# Proposal for Generic R&D on EIC Detectors

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# Overview

- The University of Iowa group, in collaboration with US national laboratories and universities, is expert in developing calorimetry for lepton and hadron colliders.

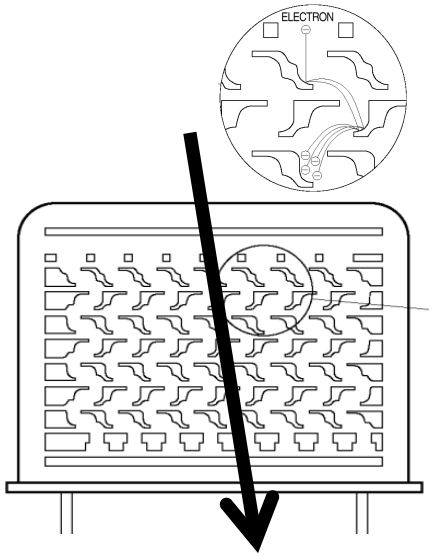
- We would like to pursue R&D on various sub-topics which we think are likely to produce useful results for the EIC detectors.

- We would like to expand our expertise in collaboration with the EIC community.

# R&D for Electromagnetic Calorimetry

## Secondary Emission Ionization Calorimeter

- **Secondary Emission (SE) signal:** SE surfaces inside em/had showers:
  - SE yield $\delta$: Scales with particle momentum
  - $e^{-}$: $3 < \delta < 100$, per $0.05 < e^{-} < 100$ keV (material dependent)
  - $\delta \sim 0.05 - 0.1$ $SEe^{-}$ per MIP
- **SE is:** Rad-Hard + Fast
  - a) Metal-Oxide SE PMT Dynodes survive > 100 GigaRad
  - b) SE Beam Monitors survive $10^{20}$ MIPs/cm$^2$




**$SEe^{-}$ is amplified exactly like photoelectrons (p.e.)!**

## Secondary Emission Ionization Calorimeter

The modules envisioned are:

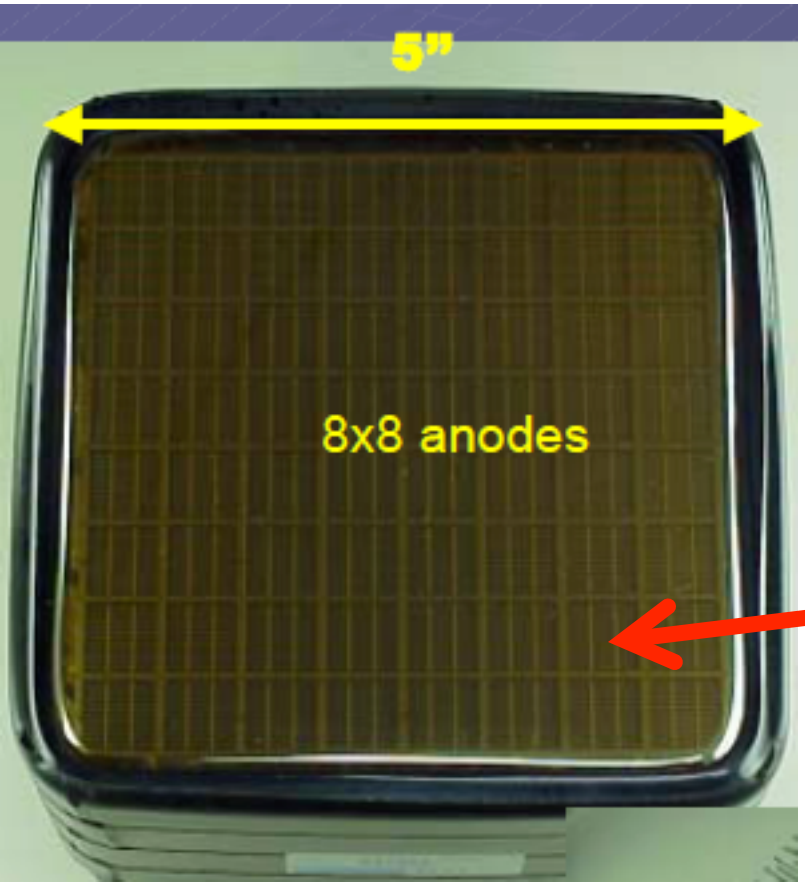
- compact,
- high gain,
- high speed,
- exceptionally radiation damage resistant,
- robust,
- cost effective and
- can be fabricated in arbitrary tileable shapes.

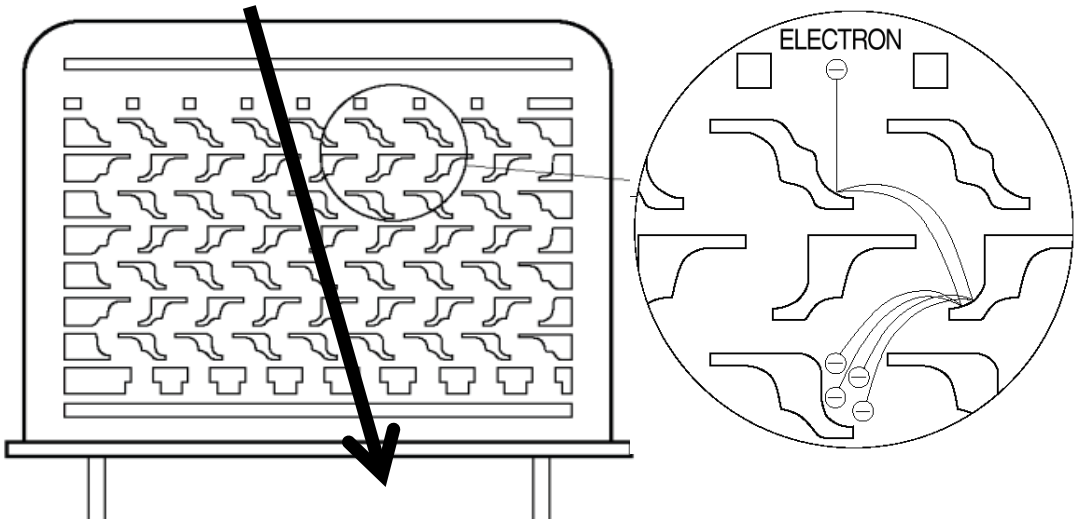
The SE sensor module anodes can be segmented transversely to sizes appropriate to reconstruct electromagnetic cores with high precision.

