# E97-110: Small Angle GDH

## *Analysis Status Update*

**Jaideep Singh**

**University of Virginia**

**on the behalf of the Spokespeople: J.P. Chen, A. Deur, F. Garibaldi**

**Thesis Students: J. Singh, V. Sulkosky, and J. Yuan**

**and the rest of the Polarized $^3$He Collaboration**

Hall A Collaboration Meeting

CC Auditorium, June 22, 2006

# Motivation

- Proposal Title: The GDH Sum Rule and the Spin Structure of $^3$He and the Neutron Using Nearly Real Photons
- Measured "double" polarized cross sections and asymmetries for inclusive electron scattering from a $^3$He target
- $^3$He target cells were specifically designed and constructed to minimize radiative corrections
- Detected scattered electrons at 6 and 9 degrees using the right septum magnet and the standard Hall A HRS package
- Among other things, this precision measurement will allow us to extract the generalized GDH integral over a $Q^2$ range of 0.02-0.30 GeV$^2$

# GDH Sum Rule $\left(Q^2 = 0\right)$

For circularly polarized real photons ($Q^2 = 0$):

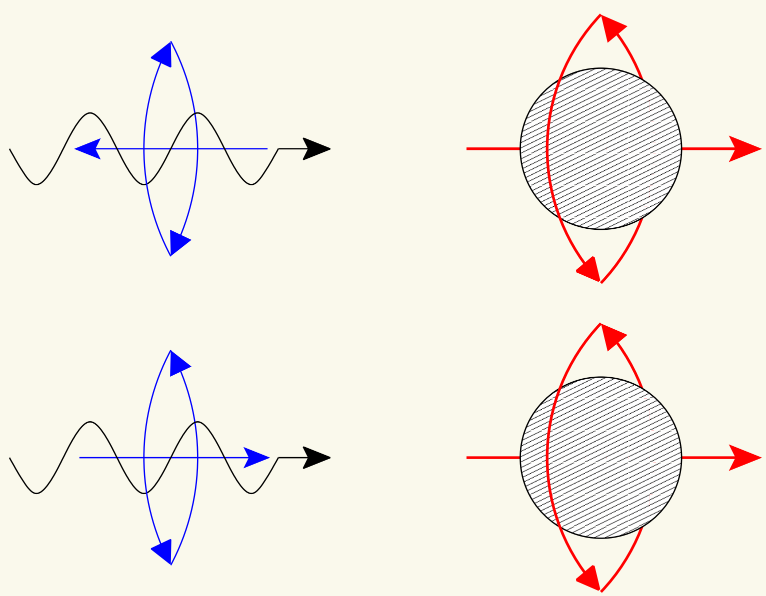
$$I_{\mathrm{GDH}} = \int_{\nu_0}^{\infty} \left[\sigma_{\frac{1}{2}}(\nu) - \sigma_{\frac{3}{2}}(\nu)\right] \frac{\mathrm{d}\nu}{\nu} = -2\pi^2\alpha \left(\frac{\kappa}{M}\right)^2$$

$$I_{GDH}^{\mathrm{n}} = -233\ \mu\mathrm{b}\ \ \&\ \ I_{GDH}^{^3\mathrm{He}} = -498\ \mu\mathrm{b}$$

This sum rule relates real photoabsorption cross section difference to anomalous part of target magnetic moment $\kappa$.

$\sigma_{\frac{1}{2}}$:

$\sigma_{\frac{3}{2}}$:



# Generalized Integral for $S = 1/2$

When the integrand is generalized to $Q^2 > 0$:

$$I = \int_{\nu_0}^{\infty} \left[\frac{K(\nu,Q^2)}{\nu}\right] \left[\sigma_{\frac{1}{2}}(\nu, Q^2) - \sigma_{\frac{3}{2}}(\nu, Q^2)\right] \frac{\mathrm{d}\nu}{\nu}$$

$$K(\nu, 0) = \nu$$

...the integral can form a sum rule when set equal to the virtual photon Compton Amplitude $S_1(\nu, Q^2)$ [see for example: X. Ji & J. Osbourne J. Phys. G: Nucl. Part. Phys. 27, 127 (2001)], which can be calculated over the full $Q^2$ range using different theoretical tools.

**This versatile experimental observable provides a bridge from the non-perturbative region to perturbative region of QCD!**

# Essentially Completed!

1. Experimental Run Database (J. Singh)
2. Beamline: BCM Calibration (T. Holmstrom)
3. Beamline: BPM and Raster Calibration (V. Sulkosky)
4. Beamline: Bleedthrough Parameterization (T. Holmstrom)
5. Beamline: Polarimetry (T. Holmstrom)
6. Target Cell Characterization (J. Singh)
7. Background Studies: Quick Check (A. Deur, S. Dhamija)
8. Spectrometer: Optics (V. Sulkosky, N. Liyanage)
9. Detector Calibrations: PID (H. Lu, J. Yuan)
10. Helicity Decoding (V. Sulkosky)
11. False Asymmetry Crosscheck (T. Holmstrom)

# Beam Polarization

Bleedthrough is defined by:

$$B \equiv \frac{I'_C}{I_A} = \frac{I'_C}{I'_A + I'_C}$$

where $I'_C$ is a function of the Hall A slit position and Hall C current.

