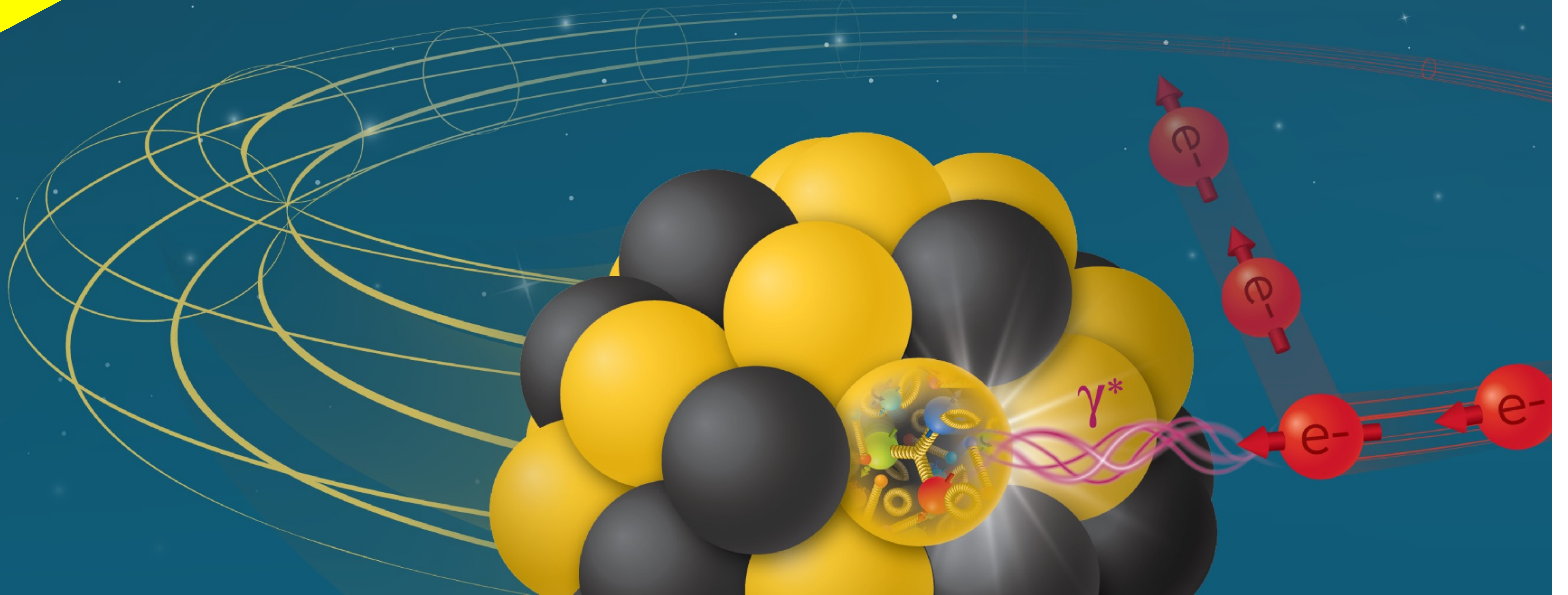
Brookhaven National Laboratory
Jefferson Lab
U.S. DEPARTMENT of ENERGY | Office of Science

nHCal (backward hadronic calorimeter)

C. Riedl (UIUC), DSTC
L. Kosarzewski (OSU), DSL
D. Brandenburg (OSU)

DRAFT 2025-05-27

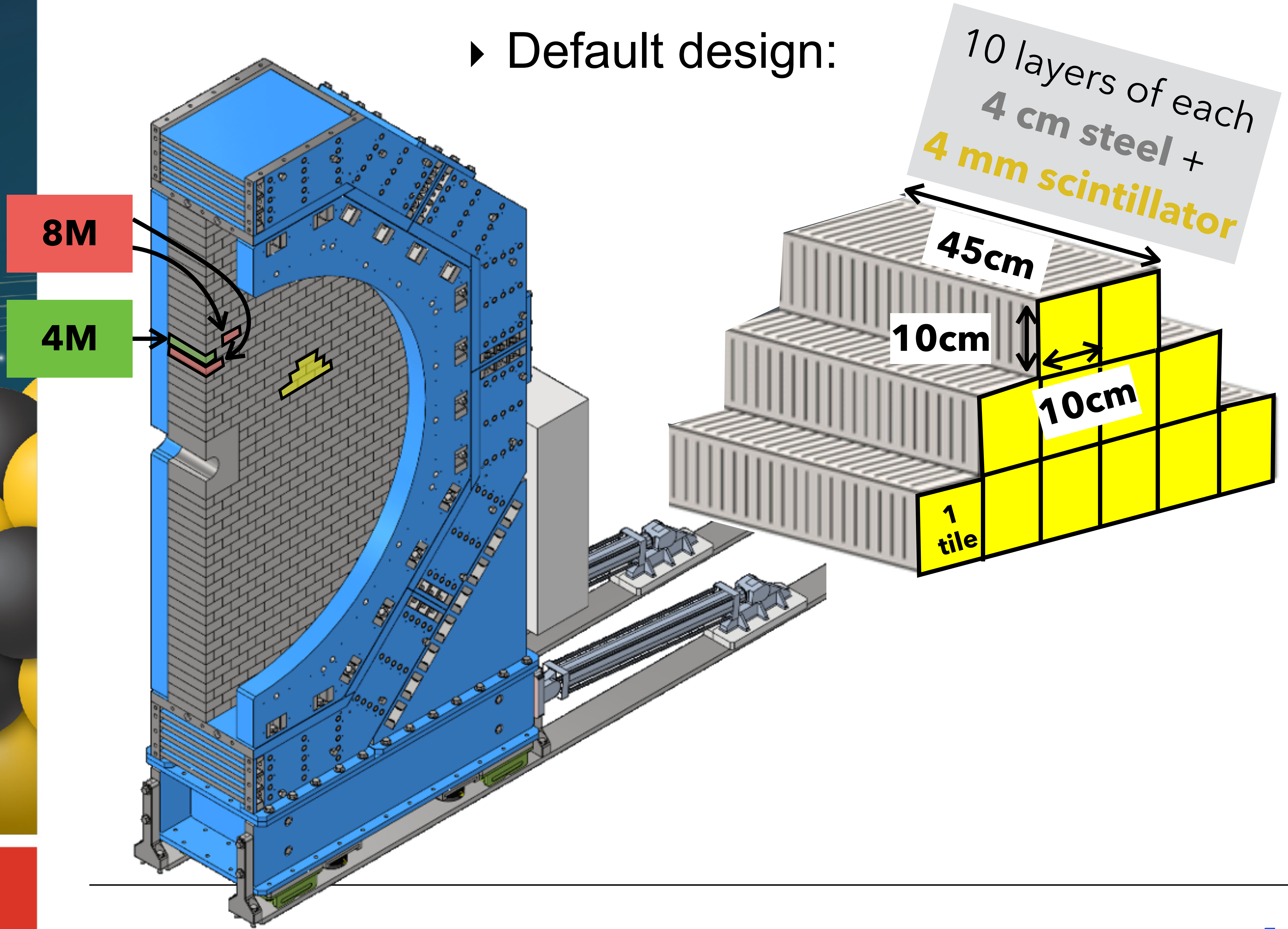
10th EIC DAC Review
June 11th – 13th, 2025

