The Q^p_{Weak} Experiment

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University of Manitoba

January 2007 Hall C Collaboration Meeting

The Qweak Collaboration

Qweak Collaboration Spokespersons

Bowman, J. David - Los Alamos National Laboratory
Carlini, Roger (Principal Investigator) – Thomas Jefferson National Accelerator Facility
Finn, J. Michael - College of William and Mary
Kowalski, Stanley - Massachusetts Institute of Technology
Page, Shelley - University of Manitoba

Qweak Collaboration Members

Armstrong, David - College of William and Mary
Averett, Todd - College of William and Mary
Birchall, James - University of Manitoba
Bosted, Peter - Thomas Jefferson National Accelerator Facility
Botto, Tancredi - Massachusetts Institute of Technology
Bruell, Antje - Thomas Jefferson National Accelerator Facility
Chattopadhyay, Swapan - Thomas Jefferson National Accelerator Facility
Coppens, Alexandre – University of Manitoba
Covrig, Silviu – University of New Hampshire
Davis, Charles - TRIUMF
Doornbos, Jaap - TRIUMF
Dow, Karen - Massachusetts Institute of Technology
Dunne, James - Mississippi State University
Ent, Rolf - Thomas Jefferson National Accelerator Facility
Erler, Jens - University of Mexico
Falk, Willie - University of Manitoba
Farkhondeh, Manouchehr - Massachusetts Institute of Technology
Forest, Tony - Louisiana Tech University
Franklin, Wilbur - Massachusetts Institute of Technology
Gaskell, David - Thomas Jefferson National Accelerator Facility
Gericke, Michael – University of Manitoba
Grimm, Klaus - College of William and Mary
Hagner, Caren - Virginia Polytechnic Inst. & State Univ.
Hersman, F. W. - University of New Hampshire
Holtrop, Maurik - University of New Hampshire
Johnston, Kathleen - Louisiana Tech University
Jones, Richard - University of Connecticut
Joo, Kyungseon - University of Connecticut
Keppel, Cynthia - Hampton University
Khol, Michael - Massachusetts Institute of Technology
Korkmaz, Elie - University of Northern British Columbia
Lee, Lawrence - TRIUMF
Liang, Yongguang - Ohio University
Lung, Allison - Thomas Jefferson National Accelerator Facility
Mack, David - Thomas Jefferson National Accelerator Facility
Majewski, Stanislaw - Thomas Jefferson National Accelerator Facility
Mammei, Juliette - Virginia Polytechnic Inst. & State Univ.
Mammei, Russell - Virginia Polytechnic Inst. & State Univ.
Martin, Jeffery – University of Winnipeg
Meekins, David - Thomas Jefferson National Accelerator Facility
Mkrtchyan, Hamlet - Yerevan Physics Institute
Morgan, Norman - Virginia Polytechnic Inst. & State Univ.
Opper, Allena - Ohio University
Pitt, Mark - Virginia Polytechnic Inst. & State Univ.
Poelker, B. (Matt) - Thomas Jefferson National Accelerator Facility
Porcelli, Tracy - University of Northern British Columbia
Prok, Yelena – Massachusetts Institute of Technology
Ramsay, W. Desmond - University of Manitoba
Ramsey-Musolf, Michael - California Institute of Technology
Roche, Julie - Thomas Jefferson National Accelerator Facility
Simicevic, Neven - Louisiana Tech University
Smith, Gregory - Thomas Jefferson National Accelerator Facility
Smith, Timothy - Dartmouth College
Suleiman, Riad - Massachusetts Institute of Technology
Tsentalovich, Evgeni - Massachusetts Institute of Technology
van Oers, W.T.H. - University of Manitoba
Wang, Peiqing – University of Manitoba
Wells, Steven - Louisiana Tech University
Wilburn, W.S. - Los Alamos National Laboratory
Wood, Stephen Thomas - Jefferson National Accelerator Facility
Zhu, Hongguo - University of New Hampshire
Ziskin, Vitaliy – MIT Bates Linear Accelerator
Zorn, Carl - Thomas Jefferson National Accelerator Facility
Zwart, Townsend - Massachusetts Institute of Technology

Q^p_{Weak} measures the electron beam helicity correlated asymmetry in the number of elastically scattered electrons from protons in a liquid hydrogen target at very forward angles, corresponding to a momentum transfer of 0.03 GeV ^{2} , to extract the weak charge of the proton.

$$A_{LR}(\vec{e},p) = \frac{d\sigma_L - d\sigma_R}{d\sigma_L + d\sigma_R} = k(A_{Q^p_W} + A_{H,V} + A_{H,A})$$

Quantity of interest = -0.288 ppm

$$A_{Q^p_W} = Q^2 Q^p_W$$

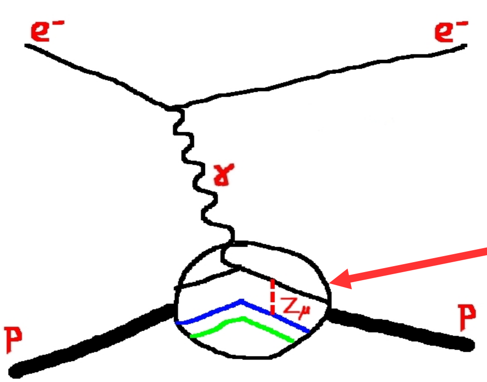
$$A_{H,V} = Q^n_W \frac{\epsilon G_E^{p,\gamma} G_E^{n,\gamma} + \tau G_M^{p,\gamma} G_M^{n,\gamma}}{\epsilon \left(G_E^{p,\gamma}\right)^2 + \tau \left(G_M^{p,\gamma}\right)^2} + Q^s_W \frac{\epsilon G_E^{p,\gamma} G_E^{s} + \tau G_M^{p,\gamma} G_M^{s}}{\epsilon \left(G_E^{p,\gamma}\right)^2 + \tau \left(G_M^{p,\gamma}\right)^2}$$

$$A_{H,A} = Q^e_W \frac{\epsilon' G_A^{p,Z} G_M^{p,\gamma}}{\epsilon \left(G_E^{p,\gamma}\right)^2 + \tau \left(G_M^{p,\gamma}\right)^2}$$

Well constraint from world data: HAPPEX, G0, A4, and many others

$A_{H,V}$ ~ -0.101 ppm

$A_{H,A}$ ~ -0.012 ppm



$G_A^{p,Z}$ Axial form factor due to q-q weak interaction

Quark structure: Must know hadronic wave function or measured form-factors

New Physics

Measurement

$$A_{LR}(\vec{e},p) = \frac{d\sigma_L - d\sigma_R}{d\sigma_L + d\sigma_R} = k(A_{Q_W^p} + A_{H,V} + A_{H,A})$$

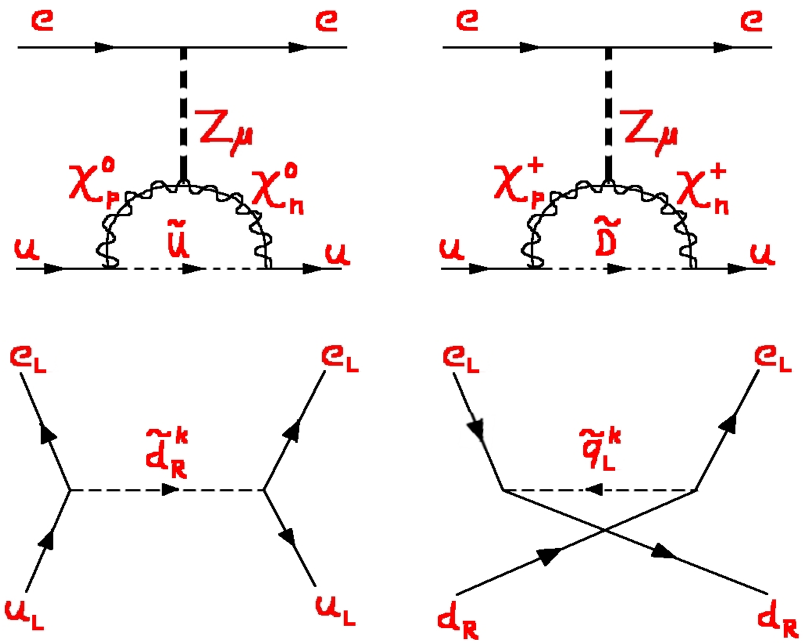
$$Q_W^p = (1 - 4\sin^2\theta_W)$$

Tree Level

$$Q_W^p = \rho_{PV}\,(1 - 4\kappa_{PV}\sin^2\theta_W) + \lambda_p$$

Theory

$$S_{fi}^W \to S_{fi}^W + i\frac{g_W^2}{4\Lambda^2} J^{\mu'}_{e,W} J_\mu^{H,W'}$$



$$\rho_{PV} = 1 + \delta\rho^{SM} + \delta\rho^{SUSY}$$

$$\kappa_{PV} = 1 + \delta\kappa^{SM} + \delta\kappa^{SUSY}$$

$$\lambda_p = 1 + \delta\lambda_p^{SM} + \delta\lambda_p^{SUSY}$$

Non tree-level modifications (SM)

New physics modifications (SUSY)

Kurylov, Musolf, Su Phys. Rev. D 68, 035008 (2003)

The corrections $\delta\rho$, $\delta\kappa$, $\delta\lambda$ are q^2 dependent.

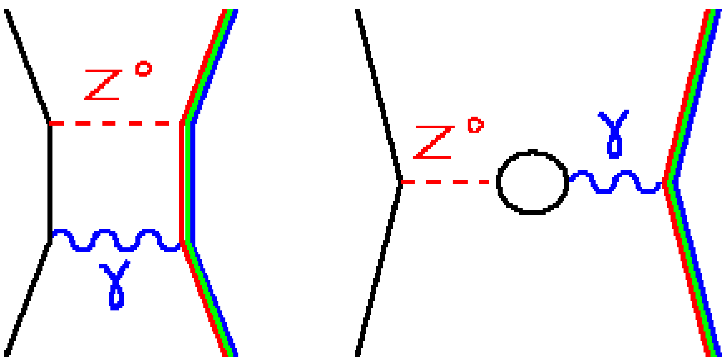
κ_{PV} ← **Defines scale dependence of the weak mixing angle:**

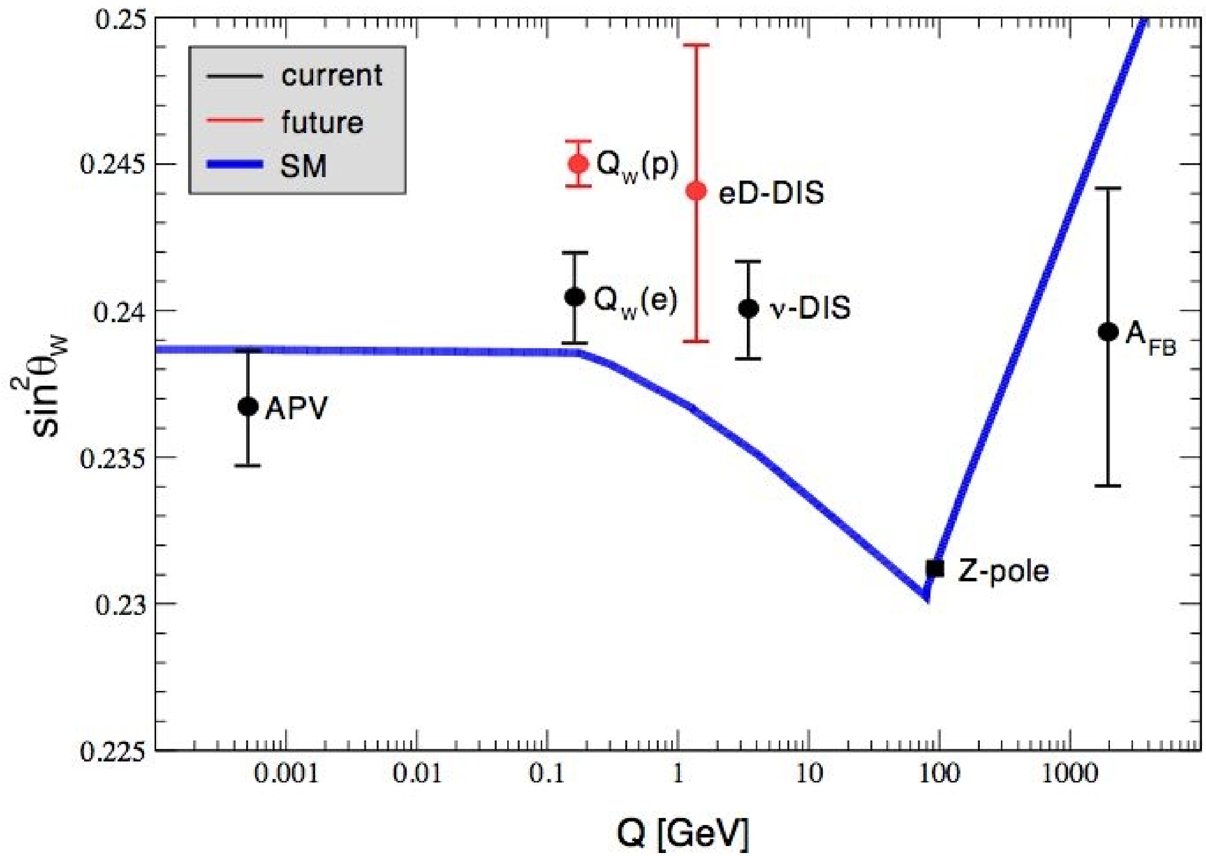
$\delta\kappa$

$$\sin^2\theta_W(q^2) = \kappa_{PV}(q^2)\sin^2\theta_W^Z$$

$$\sin^2\theta_W^Z = 0.23113 \pm 0.00015$$

Radiative Corrections:





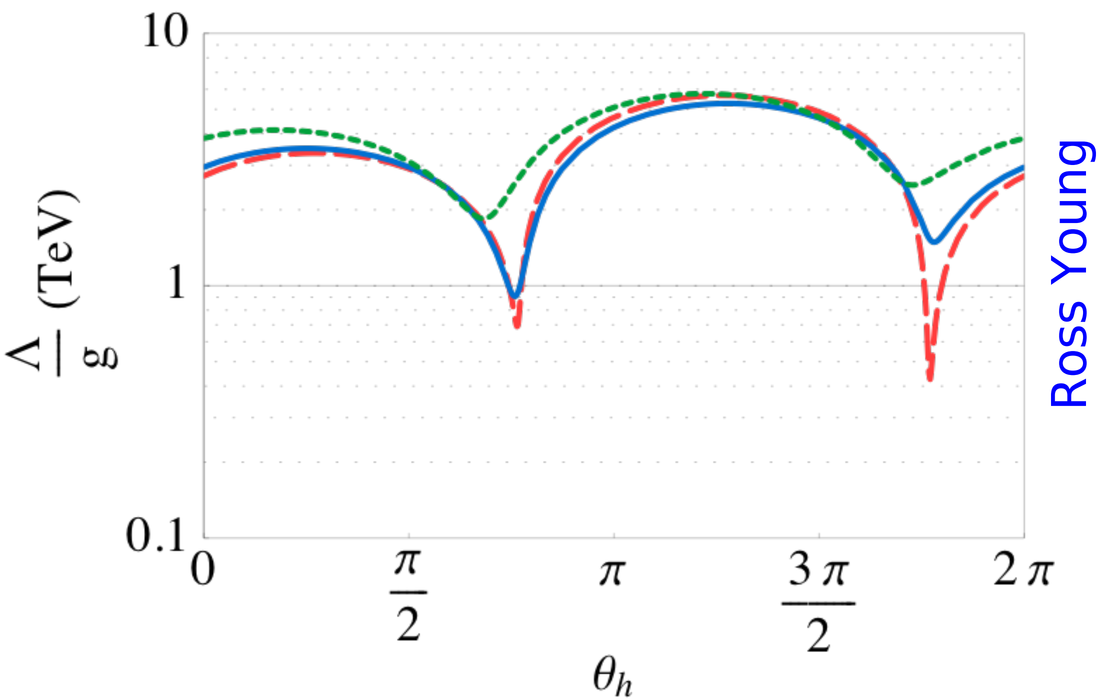
The running of the weak mixing angle from high to low energies is a SM prediction with minimal ambiguity.

A significant deviation would require new physics.

Estimated Uncertainties

	$\Delta A_z/A_z$	$\Delta Q_w/Q_w$
Statistical (2200 hours)	1.8%	2.9%
Systematic:		
Hadronic structure uncertainties	--	1.9%
Beam polarimetry	1.0%	1.6%
Absolute Q2 determination	0.5%	1.1%
Backgrounds	0.5%	0.8%
Helicity correlated beam properties	0.5%	0.8%
Total:	2.2%	4.1%

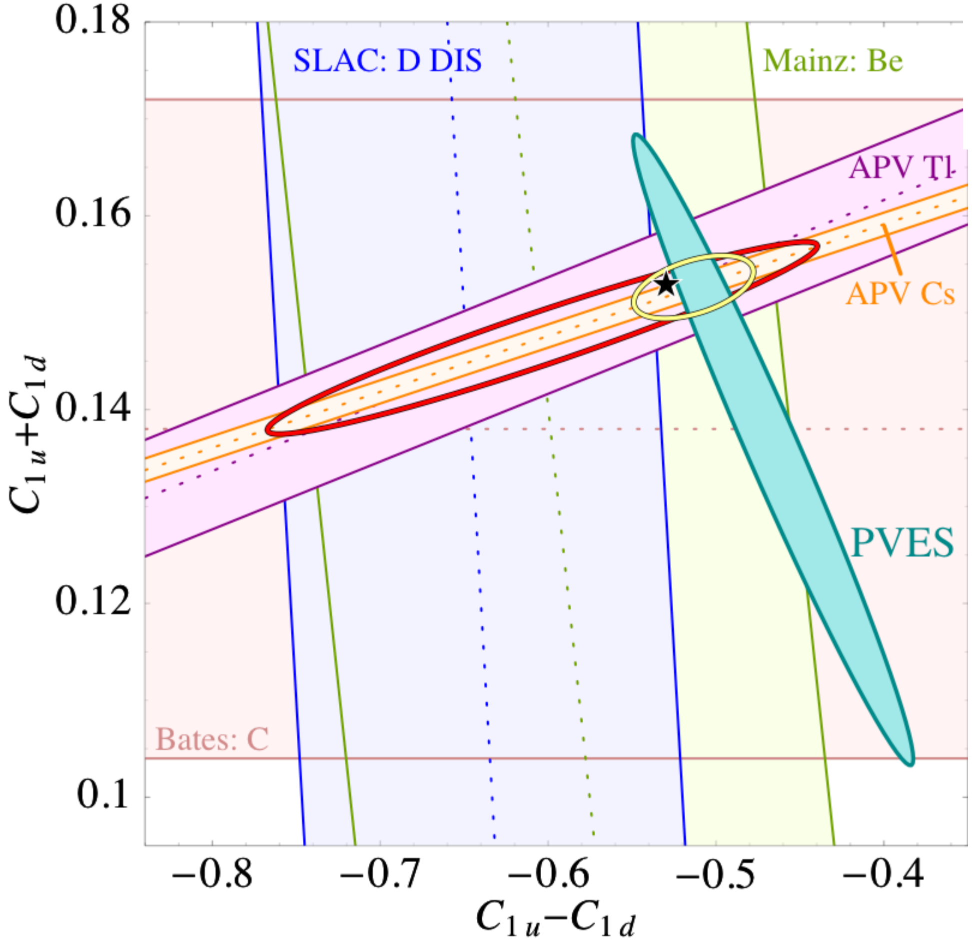
An additional uncertainty associated with QCD corrections applied to the extraction of $\sin^2\theta_W$: it raises $\Delta\sin^2\theta_W / \sin^2\theta_W$ from 0.2% to 0.3%.



Momentum transfer selection is based on event rate maximization, asymmetry maximization and minimization of hadronic dilution.

