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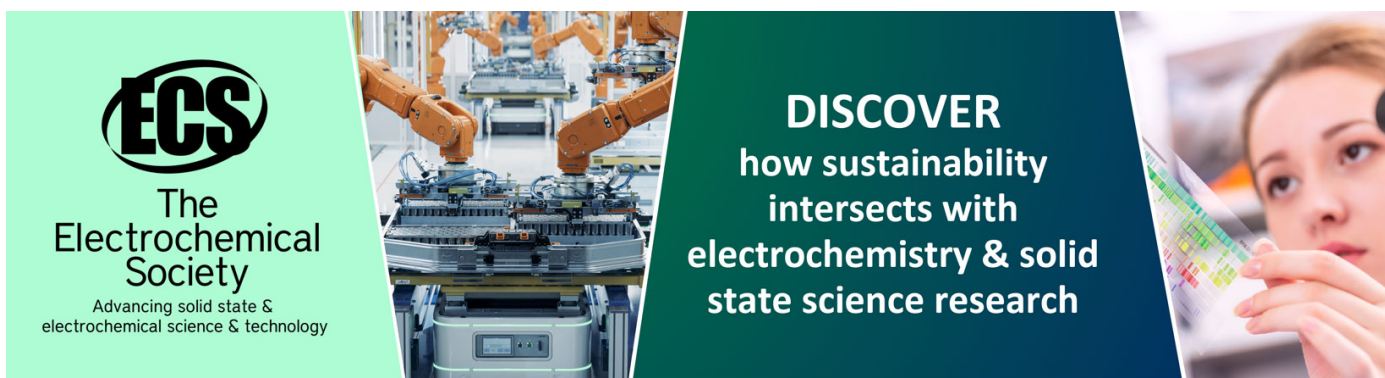
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Quality control of MPD electromagnetic calorimeter modules

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Abstract. The Multi-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. The 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.

1. Introduction

The Multi-Purpose Detector (MPD) is constructing to study the property of nuclear matter created in heavy-ion collisions in the Nuclotron-based Ion Collider fAcility (NICA) in JINR (Dubna, Russia). One of the main detectors of the new experimental setup is a large-sized barrel electromagnetic calorimeter (ECal), optimized to measure energy and coordinate of photons and electrons with high precision. The Shashlyk-type electromagnetic calorimeter with projective geometry has been selected for the MPD experiment to reach high energy and timing resolutions in ions collisions with the energy of 4-11 A*GeV and the maximum baryonic density [1].

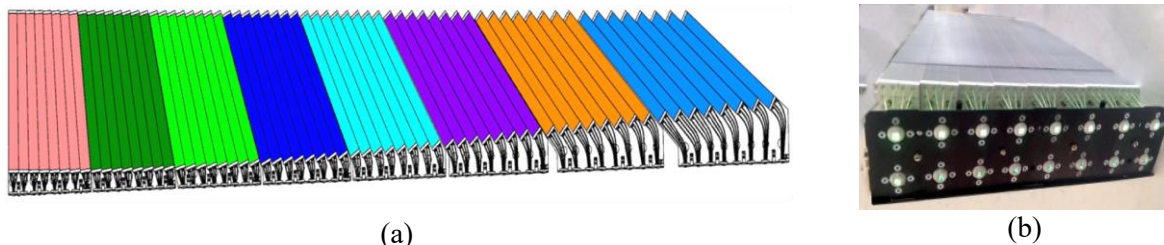


Figure 1. (a) - a schematic view of 8 modules (8 different types, 1/12 sector) of the calorimeter barrel. Pink color corresponds to the center of ECal, blue color corresponds to the edge. (b) - the snapshot of one of the first mass-production modules (16 towers).

ECal tower consists of 210 layers of lead plates and scintillator tiles LEGO-type with 16 light collection fibers Y11-200 penetrated the tower. Diffuse glue paint is used as light reflectors for the edges of tiles and powder white paint has covered the surface of lead plates to reflect light from the

big surface of the scintillator. The effective Moliere radius is 62 mm and the radiation length is $\sim 11.8 X_0$ accordingly. ECal consists of 38400 towers of 64 different types combined into 2400 modules and 25 sectors (see figure 1).

The mass production of ECal modules has been started: the scintillators tiles were produced in the two factories and the assembling areas are located in three different places. Therefore the quality control of mass production towers and its component is necessary.

2. Quality control

2.1. Quality control of towers component

The quality of the tower's components is monitored at every stage of the technological chain.

