Beam Test Analysis Status

Michael Nycz

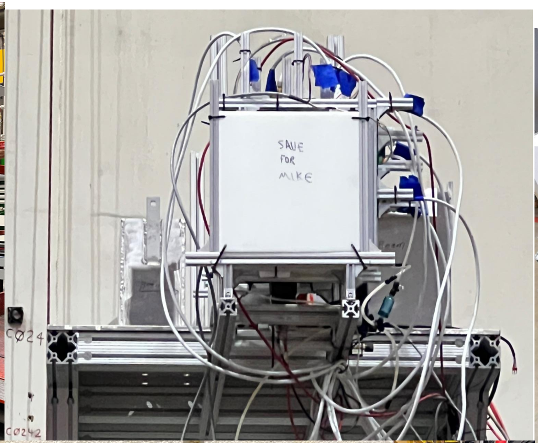
SoLID Collaboration Meeting

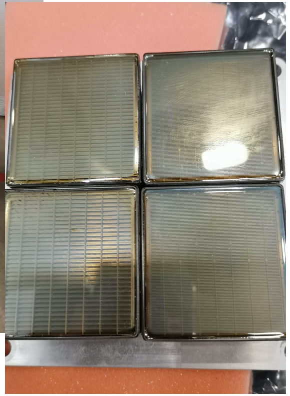
Argonne National Laboratory June 21 2024

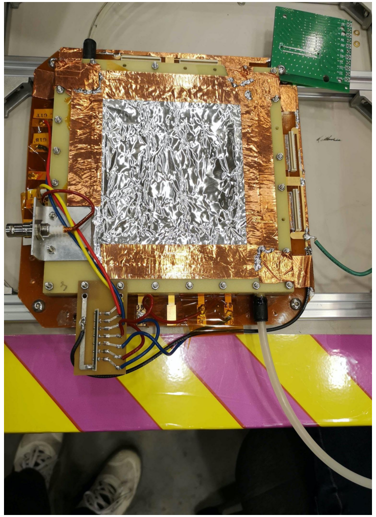
Xinzhan Bai, Alexandre Camsonne, Jimmy Caylor, Carter Hedinger, Tim Holmstrom, Simona Malace,Spencer Opatrny, Richard Trotta, Ye Tian, Darren Upton, Jixie Zhang, Xiaochao Zheng

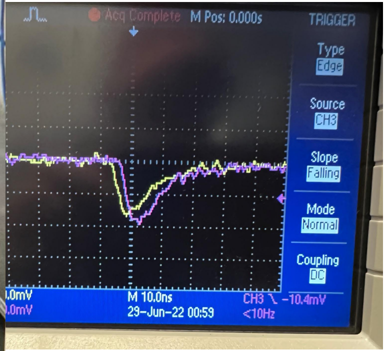
University of Virginia

One Slide Summary









Beam Test Overview

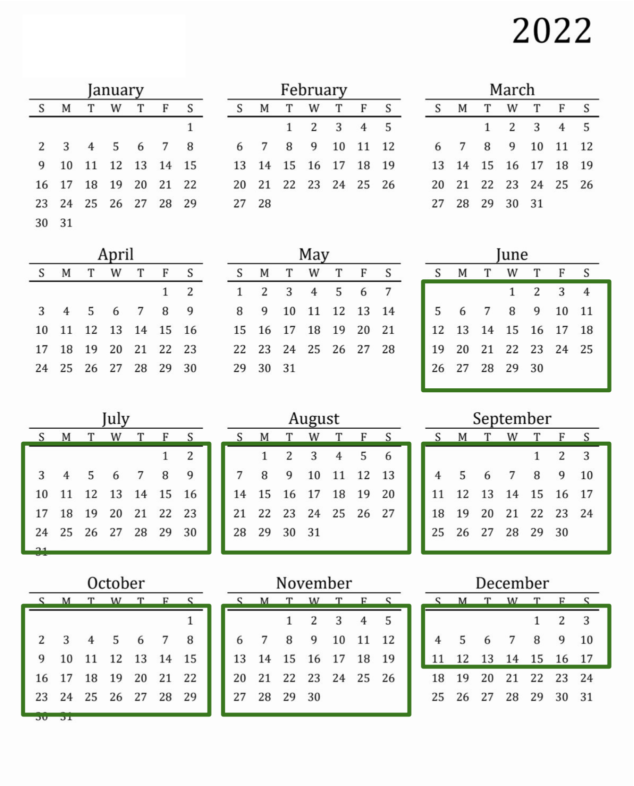
SoLID Director's Review (2021)

- Calorimeter and SPD detectors not tested under high rate / high luminosity environment
- Detector test utilizing a full set of SoLID prototype detectors under "realistic SoLID running condition"

Goals

1. Ensuring scintillators and ECal can trigger at high rates
2. Identifying MIP signals in ECal above background
3. Ensuring GEMs work properly and can find tracks
4. Comparison with and benchmark of the SoLID simulation (**see Ye Tian's talk**)

