



2018

XXVI International Workshop on
Deep Inelastic Scattering and
Related Subjects



indico.cern.ch/event/656250/contributions/2915733/

Next-generation neutron structure measurements with spectator tagging at EIC

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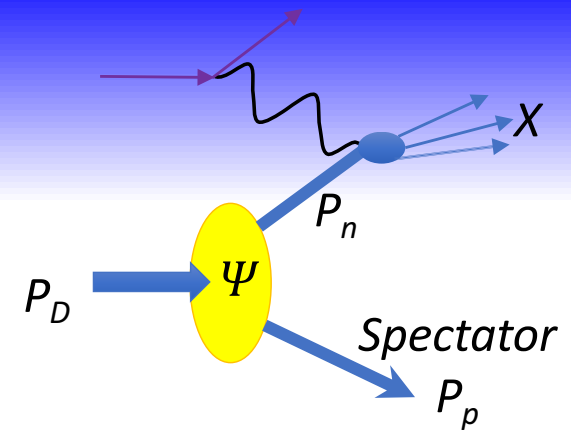


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Collider Kinematics

- Natural light-cone direction is event-by-event frame with \mathbf{q} and \mathbf{P}_D anti-collinear.
 - Spectator proton (or neutron) emitted in forward direction with $\sim 50\%$ of beam momentum
- Beam emittance envelope is comparable to Far-Forward tracking resolution of spectator proton
- Both effects (and crossing angle) included in $e D \rightarrow e' p X$ Monte-Carlo
 - Jlab LDRD 2014-2015
www.jlab.org/theory/tag/
Codes, references...

Light-Cone Variables: (α , \mathbf{p}_\perp)



$$P_D^{[+, -, \perp]} = \left[P_D^+, \frac{M_D^2}{2P_D^+}, \mathbf{0}_\perp \right],$$

$$p_S = p_p^{[+, -, \perp]} = \left[\frac{\alpha}{A} P_D^+, \frac{M_N^2 + \mathbf{p}_\perp^2}{2\alpha P_D^+/A}, \mathbf{p}_\perp \right],$$

