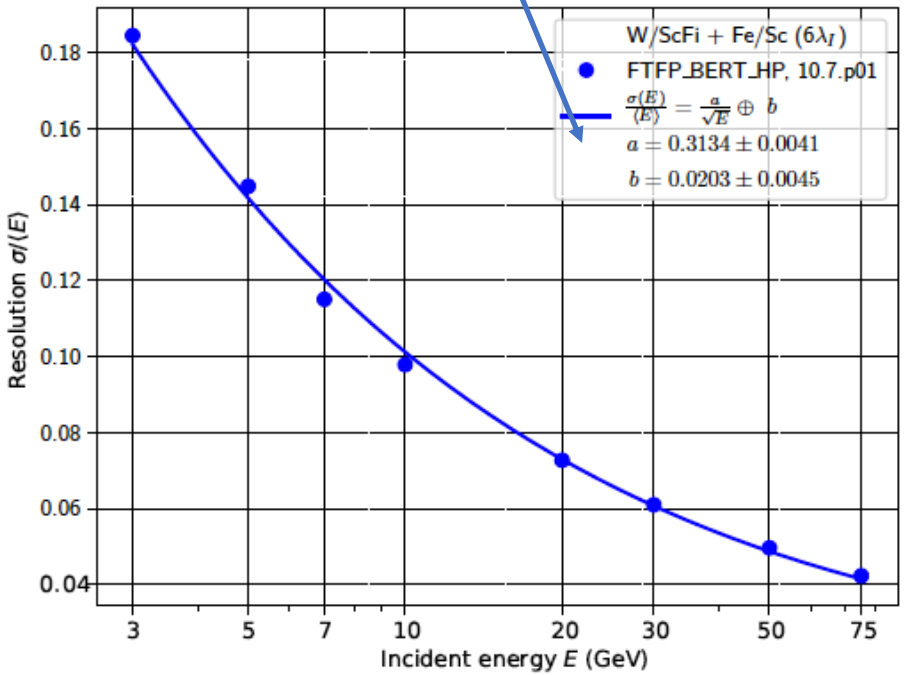
Targeted R&D for Hadron Endcap system. eRD106, eRD107 H.Z.Huang, O.Tsai

- All HCals and some ECal will be on critical pass, to meet CD4. HCals are the first one that should be installed -> the sooner construction will start the better -> the sooner design is frozen the better-> pre-production prototype.
- CD2, CD3 in two years or so.
- Hadron endcap – need both EMcal and HCal designs to be validated and frozen at CD2/CD3.
- Validated experimentally, i.e. test run(s). Open questions had to be closed (in separate slide).
- EMcal – main 'semi-open' question uniformity of response.
- HCal + EMcal we need test beam data! MC looks very very good on paper, so good that it is hard to believe ☺

- We reached out to CORE and ECCE. No response from ECCE calorimetry conveners. well…
- We also had talks with our STAR FCS colleagues.

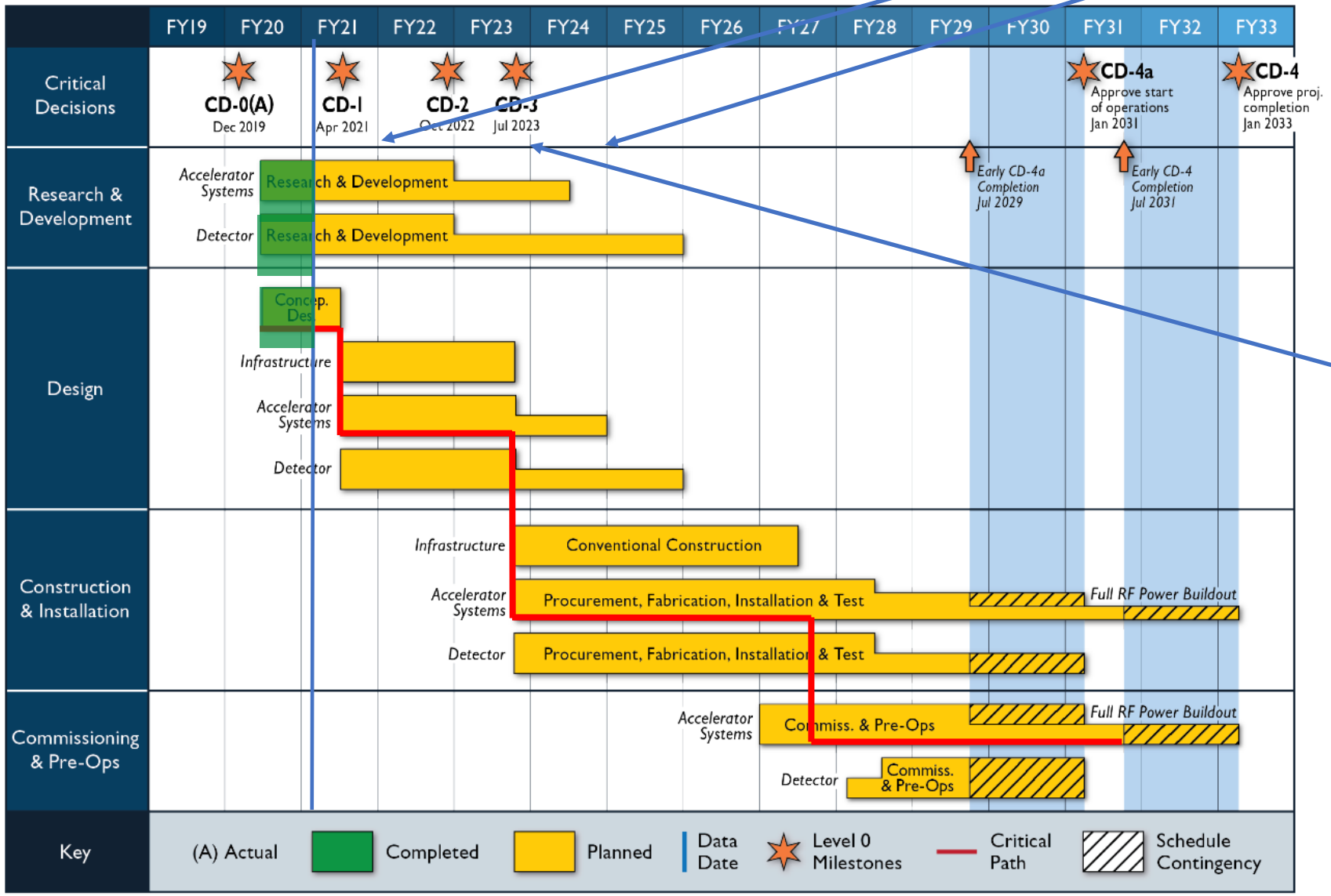
- Team eRD106 - Fudan, Shandong University, Tsinghua and South China Normal University, UCLA, IUCF, BNL
- Chinese groups just finished their production of WScFi blocks for sPHENIX and will be available for EIC block production

