Neutron Elastic Form Factor Ratio from Recoil Polarization

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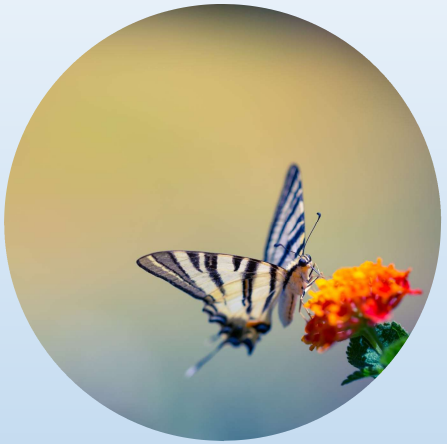
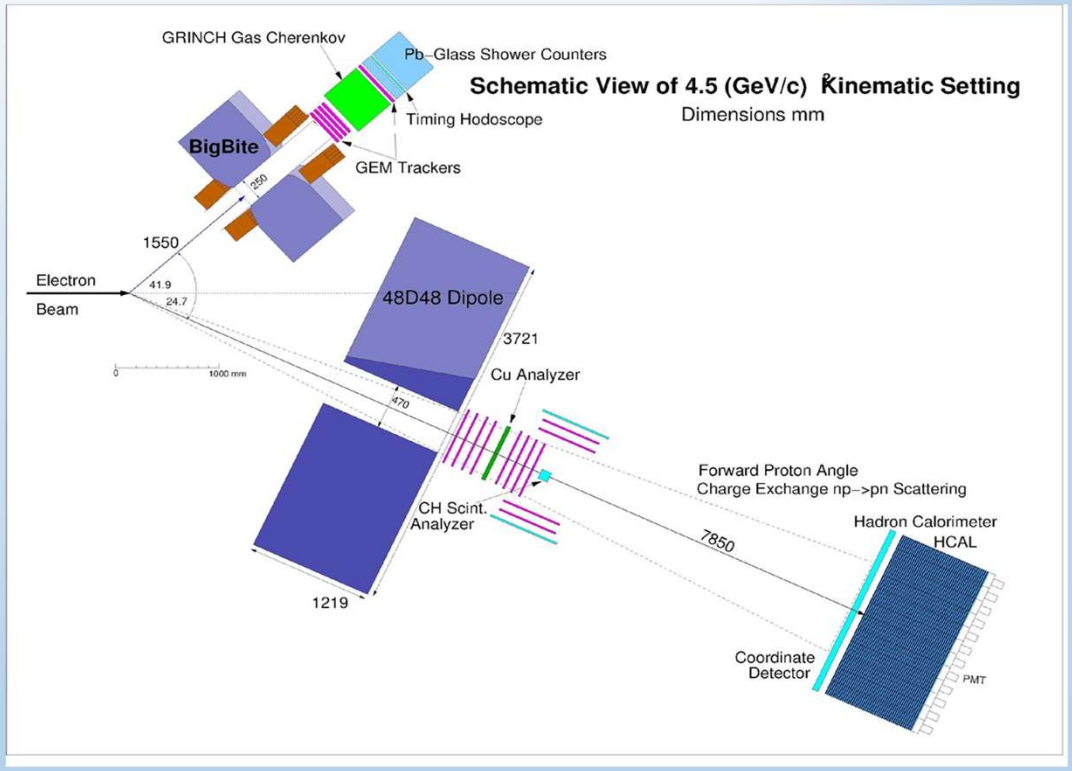
Motivation

- Previous experiments have measured GEn/GMn ratio from the polarization of the recoiling nucleon at Q^2 of 0.45, 1.13 and 1.45 $(GeV/c)^2$
- GEn-II:
  - Polarized He-3 (Effective polarized neutron target)
  - High Q^2 reach of upto 10 $(GeV/C)^2$
- GEn-RP (Recoil Polarization):
  - Unpolarized Deuterium (Unpolarized quasi-free neutron target)
  - High Q^2 of 4.5 $(GeV/C)^2$
- Deuteron RP -Less prone to nuclear corrections -Important cross check to validate the He-3 polarized target method
- If the new polarimetry technique with charge exchange proves feasible, then the Q^2 reach of deuteron RP could be similar to that of polarized He3 target



