The $Q_{\text{WEAK}}$ Experiment –

A search for new physics at the TeV scale by measurement of the Proton’s weak charge.  
Or  
Measurement of Parity Violation in $ep$ scattering

Des Ramsay  
University of Manitoba/TRIUMF

- $Q_{\text{weak}}$ scatters longitudinally polarized electrons from liquid hydrogen  
- We flip the electron spin and see how much the scattered fraction changes  
- The difference is proportional to the weak charge of the proton
The Parity Operation:

- Simultaneous reflection of all space coordinates through the origin
- Equivalent to reflection plus $180^\circ$ rotation
- If we assume rotational invariance it is a mirror reflection
Parity operation plus 180 rotation:
parity violation experiments with longitudinally polarized beam

In the mirror image experiment the helicity is reversed. Left-handed -> Right-handed

If mirror experiment does not give same result – Parity Violation
Parity Violating Electron Scattering

\[ A_{PV} = \frac{\sigma_R - \sigma_L}{\sigma_R + \sigma_L} \sim \begin{array}{c}
\gamma \\
\hline
\end{array} \begin{array}{c}
Z^0 \\
\hline
\gamma \\
\end{array}^2 \sim \frac{Q^2}{M_Z^2} \]

- Difference between cross section for left and right handed electrons
- Measures interference between \( \gamma \) and \( Z^0 \) exchange.
we are slightly more likely to “hit a proton” if the electron is spinning to the left (parity violation)

expect \( A_z = (\sigma^+ - \sigma^-)/(\sigma^+ + \sigma^-) \approx -300 \text{ ppb} \ (\text{-300 x 10}^{-9}) \)

want \( \pm 5 \text{ ppb statistics in 2500 hours} \)

use eight detectors at 800 MHz each

run in current mode
Why measure parity violation?

• Parity *conserving* electron scattering measures the proton’s *electric* charge. This is well measured; even the charge and current *distributions* are known.

![Feynman diagram of parity conserving electron scattering](image)

• Parity *violating* electron scattering measures the proton’s *weak* charge. This has not been measured yet.

![Feynman diagram of parity violating electron scattering](image)

*Feynman diagrams: Dave Mack*
Why measure the Proton’s Weak Charge?

- From a distance (low momentum transfer) the charge is seen through the distorting effect of clouds of virtual particles.

- All particles, not only known ones, will contribute.

- If the measured weak charge does not agree with the calculations, then it may indicate new physics.

- $Q_{weak}^p = 1 - 4\sin^2 \theta_w$, so $Q_{weak}^p$ is also a good stand-alone measure of the weak mixing angle, $\theta_w$. 
What we actually measure

- The parity violating longitudinal analyzing power, \( A_z = (\sigma^+ - \sigma^-)/(\sigma^+ + \sigma^-) \)
- This experiment uses forward angles and low \( Q^2 \), where

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

\[
= -90 \left( Q^2 Q_{weak}^p + Q^4 B \right) \quad \text{(in ppm, with Q in GeV/c)}
\]

- For point-like proton
- Correction involving hadronic form factors

*The lower the momentum transfer, Q, the more the proton looks like a point and the less important are the form factor corrections.*
How Low Should We Go in $Q^2$?

- low $Q^2$ reduces the hadronic correction, but also reduces $A_z$
- we will use $Q^2 = 0.03 \text{ (Gev/c)}^2$, $\theta = 8^\circ$, where

$$A_z = -194 \text{ ppb} - 74 \text{ ppb} = -268 \text{ ppb}$$

- The -300 ppb (-0.3 ppm) is technically manageable
- The hadronic corrections should introduce <2% error in $Q_W$

*Calculations Ross Young, JLab*
Extrapolation to $Q^2 = 0$

\[
\frac{A_z}{-90Q^2} = Q_{\text{weak}}^p + Q^2 B
\]
Measured Charges Depend on Distance
(running of the coupling constants)