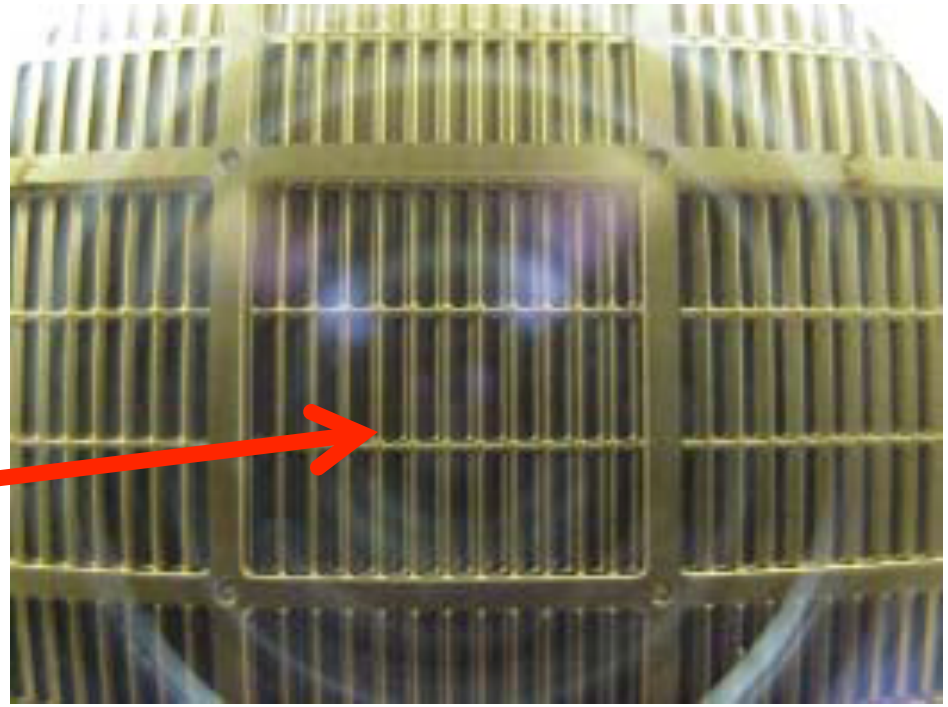
Detailed GEANT4 simulations estimated between 35-50 (7-10) Secondary Emission electrons per GeV in a 1(5) cm sampling Cu calorimeter. The gain per SEe is estimated to be $>10^5$, and the response close to compensating with an e/pi<1.2. The calorimeter pulse width is estimated to be <15 ns.

