The Calorimeter Consortium
&
RD1 Year 2 Renewal Proposal

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EIC Calorimeter R&D Consortium

Work towards an optimal design of calorimeters at EIC
Share our knowledge, expertise, resources and test beam runs

E. Kistenev, S. Stoll, A. Sukhanov and C. Woody
PHENIX Group
E. Aschenauer and S. Fazio
Spin and EIC Group
Physics Department, BNL

S. Heppelmann
Pennsylvania State University

C. Gagliardi
Texas A&M University

L. Dunkelberger, H.Z. Huang, G. Igo, K. Landry, S. Trentalange, O. Tsai and Q. Zhang
University of California at Los Angeles

H.F. Chen, C. Li, Z. Tang and Y. Zhang
University of Science and Technology of China

The Calorimeter Consortium

E. Aschenauer et al (BNL Spin/EIC group) – Physics simulations and work with the hardware groups to optimize detector solutions for physics/cost issues at EIC;

Y. Zhang et al (USTC group) – R&D for BSO and/or doped PWO crystal detector using SICCAS crystals;

C. Woody et al (BNL PHENIX group) – Development of accordion shaped tungsten plate and scintillating fiber sampling calorimeter;

RD1 Team-H.Z. Huang et al (UCLA/TAMU/PSU) – Developed tungsten powder and scintillating fiber SPACAL detector in year-1, propose to study compact read-out schemes and mechanical stabilities of the SPACAL module.

Contact persons: H.Z. Huang (huang@physics.ucla.edu); C. Woody (woody@bnl.gov).

We need more groups to help the calorimeter detector development; especially on electronics when we start to develop readout/trigger electronics related to EMC at EIC in the coming years.

Year-1 Results and Plan for Year-2

RD1 Team:

UCLA -- L. Dunkelberger, H.Z. Huang, G. Igo, K. Landry, S. Trentalange, O. Tasi and Q. Zhang

TAMU – C. Gagliardi

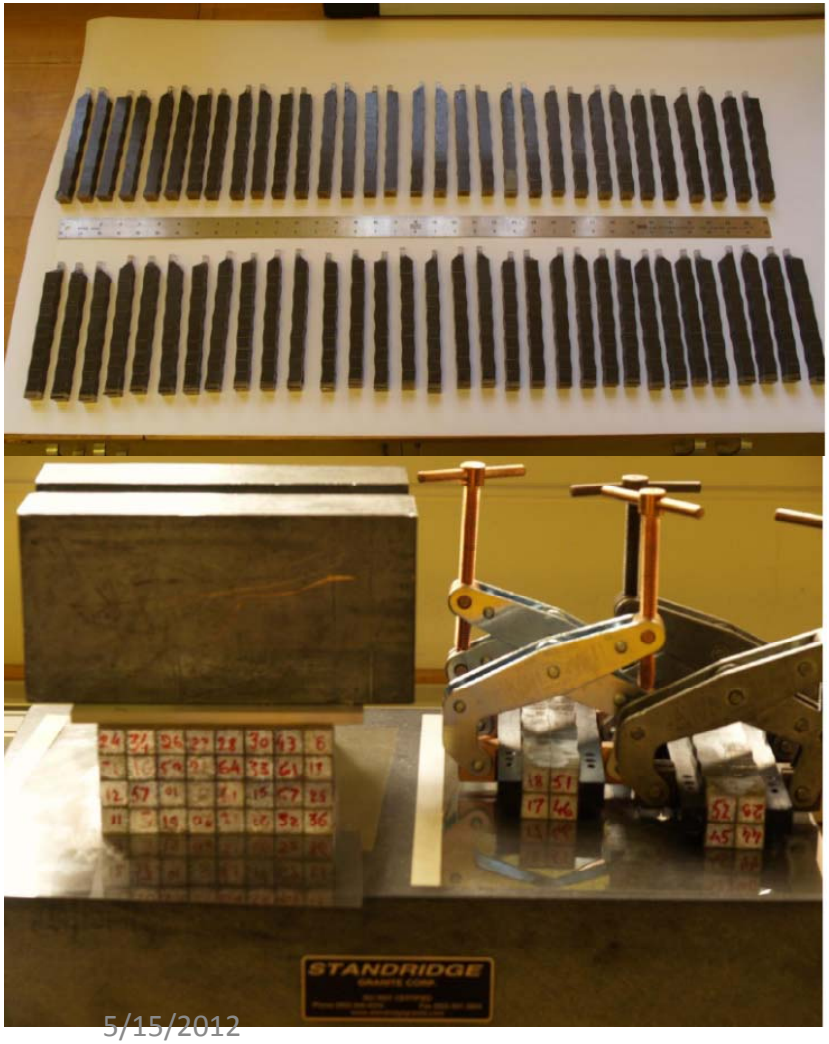
PSU -- S. Heppelmann

RD1 Proposal --

Develop simple, cost effective, flexible techniques to build compact sampling calorimeters with excellent performances that meet EIC physics requirements.

