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QCALT: A tile calorimeter for KLOE-2 upgrade

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ABSTRACT

The upgrade of the DaΦne machine layout requires a modification of the size and position of the inner focusing quadrupoles of KLOE-2, thus asking for the realization of two new calorimeters, named QCALT, covering this area. To improve the reconstruction of $K_L \to 2\pi^0$ events with photons hitting the quadrupoles, a calorimeter with high efficiency to low energy photons (20–300 MeV), time resolution of less than 1 ns and space resolution of few cm, is needed. To match these requirements we are now constructing a scintillator tile calorimeter where each single tile is readout by mean of SiPM for a total granularity of 1760 channels. We show the design of the different calorimeter components and the present status of the construction.

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1. The KLOE-2 proposal

In the last decade, a wide experimental program has been carried out at DaΦne [1], the e^+e^- collider of the Frascati National Laboratories, running at a center of mass energy of the ϕ resonance. During KLOE [2] run, DaΦne delivered a peak luminosity of 1.5×10^{32} cm^{-2} s^{-1}, corresponding to 1 fb^{-1} per year.

In 2008, a new interaction scheme has been proposed for DaΦne, to increase the luminosity of the machine up to a factor 3 [3]. This possible improvement pushed for a new data taking campaign of the KLOE experiment, starting a new experiment named KLOE-2, aiming to complete KLOE physics program.

To improve the performances of the detector, we expect to add new subdetector system such as an inner tracker, a tagger system to study $\gamma\gamma$ physics, a new small angle calorimeter and a new quadrupole calorimeter. These new sub-detectors are now in construction, and in this paper we report about the new quadrupoles calorimeter.

2. QCALT design and components

In the old IP scheme of DaΦne, the inner focalizing quadrupoles have two surrounding calorimeters, named QCAL [4], covering a polar angle down to 21°. Each calorimeter consists of 16 azimuthal sectors composed of alternating layers of 2 mm lead and 1 mm BC408 scintillator tiles, for a total thickness of $\sim 5\ X_0$. The back bending fiber arrangement allows the measurement of the longitudinal coordinate by time difference with a resolution of 13 cm. These calorimeters are characterized by a low light response (1–3 pe/mip/tile) due to the coupling in air, to the fiber length (~ 2 m for each tile) and to the quantum efficiency of the used photomultipliers (standard bialkali with $\sim 20\%$ QE).

The new QCALT consist of two calorimeters with a dodecagonal structure, 1 m long, covering the region of the new quadrupoles. Each module is made by a sampling of five layers of 5 mm thick scintillator plates alternated with 3.5 mm thick tungsten plates, for a total depth of $5\ X_0$. The active part of each plane is divided into 16 tiles, 5 cm long, with 1 mm diameter WLS multicladding fibers embedded in circular grooves. Each fiber is optically connected to a silicon photomultiplier, for a total of 1760 channels (one module in each QCALT is left empty for photons tagger insertion).

2.1. Detector components

A specific R&D phase has been carried out to decide each single component of the QCALT calorimeter. Different scintillator types and fiber producers have been compared to better match calorimeter requirements while maintaining reduced cost for the project.

Scintillator tiles are made using EJ-200 plastic scintillator produced by Eljen and painted using BC-620 refractive paint. To maximize light collection, WLS fibers are inserted in circular grooves at different depths along the path and with 6° angular exit. In QCALT, we use BCF92 multicladding fibers, produced by Saint

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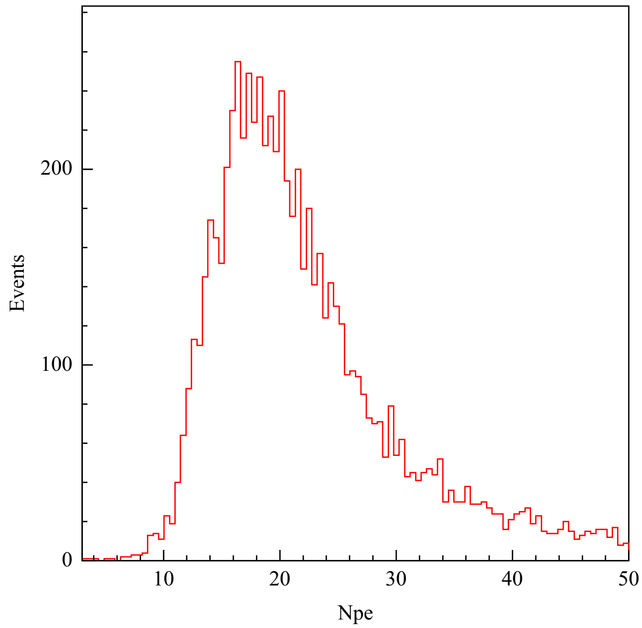

Fig. 1. Charge tile response using cosmic rays.

