Møller Polarimetry Measurements

Hall C Collaboration Meeting
January 28th, 2020
Bill Henry (Jefferson Lab)

Møller Polarimetry Basics

- **Møller scattering is exactly calculable in QED.**
- **At 90 deg in the CM frame the analyzing power is large. The measured asymmetry is ~5%.**
- **In the lab frame the scattering angle is ~0.5 deg at 10.4 GeV.**

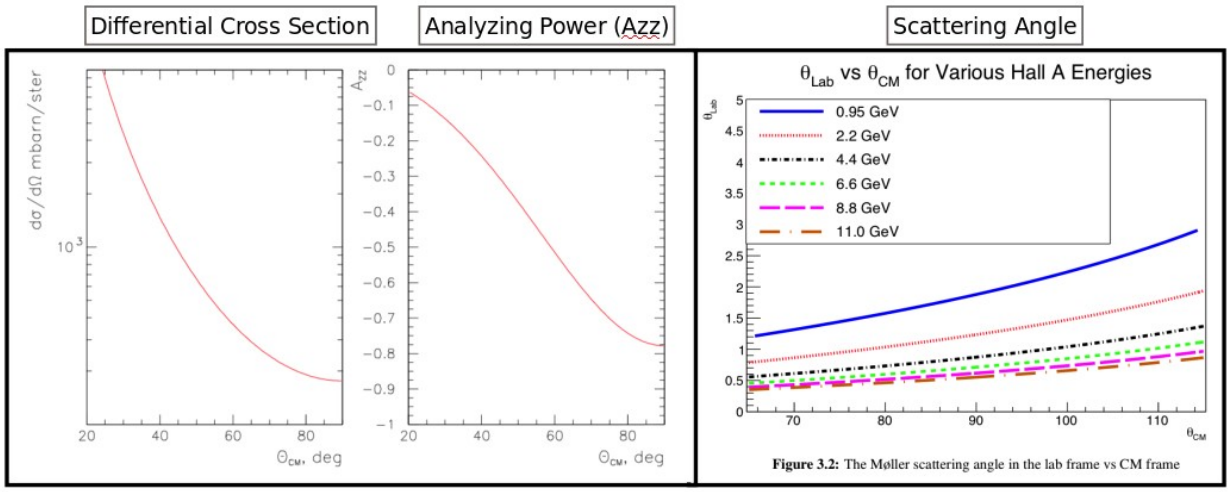


Figure 3.2: The Møller scattering angle in the lab frame vs CM frame

Beam Polarization

Measured Asymmetry

$$\mathcal{P}_z^{beam} = \frac{A_{beam}}{\mathcal{P}^{Foil}\langle A_{zz}\rangle}$$

Target Polarization from **Theory**

Average analyzing power from **Simulation**

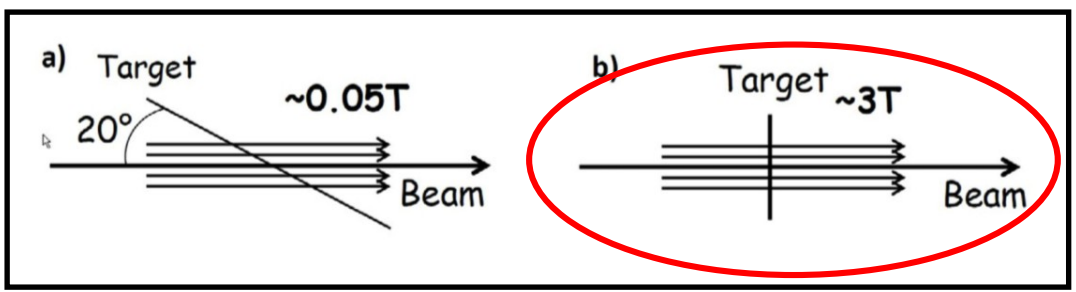
Large at 90°CM = -7/9

$$\mathcal{A}_{beam} = \frac{N_{\uparrow\uparrow} - N_{\uparrow\downarrow}}{N_{\uparrow\uparrow} + N_{\uparrow\downarrow}} = \mathcal{A}_{zz}(\theta_{CM})\mathcal{P}_z^{Beam}\mathcal{P}^{Foil}$$

$$\mathcal{A}_{zz}(\theta_{CM}) = \frac{-\sin^2\theta_{CM}(8 - \sin^2\theta_{CM})}{(4 - \sin^2\theta_{CM})^2}$$

