SBS Weekly Meeting, Mon Oct. 3, 2022

Status of GEn-RP (E12-17-004)

Michael Kohl <kohlm@jlab.org> *
for the SBS Collaboration

Hampton University, Hampton, VA 23668
Jefferson Laboratory, Newport News, VA 23606

* Supported by DOE DE-SC0013941, and by NSF PHY-1812402 and PHY-2113436

Thank you for input from

- **Senior physicists**
  David Hamilton, Brad Sawatzky,
  Holly Szumila-Vance, Nilanga Liyanage

- **Graduate students**
  Anuruddha Rathnayake, John Boyd, Manukrishna Suresh,
  Sarashowati Dhital

- **For a detailed review of GEn-RP (E12-17-004) see**
  B. Sawatzky's/D. Hamilton's talk at Hall-A Winter Collaboration Meeting, Feb 10-11, 2022
  https://indico.jlab.org/event/503/contributions/9345/attachments/7506/10439/RPGEN-Uupdate-Sawatzky_DJH1.pdf

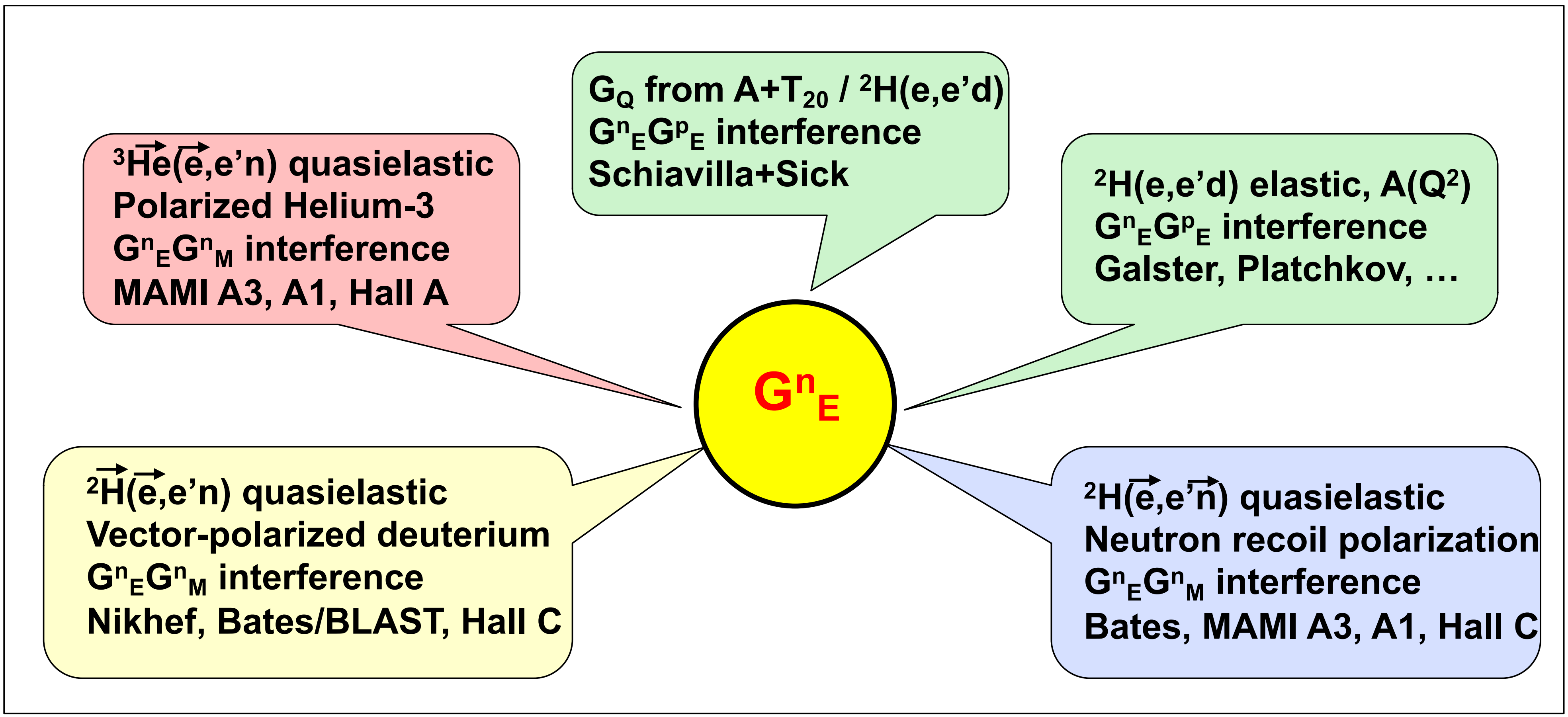
- **Focusing on updates today**

G^n_E in absence of a free neutron target

No free neutron target → elastic and quasi-elastic scattering

Nuclear corrections (FSI, MEC, …)

Smallness of G^n_E has not allowed L-T sep. of d(e,e'n) or d(e,e')–d(e,e'p)



