Choice of technology for forward ECal.

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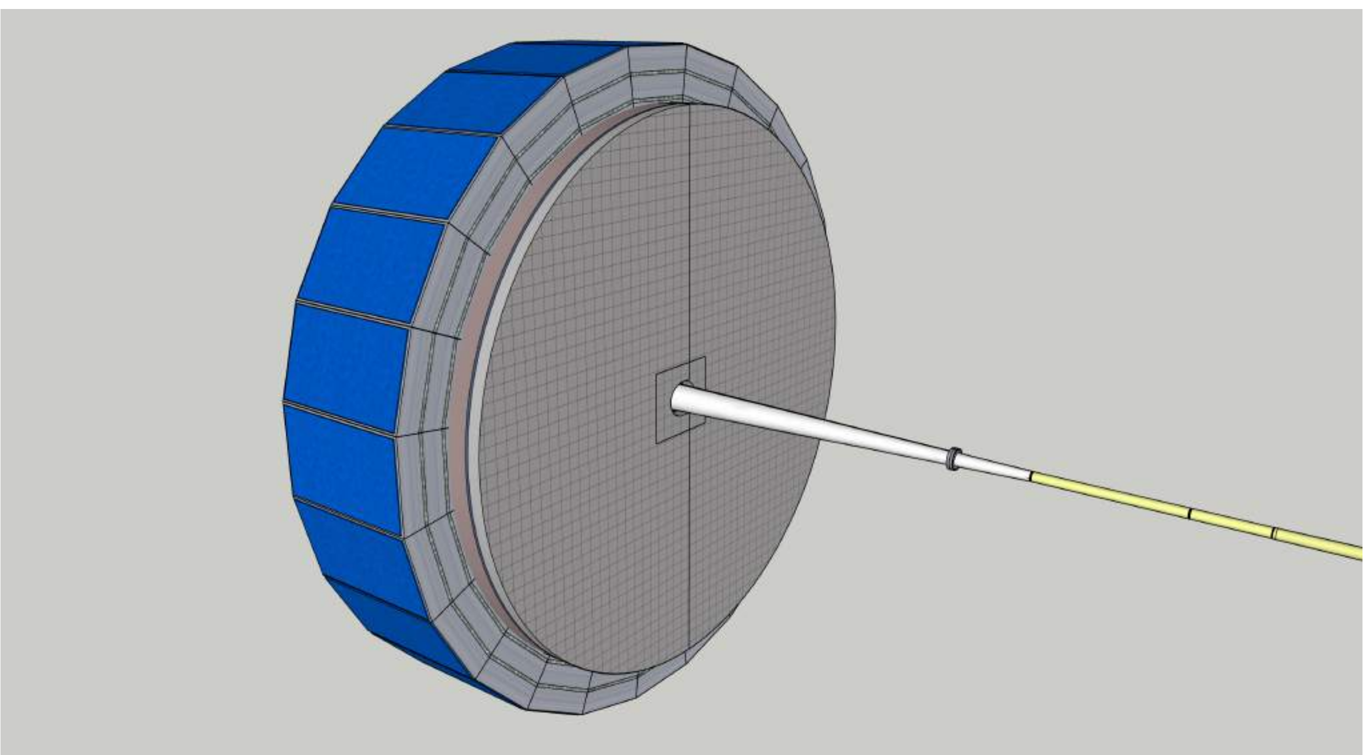
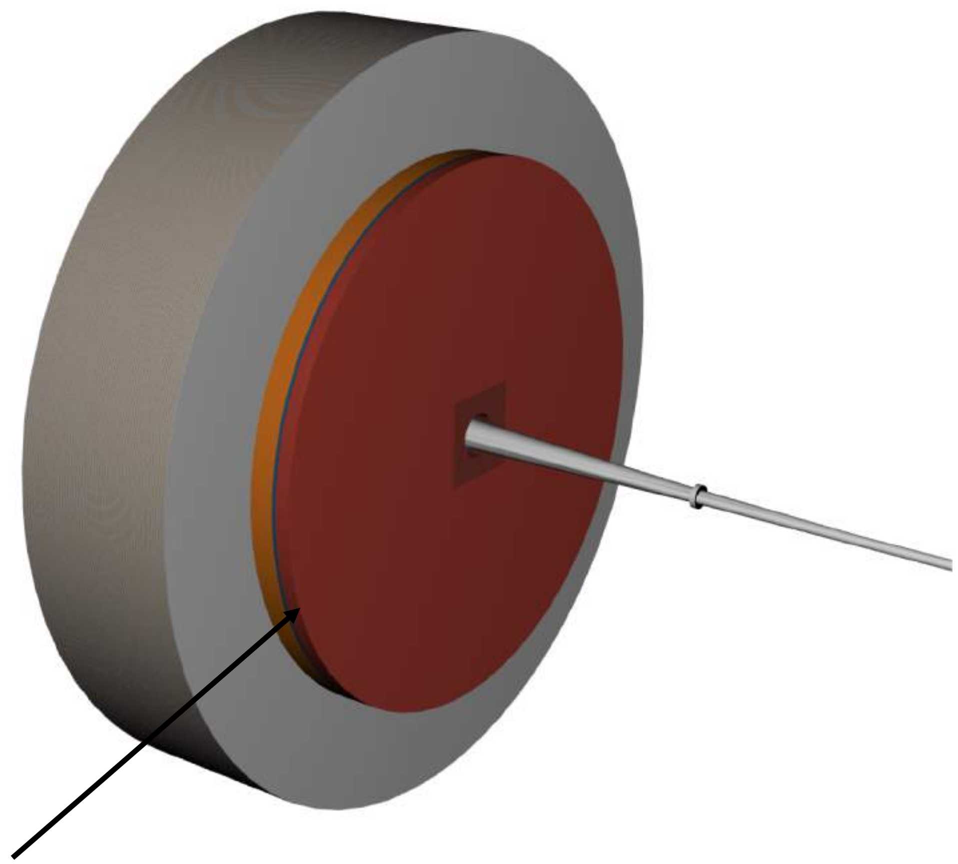
GD/I meeting 06/27/2022





Hadron End Cap, ECal + Hcal

ECCE Ecal – Pb/Sc Shashlyk

ATHENA Ecal - WScFi

1. Details on the work done to provide the necessary input for your decision making process. This includes both collection of existing information and any new studies your WG initiated to establish the expected system performance.

a) Introductory meeting. Overview of forward calorimeter system for ECCE and ATHENA https://indico.bnl.gov/event/15493/

b) Dedicated meeting for forward Ecals https://indico.bnl.gov/event/15686/

c) Follow up discussions between proponents (ORNL, UC_EIC, Chinese Consortium)

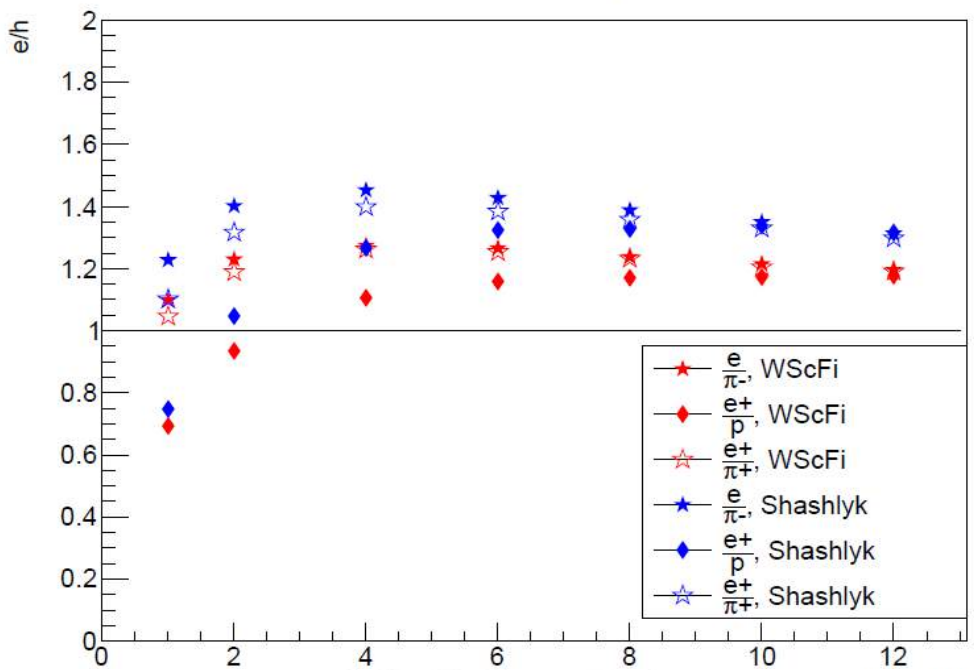
Details (b):
Minireview of technology details, including performance studies, assumptions used for simulations in proposal, integration and cost. Cost numbers were updated for ECCE and cost review were made by A. Bazilevsky. Detailed questions and information for future discussion were generated and provided.

