Non-Nucleonic Components in Short Nuclear Distances

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Why are nuclei not collapsing?

- Because of Nuclear Repulsive Core

What is Nuclear Repulsive Core?

- Repulsion in the NN System
- Repulsion in NNN+ system

How to probe the Repulsion

- Probe nuclei at larger and larger densities

Probing NN Repulsive Core

- NN force is attractive: But Nuclei are Stable

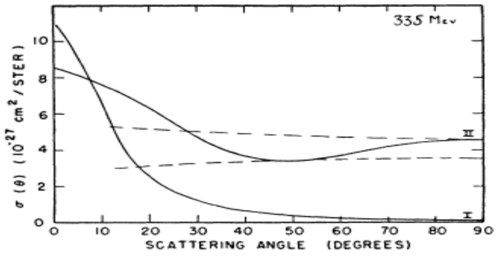
"If the two-body forces are everywhere attractive and if many-body forces are neglected then the nucleon pairs are sufficiently close to take advantage of attractive interactions and a collapsed state of nuclear matter results "

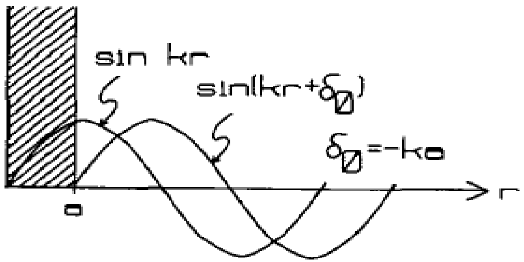
With binding energy 1600MeV/N for A=200 (compare 8 MeV/N)

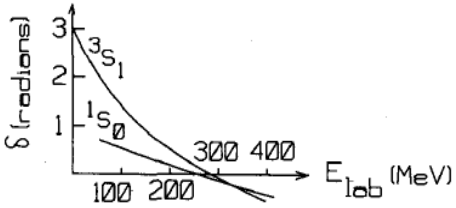
G. Breit and E.P. Wigner, Phys. Rev. 53, 998 (1938).

Many body forces keeping nucleus stable

- Jastrow 1950/51 assumed the existence of the infinite hard core to explain the angular distribution of pp cross section at 340 MeV (r_0=0.6fm)







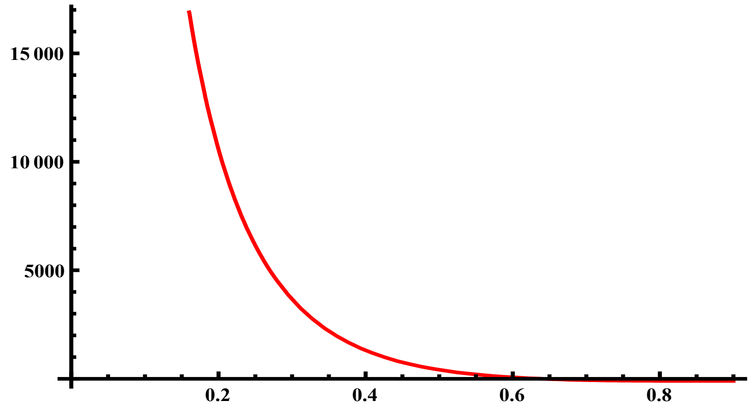
Non-monotonic NN central potential with the repulsive core was introduced: Brueckner & Watson 1953 to obtain nuclear density saturation.

Modern NN Potentials

$$V^{2N} = V_{EM}^{2N} + V_{\pi}^{2N} + V_{R}^{2N}$$

$$V_R^{2N} = V^c + V^{l2}L^2 + V^t S_{12} + V^{ls} L\cdot S + v^{ls2}(L\cdot S)^2$$

$$V^i = V_{int,R} + V_{core}$$

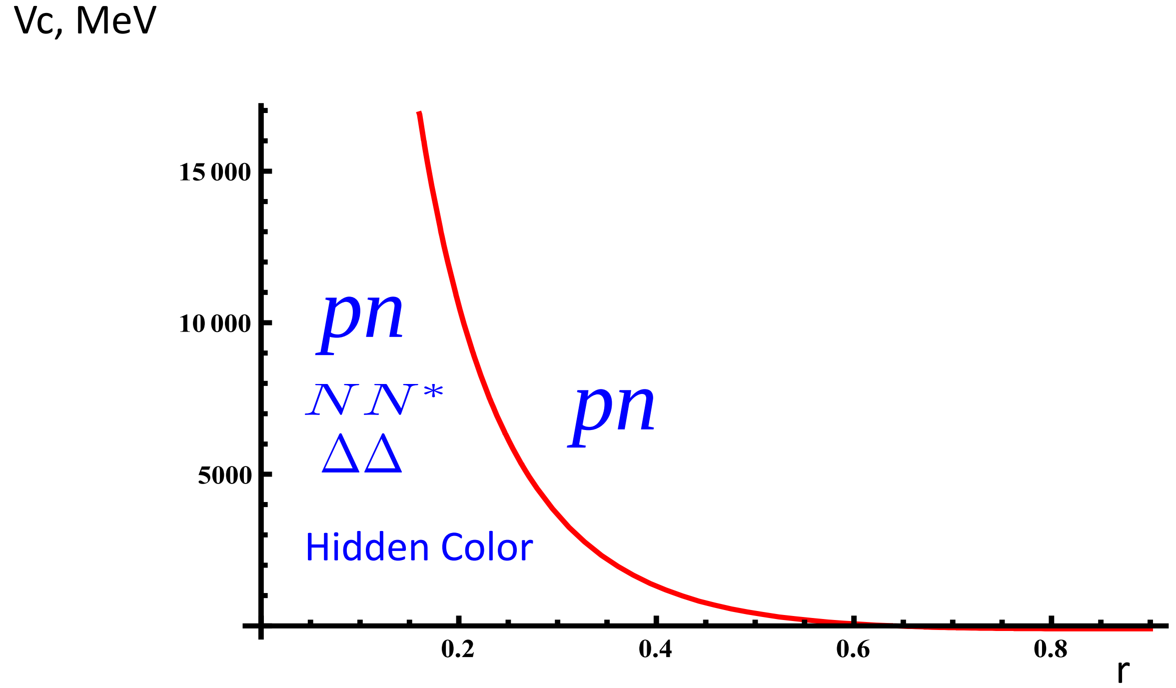


$$V_{core} = \left[1 + e^{\frac{r-r_0}{a}}\right]^{-1}$$

60's

- understanding of the dynamics of transition between hadronic to quark-gluon phases above saturation densities

- relevant for stability of atomic nuclei as well as structure disappearance at very high densities.

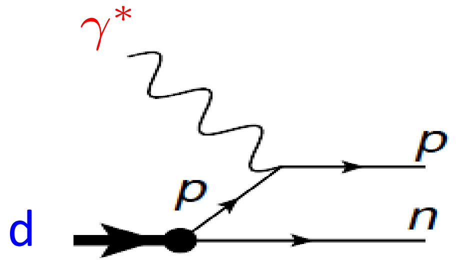


$$\langle \Psi_{NonNucleonic} \mid \Psi_{NN} \rangle = 0$$

$$\Psi^{6q}_{T=0,S=1} = \sqrt{\frac{1}{9}}\Psi_{NN} + \sqrt{\frac{4}{45}}\Psi_{\Delta\Delta} + \sqrt{\frac{4}{5}}\Psi_{CC}$$

Considering mainly high Q^2 d(e,e'N)N reaction

Theory of high energy semi-inclusive electro-nuclear processes:



$$|p_i| = |p_f - q| \leq 550 \text{ MeV/C}$$

Deuteron consist of proton and neutron

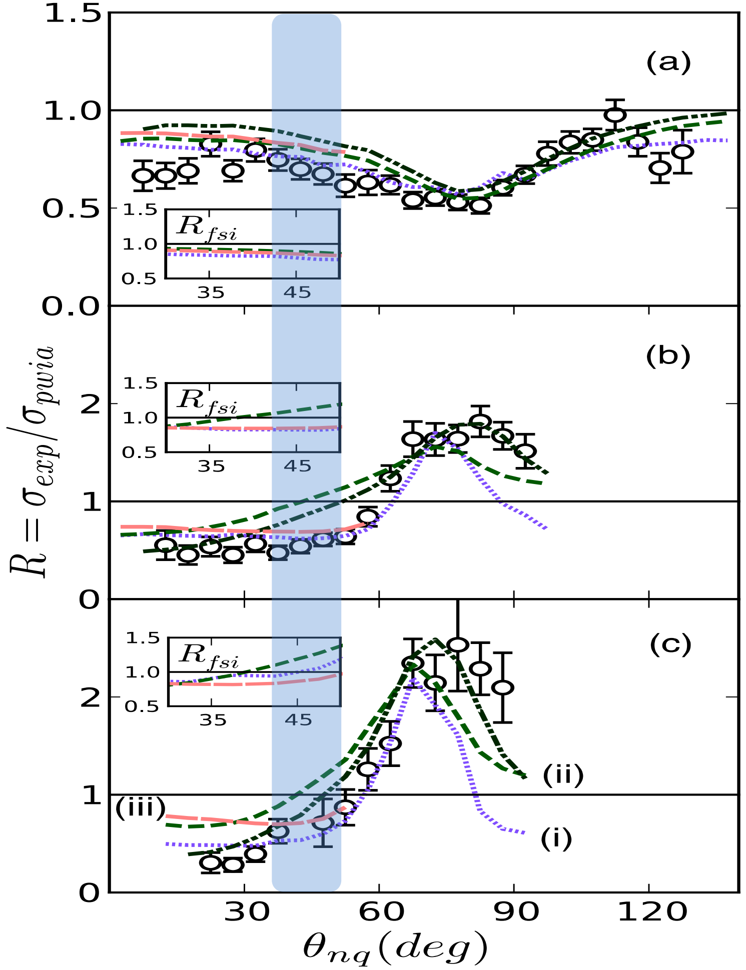
Exclusiveness of the reaction as an advantage in probing unintegrated density matrix of the deuteron at given missing momentum

not entirely true: final state hadronic interactions are never dynamically small

In High Energy and Momentum Transfer limit: $Q^2 > 1\text{GeV}^2$: MEC is dynamically suppressed, Delta is possible to suppress both kinematically and dynamically

