Moller Polarimetry Progress Update

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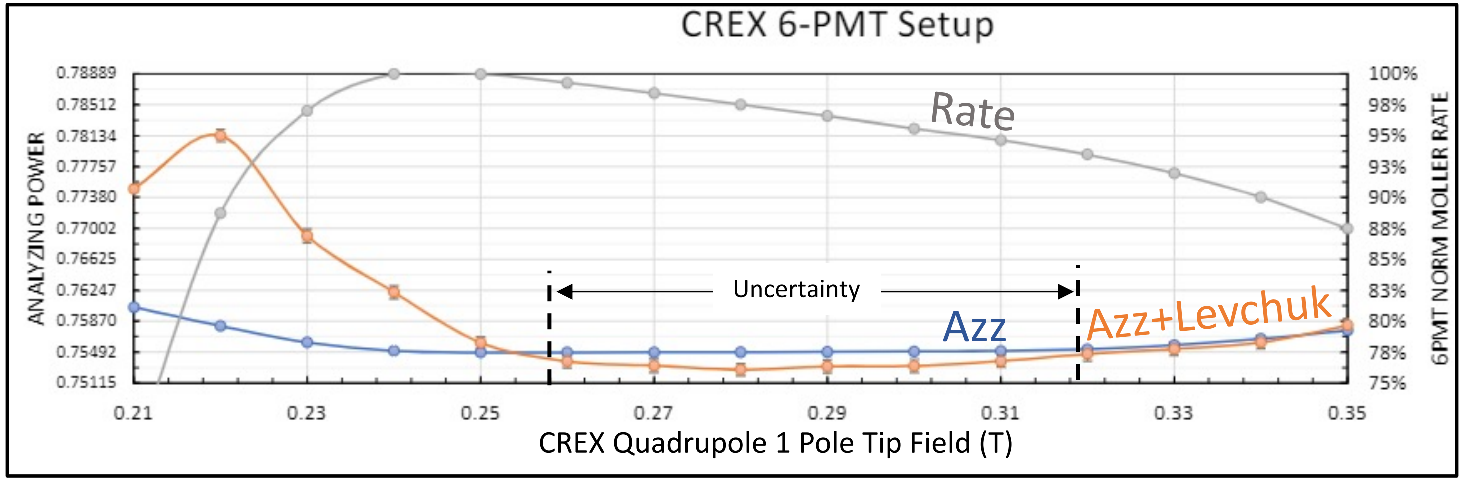
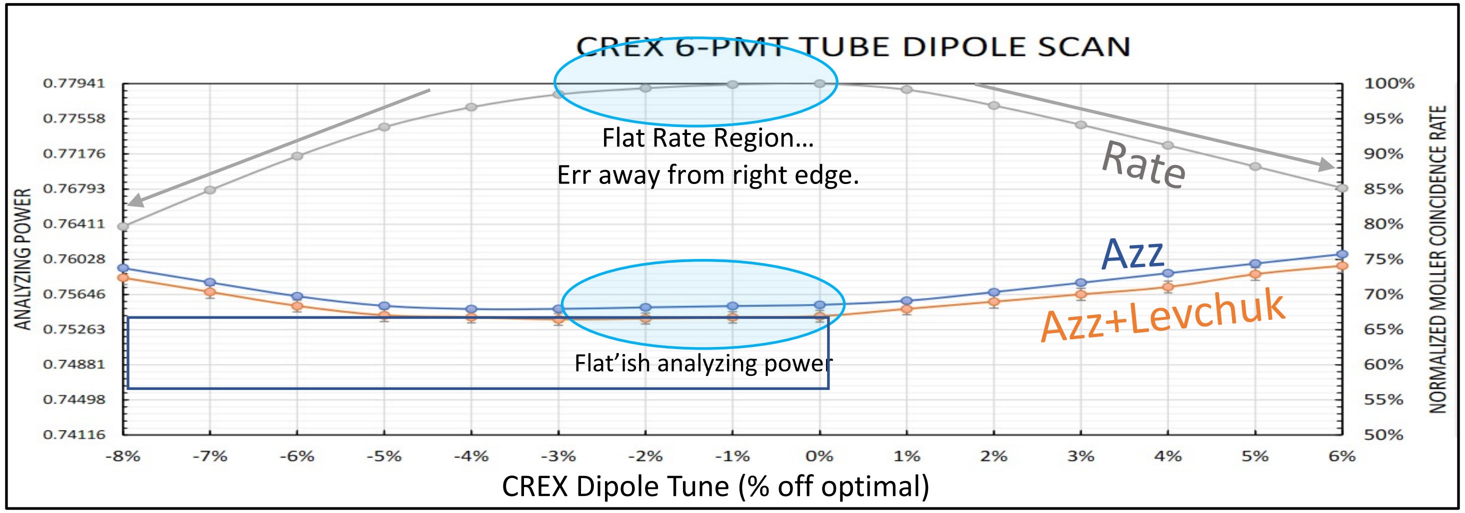
Error Table for CREX

