UNIVERSITÀ DI SIENA 1240

dual readout calorimeters (Scintillation + Cherenkov)

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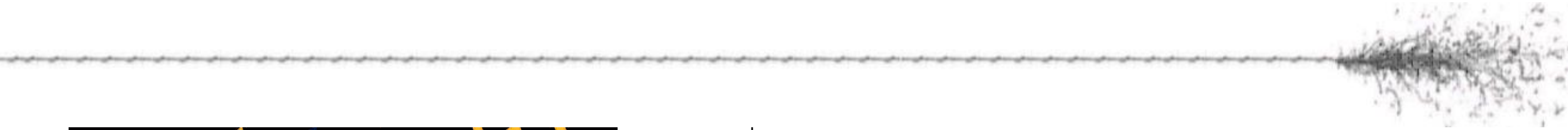
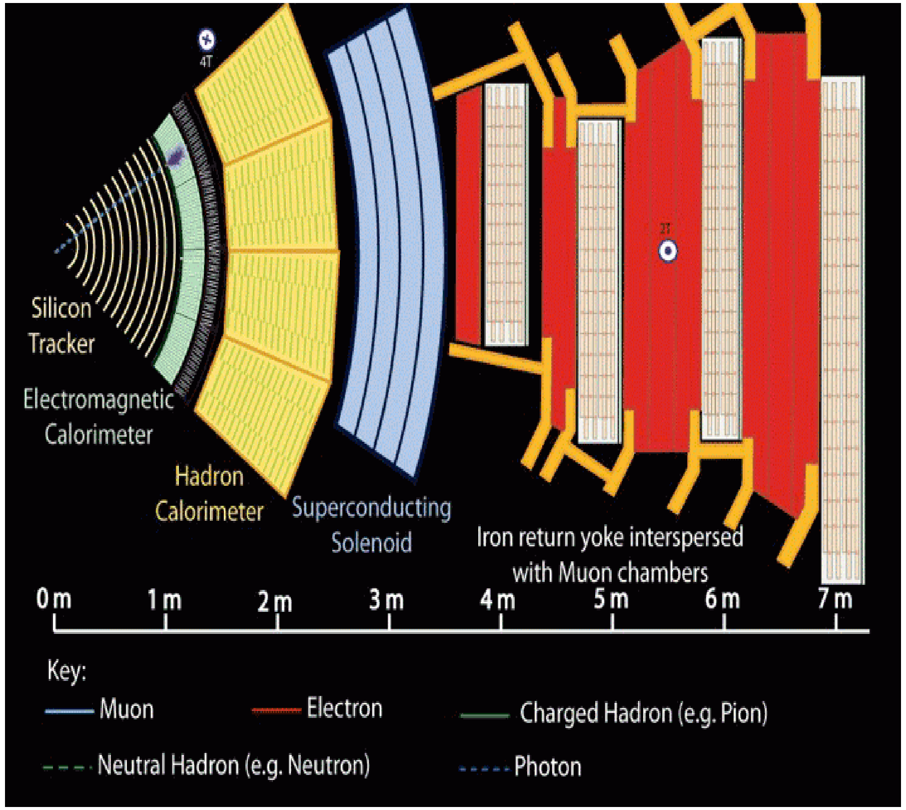
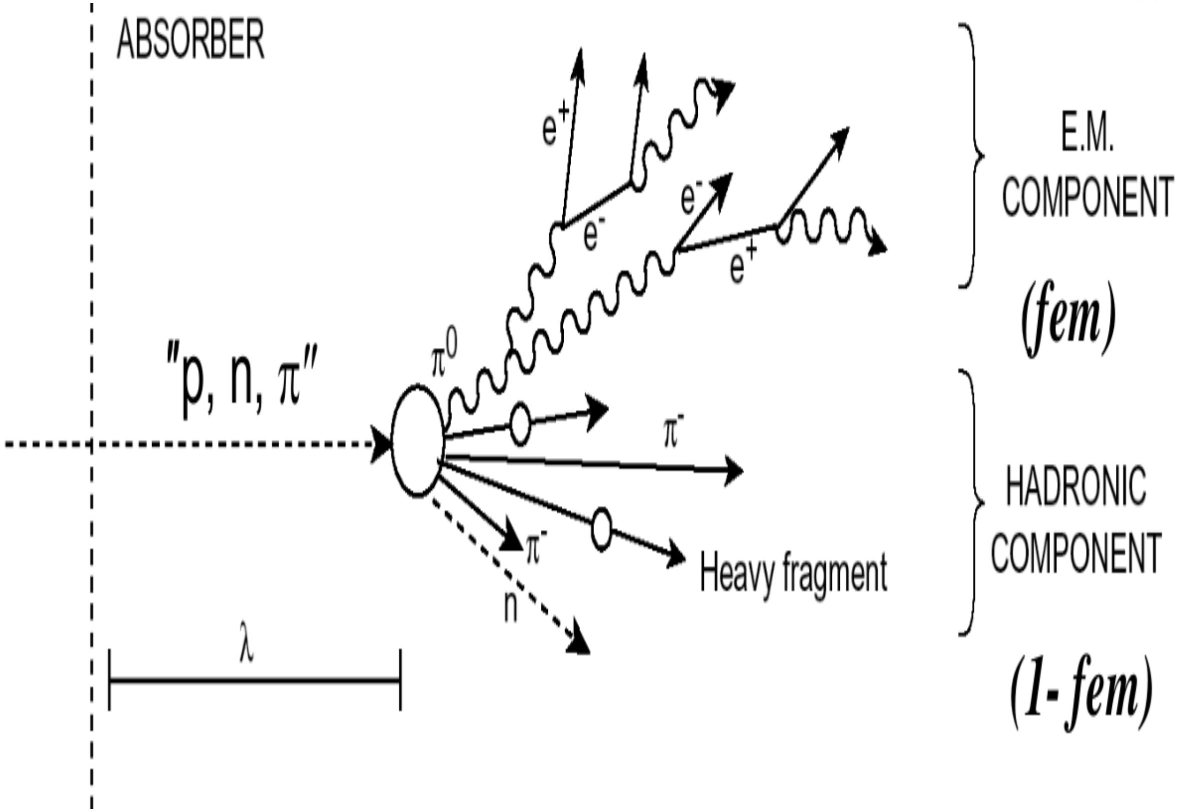
High Energy Seminar-16.11.2023

