# Hall A Moller Polarimeter: Overview and Recent Polarization Measurements

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Jefferson Lab

PSTP 2019

# Outline

- Brief overview of the Hall A Moller polarimeter at JLab

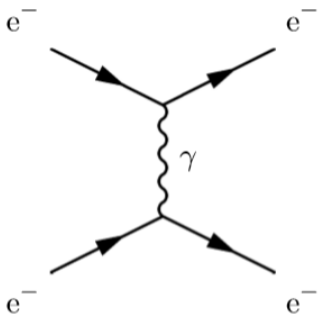
  → spectrometer
  → target magnet
  → targets
  → detectors

- Very preliminary recent measurements (Summer 2019) of the beam polarization in Hall A

# Measurement of Beam Polarization via Moller Scattering

- Elastic scattering of polarized beam electrons off polarized Fe target atomic electrons

$$\left(\frac{d\sigma}{d\Omega}\right)_{zz} = [1 + P_b^z P_t^z A_{zz}(\theta_{CM})] \frac{d\sigma_0}{d\Omega} \qquad \frac{d\sigma_0}{d\Omega} = \left[\frac{\alpha(4 - \sin^2\theta_{CM})}{2m_e\gamma \sin^2\theta_{CM}}\right]^2$$



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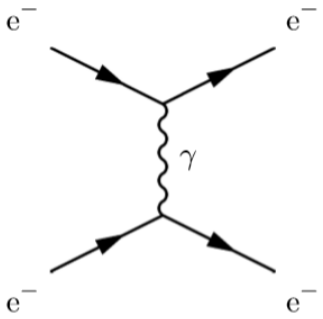
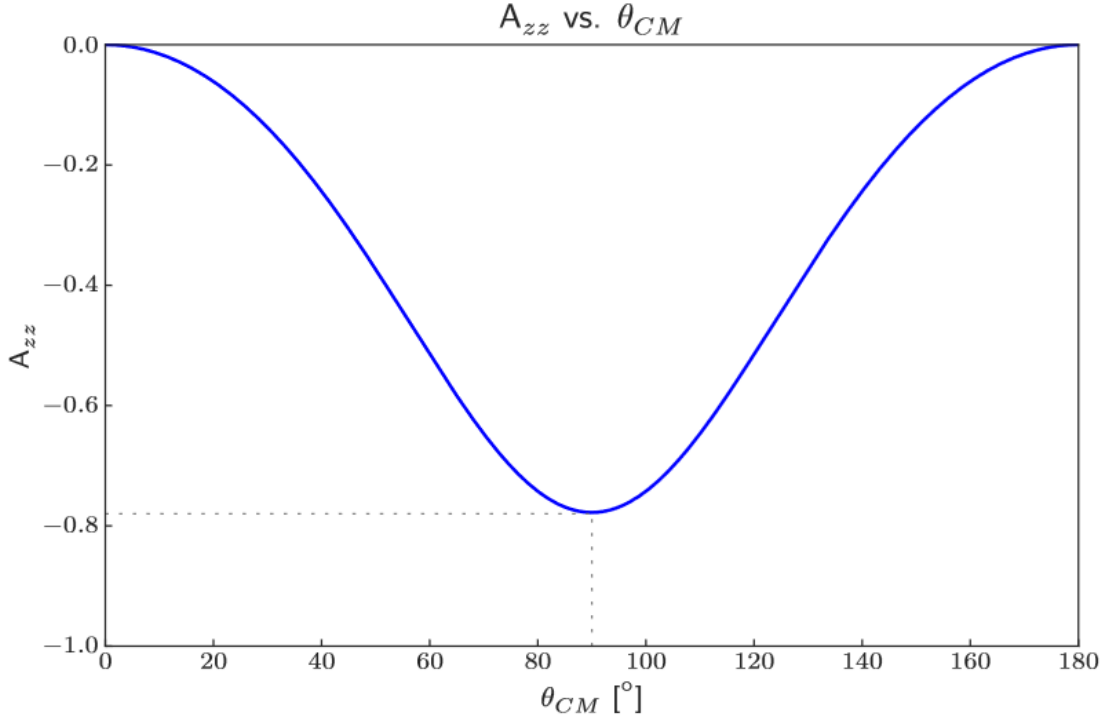



$$A_{zz}(\theta_{CM}) = \frac{-\sin^2\theta_{CM}(8 - \sin^2\theta_{CM})}{(4 - \sin^2\theta_{CM})^2}$$

- Maximum analyzing power: -7/9 at 90 deg CM scattering angle
- Slowly varying around the peak



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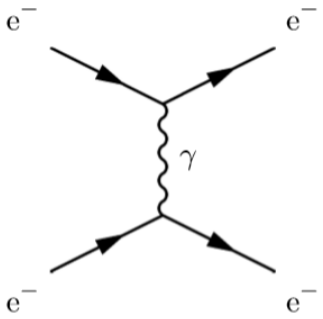


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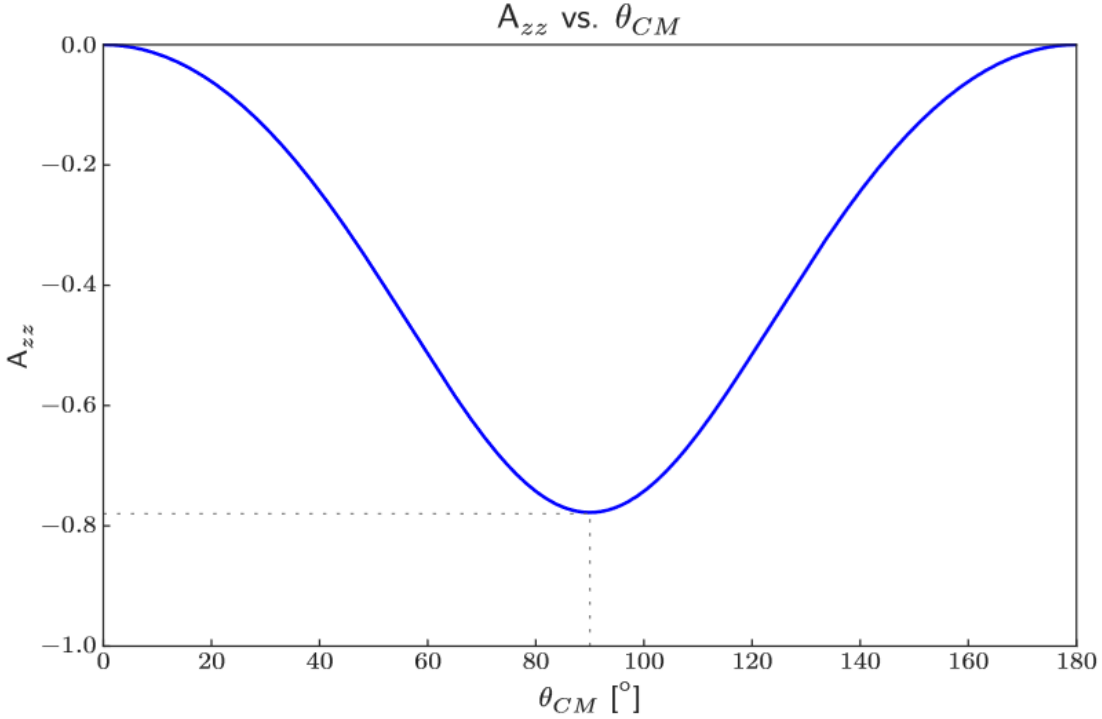


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$$\text{Asymmetry} = \frac{\sigma_{\uparrow\Uparrow} - \sigma_{\downarrow\Uparrow}}{\sigma_{\uparrow\Uparrow} + \sigma_{\downarrow\Uparrow}} = P_b^z P_t^z A_{zz}$$

spin of beam electron

spin of target electron

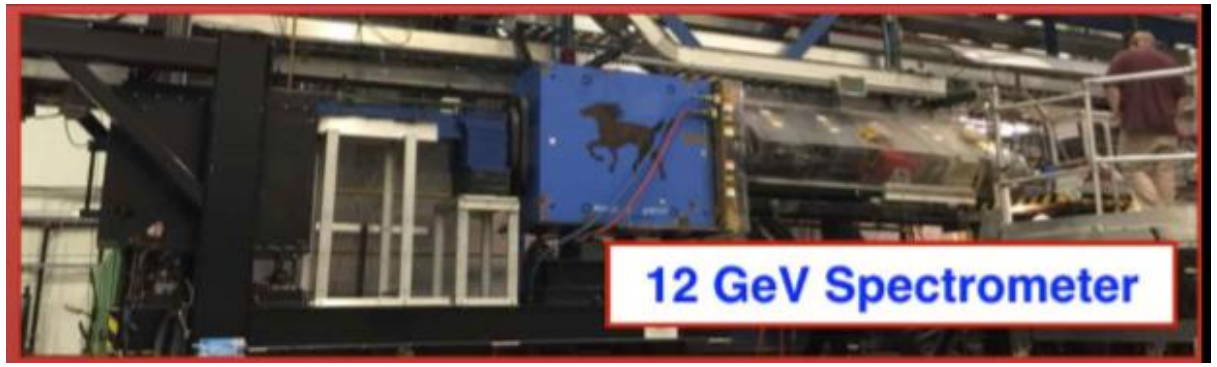
# Measurement of Beam Polarization via Hall A Moller Polarimeter

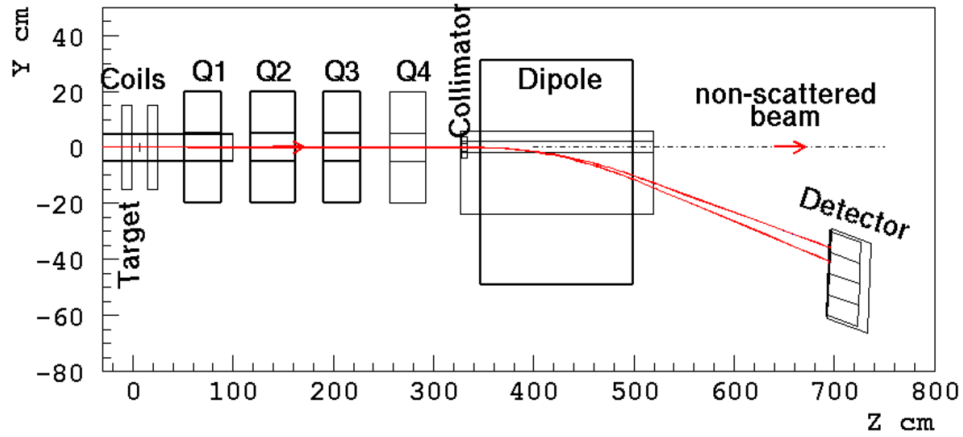
$$A_{beam} = A_{zz}\, P_{Fe\ foil}\, P_{beam}$$

