Hall A Winter Workshop, Jan 16-17, 2024

Preparing for GEn-RP and KLL

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

GEn-RP Spokespeople: D. Hamilton, M.K., W. Tireman, B. Wojtsekhowski, J. Annand**, E. Bellini** and N. Piskunov**

KLL: J. Arrington, A.J.R. Puckett, A.S. Tadepalli, B. Wojtsekhowski

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** Retired

Thank you for input from

- Senior physicists
  D. Hamilton, W. Tireman, B. Wojtsekhowski, H. Szumila-Vance, N. Liyanage, E. Brash
- Graduate students
  Sarashowati Dhital
- For the latest previous review of GEn-RP (E12-17-004) see
  W. Tireman, SBS Collaboration meeting, July 17–18, 2023
  https://indico.jlab.org/event/721/contributions/13219/attachments/10047/14951/Tireman_GEnRP_July17_Update_v2.pdf
- The GEn-RP collaboration likes to thank John Annand and Brad Sawatzky for their substantial and essential contributions during the earlier project stages related to proposal, planning, reviews and early preparations
- Focusing on updates today

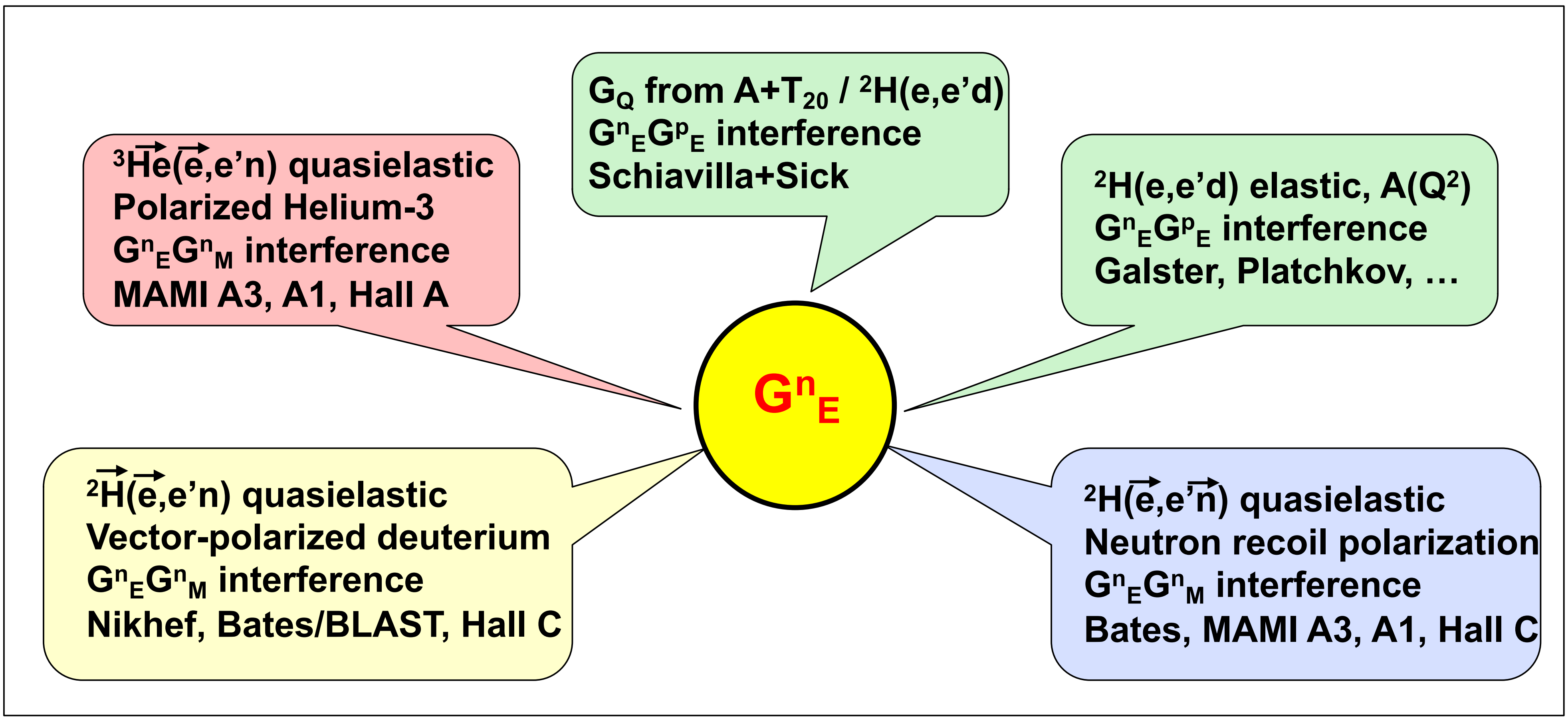
- GEn-RP = E12-17-004 (PAC45)
- KLL = E12-20-008 (PAC48)