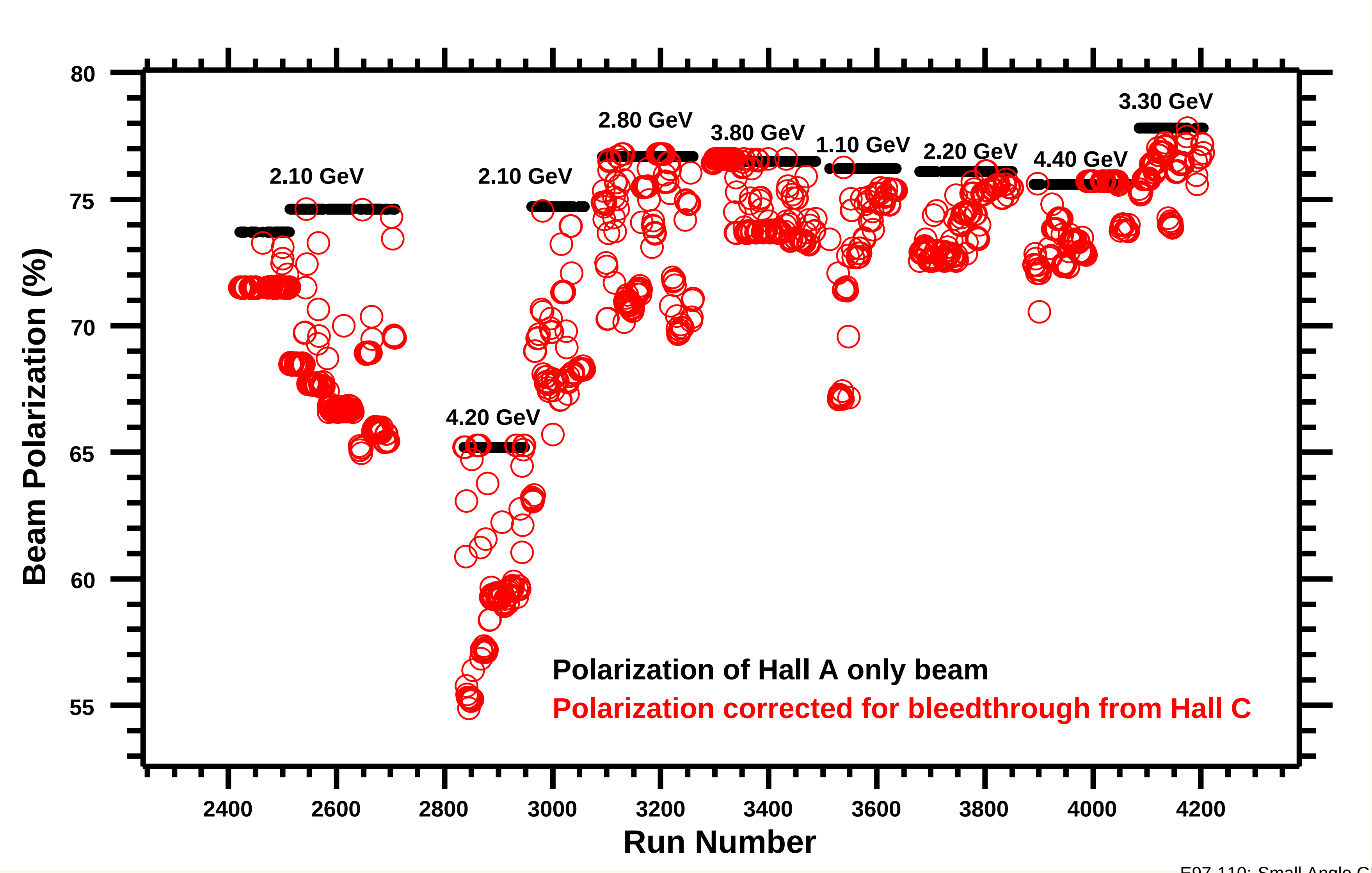
The polarization of the Hall A beam is therefore:

$$P_A = \frac{I'_A P'_A + I'_C P'_C}{I_A} = P'_A \left[ 1 - B \left( 1 - \frac{P'_C}{P'_A} \right) \right]$$

where $P'_{A,C}$ are both measured during the Møller measurement.

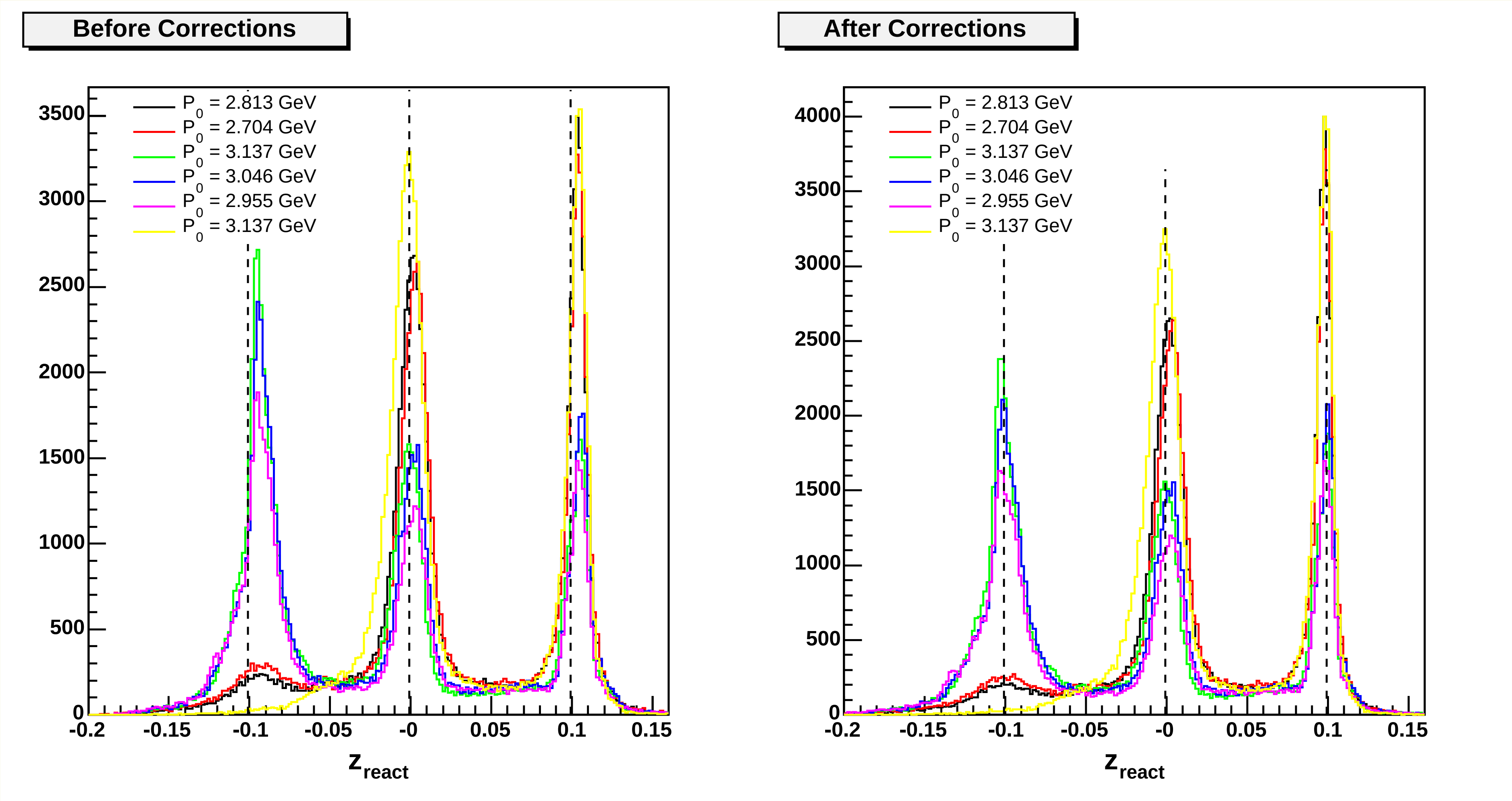
# Beam Polarization

A few more small issues to resolve, but basically...