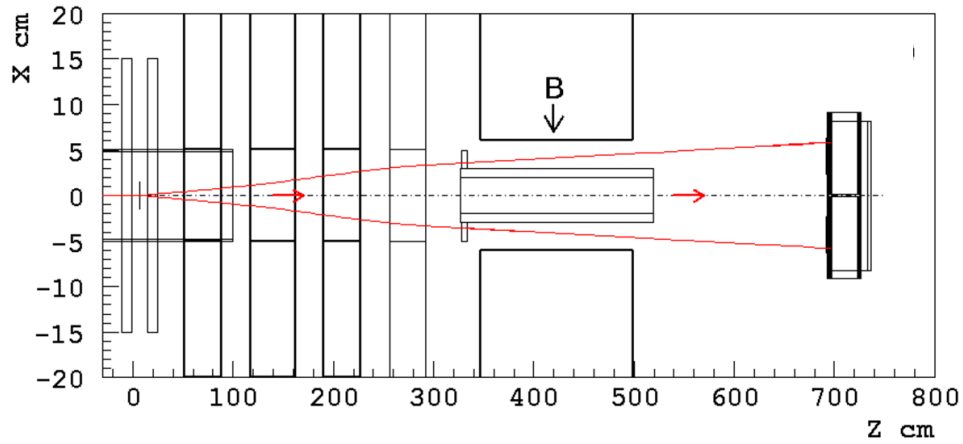
- $A_{beam}$: measured
- $A_{zz}$: from simulation
- $P_{Fe\ foil}$: from theory assuming saturation
- $P_{beam}$: extracted

- Need to know/understand:

- Target polarization: achieve saturation
- Moller spectrometer acceptance: magnet field maps, apertures, precise location of detector
- Simulation: Levchuk and radiative effects



# Hall A Moller Polarimeter: Target Magnet

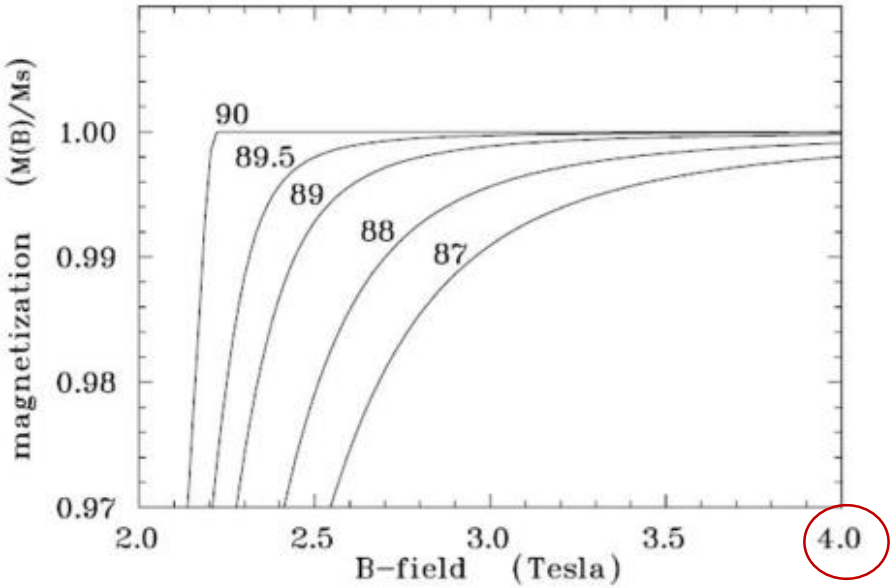
- Split coil, superconducting magnet from American Magnetics saturates the Fe foils we use as targets

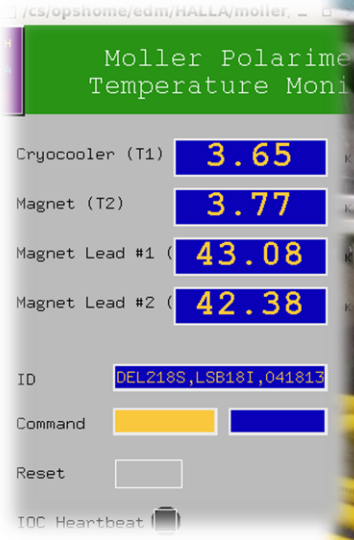
  - Conduction cooled by a pulse tube cryogenic refrigerator

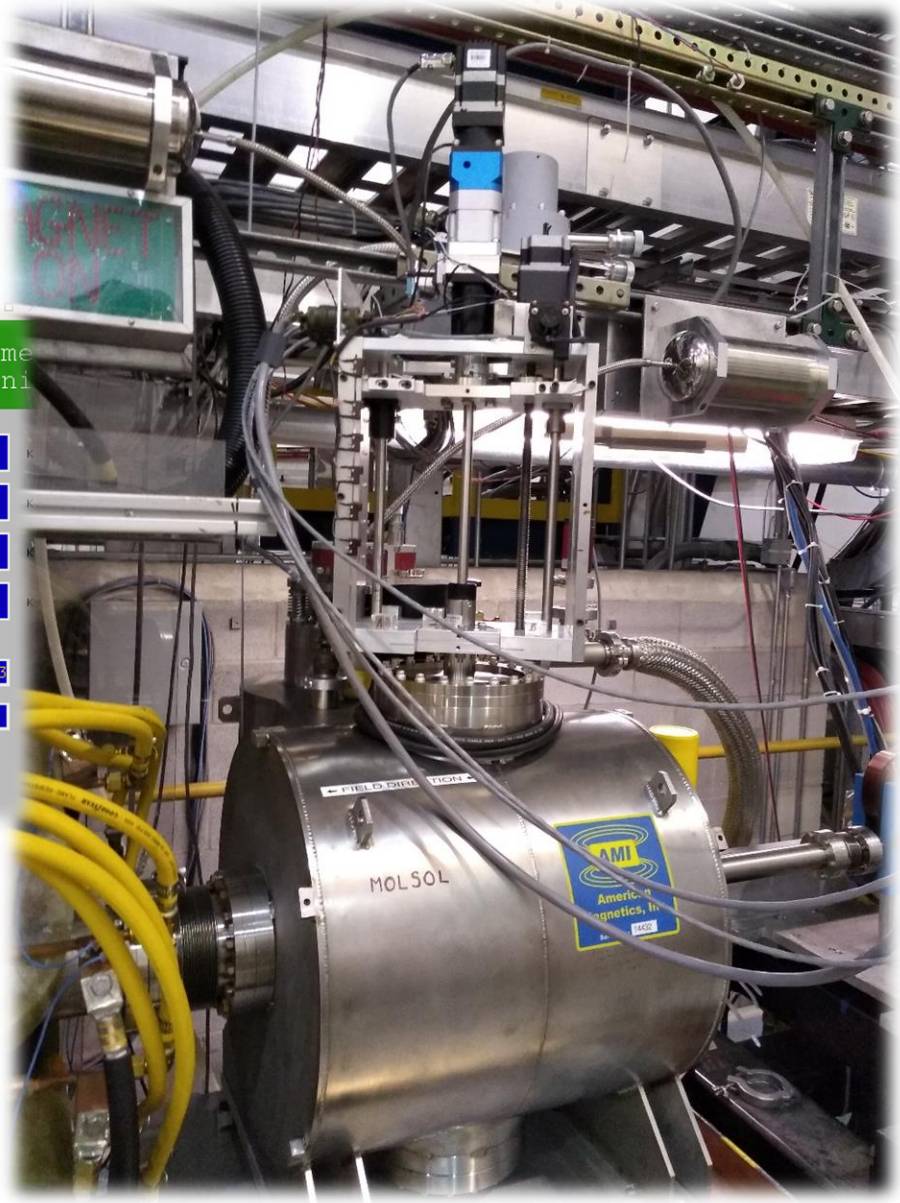
    Ramp rates:

    → from 0 to 70 A: 0.0254 A/s
    → from 70 to 80 A: 0.0213 A/s

    The field to current ratio is: 0.0536 T/A

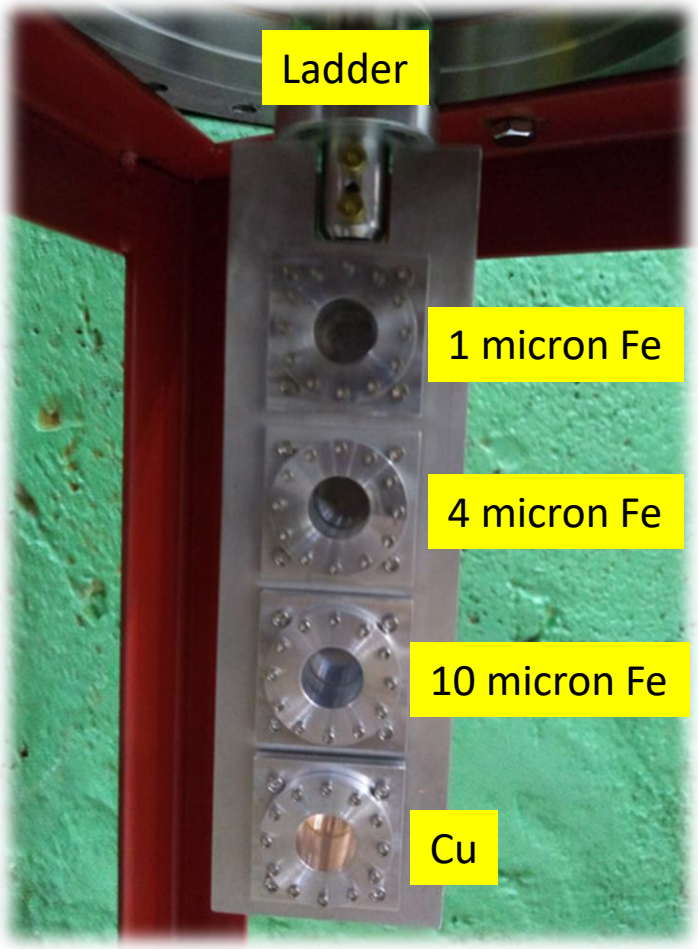


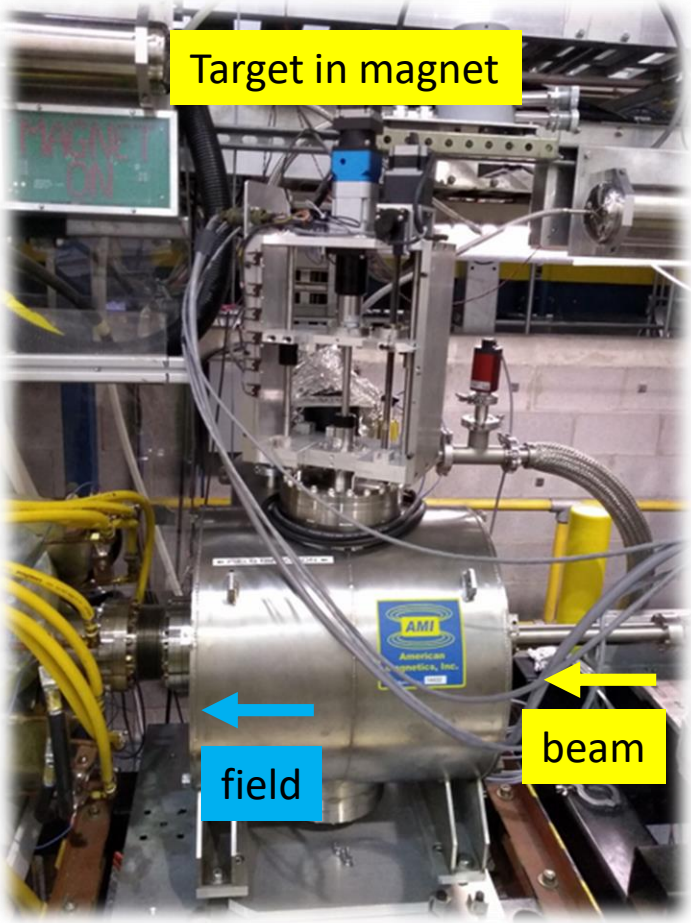



# Hall A Moller Polarimeter: Target

- Target ladder with 4 foils: 1, 4 and 10 micron Fe foils (1 micron is 99.85 % purity while the other are 99.99%) and one Cu foil for null asymmetry checks

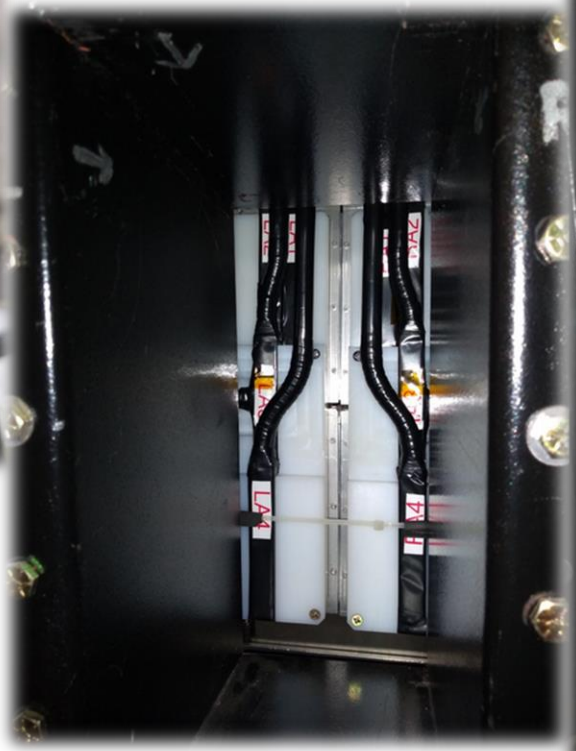


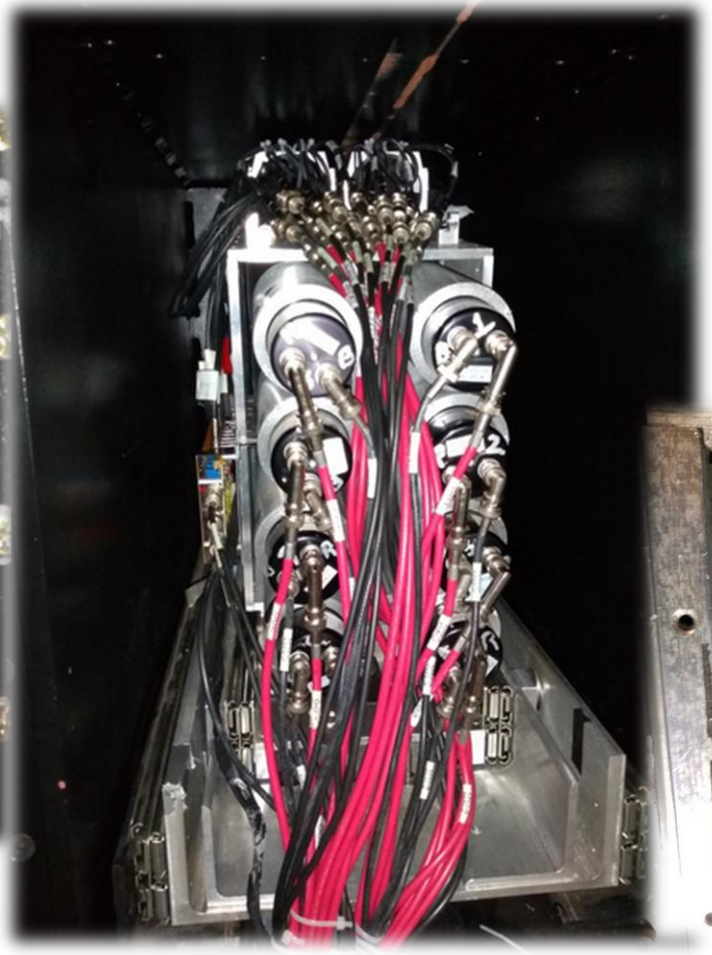


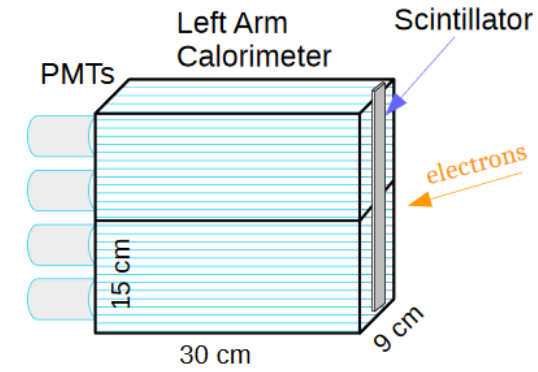


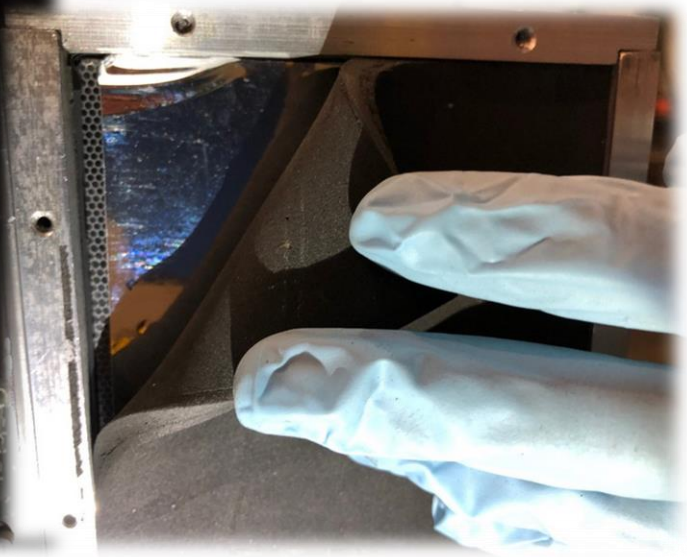
# Hall A Moller Polarimeter: Detectors

- Scintillators: 4 paddles per side connected via light guides to Hamamatsu 1 inch PMTs (Hamamatsu R4124)
- Calorimeter: lead+scintillating fiber, 2 bocks per side each block connected to two 2 inch PMTs (Photonis XP2282B)

