Status of GEn-II Analysis

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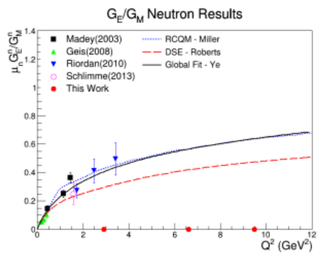
Neutron Form Factors

- GEn-II experiment extends the current world data up to $9.8\ GeV^2$
- This provides strong constraints for theoretical models for nucleon structure
- Quark flavor decomposition can be achieved by combining neutron and proton data



Selected G_E^n world data with only porposed GEn-II Q^2 points, proposed error bars are not shown [1]

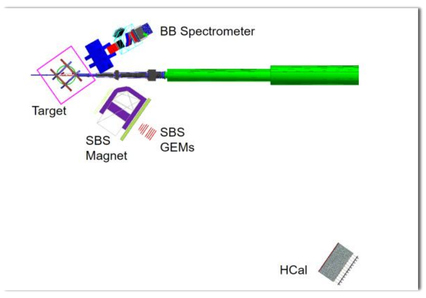
Analysis Software and MC Simulation

Analysis Flowchart

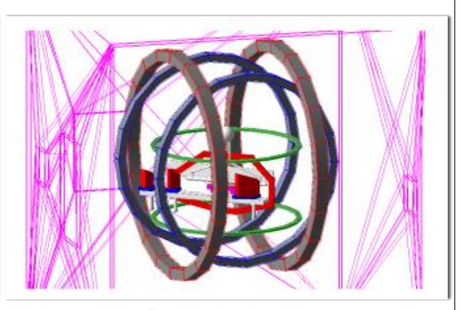
Raw Data Files (evio)
↓ SBS-offline
Detector Variables
↓ Standalone Analysis Library
Physics Variables
↓ Analysis Scripts
Final Asymmetry

Monte Carlo Simulation (G4SBS)

- G4SBS was created using the Geant4 Framework
- All detector materials are implemented in the simulation
- QE processes are simulated and propagated through detectors
- Simulation output is digitized and processed exactly like real data
- Simulated and real data are compared to extract the physics



Experiment layout in the simulation

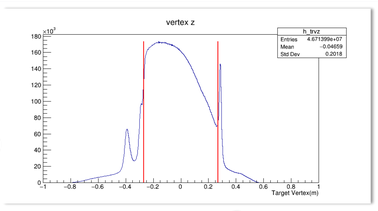


Target in the simulation

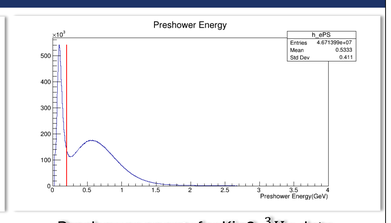
QE Event selection, Simulation fitting, and Polarizations

QE Event Selection cuts

- Track vertex (|vertex z| < 0.27m)
- Preshower Energy (>0.2 GeV)
- Invariant Mass (Kin2 : 0< W^2 <1.6 GeV^2)
- Coincidence Time(Kin2:90<cointime<110ns)
- Hadron Particle Identification
  (Kin2: |dx|<0.5m and |dy|<0.5m)