- Team eRD107 - ACU, BNL, IUCF, Rutgers, UCLA, UCR, Valpo
- Members of these team build STAR Forward Calorimeter System (FCS).



CD-1 Review Schedule

R&D Start and Ends (second Test Run?).



Test Run at FNAL
1 month

R&D Deliverables:

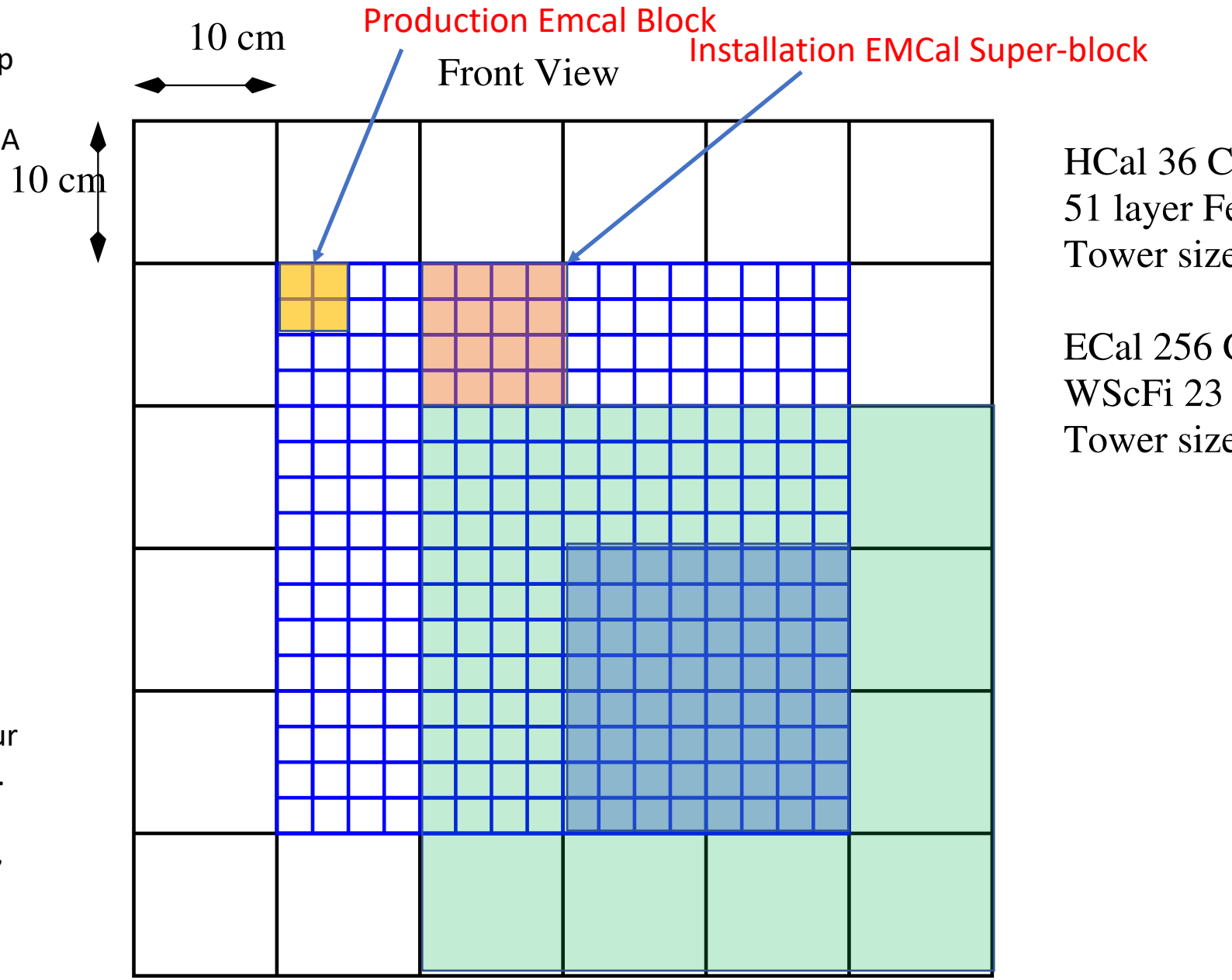
1. Design, Construction techniques for Hadron EndCap
2. Design of Readout. FEE – final?, Digitizers – somewhat advanced (compare to FCS TBD), ATHENA DAQ not in scope
3. Exp. data for ATHENA MC validations.
   Exp. data for ML/AI developments (UC Consortia).

Institutions:

- UC Consortium + STAR FCS team -> Hcal
- Chinese Consortia -> Emcal Block Production technique
- IUCF -> FEE
- BNL/IUCF -> DEP (at this stage it is STAR FCS system baseline for test run / anticipated DEP with streaming readout available in Summer 2022.

Full Scale prototype:
6 x 6 matrix of Hcal (~ 51 layer of Fe/Sc (20/3), and four section longitudinal segmentation, sections length TBD.

Ecal 16 x 16 matrix, Side rows will not be instrumented, not critical for leakages.



eRD107 Hcal.

STAR FCS construction method works very well because it is very simple!

What is new for hcal towers? Desire to have 3D shower imaging, (re-weighting section with high f_{em} like H1)
Need for longitudinal segmentation.
Want to keep FCS simple method of construction and re-use STAR FCS for EIC.

