FORWARD TAGGING WITH THE EIC@JLAB FULL ACCEPTANCE DETECTOR

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Forward Tagging in *ep*, *ed*, e^3He

Transverse and Longitudinal Polarized Ion Beams
Longitudinal Polarized Electron Beam

- **Tag DIS and current-jet SIDIS with respect to diffractive or non-diffractive DIS process.**
- **Projectile Fracture Distributions ($x_F < 0$):**

  Forward Dipole & Tracker
  - **Flavor-Momentum correlations between target-jet and current-jet hadrons.**

- **Deep Virtual Exclusive Scattering**

  Far-Forward Spectrometer, ➔ Exclusivity
  - **Generalized Parton Distributions**
  - **Transverse Spatial Imaging**
- **Spectator Tagging: D, ^{3}He Beams**

  Far-Forward Spectrometer, High-Resolution ZDC
  - **Neutron Structure Functions, Bjorken Sum Rule, *Δg(x)*.**
  - ***u/d* flavor separation: *GPDs, TMDs***
  - ***EMC* effect in the deuteron**

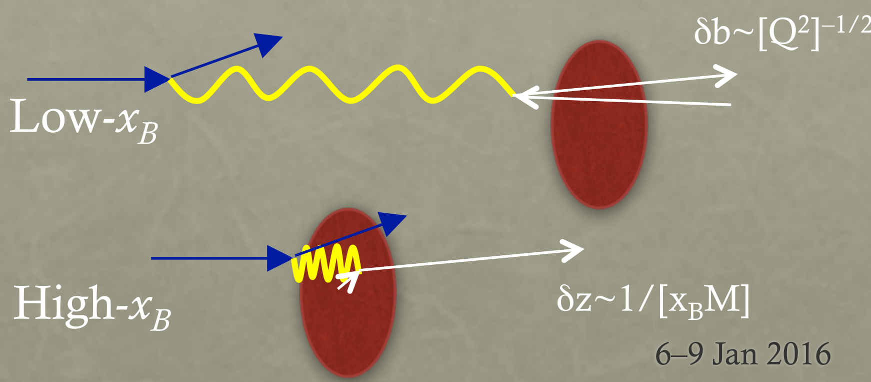
Forward Tagging for *eA* Physics

- Rapidity-Gap *vs* ordinary DIS events
- Hadronization Mechanism
  - p_T distributions of nuclear fragments
  - Gluon Saturation signals
- ‘Spectator’ Multiplicities
  - Nucleons, Light fragments, Fission fragments, Evaporation Residue

    ZDC & Far-Forward Spectrometer
  - Multiplicity tag on current-jet propagation distance:
    - DPMJetHybrid generator:

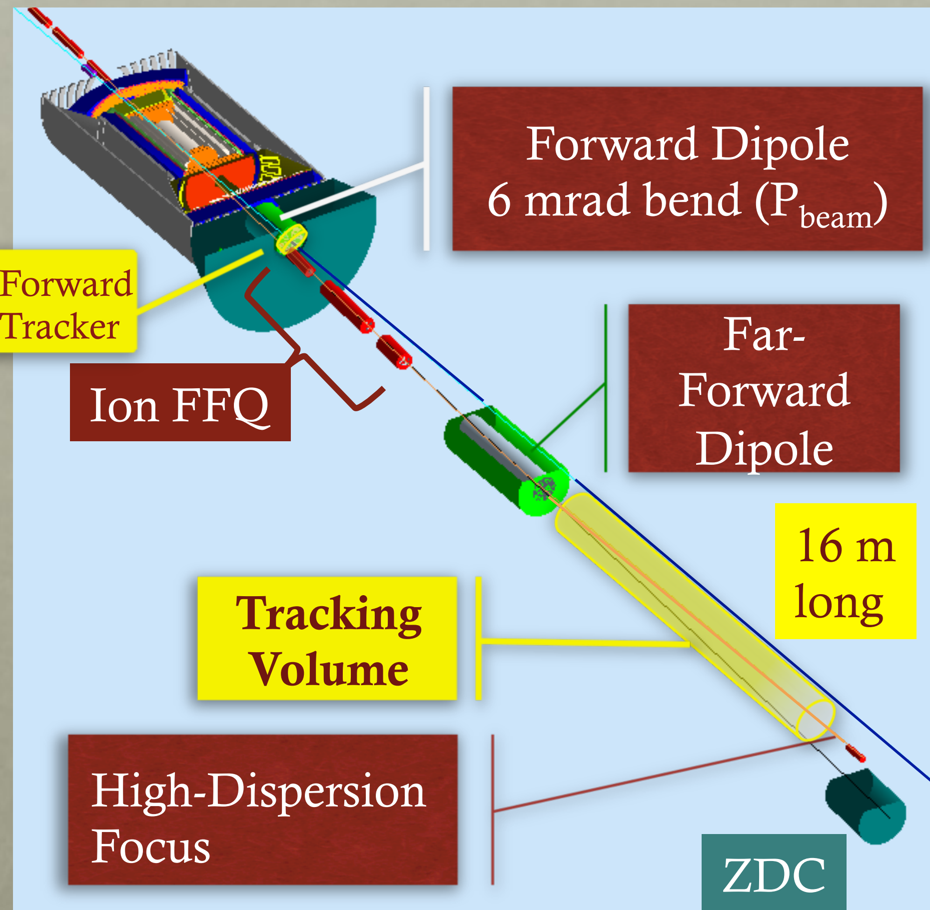
      M. Baker, ECA, EIC R&D, also 1405.4555

- Deep Exclusive Processes
  - 3-D imaging: quark and gluon densities *vs* Charge densities
  - Gluon Saturation signals
  - Veto on nuclear breakup
  - Tag nucleus for $x_{Bj} \geq 0.01$ A
  - Boosted photons from nuclear excitation



