# Hall A Update and Activities

**Maria Satnik**
William & Mary

*Jefferson Lab User's Organization Satellite Meeting*

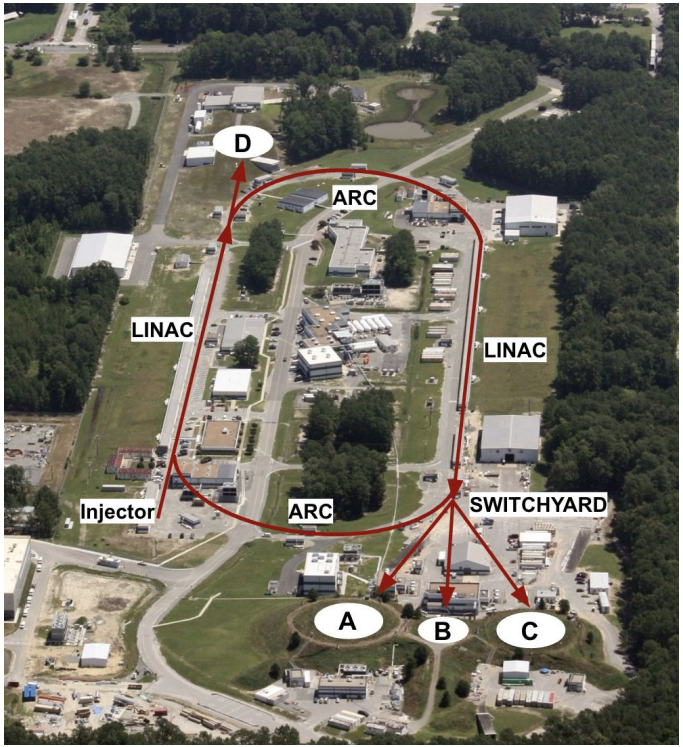
6th Joint Meeting of the APS Division of Nuclear Physics and the Physical Society of Japan

29 November 2023

WILLIAM & MARY
CHARTERED 1693

Jefferson Lab

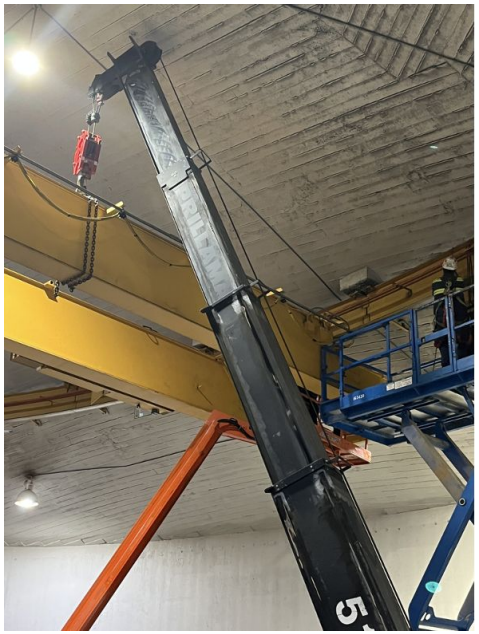
# Jefferson Lab (JLab) Hall A




- Continuous Electron Beam Accelerator Facility **(CEBAF)**
  - **Injector**: photocathode gun creates continuous waveform (CW) bunches of electrons that are injected into the “racetrack” accelerator.
  - Two Linear Accelerators **(LINAC)** utilize superconducting radio frequency (SRF) niobium cavities.
  - **Arc magnets** allow for beam recirculation.
  - Up to **11 GeV Beam Energy** (12.5 GeV to Hall D).

- **Hall A**
  - High Current, High Luminosity
    - 60 uA, L = 10e39 e/cm^2/s
  - User-Driven, Open-Floor experiments
  - **SBS** program focuses on probing the nucleus by resolving the electromagnetic form factors of nucleons using the **SBS spectrometer**.

