Run Plan for Experiment E02-013
Measurement of the Neutron Electric Form Factor G_{En} at High Q^2

Draft 1.0 *J.R.M. Annand and B. Wojtsekhowski, 28th January 2006*
Draft 1.1 *J.R.M. Annand and B. Wojtsekhowski, 2nd February 2006*
1.2 *B. Wojtsekhowski, 24nd February 2006*

24th February 2006

1 Introduction

This experiment seeks to determine the charge form factor of the neutron through measurement of the electron-helicity asymmetry in the quasi elastic $^3\overrightarrow{\mathrm{He}}\,(\overrightarrow{e}, e'n)$ reaction. When the target spin (essentially the spin of the unpaired neutron in ^{3}He) is aligned perpendicular to the 3-momentum transfer this asymmetry may be expressed as:

$$A_\perp = -\frac{G_{En}}{G_{Mn}} \cdot \frac{2\sqrt{\tau(\tau+1)}\tan(\theta/2)}{(G_{En}/G_{Mn})^2 + \{\tau + 2\tau(1+\tau)\tan^2(\theta/2)\}}$$

and the measured asymmetry is given by:

$$A_{exp} = 0.86 \times A_\perp \times P_e \times P_{He} \times D \times V$$

where the factor 0.86 is the fraction of ^{3}He spin carried by the neutron, P_e is the polarization of the electron beam, P_{He} is the target polarization, D is the target-N_2 dilution factor and V is the dilution arising from random-coincidence and non quasi-elastic background. Thus an accurate knowledge of the polarizations and dilutions is imperative. It is also vital that the polarizations and dilution factors be maintained as large as possible as, for a given number of counts, the obtained statistical uncertainty in asymmetry is proportional to $1/(P_e \cdot P_{He} \cdot D \cdot V)^2$. Accordingly a sizable fraction of the available beam time must be spent on polarimetry. Target polarimetry by NMR and EPR techniques must be performed frequently and requires the beam to be off. Beam polarimetry by Möller scattering from a magnetised Fe foil is likewise invasive, although Compton-back-scattering polarimetry has a negligible effect on the electron beam and may be performed in parallel with production running.

Task Description	Section	Start Date	Duration
1. Pre-beam beam-line checks	2.1	1 Feb	→15/2
2. Pre-beam detector checks	2.6	1 Feb	→15/2
3. Pre-beam target checks	2.7	1 Feb	→15/2
4. Final readiness checks	2.8	15 Feb	→20/2
5. Beam-line commissioning	3.0.1	24 Feb	1.5 shift
6. BigBite detector calibration	3.1.1	24 Feb	→28/2
7. BigBite magnetic optics	3.1.6	24 Feb	→28/2
8. Neutron Arm calibration	3.1.8	24 Feb	→28/2
9. Background Studies	3.1.9	24 Feb	→28/2
10. Polarized ^{3}He target	4	24 Feb	→28/2
11. $^3\overrightarrow{\mathrm{He}}\,(\overrightarrow{e}, e'n)$ Kin I $Q^2 = 1.20$ (GeV/c)^2	5.1	28 Feb	15 shifts
12. $^3\overrightarrow{\mathrm{He}}\,(\overrightarrow{e}, e'n)$Kin II $Q^2 = 2.48$ (GeV/c)^2	5.2	5 Mar	48 shifts
13. $^3\overrightarrow{\mathrm{He}}\,(\overrightarrow{e}, e'n)$ Kin III $Q^2 = 3.43$ (GeV/c)^2	5.3	21 Mar	121 shifts
14. BigBite removal and HRS(R) setup	6.1	30 Apr	26 shifts
15. Elastic $^3\overrightarrow{\mathrm{He}}\,(\overrightarrow{e}, e')$ calibration	6.2	9 May	10 shifts

Table 1: List of tasks, the section where the task is described and approximate time lines for experiment E02-013

In addition to the state-of-the-art polarized electron beam and target, the present experiment depends on large-acceptance electron and neutron detectors, which are major new developments for Hall-A. Consequently a comprehensive commissioning procedure is required for these previously untried apparati, which constitutes one of the major tasks at the start of the experiment.

The list of tasks to be carried out, and estimates of the required time are summarized in the following Table 1.

The following sections lay out in detail, the commissioning procedures, prescriptions for production measurements at the three kinematic settings (which also schedule polarimetry and other recurrent calibrations) and final measurements of polarization using HRS(R).

2 Pre-Beam Checks

Responsible persons: Spokespeople

Detailed preparation for this experiment is VERY important, specially due to extremely small allocation of beam time for commissioning and short period of run at 1.5 GeV beam energy, which is needed for detector testing and for the first kinematic point.

This chapter includes items 1, 2, and 3 of Table 1.

2.1 Beam-Line

Responsible person: D. Higinbotham

List of items to do:

1. Corrector magnet test
2. Target magnet test
3. BigBite magnet test

2.1.1 Beam diagnostics tools

1. Harp scans
2. Beam position on BeO target
3. Position check BPM vs. Harp
4. Rastering limits check/set
5. Beam energy measurement
6. Bullseye scan (BigBite magnet energized)
7. Polarized beam - beam charge, position helicity variations.

2.1.2 The Möller Polarimeter

A description of the Compton-back-scattering polarimeter and of setup and running procedures is found at `http://www.jlab.org/~moller/index.html`.

2.1.3 The Compton Polarimeter

A description of the Compton-back-scattering polarimeter and of setup and running procedures is found at `http://hallaweb.jlab.org/compton/`. Will be operation during second and third parts of experiment at higher beam energy.

2.2 Magnets

2.2.1 The BigBite magnet

Responsible person: D. Higinbotham

The magnet operation will be tested according TOPS. The field values on beam line will be measured.

2.2.2 The holding field magnet

Responsible person: G. Cates

The magnet operation will be tested according target OSP. The field values on beam line will be measured. Direction of the holding field will be measured to allow to find average direction to an accuracy of ± 1 mr.

2.2.3 The compensation magnet

Responsible person: E. Folts

The magnet operation will be tested. The field values on beam line will be measured.

2.3 BigBite and BigHand Position Survey

Responsible person: E. Chudakov

The following and some other geometry parameters will be measured.

1. Beam line: HARPs, Be windows at the target area, target He and reference cells, and the solid targets.
2. BigBite detector mid-plane angle and location.
3. BigHand detector position and angle.
4. Angular position of the long calibration counters.

