E12-17-004 GEn-RP Update

SBS Collaboration Meeting
Feb 17–18, 2021

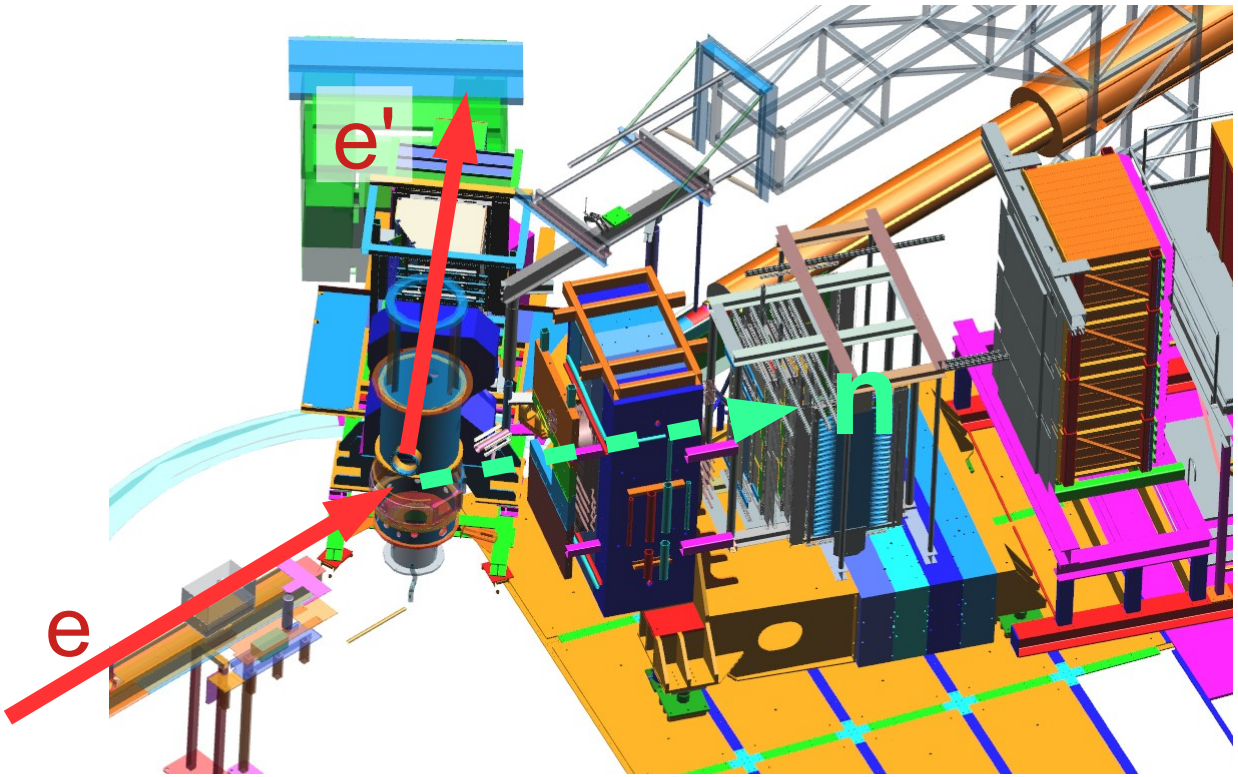
E12-17-004 Wiki Page

Brad Sawatzky

GEN-RP Physics / Experimental Approach

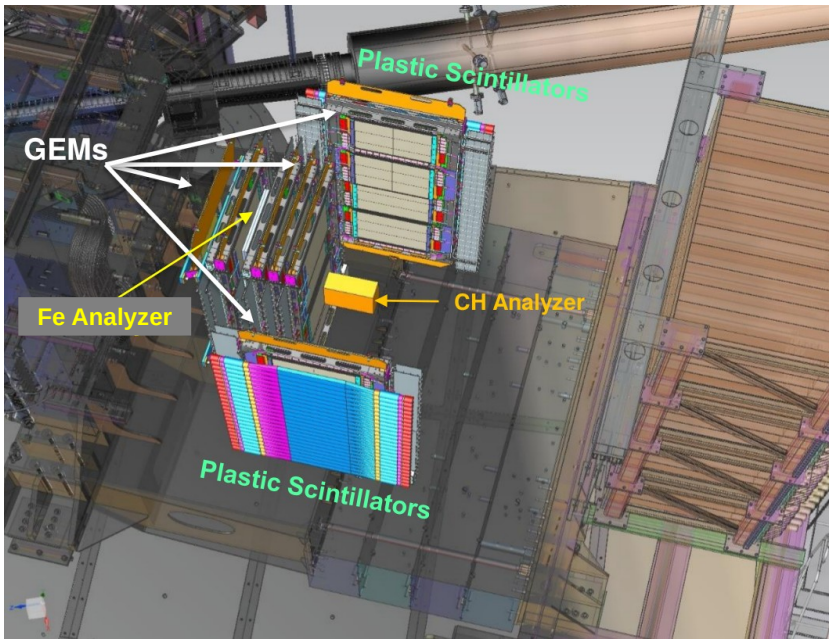
- E12-17-004 will measure GEn/GMn using two recoil pol. techniques at Q^2 = ~4.4 $(GeV/c)^2$
  - → "GMn" beam, beamline, target, BB
    - » Beam: ~5.56 GeV/c, ~40 μA, P_b = ~80%
    - » Target: 15 cm LD2 (unpolarized)
  - → Scattered electron measured in BigBite
  - → Charge-Exchange np → pn channel (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 (WAPP)
    - » SBS Inline GEM stack + Steel analyzer



Addl. 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)



Required Electronics/Cabling (non-GEM)

Count	Item	Status
6+2	F250 FADC	Draw from 'NPS/LAD' inventory + Hall C (*)
1	C1190 TDC	In hand (1+spare: Hall C + Glasgow)
1	VXS crate + CPU + TI + SD	In hand (1+spare: Hall C + Glasgow)
6+2	CAMAC Discrim.	In hand (w/ spares)
	CAMAC crate	In hand
96+32 ch	HV supply	In hand (96 neg; + 32 pos)
10+	Ribbon cables	In hand
128	Passive splitter (chan)	In hand
128	SHV cables (~100')	In hand in Phys Storage
128	Signal cables (~100')	In hand in Phys Storage

- (*) F250 FADCs are essentially 'in-hand' (6 'Hall C' spares + existing Phys Div units cover us)

GEn-RP non-GEM Hardware

- GEn-RP scintillator hw is being commissioned in the ESB
  - → Minor repairs, gain matching nearly complete and ready for assembly into frames
  - → Production FADC based readout (CODA3; F250s, 1190, etc) being assembled now
    - » Existing FB based test stand will be used in parallel
