Letter of Intent

Studying the Small-Distance Structure of pp and np Pairs via Triple Coincidence $^3\mathrm{He}(e, epp)$ and $^3\mathrm{He}(e, epn)$ Measurements

Exp 97-106 Collaboration

Submitted to PAC19, JLab

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1 Scientific motivation.

This measurement is focused on a specific part of the ^{3}He ground state wave function in which the two nucleon short range correlation (SRC) plays an important role. In this configuration two of the nucleons in ^{3}He have very large relative momenta, while the center of mass (CM) momentum of the correlated pair is nearly at rest. Thus, the third nucleon is almost at rest in the ^{3}He CM system. There are two configurations of this type. One, in which two protons are correlated and the neutron is at rest (Fig.1A) and the other with a correlated proton-neutron pair and the second proton is at rest (Fig.1B).

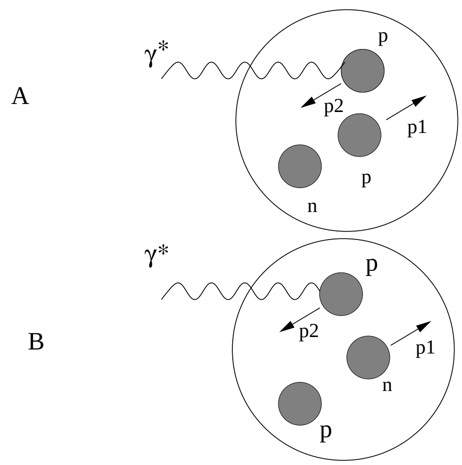

Figure 1: Breakup of a (pp) and a (pn) SRC pair in ^{3}He induced by a virtual photon.

Due to quantum number restrictions it turns out that a back to back $p-p$ pair must be in a relative S-wave configuration, as will be explained below. The $n-p$ pair on the other hand is not restricted to the relative $l=0$ angular momentum and has a substantial contribution from the $D(l=2)$ state. Since $l=0$ is an important component in the short range structure of two nucleons, this difference between $p-p$ and $p-n$ pairs opens up a unique possibility to study the relative importance of the short-range S-state NN interaction by measuring ^{3}He$(e, ep + p)$ and the ^{3}He$(e, ep + n)$ reactions in the above described configurations.

The fact that we choose two protons ($T = 1$) means that the two nucleon isospin wave function is symmetric. Since in the ^{3}He ground state wave function the two protons have $S = 0$ it follows that the 2N spin wave function is antisymmetric. In order for the total wave function to be antisymmetric the space wave function has to be symmetric. This constraint means that in the above described configurations, when the third (uncorrelated neutron) is almost at rest (dominated by S-state wave function), the angular momentum of the relative motion in pp correlation has to be zero (S-state). Thus this configuration (Fig.1A) will allow us to directly measure the high-momentum pp wave function in the S- state. *The importance of studying a high relative S state is that it is very sensitive to the structure of the repulsive core of the nucleon.* Namely, the change of the sign of the NN interaction (dominance of the repulsion over the attraction) is reflected in the change of the sign in the pp wave function. *As a result, the momentum distribution of the pp correlation has a node.*

For pn correlation such a node does not exist since the $T = 0$ component of the pn correlations allows a $D(l = 2)$ state contribution in the wave function of the pn pair.

Using a realistic ^{3}He wave function[1] the calculated proton momentum distribution[2] shows the node near 400 MeV/c that corresponds to the case of pp pair and n at rest (see Fig. 2). This node is missing from the proton momentum distribution for the case of one proton at rest and a np pair with relatively high momentum. Below 300 MeV/c and above 500 MeV/c the $n(p)$ distributions in the two cases have similar shapes. Since the probability of both np and pp to be in large relative momentum falls off strongly with increasing relative momentum, the ratio of the np/pp is a better observable than the individual cross sections to search for the minimum in the pp correlation.

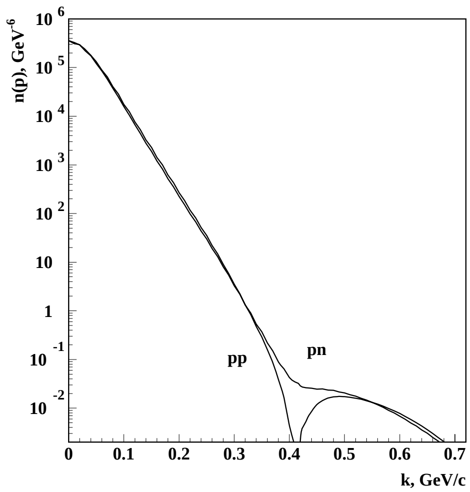

Figure 2: Proton momentum distribution in pp and pn pairs in ^3He.

2 The selected kinematics for the measurements.

The proposed measurement is a triple coincidence measurement of a fairly small cross section corresponding to a rather delicate feature of short range NN correlations. Favorable conditions should be provided in order to suppress meson exchange currents, isobar contributions and final state interactions which can obscure the genuine features of short range correlations.

