Precision Møller Polarimetry

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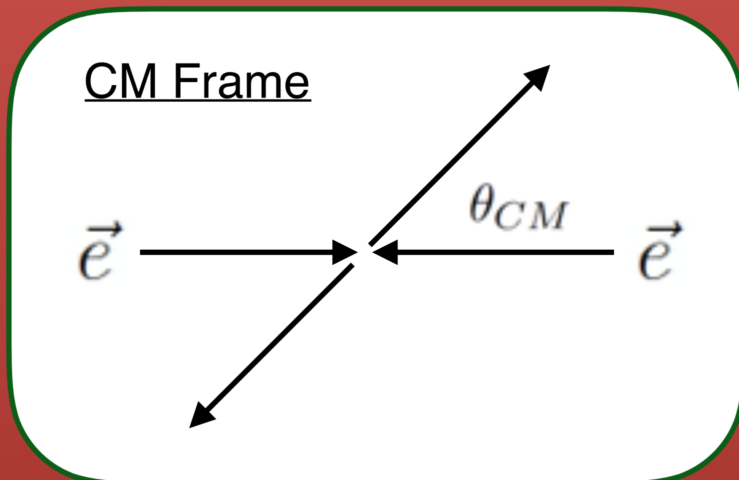
Pedagogy: Goals for Polarimetry

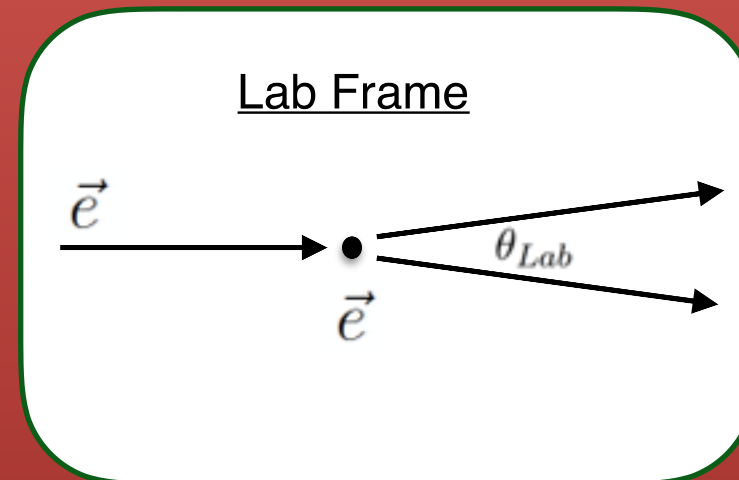
- Capable at operating at entire range of beam energies (1-11Gev)
- Precision longitudinal polarization measurements

  Short Term: ~1%

  Long Term: < 0.5% (0.42% MOLLER)
- Strive for 0.1% uncertainty on all systematics
- Demonstrate saturation of target

Pedagogy: Møller Scattering





Large at 90°CM = -7/9

In the CM Frame:

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

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

Pedagogy: Calculating Beam Polarization

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

- **Beam Polarization**: $\mathcal{P}_z^{beam}$
- **Measured** Asymmetry: A_{beam}
- Target Polarization from **Theory**: $\mathcal{P}^{Foil}$
- Average analyzing power from **Simulation**: $\langle A_{zz}\rangle$

Error Budget

Table 2: Systematic error summary for Møller polarimeters at JLab. The Hall C polarimeter is described in [10] and the tilted-foil Hall A polarimeter is described in [7, 8].

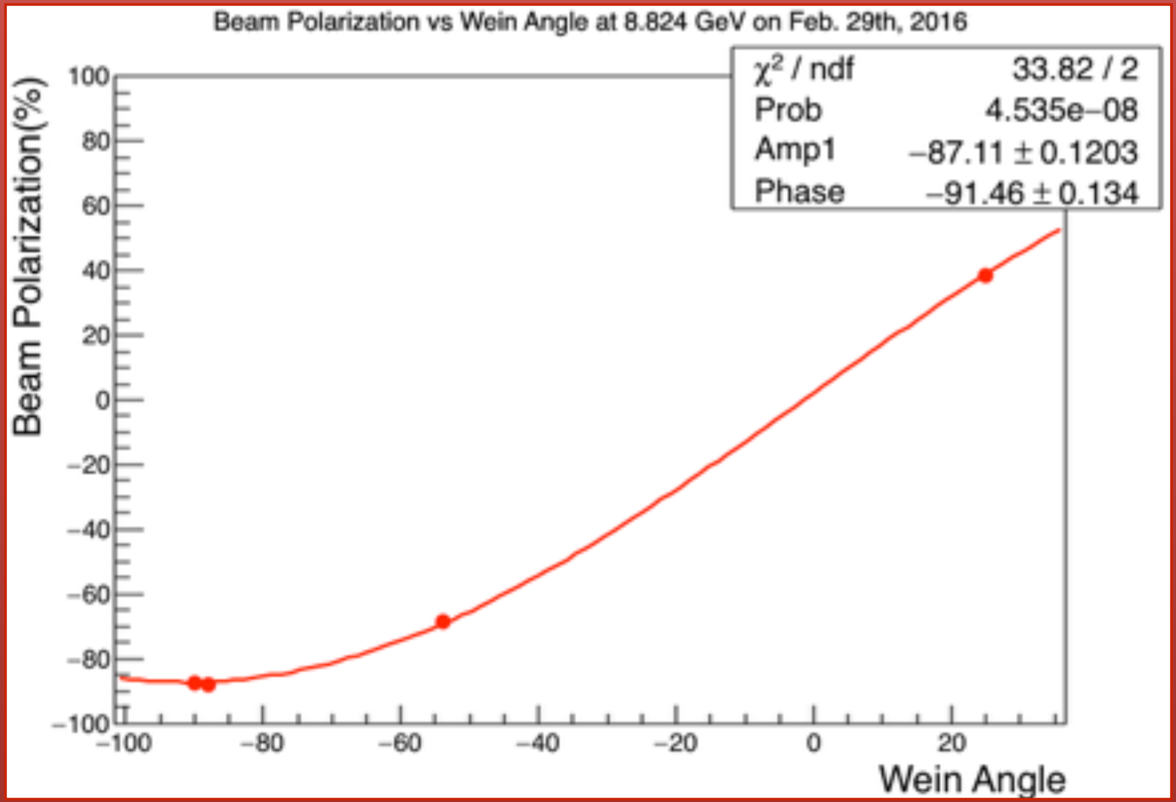
Systematic Effect	Hall C	Hall A		Strategic Approach
		Tilted	**Proposed**	
Target polarization	0.25%	1.50%	**0.25%**	Demonstrate saturation vs **B** ...
Target angle	⋆	0.50%	⋆	... and tilt angle
Analyzing power	0.24%	0.30%	**0.20%**	Accurate spectrometer simulation
Levchuk effect	0.30%	0.20%	**0.20%**	Simulation w/atomic modeling
Target heating	0.05%	‡	**0.05%**	Match data to heating calculation
Dead time	‡	0.30%	**0.10%**	Confirm "zero dead time" w/FADC
Background	‡	0.30%	**0.10%**	Measurements with beam
Others	0.10%	0.50%	**0.10%**	*See text*
Total	0.47%	1.8%	**0.42%**	

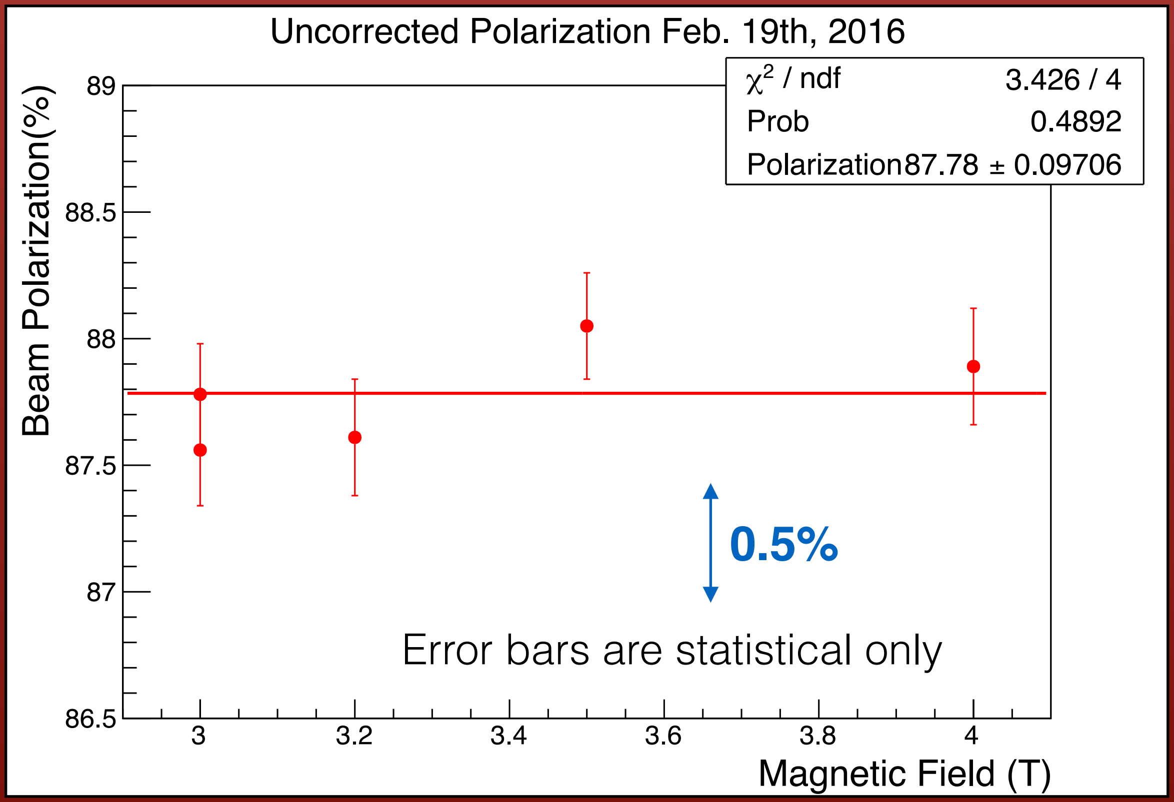
⋆: Not applicable ‡: Assumed zero

See Don Jones' new tech note

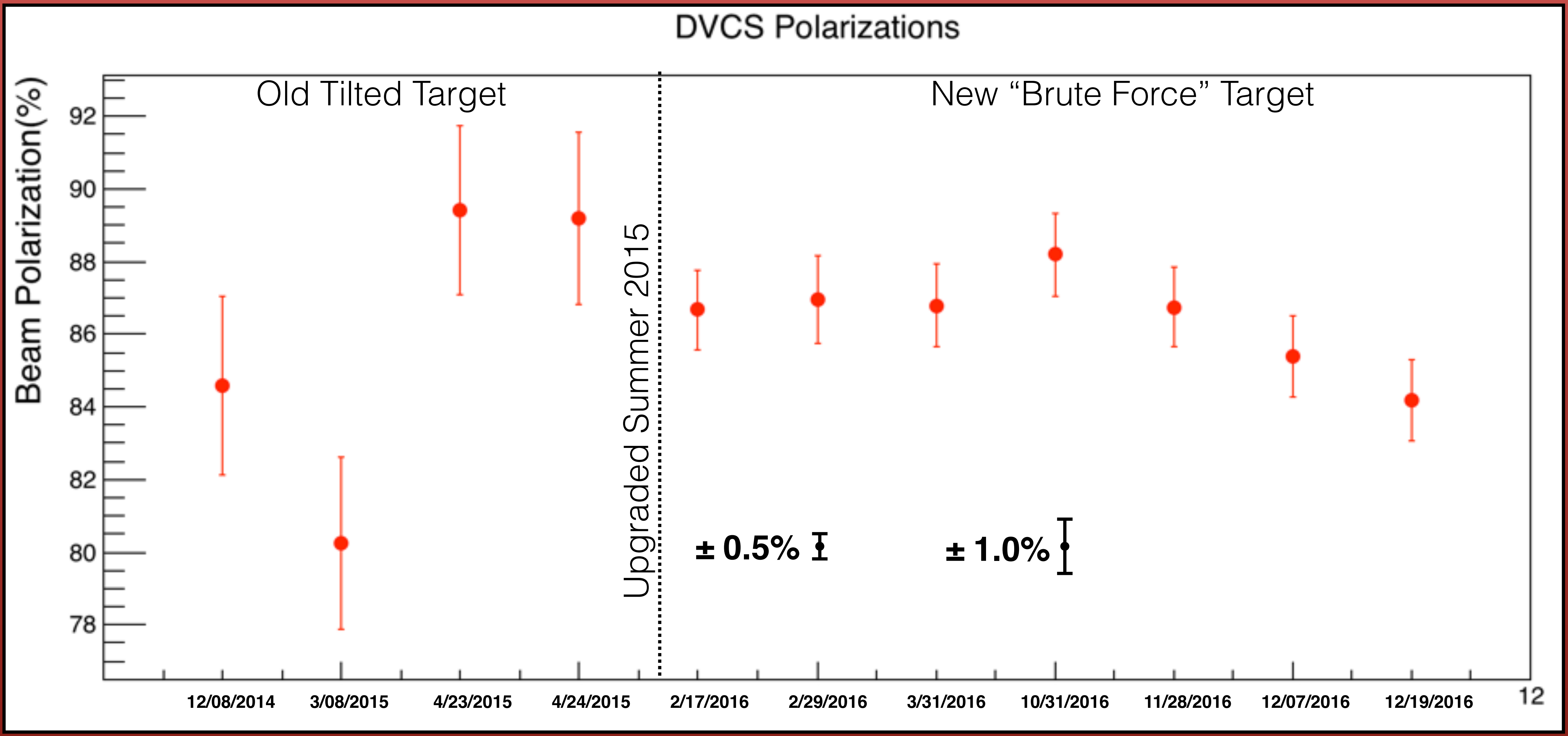
Geant3 (Sasha)
Geant4 under development (Sangwha)