- Hardware for Frames/Stands is procured and on-site in ESB
  - → Assembly of large-angle side detectors (hodoscopes + UVa GEM layer) underway
  - → "Inline" GEM stack + Fe Analzyer assembly done in EEL (w/ Hall C Tech support)

High Level Tasks / Todo List (Non-GEM)

- Near Term tasks w/ ESB DAQ testbed (To be completed by March)
  - → PR Hodoscope Bars
    - » Finish regluing broken joints
      - – Retest and install into frames
  - → Active Analyzer
    - » Verify functionality
    - » Gain match w/ cosmics
  - → Sort and re-label cables
    - » Presently in Phys Storage Mezz.
- Assemble 'Production-ready' DAQ rack (Underway now)
  - → F250s, CAEN 1190, etc
  - → Same DAQ rack will move with the detectors to Hall
  - → Will test this system in ESB with active analyzer and hodoscopes after frames assembled.

- SBS fringe field test with PMTs (March/April)
  - → Validate B-shielding options with actual PMTs using HH coil PMT test stand in TestLab
  - → Implement verified solution in Mar/Apr

- Install into final detector stands (Ongoing)
  - → Side-detector stands being assembled now
    - » Re-check all bars w/ cosmics
    - » Complete by mid-April
  - → Integrate UVa GEMs into PR sub-assemblies at best opportunity
    - » See Kondo's talk (target: end of April)
  - → Software work (Analyzer)
    - » Add GEN-RP PMT arrays to PODD (easy)
    - » Add SBS GEM tracking to PODD (harder)
      - – Will rely on BigBite tracking modules (Andrew's group)

Local support: Brad, Bill Henry

Software / Analyzer Notes

- 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
    - » See afternoon talks