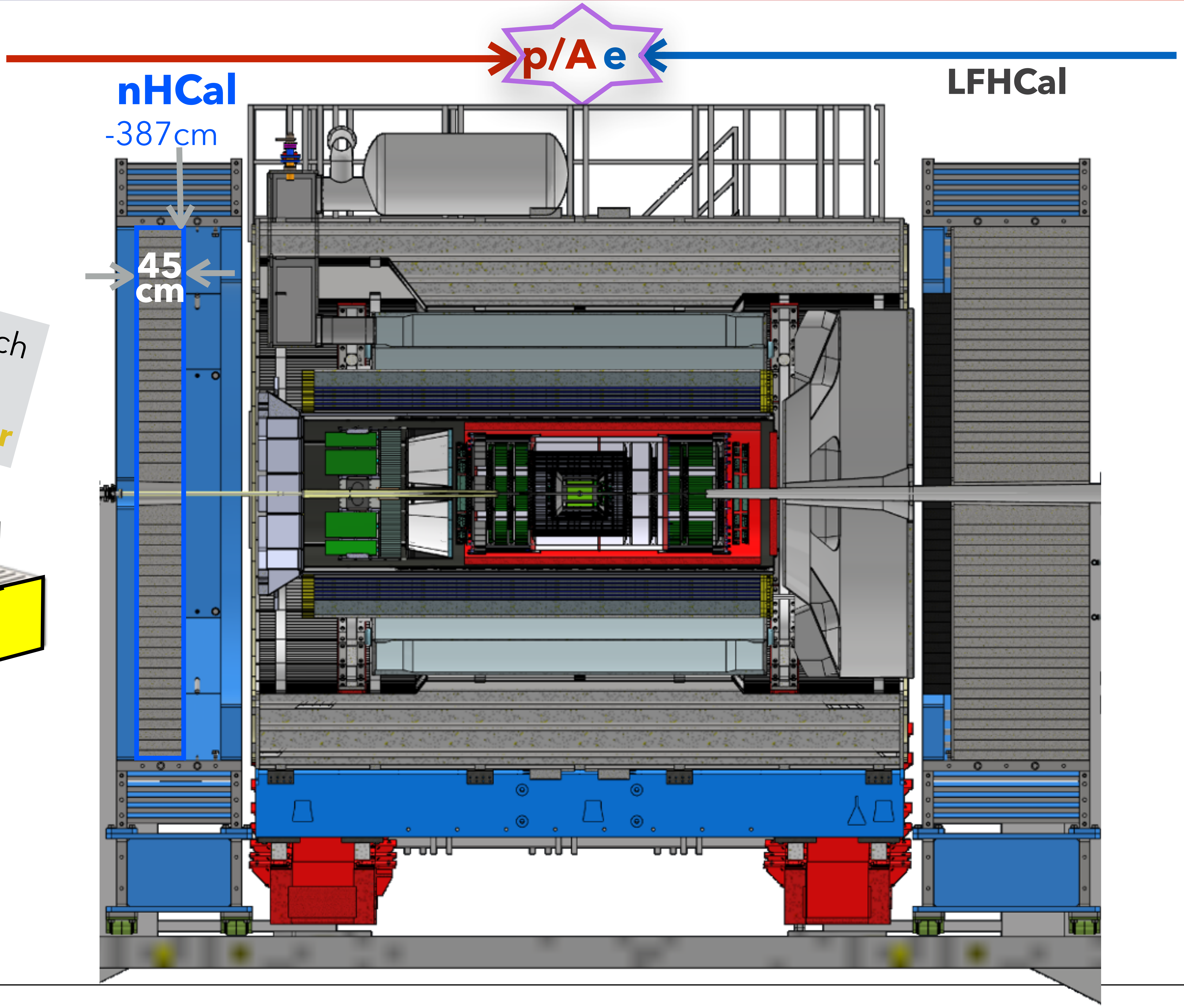


Electron-Ion Collider

Backward (electron-going) hadronic calorimeter - **nHCal**

- Sampling calorimeter with alternating Fe / SciTiles layers
  - Interaction lengths: 2.4 (LFHCal: 6
    - Default design:





−4.14 < η < −1.18

nHCal project design - purposes and requirements

<table>
<tr><th colspan="2">Purpose</th><th>Requirements</th></tr>
<tr><td colspan="2">Low x and Q^2, high y
high gluon densities</td><td>Coverage in backwards direction</td></tr>
<tr><td rowspan="2">diffraction</td><td>vector mesons</td><td>Good μ/π separation via MIP signal</td></tr>
<tr><td>dijets</td><td rowspan="2">High efficiency for low-energy neutron detection</td></tr>
<tr><td colspan="2">Neutral jets / neutral veto</td></tr>
<tr><td colspan="2">Charged jets</td><td rowspan="2">Good spatial resolution to distinguish clusters (neutral vs. charged)</td></tr>
<tr><td colspan="2">Scattered electron ID (h veto)</td></tr>
<tr><td colspan="2">Improved hermiticity
(↗ kinematic resolution in CC)</td><td>Good timing resolution</td></tr>
</table>

nHCal crucial for core aspects of EIC physics mission

Lessons from HERA / H1 backward SPACAL

NIMA 386 (1997), 397-408
PLB 665 (2008), 139-146

nHCal design optimization - overview

- **Is the design of the ePIC detector and its sub-systems appropriate and progressing well?**
- Design optimization →
- Variations from default: transverse tile size, number of layers, scintillator & absorber thickness
- Dedicated simulations
  - "Single particle" - in progress
  - Then full simulations with background

Physics impact ➡ / Design parameter ⬇	σ_E/E	Eff	μ/π sep.	λ_{int}
Gross length	x	x		
Tile configuration	x	x		
Z-layer readout	x		x	
Sampling fraction, absorber/scintillator ratio				x
Absorber material	x			x

5x5 or 10x10	scintillator thickness	0.4				0.6	0.8
[cm]	absorber thickness	4	3	2	1.52	2	4
10 layers		45					
12 layers		54					
13 layers			46				
15 layers		68					
20 layers				50		54	58
28 layers					57		

gross length

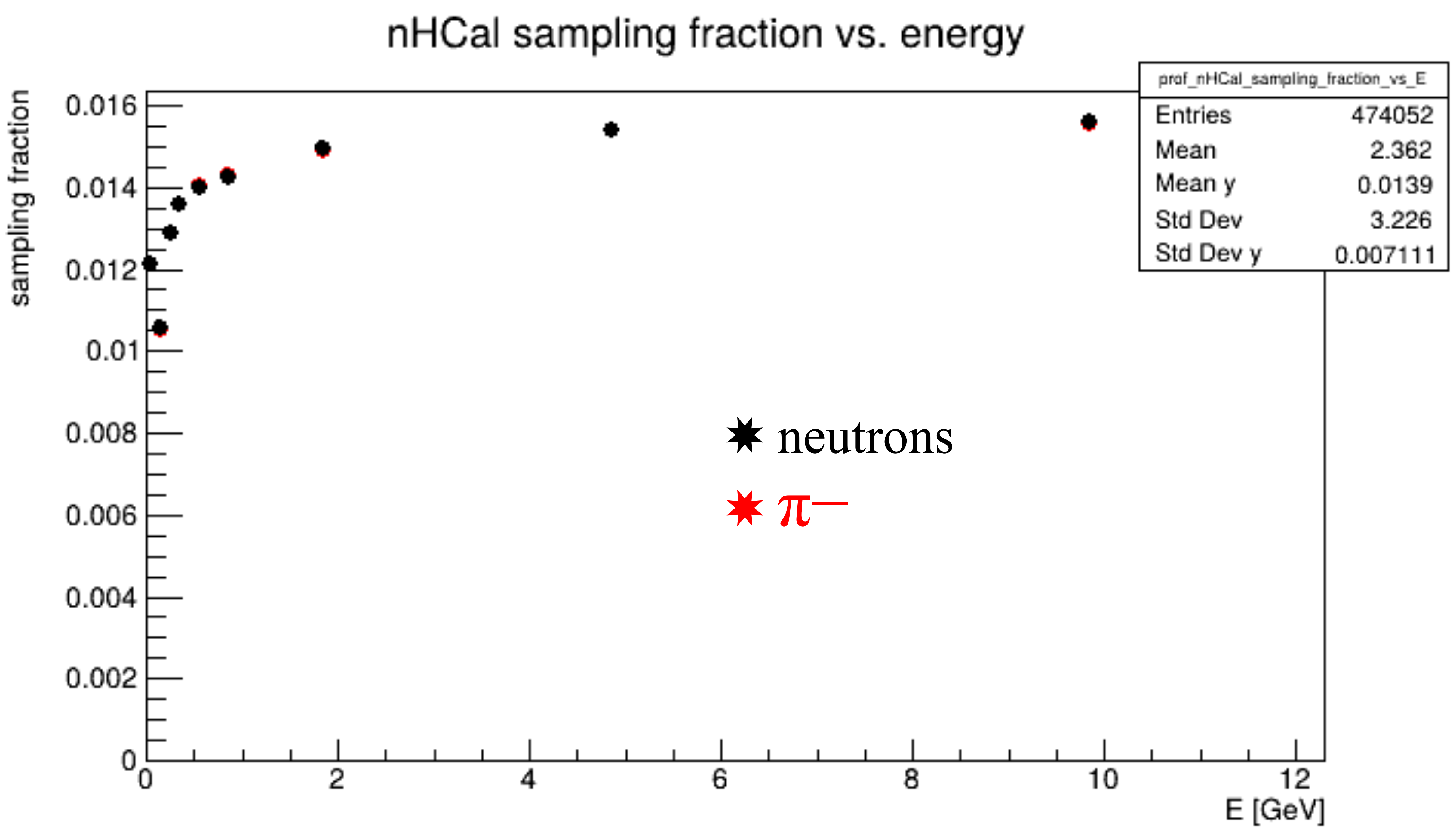
nHCal default design (5x5)

LFHCal configuration (5x5)

- Experimental performance evaluation
  - Testing different tile configurations and sizes in the lab
  - Possible confirmation of simulated parameters with prototype in a testbeam

