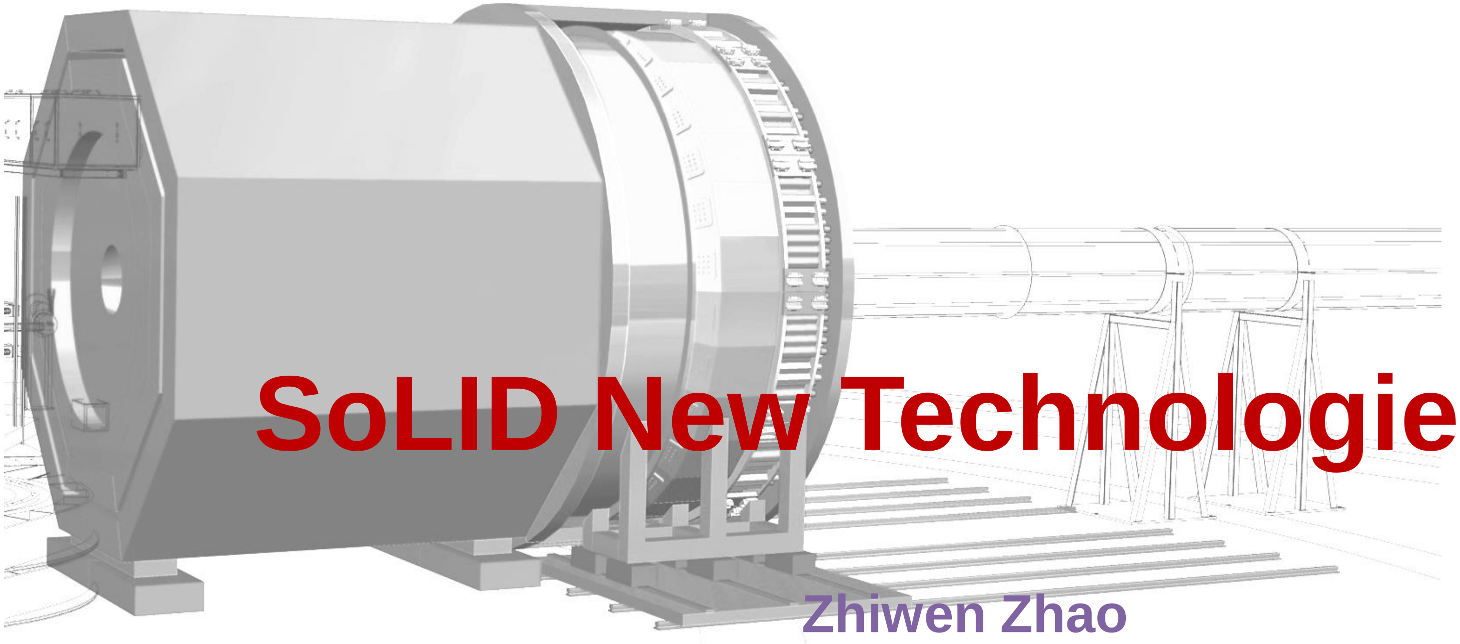


SoLID New Technologies in Use

Zhiwen Zhao
Duke University

SoLID Collaboration

2024 Summer Hall A/C Collaboration Meeting
July 15-16, 2024

SoLID@12-GeV JLab: QCD at the intensity frontier

SoLID will ***maximize*** the science return of the 12-GeV CEBAF upgrade by **combining...**

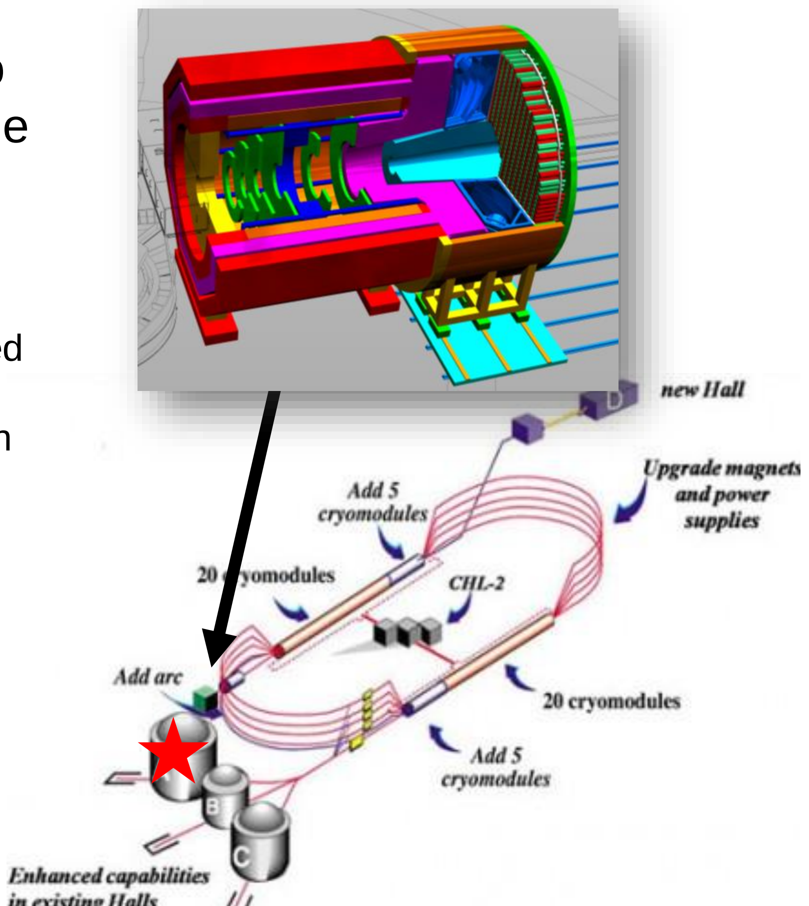
High Luminosity
$10^{37\text{-}39}$ /cm^2/s
[>100x CLAS12][>1000x EIC]

+

Large Acceptance
Full azimuthal ϕ coverage

Research at **SoLID** will have the ***unique*** capability to **explore** the QCD landscape while **complementing** the research of other key facilities

- Pushing the phase space in the search of new physics and of hadronic physics (**PVDIS**)
- 3D momentum imaging of a relativistic strongly interacting confined system (**nucleon spin**)
- Superior sensitivity to the differential electro- and photo-production cross section of J/ψ near threshold (**proton mass**)



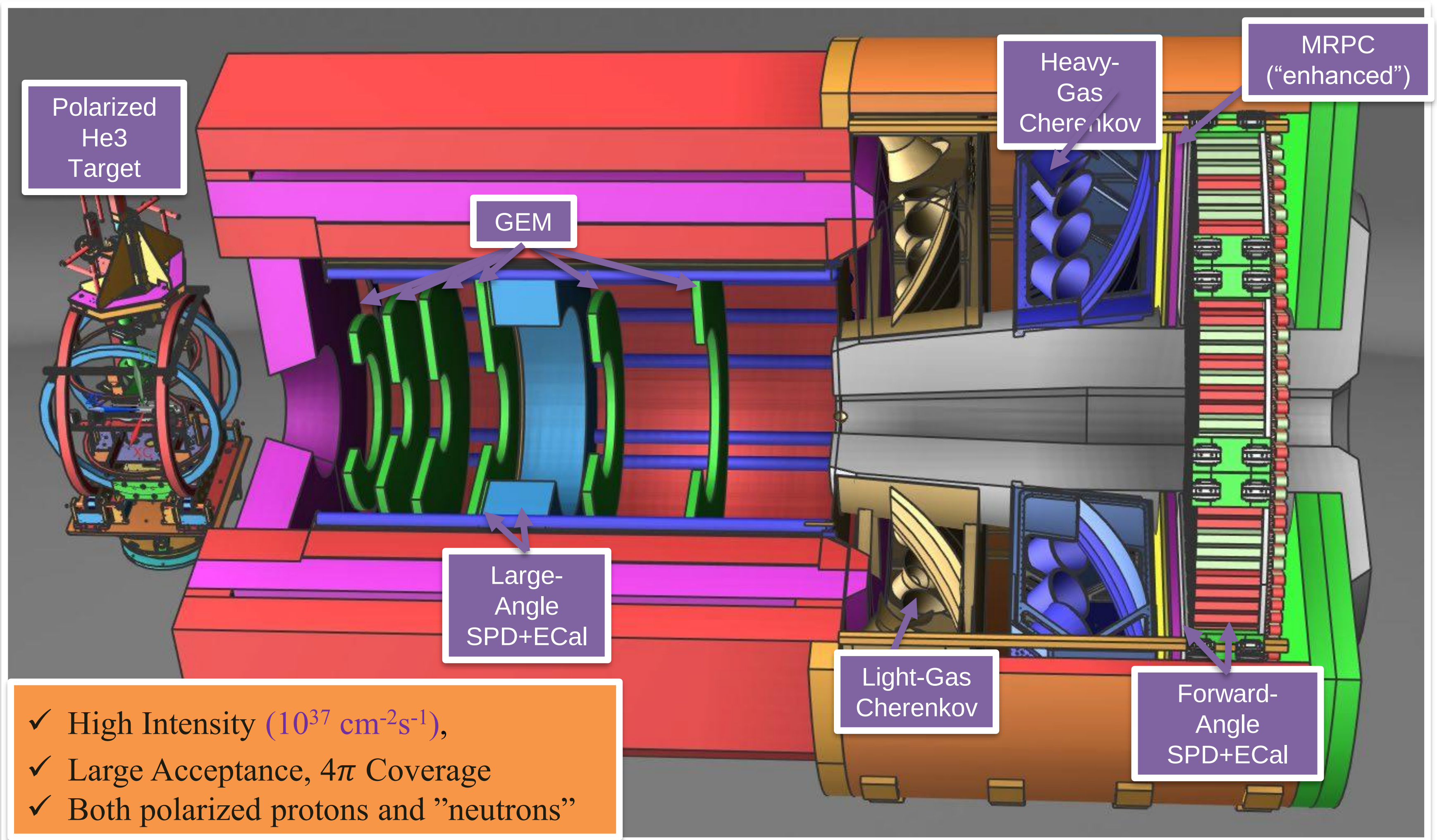
Synergizing with the pillars of EIC science (**proton spin** and **mass**) through high-luminosity valence quark tomography and precision J/ψ production near threshold

