

Exploring the QCD Structure of the NN Interaction *via* Tagged DIS and DVES on Light Nuclei

Charles Hyde

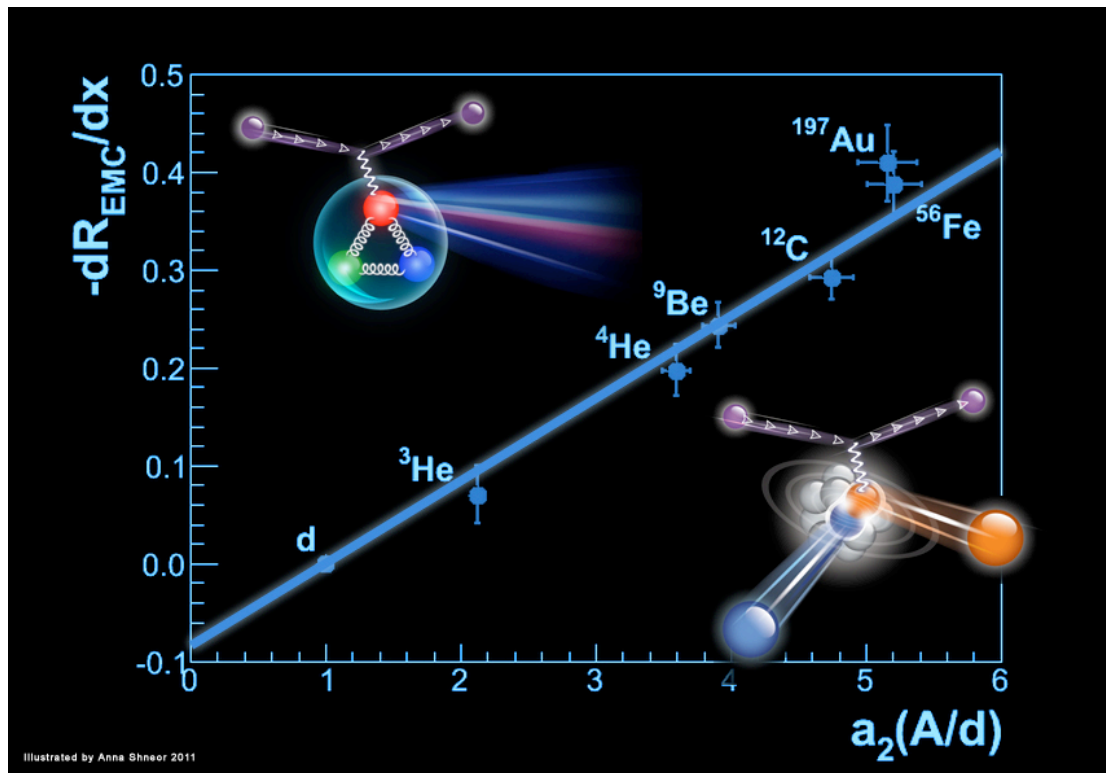
Old Dominion University

Norfolk VA



NN Correlations and the EMC Effect

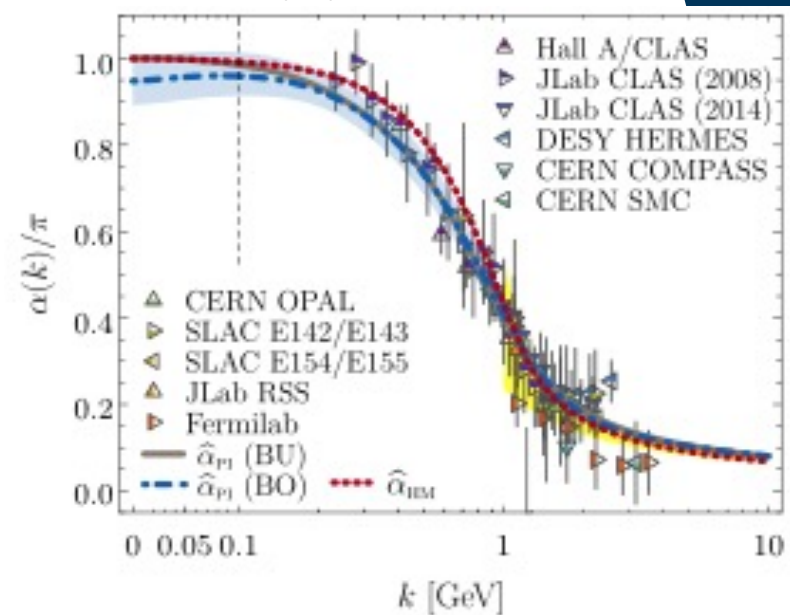
- Or Hen (Previous talk)
 - DIS at $x_B > 1$ correlates with the EMC effect