(a) ATHENA related work, Introductory detector -1 meeting

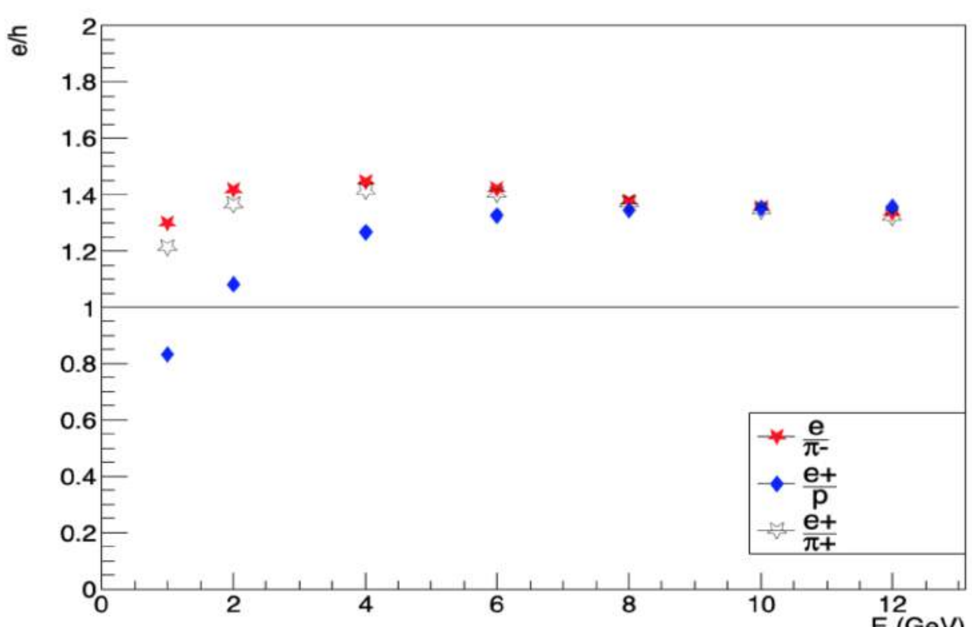
- $e/h \neq 1$
- $e/h\_ecal \neq e/h\_hcal$
- $e/h = f(E)$
- $e/p \neq e/\pi$
- $f_{em} = 0.11 \ln[E(GeV)]$

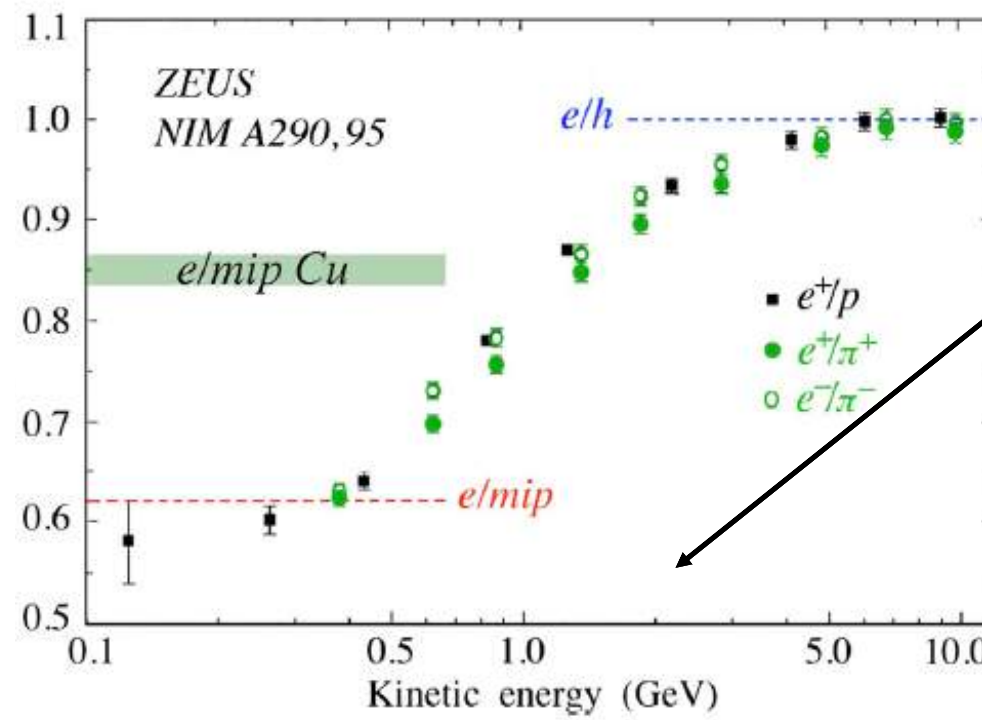
Jet energy resolution is always poorer than for a single hadron. Despite ~ 20% of jet energy (em) measured very accurately by Ecal.

e/h for WScFi vs Shashlyk at 20 degree



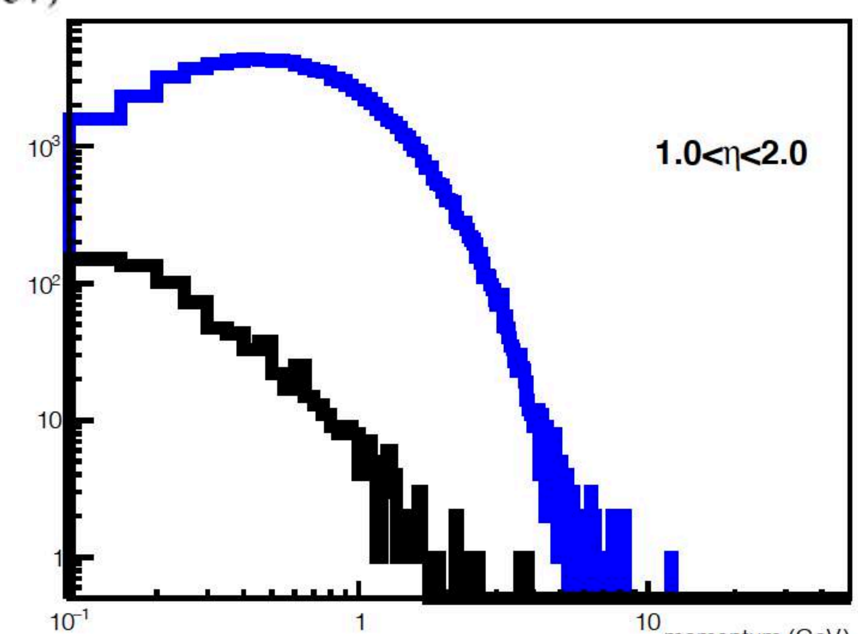
e/h for Fe/Sc at 20 degree





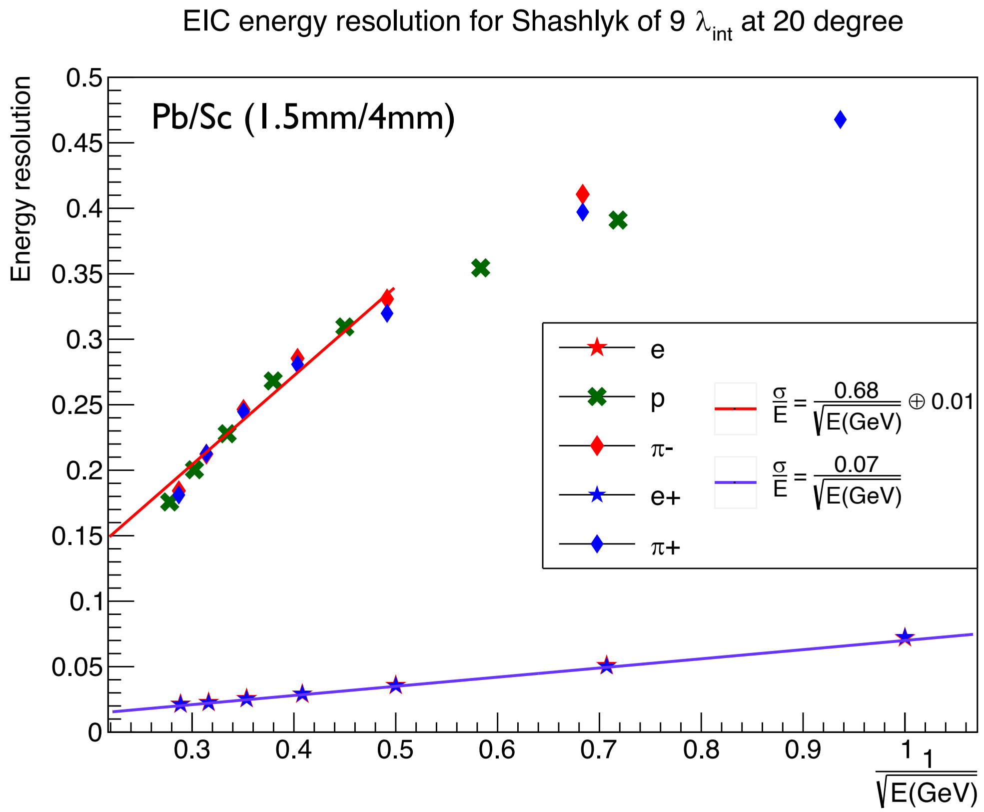
EIC Calorimetry need measurements In this energy range.

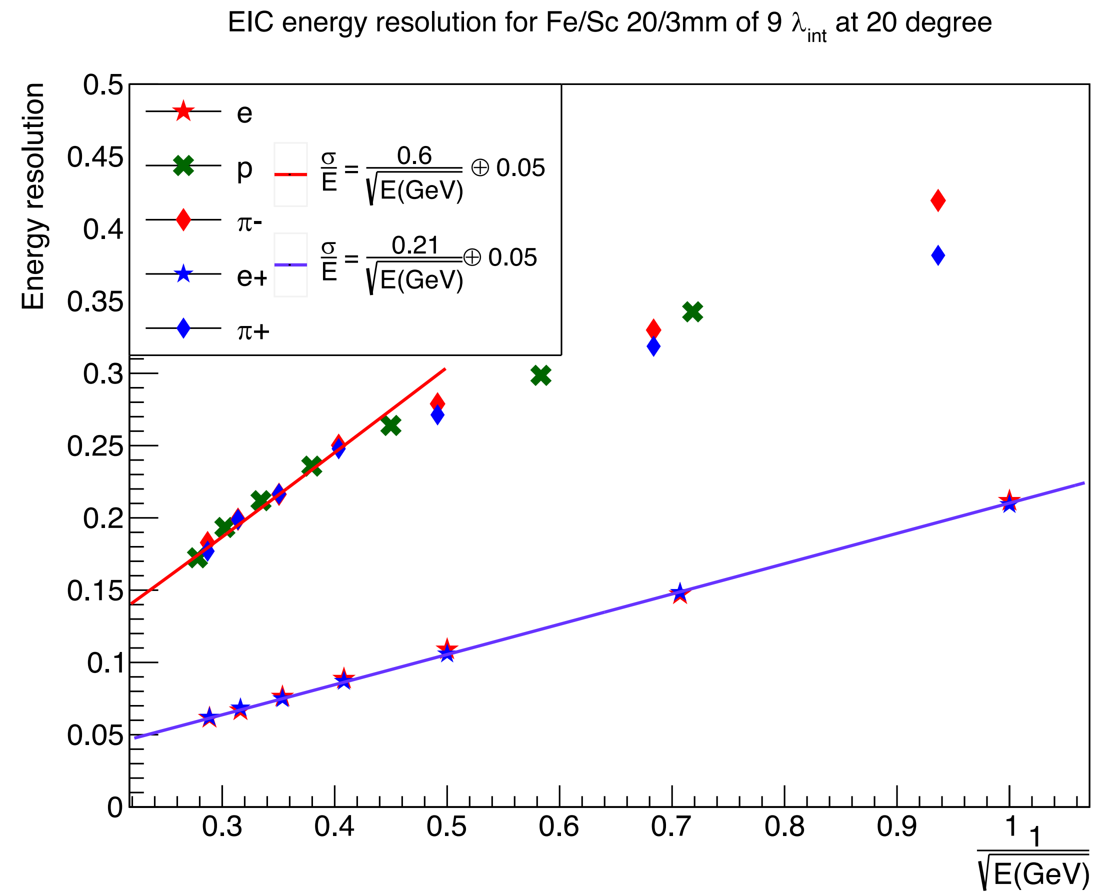
- ZEUS are experimental results
- eRD1 – GEANT4 with physics list validated for LHC (FTFP_BERT_HP).
- Validation of MC can be done only using experimental data form detector with correct chemical composition.