# Shift Corrections

## Only needed at high spectrometer momentum settings...

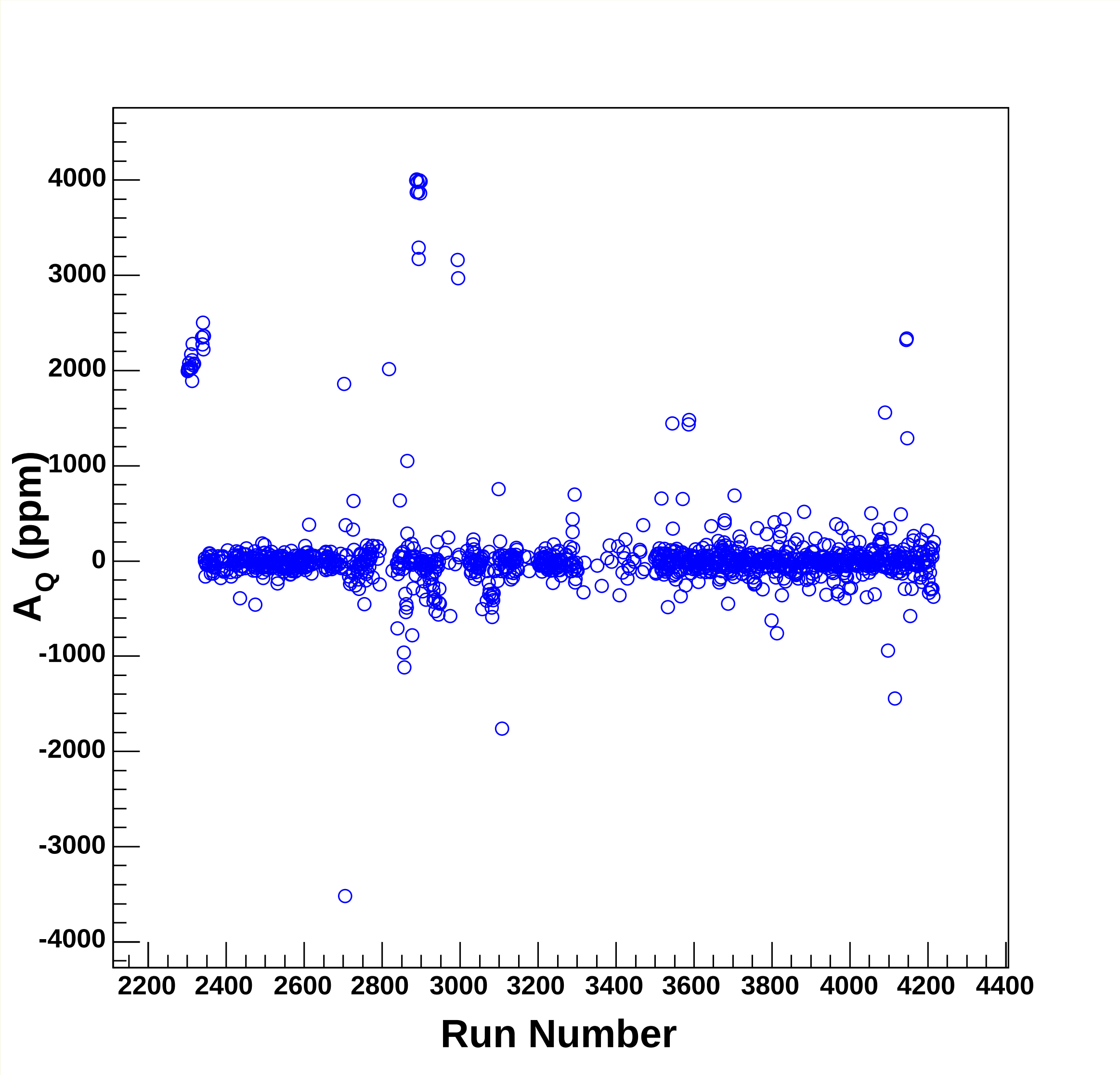


# Work Well Under Way...

1. Scalar Analysis (T. Holstrom, H. Lu, V. Sulkosky)
2. Detector Calibrations: Scintillators (H. Lu, J. Singh)
3. Spectrometer: Acceptance at 6 degrees (V. Sulkosky)
4. Background Studies: GEANT Simluation (A. Beck, A. Deur)
5. Pressure Curves (X. Zhan)
6. $N_2$ Dilution (X. Zhan)
7. Target Polarimetry (J. Singh)

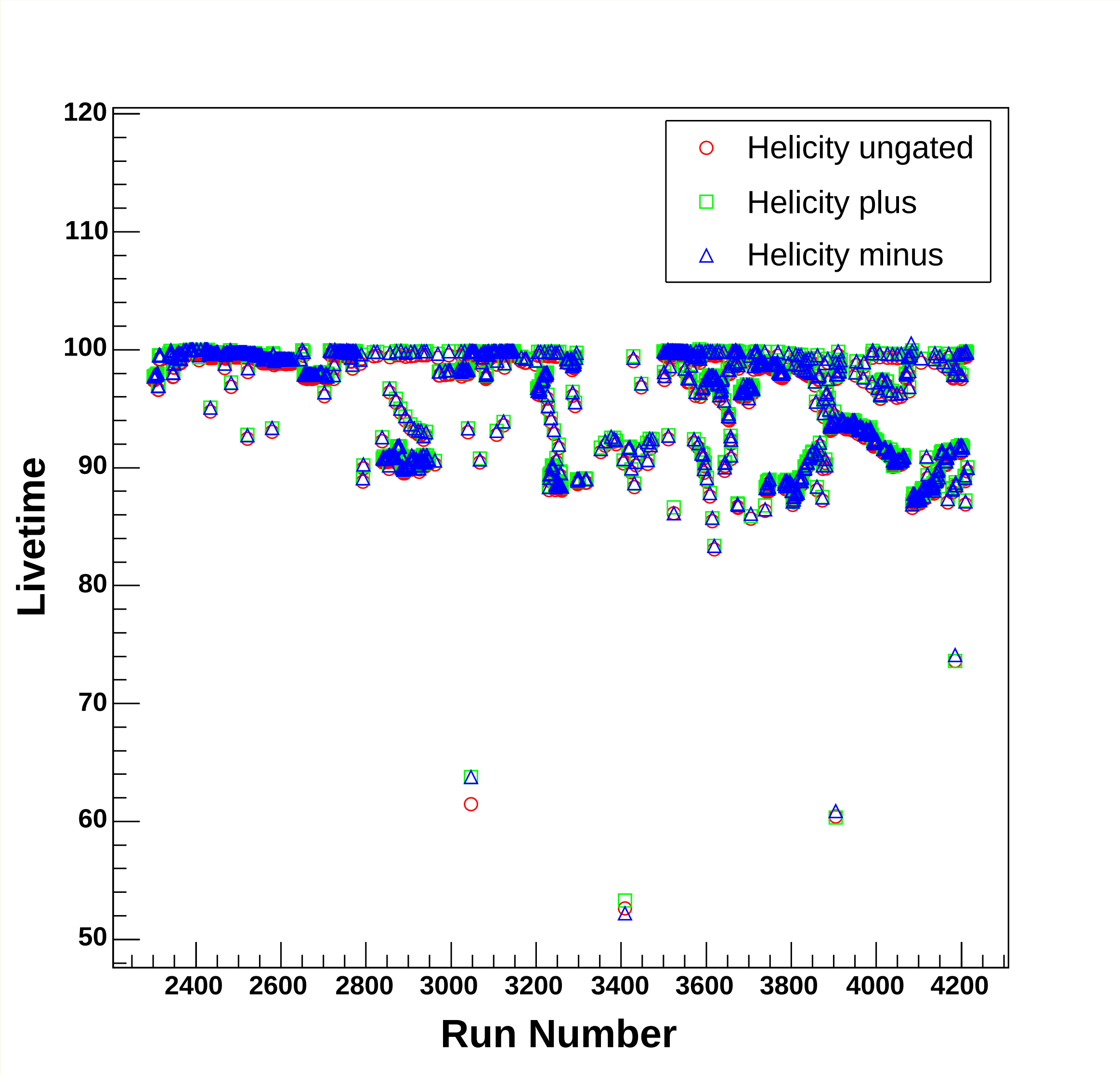
# Charge Asymmetry

Parity DAQ was not running at the beginning...