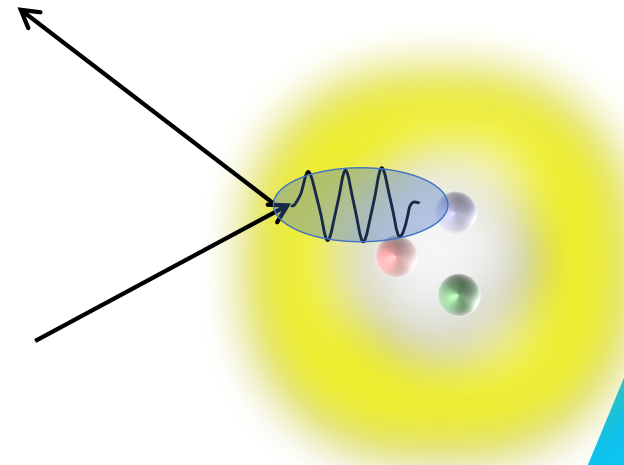
Dynamics and Kinematics of DIS

J. Rodríguez-Quintero, *et al.*,
Few Body Syst. **59** (2018) 121

- $\alpha_S(k)/\pi < 0.3$ for $k > 1$ GeV



- Virtual photon probes a volume $\left[\frac{1}{Q^2} \right]_T \otimes \left[\frac{1}{2xM} \right]_L$