Target vertex for Kin2 ^3He data

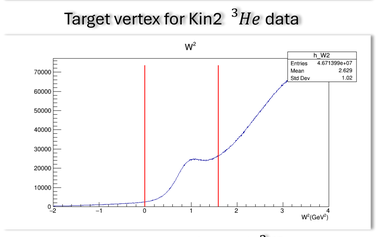


Preshower energy for Kin2 ^3He data

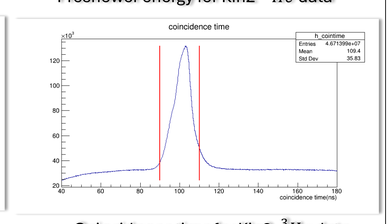
Simulation Fitting

$sim = N(p_{sim} + R * n_{sim} + N_{bg} * bg_{dist})$

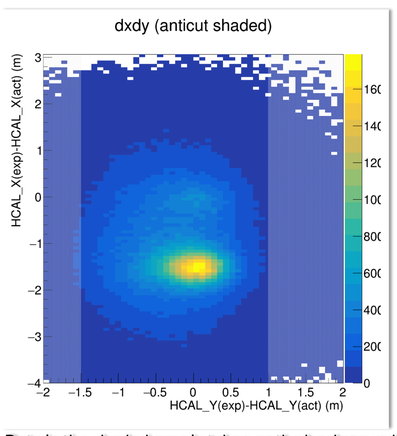
– p_{sim} - proton shape (simulation)
– n_{sim} - neutron shape (simulation)
– bg_{dist} - background shape (data anti-cut)
– N, R, N_{bg} - fit parameters
(all are normalizations, so the shapes are preserved)



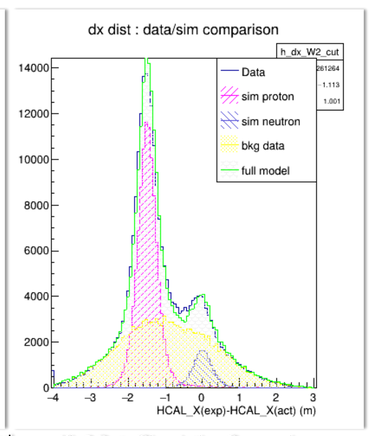
Invariant mass for Kin2 ^3He data



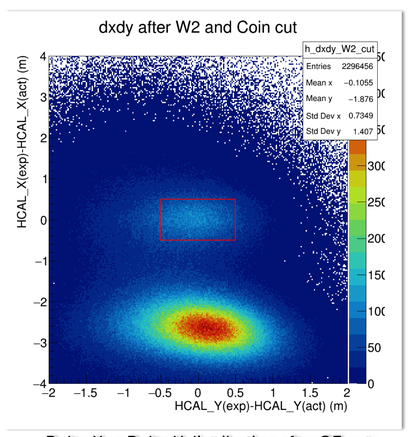
Coincidence time for Kin2 ^3He data



Data in the shaded area is taken as the background

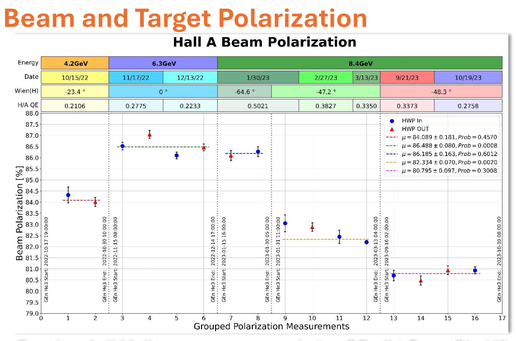


Kin3 Data/Simulation Comparisons

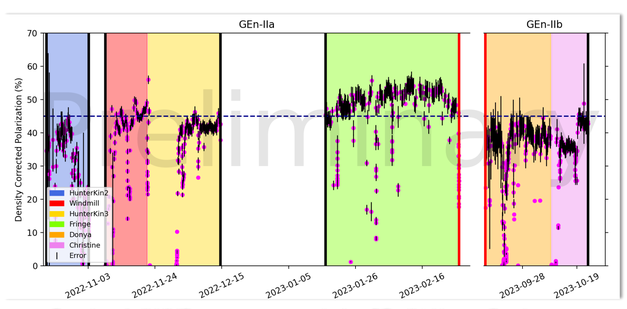


Delta-X vs Delta-Y distribution after QE cuts

Beam and Target Polarization



Results of all Møller measurements during GEn-II * Faraz Chahili



Results of all NMR measurements during GEn-II * Hunter Presley

On going efforts and path forward

- Improve the Calibrations
  - Hadron Calorimeter – timing and energy
  - BigBite timing
  - GRINCH
  - GEMs on Hadron arm
- Inelastic Background Simulation and improving the background fitting
- SBS tracking data to improve the Hadron calorimeter calibrations
- Improving calibrations of all detectors will help to optimize the statistical uncertainty
- Pass2 replay

