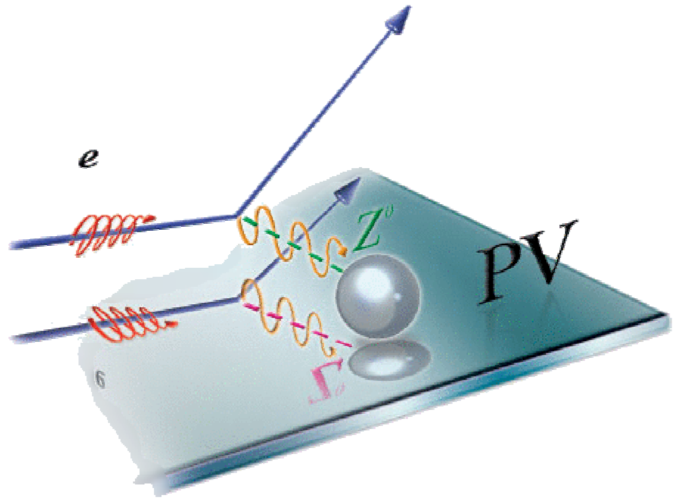
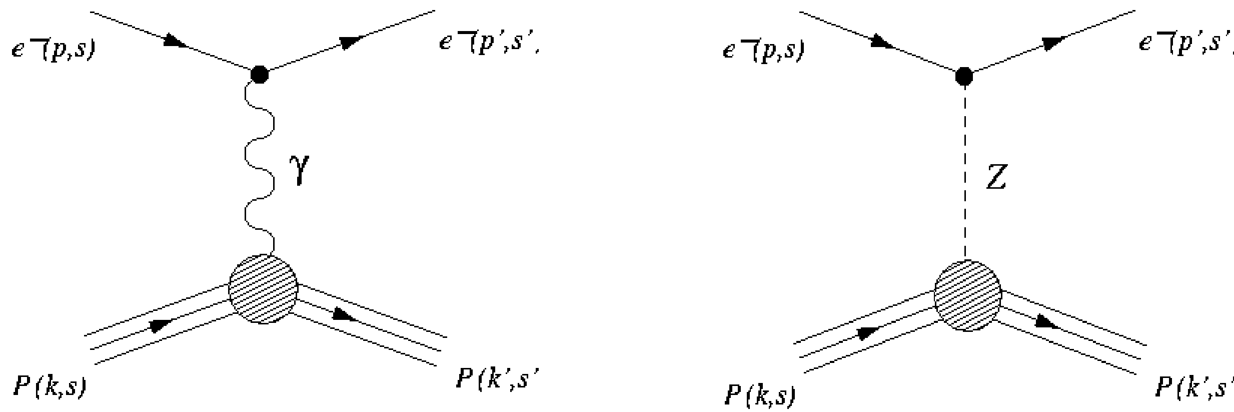
HAPPEX Experiments



Tim Holmstrom
(for the HAPPEX collaboration)
College of William and Mary
December 16, 2004
Hall A Collaboration Meeting

Weak Probe of the Nucleon



$$A_{PV} = \frac{\sigma_R - \sigma_L}{\sigma_R + \sigma_L} \propto \frac{M_{z^0} M_\gamma}{(M_\gamma)^2} = -\frac{G_F Q^2}{\sqrt{2}\pi\alpha} F(G_{E,M}^{\gamma p}, G_{E,M}^{Zp}, G_A^{e})$$

$G^{\gamma,p}_{E,M}$		$G^{u}_{E,M}$
$G^{\gamma,n}_{E,M}$	Isospin symmetry →	$G^{d}_{E,M}$
$G^{Z,p}_{E,M}$		$G^{s}_{E,M}$
Weak Form Factors		$\langle N \vert\, \bar{s}\gamma^\mu s\, \vert N \rangle$

HAPPEX 1

Hydrogen Target: E=3.3 GeV, θ=12.5 deg, Q^2=0.5 $(GeV/c)^2$

$$A^{PV} = \left[\frac{-G_F M_p^2 \tau}{\pi\alpha\sqrt{2}}\right]\left\{(1-4\sin^2\theta_W) - \frac{[\varepsilon G_E^{p\gamma}(G_E^{n\gamma} + \boxed{G_E^s}) + \tau G_M^{p\gamma}(G_M^{n\gamma} + \boxed{G_M^s})]}{\varepsilon(G_E^{p\gamma})^2 + \tau(G_M^{p\gamma})^2}\right\} - A_A$$

A^{PV} = -14.92 ppm ± 0.98 (stat) ppm ± 0.56 (syst) ppm

$$G^s_E + 0.39 G^s_M = 0.014 \pm 0.020\ (exp) \pm 0.010\ (FF)$$

“Parity Quality” Beam @ JLAb

HAPPEX 2

- **Steep Q^2 dependence? → Choose different Q^2 range**

- **Fortuitous E/M cancellation? → Separate G^s_E , G^s_M**

  →Combined measurements at lower Q^2 on two nuclei:

- **Hydrogen** : $G^s_E + \alpha\, G^s_M$
- **^{4}He**: Pure G^s_E : $A^{PV} = -\frac{A_0}{2}\left(2\sin^2\theta_W + \frac{G_E^s}{G_E^{p\gamma} + G_E^{n\gamma}}\right)$

Kinematics and Errors

E=3 GeV θ=6 deg Q^2=0.1 $(GeV/c)^2$

target	A_{PV} $G^s = 0$ (ppm)	Stat. Error (ppm)	Syst. Error (ppm)	sensitivity
^1H	-1.4	0.08 (5.7%)	0.04 (2.9%)	$\delta(G^s_E+0.08G^s_M) = 0.010$
^4He	+7.8	0.18 (2.2%)	0.18 (2.1%)	$\delta(G^s_E) = 0.015$

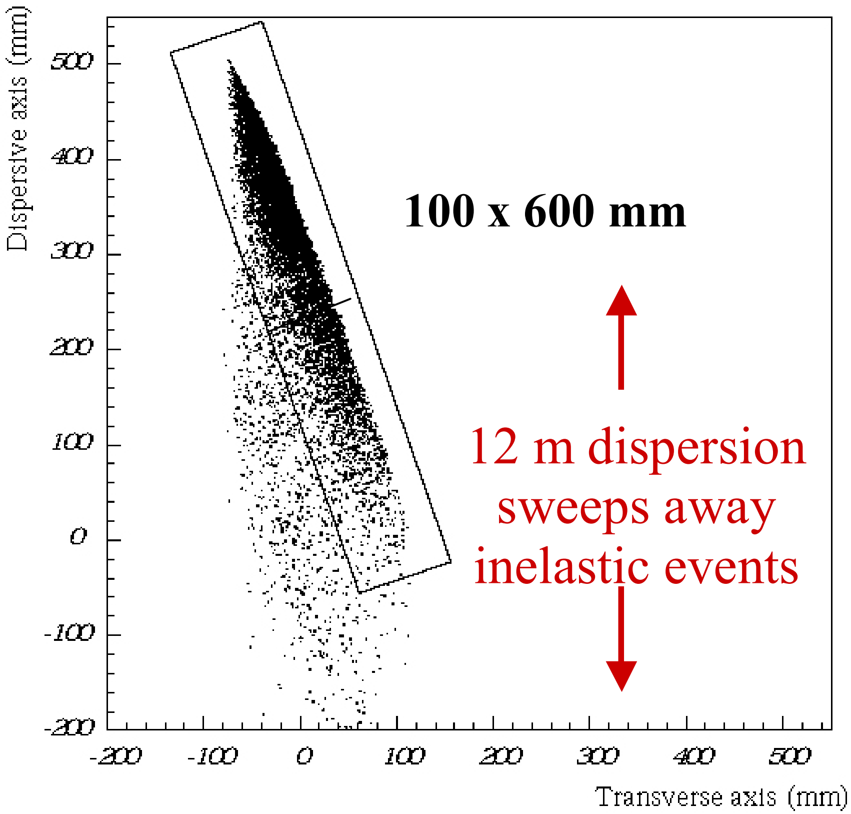
Apparatus Upgrade

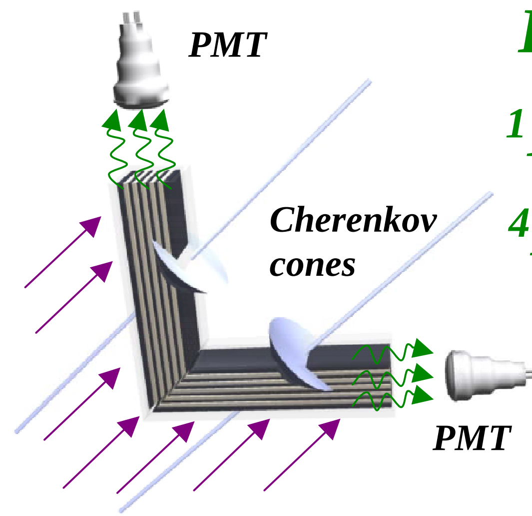
Increase sensitivity:

- High Luminosity => High I and P_e (superlattice), thick new targets, rad-hard integrating det., improved DAQ.
- Small forward angle => use the Septum magnets
- Accurate Normalization => improved polarimetry, new focal plane profile scanner
- High systematic accuracy => improved polarized source, close attention to beam optics, luminosity monitor.

