sPHENIX EMCAL Project Status

Overview of the EMCAL System

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Overview of the EMCAL Design

EMCAL Design Specs:

- Coverage: $\pm$ 1.1 in η, 2π in ϕ
- Segmentation: $\Delta\eta \times \Delta\phi \approx 0.025 \times 0.025$
- Readout channels: 96x256 = 24576 (towers)
- Energy Resolution: $\sigma_E/E < 15\%/\sqrt{E}$
- Provide an e/h separation > 100:1
- Approximately projective
- Compact (in order to fit inside Babar solenoid)
- Works inside a 1.5T magnetic field

Contributions to sPHENIX physics measurements :

- Jet measurements
- Photon measurements
- Υ measurements

Physics Measurements with the EMCAL

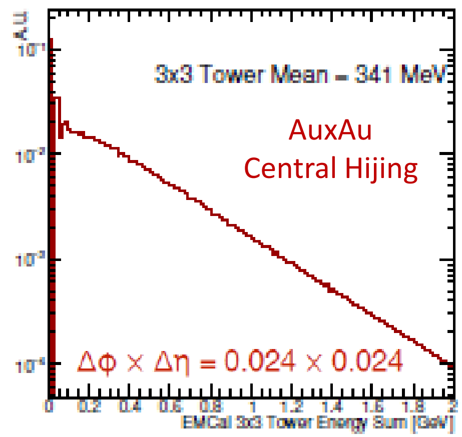
sPHENIX

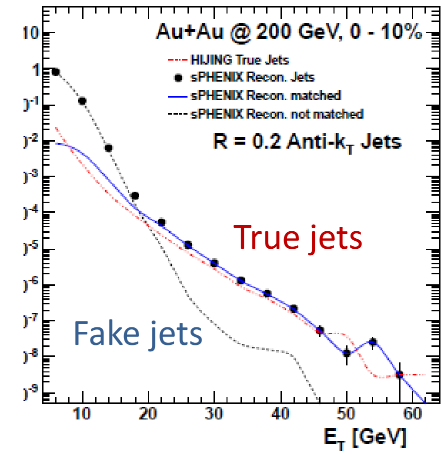
Jet measurements

- Measure the EM component of the jet energy along with HCAL
- Requirements on energy resolution and segmentation are determined mainly by the underlying event

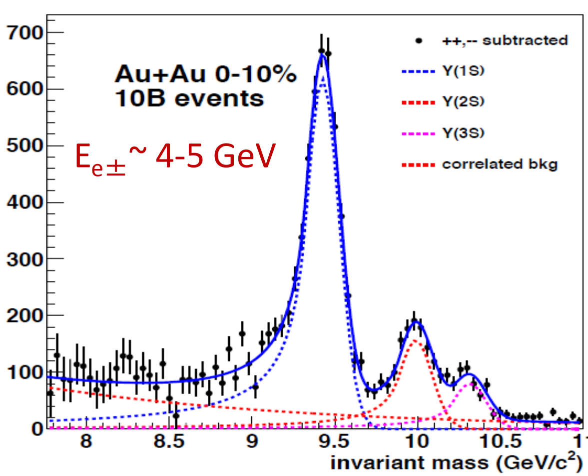
For a 5 GeV electron from ϒ decay
15%/√E ⇒ ~ 335 MeV

True jets begin to dominate fake jets for p_T > 20 GeV/c



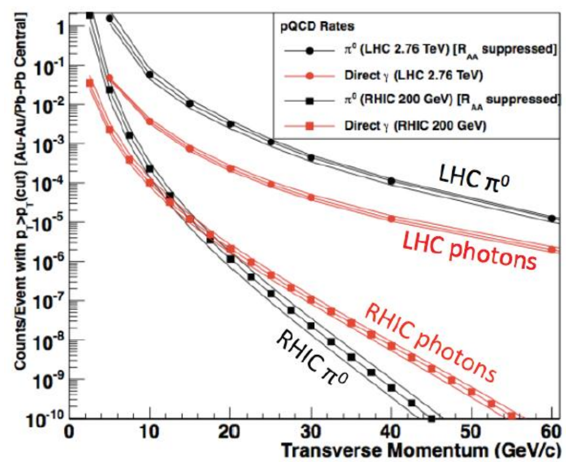


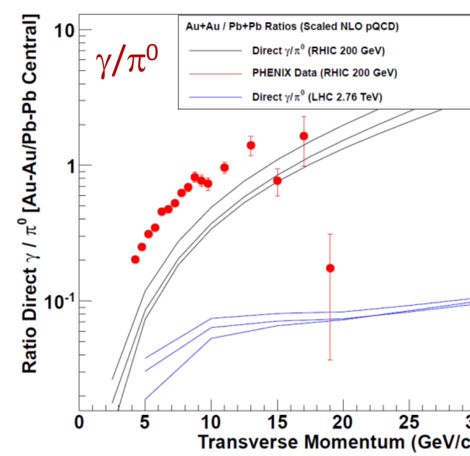
ϒ measurements



Provide electron id (e:h > 100:1)