G_{En} 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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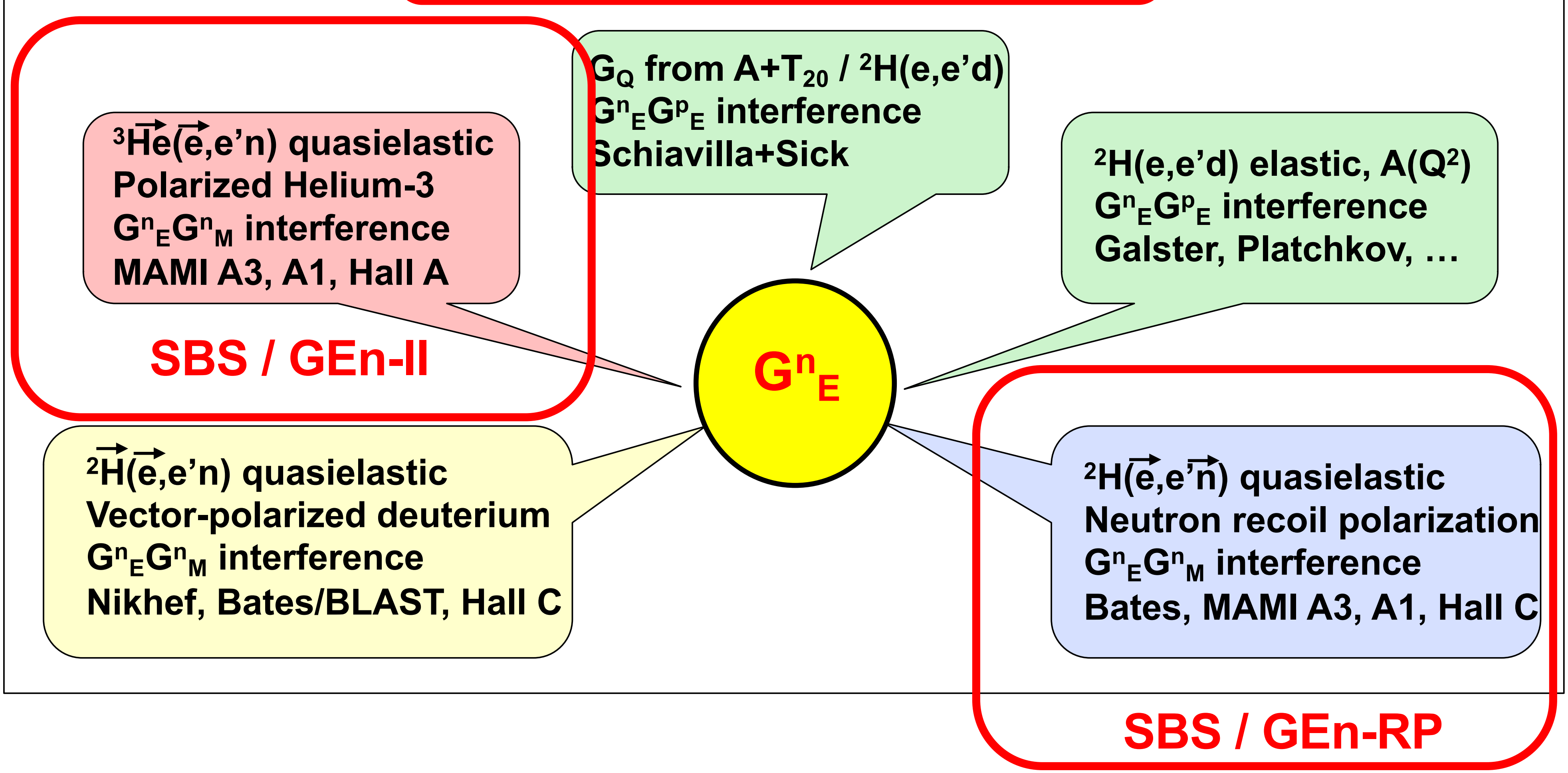
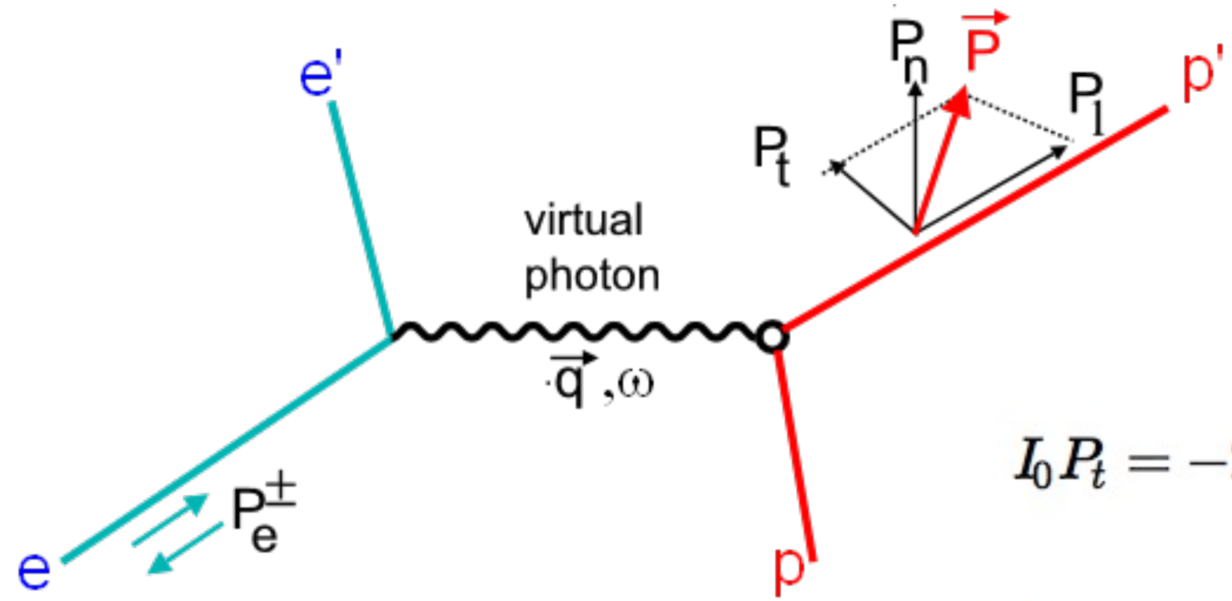
SBS / nTPE



Recoil polarization technique for G_E/G_M



$P_t = P_x$
$P_n = P_y$
$P_l = P_z$

$$I_0 P_t = -2\sqrt{\tau(1+\tau)}G_E G_M \tan\frac{\theta_e}{2}$$

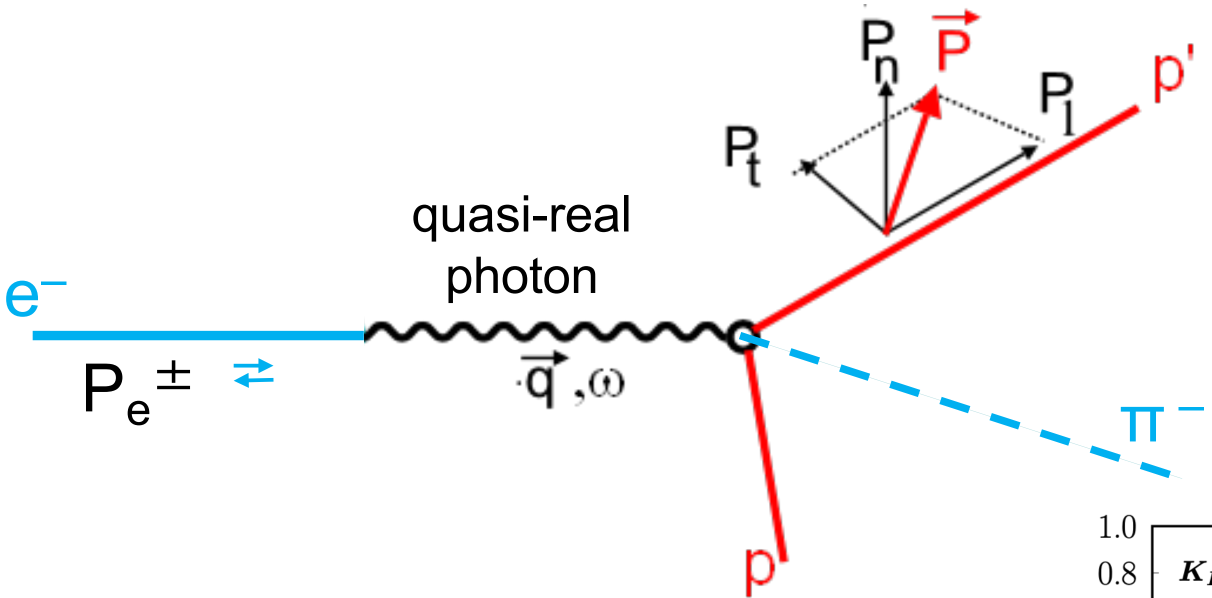
$$I_0 P_\ell = \frac{1}{M}(E_e + E_e')\sqrt{\tau(1+\tau)}G_M^2 \tan^2\frac{\theta_e}{2}$$

$$\frac{G_E}{G_M} = -\frac{P_t}{P_\ell}\frac{(E_e + E_e')}{2M_p}\tan(\frac{\theta_e}{2})$$

