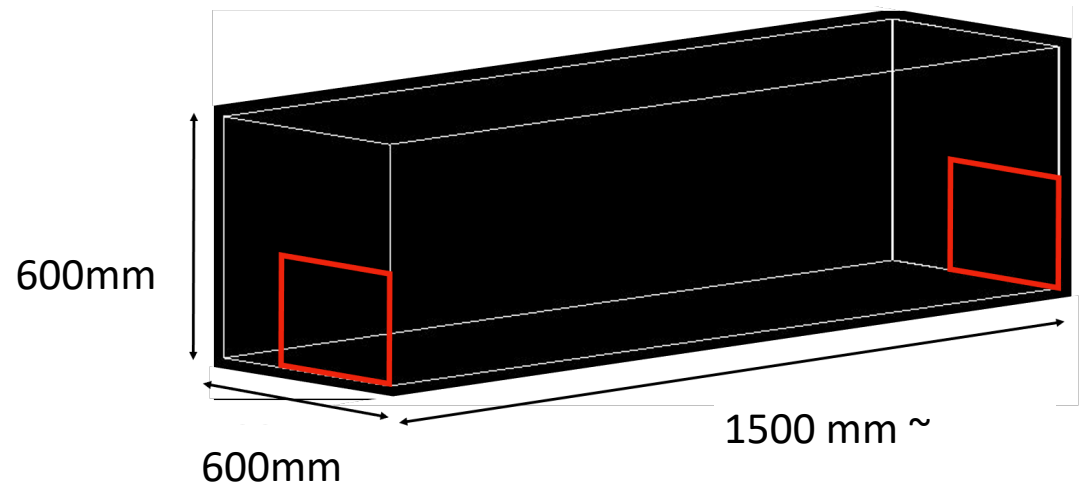


Hadronic ZDC for EPIC

Yongsun Kim

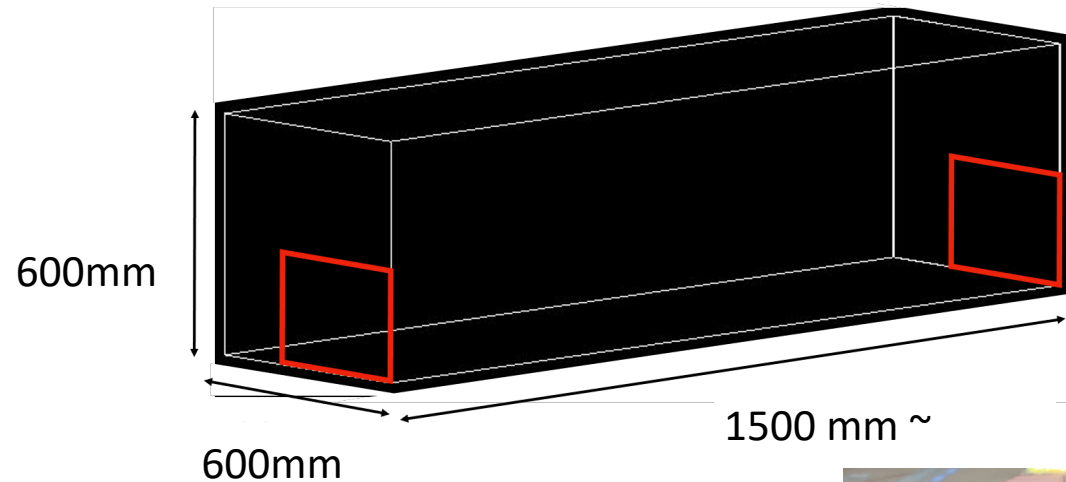
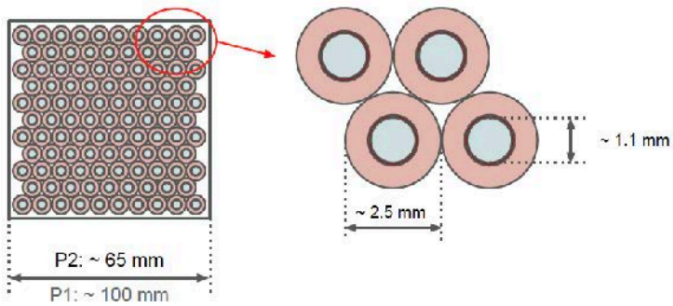
Sejong University