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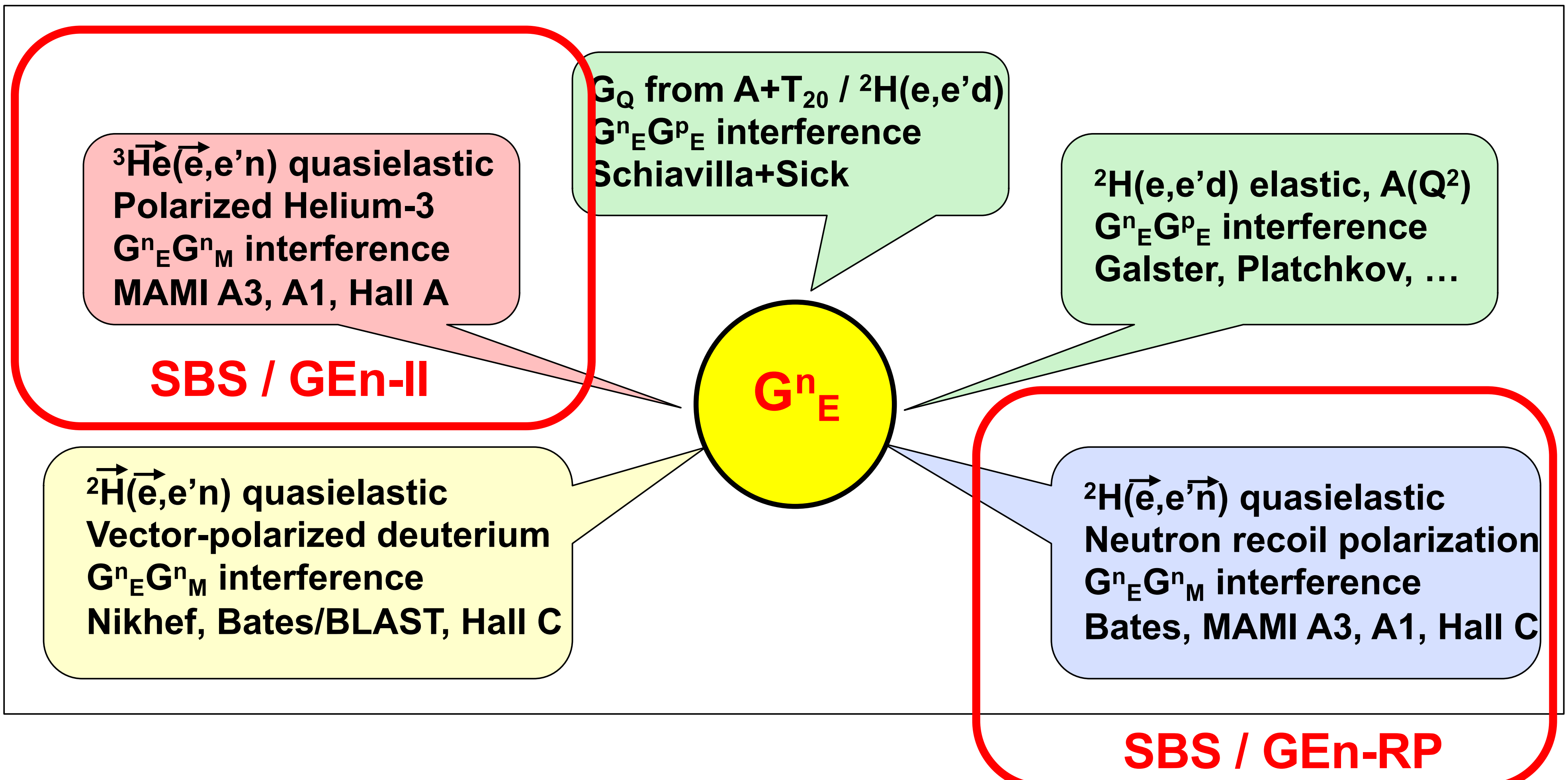


Experimental technique of GEn-RP (SBS)

Measure double-polarized $^2H(\vec{e}, e'\vec{n})p$

- Final-state neutron P_x / P_z → G_{En} / G_{Mn}
  (precess P_z → P_y in dipole magnetic field)

$$P_x = -hP_e \frac{2\sqrt{\tau(1+\tau)}\tan\frac{\theta_e}{2} G_E G_M}{G_E^2 + \tau G_M^2 (1 + 2(1+\tau)\tan^2\frac{\theta_e}{2}}$$

$$P_y = 0$$

$$P_z = hP_e \frac{2\tau\sqrt{1+\tau+(1+\tau)^2\tan^2\frac{\theta_e}{2}}\tan\frac{\theta_e}{2} G_M^2}{G_E^2 + \tau G_M^2 (1 + 2(1+\tau)\tan^2\frac{\theta_e}{2})}$$

$$\frac{P_x}{P_z} = \frac{1}{\sqrt{\tau + \tau(1+\tau)\tan^2\frac{\theta_e}{2}}} \cdot \frac{G_E}{G_M}$$

- Liquid D_2 target (10 cm),
  40 μA polarized electron beam (P=80%)
  Luminosity L = 1.26 x 10^{38} cm^{-2} s^{-1}

- BigBite electron spectrometer and SBS hadron spectrometer
  apart from polarimeter, identical to G_{Mn} / G_{Mp} E12-09-019 setup

- SBS Neutron polarimeter: acceptance well matched to electron arm

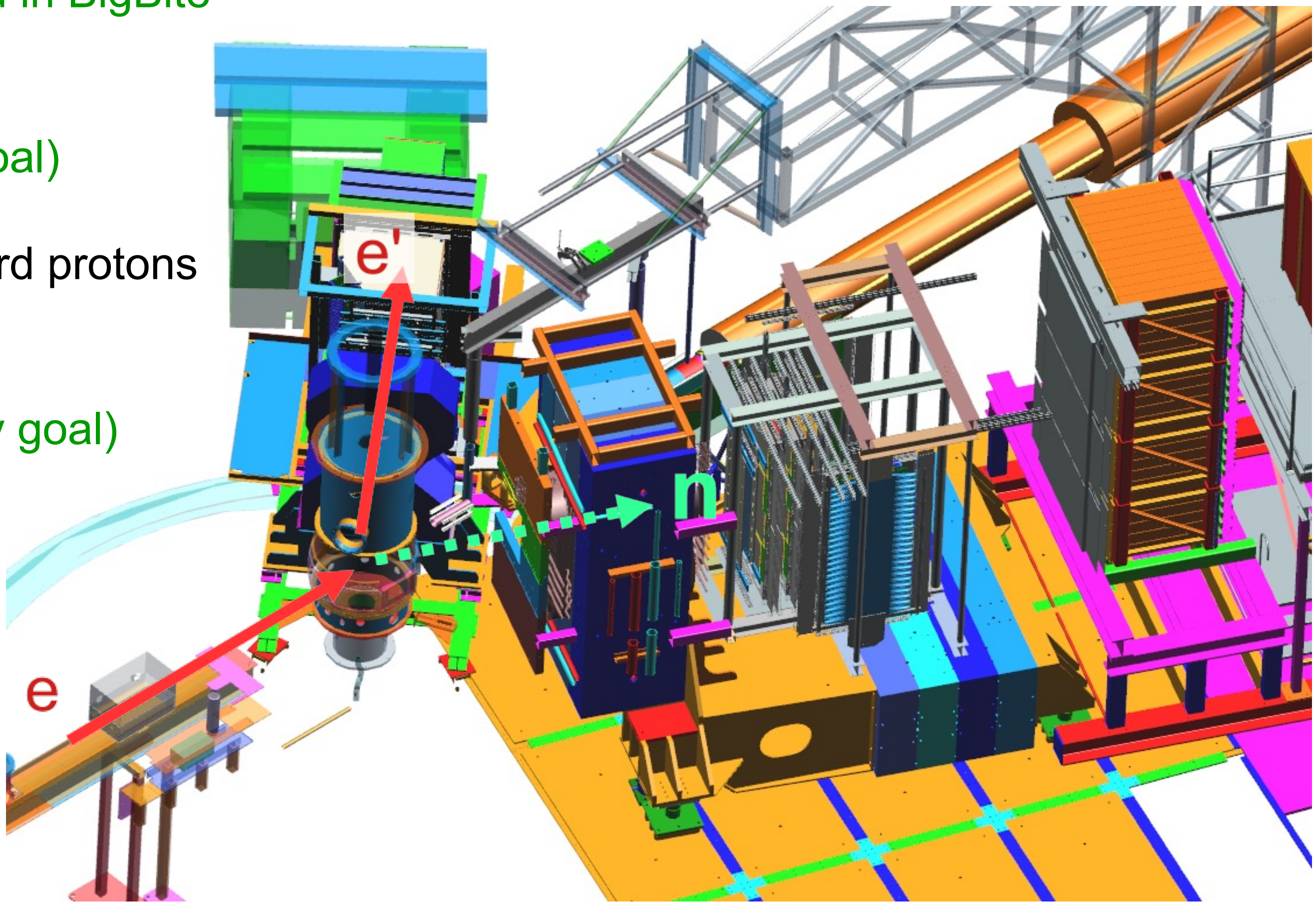
- Dipole magnet, integrated field ~ 2 Tm