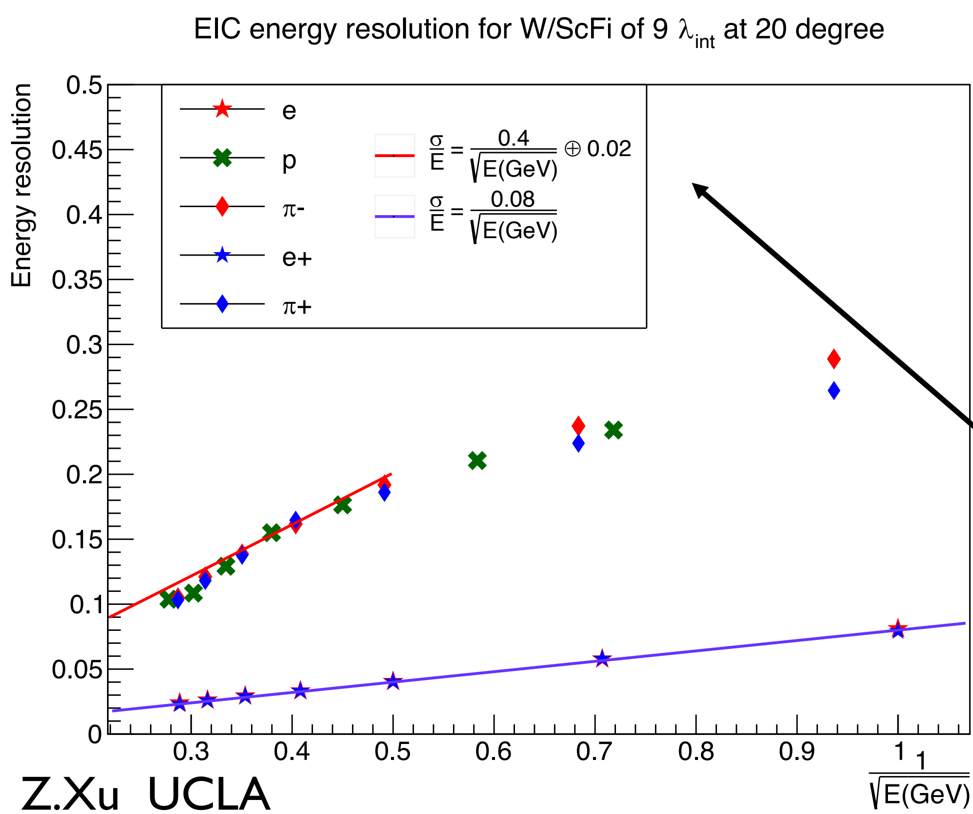


Inclusive, 18 GeV x 275 GeV

(a) Introductory detector-1meeting, pECal, e/h







Z.Xu UCLA

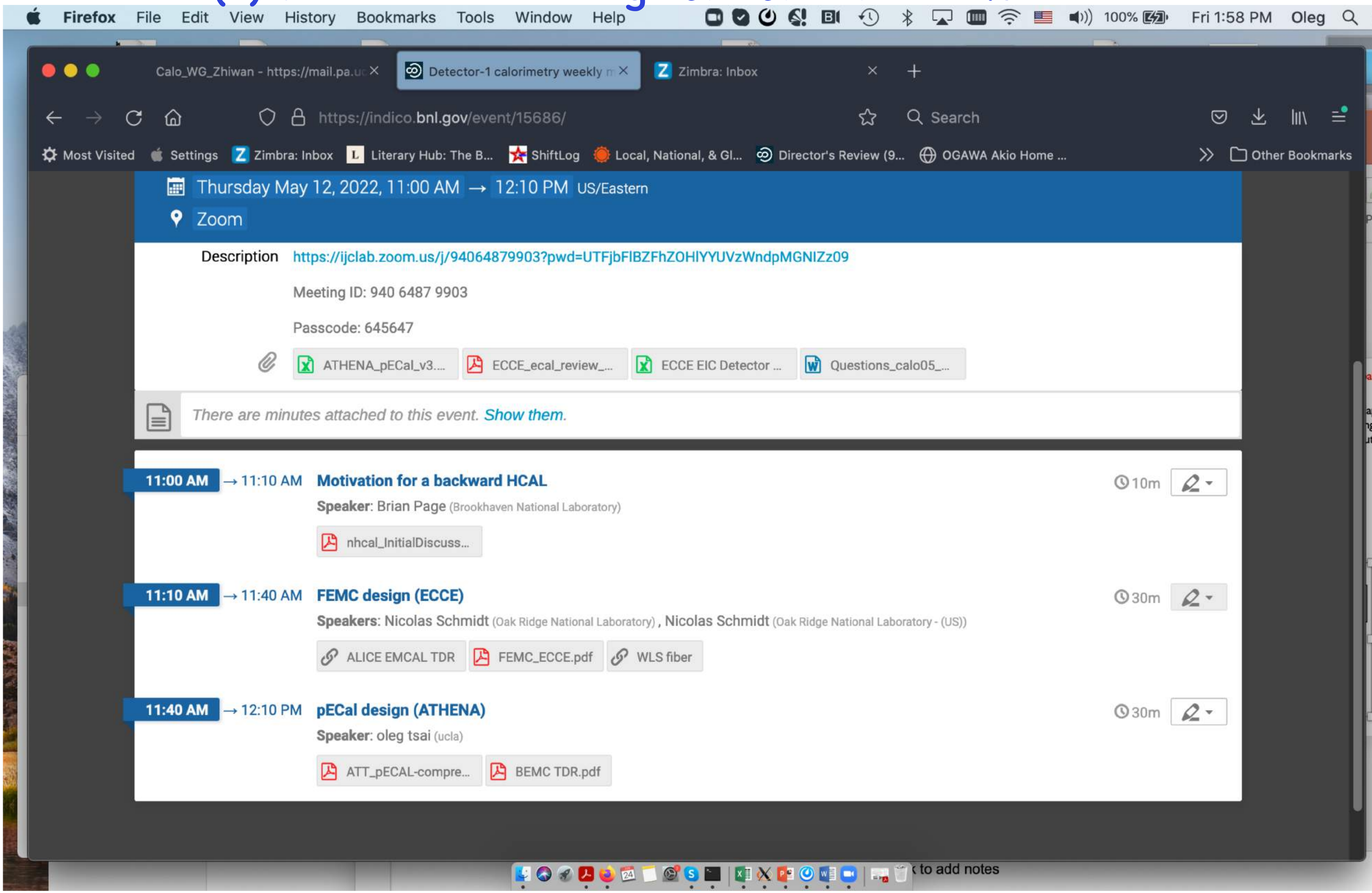
Hypothetical variant, 9 interaction lengths long calorimeters. Same structure for Ecal and Hcal sections. Three different technologies:

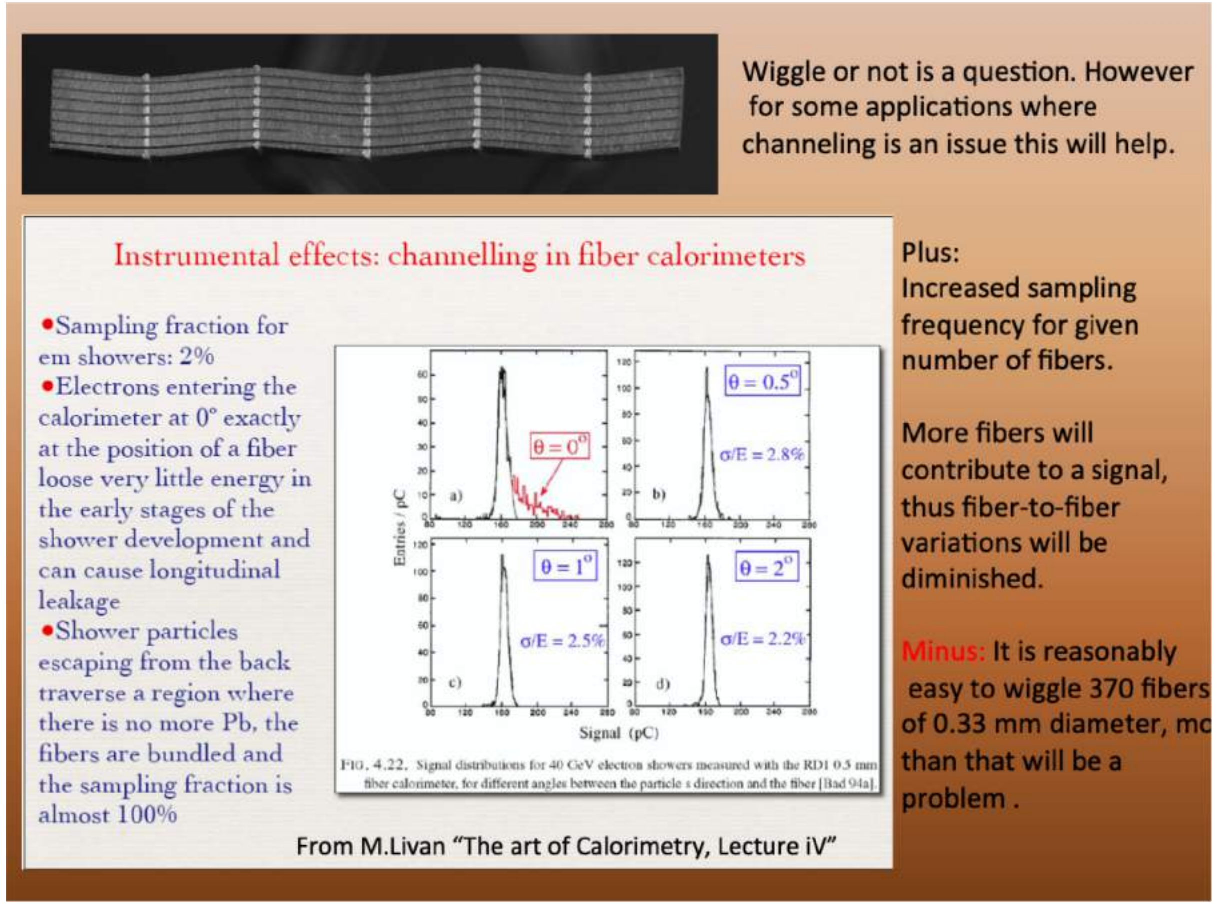
- SHASHLYK (Phenix, STAR Forward)
- WScFi (STAR Forward 2014) – compensated
- Fe/Sc (STAR Forward 2020)