2.4 Wire Chamber gas

Responsible person: J. Segal

1. The Ar-Ethan gas system for BigBite MWCH with the alcohol.
2. Standard HRS gas system for VDC in HRS-Right

2.5 Data Acquisition and Software

Responsible person: R. Michaels

The DAQ will be operational at rate at least 1 kHz with 15% dead time unbuffered mode. DAQ will record data from BigBite and BigHand, beam helicity, charge and position information. EPIC system will be used to record the polarized target information, target ladder position, beam intensity in each of three halls, Hall A beam charge asymmetry and beam intensity.

2.5.1 DAQ Trigger logic

Responsible persons: B. Sawatzky, S. Abrahamyan

2.5.2 DAQ BigBite

Responsible persons: B. Sawatzky, B. Craver, S. Abrahamyan

2.5.3 DAQ BigHAND

Responsible persons: A. Camsonne, J. MIller, S. Tajima

2.5.4 DAQ scalers, helicity monitors

Responsible persons: R. Michaels, A. Kolarkar

2.5.5 Analysis Software

Responsible persons: R. Feuerbach, O. Hansen

List of items to do:

1. Set of analysis tools for the detector cosmic checkout
2. Set of directories for beam commissioning
3. Prepare and test of tools for system commissioning
4. Prepare analysis for *ep* elastic events with analysis rate at least 100 events per second.

2.5.6 Scaler display for BigHAND

Responsible persons: S. Wood

2.5.7 Detector HV and slow control software/hardware

Responsible person: E. Chudakov

1. The HV system will be operational with system of files where the used setting are recorded.
2. Threshold settings for BigBite and BigHand triggers
3. Reset of CPUs and crates of DAQ system

2.6 Detectors and front-end electronics

Responsible person: B. Wojtsekhowski

2.6.1 BigBite Detector Stack

Responsible persons: S. Abramhamyan, B. Craver

List of items to do:

1. Cosmic check/calibration with daily report to run coordinator
2. Software for calibration, resolution and efficiency study

2.6.2 BigHand Detector

Responsible persons: J. Miller, S. Tajima

List of items to do:

1. Cosmic check/calibration with daily report to run coordinator.
2. Software for calibration, resolution and efficiency study.

2.7 Target

Responsible person: G. Cates

2.7.1 Polarized cells

Responsible person: V. Nelyubin/A. Kelleher

List of items to do:

1. Pump polarization and fully characterize 6 cells.

2.7.2 Laser system

Responsible person: A. Kolarkar, J.P. Chen

List of items to do:

1. Prepare operation of 6 lasers
2. Prepare five optical fibers
3. Prepare five-to-one combiner

2.7.3 Optical system

Responsible person: A. Kolarkar, V. Nelyubin

List of items to do:

1. Polarizing, transporting and focusing optics
2. Instrumentation to monitor a laser beam
3. Temperature and safety interlocks

2.7.4 Target motion system

Responsible person: A. Gavalya, J. Segal

List of items to do:

1. Operational target ladder and motion system
2. Position calibration
3. End switches/motion safety system

2.7.5 Oven and heaters

Responsible person: A. Kelleher, A. Gavalya

List of items to do:

1. Operational oven and air heating system

2.7.6 NMR

Responsible person: A. Kelleher

List of items to do:

1. Test operation of NMR system
2. Measure the target polarization and losses

2.7.7 EPR

Responsible person: A. Kolarkar

List of items to do:

1. Test operation of EPR system
2. Measure the target polarization and losses

2.7.8 Reference cell and cooling jets

Responsible person: T. Averett

List of items to do:

1. Test operation of reference system.
2. Concern about effect of gas line on target ladder position.
3. Cooling jets of 5 SQFM each with interlock to beam delivery

2.7.9 Holding field direction

Responsible person: D. Nikolenko, A. Kolarkar

List of items to do:

1. Measure the field direction with magnetic compass and Hall probe at conditions of BB ON/OFF, along the target, different stage of holding field cycles to an accuracy of 1 milli radian.

2.7.10 Motion Check and TV Monitoring

Responsible person: J. Segal

List of items to do:

1. Target ladder position calibration, GUI test, beam interlock test.
2. Obtain view of BeO target on the monitor in counting room.
3. Obtain view of the laser room on the monitor.

2.8 Final Readiness

Responsible person, first run coordinator: B. Sawatzky

Readiness report due 23rd February.

2.9 Closing of the Hall Check-List

Responsible person, run coordinator: B. Sawatzky

List of items to do:

1. Detector check-list - by the detector expert on-shift.
2. Beam line check-list - by tech on-call.
3. Target check-list - by target expert on-shift.

3 Beam-line

Responsible person: D. Higinbotham

This chapter provide a list to do on the beam line after beam delivery begin.

List of items to check:

3.0.1 Beam steering tests

1. Corrector magnet test
2. Target magnet test
3. BigBite magnet test

3.0.2 Beam properties

1. Harp scans
2. Beam position on BeO target
3. Position check BPM vs. Harp
4. Rastering limits check/set
5. Beam energy measurement
6. Bullseye scan (BigBite magnet energized)
7. Polarized beam - beam charge, position helicity variation.

3.0.3 The Möller Polarimeter

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3.1 Comissioning of the Detectors

Responsible person: B. Wojtsekhowski

This chapter provide a list to do on the detectors after beam line checkout completed.

The BB detector stack includes multi-wire drift chamber trackers (BB-MWDC), a timing plane of plastic scintillators (BB-Time) and two arrays of lead-glass Cerenkov counters, a preshower (BB-PSh) and a main shower (BB-Sh) detector of the electromagnetic shower induced by incident electrons. The pulse height from BB-PSh and BB-Sh provides energy information, additional to the momentum information obtained from the bend angle through the BB dipole, which is used to select electron events cleanly.

The BH neutron detector is a very large array of position-sensitive plastic scintillators, sandwiched with Fe converter plates, which measure neutron velocity by time of flight (TOF). The long horizontal plastic bars are equipped with a photomultiplier at each end. The mean time of the photomultiplier signals gives the time of flight and the time difference gives the hit position along the bar. 2 cm thick "veto" bars, placed in front of the main array, allow differentiation of incident charged from uncharged particles and an additional 4, $2.5\times2.5\times305$ cm vertical strips are used for calibration of the horizontal hit position.