Acknowledgement

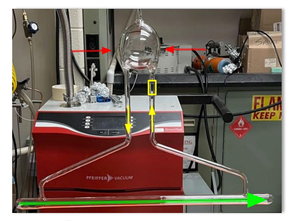
- GEn – II Students : Sean Jeffas, Gary Penman, Hunter Presley, Kate Evans, Jack Jackson, Faraz Chahili, Braian Mederos, Jacob Koenemann
- SBS Collaboration
- UVA group members : Nilanga Liyanage, Huong Nguyen, Xinzhan Bai, Asar Ahamed, Anuruddha Rathnayake, John Boyd, Sean Jeffas, Bhashitha Dharmasena, Jacob McMurtry, Mihitha Maithripala, Minh Dao
- Jlab Staff
- Department of Energy

GEn-II Experiment Overview

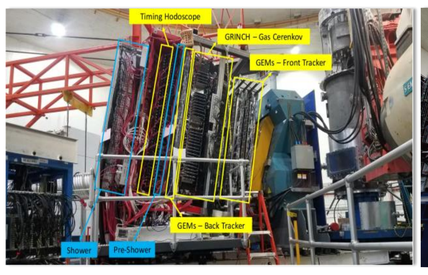
- Ran from Oct 2022 to Mar 2023 and again from Sept to Oct 2023
- Polarized electron beam collided onto polarized ^3He target
- Measured the form factor ratio at $Q^2 = 2.9,\ 6.5,\ 9.8\ GeV^2$ (Kin2, Kin3, Kin4)

Kin	Q^2 (GeV^2)	E_{beam} (GeV)	θ_{BB} (deg)	θ_{SBS} (deg)	run time (days)
1	1.79	2.206	29.5	34.7	1
2	3.00	4.291	29.5	34.7	13
3	6.83	6.373	36.5	22.1	33
4	9.82	8.448	35	18	86

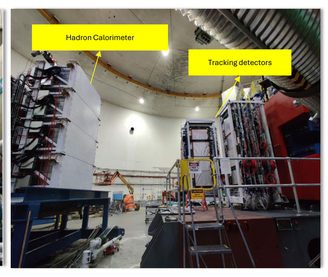
Kinematic settings for GEn-II [1]



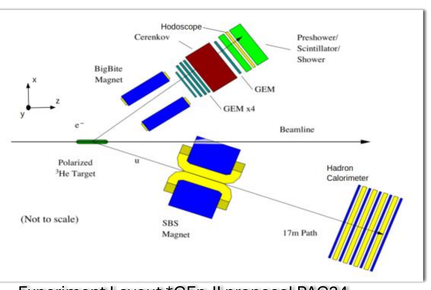
Polarized ^3He Target *Picture from H. Presley



BigBite Spectrometer



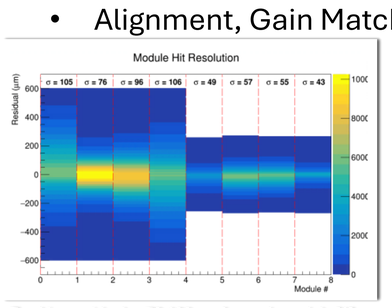
Super BigBite Spectrometer



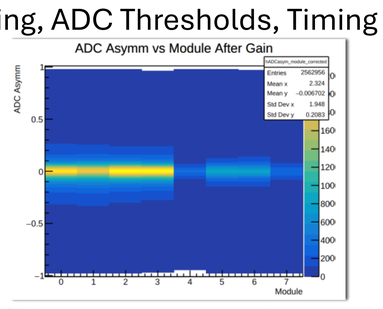
Experiment Layout *GEn-II proposal PAC34

