Instrumentation in the first experiments of SBS

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University of Connecticut
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Hall A/C joint summer collaboration meeting

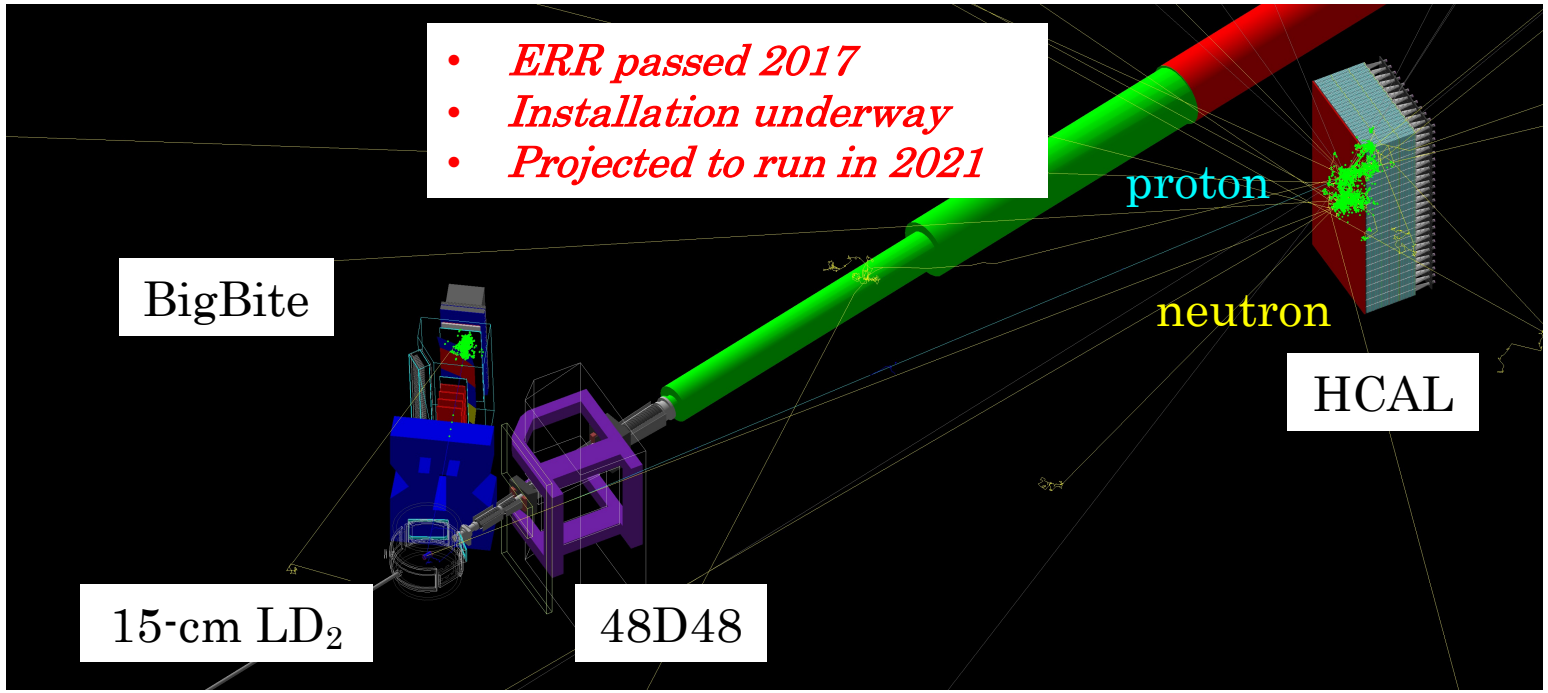
UCONN

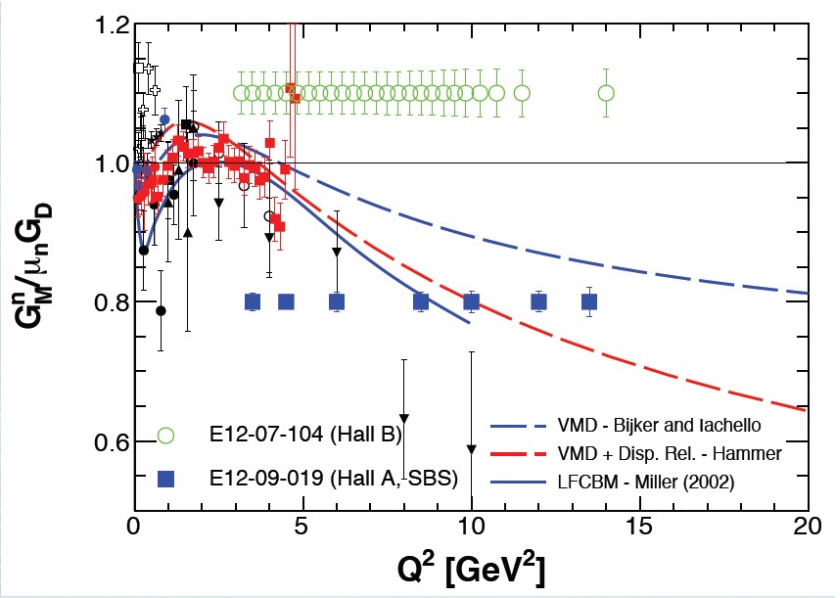
Acknowledgements

- This work is supported by the US Department of Energy Office of Science, Office of Nuclear Physics, Award ID DE-SC0021200
- Additional support from Jefferson Lab and the University of Connecticut
- This talk represents the work of many, many SBS and Hall A Collaborators and institutions—too many to name here
- Thanks in particular to Scott Barcus, Ezekiel Wertz, Evaristo Cisbani, David Flay, Bradley Yale, Thia Keppel, Kondo Gnanvo and others for contributing material for this talk
- The Hall A/C meeting organizers.

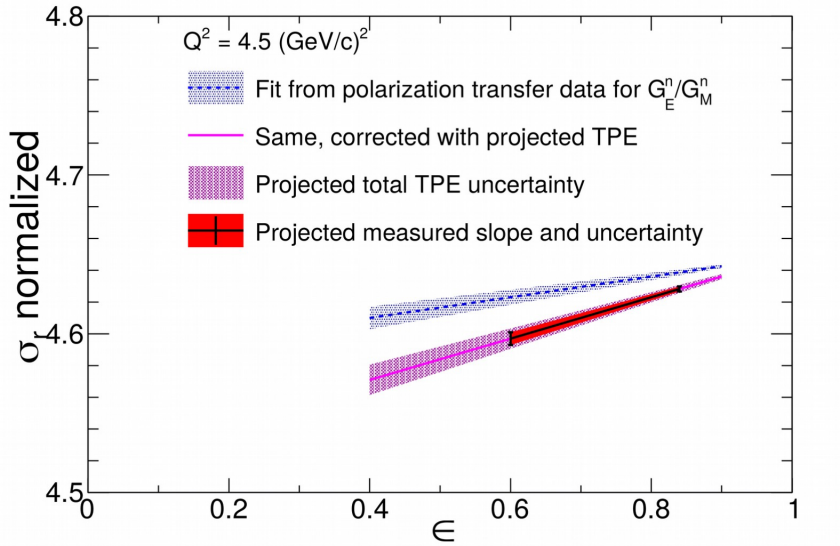
Review of the first SBS experiments

E12-09-019: Neutron magnetic form factor G_M^n to $Q^2 = 13.5$ GeV²

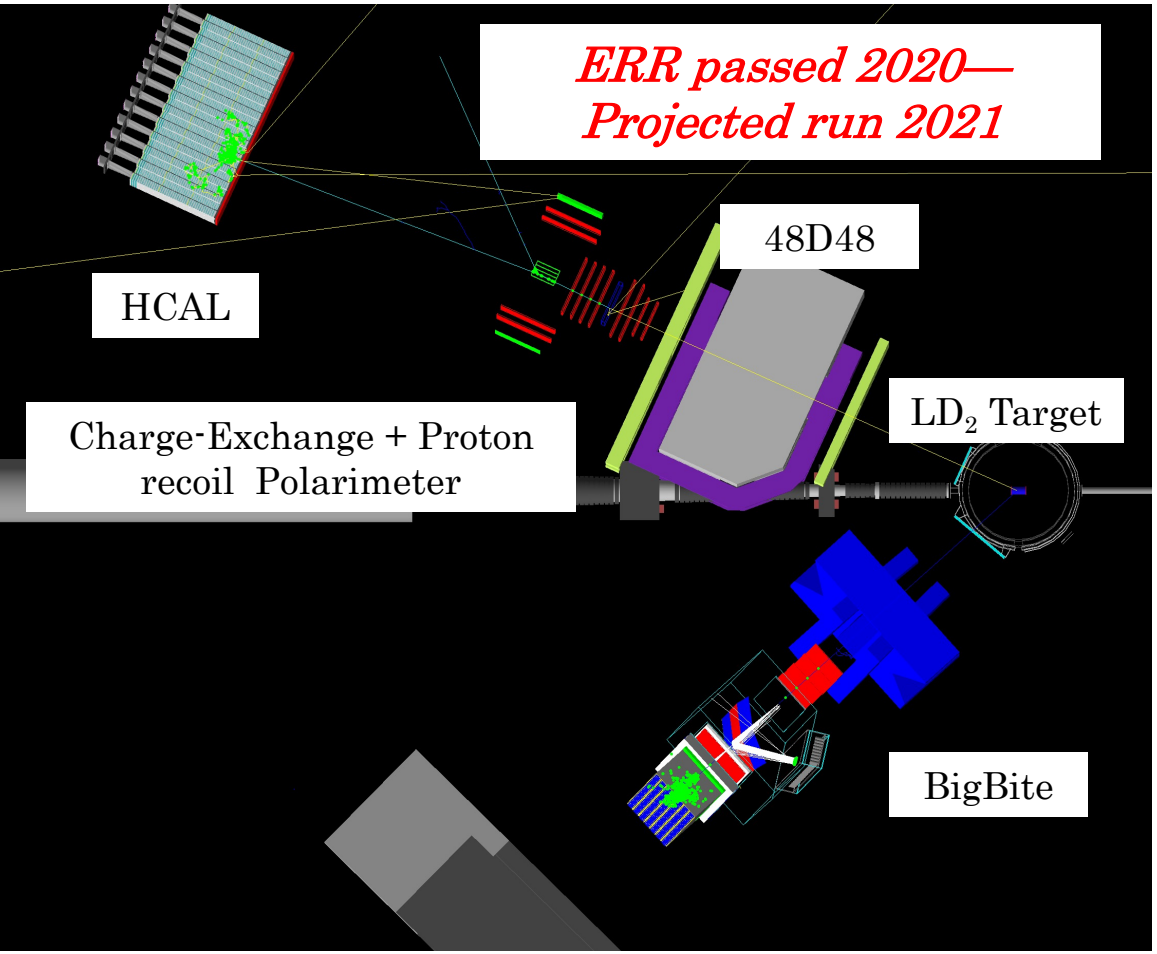


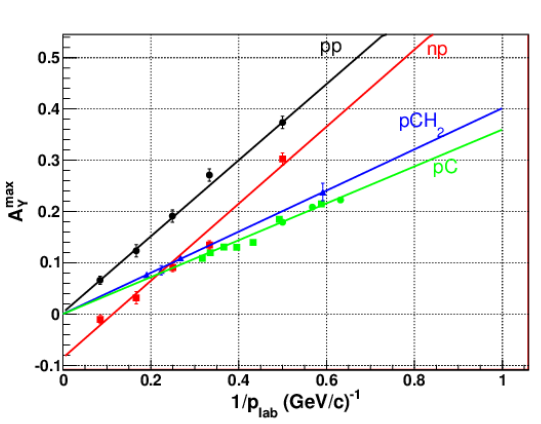


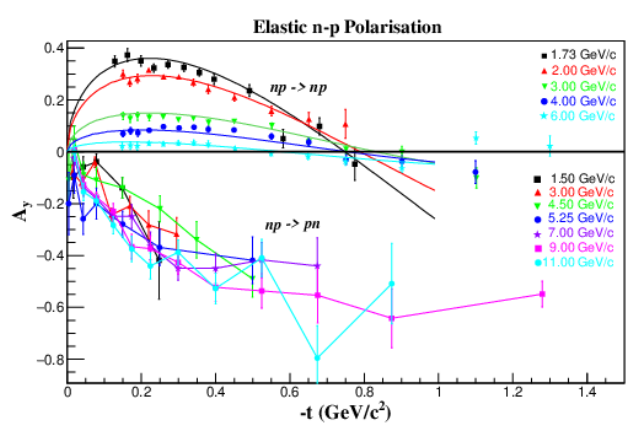
- E12-09-019 will measure neutron magnetic form factor G_M^n to 13.5 GeV² using the "ratio" method on deuterium.
- E12-20-010, a recently approved "add-on" measurement, will determine the Rosenbluth slope in elastic *en* scattering for the first time at $Q^2 = 4.5\ GeV^2$
- Uses hadron calorimeter for efficient nucleon detection; magnetic deflection for charge ID
- BigBite detects electron, defines $\vec{q}$ vector, vertex for selection of quasi-elastic



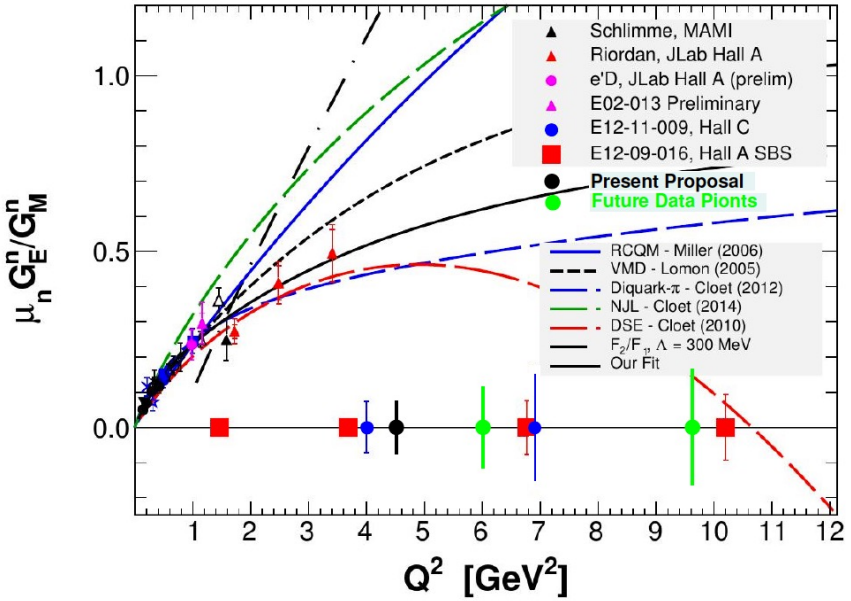
E12-17-004: G_E^n/G_M^n to 4.5 GeV² via charge-exchange recoil polarimetry