A plan view of the detector layout with respect to the beam line and target is given in A.1. Detector commissioning is performed in the following kinematic conditions:

E_e (GeV)	Q^2 (GeV/c)^2	$E_{e'}$ (GeV)	θ_e	E_p (GeV)	P_p (GeV)	θ_p	R_p (m)
1.518	1.19	0.880	56.5	0.638	1.27	35.4	6.51/12.5

The subsequent subsections provide basic running conditions, summarised in tables of the following type:

Task	Target	$\mathrm{I_{beam}}$	Raster	$\mathrm{I_{BB}}$	MWDC	$\mathrm{TH_{PSh}}$	$\mathrm{TH_{Sh}}$	$\mathrm{TH_{BH}}$
—	—	—	—	—	—	—	—	—

Trigger								
—	—	—	—	—	—	—	—	—

which specifies the target, electron beam current ($\mathrm{I_{beam}}$), beam rastering (ON/OFF), BB dipole current ($\mathrm{I_{BB}}$), BB-PSh discriminator threshold setting ($\mathrm{TH_{PSh}}$), BB-Sh discriminator setting ($\mathrm{TH_{Sh}}$), BH sum discriminator setting ($\mathrm{TH_{BH}}$) and the main trigger for the DAQ system.

Descriptions of "how to" are given in B.

3.1.1 Rate dependencies on detector thresholds

Target	I_{beam}	Raster	I_{BB}	MWDC	TH_{PSh}	TH_{Sh}	TH_{BH}
40 cm H_2	1 μA	ON	OFF	OFF	20 MeV	Vary	Vary
Trigger							
Mixed							

The 1st exploratory step, made under the above conditions, measures the counting rate in the BB and BH detectors as a function of applied detection threshold. The procedure for the rate scan, which will be repeated throughout the experiment, is as follows:

- Set trigger control to record BB, BH singles and BB&BH coincidences. Adjust prescale factors to give a combined rate of $\sim$ 500 Hz and take data for $\sim$ 5 min for each permutation of discriminator settings.
- Set TH_{PSh} to the minimum of 20 MeV (conversion factor ** mV = ** MeV) and set TH_{BH} to 100 MeV (neutron-detector conversion factor ** mV = ** MeV).
- Record both the BB singles rate (scaler #i) and BB-BH coincidence rate (scaler #j) as TH_{Sh} is varied from 100 MeV to 1500 MeV in steps of 100 MeV (conversion factor ** mV = ** MeV).
- Leave TH_{PSh} at the minimum of 20 MeV and set TH_{Sh} to 1000 MeV.
- Record both the BH singles rates (scaler #k) and the BB-BH coincidence rate (scaler #j) as TH_{BH} is varied from 25 MeV to 150 MeV in steps of 25 MeV.

This procedure must be repeated after BB and BH pulse height re-calibrations and after kinematic configuration changes. For the 1st step repeat the above sequence of operations with the evacuated 40 cm cell and then the single-foil ^{12}C target in beam.

3.1.2 Big-Bite drift chamber efficiency

Target	I_{beam}	Raster	I_{BB}	MWDC	TH_{PSh}	TH_{Sh}	TH_{BH}
$^{12}C or H_2$	1 μA	ON	ON	ON	20 MeV	700	N/A
HV sets							
Beam I							

The goal is to measure efficiency plato for each chamber and study effect of the beam on the chamber anode currents.
The procedure, is as follows:

- Set trigger control to record BB singles and BB&BH coincidences. Adjust prescale factors to give a combined rate of $\sim$ 500 Hz and take data for $\sim$ 5 min for each permutation of discriminator settings.
- Set HV_{Ch1} to the minimum of 1400 V and set $HV_{Ch2,Ch3}$ to 1800 V. Take 5 min run. Change HV up to 1900 V with steps of 100 V. Repeat procedure with Ch2, Ch3. Ask analysis group to evaluate the data.
- Set HV_{Ch1} to 1600 V, HV_{Ch2} to 1700 V, HV_{Ch3} to 1800 V. Record the anode currents in each chamber using HV GIU. Scan beam current from 0 to 15 μA with steps of 2 μA.

3.1.3 Effect of collimators on detector rates

Target	I_{beam}	Raster	I_{BB}	MWDC	TH_{PSh}	TH_{Sh}	TH_{BH}
$^{12}C or H_2$	5 μA	ON	ON	ON	20 MeV	700	N/A
Collimator sets							
Beam I							

The goal is to measure BB and BH rates for several target configurations with and without collimators on the beam line and the effect of these conditions on the chamber anode currents.
The procedure, is as follows:

- Set trigger control to record BB singles and BB&BH coincidences. Adjust prescale factors to give a combined rate of $\sim$ 500 Hz and take data for $\sim$ 5 min for each permutation of discriminator settings.
- Set HV_{Ch1} to 1600 V, HV_{Ch2} to 1700 V, HV_{Ch3} to 1800 V. Record the anode currents in each chamber using HV GIU. Keep beam current fix of 5 μA. Take CODA run for 10 min for each configuration.

3.1.4 $^1\mathrm{H}\,(e, e'p)$ shower pulse height calibration and HV adjustment

Target	I_{beam}	Raster	I_{BB}	MWDC	TH_{PSh}	TH_{Sh}	TH_{BH}
40 cm H_2	5 μA	ON	OFF	OFF	20 MeV	700 MeV	100 MeV
Trigger							
BB&BH							

Overdetermined elastic electron scattering from the proton is used to calibrate and cross check position, pulse height and time-of-flight response of the detection system. This starts with calibration of the shower detectors, using the above conditions. The goals of the procedure are:

1. To align the gains of the individual elements of the BB-Sh and BB-PSh arrays.

2. To set the gains to achieve pulse-height to energy conversion factors of 1.00 ± 0.01, equivalent to 0.5 MeV per pulse-height histogram channel. This will ensure that hardware thresholds (especially sum thresholds) are accurately determined.

3. Optimize the energy resolution and hence π^- rejection efficiency of the shower counters.

The procedure is as follows:

- Record ${}^1\mathrm{H}(e, e'p)$ coincidence data for $\sim$ 10 min (to accumulate $\sim$**** events) and check the on-line histograms *(insert name of histogram at ****)* listed below.

  1. 1D ****, the $e' - p$ coincidence time distribution. Define a "window" cut ($\sim$ 20 ns wide) to select prompt coincidences in the time distribution.
  2. 2D ****, the vertical position of p in BH vs. e^- in BB-Sh. Define a cut on $X_p - X_e^-$ to select tightly on events on the elastic-scattering locus. The expected position resolution from shower reconstruction is $\sim$ 10 cm and a relatively crude BH position is obtained from the BH sum outputs Σ_i (A.2.2) This cut and that described in the previous item are then applied to the following histograms.
  3. 1D ****, E_{tot}^{PSh} the total energy deposited in BB-PSh
  4. 1D ****, E_{tot}^{Sh} the total energy deposited in BB-Sh
  5. 2D ****, E_{tot}^{PSh} *vs.* E_{tot}^{Sh}. One expects $\sim$ 30% energy deposition in BB-PSh and $\sim$ 70% in BB-Sh
  6. 1D ****, the total energy deposited in the shower counters $E_{tot} = E_{tot}^{PSh} + E_{tot}^{Sh}$
  7. 1D ****, the energy difference $E_{diff} = E_{tot} - E_e^{Angle}$, where E_e^{Angle} is the e' energy obtained from θ_e determined by the electron hit position in BB-Sh and the proton hit position in BH (use time of Sums-Left vs time of Sums-Right).

