Probing $^3$He Ground-State in Spin-Asymmetry Measurements in Jefferson Lab

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Outline

- Physics motivation
- Experimental set-up
- Conclusion
Physics motivation

- A variety of $^3\text{He}$ based experiments seeking to extract neutron information rely on a perfect theoretical knowledge of the ground state spin structures of $^3\text{He}$
- Fadeev calculations predict three components in ground-state wave-function. Understanding the role of $S'$ and $D$ states helps us understand “standard model” of few-body theory
- Double polarization measurements has large sensitivities to both ($S'$ and $D$) components
Ground State

S: 90% Spatially Symmetric
S': ~1.5% Mixed Symmetry Configuration
D: ~8.5%
\( ^3 \text{He} \) target in related measurements

- Elastic scattering: to measure neutron electromagnetic form factors
- Deep inelastic scattering (DIS): to probe polarized nucleon spin structure
- Problem: in E99-117 experiment, leading error comparable with the uncertainty of polarization of neutron and proton
Helium Asymmetry sensitive to $S'$ and D waves (theoretical calculation)
Non-zero asymmetries, $A_x$ and $A_z$
Formalism of $^3\text{He}(\bar{e},e'd)p$

$$\frac{d\sigma(h, \vec{S})}{d\Omega_e dE_e d\Omega_d dp_d} = \frac{d\sigma_0}{d\Omega_e dE_e d\Omega_d dp_d} [1 + \vec{S} \cdot \vec{A}^0 + h(A_e + \vec{S} \cdot \vec{A})]$$

In PWIA, only part of $\vec{A}$ that is nonzero is $A_{x,z}$ since $\vec{S}_x \perp \vec{q}$ and $\vec{S}_z \parallel \vec{q}$

$$A_{x,z} = \frac{[d\sigma_{++} + d\sigma_{--}] - [d\sigma_{+-} + d\sigma_{-+}]}{[d\sigma_{++} + d\sigma_{--}] + [d\sigma_{+-} + d\sigma_{-+}]}$$

$(\pm, \pm)$ refer to beam helicities and projection of target spin on quantization axis
Experimental Set-up

- Beam energy 2.4 GeV
- Electron scattering angle of 15 degrees
- Momentum transfer of 620 MeV/c
- BigBite get kinematics up to ~200 MeV/c
- Beam helicity fast-flipped (30Hz)
- Target spin flipped every 24 hours
Detectors scheme
High-resolution spectrometers (HRS)

- Detects scattering electrons with high resolution and relatively low acceptance
- Angular resolution:
  - ~0.6mr in non-dispersive plane
  - ~0.2mr in dispersive plane
- Momentum acceptance: ±4.5%
- Angular acceptance:
  - ~22mr in non-dispersive plane
  - ~60mr in dispersive plane
A pair of HRS

- Right spectrometer (RHRS) measures elastically scattered electrons, monitors the product of beam and target polarization and luminosity
- Left spectrometer (LHRS) measures production electrons
BigBite spectrometer

- Detects deuterons with large acceptance and relatively low resolution
- Solid angle of 96 msr
- Momentum acceptance: 200-900 MeV/c
- Two wire chambers and two scintillator planes
BigBite geometry

Geant-4 BigBite Model
Geometry

Momentum Reconstruction

Target Position \( (0,0,0) \)

Effective Field Boundary

Centre Line

Supplemental Scintillator Plane

Proton Tracks

\( 550 \text{ MeV/c} \)

\( 500 \text{ MeV/c} \)

\( 250 \text{ MeV/c} \)

\( \text{X-Y Trigger Plane} \)

0 1 2 m
Wire chambers

- Gas: 50% argon and 50% ethane
- Particles produce signals in gas and pass signals on wires
- Wires in three orientations between 30-degree angles
- Detect particle time and position information
140 x 35 cm² drift chamber plane

90μ- BeCu field and 20μ-W anode wire

Test set up with radioactive source

100 mv/cm, 100 ns/cm

Nuclear Phys Lab Department of Physics University of Virginia
BigBite trigger plane

Two scintillator planes: E and dE plane
Scintillator planes

- Two planes in parallel, E and dE
- Each plane has 24 scintillator bars
- “Plastic”, produces light when a particle comes in
- Different scintillator bars detect position information, and also time information
Differentiate between protons and deuterons by time-of-flight method and E-dE plot
Beam-time allocation

- 15 PAC days

<table>
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<tr>
<th></th>
<th>Beam-time [days]</th>
<th>Radiative loss [days]</th>
<th>Total beam-time [days]</th>
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<td>$\Lambda_x$</td>
<td>5.5</td>
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<tr>
<td><strong>Total</strong></td>
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<td></td>
<td><strong>15.0</strong></td>
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</table>
Conclusion

- Using double-spin asymmetry measurements to probe minority states
- HRS and BigBite as main detecting devices
- Experiment: May 4th ~ June 15th
- Webpage: http://hallaweb.jlab.org/experiment/E05-102/