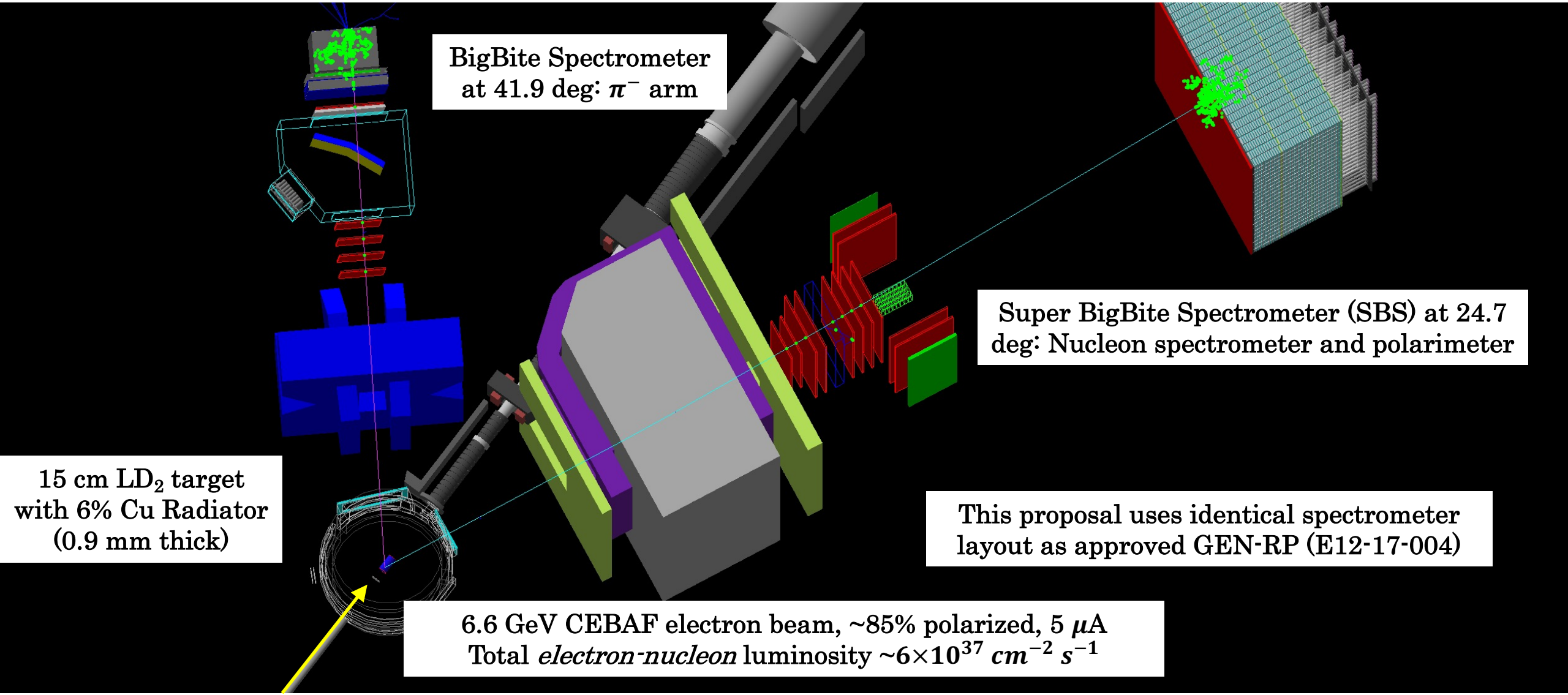


Analyzing powers for np, pp, pA scattering vs. initial momentum (left) and vs. transferred momentum (right)

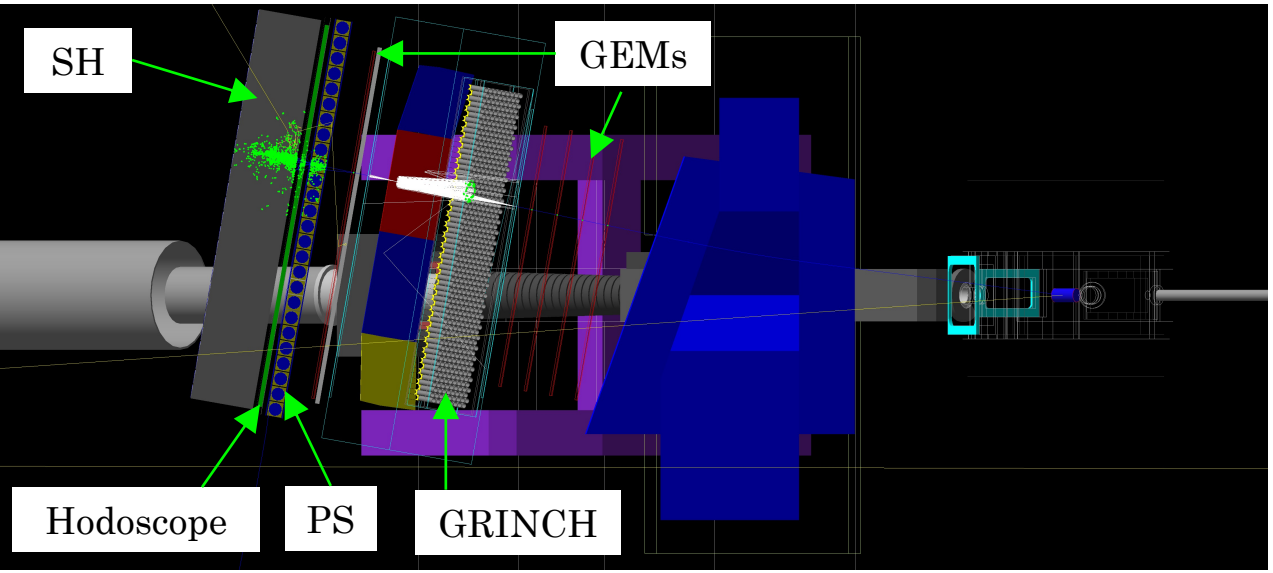


- E12-17-004 layout (above) and projected results (right):
  - First use of charge-exchange polarimetry in a FF experiment
- E12-20-008 approved as add-on to measure K_{LL} for $\gamma n \to \pi^- p$

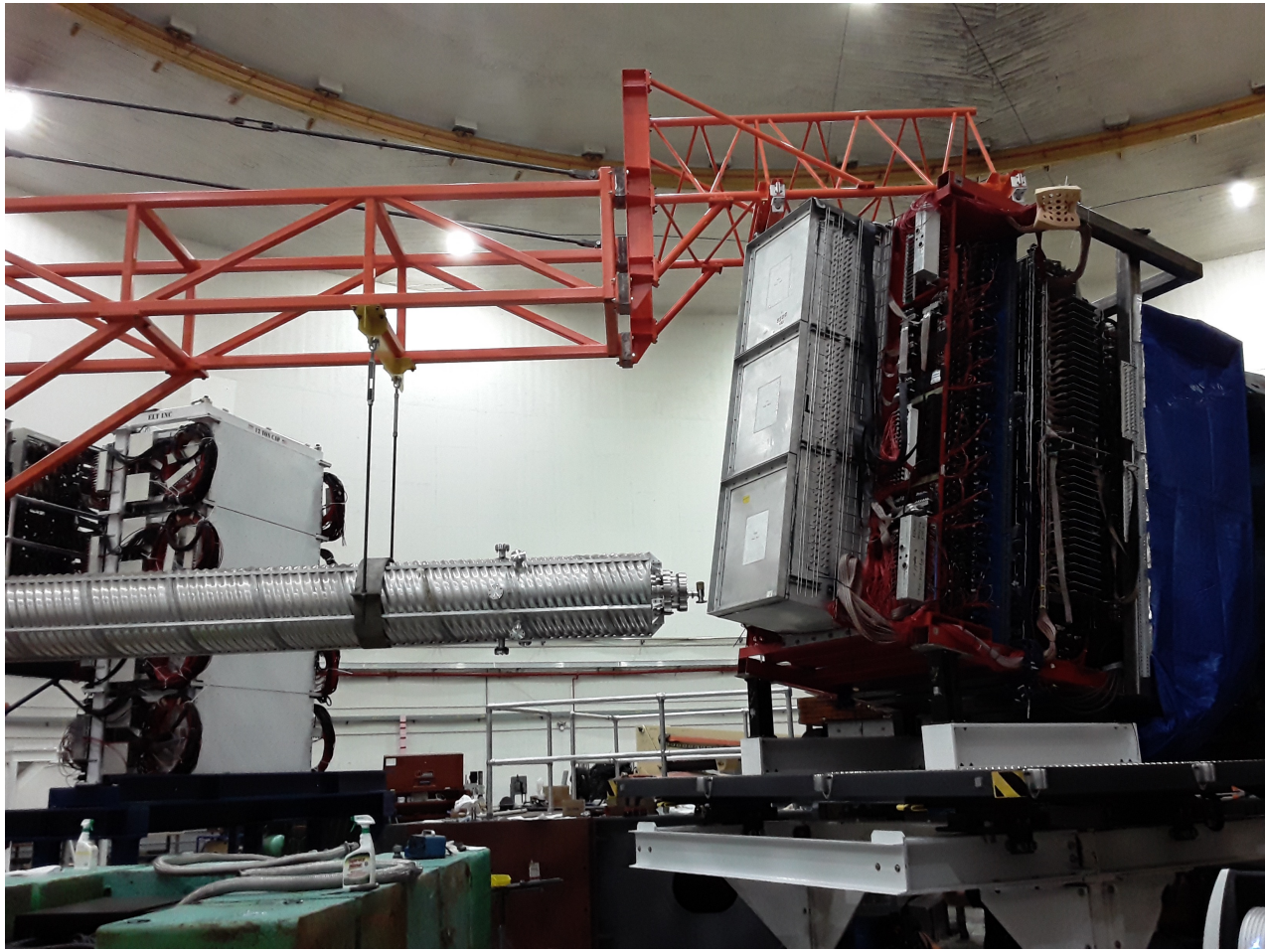
A simulated WAPP ($\vec{\gamma}n \rightarrow \pi^{-}\vec{p}$) event in the GEN-RP setup



Electron Arm: BigBite Spectrometer

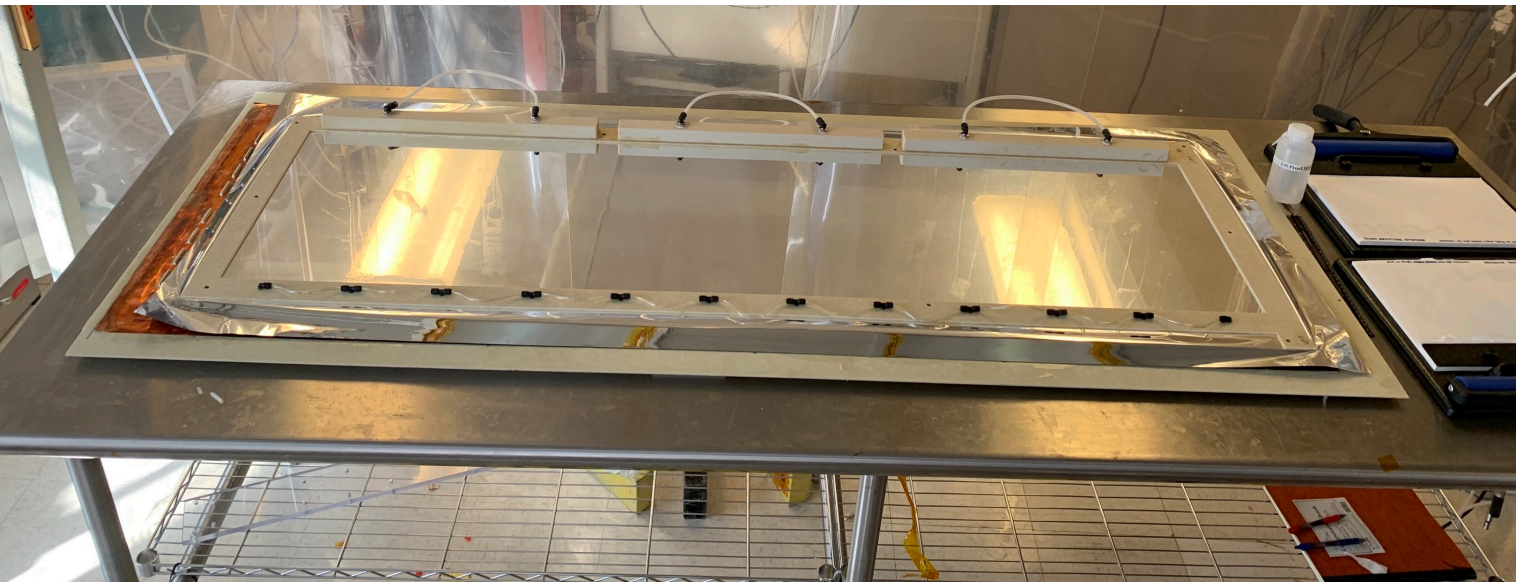


- 5-layer GEM-based charged-particle tracking
- BigBite dipole magnet: BdL ~= 1 T*m
- GRINCH (Gas Ring Imaging Cherenkov): pion rejection
- Pre-shower calorimeter: more pion rejection (or electron/photon "veto" in pion experiment), triggering
- Timing hodoscope: fast timing measurements
- Shower calorimeter: energy measurement, triggering



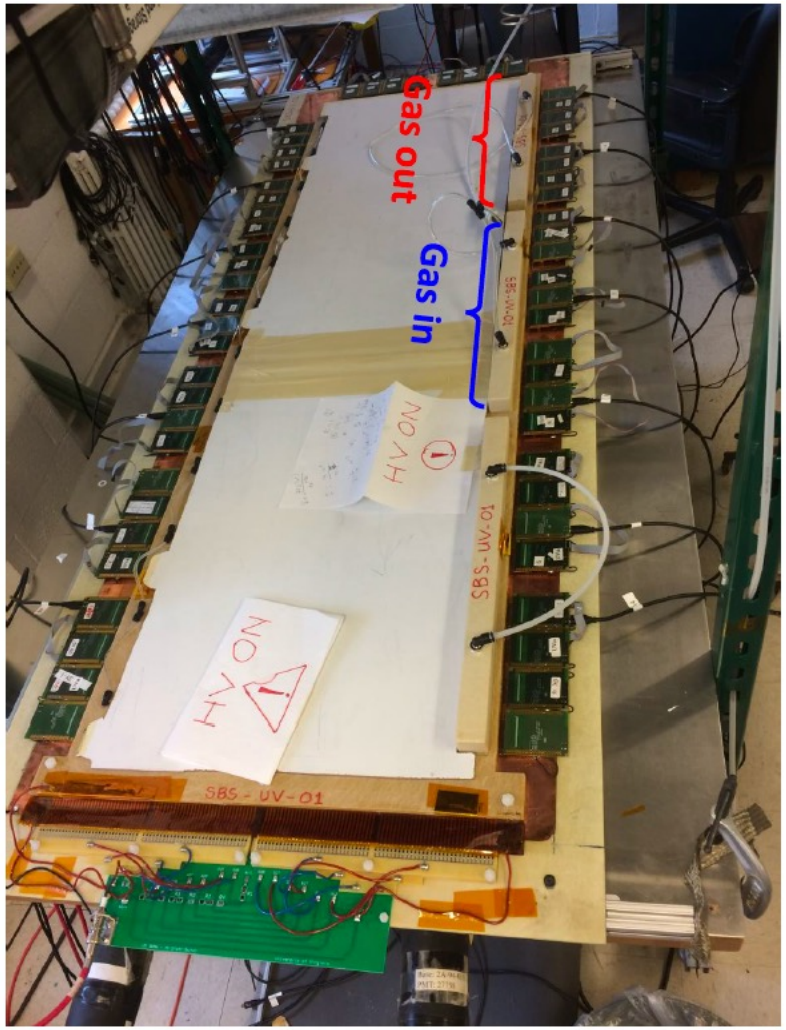
BigBite in Hall A

U/V GEM project at UVA (outdated slide from January)



- UV GEM building going on at UVa.
- Advantages:
  - no dead areas within acceptance
  - ±30° strip angles complementary to X/Y strips in other layers, help resolve tracking ambiguities
- Construction of 4 U/V GEM layers funded by JLab & SBS Collaboration
- The construction of first two detectors already complete: testing to start soon
- Expect to build the other two by April.

