Future Plan on ECal and SPD

SoLID Collaboration Meeting 2024

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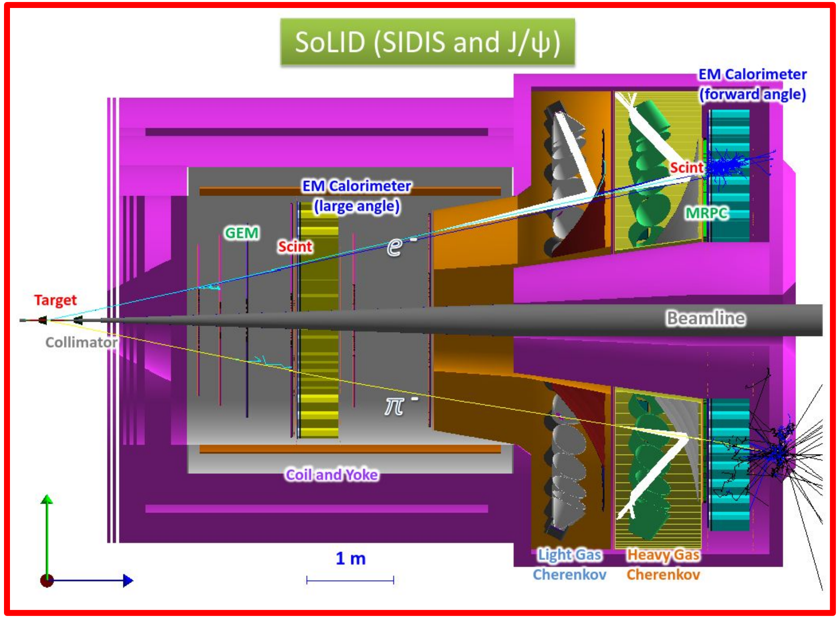
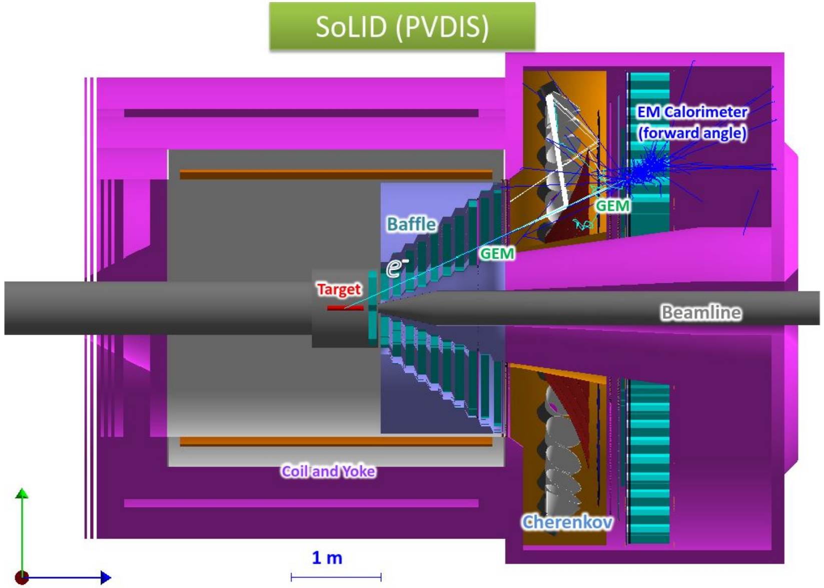
Detector System of SoLID

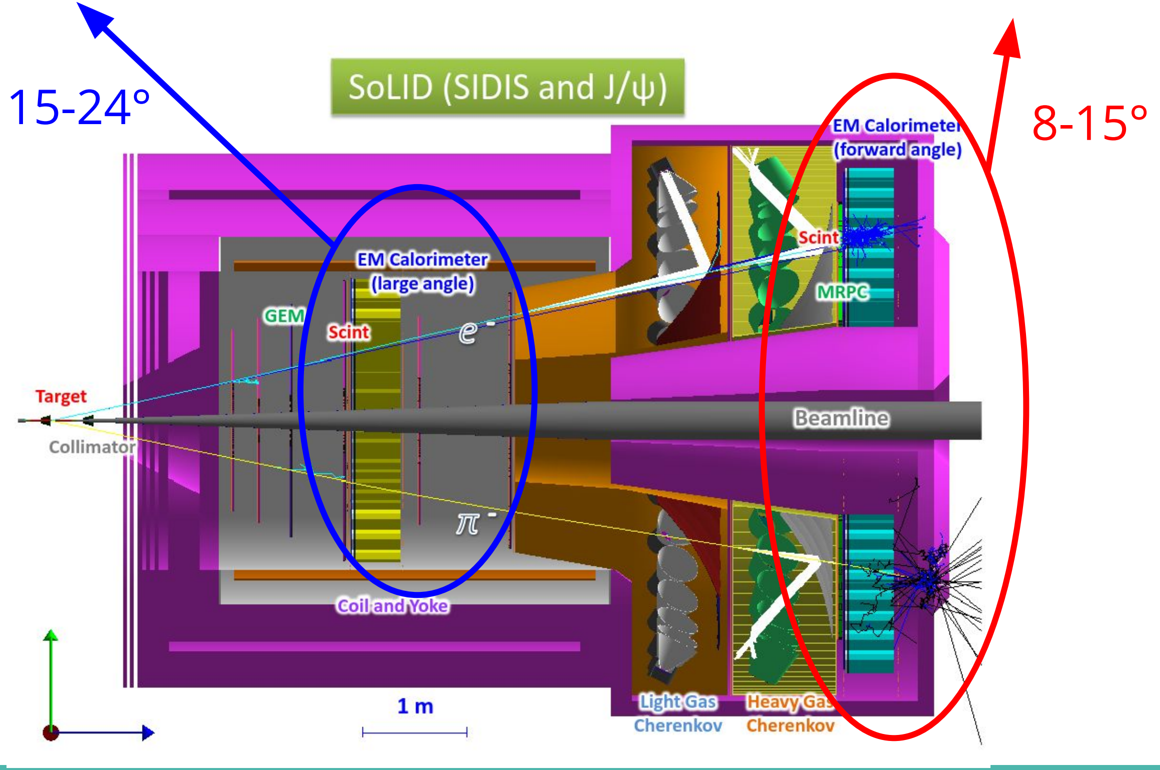
- The detector system of SoLID includes two configurations: the "SIDIS and J/ψ" configuration and the "PVDIS" configuration.