$$p_n^2 = (P_D - p_p)^2 \equiv t$$

$$M_N^2 - t \approx 2M_N B + 2\mathbf{p}_{\text{Rest}}^2$$

$$P_D^+ \gg M_D = 2M_N - B;$$

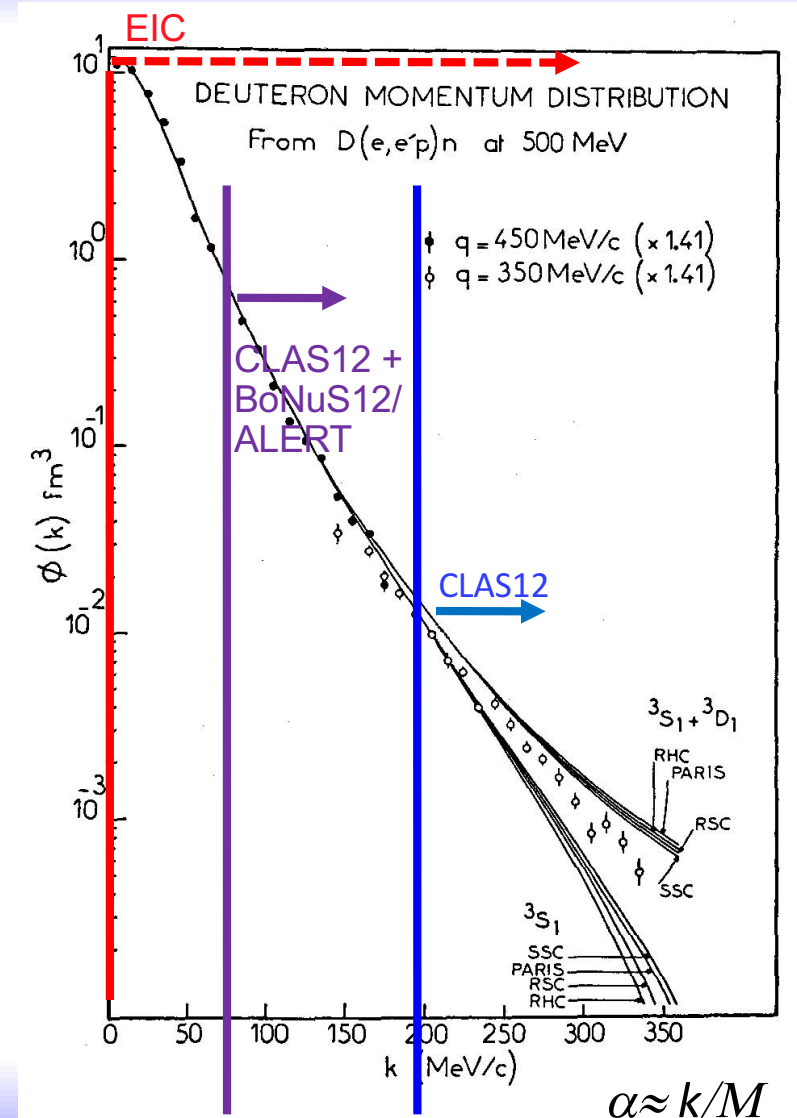
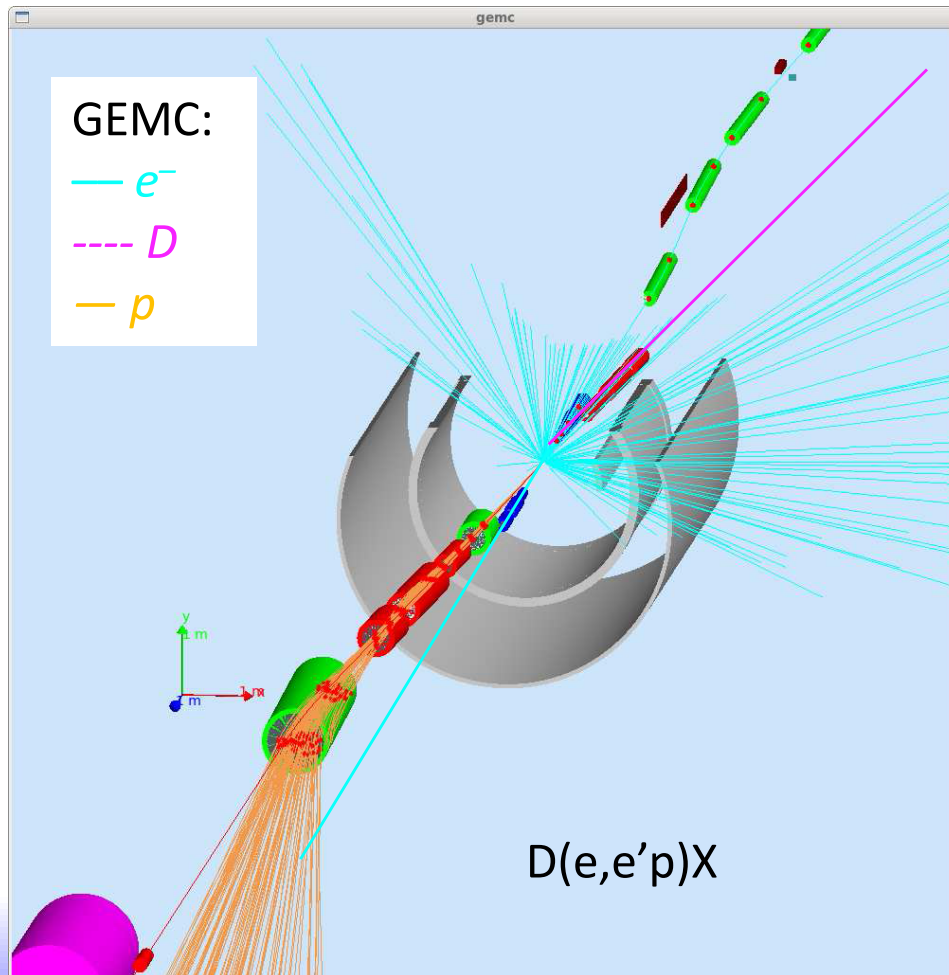
$$0 < \alpha < A = 2;$$