Calorimeter

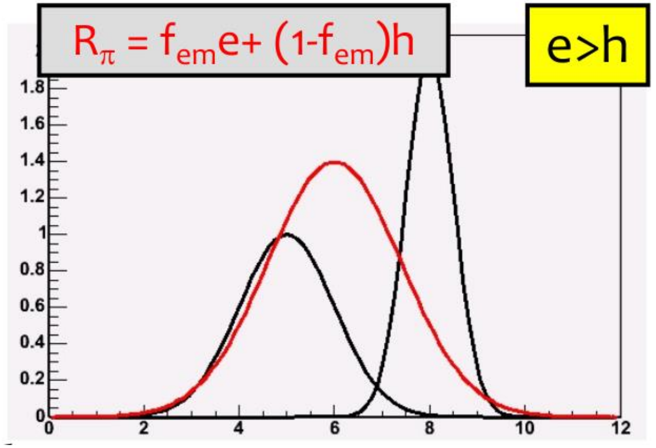




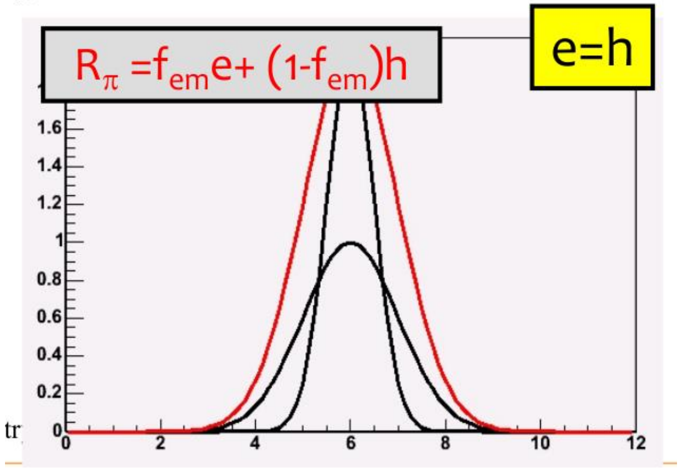


Hadron shower

(1) most calorimeters generate a larger signal per unit deposited energy for the electromagnetic shower component (e) than for the hadronic one (h); that is e/h > 1
(2) the fluctuations in the energy sharing between these two components are large.
=>the hadronic response function is non-Gaussian.



How could we make e/h=1?
Compensating calorimeters
Off-line compensation
Dual Readout Method: 1. In a Fiber calorimeters
2. In a crystal calorimeter



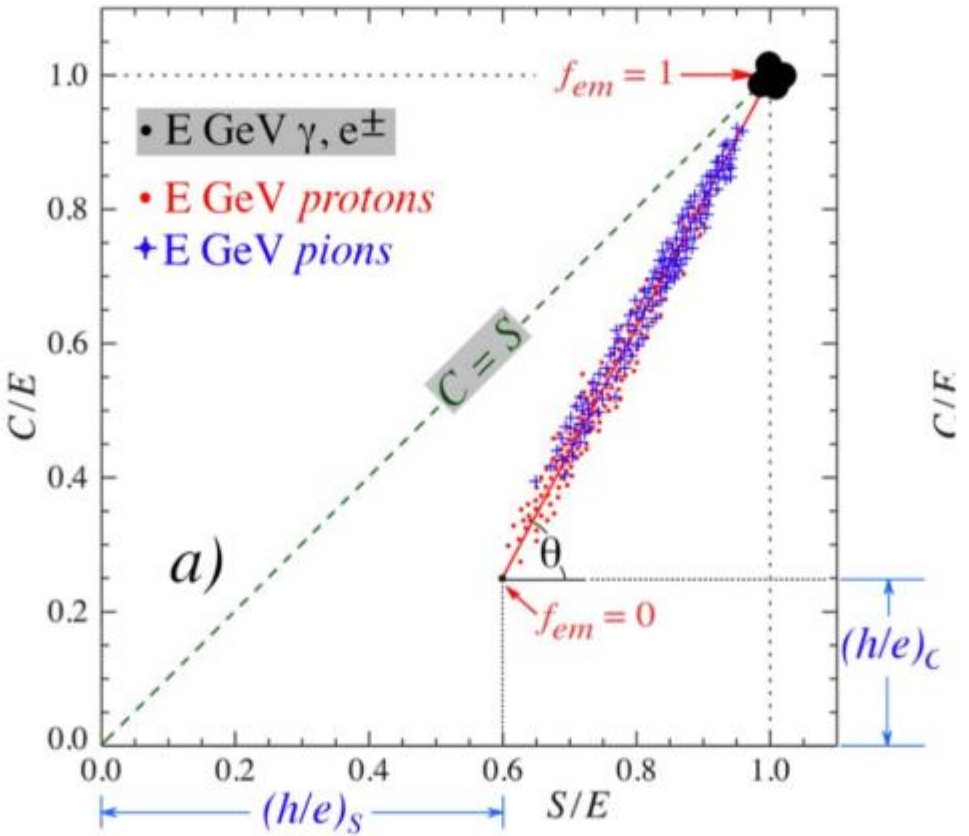
The Dual READout Method(DREAM)

Cherenkov light (C)	only produced by relativistic particles, dominated by electromagnetic shower component
Scintillation light (S)	measure dE/dx