Focal Plane Detectors

Very clean separation of elastic events by HRS optics → Overlap the elastic line above the focal plane and integrate the flux





Elastic Rate:

^{1}H: 120 MHz

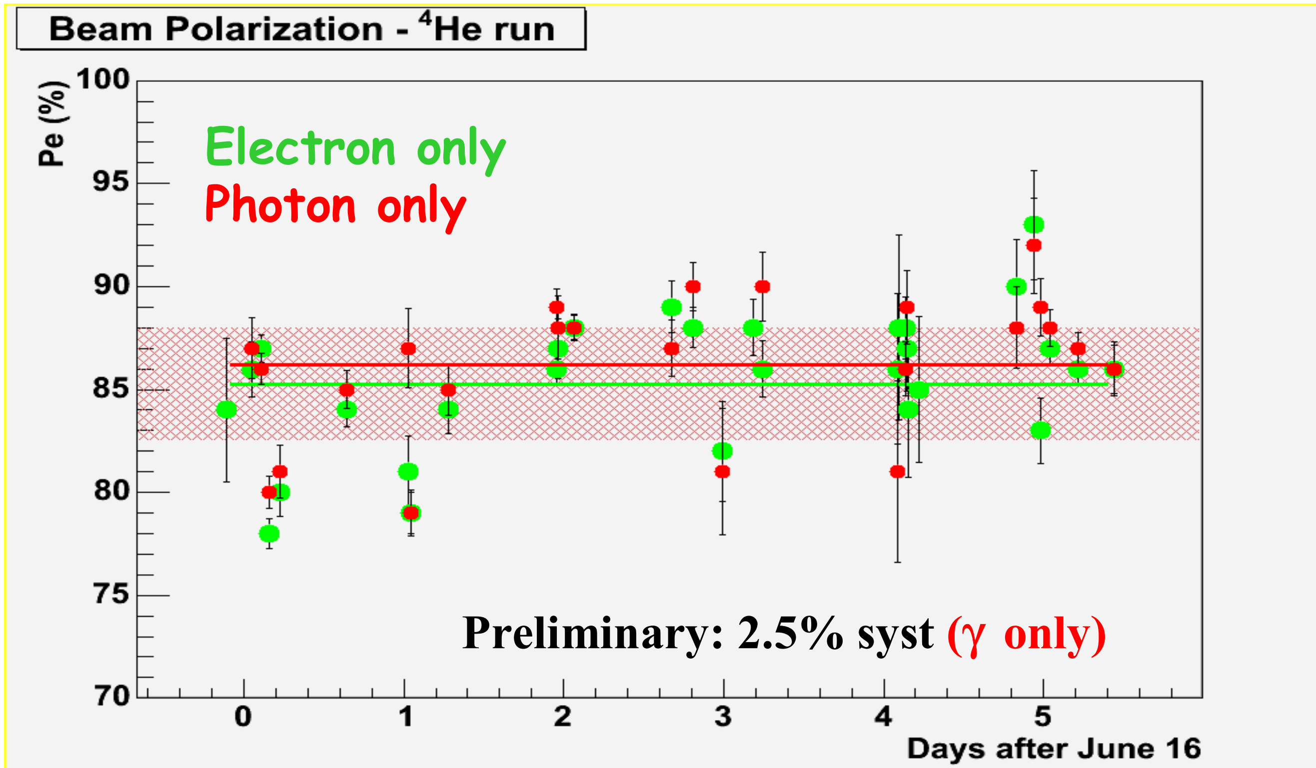
^{4}He: 12 MHz

Brass-Quartz integrating detector

Polarimetry

Møller: $\delta P_e/P_e \sim 3$ % (foil polarization)

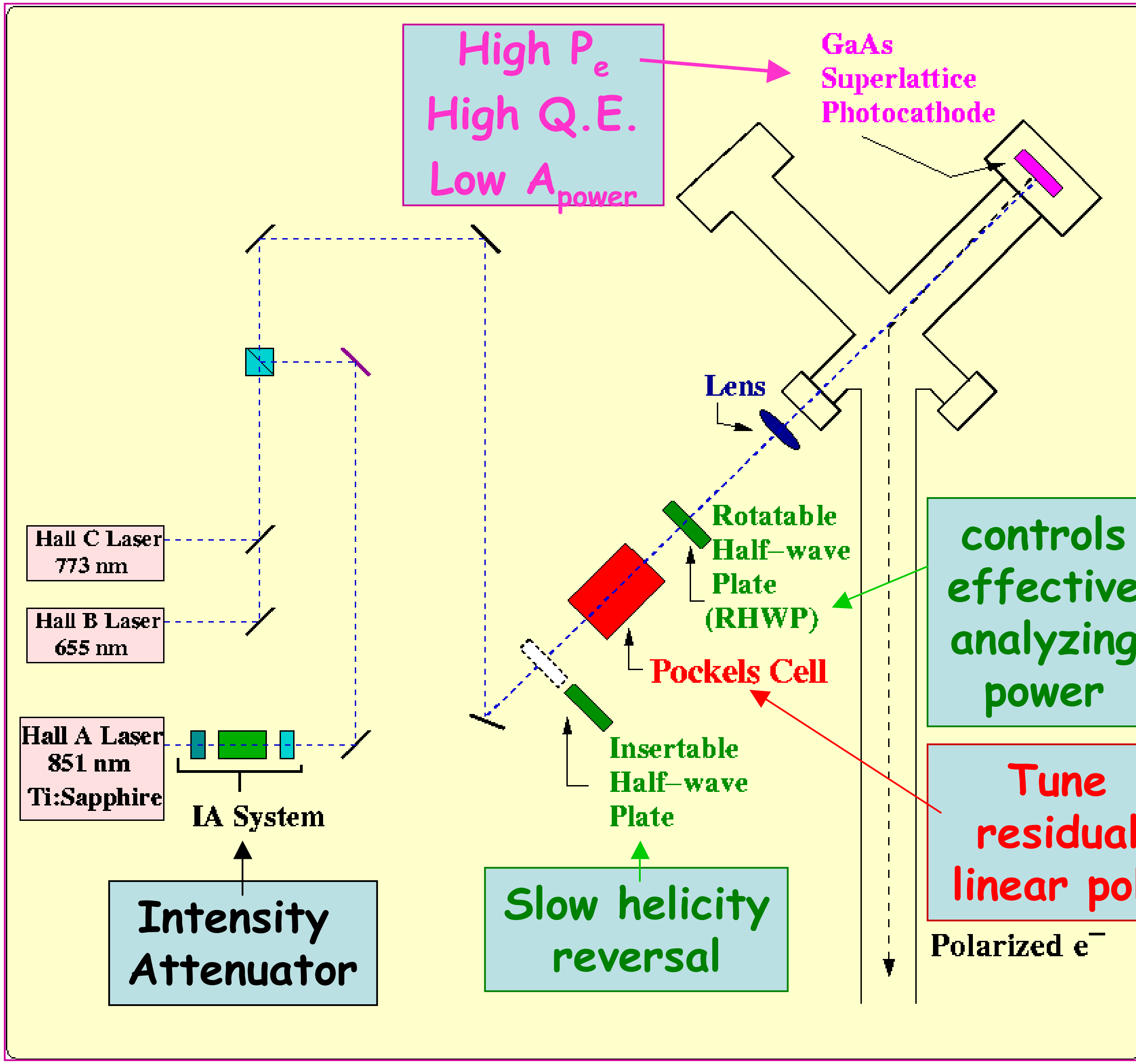
→**Compton**: 2% syst. expected



2 analyses based on either electron or photon detection

Superlattice:
P_e=86% !