Latest Results from DVCS





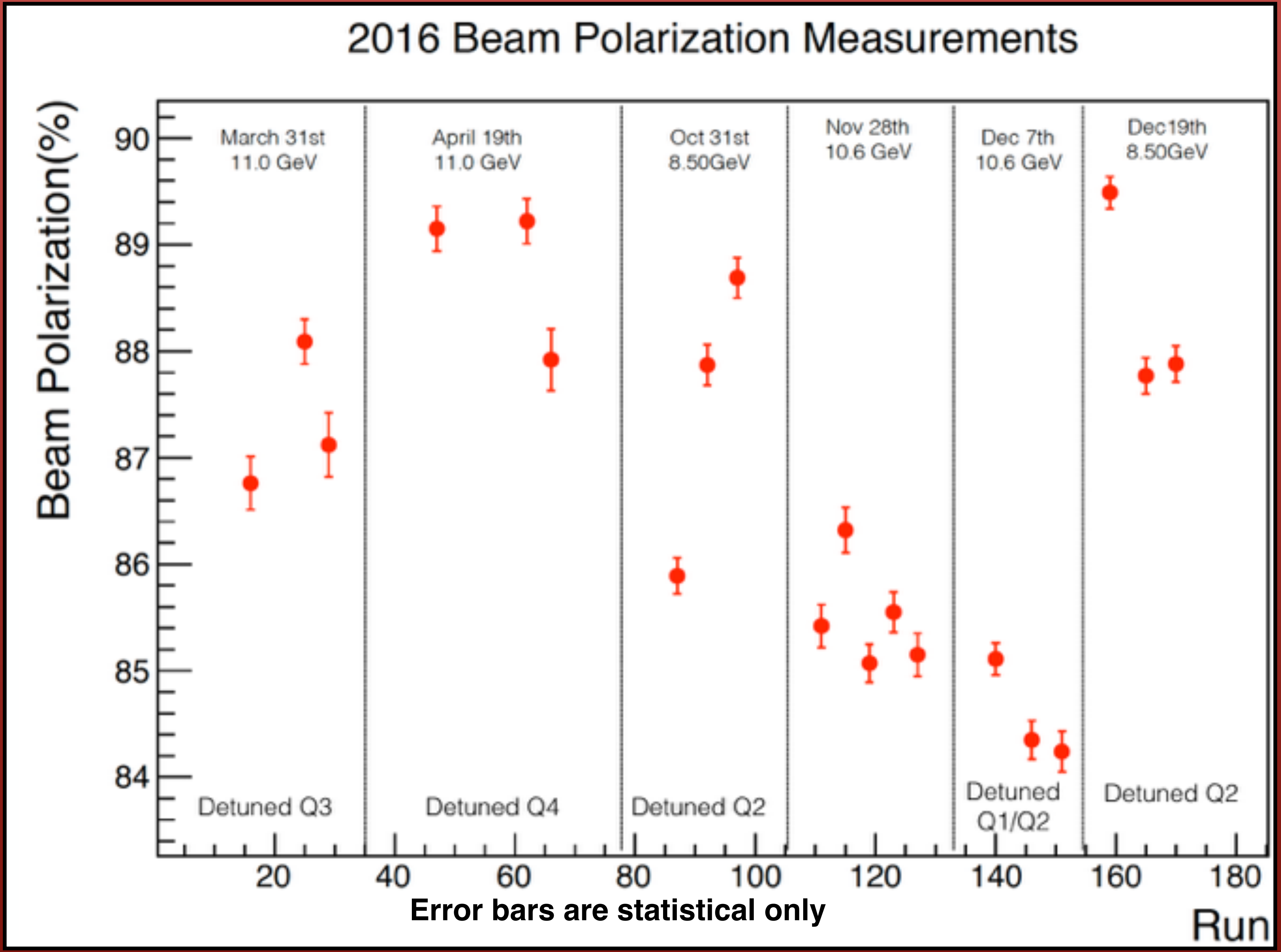
Latest Results from DVCS



Error Bars include statistical and systematic errors

Latest Results from DVCS

"Raw" polarizations not corrected for Levchuk effect and different analyzing powers at different quad settings

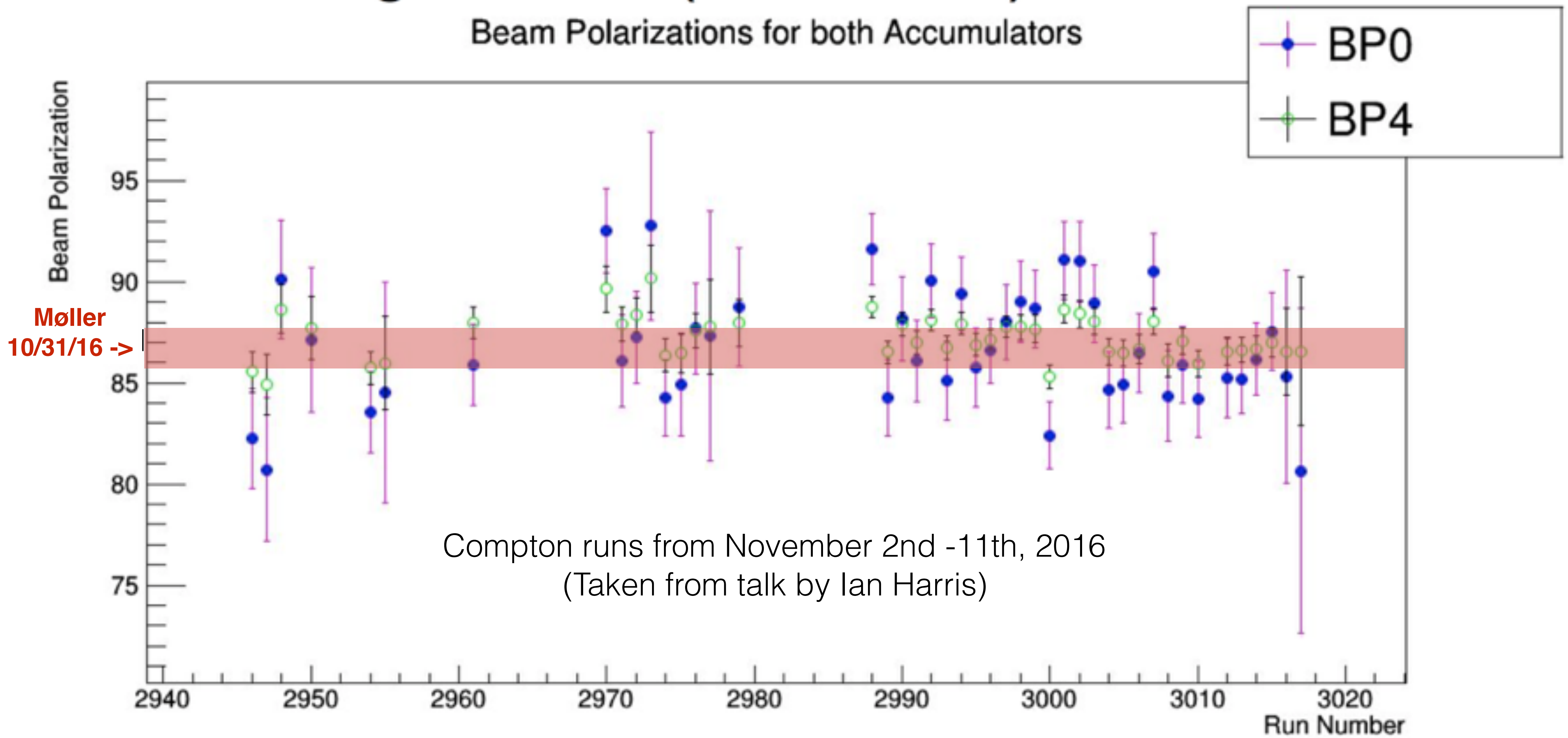


Need accurate simulation to compute corrections at sub 1% level!

Latest Results from DVCS

Comparison with Compton

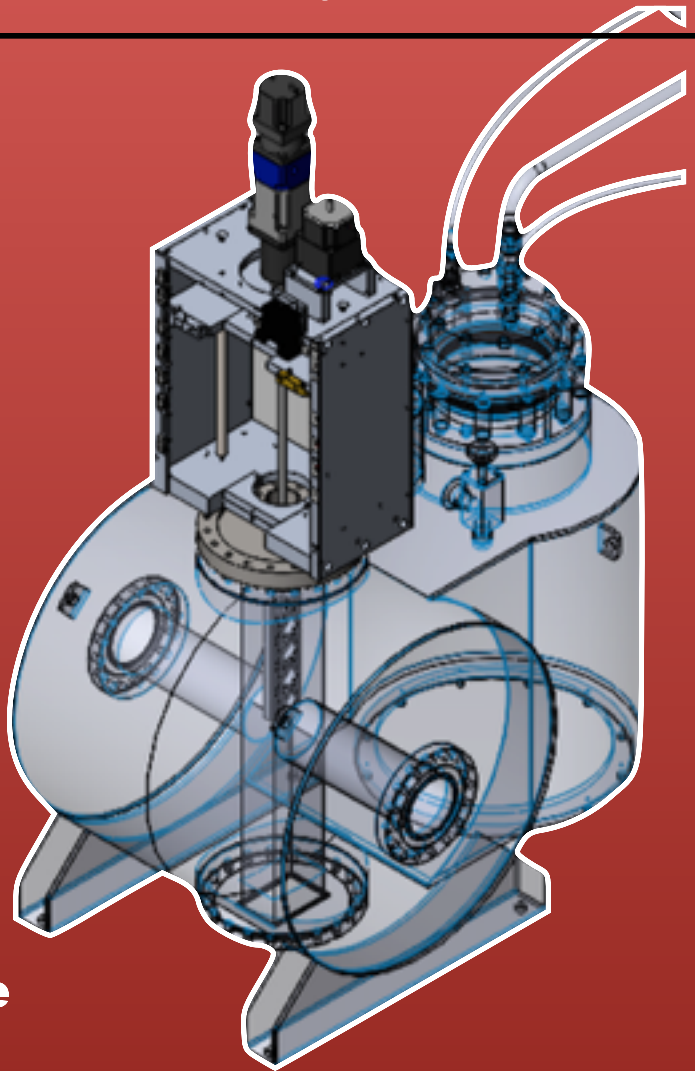
Beam polarizations given by accumulators 0 and 4 were in fair agreement (1.13 stdev)

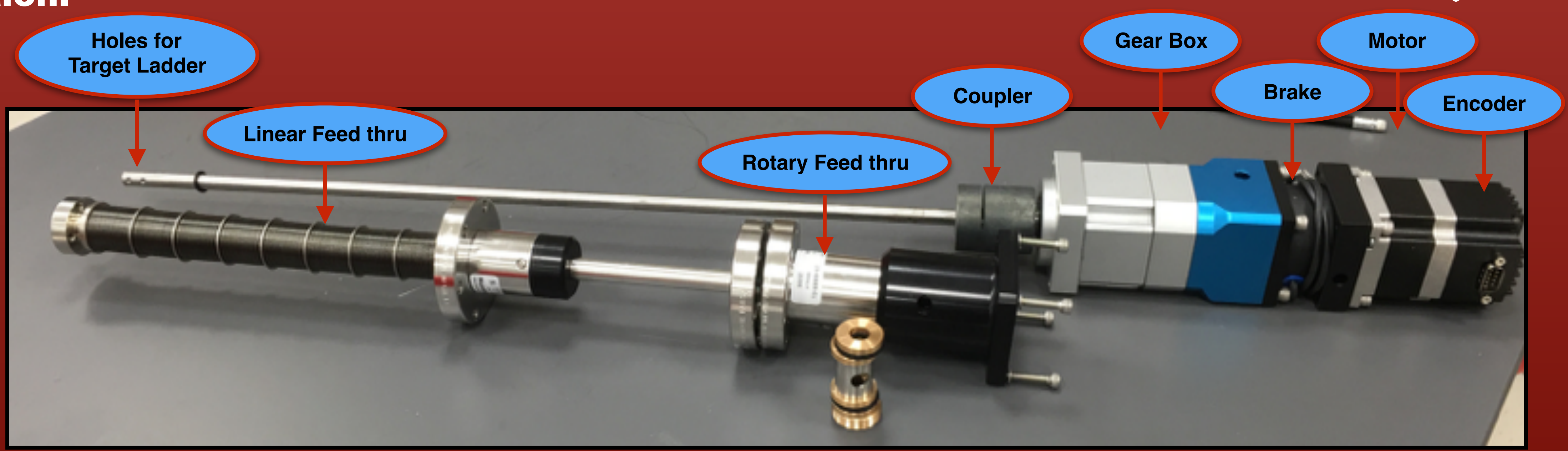


Møller error band includes statistical and systematic errors

Ongoing Projects and results: New Motion System

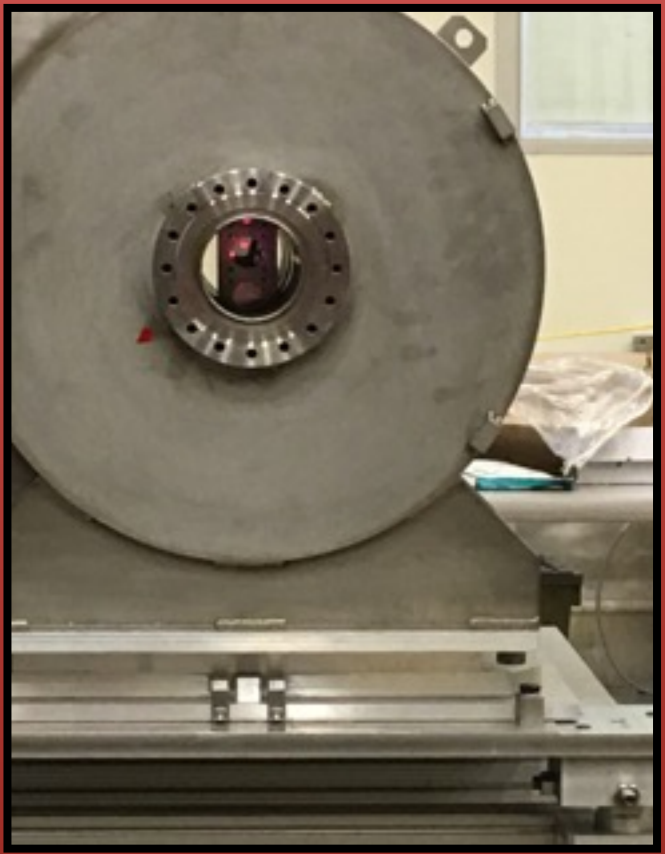
- Larger 3/8" Direct Drive Shaft with replaceable EPDM seals
- Linear Bearings for increased lateral support
- 50:1 Gearbox (greater precision while reducing motor load)
- Power Off Brake (reduces motor load and lock rotation)
- Digital Encoder with home index (Resolution <0.001°)
- Tests at Temple JLab, with an Arduino micro controller, demonstrate repeatability and < 0.01° precision
- Absolute angular position found with index channel on encoder ("Home" every 7.2°)
- Built an additional angular position readback using potentiometer. This will be a back up for the encoder as well as removing ambiguity of home position.

