The Q_{weak} Collaboration: www.jlab.org/qweak/

Qweak Collaboration Spokespersons

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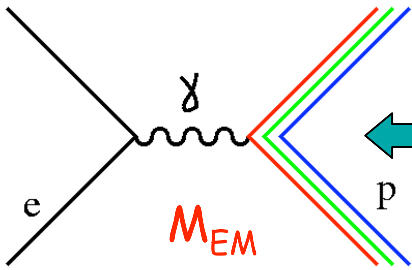
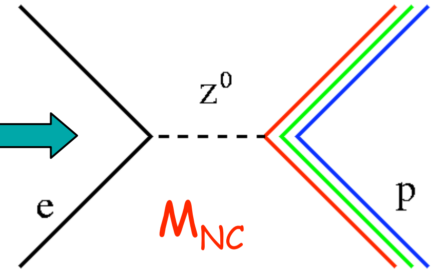
Zwart, Townsend - Massachusetts Institute of Technology

Parity violating scattering asymmetry



Interference gives parity violating scattering asymmetry for polarized beam



Q^2 Dependence:

$$A \equiv \frac{d\sigma_+ - d\sigma_-}{d\sigma_+ + d\sigma_-} = \frac{2M_{NC}}{M_{EM}}$$

$$\xrightarrow[\theta \to 0]{Q^2 \to 0} \left[\frac{-G_F}{4\pi\alpha\sqrt{2}}\right]\left[Q^2 \boxed{Q^p_{weak}} + Q^4 B\left(Q^2\right)\right]$$

"hadronic form factor" correction

Anticipated Q^p_{Weak} Uncertainties

This has now been determined from PVES data !

	$\Delta A_{phys} / A_{phys}$	$\Delta Q^p_{weak} / Q^p_{weak}$
Statistical (2200 hours production)	1.8%	2.9%
Systematic:		
Beam polarimetry	1.0%	1.6%
Absolute Q^2 determination	0.7%	1.1%
Backgrounds	0.5%	0.8%
Helicity-correlated Beam Properties	0.5%	0.8%
Totals: (with hadronic structure uncertainties)		~4.5% (mostly theory free)
		~4.1% (+ Zhu et al. theory)
		~3.8% (+ strange theory)

An additional uncertainty associated with QCD corrections applied to the extraction of $\sin^2\theta_W$: it raises $\Delta\sin^2\theta_W$ / $\sin^2\theta_W$ from 0.2% to 0.3%.

Experimental Sensitivity to Hadronic Form Factors

$$Q_W^p = (1 - 4\sin^2\theta_W) \cong 0.072$$

Measurement Precision

$$\delta Q_W^p = \pm 4\% \Rightarrow \delta(\sin^2\theta_W) = \pm 0.3\%$$

Actually: ~4.5% (mostly theory free)
~4.1% (with Zhu et al. theory)
~3.8% (including Strange Theory)

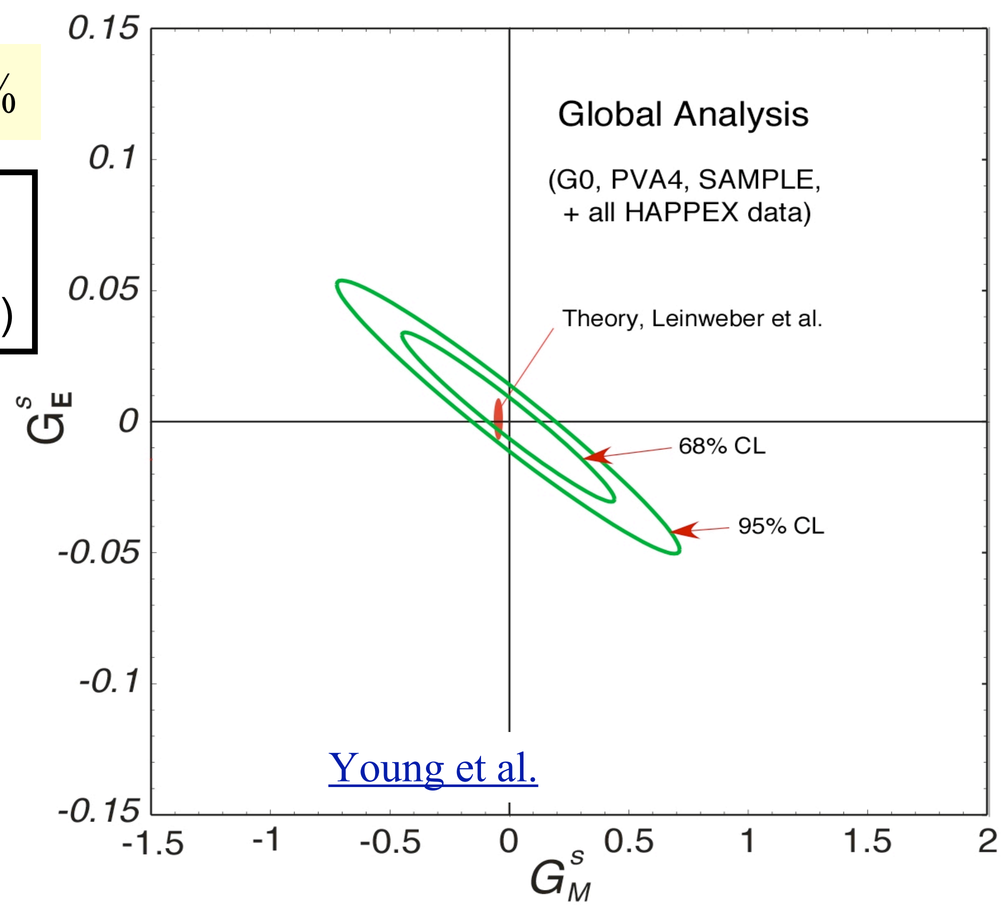
Physics Asymmetry

$$A(Q^2 \to 0) = -\frac{G_F}{4\pi\alpha\sqrt{2}}\left[Q^2 Q_{weak}^p + Q^4 B(Q^2)\right]$$