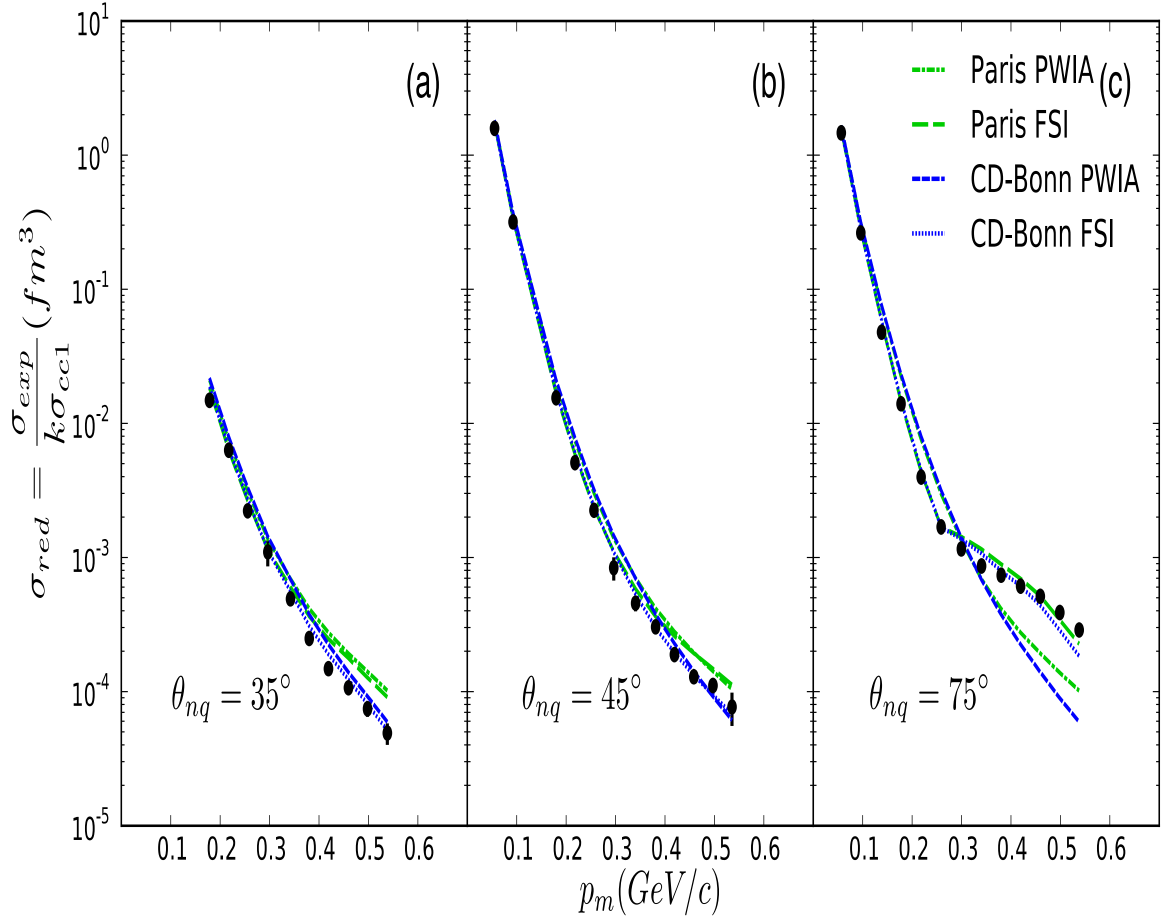
For FSI eikonal regime is established: allowed to develop self-consistent theoretical framework that allows to account for the short distance nuclear dynamics

Probing Deuteron at Small Distances at large Q^2



JLab, $Q^2 = 3.5$ GeV^2

MS PRC 2010

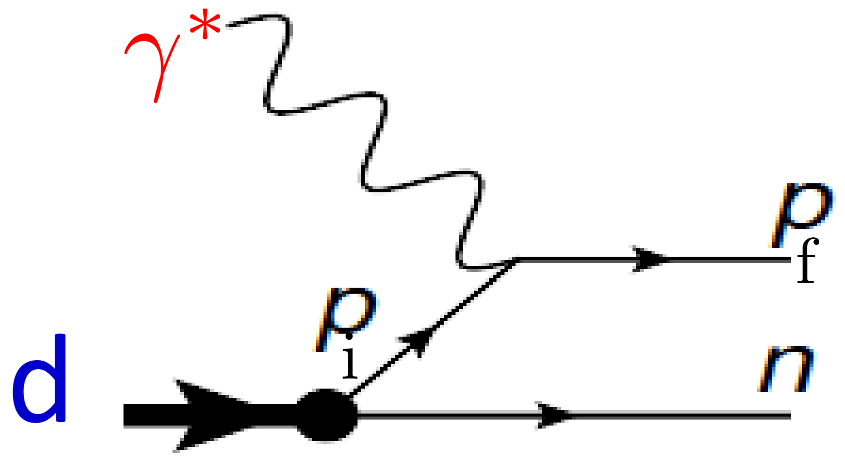


Boeglin et al PRL 2011, deuteron probed at up to 550MeV/c

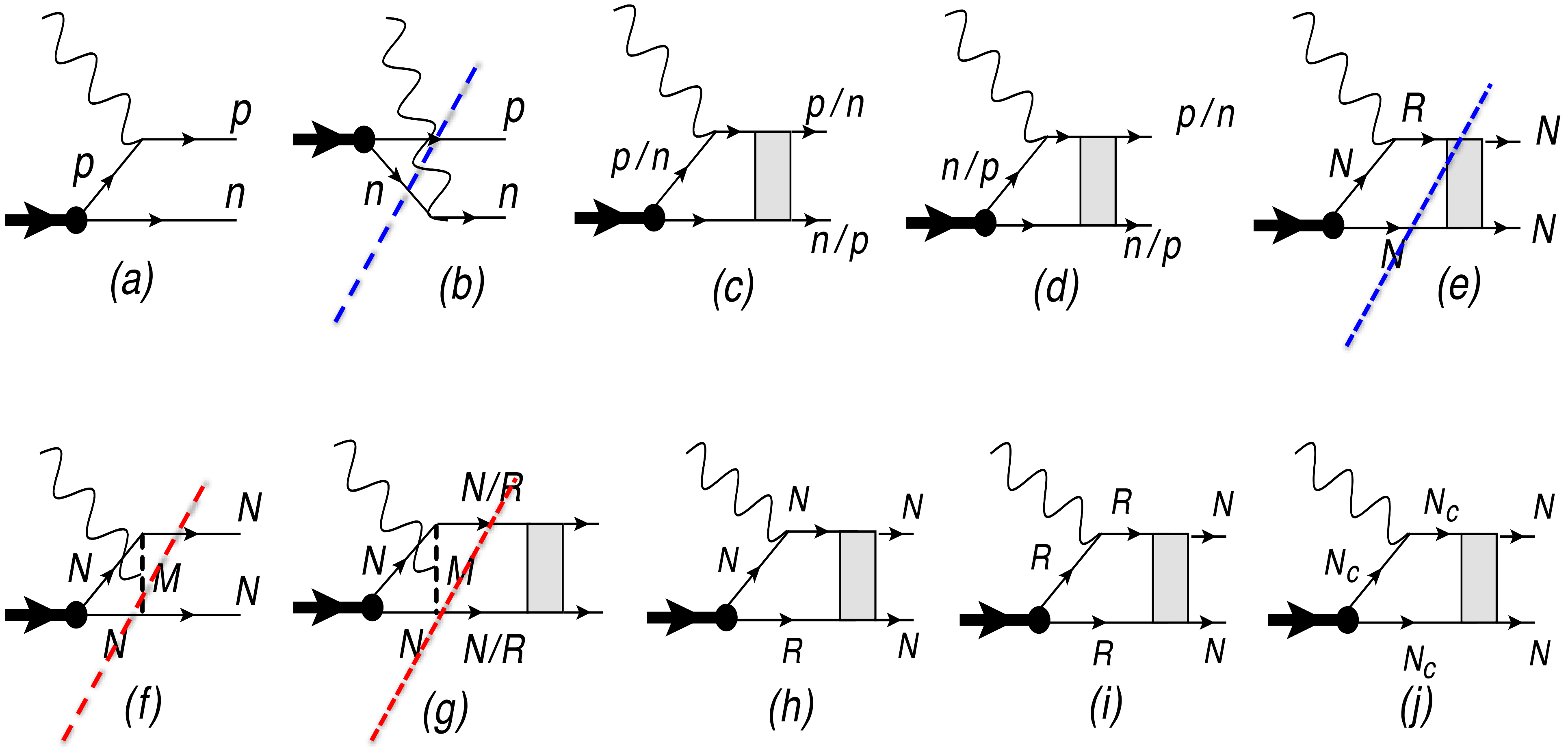
Probing NN interaction at very short distances