4.1% measurement mass sensitivity at 95% confidence level:

$$\frac{\Lambda}{g_W} \simeq \frac{1}{2\sqrt{\sqrt{2}G_F|\Delta Q_W^p|}} \geq 2\ \text{TeV}$$

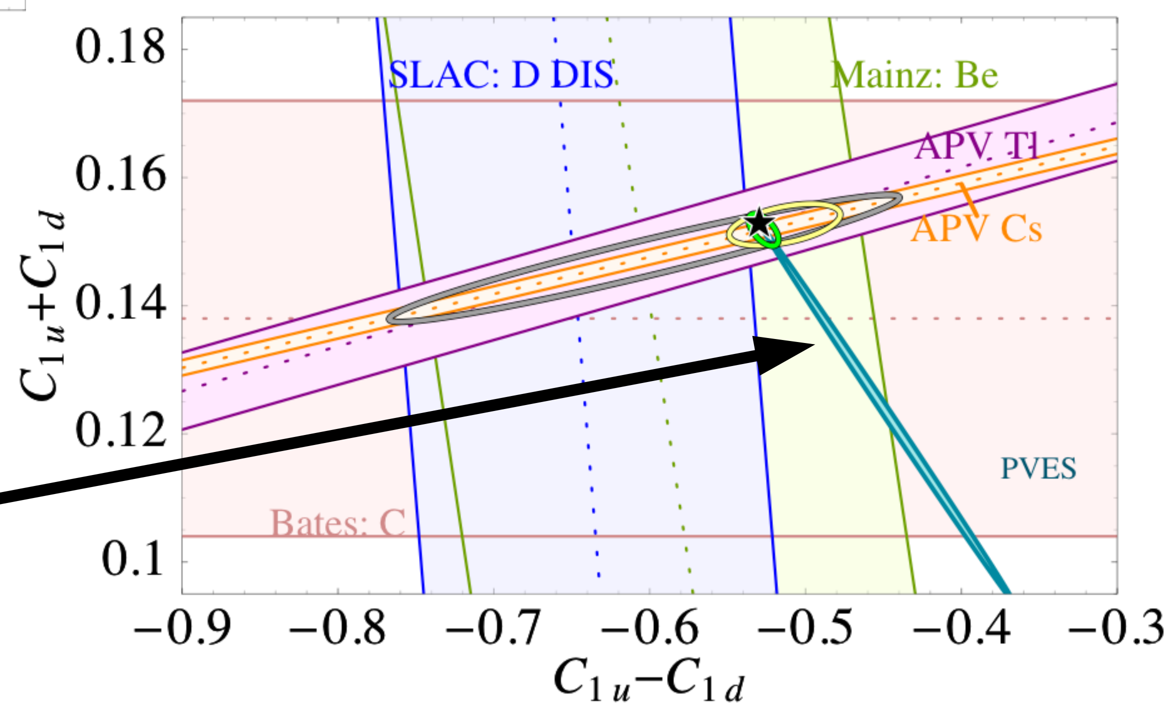


$$-\mathcal{L}^{eHadron} = -\frac{G_F}{\sqrt{2}} \sum_{i=u,d,s} [C_{1i}\bar{e}\gamma_\mu\gamma^5 e\bar{q}_i\gamma^\mu q_i + C_{2i}\bar{e}\gamma_\mu e\bar{q}_i\gamma^\mu\gamma^5 q_i]$$

$$Q_W^p = -2\,(2C_{1u} + C_{1d})$$

Constraints with currently available PVES data and theory.

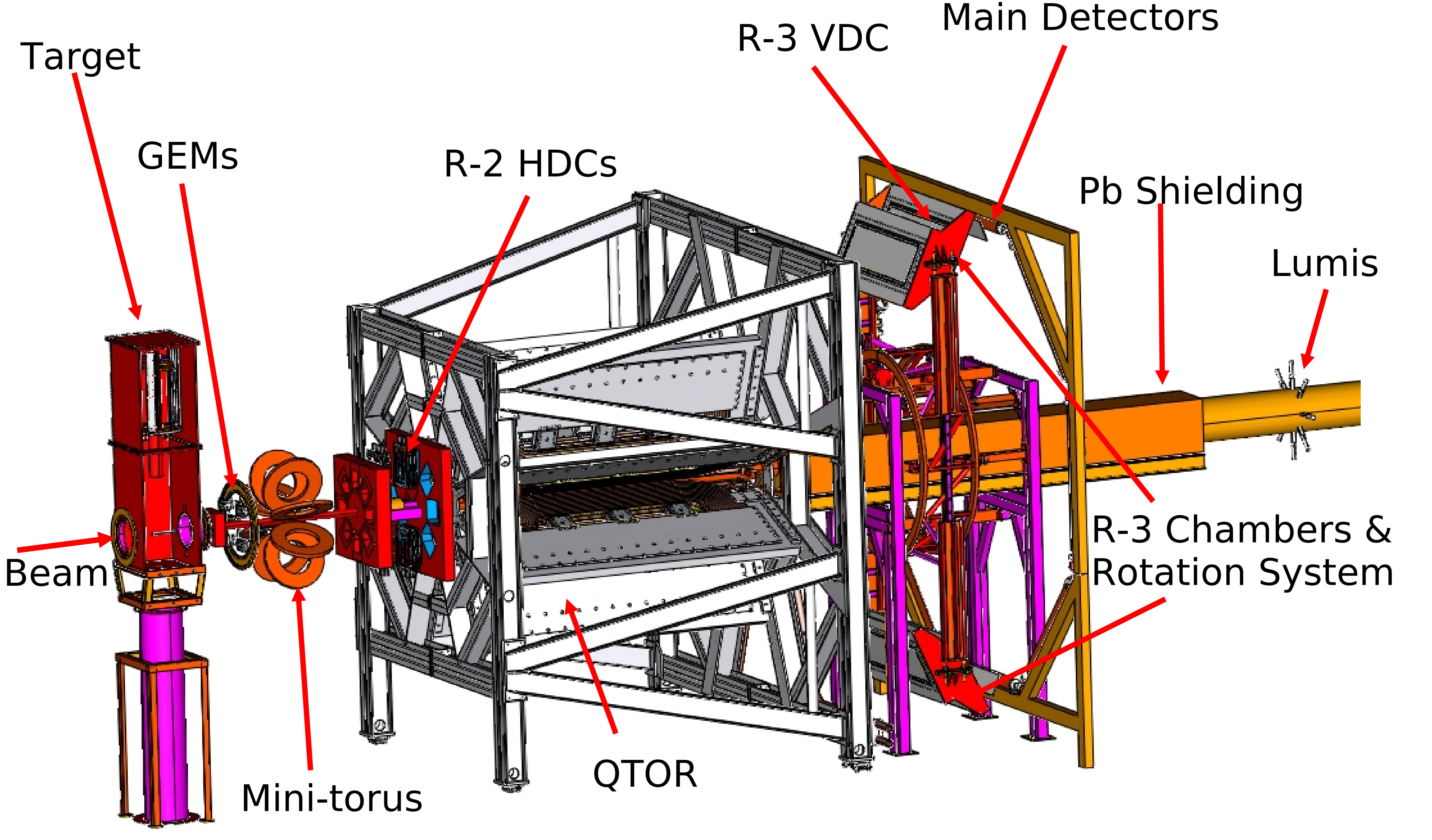
All hadronic uncertainties are constrained by data.



Constraints with currently available PVES and Qweak.

Plots courtesy of Ross Young, JLab

Experiment Component Details

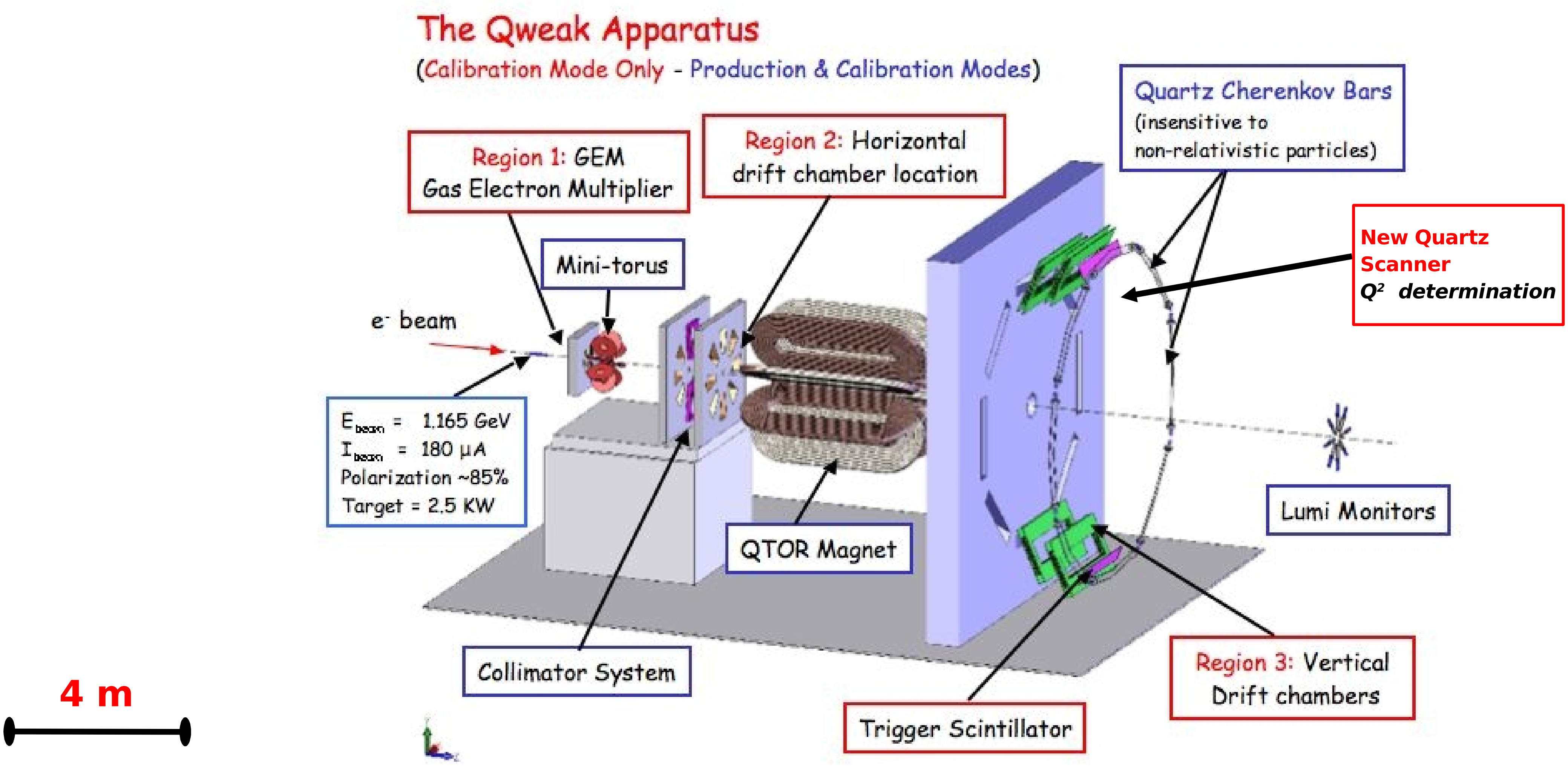


Production Mode: Actual asymmetry measurement

180 μA electron beam, high detector rate, current mode readout

Calibration Mode: Background and Q^2 determintation

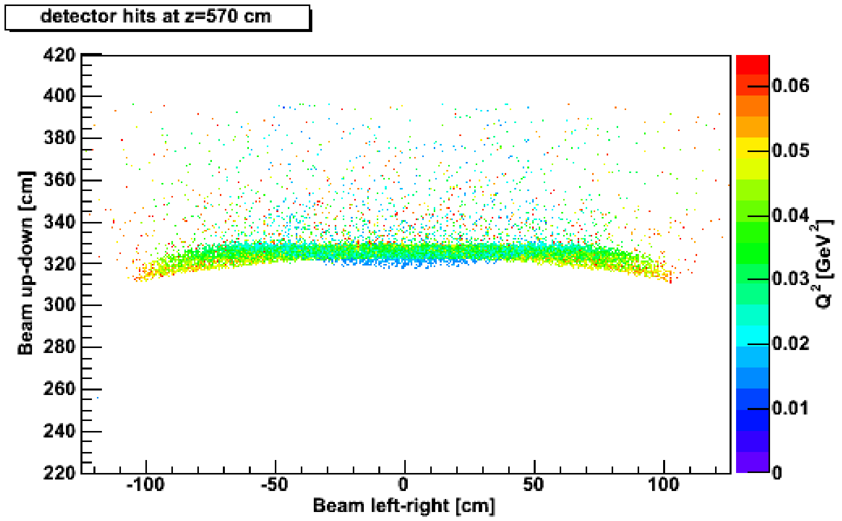
Low current (~ 10 nA), low detector rate, pulsed mode readout

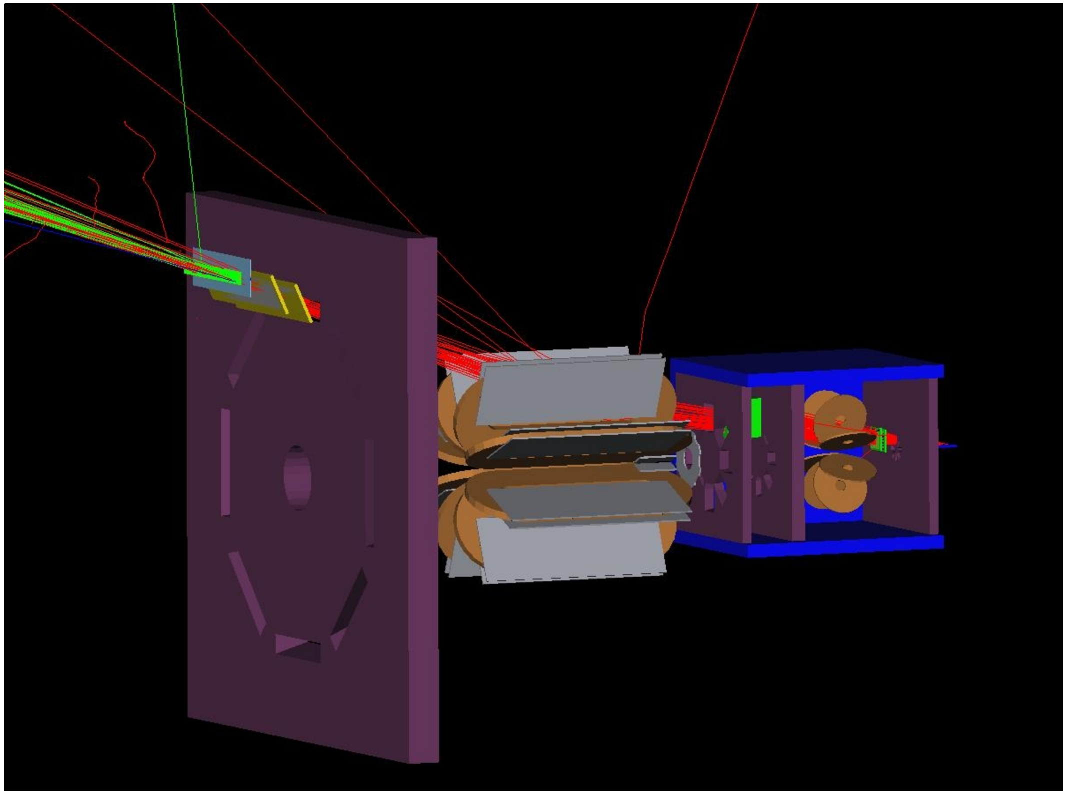


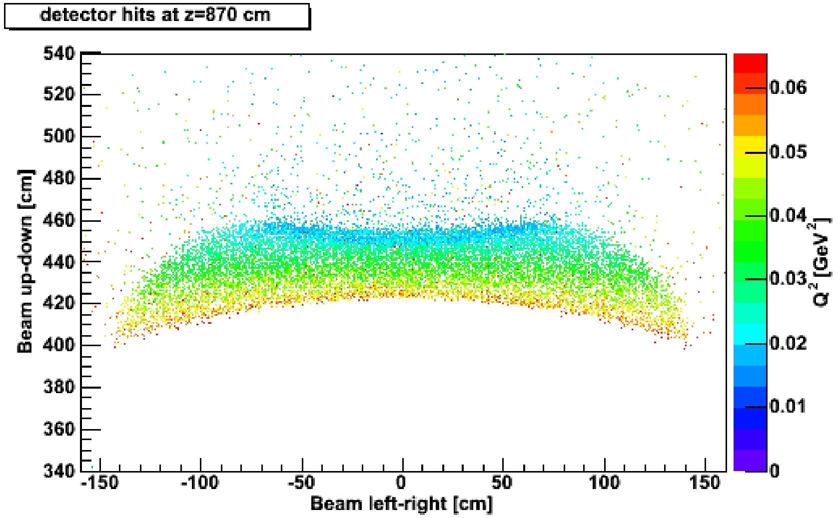
Collimator/Detector size and position studies (JLab, VT, U. Manitoba)

Together with the main magnet and the "mini" torus, the 3 collimators have been designed to focus only the elastic electrons onto a detector size and position that is optimized for:

- **Elastic rate maximization**
- **Exclusion of inelastic electrons**
- **Magnet position and field integral error insensitivity**
- **Background suppression**







Central scattering angle: ~8.4° ± 3°

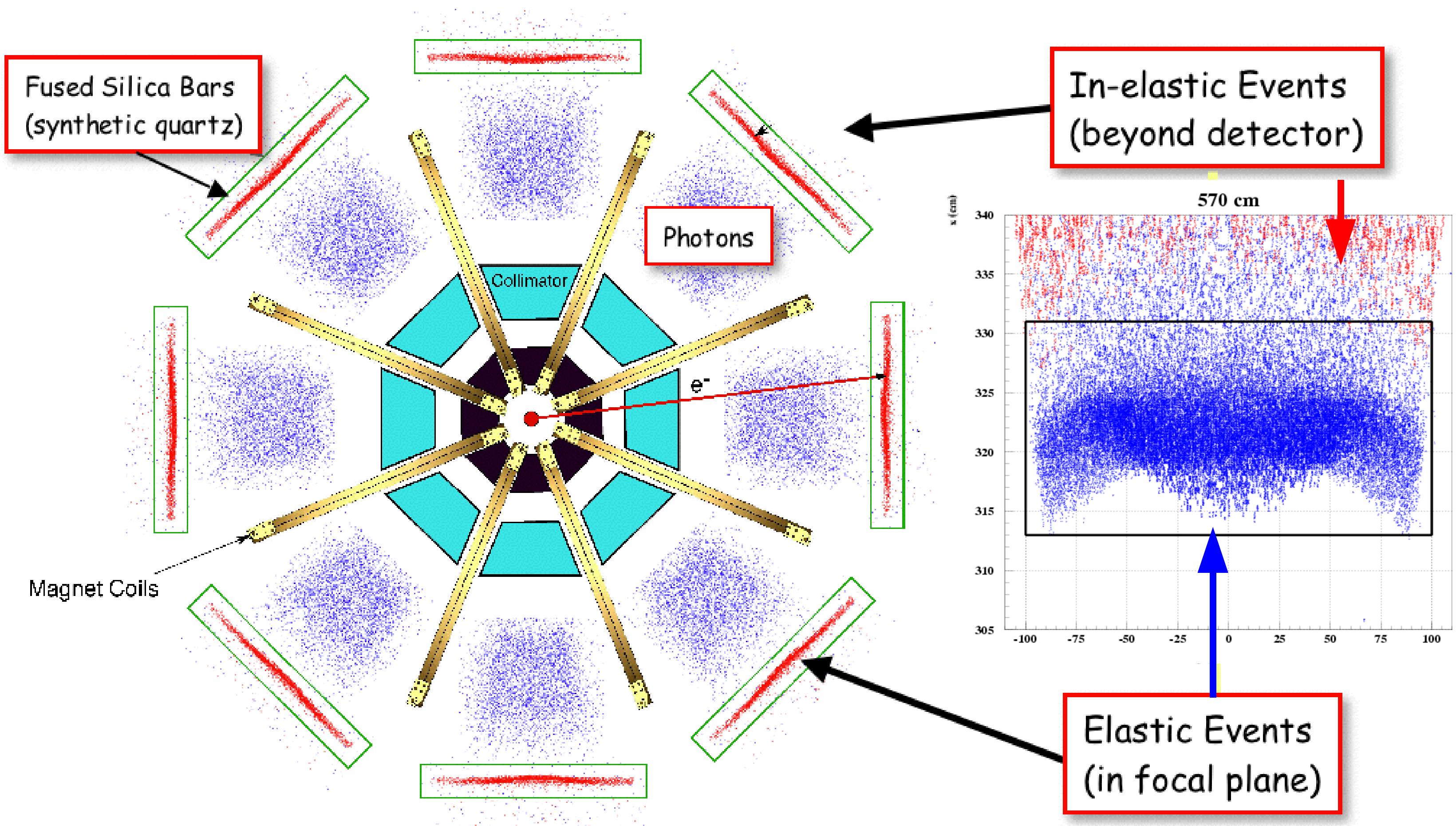
Phi Acceptance: > 50% of 2π

Average Q^2: 0.030 GeV^2

Acceptance averaged asymmetry: –0.29 ppm

Integrated Rate (per detector): ~801 MHz

Inelastic/Elastic ratio: ~0.026%



Black region in center
is Pb shielding

Beam / Source properties for Qweak

Qweak needs high polarization at high current (This is new, but...)

Solutions: Install fiber-based laser for high power and reliability
Install install load locked gun to facilitate the rapid (hours rather than days) exchange of photocathodes without the need for bakeout.

Beam polarizations of 85% are now typical and 80% can be guaranteed.