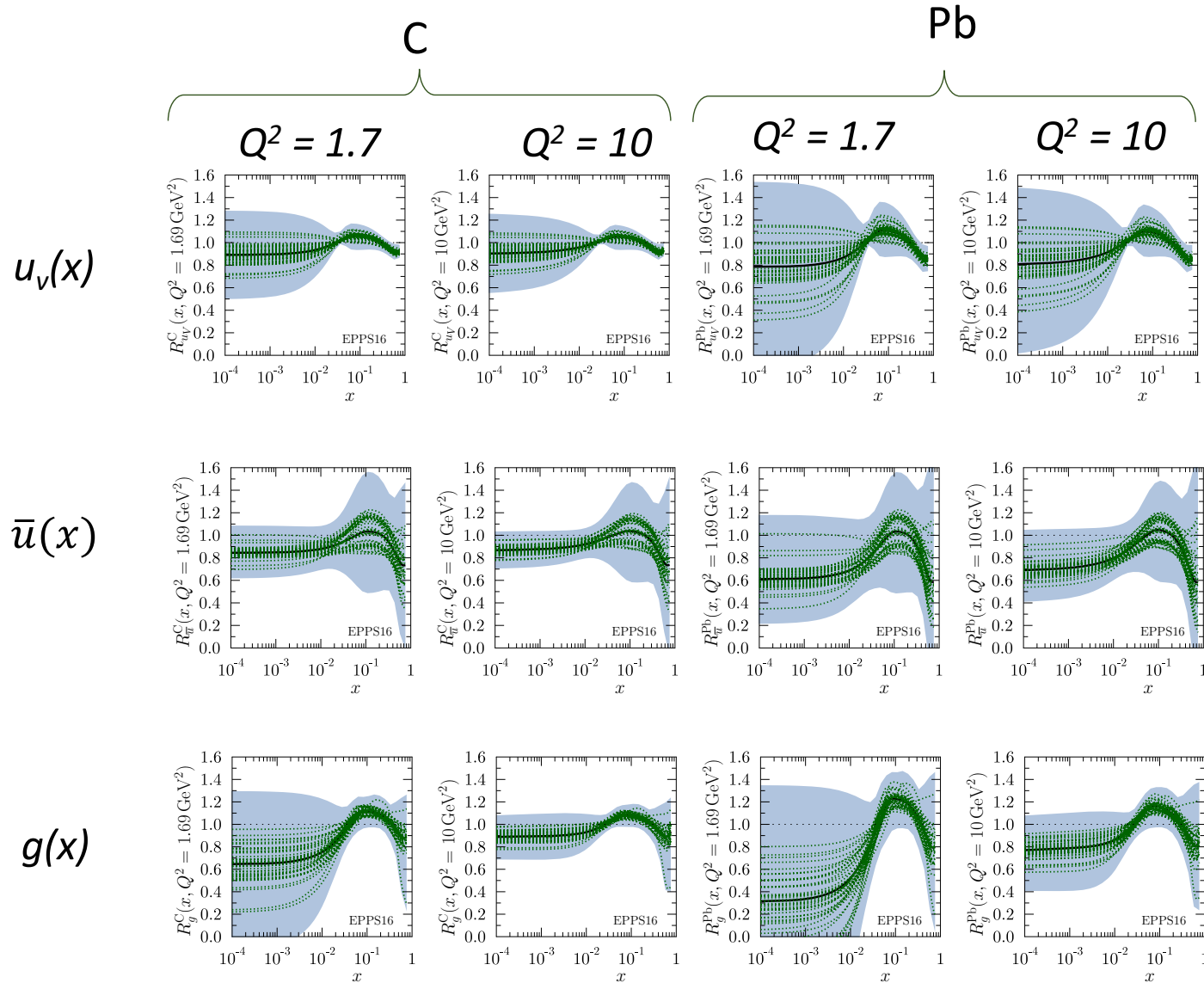


Long-Distance Color Entanglement – I.

- $x \approx 0.1$: “Anti-Shadowing”
 - DIS enhancement: $q(x) + \bar{q}(x)$
 - No $\bar{q}(x)$ enhancement in Drell-Yan (FermiLab E772)
 - Hard Core of NN-interaction from qqg interchange?
- Expect gluon enhancement in nuclei
 - JLab LDRD program on open-charm in nuclear DIS @ EIC

Nuclear PDF ratios to A•Nucleon

EPPS, Eur. Phys. J. C (2017) 77:163

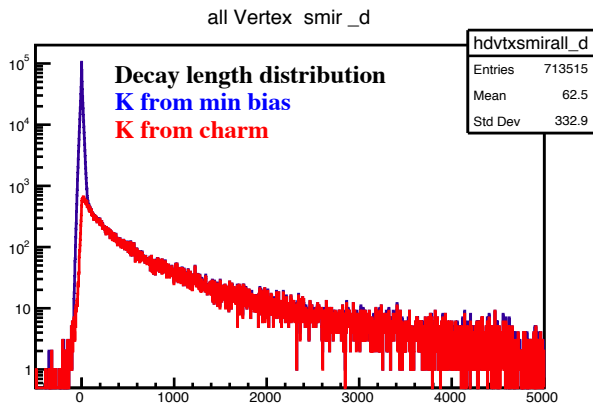
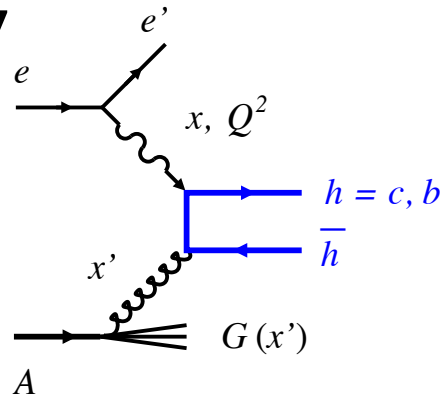




