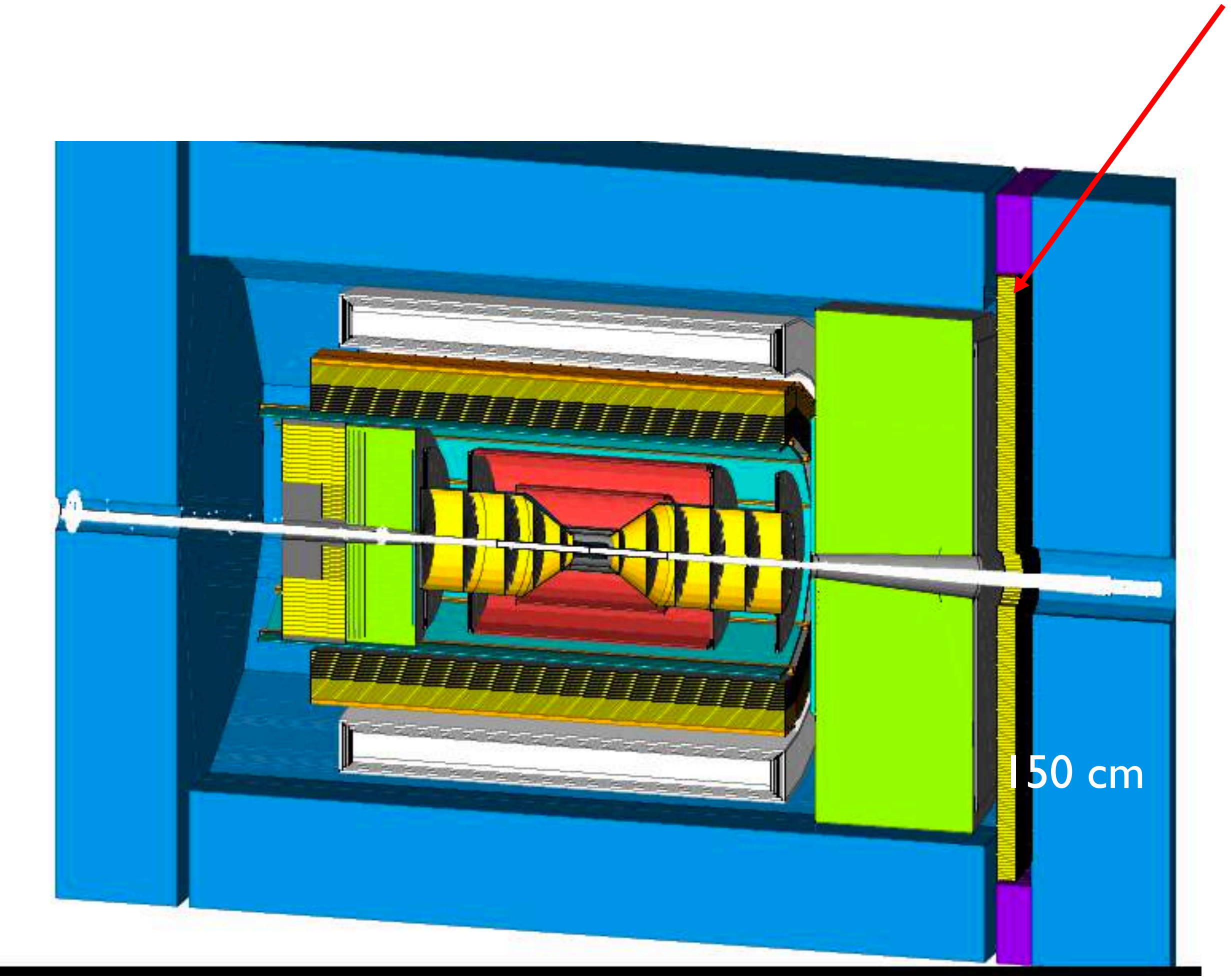
pECal in ATHENA. Details

O.Tsai (UCLA) Fudan, Shandon University, Tsinghua, South China Normal University, UCLA, IUCF, BNL eRD106 (WScFI)



ATHENA Integrations:
IP shifted by 50 cm (Accelerator-Detector)
pRICH requires more space (Detector sybsustems)

Integration Envelope:
Length along Z – 30 cm (back side of ecal is at 380 cm from IP), R out -230 cm

Integration envelope sub-division:
- WScFi length – 17 cm (23 X0)
- Light Guides – 2.5 cm
- Readout (FEE+LED+Cooling) – 10 cm

Nomenclature:
- Tower – 2.5 x 2.5 cm^2
- Production Block – 2 x 2 towers
- Installation Unit – superblock 4 x 4 towers

Photosensors:
4 HPK S13360-6050PE per tower

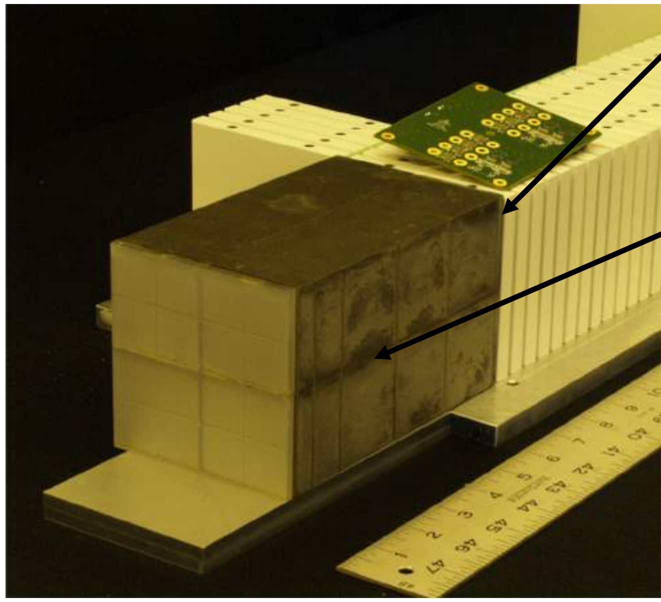
Costed for 26600 towers (6650 production blocks)

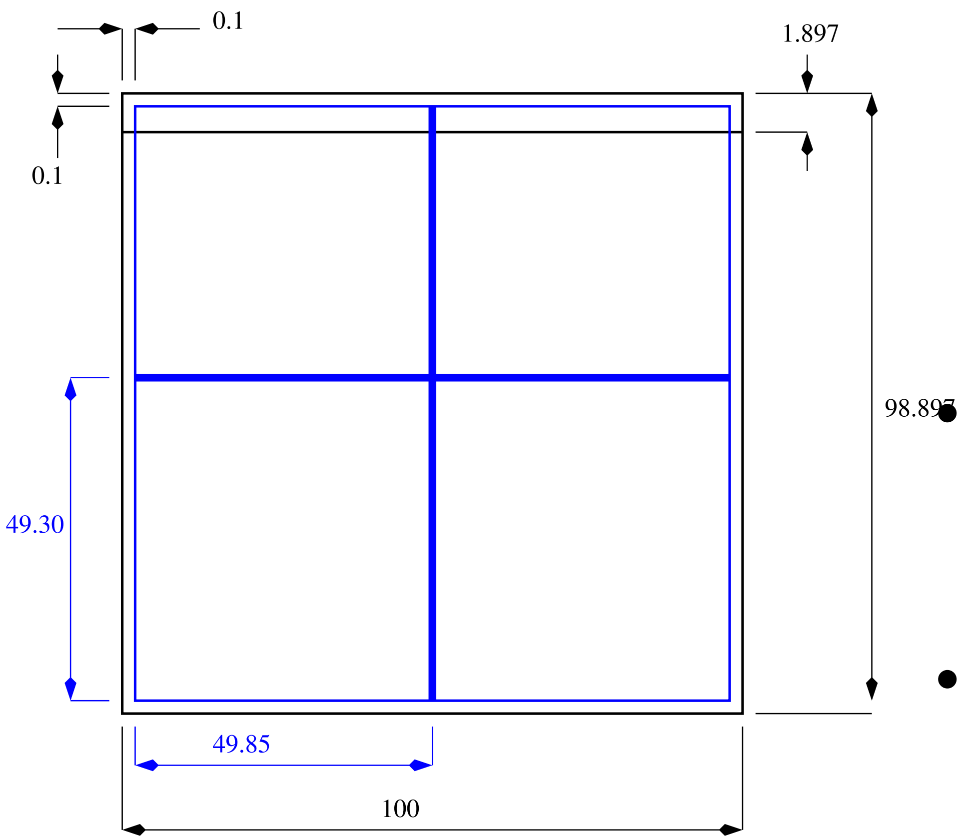
Cost drivers (ATHENA dimensions)

- Scintillating fibers – $1.87M (Quoted, KURARAY)
- W powder - $1.38M (sPHENIX, price in China)
- SiPMs - $2.44M (Quoted)
- Electronics - $1.33M (Direct scaling from STAR FCS)
- Labor - $4.1M ($1.98M to project) (mostly historical)

Total: ~$12.7M (using project templates)

Integration with HCal





Glue Joint between EMcal blocks is 0.1 mm thick

EMcal block external dimensions are 49.85 x 49.30
HCal tower external dimensions are 100 x 98.897
Clearance gap between edges of EMcal and Hcal towers is 0.1mm

- First absorber plate of Hcal is a ‘strong back’ for ECal
- Installation block glued to that plate prior assembly of Hcal.
- Installation of ECal goes along with assembly of Hcal, i.e. layer by layer as it was done for STAR FCS. First absorber blocks of Hcal bolted to each other.
- Installation gaps 0.2 mm seemingly easy to achieve (production tolerances of ECal and tolerances for Hcal assembly, which were verified with STAR FCS (2m high, 30 t, better than 0.1 mm tolerances achieved)
- ECal is self supporting, in current version there is no pressure from one ecal installation block to another.
- Mechanical properties of compound is close to construction steel.

N.B. Gaps, Dead areas in modular calorimeters and resolution.

WScFi technolgy key points:

- WScFi is a unique technology allowing to achieve e/h ~1 and at the same time keep em energy resolution at ~10%/√ E + 2%, no other known technology for EMcals can achieve this.
- WScFi technology is unique allowing to build detectors with different configurations (SPACAL, 1D SPACAl, 2D SPACAL, Optical Accordeon) eRD1, sPHENIX
- WScFi technology allows to build very high density (compact) calorimeters.
- WScFi method is very simple requires only few components to build detector free from dead areas.
- Very simple mechanical integration (with Hcal and readout).
- Performance, cost and risk are well understood due to almost 10 years long R&D and sPHENIX construction
- Technology is simple and can be easily transferred (US, China), has minimal requirements on infrastructure at production site.

- R&D plan was submitted (pended now) eRD106 to address uniformity of light collection with compact readout.