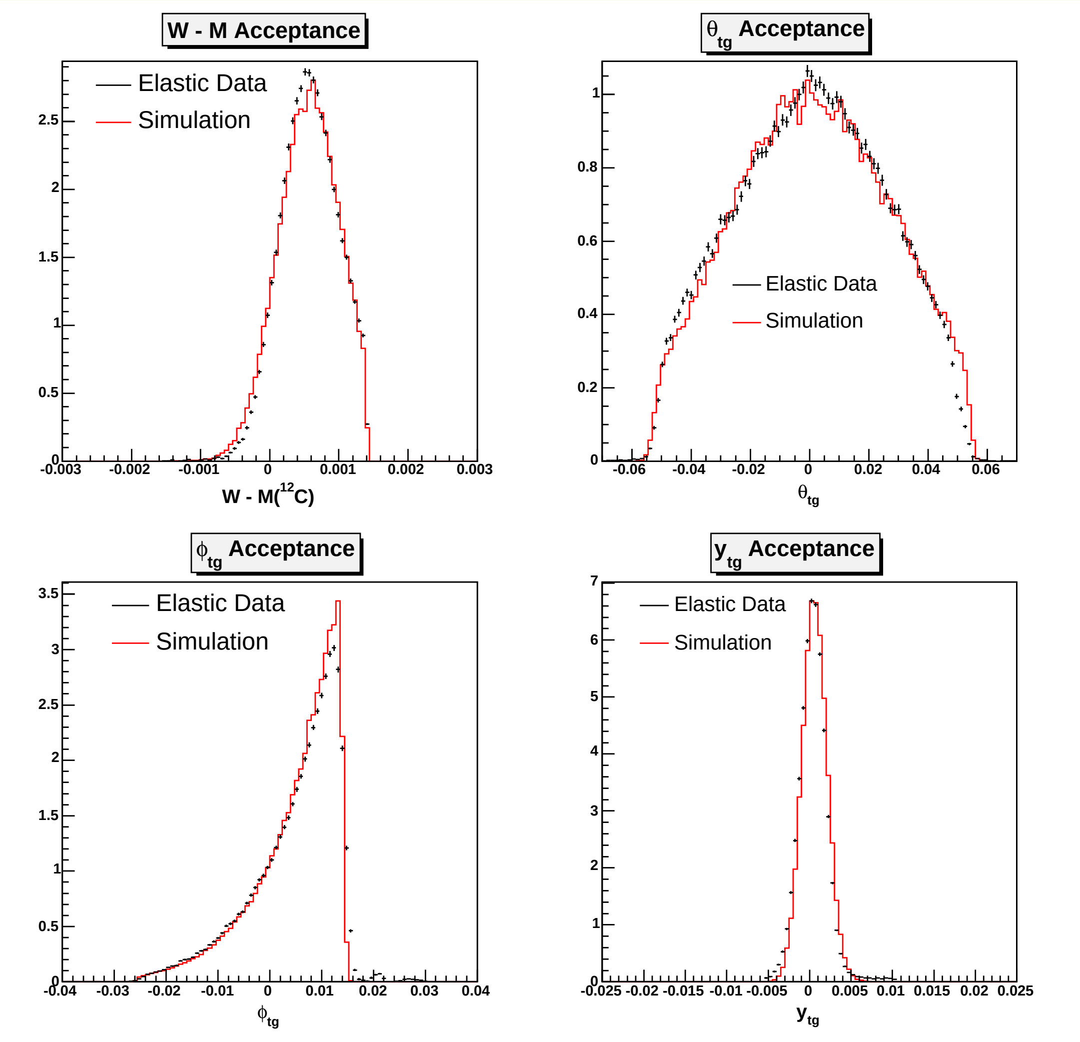
# Livetime

A few outliers, but otherwise looks good...