U/V GEM project @UVA: April 2021 update

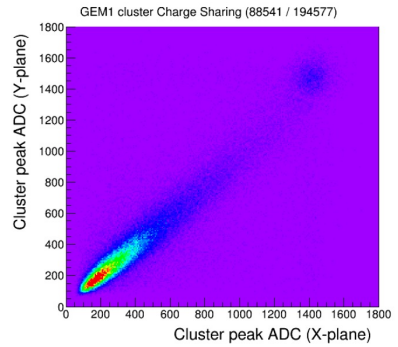


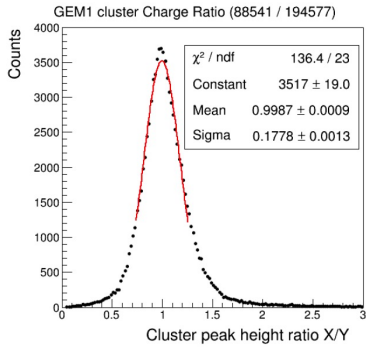
U/V GEM #1 on cosmic stand

2

U/V strips charge sharing

- Very good U/V charge sharing





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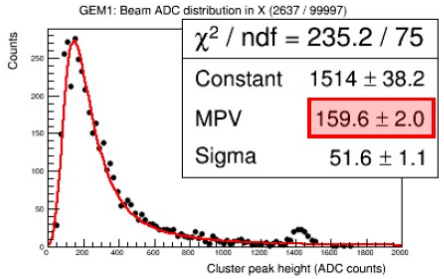
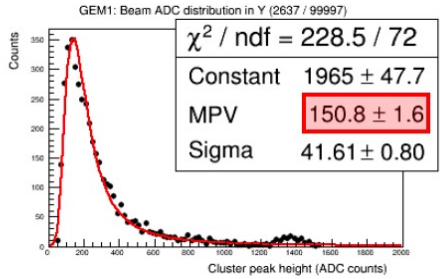
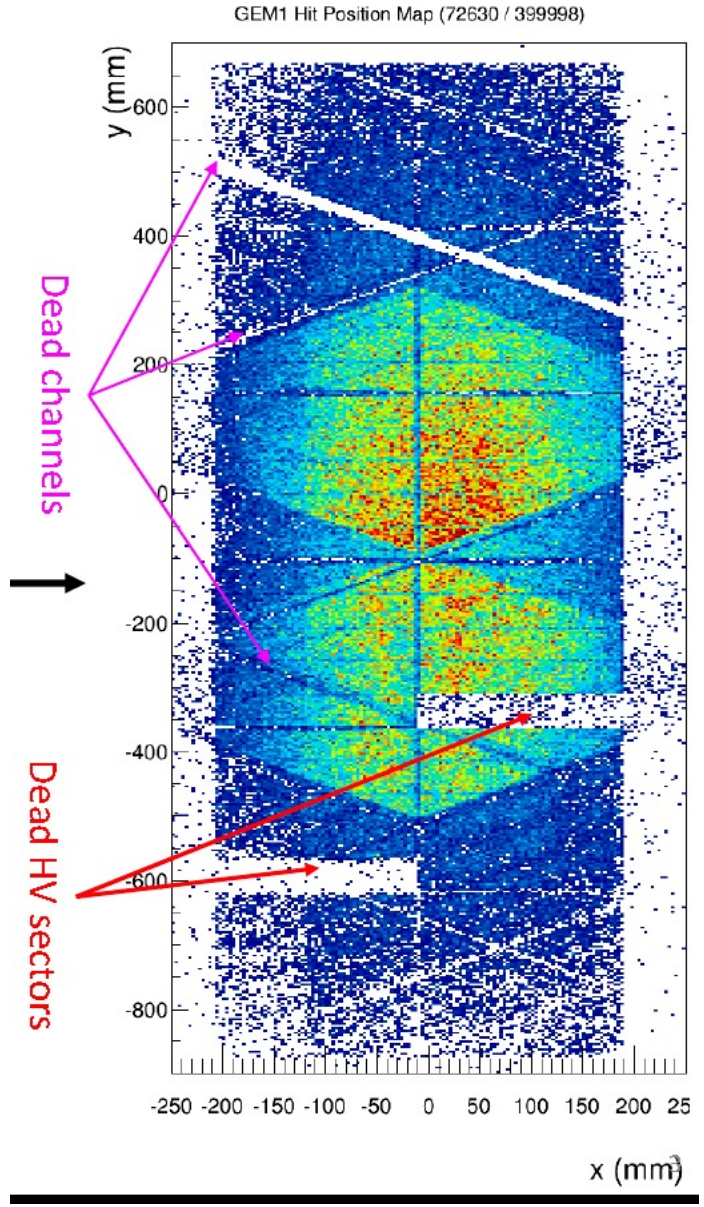
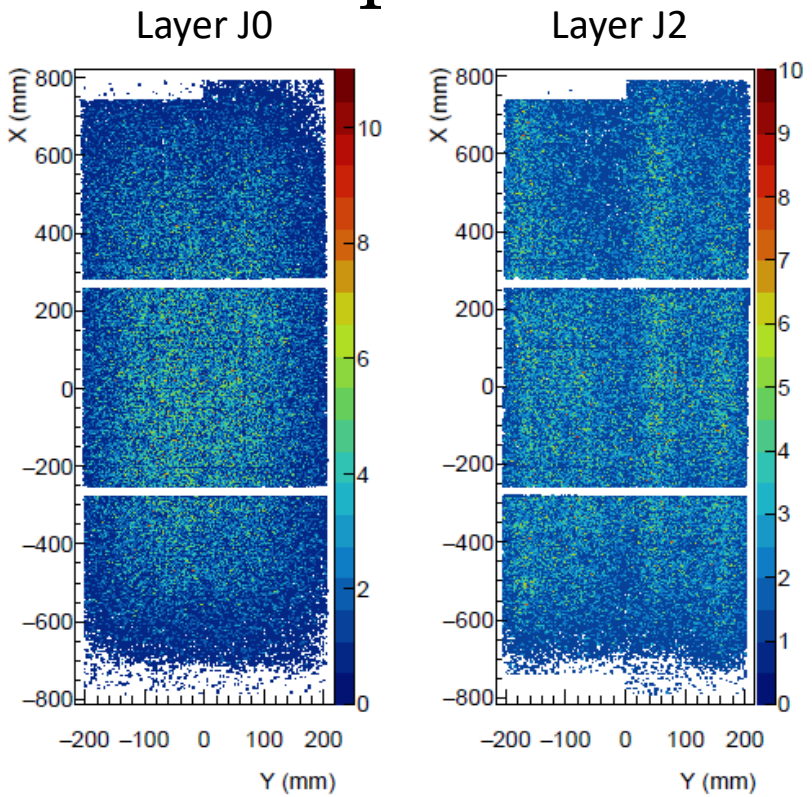




- PRELIMINARY cosmic tests of first U/V GEM layer



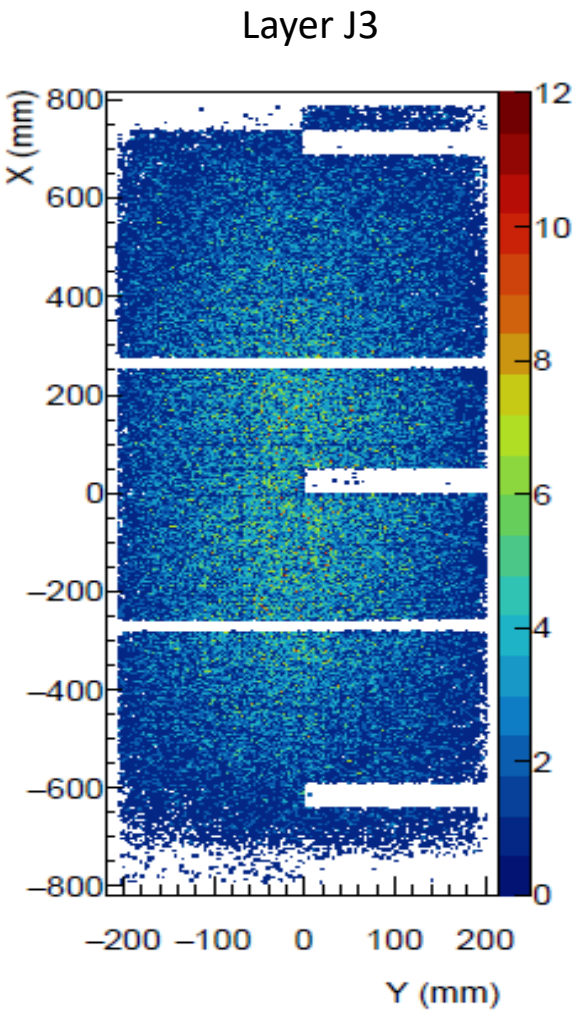
INFN Gas Electron Multipliers (GEMs) for BigBite Spectrometer



Left: BigBite Spectrometer being lowered from transport to Hall A. GEMs under blue tarp.
Middle: XY Hit maps from cosmic data for the 2 INFN GEM layers in BigBite.
Right: BigBite Spectrometer in-place near BigBite Magnet in Hall A

Slide courtesy of E. Wertz

INFN GEMs for Super BigBite Spectrometer

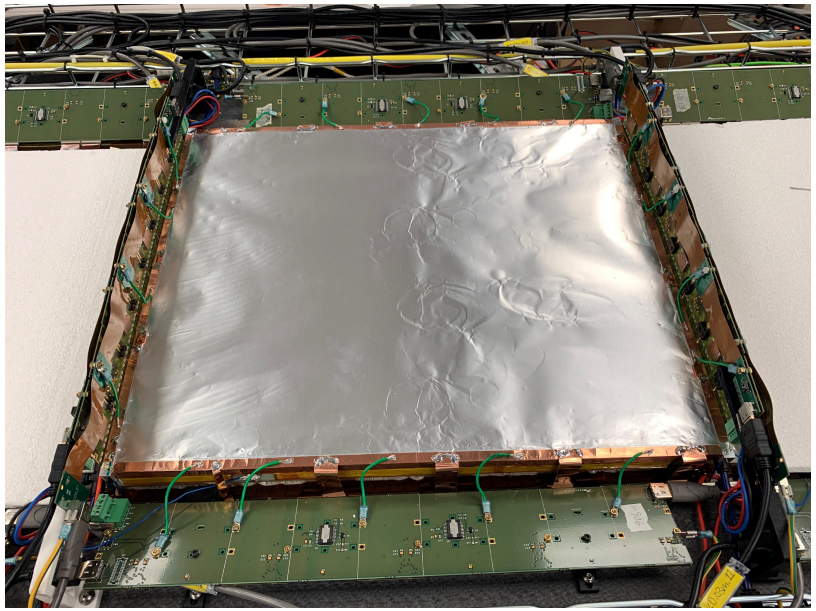


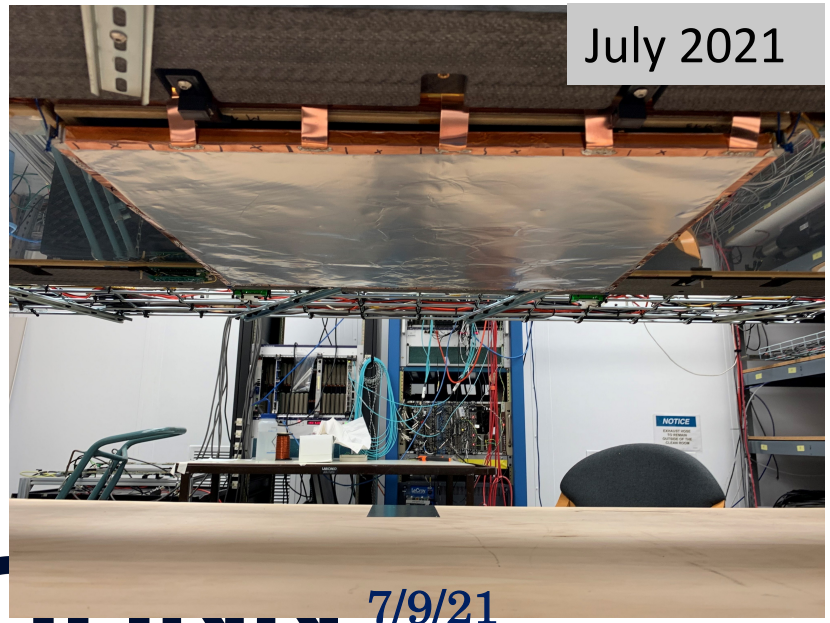
Left: INFN GEM layers in cosmic stand in Test Lab
Right: XY Hit maps from cosmic data for the 1 INFN GEM layer in SBS.

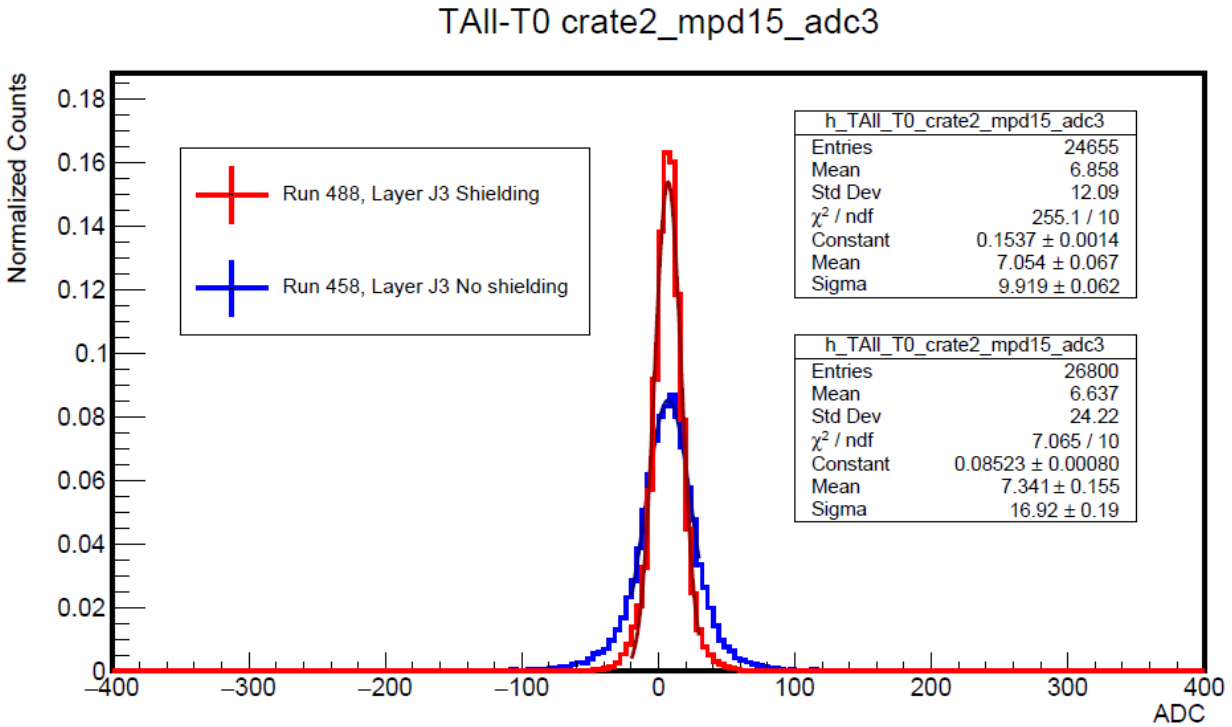
Note: Layer J1 and J3 are finalized for cosmic test before installation in SBS arm. Layer J4 will require detector debugging, after higher priority tasks completed.