Experimental Layout

- GEn-RP will measure GEn/GMn using two polarimetry techniques at Q^2 = ~4.5 $(GeV/c)^2$
- Beam Polarization = ~80%
- Target: 15 cm LD2 (unpolarized)
- Electron (BB) Arm: Measures scattered electrons
- Hadron (SBS) Arm: Measures scattered nucleons



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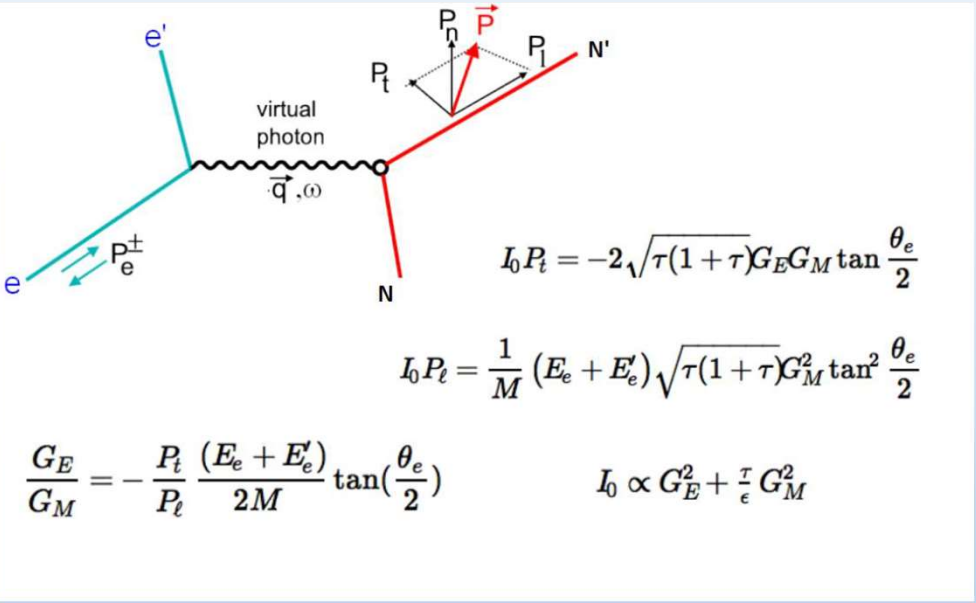
Recoil Polarization Technique



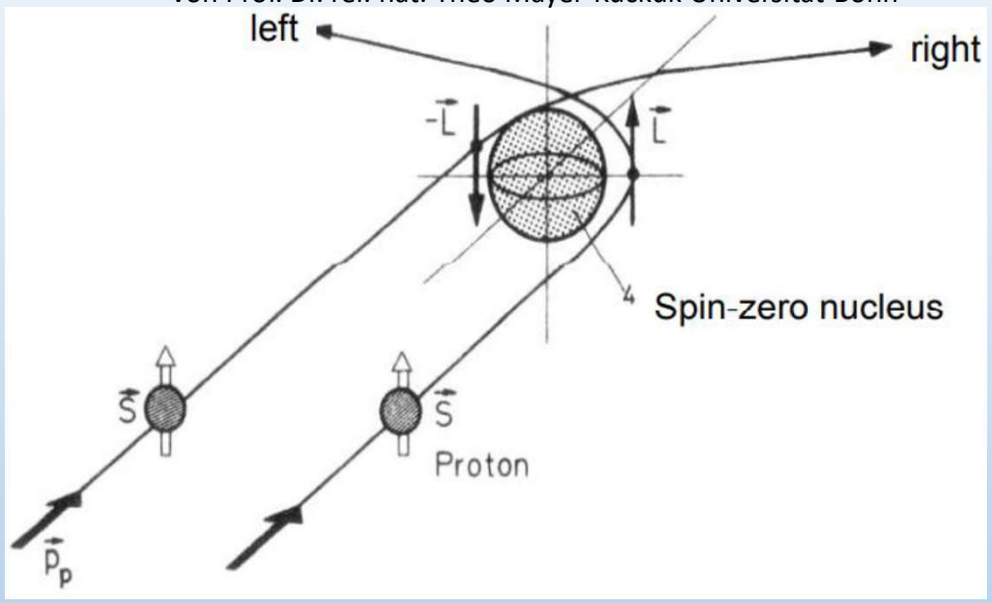
$$I_0 P_t = -2\sqrt{\tau(1+\tau)}\,G_E G_M \tan\frac{\theta_e}{2}$$

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

$$\frac{G_E}{G_M} = -\frac{P_t}{P_\ell}\frac{(E_e + E_e')}{2M}\tan\left(\frac{\theta_e}{2}\right) \qquad I_0 \propto G_E^2 + \frac{\tau}{\epsilon}G_M^2$$

Kernphysik, Eine Einführung

Von Prof. Dr. rer. nat. Theo Mayer-Kuckuk Universität Bonn



- Applicable to both protons & neutrons
- Recoil Polarization components related to form factor.