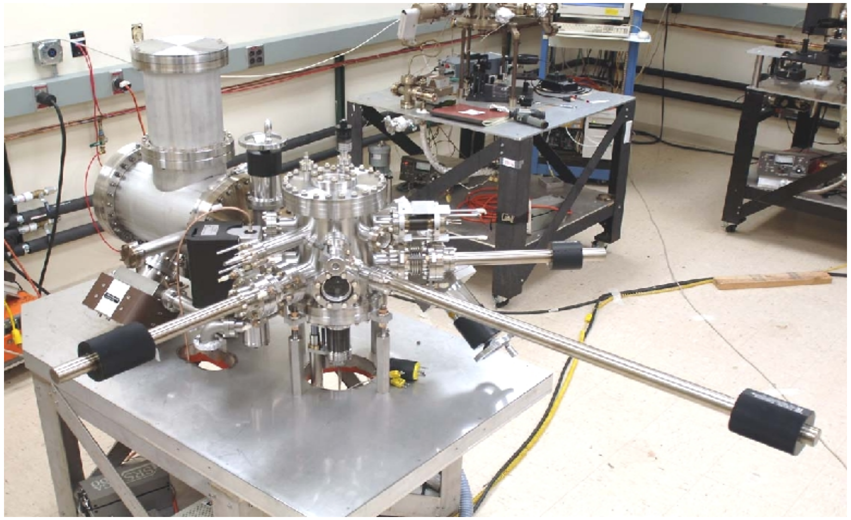
Parity Quality:

Qweak requires run-averaged helicity correlated

position asymmetry: 20 nm

current asymmetry: 0.1 ppm

HAPPEx 2004 and 2005 runs achieved 1 nm and 0.1 ppm respectively



Helicity Correlated Beam Properties: False Asymmetry Corrections (D. Mack)

$$A_{meas} = A_{phys} + \sum_{i=1}^{N} \frac{1}{2Y} \left(\frac{\partial Y}{\partial P_i} \right) \Delta P_i$$

$$Y = \mathrm{Detector Yield}$$

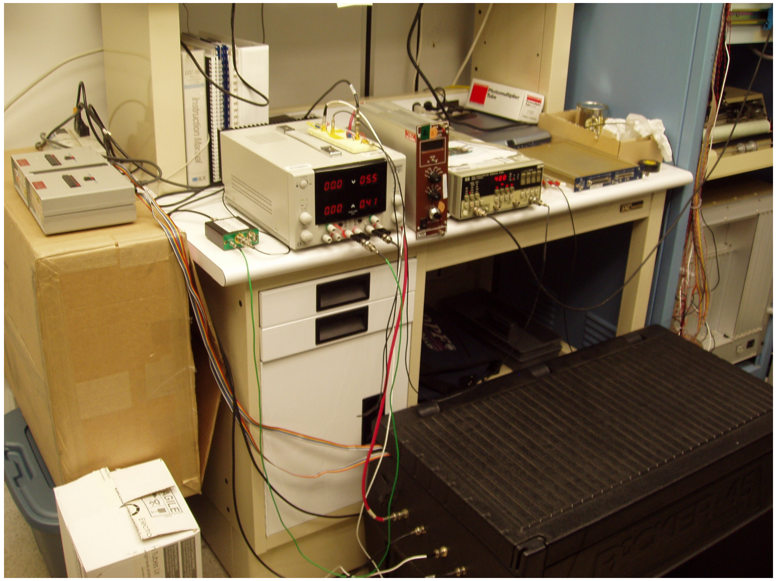
$$\Delta P_i \equiv P_{i,+} - P_{i,-}$$

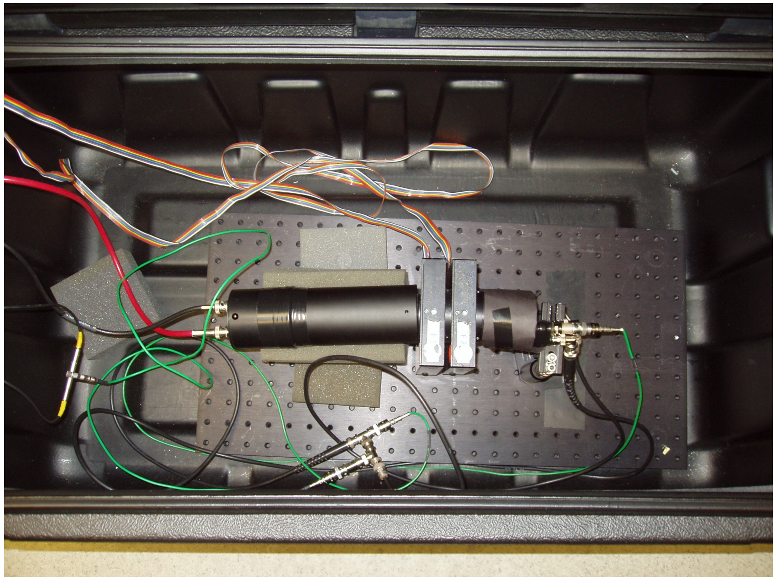
(*P* = beam parameter ~ energy, position, angle, intensity)

$\Delta P_i \equiv P_{i,+} - P_{i,-}$ → **keep small with feedback and careful setup**

$\frac{1}{2Y} \left(\frac{\partial Y}{\partial P_i} \right)$ → **keep small with symmetrical detector setup**

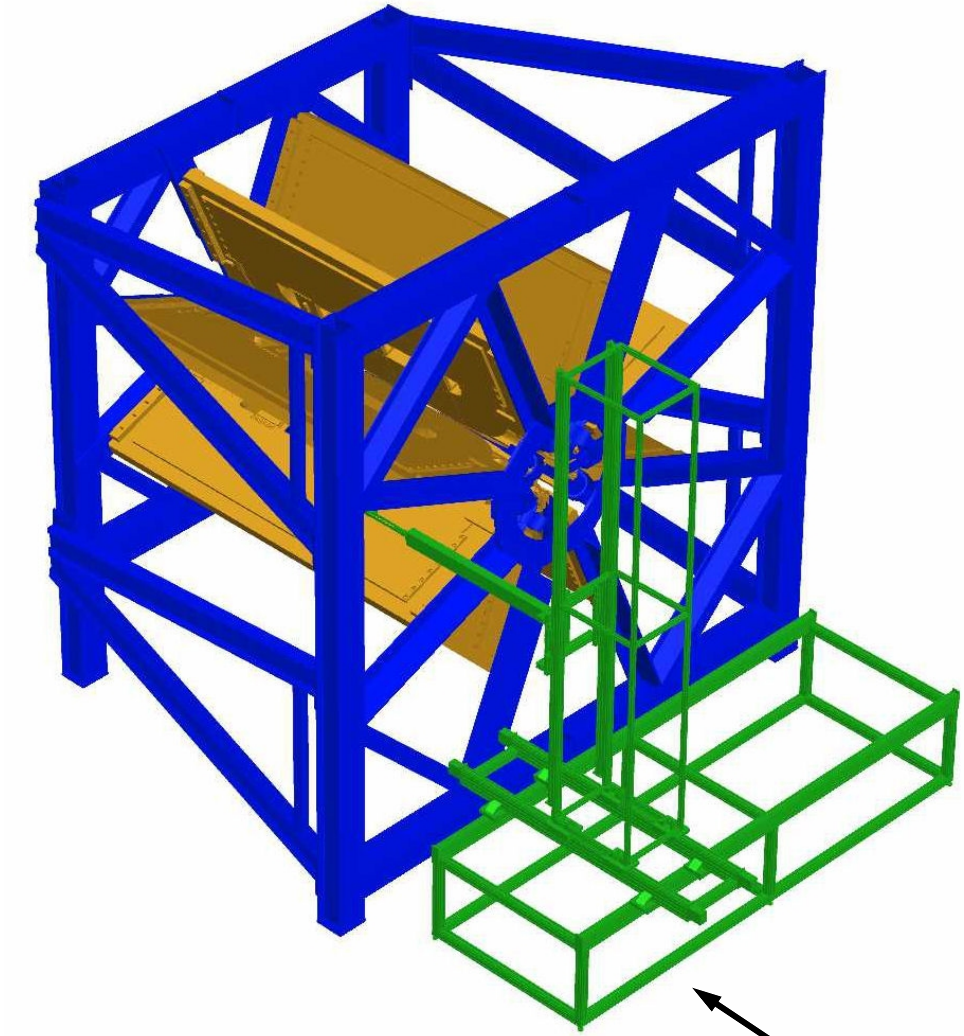
Use luminosity monitors to check for helicity correlated beam parameter corrections: (Riad Suleiman, Virginia Tech.)





“QTOR” Spectrometer Magnet

U of Manitoba / TRIUMF / UNBC



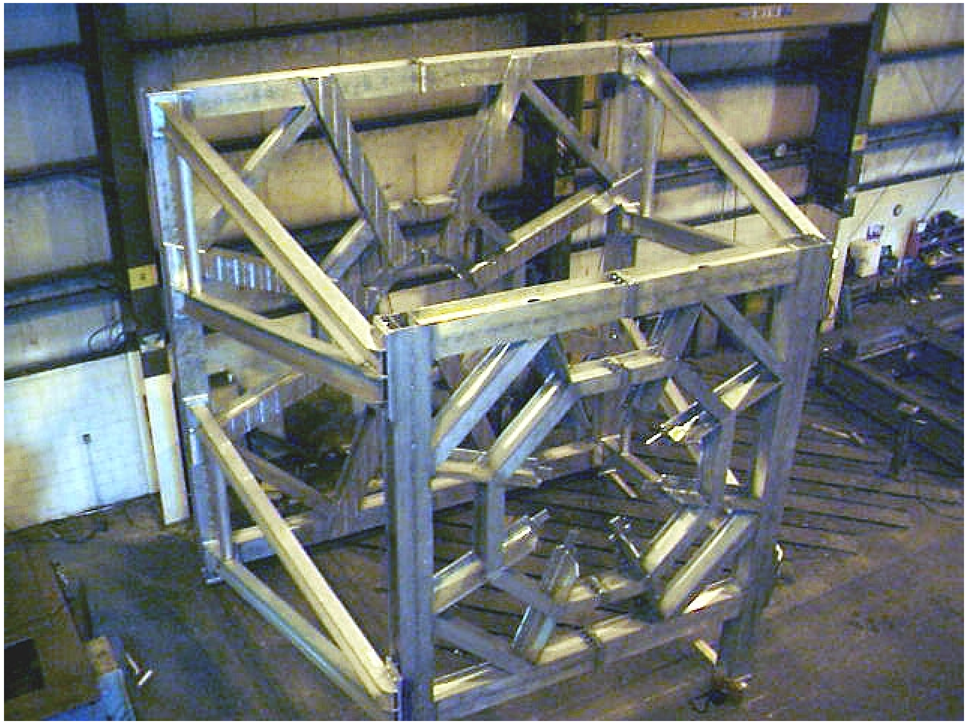
- 8 sector toroidal magnet
- water cooled copper coils
- 9500 A, 1.5 MW maximum
- 4.3 m long, 1.5 m wide coils, simple racetrack shape
- ~3300 kg per coil
- Field mapping with TRIUMF field mapping equipment.

$$\int B \cdot dl = 0.89 \text{ T.m}$$

TRIUMF field mapper used on G zero

All magnet and stand parts are now at MIT/ Bates

- assembly started at MIT
- power supply ordered
- power-up October 2007
- Field map Fall 2007
- deliver to JLab in 2008



Detector Design (JLab, U. Manitoba, TRIUMF)

• Sensitive only to elastic electrons	Insensitive to π's , n's, and γ's (simulations underway)
• Operation at counting statistics	Need > 10 photoelectrons (sims. Predict ~40 pe's) Signal undiluted by showering, spallation, etc. PMTs out of the scattered beam envelope
• Stable performance	Mechanical integrity and optical transmission are rad-hard
• No pathological bias in Q^2	Q^2 preferably uncorrelated with detector (x,y) If correlated it must be straight forward to simulate (simulations under way)

Tasks completed or well under way:

• Detector size and position studies	Optimize for maximum rate / minimum background
• Detector thickness studies	Optimize for maximum light yield / minimum noise
• Detector tilt or rotation angle studies	Optimize for maximum light yield / minimum Q^2 bias
• Soft photon background studies	How many can we expect at what energy (scintillation)?
• Background shielding (pre-radiator) studies	Can we shield with a pre-radiator? At what cost (noise))?
• Light guide, PMT position and yield studies	How to get the PMTs out of the beam and keep the yield
• PMT base design and tests	Gain and dark current optimization, linearity and noise

Soft photon background

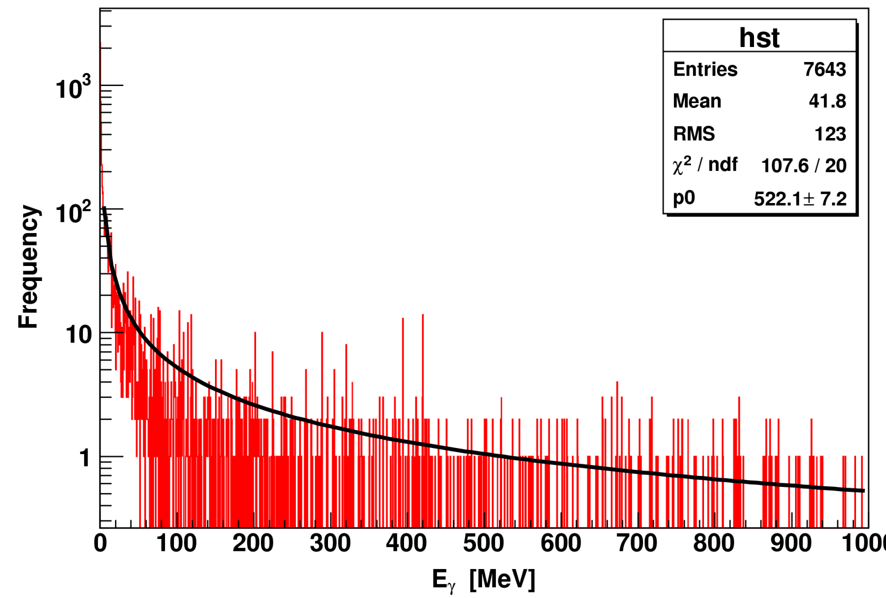
The 10 keV to 1 MeV photon rate is as high as the elastic electron rate !

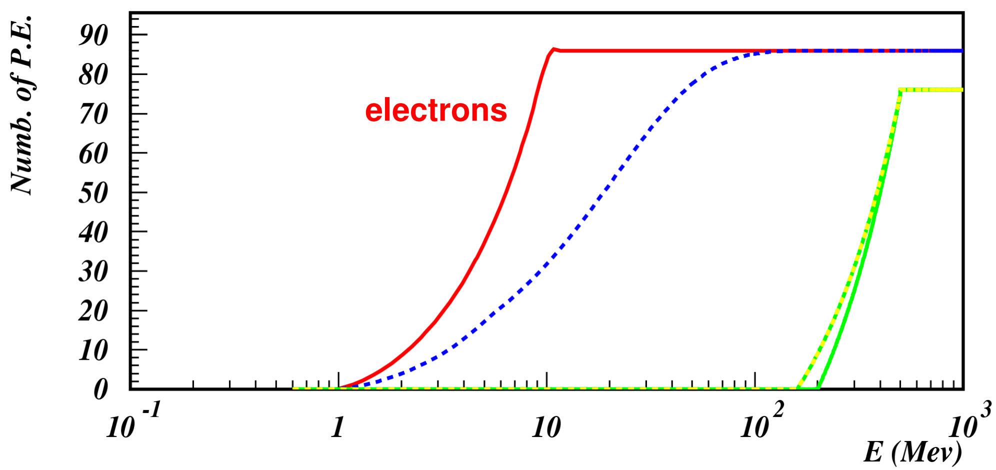
Photons with E < 10 keV mostly stopped in detector housing or wrapping.

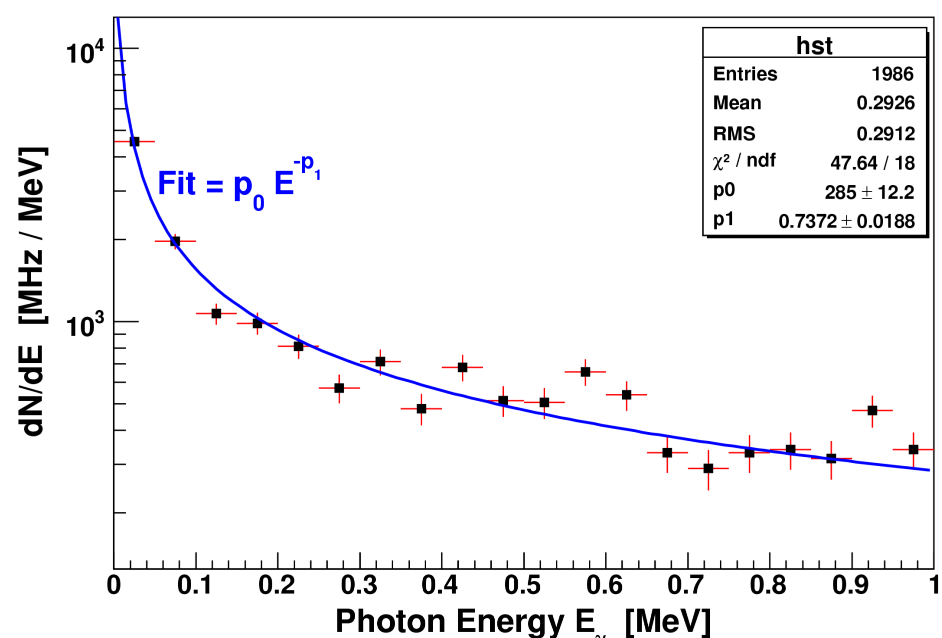
Photons with 10 keV ≤ E < 1MeV potentially stopped in the detector.

Photons with E ≥ 1 MeV deposit ~10%.

Photons with E ≤ 10 MeV produce ≤ 30% of electron Cherenkov light (photon rate is down by 2 orders of magnitude for E ≥ 10 MeV).







Soft photons produce a ~1% background which may be difficult to measure.

Scintillation light yield could get us if the rates are too high (tests are in progress).

Detector Size : 200 cm x 18 cm x 1.25 cm
PMT + Base Size : 13.5 cm diameter x ~ 40 cm

Space constraint **mount PMTs at 90 degrees to detector surface and mirror the edges.**

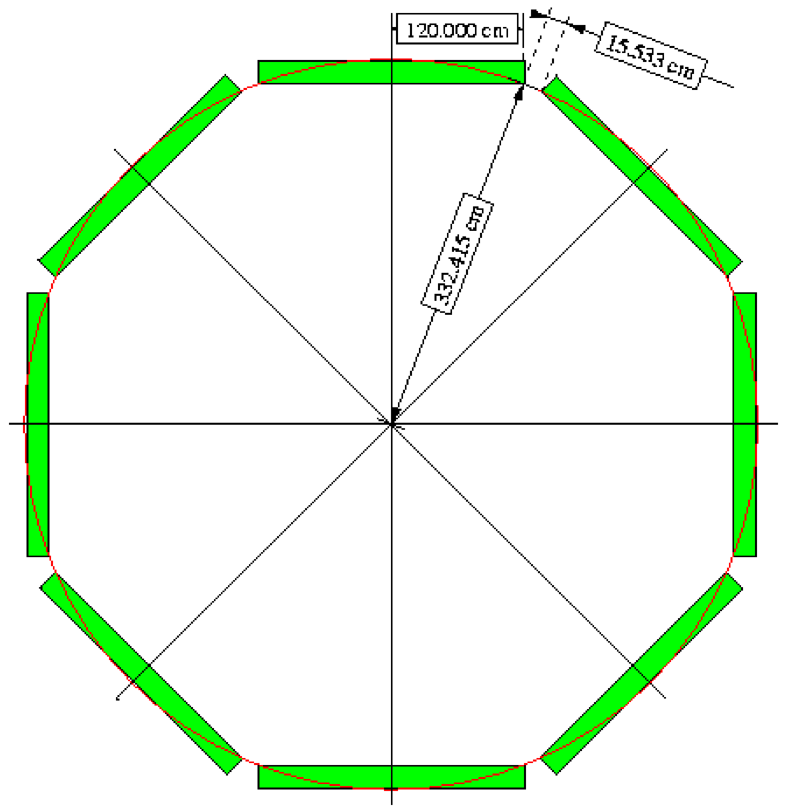
All PMTs are at Jlab and have undergone initial testing

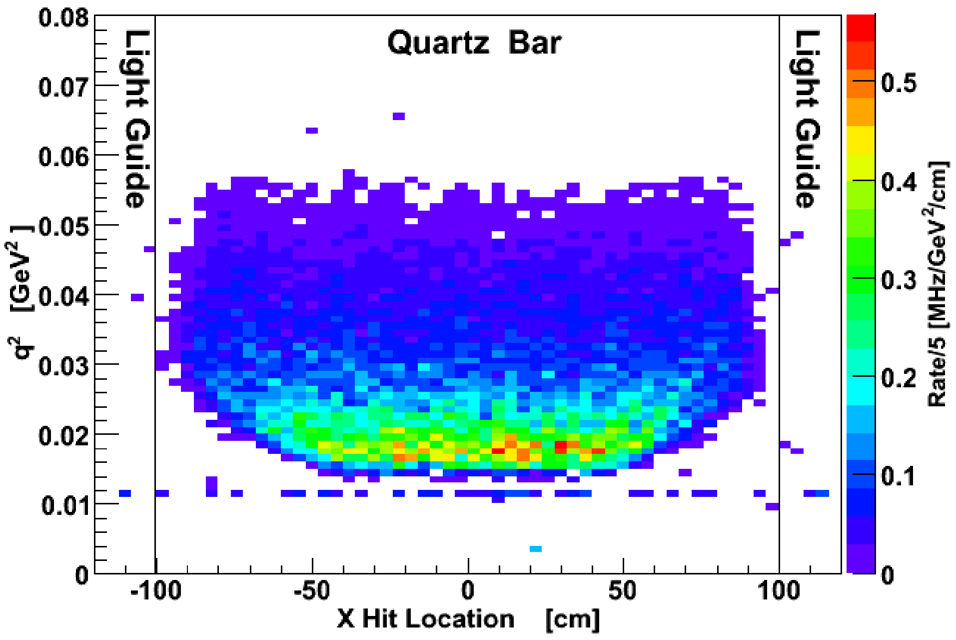
All 19 meter long quartz bars are now at Jlab