- **Meson Exchange Currents (MEC)**: MEC contributions are expected to be small for pp correlations[3]. Contributions from mesons exchanged between correlated protons and the uncorrelated neutron are expected to be small due to a strong cut on the momenta of the spectator neutron ($p_n \leq 50MeV/c$). MEC will be also suppressed because of the large Q^2 ($\geq 1\ GeV^2$).
- **Isobar Contribution (IC)**: Choosing $x > 1$ (anti-parallel kinematics) will suppress IC.
- **Final State Interactions (FSI)**: choosing a larger Q^2 (eikonal regime) and parallel or anti-parallel kinematic reduces the elastic rescatterings[4].

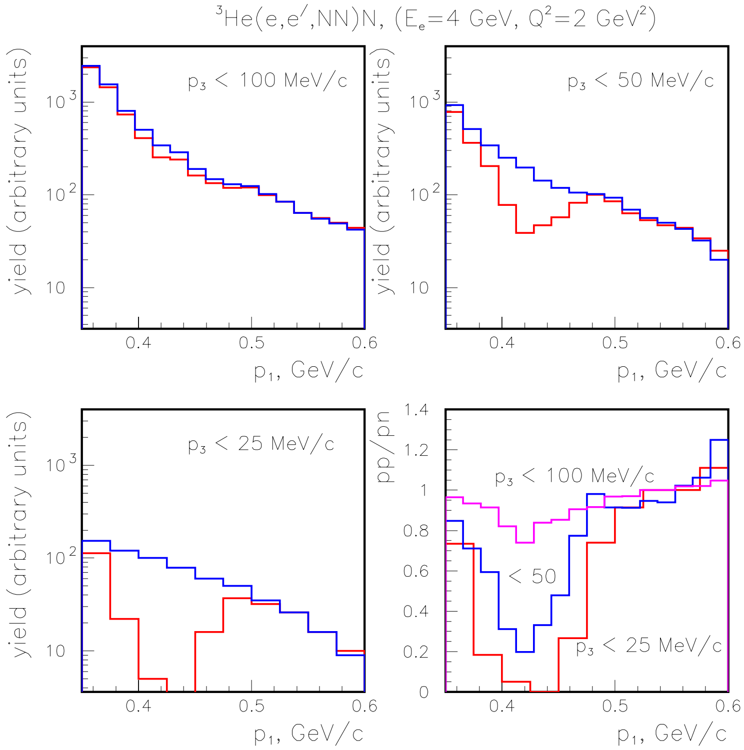

Figure 3: Expected yield for $(e, e'pn)$ and $(e, e'pp)$ events as a function of p_1 for different cuts restricting the size of the spectator recoil momenta (p_3). Also shown is the ratio of pp to pn events

The following kinematical setup is considered for such measurement.

- high incident energy (4 GeV/c)
- large Q^2 (Q^2=1-2 GeV/c)
- $x > 1$, "almost anti parallel" geometry
- large initial relative momentum for the pair members $p_1 = -p_2$=300-500 MeV/c.
- small initial momentum for the third spectator: $p_3 < 50$ MeV/c

3 Preliminary consideration of the experimental parameters

Figure 2 shows the $n(p)$ distributions for np and pp pairs with the spectator (p or n respectively) at rest. Figure 3 is a Monte Carlo simulation of the expected yield for pp pairs and pn pairs as a function of a cut on the size of the spectator momentum (p_3). The relative number of events with each cut is according to what one expects based on the cross section and the ^{3}He wave function. The ratio of the expected number of np to pp pairs as a function of the momentum of the partner in the pair is also shown in the same Figure. There are PWIA calculations [2], in which the electron scattering of a bound proton is described within a virtual nucleon approximation. A realistic wave function from Ref.[1] is used for the ^{3}He ground state wave function. We will estimate the MEC, FSI, and isobar production contributions for the proposal.

4 Experimental setup.

Hall A has two spectrometers (HRS$_h$ and HRS$_e$) which are used routinely for $(e, e'p)$ coincidence measurements. The proposed measurement requires a third spectrometer (BigBite) and an array of scintillation counters, to measure, simultaneously, neutrons and protons in coincidence with the outgoing high momentum electron and proton. We propose to use segmented scintillators as the only focal plan detectors for BigBite. This will allow high single rates with sufficient resolution for this measurement.

The BigBite magnetic field will allow momentum analysis of the protons and will sweep away the charged particles from the neutron counters, thus reducing the singles rate on the neutron counters. We will also be able to install a relatively thick lead shield in front of the neutron counters since we do not plan to use them to detect the protons.

With the proposed set up we can measure the proton (neutron) momentum with resolution better than ± 25 MeV/c (± 12.5 MeV/c) up to 500 MeV/c. This experimental setup is the same as proposed for the update of proposal 97-106.

5 Related experiments and proposals at JLAB

The propose experiment is filling the gap between two proposal submitted to this PAC. The first proposal[5] is to study the exclusive electro-disintegration of the deuteron. The second proposal[6] will study the (pp) and (np) short range contributions in ^{12}C. These proposals, as the proposed measurement in this letter, utilize large Q^2, large missing momentum and $x > 1$ to study the NN short range correlations in nuclei.

This measurement is also complementary to Hall B and Hall A proposals and measurements of the ^{3}He system which emphasize the large missing momentum structure of ^{3}He using (e, ep), (e, epp) and (e, epn) reactions [7, 9, 10].

6 Experimental considerations

Rate estimates, signal/background ratio, beam time request will be attached to the proposal.

References

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