The Forward Calorimeter at STAR

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Abstract

A forward calorimeter utilizing hadronic and electromagnetic calorimetry at the STAR experiment of RHIC will achieve a variety of physics goals. These goals include studying long-range rapidity and event plane correlations in heavy ion interactions as well as the gluon contribution to the proton spin problem achieved by studying forward di-jets and forward-mid rapidity jet correlations. Upgrades to the AGS E864 lead-scintillating fiber calorimeter have increased spatial resolution by utilizing cell pixelization. Pixelization increases spatial resolution by replacing a single photosensor on individual 10cm x 10cm cells by a set of nine photosensors, resulting in 3.3cm x 3.3cm pixels. Pixelizaion was tested with colliding beams at STAR and fixed target test beams at FNAL. Light collection has been optimized and fringe field effects have been minimized by the introduction of Fresnel lenses and mu-metal shielding. These upgrades increase light collection efficiency and reduce fringe field effects to near-negligible levels. A prototype consisting of a 2x3 cell stack was installed into the east end of STAR for the end of run16. This prototype investigated the introduction of these new techniques as well as a trial of Silicon Photomultipliers (SiPMs) as an alternate to traditional Photomultiplier Tubes (PMTs). SiPMs do not suffer from fringe field effects but direct observation of radiation effects was required. The prototype observed Au+Au collisions at 200GeV. There is a proposal to install two 9-column x 12-row cell stacks as forward jet detectors at STAR, with 16 cells in each stack pixelized. This poster discusses the effects of Fresnel lenses on light collection, mu-metal shielding effects on PMTs, and radiation effects on SiPMs.

The Forward Calorimeter

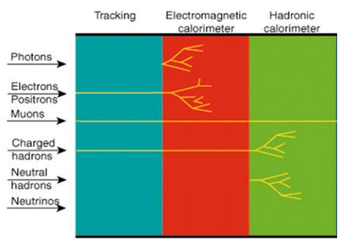
Physics Motivation

Event plane detector for all energies

- Strong flow at large η ➔ Better event plane resolution
- Large η gap ➔ Smaller non flow contribution to flow analyses

Long range near side rapidity correlation

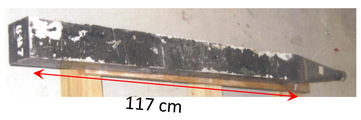
Forward jets in asymmetric HI collisions

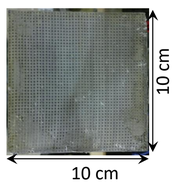


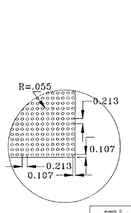
What we started with

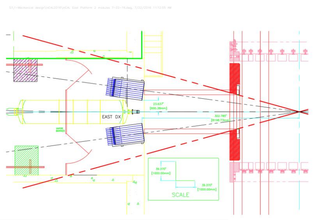
AGS-E864 Collaboration calorimeter previously at AnDy

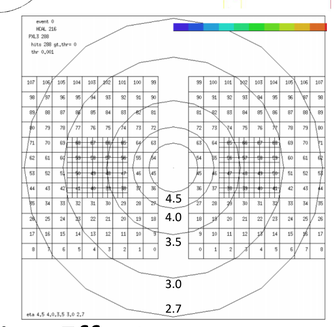
- Two 9x12 stacks
  - 10 cm x 10 cm x 117 cm per cell
  - Acrylic light guides and Photomultiplier tubes
- Lead blocks with Spaghetti-type scintillators
- 47 x 47 array of fibers per cell
- 7 Nuclear interaction lengths
- Hadronic resolution of 34%/ √E
- 2.7 η to 4.5 η coverage









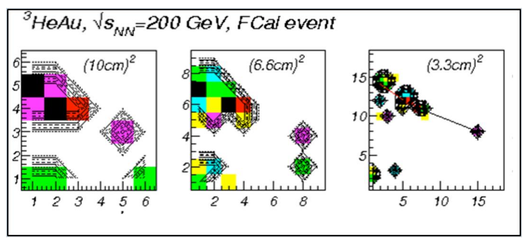


Improvements

Central pixelization of 4x4 set of cells

- 3.3 cm x 3.3 cm per pixel
- Fresnel Lenses and Photomultiplier tubes

Utilization of Mu-Metal to reduce magnetic field effects



Pixelization Effects

Increased spatial resolution

- Allows resolution of distinct jet events

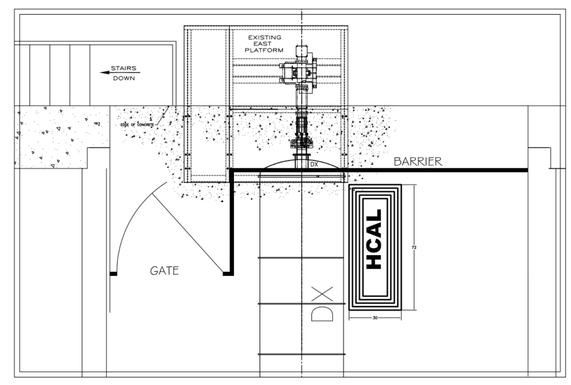
One Di-jet pair resolves to two separate di-jet pairs

Run 16 Prototype

Prototype Location

North side of the east tunnel

- Less iron ➔ Lower field effects



Prototype Purpose

Reaffirming Run 14 Findings

- Retain high stability

Hardware Tests

- Mu-metal Shielding
- Fresnel Light Guides
- Silicon Photomultipliers (SiPMs)

Neutral Pion Finding

- Calibration

Testing Specifications

54 pixels at 3.3 cm x 3.3 cm

- 9 Fresnel lenses with SiPMs
- 18 Fresnel lenses with PMTs
- 27 Acrylic Light Guide with PMTs