$$\alpha \approx 1 + \frac{p_z^{\text{Rest-frame}}}{M}$$

$$|\alpha - 1| \lesssim p_F$$

Detector implementation

- JLEIC example

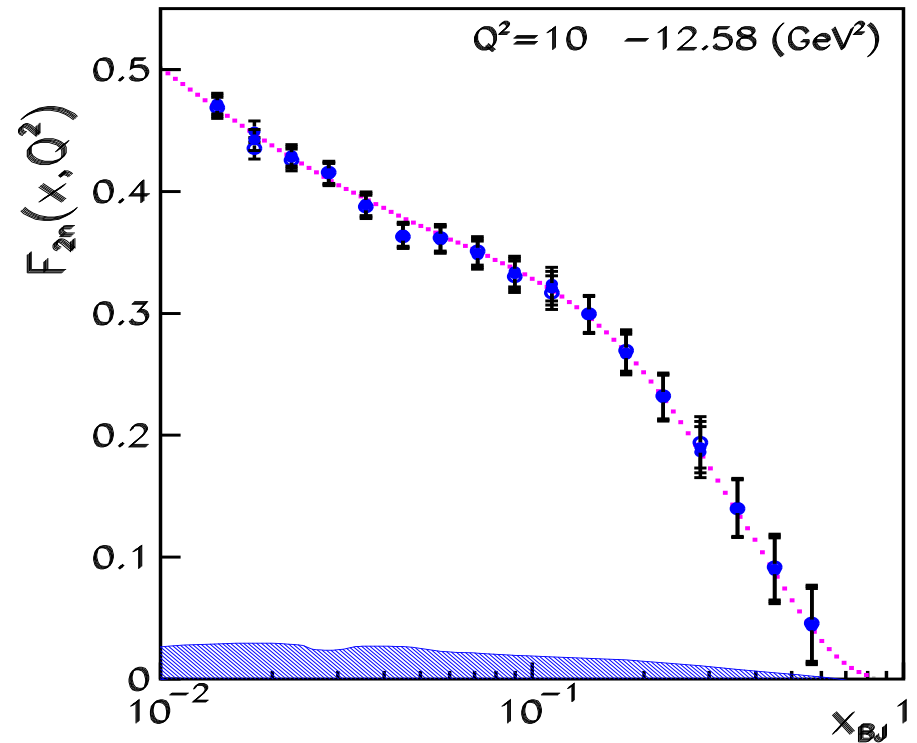
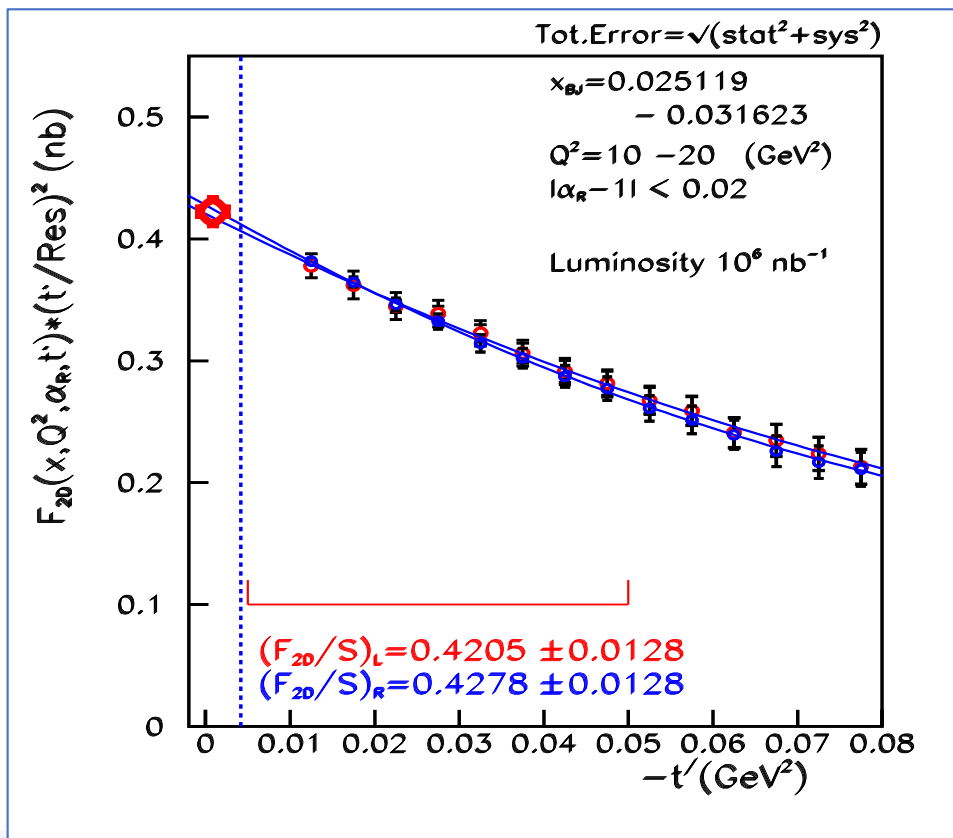


Beam Emittance & Detector Resolution

- Beam emittance envelope (JLEIC)
 - $\sigma(P_D)/P_D \approx 3 \cdot 10^{-4}$, $\sigma(P_{\perp})/P_D \approx 2 \cdot 10^{-4}$
- Spectator tracking resolution
 - $\sigma(x) \approx 100 \mu\text{m}$, Dispersion $\approx 1\text{m}$
 - $\sigma(P_{||}, P_{\perp})/P_p \leq 2 \cdot 10^{-4}$
 - Requires relative stability/position measurement of transverse beam crossing to $\sim 100 \mu\text{m}$
 - On-shell extrapolation is smooth in $(t')^2 d\sigma$
 - Sensitive to resolution of t' : Simulation results assume emittance is known/stable to $\pm 10\%$
- $P_D = 100 \text{ GeV}/c$
 - $\sigma(p_{\perp}) \approx 15 \text{ MeV}/c$
 - $\sigma(\alpha) \approx 0.0002$