- Run the analysis code to obtain the energy conversion factors. Details are given in B.3.1.

- Adjust the HV of BB-PSh and BB-Sh to bring the conversion factors to ~ 1.0

- Repeat the measurement, analysis and HV-adjust cycle until calibration factors are 1.00 ± 0.01. The E_{tot}^{PSh} *vs.* E_{tot}^{Sh}ratio should remain cleanly defined and the FWHM of E_{diff} plot **** should be$\leq$ 50 MeV.

- Determine the maximum software energy cut which can be applied to E_{tot}^{PSh} without reducing detection efficiency significantly (20%).

The data taken in the above shower calibration also provide the 1st crude check of the position in BH.

3.1.5 Calibration of the BB-MWDC geometry and drift times

Target	$I_{\rm beam}$	Raster	$I_{\rm BB}$	MWDC	$TH_{\rm PSh}$	$TH_{\rm Sh}$	$TH_{\rm BH}$
Single-foil ^{12}C	1 μA	OFF	OFF	ON	100 MeV	700 MeV	100 MeV
Trigger							
BB&BH							

This calibration checks the track reconstruction from a "point" target through the BB-MWDC into BB-Sh. With no magnetic field the hit positions obtained from all BB-MWDC planes should fall on the same straight line, which should also point to the hit position given by BB-Sh. The BB-MWDC's are horizontal drift chambers, where the charged particle is at approximately perpendicular incidence to the planes of wires. HV control and leakage-current monitoring is described in B.2.1. To avoid the complication of having to untangle the signatures of many tracks, only those whose coordinates are consistent with those to a high-energy shower in BB-Sh ($TH_{\rm Sh}$ = 700 MeV) are analyzed.

For the commissioning process the reconstruction is performed in 2 modes:

1. Based on wire position only. This is a basic check that the physical coordinates of the chambers and the wires themselves are correctly known, free from any inaccuracies in the drift-time calibration
2. Including drift time to the wires. The conversion factors of the TDCs are sufficiently known, but the drift-time TDC offset is also needed to determine t_0. A 1st order linear drift-time to distance relation is applied to obtain the distance of the ionization track from the wire.

The procedure is as follows:

- Note the leakage currents in BB-MWDC @ 1 μA. If the currents in any of the chambers exceeds 30 μA switch off the HV and seek expert help. Ensure that $TH_{\rm Sh}$ = 700 MeV. Note singles rates in BB and BH.
- Start the on-line analysis and take data for 10 min. Ensure that "sensible" distributions accumulate in the following histograms:
  1. 1D ****, the $e' - p$ coincidence time distribution. Apply prompt-coincidence cut (Sec.3.1.4) to all subsequent histograms.
  2. 1D ****: the BB-Sh E_{diff} pulse height distribution (Sec.3.1.4). Define a window cut $\sim$ 100 MeV wide around the elastic peak and apply to all subsequent histograms.

3. 1D ****: the drift times for planes ****. The level of random coincidences should be less than 10% of the "peak" in the prompt-coincidence distribution. Reduce beam current and seek expert help if this condition is not met. Define a time window to select prompt coincidences and apply to subsequent histograms.
4. 1D ****: wire# hit maps
5. 1D ****: occupancy, the number of roughly simultaneous hits in each plane.
6. 2D ****:$u - u'$, $v - v'$, $x - x'$, ... correlations in wire #.
7. 2D ****: $Y_{sh} - Y_3^{uvx}$ vs. $X_{sh} - X_3^{uvx}$, the differences of vertical/horizontal coordinates determined by the shower counters and the $u-v-x$ intersection in MWDC 3 (closest to the shower counters). Define a polygon cut to select events where $(Y_{sh} - Y_3^{uvx}) < 15$ cm and $(X_{sh} - X_3^{uvx}) < 15$ cm. Apply this cut to subsequent histograms.
8. 1D ****: co-linearity parameters, $d_i = \left|\mathbf{R}_i^{uvx} - \mathbf{R}_i^{fit}\right|$ the deviation of each chamber hit position from the best-fit straight line through the chambers which originates at the target. Define cuts to select $d_{1,3} < 0.5$ cm and $d_2 < 2.0$ cm, which should then be applied to subsequent histograms.
9. 1D ****: efficiency. The fraction of events which induce a high-energy shower in BB-Sh which produce a good straight-line reconstruction in the MWDC. The efficiency should be plotted both as a function of the horizontal x coordinate and the dispersive y coordinate in chamber 3
10. 1D ****: target vertex z position.

- Check and if necessary modify the BB-MWDC coordinates for all chambers without drift-time position compensation.
- Determine the drift-time TDC offsets and enter in the analysis configuration files.
- Determine the accuracy of straight-line reconstruction with and without drift-time position compensation.
- Determine the accuracy of vertex reconstruction with and without drift-time position compensation.
- Determine occupancies and efficiencies.
- Raise the beam current to 5 μA keeping a careful eye on leakage currents in the BB-MWDC. If OK record these and the singles and coincidence counting rates in BB and BH triggers.
- Take data for $\sim$ 10 min. and check BB-MWDC occupancies, efficiencies and accuracy of reconstruction of tracks and vertices.

- Turn on rastering, check the limits of the raster position sweep using `spot++`, and take data for a further ~ 10 min.
- Demonstrate that the reconstructed vertices are consistent with the raster limits.
- Move in the multi-foil carbon target, set current to 5 μA and turn on rastering. Check reconstruction of z vertex. Straight-line reconstruction should now account for z variation.