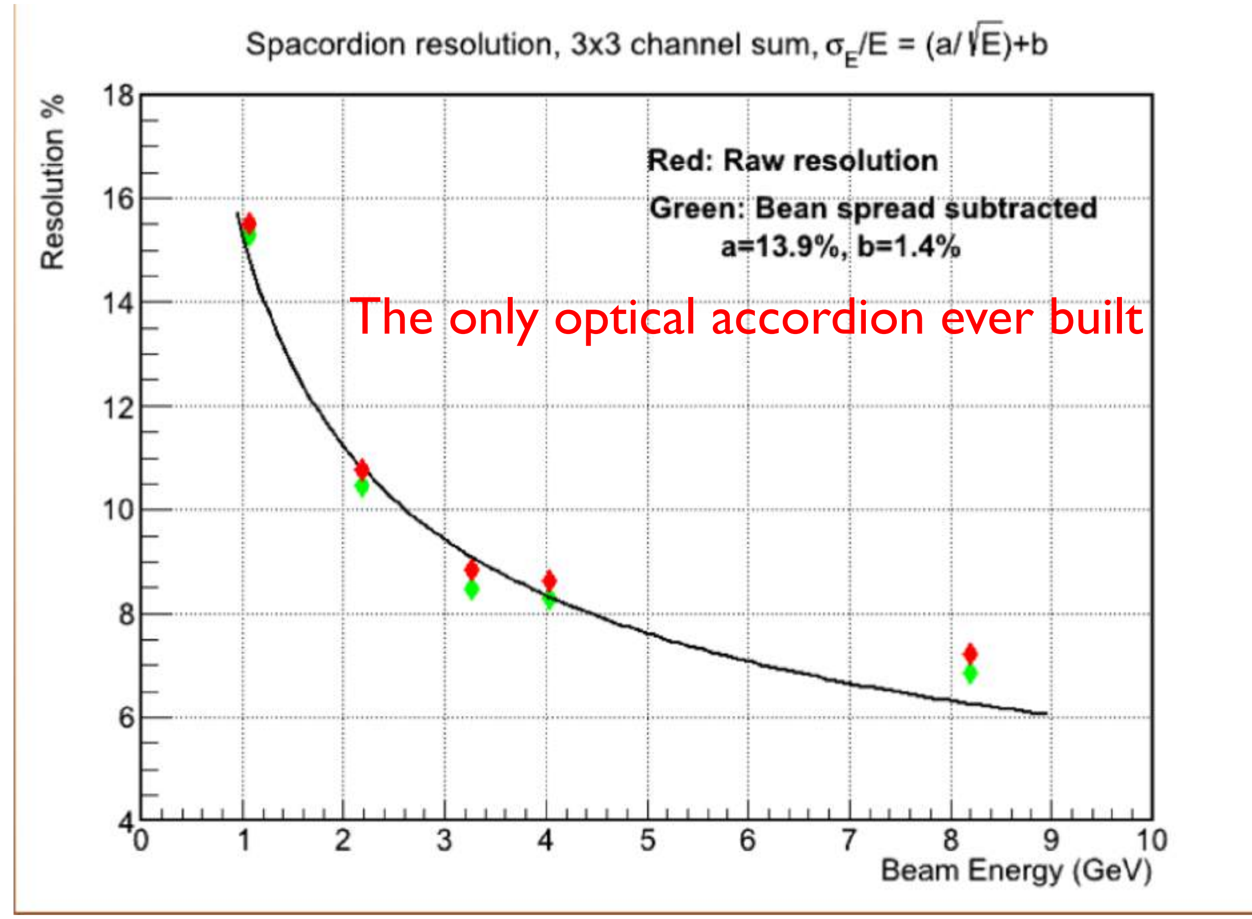
Proper detector composition required for good hadronic resolution. I.e. desired to keep e/h as close as practically possible to 1.

N.B. these are MC not an experimental results.

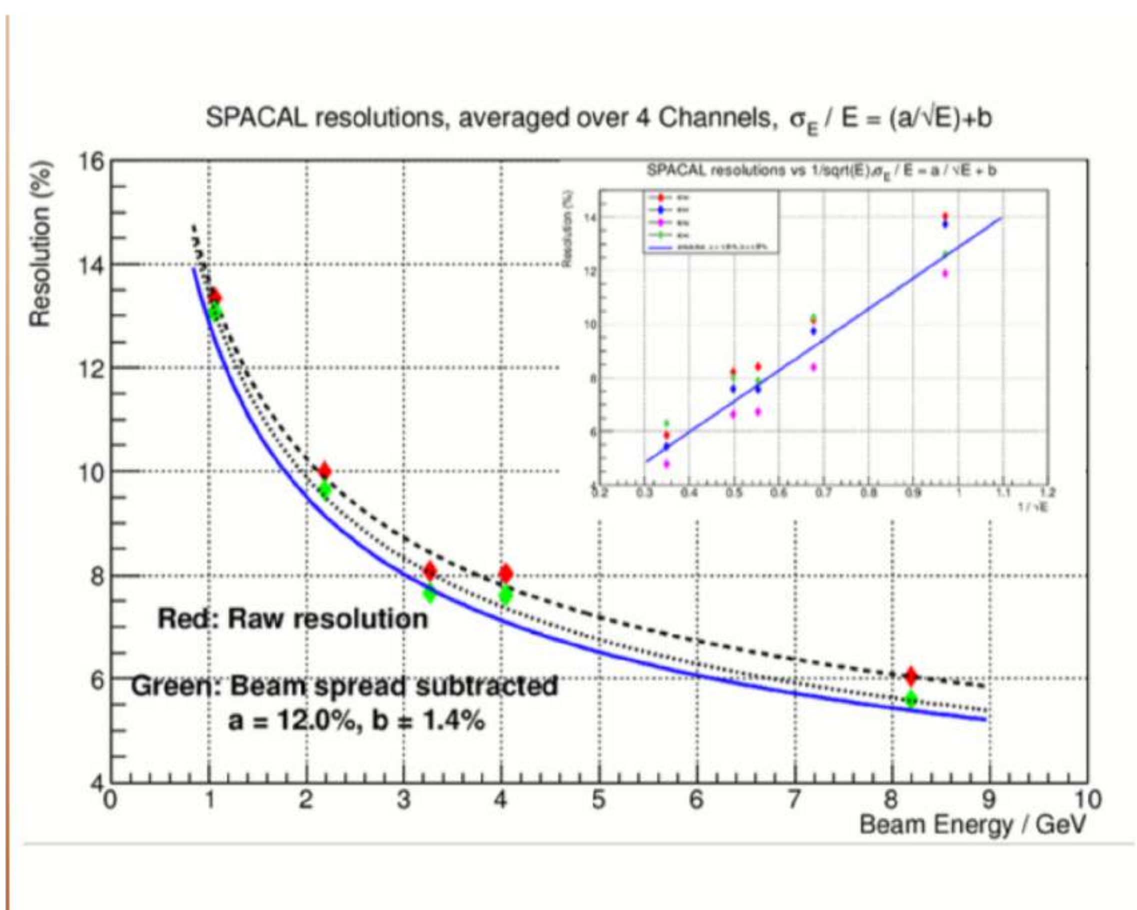
(b) Dedicated meeting for forward Ecals.







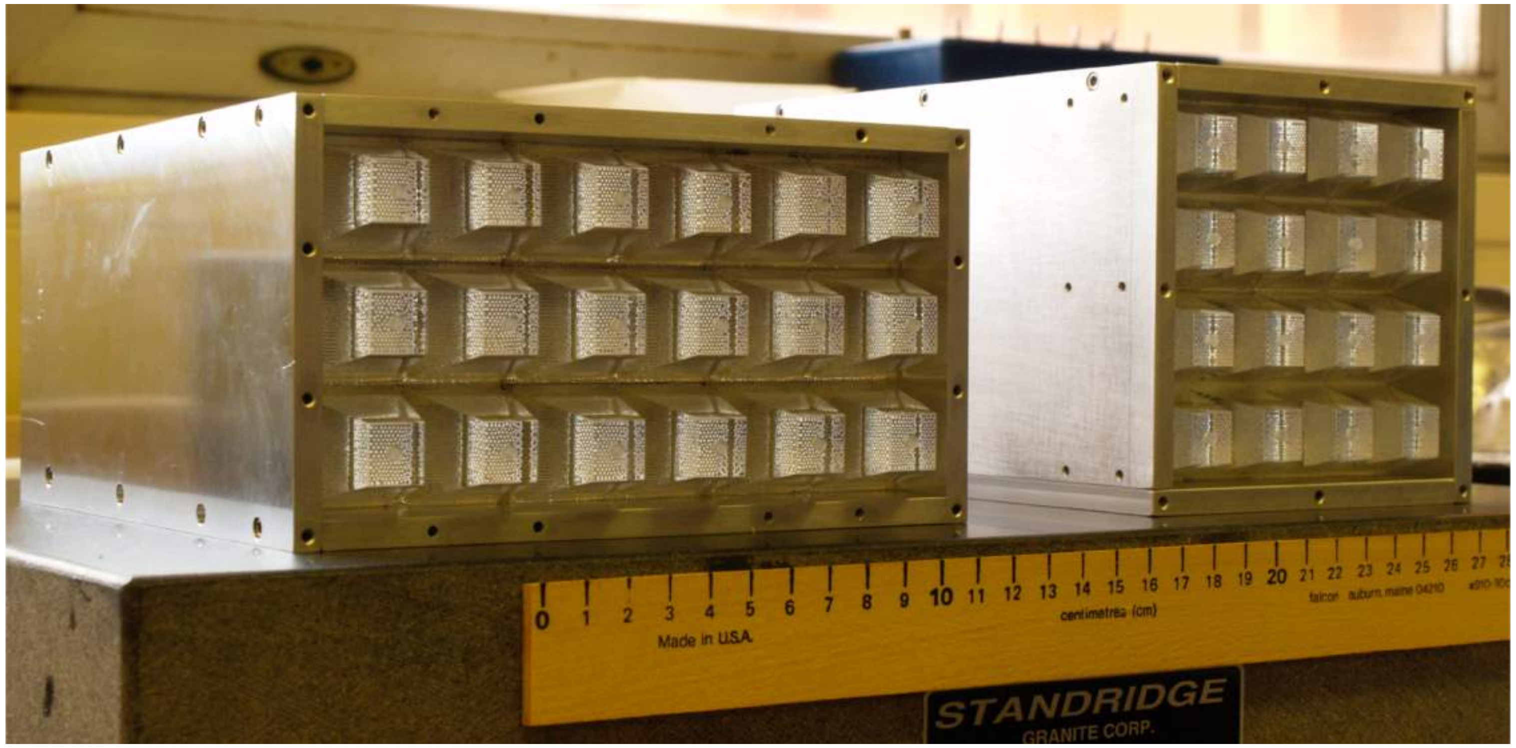
- https://wiki.bnl.gov/conferences/images/d/d4/RD-1_RDproposal_April-2011.pdf



Good agreement with MC (spacordion geometry was not implemented)

WScFi technology capabilities.