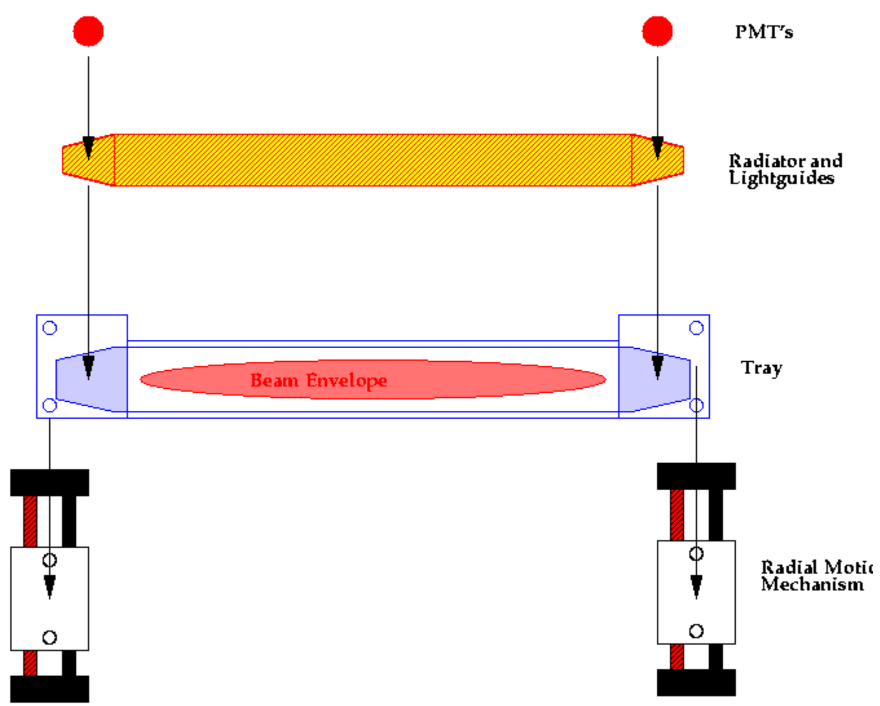
Rectangular 18 cm x 18 cm light guides are on order

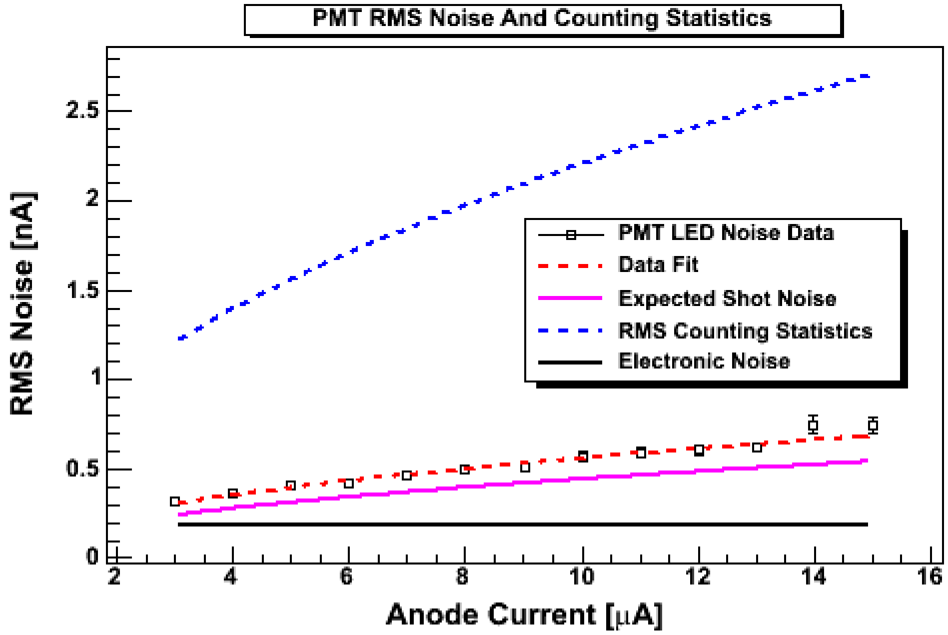
Extensive PMT property , quartz scintillation and QA tests and glue tests have been done or are underway

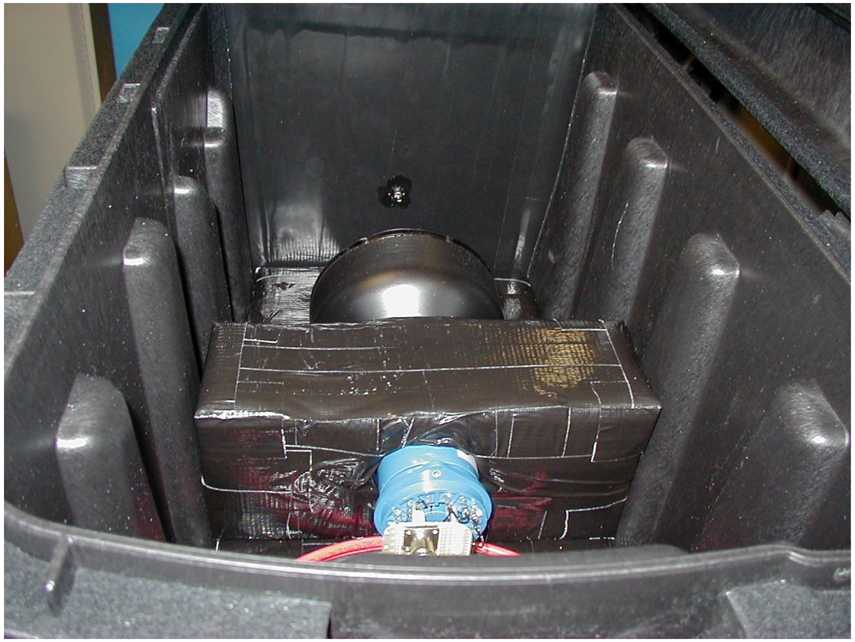
Expected date of completion before 12/2008

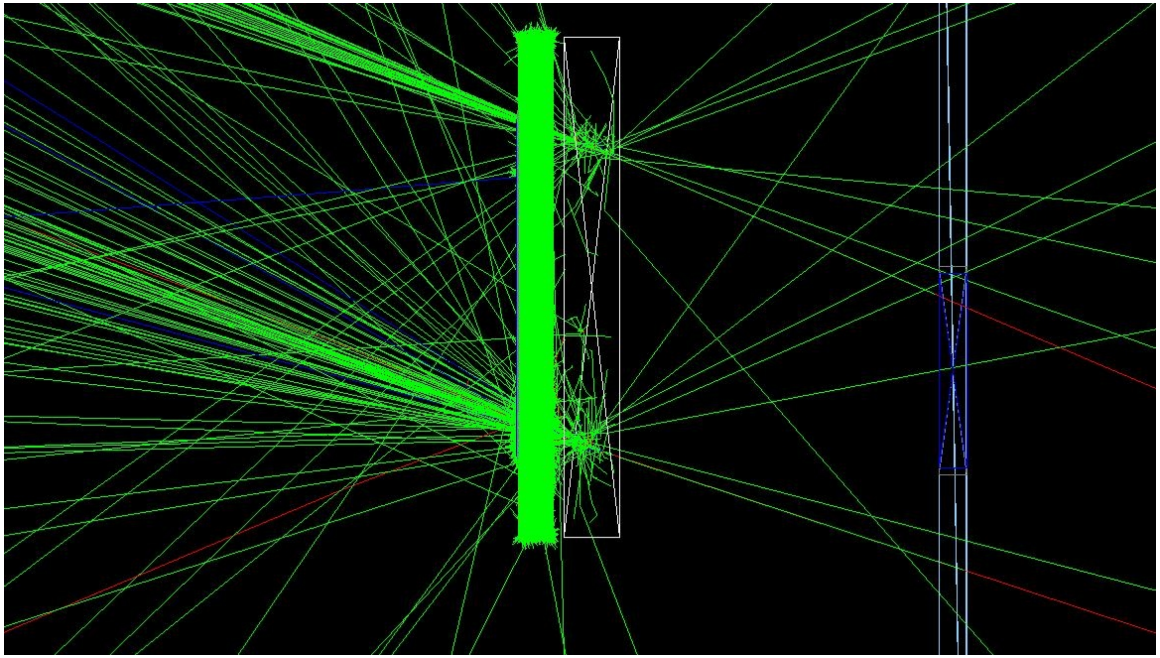


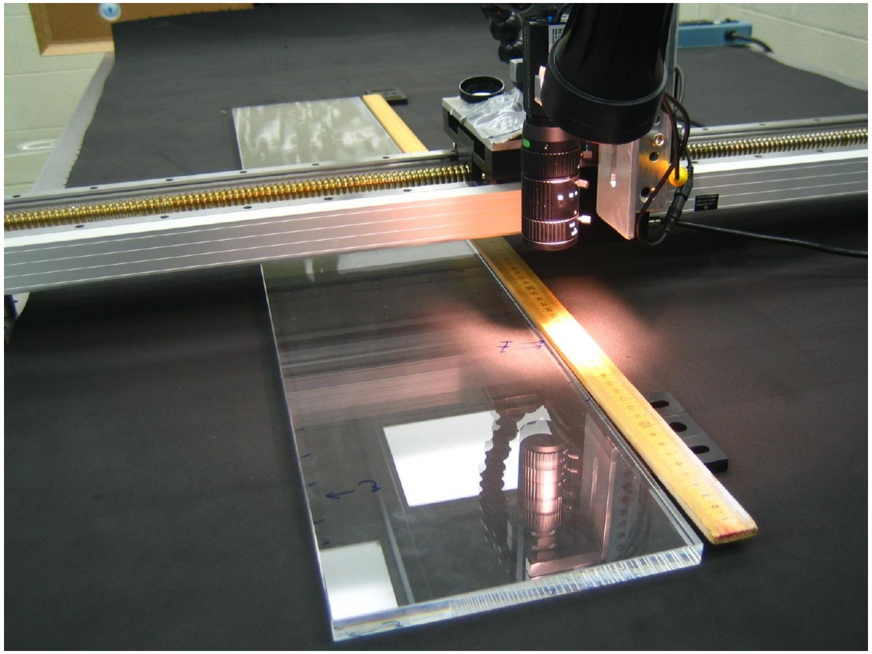




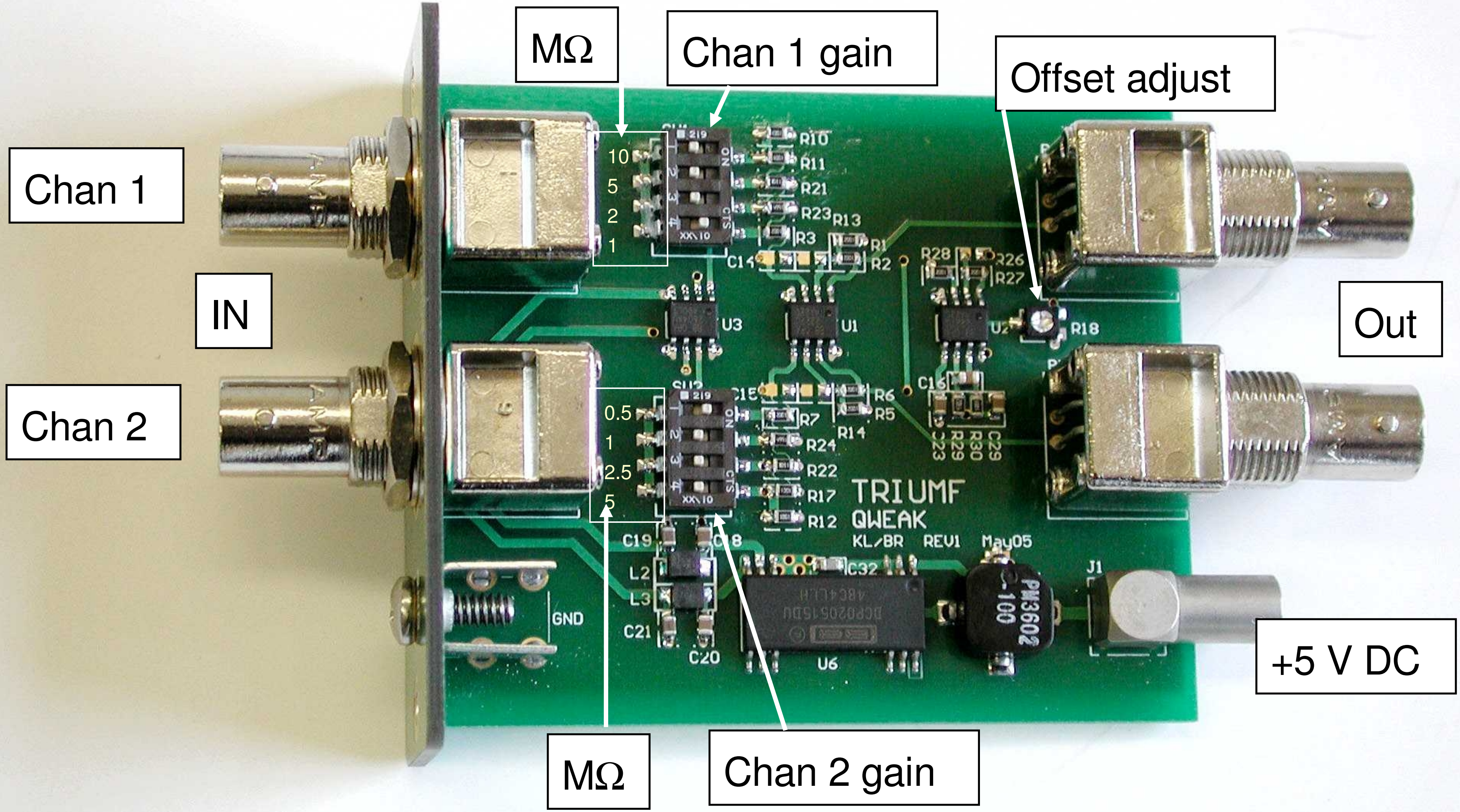

PMT RMS Noise And Counting Statistics
RMS Noise [nA]
Anode Current [μA]
PMT LED Noise Data
Data Fit
Expected Shot Noise
RMS Counting Statistics
Electronic Noise
0
0.5
1
1.5
2
2.5
2
4
6
8
10
12
14
16







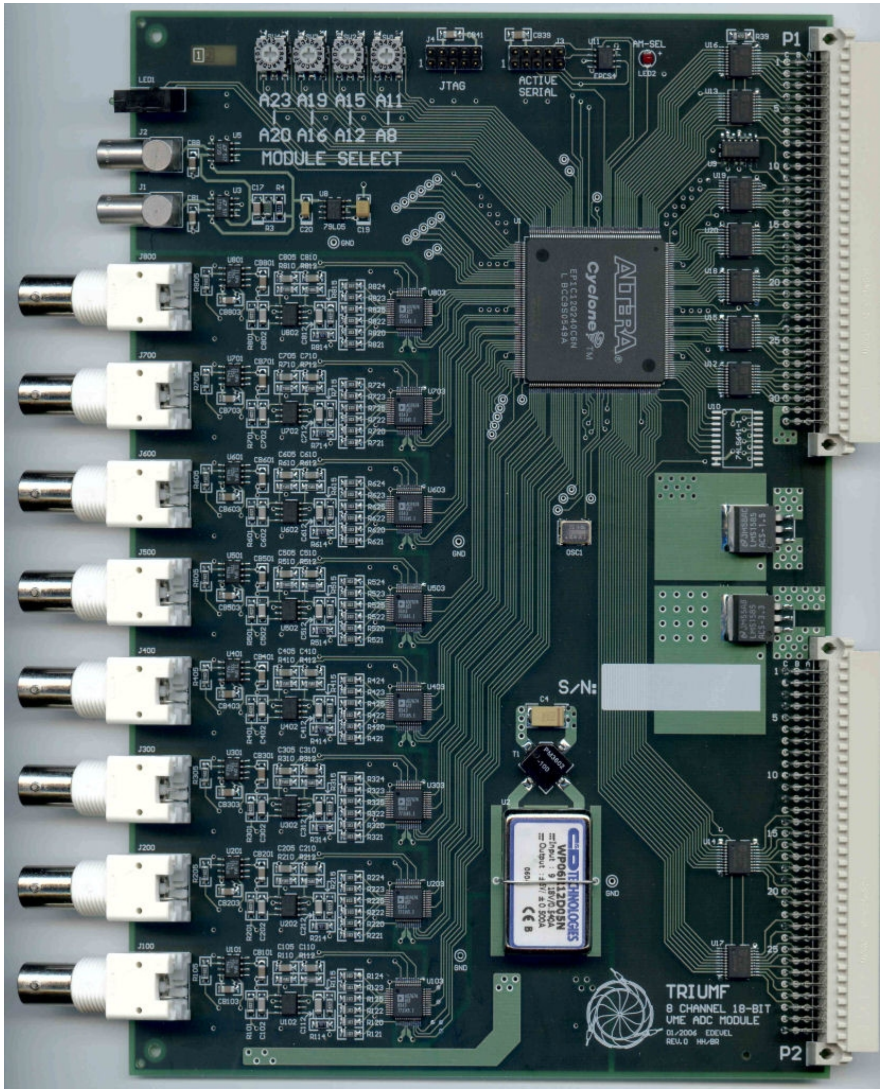
MK2 Preamplifier



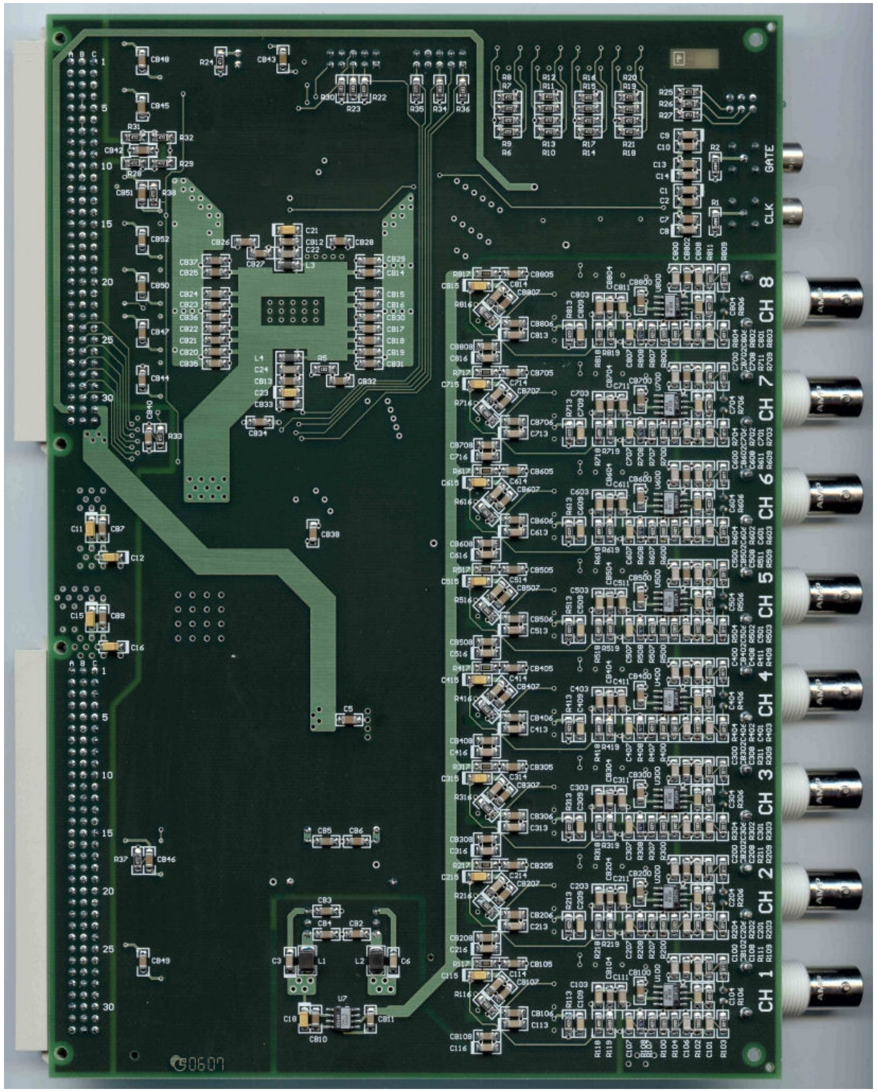
- Reduced power supply noise
- Switchable gains

