test beam results on W-fiber and tilted plate calorimeters for an updated RHIC experiment

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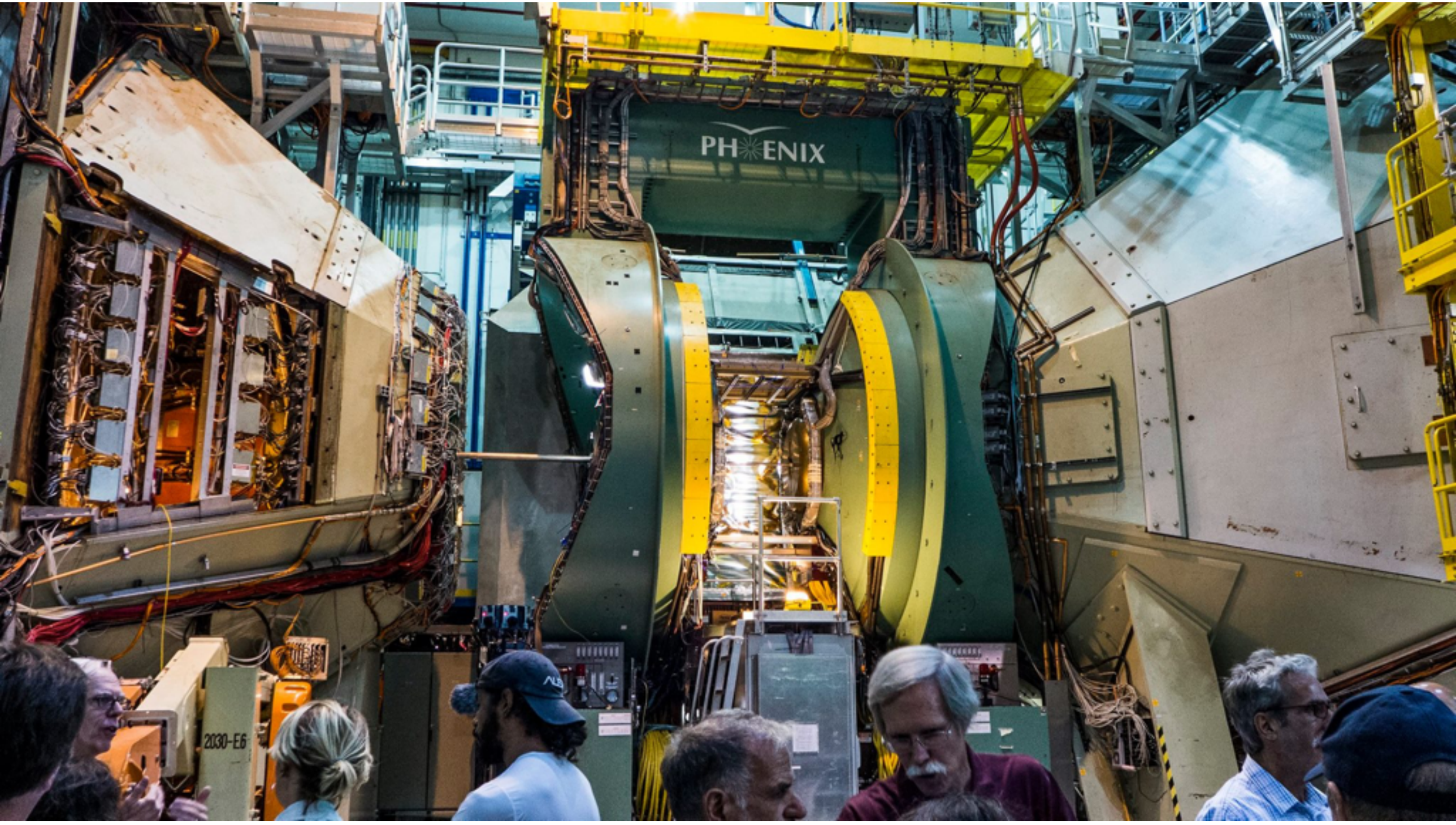
Old PHENIX



taken last Sunday at the BNL - RHIC Open House

The PHENIX experiment

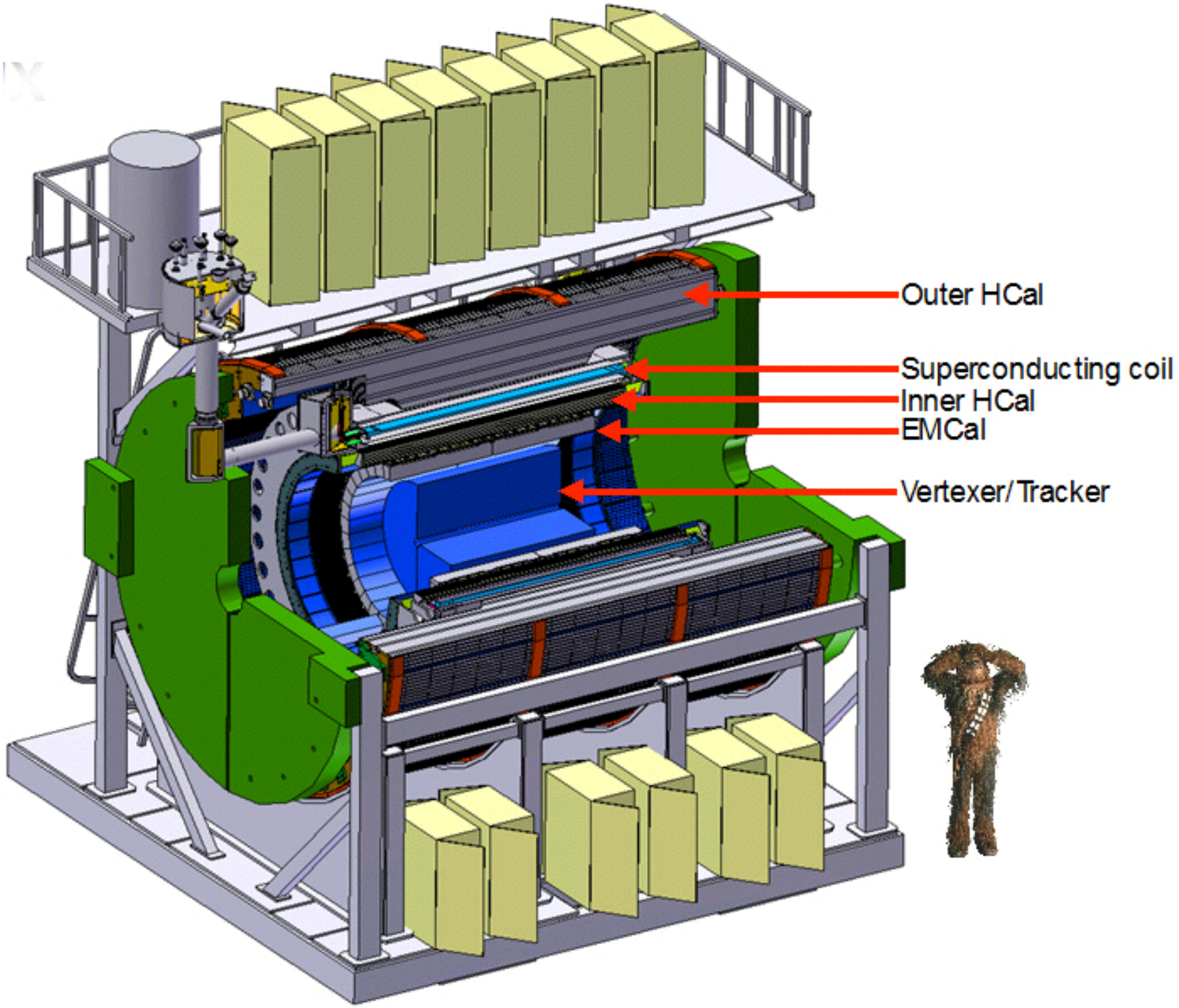
- Major upgrade to the PHENIX Experiment at RHIC
  new collaboration with currently 57 Institutions signed up
  https://www.bnl.gov/rhic/news2/news.asp?a=6258&t=today