Most difficult

Source	Value	$\delta P/P$ (%)	Goal(%)
A_{zz}	0.75421	0.16	0.12
Foil Polarization	0.08005	0.57	0.30
Dead Time Correction	0.148%	0.148	0.10
Accidental Correction	0.205%	0.041	0.05
Charge Normalization	0.029%	0.009	0.00
Null Asymmetry (Cu Foil)	0.0%	0.220	0.10
PITA Variation	—	0.06	0.10
Spin Precession (dP/P)	—	0.04	0.10
High Current Extrapolation	—	0.5	0.10
Bleedthrough	—	0.18	0.10
Slit Dependence	—	0.1	0.10
	Total	**0.849**	0.42

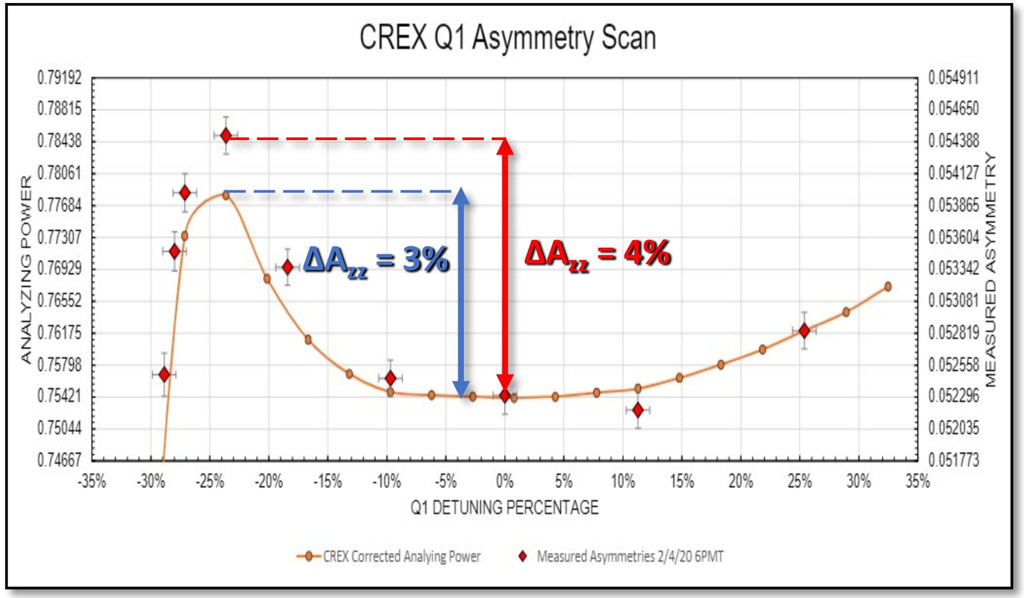
Azz matured during PREX/CREX





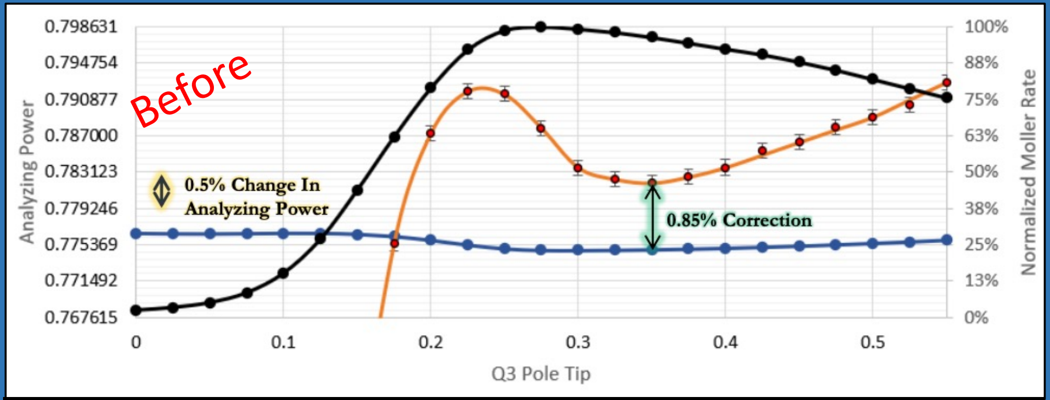
CREX errors on Azz

Uncertainty Source	$\delta A_{zz}/A_{zz}$ (%)
Q1	0.10
Q2/Q4	0.00
Dipole	0.05
Corrections / Levchuk	0.06
Holding Field Alignment	0.03
Lead Block Bleedover	0.04
Phi Acceptance	0.01
Monte Carlo Statistics	0.08
Total	**0.16**



