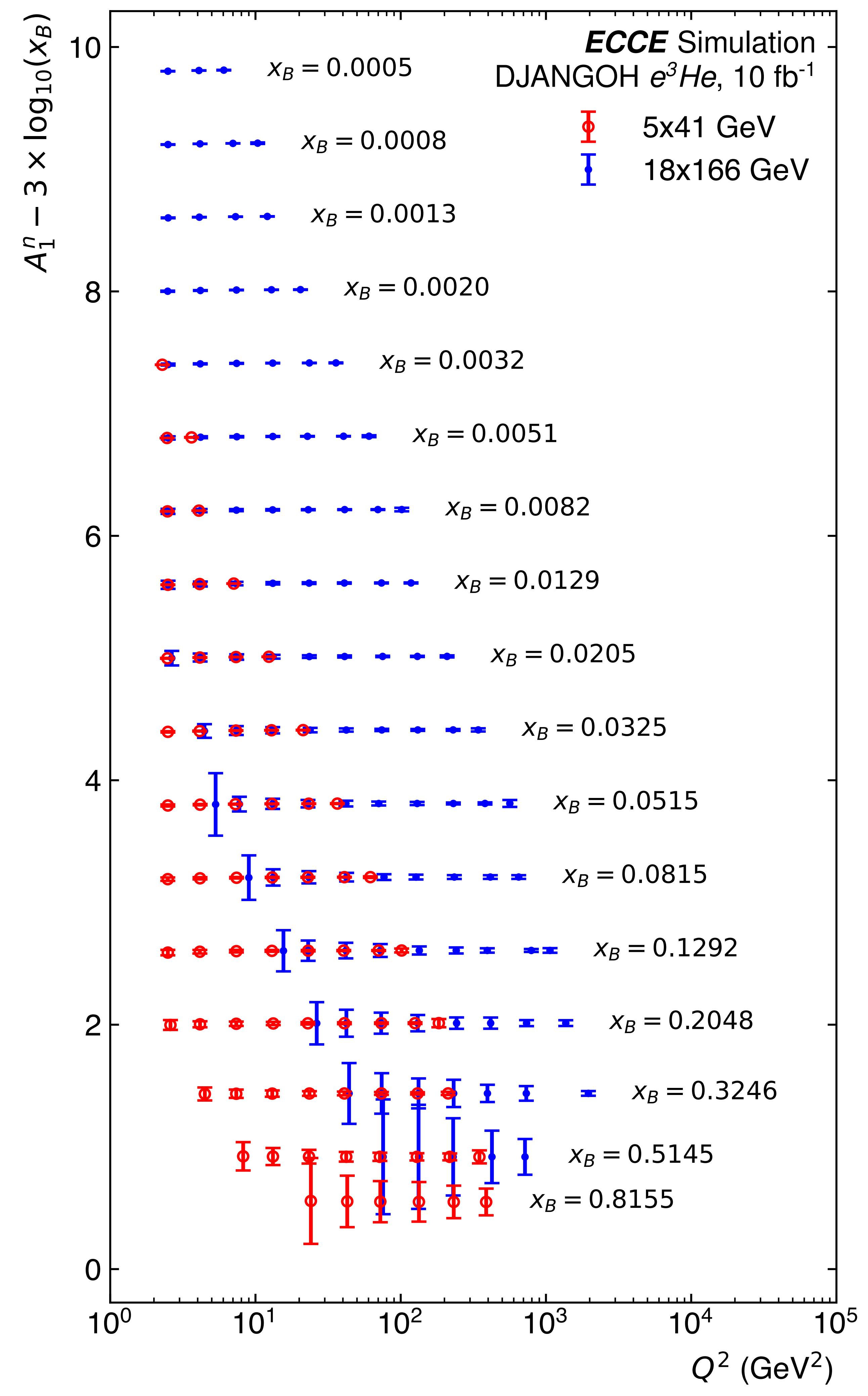
Conclusions

- EIC provides unique opportunity to measure neutron spin structure over wide kinematics
- Spectator tagging critical to fully realize this potential





Backup

A_1 Spin Asymmetry

- Quark spin structure function:

$$g_1\left(x, Q^2\right) = \frac{1}{2}\sum_i e_i^2 \left[q_i^{\uparrow}\left(x, Q^2\right) - q_i^{\downarrow}\left(x, Q^2\right)\right]$$

- Accessed by measuring virtual photon asymmetry:

$$A_1\left(x, Q^2\right) = \frac{\sigma_{1/2} - \sigma_{3/2}}{\sigma_{1/2} + \sigma_{3/2}} \approx \frac{g_1\left(x, Q^2\right)}{F_1\left(x, Q^2\right)}$$

- Can be calculated from electron-nucleon spin asymmetries:

$$A_1 = \frac{A_{||}}{D(1+\eta\xi)} - \frac{\eta A_{\perp}}{d(1+\eta\xi)}$$