3.1.6 BB magnetic optics calibration

Target	$I_{\rm beam}$	Raster	$I_{\rm BB}$	MWDC	$TH_{\rm PSh}$	$TH_{\rm Sh}$	$TH_{\rm BH}$
Single foil ^{12}C	1 μA	OFF	$\equiv 0.9$T	ON	20 MeV	700 MeV	100 MeV
Trigger							
BB&BH							

The optics procedure seeks to determine how precisely the momentum is measured from bend angle through the dipole and possible distortion of determined polar and out-of-plane angles:

- Energize the BB dipole. As the commissioning is performed at rather lower beam energy than the production measurements, a reduced field of 0.9 T is used. Take data for ~ 10 min.
- Histograms of the following should be accumulated:
  1. 1D ****:Shower counter stuff, cuts,π^- rejection monitor
  2. 1D ****: z the distribution of events along the beam line
  3. 1D ****:$\left|P^{BB}\right| - \left|P^{Calc}\right|$vs. z, θ_e, $\phi_e$the deviation of 3 momentum magnitude. The 1st order method to obtain momentum from deflection angle through the dipole is given in B.3.3.
- XXX

Target	$I_{\rm beam}$	Raster	$I_{\rm BB}$	MWDC	$TH_{\rm PSh}$	$TH_{\rm Sh}$	$TH_{\rm BH}$
40 cm H_2	5 μA	ON	$\equiv 0.9$T	ON	20 MeV	700 MeV	100 MeV
Trigger							
BB&BH							

3.1.7 Pulsed beam BB and BH TOF calibration

Target	$I_{\rm beam}$	Raster	$I_{\rm BB}$	MWDC	$TH_{\rm PSh}$	$TH_{\rm Sh}$	$TH_{\rm BH}$
Single foil ^{12}C	0.1 μA	OFF	OFF	OFF	20 MeV	700 MeV	100 MeV
Trigger							
BB, BH							

Calibration of TOF in both BB and BH starts using by using the electron beam in pulsed mode. The time pick off from the beam bunch has to be referenced to the TOF start signal which will generally be the aligned OR from BB-Trig. **For pulse beam of 100 ns time interval the beam phase signals should be also at least 100 ns apart, which is quite different from standard CW beam when we using 40 ns interval between beam phase pulses.**

- Set the beam-bunch interval to 100 ns
- Correlate bunch time to detector times

3.1.8 BH position and TOF calibration

Target	I_{beam}	Raster	I_{BB}	MWDC	TH_{PSh}	TH_{Sh}	TH_{BH}
40 cm H_2	5 μA	ON	OFF/$\equiv$ 0.9T	ON	20 MeV	700 MeV	25 MeV
Trigger							
BB&BH							

Again over-determined ${}^2\mathrm{H}\,(e, e'p)$ is used for calibration of the momentum of the proton detected in BH, based on the electron track reconstructed in BB. This is performed with and without the BB dipole energized. Thus cross-checks may be made on:

1. electron angle determination in BB.
2. uncertainties in the BH TDC start time, which is provided by the BB-trig time. This would be due to uncertainty in the e' trajectory and hence flight time through the dipole.

Proceed by the following series of steps:

- Start with $I_{BB} = 0$ A. Take data for ~ 30 min
- Histograms
    1. xxx
- Determine the accuracy of position reconstruction in the veto counters
- Determine the accuracy of position reconstruction in the main TOF bars
- TOF zero calibration
- Veto proton rejection efficiency

3.1.9 Background studies

Target	I_{beam}	Raster	I_{BB}	MWDC	TH_{Psh}	TH_{Sh}	TH_{NTOF}	Trigger
Empty 40 cm	1 μA	OFF	OFF	ON	20 MeV	1000 MeV	100 MeV	BB&BH

Move the empty He glass cell in beam and record background for ~ 1 hr.

4 The Polarized ^{3}He Gas Target comissioning

The target works on the principle of spin exchange between optically pumped Rb vapor and ^{3}He gas. It consists of a 40 cm long sealed glass cell filled to 10 atm with ^{3}He gas, equivalent to a thickness of 10^{22} atoms/cm^2, and achieves polarizations of 40-50%. Information on target developments may be found at `http://hallaweb.jlab.org/equipment/targets/polhe3/polhe3_tgt.html`.

4.1 Holding field magnet

4.2 Beam line inside magnet

4.3 Target elements

4.4 Position alignment, survey

Large solid angle of detector system in this experiment lead to high background rate and sensitivity to beam-target alignment.

4.5 Vertical motion calibration

4.6 Commissioning with beam

4.7 Polarization measurements

The important new aspect of the GEN polarized target is a short up-time. This means that polarization can quickly grow when the beam is off. So, it is important to keep accurate record of EPIC variables related to the beam, lasers, and target to allow off-line analysis and correction of the polarization on beam intensity changes.

5 $^3\overrightarrow{\mathrm{He}}\,(\vec{e}, e'n)$ Production Kinematics

The 3 kinematic settings for $^3\overrightarrow{\mathrm{He}}\,(\vec{e}, e'n)$ are summarised in the following table:

Kin	$Q^2\,(\mathrm{GeV/c})^2$	E_e (GeV)	$E_{e'}$ (GeV)	θ_e	E_n (GeV)	β_n (GeV)	θ_n	R_n (m)
I	1.20	1.518	0.88	56.5	0.638	0.80	35.4	9.26
II	2.48	2.637	1.32	50.0	1.32	0.91	29.4	12.00
III	3.43	3.287	1.46	50.0	1.83	0.93	25.5	12.00

The estimated counting rates, production-running times and uncertainties are given in the following:

(based on proposal...more up-to-date available?)

Kin	$^3\mathrm{He}\,(e, e'n)$ rate (Hz)	Prod. Time (hr)	Stat. $\Delta A_{\perp}/A_{\perp}$	Sys. $\Delta G_{En}/G_{En}$
I	13.8	24	0.082	0.105
II	1.49	104	0.137	0.104
III	0.45	456	0.134	0.104

During production data taking the parameters for monitoring physics results the following should be observed (examples from E02-013 proposal):

1. The quasi-elastic events should be separated well in distribution over missing momentum, see Fig. 1.
2. Target Z-vertex distribution, see Fig. 2.
3. Q^2 distribution for KIN-3, see Fig. 3.

5.1 Kinematics I

Kinematics I is allocated 15 shifts of which the 1st 1 shift is to change BH flight path from 12.0 m to 9.26 m. The experimental proposal requested a total of 3 shifts of production running on the basis of an estimated quasi-elastic $^3\mathrm{He}\,(e, e'n)$ counting rate of 13.8 Hz at a beam current of 12 μA. This gives a total of 1.49×10^5 counts, yielding an estimated statistical uncertainty of 0.082 in $\Delta A \perp / A \perp$. Total beam integral of 25 Coulomb for the production data should be collected.

5.1.1 Calibrations

Only a short run on hydrogen with coinciidence trigger needed to be done for calibration of TOF - 15' with 5 μA and 15' with 15 μA. The rest of calibration data are already collected during comissioning of the BB and BH.