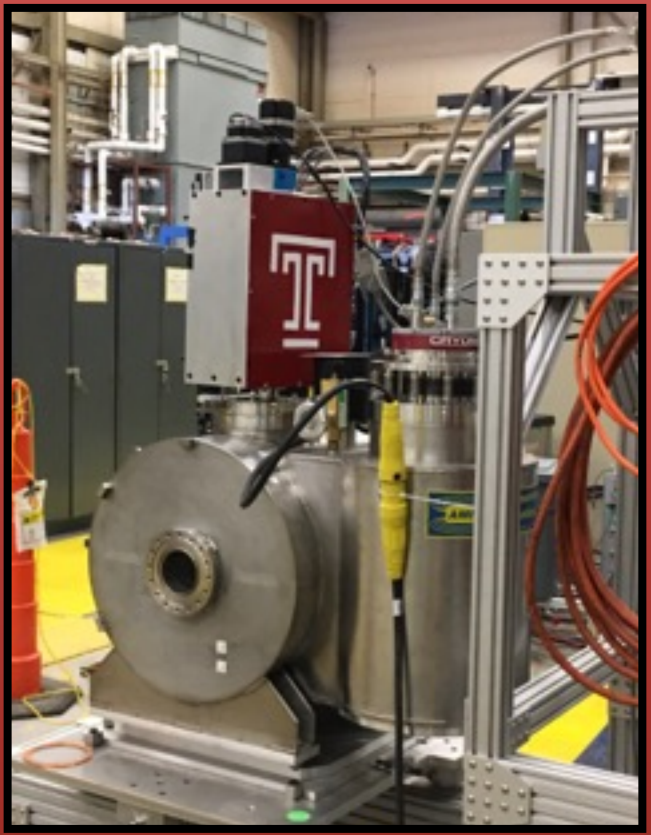




Ongoing Projects and results: New Motion System

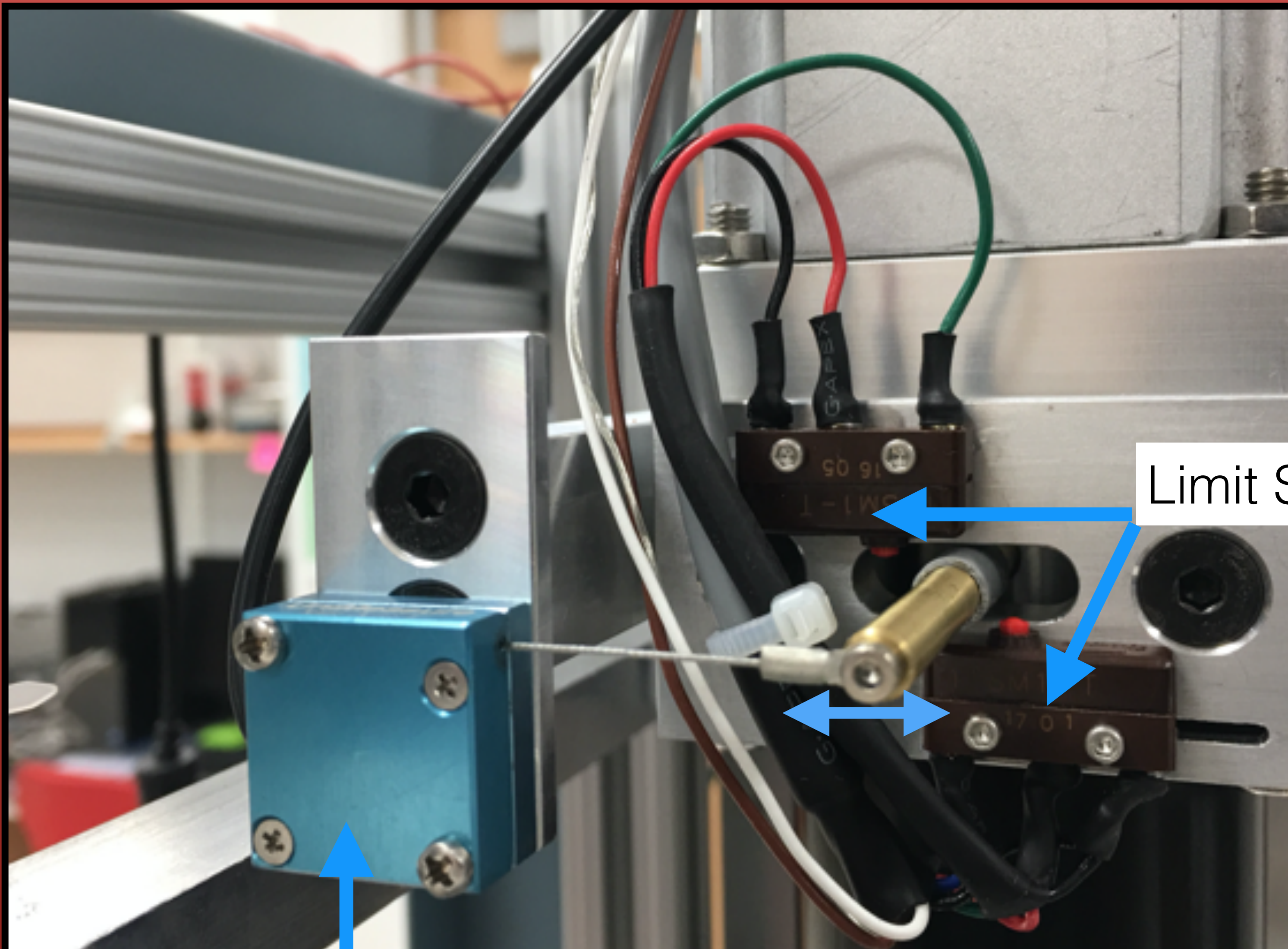
Test Lab

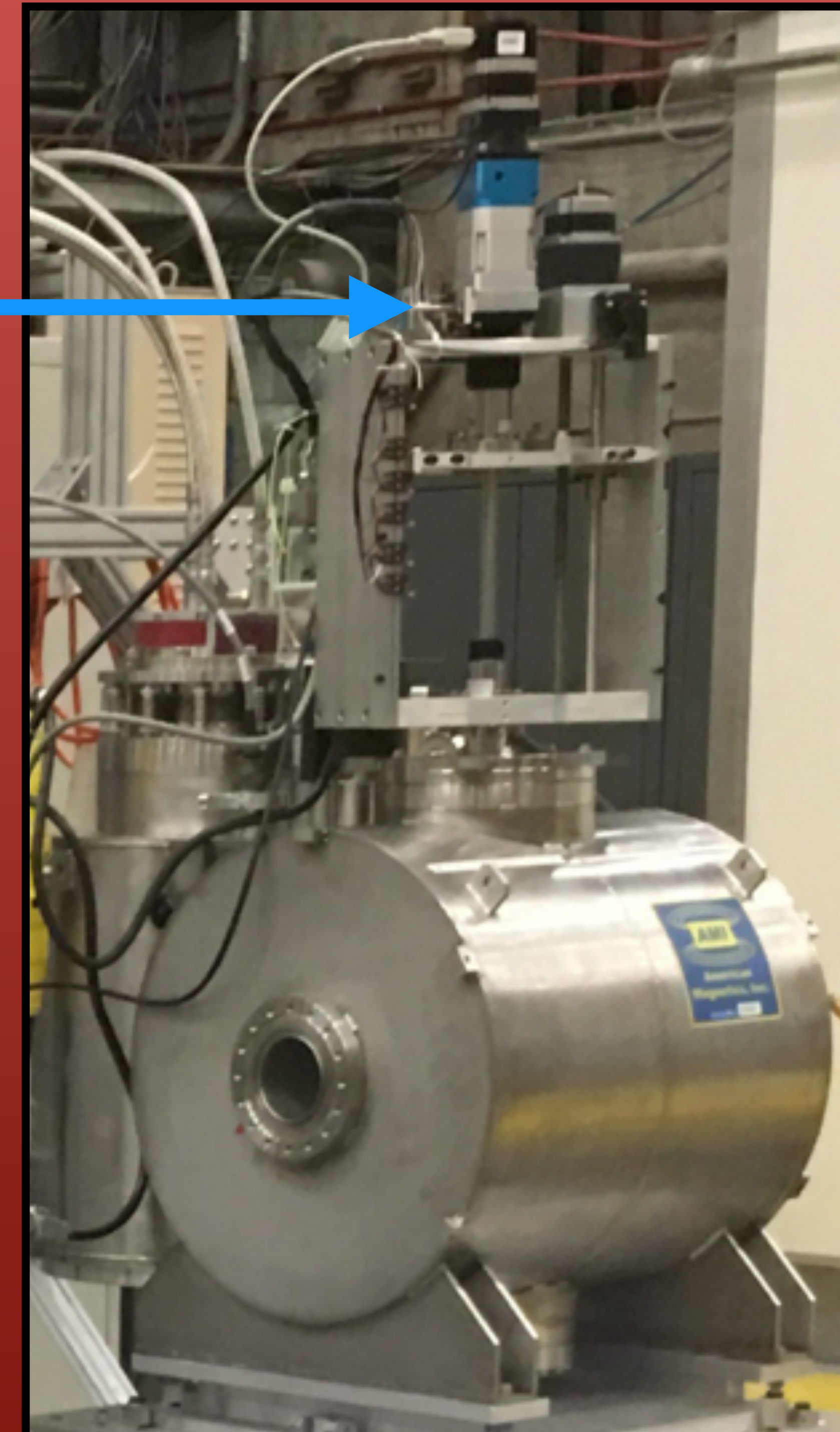




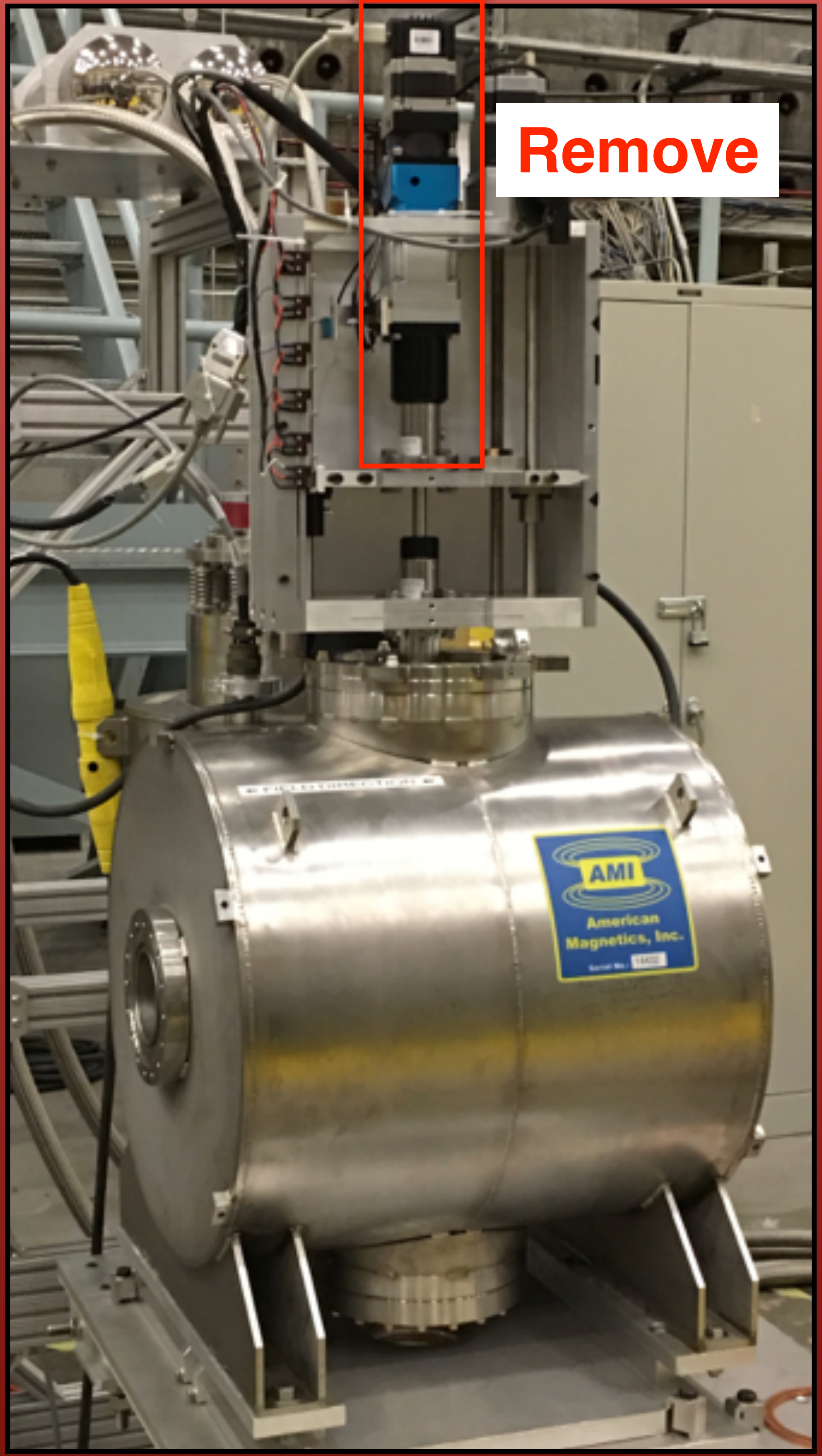
Ongoing Projects and results: New Motion System

Additional “Encoder” Add-on





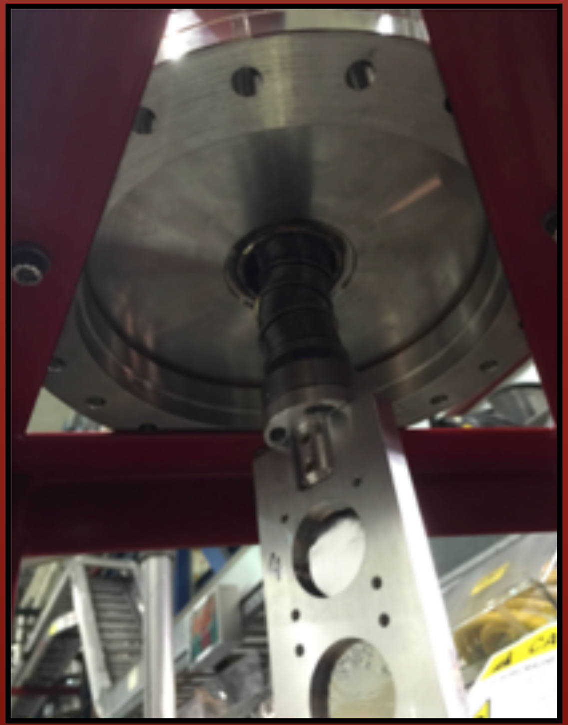
Ongoing Projects and results: Plan for if o-rings fail