- Upstream GEMs are a used as *charge-veto only* for GEN-RP (relatively low bar)
  - → Tracking required in this region for WAPP

- Hodoscope / Active analyzer fairly easy to implement and monitor with existing Podd
  - → Kinematics and online "physics" monitoring modules/scripts need to be developed though
  - → (Will Tireman supporting this effort)

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
  - → Jesse's schedule indicates
    - » Schedule for SBS/GEN-RP equipment moving into the Hall: Mar—Jun 2021
    - » Schedule for SBS/GEN-RP hookup and prebeam tests: July—Aug 2021
- GEn-RP will run adjacent to associated 4.5 $(GeV/c)^2$ GMn kinematic setting
  - → Current plan has us running 1st in the GMn program immediately after BB/HCAL commissioning
    - » BB, HCAL, GEM commissioning w/ beam must all be completed before production begins
    - » Prior beam schedule had 3 weeks of dedicated SBS commissioning w/ beam (good!)
  - → Removal of GEn components prior to GMn 4.5 $(GeV/c)^2$ GMn data taking
    - » Side GEMs + hodoscope packages will be decabled and craned out as units
    - » (*) Steel analyzer remains for WAPP
    - » (*) Inline GEM package remains for WAPP
- Intent is to schedule all transitions during opportunistic Accelerator downs
  - → Beam studies, RF recover, etc.

Local Personnel

- GEM Systems
  - → UVa Group
    - » Kondo, Nilanga, et al.
    - » John Boyd (Grad Student; SCGSR award recip.)
  - → Hampton Group
    - » Michael K. (Lead)
    - » Thir (Postdoc)
    - » Malinga (MSc student)
    - » Manju (new PhD st.)

- When/if things return to normal'ish and travel options return:
  - → David H. group (Glasgow)
    - » Ralph Marinaro (PhD st.)

- PMT based detectors / DAQ (Hodoscopes, Active analyzer)
  - → JLab
    - » Brad, Bill Henry
  - → Hampton
    - » Might steal some time from Michael's team as COVID and GEM work allows.

High Level Tasks / Todo List (Non-GEM)

- Near Term tasks w/ ESB DAQ testbed (Complete by mid-April)
  - → PR Hodoscope Bars (80% done)
    - » Finish regluing broken joints
    - » Finish frame installation
  - → Active Analyzer
    - » Recheck functionality
    - » Gain match w/ cosmics
  - → Complete and test production DAQ rack
  - → Sort and re-label cables

