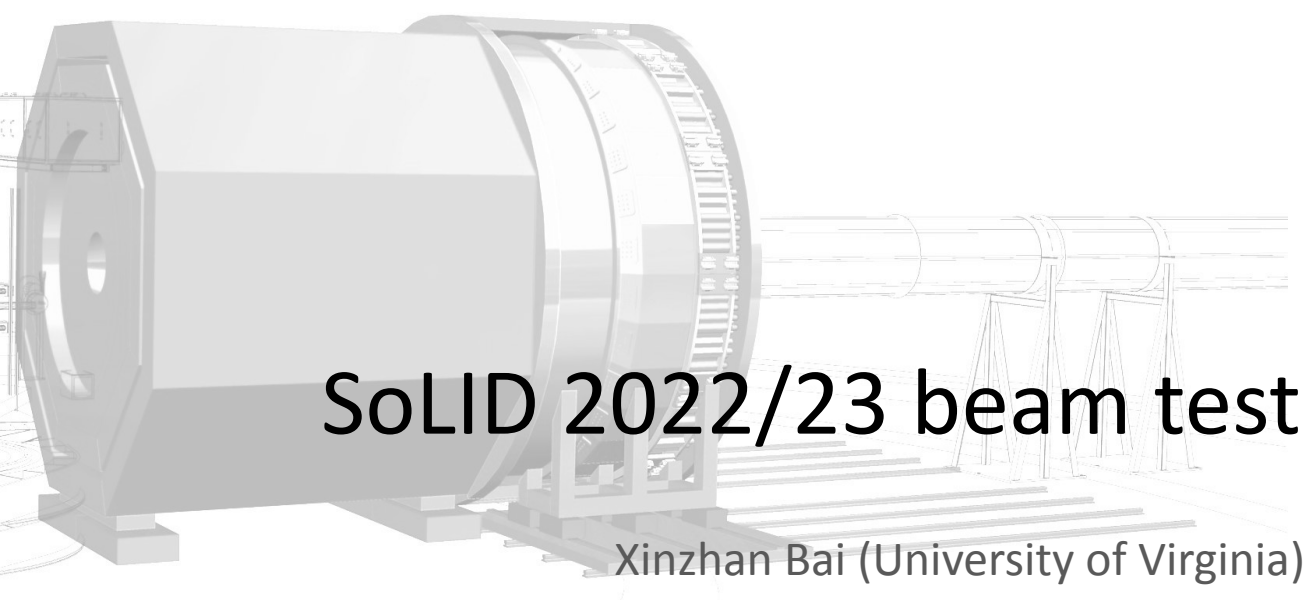


SoLID 2022/23 beam test update

Xinzhan Bai (University of Virginia)

Jan. 26, 2023

(for Jimmy Caylor, Michael Nycz, Ye Tian, Darren Upton, Jixie Zhang, Zhiwen Zhao, Xiaochao Zheng

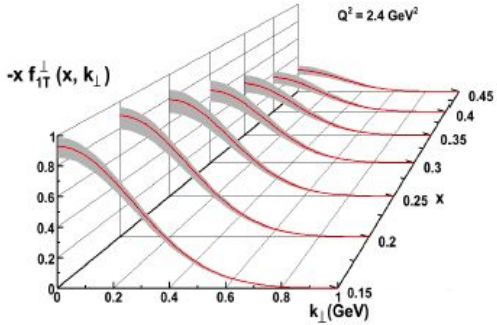
And the SoLID Collaboration)

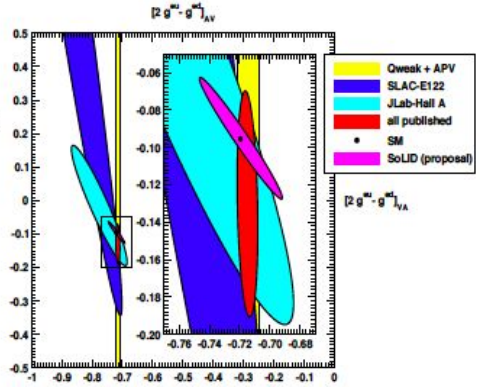
SoLID Overview

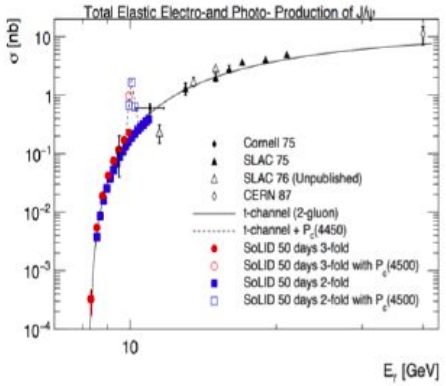
- **Full exploitation of JLab 12 GeV Upgrade to maximize scientific return**

A Large Acceptance Detector AND Can Handle High Luminosity (10^{37}-10^{39})

- SIDIS - reaching ultimate precision for tomography of the nucleon (E12-10-006, E12-11-007, E12-11-108)
- PVDIS in high-x region - providing sensitivity to new physics at 10-20 TeV (E12-10-007)
- Threshold J/ψ - probing strong color fields in the nucleon and the origin of its mass (trace anomaly) (E12-12-006)







- **2015 LRP recommendation IV**

- We recommend increasing investment in small-scale and mid-scale projects and initiatives that enable forefront research at universities and laboratories – **SoLID – mid-scale project**

Hot & Cold QCD Town Meeting Recommendations

Recommendation 1: Capitalizing on past investments

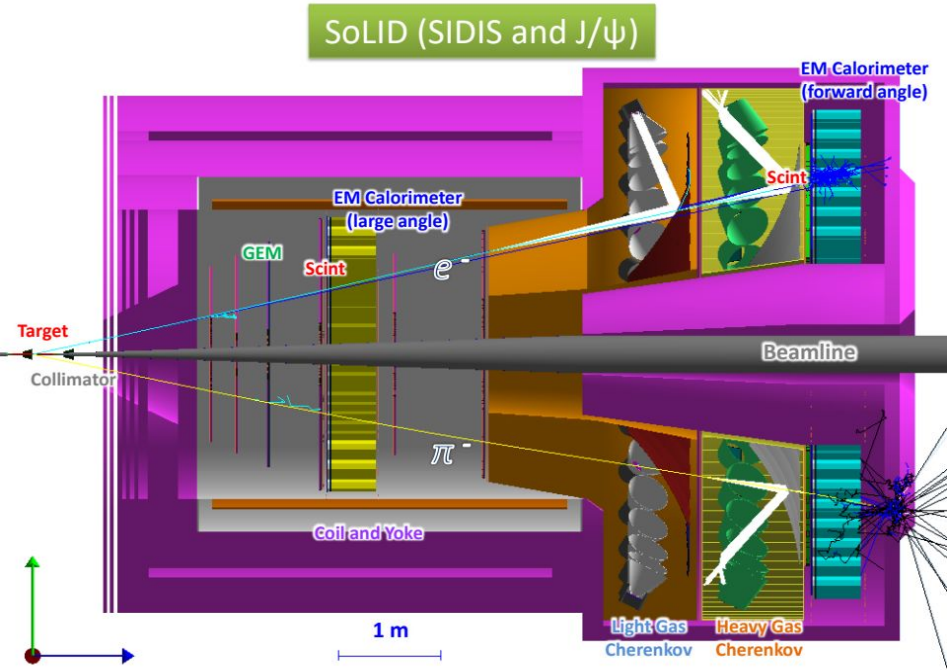
The highest priority for QCD research is to maintain U.S. world leadership in nuclear science for the next decade by capitalizing on past investments. Maintaining this leadership requires recruitment and retention of a diverse and equitable workforce. We recommend support for a healthy base theory program, full operation of the CEBAF 12-GeV and RHIC facilities, and maintaining U.S. leadership within the LHC heavy-ion program, along with other running facilities, including the valuable university-based laboratories, and the scientists involved in all these efforts.

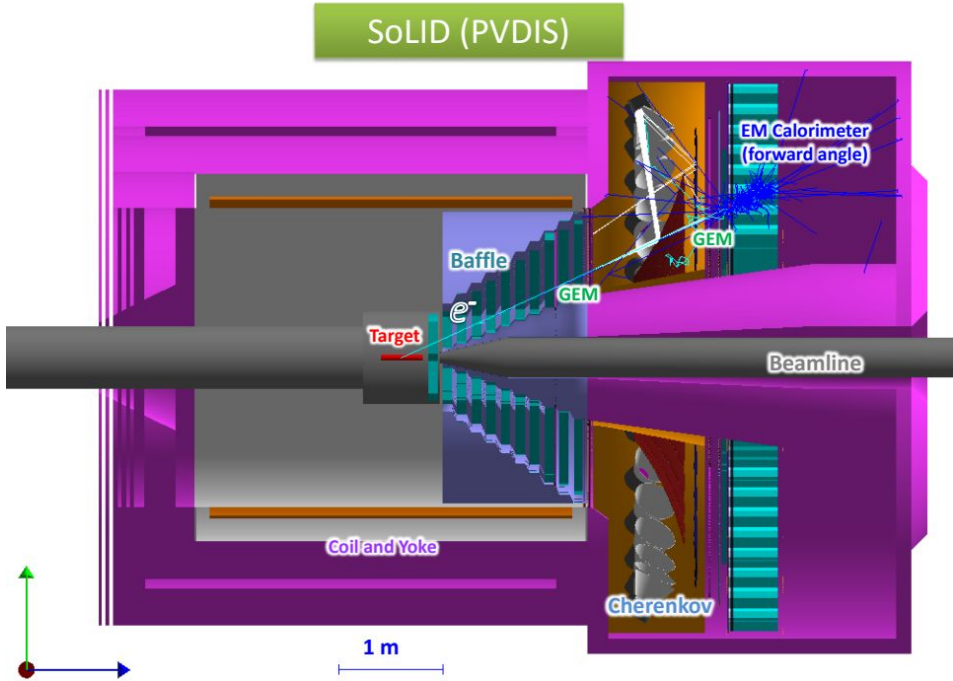
This includes the following, unordered, programs:

- The 12-GeV CEBAF hosts a forefront program of using electrons to unfold the quark and gluon structure of visible matter and probe the Standard Model. We recommend executing the CEBAF 12-GeV program at full capability and capitalizing on the full intensity potential of CEBAF by the construction and deployment of the Solenoidal Large Intensity Device (SoLID).
- … (RHIC)
- … (LHC)
- … (Theoretical nuclear physics)

SoLID Apparatus

- Two configurations



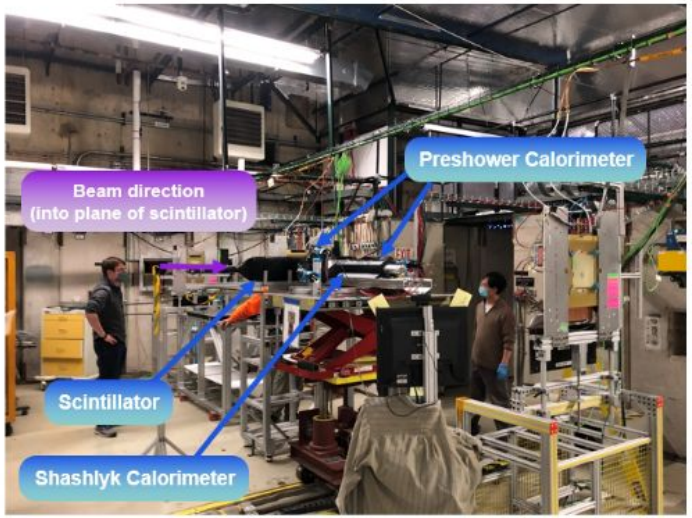


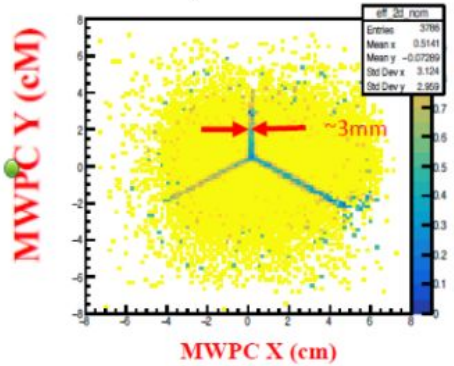
Beam Test Overall Status

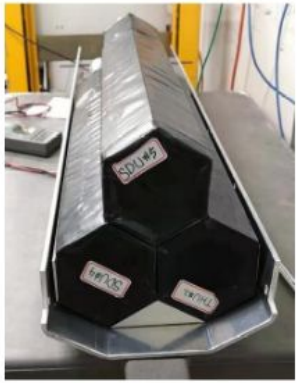
- Cherenkov detector was tested at high rate condition in July-September 2020, Hall C - lead by Simona, et al.
- ECal was tested at Fermilab Test Beam Facility (FTBF) with a focus on energy and position resolution
- Current Detector test in Hall C
  - Goals
    - Benchmarking simulation of rate and background
    - Study ECal and LASPD performance under high rate, high radiation, high background condition
    - Study ECal and LASPD PID
  - Status
    - September – December 2022: low rate test at 82 deg, SHMS side (beam left)
    - Winter break 2022/23: cosmic calibration
    - January – February 2023: high rate test at 7 deg, HMS side (ongoing)
    - February – March 2023: high rate test at 20 deg, HMS side

Ecal Test at FermiLab Test Beam Facility (FTBF)

- Jan 13—27, 2021
- **Goal:** Determine the detector resolution and efficiency of preshower and shower calorimeter modules
- **Detectors:**
  - Preshower: 2-cm thick Pb blocks (x3)
  - Shower: Shashlyk (Pb + scintillator layers), 80-cm long (x3)
  - Scintillator used for triggering
- **FNAL beam parameters**
  - Composition: Mixture of e-, π-
  - Energies: 1, 2, 4, 6, 8, 10, 12, 16 GeV







- Beam test with 3 modules of Ecal using the secondary electron and pion mixture beam at FTBF
- The position resolution of the Ecal and is ~~1.36 cm (horizontal) and 0.72 cm (vertical)~~

0.8 cm in both X and Y directions

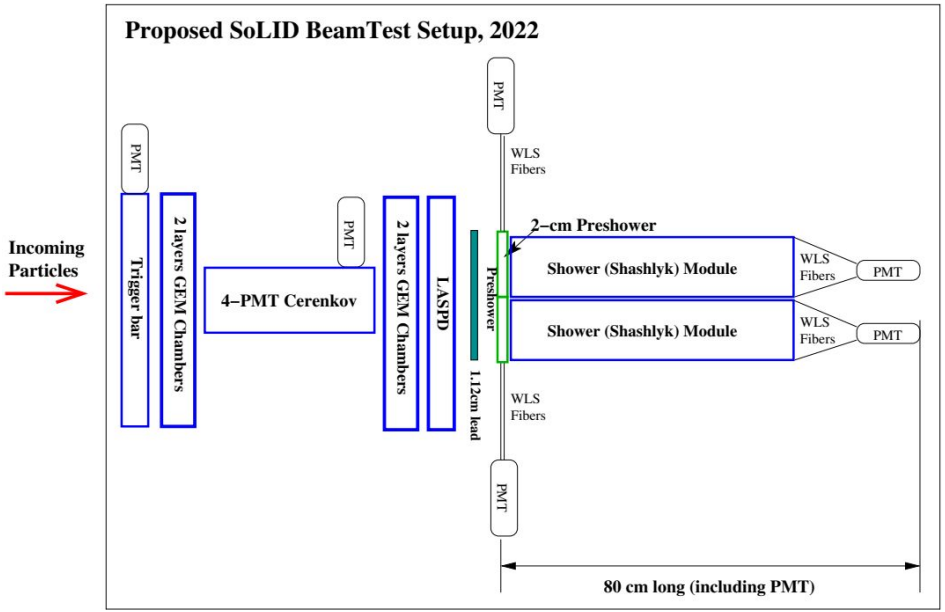
- Energy resolution of the Ecal $\frac{\sigma_E}{E} = 4.6\% \oplus \frac{10.4\%}{\sqrt{E}}$ PRELIMINARY

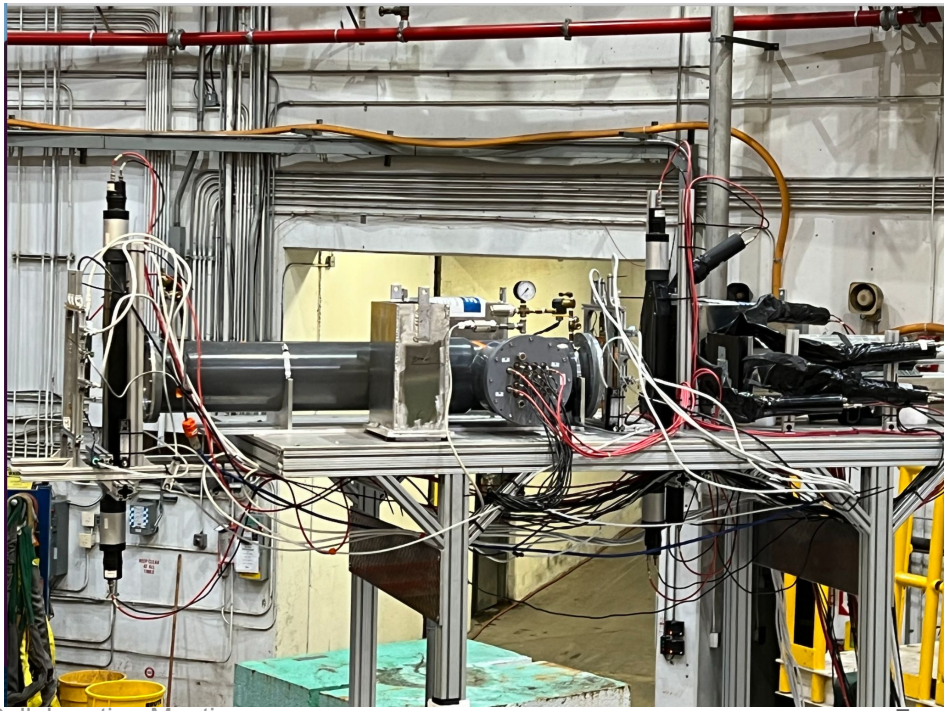
This work was led by X. B., Alexandre Camsonne, Jixie Zhang; analysis led by Jixie Zhang, Zhenyu Ye; Simulation support by Ye Tian

Slide Courtesy of Bishnu Karki

Hall C Beam Test Setup (low rate)

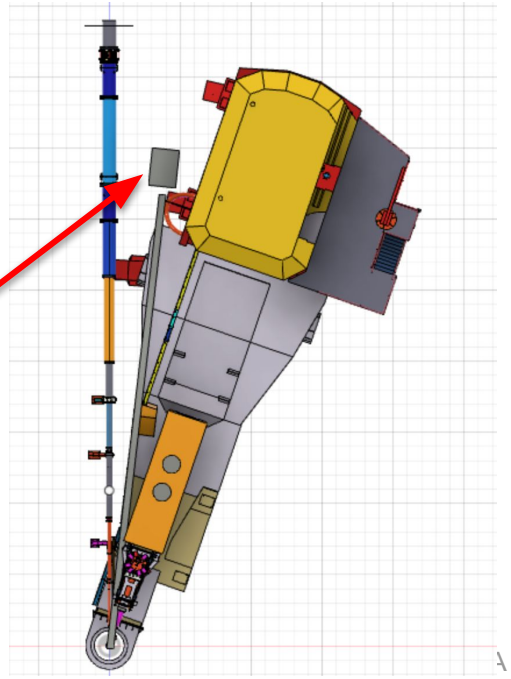
- Front to back: SC, GEM1, Cer, GEM2, SC, LASPD, Preshower, Shower





Hall C Beam test setup (high rate)

- Front to back GEM1+2, SC-A, Cer, GEM3+4, SC-C, LASPD, Preshower, Shower, SC-B
- Two test conditions: 7 and 20 degree

