
Universe 5-IV-71 #200, Whanki Kim

ZDC-h for ePIC

Yongsun Kim
(Sejong University)

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Dual-readout calorimetry

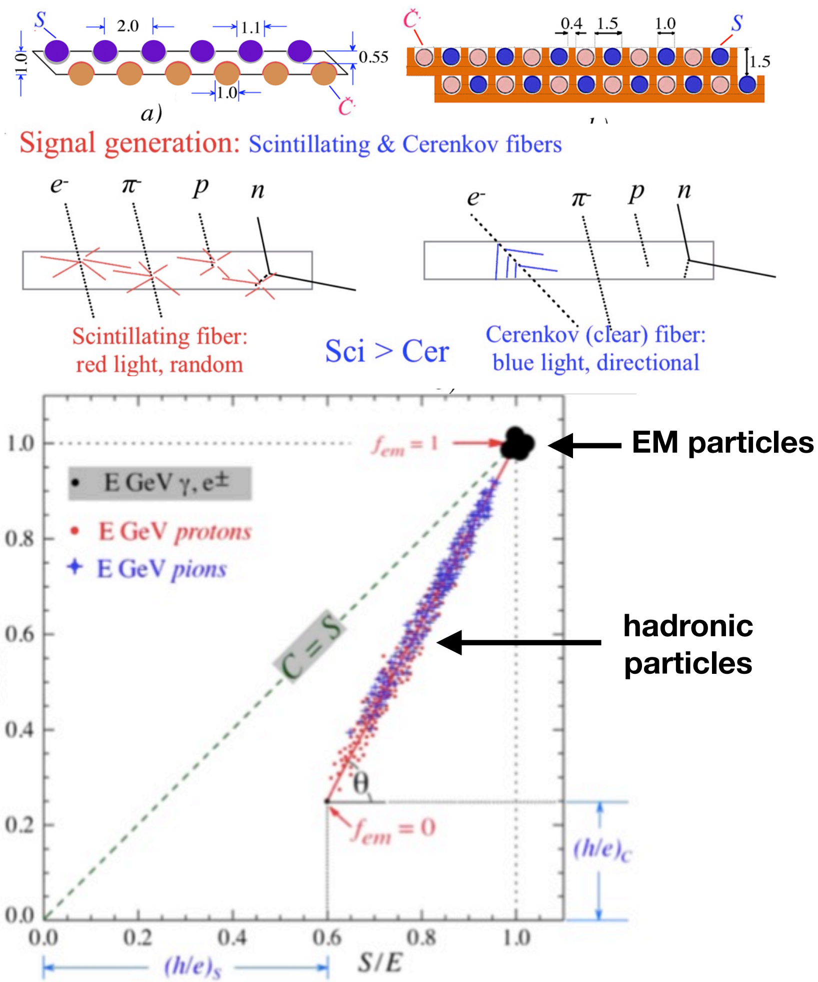
- Dual-readout 101
  - The major difficulty in measurement of hadronic shower comes from EM fraction (f_em)
  - f_em can be precisely measured by implementing two channels with different h/e response in a same module

$$S = E[f_{em} + \frac{1}{(e/h)_S}(1 - f_{em})], \qquad \cot\theta = \frac{1-(h/e)_S}{1-(h/e)_C} \equiv \chi,$$

$$C = E[f_{em} + \frac{1}{(e/h)_C}(1 - f_{em})].$$

$$f_{em} = \frac{(h/e)_C - (C/S)(h/e)_S}{(C/S)[1-(h/e)_S] - [1-(h/e)_C]} \qquad E = \frac{S - \chi C}{1 - \chi}.$$

- Can offer high-quality energy resolution for both EM and hadrons
- Demonstrate engineering aspects for full geometry detector
- 20+ years R&D: CERN RD52 experiment

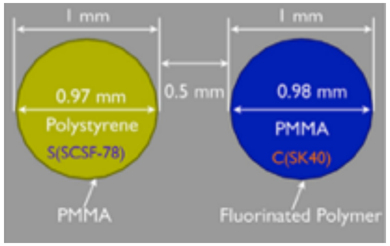


Energy measured from scintillation channel vs Cerenkov channel for EM particle, π & p.