Sampling fractions for neutrons and negative pions

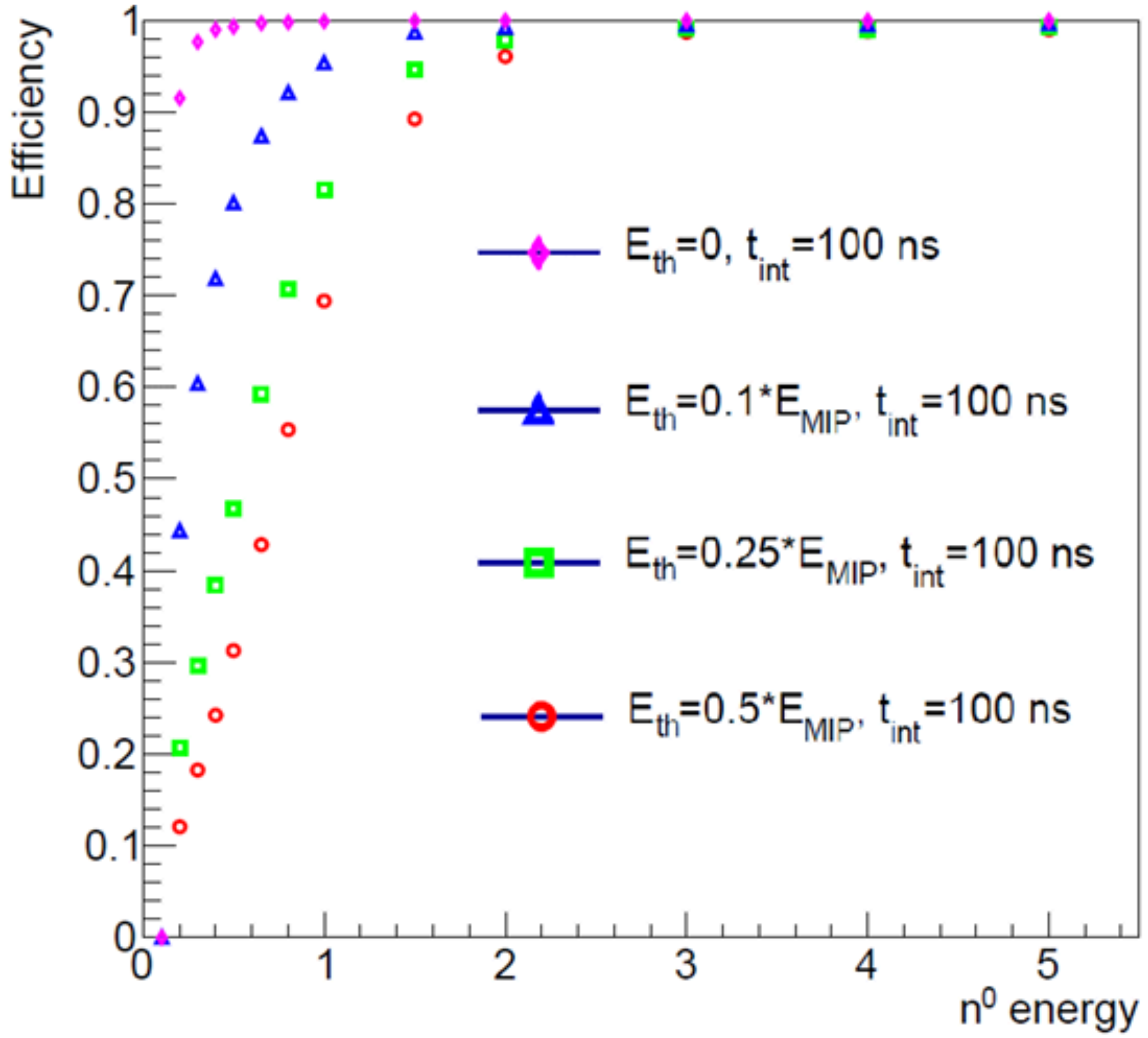
- Sampling fraction = energy deposit in absorber / incident energy
  - Plotted vs. kinematic energy
  - Single particle simulations
  - Default design (10 layers, 4cm absorber, 4mm scintillator)
- Sampling fraction ~1-1.5%
  - XXX what is the takeaway message? Is this sufficient?
  - XXX How were the individual data points acquired?



Leszek Kosarzewski (OSU)

Efficiency for neutrons

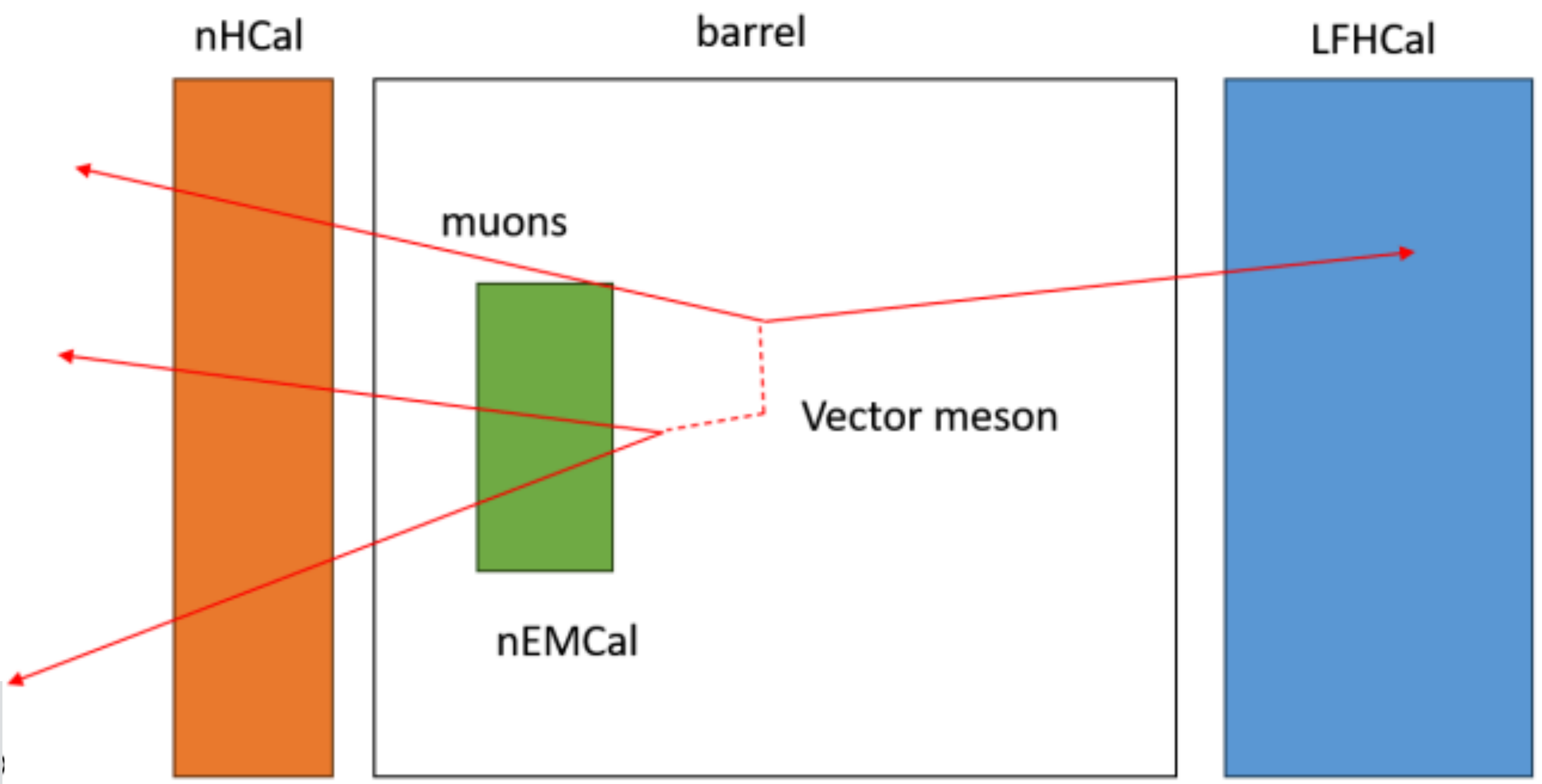
- Neutron detection efficiency for different energy thresholds at fixed integration time
  - Plotted vs. neutron energy
  - Single particle simulations
  - Default design (10 layers, 4cm absorber, 4mm scintillator)
- XXX what is the takeaway message? Are we satisfied with this?
- XXX How were the individual data points acquired?
- XXX Sam is working on similar plots - instead of different thresholds, will have different geometries