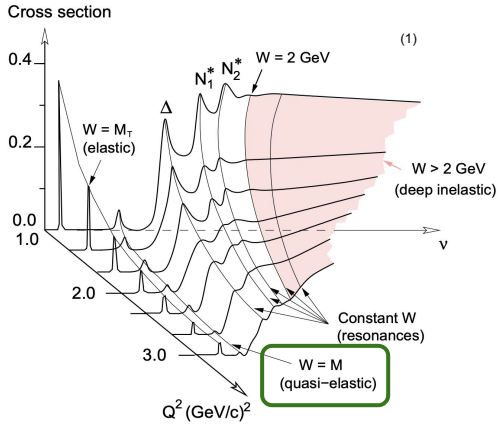
# Crane Repair Complete Aug 2023



# Super BigBite Spectrometer (SBS): Form Factors

- Nucleons are not point-like fermions! They have internal structure
- Resolve the **Sachs Electric and Magnetic Form Factors** for the **Proton** and the **Neutron** to high precision.
- Related to the electric and magnetic moments of the nucleons, respectively.
- The Super BigBite Spectrometer (SBS) experiments utilize both polarized and unpolarized electron beams and targets.
- Ratio Method/Rosenbluth Separation.
- Polarization Transfer.

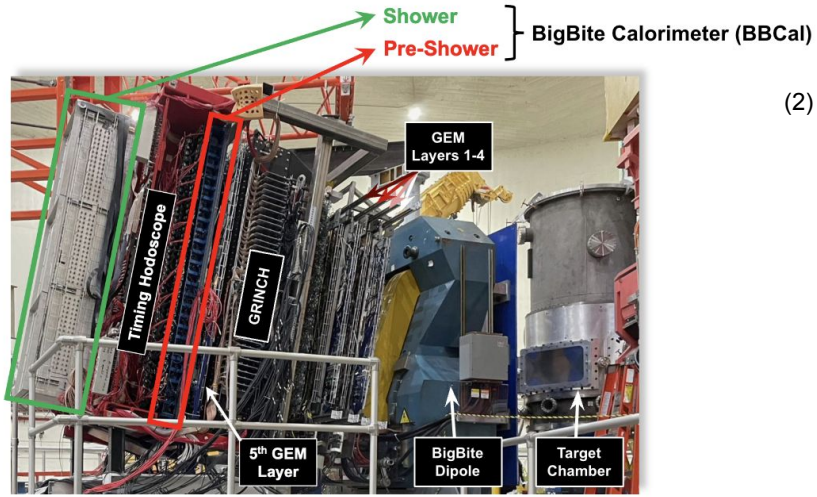
$$\frac{d\sigma}{d\Omega} = \eta \frac{\sigma_{\text{Mott}}}{1+\tau} \left( (\boldsymbol{G_E})^2 + \frac{\tau}{\epsilon} (\boldsymbol{G_M})^2 \right)$$



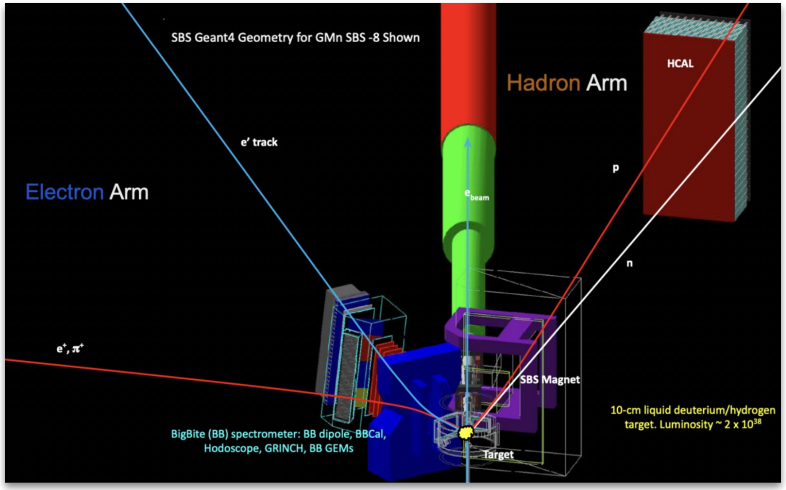

(1) *Xiaochao Zheng, Precision Measurement of the Neutron Spin Asymmetry A1n at Large x_bj Using CEBAF at 5.7 GeV, UVA*

# SBS Setup for GMn + GEn

(1)




(2)




**Electron Arm**
Tracking: **Gas Electron Multipliers (GEM)**
Electron Calorimeter: **BBCal (Shower + Preshower)**
Cherenkov Detector: **GRINCH**
BigBite Dipole Magnet: **0.9 T*m**
Scintillator Array: **Timing Hodoscope**