- Hadron calorimeter, high p & n efficiency, effective suppression soft background
  + passive steel analyzer
  + GEM charged-particle tracking systems
  + active CH analyzer and side scintillator planes

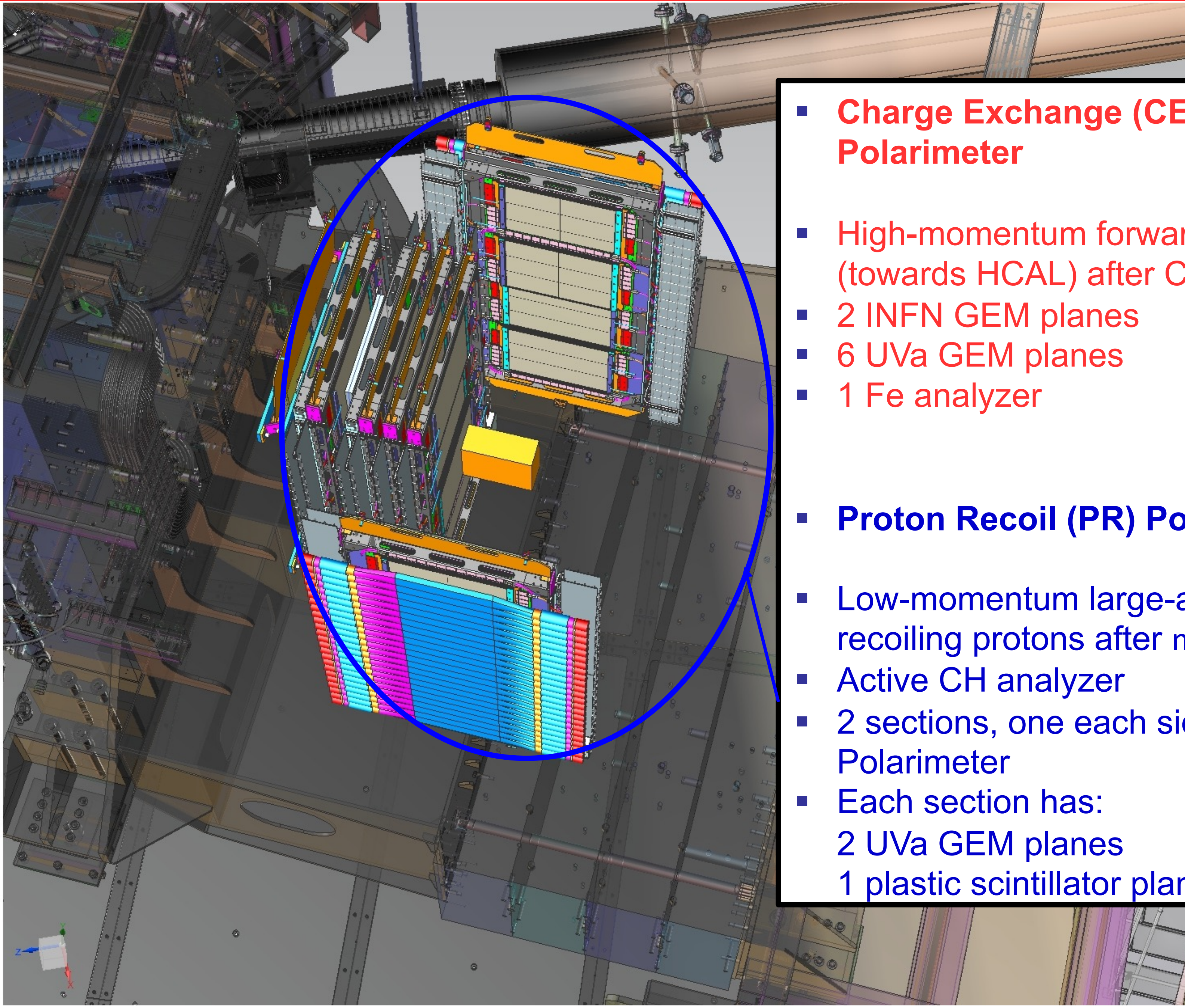
- Detecting high-momentum, small angle protons produced by np→pn
  AND low-momentum large-angle protons produced by np→np scattering

Experimental technique of GEn-RP (SBS)