- Primary purpose is to measure jets and heavy quarkonia in heavy ion collisions (@ 200GeV/c)
  - Measure total energy using calorimetry
    (including hadronic – first HCAL at central η at RHIC)
  - Good solid angle coverage ($|\eta|< 1$, $\Delta\phi=2\pi$)
  - Measure Υ to σ_M~ 100 MeV

- Provide a basis for a future Day 1 detector for eRHIC (Brookhaven's version of the Electron Ion Collider)
  - Study nucleon structure and QCD in nuclei over a broad range of x and Q^2 using deep inelastic polarized ep and eA collisions

- talk by Abhisek Sen, Friday

sPHENIX layout



http://arxiv.org/pdf/1501.06197v1.pdf

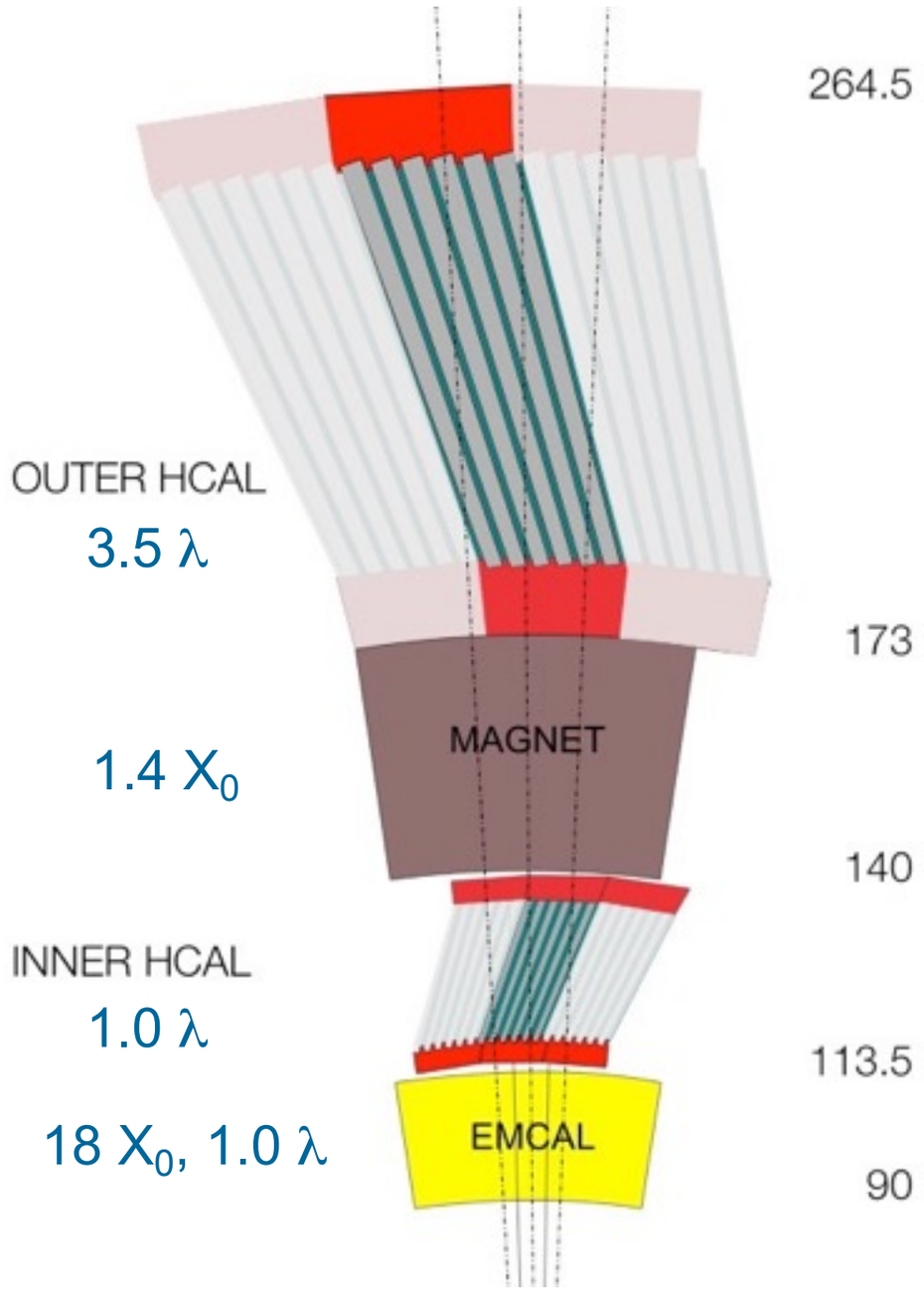
The sPHENIX Calorimeter Systems

EMCAL – Tungsten SciFi SPACAL

- ± 1.1 in η, 2π in ϕ
- $\Delta\eta \times \Delta\varphi \approx 0.025 \times 0.025$
- 96x256 = 24576 readout channels
- $\sigma_E/E < 15\%/\sqrt{E}$

HCAL – Steel plates + scintillating tiles with WLS fiber readout

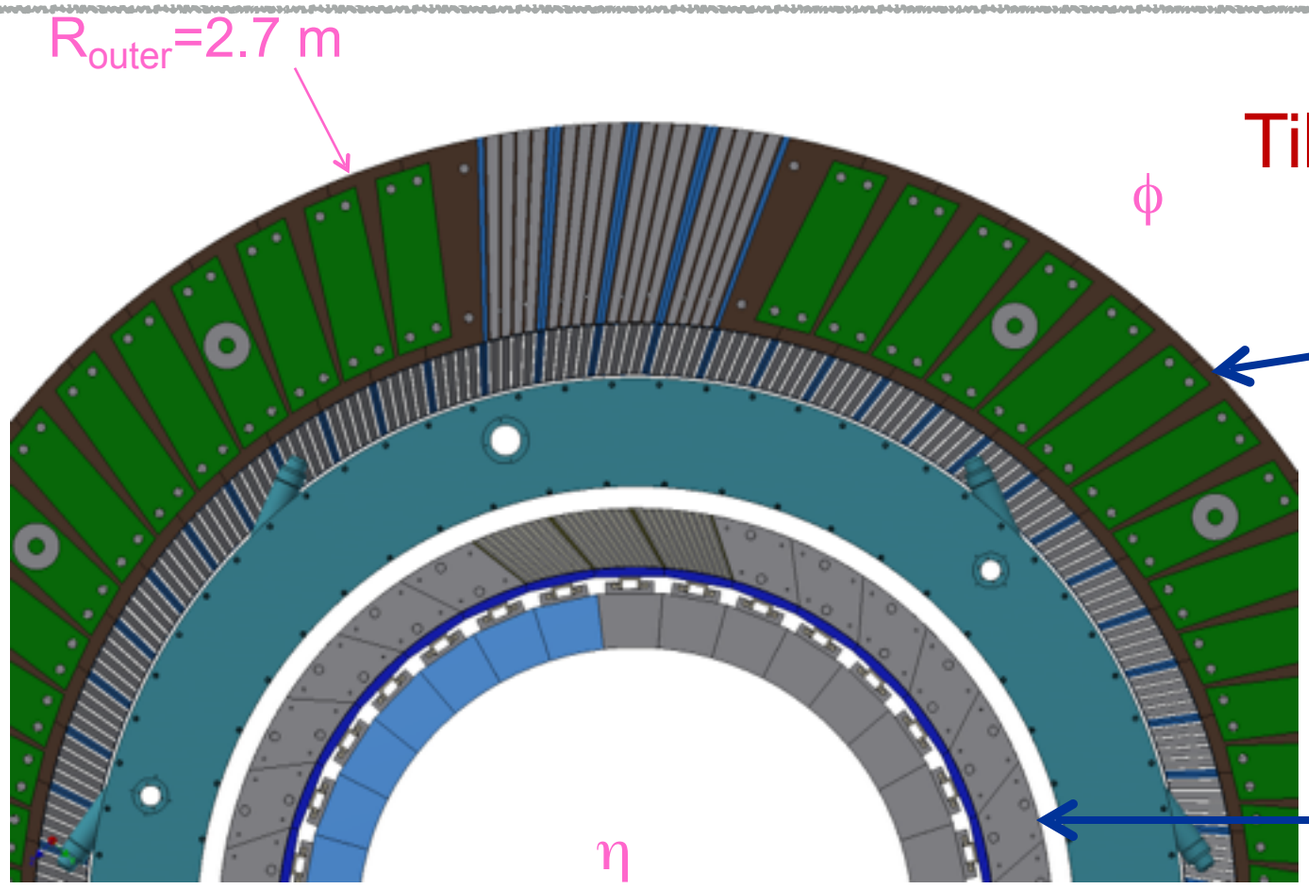
- Plates oriented parallel to beam
- Iron serves as flux return
- Plates are tilted to avoid channeling
- Two longitudinal sections (~ 4.5 λ)
  - Inner HCAL inside magnet
  - Outer HCAL outside magnet
- $\Delta\eta \times \Delta\varphi \approx 0.1 \times 0.1$
- 2x24x64 = 3072 readout channels
- $\sigma_E/E < 100\%/\sqrt{E}$ (single particle)