Azz during MOLLER

1. Moving the target magnet upstream 30cm

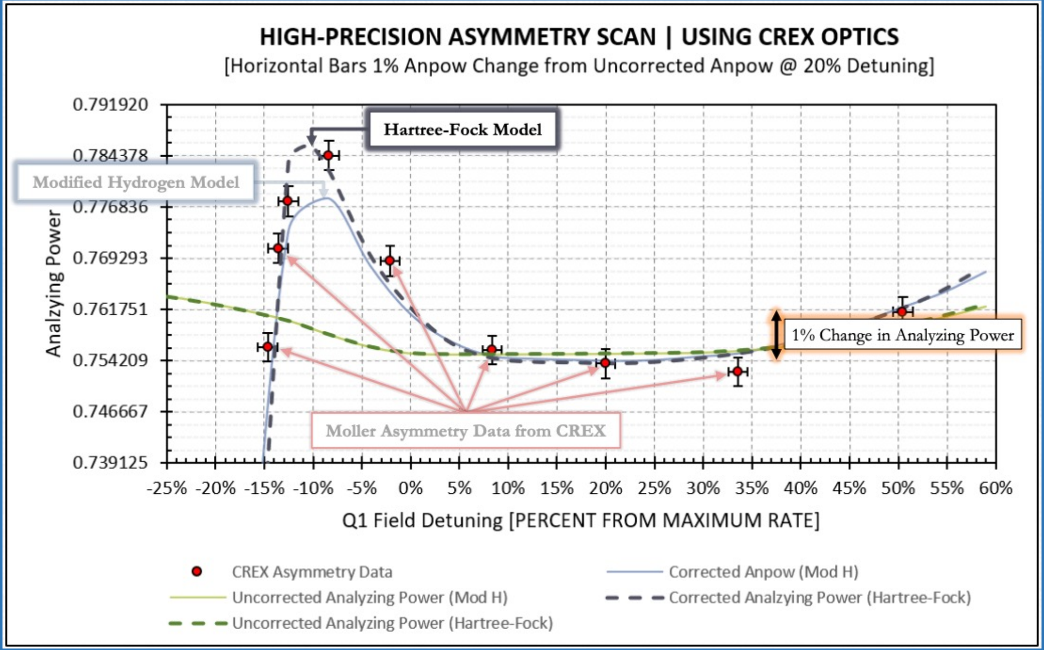


Caveat: based on 4.5 cm detector vertical face size, where current detector is 7.5 cm at minimum.

Need to investigate alternate solutions before modifying detector including different optics configurations, moving detector slightly, installing collimator...

Target move now in design!
Final uncertainty depends on details of detector acceptance Q3 tune precision.

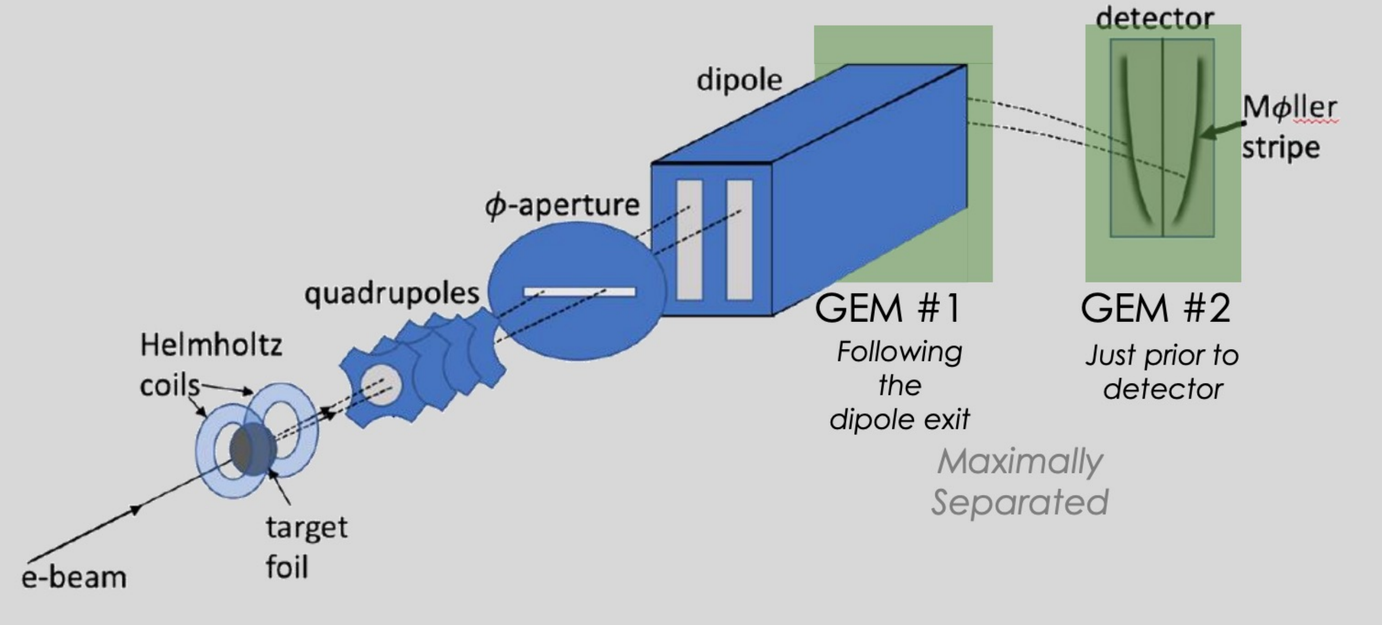
2. Better Levchuk model essentially eliminates model error uncertainty



