Q^2 Measurement, Calibration and Commissioning

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Outline

- Motivation
- Measurement Techniques
- Run Plan

Sensitivity to Q^2

To first order in Q^2, the parity-violating asymmetry is:

$$A^{PV} = \frac{-G_F Q^2}{4\pi\alpha\sqrt{2}}[(1-4\sin^2\theta_W)+\tau(\mu_n-\rho_s-\mu_p(\mu_n+\mu_s))]$$

$$Q^2 = EE'(1-\cos\theta)$$

such that the uncertainty on the extracted asymmetry is directly proportional to the uncertainty in Q^2. In turn, the uncertainty in Q^2 is dominated by the scattering angle.

As pointed out in the discussion, $\tau = \frac{Q^2}{4M^2}$. The quantities of interest then have a prefactor of $\langle Q^2 \rangle$, so at least $\langle Q^2 \rangle$ and $\langle Q^4 \rangle$ need to be measured.

Distribution of Q^2

The Q^2 distribution is measured by running in 'counting' mode, looking event-by-event and assembling the average weighted by the ADC response of the HAPPEX detector:

$$\langle Q^2 \rangle = \frac{\sum ADC_i \, Q_i^2}{\sum ADC_i}$$

Concerns for collecting and relating the measured Q^2 distribution to with the integration-mode data:

Assuming production running is $\mathcal{L} = 4 * 10^{38}/(\mathrm{cm}^2\mathrm{s})$ at $100\mu\mathrm{A}$.

- Trigger: HAPPEX detector
- Rate VDC's can take (100kHz/wire) gives us upper limit of $.8\mu A$.

- Multi-track percentage in VDC's.
- Matching of beam-conditions between High and Low luminosity.
  - Feedback controls for $< 1\mu A$ beam?
  - Raster and central position should be the same as for production data.
  - Beam quality monitoring

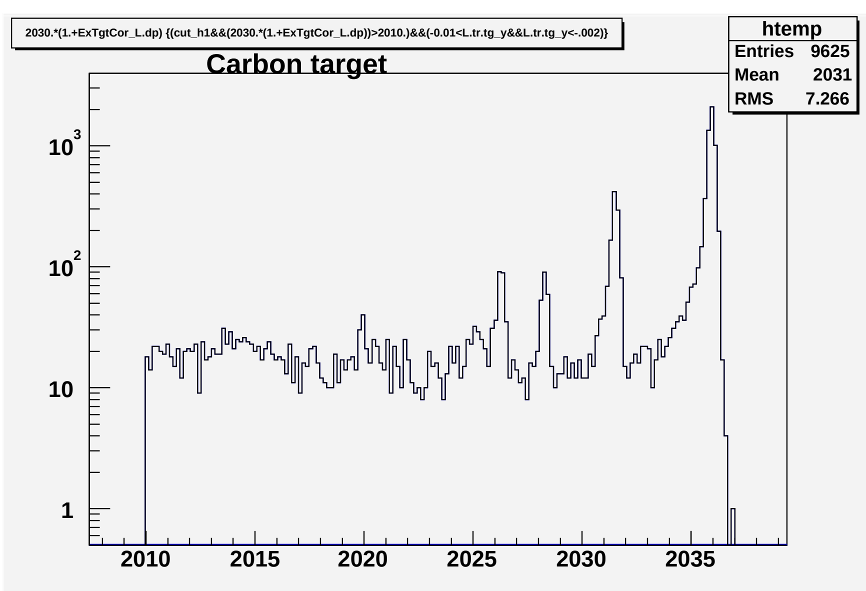
Due to the shape of the HAPPEX detectors, the average Q^2 over **EACH** bar is measured.