2023.Oct.9

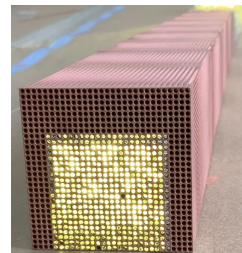


ZDC-h design

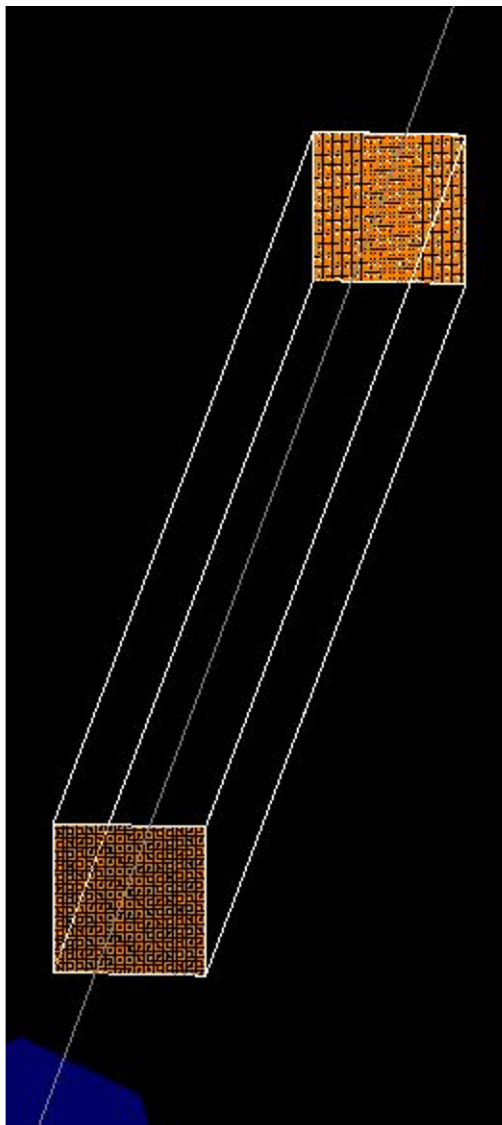
- 2nd design
 - No Pb-Si imaging calorimeter
 - Pb-(Scintillator + Fused silica) by Korea group (Sejong U. & Korea U.)
 - Capillary design
 - 1 on 1 SiPM: each SiPM connected to single fiber
 - Or grouping SiPM: each SiPM to 9 fibers



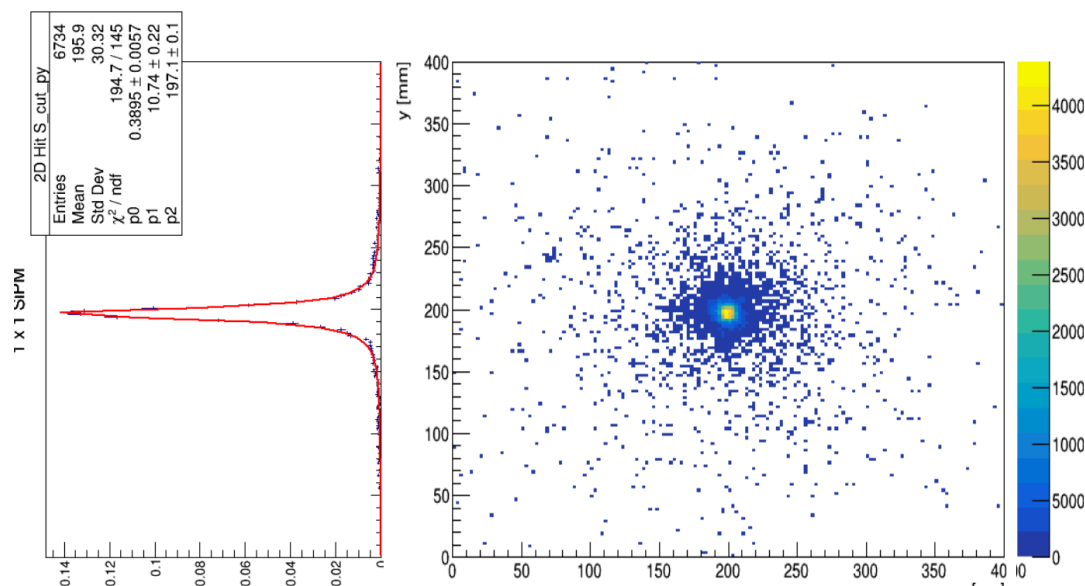
- ALICE Focal-h as the reference
- Fiber size : 1mm
- Spacing = 2.5 cm
- Scintillator fib. mode: Good energy resolution
- Sc+Cherenkov mode : resilient against radiation and useful for PID