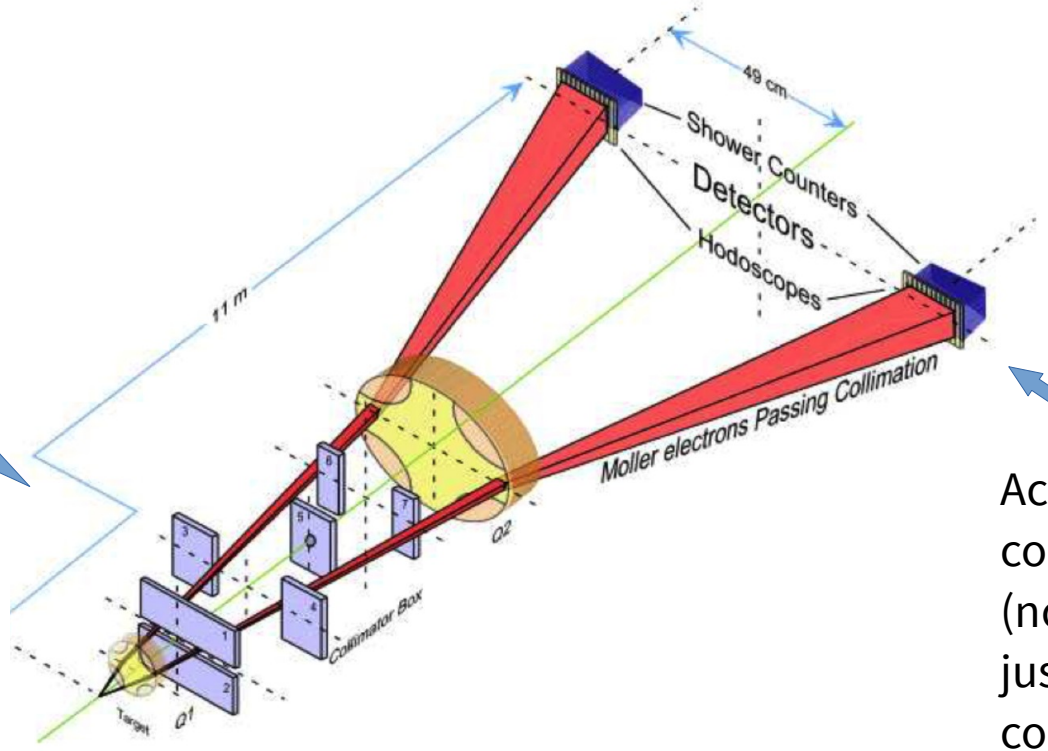
Møller Polarimeter Apparatus

- Fe target polarized out of plane (Brute force)
- Target polarization is often the largest systematic error
- Target polarization 8.014% +/- 0.022%
- ΔP/P ~ 0.30% with beam heating



