E12-17-004 GEn-RP Update

Hall A Collaboration Meeting
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E12-17-004 Wiki Page

David Hamilton
(University of Glasgow)

Experimental Technique

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

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

$$P_y = 0$$

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

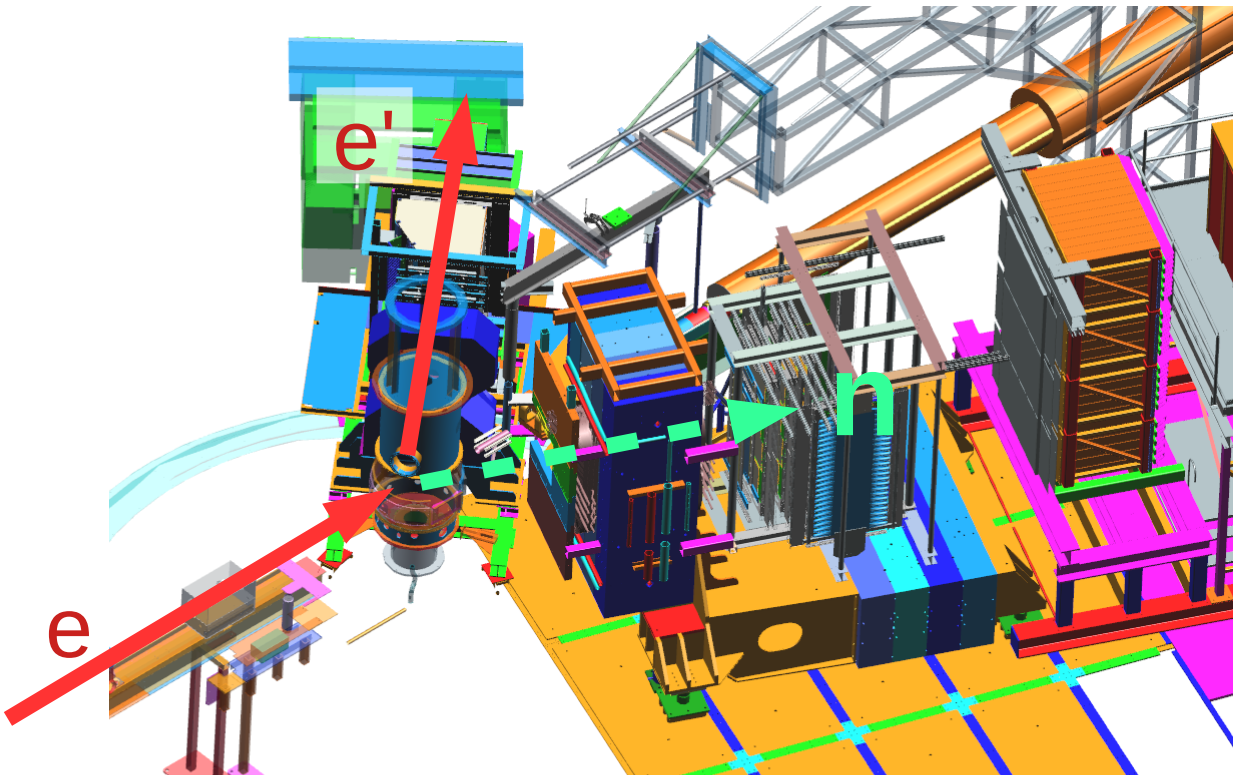
$$\frac{P_x}{P_z} = \frac{1}{\sqrt{\tau + \tau(1+\tau)\tan^2\frac{\theta_e}{2}}} \cdot \frac{G_E}{G_M}$$

- 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 μA polarized electron beam (assume 80%), 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
- This polarimeter detects high-momentum, small angle protons
  produced by np→pn **AND** low-momentum large-angle protons produced by np→np scattering

