MOLLER POLARIMETRY HALL A JEFFERSON LAB

2021 Hall A Winter Collaboration Meeting

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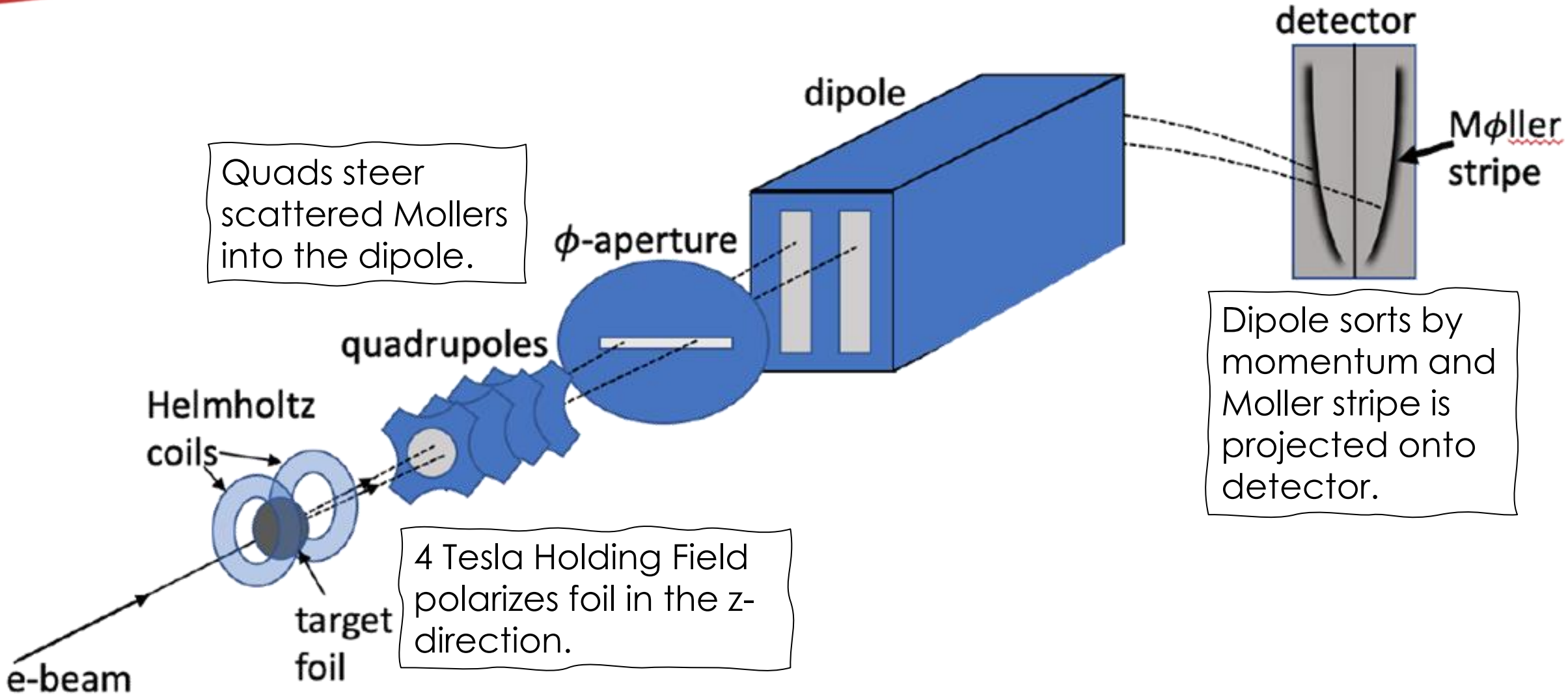
HALL A MOLLER POLARIMETER