SoLID whitepaper: *J. Phys. G: Nuclear and Particle Physics* ***50,*** *110501 (2023)*
12GeV physics: Progress in Particle and Nuclear Physics ***127****, 103985 (2022)*

Outline

- Magnet Solenoid
- ECal
- MRPC
- Cherenkov

SoLID Open Geometry Setup

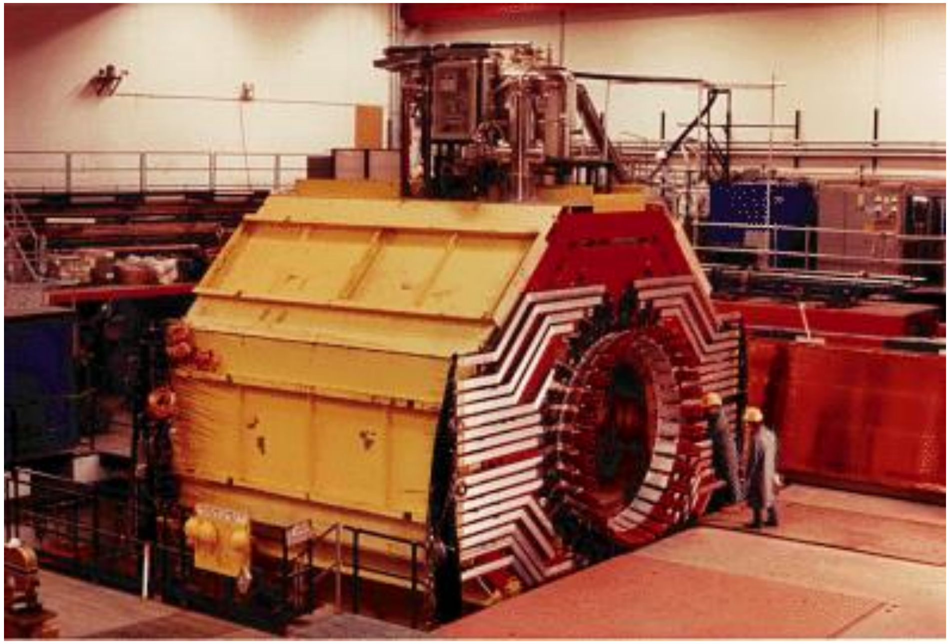


Not an overview of SoLID detectors
Only to highlight some selected new technologies
Slides from collaborators

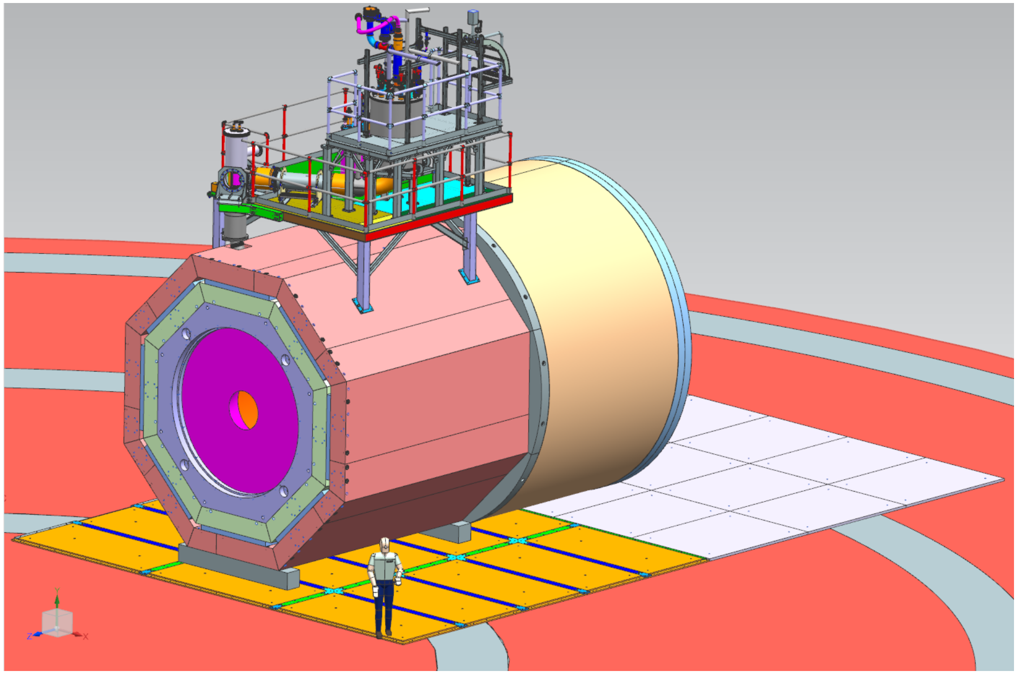
Magnet Solenoid

- Coil/cryo/yoke of CLEO-II were moved from Cornell to JLab
- Coil Collars to be modified
- Endcap to be made

CLEO-II photo



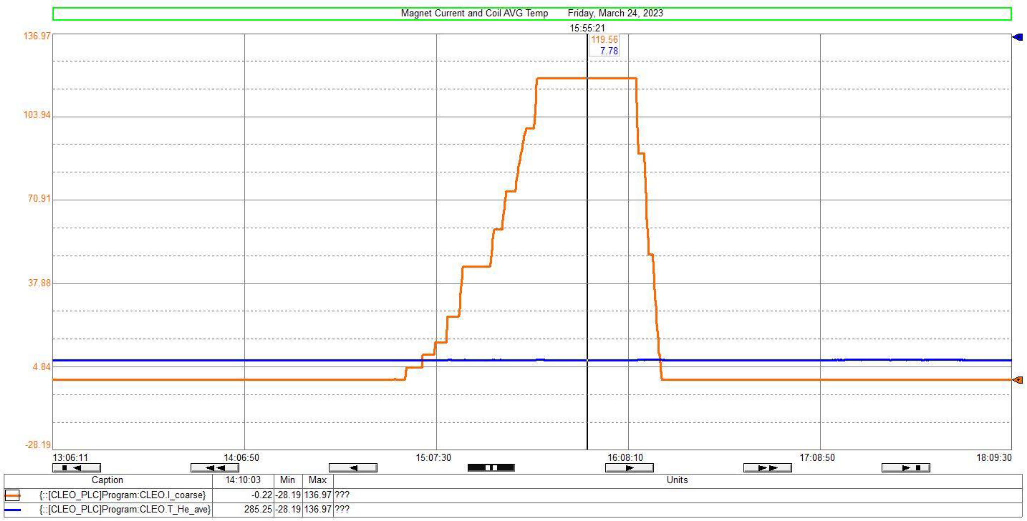
SoLID CAD

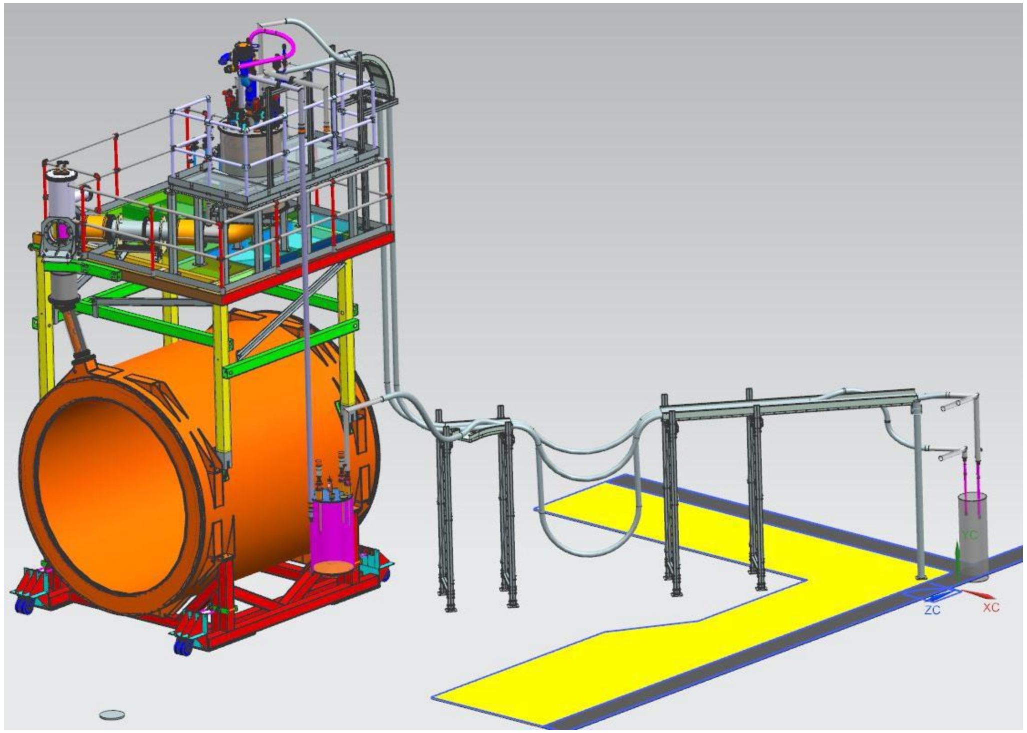


Whit Seay et al. at JLab

Magnet Cold Test

- Magnet assembly completed
- Cryogenic system assembled and commissioned
- Instrumentation and control system commissioned
- Energized the coil with 120 A while temperature was stable
- Under data analysis and report writing