γ-jet and direct photon measurements



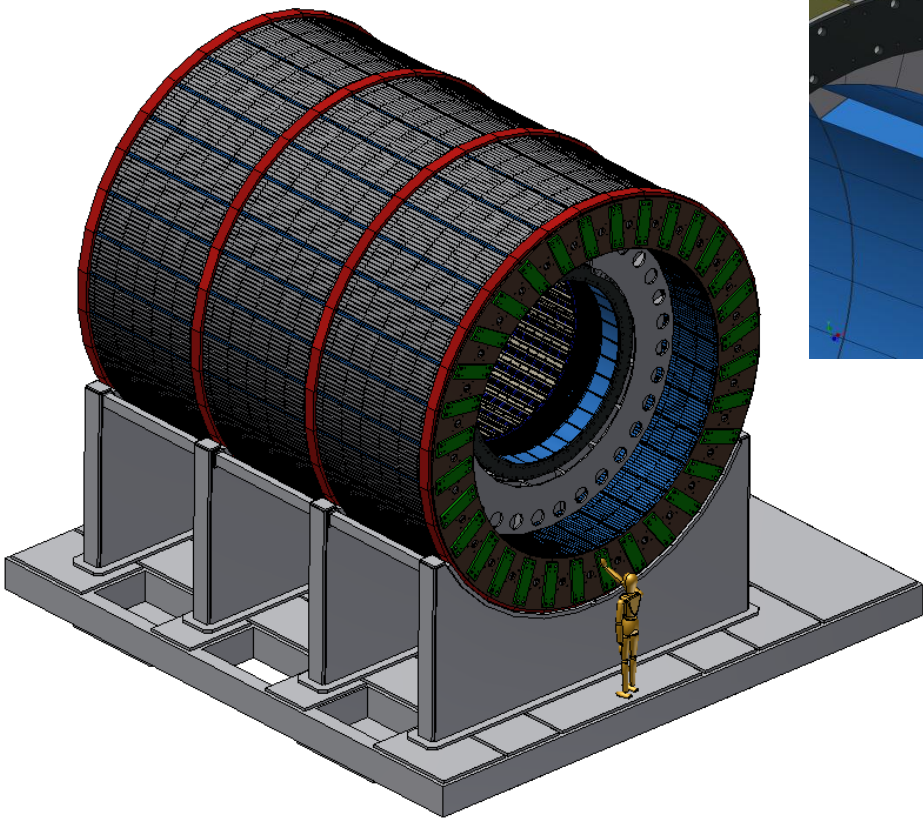


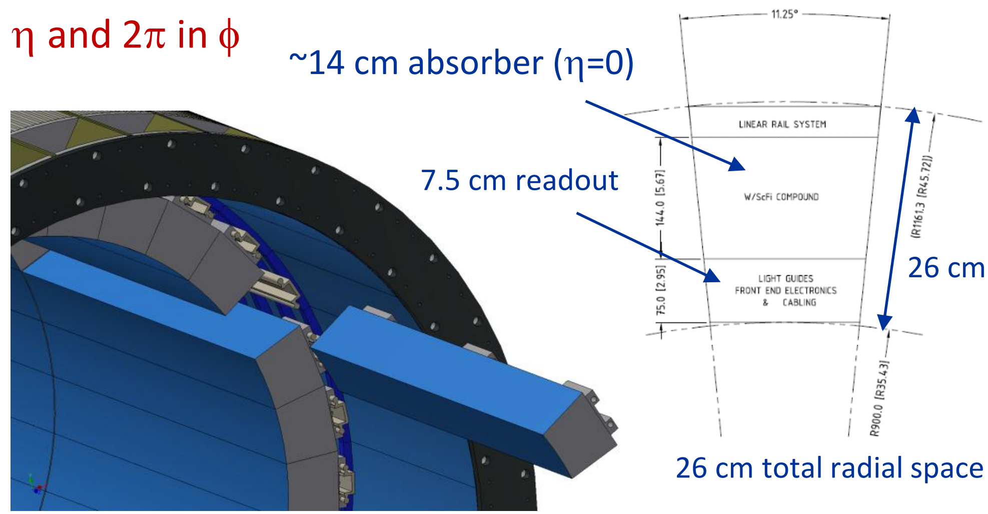
Tag and measure photons for p_T > 20 GeV

EMCAL Subsystem

Electromagnetic calorimeter covering ± 1.1 in η and 2π in ϕ

2(±η) x 32 (ϕ) = 64 Sectors



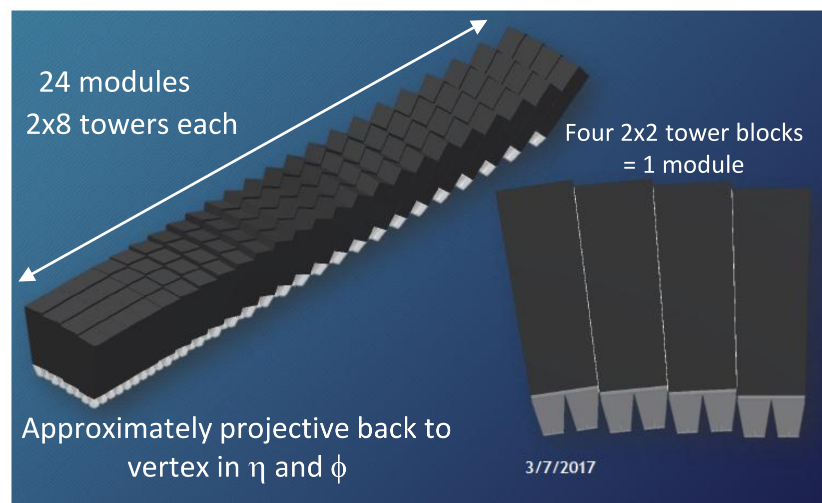


26 cm total radial space

Designed to be compact to fit inside the BaBar magnet

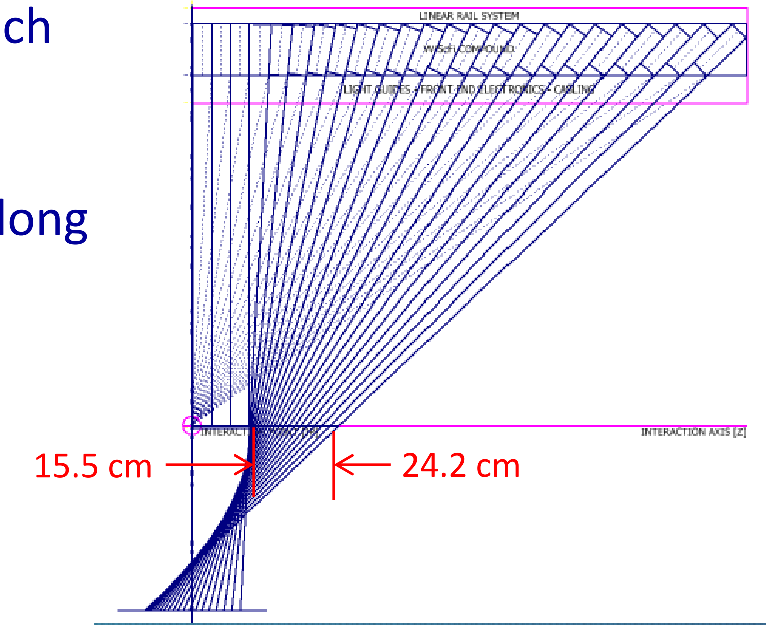
1 Sector = 24 modules
= 96 Blocks
= 384 towers

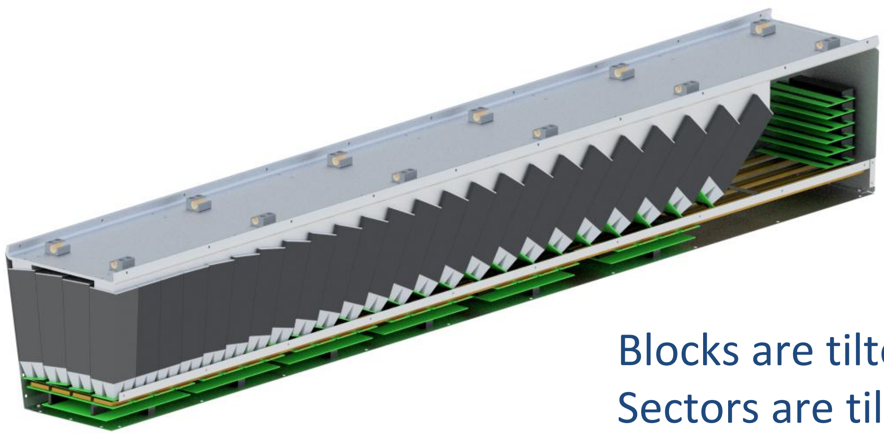
EMCAL Sector



Tilted Block Configuration

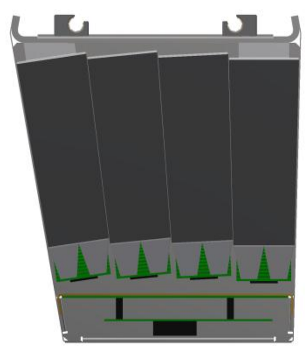
- Sectors consist of 96 blocks each of which consist of 2x2 projective towers
- The blocks are tilted in both η and ϕ in order to avoid channeling of particles along projective lines