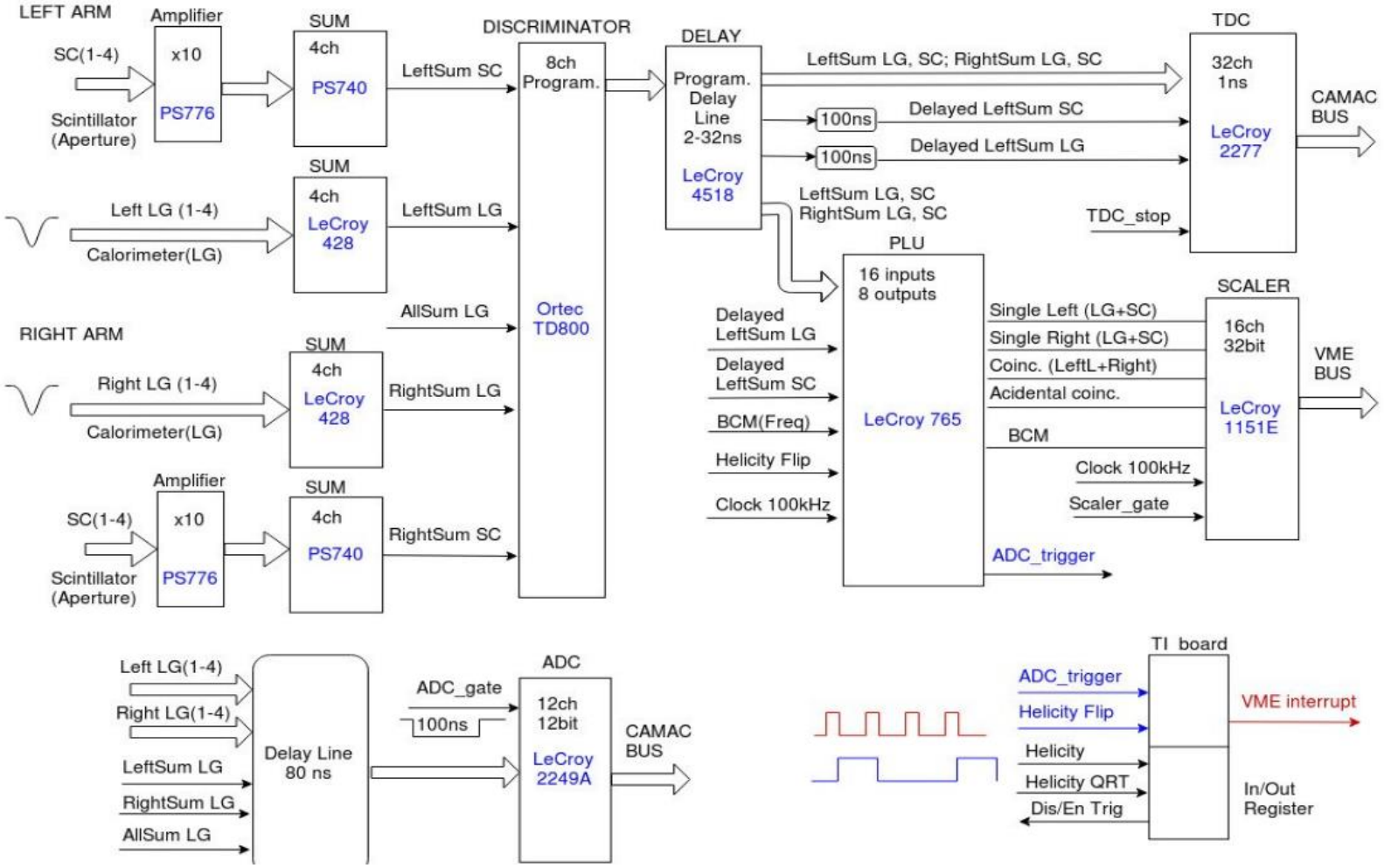






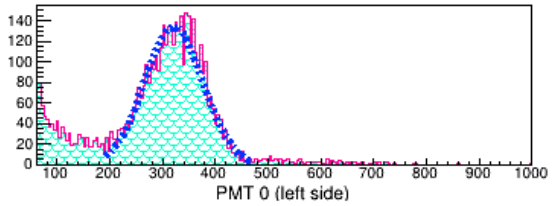
# Hall A Moller Polarimeter: Trigger and DAQ

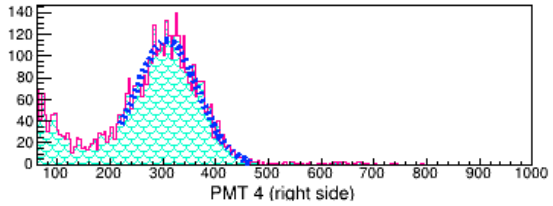


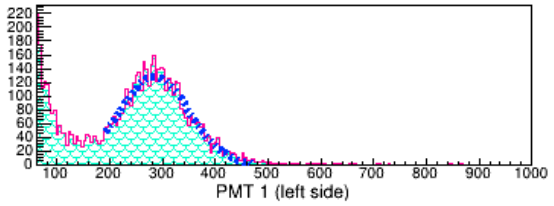

- Calorimeter signals per side are summed
- The sums are discriminated
- A coincidence between the discriminated sums is formed
- A scaler counts the coincidences between left and right calorimeter sums per helicity window
- Accidental coincidences are measured by delaying the left side sum
- ADC and TDC data are acquired as well

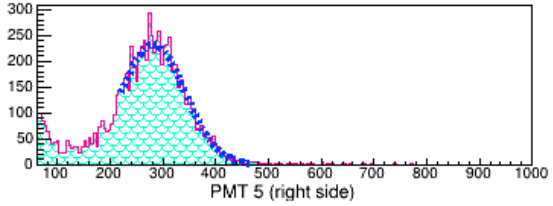
# Hall A Moller Polarimeter: Calorimeter ADC Spectra

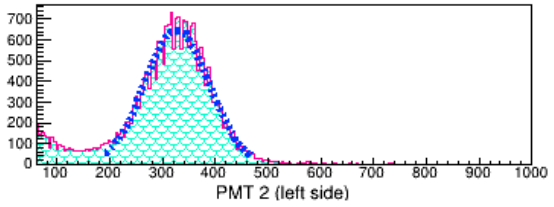
- Helps with adjusting PMTs HVs for gain matching and with visualizing the effect of the discriminator thresholds on the calorimeter Left and Right sums