Whit Seay et al. at Jlab

Magnet Field Modeling

- Detailed field modeling in TOSCA/Opera
- Minimize field leakage outside
- Minimize field near photonsensors
- Minimize force on coils

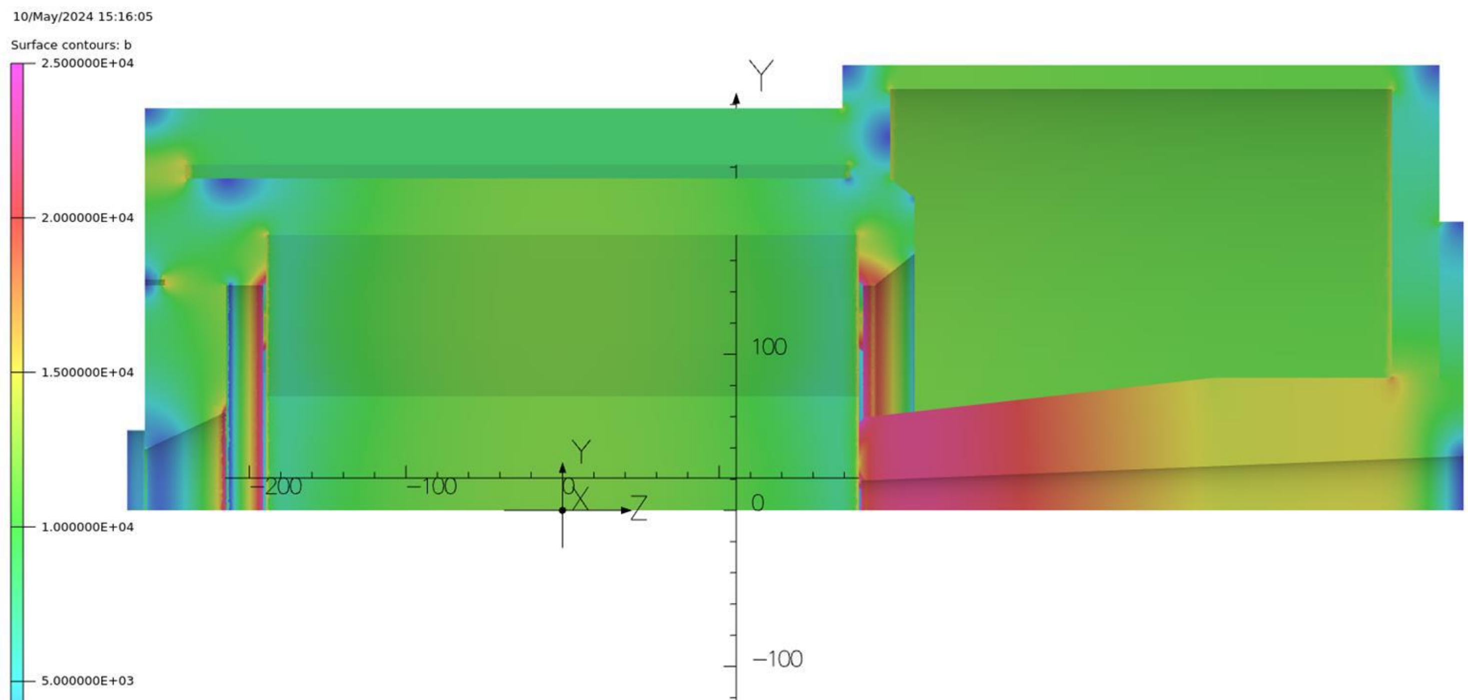


Table detailing model variations

model	plug_downstream_Z	plug_material	plug_Z_extent_cm	cone_material	coil_collar_step(Y/N)	coil_force_N	coil_force_lbf	plug_Z_inch
A	-214.25	JLab_spec	52.45	JLab_spec	N	-2520	-566	20.65
B	-214.25	JLab_spec	52.45	1010	N	-26553	-5969	20.65
C	-214.3	JLab_spec	52.4	JLab_spec	N	6504	1462	20.63
D	-214.4	JLab_spec	52.3	JLab_spec	N	9695	2179	20.591
E	-214.25	JLab_spec	52.45	1010	Y	-27373	-6153	20.65
F	-214.25	JLab_spec	52.45	JLab_spec	Y	-3340	-751	20.65
G	-214.25	1010	52.45	1010	N	-26070	-5861	20.65
H	-214.63	1010	52.07	1010	N	-6431	-1446	20.5
I	-214.25	1010	52.45	1010	Y	-26843	-6034	20.65
J	-214.7	1010	52	1010	Y	-3978	-894	20.472
K	-214.75	1010	51.95	1010	Y	-2287	-514	20.453
L	-214.8	1010	51.9	1010	Y	-758	-170	20.433

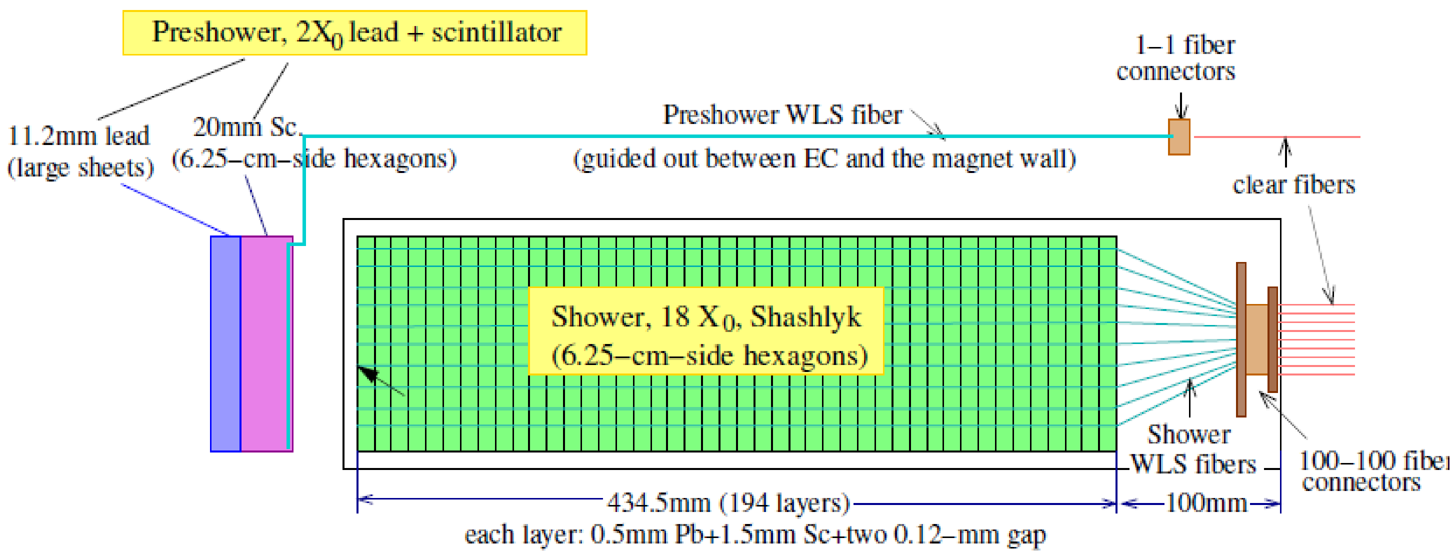
Comparing models A and C one sees that with the JLab steel BH curve plug extent 52.435 cm would approximately null the force on the coils, 0.015 cm or 0.006" from model A. Hard to hold that tolerance on a piece this size. With 1010, models K and L, 0.030" less than K gets close to null.