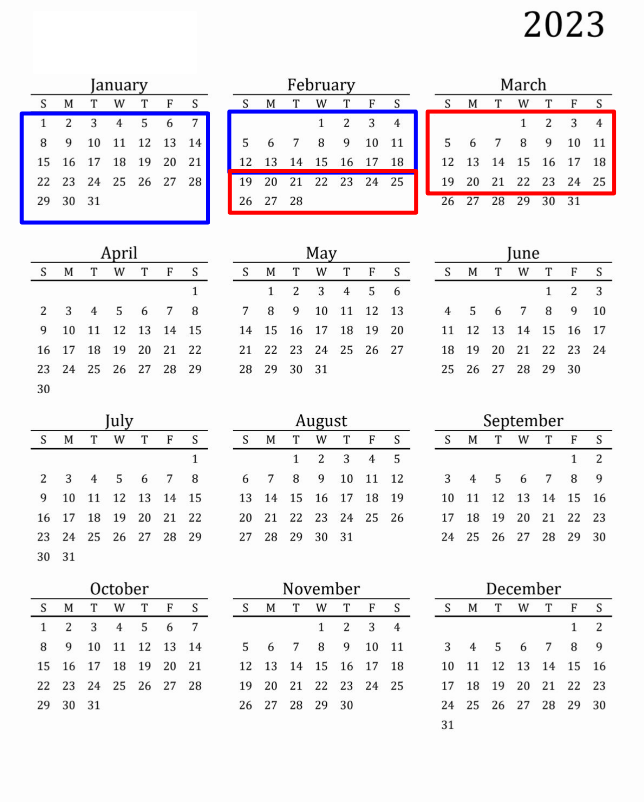
SoLID Beam Test Timeline

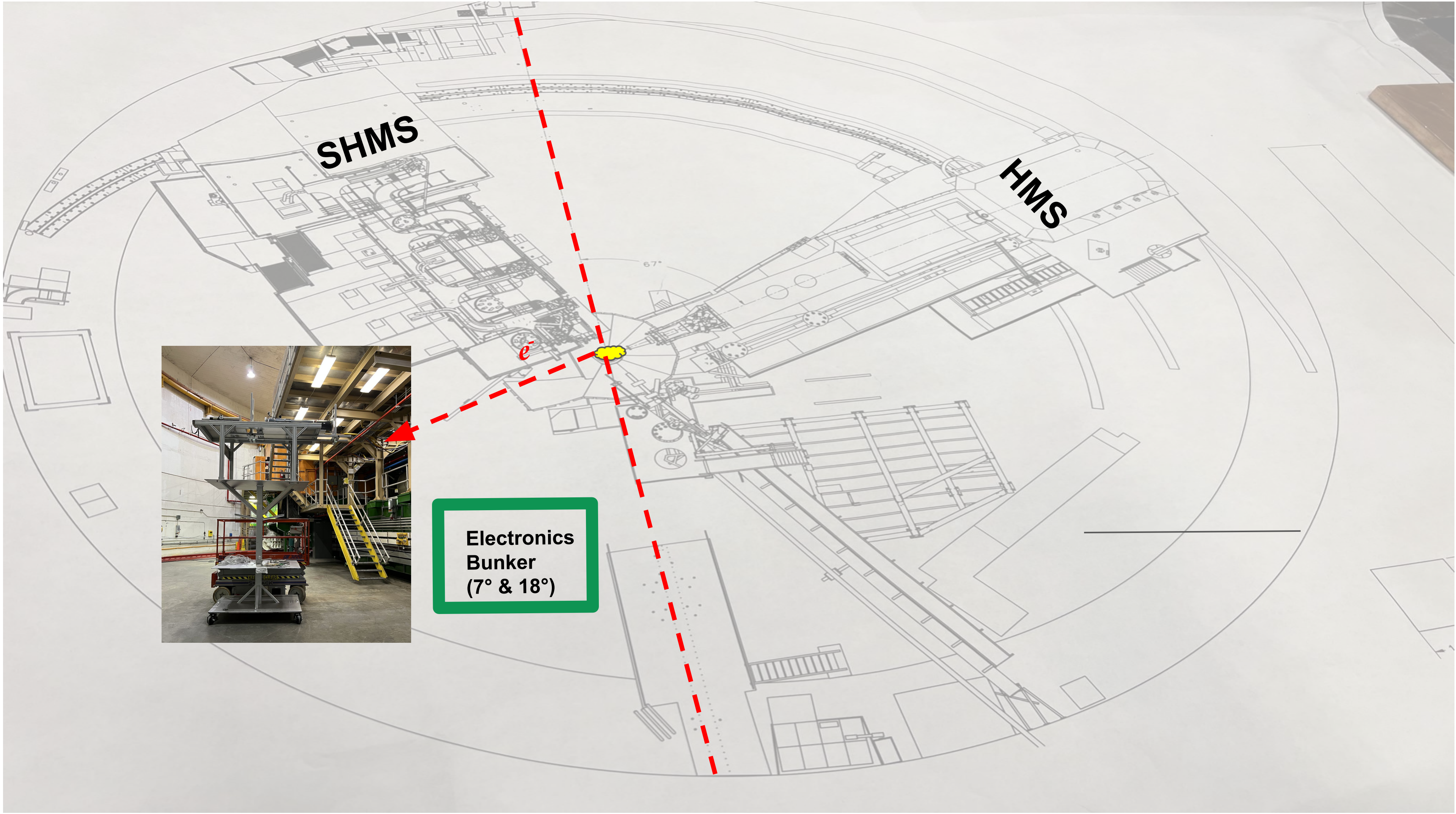


Data taken during

1. Pion L-T
2. XEM
3. Deuteron e^- Disintegration

- ☐ 82° setting
- ☐ 7° setting
- ☐ 18° setting



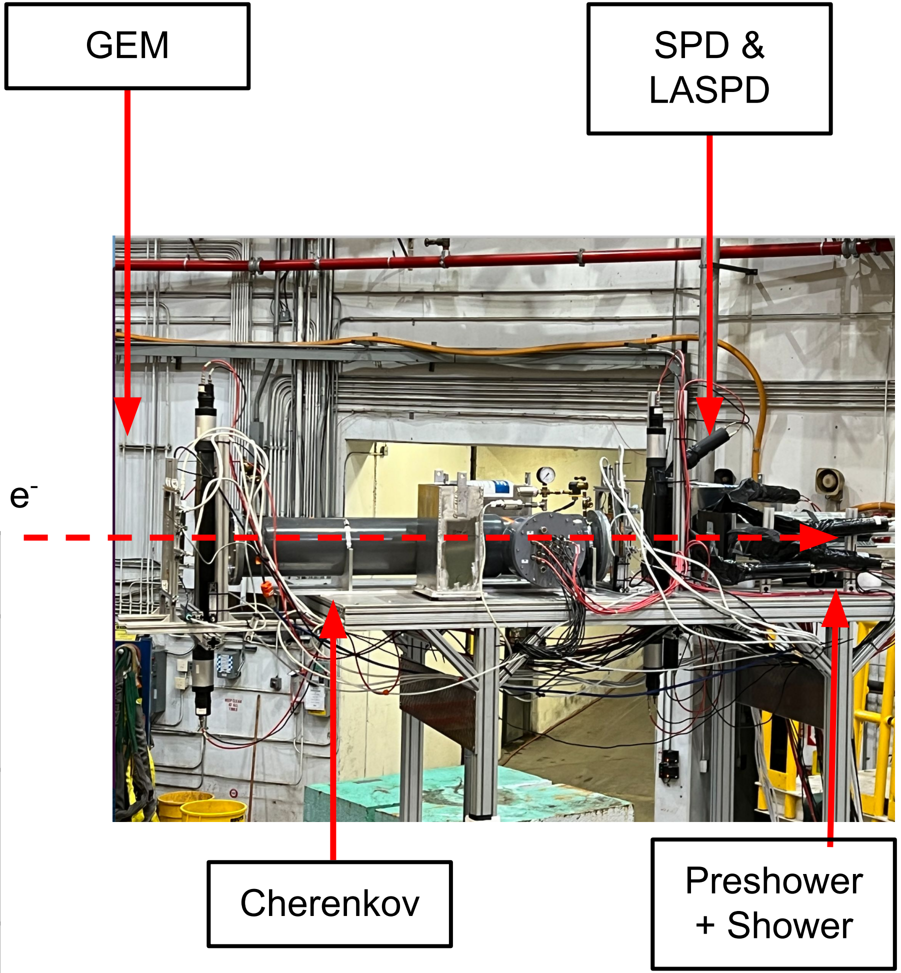

SHMS
HMS
e⁻
67°
Electronics
Bunker
(7° & 18°)