Electromagnetic coupling is **stronger** close to the bare charge

Strong coupling is **weaker** close to the bare charge

\[ \alpha_{\text{QED}} \]

\[ \alpha_s \] (QCD)
Weak charge of the proton depends on the Weak mixing angle, $\theta_w$

- $Q^p_{\text{weak}} = 1 - 4 \sin^2 \theta_w + \text{corrections}$
- The exact value of the corrections depends on how much is included in the definition of $\sin^2 \theta_w$ (normalization scheme).
- At the Z-pole, $\sin^2 \theta_w = 0.23122$ in the MSbar scheme, but is 0.22306 in the on-shell scheme.
- You can take the value of $\sin^2 \theta_w$ measured at the Z-pole and “run” it to other energies.
Running of $\sin^2\theta_w$

scale dependence of weak mixing angle in MS scheme

Both Proton and Electron Measurements Are Useful
Both Proton and Electron Measurements are Important

- arrows show allowed “pull” of weak charges by new physics as constrained by previous experiments
- electron and proton weak charge experiments are complementary
The proton’s weak charge is almost zero because $\sin^2 \theta_W$ is so close to $\frac{1}{4}$. The near cancellation of the proton’s weak charge at tree level, makes it a sensitive measure of new physics.
What Energy Scale Are We Sensitive To?

If LHC uncovers new physics, then precision low $Q^2$ measurements will be needed to determine charges, coupling constants, etc.

Roger Carlini
Technical details

\[ A_z = \frac{1}{P_z} \left( \frac{N^+ - N^-}{N^+ + N^-} \right) = -90 \left( Q^2 Q_{weak}^p + Q^4 B \right) \]

We want: \( 2\% \) on \( A_z \approx 4\% \) on \( Q_w \approx 0.3\% \) on \( \sin^2 \theta_w \)

How do you do that?

- 5 x 10^{-9} statistics: Count for 2500 hr at 6.5 GHz.
- Beam polarization: New Hall-C Compton polarimeter.
- Absolute Q^2: Dedicated runs with full tracking.
- Accurate magnetic field map: Theory and existing experiment
- hadronic correction
- Background fraction.
- Beam Properties: Dedicated runs with tracking and TOF
- Online measurement and correction.

How hard is that?

Typical \( A_z \) uncertainties, adding statistical and systematic in quadrature.

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Uncertainty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gzero</td>
<td>500 ppb</td>
</tr>
<tr>
<td>HAPPEX 2</td>
<td>130 ppb</td>
</tr>
<tr>
<td>TRIUMF E497</td>
<td>35 ppb</td>
</tr>
<tr>
<td>Qweak</td>
<td>6 ppb</td>
</tr>
</tbody>
</table>
A resistive toroidal magnetic spectrometer focuses elastic electrons onto a rad-hard quartz Cerenkov detector array.
Principal Parts of the Qweak Experiment

- Synthetic Quartz Scintillator Bars
- Region 3: VDCs
- Lumi Monitors
- Collimator System
- Toroidal Spectrometer Magnet
- Trigger Scintillator

**Liquid Hydrogen Target (2.5 kW)**

**Electron Beam**

1.165 GeV

180 $\mu$A (0.2 nA)

P $\sim$ 85%

**Region 1: GEMs**

**Region 2: HDCs**

**Region 3: VDCs**

**light blue = counting mode**

**black = current mode**
The QTOR Resistive spectrometer magnet:

- Decreasing slope of transverse magnetic field gives the required focusing property for the toroidal magnetic spectrometer.
- Electrons with larger scattering angles experience small field integral.
- Electrons with smaller scattering angles experience large field integral.
- Inelastic electrons bent away from detector’s acceptance.
- Elastic electrons focused onto Čerenkov bars.

Diagram showing the magnetic field lines and the path of electrons through the spectrometer.
Beam’s Eye View with GEANT Simulated Events

A small cm-sized scanning quartz detector (Winnipeg/TRIUMF) will map the event distribution at full beam current.