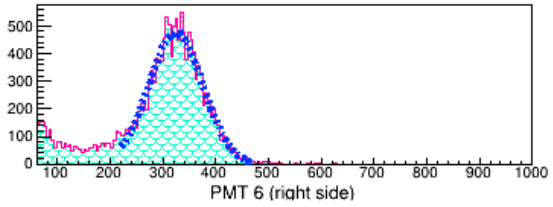


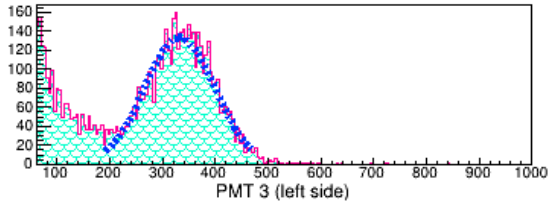



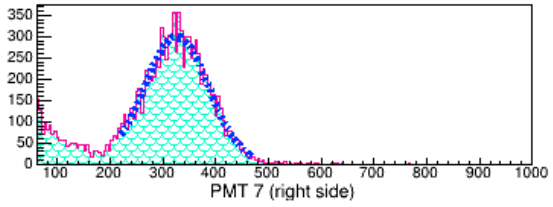



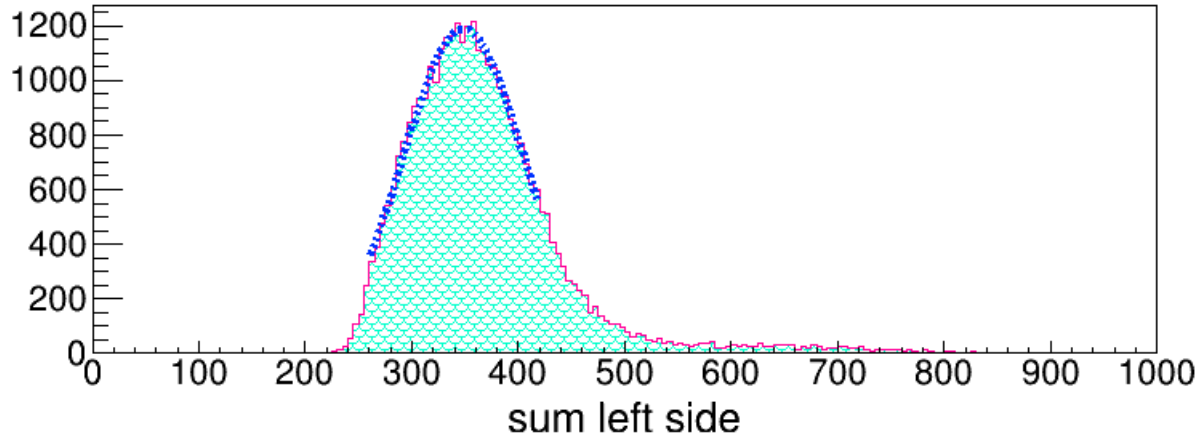



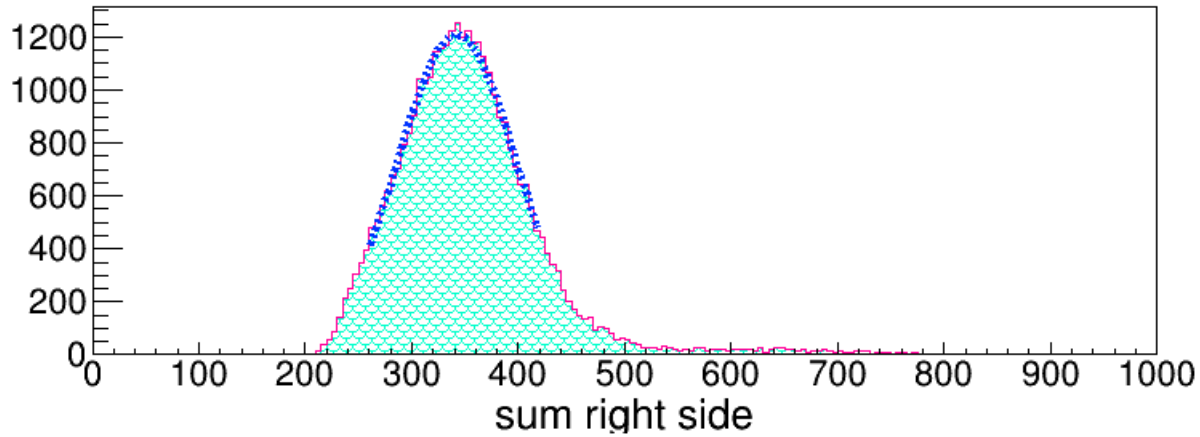



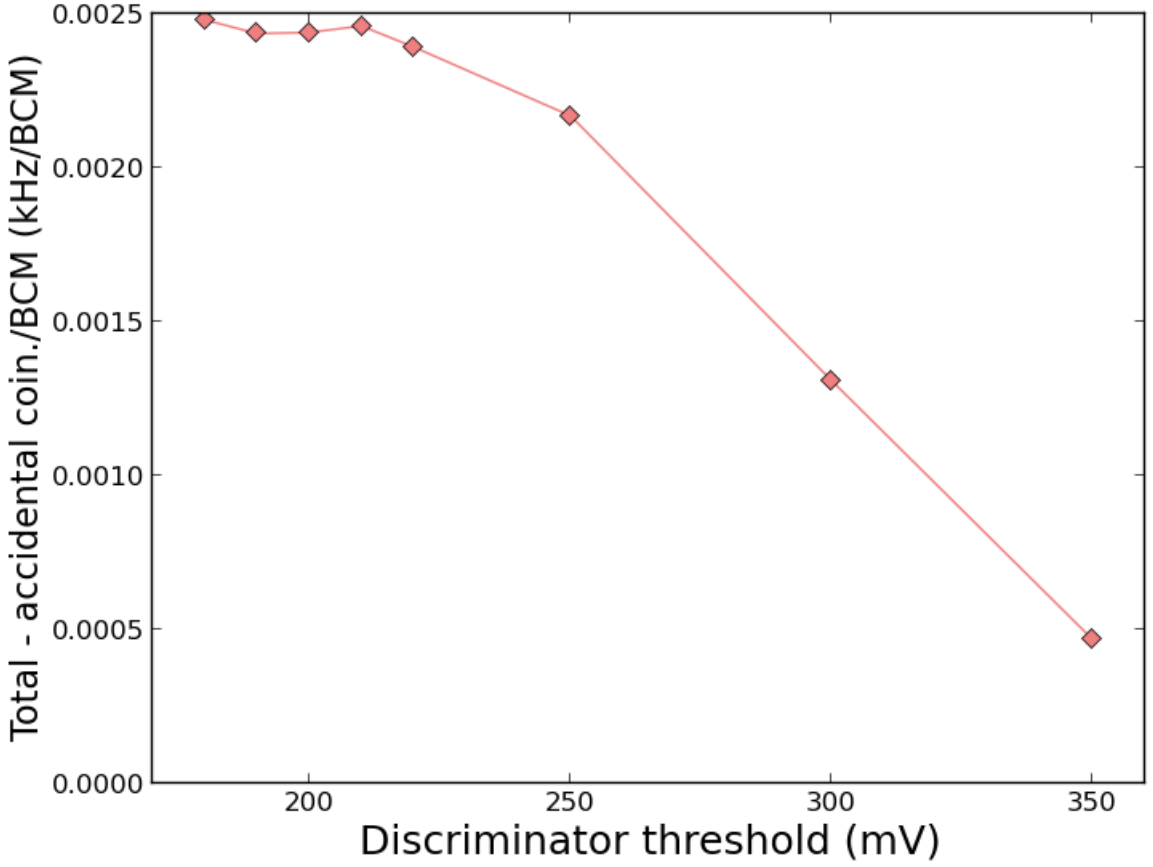



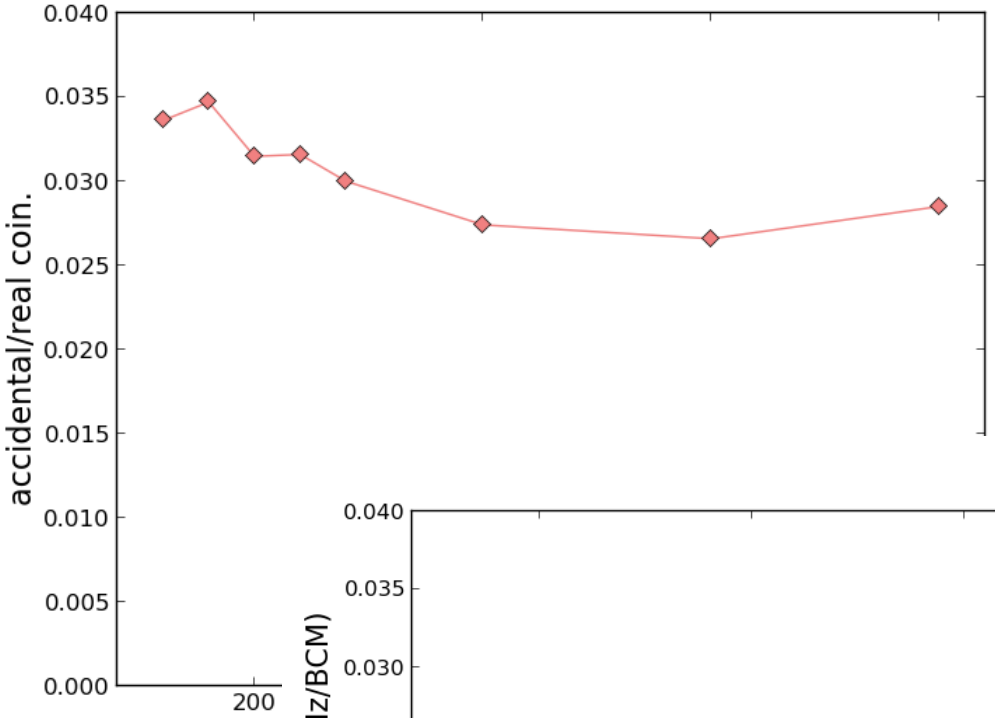



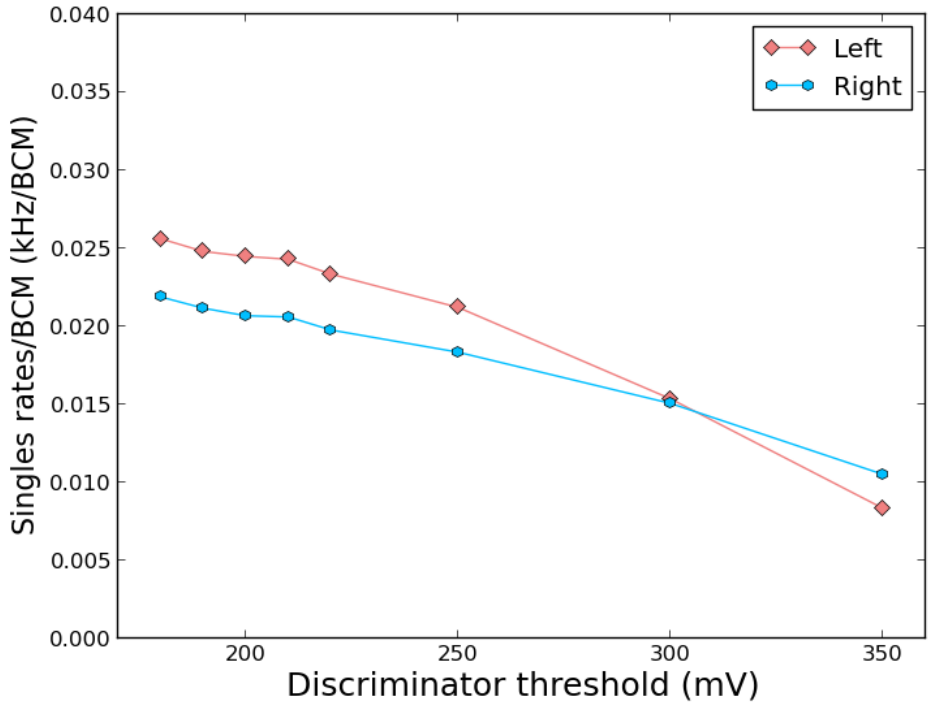



# Hall A Moller Polarimeter: Setting Discriminator Thresholds

- A scan of discriminator thresholds on left and right calorimeter sums is performed and scaler rates are monitored to select the optimal threshold



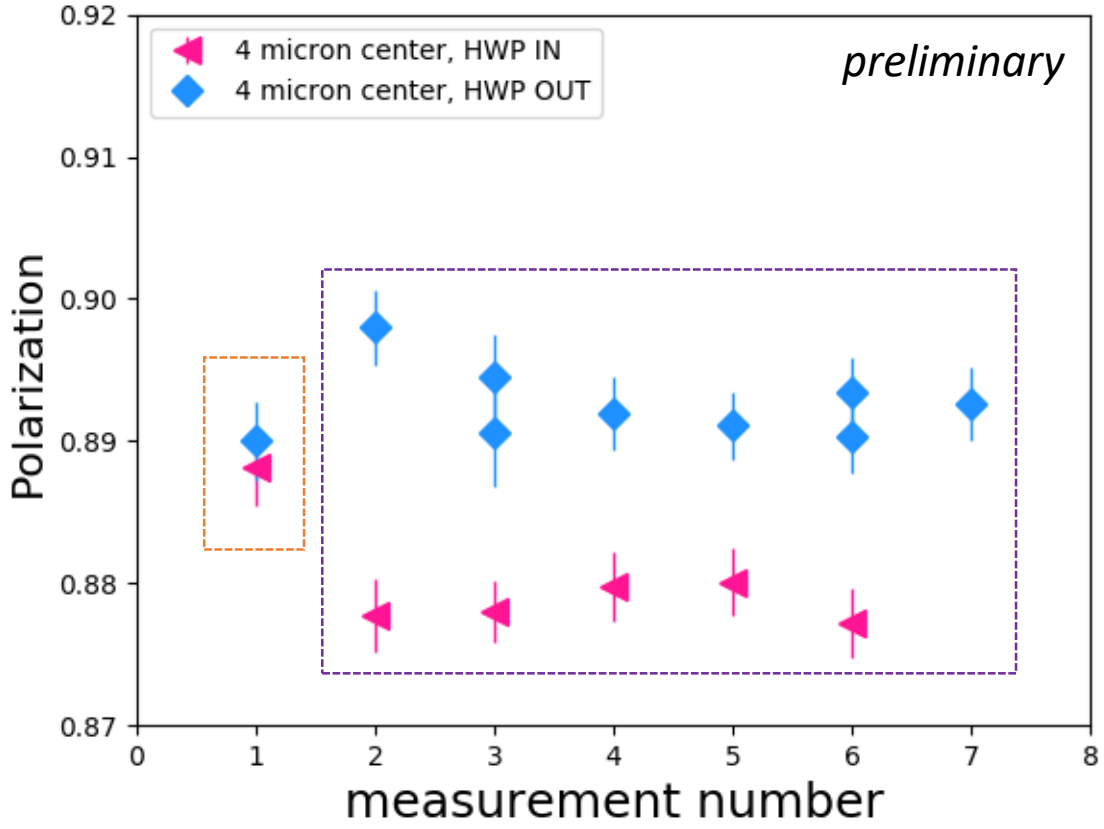



# Summer 2019: Polarization Measurements on 4 micron Fe Foil

- **2 PMTs** optics solution (see next talk by Eric King): simulation showed that limiting the acceptance to 2 out of 8 PMTs will ensure a small and almost constant Levchuk correction