$$I_0 \propto G_E^2 + \frac{\tau}{\epsilon}G_M^2$$

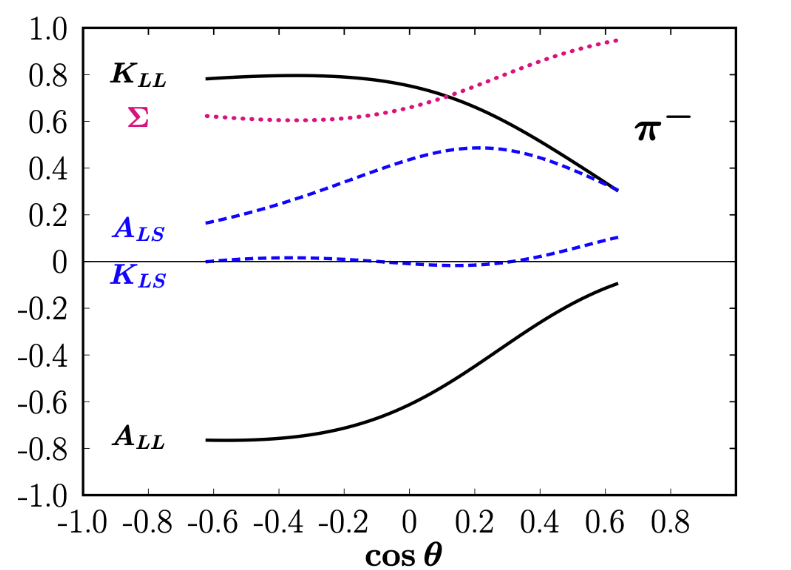
- **E12-17-004 (GEn-RP): Quasielastic $^2H(\vec{e},e'\vec{n})p$**
- **Dipole field for spin precession of P_l and P_n (P_t ~unaffected)**
- **Applicable to protons and neutrons**

Recoil polarization technique for K_{LL}



$P_t = P_x$
$P_n = P_y$
$P_l = P_z$

$$K_{LL} = \frac{d\sigma(+,\rightarrow) - d\sigma(-,\rightarrow)}{d\sigma(+,\rightarrow) + d\sigma(-,\rightarrow)}$$

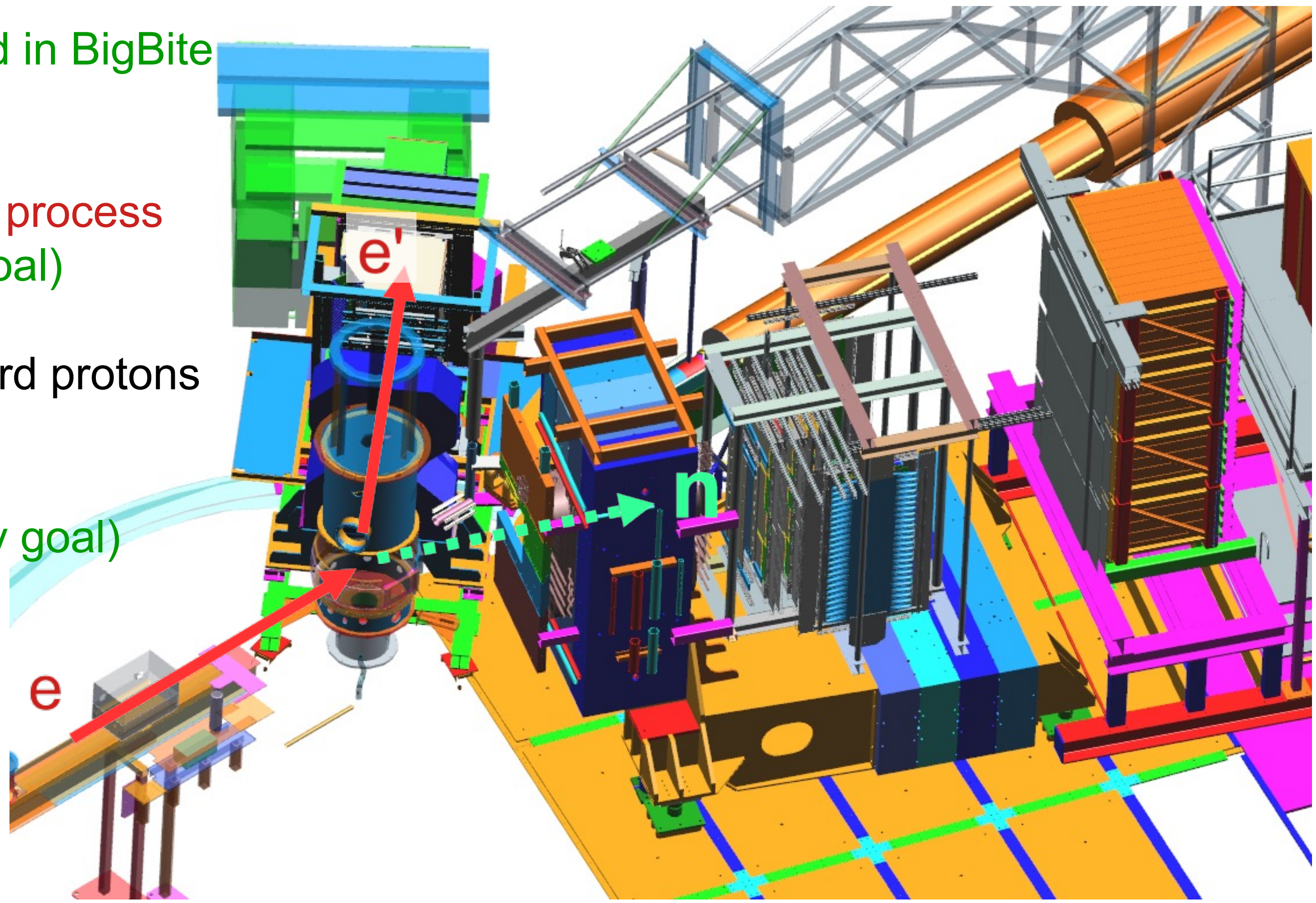


- **E12-20-008 (KLL):**
  Wide-angle pion photoproduction on the neutron, $^2H(\vec{\gamma},\pi^-\vec{p})p$
- **Spin correlation between polarized photon and recoil proton**
- **Large asymmetry expected, motivated by Twist-3 (Kroll)**