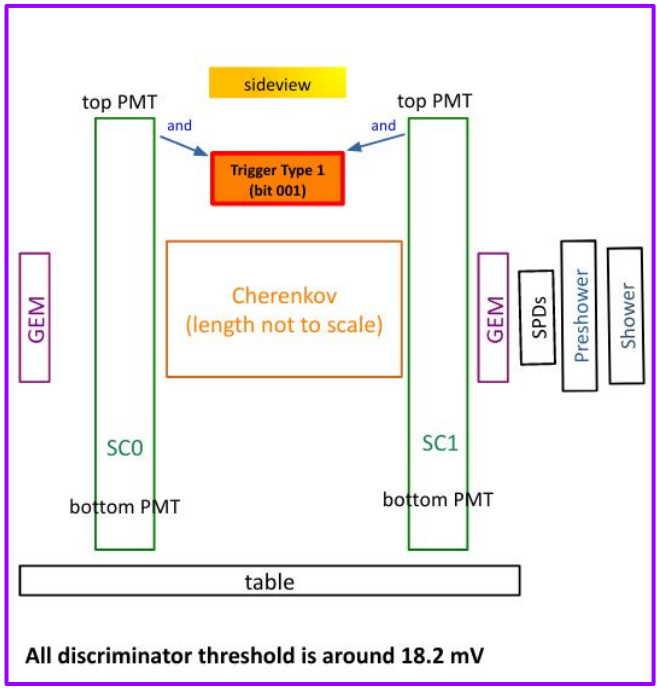


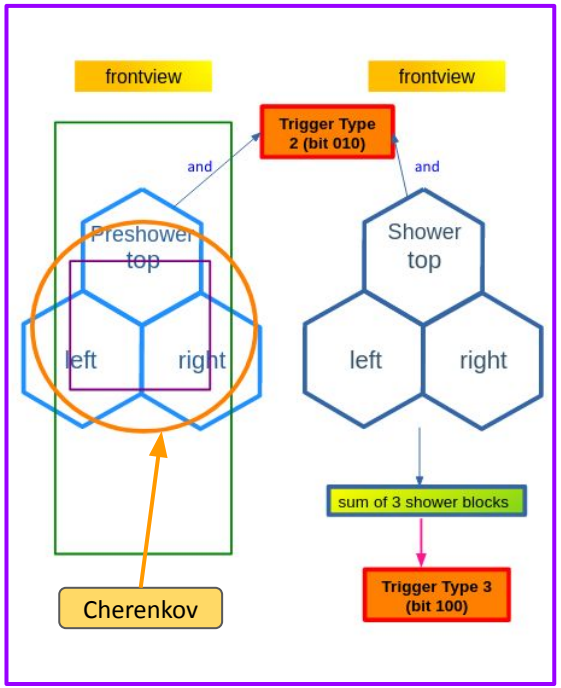
Small angle location

Trigger Configuration for Low Rate Test

- 3 trigger configurations for low rate test

Trigger	Bit	TrigType	Condition
TS1	0001	1	SC0_t, SC1_t
TS2	0010	2	PreSh_t, Shower_t
TS3	0100	4	ShowerSum



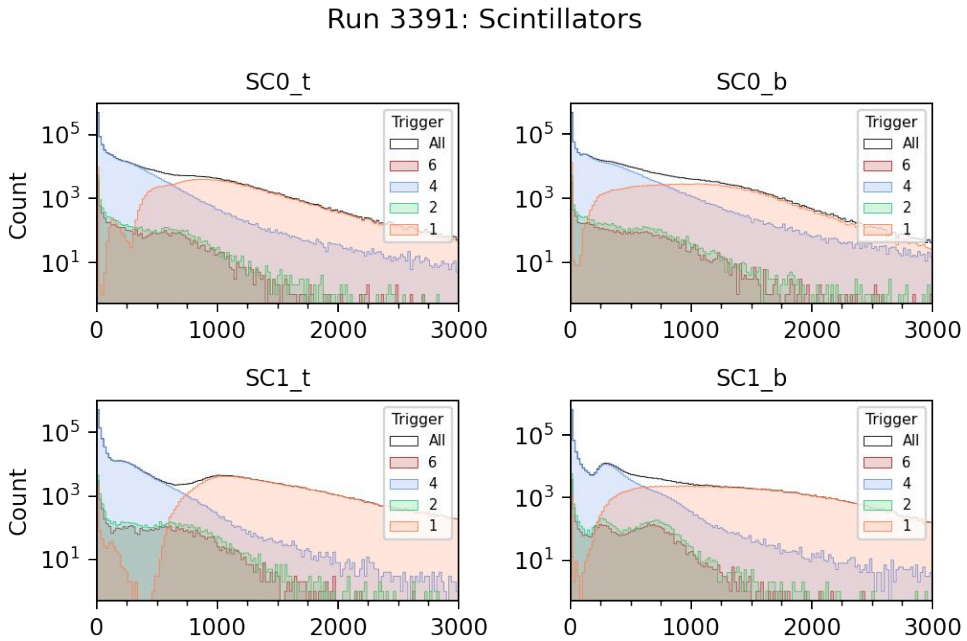


Low Rate Test

- Identified MIP in scintillators and preshowers; at our current HV setting
- Determine threshold for comparison with simulation (off-line)

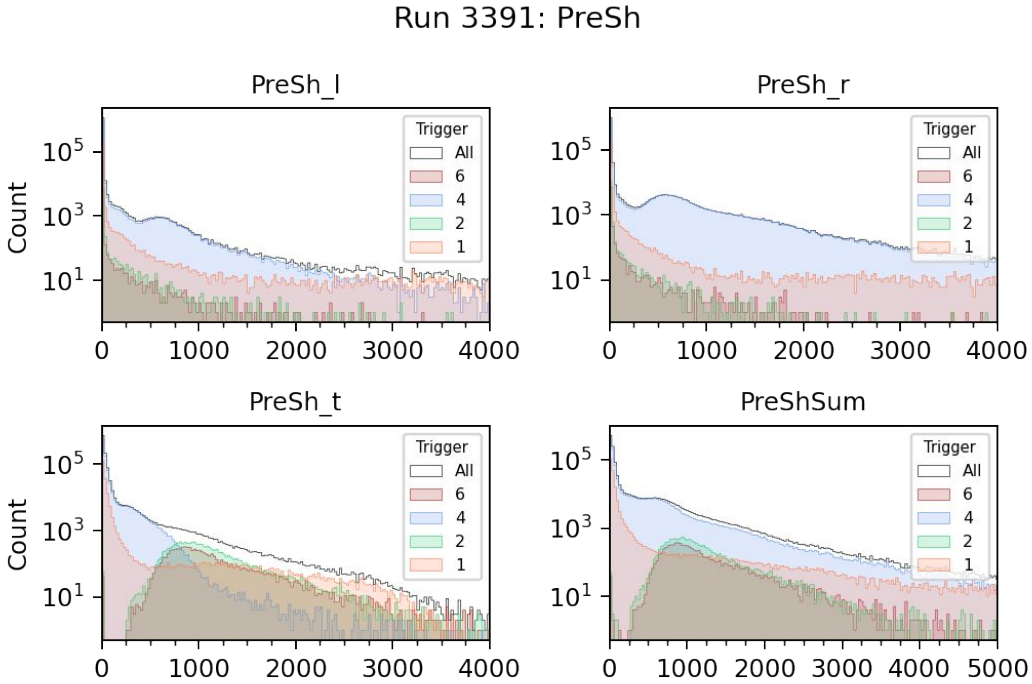
Variable	MIP 1	MIP 2	Thresh
SC0 Top	394	699	373
SC0 Bottom	362	703	163
SC0 Sum	739	1414	625
SC1 Top	264	775	669
SC1 Bottom	258	682	236
SC1 Sum	261	1506	997

Analysis by Darren Upton (UVA)



Low Rate Test

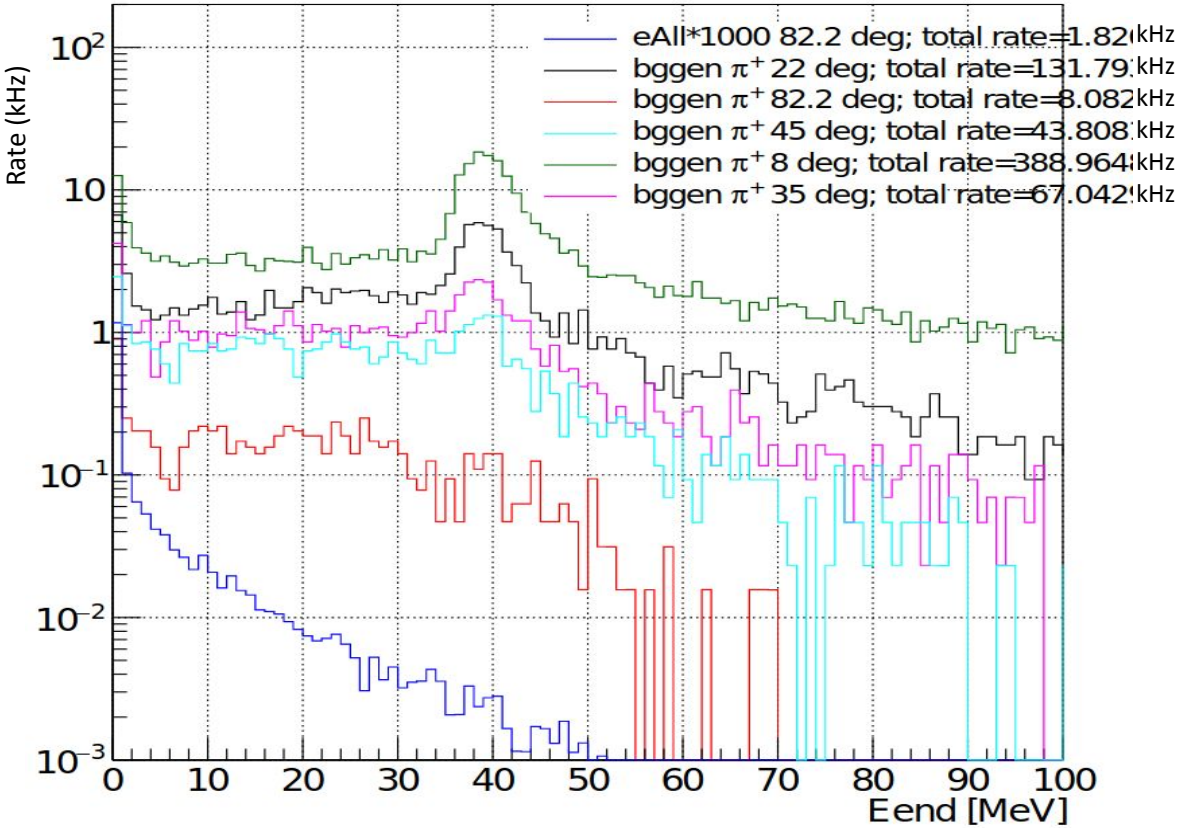
- Identified MIP in scintillators and preshowers
- Determine threshold for comparison with simulation (off-line)