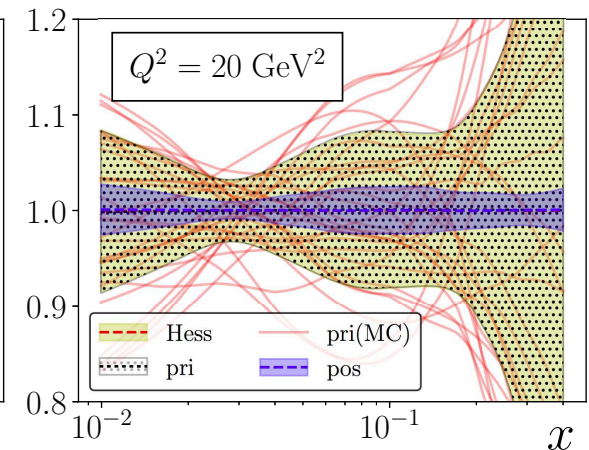
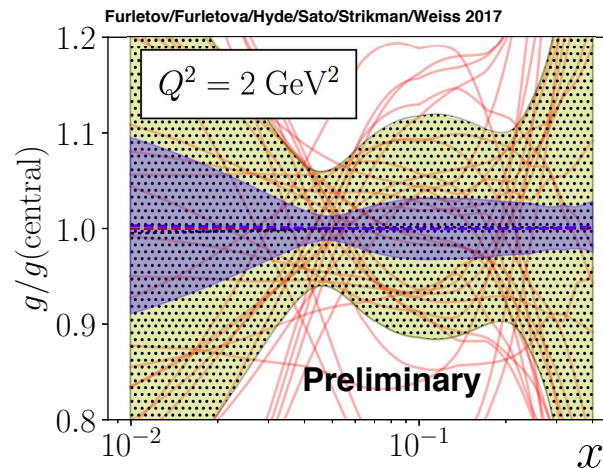
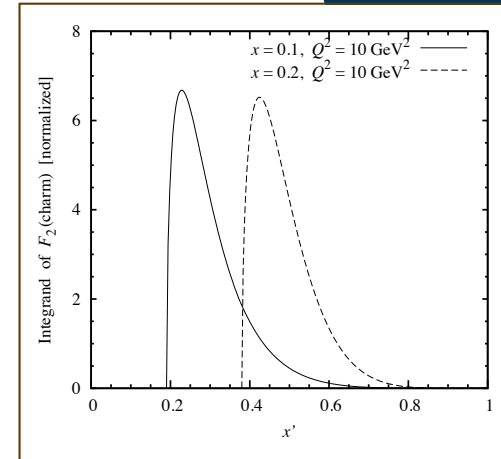
EIC Open Charm

JLab LDRD 16-01/17-01, C. Weiss, *et al*,

• $eA \rightarrow e'c\bar{c}X \rightarrow e'DX'$



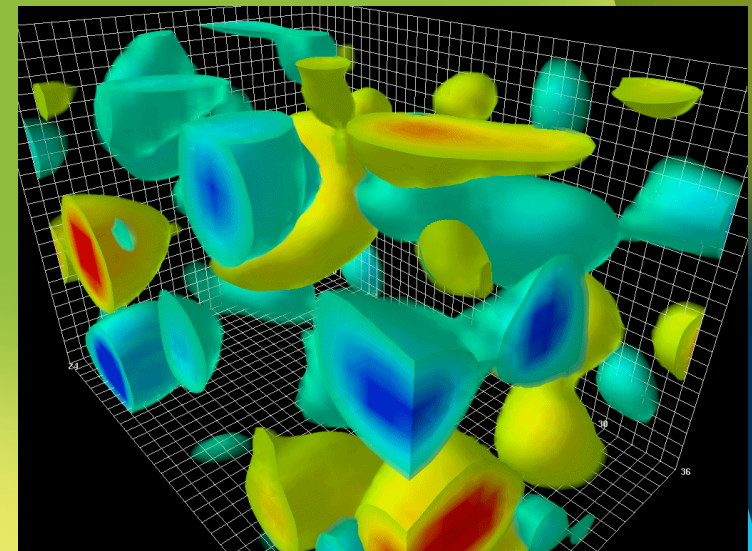
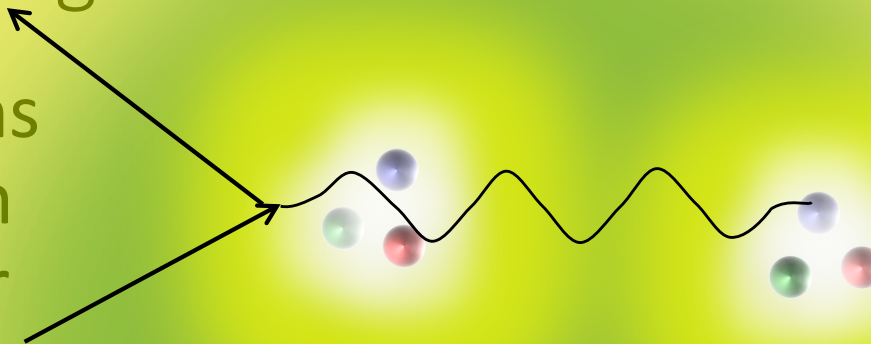
• 10 fb^{-1}



Long-Distance Color Entanglement – II.