82°: Low Rate Setting

<u>Goals of Low Rate Setting</u>

1. Detector/trigger checkout and optimization
2. GEM setup
    - Only single upstream GEM (no tracking)
    - Used to identify clusters

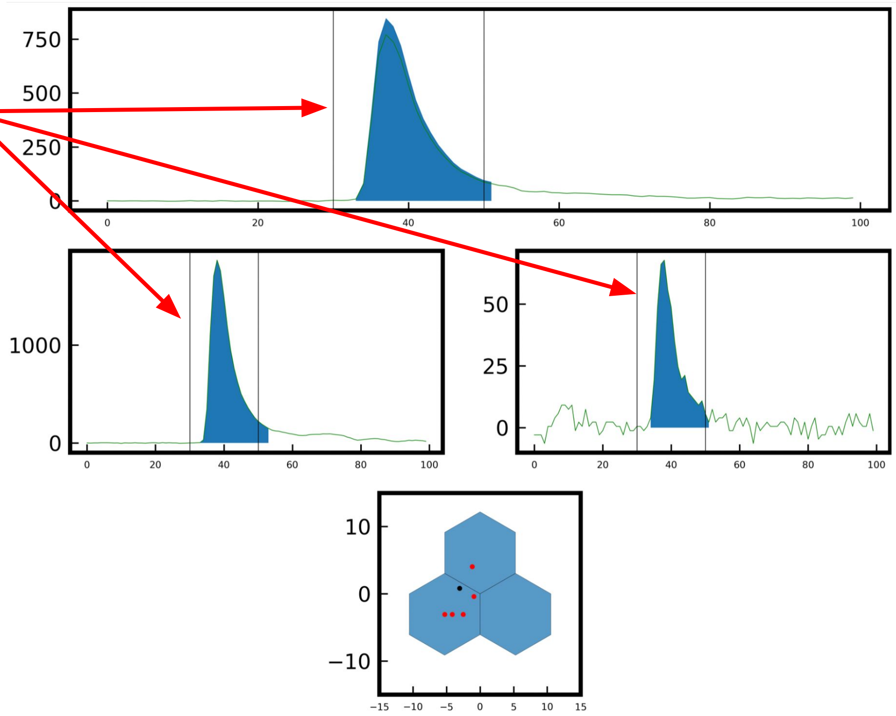
Trigger	Logic	Threshold*	Particle
TS 1	Scin 1 top .and. Scin 2 top	~20 mV	e^-
TS 2	Preshower Top .and. Shower Top	~20 mV	π
TS 3	Shower Sum	~20 mV	e^-

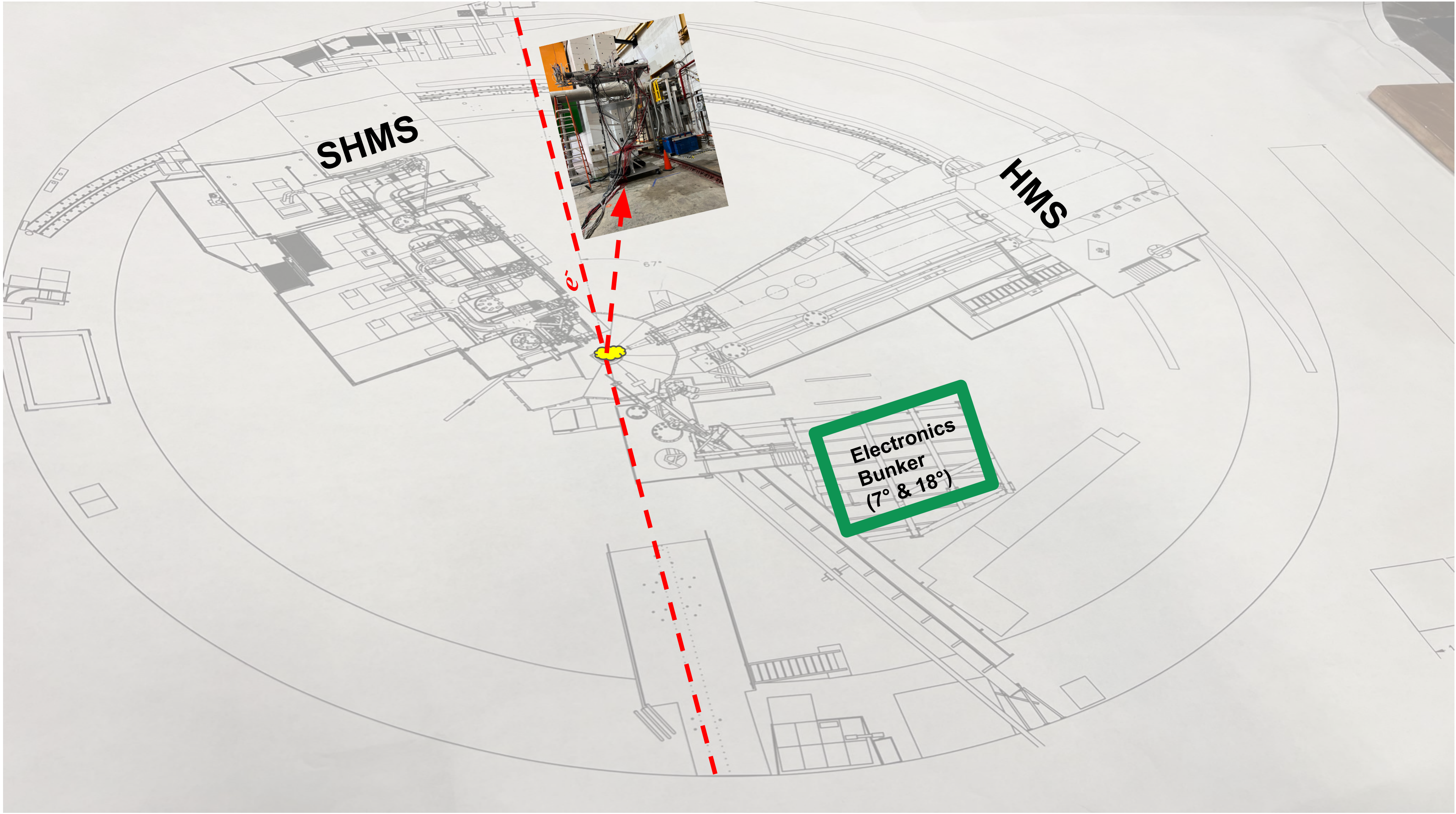


*Minimum NIM module threshold ~ 20 mV

82°: Low Rate Setting

- Detectors partially blocked when SHMS was below 15° (majority of the run low rate period)
- Recorded waveform information for each event
  - **Offline signal integration** (Jixie Zhang)
- Identified MIP in Preshower
  - Scintillators, SPD, and LASPD
- No MIP in Shower at 82°
  - Agreement with simulation
  - Shower spectra used for calibration