Neutron F_2

- On-shell extrapolation

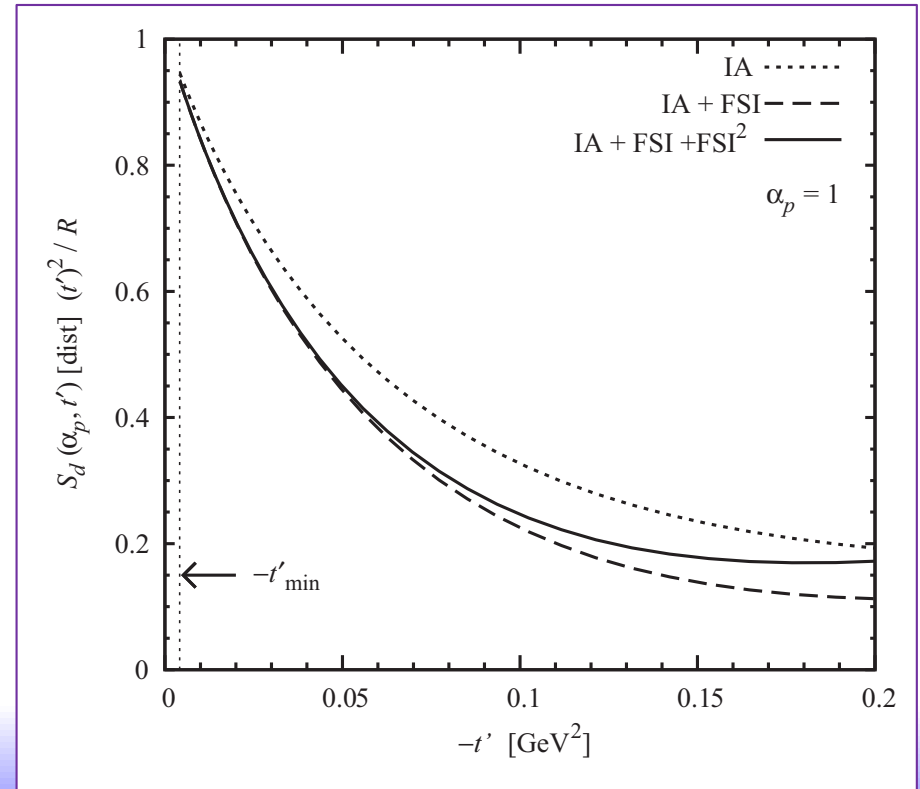
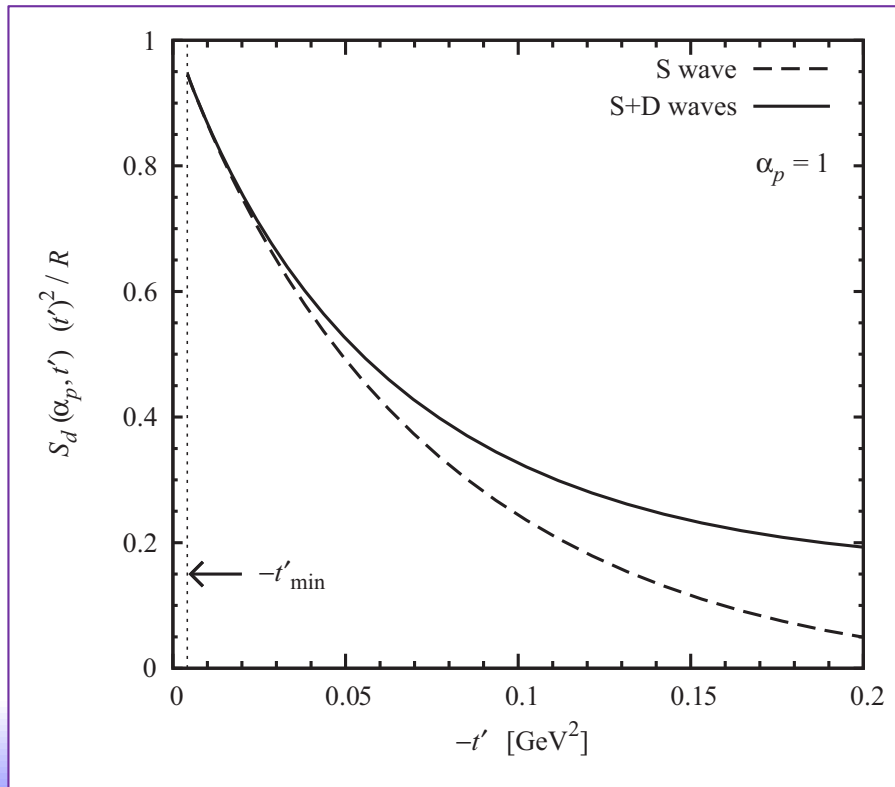