Neutron beam simulation



- Full simulation for fibers
 - Package well verified by dual-readout calo studies
 - To be integrated to DD4HEP
- Neutron Energy: 10 ~ 150 GeV
- Normal angle = 4 mrad
- Caveat: Space between fibers are filled by Cu. To be updated with Capillary structure

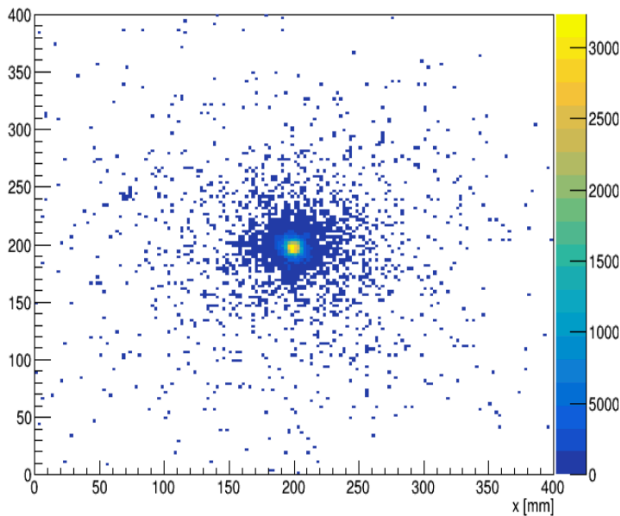


Event display for a 50 GeV neutron

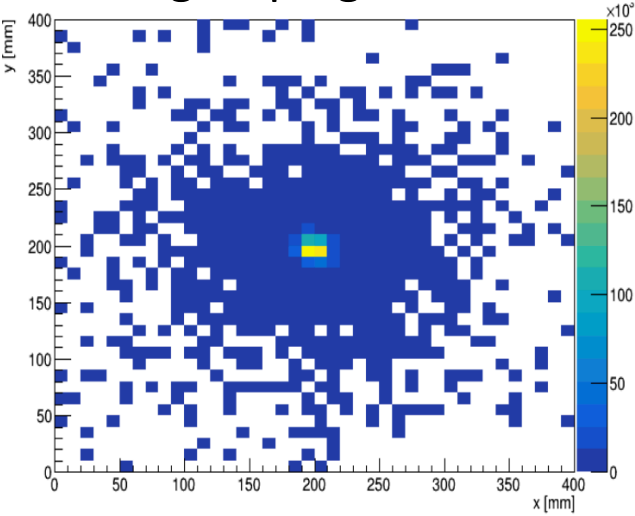
Fiber grouping

- For every fiber to be independent read, we need $240 \times 240 = 57.6 \text{ k}$ SiPMs
- Since the majority of cost is from SiPM and electronics, fiber grouping can dramatically reduce the price

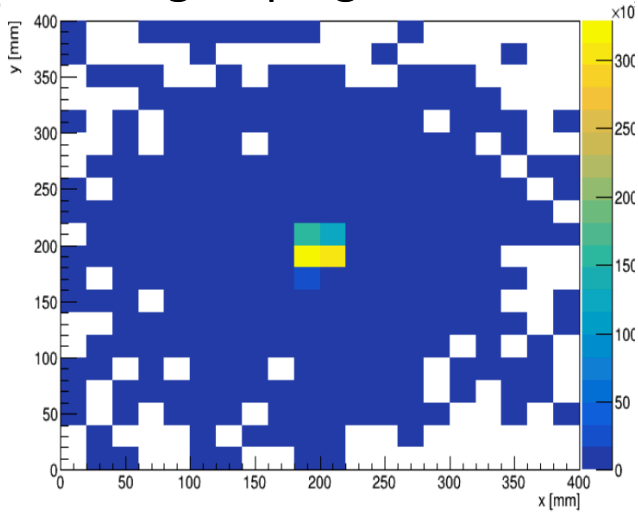
(Total 160x160 fibers)