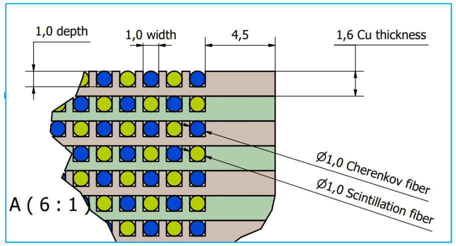
See R. Ferrari's talk yesterday for detail

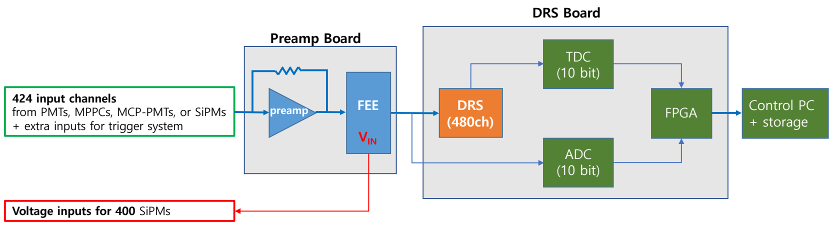
Beam test plan in 2021 (at CERN)

Specification of fibers



NIM A 762 (2014) 100, N. Akchurin et al.



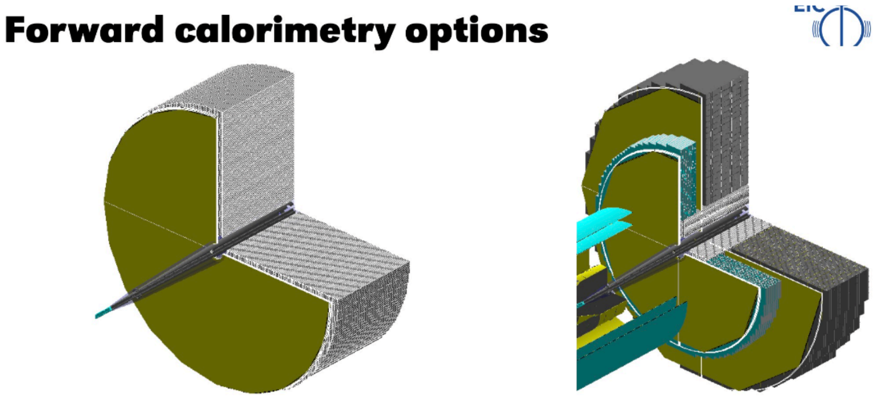


Electronics

- Copper trays are grooved for the space for fibers (cave) and stacked layer by layer
- Fiber diameter = 0.98 mm
- Cave diameter = 1.1 mm
- Fiber installed every 2.5 mm, making 0.5 mm space between neighboring ones
- PMT or SiPM
  - Each PMT takes 450 fibers
  - Each SiPM handles 9 fibers
- (Much) over-specification for ZDC-h

Sc/fi design for ZDC-h?

	$
Scintillation fiber (/m)	2
Cerenkove fiber (/m)	0.38
Cu (/kg)	9.75
W (/kg)	39.25
Generic PMT (/piece)	1122
SiPM (/piece)	10
Elecronics for generic PMT (/channel)	50
Elecronics for SiPM (/channel)	10



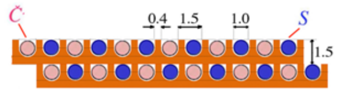
(million $)

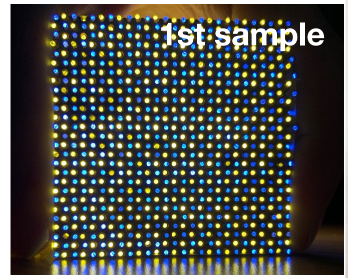
	M$	Inlay	Full
Cu	Generic PMT	1.3	30.7
	1-on-1 SiPM	6.4	147.3
	Grouping SiPM	1.8	40.1
W	Generic PMT	1.8	40.6
	1-on-1 SiPM	6.9	157.2
	Grouping SiPM	2.2	50.0