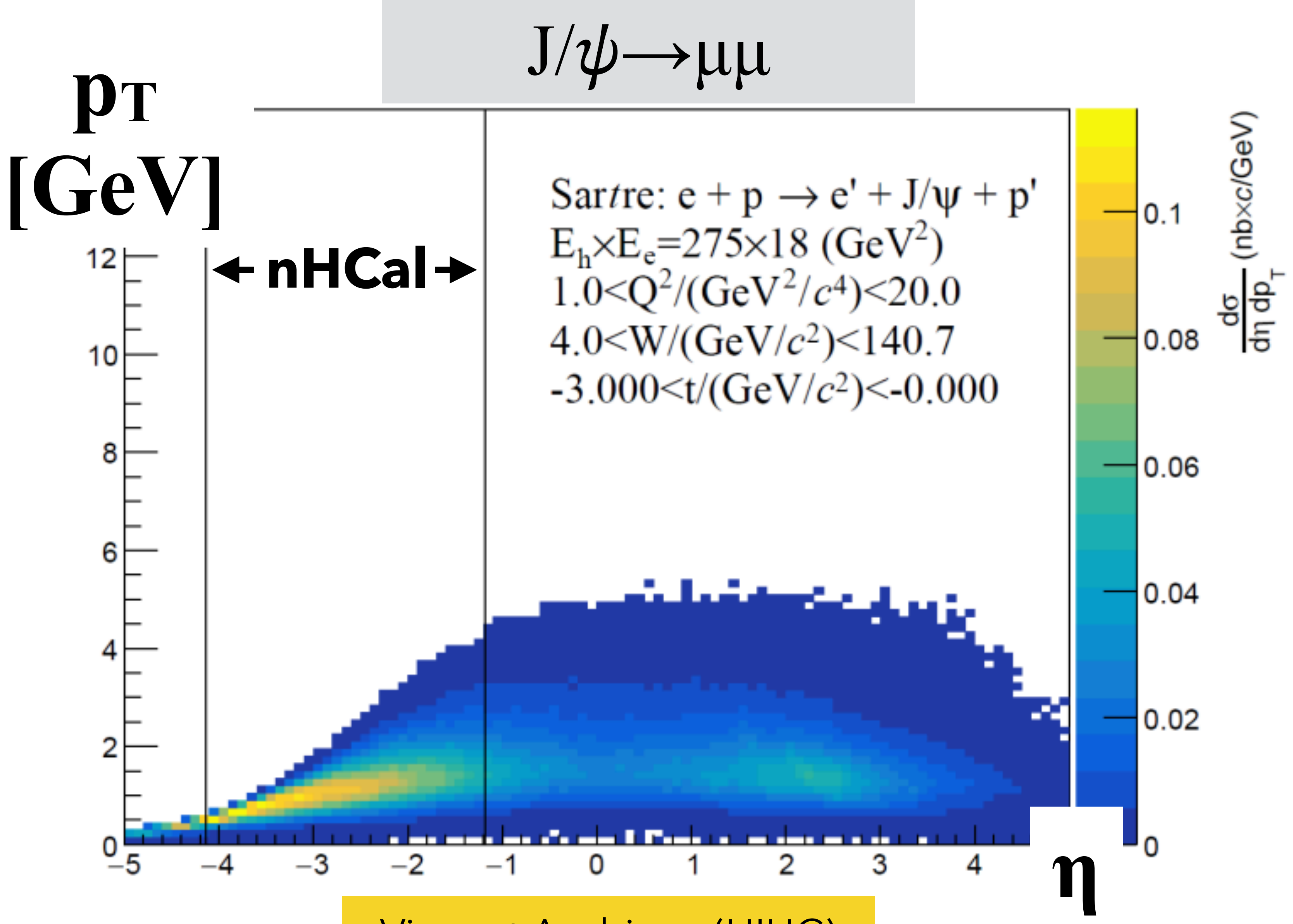


Sam Corey (OSU)