# SEe Dynodes: a) Etched Metal Sheets

*Hamamatsu Dynodes*
*15 cm now → ~50 cm*
*Already diced from large sheets*

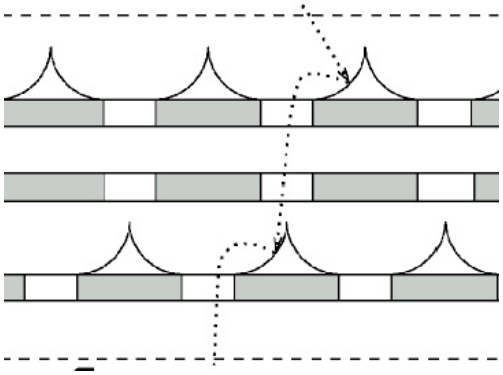


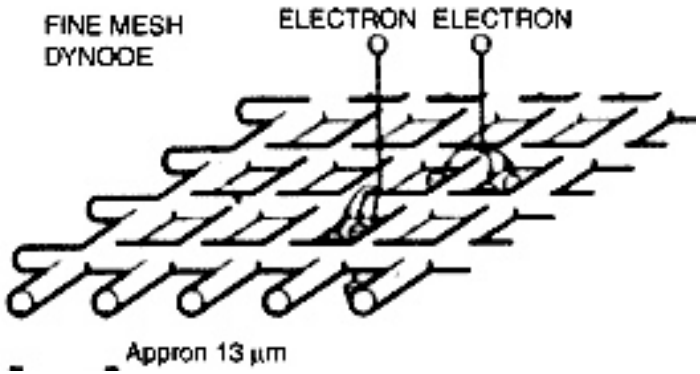



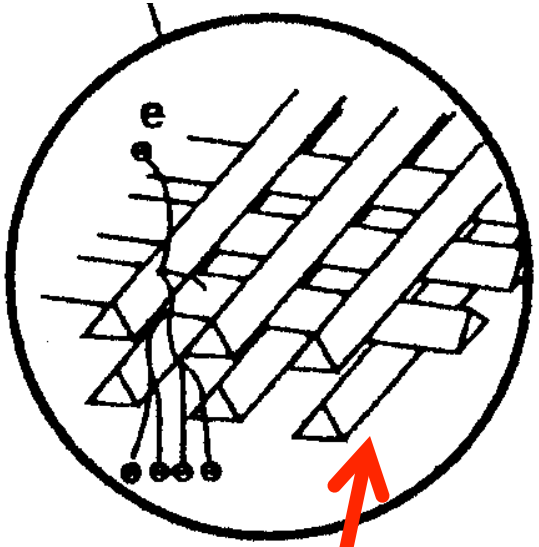



# SEe Dynodes: b) Metal Screen Dynodes: 15D - g~$10^5$

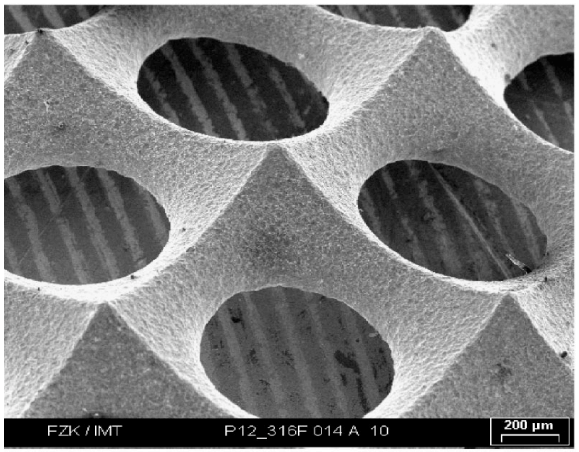
## MESH DYNODE VARIANTS

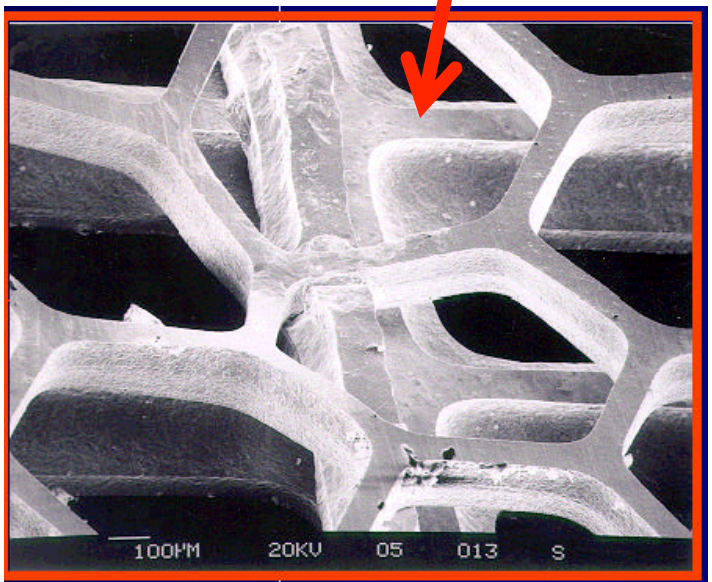


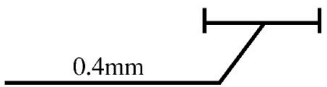



$D_n$-$D_{n+1}$: 0.9 mm
C-C mesh: 13 µm
Wire diameter: 5 µm



# SE Module Beam Test

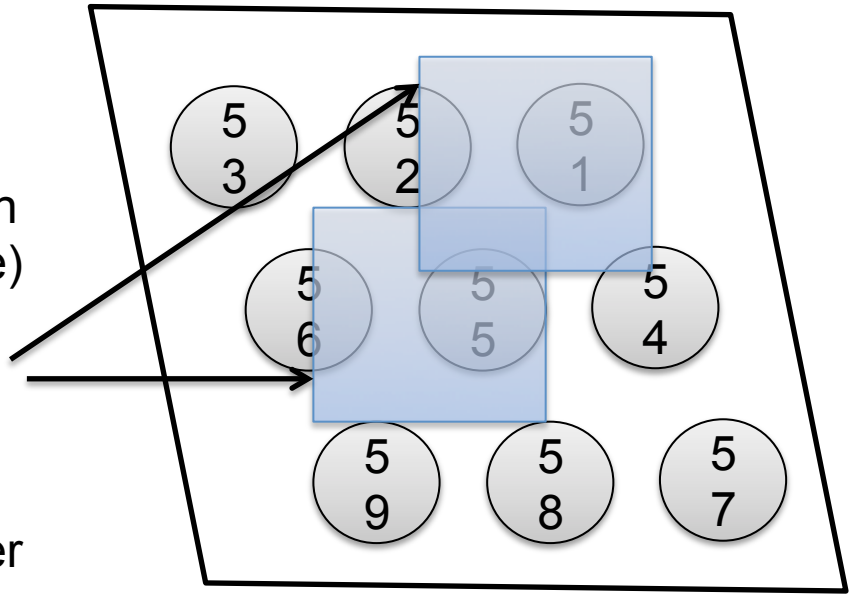
Using mesh dynodes from PMTs

CERN SPS, Nov. 2012

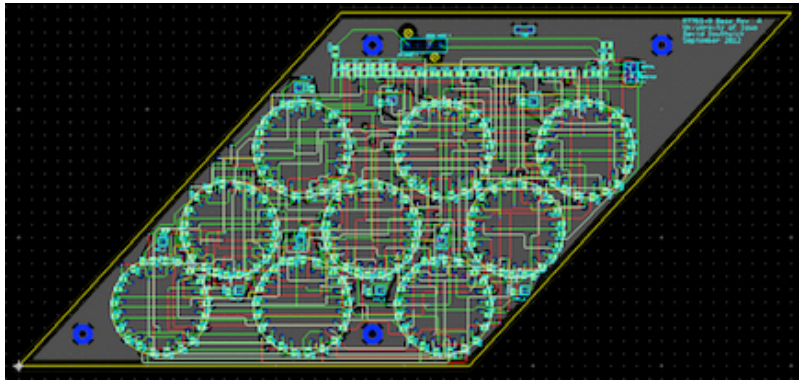
Beam position
(into the page)

