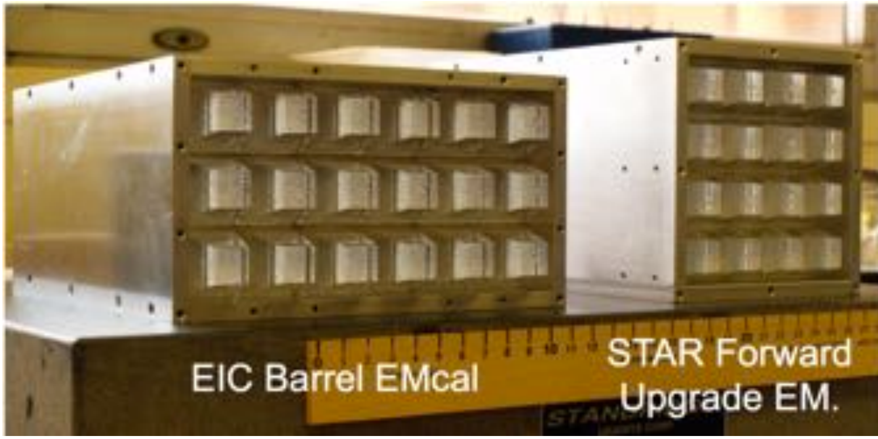
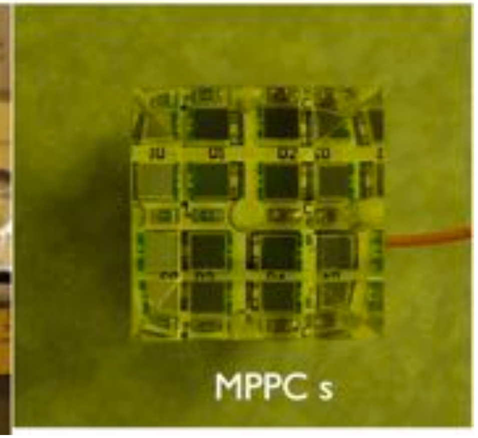
WScFi as a candidate technology for Lumi Ecals. Some details.

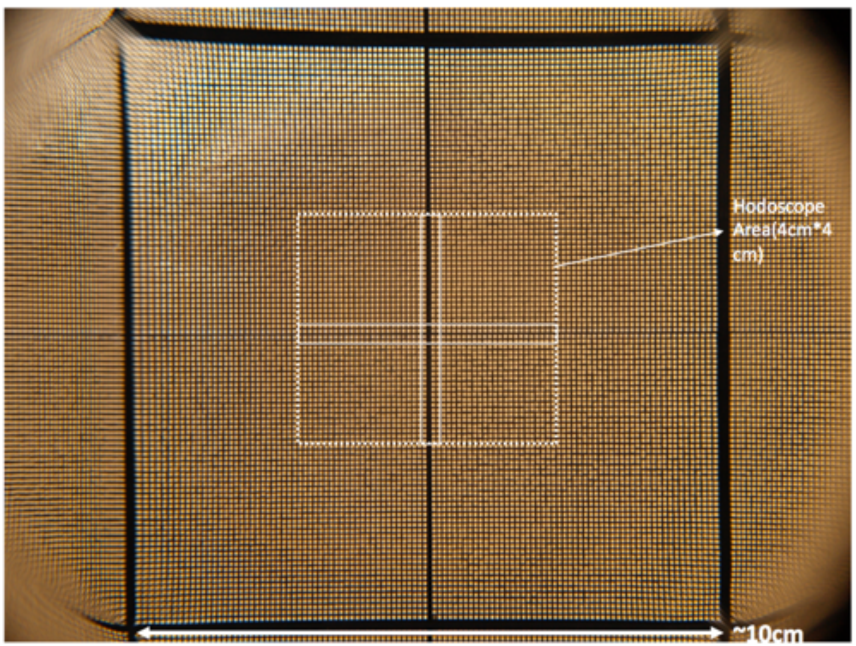
O.Tsai (UCLA/BNL) 06.27.2023

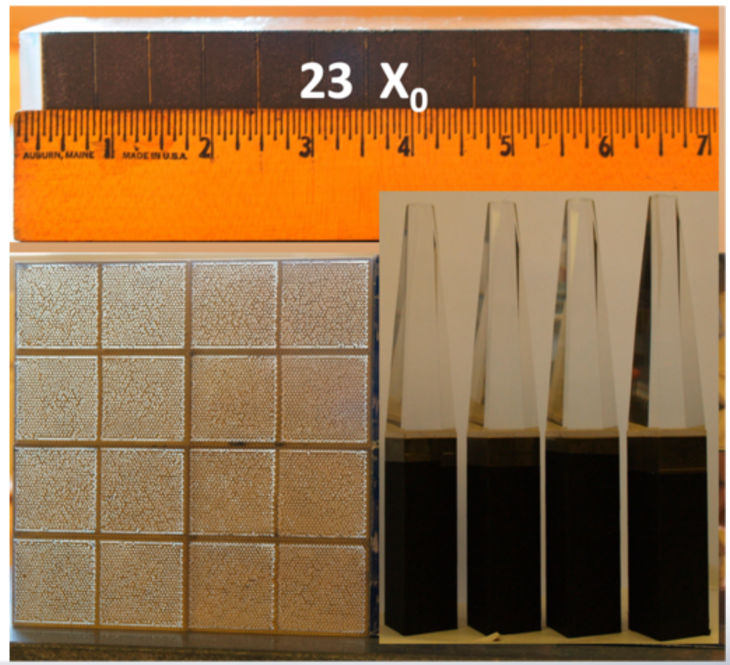
Highlights from generic EIC R&D.





Different WScFi prototypes were tested at FNAL from 2012-2016.





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

Results from generic EIC R&D. FNAL 2012

Parameters:

Final Density - 10.17 g/cm^3,

X_0 ~ 7 mm, R_m ~ 2.3 cm (KPR)

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.)

