Electromagnetic Calorimetry and Calorimeter Electronics

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EMCal Performance Specs

- energy resolution:
- \(<15\% / \sqrt{E}\), driven by \(\gamma\) and \(e^\pm\) measurement
- segmentation to allow \(\gamma\) and \(e^\pm\) reconstruction in central AuAu collision
- acceptance over \(2\pi\) and \(\pm 1.1\) in \(\eta\)
- together with HCal provide good jet reconstruction in central AuAu collisions
- high density to minimize radial space inside solenoid (allow room for inner HCal & tracking)
- \(>90\times \pi\) rejection @ 70% electron eff. (=50% \(\Upsilon\) eff.)
W-Fiber EMCal

- tungsten powder-epoxy embedded into matrix of scintillating fibers
  - fibers
    - diameter: 0.47mm
    - spacing: ~1mm
  - density ~10g/cm³ → $X_0 = 7\text{mm}$, $R_M = 2.3\text{cm}$
  - can point the fibers back to collision point in 1 (or 2) dimensions to generate 1D (2D) projectivity
  - tower size: ~1"x1", 0.025x0.025 in $\Delta\eta\times\Delta\phi$
light collection & electronics

- light collection via acrylic light guides
- SiPM readout
  - 4 tiled per tower
  - ~25k towers → ~100k SiPMs
  - Hamamatsu S12572-33-015P; 15μm pixels
    - 3x3mm², 40k pixels, ~$10^4$ dynamic range (5MeV - 50 GeV)
- read out from the inner radius of the calorimeter
- preamps with temperature compensation to provide gain stabilization of SiPM gain variation with T
- digitizer design based on those already used in PHENIX
  - 14 bit ADC, 65 MHz digitization
EMCal geometry

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inner radius (envelope)</td>
<td>mm</td>
<td>900</td>
</tr>
<tr>
<td>Outer radius (envelope)</td>
<td>mm</td>
<td>1161</td>
</tr>
<tr>
<td>Length (envelope)</td>
<td>mm</td>
<td>$2 \times 1495 = 2990$</td>
</tr>
<tr>
<td>Number of towers in azimuth ($\Delta \phi$)</td>
<td></td>
<td>256</td>
</tr>
<tr>
<td>Number of towers in pseudorapidity ($\Delta \eta$)</td>
<td></td>
<td>$2 \times 48 = 96$</td>
</tr>
<tr>
<td>Number of electronic channels (towers)</td>
<td></td>
<td>$256 \times 96 = 24576$</td>
</tr>
<tr>
<td>Number of SiPMs per tower</td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>Number of towers per module</td>
<td></td>
<td>$2 \times 8 = 16$</td>
</tr>
<tr>
<td>Number of modules per sector</td>
<td></td>
<td>24</td>
</tr>
<tr>
<td>Number of towers per sector</td>
<td></td>
<td>384</td>
</tr>
<tr>
<td>Number of sectors</td>
<td></td>
<td>$2 \times 32 = 64$</td>
</tr>
<tr>
<td>Sector weight (estimated)</td>
<td>kg</td>
<td>326</td>
</tr>
<tr>
<td>Total weight (estimated)</td>
<td>kg</td>
<td>20890</td>
</tr>
<tr>
<td>Average sampling fraction</td>
<td></td>
<td>2.3%</td>
</tr>
</tbody>
</table>
EMCal scope

- 4 SiPM/tower: ~100k SiPM
- 3 rounds of prototyping
- module production, QA, and assembly
  - 384 towers/sector
  - 64 sectors in full detector
  - 4 SiPM/tower
- calibration and integration into sPHENIX
design drivers—EMCal

- segmentation and energy resolution
- reconstruction of 5 GeV electrons in central HI environment
- $<15\%/\sqrt{E} \rightarrow$ EMCal will not limit photon resolution
- 2D projectivity
- driven by electron ID requirements in central HI environment for $\Upsilon$ reconstruction
- with only 1D projectivity electron-hadron separation degrades with increasing $|\eta|$ 
- reduce statistics of already statistics limited measurement
design drivers—electronics