$x \ll 0.1$: “Shadowing”

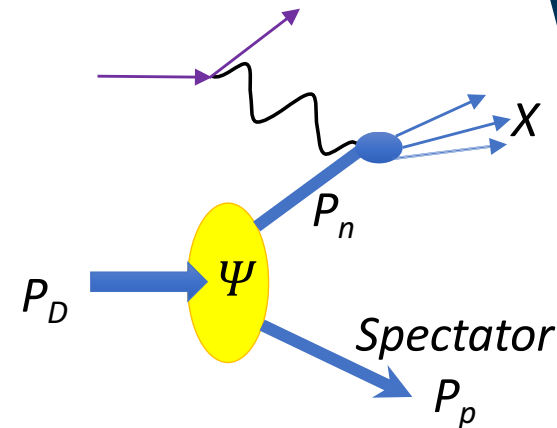
- DIS probes fluctuations with coherence length larger than nucleon or even nuclear size
 - Low energy probes cannot distinguish this from vacuum fluctuations
- Precursor to saturation



Animations at

www.physics.adelaide.edu.au/theory/staff/leinweber

Nuclear Final State



- Naïve spectator kinematics:

$$p_i^\mu = \left[\frac{\alpha_i}{A} P_A^+, \mathbf{p}_{i,T}, p_i^- \right]$$

$$\sum_{i=1}^A \alpha_i = A$$

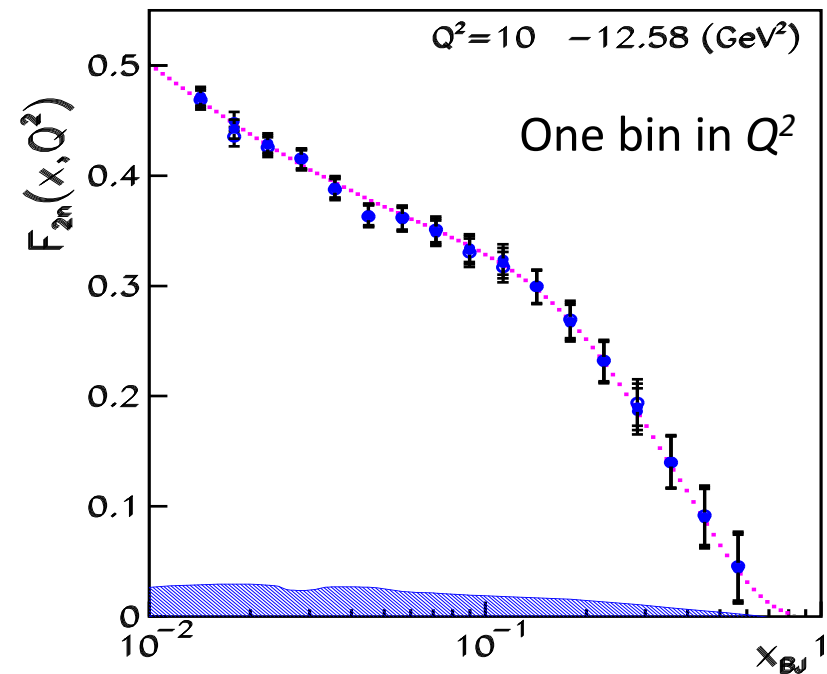
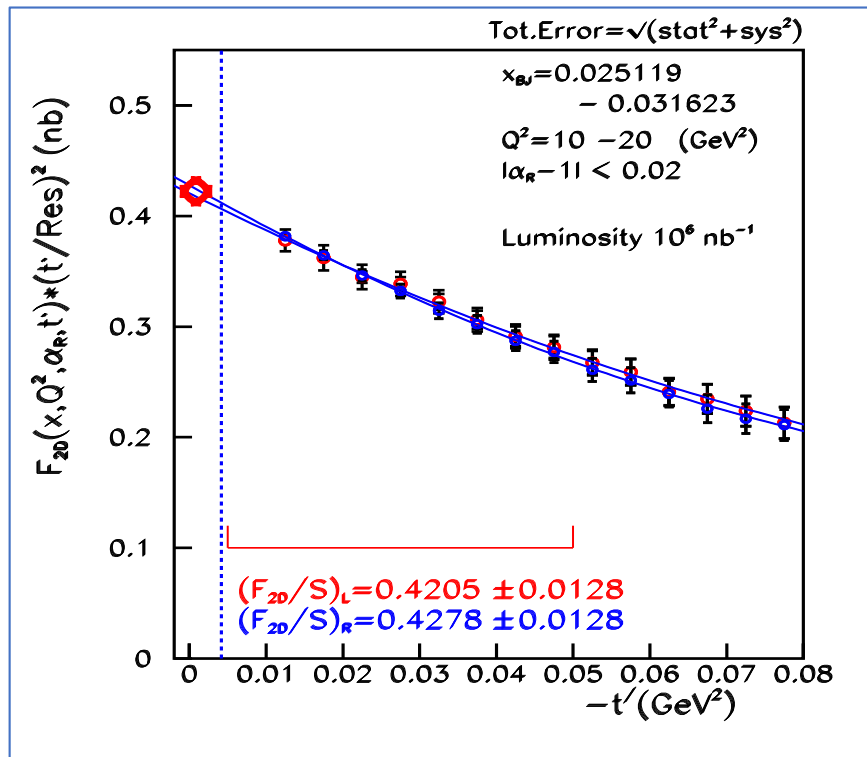
$$\sum_{i=1}^A \mathbf{p}_{i,T} = 0$$