Black region in center is Pb shielding.
Synthetic Quartz Čerenkov Detectors

Focal plane detectors:

- 200 x 18 cm x 1.25 cm synthetic quartz bars
- Radiation hardness (expect > 300 kRad).
- Insensitivity to background $\gamma$, $n$, $\pi$.
- Operation at counting statistics.

Quality control
Nature of the Current Mode Signals

20 p.e. per event

50,000 e per event

800 MHz

x 2500

1 MΩ I-V

6.4 µA 6.4 V

in shielding outside hall

VME digital signal integrator

to DAQ

shot noise: \( i_n^2 = 2QIB \)
Size of $Q_{\text{weak}}$ Signal

- Figure shows regular spin flip; in practice may be some randomization.
- For 50 kHz noise bandwidth, rms shot noise is 70 nA.
- On a scope the noise band would be $\approx 100,000 \times$ the signal!
- On printed page, origin is 6 km off bottom.
Shot Noise Numerical Example

\[ i_n^2 = 2QIB \quad [A^2] \]

- one-sided shot noise
- \( \frac{1}{2T} \) or \( f_{3db}(\pi/2) \)
- equivalent noise bandwidth [Hz]
- charge quantum [C]
- current [A]

Example, 1 ms integration with beam on, assuming 800 MHz:
- \( Q = 50,000 \) e
- \( I = 6.4 \, \mu A \)  (800 MHz x 50,000 e)
- \( B = 500 \) Hz
- \( i_n = 7.2 \) nA rms  (7.2 mV with a 1 MΩ preamp)

Note that in 1 ms, \( N = 8 \times 10^5 \) counts.
\[
\frac{1}{\sqrt{N}} = 1120 \text{ ppm, same as } 7.2 \text{ nA/6.4 } \mu A
\]
Comparison of Different Noise Sources

<table>
<thead>
<tr>
<th>Condition</th>
<th>noise (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>beam-ON shot noise</td>
<td>1120</td>
</tr>
<tr>
<td>shot noise during LED tests</td>
<td>160</td>
</tr>
<tr>
<td>shot noise during battery tests</td>
<td>5</td>
</tr>
<tr>
<td>preamplifier noise</td>
<td>2</td>
</tr>
<tr>
<td>digital integrator noise</td>
<td>1-2</td>
</tr>
</tbody>
</table>

rms noise on a 1 ms integral
Low Noise Current-Mode Preamplifier at TRIUMF

- Radiation hardness tested at JLab to 18 krad – no effect (spec. 1 krad)
- Small size to fit in shielding boxes on Qweak
- 28 modules now delivered to the Qweak collaboration.
TRIUMF Preamplifier

Chan 1

Chan 1 gain

Offset adjust

Chan 2

Chan 2 gain

IN

Out

+5 V DC

MΩ

MΩ

10

5

2

1

0.5

1

2.5

5
Preamp Irradiation Setup
37Cs 0.662 MeV gamma (85%) 86 Rads/hr

Preamplifier with signal cables and dosimetry

Battery
Gammas emitted from here

**Preamplifier Setup:**
- 3.6 microA input from battery (2’ RG58)
- 1 MOhm transimpedance
- 4.7 V output (with 1 V offset)

**Spectrum Analyzer Setup:**
- AC coupled, 0-400 Hz in 800 bins

No deterioration at 18 krad
Possible DAQ pattern

- Integrates for 4 ms
- Stored as four 1 ms integrals
- \( T_{\text{settle}} \) as short as 50 \( \mu \text{s} \) allowed

- Rapid spin flip reduces noise from target boiling
- Have capability to run as short at 1 ms per state
TRIUMF VME integrator details

- FPGA
- FPGA Prog/Debug Ports
- VME Module Select Switches
- Status LEDs
- VME Access
- Ext Clock Enb
- Ext Gate Enb
- Ext NIM Gate
- Ext NIM Clock
- VME Analog Filters
- 8 inputs
- ADC
- DC-DC Converter
- FPGA
- FPGA Prog/Debug Ports
- Analog Filters
- 8 inputs
- ADC
- DC-DC Converter
VME integrator tests at TRIUMF