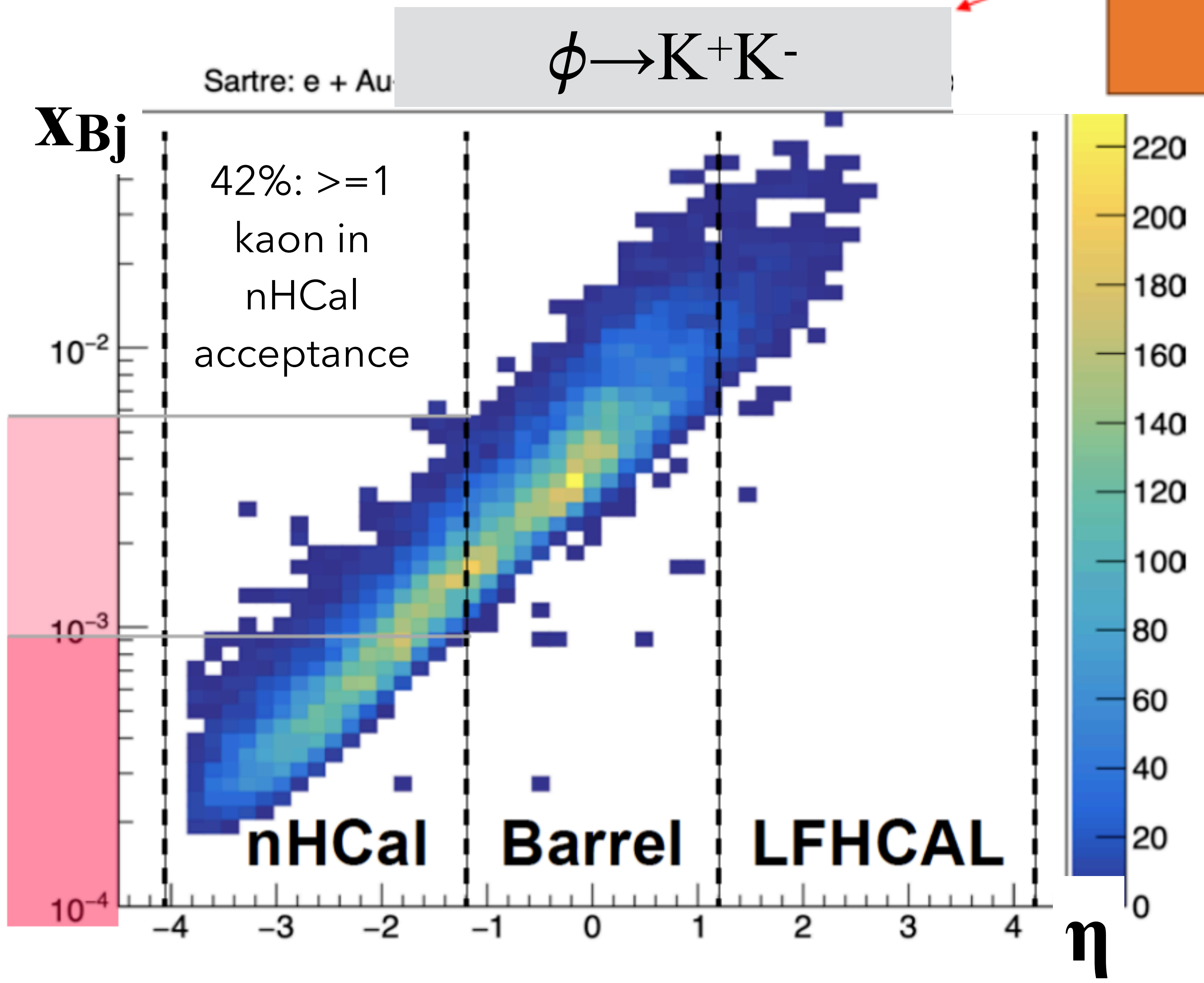
VM decay & efficiency for muon ID

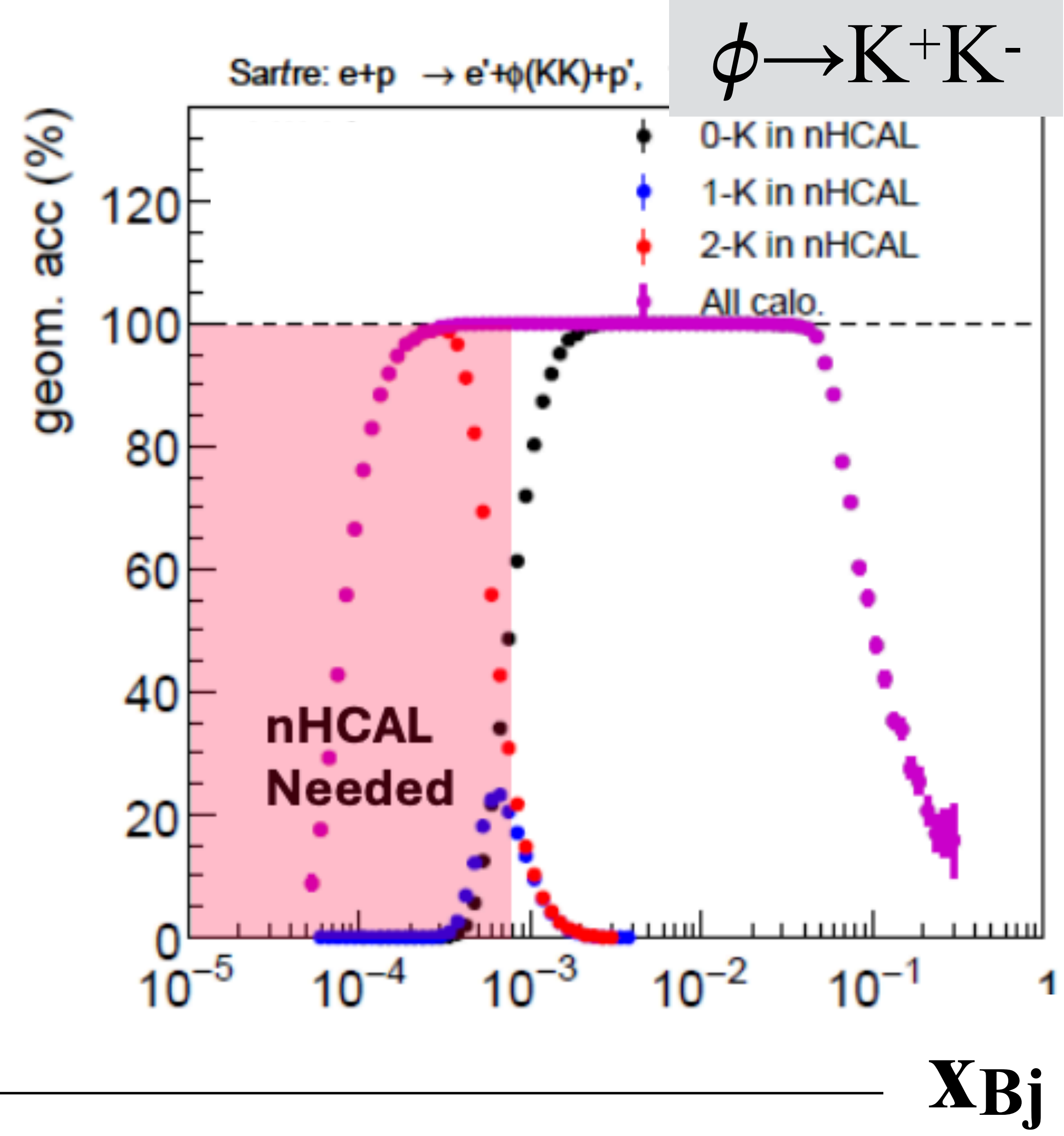
- Additional backward acceptance provides access to a more complete set of vector-meson decay topologies
  - nHCal crucial for low-x
- Muon ID efficiency studies ongoing
  - Also enhances clean separation of scattered beam electron from di-muon final states





Vincent Andrieux (UIUC)



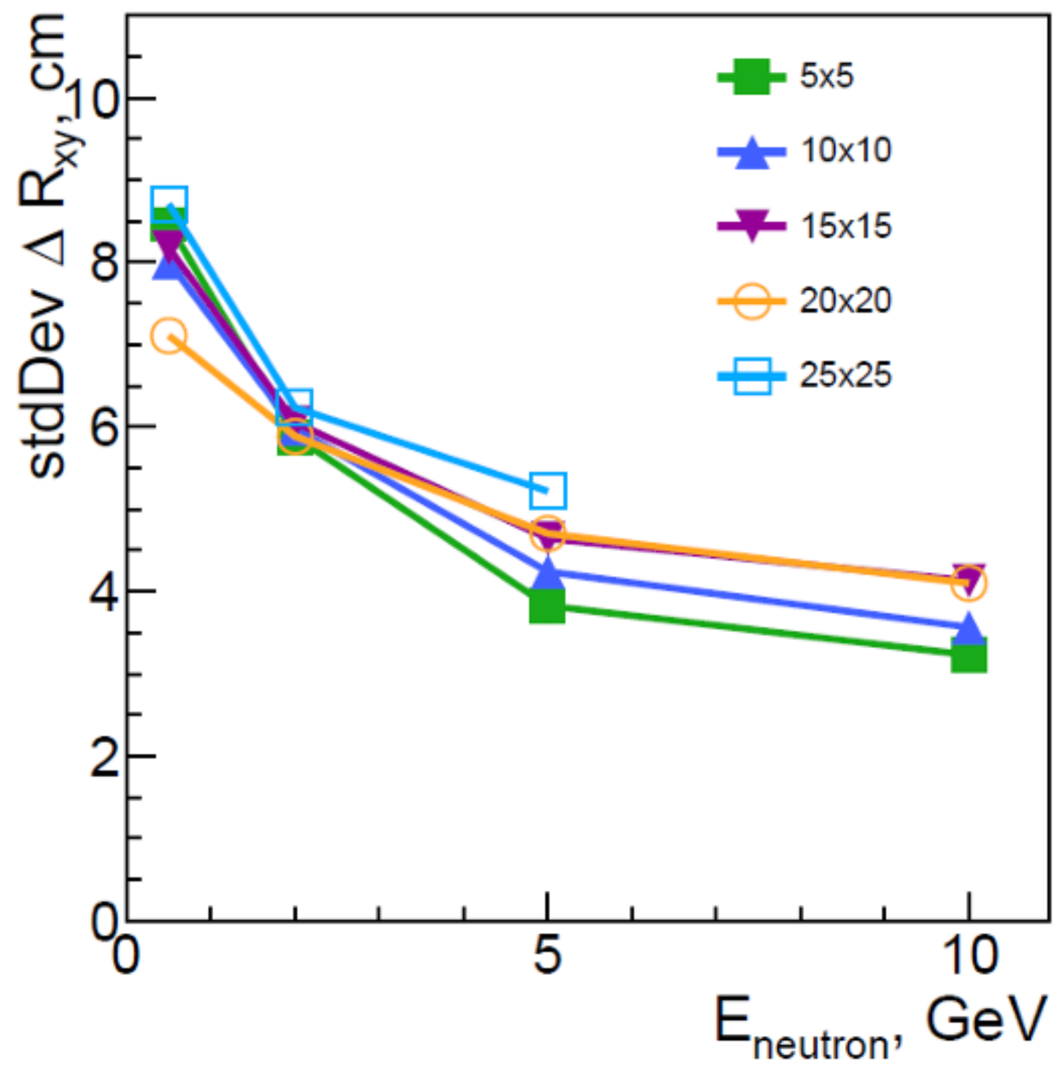


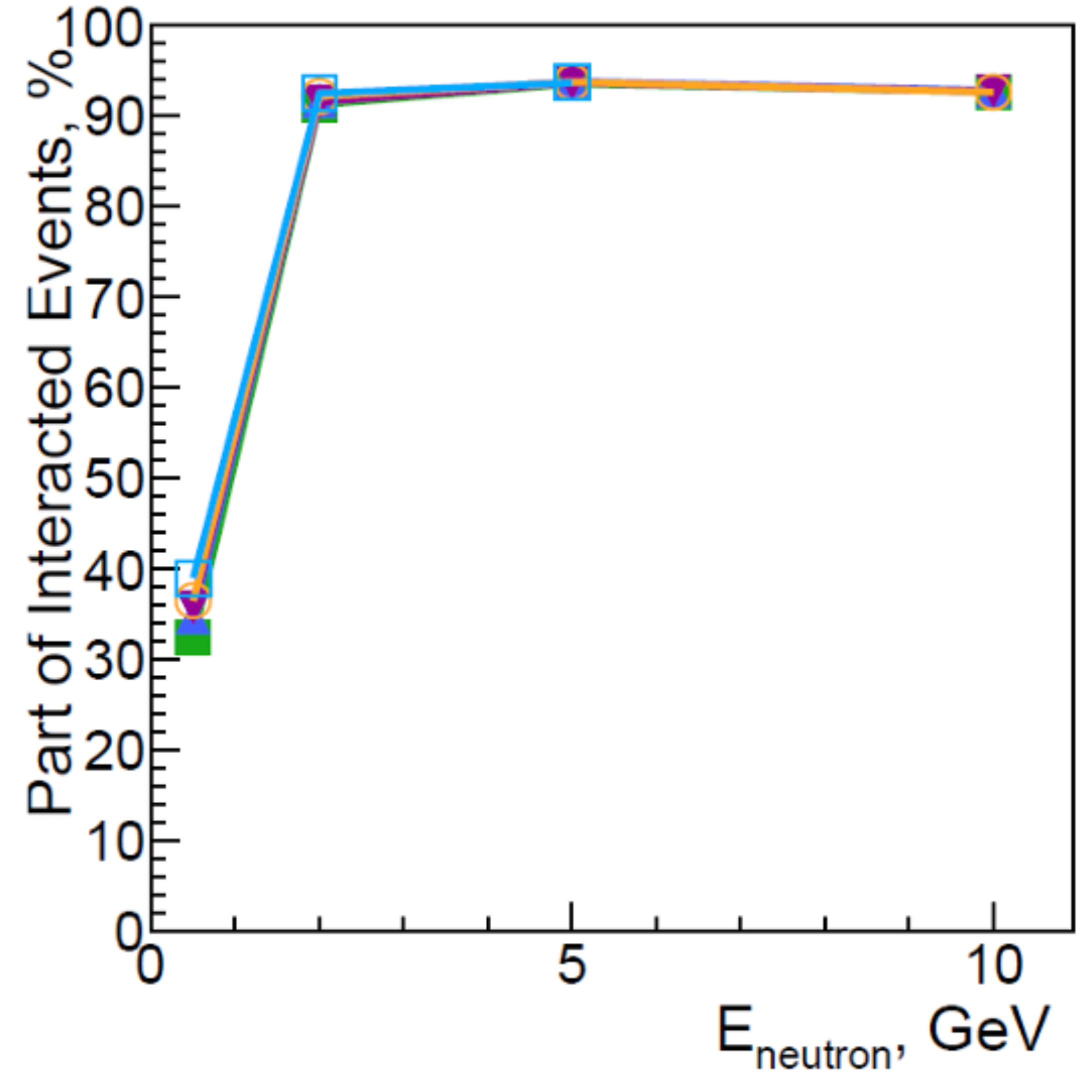
Dhruv Sharma (UIUC)