- E12-17-004 will measure GEn/GMn using two recoil pol. techniques at Q^2 = ~4.5 (GeV/c)^2
- "GMn" beam, beamline, target, BB
  Beam: ~4.4 GeV/c, ~30 μA, P_b = ~80%
  Target: 15 cm LD_2 (unpolarized)
- Scattered electron measured in BigBite
- Charge-Exchange
  np → pn channel (primary goal)
  Steel analyzer (passive)
  GEM tracking + HCAL forward protons
- Conventional
  np → np channel (secondary goal)
  Plastic analyzer (active)
  Large-angle recoil protons
  → Side detectors
  (GEM + hodoscope)
  Forward neutron
  → HCAL
- Detector components also used in:
  Wide-angle Charged Photoproduction (KLL)
  SBS Inline GEM stack + Steel analyzer



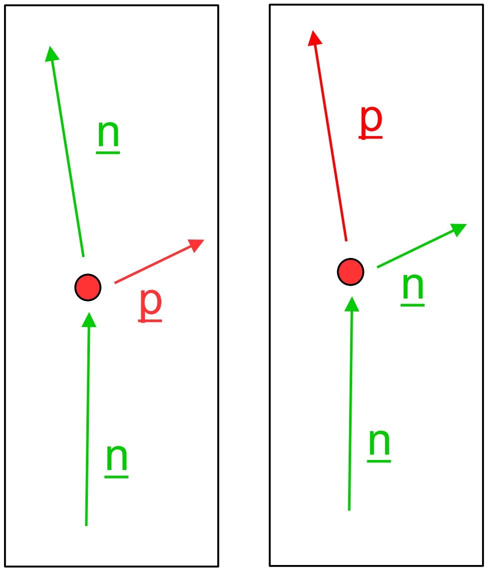
SBS Neutron Polarimeter



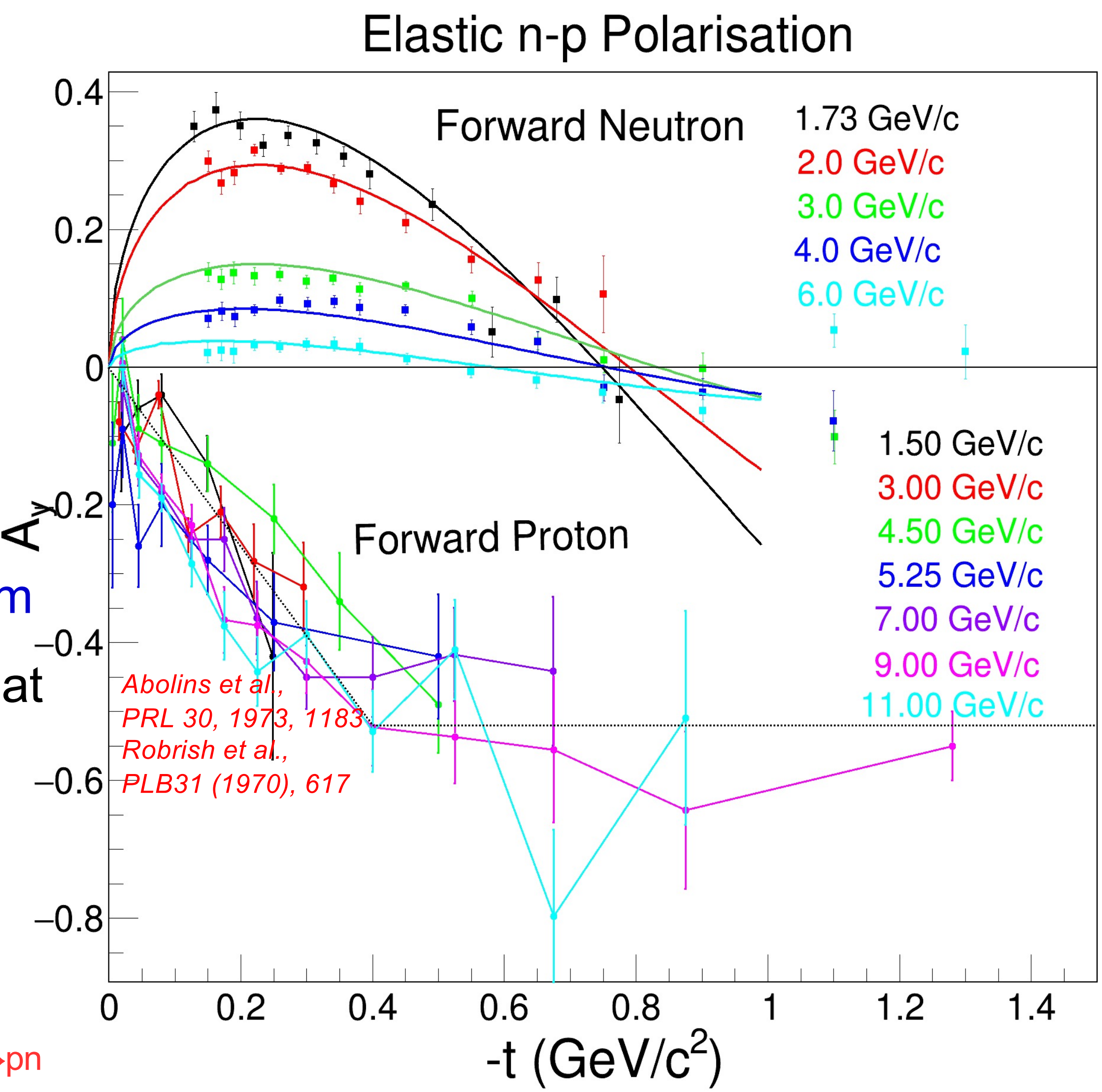
- **Charge Exchange (CE) Polarimeter**
- High-momentum forward protons (towards HCAL) after CE $np \rightarrow pn$
- 2 INFN GEM planes
- 6 UVa GEM planes
- 1 Fe analyzer

- **Proton Recoil (PR) Polarimeter**
- Low-momentum large-angle recoiling protons after $np \rightarrow np$
- Active CH analyzer
- 2 sections, one each side of CE Polarimeter
- Each section has:
  2 UVa GEM planes
  1 plastic scintillator plane

Analyzing power for elastic n-p scattering



Diebold et al., PRL 35,(1975),632
Fits: Ladygin JINR E13-99-123 (1999)