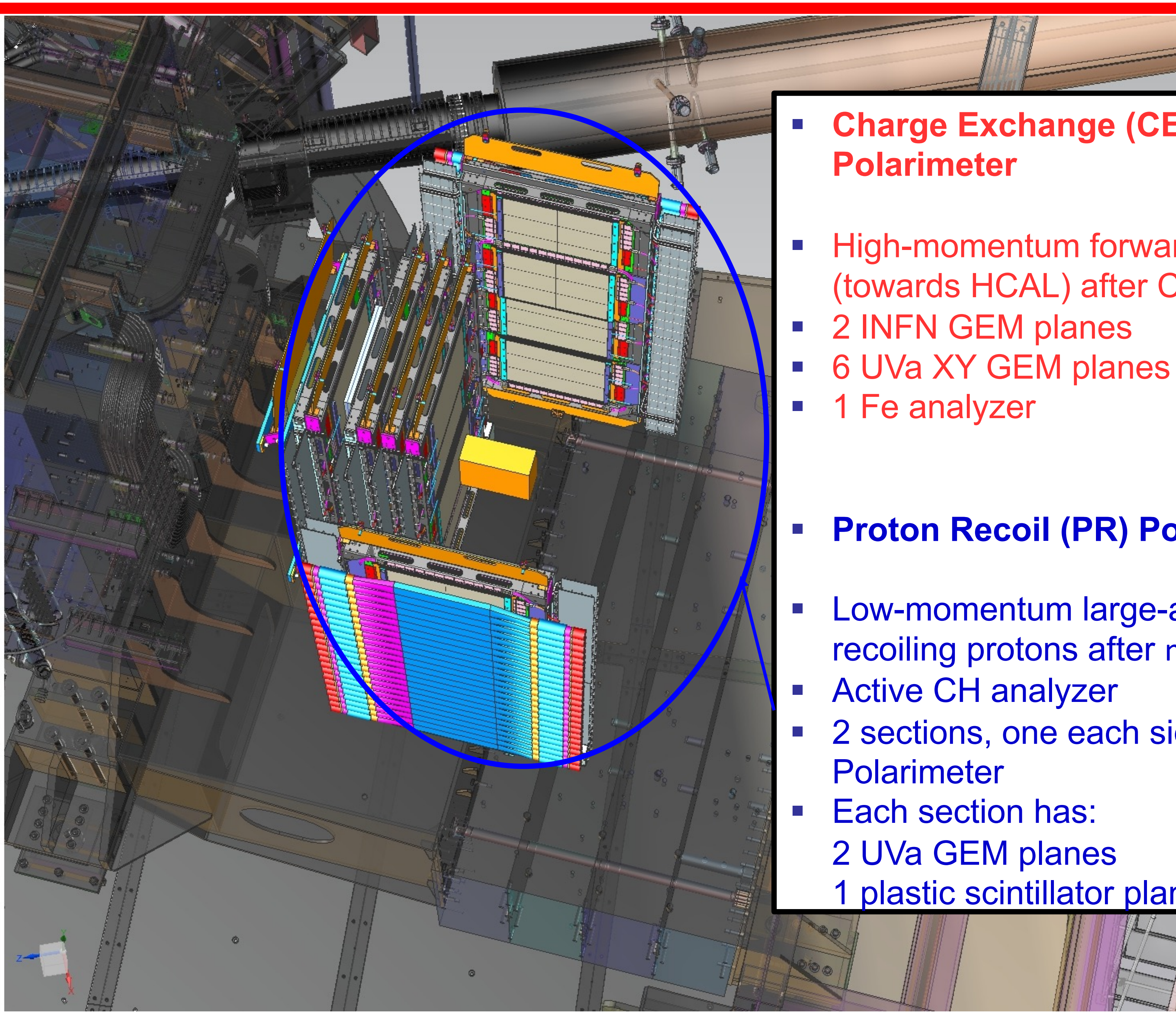
Experimental technique of GEn-RP (SBS)

- E12-17-004 will measure GEn/GMn using two recoil pol. techniques at Q^2 = ~4.4 (GeV/c)^2
- "GMn" beam, beamline, target, BB
  Beam: ~4.3 GeV, ~30 μA, P_b = ~80%
  Target: 15 cm LD_2 (unpolarized)
  6% Cu radiator (KLL)
- Scattered electron measured in BigBite
  (π^- in case of KLL)
- Charge-exchange analyzing process
  np → pn channel (primary goal)
  Steel analyzer (passive)
  GEM tracking + HCAL forward protons
- Elastic analyzing process
  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 (orig. proposed)



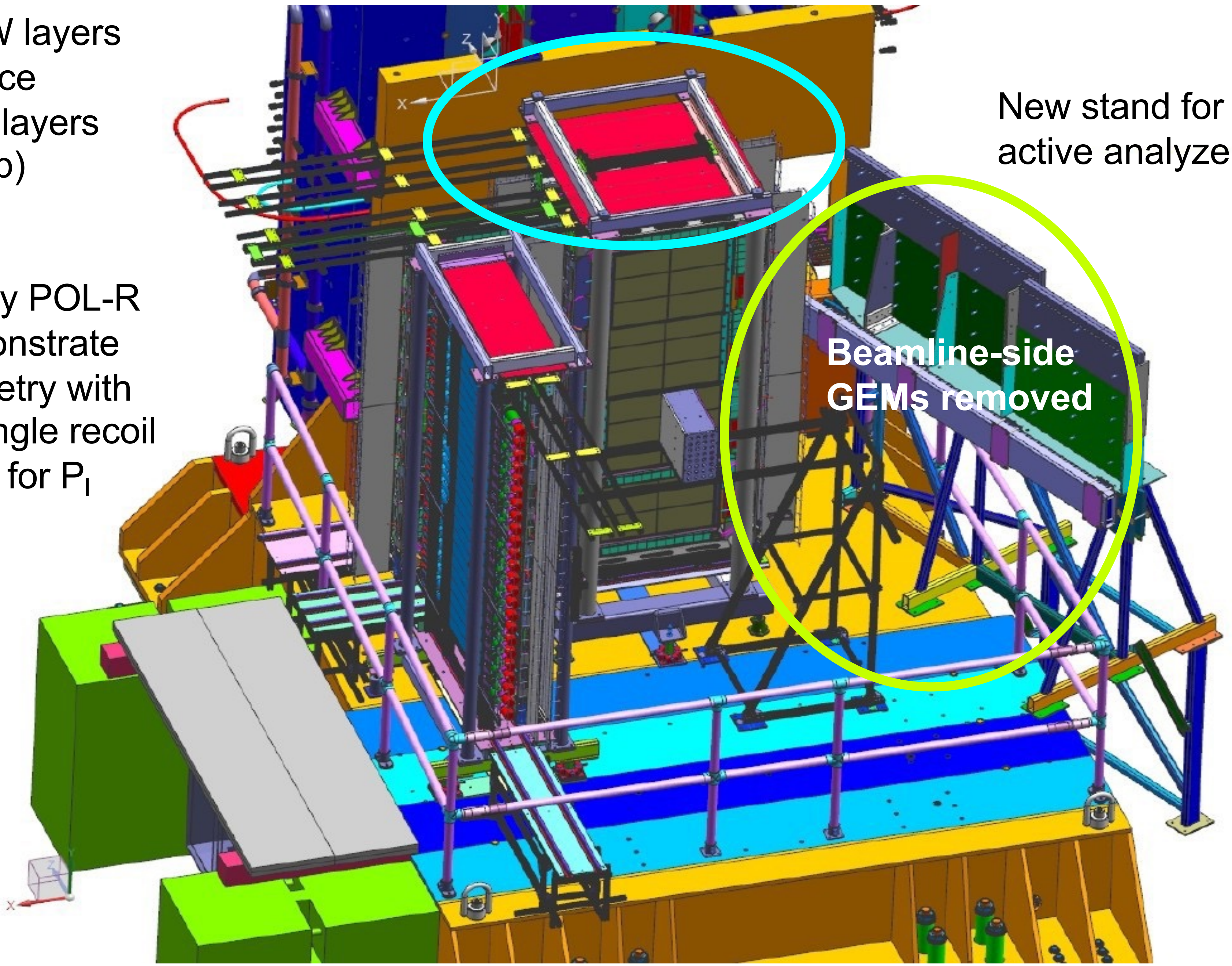
- **Charge Exchange (CE) Polarimeter**
- High-momentum forward protons (towards HCAL) after CE np → pn
- 2 INFN GEM planes
- 6 UVa XY GEM planes
- 1 Fe analyzer

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

Descoping of beamline-side RP arm

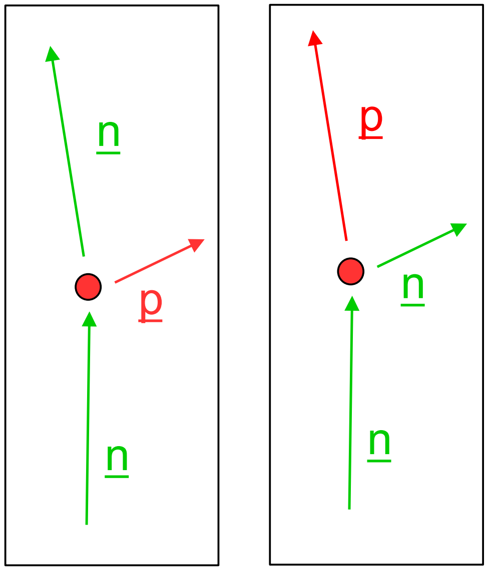
UVa XW layers to replace 2 INFN layers (for GEp)