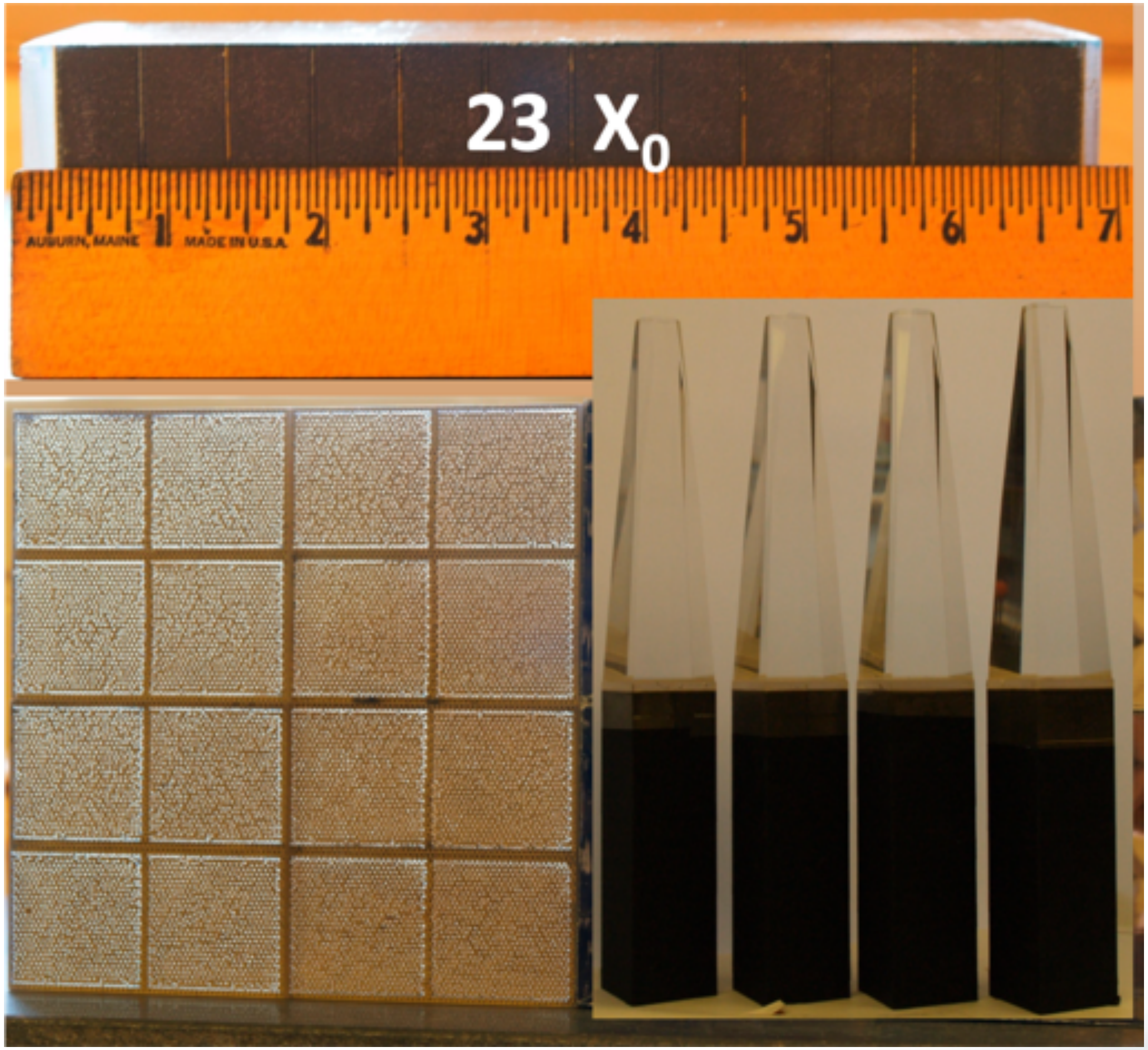
Number of fibers -3120

Resolution ~12%/√E (GEANT4)

Light collection. Acrylic light guide + ESR mirror pipe.

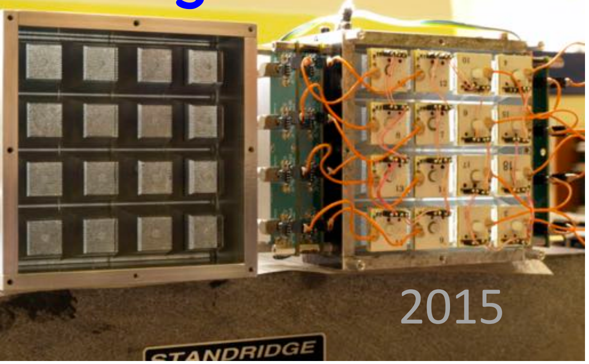
PMT – Electron Tube 9125B

Optical contacts, BC-600, BC-630



The front face mirror was made from ESR coupled with BC-630
This was the weakest link (uniformity) going to the test run.

High Resolution Sampling BEMC, 2016 R&D.



'is W/ScFi technology still feasible towards high-resolution calorimeters with future development?' (After 2015 Test Run)

Potential problems with the first 'O' HR prototype in 2015:

- homogeneity of the composite absorber
- consistency of the sampling frequency with thin fibers
- damage at the end of the fibers due to machining
- efficiency of light collection with compact readout.

In 2016 we proposed to build an additional 'S' prototype which did not have complications with the homogeneity of absorber and consistency of sampling frequency. This prototype consisted of thicker, square fibers and an absorber of 100% W-powder.

Detector	Fibers SCSF 78	Absorber	Sampling Frequency	Composition by weight	Number of fibers in superblock
"Old" High sampling frequency	Round, 0.4mm	75% W 25% Sn	0.671 mm Staggered Pattern	W -0.665 Sn – 0.222 Sc – 0.057 Epoxy- 0.056	25112 Damaged 3
"Square" High sampling fraction	Square, 0.59 x 0.59 mm²	100% W	0.904 mm Square Pattern	W – 0.858 Sc- 0.075 Epoxy- 0.067	11664 Damaged 0

BEMC ‘S’ type, 2016 R&D.

Why to try square scintillation fibers?

No ScFi calorimeters in the past were built with square fibers.

Pros:

- better light yield (according to Kuraray ~ 30% better trapping efficiency compared to round fibers, which is particularly interesting for compact light collection scheme)
- internal structure of the detector can be made more homogeneous
- easier to preserve sampling fraction and frequency within and between superblocks (glued from four production blocks).
- larger surface area for a given volume

Cons:

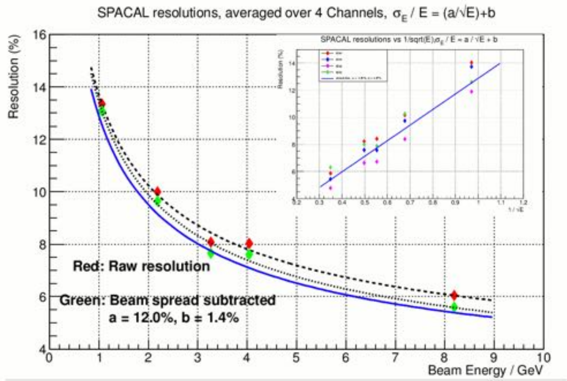
- more expensive
- more difficult to feed through the set of screens

Joint between two production blocks

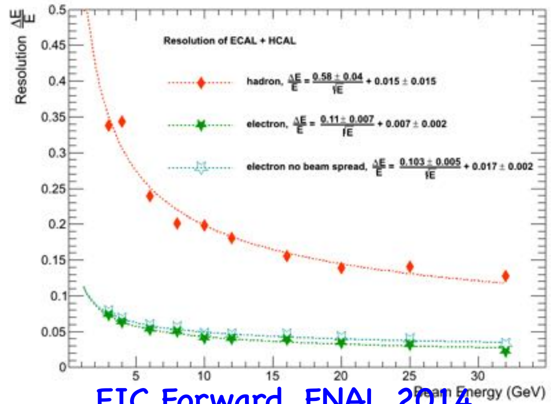
Joint between two doublets (‘Crack’)

Highlights from generic EIC R&D.