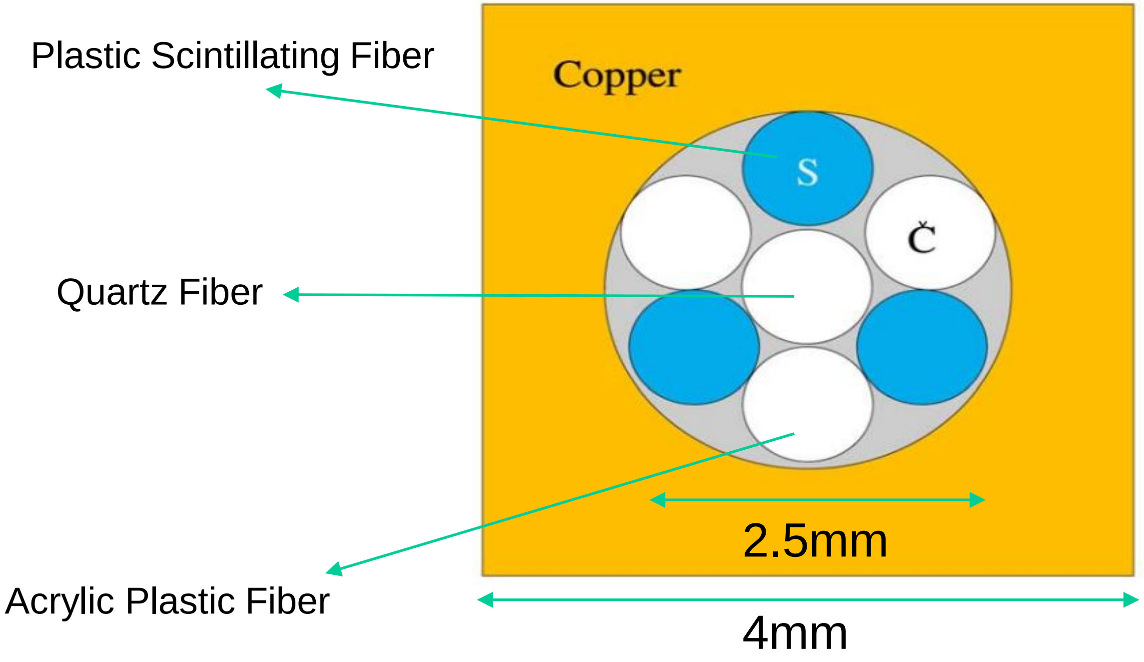
$$\left.\begin{aligned}\frac{S}{E} &= f_{em} + \left(\frac{h}{e}\right)_S (1 - f_{em}) \\ \frac{C}{E} &= f_{em} + \left(\frac{h}{e}\right)_C (1 - f_{em})\end{aligned}\right\} \Rightarrow E = \frac{S - \chi C}{1 - \chi}$$

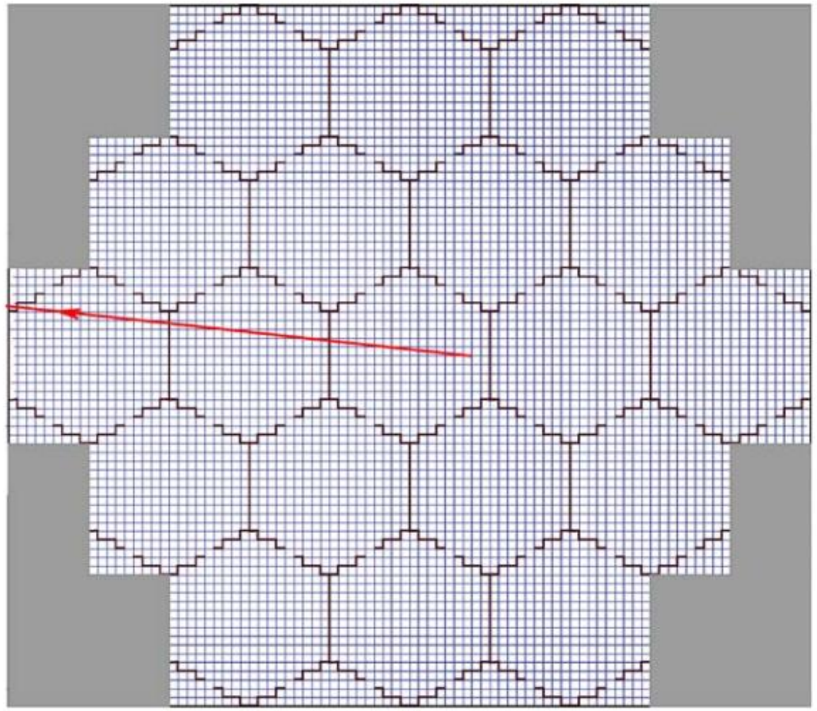
$$\chi = \frac{1 - (h/e)_S}{1 - (h/e)_C}$$