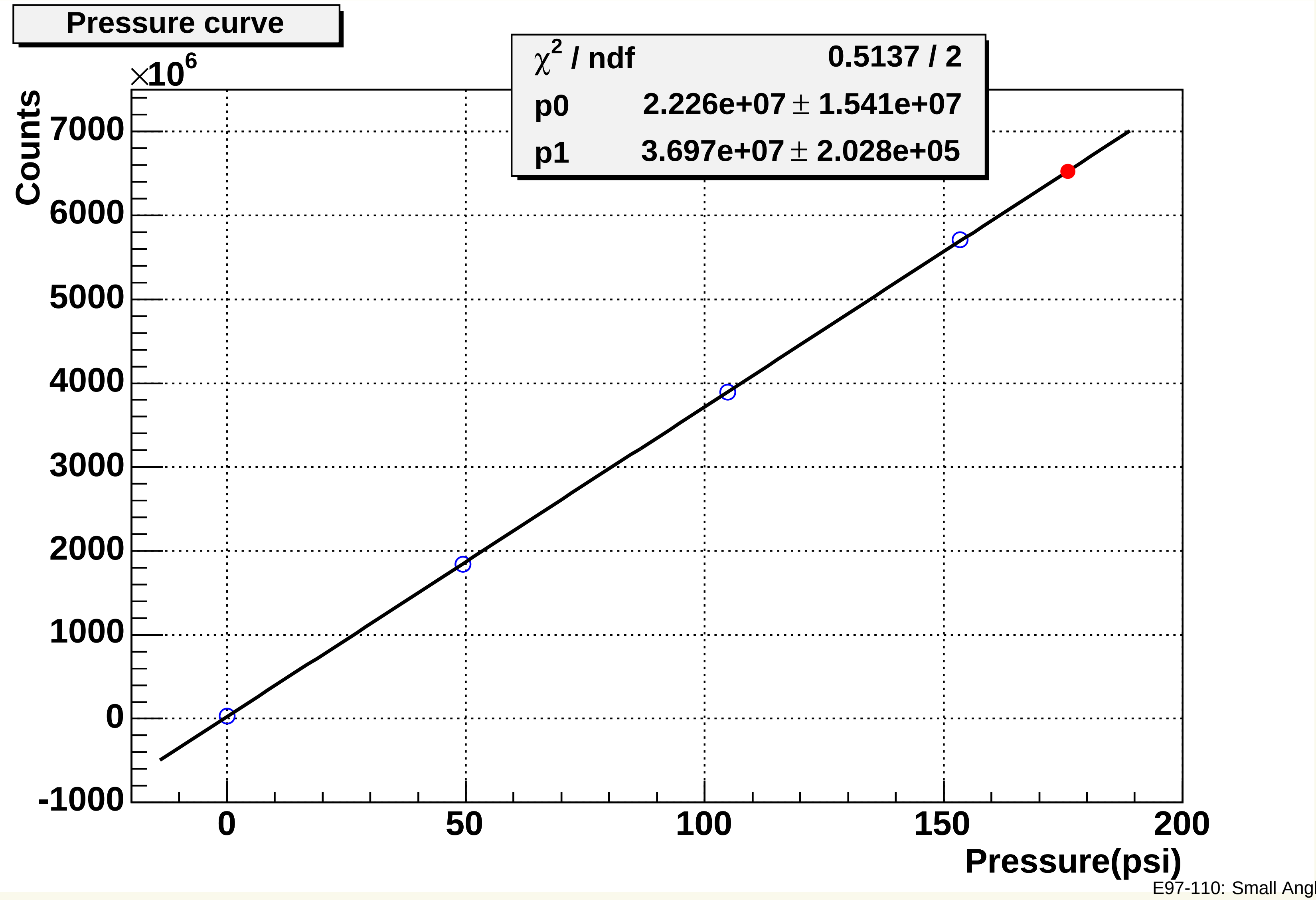
# Acceptance with Carbon Foil

Comparison between Data (black) and Monte Carlo (red)



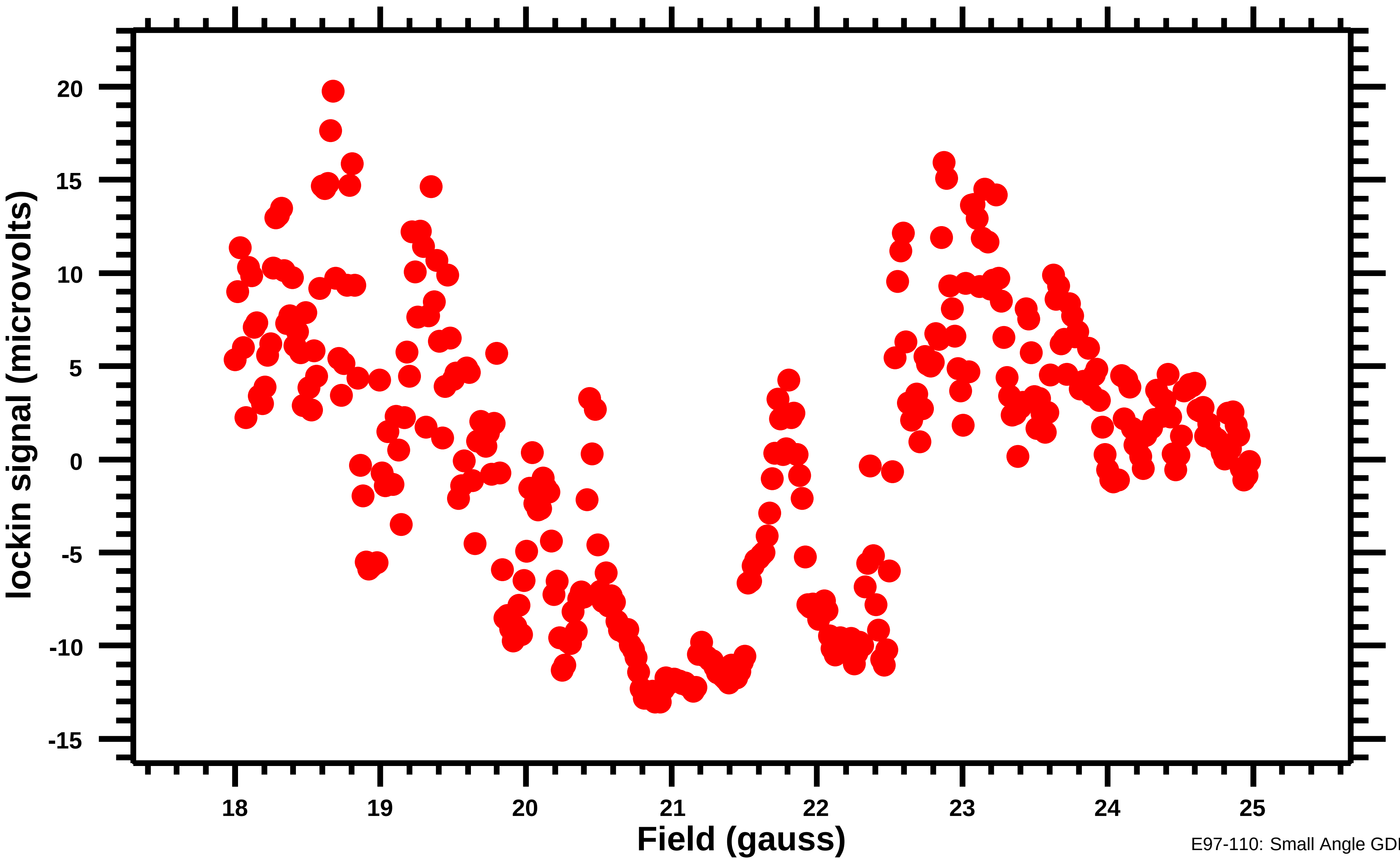
# Helium Pressure Curve

Crosscheck of target density $\rightarrow [\rho_{\mathrm{PC}}/\rho_{\mathrm{fill}}]_{^3\mathrm{He}} = 0.997 \pm 0.017$