Fudan, Shandon University, Tsinghua, South China Normal University, UCLA, IUCF, BNL
eRD106 (WScFI)

Technology 1

- First prototypes 2011, spacordion and spacal types
- https://wiki.bnl.gov/conferences/images/d/d4/RD-1_RDproposal_April-2011.pdf

Technology 2. Important measurements, LY, homogeneity transvers and longitudinal to separate effects due to readout and properties of WScFi compound

Parameters:

Final Density - 10.17 g/cm^3,
X_0 ~ 7 mm, R_m ~ 2.3 cm,
S_f -2% (electrons),
Sc. Fibers -SCSF78
Ø 0.47 mm
Spacing 1 mm center-to-center.

Supermodule 2x2 towers.

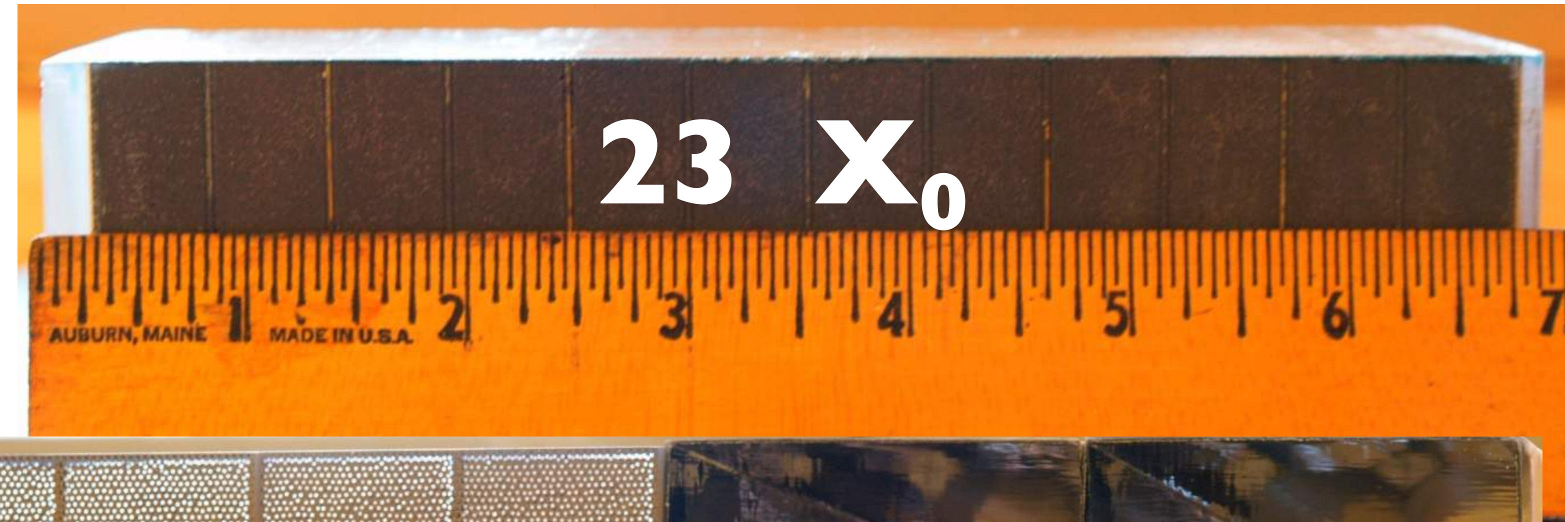
Details:

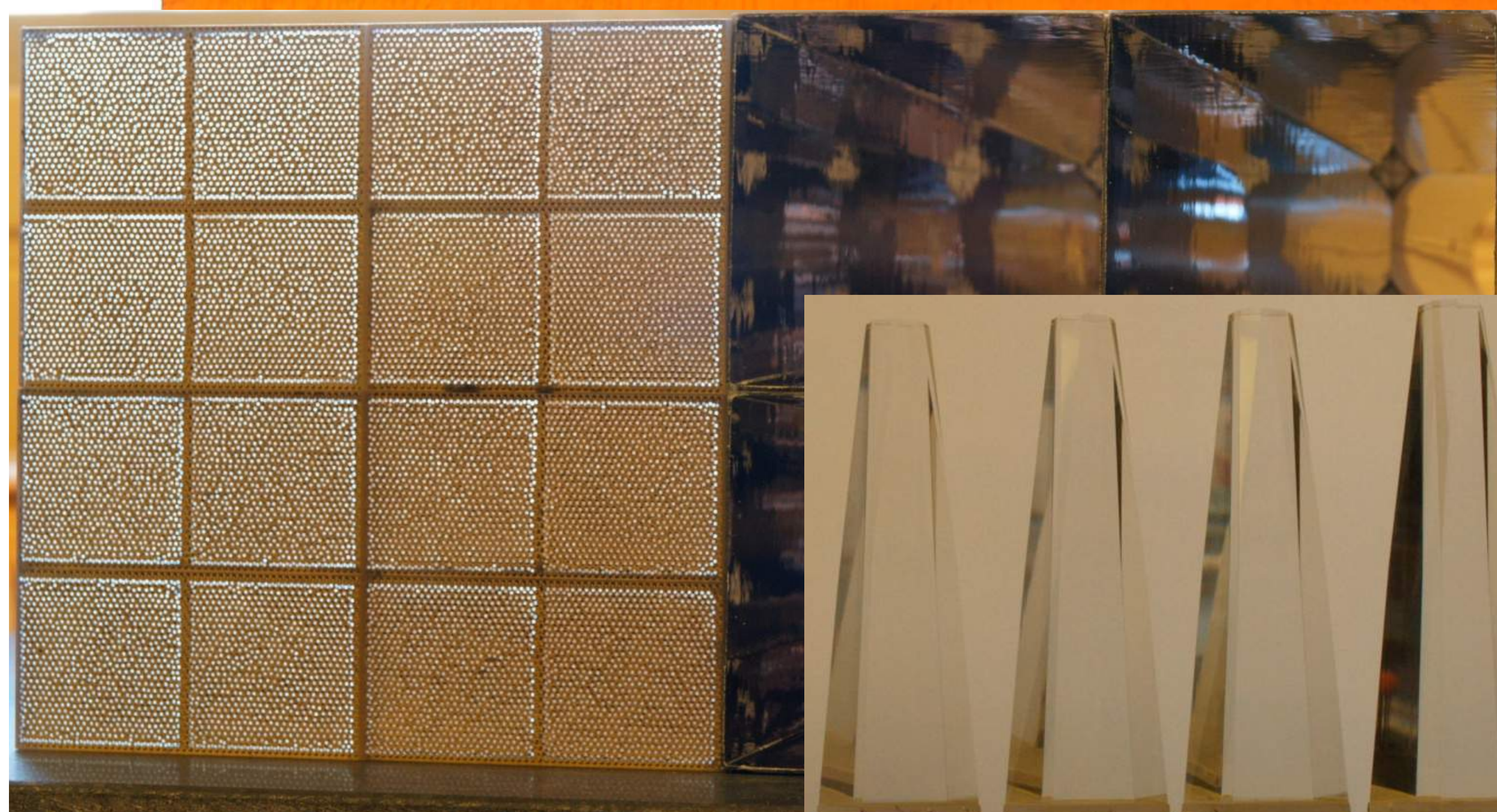
Dimensions 16.6 × 5.33 ×5.33 cm^3
Weight of supermodules (4567, 4651, 4627,4630 g.)
Number of fibers -3120

Resolution ~12%/√E

Light yield 2000 p.e./GeV

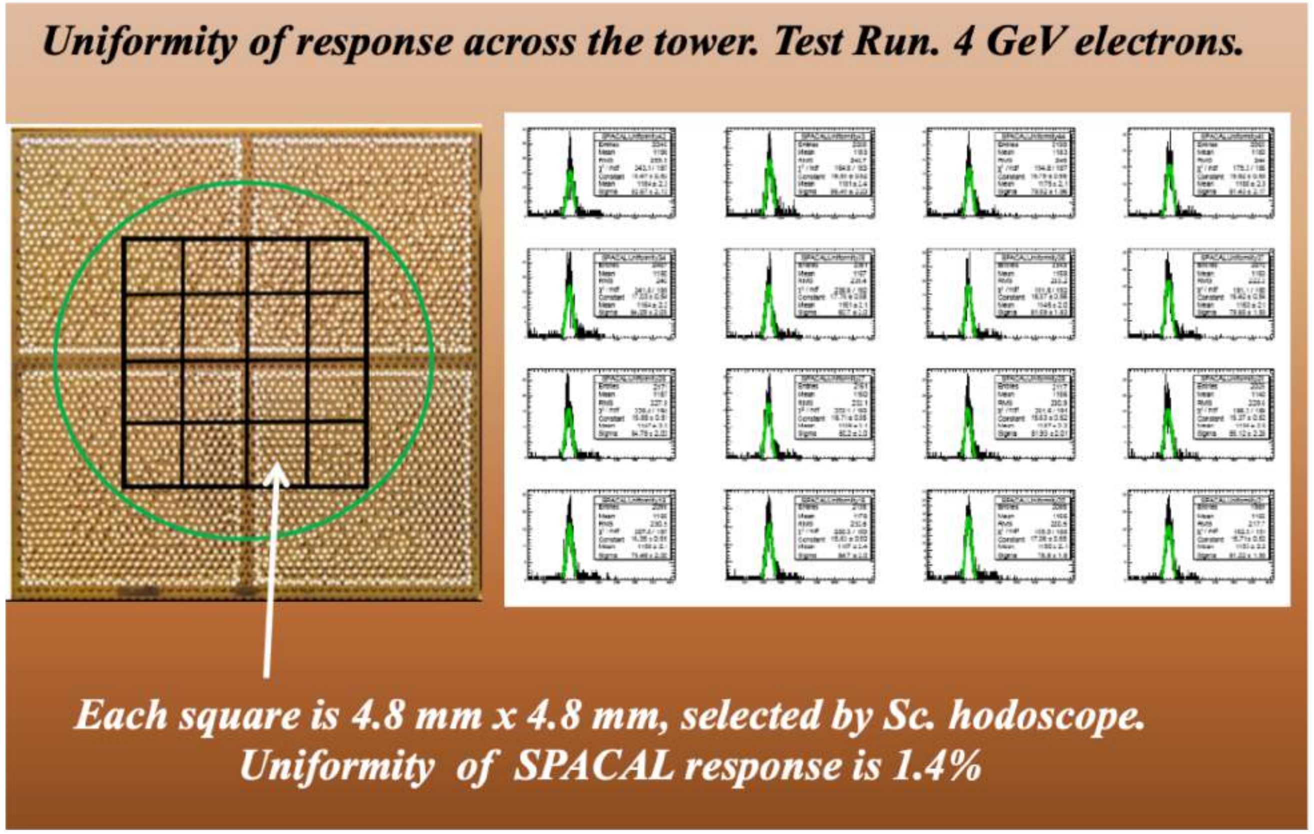
SiPM Readout Possible.