2 datasets

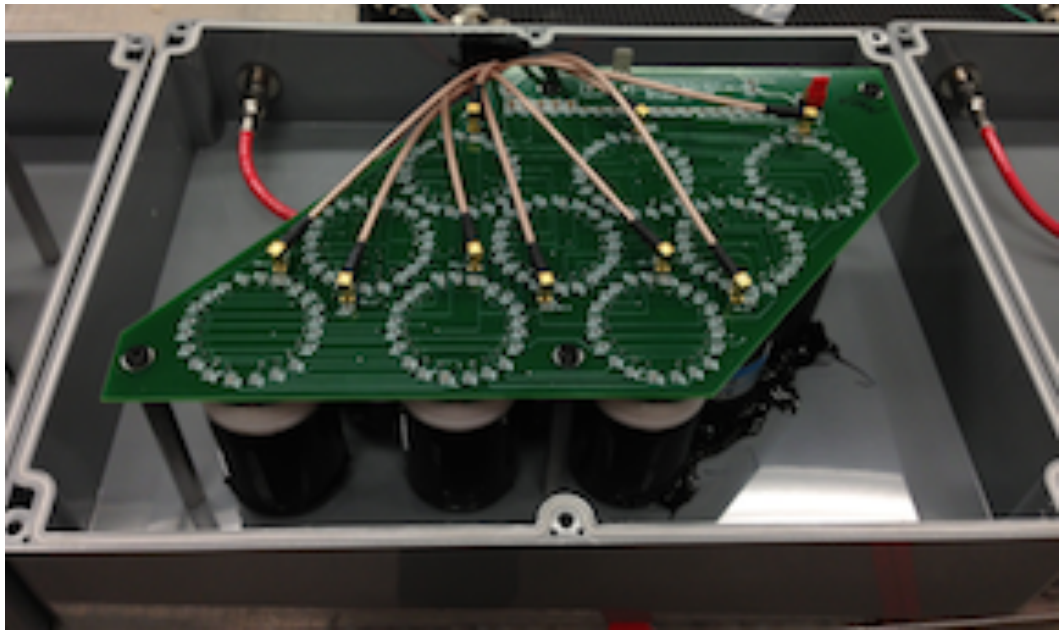
Selected with
Wire Chamber




51, … , 59: PMT IDs

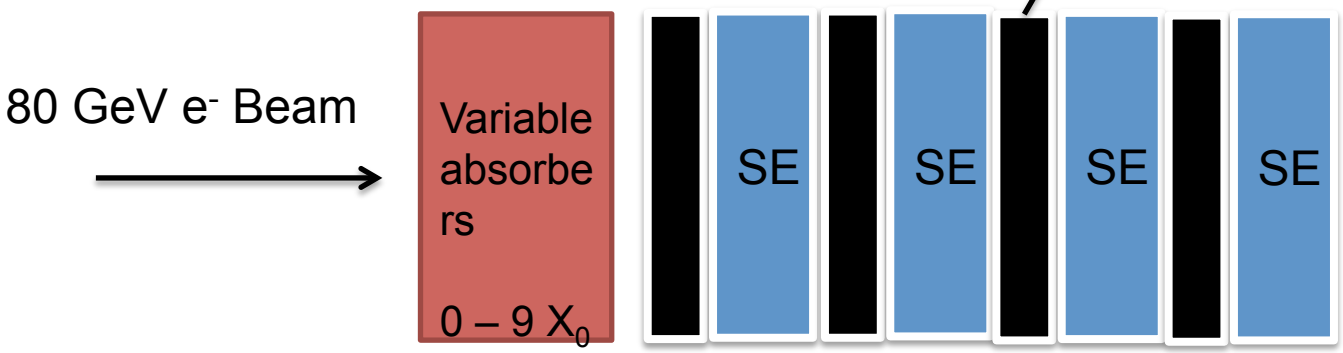


# SE Module Beam Test



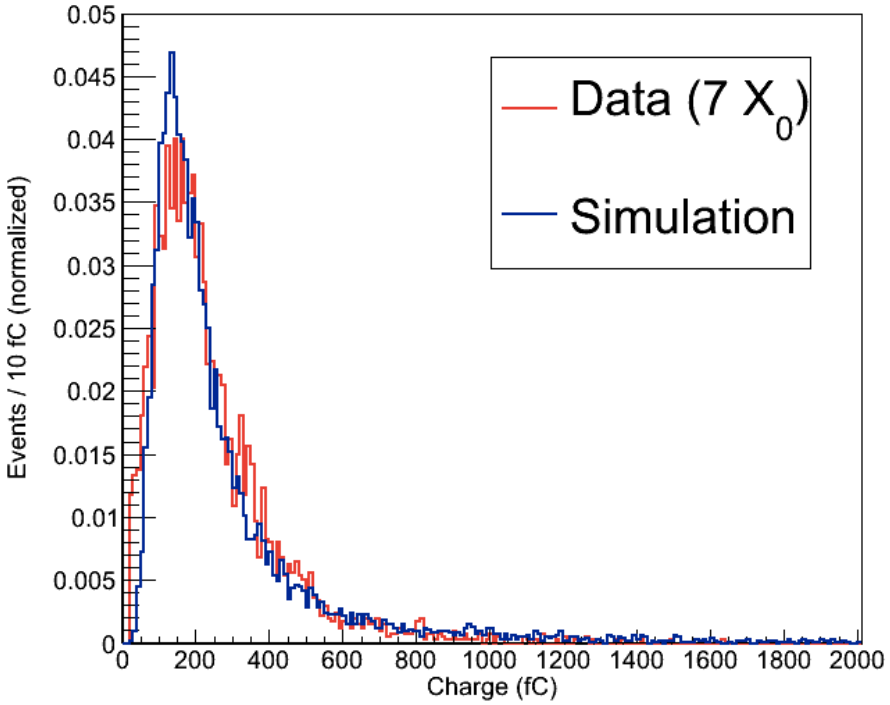
2-cm iron absorbers:

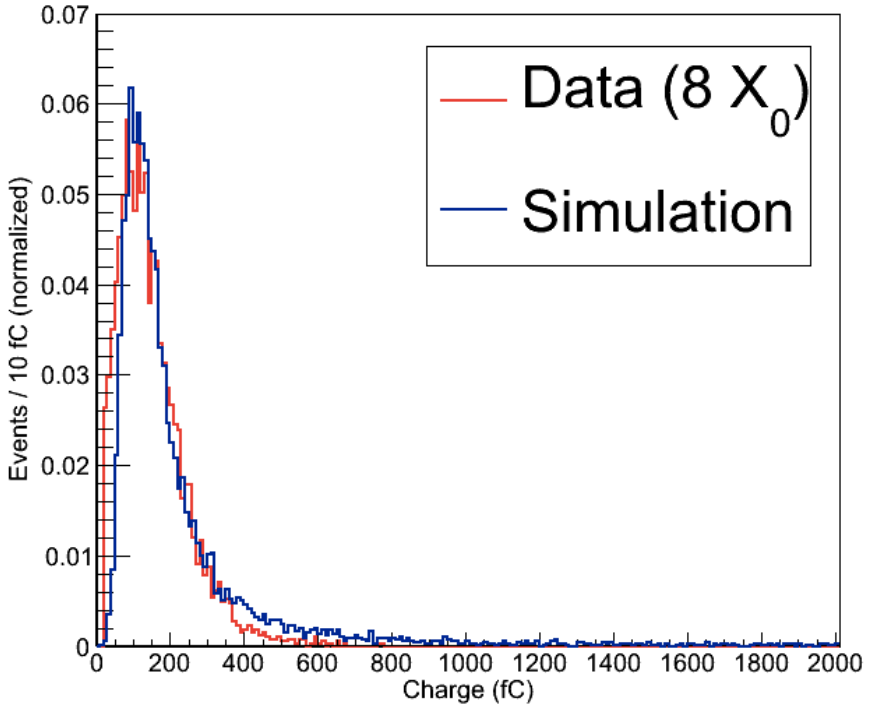
$X_0$ = 1.75 cm
Molière Radius: 1.72 cm




Shower not contained laterally or longitudinally
→ Results require estimates and approximations

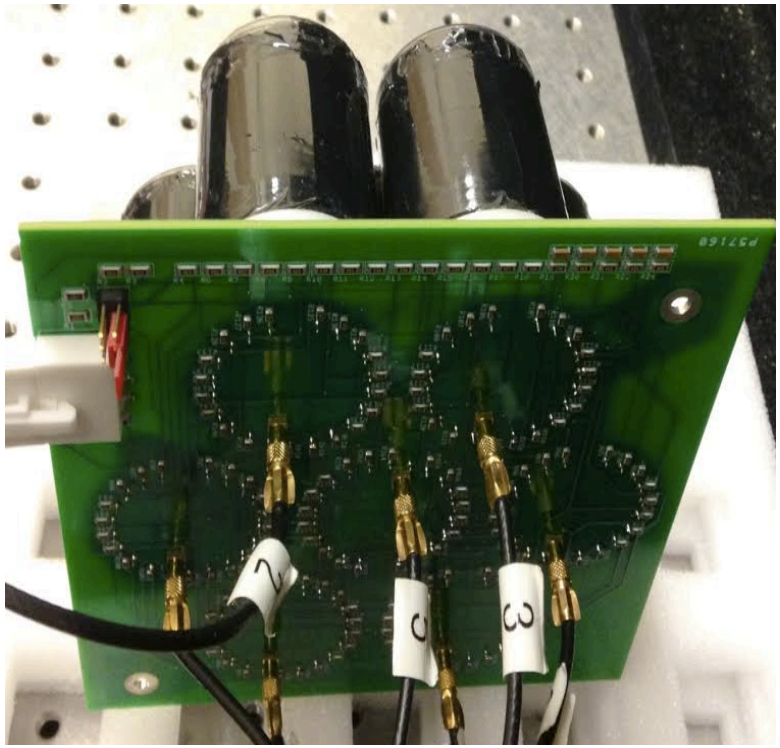
# SE Module Simulation

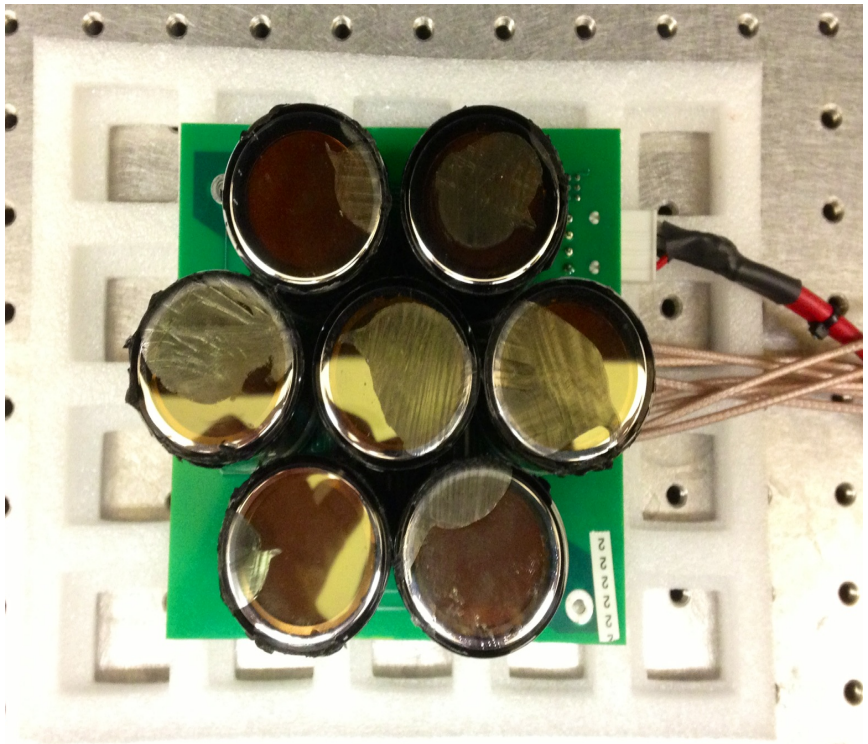



Geant4 simulation of the SE module test beam setup:
80 GeV $e^-$ beam
19 stage mesh dynodes generate SE electrons (dynodes ~ sheets)
Gain is simulated offline ($10^6$)
Landau fluctuations are implemented offline
**Single parameter to tune: Efficiency of SEe production**
**(mesh dynodes are simulated as solid sheets)** → 0 - 0.35% flat random

# SE Module Beam Test – Second Generation Board





Same PMTs, closest packed assembly.