Use only POL-R to demonstrate polarimetry with large-angle recoil protons for P_l

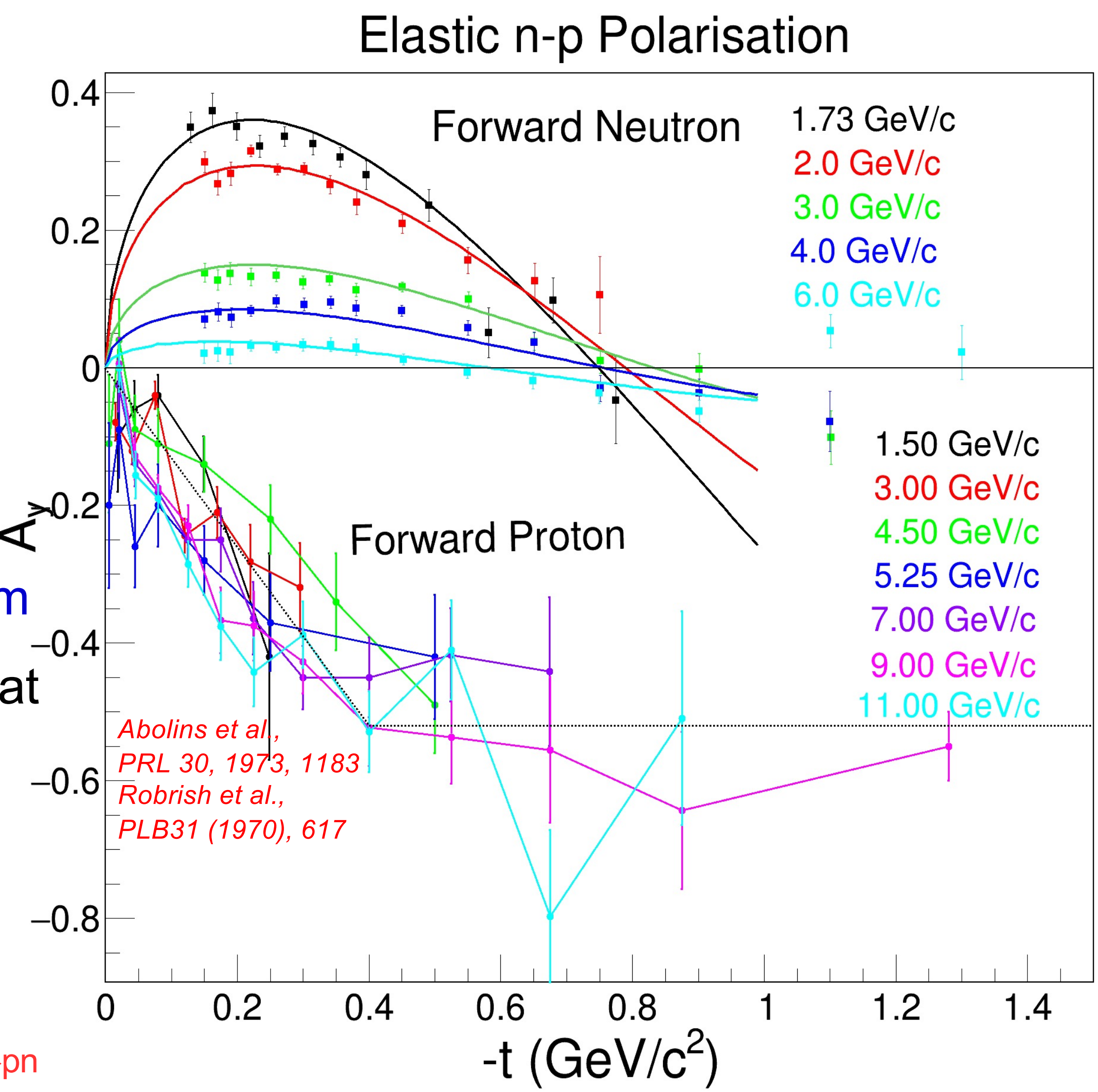


New stand for active analyzer

Analyzing power for elastic n-p scattering



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

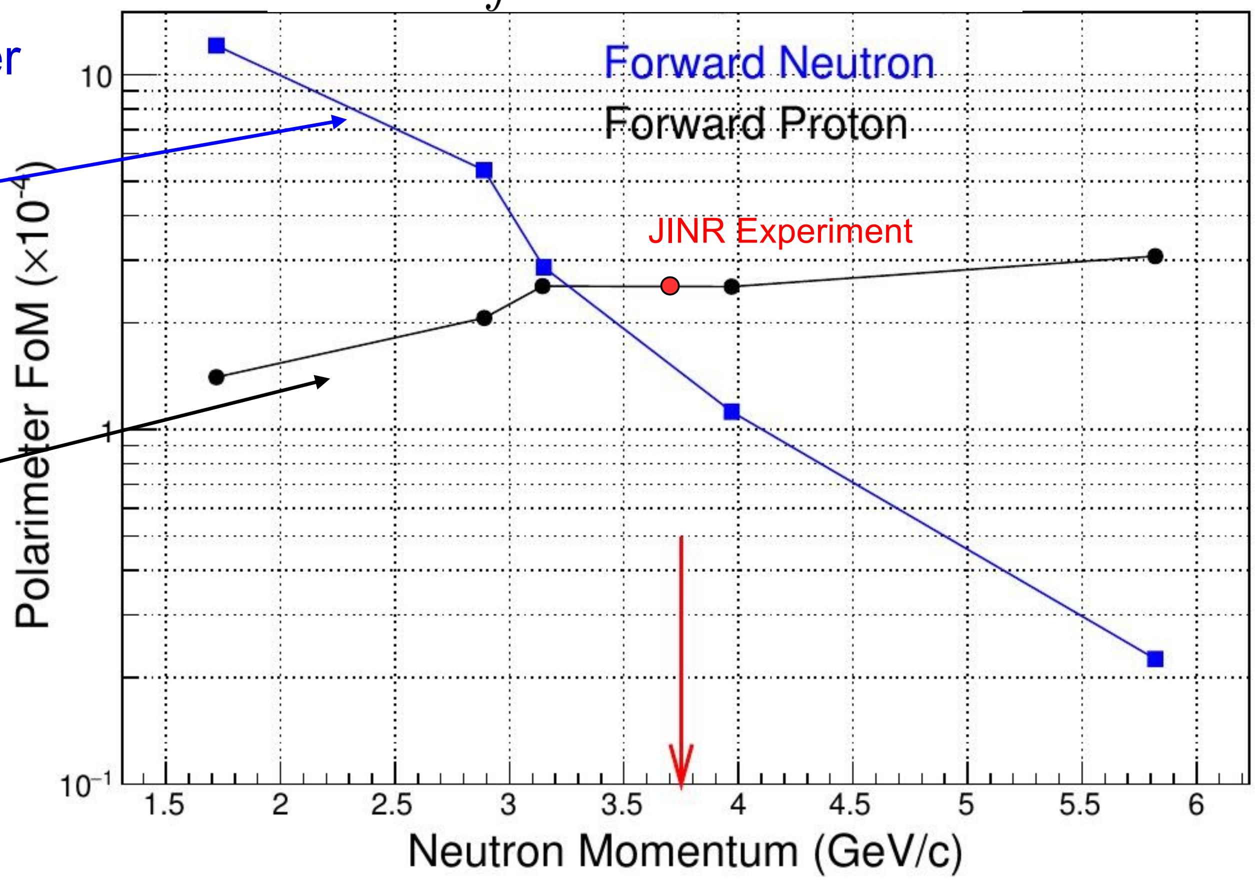


- A_y for n-p (or p-n) falling rapidly with increasing neutron momentum
- A_y for charge-exchange n-p large at sufficiently large t (θ_p ~ few deg.)
- No apparent strong incident momentum dependence for charge-exchange A_y
- $\sigma_{np\rightarrow np}$ factor ~10 higher than $\sigma_{np\rightarrow pn}$