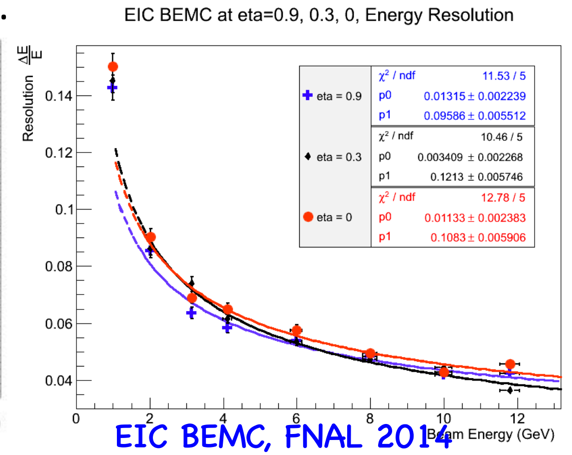
Performance of forward Ecal matches well to EIC needs.



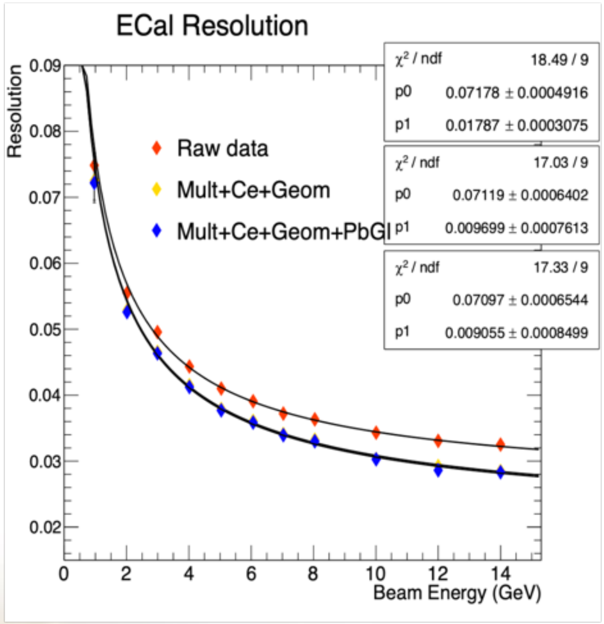
Proof of principle, FNAL 2012



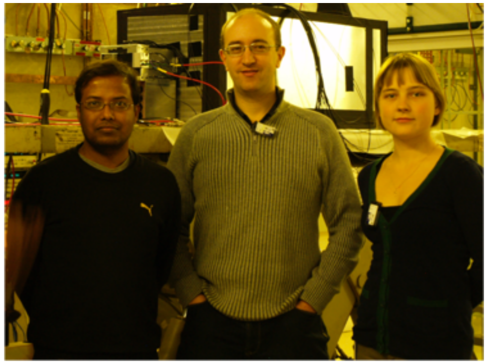
EIC Forward, FNAL 2014

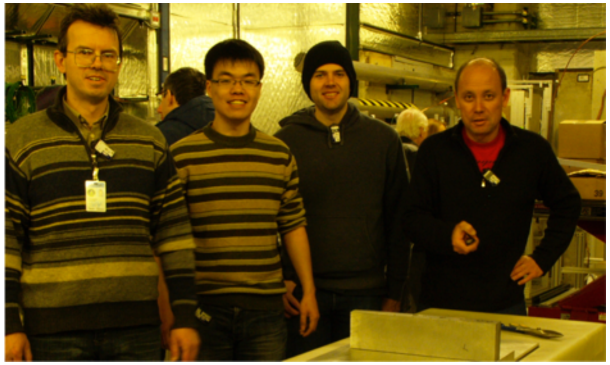


EIC BEMC, FNAL 2014



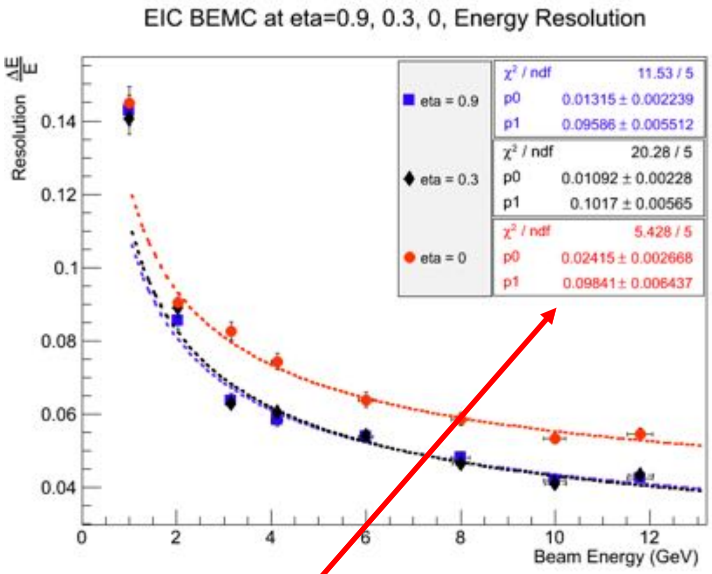
EIC Backward, FNAL 2016

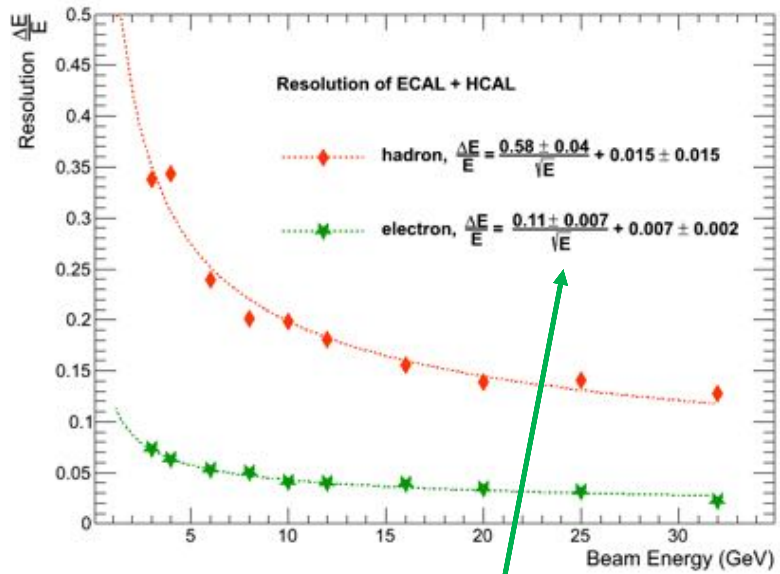


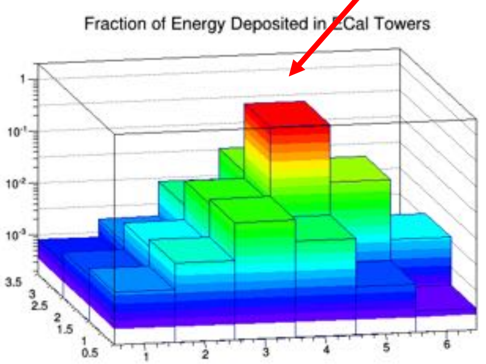


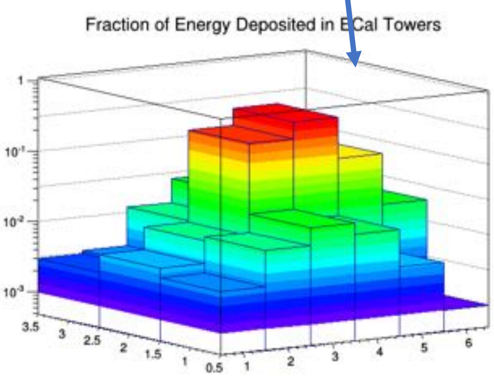
Test Runs 2012 -2016

Highlights from generic EIC R&D.







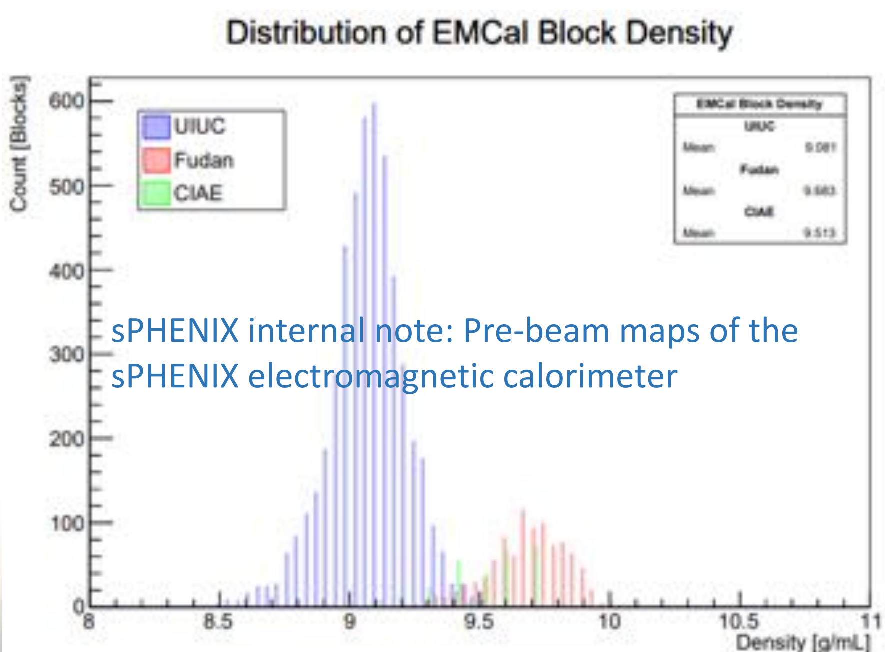


- Forward Ecal (4 x 4 towers).
- Energy corrected on impact position using calorimeter information only.
- That matches EIC needs.

Indication, that for $\eta < 2$ current non-uniformities may be acceptable as it is, for stochastic and constant terms satisfied.

Major Components. Tungsten Powder

Tungsten Powder QA at Fudan:
Tap density: ~ 11.5 g/ml
Purity: >99.9%, Fe, Co, Ni <0.1%
Size: 70μm~160μm
EMCal block desity: ~9.6 g/cm^3



sPHENIX internal note: Pre-beam maps of the sPHENIX electromagnetic calorimeter

All prototypes build in 2013-2016 used Tungsten Heavy Powder (THP, San Diego) powder.

Fudan group did extensive search (for sPHENIX) in China to locate vendor for W powder similar to one used in UCLA prototypes.

Important parameters for W powder are particle size and distribution.