The detector response parameter χ is measured separately



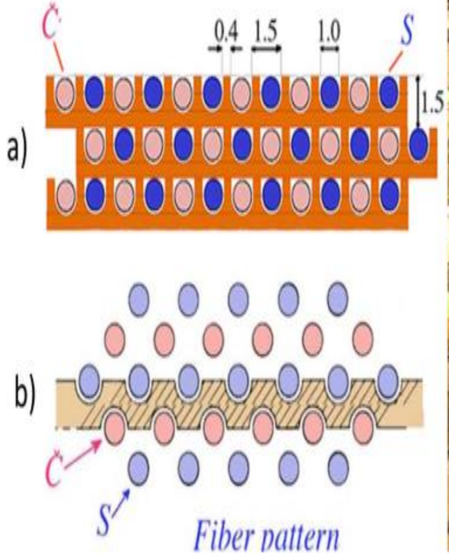
DREAM calorimeter-First prototype-2003

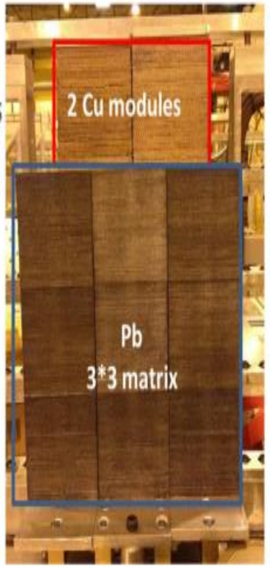


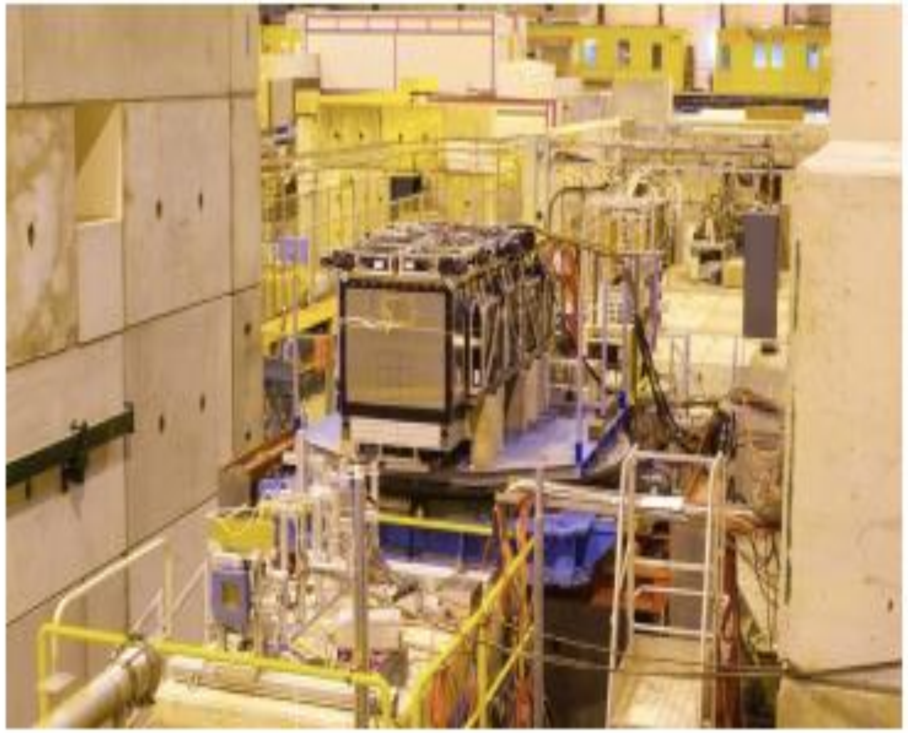


19 hexagonal tower
Inner ring(6 towers)
Outer ring(12 tower)
The Fibers are not
longitudinally segmented

