test beam results on W-fiber and tilted plate calorimeters for a new RHIC experiment

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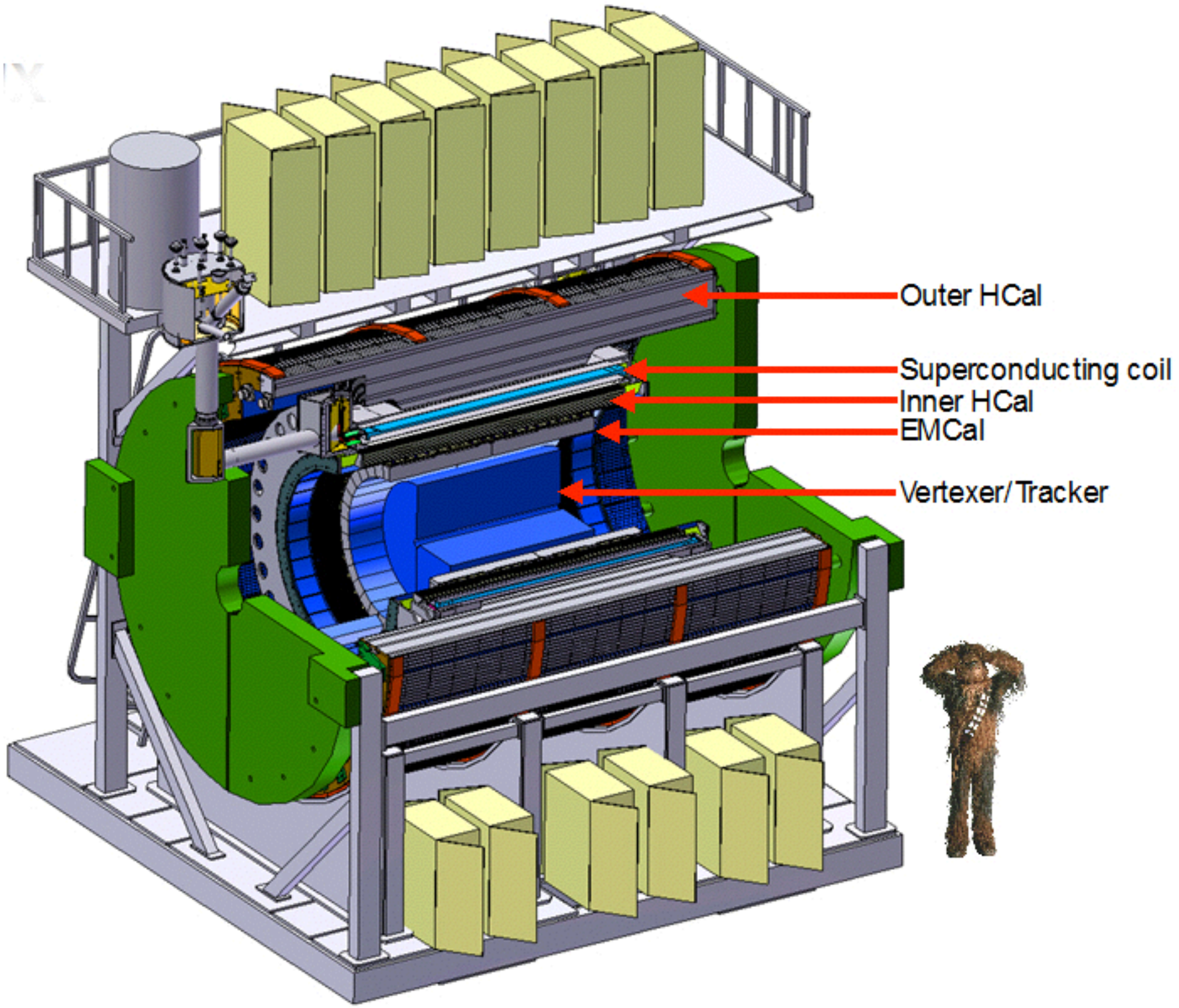
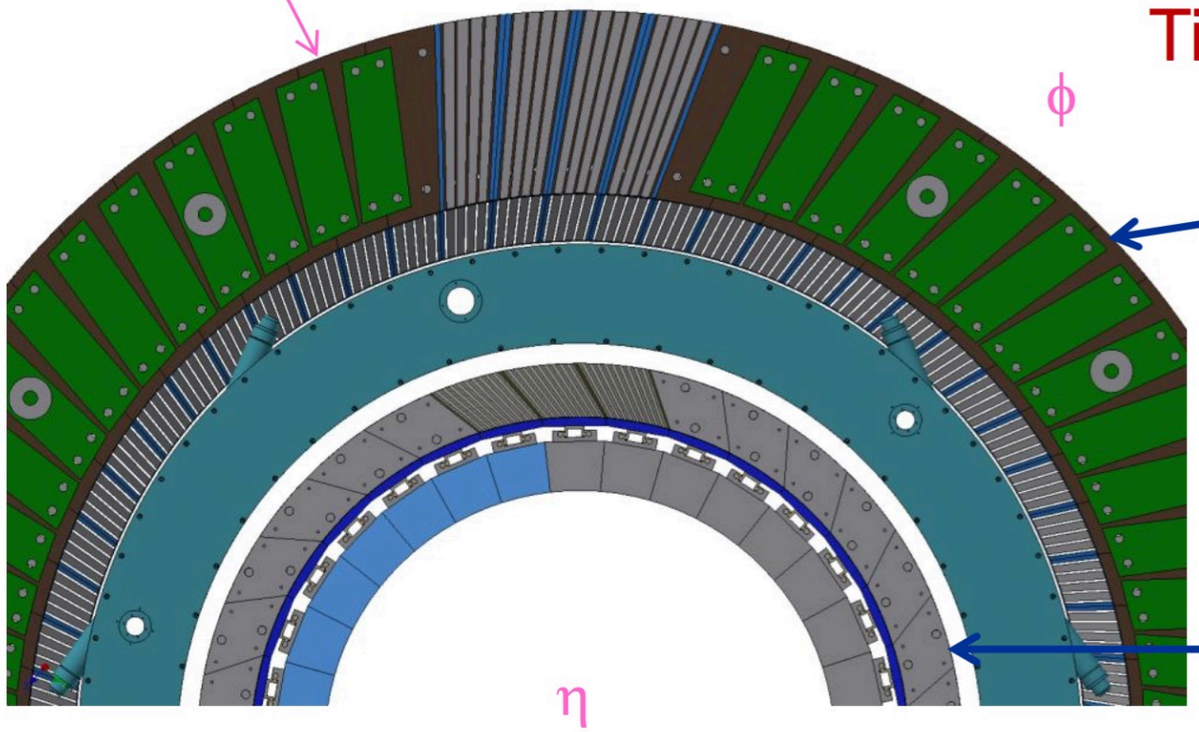
sPHENIX layout



