Quality control of MPD electromagnetic calorimeter modules.

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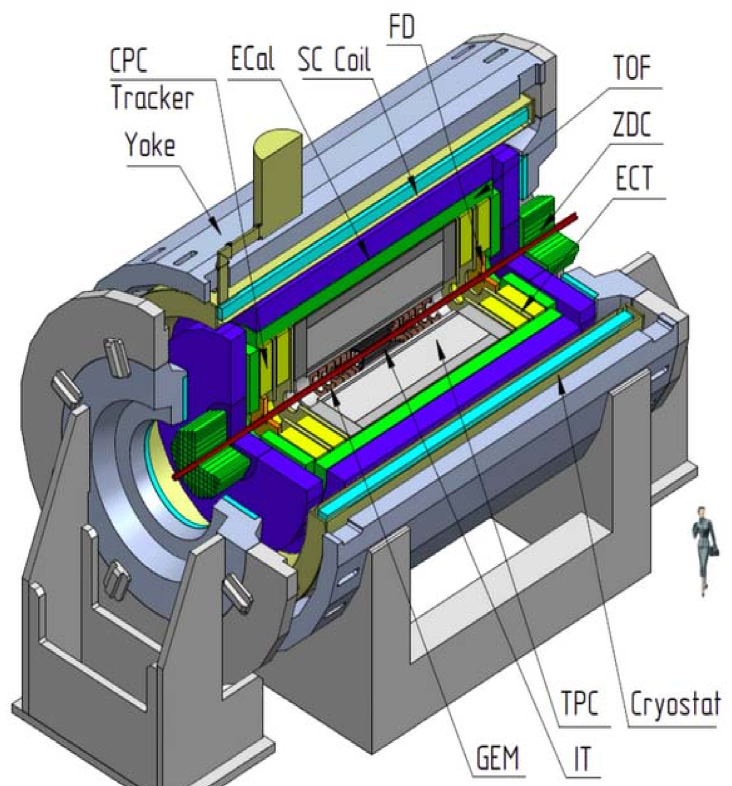
Abstract

The Multy Purpose Detector (MPD) is constructing to study the properties of the hot and dense matter created in heavy-ion collisions in the energy range of 4-11 A*GeV where the maximum baryonic density is expected. Crucial detector in the new experimental setup is a large-sized barrel electromagnetic calorimeter (ECal), designed for precise spatial and energy measurements for photons and electrons. Taking into account the requirements of high energy resolution, dense active medium with the small Moliere radius and high segmentation of ECal, the Shashlyk-type electromagnetic calorimeter with projective geometry has been selected. The mass production of ECal modules has been started. In this talk, we report about methods and technologies for the quality control of ECal modules and their components.

ECal MPD Overview

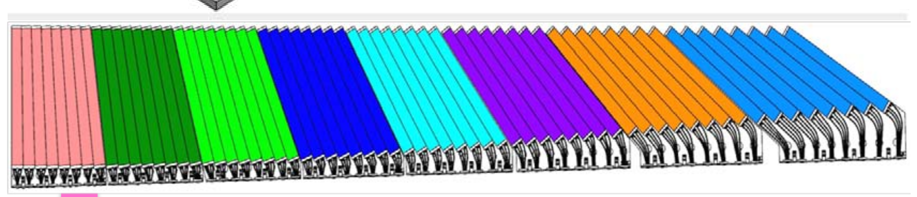


ECal design:

- Sandwich structure, projective geometry
- 38400 towers
- 2400 modules of 8 different geometry types

Each Ecal tower consist of 210+/-1 layers

- Pb t_{max}= 0.3 /-0.05 mm
- Sc t_{max}= 1.5 mm, 40x40mm, LEGO type
- 16 fibers, 1.2 mm diameter
- Moliere radius 62mm
- Radiation lengths $Z \sim 11.8\ X_0$
- Photodetector *HAMAMATSU S13360-6025PE MAPD*
- Diffuse glue paint as reflector between towers
- Powder white paint as reflector on Pb plate



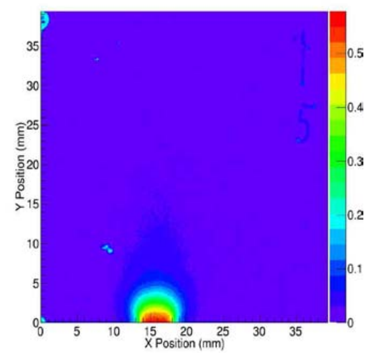
Schematic view of 1/12 sector, half line (8 modules)

One of the first mass production ECal modules (16 towers)