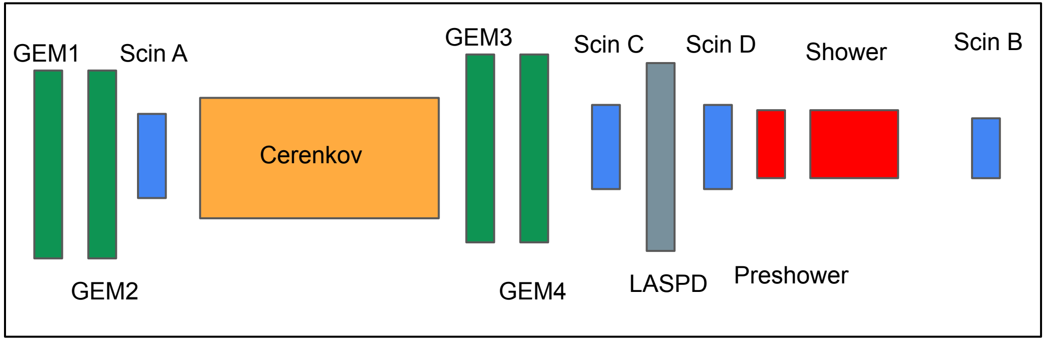


SHMS
HMS
e'
67°
Electronics
Bunker
(7° & 18°)

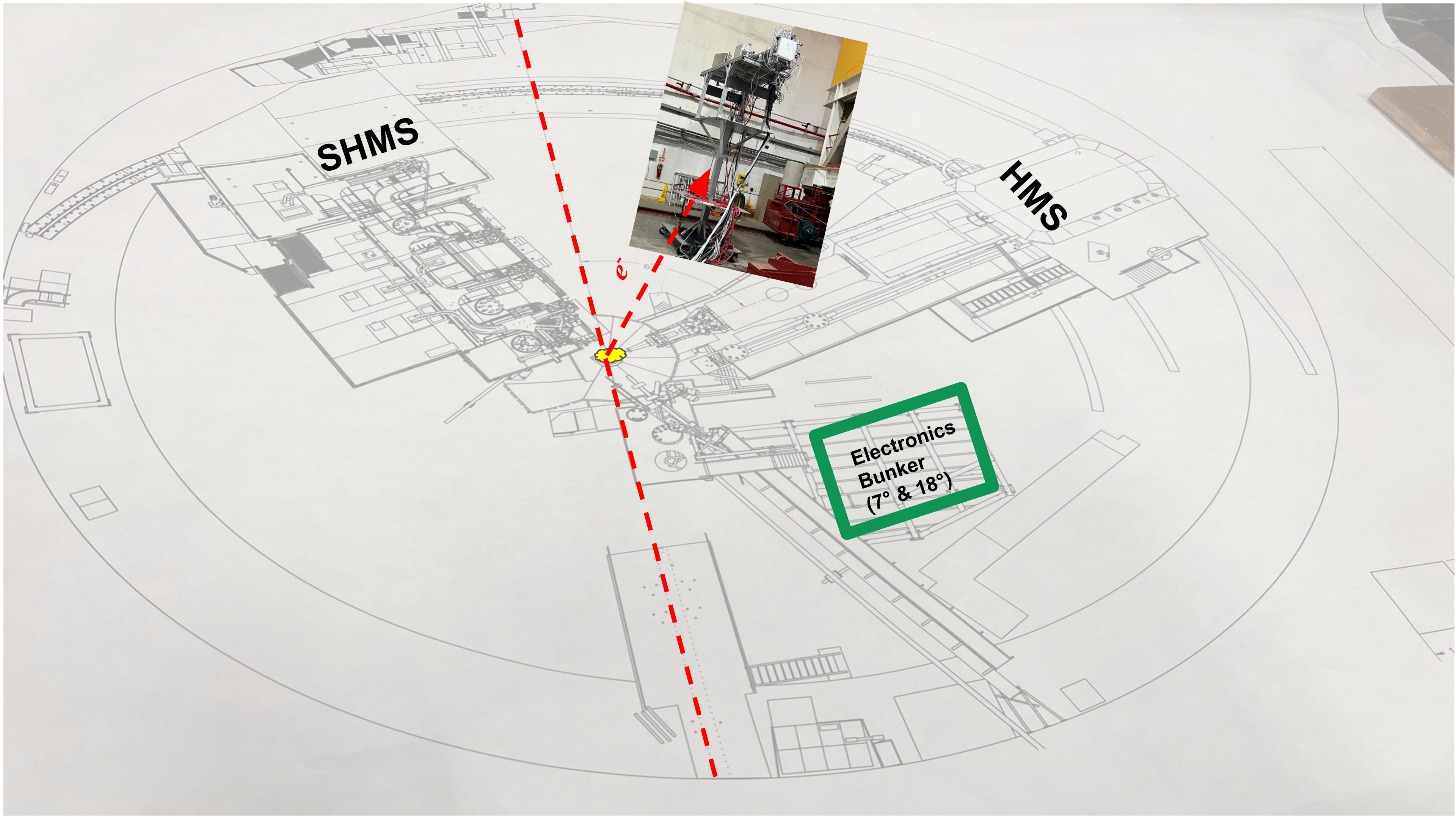
7°: High Rate Setting 1

- All 4 GEM layers included
- Removed both scintillators and FASPD
  - **Added 4 smaller scintillators**
- Remotely controllable threshold
- Dedicated 15 minutes runs each week
  - 3-5 μA (Lowest stable current)
  - Limited data with optimized GEMs
- Experimental dosimetry
  - ~150 kRad

