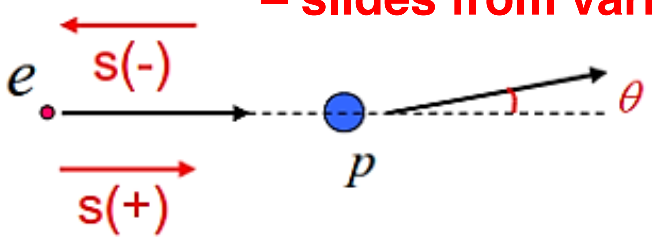
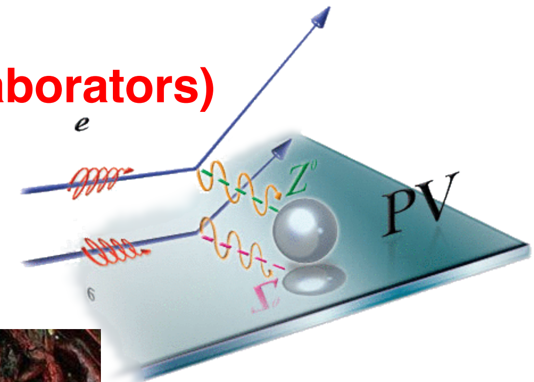
Qweak + Torroidal Spectrometer Spectrometer Options

(+ Kinematics, Backgrounds and Technology for a Next Generation Q^pweak Measurement)

IEB Workshop – Cornell 6/18/2015

Roger D. Carlini
Jefferson Laboratory
(for the Qweak collaboration
– slides from various talks given by many collaborators)





The Qweak Collaboration

97 collaborators
10 post docs
23 grad students
23 institutions

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[5] Thomas Jefferson National Accelerator Facility
[6] Ohio University
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[9] University of Virginia
[10] TRIUMF
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[12] Mississippi State University
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[14] Southern University at New Orleans
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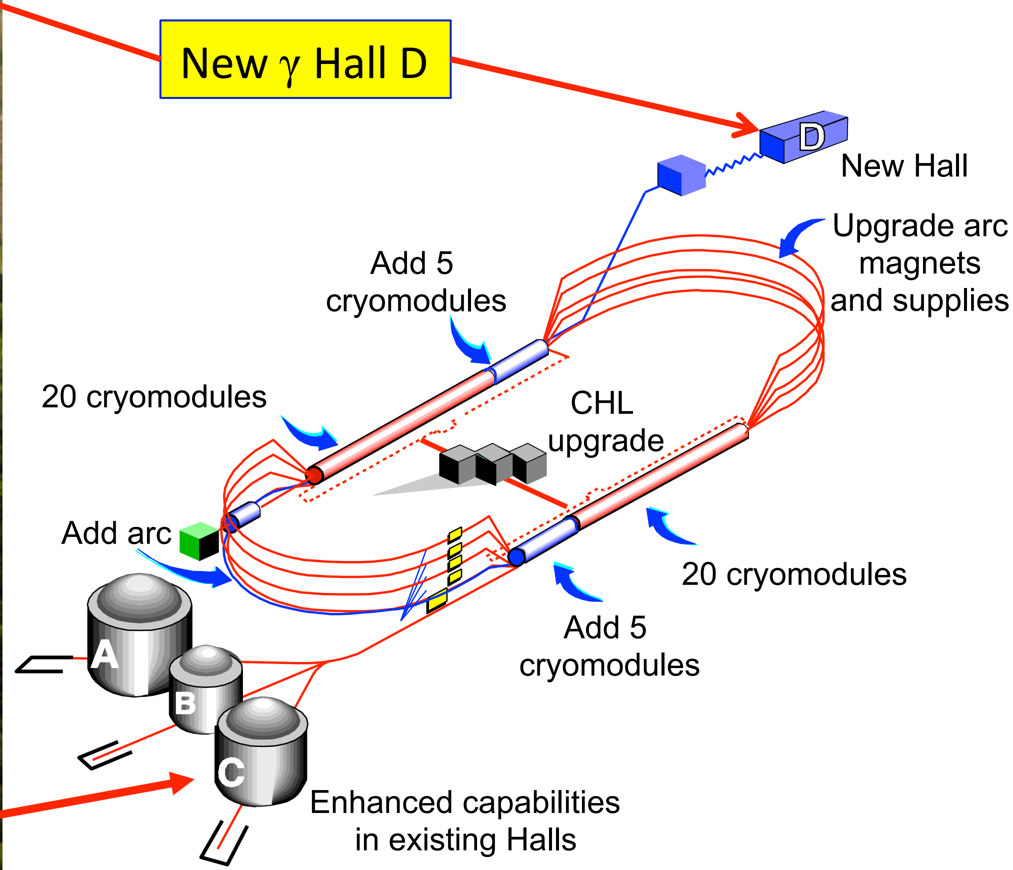
Spokespersons Project Manager Grad Students

Jlab Accelerator Complex

- Superconducting RF Accelerators
- Continuous e^- beam (499 MHz)
- 4 Experimental Halls
- 12 GeV Upgrade Almost Complete



Qweak: Current Status

- **Experiment finished successfully:**
  - **Most precise measure of $\vec{e}p$ scattering asymmetry**
  - **2 years in situ, ~1 year of integrated beam**
  - **Commissioning run published (PRL 111, 141803 (2013))**
    - **~ 1/25th of total data collected**

  – 1st Determination of $Q_w(p)$, C_{1u}, C_{1d}, & $Q_w(n)$

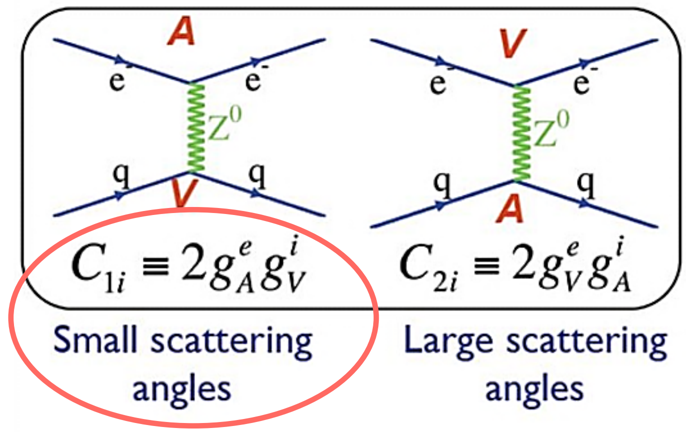
  - **Remainder of experiment still being analyzed**
    - **Expect final result ~ early next year**
    - **Expect final asymmetry will have ~5 x better precision**
    - **Experimental apparatus described in NIM A781, 105 (2015)**

The Weak Charges

$Q_w(p)$ is the neutral-weak analog of the proton's electric charge

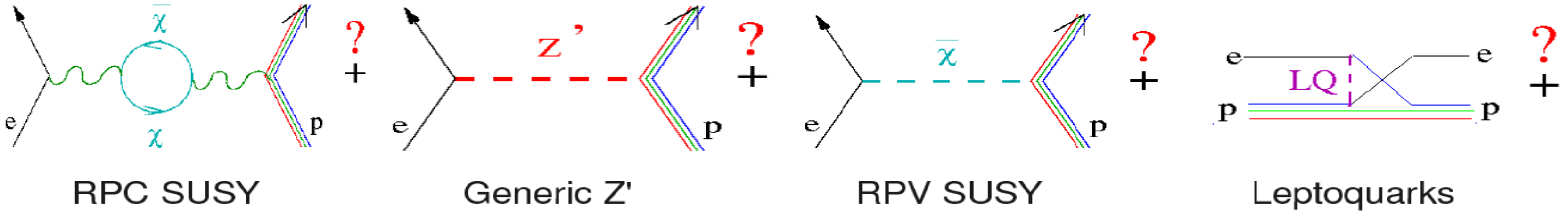
$Q_W(p)$ is particularly sensitive to the quark vector coupling C_{1u} & C_{1d}

	Q_{EM}	Weak Vector Charge
u quark	2/3	$-2C_{1u} = 1 - \frac{8}{3}\sin^2\theta_W \approx 1/3$
d quark	-1/3	$-2C_{1d} = -1 + \frac{4}{3}\sin^2\theta_W \approx -2/3$
p (uud)	+1	$1 - 4\sin^2\theta_W \approx 0.07$
n (udd)	0	≈ -1

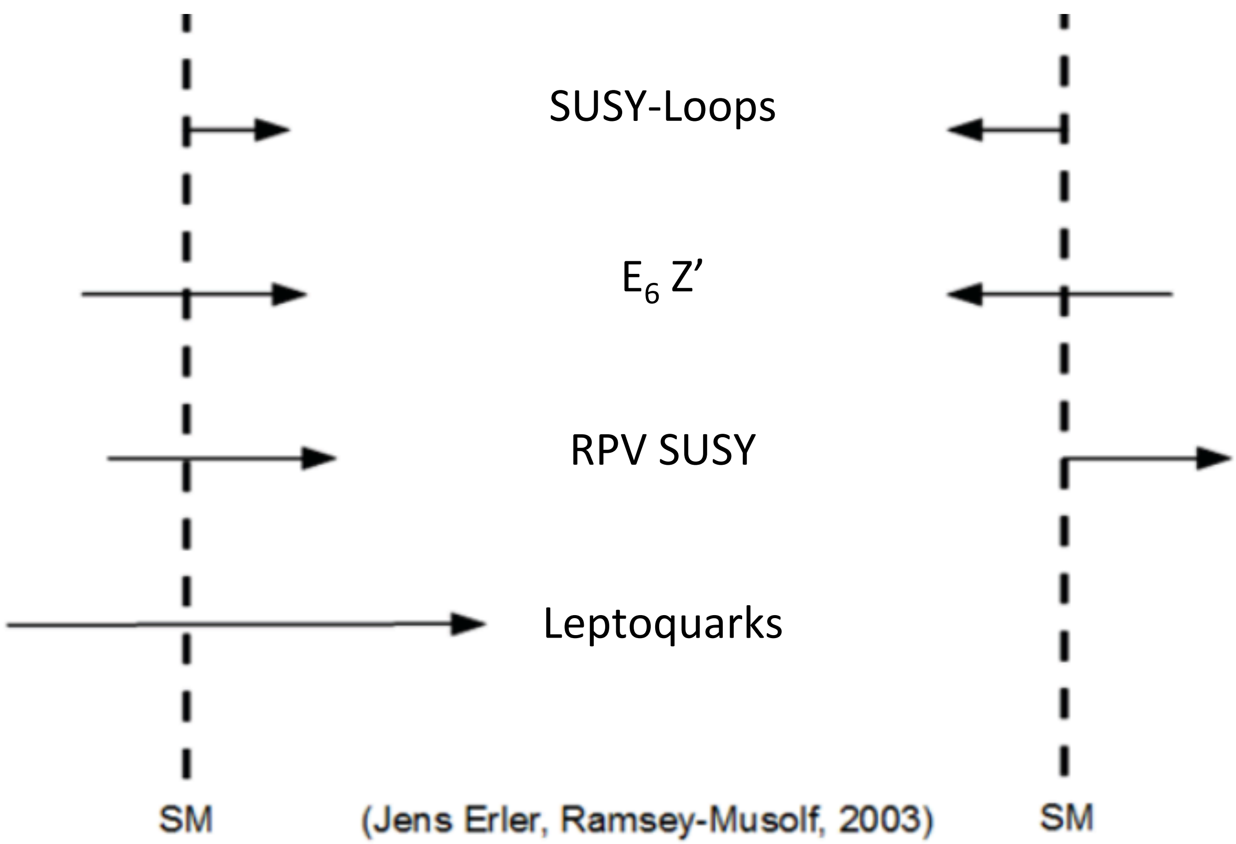


- **General: $Q_w(Z,N) = -2\{C_{1u}(2Z + N) + C_{1d}(Z + 2N)\}$**
  - **Ex: $Q_w(p) = -2(2C_{1u} + C_{1d})$ (this experiment)**
    - Uses higher Q^2 PVES data to constrain hadronic corrections (about 20%)
  - **Ex: $Q_w(^{133}Cs) = -2(188C_{1u} + 211C_{1d})$ (APV)**
    - Latest atomic corrections from PRL 109, 203003 (2012)
- **Combining $Q_w(p)$ and $Q_w(^{133}Cs)$ → C_{1u} & C_{1d}, $Q_w(n)$**

Complementarity Between Weak Charges of Proton & Electron



Weak charge of the proton | **Weak Charge of the electron**



The Qweak Experiment Methodology

Technical milestones for beam intensity, polarization, high power liquid hydrogen target , ….

(elastic) scattered e^- at small angle (~8°) and small Q^2 (0.025 GeV/c)^2

1.16 GeV e^- beam

(180 μA for ~2000 hr)

spin (+)

spin (–)

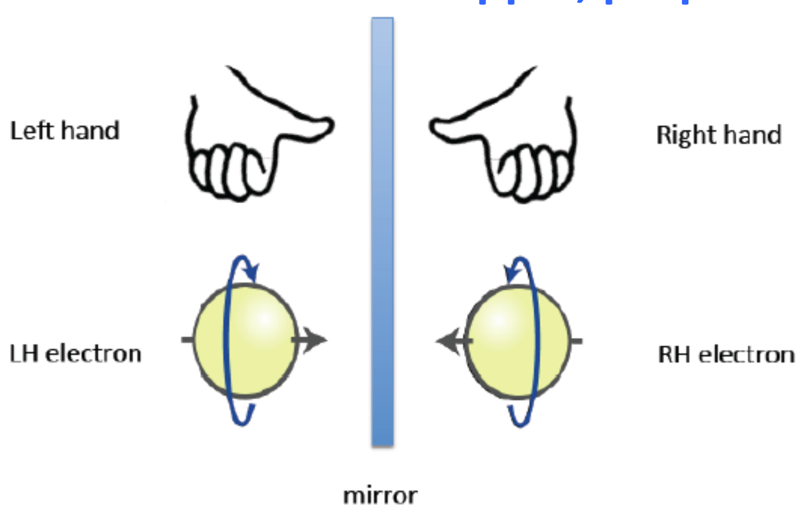
LH_2 target

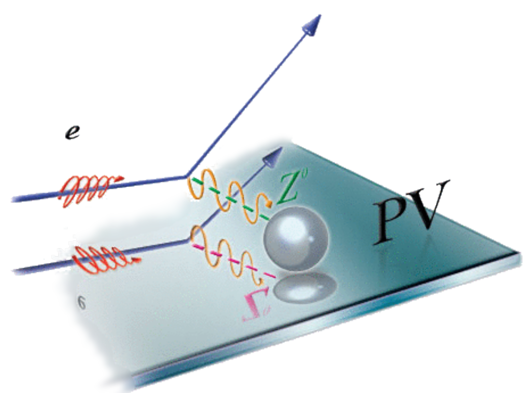
10^{16} (1 + A) e^-

10^{16} (1 – A) e^-

Difference proportional to the parity violating asymmetry:
(Strong & EM interactions conserve parity)

A ~ –2 × 10^{-7} or –0.2 ppm, proportional to the proton's weak charge ("Qweak")





Extracting $Q_w(p)$

EM (PC) + neutral-weak (PV)

- $A_{ep} = \left[\frac{\sigma^+ - \sigma^-}{\sigma^+ + \sigma^-}\right] \sim \frac{|M^{PV}_{weak}|}{|M_{EM}|}$ where $\sigma^\pm$ is $\vec{e}p$ x-sec for e's of helicity ±1

- $$A_{ep} = \left[\frac{G_F\, Q^2}{4\pi\alpha\sqrt{2}}\right] \frac{\epsilon G_E^\gamma G_E^Z + \tau G_M^\gamma G_M^Z - (1-4\sin^2\theta_W)\epsilon' G_M^\gamma G_A^Z}{\varepsilon(G_E^\gamma)^2 + \tau(G_M^\gamma)^2}$$

  – where $\varepsilon = [1 + 2(1+\tau)\tan^2(\theta/2)]^{-1}$, $\varepsilon' = \sqrt{\tau(1+\tau)(1-\varepsilon^2)}$,
  $\tau = Q^2/4M^2$, $G^\gamma_{E,M}$ are EM FFs, $G^Z_{E,M}$ & G^Z_A are strange & axial FFs,
  and $\sin^2\theta_w = 1 - (M_W / M_Z)^2$ = weak mixing angle

