LOI12-24-005 PAC Response

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1 Reader Comments

The main goal of the LOI is to study the repulsive core of the short-range neutron-proton correlation inside deuterium. To this aim, the main problem is to find a kinematics where all other possible effects, in particular FSI, are suppressed.

Both theory expectations (Fig.1), previous experimental results (Fig.2), and your simulations of Fig.12 deliver the same message that the peak of FSI effects shifts to lower recoiling-neutron angles theta_nq at increasing missing momentum pmiss. The results in Fig.3 from previous Hall A experiment seem consistent: if the peak FSI shifts at lower theta-nq at larger pmiss, then the larger theta_nq the earlier (= the smaller pmiss) for the onset of FSI. Indeed, Fig.3 shows solid curves (FSI) that deviate from dashed ones (PWIA) for pmiss well below 700 MeV/c, even at 500 MeV/c at the largest angle (rightmost plot).

However, the puzzling feature of Fig.3 is that starting from some pmiss theory calculations (with or without FSI) start deviating from data. In the LOI, emphasis is put on the results for the CD Bonn optical potential, which deviate from data at very large pmiss > 700-800 MeV/c, depending on the angle. I understand that the reason for this emphasis is that at these pmiss there is the inelastic threshold of proton-neutron channel, opening up non-nucleonic degrees of freedom.

But results from other optical potential show very different deviations, even at pmiss as low as 500 MeV/c (green and blue curves in the leftmost plot). All the calculations (optical potential, off-shell electron-nucleon cross section in Eq.(4)) are all done in a non-relativistic framework, which is definitely not adequate for pmiss $\sim$ 800 MeV/c which is the focus of the LOI. Moreover, relativistic corrections could heavily modify the simulations in Fig.12 for the largest pmiss values.

So, why invoking "exotic" effects (".. possible indication of the onset of non-nucleonic degrees of freedom...") before having all relativistic corrections under control?

I have also another question. In all previous experiments, and in the simulation discussed in Fig.12, there seems to be a specific angle, theta_nq $\sim$ 40 deg, at which FSI "switch off", irrespective of the kinematics explored (small or large pmiss, it does not matter). Since the indication instead is for a peak of FSI over PWIA shifting with pmiss, I'm wondering if there is any special reason for this 40 deg. angle. If there were one, it could solve the main problem raised in the LOI (= switch off FSI) without any additional measurement...

1.1 Question:

So, why invoking "exotic" effects (".. possible indication of the onset of non-nucleonic degrees of freedom...") before having all relativistic corrections under control?

Response:
We agree that one should expect significant relativistic effects for momenta above $\sim$ 800 MeV/c, without attributing it to exotic non-nucleon component in the deuteron. However, as it was predicted in Ref.[1] the existence of non-nucleon components above the pn threshold will result in a violation of so-called"angular condition", in which case the extracted light-cone momentum distribution of the deuteron will depend on light cone momentum k and its transverse component $k_\perp$ independently. Or in other words the non-polarized momentum distribution will depend on the direction of the internal momentum of the deuteron on the light-front. Even for the most relativistic case, if deuteron consists of proton and neutron only, the angular condition is satisfied and light-cone momentum distribution depends on the magnitude of k only. However, the existence of non-nucleonic component in the deuteron will result in an angular anisotropy[1]. Thus to obtain the signature of non-nucleon component the experiment needs to isolate the light-cone momentum distribution of the deuteron without effects of final-state interaction. As a result, exploring the possible onset of non-nucleonic degrees of freedom in the deuteron requires a solid understanding of final-state interactions at bound nucleon momenta above $\sim$ 800 MeV/c.

As such this proposal does **not** focus on searching for non-nucleonic components, but rather focuses on investigating the angular dependence of final-state interactions with θ_{nq} at momenta where non-nucleonic effects are expected to emerge in the ground state of deuteron wave function, i.e., $\sim$ 800 MeV/c, (above the inelastic threshold of pn system) as there is currently **no** data that explores FSI in this region.

It is worth mentioning that non-nucleonic components will not render ambiguity in evaluating FSI, since as previous investigations[2, 3] demonstrated the rescattering amplitude is sensitive to the deuteron wave function at smaller momenta for which case one expects dominance of the pn component. Proposed measurement will allow to investigate the role of the relativistic effects in the rescattering dominated by the pn component.

1.2 Question:

In all previous experiments, and in the simulation discussed in Fig.12, there seems to be a specific angle, theta_nq $\sim$ 40 deg, at which FSI "switch off", irrespective of the kinematics explored (small or large pmiss, it does not matter). Since the indication instead is for a peak of FSI over PWIA shifting with pmiss, I'm wondering if there is any special reason for this 40 deg. angle. If there were one, it could solve the main problem raised in the LOI (= switch off FSI) without any additional measurement...

Response:
Experimentally, there is **no** angle at which FSI are "turn off". The mention of a specific angle $\theta_{nq} \sim 40^\circ$ just refers the central value of a broader angular region at which FSI are suppressed. There are only certain angular regions in which FSI are the dominant contribution to the $\mathrm{d}(e, e'p)n$ cross-section, and there are other regions in which FSI are suppressed, mainly at forward ($\theta_{nq} \lesssim 40^\circ$) and backward ($\theta_{nq} \gtrsim 120^\circ$) angles. At backward angles, the kinematics are inelastic ($x_{Bj} < 1$) and intermediate nucleonic excitations like Isobar contributions contribute significantly to the cross-section, whereas at forward angles, $x_{Bj} > 1$, the PWIA becomes the dominant contribution to the $\mathrm{d}(e, e'p)n$ cross-section.

The suppression of FSI at $\theta_{nq} \sim 40^0$ is due to cancellation of PWIA-FSI interference term with the $|FSI|^2$ term. This is a feature of eikonal (high energy) regime of FSI in which case pn rescattering amplitude is mainly imaginary and as a result Real part of the $iA_{FSI}A_{PWIA}$ interference term is negative, cancelling the $|A_{FSI}|^2$ term. As a result of this cancellation the cross section in this case is dominated by $|A_{PWIA}|^2$ term. This cancellation is in a fairly broad range of θ_{nq} and p_m. It was investigated in Ref.[3] withing generalized eikonal approximation (GEA) and has been found that its position is defined by the average characteristics of the deuteron, pn re-scattering amplitude and kinetic energy of recoil particle. In the most simplified version (assuming single exponential form of the deuteron wave function) the cancellation happens at the transverse momentum of recoil nucleon:

$$p_{r\perp} \sim \sqrt{\frac{1}{\alpha_d} \ln \frac{32\pi\alpha_d}{\sigma_{pn}} + \frac{B_{pn} M_N^2}{2} \Delta^2},$$

where σ_{pn} is the total cross section of pn scattering, $\alpha_d = \frac{r_{rms}}{2p_{rms}}$, where r_{rms} and p_{rms} are RMS values of deuteron radius and internal momentum, B_{pn} is the exponent of the pn scattering amplitude presented in the diffractive form, M_N - is the mass of the nucleon, and $\Delta = \frac{q_0}{q} T_r$ where T_r, q_0 and q are the kinetic energy of the recoil nucleon, energy and momentum of the virtual photon respectively. Note that the Δ term accounts for the non-zero momenutum of the of the scatterer in the deuteron which is not accounted in the standard Glauber approximation[4].

It is important to note that the angular dependence of the cross-sections on FSI has only been measured for recoil neutron momenta up to $\sim$ 500 MeV/c[2], and predictions made about the suppression of FSI above $\sim$500 MeV/c can be checked in the proposed experiment.

References

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