Considering reaction: $e + d \to e' + p_f + n$

$$|p_i| = |p_f - q| > 550 \text{ MeV/C}$$



M.Sargsian & F. Vera, PRL 2023


p
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Some Paradigm Shift

Our current mindset about deuteron is fully non-relativistic, the observation that it has total spin, J=1 and parity, P=+, together with the relation that for non-relativistic wave function, $P= (-1)^l$, one concludes that the deuteron consists of S- and D- partial waves for proton-neutron system.

Paradigm Shift: The above reaction at high Q^2, measures the probability of observing proton and neutron in the deuteron at very large relative momenta.
In such a formulation the deuteron is not a composite system consisting of proton and neutron but it is a composite pseudo - vector (J=1, P=+) ``particle" from which one extracts proton and neutron.

How such a proton and neutron produced at such extremal conditions is related to the dynamical structure of Light-Front deuteron wave function, which may include internal elastic $pn \to pn$ as well as inelastic $\Delta\Delta \to pn$, $N^*N \to pn$ or $N_C N_C \to pn$ transitions.

New Structure in the Deuteron and possible non-nucleonic components

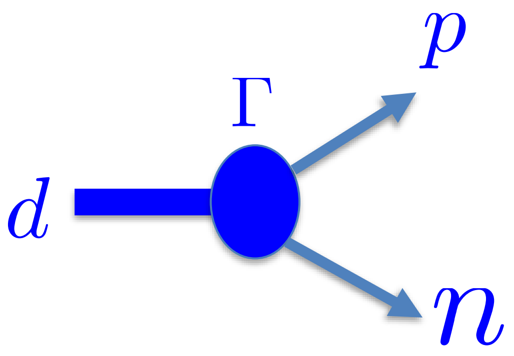
M.S & Frank Vera PRL 2023

Paradigm shift:

- consider a deuteron not a nucleus that consist of proton and neutron
- but ***pseudovector composite particle*** from which we ***extract*** proton and neutron

- Light-Front Deuteron wave function

$$\psi_d^{\lambda_d}(\alpha_i, p_\perp, \lambda_1\lambda_2) = -\frac{\bar{u}(p_2,\lambda_2)\bar{u}(p_1,\lambda_1)\Gamma_d\chi^{\lambda_d}}{\frac{1}{2}(m_d^2 - 4\frac{m_N^2+p_\perp^2}{\alpha_i(2-\alpha_i)})\sqrt{2(2\pi)^3}}$$



- Absorbing the energy denominator into the vertex function and using crossing symmetry

$$\psi_d^{\mu}(\alpha_i, p_\perp, \lambda_1, \lambda_2) = -\bar{u}(p_2,\lambda_2)\Gamma_d^{\mu}(k)\frac{(i\gamma_2\gamma_0)}{\sqrt{2}}\bar{u}(p_1,\lambda_1)^T = -\sum_{\lambda_1'}\bar{u}(p_1,\lambda_1)\Gamma_d^{\mu}\gamma_5\frac{\epsilon_{\lambda_1,\lambda_1'}}{\sqrt{2}}u(p_1,\lambda_1')$$

$$\psi_d^\mu(\alpha_i, p_\perp, \lambda_1, \lambda_2) = -\bar{u}(p_2, \lambda_2)\Gamma_d^\mu(k)\frac{(i\gamma_2\gamma_0)}{\sqrt{2}}\bar{u}(p_1, \lambda_1)^T = -\sum_{\lambda_1'} \bar{u}(p_1, \lambda_1)\Gamma_d^\mu \gamma_5 \frac{\epsilon_{\lambda_1, \lambda_1'}}{\sqrt{2}} u(p_1, \lambda_1')$$

- Γ_d^μ - is a four-vector, which can be constructed in a most general form satisfying time reversal, parity and charge conjugate symmetries

- Because the deuteron is a bound system, in addition to on-shell p_1 and p_2 four momenta one introduces

$$\Delta^\mu \equiv p_1^\mu + p_2^\mu - p_d^\mu \equiv (\Delta^-, \Delta^+, \Delta_\perp) = (\Delta^-, 0, 0)$$

$$\Delta^- = p_1^- + p_2^- - p_d^- = \frac{m_N^2 + k_\perp^2}{p_1^+} + \frac{m_N^2 + k_\perp^2}{p_2^+} - \frac{M_d^2}{p_d^+} = \frac{1}{p_d^+}\left[\frac{4(m_N^2 + k_\perp^2)}{\alpha_1(2-\alpha_1)} - M_d^2\right] = \frac{4}{p_d^+}\left[m_N^2 - \frac{M_d^2}{4} + k^2\right]$$

- Constructed vertex:

$$\Gamma_d^\mu = \Gamma_1 \gamma^\mu + \Gamma_2 \frac{(p_1 - p_2)^\mu}{2m_N} + \Gamma_3 \frac{\Delta^\mu}{2m_N} + \Gamma_4 \frac{(p_1 - p_2)^\mu \not{\Delta}}{4m_N^2}$$

$$+ i\Gamma_5 \frac{1}{4m_N^3}\gamma_5 \epsilon^{\mu\nu\rho\gamma}(p_d)_\nu (p_1 - p_2)_\rho (\Delta)_\gamma + \Gamma_6 \frac{\Delta^\mu \not{\Delta}}{4m_N^2}$$

High Momentum Transfer Kinematics

For large Q^2 limit, Light-Front momenta for the reaction are chosen as follows:

$$p_d^\mu \equiv (p_d^-, p_d^+, p_{d\perp}) = \left(\frac{Q^2}{x\sqrt{s}} \left[1 + \frac{x}{\tau} - \sqrt{1 + \frac{x^2}{\tau}} \right], \frac{Q^2}{x\sqrt{s}} \left[1 + \frac{x}{\tau} + \sqrt{1 + \frac{x^2}{\tau}} \right], 0_\perp \right)$$

$$q^\mu \equiv (q^-, q^+, q_\perp) = \left(\frac{Q^2}{x\sqrt{s}} \left[1 - x + \sqrt{1 + \frac{x^2}{\tau}} \right], \frac{Q^2}{x\sqrt{s}} \left[1 - x - \sqrt{1 + \frac{x^2}{\tau}} \right], 0_\perp \right)$$

where $s = (q + p_d)^2$, $\tau = \frac{Q^2}{M_d^2}$ and $x = \frac{Q^2}{M_d q_0}$, with q_0 being virtual photon energy in the deuteron rest frame.

- One observes that for fixed x, $p_d^+ \sim \sqrt{Q2} \gg m_N$

$$\Delta^\mu \equiv p_1^\mu + p_2^\mu - p_d^\mu \equiv (\Delta^-, \Delta^+, \Delta_\perp) = (\Delta^-, 0, 0),$$

where

$$\Delta^- = p_1^- + p_2^- - p_d^- = \frac{m_N^2 + k_\perp^2}{p_1^+} + \frac{m_N^2 + k_\perp^2}{p_2^+} - \frac{M_d^2}{p_d^+}$$
$$= \frac{1}{p_d^+}\left[\frac{4(m_N^2 + k_\perp^2)}{\alpha_1(2-\alpha_1)} - M_d^2\right] = \frac{4}{p_d^+}\left[m_N^2 - \frac{M_d^2}{4} + k^2\right].$$

In high Q^2 limit $\quad \frac{\Delta^-}{2m_N} \ll 1$

$$\Gamma_d^\mu = \Gamma_1 \gamma^\mu + \Gamma_2 \frac{(p_1 - p_2)^\mu}{2m_N} + \Gamma_3 \frac{\Delta^\mu}{2m_N} + \Gamma_4 \frac{(p_1 - p_2)^\mu \not{\Delta}}{4m_N^2}$$
$$+ i\Gamma_5 \frac{1}{4m_N^3} \gamma_5 \epsilon^{\mu\nu\rho\gamma} (p_d)_\nu (p_1 - p_2)_\rho (\Delta)_\gamma + \Gamma_6 \frac{\Delta^\mu \not{\Delta}}{4m_N^2}$$

