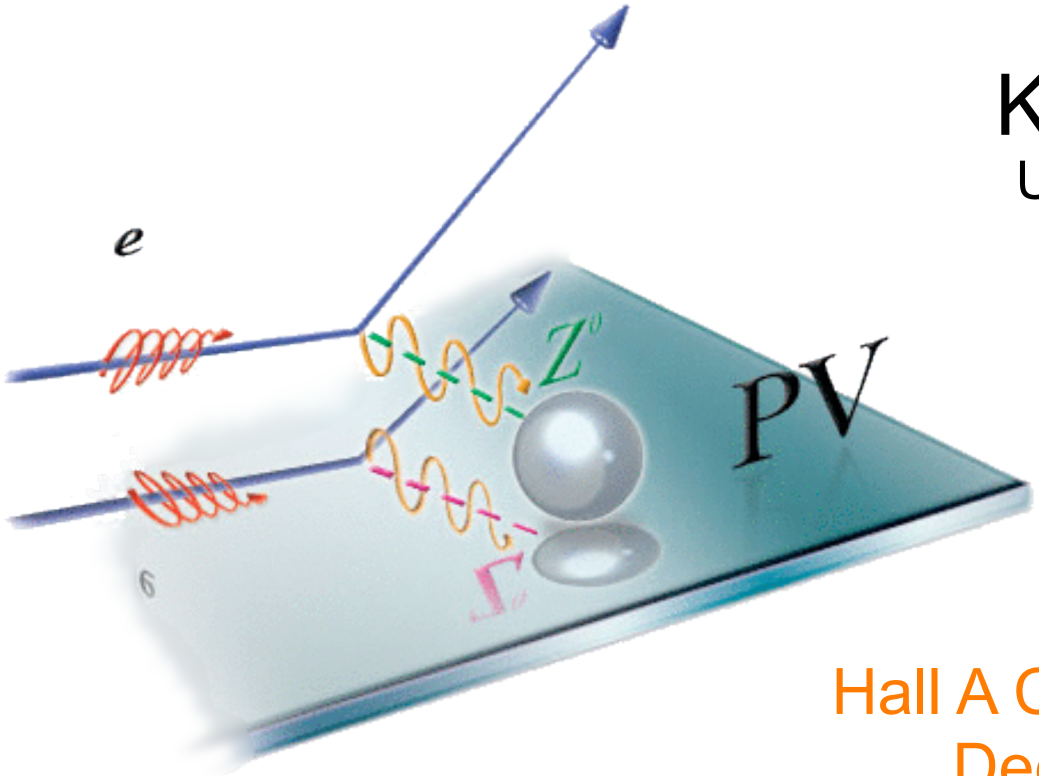
E05-009: HAPPEX-III Update

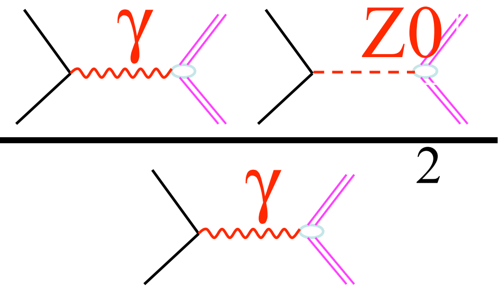


Kent Paschke
University of Virginia

Hall A Collaboration Meeting
December 14, 2009

Measuring Strange Vector Form Factors

$$A = \frac{\sigma_R - \sigma_L}{\sigma_R + \sigma_L} \propto$$



$$\sim \frac{10^{-4} Q^2}{\mathrm{GeV}^2}$$

Interference with EM amplitude makes Neutral Current (NC) amplitude accessible

For a proton:

$$A = \left[\frac{-G_F Q^2}{4\pi\alpha\sqrt{2}}\right] \frac{A_E + A_M + A_A}{\sigma_p}$$ ~ few parts per million

$$A_E = \epsilon G_E^p G_E^Z \qquad A_M = \tau G_M^p G_M^Z \qquad A_A = (1 - 4\sin^2\theta_W)\epsilon' G_M^p \tilde{G}_A$$

Forward angle → Backward angle

For spin=0,T=0 ^{4}He:

G^s_E only!

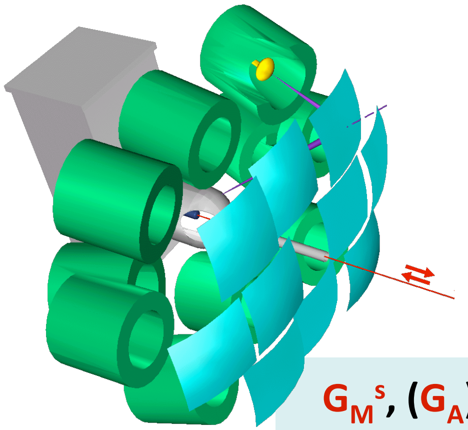
nuclear corrections: forward angle, low Q^2 only

For deuterium:

Enhanced G_A

Back-angle quasi-elastic.

