Polarized Target for Nuclear Spin Structure of CLAS12

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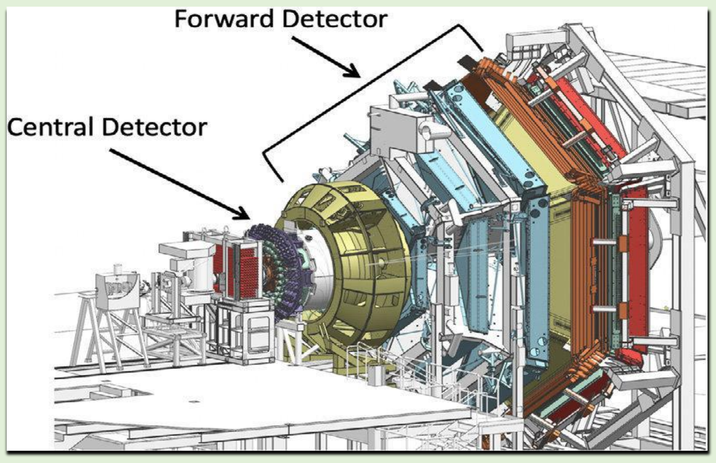
Introduction

The Solid Polarized target was built at Jefferson Lab in Newport News, VA to study nucleon internal structure by scattering polarized electrons off polarized nuclear targets in Hall B. Scattered electrons and fragments of the nuclear targets detected with the CEBAF Large Acceptance Spectrometer (CLAS12) are useful for studying hadron spectroscopy, structure functions, and sum rules.

In this study, we discuss the calculation of the nuclear spin asymmetries used to extract the spin structure functions, the Dynamic Nuclear Polarization (DNP) method used to polarize proton and deuteron targets and discuss NMR measurements needed to determine the target polarization.

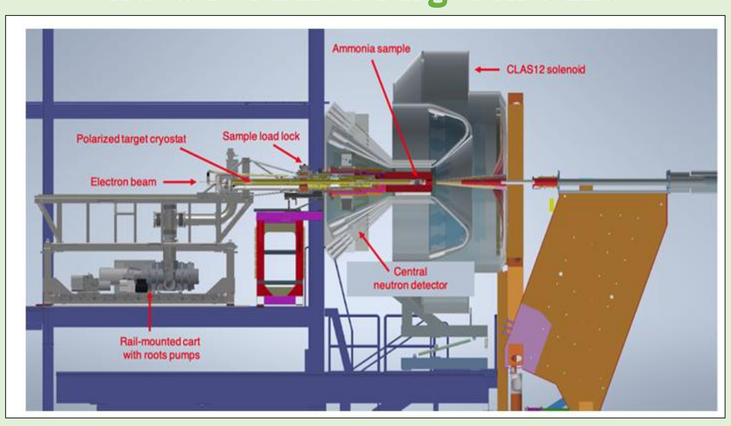
An Opportunity in Hall B's CLAS 12



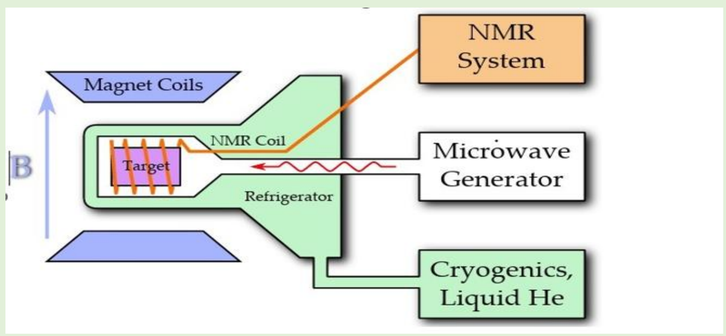
The Run Group C Polarized Target

- CLAS12 detector at Hall B- 12Gev for high luminosity electron scattering and multi-particle final state response
- Dynamic Nuclear Polarization (DNP) at 1K in 5T field apply 140 GHz microwaves to nucleons
- Free electronic magnetic centers transfer polarization
- Maximum Polarization: ~90% protons, ~40% deuterons