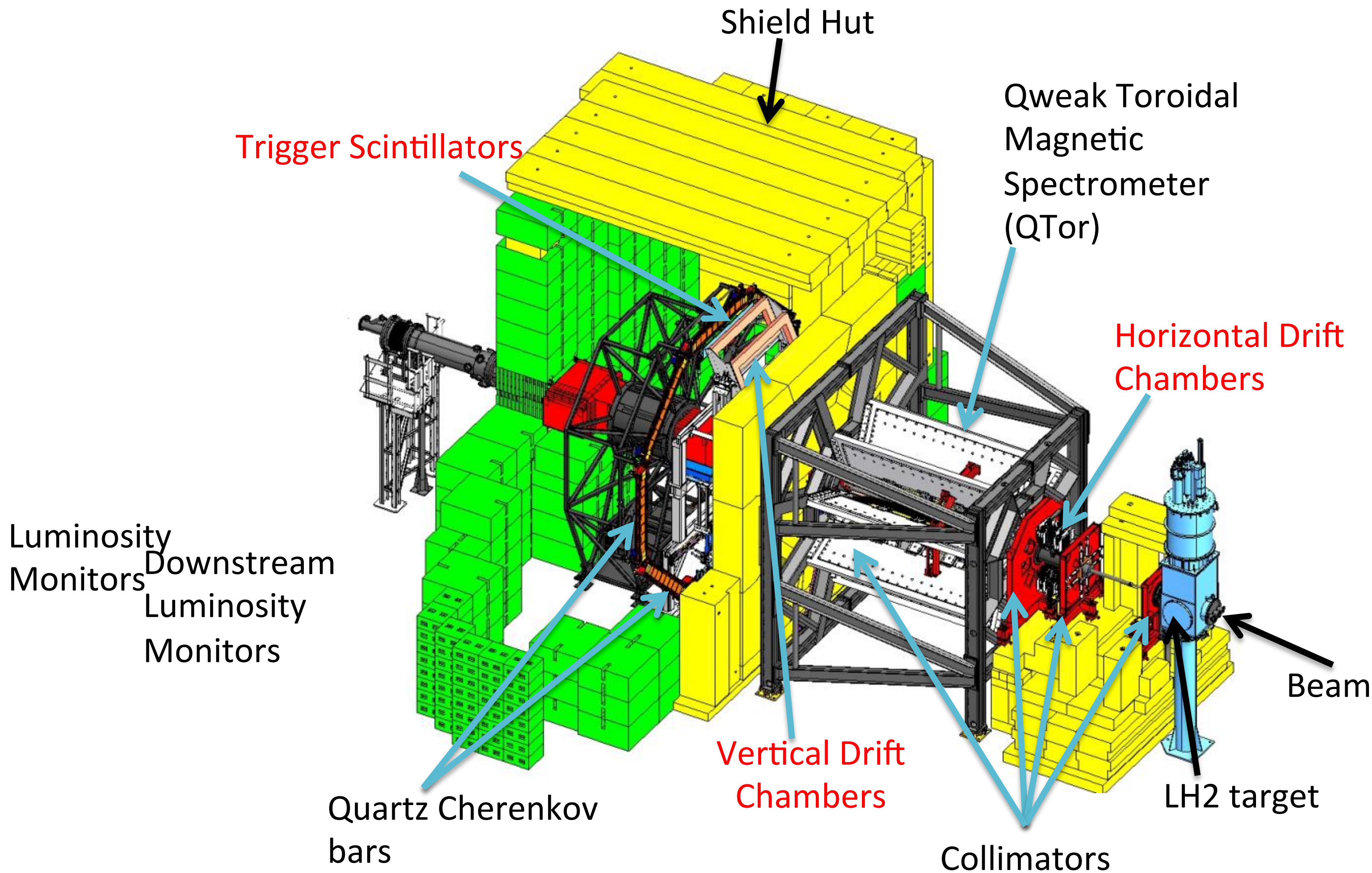
- Recast $A_{ep} = \frac{G_F\, Q^2}{4\pi\alpha\sqrt{2}}\left[Q^p_w + Q^2 B(Q^2,\theta)\right]$

  73% 26%

  – So in a plot of $A_{ep}/\left[\frac{G_F\, Q^2}{4\pi\alpha\sqrt{2}}\right]$ vs Q^2:
    - Q^p_w **is the *intercept*** (anchored by precise data near Q^2=0)
    - $B(Q^2,\theta)$ is the ***slope*** (determined from higher Q^2 PVES data)

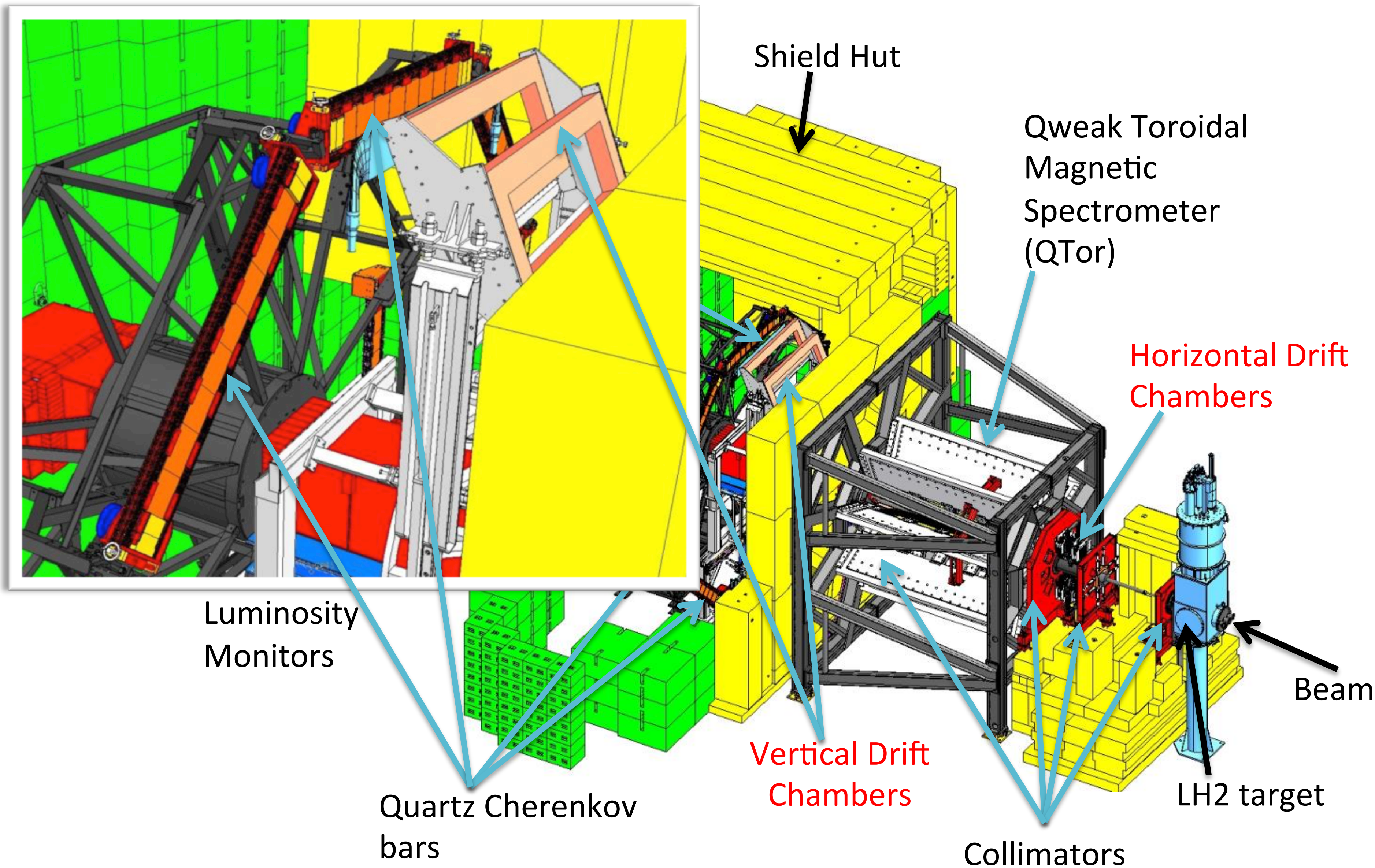
This Experiment

Experimental Apparatus



Used only during low current tracking mode operation

Experimental Apparatus



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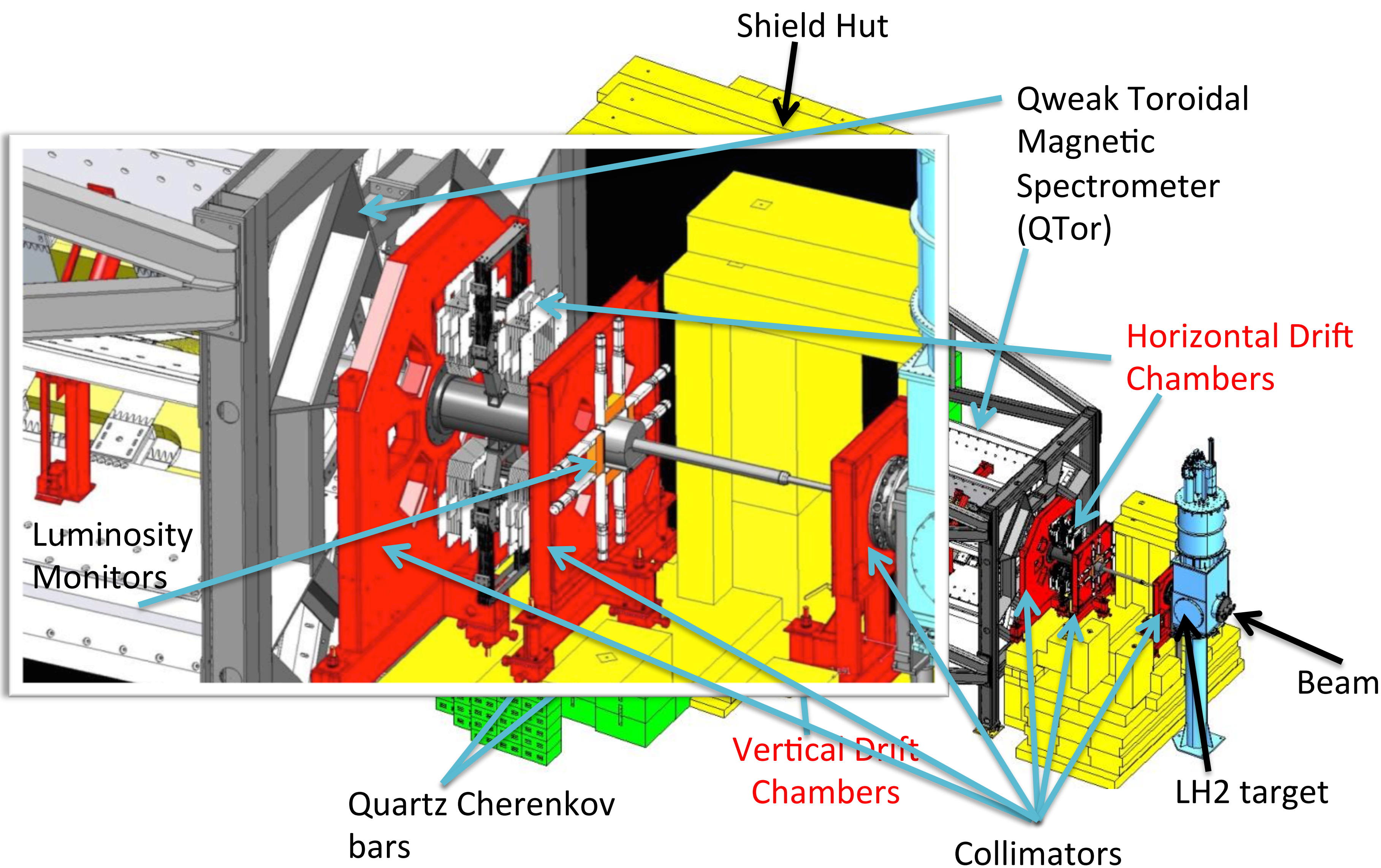

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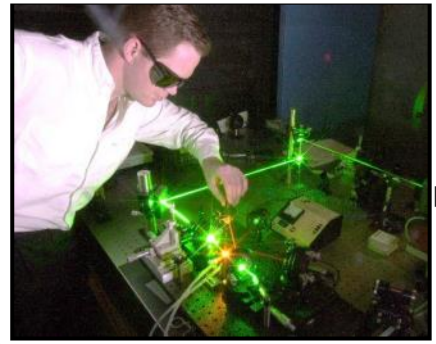
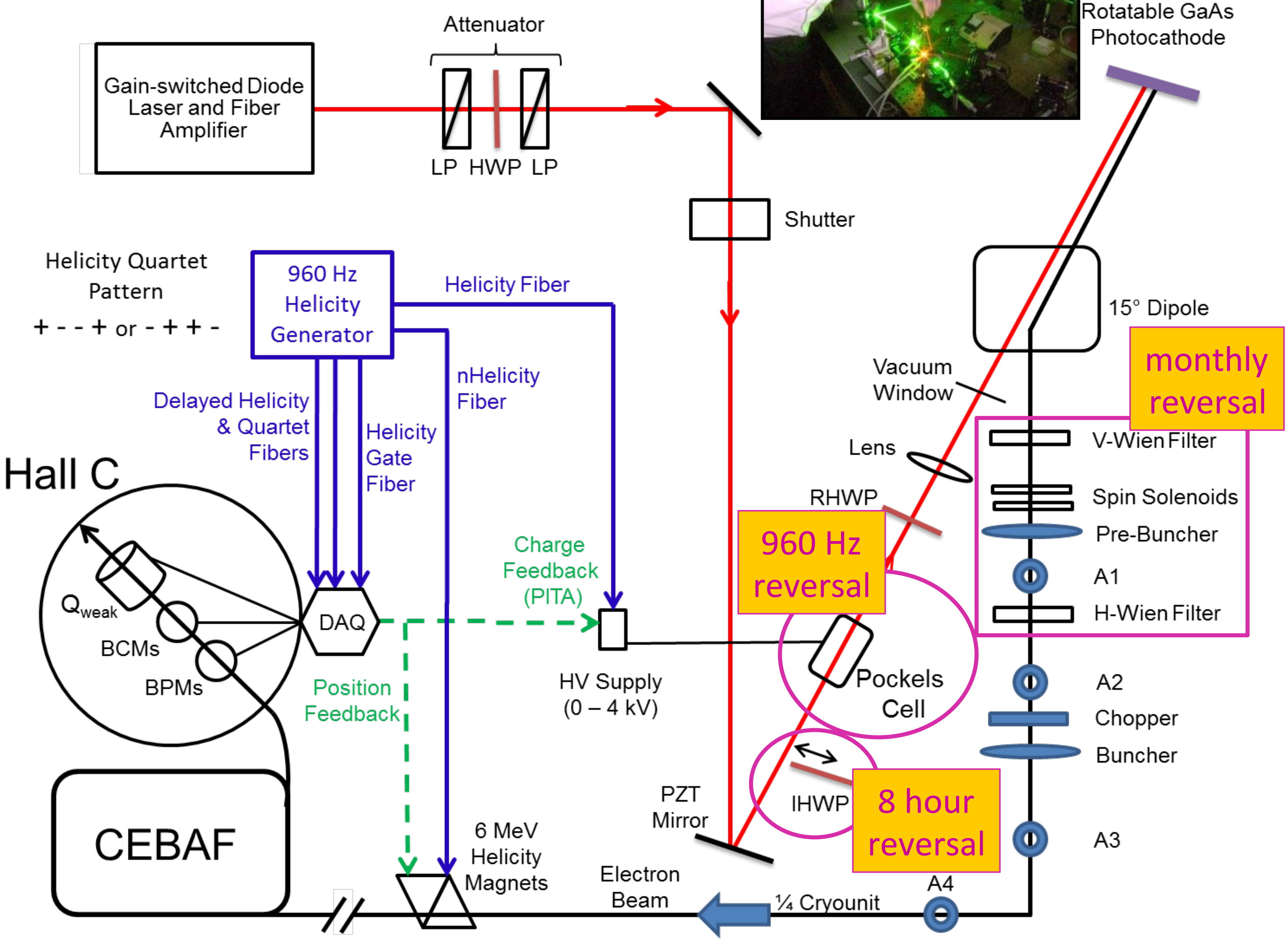
The Polarized Injector





Measurement Process

"Helicity windows" occur at 960 Hz

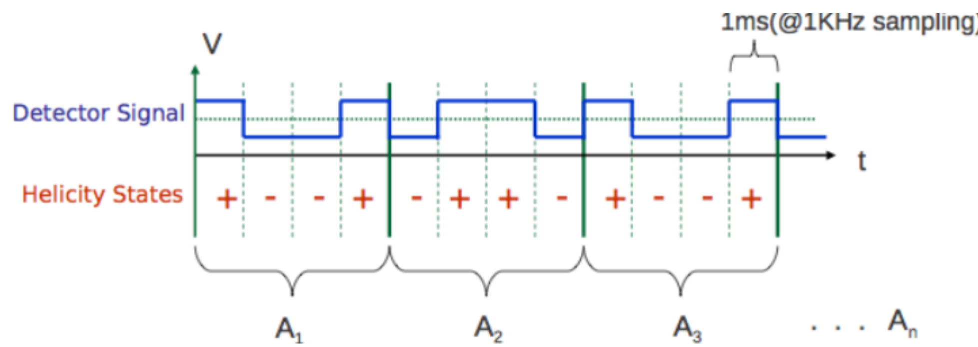
Groups of four windows have helicity pattern:

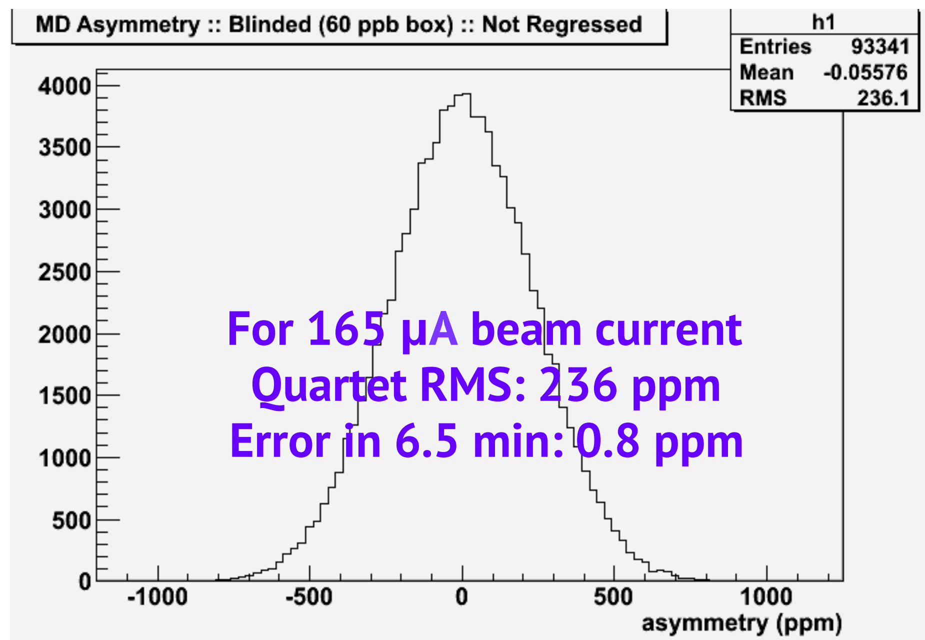
[+ - - +] or [- + + -]

chosen pseudo randomly

Helicity reporting is delayed to prevent real time electrical pickup.