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

Hadronic Calorimeters

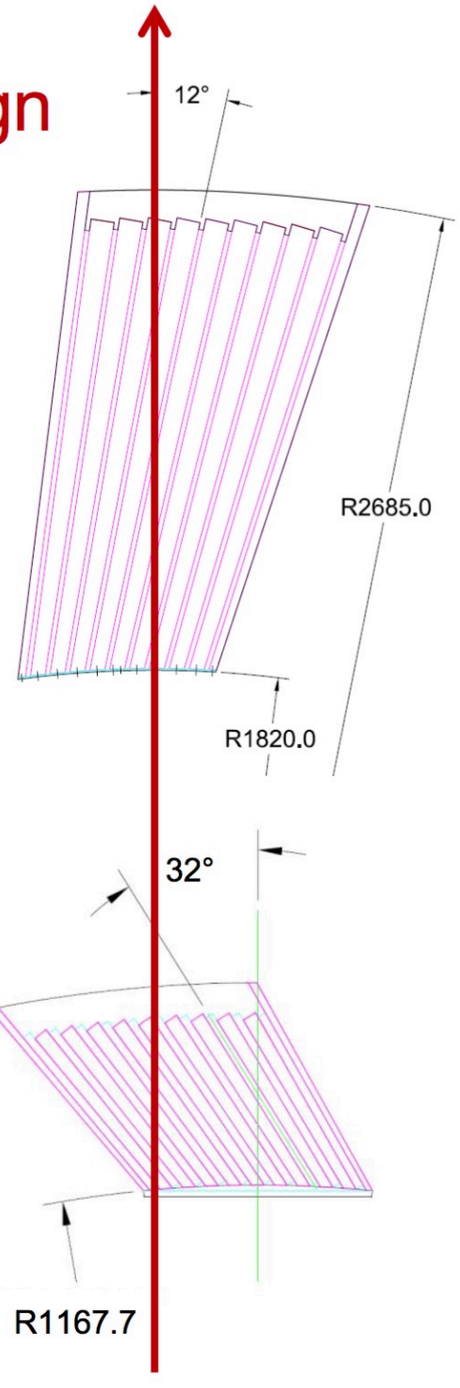


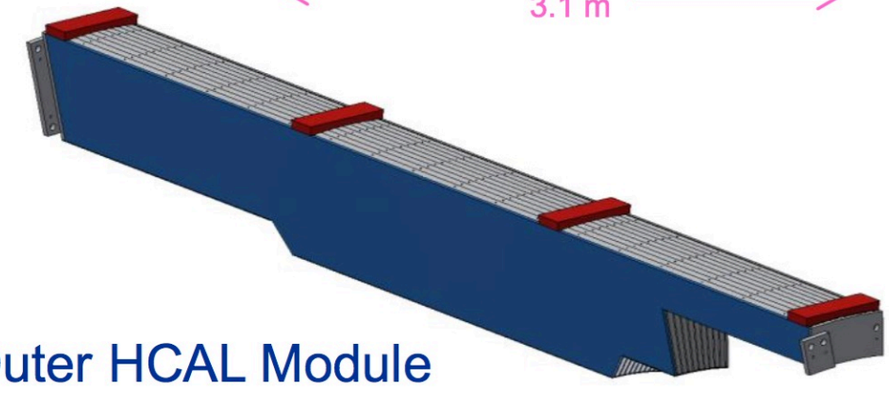
Tilted Plate Design

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

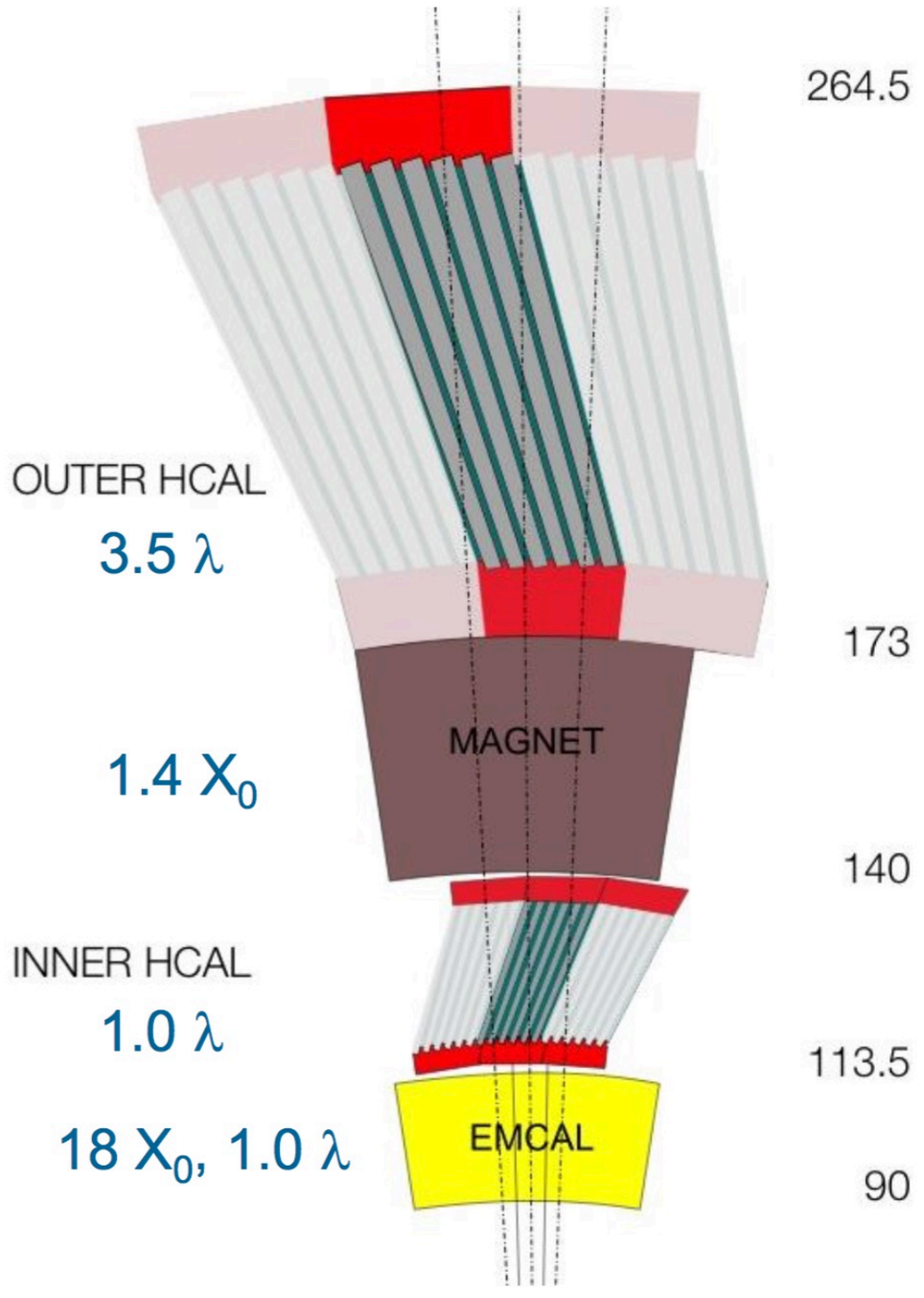
Sampling fraction changes with depth (~25%)

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
- $\sigma_E/E < 15\%/\sqrt{E}$