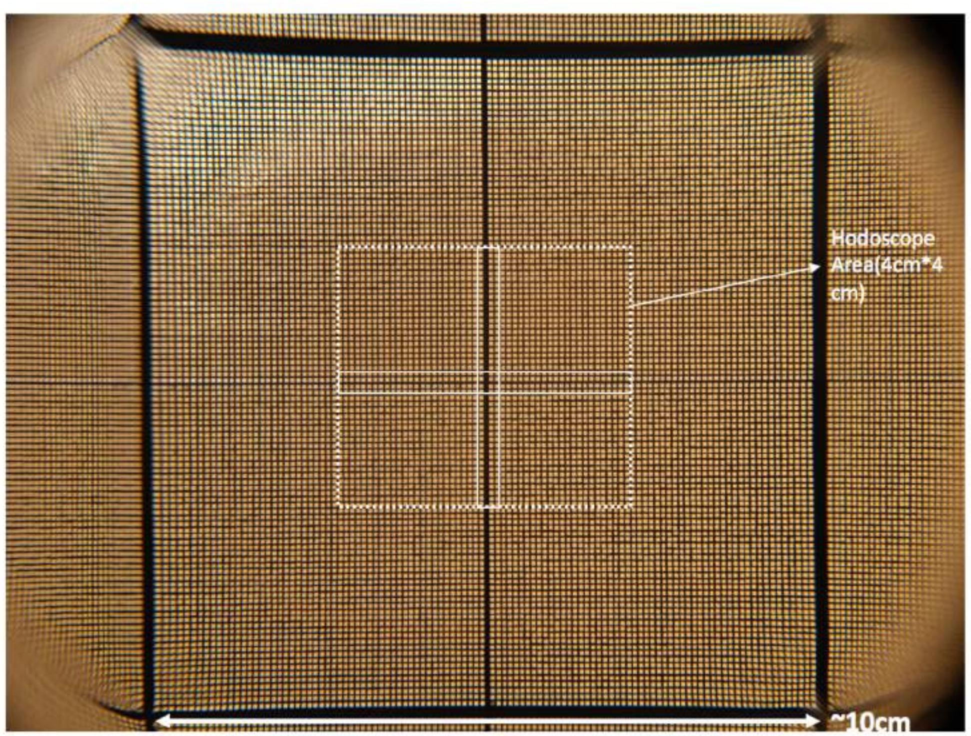
Technology 2 Examples, WScFi technology capabilities

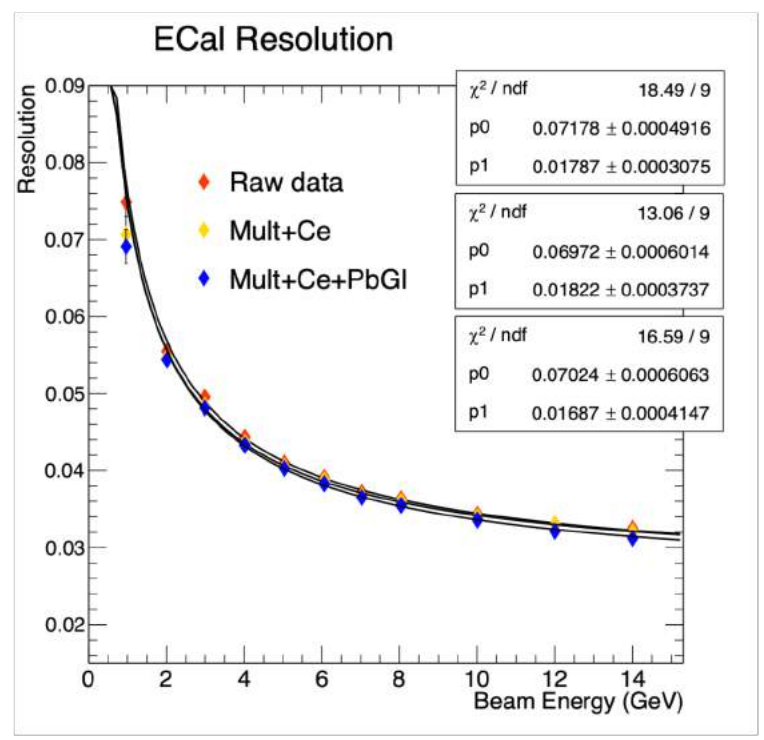


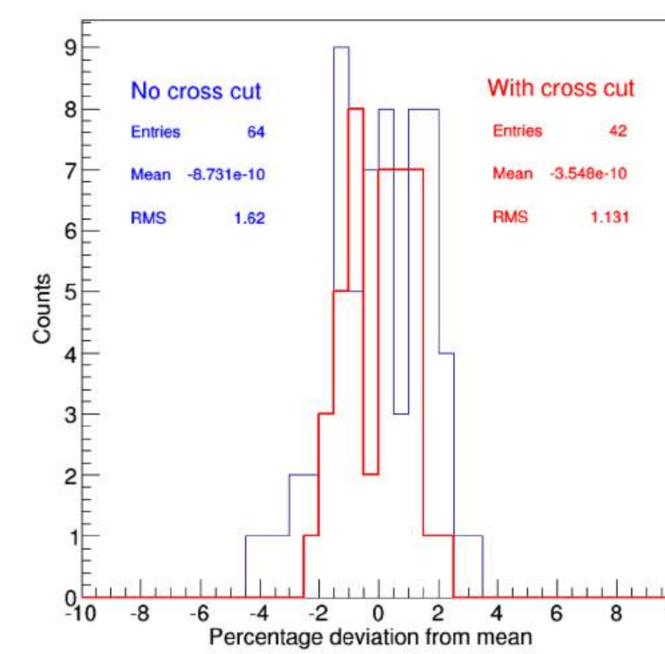
SPACAl and 1D,
FNAL 2014

SiPM Readout

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



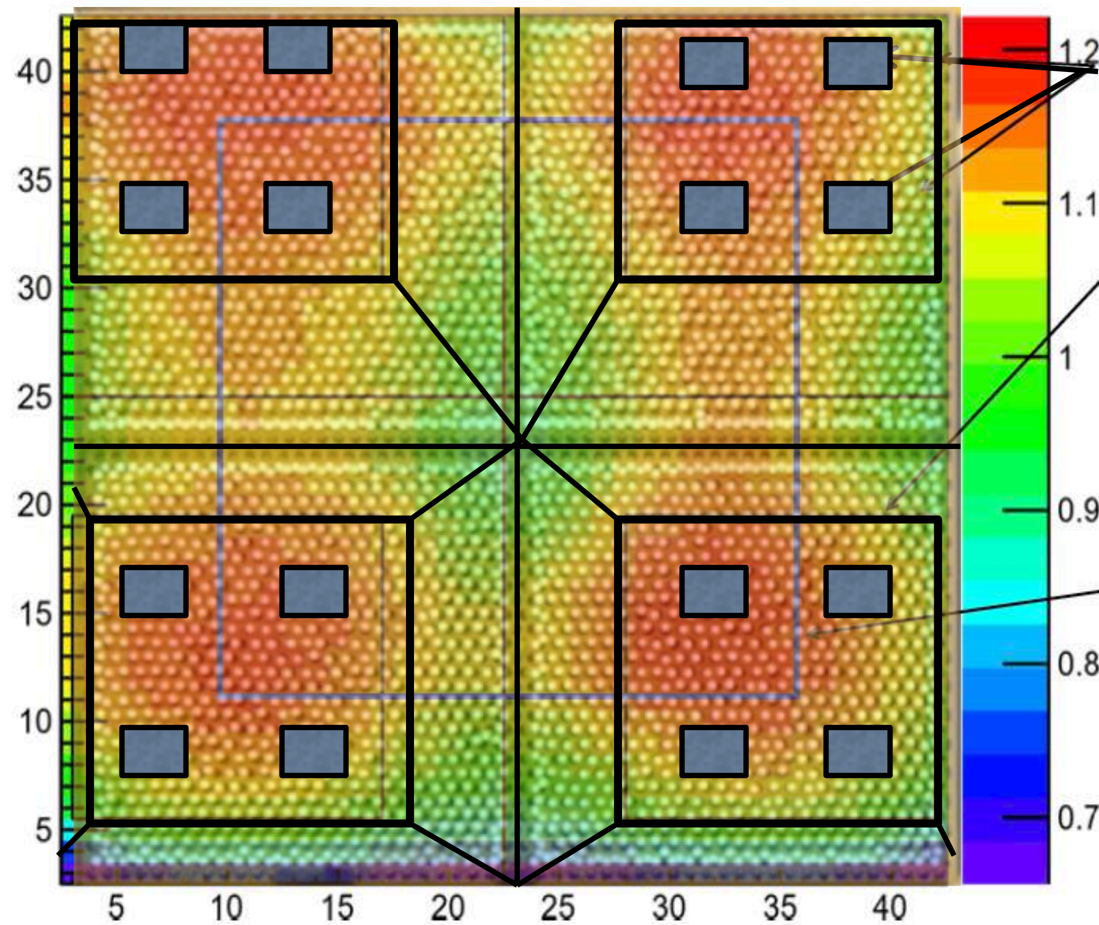




FNAL 2016. High resolution, square fibers, constant term

Optimization of light collection (2016): Areas where improvements nee[d]