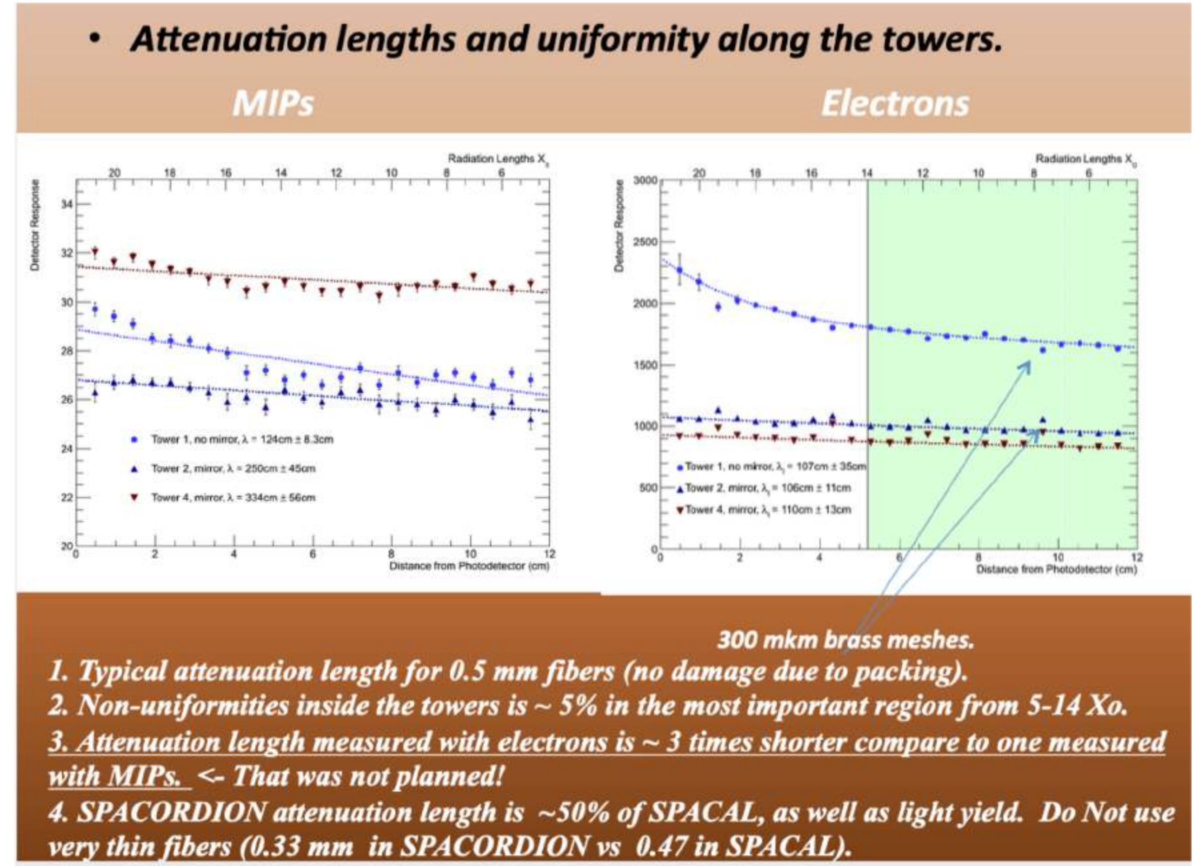


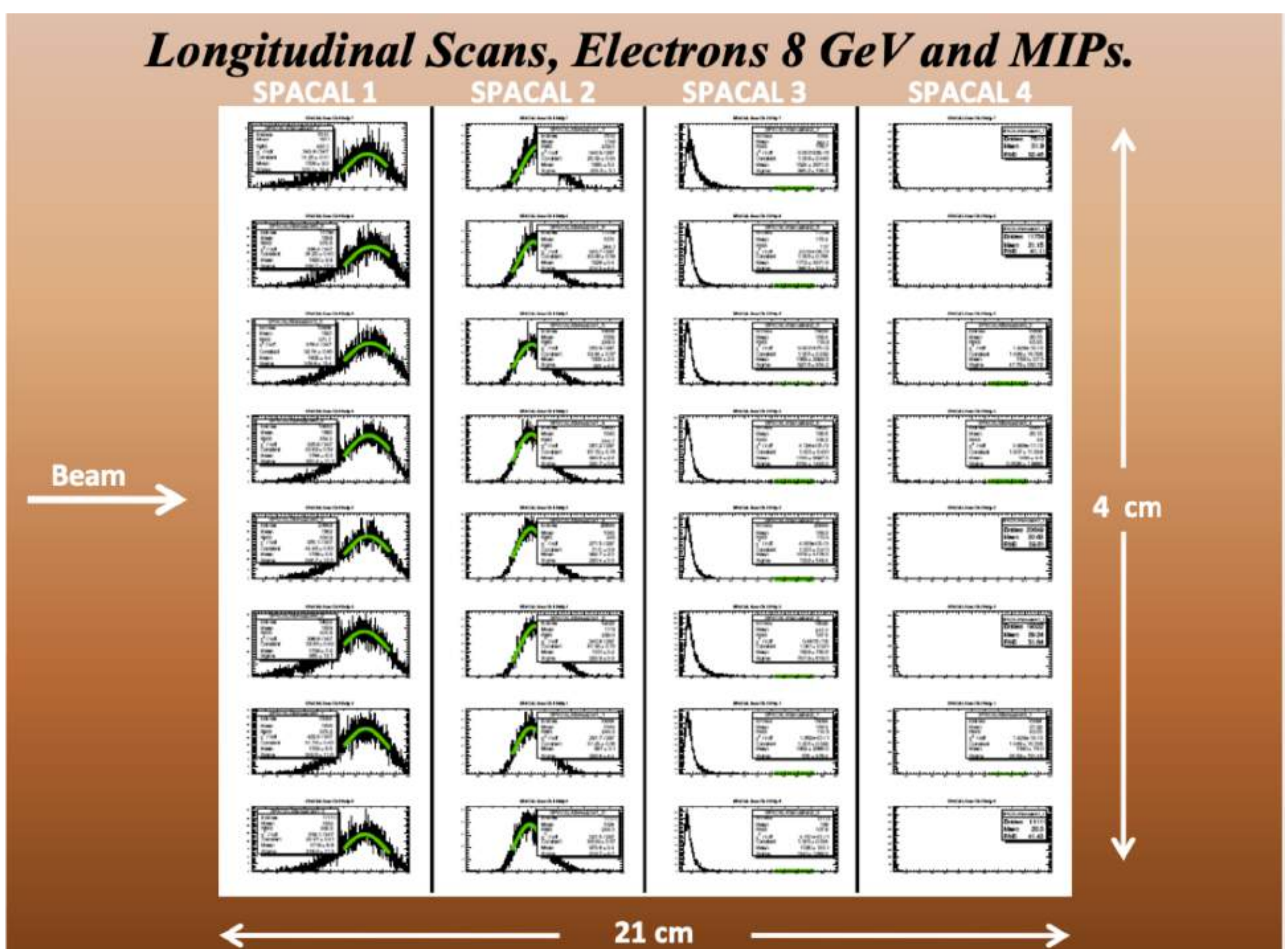


RD1 Collaboration, EIC R&D
Proof of principle, Jan 2012
Test Run at FNAL T1018

Technology 2. Important measurements, LY, homogeneity transvers and longitudinal



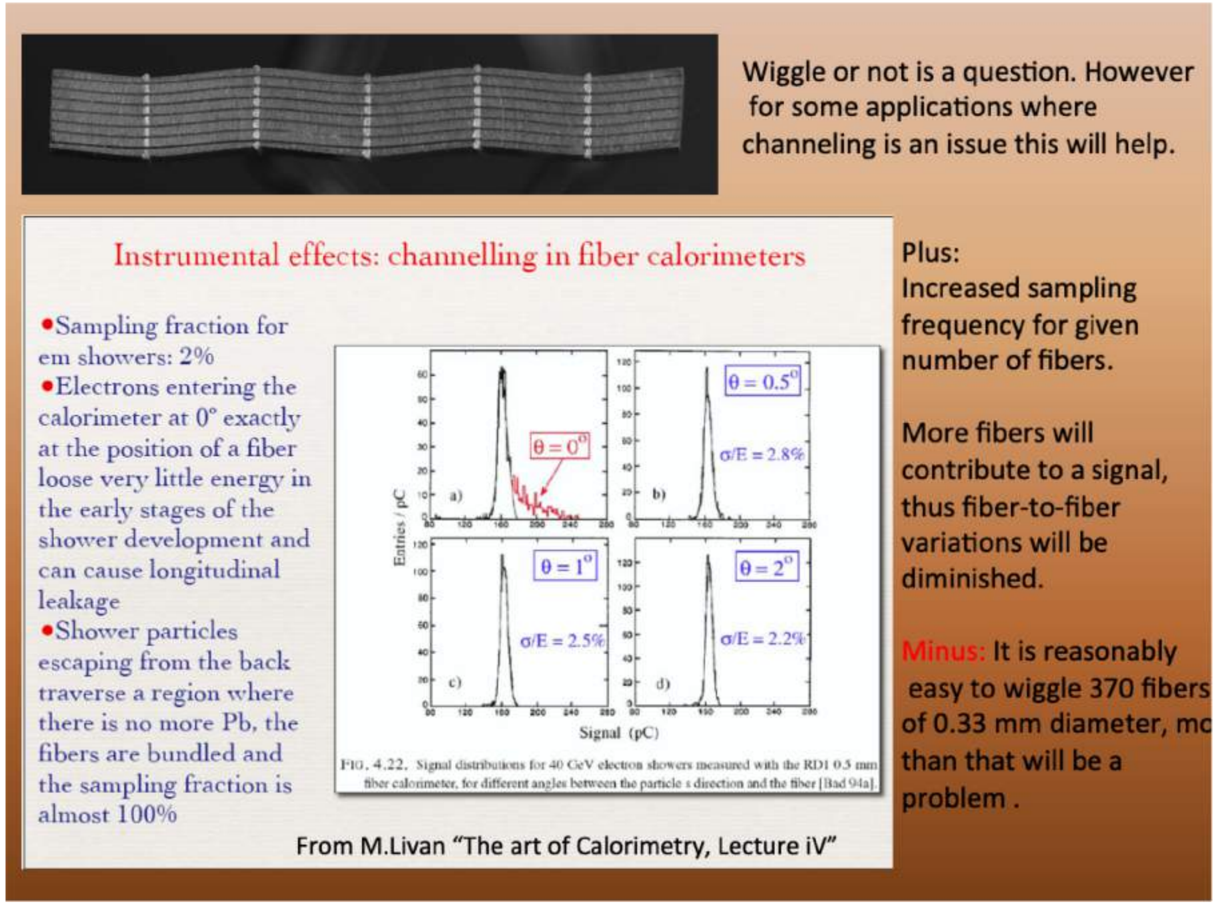


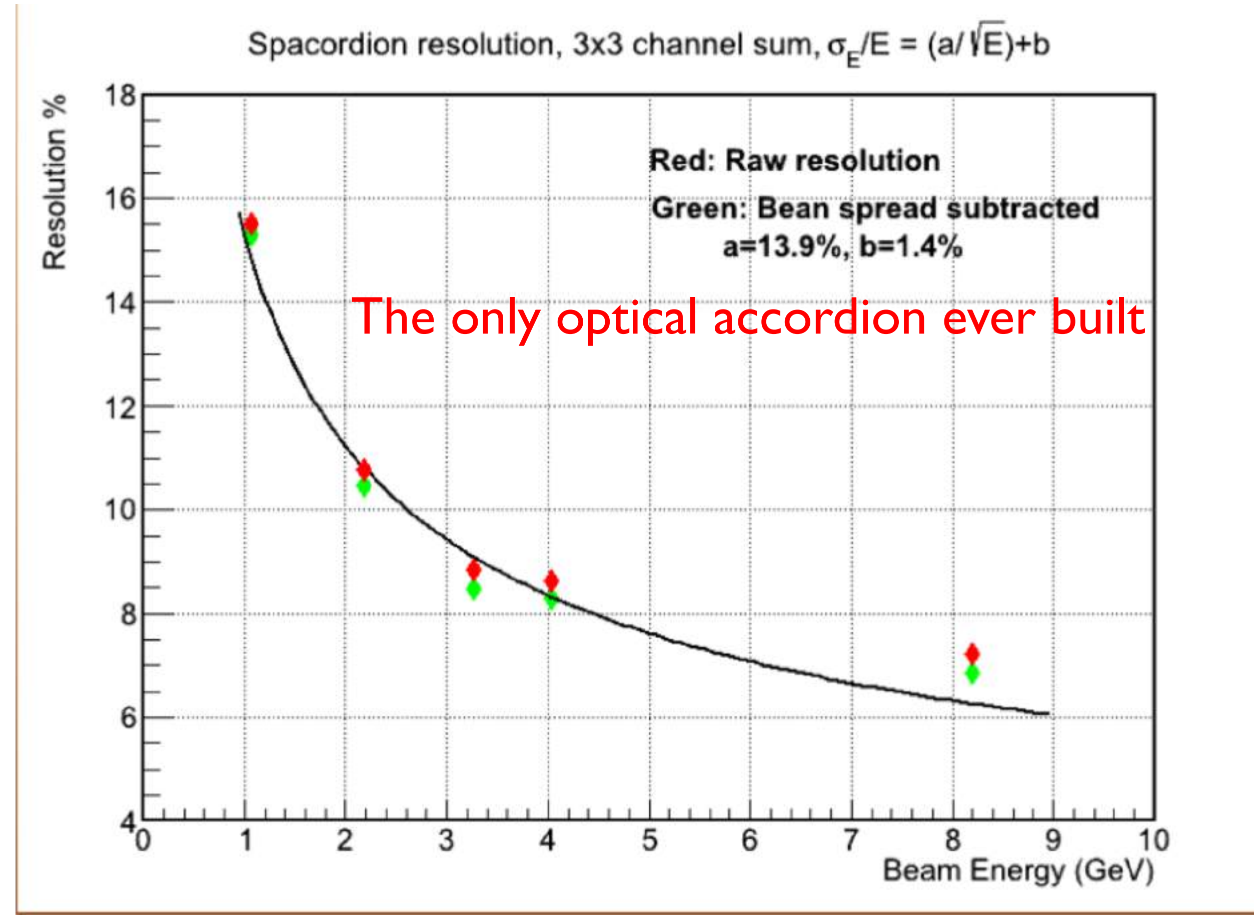


Excellent homogeneity of WScFi compound confirmed in test run.