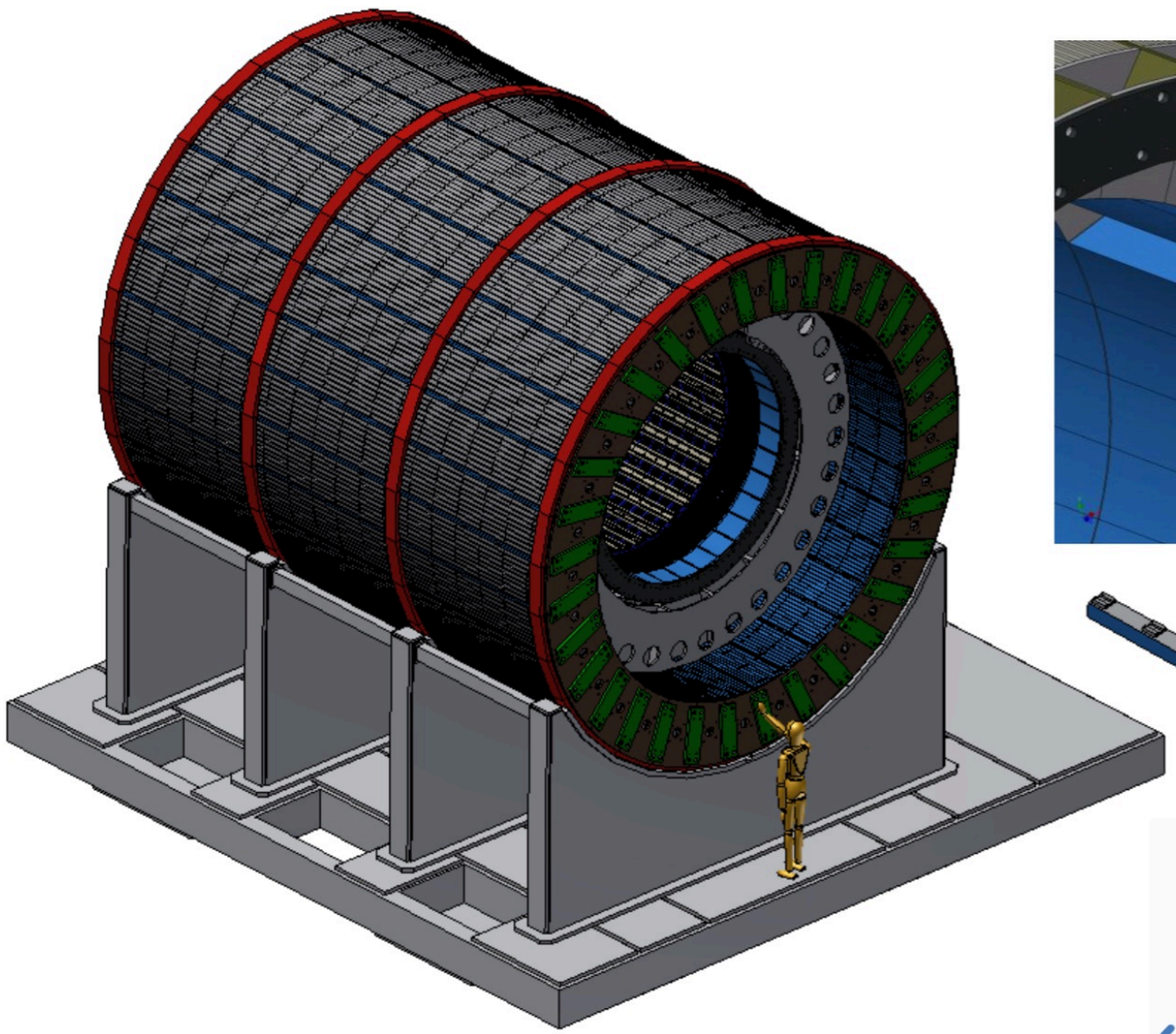
HCAL – Steel plates + scintillating tiles with WLS fiber readout

- 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)



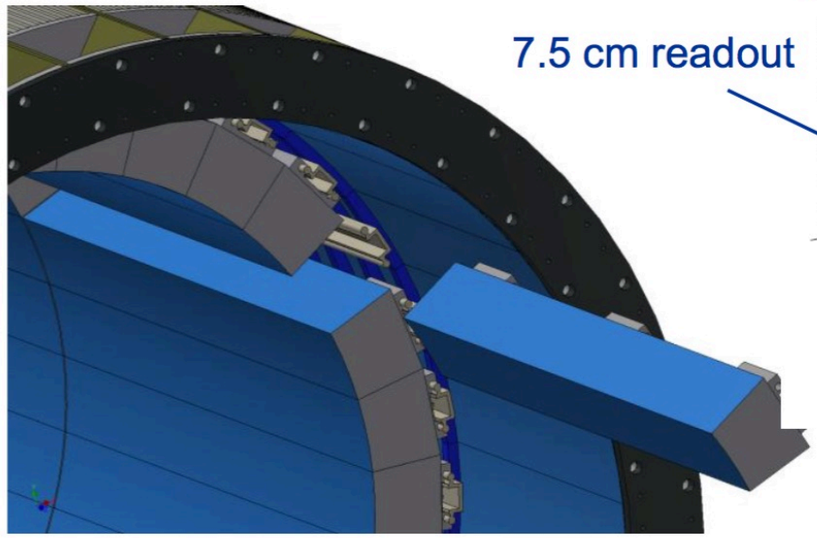
EMCAL + HCAL ~ 5.5 λ

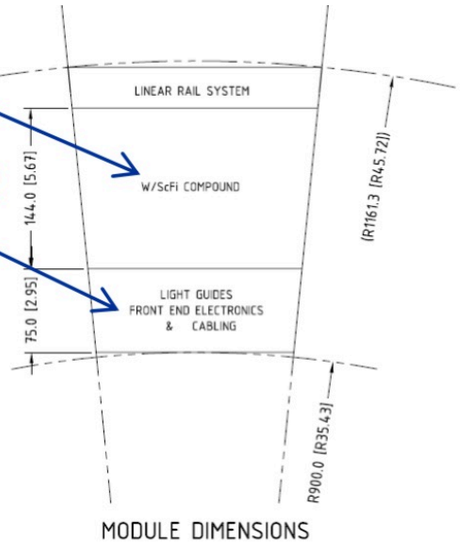
Both EMCAL and HCAL read out with SiPMs



14 cm absorber (η=0)

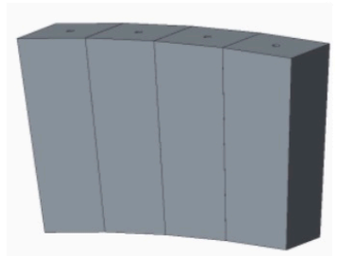
7.5 cm readout





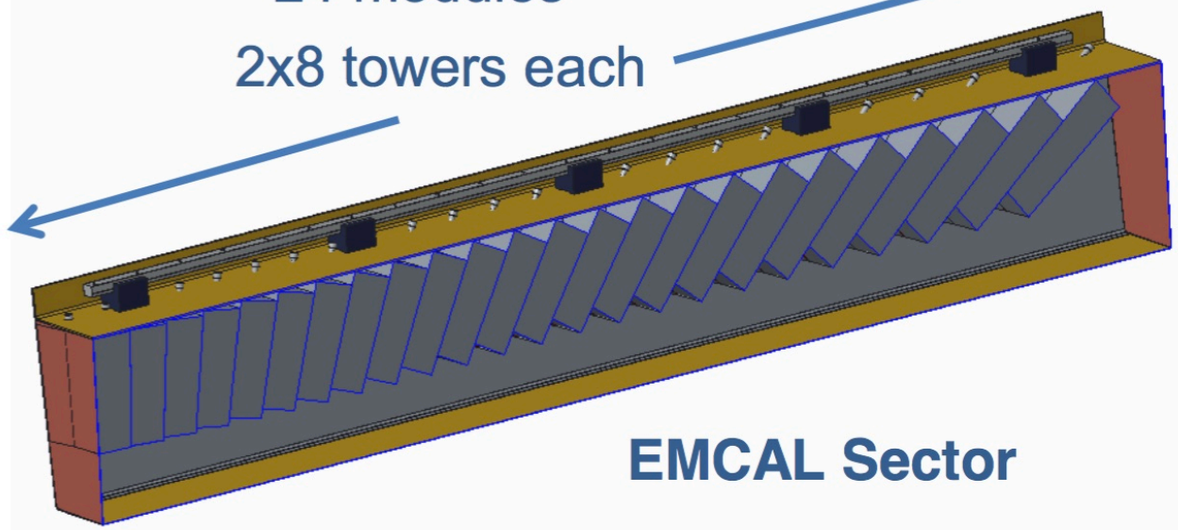
MODULE DIMENSIONS

Four 2x2 tower blocks = 1 module



24 modules

2x8 towers each



EMCAL Sector

2(±η) x 32 (ϕ) = 64 Sectors

24 modules per sector
2x8 towers per module
384 towers per sector
Sector weight ~ 950 lb