Detector layout



Trigger Name	Logic	Particle	
TS 1	Cherenkov Sum + Shower Sum	e^-	SoLID e^- trigger
TS 2	Scin D + Shower Sum + Scin B	π	SoLID π like trigger
TS 3	Cherenkov Sum + Scin D + Shower Sum		⅔ Trigger (efficiency)
TS 4	Shower Sum	"clean" e^- or photon	
TS 5	Scin B	"clean π"	


SHMS
HMS
e'
Electronics
Bunker
(7° & 18°)

18°: High Rate Setting 2

- Data summary
  - Beam Current
    - High current: 40 - 65 μA
    - Low current: 10 μA (Boiling study)
    - Dedicated: 5 μA (short-Detector checkout)
  - Targets
    - Deuterium, Carbon, and Dummy
- Experimental dosimetry (on front GEM)
  - 70 kRad

Trigger Name	Logic	Threshold	Particle
TS 1	Cherenkov Sum + Shower Sum	Cherenkov: 2 pe Shower Sum: 0.5 mip	e
TS 2	Scin D + Scin B	0.5 mip	π
TS 3*	Scin A + Scin D		MIP
TS 4	Shower Sum	Variable	High energy e and γ
TS 5	2 out 16 Cherenkov		

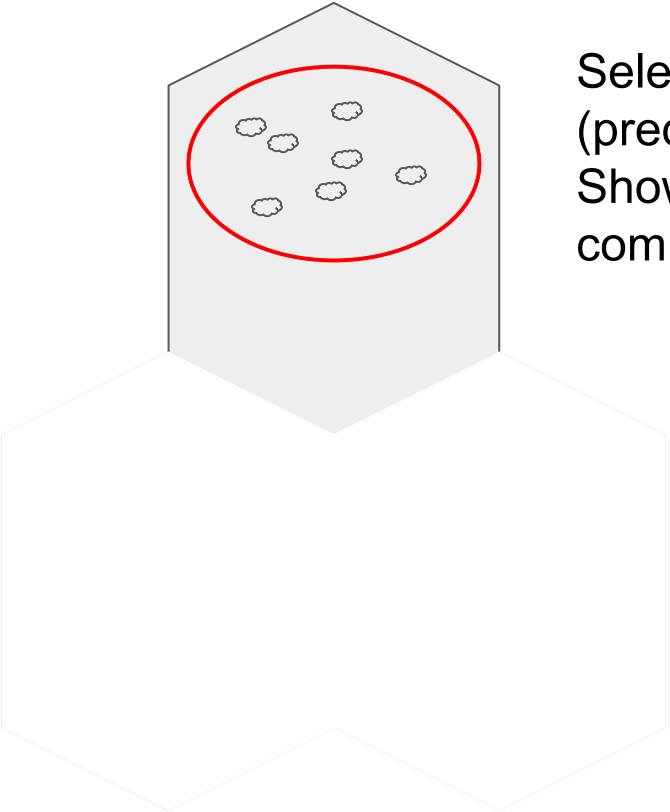
*TS 3 was modified due to the high rate in Scin A

TS 3 = Scin C + Scin D + Shower Sum

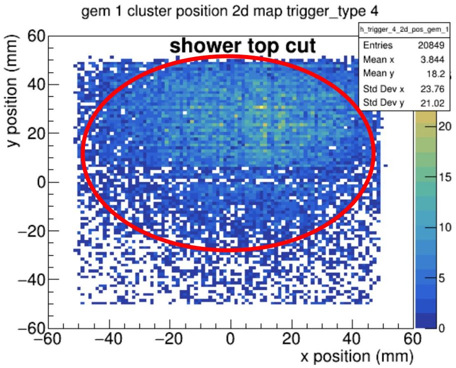
Summary of work since the last collaboration meeting

1. GEM optimization
2. Beam test comparison with simulation - see Ye Tian's update
3. SPD timing study (Carter Hedinger)
4. Pileup at high current
   a. Deconvolution algorithm implemented (Jixie Zhang)
5. Cherenkov SPE (Zhiwen Zhao & Bo Yu)
   a. Bench test with JLab Detector Group
6. Gain shift in shower pmt
7. **$\pi^{+/-}$ Rejection of ECal**
   a. Simulation - Machine Learning
   b. Simulation - Classical PID
   c. Data