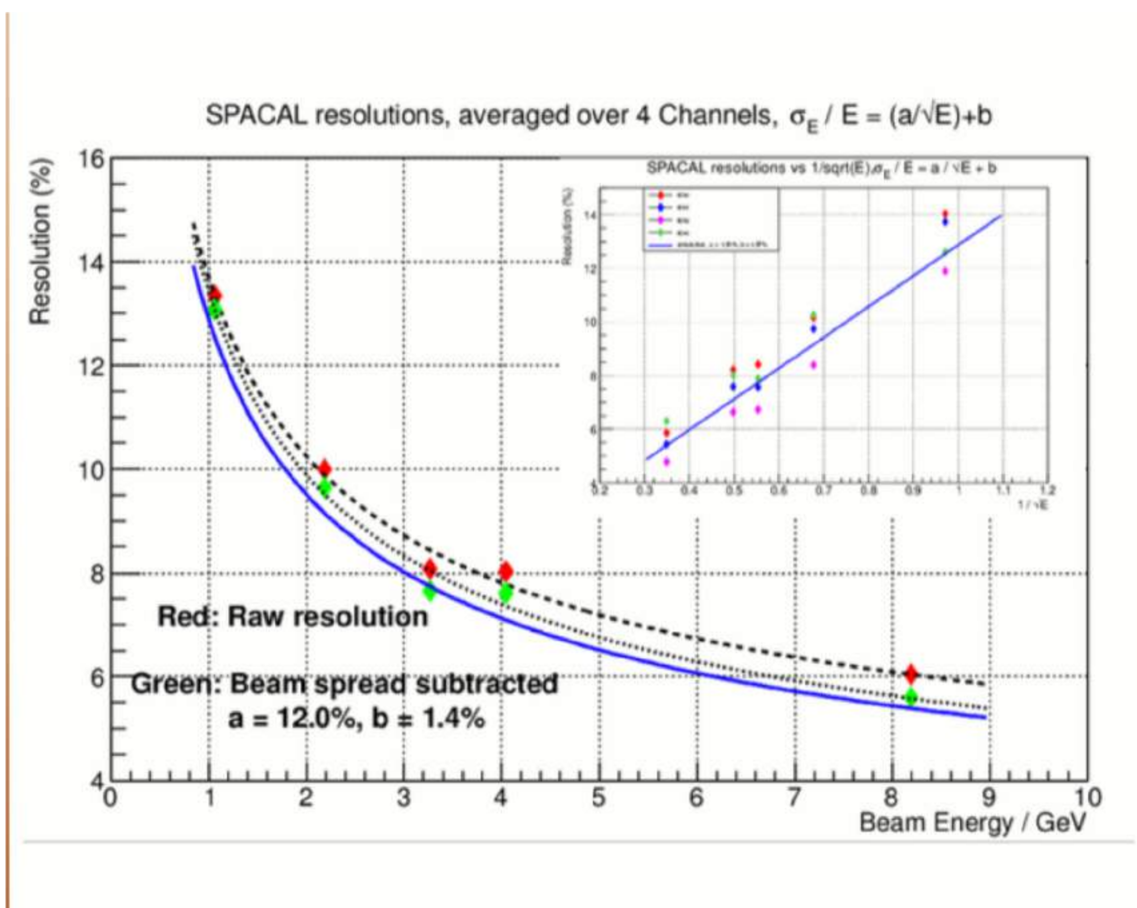
Prior to that density was measured by cutting blocks.

Some concerns of working with thin scintillation fibers.



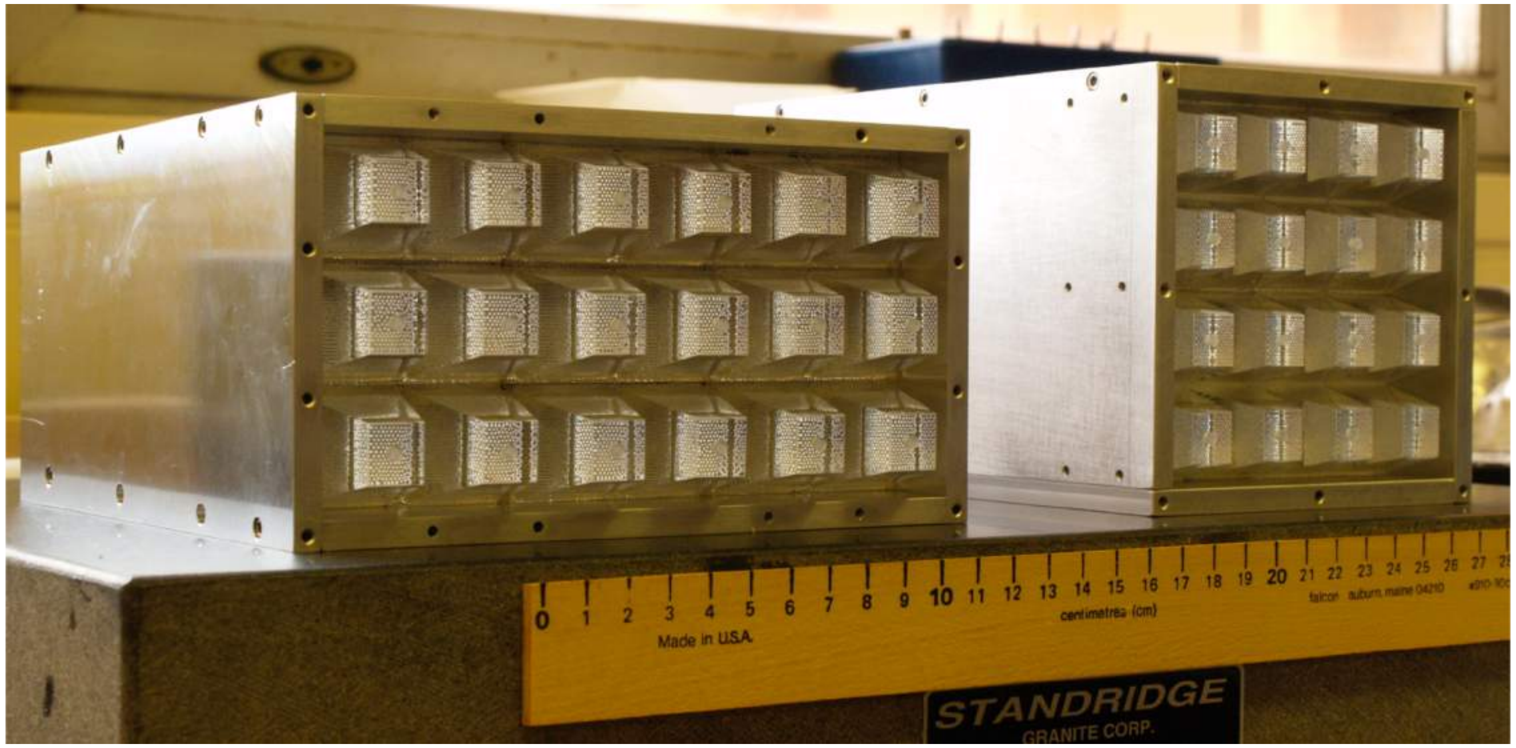


- https://wiki.bnl.gov/conferences/images/d/d4/RD-1_RDproposal_April-2011.pdf



Good agreement with MC (spacordion geometry was not implemented)