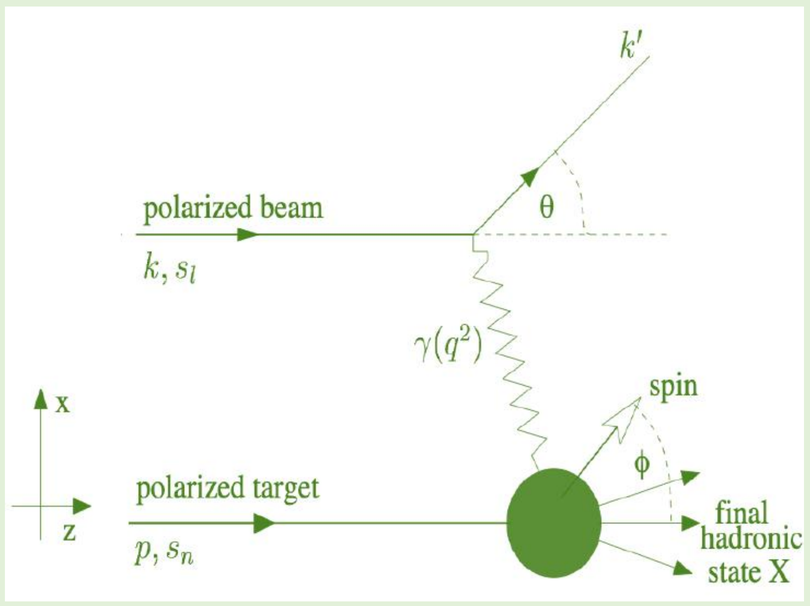
RG-C Polarized Target APOLLO



Dynamic Nuclear Polarization System



Polarized Electron Nucleon Scattering



Double Spin Asymmetry ($A_{||}$) connected to spin structure function

$$A_{||,raw}(x,Q^2) = \frac{n^{\downarrow\uparrow} - n^{\uparrow\uparrow}}{n^{\downarrow\uparrow} + n^{\uparrow\uparrow}}$$

$$A_1(x,Q^2) = \frac{\sum_i e_i^2 \Delta q_i(x,Q^2)}{\sum_i e_i^2 q_i(x,Q^2)} \text{ (to first order)}$$

$$A_{\|,phys} = D(A_1 + \eta A_2)$$

$$A_1 = \frac{g_1 - \gamma^2 g_2}{F_1}, \qquad A_1 \approx \frac{g_1}{F_1}$$

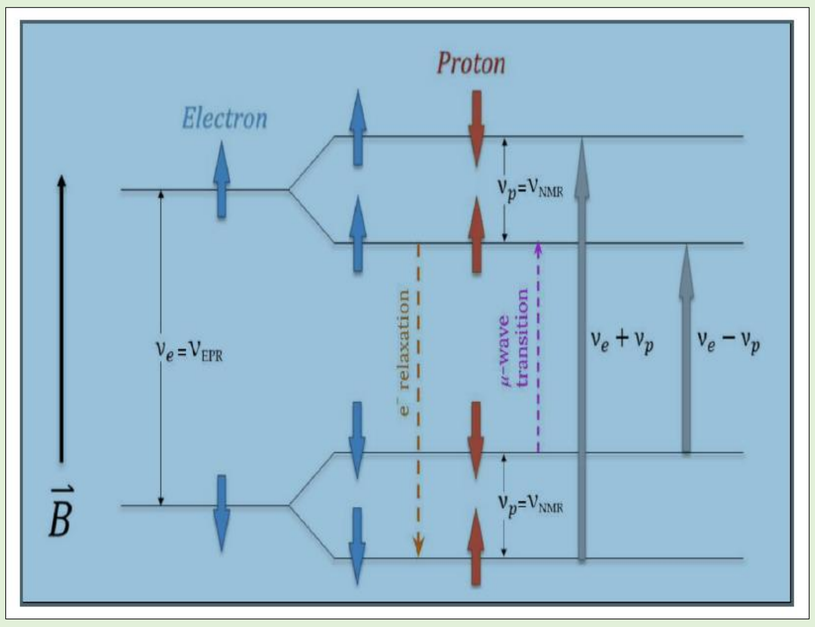
$$g_1(x) = \frac{1}{2}\sum_q e_q^2 \Delta q(x)$$

$$\boxed{A_{||,phys} = \frac{1}{f\, P_b P_t} \frac{n^{\downarrow\uparrow} - n^{\uparrow\uparrow}}{n^{\downarrow\uparrow} + n^{\uparrow\uparrow}}}$$

