Test Beam Performance of the sPHENIX EMCal Prototype

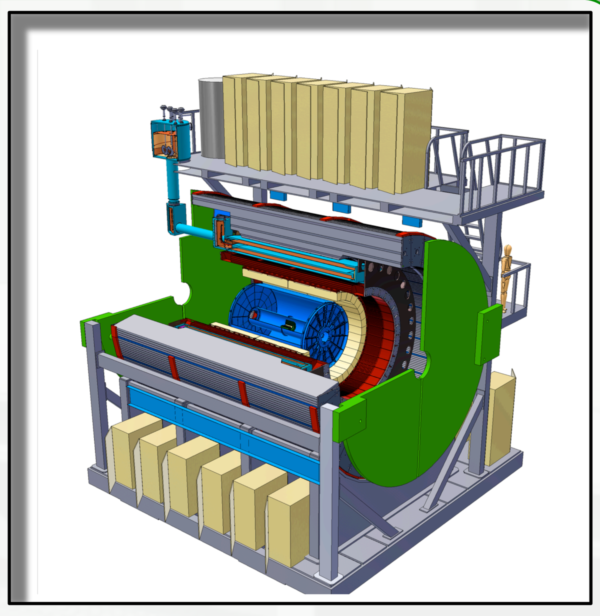
Virginia Bailey, University of Illinois Urbana-Champaign,
for the sPHENIX Collaboration

Abstract

The sPHENIX detector is a proposed new detector at the Relativistic Heavy Ion Collider (RHIC). The sPHENIX detector will measure properties of quark gluon plasma (QGP) through the study of jets and hard probes. The electromagnetic calorimeter (EMCal) consists of tungsten powder and epoxy blocks with embedded scintillating fibers. The approximately 7 mm radiation length allows a compact calorimeter with fine segmentation. A prototype EMCal consisting of an 8 by 8 array of towers was tested at the Fermilab Test Beam Facility in April 2016. This poster will present the design and performance of the prototype EMCal and future plans.

sPHENIX

The sPHENIX detector is designed to study the properties of QGP in gold ion collisions at RHIC. The full detector will have 2π acceptance in azimuth and |η|<1 coverage in pseudorapidity. The EMCal and inner HCal sit inside the solenoid magnet, and the outer HCal sits outside the magnet. The EMCal is designed to be compact to fit inside the magnet, and must also have a resolution better than the underlying event fluctuations. This corresponds to a resolution no greater than 15.5%/√E.

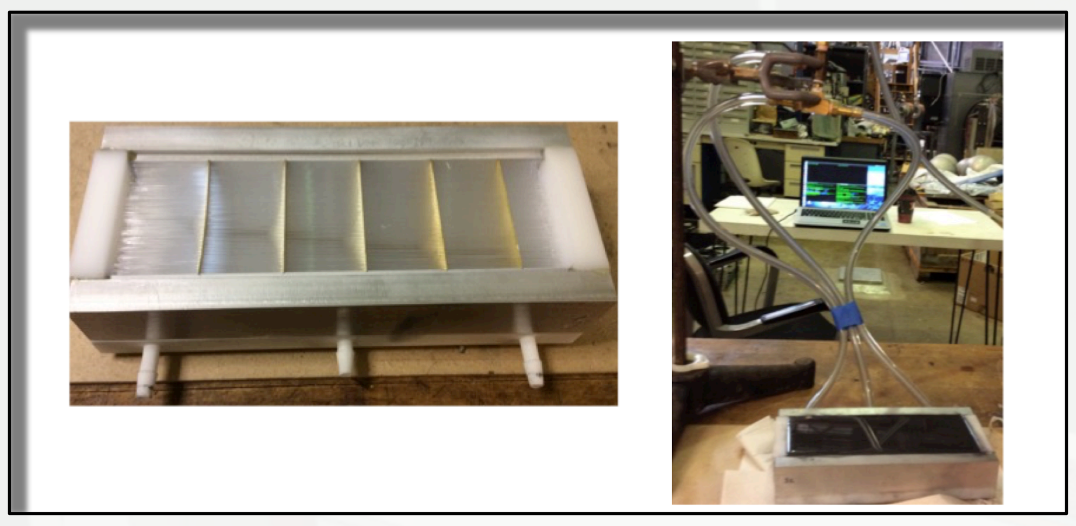


Construction

Modules

The prototype EMCal is made of 32 tungsten and epoxy blocks embedded with scintillating fibers. Each block is tapered in one dimension and consists of two towers. Brass meshes align the fibers in a mold that is then filled with the tungsten and epoxy to create the blocks. Finally the ends of the blocks are machined with a diamond tip to avoid damage to the fibers.