Calibrating θ

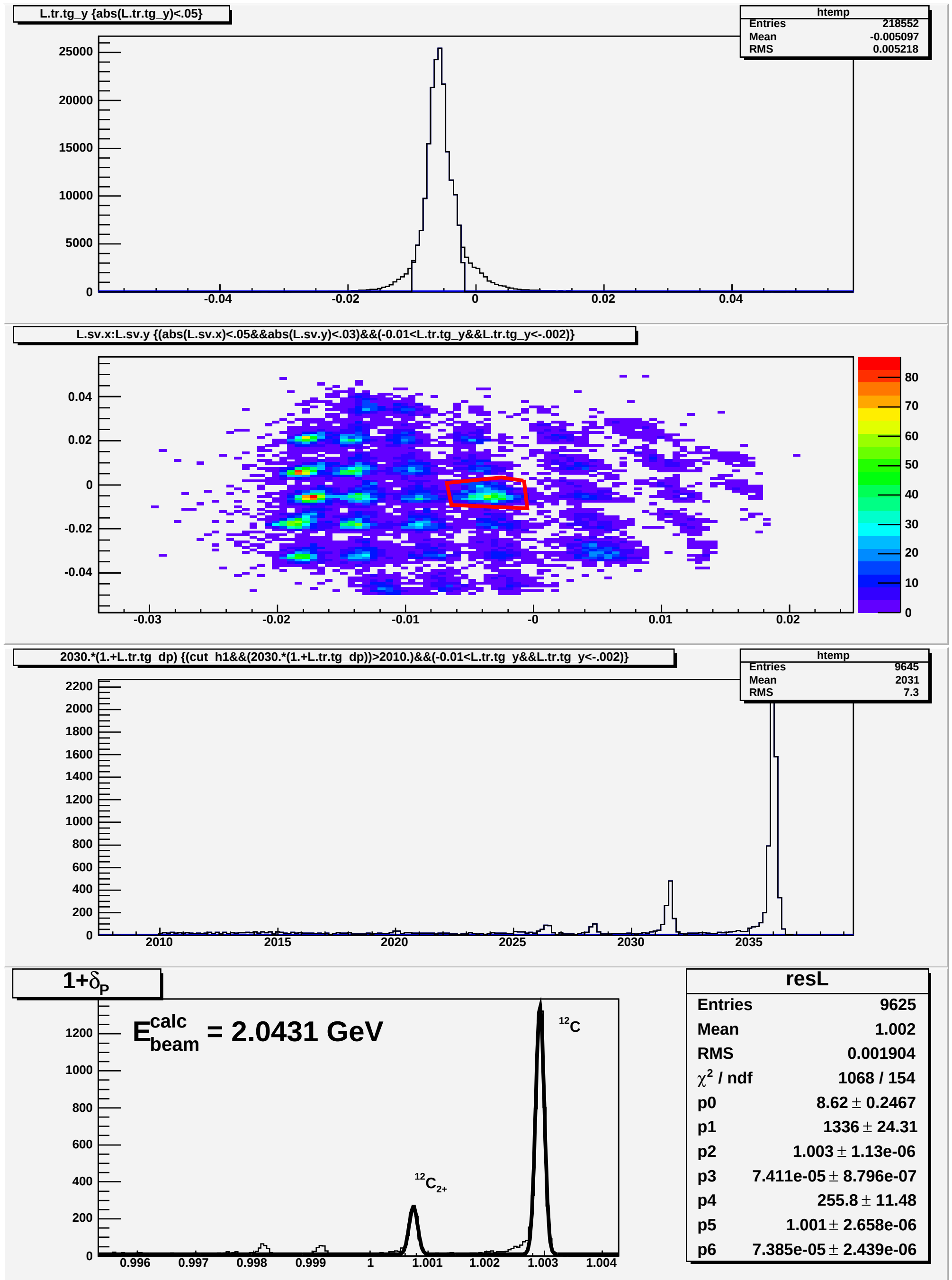
Nilanga's idea was to use elastic scattering off different nuclei as a way to measure θ. We can also use the excitation of nuclear states to specify the kinematics. See Appendix for expressions.

Elastic Scattering ($M = M^*$)
Nuclear Excitation (e + A $\rightarrow$ e$'$ + A*)