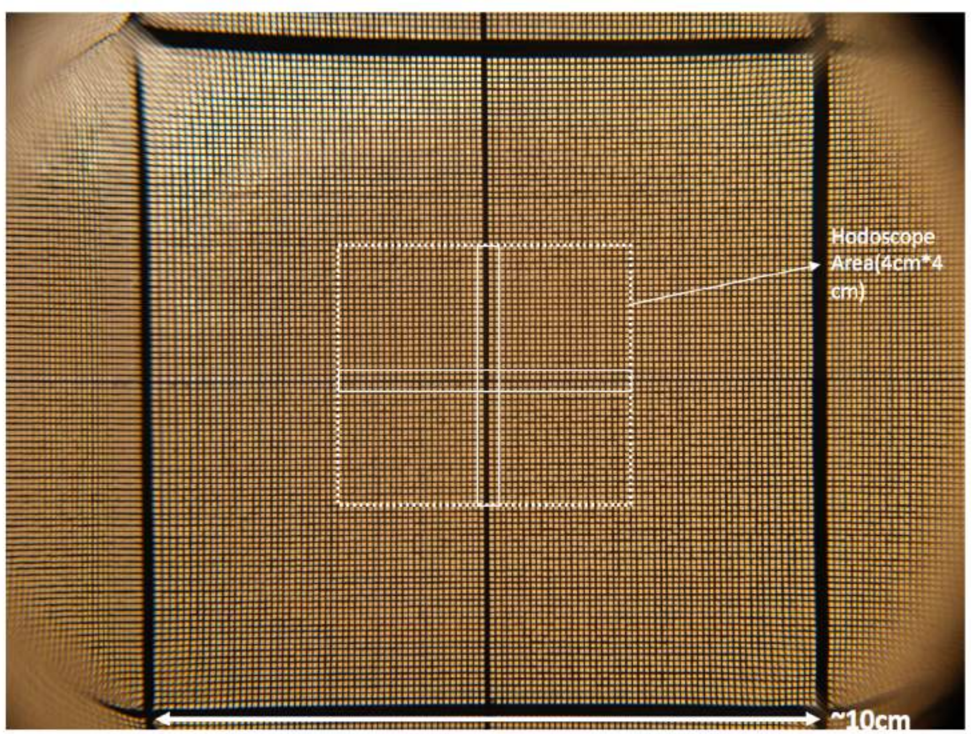
Technology 2 Examples

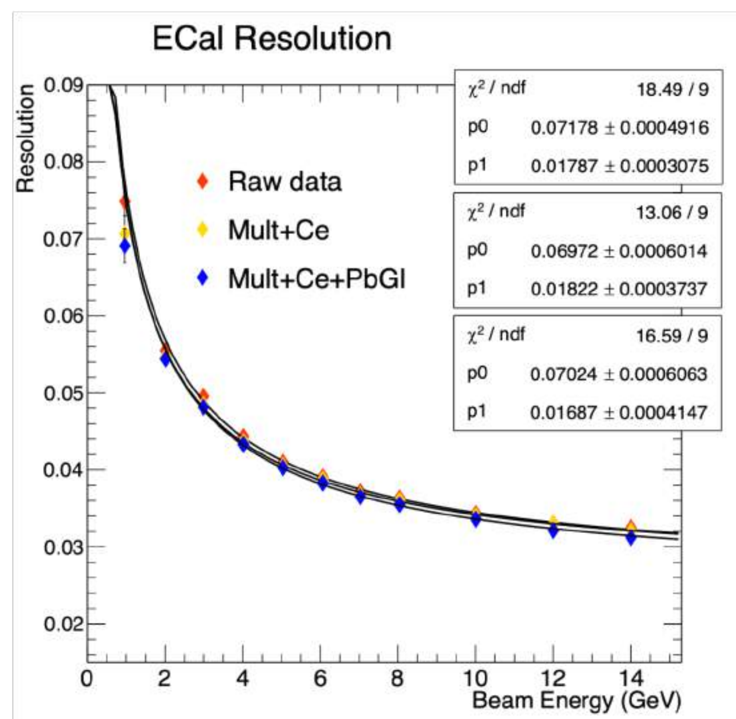


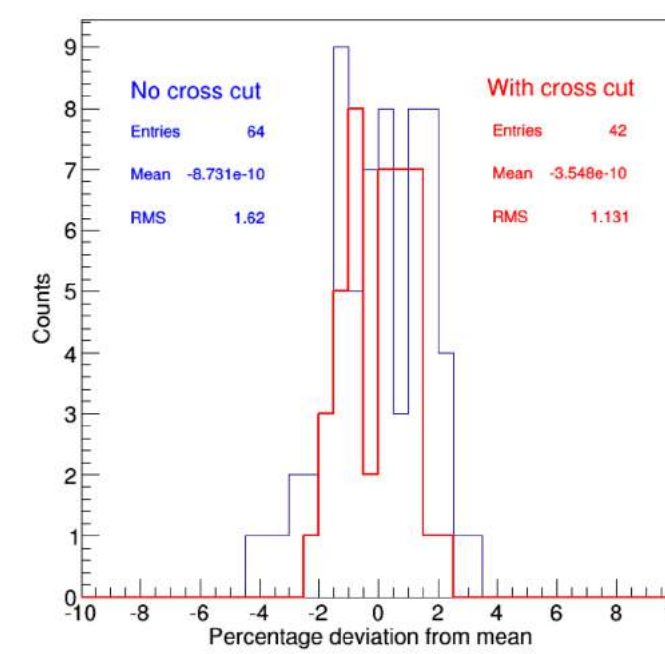
SPACAl and 1D,
FNAL 2014

SiPM Readout

CALOR 2012, J.Phys.: Conf. Ser. 404 012023
CALOR 2014, J. Phys.: Conf. Ser. 587 012053



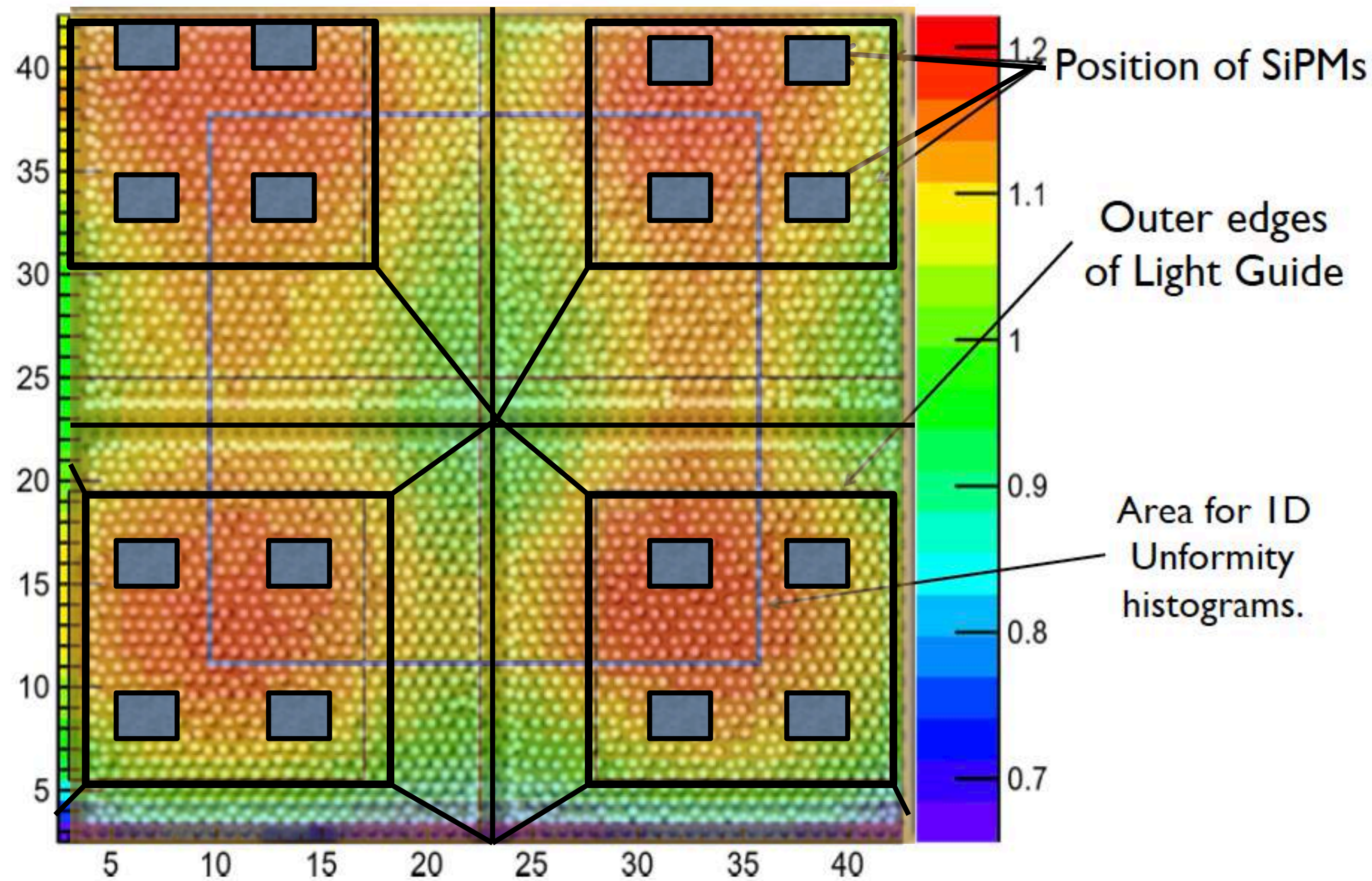




FNAL 2016. High resolution, square fibers, constant term

Optimization of light collection (2016):