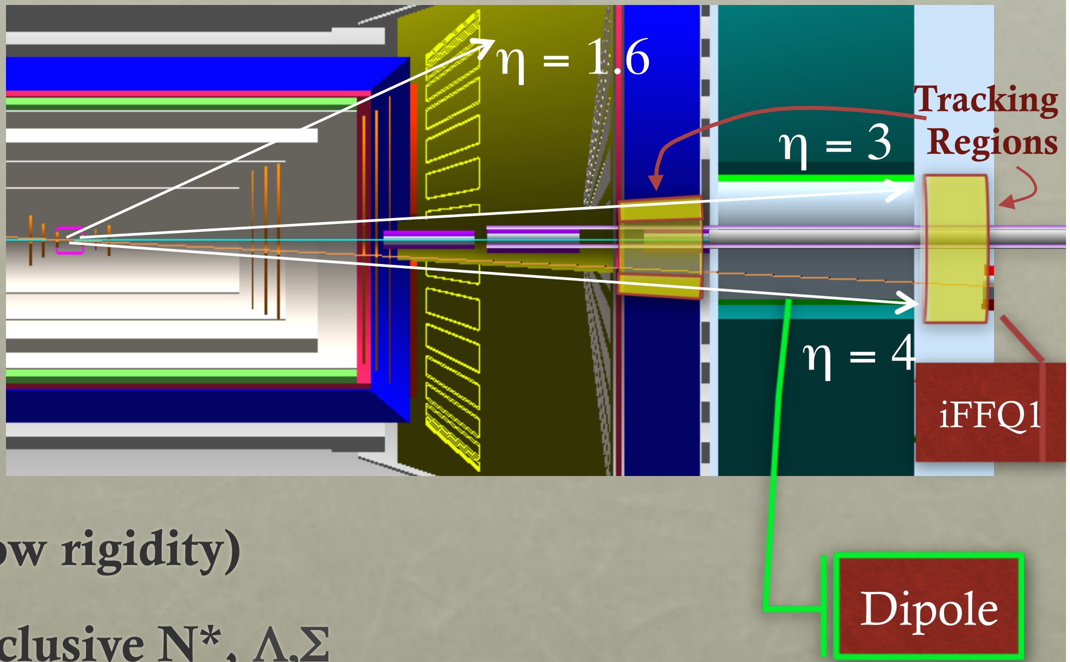
Ion Forward and Far-Forward Regions

- Forward Dipole (z=5.5m)
  - 2 T-m (scaled to 100GeV/c proton)
    - Flux exclusion for *e*-Beam
  - Acceptance $25 < \theta \leq 80$ mr (relative to electron axis)
  - > 50cm Tracking space after magnet
- FFQ triplet acceptance:
  - ± 10 mr horiz, ±14 mr vert, for $|\Delta p/p| \leq 0.5$
  - 25 mrad cone (full opening) line-of sight to ZDC
- High Dispersion Focus @36m
  - Full Acceptance:
    $0.5 > |\Delta P/P| > 0.005$
    or $\theta_{IP} > 4$ mrad



END-CAP & FORWARD REGIONS

- 2 Tesla-m Dipole (z=5.5m)
  - (*cf.* For θ < 80 mrad, Solenoid Bdl < 0.6 T-m)
  - Acceptance ± 90 mrad (relative to electron) (+40, –140 mrad to ion)
- Full Reconstruction of Projectile Fragmentation
  - High-P_T , and/or small $-x_F$ (low rigidity)
  - $3.5 < \eta < 5$
  - Mesons from decay of near exclusive N*, Λ,Σ
- NN correlations in heavy nuclei
  - $P_T/P_{||}$ < (1 GeV/c)/(40 GeV/c) = 25 mrad relative to ion-beam < 75 mrad relative to electron axis



Far-Forward Spectrometer

- **Deep Virtual Exclusive Processes. Acceptance:**
  - **x_{Bj}>0.005, or $-t \sim (P_T)^2 > (400\ MeV/c)^2$ @ $100\ GeV/c$**
- **Spectator Tagging**
  - **P_p ~0.5 P(deuteron), 0.33 P(^{3}He),**
    tracking resolution ≈ beam emittance
  - **ZDC can achieve 30%/$\sqrt{E_n}$ ≈ 4% for spectator neutrons**
    ~ 20 MeV/c longitudinal resolution
    ~ 10 mm/40 m = 0.25 mrad transverse ➔ $\sigma(p_T)$=12.5 MeV/c
    P_T acceptance for neutrons and protons up to 700 MeV/c
- **Nuclear Fragmentation**
  - **Neutron evaporation, p_T ≈ 100 MeV/c ➔ $\theta_n \leq 2.5$ mrad**
  - **Evaporation Residues: Z/A ≠ rigidity of incident nucleus**
  - **Nuclear disassembly, p_T ≈ 200 MeV/c ➔ $\theta_n \leq 5$ mrad**
    - **^{3}He fragments from N=Z nuclei have rigidity 4/3 × incident ion**
    - **Fragment ID from dE/dX**

Spectator Tagging

- Spectator Tagging:

$$p_R = p_p^{\{+,\perp,-\}} = \left[\frac{\alpha}{2}P_D^+, \mathbf{p}_{R\perp}, \frac{M^2}{\alpha P_D^+}\right] \approx P_D^\mu/2$$