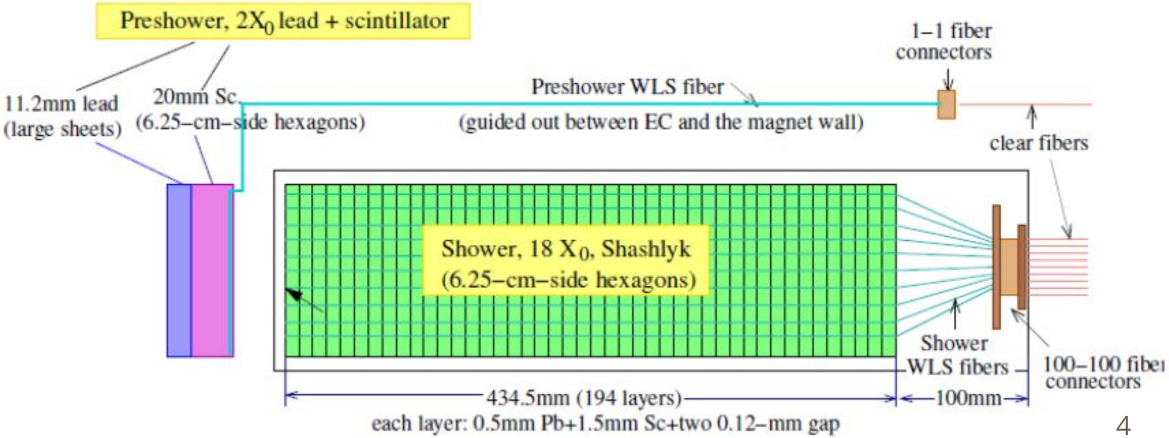
SIDIS and J/ψ Configuration

- The “SIDIS and J/ψ” configuration consists of two groups of sub-detectors: the Large Angle Detector group (LAD) and the Forward Angle Detector group (FAD).



ECal Overview

- Preshower: $2X_0$ pre-radiator and a 2-cm thick scintillator with wave-length shifting (WLS) fibers embedded for light readout
- Shower: $18X_0$ long, based on the **Shashlyk-type** sampling with alternating layers of 1.5-mm thick scintillator and 0.5-mm thick lead absorber layers.
- A unique aspect of SoLID's ECal is its light readout
  - Due to high radiation of SoLID, all WLS fibers will be connected to clear fibers and light will be routed outside the solenoid magnet for readout by PMTs
- ~1800 modules, each with a transverse size 100 cm^2 in a hexagon shape such that they can be rearranged between the two configurations.