In year 1 we focused on demonstration of "proof of principle" with the construction and beam test of prototypes.

Prototype-1 SPACCORDION-type



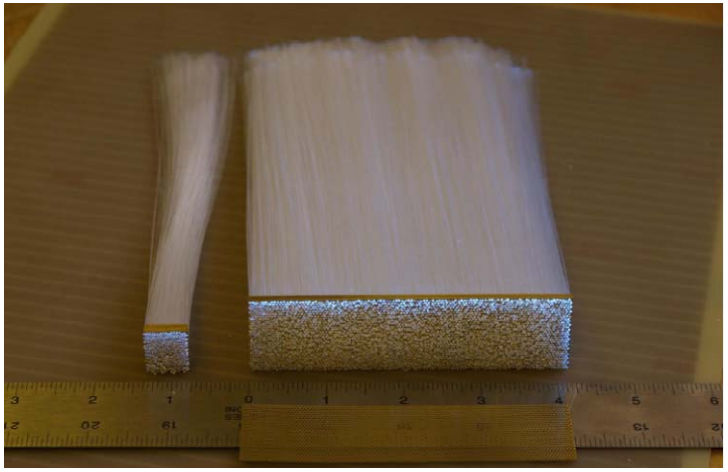
SPACCORDION was the first prototype.
We built it using technique we have developed in the past. Each tower were glued from four subassemblies. Then all 16 towers were glued to a single matrix. The fibers were bundled at the end.

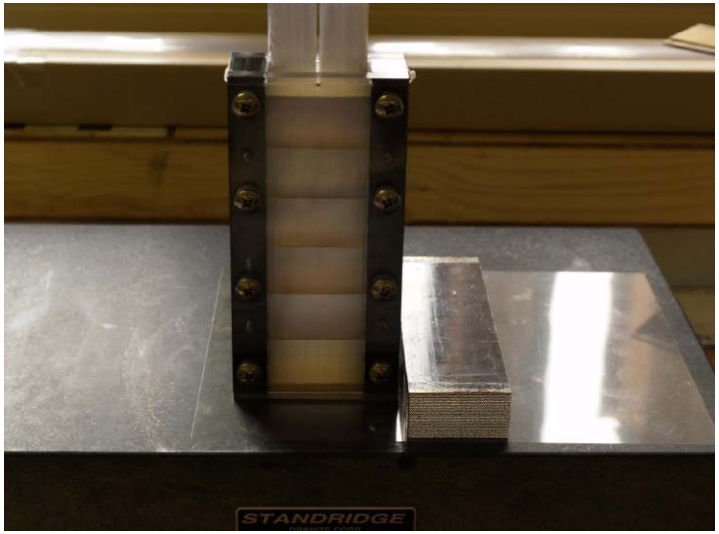
Main problem with this approach is: matching four pieces to make a single tower. It was quite labor extensive process.

Not Simple Enough.

So, we refined technique for second prototype.

Prototype-2 SPACAL-type





First, SPACAL replaces SPACCORDION. In principle we can build a large block of multiple modules at once. An optimistic attempt was made to build four towers at once. It didn't work right away, and at this point it became clear that we better to postpone HCAL development with this technique because handling of large assemblies will not be simple. (Feeding fibers was simple, but arranging all into a matrix creates problem due to the flimsiness of the long meshes.)