Improving Calibrations in progress

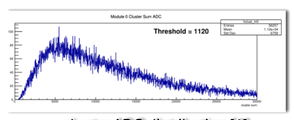
- **GEM Trackers**
  - Alignment, Gain Matching, ADC Thresholds, Timing



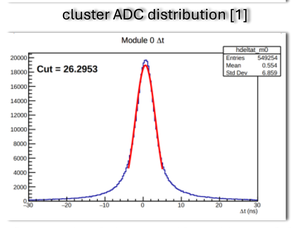
Tracking residuals ~70-100 μm for each module [1]



ADC Asymmetry centered around zero for each module [1]

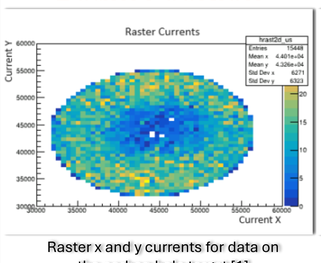


cluster ADC distribution [1]



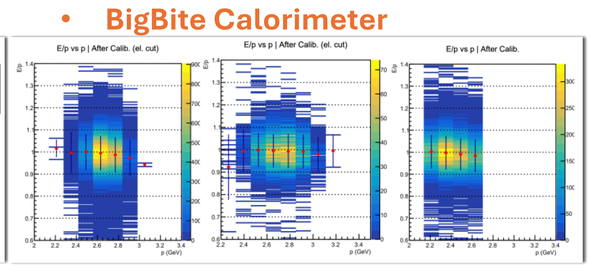
Δt gaussian fit between U and V strips [1]

- **Beam Position**



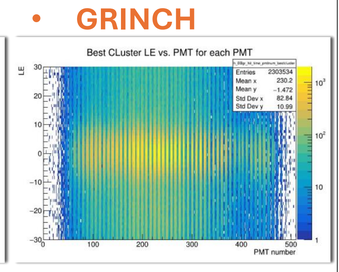
Raster x and y currents for data on the carbon hole target [1]

- **BigBite Calorimeter**



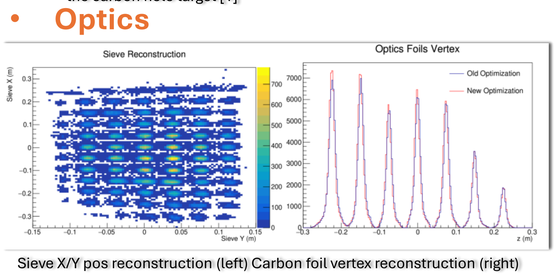
E/p calibration vs momentum for Kin2, Kin3 and Kin4 (left to right) *Kate Evans

- **GRINCH**



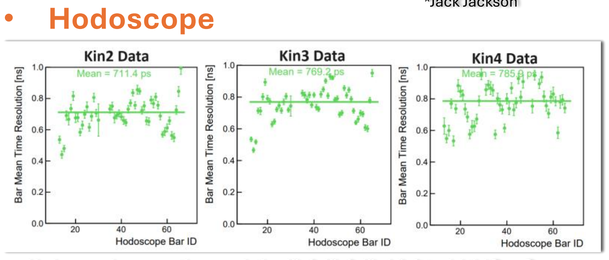
GRINCH leading edge calibrations *Jack Jackson

- **Optics**



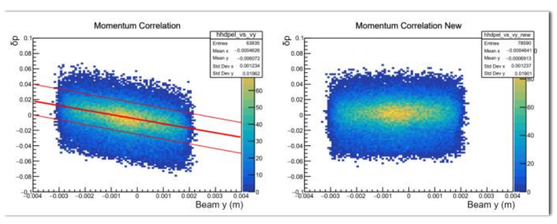
Sieve X/Y pos reconstruction (left) Carbon foil vertex reconstruction (right)