Slide courtesy of E. Wertz

RF shielding for INFN GEMs







Left Top: Shielding from the readout electronics side of the GEM module
Left Bottom: Shielding from the drift side of the GEM module
Right: Example of noise level comparison (Normalized Counts vs ADC)

Note: Shielding the GEM module reduces the level of the noise fluctuation. Pictures depict installation on one GEM module, but shielding must be completed for all GEM layers

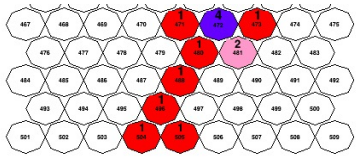
Slide courtesy of E. Wertz

GRINCH Status (h/t Bradley Yale)

- Preparing to re-cable in the hall once allowed, like other subsystems

- Meanwhile, GRINCH TDC/ADC data is now able to be decoded with SBS-Offline
  - A VETROC module had to be added to the Hall A analyzer
  - Special considerations still need to be made for the SBSGenericDetector geometry to accommodate the GRINCH (alternating rows of 8-9 PMTs, offset)

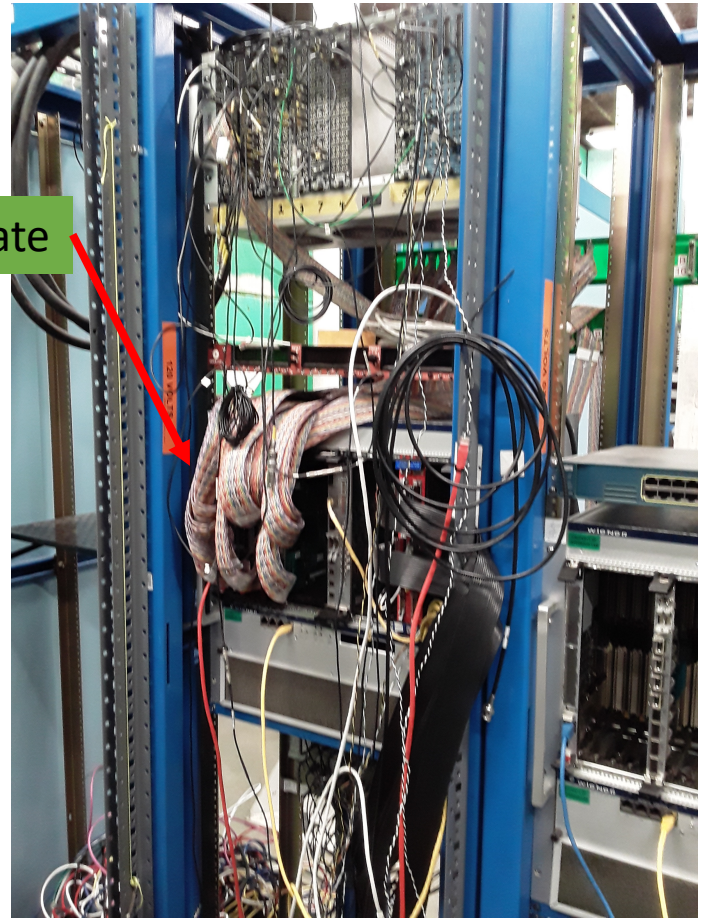
- The development of monitoring plots is ongoing
  - Integration with the standard Hall A GUI framework is next, then port everything to the counting house



GRINCH equipment in the hall

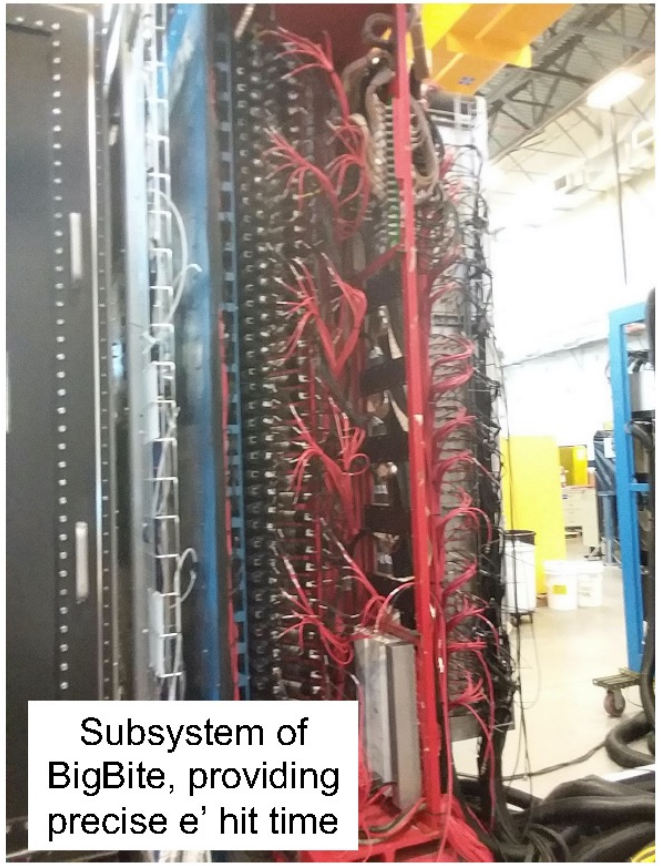
The level translator rack should stay inside the bunker for shielding, if possible

GRINCH crate

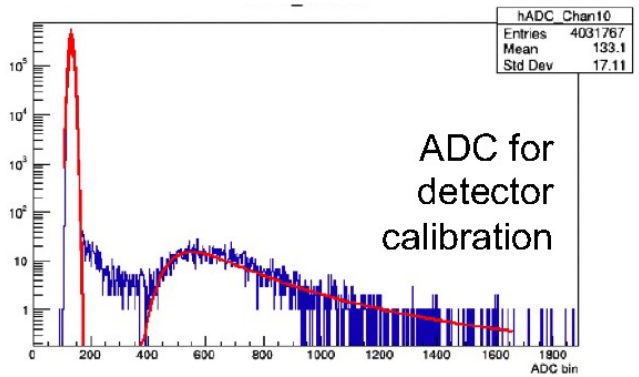


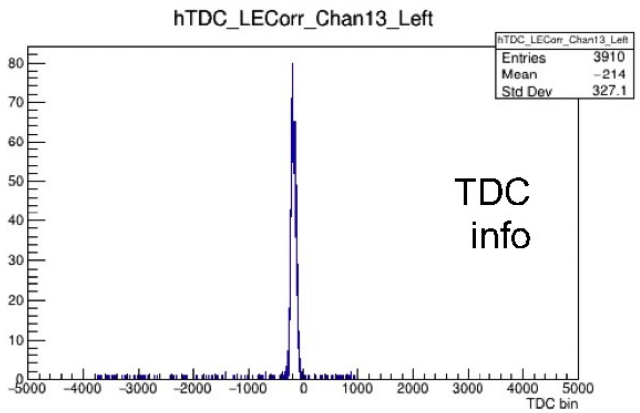
Gas rack in the hall

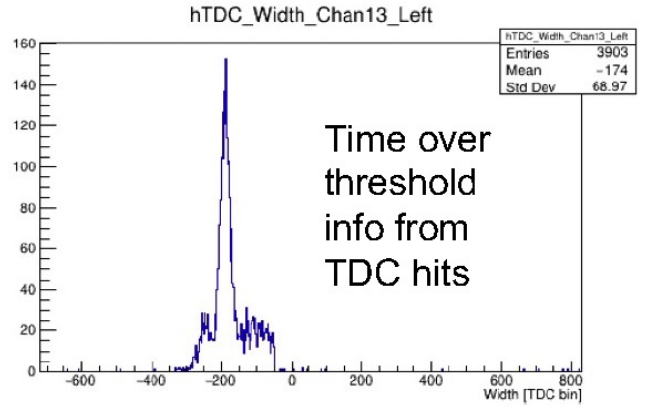
BigBite Hodoscope



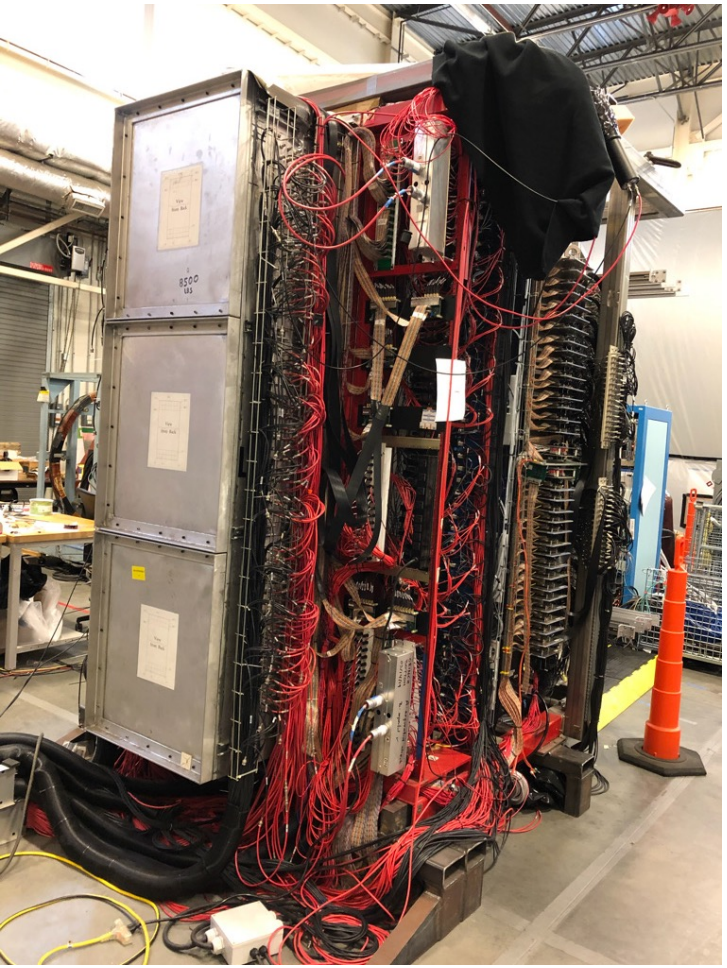
Slide credit: Rachel Montgomery



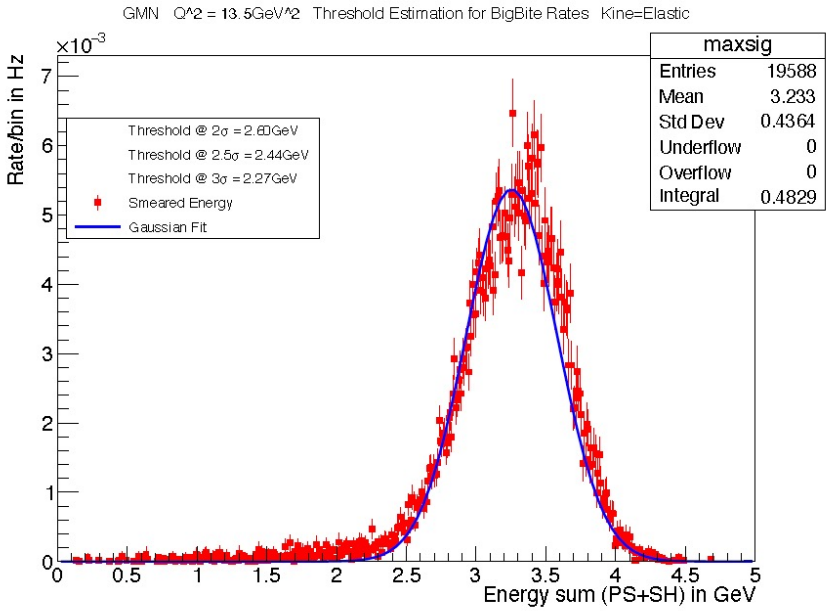




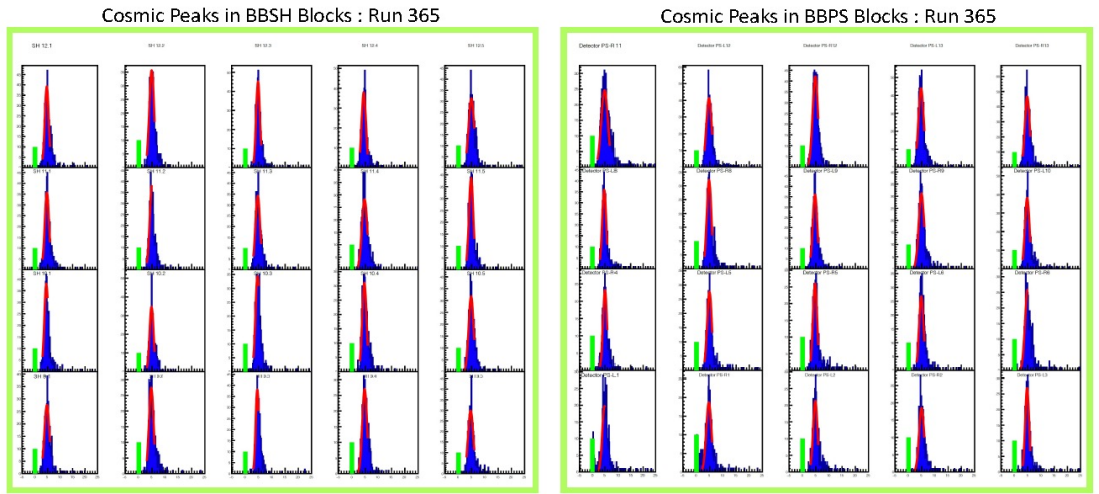
BigBite Calorimeters



- Purpose: Provide efficient and selective trigger for high-energy electrons, energy measurement, pion rejection, and spatial constraint for track-finding in GEMs
- Expected energy resolution ~5% or better for electron energies of SBS GMN
- Spatial resolution ~few cm