BEMC Superblock 2 x 2 towers, 4 SiPMs / tower, UV LED Map



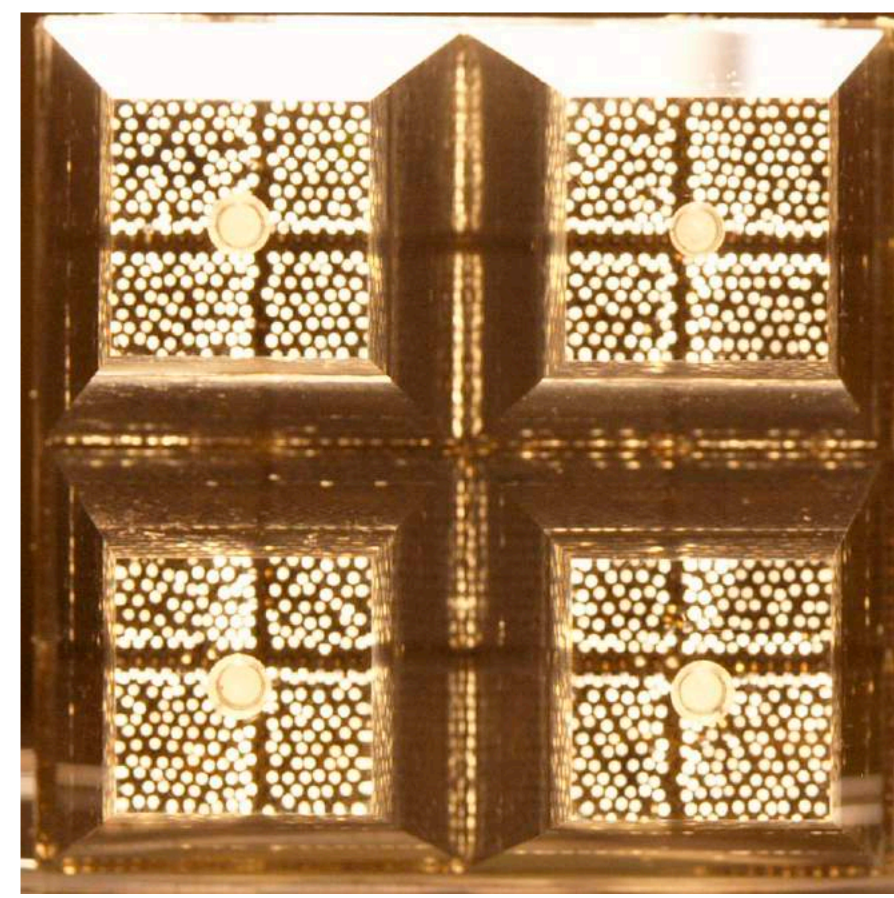
Compact scheme (short light guide with 4 SiPMs, which only partially covering output area of light guide) especially prone to be non-uniform.

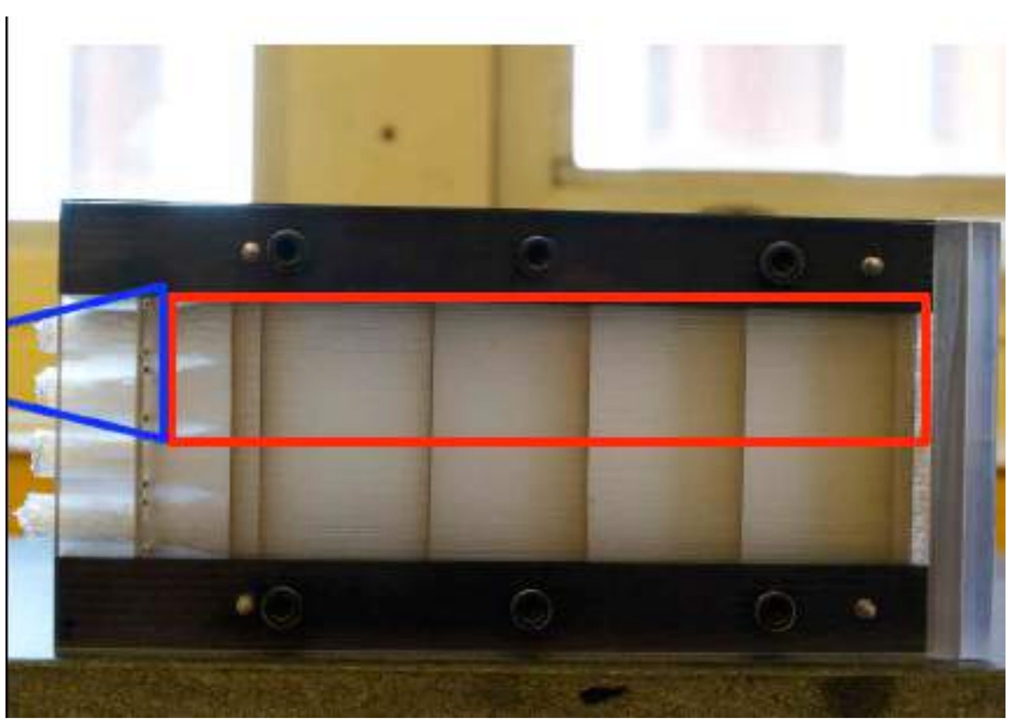
Solutions we tried in the past:

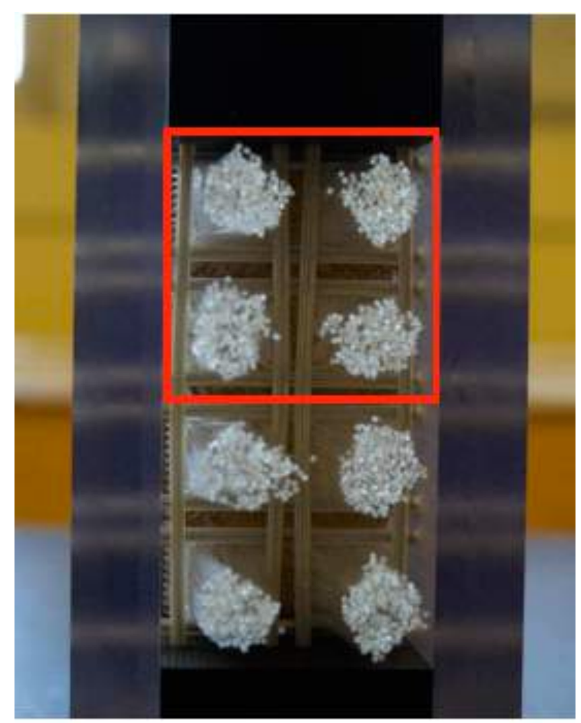
1. Compensation Filter between fibers and light guide. Loss about 30% of light (test run 2015). Will not work for FEMC.

2. Compensation with gradient reflector from the back side of the superblock. Practicality issues.

New Approach. Introduce controlled angular irregularities in fibers within tower, so that fibers in the corners and in the middle of the tower provide same LY.

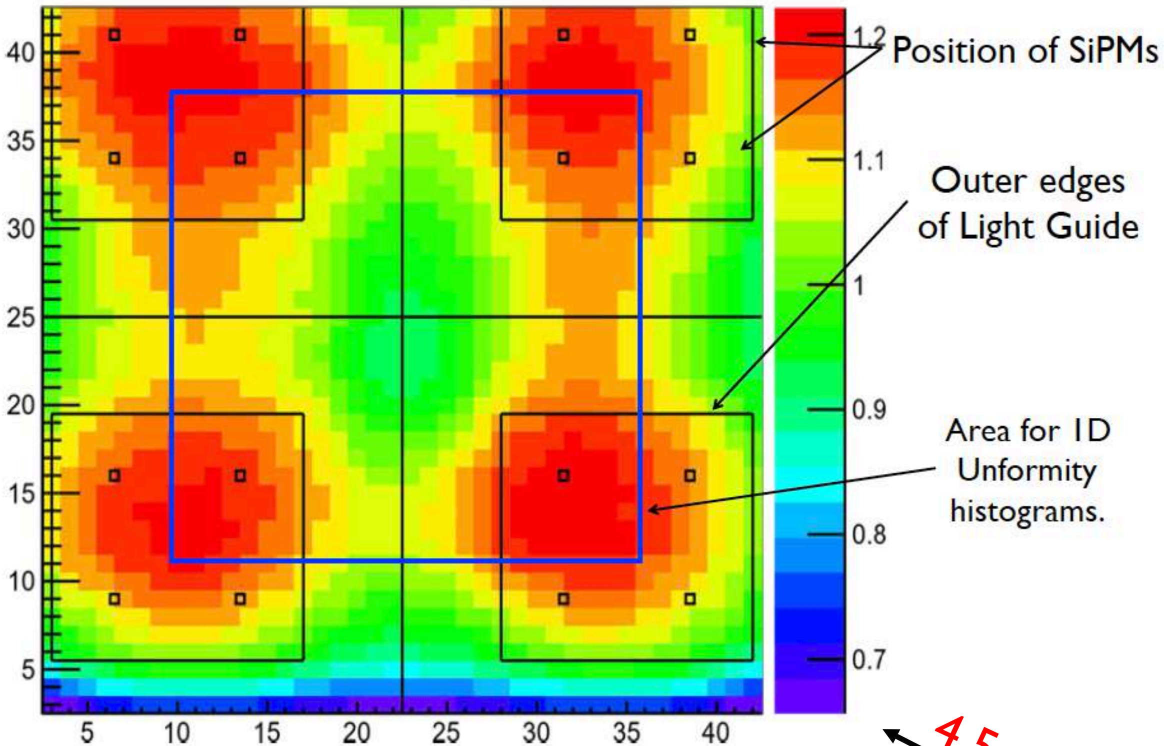




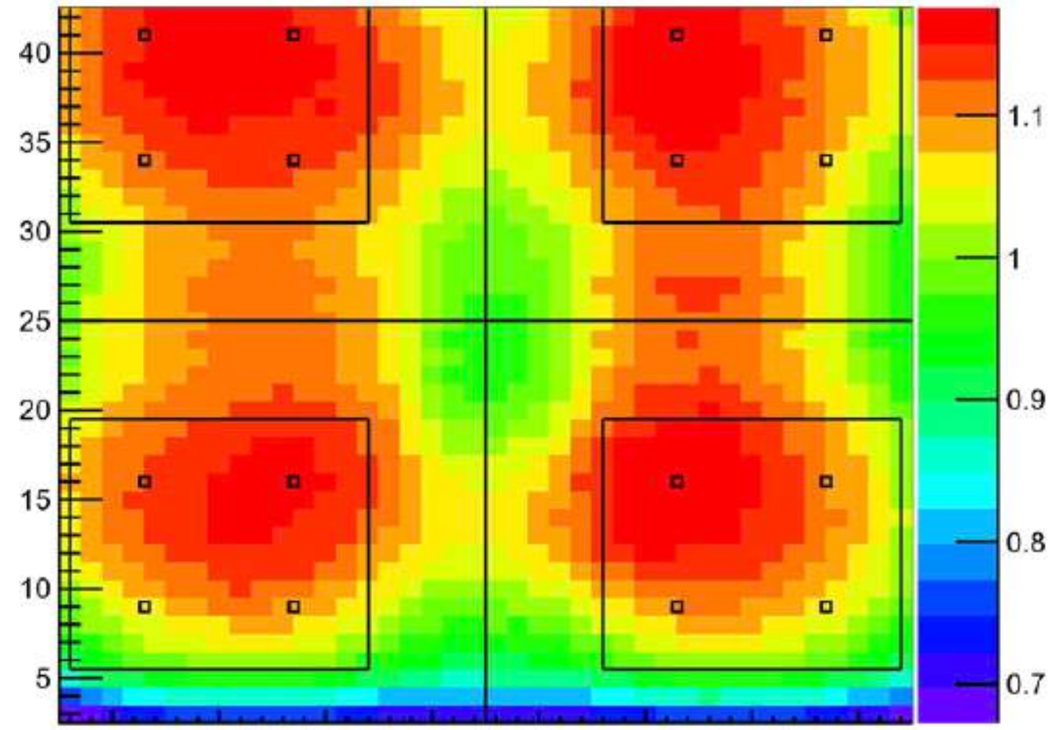


Optimization of light collection:

BEMC Superblocks, UV LED Map

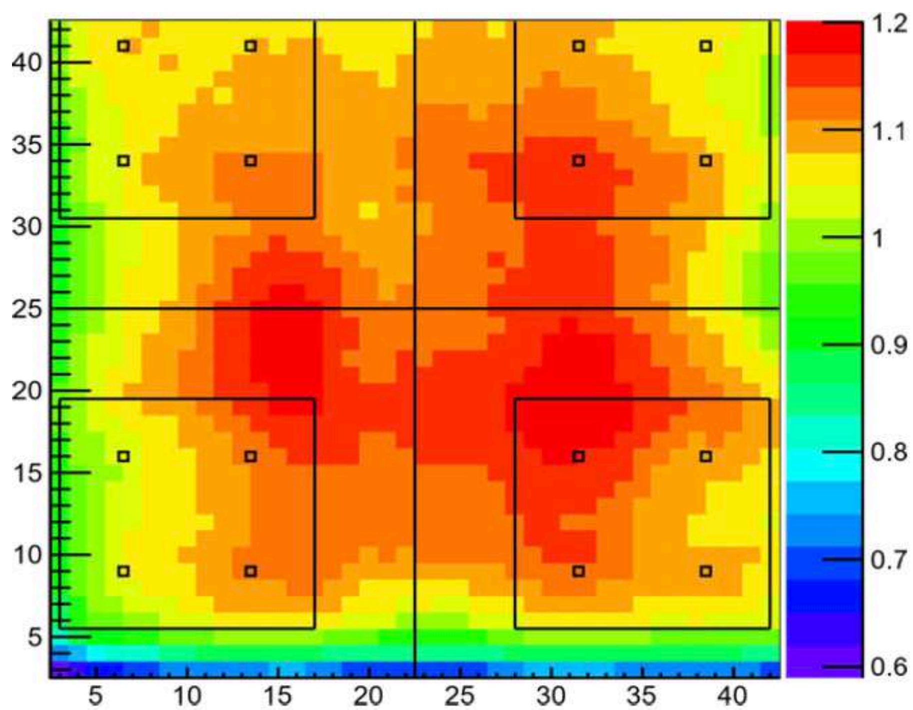


Old BEMC, Sylgard 184, 3mm

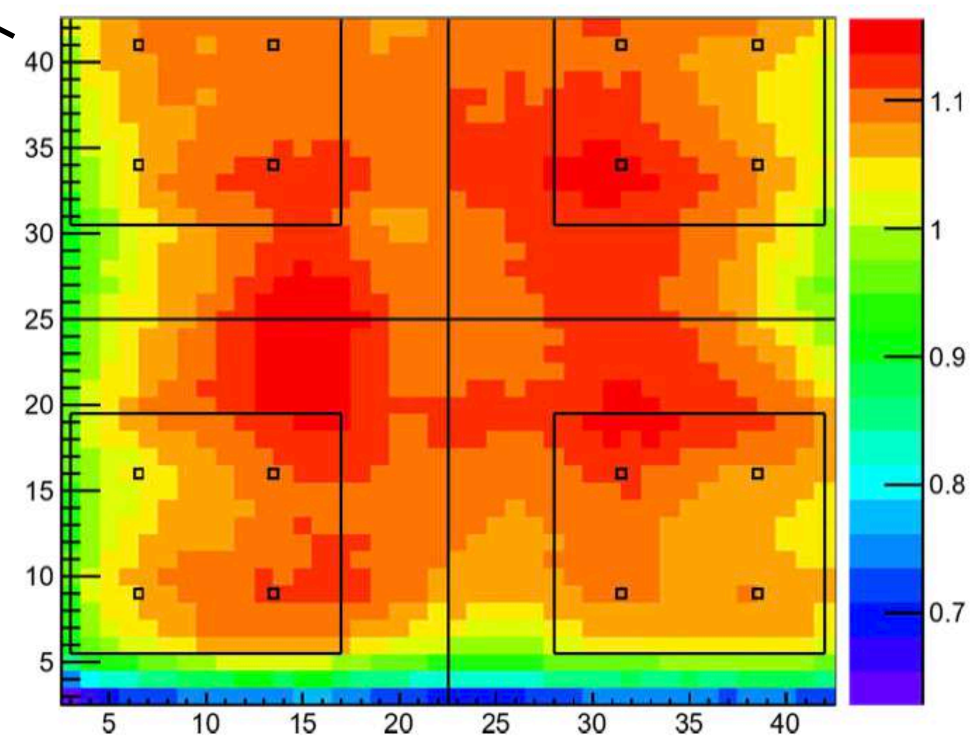


Old BEMC, BC-630, coupling is important

4.5 times better

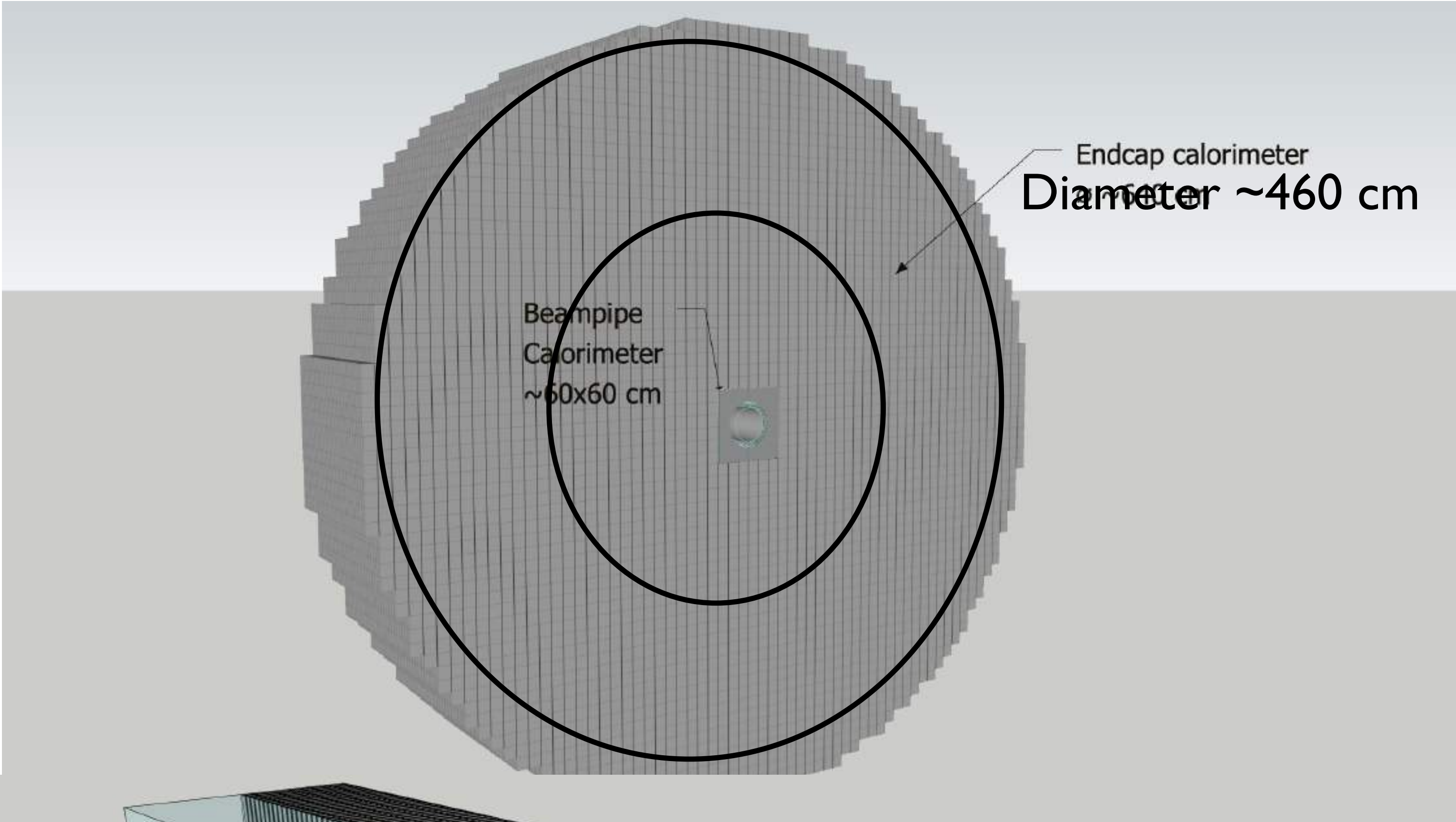


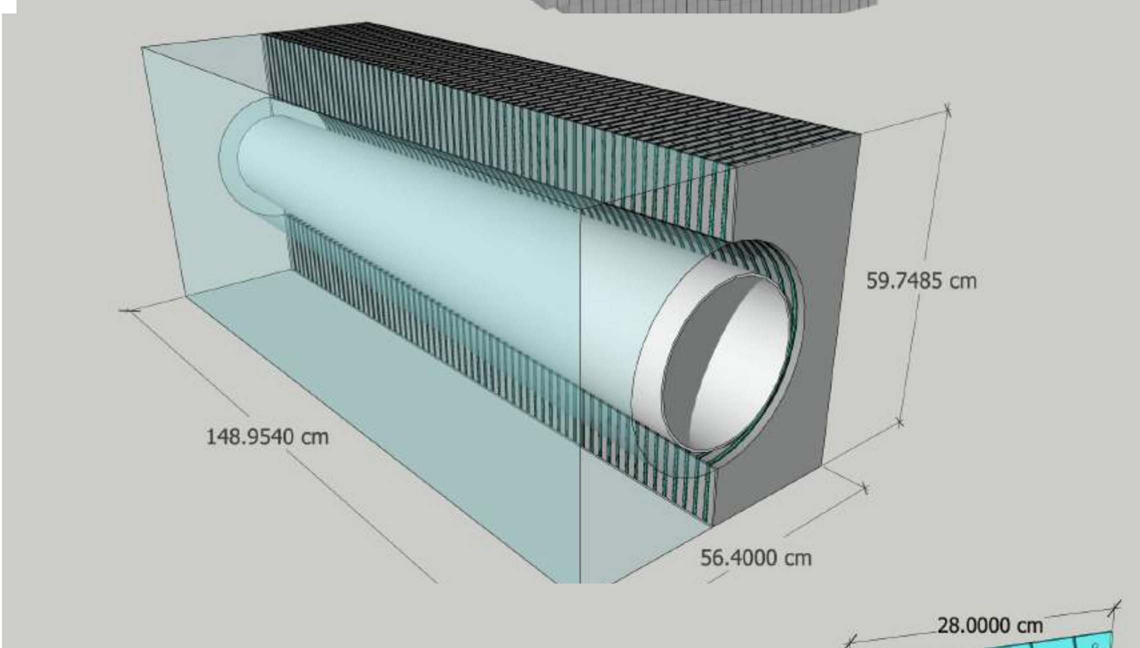
New BEMC, BC-630.
New arrangement of fibers works quite well.