Analysis by Darren Upton (UVA)

Low Rate Test

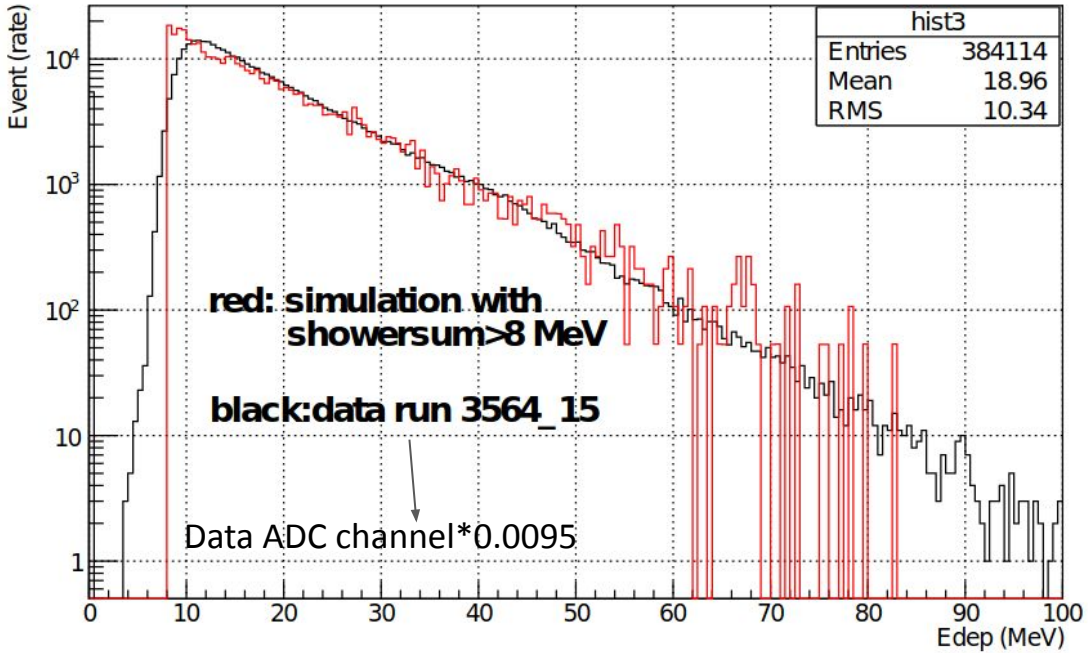
- Do not expect to see MIP at 82 deg in the Shower



Simulation by Ye Tian (Syracuse)

Shower Calibration with the Simulation

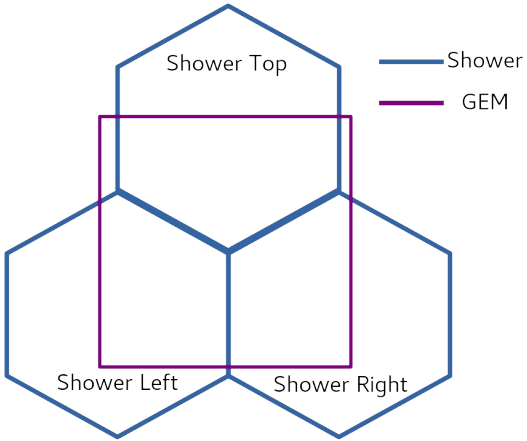
- At 82 deg, the shower deposit energy tail follows an exponential function for both the simulation and the data, providing an alternative method for “calibration” in the absence of MIP peaks



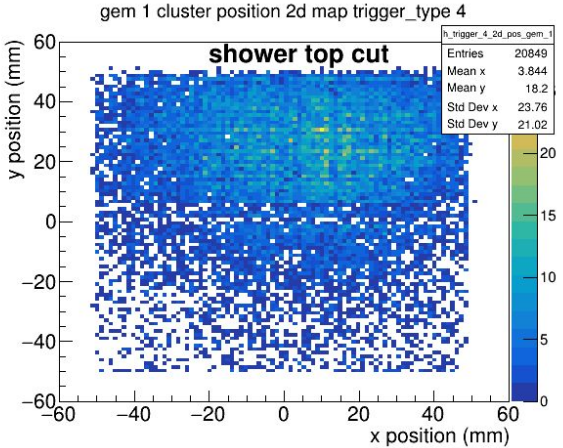
Simulation by Ye Tian (Syracuse)

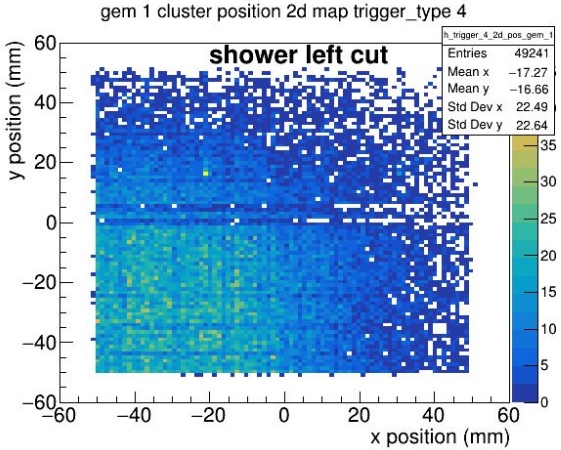
Low Rate Test

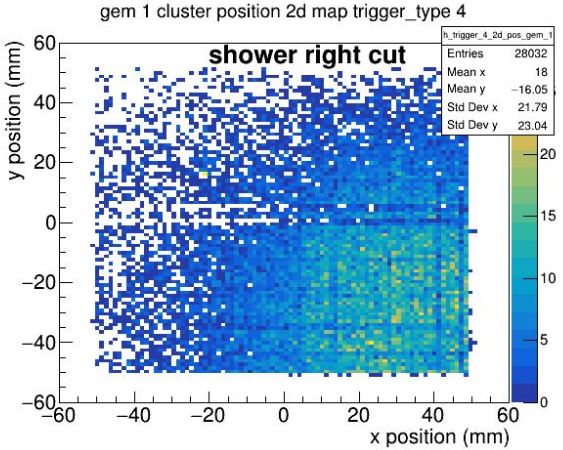
- Two 10 cm X 10 cm small GEM detectors
- First GEM installed upstream, before the Cherenkov detector, the second GEM behind the Cherenkov, in front of the Pre-shower and Shower detectors, roughly 1.5 meters apart
- 4 GEM chambers already installed for high rate test



GEM and Shower Layout





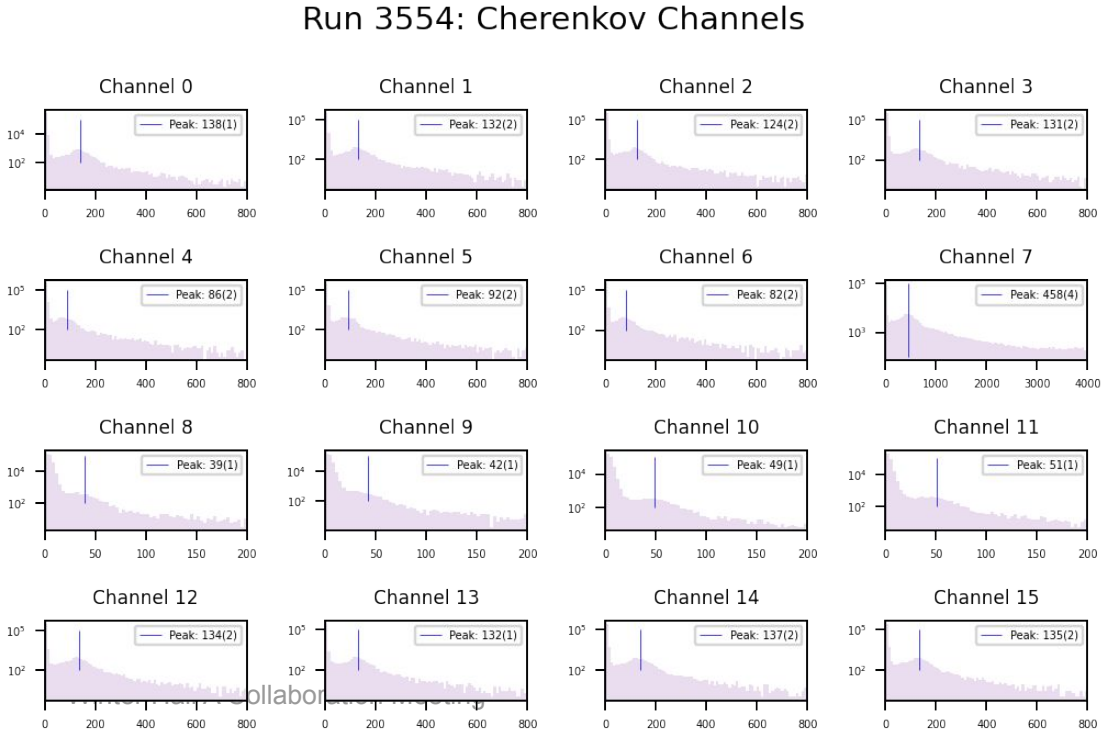


Analysis by Jimmy Caylor (Syracuse)