**Hadron Arm**
Hadron Calorimeter: **HCal**
SBS Dipole Magnet: **3 T*m**

**Semi-inclusive, simultaneous measurement of protons and neutrons allow for many systematic errors to cancel!**

(1) Photo Credit: P. Datta, *SBS electron arm.* (2) S. Seeds, *GEANT4 visualization, South Eastern APS Meeting, 2023*

Jefferson Lab

# *Analysis Status: GMn (E12-09-019)

- **Relative statistical uncertainties** in GMn/GMp is estimated from the raw yields obtained from experimental data analysis.
- Projected systematic uncertainties have been taken from the experiment proposal.
- Additional considerations **not yet taken into account** in this plot:
  - HCal proton and neutron detection efficiency corrections.
  - Nuclear and Radiative corrections.
  - Nucleon misidentification probabilities.
  - And many more!

**GMn Projections on World Data**

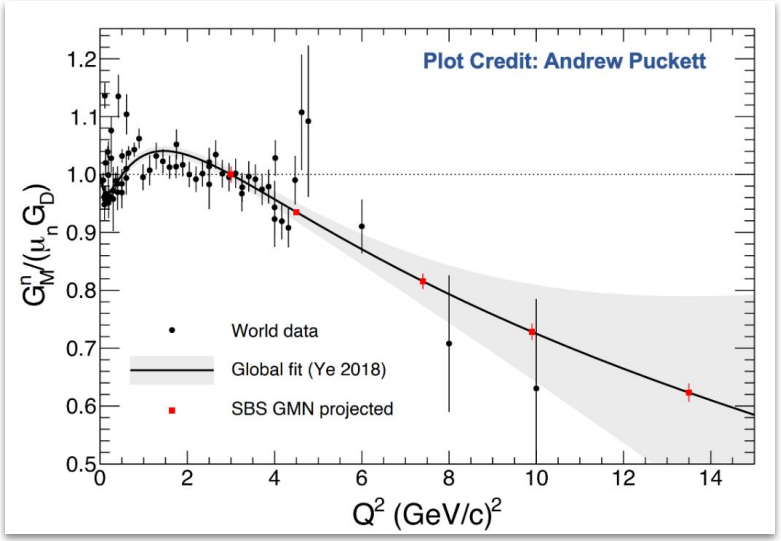



Table I: Estimated Raw QE Yields from SBS-$G_M^n$ dataset

| $Q^2$ (GeV/c)$^2$ | $E_{beam}$ (GeV) | Raw QE Yields | Projected $\Delta_{stat}(G_M^n/G_M^p)$ | Projected $\Delta_{syst}(G_M^n/G_M^p)$ |
|---|---|---|---|---|
| 3.0 | 3.73 | 471,000 | 0.12% | 1.4% |
| 4.5 | 5.97 | 1,092,000 | 0.07% | 0.6% |
| 7.4 | 5.97 | 76,700 | 0.30% | 1.6% |
| 9.9 | 7.91 | 13,100 | 0.70% | 1.8% |
| 13.5 | 9.86 | 19,200 | 0.60% | 2.5% |