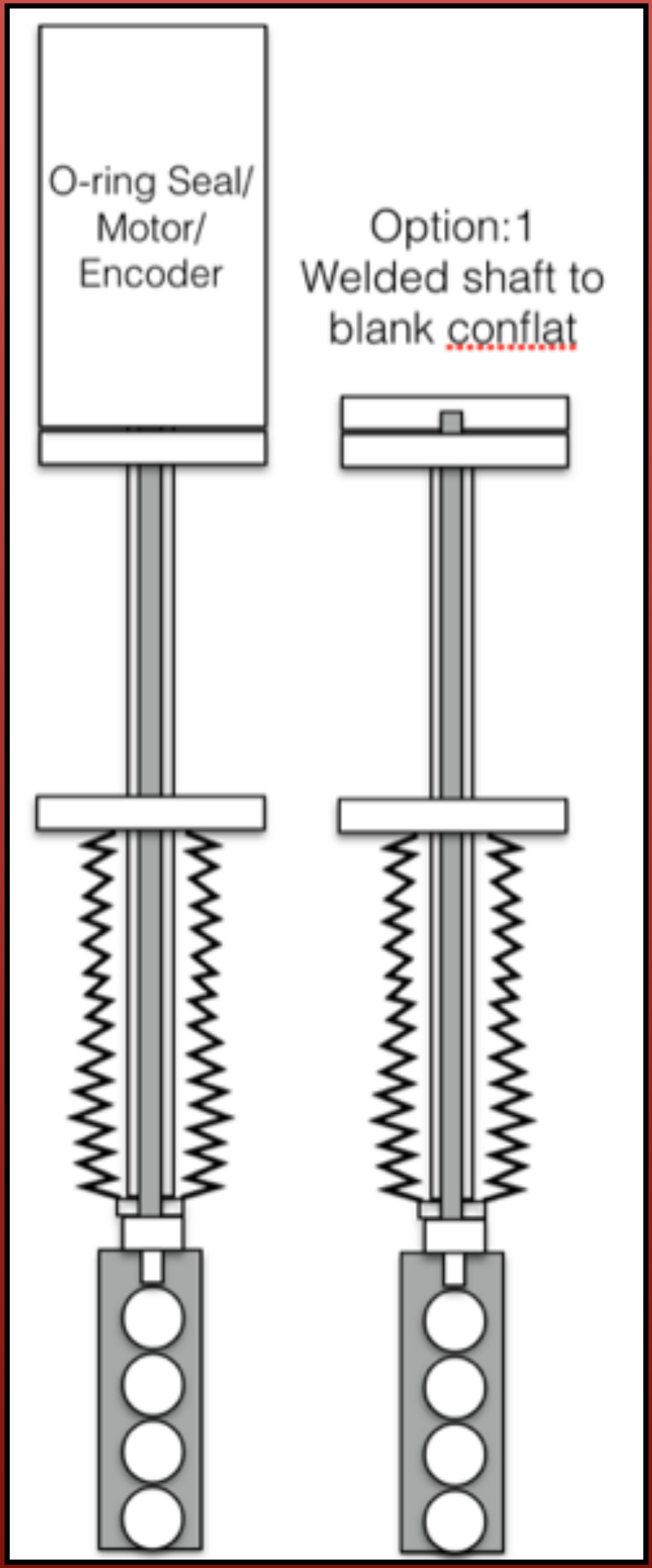


Note: Would mean loss of foil rotation

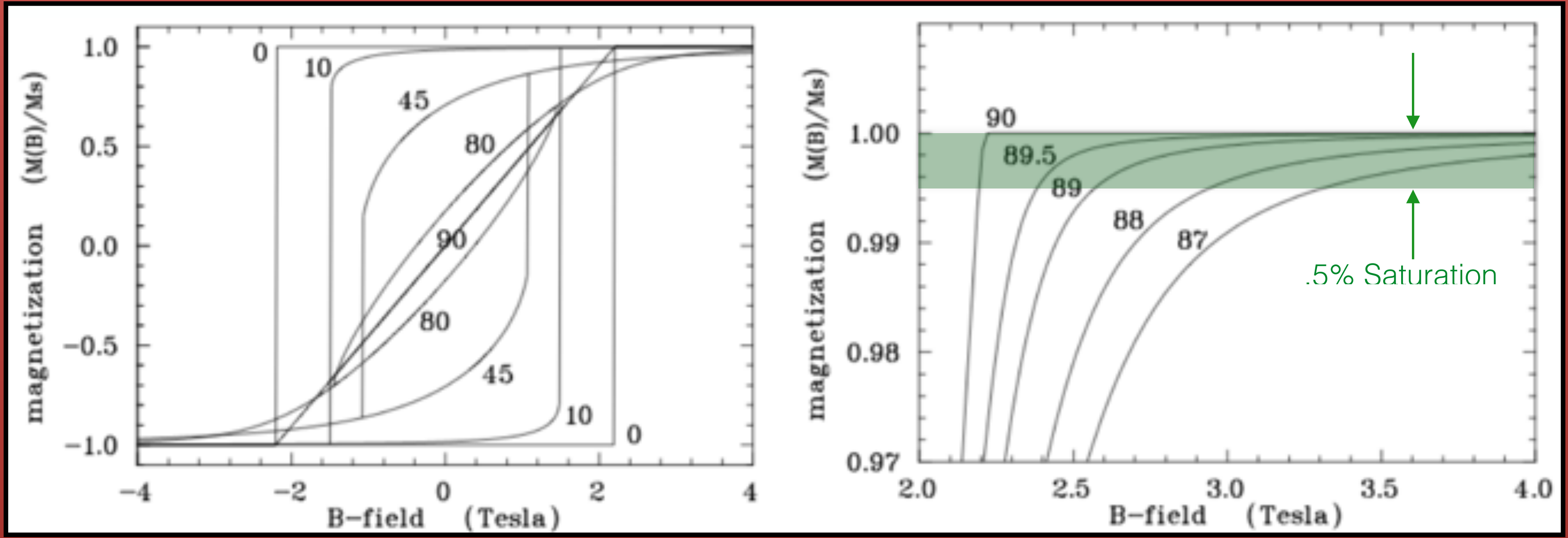
Replacement shaft

There is also tapped holes at the end of the bellows where one could attach the target ladder.

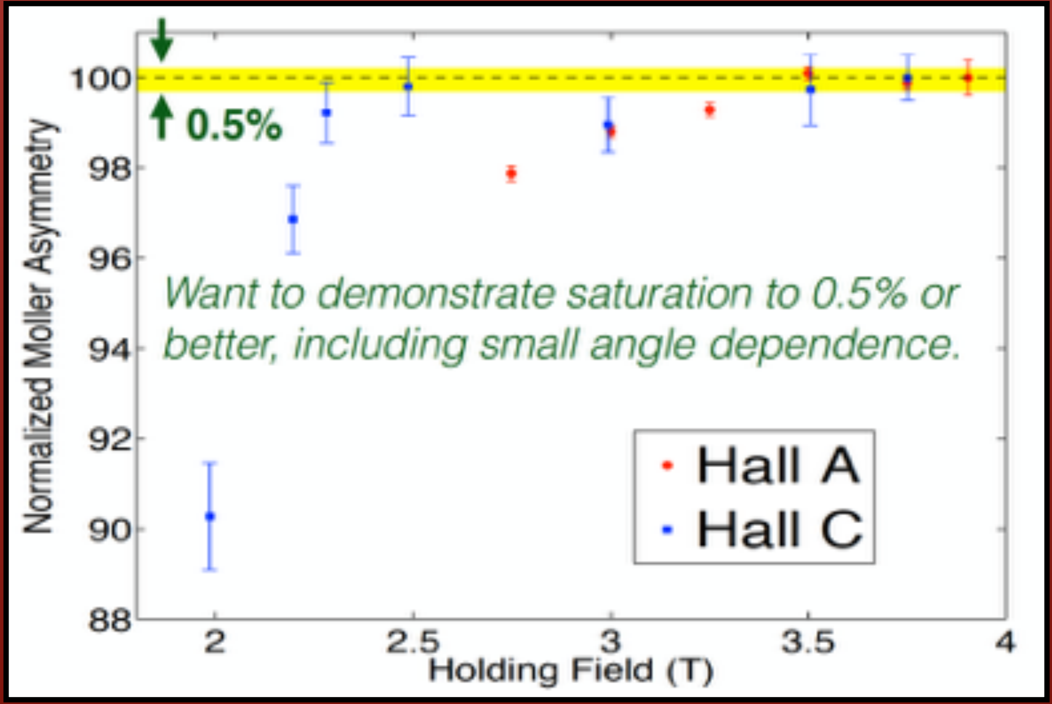




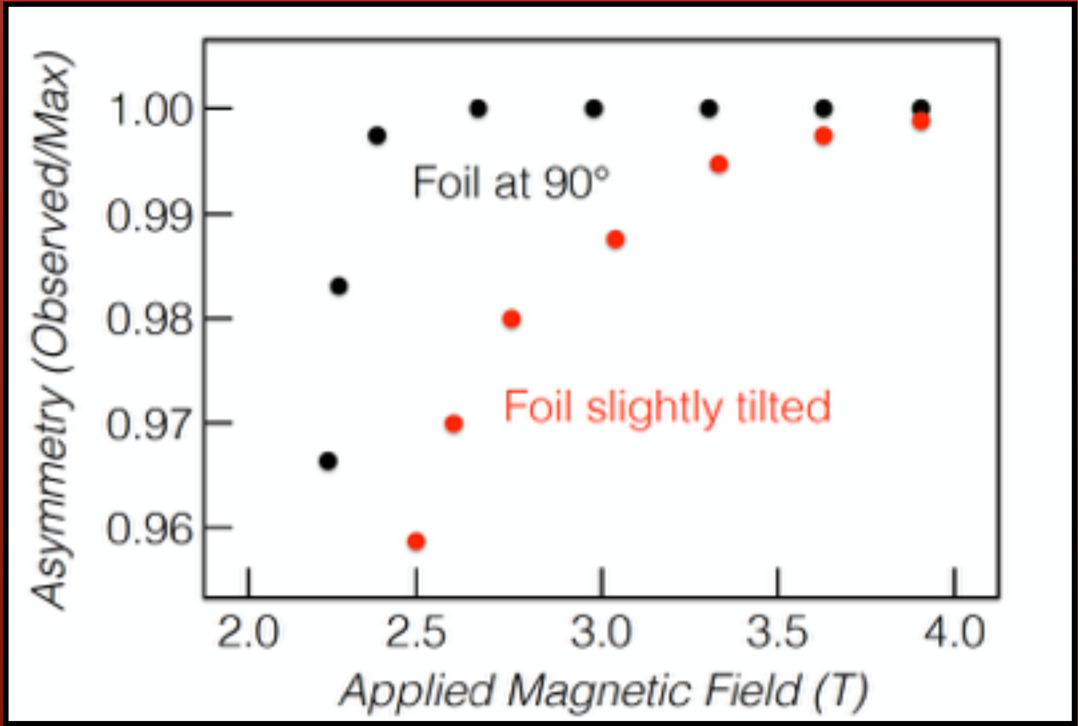
Ongoing Projects and results: Kerr Effect and Target Angle



Old Data



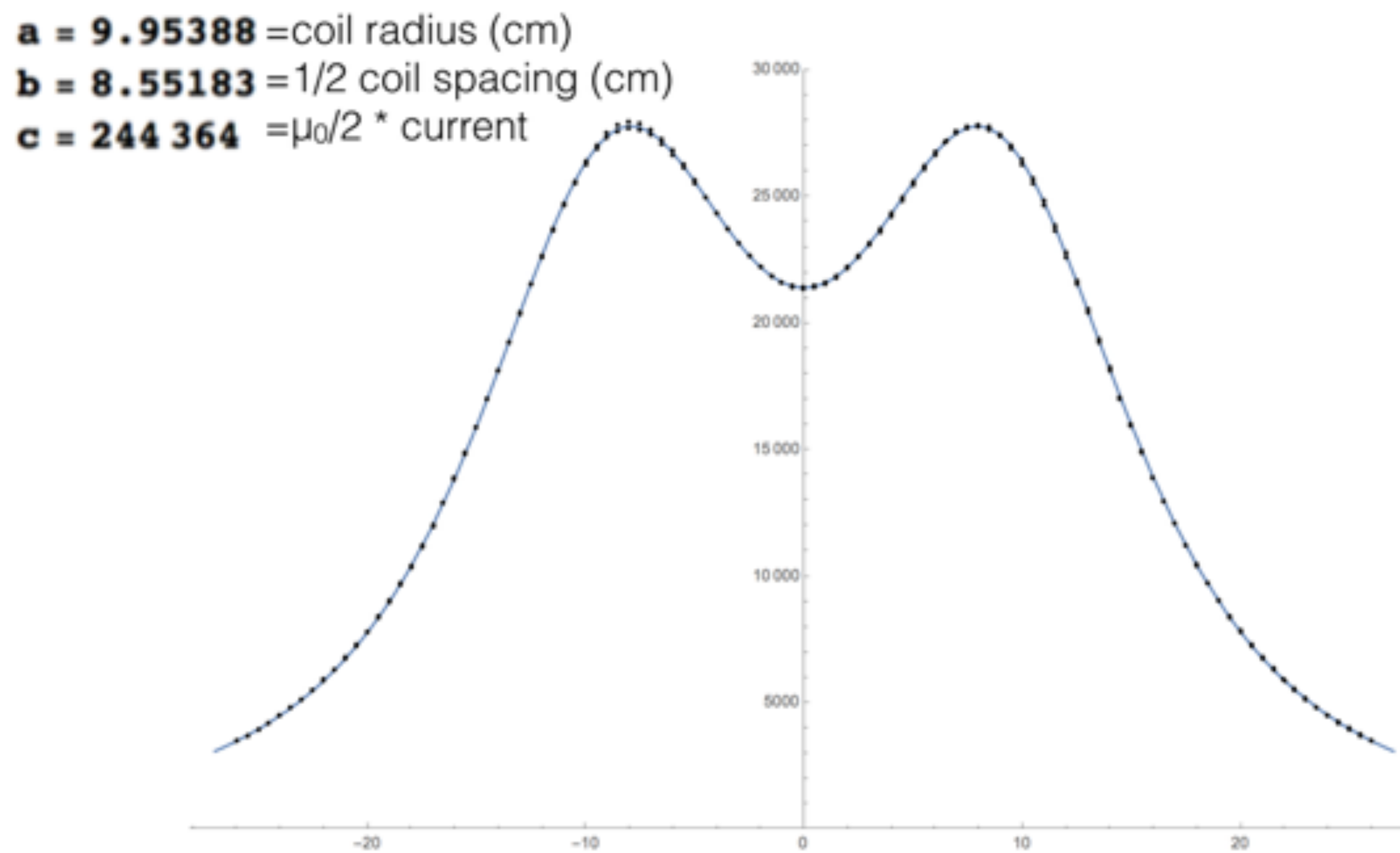
Ultimate Demonstation



Ongoing Projects and results: SC Magnet Mapping

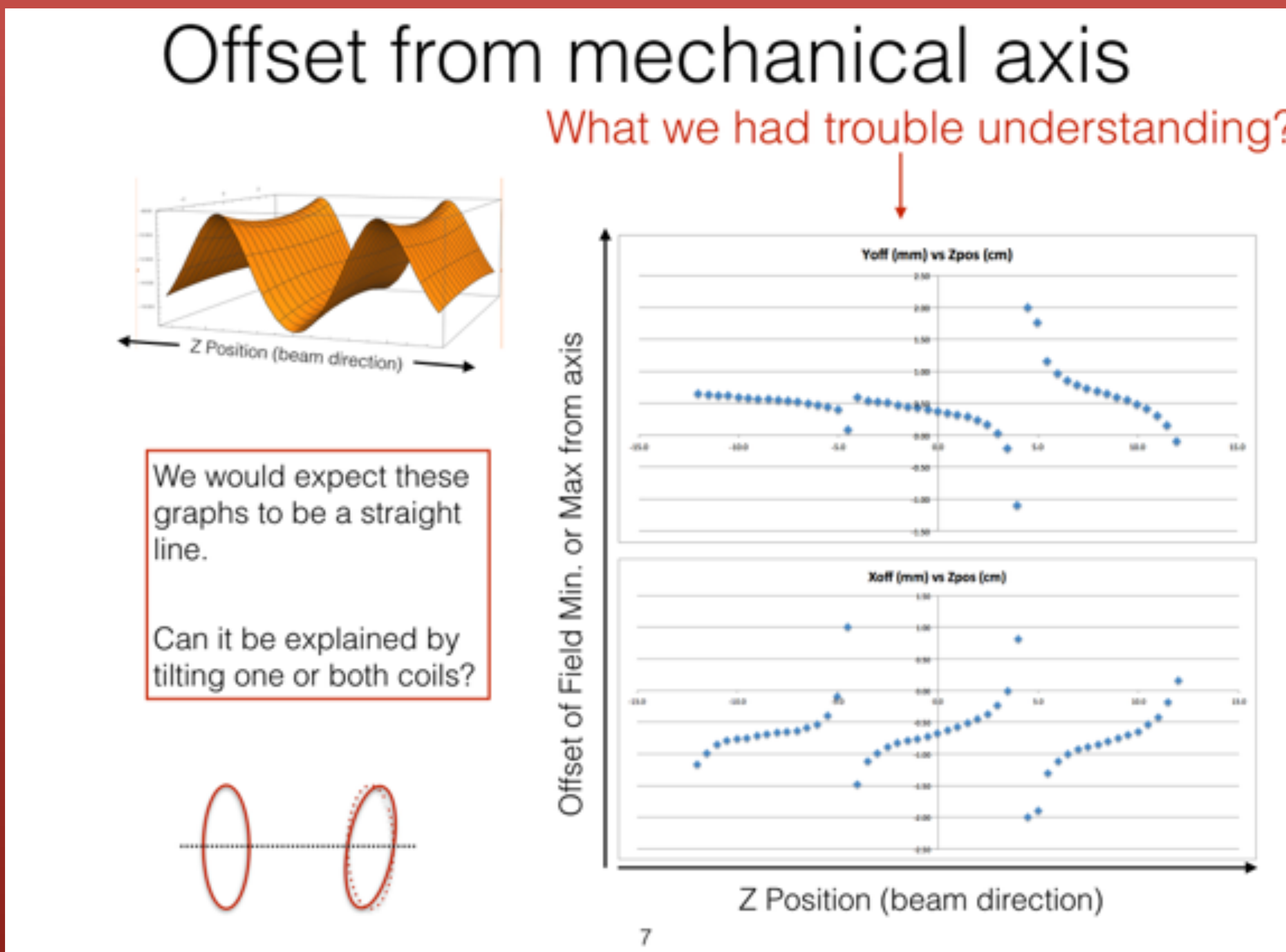
- SC Magnet was mapped Sept 2015
- Data has been analyzed and well understood
- Mechanical and Magnetic axis are aligned to within 0.25° and < 1mm
- To Do: Incorporate into optic model to ensure single iteration on alignment is sufficient