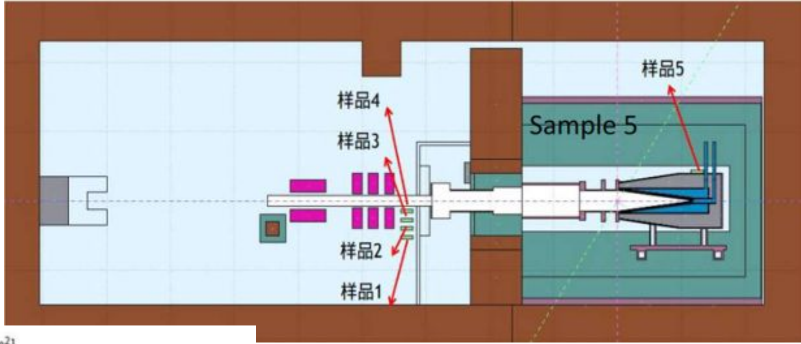


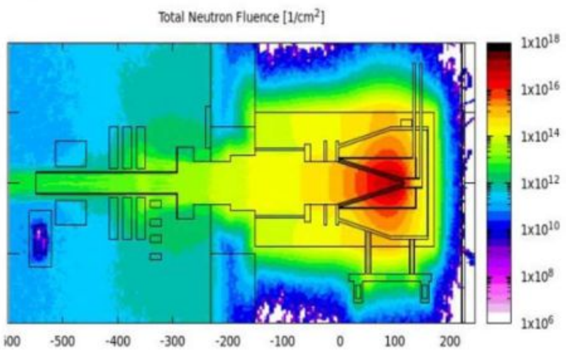
SPD Overview

- The Scintillator Pad Detector (SPD) will be used at both large-angle (10:1) and forward-angle (5:1) locations of the SIDIS configuration
- Reduce ECal-based trigger rates by requiring coincidence signals between the SPD and the ECal.
- The large-angle SPD (LASPD): TOF with a timing resolution goal of 150 ps
  - 2-cm thick long, wedge shape scintillators with readout directly by field-resistant fine-mesh PMT on the edge of the solenoid field
- The forward-angle SPD (FASPD): 240 pieces of thin, large scintillator pads with WLS fibers embedded on the surface.
  - Light from the WLF fibers will be guided through clear fibers in a similar manner as for the preshower ECal.

Irradiation test (1)

- Started in 2021 at Institute of Modern Physics, Lanzhou, China
  - SDU/IMP group: Cunfeng Feng, Dong Liu, Mengjiao Li, Ye Tian

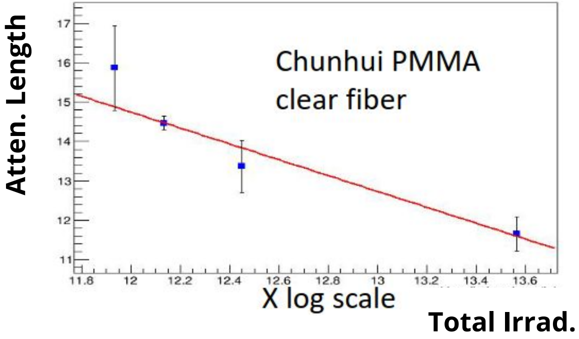


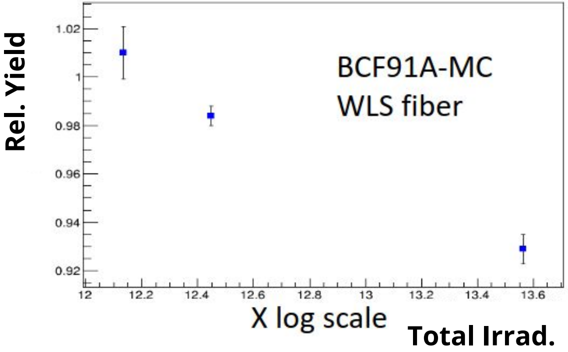


	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Total Irrad. [MeV/cm^2] (sim. w/ δ~10%)	8.6e11	1.4e12	2.8e12	3.7e13	1.1e14
Material	Clear fiber	Clear fiber BCF91A-MC	Clear fiber BCF91A-MC	Clear fiber BCF91A-MC	BCF91A-MC

Irradiation test (2)

- Started in 2021 at Institute of Modern Physics, Lanzhou, China
  - SDU group: Cunfeng Feng, Dong Liu
  - Reflector layer test
  - Coating
  - Fiber testing
    - Attenuation length, performance, end reflector selection, connectors
- For all tested fibers and scintillators:
  - No difference in appearance and mechanical properties
  - Same color/elasticity after irradiation