EMCAL + HCAL ~ 5.5 λ

Both EMCAL and HCAL read out with SiPMs

Hadronic Calorimeters



Tilted Plate Design

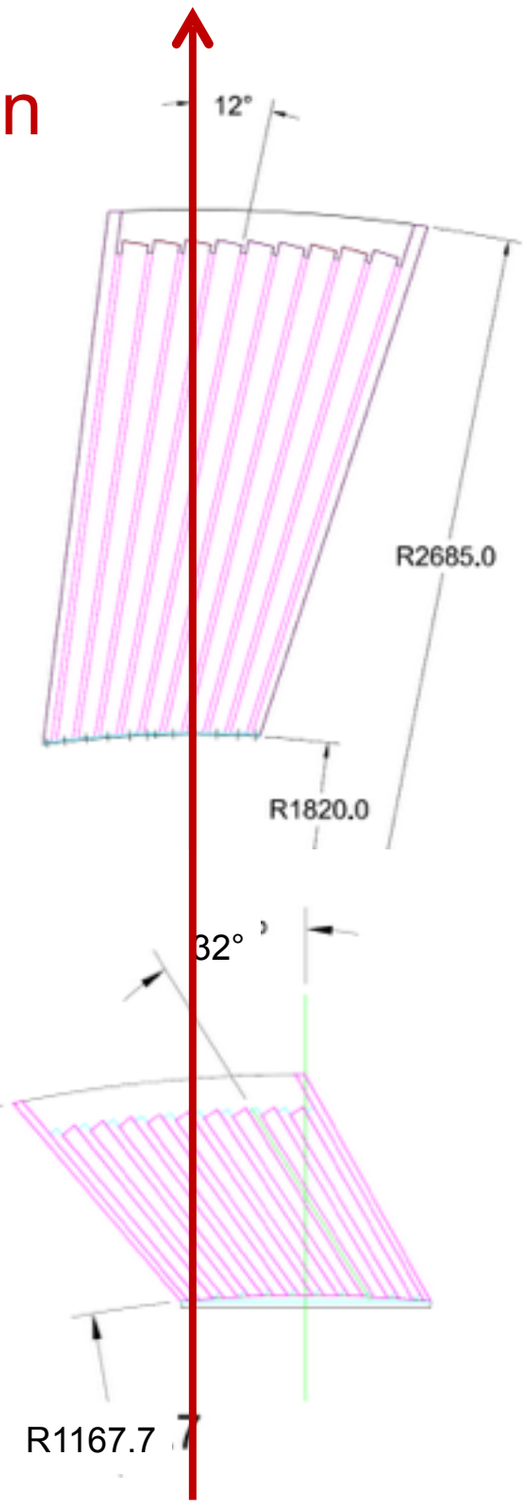
Outer HCA L
64 modules in ϕ

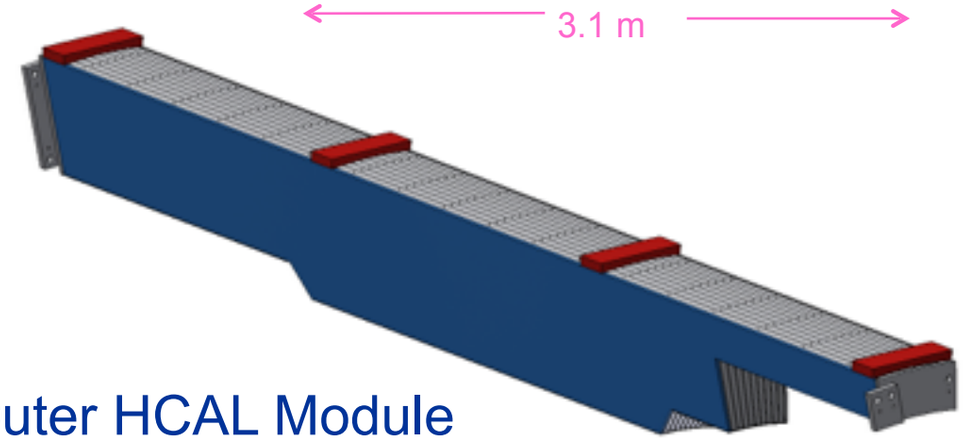
<SF> = 3.5%

MIP crosses
4 tiles in each
calorimeter

Inner HCAL
32 modules in ϕ

<SF> = 6.7%





Outer HCAL Module
(13.5 tons)

2x12 towers in η

3072 towers total

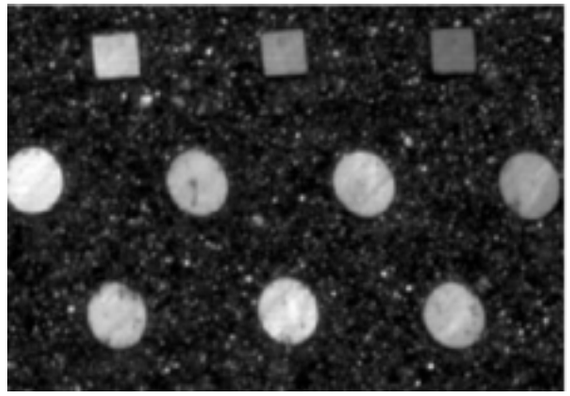
Sampling fraction changes with depth (~25%)

W/SciFi SPACAL (originally developed by Oleg Tsai at UCLA)

Absorber

- Matrix of tungsten powder and epoxy with embedded scintillating fibers
- Density ~ 10 g/cm^3
- X_0 ~ 7 mm (18 X_0 total), R_M ~ 2.3 cm
- Energy resolution ~ 12%/√E