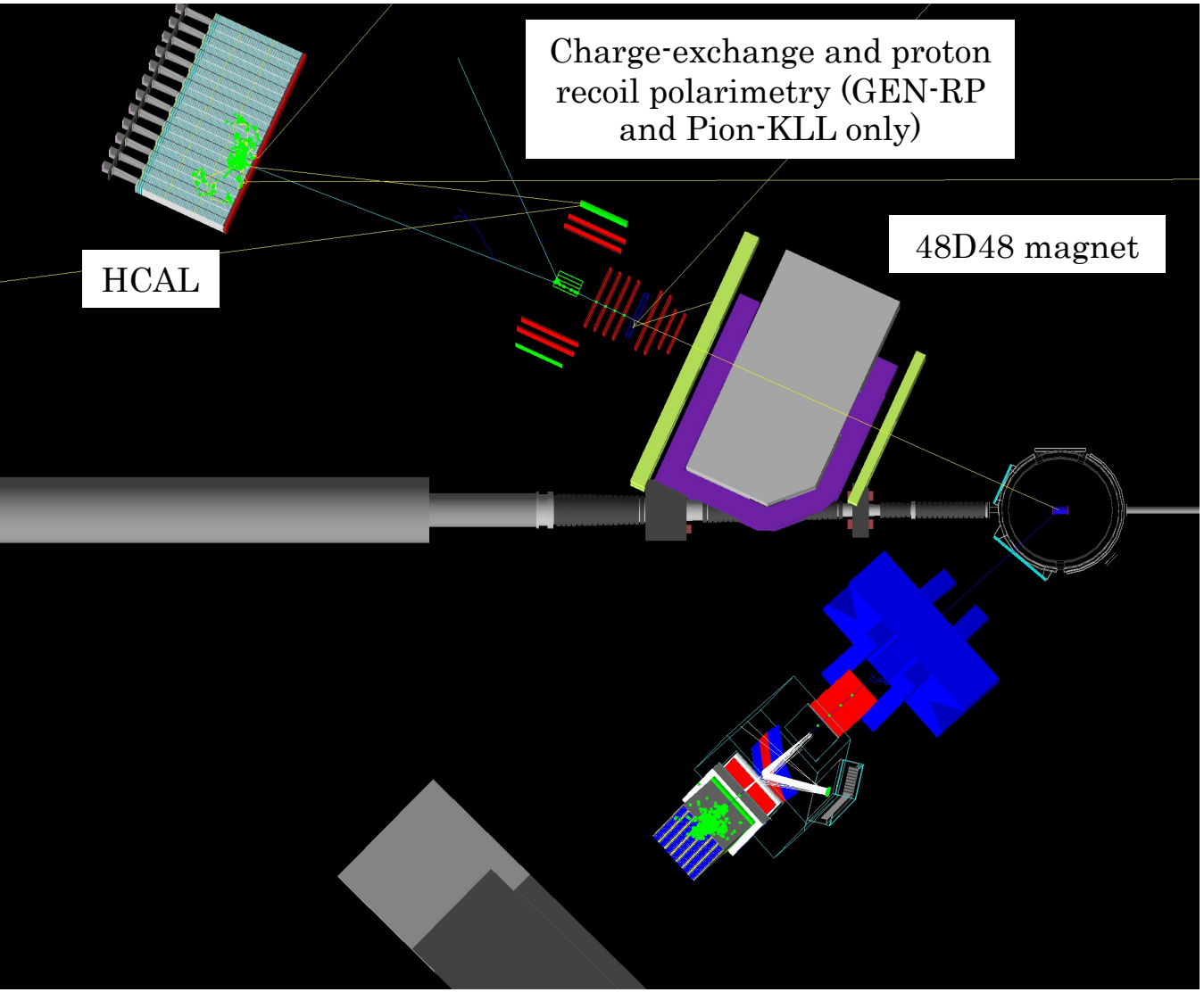


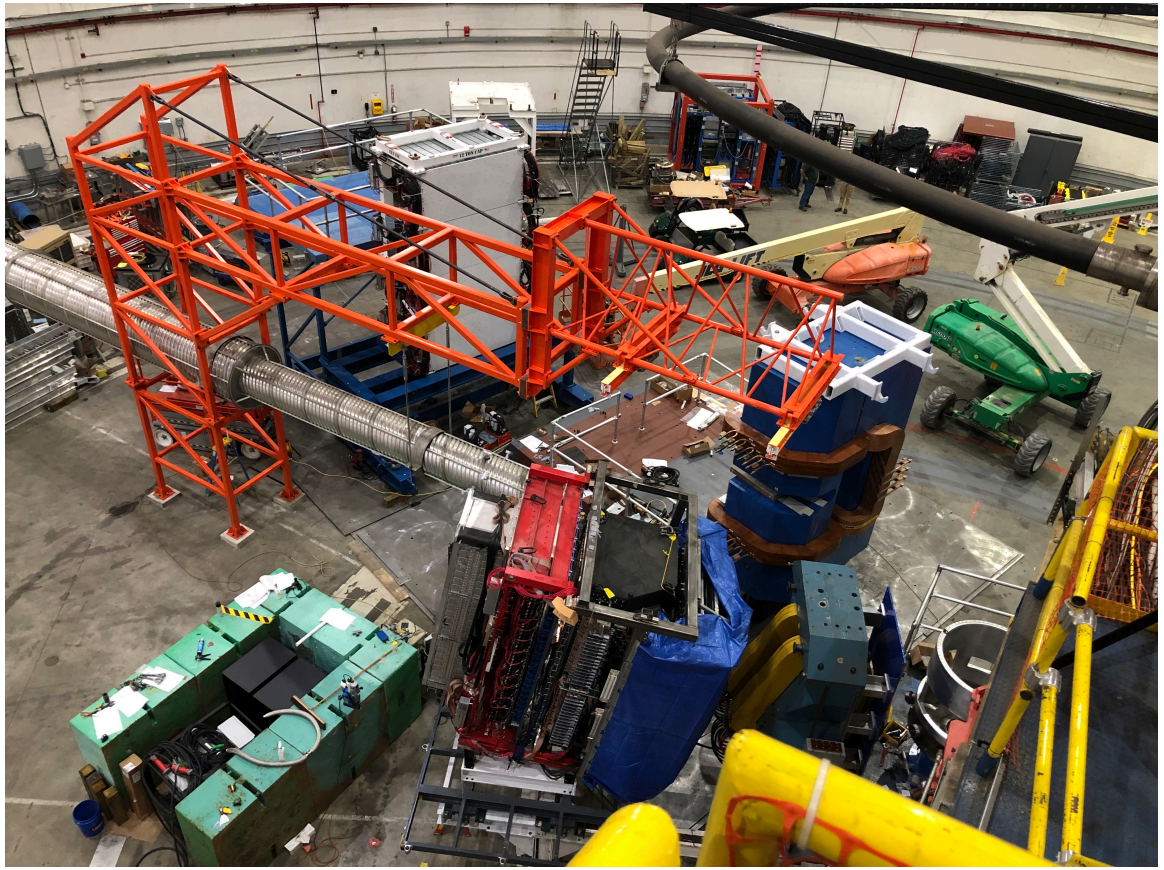
BBCal Cosmic Calibration: FADC Upgrade



- Above: simulated BigBite calorimeter signals from quasi-elastic electrons from deuterium (used to choose trigger threshold setting)
- Left: BB calorimeter cosmic calibration data

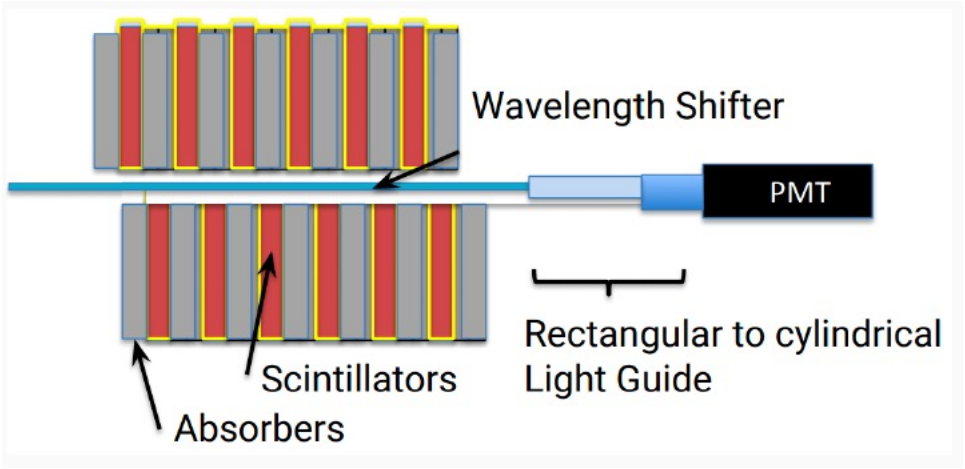
Hadron arm: SBS



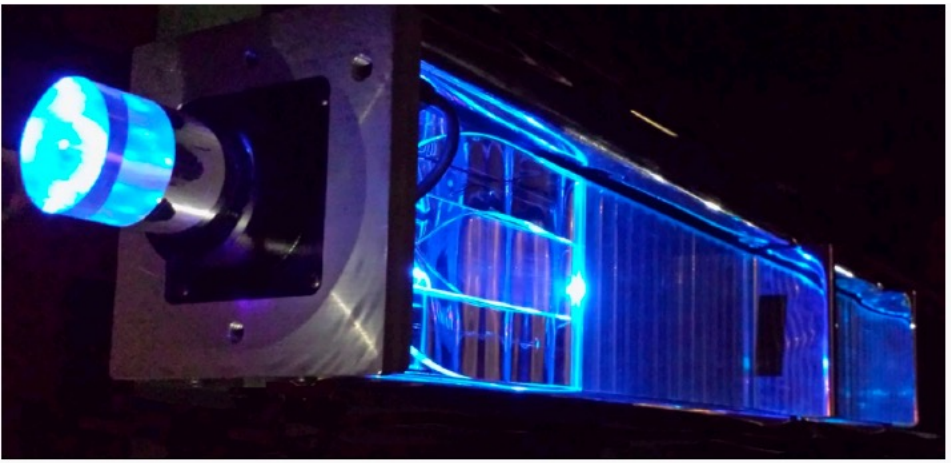


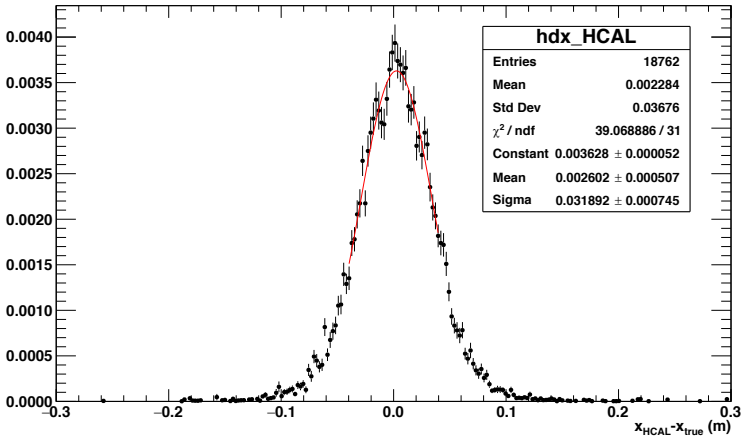
- Left: a charge-exchange d(e,e'n) event in *g4sbs*
- Above: A nice photo of SBS installation progress stolen from Thia's talk yesterday

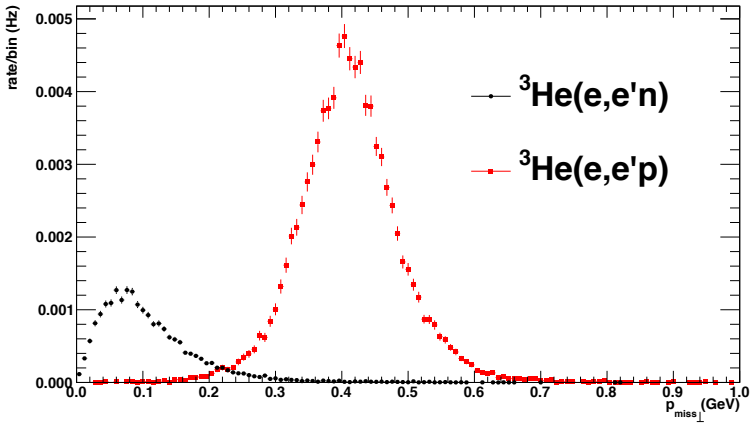
HCAL design/purpose



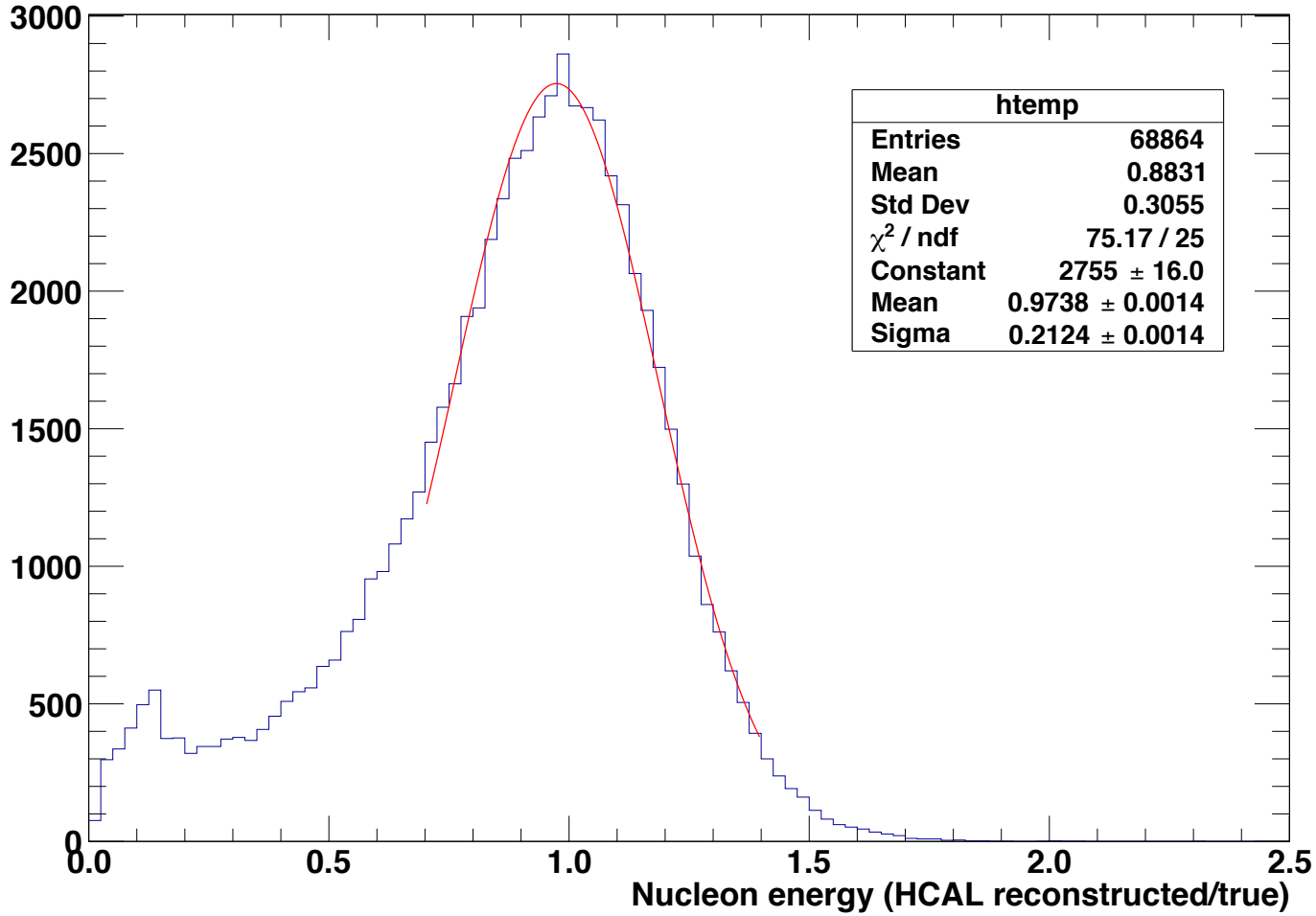
- Used in every SBS experiment
- Iron-scintillator sampling calorimeter
- Detect high-energy hadrons (protons/neutrons/pions) with high efficiency, participate in coincidence trigger
- Moderate energy resolution
- ~0.5-1 ns timing resolution: reject accidentals and reconstruct hadron momentum (at lower momenta)
- Good coordinate resolution for hadronic showers ~3 cm (with some energy dependence)
- Photon-neutron discrimination via pulse shape at higher energies





