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THE DESIGN OF A MODULE
OF A NEW ELECTROMAGNETIC CALORIMETER
FOR COMPASS II

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Дизайн модуля нового электромагнитного калориметра
для COMPASS II

Разработан и создан высокогранулярный ЭМ-калориметр нового поколения типа «шашлык» со съемом информации микропиксельными лавинными фотодиодами с термостабилизацией на элементе Пельтье.

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Chirikov-Zorin I. et al.

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The Design of a Module of a New Electromagnetic Calorimeter
for COMPASS II

A new-generation high-granularity Shashlyk EM calorimeter read out by micropixel avalanche photodiodes with thermostabilization based on the Peltier element is designed and constructed.

The investigation has been performed at the Dzhelepov Laboratory of Nuclear Problems, JINR.

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A new-generation high-granularity Shashlyk electromagnetic calorimeter ECAL0 covering a wide range of photon angles was designed at JINR for studying generalized parton distributions at COMPASS II [1].

Previously, we built and tested a number of different prototypes of the electromagnetic calorimeter read out by PMTs and micropixel avalanche photodiodes [2, 3]. The design of the Shashlyk module 120×120 mm in cross section is shown in Figs. 1 and 2. The module consists of a calorimeter and a photodetector unit. The mechanical design of the calorimeter is similar to that of the EM calorimeters described in [4, 5] but has some significant differences.

The Shashlyk EM calorimeter is a sandwich of alternating perforated stamped lead plates and injection-molded BASF124HL-based scintillator (PS + 2% PTP + 0.05% POPOP) tiles read out by means of WLS fibers passing through holes in the scintillator and lead. The scintillator tiles and the lead plate are shown in Fig. 3. To improve uniformity and increase light collection, edges of the tiles and surface of lead plates were painted white to get diffuse reflection. There