- Analog input range: -10 V to +10 V
- Front-end ADC: 500 ksp
- 4 ms integrals stored as 4 x 1ms blocks
- Shown here with 6µA current source and 200 pf cable.
Realistic VME Integrator Tests With Qweak DAQ at Ohio

- 6\( \mu \text{A} \) into 1 M\( \Omega \) preamp: 6V above baseline
- 4 ms integration time; 4.2 ms gate period
- Quartets are +++-; QRT period is 16.4 ms

\[
RMS_{asym} = 2.2 \text{ ppm}
\]
\[
\Delta V = 11.1 \mu \text{V}
\]
\[
\text{Noise} \rightarrow 1.4 \mu \text{V}/\sqrt{\text{Hz}}
\]
Null Asymmetry Check

Scaling to a 10 h run

\[ 2.2 \text{ ppm} \times \sqrt{\frac{16.4 \text{ ms}}{10 \text{ hr}}} = 1.5 \times 10^{-9} \]

- Preamp and integrator noise is low enough that we can perform a null asymmetry test in less than a day.
Choice of Spin Sequence

Some authorities prefer pairs

\[ (+-) \quad (+) \]

Some prefer quartets

\[ (+-+-) \quad (-+--+) \]

Or even octets

\[ (+-+-+-++) \quad (-+++-+-+) \]

Linear drifts cancel over a quartet:

\[ +1-2-3+4=0 \]

Quadratic drifts cancel over an octet:

\[ +1-4-9+16-25+36+49-64=0 \]
Quartets or Doublets

Quartets accept more low frequencies

~50 Hz

~100 Hz

222.2 spin states per second

Quartets

Doublets

~222.2 spin states per second
Regular or Random Doublets

Non-random spin flip concentrates signal at spot frequencies

Regular

- 400 spin states per second
- 2.4 ms
- 0.1 ms

1 second run, +++-- etc. toggling
2.4 ms/state integration time
0.1 ms/state settling time
accepts odd multiples of 200 Hz

Random

1 second run, +-- or --+ chosen at random
2.4 ms/state integration time
0.1 ms/state settling time

-2 -1 0 1 2
helicity
-2 -1 0 1 2
2.4 ms
0.1 ms

0 1 2 3 4 5
time (ms)
Vertical scale is proportional to noise/ (Hz$^{1/2}$)

Black curve is Hall A LD$_\gamma$ data.

Red data are carbon and indicates that there was negligible electronic rolloff.

Magnitude of the red line is probably the noise floor of non-parity quality ADC's in use at the time.
“QTOR” Spectrometer Magnet
U of M / TRIUMF / UNBC

- 8 sector toroidal magnet
- Water cooled copper coils
- 9500 A, 1.5 MW maximum
- 4.3 m long, 1.5 m wide coils, simple racetrack shape
- ~3300 kg per coil
- Field mapping with TRIUMF field mapping equipment.
- Contract management by TRIUMF engineers.
- ~$420k NSERC money

\[ \int B \cdot dl = 0.89 \text{ T.m} \]
All magnet and stand parts are now at MIT/ Bates

- ready to go at MIT
- full-power May 2008
- Field map May and September 2008
- to JLab April 2009
Coils are a close fit
Preparing the TRIUMF field mapper at MIT-Bates
TRIUMF Magnetic Field Mapper

- used for Gzero
- Now at MIT-Bates
- Scans 4 m x 4 m x 2 m
- repeatability ~0.025 mm
- calibration ±0.2 mm
- ±0.2 gauss
Water Manifold Moved For Field Mapping

Karen Dow
Features of the QTOR Resistive spectrometer magnet:

- Decreasing slope of transverse magnetic field gives the required focusing property for the toroidal magnetic spectrometer.
- Elastic electrons focused onto Čerenkov bars.
- Inelastic electrons bent away from detector's acceptance.
- Electrons with larger scattering angles experience small field integral.
- Electrons with smaller scattering angles experience large field integral.
Tracking Systems (counting mode)

- Run in counting mode at 0.2 nA
- Determine $Q^2$ to 0.5%
- Understand backgrounds
Region 2 First Production Chamber

Region 2 chambers: horizontal drift chambers with 6 planes per chamber (xuvx’u’v’)
active area 38 cm x 28 cm, wire pitch of 5.84 mm
Compton can run all the time (unlike the Møller).

