# Precision “High Field” Møller Polarimetry in Hall A

*Status Report*

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Work Carried Out by
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# The Goal

- Measure longitudinal polarization of the CEBAF beam in Hall A with relative **precision < 0.5%**
- Fast turnaround time, i.e. high rate needed, so that Compton polarimeter has a cross check
- Need to have system that will get polarization for beam energies from 1 GeV (PREX) to 11 GeV
- Use existing equipment as much as possible

➥ *Møller scattering using "high field" iron target and the existing (modified) QQQQD spectrometer.*

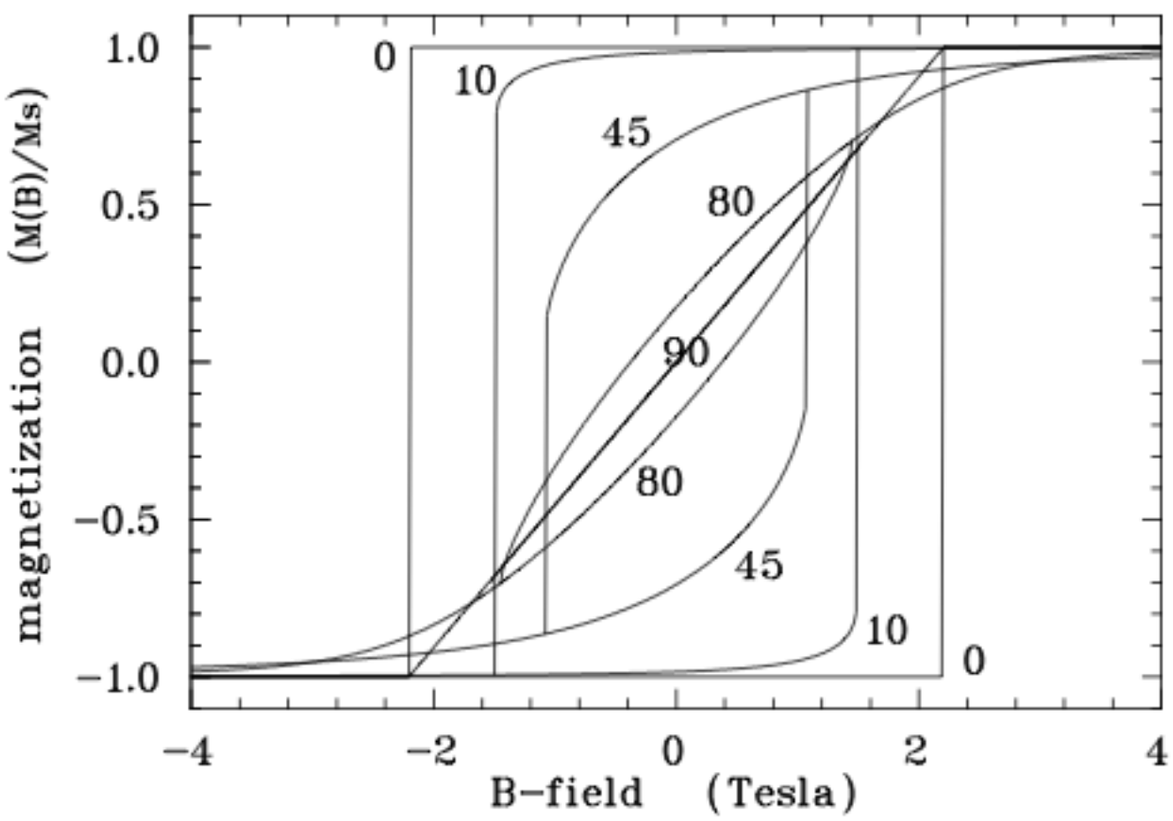
Strive for 0.1% uncertainty on all systematics

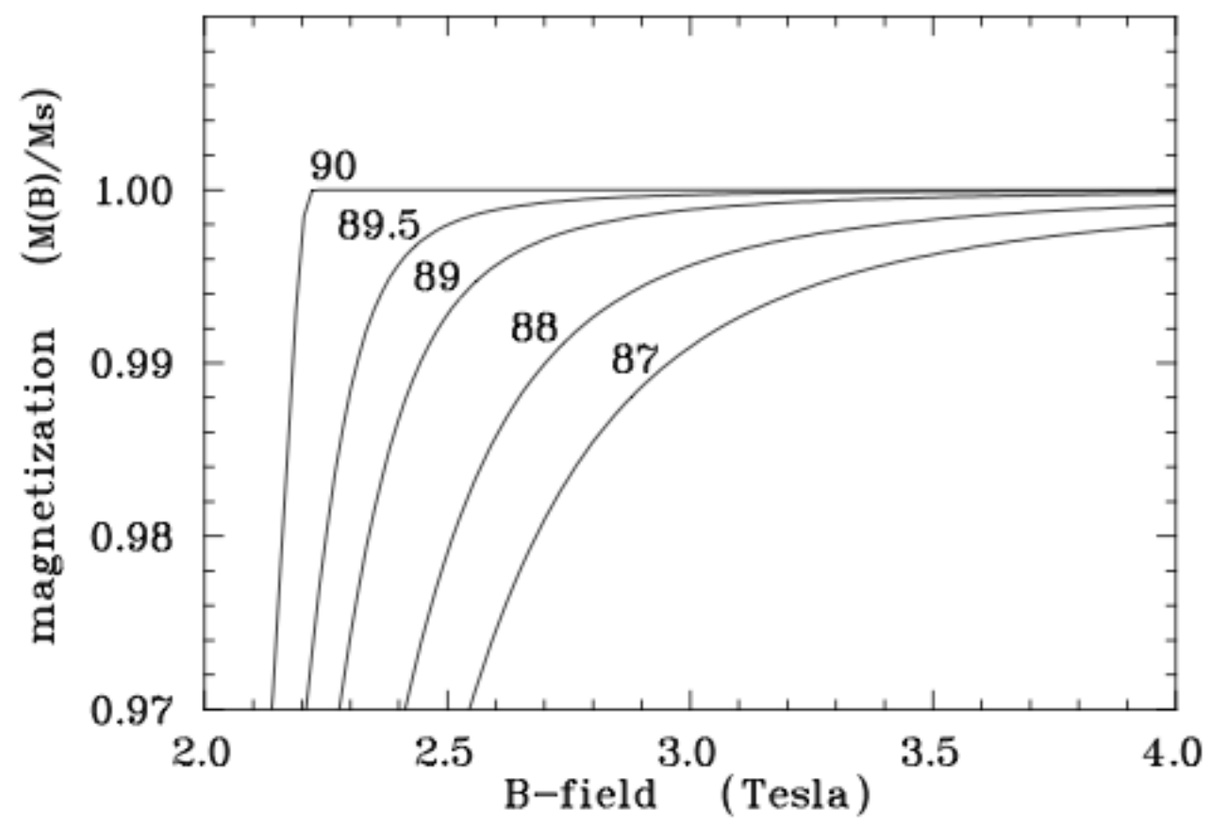
# The Principle

- Møller ($e^-e^-$) scattering near $\theta_{cm}=90°$ has a large and well understood analyzing power.
- The magnetization (magnetic dipole moment per unit volume) of **<u>pure iron at full saturation</u>** can be turned into electron polarization with high precision.
- Various other effects can be understood using a straightforward approach, at least in principle.
  - Spectrometer acceptance, magnet alignment and alignment, Levchuk effect, radiative corrections, dead time, target heating, backgrounds, … (?)