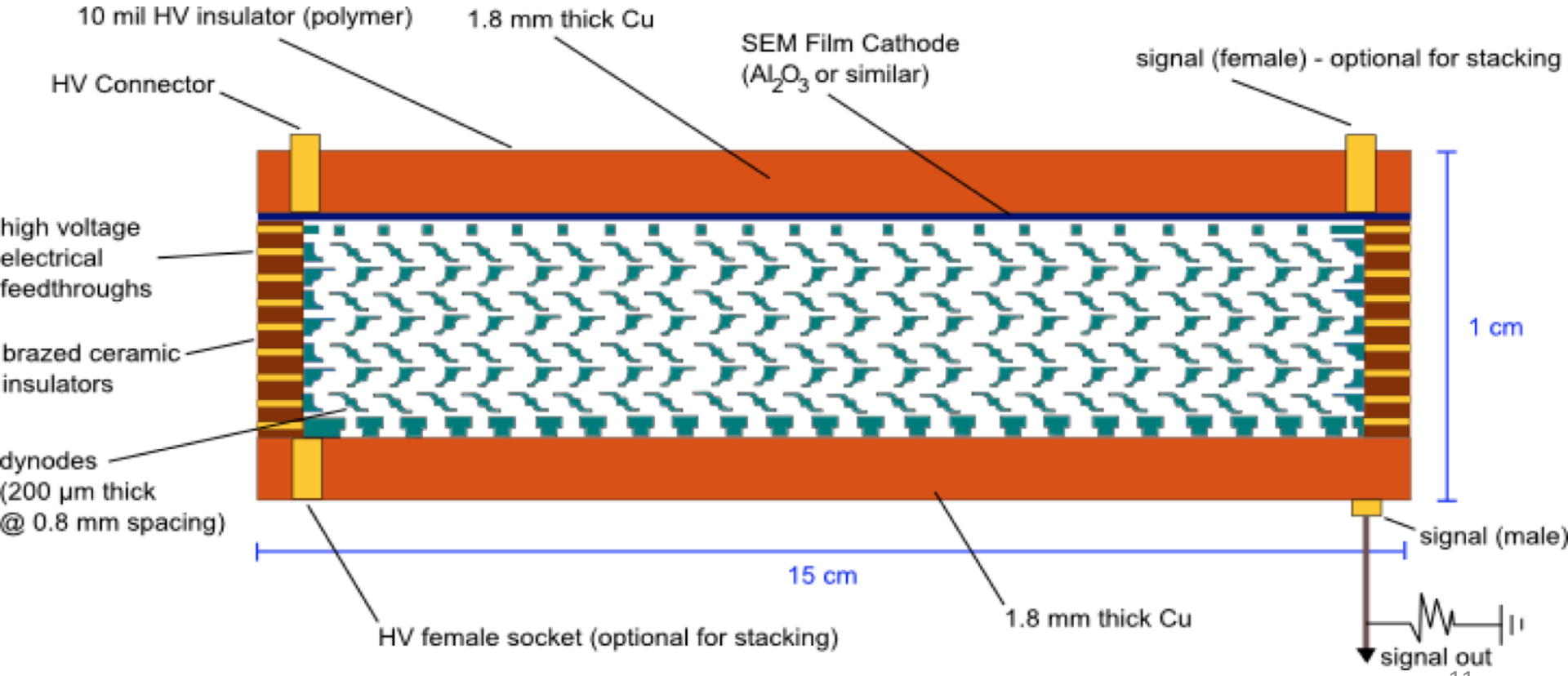
Single layer with variable absorbers upstream.

Was in test beam in late November 2013, analysis underway.

# R&D for Electromagnetic Calorimetry

## Proposal

Construction and testing of the first, dedicated SE module with larger and continuous lateral coverage.



# R&D for Zero Degree Calorimeter

Investigate the possibility of utilizing

- quartz fiber calorimeter,
- quartz and scintillating fiber dual readout calorimeter,
- sampling calorimeter using doped/coated quartz plates and/or secondary emission modules.

The University of Iowa group constructed prototypes of most of the mentioned options in the past. However, a detailed study of feasibility for the EIC conditions was not performed so far.

## Proposal

Support ½ graduate student to perform simulations for feasibility/optimization study.