Position resolution for neutrons

- Transverse position resolution
  - Plotted vs. neutron energy
  - Single particle simulations, nHCal only
  - Default design (10 layers, 4cm absorber, 4mm scintillator)
- Position resolution rather insensitive to tile size
  - XXX Explain what this plot demonstrates and what it can NOT. How were the individual data points acquired? Mean of a distribution… Show examples. Uncertainty is standard deviation
  - XXX Check 0.5 GeV 20x20 - why is it fluctuating?
  - XXX what significance does the plot “interacted events” have? Do we need to show it?

Alexandr Prozorov (CTU)

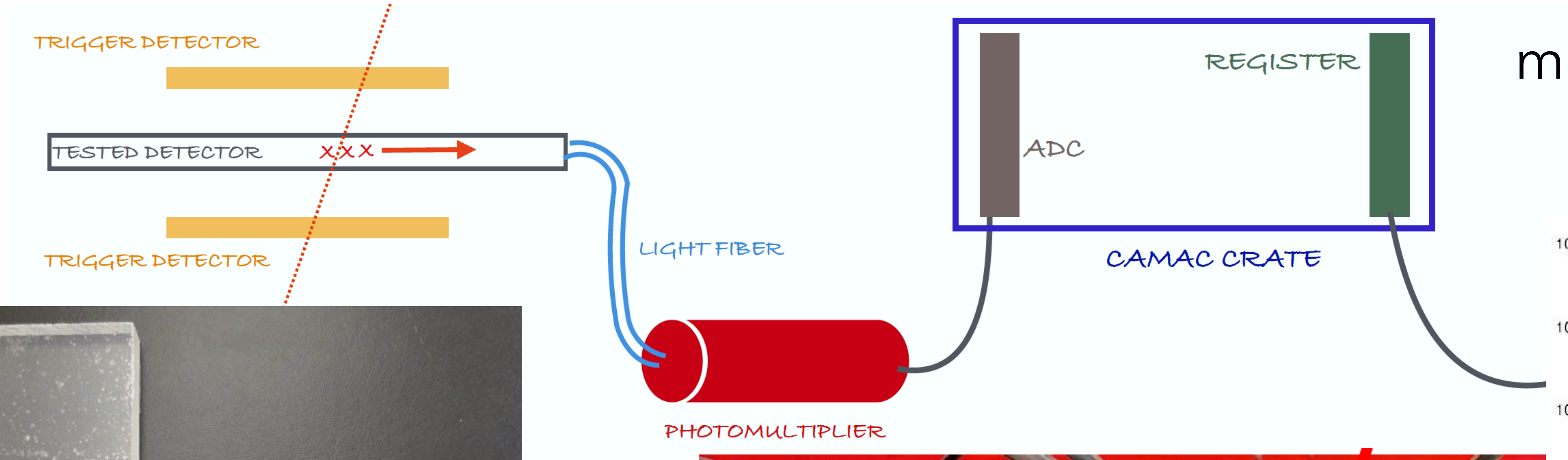




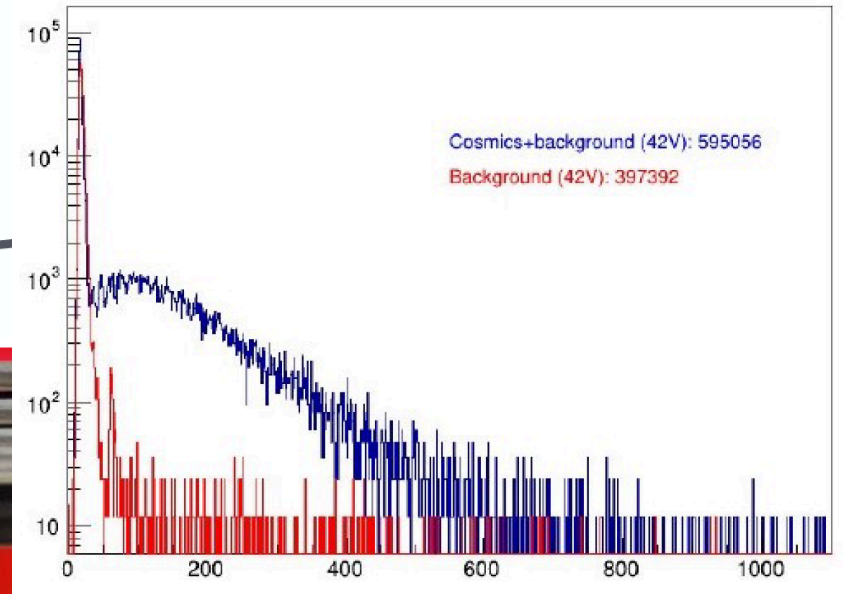
nHCal performance evaluation

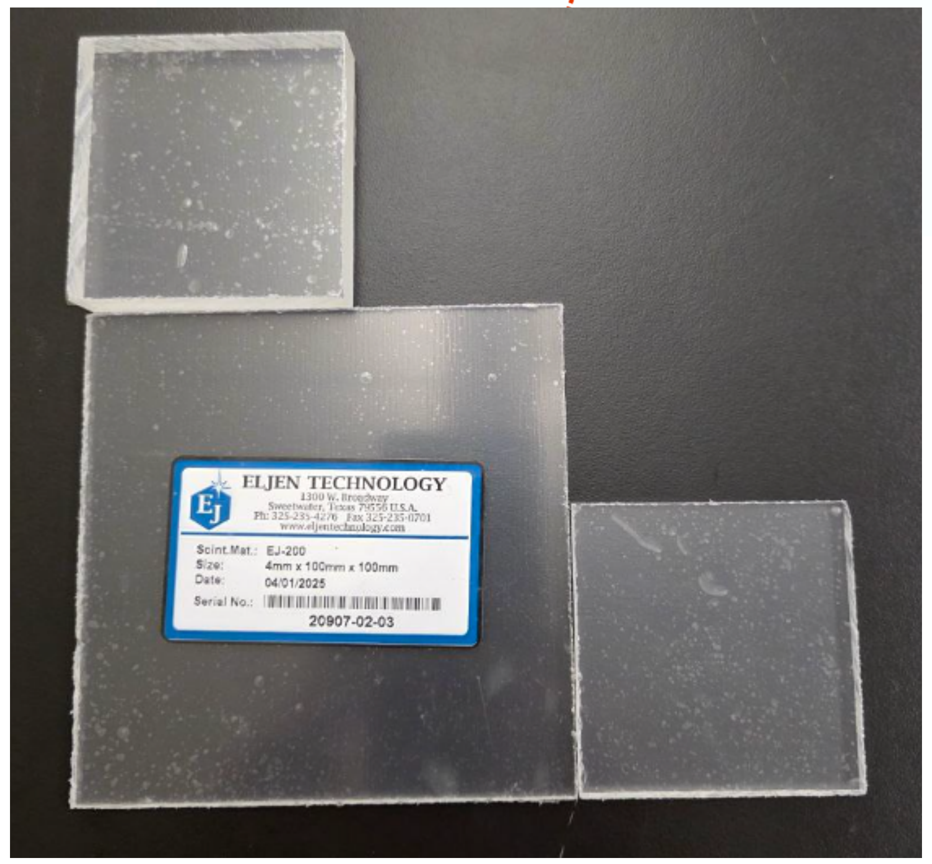
- Tile testing at OSU (XXX timeline?)
  - Cosmics and Sr source
    - Vary tile size (5x5, 10x10)
    - Vary tile thickness (4, 6, 8 mm)
    - Vary SiPM placement (center, corner, edge)
  - Performance evaluation
    - Light yield per MIP, uniformity, cross-talk