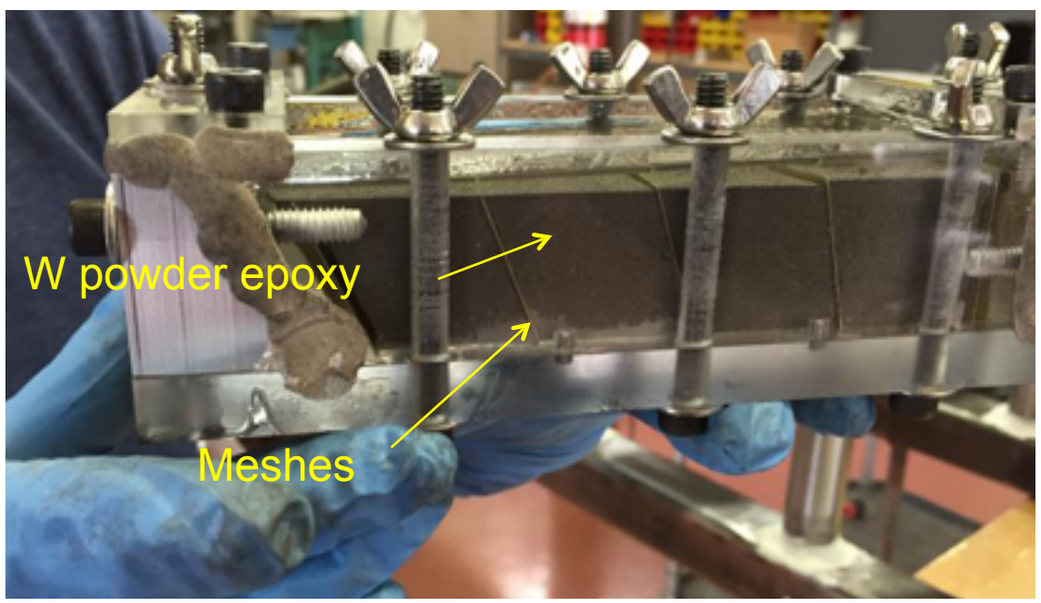
Powder supplier



Scintillating fibers (Kuraray SCSF78)

- Diameter: 0.47 mm, Spacing: 1 mm
- Sampling Fraction ~ 2.3 %

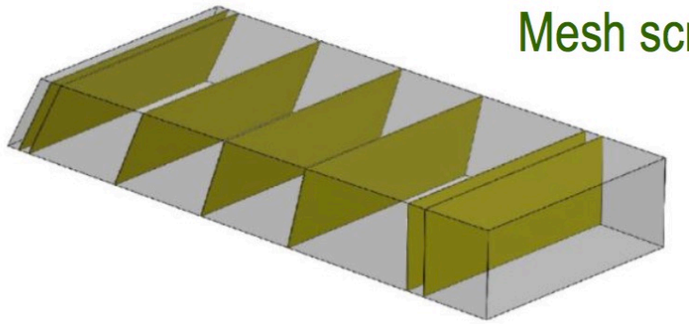
- Modules are formed by pouring tungsten powder and epoxy into a mold containing an array of scintillating fibers
- Fibers are held in position with metal meshes spaced along the module