*Uncertainties shown are statistical only*

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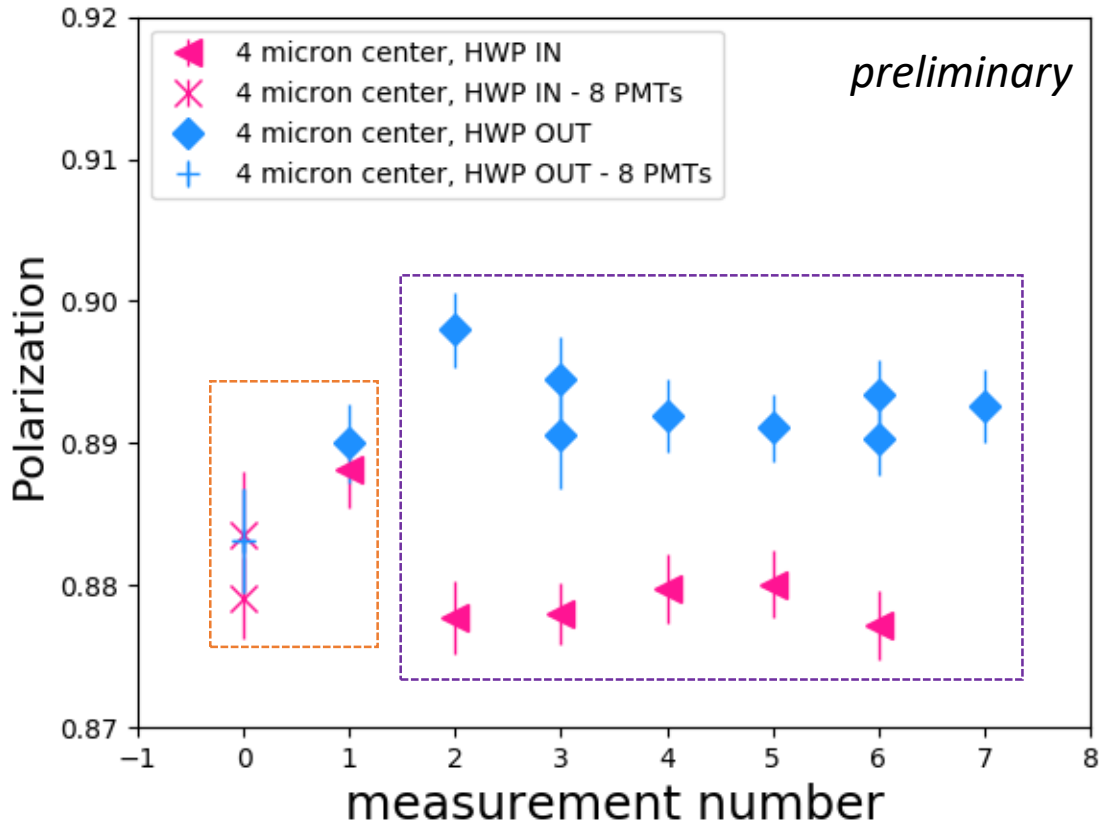


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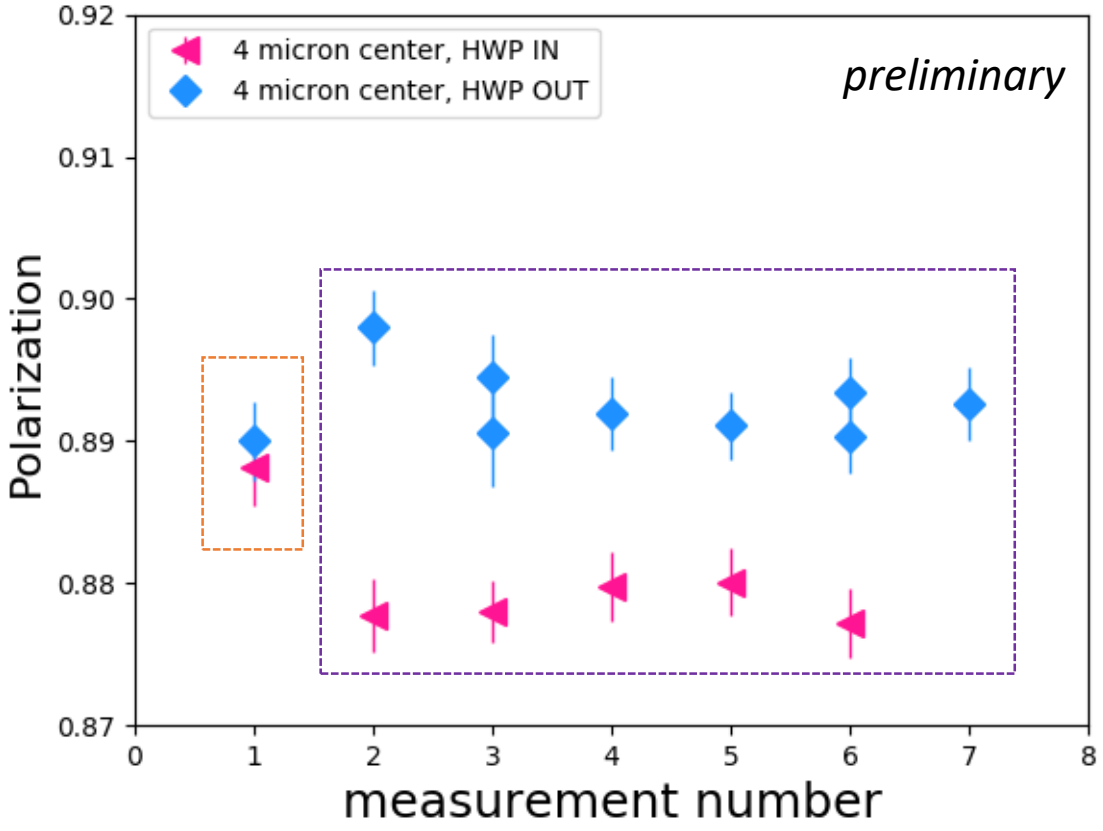
# Summer 2019: Polarization Measurements on 4 micron Fe Foil

- Difference in beam polarization between IN and OUT HWP plate states

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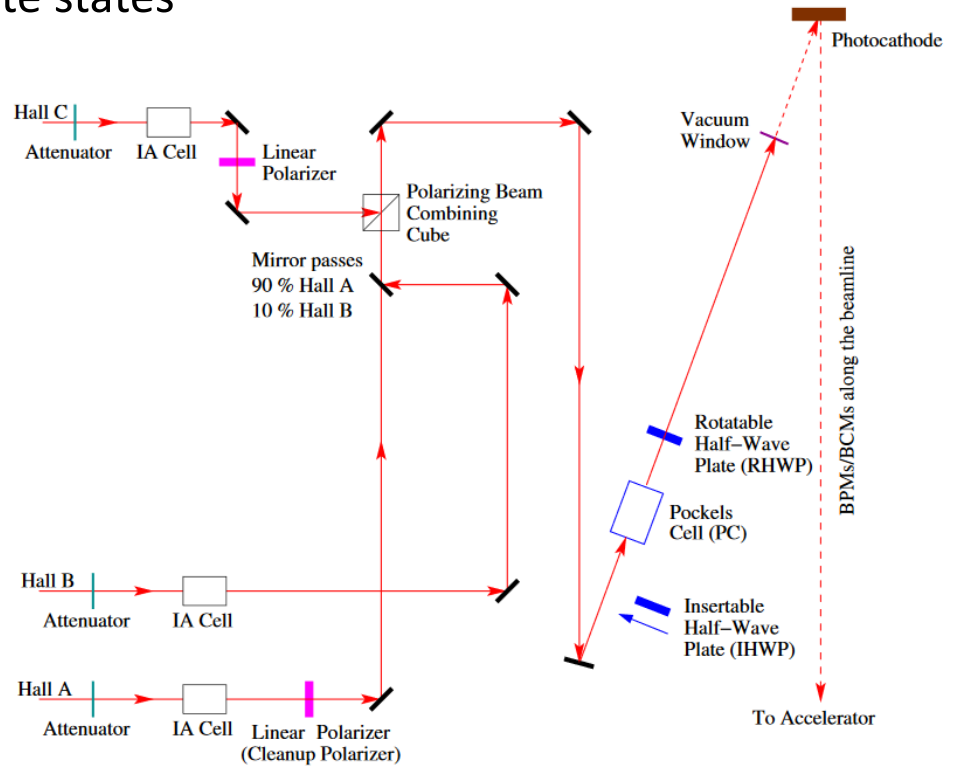
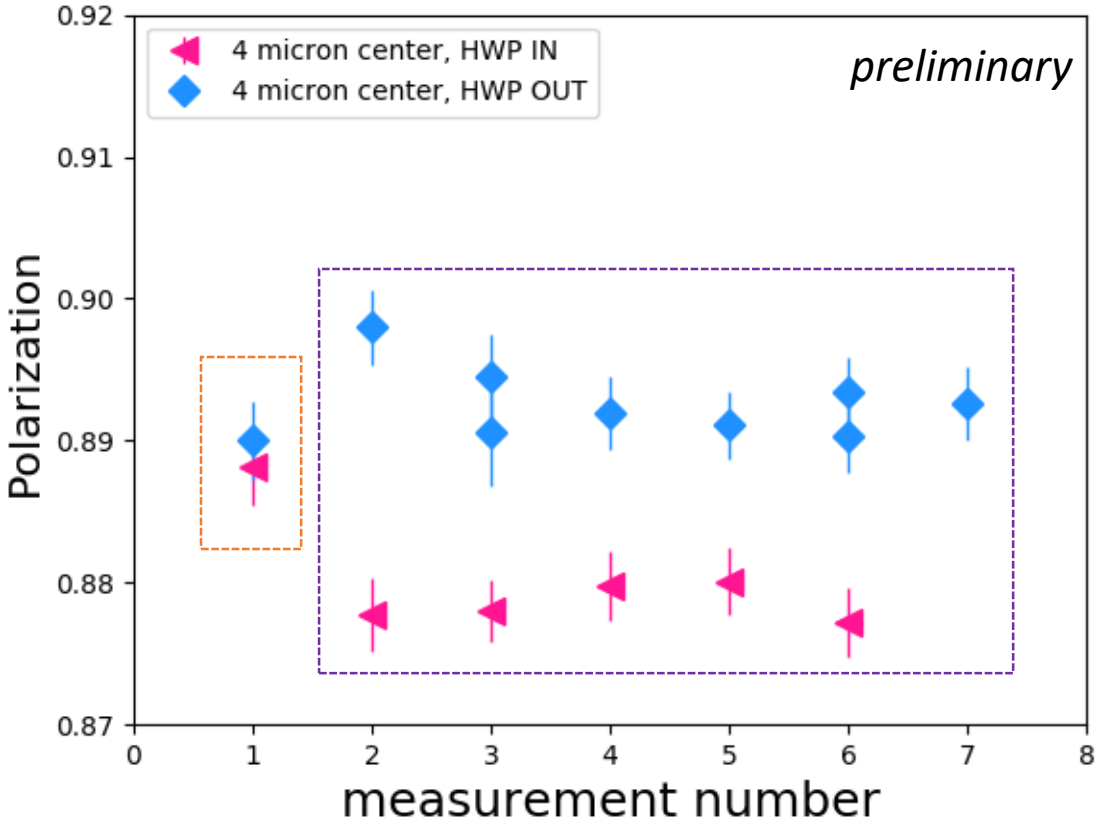
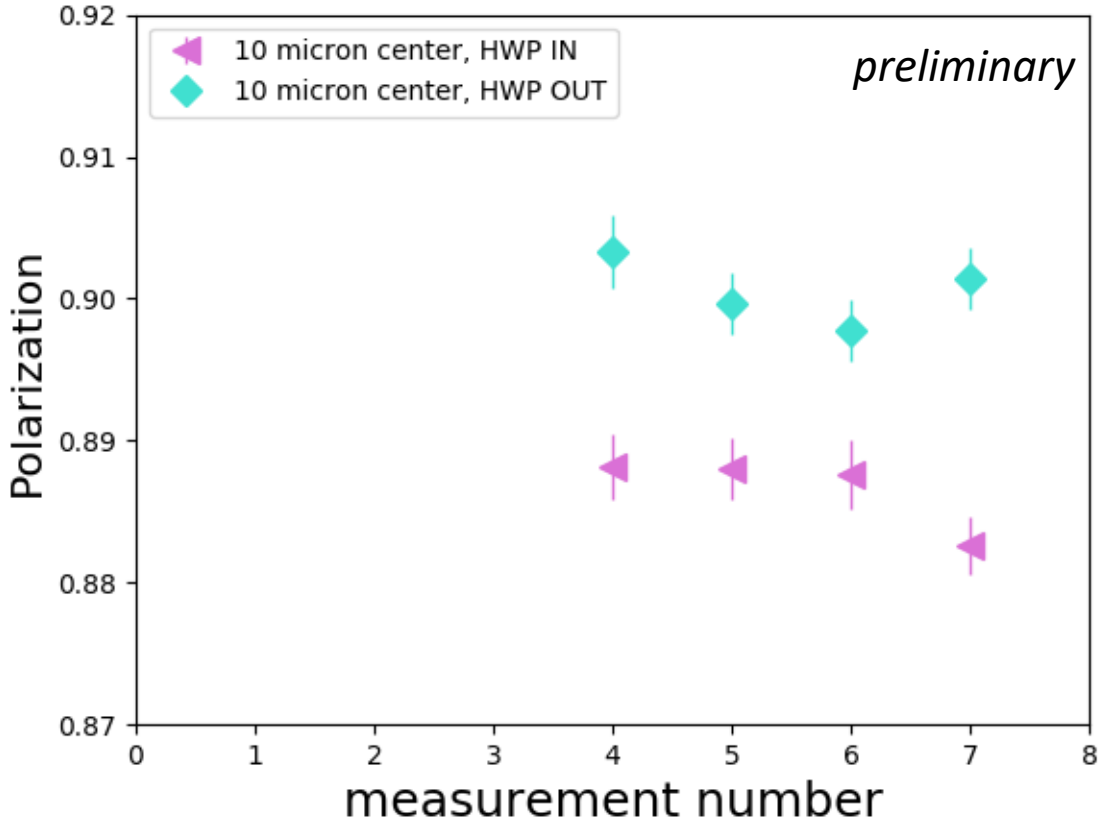