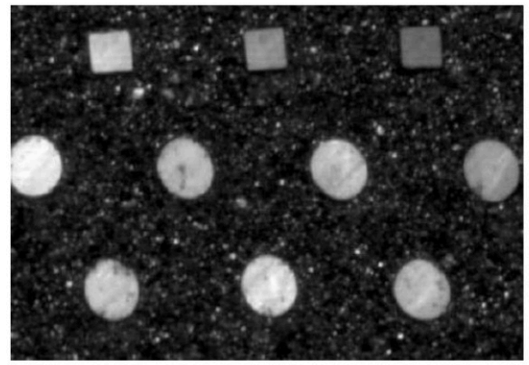
~25K towers total

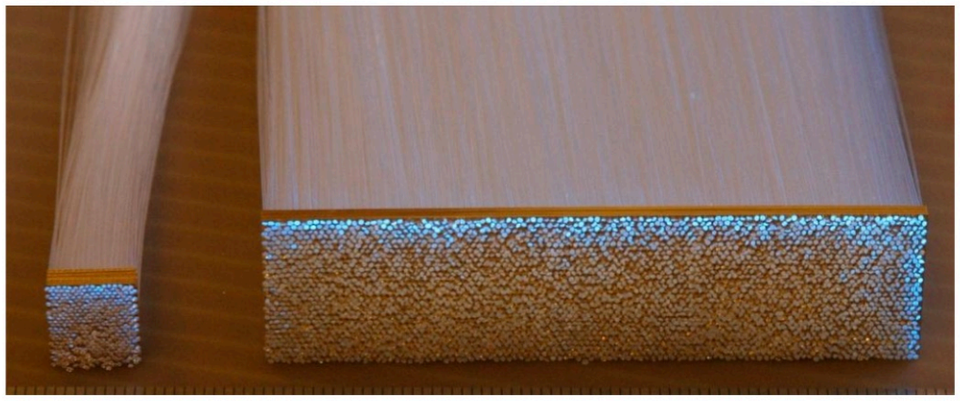
W/SciFi SPACAL (originally developed by Oleg Tsai at UCLA)

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%/$\sqrt{E}$

Powder supplier

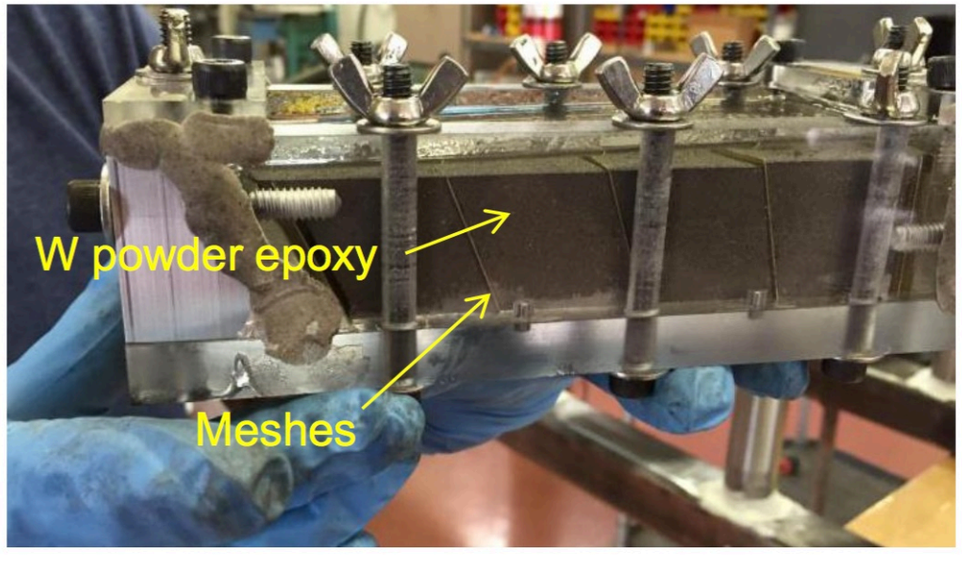




Scintillating fibers (Kuraray SCSF78)

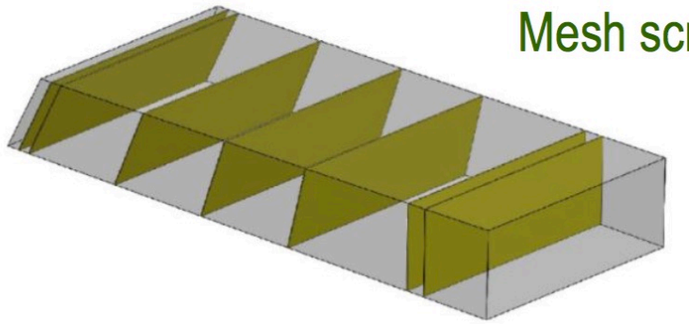
- Diameter: 0.47 mm, Spacing: 1 mm
- Sampling Fraction ~ 2.3 %