- Detector and beam monitor signals are integrated over the window (gate).
- Asymmetries are constructed for each pattern.





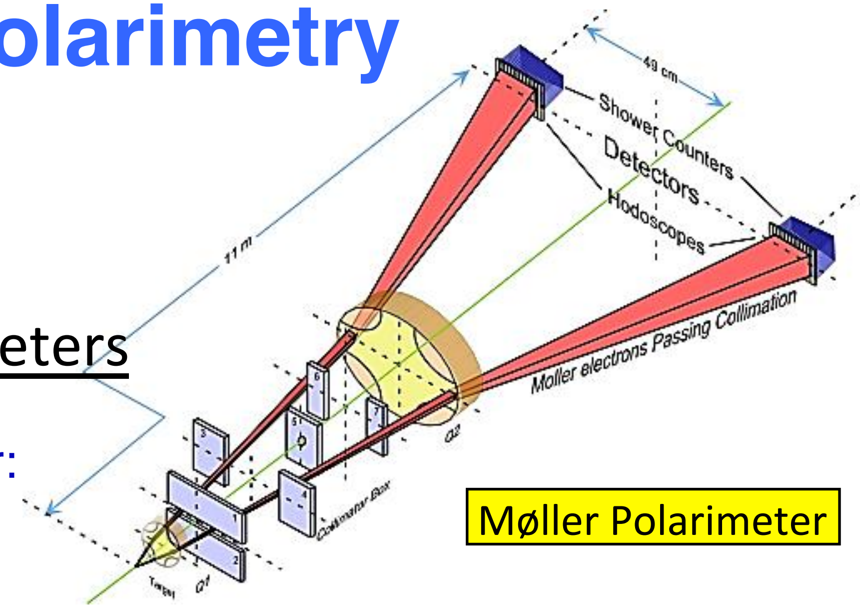
Precision Polarimetry

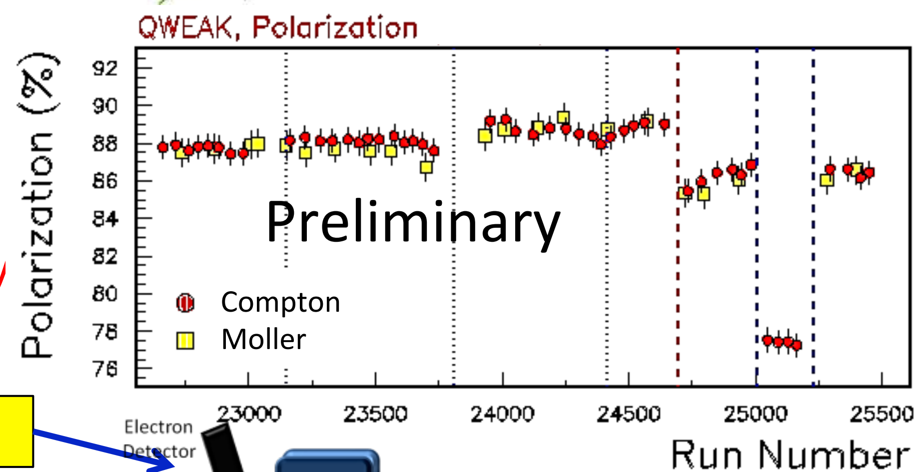
Qweak required ΔP/P ≤ 1%

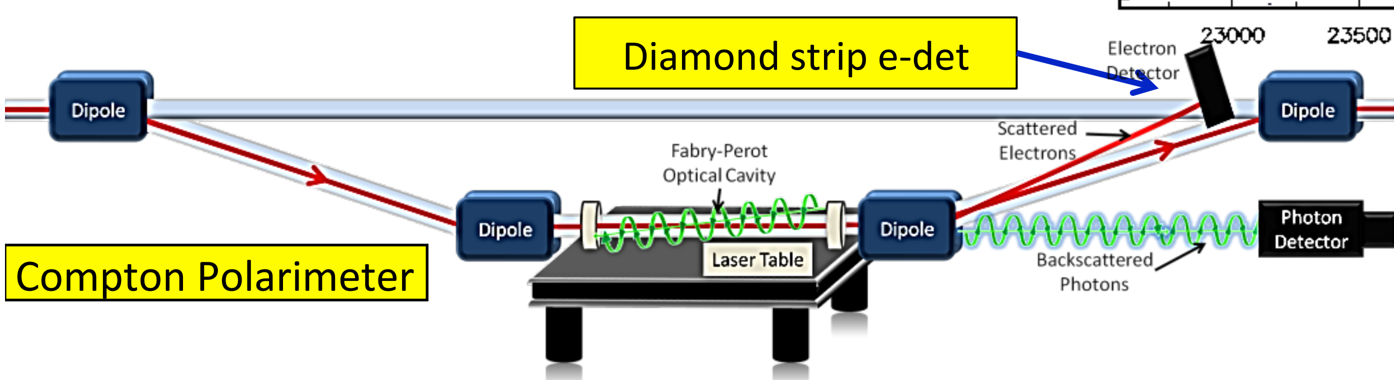
Achieved 0.61% !

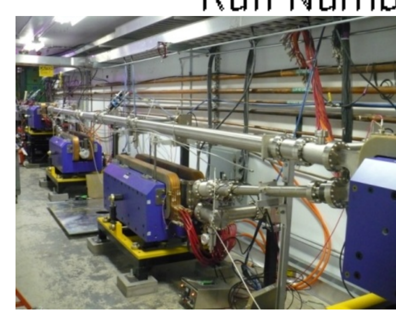
Strategy: use 2 independent polarimeters

- Use existing < 1% Hall C Møller polarimeter:
  - Low beam currents, invasive
  - Known analyzing power provided by polarized Fe foil in a 3.5 T field.
- Use new Compton polarimeter (1%/h)
  - High I_{beam}, non-invasive
  - Known analyzing power provided by circularly-polarized laser







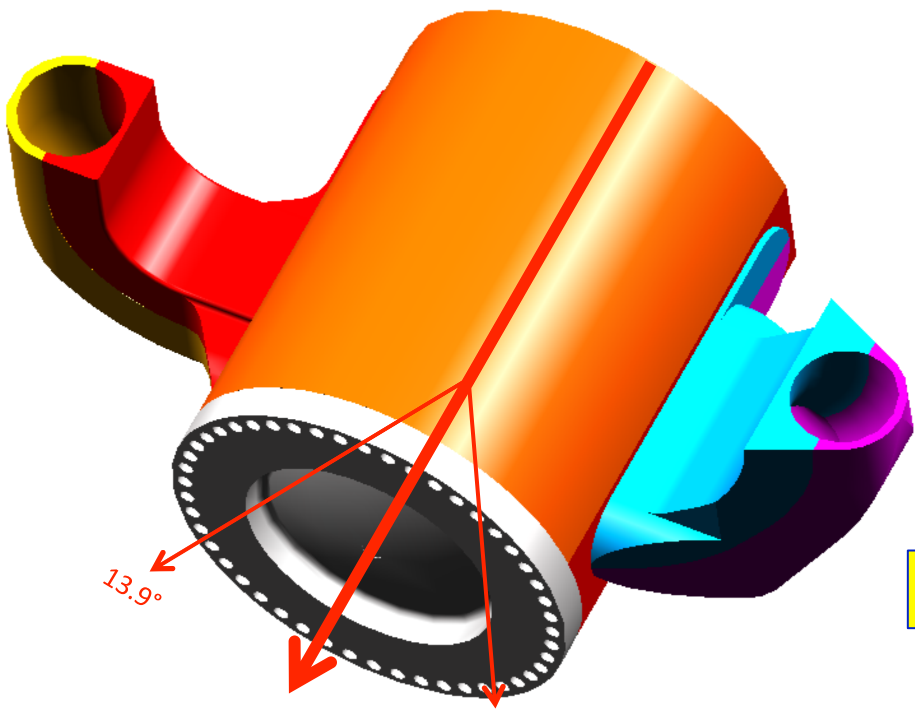


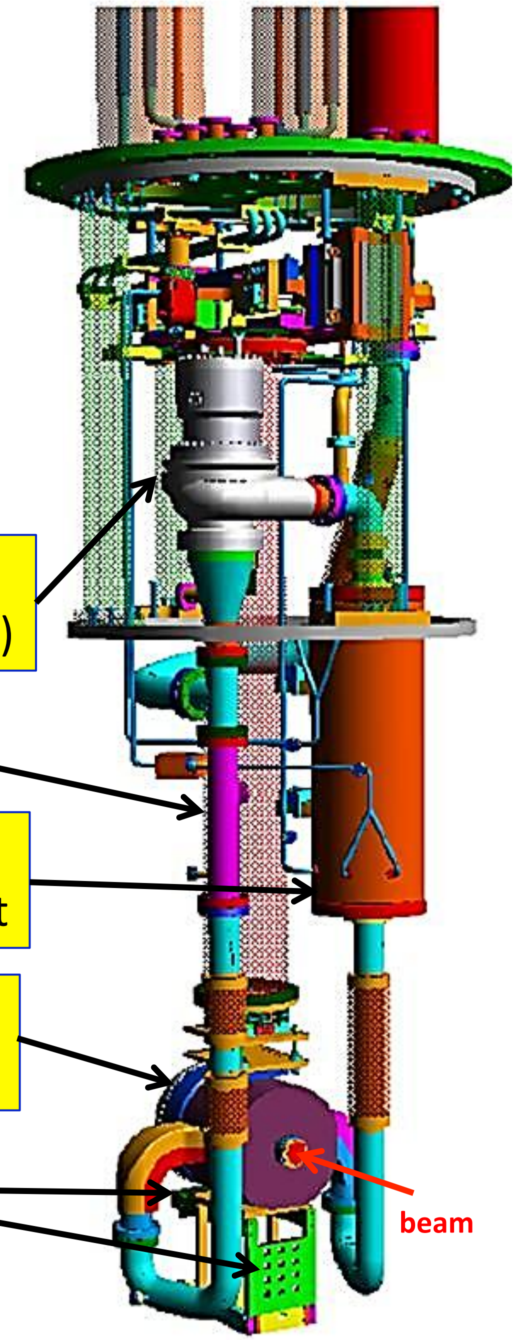
I_{Beam} = 180 uA
L = 35 cm (4% X_0)
P_{beam} = 2.2 kW
A_{spot} = 4x4 mm^2
V = 57 liters
T = 20.00 K
P ~ 220 kPa

Smith-Covrig Target

(designed using CFD)

World's highest power
<u>and lowest noise</u>
cryogenic target ~3 kW





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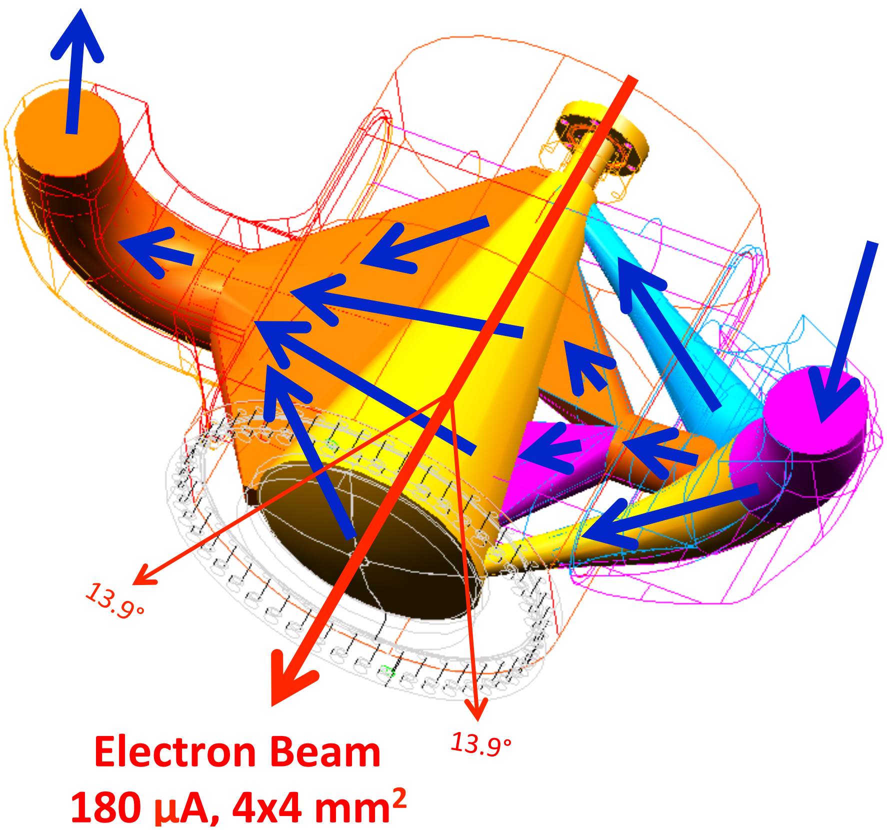
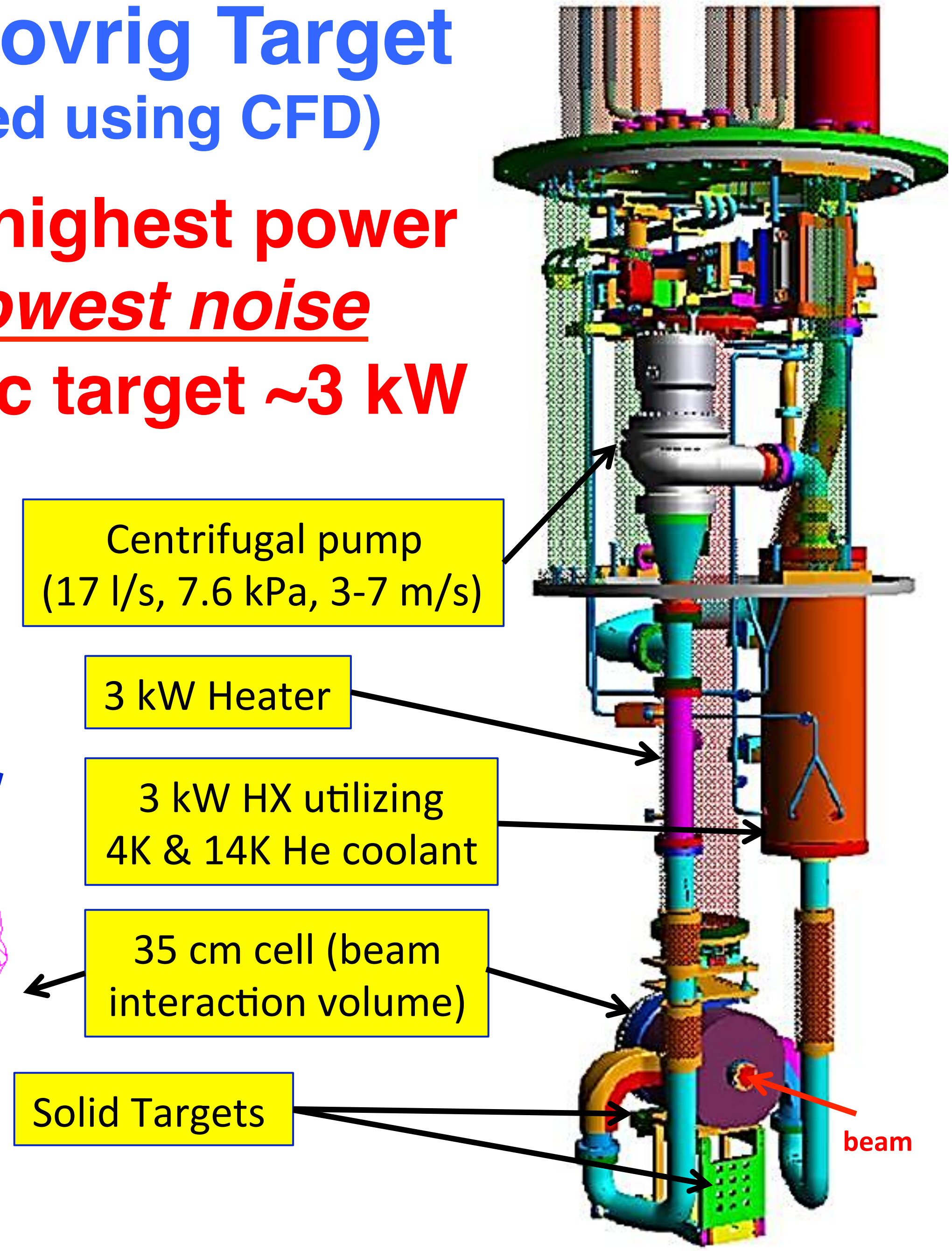
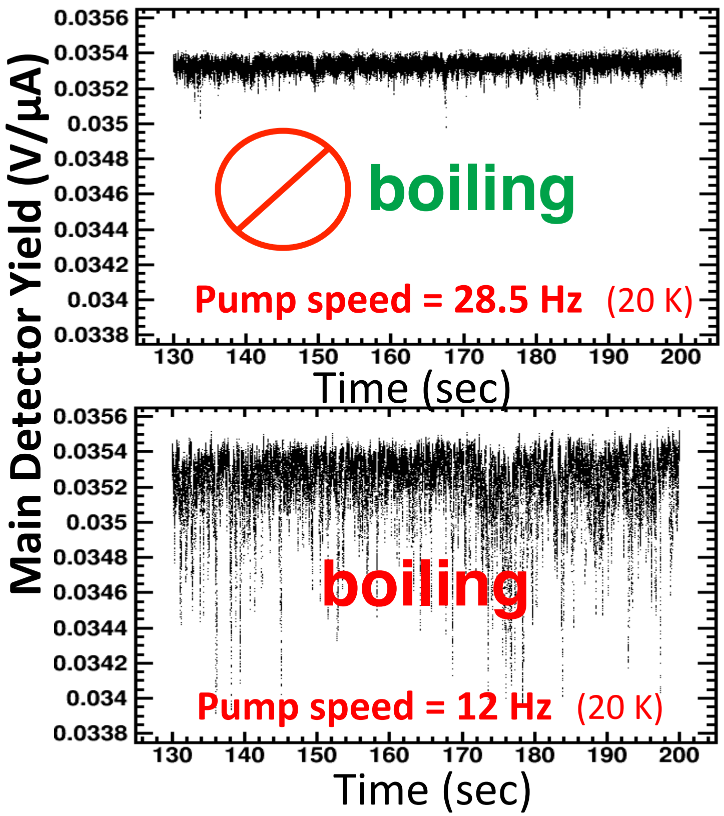