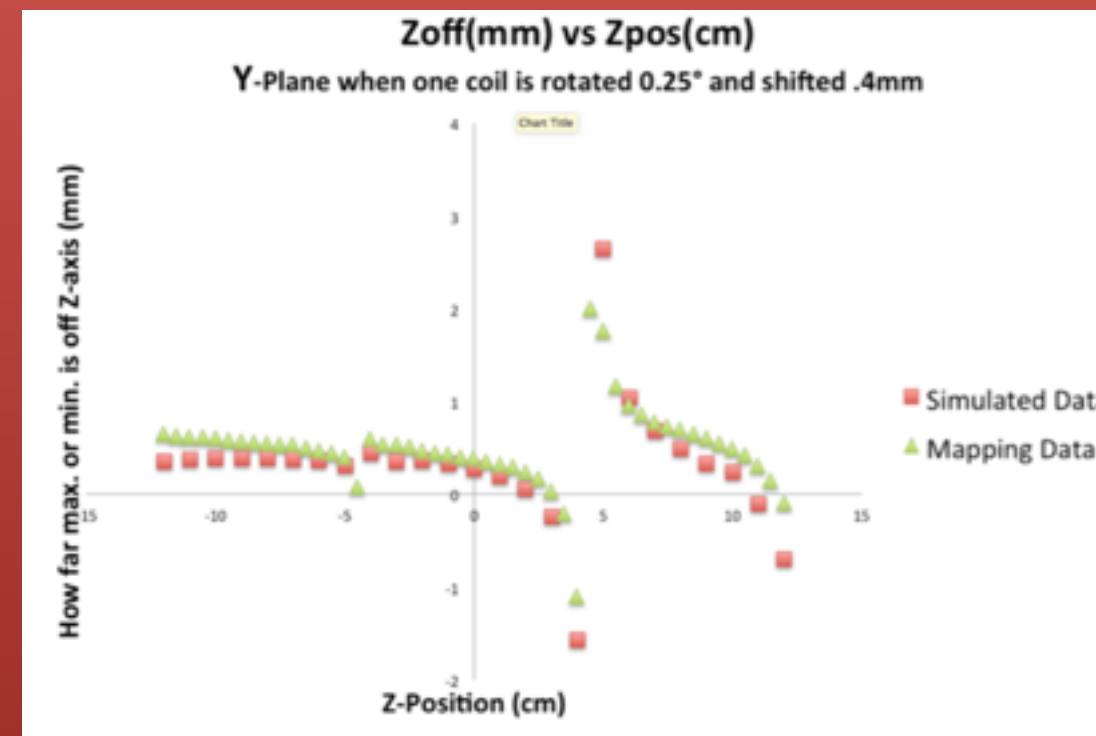
Three parameter fit with mathematica

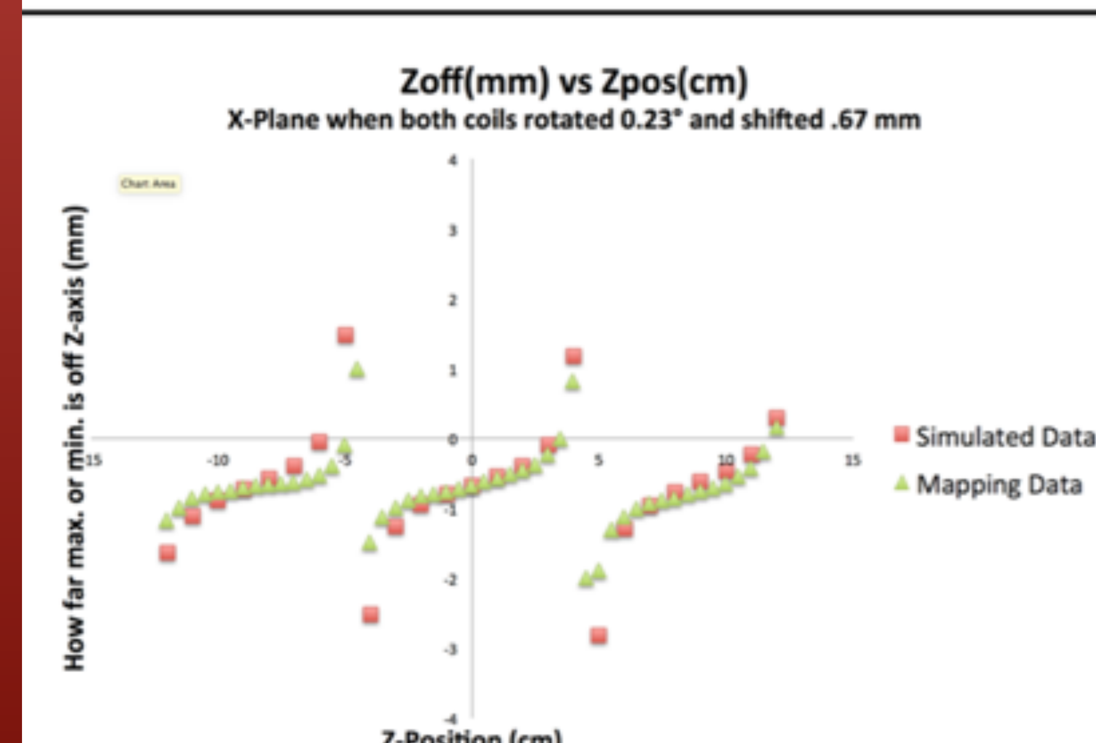


Equation with parameters is accurate to within 1%

Ongoing Projects and results: SC Magnet Mapping





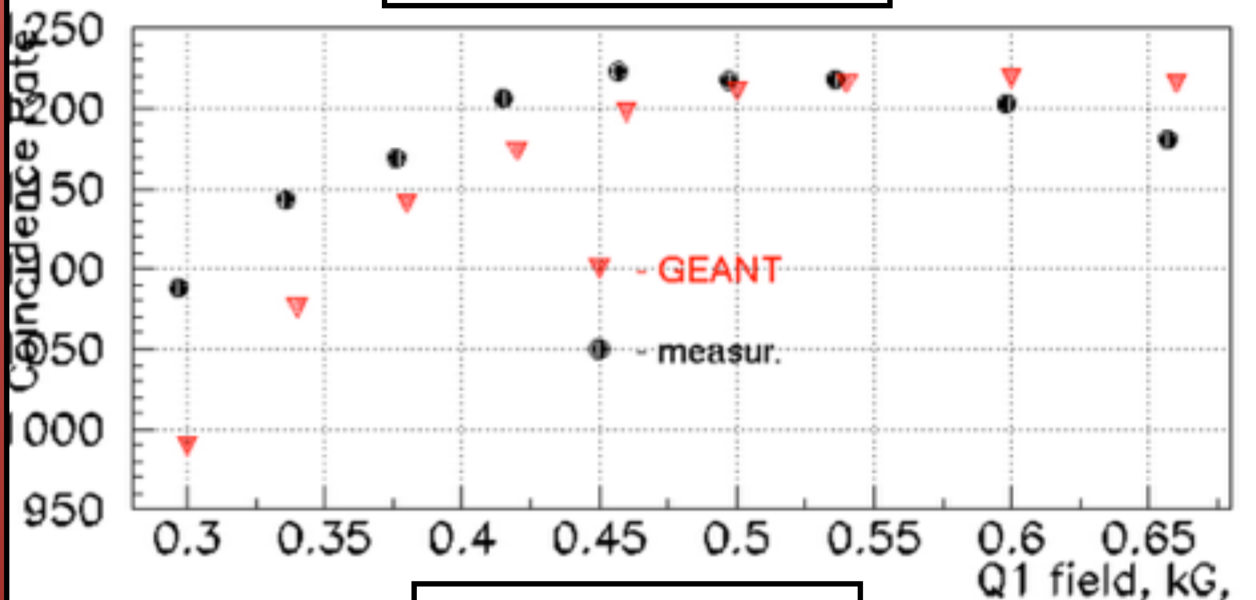


- This summer we explained some confusion with the data

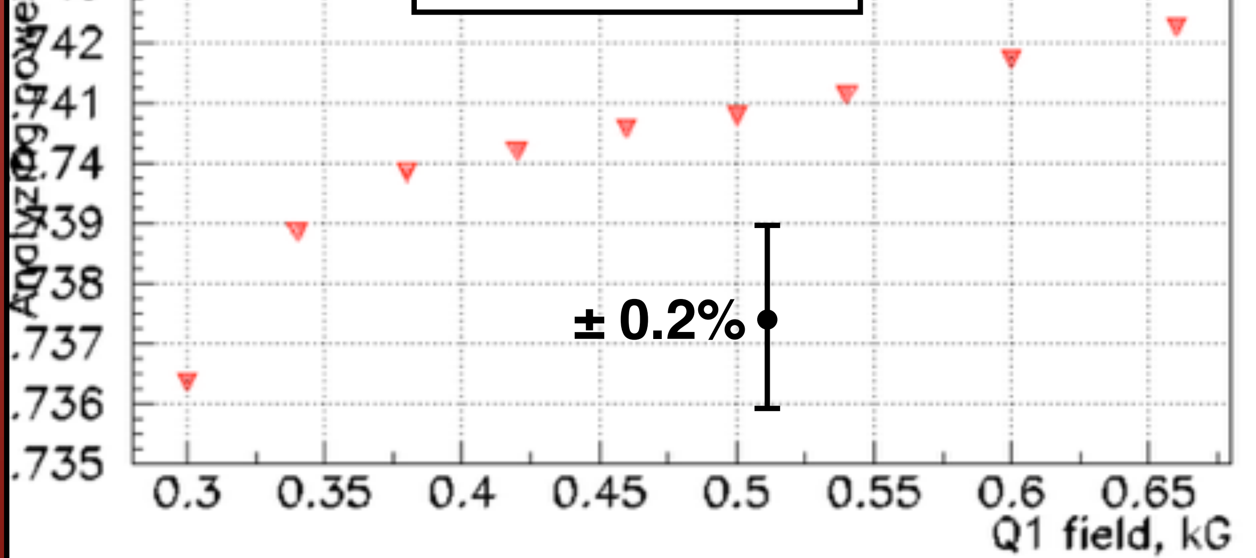
Ongoing Projects and results: SC Magnet Mapping

