Precision Measurement of the Proton Elastic Cross Section at High Q^2

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for the E12-07-108 Collaboration

Hall A Collaboration Meeting

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Nucleon Form Factors

- The EM form factors encode the spatial distributions of charge and magnetization in the nucleon
- Investigation of FFs provides a powerful tool for understanding of quark dynamics in the nucleon
- Two measurement method:

  1) Rosenbluth separation method
  2) Recoil polarization technique (measurement of the ratio between electric and magnetic FF)

Goals for GMp Experiment

- Accurately measure the elastic e-p cross section at kinematics used in other JLab form factor measurements (Q^2 = 7-14 GeV^2)
- Determine the form factor G^p_M using Rosenbluth separation method with accuracy several times higher than previous experiments

$$\frac{d\sigma}{d\Omega} = \left(\frac{d\sigma}{d\Omega}\right)_{Mott} \frac{\tau\left(G_M^p\right)^2 + \varepsilon\left(G_E^p\right)^2}{\varepsilon\left(1+\tau\right)}$$

Reduced cross section

$$\tau = Q^2/4M_p^2 \qquad \varepsilon = \left[1+2\left(1+\tau\right)\tan^2\left(\theta/2\right)\right]^{-1}$$

Status of HRS Detectors

- Old VDC disc. Card were replaced with new MAD cards
- One straw chamber was installed in each spectrometer to improve track reconstruction efficiencies
- Aging 5” PMTs in Gas Cherenkov were replaced with fresh tubes
- Wavelength shifting paint was applied to all 20 Gas Cherenkov PMTs
- New splitters for EDT measurement were installed on left arm (will be done for right arm in the future)

Results from March Run

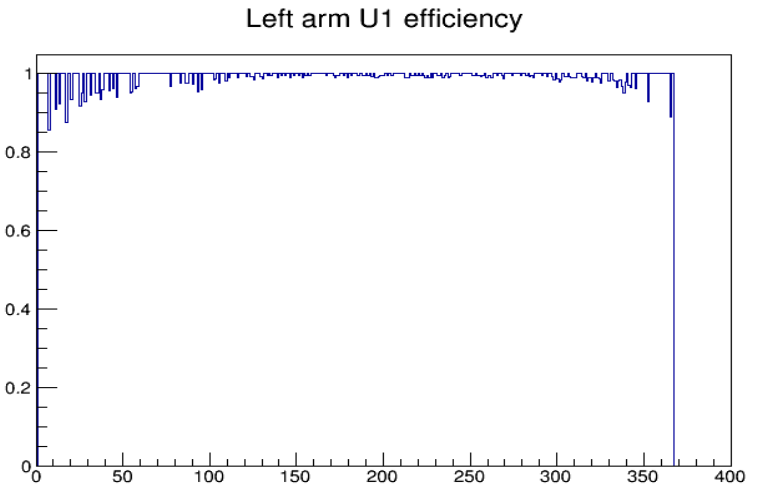
Detectors in both spectrometers were checked out in March

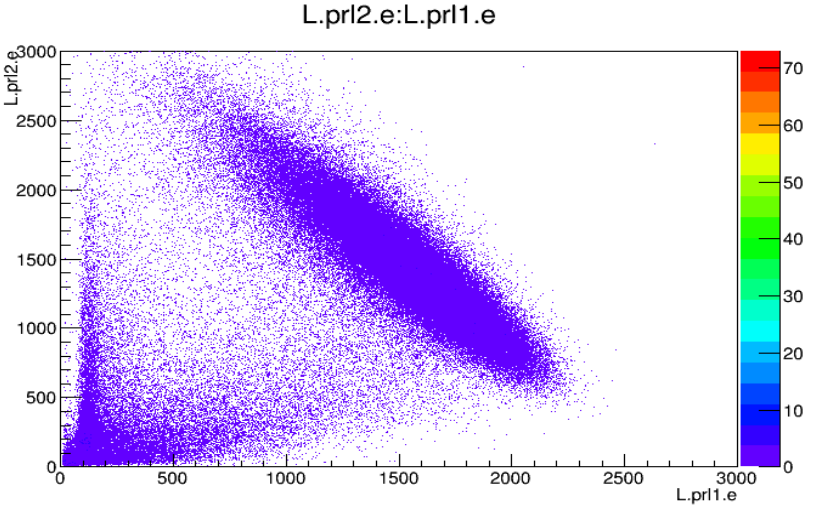
- Data was collected for electrons scattering from solid targets and LH_2
- Different types of triggers were used for study of trigger efficiencies and time resolution (S0&S2, GC&SH, etc.)
- HRSs were set at elastic as well as deep inelastic kinematics