# R&D for Forward Tracking with RPCs

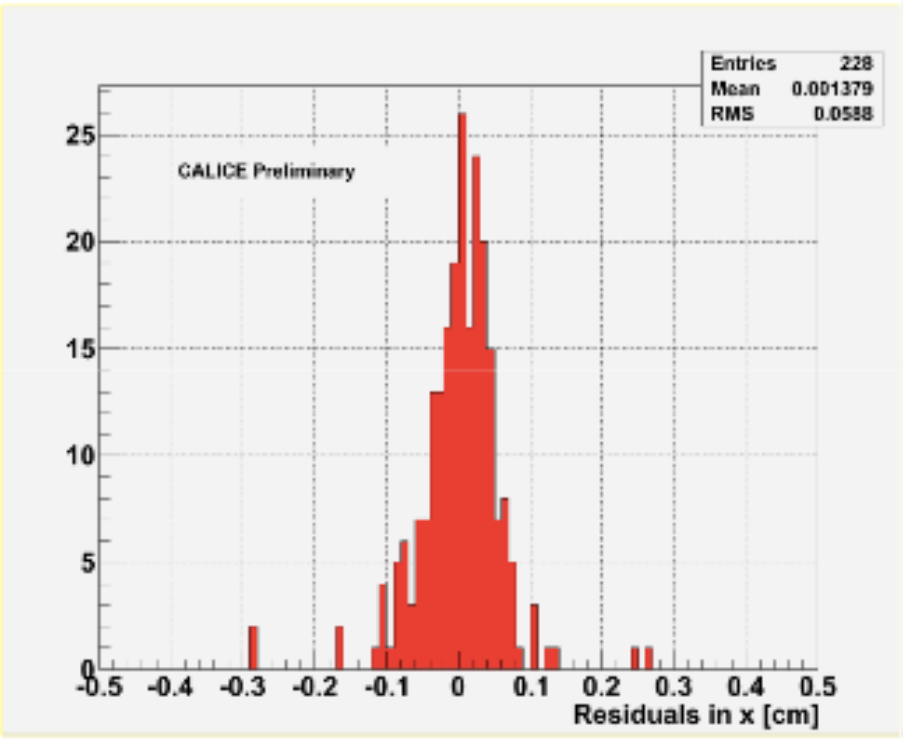
We would like to investigate the possibility of utilizing RPCs (Resistive Plate Chambers) in the forward region as an alternative to GEMs (Gas Electron Multipliers).

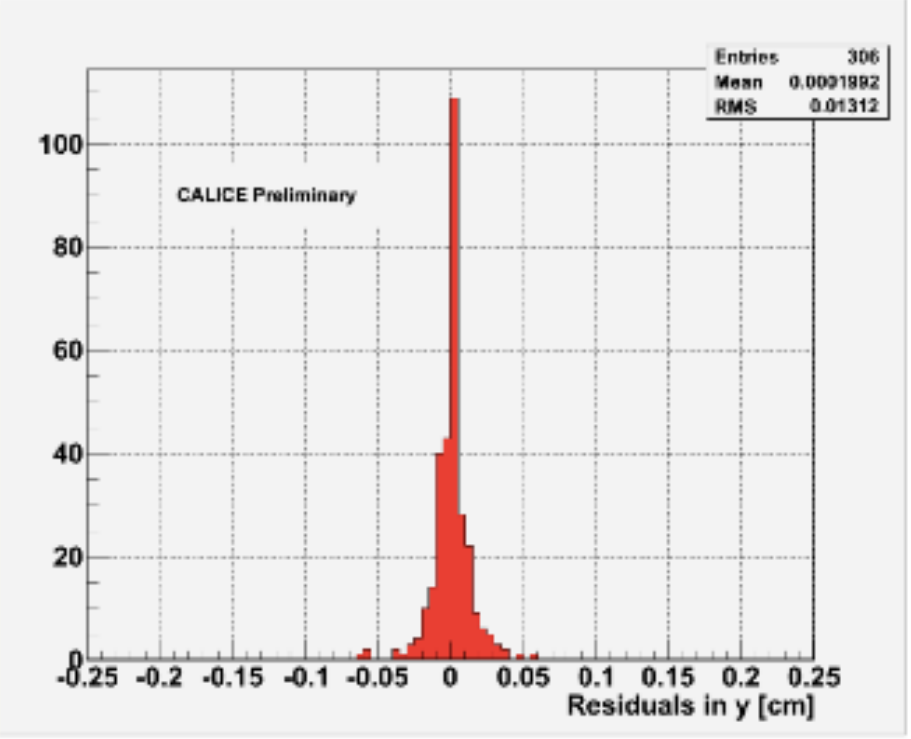
As the CALICE DHCAL (Digital Hadron Calorimeter) collaboration centered at Argonne National Laboratory, we designed, constructed and tested the digital hadron calorimeter prototype which utilizes RPCs as active medium and a 1-bit resolution (hence the name digital) readout of 1 cm x 1 cm lateral size pads.

With an efficient optimization of the pad size, the momentum resolution of the central tracker can be approached. The preference towards the RPCs is because the RPCs are simple in design, robust, reliable (when utilizing glass as resistive plates), and cheap, and their readout can be segmented into small pads.

# R&D for Forward Tracking with RPCs

## Tracking with muons




Distribution of the residuals after alignment

$$R^i_x = x^i_{cluster} - x^i_{track}$$
$$R^i_y = y^i_{cluster} - y^i_{track}$$

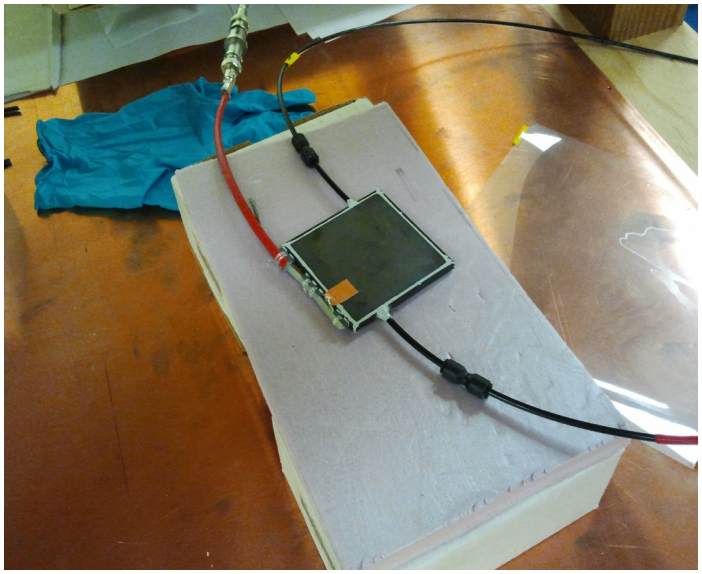
# R&D for Forward Tracking with RPCs

## Proposal

We would like to develop low resistivity glass with the optimum resistivity to allow larger counting rates but still have the desirable RPC performance.