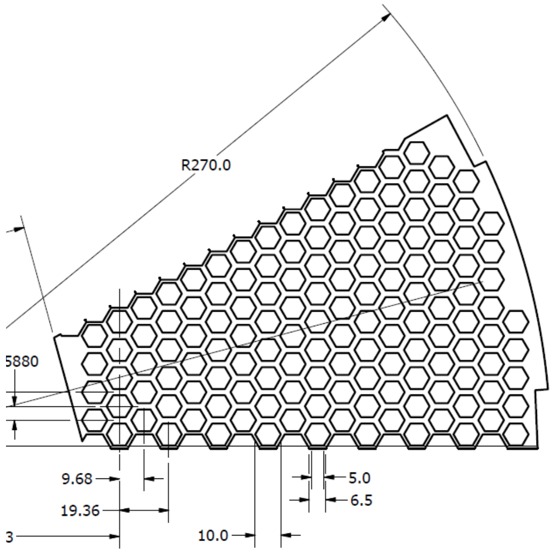
Jay Benesch at JLab

Shashlyk Style ECal

New Production
quality, cost, and mass production capability

- ➢ Longitudinal design: preshower + shower (2+18 X_0)
  - Preshower: one layer lead and scintillator.
  - Shower module: (0.5mm lead + 0.1mm reflector×2 + 1.5mm scintillator) ×194 + 96 WLS fibers penetrate.
- ➢ Transversal design: 100 cm^2 hexagon, arranged in a ring shape

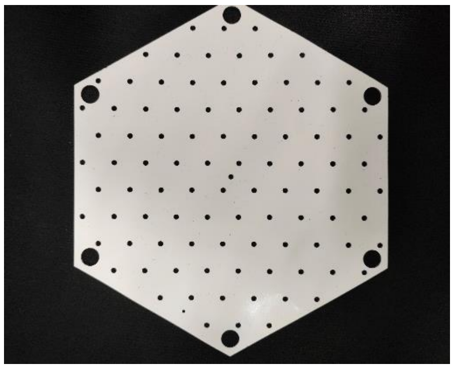




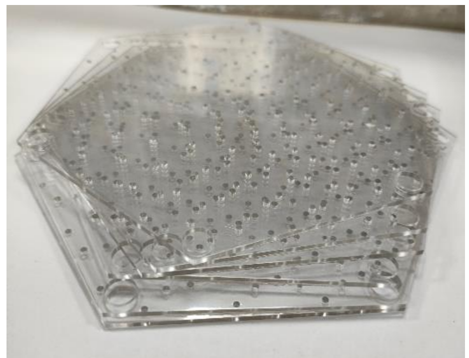
Shandong U., Tsinghua U., UVa, Argonne, Syracuse

ECal Materials

Exploration of various materials to find the best solution



Lead Sheet with Reflective Coating



Plastic Scintillator

ESR

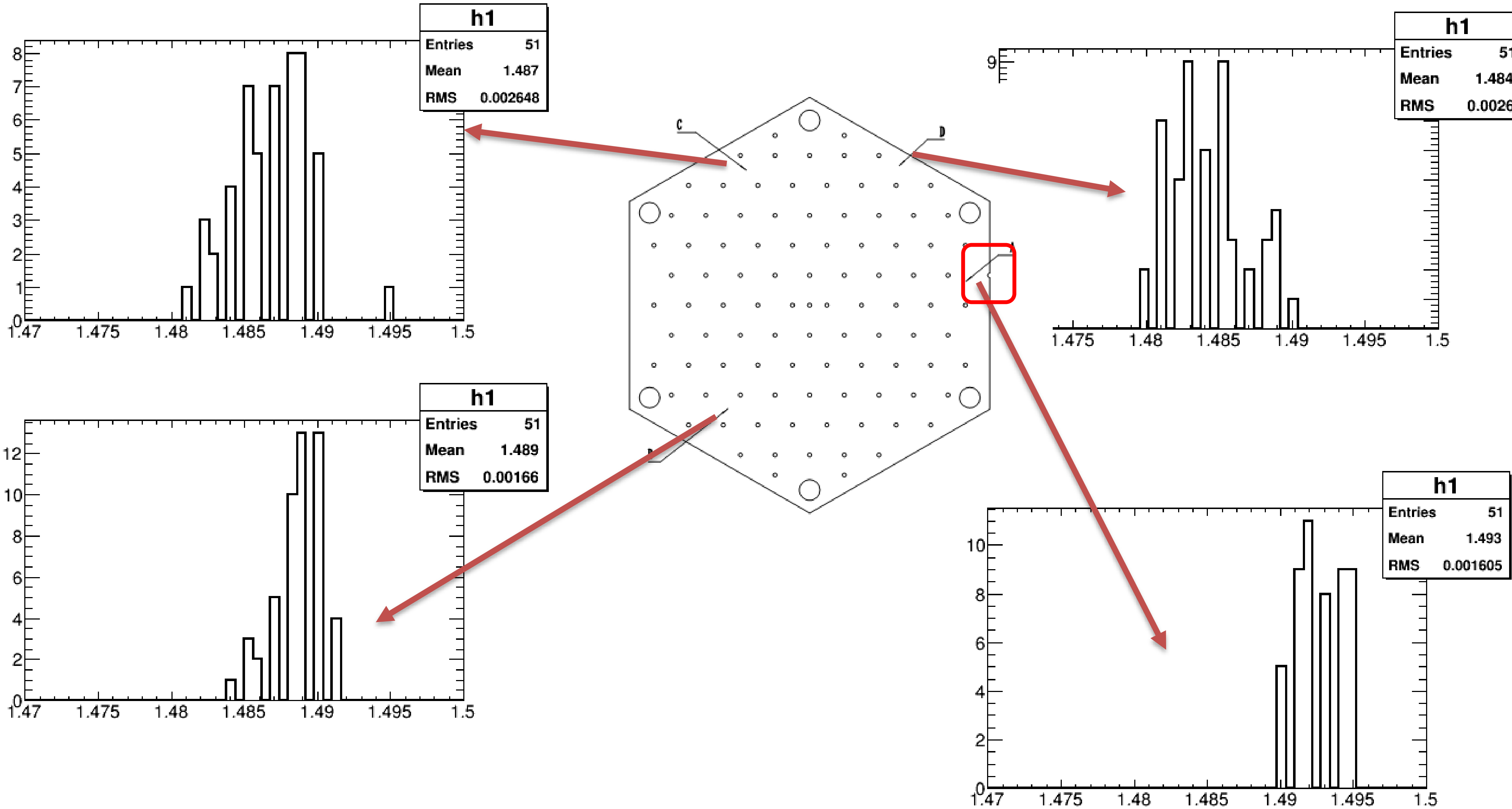
Part	Type/Material
Scintillator	KEDI/Hengxin
WLS fiber	Y11 multi-cladding
outside surface	TiO_2
fiber end reflector	ESR film
lead	paint TiO_2*

*instead of reflective layer between lead

optical reflective glue

tyvek

ECal Quality Control (scint thickness)



ECal Quality Control (scint transparency)

Scintillator	Hengxin	Kedi	
		light	dark
sample1	86.9	87.8	84.2
sample2	87.6	87.9	84.7
sample3	87.6	86.4	86.9
sample4	87.6	86.4	86.1
sample5	87.6	87.7	85.3
sample6		87.5	85.2
Average	87.5	87.3	85.4

ECal Quality Control (lead reflectivity)

lead	current	for 7 towers	Nica
sample1	88.45	79.95	89.25
sample2	89.43	85.18	89.23
sample3	88.81	82.66	86.97
sample4	89.06	83.01	88.98
sample5	85.77	90.44	88.99
sample6	89.47	80.29	87.08
Average	**88.5**	**83.6**	**88.4**

ECal Module Assemble

Latest New Module

New Hole Design and Injection Mold:

KURARAY Y11 Multi-Cladded WLS Fiber

Hengxin batch2 Scintillator

3M ESR Film as Fiber End Mirror (Reflectivity >98%)