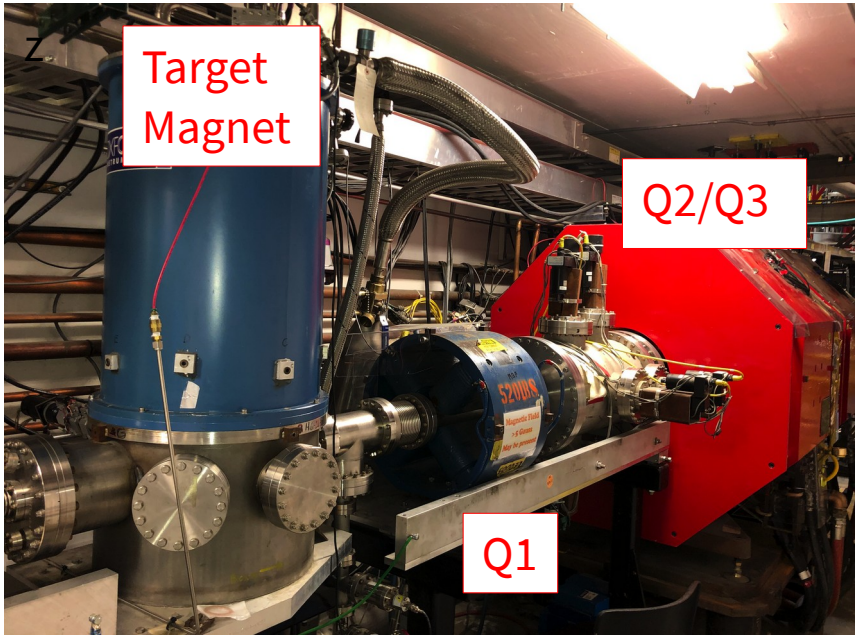
Møller Polarimeter Apparatus

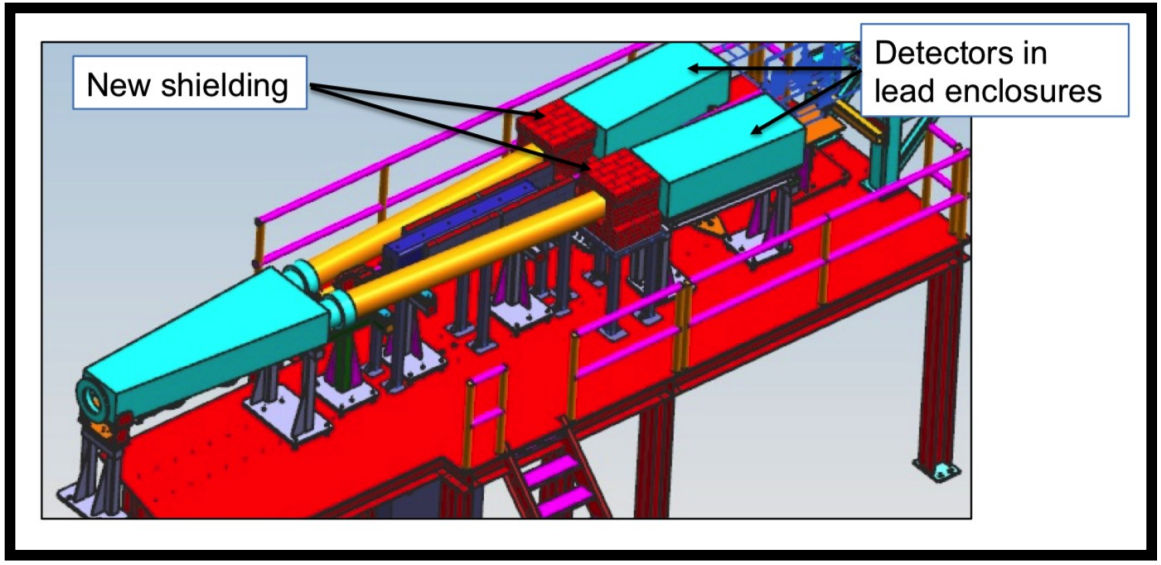
Collimators to reduce accidental backgrounds



Acceptance defining collimators (not shown). Located just before shower counters

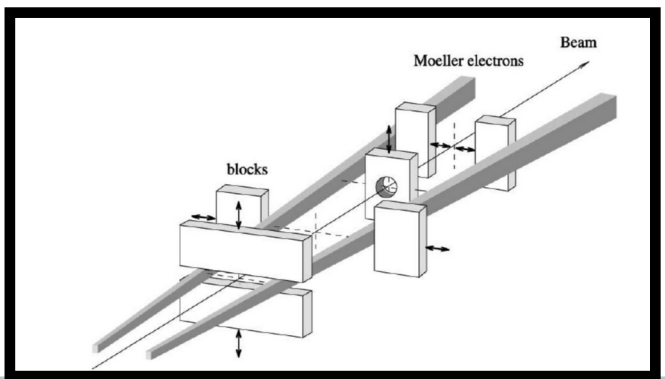
Møller Polarimeter Apparatus

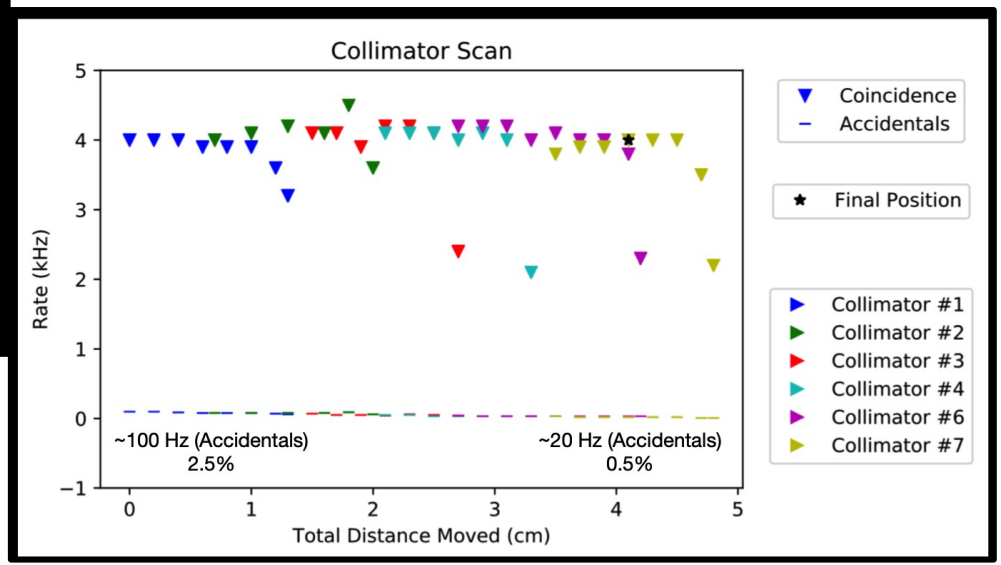




Møller Procedure: Collimator Scan

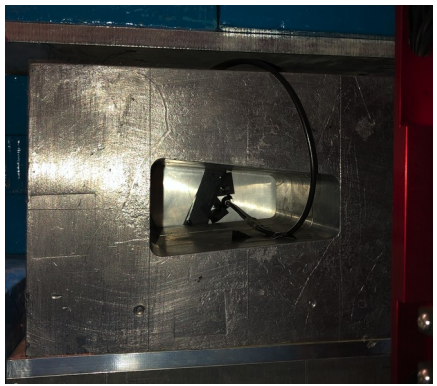
- Movable collimators are tuned for each beam energy
- First area of collimation in Møller polarimeter
- Used to reduce singles rates and accidental coincidences but not real Møller coincidences.
- Modified slightly as part of 12 GeV upgrade