World Data

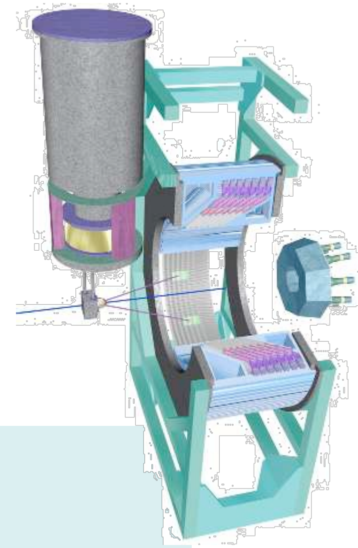


SAMPLE

open geometry, integrating

G_M^s, (G_A) at $Q^2 = 0.1$ GeV^2

A4



Open geometry

Fast counting calorimeter for background rejection

$G_E^s + 0.23\, G_M^s$ at $Q^2 = 0.23$ GeV^2

$G_E^s + 0.10\, G_M^s$ at $Q^2 = 0.1$ GeV^2

G_M^s, G_A^e at $Q^2 = 0.23$ GeV^2

HAPPEX

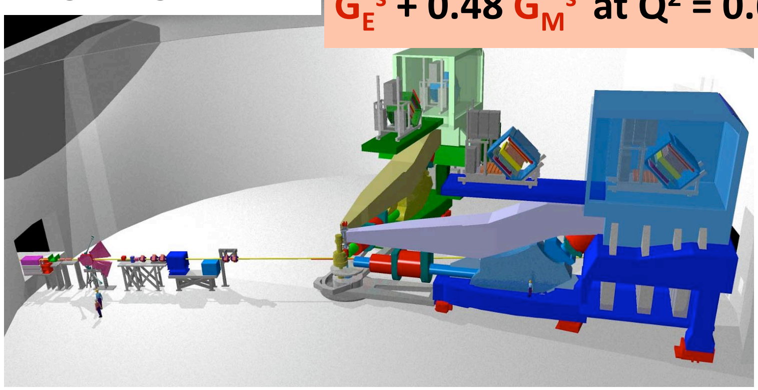
Precision spectrometer, integrating

$G_E^s + 0.39\, G_M^s$ at $Q^2 = 0.48$ GeV^2

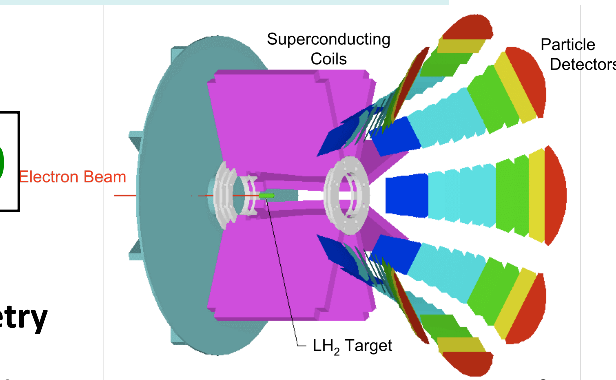
$G_E^s + 0.08\, G_M^s$ at $Q^2 = 0.1$ GeV^2

G_E^s at $Q^2 = 0.1$ GeV^2 (^{4}He)

$G_E^s + 0.48\, G_M^s$ at $Q^2 = 0.62$ GeV^2



G0



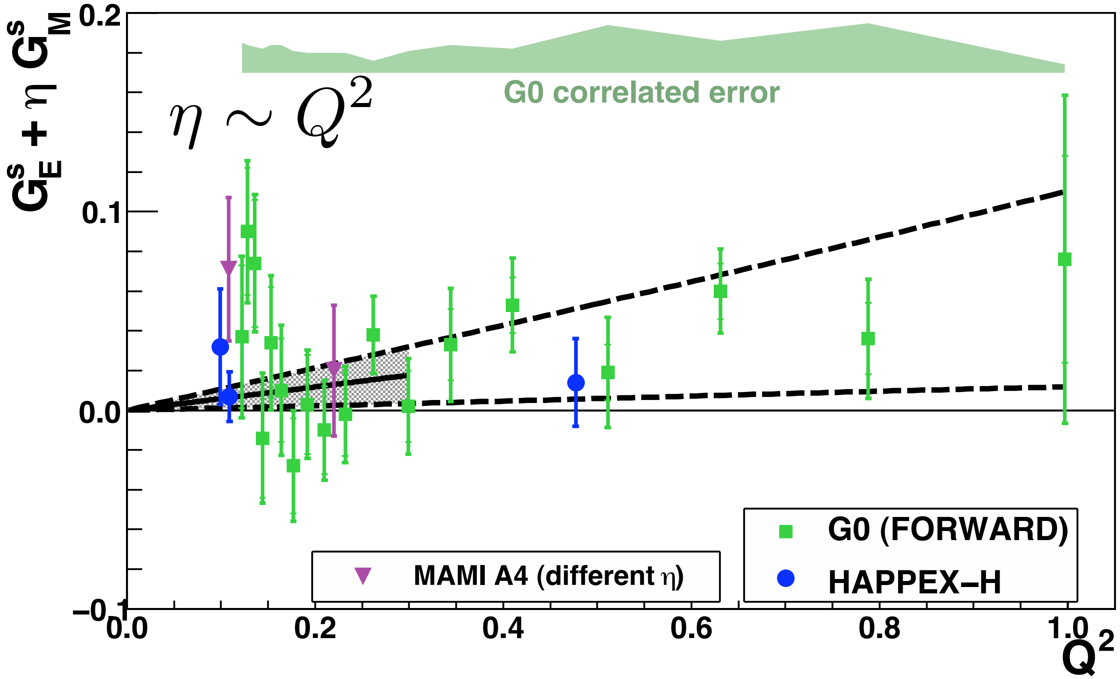
Open geometry

Fast counting with magnetic spectrometer + timing for background rejection

$G_E^s + \eta\, G_M^s$ over $Q^2 = [0.12, 1.0]$ GeV^2

G_M^s, G_A^e at $Q^2 = 0.23, 0.62$ GeV^2

Summary of World Data



Simple fit to "leading order" in Q^2

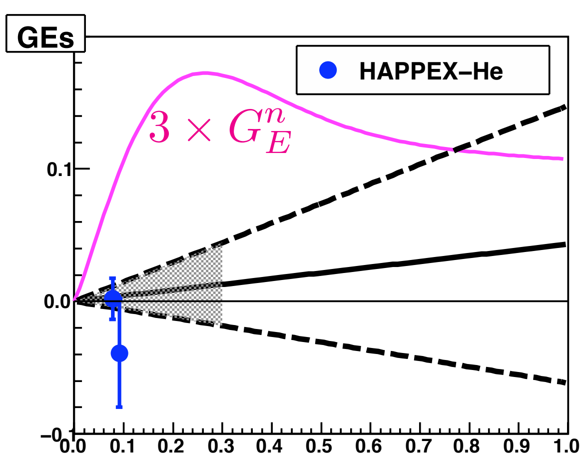
$$G_E^s = \rho_s * \tau$$

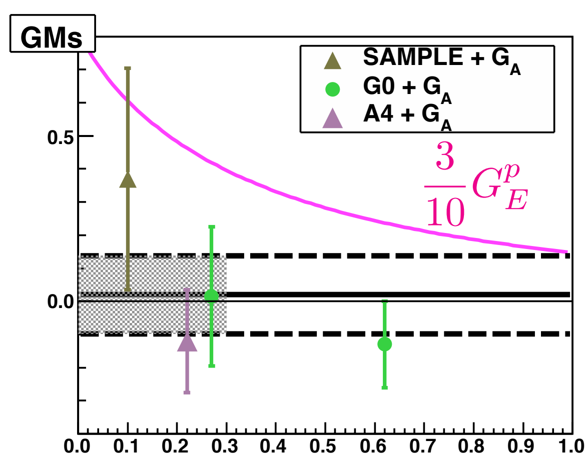
$$G_M^s = \mu_s$$

Includes only data $Q^2 < 0.3$ GeV^2

Data set biased towards positive signal at higher Q^2

Sizeable contributions are not still not definitively ruled out.