# Saturation: The Hard Part

*Model Calculation:*
*Phil.Trans.R.Soc.London Series A, 240(826):599,1948.*



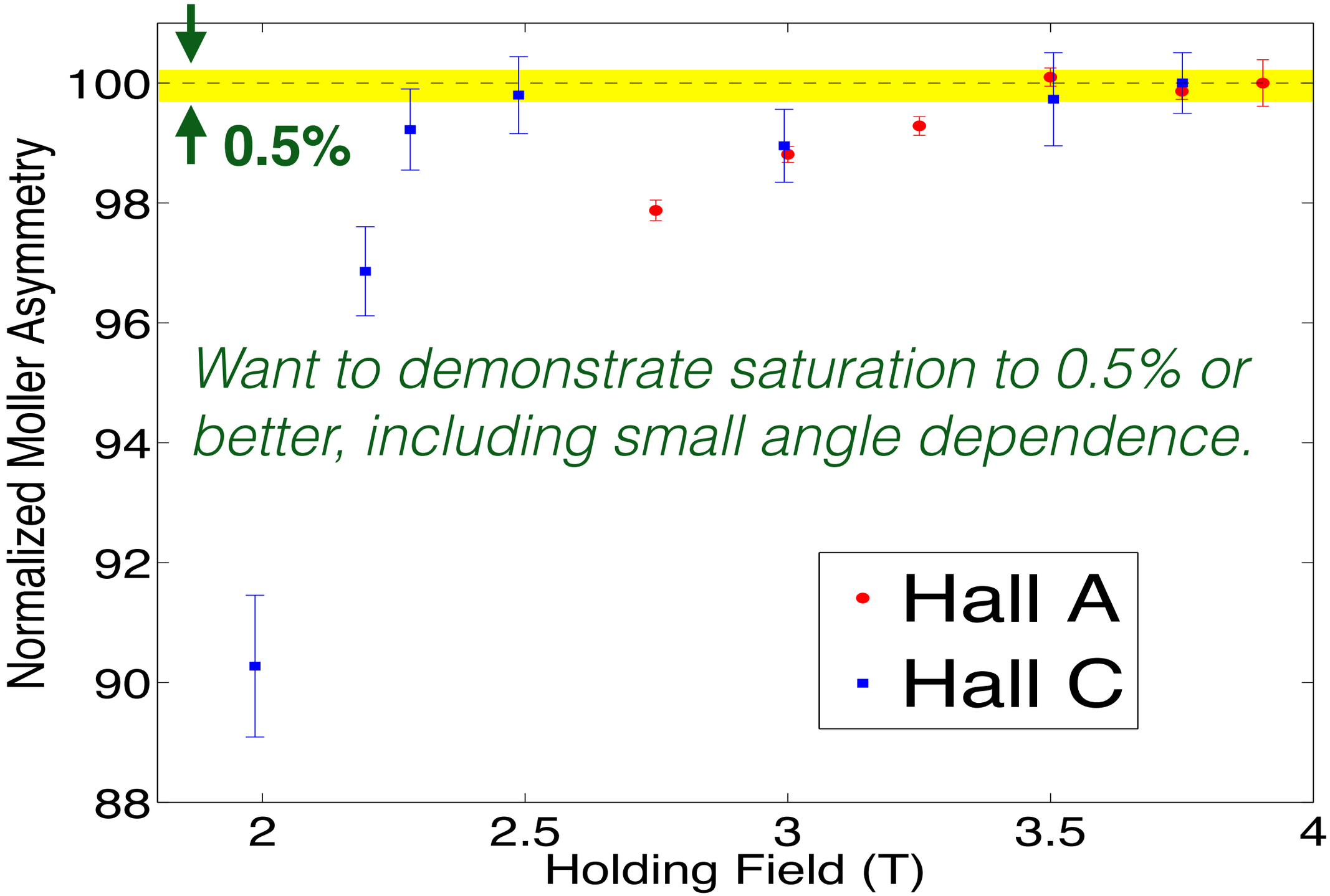




➥ *Need "perpendicularity" to ~1° for a 4T magnet.*

# Some History

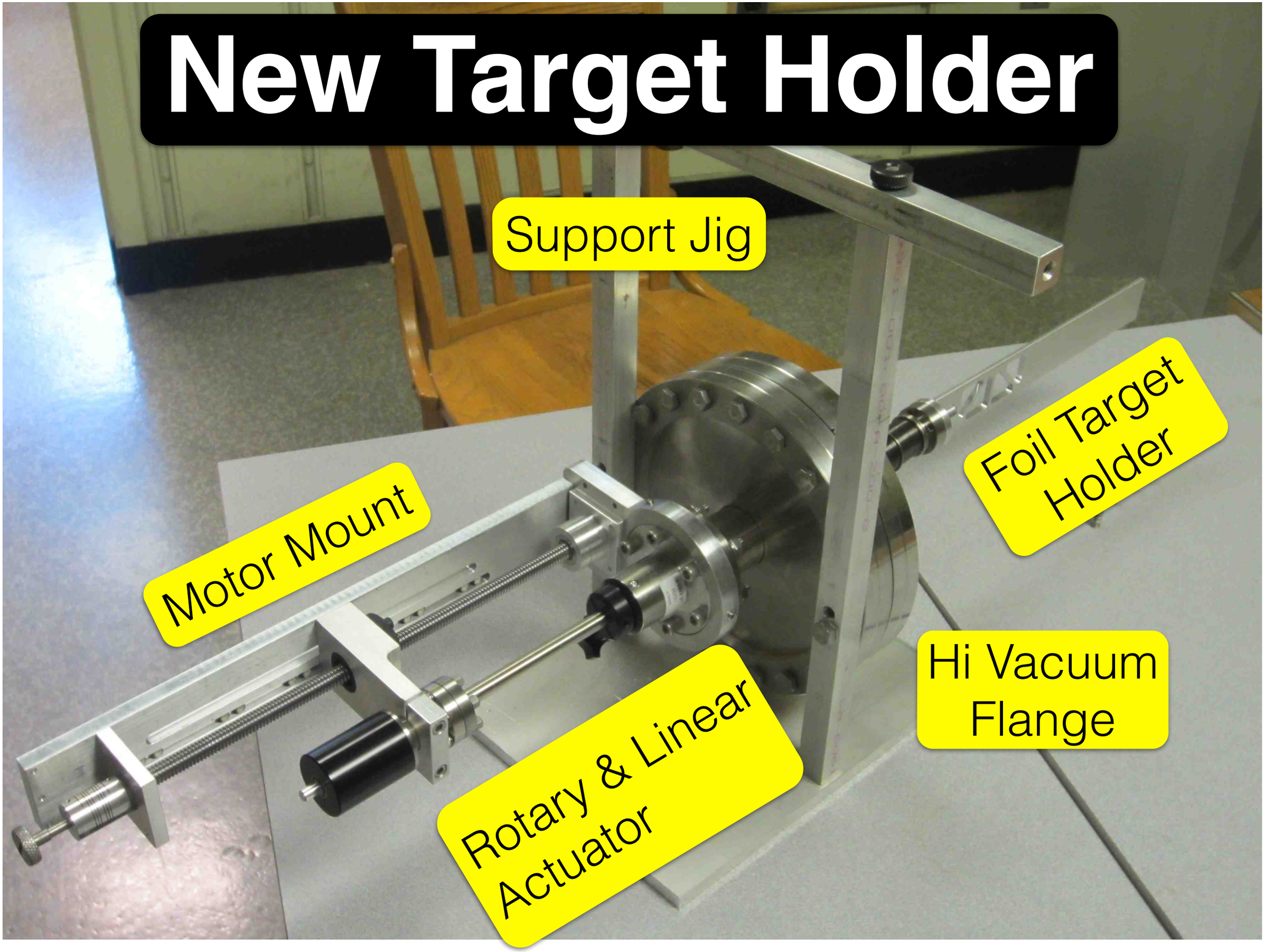
- First effort (late 1990's) in Hall C by Basel group worked out well. See NIM A462(2001)382.
- Hall C upgraded their system with new 4T magnet.
- Hall A acquired old magnet and adapted to existing "Low Field, Tilted Foil" polarimeter system.
- Hall A used different spectrometer (QQQD vs QQ)
  - Highly articulated target (six deg of freedom)
  - Measurements in Hall A were inconclusive
- Upgrades in progress to Hall A system
  - Note: Additional Quad added for 12 GeV