Polarized Source



(Kaufman and Paschke)

- Optical pumping of solid-state photocathode
- High Polarization
- Pockels cell allows rapid helicity flip
- Careful configuration to reduce beam asymmetries.
- Slow helicity reversal to further cancel beam asymmetries

First Run

June 8 – June 22	HAPPEX-He • about 3M pairs at 1300 ppm => $\delta A_{stat} \sim 0.7$ ppm
June 24 – July 26	HAPPEX-H • about 8M pairs at 600 ppm => $\delta A_{stat} \sim 0.2$ ppm
Second Run Starting ~ July '05	

First run preliminary results already available!

Analysis

Raw Asymmetry

- Charge Asymmetry
- Position Difference Corrections
- Sources of False Asymmetry

Most significant challenge for Hydrogen

Normalization

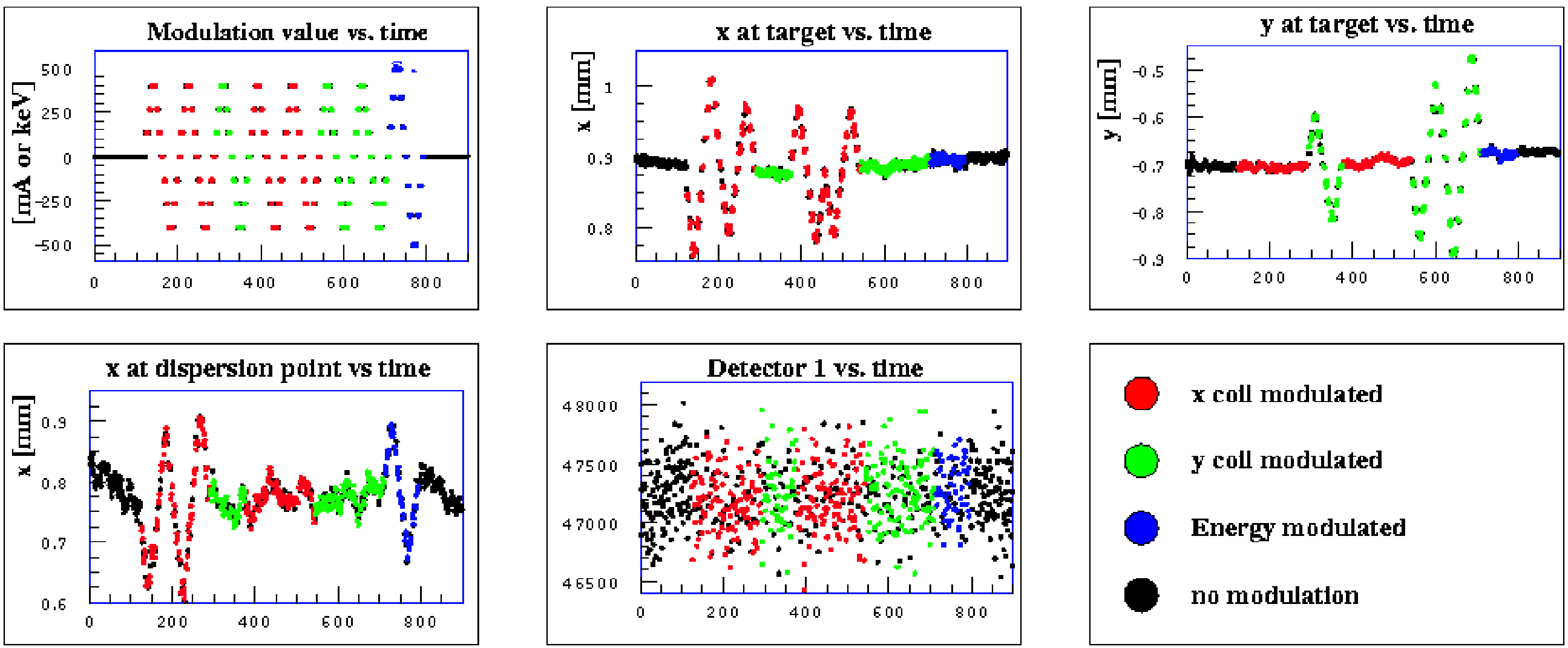
- Polarization
- Linearity
- Q^2 determination
- Background Fraction

Most significant challenge for Helium

Beam Asymmetries

$$A_{raw} = A_{det} - A_Q + \alpha\Delta_E + \Sigma\beta_i\Delta x_i$$

Slopes from
- natural beam jitter (regression)
- beam modulation (dithering)

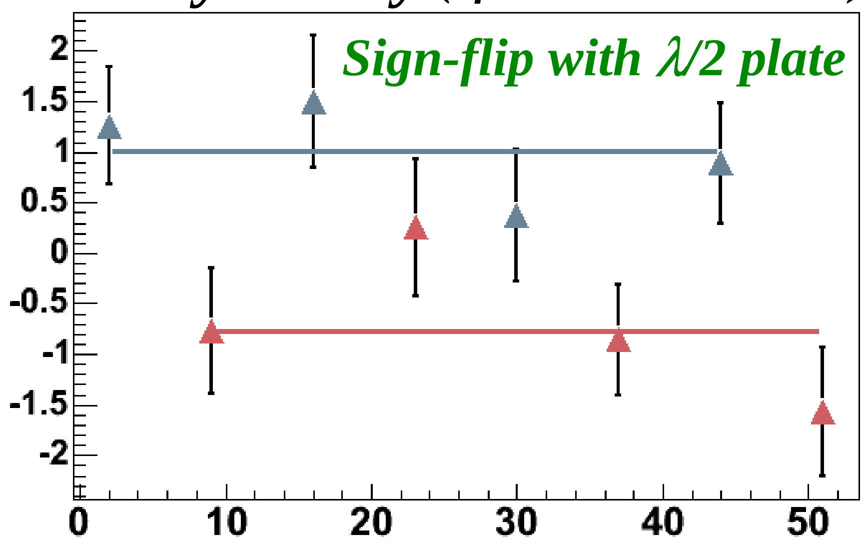


Raw Asymmetry Corrections

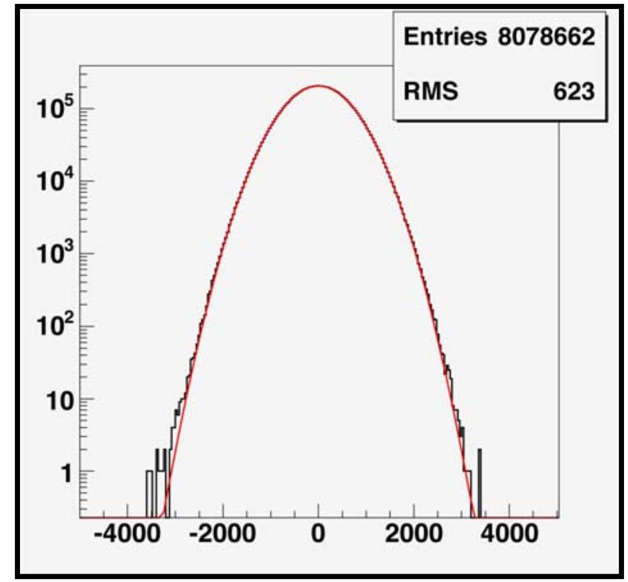
Hydrogen	Magnitude	Approximate Correction
Charge Asymmetry	-1.7 ppm	-1.7 ppm (2% linearity)
Energy Asymmetry	23 ppb	-140 ppb
Position Difference	-7 nm	<5 ppb
Angle Difference	-10 nrad	80 ppb