- as common as possible for EMCal and HCal
  - same sensors for both systems
  - large gain
  - work in magnetic field
  - compact
    - SiPMs
- LED monitoring/calibration system
- provide L1 trigger information from EMCal & HCal
- utilize existing PHENIX DAQ, event rate ~15kHz
- digitizer design based on those already used in PHENIX
schedule drivers

• R&D on 2D projective design

  • 1D projective modules (2x1 towers) have been successfully produced at UCLA, Tungsten Heavy Powder (industry), Illinois and BNL
    • production process well under control

  • 2D projective production process being developed

    • 2D projective blocks (1x1 tower) have been produced at BNL and Illinois

    • goal: 2D projective modules for v2 prototype (10/16) with a production process that will scale to full detector

    • want to make blocks bigger than 1x1 tower
cost/schedule drivers

- assembly/testing of sectors
- large number of towers/SiPMs
- current schedule based on university based module production assembly and testing
- pursuing alternate industry based module production (THP), university based assembly and testing
- understand feasibility of both module production options
  - unclear how industry module production affects cost—this will be more clear after prototyping process
## EMCal schedule summary

<table>
<thead>
<tr>
<th>Stage</th>
<th>Timeline</th>
</tr>
</thead>
<tbody>
<tr>
<td>v1 prototype</td>
<td>ongoing-Jun '16</td>
</tr>
<tr>
<td>v2 prototype</td>
<td>Jun '16- Aug '17</td>
</tr>
<tr>
<td>preproduction</td>
<td>Aug '17 - Aug '18</td>
</tr>
<tr>
<td>conceptual design</td>
<td>Apr '16 - Dec '17</td>
</tr>
<tr>
<td>technical design</td>
<td>Dec '17 - Jul '18</td>
</tr>
<tr>
<td>initiate production</td>
<td>Jul '18</td>
</tr>
<tr>
<td>tower fabrication</td>
<td>Feb '19 - Oct '20</td>
</tr>
<tr>
<td>supermodule</td>
<td>May '19 - Mar '21</td>
</tr>
<tr>
<td>ready for detector</td>
<td>Mar '21</td>
</tr>
</tbody>
</table>
organization: EMCal & electronics

EMCal

L2
C. Woody

Design
C. Cullen

Prototyping
S. Stoll/O. Tsai

Production
A. Sickles

Calorimeter Electronics

L2
E. Mannel

On Det.
Electronics
S. Boose

Optical Sensor
S. Stoll

Digitizer
CY Chi
technical/project status

• 1D projective modules (2x1 towers) have been successfully produced at UCLA, Tungsten Heavy Powder (industry), Illinois and BNL
  • density: ~10g/cm³
• v1 prototyping:
  • produced both at Illinois Nuclear Physics Lab & THP
  • to be assembled, tested at BNL
• v2 prototyping:
  • ongoing work to develop 2D projective production
technical/project status

- sector structure designed
- issues of cabling, cooling and electronics in empty space to be done
- deflection analysis to be done
technical status—SiPMs

- SiPMs subject to damage from MeV neutrons
- neutron fluence ≈ $2 \times 10^{10}$ n/cm$^2$/run year
- measurements at STAR show increased leakage current but stable MIP peak
- expect leakage current in 3 yrs of sPHENIX will not significantly impact signals of interest
issues & concerns

- 1D vs 2D modules
  - need to develop 2D production process to mass produce modules
    - v2 prototype targeted to answer this question
    - work underway at BNL, Illinois
- where are the modules to produced?
  - industry or university
    - both options being pursued, cost/schedule of industry solution not known yet
  - v1 prototype: constructed partially at both Illinois Nuclear Physics Lab and THP
- development of monitoring/calibration scheme