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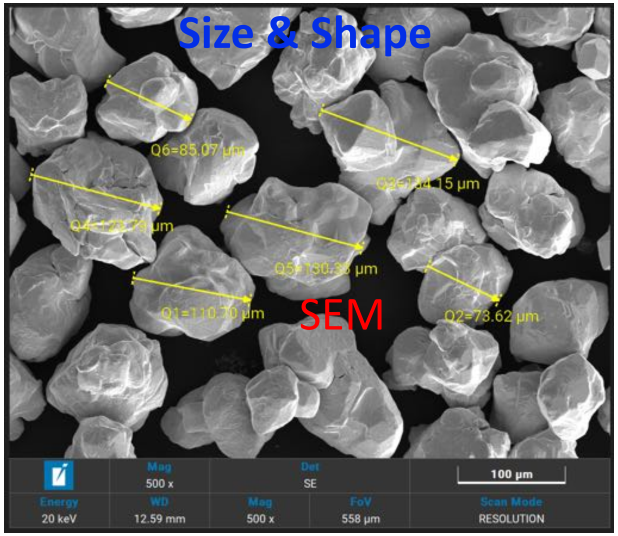
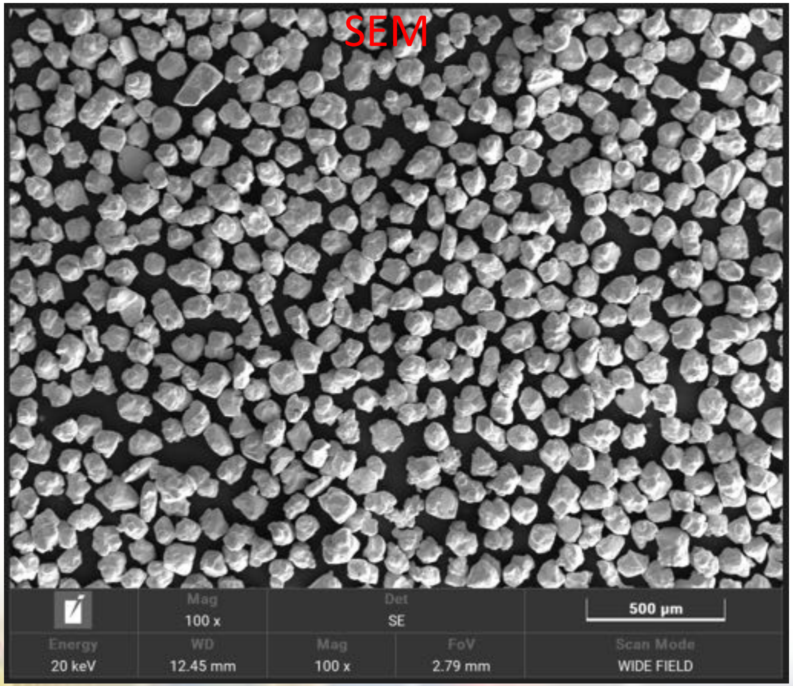
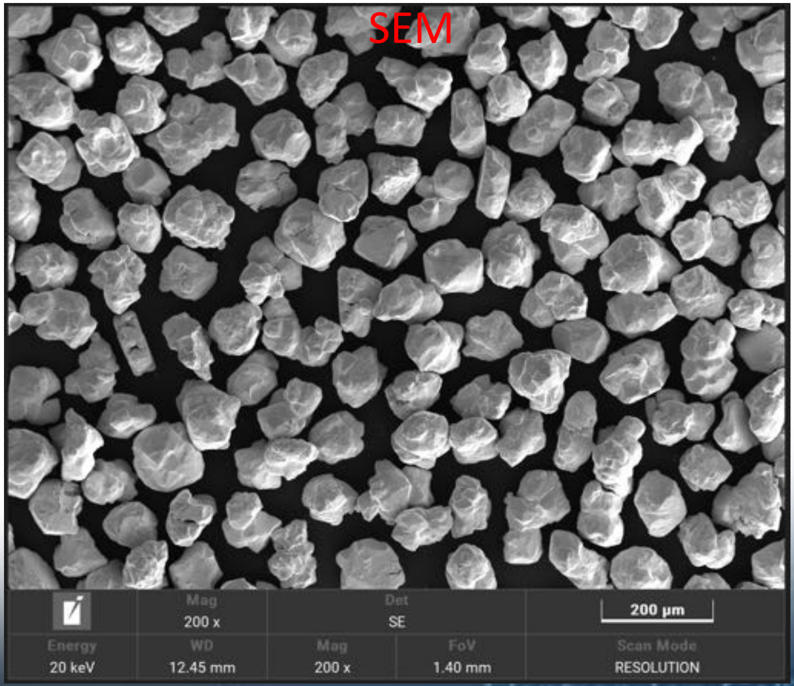






Major Components. Scintillating Fibers.

Extensive communications with KURARAY and SAINT-GOBAIN (now it is SGC/Luxium Solutions).
(SGC/Luxium will visit UCLA on 12/14)

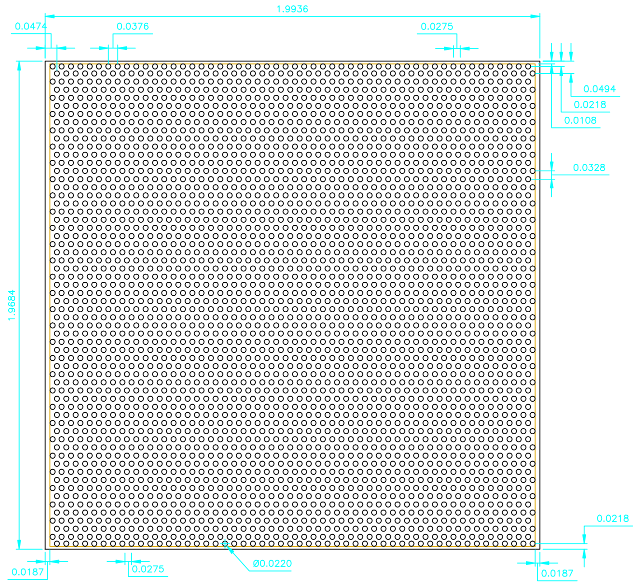
Both companies are very interested to bid on fibers. (Production of 0.47 mm fibers poses no problem for either of them)

SG was notified (a year ago) that LY from their fibers is about 30% lower than KURARAY.

- SG worked on improved version.
- First samples delivered to UCLA.
- Tests will be run soon to compare LY from both vendors.

Currently budgeted KURARAY.
eRD106, will use KURARAY fibers

Other components.



5 cm mesh, designed 2014.
FotoFab production drawing.

The Epoxy Test Dummy.
A Just in case scenario.

A test block using Denepox 1-40 was cast. It will be machined and tested. The potting procedure was relatively the same and the block quality is good. Testing and then retesting after some time will tell us more.

It looks like a block, feels like a block, and so far it acts like a block.

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Epoxy. DE NEEF Denepox I-40 as replacement for Epotek 301.
(GCP Applied Technologies Inc, Cambridge MA, USA)
Better properties, cheaper, seemingly produced for large volumes, tested by US Army Corps. Of Engineers.

UIUC, potted one block. Properties very similar to Epotek.

At UCLA first test with infusion shows same results.

Sample of fibers will be embedded into Epotek and Denepox for long term effect studies soon.

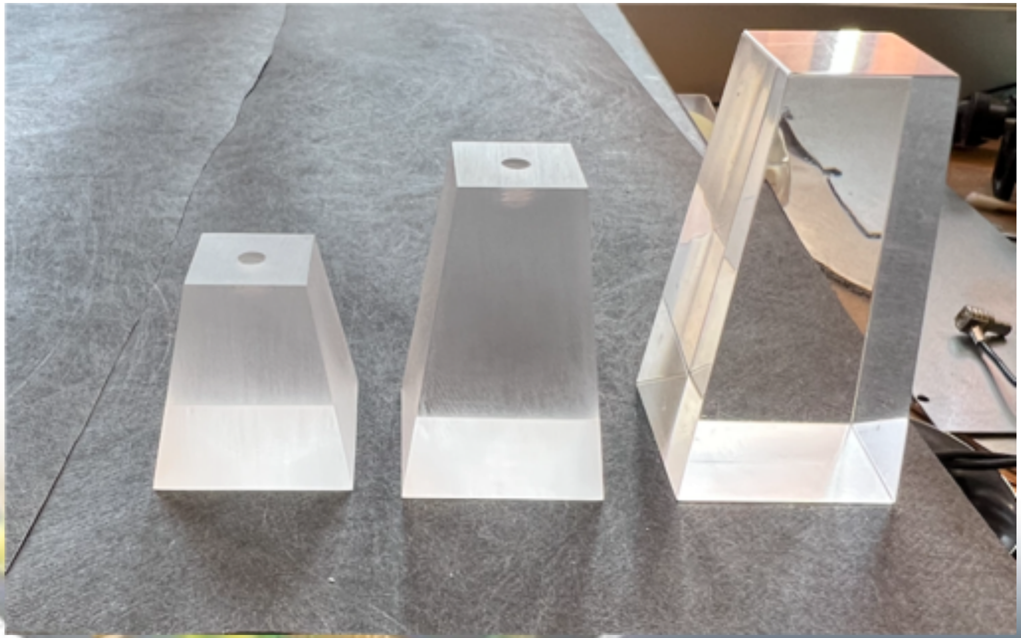
PROPERTY	MIXED A AND B	TEST
Viscosity	85 cps	Brookfield
Pot Life 77°F	80 min.	N/A
Tensile Strength	9,000 psi	D-638
Flexural Strength	14,400 psi	D-790
Compressive Strength	12,000 psi	D-695
Bond Strength (Dry Concrete)	870 psi	C-321
Bond Strength (Wet Concrete)	520 psi	C-321
Elongation	9%	D-638
*Slant Shear Dry Concrete	1985 psi	C-882
*Slant Shear Water Saturated	1110 psi	C-882
*Splitting Tensile Strength Air Dried Concrete	923 psi	C-496
*Splitting Tensile Strength Water Saturated Concrete	703 psi	C-496 (modified)