Consider: $\epsilon^{\mu,+,\perp,-} p_{d,-} k_\perp \Delta_+$

Since: $p_{d,-} = \frac{1}{2} p_d^+$ and $\Delta_+ = \frac{1}{2}\Delta^-$ then $p_d^+ \Delta^- = p_d^+ \frac{1}{p_d^+}\left[\frac{4(m_N^2 + k_\perp^2)}{\alpha_1(2-\alpha_1)} - M_d^2\right] = \left[\frac{4(m_N^2 + k_\perp^2)}{\alpha_1(2-\alpha_1)} - M_d^2\right]$

$\epsilon^{\mu,+,\perp,-} p_{d,-} k_\perp \Delta_+ = \frac{1}{4}\epsilon^{\mu,+,\perp,-} p_d^+ k_\perp \Delta^-$ Leading Oder!

$$\Gamma_d^\mu = \Gamma_1 \gamma^\mu + \Gamma_2 \frac{(p_1 - p_2)^\mu}{2m_N} + \Gamma_3 \frac{\Delta^\mu}{2m_N} + \Gamma_4 \frac{(p_1 - p_2)^\mu \not{\Delta}}{4m_N^2}$$
$$+ i\Gamma_5 \frac{1}{4m_N^3}\gamma_5 \epsilon^{\mu\nu\rho\gamma}(p_d)_\nu (p_1 - p_2)_\rho (\Delta)_\gamma + \Gamma_6 \frac{\Delta^\mu \not{\Delta}}{4m_N^2}$$

$$\psi_d^{\lambda_d}(\alpha_i, k_\perp) = -\sum_{\lambda_2,\lambda_1,\lambda_1'} \bar{u}(-k,\lambda_2)\left\{\Gamma_1\gamma^\mu + \Gamma_2 \frac{\tilde{k}^\mu}{m_N} + \sum_{i=1}^{2} i\Gamma_5 \frac{1}{8m_N^3}\epsilon^{\mu+i-} p_d'^{+} k_i \Delta'^{-}\right\}\gamma_5 \frac{\epsilon_{\lambda_1,\lambda_i'}}{\sqrt{2}} u(k,\lambda_1') s_\mu^{\lambda_d}$$

where $\tilde{k}^\mu = (0, k_z, k_\perp)$

$$\psi_d^{\lambda_d}(\alpha_i, k_\perp) = -\sum_{\lambda_2,\lambda_1,\lambda_1'} \bar{u}(-k,\lambda_2)\left\{\Gamma_1\gamma^\mu + \Gamma_2\frac{\tilde{k}^\mu}{m_N} + \sum_{i=1}^{2} i\Gamma_5\frac{1}{8m_N^3}\epsilon^{\mu+i-}p_d'^{+}k_i\Delta'^{-}\right\}\gamma_5\frac{\epsilon_{\lambda_1,\lambda_i'}}{\sqrt{2}}u(k,\lambda_1')s_\mu^{\lambda_d}$$

$$\psi_d^{\lambda_d}(\alpha_1, k_t, \lambda_1, \lambda_2) = \sum_{\lambda_1'}\phi^\dagger_{\lambda_2}\sqrt{E_k}\left[\frac{U(k)}{\sqrt{4\pi}}\sigma\mathbf{s}_\mathbf{d}^{\lambda_d} - \frac{W(k)}{\sqrt{4\pi}\sqrt{2}}\left(\frac{3(\sigma\mathbf{k})(\mathbf{k}\mathbf{s}_\mathbf{d}^{\lambda})}{k^2} - \sigma\mathbf{s}_\mathbf{d}^{\lambda}\right) + (-1)^{\frac{1+\lambda_d}{2}}P(k)Y_1^{\lambda_d}(\theta,\phi)\delta^{1,|\lambda_d|}\right]\frac{\epsilon_{\lambda_1,\lambda_1'}}{\sqrt{2}}\phi_{\lambda_1'}$$

$$U(k) = \frac{2\sqrt{4\pi}\sqrt{E_k}}{3}\left[\Gamma_1(2+\frac{m_N}{E_k}) + \Gamma_2\frac{k^2}{m_N E_k}\right]$$

$$W(k) = \frac{2\sqrt{4\pi}\sqrt{2E_k}}{3}\left[\Gamma_1(1-\frac{m_N}{E_k}) - \Gamma_2\frac{k^2}{m_N E_k}\right]$$

Where: $Y_1^{\pm}(\theta,\phi) = \mp i\sqrt{\frac{3}{4\pi}}\sum_{i=1}^{2}\frac{(k\times s_d^{\pm 1})_z}{k}$

$$P(k) = \sqrt{4\pi}\frac{\Gamma_5(k)\sqrt{E_k}}{\sqrt{3}}\frac{k^3}{m_N^3}$$

fully relativistic: in addition to $\frac{k^{l=1}}{m_N}$ term

has additional $\frac{k^2}{m_N^2}$ term

Light Front Density Matrix and Momentum Distribution

$$\psi_d^{\lambda_d}(\alpha_1, k_t, \lambda_1, \lambda_2) = \sum_{\lambda_1'} \phi^\dagger_{\lambda_2} \sqrt{E_k} \left[\frac{U(k)}{\sqrt{4\pi}} \sigma \mathbf{s}_\mathbf{d}^{\lambda_\mathbf{d}} - \frac{W(k)}{\sqrt{4\pi}\sqrt{2}} \left(\frac{3(\sigma \mathbf{k})(\mathbf{k}\mathbf{s}_\mathbf{d}^\lambda)}{k^2} - \sigma \mathbf{s}_\mathbf{d}^\lambda \right) + (-1)^{\frac{1+\lambda_d}{2}} P(k) Y_1^{\lambda_d}(\theta,\phi)\delta^{1,|\lambda_d|} \right] \frac{\epsilon_{\lambda_1,\lambda_1'}}{\sqrt{2}} \phi_{\lambda_1'}$$

$$\rho_d(\alpha, k_\perp) = \frac{n_d(k,k_\perp)}{2-\alpha}$$

$$n_d(k, k_\perp) = \frac{1}{3} \sum_{\lambda_d=-1}^{1} \mid \psi_d^{\lambda_d}(\alpha, k_\perp) \mid^2 = \frac{1}{4\pi} \left(U(k)^2 + W(k)^2 + \frac{k_\perp^2}{k^2} P^2(k) \right)$$

Baryonic and Momentum Sum Rules $\int \rho_d(\alpha, k_\perp) \frac{d\alpha}{\alpha} = 1$ and $\int \alpha \rho_d(\alpha, k_\perp) \frac{d\alpha}{\alpha} = 1$

$$\int \left(U(k)^2 + W(k)^2 + \frac{2}{3} P^2(k) \right) k^2 dk = 1.$$

Non-Nucleonic Components and the New Structure

$$n_d(k,k_\perp) = \frac{1}{3}\sum_{\lambda_d=-1}^{1} \mid \psi_d^{\lambda_d}(\alpha,k_\perp) \mid^2 = \frac{1}{4\pi}\left(U(k)^2 + W(k)^2 + \frac{k_\perp^2}{k^2}P^2(k)\right)$$

- Momentum distribution depends on $k_\perp$ separately

- This is impossible for non-relativistic quantum mechanics of the deuteron since in this case the potential of the interaction is real (no inelasticities) and the solution of Lippmann-Schwinger (or Schroedinger) equation for partial S- and D-waves satisfies ``angular condition", according to which the momentum distribution in unpolarized deuteron depends on the magnitude of relative momentum only.

- On the other hand, in the relativistic domain the definition of the interaction potential is not straightforward to allow to use quantum-mechanical arguments in claiming that momentum distribution should satisfy the angular condition (i.e. depends on magnitude of k only).