Measurements at the source suggest that for the IHWP OUT state the vacuum window birefringence is largely cancelled while for IHWP IN it is not. The difference is large enough to account for about 1% difference in degree of circular polarization of laser light on the photocathode

# Summer 2019: Polarization Measurements on 4 and 10 micron Fe Foils

- There is ~ 1% difference between polarization measurements on 4 and 10 micron

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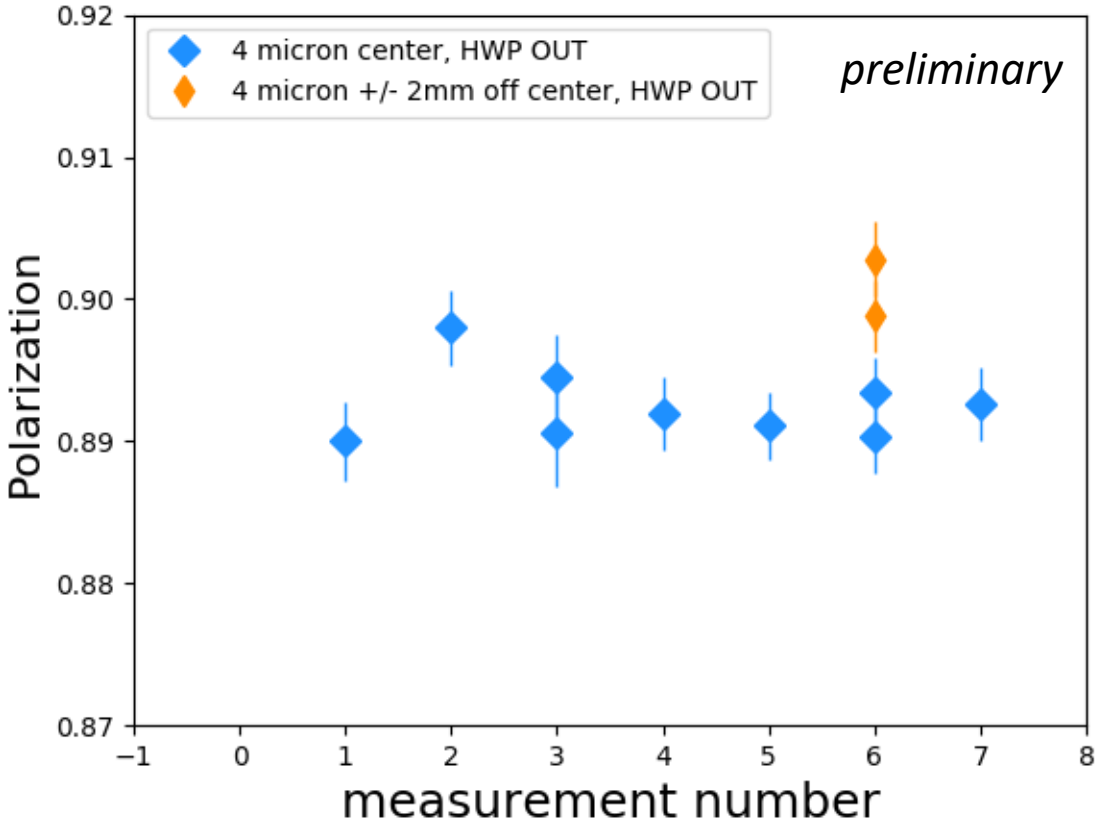
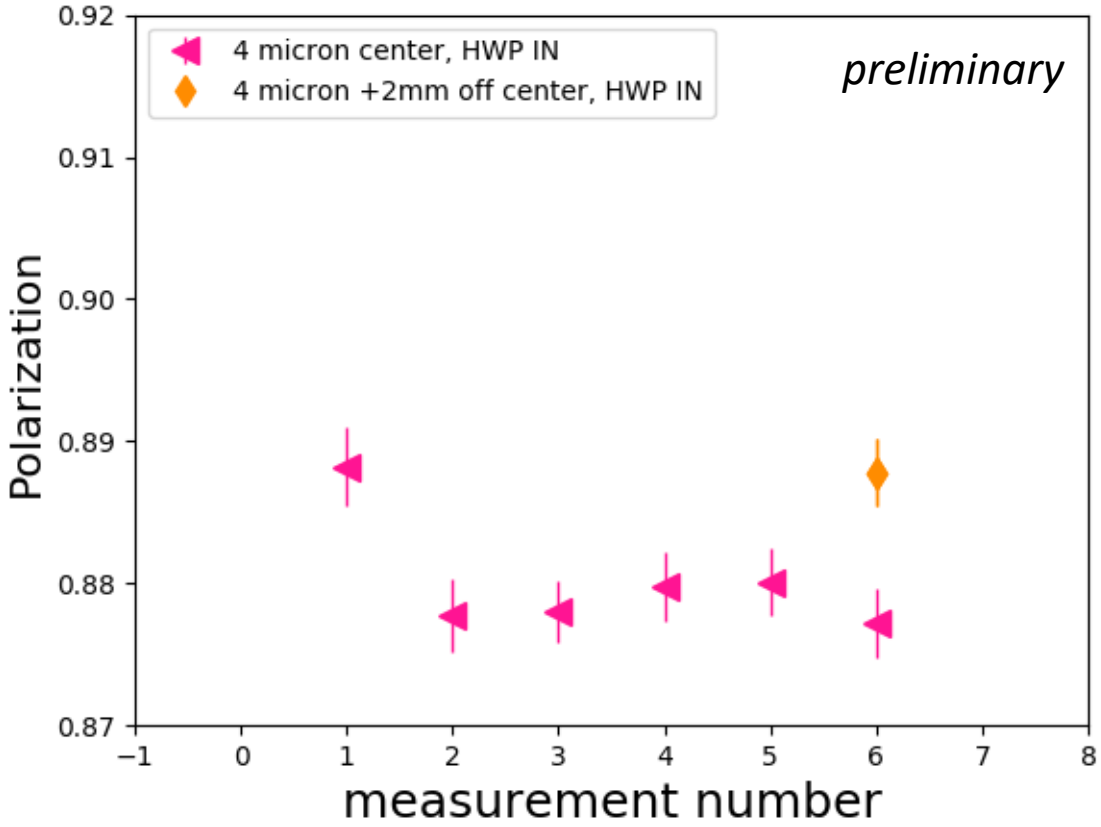
# 2019 Polarization Measurements: Systematics, 4 micron Fe Foil Quality

- There is ~ 1% difference between polarization measurements on 4 micron at different locations on the foil

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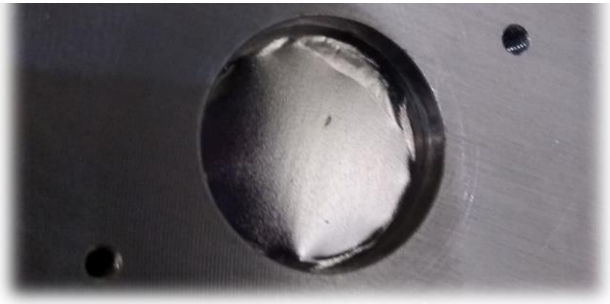