# Existing Saturation Data




*Want to demonstrate saturation to 0.5% or better, including small angle dependence.*

# New Target Holder

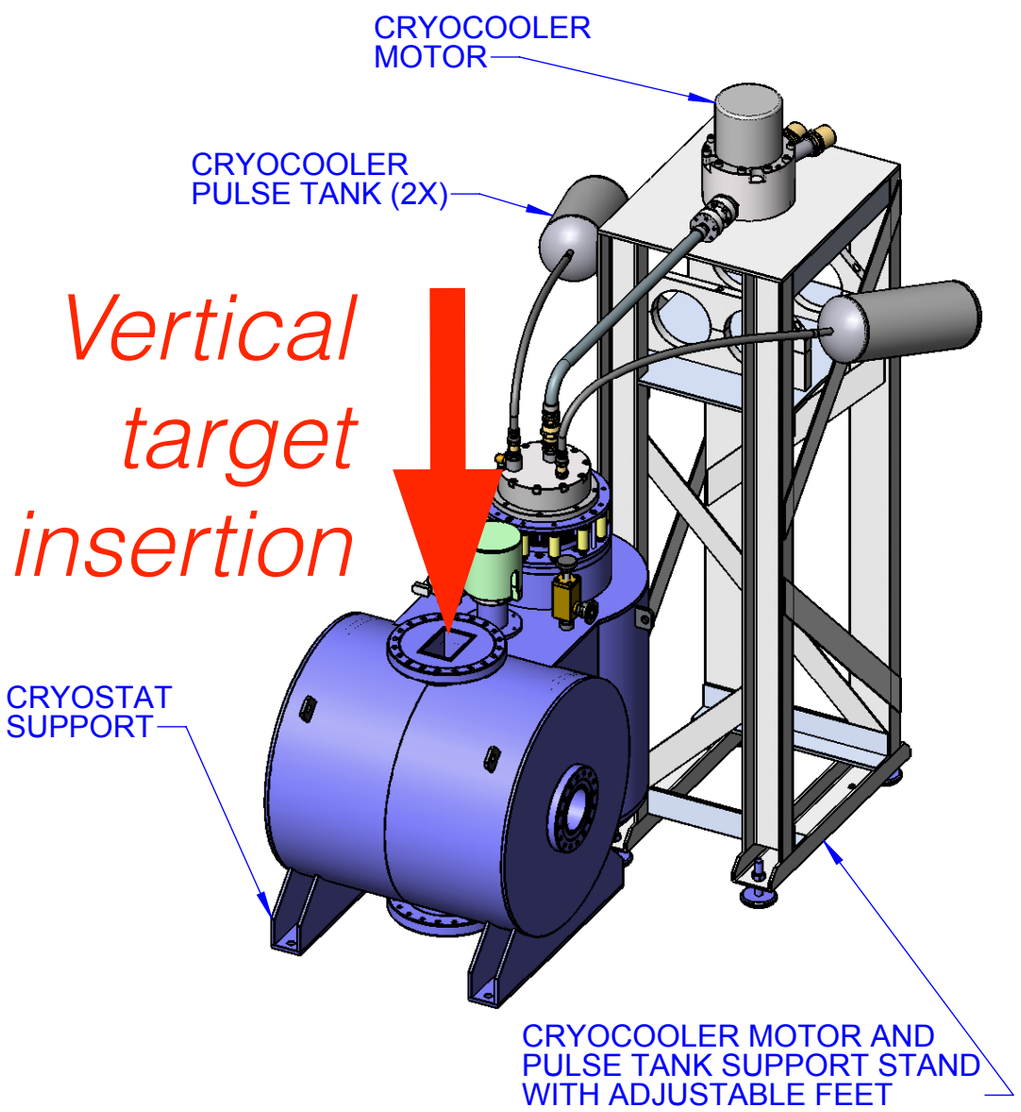


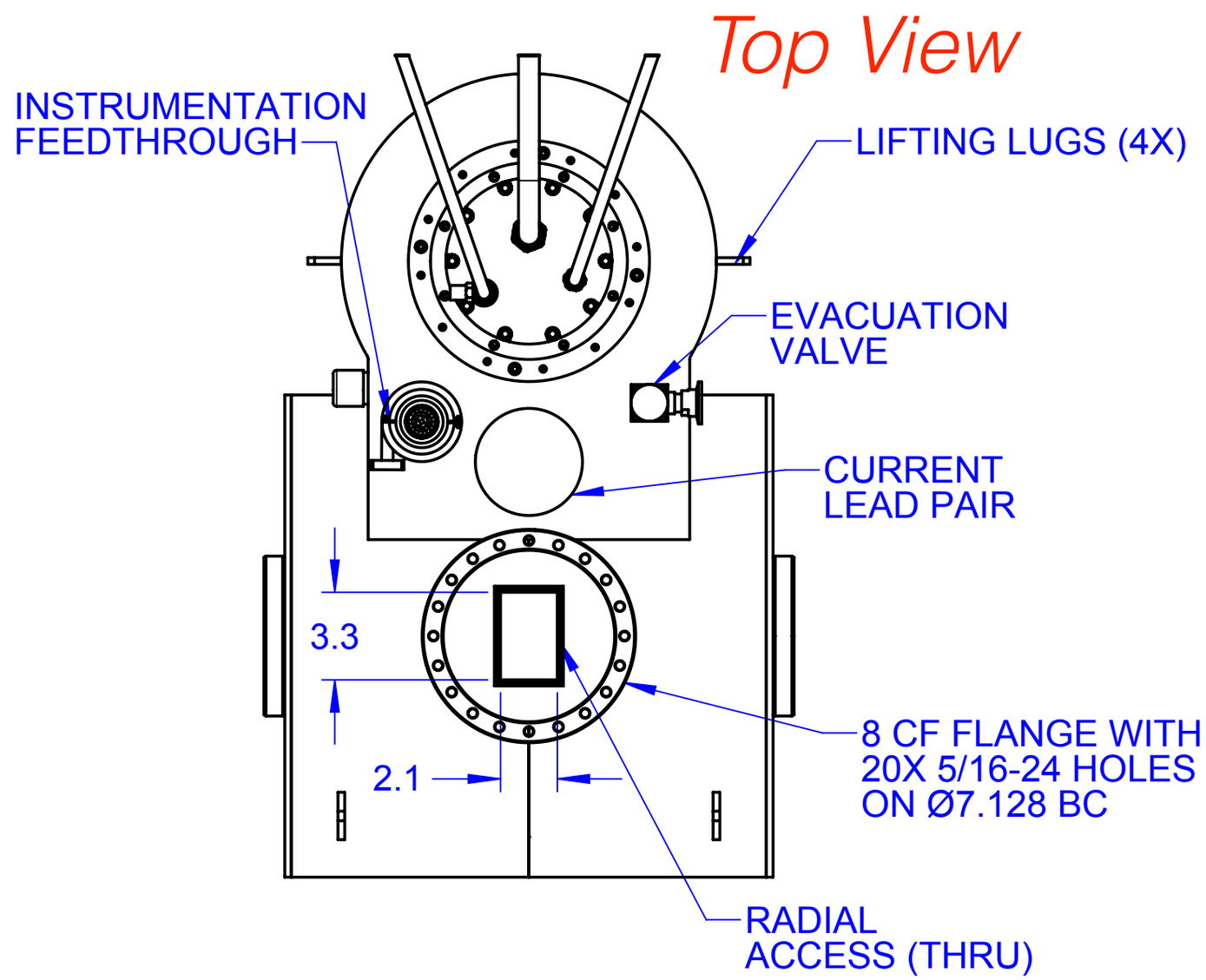
# Target Holder: Notes

- Support jig is only for dry assembly and testing the stepper motor mounting and operation
- Rotary and linear action measured and confirm less than one-degree tolerances
- Target holder is blank, waiting for specs on foil holders before cutting openings
- Want to mount and test stepper motor control at Temple before moving to Jefferson Lab