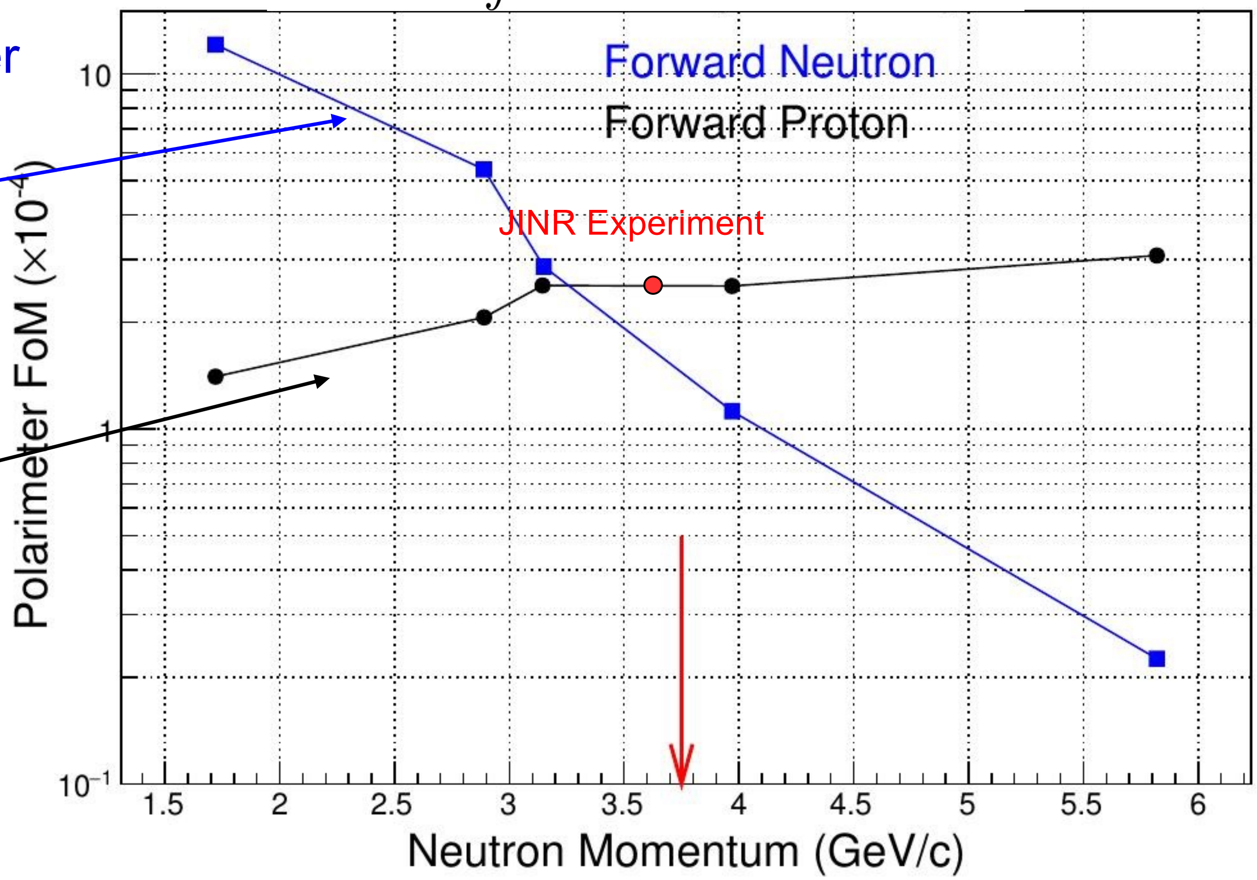


- A_y for n-p (or p-n) falling rapidly with increasing neutron momentum
- A_y for charge-exchange n-p large at sufficiently large t (θ_p ~ few deg.)
- No apparent strong incident momentum dependence for charge-exchange A_y
- $\sigma_{np\rightarrow np}$ factor ~10 higher than $\sigma_{np\rightarrow pn}$

Figure of merit: elastic vs. charge exchange

$$\mathcal{F}^2(p_n) = \int \varepsilon(p_n, \theta_n^{'})\, A_y^2(p_n, \theta_n^{'}) d\theta_n^{'}$$

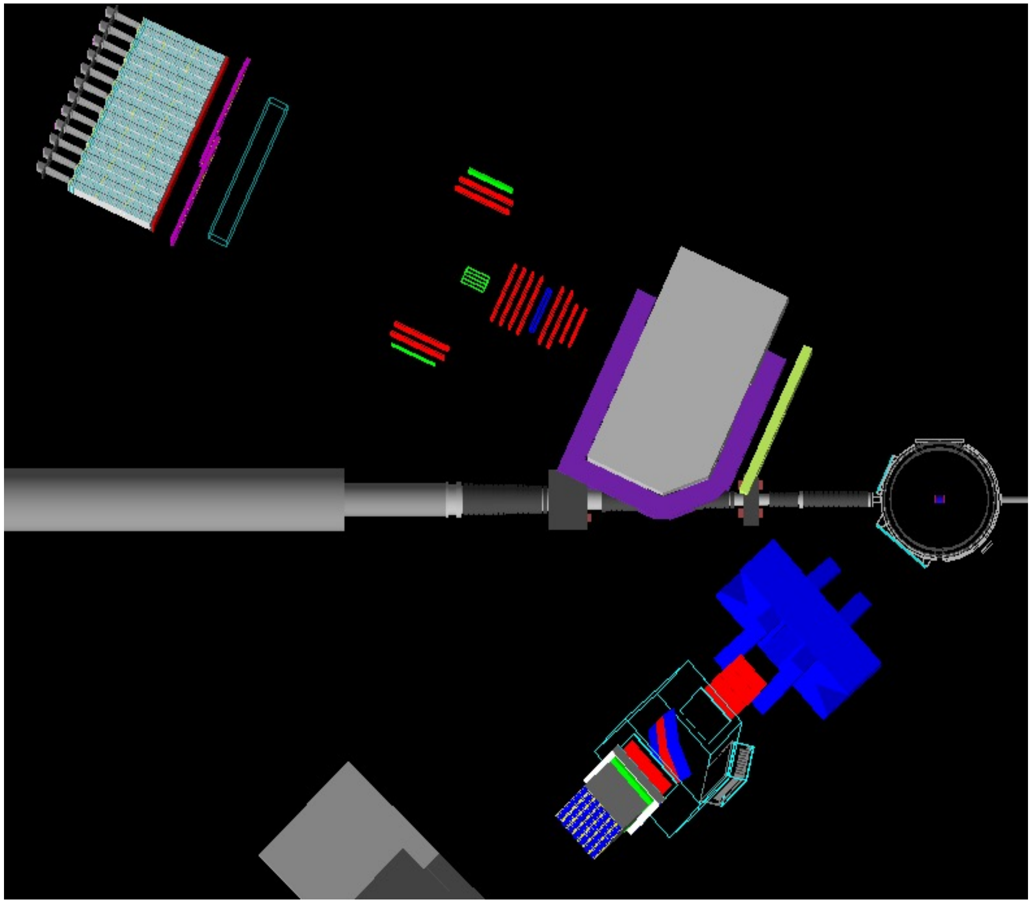
- Plastic scintillator analyzer
- np→np (forward neutron)