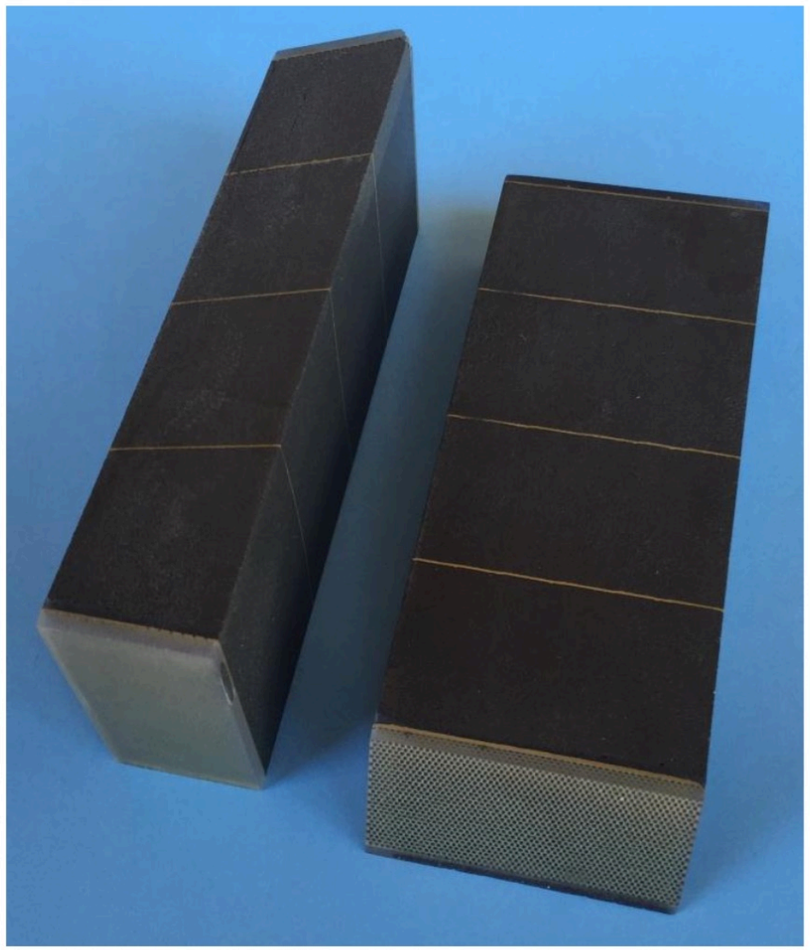
EMCal Modules

1D Projective

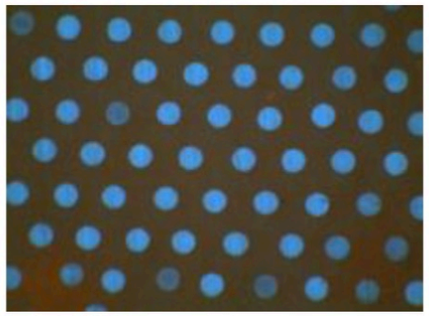
Mesh screens

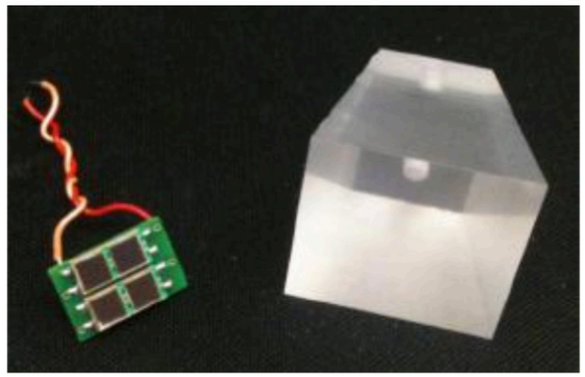


Produced at UCLA, BNL, UIUC and THP

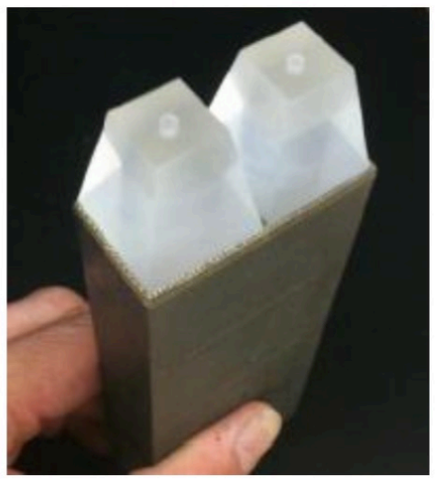


Fiber ends are finished by with fly cutting

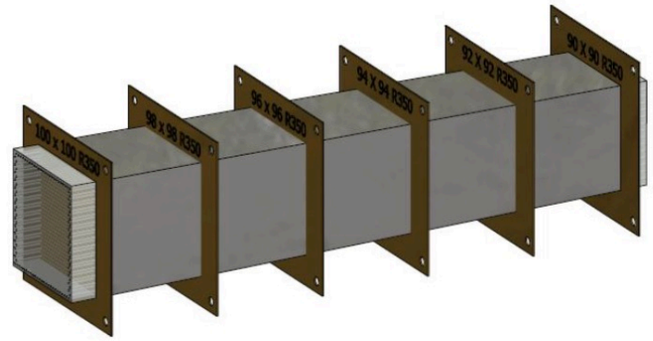




Light guides and SiPMs are attached to module ends to form towers



2D Projective



Cal Prototype for FNAL test-beam

Inner and Outer HCAL prototypes each consist of 4 x 4 towers

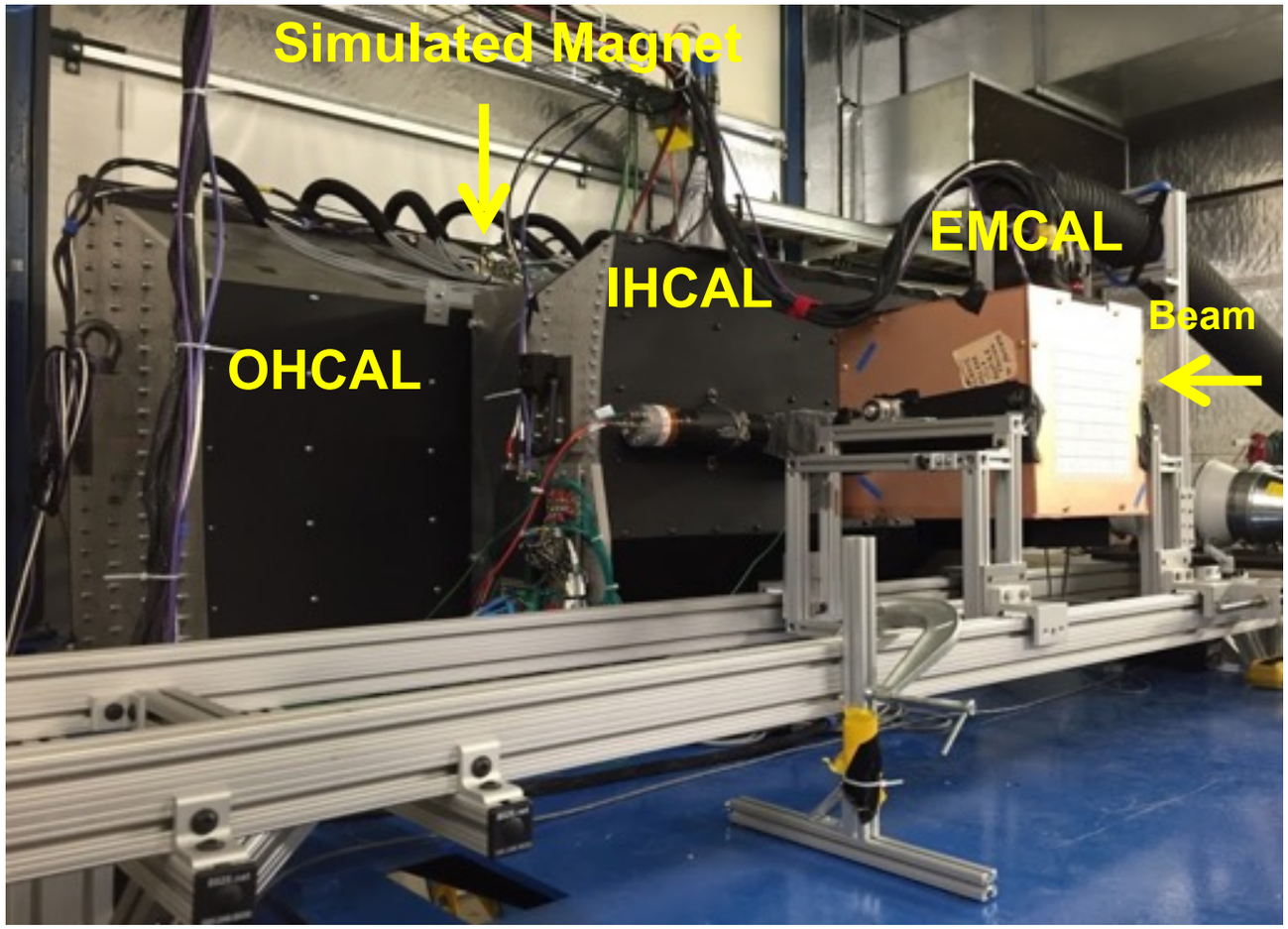
- Inner: ~ 0.5 m^2 (56 x 94 cm^2)
- Outer: ~ 1.2 m^2 (74 x 165 cm^2)

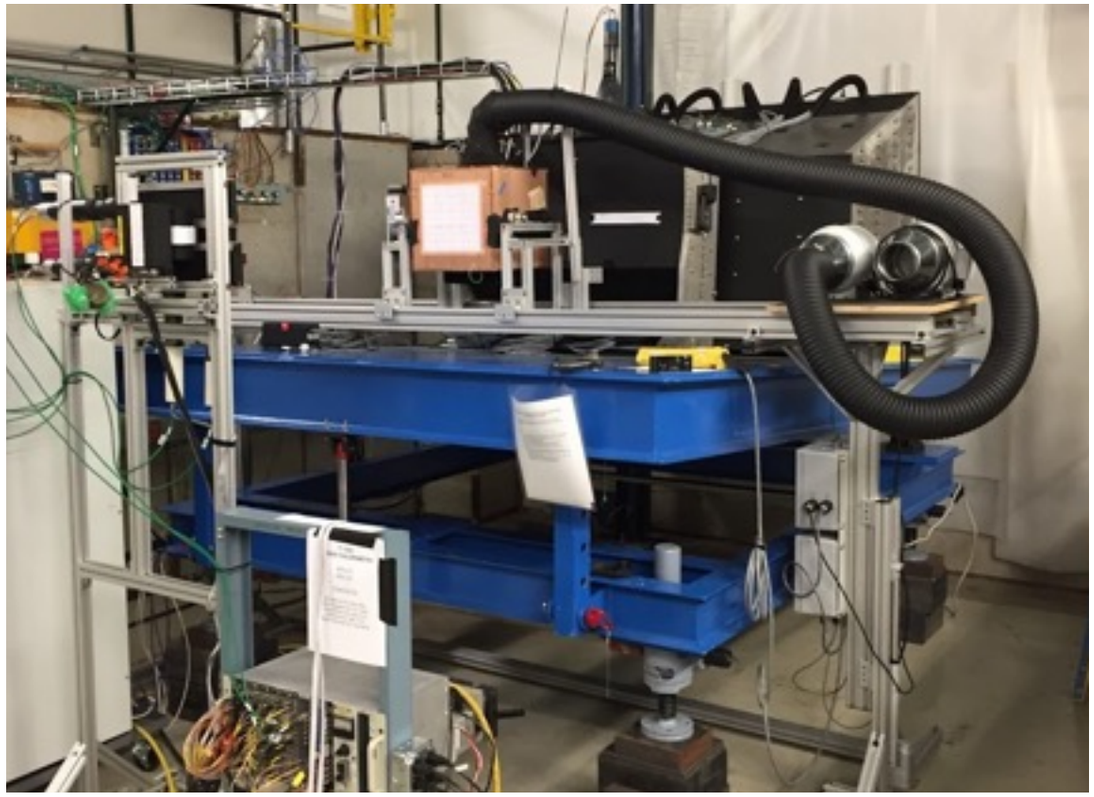
Outer HCAL prototype with assembled steel plates and readout electronics