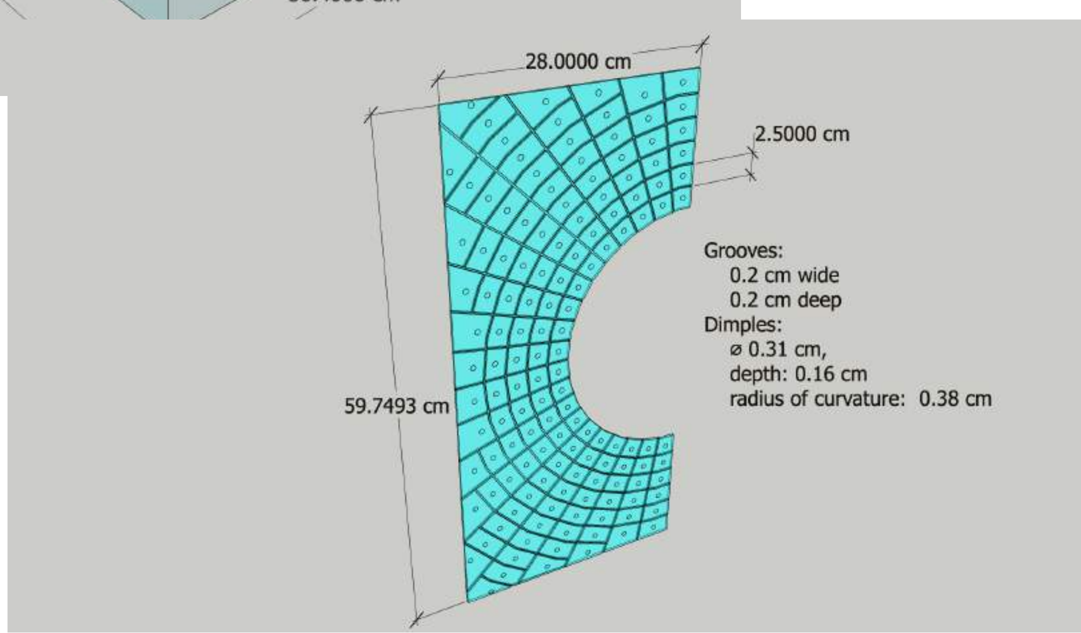
New BEMC, Lumisil 591
Better fiber arrangement and better coupling.

eRD106





M.Arratia (UCR)



Post proposal 'optimization'of pECal directions under discussion:

Outer area Ecal segmentation?
Reduction of readout channels?

Insert around beam pipe
Highest density, i.e. lower sampling fraction, thinner fibers, accordion?

Readout – moving ADC to FEEs pros/cons.

Summary:

- WScFi is a unique and mature technology.
- Lots of know how accumulated in EIC community during last ten years, eRD1 and construction of sPHENIX.
- pECAL build with this technology meet YR requirements.
- Performance, cost, risks are well understood.
- Design, and integration of pECAL looks very simple.
- Small developments are still needed to improve light collection.
- Discussions on readout scheme is needed, i.e. pushing ADCs to FEEs ?

Backup

Prototypes. Spacordion. Not There Yet!

2011 construction

SPACORDION was the first prototype. We build it using technique we 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.

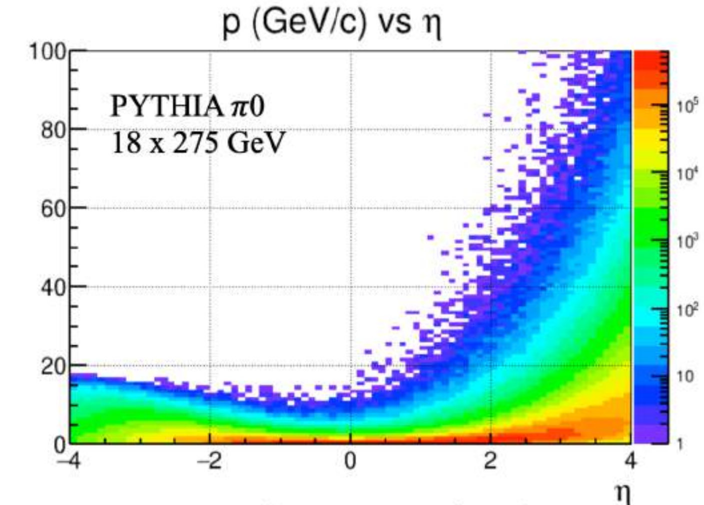
Not that Simple.

So, we refine technique for second prototype.

pECal functionality   Pi0/gamma separation

See https://indico.bnl.gov/event/14906/   talk by A.Bazilevsky

YR: Fig11.80



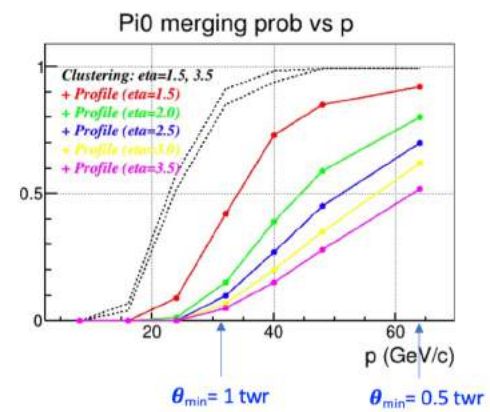
e-endcap: up to e-beam momentum

h-endcap: up to 50-100 GeV/c

Shower Profile Analysis

YR: Fig11.80

GEANT4: Forward EMCal with granularity ~0.008 (2.5×2.5 cm² at z=3m)



Shower Profile analysis:

$$\chi^2 = \sum \frac{(E_i^{meas} - E_i^{pred})^2}{\sigma_i^2}$$

E_i^{pred} and σ_i are f(x, y, E, θ, φ)

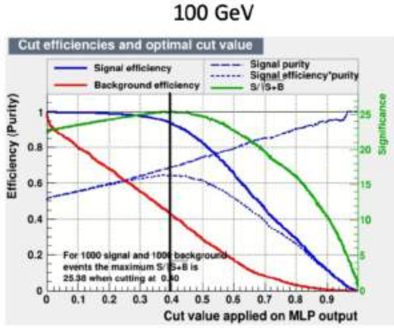
- Considerably extends the momentum range for $\pi 0/\gamma$ discrimination
- Strong dependence on rapidity (for non-projective)
- There is room for improvement ...

Pi0 merging prob after MLP

Signal/Background efficiency after MLP

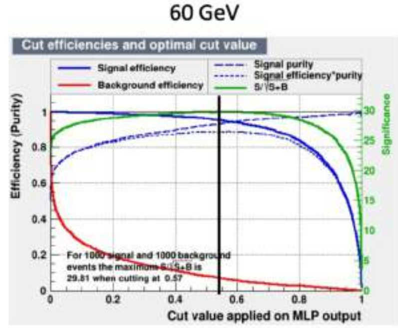
h-endcap: 2.5x2.5cm at z=3.5m, η=3

100 GeV



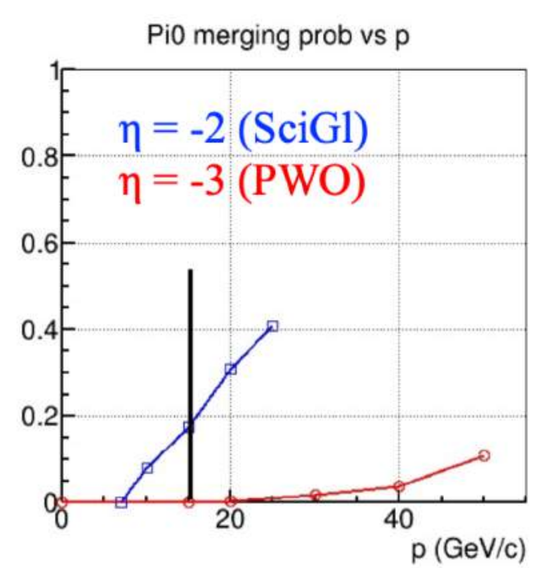
ε_{Bg} = 42% for ε_{Sg} = 95%

60 GeV

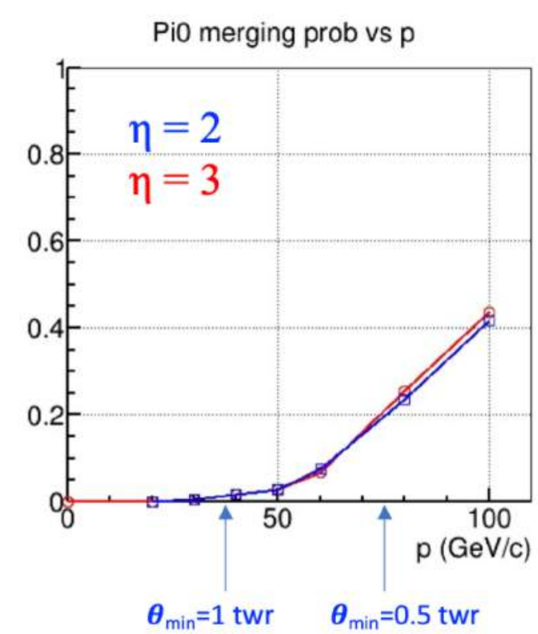


ε_{Bg} = 7% for ε_{Sg} = 95%

e-endcap:
PWO: 2x2cm at z=-2.1m
SciGl: 4x4 cm at z=-2.1m



h-endcap:
W/SciFi: 2.5x2.5cm at z=3.5m



Can effectively discriminate $\gamma/\pi 0$ even when two photons are separated by 0.5 tower size

Compactness of pECal is handy.