n-p Short-Range Correlations
from (p,2p + n) Measurements

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Abstract. Recently, a new technique for measuring short-range NN correlations in nuclei (NN SRCs) was reported by the E850 collaboration, using data from the EVA spectrometer at the AGS at Brookhaven Nat. Lab. In this talk, we will report on a larger set of data from new measurement by the collaboration, utilizing the same technique. This technique is based on a very simple kinematic approach. For quasi-elastic knockout of protons from a nucleus \((^{12}\text{C}(p,2p)\) was used for the current work), we can reconstruct the momentum \(p_f\) of the struck proton in the nucleus before the reaction, from the three momenta of the two detected protons, \(p_1\) and \(p_2\) and the three momentum of the incident proton, \(p_0\) :

\[
p_f = p_1 + p_2 - p_0
\]

If there are significant n-p SRCs, then we would expect to find a neutron with momentum \(-p_f\) in coincidence with the two protons, provided \(p_f\) is larger than the Fermi momentum \(k_F\) for the nucleus (~220 MeV/c for \(^{12}\text{C}\)). Our results reported here confirm the earlier results from the E850 collaboration.
For the past half century the dominant model for the structure of nuclei, especially light nuclei, has been the nuclear shell model. In the shell model, the long-range ($\sim 2$ fm) part of the N-N force, in combination with the Pauli principle, produces an average potential in which the nucleons undergo nearly independent motion, and the residual interactions can be treated by perturbation theory. However the N-N interaction is also highly repulsive at short-range ($\sim 0.4$ fm) and it has long been a goal of nuclear physics to observe the effects of this short-range repulsion. These effects are most easily pictured in terms of momentum correlations rather than in terms of spatial correlations. When two nucleons in a nucleus interact at short range, they must have large relative momenta (because of their strong repulsion at short range). Following such a collision they will have equal and opposite momenta in their two-body c.m. frame. Typically, to obtain high enough relative momenta to probe the N-N repulsive core, one would expect the two-body c.m. frame to coincide roughly with the c.m. frame for the nucleus as a whole.

Recently, Aclander et al.[1] described new technique for observing such short-range correlations using data taken with the EVA spectrometer[2,3] at the AGS. This technique is based on a very simple kinematic approach. For the quasi-elastic knockout of protons from nuclei, e.g. $^{12}$C(p,2p) in [1] and for this work, we can reconstruct (event by event) the three momentum $p_f$ that each struck proton had before the reaction:

$$p_f = p_1 + p_2 - p_0$$

where $p_0$ is the momentum of the incident proton and $p_1$ and $p_2$ are the momenta of the two detected protons. The question we then ask is whether or not there is a coincident neutron with $p_n \approx -p_f$. To answer this question, we deployed 36 neutron detectors to look for triple coincidences of the kind $^{12}$C(p,2p+n).

The EVA spectrometer is designed to detect proton pairs from quasielastic collisions with $\theta_{\text{cm}} \approx 90^\circ$. Because the cross section for this geometry fall steeply with the Mandelstam variable $s$, the (p,2p) reaction preferentially occurs for nuclear protons with $p_f$ in the forward going lab direction. Therefore most of our 36 neutron detectors were placed in the backward laboratory hemisphere. Figure 1 shows the layout of the 36 neutron detectors relative to EVA. The detectors in arrays 1 and 2 had dimensions 10 cm x 12.5 cm x 1m. The detectors in array 3 had dimensions 25 cm x 10 cm x 1 m.

Our initial objective with the new, more extensive, triple coincidence measurement with EVA in 1998 was to confirm the results from the 1994 data reported in [1]. To this end we applied the following cuts:

(1). There should be two (and only two) high $p_t$ positive tracks - kinematics dictates that these are both protons.
(2). The missing energy, $E_{\text{miss}}$ should be appropriate for quasi-elastic scattering (within our resolution): $-0.2 < E_{\text{miss}} < 0.8$ GeV.

(3). $0.05 < p_n < 0.55$ GeV/c.

There is another cut we can apply to more fully reproduce the conditions of the 1994 run. For that data, only the straw-tube sectors near the midplane of EVA were working. So we can impose a fourth cut:

(4). The two detected protons were limited to a plane parallel to the neutron detectors within $\pm 25^\circ$.

Figure 2 shows our preliminary momentum correlation results for $^{12}$C$(p,2p+n)$ at 5.9 GeV/c with cuts (1), (2), (3) and (4). Figure 2 is a plot of $p_{fx}$, the reconstructed x component of $\mathbf{p}_f$, vs. the measured $p_n$. Since the neutrons are detected largely going “downward” in the laboratory we would expect $p_{fx}$ to be “upward” for correlated high-momentum n-p pairs. We see in Fig. 2 that for events with $p_n > 0.22$ GeV/c (the Fermi momentum for $^{12}$C) that indeed $p_{fx}$ is predominantly “upward”. For $p_n < 0.22$ GeV/c there is no evident correlation, which is also as expected. For $p_n \geq 0.22$ GeV/c, the ratio of events with $p_{fx} \geq 0$ and $p_{fx} < 0$ in Fig. 2 is $18/3$. This result is completely consistent with the ratio of 17/1 reported in [1] and provides strong confirmation of that result.

With cut (4) we are selectively rejecting events with an approximately “coplanar” geometry where all four transverse momenta $\mathbf{p}_1$, $\mathbf{p}_2$, $\mathbf{p}_{tf}$ and $\mathbf{p}_{tn}$ all lie roughly in the same plane with $\Delta \phi = |\phi_2 - \phi_1| \approx 180^\circ$. The type of events selected by (4) are then of the “non co-planar” type where $\Delta \phi$ differs significantly from 180°. This preferential selection of non co-planar events has an unintended benefit, in that our reconstruction of $\mathbf{p}_f$ has much better resolution for non co-planar events than for co-planar events.

The data in Figs. 2 represents 10% to 20% of the total data recorded in 1998. As we continue the analysis, we will be exploring the kinematic and geometric constraints on where we find strong evidence of n-p correlations - such as were reported in [1] and are seen in Fig. 2.

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FIGURE 1. Layout of the experiment

FIGURE 2. Pfx vs. Pn with cuts 1,2,3 and 4 for $^{12}$C(p,2p+n) at 5.9 GeV/c