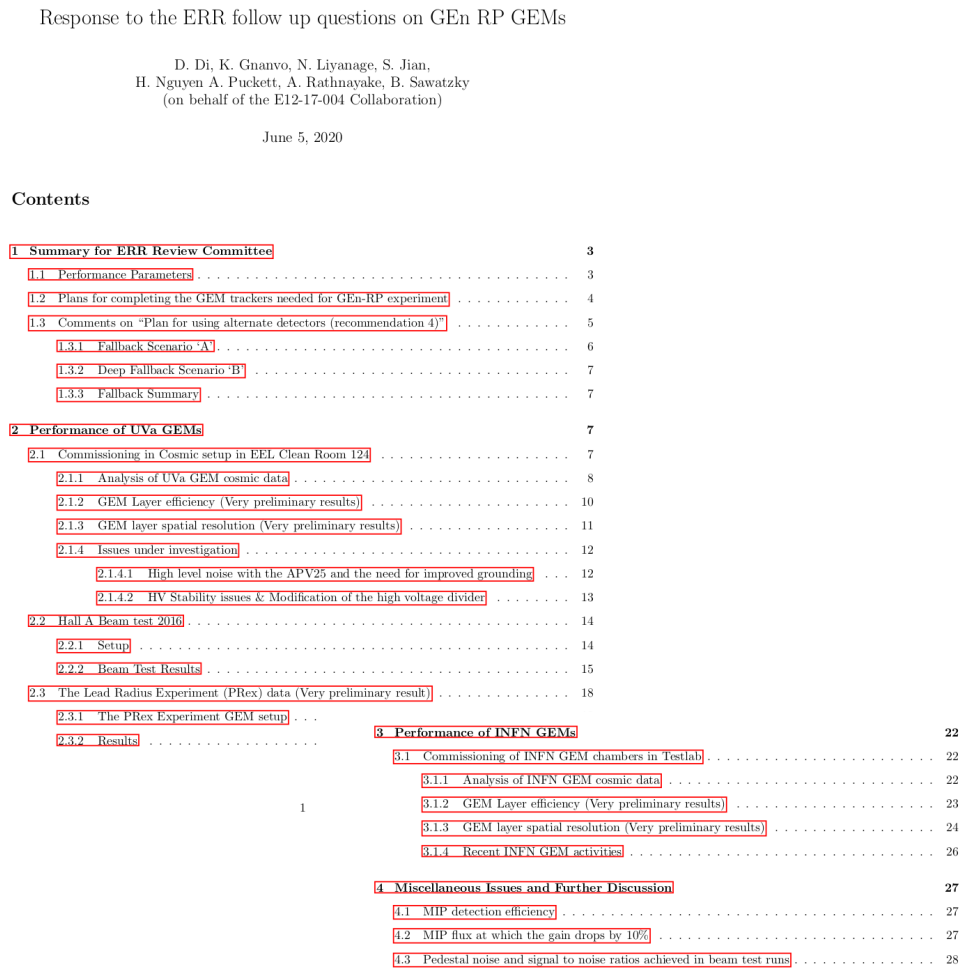
Local support: Brad, Bill Henry

- SBS fringe field test with PMTs (Mar/Apr)
  - → Validate B-shielding options with actual PMTs using HH coil PMT test stand in TestLab
- Longer Term (Apr/May)
  - → Integrate UVa GEMs into PR sub-assemblies
    - » Integration test w/ cosmics and GEM readout crate
  - → Software work (Analyzer)
    - » Hodoscope detector classes will be part of DAQ checkout
    - » GEM classes will be based off BigBite classes

Thank you

ERR Wrapped up in Nov 2020

- GEN-RP and GEM group provided 70+ pages of documentation to address issues raised by committee
  - → Link: GEn-RP ERR Wiki
  - → Reflects an *enormous* amount of work by the UVa GEM group and Andrew's software team in particular.
- Interested parties for all SBS experiments should review that document as a baseline for expected performance in upcoming SBS/BB measurements



Response to the ERR follow up questions on GEn RP GEMs

D. Di, K. Gnanvo, N. Liyanage, S. Jian,
H. Nguyen A. Puckett, A. Rathnayake, B. Sawatzky
(on behalf of the E12-17-004 Collaboration)

June 5, 2020

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ERR: GEN-RP “Fallback Options”

- Issues driven by questions around current INFN GEM status
  - → Cosmics hitmaps for 4 planes shown below (as of Fall 2019)
  - → 2 addl planes in progress
    - » 5th plane similar to J1 (left)
    - » 6th plane TBD