Expected Value

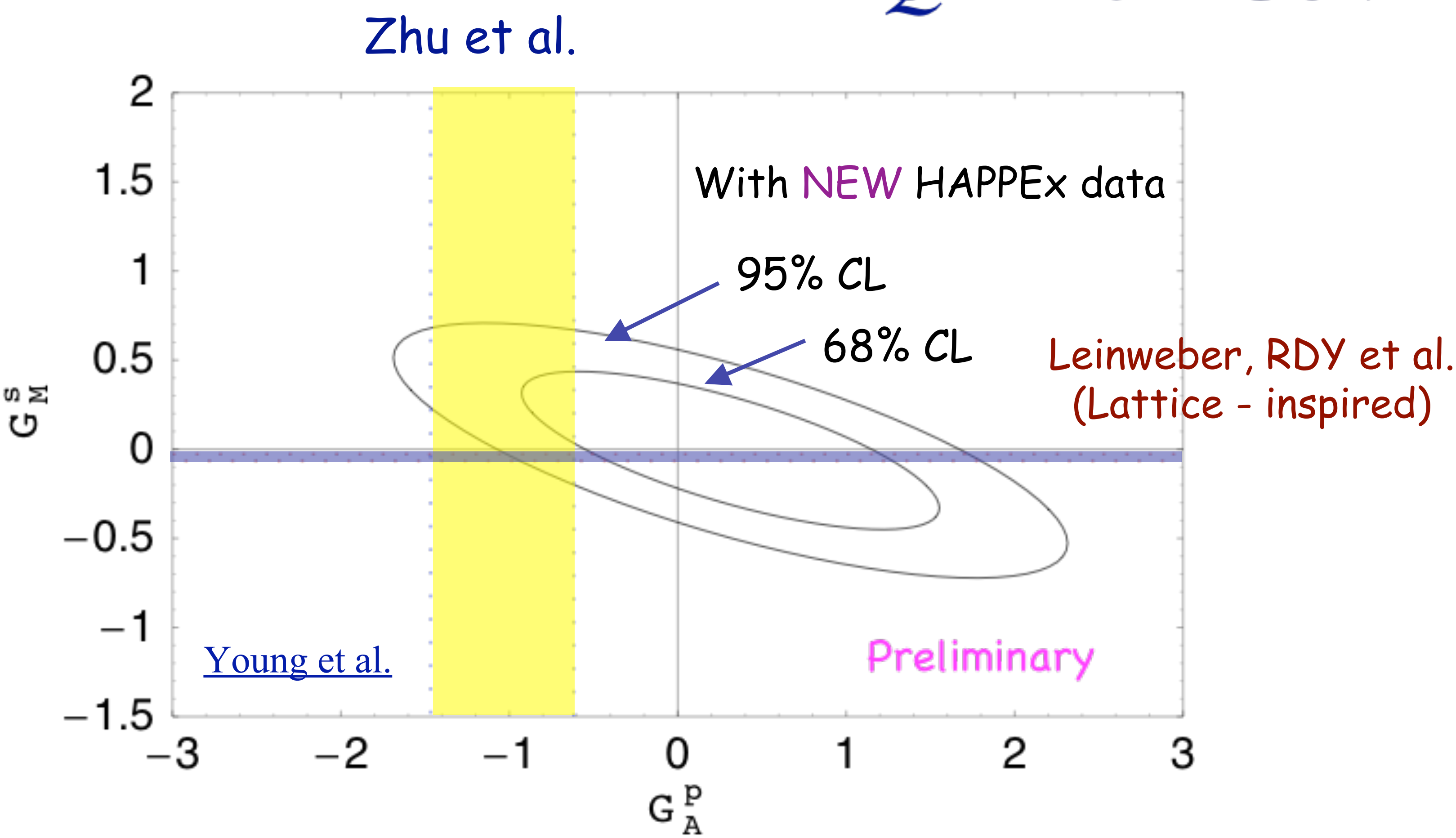
$$A(0.03\ \mathrm{GeV}^2) = A_{Q_W^p} + A_{B(Q^2)}$$
$$= -.19\ \mathrm{ppm} \quad -.10\ \mathrm{ppm}$$

Existing parity data via conservative extrapolation to Q^2 = 0.03 GeV^2 now determines Hadronic & Axial contributions to Q_{weak} to sufficient accuracy.