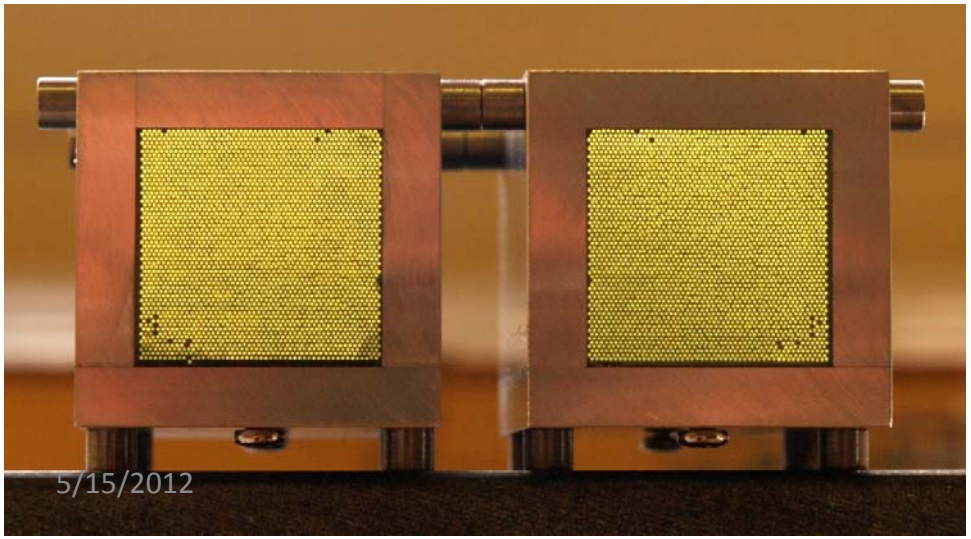
We scaled back to two tower assembly and used thicker meshes and that worked very well. This construction technique appears to be simple and cost effective, but probably not that flexible
(We propose to postpone the HCAL construction until after we conduct a mechanical engineering study of the EMC prototype modules).

Prototype-3 Variation on SPACAL

SPACAL prototype-2:

1. Uniformity (mass difference <1%) after supermodules were machined to sizes (assured flatness for stacking).

2. Already developed simple method to make Integration gaps between towers for future compact readout.



Variations:

Ultrafine sampling with green fibers. Fibers 0.33 mm diameter, spacing center-to-center 0.53 mm.

One infused with Liquid Scintillstor. These were made after the test run, no applications for EIC.

Construction Technique Summary

- *Typical Parameters (SPACAL):*

density 10.17 g/cm3, sampling fraction 2%, fibers 0.5 mm in diameter, sampling frequency 1mm, radiation length 7 mm, Molere radius 2.3 cm. (GEANT4, resolution ~12%/sqrt(E))

- *Sampling frequency. Limit is close to 0.5 mm*
  (below 0.5 mm problems with feeding fibers thru the meshes)
- *Size of assemblies. Limit (~ 3.5 cm x 7 cm)*
  (thickness to infuse epoxy, control of uniformities)

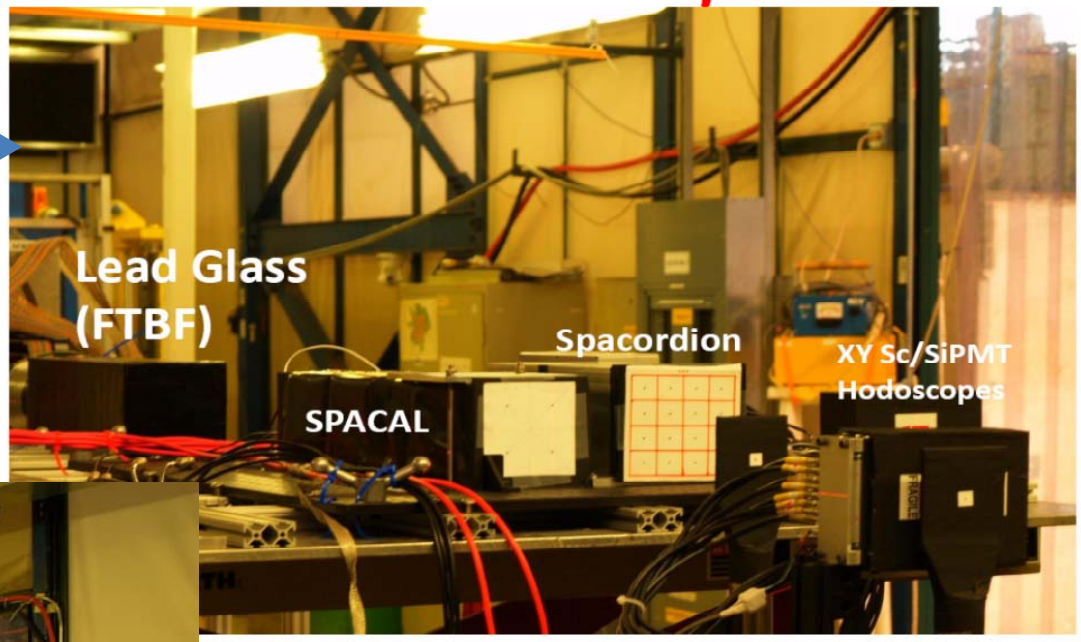
Expected best performance for this technology – compact calorimeters with energy resolution about ~8%/sqrt(E), if compensation requirement can be relaxed.