3. Power supply from former HKS will power the dipole and allow us flexibility to tune optimally at 11 GeV.

Ambitious but plausible to improve CREX’s 0.16% to 0.12%

Improving Azz with GEMS



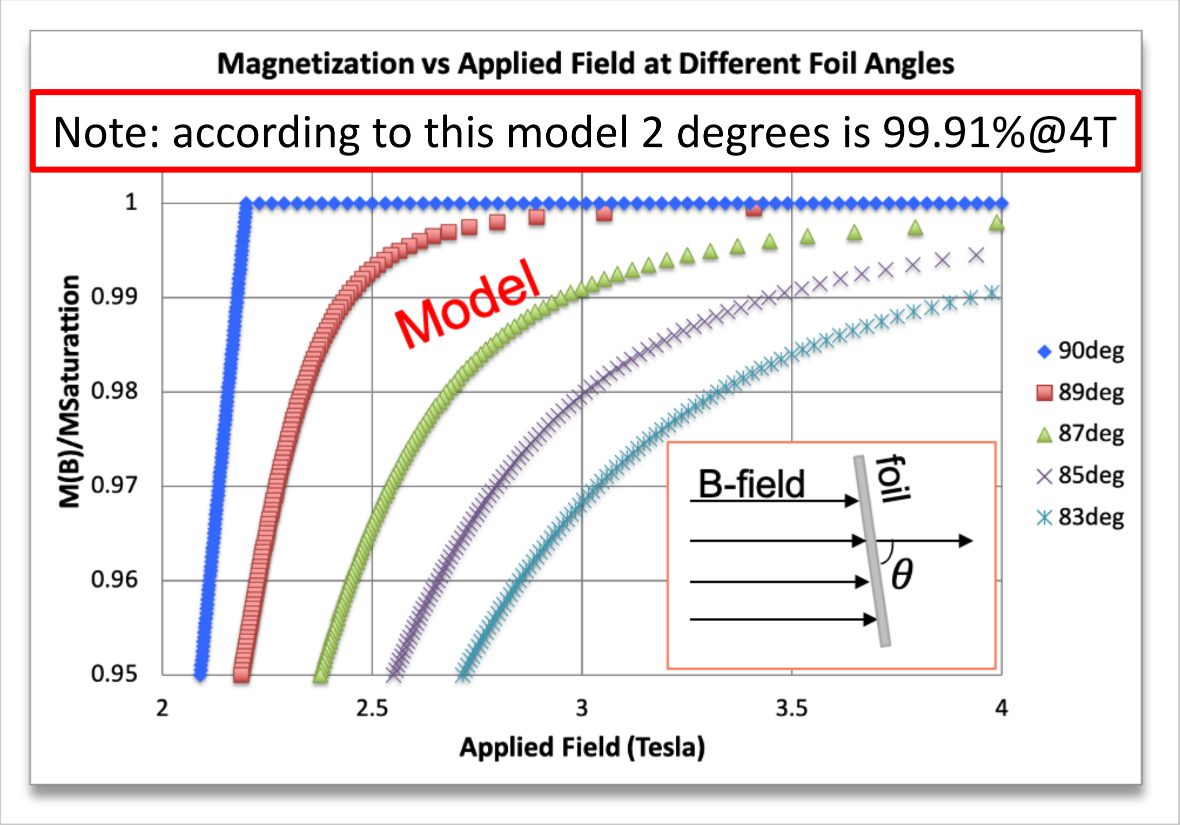
- Plan to install two GEMS ~1 m apart between dipole and detector
- Help to verify model of Levchuk, multiple scattering and radiative corrections
- Studies begun by Syracuse group on how to use information to quantitatively assess model uncertainties in these classes