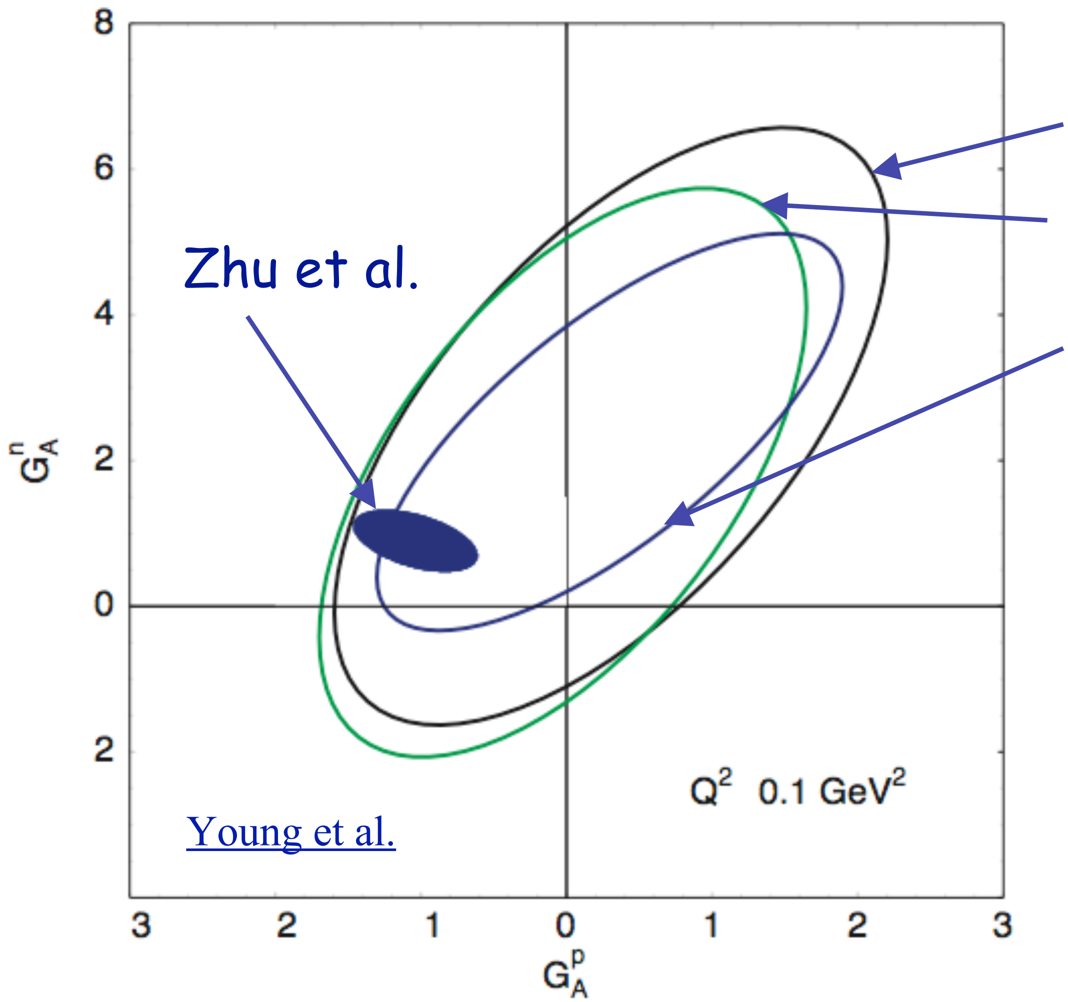
Global Fit for G^p_A versus G^s_M

$$Q^2 = 0.1\,\mathrm{GeV}^2$$



Global Fit for G^p_A versus G^n_A

$$Q^2 = 0.1\,\mathrm{GeV}^2$$



Present - All final data 95% CL

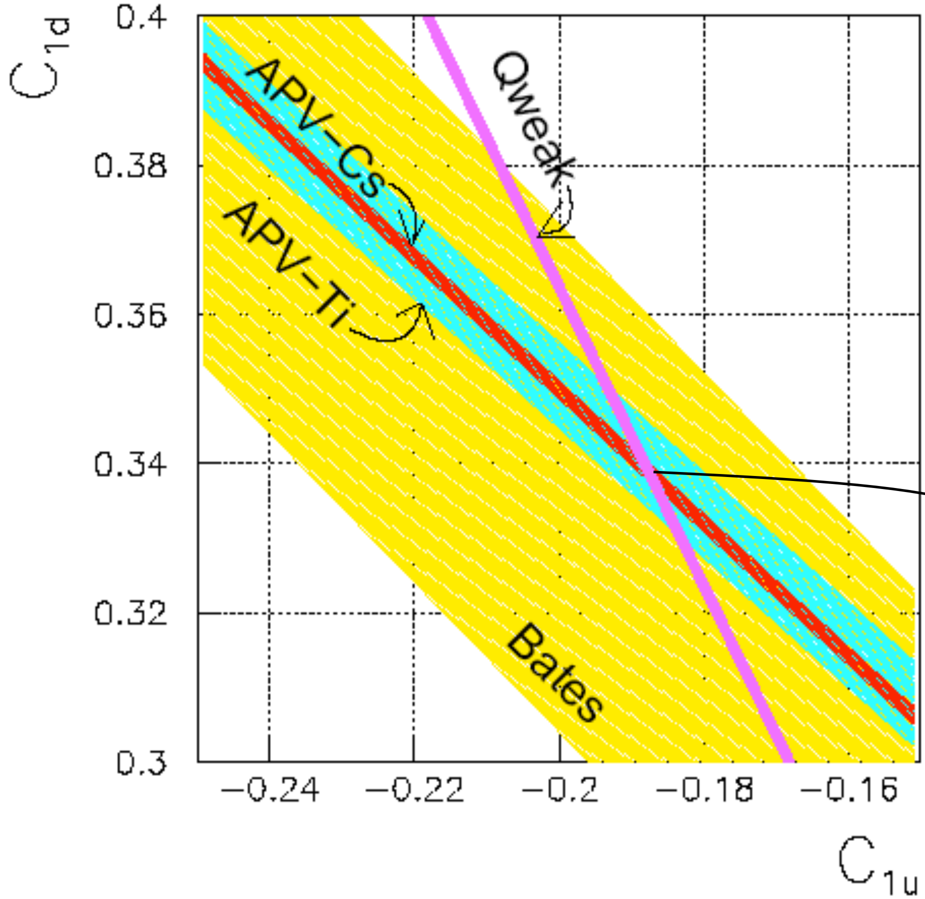
\+

PVA4 preliminary 95% CL

\+

Anticipated uncertainty 95%Cl from G0 380 MeV running (assumes present global fit central value)

Impact via "Model-independent Semi-Leptonic Analysis"



Effective electron-quark neutral current Lagrangian:

$$L^{PV}_{e\text{-}q} = -\frac{G_F}{\sqrt{2}} \bar{e}\gamma_\mu\gamma_5 e \sum_q C_{1q} \bar{q}\gamma^\mu q$$

$$\rightarrow \quad A(e) \quad x \quad V(q)$$

Existing data:
MIT-Bates ^{12}C (elastic)
APV Measurements

Impact of Q^p_{Weak} measurement assuming agreement with the Standard Model)

Energy Scale of an "Indirect" Search for New Physics

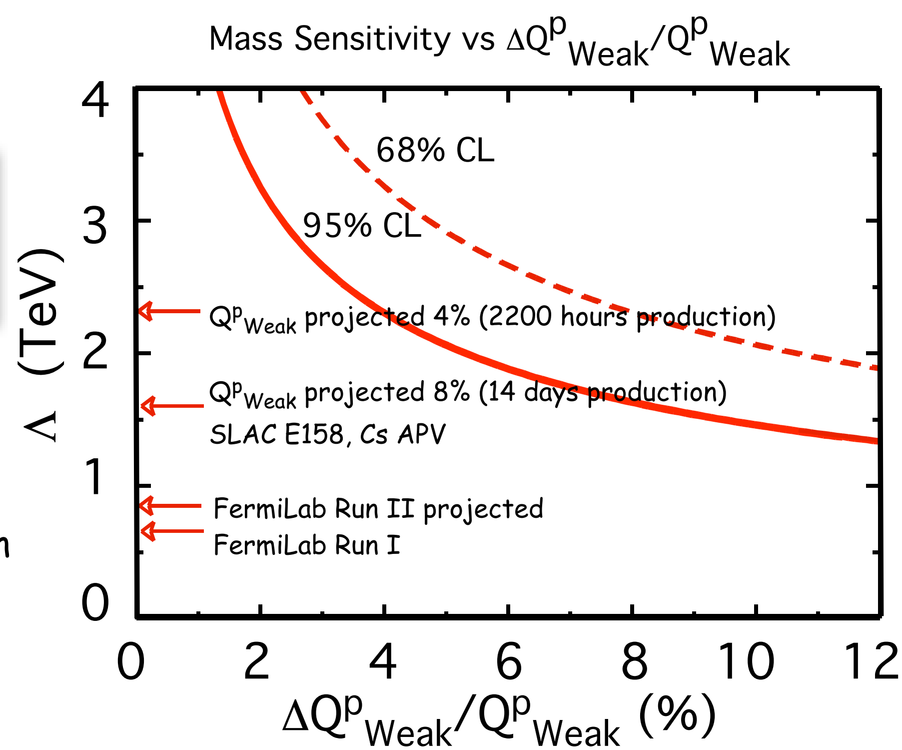
- Parameterize New Physics contributions in electron-quark Lagrangian

$$L^{PV}_{e\text{-}q} = L^{PV}_{SM} + L^{PV}_{NEW} = -\frac{G_F}{\sqrt{2}}\bar{e}\gamma_\mu\gamma_5 e\sum_q C_{1q}\bar{q}\gamma^\mu q + \frac{g^2}{4\Lambda^2}\bar{e}\gamma_\mu\gamma_5 e\sum_q h^q_V\bar{q}\gamma^\mu q$$

g: coupling constant, Λ: mass scale

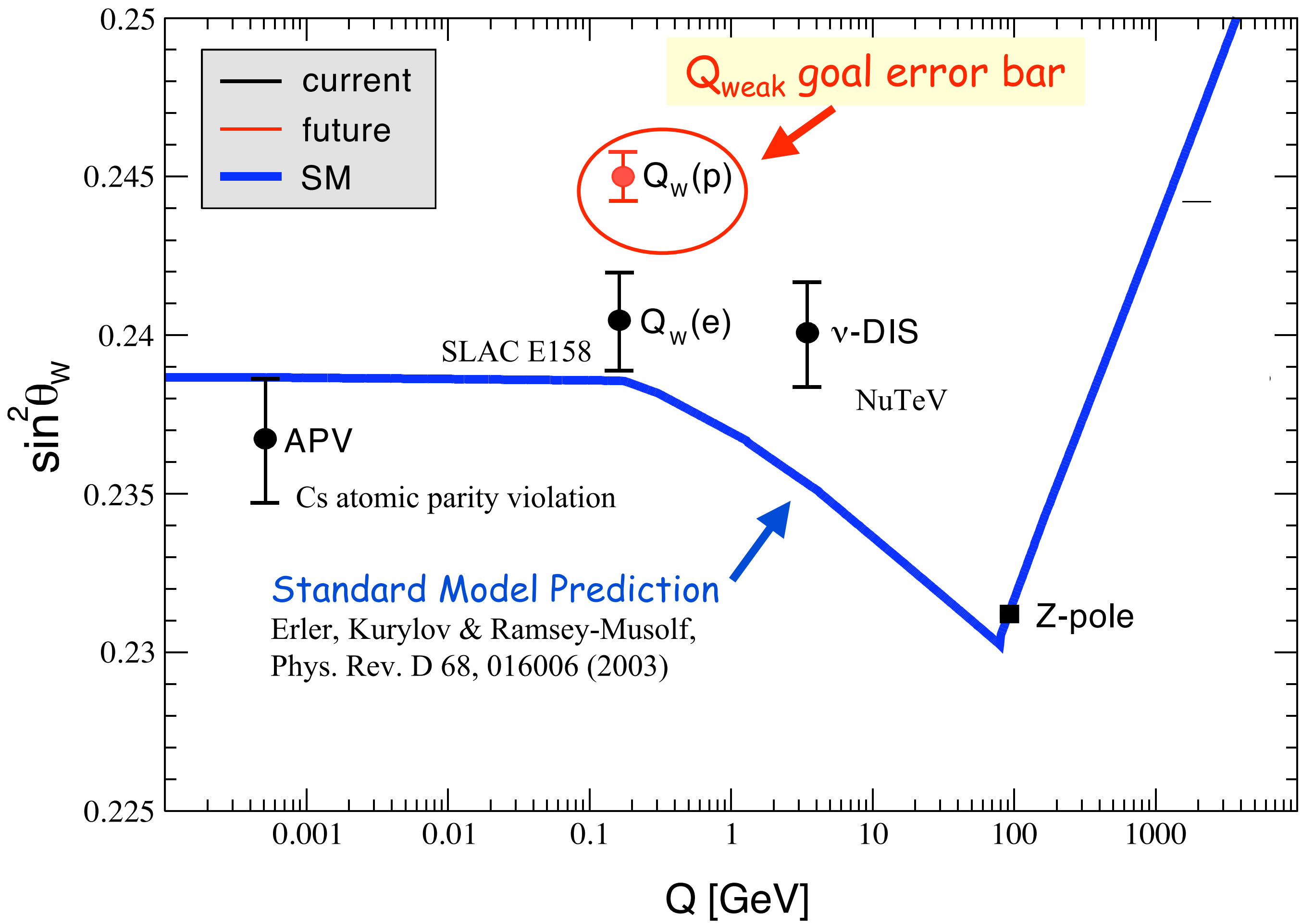
- A 4% Q^p_{Weak} measurement probes with 95% confidence level for new physics at energy scales to:

$$\frac{\Lambda}{g} \sim \frac{1}{2\sqrt{\sqrt{2}G_F\left|\Delta Q^p_W\right|}} \approx 2.3\ \text{TeV}$$



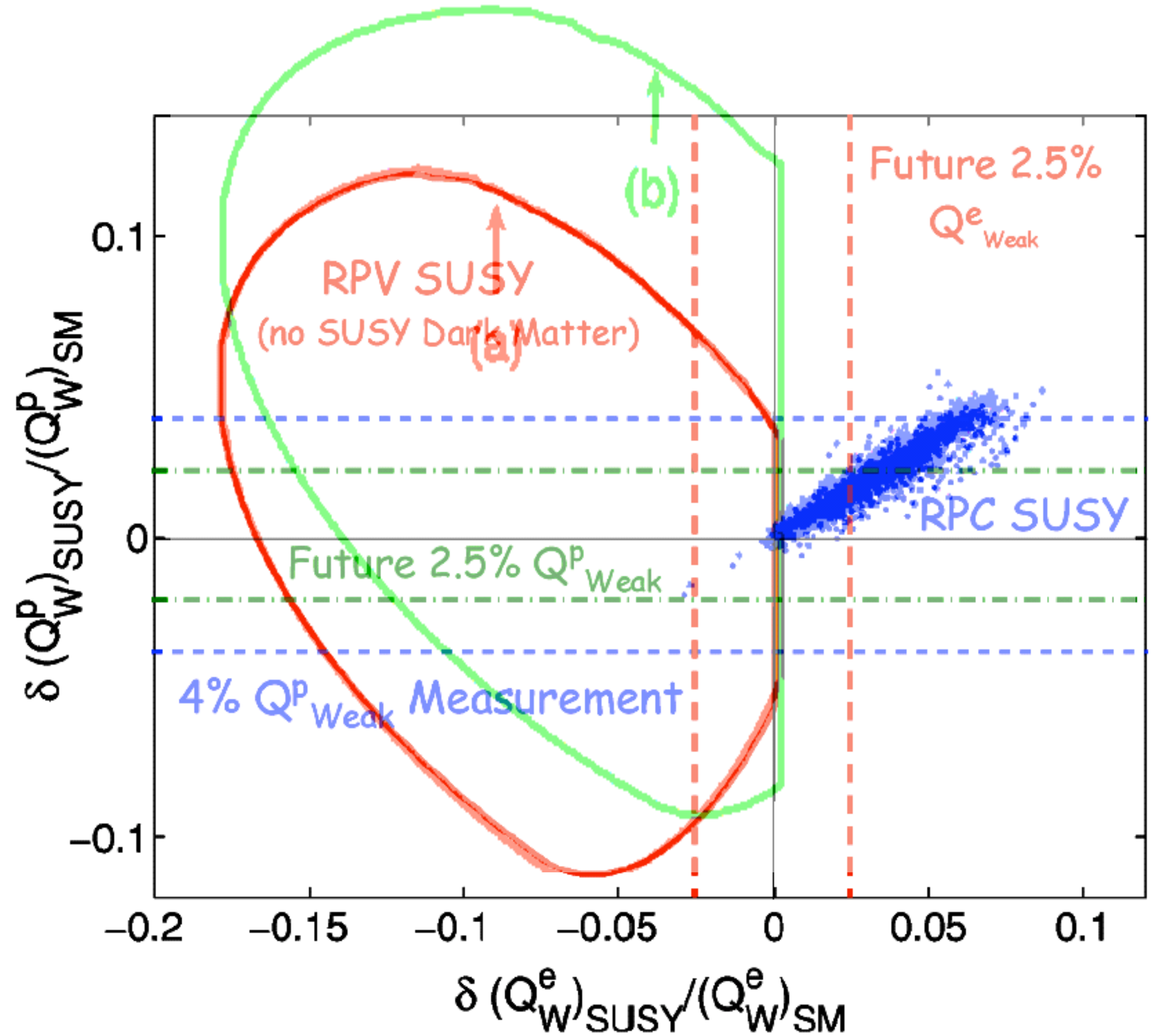
- The weak charge measurements have multi-TeV reach.
- If LHC uncovers new physics, then precision low Q^2 measurements can help to determine charges, coupling constants, etc.

Energy Scale dependence of the weak mixing angle:

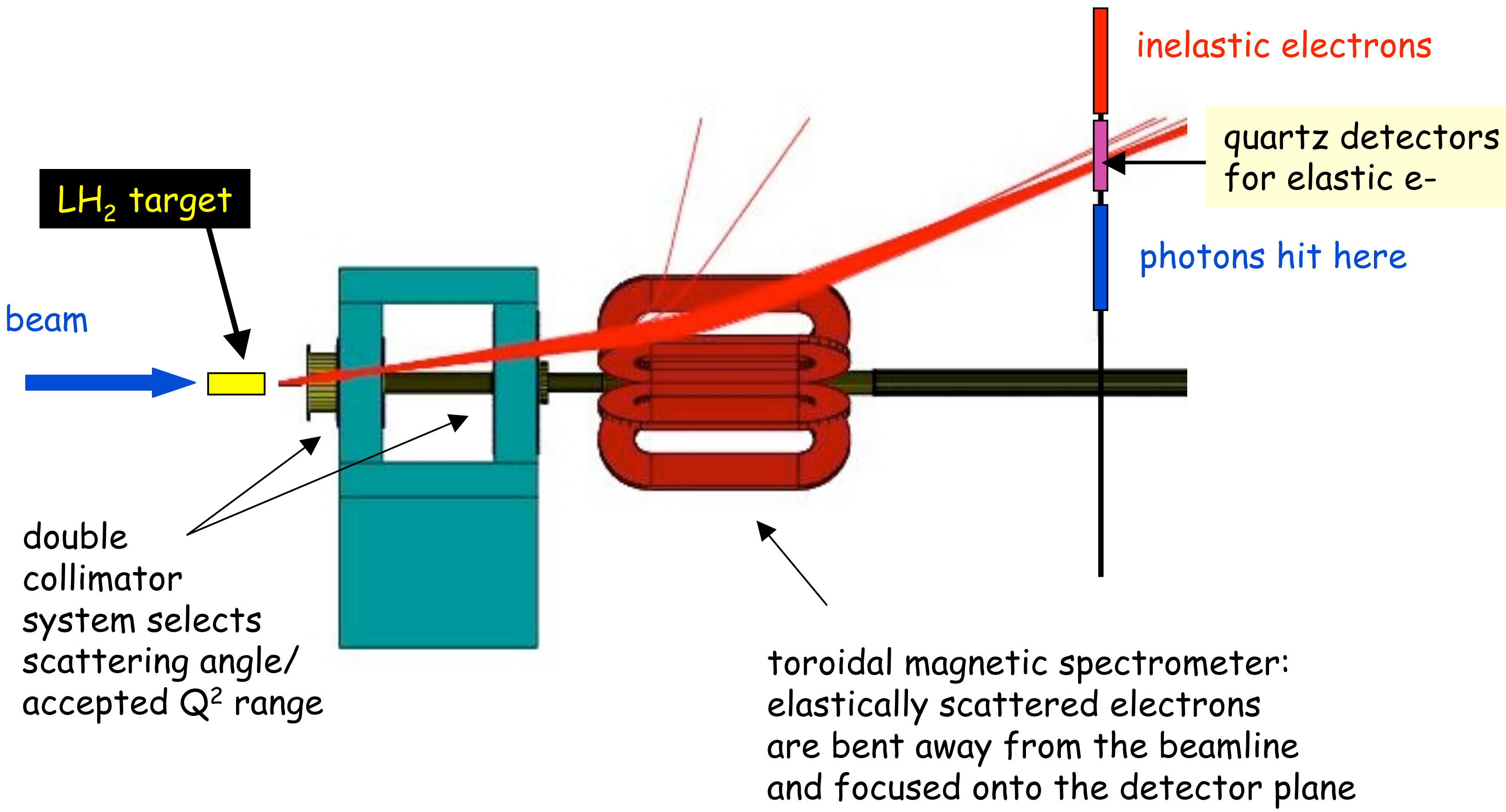


<u>Significance:</u> Anticipated error bar corresponds to a 10σ measurement of the Standard Model prediction.

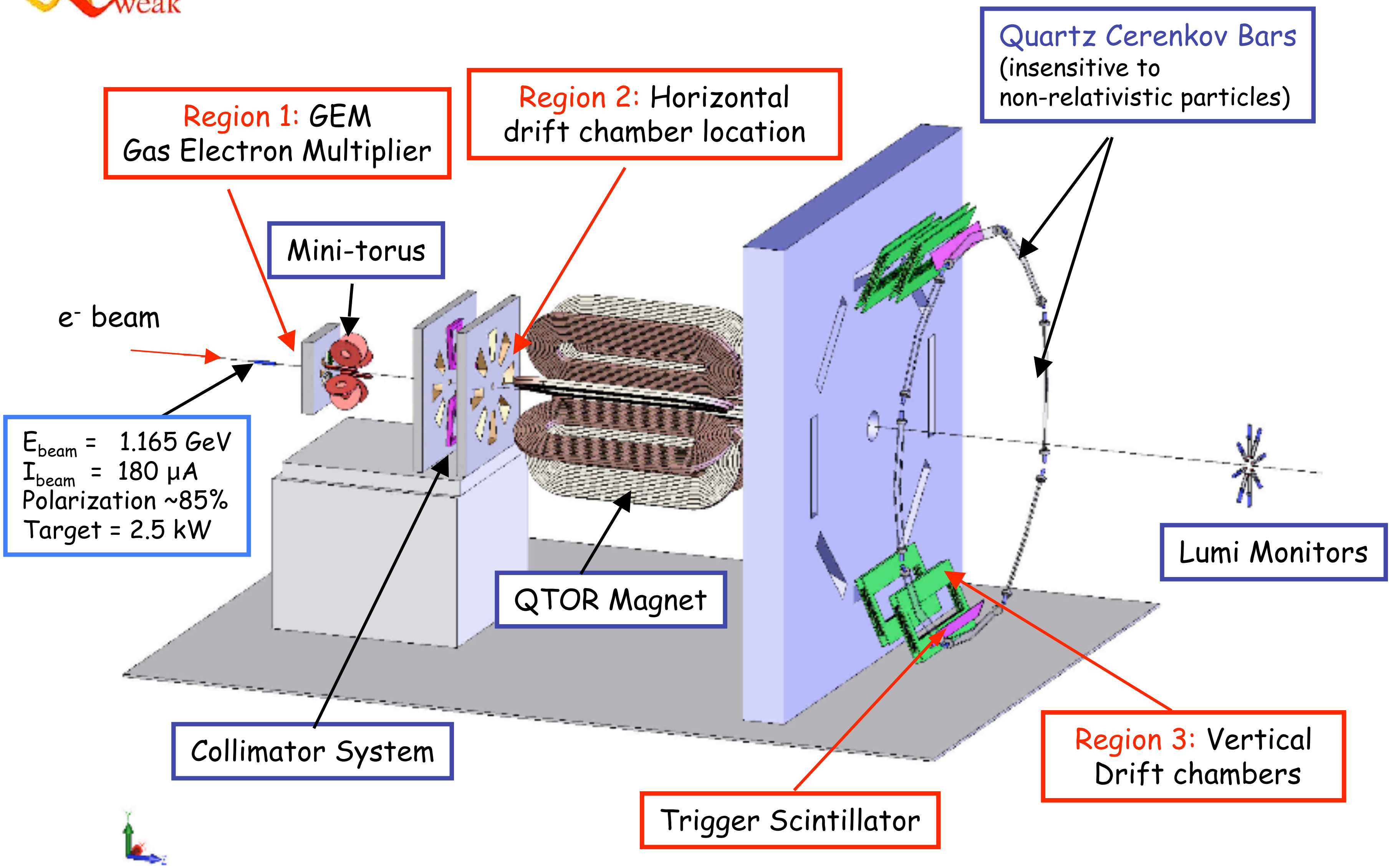
Relative Shifts in Proton and Electron Weak Charges due to SUSY Effects



Main apparatus: target plus toroidal magnetic spectrometer



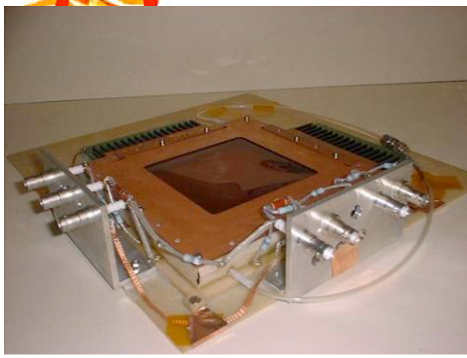
Layout drawing: main asymmetry plus tracking apparatus for ‹Q^2›, ‹Q^4›

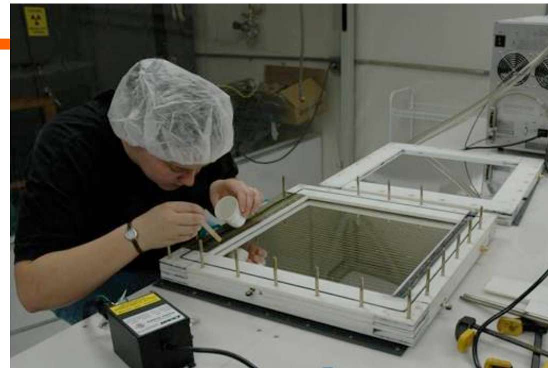


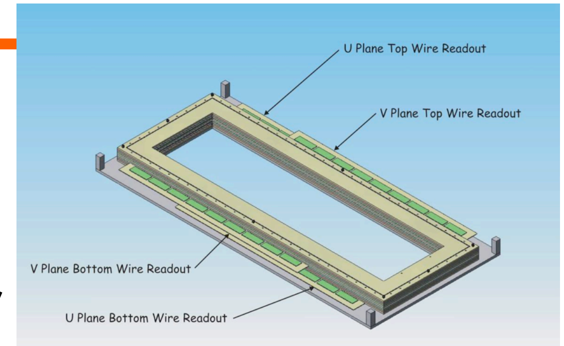
(We will turn down the beam current and track particles to determine ‹Q^2›, ‹Q^4›)