One (small) bin in Q^2

Cross section multiplied by $(t')^2$

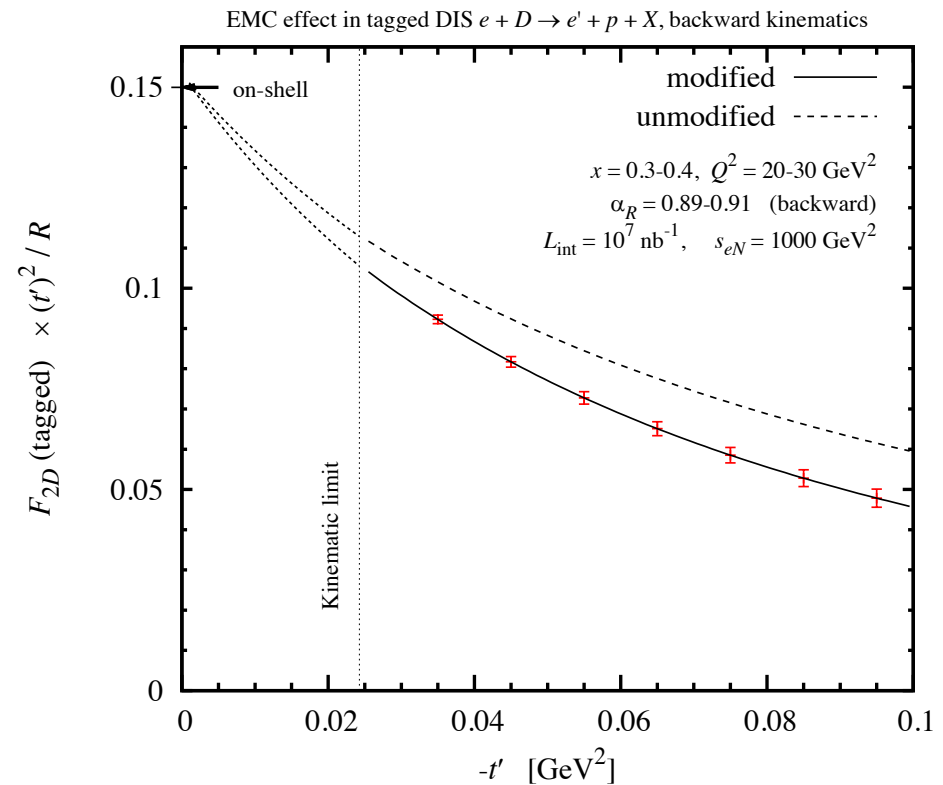
$D(e,ep_s)X: p_s+X$ FSI

- Final State Interactions alter the shape of the On-Shell extrapolation, not the residue F_{2n} at the pole $1/(t')^2$
 - M.Strikman, C.Weiss, PRC **97** (2018)