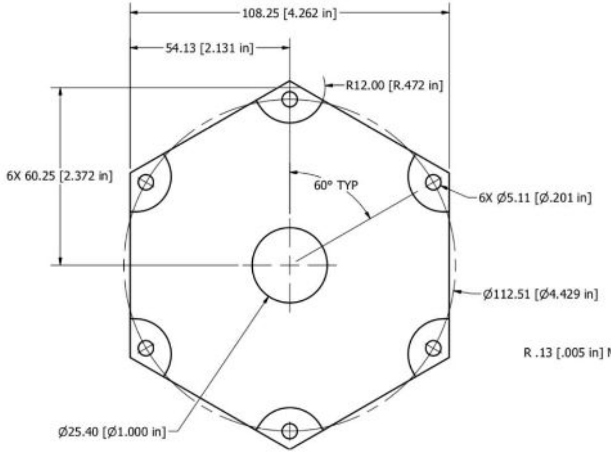




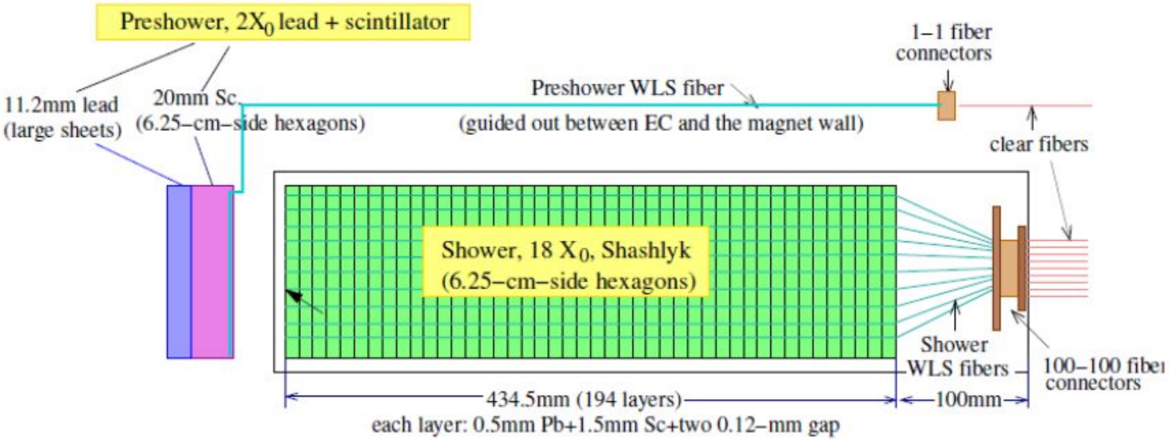
Component	Material choice
Scintillator	Hengxin batch2 Scintillator
Reflective layer	Powder painting
WLS Fiber	Kuraray Y11-MC
Fiber end mirror	3M ESR film (>98%)
Fiber connector	Chunhui connector?
Coating	lead paint TiO2

FTBF Result (1)

- Performed 2021-2022
  - UVA group: Jixie Zhang, Syracuse group: Ye Tian
  - Fermilab Test Beam Facility (FTBF)



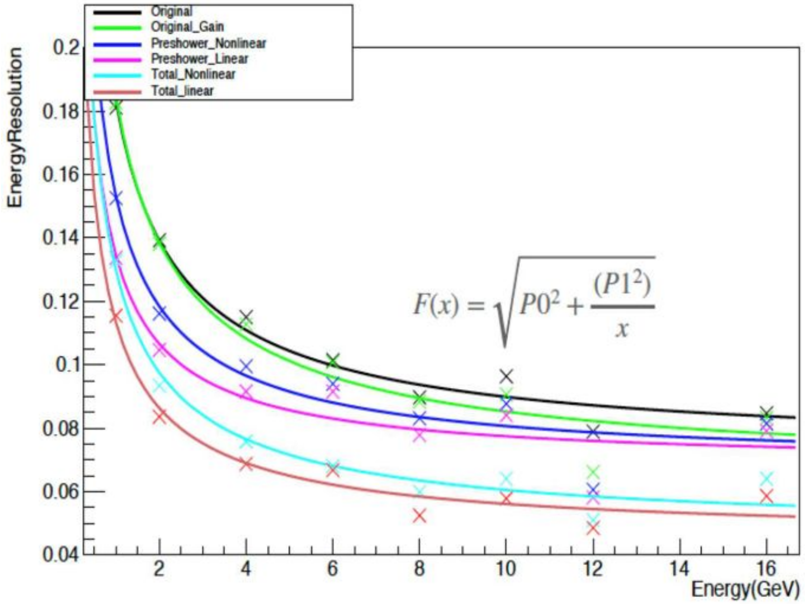
SoLID shashlyk style ECal design

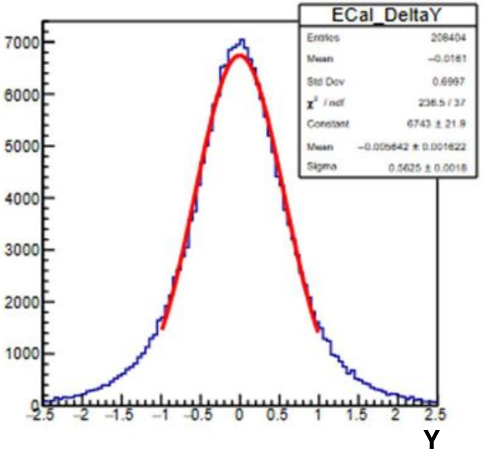


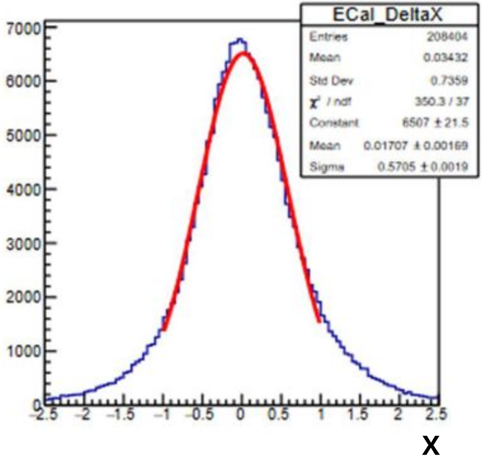
- Diameter of the Supporting Rod of Ecal Module
  - Simulation done by Ye Tian shows that the 8-mm diameter rods will have noticeable effect on the ECal performance, but 6-mm diameter is acceptable.