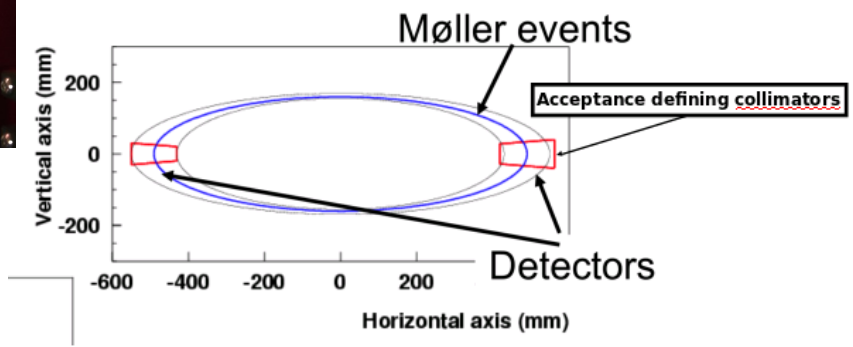


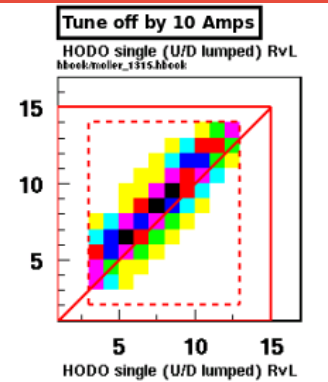
Møller Measurement Procedure: Tune checks

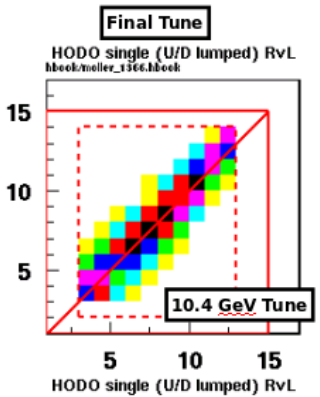
Collimator
(1 of 2)



- Simulation is used to determine initial quadrupole settings
- Special runs are taken to check the tune
- Q2/Q3 are adjusted to get an acceptable tune
- Tune is checked for each Møller measurement







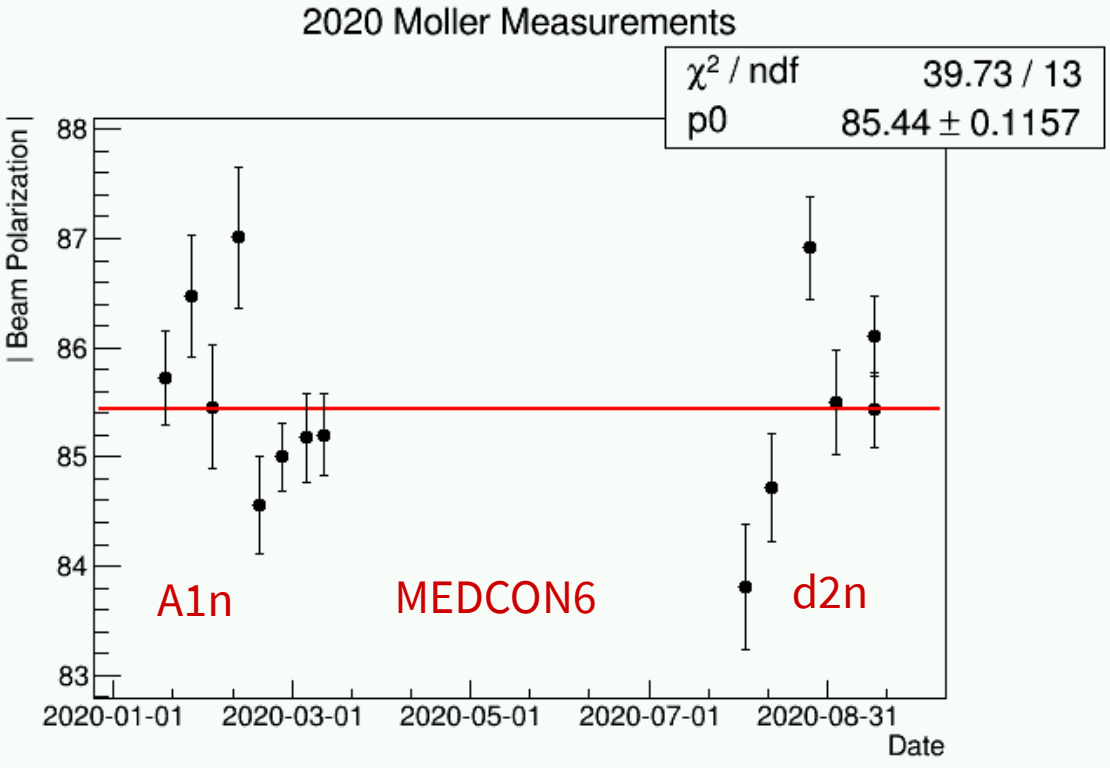
Hodoscope
(1 of 2)

Møller Measurement Procedure: Bleed thru

- Bleed thru from the other Halls proved to be challenging during measurements. (HV trips when moving collimators, high rates when beam was off in C, coincidence rates with target retracted etc).
- Special procedures were added to deal with and measure the bleed thru.
- Since we had to share our slit with Hall D, closing it was not an option. In the future running with our own dedicated slit is highly recommended.
- The bleed thru was measured, treated as a dilution and corrected online. Corrections ranged from 0.0 % to 1.0 %.