IDEA RD52 detector-Developed prototype-2012

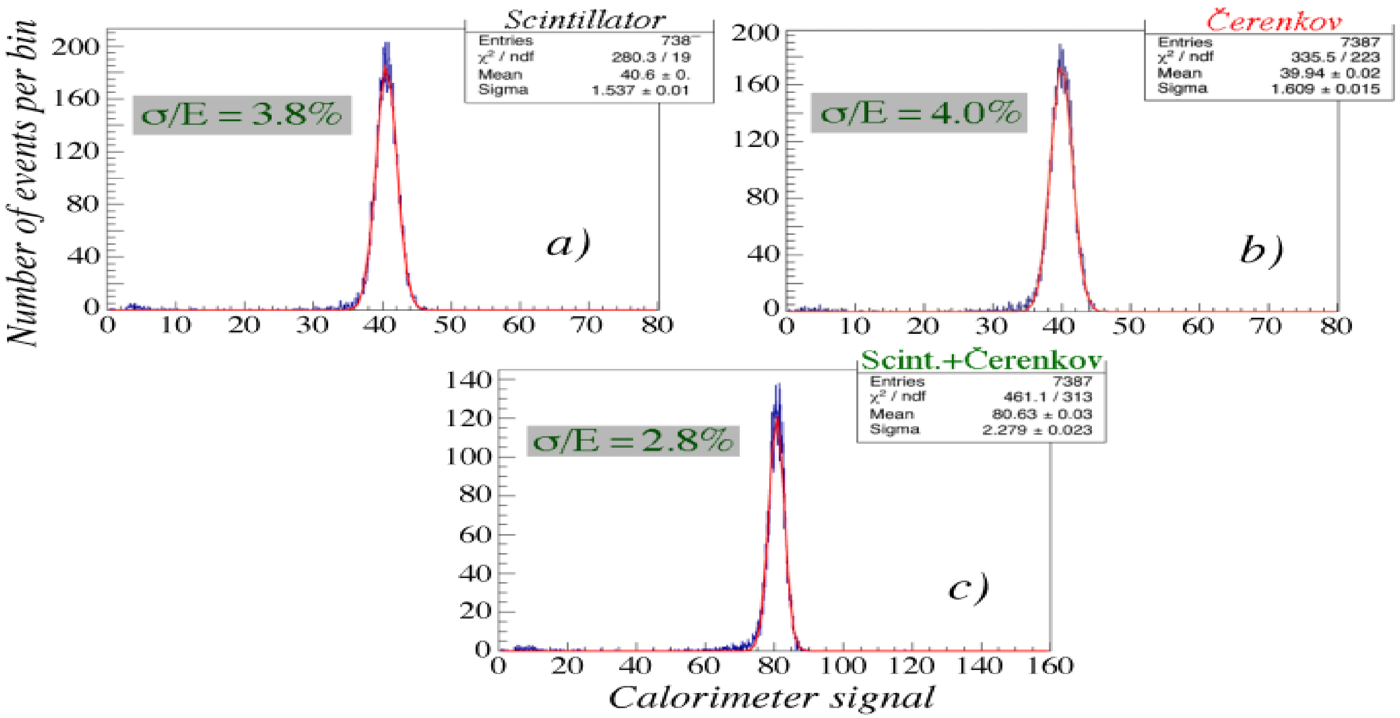




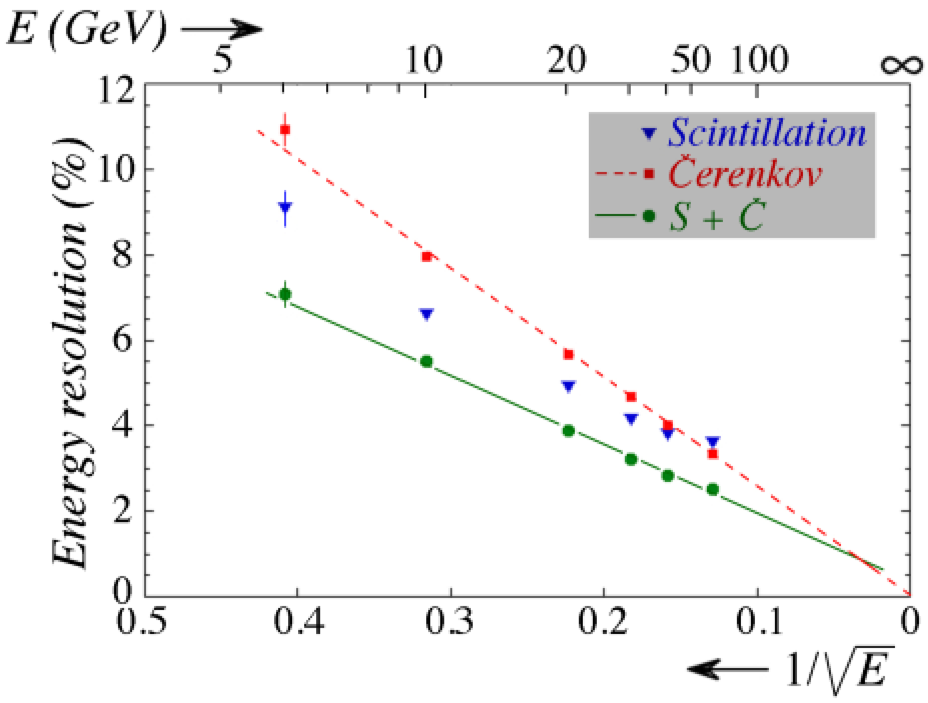


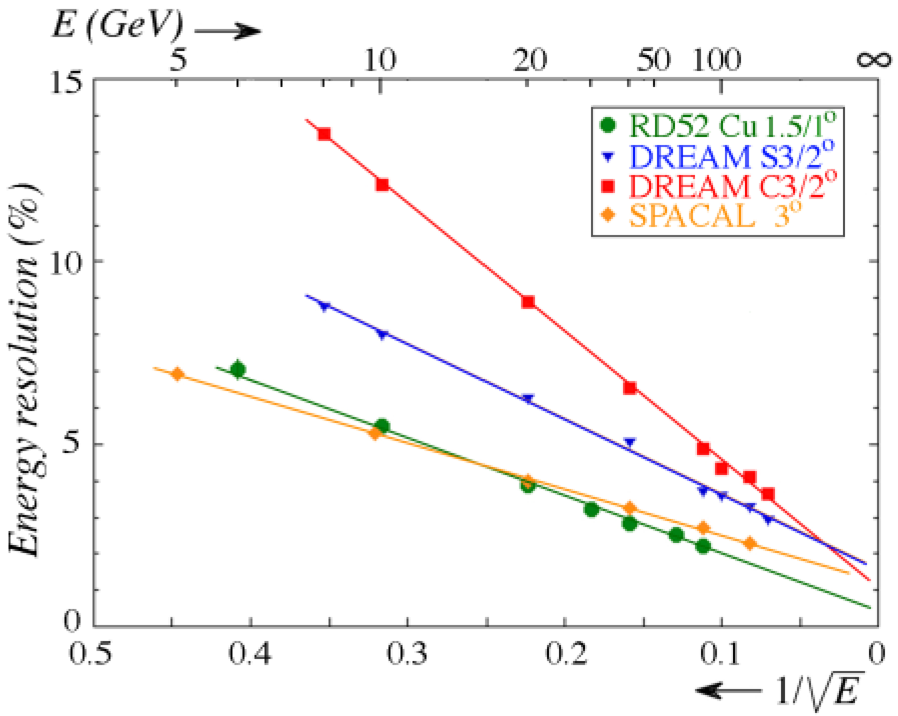
Electromagnetic performance

Response of the aluminised Cu-fiber calorimeter to 40 GeV electrons



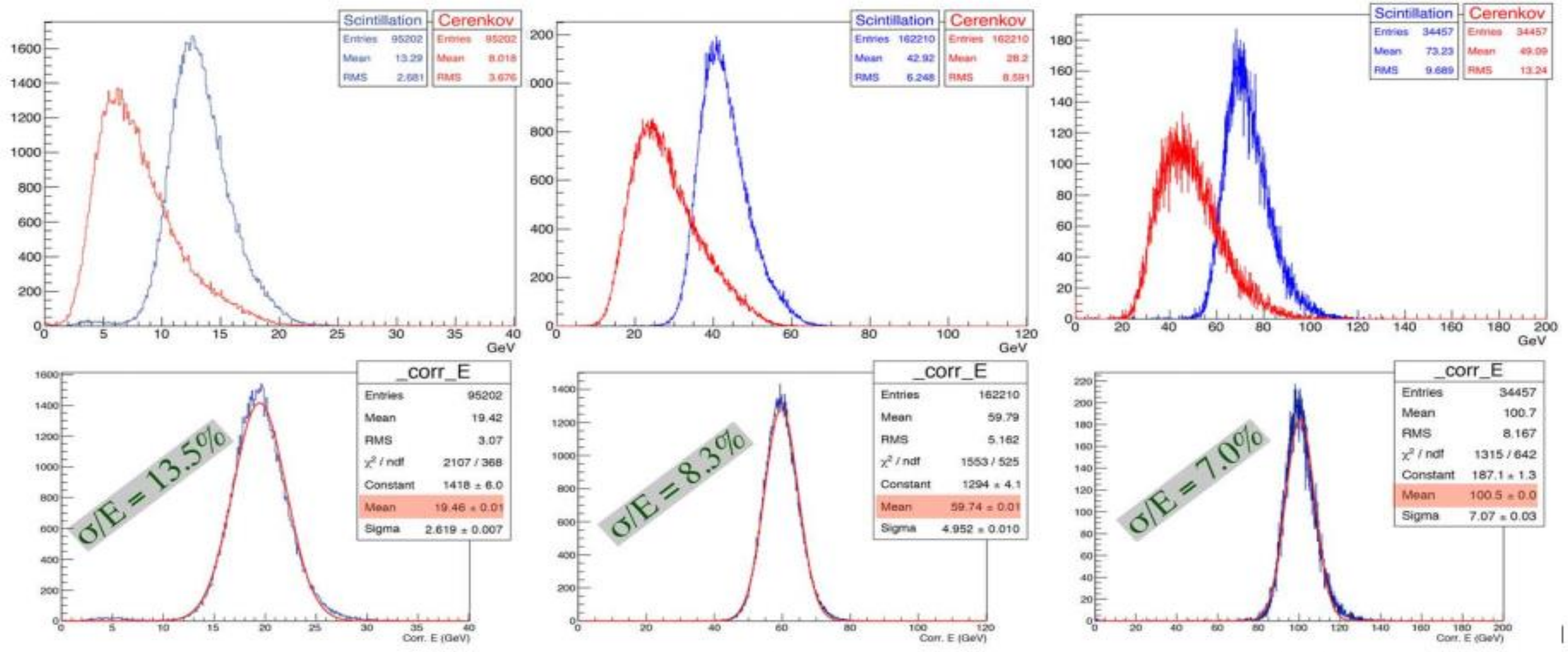
Electromagnetic performance





Hadronic performance

Pb-fiber calorimeter responses to of 20 GeV, 60GeV, and 100 GeV pions



(a) (b) (c)

Dual Readout Calorimetry with Crystals

They can eliminate or reduce sampling fluctuations and fluctuations in the Cherenkov light yield

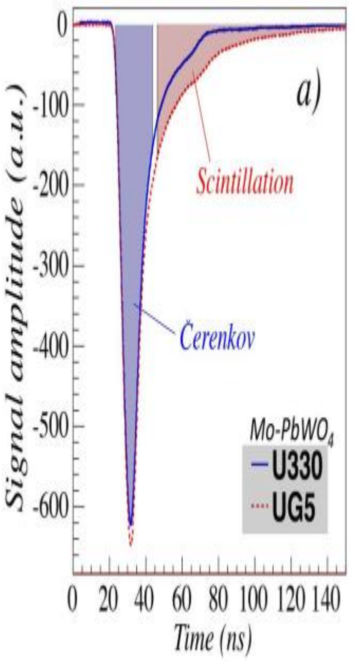