*Tested by U.S. Army Corps. Of Engineers. (REMR CS-11)

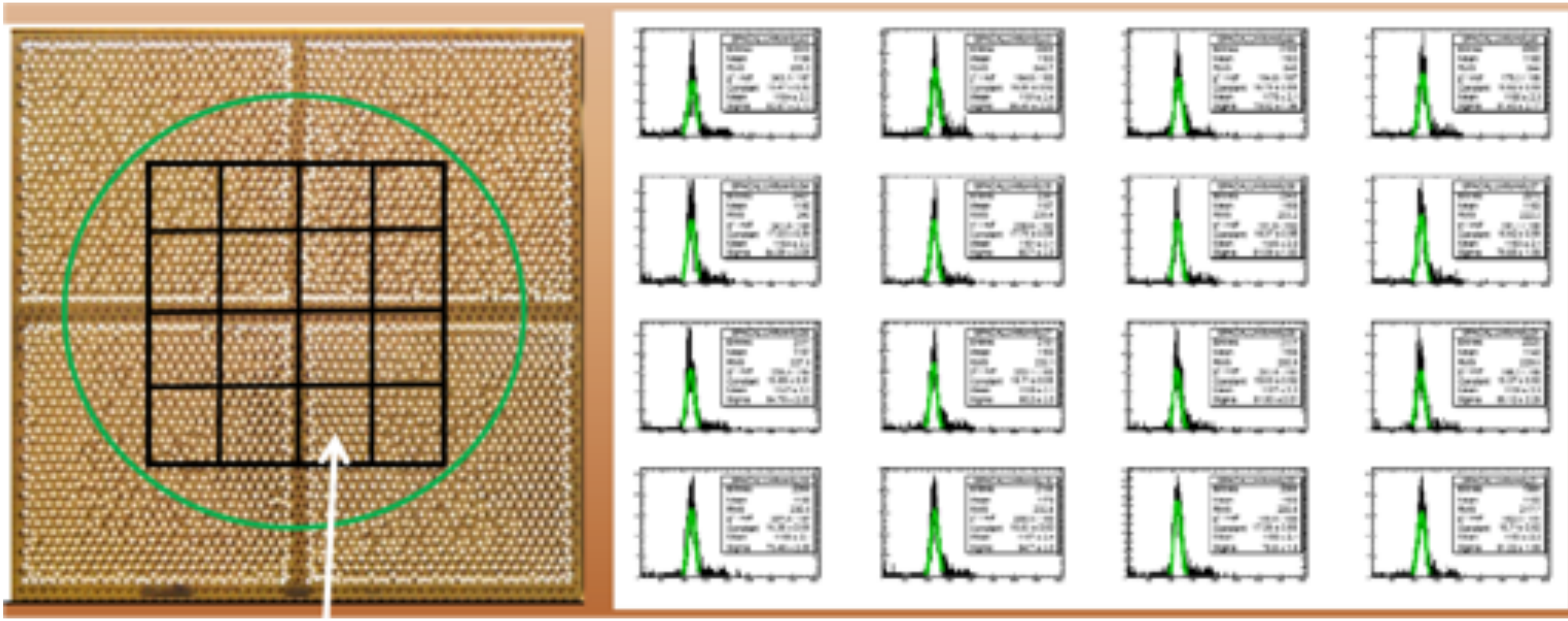
Major components. Light Guides.

- For pre-bunched fiber modules will use same 1” light guides as before (very similar to sPHENIX version). Potentially we will order with the same vendor.

- For longer light guides, after dimensions will be frozen will need to find a vendor.