Low Rate Test

- Cherenkov performance (HV at -1000V, too high, waveform distorted)
- Channel 7 has large noise -> disabled in analysis

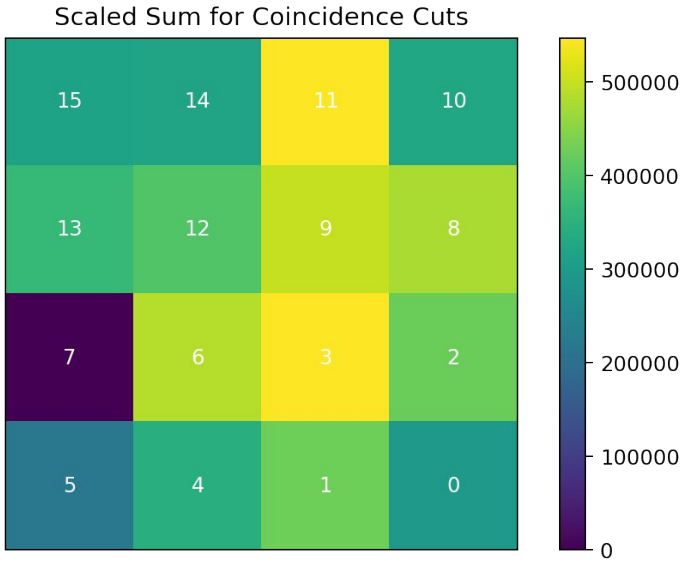
Cherenkov Channel Spectrum and Fitted Single photoelectron peak (SPE peak)

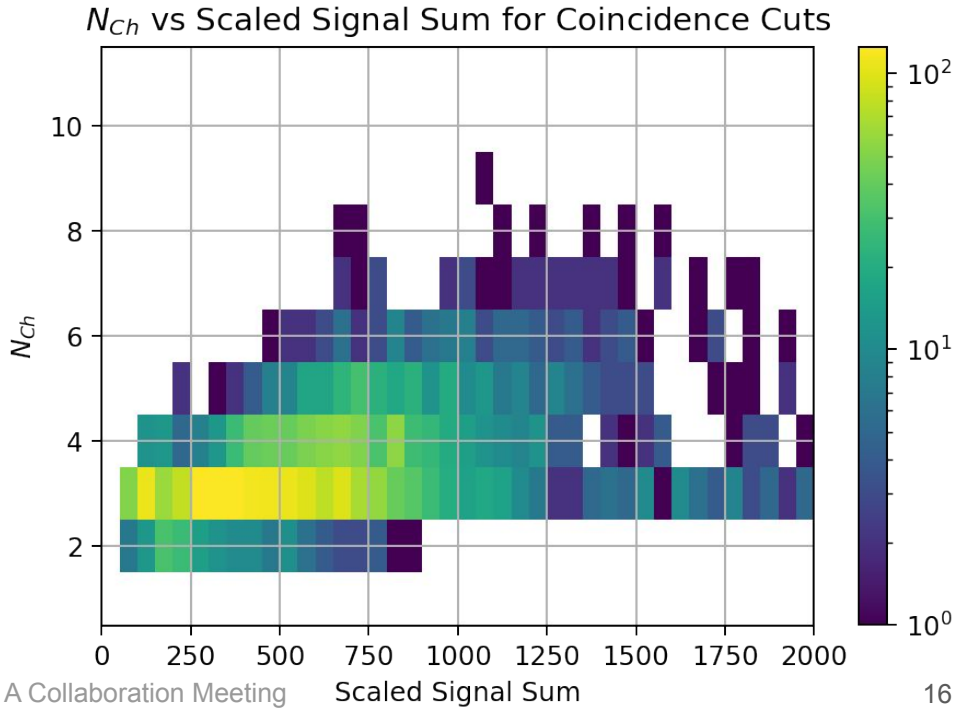


Analysis by Darren Upton (UVA)

Low Rate Test

- Requiring 2 adjacent channels to “fire” - good cherenkov trigger
- Electron signals emerge at Nch=3 and focused at channel 3

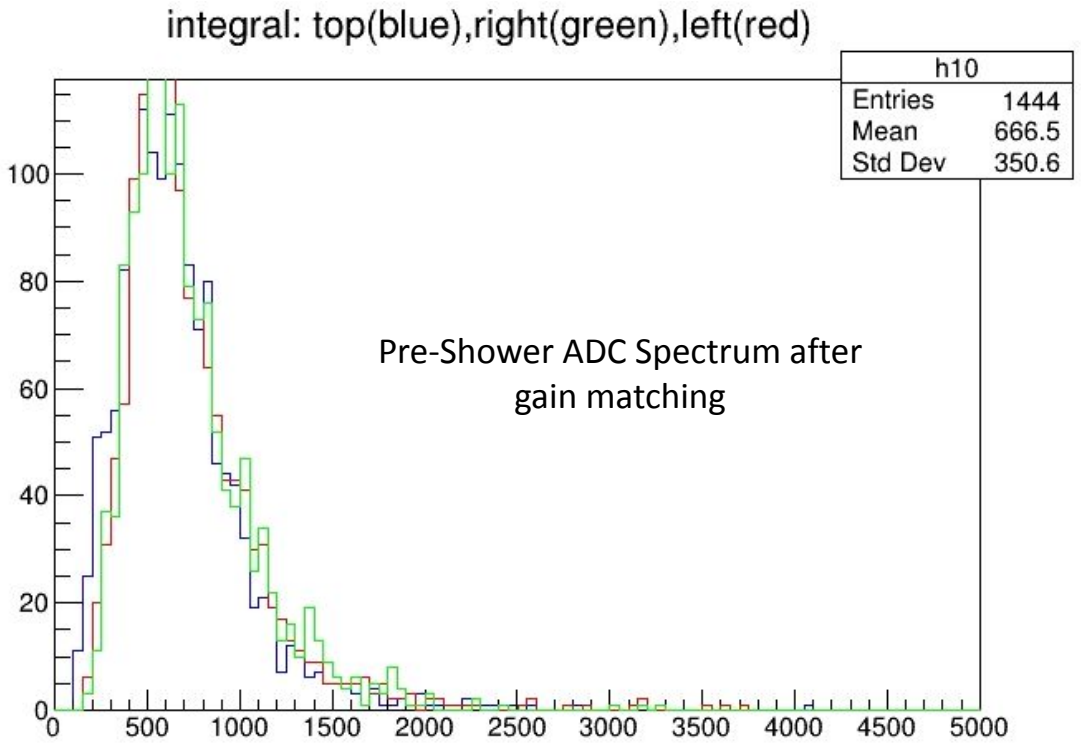




Analysis by Darren Upton (UVA) following algorithm developed by Chao Peng

Cosmic Calibration - Pre-Shower (Winter break 2022/23)

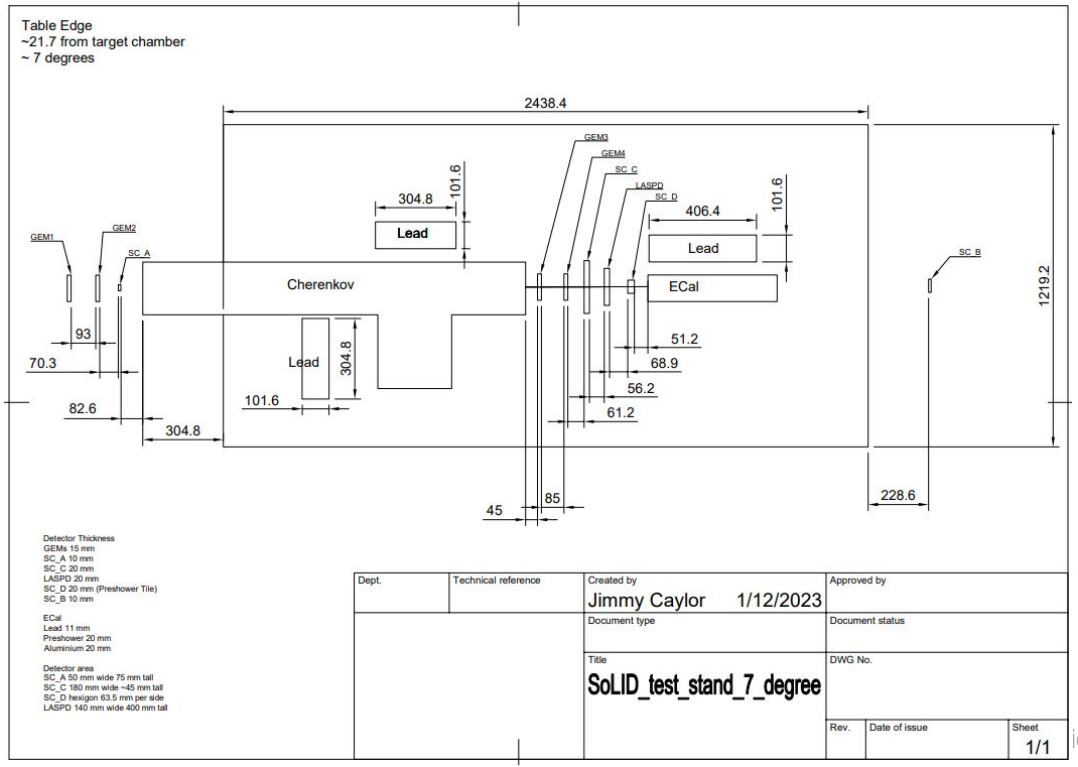
- Using cosmic to do gain match for Pre-Showers
- Stack 3 Pre-showers together
- Adjust HV to let them have same averaged signal amplitude
- True ADC spectrum, with optimized HVs
- Shower not done due to geometry effect
- Trigger can't cover all showers, only ~half were covered