DESIGN OVERVIEW

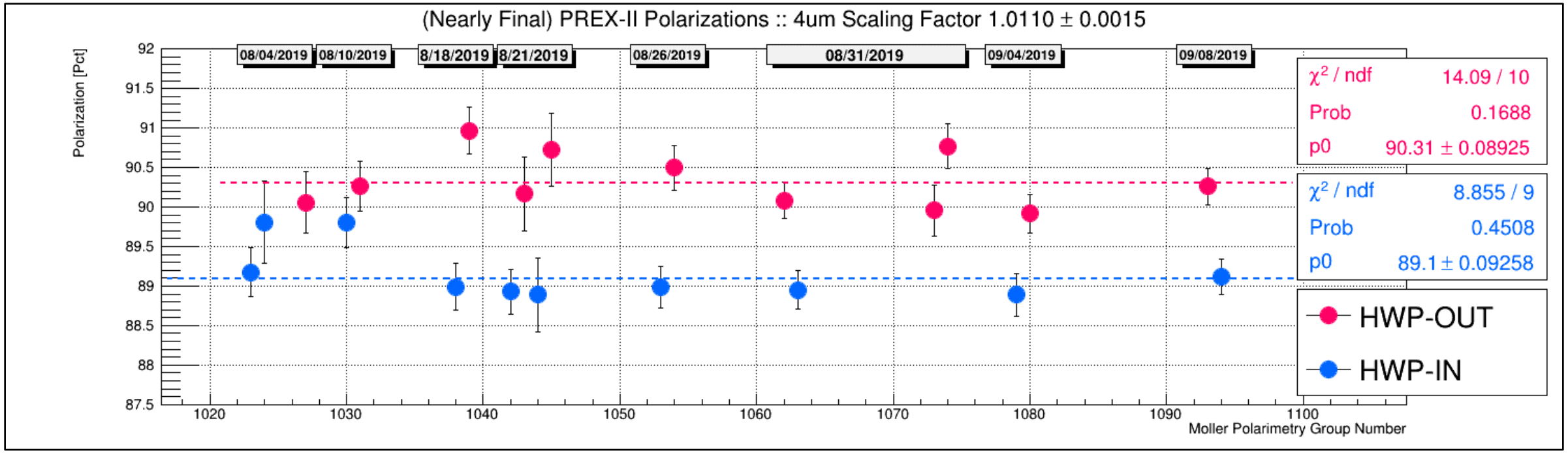


2019-2020 RUNNING – PREX & CREX

D. Eric King – 2021 Hall A Winter Meeting

2019-2020 PREX-II & CREX

PREX-II RESULTS



- Achieved a statistical 0.1% error on polarization

- Suffered from HWP IN/OUT differences.
- Unforeseen issue with wrinkling on the 4um foil

2019-2020 PREX-II & CREX

PREX-II SYSTEMATICS

Source	Value	dP/P (%)
A_{zz}	0.77304	0.36
Foil Polarization	0.08005	0.63
Dead Time Correction	0.00051	0.05
Null Asymmetry (Cu Foil)	0.0	0.10
Accidental Correction	0.0012	0.02
PITA Dependence	—	0.10
Spin Precession	—	0.02
High Current Cathode Heating	—	0.40
Slit Dependence	—	0.11
July Running	—	0.24
	Total	**0.89**

- Achieved a 0.89% systematic error.
- Beam orbit uncertainties contributed ~0.3% to the Azz uncertainty. An additional harp was installed after PREX to solve the problem.
- Asymmetry measurements further tightened our understanding of Levchuk effect.
- Foil angle and wrinkling concerns account for a 0.5% systematic for foil saturation.
- The effects of high current cathode heating are still insufficiently understood.

2019-2020 PREX-II & CREX

CREX

- Analyzing power systematic reduced to 0.18% (50% reduction)
  - Beam orbit issue was resolved over winter break 2019-2020;
  - Additional harp allows for ensured angle entering holding field;
  - Setup from week to week is now **HIGHLY REPRODUCIBLE.**
- There were additional gains in systematics from problems which we learned from in PREX-II.
- Repeated Helmholtz coil quenches left us with less data than desired.
- The current expectation is that we will **remain under** 0.86% systematic error.

PREX-II & CREX LESSONS LEARNED

FOIL WRINKLES / ANGLE

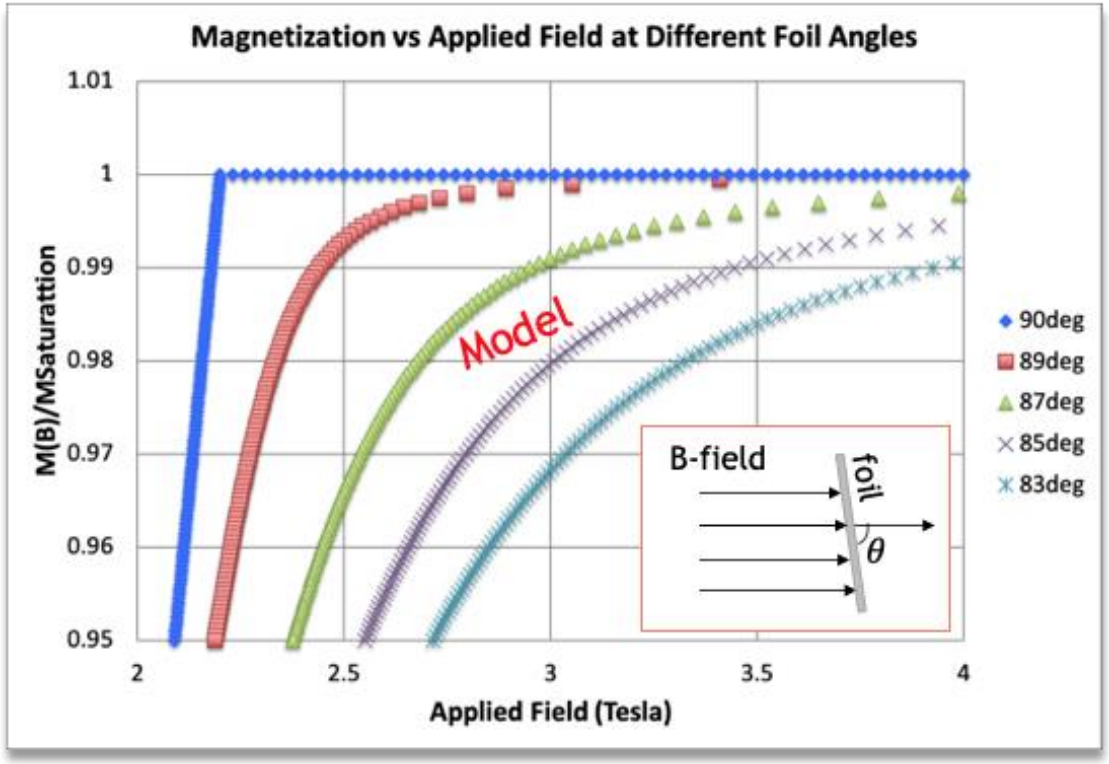


Image Courtesy of Donald Jones

- Work is currently under way utilizing Kerr apparatus to study foil polarization sensitivity to alignment and warping.