Target Performance

$$\Delta A_{qrt} = \sqrt{(\sigma_{fixed})^2 + (\sigma_{tgt})^2}$$

Where ΔA_{qrt} is measured main detector asymmetry width (over each helicity quartet)

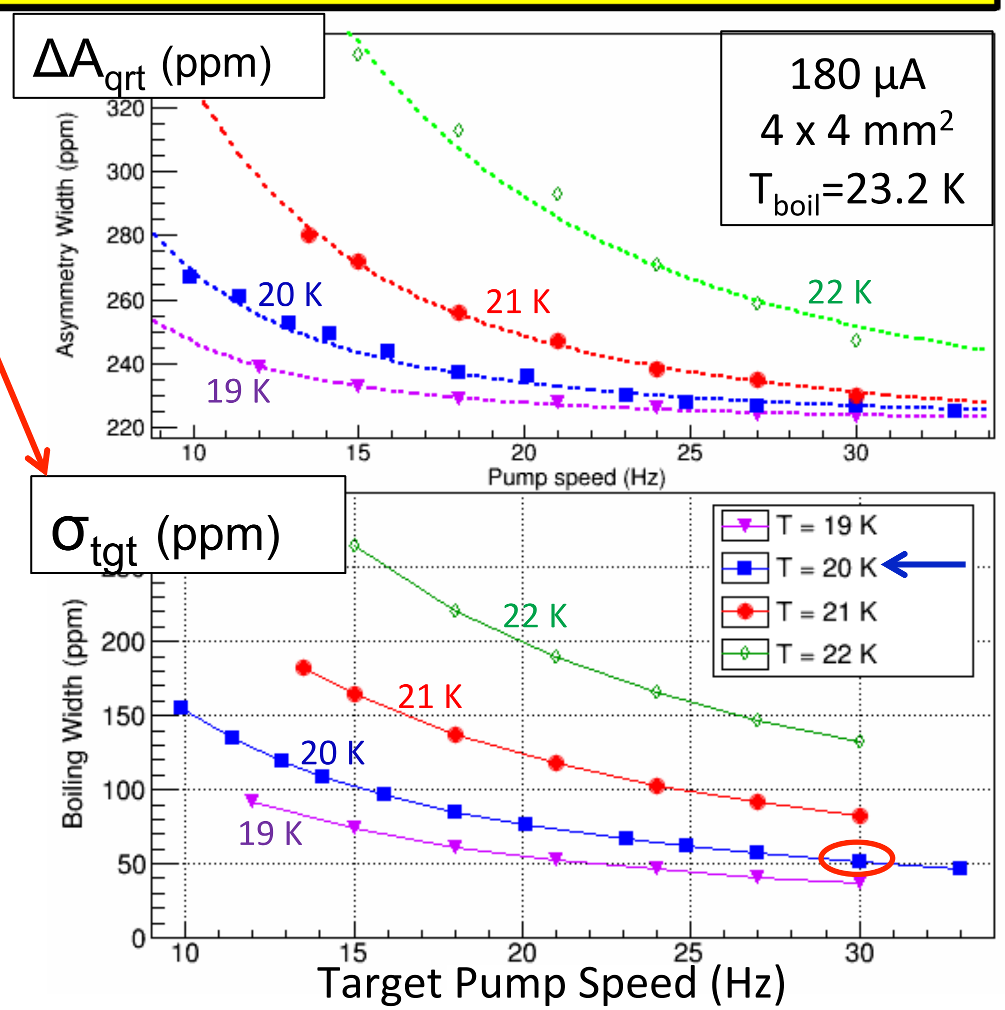


Measured helicity correlated target noise:

With 2.2 kW of beam heating!

At **960 Hz reversal rate**, the target noise (**~50 ppm**) is small compared to our measured helicity quartet (±∓∓±) asymmetry width ΔA_{qrt} (~230 ppm).

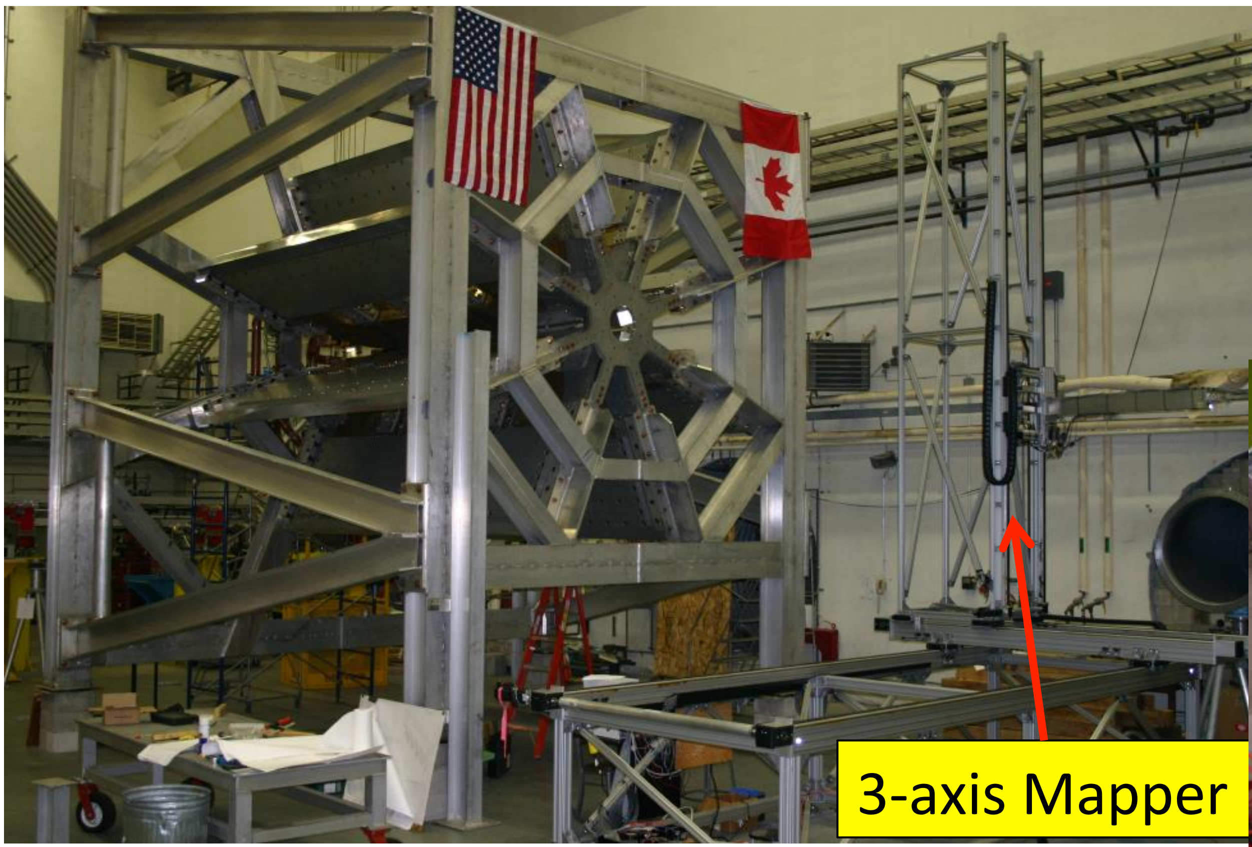
(statistical power ~ $\Delta A_{qrt}/\sqrt{N_{qrts}}$).



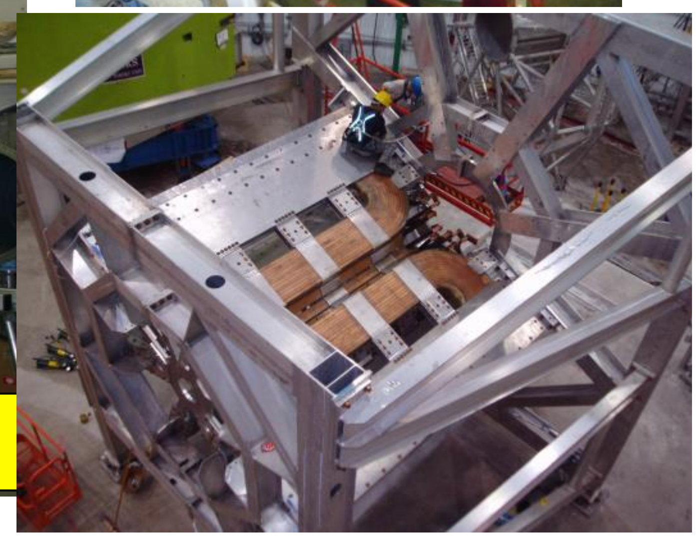
QTOR Magnet

- Manitoba / TRIUMF / MIT-Bates / JLab
- Open geometry resistive toroid, for maximum solid angle acceptance
- Eight water cooled, dble pancake coils
- Separates elastics from inelastics at focus

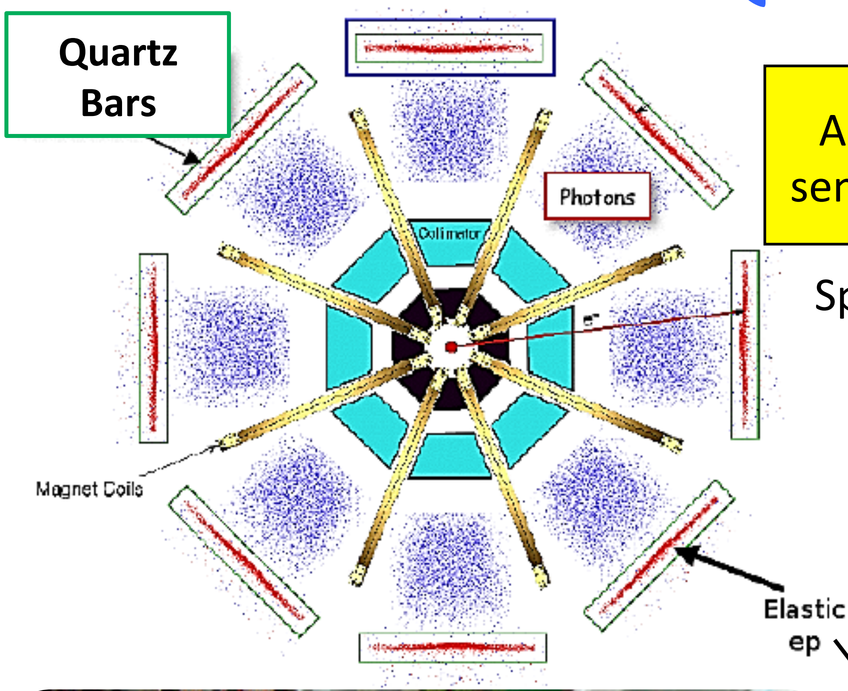
Power Supply:
150 V, 9100 A



3-axis Mapper



Quartz Cerenkov Detectors

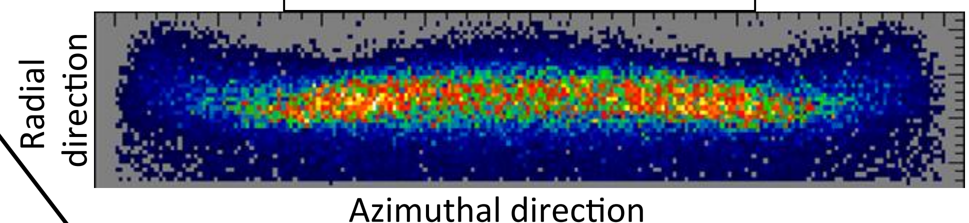


Azimuthal symmetry maximizes rate and decreases sensitivity to HC beam motion, transverse asymmetry.

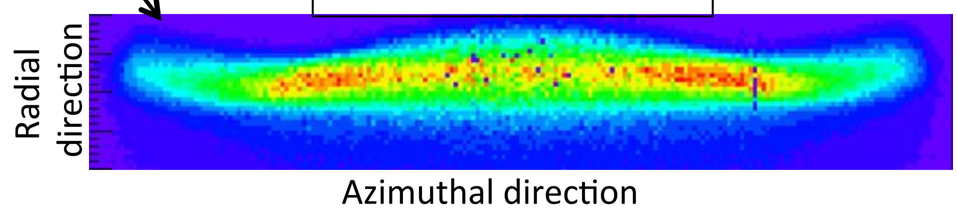
Spectrosil 2000 (fused silica) Cerenkov radiators:

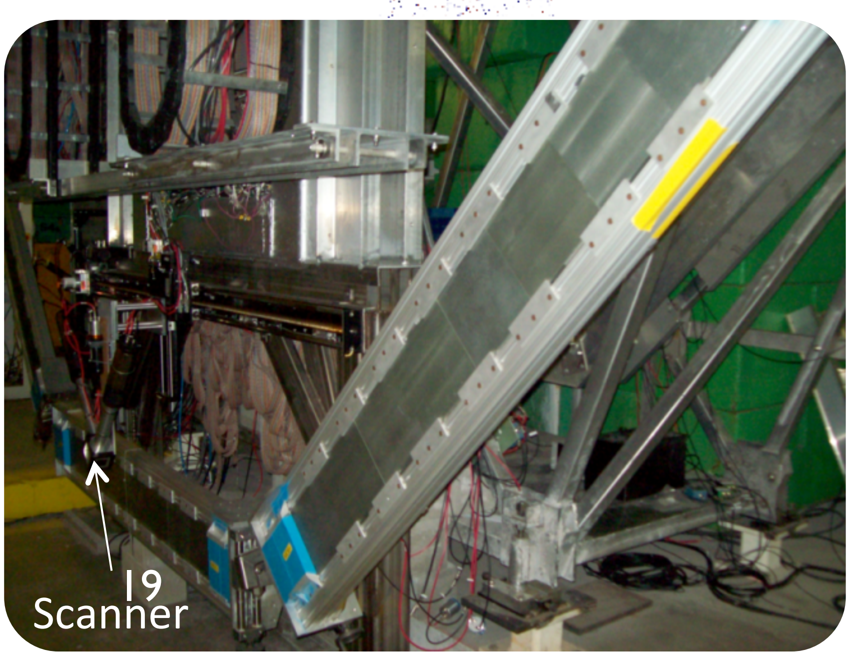
- Eight bars, each 2 m long, 18 cm hi, 1.25 cm thick
- Rad-hard. non-scintillating, low-luminescence

Simulation of MD face:



Measured



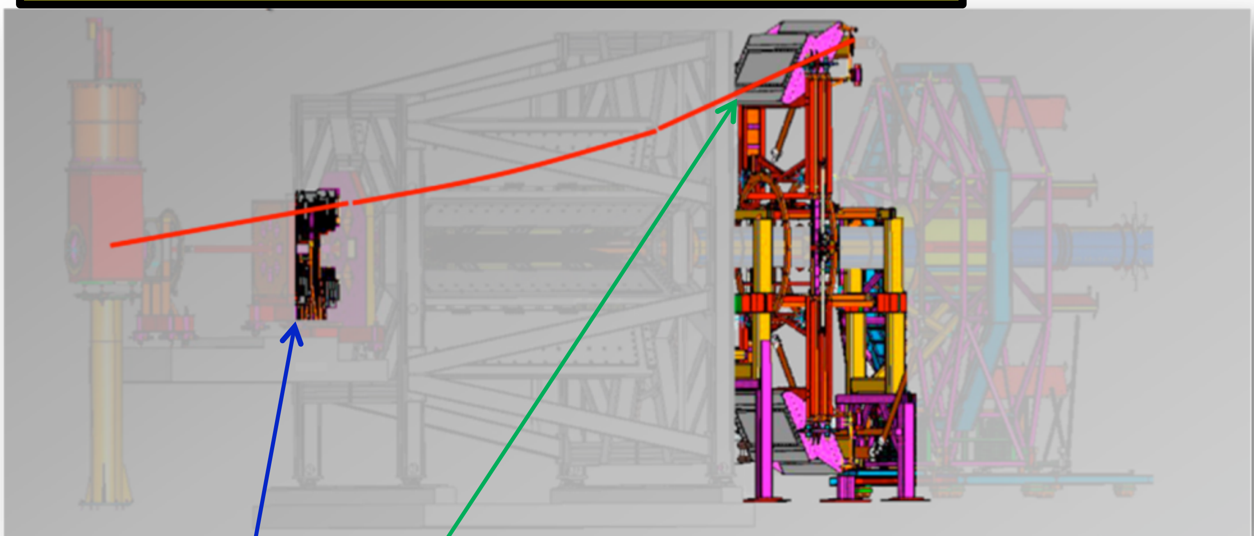


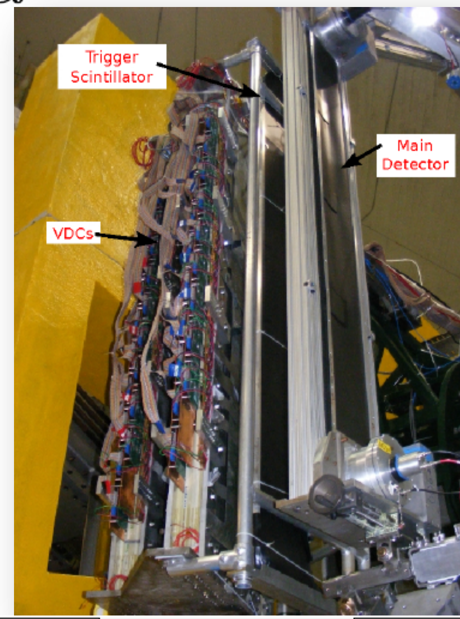
Yield 100 pe's/track with 2 cm Pb pre-radiators
Resolution (~10%) limited by shower fluctuations.

