Outline

- Overview of Topic
- CLAS Detector
- DNP process
- Collaboration
  - Target NMR measurements
  - Cooking
Spin of the Nucleon

- Protons and Neutrons are composed of quarks held together by gluons
- Spin $\frac{1}{2}$ particles
- Where does spin come from?
Spin Crisis

- Spin not accounted for by quarks alone
  - Contributions from valence quarks, sea quarks, gluons, angular momentum
- Only ~25% nucleon spin carried by quarks
- What are the contributions from each part?

\[ \frac{1}{2} = S_q + \Delta G + L_z \]
How do we investigate internal structure of a nucleon?

High energy beams resolve details of nucleon

Variables:
- $Q^2$: Square of 4-momentum transferred to target
- Bjorken $x$: Fraction of nucleon's momentum, in Breit frame, carried by struck quark
Deeply Virtual Compton Scattering

- Virtual photon comes from incoming electron
- Allows access to angular momentum inside nucleon
Jefferson Lab

- 6 GeV electron beam
- 3 experimental halls
- eg1-dvcs is a Hall B experiment
eg1-dvcs experiment has three parts
  - Part A: proton target, February 2009
  - Part B: proton target, April-May 2009
  - Part C: deuteron target, August-September 2009

I switched groups just in time for part C
Continuous Electron Beam Accelerator Facility
Provides 6 GeV electron beam
Longitudinally polarized
CLAS Detector

- Superconducting Torus
- Drift Chambers
- Cherenkov Counter
- Scintillation Counter
- Electromagnetic Calorimeter
Superconducting Torus

- Provides Azimuthal Magnetic Field
  - Charge discrimination, momentum resolution
- Allows for polarized target
- Divides CLAS into 6 sectors
Drift Chambers

- Multi-wire drift chambers
- Determines particle trajectory
- 3 regions, each divided into 2 superlayers
Cherenkov Counter

- Threshold type, to discriminate between charged pions and electrons
- Uses perfluorobutane ($\text{C}_4\text{F}_{10}$)
  - $n = 1.00153$
  - Momentum threshold = 2.5 GeV/c for pions, 9 MeV for electrons
Scintillation Counter

- Scintillator Paddles with photomultipliers
- Time of Flight measurement
  - Electrons travel at nearly the speed of light
  - Calculate start time of interaction
  - Calculate time for other particles from that
Electromagnetic Calorimeter

- Layers of lead and scintillator
  - Rotated to determine position
- Detect neutral particles
- Discriminate electrons and hadrons
  - Electrons create shower
  - Hadrons are minimum ionizing
Dynamic Nuclear Polarization

- Provides polarized target for scattering
- Works for proton or deuteron
  - Proton ~95% polarization
  - Deuteron ~50% polarization
- Multiple materials possible
  - NH$_3$ and ND$_3$ used for eg1-dvcs
Dynamic Nuclear Polarization

- Requires paramagnetic centers
  - Couple electron spin to nuclear spin
  - Produced by irradiation or chemical doping

- Thermal Equilibrium Polarization:
  - Electron: >99%
  - Proton: ~0.5%
Dynamic Nuclear Polarization

- Microwaves drive "forbidden" transitions

- Proton relaxation:
  - ~10 minutes

- Electron relaxation:
  - ~milliseconds
DNP on the Deuteron

- Same process for Deuteron except it's spin 1

- Spin 0 state limits maximum polarization

- Asymmetries give rise to peak shifts
Polarized Target
Polarized Target
- Nuclear Magnetic Resonance setup used to measure polarization of sample
- Q-meter uses series-LRC resonance to detect small signal
  - Baseline must be subtracted to obtain signal
Target NMR

- Thermal Equilibrium measurement relates area of curve to polarization
- Determined from magnetic field and temperature
Polarization also determined from ratio of two components

Lineshape is fit to signal, asymmetry parameter determines polarization
Collaboration

- Prohibitive amount of work required for solo completion of full experiment
- Calibrations divided between members
- Multiple physics topics come from each data set
## Collaborators

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<th>Calibration</th>
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<td>Electromagnetic Calorimeter</td>
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<td>Cooking</td>
<td>E. Seder and N. Kvaltine</td>
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</table>
- Run Numbers: 60242 – 60648
- Approx. 15,000 files
  - Pass 0 finished
- ~1000 failed files
- Switched to 64-bit executable at run 60503
Target NMR Calibration

- 80,000 scans from Run Period
- Subtract Baseline and fit polynomial
- Use Chris Dulya's lineshape fitting program
- Get polarization from ratio of two components
Target NMR

- Compare all runs to Online Polarization

- Next Step: Compare with offline area method
Conclusion

- Shed light on angular momentum distribution of nucleon
- Have assigned responsibilities among collaborators
- Calibration proceeding
- When calibrated, cook files again
- Begin physics analysis