# Update on the First SBS Experiments

## $G_M^n/G_M^p$ by the cross-section ratio method

*E12-09-019*

## $G_E^n/G_M^n$ by recoil polarimetry

*E12-17-004*

David Hamilton
School of Physics and Astronomy

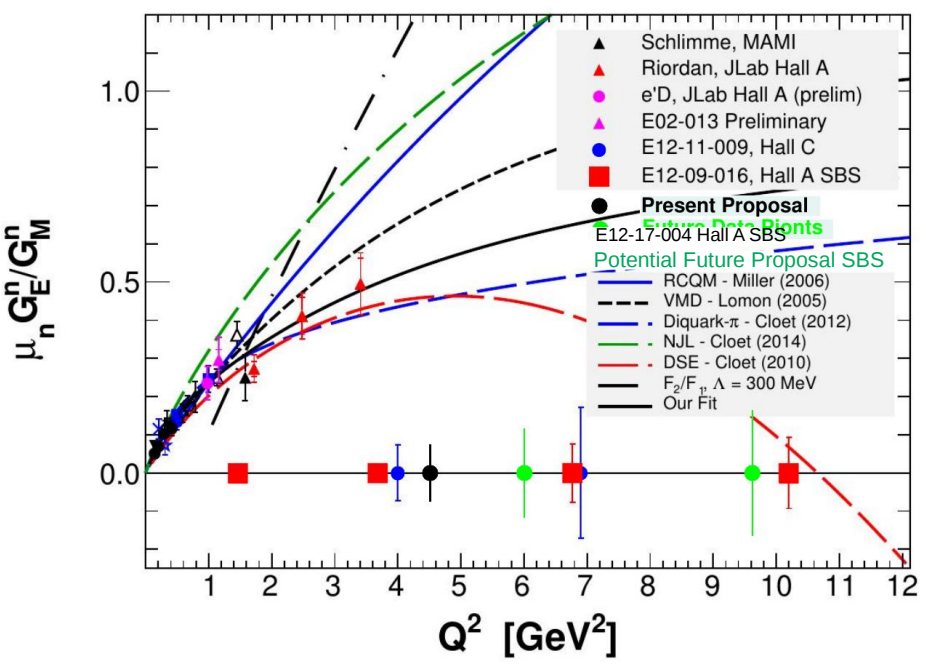

University of Glasgow

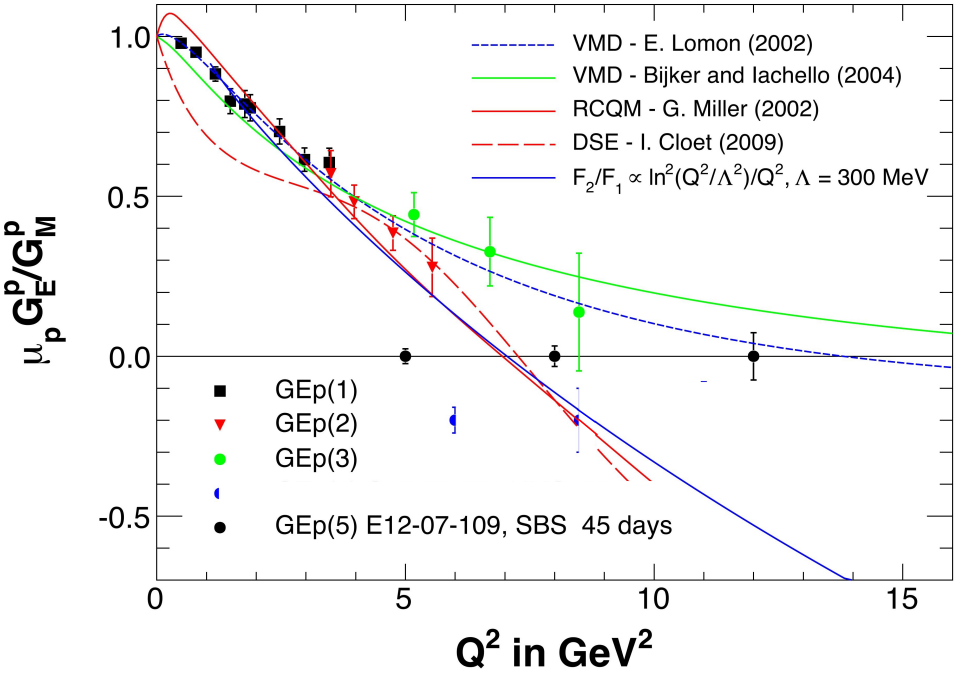
for the

## SBS Collaboration

31st January 2019

# New Form Factor Experiments in Hall A




E12-07-108 $G_{Mp}$ using HRS up to $Q^2$ = 16 (GeV/c)$^2$

Cross Section

$$\sigma_{ep} \propto \frac{E^2}{Q^{12}}$$

Polarimetry

$$A_y \propto \frac{1}{p_n} \sim \frac{M}{Q^2}$$

$$FOM \propto N A_y^2 \sim \frac{E^2}{Q^{16}}$$

**SBS programme of nucleon FF measurements:**

- E12-09-019 $G_{Mn}/G_{Mp}$ (by ratio *d(e,e'n)/d(e,e'p)* method)
- E12-17-004 $G_{En}/G_{Mn}$ (with polarized beam & recoil polarimetry)
- E12-09-016 $G_{En}/G_{Mn}$ (with polarized beam & target)
- E12-07-109 $G_{Ep}/G_{Mp}$ (with polarized beam & recoil polarimetry)

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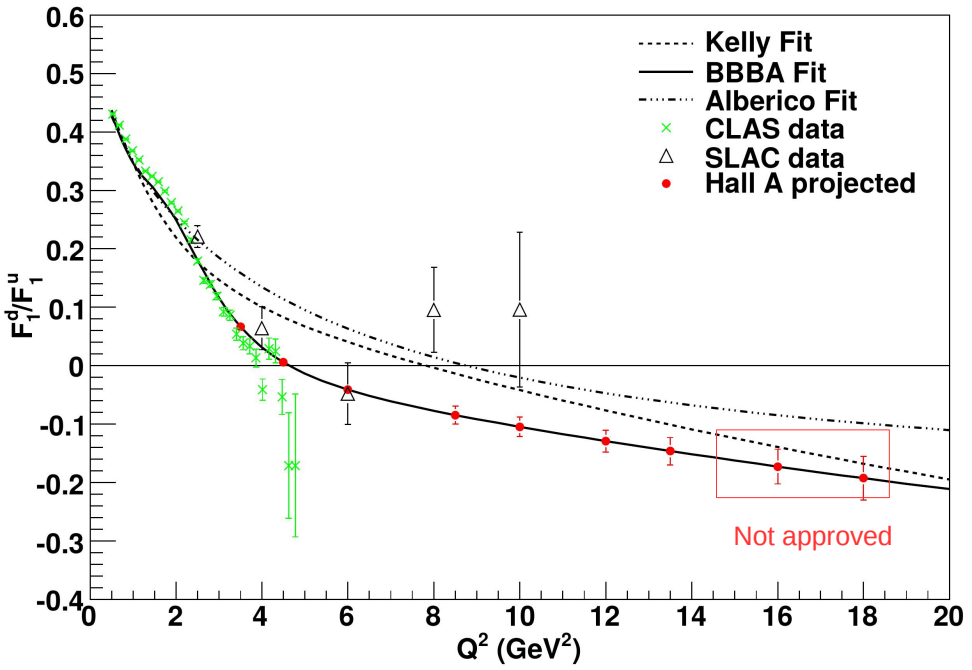
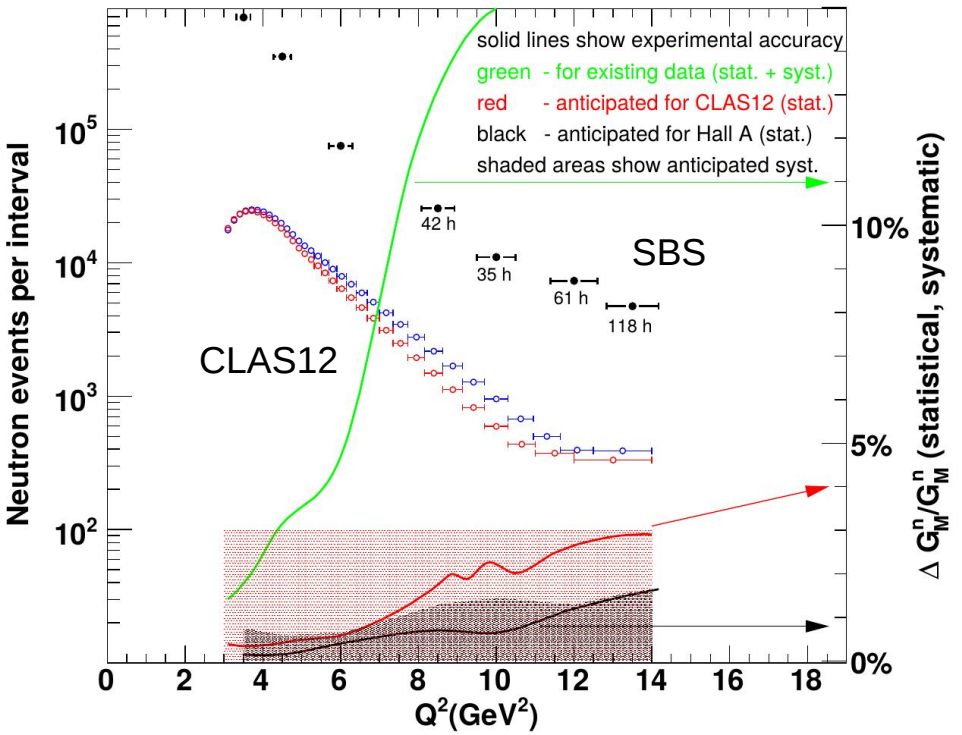
# GMn Update