Determining the Kinematics

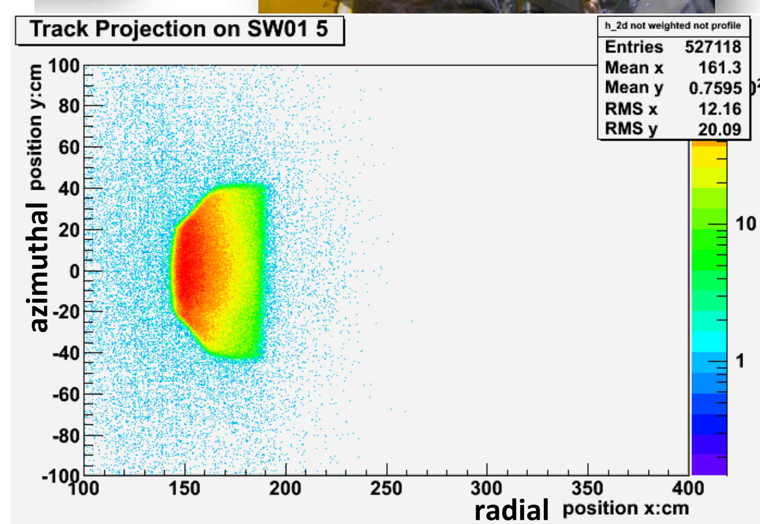
Required uncertainty on Q^2 is 0.5%
Combination of tracking and simulation

$$A_{PV} = -\frac{Q^2 G_F}{4\sqrt{2}\pi\alpha}\left[Q_W^p + F(\theta, Q^2)\right]$$





- HDCs before magnet to msr θ
  - $Q^2 = 2E^2(1-\cos\theta) / [1 + E/M(1-\cos\theta)]$
- VDCs & trigger scintillators after magnet to measure light weighted Q^2 across quartz bars



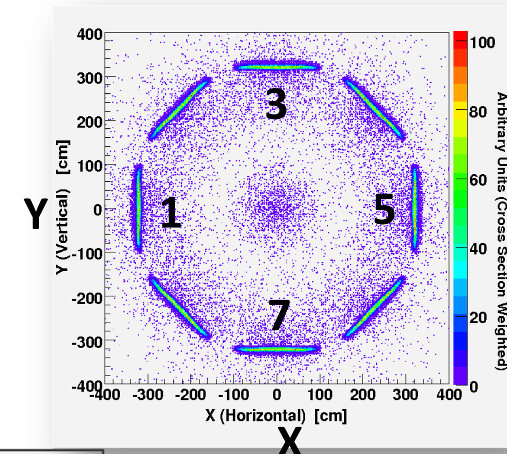
Beam Properties & Corrections

A_{reg} = -35 ± 11 ppb

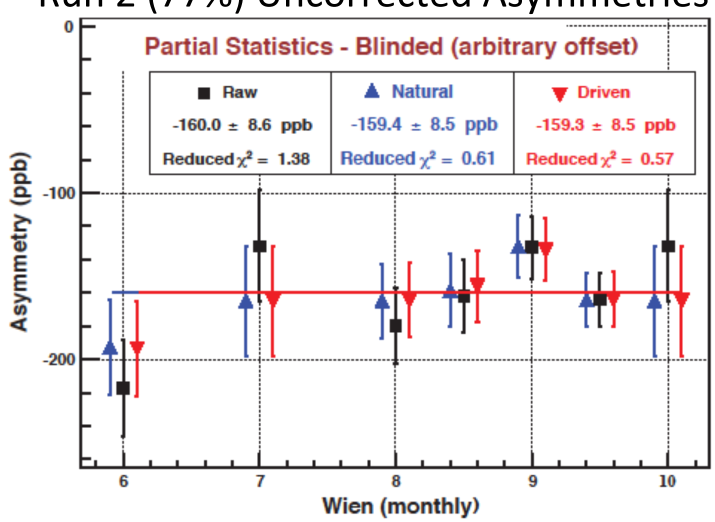
$$A_{reg} = -\sum_{i=1}^{5} \frac{\partial A}{\partial \chi_i} \Delta\chi_i$$

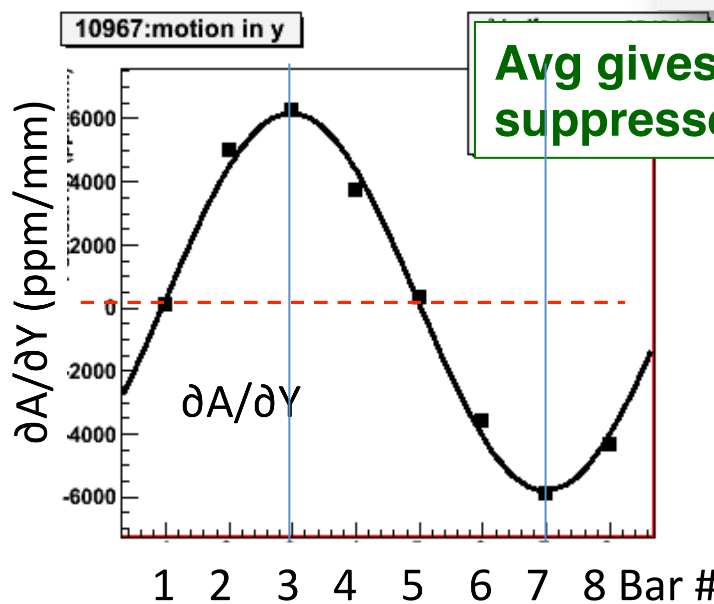
Beam Property	Modulation Amplitude	Msrd $\Delta\chi_i$ (monthly)	Msrd $\partial A/\partial\Delta\chi_i$ (monthly)
X	± 125 μm	-3.3 nm	-2.11 ppm/μm
Y	± 125 μm	2.5 nm	0.24 ppm/μm
X′	± 5 μrad	-0.7 nrad	100.2 ppm/μrad
Y′	± 5 μrad	0.02 nrad	0.0 ppm/μrad
E	± 61 ppm (70 keV)	0.1 nm	-1.56 ppm/μm

cancels (X, Y, X′)



Run 2 (77%) Uncorrected Asymmetries





Avg gives net correction, suppressed by symmetry

Both Driven and Natural beam motion used to determine detector sensitivities

Corrections and Uncertainties:
(for commissioning data result)

UNITS: parts per billion (ppb)

$$A_{msr} = A_{raw} + A_T + A_L - A_{reg}$$

$$A_{msr} = -204 \quad \pm 31\,(stat) \quad \pm 13\,(sys)$$

$$A_T = 0 \pm 4$$

$$A_L = 0 \pm 3$$

$$A_{reg} = -35 \pm 11$$

~ 1σ correction to A_{raw}

$$A_{ep} = \left(\frac{R_{tot}}{P\,(1 - f_{tot})} \right) \times \left(A_{msr} - P \sum_{i=1}^{4} f_i A_i \right)$$

f_i : fraction of light from background i

$f_{tot} = \Sigma f_i = 3.6\%$

R: product of factors ~ unity:
(Rad. corr, kinematics, detector response)

$$A_{ep} = -279 \quad \pm 35\,(stat) \quad \pm 31\,(sys)$$

← Published commissioning result
From 1/25th of total data collected

$$R_{TOT} / (P(1 - f_{tot})) = 1.139$$

$$P f_i A_i = -51 + 11 + 0 + 1 = -39$$

~ 1σ correction

(Al windows + beamline bgd. + soft neutrals + inelastic)

Global PVES Fit Details:

(for commissioning result)

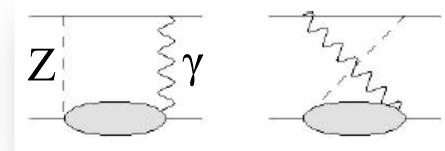
- **5 free parameters - Young, et al. PRL 99, 122003 (2007):**
  - C_{1u}, C_{1d}, ρ_s, μ_s, & isovector axial FF G_A^Z

    Note: $Q_W=-2(2C_{1u}+C_{1d})$
  - $G_E^S = \rho_s Q^2 G_D$, $G_M^S = \mu_s G_D$, & G_A^Z use G_D where
    - $G_D = (1 + Q^2/\lambda^2)^{-2}$ with λ = 1 GeV/c
- **Employs all PVES data up to Q^2=0.63 (GeV/c)^2**
  - **On p, d, & ^{4}He targets, forward and back-angle data**
    - **SAMPLE, HAPPEX, G0, PVA4 & this expt. (Qweak):**

Target	# pts
p	27
d	4
^{4}He	2
χ^2/ν	1.25

- **Uses constraints on isoscalar axial FF G^Z_A**
  - **Zhu, et al., PRD 62, 033008 (2000)**
- **All ep data corrected for E & Q^2 dependence of □$_{\gamma Z}$ RC**
  - **Hall et al., PRD88, 013011 (2013) & Gorchtein et al., PRC84, 015502 (2011)**
- **Effects of varying Q^2, θ, & λ studied, found to be small**

Electroweak Corrections

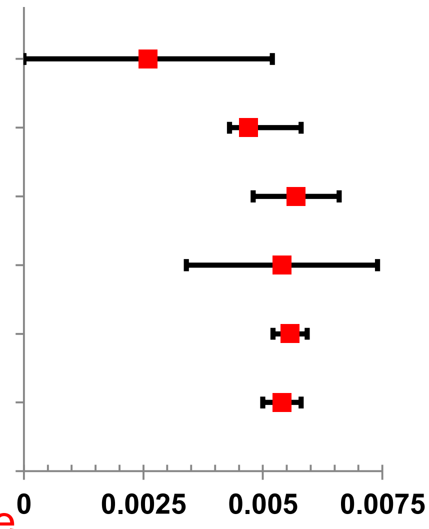


$$Q_W^p = [\rho_{NC} + \Delta_e][1 - 4\sin^2\hat{\theta}_W(0) + \Delta_e'] + \Box_{WW} + \Box_{ZZ} + \Box_{\gamma Z}$$

Table 1: $\Box_{\gamma Z}^V$ contribution to Q_W^p (Qweak kinetmatics)

Gorchtein & Horowitz Phys. Rev. Lett. **102**, 091806 (2009)	0.0026 ± 0.0026
Sibirtsev, Blunden, Melnitchouk, & Thomas Phys. Rev. D **82**, 013011 (2010)	$0.0047^{+0.0011}_{-0.0004}$
Rislow & Carlson Phys. Rev. D **83**, 113007 (2007)	0.0057 ± 0.0009
Gorchtein, Horowitz, & Ramsey-Musolf Phys. Rev. C **84**, 015502 (2011)	0.0054 ± 0.0020
Hall, Blunden, Melnitchouk, Thomas, & Young Phys. Rev. D **88**, 013011 (2013)	0.00557 ± 0.00036

Hall, Blunden, Melnitchouk, Thomas & Young 0.0054 ± 0.0004
arXiv:1504.03973 **(2015)**

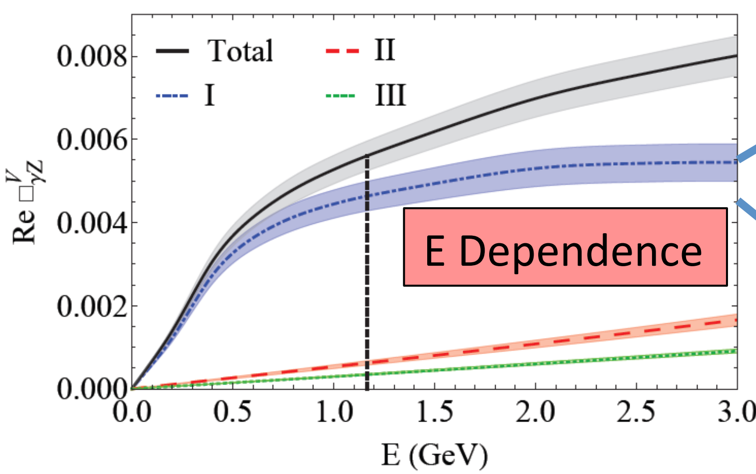


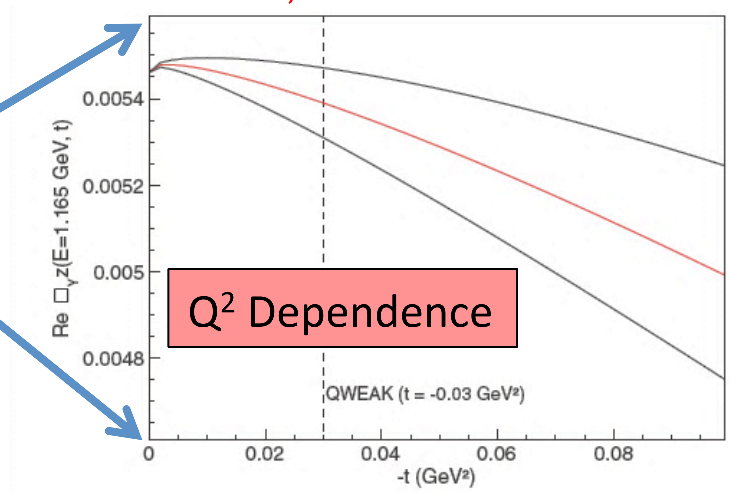
Re$\Box^V_{\gamma Z}$ corr. to $Q_W(p)$

~7% correction

The $\Box_{\gamma Z}$ is the only E & Q^2 dependent EW correction.
→ Correct the PVES data for this E & Q^2 dependence.

- Calculations are primarily dispersion theory type
  - error estimates can be firmed up with data!
- Qweak: inelastic asymmetry data taken at W ~ 2.3 GeV, Q^2 = 0.09 GeV^2



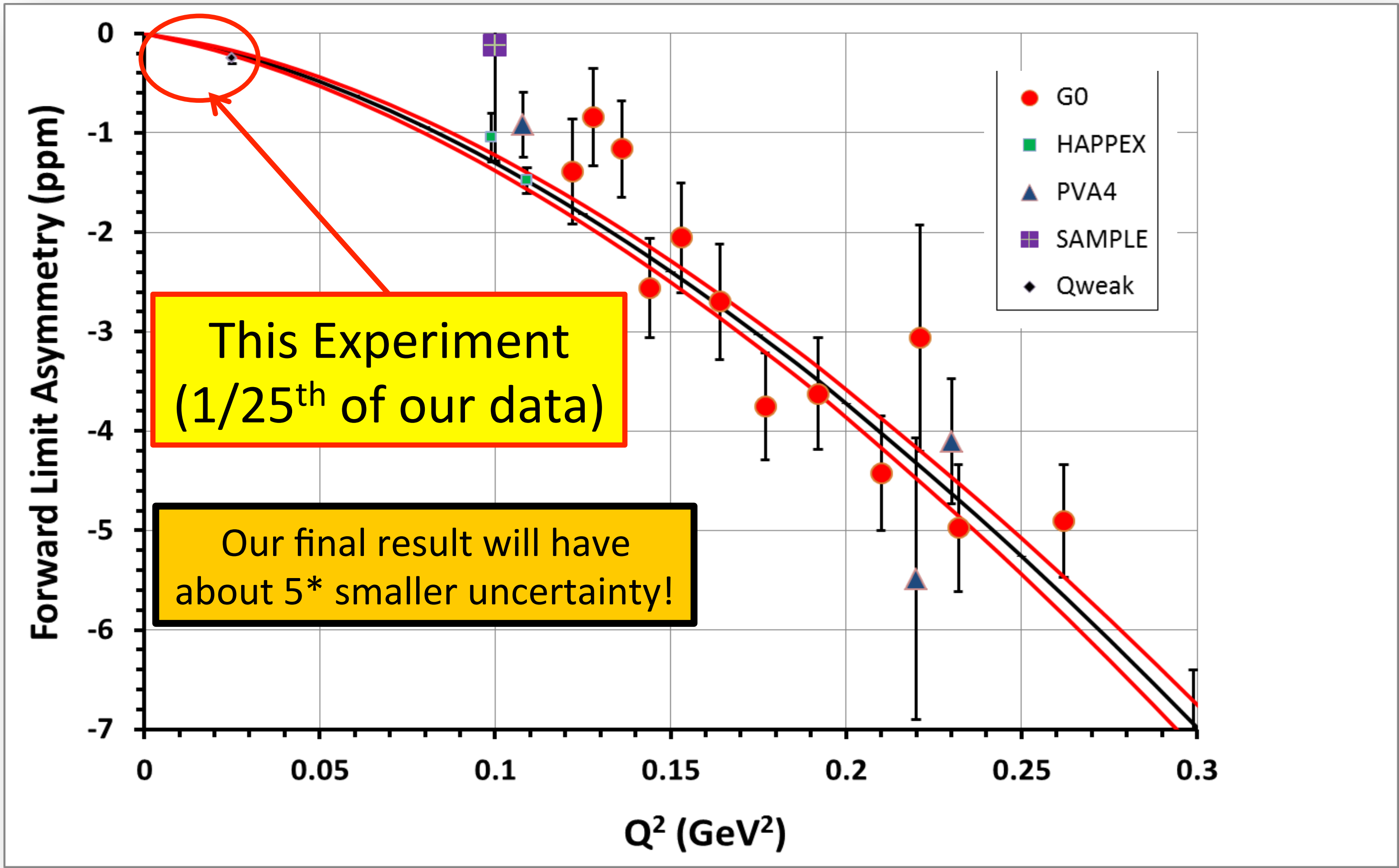


Measured Asymmetry (rotated to θ=0°)