Hydrogen Results

Raw Asymmetry *(after beam corrections)*



A_{raw} correction ~ 0.06 ppm



Detector asymmetry gaussian over 5 orders of magnitude

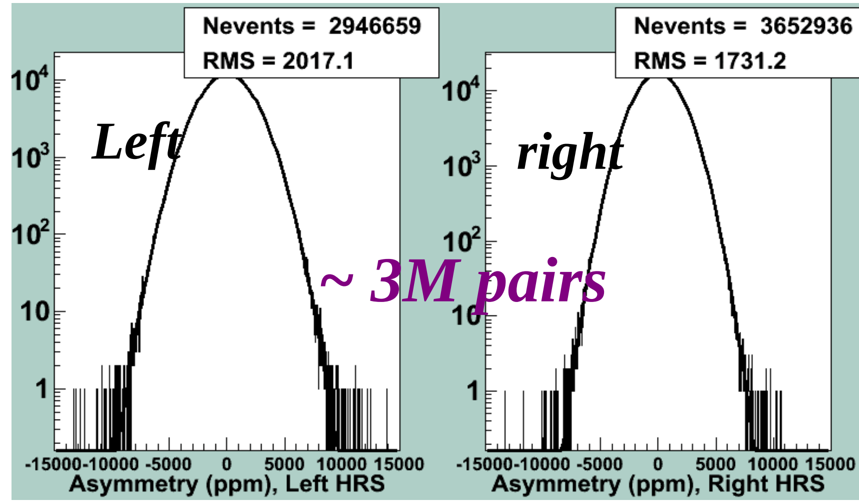
Preliminary

A_{raw} =

-0.89 ppm +/-0.22 ppm (stat)

^{4}He Results

Raw Parity Violating Asymmetry

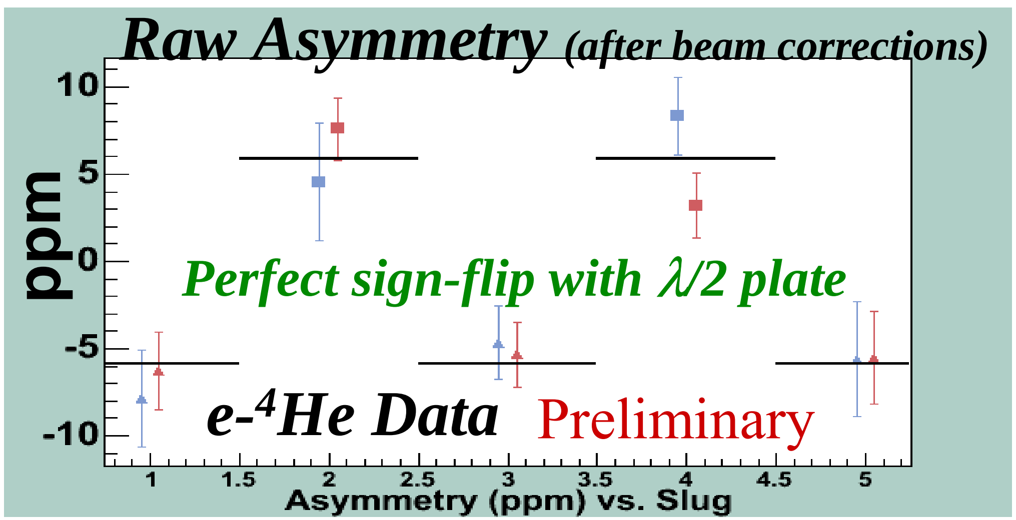


Helicity Window Pair Asymmetry

A_{raw} correction < 0.2 ppm

A_{raw} =

+ 5.87 ppm +/-0.71 ppm (stat)



- Helium Quasielastic Background:
  estimated fraction at 3% ± 3%
  => 300 ppb systematic error

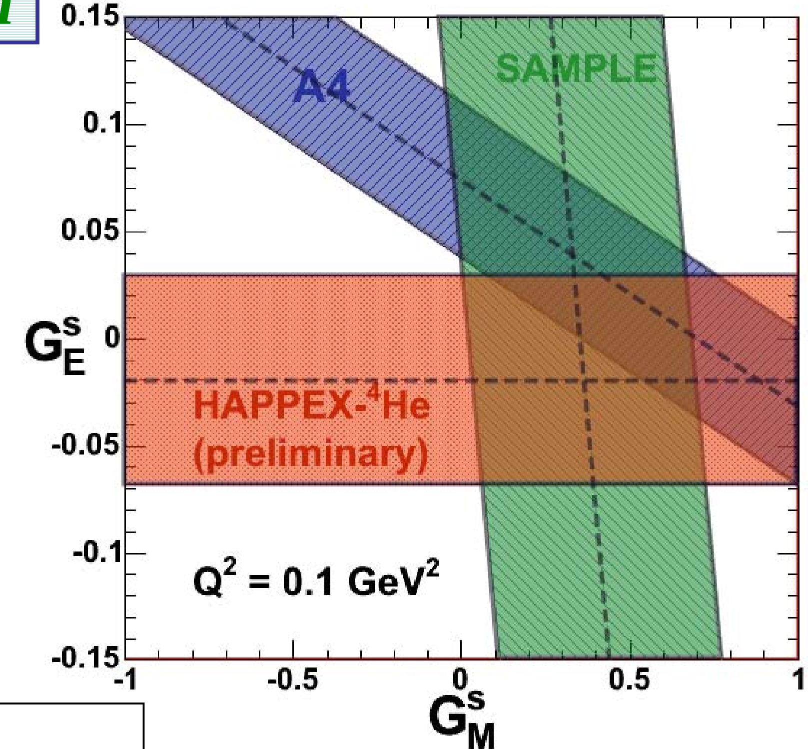
- Q^2, Polarization, other normalization errors are comparable

Preliminary ^{4}He Physics Result

A_{PV} (after all corrections) =
+7.40 ± 0.89 (stat) ± 0.57 (syst) ppm

- *Normalization errors dominate*
- *Ongoing analysis*

Theory prediction
(no strange quarks):
+7.82 ppm



$Q^2 = 0.1\ (GeV/c)^2$

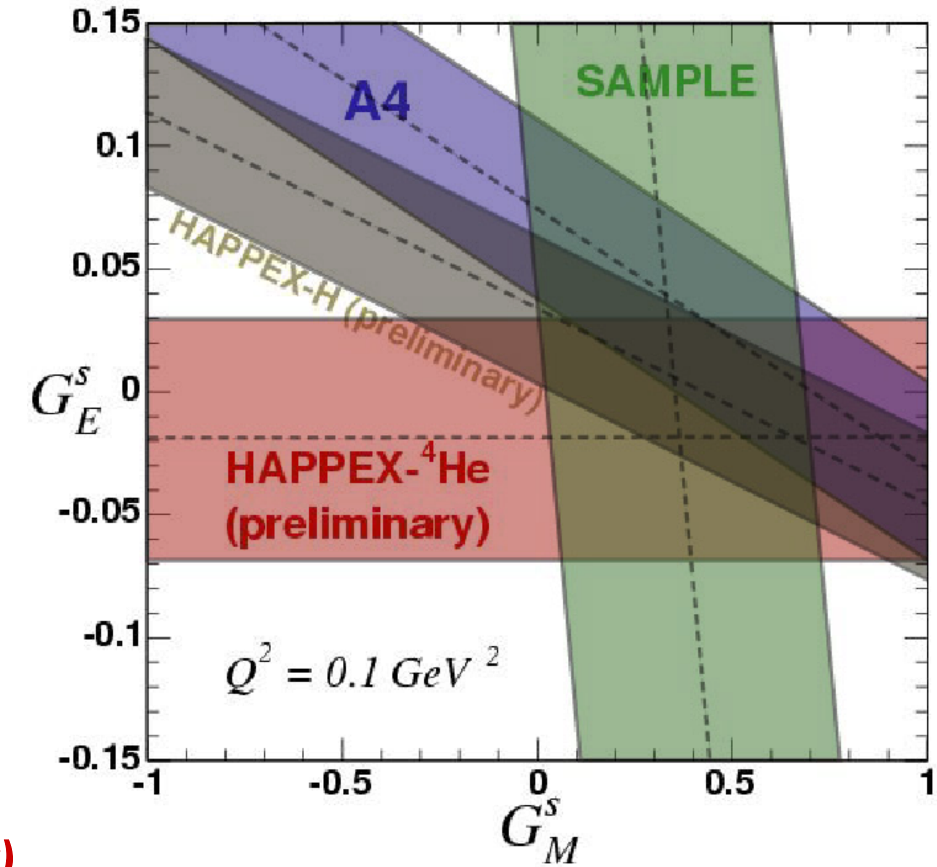
$G^s_E = -0.019 \pm 0.041\ (stat) \pm 0.026\ (syst)$

Preliminary Hydrogen Physics Result

A_{PV} (after all corrections) =
-1.10 ± 0.27 (stat) ± 0.10 (syst) ppm

- *Ongoing analysis*

Theory prediction
(no strange quarks):
-1.43 ppm +/- 0.09 ppm (FF)