Modules were built at both University of Illinois (UIUC) and Tungsten Heavy Powder Inc. (THP).

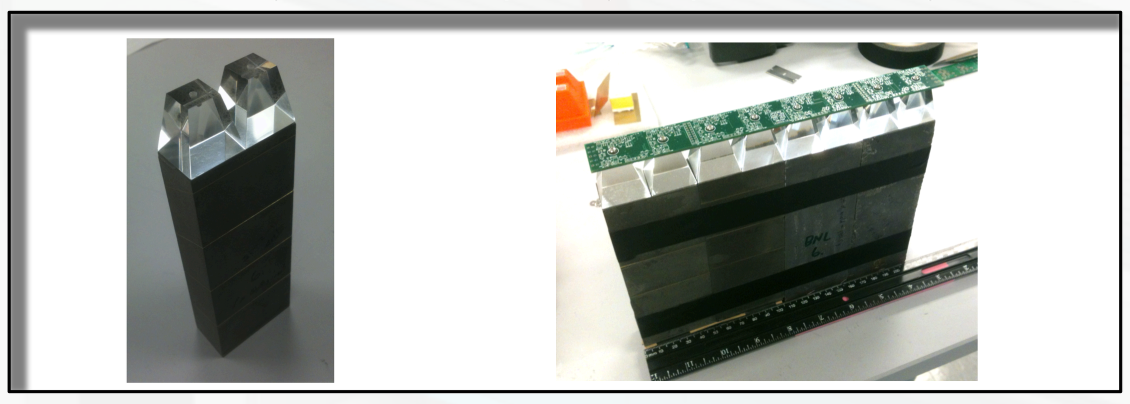


Left: First the fibers are placed in brass meshes which are then placed in the bathtub-style mold.

Right: The mold is filled with tungsten powder and epoxy and light vacuum is applied to evenly fill the mold with epoxy.

Light Guides

Light is collected from the modules using trapezoidal acrylic light guides optically coupled to the modules. Two guides are attached to each module, separating it into two towers. The light guides are then readout by four SiPMs optically coupled to the acrylic.



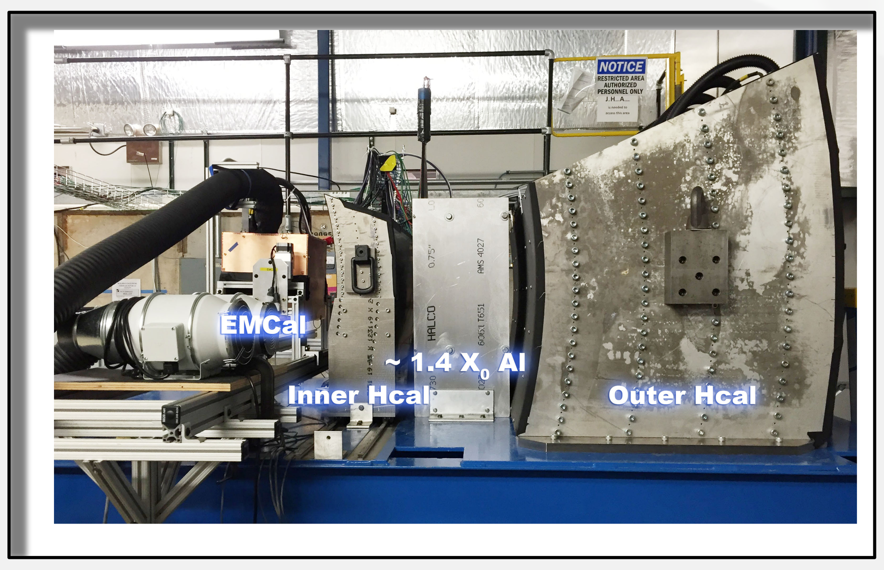
Left: An EMCal module consisting of two towers with attached acrylic light guides.