Progression:

STAR FCS -> EIC (FCS like with integrated tail catcher, generic R&D) -> EIC (FCS like with fast/slow sc tiles and 4 segment per tower)

All new is well forgotten old… We want to use caleido2 idea (tested in the test beam and worked well, emcal for ILC, 1999).

- Each tower will have four segments, two with fast scintillator, two with slow. Requires just two WLS plates per tower to get information from four segments.

- Implementation seems to be straightforward and fully compatible with existing STAR FCS design.

Frascati Physics Series Vol. nnn (2001), pp. 000-000
IX Int. Conf. on Calorimetry in Part. Phys. - Annecy, Oct. 9-14, 2000

A SHASHLIK CALORIMETER WITH LONGITUDINAL SEGMENTATION FOR A LINEAR COLLIDER

I. Britvich, A. Feniouk, V. Lishin, V. Obraztsov, V. Poliakov,E. Vlasov
Institute for High Energy Physics, Serpukov, Russia
T. Camporesi, L. Masetti, F. Marcucci, E. Piotto
CERN, European Organization for Nuclear Research, Geneva, Switzerland
S. Ask, V. Hedberg
Department of Physics, University of Lund, Lund, Sweden
M. Paganoni, F. Terranova
Dipartimento di Fisica, Università di Milano Bicocca and INFN, Milan, Italy
P. Checchia, M. Margoni, M. Mazzucato, F. Simonetto
Dipartimento di Fisica, Università di Padova and INFN, Padua, Italy
Presented by: P. Checchia

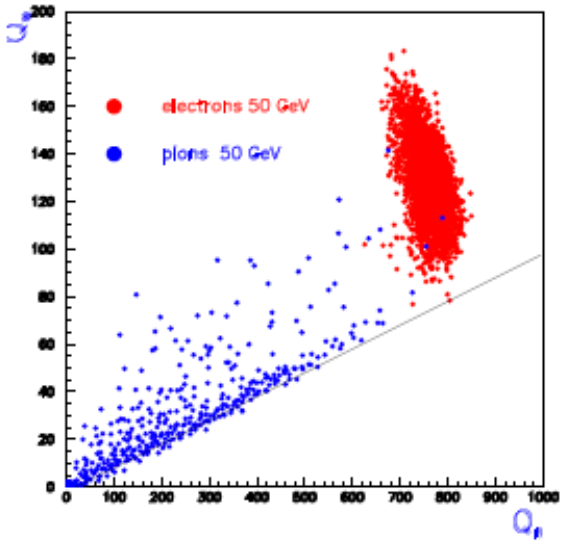


Figure 4: *Signal collected in the wide gate versus the signal collected in the narrow gate for 50 GeV electrons and pions. The line corresponds to the contribution to the wide gate signal attributed to the fast scintillator.*

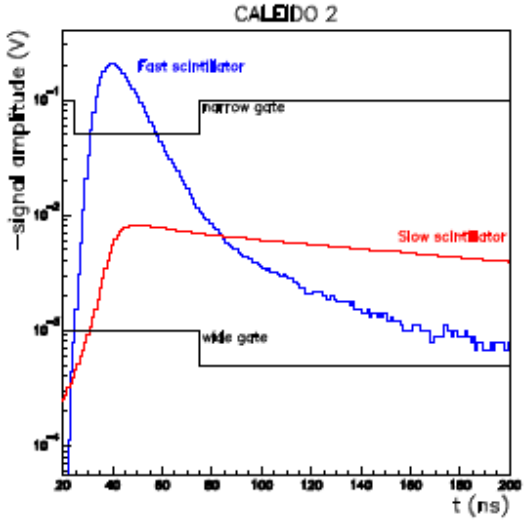
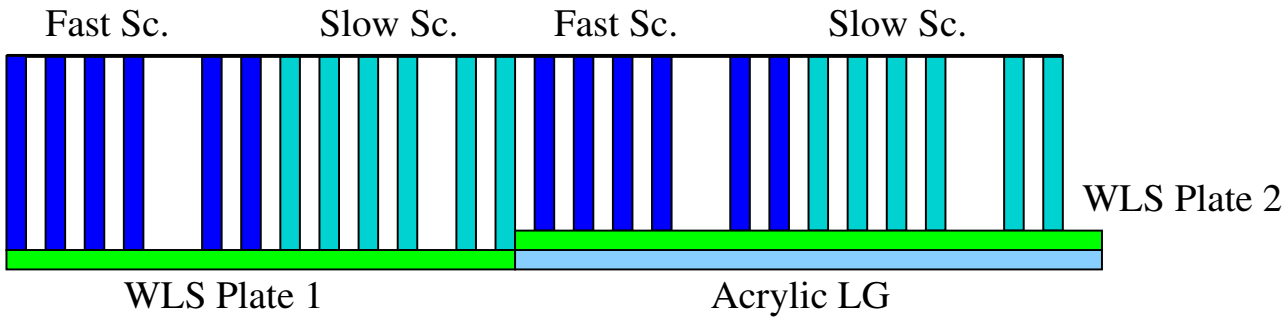


Figure 3: *Time profile of the signals from fast and slow scintillator for FEU 115-M photomultiplier. The narrow and wide gates are also showed.*



Concept of HCal Tower. Two Independent readout Channels –> four sections.

eRD107. Timescale.

Timescale: Need to order sc. plates from EJ this calendar year –> get all tiles machined before summer (2022) students will finish them for prototype. Factory will be set at BNL, most likely. Want to get UC undergrad students involved, they will be funded from UC MRPI.

Other technical things.
LY need to be increased compare to STAR FCS.
That should be straightforward with larger pixel size SiPMs we can put for EIC for Hcal with longitudinal segmentation.
Shaping on FEEs had to optimized for fast/slow readouts.
Need to tweak LED monitoring system, compare to what is in STAR, due to second channel.

eRD106 ECal. Continue from 2015 R&D UCLA EIC Generic Det. R&D.