Q^2 = 0.1 (GeV/c)^2

$G^s_E + 0.08\ G^s_M$ = 0.034 ± 0.028 (stat)
± 0.010 (syst) ± 0.009 (FF)

Changes for Second Run

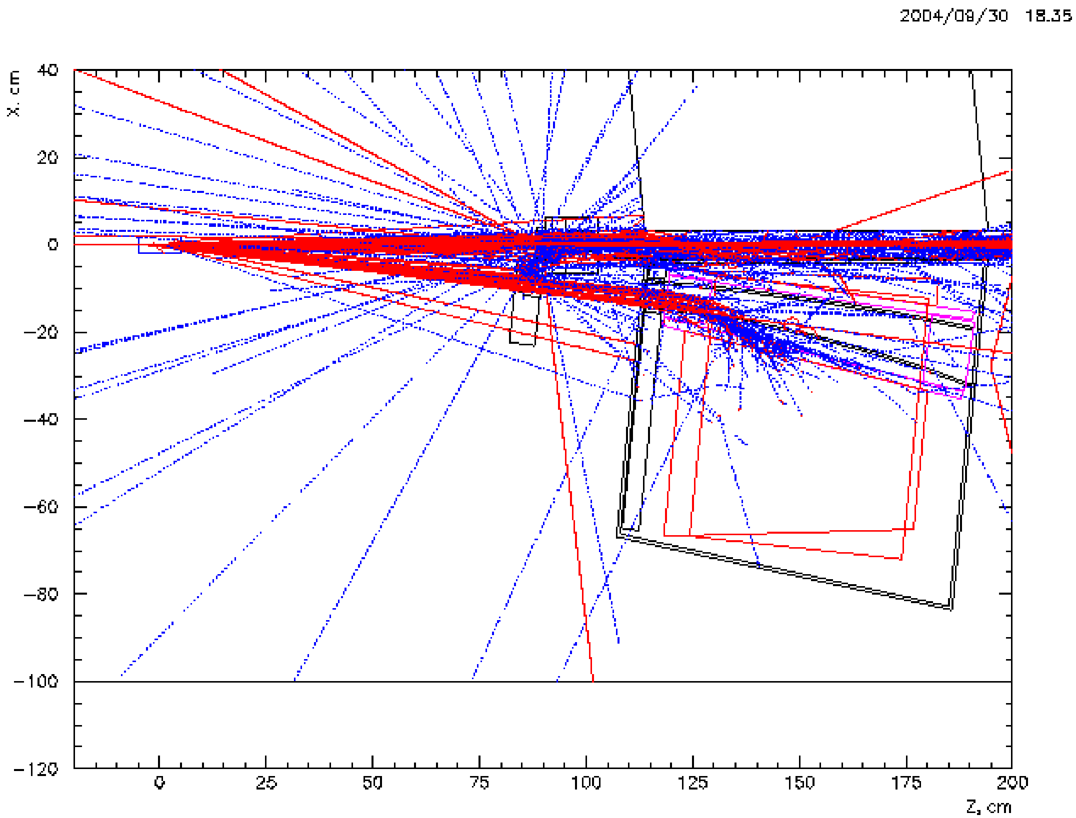
- Hall C will not run during HAPEX-H, helping reduce raw asymmetry corrections
- New S0 to improve triggering. The design is complete, and parts are ordered.
- Reduced septum heating and improved septum cooling.
- Larger raster should reduce target density fluctuations.
  - Beamline Optics Changes (Jay Benesch)
    - Maintain phase advance in front of target for dithering
    - But allow 5x5 raster.
    - Other constraints.

Septum Heating

- Current limited to ~35μA during the summer 2004 run period.
- The primary reason is heating of the Septum magnets to quench temperatures.
- Studies done at the end of the run suggest that most of the heating occurred in the bore of the magnet.
- After the run at was discovered that a piece of paper was blocking one of the right septum flow valves. This septum will be tested in February.
  - The left Septum could run at ~ 60μA without a quench.
- E. Chudakov studied the Moller rate into the septum magnets and found that heating can be further reduced by a sweeper magnet.

