E12-17-004 GEn-RP Update

Hall A Collaboration Meeting
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E12-17-004 Wiki Page

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Experimental Technique

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

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

- Liquid $D_2$ Target 10 cm, 40 $\mu$A polarized electron beam (assume 80%), $L = 1.26 \times 10^{38}$ 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 $\sim 2$ 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

- This polarimeter detects high-momentum, small angle protons
  produced by np $\rightarrow$ pn AND low-momentum large-angle protons produced by np $\rightarrow$ np scattering
GEN-RP Physics / Experimental Approach

- E12-17-004 will measure GEn/GMn using two recoil pol. techniques at $Q^2 = \sim 4.5 \text{ (GeV/c)}^2$
  - “GMn” beam, beamline, target, BB
    - Beam: $\sim 4.4 \text{ GeV/c, } \sim 30 \mu A, P_b = \sim 80\%$
    - Target: 15 cm LD2 (unpolarized)
  - Scattered electron measured in BigBite
  - Charge-Exchange $np \rightarrow pn$ channel (primary goal)
    - Steel analyzer (passive)
    - GEM tracking + HCAL measure forward protons
  - Conventional $np \rightarrow np$ (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 ($K_{LL}$)
    - SBS Inline GEM stack + Steel analyzer

- NOTE: HCAL trigger is required for BB+HCAL DAQ trigger
Analyzing Power for Elastic n-p Scattering

- $A_y$ for n-p (or p-n) falling rapidly with increasing neutron momentum
- $A_y$ for charge-exchange n-p large at sufficiently large $t$ ($\theta_p \sim \text{few deg.}$)
- No apparent strong incident momentum dependence for charge-exchange $A_y$
- $\sigma_{np \rightarrow np}$ factor $\sim 10$ higher than $\sigma_{np \rightarrow pn}$
Addl. SBS Hardware for GEn-RP / E12-17-004

- **Active Analyzer (PR)**
  - segmented plastic scint. array
  - np recoil vertex identification

- **Recoil proton detectors (PR)**
  - 2 packages total:
    - One on SBS Left
    - One on SBS Right
  - Each package contains
    - 1x Hodoscope array
      - timing, coarse location
    - 2x UVa GEM planes
      - Tracking protons from CH analyzer

- **Inline GEMs (PR + ChEx)**
  - 2x INFN + 6x UVa GEMs
  - Charged particle veto (both)
  - forward proton tracking (ChEx)

- **Steel Analyzer (ChEx)**
Monte Carlo Simulation

- Realistic description of polarimeter components added to g4sbs
- Modified to include 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 ($\times 0.5$) 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
GEn-RP (E12-17-004)

- GEn/GMn form factor measurement
  - Models with diff. assumptions of quark dynamics diverge rapidly as $Q^2$ rises.
  - Full program supports nuclear $u$ and $d$ quark decomposition
- E12-17-004 is a “Proof of Principle” measurement of GEn/GMn:
  - Validate new neutron polarimetry technique exploiting Charge Exchange channel (promises much better FoM at high $Q^2$!)
  - Cross checked using the “conventional” large angle np scattering polarimetry
- GEn-RP is allocated 5 PAC days to do single $Q^2$ point at $4.5 \text{(GeV/c)}^2$
  - Was designed to overlap with GMn setting
  - If all works, will return to PAC for full measurement

E12-17-004 (projected)
Update GEM status (EEL/125)

- 8 (of 10) X-Y GEM layers installed and being read out with VTP hardware
  - 6 layers in the production “Inline Stack”
  - 2 layers in one “Side Detector” Assem.
- Still in development
  - 2 UVa X-Y layers partially assembled
  - 2 INFN layers (J1 and J3) in TestLab
Hodoscopes Assembled in ESB

- HV and Signal cables labeled and spooled in ESB (right)
- One “Side Detector” under test in ESB (left)
  → 2nd Hodo layer also complete
Scintillator DAQ / Readout Hardware

- RP-GEn DAQ rack assembled in ESB
  → Testing with CODA3 HallA / SBS readout
- HV crate also production ready
  → (just to the right but not in frame…)
- Cable runs measured/confirmed between SBS and DAQ bunker
  → Should confirm layout with Jesse/Robin
- Power in SBS DAQ bunker is arranged
  → Require ~25A/120V (Jack Segal knows)
- DAQ folks:
  → DAQ fiber to the VXS crate for triggering
  → Need Ref-time for the v1190 TDC (&FADC)
  → Add ‘Side Detector’ trigger to TS (“Like”)
Upcoming Plans