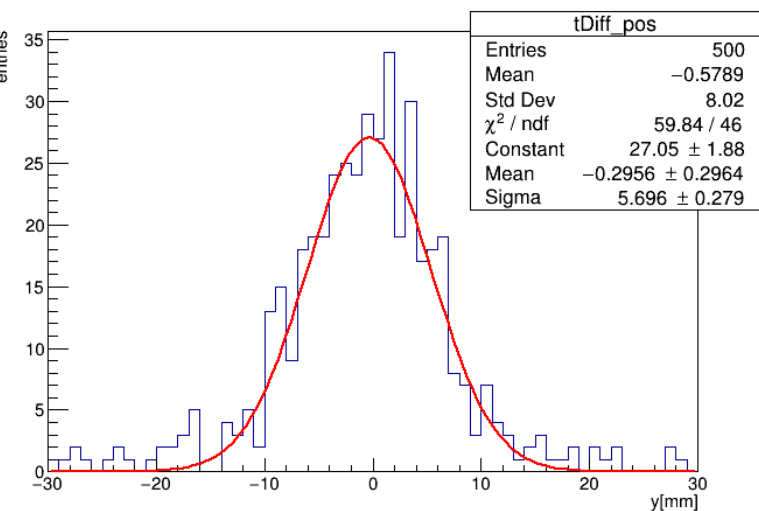
4x4 grouping



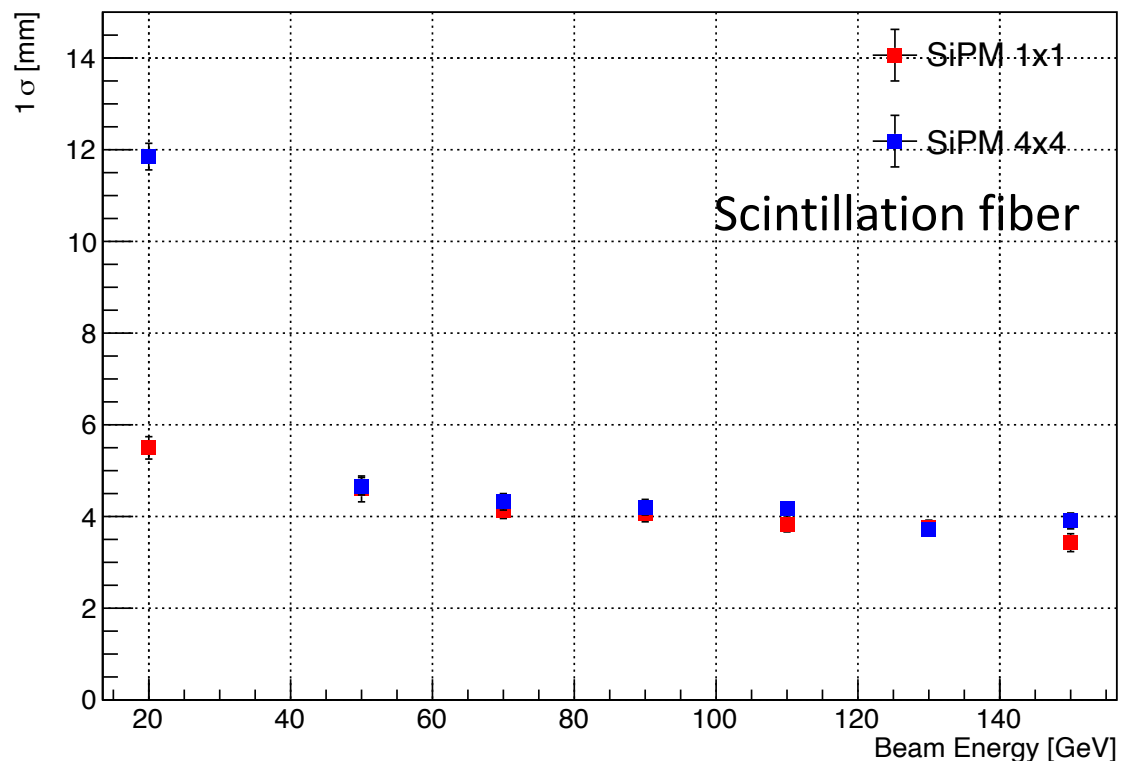
8x8 grouping



Grouping dependence of Position Resolution



Reconstructed position for
20 GeV neutron

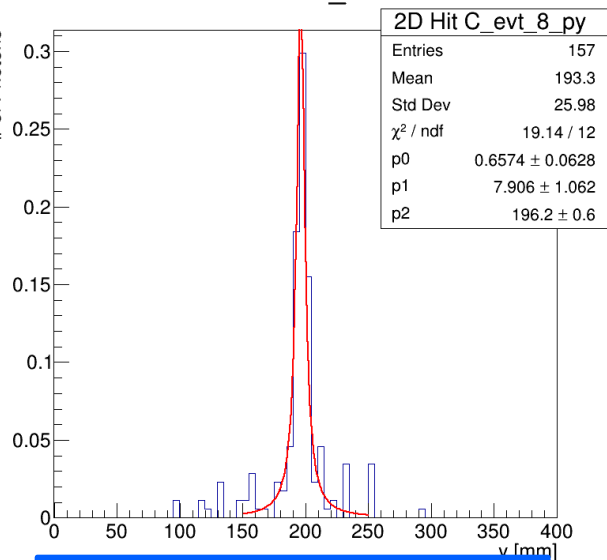


Position resolution as a function of neutron energy.