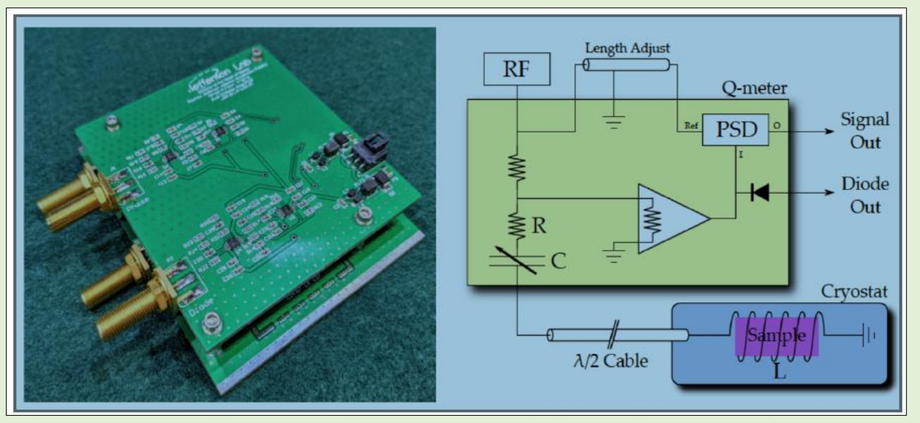
$\Delta q(x,Q^2)$ = polarized parton distribution function
$q(x,Q^2)$ = unpolarized parton distribution functions
e_i = quark charge **D** = depolarization factor
η= kinematic term **f** = dilution factor
$n^{\downarrow\uparrow}$ = Counts for negative helicity
$n^{\uparrow\uparrow}$ = Counts for positive helicity
$A_{||raw}$ = Measured raw longitudinal asymmetry
$A_{||\text{phys}}$ = Corrected physical asymmetry
A_1, A_2 = Virtual photon asymmetries
P_b = Beam Polarization P_t = Target Polarization

Dynamic Nuclear Polarization (DNP) Method

- **5T Super conducting magnet** provides a uniform field and splits energy levels
- **A cryogenic refrigerator** provides a stable temperature for the target material of 1K
- **Microwave system** transfers electron polarization to nucleons at 140 GHz
- **A target insert stick** carrying the target materials to microwave system
- **NMR system** continuously measures polarization to monitor target polarization during data collection

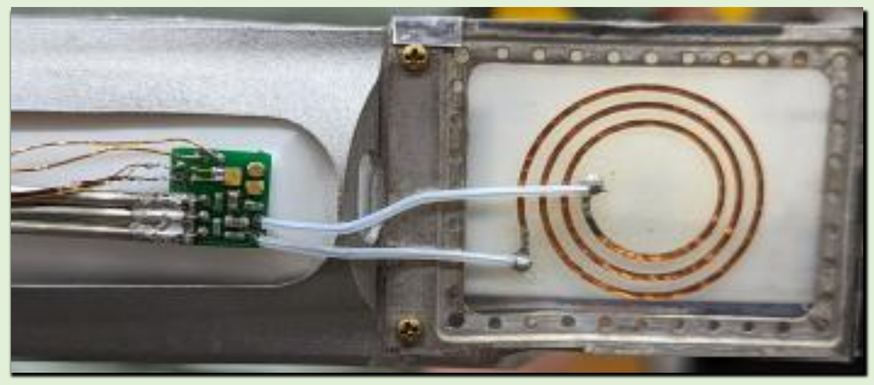


Continuous-wave Nuclear Magnetic Resonance (NMR)