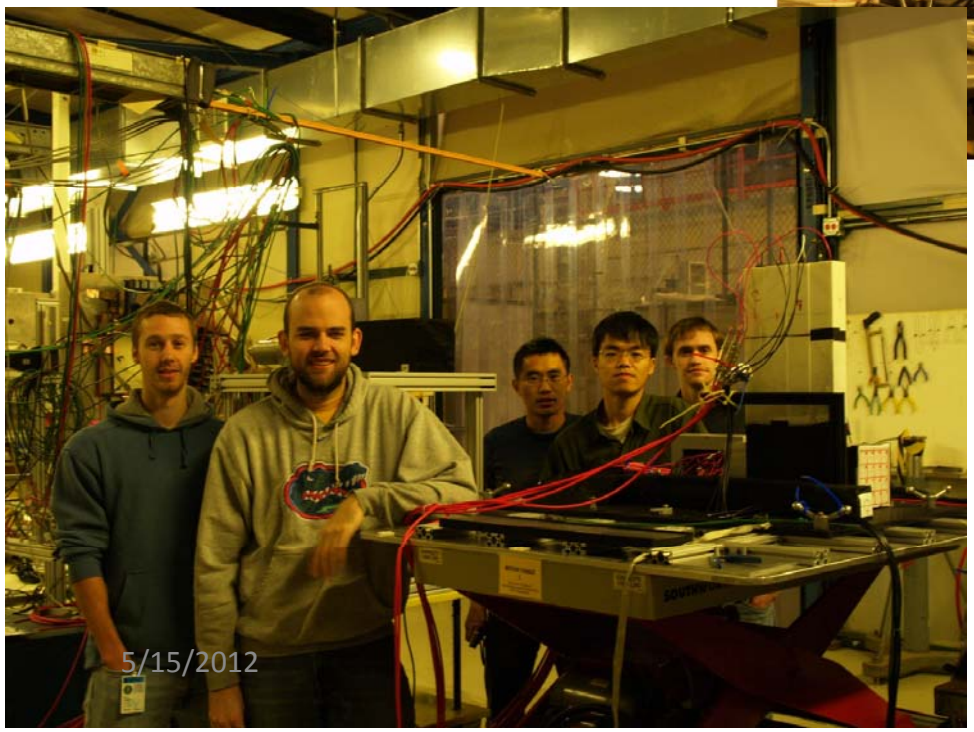
Test Run, FNAL MTBF (Jan. 18-30, 2012)