Results from March Run

Detectors in both spectrometers were checked out in March

- Track reconstruction efficiency of VDC is above 98%
- S2m has a time resolution of better than 1 ns and geometrical efficiency higher than 99%
- Energy resolution of pion-rejectors on left arm is about 6%@3GeV
- Energy resolution of shower detectors on right arm is 6%@1GeV

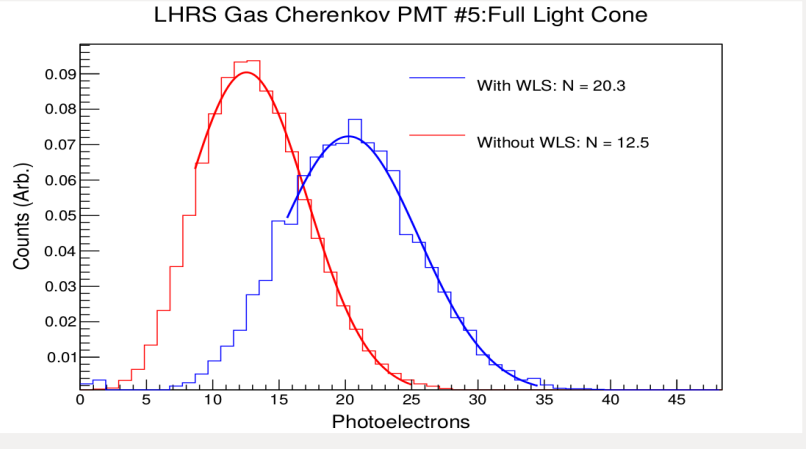


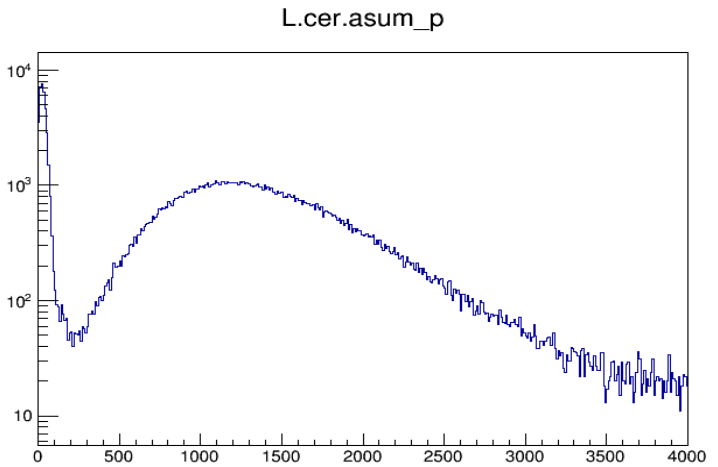


Results from March Run

Detectors in both spectrometers were checked out in March

- Effects of wavelength shifting paint were tested
  - ✔ About 50% increase in #ph.e. was observed
  - ✔ Typically 15-20 ph.e. were observed in electron events after application of paint
  - ✔ Paper on this test submitted to NIM A in August 2014





Results from March Run

- The electronics for BCM was not finished during the March run
- Hydrogen elastic cross section was normalized to carbon DIS cross section
  - Carbon DIS run: Q^2=1.00GeV^2, W=1.85GeV
  - Hydrogen elastic run: Q^2=3.48GeV^2, W=1.00GeV
- The measured cross section for e-p elastic scattering was found to be consistent with expectation within 2.5%

Work done by Y. Wang (College of W.M.)