- Fermi gas: $|\alpha_i - 1| \lesssim p_F / M \approx 0.25$ $\mathbf{p}_{i,T} \leq p_F$
- EIC: In a heavy nucleus of momentum $Z \bullet (100 \text{ GeV}/c)$, spectator neutrons, protons have laboratory momenta $(p_{||}, p_T) \approx [\alpha_i(40 \text{ GeV}/c), \mathbf{p}_{i,T}]$
- Forward Tagging!



Spectator Tagging DIS

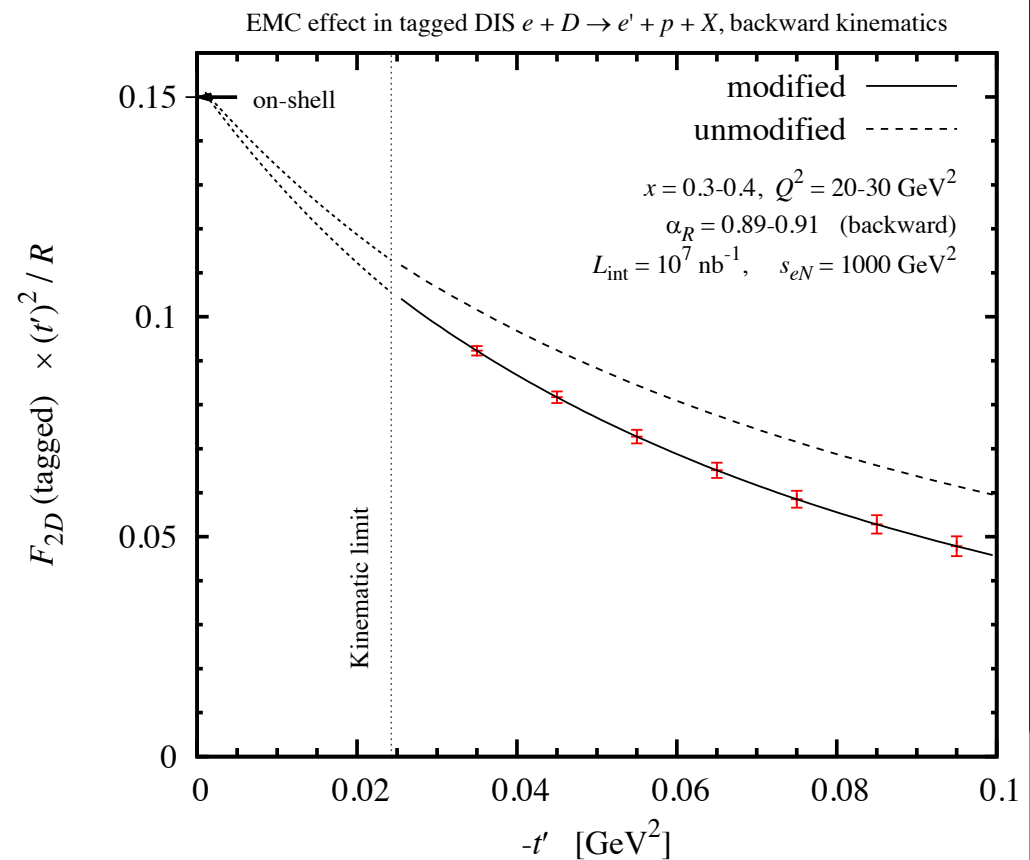
- Neutron on-shell extrapolation for $\alpha_p \approx 1$, $p_{\perp} \rightarrow 0$