# E12-09-019 $G_{Mn}/G_{Mp}$ Motivation

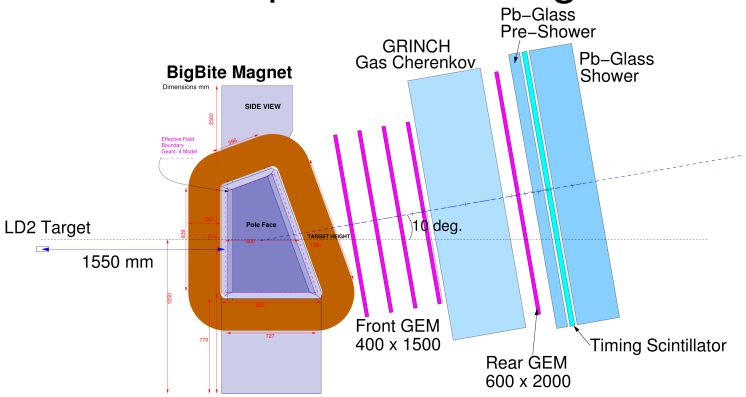



- Assuming negligible nucleon strange content $G_{Mn}$(+ the other 3 Sachs FF) enables iso-spin analysis of form factors.
- Also gives info on neutron transverse charge density down to scale ~0.05 fm.
- Approved experiment will measure at $Q^2$ = 3.5 – 13.5 (GeV/c)$^2$
- Smaller statistical and systematic uncertainties at each $Q^2$ bin than CLAS12 experiment E12-07-104 (which has finer $Q^2$ granularity)

# Experimental Apparatus

## Electron Spectrometer BigBite



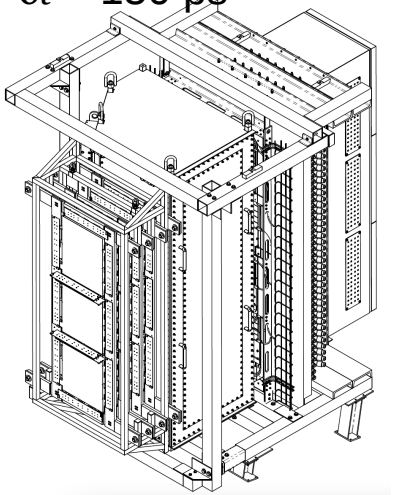

Ω ~ 55 msr

$\delta p/p$ ~ 0.5%

δθ ~ 1 mr

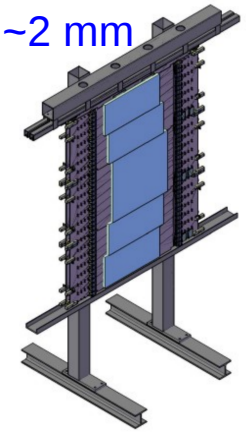
$\delta z$ ~ 2 mm @ target

$\delta t$ ~ 150 ps



## Coordinate Detector CDet

$\delta x$, $\delta y$ ~2 mm

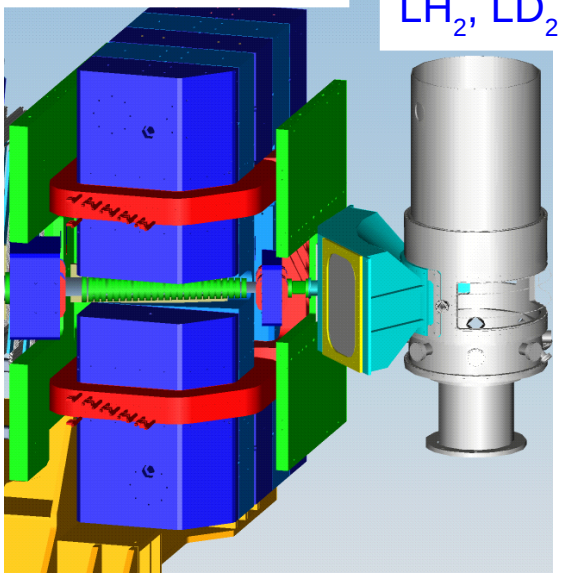


## 48D48 Dipole

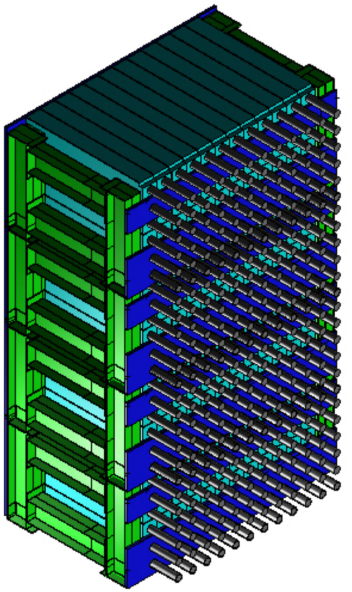
~2 Tm integrated field

## Hall-A Target

$LH_2$, $LD_2$, C-foil



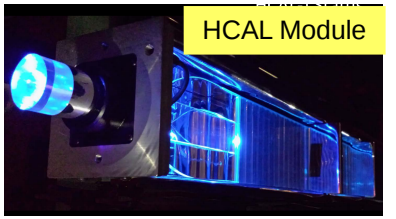
## Hadron Calorimeter HCAL



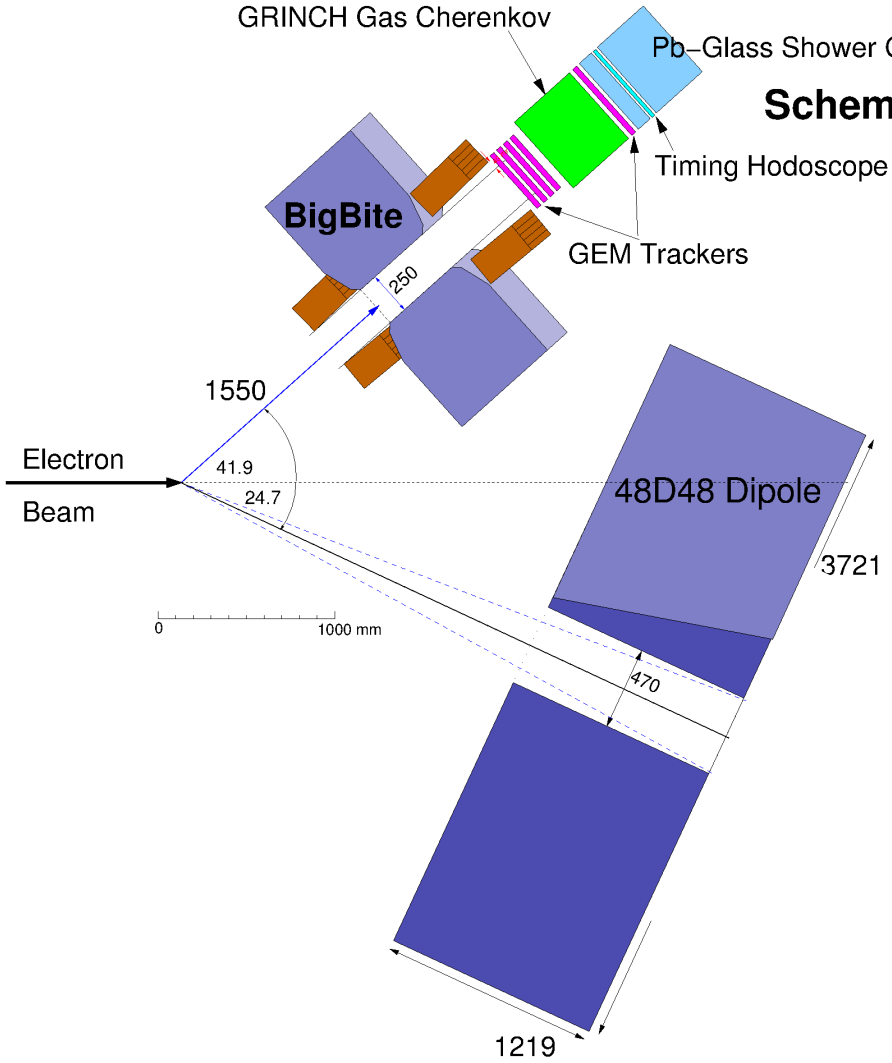
80 – 90% efficiency multi-GeV $p$ and $n$