Setup on Jan. 18

Setup on Jan. 30

T1018 Setup

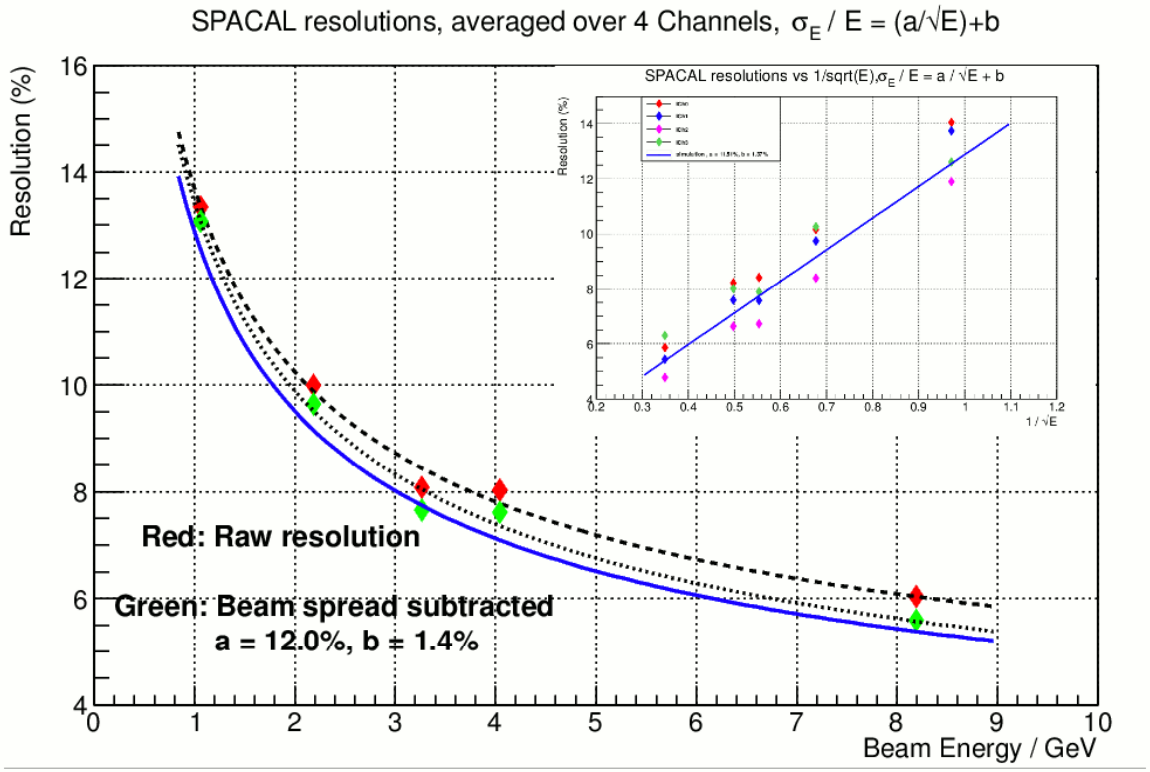




Main Goals:

1. Measure energy resolution, compare to MC.
   ("proof-of-principle").
2. Measure the light yield.
   (defines direction for year 2 R&D)

T1018 @FNAL SPACAL works!



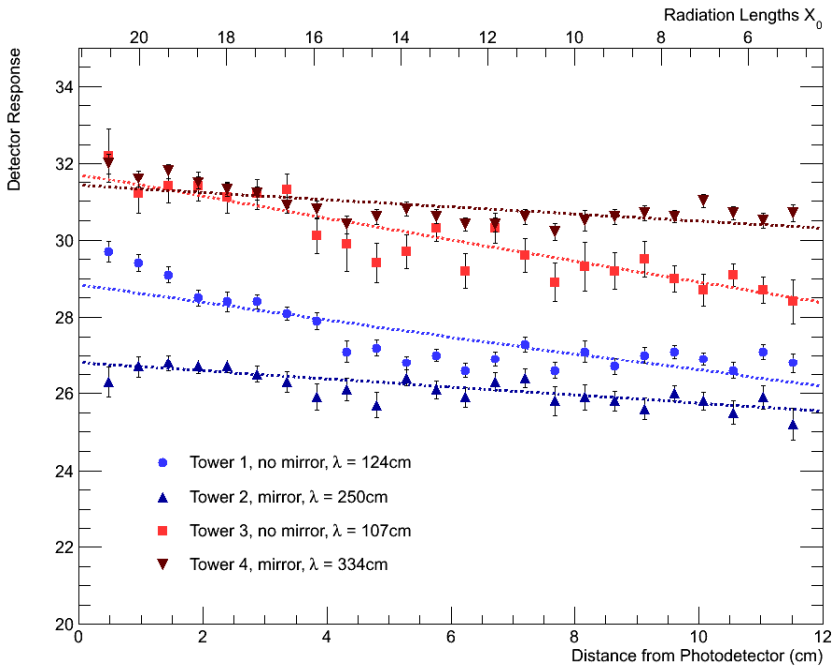
Also measured:

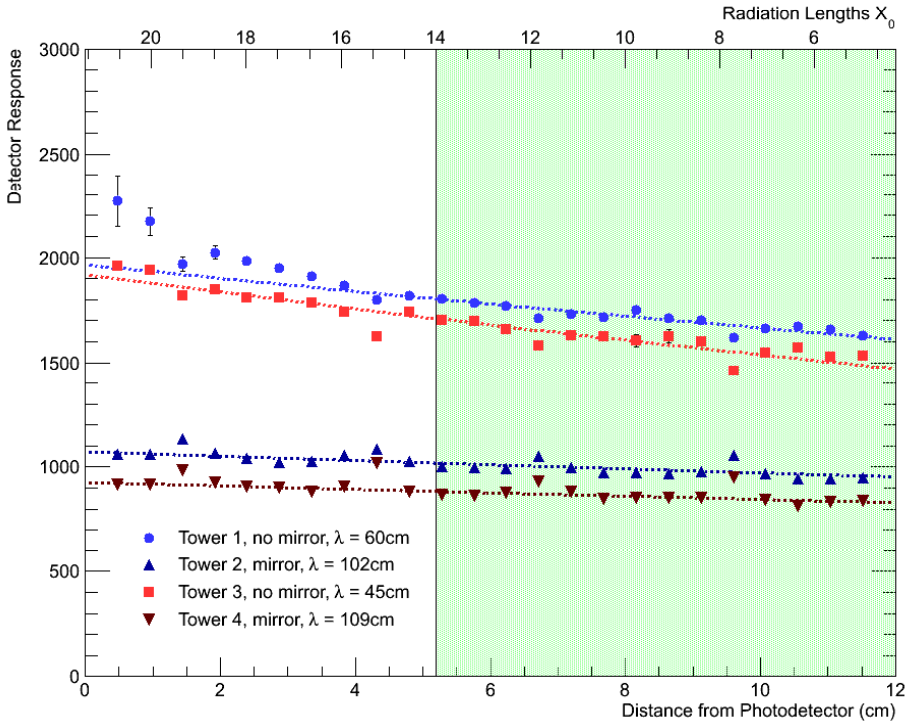
1. ***Uniformity of response across the towers.***
2. ***Energy resolution with and without mirror.***
3. ***Perform scans along the tower length with electrons and muons.***
4. ***Estimated effects of attenuation and towers non-uniformities on resolution.***

1. ***Resolution is close to expected.***
2. ***Light yield is quite good ~ 2000 Phe/GeV***

Preliminary Results from T1018

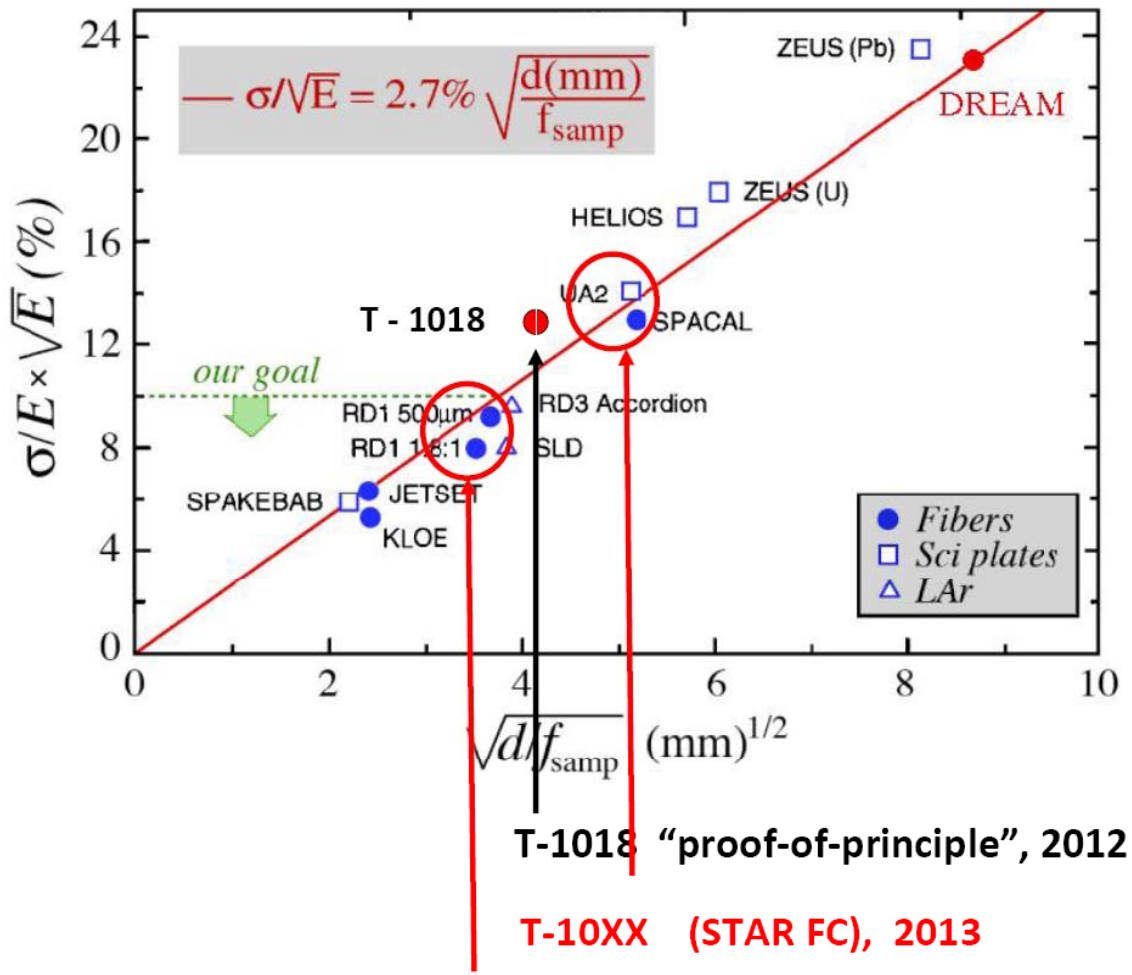
- *Measured resolution with and without mirrors. (Attenuation length)*
- *Do scans along the towers with muons and electrons. (Non-uniformities)*