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



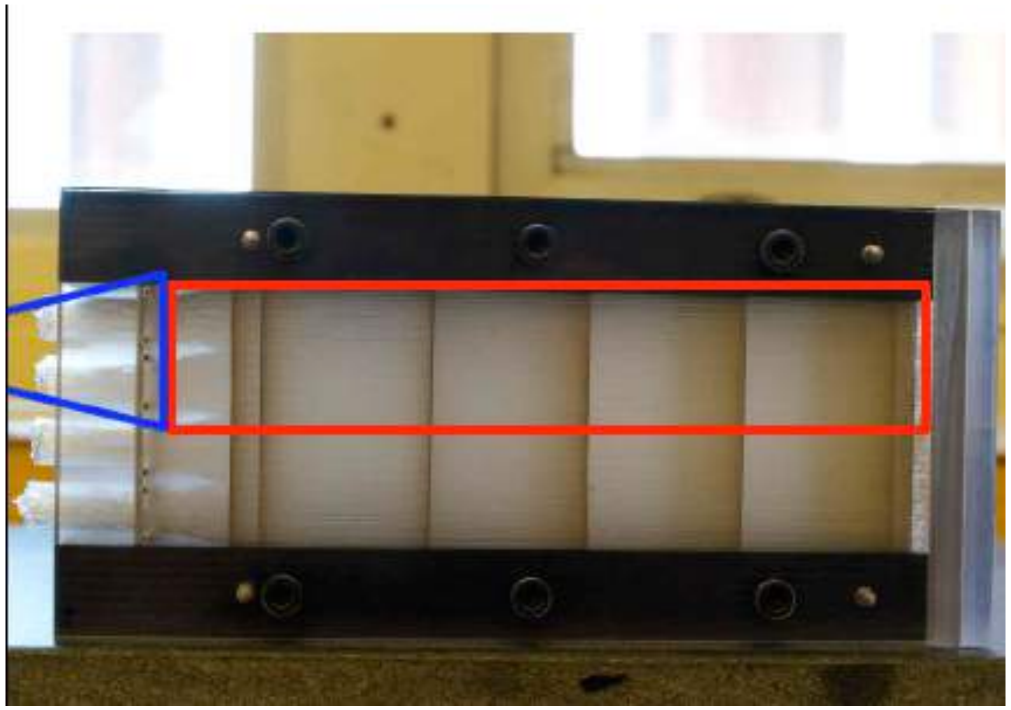
Compact scheme (short light guide with 4 SiPMs, which only partially covering output area of light guide) especially prone to be non-uniform.

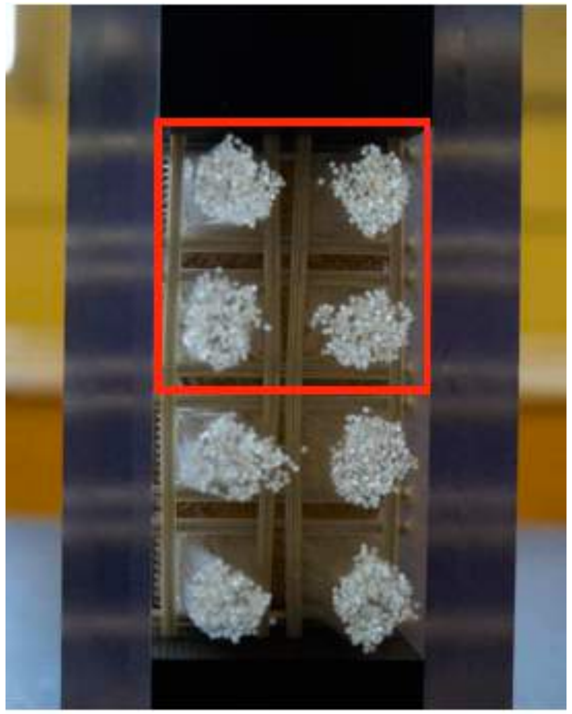
Solutions we tried in the past:

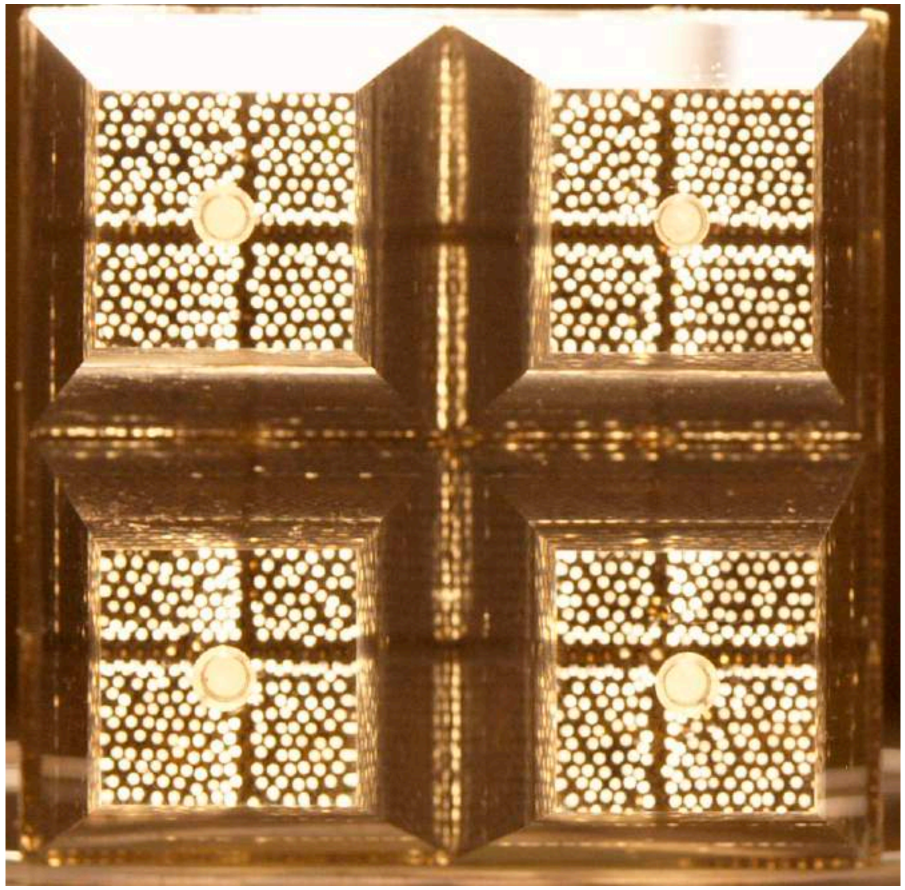
1. Compensation Filter between fibers and light guide. Loss about 30% of light (test run 2015). Will not work for FEMC.

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.