- Impulse Approximation:

$$p_n^2 = (P_D - p_R)^2 = t = M_n^2 + t'$$

$$-t' > M_D B + B^2/2 = 4.1 \cdot 10^{-3}\ \mathrm{GeV}^2$$

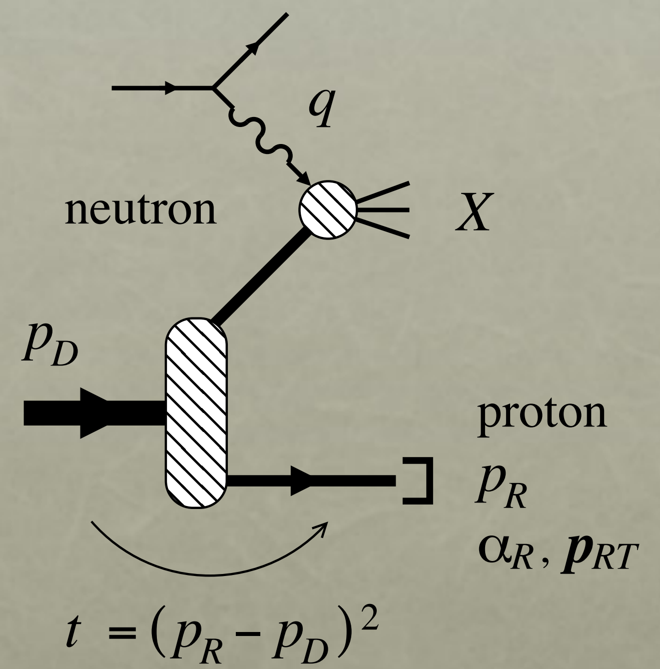
- In Deuteron rest-frame:

$$\mathbf{p}_p \to \frac{(\alpha-1)}{2} M_N \hat{z} + \mathbf{p}_\perp$$
for $\alpha \approx 1$ and $|\mathbf{p}_\perp| << M_N$

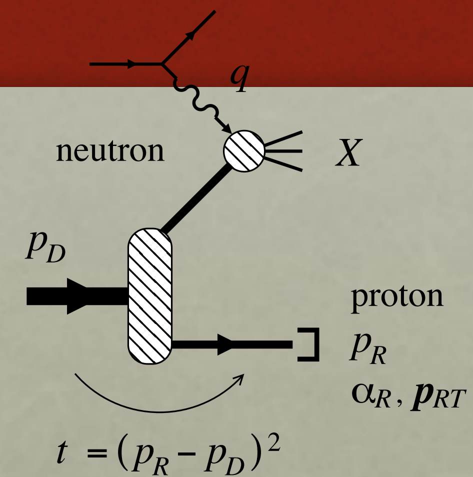
- In Collider Frame:

$$\mathbf{p}_p \approx \tfrac{1}{2}\mathbf{P}_D + \mathbf{p}_\perp$$

$$\mathbf{p}_p \approx \tfrac{\alpha}{2}\mathbf{P}_D + \mathbf{p}_\perp$$



ON-SHELL EXTRAPOLATION



- Spectator Tagging in Impulse Approximation:

$$p_n^2 = (P_D - p_R)^2 = t = M_n^2 + t'$$

$$-t' > M_D B + B^2/2 = 4.1 \cdot 10^{-3}\ \mathrm{GeV}^2$$

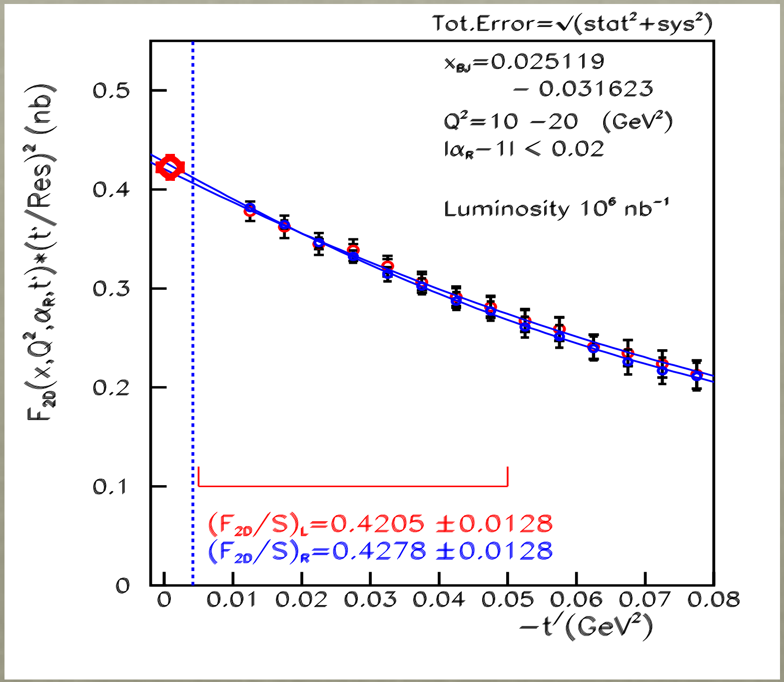
- Example on-shell extrapolation

$$k_e \otimes P_D = 5 \otimes 100\ (\mathrm{GeV/c})^2$$

$$\int \mathcal{L} dt = 1\,/\,\mathrm{fb}$$

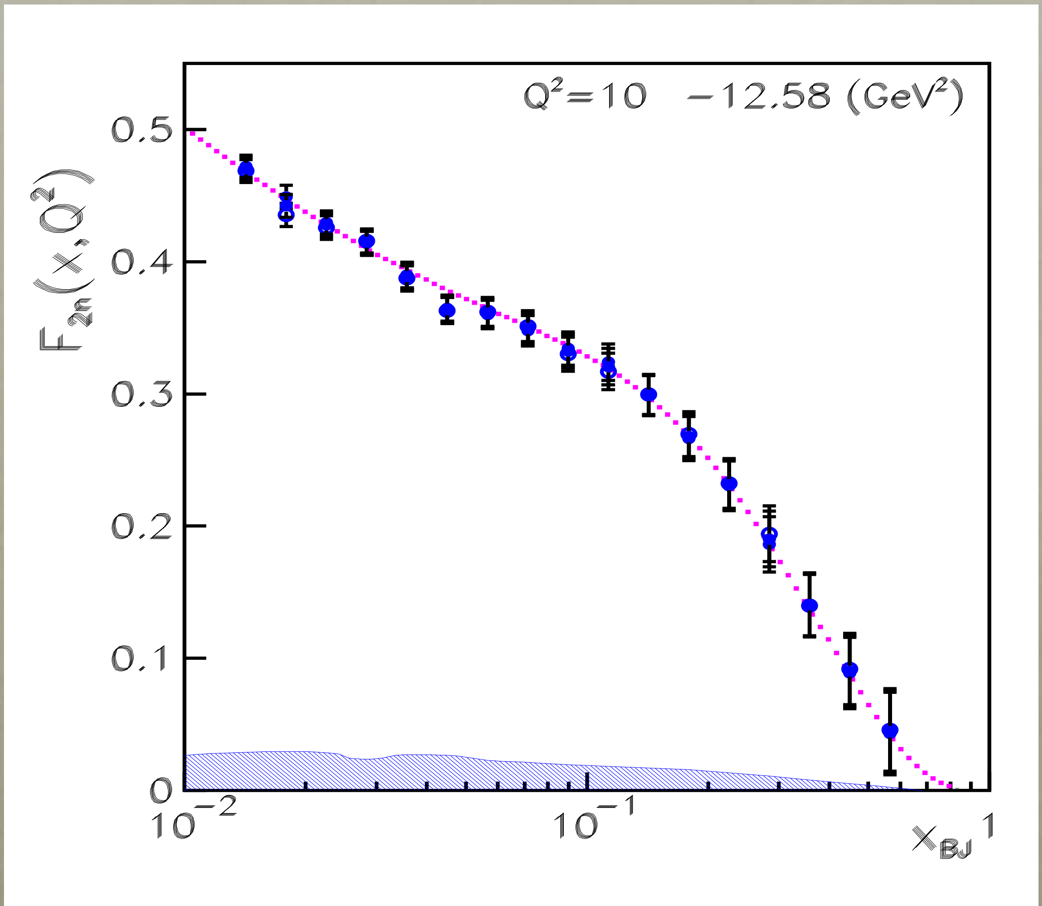
$$x_{\mathrm{Bj}} \in [0.025, 0.032],\ \ Q^2 \in [10, 20]\ \mathrm{GeV}^2$$