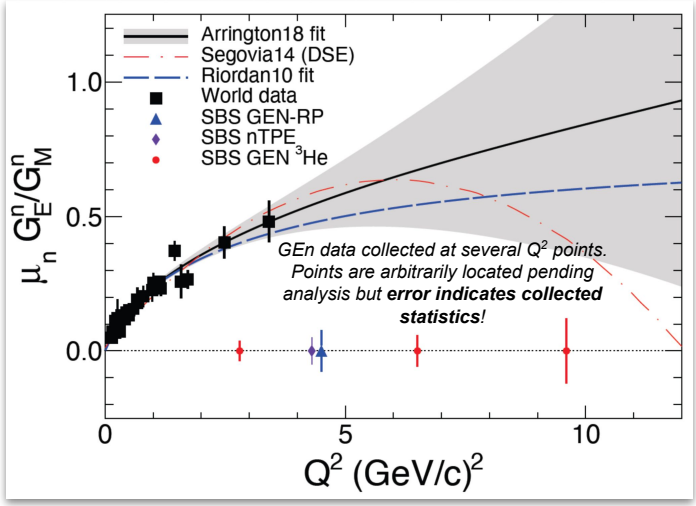


*Slide Adapted from P. Datta, *DNP November 2023*

# *Analysis Status: GEn (E12-09-019)

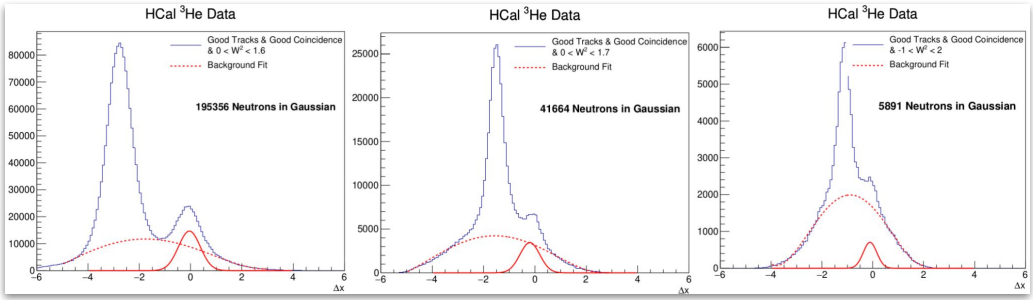
- Asymmetry measurement
- Novel Polarized He3 target. Up to 50% polarization achieved!
- *Fall data collection is complete as of early November!*
- Beam asymmetries look reasonable
- Statistical error bars updated at each kinematic point.

**GEn Projections on World Data**

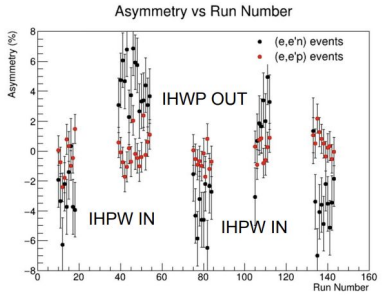



(1)

*Preliminary Neutron Yield Estimates*




(2)




(3)

*Preliminary asymmetry data encouraging*

***Slide Adapted from S. Seeds, *Southeastern APS Section 2023***

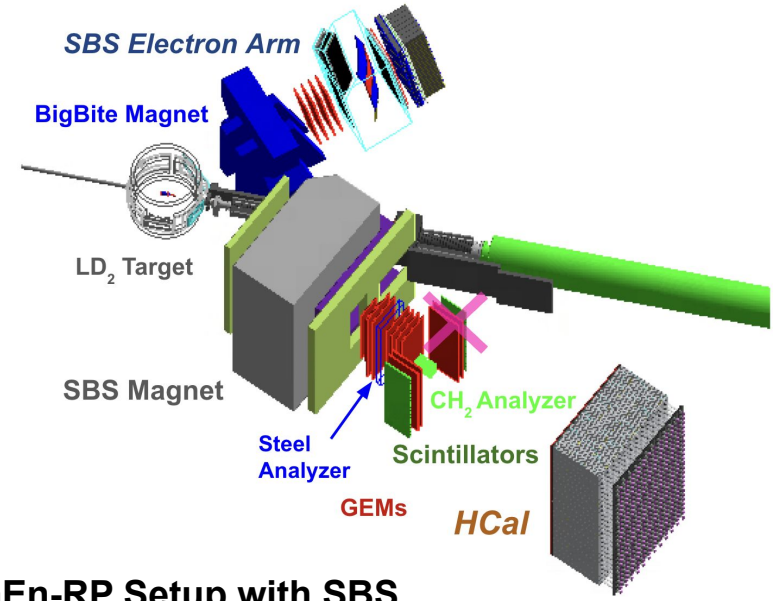
*(1) A. Puckett, SBS Weekly Update Nov. 2023 (2) S. Jeffas, SBS Weekly Software Meeting Nov. 2023 (3) S. Jeffas, GEn-II Analysis and Thesis Progress*