- Nucleon polarimetry : strong LS coupling connects nucleon polarization to spatial asymmetry

Recoil Polarization Technique

V. Punjabi et al.,
Phys. Rev. C71 (2005) 05520

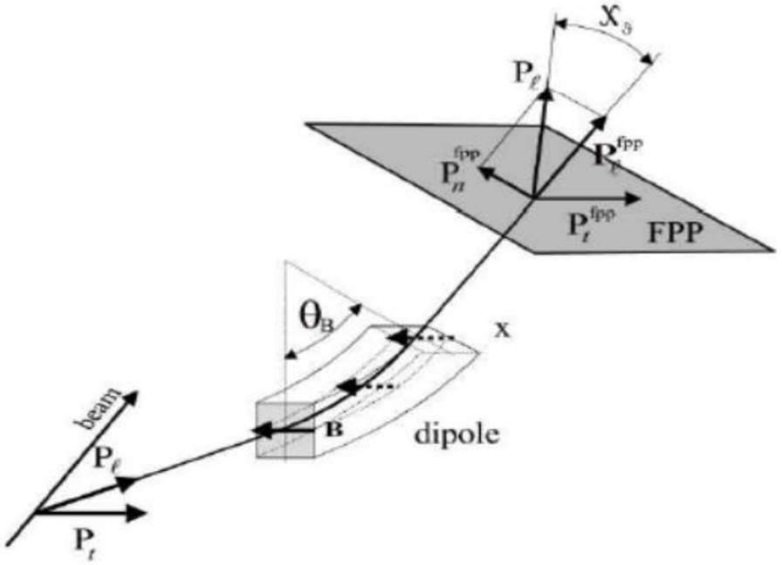


FIG. 15: Schematic drawing showing the precession by angle χ_θ of the P_ℓ component of the polarization in the dipole of the HRS.

- Incoming proton swept up by the dipole magnet
- Precession of the longitudinal polarization component occurs within the plane of deflection, perpendicular to magnetic field
- Analyzing power: Quantity that converts polarization of nucleon to the asymmetry observed
- Can calibrate analyzing power against polarization
- If analyzing power is known, polarization can be measured
  Ratio of Pt/Pl directly probes FF ratio, even without knowing of analyzing power

Analyzing Power For Elastic n-p Scattering

- Ay for n-p scattering (forward neutron) falls rapidly with increasing neutron momentum
- Ay for n-p charge-exchange (forward proton) is large at sufficiently large neutron momentum(θp~ few degrees)
- No apparent strong incident momentum dependence for charge-exchange Ay