Effective suppression of soft background

~0.5 ns timing resolution



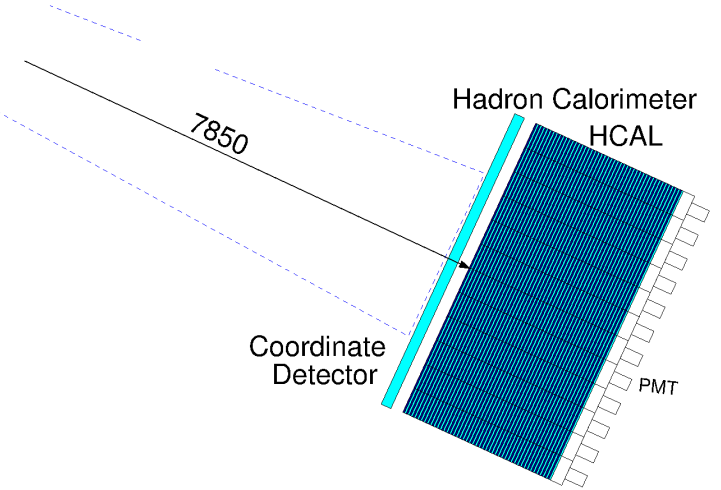
# GMn Experimental Layout




**Schematic View of 4.5 (GeV/c)² Kinematic Setting**

Dimensions mm

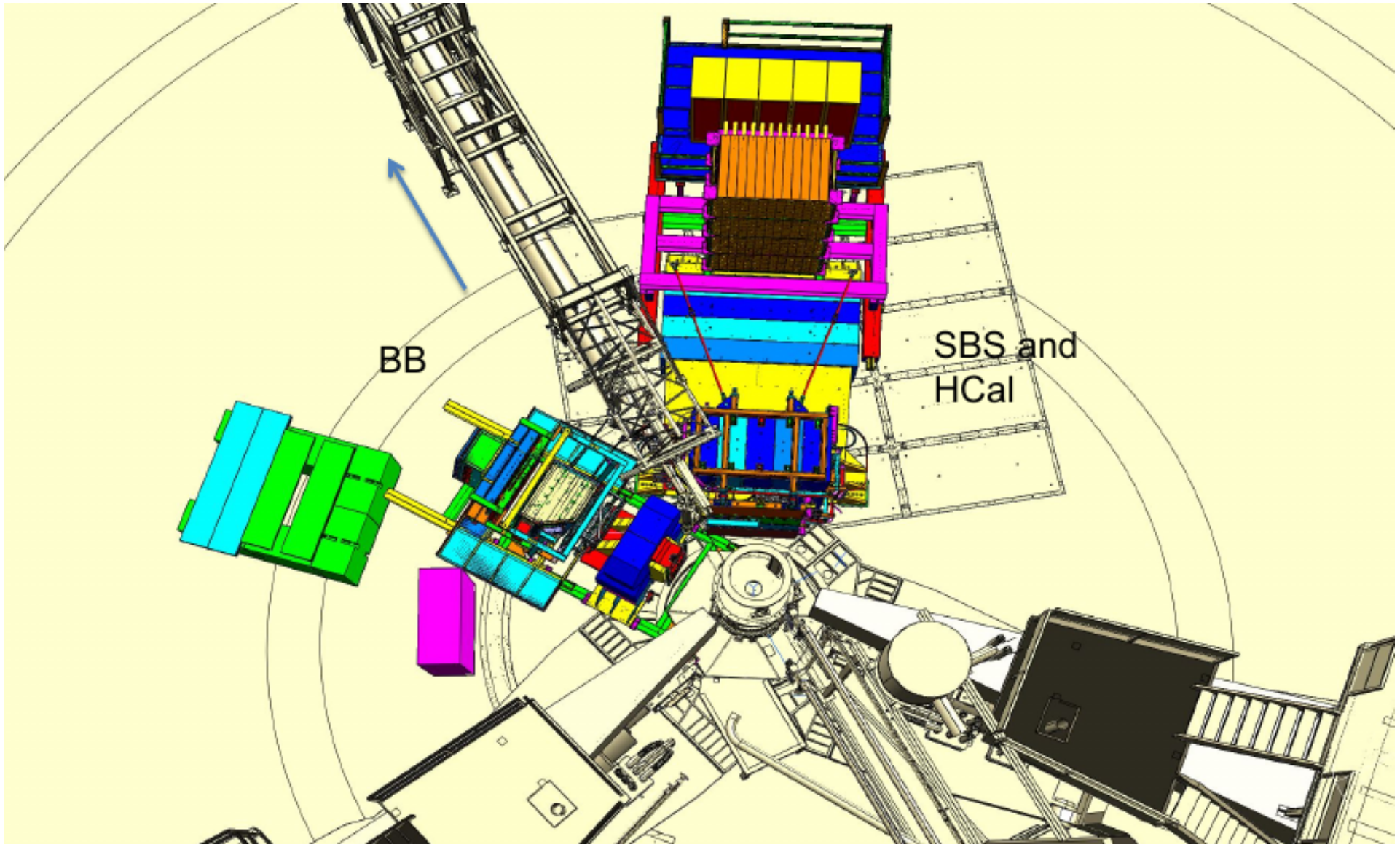
| $Q^2$ [GeV²] | $\theta_{BB}$ [deg] | $d_{BB}$ [m] | $\theta_{48D48}$ [deg] | $d_{48D48}$ [m] | $d_{HCAL}$ [m] |
|---|---|---|---|---|---|
| 3.5 | 32.5 | 1.80 | 31.1 | 2.0 | 7.2 |
| 4.5 | 41.9 | 1.55 | 24.7 | 2.25 | 8.5 |
| 5.7 | 58.4 | 1.55 | 17.5 | 2.25 | 11 |
| 8.1 | 43 | 1.55 | 17.5 | 2.25 | 11 |
| 10.2 | 34 | 1.75 | 17.5 | 2.25 | 11 |
| 12.0 | 44.2 | 1.55 | 13.3 | 2.25 | 14 |
| 13.5 | 33.0 | 1.55 | 14.9 | 3.1 | 17 |




30 uA on 15cm $LD_2$ target

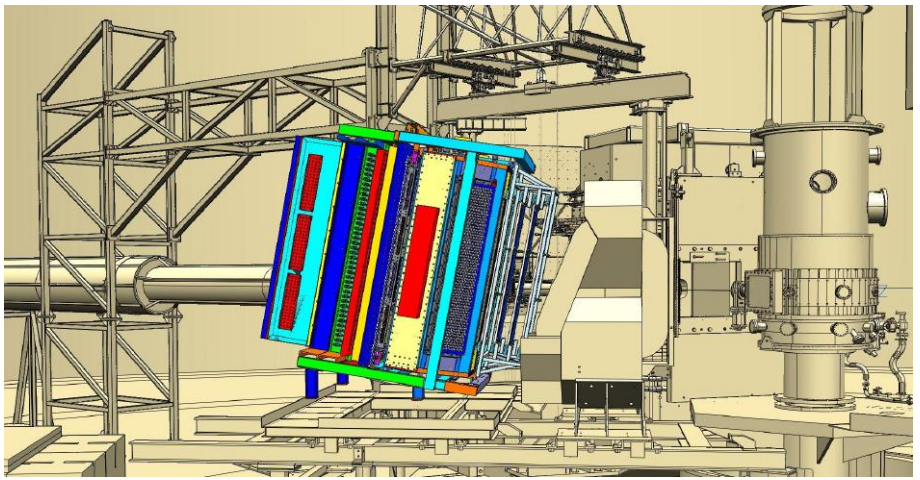
Max GEM occupancy ~30%
Max Trigger rate ~ 5 kHz
Data rate 200 MB/s