# New Magnet Assembly

## 5T System purchased from American Magnetics by JLab



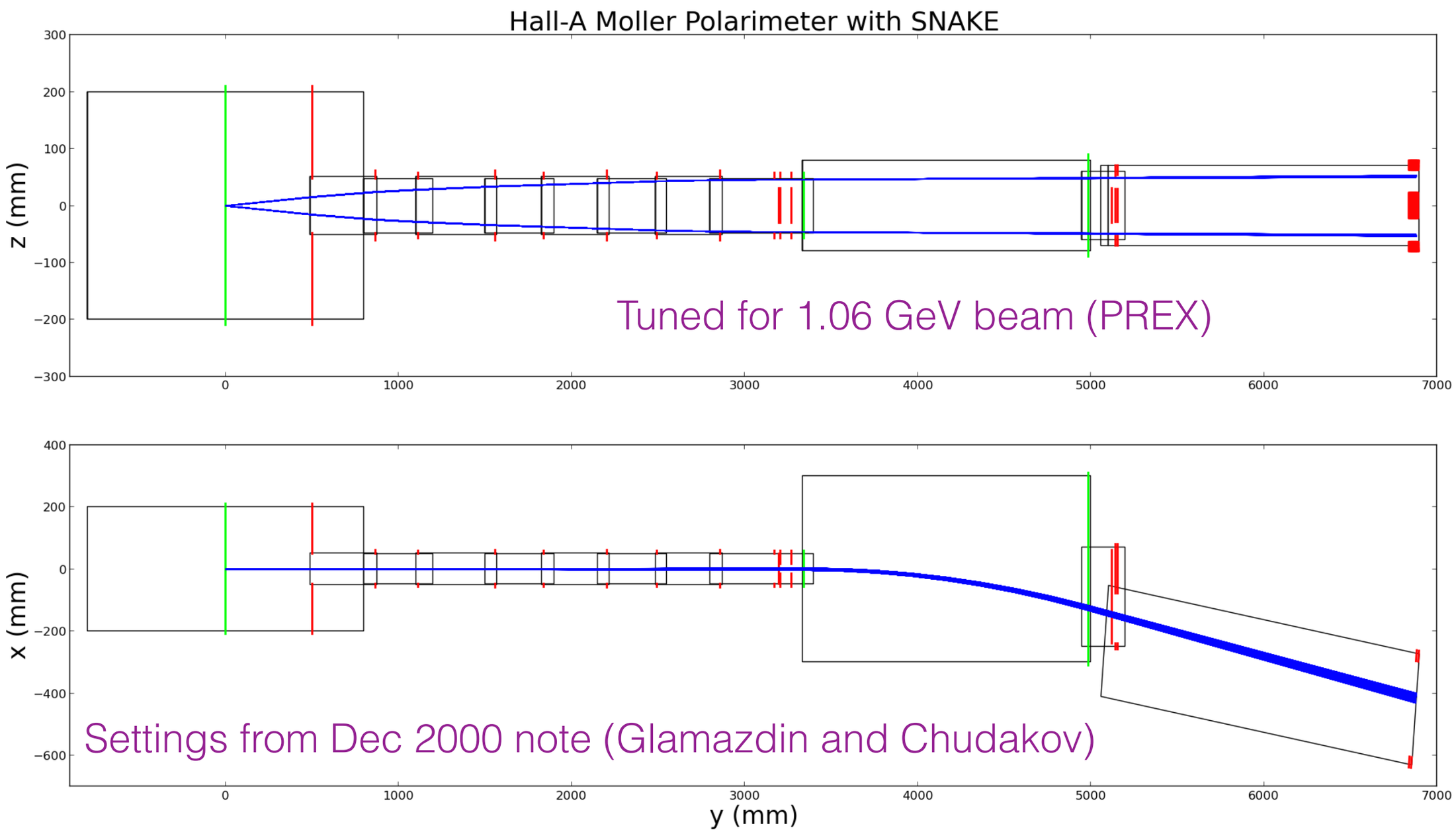
# Beyond Saturation

*What else is needed for precision 0.5% or better?*

- Must understand spectrometer acceptance, including potential magnetic field uncertainties, to this precision.
  - *This is underway, more slides to follow*
- Magnet mapping critical, including beam line survey and possible effects of nearby yoke steel
- Levchuk effect: Need simulations with our geometry
- Radiative corrections: Simulations (see Duke group)
- Target heating and possible depolarization studies
- Electronics and DAQ dead time (should be small)
- Scattering background determination