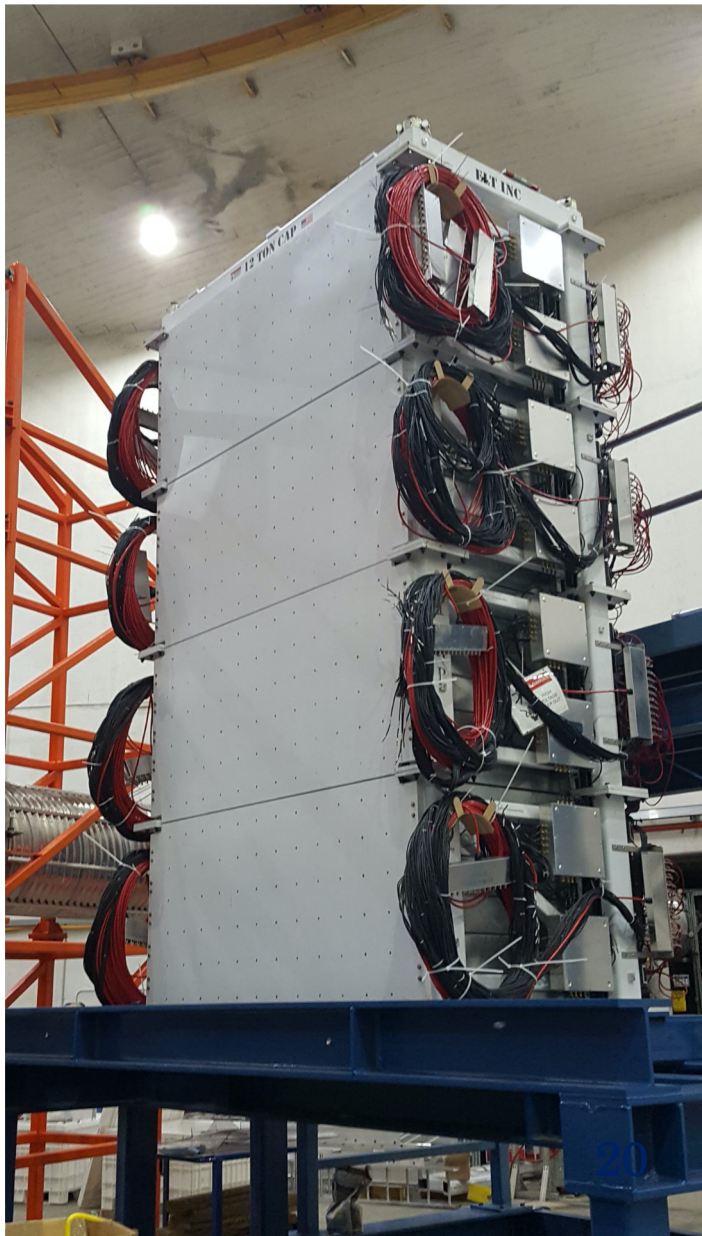


Simulated HCAL energy resolution (~20% at $p_{Nucleon}$ ~8 GeV as in this example)

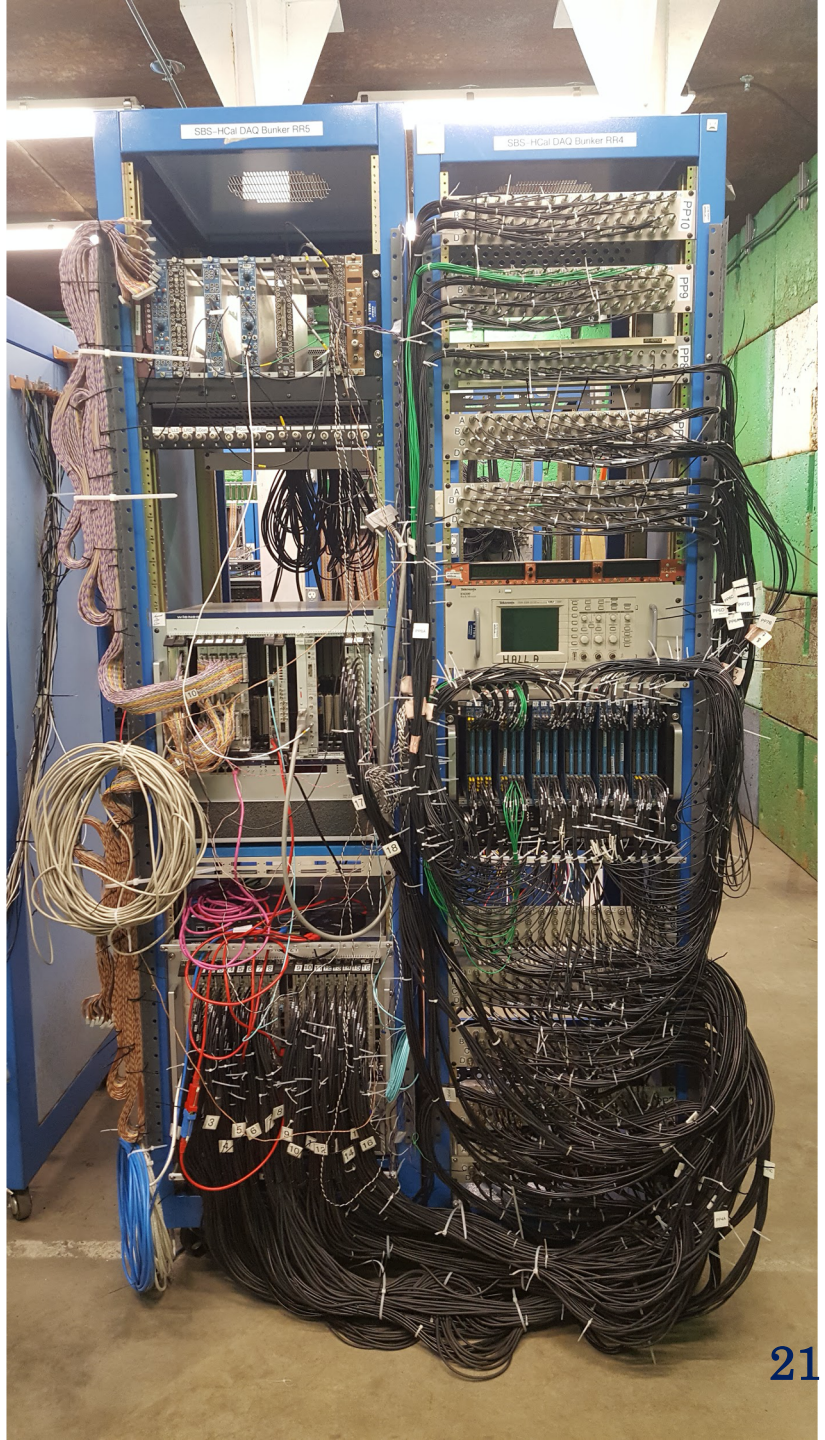


HCAL status

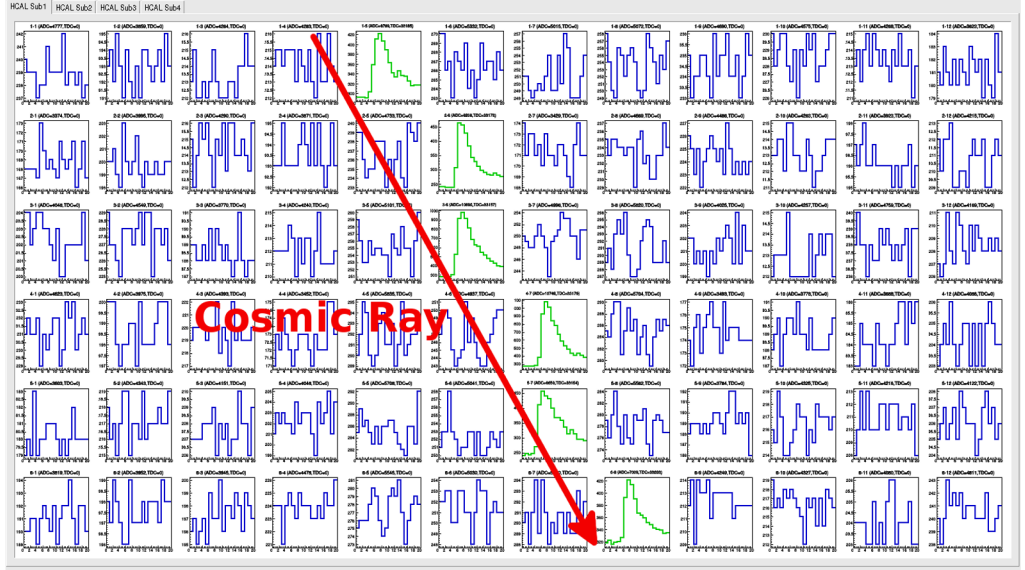
- HCal now moved to Hall A!
- Huge (ongoing) thanks to Jessie Butler and the Hall A tech crew!

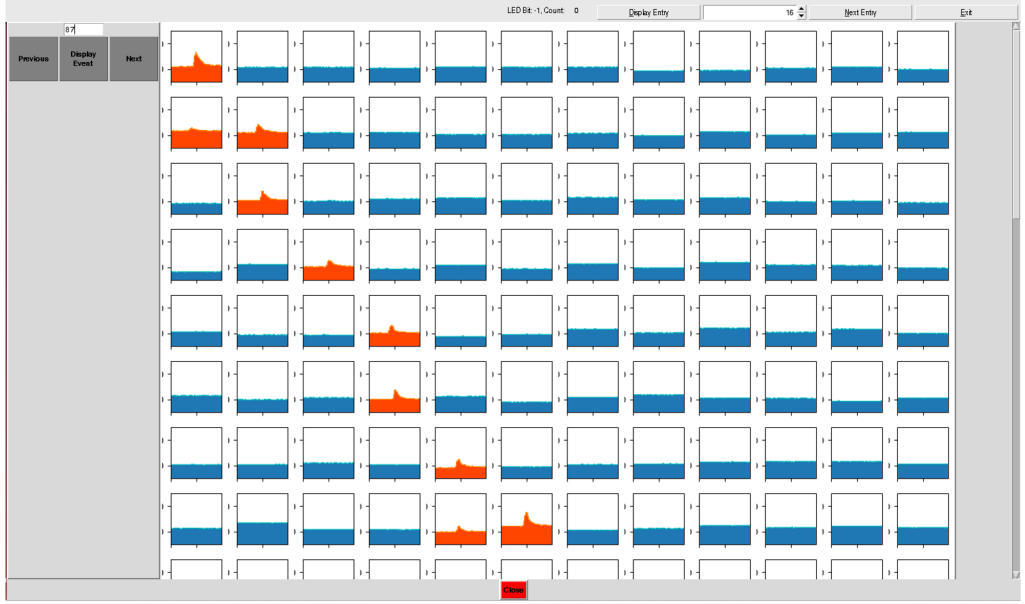


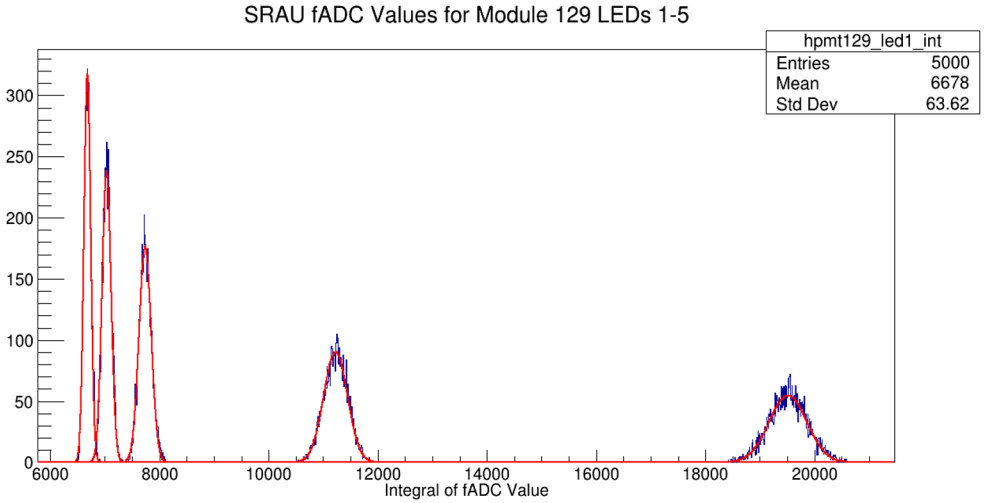
- Cabling underway for DAQ bunker (right) and front-end electronics on HCal platform (bottom).
- Tech crew installing access platform and cable trays.
  - Timeframe ~1-2 weeks then remaining cabling can begin.
  - Need ladder training (SAF307) for HCal access.

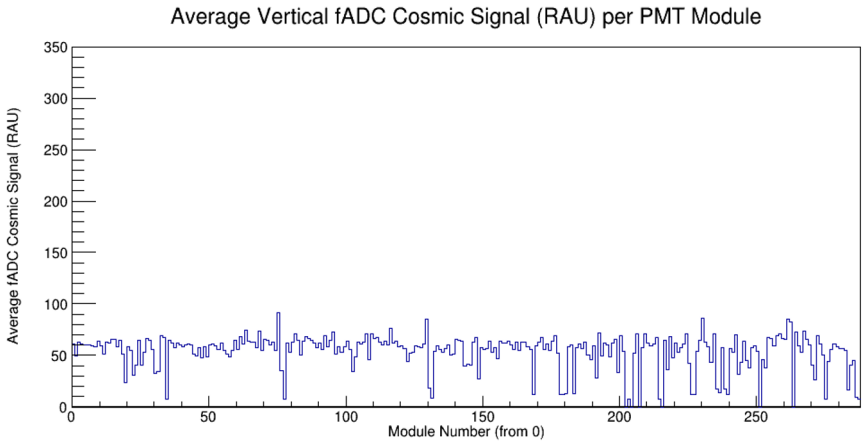


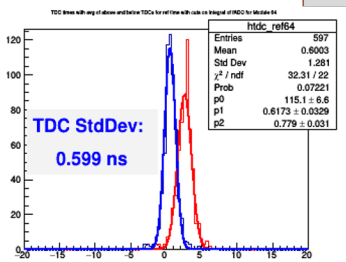
- Event-by-event displays (fADC waveforms).
  - New display under development (right middle).
- Analysis scripts written:
  - LED analysis and HV calibration.
  - Cosmic analysis and HV calibration.
  - Timing resolution scripts.