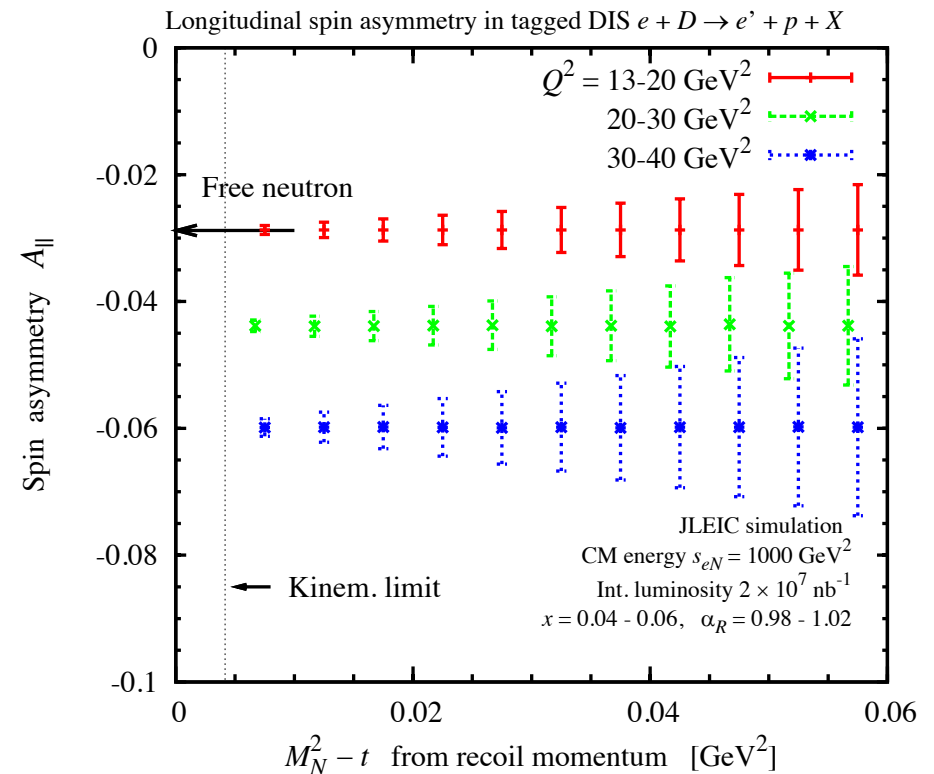
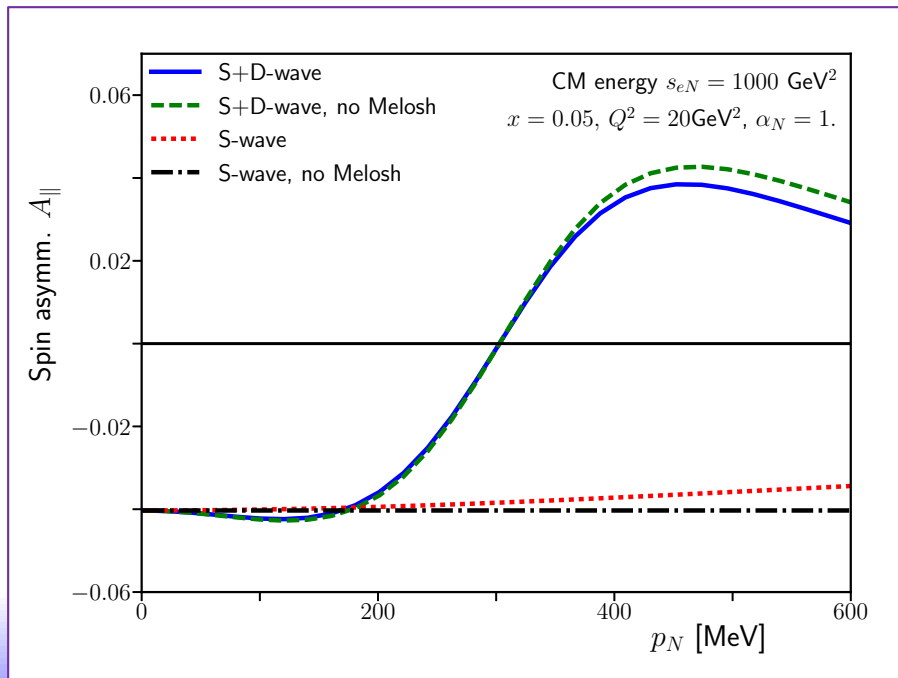
The EMC Effect in the Deuteron

- Concept: EMC effect arises from short range fluctuations in D wave-function
- Extract on-shell point for $|\alpha-1| < 0.02$
- Dashed line is IA for $\alpha = 0.9$
- Pseudo-data shows possible magnitude of EMC effect
- “Model-Independent” extraction