- Foils must be carefully aligned to field in order to reach saturation.
- Small changes in foil angle relative to field can cause significant changes in polarization.
- Foils must be free of wrinkles.
  - During PREX-II we had problems with the wrinkling of the 4um Fe target—jogging 2mm in either direction altered polarization measurements 1%;
  - Our working hypothesis is that the foil was slightly wrinkled/warped.

PREX-II & CREX LESSONS LEARNED
PITA VOLTAGES

- **Active feedback on the PITA voltage on Pockels cells is used to suppress charge asymmetry. This results in small changes in polarization which are negligible if the laser is 100% circularly polarized.**

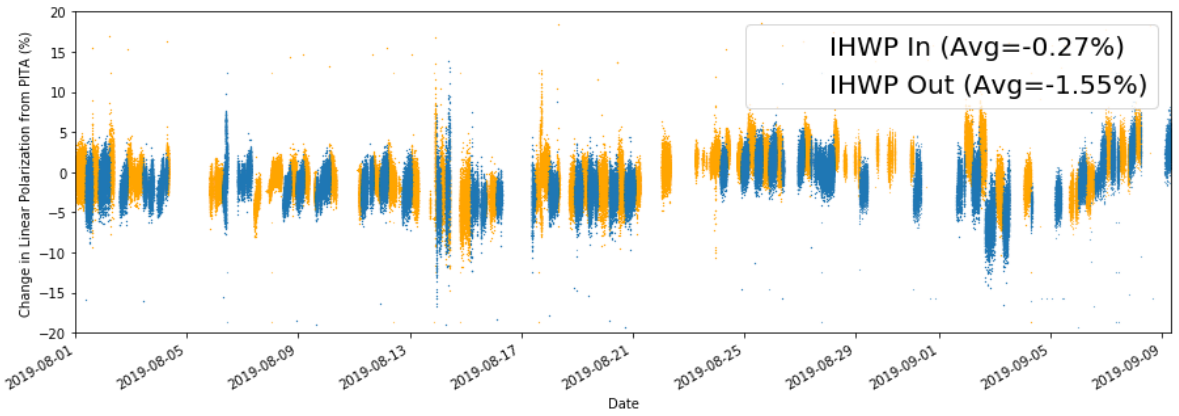


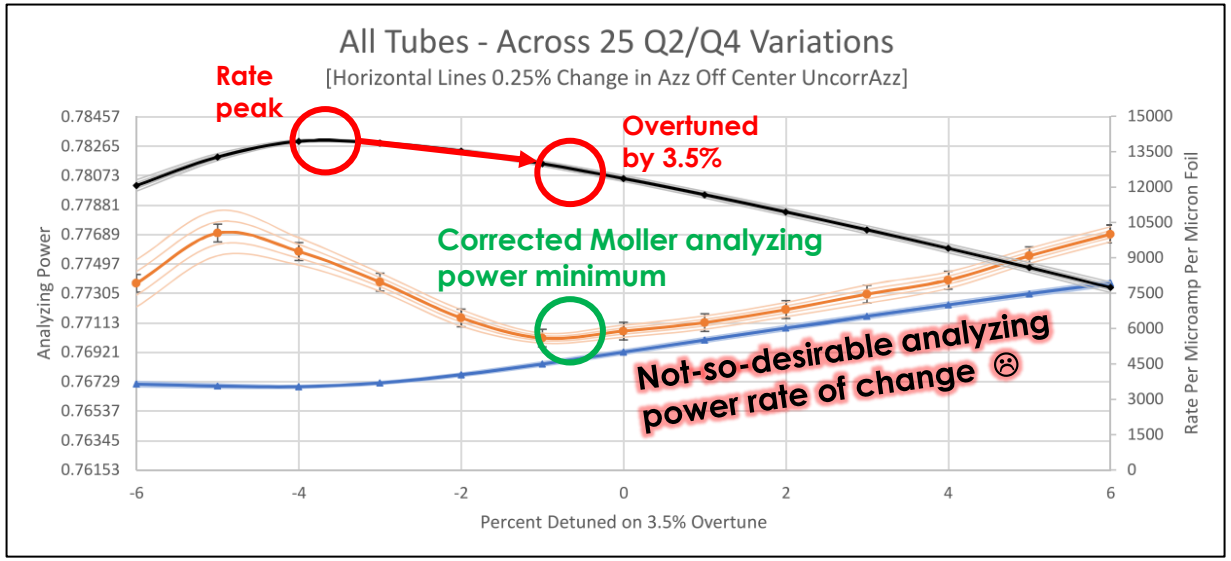
Image Courtesy of Donald Jones

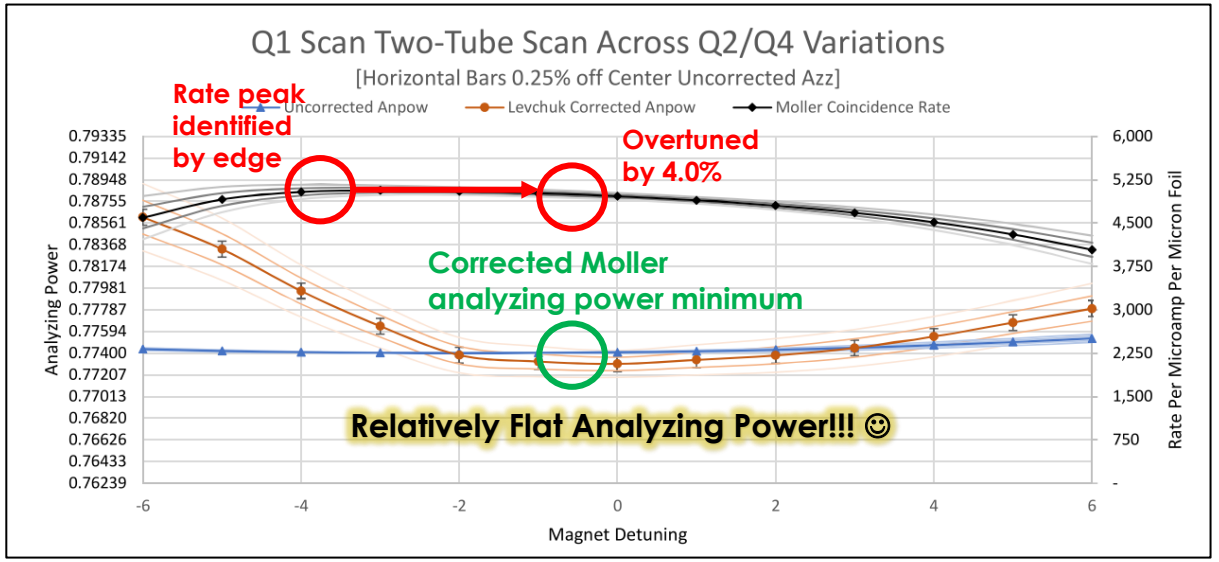
The above chart shows changes in the linear polarization of the beam due to charge feedback changes made to the PITA voltage during the August thru September period of PREX-II.