- differences in the angular distribution of the emitted light,
- differences in the spectral characteristics,
- differences in the time structure of the signals,
- light polarization in case of Cherenkov

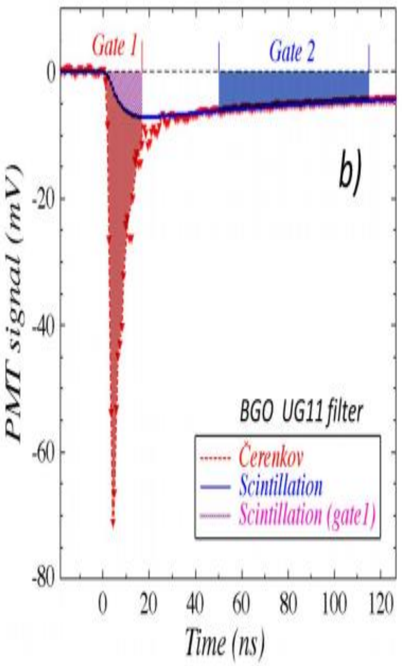
Compact: short radiation length;
Fast signals, high light yields;
Good separation in wavelengths between S and C signals;
Cost effective, radiation hard, …

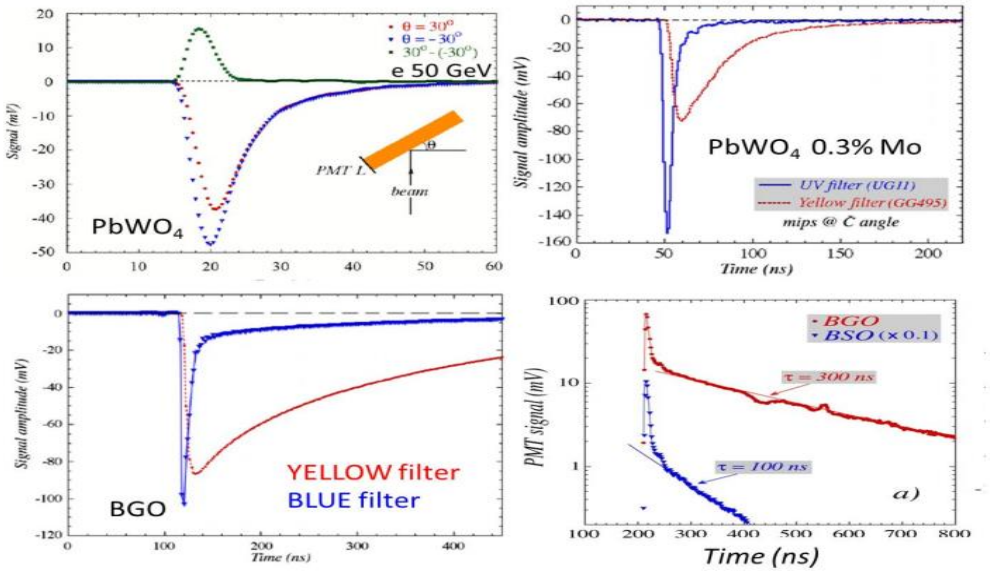
Crystal	Density g/cm^2	X_0 cm	λ_I cm	R_M cm	Relative Yield	Decay time ns	Refractive index
PWO	8.3	0.89	20.9	2.00	1.0	10	2.20
BGO	7.1	1.12	22.7	2.23	70	300	2.15
BSO	6.8	1.15	23.4	2.33	14	100	2.15
CsI	4.5	1.86	39.3	3.57	550	1220	1.94