Lead Paint with TiO_2

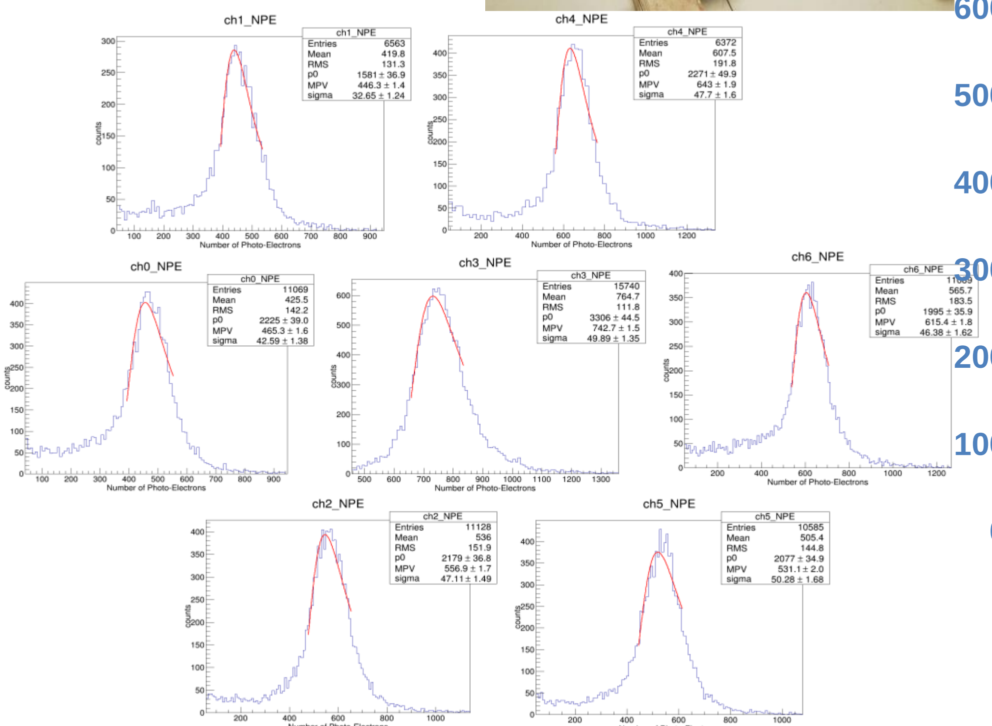
Module Outside Surface Paint with TiO_2

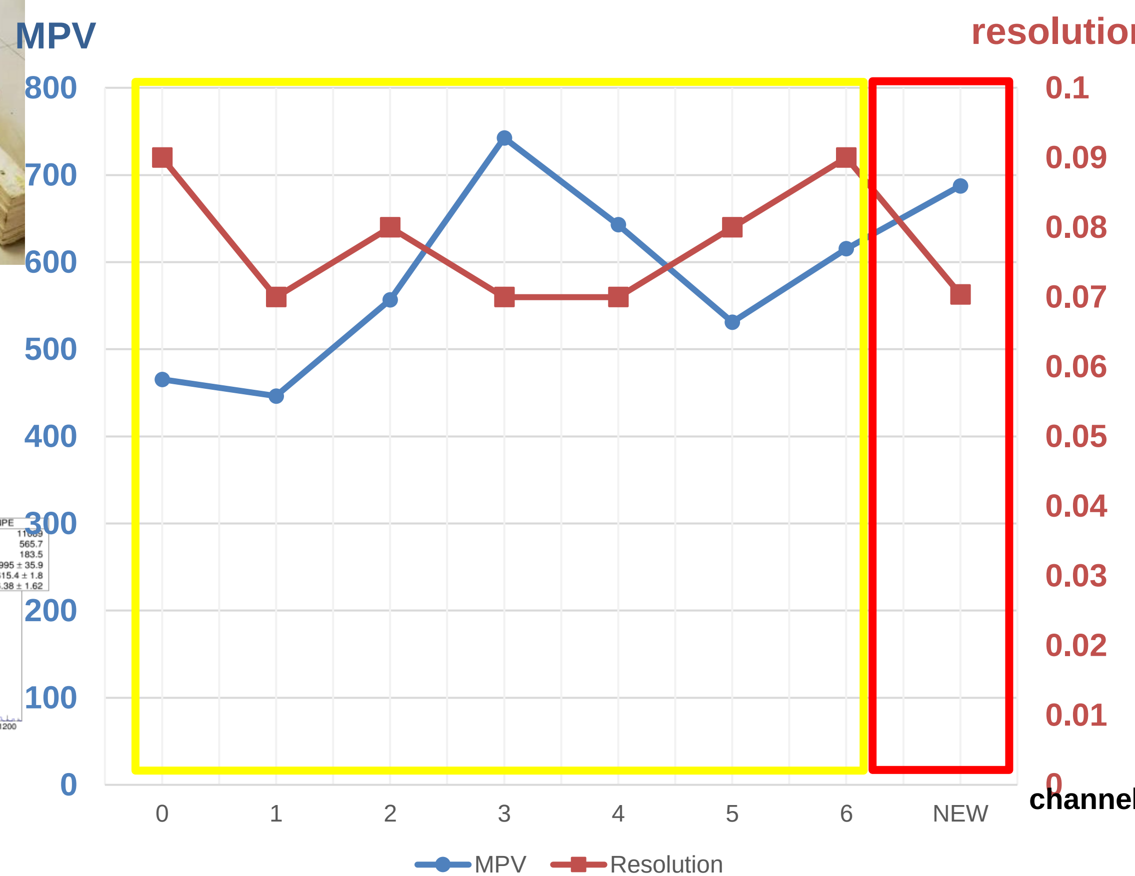
ECal (6+1 Super Module 2023)

Cosmic test results

Much improvement comparing to the previous 3 Super Module used in the Fermi Lab and HallC beam tests

The position of histograms corresponds to the module position in the frame

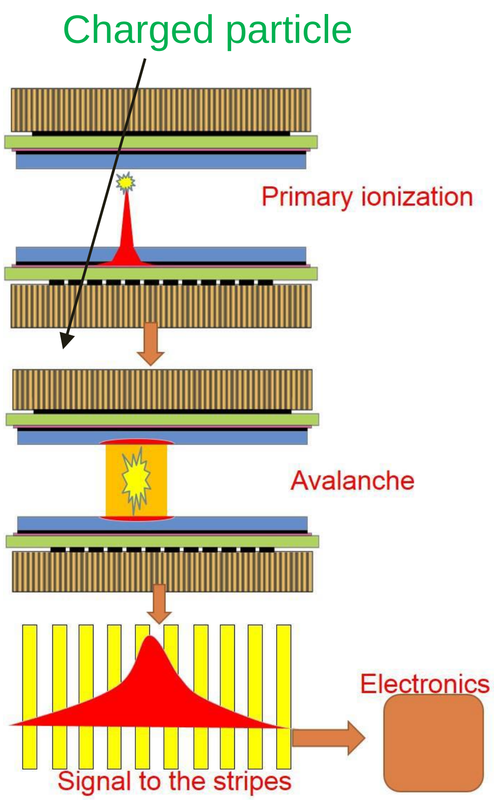




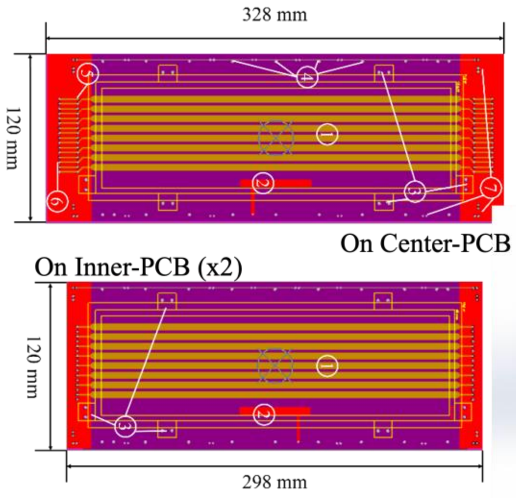
Resolution = σ /mpv

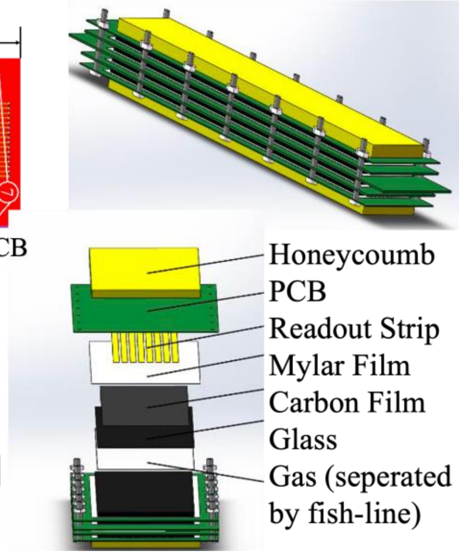
Multi-gap Resistive Plate Chamber (MRPC)

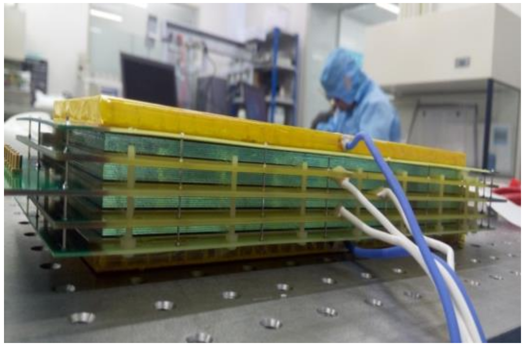
➢ General Principle



- Low-resistivity glass plates, Standard gas (95% F134a + 5% iso-butane), HV(~12kV)
- Good performances:
  time resolution, efficiency, rate capacity (>30kHz/cm^2), radiation-hard, magnet safe
- Certain spatial resolution (by strip pitch, 0.5cm~1.0cm)
- Low cost, easy manufacturing, large sensitive area (up to 1.0mx0.5m)
- Used by ALICE, STAR, etc.