FTBF Result (2)

- Energy Resolution
  - Gain and preshower correction: ~10% improvement
  - Position dependence correction: ~30% improvement



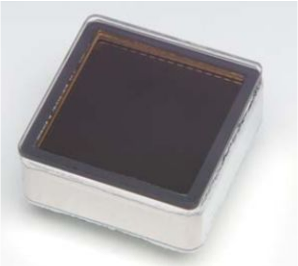




- Position Resolution
  - Position RMS: (dX = 0.67, dY = 0.56)
  - Includes beam spread into Geant4

ECal Preshower Readout

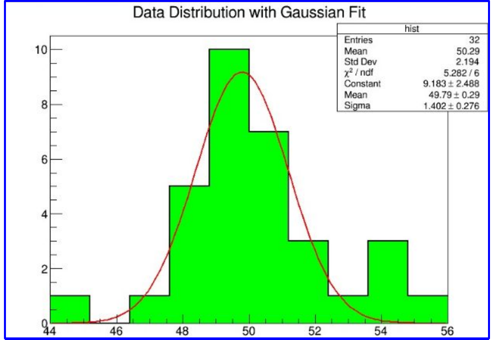
- Starting in next few weeks
    - Argonne group: Junqi Xie
        - PMT samples for readout, lifetime
    - UVA + JLab Detector group
        - ECal scintillator simulations
        - PMT Readout studies
            - MCP-PMT (R10754)
            - MAPMT (R11265, H12445)
        - Design radiation-hard bases for the MAPMTs and another type of regular PMTs, with pre-amp, similar to what NPS experiments are using now in Hall C.



ECal Scintillator Readout

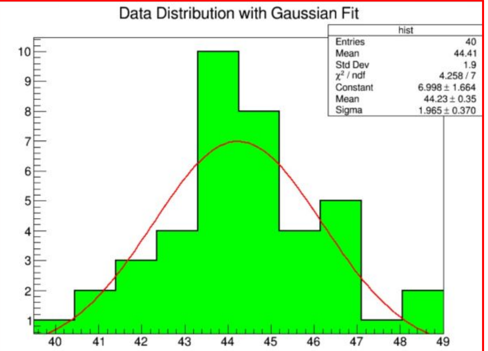
- Started 2023
  - SDU group
    - Kedi Scintillator: old hole design (Thick=~1.49 mm)
    - Hengxin Scintillator: new hole design, new injection mold
  - Each group is 5 pieces of scintillators
  - Scintillator transmissivity & reflectivity test
    - Averages: 87.5 (Hengxin) vs 87.3 (light Kedi)
  - Reflectivity test for lead
    - Averages: 88.5 (current) vs 83.6 (7 towers) vs 88.4 (Nica)

Cosmic test



Batch1 (June 2023)
200 pieces total
32 groups
(σ =1.4 , Mean=49.8)
Thick=~1.54 mm

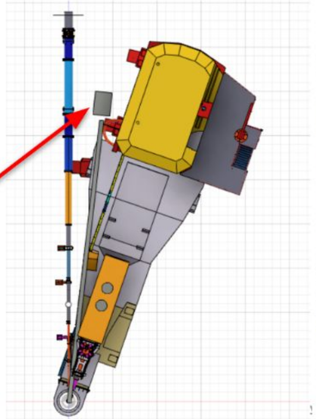
Batch2 (March 2024)
1500 pieces total
40 groups
(σ =2.0 , Mean=44.2)
Thick=~1.49mm

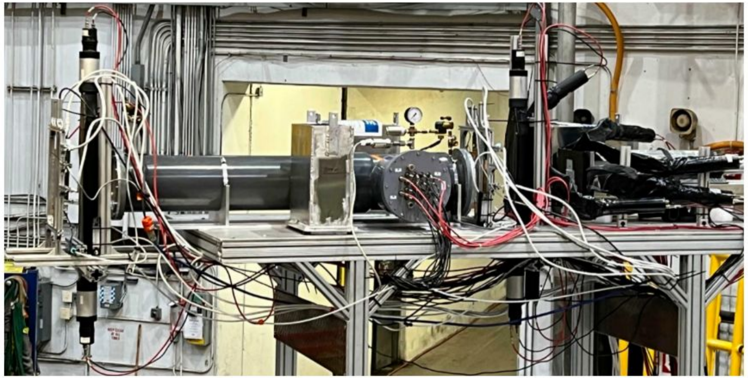


Jlab Beam Test

- Performed 2022-2023
  - Goals
    - High-rate and high-radiation environment expected for SoLID
      - Test Ecal and SPD
      - Test GEMs with APD readout and the DAQ system
      - Can ECal distinguish pion MIP from background, and electrons from pions?
  - See Michael Nycz and Ye Tian's talks

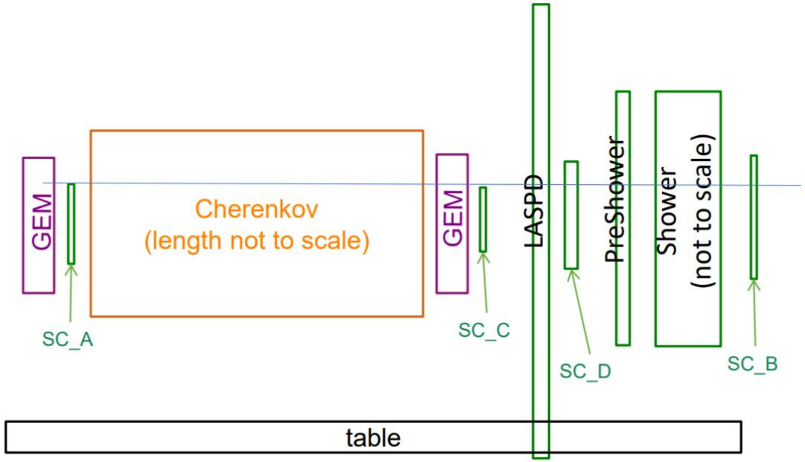
Small angle location





PID Using ML Methods for SoLID Beam Test Analysis (1)