- **Moller measurements are taken with charge feedback off. First iHWP measurement at a non-optimized set point creates a potential difference.**
- **Minor issue during PREX (luckily).**
- **Setup at laser table minimizes the issue.**
- **Setup during Moller measurements would be wise to ensure that PITA voltages are reset with flipper to proper HWP values before starting.**
- **Together, this should eliminate systematic concerns on this front.**

PREX-II & CREX LESSONS LEARNED

DIAGNOSTIC TUNING & SMALLER DETECTOR



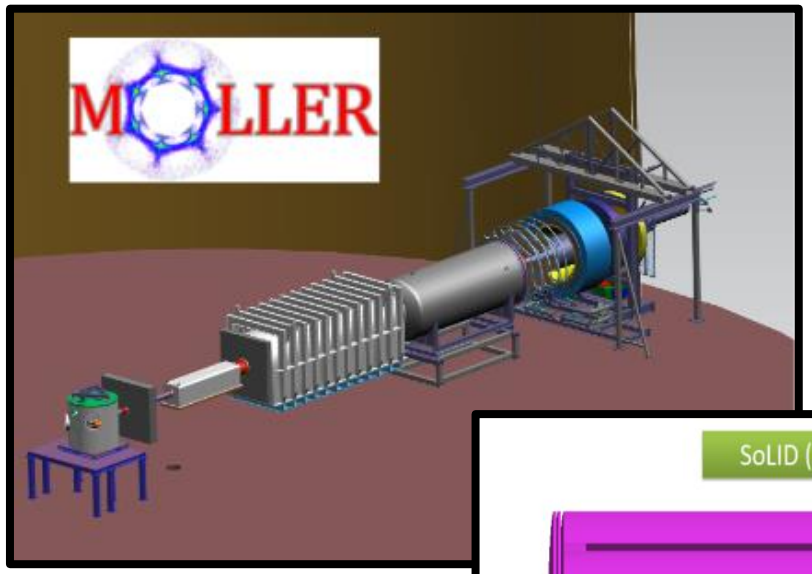


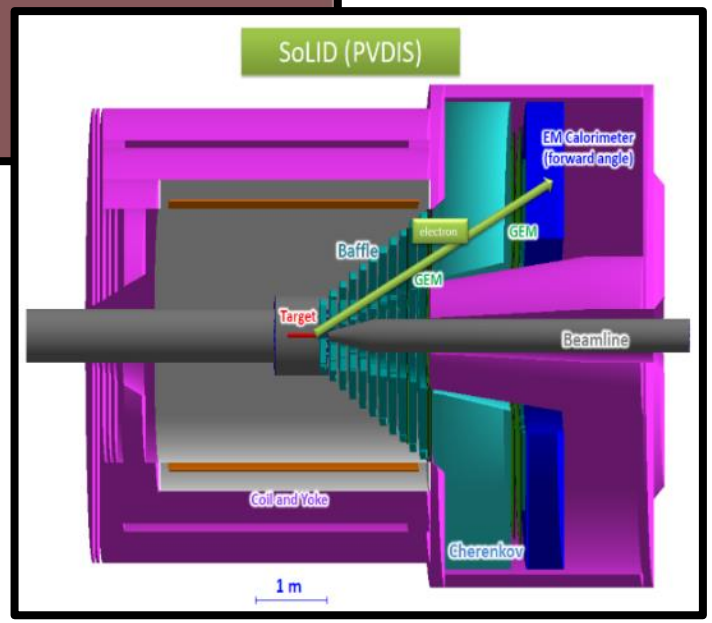
- The plot above shows the asymmetry with respect to the Q1 setting and uncertainties about Q2 and Q4.
- The first insight we gained during PREX, due to concerns about reproducibility and magnet unknowns, was to diagnostically tune Quad1 to find the Moller rate peak then over-tune by 3.5%.

- The plot above shows the asymmetry curve when using only two (2) of the PMTs of the Moller Spectrometer.
- The second valuable insight was using the detector to define acceptance to eliminate additional Levchuk problems.