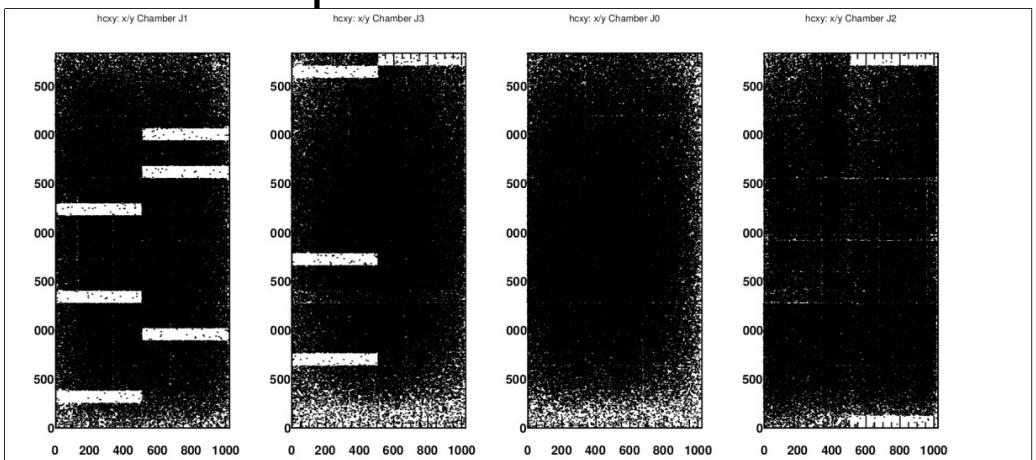
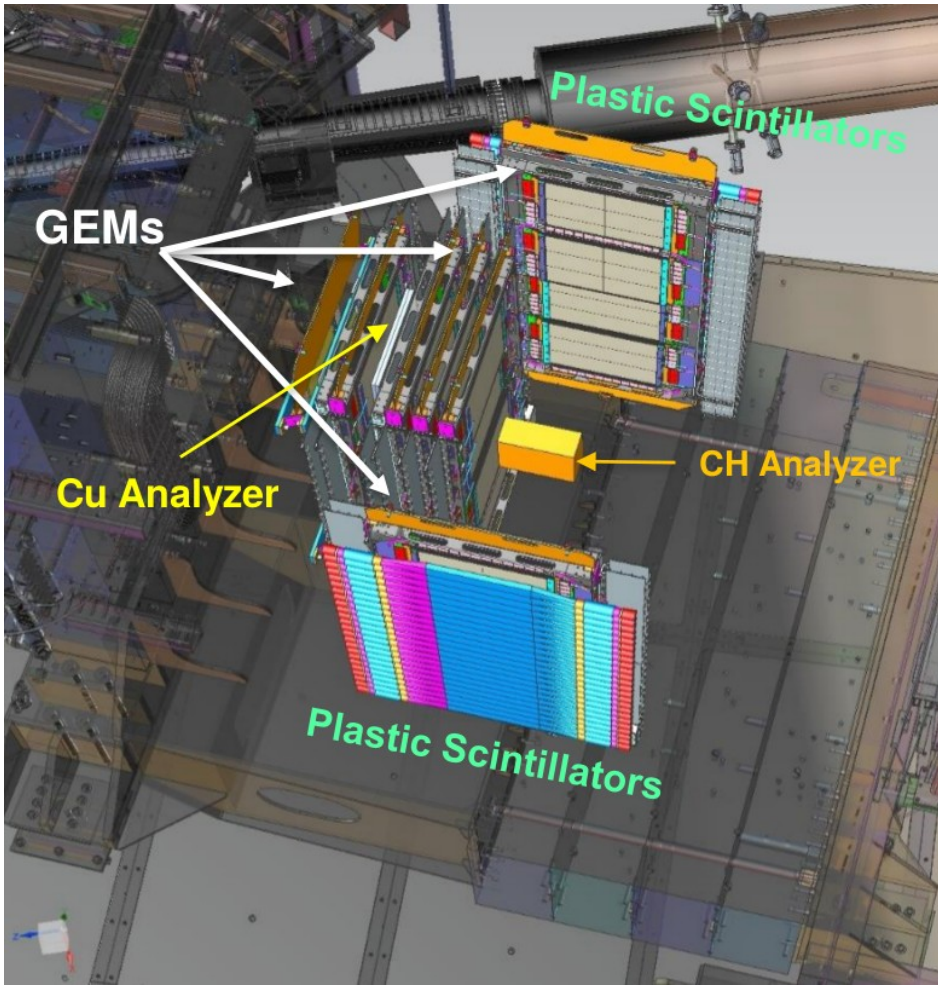
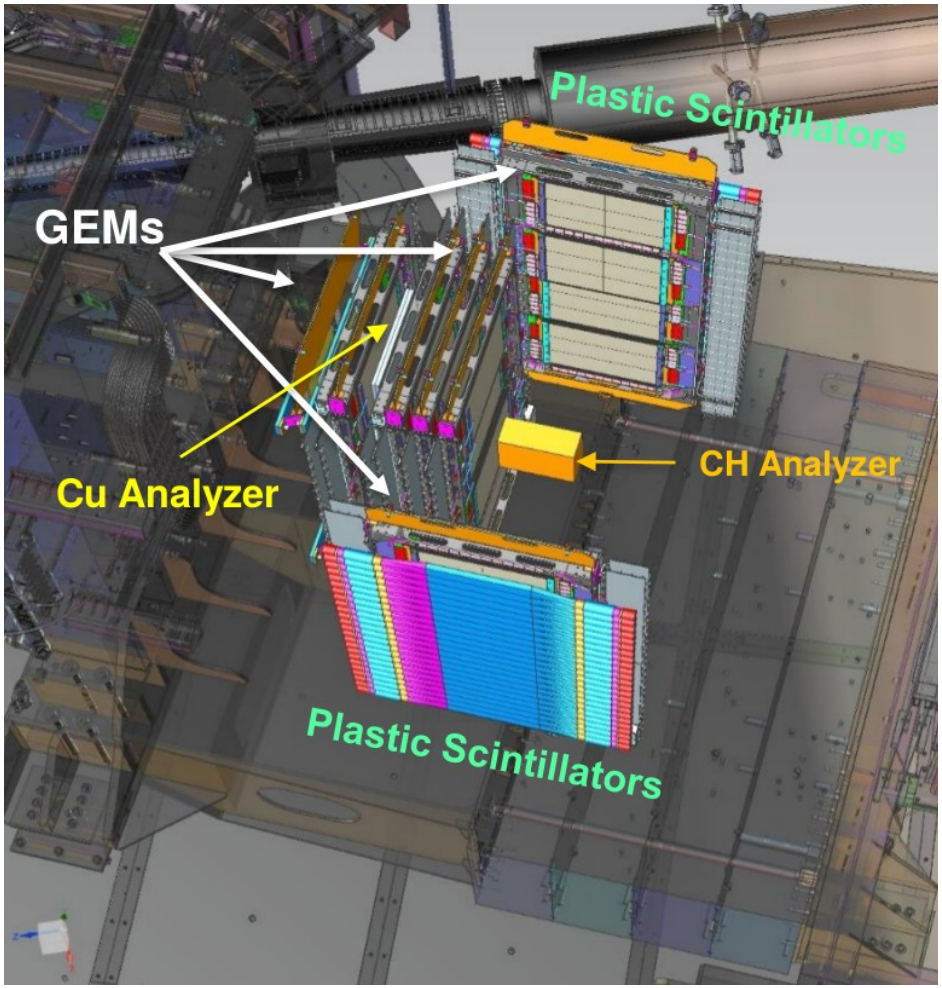