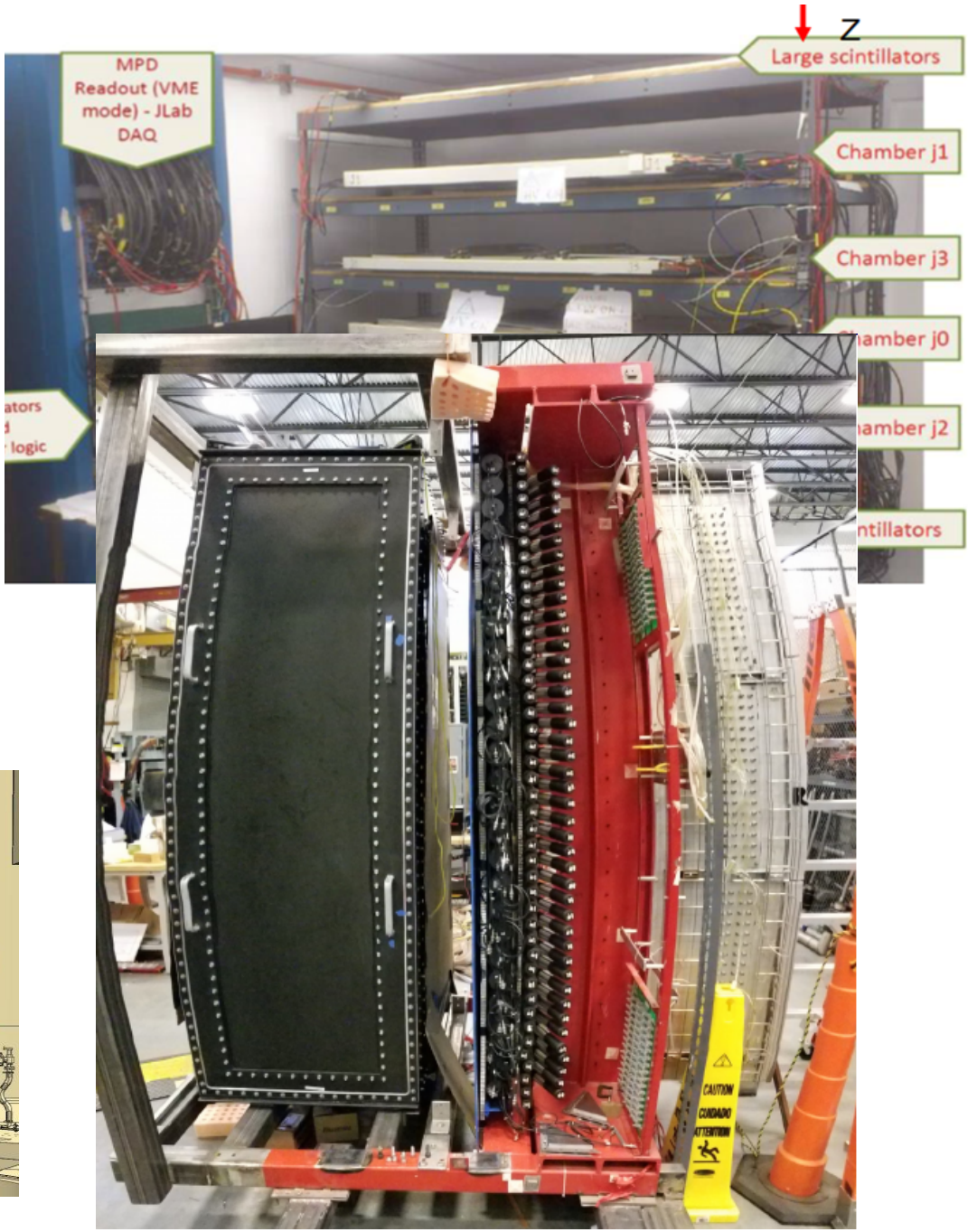
# GMn Experimental Layout



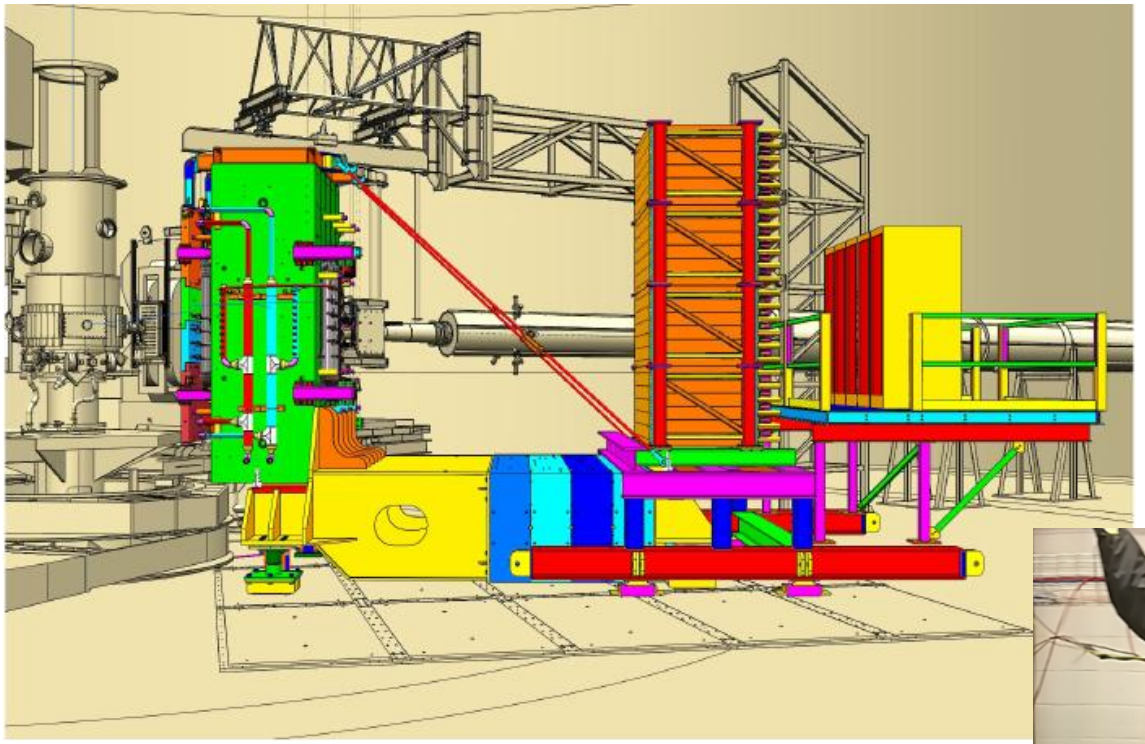
# BigBite Status

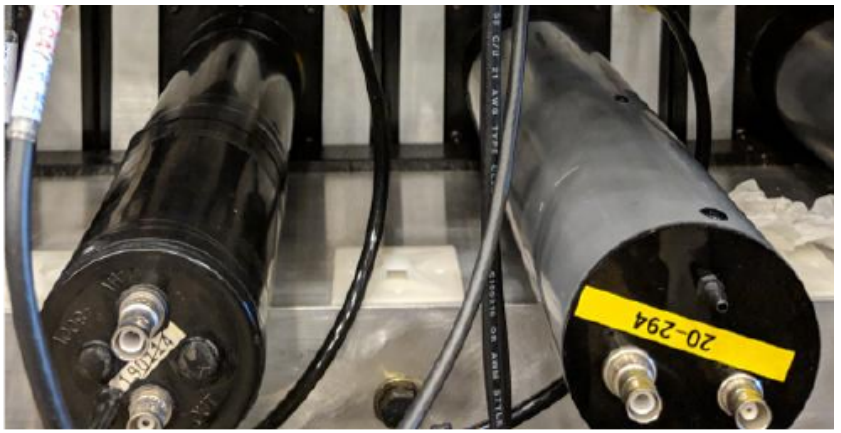
- Magnet and Pb-Glass shower counters unchanged from 6 GeV JLab experiments.
- New GEM trackers, GRINCH Gas Cherenkov and timing hodoscope.
- All detectors in frame except GEMs – planned for April 2019.
- All subsystems electronics integrated in BB weldment and start of cosmic testing May 2019.

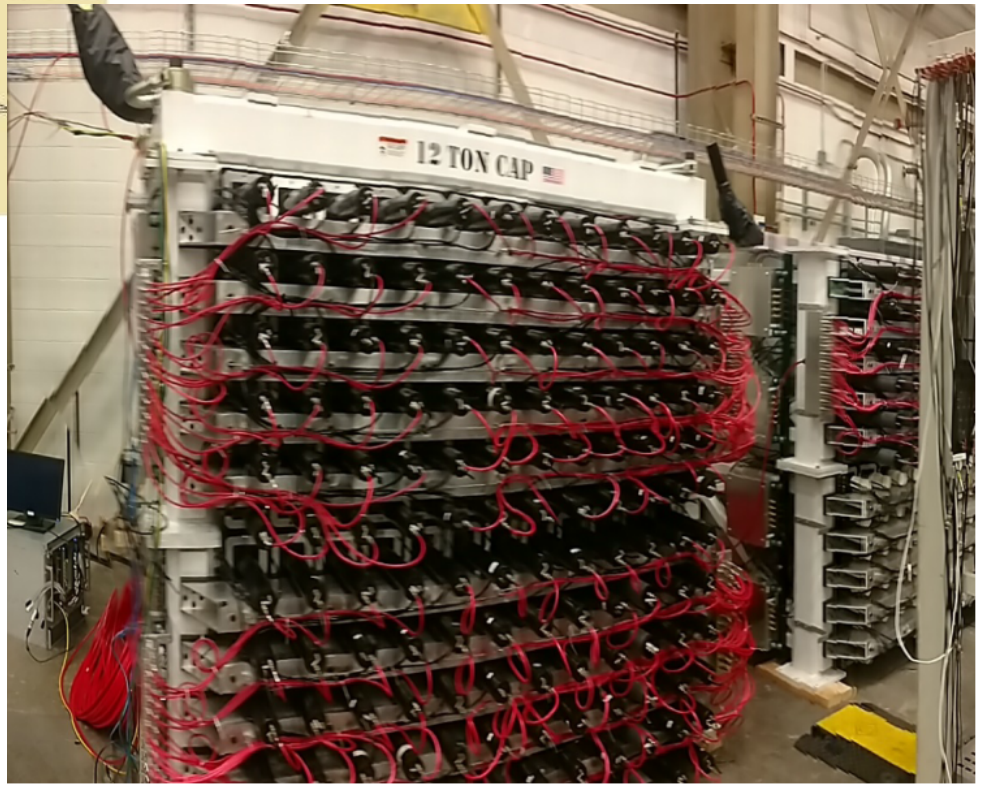




# Hadron Calorimeter Status






- 288 Calorimeter modules:
  4 10-ton sub-assembly (crane capacity)
- Module fabrication and assembly of sub-assemblies complete (Spring 2018).
- Cables and electronics systems installed (October 2018).
- All PMTs tested and cosmics tests underway.