- 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

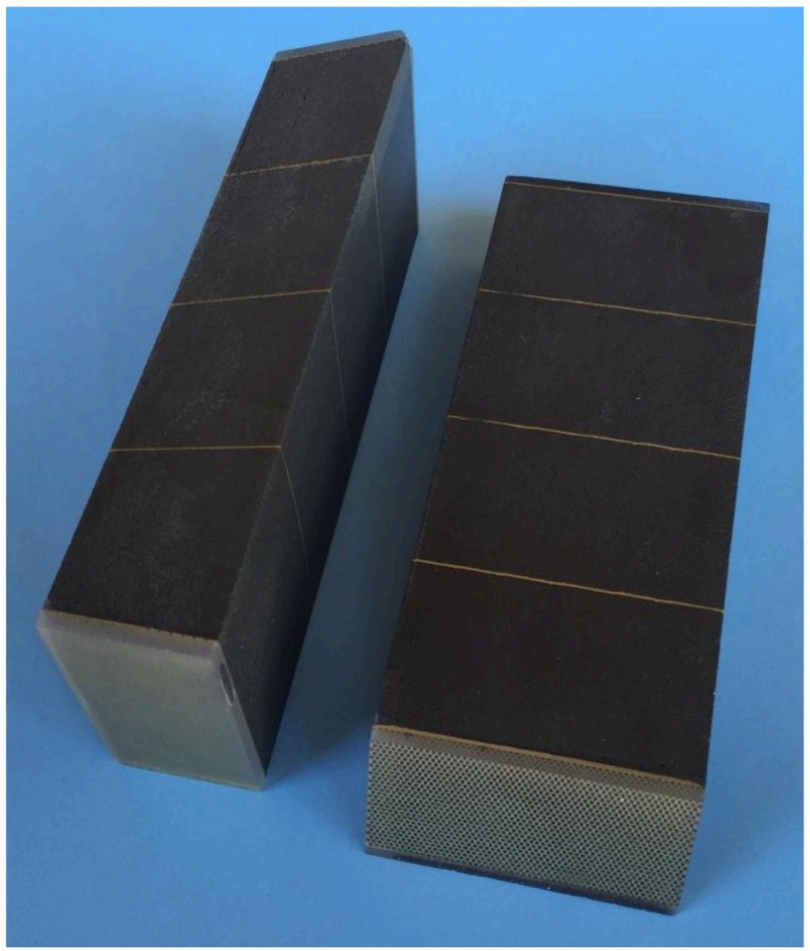


1D Projective

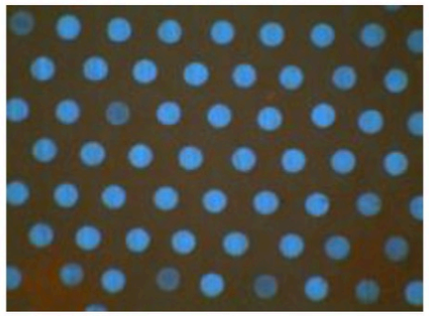
Mesh screens

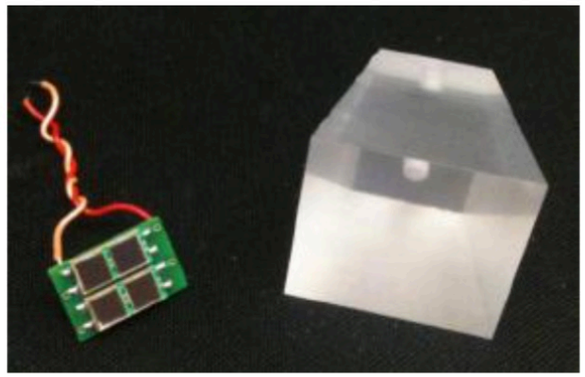


Produced at UCLA, BNL, UIUC and THP

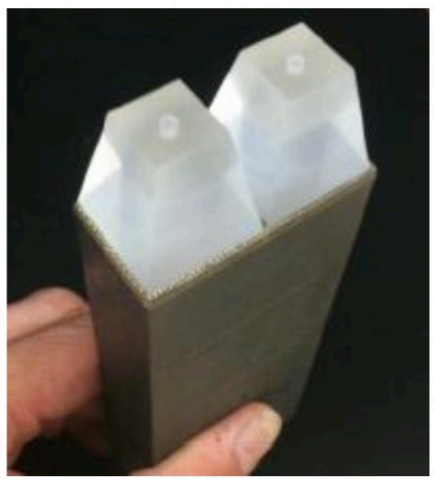


Fiber ends are finished by with fly cutting

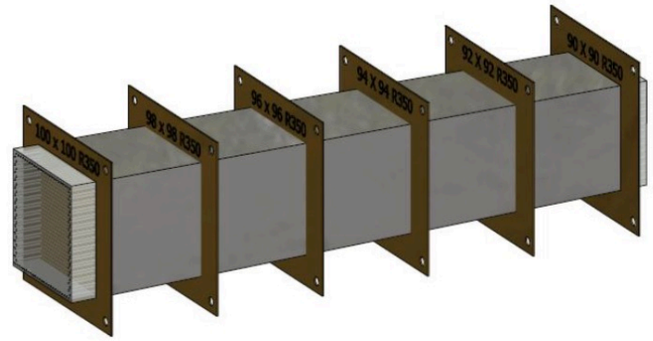




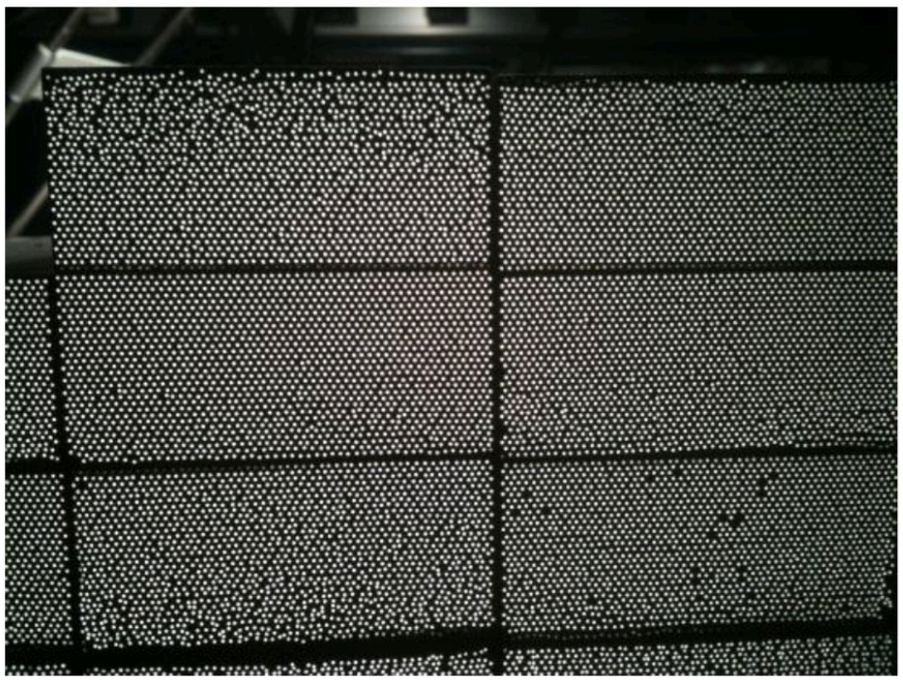
Light guides and SiPMs are attached to module ends to form towers