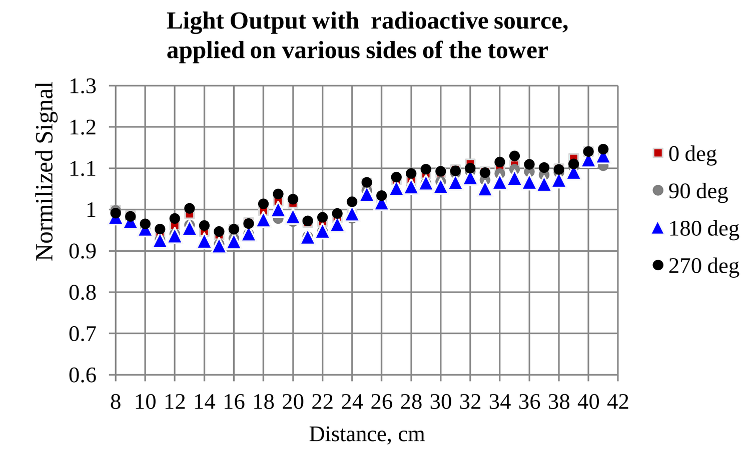
Quality control

- Quality of Sc tiles is controlled with a spectrophotometer and with a special test bench by comparison light yields from the tested Sc tiles and a reference tile on the LED or with radioactive source. Achieved accuracy is better than 5%
- The thickness of Pb plates is controlled by measuring the thickness at 8 points along the edge and centre of plate before coating by reflector and after the coating procedure
- The size of each tower is controlled by the Mistral 100707 three-axis machine with an accuracy of 4.5 microns after milling to achieve projective geometry

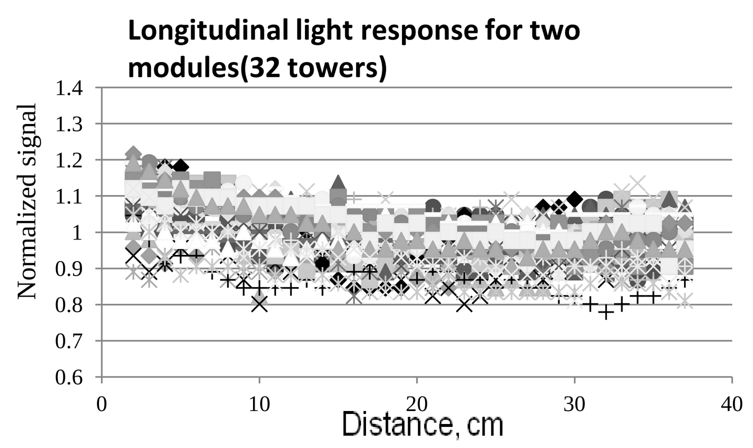
The towers are controlled by the measuring light yield during the longitudinal scan with β-radioactive source



Penetration profile in scintillator tile from β-radioactive source with 3mm collimator.



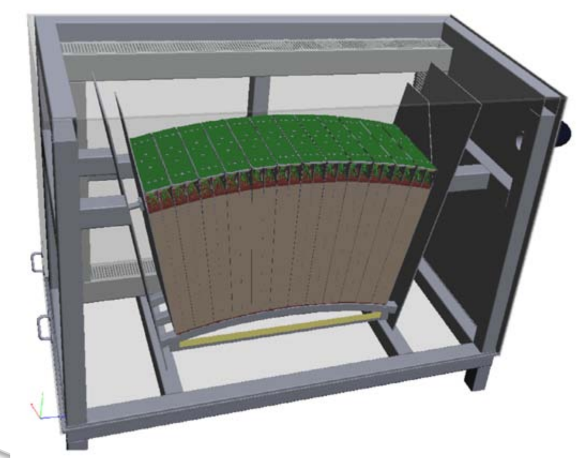
Longitudinal 1 cm scan for first preproduction tower prototype (220 layers) with radioactive source applied from different sides of unmilled tower. These results show the same trend that give us a signal that the quality control methodology was working properly. Heterogeneity is explained by not perfect first samples of scintillator tiles and absorption lengths of fibers.



Longitudinal 2 cm scan for two mass-production modules. Photo detector location is on the right. Diffuse coating of not-very-well controlled thickness as a reflector was not applied to external sides of modules, and Tyvek (DuPont) paper was applied instead to provide stable penetration length of electrons from β-source. With the projective geometry for these towers, we observe more light from the far end from the photodetector. The dispersion of light yield from the towers is less than 7%.

- ➢ Advantages of this method - very high accuracy.
- ➢ Disadvantages of this method – long time to scan.