LOOKING FORWARD ➔ 12 GEV ERA

LOOKING FORWARD INTRO
11 GEV ERA POLARIMETRY





11 GeV Era Experiments with stringent polarimetry requirements.

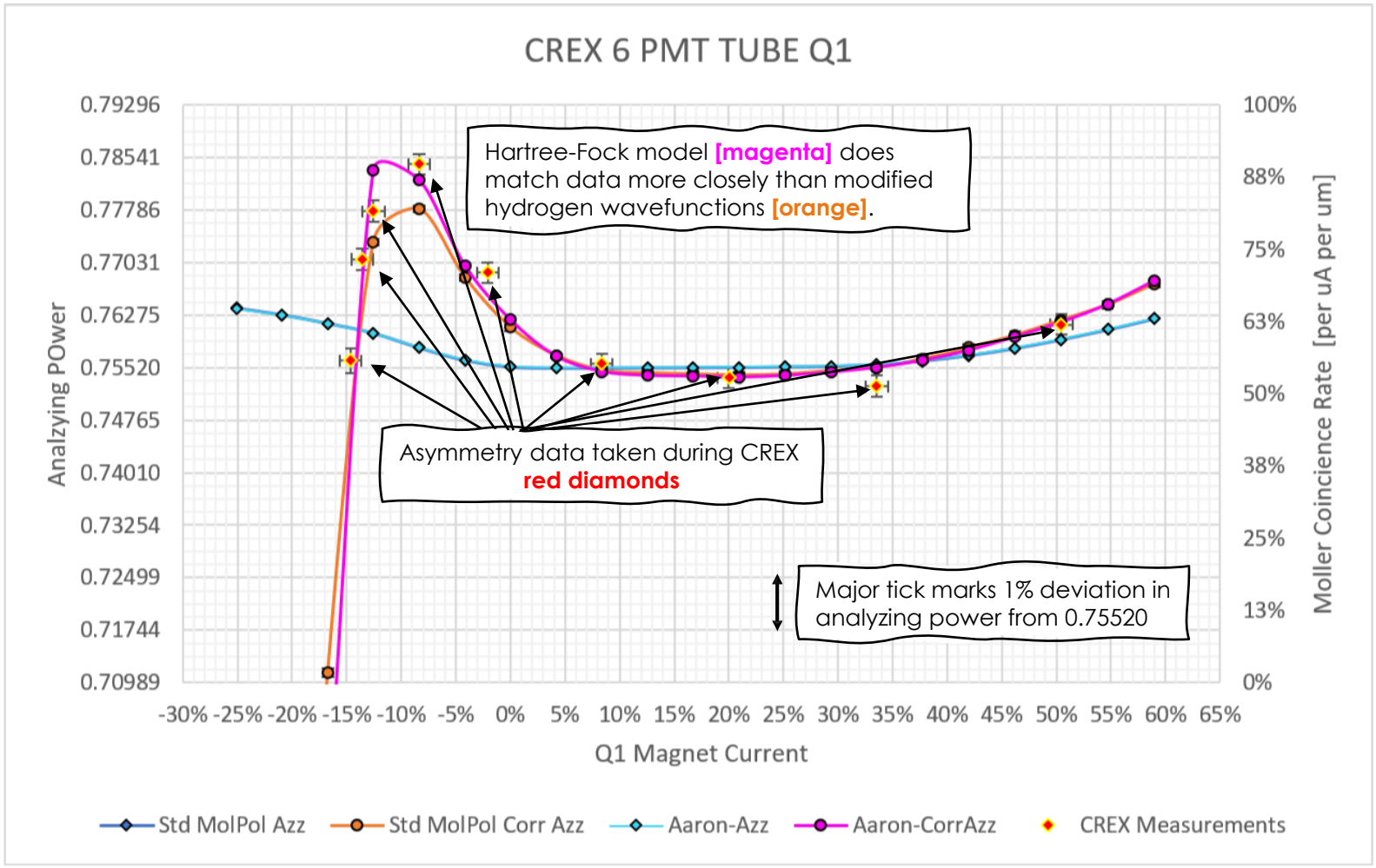
MOLLER Experiment:

0.45%

SoLID

0.40%

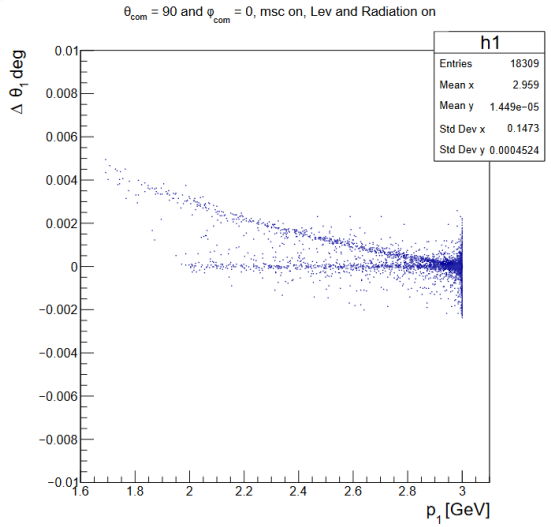
CURRENTLY EXPLORING
BETTER LEVCHUK MODELING

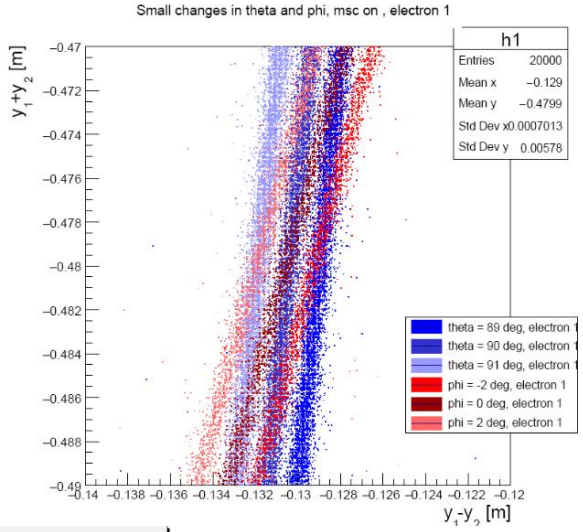


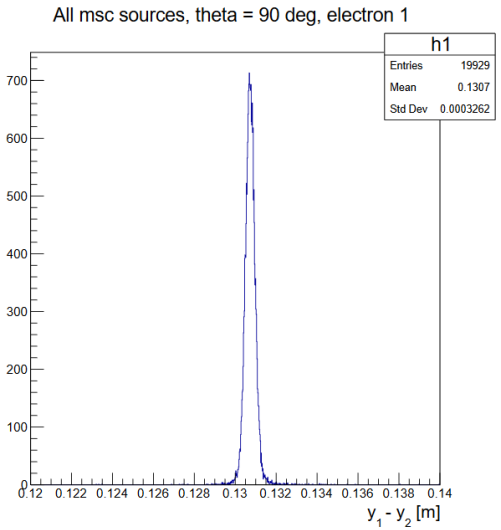
- Proper Levchuk Effect modeling is dependent on accurate momentum distributions of Fe e-.
- Have been using modified hydrogen wavefunctions since late 1990's.
- Precision asymmetry data taken during CREX shows a ~35% discrepancy between data and prediction at peak asymmetry.
- Exploring Hartree-Fock model with Aaron Kaplan (Condensed Matter Graduate student at Temple University) to see if this model shows improvement.
  - Looks to be a better data fit;
  - Cautiously optimistic.