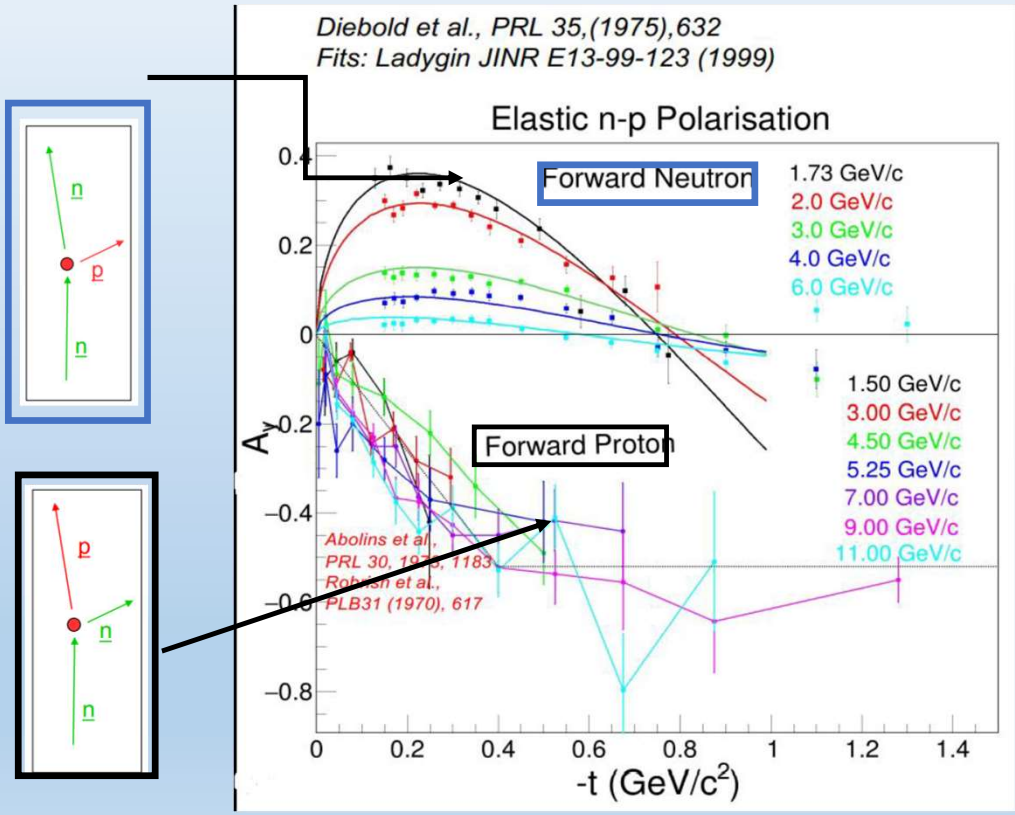
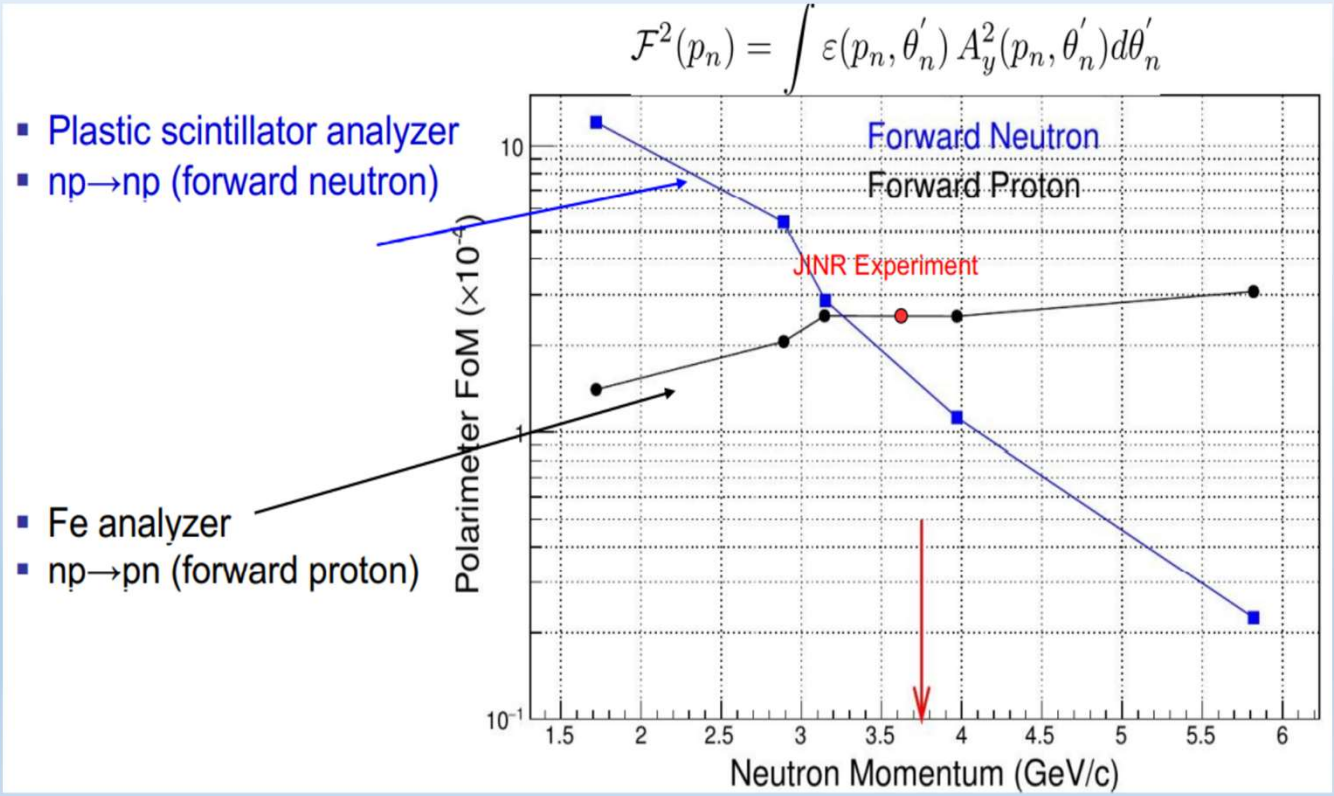