- **Hodoscope**



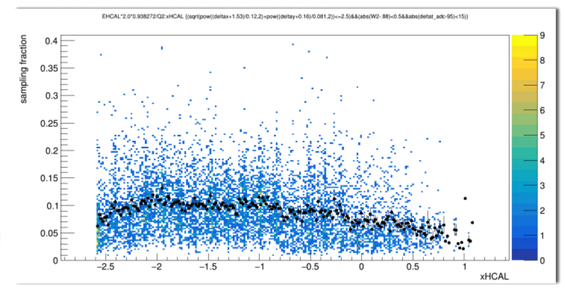
Hodoscope bar mean time resolution Kin2, Kin3, Kin4 (left to right) *Gary Penman

- **Momentum**



Momentum correlation with beam y position before (left) and after (right) correction [1]

- **Hadron Calorimeter**



Sampling fraction vs Hcal x (m) * Andrew Puckett

Asymmetry Formalism and G_E^n Extraction

$$h_{raw} = P_{IHWP} P_{kin} h_{meas}$$

$$A_{raw} = \frac{N^+ - N^-}{N^+ + N^-} \Rightarrow A_n = \frac{A_{raw} - \sum_{x \neq n} f_x A_x}{f_n}$$

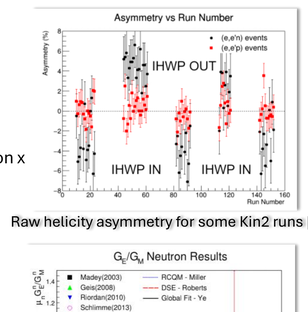
$$A_{phys} = \frac{A_{raw} - \sum_{x \neq n} f_x A_x}{P_{beam} P\,{}^3_{He} P_n f_n} \Leftarrow A_n = P_{beam} P\,{}^3_{He} P_n A_{phys}$$

h_{raw} = corrected helicity
h_{meas} = recorded helicity
P_{IHWP} = IHWP in/out +1/-1
P_{kin} = Kin2 / Kin 3 & 4 (-1/+1)
A_{raw} = raw asymmetry
A_n = neutron asymmetry
A_{phys} = physics asymmetry
A_x = asymmetry from contamination x
f_x = fraction from contamination x

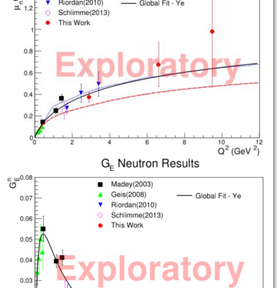
$$A_{phys} = \frac{A_{raw} - f_{acc}A_{acc} - f_\pi A_\pi - f_{in}A_{in} - f_p A_p - f_{FSI}A_{FSI}}{P_{beam} P\,{}^3_{He} P_n (1 - f_{acc} - f_{N_2} - f_\pi - f_{in} - f_p - f_{FSI})}$$

$$\left(\frac{\bar{\epsilon}}{\bar{\tau}} A_{phys}\right)\Lambda^2 + \left(\sqrt{\frac{2\bar{\epsilon}(1-\bar{\epsilon})}{\bar{\tau}}}\,\bar{P}_x\right)\Lambda + \left(A_{phys} + \sqrt{1-\bar{\epsilon}^2}\,\bar{P}_z\right) = 0$$

where $\Lambda = \frac{G_E^n}{G_M^n}$ is extracted by solving the quadratic equation



Raw helicity asymmetry for some Kin2 runs [1]



Exploratory results from Sean Jeffas [1]

References

[1] Jeffas, Sean. Measurement of the Neutron Electromagnetic Form Factor Ratio At High Momentum Transfer. University of Virginia, Physics - Graduate School of Arts and Sciences, PHD, 2024, doi.org/10.18130/tdeq-rr09.

[2] Riordan, Seamus Patrick et al. “Measurements of the Electric Form Factor of the Neutron at Q2 = 1.7 and 3.5 GeV2 /.” Carnegie Mellon University, 2008. Print.