2D Projective



Half of the absorber blocks were manufactured at THP and half at UIUC

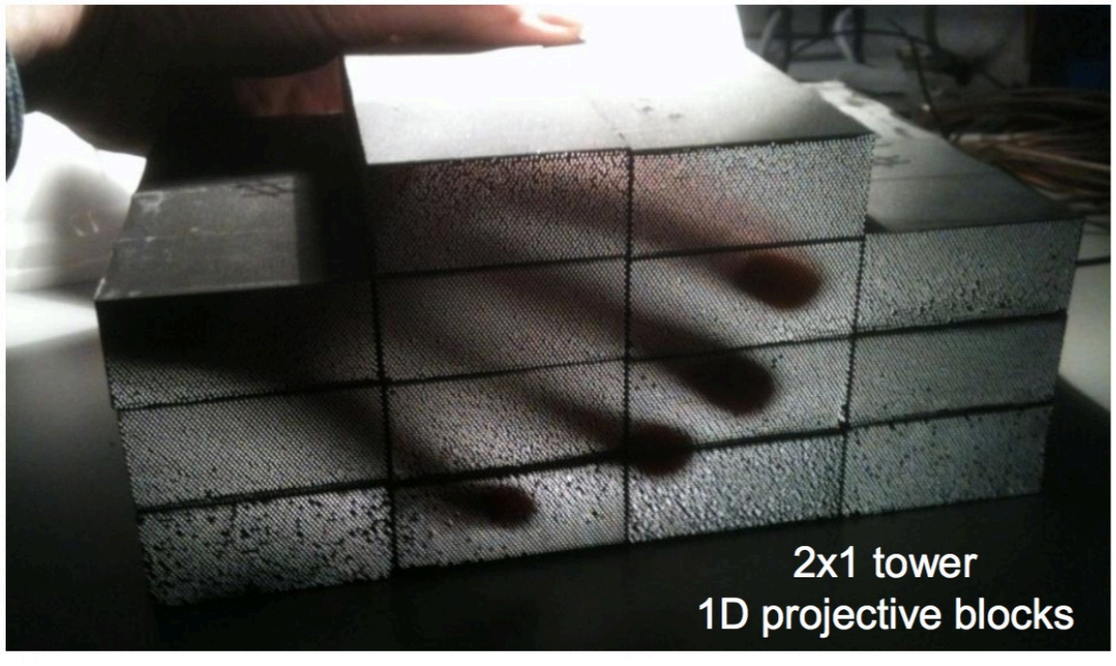


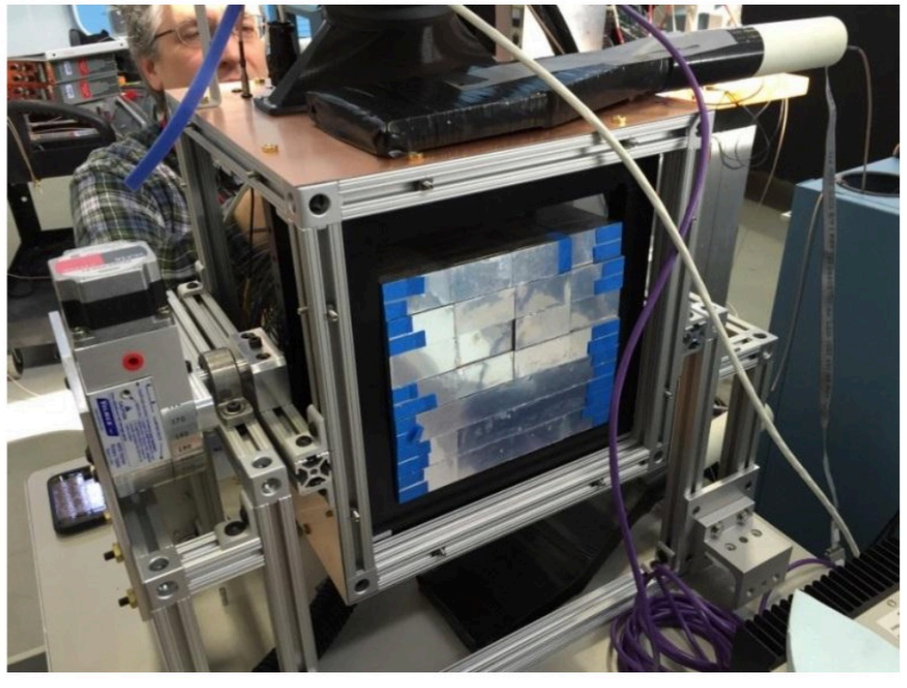
Density varied from ~ 8.5 – 10 g/cm^3

Slight fiber misalignment at one end but can be easily corrected in the future

8x8 array of towers

THP 10.2	THP 10.5	THP 8.5	THP 8.5	THP 9.0	THP 9.0	THP 9.8	THP 9.8
THP 9.7	THP 9.7	THP 10.0	THP 10.0	THP 10.0	THP 10.0	THP 9.9	THP 9.9
THP 9.2	THP 9.2	THP 9.8	THP 9.8	THP 9.3	THP 9.3	THP 10.1	THP 10.1
UIUC 9.6	UIUC 9.6	UIUC 9.4	UIUC 9.4	THP 10.1	THP 10.1	THP 9.6	THP 9.6
UIUC 9.5	UIUC 9.5	UIUC 9.5	UIUC 9.5	THP 9.3	THP 9.3	THP 9.3	THP 9.3
UIUC 9.4	UIUC 9.4	UIUC 9.4	UIUC 9.4	UIUC 9.4	UIUC 9.4	UIUC 9.6	UIUC 9.6
UIUC 9.2	UIUC 9.2	UIUC 9.6	UIUC 9.6	UIUC 9.3	UIUC 9.3	UIUC 9.3	UIUC 9.3
UIUC 9.5	UIUC 9.5	UIUC 9.6	UIUC 9.6	UIUC 9.3	UIUC 9.3	UIUC 9.2	UIUC 9.2





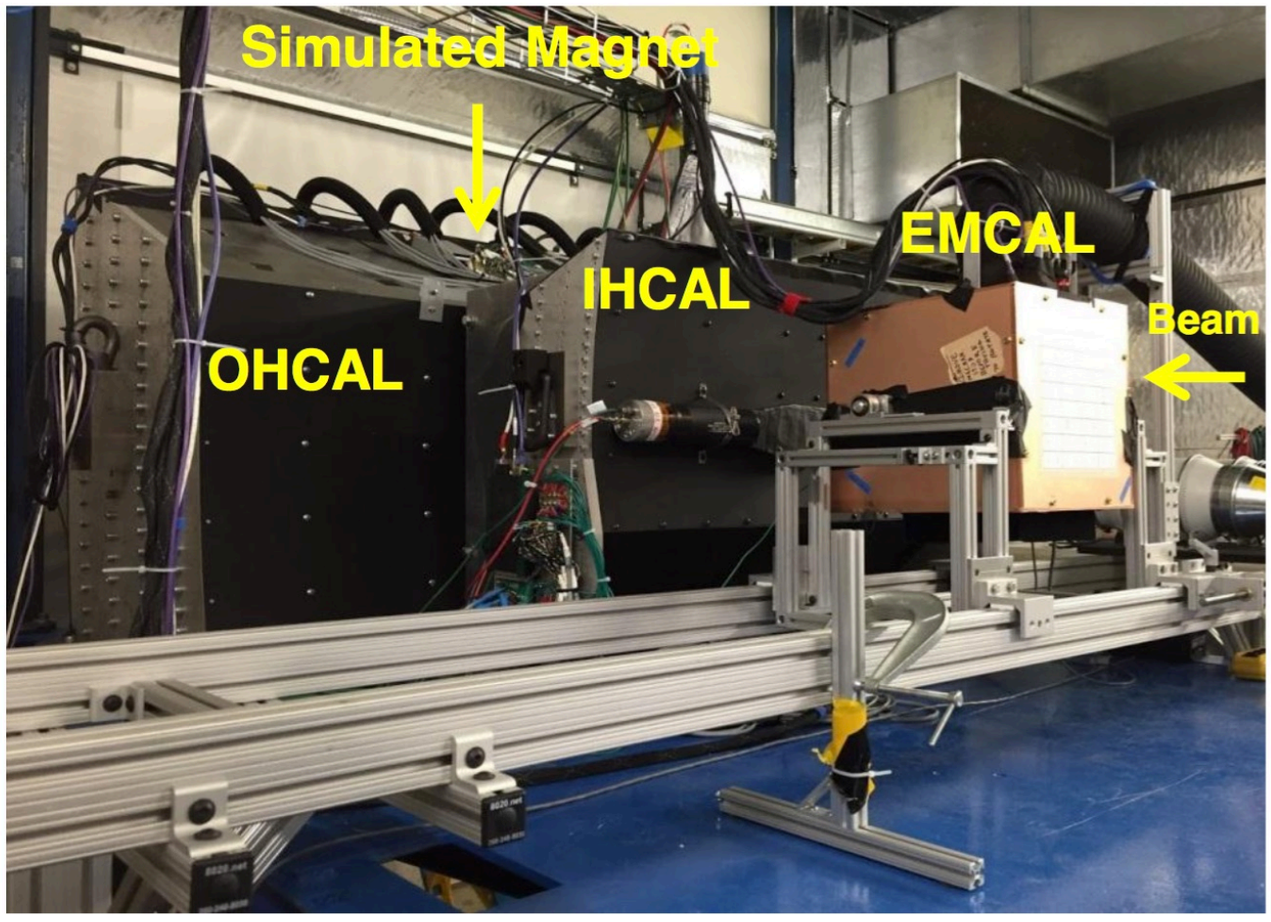
Inner and Outer HCAL prototypes each consist of 4 x 4 towers

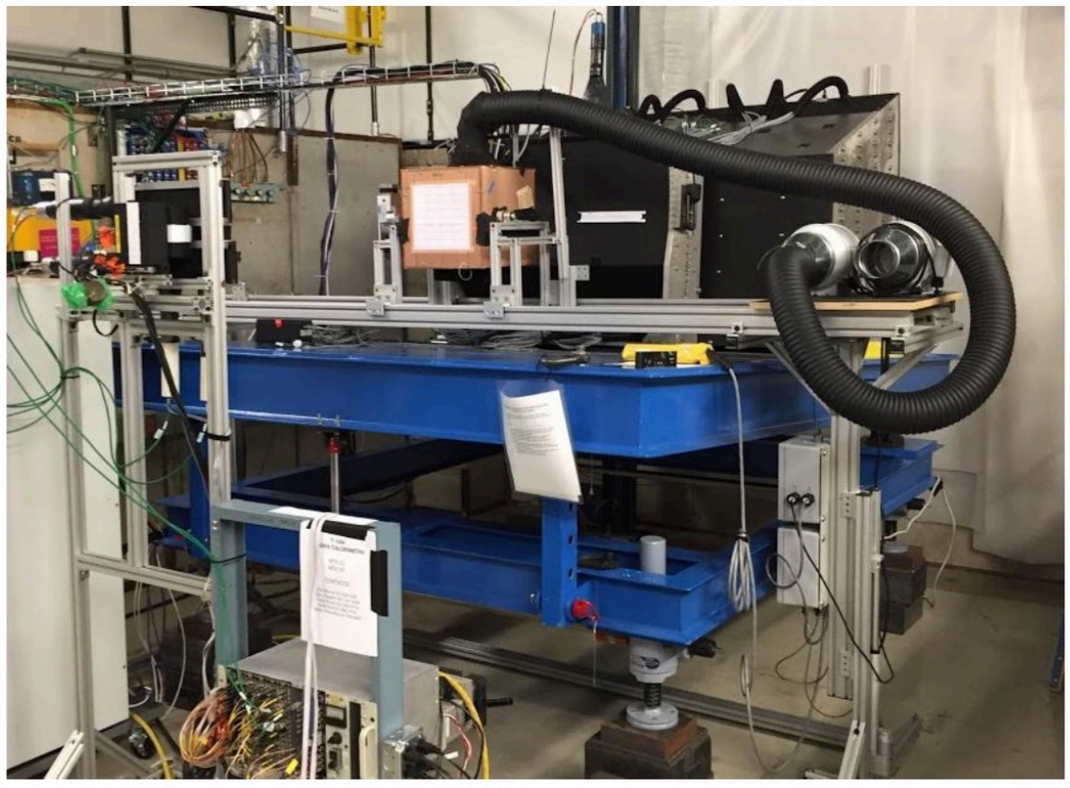
- Inner: ~ 0.5 m^2 (56 x 94 cm^2)
- Outer: ~ 1.2 m^2 (74 x 165 cm^2)