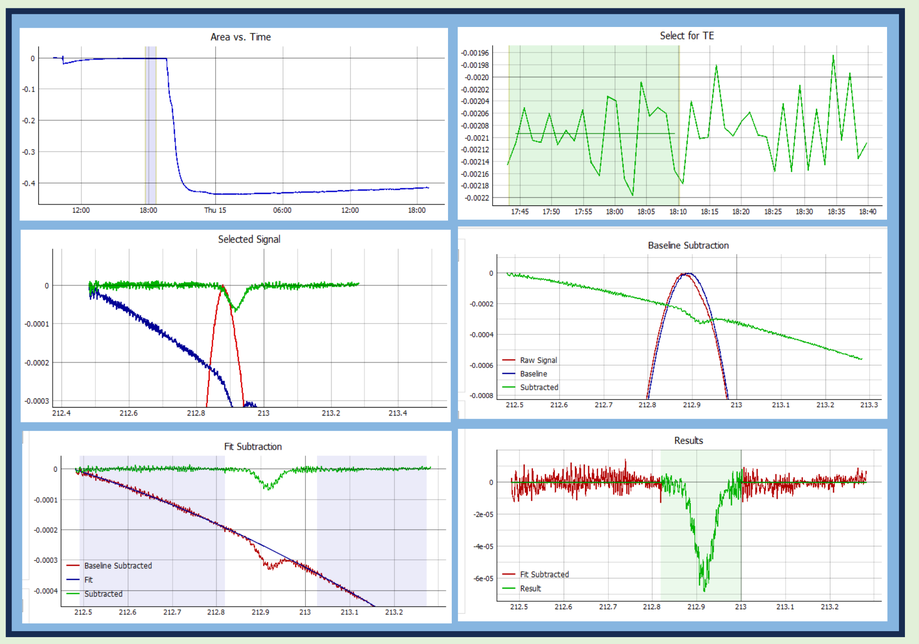


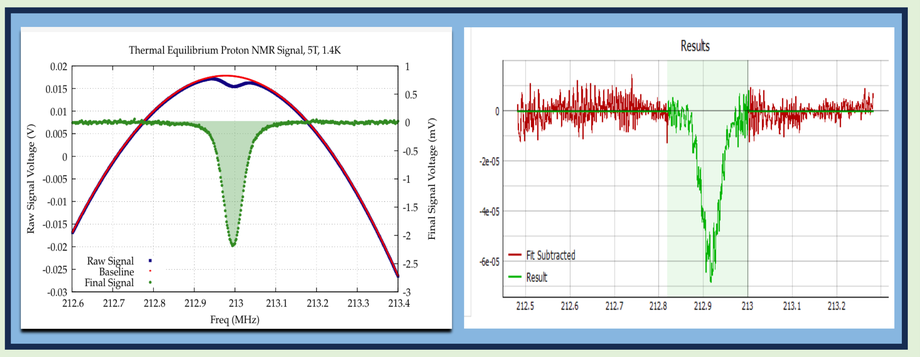
Left : A new Jefferson Lab Q meter, **Right:** Schematic diagram of Q-meter circuit with a phase-sensitive detector (PSD), RLC component, RF generator, and target material inside the inductor coil

Polarization Measurement Using NMR



Preliminary Results of NMR analysis of Proton





Top: Calibration tab's sub panels for Area verses Time Pannel, Select for "TE" signal, Selected signal Pannel, NMR Analysis showing three modular steps for base line subtraction, fit subtraction, results
Bottom: Raw signal of NMR at Thermal Equilibrium proton NMR signal at 5T, 1K Calibration Tab for ammonia comparing with results

References

- CLAS12 Diagram: "The CLAS12 software framework and event reconstruction", Ziegler et. al.
- CLAS Note: The NMR Polarization Data Analysis for Jefferson Lab Hall-B Run Group by CI. P. Fernando, P. Pandey, J. Maxwell, D. Seay, J. Roberts, D. Keller, C. Keith
- Sebastian Kuhn: "Solid Polarized Targets in particular for physics with CLAS 12 at Jefferson Lab"
- D.G.Crabb and W.Meyer: "Solid Polarized Targets for Nuclear and Particle physics Experiments"
- A New cw-NMR Q-meter for Dynamically Polarized Targets for Particle Physics J. Maxwell, J. Brook, Cuevas, H. Dong, C.D.Keth