Plot by Jixie Zhang

High Rate Test (7 degree ongoing) - Trigger Design

- Front to back GEM1+2, SC-A, Cer, GEM3+4, SC-C, LASPD, Preshower, Shower, SC-B



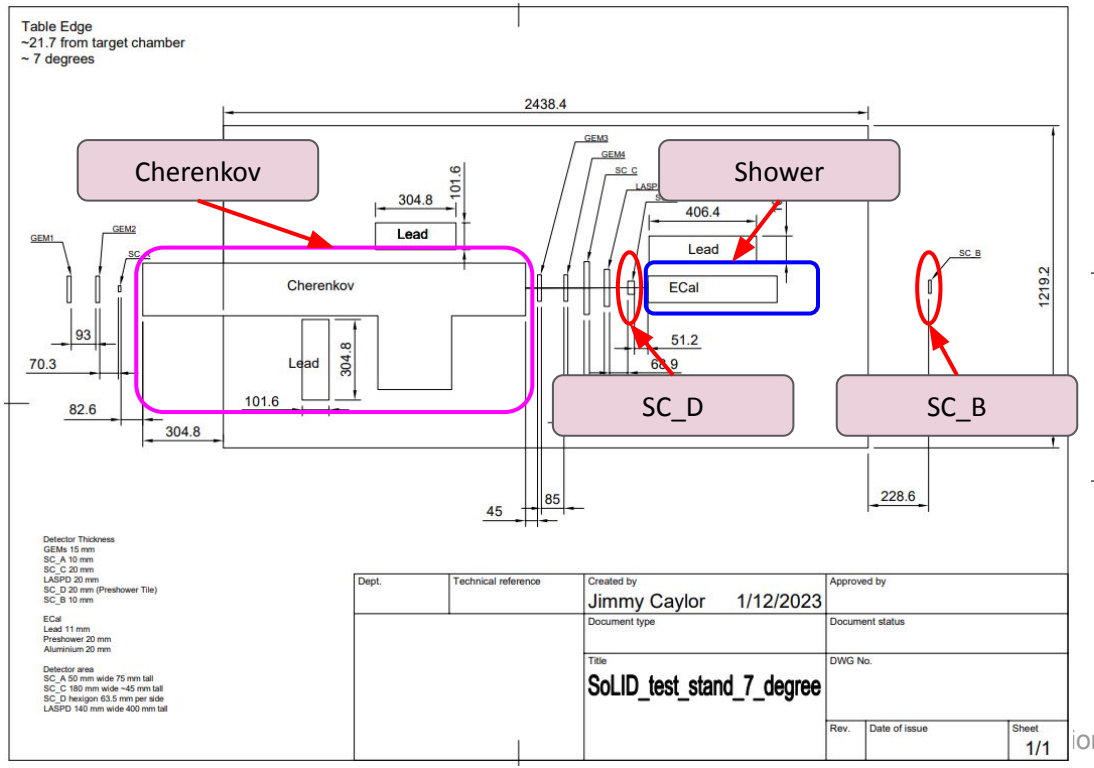
Trigger	Bit	TrigType	Aim	Condition
TS1	000001	1	e	Č Sum, ShSum
TS2	000010	2	π	SC_B, ShSum, SC_D
TS3	000100	4	2/3	Č, SC_D, ShSum
TS4	001000	8	high e	ShSum
TS5	010000	16	Clean π	SC_B
TS6	100000	32	Good Č	2/15 FADC Č

Trigger Configuration

Plot by Jimmy Caylor (Syracuse)

High Rate Test (7 degree ongoing) - Trigger Design

- Front to back GEM1+2, SC-A, Cer, GEM3+4, SC-C, LASPD, Preshower, Shower, SC-B



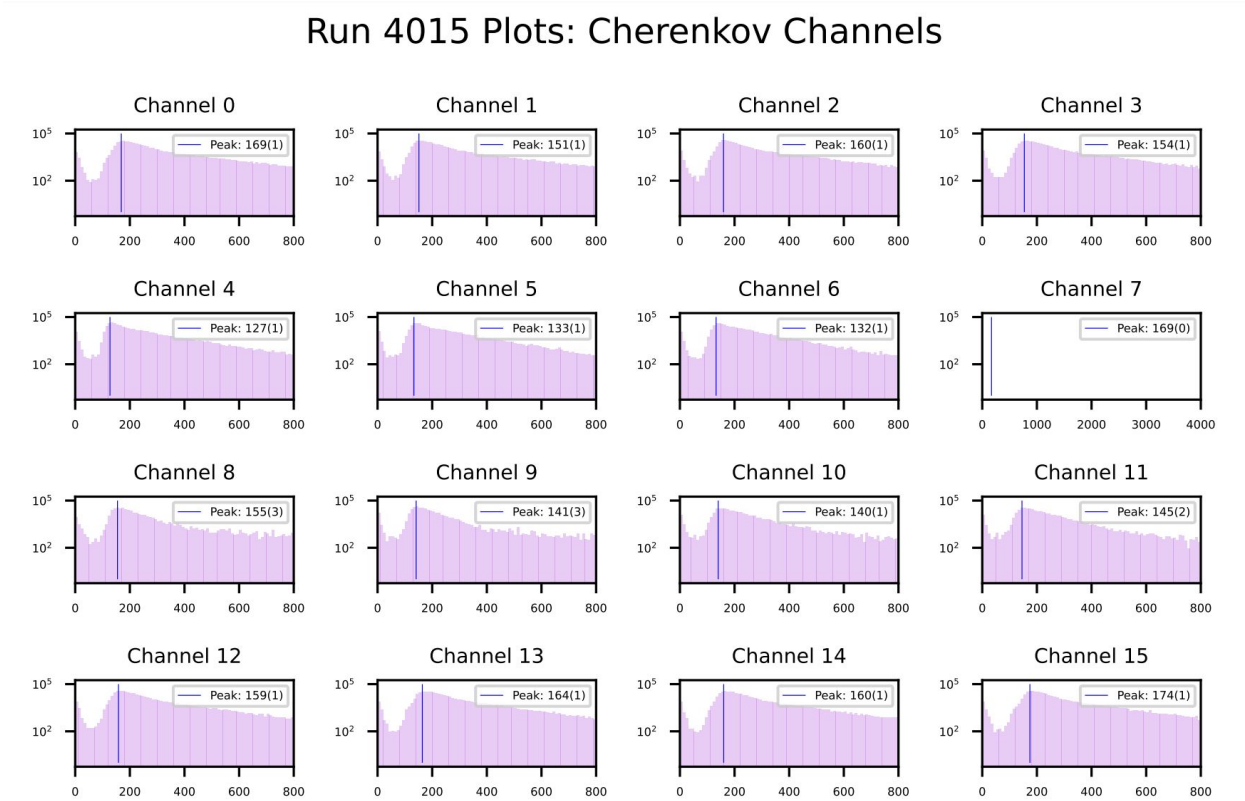
Trigger Configuration

Trigger	Bit	TrigType	Aim	Condition
TS1	000001	1	e	Č Sum, ShSum
TS2	000010	2	π	SC_B, ShSum, SC_D
TS3	000100	4	2/3	Č, SC_D, ShSum
TS4	001000	8	high e	ShSum
TS5	010000	16	Clean π	SC_B
TS6	100000	32	Good Č	2/15 FADC Č

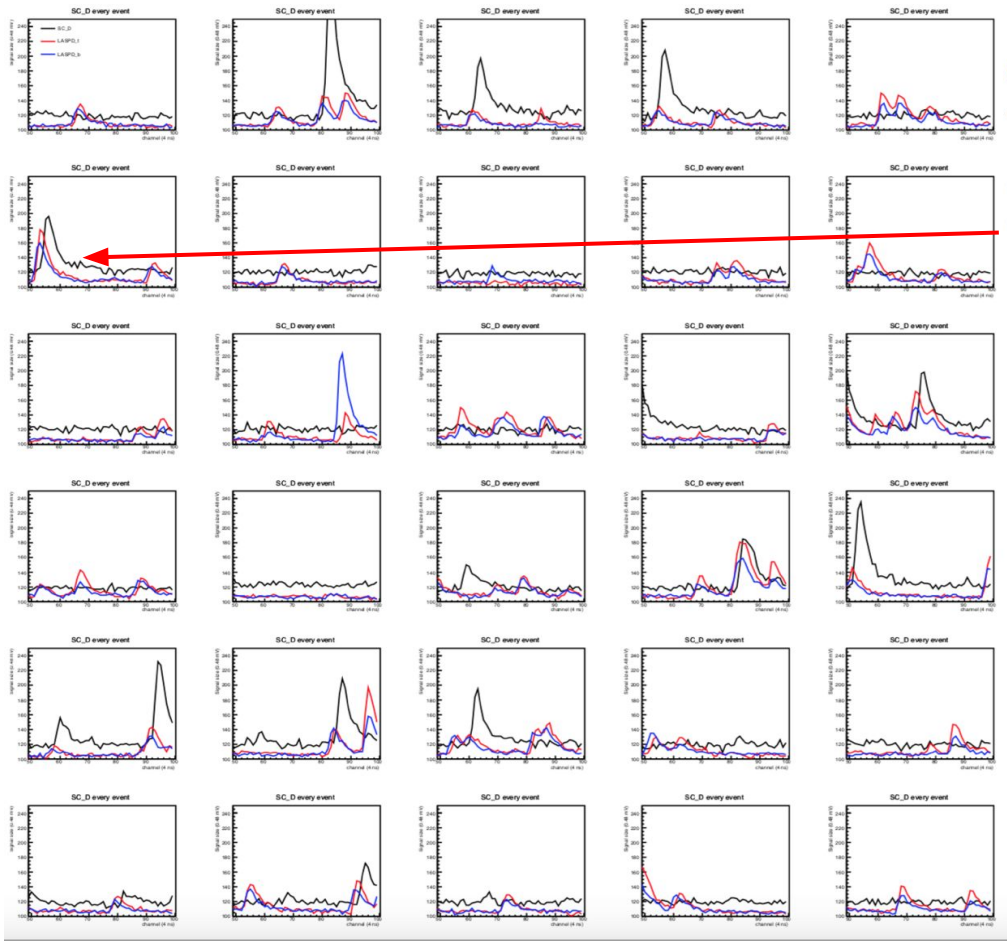
CAD Plot by Jimmy Caylor (Syracuse)

High Rate Test (7 degree ongoing)

- Beam data
- 1uA on 3He target
- Cherenkov: HV=-950V
- We can see clear single photoelectron peak (well aligned)