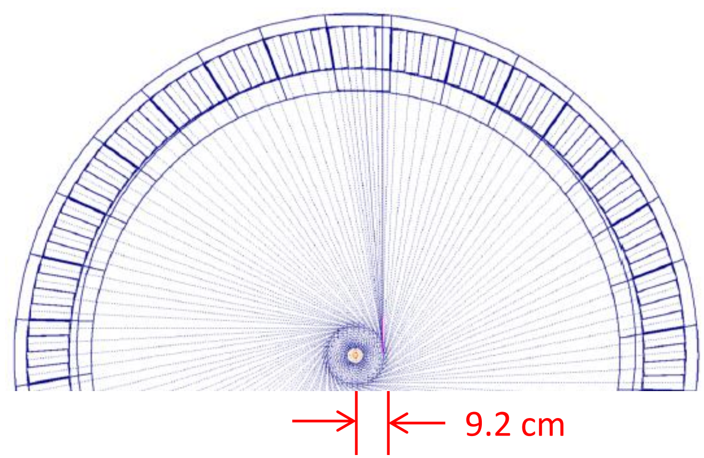




ϕ tilt = 87.6 mrad
η tilt = 160.0 mrad

Blocks are tilted in η
Sectors are tilted in ϕ



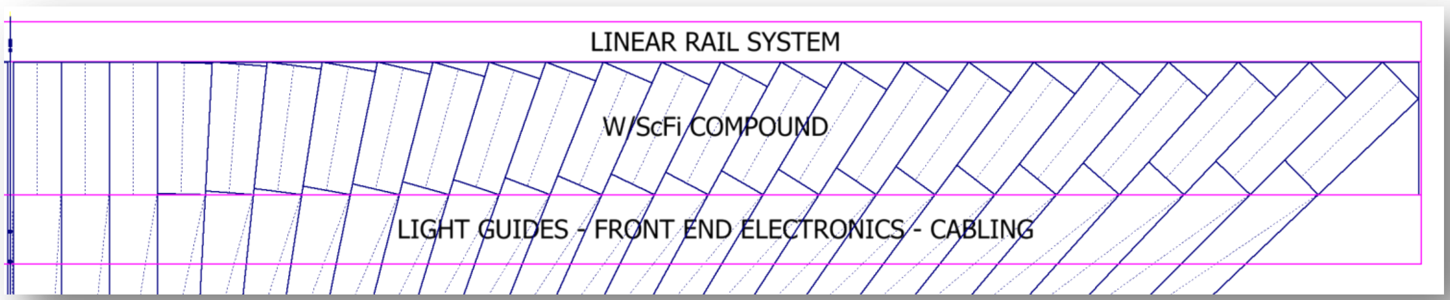


Sector Design

First three ϕ slices are 1D projective

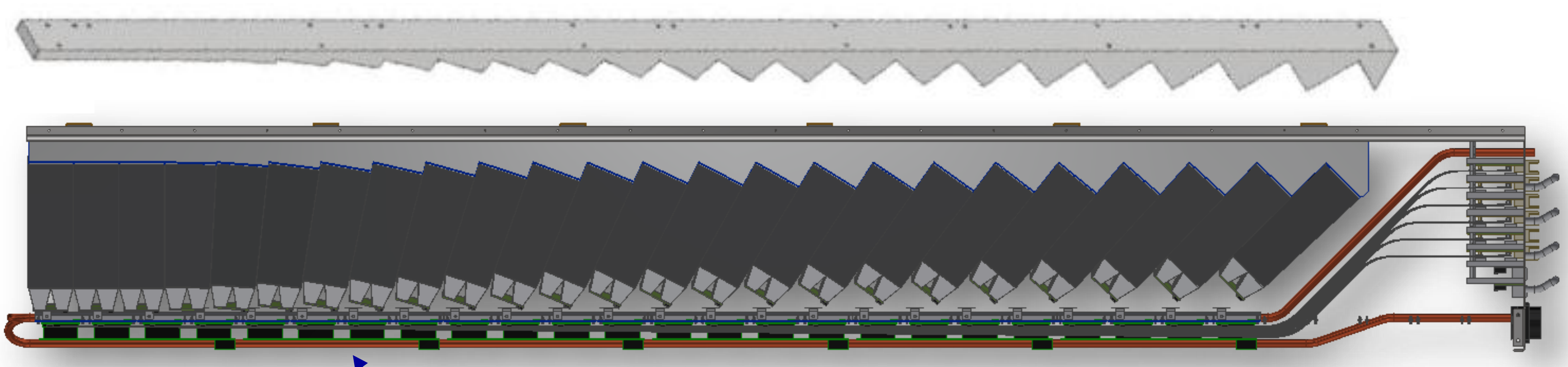
Remaining ϕ slices are 2D projective

$\eta = 0$



$\eta = 1.1$

Sawtooth support structure for blocks

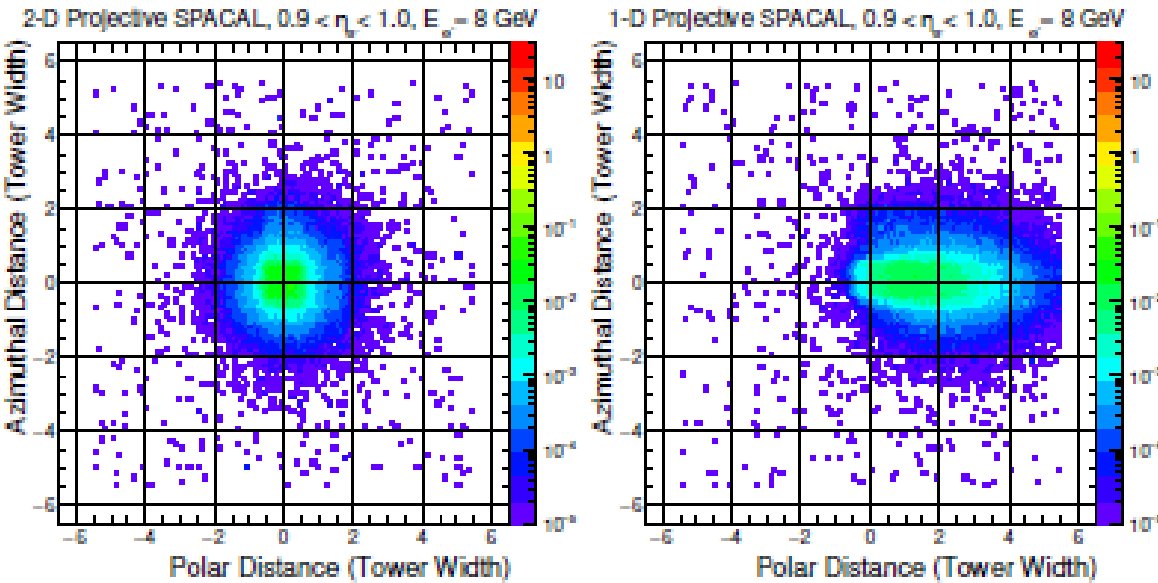


Electronics, cables and cooling

1D Projective vs 2D Projective

Projectivity in 2 dimensions is required to minimize the transverse size of the showers at large rapidity

2D Projective 1D Projective



Transverse shower profile for 8 GeV electrons at large rapidity

Energy from the underlying event is a large background in central heavy ion collisions and having a small transverse shower size helps to reduce this

Improves energy resolution and e/h separation

EMCAL Absorber Blocks

Design driver: Must be compact to fit inside Babar magnet & minimize cost of HCAL ⇒ **W/SciFi SPACAL**

Absorber

- Matrix of tungsten powder and epoxy with embedded scintillating fibers
- Density ~ 9-10 g/cm^3
- X_0 ~ 7 mm (18 X_0 total), R_M ~ 2.3 cm