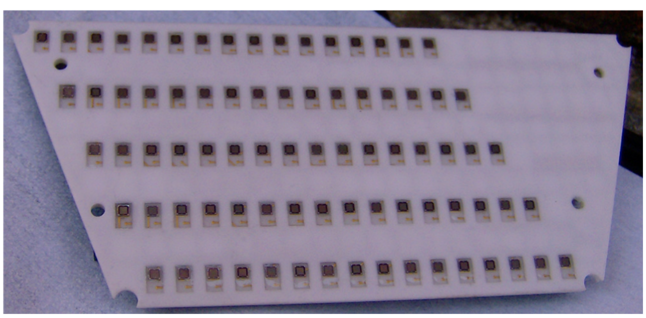

Fig. 2. PCB prototype realized in collaboration with FBK.

Gobain, ensuring a fast emission time (5 ns/pe), long attenuation length and a large light yield respect the single cladding ($\times 1.5$).

The sampling absorber is made with an alloy, 90% tungsten and 10% copper. This permits the preparation of mechanical shaped tungsten while keeping reduced cost.

A module-0 of QCALT calorimeter, consisting of 1/12 of one calorimeter, has been prepared in 2011 and tested using both cosmic rays and electrons. We measured a light yield of ~ 20 pe/mip/tile with a time resolution of 750 ps (see Fig. 1). This results already satisfied the requirements for KLOE-2 experiment.

2.2. SiPM board

Fibers coming from each module are glued in a plexiglas holder and then polished maintaining a planarity below 0.05 mm. In QCALT we use custom smd circular SiPM produced by FBK with 1.2 mm diameter, 25 μm pixel and peaked on green. The 80 photodetectors for each module are bonded on an aluminum PCB and covered with optical resin. In Fig. 2 a picture of a prototype PCB is shown. The entire process is done keeping under control planarity and SiPM positioning with precision below 0.2 mm. The bias voltage required is between 30 and 35 V. Good results has been obtained comparing these custom devices with standard Hamamatsu MPPC.

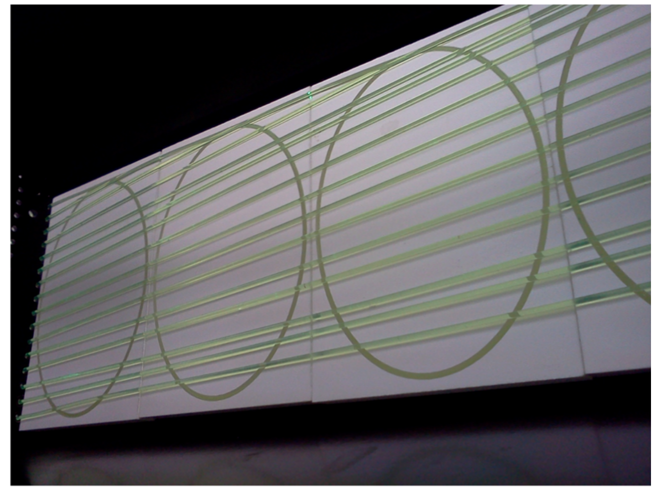

Fig. 3. QCALT construction.

2.3. FEE

Each PCB is connected with four boards, 20 channels/each, including $\times 20$ transimpedence preamplifiers, HV regulators (0.1% precision, 0.01% stability) and single threshold discriminator with differential outputs. Each module requires a power consumption of 2W. Boards are inserted in a brass Faraday cage with air cooling.

Calorimeter reconstruction based only on timing using 0.5 ns resolution TDC. Global interface board has been developed for KLOE-2 projects to control FEE.

QCALT calibration achieved using SiPM dark counts rate when varying discriminator threshold and using 10 bit scaler.

3. QCALT construction

First half calorimeter has been already prepared. In Fig. 3 a picture of module construction is shown. Each channel is tested using Sr source to check fiber-tile coupling and module tested using cosmic rays. During June 2012 an electron test beam will be carried out at Frascati beam test facility with final PCB boards and FEE. End of construction is expected on October 2012.

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