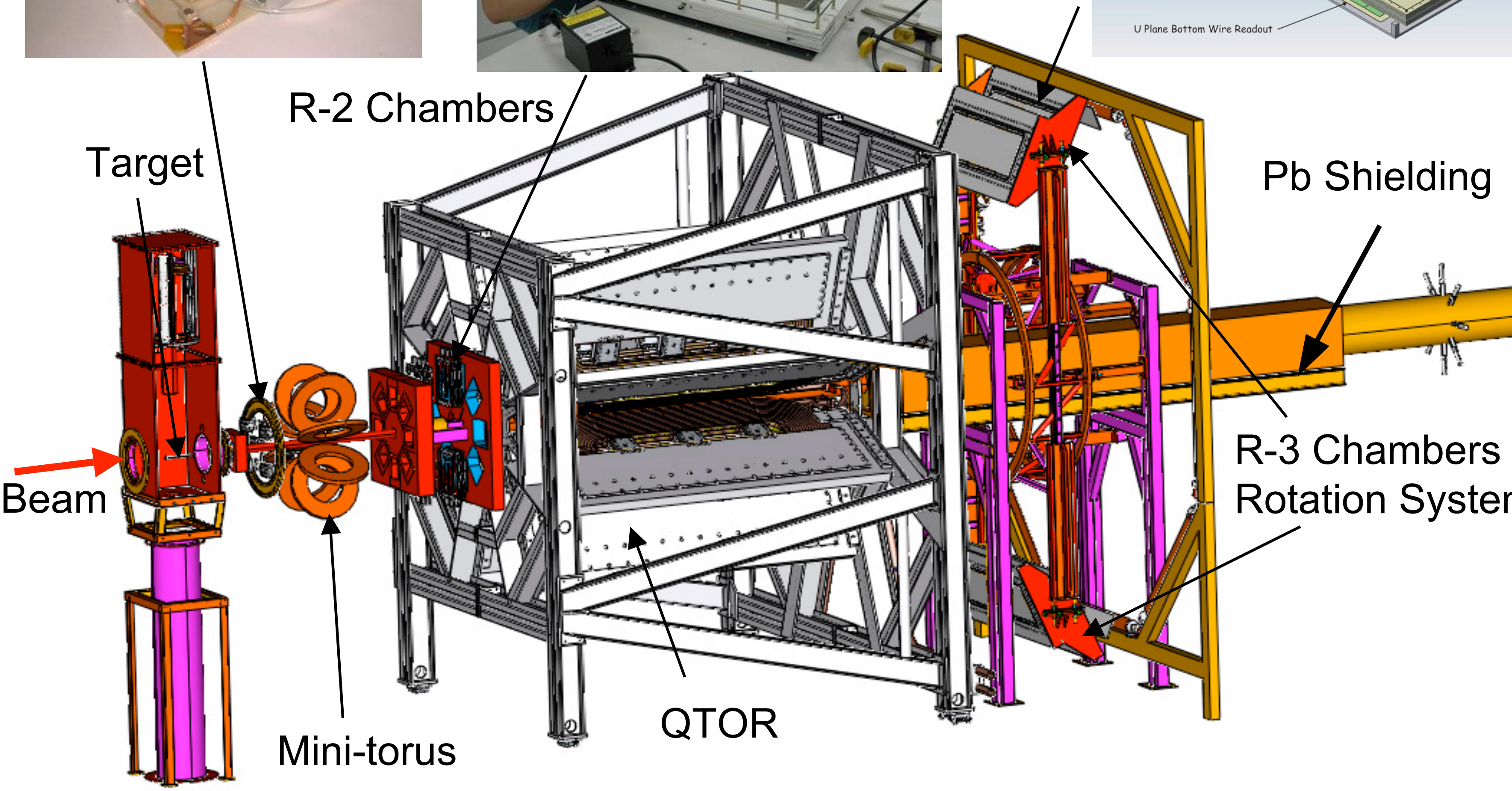
Tracking Systems (counting mode)

