Progress Report
EIC Sampling Calorimeter Developments

O. Tsai (UCLA) for eRD1 Consortium

Contact Persons: H.Z. Huang huang@physics.ucla.edu and C. Woody woody@bnl.gov
S.Boose, J.Haggerty, J.Huang, E.,Kistenev, E.Mannel, C.Pinkenberg, M. Purschke,
S. Stoll, and C. Woody
(PHENIX Group, Physics Department)
E. Aschenauer, S. Fazio, A. Kiselev
(Spin and EIC Group, Physics Department)
Y. Fisyak
(STAR Group, Physics Department)
Brookhaven National Laboratory
F. Yang, L. Zhang and R-Y. Zhu
California Institute of Technology
S.Ali, M.Carmignotto, T. Horn, I.Pegg, A. Mkrtychyan
The Catholic University of America and
Thomas Jefferson National Accelerator Facility
W. Jacobs, G. Visser and S. Wissink
Indiana University
A.Sickles, V.Loggins
University of Illinois Urbana-Champaign
C. Munoz-Camacho, G.Charles, F. Georges, G.Hull
IPN Orsay, France
S. Heppelmann
Pennsylvania State University
C. Gagliardi and M.M. Mondal
Texas A&M University
L. Dunkelberger, H.Z. Huang, K. Landry, M.Sergeeva, S. Trentalange, O. Tsai
University of California at Los Angeles
Y. Zhang, H. Chen, C. Li and Z. Tang
University of Science and Technology of China
H. Mkrtychyan
Yerevan Physics Institute

EIC R&D Committee Meeting, Jan 26 2017

Topics investigated in the past six months.

Technology development for W powder ScFi emcals.

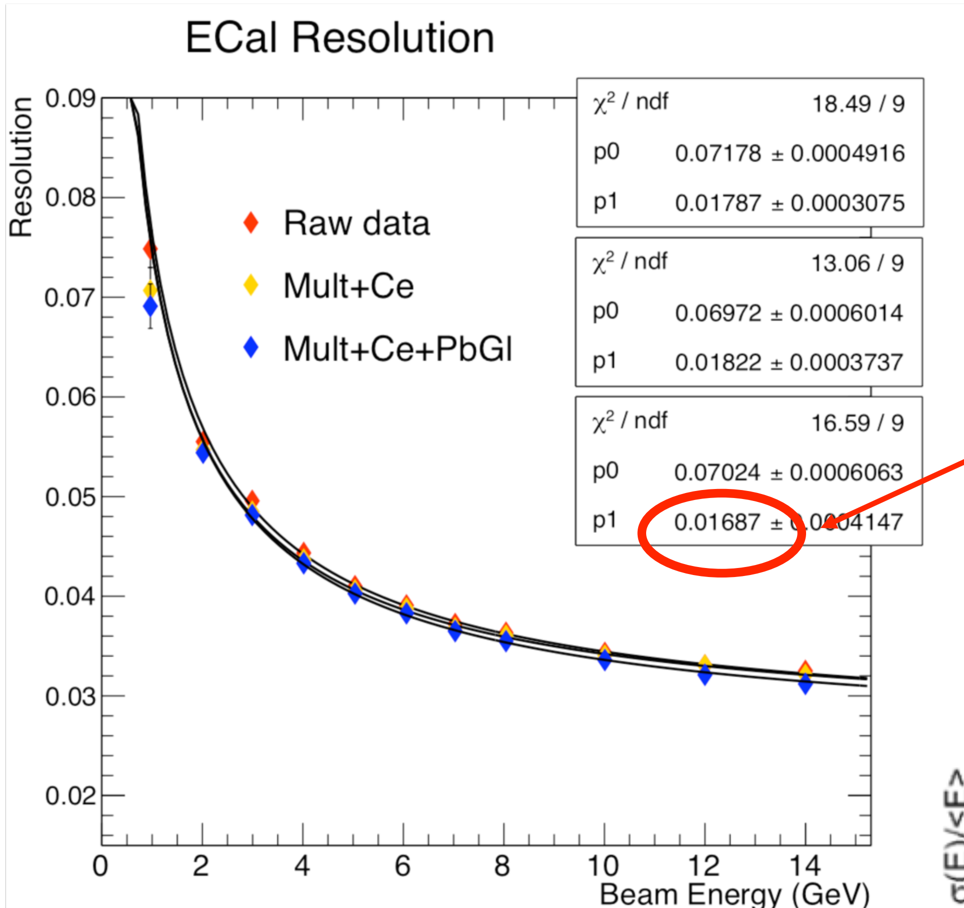
- Optimization of light collection scheme.
- sPHENIX R&D on 2D projectivity.

Evaluation of SiPMs readout sensors.

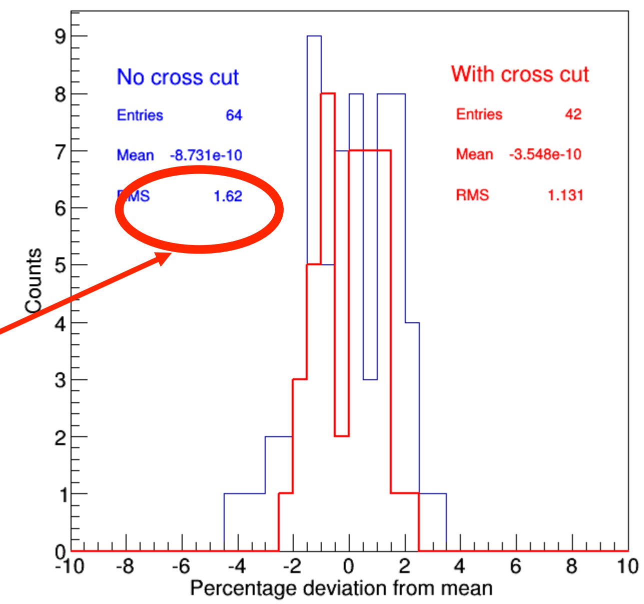
- Radiation hardness (neutrons vs gammas).
- Anomalous signals.

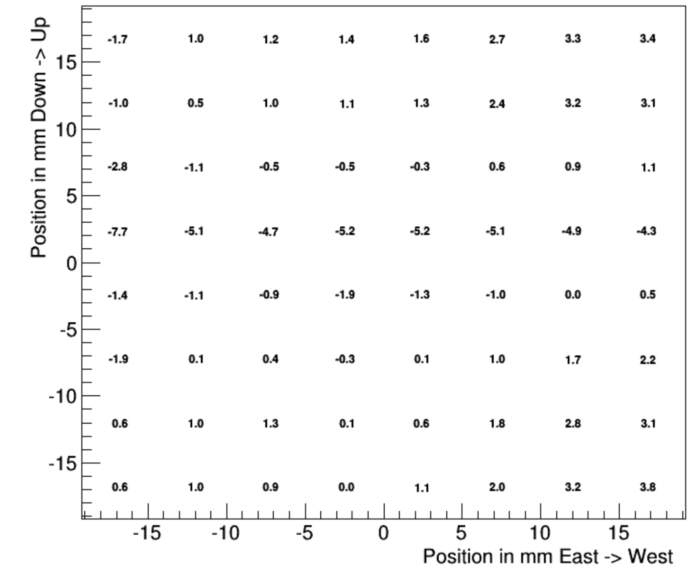
Optimization of light collection:

Uniformity of response 'S' BEMC, Test Run 2016
Ideal Light Collection Scheme

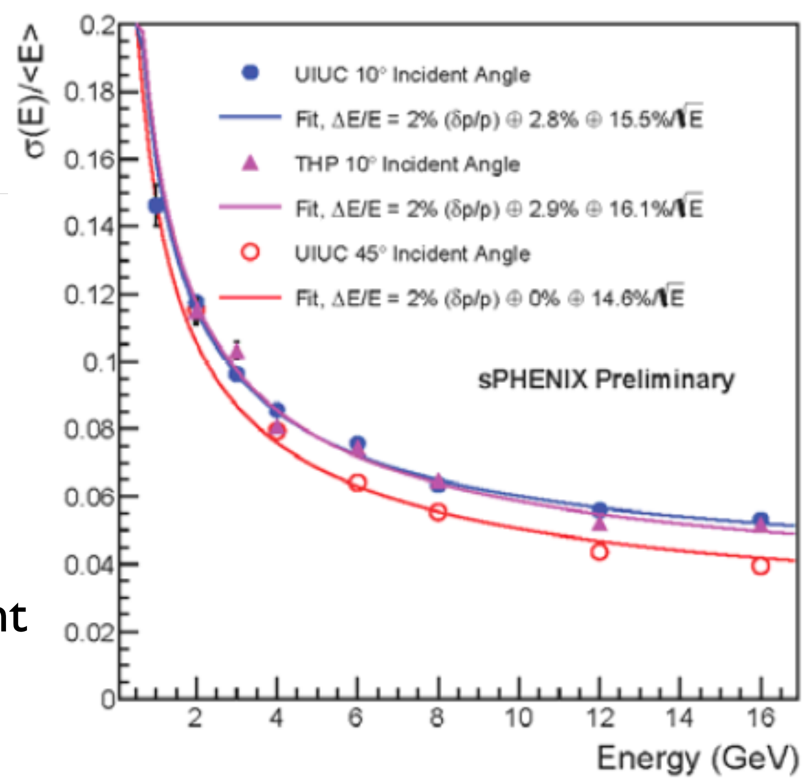


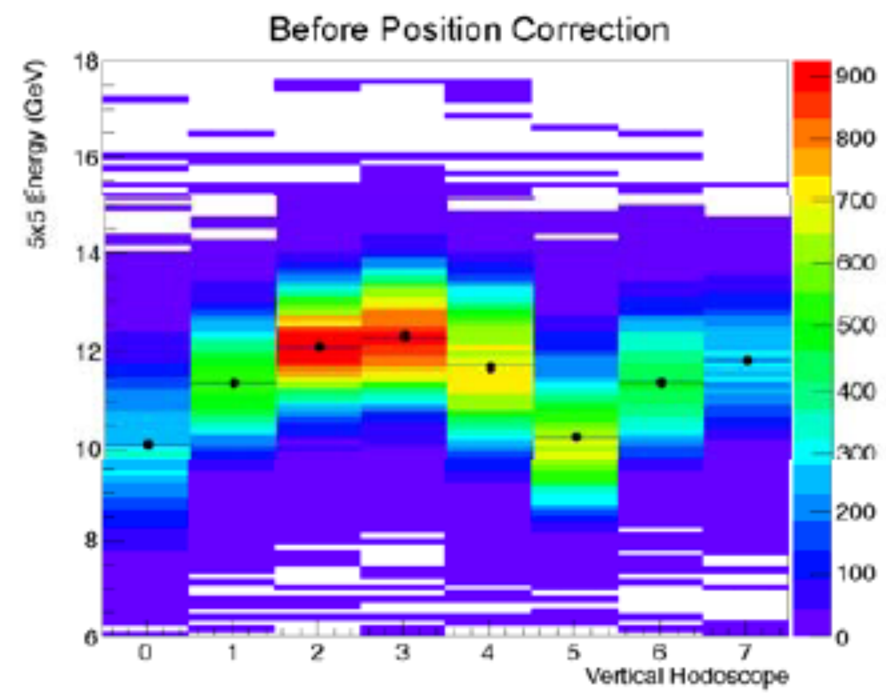
'S' BEMC, Test Run FNAL 2016





1D sPHENIX W/ScFi, Test Run 2016





Energy resolution after making correction for position dependent response using hodoscope.

- Non-uniformity of compact scheme of light collection in current design of W/ScFi is a major contributor to constant term in energy resolution.

Optimization of light collection:

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

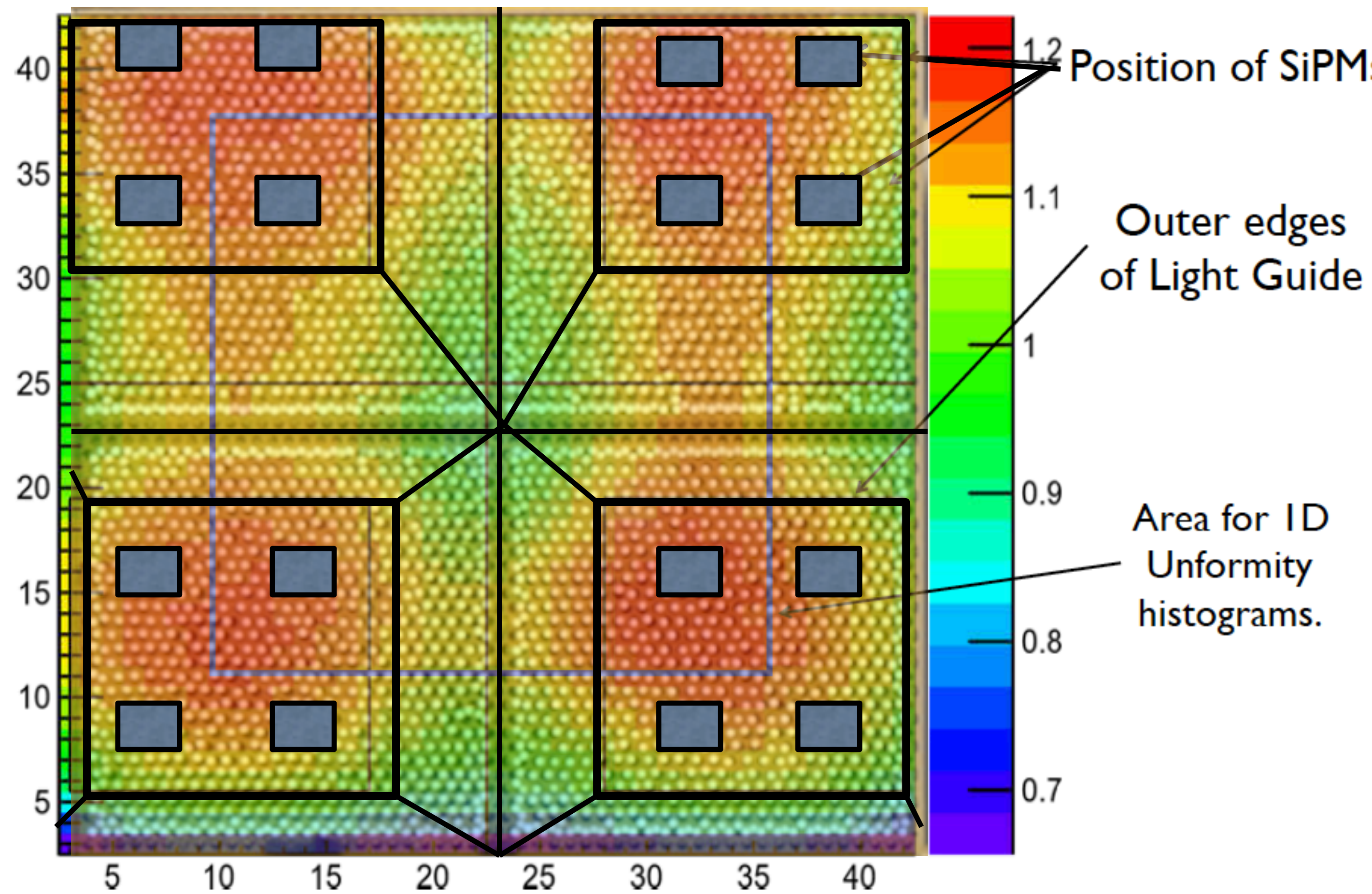
Solutions we tried in the past:

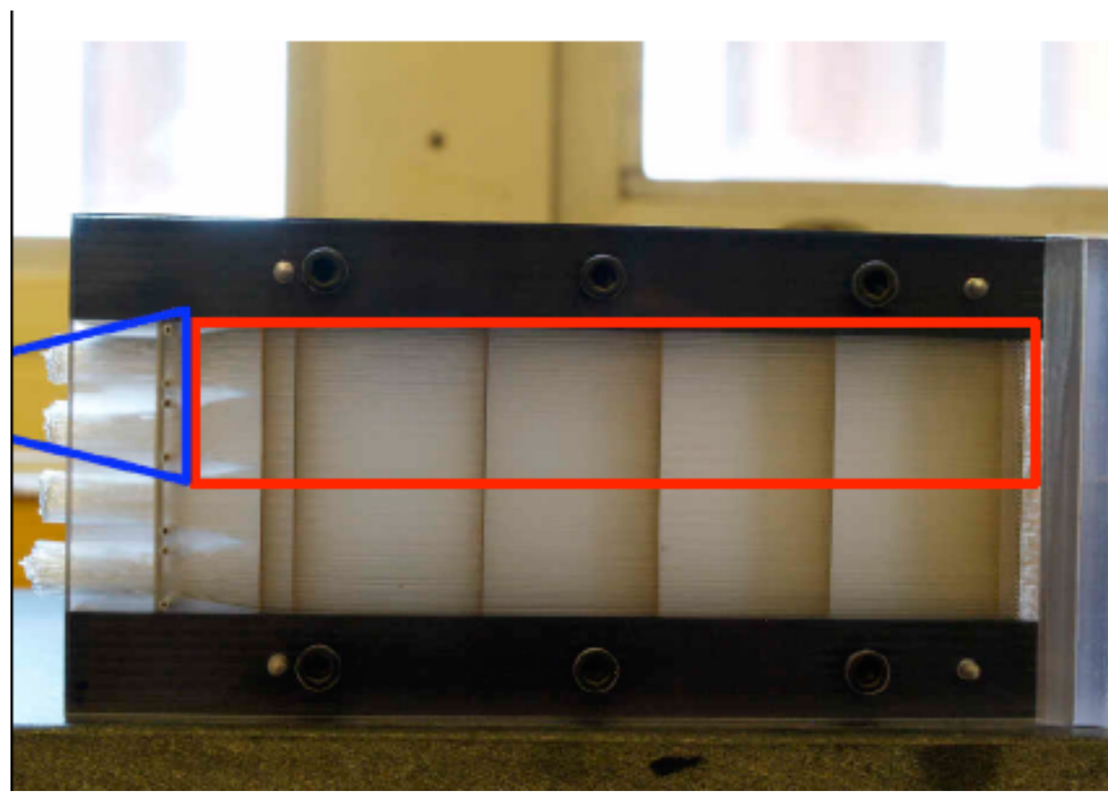
1. Compensation Filter between fibers and light guide. Loss about 30% of light (test run 2015). Will not work for FEMC.