- Fe analyzer
- np→pn (forward proton)

- Calculate efficiency of polarimeter as function of θ_n by Monte Carlo
- A_y for free np→np: JINR fit to $\boldsymbol{p_n}$ and $\boldsymbol{\theta_n}$ dependence, scale A_y by 0.5 for ^{12}C scattering (agrees with JINR 2016-17 data)
- A_u for np→pn on Cu: new 2016-17 measurement from JINR

Geant4 Monte Carlo simulation



FOM study: D. Hamilton (U. of Glasgow)

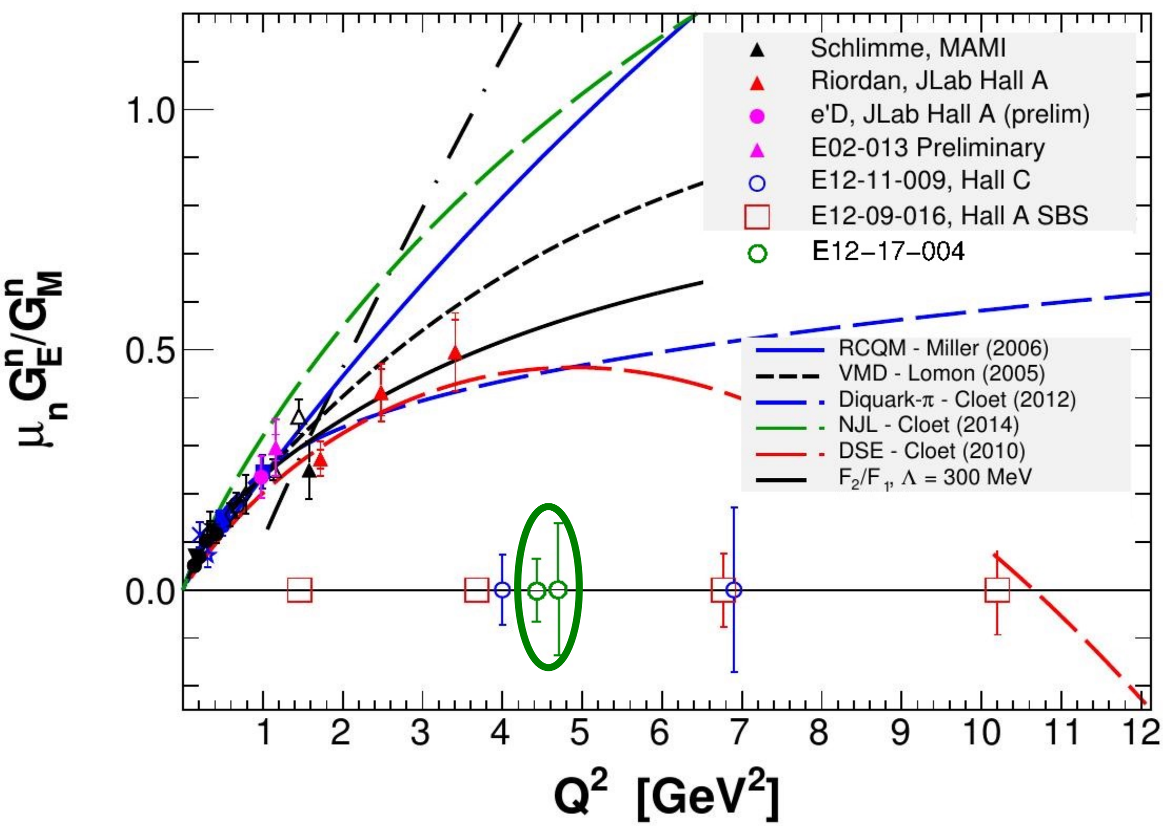
Rate studies: W. Tireman (Northern Michigan)

- Realistic description of polarimeter components in g4sbs
- Included spin-dependent hadronic processes and precession
- Full quasi-elastic pseudo-data set simulated for expected luminosity
- Two-arm data analysis performed for both CE and PR polarimeter with realistic detector efficiencies and resolutions
- Analyzing power parametrizations based on Ladygin (x0.5) for PR and Dubna results for CE
- Extracted effective analyzing power (due to depolarization), overall efficiency, FOM and statistical uncertainty on polarization components and form factor ratio

Projected form factor ratio uncertainty

$$\delta P = \sqrt{\frac{2}{N_{inc}\mathcal{F}^2}} \qquad R = \mu_n G_E^n / G_M^n \qquad \left(\frac{\delta R}{R}\right)^2 = \left(\frac{\delta P_x}{P_x}\right)^2 + \left(\frac{\delta P_z}{P_z}\right)^2$$

E_{beam} (GeV)	Q^2 $(GeV/c)^2$	p_n (GeV/c)	Rate (Hz)	Time (hours)	FOM $x10^{-4}$	dP (absolute)	dR (absolute)
4.4	4.5	3.15	48.8	120	2.6 (CE)	0.019	0.078
					0.8 (PR)	0.034	0.140
					3.4 (Total)	0.017	0.070