G0 Global error allowed to float with unit constraint

Zhu et al axial constraints are used

Includes backangle results as constraint on G_M^s only (neglects correlations with G_E^s from extraction)

Sources of correlated error, such as electromagnetic form factor assumptions are neglected

Again, a more careful fit with somewhat different assumptions is available::

R. Young et al., Phys. Rev. Lett 97, 102002 (2006)

Summary of run

Optics / Commissioning

Optics at 1 pass
PREX detector study at 1 pass

Production Data set

"parity" commissioning went smoothly

Low beam availability at start
Power outages brought down the hall at end

Total: about 2/3 proposed beam hours collected

Calibration / Background measurements

Suitable linearity measurements during run

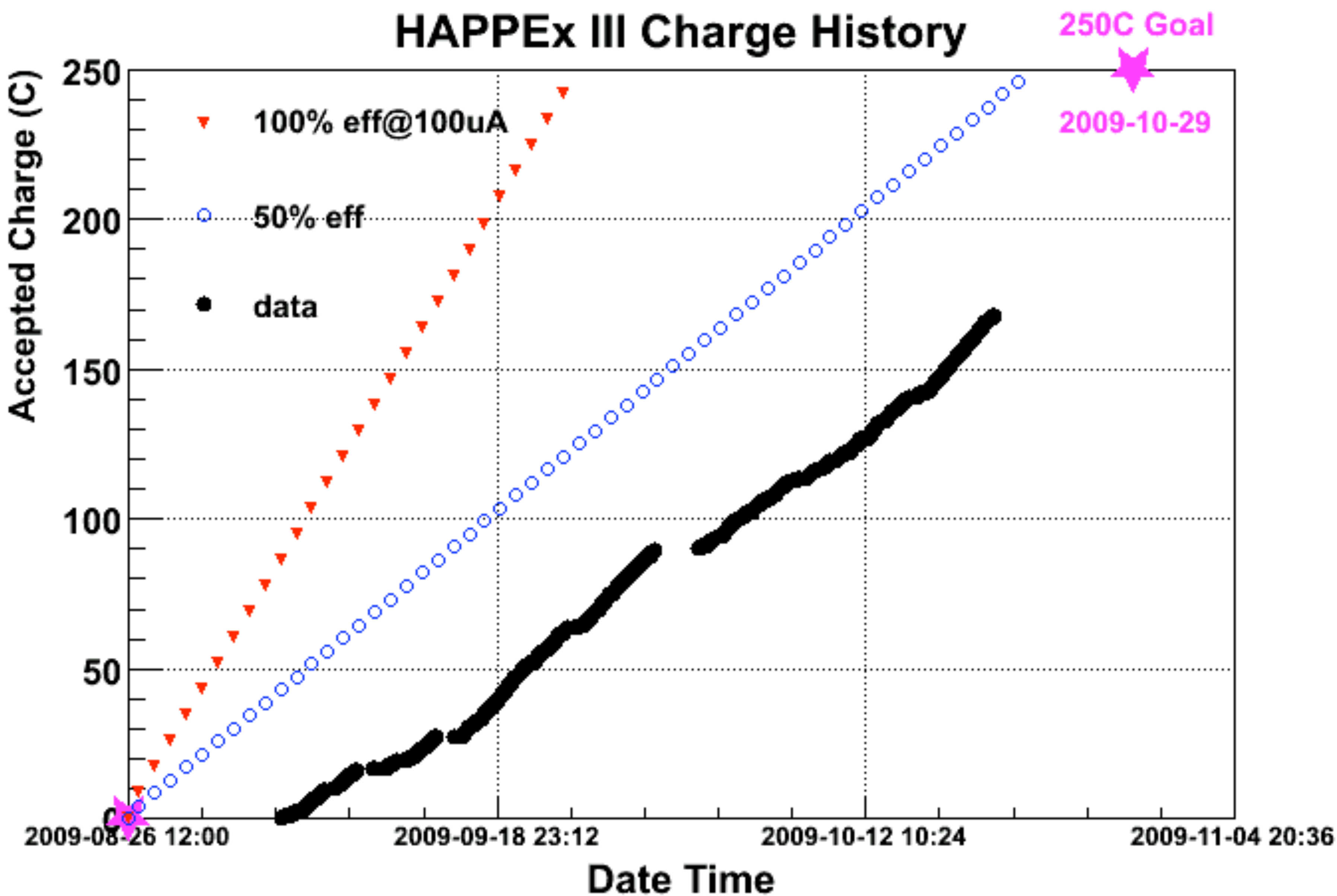
Recovered from 1st power outage for a few hours, got
Aluminum target window thickness measurement!

Other studies: extremely similar to HAPPEX-I

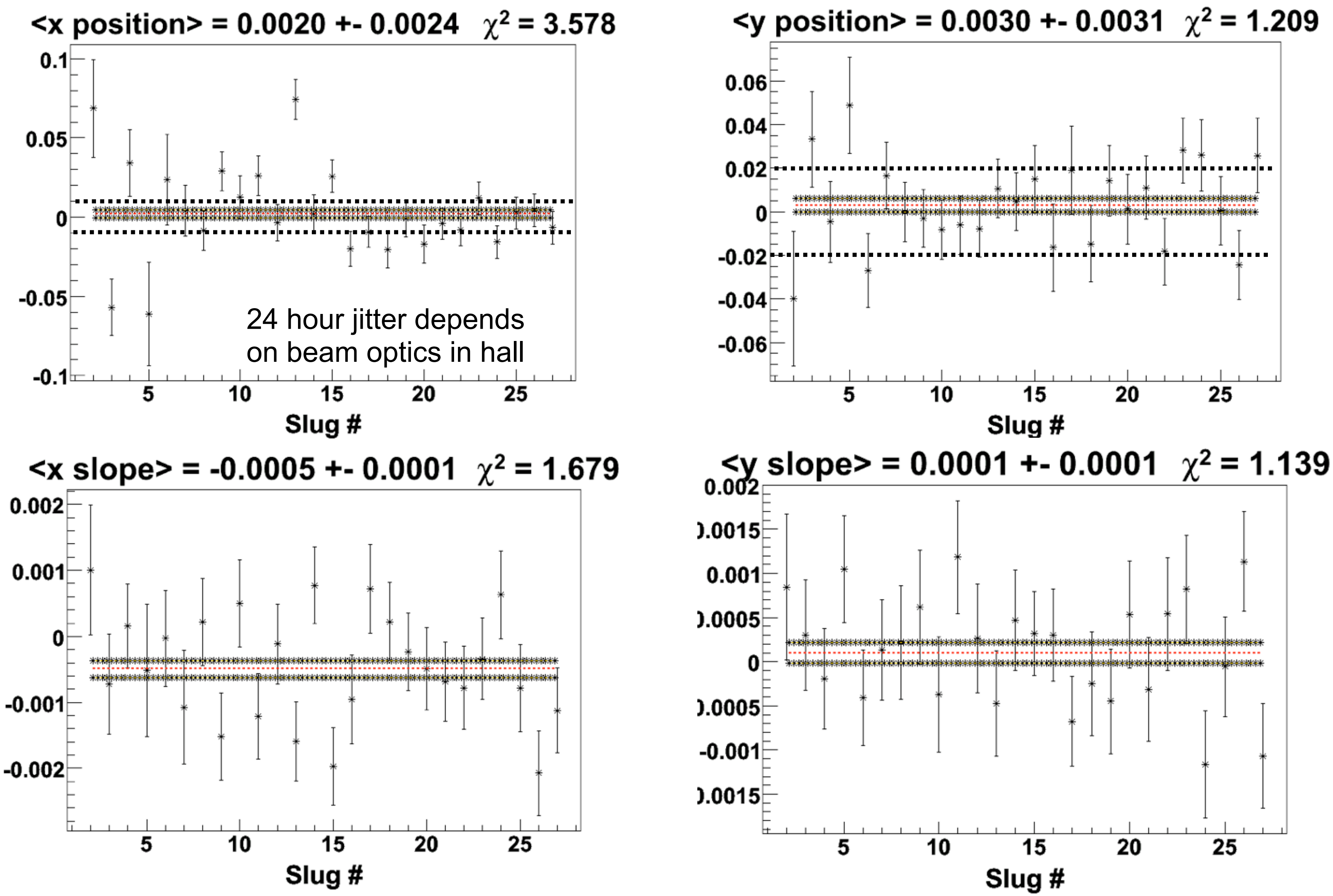
Polarimetry

Moller polarimetry - expensive!