Jefferson Lab

# GEn-RP (E12-17-004)

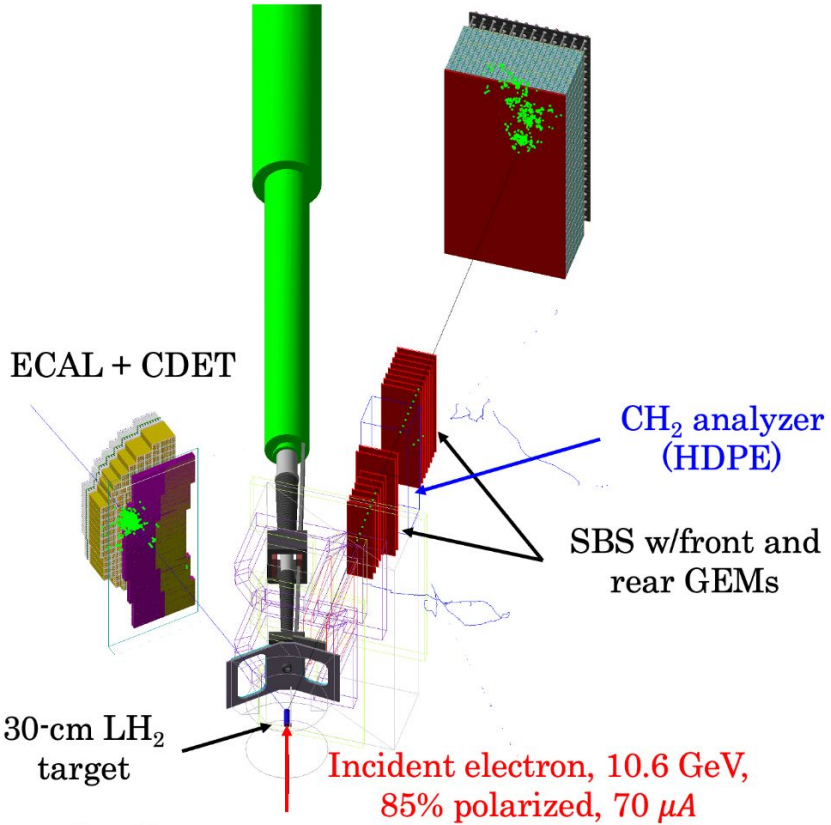
- Scheduled April 2024, installation begins Dec 4!
- Measure at $Q^2$ = 4.4, D(e,en), measure GEn with neutron recoil polarization asymmetry method.
- In combination with nTPE (run during GMn), GEn-RP provides polarization transfer comparison data point to characterize two-photon-exchange contribution to electron-neutron elastic cross section.
- First experiment to measure GEn using recoil neutron polarimetry at high $Q^2$

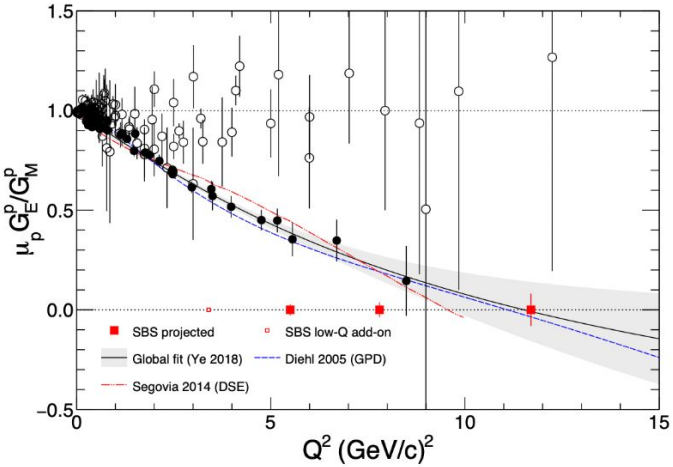
Inline SBS GEMs installed and tested during GEn




**GEn-RP Setup with SBS**

# The SBS $G_E^p$ Experiment (E12-07-109): Scheduled 2024-2025




- Original motivation for SBS concept—first approved 2007
- **Designated "High Impact Experiment" by JLab PAC41**
- Jeopardy proposal reapproved by PAC47 in 2019
- **Currently scheduled to run 2024-2025**
- Novel high-temperature lead-glass calorimeter detects scattered electron with scintillator-based coordinate detector—trigger, aid tracking in front GEMs, and reject inelastics
- GEM-based trackers with $CH_2$ analyzer for proton polarimetry
- HCAL for trigger and preferential selection of nuclear scattering events with high analyzing power
- High-Temperature ECAL: Reduce radiation-induced darkening of lead glass