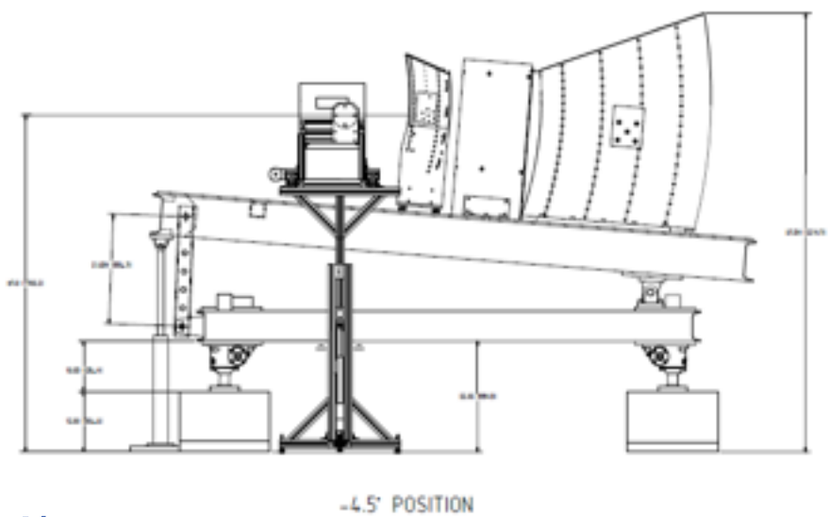
Polystyrene scintillating tiles (7 mm) with WLS fiber (1 mm) in groove. One SiPM reads out both ends of fiber. SiPMs from 5 tiles summed together to form one tower

Test Setup at Fermilab

All three prototype calorimeters in the beam line at Fermilab







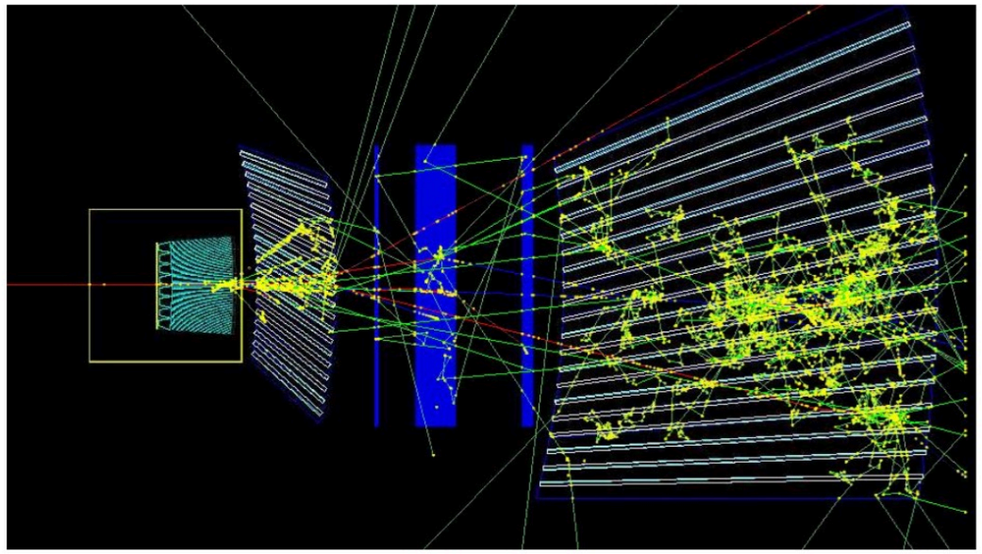
Three calorimeters in their sPHENIX configuration

Measured at three tilt angle positions (0, ± 4.5°)

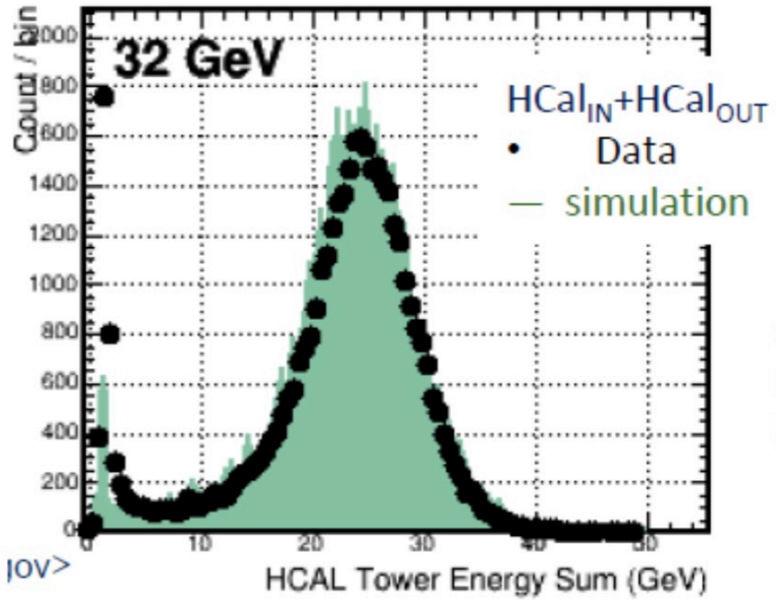
beams with different particle compositions from 1-120GeV/c

simulation

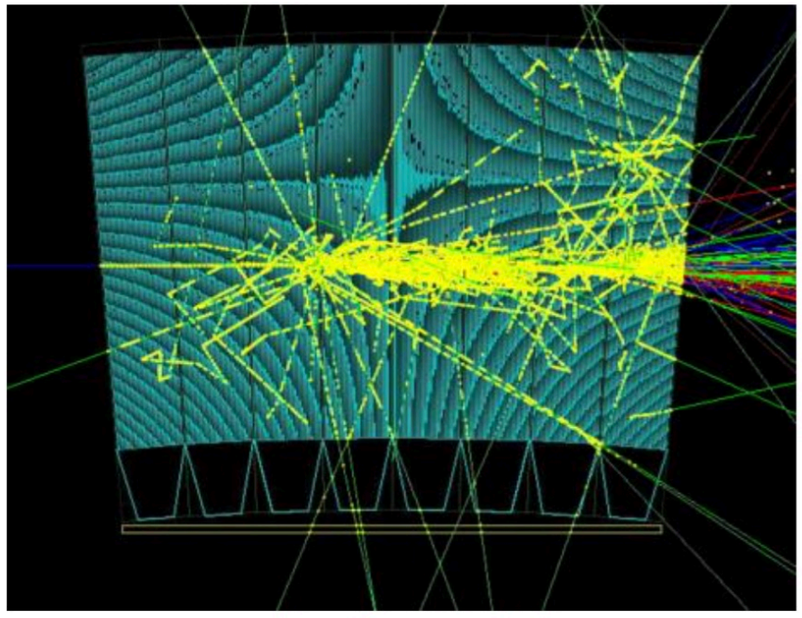
Entire test beam setup was simulated in GEANT4