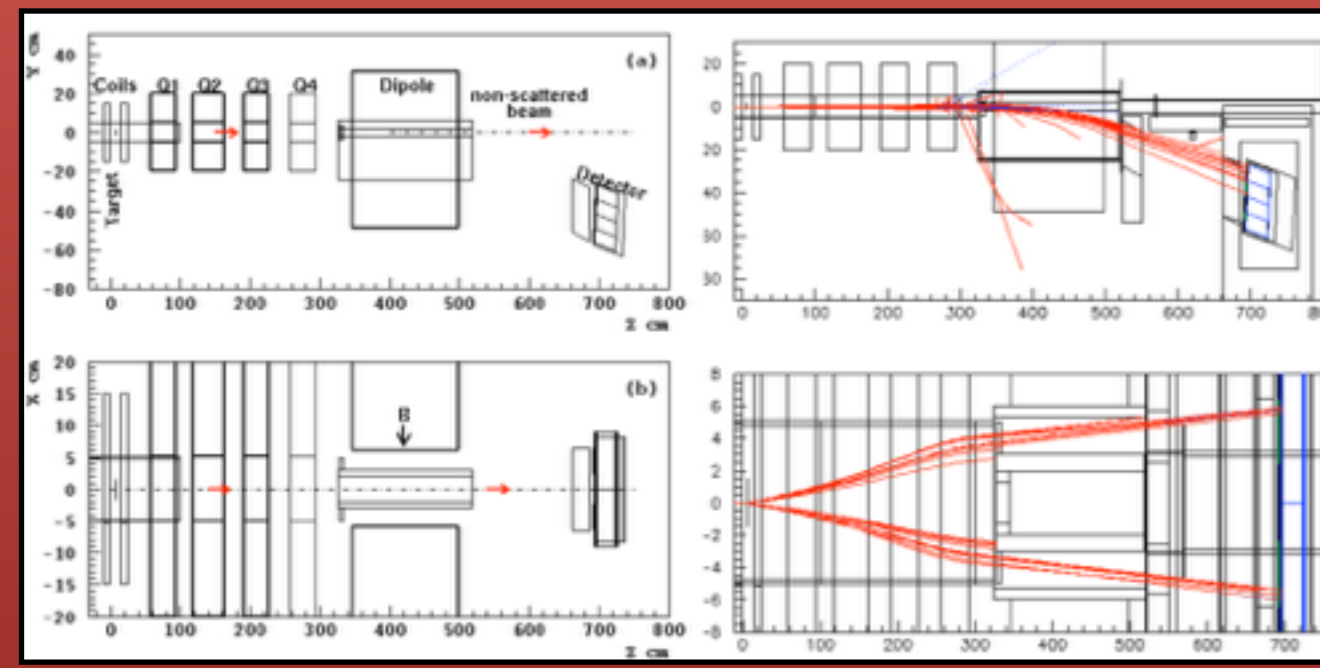
Geant3

Coincidence Rates

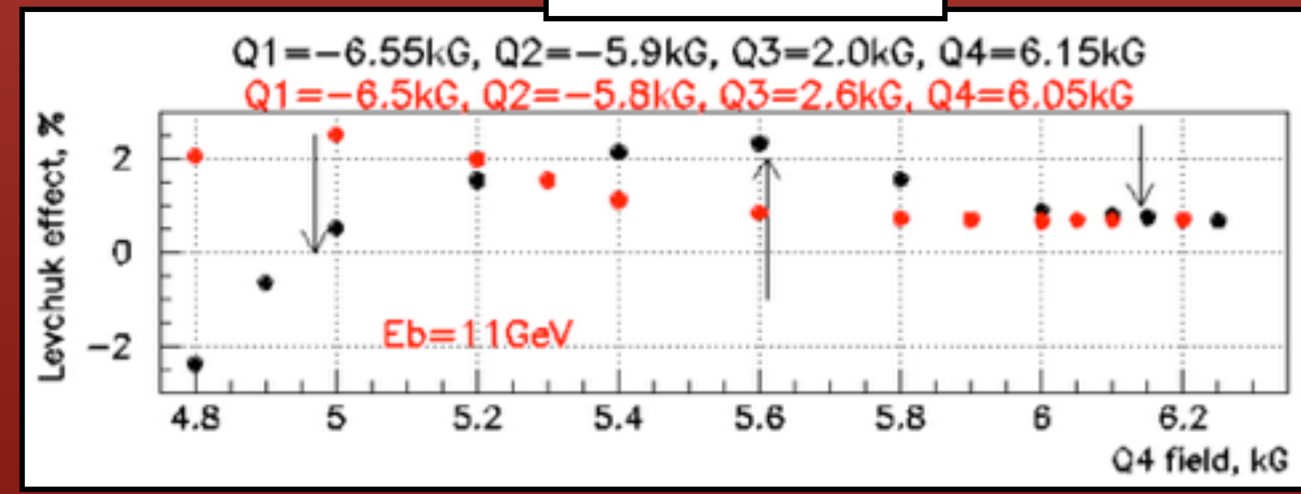


Analyzing Power





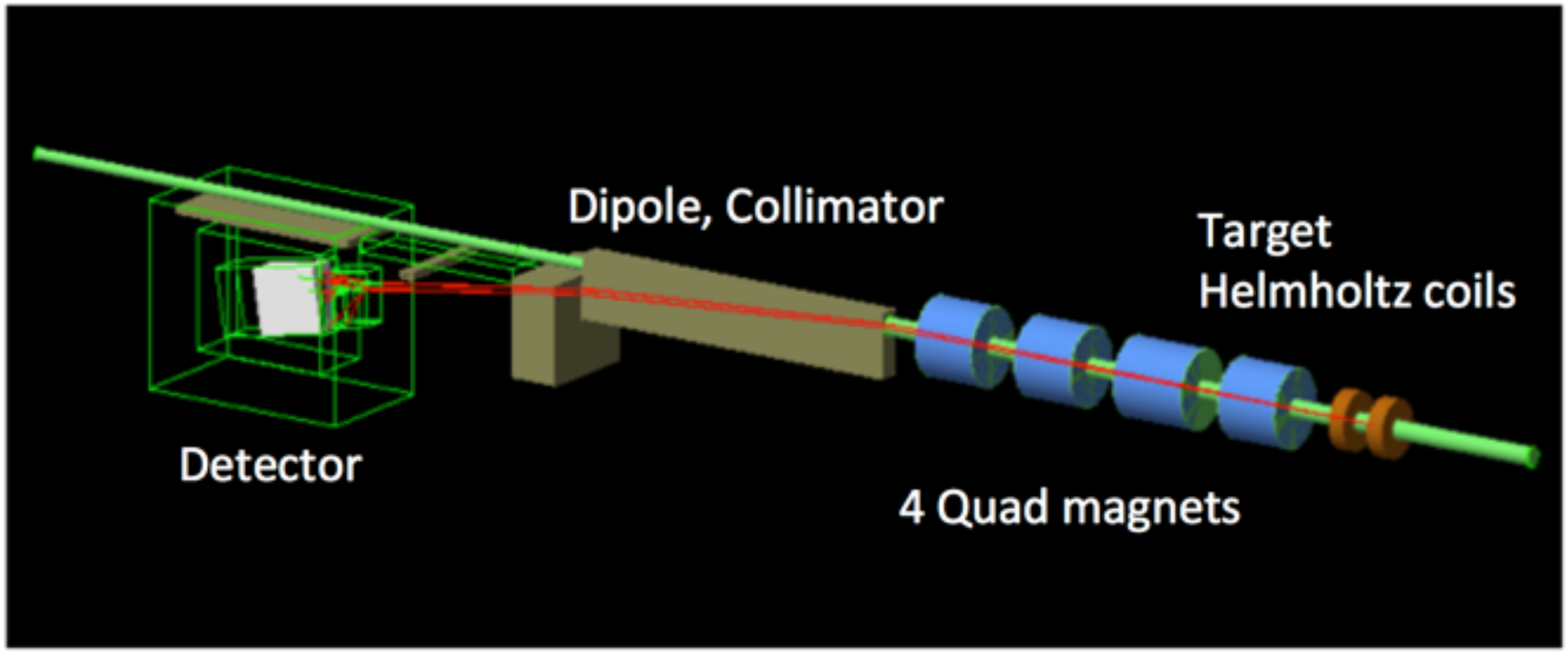
Levchuk Effect



Figures from Sasha's elog entry

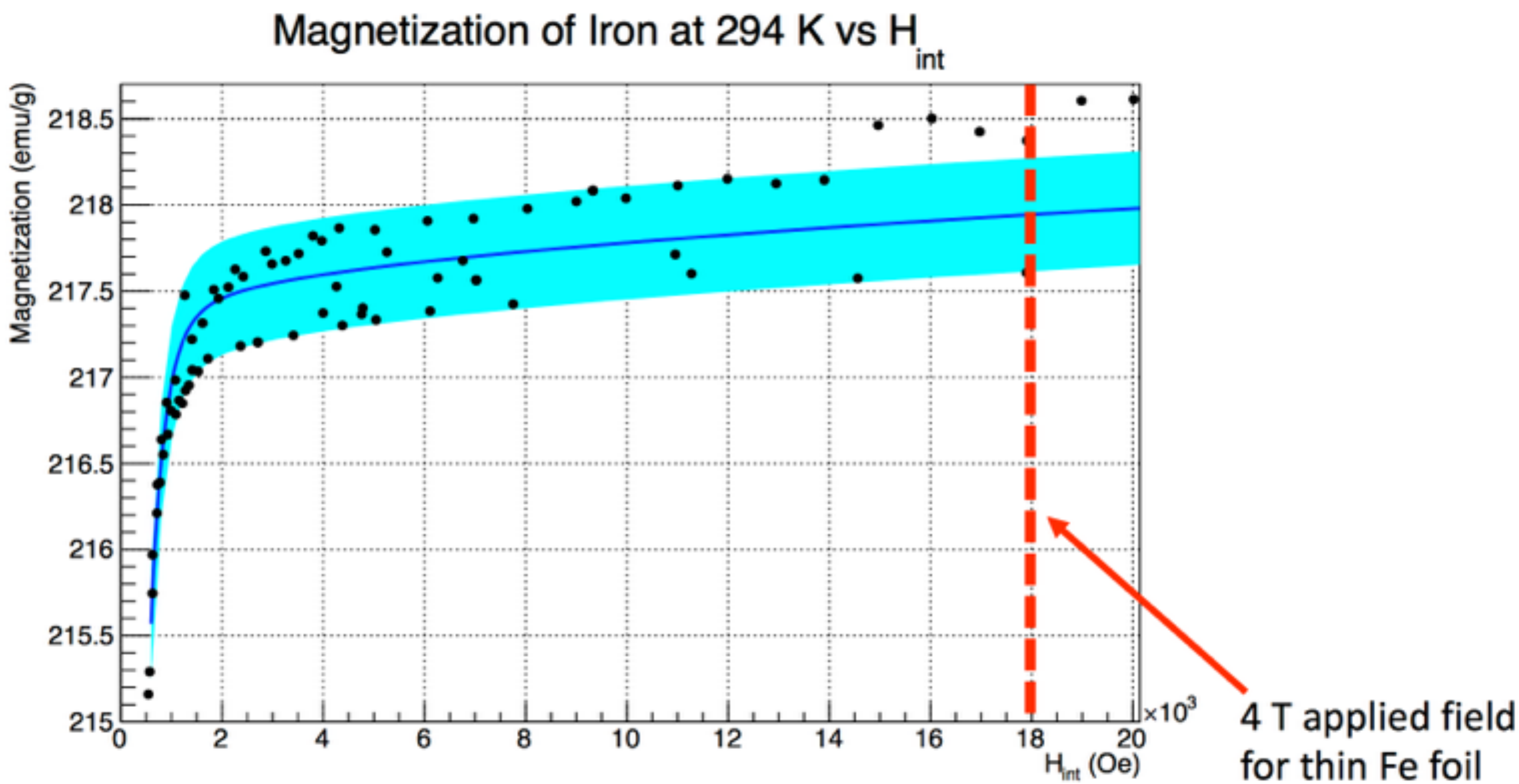
Geant4 Development

- New Geant4 based simulation package has been developed.
- Moller event generators, all spectrometer geometry has been implemented and tested.
- Consistency check with Geant3 simulation is ongoing.



Slide provided by Sanghwa Park

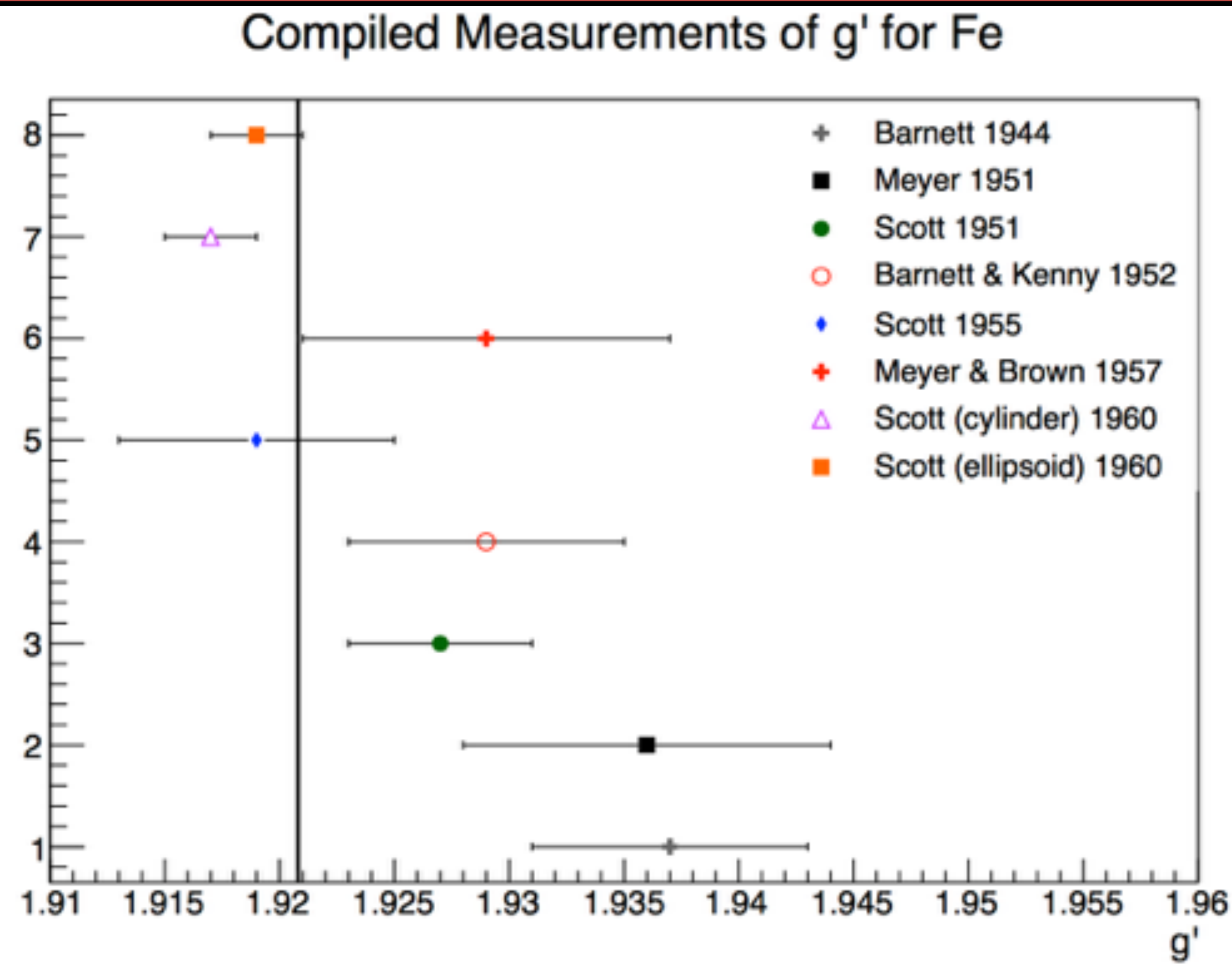
World Data on Fe magnetization



Magnetization 217.95 ± 0.33 emu/g or 2.1793 ± 0.0033 μ_B/atom.

Error band ~0.15%.