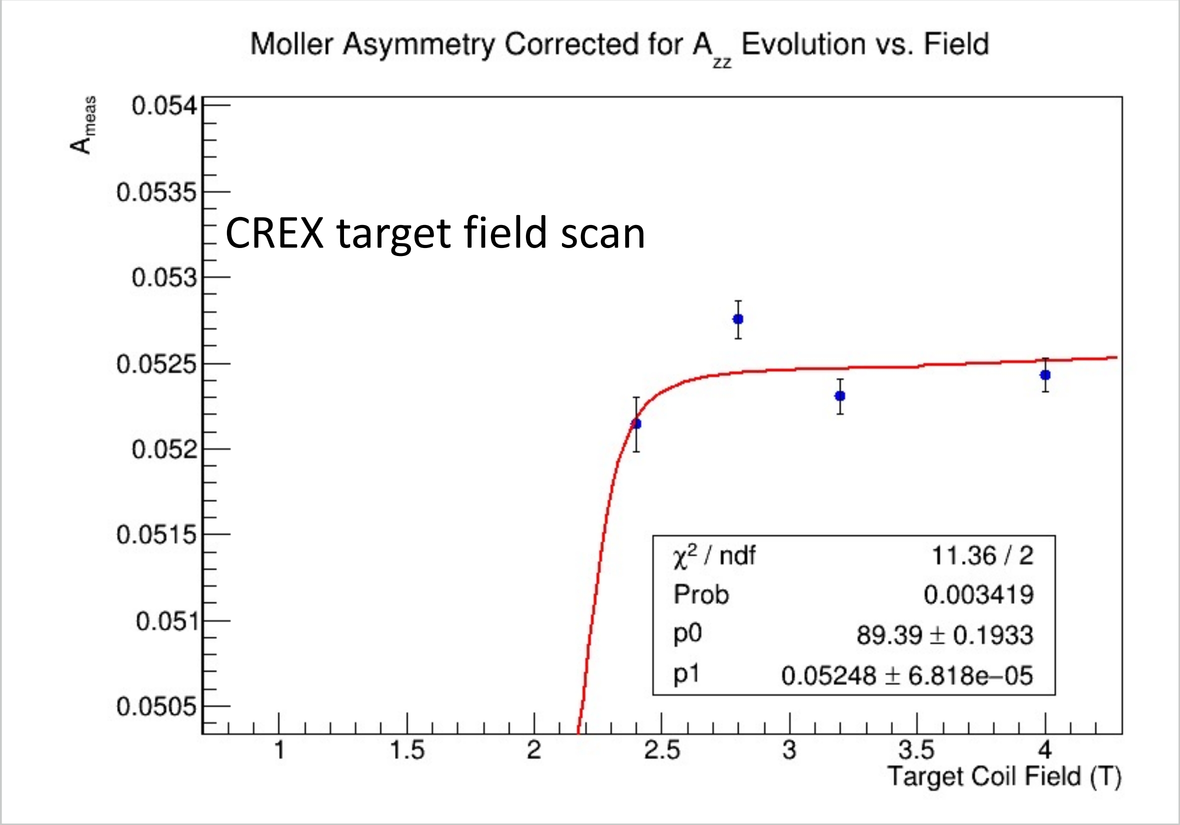
Caution

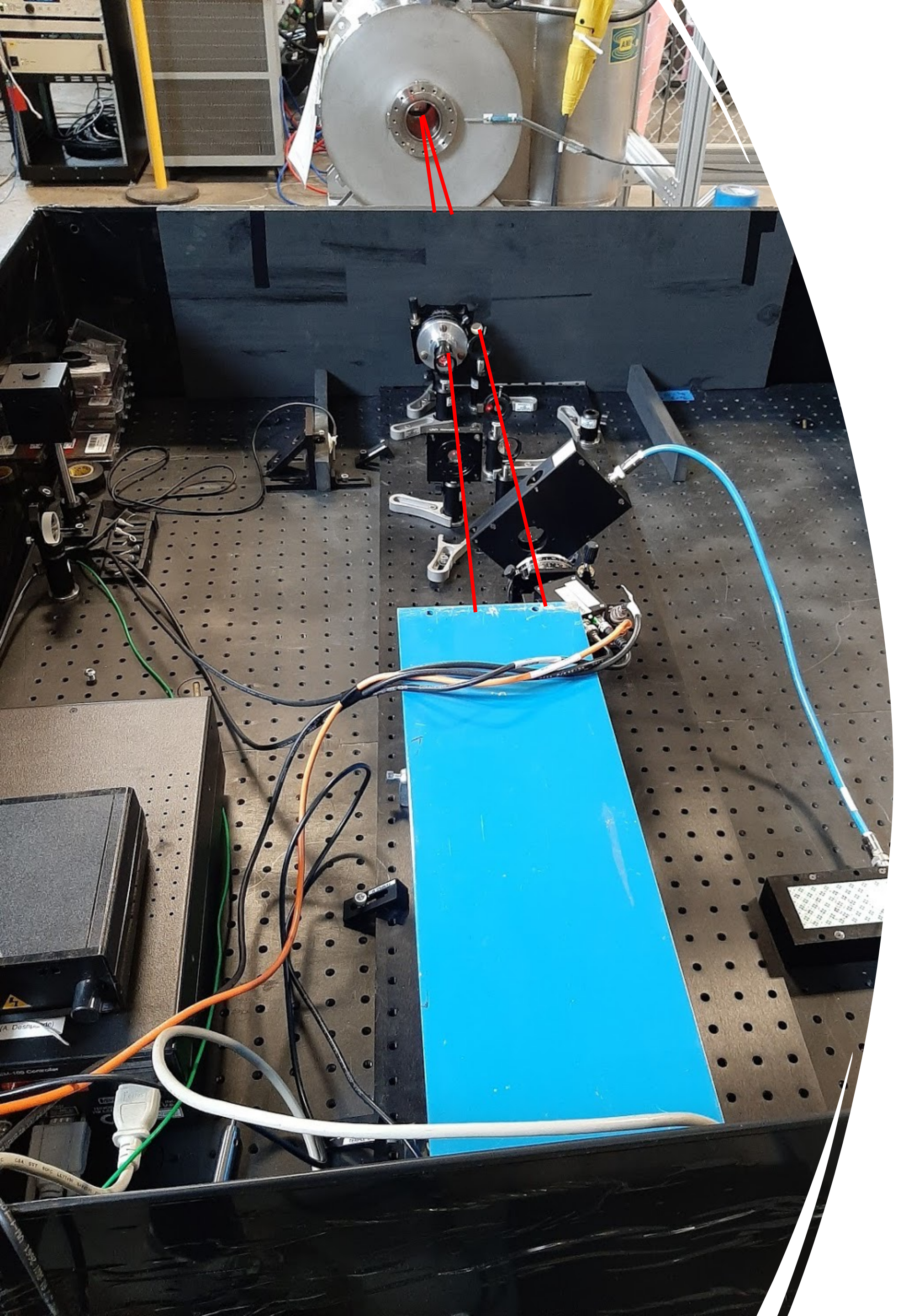
In my experience, adding new information/better diagnostics has a significant probability of increasing rather than decreasing the systematics.

Foil polarization

- Target foil polarization is likely our largest systematic error (0.3%)
- Known accurately at saturation→sensitive to foil alignment angle
- During PREX-2 measured 1% lower polarization on 4 μm foil than on 10 μm (likely running on a wrinkle)
- During CREX, scan of asymmetry vs target holding field hard to interpret
  - Laser pointing during ramp showed angle changes of a few degrees during ramp but stable above 3T
  - Not a well designed study but hope to repeat with better control