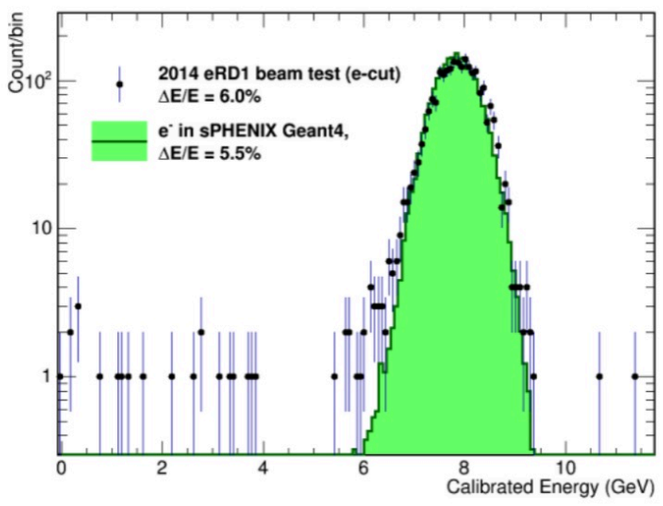
Hadronic shower in 3 calorimeters

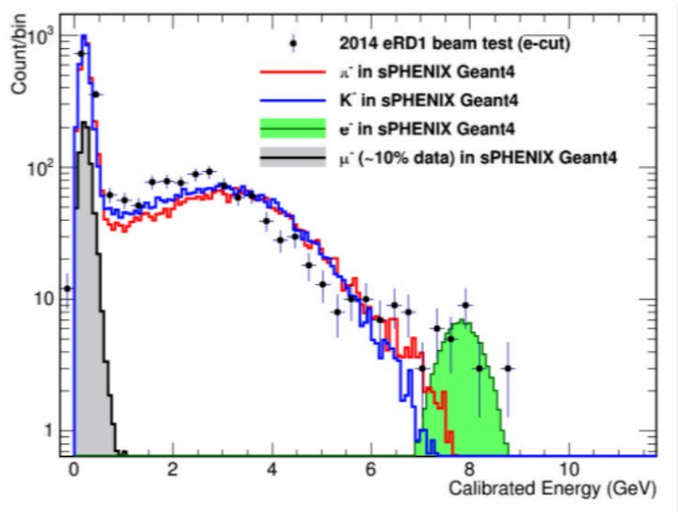


Comparison of IHCAL+ OHCAL line shape with simulation



Hadron entering EMCAL in “nose down” position





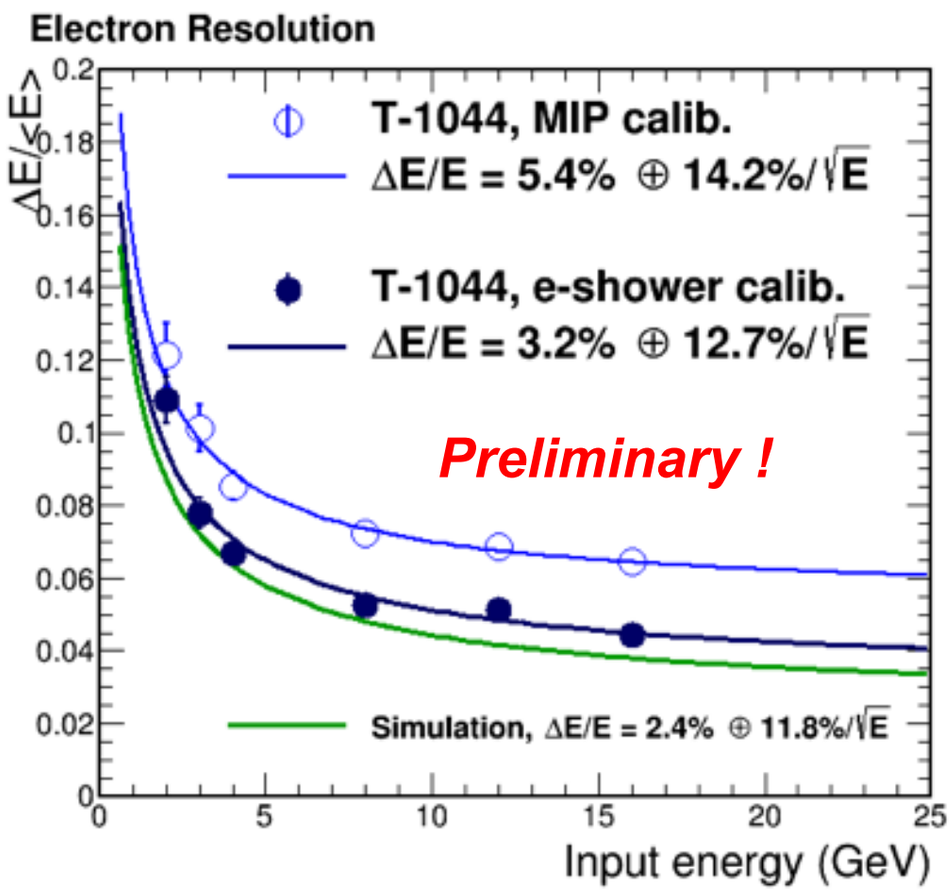
Comparison of EM and hadronic showers in EMCAL prototype with eR1 test beam data

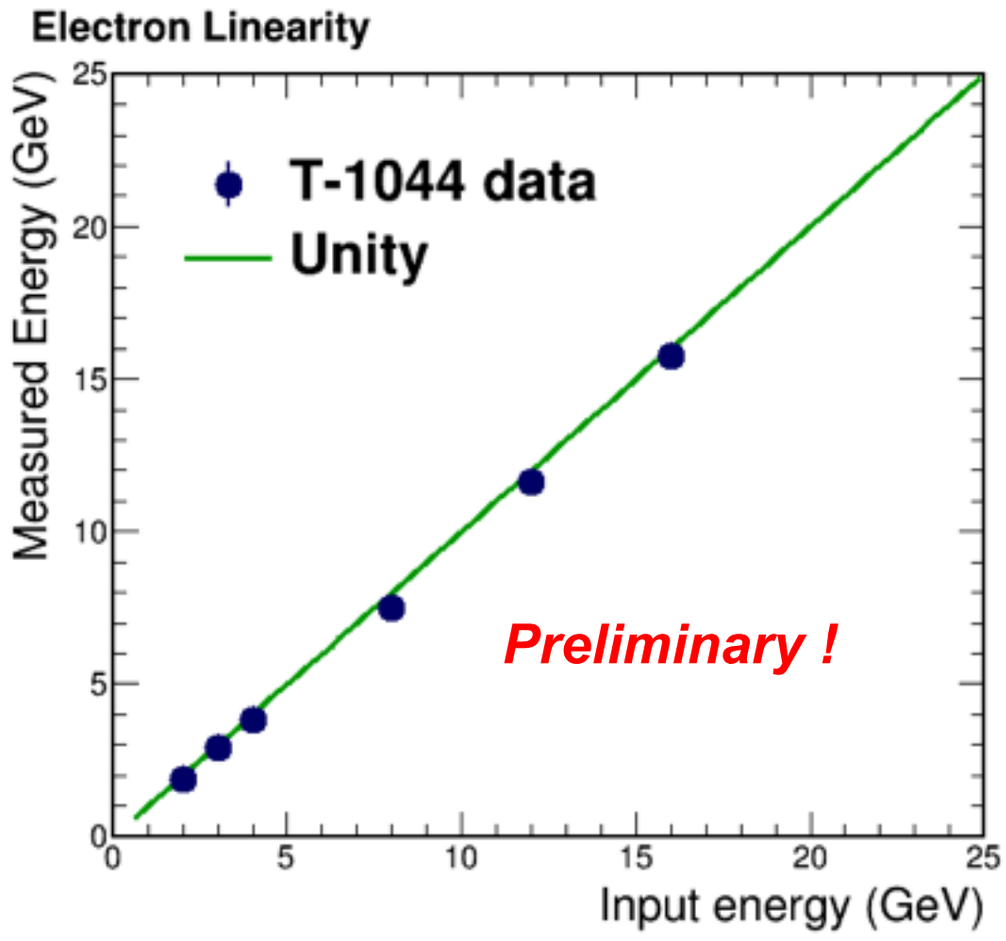
EMCAL Energy Resolution and Linearity

Electrons selected using beam Cherenkovs

(Also require hodoscope hit + no veto hit)