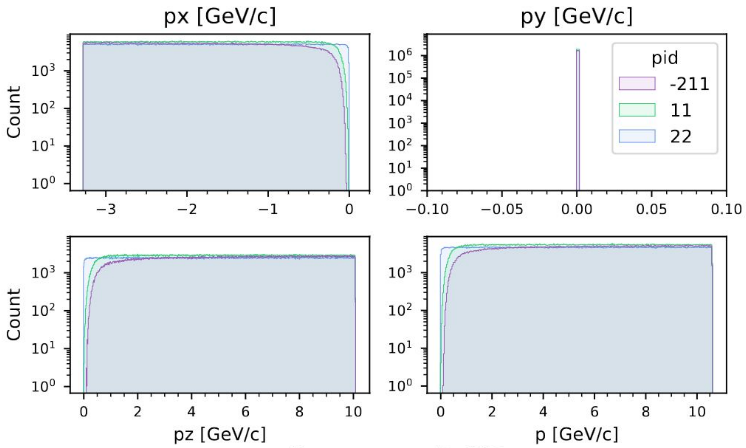
- Started in 2023
  - Started Summer 2023 SULI (Darren Upton)
  - UVA group: Richard Trotta, Mohammed Rafi, Taylor Conner (UG), Kadosa Schaffer (UG)
  - Integrate machine learning approaches within the SoLID collaboration, employing the ECal beam test (M. Nycz) to showcase their practical benefits.
  - By utilizing simulated events (Ye Tian) for the beam test, machine learning-assisted particle identification (ML-Assisted PID) methods are used to apply to the beam test data.

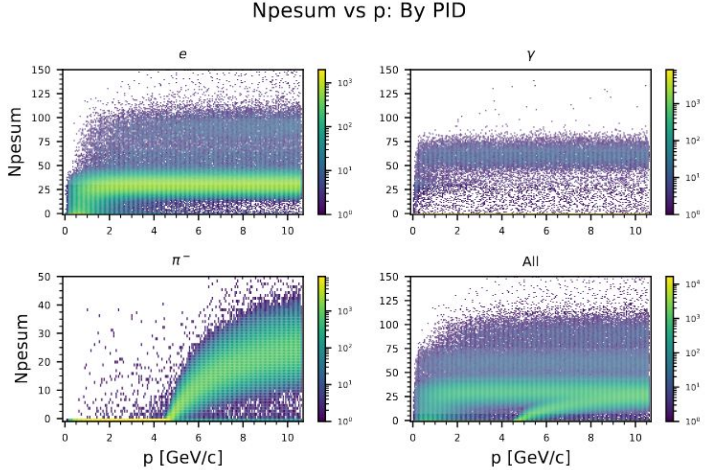


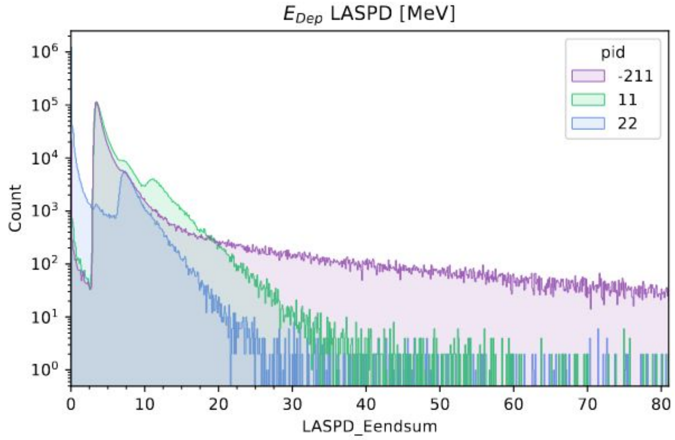
- Preliminary samples of e and $\pi^{+/-}$ have already been determined, yet further actions are necessary to enhance the agreement between simulation and experimental data.

PID Using ML Methods for SoLID Beam Test Analysis (2)

- As a first step, “pencil simulations” were used
- Starting with the ”simplest” case, can control for variables, such as particles tracks, statistics-limiting geometric effects, and other variables that confound analyses.