Dead-Time Measurement

- Accurate dead-time measurements are necessary to reconstruct correct rates
- DAQ dead-time usually dominates and can be determined by comparing the number of triggers recorded to the number counted on scalars
- New electronics for EDTM (electronic dead-time measurement) was implemented in LHRS in summer
  - Logical EDTM pulses have been mixed with signals from the Gas Cherenkov, S0, and S2m detectors
  - Monitoring the number of 'tagged' EDTM pulses that are recorded will provide a better understanding of the dead-time

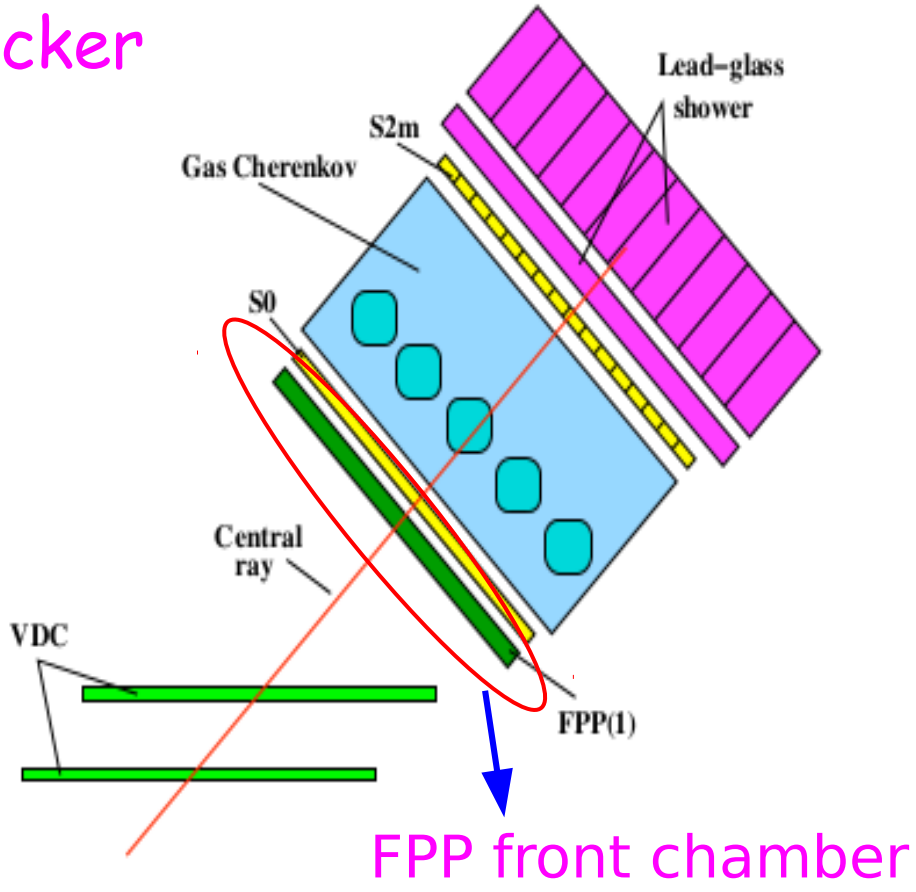
Usage of Straw Chamber

- The standard detector stack contains two VDCs for tracking
- Multiple-clusters cause *u*-*v* matching ambiguity and increased probability of mis-reconstructed track
- Old strategy: Consider only one-track event and make corrections by calculating the fraction of these events in the whole data sample
  - Up to a few percent of events may not be correctly reconstructed