- However, for the Light-Front, there is a remarkable theorem by Frankfurt and Strikman which states that if one considers only pn component in the deuteron, then for most acceptable forms of NN potential – constructed from elastic pn → pn scattering, the angular condition should be satisfied also for LF momentum distribution.

$$T_{NN}(\alpha_i, k_{i\perp}, \alpha_f, k_{f,\perp}) \equiv T_{NN}(k_{i,z}, k_{i\perp}, k_{f,z}, k_{f,\perp}) = V(k_{i,z}, k_{i\perp}, k_{f,z}, k_{f,\perp}) + \int V(k_{i,z}, k_{i\perp}, k_{m,z}, k_{m,\perp}) \times \frac{d^3 k_m}{(2\pi)^3 \sqrt{m^2 + k_m^2}} \frac{T_{NN}(k_{m,z}, k_{m\perp}, k_{f,z}, k_{f,\perp})}{4(k_m^2 - k_f^2)}$$

-The realization of the angular condition for relativistic case will require that light-front potential to satisfy a condition

$$V(k_{i,z}, k_{i\perp}, k_{m,z}, k_{m,\perp}) = V(\vec{k}_i^2, (\vec{k}_m - \vec{k}_i)^2)$$

- Lorentz invariance for on-shell NN amplitude requires

$$T_{NN}^{on\ shell}(k_{i,z}, k_{i\perp}, k_{m,z}, k_{m,\perp}) = T_{NN}^{on\ shell}(\vec{k}_i^2, (\vec{k}_m - \vec{k}_i)^2)$$

- Existence of the Born term indicates that

$$T_{NN}^{on\ shell}(\vec{k}_i^2, (\vec{k}_m - \vec{k}_i)^2) = V_{NN}^{on\ shell}(\vec{k}_i^2, (\vec{k}_m - \vec{k}_i)^2) \quad + \int V_{NN}(k_{i,z}, k_{i\perp}, k_{m,z}, k_{m,\perp}) \times \frac{d^3k_m}{(2\pi)^3\sqrt{m^2+k_m^2}} \frac{T_{NN}(k_{m,z}, k_{m\perp}, k_{f,z}, k_{f,\perp})}{4(k_m^2 - k_f^2)}$$

- Iterating the equation around the on-shell kinematic point.

$$T_{NN}(\alpha_i, k_{i\perp}, \alpha_f, k_{f,\perp}) \equiv T_{NN}(k_{i,z}, k_{i\perp}, k_{f,z}, k_{f,\perp}) = V(k_{i,z}, k_{i\perp}, k_{f,z}, k_{f,\perp}) + \int V(k_{i,z}, k_{i\perp}, k_{m,z}, k_{m,\perp}) \times \frac{d^3k_m}{(2\pi)^3\sqrt{m^2+k_m^2}} \frac{T_{NN}(k_{m,z}, k_{m\perp}, k_{f,z}, k_{f,\perp})}{4(k_m^2 - k_f^2)}$$

- will result in:

$$T_{NN}(k_{i,z}, k_{i\perp}, k_{m,z}, k_{m,\perp}) = T_{NN}(\vec{k}_i^2, (\vec{k}_m - \vec{k}_i)^2)$$

$$V_{NN}(k_{i,z}, k_{i\perp}, k_{m,z}, k_{m,\perp}) = V_{NN}(\vec{k}_i^2, (\vec{k}_m - \vec{k}_i)^2)$$

for the general case

- V_{NN} – analytic function of angular momentum and it does not diverge exponentially in the complex-angular momentum space it was shown that also for the off-shell case

- For Non-nucleonic components no such iteration can be done

$$T_{NN}(k_{i,z},k_{i\perp},k_{f,z},k_{f,\perp}) = \int V_{NN^*}(k_{i,z},k_{i\perp},k_{m,z},k_{m,\perp})\frac{d^3k_m}{(2\pi)^3\sqrt{m_m^2+k_m^2}}\frac{T_{N^*N}(k_{m,z},k_{m\perp},k_{f,z},k_{f,\perp})}{4(k_m^2-k_f^2+m_m^2-m_N^2)}$$

- transition amplitudes such is $T_{\Delta\Delta\to NN}$, $T_{N^*,N\to NN}$ or $T_{N_c,N_c\to NN}$ where N^cN^c represents a hidden color component in the deuteron could not be described with any combination of interaction potentials that satisfies angular condition

- if Γ_5 term is not zero then it should originate from non-nucleonic component in the deuteron.

- Our prediction is that the observation of LF momentum distribution depending on the center of mass k and $k_\perp$ separately will indicate the presence of non-nucleonic component in the deuteron

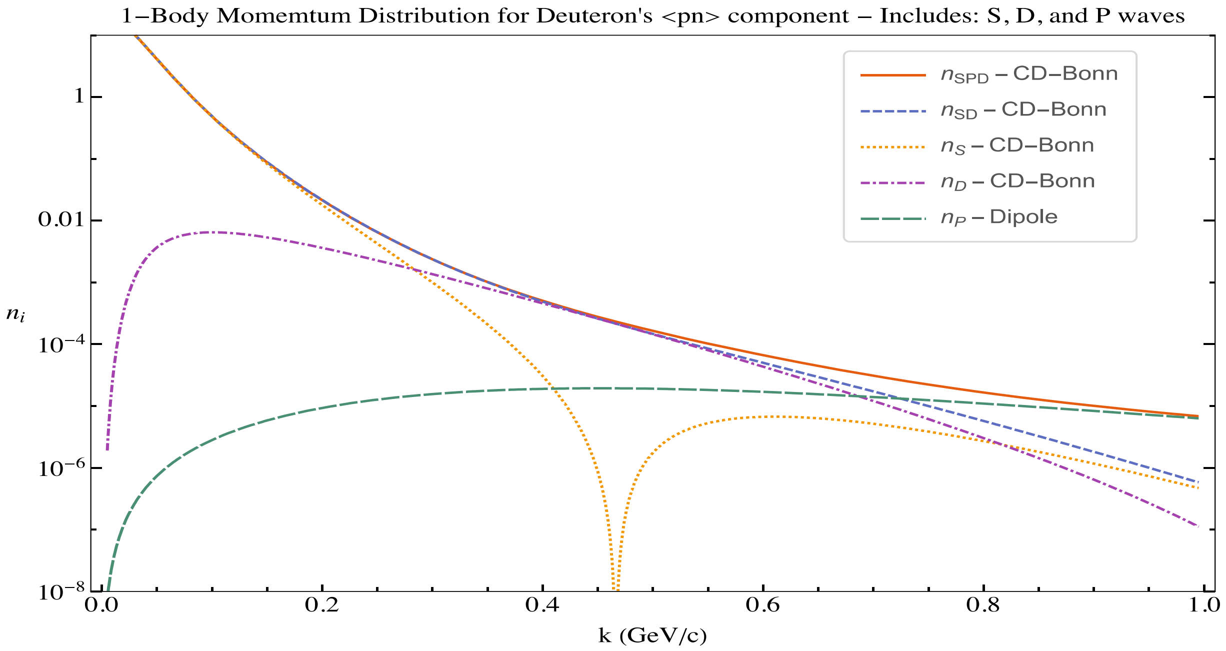
Estimate of the effect

$$n_d(k,k_\perp) = \frac{1}{3}\sum_{\lambda_d=-1}^{1} |\psi_d^{\lambda_d}(\alpha,k_\perp)|^2 = \frac{1}{4\pi}\left(U(k)^2 + W(k)^2 + \frac{k_\perp^2}{k^2}P^2(k)\right)$$

$$P(k) = \sqrt{4\pi}\frac{\Gamma_5(k)\sqrt{E_k}}{\sqrt{3}}\frac{k^3}{m_N^3}$$

$$\Gamma_5(k) = \frac{A}{(1+\frac{k^2}{0.71})^2}$$

A is estimated by assuming 1% contribution to the total normalization.