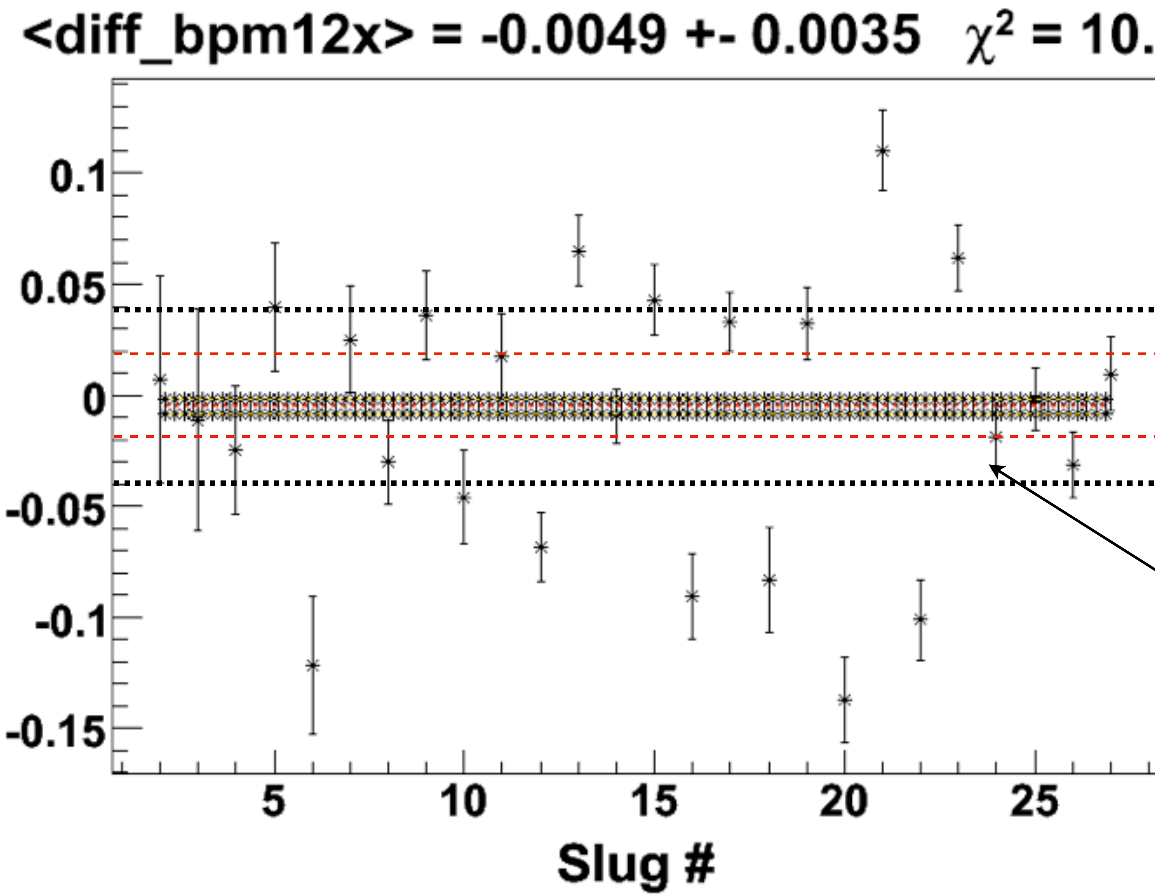
Compton polarimetry - major challenge of the run


HAPPEx III Charge History
250C Goal
2009-10-29
100% eff@100uA
50% eff
data
Accepted Charge (C)
250
200
150
100
50
0
2009-08-26 12:00
2009-09-18 23:12
2009-10-12 10:24
2009-11-04 20:36
Date Time