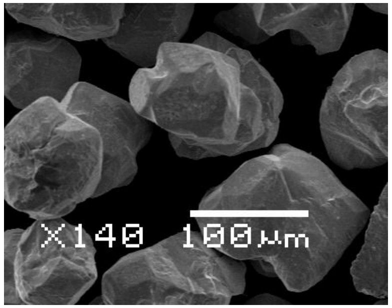
Scintillating fibers

- Diameter: 0.47 mm, Spacing: 1 mm
- Sampling Fraction ~ 2 %

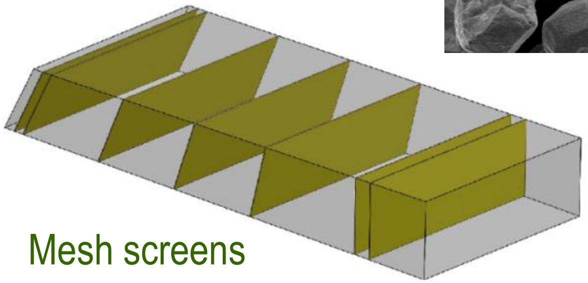
- Modules are formed by pouring tungsten powder into a mold containing an array of scintillating fibers and infusing with epoxy
- Fibers are held in position with metal meshes spaced along the module

Design originally developed by O.Tsai at UCLA

100 Mesh tungsten powder

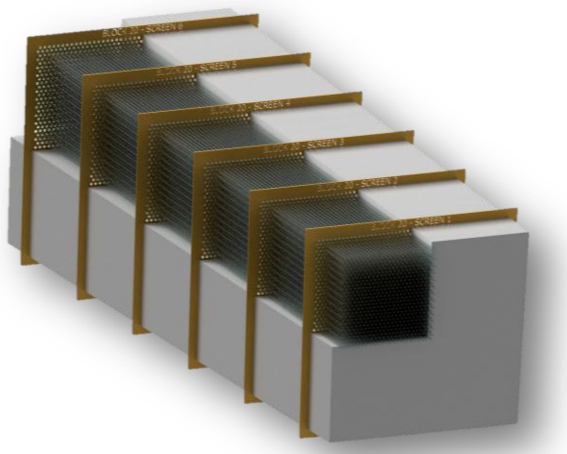


1D Projective

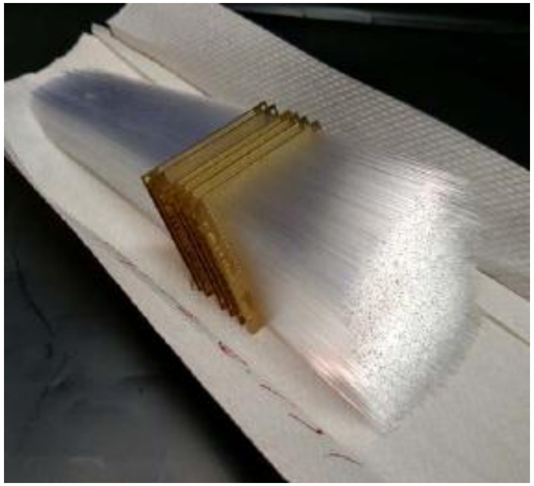


Mesh screens

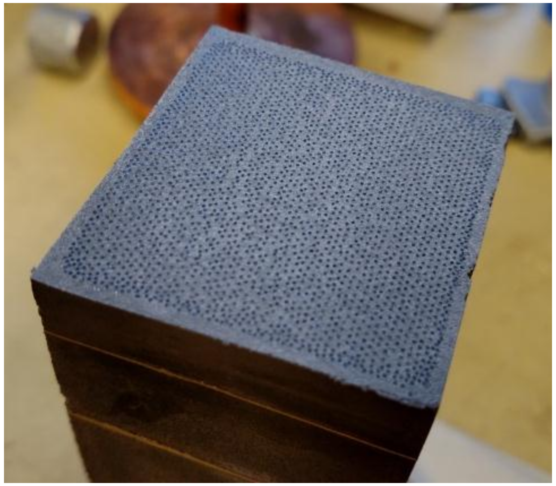
2D Projective Absorber Blocks



2D Projective Block

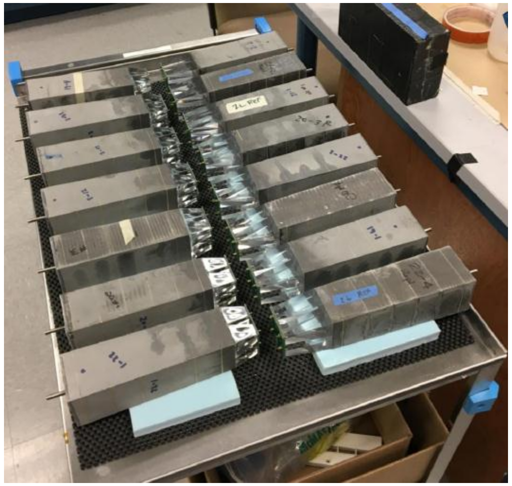


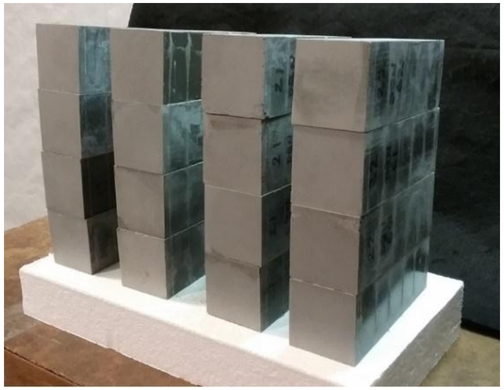
Fiber Assembly



Fibers are tapered inward at readout end to improve light collection

Block fabrication area at UIUC

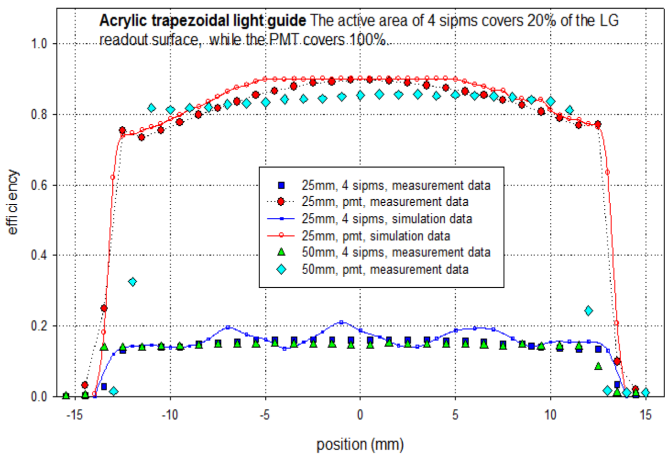


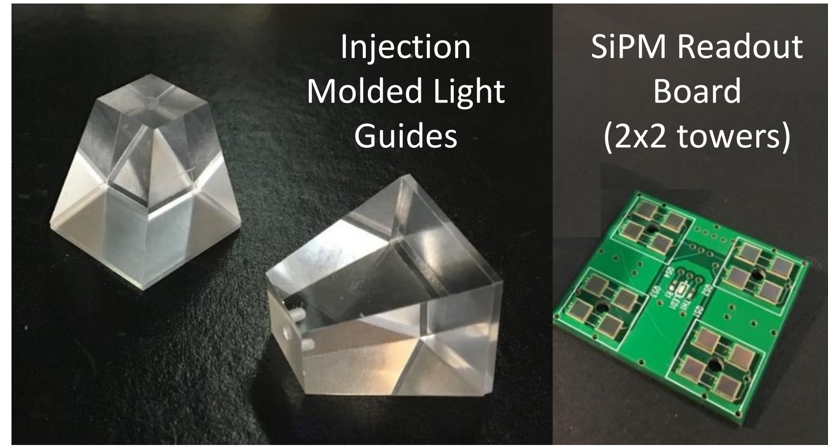


2D projective blocks for the large η prototypes

Light Collection and Readout