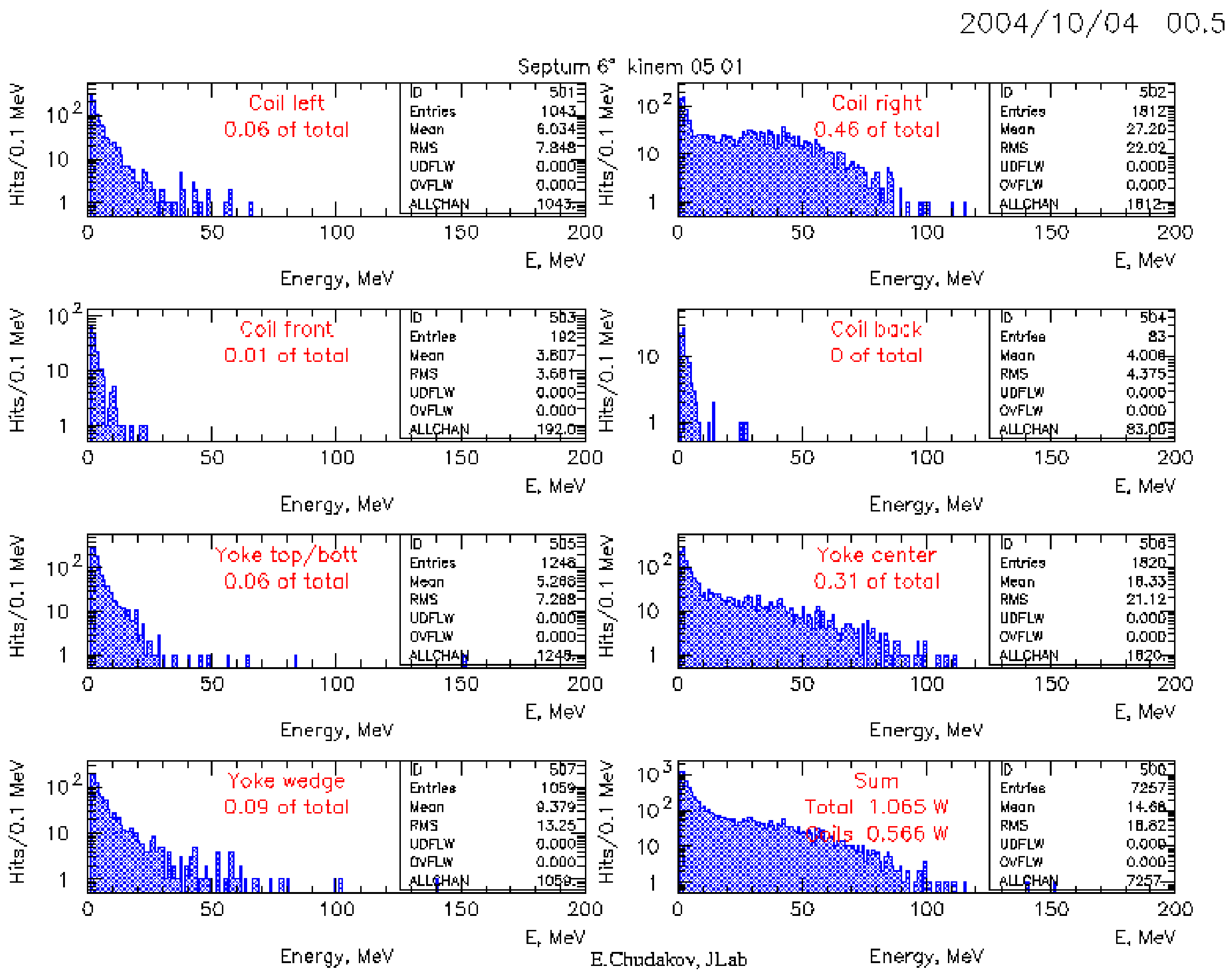
Septum Layout

Background: mostly Møller e^- at $\sim$ 80 MeV



Simulation of Septum Magnet Heating

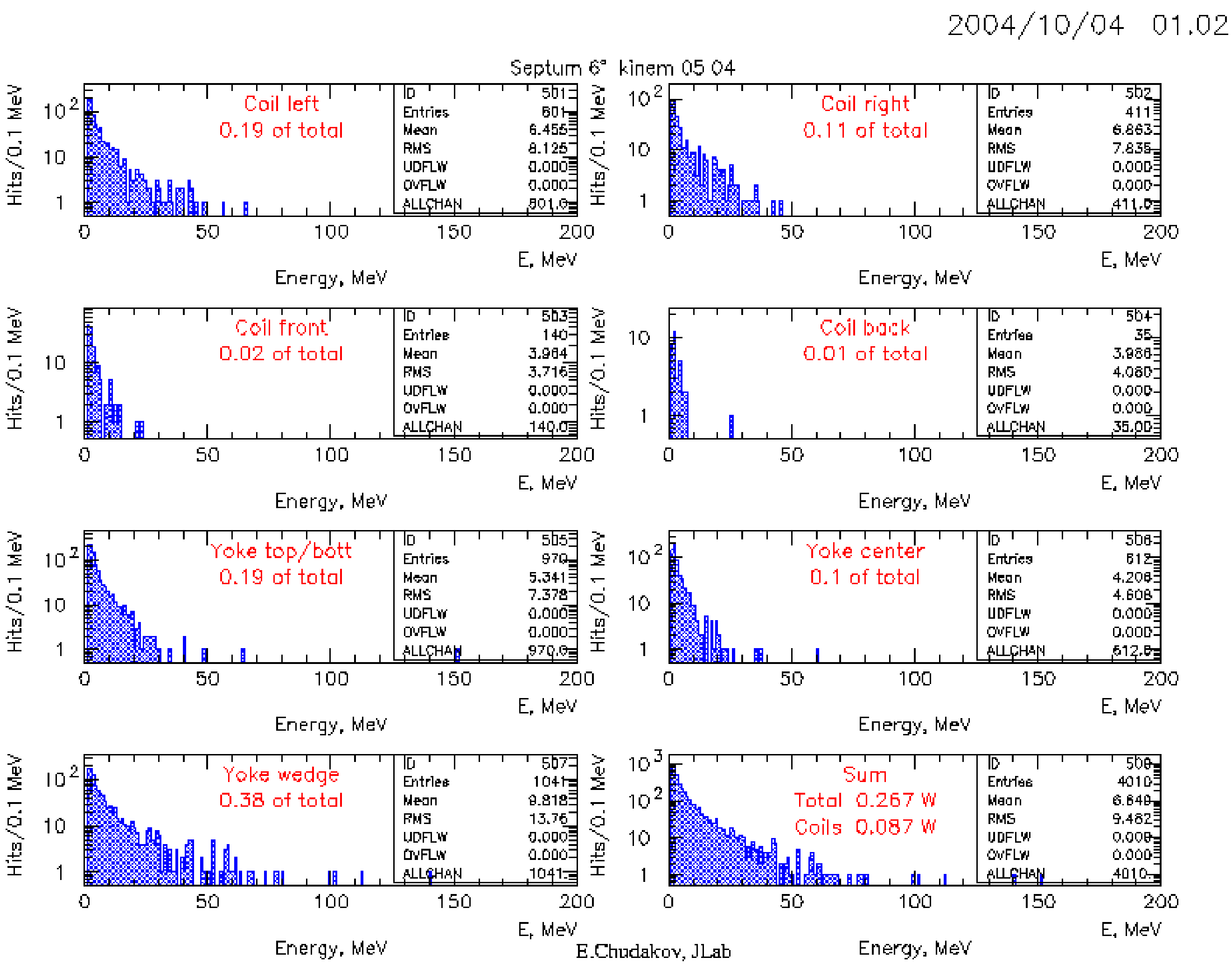
Heating: no additional shielding



E.Chudakov, JLab

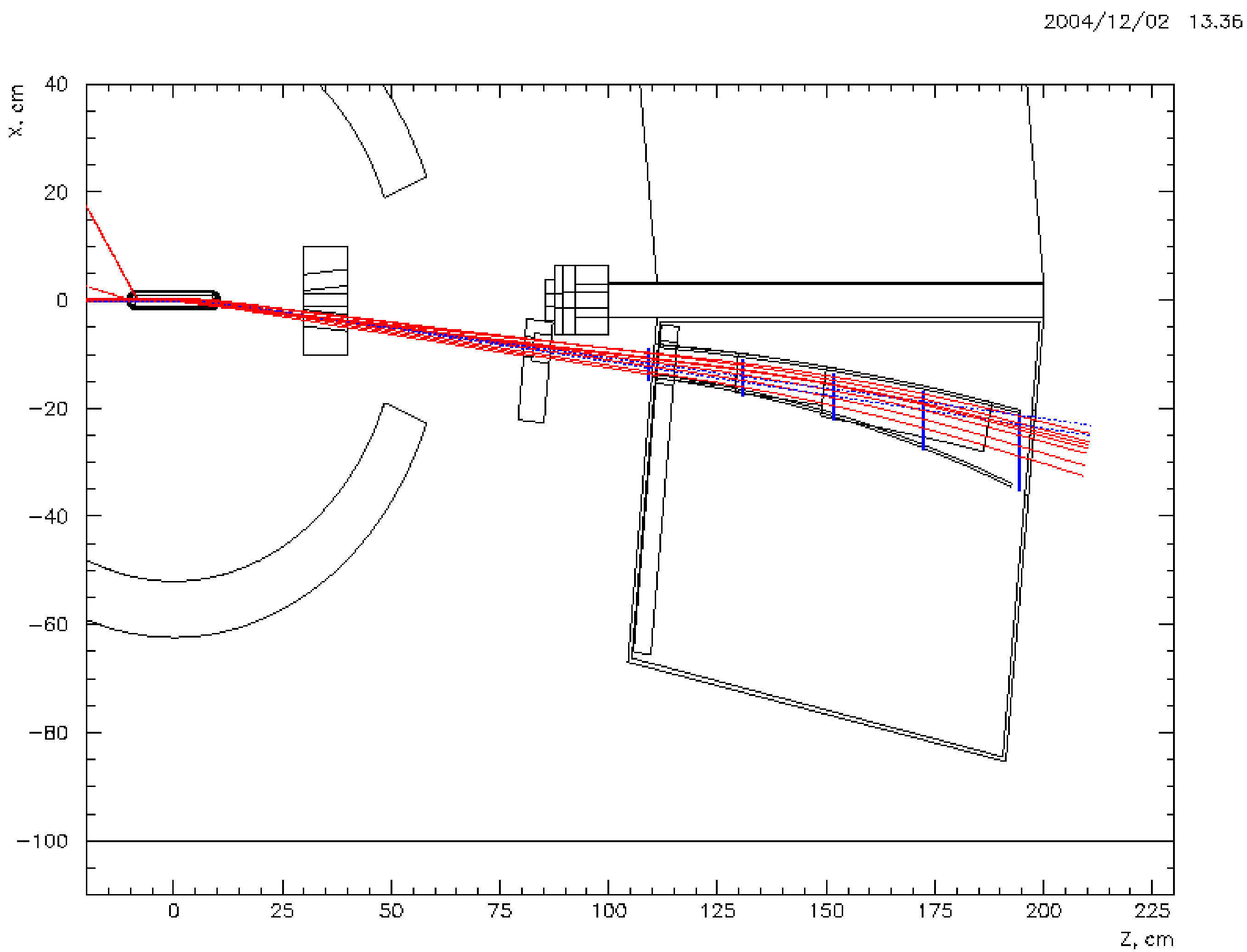
Simulation of Septum Magnet Heating

Heating: Sweeping magnet 0.03 T·m - horizontal deflection → beam pipe



E.Chudakov, JLab

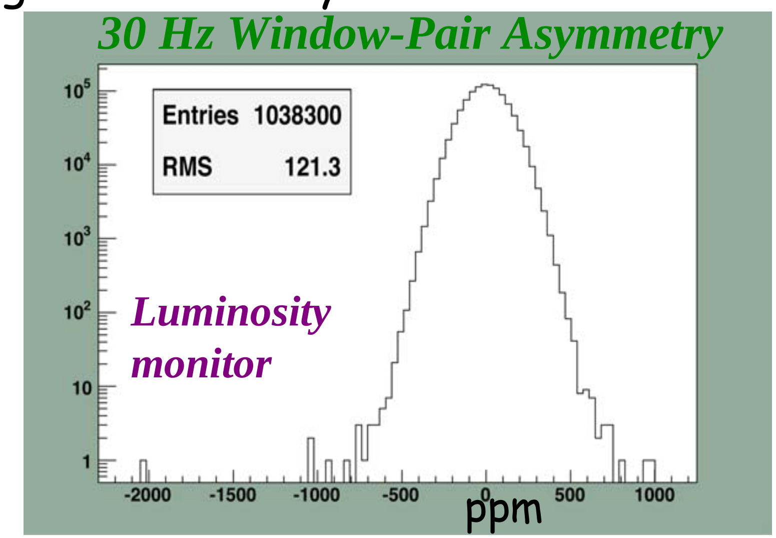
Magnet and collimator