Prototype TRIUMF VME integrator

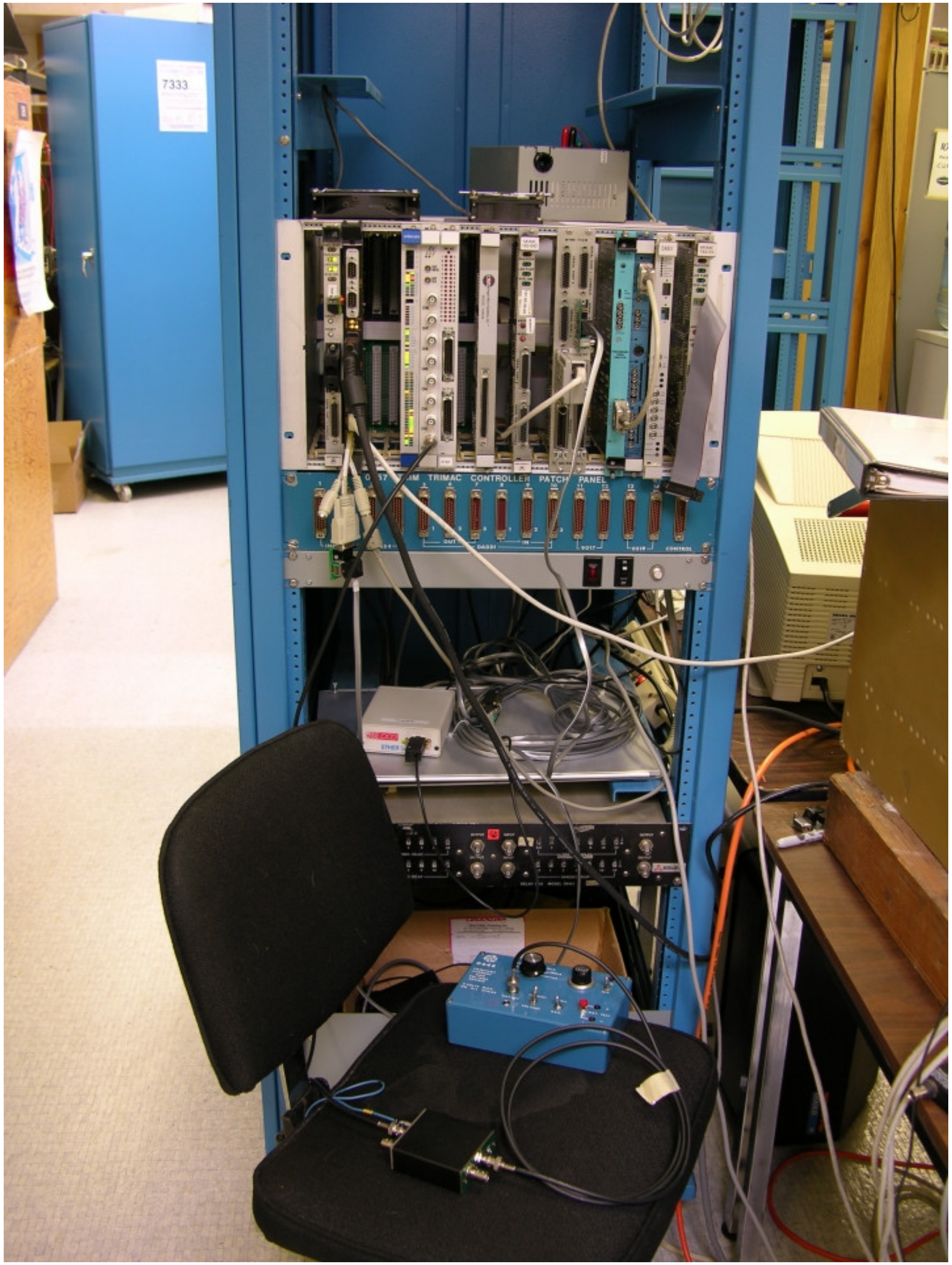
component side:

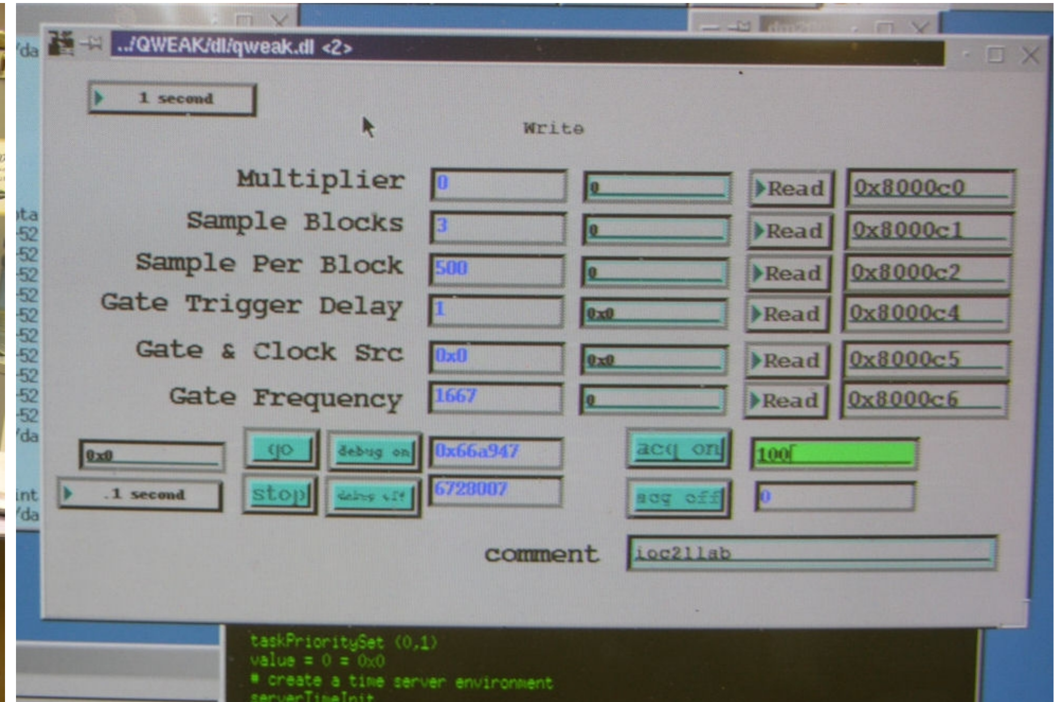


solder side:



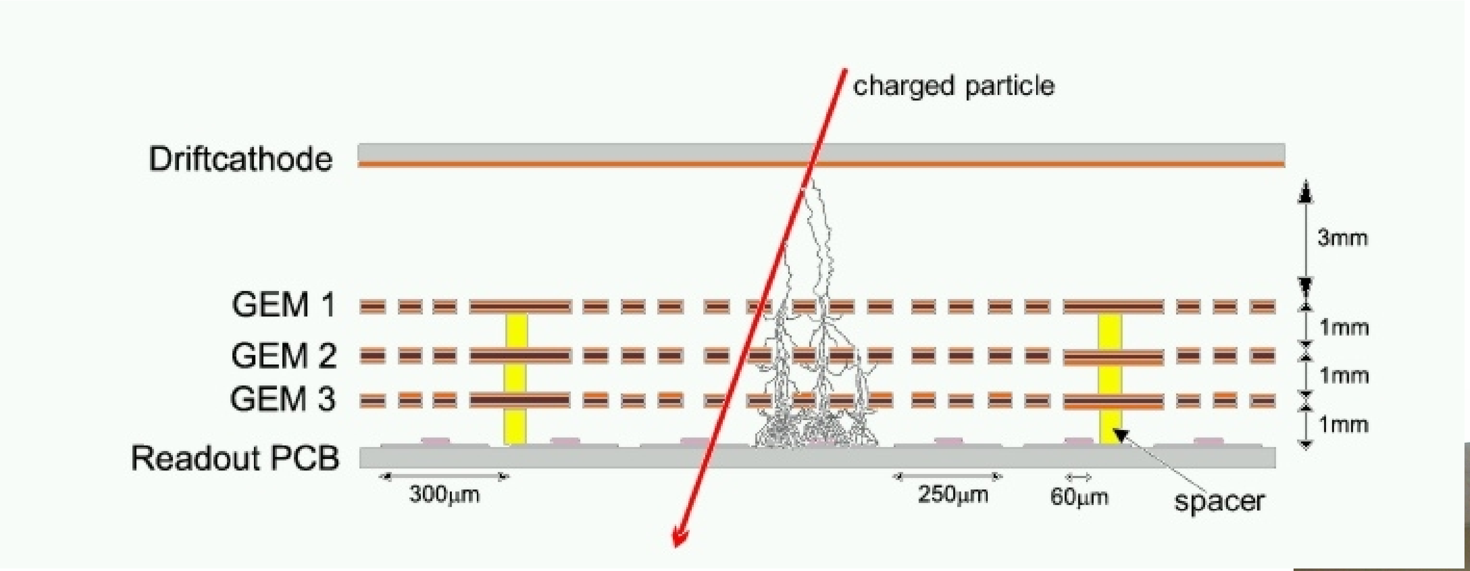
VME integrator tests at TRIUMF

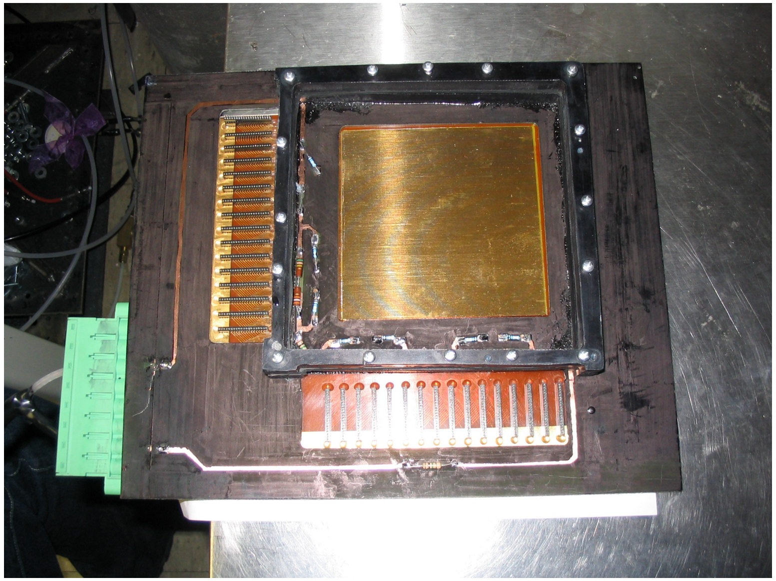




- Analog input range: -10 V to +10 V
- Front-end ADC: 500 ksps
- 4 ms integrals stored as 4 x 1ms blocks
- Shown here with 6μA current source and 200 pf cable.

Region 1 GEM detectors (Louisiana Tech/ Iowa)





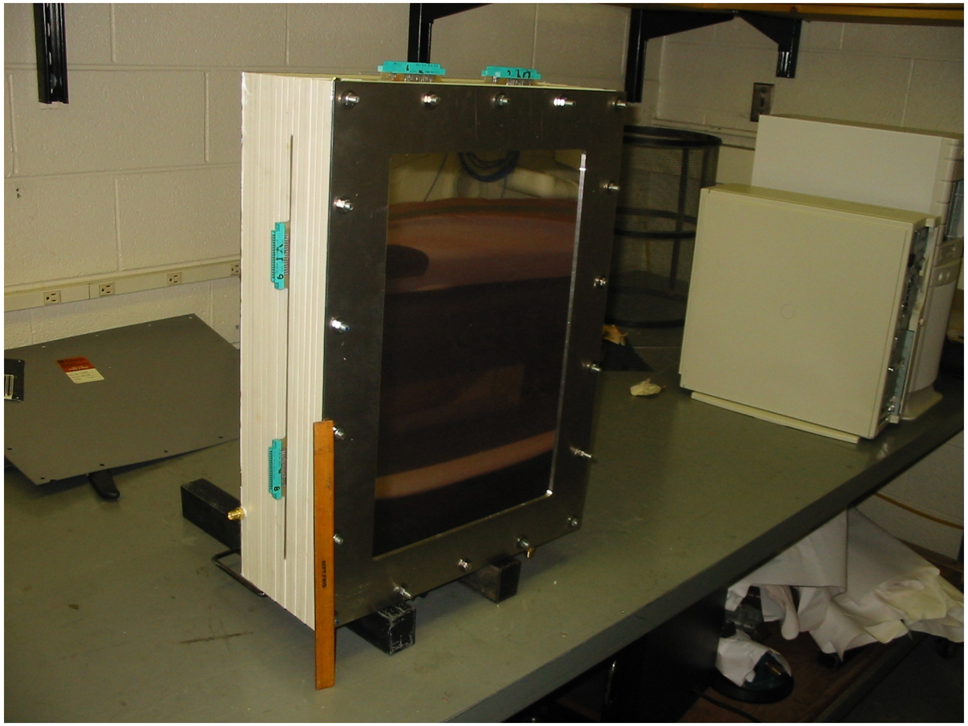
GEM detectors to arrive at Jlab in January 2009

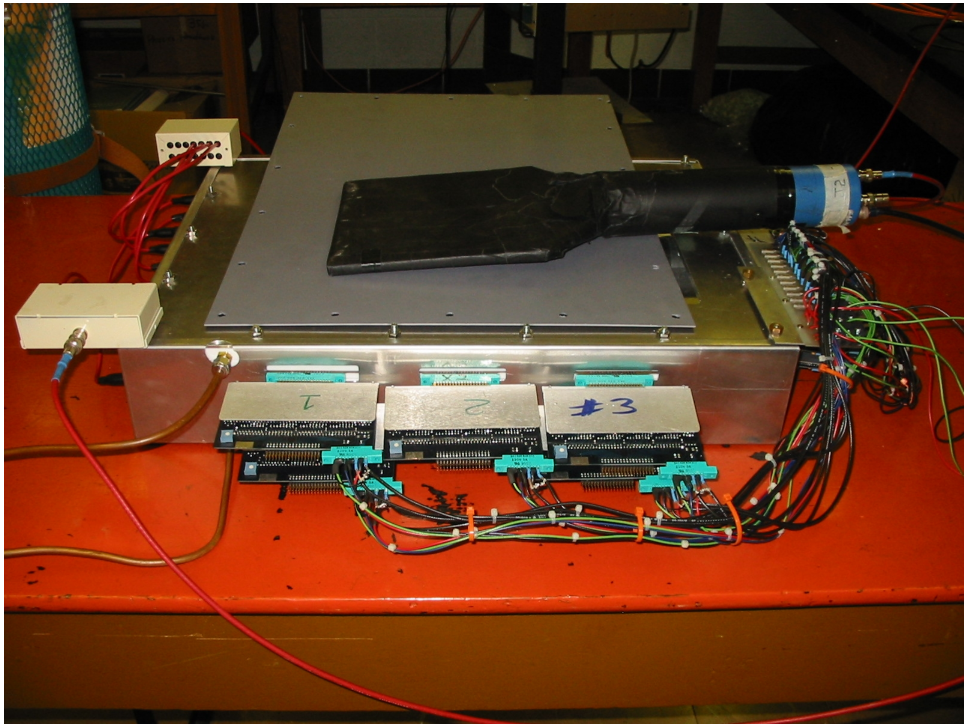
Region2 HDC Tracking Chambers (Virginia Tech.)

Full size chamber has been build with four active wire planes

Prototype testing to be completed in early 2007

Start production in 2007

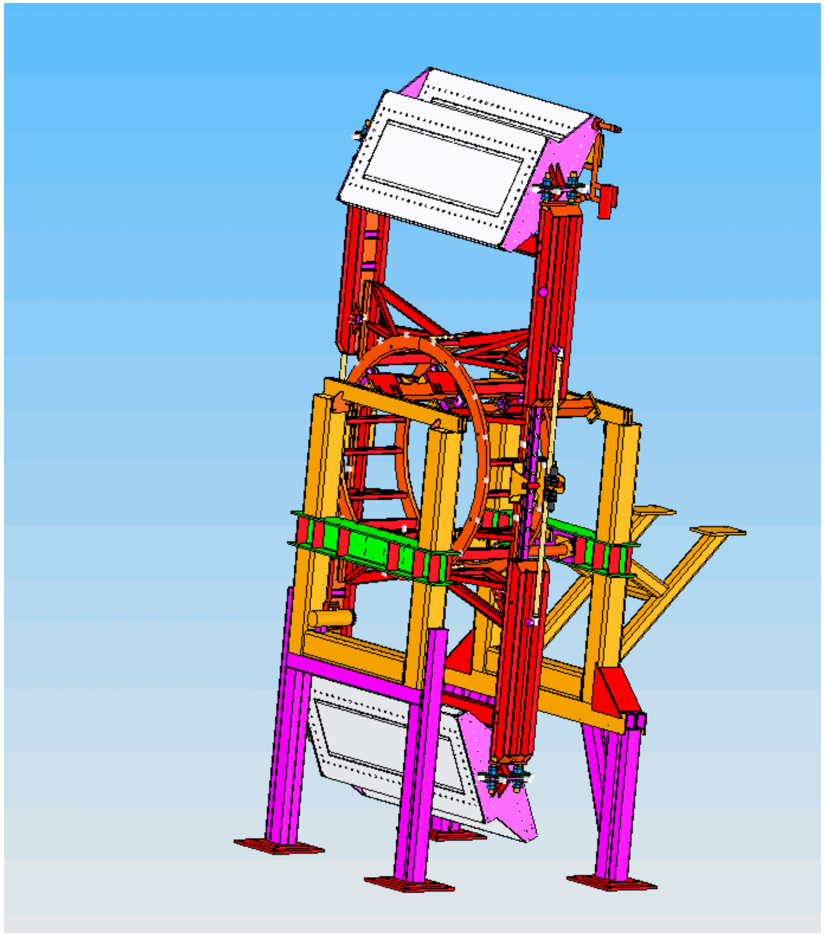




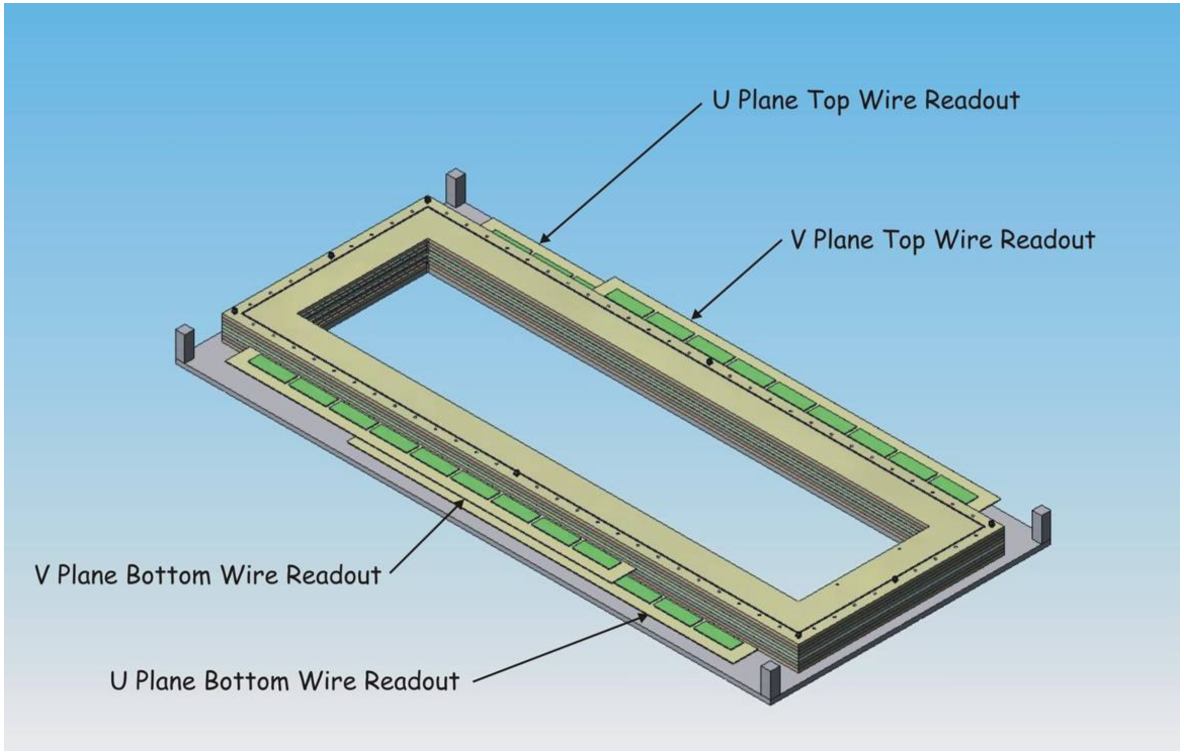
Region 3 VDCs and Rotator Mounting (W&M)

- 1st VDC : Apr-June 07
- Testing : July (mainly gas flushing, HV training, first wire signals)
- 2nd VDC: July-Aug 07

- 3rd VDC : Sep-Oct 07
- 4th VDC : Nov-Dec 07

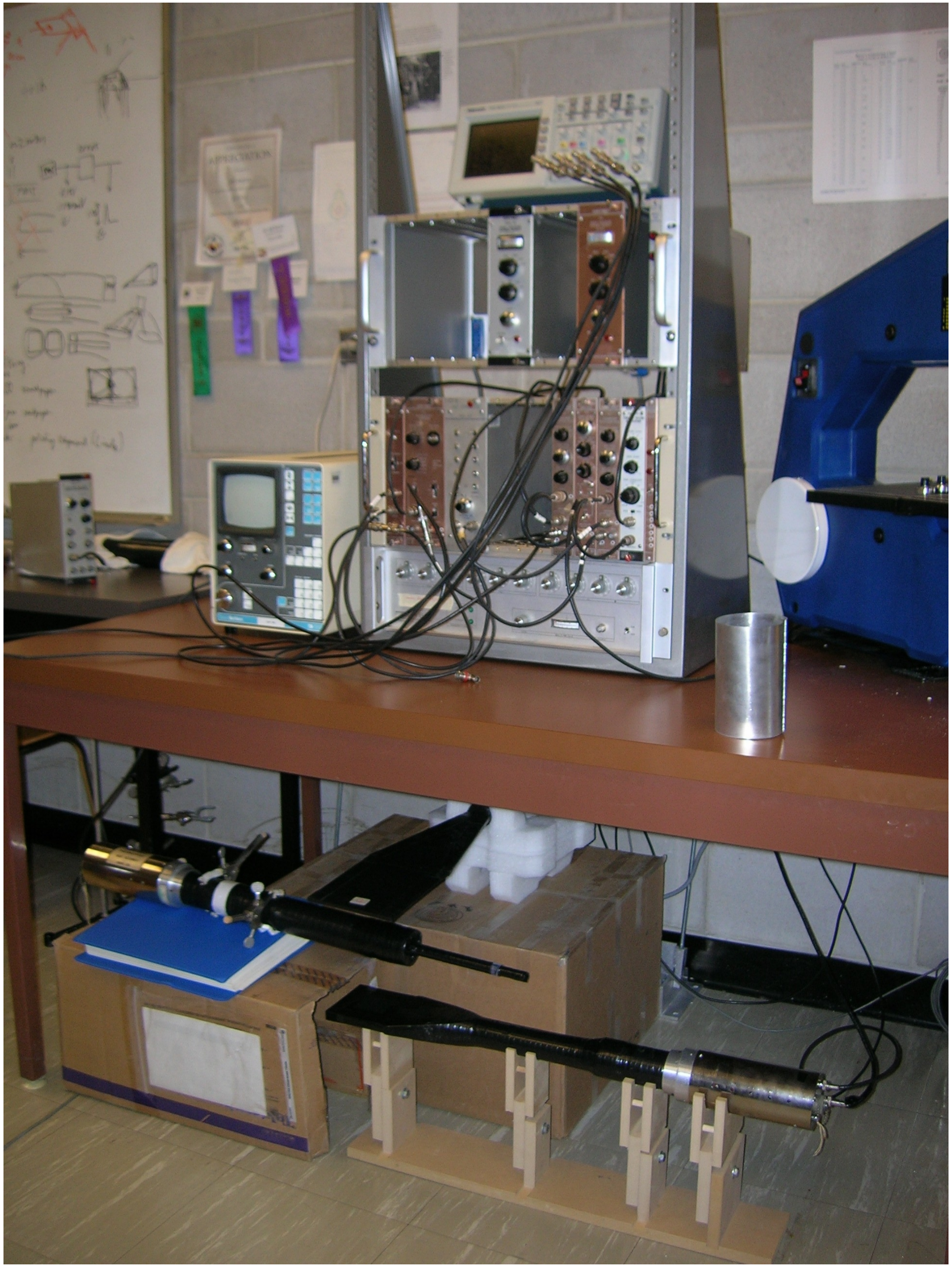


Expected delivery to JLab in 2008



Quartz Scanner Prototyping Tests (U. of Winnipeg) (U. of Manitoba)

- MCA reads out shaped pulse height.
- Begun work with small scintillator samples. (Plan to transition to quartz)
- Begun work with high reflectivity light pipes.
- Electronics to be replaced with CFI funded detector lab.