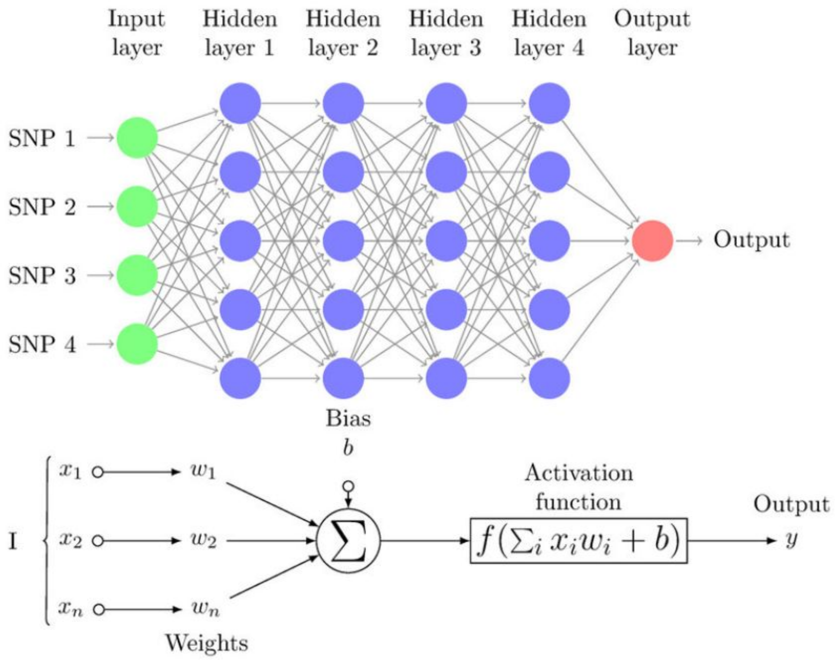






PID Using ML Methods for SoLID Beam Test Analysis (3)

- For this work, primarily explored a fully-connected, Multi-Layer Perceptrons (MLP) neural networks
- Activation function: ReLU for hidden layers
- Final value is compared to the true value and the optimizer backward propagates to change weights and biases such that the output matches the true value for this event
  - Used ADAM optimizer, which is an improved Stochastic Gradient Descent (SGD) algorithm
- By repeating this process of forward and backward propagating, the ML model converges to an ideal set of weights and biases

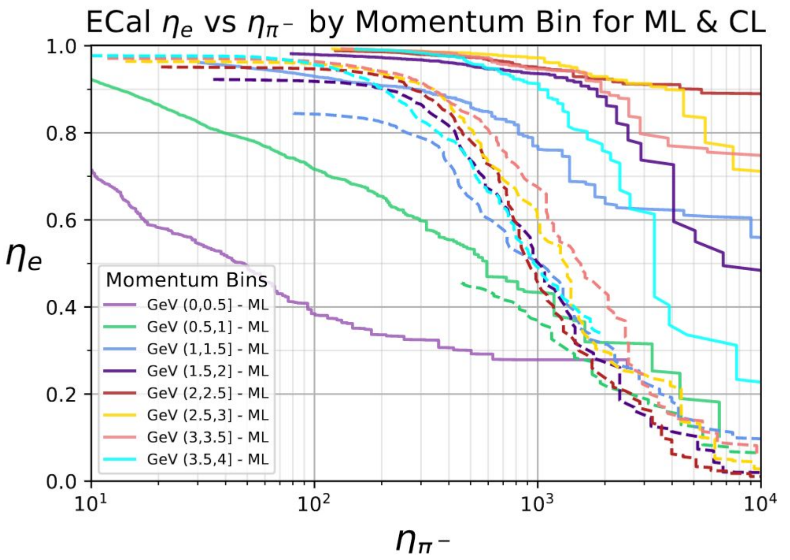


PID Using ML Methods for SoLID Beam Test Analysis (4)

- Samples are divided into separate momentum bins of width 0.5 GeV/c to check effect of ML classification on pencil sim
- Allows understanding the limits using only the ECal to distinguish between e and π^-
- For this process, binned charged particles then trained individual classifiers for each bin, resulting in eight separate classifiers. To validate the results
  - Traditional cuts were applied to the same samples as the ML model

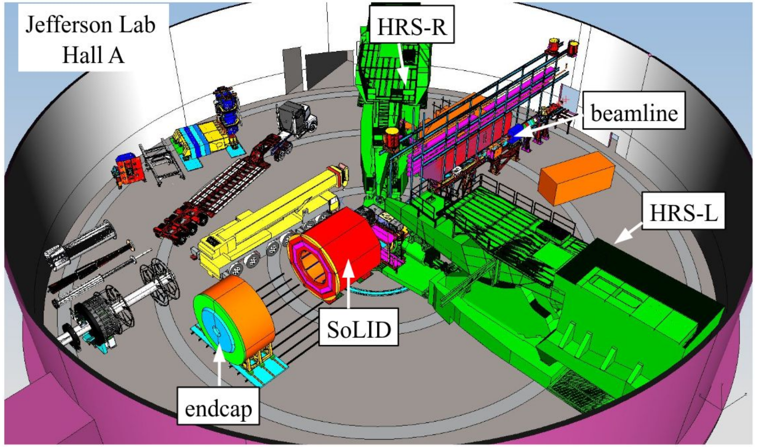
– – – – – –	Classical
———	Pen. Sim+ML

- Summer 2024, expand studies from pencil simulations to BT data
- Train NN with BT data
  - Apply trained NN on full simulations