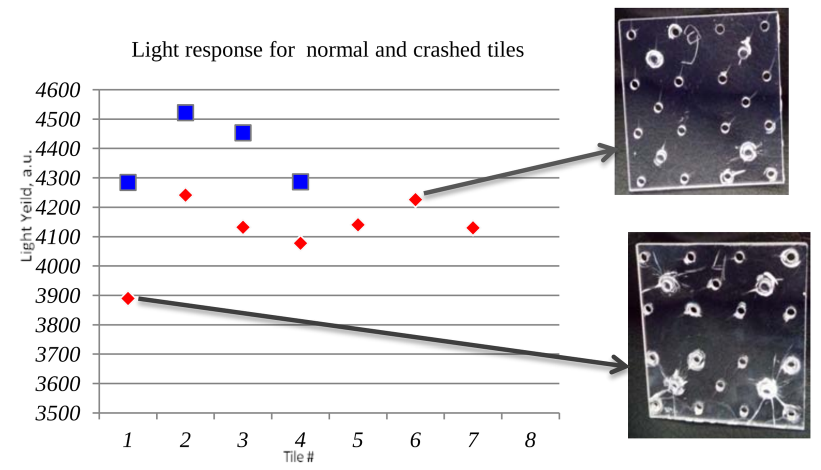
Strategy -> cosmic runs to get initial calibration coefficients and check the status of each tower. If problems will appear -> go to longitudinal scan.



The test bench to test simultaneously 12 ECal modules with cosmic muons.
(from poster on the CHEF-2019 conference)
https://doi.org/10.1088/1748-0221/15/05/C05077

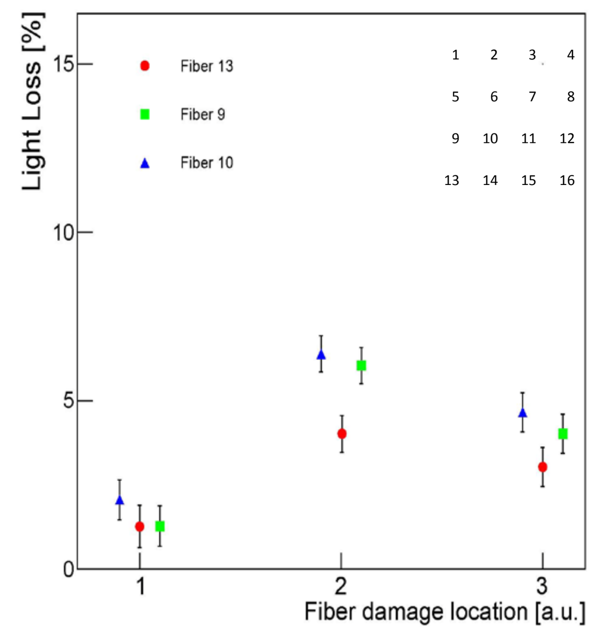
Crash test and crashed control.

Sc tiles problems



The result of special crash test is shown in the left picture. Blue points corresponds to light response for normal tiles, red points to light response for broken tiles due to overpressure (picture of the tile #9 is in the top right, corresponded red points #6 in the chart) or overpressure plus glue between Sc and Pb plates (picture of the tile #4 is in bottom right, corresponded red point #1). The degradation in the light output for broken tiles in the worst case is less than 10% compared to conventional tiles. This test demonstrated if something happens with few tiles during assembly it is not as bad as it seems. The leakage of glue is more dangerous than cracks also.

Problems with fibers



Fiber damage location	LY loss for fiber #9, simulation	LY loss for fiber #10, simulation	LY loss for fiber #13, simulation	LY loss for fiber #9, experiment
Near the reflector	1.33 ± 0.61	2.12 ± 0.62	1.32 ± 0.64	1.25 ± 0.07
In the middle of the tower	4.09 ± 0.60	4.68 ± 0.58	3.47 ± 0.61	-
Near the MAPD (SiPM)	5.89 ± 0.56	6.41 ± 0.53	3.55 ± 0.58	6.23 ± 0.31

Result from simulation of the light yield (LY) loss for various fibers due to damage is shown in the left. The data are given for a 1 GeV muon beam that hits the ECal tower uniformly. We investigated three fiber damage location: near the reflector, in the middle of the tower and near the MAPD. The fiber numbering is insert in this picture in the top right. The result is shown in the table also. It can be seen that the light collection falls by 1–2% when a reflector is lost on one fiber; 3-5% when the fiber broke in the middle of the tower and 4-6% when the fiber broke near the MAPD. The first value is consistent with our LY measurement for fiber with LED (see detail in https://doi.org/10.1051/epjconf/201922202007). The last data is consistent with our experimental measurements when we removed one fiber from the readout when tested the tower with the muon beam from accelerator U-70 in IHEP, Protvino. The damage of the fiber near the MAPD is usually easy to spot with the eyes unless when the fiber damage is in the other place.

Conclusion

The mass production of ECal modules has been started. A quality control procedure has been developed, including control of the geometric dimensions of the modules. Corresponding test benches have been created. A methodology and technology for checking modules at all stages of production and assembly have been developed. It has been shown that even small breakdowns inside the towers do not lead to a significant deterioration in the light output. A technology has been developed to replace a fiber in case of breakage. Calibration of modules on cosmic muons will begin soon.

Acknowledgments

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