Need to know spin magnetization



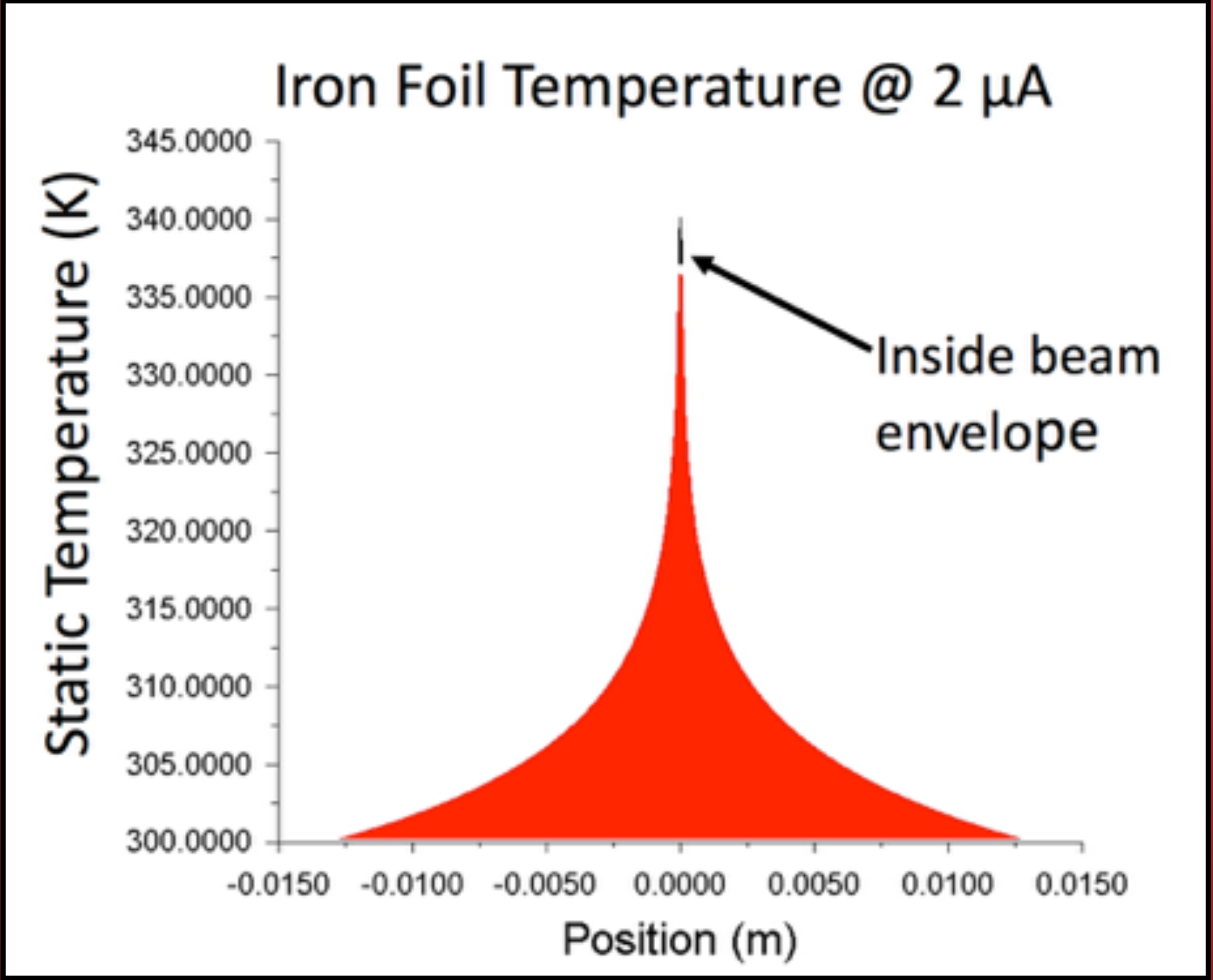
Simple error-weighted fit
$g' = 1.9208$

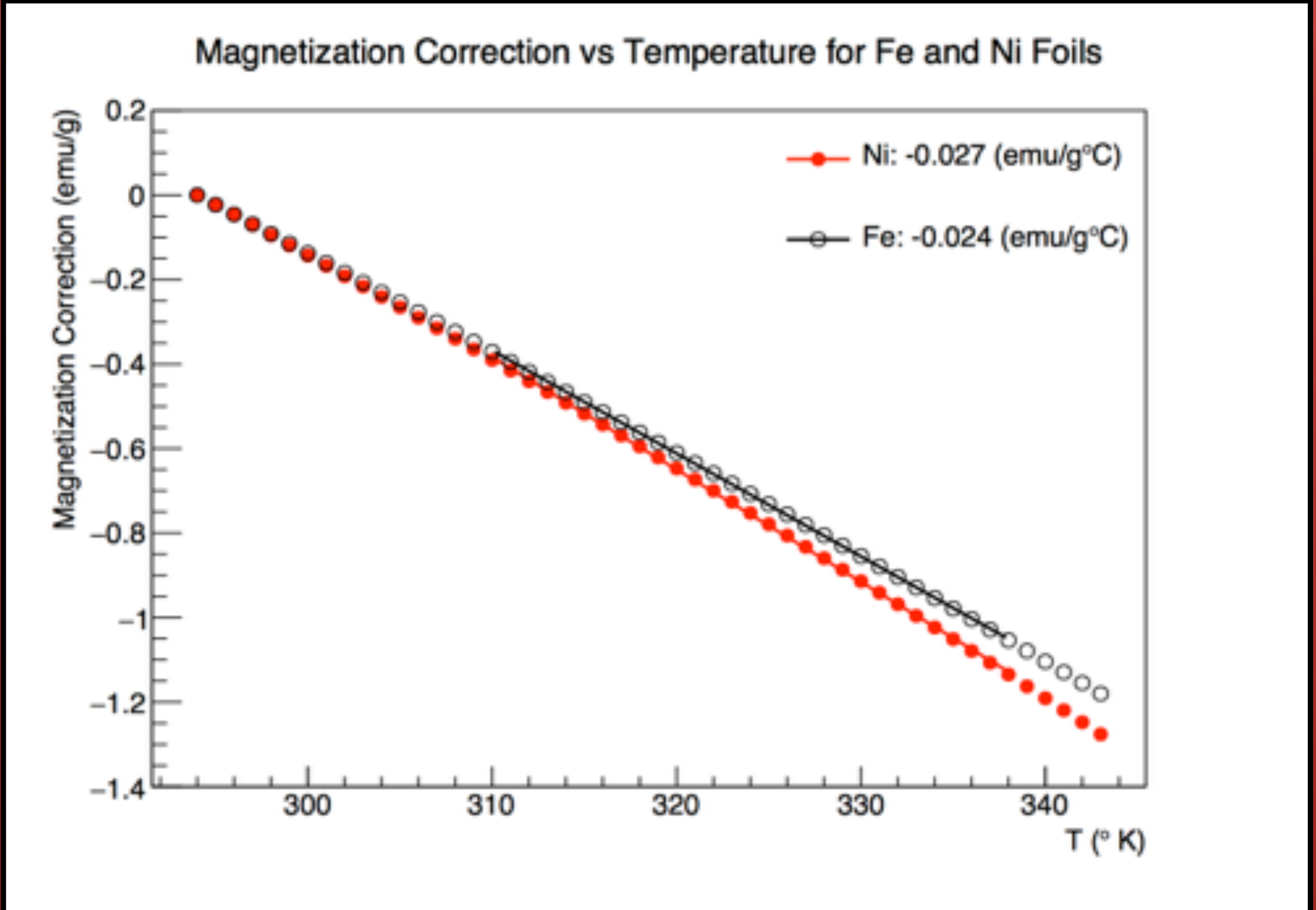
Recommendation: $\boldsymbol{g' = 1.920 \pm 0.004}$

- Close to Scott's recommendation of his latest measurement 1.919 ± 0.002
- Double error reflects tension from other world data from systematics not accounted for like impurities

Ongoing Projects and results: Target Polarization

Target Heating





Added uncertainty of ± 0.08 emu/g°C or 0.15% for Ni and 0.04% for Fe.

Recommendation: assume average temperature is about 1-2 degrees less than the maximum temperature differential and that uncertainty is about 15%

$\Delta T = 19 \pm 3 (°C/\mu A)$ for both nickel and iron

CFD Calculation provided by Silviu Covrig

Ongoing Projects and results: Target Polarization

Updated Theoretical Values

Quantity	Value	Error	Unit
Saturation Magnetization M_s	217.95	0.33	emu/g
Saturation Magnetization M_s	2.1793	0.0033	μ_B/atom
g'	1.920	0.004	–
$\frac{M_{orb}}{M_{tot}} = \frac{g_{sp}-g'}{g'(g_{sp}-1)}$	0.0428	0.0022	–
Magnetization from orbital motion M_{orb}	0.0932	0.0048	μ_B
Magnetization from spin $(M_s - M_{orb})$	2.0861	0.0058	μ_B
Average electron magnetization (T=294 K, B=4 T)	0.08023	0.00022	μ_B/atom
Average electron magnetization (T=313 K, B=4 T)	0.08008	0.00024	μ_B/atom
Average electron polarization (T=294 K, B=4 T)	0.08014	0.00022 ← 0.27%	
Average electron polarization (T=313 K, B=4 T) *	0.07999	0.00024 ← 0.30%	

*Target heating corrections for 1 μA beam load

Differs from DeBevers recommendation by 0.32%

Conclusions from study

- Easy to make errors that matter when dealing with this level of precision
- Iron foil polarization is known to 0.3% and nickel to 0.5%
- Combining both will allow us to reach the 0.25% in the MIE
- Nickel will run at 2 T field and iron at 4 T
- Target heating is linear in current and independent of thickness so have thicker targets and low currents (1 μA) to maintain desired rate but with small target heating correction
- Difficult to account for uncertainties from target impurities so to utilize high purity material 99.99%

Stay tuned for possible publication

See Don's Tech Note: https://mollerpol.jlab.org/cgi-bin/DocDB/private/ShowDocument?docid=5

PREX Commissioning Proposal

Commissioning Proposal

1. One 8 hour shift for magnet alignment data. Ramp magnet to 4 T in both directions and observe motion of beam on downstream targets.
2. One to two days to analyze beam optics data and determine misalignment values. This can happen while other commissioning tasks continue.
3. Less than one 8 hour shift in the hall with beam off to realign magnet. This can happen in concert with other in hall activities. Not necessary to dedicate beam off time for this.
4. Two or three 8 hour shifts to verify magnet alignment and perform other commissioning tasks including checking tune of quadrupoles, tuning detector HV levels and ADC thresholds, verifying target motion system works as expected and verifying target saturation.

Moving Forward

Completed Tasks

- More precise "Brute Force" polarization measurements during DVCS
- Super conducting magnet mapping
- New motion system hardware installed in test lab
- New target polarization study
- Target heating model

Ongoing Tasks

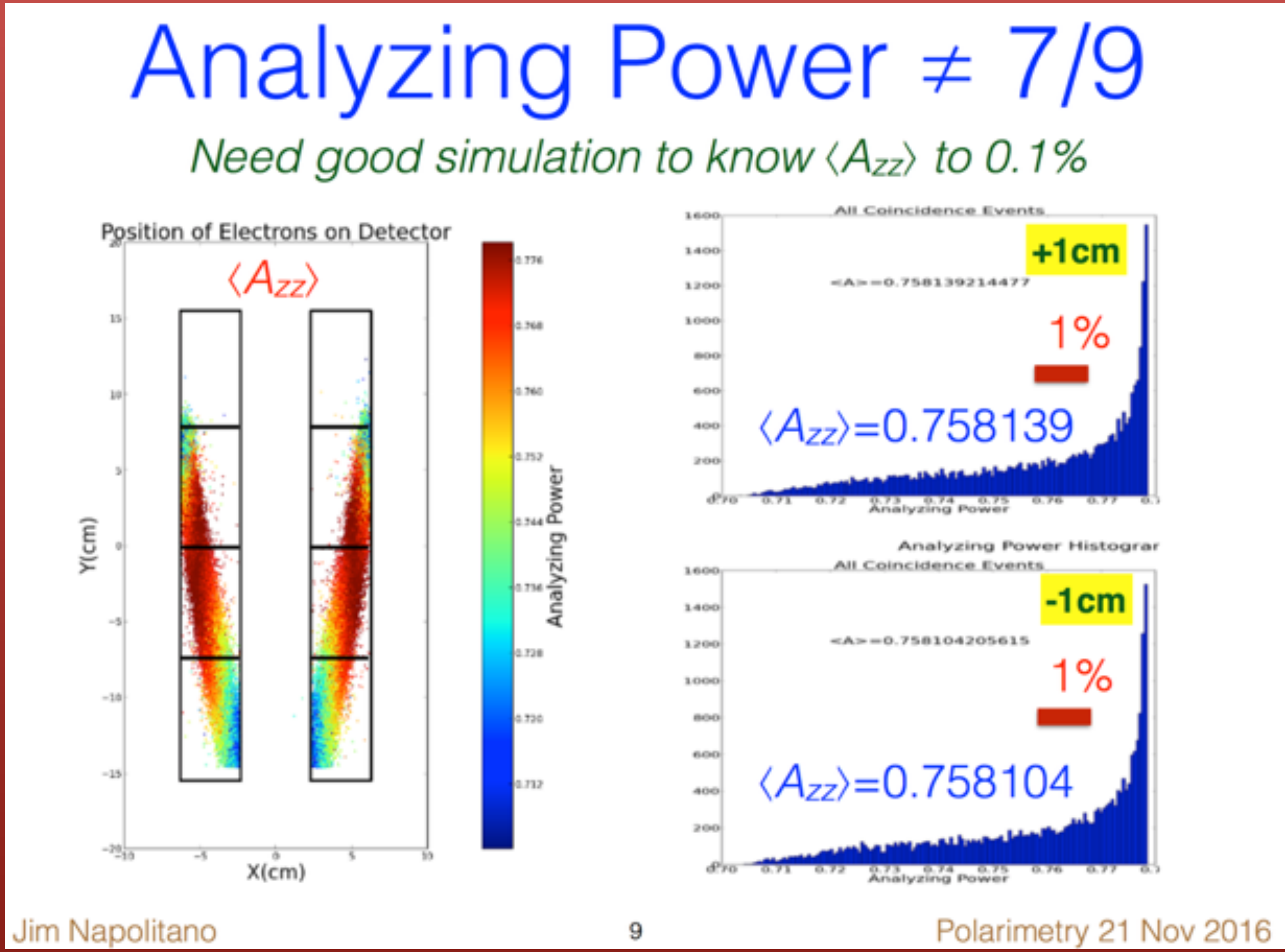
- Kerr Effect (Finish by 2018)
  - Target Angle Sensitivity
  - Shape of magnetization curve
  - disentangling bulk vs foil effects
- Vacuum test new motion system(Today)
- Geant4 Simulation (Finish by 2018)
- Test irradiated o-rings with known exposure (during Tritium running)

To Do

- Optics Model
- Publish Target Polarization Findings?
- Interface motion system to EPICS
- Install SC magnet in Hall
- Polarimeter Commisioning
- More accurate Levchuk model?
- Determine optimal setting parameters for quads/dipole for low E in 12GeV era
- Both DAQs need upgrading?

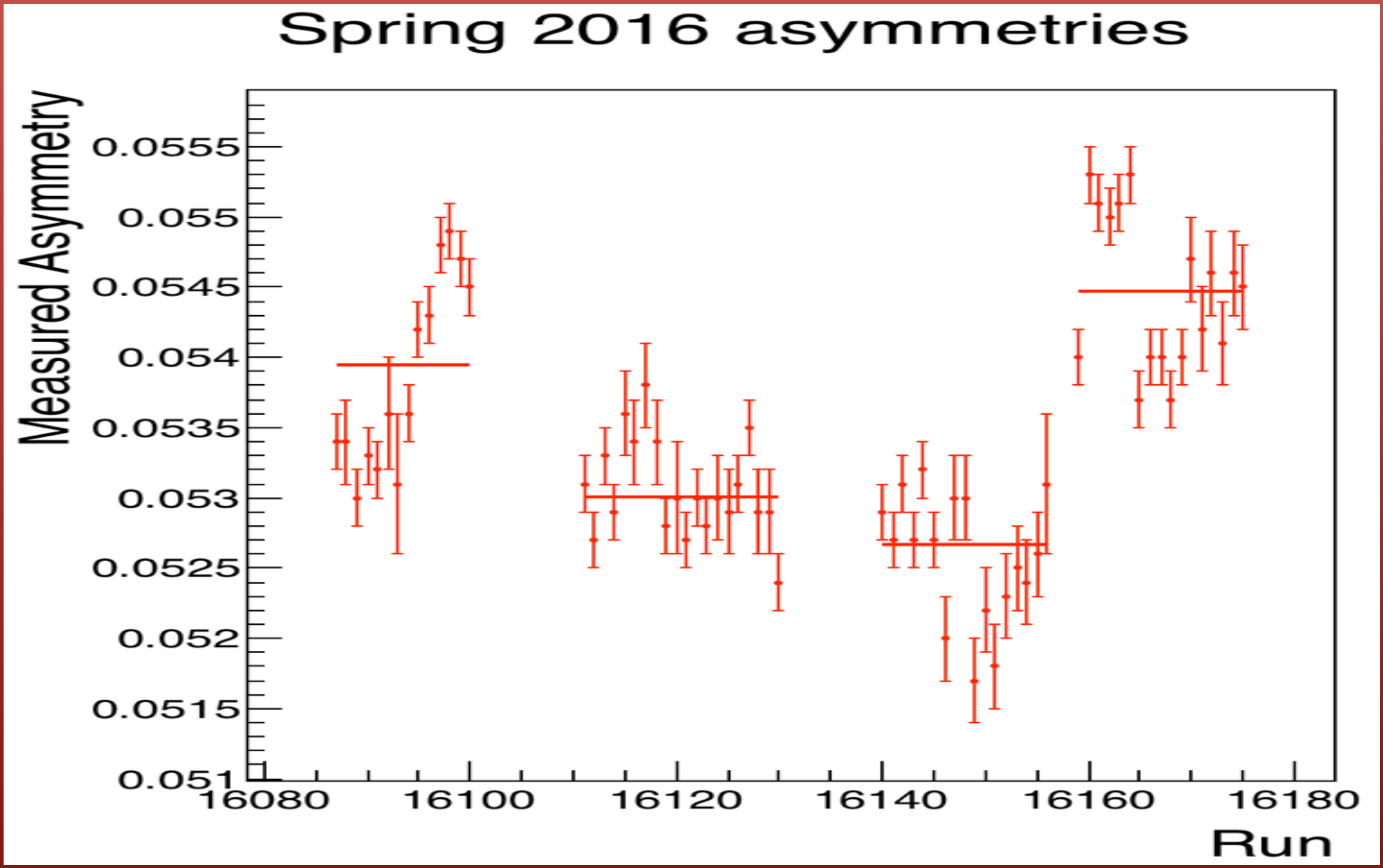
Thank You!