- Move SBS RP-GEn detectors to the Hall for comm. during Pol He3 run in Fall 2022
  - Inline GEM layers installed in final location
  - Side Detector locations TBD
    » Beamline-side detector has interference
    » Perhaps locate both on floor beam-right of SBS?
  - No SBS rear field clamp
  - No Beamline shield wall

- Rough Timeline
  - Detectors to Hall: Apr/May
  - Hook-up and Test: May/June
Hardware Todo Lists

• DAQ rate questions
  → Significant VTP work has been done on EEL/125 GEM stack
    » Good progress, but more to do...
    » Load testing of VTPs in test setup a must
  → Need to assess potential data rate limitations in the Hall A DAQ system
    » “Max” rate @ 4.5 kHz with all GEM layers: ~3 GB/sec
    » Bandwidth, stability, sustainability?

• Magnetic fringe field check on SBS carriage
  → Existing shielding good to 50–60 G
  → Would like to re-measure in final config with rear field clamp installed
    (may not be possible)
  → Otherwise (re-)measure fields at planned SBS production current w/o clamp to validate model predictions

GEM Assembly Issue

• 79 APVs needed to complete assembly and readout GEM layers
  → Reuse idle INFN APVs?
    » Need connector adapter to be fabricated
  → 31 APVs damaged
    » Some fraction repairable
    » Maybe small fraction...
  → Buy/build new APV cards?
    » Availability and timeline?
  → APVs may be in contention with other projects
    » New SBS layers? Other projects?

• Complete GEM layer assembly and Cosmics testing
Software / Analyzer Todo

• The 4 UVa GEMs downstream of Steel Analyzer provide track for Charge-Exchange proton
  → Supported by kin. constraints from e- in BB and HCAL cluster
  → Assumption was that we would leverage existing GEM tracking infrastructure for BigBite in Podd
    » Still to be completed
    » Needs expert support, experts are stretched thin...

• Upstream GEMs are a used as charge-veto only for GEN-RP (relatively low bar)
  → Tracking required in this region for $K_{LL}$

• Hodoscope / Active analyzer fairly easy to implement and monitor with existing Podd
  → Kinematics and online “physics” monitoring modules/scripts still need to be developed
Staging and Run-plan Integration

- Hardware to move to the Hall
  - 1 DAQ rack (pre-assembled) + 1 HV crate + Cables (will be in a basket for transport)
  - Three sub-detectors frames (Inline GEM stack; 2x side-detector assemblies)

- GEn-RP detectors will be installed in SBS detector stack and verified in-situ prior to start of beam
  - This includes the all GEMs and side hodoscopes
  - Active analyzer will be cabled and checked out in-situ w/ cosmics as well
  - Passive (steel) analyzer will NOT be installed
  - Jesse's schedule indicates
    - Schedule for SBS/GEN-RP equipment moving into the Hall: Apr—May 2022
    - Schedule for SBS/GEN-RP hookup and prebeam tests: May—Jun 2022

- SBS GEMs (hardware and DAQ support) will be worked on parasitically during the Fall 2022 program
  - Plan to demonstrate:
    - Operational stability and tracking in 8 inline GEM layers + HCAL
    - Operational stability and tracking/spatial coincidence in side-detector assemblies
Outstanding Performance Questions

• **BB + SBS performance vs luminosity**
  → Absolute tracking efficiency on electron arm vs. luminosity (or beam current on LD2)
    » Proposals assumed ~40 uA on 10cm LD2
  →

• **BigBite electron arm performance metrics**
  → Electron trigger efficiency?
    » What fraction of incident electrons are we able to measure after trigger dilution due to gammas, pions, etc

• **HCAL performance metrics?**
  → HCAL trigger status / efficiency?

• **Rates / tracking performance in GEM layers**
  → Tracking less important for GEn-RP than for $K_{LL}$

• **DAQ rates limit check**
  » GMn: 5 BB GEM layers: 700 MB/sec @ 2.5 kHz trigger rate
  » GEn-RP: +12 GEM layers: ~1700 MB/sec @ 2.5 kHz trigger rate
Thank you