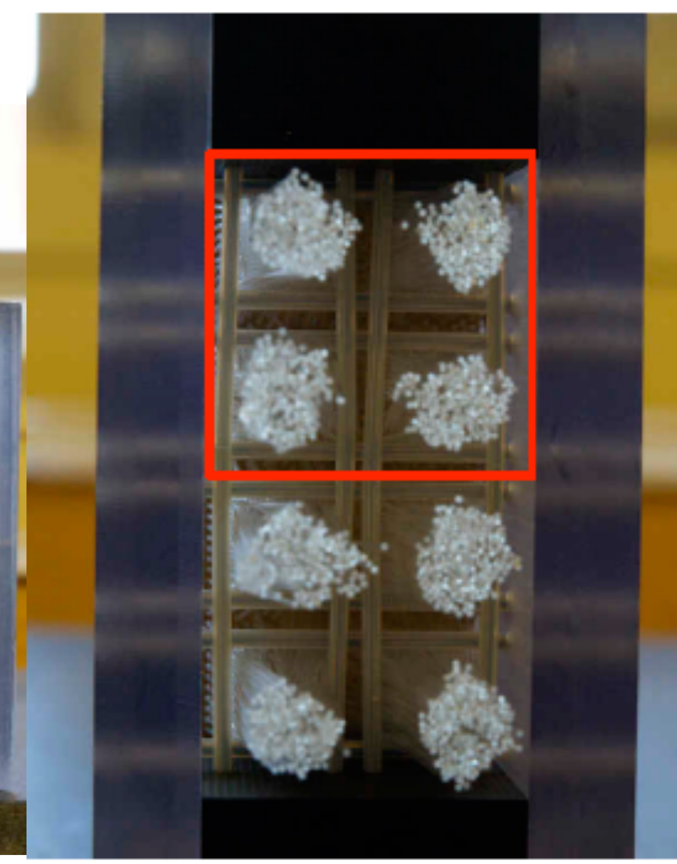
2. Compensation with gradient reflector from the back side of the superblock. Practicality issues.

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.

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





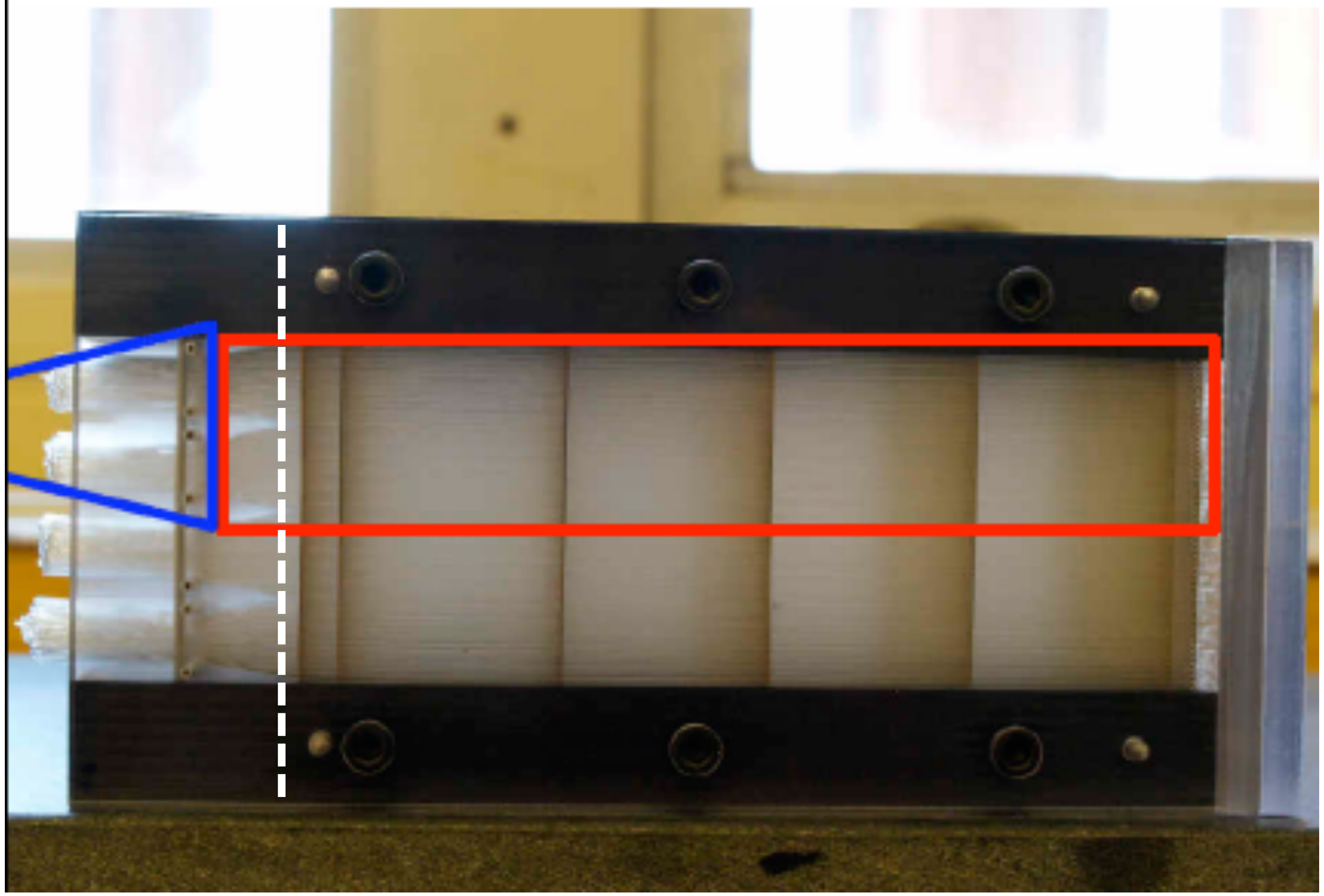


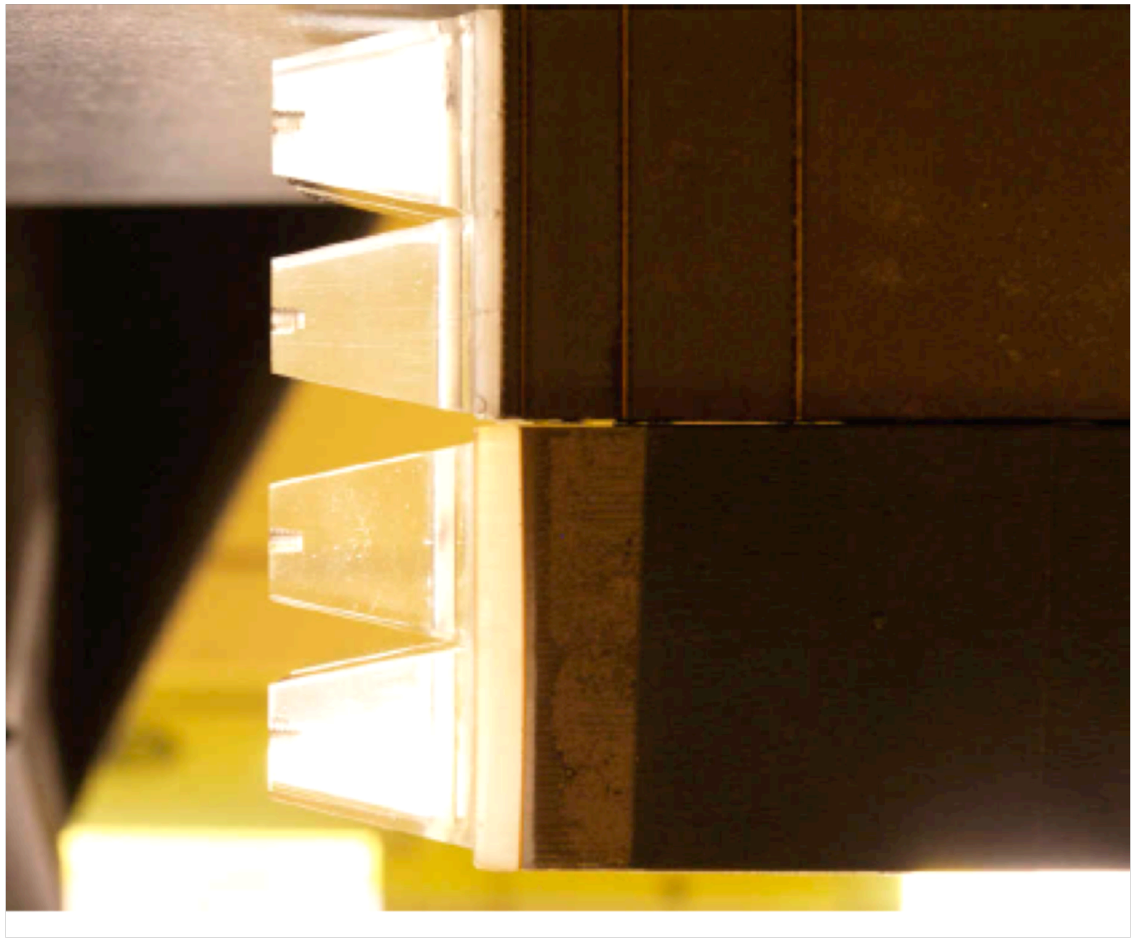
In 2014 we dropped development of 'bunched fiber' configuration for two reasons:

1. Introduction of volume in tower with 100% sampling fraction.
2. Practical issues; four independent light guides, mechanical mounting of FEEs to towers.

However, if one need to change angles of fibers only, then cut can be done close to the last mesh and one can use the same single light guide as in previous versions.