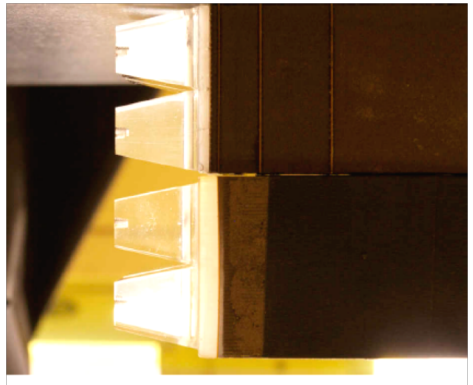
1. Improve uniformity of LY (by 4.5 times) (STAR FCS 2014/sPHENIX)
2. Improve efficiency of LY (by 2.5 times) (STAR FCS 2014/sPHENIX)

Hardware Scope for Chinese groups:

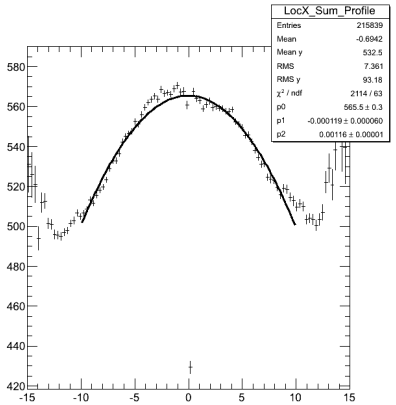
- Produce 64 WScFi Blocks, each block is 2 x 2 towers.
- Fibers in each tower arranges as in latest UCLA prototype (2015/16).
- Length of blocks ~ 23 X0, 17 cm (powder/fibers) + few mm on both tips (clear epoxy fibers)
- Block size should be ~ 5cm x 5 cm (exact size is 4.98 cm x 5 cm), tolerances TDB
- Additional scope is to find producer in China for light guides (TBD).

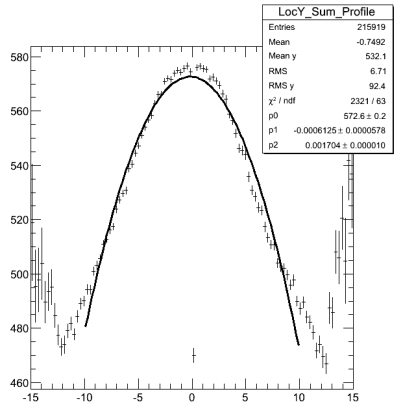
All materials cost will be covered from R&D budget (powder, fibers, meshes, epoxy, parts for molding forms etc.)
Kuraray fibers need to be ordered before the end of this year.
Labor is contributed by Chinese groups.

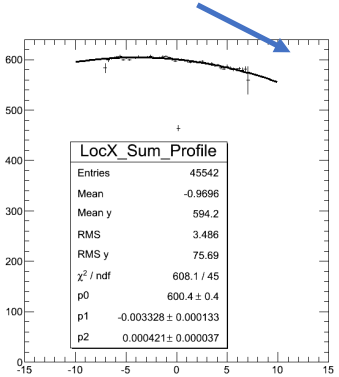
Same is for HCal part.
The only labor cost that will be requested from R&D funds is for electrical engineer from IUCF to work on FEEs and students at ACU or summer students at BNL.

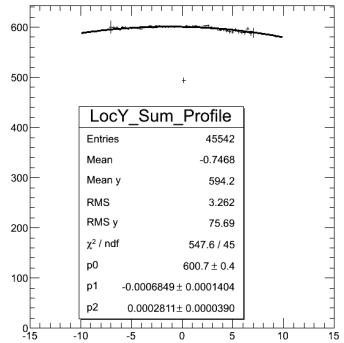


Question to close:
Compact Light Collection scheme prone to non-uniformities.
Test Run 2014 (1” long light guides, Four 3 mm x 3mm SiPMs per tower.)
Corrections for energy reconstruction done using calorimeter only information on impact position.

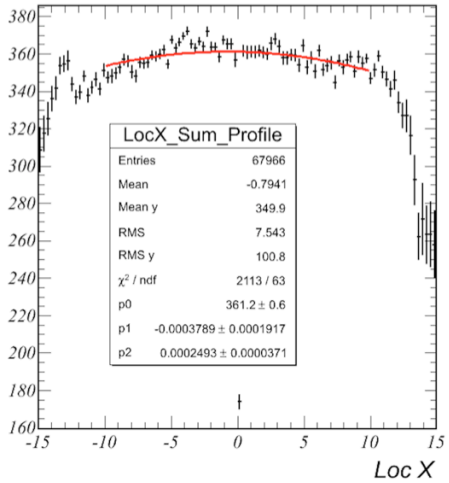








Test Run 2015/2016 Introduced masking between fibers and light guides. (Variable transparency printed on acrylic plate)



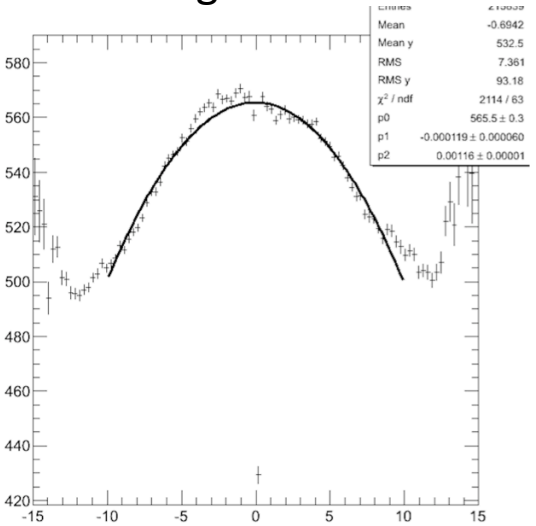


Figure 6. Response of the old EMcal to 4 GeV vs impact point. Left 2015 data, right 2014 data.