Blocks are read out in individual towers using optical light guides and SiPMs





Four SiPMs are passively summed for each tower

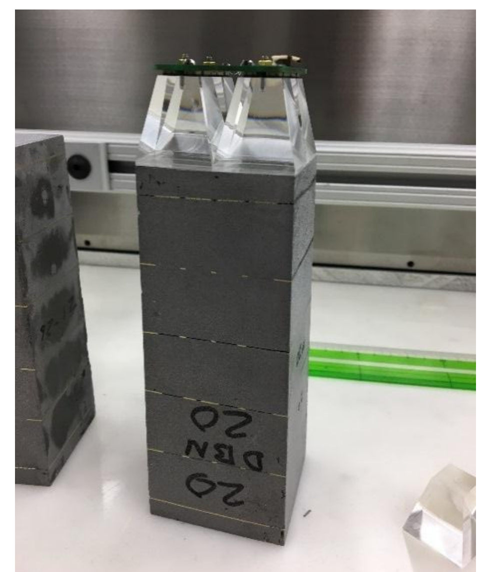
Light guide focuses light onto four 3x3 mm^2 SiPMs

Important factors affecting the energy resolution are light collection efficiency and uniformity

- Area matching between tower readout area and 4 SiPMs is only 6.4%
- Short light guide is a poor mixer
- Photostatistics gives ~ 500 p.e./GeV

⇒ ~ 4.5%/√E contribution to energy resolution

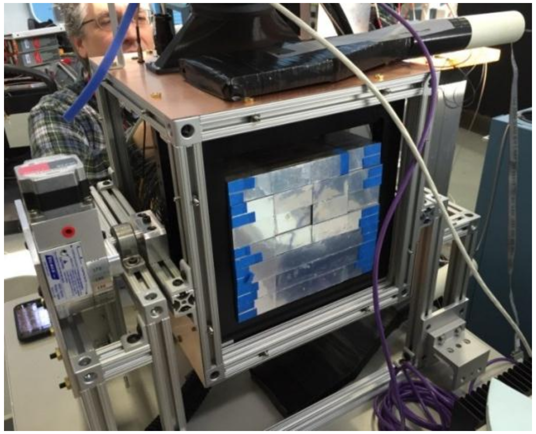
⇒ 0.5 pixels/MeV (each SiPM has 40K pixels)



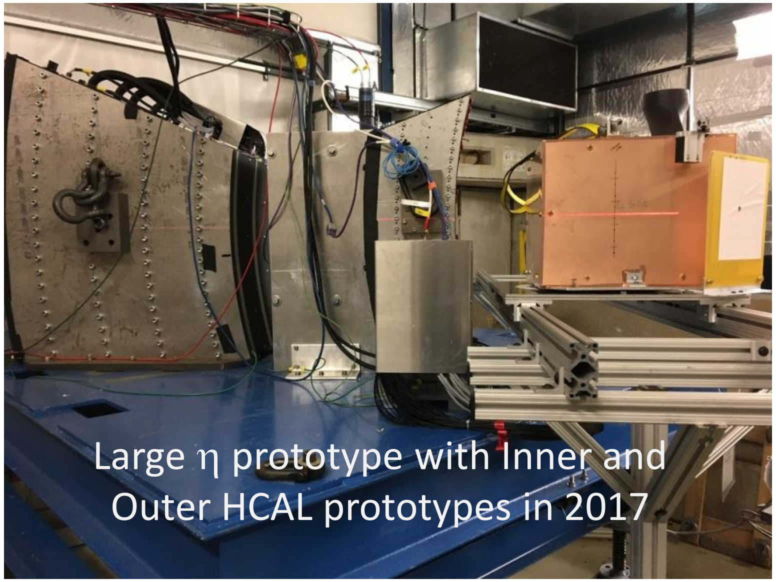
Prototyping and Testing

The design has undergone 3 stages of prototyping and testing in the test beam at Fermilab

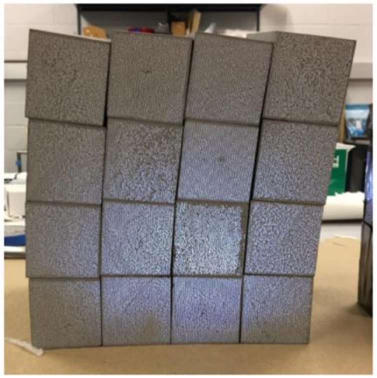
2016 - 1D Projective (η~0)



2017 & 2018 - 2D Projective (η~0.9)

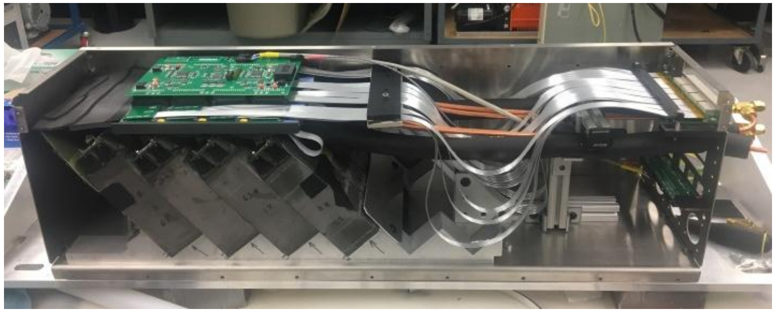


Large η prototype with Inner and Outer HCAL prototypes in 2017



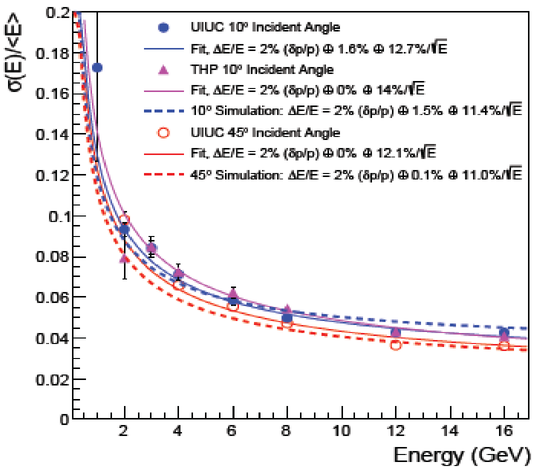
4x4 array of 2x2 tower blocks (64 towers)