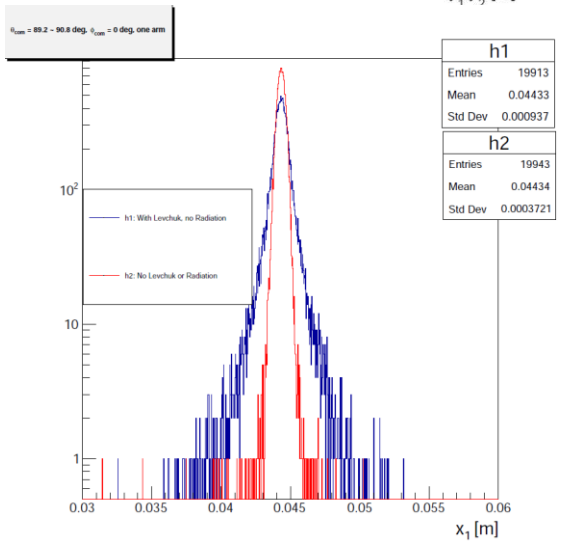
POLARIMETER TRACKING

UTILIZING GEMS FOR ADDT'L INFO





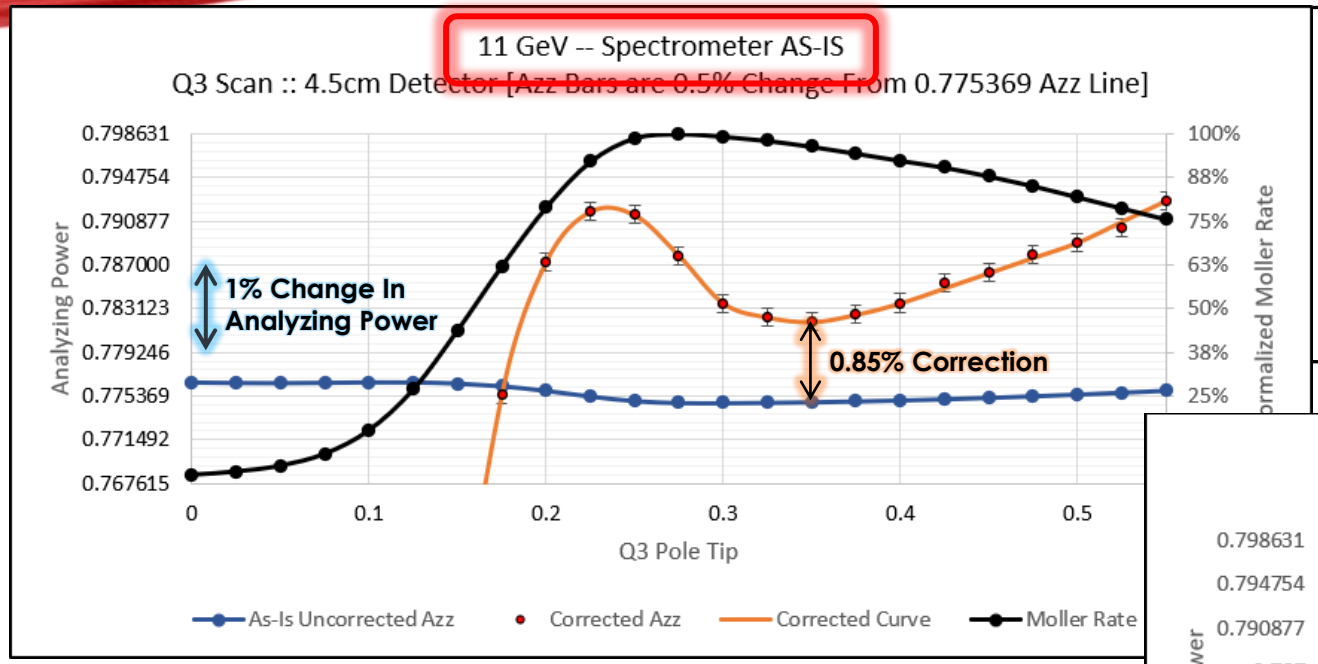




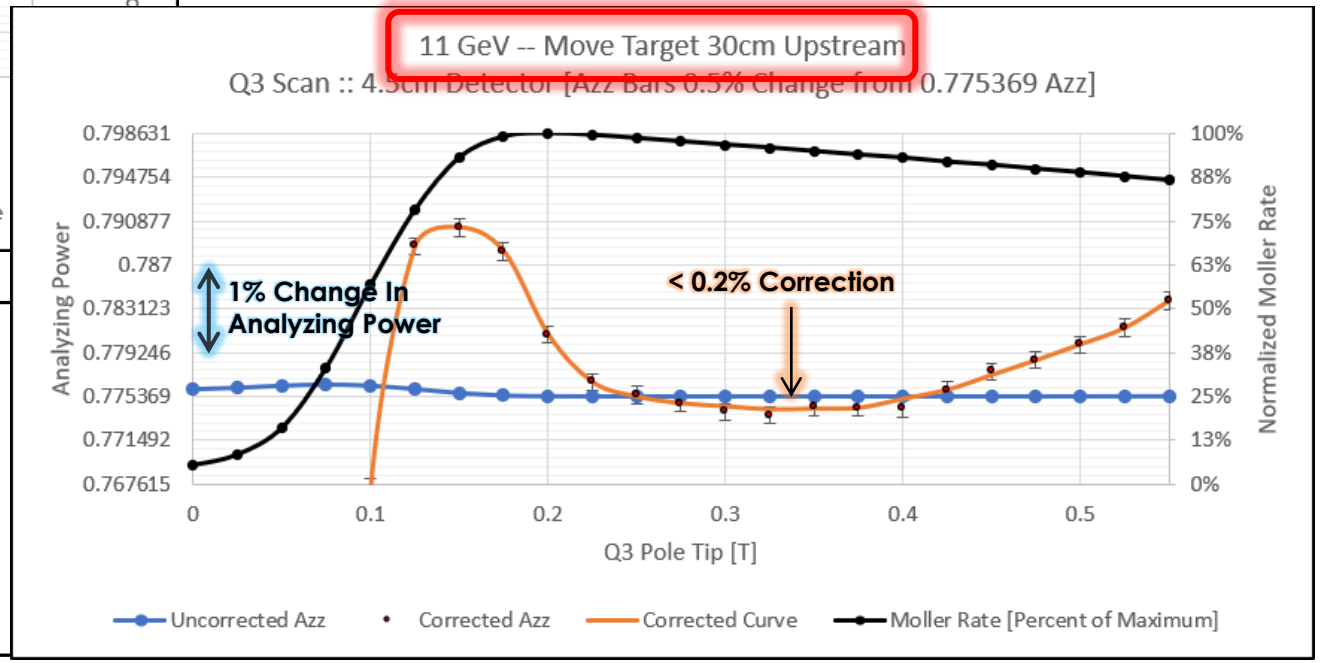
- Preliminary work has started on understanding the data we can collect from GEM tracking and determining the required GEM resolution.
- Tracking will provide a clearer understanding of Moller events.
  - Will allow smearing from Levchuk to be compared to models in simulation;
  - Will shed light on accuracy of multiple scattering models used in simulation;
  - May provide insights on whether current radiative model is sufficiently.
- Will ultimately help further constrain systematics on the analyzing power.

REQUESTED BEAMLINE MOD

MOVING SOLENOID 20-30CM UPSTREAM

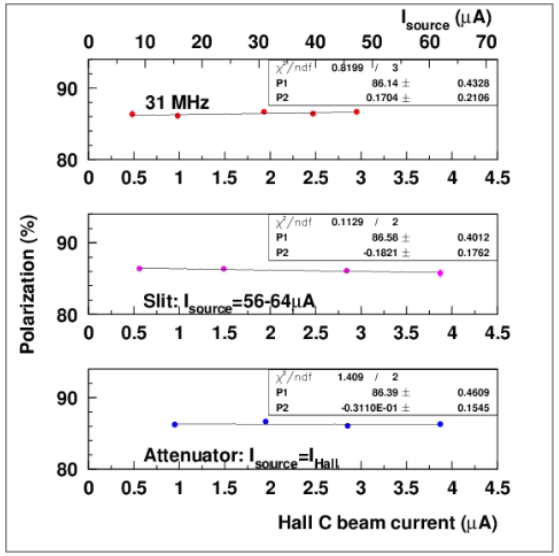


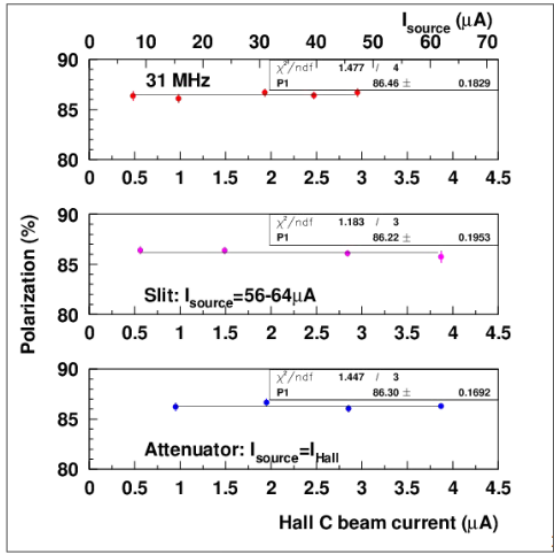
- Image to the right shows analyzing power curve with respect to Quad3 tuning **with spectrometer AS-IS.**
- Here we are left with a sizable Levchuk correction which with current understanding would leave us with a 0.25% systematic.
- Even doubling our understanding would leave us with 0.13% understanding.