Polarization: On-Shell Extrapolation

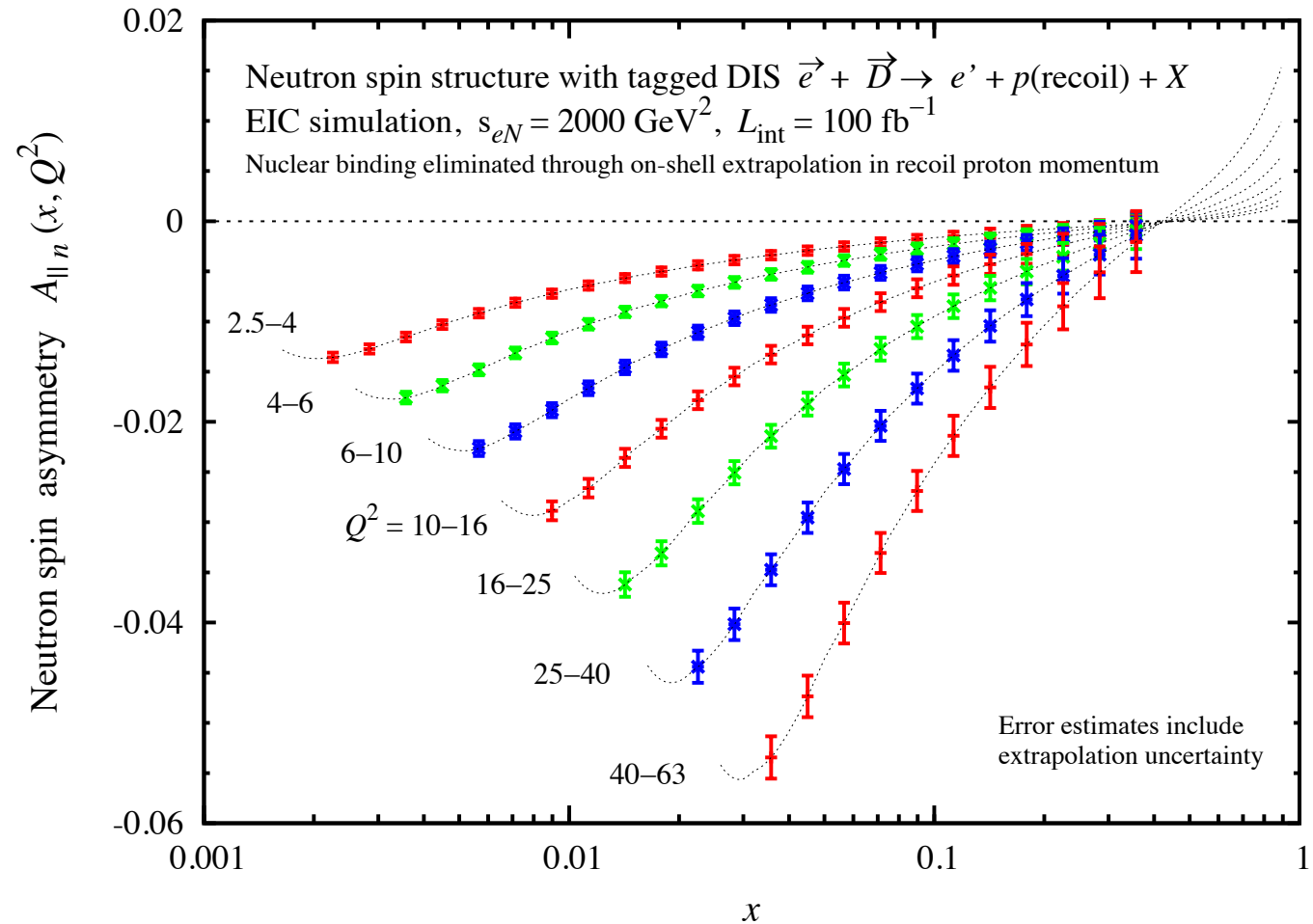
- Simulation with S-state only
 - Asymmetry independent of t'



- S+D state:
 - Sargsian, Cosyn, Weiss 2017
 - Extrapolation smooth for $t' < 0.08 \text{ GeV}^2$