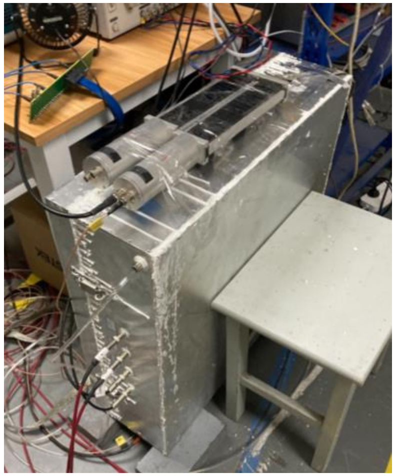


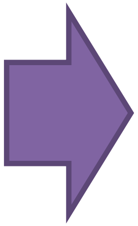
Tsinghua U., USTC,JLab

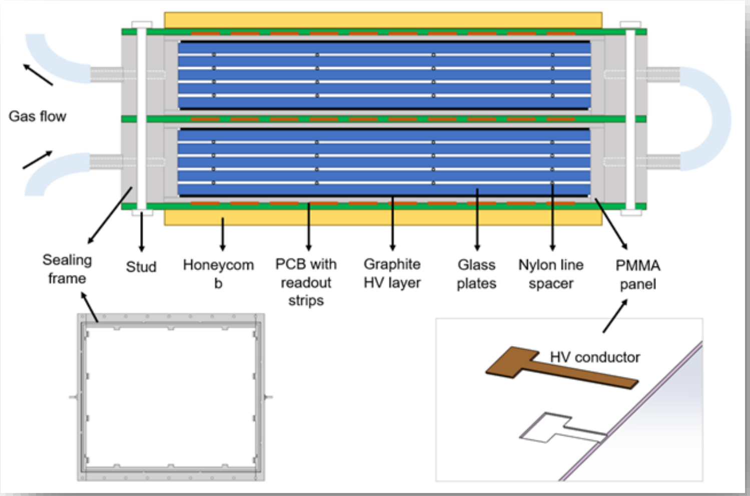
Sealed MRPC

➢ Tsinghua's new Sealed MRPC (sMRPC)

- Gen3 MRPC with sealed gas → No more boxes!
- More compact, less radiation length
- Reduce greenhouse gas emmission (20cc/cm^2/min)
- Regular glasses (max. rate limited)
- Can make into big sizes

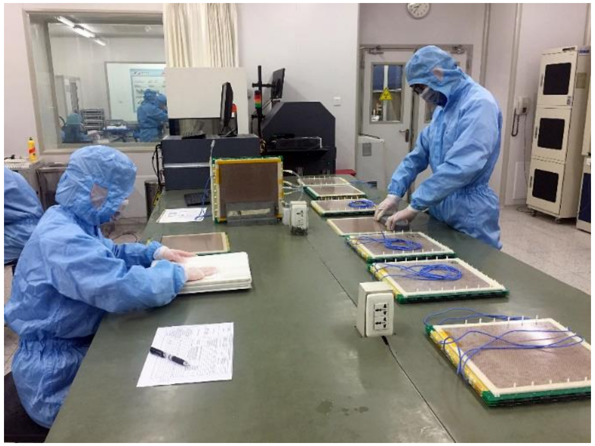






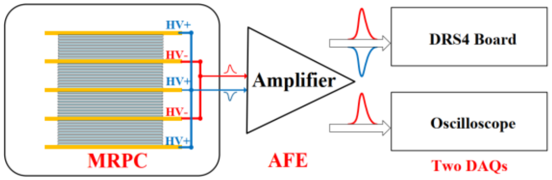
- sMRPC for CEE & CBM experiments
  - ✓ 32 x 27 cm^2
  - ✓ handle up to 25KHz/cm^2
  - ✓ 8x2 layers at 140um → 60ps!
  - ✓ Readout by NINO+TDC
  - ✓ Mass production at Tsinghua's Miyun workshop

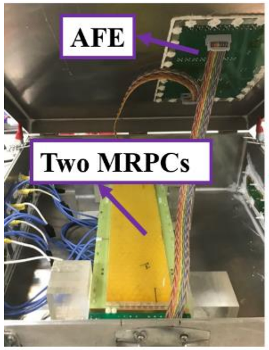
Y. Wang et al 2019 JINST 14 C06015
D. Hu et al 2019 JINST 14 C09014

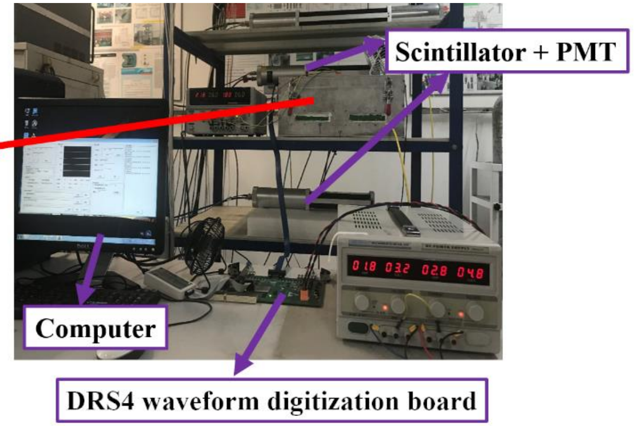


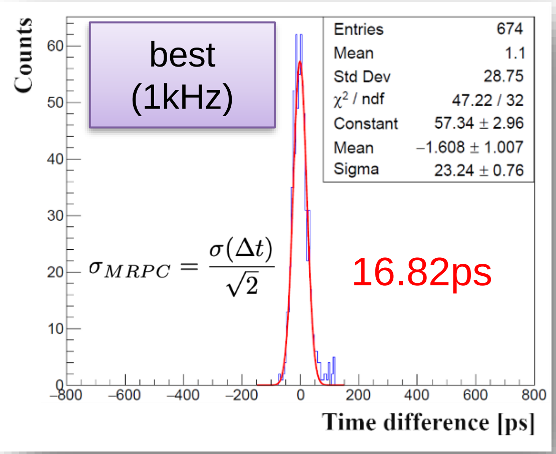
High Time Resolution MRPC

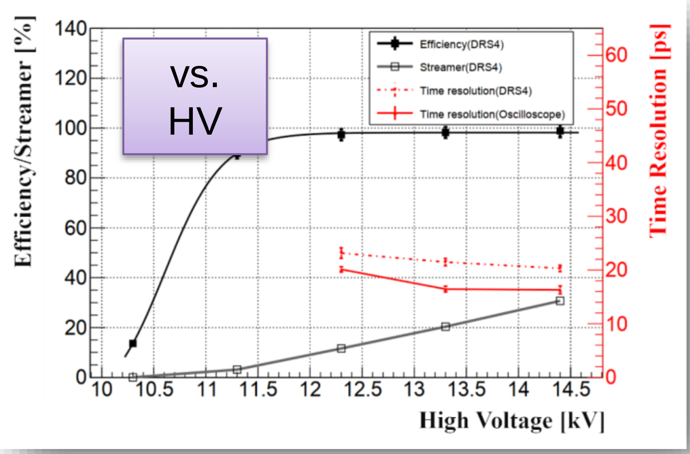
- Tsinghua's High-Time Resolution MRPC
  - For SoLID's high-rate & high-background environment
    - ✓ Low resistance glass ($10^{10}\Omega \cdot cm$, best quality)
    - ✓ 32-gaps (4 stacks), 400um thin glasses
    - ✓ 104um gas-gap + waveform-sampling
      - → 20ps & 95% efficiency at 15kHz
    - ✓ 128um gas-gap + ToT method → 20ps at 15kHz
    - ✓ Small sizes & not sealed yet
  - Not proven in real beam yet

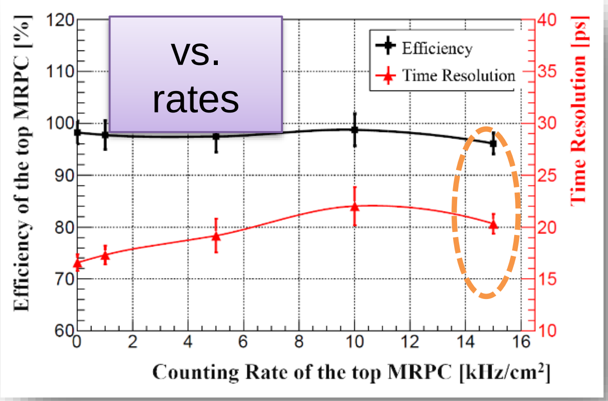












Y. Yu et al 2022 JINST 17 P02005

Y. Yu et al 2020 JINST 15 C01049

FEE for MRPC

➢ Readout Electronics

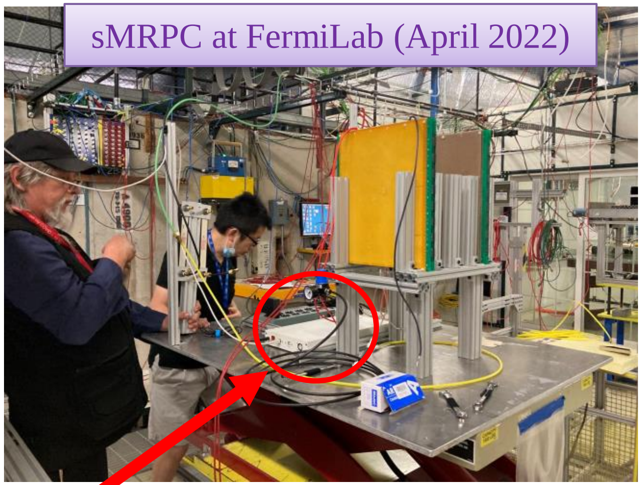
❑ <u>Goals:</u> Test out time-resolution w/ front-end electronics options

❑ Supports from Crispan Williams, Jorgen Christiansen, David Porret (CERN), Lei Zhao (USTC), & Zhen Hu (Shenzhen Advanced Research Inst.)…

❑ PreAmp + DIS
  - NINO (discontinued)
  - pico2023 (*NEW*)

❑ TDC
  - FPGA base (not rad. dard)
  - picoTDC (*NEW*)