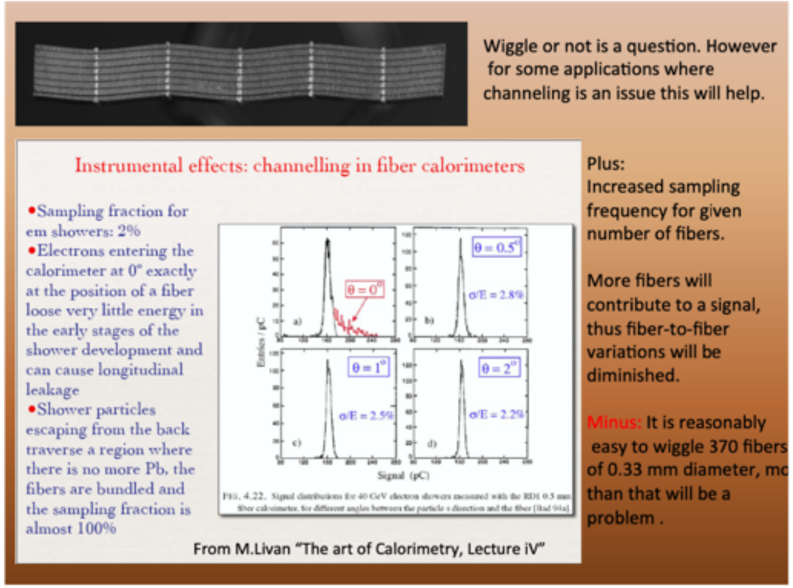


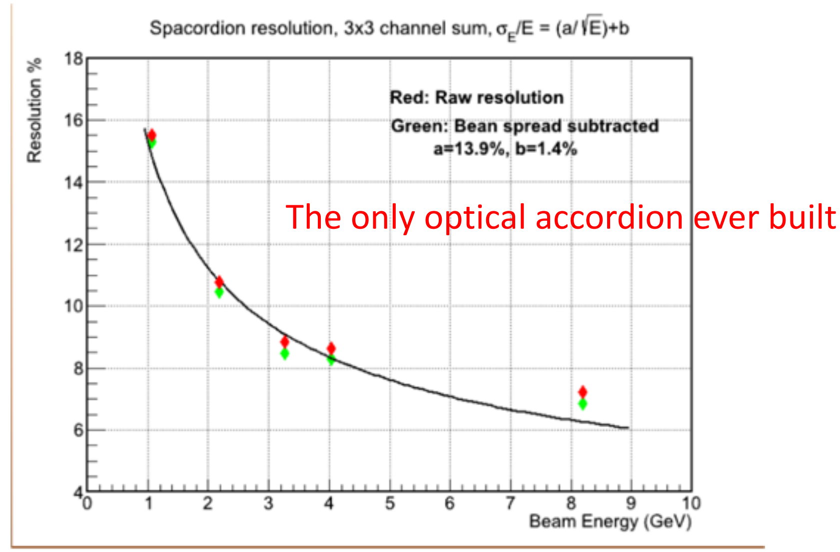
Results from generic EIC R&D. FNAL Test Run 2012



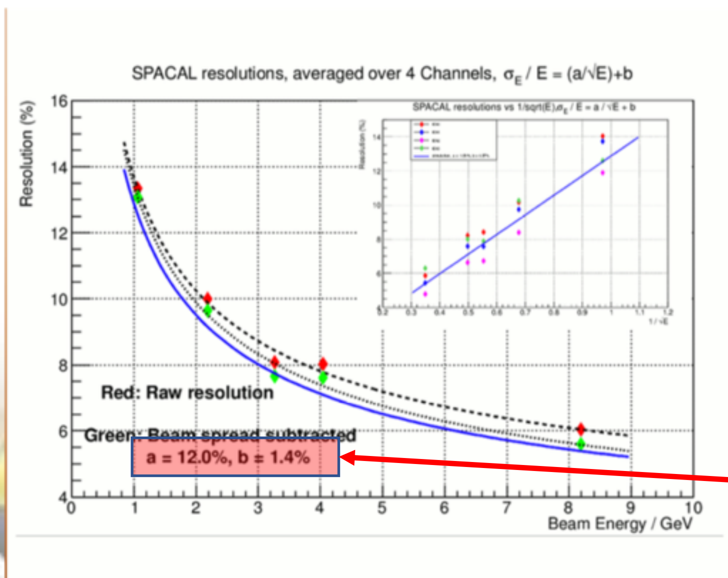
Beam position selected by hodoscope ~ 5 mm x 5 mm
Non-uniformity of response is 1.4% for a single 5 cm x 5 cm production block.
~ 1.4% may be a limit for a constant term for forward ECla (ideal readout with long light guides) which allows to meet KPR (2%). (N.B. measurements done at ~3 degrees impact angle, non-uniformities greatly reduced at large impact angles in forward ePIC Ecal)

Results from generic EIC R&D. Proof of principle. FNAL Test run 2012





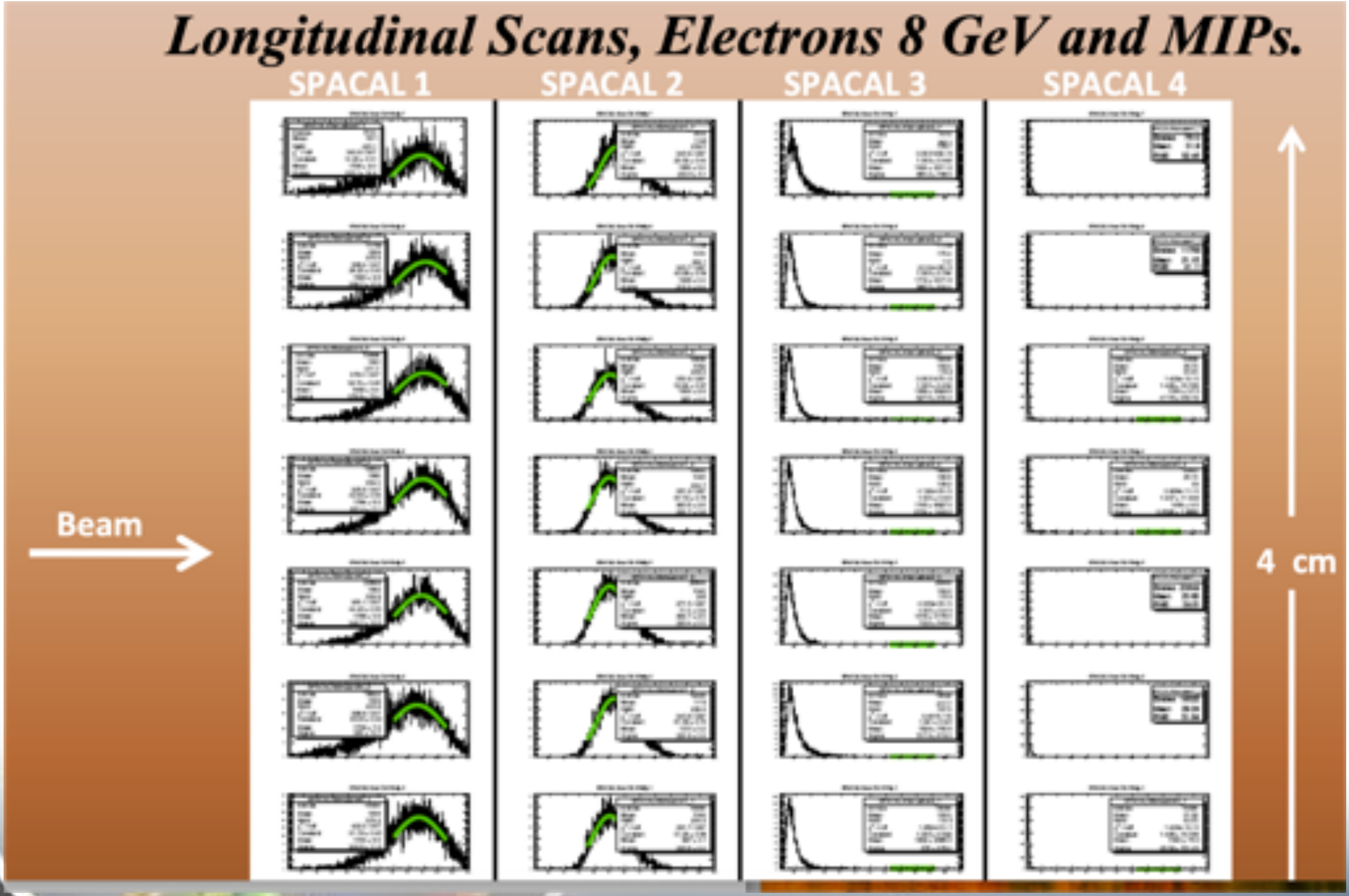
- https://wiki.bnl.gov/conferences/images/d/d4/RD-1_RDproposal_April-2011.pdf