High rate test (7 degree ongoing)



Coincidence Check

- LASPD and SC_D

✓ 1 MHz coincidence
✓ Moller e⁻

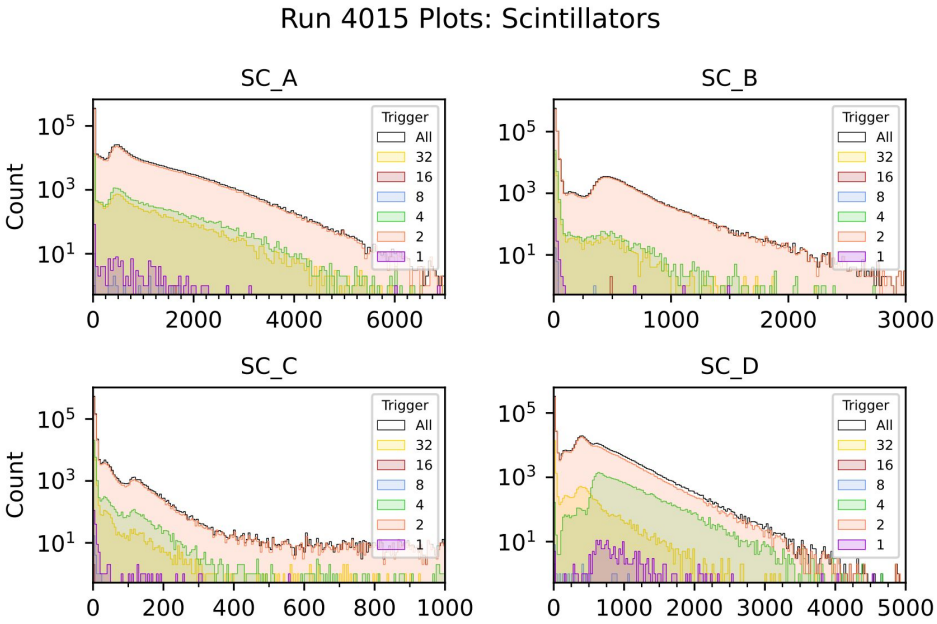
LASPD: 560 cm^2
SC_D: 104.8cm^2

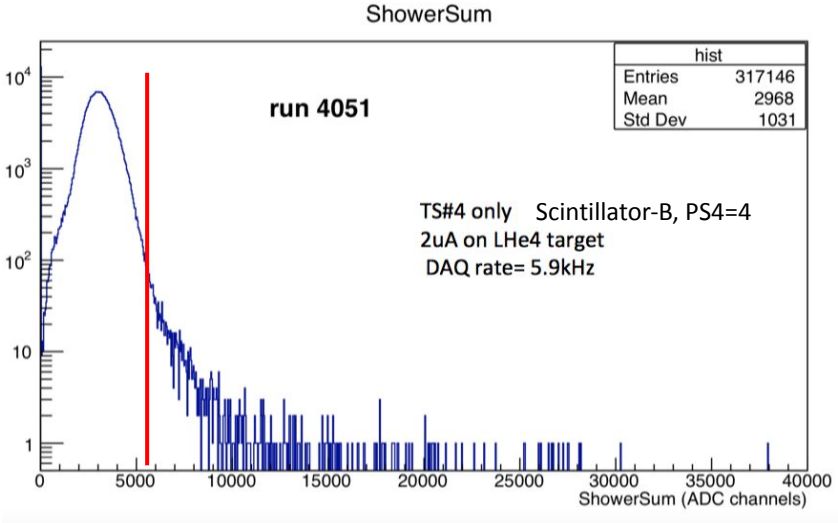
Run 4022:
1.8 uA on He3 target
DAQ rate= 5.7kHz

Analysis by Ye Tian (Syracuse)

High rate test (7 degree ongoing)

- 2uA on 4He target beam data

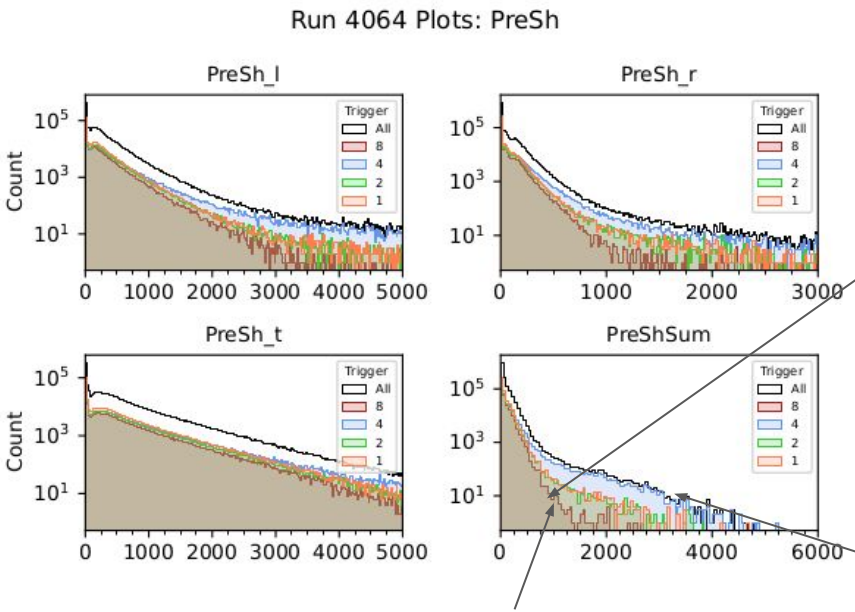


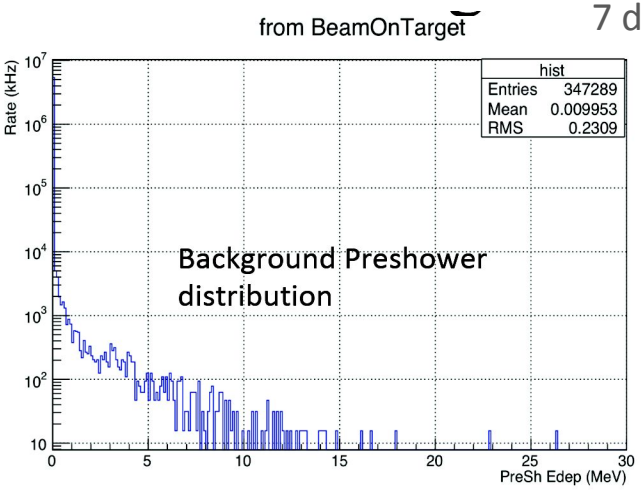


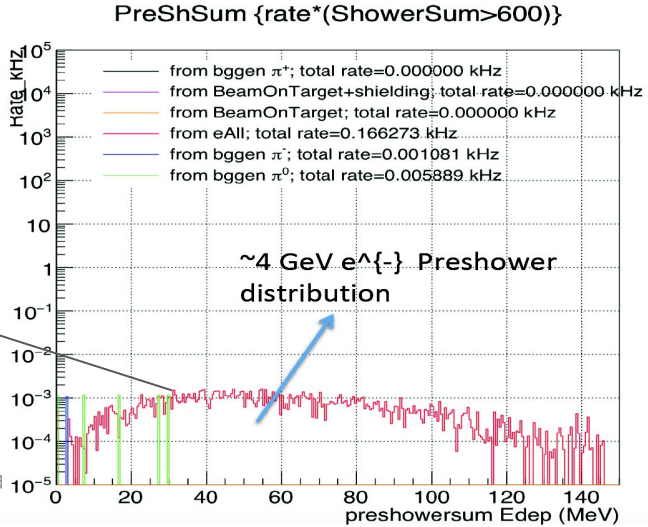
High rate test (7 degree ongoing)

7 deg simulation (Ye Tian)

- 1uA on 3He target beam data







Spectrum with trigger from SC-B from data agree with background simulation very well