The recent developments by the COE College show that resistivities at the order of $10^7$ and $10^9$ Ωcm can be acquired with iron and copper doped lead vanadates.

A first round of production proved the feasibility of the production process and of the possibility of building an operational RPC with these new samples.

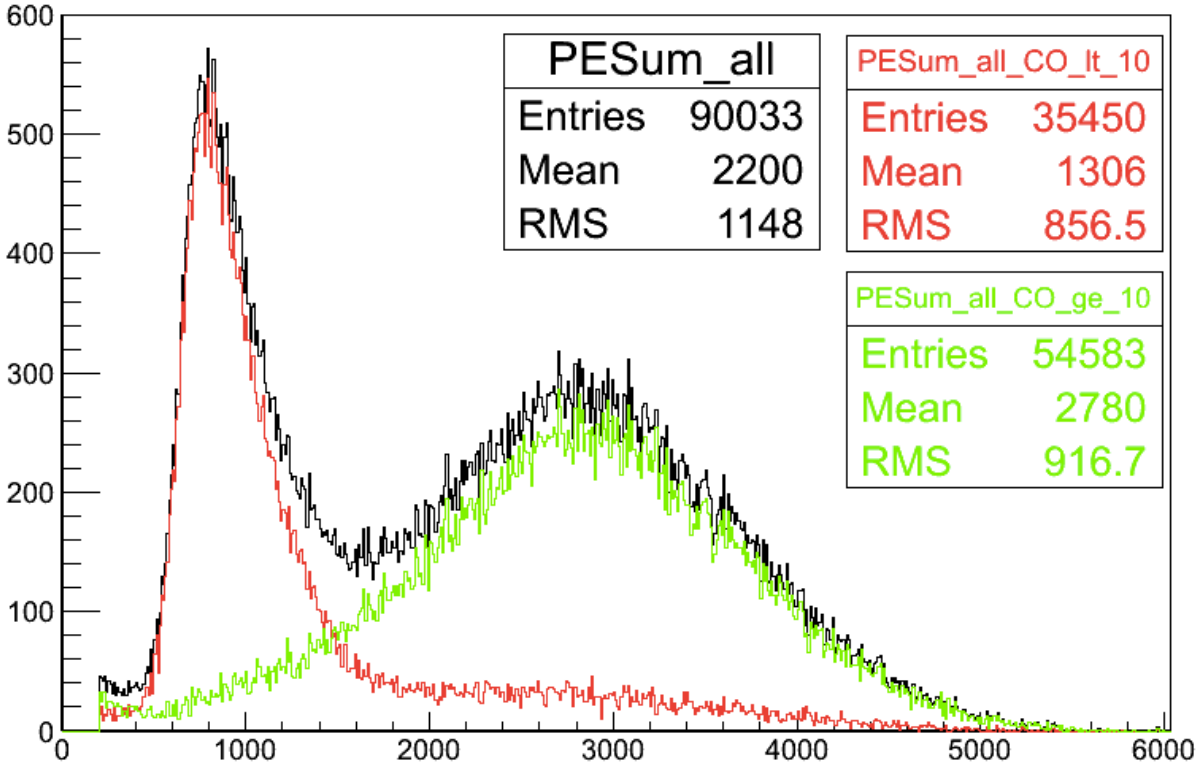


# R&D for Quartz-Based Particle ID

## Proposal

We would like to investigate the possibility of using quartz variants with different dopes, thicknesses, index of refractions and coatings as effective Čerenkov radiators that would be useful for particle ID both for the barrel and the forward regions.

We tested a quartz block of size 7 cm x 7 cm x 12.5 cm equipped with 10 PMTs in the Fermilab test beam in December 2013. Preliminary results are encouraging, analysis underway.




Signal spectrum for:

- All events
- Čerenkov counter selected positron events
- Events not selected by the Čerenkov counter

Very preliminary. No tracking information was implemented yet.

# University of Iowa Budget Request

| Item | Cost |
|---|---|
| Secondary Emission Module | $12K |
| High Rate RPC Glass Production | $5K |
| Production and Tests of Cerenkov Radiators | $3K |
| 2 x 1/2 Graduate Students | $15K |
| **Total** | **$35K** |

**Material:** At this initial stage of the detector R&D for the EIC, we would like to request funding for the construction of the first dedicated Secondary Emission module with continuous lateral coverage including the readout. We also request funding for special glass production/purchase.

**Effort:** We would like to request funding for two half time graduate student salaries for the simulation of different design concepts. They are expected to perform both standalone simulations of the detector designs and realistic response analysis using events generated for the EIC.

We would like to request RACF cluster accounts for these students and access rights to the generated Pythia samples.

The funding request for the Secondary Emission module construction and glass production/coating effort is also included in this proposal. There is no test beam funding request at this stage.

# References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2. D. Winn, CHEF 2013, Secondary Emission Calorimetry R&D, https://indico.in2p3.fr/getFile.py/access?contribId=49&sessionId=23&resId=0&materialId=slides&confId=7691 .

3. G.Drake et al., “Resistive Plate Chambers for hadron calorimetry: Tests with analog readout”, Nucl. Instrum. Meth, **A578**, 88-97 (2007).

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5. B. Bilki et.al., “Measurement of the rate capability of Resistive Plate Chambers”, JINST 4 P06003, 2009.

6. B. Bilki et.al., “Measurement of positron showers with a digital hadron calorimeter”, JINST 4 P04006, 2009.

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