Right: A row of eight modules with attached light guides and preamp board containing SiPMs.

Test Beam

The prototype EMCal and HCal were tested at the Fermilab Test Beam Facility in the spring of 2016 as experiment T-1044. The test beam included a primary beam of 120 GeV protons and a secondary beam comprised mostly of electrons, pions, and muons with energies ranging from 1 to 32 GeV with a beam momentum spread of approximately 2%. Data was taken both with the combined calorimeter system as well as with the EMCal and Hcal separately.

A hodoscope, veto counters, and Cherenkov detectors were placed upstream of the calorimeters. The hodoscope was comprised of 8 horizontal and 8 vertical 5mm fingers. Four veto counters were placed around the beam and Cherenkov counters were tuned to distinguish electrons from hadrons.



Test beam setup for T-1044 with both calorimeter systems. The EMCal prototype is placed in front of the HCal system comprised of an inner and outer HCal separated by a mock cryostat.

Analysis and Results

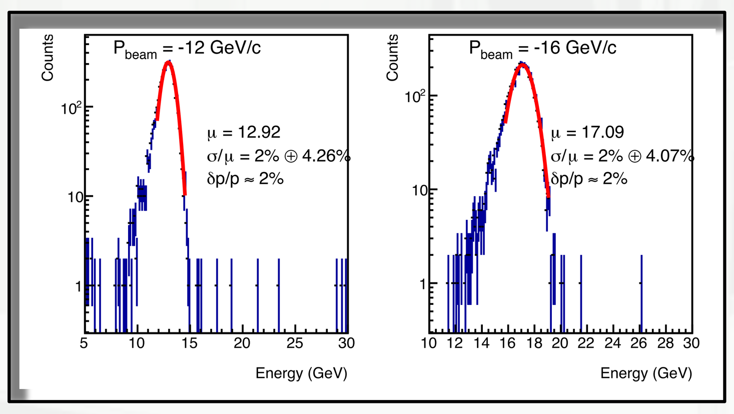
Resolution and Linearity

Resolution and linearity for the EMCal are determined for both the center of the tower and across the entire hodoscope. Both sets of data use cuts on the Cherenkov detector to ensure only electron events are included. Resolution and linearity are computed for modules made at UIUC and THP and for different orientations of the prototype (tilted 10° and 45°).

Resolution is found using the mean and spread of the energy distributions of electron showers for each beam energy. The ratio of ΔE/E is plotted against beam energy and fit to the function:

$$\Delta E / E = \sqrt{a^2 + b^2 / E}$$

with the 2% beam momentum spread unfolded.