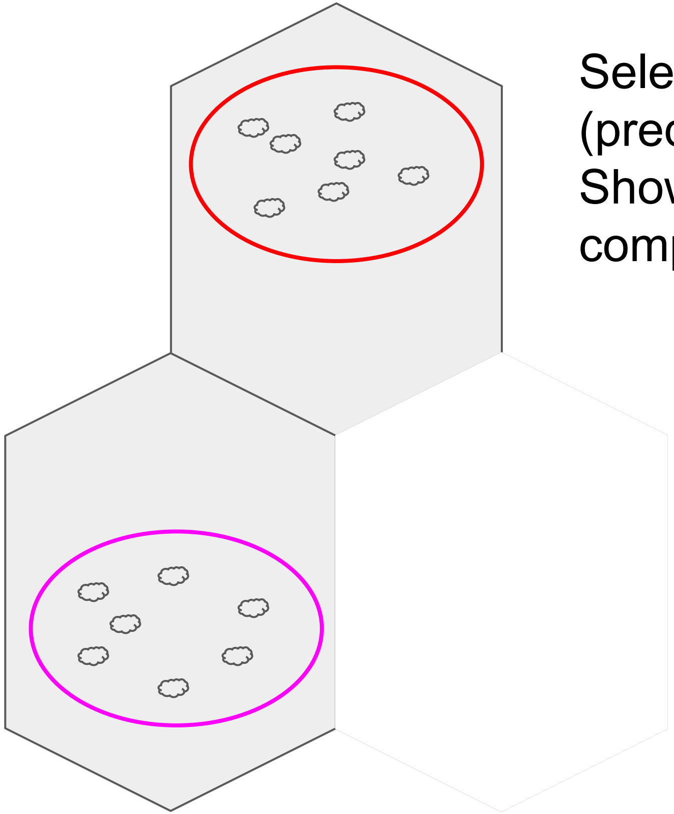
GEMs



Selecting events (predominantly) in Shower_t,l,r and compare GEM cluster



GEMs



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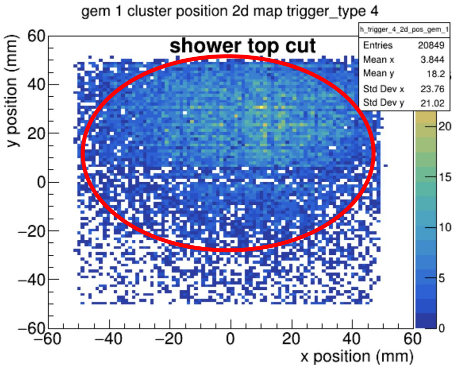
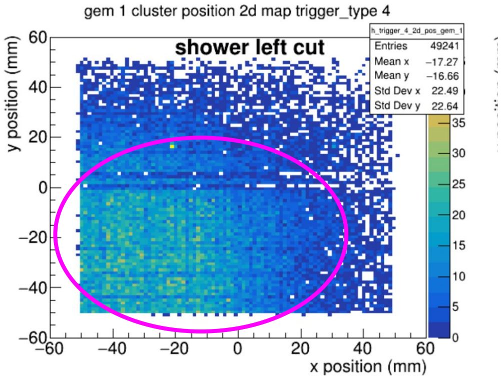
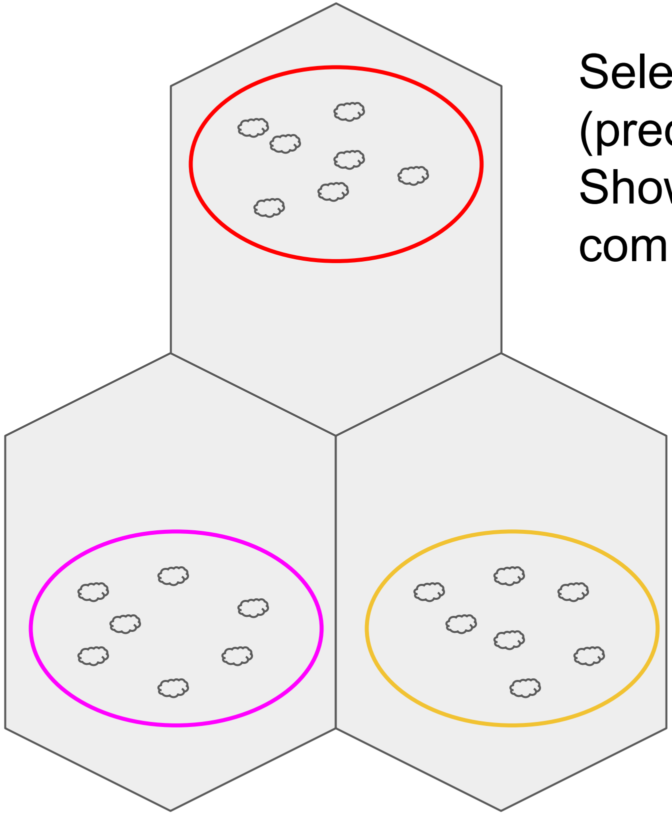




GEMs



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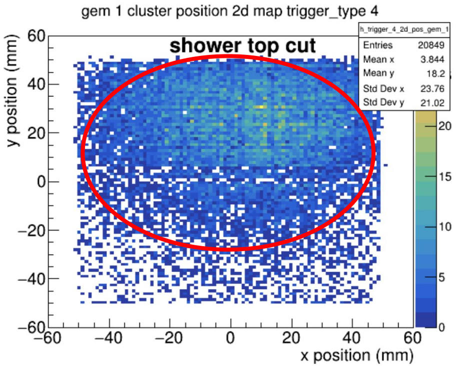
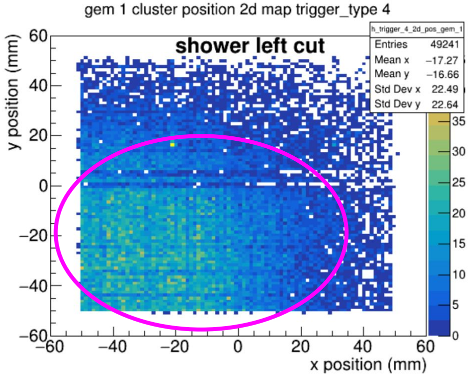
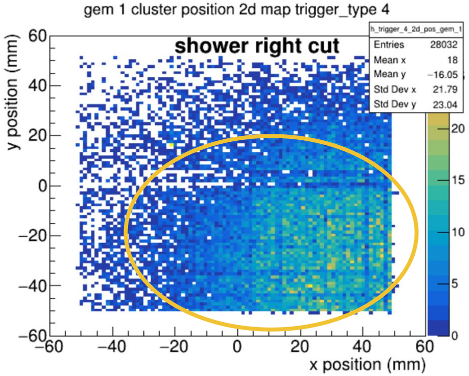
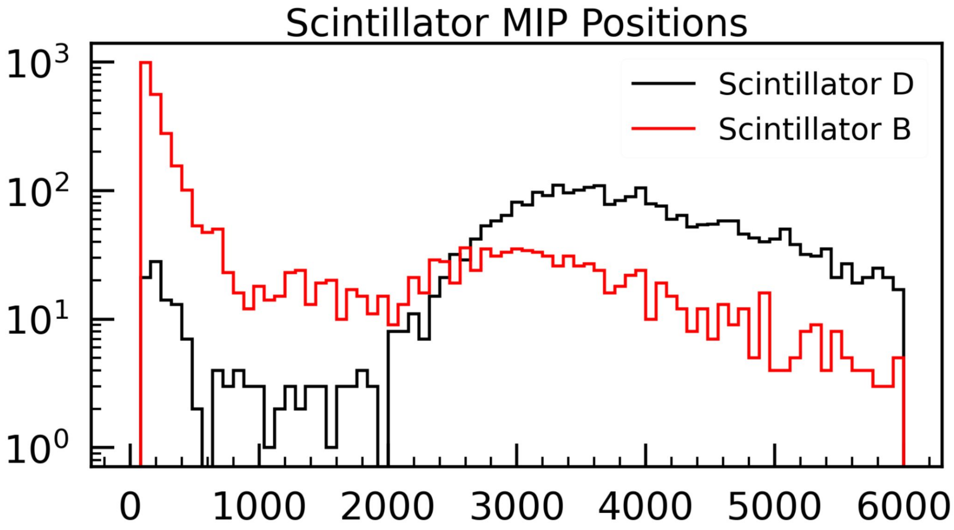