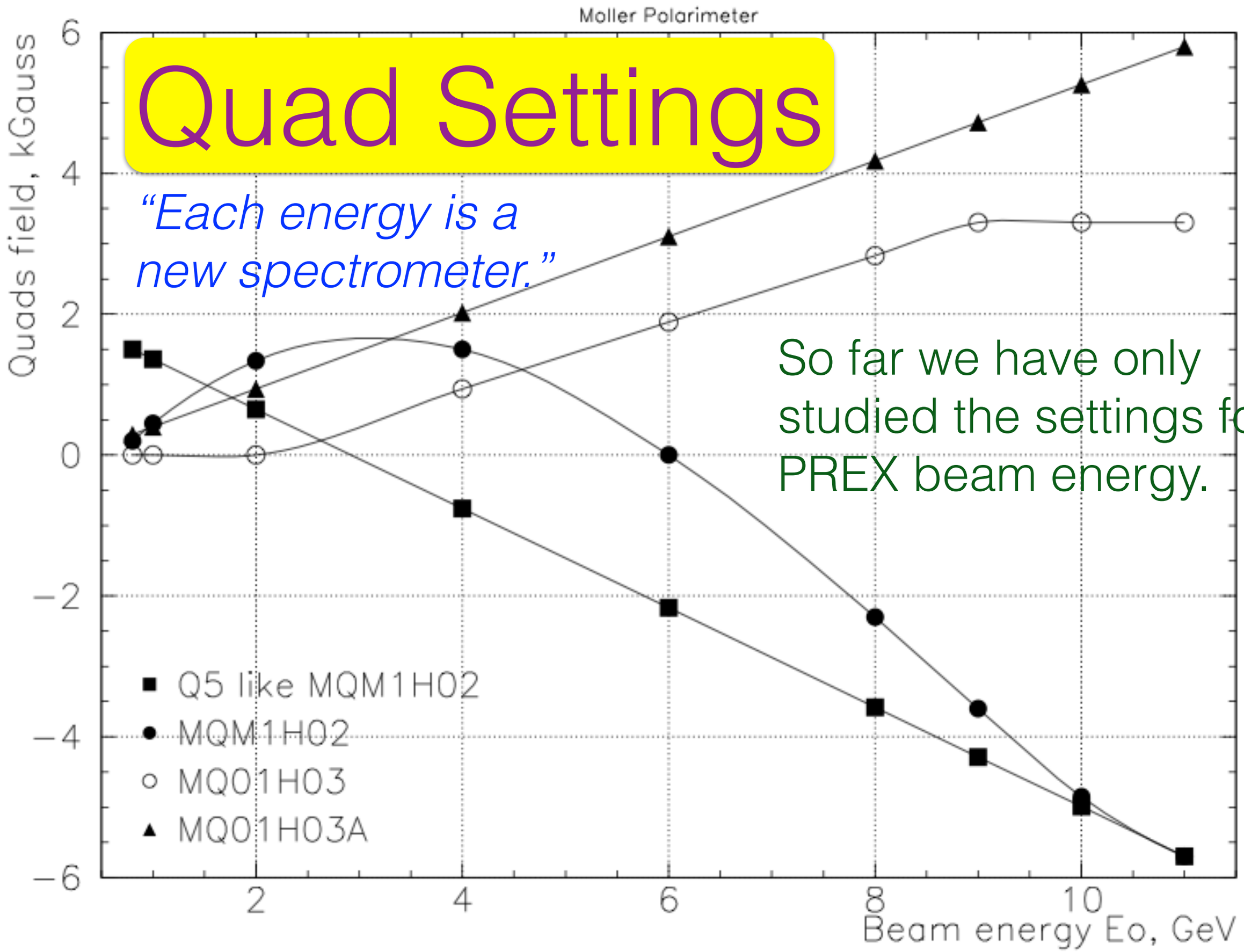
# Spectrometer Simulations

*Much already done as MS Project for Ted Berger (RPI)*



# Quad Settings

*"Each energy is a new spectrometer."*




So far we have only studied the settings for PREX beam energy.