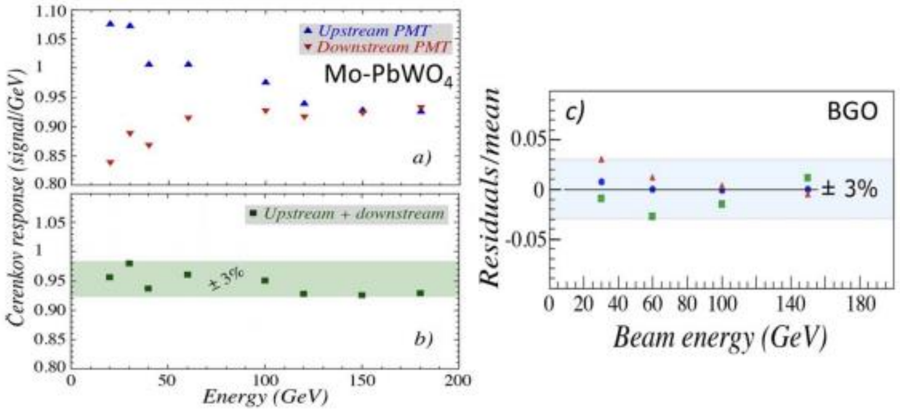
Dual Readout Calorimetry with Crystals

UG11: λ < 400 nm ,
UG330: λ < 410 nm,
UG5: λ < 460 nm,
GG495: λ > 495 nm

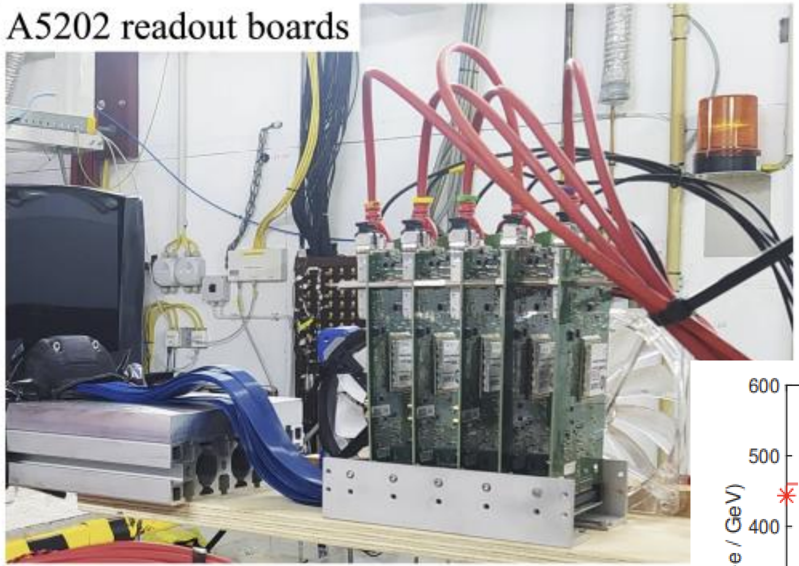


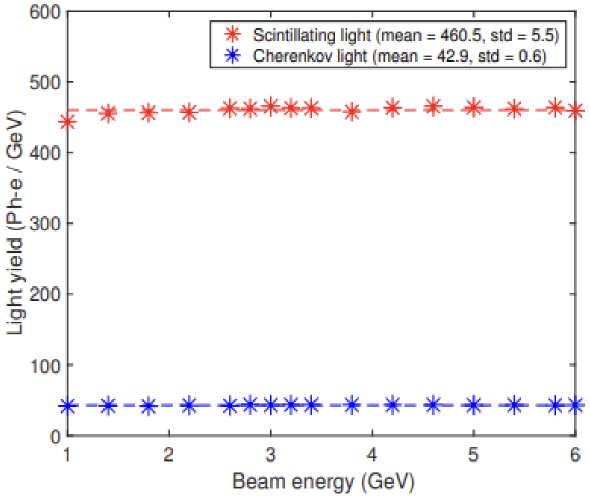


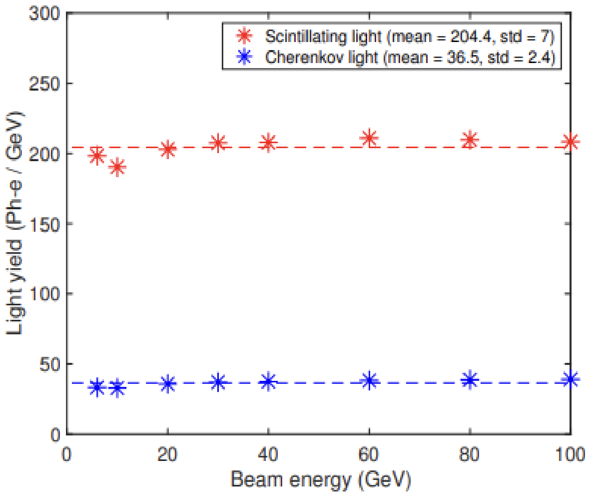




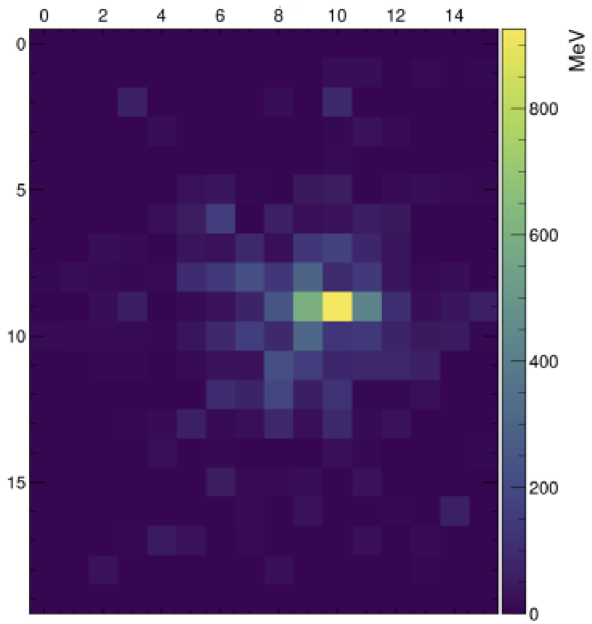
SIPM for Dual-Readout Calorimetry-2022

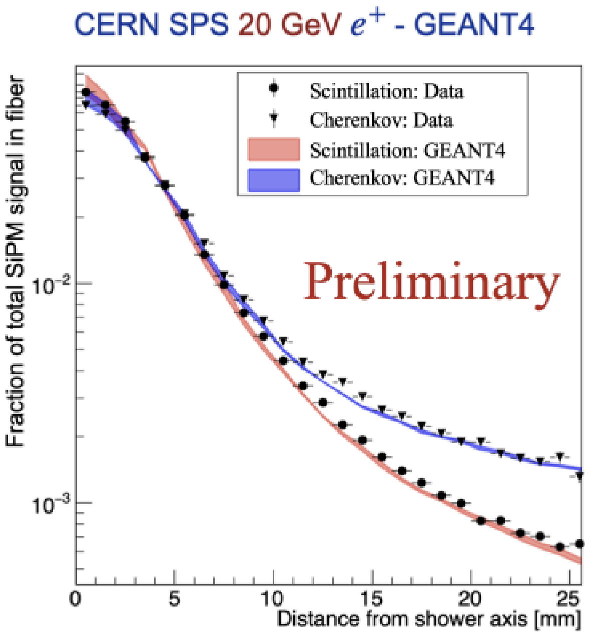


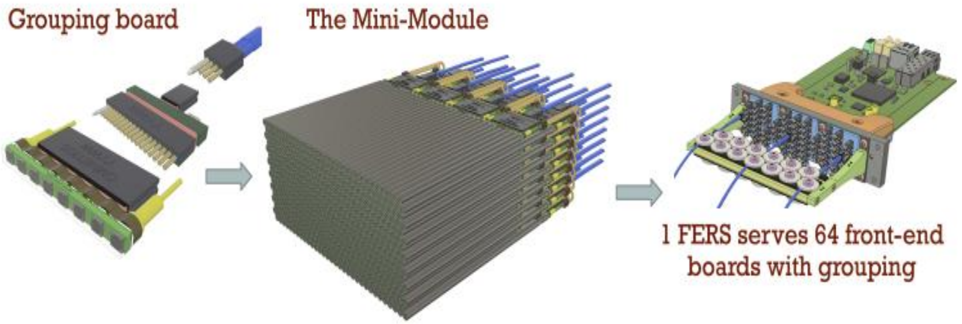




SIPM for Dual-Readout Calorimetry







HiDRa calorimeter-current

High-Resolution Highly Granular Dual Readout Demonstrator.

Brass or stainless steel are, at present, the baseline options for the absorber material due to their mechanical and shower development properties. The target is to build a Hadronic-Scale Prototype (HSP) made of 16 Highly Granular Modules (HGM), ~ 13×13×200 cm3 each, where the two core modules are equipped with SiPMs and the rest with PMTs.

Conclusion

The conclusion reached after after a long and in-depth study of crystal performances for dual readout calorimetry is that no such significant improvements in term of Cherenkov light yield seem to be offered by crystals in combination with filters in dual-readout calorimeters. The RD52 collaboration decided therefore to focus on the fiber option.
for a future collider experiment:
the RD52 collaboration is also equipping one of the copper modules with Silicon photomultipliers readout. This readout way offers the possibility to eliminate the forests of optical fibers that stick out at the rear end and also to chose a trasnversal segmentation at a fiber level, if it is needed.