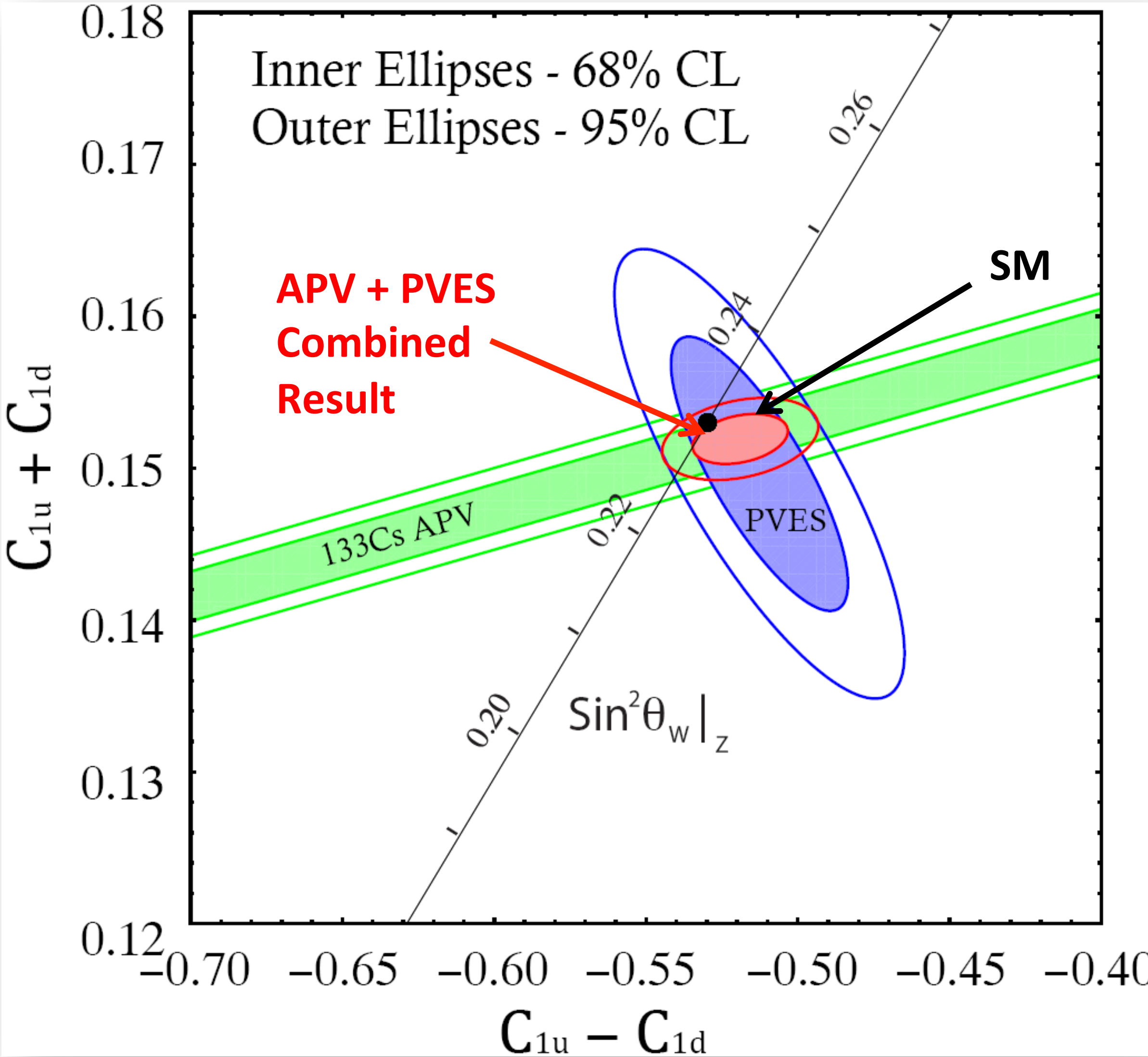
A_{PV} = -279 ± 35 (statistics) ± 31 (systematics) ppb

<Q^2> = 0.0250 ± 0.0006 $(GeV/c)^2$

<E> = 1.155 ± 0.003 GeV



Qweak Commissioning Run - PRL 111,141803 (2013)



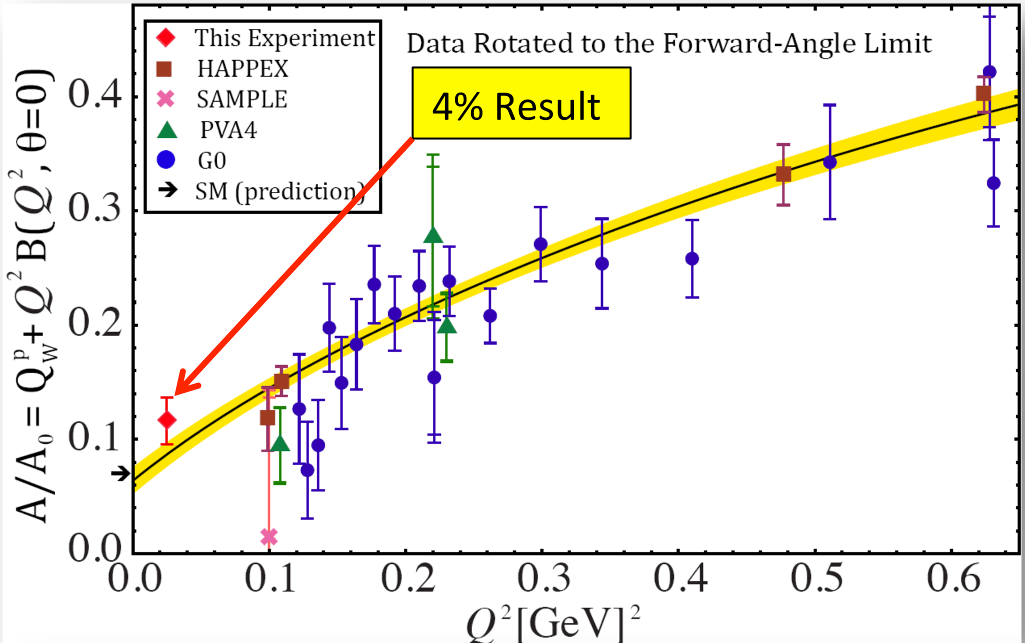
C_{1u} = -0.184 ± 0.005
C_{1d} = 0.336 ± 0.005
Correlation. coef. -0.98
(only 1/25th of data)

$Q_W(p) = -2(2C_{1u} + C_{1d})$
= 0.063 ± 0.012
(only 1/25th of data)
SM value = 0.0710(7)

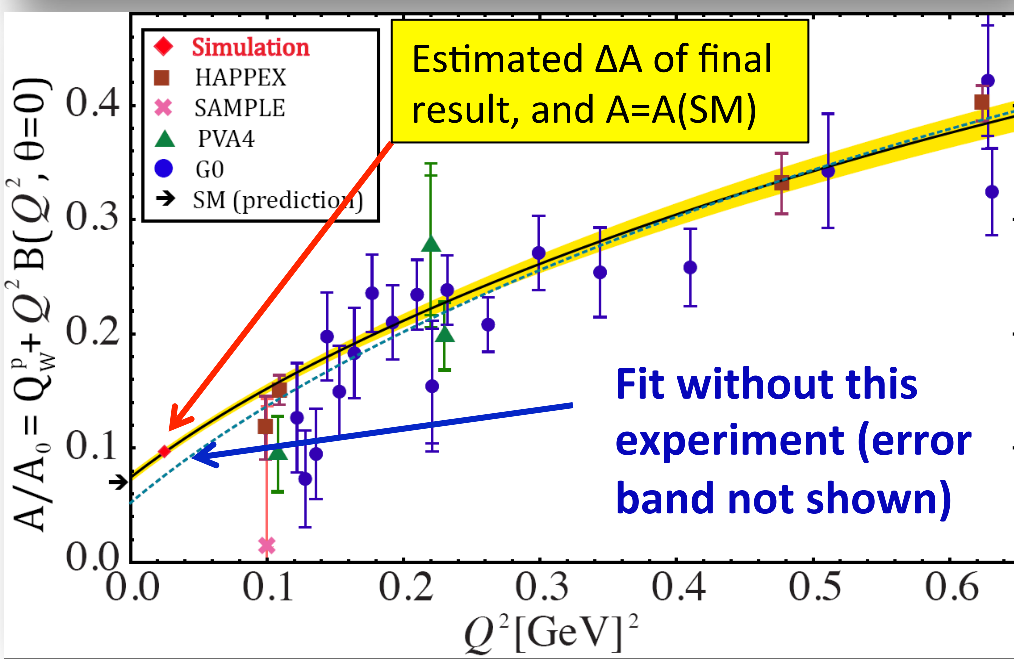
$Q_W(n) = -2(C_{1u} + 2C_{1d})$
= -0.975 ± 0.010
(only 1/25th of data)
SM value = -0.9890(7)

25x more production data still being analyzed, final result 2015

Global fit of $Q^2 < 0.63\ (GeV/c)^2$ PVES Data



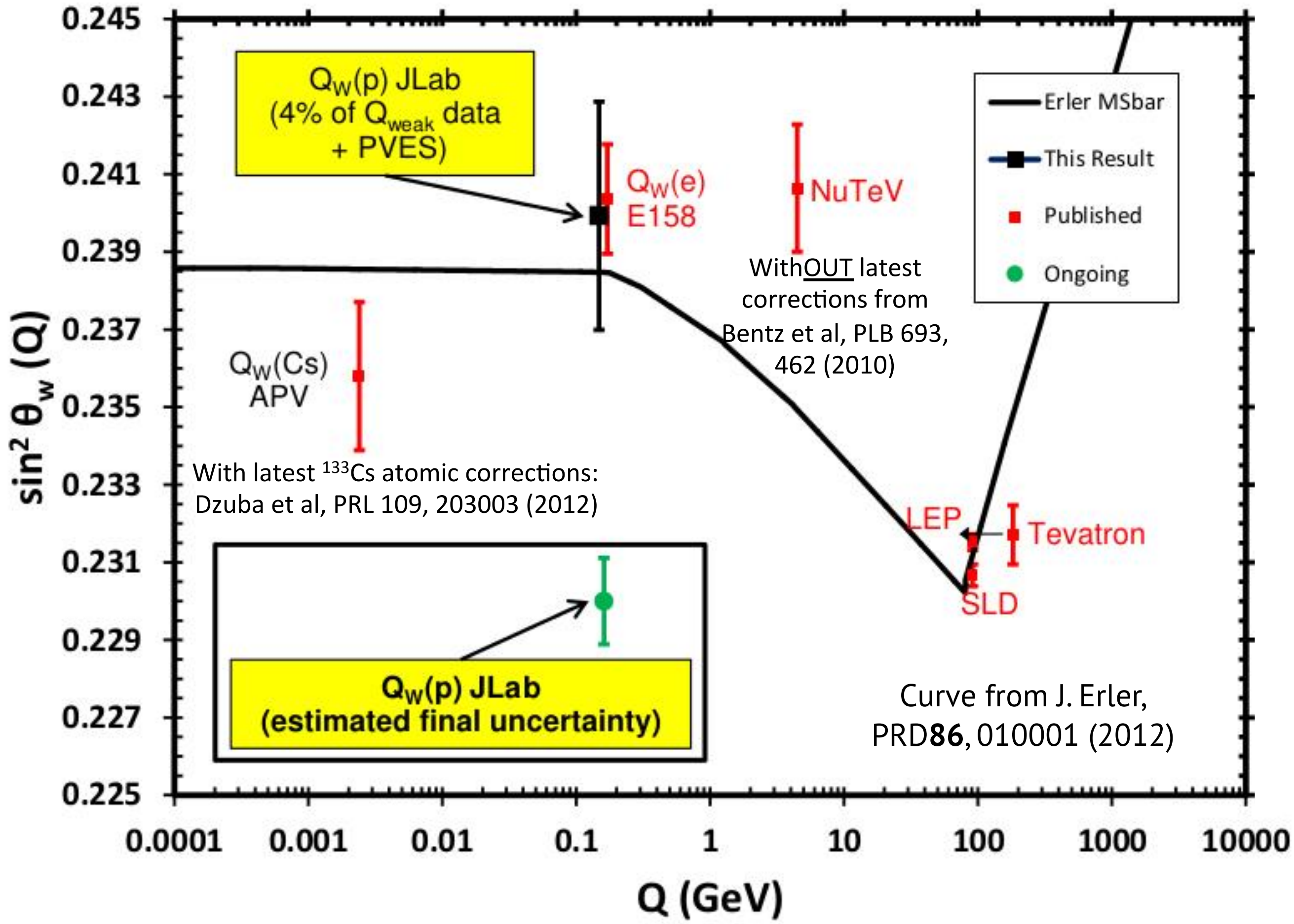
A = -279 ± 35 ± 31 ppb
$Q_W(p)$ = 0.064 ± 0.012
(only 1/25th of all data collected)
SM value = 0.0710(7)



Estimated Fit Uncertainties with Final Result (Assuming SM Value)

First Results: Weak Mixing Angle

$$\sin^2\theta_W = \frac{1}{4}\left\{1 + \Delta'_e - \frac{Q_W(p) - \Box_{WW} - \Box_{ZZ} - \Box_{\gamma Z}}{\rho_{NC} + \Delta_e}\right\}$$



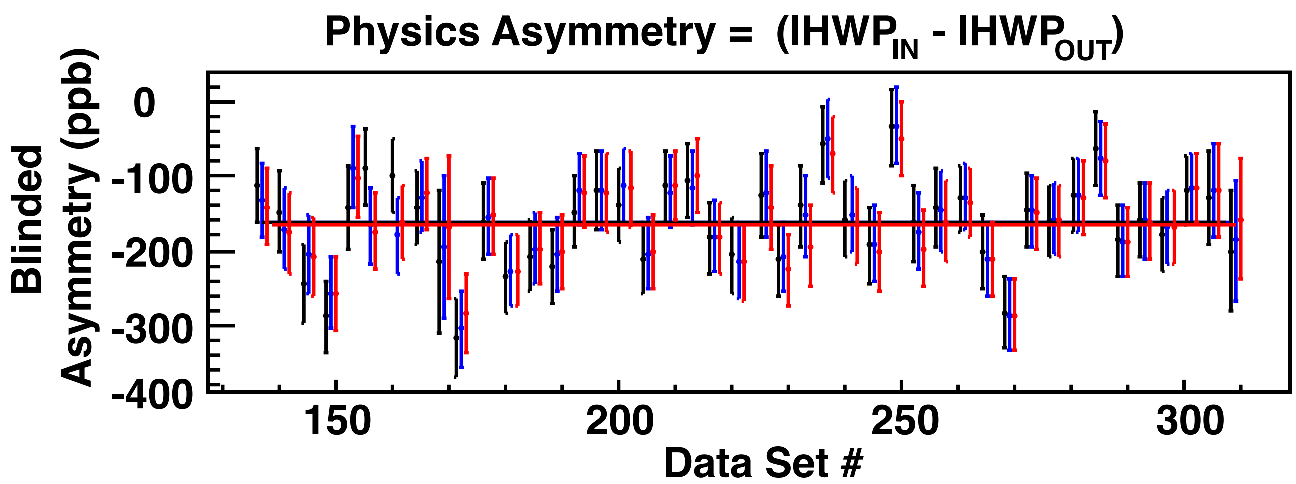
Piece	Value
ρ_{NC}	1.00833
Δ_e	-0.00116
Δ'_e	-0.00142
$\hat{\alpha}$	1/127.944
$\hat{s}^2$	0.23116
$\Box_{WW}$	0.01832
$\Box_{ZZ}$	0.00193
$\Box_{\gamma Z}$	0.00440

Values derived from PDG PRD86, 010001 (2012) and Erler, Kurylov & Ramsey-Musolf, PRD68, 016006 (2003)

Qweak - 25x More Data in Runs 1 & 2 to Un-blind!

Qweak Run 2 - Blinded Asymmetries

(statistics only - not corrected for beam polarization, Al target windows, ΔQ^2, etc.)