Summary

- Simulations for Beamline Design (Juliette Mammei, VT)
- Background Simulations (GWU, VT, U. of M. etc...)
- Tracking/Reconstruction Software (B. Stokes, GWU)
- DAQ and Analysis Software (Ohio Univ.)
- QTOR Magnet:
  - Coil and Coil Carrier fabrication complete - NSERC - delivered to MIT/Bates site.
  - Magnet support structure construction complete - Jlab - delivered to MIT/Bates site.
  - General purpose 2 MVA power supply under fabrication.
- Target:
  - Fan prototyping underway. Flask concepts developing. Heat exchanger design underway
  - Solutions for achieving the necessary cooling power developed.
  - Scattering chamber from Bates “SAMPLE Exp.” being recycled.
  - Concept target motion design completed.
- Detector System:
  - Electronics (18 bit ADC’s and I-to-V’s) in production at TRIUMF.
  - All 5’ photomultipliers delivered. All 19 of the quartz bars have been delivered.
  - Detailed collimation, shielding and detector optimization/simulation ongoing.
- Tracking / Calibration System:
  - Region I GEM nearly complete, a version of the GEM rotator built - La Tech.
  - Region II drift chamber testing underway - Virginia Tech.
  - Region III drift chamber stringing getting close - W&M.
  - Trigger counter prototype tests completed – OU & GWU
  - Region III rotation system designed and under procurement at W&M - NSF/Va State $’s
- Infrastructure:
  - Prototype collimator manufactured & measured. Final desgns being tweaked!
  - Master CAD layout/installation/integration drawings well developed.
  - MOU for MIT work on a Hall C Compton polarimeter making progress.

Thickness Study

Optimal quartz thickness based on excess noise simulations at 0 degree tilt-angle.

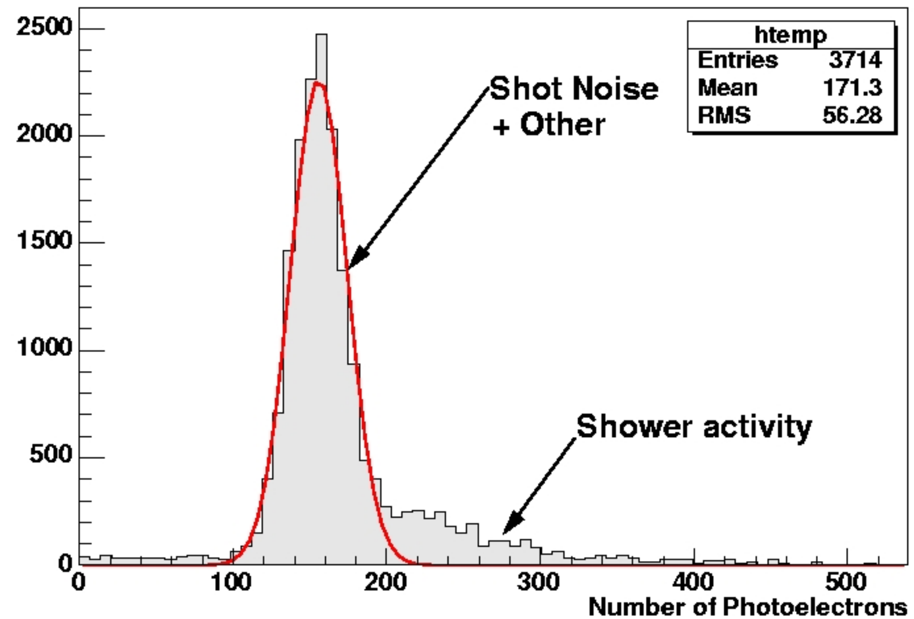
QWeak Statistical Error + Excess Noise:

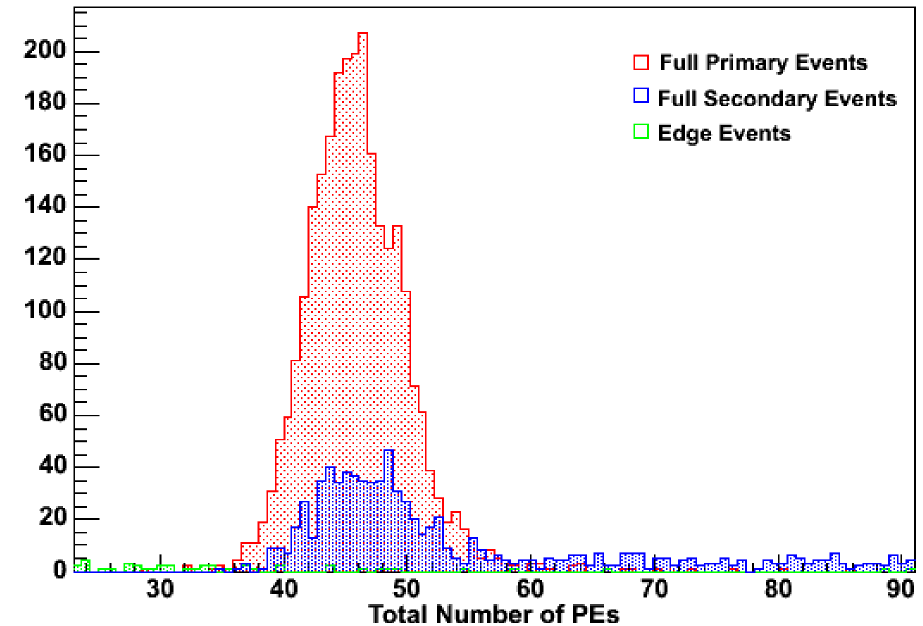
$$\sigma_A \simeq \frac{1}{\sqrt{N}}\sqrt{1+\frac{\sigma_q^2}{\langle q\rangle^2}}$$

Modeled as a contribution from photoelectron noise and shower noise:

$$\frac{\sigma_q^2}{\langle q\rangle^2} \simeq \frac{1}{n_{pe}l} + \alpha l.$$

Shower activity inside the detector increases with detector thickness.
The number of PEs will decrease as the detector is made thinner to suppress shower activity.
The two competing processes lead to an optimal detector thickness which minimizes the total excess noise.



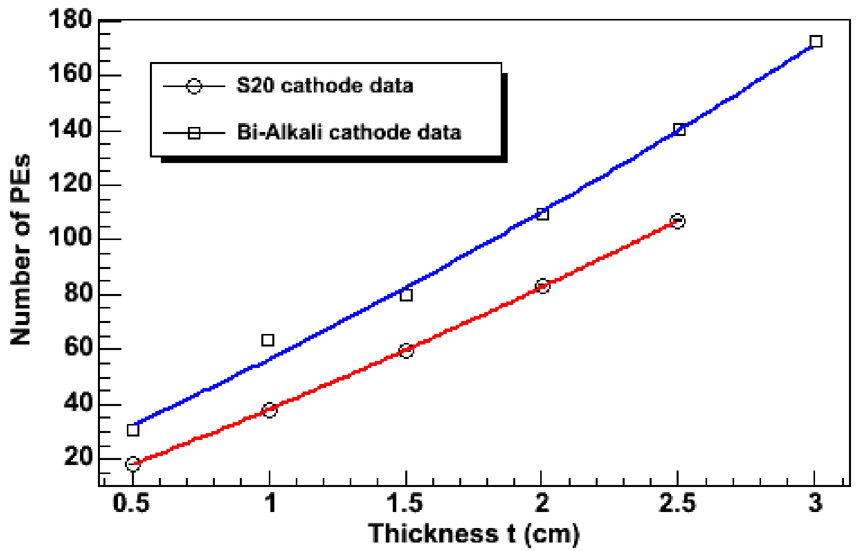


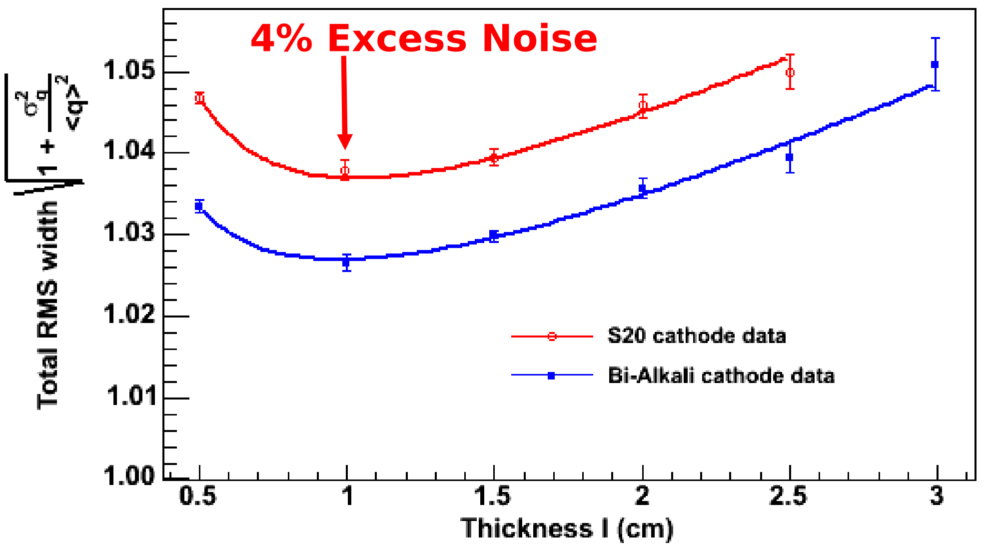
Bialkali Cathode

- $n_{pe} = 37 \pm 1.6 \quad [\mathrm{PEs/cm}]$
- $\alpha = 0.026 \pm 0.003 \quad [\mathrm{cm}^{-1}]$

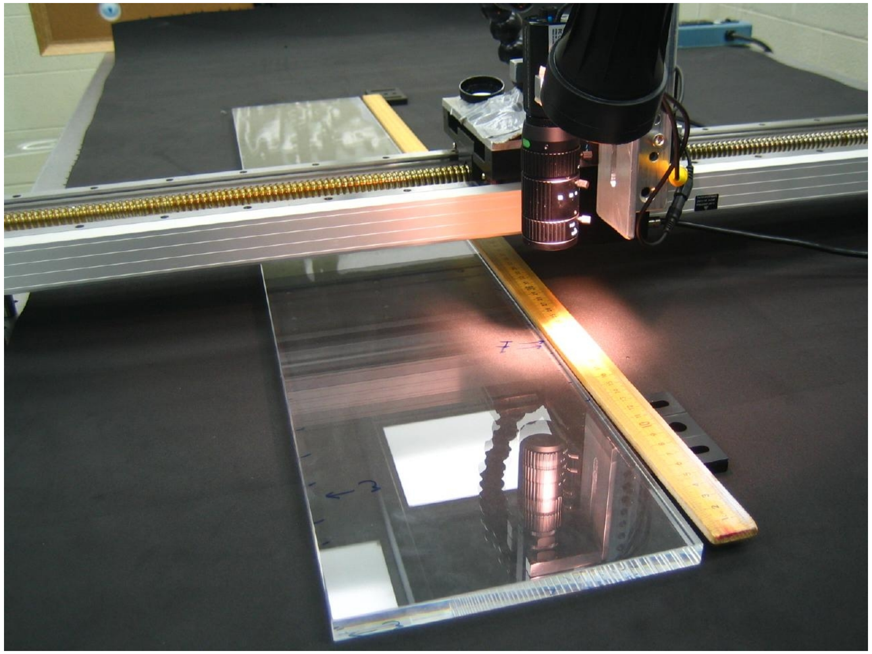
S20 Cathode

- $n_{pe} = 26 \pm 1.0 \quad [\mathrm{PEs/cm}]$
- $\alpha = 0.036 \pm 0.001 \quad [\mathrm{cm}^{-1}]$



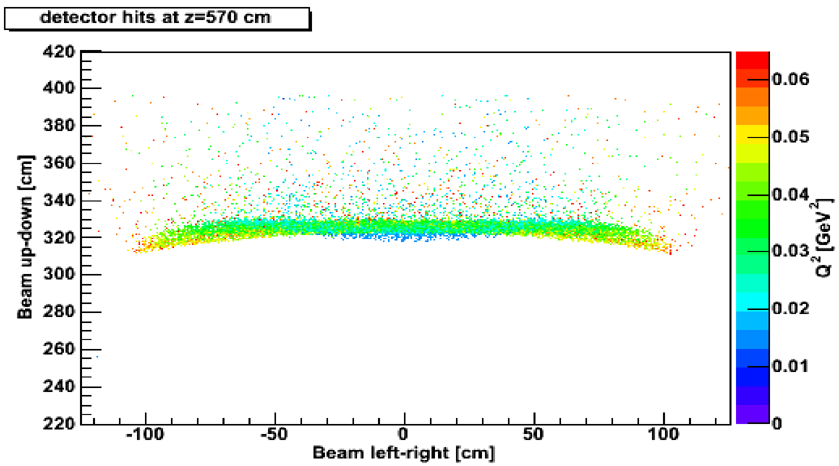


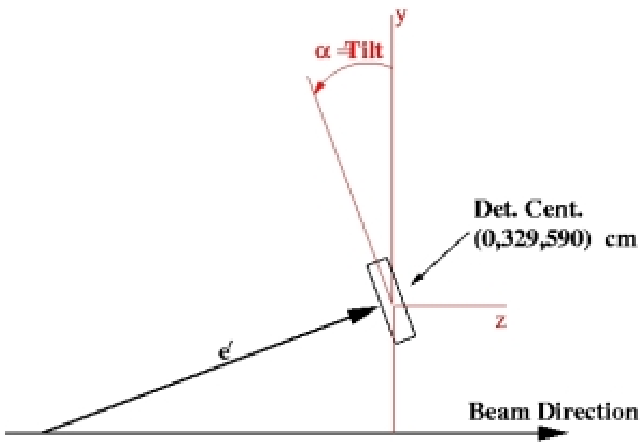
Detector thickness was selected at 1.25 cm

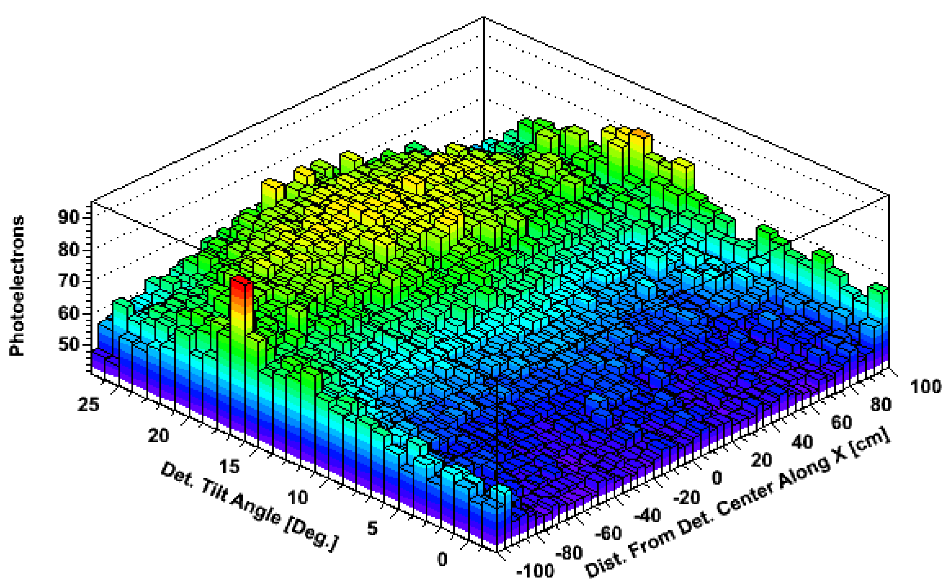


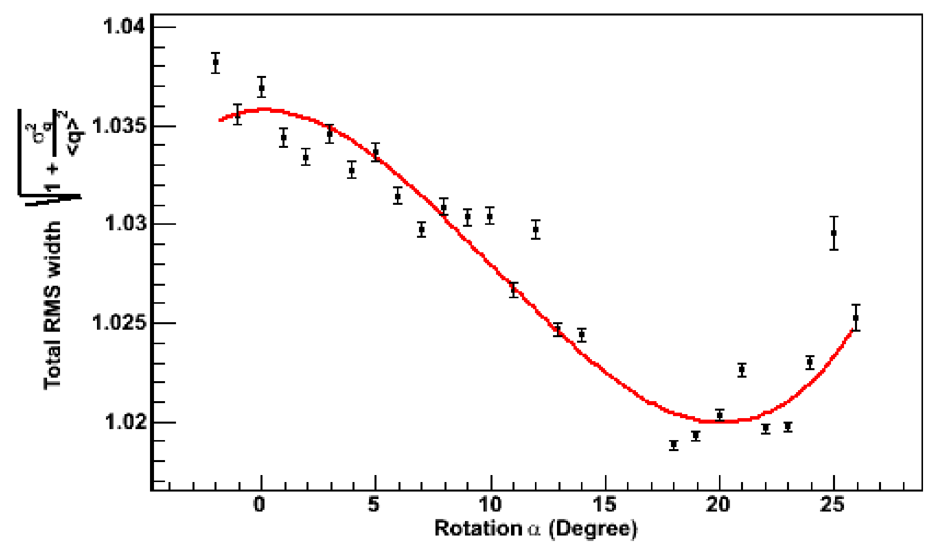
Tilt Angle Study

The optimal tilt angle is based on the excess noise seen as a function of detector angle and the light yield uniformity as a function of electron hit position along the length of the quartz bar, together with the Q2 distribution across the bar.









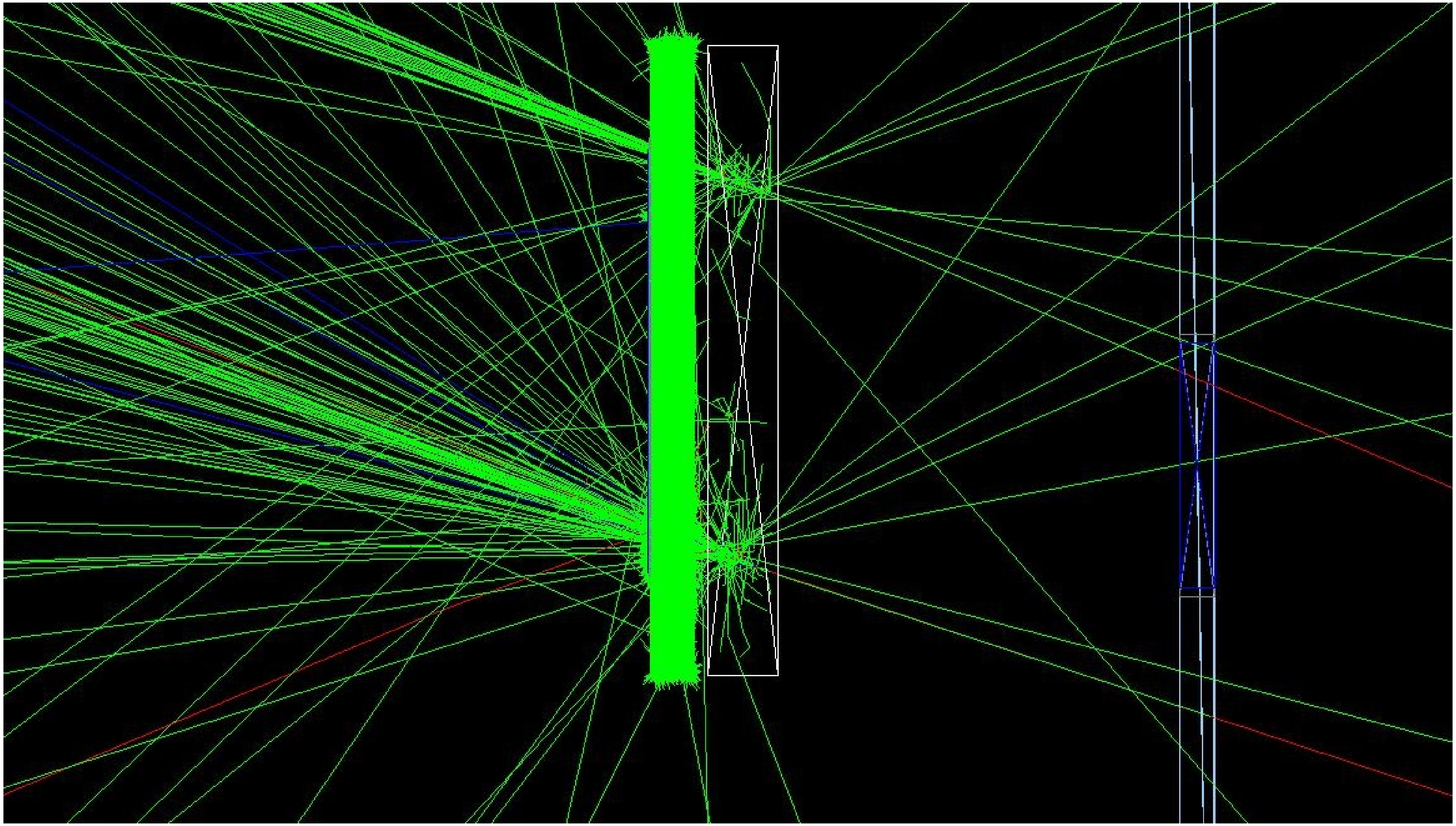
Excess noise varies by only ~1.5% over angle range

Lead Pre-Radiator Study

PLAN B

Can we cut soft photon background using a pre-radiator?