Typical attenuation length for 0.5 mm fibers (no damage due to packing). Non-uniformities inside the towers is ~ 5% in the most important region from 5-14 Xo.

Further Optimization of the EMC is Possible



T-1018 "proof-of-principle", 2012

T-10XX (STAR FC), 2013

T-10xx (EIC BEMC), 2014

We will build next optimized EMC prototype for EIC application in the future with guidance from detector geometry and physics simulations

Summary on Beam Test of Prototypes

- ***The SPACAL geometry is the our choice now***
- ***Energy resolution is close to expected.***
- ***Light yield is sufficiently high to look at different schemes of compact readout.***
- ***Understood importance to keep attenuation length high.***
- ***The current level of non-uniformities inside the towers will not be a limiting factor for resolution at EIC energy range.***

Lessons from Year-1 R&D Effort

- ***Focus only on the SPACAL type geometry for optimization of EIC EMC application.***
- ***Work with fiber diameters larger than 0.5 mm.***
- ***Relax compensation requirement to go below 10% for energy resolution (boost sampling fraction, while keeping sampling frequency we have for SPACAL).***
- ***The mechanical properties of the W-powder SPACAL need to be investigated by a mechanical engineer.***

Proposed Year-2 Scope of Work from RD1

1. ***Measure mechanical properties of our prototype detectors and investigate possible design for a large calorimeter system.***
2. ***Develop schemes for compact readout.***
3. ***Investigate possible extension of construction technique for a wedge-shaped EMC module for Barrel EMC application.***

Study Mechanical Properties

- ***Measure mechanical properties of W/ScFi/Epoxy compound.***
- ***Perform static stress analysis of prototype modules.***
- ***Perform short and long term stress tests with monitoring of light yield at the same time.***
- ***Plan to subcontract a mechanical engineer to carry out most of the work.***

R&D on Compact Readout

- *Optimization of light collection for APD and SiPMT detectors. (Short light guides or WLS plates). Run both GEANT4 and tests in the lab.*
- *APD – proceed with Hamamatsu (PANDA type 10mm x 10mm).*
- *SiPMT – proceed with ZECOTECK MAPD-3N, and Hamamatsu MPPC.*
- *Continue MC effort to optimize EMC requirement for EIC with physics considerations.*
- *We plan to work on electronics development starting year-3.*

Wedge-Shaped Towers

- ***Evaluate techniques to build wedge-shaped towers for barrel calorimeter application.***
- ***Run GEANT4 to understand effects of varying sampling fraction and frequency on resolution and linearity for different impact angles (barrel geometry).***

RD1 Outlook for Year 3 and Beyond

1) Use the best read-out scheme and the optimized module geometry to build EMC prototypes that meets the EIC physics requirements and the final EIC detector system design
2) Develop readout/trigger electronics for the EMC detector
3) Work on an EIC EMC calorimeter system design

In parallel for the coming years --

STAR is pursuing a forward instrumentation upgrade including a combined EMC and HCAL in the forward direction. It is expected that the STAR upgrade and the EIC R&D efforts will complementary to each other with the STAR effort centering on HCAL and EIC on EMC related detector development.

The End