Beam momentum spread of ~ 2% ***not*** unfolded

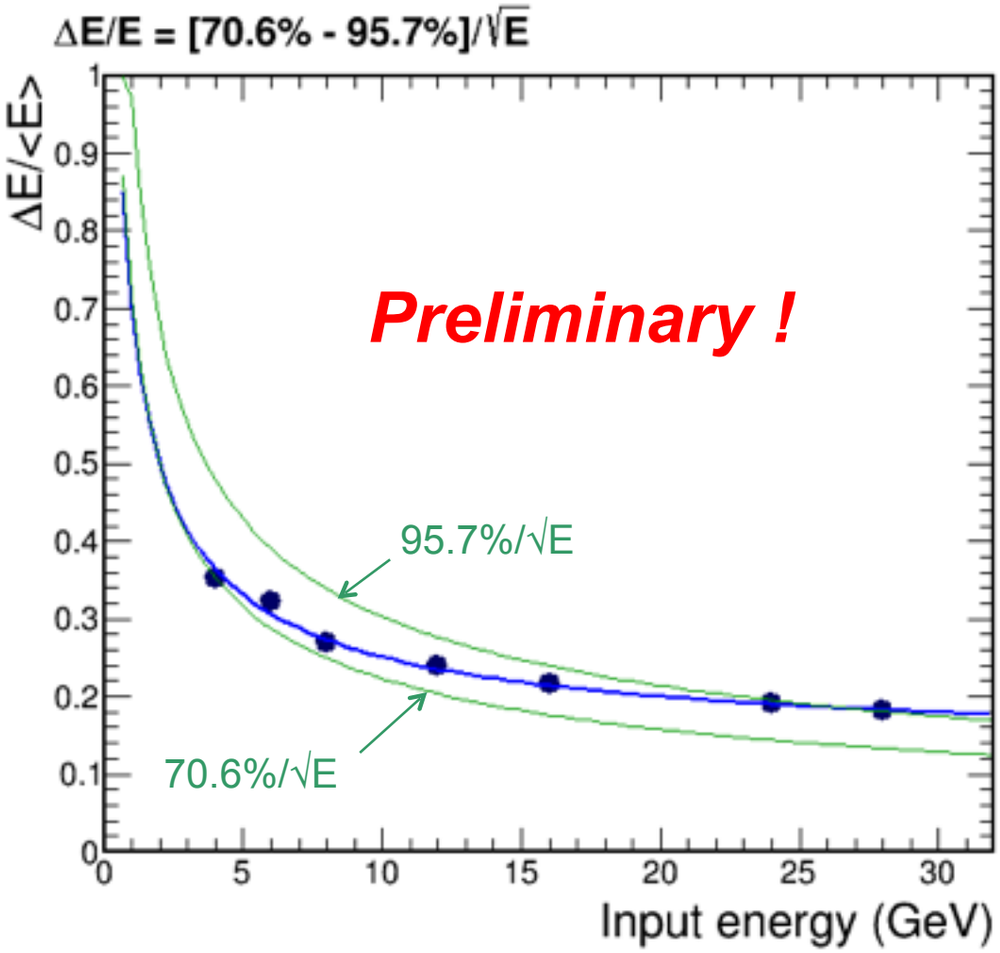


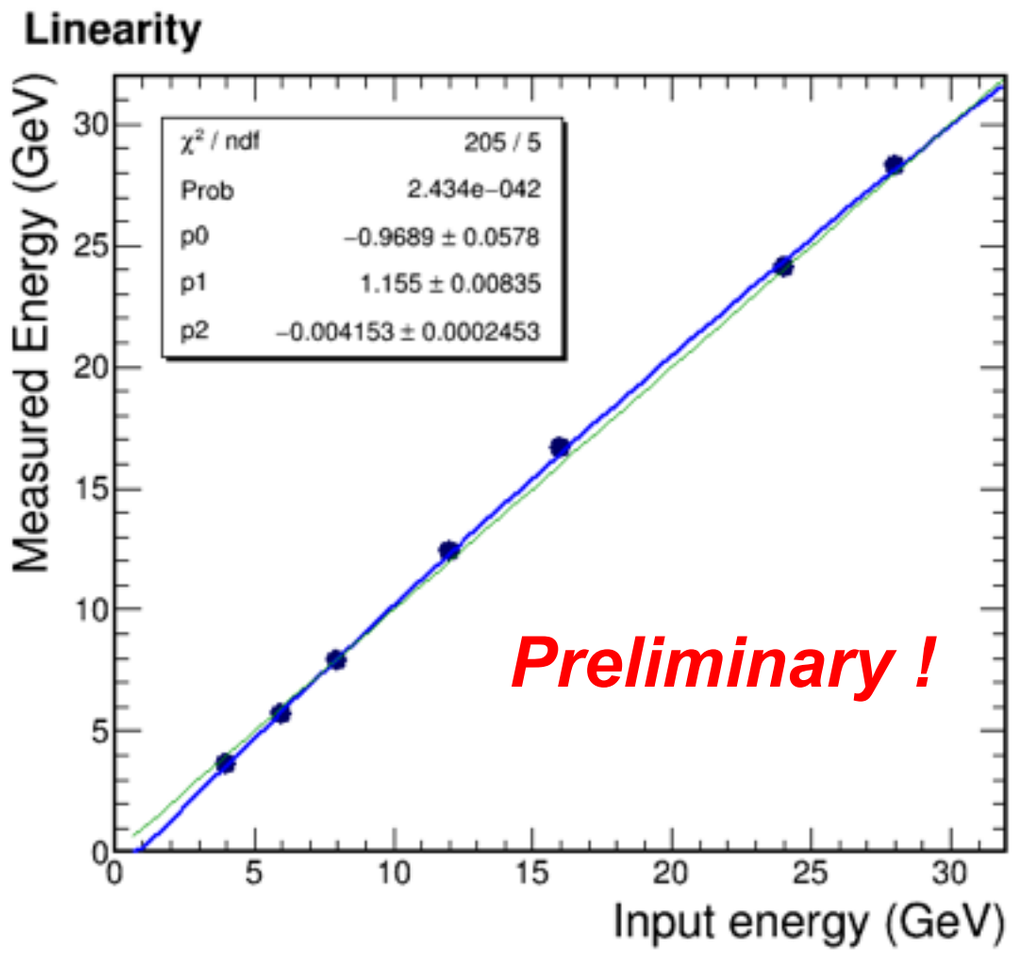


First pass MIP calibration already meets our design goal

Improvement using optimized tower to tower calibration using electron showers

Combined EMCAL + HCAL Energy Resolution and Linearity





- Two component fit gives **~ 70-80 %/√E ⊕ ~ 10-15 %**
- Calibration done using muons
- Final calibration is still work in progress, but first results already show that we are able to meet our design goal < 100%/√E

Summary

- A new upgraded detector, currently called sPHENIX, is being proposed for RHIC.
- Purpose is to do a systematic study of the QGP around the region of the critical temperature using full calorimetry measurements of jets at central rapidity and a high resolution measurement of the three upsilon states.
- The calorimeter system will consist of a compact W/SciFi EMCAL and a steel plate scintillating tile hadronic calorimeter divided in two sections.
- Prototypes of all three calorimeters have been built and tested in a month long test beam run at Fermilab which just ended. Another test planned for next year.
- A large collection of data was taken and is currently being analyzed but the preliminary analysis results indicate that all three detectors will meet the design goals of the new experiment.
- Looking forward for some exciting new results !