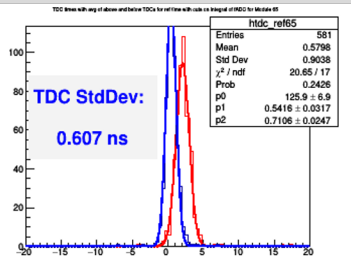


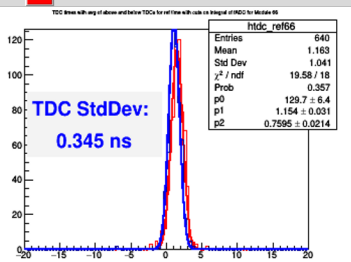


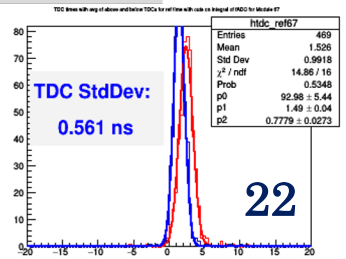






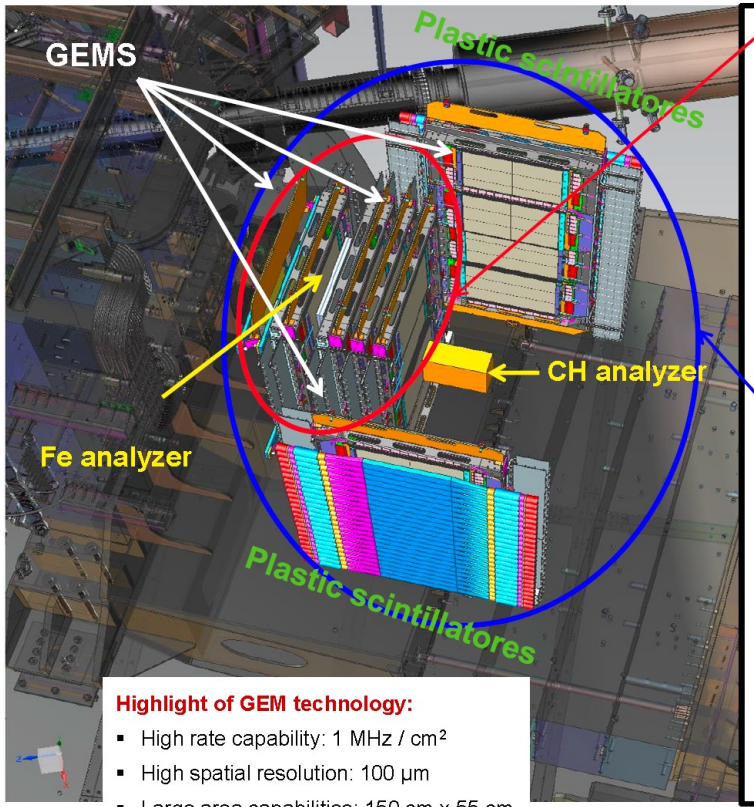






UVA GEMs for BigBite (5th layer) and SBS

SBS GEM for GEn-RP: Purpose

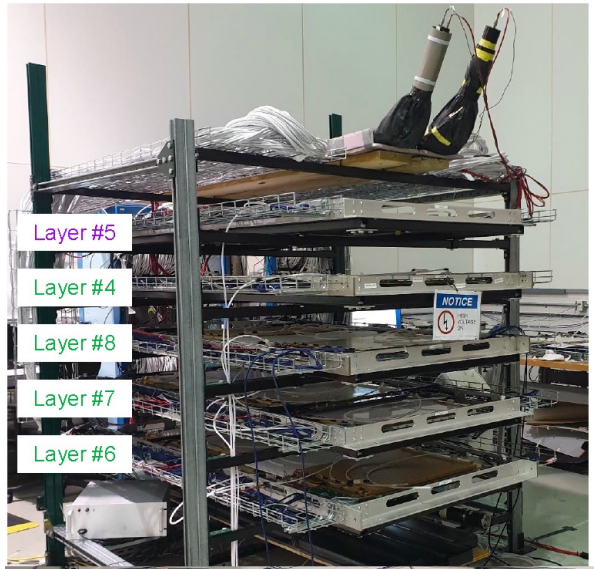


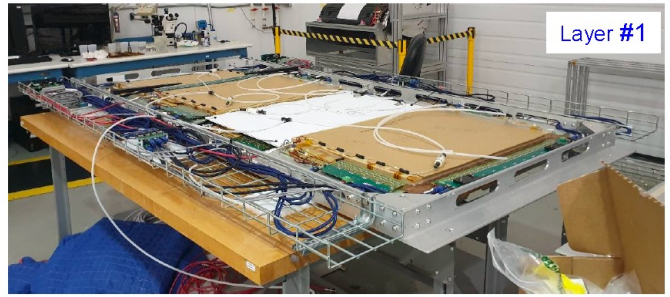
- **Charge Exchange (CE) Polarimeter**
  High-momentum forward protons (towards HCAL) after CE np → p
- 2 INFN GEM planes
- 6 UVa GEM planes
- 1 Steel analyser
- **Proton Recoil (PR) Polarimeter**
  Low-momentum large-angle recoiling protons after np → np and also signal in HCAL (nn sct)
- Active CH analyser
- 2 sections, one each side of CE Polarimeter
- Each section has 2 UVa GEM planes and 1 plastic scintillator plane

Highlight of GEM technology:

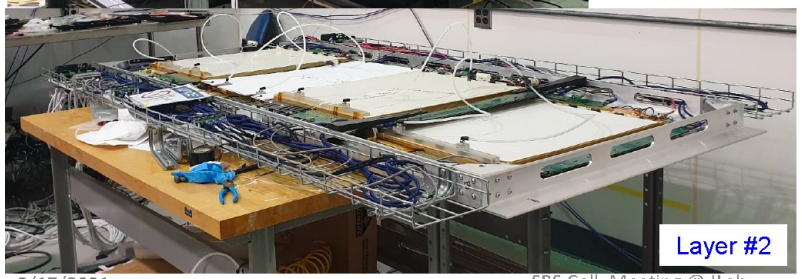
- High rate capability: 1 MHz / cm²
- High spatial resolution: 100 μm
- Large area capabilities: 150 cm x 55 cm
- Low cost technology

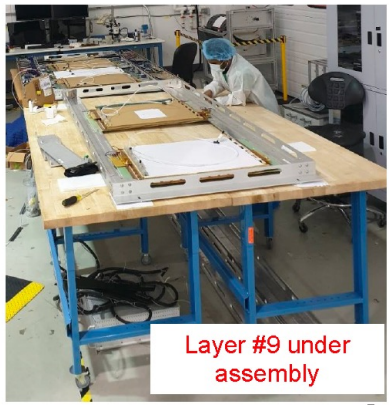
GEn-RP GEM layers: Assembly of UVa X/Y GEMs





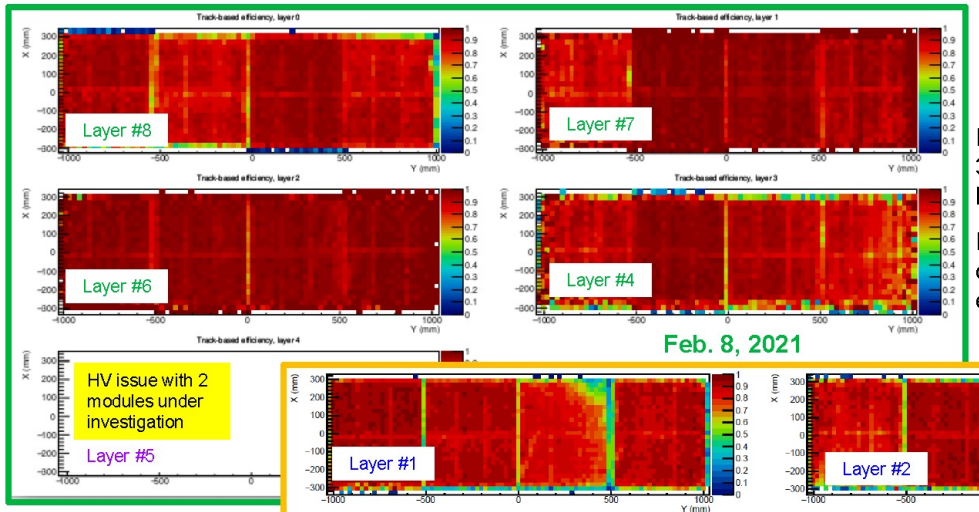
- Ready for installation in GEn-RP frames
- Assembly completed, Need cosmic test validation
- Layer #5: HV issue with 2 modules, still with old divider ⇨ will be fixed later
- Ongoing layer assembly

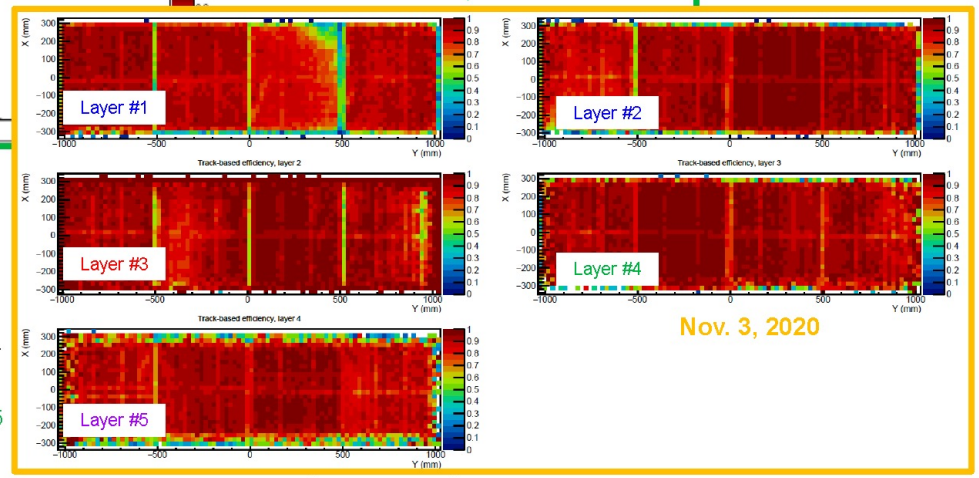




Performance of UVA GEMs: efficiency and spatial resolution

Performances of UVa X/Y GEMs: Efficiency Map





Tracking software for SBS GEMs by Andrew Puckett

Efficiency ~ 90% in all 32 modules of the 8 layers tested so far

HV scan to identify the optimal operating HV for each individual module

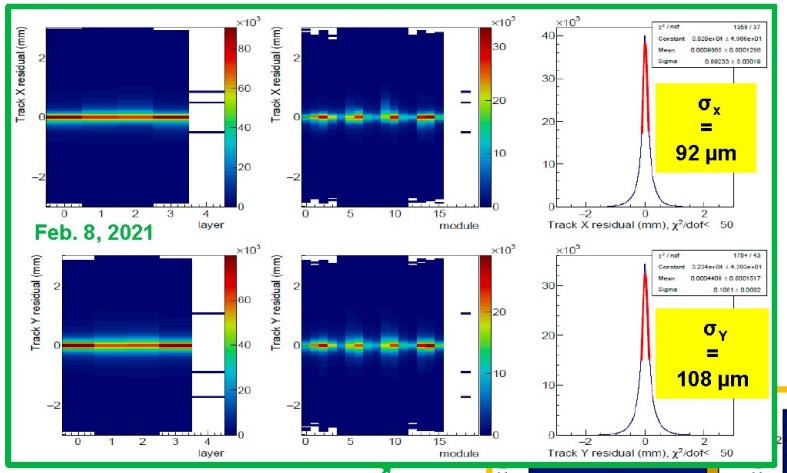
Layer #1 & #2: back on assembly tables

Layer #3: installed in BB frame in TEDF

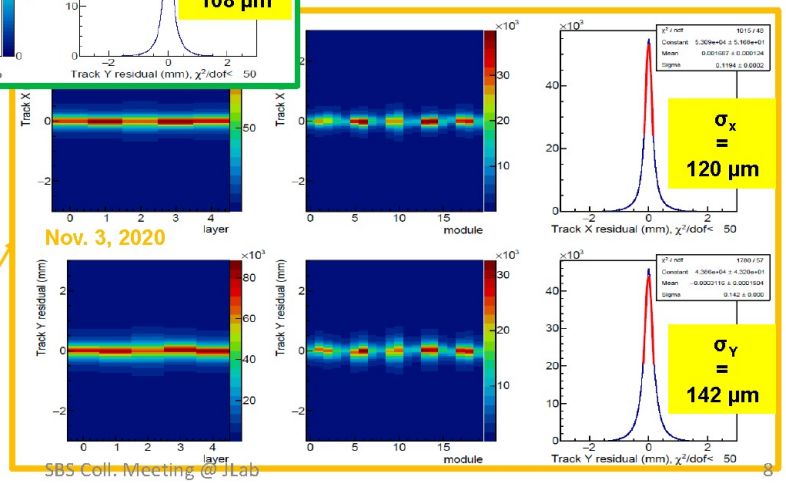
Layer #5: HV issue with 2 modules, still with old divider ⇨ will be fixed later