GEM's



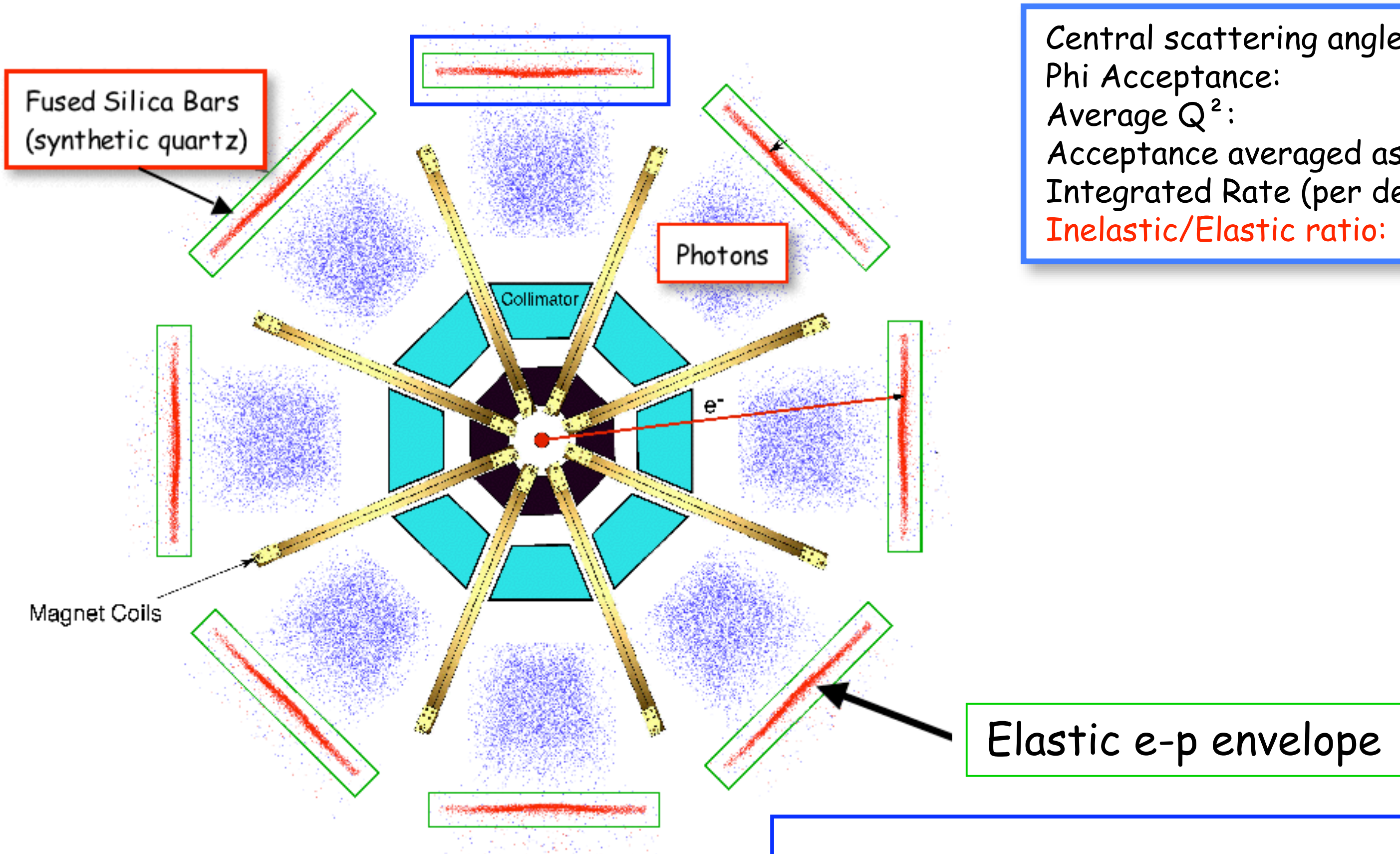




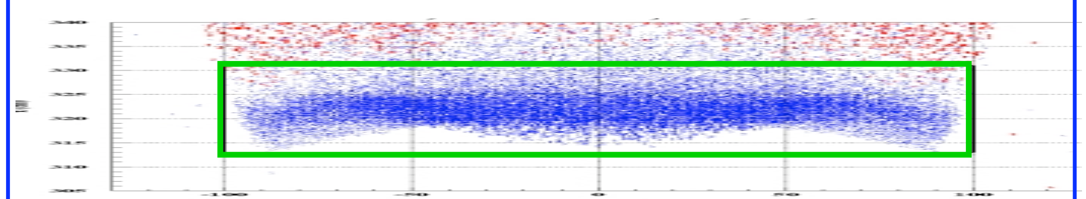


View of Q^p_{Weak} Apparatus collapsed along beam direction - Simulated Events

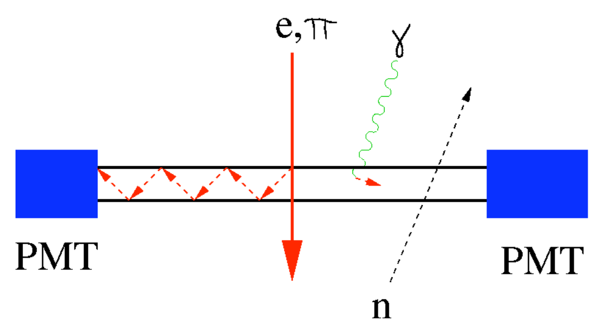
Central scattering angle: ~8° ± 2
Phi Acceptance: > 50% of 2π
Average Q^2: 0.027 GeV^2
Acceptance averaged asymmetry: -0.29 ppm
Integrated Rate (per detector): ~900 MHz
Inelastic/Elastic ratio: ~0.01%



Black region in center
is Pb shielding



Main Detector and Electronics System



Focal plane detector requirements:

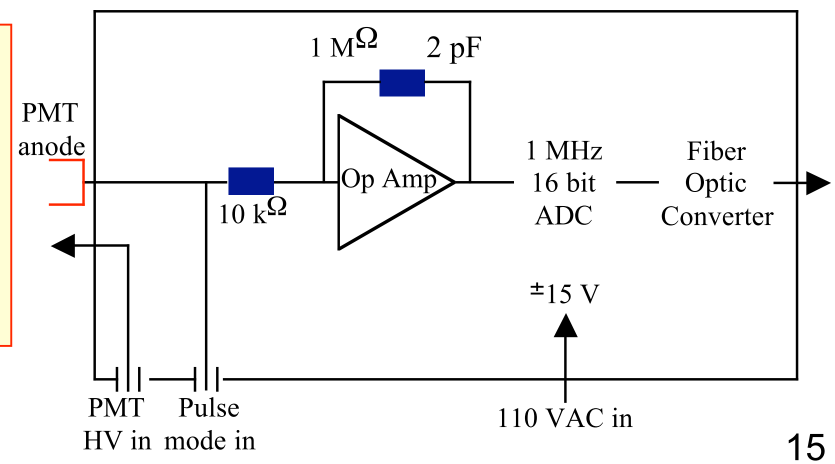
- Insensitivity to background γ, n, π.
- Radiation hardness (expect > 300 kRad).
- Operation at ~ counting statistics
- nonlinearity less than 1%

Fused Silica (synthetic quartz) Cerenkov detector.

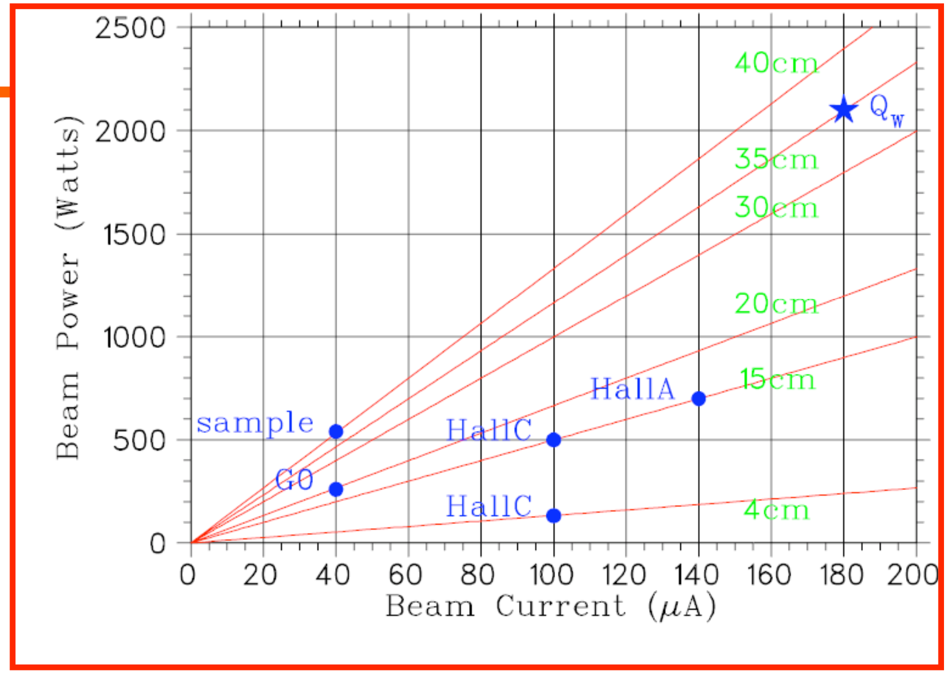
- Plan to use 18 cm x 200 cm x 1.25 cm quartz
- bars read out at both ends by S20 photocathode PMTs (expect ~ 50 pe/event)
- n =1.47, $\theta_{Cerenkov}$=47°, total internal reflection θ_{tir}=43°
- reflectivity = 0.997

Electronics (LANL/TRIUMF design):

- Normally operates in integration mode.
- Will have connection for pulse mode.
- Low electronic noise contribution. compared to counting statistics.
- 18 bit ADC will allow for 4X over sampling

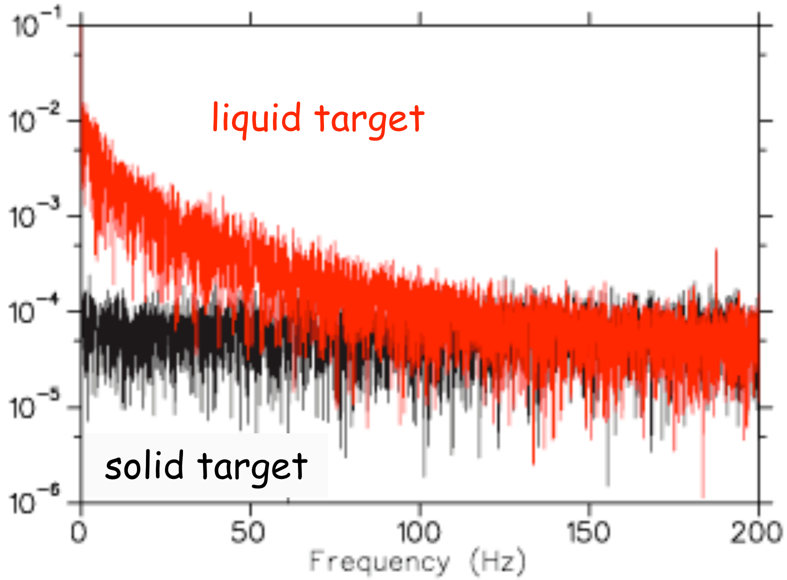


Q_{weak} LH_2 target



Requirements:

- 2500 W cooling power !
- raster size 4 x 4 mm^2

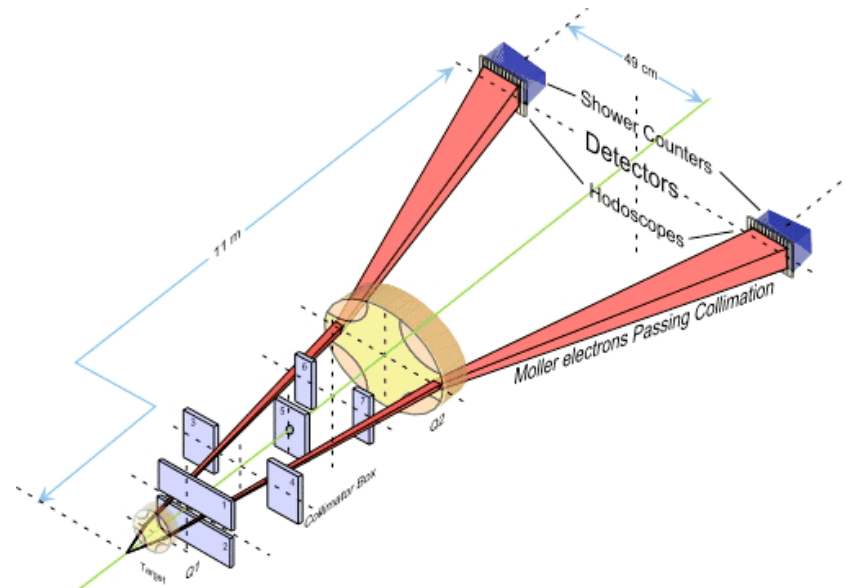


Noise spectra measured in Hall A -- great improvement at higher spin flip frequency

(up to 250 Hz implemented at the polarized source already)

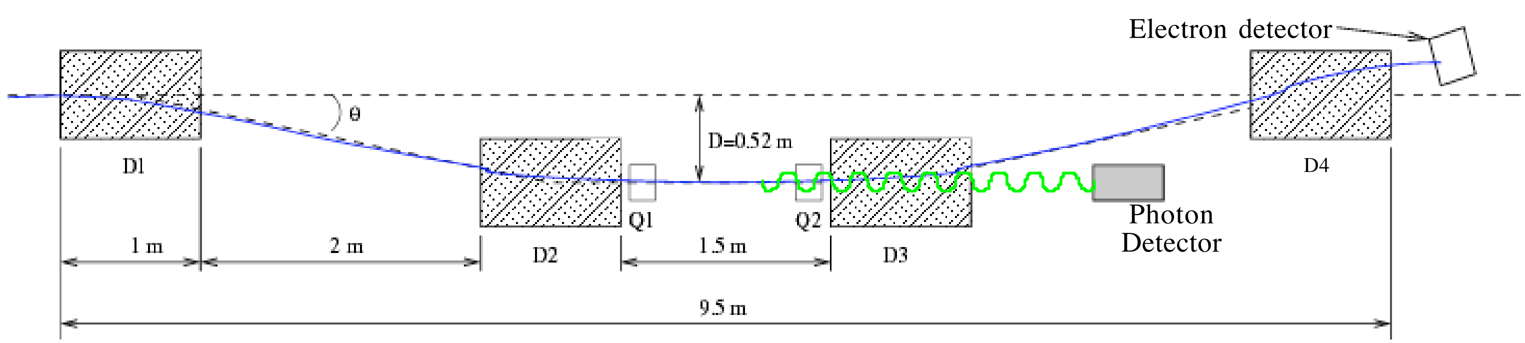
Precision Polarimetry

- Moller polarimeter
  - I_{Max} ~ 10 μA average --> 100 μA chopped!
  - Chopped beam helps power low so the Fe target won't depolarize.
  - Measurement is invasive.



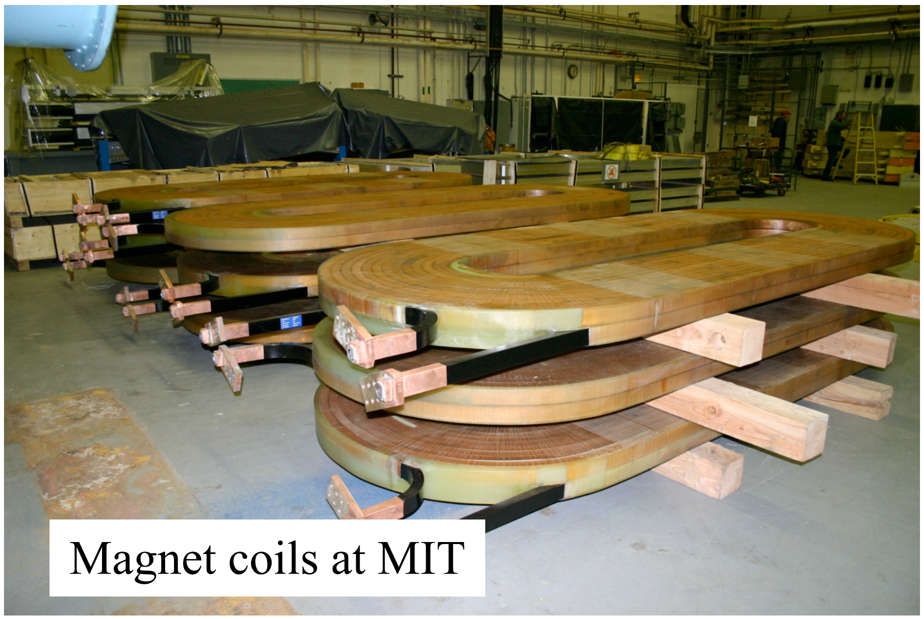
- Schematic of planned new Hall C Compton polarimeter.

Existing Hall C Møller can achieve 1% (statistics) in a few minutes.

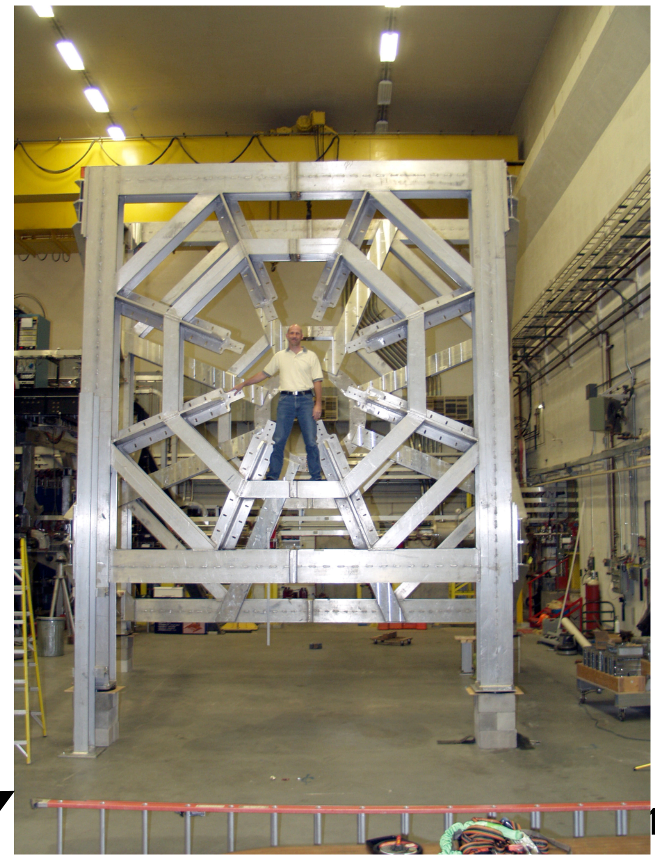


Summary and Schedule

- Measure the proton's weak charge, Q_W^p to ± 4% and determine $\sin^2\theta_W$ to ± 0.3% from low Q^2 parity-violating elastic scattering at.
- Schedule: Installation in 2009 and ~18 months on the floor before 12 GeV upgrade.



Magnet coils at MIT



Support Structure at MIT