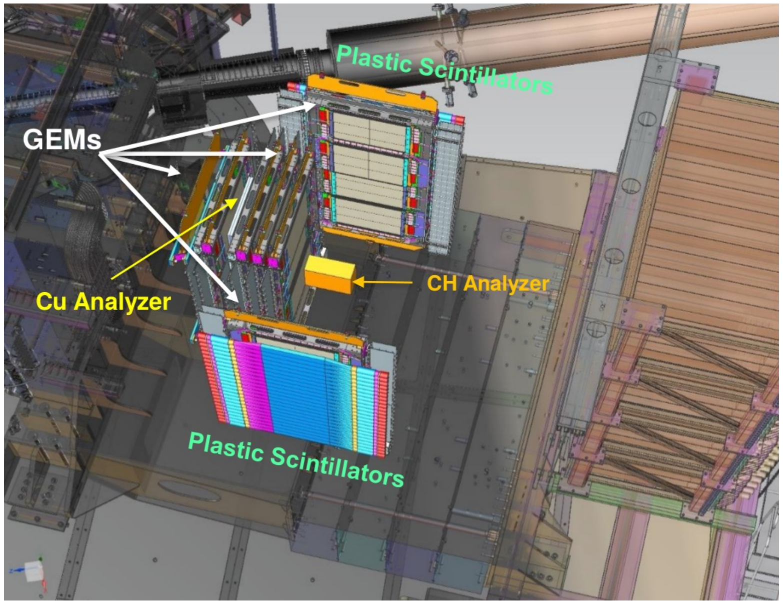


- Estimates from g4sbs agree very well with proposal
- *dR* based on Galster G_{En} and Kelly G_{Mn} parametrizations
- Expect overall systematic error to be ~3.0%

Status non-GEM detectors

Hodoscopes for left/right polarimeter arms
Active analyzer

- HV, FADC for 128 PMT channels returned to NPS
- 8 FADCs at hand; use VXS+NIM from BB hodoscope+grinch commissioning setup; ROC available
- Require signal cables BNC to Lemo 128 x 150’ (to be purchased)
- HV cables set aside (128 x 110’ SHV) – tight but workable
- HV supplies:
  - LeCroy Mainframes available from CLAS-6
  - CAEN 1527 in test lab, not working well with Epics, telnet ok
- Analyzer needs positive HV (32 channels)



GEM status in the Hall

Current Hall A installation:

- Inline GEMs to be commissioned during GEn
    - 6 UVa XY layers (24 modules)
    - 2 INFN XY layers (6 modules)
- BB GEMs have new parallel (2-path) dividers which will be tested during GEn for upgrading the SBS GEMs
- One individual-channel power supply connected to a UV GEM
- Commissioning of the gas mixing system for the SBS GEMs will happen this fall during GEn (using pre-mixed Ar:CO2 for now)

Planned studies during GEn:

- Evaluate new power supply performance
- Test shorter (5m) HDMI cables
- Evaluation of negative signals on APV readout, common mode sag

GEM status in the EEL

Other changes for GEn-RP:

- Pol-R stack with 2 XY layers ready to go, is in EEL
- Pol-L stack:
    - Layer-9: almost complete; needs 28 APVs added, some were taken to be used in BB
    - Layer-10: needs complete set of 60 APV cards to be completed; frame in EEL/126
    - Assembly takes 2 weeks
- APV cards arriving probably in Oct-Nov timeframe for finishing layers in EEL

Need details here (maybe a picture) of plans for the frame
And details on last GEM –Nilanga?

GEn-RP software

- QE event selection code to be reused from GMn and GEn-II
- Polarimetry code (Glasgow) is standalone, to be integrated in sbs-offline
- Need complete digitization of polarimeter pseudo data in g4sbs
- Physics analysis

Manpower update

Out:

Brad Sawatzky (Jlab), Thir Gautam (HU)

In:

Oliver Jevons (Glasgow postdoc)
Gary Penman (Glasgow grad, GEn-II)
Ed Brash (CNU + UG students)
Vimukthi Gamage, Bhasitha Dharmasena (UVA),
expected to move to Jlab in Dec 2022

Manjukrishna "Manju" Suresh, Sarashowati "Saru" Dhital (HU)
Malinga Rathnayake (HU MS 2021) expected to return in Sp23 for PhD
HU postdoc (TBD)

Timeline

Oct 2022	**Inline GEM commissioning with beam**
Nov 2022	**APV card delivery + testing**
Nov 2022 – Mar 2023	**Non-GEM detector HV; VXS setup for DAQ; NIM logic**
Dec 2022 – Jan 2023	**Assembly of POL-L**
Jan – Feb 2023	**Commissioning of POL-R + POL-L with cosmics**
Apr 2023	**Installation of POL-R, POL-L, active analyzer**
May – July 2023	**Commissioning of new components with cosmics; complete checkout**
July – Aug 2023	**GEn-RP running**

Desired GEn-RP activities during GEn-II

- **Rear field clamps not mounted, stray fields unsuppressed**
  → Could affect PMT performance and cause tracks to be curved
  → Take some field measurements near PMT locations

- **Temporarily mount a slab of material at location of passive analyzer to establish reconstruction of second scattering vertex with inline GEMs**

Thank you!

Questions?