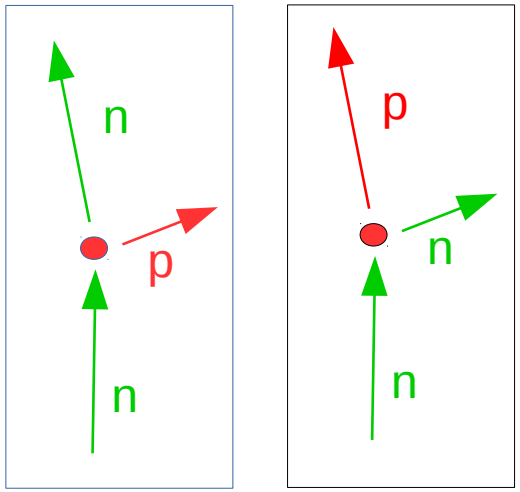
GEN-RP Physics / Experimental Approach

- 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 LD2 (unpolarized)
  - → Scattered electron measured in BigBite
  - → Charge-Exchange np → pn channel (primary goal)
    - » Steel analyzer (passive)
    - » GEM tracking + HCAL measure forward protons
  - → Conventional np → np (secondary goal)
    - » Plastic analyzer (active)
    - » Large-angle recoil protons → Side detectors (GEM + hodoscope)
    - » Forward neutron → HCAL
- NOTE: HCAL trigger is required for BB+HCAL DAQ trigger

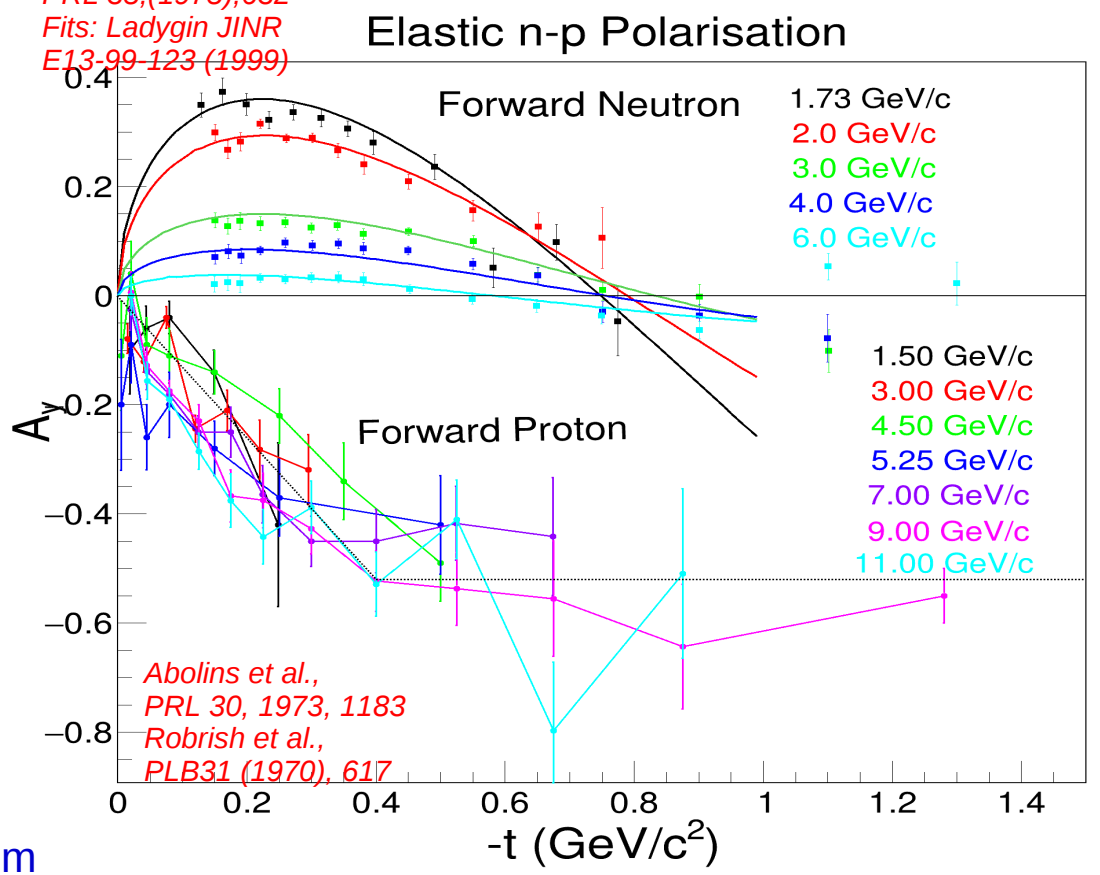
- Detector components also used in:
  - → Wide-angle Charged Photoproduction (K_{LL})
    - » SBS Inline GEM stack + Steel analyzer