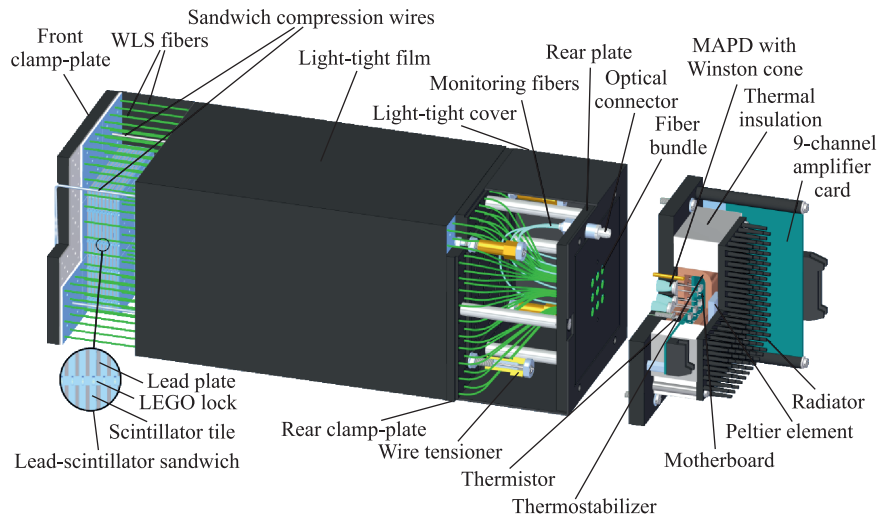


Fig. 1. Design of the Shashlyk calorimeter module



Fig. 2. View of the Shashlyk calorimeter module and components

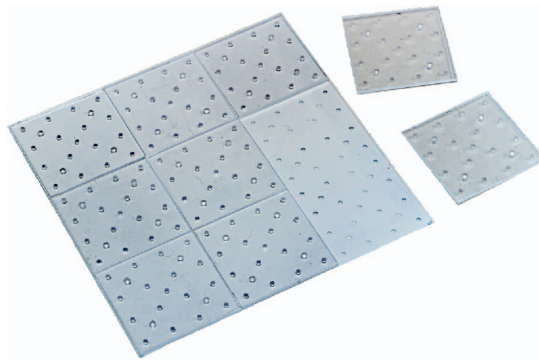


Fig. 3. View of the molded scintillator tiles and perforated stamped lead plate

are 109 sampling layers, each consisting of a 0.8 mm thick lead plate with dimensions 119.8×119.8 mm and nine 1.5 mm thick scintillator tiles with precise dimensions 39.95×39.95 mm. This precise size was obtained after several improvements of the mold. The total length of the calorimeter is about $15X_0$.

A polystyrene-based scintillator tile has 16 holes spaced 10.6 mm apart and equidistantly arranged in a 4×4 matrix for WLS fibers and one hole at the centre for the compression wire (Fig. 4). The edges of the tiles had white coating 20–30 μm thick and thus formed nine light-isolated towers. Each tower is read out by means of 16 BCF-91A WLS fibers 1.2 mm in diameter. The fiber ends are shaped into a bundle 6 mm in diameter and glued inside the corresponding holes of the rear plate, cut and polished. The other ends of WLS fibers were cut, polished and mirrored by special SILVER SHINE M415001 paint. An additionally monitoring BCF-98 clear fiber 0.8 mm in diameter was inserted in each bundle to transport light from the optical distribution connector (Figs. 1, 5). This connector is designed on the basis of conventional SMA RF connector. The PFU-CD1001-22E plastic optical cable comes from the LED of calibration and monitoring system [6], and the light is distributed to a bundle of nine monitoring fibers. To improve uniform light output the cylindrical surface of the light mixer was painted white which provides diffuse reflection and uniform light output at a level of 10%.

Each scintillator tile has four LEGO-type locks (Fig. 4). These locks are used to simplify the lead-scintillator sandwich assembling process and maintain the alignment of the tiles and the lead plates (Fig. 6). This tile design allows