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)



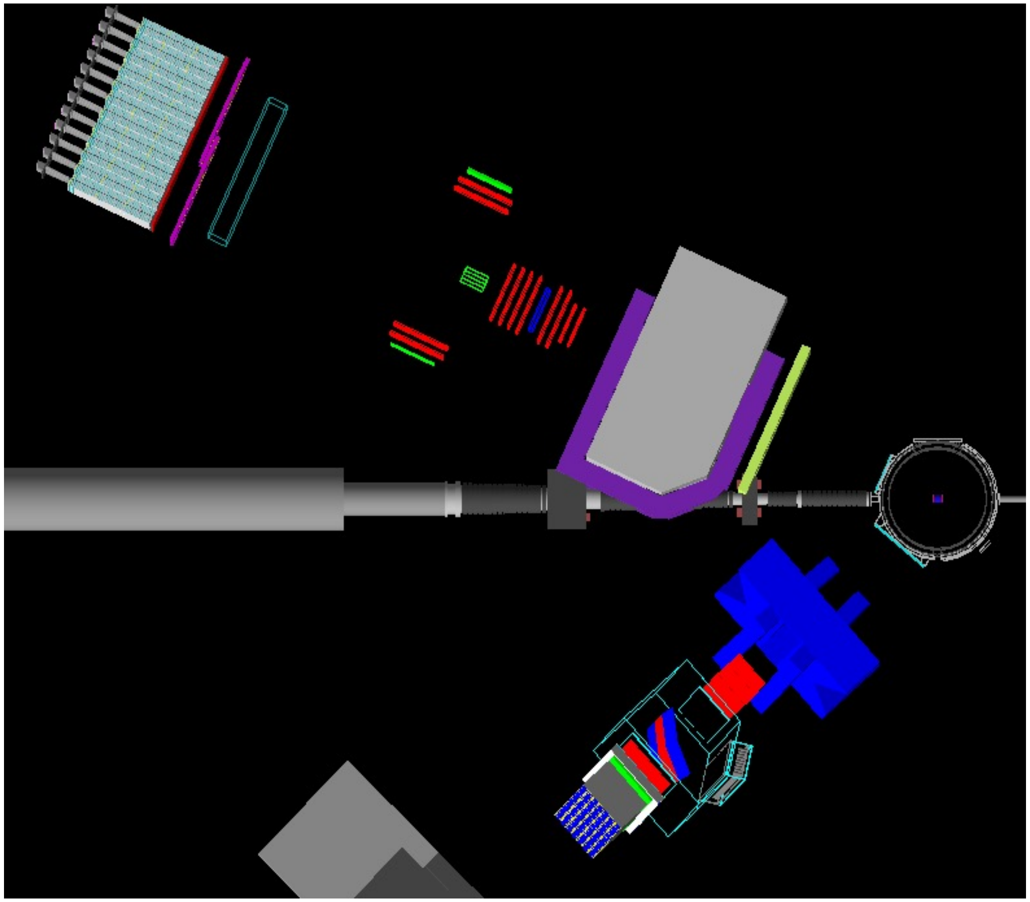
- Fe analyzer
- np→pn (forward proton)

- A_y for np→pn on Cu: new 2016-17 measurement from JINR

S.N. Basillev et al.
EPJ A 56, 26 (2020)

- 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)

Geant4 Monte Carlo simulation



g4sbs framework: A. Puckett (U. Connecticut)

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

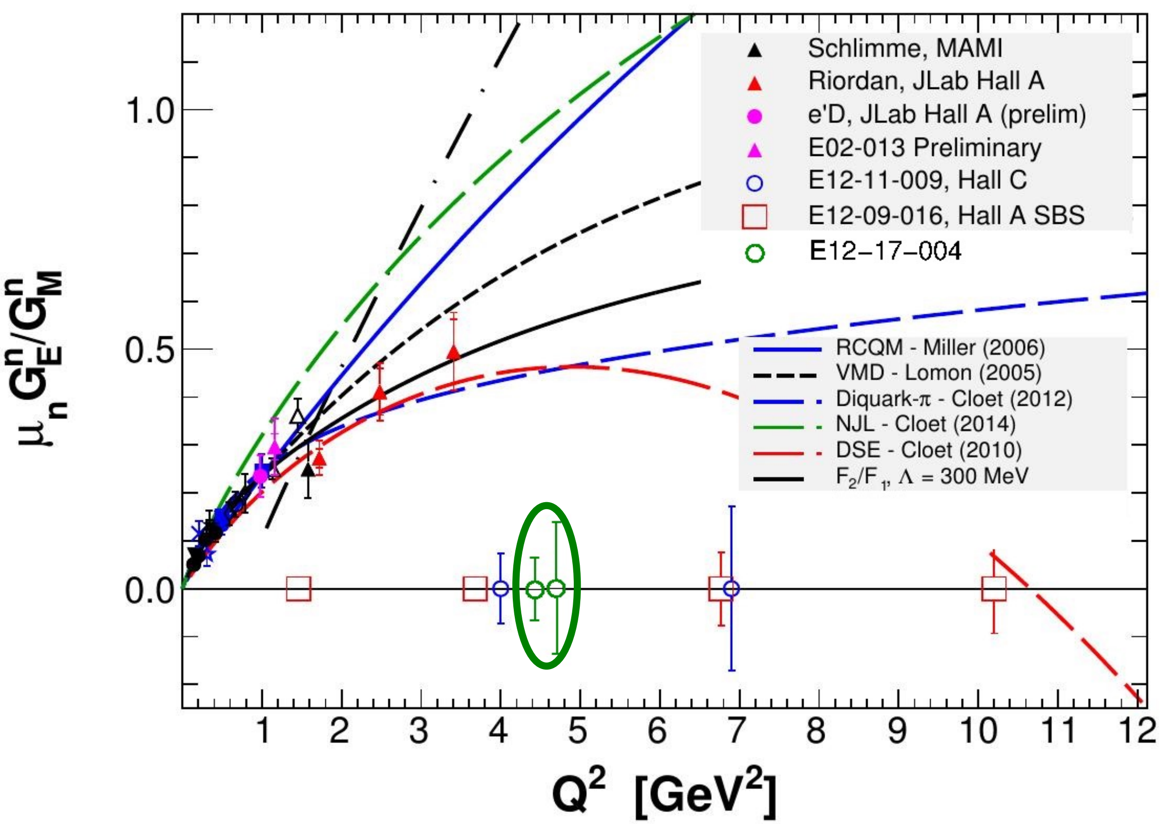
Rate studies: W. Tireman (Northern Michigan)