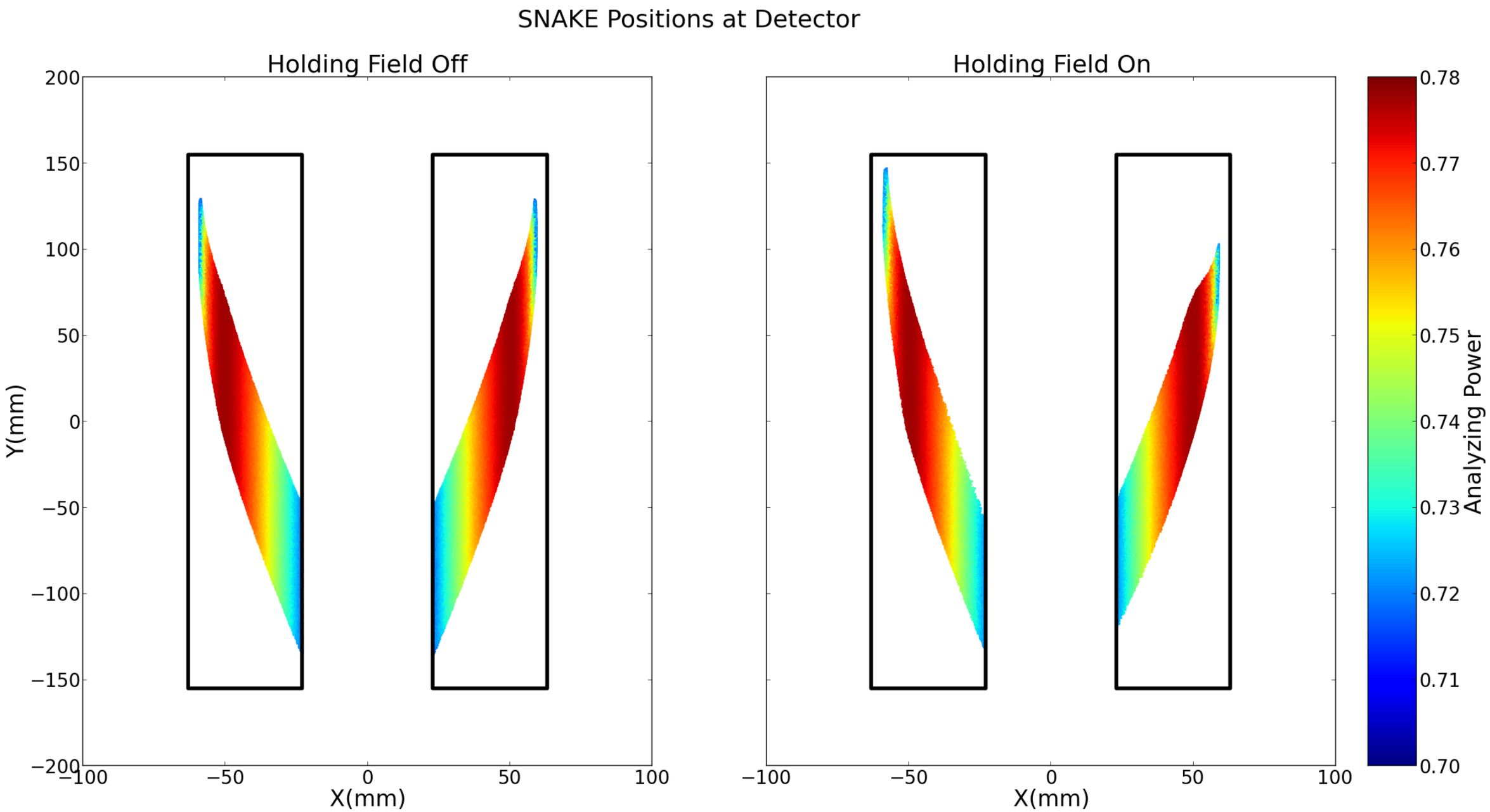
# Simulation Details

- Started with GEANT simulation inherited from Sasha and others; Mainly studied 11 GeV.
- Wanted to have close control over parameters, including holding field, collimators, and so on.
- Decided to build a SNAKE simulation starting from fundamentals, including our own fields.
- Good progress made, package now in place, documentation and authors are available.

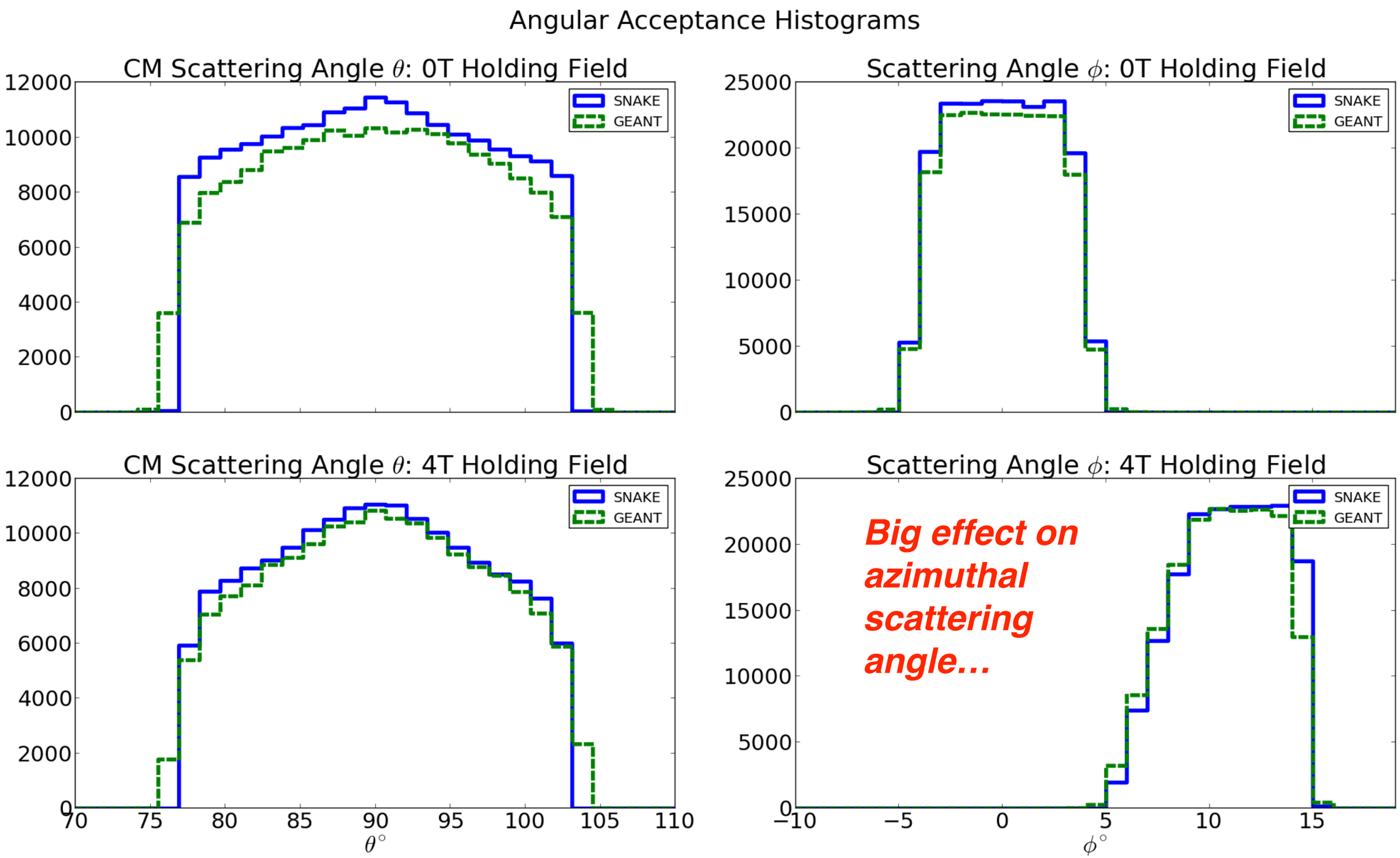
*<u>Promising first result</u> on systematic uncertainties: GEANT and SNAKE result for $\langle A_{long} \rangle$ differ by 0.2%*