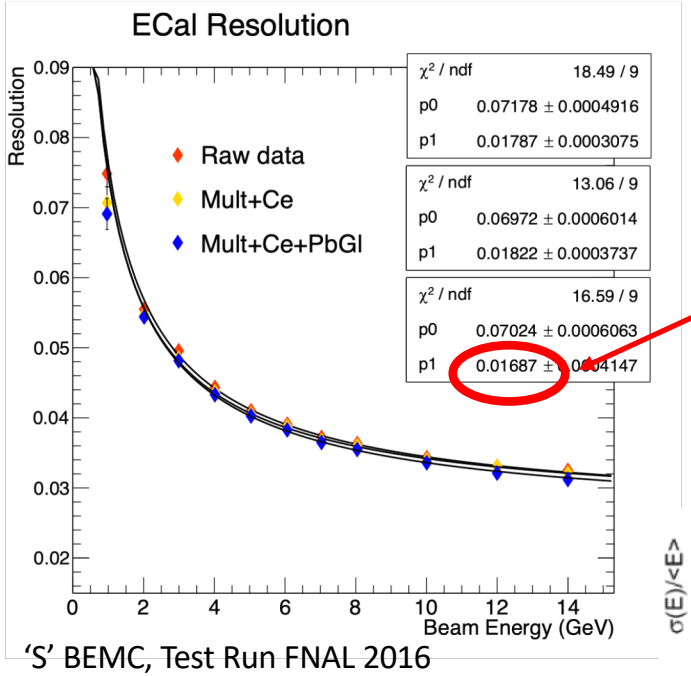
Helps, but loosing light due to additional glue joints.
Questions with long term stability.

sPHENIX adopted construction technique in 2014, but did not advanced compact light collection schemes.

UCLA Stopped R&D for WScFi In 2016, after test run at FNAL With high resolution Prototype.

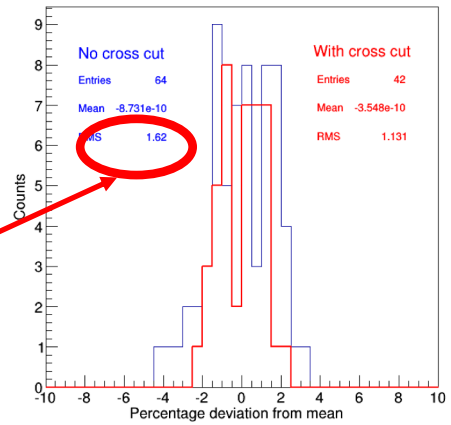
What we marked in **bold** in our 2016 eRD1 report non-uniformities in the detector should be non-projective.

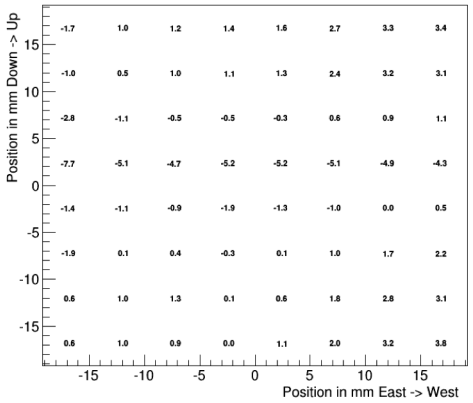
Optimization of light collection:



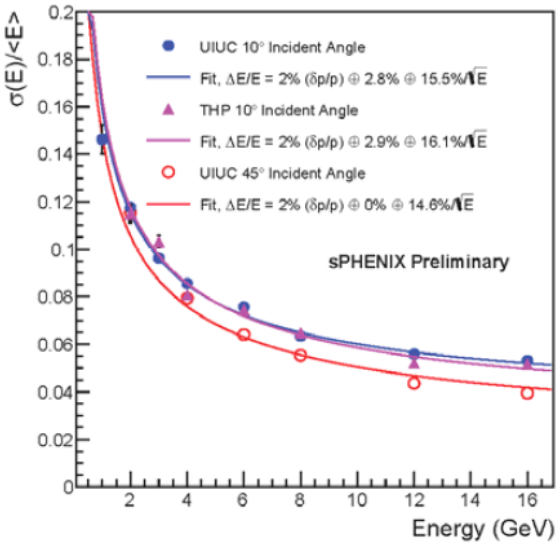
'S' BEMC, Test Run FNAL 2016

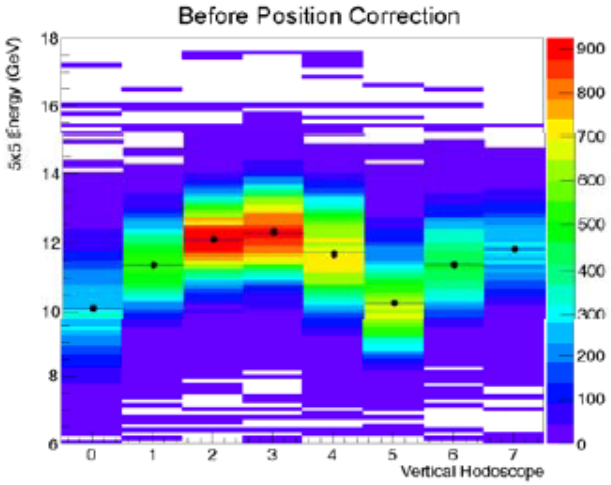
Uniformity of response 'S' BEMC, Test Run 2016
Ideal Light Collection Scheme





1D sPHENIX W/ScFi, Test Run 2016





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

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.

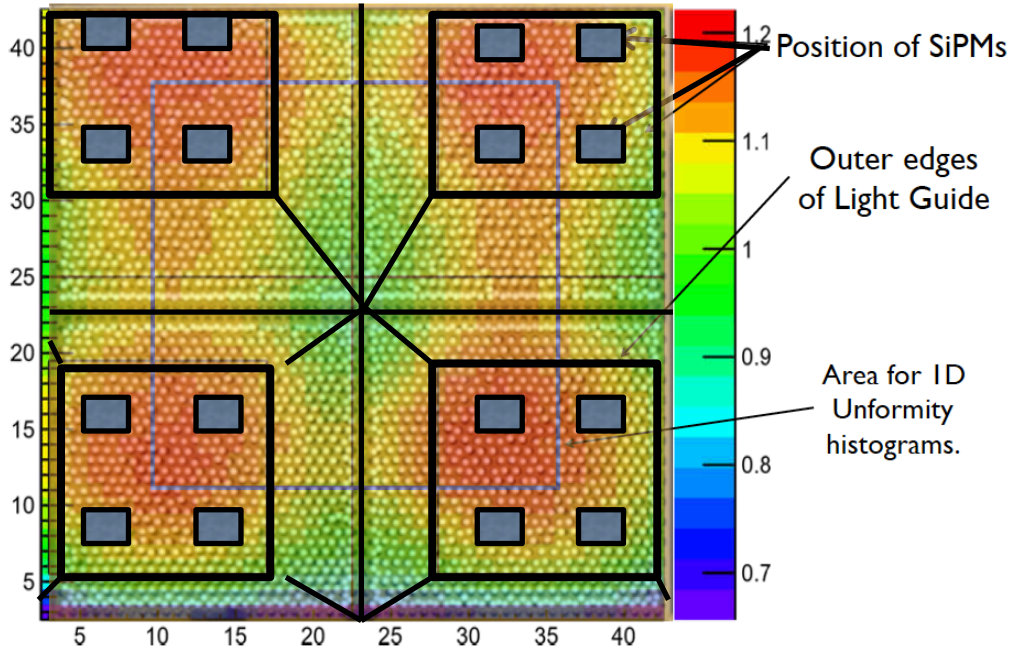
Solutions we tried in the past:

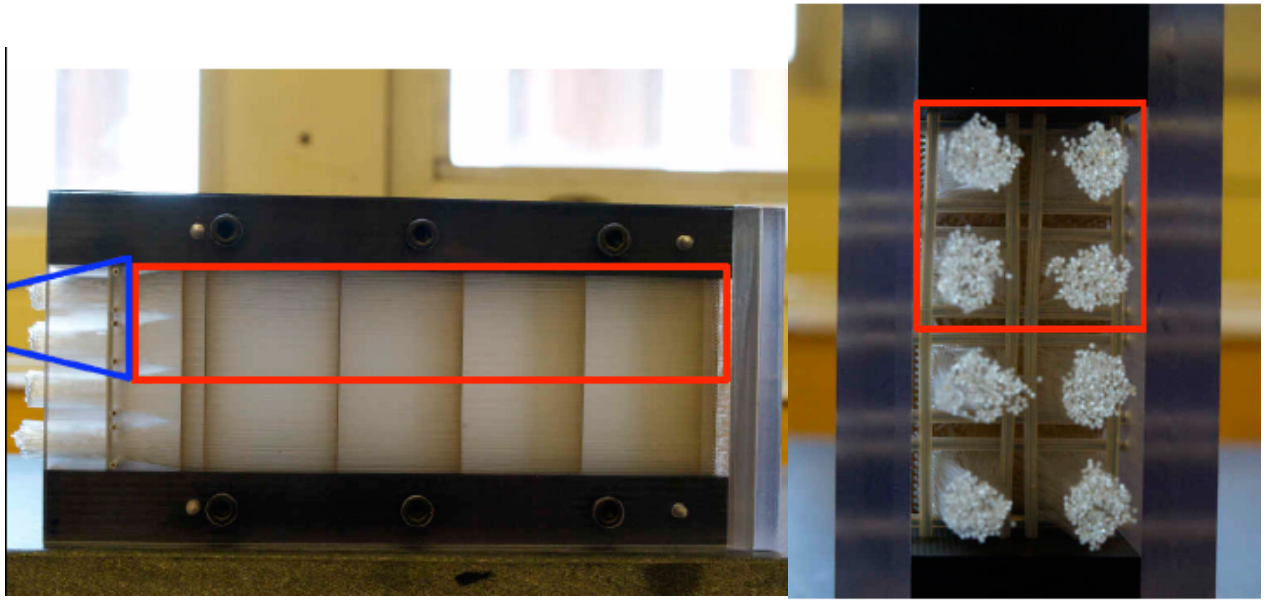
1. Compensation Filter between fibers and light guide. Loss about 30% of light (test run 2015). Will not work for FEMC.