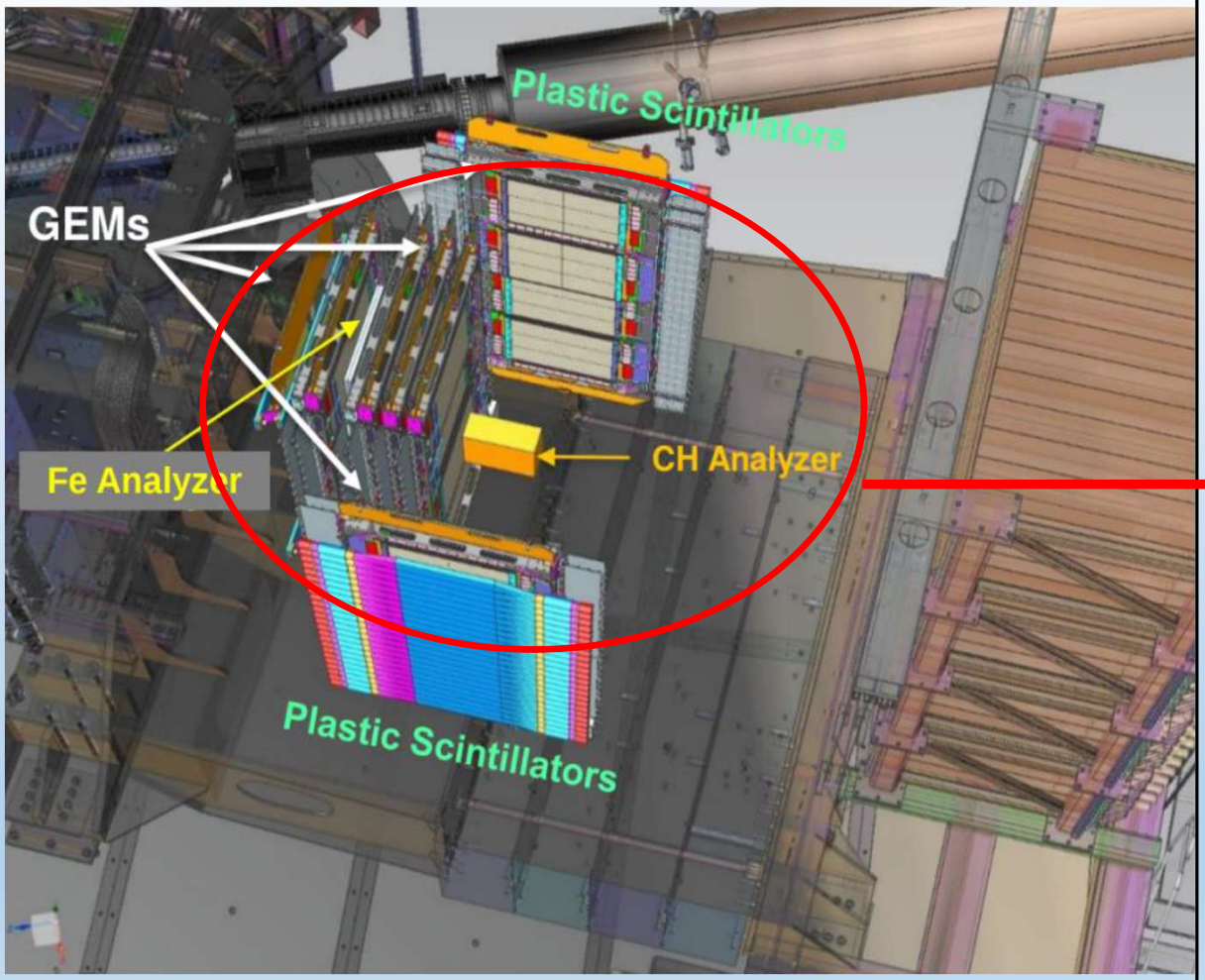
Figure of Merit of Analyzing Power

- Simulated figure of merit of polarimeter as a function of θn and pn by monte carlo
- FOM of np- np declines
- FOM for np-pn stays up
- Gen-RP kinematics near crossing region