Usage of Straw Chamber

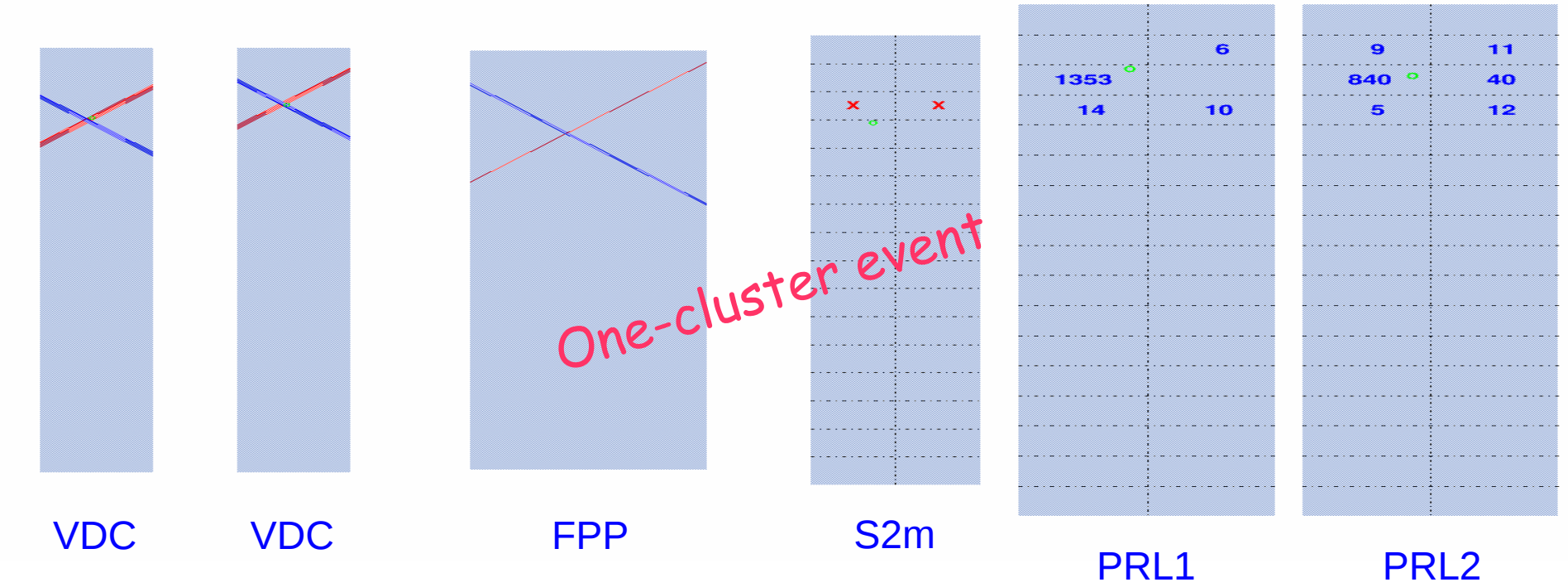
Our strategy: Adding a 3rd tracker

- This can help to reduce systematics of track reconstruction efficiencies and insure an accurate measurement of the absolute cross section
  - ✔ The front chamber of FPP was installed in both spectrometers between the two VDCs and the Gas Cherenkov counter



Usage of Straw Chamber

- Straw chambers on both spectrometers are operational on hardware level
- Software development ongoing…



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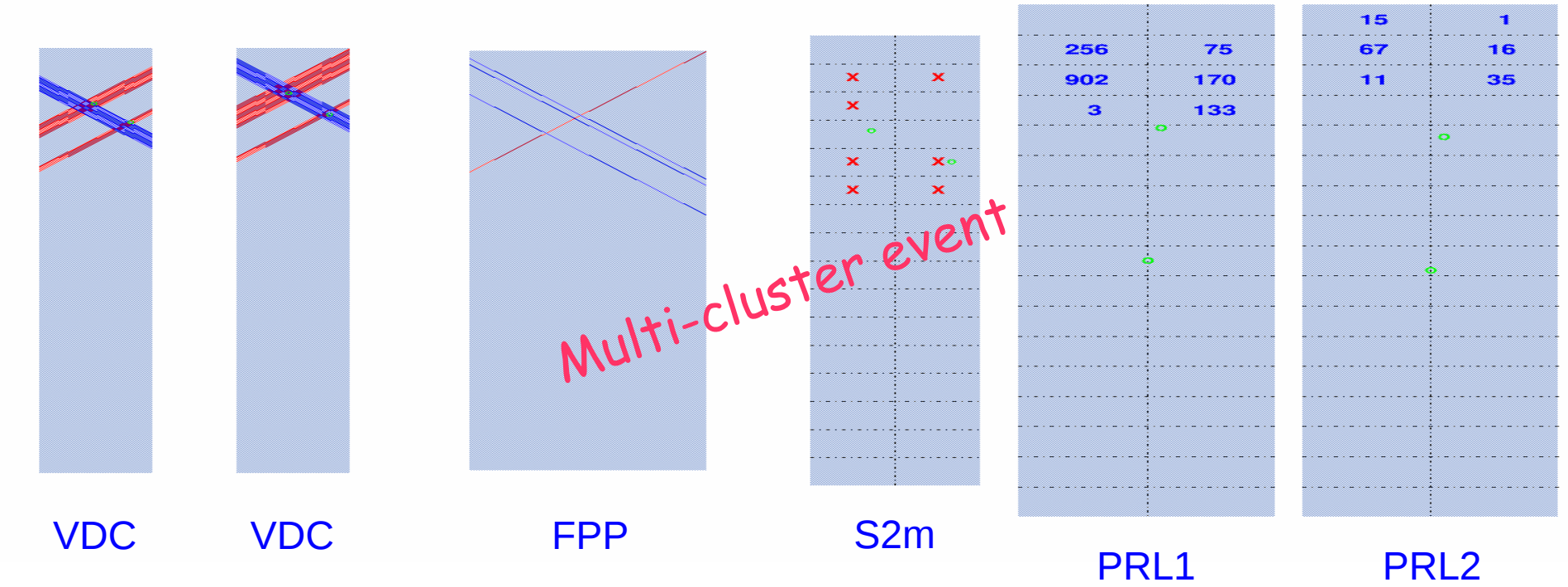