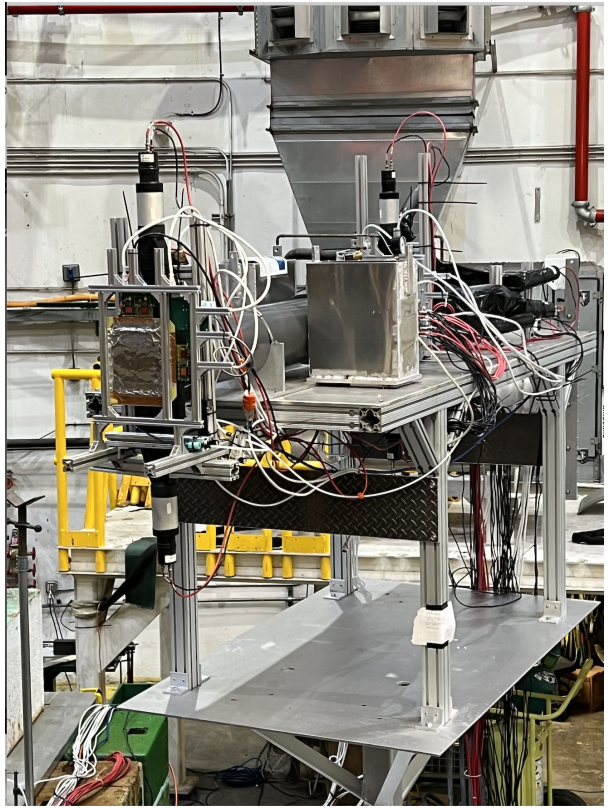
Summary and Outlook

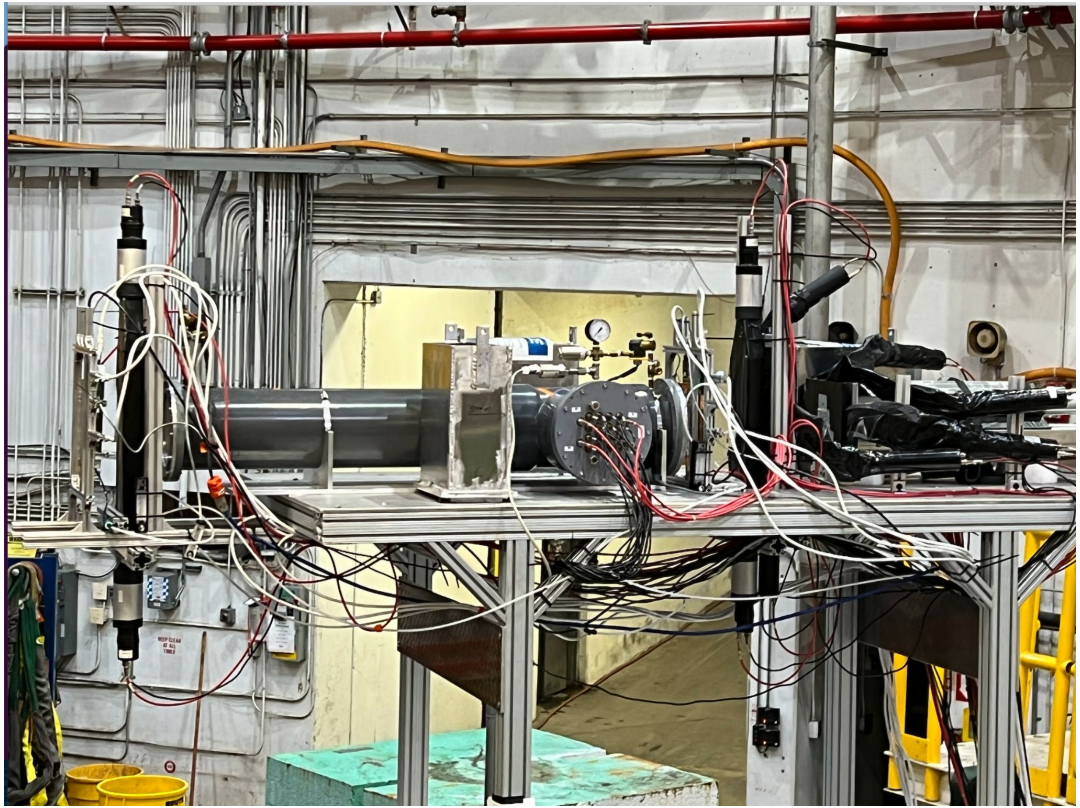
- Test ongoing for ECal and other detectors overall performance under high rate, high background condition
- Will move setup to 20 degree (Feb. 20th) for further testing
- Offline analysis will focus on PID and other performance evaluation, and benchmark simulation of background

Thank you to the Hall A/C staff, techs, and engineers for help their help with Hall layout plans, locating materials, and many helpful suggestions!

Backup Slides

Beam test setup (low rate)

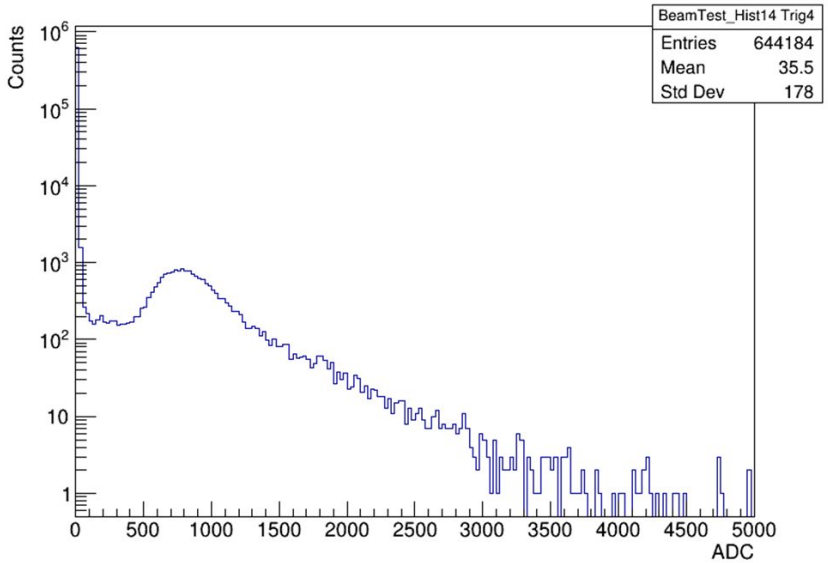




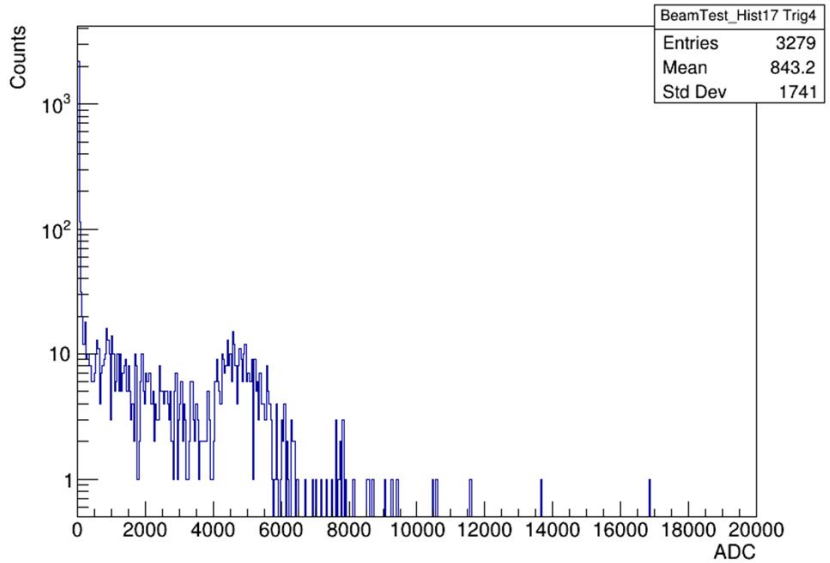
Front to back: GEM1, SC, Cer, GEM2, SC, LASPD, Preshower, Shower

Cosmic calibration (Winter break 2022/23)
MIP Peak in the Preshower and Shower

Right Preshower



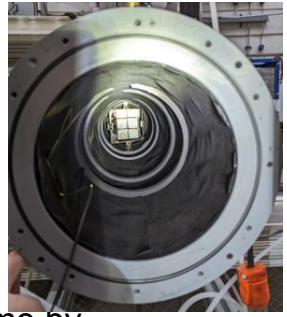
Right Shower

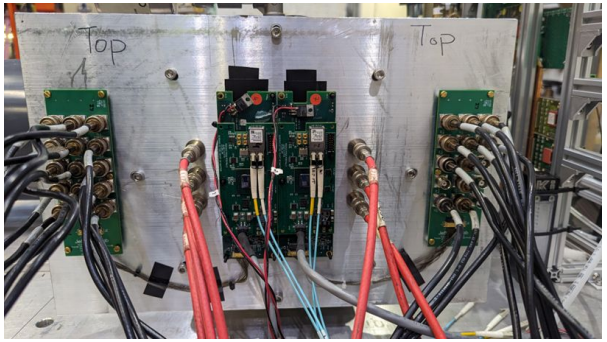


Analysis by Jimmy Caylor (Syracuse)

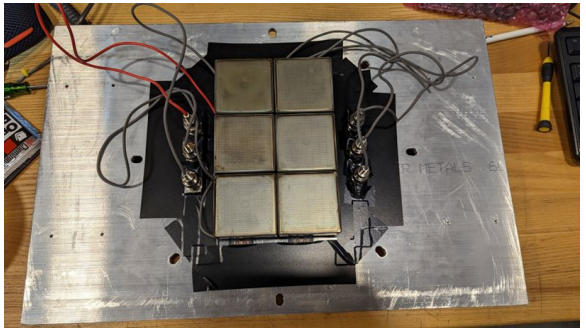
Cherenkov MAROC sum readout for MAPMT

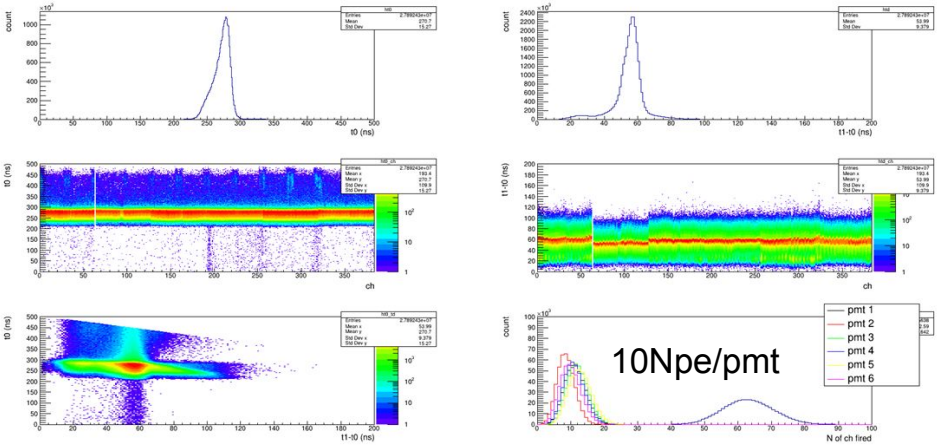
MAROC sum boards



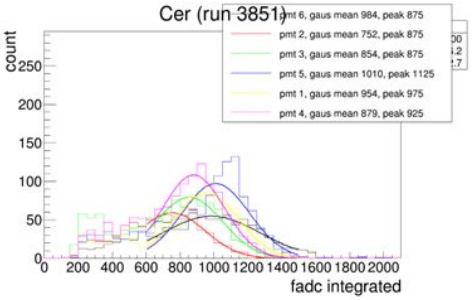


- provide pixel/quad sum/pmt sum information at same time by MAROC+FADC and thus better background rejection
- Hope to install during the later stage of this beamtest





Bench test with LED shows reasonable results



Simulation background signals for the beam test

1) 82 deg—low rate test
- dominant by pi0
- charged pion energy is not large enough to see the MIP at shower

2) 7 deg— high rate test
- 60 MeV Moller electron from the target
- Photons from beam line (high energy photons covered the MIP at shower)

3) 20 deg—high rate test
- few MeV Moller electron -—can be shield easily
- have a good chance to MIP at shower