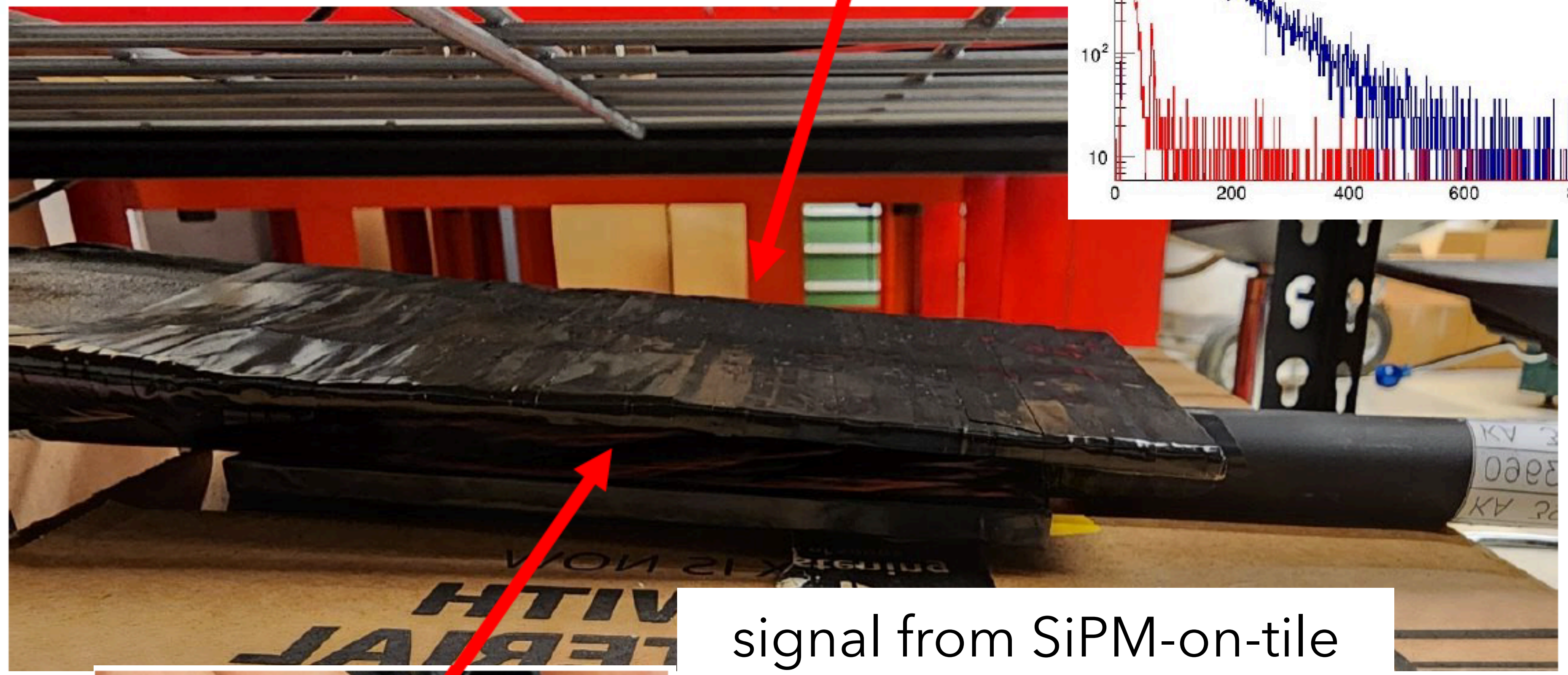
- Beams tests to verify simulations
  - Position resolution, e/h, sampling fraction