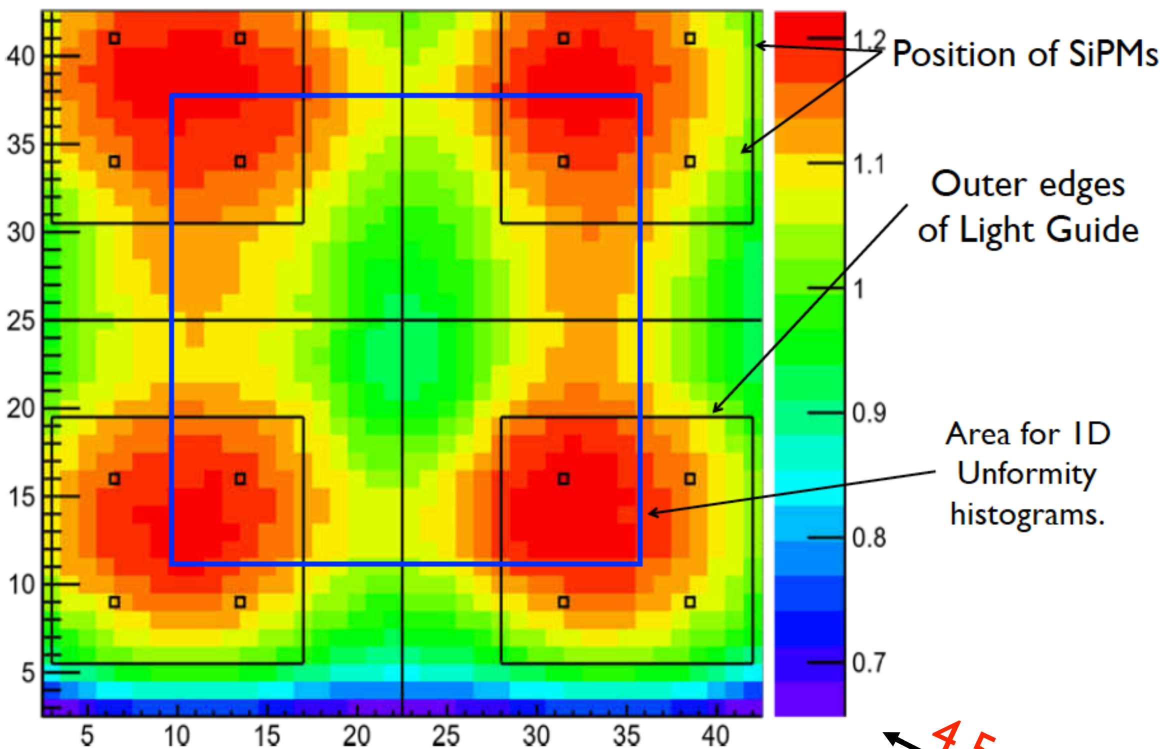
The last mesh has larger diameter holes to allow bending of fibers.



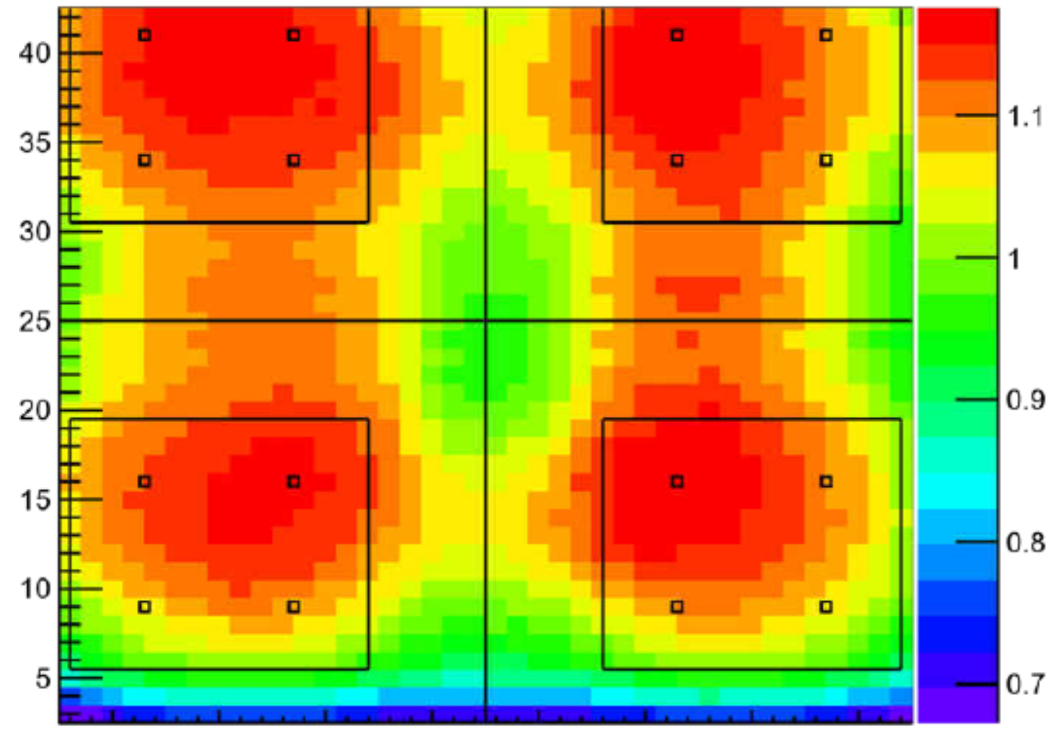


Optimization of light collection:

BEMC Superblocks, UV LED Map

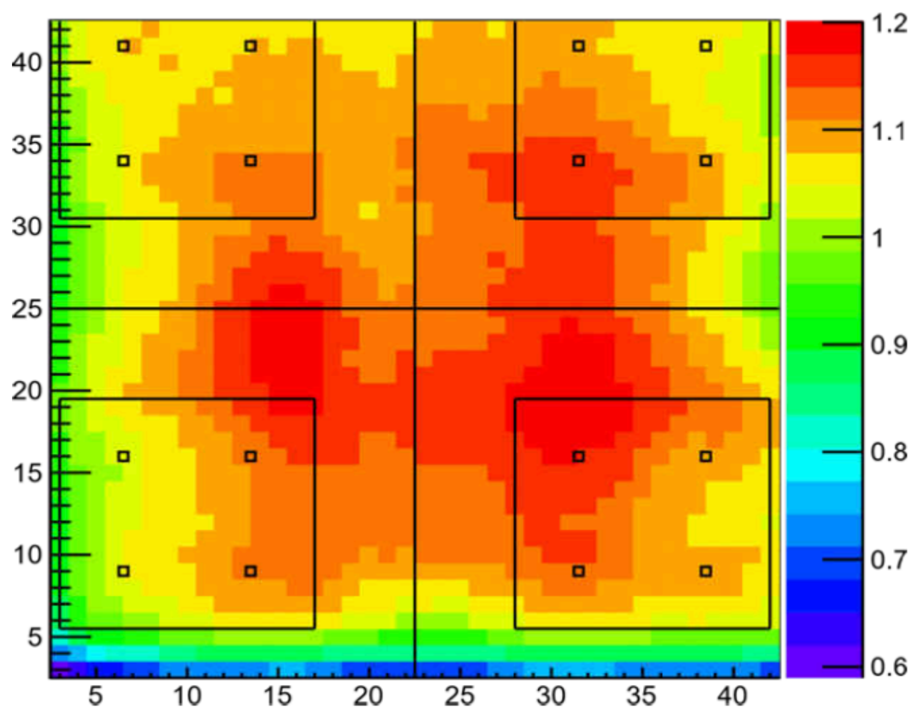


Old BEMC, Sylgard 184, 3mm

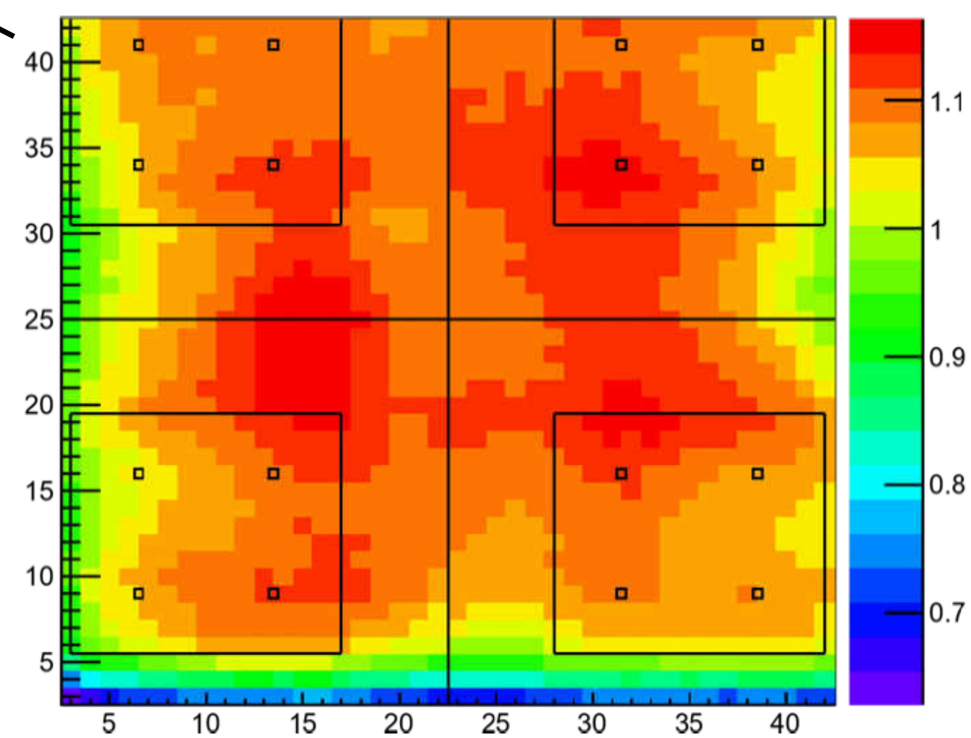


Old BEMC, BC-630, coupling is important

4.5 times better

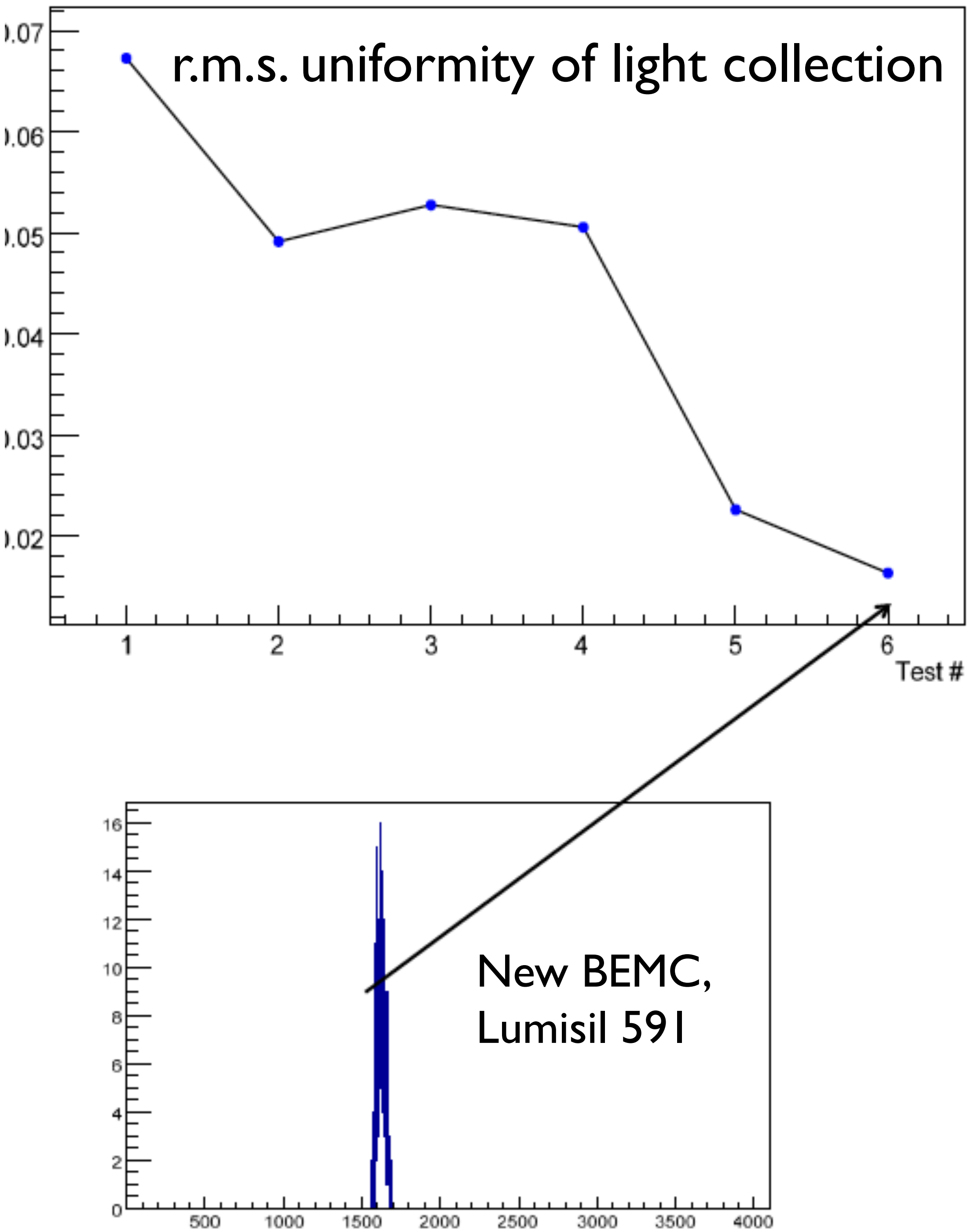


New BEMC, BC-630.
New arrangement of fibers works quite well.



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

Optimization of light collection cont.:

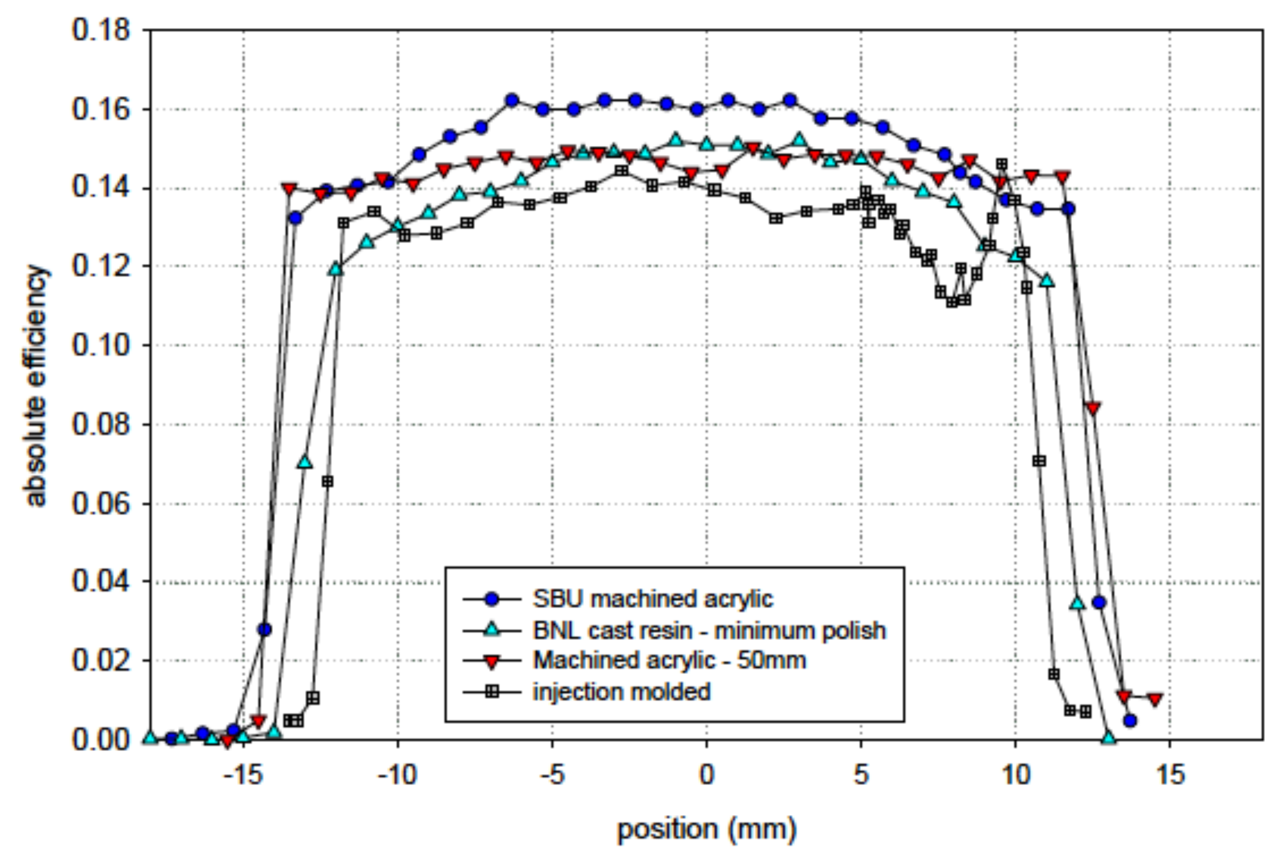


For new BEMC Superblocks with Lumisil coupling non-uniformity is 1.6% (r.m.s.), which is close to what was achieved for HR version with long light guides/PMT in the test run 2016 (see slide 3).

Things to complete, perform scans with new BEMC module equipped with 1.25″ and 1.5″ long light guides.