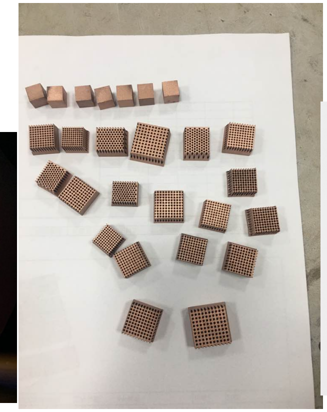
- Tower size: 46x46x250 mm^3
- Each tower has 30x30 fibers
- One PMT corresponds to 450 fibers
- 1-on-1 SiPM: Each SiPM connected to single fiber
- Grouping SiPM: Each SiPM to 9 fibers

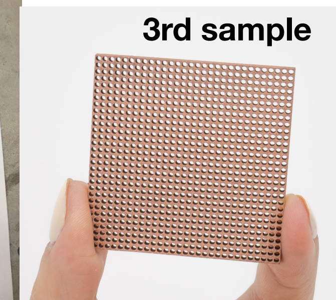
3d printing for copper module

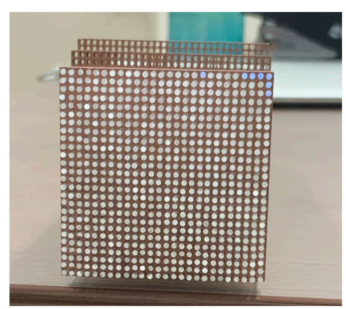
- Two major questions on the DRC for engineering aspects
  - Complex design, projective shape
  - Innovative 3D printing technology can be a solution
- Use 3D metal printer to materialize Cu blocks with fine structure holes
  - 1mm hole diameter, 0.5 mm wall thickness between holes
- Prototype under test and discussion
  - 1st samples (from Finland), 2nd & 3rd samples (from China) tested
  - 50 cm length prototype module is being produced

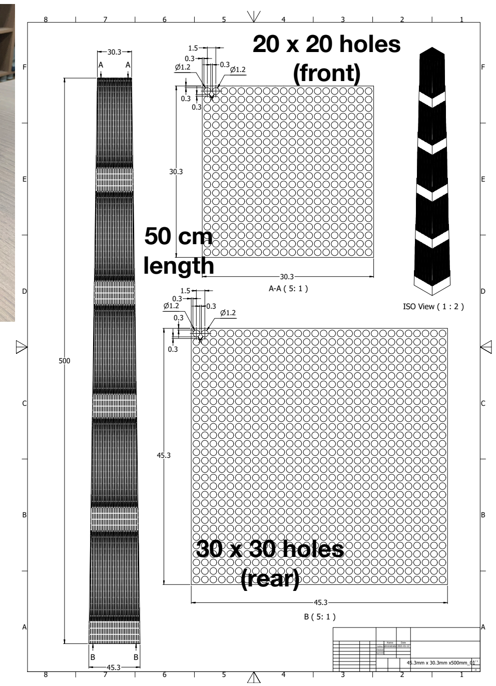






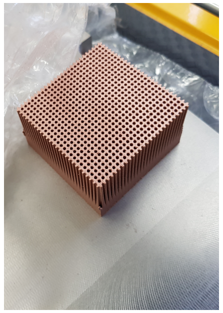
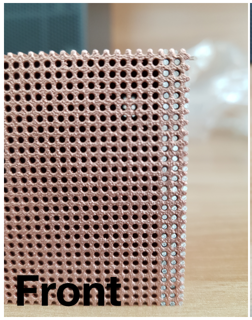