Photon and electron coincidences greatly reduce systematic uncertainties due to backgrounds.

< 1% precision is guaranteed, cross-calibrate against existing Møller polarimeter.

Hall C has calibrated ~1% Møller polarimeter based on magnetized foil in several Tesla field. It needs dedicated Møller runs.
- Highest power (2500 watt) cryotarget ever
- ~50 litre liquid hydrogen inventory
- 35 cm long, 2200 watt beam load
- High capacity combined 4K and 15K heat exchanger
- LN2 pump tests this summer
- Cold helium gas tests at end 2008
Heat Exchanger

• Combine 4K & 15K HXs to reduce Volume
  – Retain balanced ΔP for each layer
  – Replace conical transition flanges with more abrupt flanges
    • heater moves to unused leg
  – Still adequate cooling power:
    • (>4 kW 4K, >600 W 15K)
Helicity Correlated Beam Properties

- If a beam parameter changes with helicity, it can imitate parity violation.
- We must measure and, if necessary, correct for such modulation.
# Errors from Helicity Correlated Beam Properties

<table>
<thead>
<tr>
<th>Source</th>
<th>Conditions</th>
<th>Perfect array</th>
<th>Extra contribution from imperfections</th>
</tr>
</thead>
<tbody>
<tr>
<td>Position modulation</td>
<td>$x_0 = 1.0 \text{ mm}$</td>
<td>$4 \times 10^{-10}$</td>
<td>$2 \times 10^{-10}$</td>
</tr>
<tr>
<td></td>
<td>$\delta x = \pm 2 \text{ nm}$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Size modulation</td>
<td>$4 \text{ mm} \times 4 \text{ mm raster}$</td>
<td>$5.3 \times 10^{-10}$</td>
<td>$2.7 \times 10^{-10}$</td>
</tr>
<tr>
<td></td>
<td>$\delta_{\Delta x} = \delta_{\Delta y} = \pm 2 \text{ nm}$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Direction modulation</td>
<td>$\theta_0 = 60 \mu\text{rad}$</td>
<td>$7 \times 10^{-10}$</td>
<td>$47 \times 10^{-10}$</td>
</tr>
<tr>
<td></td>
<td>$\delta \theta = \pm 30 \text{ nrad}$</td>
<td></td>
<td>Independent of $\theta_0$</td>
</tr>
<tr>
<td>Transverse polarization and position</td>
<td>$P_y = 0.04, A_y = 10^{-5}$, $x_0 = 1.0 \text{ mm}$</td>
<td>$24 \times 10^{-10}$</td>
<td>$-34 \times 10^{-10}$</td>
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<td></td>
<td></td>
<td></td>
<td>Independent of $\theta_0$</td>
</tr>
<tr>
<td>Energy Modulation</td>
<td>$\delta E/E = 10^{-9}$</td>
<td>$&lt;6 \times 10^{-10}$</td>
<td>$0$</td>
</tr>
</tbody>
</table>
# Errors from Helicity Correlated Beam Properties

<table>
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<tr>
<th>Source of error</th>
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<th>Extra contribution from distorted array</th>
</tr>
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<tbody>
<tr>
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<tr>
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</tbody>
</table>
Summary of Error Budget

\[ 2\% \text{ on } A_z \approx 4\% \text{ on } Q_w \approx 0.3\% \text{ on } \sin^2\theta_W \]