DIS on the Deuteron: Spectator Tagging

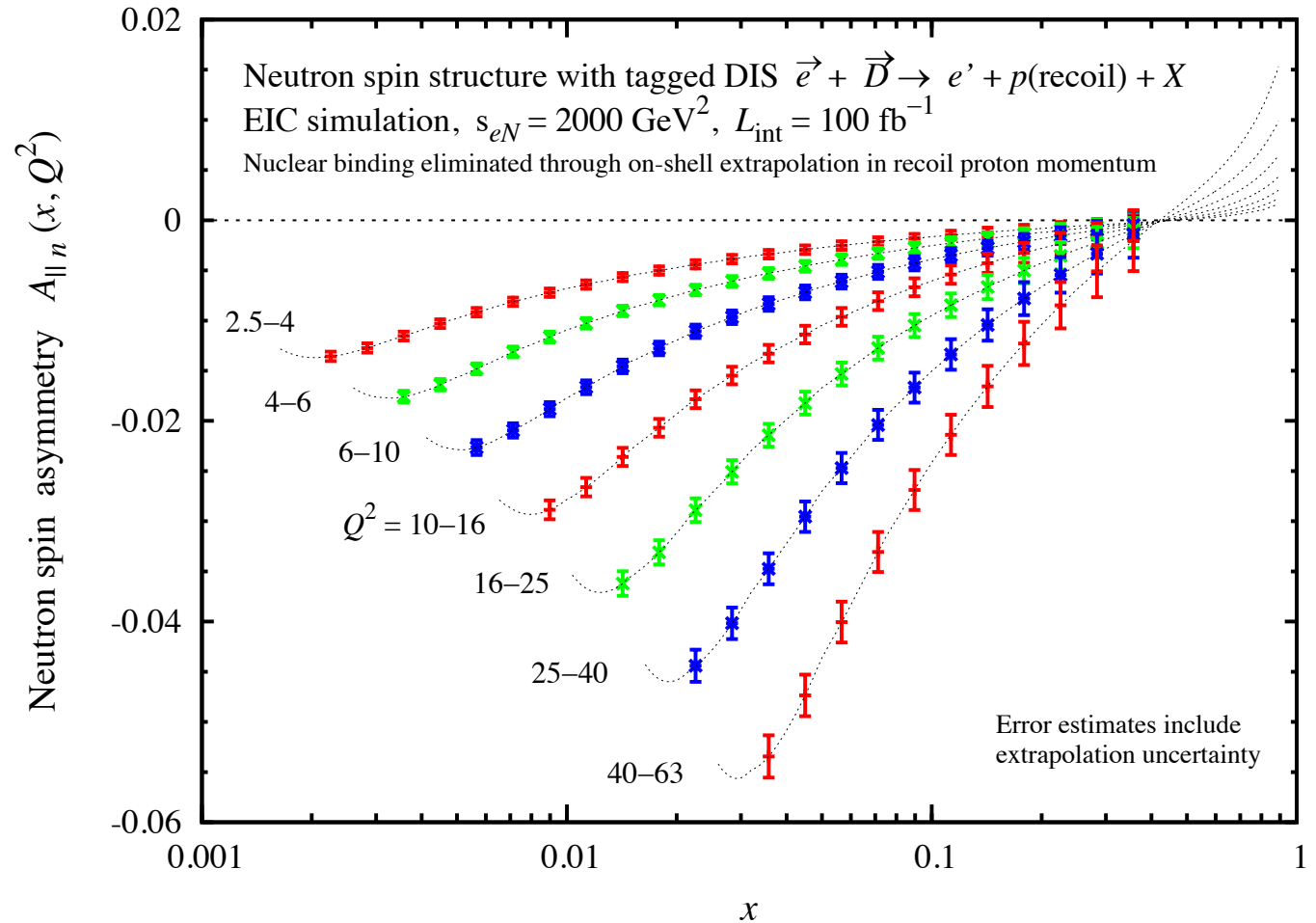
- $\alpha_p \approx 1, \mathbf{p}_{p,T} \approx 0$
→ on-shell extrapolation of DIS on neutron
- Calibrate with ZDC tagging of spectator neutron
 - $30\%/E_n^{1/2} \approx 4\% @ 50 \text{ GeV}$
 $\delta\alpha_p \approx 0.04$ →
Rest frame resolution of initial NN relative momentum $\sim 40 \text{ MeV}/c$ for DIS on nearly on-shell proton
- On-shell point measured for $|1-\alpha_p| < 0.02$
 - EMC effect in Deuterium with $|1-\alpha_p| > 0.2$!!