The quality of scintillator tiles is controlled with a spectrophotometer in the first factory. The special test bench was created for the second factory. It consists of a minitower for one tile, a light-emitting diode (LED), an LED driver, a photomultiplier that worked in current mode, a high voltage power supply and a multimeter. The light yield from the tile is controlled by a comparison of the signals from the tested scintillator tiles and a reference tile. The light yields from some tiles for each production party are controlled with the radioactive source before assembling the tower. The achieved accuracy is better than 5%.

The thickness of lead plates is controlled by measuring the thickness at 8 points along the edge and center of the plate before coating by the reflector and after the coating procedure with the necessary accuracy.

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.

2.2. Towers and modules quality control with the radioactive source

For quality control of towers and modules, the β -radioactive source $^{90}\text{Sr}+^{90}\text{Y}$ in collimator (with 3mm hole and 80 mm length) is used. The penetration length of electrons from the source was studied before the test. The research was carried out with the short tower of ten scintillation plates, with pre-grinded LEGO pins, padded with EBT dosimetry film instead of lead plates. The exposure time was ~ 30 hours. The penetration profile is presented in figure 2. Is this radioactive source a sufficient tool to study tower heterogeneity?

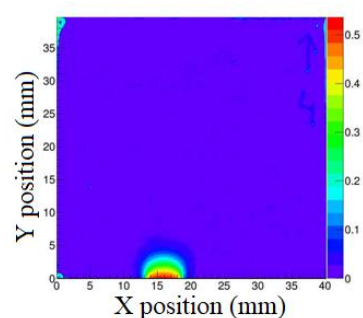


Figure 2. Penetration profile of electrons from radioactive source in EBT film (sample #4 is shown).

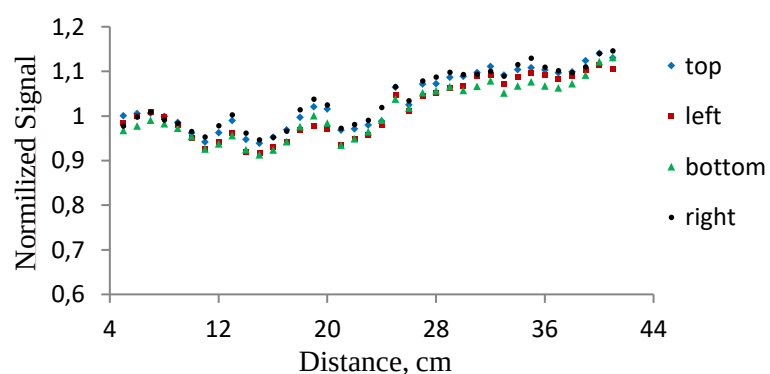


Figure 3. Longitudinal scan with 1 cm step. The β -radioactive source was applied from different sides of unmilled tower: blue rhombus corresponds to top side, red square - to left side, green triangle - to bottom side, black circle - to the right side accordingly.

To answer this question, one of the first preproduction tower prototype (220 layers, test batch of the scintillators production) was selected to better observe the possible problems. The radioactive source

was applied from different sides of the unmilled tower, and the result of this scan is shown in figure 3. In this picture, the zero X coordinate corresponds to the far end of the tower from the photodetector. Tower was wrapped by Tyvek (DuPont) paper. These results show the same trend for each side of the tower that gives us a signal that the tower quality control methodology works properly. Heterogeneity is explained by not perfect first test samples of scintillator tiles and absorption lengths of fibers.

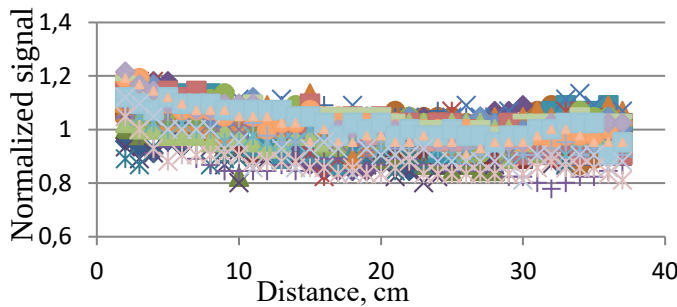


Figure 4. Longitudinal light response for two mass-production modules (32 towers). The scan was done with a 2 cm step, the zero X coordinate corresponds to the far end of the tower from the photodetector. Points of different color and shape correspond to the light response from different towers.

The same method was applied to check the quality of the mass-production module. The result is shown in figure 4. 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%. We estimate the total uncertainties associated with the photodetector signal drift due to not perfect working of monitoring system <1%, radioactive source position accuracy better than 0.5 mm, heterogeneity of external light reflector thickness between the radioactive source and scintillator, possible dust on the fiber bundle, etc. as 3% from the value or less.