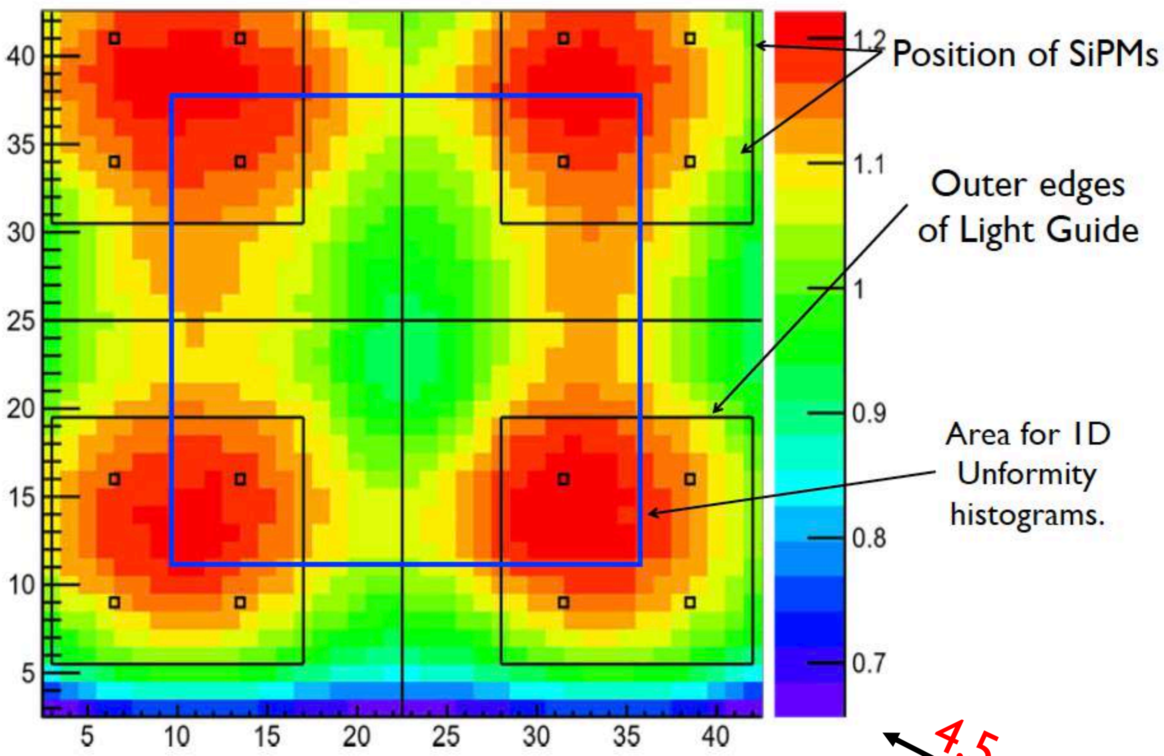




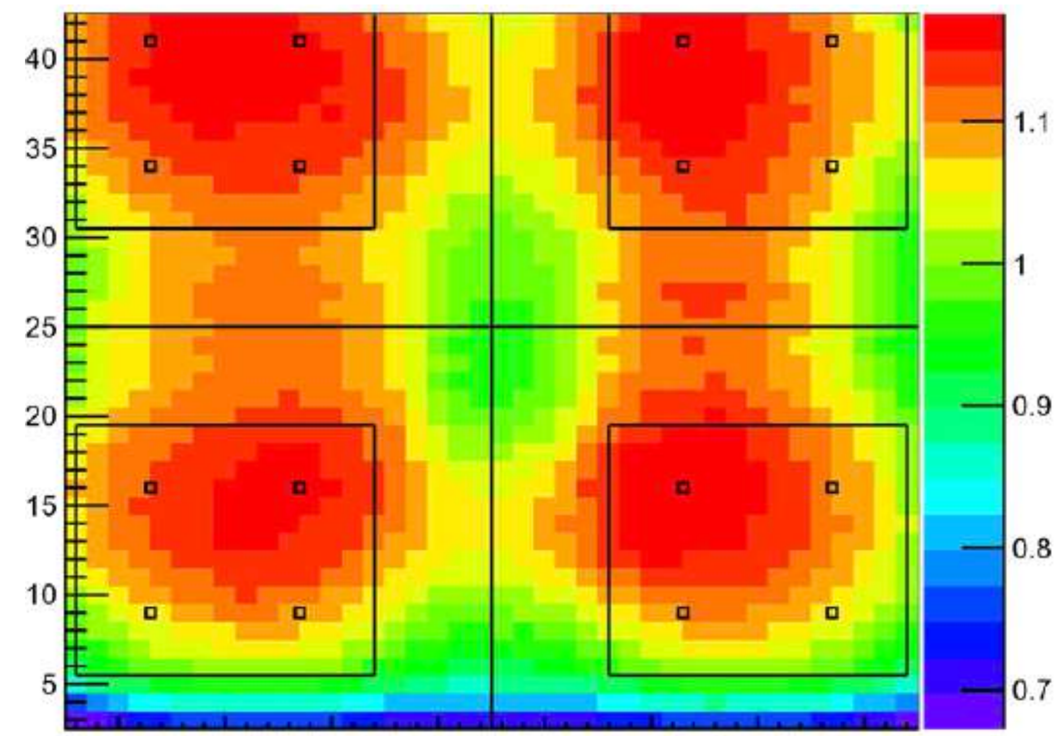


Optimization of light collection:

BEMC Superblocks, UV LED Map

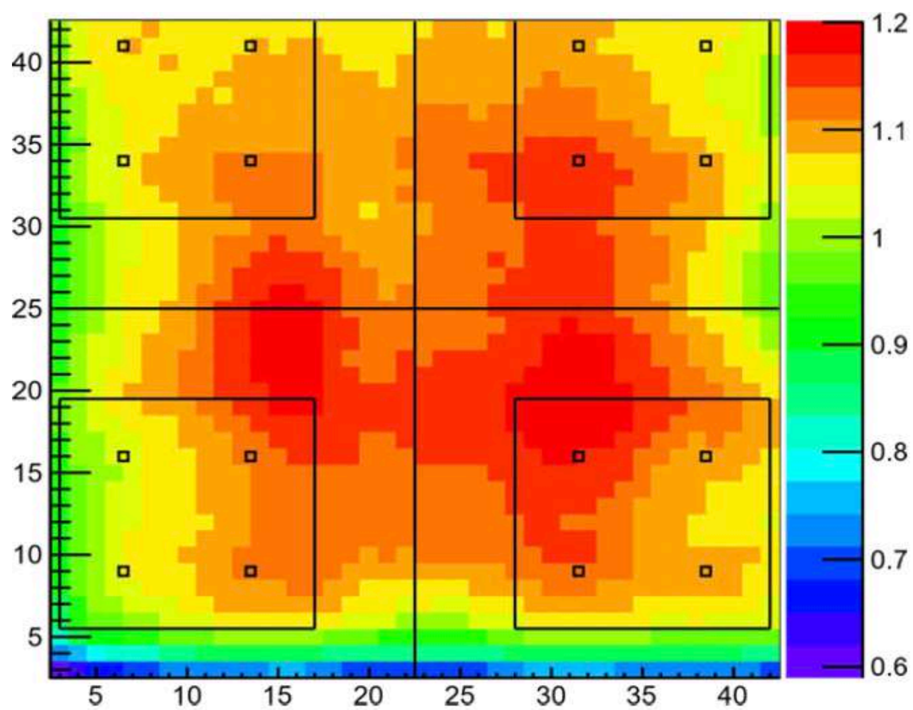


Old BEMC, Sylgard 184, 3mm

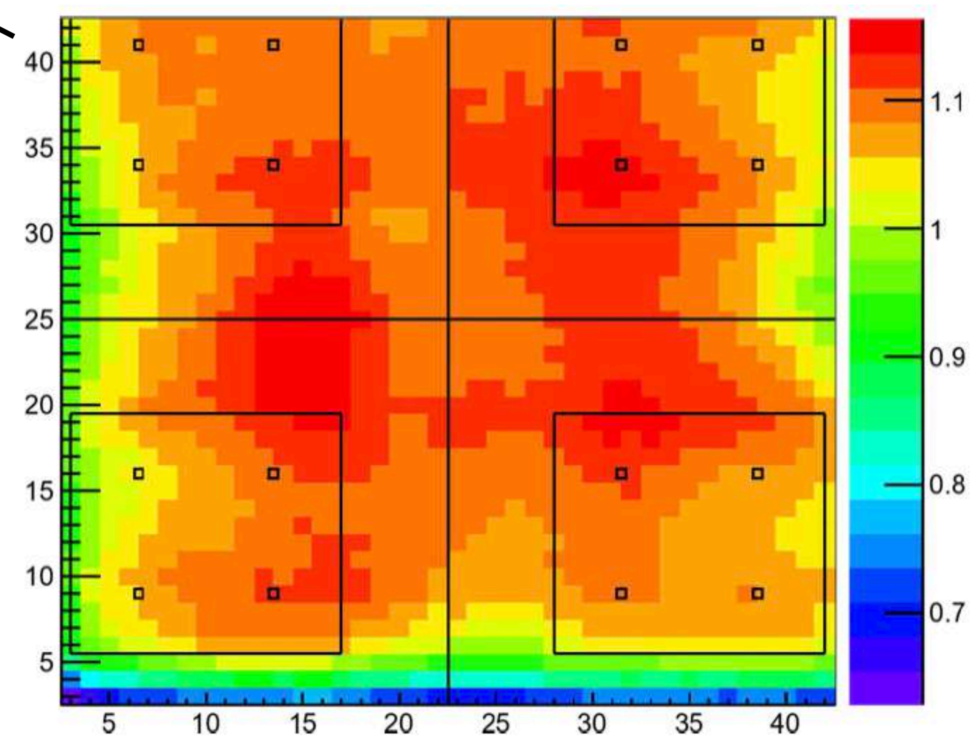


Old BEMC, BC-630, coupling is important

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

2. The full pro/con list that was used to inform your recommendations. This should include any and all considerations that helped the WG form your recommendations.

Technology Pro:

- WScFi is a unique technology allowing to achieve e/h ~1 (response to hadrons) and at the same time keep em energy resolution at ~10%/√ E + 2%, no other known technology for EMcals can achieve this. (details https://indico.bnl.gov/event/15493/)
- WScFI is a self supporting structure – no dead areas within detector volume.
- WScFi technology allowing to build detectors with different configurations such as an Optical Accordeon, eRD1. Insert next to beam pipe (channeling).
- WScFi technology allows to build very high density calorimeters. Insert next to the beam pipe. 23X_0 WScFI 30 cm integration length in Z vs 18X_0 SHASHLYK with ~60 cm in Z.
- WScFi method is very simple requires only few components to build detector.
- Very simple mechanical integration (with Hcal and readout).

Technology Con:

- Absolute light yield is lower than in SHASHLYK (small sampling fraction).
- Uniformity of light collection need to be improved, compared to sPHENIX

Important considerations:

- Strong/good record team interested in pECAL (UC_EIC Consortia, Chinese Consortia, eRD106) see presentation from Chinese consortia https://indico.bnl.gov/event/15812/
- Performance, cost and risk are well understood due to almost 10 years long R&D and sPHENIX construction. Know How well spread in EIC Users community.
- 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 LY and uniformity of light collection with compact readout.

3. Your view of how these recommendations fit with the global detector. e.g. Did you ensure the system fits within the geometrical constraints. Have you considered how service routing might work?

- Yes, system will fit into integration volume, allowing more space for HCal.
- We have concept of how service routing might work. No detailed studies. It depends on readout concept. Integration volume for readout seemingly sufficient for both schemes.

4. What is the assumption of performance and material distribution of other subsystems that were relevant for your study?

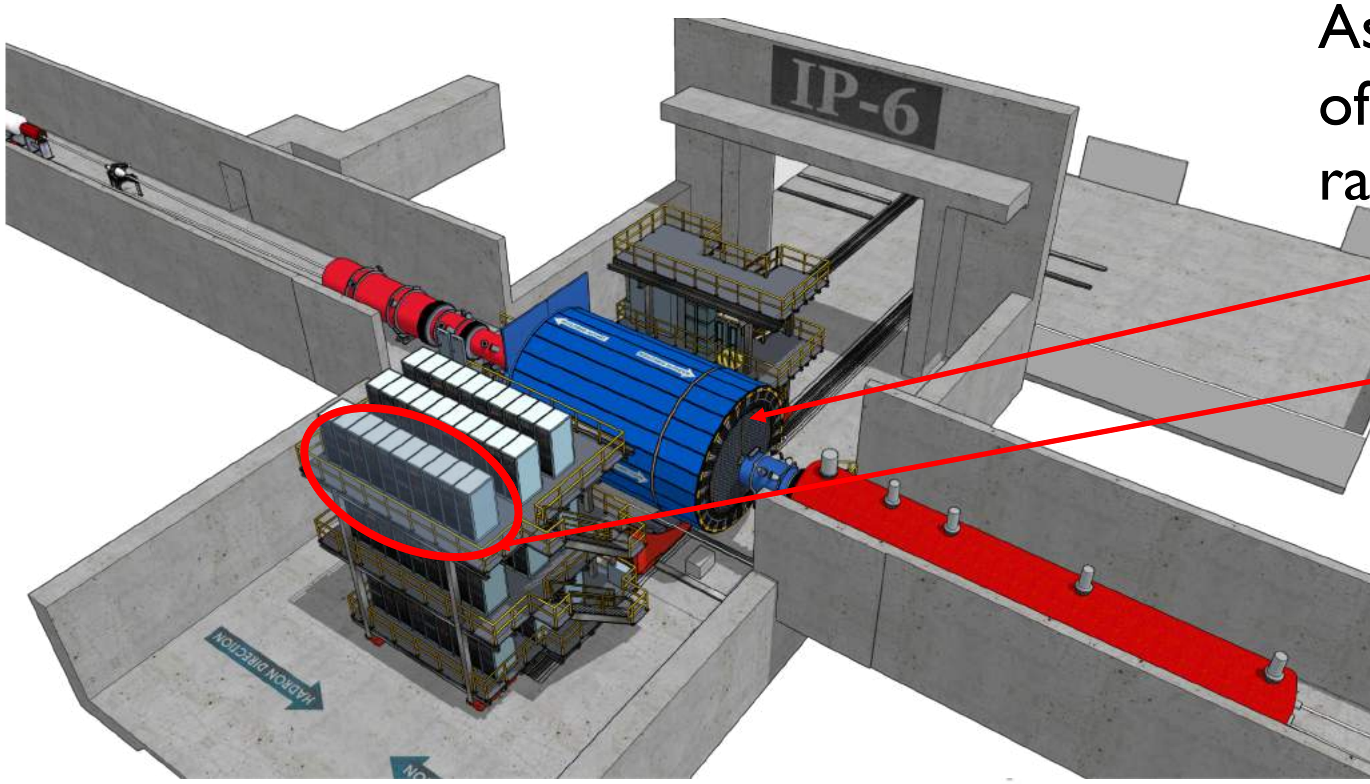
- In ATHENA DD4HEP all materials upfront of the detector were included in simulations.