Frank Vera, PhD Thesis 2021

Estimate of the effect

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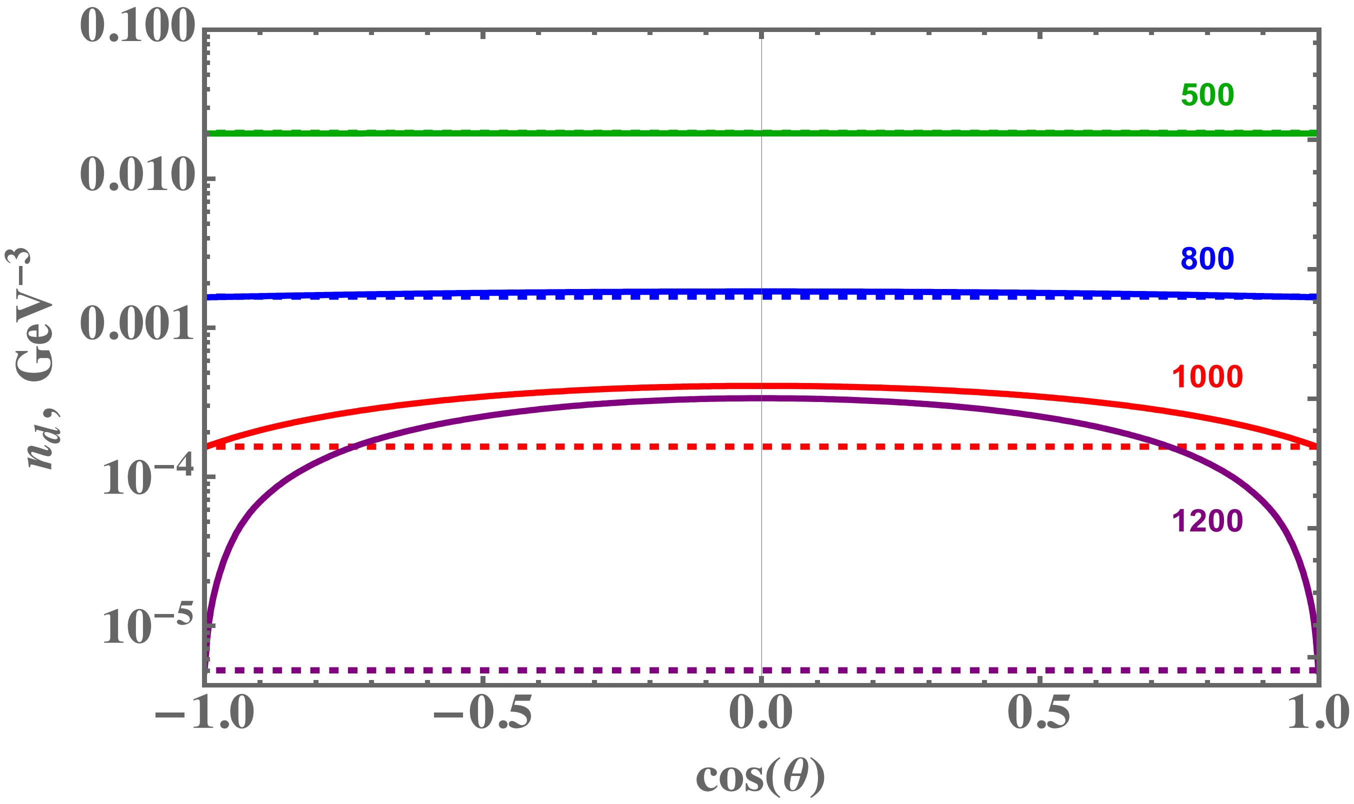
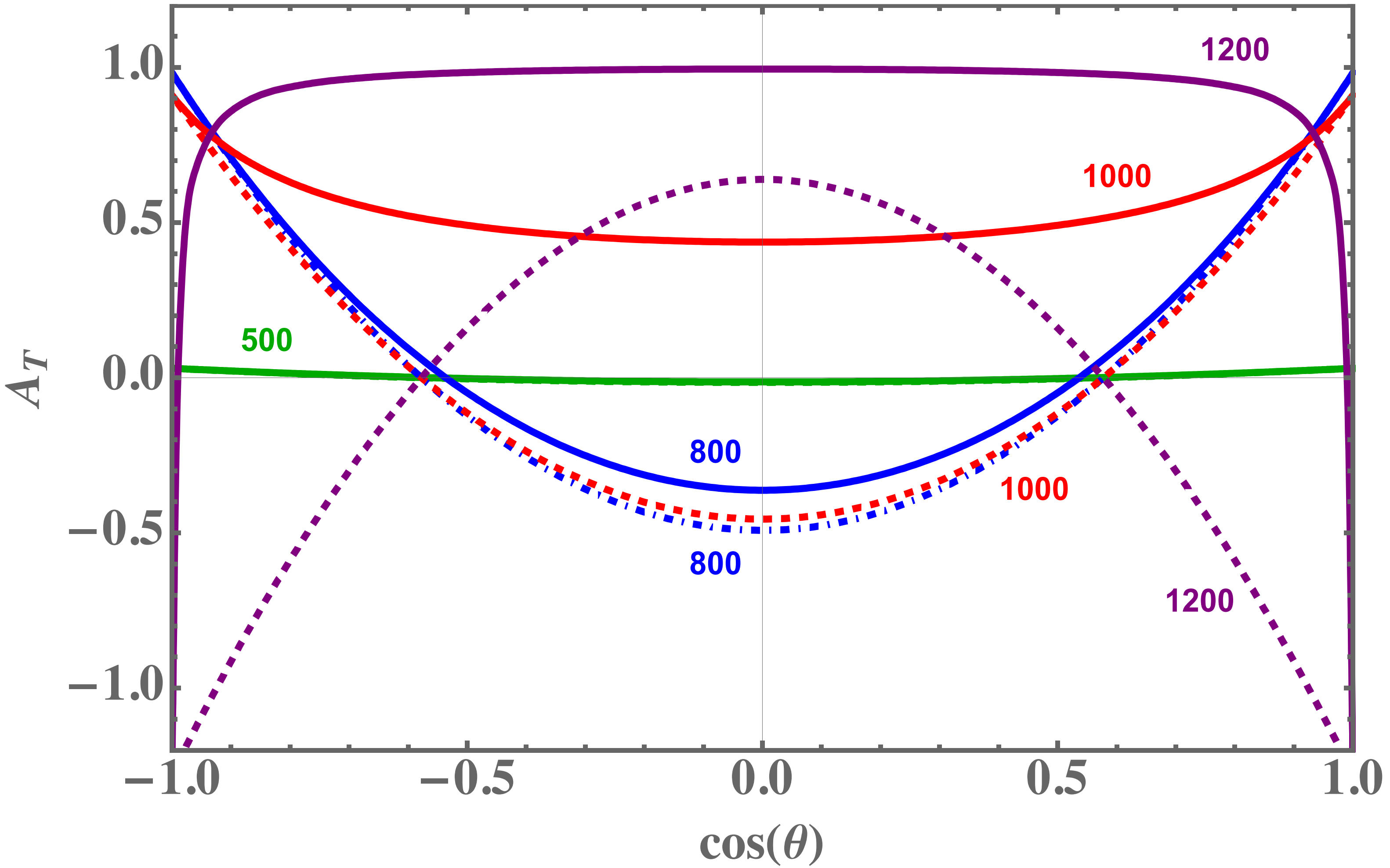


$$\cos\theta = \frac{(\alpha-1)E_k}{k}$$

Estimate of the effect

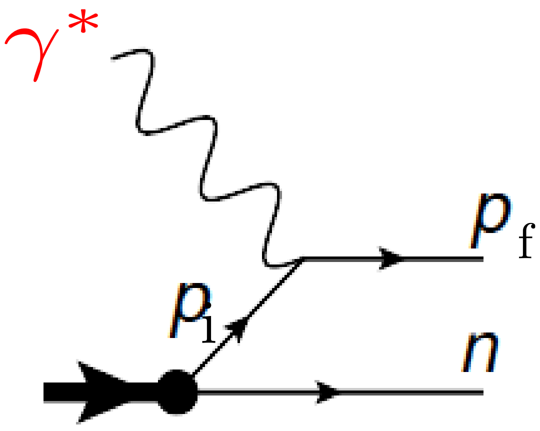
$$A_T = \frac{n_d^{\lambda_d=1}(k,k_\perp)+n_d^{\lambda_d=-1}(k,k_\perp)-2n_d^{\lambda_d=0}(k,k_\perp)}{n_d(k,k_\perp)}$$



$$\cos\theta = \frac{(\alpha-1)E_k}{k}$$

Possibility of Experimental Verification

Considering reaction: $e + d \to e' + p_f + n$

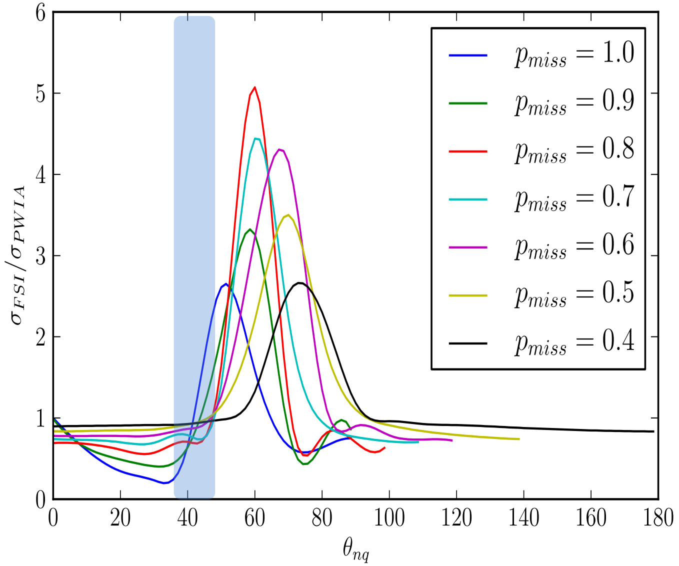


$$|p_i| = |p_f - q| \gtrsim 800\text{MeV}/c$$

PAC-36, 2010

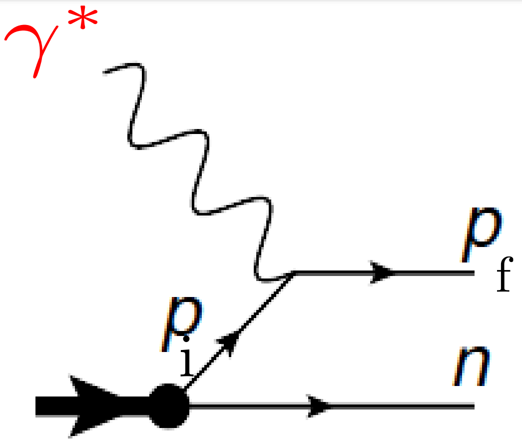
■ **E12-10-003 (p_m □ 300 MeV)**: "Deuteron Electro-Disintegration at Very High Missing Momentum"

<u>Rating</u>: B+



data are essential to constrain further theory developments. Overall the experiment was viewed very highly; the lower rating simply reflects the likelihood that the data will not reveal any particular surprise and that their impact may thus be limited to experts in the field.