# 2019 Polarization Measurements: Systematics, 10 micron Fe Foil Quality

- No systematic difference between polarization measurements on 10 micron at different locations on the foil

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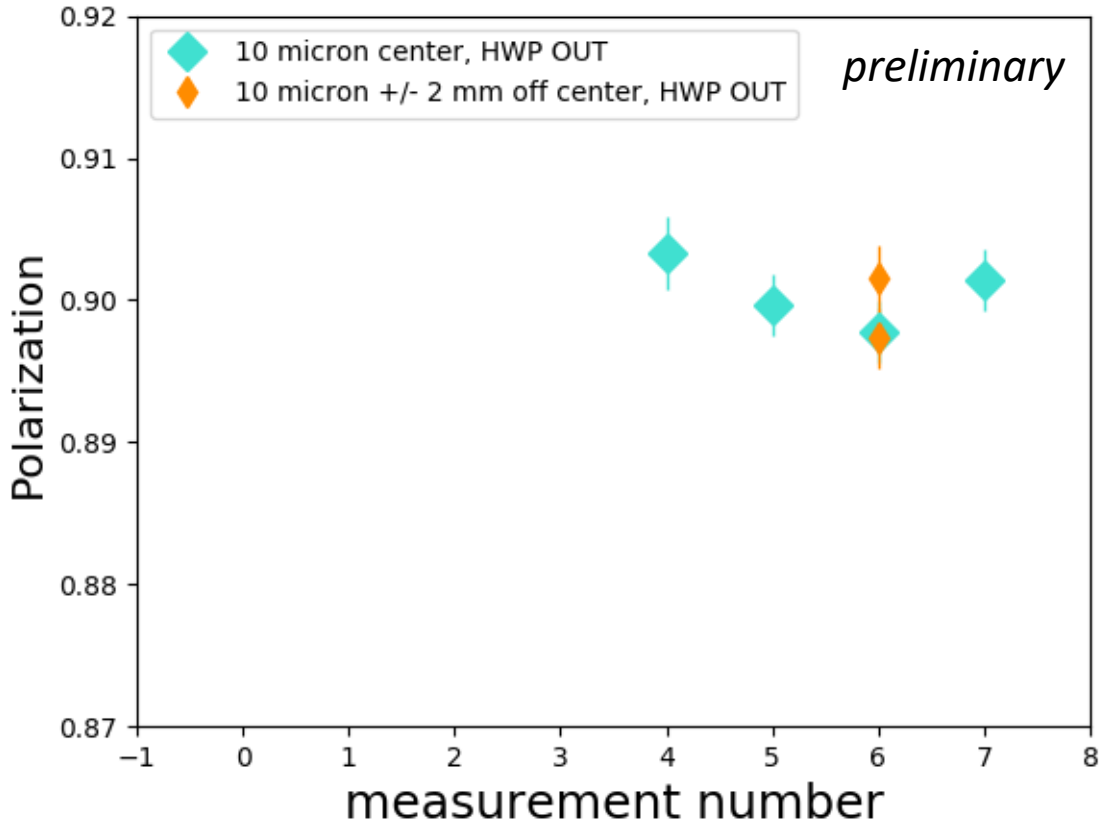


# 2019 Polarization Measurements: Systematics, Foil Saturation

- No systematic difference between polarization measurements on 4 micron at 3.5 and 4 T

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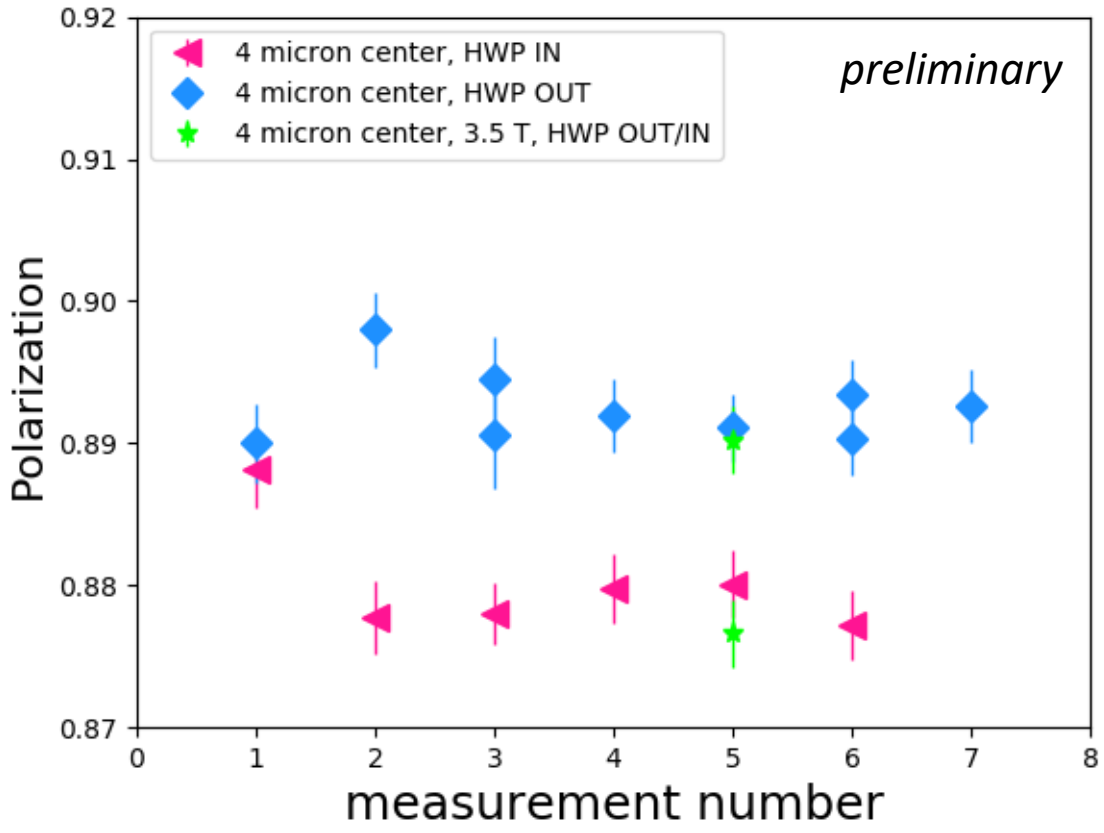

# 2019 Polarization Measurements: Systematics, Null Asymmetry on Cu

- No significant systematic deviations in the null asymmetry measurements

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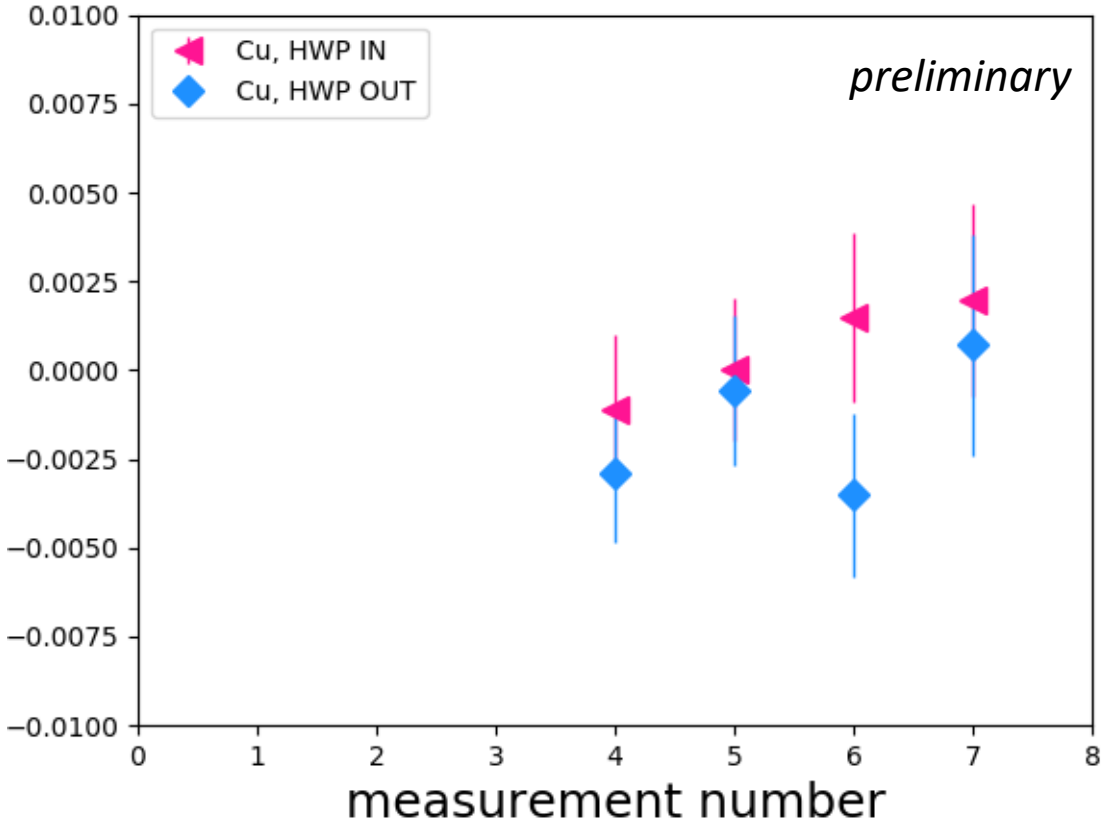

# Summary

- Hall A Moller polarimeter was used this Summer to measure the beam polarization in Hall A at JLab during PREX II
- A good optics solution was found where the Levchuk correction was shown to be small (see next talk by Eric King)
- We've done polarization measurements using two different Fe foils (4 and 10 micron)
- The quality of the 4 and 10 micron Fe foils was investigated: the 4 micron foil gave up to 1 % difference in polarization measurements depending on which part of the foil the beam sampled
- Measurements at a lower solenoid field confirmed that we have been saturating the Fe foils
- Only very preliminary results have been shown; a complete analysis in under way including the determination of the measurement's systematic uncertainty
- The Hall A Moller polarimeter will be used again to measure the beam polarization for CREX November 2019 through May 2020