The advantage of this method is a very high accuracy but a slow scan time and a long time to replace modules in the test bench are disadvantages. We made a solution to the strategy of a quality control procedure. We plan to put the 12 modules of each type in the special test benches to obtain initial calibration coefficients with cosmic muons [2]. It will give us information about the quality of the modules also. If a problem arises, we will continue the quality control with radioactive source viz., the longitudinal towers scan.

3. Crash test and crashed control

We investigated a few possible scintillator or fiber problems which can happen during modules assembling procedure. Scintillator tiles can be crashed due to overpressure or glue paint can leak inside the tower. In the last case, the glue paint can spoil the surface of the scintillator or even fill fiber holes. The result of a special crash test is shown in figure 5. The degradation in the light output for broken tiles in the worst case is less than 10% compared to conventional tiles. This crash test demonstrated that damage to a few tiles during assembly does not lead to a serious problem with the light collection. The leakage of glue is more dangerous than cracks.

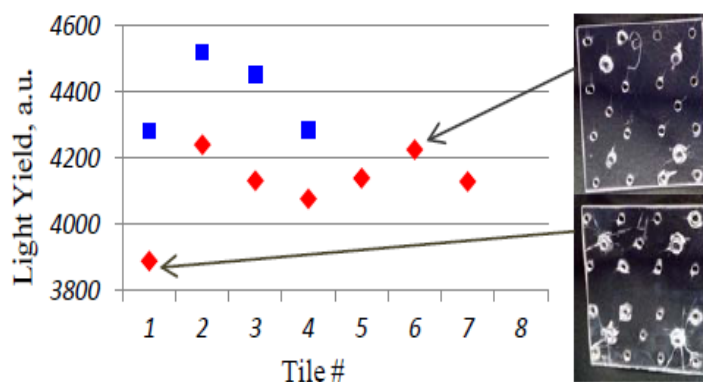


Figure 5. The result of the special crash test. The blue square corresponds to light response for normal tiles, the red rhombus to light response for broken tiles due to overpressure (snapshot of the tile #9 is on the top right, corresponding to the red rhombus #6 in the chart) or overpressure plus glue between Sc and Pb plates (snapshot of the tile #4 is on the bottom right, corresponded red rhombus #1).

The main fiber problem is related to fiber breakage. The GEANT simulation was performed for a 1 GeV muon beam that hits the ECal tower uniformly. We investigated three fiber damage locations: near the reflector, in the middle of the tower, and near the photodetector (see figure 6).

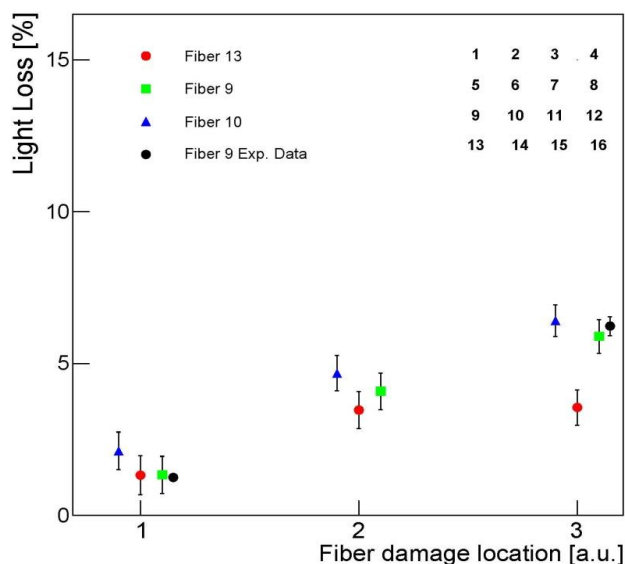


Figure 6. The result from GEANT simulation of the light yield loss for various fibers due to damage. The fiber numbering is shown in this picture on the top right. The red circle corresponds to the fiber #13, the green square to the fiber #9, blue triangle to the fiber #10, accordingly. The fiber damage location is shown on the X-axis, where point 1 corresponds to the damage near the reflector, point 2 - in the middle of the tower, and point 3 - near the photodetector. The black circle corresponds to experimental data for fiber #9 with two damage location only – near the reflector and photodetector.

It can be seen that the light collection falls by 1–2% when the reflector is lost on one fiber; 3–5% when the fiber is broken in the middle of the tower and 4–6% when the fiber is broken near the photodetector. The first value is consistent with our light yield measurement for fiber with LED [3]. The last data are consistent with our experimental measurements when we removed one fiber from the readout during the tower test with the muon beam from accelerator U-70 in IHEP, Protvino. The damage of the fiber near the photodetector is usually easy to spot with the eyes compared to when the fiber damage is in the other place.

4. Conclusion

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

Acknowledgments

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References

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