# Focus so far on $\langle A_{long} \rangle$

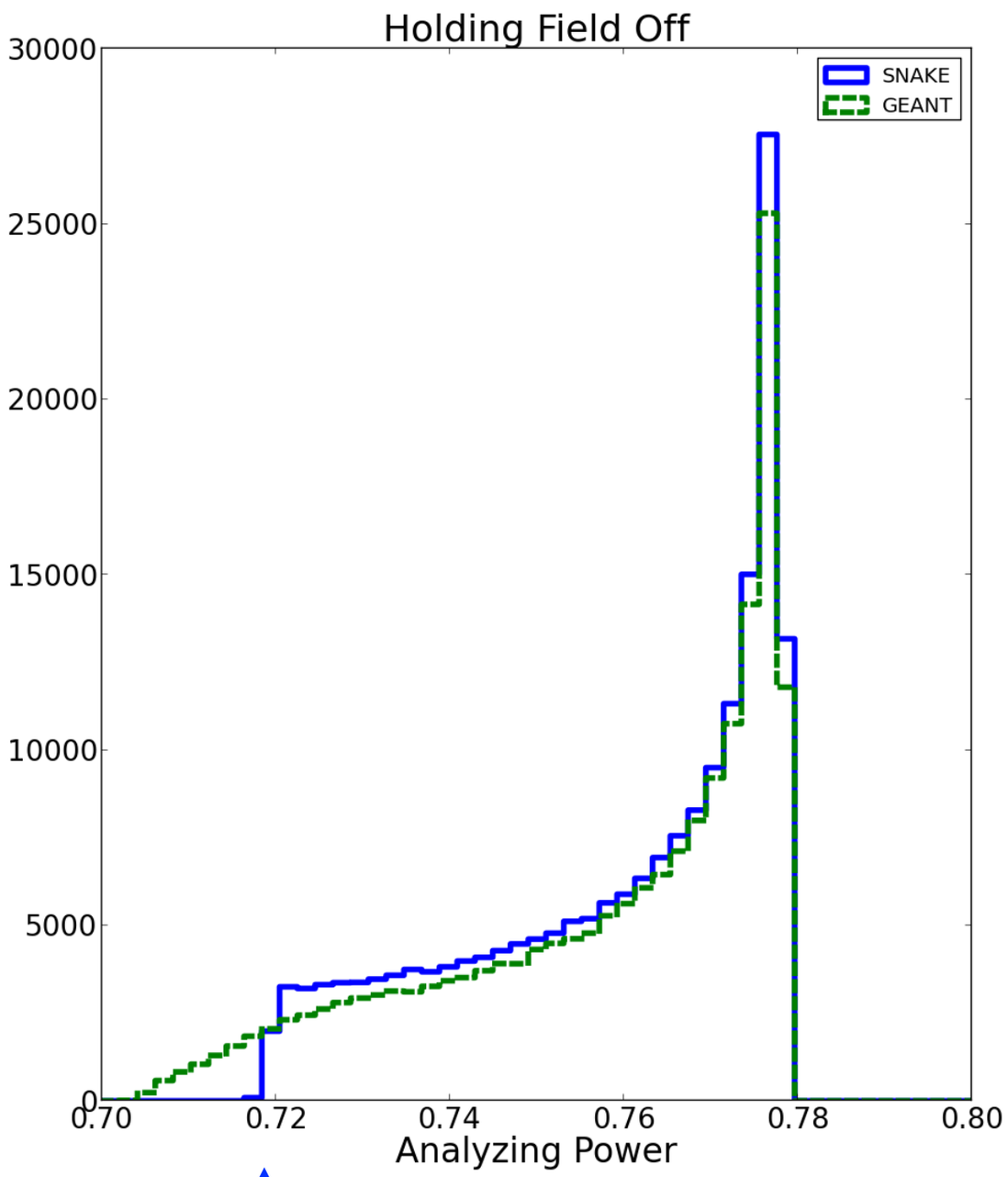
*Must know average accepted analyzing power to sufficient precision for a 0.5% polarization measurement.*