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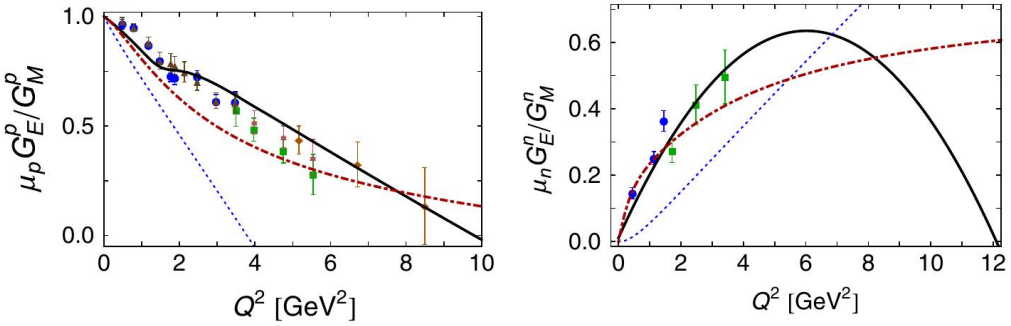
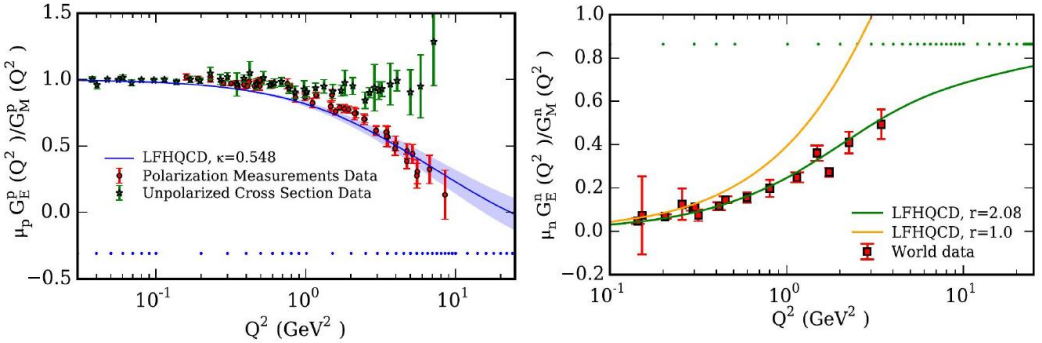
# GEn-Recoil Update

# E12-17-004 $G_{En}/G_{Mn}$ Motivation

J. Segovia et al., Few-Body Syst. 55 (2014), 1185.
DSE common framework N-elastic and Δ-transition form factors




R. S. Sufian et al., Phys. Rev. D95(2017),014011.
Light Front Holographic QCD



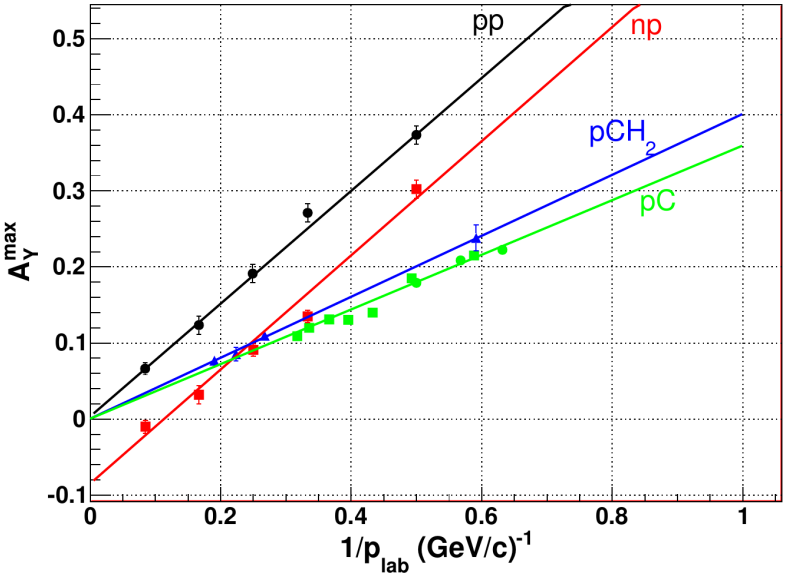

Different theoretical frameworks…

Very different predictions for $\mu_n G_{En}/G_{Mn}$

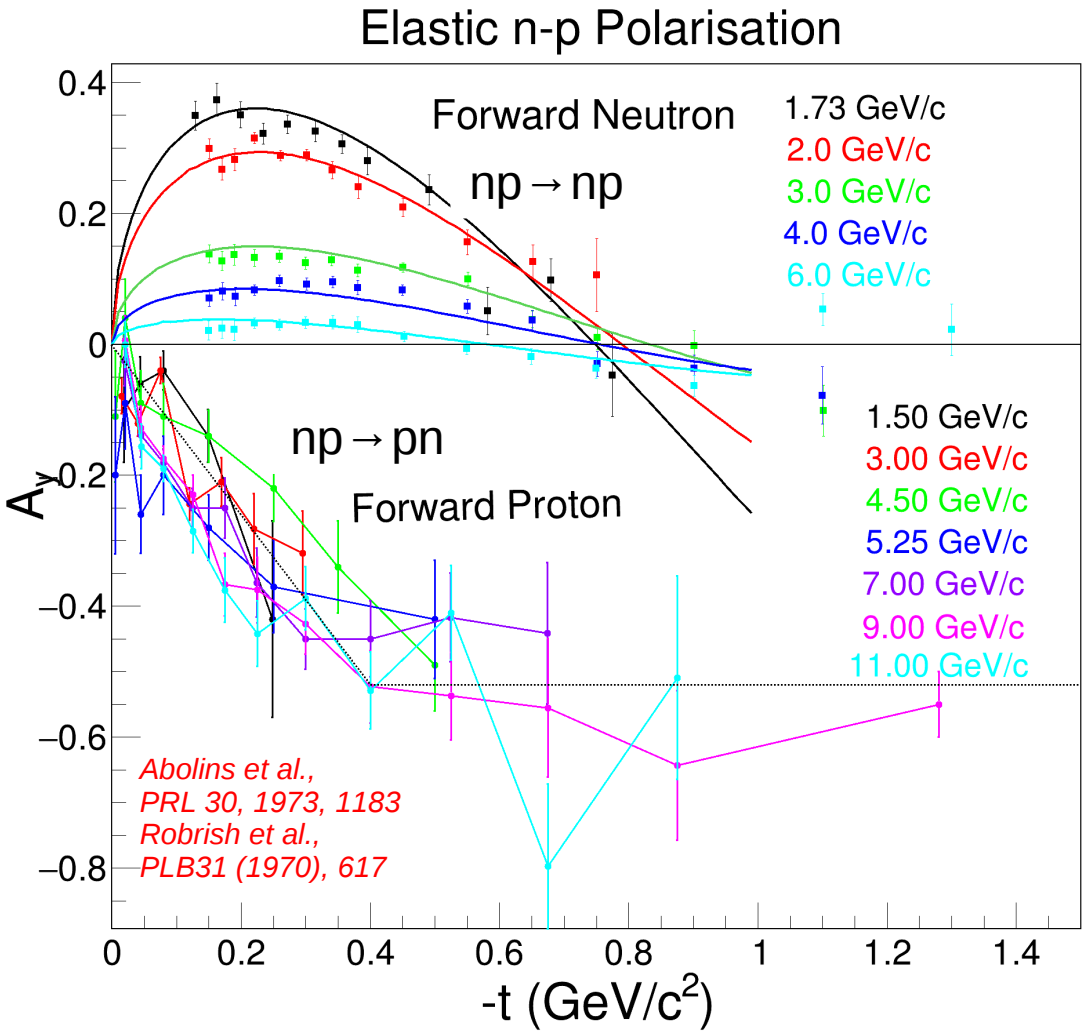
- In terms of $Q^2$ range and precision, neutron measurements lag way behind proton measurements
- For measurements in space-like domain at medium-high $Q^2$ JLab is the only viable lab. Use double-polarized, Quasi-elastic $^2$H(e,e'n), $^3$He(e,e'n)
- JLab: E12-09-016 $G_{En}/G_{Mn}$ with polarized electron beam & $^3$He target up to $Q^2$ of ~10 (GeV/c)$^2$
- Independent verification of results … alternative method with polarized electron beam, unpolarized $^2$H target and polarimeter to measure polarisation transfer to recoiling neutron.
- New polarimetry technique, enable access to $Q^2$ ~ 10 (GeV/c)$^2$, impact future GEn and GEp experiments?