Parity-Quality Beam



Parity-Quality Beam



Dispersion ~4 :
4x larger than dE/E

PREX jitter requirement

injector configuration fixed to reduce MS interception

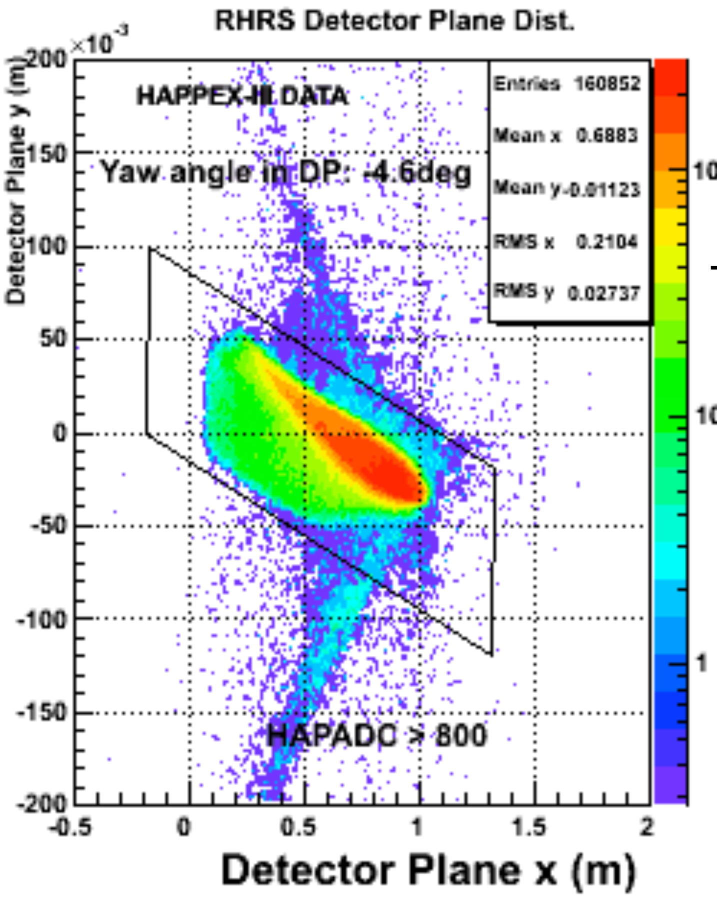
Optics / Q^2 / Backgrounds

Optics calibration - data looks good

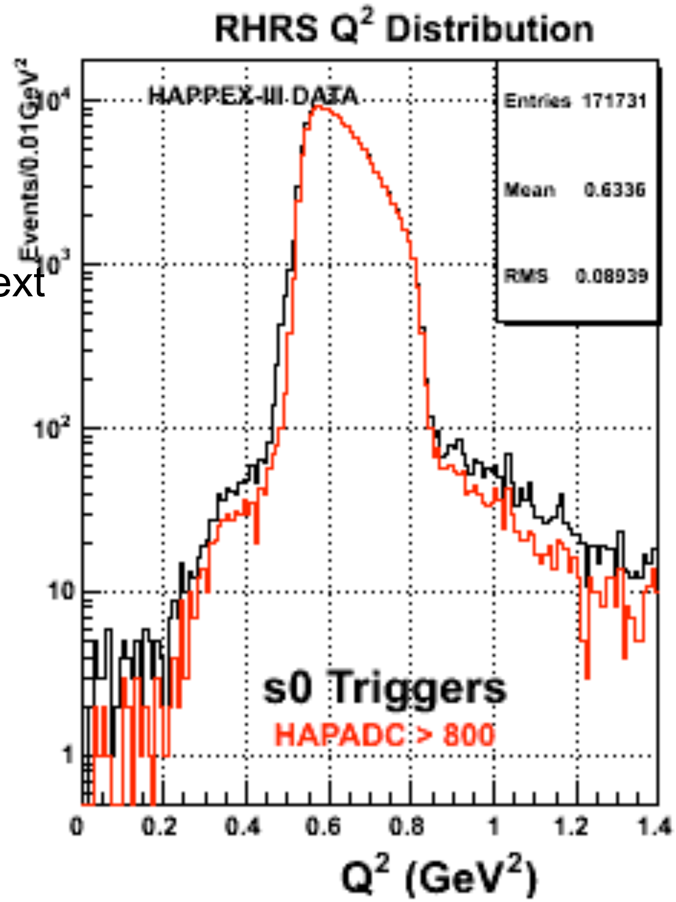
Preliminary Q^2 estimate, ~0.63 GeV^2

Target alignment, Al backgrounds estimated

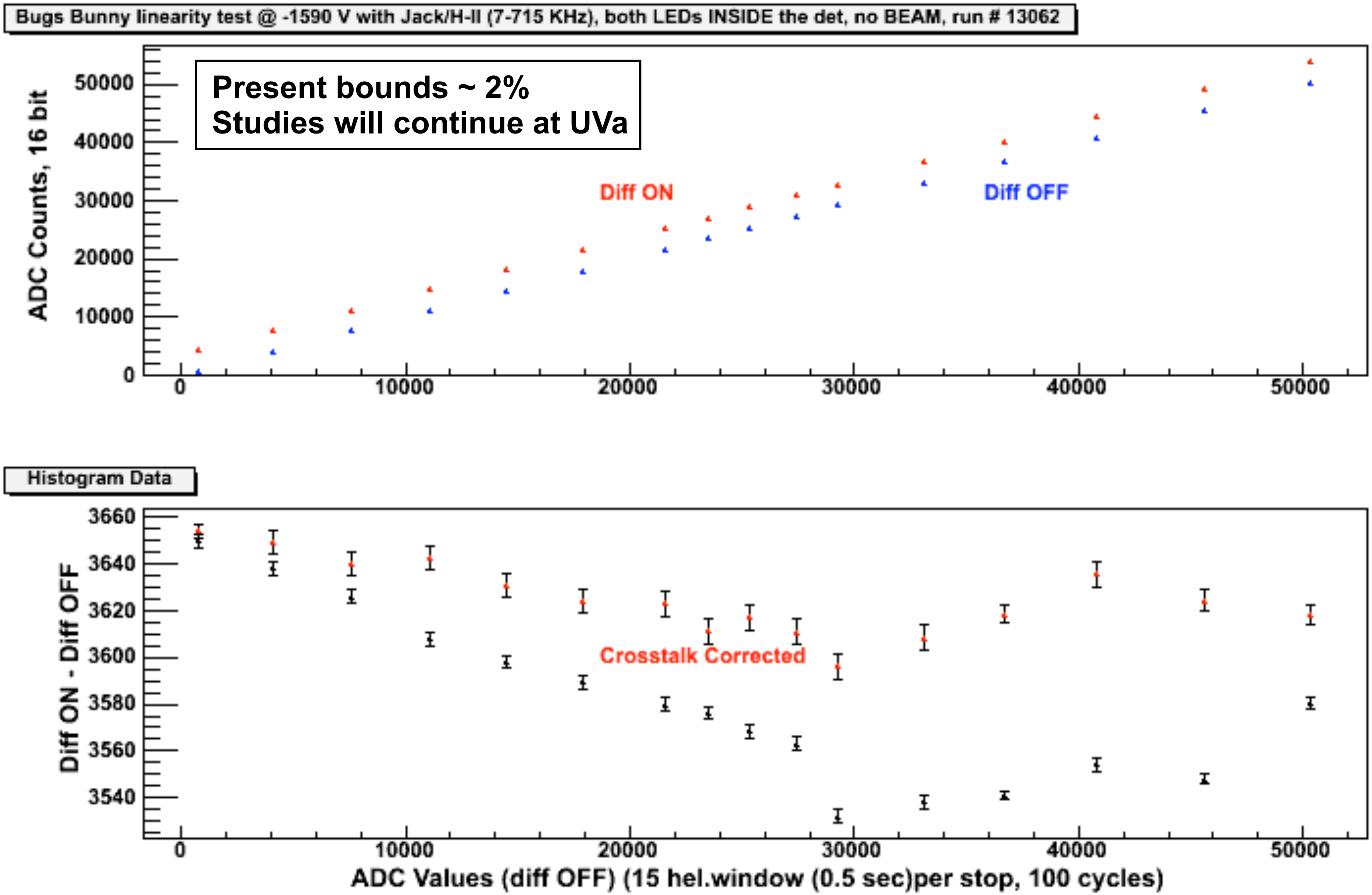
Optics stability cross-check data



Text



Detector Linearity



Compton Polarimetry

Polarimetry precision at 1% desired, 2% needed

Compton DAQ problems

- decay
- incorporating new electron detector readout board