2018 Prototype (V2.1) was constructed as part of an actual sector in terms of mechanics, electronics and cooling

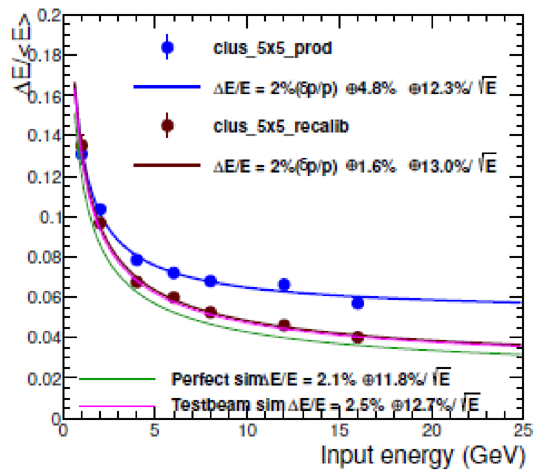


Test Beam Results

2016 Beam Centered on a single tower 2017

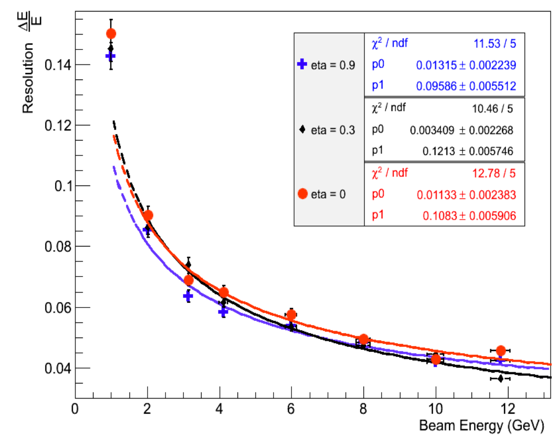


1D Projective (η = 0)



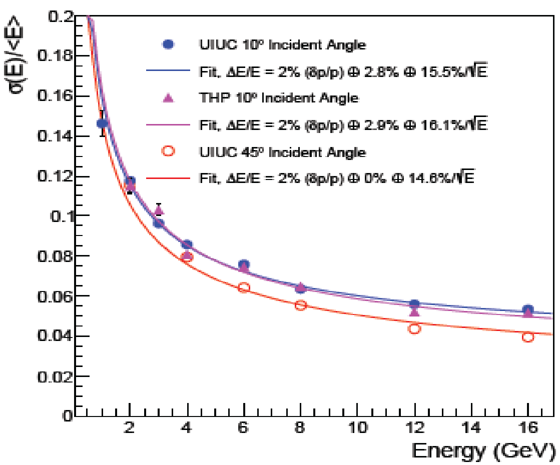
2D Projective (η ~ 0.9)

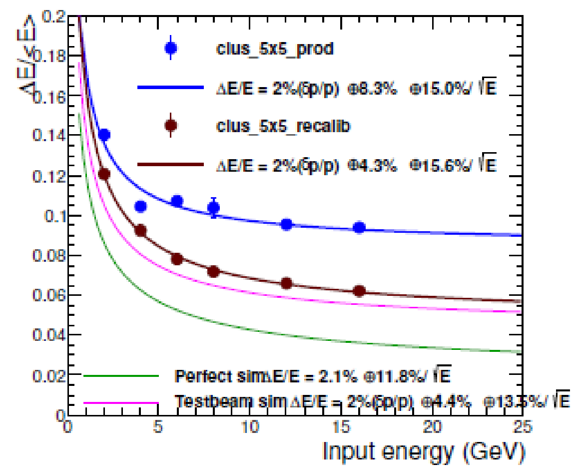
2014 - UCLA



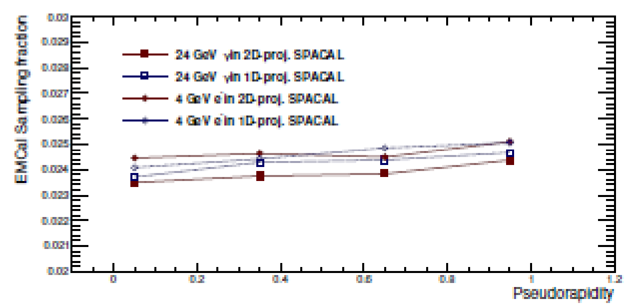
1D Projective (η = 0, 0.3, 0.9)

O.Tsai (2014)





Sampling fraction changes with rapidty



Beam spread over more than one block

Current Status

- The engineering design for the EMCAL is in a very mature state. Full 3D models exist for all major components.
- We have gone through numerous design reviews and prototype testing and are very close to a final design.
- We are now preparing for the CD-1/OPA review that will take place on May 23-25, 2018 at BNL.
- Approval of CD-1 will allow us to begin procurement of long lead time items such as tungsten powder, fibers and SiPMs.

Sector 0 Pre-Production Prototype

- Our next prototyping phase will be the construction of a pre-production prototype of a complete sector (Sector 0). This sector is not intended to be used in the final detector, but will allow us to complete the overall sector design.
- All materials (powder, fibers, screens, etc) for Sector 0 are in hand at UIUC.
- Final block design for Sector 0 has been approved.
- We expect production of the 96 blocks for Sector 0 to begin soon at UIUC.

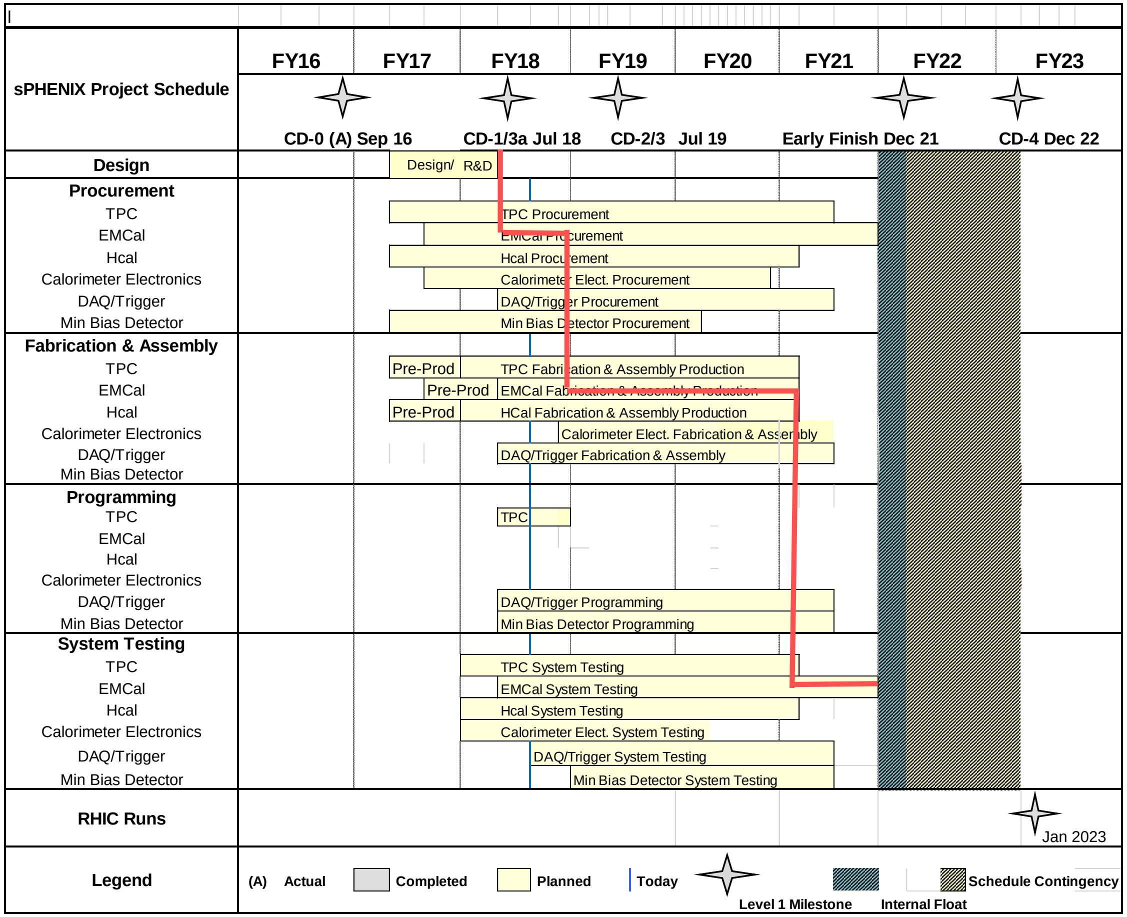
Additional Pre-Production Sectors

- After the completion of Sector 0, any subsequent design changes will be implemented for the final blocks and sectors.
- We then plan to build 12 complete additional preproduction sectors (Sectors 1-12). These will be built to cover the full rapidity range to η=1.1. It is envisioned that these sectors *would be* used in the final detector.
- Orders for the materials for these sectors are now starting to make their way through BNL Contracts & Procurements.