For SIPM, A larger prototype, capable of containing hadronic showers, will be built in the next two years. As for the electromagnetic prototype, only the central part will be equipped with SiPMs but, in this case, the collaboration wants to target a real scalable solution from both the mechanical and readout point of view. This prototype will be equipped with more than 10,000 SiPMs with the final goal to target the study of the hadronic performance of the dual readout technique.

- Wigmans, Richard. "25 Years of Dual-Readout Calorimetry." *Instruments* 6.3 (2022): 36.
- Cascella, Michele, Silvia Franchino, and Sehwook Lee. "Fiber and crystals dual readout calorimeters." *International Journal of Modern Physics A* 31.33 (2016): 1644024.
- Muon detection with a dual-readout calorimeter.
- Fabjan, Christian W., and Fabiola Gianotti. "Calorimetry for particle physics." *Reviews of Modern Physics* 75.4 (2003): 1243.
- Antonello, M., et al. "Dual-readout calorimetry, an integrated high-resolution solution for energy measurements at future electron–positron colliders." *Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment* 958 (2020): 162063.
- Santoro, Romualdo. "SiPMs for dual-readout calorimetry." *Instruments* 6.4 (2022): 59.
- Pezzotti, I., et al. "Dual-Readout Calorimetry for Future Experiments Probing Fundamental Physics." *arXiv preprint arXiv:2203.04312 (2022*).

Thanks for your time