$0.98 \leq \alpha < 1$ $\quad$ $1.0 < \alpha \leq 1.02$



NEUTRON F_2 FROM ON-SHELL EXTRAPOLATION

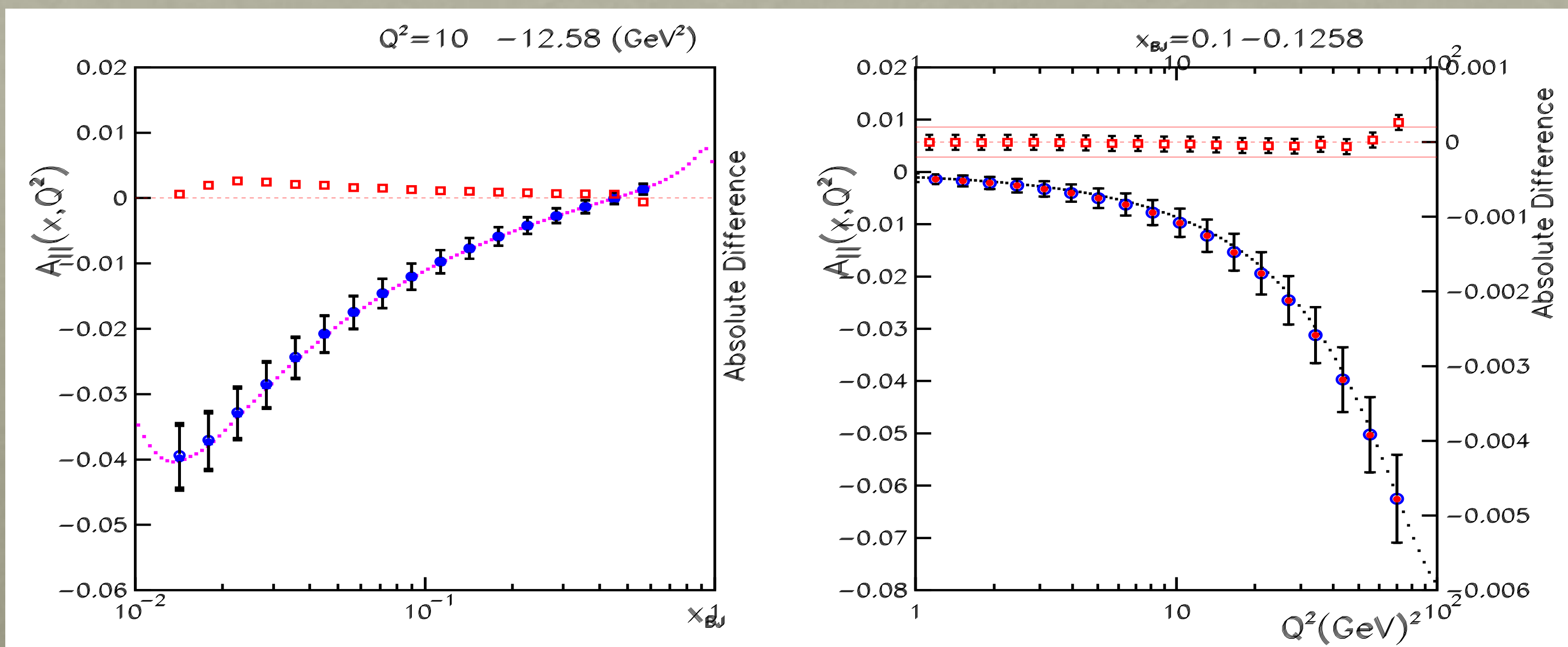
- A sample bin in Q^2
  - Error bars are statistical
  - Error band is systematic error from assumed 10% uncertainty in incident beam emittance
- Radiative effects not yet included.
- QCD Evolution not yet included.