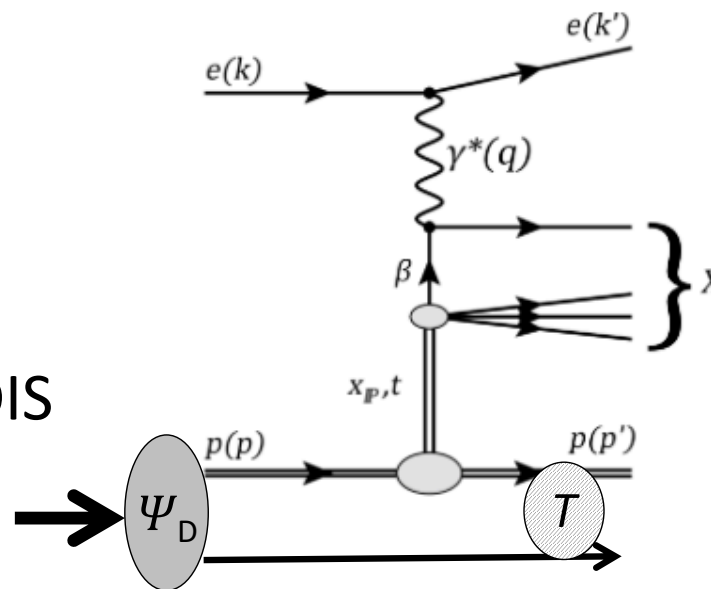
Polarized Deuterium 100 fb^{-1}

- Depolarization favors lower energy:
 $D = y(2-y)/(2-2y+y^2)$
- $p \pm n$
 - flavor
 - Bjorken Sum Rule
 - $\alpha_s(Q^2)$
- Tensor polarization also
 - $b_1(x)$



Diffractive DIS (Double Tagging)

- A probe of multi-nucleon dynamics
- Low p_{\perp}
 - Coherent scattering from quasi-free $n+p$
 - Calculable from ep DIS
- High p_{\perp} (high M_{n+p})
 - Pomeron exchange from short range NN pair.

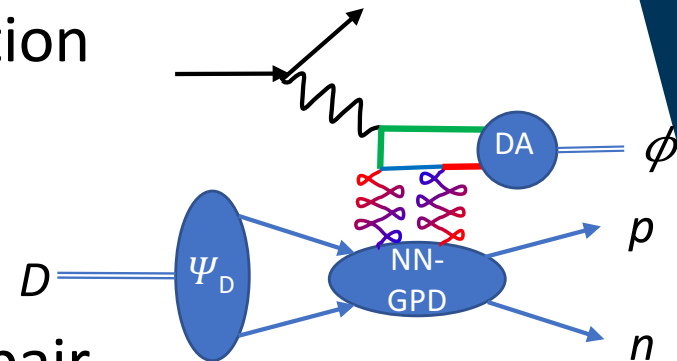


Color-neutral
 $\delta b > 1/[Q^2]^{1/2}$
No FSI!

Coherent Diffractive DIS

- $eD \rightarrow e V pn$

- Miller, Sievert, Venugopalan, Phys.Rev. C93 (2016) 045202
- *e.g.* Deep exclusive ϕ -production
- $\Delta^2 = (P_D - p_p - p_n)^2 = (q - q_\phi)^2$
- Small $-\Delta^2$, large $\mathbf{p}_{p\perp}$
 \rightarrow Transverse gluon distribution of interacting np pair



- Challenges:

- Large $\mathbf{p}_{p\perp} \rightarrow$ large $M_{np} \rightarrow$ increases minimum value of $-\Delta^2$
- Count rate? GPD structure of continuum np system?

- Opportunities:

- CLAS12 Run Group B: $e+D$, 2019.
- ODU student Mitchell Kerver



Conclusions

- DIS and DVES on Polarized Light Nuclei
- Full or partial reconstruction of the nuclear final state
 - BONuS12 at JLab-CLAS12
 - Spectator tagging at EIC
 - “low-energy” spectators boosted by ion β
 - Neutron tagging with $\delta\alpha \leq 0.05$
- Novel probes of the QCD dynamics of low-energy nuclear physics
 - Polarized ^3He for NNN interaction.
 - Polarized $^{6,7}\text{Li}$