<table>
<thead>
<tr>
<th>Source</th>
<th>( \Delta A_z/A_z )</th>
<th>( \Delta Q_w/Q_w )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Statistical (2500 hours)</td>
<td>2.1%</td>
<td>3.2%</td>
</tr>
<tr>
<td>Systematic:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hadronic structure uncertainties</td>
<td>--</td>
<td>1.5%</td>
</tr>
<tr>
<td>Beam polarimetry</td>
<td>1.0%</td>
<td>1.5%</td>
</tr>
<tr>
<td>Absolute Q2 determination</td>
<td>0.5%</td>
<td>1.0%</td>
</tr>
<tr>
<td>Backgrounds</td>
<td>0.5%</td>
<td>0.7%</td>
</tr>
<tr>
<td>Helicity correlated beam properties</td>
<td>0.5%</td>
<td>0.7%</td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td><strong>2.2%</strong></td>
<td><strong>4.1%</strong></td>
</tr>
</tbody>
</table>

*(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\%).*
What if we combine Qweak with other experiments with differing sensitivity to up and down quarks?
The $C_1$ coupling is half the quark “weak charge” I showed earlier.

For the proton (UUD), $Q_{\text{weak}} = 2(2C_{1u} + C_{1d})$
All Data & Fits Plotted at 1 $\sigma$

SLAC: D DIS
Mainz: Be

APV Tl
APV Cs

Bates: C

Latest from Ross Young
HAPPEX: H, He
G₀: H, He
PVA4: H
SAMPLE: H, D

All Data & Fits Plotted at 1 σ

Latest from Ross Young

SLAC: D DIS
Mainz: Be

Bates: C
All Data & Fits
Plotted at 1 $\sigma$

SLAC: D DIS
Mainz: Be

APV Ti
APV Cs

PVES

HAPPEX: H, He
G$^0$: H,
PVA4: H
SAMPLE: H, D

Latest from Ross Young
All Data & Fits Plotted at 1σ

HAPPEx: H, He
G⁰: H, He
PVA4: H
SAMPLE: H, D

Latest from Ross Young

SLAC: D DIS
Mainz: Be

APV Tl
APV Cs

PVES

Q−weak

Bates: C
Final Impact of Qweak
\[ \mathcal{L}_{\text{SM}}^{PV} = -\frac{G_F}{\sqrt{2}} \bar{e} \gamma_\mu \gamma_5 e \sum_q C_{1q}^{\text{SM}} \bar{q} \gamma^\mu q \]

\[ \mathcal{L}_{\text{NP}}^{PV} = \frac{g^2}{4\Lambda^2} \bar{e} \gamma_\mu \gamma_5 e \sum_q h_{V}^{q} \bar{q} \gamma^\mu q \]

Full isospin coverage for limits on new physics!

\[ h_{V}^{u} = \cos \theta_{h} \quad h_{V}^{d} = \sin \theta_{h} \]

Data sets limits on \[ \frac{g^2}{\Lambda^2} \]
Sensitivity to new physics depends on relative importance of the new up and down quark couplings.

\[ \Delta \left( \text{TeV} \right) \]

- future Qweak with PVES
- No PVES

Qweak constrains new physics to beyond 2 TeV
Progress of Qweak -- Past

- **May 2000**  Collaboration formed
- **July 2001**  JLab Letter of Intent
- **December 2001**  JLab Proposal Submitted
- **January 2002**  JLab Proposal Approved with ‘A’ rating
- **January 2003**  Technical design review completed,
- **2003 - 2004**  Funding approved by to DOE, NSF & NSERC
- **January 2005**  JLAB Jeopardy Proposal approved with ‘A’ rating
- **March 2007**  Two day engineering run (at end of G zero) Beam noise and target boiling studies.
- **January 2008**  PAC33 Jeopardy review. Qweak granted 198 PAC days as requested.
Progress of Qweak -- Present

As of April 2008:

- All QTOR magnet parts assembled and surveyed at MIT-Bates
- Power supply ready to go at MIT-Bates. Power-up 6 May 2008
- Field mapping with TRIUMF mapper to follow.
- All main preamplifiers delivered. TRIUMF VME modules ready later this summer.
- All silica (quartz) bars for main detectors are at JLab and being glued.
- LH2 target well under way. Expect LN2 pump tests this summer and cold helium gas tests later in year
- Hall C Compton proceeding. MIT chicane. Winnipeg electron detector.
- All Qweak geometry in incorporated in GEANT4 simulation.
- All tracking detectors designed and production started.
- Full 3D CAD model or experiment prepared at JLab. Designs proceeding on shield house, etc.
- JLab working on beamline instrumentation.
Progress of Qweak -- Future

Shutdown for JLab 12 GeV upgrade is scheduled for May 2012, so we must finish the full 4% measurement *before* then.