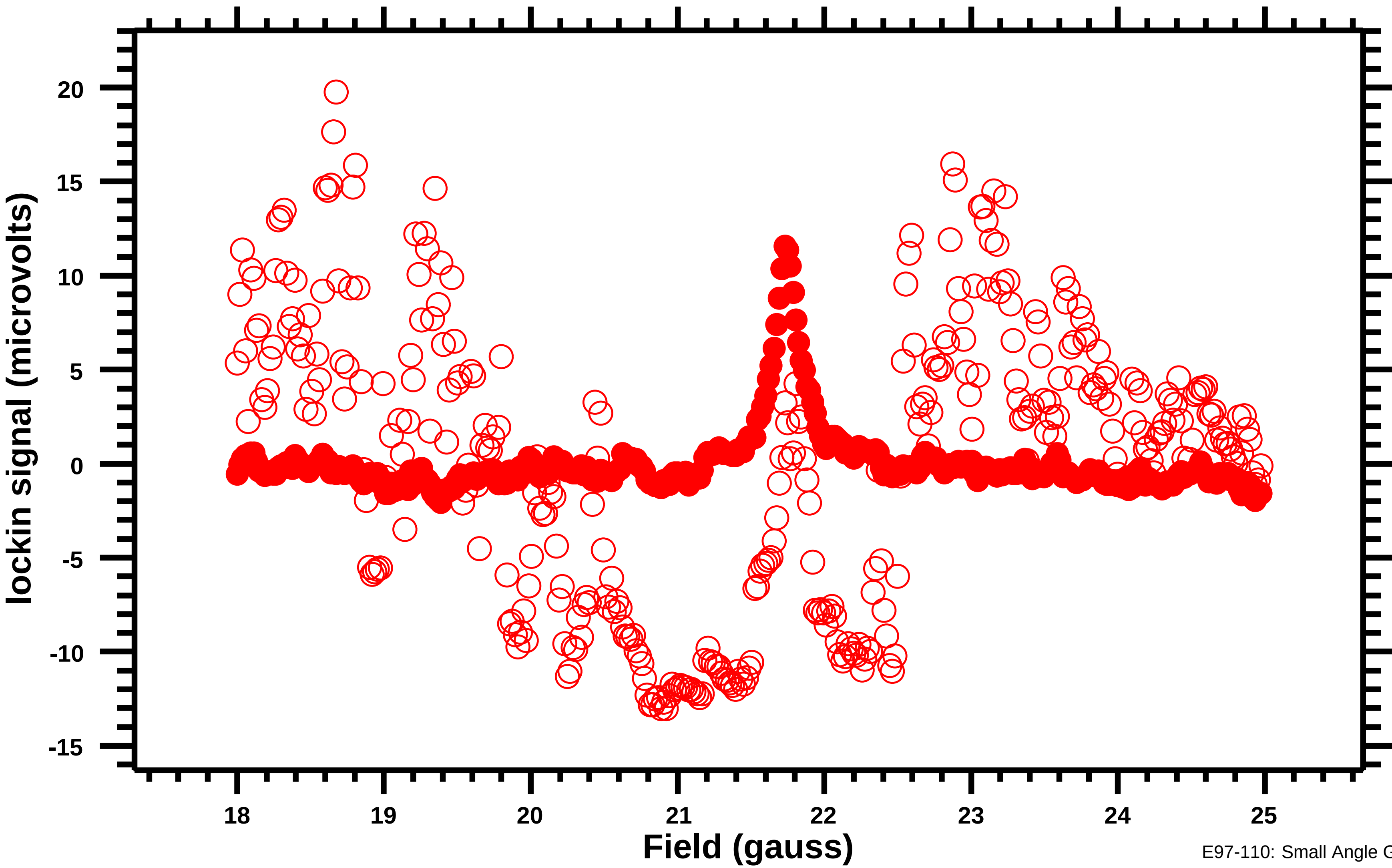
# Water Calibrations

Typical water signal before “noisy” signal cuts...



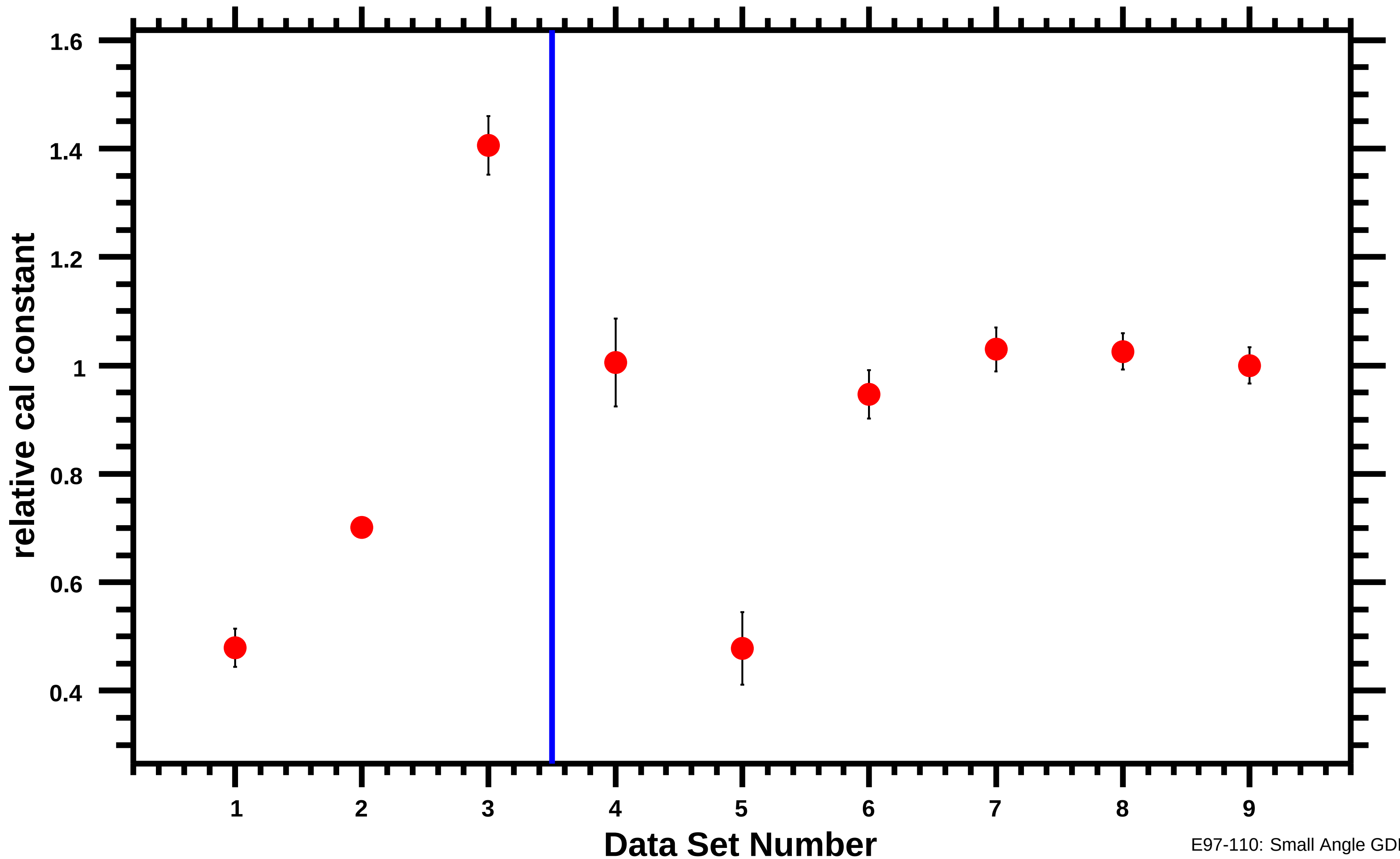
# Water Calibrations

Getting rid of just a few bad sweeps gives...