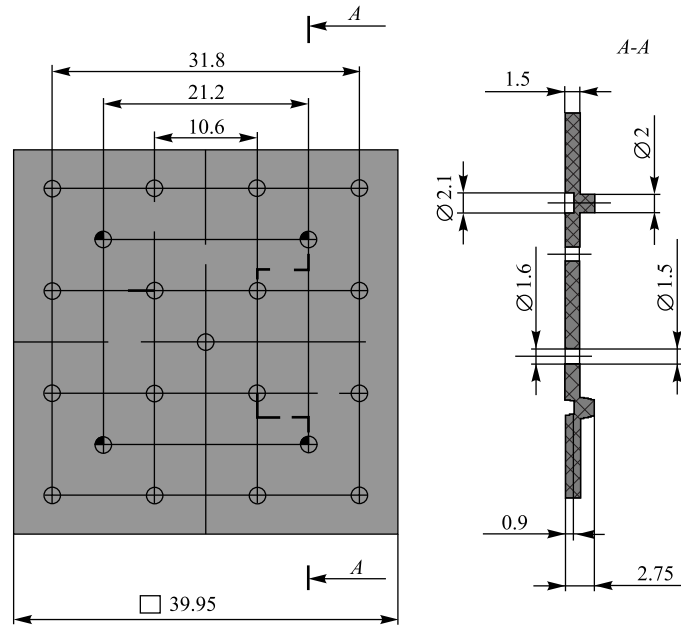


Fig. 4. Drawing of a scintillator tile

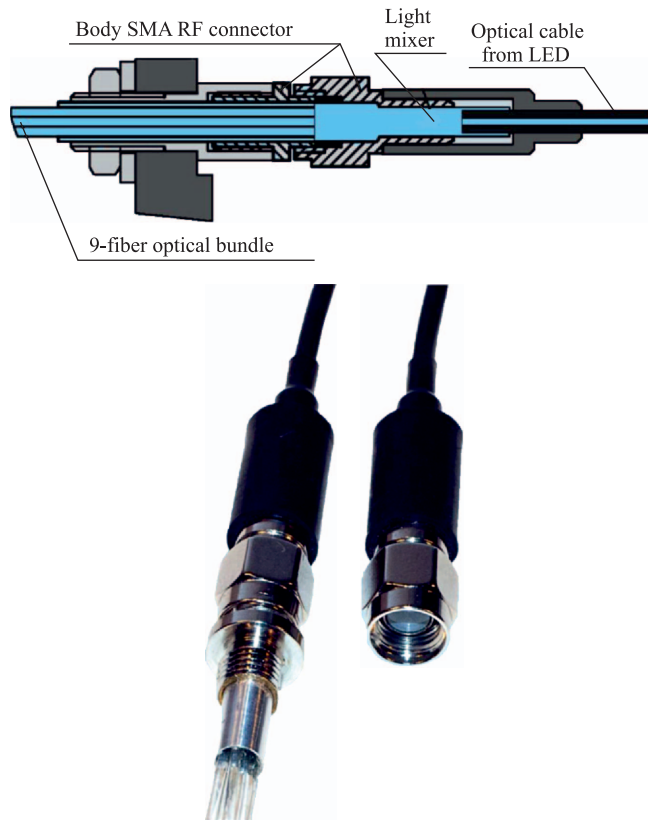


Fig. 5. Design and photo of the optical distribution connector

using lead plates with thickness ranging from 0.35 to 1 mm. The complete stack of lead-scintillator layers is held in compression between the front and rear plastic clamp-plates using four stainless steel wires 1.2 mm in diameter and tensioners. This self-maintaining design ensured high mechanical strength of the module due to static friction between the surfaces of the lead plates and the scintillator tiles.

The light-tight cover, rear and clamp-plates were made using the ABS plastic injection molding technique. The module is wrapped with a 0.1 mm black polyester film for light tightness. The main parameters of the Shashlyk electromagnetic calorimeter are summarized in Table 1.

Since the ECAL0 calorimeter will be installed close to the magnet, the photodetector should be insensitive to the magnetic field and a PMT cannot be used. Therefore, the MAPD-3N micropixel avalanche photodiodes [2] (gain $4 \cdot 10^4$, photon detection efficiency (PDE) $\simeq 25\%$ in the green region, superhigh pixel

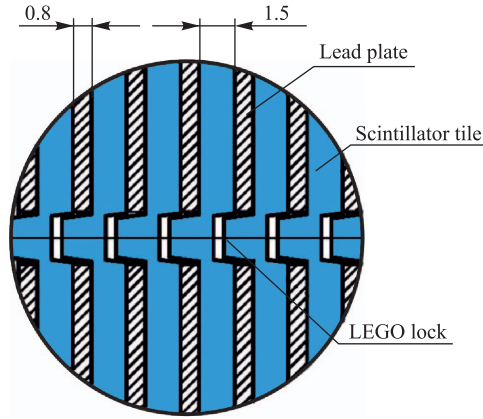


Fig. 6. Design of a lead-scintillator sandwich with LEGO-type locks

density $1.5 \cdot 10^4 \text{ mm}^{-2}$, area $3 \times 3 \text{ mm}$ manufactured by the Zecotek Company [7]) were used in the photodetector unit (Fig. 1).

Because the fibers bundle is 6 mm in diameter while the sensitive area of MAPD-3N is square-shaped and $3 \times 3 \text{ mm}$, the injection-molded polystyrene Winston cone light guide ($L = 10.1 \text{ mm}$, $D_1 = 7.2 \text{ mm}$, $D_2 = 3.3 \text{ mm}$) glued