Possible schedule:

- April 2009 – Move magnet to JLab from MIT
- Oct 2009 start installation (6 months)
- Apr 2010 start engineering run (4 months)
- Aug 2010 start phase I (8%, 3 ½ months)
- Dec 2010 possible break then first part of phase II
- May 2011 start 6 month mini-shutdown
- Nov 2011 resume phase II running
- May 2012 beam off for 12 GeV upgrade; Qweak run ends.
The Qweak Collaboration


¹Spokespersons  ²Project Manager

Institutions:  19 American, 4 Canadian, 1 Mexican, 1 British, 1 Armenian

College of William and Mary, University of Connecticut, Instituto de Fisica, Universidad Nacional Autonoma de Mexico, University of Wisconsin, Hendrex College, Louisiana Tech University, University of Manitoba, Massachusetts Institute of Technology, Thomas Jefferson National Accelerator Facility, Virginia Polytechnic Institute & State University, TRIUMF, University of New Hampshire, Yerevan Physics Institute, Mississippi State University, University of Northern British Columbia, Cockroft Institute of Accelerator Science and Technology, Ohio University, Hampton University, University of Winnipeg, University of Virginia, George Washington University, Syracuse University, Idaho State University, University of Connecticut, Christopher Newport University
END
If LHC uncovers new physics, then precision low $Q^2$ measurements will be needed to determine charges, coupling constants, etc.
What about significant deviation from Standard Model?

Assume Qweak takes central value of current measurements

If LHC finds new Z', Qweak will help determine nature of interaction

\[ 1.5 \frac{\Lambda}{g} < 2.5 \text{ TeV} \]
Transverse Flow Model 606-3
Region 2 First Production Chamber

Region 2 chambers: horizontal drift chambers with 6 planes per chamber (xuvx’u’v’)
active area 38 cm x 28 cm, wire pitch of 5.84 mm
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incident Beam Energy</td>
<td>1.165 GeV</td>
</tr>
<tr>
<td>Beam Polarization</td>
<td>85%</td>
</tr>
<tr>
<td>Beam Current</td>
<td>180 µA</td>
</tr>
<tr>
<td>LH$_2$ Target Length</td>
<td>35 cm (0.04 X$_0$)</td>
</tr>
<tr>
<td>Production Running Time</td>
<td>2544 hours</td>
</tr>
<tr>
<td>Nominal Scattering Angle</td>
<td>7.9 deg</td>
</tr>
<tr>
<td>Scattering Angle Acceptance</td>
<td>±3 deg</td>
</tr>
<tr>
<td>Acceptance</td>
<td>49% of 2π</td>
</tr>
<tr>
<td>Solid Angle</td>
<td>$\Delta\Omega = 37$ msr</td>
</tr>
<tr>
<td>Acceptance Averaged Q$^2$</td>
<td>$&lt; Q^2 &gt; = 0.026$ (GeV / c)$^2$</td>
</tr>
<tr>
<td>Acceptance Averaged Physics Asymmetry</td>
<td>$&lt; A &gt; = -0.234$ ppm</td>
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<tr>
<td>Acceptance Averaged Expt'l Asymmetry</td>
<td>$&lt; A &gt; = -0.200$ ppm</td>
</tr>
<tr>
<td>Integrated Cross Section</td>
<td>4.0 µb</td>
</tr>
<tr>
<td>Integrated Rate (all sectors)</td>
<td>6.5 GHz (.81 GHz per sector)</td>
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</tbody>
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