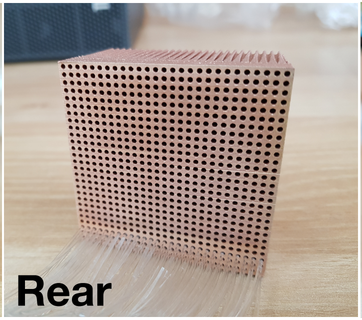


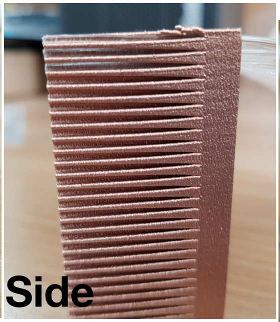


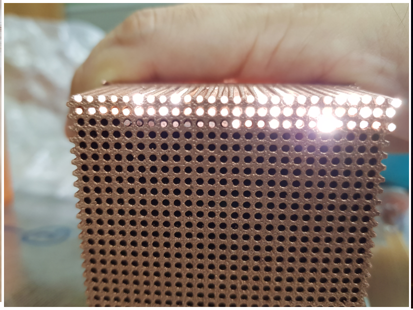
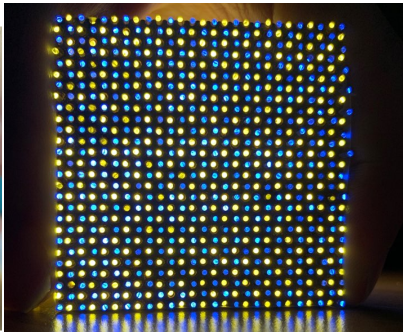
3d printing for copper module

- 1st samples (from Finland, using EOS 3D printer)

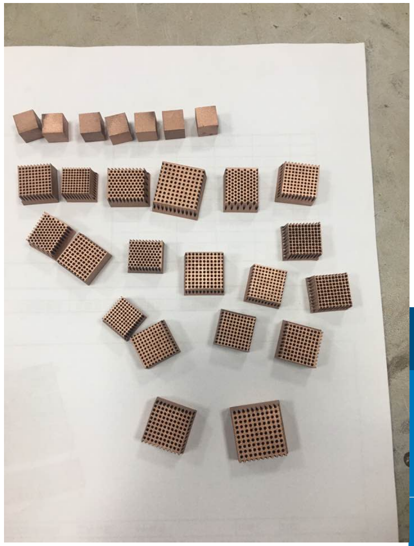
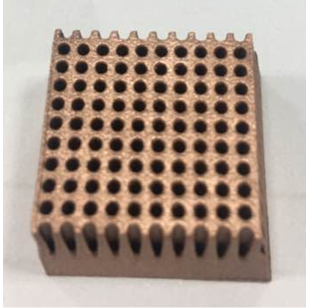
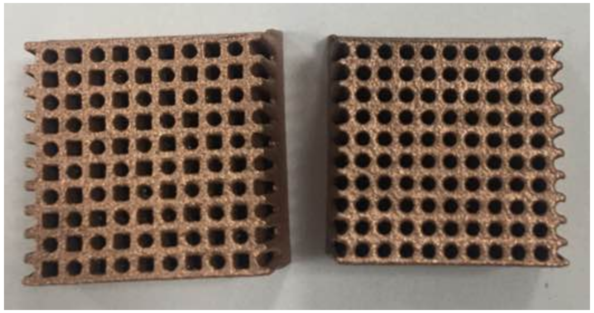