Analyzing Power for Elastic n-p Scattering

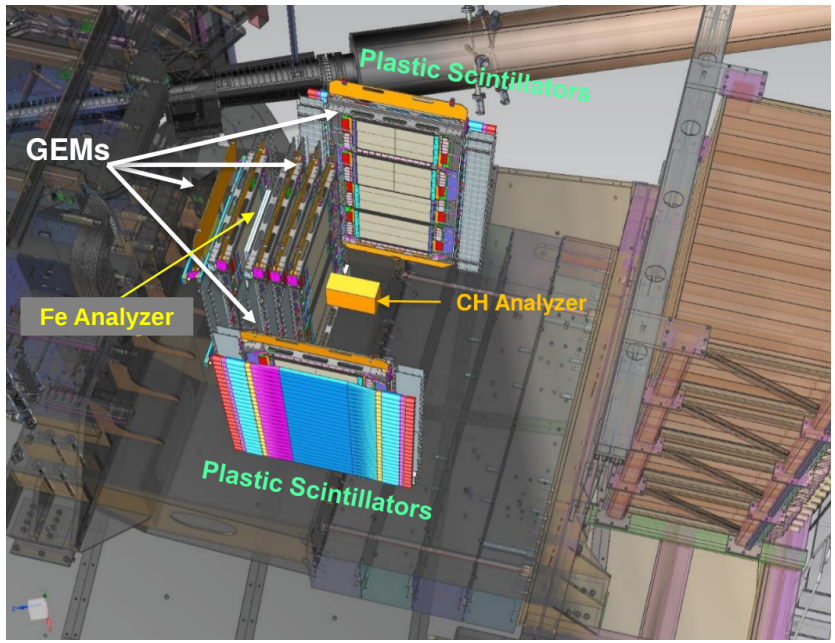


- A_y for n-p (or p-n) falling rapidly with increasing neutron momentum
- A_y for charge-exchange n-p large at sufficiently large t (θ_p ~ few deg.)
- No apparent strong incident momentum dependence for charge-exchange A_y
- $\sigma_{np\to np}$ factor ~10 higher than $\sigma_{np\to pn}$

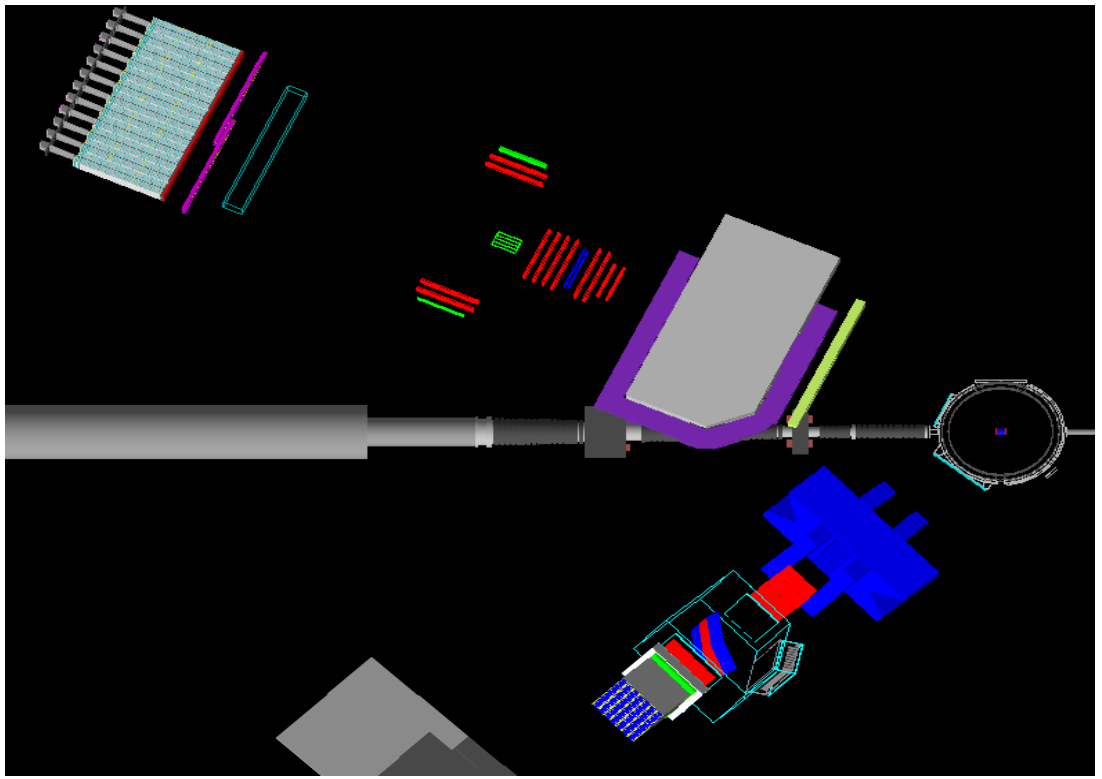


Addl. SBS Hardware for GEn-RP / E12-17-004

- 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)