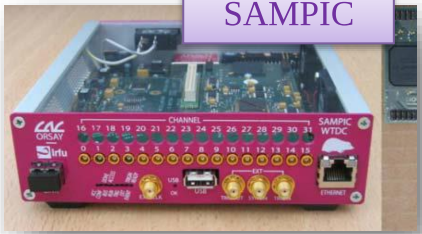
❑ Waveform Sampler
  - DSR4 (slow)
  - SAMPIC (JLab ordered)
  - NALU AARDVARC



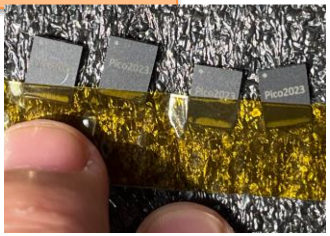
sMRPC at FermiLab (April 2022)

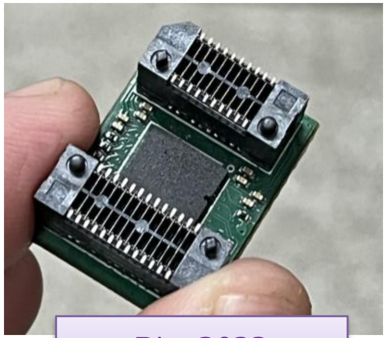
USTC FEE (NINO+FPGA-TDC)

NALU

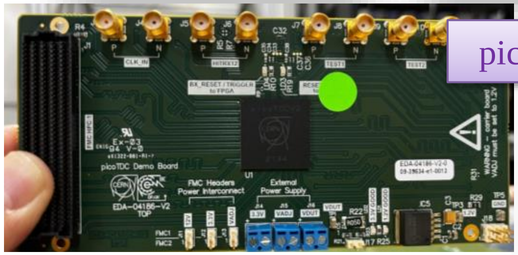


SAMPIC





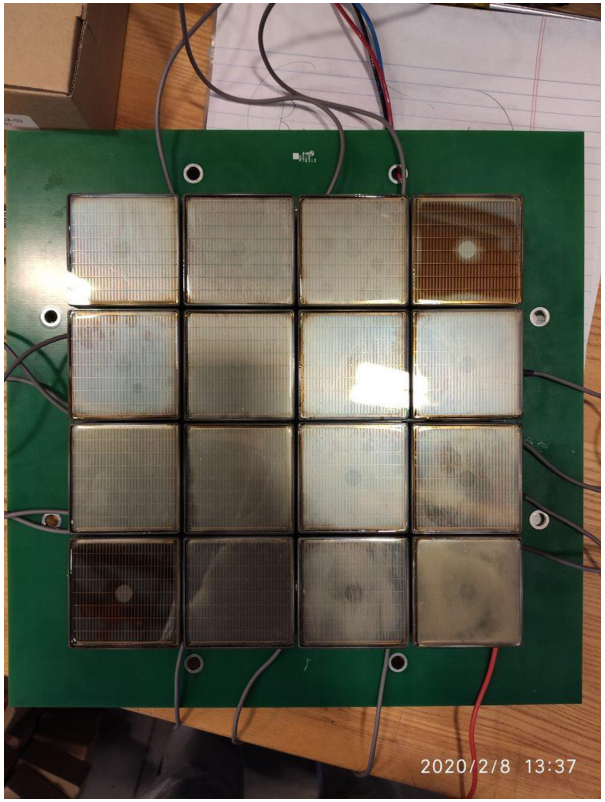
Pico2023 (replacing NINO)



picoTDC

Cherenkov Readout

4x4 MAPMT array



Light Gas Cherenkov (LGC)

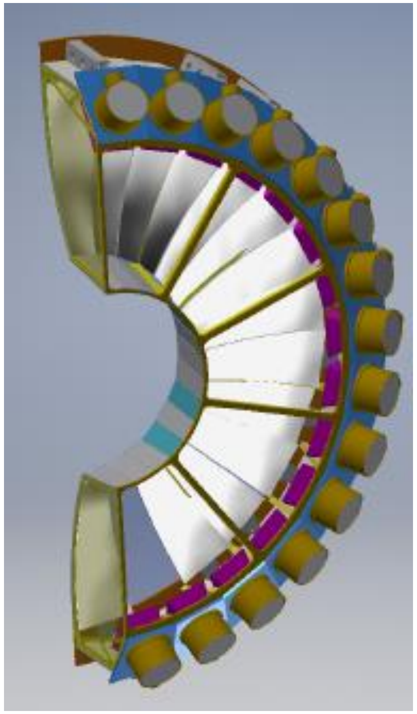
Heavy Gas Cherenkov (HGC)

- Threshold detector : identify e and reject pion for LGC and identify pion and reject kaon for HGC
- 30 sectors of 3x3 or 4x4 MAPMT array

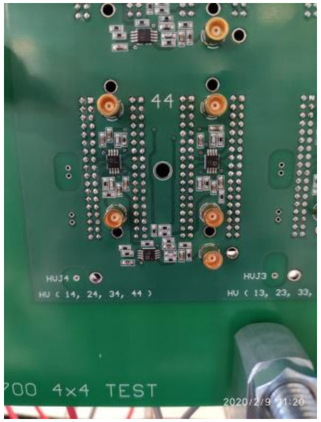
64-pixel MAPMT H12700
readout by pmt and quad and pixel

1 32	2 30	3 31	4 29	5 33	6 35	7 34	8 36
9 28	10 26	11 27	12 25	13 37	14 39	15 38	16 40
17 24	18 22	19 23	20 21	21 41	22 43	23 42	24 44
25 20	26 18	27 19	28 17	29 45	30 47	31 46	32 48
33 16	34 14	35 15	36 13	37 49	38 51	39 50	40 52
41 12	42 10	43 11	44 9	45 53	46 55	47 54	48 56
49 8	50 6	51 7	52 5	53 57	54 59	55 58	56 60
57 4	58 2	59 3	60 1	61 61	62 63	63 62	64 64

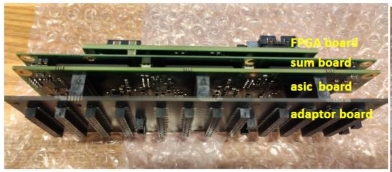
pixel
maroc



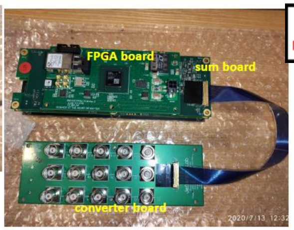
Simple sum readout (total+quad)



MAROC sum readout (total+quad+pixel)



MAROC sum boards

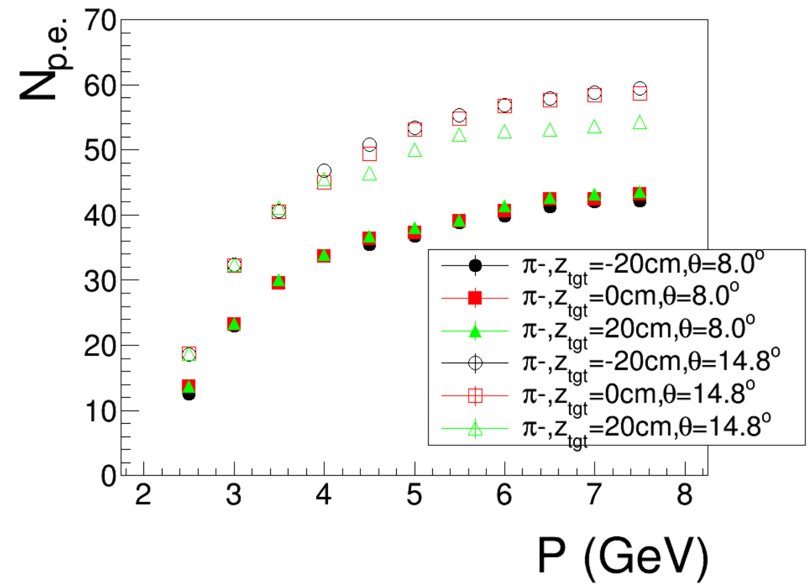


Duke,Regina,Argonne,NMSU,Temple,Stony Brook,MSU

Cherenkov (HGC, Npe)

Geant4 simulation

- HGC performance can be judged by the following figure of merit using Npe:
  1. FOM pion:
     efficiency =(Nevent of >Npe)/Ntotal
  2. FOM kaon:
     1-1/rejection = (Nevent of <Npe)/Ntotal