Usage of Straw Chamber

Our idea of tracking with straw chamber:

- VDCs are the main detectors for tracking and Fpp is auxiliary for resolving multi-cluster ambiguity
- Fpp class will be modified for cluster formation
- Tracks formed by VDCs are projected to straw chamber plane
- For each combination of clusters in the two VDCs, locate the corresponding track projection and compare it with clusters formed by straw chamber
- Establish a criterion for selecting 'golden track'

Beam Current Calibration

- We have multiple current measurement devices in Hall A: Unser/BCM/Faraday Cup, which will eventually be cross calibrated
- We will focus on the BCMs calibrated against the Unser
- We have two BCMs: upstream(U1) and downstream(D1,D3 and D10)
- D1,D3 and D10 are the amplifiers which are used to compensate the non-linearity of DC output voltage below 5μA
- Sampled data from one of those BCMs is sent to a digital AC voltmeter and produce RMS average to the input which is proportional to beam current
- RMS to DC output voltage is converted to frequency by V to F converter in counting house

Beam Current Calibration

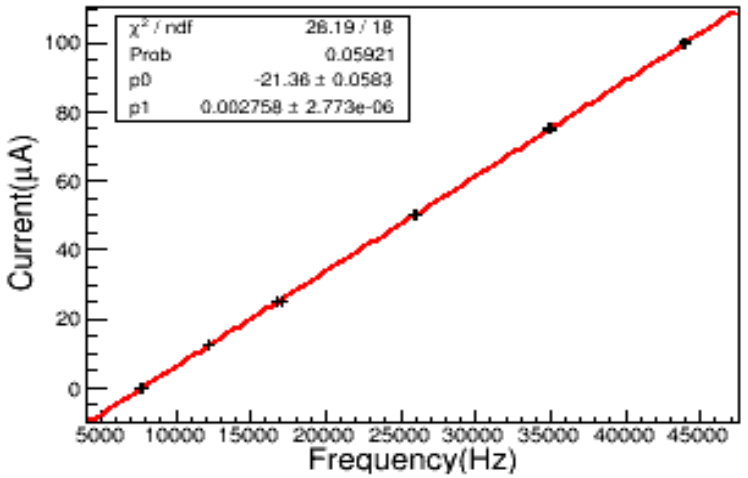
Calibration procedure:

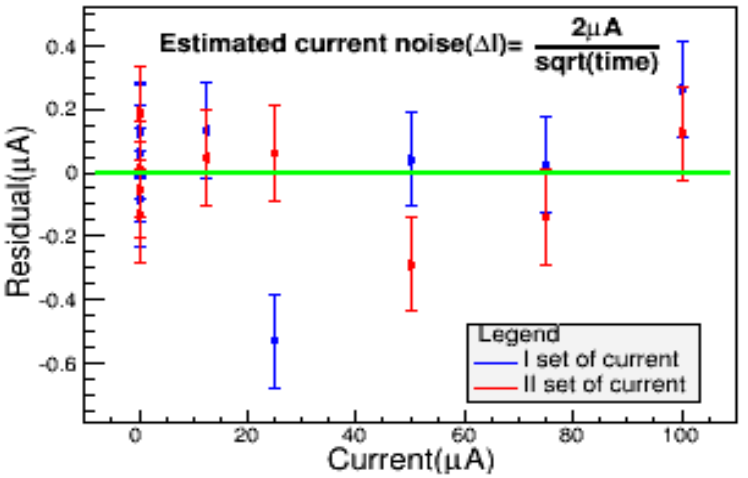
- Calibrate the Unser frequency against a known injected current in Hall A to determine $f_{unser} \rightarrow I_{unser}$
- Calibrate the BCM frequency to a few 10th of percentage against I_{unser} using beam current to determine $f_{BCM} \rightarrow I_{BCM}$

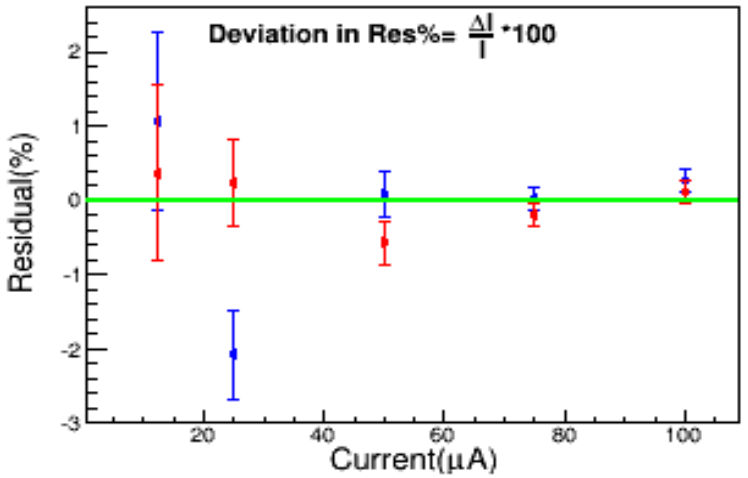
Status:

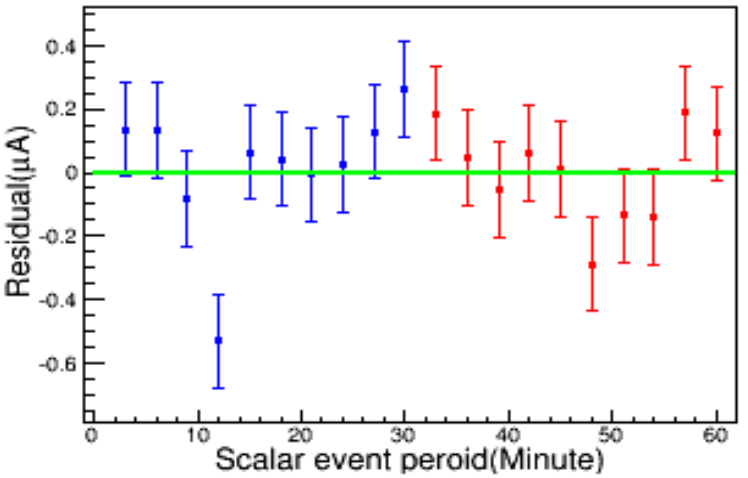
- Calibrated unser with known injected current in Hall A
- Checked gain and offset stability of unser for a range of current and found pretty much stable
- Following plots are the unser calibration results for on/off current form 0 to 100 μA

Beam Current Calibration









Plot by T. Gautam (Hampton University)