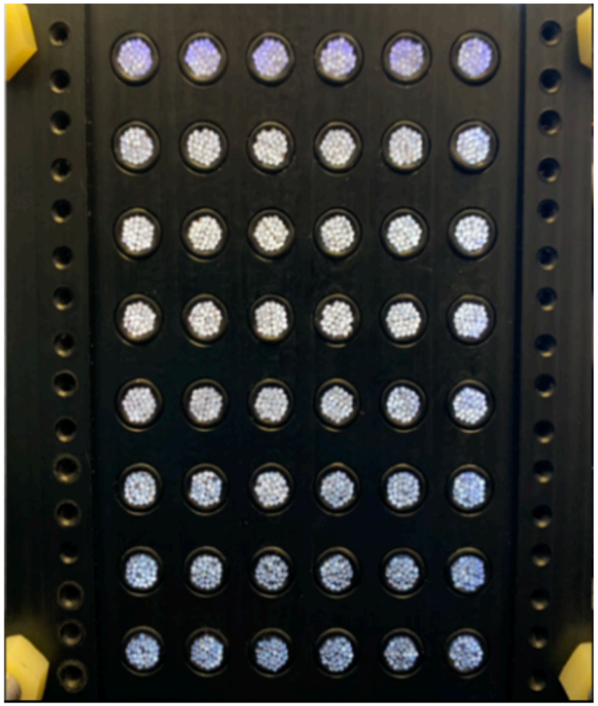



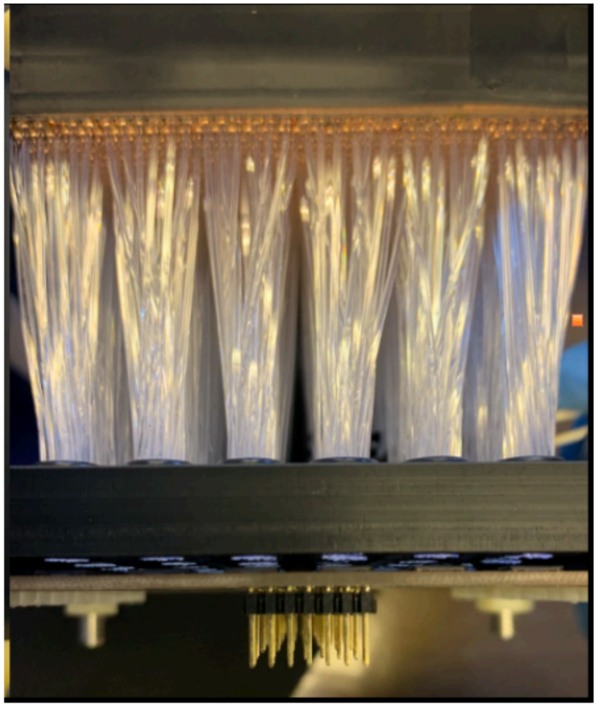
- 2nd samples (from China, using Farsoon)


	Samples	1	2	3	4	5	6	7	8	9	10
Hall diameter (mm)	Designed	1.0	1.1	1.2	1.1	1.0	1.3	1.1	1.2	1.2	1.1
	Outcome	0.9-0.95	0.9-0.95	1.0-1.05	0.8-0.85	0.8-0.85	1.1-1.15	0.9-0.95	1.0-1.05	1.0-1.05	0.9-0.95
Wall thickness (mm)	Designed	0.5	0.5	0.5	0.4	0.3	0.7	0.5	0.3	0.5	0.4
	Outcome	0.52	0.6	0.62	0.5	0.45	0.81	0.6	0.4	0.65	0.52

ALICE Focal-h



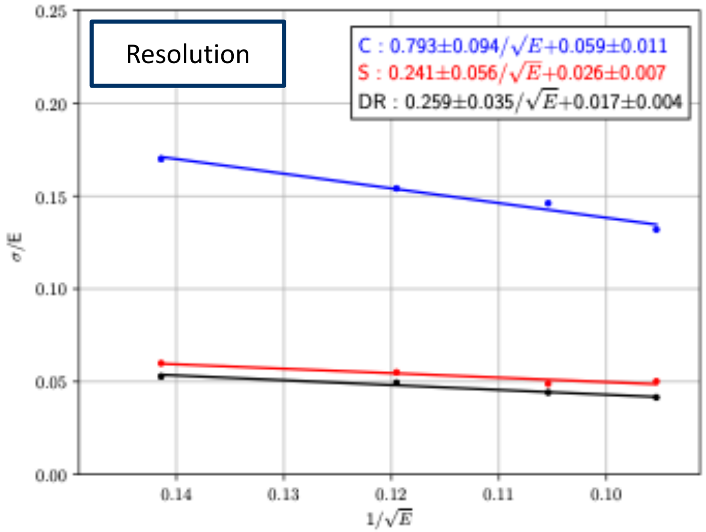


- Copper capillary tube with plastic scintillator fiber
    - Outer diameter = 2.5mm -> Spacing = 2.5 mm (x), 2.16 mm (y)
    - 1440 fibers in total, 5x6 fibers grouped in 48 bundles
    - Each bundle followed by each SiPM

ZDC-h?

- New design (Goto-san's slide)
    - No imaging (Pb-Si) layers for hcal sectors
    - Pb-(Sc + Fused silica) [10 cm x 10 cm x 48 cm] x [4 x 4 towers]
- Parameters to be fixed
    - What's the best materials? Cu, Pb, anything else?
    - Is dual (C+S) configuration necessary?
    - What is the optimal number of fiber grouping for each SiPM?
- Can we improve the resolution for single readout (Cerenkov-only) by increasing the number of SiPM?