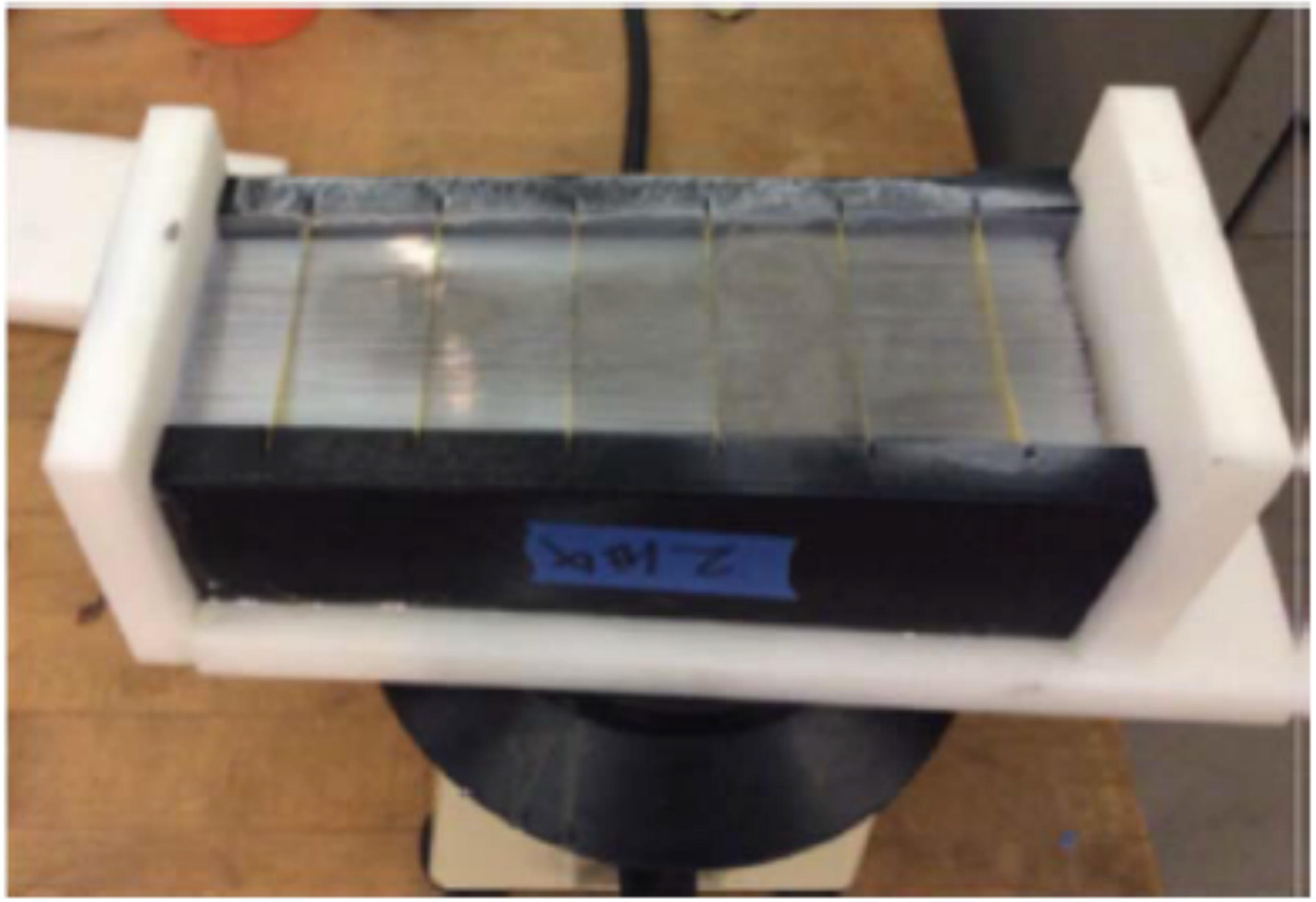
Parallel development for sPHENIX.

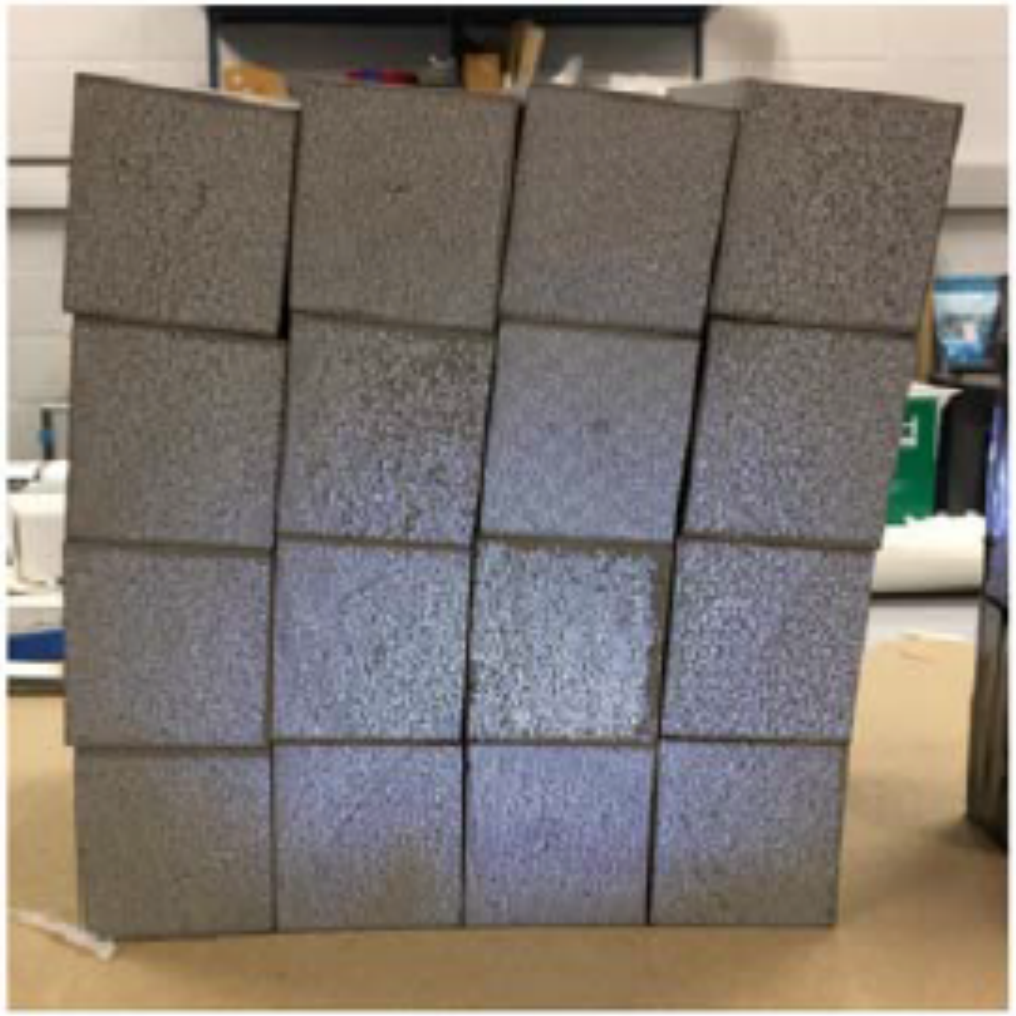
- Geometry (length of light guides).
- Method of mass production (molding, casting).



1D scans in the middle of light guide with a single fiber.

W/ScFi 2D projectivity, sPHENIX.



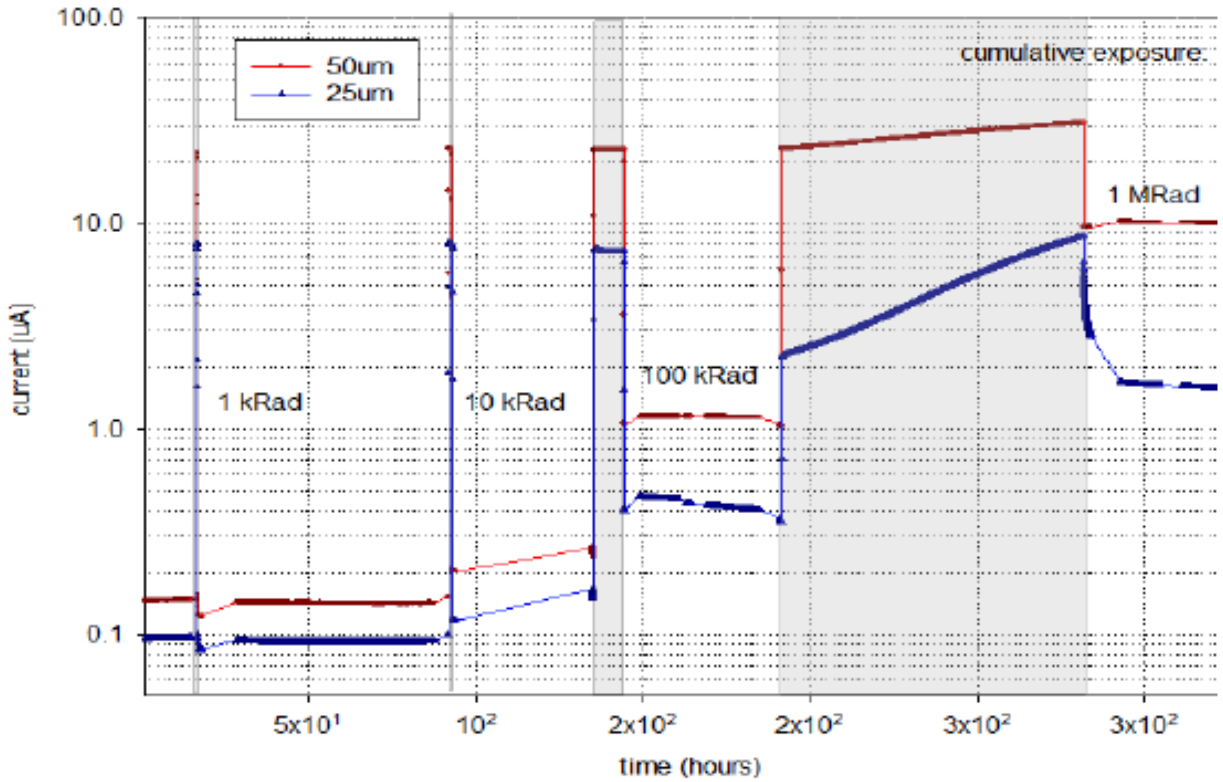


Substantial progress in learning how to build 2D projective W/ScFi blocks.