2020 Beam Polarization Measurements

- **The team: Dave Gaskell, Bill Henry, and Murchhana Roy**
- **14 Møller Measurements taken during PolHe3 experiments.**
- **Each measurement took 4 – 14 hours**
  - Beamline setup and establish orbit (MCC)
  - Bleed thru measurements (Mostly Hall A)
  - Detector Tune checks
  - Polarization measurements
  - IHWP flip when possible
- **Beam Energy: 10.4 GeV**
- **First time Møller was exercised during 12 GeV era.**
- **Often coincided with He3 target spin up**



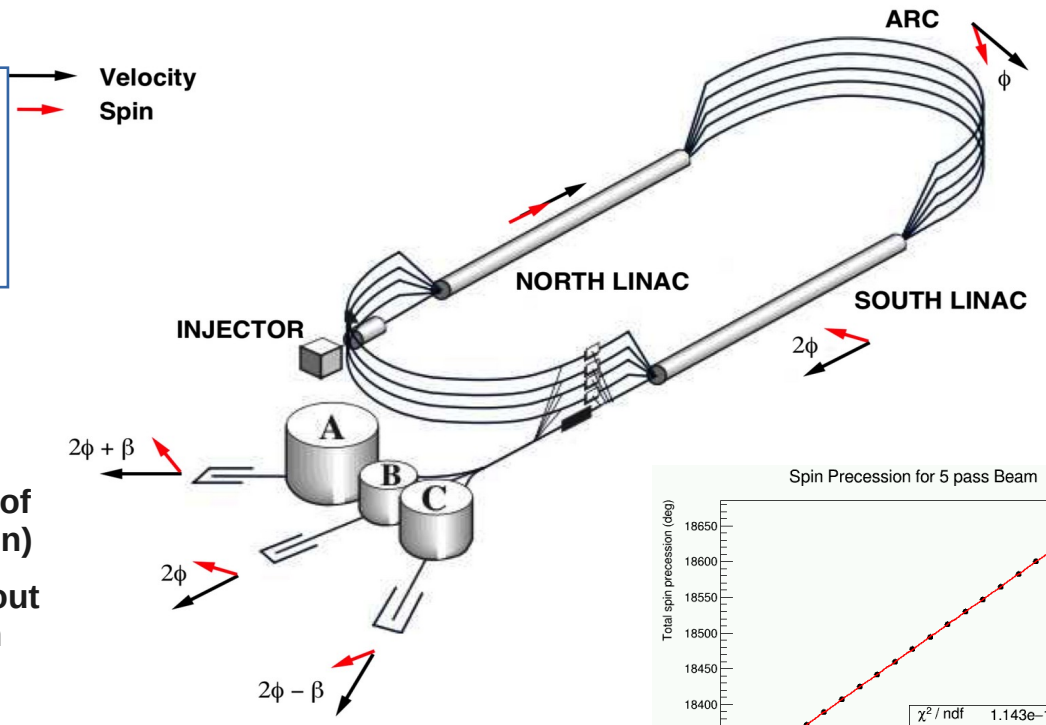
What's a spin dance?

SPIN PRECESSION

In general, the spin precession, $\Delta\phi$, of an electron of fixed energy as it bends through a series of dipole magnets is given by:

$$\Delta\phi = \frac{E}{440.65\text{MeV}} \times \Delta\theta \qquad (1)$$

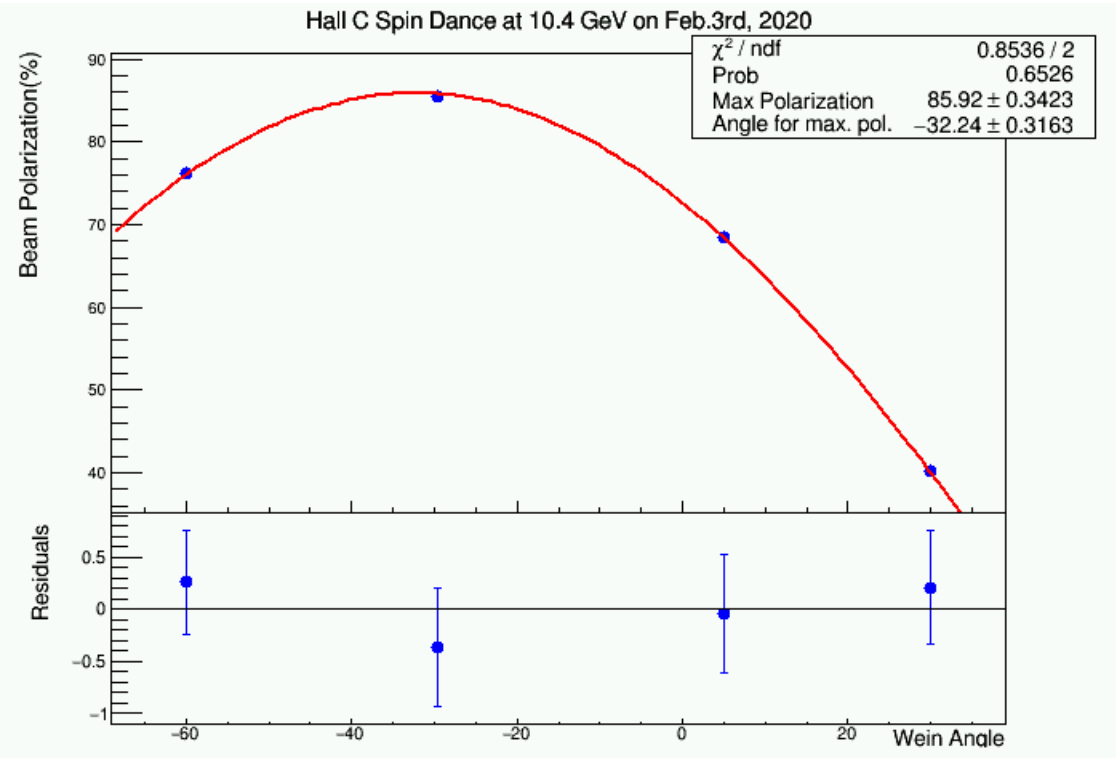
https://arxiv.org/pdf/0901.4484.pdf



- **At 10.4 GeV, the electron's spin precesses over 18,000 degrees before reaching hall C !!**
- **A 1 MeV increase in beam energy equals 1.75 degrees of additional precession (neglecting synchrotron radiation)**
- **By varying the Wien angle at the injector we can map out the polarization dependence and find the optimal Wien setting.**

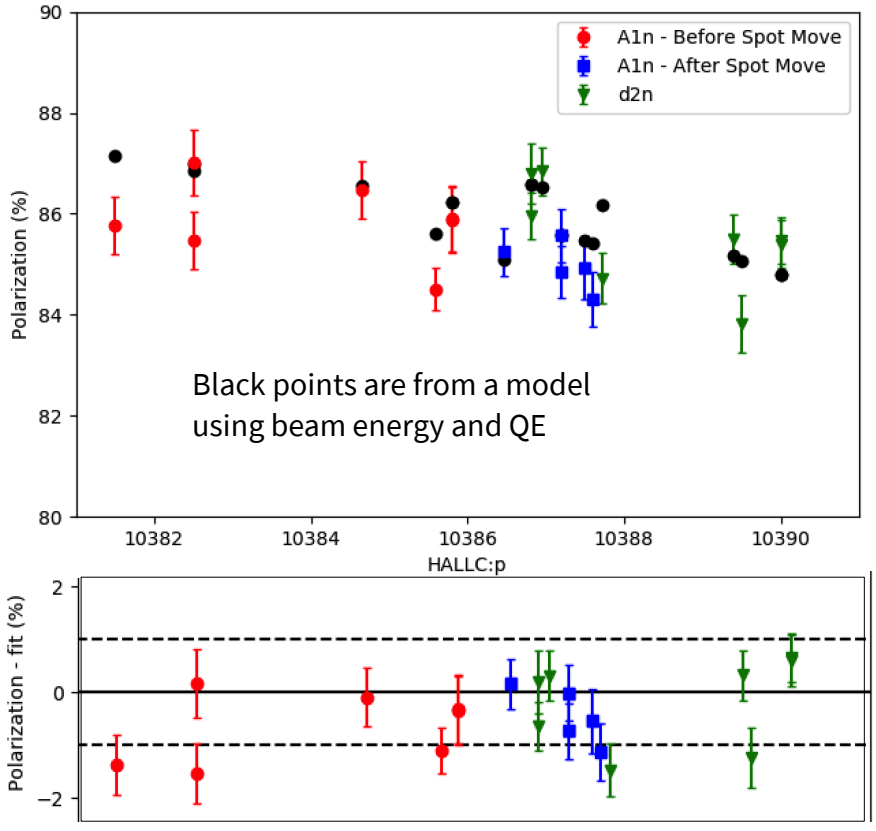
Hall C Spin Dance

- Polarization measurements were taken at four different Wien angles.
- Hall C ran at ~2.6 degrees from the optimal setting. The Wien angle was maximized for Hall A.
- Results show maximum possible polarization was 85.9% +/- 0.3%.
- The Wien angle was maximized for Hall A. Their spin dance was performed Jan. 7th found max. polarization of 86.2 % +/- 0.1 %. (online result)
- There is still a mystery that our relative optimal Wien angle seems to be inconsistent with the Hall A result. One explanation could be a 3° offset in the Wien filter.