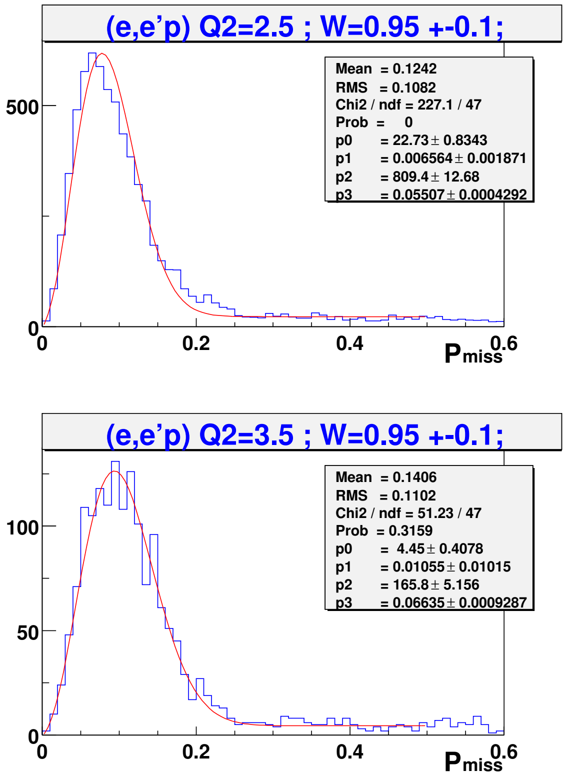


Figure 1:

5.2 Kinematics II

Kinematics II is allocated 48 shifts of which the 1st:
1 shift is to reduce the BB angle from 56.5 to 50.0 deg., reduce the BH angle from 35.4 to 29.4 deg and increase the BH flight path from 9.26 to 12.0 m and change the beam energy to 2.6 GeV.

The experimental proposal requested a total of 14 shifts of production running on the basis of an estimated quasi-elastic ^{3}He $(e,e'n)$ counting rate of 1.48 Hz at a beam current of 12 μA. This gives a total of 0.76×10^5 counts, yielding an estimated statistical uncertainty of 0.137 in $\Delta A\perp/A\perp$ Total beam integral of 120 Coulomb for teh production data should be collected.

5.2.1 Calibrations

For second kinematic point the beam a

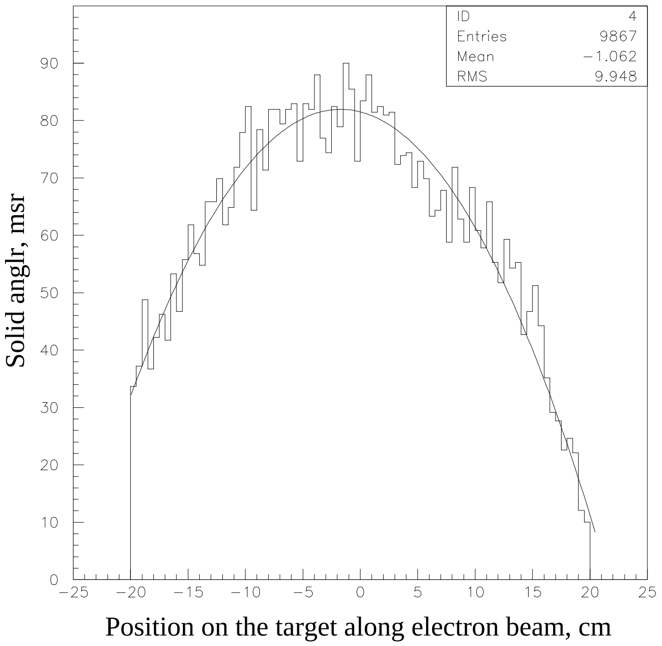


Figure 2:

5.3 Kinematics III

Kinematics III is allocated 121 shifts of which the 1st 1 shift to reduce the BH angle from 29.4 to 25.5 deg. The experimental proposal requested a total of 57 shifts of production running on the basis of an estimated quasi-elastic $^3\mathrm{He}\,(e, e'n)$ counting rate of 0.45 Hz at a beam current of 12 μA. This gives a total of 1.0×10^5 counts, yielding an estimated statistical uncertainty of 0.134 in $\Delta A \perp / A \perp$

5.3.1 Calibrations

6 End-of-Run Procedures

6.1 BB removal and HRS(R) installation

Configuration change 26 shifts. Remove BB and move HRS(R) to 23°.

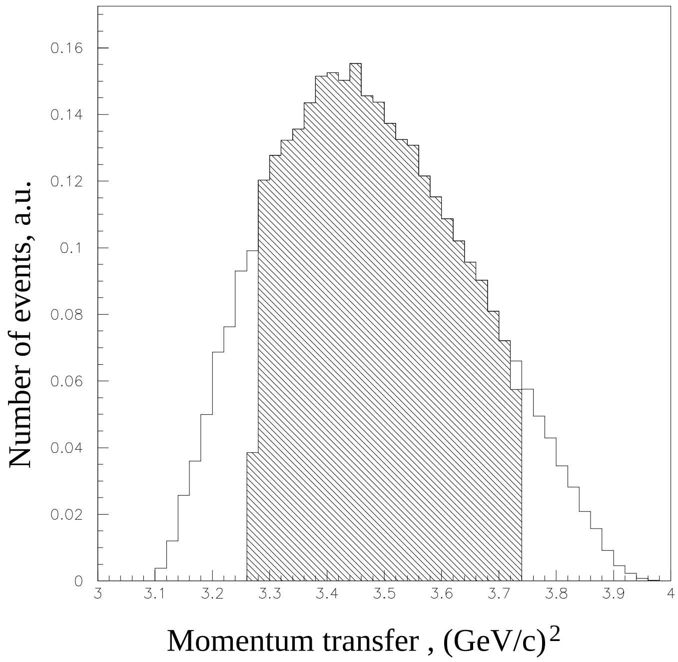


Figure 3:

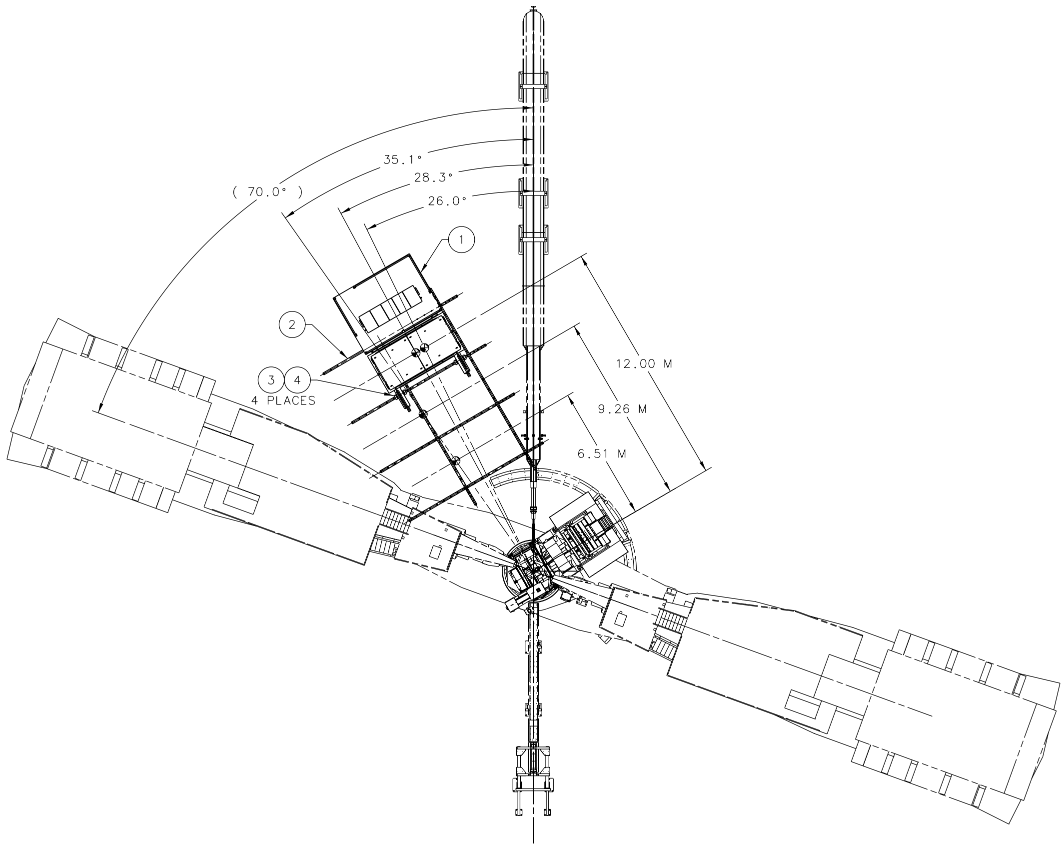
6.2 $^3\overrightarrow{\mathrm{He}}\,(\overrightarrow{e}, e')$ Elastic scattering