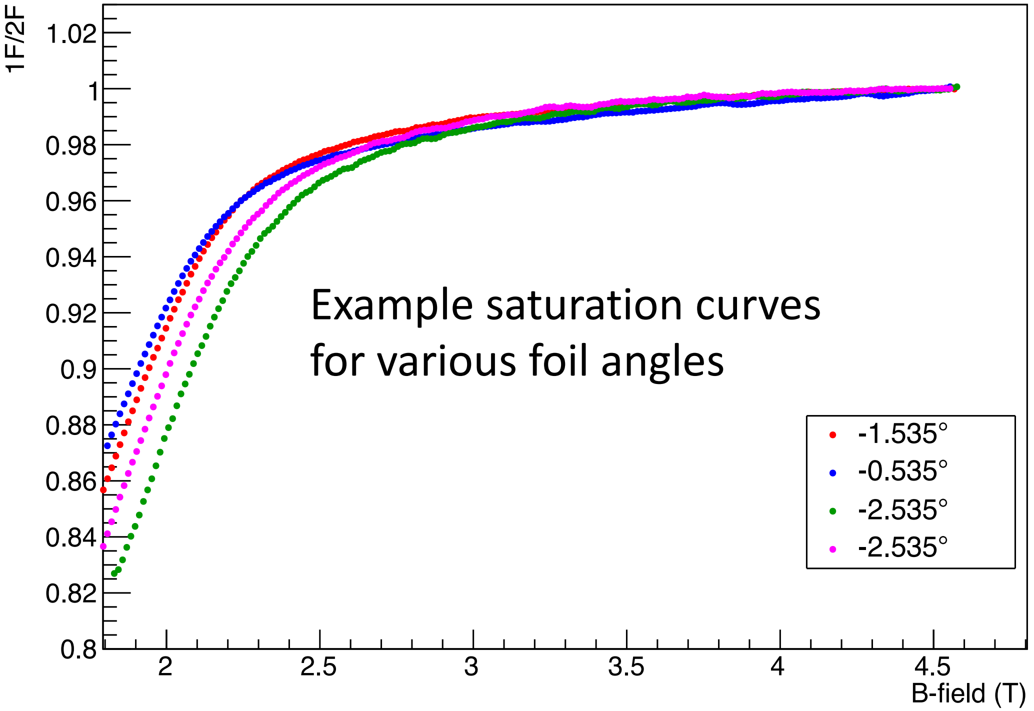






Kerr apparatus

- Built Kerr apparatus to quantify our sensitivity to foil angle and flatness
- Magnetization causes small polarization rotation of the probe laser
- Easy in principle to build, but not so easy in practice at the level of precision we need



More corrections

Dead time correction has 100% uncertainty applied since we aren't sure of the logic/inner workings of the DAQ trigger.

Working on a plan to decrease if not eliminate dead time systematic

Accidental correction taken from trigger delayed by 100 ns. Without evidence of an issue no need to improve. Likely to remain for MOLLER at 20% of the correction size.

Charge normalization error goes away if we calibrate the BCM.

Null asymmetry is statistics dominated. Take enough statistics on Cu foil to show we measure 0 with an unpolarized target.

Dead Time Correction	0.148%	0.148
Accidental Correction	0.205%	0.041
Charge Normalization	0.029%	0.009
Null Asymmetry (Cu Foil)	0.0%	0.220

Moller polarimetry is not concurrent with experiment

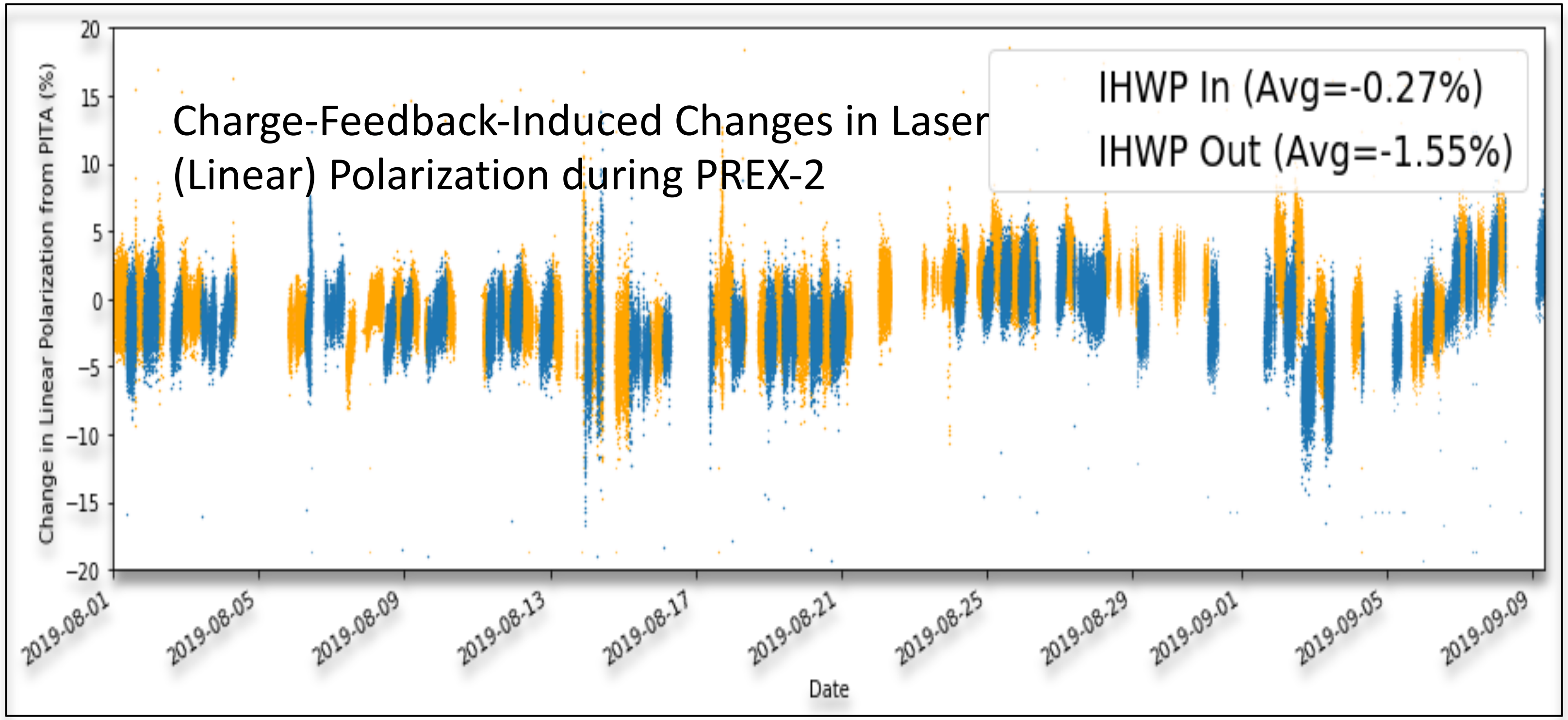
Several systematic errors are not errors in the measurement *per se* but arise from extrapolating from the dedicated measurement to the conditions of the experiment