- Similar result with 4x4 fiber grouping and 1x1 SiPM matching, for $E > 40$ GeV
- Inserting a position reading layer around $2 \lambda_I$ would improve the resolution

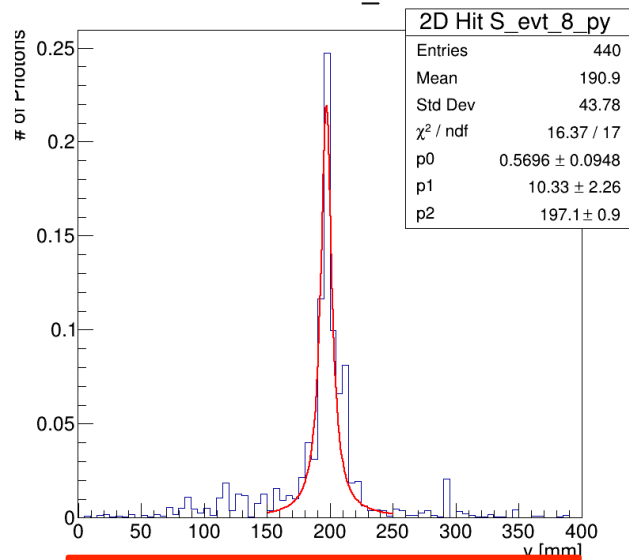
Better position resolution for Ch. channel