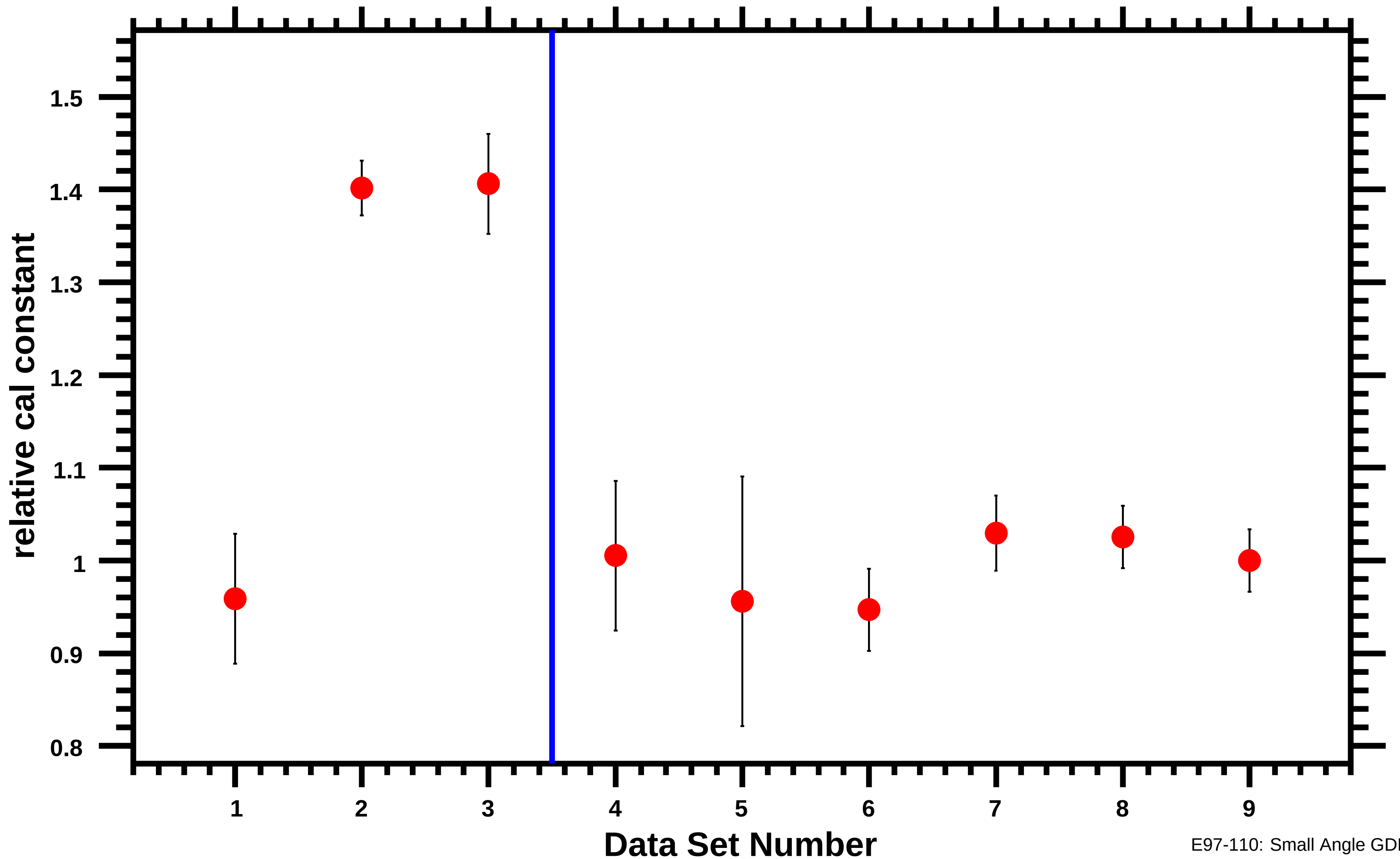
# Water Calibrations

Errors bars are stat only from fit!