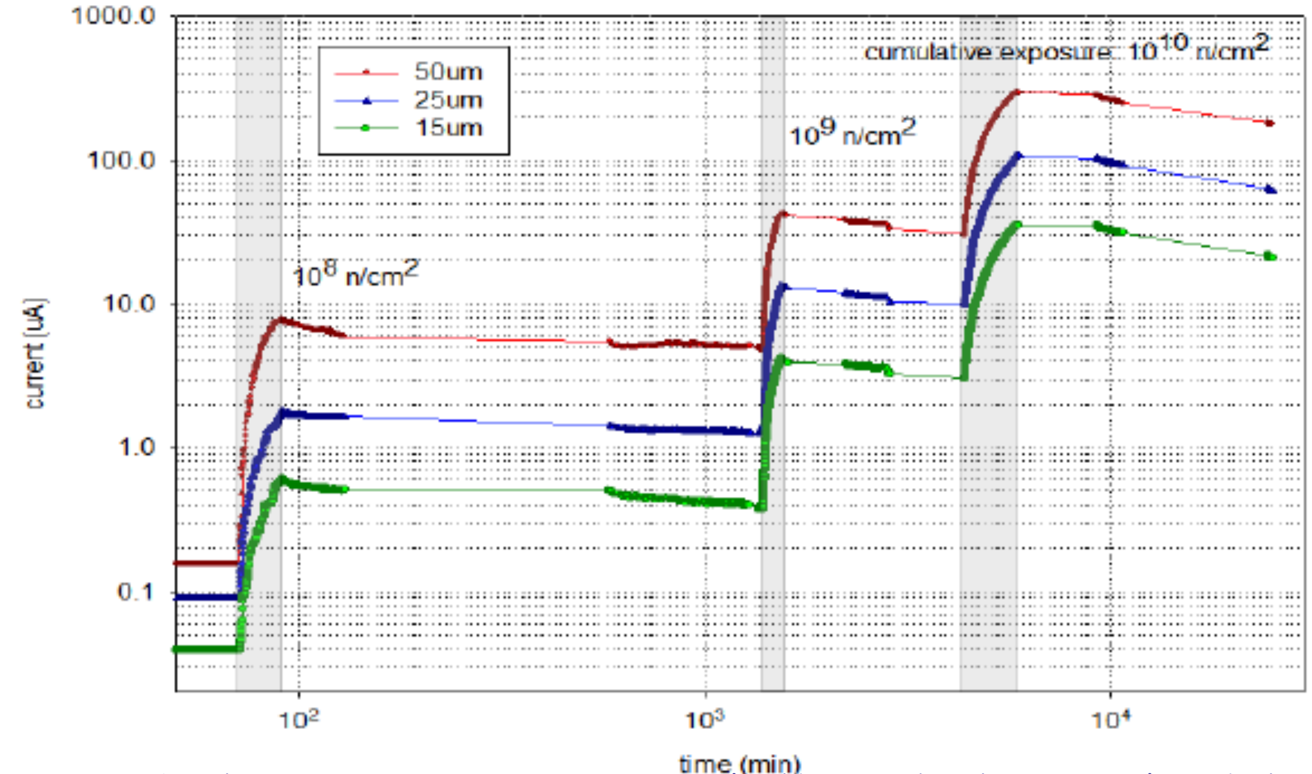
- 16 blocks will form 8x8 array of towers for high eta end of sPHENIX emcal module.
- Blocks produced at UIUC using "bath tab" method.
- Two different light guides (25 mm and 50 mm long).
- Molds produced using inexpensive 3D printing process.
- Prototype is currently at FNAL being tested along with high eta version of sPHENIX HCAL.

SiPMs evaluations:

- Radiation hardness (neutrons vs gammas), sPHENIX
- Radiation hardness of optical windows, sPHENIX
- Anomalous signals at STAR IP, Run 17

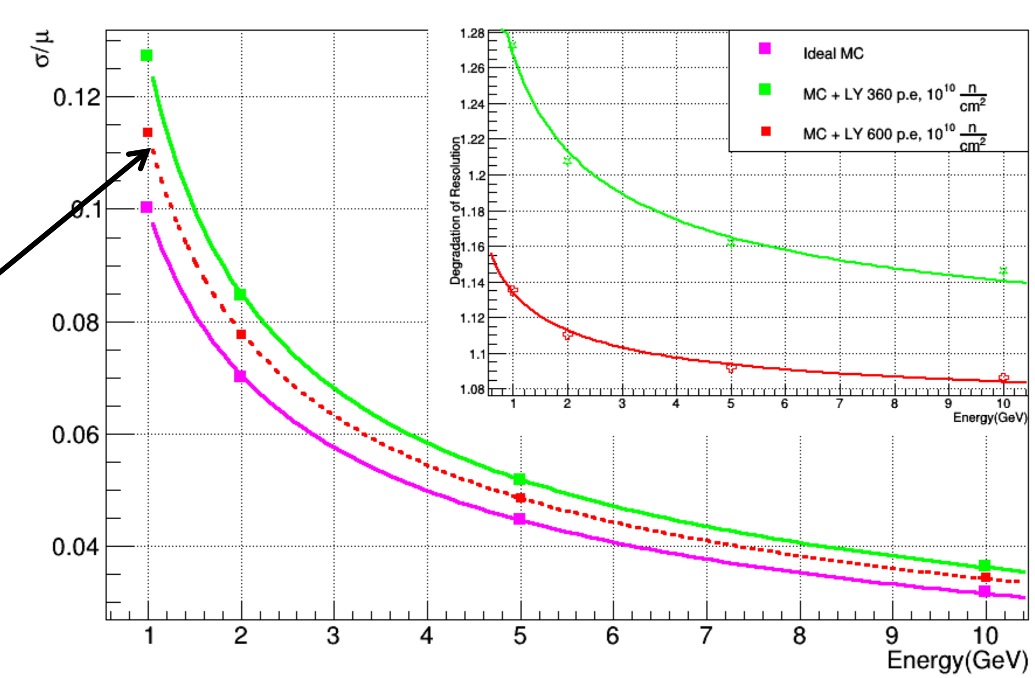


^{60}Co Irradiation. Point like defects only (e^- needs ~ 8 MeV to create cluster and ~255 keV to produce Frenkel pair).



Neutrons E_n = 14 MeV Irradiation. Clusters and point like defects. (En > 35 keV to produce cluster and 185 eV for Frenkel pair).

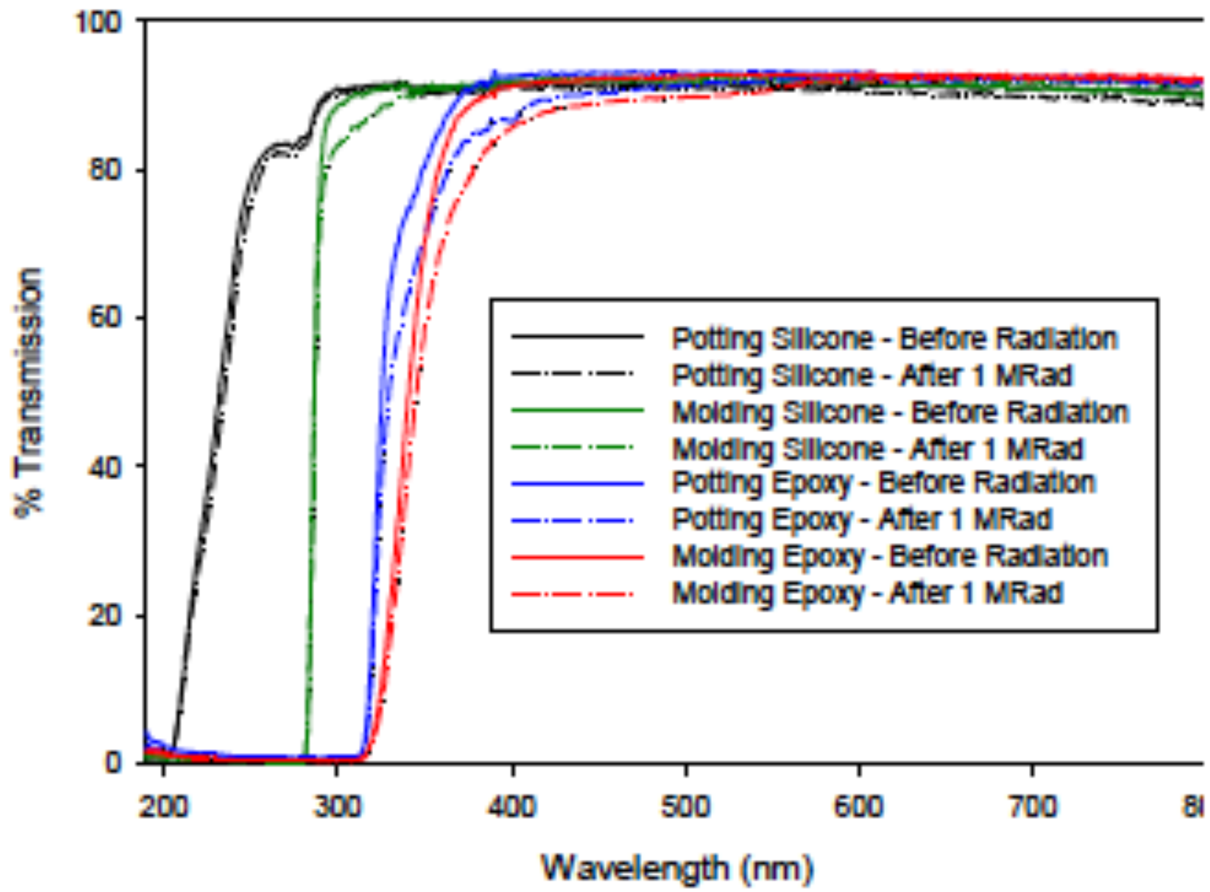
Readout 4 SiPM per Tower (FEMC,CEMC)