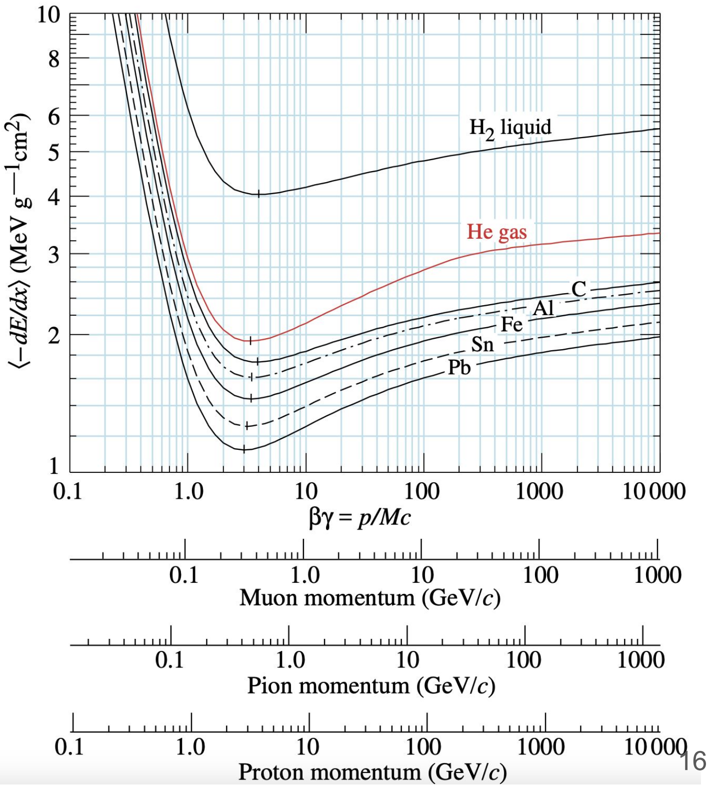




Detector Stability

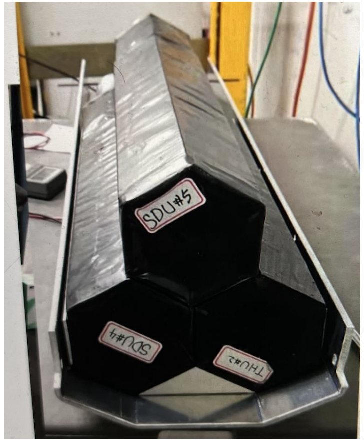
- Mean energy loss near minimum of ⟨dE/dx⟩
- Used for gain calibration and stability monitoring of detectors



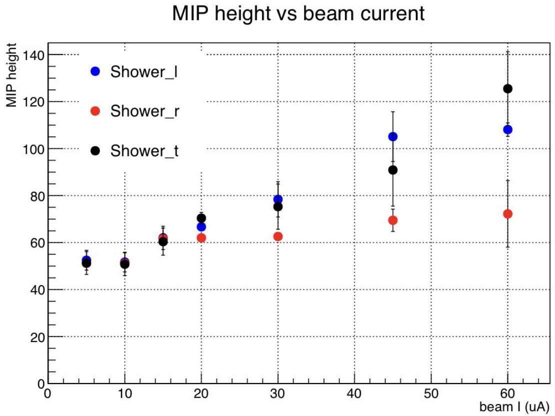


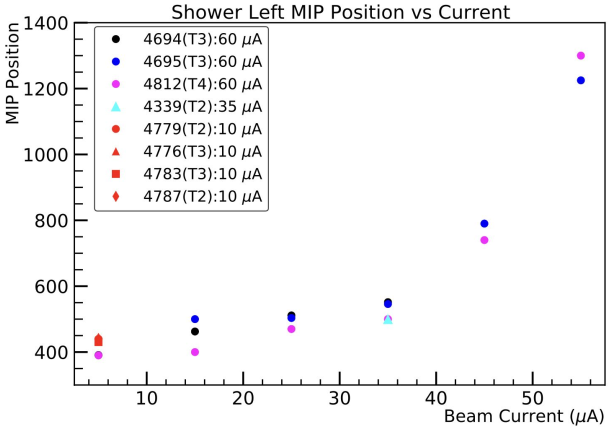
Detector Stability: Shower

- Mean energy loss near minimum of ⟨dE/dx⟩
- Used for gain calibration and stability monitoring of detectors
- Shower modules experienced a (non-linear) increase in HV with increase in beam current
- Used passive PMT bases



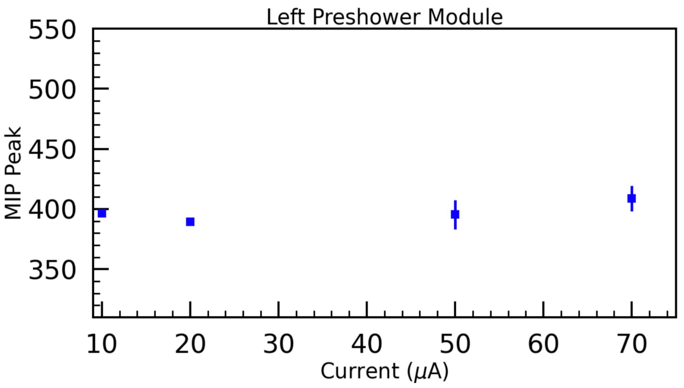
See Richard Trotta's talk on future plans on Ecal & SPD