# Recoil Neutron Polarimetry at High Momentum

- Until recently no data on n+C→n+p+X at several GeV/c (nor any nucleus)

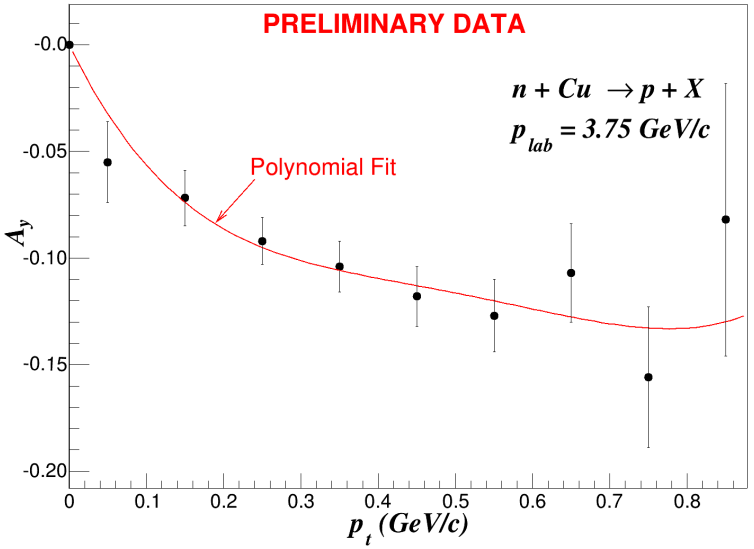



*Diebold et al.,*
*PRL 35,(1975),632*
*Fits: Ladygin JINR*
*E13-99-123 (1999)*

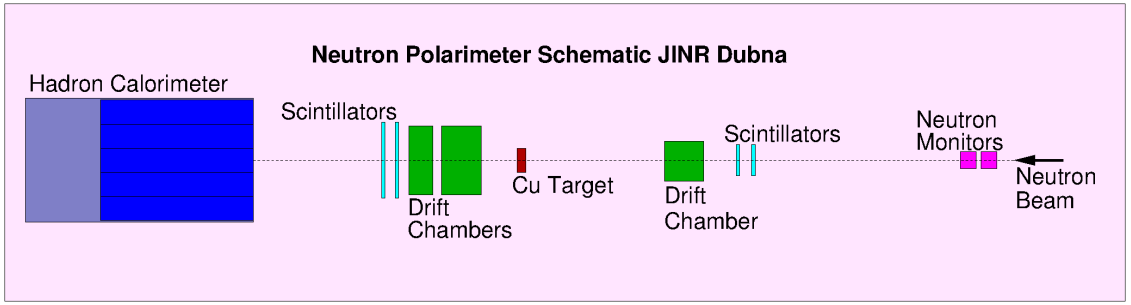



- $A_y$ for np→np falling rapidly with increasing neutron momentum
- $A_y$ for charge-exchange np→pn large at sufficiently large t ($\theta_p$ ~ few deg.)
- $\sigma_{np\to np}$ factor ~10 higher than $\sigma_{np\to pn}$

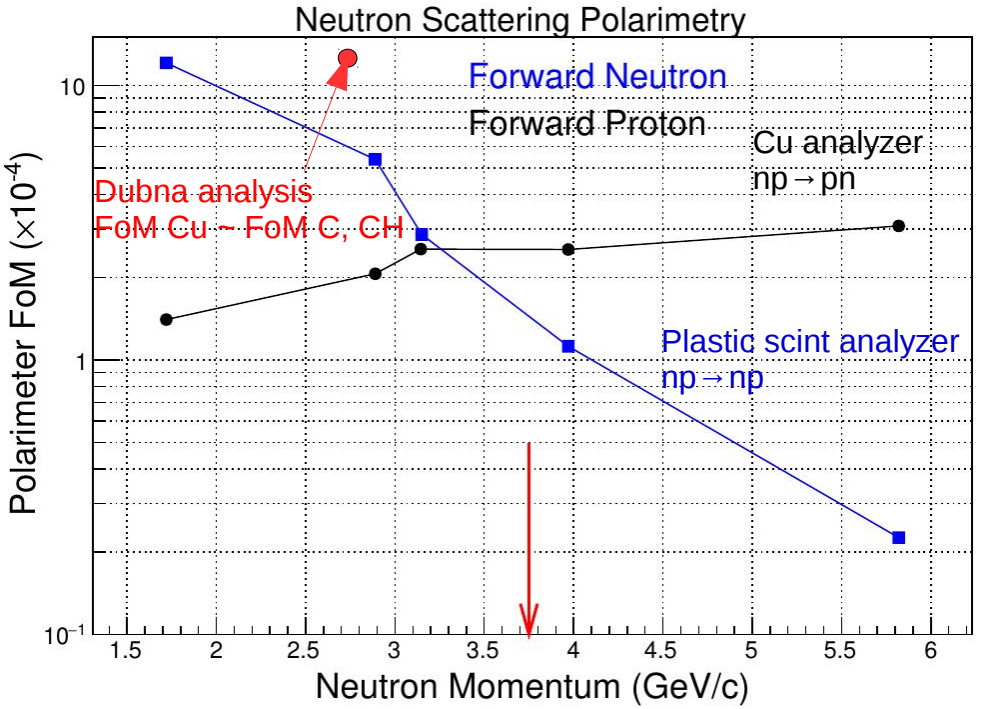
# Measurements at JINR Dubna 2016-17



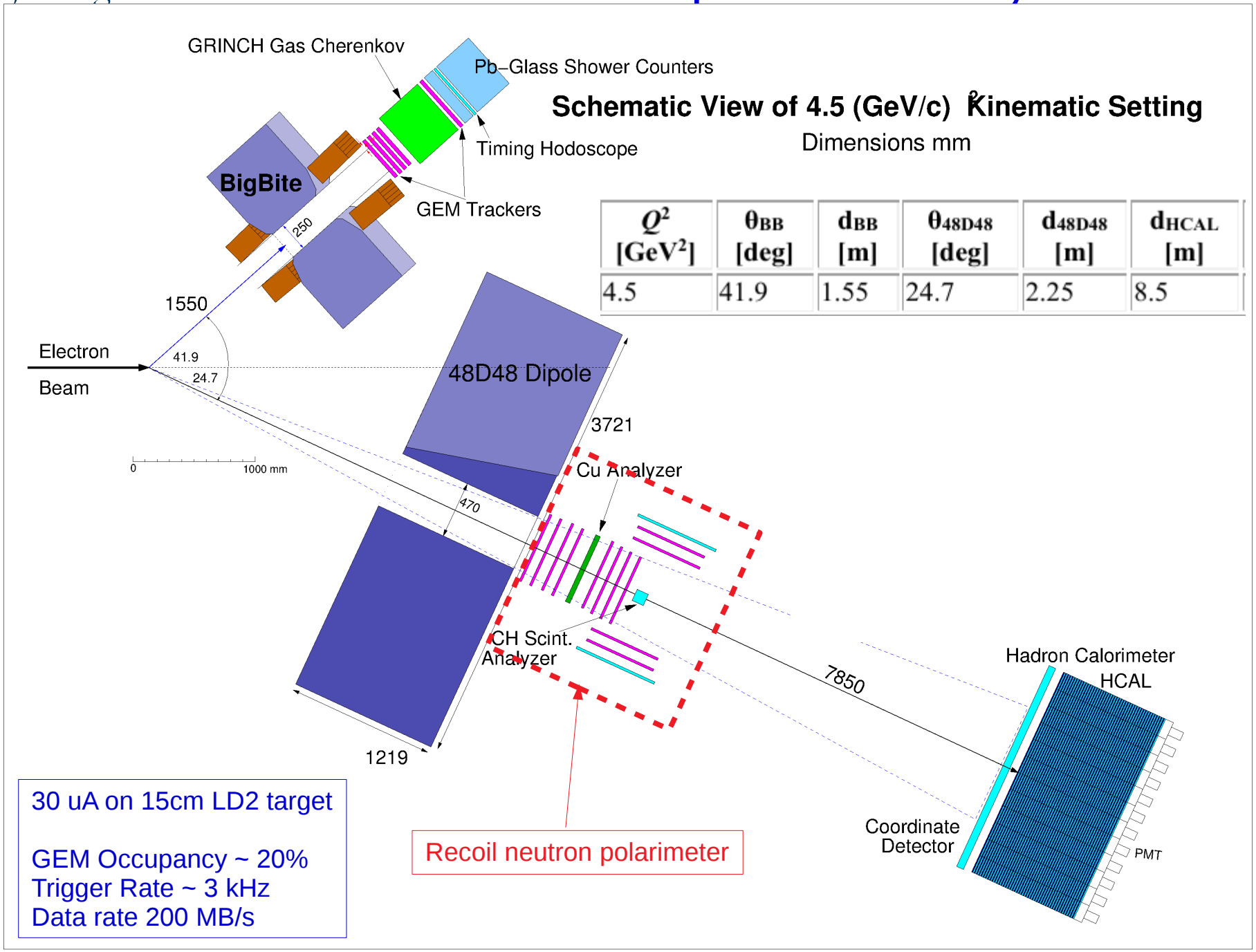

Dubna polarimeter similar to SBS device




- Measure asymmetries polarized np→pn C, CH, $CH_2$, Cu Target
- $p_{lab}$: 3.0 – 4.2 GeV/c
- Extract $A_y$ as a function of $p_t = p_{lab} sin\theta$
- Cu asymmetry similar to Carbon
- Use polynomial fit to Cu data to calculate FoM of SBS neutron polarimeter by MC