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

New Approach (2016). 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



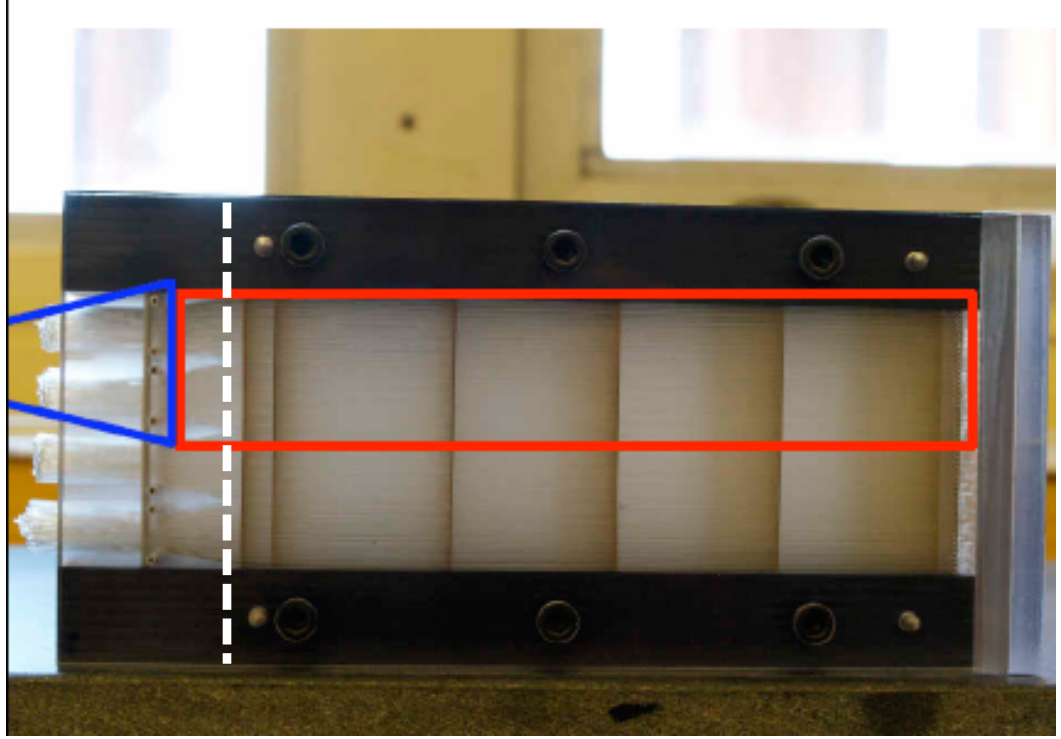


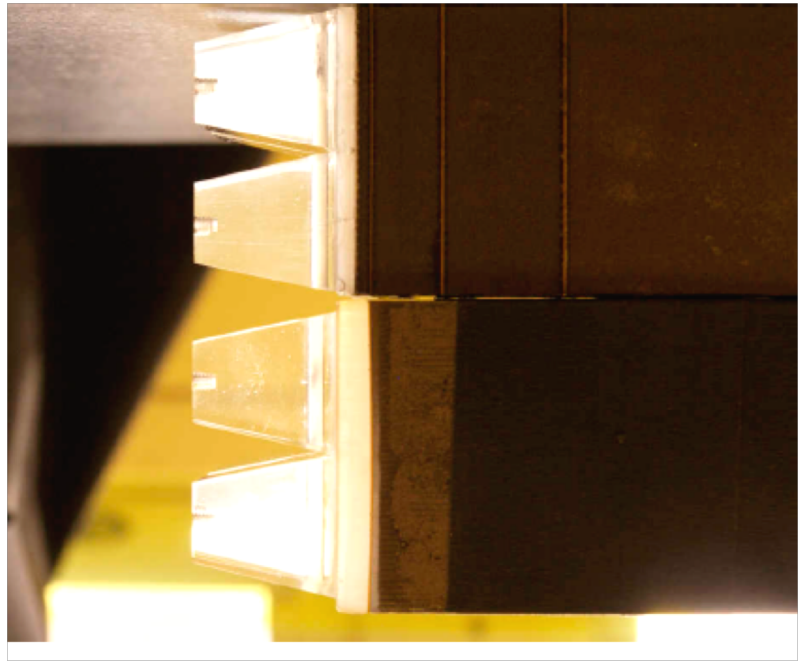
In 2014 we dropped development of 'bunched fiber' configuration for two reasons:

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.

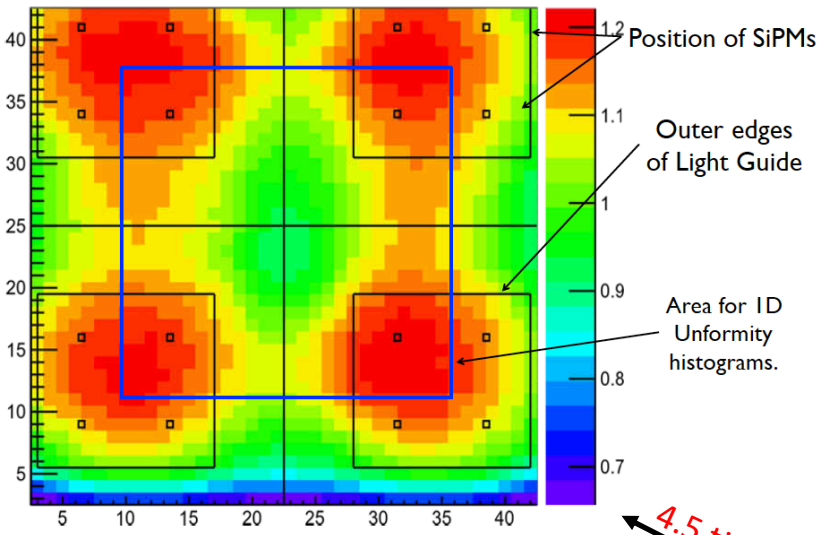




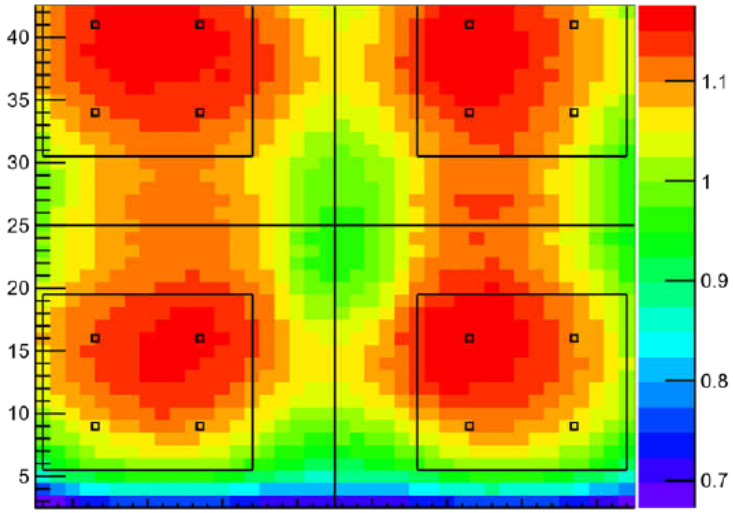
Optimization of light collection:

BEMC Superblocks, UV LED Map

UCLA 2014, sPHENIX

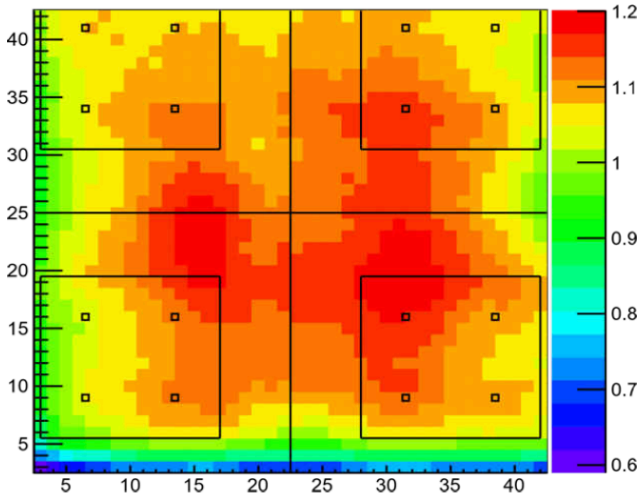


Old BEMC, Sylgard 184, 3mm

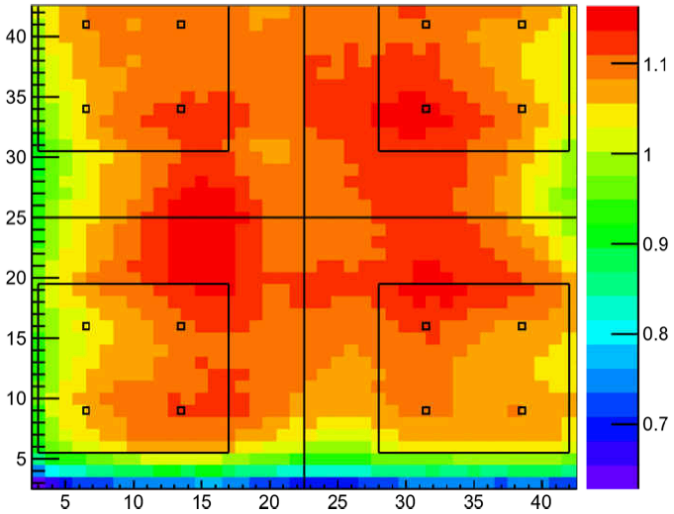


Old BEMC, BC-630, coupling is important

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.

UCLA 2015

In 2015/16 we used 3 mm x 3 mm SiPMs.

For ATHENA we'll use 6 mm x 6 mm SiPMs,

At EIC we need to improve light collection efficiency compare to previous prototypes/sPHENIX by factor of 2.5, which should be no problem.

Readout is common for Ecal and Hcal, rooted from STAR FCS readout system.

FEE for Emcal (high density) is a bit challenging but sounds like doable.

Test Run readout system will be ‘borrowed’ from STAR Detector Electronics Platform (DEP). Expected that it will be two mode operational; triggered as in STAR, and fully streamed as at EIC (promised that this may be done during Summer 2022).

But, concept of FEE->DEP->DEP(I/O)->DAQ as it is in STAR looks a bit clumsy for EIC. Too many channel, too many racks. Bottleneck is density of channels on DEP board.

Some ideas are flying already to push ADCs to FEEs, power is a major concern <- this is R&D but not fully costed in the current proposals. – potentially additional round just for this part and test run in 2024 or later.

All key persons to make this system developed and work at FNAL and write needed software signed up on this targeted R&D.

Expected that UC EIC post-docs and grad students will work with ‘key developer’ at BNL to get familiar with the readout system. (Fall 2022, Winter 2023).

eRD106 Budget

SiPMs	16 6 mm x 6 mm	1024 + 100 spares	$16	$17,984	$23k
EMCal FEEs	1	64 +6	$150	$10.5k	$13.7k
Light Guides	1 x 4 iterations	64 x 4	$50	$3200	$6.4k
Light Guides Molding form	2 iterations				$20k
Cables/patch panels etc.	1	64 + spares	$100	$6.4k	$8.3k
SiPM Boards	4	256 +10	$20	$5.3k	$5.3k
DEP/Crates System	1	8 boards	Same as for HCAl		
LV Power supplies		2		contributed	UCLA
DAQ PC		1	Same as for HCAl		
Gerard's Time	360 h/ year		$100/hour	$36k	$36k

Material	Quantity per unit	Quantity Total	Price per unit	Price total	Contingency ~30%
Sc. Fibers	3120 x 0.2m	40000m	$0.5/m	$20k	$26k
W Powder	4.6 kg	300 kg	$45/kg	$13.5k	$17.6K
Meshes	6	384		$1.5k	$2k
Epoxy	0.5 kg	32 kg	$100	$3200	$4.2k
Supplies	Shafts/tubing			$2k	$2k
Molding Forms	1	10	$300	$3k	$4k
Machining				$6k	$8.2k
Shipping	2			$4k	$4k
EMCal Block Production					$68k

Travel	Test Run FNAL (HCAL Budget)		$15k	$15k
Shipping to FNAL			$3k	$3k

Funding Profile:

- FY22 – EMCal Block Production $68k, IUCF -$46k
- FY23 – Light Guide Production $20k, UCLA - $34.7k, IUCF -$12k
- FY24 – Possibly Second Test Run, UCLA - $18k

Total for EMCal: $198.7k

eRD107 Budget

Material	Quantity	Price per Unit	Total Cost	+30% Contingency	Institution
Absorber Blocks	1836	$25	$45.9k	$59.7k	Valpo
Sc. Plates	459	$80	$36.7	$47.7k	ACU
WLS Plates	72	$350	$25k	$33k	UCR
Light Guides	72	$150	$10.8	$14k	UCR
Base Plates	1	$3000	$3000	$3.9k	Rutgers
Master Plates	24	$70	$1.6k	$3k	Rutgers
Dowel Pins/ Tyvek/Glues/Supplies	4k			$10k	UCLA
SiPMs	2304	$12	$28k	$36k	UCLA
SiPM Boards/Assemblies	72	$20	$2.5k	$4k	UCLA
FEE	72	$150	$11k	$14k	IUCF
Cables/Patch panels etc.	1	$40	$2.9k	$3.7k	IUCF
DEP Crate/boards	1/3		2k	$2.6k	BNL
LV Power supplies	3	contributed			UCLA
DAQ PC	1		6k	$7.8k	BNL
Trigger/Clock for Test Run			$10k	$10k	BNL
Shipping to FNAL	2	$6k	$12k	$12k	UCLA
Support Table/rotated	1	$5k	$5k	$6.5k	UCLA
Supplies/Tyvek/glue etc.		$5k	$5k	$5k	UCLA
Engineer Visser's Time	360 hours	$100/h	$36k	$36k	IUCF
Support Undergrads Labor (Sc tiles)			$15k	$15k	ACU
Travel (Oleg to diff. universities)			$10k	$10k	UCLA

Travel	Test Run FNAL		$15k	$15k	UCLA
Shipping to FNAL			$3k	$3k	UCLA

Funding Profile:

- FY22: ACU - $62.7k, Valpo– $59.7k, UCR- $47k, Rutgers $6.9k
- FY23: UCLA - $101.5k, BNL -$20.4k, IUCF - $53.7
- Can move Absorber Blocks into FY23
- Postdocs/grad students and senior personnel are funded from UC MRPI for EIC (2012-2024) and US DOE/NSF base grants.
- Undergrad students and G. Visser funded from the R&D project.