Acceptance-weighted integral of squared analyzing power determines statistic error



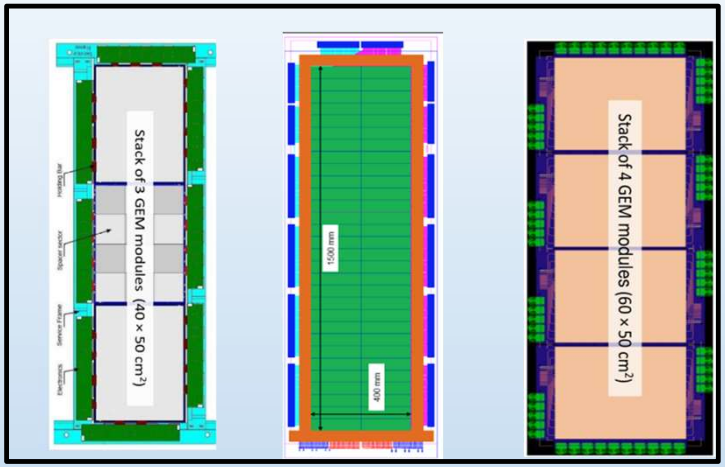
SBS Neutron Polarimeter

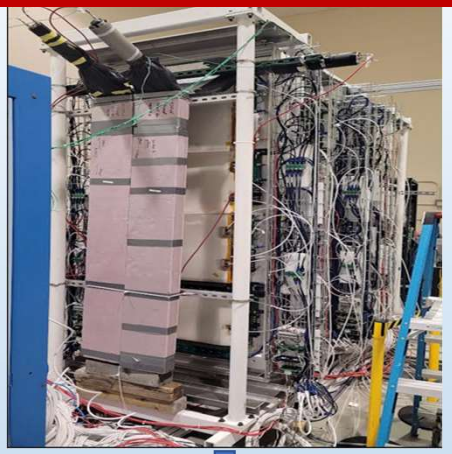


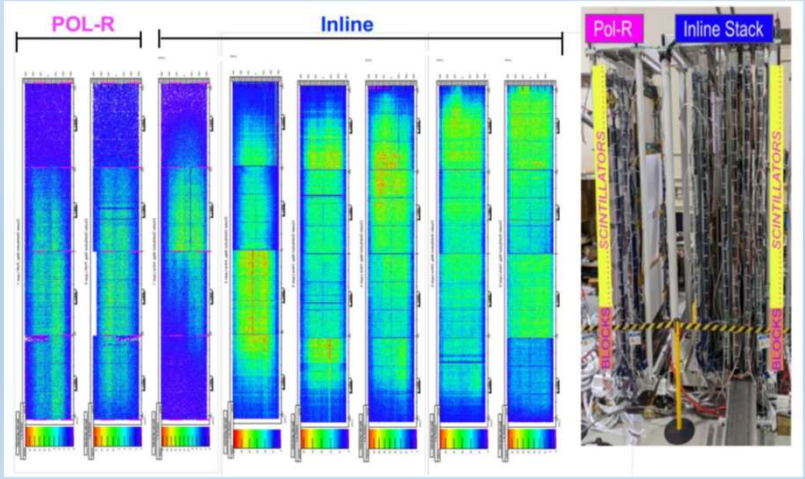
- Charge Exchange (CE) Polarimeter High momentum forward protons towards HCAL after CE np→pn
- 8 UVa GEM planes
- 1 Fe Analyzer