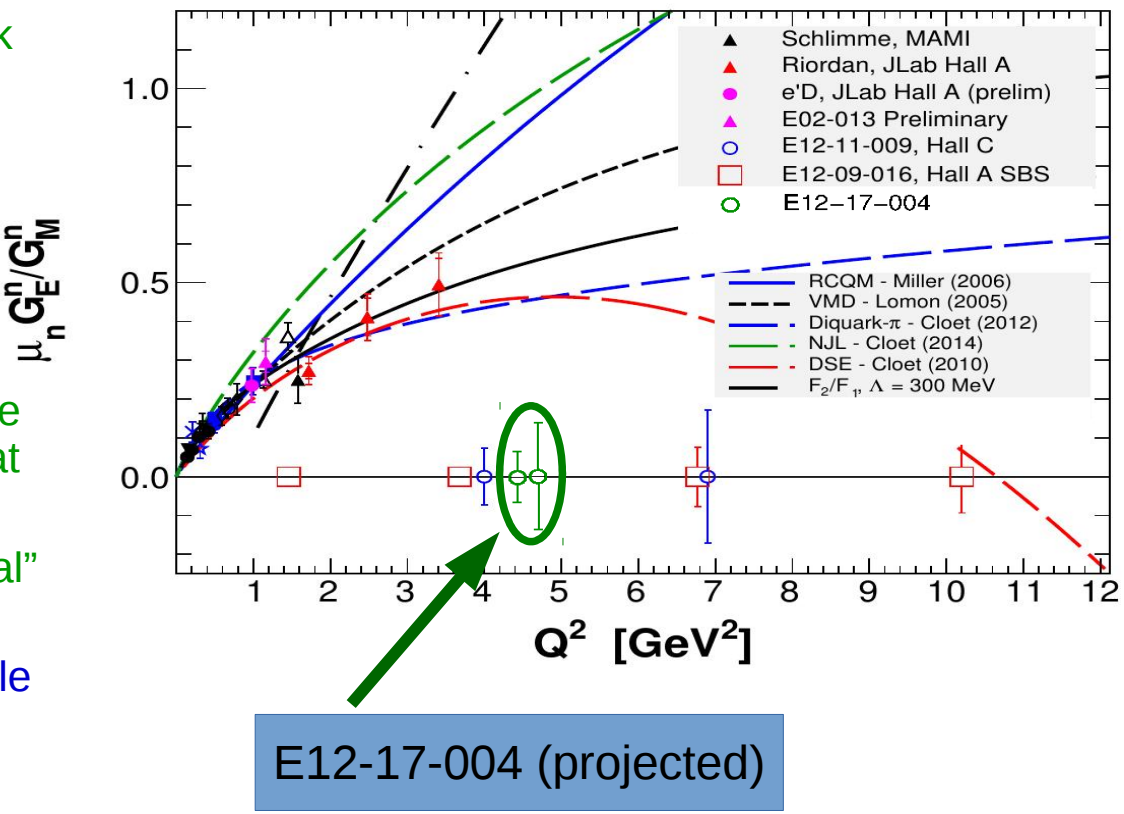
Monte Carlo Simulation



- Realistic description of polarimeter components added to g4sbs
- Modified to include spin-dependent hadronic processes and precession
- Full quasi-elastic pseduo-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 $(GeV/c)^2$
  - → Was designed to overlap with GMn setting
  - → If all works, will return to PAC for full measurement