A Detector Layout

Drawing of detector layouts and electronics diagrams

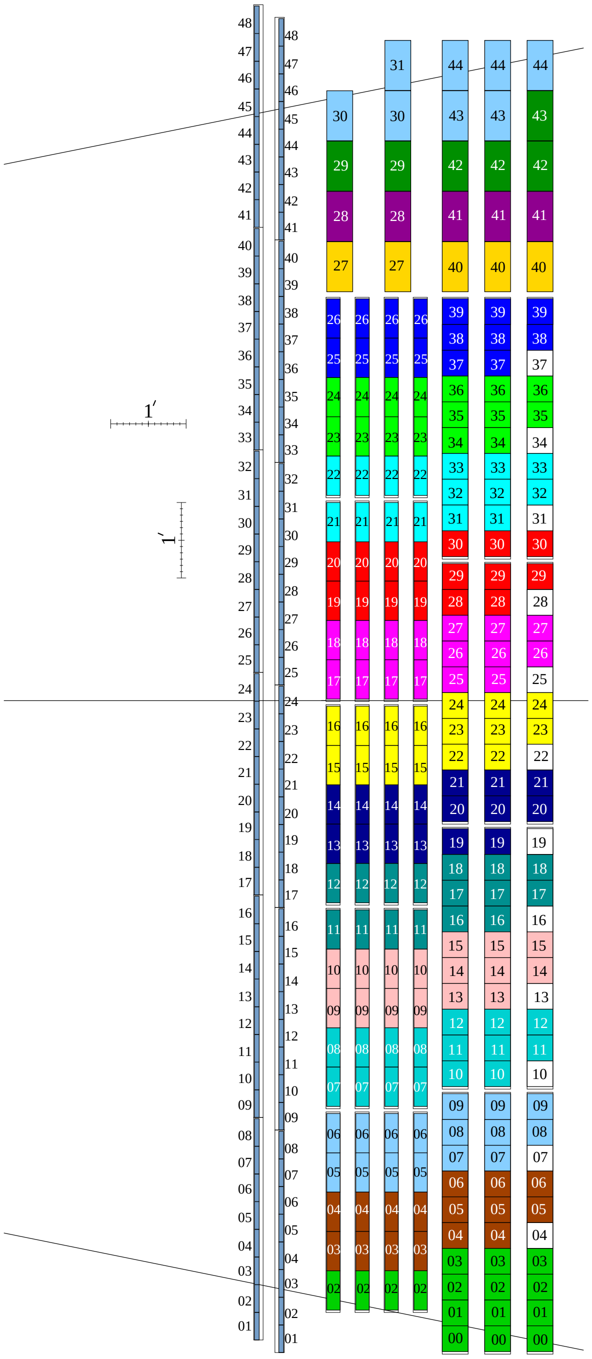
A.1 Plan Views

A.1.1 Plan view of detection system



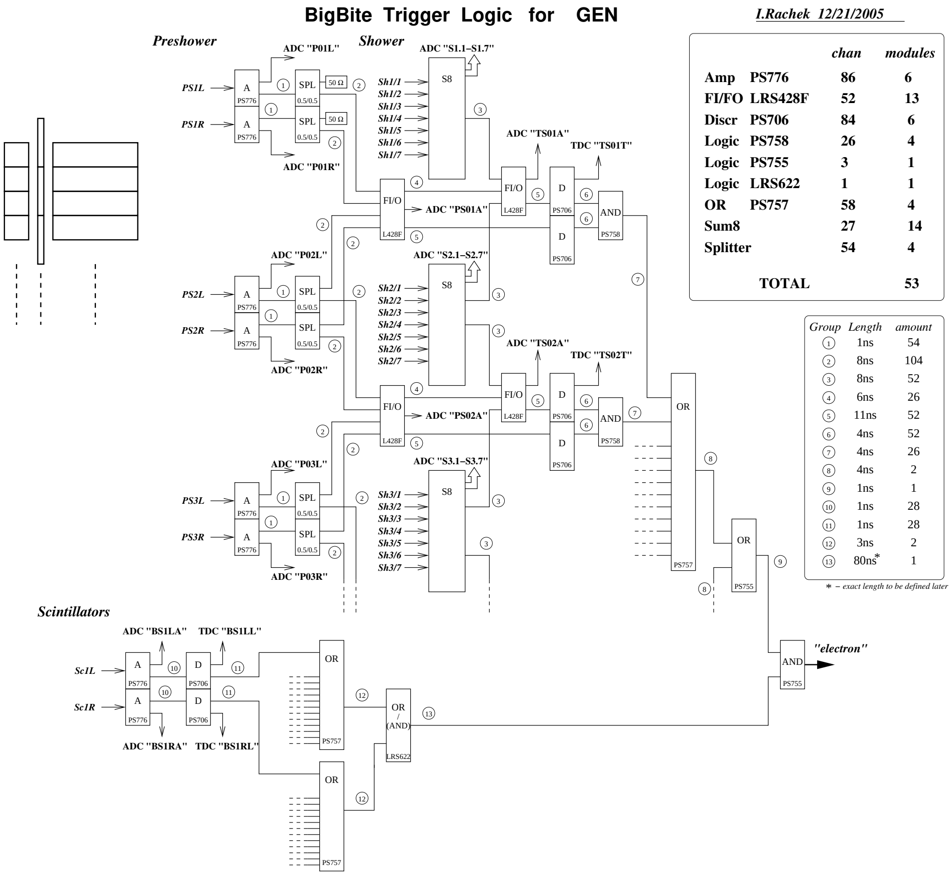
A.1.2 BH side view

A more up-to-date diagram is required

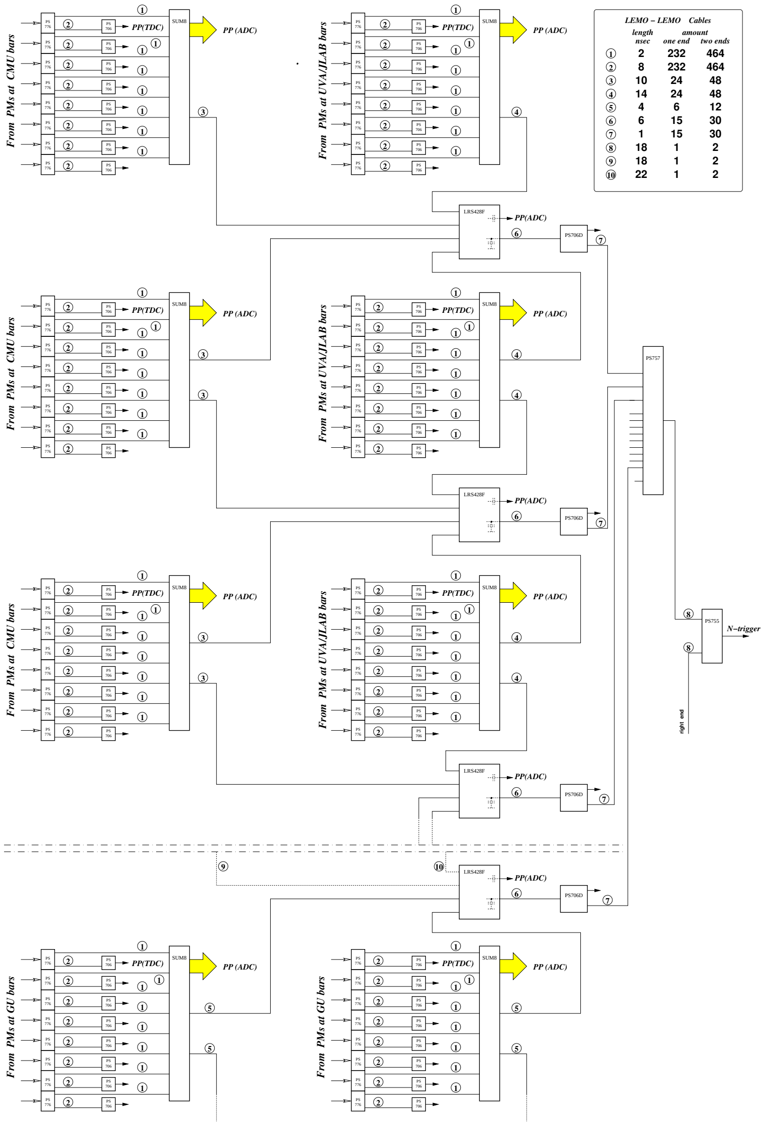


A.2 Electronics Diagrams

A.2.1 BigBite Trigger



A.2.2 BH Trigger



	length nsec	amount one end	amount two ends
1	2	232	464
2	8	232	464
3	10	24	48
4	14	24	48
5	4	6	12
6	6	15	30
7	1	15	30
8	18	1	2
9	18	1	2
10	22	1	2

B How-To's

B.1 Beam How-To's

Start the GUI for the beam-time counting table: login to `adaqs2` or `adaqs3` as user `adaq.` Passwords may be found on the Hall-A counting room white board. From the shell prompt execute the following command sequence:

- `cd ~adaq/ACCOUNT`
- `atable`

Start the beam counting script: login to `adaql1` as user `adaq` and execute the following:

- `tkABU`

Check beam rastering: login to `adaqs2` as `adaq`. Ensure CODA is running with beam ...details?? Execute the following:

- `spot++`

This should generate 3 histograms which display the x-y extent of the electron-beam "wobble" at the target. *Details of acceptable spec.* If needed perform a harp scan as described at `http://www.jlab.org/~jones/harp_halla/harp.html`.

B.2 Detector Slow Control

General slow-control information may be found at `http://hallaweb.jlab.org/experiment/E02-013/gen_slow_control.html`

B.2.1 HV Setting

B.2.2 Discriminator Setting

B.2.3 Magnet Setting

B.2.4 Scaler Reading

B.3 Detector Analysis Software

B.3.1 Shower calibration analysis

B.3.2 Drift chamber analysis

B.3.3 BB momentum reconstruction

B.3.4 TOF analysis and BH hit position reconstruction

B.4 Target Slow Control

C Summary Tables & Run Sheets

C.1 Overall Run Time (from shift schedule)

Function	# Shifts	# People/Shift
Commissioning	12	3
Production + Monitoring	30	3
Production + Monitoring	154	2
Configuration Change	26	4
Calibration	10	2
$^3\overrightarrow{\mathrm{He}}\,(\vec{e}, e'n)$ production @ 1.31 (GeV/c)^2	3	-
$^3\overrightarrow{\mathrm{He}}\,(\vec{e}, e'n)$ production @ 2.40 (GeV/c)^2	14	-
$^3\overrightarrow{\mathrm{He}}\,(\vec{e}, e'n)$ production @ 3.40 (GeV/c)^2	57	-

C.2 Run Sheets