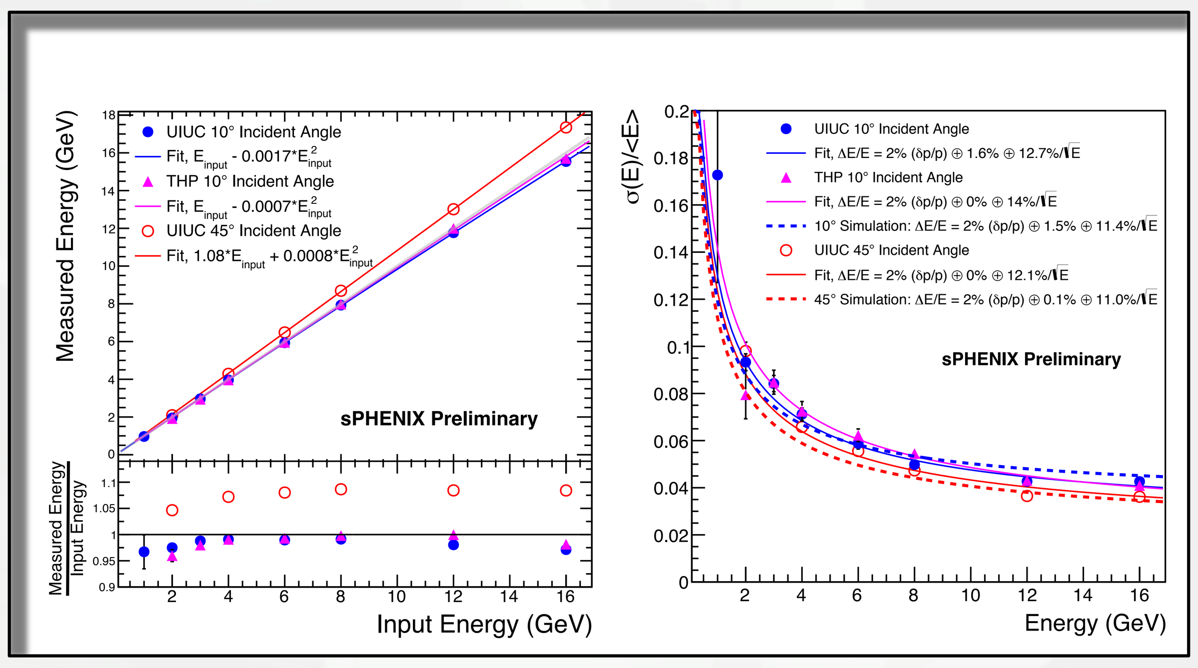


Energy distributions for electron showers in the EMCal. Data is shown for a tower produced at UIUC with an incident beam at 10°.

Center of Tower

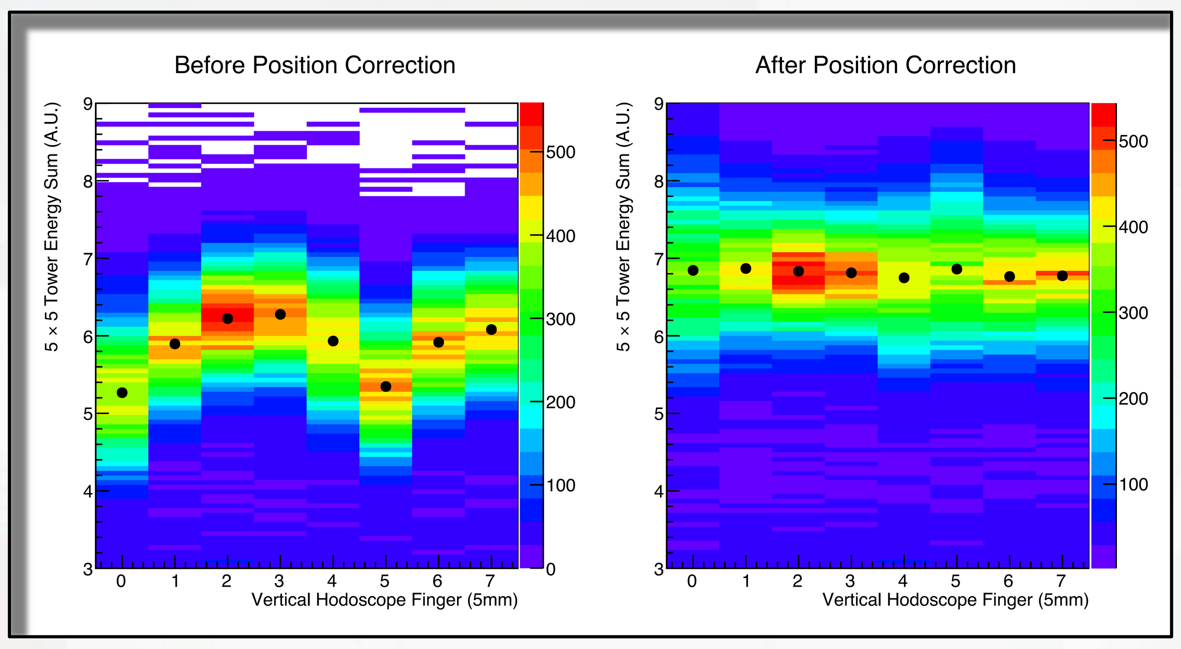
The center of the tower data gives the resolution of the tungsten and scintillating fiber blocks without the nonuniformity of the light guides. By cutting on the hodoscope, the data is restricted to an area of 10 x 5 mm at the center of a single tower.