Beam Backgrounds - Compton tuning was hard for photons, very hard for electrons

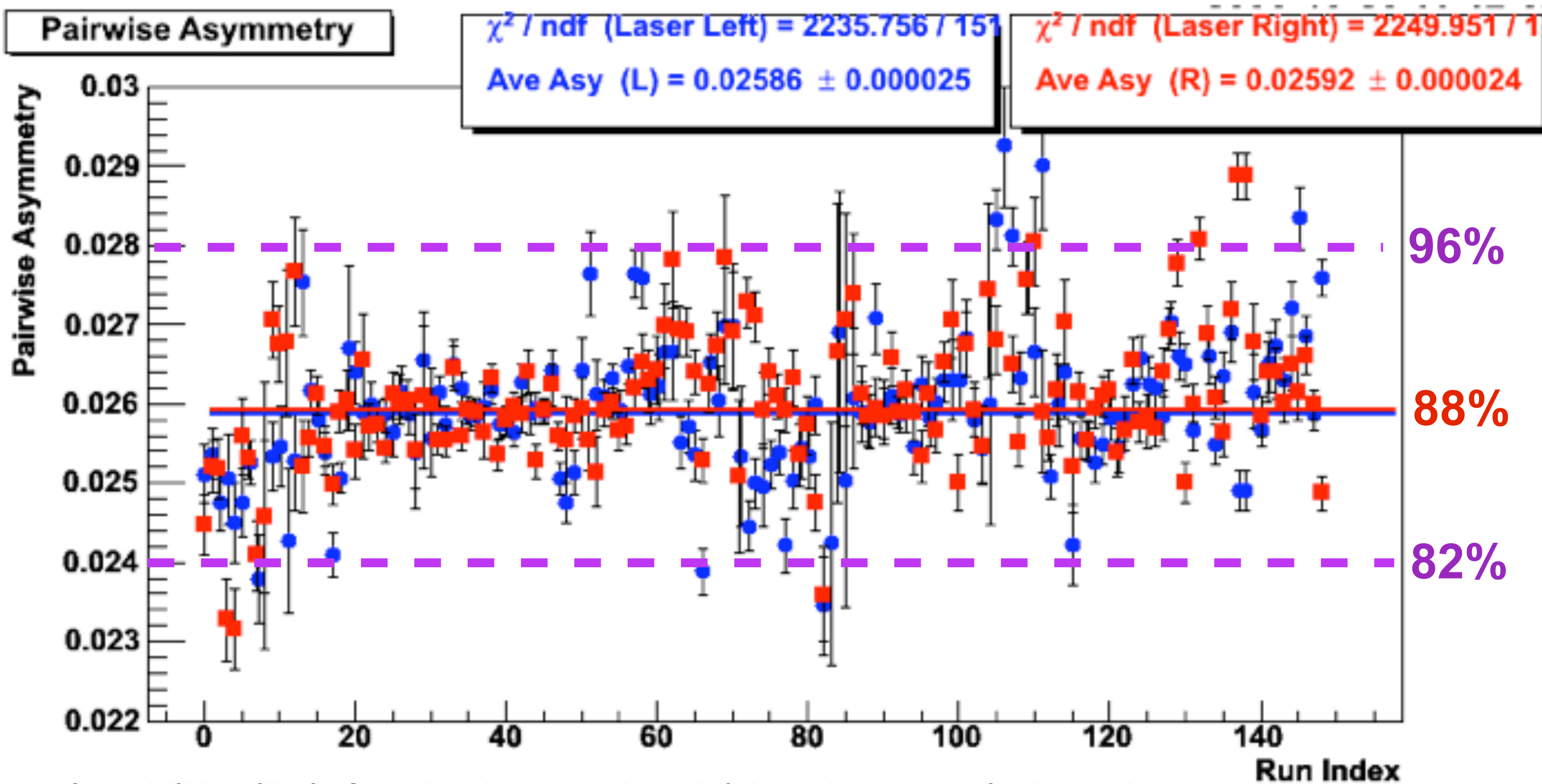
Electron synchrotron shielding: rescattering background from Compton spectrum

Standard Counting photon analysis was unstable, not well calibrated (too little electron data)

Electron-only analysis was impossible

New integrating analysis appeared stable, precise

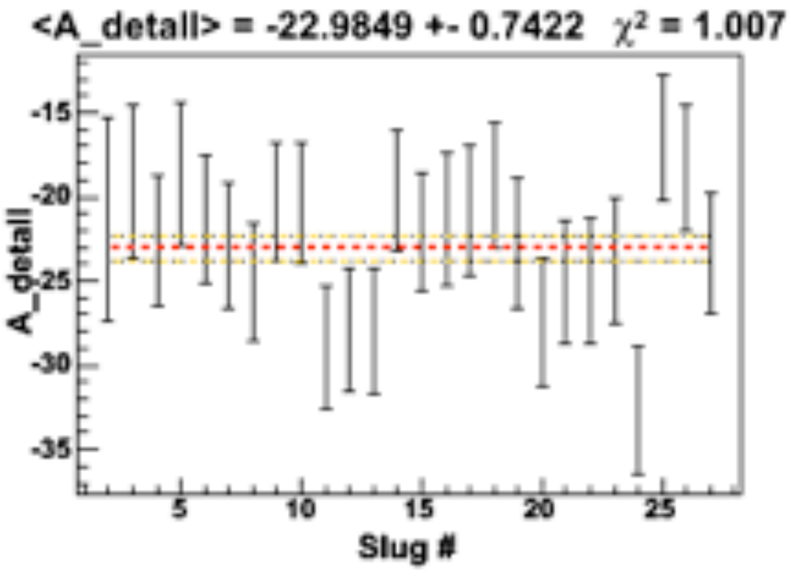
Integrating Compton

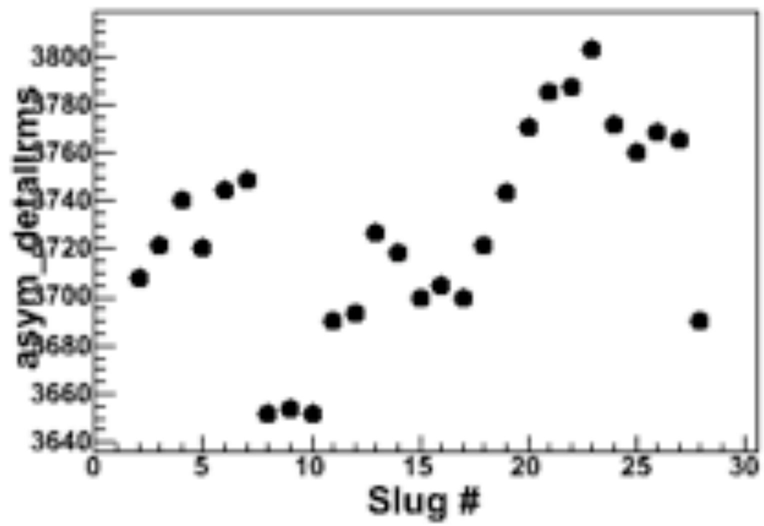


- Instabilities likely from background instabilities - better analysis on the way
- Energy-weighted integration minimizes calibration uncertainties
- Sufficient calibration from simulation / electron coincidences