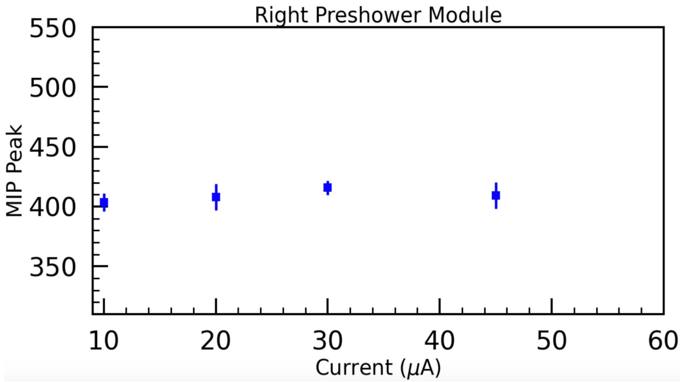


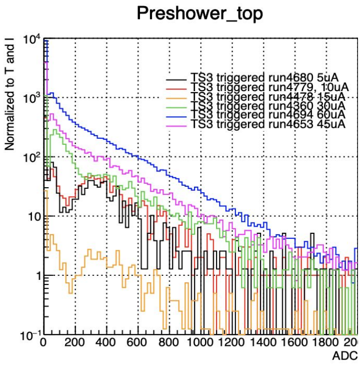


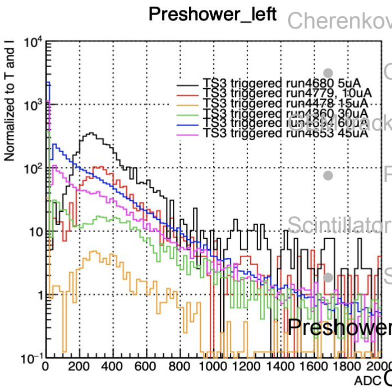
Detector Stability: Preshower

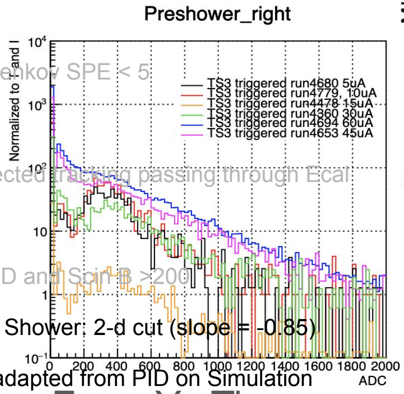
- Mean energy loss near minimum of⟨dE/dx⟩
- Used for gain calibration / stability
- Shower modules experienced a (non-linear) increase in HV with increase in beam current
- Preshower modules appeared stable during 18° setting











Cuts

Cherenkov

- Cherenkov SPE < 5

Track

- Projected tracking passing through Ecal

Scintillators

- Scin D and Scin B >200

Preshower vs. Shower: 2-d cut (slope = -0.85)

Cut adapted from PID on Simulation

From Ye Tian

Particle Identification: Electromagnetic Calorimeter

e^- Efficiency:

Not possible without momentum selection

Dominated by low energy background

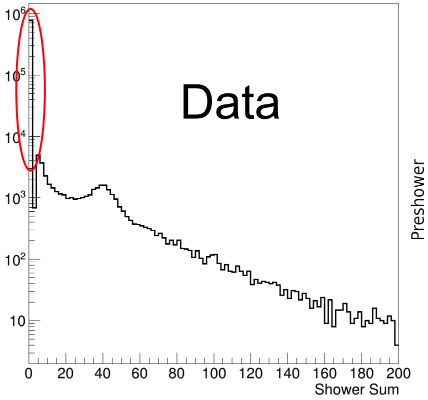
$\pi^{+/-}$ Rejection:

Comparison with SoLID simulation

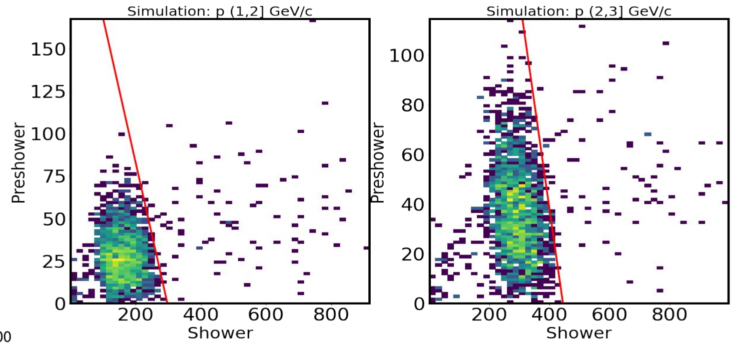
Comparison with SoLID pre-CDR

SoLID pre-CDR

	Desired performance
π^- rejection	$\gtrsim$[50:1]
e^- efficiency	$\gtrsim$90%
Energy resolution	$< 10\%/\sqrt{E}$
Radiation resistance	$\gtrsim$400 kRad
Position resolution	$\lesssim$1 cm



Electron Distribution: Simulation



Cuts

Cherenkov

- Cherenkov SPE < 5

Scintillator Coincidence timing

- Scin D and Scin B

Scintillator cuts

- Scin D > 3000 and Scin D <5000

Preshower vs. Shower: 2-d cut (slope = -0.85)

Cut adapted from PID on Simulation

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Cut adapted from PID on Simulation

Analysis Effort Tasks

1. Detector stability completed
2. $\pi^{+/-}$ Rejection will be completed in ~ 1-2 weeks

Summary and Conclusion

- Recent beam test has provided opportunity to
  - Study detector performance in high luminosity + background environment
  - Make comparison with SoLID simulation
- Shower base exhibited current dependent behavior
  - Due to passive PMT base
- Preshower stable during 18° setting
- Particle ID studies largely complete
  - $\pi^{+/-}$ Rejection of Ecal
- Documentation and summary report
  - Technical notes summarizing work and analysis
- Test data provide foundation for possible future AI/ML PID work

Thank You

Hall A/C staff, Hall C Technical Staff, Hall C Engineering Staff, RADCON, and (all) the running experiments

MIP Summary

- Shower modules experienced a (non-linear) increase in HV with increase in beam current
- Behavior was observed in test for NPS passive PMT bases (2012)
  - Passive bases used in beam test shower modules
- Left shower module (closest to beamline)
  - Started to fail around 60 μA
  - Recovered and continued to work properly at low currents
- Possible future bench test to further understand behavior with these bases

New Photomultiplier Active Base for Hall C Jefferson Lab Lead Tungstate Calorimeter

[1]Vladimir Popov, [2]Hamlet Mkrtchyan

[1]RADCON/ESH&Q, Thomas Jefferson National Accelerator Facility, Newport News, Virginia, USA
[2]A. I. Alikhanyan National Science Laboratory (Yerevan Physics Institute), Yerevan, 0036, Armenia.

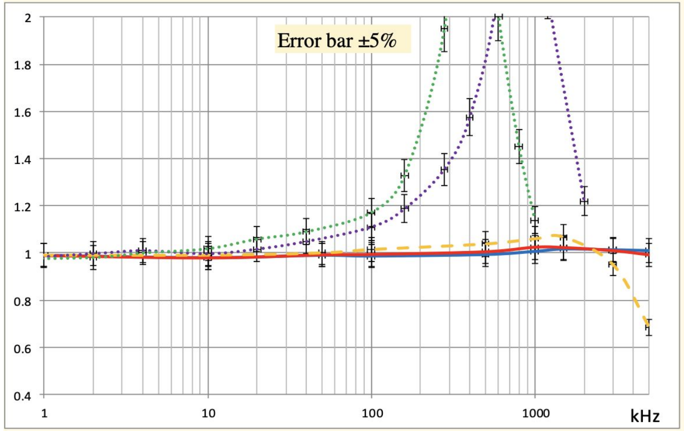

Fig. 6 Normalized gain as a function of pulse repetition rate of $PbWO_4$ scintillator similar LED light source.
Active base, initial amplitude: —— 300mV; —— 600mV; – – 1000mV
Passive base, initial amplitude: ····· 300mV; ····· 600mV