Figure 25: INFN GEM hitmap after module rearrangement in September 2019; compare to fig. 22



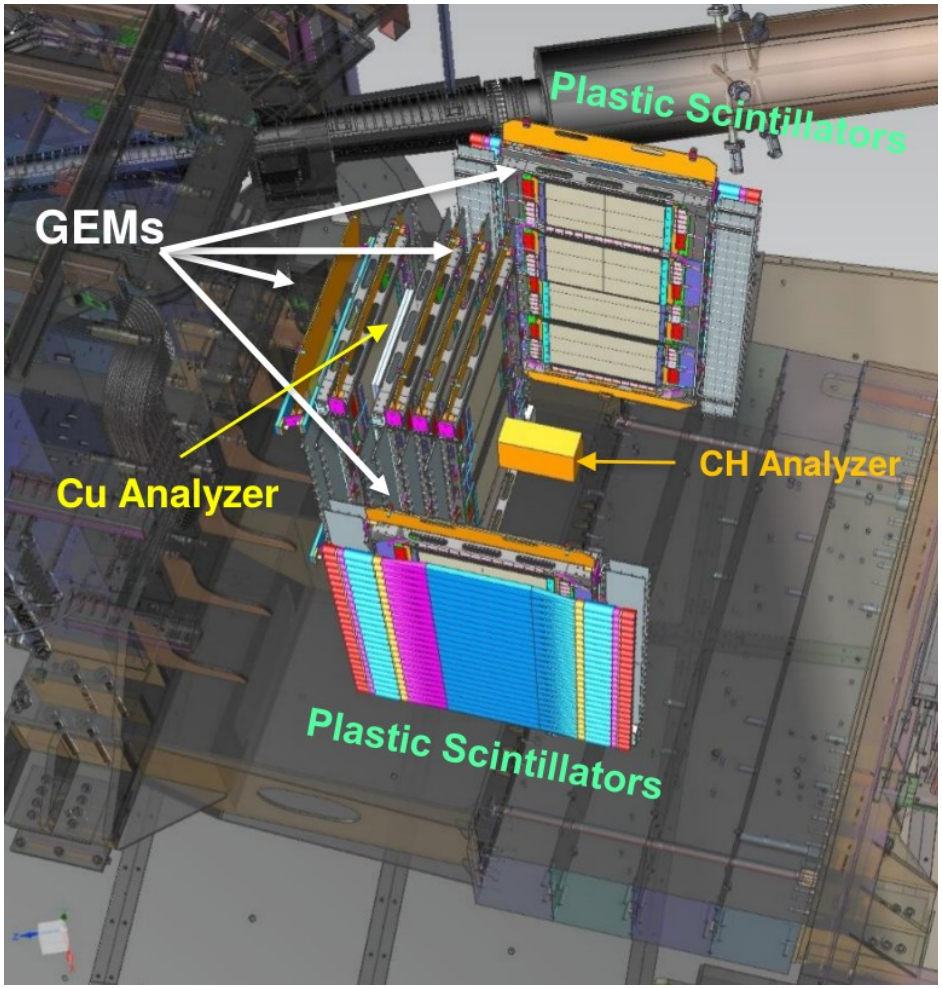
ERR: GEN-RP “Fallback Options”