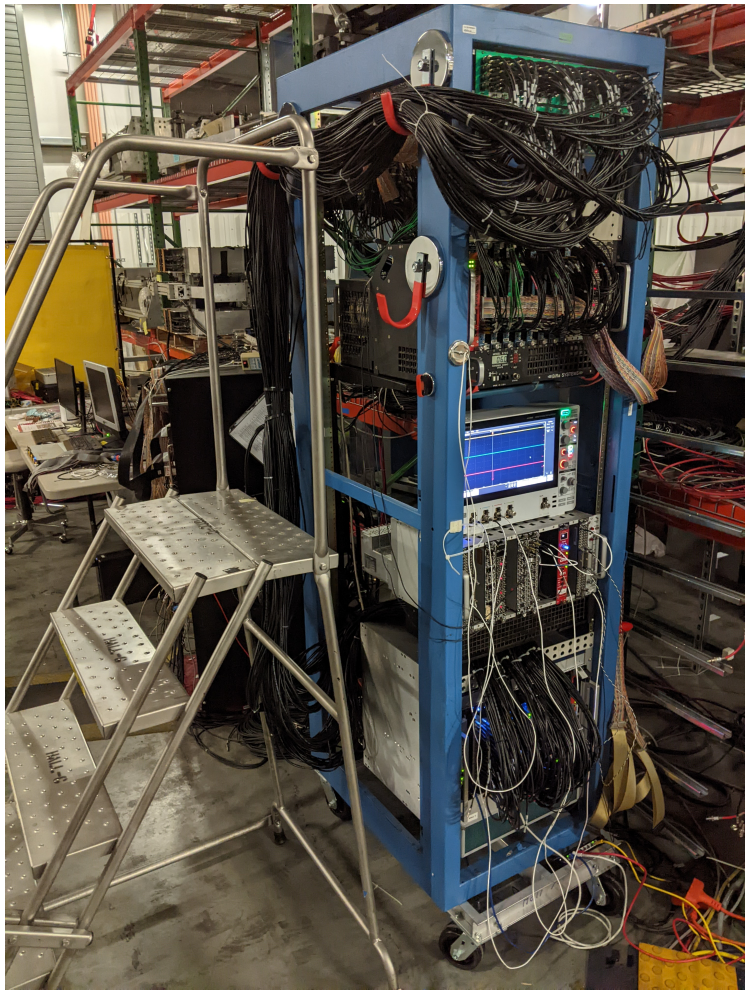
Update GEM status (EEL/125)

- 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

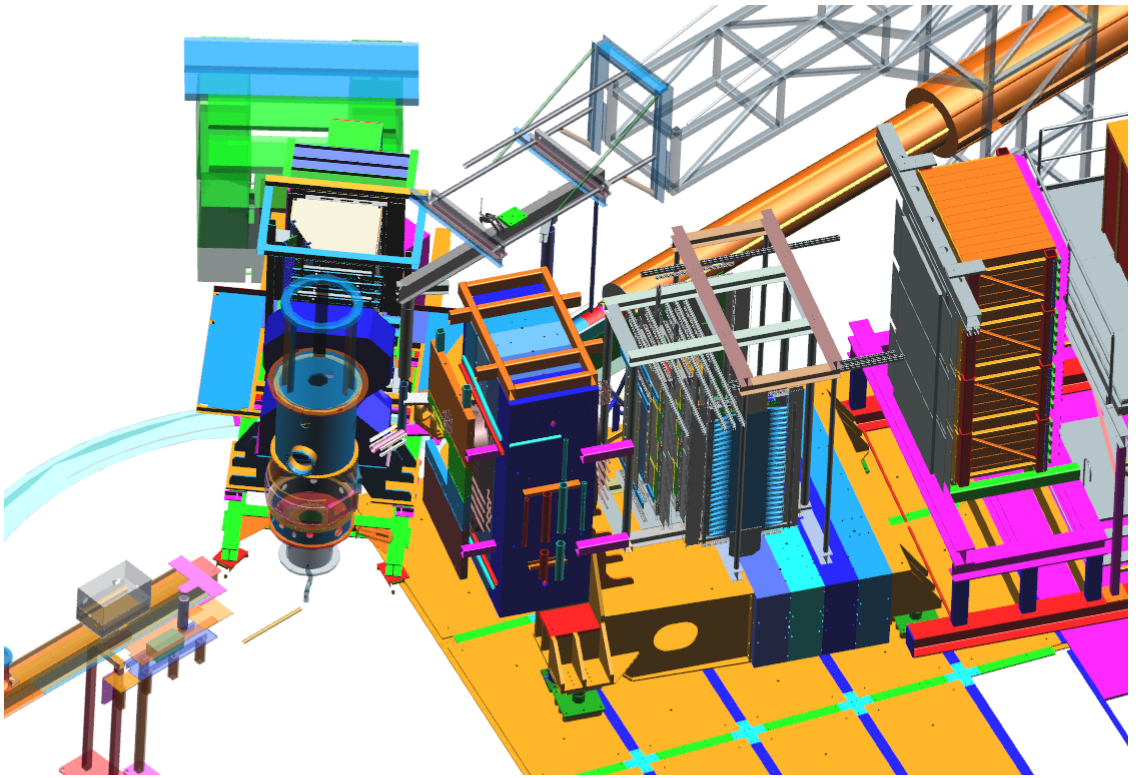
Scintillator DAQ / Readout Hardware



- 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
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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