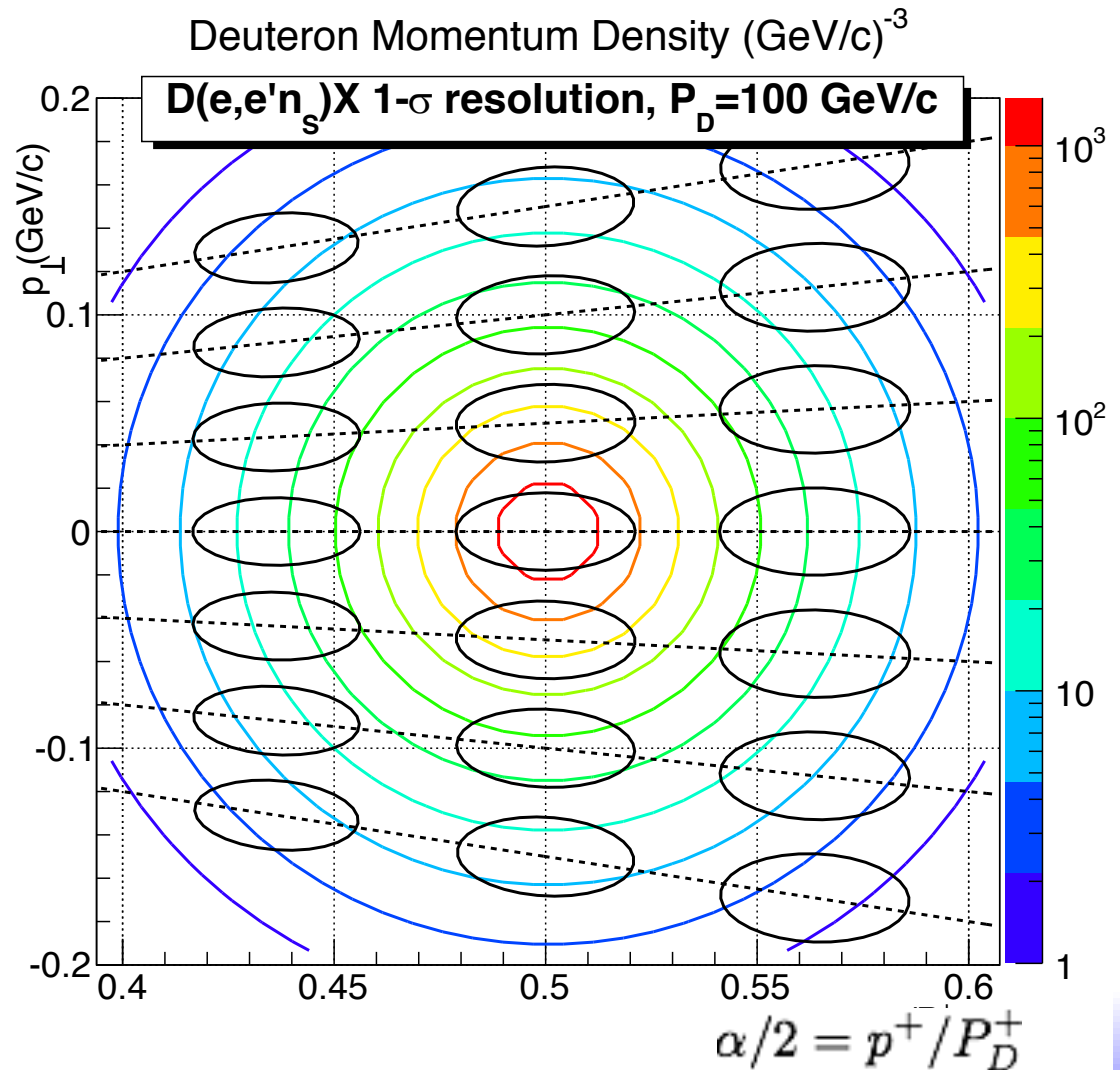
Polarization

- 1 year @ $10^{34}/\text{cm}^2/\text{s}$
- Depolarization favors lower energy:
 $D = y(2-y)/(2-2y+y^2)$
- $p \pm n$
 - flavor
 - Bjorken Sum Rule
 - $\alpha_s(Q^2)$



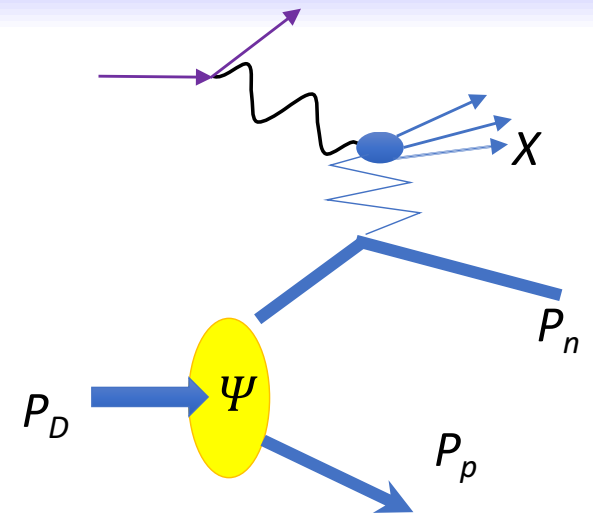
DIS from Bound Proton

- Tag spectator neutron
 - $D(e,e'n) X$
 - State-of-the-art HCal
 $\sigma(E)/E \gtrsim 30\%/ \sqrt{E}$
NIM A 866 (2017) 76.
- 3 contours/decade in D momentum distribution.
- Ovals are 1- σ envelope of tagged neutron resolution.



Diffraction, (Anti-) Shadowing and the NN interaction

- $D(e, e' pn)X$,
- Small sized color neutral “X”
 - Only FSI are ordinary pn interactions
- $D(e, e' Vpn)$
 - Transition GPD of $D \rightarrow pn$ continuum
 - G. Miller, M. Sievert, R. Venugopalan, PRC **93** (2016)
 - Final state np relative momentum Fourier Conjugate to initial state np spatial separation.
 - Study the quark-gluon structure of interacting np pair
 - Or Hen, Alterelli Prize lecture on dynamics of EMC effect



Conclusions

- Unprecedented precision study of neutron, and NN, NNN quark-gluon structure possible with spectator tagging at an Electron Ion Collider
 - Boost enables tagging to $p_s \approx 0$
 - Transverse, Longitudinal, Tensor Polarization without dilution
- ^3He (polarized) is essential too, but not a substitute for the deuteron (polarized or unpolarized)