- Always assume 4 best INFN GEMs must be in BigBite (now: 2 INFN + 2 UVa “U/V” GEMs)
- Original Plan
  - → All INFN and UVa planes have performance no worse than prior slide
- Fallback Plan “A”
  - → INFN planes 5, 6 are worse than J1
    - » Demonstrated RPGEN can tolerate significant plane inefficiencies in upstream (veto) GEMs
    - » Should be able to get by with 3 “effective” planes in GEM veto region with minimal impact on FoM
      - *ex*: Can tolerate 1 dead sector if other planes in that solid angle are OK
  - → *This situation likely inadequate for tracking upstream of analyzer (WAPP)*



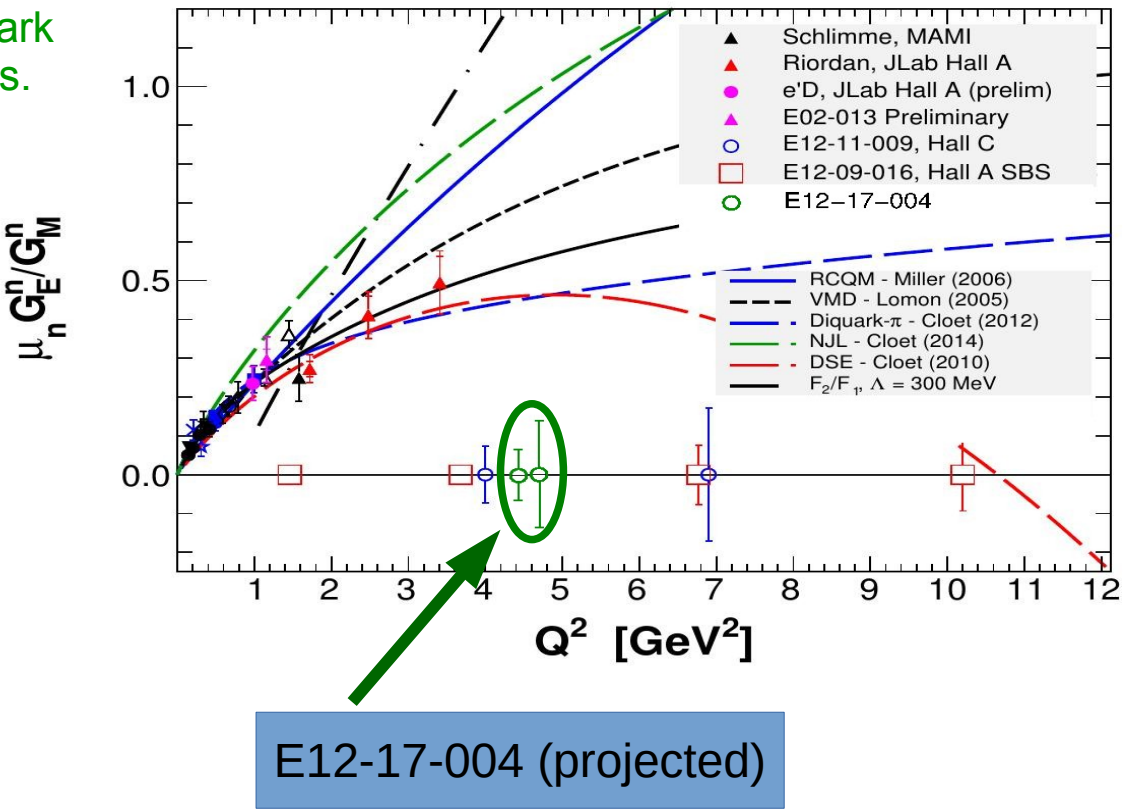
ERR: GEN-RP “Fallback Options”