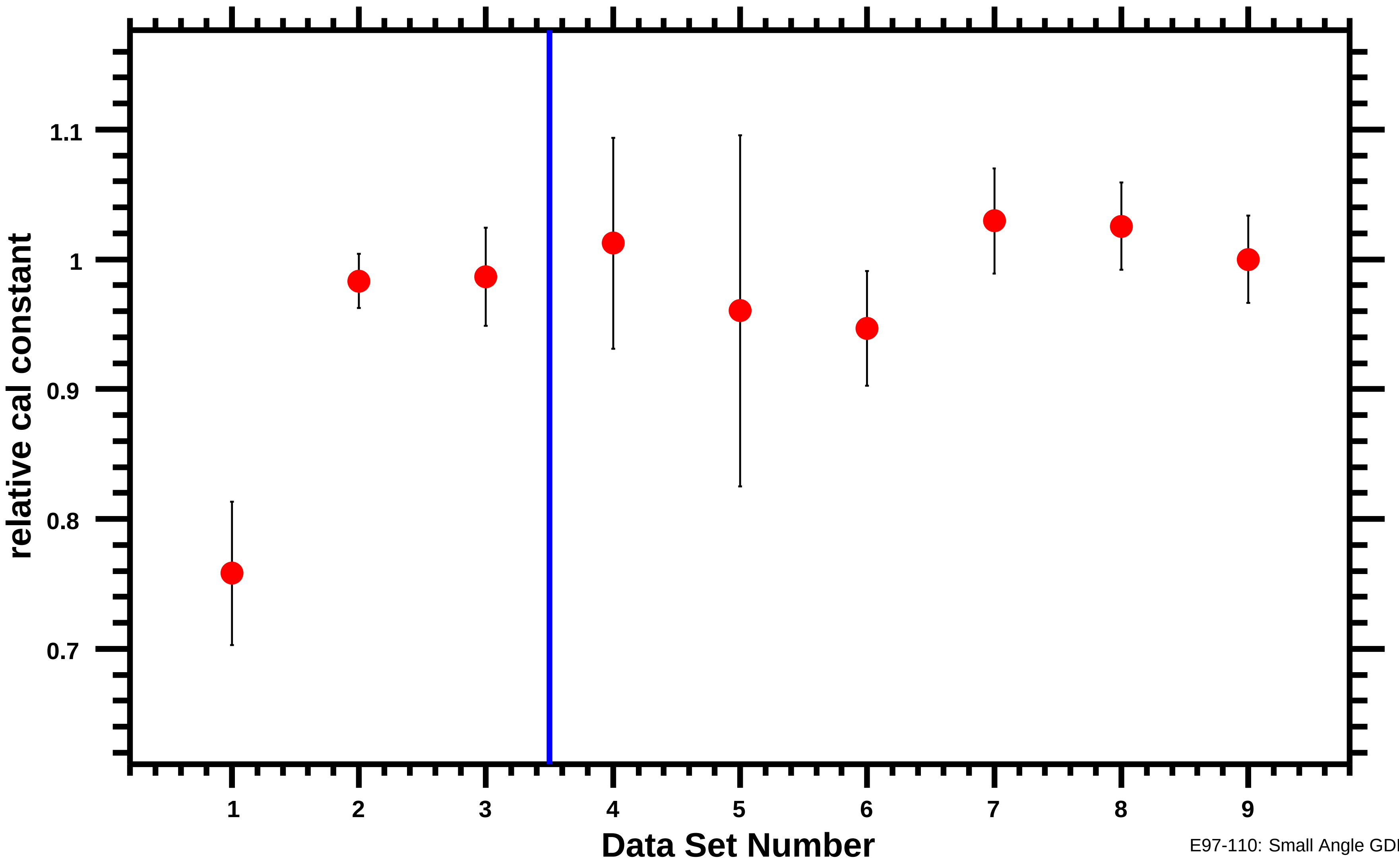
# Water Calibrations

## Dividing out preamplifier gain...



# Water Calibrations

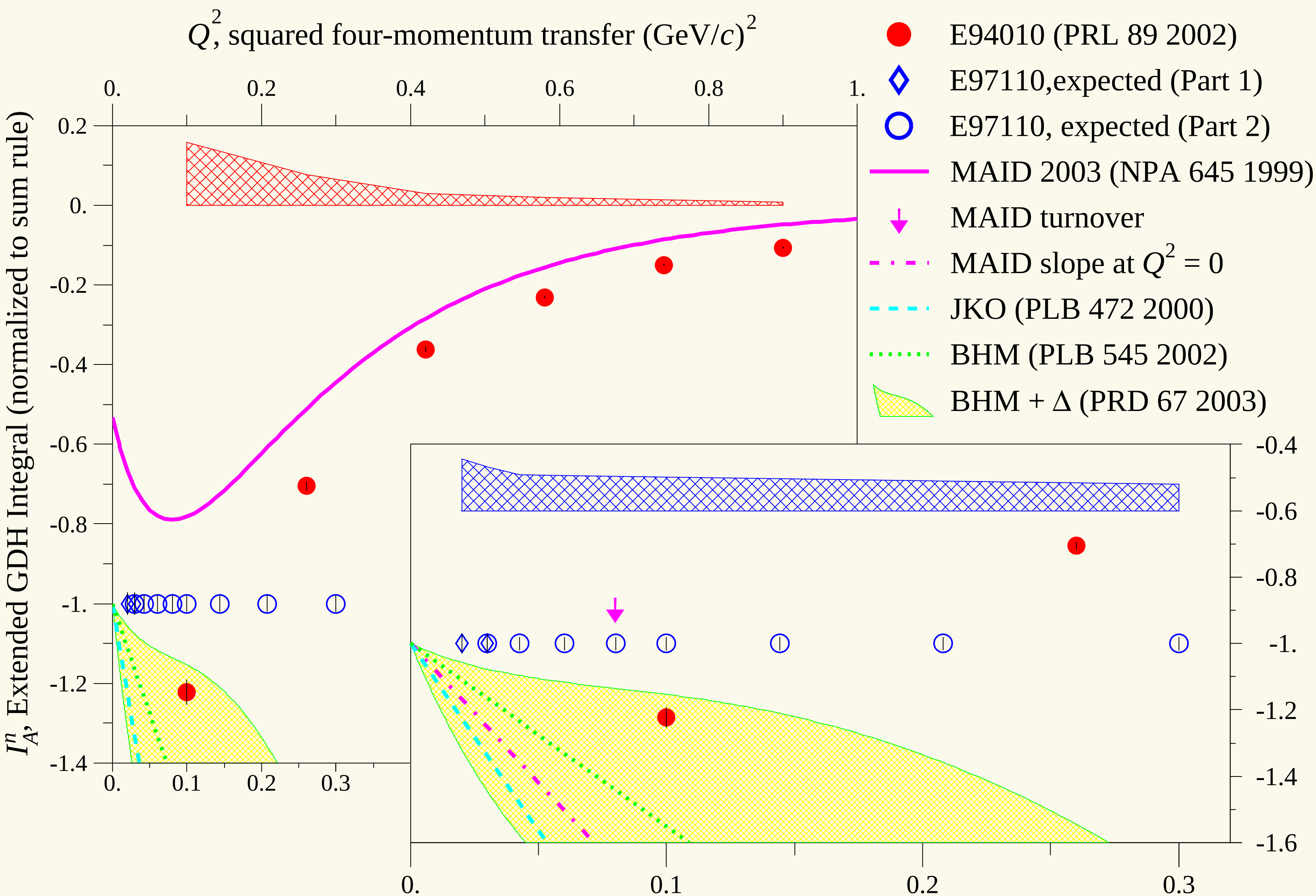
Dividing out geometrical flux factor...



# Work Well Under Way...

- Scalar Analysis - first major replay of all the good runs $\rightarrow$ learned that we needed alot more workdisk space for all 1500 runs (2 million events each)
- Carbon elastic cross section still needs more work. (V. Sulkosky)
- GEANT Simluation: Vince and Arie have established an interface between the GEANT output and the spectrometer simulation input
- Pressure curve results agree with fill values for both helium and nitrogen $\left([\rho_{\mathrm{PC}}/\rho_{\mathrm{fill}}]_{\mathrm{N}_2} = 1.09 \pm 0.22\right)$
- preliminary $\mathrm{N}_2$ Dilution factor $= 0.9390 \pm 0.0139$
- Target Polarimetry: Calibrations look consistent, lot's of loose ends to tie up...

# Summary: Expected Results



# Summary

We plan to:

1. determine the slope of the generalized GDH integral to test the dynamics of $\chi$PT.
2. extrapolate to the real photon point.
3. extract the moments of the spin structure functions and forward spin polarizabilities

This data set complements the E94010 data set below $Q^2 = 0.10\ \mathrm{GeV}^2$ with improved precision.

# Summary

Some progress has been made on the first run period:

- PID calibration is done. (H. Lu)
- Some preliminary elastic and inelastic asymmetries have been formed. (H. Lu)

But most of the focus has been on the second period:

- PID calibration is done. (H. Lu, J. Yuan)
- Spectrometer optics is done. (V. Sulkosky)
- Scalar analysis is underway. (T. Holmstrom, V. Sulkosky)
- Spectrometer acceptance is reasonably well understood for 6 degrees. (V. Sulkosky)
- Beam and Target Polarimetry is under control (T. Holmstrom, J. Singh)

# Summary

Long Term Plan:

1. Detector Calibrations: VDC Multitrack Analysis (S. Dhamija, H. Lu, J. Yuan)
2. Spectrometer: Acceptance at 9 degrees, should go much faster... (V. Sulkosky)
3. $^3$He Elastic Analysis (J. Singh)
4. Extracting Raw Observables: Cross Sections and Asymmetries (H. Lu, J. Singh, V. Sulkosky, J. Yuan)
5. Forming physical quantities from raw observables (A. Deur, H. Lu, J. Singh, V. Sulkosky, J. Yuan)
6. Radiative Corrections (T. Averett)