Backup



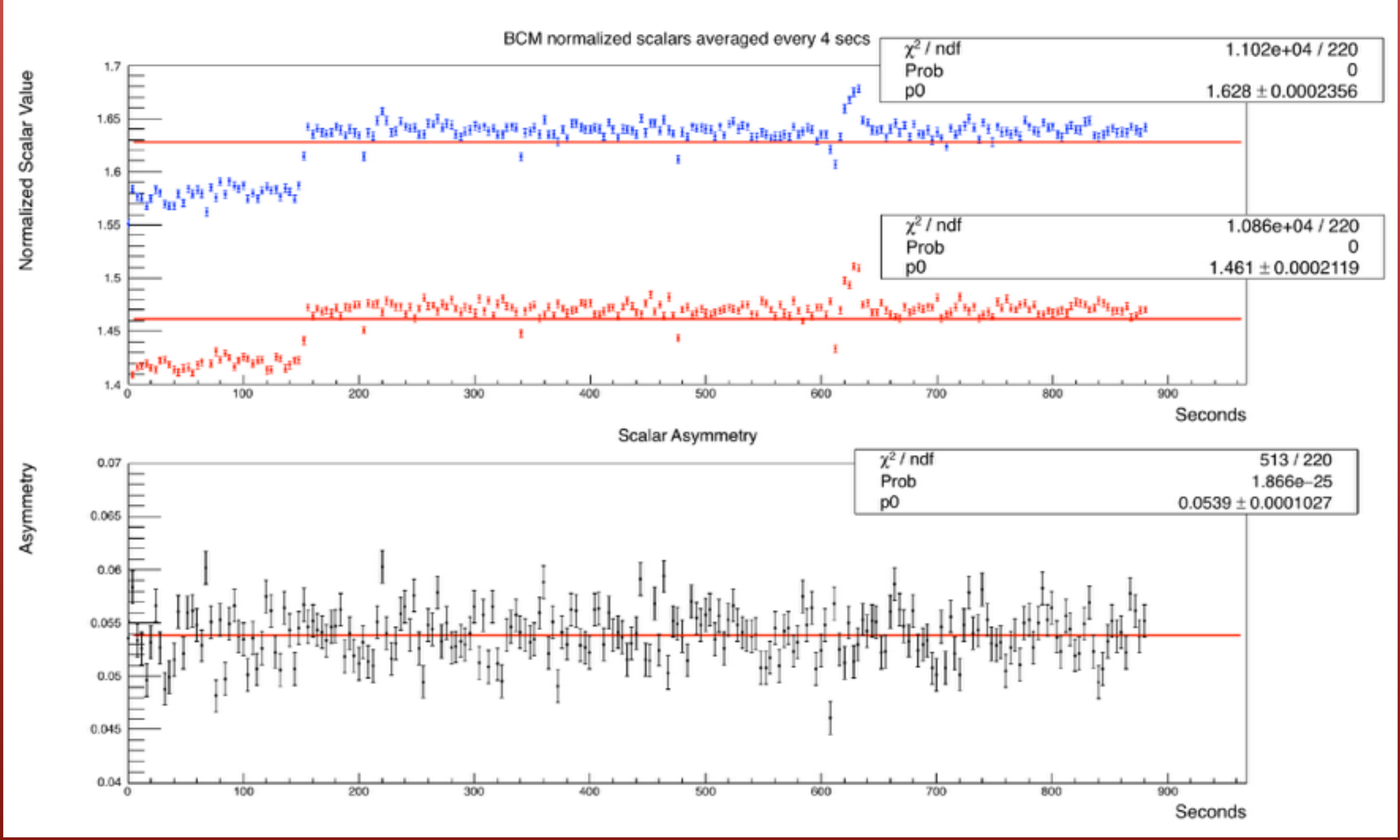
QUESTION: Should we be able to read calorimeter block by block?
Now DAQ it set up to sum the four photomultiplier tubes in each of the left and right arms.

Backup



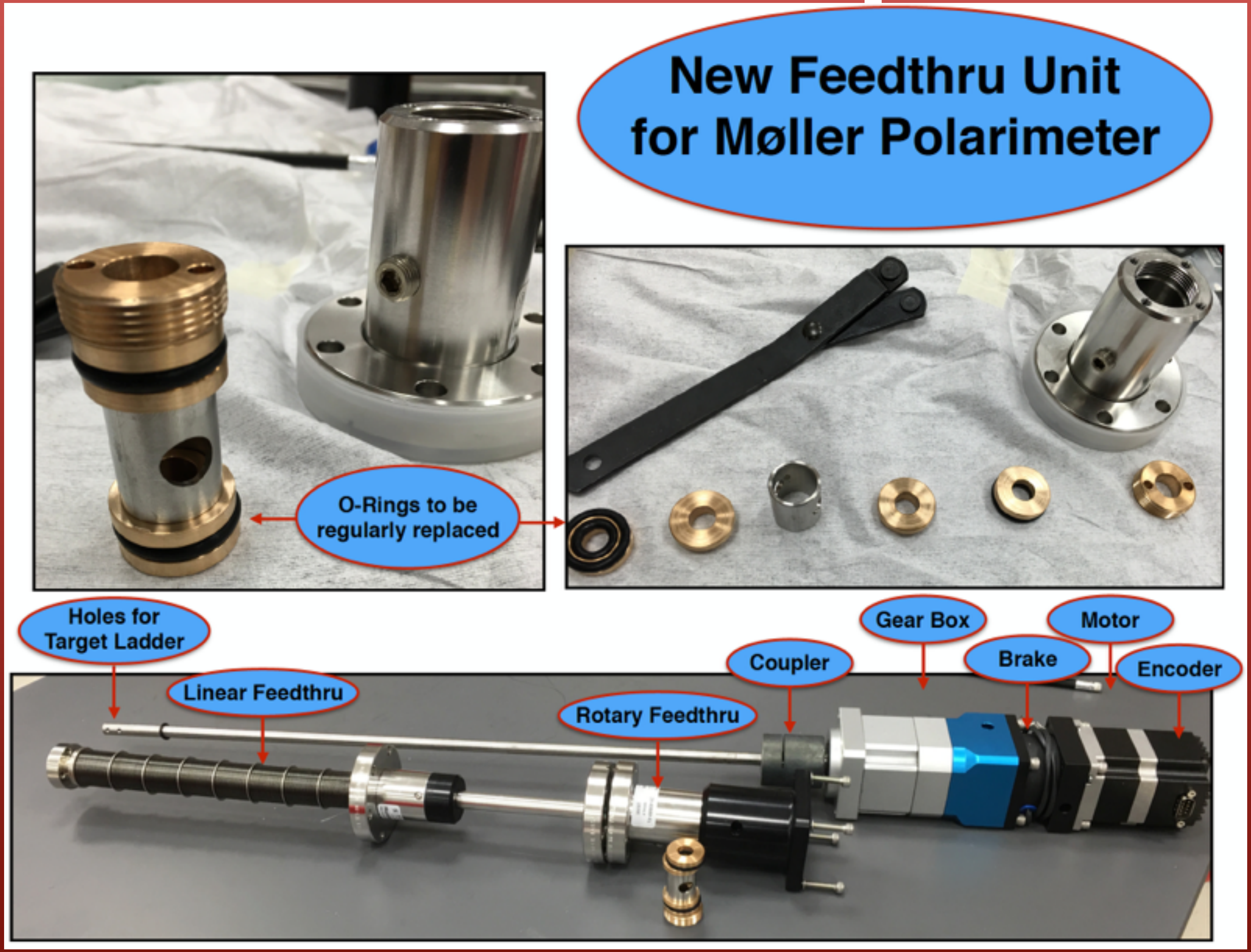
Spring 2016 asymmetries
Measured Asymmetry
0.0555
0.055
0.0545
0.054
0.0535
0.053
0.0525
0.052
0.0515
0.051
16080
16100
16120
16140
16160
16180
Run

Back up



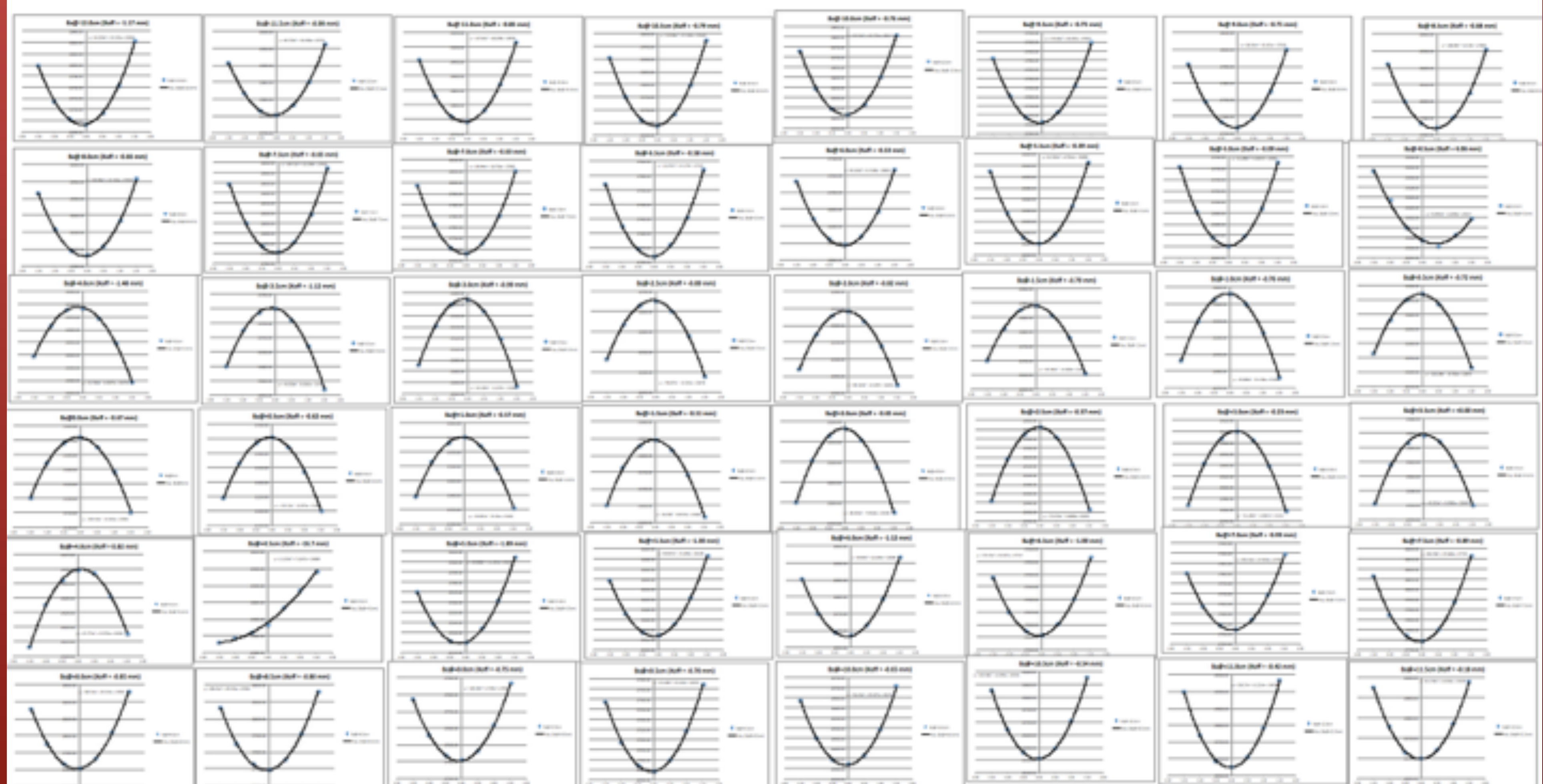
For a 15minute run- Statistical Precision 0.2%

Back Up

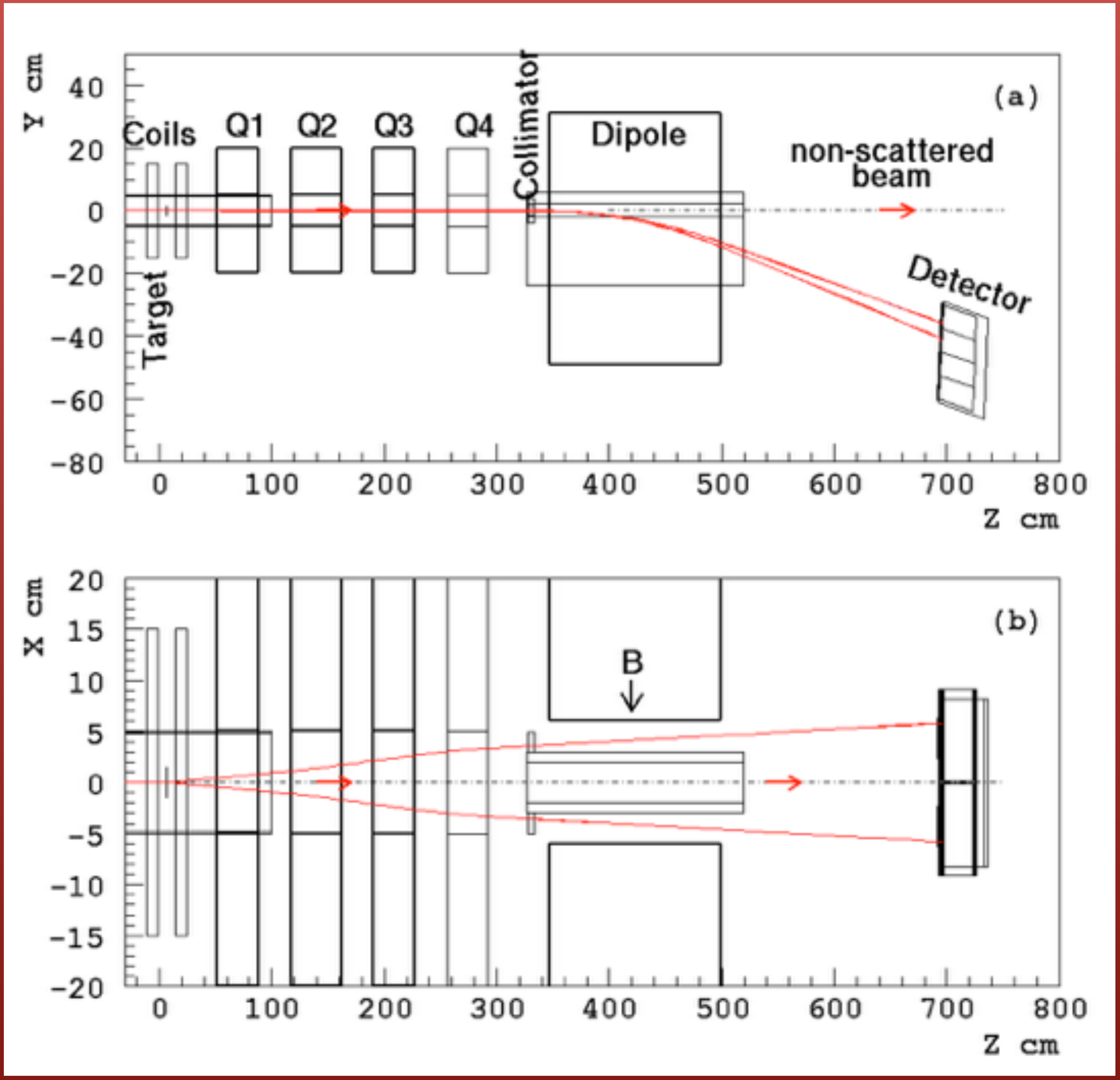

New Feedthru Unit
for Møller Polarimeter
O-Rings to be
regularly replaced
Holes for
Target Ladder
Linear Feedthru
Rotary Feedthru
Coupler
Gear Box
Brake
Motor
Encoder

Magnet Mapping

Plot and fit to 2nd order polynomial



DVCS SETUP


Y cm
Coils
Q1
Q2
Q3
Q4
Collimator
Dipole
(a)
non-scattered beam
Target
Detector
Z cm
X cm
(b)
B
Z cm