Raw = -161.8 ± 7.6

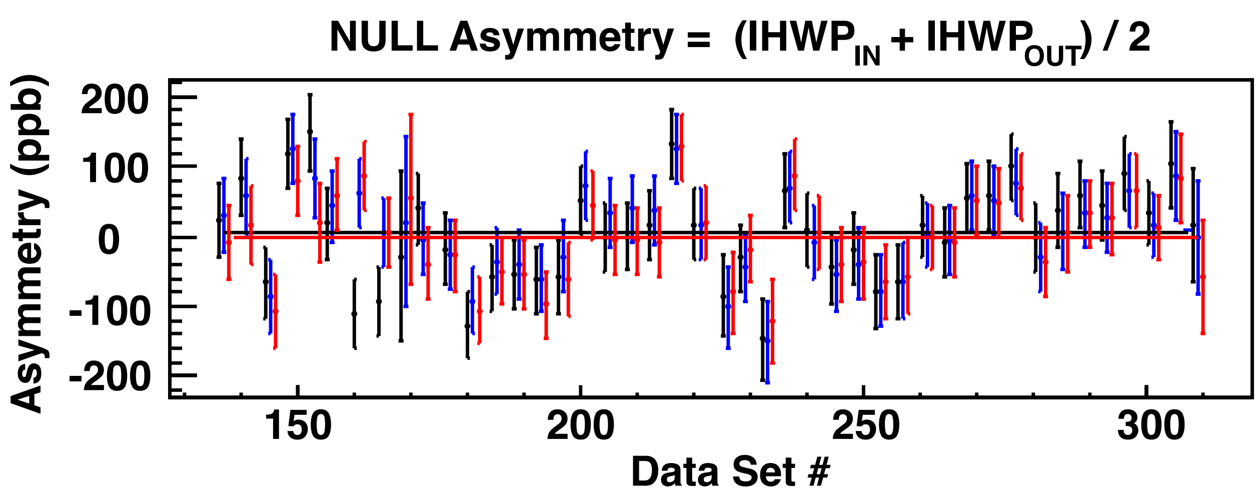
(χ^2/ NDF = 1.40, Prob = 0.043)

Regressed = -160.9 ± 7.6

(χ^2/ NDF = 1.19, Prob = 0.18)

Beamline Bkgd Corrected = -164.5 ± 7.6

(χ^2/ NDF = 1.08, Prob = 0.33)



Raw = 4.7 ± 7.7

(χ^2/ NDF = 1.84, Prob = 0.001)

Regressed = 7.9 ± 7.7

(χ^2/ NDF = 1.38, Prob = 0.048)

Beamline Bkgd Corrected = -1.4 ± 7.7

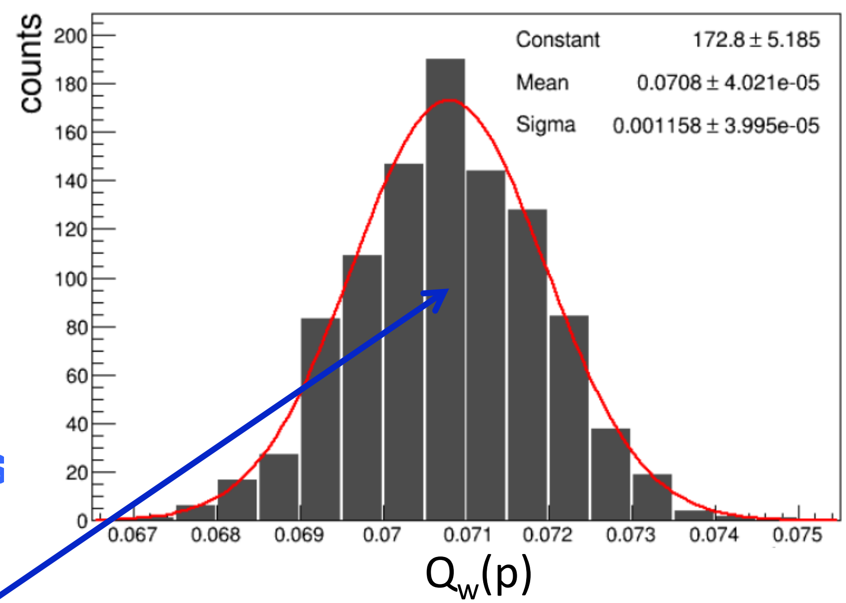
(χ^2/ NDF = 1.29, Prob = 0.097)

Sensitivity to EM FFs

- **Use "theory point" A = –213.9 ± 4.1 ppb at our kinematics**
  - **Perform $Q_w(p)$ PVES fits for each of 4 EMFF fits:**
  - **No difference**

EMFF Fit	Q^p_w	dQ^p_w
Arrington & Sick	0.0705	0.0023
Kelly	0.0702	0.0023
Simple Dipole	0.0702	0.0022
Friedrich & Walcher	0.0683	0.0022

- **Studied impact of "worst case uncertainty" estimate of EMFF's**
  - **Use Arrington & Sick EMFF fit**
    - **Low Q^2, 2γ, careful treatment of correlations, more recent…**
  - **Do $Q_w(p)$ PVES fit 1000 times, varying EMFF's within their errors using the "theory point"**
  - **Width of distribution only 1.6%**



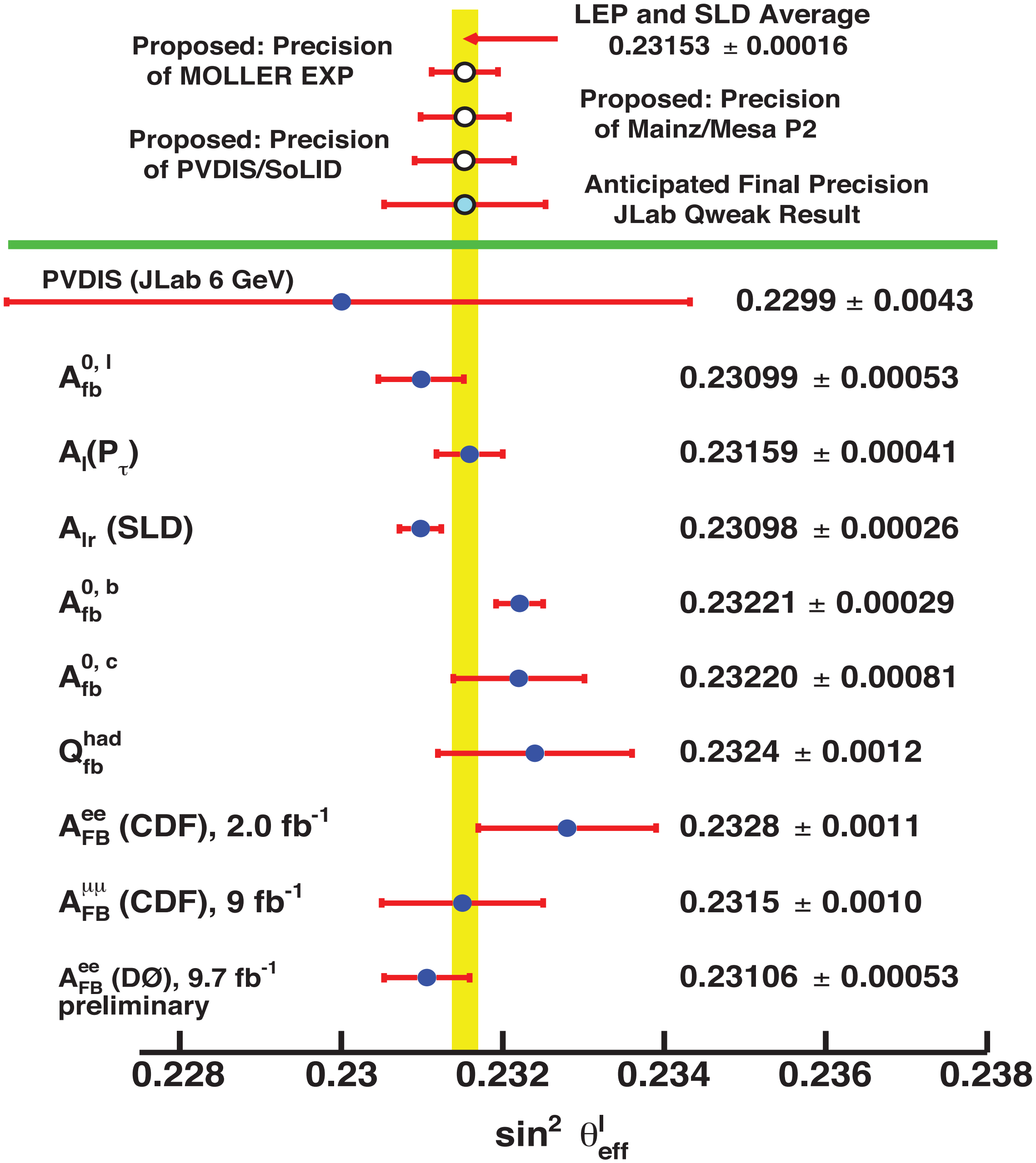
J. Friedrich and Th. Walcher. EPJ A 17(4):607–623, 2003.
J. Kelly. Phys. Rev. C, 70:068202, 2004
John Arrington and Ingo Sick. Phys. Rev. C, 76:035201, 2007.

SM Tests: Past & Future Precision Low Energy Parity Violation Measurements

$\Lambda / g_{new\ physics}$ for 95% CL using formalism of Erler, et.al.- arXiv:1401.6199v1 [hep-ph] 23 Jan 2014

Experiment	% Precision	$\Delta \sin^2 \theta_W$	Λ / g [TeV]	θ	Status
SLAC-E122	8.3	0.011	1.5	9.4°	published
SLAC-E122	110	0.44	0.25	99.4°	published
APV (^{205}Tl)	3.2	0.011	3.8	75.6°	published
APV (^{133}Cs)	0.58	0.0019	9.1	74.9°	published
SLAC-E158	14	0.0013	4.8	-	published
Jlab-Hall A	4.1	0.0051	2.2	26.2°	published
Jlab-Hall A	61	0.051	0.82	116.2°	published
JLab-Qweak (~3 days)	19	0.0030	4.8	53.1°	published
JLab-Qweak (full)	4.5	0.0008	9.3	53.1°	2015
JLab-SoLID	0.6	0.00057	6.2	53.1°	seeking funded
JLab-MOLLER	2.3	0.00026	11.0	-	seeking funded
Mainz-P2	2.0	0.00036	13.8	53.1°	funded (>2020)
APV (^{225}Ra$^+$)	0.5	0.0018	9.6	75.7°	
APV (^{213}Ra$^+$ / ^{225}Ra$^+$)	0.1	0.0037	4.5	55.5°	
PVES (^{12}C)	0.3	0.0007	14	71.6°	

Summary: Measurements of $\sin^2\theta_{W(effective)}$



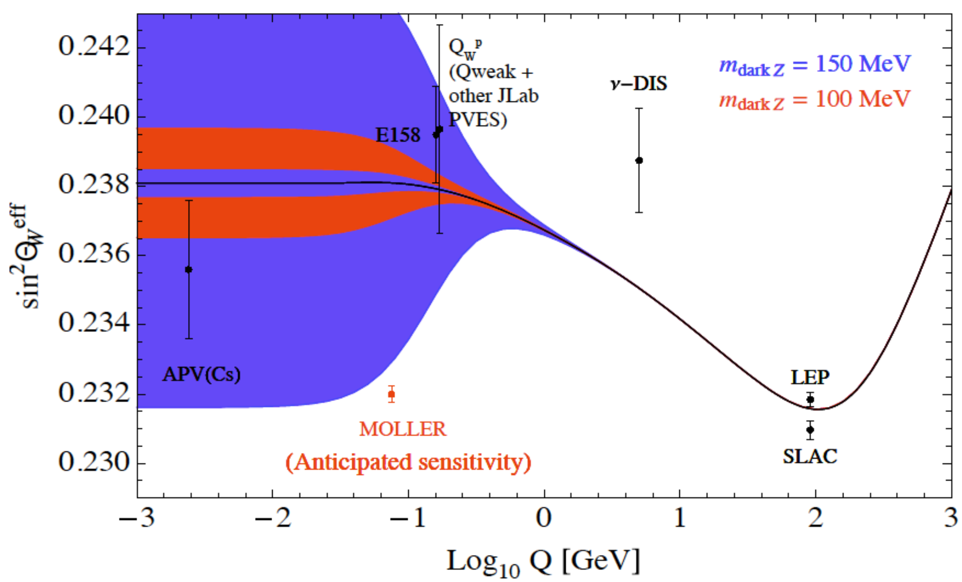
New Physics Scenarios – A Recent Example

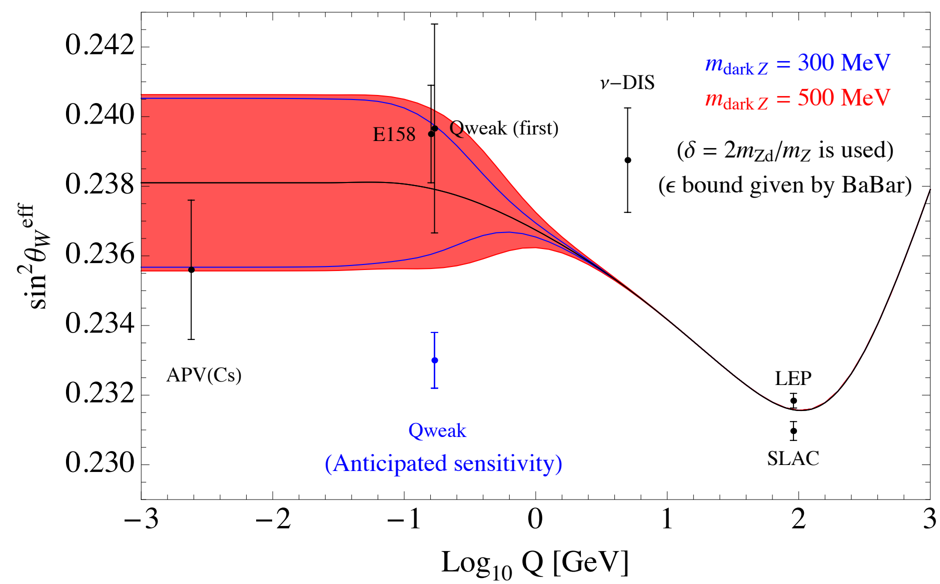
"Dark photon" – possible portal for new force to communicate with SM

- **Astrophysical motivation: observed excess in positron data.**
- **Could explain muon g-2 anomaly?**

"Dark parity violation" (Davoudiasl, Lee, Marciano, arXiv 1402.3620)

- **Introduces a new source of low energy parity violation through mass mixing between *Z* and Z_d with observable consequences.**
- **Complementary to direct searches for heavy dark photons.**





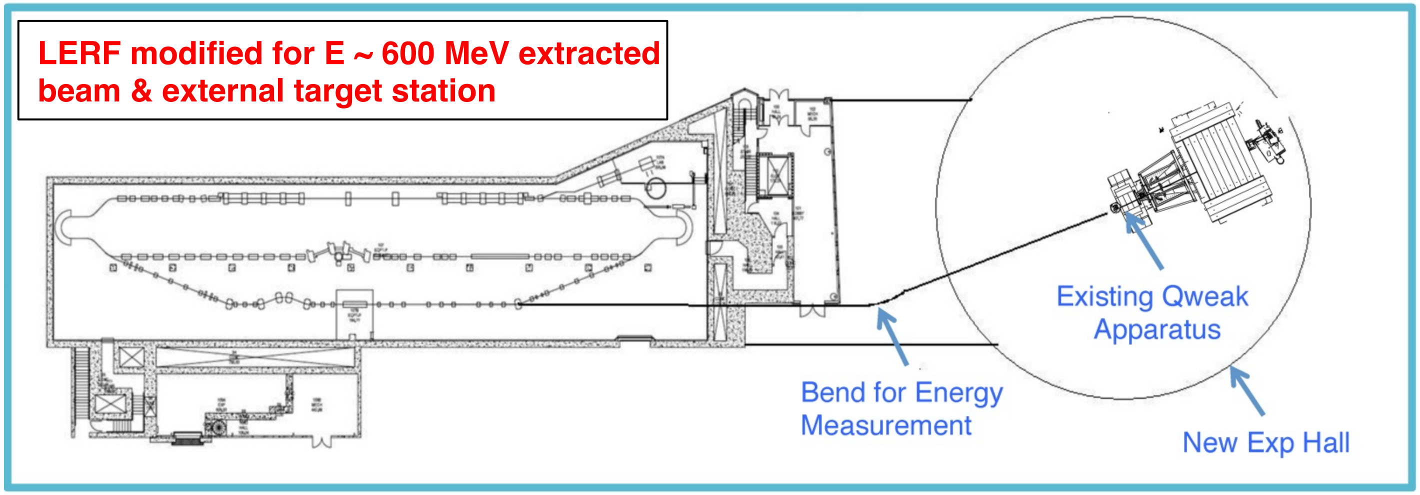
Qweak Apparatus Reused at Lower Energy

What might be achievable by re-using the Qweak apparatus at lower beam energy for a much lower Q^2 measurement of the proton's weak charge?

How Qweak Exp might look at an upgraded LERF

OR

other equivalent facility



Monte Carlo studies by Juliette Mammei and Kurtis Bartlett (using Qweak apparatus with same relative target/collimators/spectrometer postions, etc.) indicates there is a focus at lower energies (200 MeV to 600 MeV).

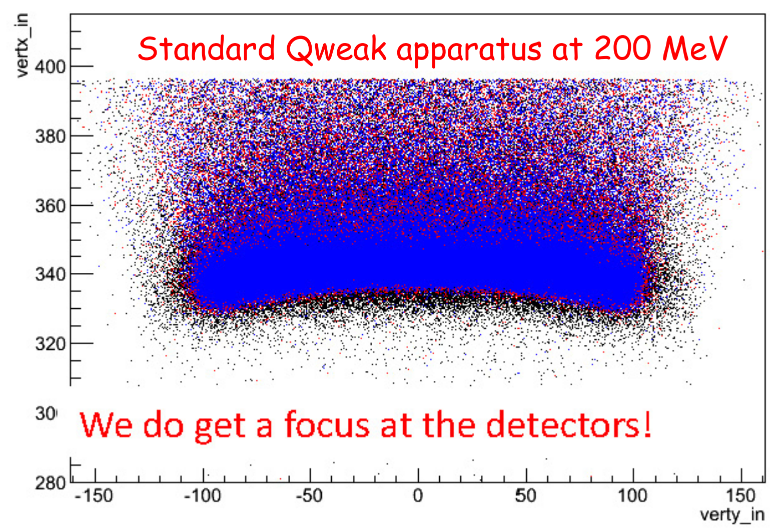


Figure-of-Merit for Torroid Spectrometer

The relative FOM for e-p elastic scattering at forward angles for:

- **Fixed running time**
- **Fixed angular acceptance**
- **Fixed target length**
- **Fixed beam current**

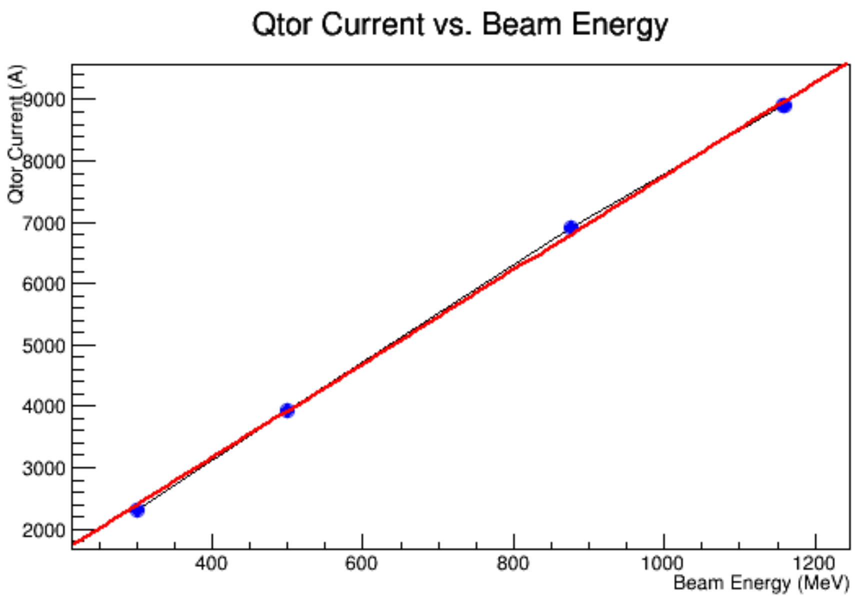
The FOM is [A x $\sigma^{1/2}$] where A = asymmetry and σ = cross section integrated over experimental acceptance.