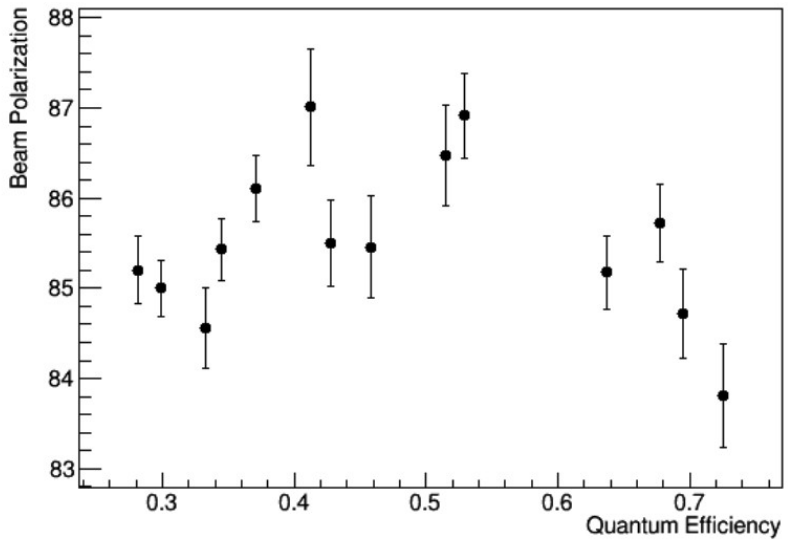
Beam Polarization vs Beam Energy

- Even though we were near the optimal Wien angle, small changes in beam energy were noticeable.
- Given the linac and injector energies this dependence can be modeled.
- The linac and injector energies were not as stable during d2n as they were during A1n



Changes at the source that effect beam polarization

- Spot moves/size, cathode heating and reactivation, and changes in quantum efficiency can all effect beam polarization
- Here I plot the QE vs the 2020 Møller measurements. The red line is the “known” QE dependence from past studies.
- Todo: Since the beam energies for all the points were not equal this plot should be done again by precessing each measurement back to the injector



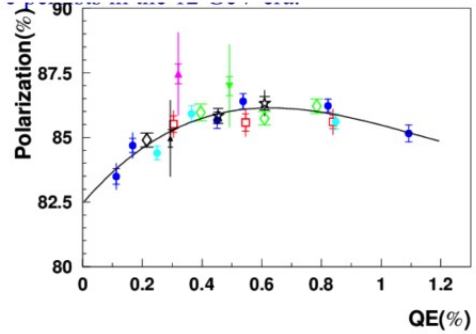
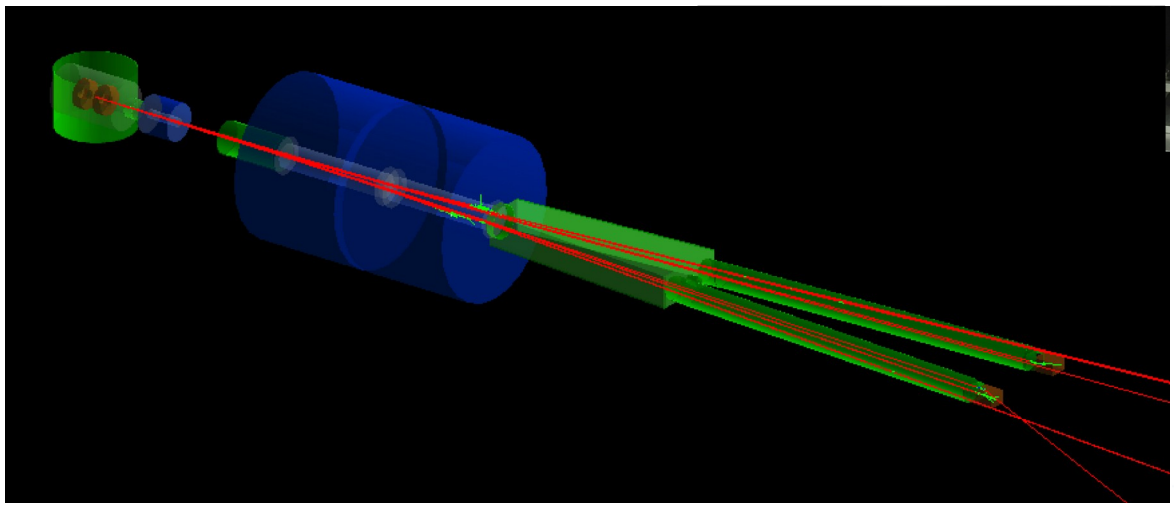


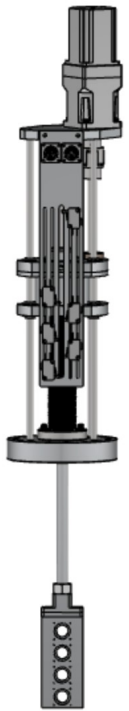
Fig. 2: Moller data from the GEp and GEp-2gamma experiments at several bam energies

https://hallcweb.jlab.org/wiki/images/4/44/3He_ERR_Reply_to_Final_Report-updated-08July2019v2.pdf

Future Upgrades to the Hall C Møller

- New Magnet and target motion system will be installed to match the Hall A system
- Geant4 simulation exists but needs further development. (New Levchuk model?)