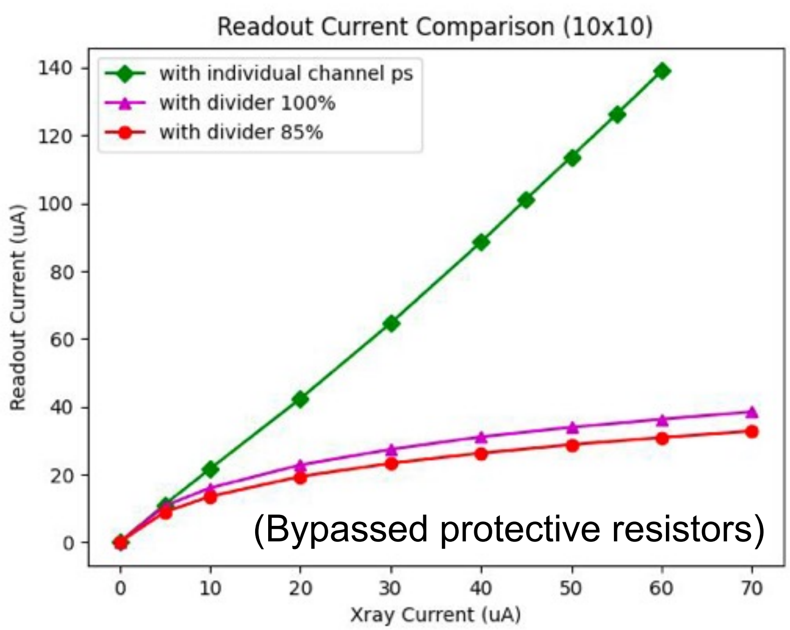
Backup

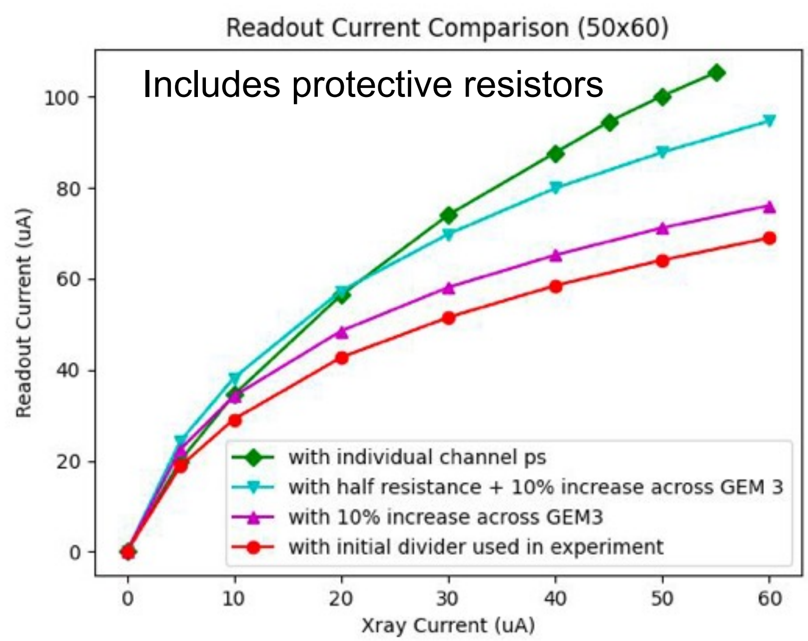
High-rate performance

Upgrade of HV dividers:

- From GMn running, we observed a loss of tracking efficiency that was correlated with occupancy due to the HV divider configuration (XY tracker not strongly affected due to smaller module areas and placement in stack)

- We observed a non-linear increase in the current draw (a measure of the gain) with the occupancy (replicated in lab in red curves below) due to inefficiencies related to the divider





Individual-channel PS, with protective resistors

2-path divider

tested during GMn

Lack of linearity for individual channel supply due to voltage drops across protective resistors. Supply voltages could be adjusted to compensate.

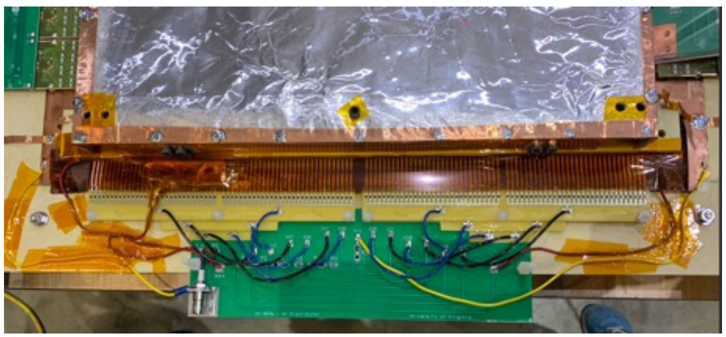
Plots and testing courtesy of Vimukthi Gamage, UVa

Upgrade of HV divider

During May-June 2022, we upgraded the HV dividers for tracking layers 1, 3, and 4:

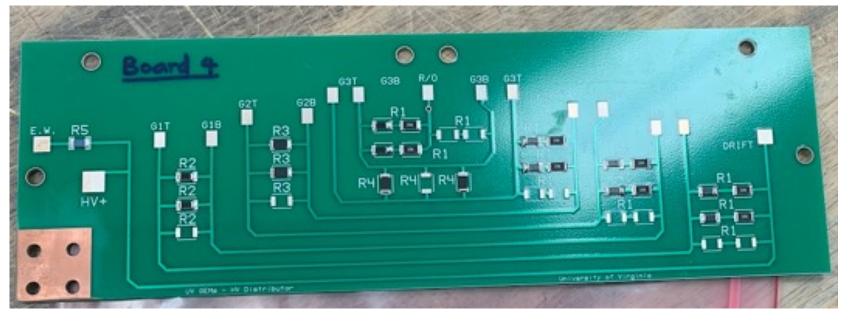
- Layer 1 is outfitted with a parallel-path (resistors removed) divider for use with individual-channel PS
- Layers 3 and 4 currently have a 2-path (2 resistors in parallel) dividers installed
- These will be tested with beam starting September 2022.
- Voltage adjustment for individual channel protective resistors will be programmed into Epics.

Original board:

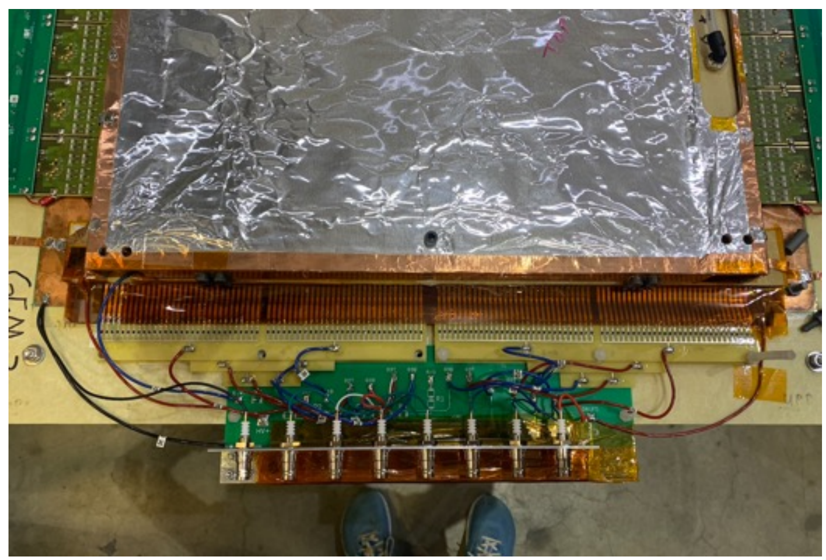


Best solution is parallel divider:

- Will have individual channel power supplies to supply 9 GEM modules (parallel)
- March 2023, will equip the 4 UV BB layers and 5 XY modules
- All remaining modules will have 2-path dividers



2-path



All parallel