Table 1. The parameters of the Shashlyk electromagnetic calorimeter

Transverse dimension, mm	120×120
Dimensions of the tower, mm	40×40
Number of the towers	9
Number of the layers	109
Polystyrene scintillator thickness, mm	1.5
Lead absorber thickness, mm	0.8
Diameter of BCF-91A WLS fibers, mm	1.2
Number of WLS fibers per tower	16
WLS fibers per module	$0.41 \cdot 144 \approx 59 \text{ m}$
Diameter of BCF-98 clear fibers, mm	0.8
Clear fibers per module	$0.18 \cdot 9 = 1.62 \text{ m}$
Effective radiation length X_0 , mm	16.4
Effective Moliere radius R_M , mm	35
Active depth, mm	$256 (15.3X_0)$
Total depth (without photodetector unit), mm	344
Total weight, kg	16



Fig. 7. View of the MAPD with and without the Winston cone

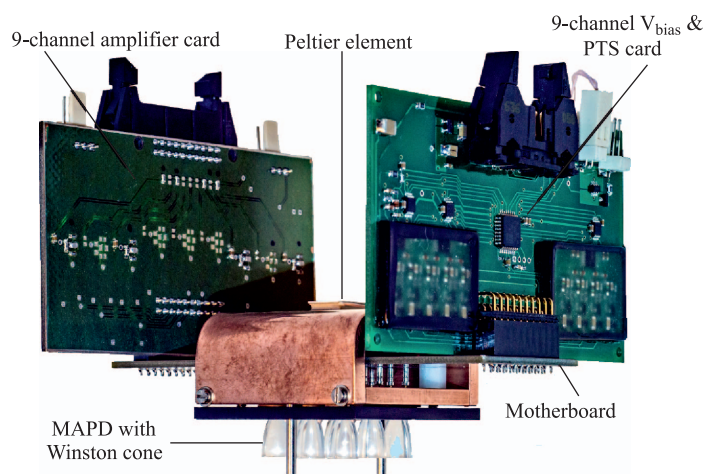


Fig. 8. View of the thermostabilizer with the MAPD etc.

to the MAPD surface is used to increase light collection (Fig. 7). The measured light collection efficiency of the Winston cone is about 95%. Thus, the use of the Winston cone increases the effective sensitive area of the photodiode more than 4 times, which significantly extends the area of application of the MAPD.

The gain and PDE of the MAPD significantly depend on the temperature (few percent per degree). It is therefore necessary to stabilize the temperature of the MAPD.

Table 2. The parameters of the photodetector unit

Polystyrene light guide	Winston cone ($L = 10.1$ mm, $D_1 = 7.2$ mm, $D_2 = 3.3$ mm)
Photodetector	MAPD-3N with glued Winston cone
Number of the photodetectors	9
Cooling MAPD-3N	TB-66-0,45-1,3HT(200) Peltier element ($12 \times 9 \times 2.3$ mm)
Signal amplification	9-channel amplifier-shaper card (54×101 mm)
Bias voltage MAPD and temperature stabilization	9-channel V_{bias} and PTS card (56×101 mm)
Photodetector unit size, mm	$118 \times 118 \times 90$
Photodetector unit weight, kg	0.67

The thermostabilizer of the photodetector unit is based on the compact high-resistance ($R = 10 \Omega$) TB-66-0,45-1,3HT(200) Peltier element with the dimensions $12 \times 9 \times 2.3$ mm and is made of copper plates (Fig. 8). The Peltier element is glued to the outside surface of the thermostabilizer with heat-conducting glue. The motherboard is installed on the thermostabilizer and has connectors for the MAPD, 9-channel amplifier-shaper card, 9-channel bias voltage MAPD and Peltier temperature stabilization (PTS) card [6]. The thermal insulation of the thermostabilizer against ambient temperatures is made of cellular polythene. The heat side of the Peltier element is cooled by the radiator. The main parameters of the photodetector unit with MAPD and thermostabilization based on the Peltier element are listed in Table 2.

In conclusion, we would like to note that a similar design of the module is dedicated for electromagnetic calorimeter of the MPD and SPD detectors for the NICA experiment [8, 9].

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