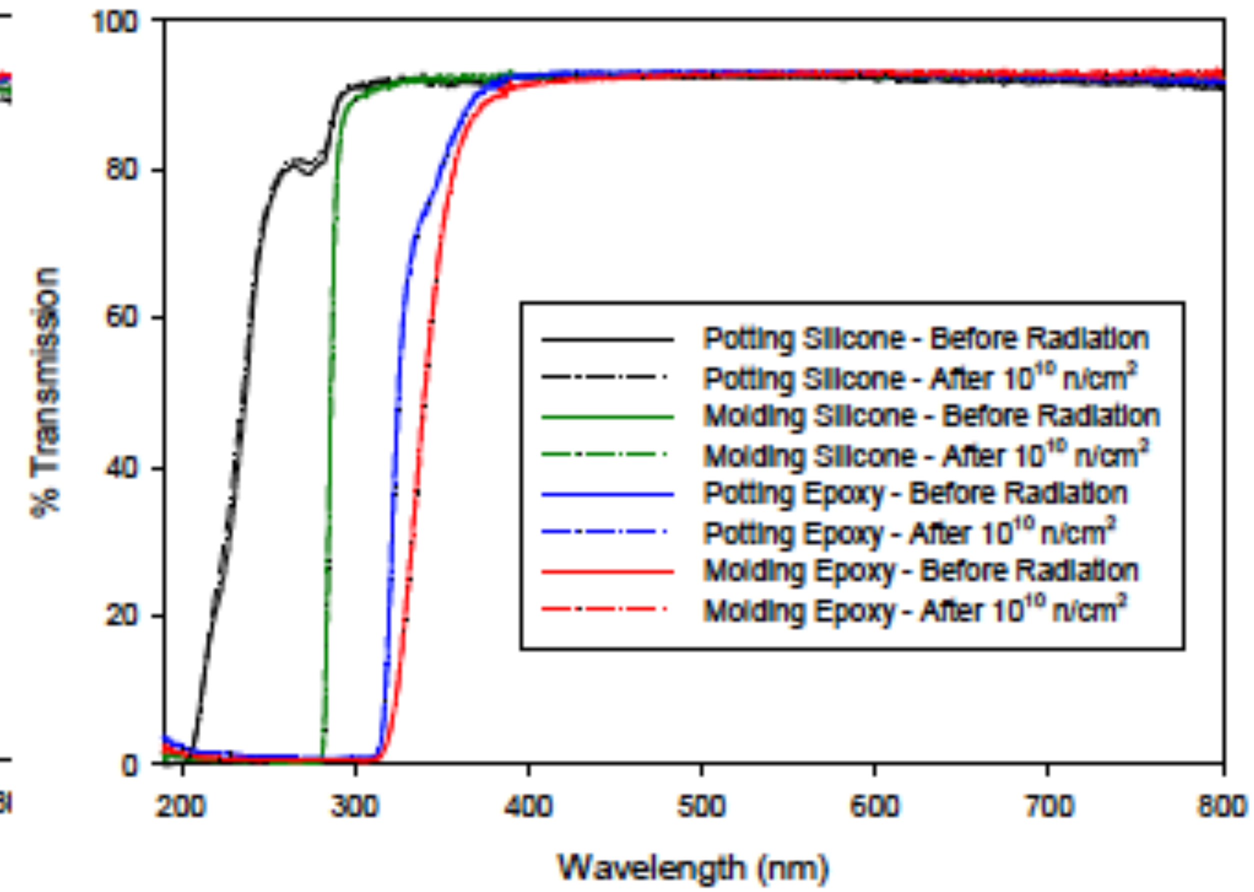


- Leakage current, well understood behavior.
- 10^{10} n/cm^2 expected only for central region of BEMC. It is two orders of magnitude lower for Central Emcal.
- Effect on energy resolution was estimated, and with assumption light yield will eventually reach 600 p/GeV degradation after exposure to 10^{10} n/cm^2 will be less than 10% above 3 GeV.

Optical components:

- Light guides, coupling media, epoxy window in SiPMs
- We used component tested to much higher doses (CMS R&D)





Conclusion from these studies is that there should be no degradation in performance of these components (loss of transparency).

SiPMs 2017 tests at STAR IP cont.:

- SiPMs insensitive to NCE (Established. Tests during Run16).
- SiPMs may be sensitive to ‘showers’ (Indications. Tests during Run 16, also reported by CMS HCAL upgrade R&D studies).

Run 17 want to turn ‘Indications’ into solid numbers, i.e. $N_{abn.\ pixels}$/GeV

- BEMC was outfitted with large light guide to have 100% eff. Light collection for PMT end.

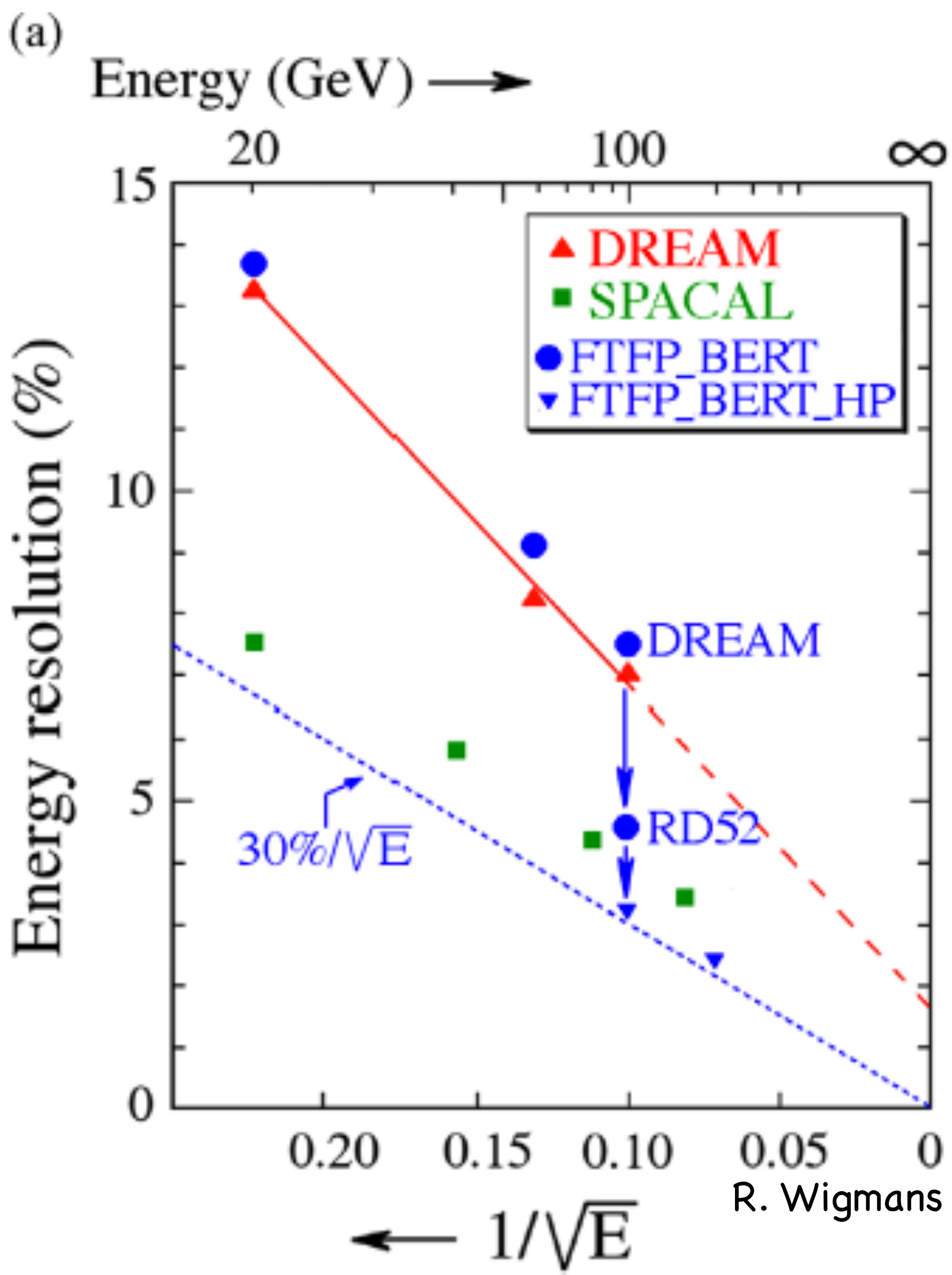
- Produced new sets of FEEs with new sensors for BEMC (64 SiPMs collecting scintillation light + 64 blind SiPMs sensitive only to ionization).

- Installed at the East Side of STAR ~ 1 meter away from the beam pipe.

- Result(s) is very important to make decision on readout sensors for Bacward HCAL. Development HCAL readout, part of R&D for next year.

Summary and Future Planning:

- Most of the goals consortium set for past six months were reached.
- Some tasks had to be scaled due to restricted budget.
- Part of R&D program for next year is defined - optimization of Backward HCAL.



R. Wigmans NIM A824 (2016)

For Discussion:

- High Resolution (30%/√(E) Hadron Calorimetry is needed for EIC (forward spectators tagging, see C. Hyde (ODU) talk at last EIC users meeting at ANL).
- Very Challenging! Can not be borrowed from somewhere. Has to be developed.
- But, it is very costly. Will require 'creative' funding. May be few (different from EIC R&D) sources contributing?
- To prove it works require to build large scale prototype (leakages) and advanced readout.

Backup Slides.