Searching for Short Range Correlations in Carbon

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for the E01-015 and Hall A Collaborations

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Physics Motivation

- Independent particle shell model (IPSM) predicts all states below Fermi level are occupied.
- Experiments from NIKHEF showed only 50-70% states below Fermi level occupied.
- IPSM neglects correlation functions between two or more nucleons.
- Nucleon-nucleon interaction highly repulsive at short distances, $\sim < 1$ fm.
- Short distance NN interaction leads to states above Fermi energy being populated.
- Define *short range correlation* as a nucleon-nucleon pair with strongly overlapping wavefunctions.

Reaction Mechanism

- Small internucleon separation leads to large relative momentum of NN pair.
- Reaction proceeds with electron scattering from a single proton.
- Proton ejected from nucleus, leaving partner nucleon recoiling with initial state momentum.
- Expect directional correlation between struck and recoil partner nucleons.
- Measure fraction of (e,e'p) events which have a recoil partner nucleon.

Jlab Hall B (e,e') Results

- SRC arise from localised behaviour of nucleons.
- Expect similar behaviour for different nuclei
 - example of scaling
- Inclusive cross-section ratios relative to ^3He measured in Hall B.
- Observed two scaling regions
 - $1.5 < x_B < 2$ — 2N SRC
 - $x_B > 2.25$ — 3N SRC

K. S. Egiyan *et al.*, Phys. Rev. Lett. 96, 082501 (2006)

$^{12}\text{C}(p,2pn)$ Results from BNL

- Measured angle between proton and neutron initial state momentum vectors.
- Observed strong directional correlation between protons and neutrons with measured momenta larger than Fermi momentum.
- Clear signature of SRC.
- Results consistent with Hall B ^3He data.

A. Tang *et al.*, Phys. Rev. Lett. 92, 052303 (2004)

Triple Coincidence experiment on ^{12}C

- Simultaneously measure (e,e'p), (e,e'pp) and (e,e'pn) reaction channels.
- Previously unexplored kinematic region
 - Large momentum transfer; $Q^2 = 2 \text{ (GeV/c)}^2$.
 - $x_B > 1$.
 - Electron kinematics fixed.
 - Detected proton momentum changed to scan a range of missing momentum
- Utilised spectrometer pair in Hall A at Jefferson lab.
- Required construction of third spectrometer
 - Recoil partner nucleon detected in *BigBite* spectrometer.

Jefferson Lab

- Superconducting electron accelerator with three experimental halls – A, B and C.
- Beam energy upto 6 GeV, with beam currents upto 200 μA .

Hall A at JLab

- Two high resolution magnetic spectrometers (HRS)
- 6 msr acceptance; 2×10^{-4} FWHM resolution
- Ideal for (e,e'p) coincidence experiments

Experiment Set-up – Add third arm

- BigBite consisted of a dipole magnet, a charge-particle detector and a neutron detector
- BigBite has 16x acceptance of HRS spectrometers – 96 msr vs. 6 msr

BigBite Spectrometer

Measured ratios of pp and np pairs

- Yield ratio shows majority of (e,e'p) events include emission of recoil nucleon.
- Results consistent with BNL experiment.

Structure of ^{12}C

- Almost all nucleons with momentum above the Fermi level form pairs.
- n-p pairs almost 20 times more prevalent than p-p pairs.
- n-p dominance indicative of nucleon-nucleon tensor force.

R. Shneor *et al.*, Phys. Rev. Lett. 96, 082501 (2006)
R. Subedi *et al.*, Science 320, 1476 (2008)

$^{12}\text{C}(e,e'p)^{11}\text{B}$ Results

- Bound state $(e,e'p)$ data at $x_B \sim 1.1$.
- Extracted five-fold differential cross-section.
- Comparison with theory
 - Full calculation required
- Low statistics at large missing momentum.
- Comparison of data in two kinematics for overlap region in P_{miss} .

Future Plans

- Further studies of short range correlations.
- New experiment approved in Hall A at Jlab
 - E07-006: Triple coincidence (e,e'pN) experiment on ^4He
 - Extended missing momentum range: 400 – 875 MeV/c
 - Explore repulsive core of nucleon-nucleon interactions
- Theory groups interested in new data.
- Stimulate new theoretical calculations for short range NN interaction.

Summary

- Performed experiment to study short range nucleon-nucleon correlations in carbon.
- Large Q^2 and $x_B > 1$ kinematics.
- Triple coincidence measurement with first use of BigBite spectrometer.
- Simultaneously measure (e,e'p), (e,e'pp) and (e,e'pn) reaction channels.
- Yield results show majority of (e,e'p) events are accompanied by emission of a recoil partner nucleon.
 - Correlations dominant regime
- Observed dominance of n-p pairs over p-p: ~ 20 times!
 - Indicates short range NN tensor force
- Cross-section data for (e,e'p) reaction for large missing momentum range.
- Further study of short range correlations in helium planned.