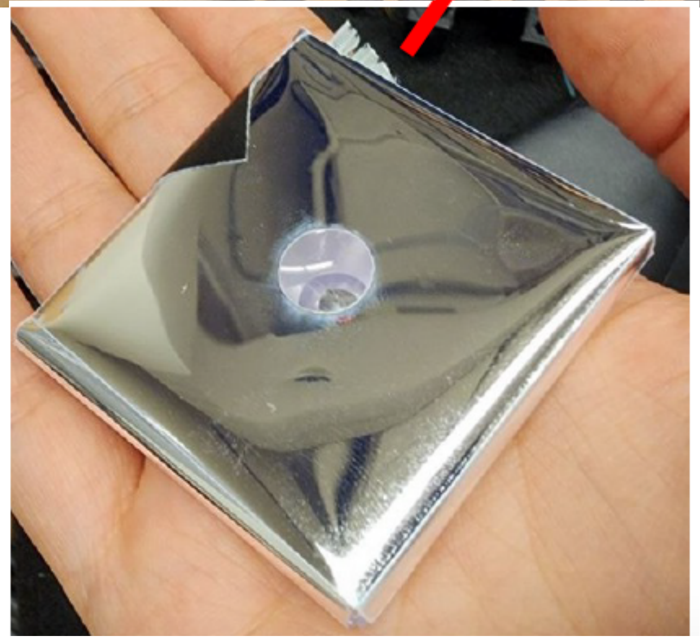


muon telescope for cosmics testing

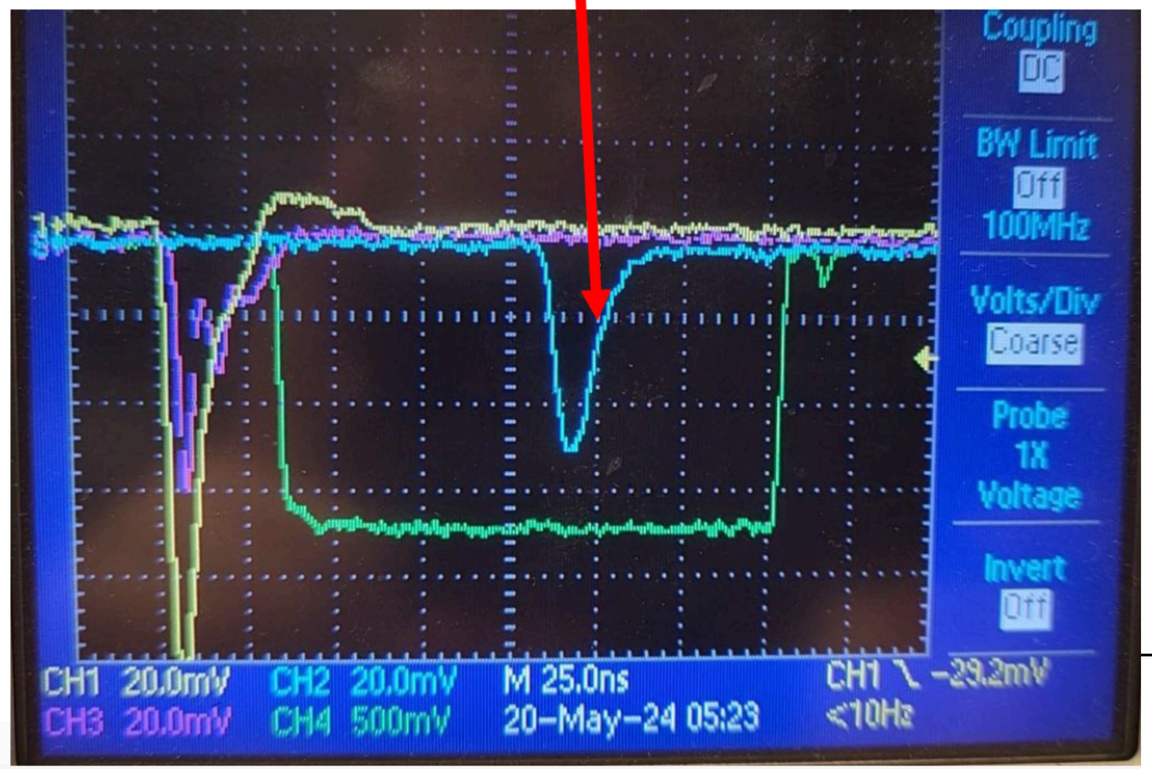








signal from SiPM-on-tile



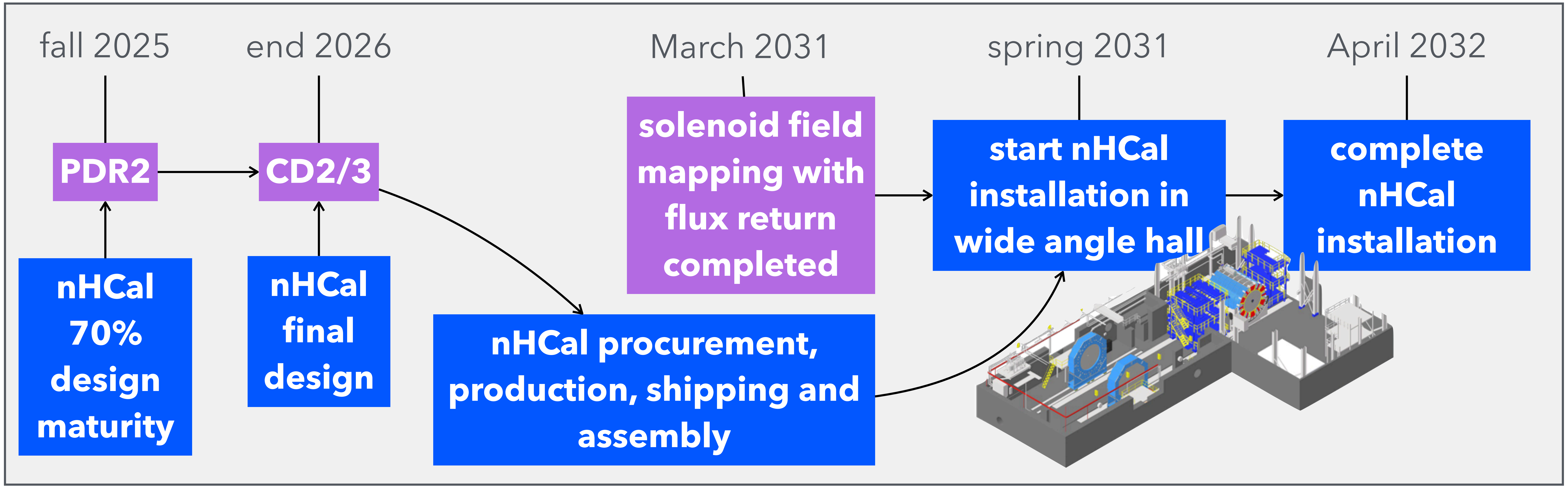
Maria Stefaniak, Yevheniia Khyzhniak (OSU)

SiPM: S14160-1315PS
C. Riedl, L. Kosarzewski, D. Brandenburg

nHCal risks and opportunities

- **Are the remaining work and technical, cost and schedule risks adequately understood? Are there opportunities?**

nHCal baselining and start of construction



- **Will the detector be technically ready for baselining by late 2025?**
  - PDR2 (70% design maturity) in fall 2025, and aim for baselining (final design) by late 2025
- **Will the detector be ready for start of construction by late 2026?**
  - Aim for start of construction in late 2026, or soon thereafter
  - The nHCal can be delivered later than most other detectors because it is decoupled from the flux return and does not need to be in place for the solenoid field mapping

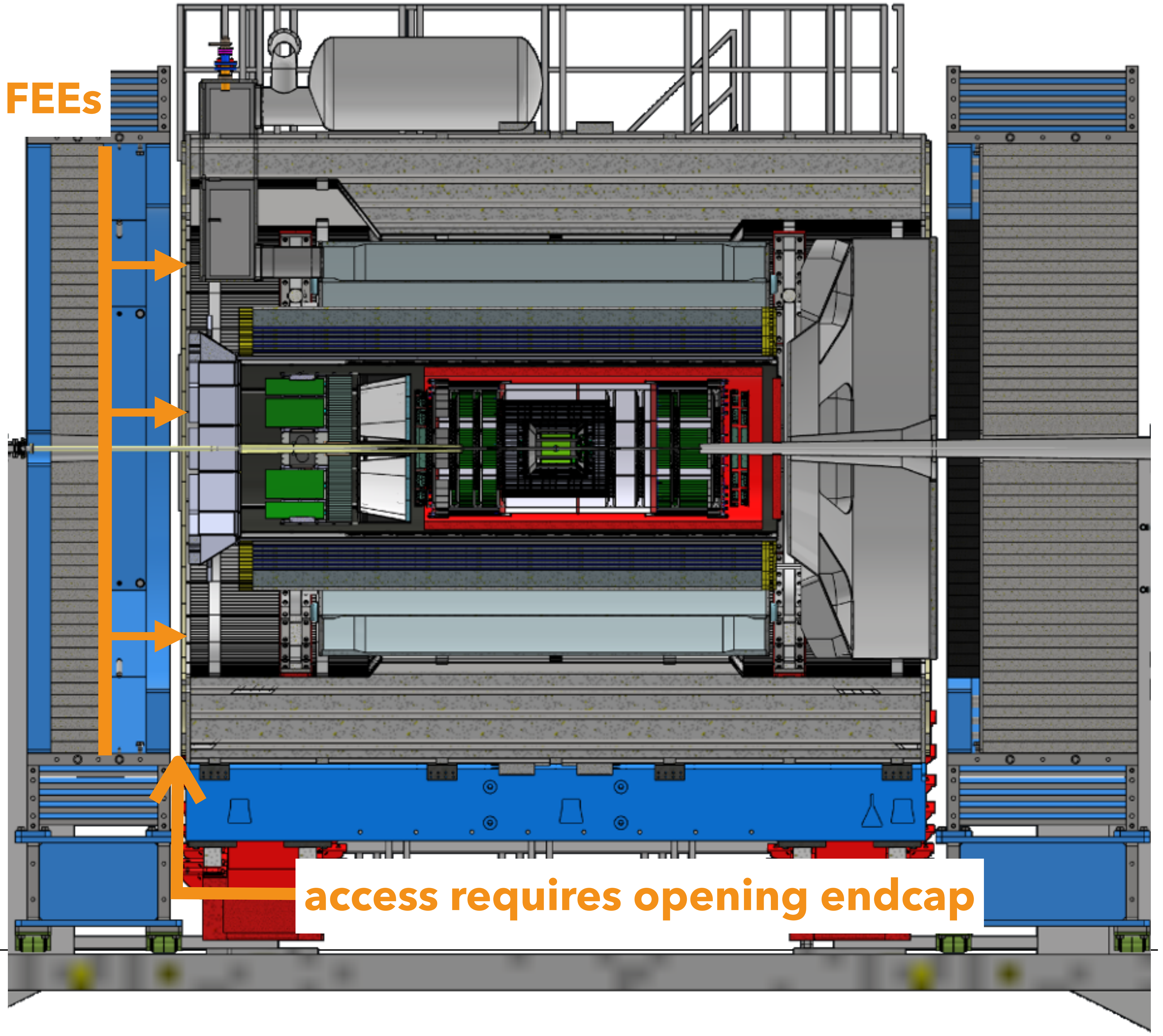
nHCal integration and planning for installation & maintenance

- **Are the detector integration and planning for installation and maintenance progressing well? Are there areas where further ideas should be pursued?**

- Integration: services (LV, signal, slow control cables) and possibly cooling
  - Total dissipated heat: 0.5-2.4 kW (10cmx10cm tiles)
  - **FEEs** towards the IP ⇒ nHCal has to be serviced and maintained from the front (unlike LFHCal)

Services Summary

Item	Cross Sectional Area	Units	Endpoint 1	Endpoint 2
LV cable to FEE	24x1.13	cm2	FEE	Rack
Data signal cable	24x3.3912	cm2	FEE	Rack
Slow controls cable	24x0.07065	cm2	FEE	Rack



nHCal summary

- Needed?

backup slides

nHCal timeline

calendar year	Q1 2025	Q2 2025	Q3 2025	Q4 2025	Q1 2026	Q2 2026	Q3 2026	Q4 2026	Q1 2027	Q2 2027	Q3 2027	Q4 2027	Q1 2028	Q2 2028	Q3 2028	Q4 2028	Q1 2029	Q2 2029	Q3 2029	Q4 2029	Q1 2030	Q2 2030	Q3 2030	Q4 2030	Q1 2031	Q2 2031	Q3 2031	Q4 2031	Q1 2032	Q2 2032
simulations																					2025-05-21									
finalize design			70%																											
tile testing																														
full chain test																														
prototype constructi																														
beam test																														
test beam availability	no test beam at FNAL						long shutdown at CERN / no test beam in North Area																							
procurement																														
construction																														
shipping to BNL																														
assembly at BNL																														
milestones			**PDR 2**				**CD2/3**																		**magnet test**	**start installation**				**complete installation**