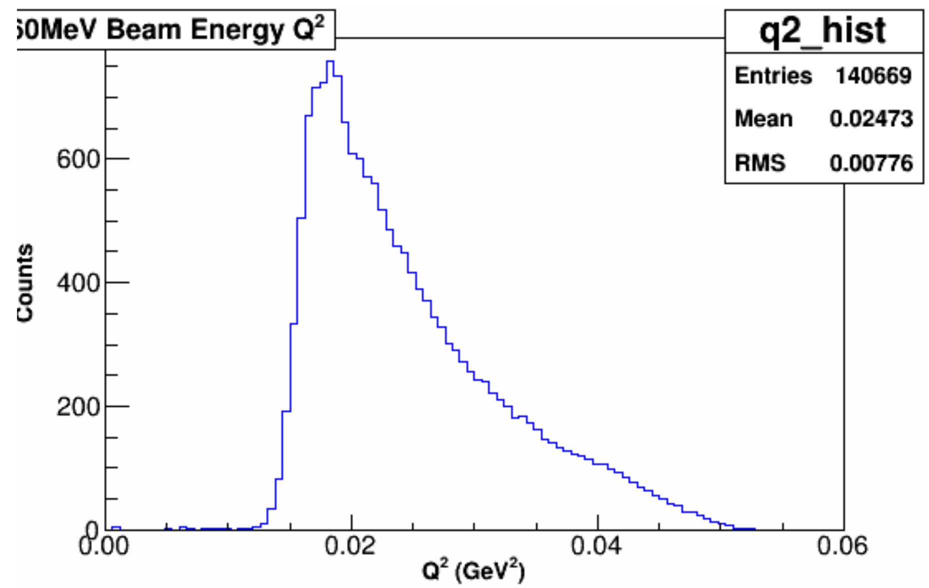
Since $A \sim Q^2 \sim E^2$ and sigma $\sim E^2/Q^4 \sim 1/E^2$

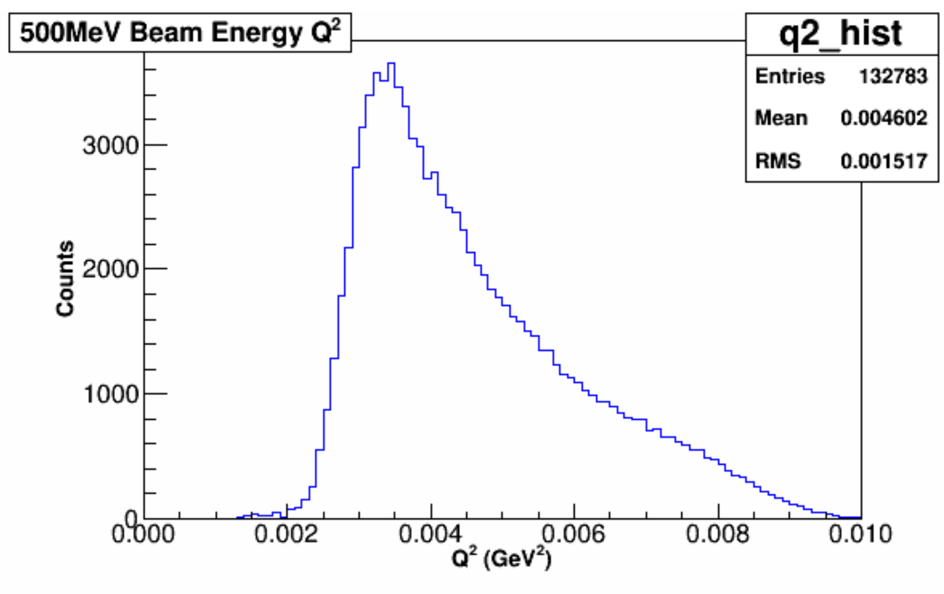
To zeroth order FOM ~ E, is basically independent of energy in this region - modified slightly for the B term magnitude and form factor variation.

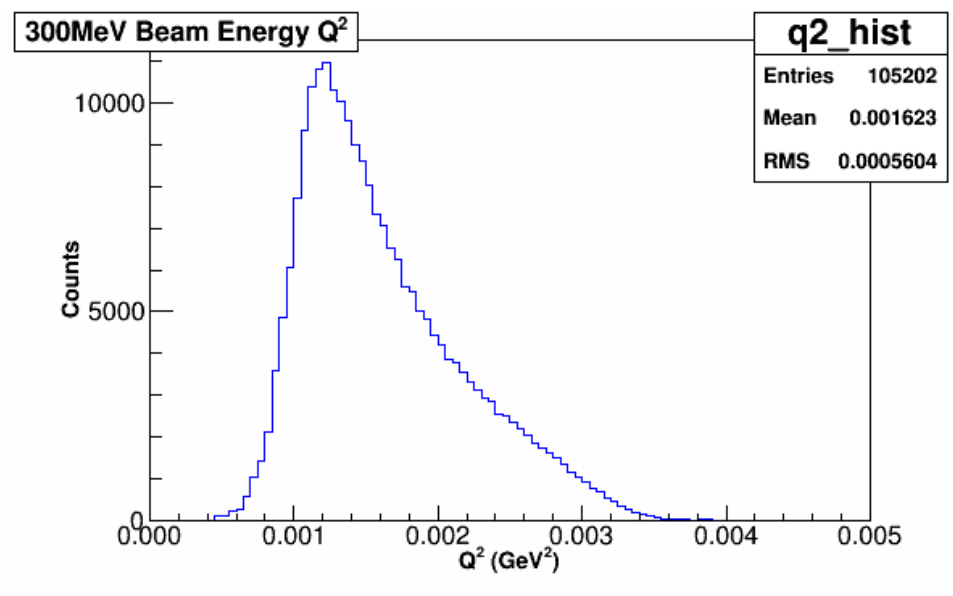
Other significant factors include the handicap of dealing with a "very small asymmetry" with respect to helicity-correlated beam parameters and other false asymmetries) that drives the beam energy choice.

Q^2 for 0.3 GeV, 0.5 GeV & 1.16 GeV









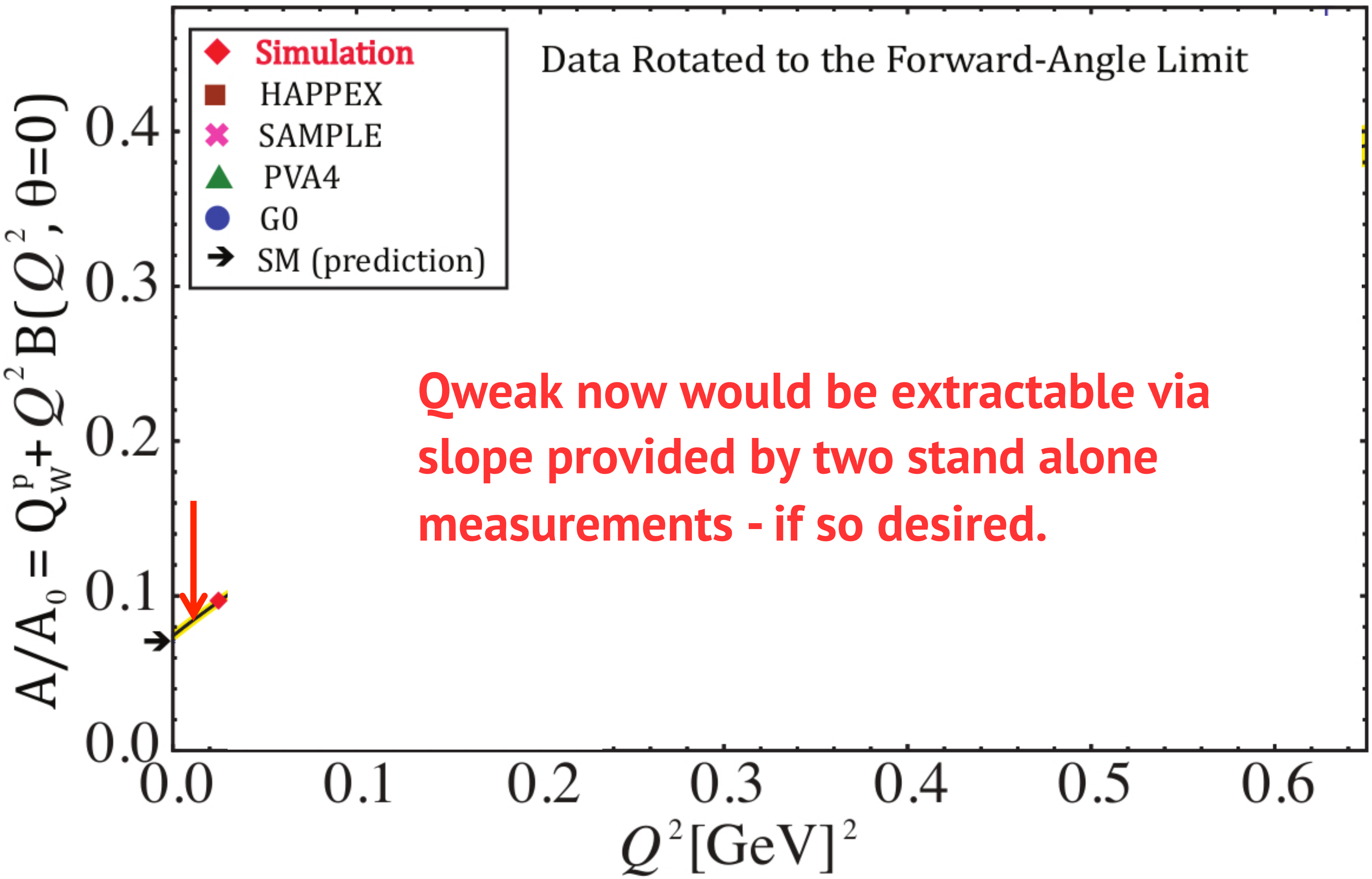
Projections for Using Qweak Apparatus at 600 MeV

Projected rates/asymmetries for standard Qweak apparatus at 600 Mev:
Case A: standard 2.5 kW LH_2 target; Case B: 3.8 kW LH_2 target

Parameter	MESA P2*	Q-weak 600, case A	Q-weak 600, case B
E_{beam}	200 MeV	600 MeV	600 MeV
Time	10000 hours	10000 hours	10000 hours
Current	150 μA	200 μA	300 μA
LH_2 Target Length	60 cm	35 cm	35 cm
Polarization	85%	85%	85%
Central θ	20^o	8^o	8^o
$<Q^2>$	.0029 GeV^2	.0065 GeV^2	.0065 GeV^2
Total rate	440 GHz	30 GHz	44 GHz
Asym. Width @240 Hz	23 ppm	89 ppm	74 ppm
A_{phys} (ppb)	-20 ppb	-46 ppb	-46 ppb
Hadronic "B" term	9%	10%	10%
ΔA (stat)	0.25 ppb (1.2%)	0.96 ppb (2.1%)	0.79 ppb (1.7%)
ΔA (syst)	0.19 ppb (0.9%)	0.41 ppb (0.9%)	0.41 ppb (0.9%)
ΔA (tot)	0.34 ppb (1.7%)	1.20 ppb (2.6%)	1.01 ppb (2.2%)
ΔQ^p_W	0.0014 (2.0%)	0.0021(3.0%)	0.0019 (2.6%)
$\Delta \sin^2\theta_W$	3.6×10^{-4} (0.15%)	5.4×10^{-4} (0.23%)	4.7×10^{-4} (0.20%)

* MESA P2 parameters come from F. Maas talk at "Dark Forces at Accelerators" Frascati, Oct. 2012

"Teaser + a Lower Q^2 Point"



Conclusions

- **The Jlab Qweak will be the first direct high precision measurement of the weak charge of the proton, but we always want more precision to continue testing the SM.**

- **A non-optimized estimate of for reusing the existing Qweak torroidal magnet apparatus at ~600 MeV beam energy indicates that a precision determination of Q^p_W at Q^2 ~ .0065 $(GeV/c)^2$ and lower appears possible with sufficient running time.**

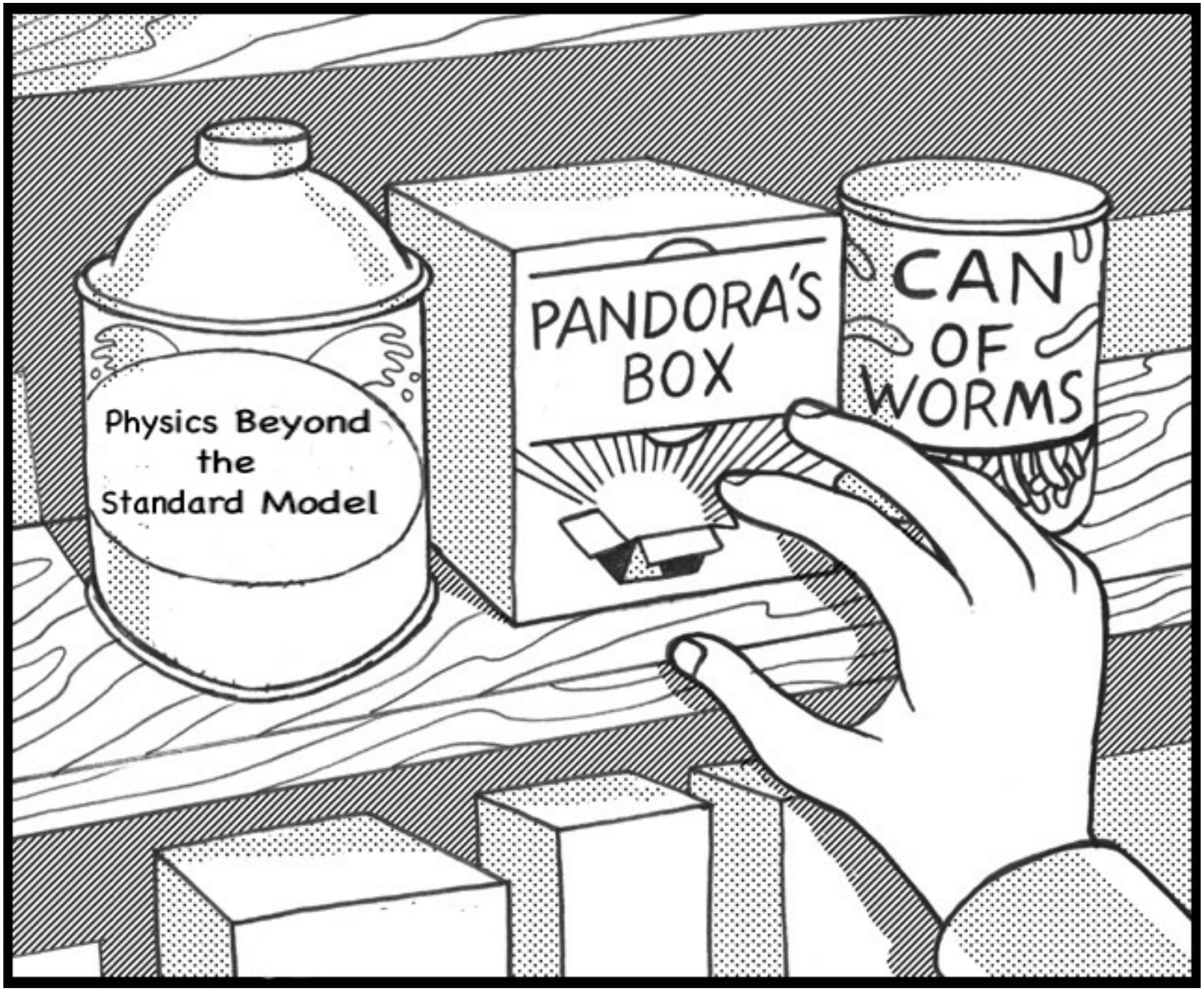
- **This option allows use of conventional polarimetry technology (Compton / backscattered laser) and other beamline instrumentation.**

- **Keeps the asymmetry as large as possible, but still low enough to suppress hadronic uncertainties to a safe level. This is the ideal figure-of-merit.**

- **Reduces the difficulty of helicity-correlated beam property suppression / control when trying to go to sub-ppb asymmetry precision.**

- **As a "bonus" there is no concern with polarizing of the LH_2 production target or its windows when using a torroidal spectrometer.**

Outlook


Physics Beyond the Standard Model
PANDORA'S BOX
CAN OF WORMS