Status of Spectrometer Magnet

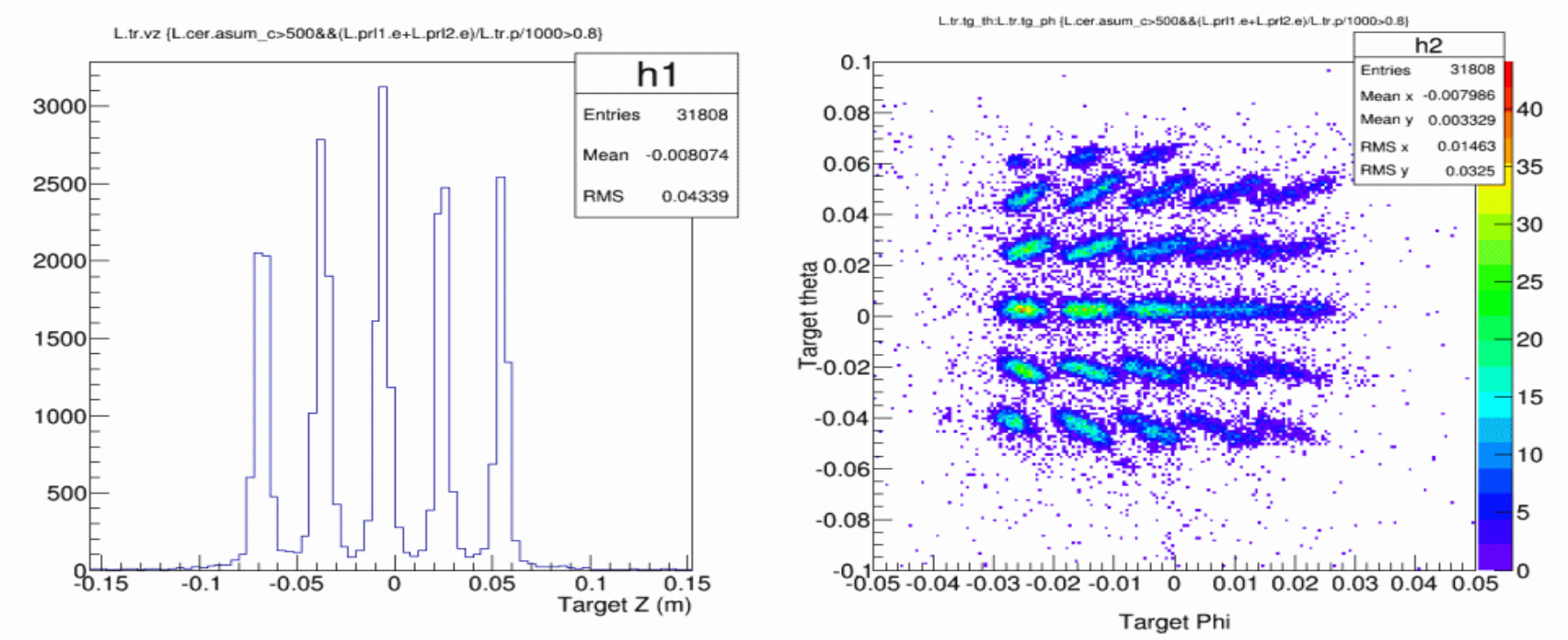
- We plan on using both L- and RHRS for e-p elastic cross section measurement
- Q1 in RHRS has been down since March run
- Q1 in LHRS is working, but the momentum setting is limited to not higher than 3.2GeV
- *Possible solution: replacing Q1 on right arm with SOS quad from Hall C*

Simulation on HRS acceptance with SOS quad is ongoing

See Barak Schmookler's talk for update

Results of Current 12GeV Run

- 12 GeV CW beam up to 20 μA is being delivered to multiple halls
- Optics data with multi-foil carbon target and 1” tungsten sieve slit was collected last weekend



(Optics reconstruction matrix not optimized yet)

Summary

- GMp will provide precise measurements of e-p elastic cross section at Q^2 up to 14 GeV^2
- Most work on hardware are done (detectors checked out, Q1 on right arm needs to be fixed or replaced, EDTM on right arm not implemented yet)
- Software:
  - Scripts for calibration of detectors done
  - Development of tracking code integrating straw chamber going on
  - Optics analysis using lead sieve data going on
- Currently taking beam data to test EDTM module, new sieve slit...
- Full production run in Spring 2015