Final Production Schedule

Delivery date for all EMCAL sectors is September 2021

EMCAL is on the Critical Path



Descoping of the EMCAL

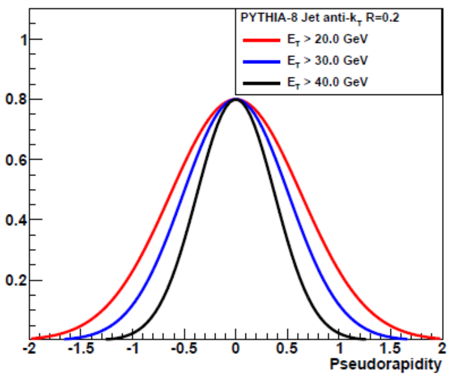
In order to stay within the \$32M spending cap, it was necessary to reduce the EMCAL acceptance from $|\eta|=1.1$ to $|\eta|\sim0.85$

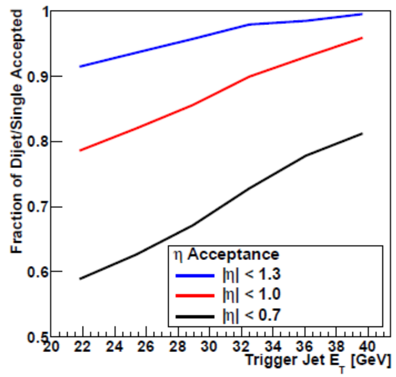
Impact on the EMCAL

- We need to save ~ \$1M from the total cost of the EMCAL (not including electronics)
- The main savings would come from purchasing less materials for fabricating the blocks (W powder, fibers) + labor. However, many of the fixed costs would remain the same.

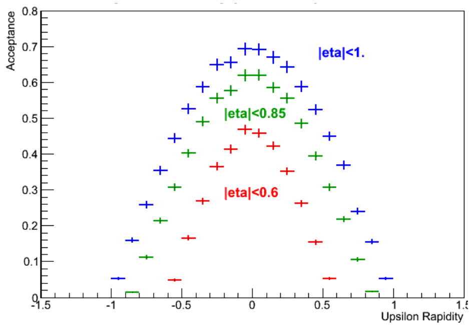
Note: A geometrical cut from $|\eta|=1.1$ to $|\eta|=0.85$ implies a fiducial cut from $|\eta|\sim 1.0$ to $|\eta|\sim 0.75$ for jet physics

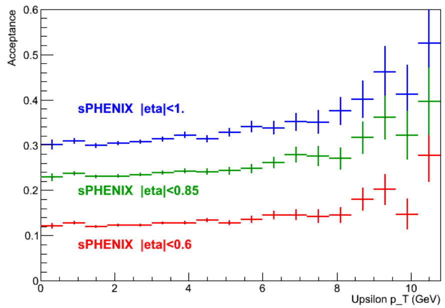
Jet acceptance - ~ 25% loss in statistics





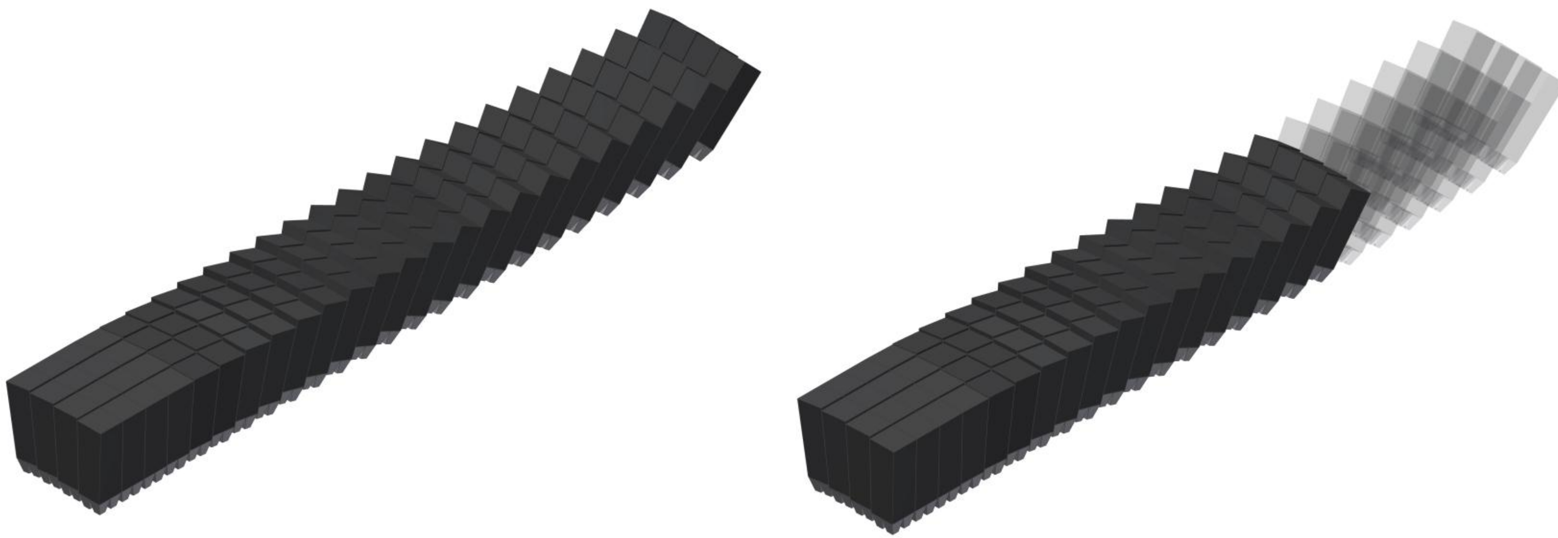
$\Upsilon \rightarrow e^+e^-$ acceptance - ~ 35 % loss in statistics





Descoped Sectors

Descoping plan eliminates blocks 19-24 at large rapidity



- Once final production begins, it would be essentially impossible to add the missing blocks after assembly of the sectors
- Possible *re-scoping* could be to start building complete coverage sectors using UIUC blocks and use Chinese blocks to build the last remaining sectors

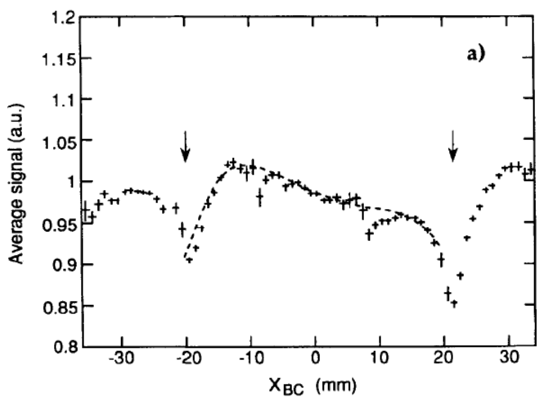
Summary

- We have been working on the EMCAL design for over four years and have brought it to a very advanced stage.
- Several prototypes have been built and tested and have been shown to meet the design requirements for sPHENIX.
- We believe the technical design for the baseline detector is technically sound and will meet the physics objectives for the sPHENIX physics case.
- Descoping the EMCAL as proposed would have a significant effect on the physics performance of sPHENIX and we would like to work with you to find ways to restore it.