- 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

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

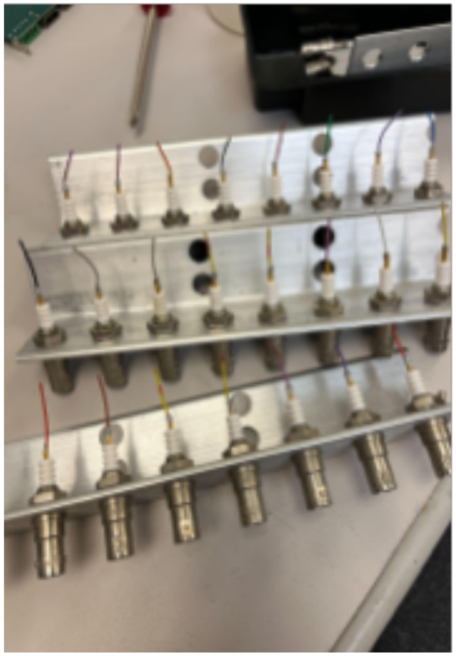
E_{beam} (GeV)	Q^2 $(GeV/c)^2$	p_n (GeV/c)	Rate (Hz)	Time (hours)	FOM $\times 10^{-4}$	dP (absolute)	dR (absolute)
4.4	4.5	3.15	48.8	120	2.6 (CE)	0.019	0.078
					0.8 (PR)	0.034	0.140
					3.4 (Total)	0.017	0.070

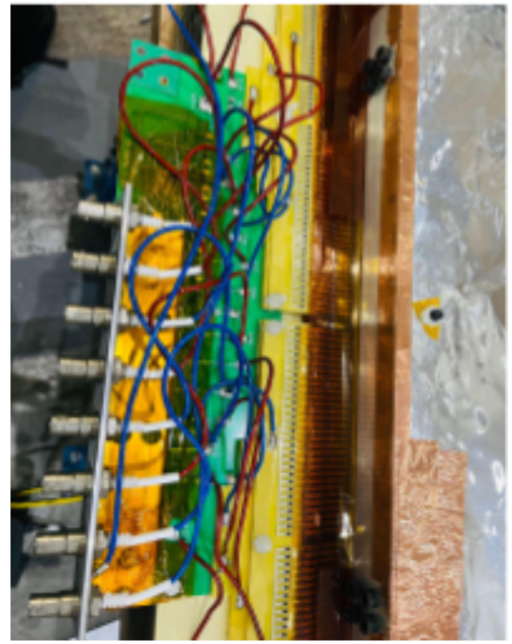


- Estimates from g4sbs agree very well with proposal
- *dR* based on Galster G_{En} and Kelly G_{Mn} parametrizations
- Expect overall systematic error to be ~3.0%

GEM status in the Hall

HV upgrade for BB GEMs inside Hall, Dec 2023





4 UV layers before + 1 XY layer after GRINCH

Some APVs fixed/swapped after GEN-II
UV layers: Directly supplying HV to each voltage step (CAEN A1515BTG)
→ MAJOR EFFORT ACCOMPLISHED

XY layer: HV upgrade optional, still to be done
For front-most layers, high-power A1515's available (A1515BTGHP-3mA)

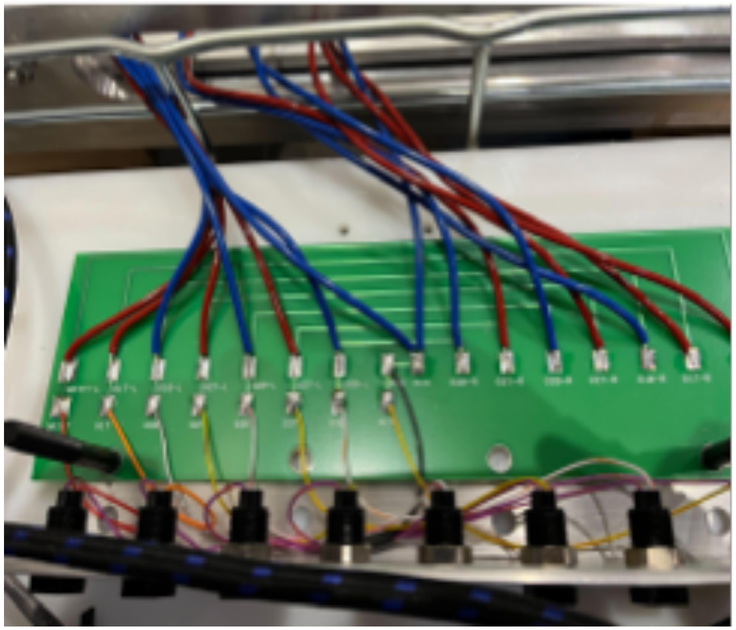
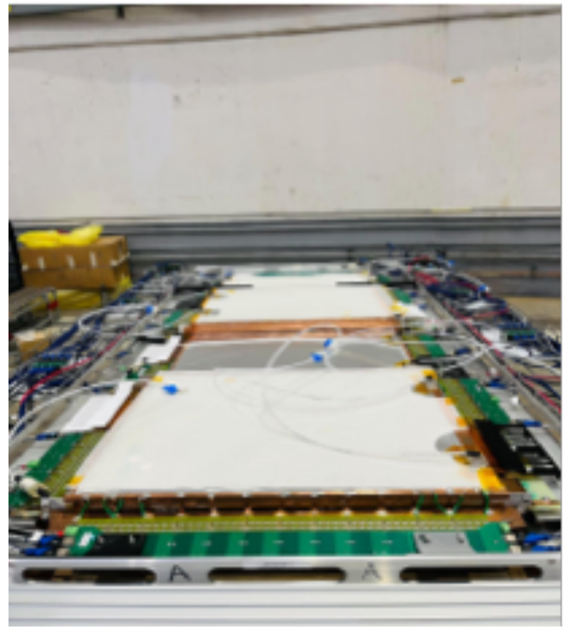
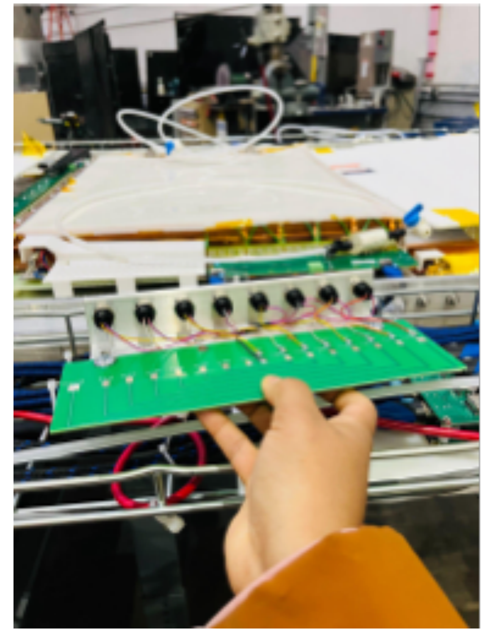
GEM status in the Hall

Moving POL-R into Hall, Jan 2024

2 XY layers, continue testing / commissioning on Hall floor

GEM status in the Hall

HV upgrade for POL-R (2 XY layers) inside Hall, Jan 2024: CAEN A1515BTG

SBS inline GEMs (6 XY layers) to be pulled out for HV upgrades Jan 25 – Feb 15
→ MAJOR EFFORT, REQUIRES COORDINATION OF AVAIL. MANPOWER, TECH SUPPORT, WORK ENVIRONMENT (ePAS etc …)