With careful analysis, expect robust results significantly better than 2%

Analysis





Asymmetry analysis - bound beam and linearity corrections

Optics analysis / Q^2

Background estimates

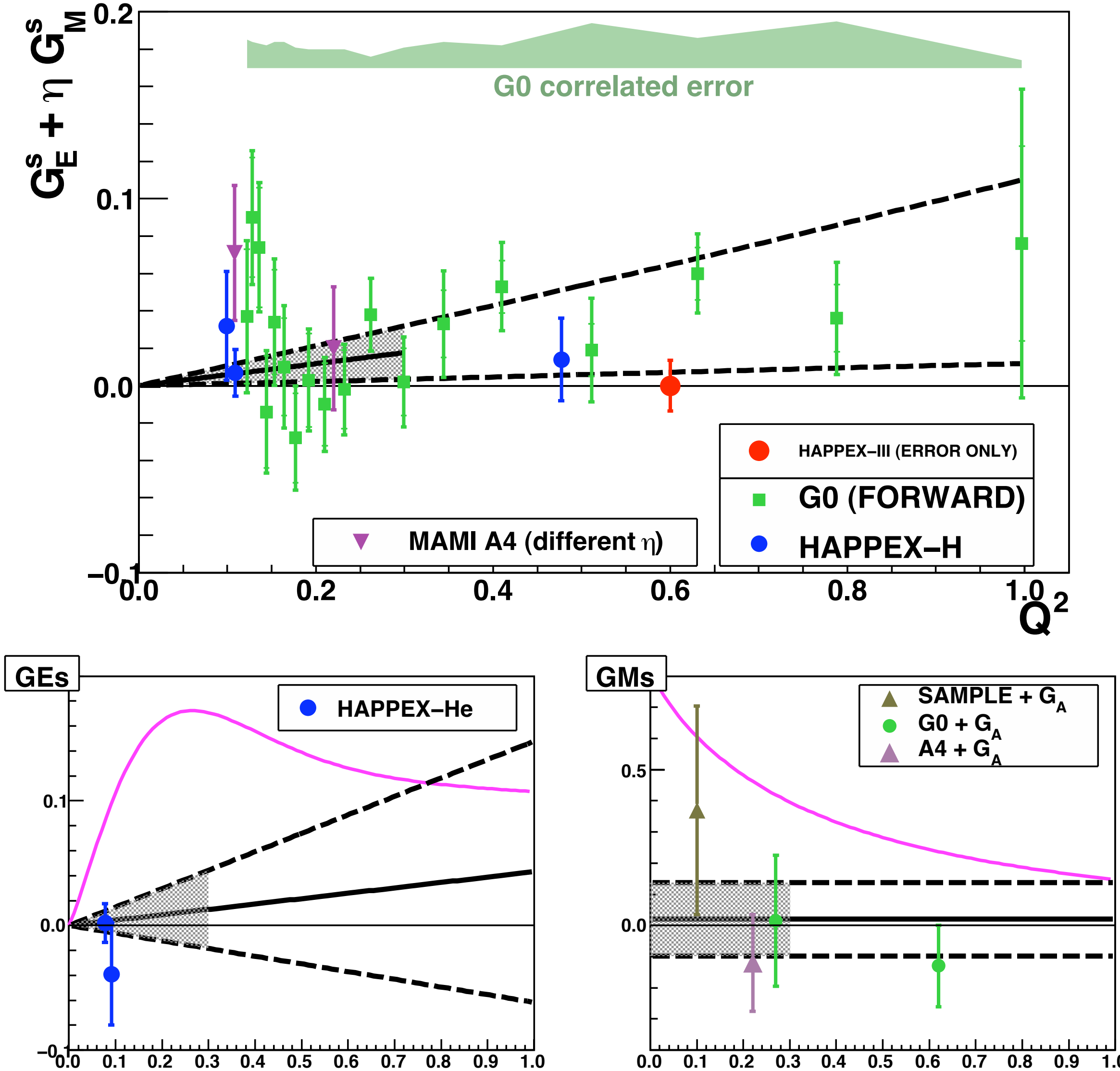
Moller polarimetry

Compton polarimetry

Goal: wrap this up in Spring

(Problem: PREX starts in March)

Summary



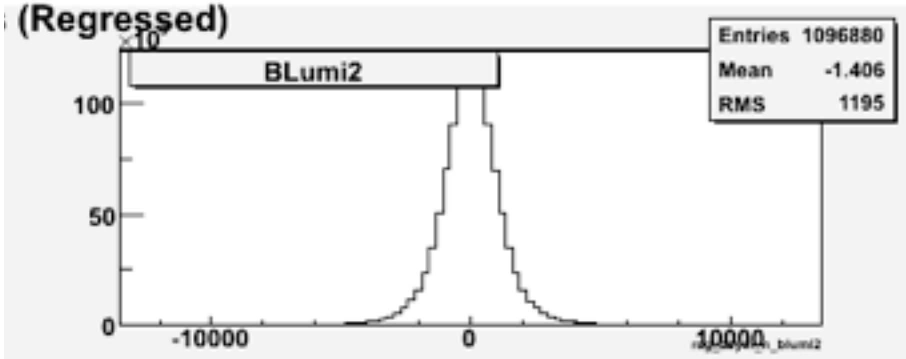
Best precision at high-Q^2

Statistics dominated

Precision test of suggestive region

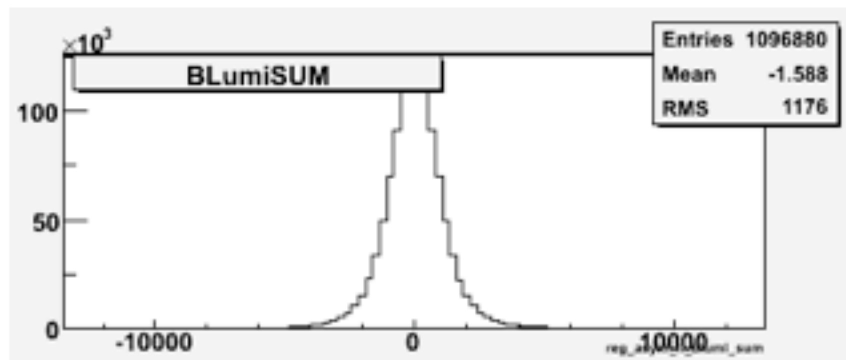
No major roadblocks expected in analysis