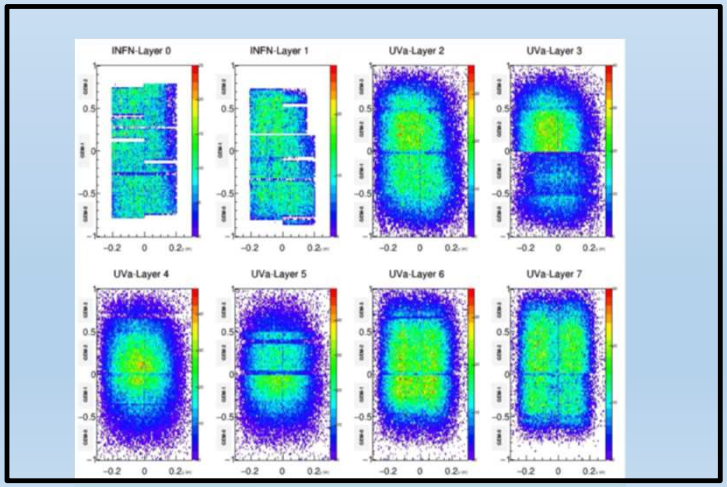
- Proton Recoil (PR) Polarimeter, Low momentum large angle recoiling, protons after np→np
- Active CH Analyzer
- 2 Sections, one each side of CE Polarimeter
- Each section has 2 UVa GEM planes & Plastic Scintillators
- Descoping of beamline –side setup is now considered

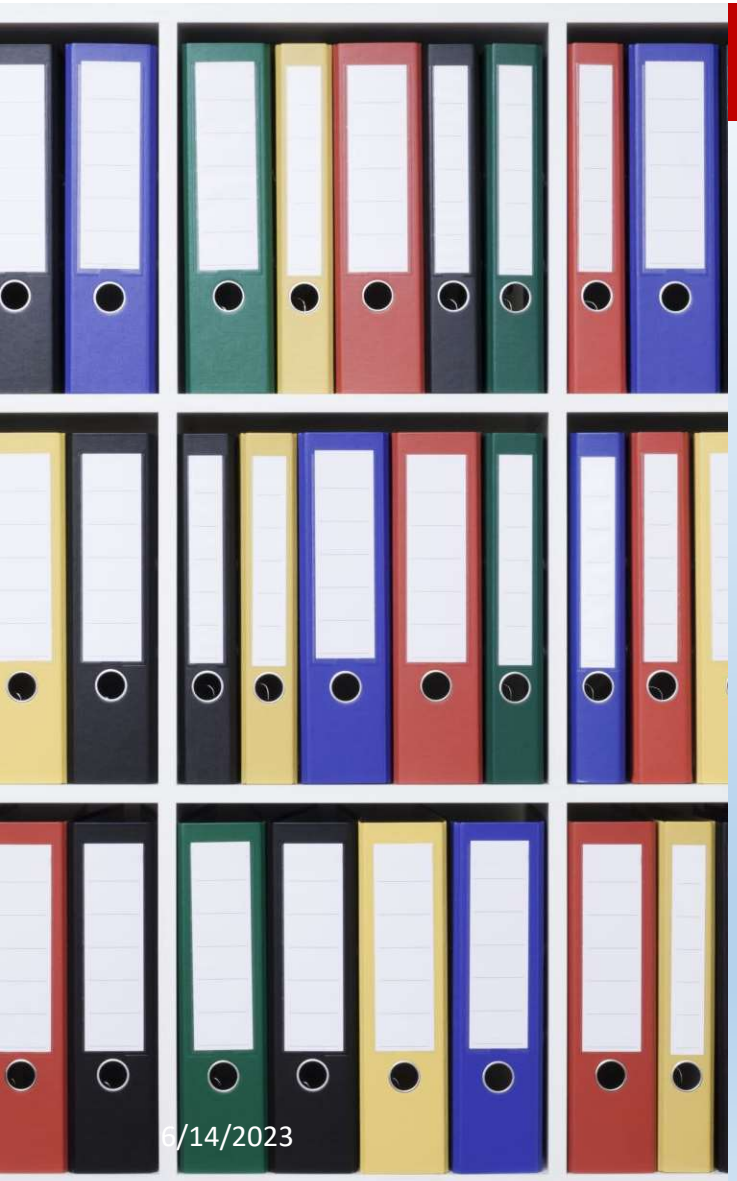
SBS GEMS Commissioning for Gen-RP











Summary

- The SBS program: Multiple form factor measurement experiments at high Q^2 values.
- GEn-RP: Proof of Principle experiment -2 recoil polarimetry techniques.
- GEn/GMn at Q^2 higher than the highest published kinematic point.
- Experimental figure-of-merit information on the polarimetry & analyzing powers -Optimize future measurements of GEn/GMn to reach higher Q^2 values using recoil polarimetry techniques.
- GEn-RP -Scheduled to run in spring (Jan-Feb 2024)

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