1 x 1 SiPM_Ceren



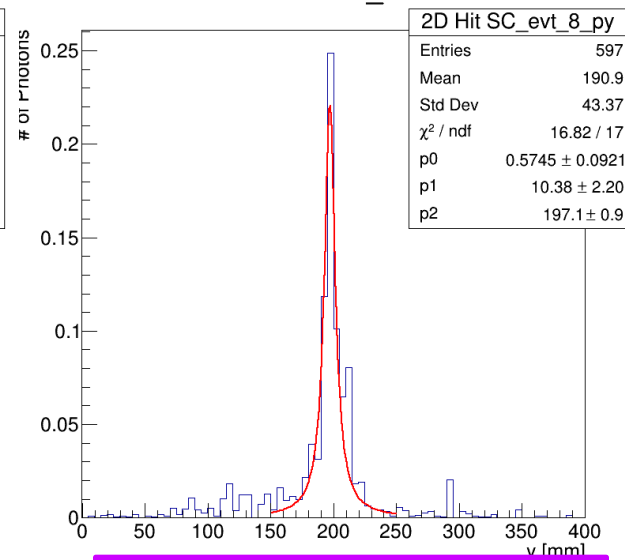
Cherenkov channels

1 x 1 SiPM_scint

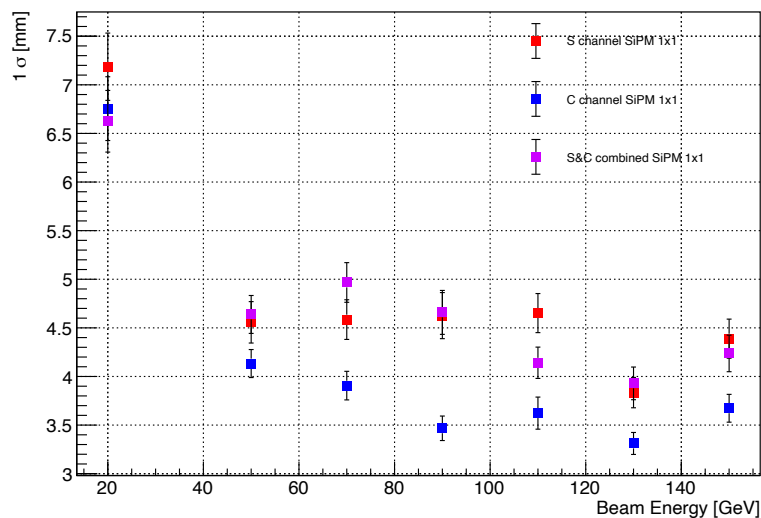


Scintillator channels

1 x 1 SiPM_S&C



S&C combined



- Some fluctuation is statistical, but is 3.5 ~ 4 mm is some good ball-park numbers
- Sc & Ch channels were simply combined at the same weight.
- There is room for improvement with adequate weighting

Cost estimation

- Price reference [link](#)

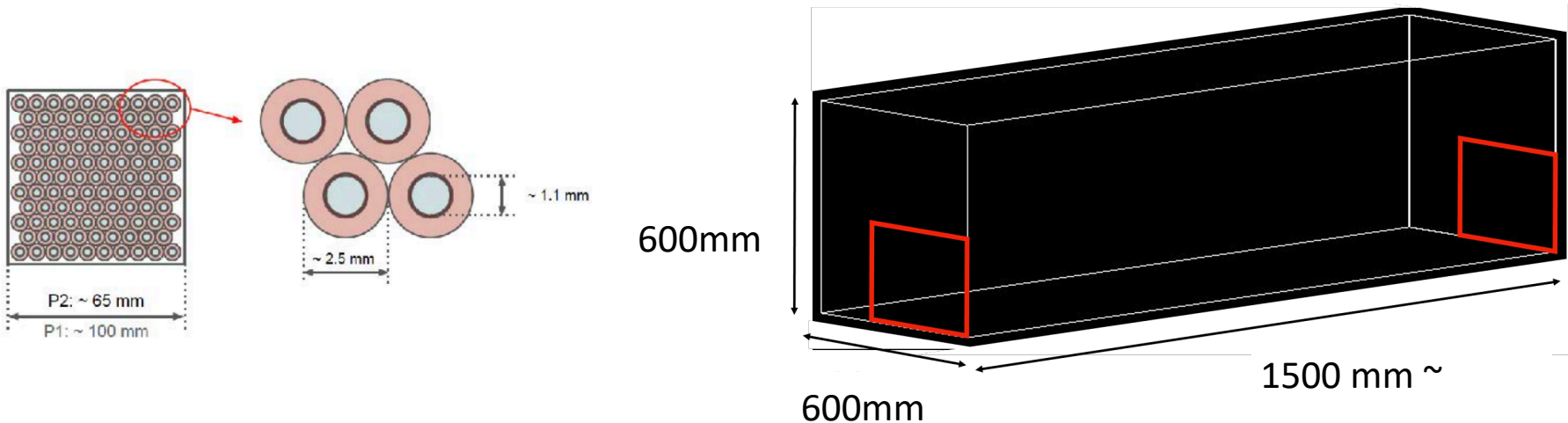
ZDC-h: [60cm x 60cm x 150cm]