Good agreement with MC
(spacordion geometry was not implemented)

WScFi technology capabilities.
Proof of principle 2012.
Close to EIC desired performance

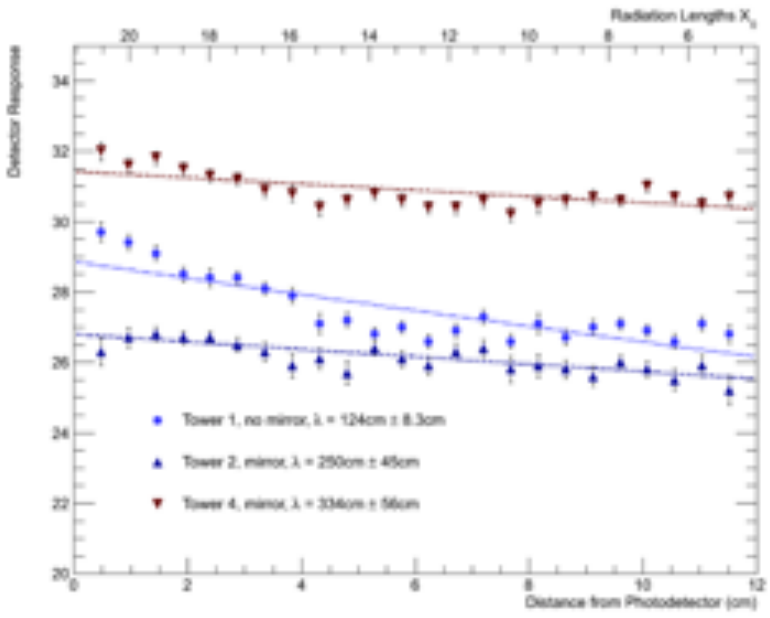
FNAL Test Run 2012

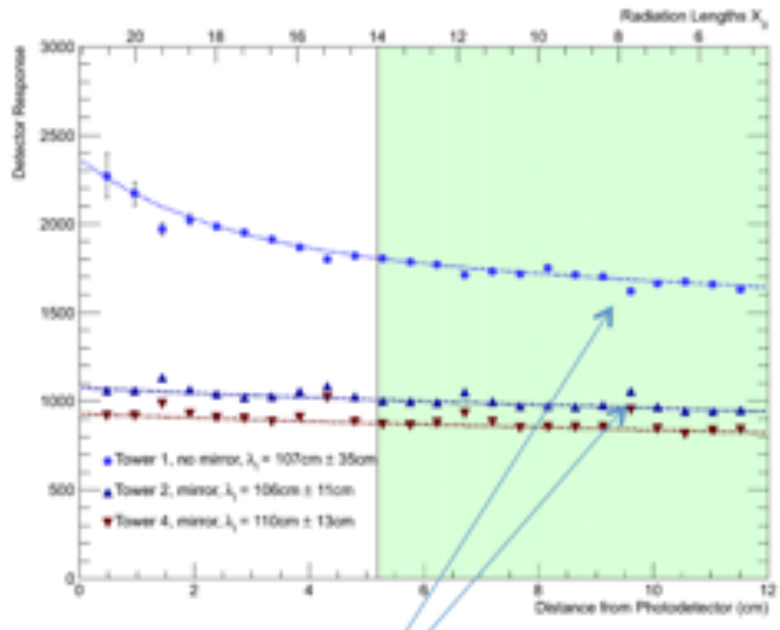


FNAL Test Run 2012

- ***Attenuation lengths and uniformity along the towers.***

MIPs ***Electrons***





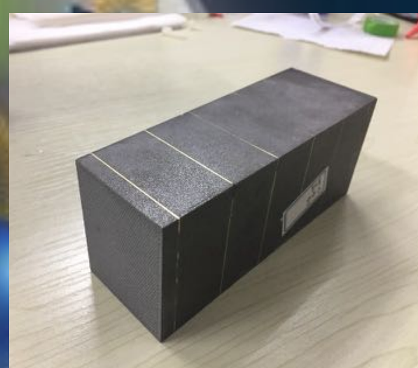
EMCal interest from China group

- **Previous experiences on EMCal R&D and production:**
  - On Pb/Sc Shashlyk EMCal, both Tsinghua and Shandong University have lot of R&D experiences based on the Jlab-SOLID project, and several prototypes already.
  - On W powder/ScFi EMCal, Fudan/PKU/CIAE responsible for sPHENIX high-eta (0.8-1.1) EMCal Blocks .

- **Collaboration with other institutes:**
  - In collaborating with UIUC, BNL, UCLA on W-powder EMCal for sPHENIX
  - In collaboration with Virginia University and Jlab on Pb/Sc Shashlyk EMCal for SOLID

➢ Blocks of W-powder/ScFi EMCal for sPHENIX produced at Fudan University.

➢ Pb/Sc Shashlyk prototypes made with SLOID at Shandong/Tsinghua University 198 layers: 0.5mm Pb +1.5mm Sc.



W/ScFi EMCal blocks

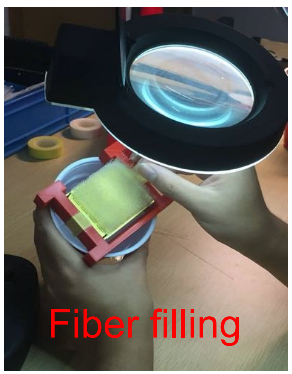
Pb/Sc Shashlyk module

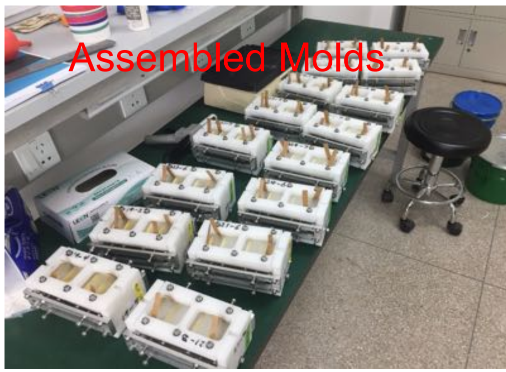
Shashlyk module testing

W-powder/ScFi ECal production at Fudan University

- Fudan University has established the infrastructure for the construction of such W-powder/ScFi ECal blocks, including raw material procurement and testing, block production and processing, testing and QA, etc.

- sPHENIX EMCal blocks production flow at Fudan:





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