# GEn-Recoil Experimental Layout




**Schematic View of 4.5 (GeV/c)² Kinematic Setting**

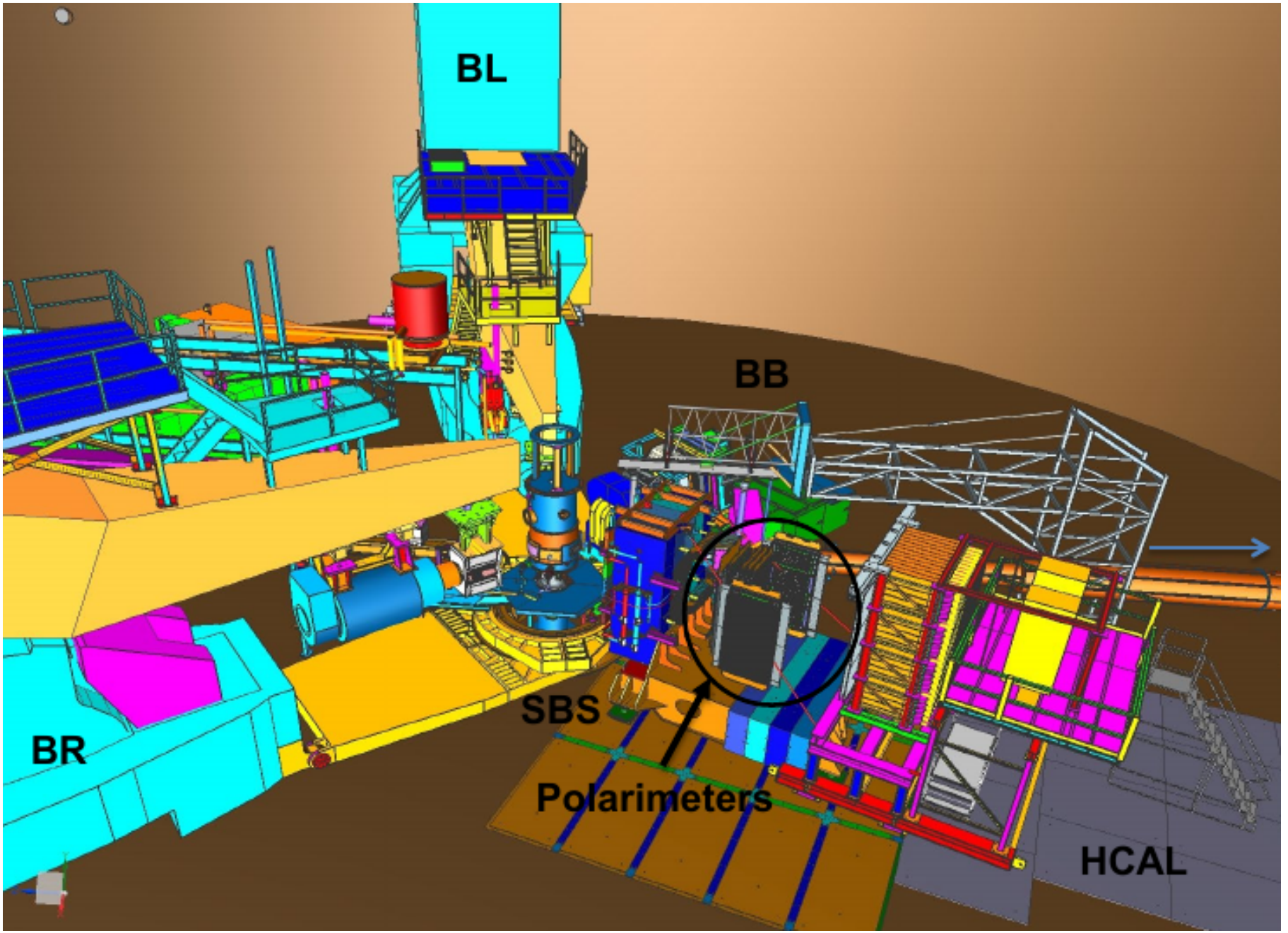
Dimensions mm

| $Q^2$ [GeV²] | $\theta_{BB}$ [deg] | $d_{BB}$ [m] | $\theta_{48D48}$ [deg] | $d_{48D48}$ [m] | $d_{HCAL}$ [m] |
|---|---|---|---|---|---|
| 4.5 | 41.9 | 1.55 | 24.7 | 2.25 | 8.5 |