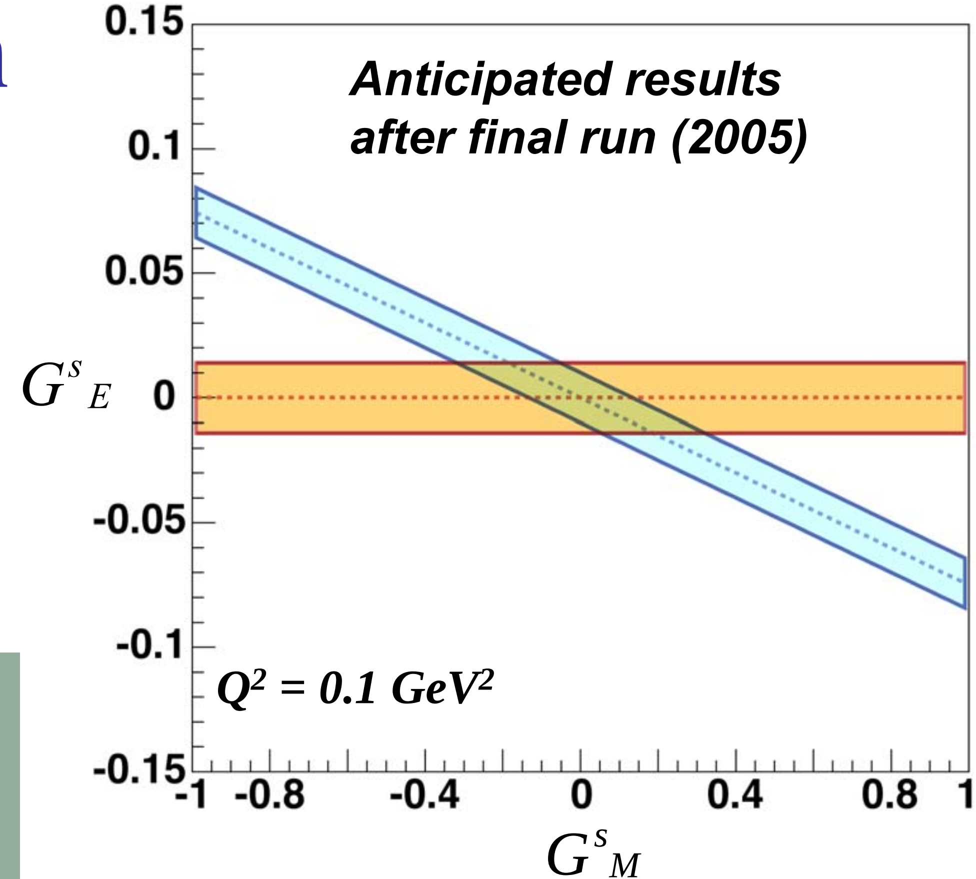


Final Precision

- *Run to completion in late 2005*
- *H Statistics to be increased by x8*
- *He Statistics to be increased by x10*

High rate luminosity monitors demonstrated capability for higher luminosity



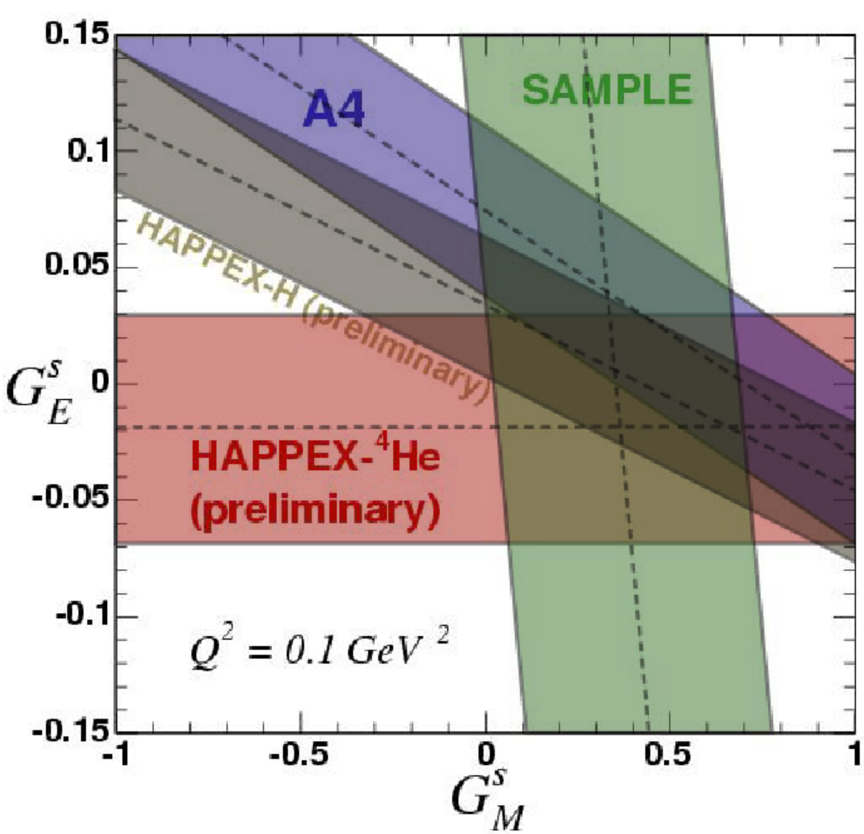


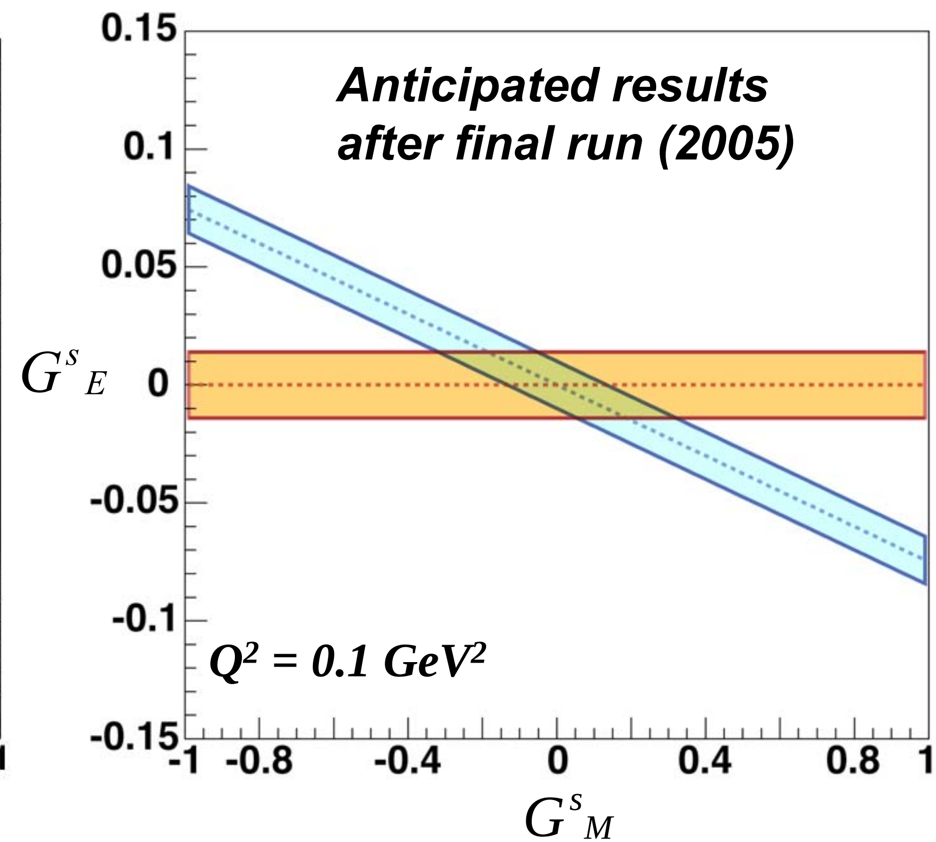
- *Repaired septum cryogenic system*
- *Sweeper magnet*
- *Target Density fluctuations under control to 70 μA*
- *Continuing improvements in beam asymmetries*