Possibility of Experimental Verification

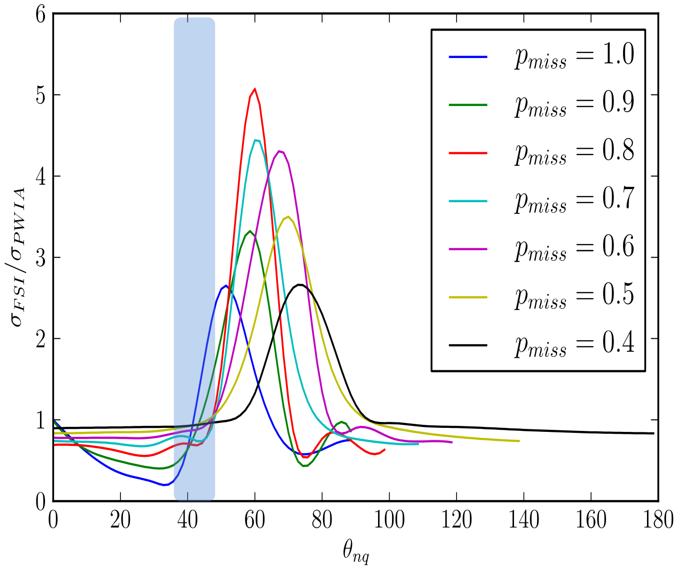


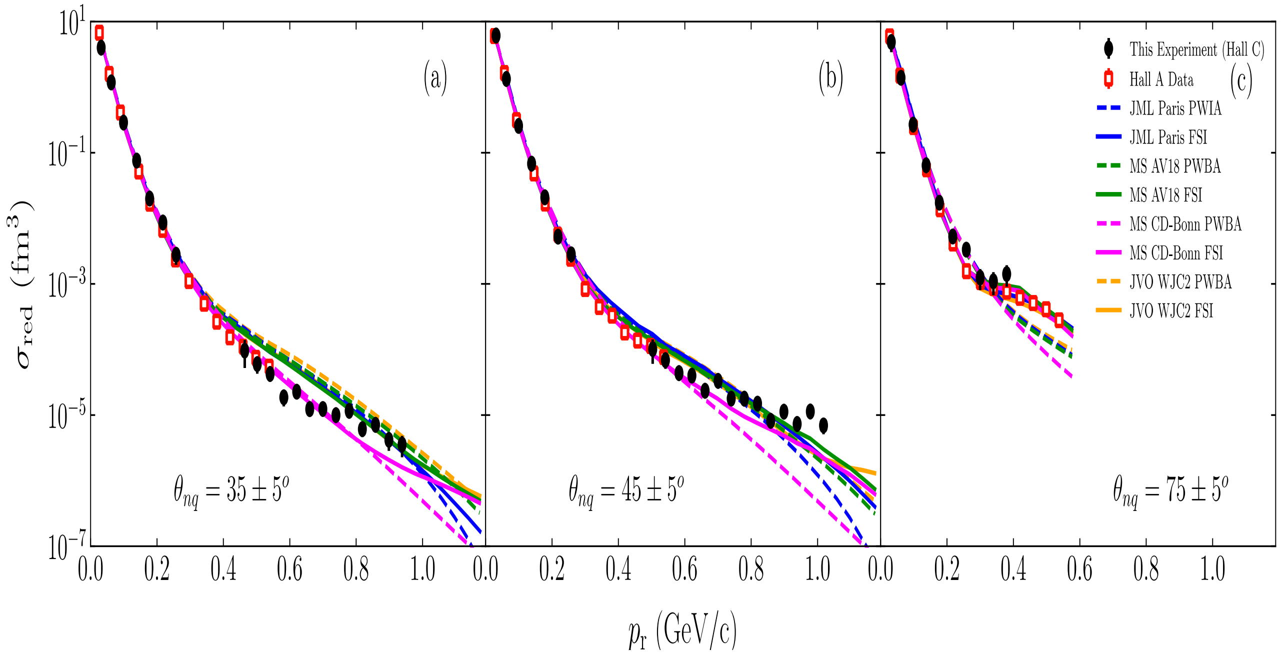
Considering reaction: $e + d \to e' + p_f + n$

$$|p_i| = |p_f - q| \gtrsim 800\mathrm{MeV/c}$$

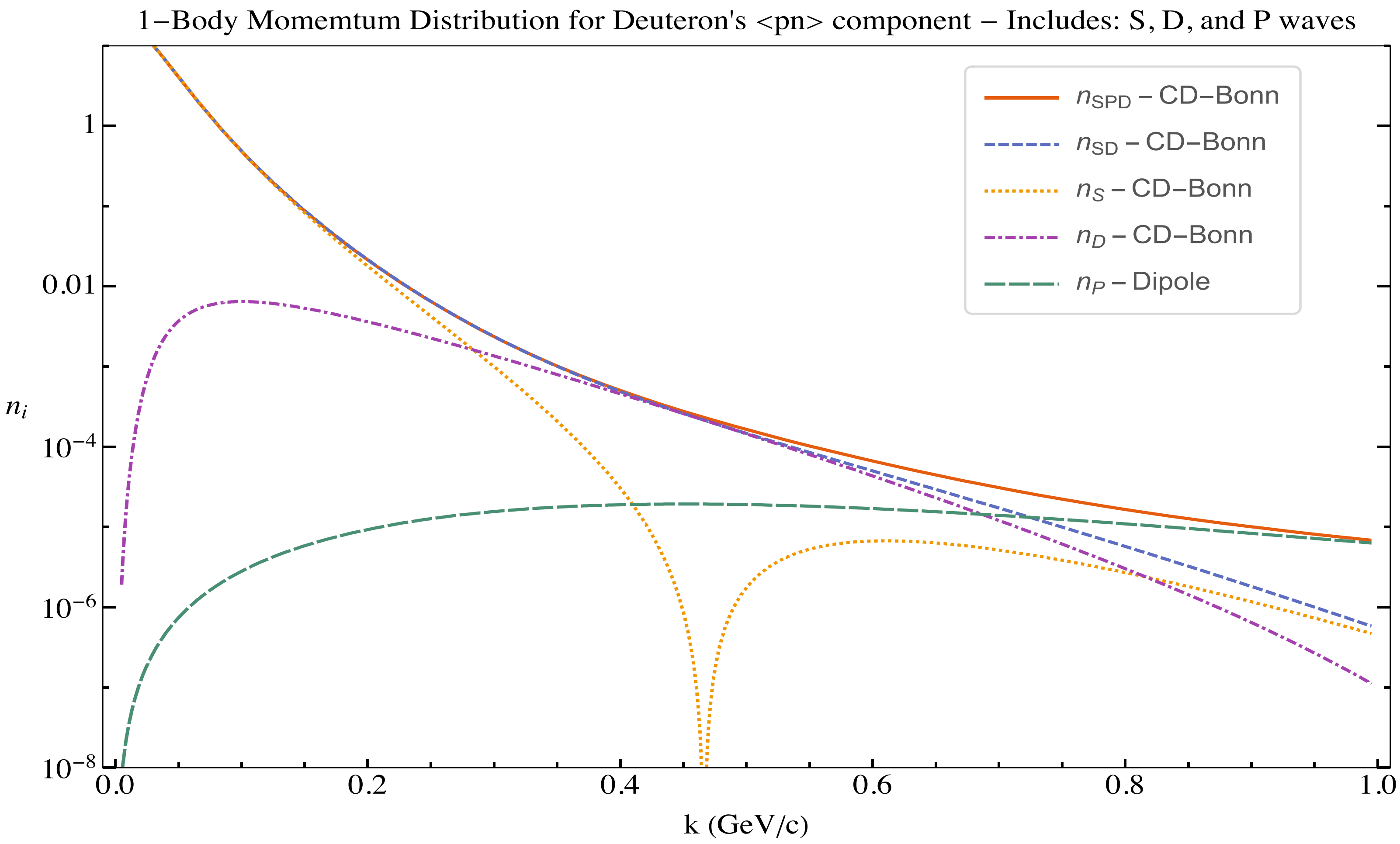
3-days of commissioning measurement,

JLab experiment $Q^2 = 4$ GeV^2





C. Yero, et al Phys.Rev.Lett. 125 (2020) 26, 262501

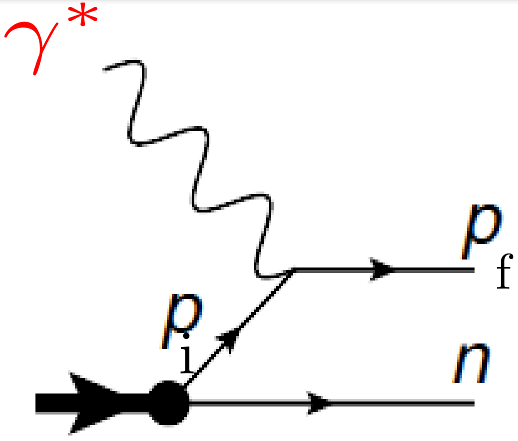


Frank Vera, PhD Thesis 2021

Possibility of Experimental Verification

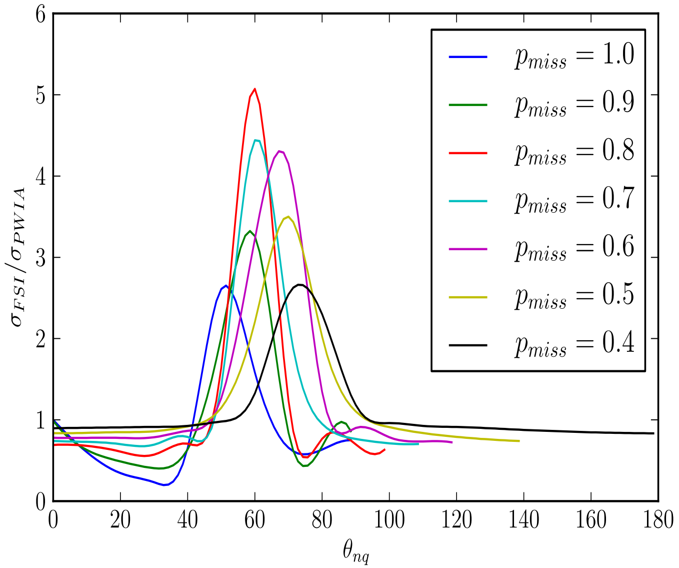
Considering reaction: $e + d \to e' + p_f + n$