Questions: How thick does this radiator have to be? Can we live with the excess noise ?



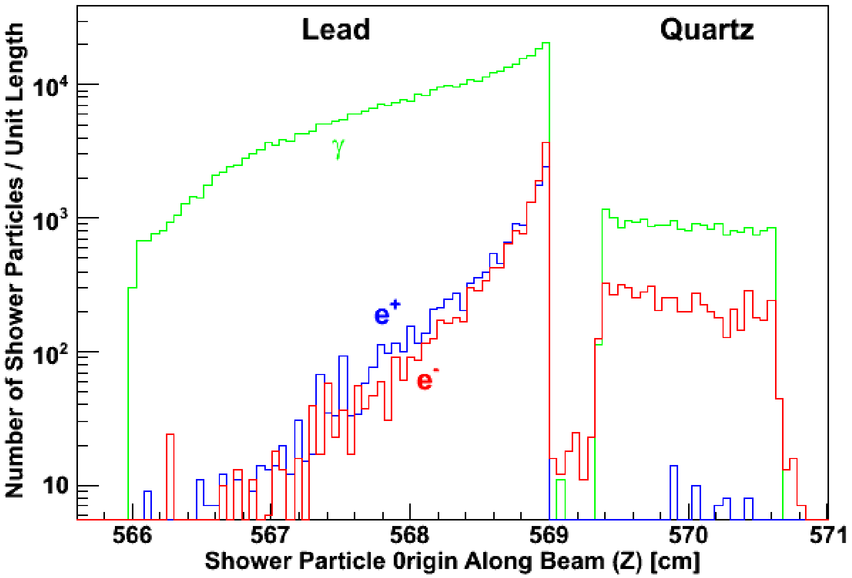
Simulate various radiator thicknesses and establish an ideal thickness that minimizes the excess noise while attenuating the soft photons:

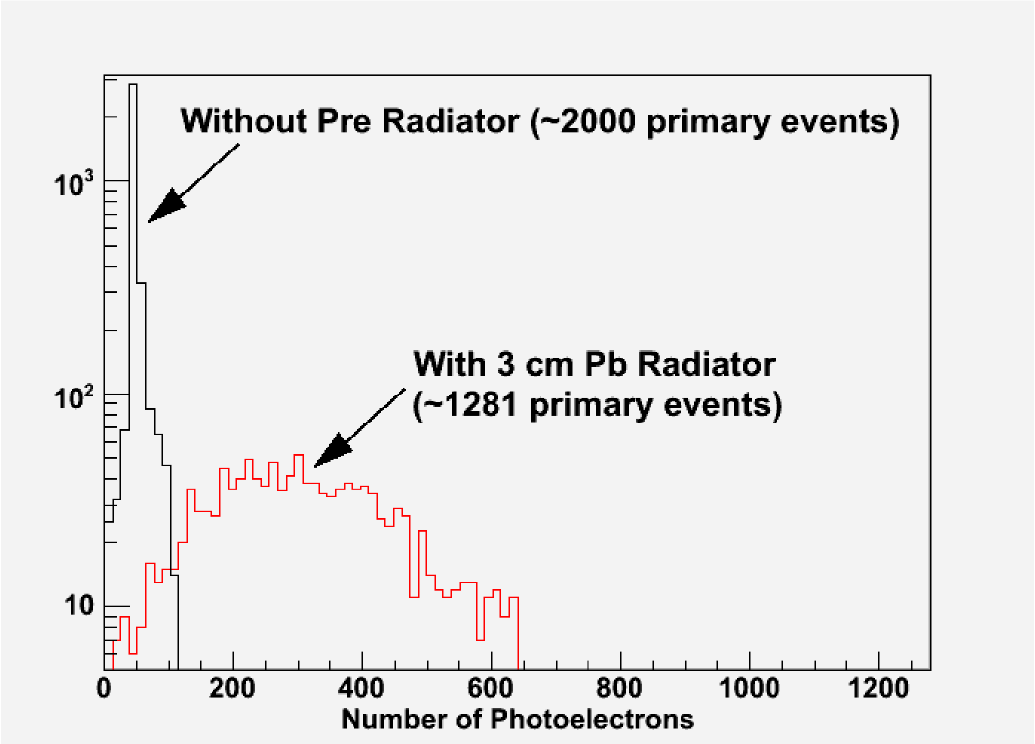
Excess noise – a function of photoelectron yield and shower size

$$\frac{\sigma_q^2}{\langle q\rangle^2} \simeq \frac{1}{n_{pe}l} + \alpha l$$

Overall asymmetry error with excess detector noise

$$\sigma_A \simeq \frac{1}{\sqrt{N}}\sqrt{1+\frac{\sigma_q^2}{\langle q\rangle^2}}$$



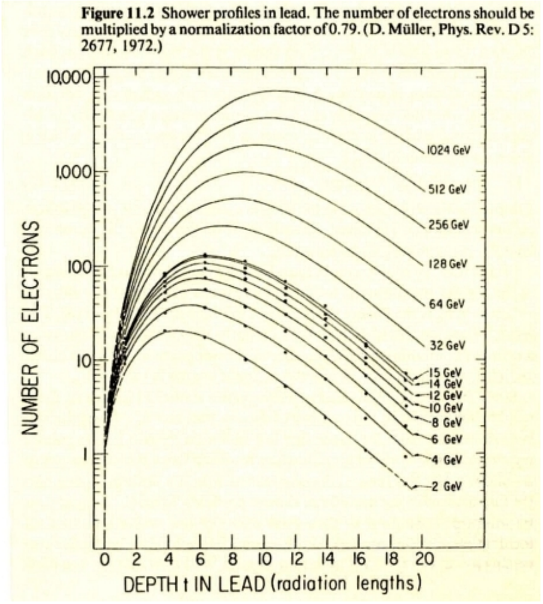


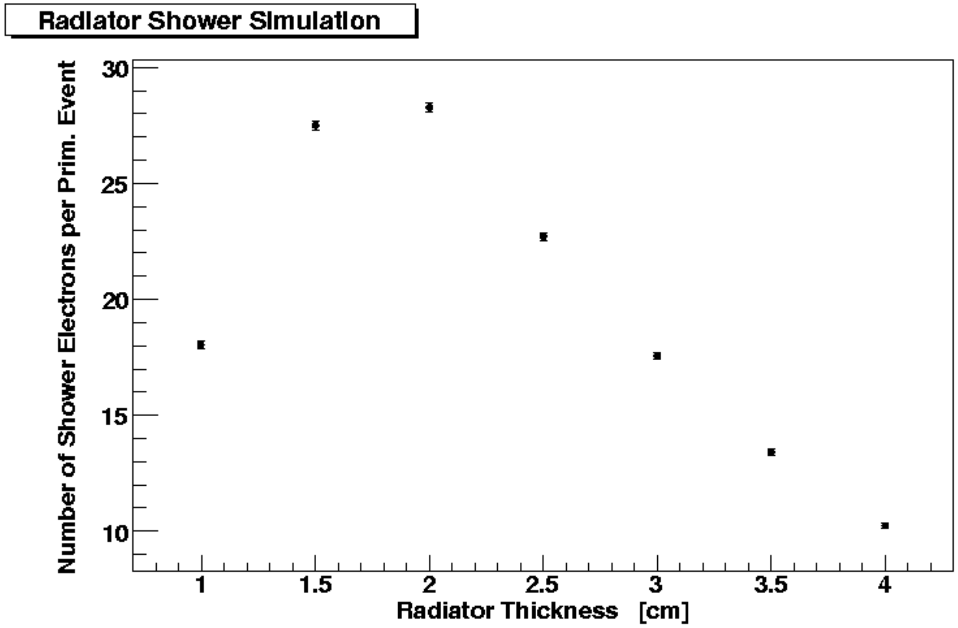
Simulations were run for 8 different setups with the lead radiator thickness varied between 1 and 4 cm.

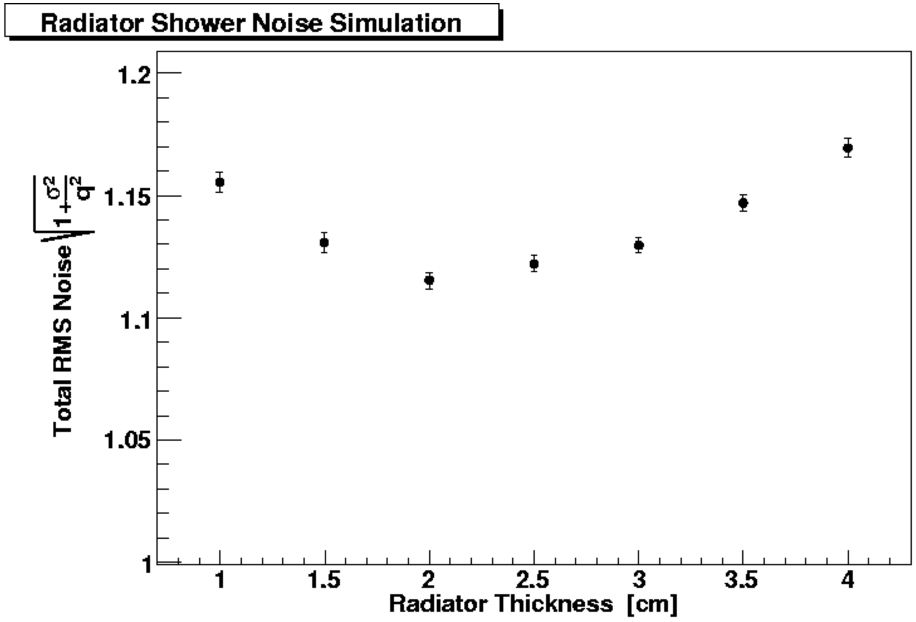
Lead radiation length = 0.5 cm

Shower max is reached at ~ 4 radiation lengths

--- on these grounds it is expected that the minimum in excess noise is reached at about 2 cm

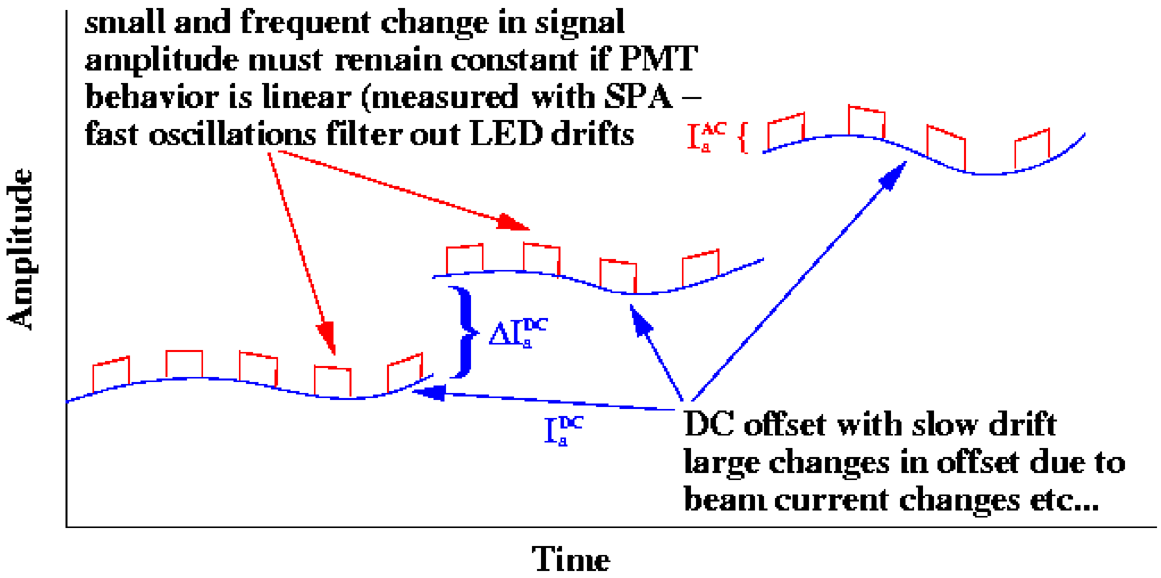






A 2 cm lead radiator would produce about 12% excess noise requiring about 370 hours of additional running time – but keep it in our back pocket if we end up seeing too much background with beam.

PMT and Base Linearity



We are interested in the size of any non-linear response in the PMT to small load changes around some DC (mean) load:

→ **false asymmetry If correlated with helicity sequence**

→ **asymmetry dilution otherwise**

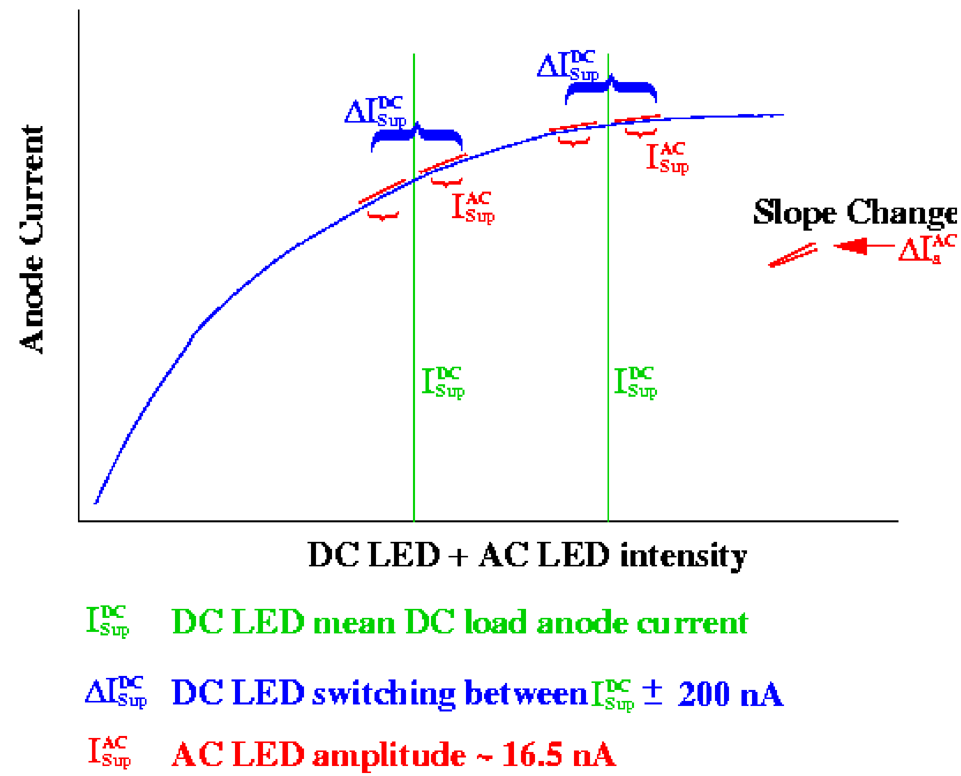
Measure the differential non linearity, using two LEDs:

One producing a DC offset and the other producing a small additional AC change.

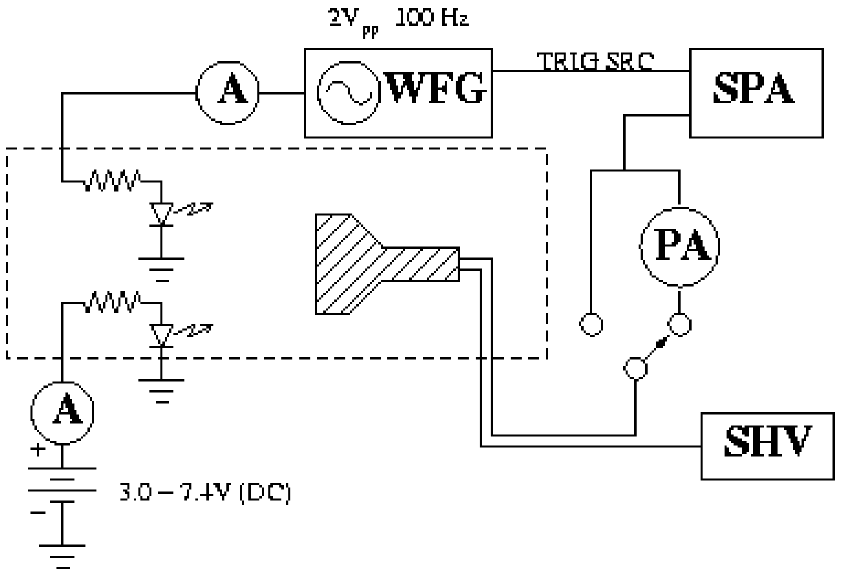
Take repeated measurements of the AC Vpp amplitude around the mean DC offset, suing a spectrum amplifier.

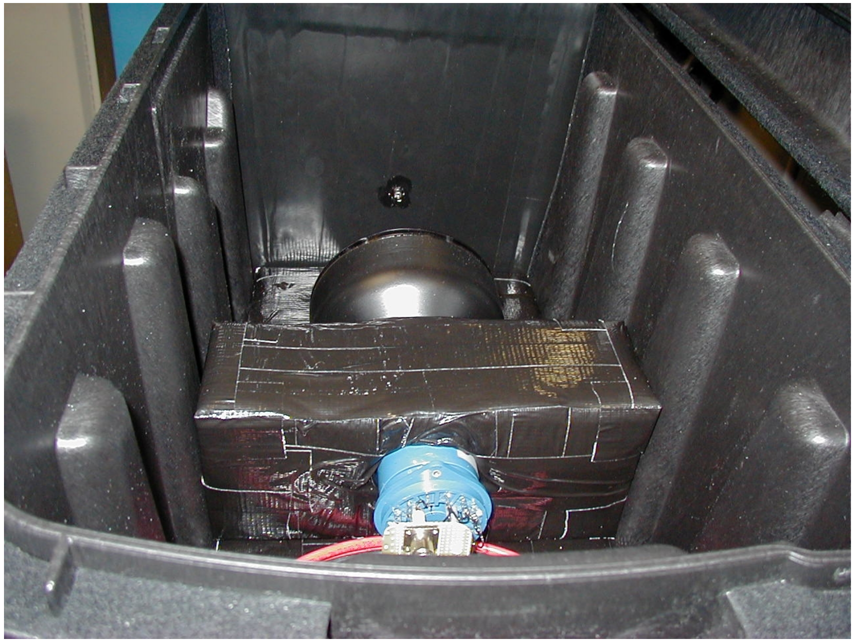
Non-linearity equal to any change in the AC Vpp amplitude