https://solid.jlab.org/DocDB/0004/000495/001/SoLID_beamtest_ML_PID_Upton.pdf

Outlook

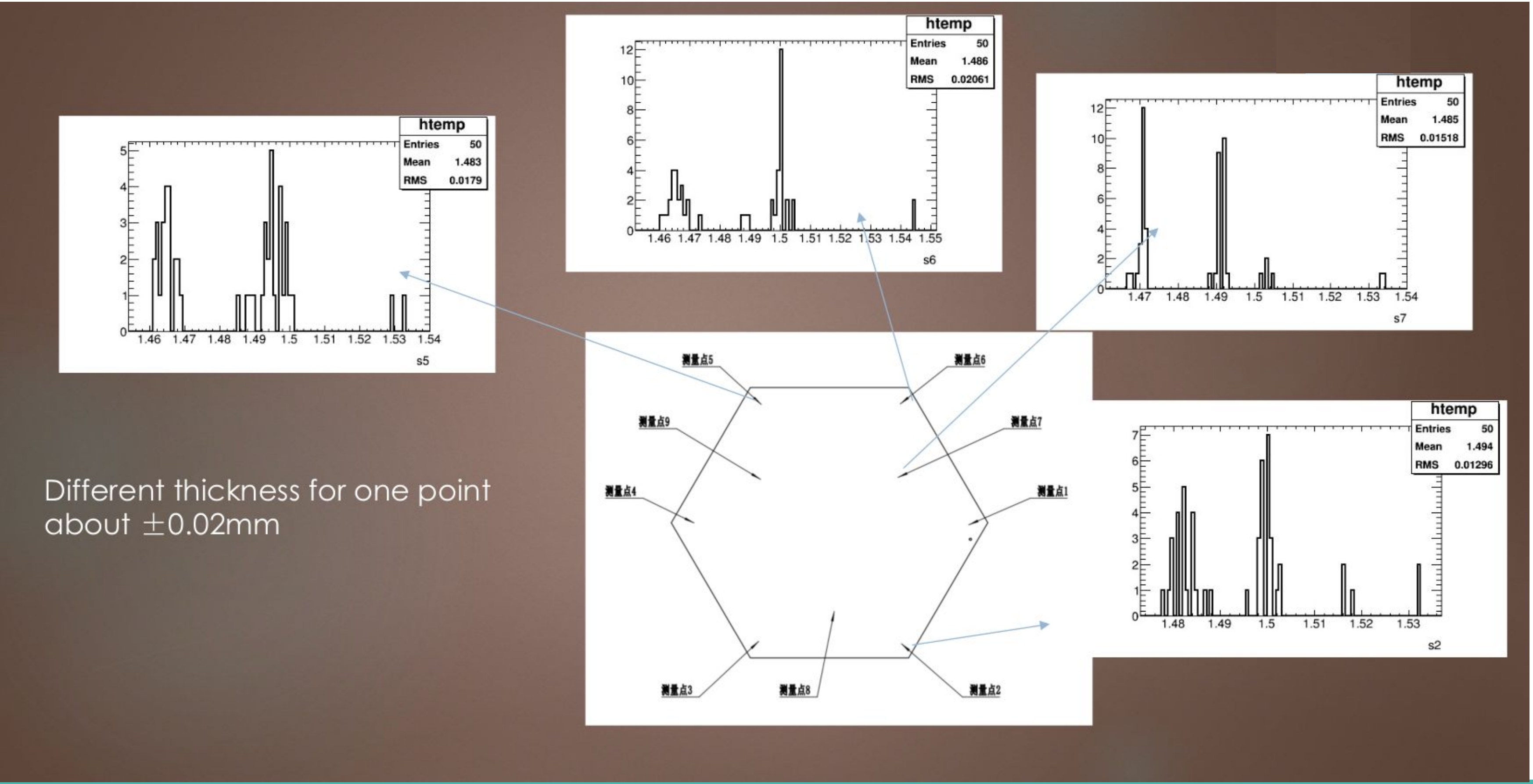


- Irradiation fiber test
  - Started in 2021
  - No difference in appearance and mechanical properties
  - Same color/elasticity after irradiation
- FTBF
  - Performed 2021-2022
  - Energy resolution
    - Gain and preshower correction: ~10% improvement
    - Position dependence correction: ~30% improvement
  - Position Resolution
    - Position RMS: (dX = 0.67, dY = 0.56)
- ECal Scintillator and Preshower Readout
  - SDU: Started in 2021, scintillator readout [ONGOING]
  - UVA: Beginning summer 2024, PMT readout [ONGOING]
- Jlab Beam Test and Simulations
  - Beam test 2022-2023, possible follow-up studies (See Michael Nycz's talk)
  - Simulations started 2022 [ONGOING] (See Ye Tian’s talk)
- PID Using ML Methods for SoLID Beam Test Analysis
  - Started 2023 [ONGOING]
  - Preliminary samples of e and $\pi^{+/-}$ have already been determined

Extra

Thickness of kedi scintillator

Slide from SDU group



Thickness of Hengxin Batch2 scintillator

Slide from SDU group