5. Do you see any potential challenges integrating your recommended solution within the global detector?

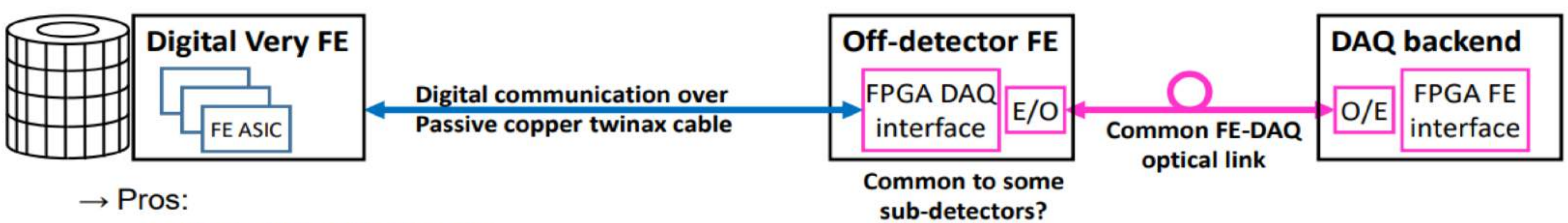
May be. This is related to readout concept (ADCs on detector vs in the racks). So far we assumed readout scheme similar to STAR FCS or sPHENIX, i.e. FEEs on detector – digitizers in the racks. Requires lot of cables/racks space next to endcap (in principle this space is there, but more elegant solution may be to push ADCs to detector, which generate other issues). Here we need preliminary engineering to consider both options. Support for engineer. Add this to eRD106 plan? TBD.

5. Do you see any potential challenges integrating your recommended solution within the global detector? Cont.

Available rack space on both sides of End Cap. Assuming STAR FCS/sPHENIX type of arrangement of FEEs/Digitizers , ECAl only will need about 10 racks



- Minimal on-detector digital very frontend electronics with remote off-detector DAQ interface



→ Pros:
- Optimal for S/N and SEU
- Near optimal for power/cooling

→ Cons:
- Two species of frontends to be developed and maintained
- Copper cables are more bulky than optical cables

→ To be understood:
- Acceptable copper cable length for O(1 Gbit/s) communication speeds
- Number of needed twinax lanes for downstream and upstream communications

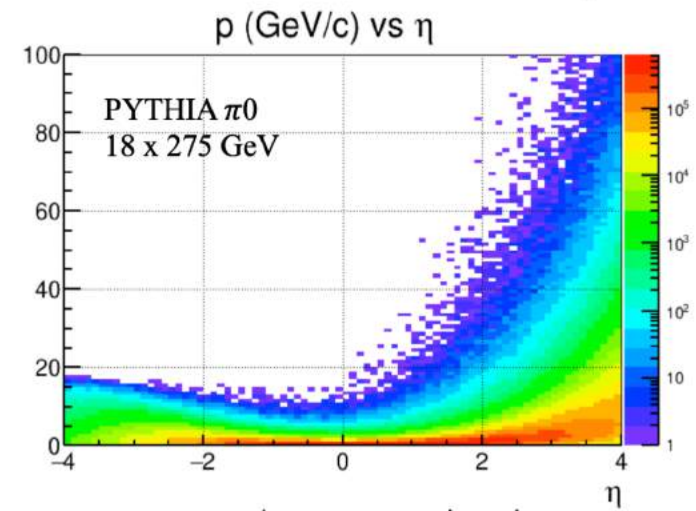
Most likely scenario, see Jeff's talk on Fri. 24

6. Further, we would like to see simulations that validate the performance of the proposed configuration.

pECal functionality Pi0/gamma separation

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

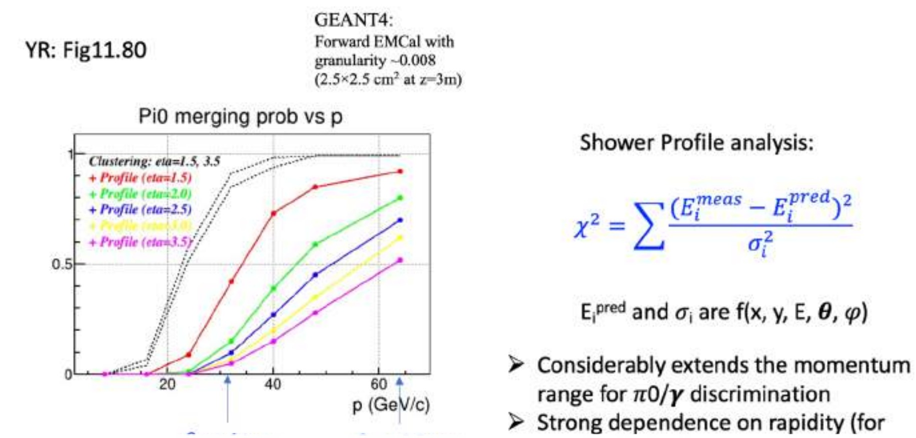
YR: Fig11.80



e-endcap:
up to e-beam momentum

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

Shower Profile Analysis

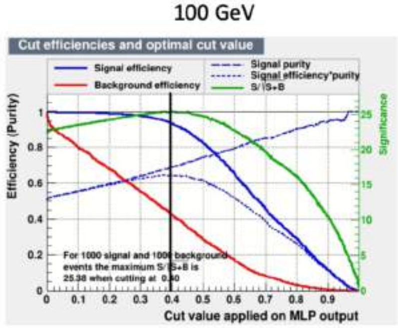


$$\chi^2 = \sum \frac{(E_i^{meas} - E_i^{pred})^2}{\sigma_i^2}$$

Signal/Background efficiency after MLP

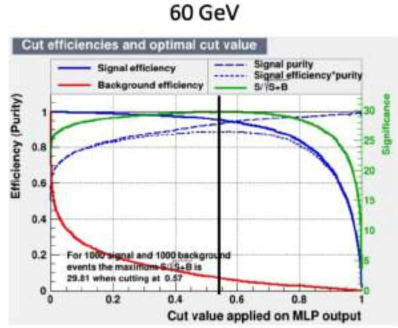
h-endcap: 2.5x2.5cm at z=3.5m, η=3

100 GeV



$\varepsilon_{Bg} = 42\%$ for $\varepsilon_{Sg} = 95\%$

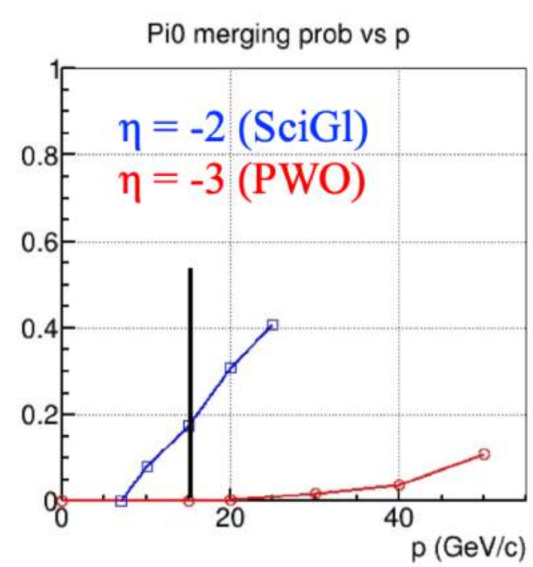
60 GeV



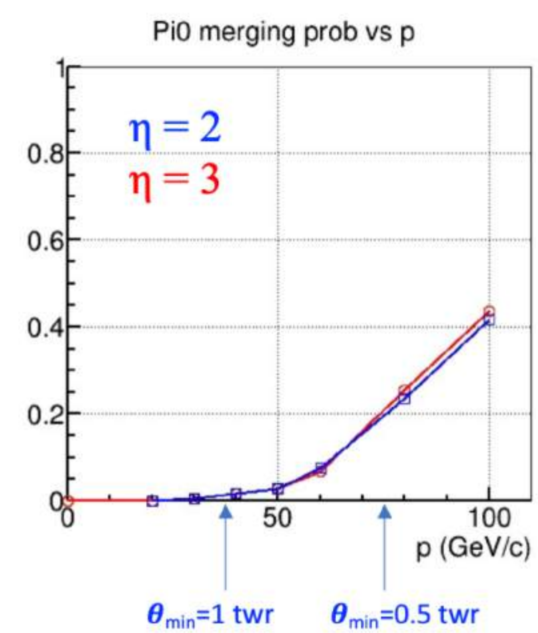
$\varepsilon_{Bg} = 7\%$ for $\varepsilon_{Sg} = 95\%$

Pi0 merging prob after MLP

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 $\gamma/\pi0$ even when two photons are separated by 0.5 tower size

θ_{min}=1 twr θ_{min}=0.5 twr

Small X_0 for non-projective pECal is important. Granularity 2.4 cm x 2.5 cm is sufficient

Backup Materials