- Always assume 4 best INFN GEMs must be in BigBite (now: 2 INFN + 2 UVa “U/V” GEMs)
- Deep Fallback Plan “B”
  - → 2–3 GEM layers (INFN + UVa) are effectively non-functional
    - » Earlier we know, the better...
  - → A few options evaluated
    - » All involve shuffling GEM layers from side detectors to fill gap(s) in Inline-GEM stack.
    - » Worst case is to drop an entire side-detector assembly
      - – lose 1/2 stats on RP meas.
      - – Loss of symmetry and assoc. systematic controls
- NOTE: UVa “U/V” GEMs increase our options



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 $(GeV/c)^2$
  - → Overlaps with GMn setting
  - → If all works, will return to PAC for full measurement

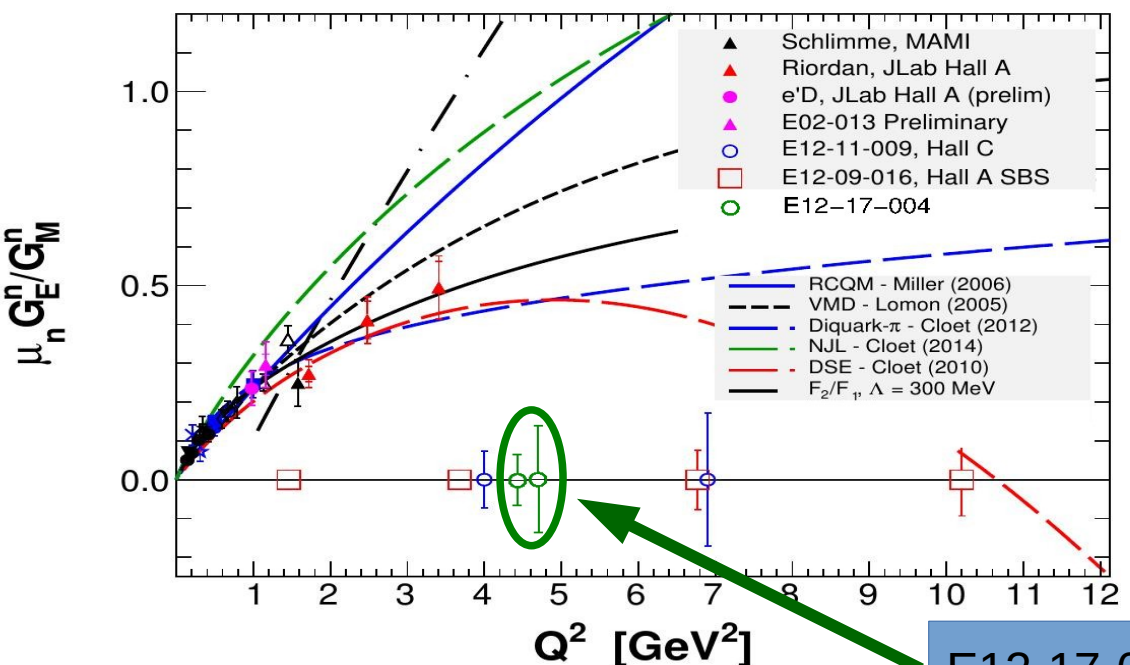


University of Glasgow

Precision on the Form Factor Ratio

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

E_{beam} (GeV)	Q^2 (GeV/c)^2	p_n (GeV/c)	Rate (Hz)	Time (hours)	FOM x 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 latest g4sbs agree very well with previous simulation studies (in proposal)
- *dR* based on Galster G_{En} and Kelly G_{Mn} parametrizations
- Expect overall systematic error to be ~3.0%

E12-17-004 (projected)

Active Analyzer

- Assembled and tested in Glasgow some time ago
  - → 4 x 8 array of scint bars w/ PMTs
    - » 4cm x 4cm x 25cm each
    - » Assembly weighs ~ 30 kg
- Current Status
  - → Shipped to JLab and is in ESB
  - → Unpacked, looks to be in good shape, but not plugged in and checked out at JLab yet.
    - » Next in queue for checkout in ESB