$$|p_i| = |p_f - q| \gtrsim 800\text{MeV/c}$$



PAC-49, 2021

PAC 49 SUMMARY OF JEOPARDY RECOMMENDATIONS							
Number	Contact Person	Title	Hall	Previously Approved Days	Days Already Rec'd	Days Awarded	PAC Decision
E12-09-011	Tanja Horn	Studies of the L-T Separated Kaon Electroproduction Cross Section from 5-11 GeV	C	40	32	8	Remain active
E12-10-003	W. Boeglin	Deuteron Electro-Disintegration at Very High Missing Momentum	C	21	3	18	Upgrade Rating to A-



1) Is there any new information that would affect the scientific importance or impact of the Experiment since it was originally proposed?

PAC 36 graded the proposal with B+ because, even though the physics motivation was viewed highly, the foreseen impact of the result was judged to be limited. The results of the three days commissioning in April 2018, published in Physical Review Letters 125, 262501 (2020), exhibit an unexpected behavior when compared with theoretical calculations. Therefore, the expected impact of future data has increased.

Outlook on Experimental Verification of the Effect

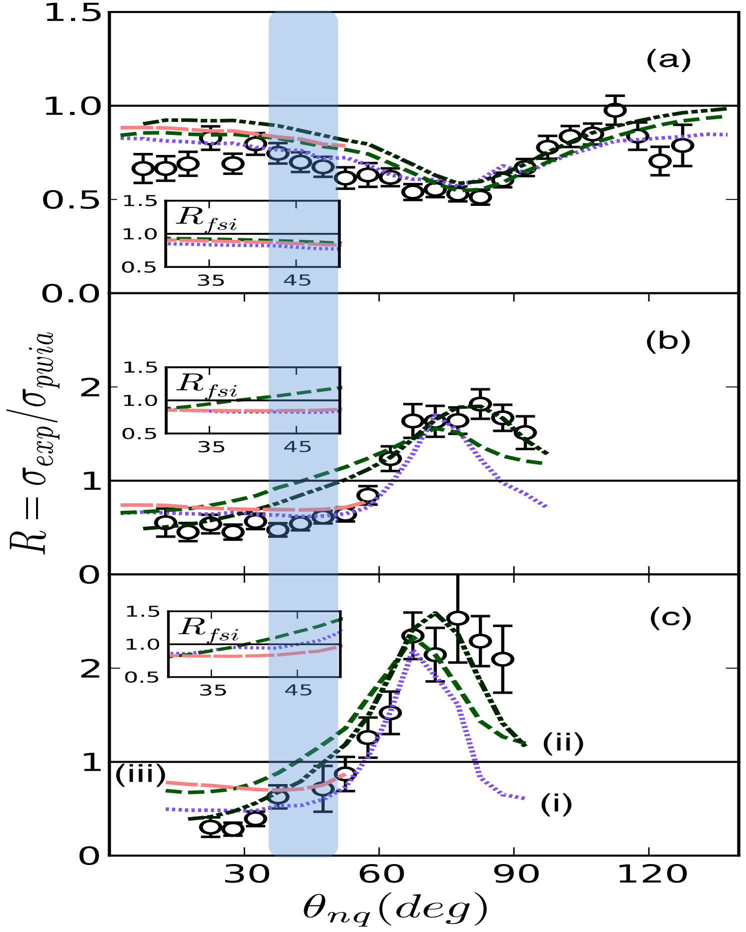
- analysis of the experiment will require careful account for competing nuclear effects most importantly final state interactions

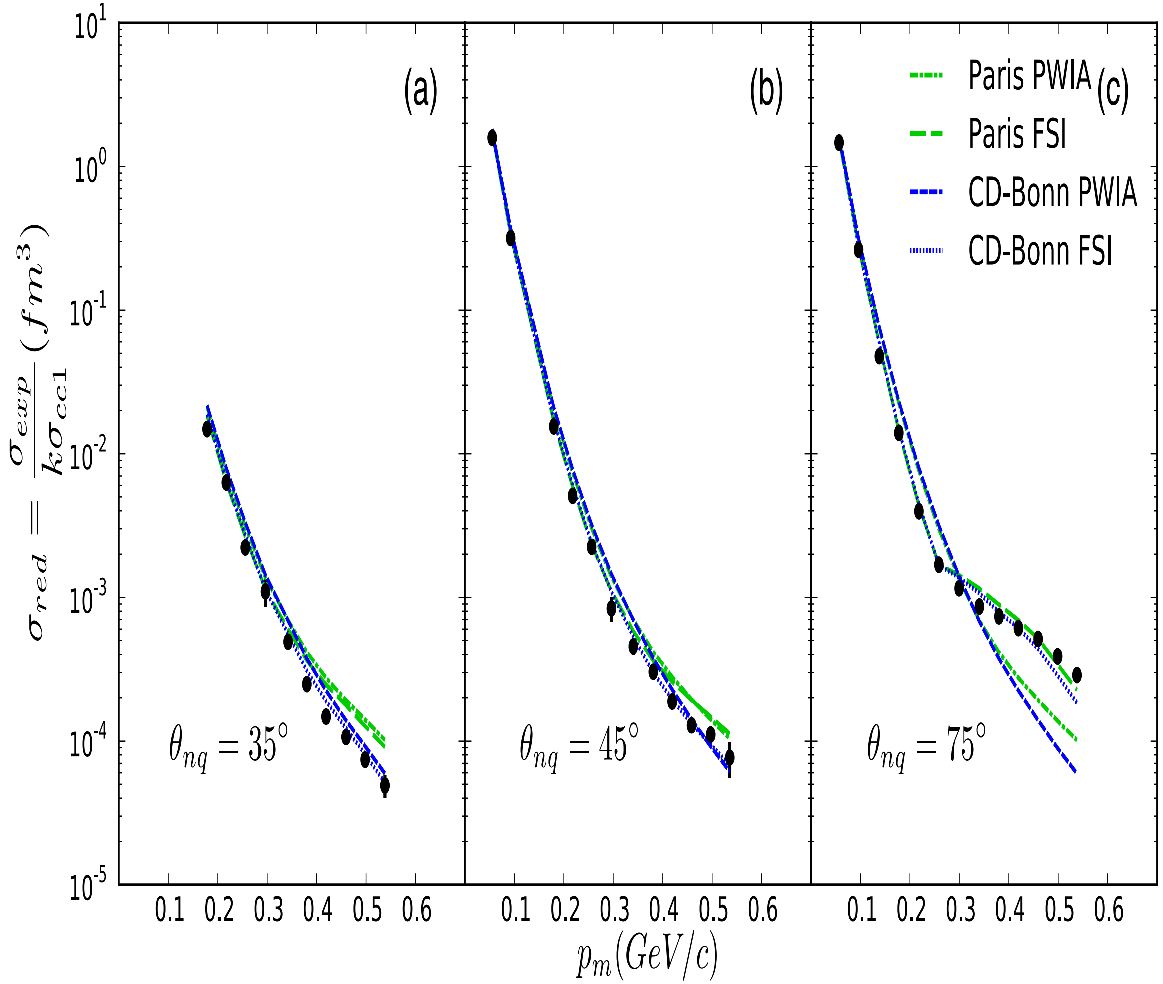
- If angular dependence is found it will motivate new area of research
  a: modeling non-nucleonic components in the deuteron,
  b: understanding their origin and nature
  c: evaluating parameters that can be used for Equation of State of high density Nuclear Matter

- If no angular dependence is found,
  a: nucleonic degrees persist at very high density fluctuations
  b: non-nucleonic components conspire to preserve angular condition
  c: theory was wrong

This work is supported by U.S. DOE grant under contract DE-FG02-01ER41172.

Probing Deuteron at Small Distances at large Q^2





JLab, $Q^2 = 3.5$ GeV^2

Boeglin et al PRL 2011, deuteron probed at up to 550MeV/c