Neutron Spin Structure

- Longitudinal Double Spin Asymmetry on the Neutron

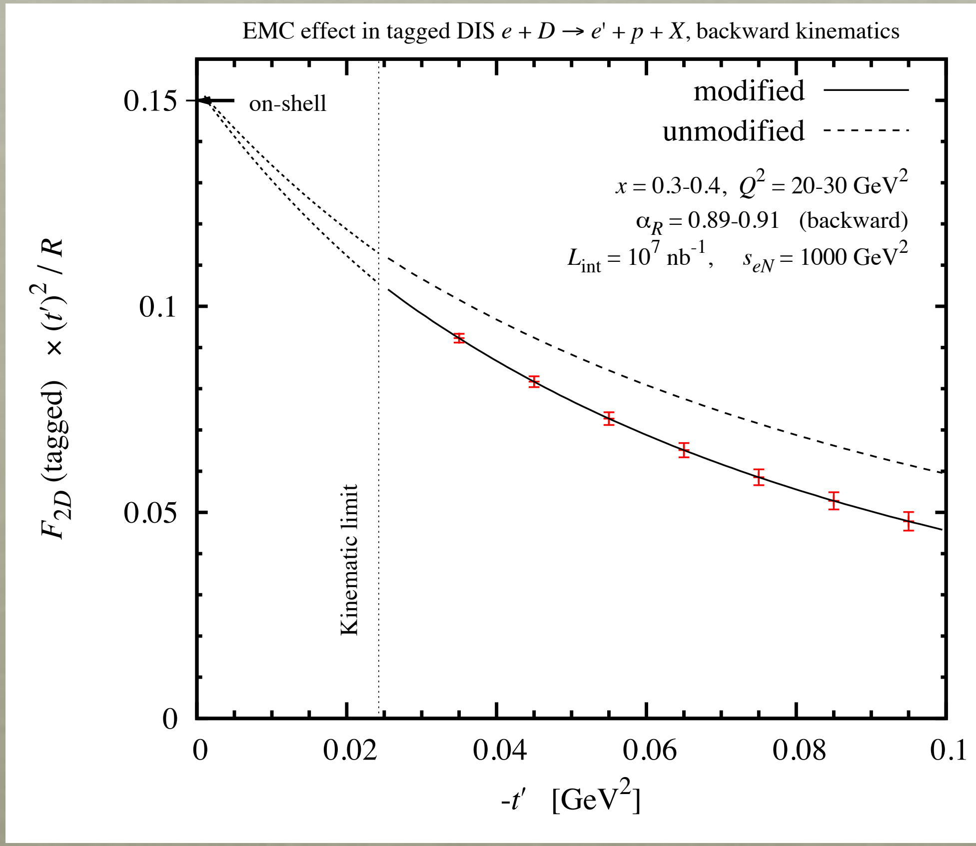
x-dependence at fixed Q^2 Q^2-dependence at fixed *x*



The EMC Effect in the Deuteron

In a given bin in (x_{Bj}, Q^2):

- First extrapolate to the on-shell point for $\alpha \approx 1$
- Compare IA (dashed) with pseudo- data (solid) at 'large' negative $\alpha - 1$
  - $\alpha < 1$ minimizes FSI
  - EMC Effect modeled via t'-dependent form factor
- Illustrated Luminosity is 10 / fb



CONCLUSIONS

- **Example of full integration of detector and accelerator design.**
- **Unprecedented tools for event-by-event control of the full final state on the nucleon, light nuclei, and medium to heavy nuclei**
- **Thanks to Zhiwen Zhao and KiJun Park for GEMC detector images and simulations.**
- **Software tools available for general use**