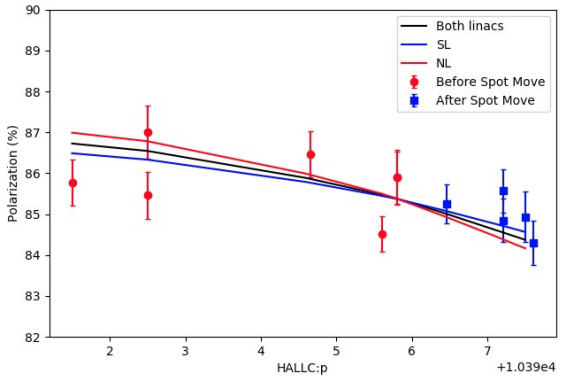


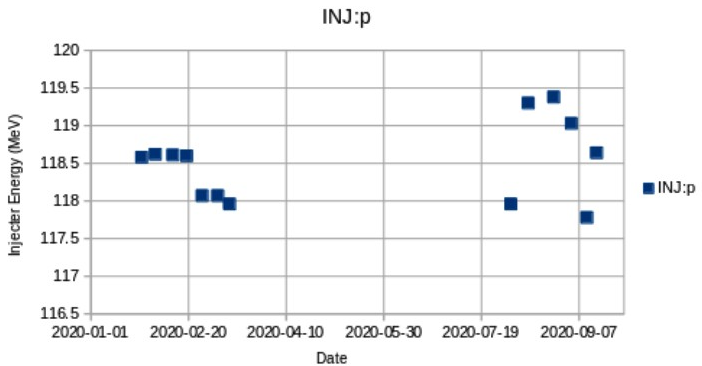


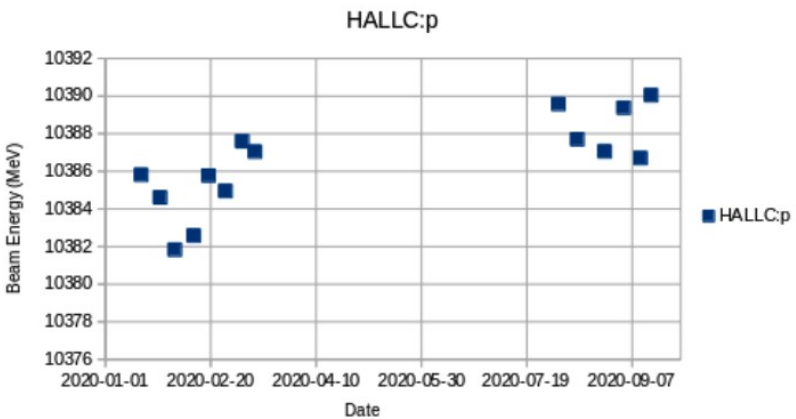
Summary

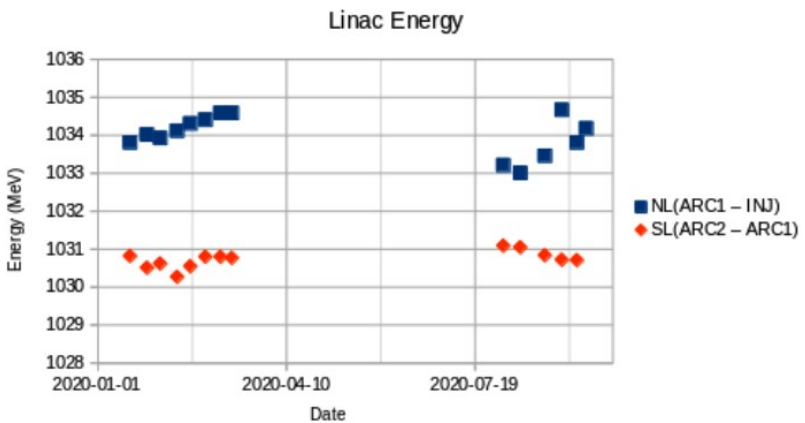
- The Møller polarimeter successfully provided beam polarization measurements for the polarized He3 experiments.
- Providing the required 2.0 % – 3.0 % precision should be relatively straightforward.
- To-do list ：
  - Check collimator scan data vs simulation
  - Check analyzing power with simulation using the measured beam positions
  - Explain the QE and energy dependence.
  - Document measurements, runlists, etc. In progress (wiki is here)
  - Reanalyze bleed thru runs and finalize corrections
- Provide the collaboration with a polarization function which will provide the beam polarization given the beam energies (and possibly the QE?)

BACKUP


Both linacs
SL
NL
Before Spot Move
After Spot Move
Polarization (%)
HALLC:p
+1.039e4


INJ:p
Injecter Energy (MeV)
INJ:p
Date


HALLC:p
Beam Energy (MeV)
HALLC:p
Date


Linac Energy
Energy (MeV)
NL(ARC1 – INJ)
SL(ARC2 – ARC1)
Date