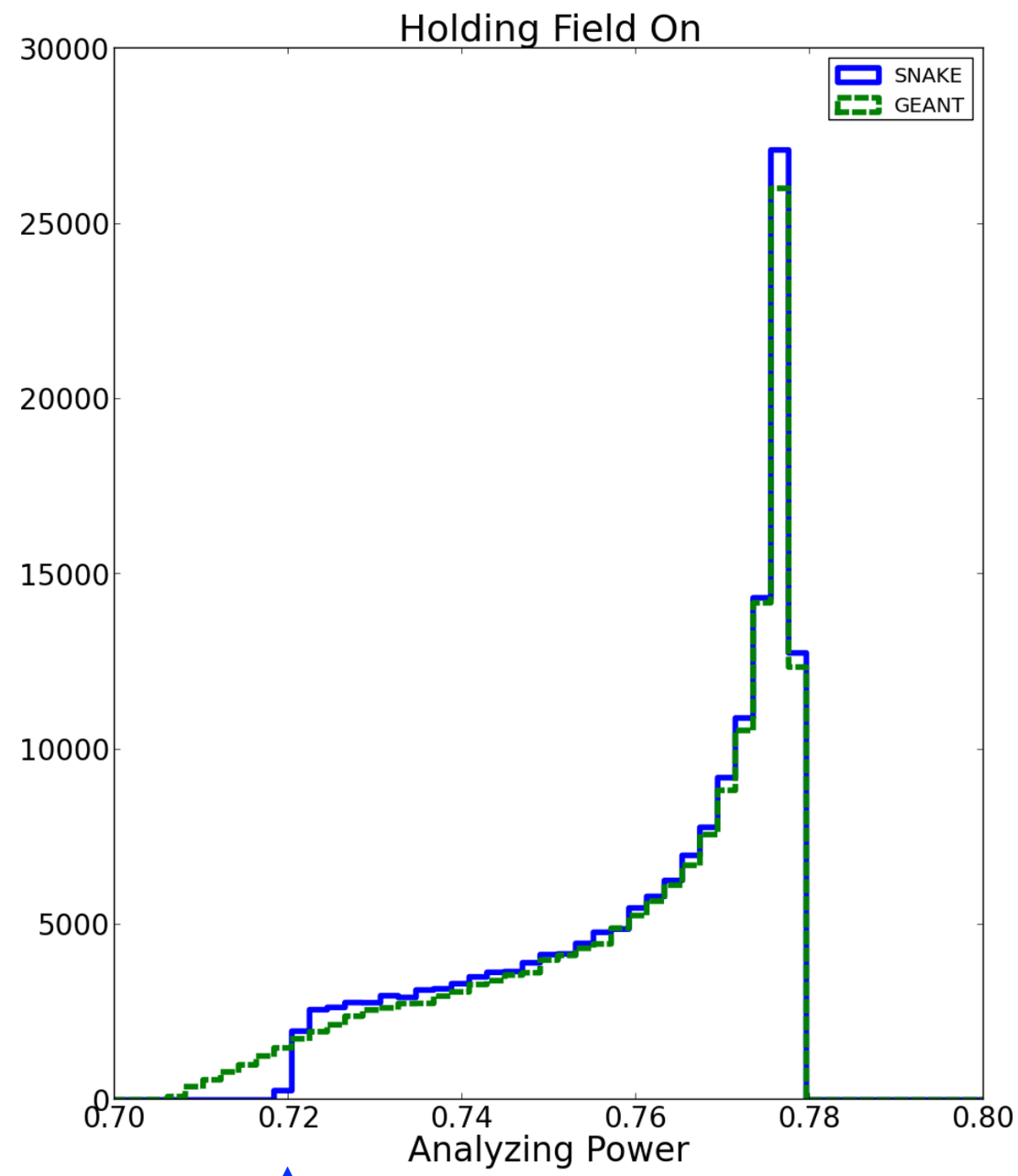


# First Exploration: Target Field



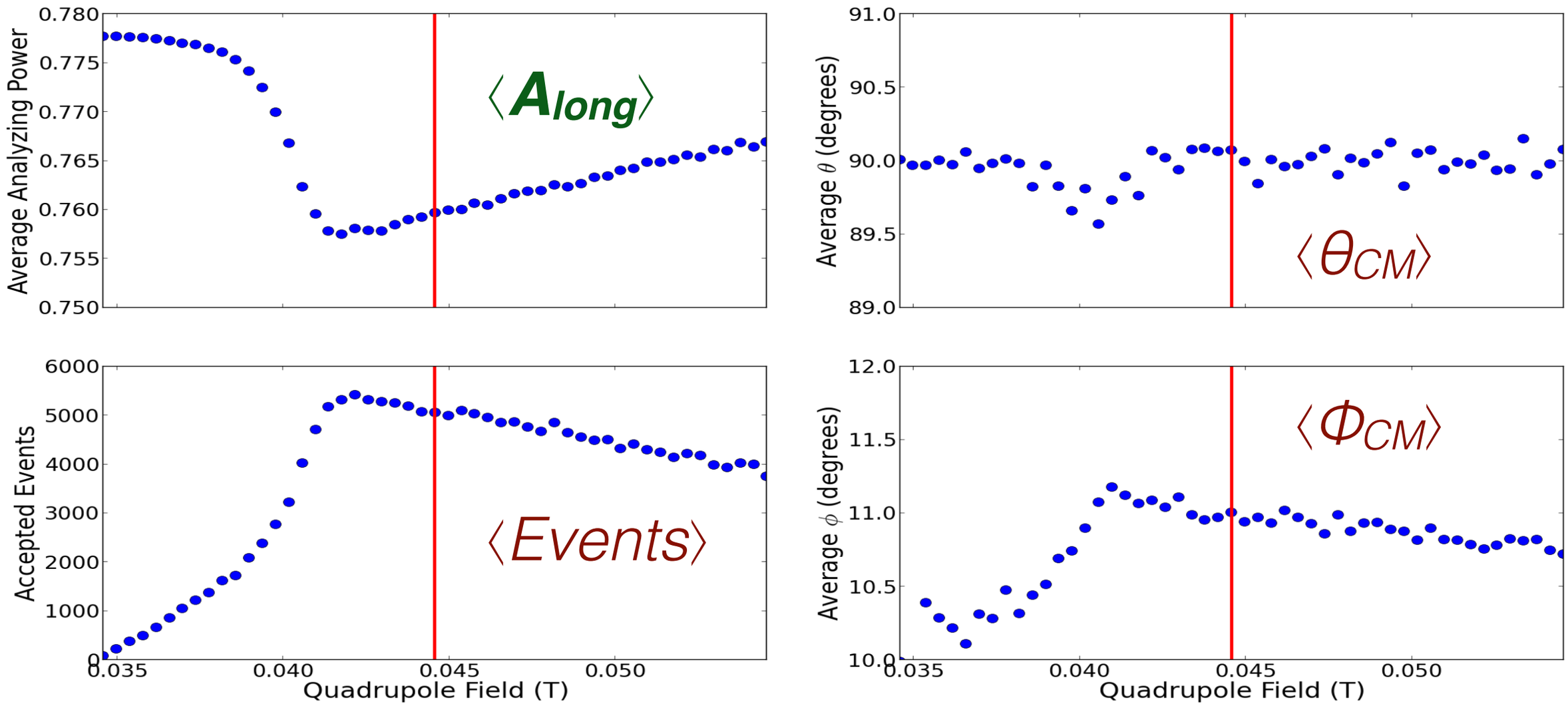
# … but the effect on the average analyzing power is minimal.




Note: This cutoff is seen in SNAKE but not GEANT and gives 0.2% difference

# Another Study: $B_{QUAD}$ Sensitivity




| Quad | $\delta\langle A_{\rm long}\rangle/\delta B_Q$ ($\mathrm{T}^{-1}$) |
|---|---|
| Q1 | 0.3631 |
| Q2 | 0.7725 |
| Q3 | 0.7337 |
| Q4 | 0.7633 |

➡ *For 0.1% uncertainty in $\delta\langle A_{long}\rangle$ need to know $B_{QUAD}$ to several Gauss.*

# Target Heating Data

*This is from the Hall C and Basel groups!*

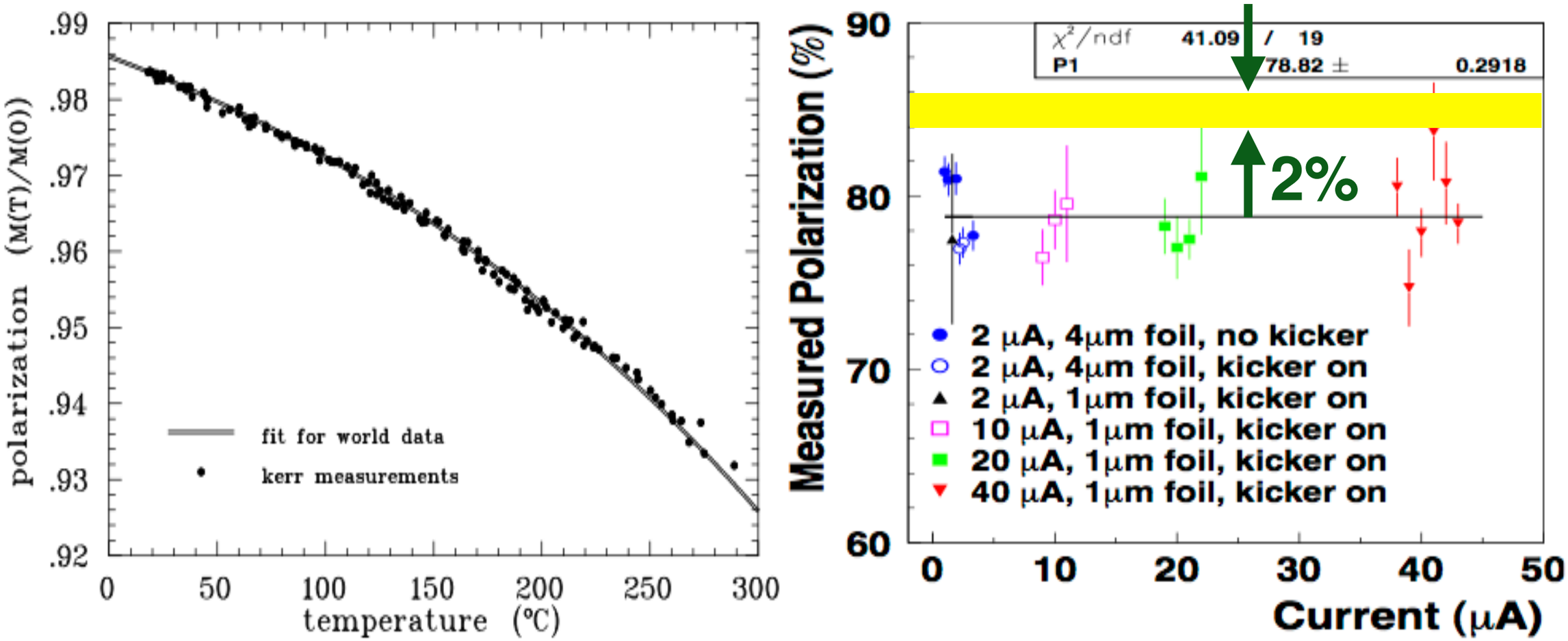



Figure 5: Target heating measurements from the Hall C/Basel group. *Left*: Magnetization versus temperature for a saturated pure iron foil [11, 12]. *Right*: Beam polarization measurements at different beam currents, with and without a beam kicker to raster the beam.

# *And in case you were wondering…*

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

# Summary and Outlook

*Remember: It is not easy to get down to 1%*

- New target holder ready to go, waiting on magnet.
- Simulation software in good shape, and first results with it look promising and point to other issues
- Magnet mapping and beamline alignment are the most critical issues to attack now
- Need to get simulation restarted to continue study of systematics, including CREX beam energy
- Given good simulation, turn attention to studies of Levchuk and Radiative Corrections
- Must come up with a plan to study target heating