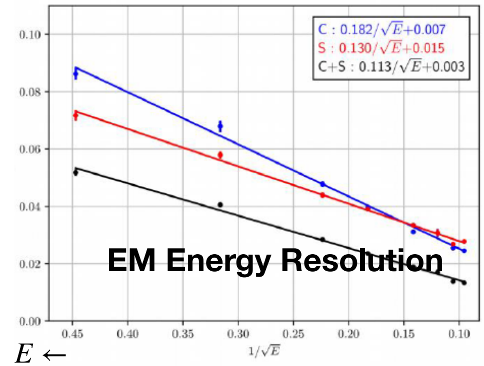
- Simulation study will start soon

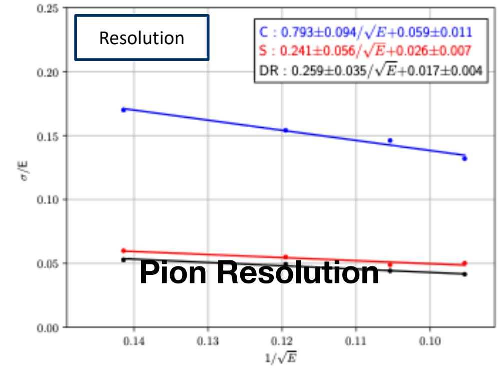


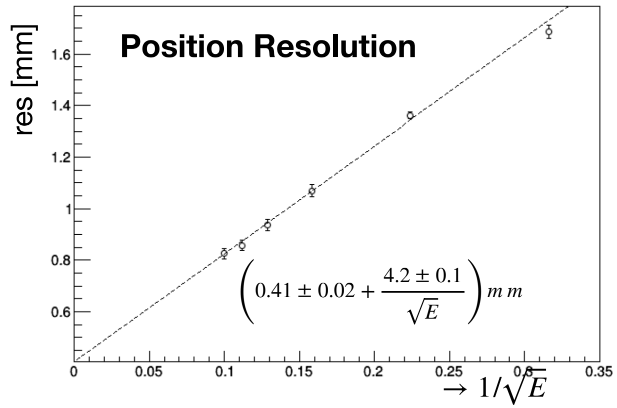
BACKUP

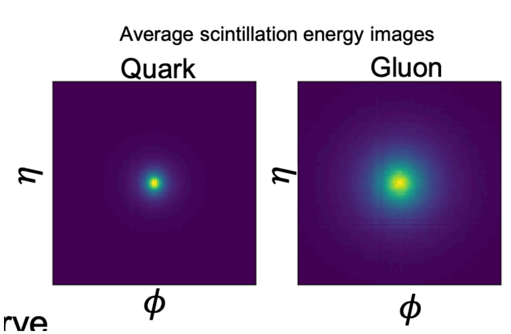
GEANT4 simulation

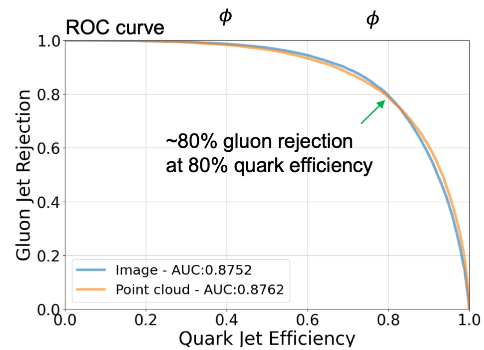
- Various simulation studies are performed
  - Using full GEANT4 simulation
  - DD4HEP migration is done
  - Develop fast simulation for optical photon transport in GEANT4
- Excellent resolutions
  - EM $\sim 11\,\%/\sqrt{E}$
  - Had $\sim 26\,\%/\sqrt{E}$
- q/g jets identification using ML
  - To be a key benefit for hard probe research at EIC











Some notes for ZDC-h development

- Parameters to be determined
  - Fiber diameter and spacing
  - Should it be dual? Only quartz?
  - Number of readouts