UCONN 11/29/2023

DNP Hawaii 2023

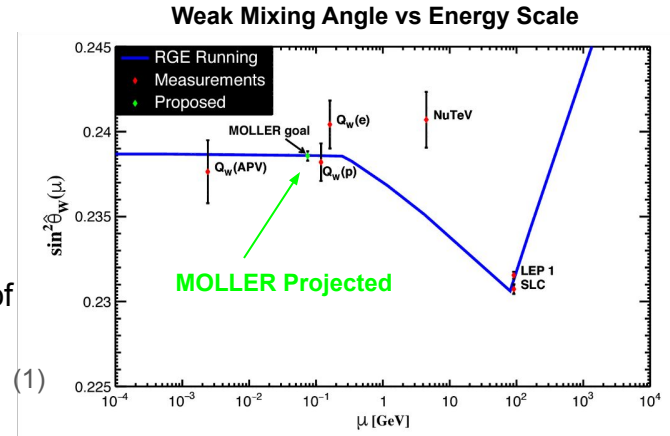
# MOLLER

**M**easurement **O**f a **L**epton-**L**epton **E**lectroweak **R**eaction

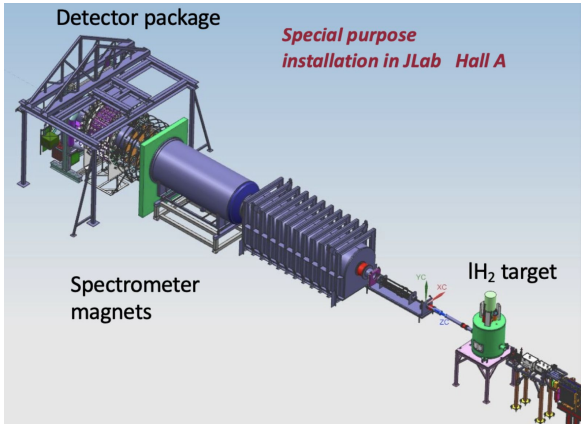
- 7-fold symmetry full azimuth experiment.
- Most precise measurement of the **parity violating asymmetry** of Møller scattered electrons. Asymmetry $A_{pv}$ allows for the extraction of the weak charge to **2.4% projected accuracy**.
- Liquid hydrogen target.
- Toroid magnets separate charged particles by momentum.
- Novel GEM detectors can be azimuthally rotated and radially moved in and out for optics calibrations.
- Detector package measures the kinematics of the scattered particles.

- Inflation Reduction Act provided full funding.
- Passed CD-3A review and spending CD-3A funds.
- CD-2/3 review in October 2023.
- Simulations and prototyping of detectors underway!
- 3 years of running.
- Installation expected to begin in May 2025.

$$A_{PV} = \frac{\sigma_R - \sigma_L}{\sigma_R + \sigma_L}$$




(1)




(1) *Moller Conceptual Design Review, 2020*

# Hall A Schedule

| Date | Activity |
|---|---|
| Dec 4 2023 – April 4 2024 | Deinstall polarized 3He target, modify beam line, install cryotarget and install new GEMs and detectors for GEn-RP |
| April 5 – May 3 2024 | Run GEn-RP and K_LL |
| May 6 2024 | Start Deinstall GEn-RP and installing GEp |
| Oct 25 2024 – April 2025 | Run GEp |
| May 2025 | Start GEp deinstallation and MOLLER installation |

# Thanks!

Thank you to Marco Contralbrigo and the Jefferson Lab User's Organization for the opportunity to give this talk.

Special thanks to Kate Evans, Provakar Datta, Sebastian Seeds, Andrew Puckett, Mark Jones, Rachel Montgomery, and Sean Jeffas for providing material and assistance with this presentation.

**Session D03: Electromagnetic Form Factors I**
**Session F03: Electromagnetic Form Factors II**
**Session F07: Instrumentation: Targets and Sources**
**Session M11: Physics Beyond the Standard Model II**
And others!

Jefferson Lab

William & Mary
CHARTERED 1693


*SBS Summer Collaboration Meeting, July 2023*

SUPER BIGBITE SPECTROMETER