Linearity and resolution for the center of an EMCal tower. Data is shown for blocks created at UIUC and THP oriented at 10° and 45°. Simulation data for the two orientations is also shown.



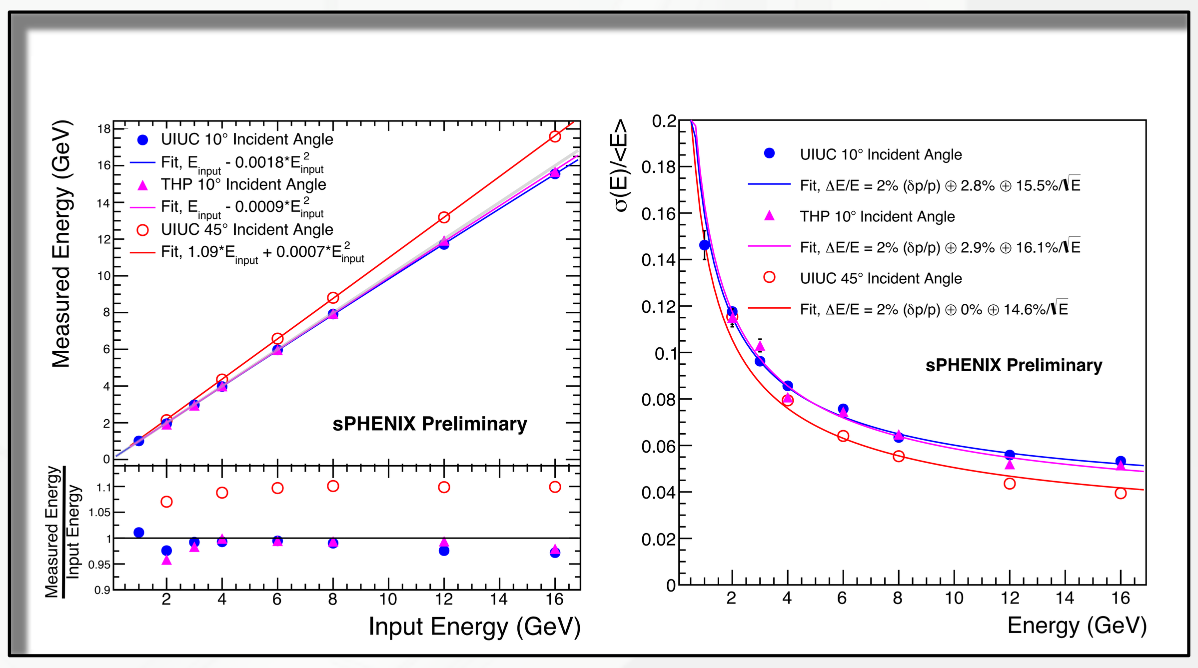
Position Correction

To correct for nonuniformities in the light collection, a position based energy correction is applied to the data across an entire tower. This corrected data is then used to find the resolution and linearity across a single tower, using a 25 x 25 mm hodoscope cut around the center of the tower.



Energy distribution before and after the position based correction has been applied.

Linearity and resolution of an EMCal tower after the position based correction has been applied. Data is shown for blocks created at UIUC and THP oriented at 10° and 45°



Conclusions and Future Work

The prototype sPHENIX EMCal was found to have a resolution of 1.6% ⊕ 12.7%/√E at the center of a tower and a resolution of 2.8% ⊕ 15.5%/√E across a tower. These satisfy the requirements of the sPHENIX physics program.

A new prototype calorimeter will be tested at the Fermilab Test Beam Facility in January and February 2017. The new EMCal prototype modules are projective in two dimensions with each module consisting of four towers. These 2D projective modules are consistent with the design for the final sPHENIX EMCal. The light guides have also been modified for this new beam test, as they were a major source of nonuniformity in the initial test.

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