- Laser polarization changes during Aq feedback
- Shifts in beam energy and north/south linac loading cause changes in precession
- Moller measurements taken at 1 μA but experiment runs at 70 μA

PITA Variation	—	0.06
Spin Precession (dP/P)	—	0.04
High Current Extrapolation	—	0.5
Bleedthrough	—	0.18
Slit Dependence	—	0.1

Charge-feedback-induced laser polarization changes

- To zero the charge asymmetry, active feedback on the laser polarization is employed
- With optimal laser setup, polarization tweaks are negligible, but can be significant as during PREX
- Moller measurement not taken in precisely same laser pol state, introduces new syst. error
- Solution:
  optimize laser setup and monitor changes resulted in 0.06% for CREX which is likely sufficient



Changes in precession

- We set up the beam for optimal longitudinal precession using a spin dance at the nominal energy (+/-2 deg?)
- Experience from PREX-2 and CREX where we had to carefully monitor energy showed that changes in beam energy of 0.02% were routine and 0.04% not that uncommon.
- Also, energy loading changes between the N and S linacs happens routinely as cavity performance changes
  - Polarization changes even if the energy is constant.
- At 11 GeV the beam precesses 21,000 degrees between the injector and the hall so
  - A 0.02% change in momentum yields a 0.27% change in polarization if you start at fully longitudinal
  - If you started 2 deg off longitudinal then a 0.02% change in momentum yields a 0.52% change in polarization

This may well be the hardest systematic error to deal with and may require

- Careful monitoring of dp/p and the N/S energy balance
- Requests for energy corrections when dp/p>0.02%
- More frequent measurements whenever the energy shifts
- A good precession model to correct for precession shifts

High current extrapolation, bleedthrough and slit dependence

- To ensure that the polarization is not current dependent we need an experimental plan to measure this
  - One model is that the cathode polarization depends on laser power/heating
  - One idea is to redo a former study from 2008 where they increased the pulse rate of the laser so that only a fraction of the individual electron pulses go through the slit
  - Another idea is to use Hall C's laser to heat the cathode and just dump the current on A2 while measuring with constant current in Hall A (requires dealing with bleedthrough)
- Bleedthrough: during CREX we routinely had 0.1% of our Moller rate from Hall C
  - Hall C is nominally opposite polarization so factor of 2 uncertainty for uncharacterized "stuff"
  - Difficult to control or get rid of without dedicated resources and studies
  - One option is to negotiate 30-45 minutes with Hall C off during weekly Moller measurements or opportunistically utilize time when Hall C is naturally off
- Slit dependence: we close the slit during Moller measurements to reduce bleedthrough from Hall C
  - If we solve the bleedthrough problem, this goes away. Otherwise, need a plan to systematically measure it.

Conclusions

- Many sources of error including bleedthrough, slit dependence, accidental, null and charge corrections, and PITA variations from Aq feedback have natural solutions from careful setup and measurement plans
- Extrapolation to high current and slit dependence can be measured with dedicated studies
- Foil saturation remains a high concern and is currently being investigated
- Energy changes at the few parts in ten thousand level that happen routinely in the accelerator can lead to significant polarization changes. Careful planning and monitoring will be required.
- Refinement/verification of our simulation model is expected with addition of the GEMs.

To-Do List before MOLLER

1. Measure and minimize sensitivity to foil alignment/angle
2. Verify dead time correction method is valid
3. Investigate options for limiting detector vertical acceptance
4. Verify new electron wave functions for Fe
5. Investigate use of new data from GEMs for understanding model
6. Build and install new GEMs
7. Incorporate GEMs into existing DAQ and analyzer
8. Create plan for measuring current dependence of polarization
9. Create plan for verifying foil alignment in beam
10. Create plan for dealing with changes in dp/p
11. Decide how to deal with bleedthrough