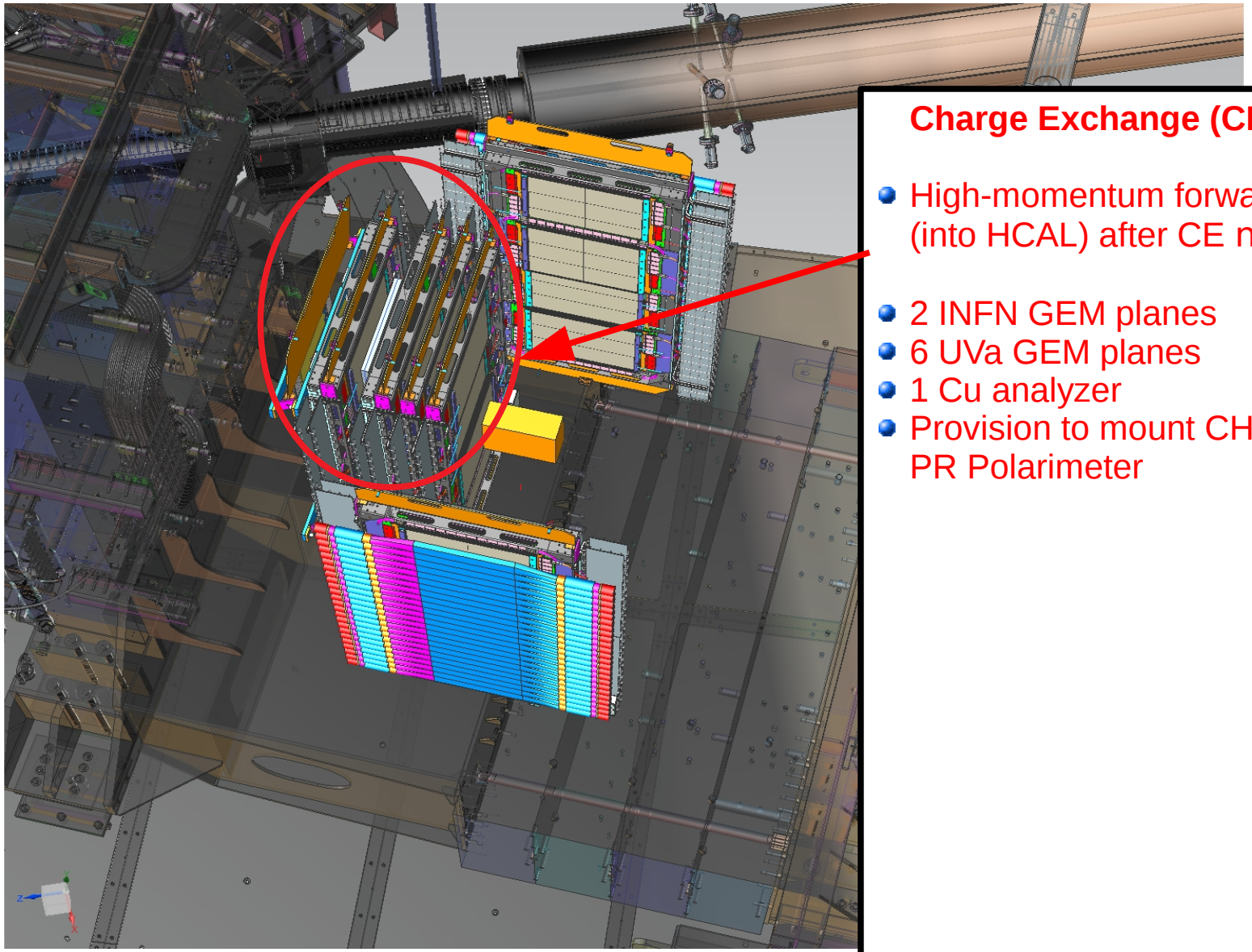
30 uA on 15cm LD2 target

GEM Occupancy ~ 20%
Trigger Rate ~ 3 kHz
Data rate 200 MB/s

# GEn-Recoil Experimental Layout



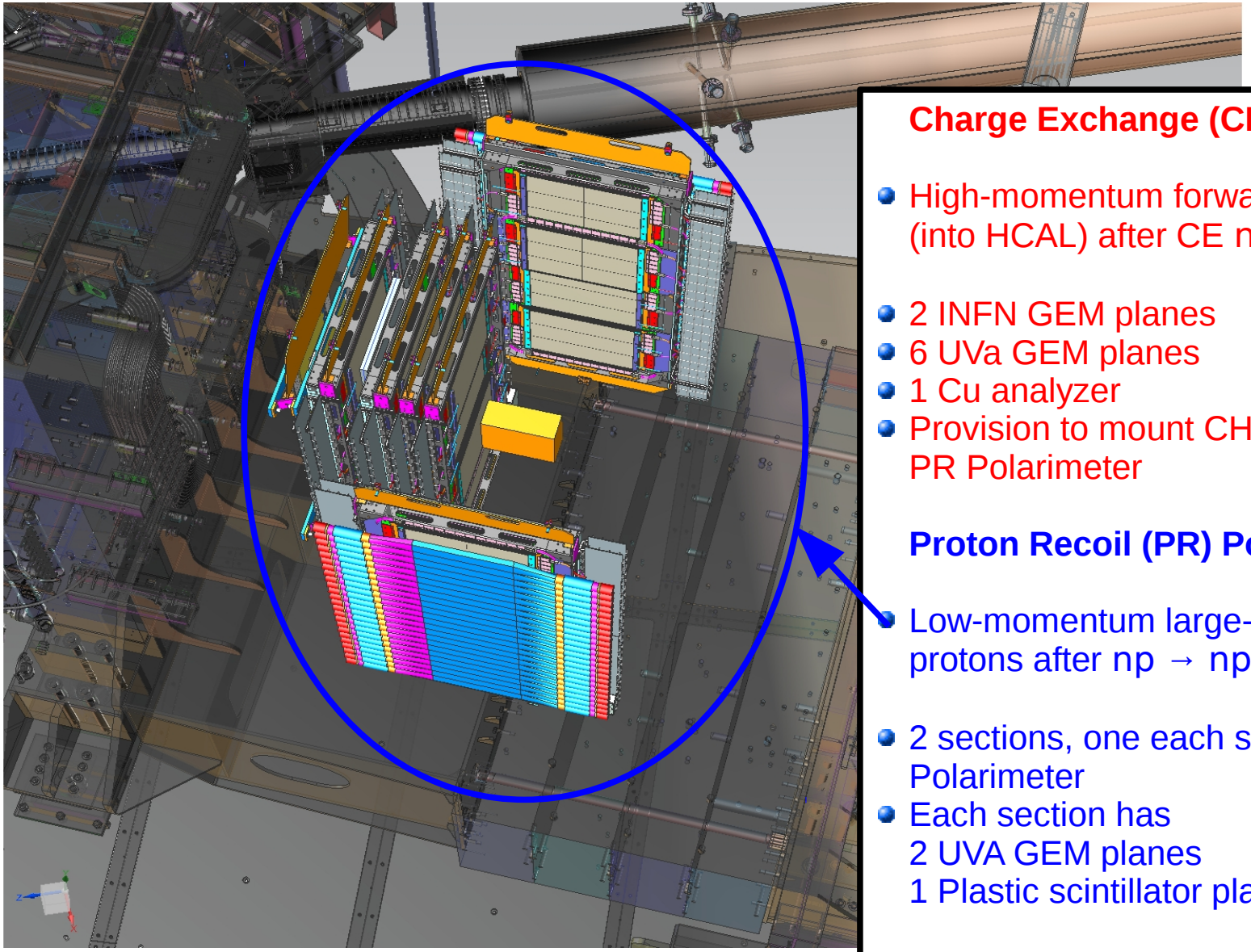
# Two Neutron Polarimeters for GEn-Recoil



**Charge Exchange (CE) Polarimeter**

- High-momentum forward protons (into HCAL) after CE np → pn
- 2 INFN GEM planes
- 6 UVa GEM planes
- 1 Cu analyzer
- Provision to mount CH analyser for PR Polarimeter

# Two Neutron Polarimeters for GEn-Recoil



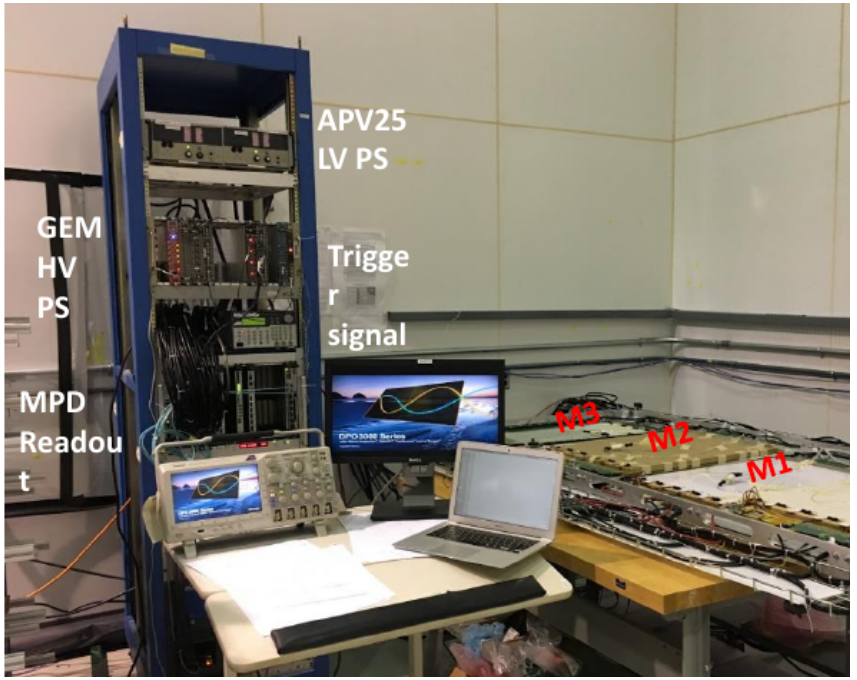
**Charge Exchange (CE) Polarimeter**

- High-momentum forward protons (into HCAL) after CE np → pn
- 2 INFN GEM planes
- 6 UVa GEM planes
- 1 Cu analyzer
- Provision to mount CH analyser for PR Polarimeter

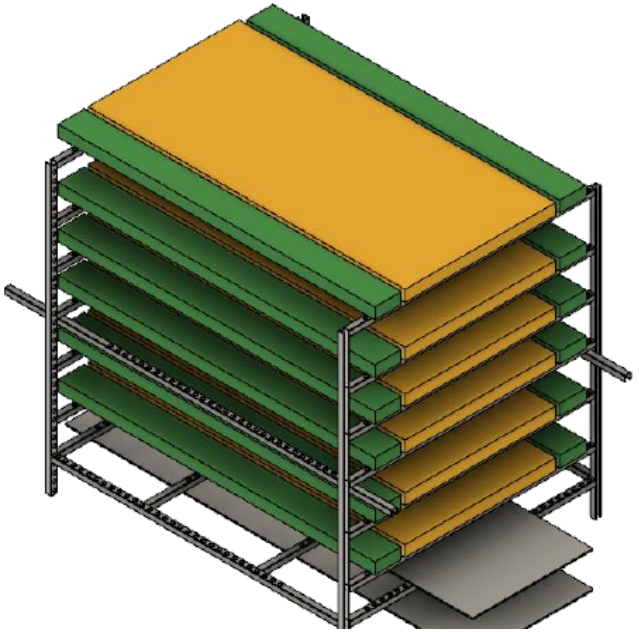
**Proton Recoil (PR) Polarimeter**

- Low-momentum large-angle recoiling protons after np → np
- 2 sections, one each side of CE Polarimeter
- Each section has
  2 UVA GEM planes
  1 Plastic scintillator plane

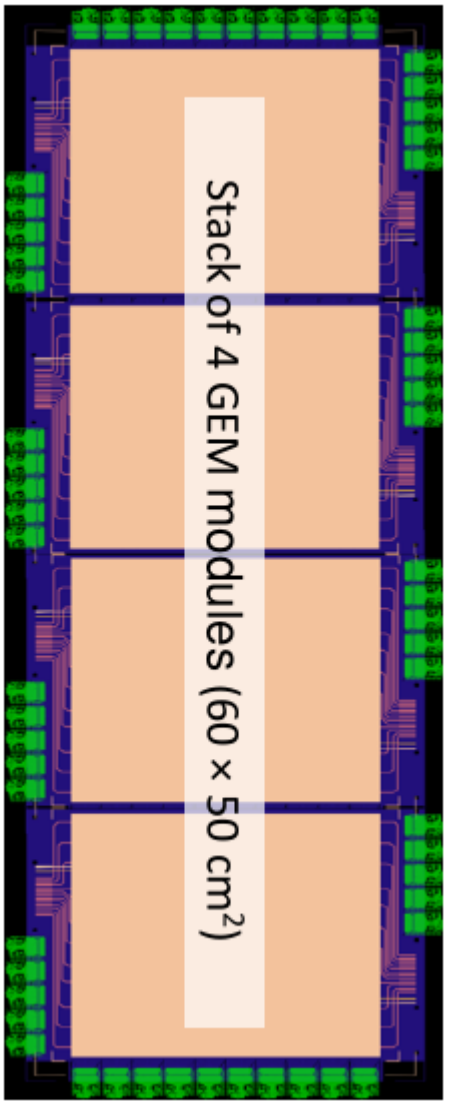
# Polarimeter Status




Cosmic Stand with GEM layers



UVa GEM layer




- Require 10 UVa GEM layers for GEn polarimeter – moving to commissioning with cosmics on dedicated stand.
- Final design of frame, subframes, rails, etc summer 2019.
- Scintillator planes for PR polarimeter from old BigBite hadron stack; active analyser design being optimized.
- Electronics and cabling identified (more MPDs being purchased).
- Installation of PR polarimeter in frame fall 2019, and CE polarimeter winter 2019.

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# Summary

- E12-09-019 GMn will be the first SBS experiment to run in Hall A. Approved for 31 days of beam.
- E12-17-004 GEn-Recoil approved by PAC only 2017. It will “piggy back” on a single E12-09-019 kinematic setting at $Q^2 = 4.5$ $(GeV/c)^2$. Approved for 5 days of beam.
- GMn passed ERR July 2017. Supplemental hall review for both GMn and GEn-Recoil in October 2018 (follow-up meeting January 2019).
- ERR for GEn-Recoil expected May 2019.
- Full cosmic testing of all GMn components by summer 2019; for GEn-Recoil by the end of the year.
- Expected installation is second half of 2020 (during CHL2k cold box installation).
- Thanks to lots of hard work by many people, there has been significant progress in constructing and testing the SBS detector components and development of data acquisition and software systems.