- Image to the right shows analyzing power curve with respect to Quad3 tuning **with target/magnet moved 30cm upstream.**
- With current understanding of Levchuk this leaves us with only a 0.06% systematic and, if we can double our understanding, we can lower that to 0.03%.

STUDY NEEDED
HIGH-CURRENT EXTRAPOLATION





During Qweak there were Moller-Compton comparisons done at the same low current. At that time, Compton limited the precision to the 1% level for a 4→180 muA dependence.

Similar tests can also be performed for MOLLER/SoLID.

- **Moller polarimetry performed at 0.6uA**
  - **Limiting factor was number of accidentals;**
  - **Target heating also a concern.**
- **MOLLER plans to run at similar current to PREX at around 70uA**
  - **PREX systematic 0.4%.**
- **The existing study of which we are aware was performed in 2007 (on left) which placed limit on PREX systematic.**
  - **We don't have as large an error budget with MOLLER or SoLID;**
  - **Study needed once a worthwhile plan of investigation is decided upon.**

ADDITIONAL CHALLENGES
HALL C BLEED & HELMHOLTZ QUENCH

Hall C Bleed

- During CREX bleed through in Hall A coming from Hall C (running at ~30uA).
  - 0.1% of our Moller rate was from bleed through;
  - Hall C helicity is opposite of Hall A which amplifies the problem.
- We can try closing the HA slit further – would require addt'l studies of slit dep'.
- Perhaps the problem can be handled at the laser table itself.

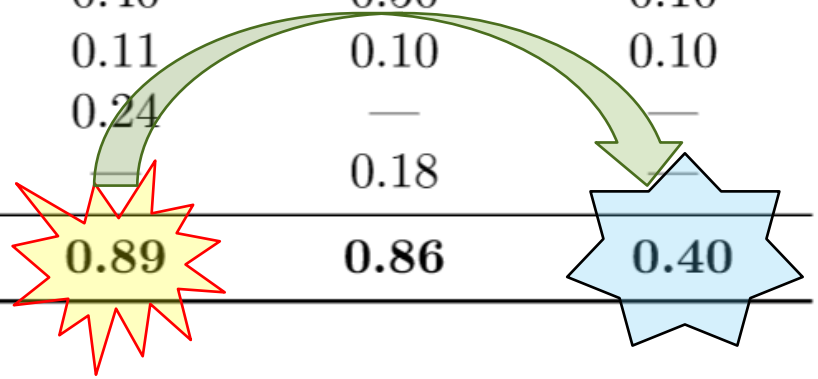
Helmholtz Quenching

- Magnet quenching disrupted two measurements during CREX.
  - Additionally, cool down time for magnet quench exceeded projected Moller measurement time impacting experimental data taking.
- Fear of additional quenches hurried along remaining Moller measurements.
- Reason for quenching, which occurs within current-rated operation, has eluded discovery with no prime suspects other than perhaps the occurrence of poor beam quality.

SYSTEMATICS IMPROVEMENTS

GOING INTO 12 GEV ERA

Systematic Source	PREX-II dP/P (%)	CREX dP/P (%)	Future dP/P (%)
A_{zz}	0.36	0.18	0.125
Foil Polarization	0.63	0.6	0.34
Dead Time Correction	0.05	0.135	0.05
Null Asymmetry (Cu Foil)	0.10	0.20	0.05
Accidental Correction	0.02	0.037	0.037
PITA Dependence	0.10	0.021	—
Spin Precession	0.02	0.039	0.04
High Current Cathode Heating	0.40	0.50	0.10
Slit Dependence	0.11	0.10	0.10
July Running	0.24	—	—
Bleedthrough	—	0.18	—
Total	**0.89**	**0.86**	**0.40**



- **Very feasible reductions** in Azz uncertainty
- Hopefully, we can reduce foil uncertainty to the theoretical 0.285% plus 0.175% saturation systematics.
- Deadtime systematic will be reduced; we're likely overestimating at this point.
- Null asymmetry uncertainty dependent on amount of data taken.
- Accidentals, assuming same proportion from CREX → Going forward.
- Diligence while running will eliminate PITA uncertainty.
- Photocathode heating is going to require study (unless someone has new information).
- Slit Dependence I've left the same.
- Hoping to return to a situation where bleed through is not an issue.

SUMMARY & COMMENTS

THANK YOU

- We managed to take sub 1% error measurements during PREX-II & CREX.
- We learned quite a bit in the process.
- There is remaining work, investigative and physical, which needs to be done as we move into the 12 GeV era.
- We are confident, given what what's been reviewed, that we will reach the required error goals for both MOLLER and SoLID.

Questions

Comments

Computational work for PREX/CREX analyzing power made possible by:

Syracuse University HTC Campus Grid and NSF award ACI-1341006