Conclusion

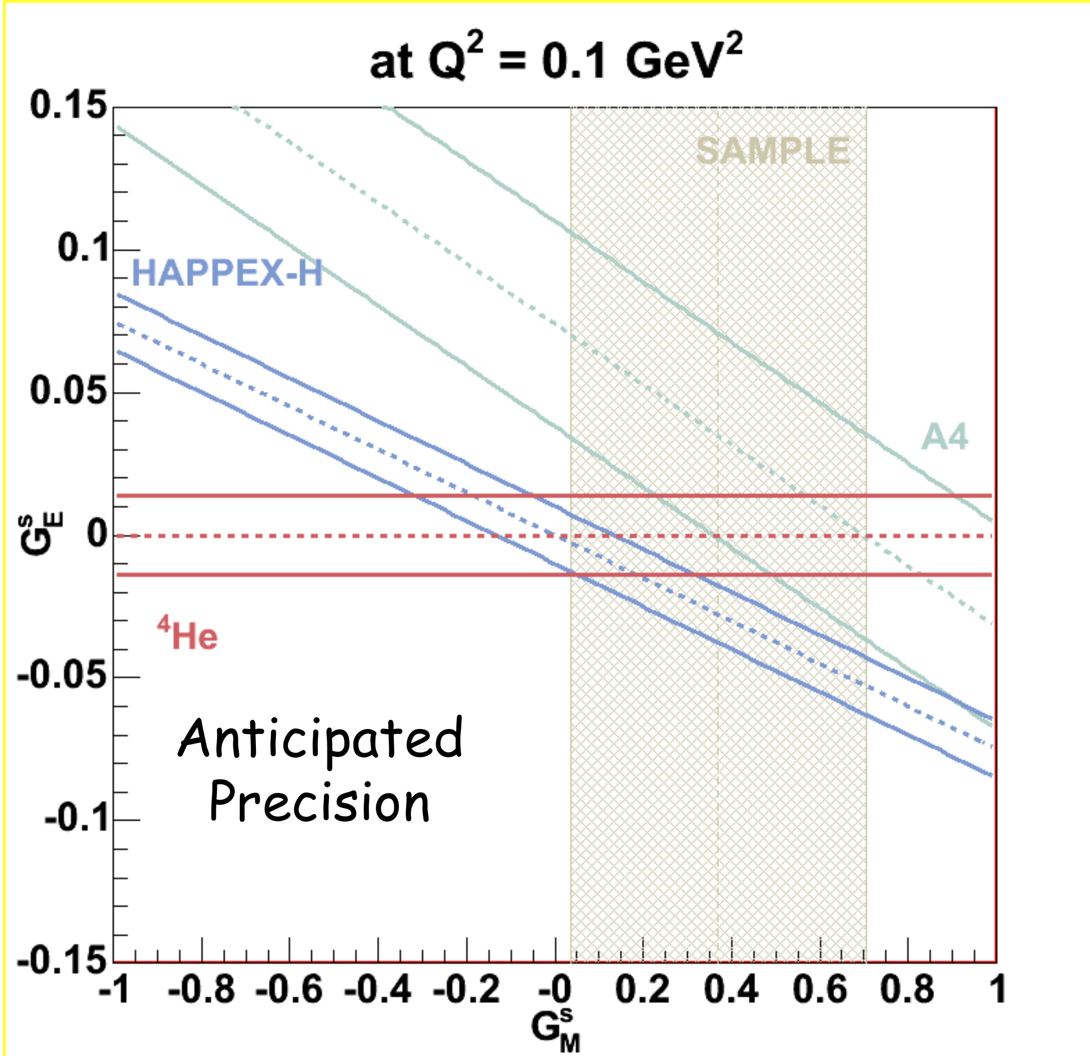
G^s_E still consistent with zero at $Q^2 = 0.1\ (GeV/c)^2$, and despite suggestions of positive G^s_M no conclusive signal yet.

Summer 2005, HAPPEX-H and HAPPEX-He are expected to acquire remainder of proposed statistics

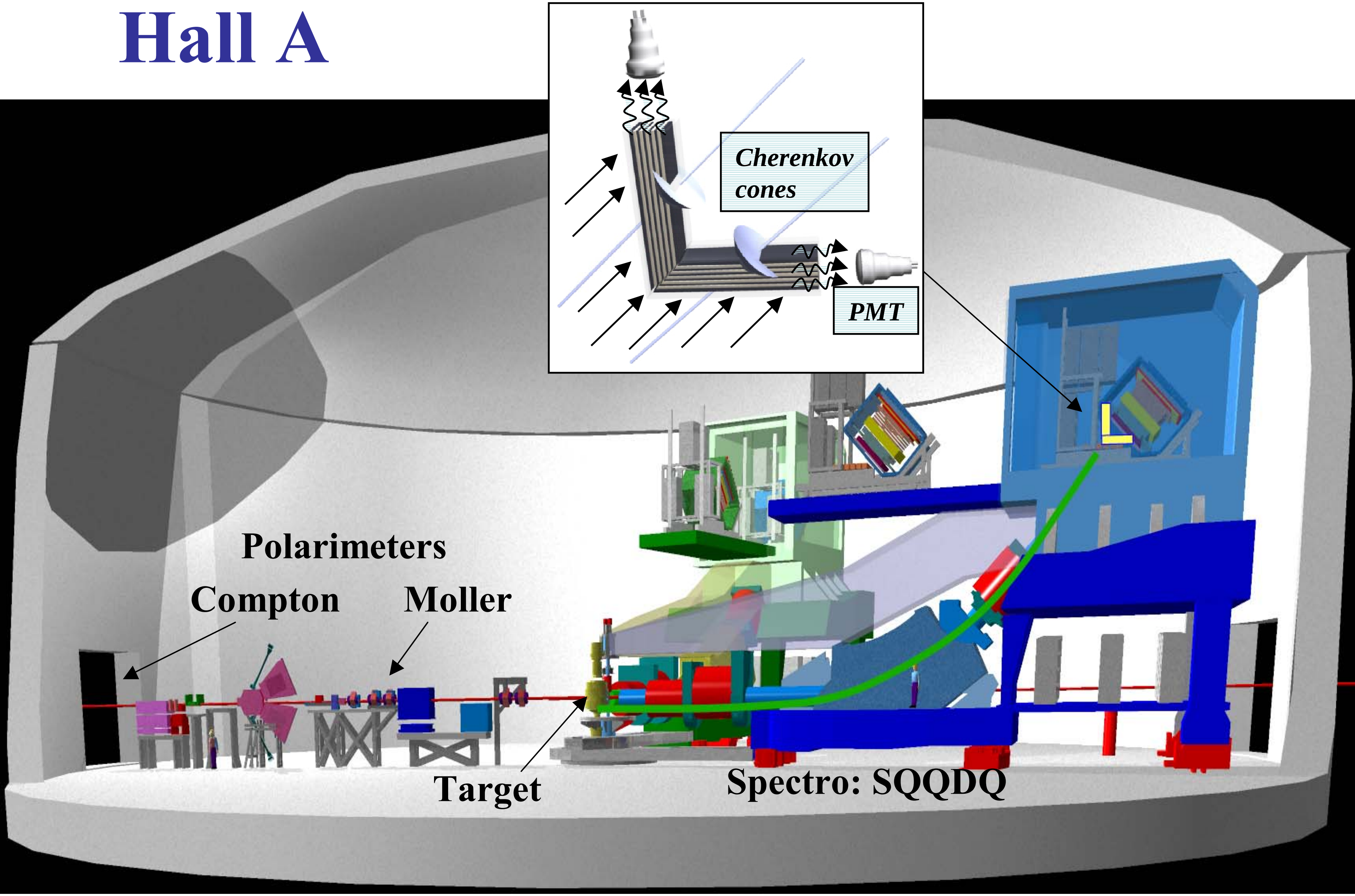




Low Q^2 Measurements



Hall A



Cherenkov cones
PMT
Polarimeters
Compton
Moller
Target
Spectro: SQQDQ

Adding a Sweeping Magnet

Magnet: $\sim\ 3\ kGs \times (\ 4 \times 6 \times 10\ cm^3) \Rightarrow$ Kink $\sim\approx 9.6\ mrad/P(GeV/c)$