Uniformity of Response

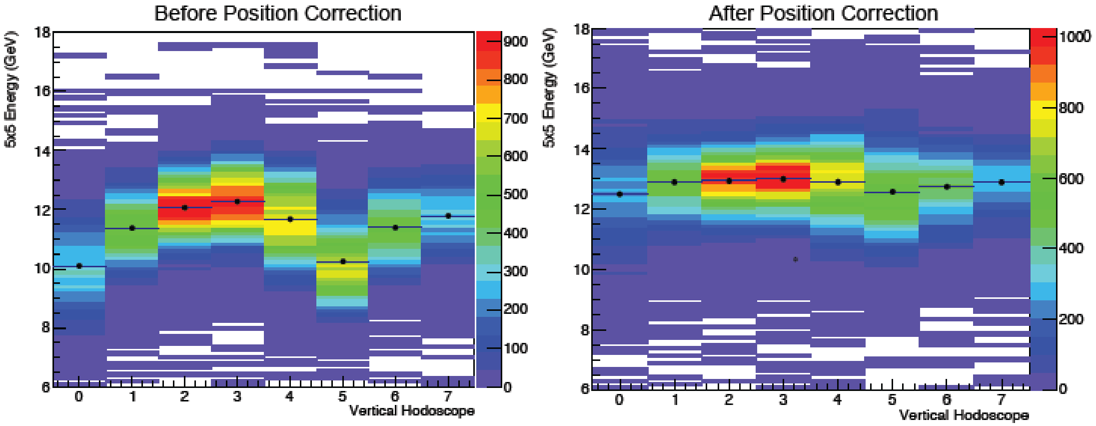
Non-Uniformities at block boundaries are an inherent property of SPACALs

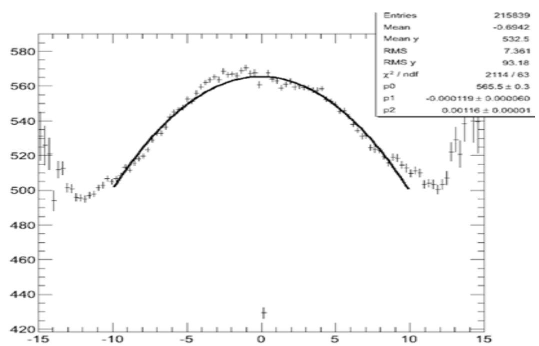
- Fibers essentially channel light to the photodetector.
- Rely on light guide to mix and randomize the light
- Difficult to do when there is limited space and limited photocathode coverage



Original SPACAL (Wigmans 1995)

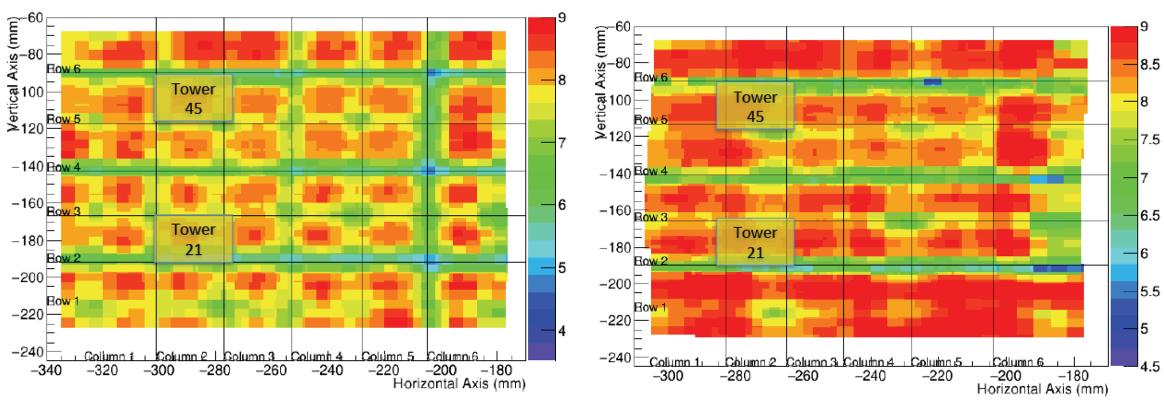
sPHENIX 1D Projective





2014 Test Beam Data (UCLA)

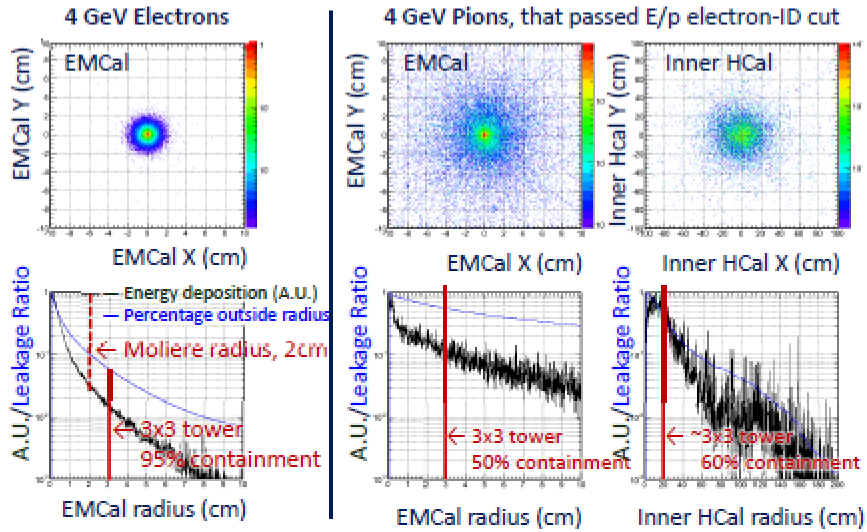
sPHENIX 2D Projective



Electron Hadron Separation

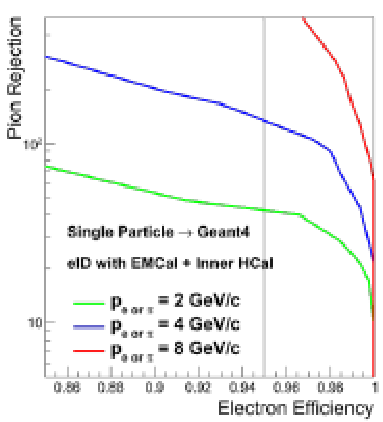
sPHENIX

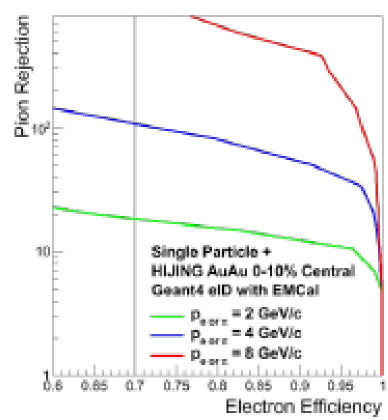
Transverse energy distribution of 4 GeV electrons and pions



Pion rejection vs electron id probability

p+p





Central Au+Au Hijing