Repeat measurements for various DC offsets



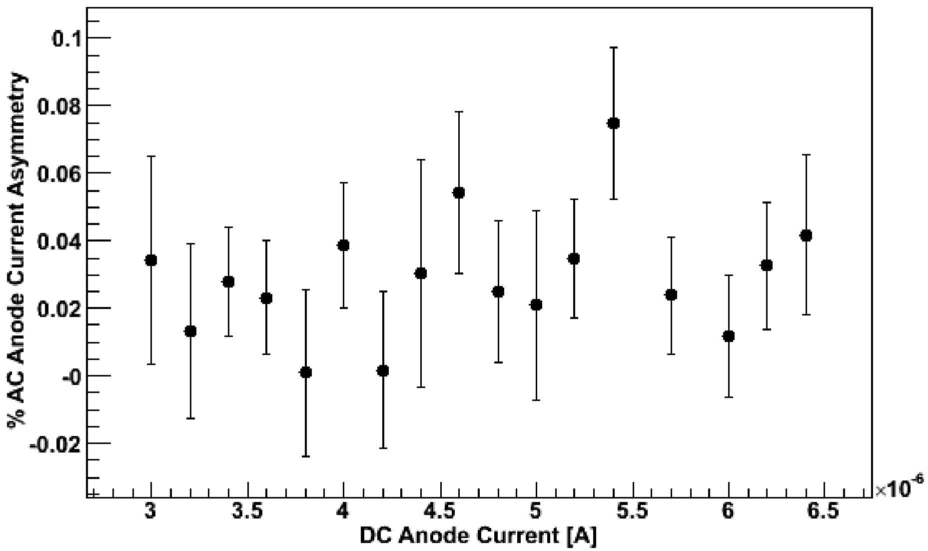
Low Gain Base Linearity Measurements

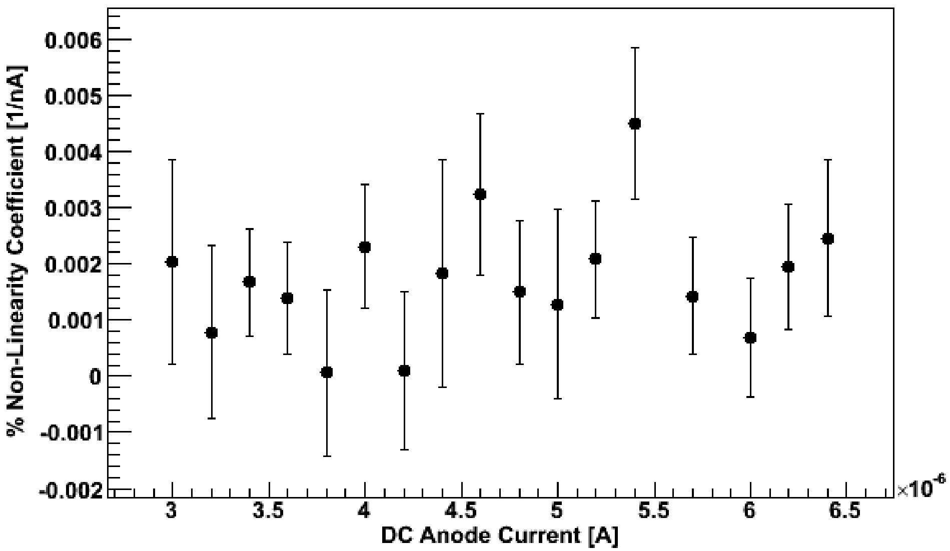




We interpret this to mean that the prototype base has less than 5×10 $^{-4}$ non-linearity for the anticipated load of 6 μA.

$$A = \frac{I_{a,2}^{AC} - I_{a,1}^{AC}}{I_{a,2}^{AC} + I_{a,1}^{AC}}$$





Model-Independent e-q New Physics Sensitivities

From $Q_W^p(q^2) \equiv A + B\sin^2\theta_W(q^2)$ **one can derive**

$$\frac{\Delta\sin^2\theta_W(q^2)}{\sin^2\theta_W(q^2)} = \frac{\Delta Q_W^p(q^2)}{Q_W^p(q^2)} \cdot F$$

$$F = \frac{A + B\sin^2\theta_W(q^2)}{B\sin^2\theta_W(q^2)}$$

Error magnification factor

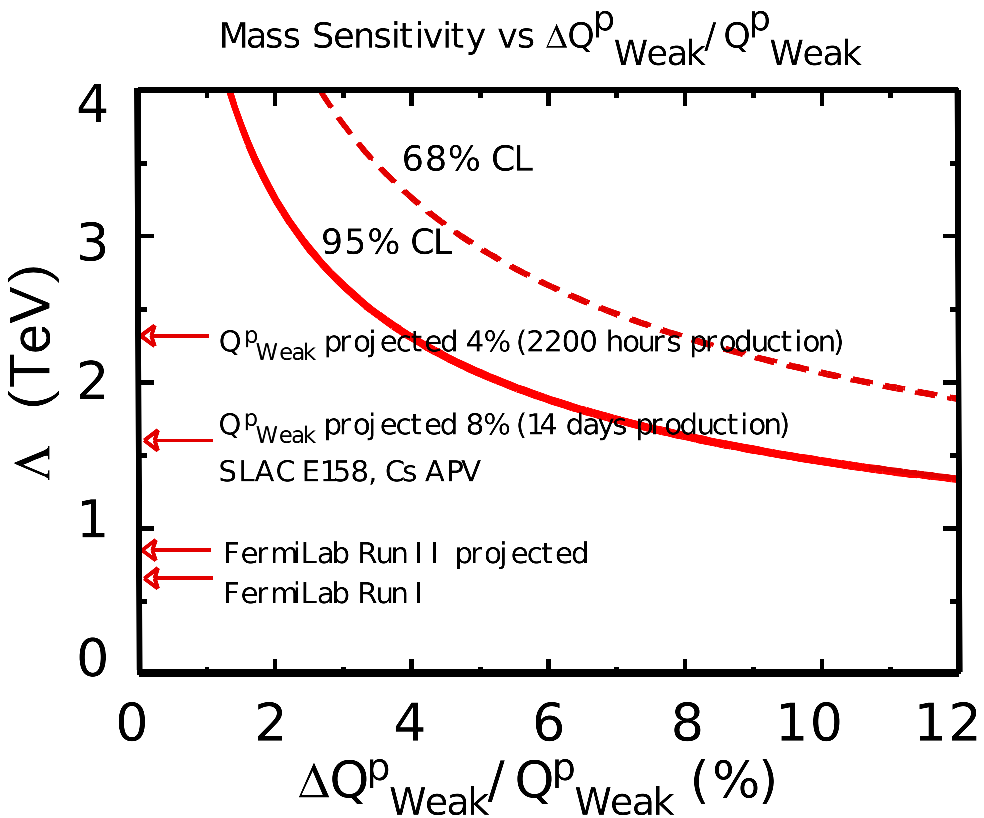
Q_w(p) has astonishing sensitivity at its particular isospin at 4% Q_w(p)

$F =$ **0.078**

$$\frac{\Delta\sin^2\theta_W(q^2)}{\sin^2\theta_W(q^2)} = \textbf{0.3\%}$$

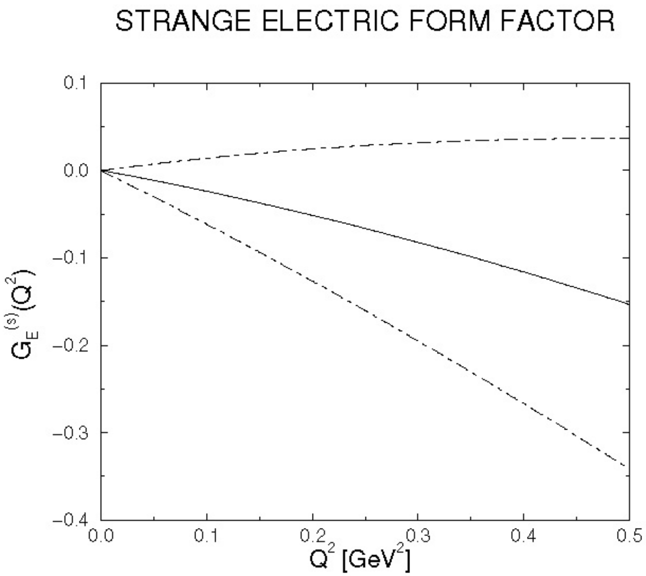
$\Delta\sin^2\theta_W(q^2)$ **= 0.00072**

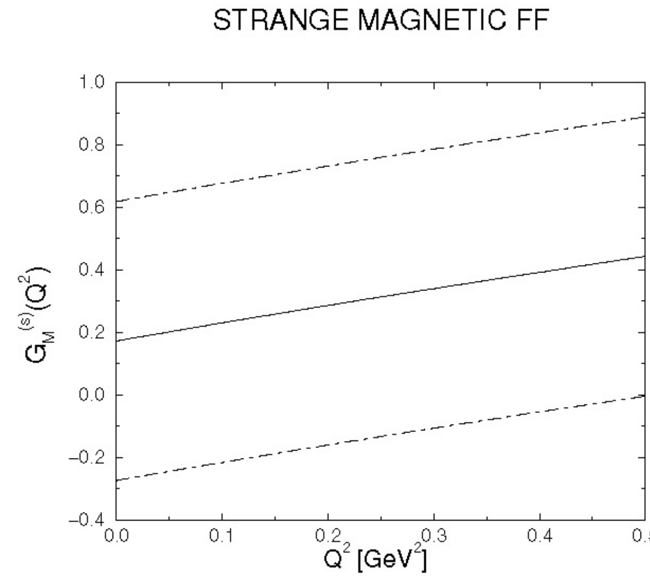
$$\frac{\Lambda}{g_W} \simeq \frac{1}{2\sqrt{\sqrt{2}G_F|\Delta Q_W^p|}} \approx 2.3 \text{ TeV}$$

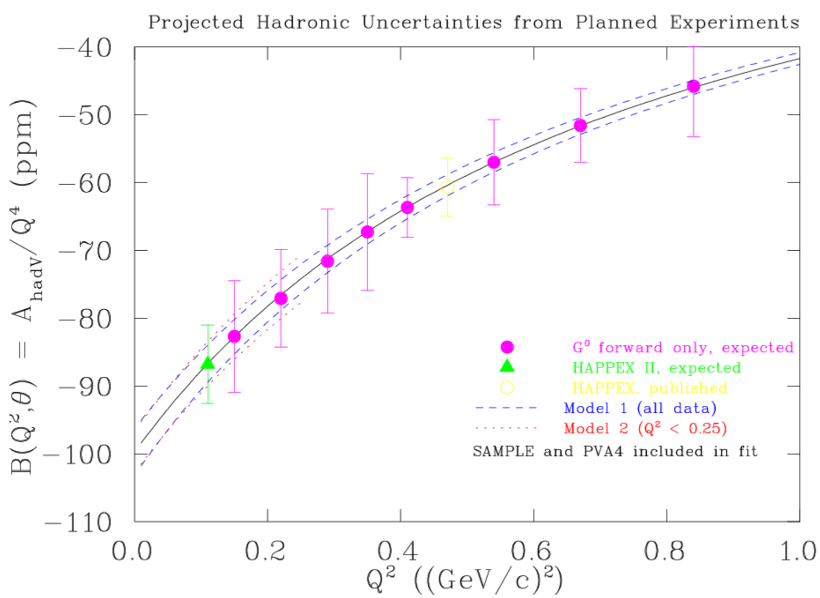


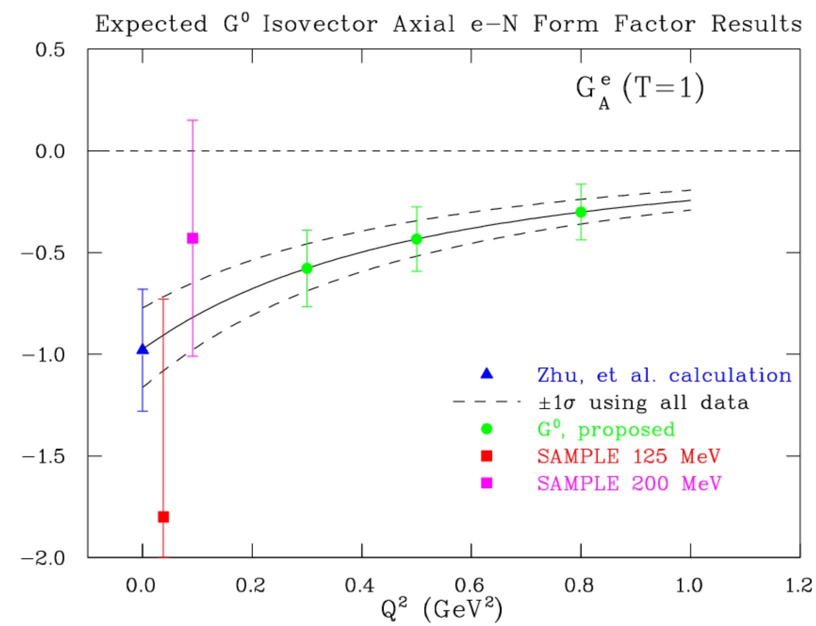
$$G_E^s(Q^2)=\rho_s\ \tau\ G_M^s(Q^2)=\mu_s\ for\ Q^2<0.025\ GeV^2$$

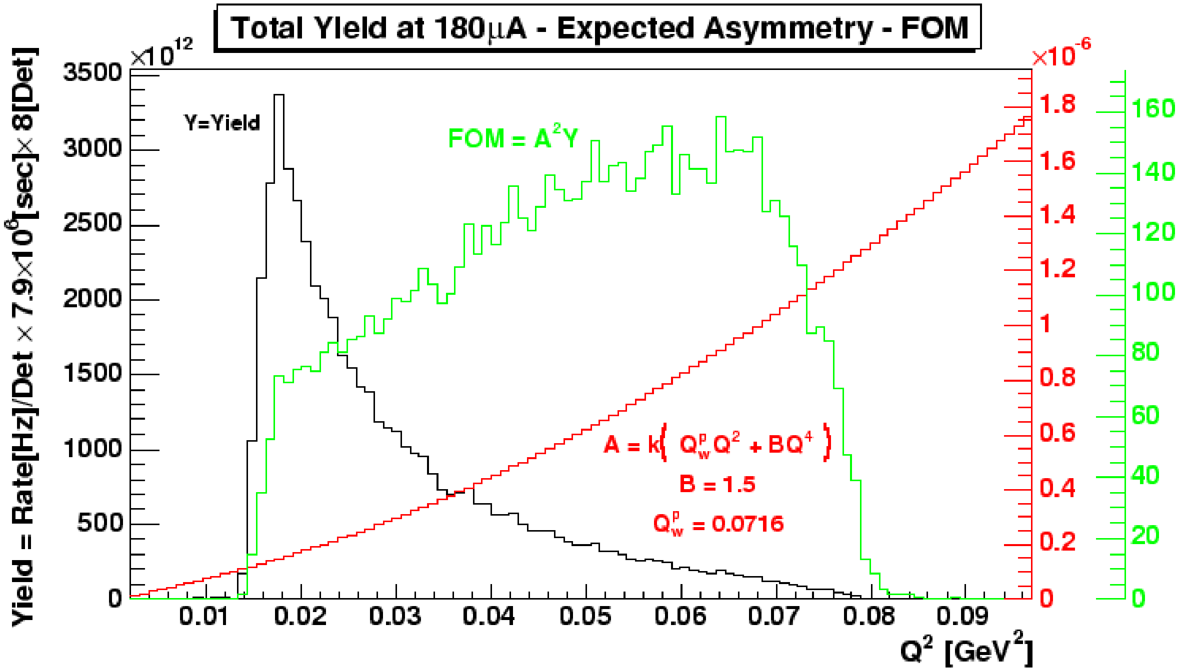
Hemmert, et al. chiral perturbation theory







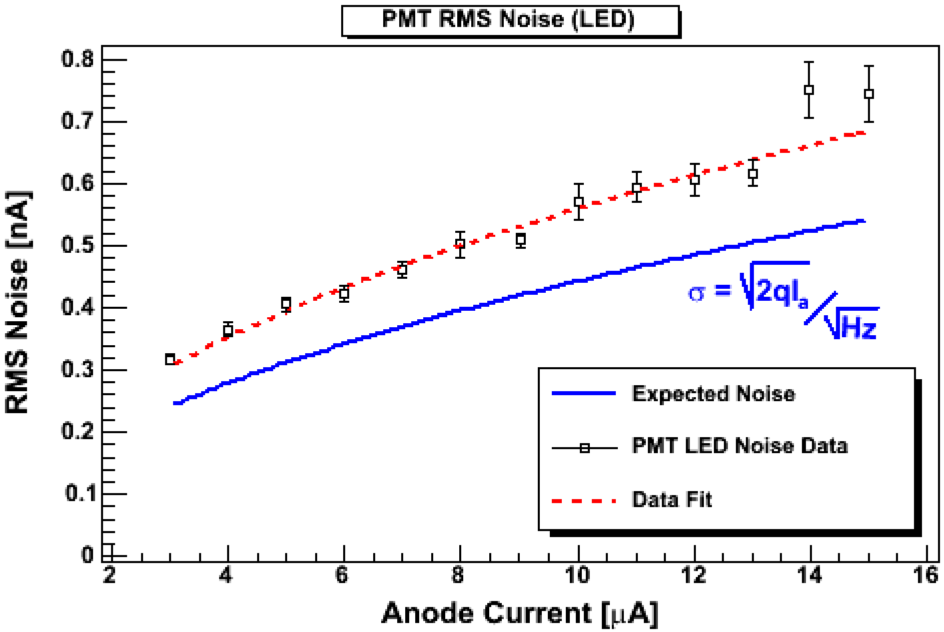


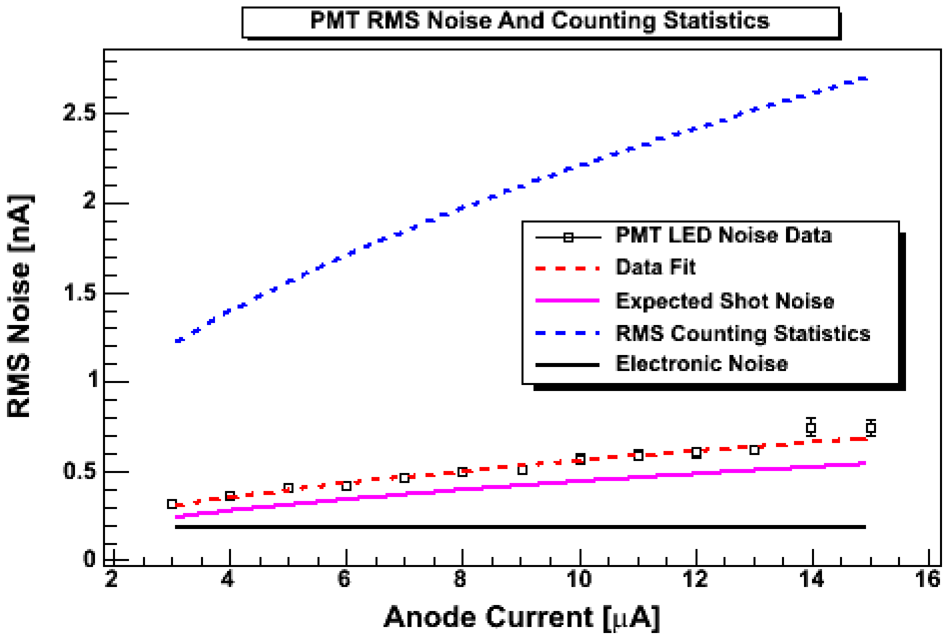


Total Yield at 180μA - Expected Asymmetry - FOM
Yield = Rate[Hz]/Det × 7.9×10^6[sec]× 8[Det]
×10^12
3500
3000
2500
2000
1500
1000
500
0
Y=Yield
FOM = A^2Y
A = k(Q^p_w Q^2 + BQ^4)
B = 1.5
Q^p_w = 0.0716
×10^-6
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
160
140
120
100
80
60
40
20
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
Q^2 [GeV^2]

Noise Tests

A first pass noise test was performed, using a 280 nm LED and the spectrum analyzer, at a bandwidth of 50 kHz.

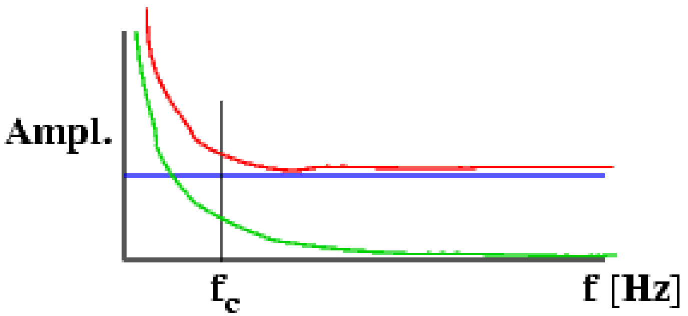




It is expected that the noise is dominated by shot noise from the fluctuations in the number of photoelectrons created at the cathode and subsequent dynodes.

1/f noise has been subtracted :

$$\sigma^2 = \int_0^B 2qI_a \left(1 + \frac{f_c}{f}\right)\, df$$



First results suggest that the noise is approximately 20% larger than expected on theoretical grounds.

What is “Parity Quality”?

Helicity-correlated asymmetry specifications

Experiment	Physics Asymmetry	Max run-average helicity correlated Position Asymmetry		Max run-average helicity correlated Current Asymmetry	
		Spec	**Achieved**	**Spec**	**Achieved**
1999 HAPPEx-I	**13 ppm**	**10 nm**	**10 nm**	**1 ppm**	**0.4 ppm**
G^0 Forward	**2 to 50 ppm**	**20 nm**	**(4 ± 4) nm**	**1 ppm**	**(0.14 ± 0.3) ppm**
HAPPEx-He [2004] HAPPEx-He [2005]	**8 ppm**	**3 nm**	**3 nm** **20* nm**	**0.6 ppm**	**0.08 ppm** **0.1 ppm**
HAPPEx-II-H [2004] HAPPEx-II-H [2005]	**1.3 ppm**	**2 nm**	**8** nm** **1 nm**	**0.6 ppm**	**2.6** ppm** **0.1 ppm**
Lead	**0.5 ppm**	**1 nm**	**-**	**0.1 ppm**	**-**
2008 Q_{weak}	**0.3 ppm**	**20 nm**	**-**	**0.1 ppm**	**-**

* Results affected by electronic crosstalk at injector.

** Results at Hall A affected by Hall C operation. Spec was met in 2005 run.

Routine Parity Violation Experiments?

We need:

- Long lifetime photogun (i.e., slow QE decay)
- Stable injector (especially RF phases)
- Properly aligned laser table, pockels cell (HAPPEx method)
- Proper beam-envelope matching throughout machine for optimum adiabatic damping
- Set the phase advance of the machine to minimize position asymmetry at target
- Eliminate electronic ground loops: isolate electronics
- Feedback loops; charge and position asymmetry
- Specific requirements for each experiment; e.g., 31 MHz pulse repetition rate, 300 Hz helicity flipping, beam halo < , etc.,