2 INFN layers to be replaced with 2 new XW layers (1st is ready, 2nd potentially)

Low-voltage (LV) supply and distribution being replaced for SBS

Timeline

Summer/Fall 2023	**Commissioning of POL-R (EEL) with cosmics**
	Commissioning of inline GEMs w/ beam during GEn-II
Dec 2023	**Upgraded HV supplies for BigBite GEMs, fixed APVs**
Jan-Feb 2024	**Moved POL-R GEMs to Hall, cabled for HV tests**
	Pull out inline GEMs; upgrade HV supplies, fix APVs
Feb-Mar 2024	**Build SBS GEM bunker after SBS+HCAL in position**
	Installation of active analyzer and POL-R+hodoscopes
	Cabling
	Commissioning of XW layers at UVa
Mar-April 2024	**Installation XW layers (if in time – relevant for KLL)**
	Final checkout
April-May 2024	**GEn-RP + KLL running**
May-October 2024	**Preparation of GEp**

Manpower update

Glasgow: David Hamilton (+ students and postdoc):
- Oliver Jevons (Glasgow postdoc)
- Andrew Cheyne (PhD student on GEn-RP)
- Gary Penman (Glasgow grad, GEn-II)

N. Michigan: Will Tireman (+ UG students)

Hampton: M.K. (+ students and postdocs):
- Sarashowati (Saru) Dhital (PhD student on GEn-RP)
- Taiga Goke (visiting grad. student from Tohoku Univ., Jan 27-Mar 3)
- Ryan Richards (HU postdoc, 20%)
- other grad. students (Manju, Tanvi, Angel, Anne) + 1 UG (Krystal)
- HU postdoc (TBD, 80%)

JLAB: Holly Szumila-Vance, Bill Henry, B. Wojtsekhowski (+staff & tech. team)

UVA: Nilanga Liyanage (+scientists, postdocs, students, and tech)
- Huong Nguyen, Xinzhan Bai (research scientists), Asar Ahmed (postdoc)
- Vimukthi Gamage, Bhasitha Dharmasena (grad students)
- Jacob McMurtry (grad student), Minh Dao (UG), Eric Fernandez (tech)

UConn: Andrew Puckett (+ students and postdoc)

CNU: Ed Brash (+ UG students)

William & Mary: D. Armstrong, T. Averett (+ students and postdocs)

Responsibilities

List of Tasks to be Done and Personnel v2
Updated: 8-December-2023

Software	Action/Description	Responsible Personnel
DAQ Software	Update DAQ	Alex
Online Analysis	Update SBS Online for new GEMs and GEn-RP hodoscopes/Analyzers	Jiwan/David H. / Gary P.
Offline Analysis/50k/100k	Replay analysis updates for updated/new detectors	Jiwan/David H. / Gary P.
Slow Controls	Integrate new detectors into slow controls	Mark/Bill H.
HV controls	Add new detectors into HV controls	
Alarm Handler	Update alarm handler for new HV supplies	
Equipment		
Cabling	80 PMTs - HV and signals (32 analzyers (1 PMT) and 24 Hodoscopes (2 PMTS)	Bill H.
DAQ Electronics	FADCs and TDCs	Coordinate with Alex/David H.
SBS inline GEMs		Holly/Nilanga
SBS side GEMs		Holly/David H.
GEn-RP Detectors		Bill H.
Target		Meekins, Ed Brash
Moller		Donald
BBCal		Kate
Hcal		Jiwan
Beam Line		Bill H.
SBS/BB Magents	Settings: Angles, location, Power supplies	Bogdan/Ellen
Other Items		
RSAD	Update radiation budget -- pavel@jlab.org	Will Tireman
Safety documents	COO, ESAD, ERG, SAF110 -- Contact Mark Jones	David Hamilton
Run Plan development		Bogdan / David H
Shift Schedule and Policy	20 days, 120 shift persons + RCs	Michael Kohl
Physics liaison		Bill Henry

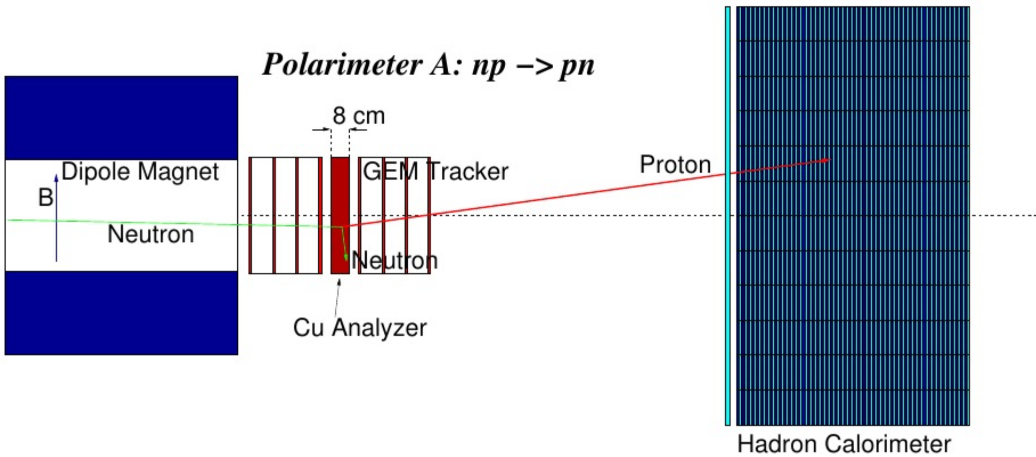
Personnel Able to Provide Assistance
Saru Dhital
Andrew Cheyne
Will Tireman

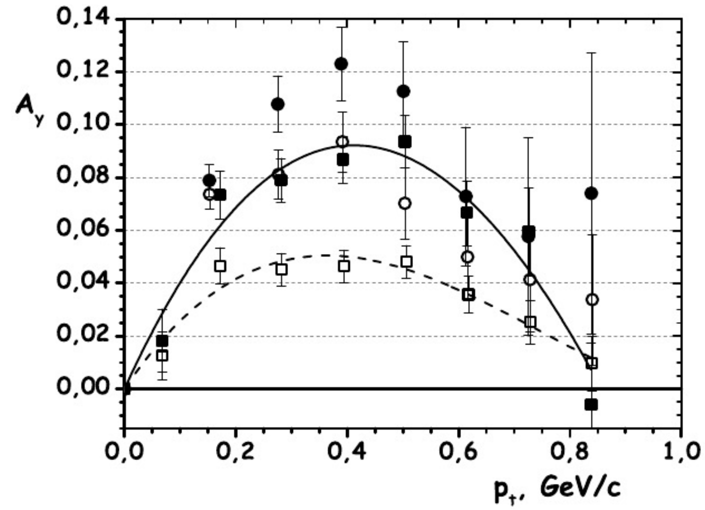
Thank you!

Questions?

Backup

Recent analyzing power data from Dubna





- Dedicated analyzing power measurements with 3.75 GeV/c nucleons with a high-Z analyzer were published in 2020 (Basillev S.N. et al. EPJ A 56, 26).
- These measurements were done with the ALPOM2 set-up at Dubna using a similar polarimeter arrangement as GEn-RP (including a hadron calorimeter).
- The results confirm that the analyzing power for charge-exchange scattering is the same for low-Z and high-Z analyzers and that the use of a hadron calorimeter enhances A_y by a factor of 2.