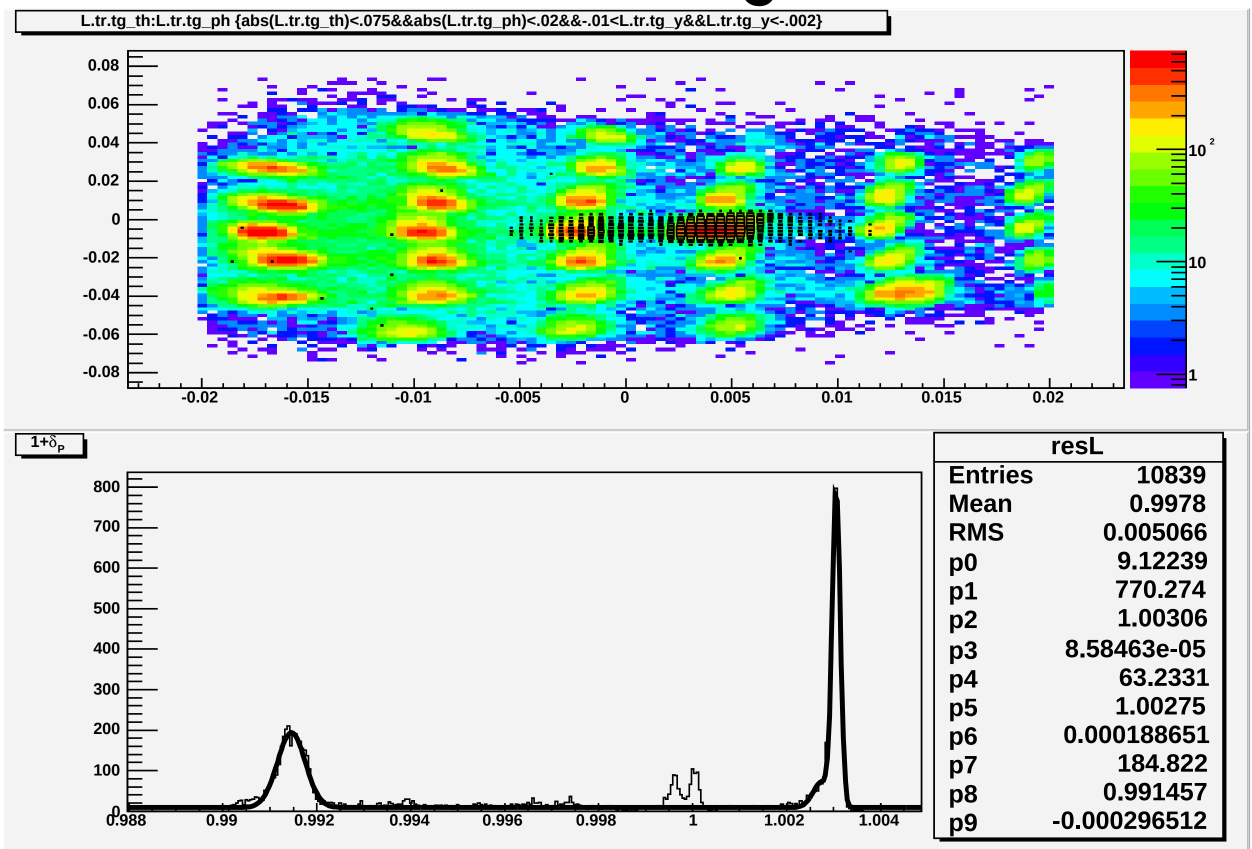
$$(1 - \cos\theta) = \frac{M(E - E') - (M^{*2} - M^2)/2}{EE'}$$



Carbon Target



Waterfall Target



Having Hydrogen and a heavier nuclide provides a large separation between the elastic peaks.

Q^2 Run-plan

VERY ROUGH

- Optics - 2 shifts (??)
  - sieve plate installed
  - Kapton target installed (C-H-O target ??)
  - multi-foil carbon target
  - similar run for BeO and kapton target ($\delta = 0$)
  - delta scan of $\pm 4\%$, steps of 1%.

- Q^2 Distribution
  - Use delta-scan results
  - Survey and picture of sieve-plate box.
  - Vary beam current to look for dead-time effects.

Appendix: Elastic/Nuclear state relations

The location of each sieve-hole, while perhaps not well known, is fixed and the scattering angle for electrons passing through it well defined. The incoming beam energy is E and scattered electron energy E'. The scattered electron momentum is measured as:

$$\begin{aligned} E' &= p_0(1+\delta') \\ &= p_0\Delta' \end{aligned}$$

where p_0 is the central momentum setting of the spectrometer.

For a target nucleus of mass m_A, we can look at events from a single sieve hole of (unknown) angle θ. The events are from either elastic or nuclear-excitation reactions, with final state nuclear mass and electron energies of (m_A, E'_A) or (m_{A*}, E'_{A*}), respectively.

$$\frac{m_A(E-E'_A)}{EE'_A} = 1-\cos\theta = \frac{m_A(E-E'_{A*}) - \frac{1}{2}(m^2_{A*} - m^2_A)}{EE'_{A*}}$$

$$E = \frac{m_{A*}^2 - m_A^2}{2m_A} \frac{E'_A}{E'_A - E'_{A*}} \quad (1)$$

$$= \frac{m_{A*}^2 - m_A^2}{2m_A} \frac{\Delta'_A}{\Delta'_A - \Delta'_{A*}} \quad (2)$$

is the measured beam energy, which is independent of the precise momentum setting and angle of the spectrometer.

Using the same idea, the spectrometer momentum setting can be measured by looking at elastic scattering for different nuclides of masses m_A and m_B (independent of the angle):

$$p_0 = E \frac{\frac{m_A}{\Delta'_A} - \frac{m_B}{\Delta'_B}}{m_A - m_B} \quad (3)$$

Using E and p_0, we can attempt to measure the θ for each sieve hole and determine the central angle of the spectrometer.

Proof of principle Test

For run e94107-1466 and 1467, the E was 'measured' by the right and left HRS to be 2042.8 MeV and 2043.1 MeV, respectively. Angles (for **specific sieve holes**) measured were $\theta_L = 6.14^\circ$ (hole near center) and $\theta_R = 4.89^\circ$ (hole approximately 1.1° from the center of the sieve in the correct direction). These results are believeable and reasonable.