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

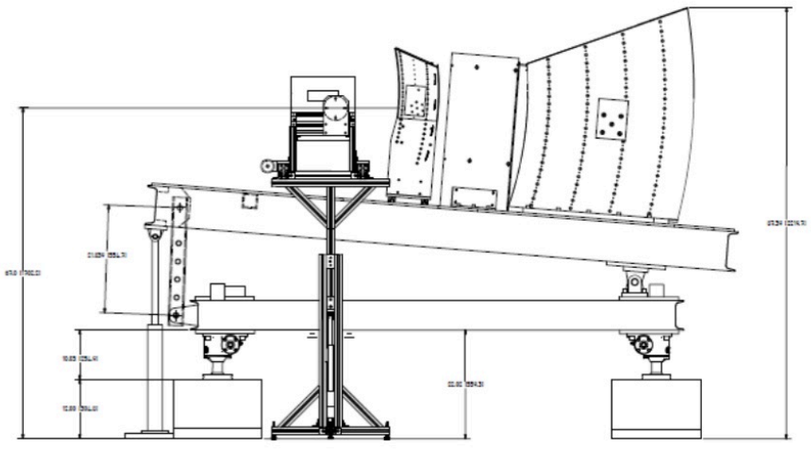
All three prototype calorimeters in the beam line at Fermilab



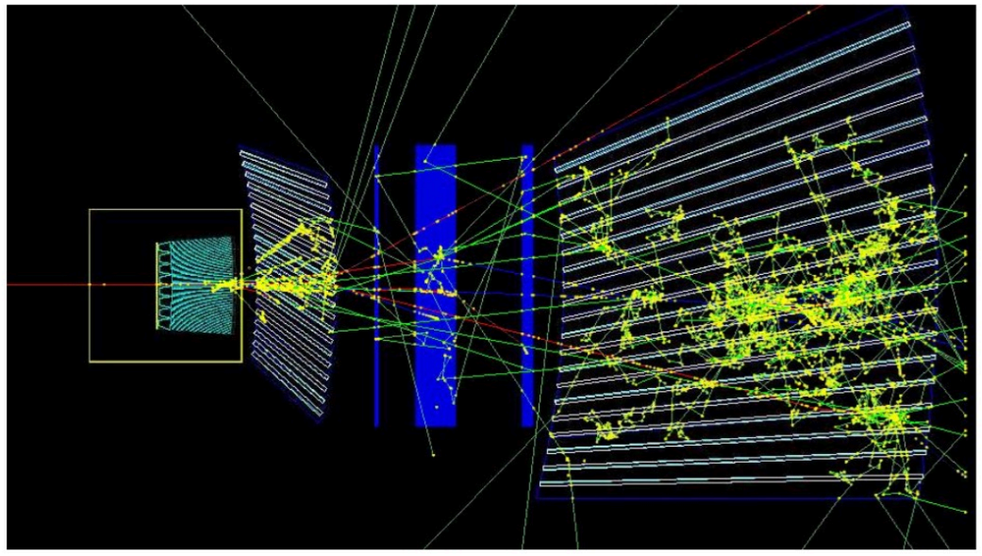


Three calorimeters in their sPHENIX configuration

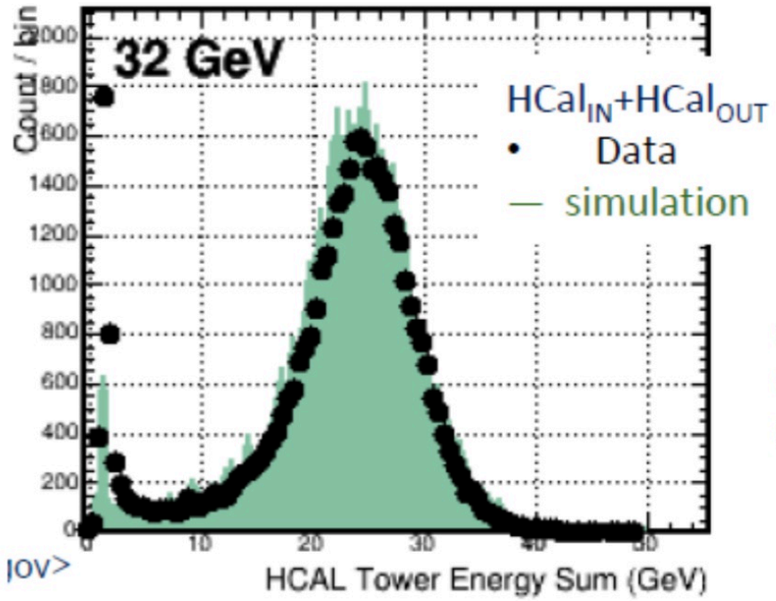
Measured at three tilt angle positions (0, ± 4.5°)



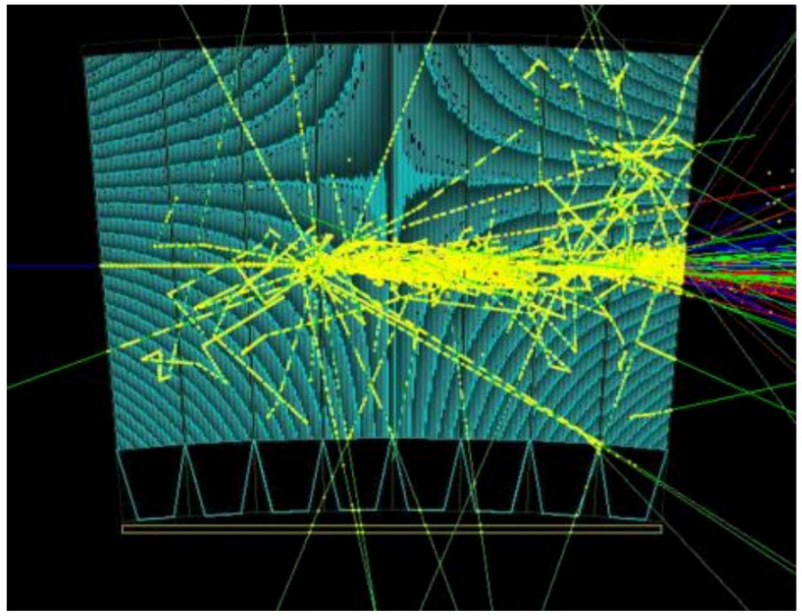
Entire test beam setup was simulated in GEANT4