	Unit price (\$)	Dim	Price (\$)		
			SiPM for each fib	1 per 16 (3x3) fib	1 per 16 (4x4) fib
Fiber-Sc (\$/m)	1.36	240x240x1.5m /2	58752	58752	58752
Fiber-Quartz (\$/m)	0.33	240x240x1.5m /2	14256	14256	14256
Cu capillary (\$/m)	0.15	240*240*2 = 115200 meters	17280	17280	17280
SiPM (piece)	10	240*240 = 57600	576000	64000	36000
SiPM electronics (piece)	10	240*240 = 57600	576000	64000	36000
Total			1242288	218288	162288
		[SiPM+electr]/ Total	0.93	0.59	0.44

- A huge price reduction even for 3x3 fiber grouping

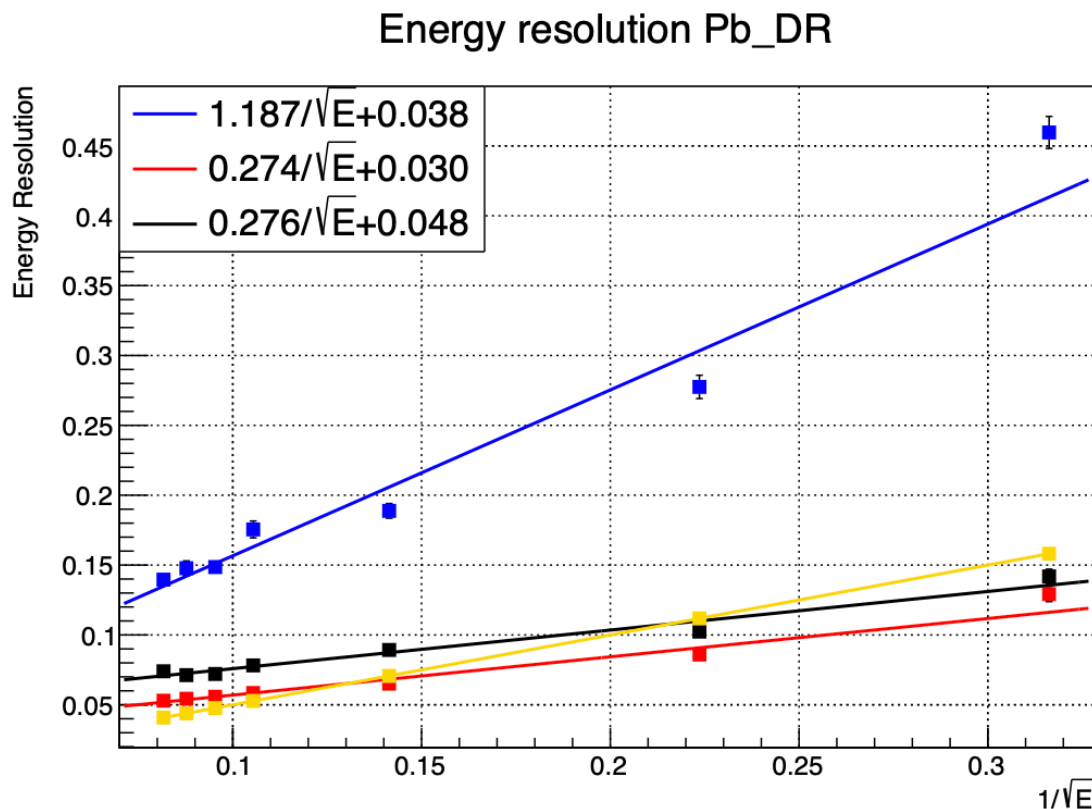
Summary

- Capillary design for ZDC-h was proposed for advantages
 - Simple and Cheap
 - No cooling required
 - Cooperative R&D with ALICE Focal
 - Fibers are routed to the SiPM outside which can reduce radiation damage
- Consideration for longitudinal segmentation for better resolution and PID



BACKUP

Energy resolution for neutron



Cherenkov fiber only

Yellow report number

Dual fibers combined

Scintillating fiber only

50 %
 \sqrt{E}

- Energy resolution is computed with only ZDC-h, excluding ZDC-E
- Quantum efficiency for SiPM is not accounted yet