All other layers other than #5 with new HV divider scheme

Performances of UVa X/Y GEMs: Spatial Resolution



Feb 08, 2021 data from layers #4, #6, #7 & #8: **new HV divider scheme**



Nov. 3, 2020 data from layers #1, #2, #3, #4 &#5: **old HV divider scheme**

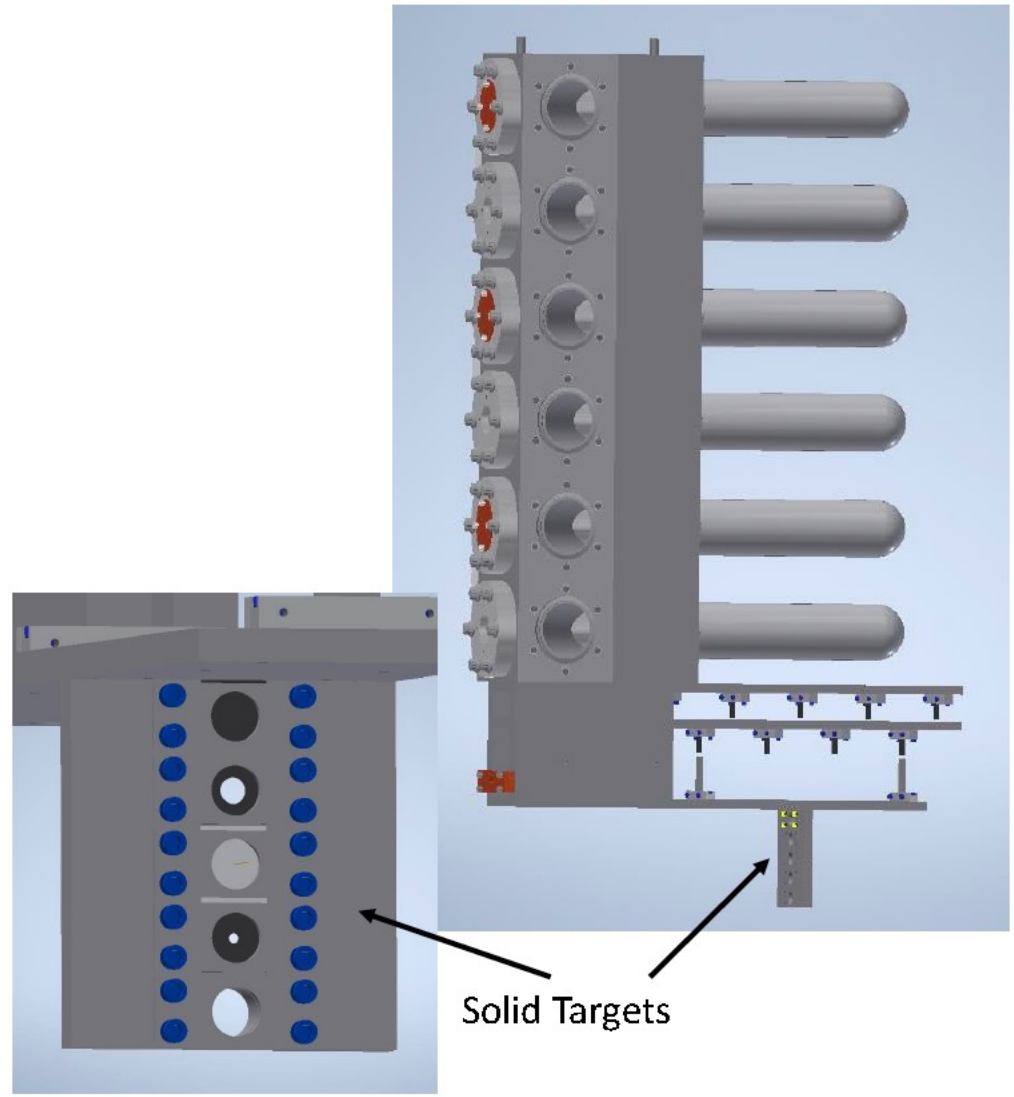
Tracking software for SBS GEMs by Andrew Puckett

- Better resolution performance for Feb. 8 2021 data probably because of better alignment
- Resolution in x always better than in y because tracks in y has a larger angular distribution because of the size

GMN Target(s)

Target Stack

- Six 15 cm cells
  - Current on 15 cm cells 50 microA
  - Each loop will have two cells With/without Radiator
- Optics Target
  - 2 sub assys with (5) foils ±10 cm. and 4 foils ± 7.5 cm.
- Dummy Target(s)
  - One 15 cm position with/without radiator
  - Current limit 20 microA
- Solid targets
  - 5 solid target positions
    - Carbon
    - C-hole 2 mm
    - C-hole 5 mm
    - BeO
    - W wire 100 µm.



Hall A Beam Line Update

Hall A/C Collaboration Meeting

July 8–9, 2021

David Flay

7/9/21

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JSA

Beam Energy, Charge Monitors, Unser, Raster

Beam Energy (D. Flay, transition from D. Higinbotham)

- Bend angle survey completed in Feb 2021
- Each beam energy measurement takes 1 hr

BCMs, Unser (D. Mack)

- Need to recover systems from parity experiments PREX/CREX
- Set up for beam currents relevant to GMn/GEn-RP/nTPE/WAPP (1—100 μA)
- Work estimate: 2 weeks @ half time

Raster (B. Michaels)

- PREX/CREX ran with 1 XY pair; need to set up for XY XY configuration
- Estimate 2 weeks for installation and testing (Bill Gunning). Work planned for July

Beam Polarimetry, Beam Position, Ion Chambers

Beam Polarimetry (for GEn-RP, WAPP)

- Moller (S. Malace): We have documented procedures for setting up the measurements
  - Beam line will stay the same for this run group => the same beam setup procedure for PREX/CREX will be used
  - Each beam energy needs a different Moller optics solution (to be determined via simulation). For each beam energy, must allocate 2 shifts: commissioning optics solution + time for one measurement
  - Moller target still in use by Parity group (Don Jones et al.) for Kerr Effect measurements
  - Early August: plans for target re-installation (S. Malace, Survey & Alignment); new Fe foils to be installed (D. Meekins)
- Compton (D. Gaskell): Not used for GEn-RP, WAPP

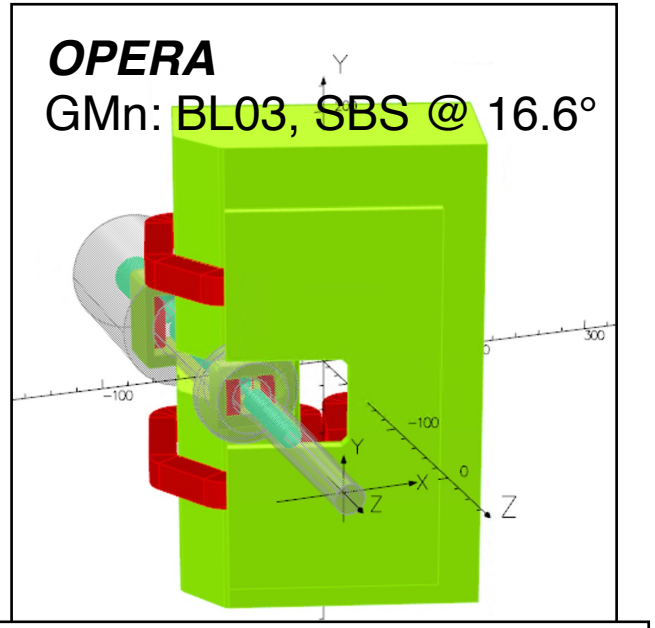
Beam Position Monitors, Harps, Ion Chambers

- Standard equipment maintained by Accelerator
- Checkout steps are included in standardized procedures
  - For Harps: Inject signal & check electronics, carriage motion; scan harps and identify wires that are faulty/need fixing
  - BPMs follow similar steps
- Ion chambers: Will follow recently updated procedures (2020)

Exit Beam Line Correctors

Why Corrector Magnets?

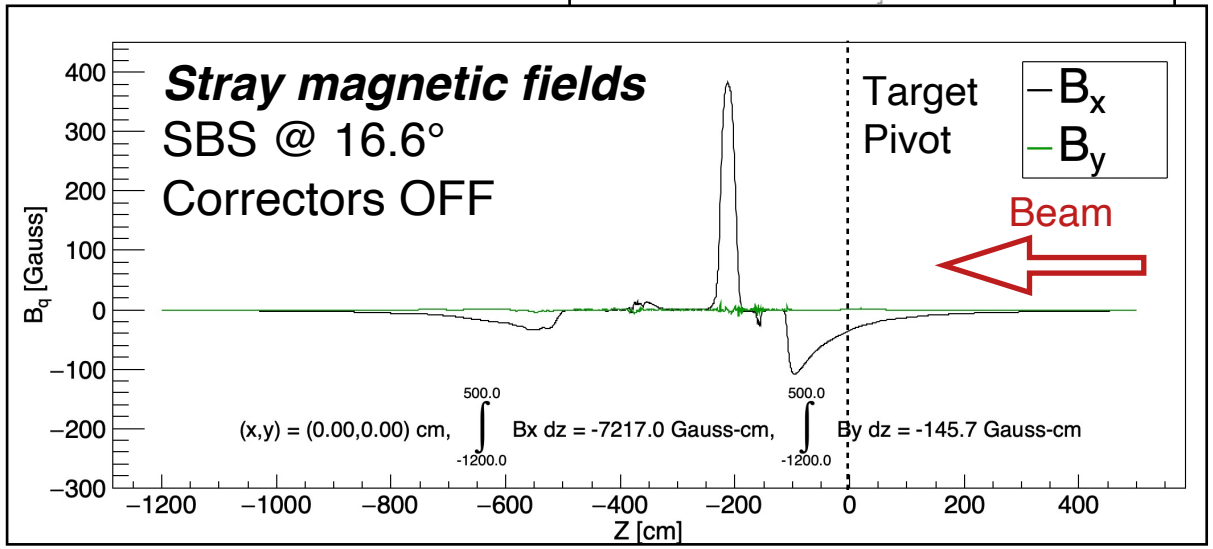
- SBS field (1.7 T-m) can have significant fringe field gradients
- Need to cancel gradients, optimize beam transport to dump
- Independent power for (beam) left and right coils => magnitude + gradient
  - Calculations performed in OPERA (D. Flay, J. Benesch)



Rough Timeline & Tasks

- Estimate to install in July/August
- 12 days for:
  - Installation, survey, alignment
  - Connection of power, temperature sensors, LCW
- Must allocate time to:
  - Power magnets
  - Measure field magnitude and direction
  - Techs are assembling beam line shielding in the Hall
- CASA & D. Flay drafted commissioning and operation plan

Personnel
J. Butler & team
J. Segal & team
Accelerator
D. Flay



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At a Glance: Tasks & Time Estimates

Task	Personnel	Time Estimate
BEAM OFF		
BCM, Unser Prep	D. Mack	2 weeks (at half time)
BPM, Harp Checkout	Accelerator	(part of ops procedures)
Corrector Installation, Checkout	J. Butler & team, J. Segal & team, Accelerator, D. Flay	2 weeks+
Raster Preparations	B. Gunning, B. Michaels	2 weeks
Moller Target Re-installation	S. Malace, Survey & Alignment	1 week
BEAM ON		
BB, SBS B = 0 Commissioning	Accelerator	13 hrs
BB, SBS B ≠ 0 Commissioning	Accelerator	TBD
Moller Setup and Measurement ★	S. Malace, Accelerator	16 hrs
Beam Energy Measurement	D. Flay, transition from D. Higinbotham	1 hr

- Beam-off tasks being scheduled with Jessie

★ Note polarimetry tasks are only valid for GEn-RP and WAPP. Tasks are required for each beam energy

Online Monitoring & DAQ Details

Monitoring Categories

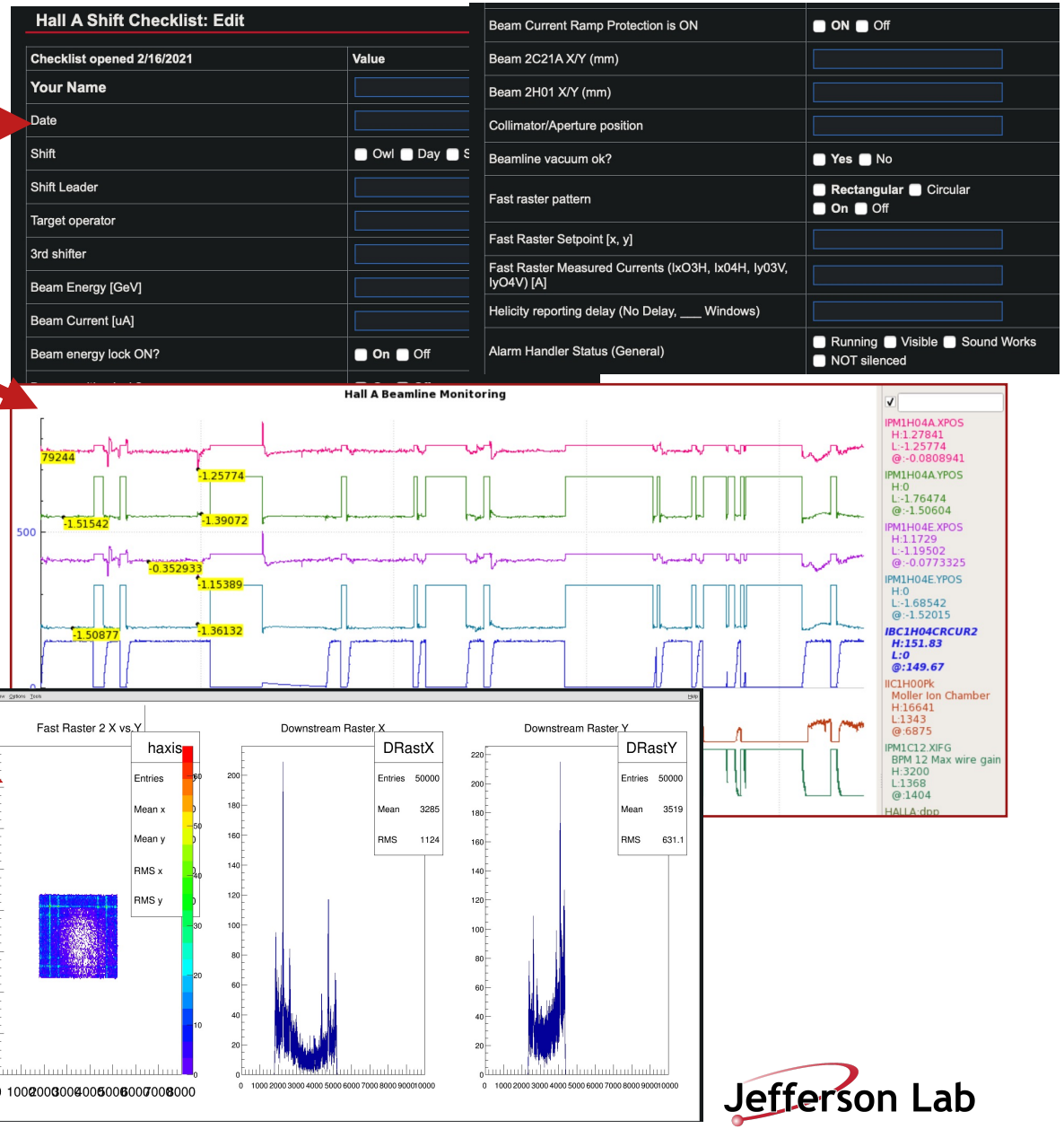
- ***Shift checklist:*** Top-level (once per shift) check of nominal items
  - —Beam energy, current
- ***EPICS variables:*** Items to monitor on the ~hr time scale
  - —BPM, beam energy & dp/p, ion chambers
- ***Alarms:*** Items that need immediate attention as needed
  - —Key BPMs, ICs
  - —Three handlers: 1) for target; 2) for spectrometers/vacuum systems; 3) an improved version of the parity alarm handler for general use (Cameron Clarke, SBU)
  - —Need to determine optimum setup/combination of these options

Raster Monitoring

- Raster spot++ usage will be similar to what it was for LHRS. Updated tool (spot_SBS) being developed (D. Flay)

DAQ Readout

- Reviving the LHRS readout of beam quantities (B. Michaels)
  - — Signals are already in the LHRS for BPM, BCM, helicity, raster currents
  - — If these data are redundant in the main SBS DAQ, instructions may be different (TBD)



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Summary and Conclusions

- ~13+ years after first proposal approved (SBS GEP, E12-07-109), the SBS program is finally about to begin!
- Core program of nucleon Form Factors and SIDIS will produce flagship/legacy results of the JLab 12 GeV program
- SBS equipment (which also includes upgraded BigBite/etc) adds significant generic science capabilities to Hall A, that could enable a rich physics program beyond the core program, IF there was room in the Hall A schedule…
- Installation is underway and running SHOULD start in 2 months! Lots of work done, much more to do…
- Thanks for your attention!