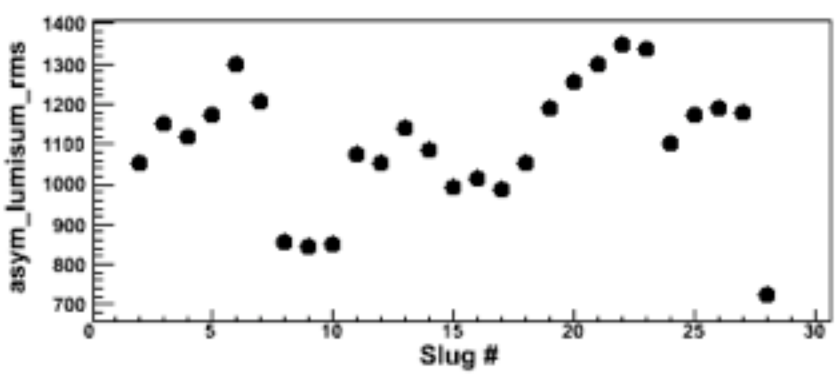
Target Boiling



One lumi

...has the same width as
all the lumis together



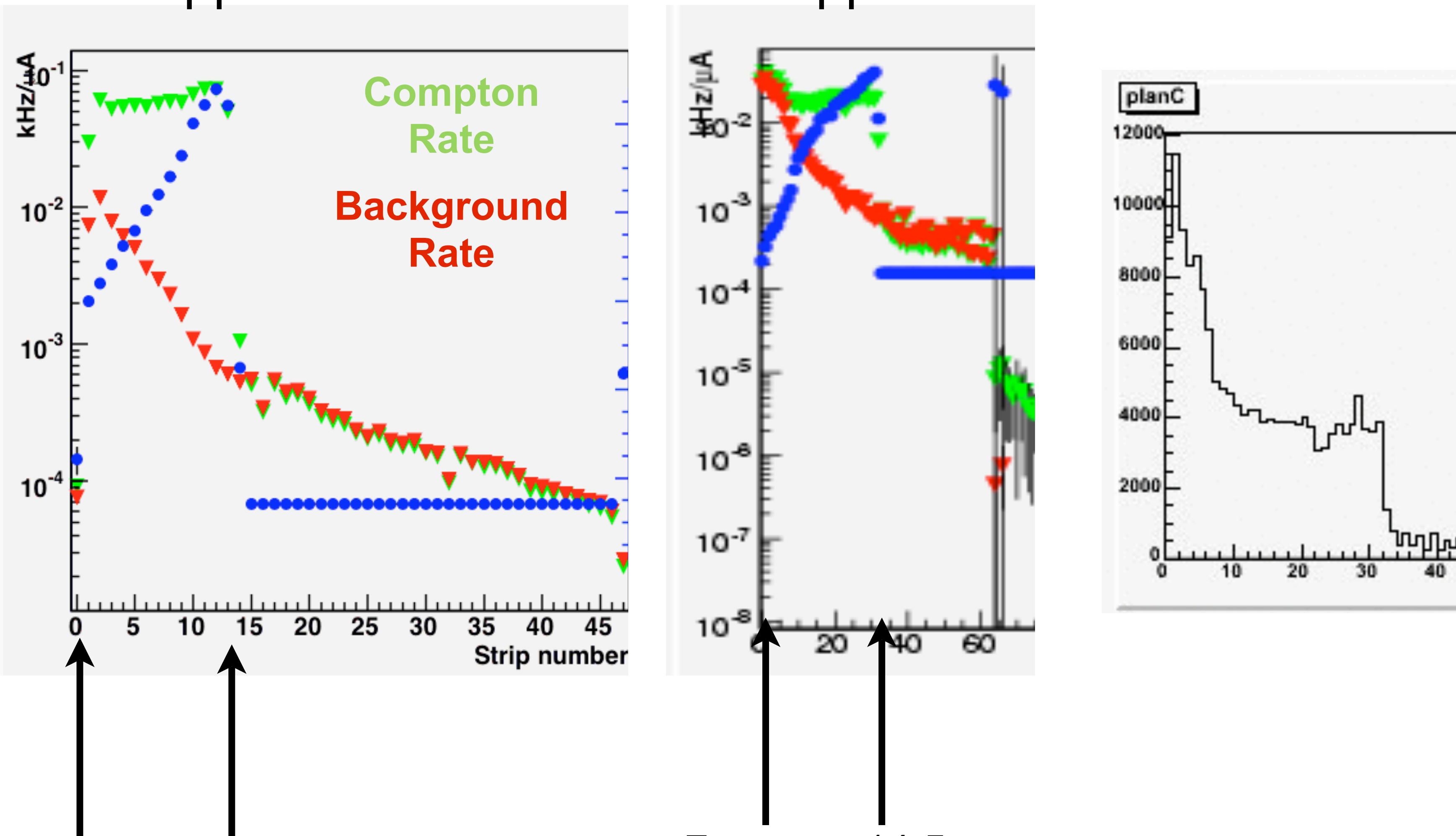


Variation in density fluctuation may
have been correlated to target pressure

This ~1000 ppm boiling
cost about 6% statistics

Electron Backgrounds Hard to Tune

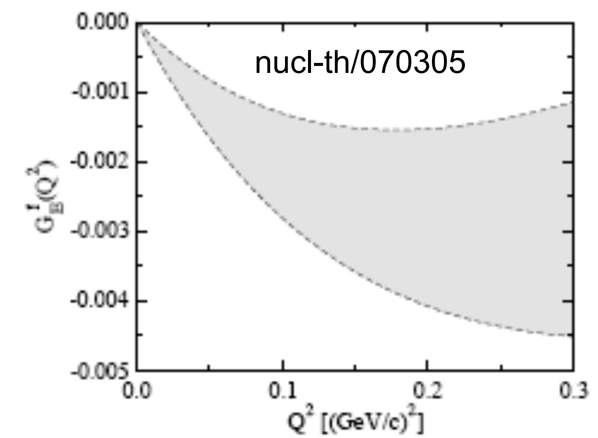
happex-2 happex-3



5.2 mm ~14 mm ~7mm ~14.5 mm

Charge Symmetry Violation

PROTON



Old Story: theoretical CSB estimates indicate <1% violations

Size of charge symmetry breaking effects <1% in low-E n,p observables:

- n - p mass difference = $(m_n - m_p)/m_n$ ~ 0.14%
- $\Delta A = A_n - A_p$ in elastic n+p, p+n Vigdor et al., PRC 46, 410 (1992)
- A_{FB} in n + p -> d + π^0 Opper et al., PRL 91 (2003) 212302

For vector FF: theoretical estimates indicate < 1% violations:

Miller PRC 57, 1492 (1998) Lewis & Mobed, PRD 59, 073002(1999)

New Story: effects could be large as statistical error on HAPPEx data!

χPBT, B. Kubis & R. Lewis Phys. Rev. C 74 (2006) 015204

Contribution from $G^{u/d}$~0.004-0.009

HAPPEX-II: $Gs_E + 0.09\, Gs_M$ = 0.007 +/- 0.011 +/- 0.004 +/- 0.005 (FF)

4He Old Story: Nuclear effects all << 1%, no explicit correction made.

- –^{4}He g.s. pure isospin state: Ramavataram, Hadjimichael, Donnelly PRC 50(1994)1174
- –No D-state admixture: Musolf & Donnelly PL B318(1993)263
- –Meson exchange corrections small: Musolf, Schiavilla, Donnelly PRC 50(1994)2173

New Story: Nuclear admixture + nucleon CSB ~ 1%

Viviani, Schiavilla, Kubis, Lewis, Girlanda, Keivsky, Marcucci, Rosati, nucl-th/070305