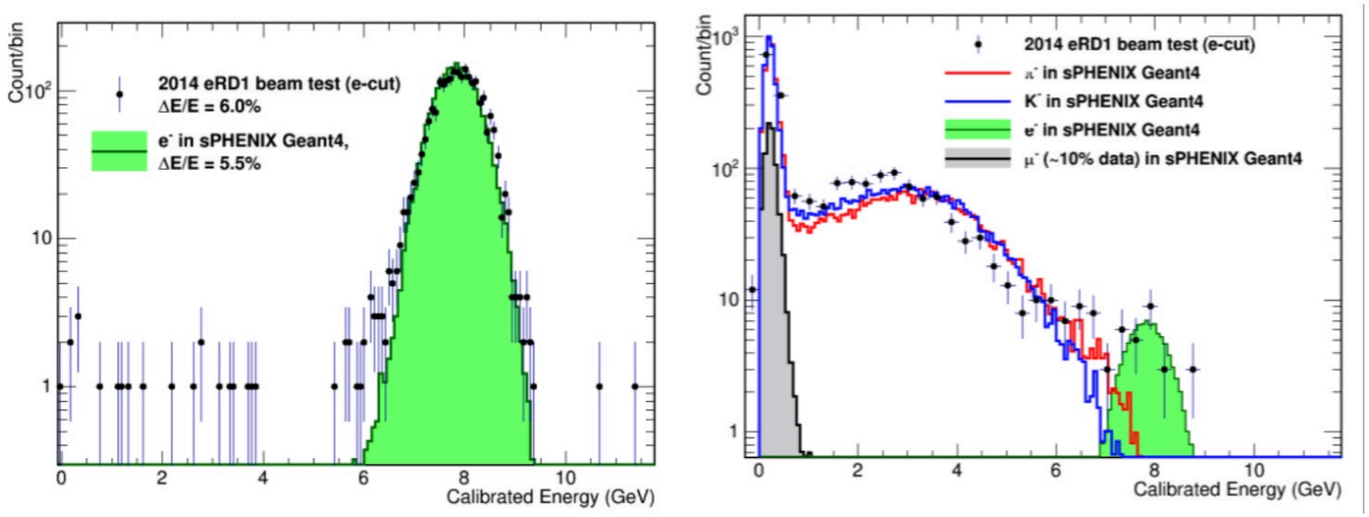
Hadronic shower in 3 calorimeters



Comparison of IHCAL+ OHCAL line shape with simulation



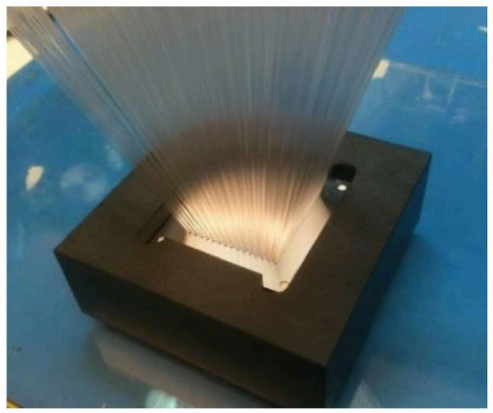
Hadron entering EMCAL in “nose down” position

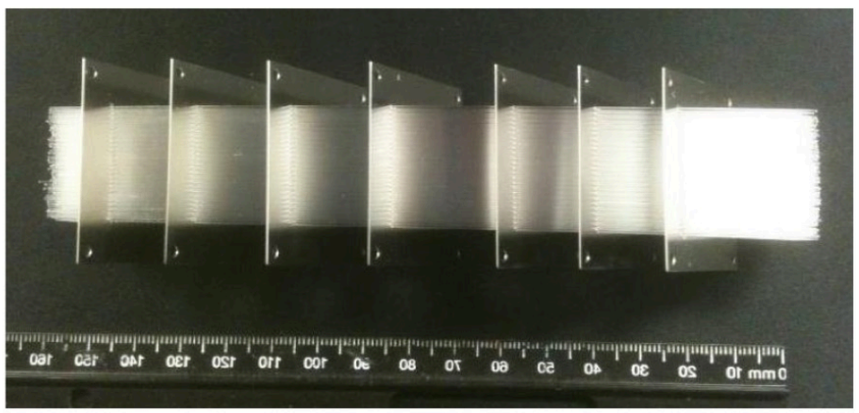


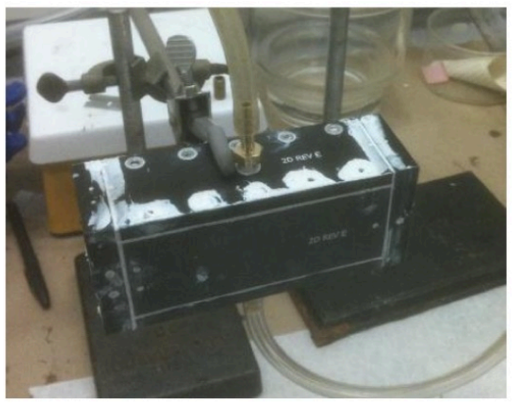
Comparison of EM and hadronic showers in EMCAL prototype with eR1 test beam data

Projective in ϕ and η with different tapers in both projections

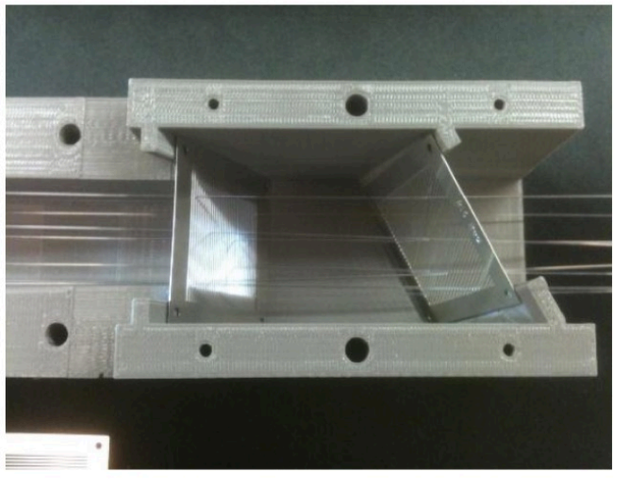
Tapered Hole Meshes: Uses a series of meshes with conical shaped holes, each with a slightly different hole spacing, to position the fibers

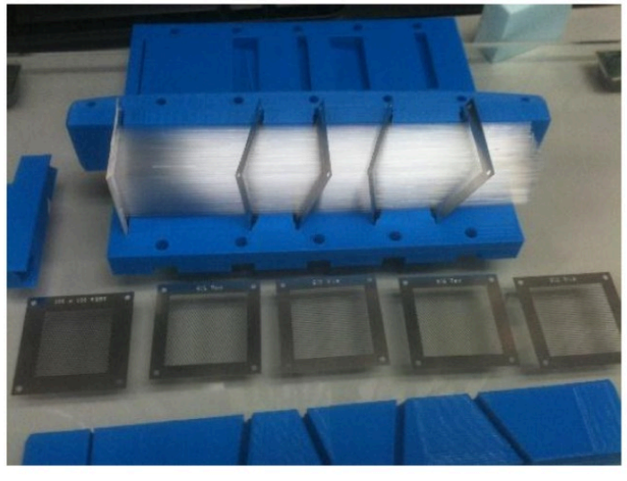


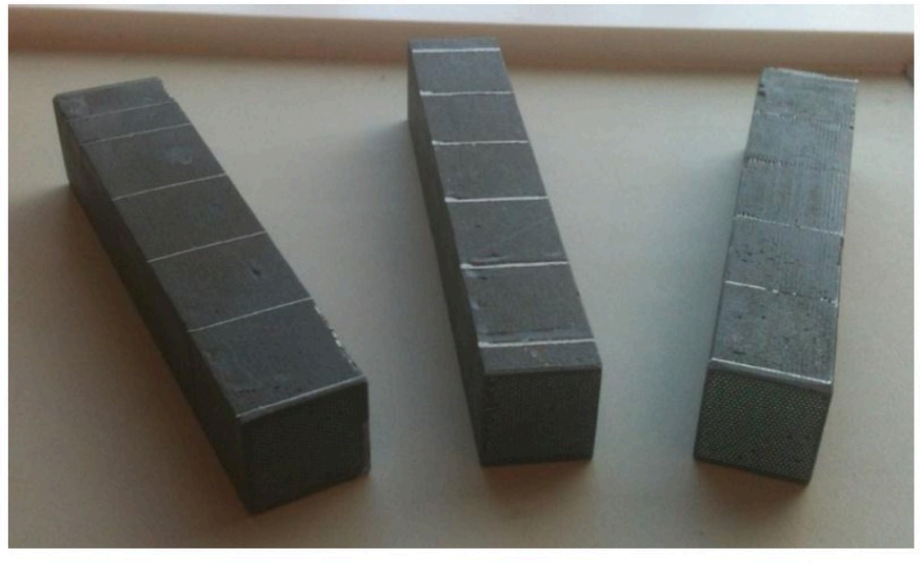




Tilted Wire Frame: Uses a series of angled wire frames to taper the array of fibers inside the tower







First 2D Tapered SPACAL Modules produced at BNL

Summary