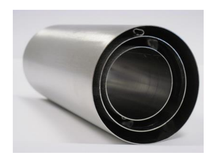
Mu-metal Shielding

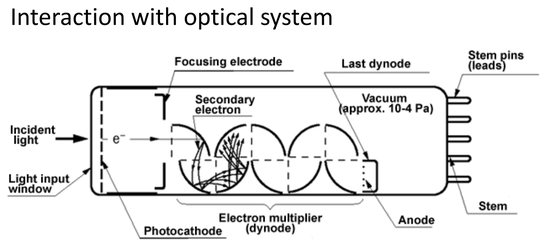
Magnetic field effects on photomultiplier tubes (PMTs)

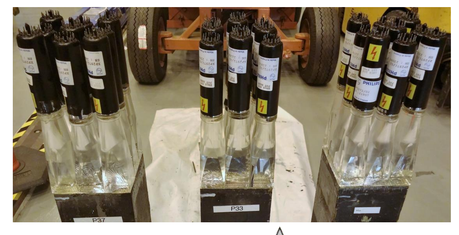
- Magnetic field alters cascade in PMTs

Magnetic field shielding

- Known passive shielding
- Amount required
- Interaction with optical system







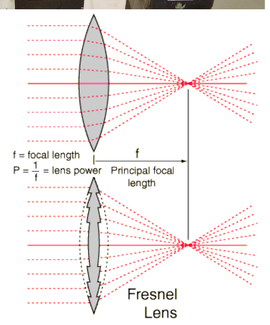
Fresnel Lens Light Guides

Replaceable parts

- Commercial item
- Can be machined to fit
- Can be installed after stacking

Alternative to acrylic light guide

- Comparison of light collection levels



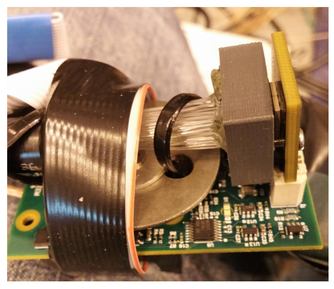
Silicon Photomultipliers

Compared to photomultiplier tubes

- No magnetic field effects
- Lower cost
- Smaller

Stability over time

- Investigation of radiation resistance

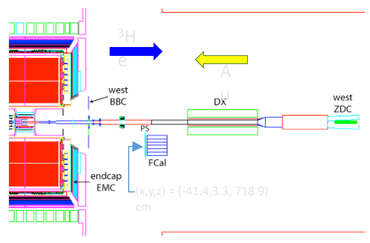


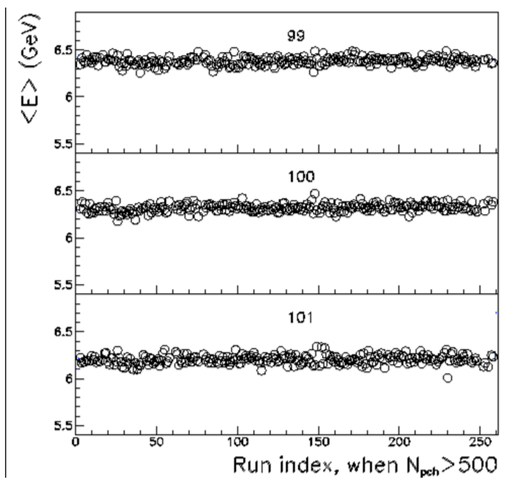
Run 14 Testing

Test Purpose

Analysis of implementation in the STAR environment

- 6 x 6 cell array in north side of the west tunnel
  - 18 x 18 pixel count
- √s_{NN} = 200 GeV Au+Au collisions for commissioning
- √s_{NN} = 200 GeV ^{3}He+Au collisions for calibration and analysis
- Best transverse resolution in forward direction
  - Granularity
  - Hadronic response
- Large rapidity window





Test Results

Average energy deposition per run shows stable response throughout the operation

Average energy deposition per run, for entire 200 GeV 3He+Au operation as a function of run number, for three selected pixels which are close to beam pipe.

Results

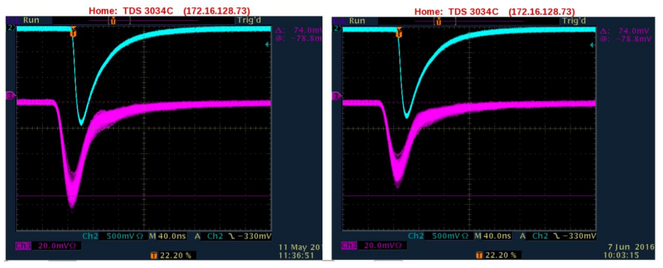
Mu-Metal Shielding

- Acrylic light guides limit length
- Fits into Fresnel lens system
- 8 degree tilt reduces field effects
- Optimal minimal recess of 5.8 cm
- Reduces magnetic field effects to <5%

Silicon Photomultipliers

- Large gain change due to radiation damage
- Not suitable for this application due to proximity to beam pipe – 1.5 m

28 Days Blue: PMT Magenta: SiPM

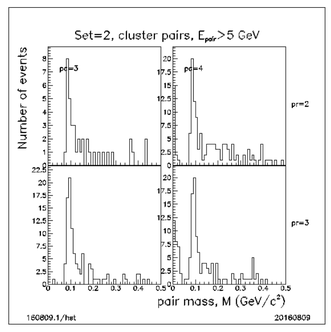


Fresnel Lens Light Guides

- Greater light levels than acrylic light guides
- More secure mounting of photomultiplier tubes
- Allows for proper recession distance

Neutral pion finding

- STAR Trigger used
- Min bias Au+Au collisions used
- 12% of available data used
- 4 pixels of Run16 data shown



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