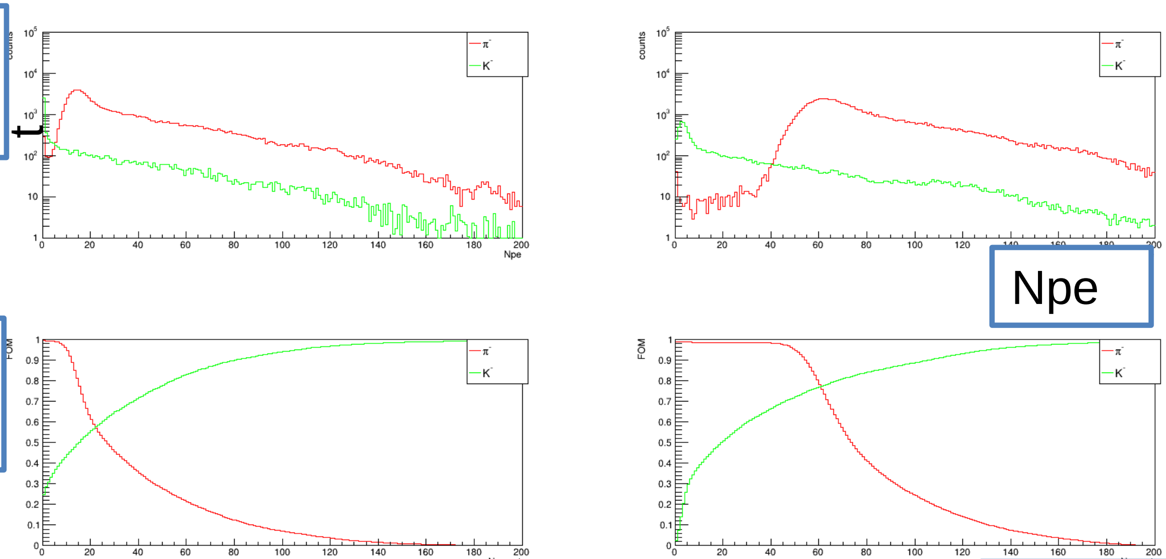


P=2.5GeV, Theta=8deg

P=7.5GeV, Theta=14.5deg

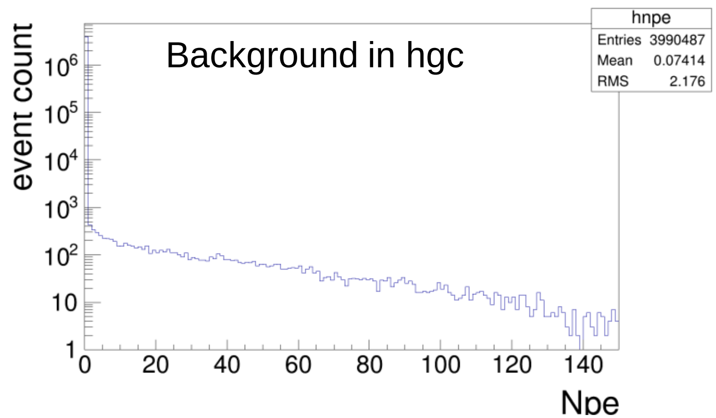
count

FOM



Npe

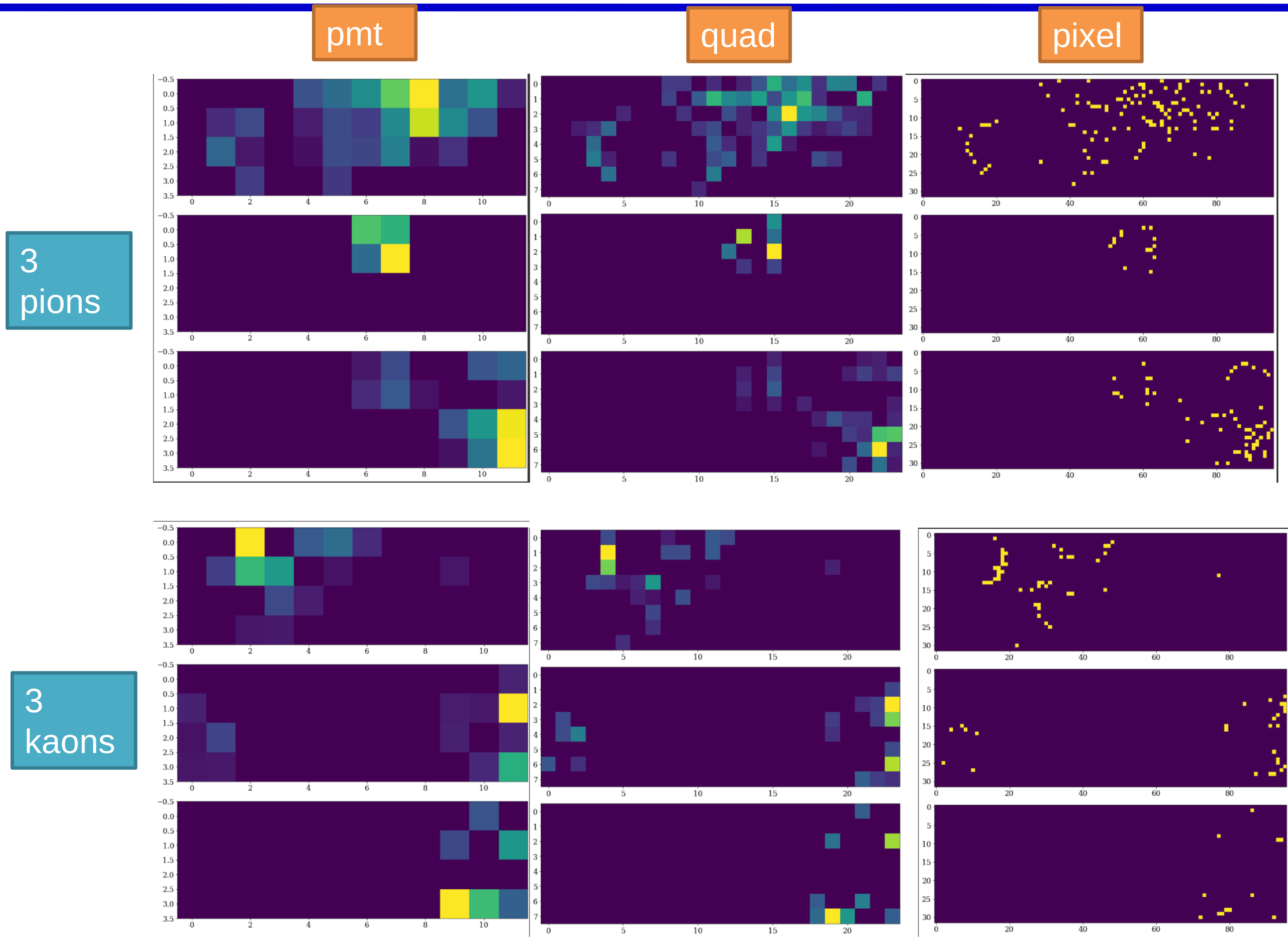
Npe cut



Only 0.5 – 0.6, too low

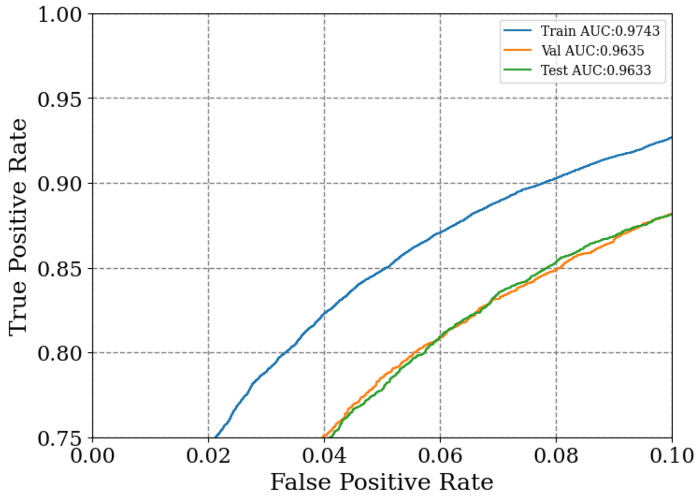
SoLID Jefferson Lab

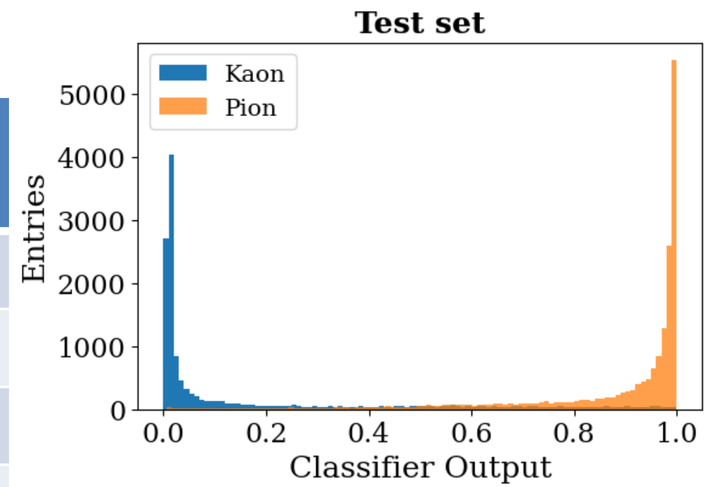
Cherenkov (HGC, 3-sector event view)



Cherenkov (HGC, AI/ML)

- Trained with a simple neural network
- ROC curve (receiver operating characteristic curve) showing the performance of a classification model at all classification values
- AUC (area under ROC) shows how good the classification
- FOM at certain output
- Error is at 0.01 level from data science group initial study





FOM		Without Bg	With Bg
p2.5_theta8.0	pmt	0.996	0.770
	quad	0.996	0.880
p7.5_theta14.5	pmt	0.998	0.991
	quad	0.998	0.994

- AI/ML with location information is much better than Npe cut
- Readout size matters

Summary

- SoLID: a **large acceptance** device which can handle **very high luminosity** to allow full exploitation of JLab12 potential

- SoLID subdetectors use new technologies in hardware and software to help reach that goal

Thank you!

supported in part by the U.S. Department of Energy under contract number DE-FG02-03ER41231