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Scintillator pad detector for OKA experiment read-out by multi-pixel avalanche photodiodes operating in Geiger mode.

Experiment "OKA"(U-70, Protvino) is one of new generation of the experiments studying the rare decays "on-flight"of charged K mesons using RF separated beam on U-70 accelerator (IHEP, Protvino). The pad detector in front of electromagnetic calorimeter is a part of trigger/tracking system developed for low-level multiplicity trigger operation. The detection of charged particles using plastic scintillator readout with embedded WLS fiber is explored in many HEP experiments. The development of the pad detector for OKA experiment is based on our experience in construction of preshower detector for LHCb experiment but using excellent characteristics of recently developed multi-pixel APD operating in Geiger mode. This gives advantages with respect to conventional multi-anode PMT in improvement of detector performance. A large quantum efficiency, compact dimensions and low operation voltage of MRS APD, produced by the CPTA (Moscow) allow achieving high light response of more than 30 photo-electrons per MIP with simple and economical scintillator pad design.

In this presentation we describe the design and performance of pad detector for OKA experiment. It consists of 284 scintillator pads of 12 x 12 and 4 x 4 cm² size read-out by 1.1 mm² multi-pixel avalanche photodiodes. We describe also the quality control and selection procedure for APD on the detector production stage. First beam results on detection efficiency and timing characteristics are also presented.

Summary (Additional text describing your work. Can be pasted here or give an URL to a PDF document):

The "OKA"experiment [1] is aimed on study of changed K mesons decaying "on flight"in radio-frequency separated beam of U-70 accelerator (IHEP, Protvino). In order to improve data quality and to enrich experimental statistics the physical data selection at the low level trigger is essential. One of the important detectors for fast multiplicity trigger is a scintillator pad hodoscope (pad detector) placed in front of electromagnetic calorimeter constructed of lead glass. Therefore the main requirements for the pad detector are to have a high detection efficiency for charged particles > 95% , a small time of signal development, a good time resolution better than 5 nsec, and a small material budget in order not to disturb energy resolution of ECAL. The granularity of the pads should correspond to electromagnetic cluster size of 12x12 cm² in ECAL. In order to match high occupancy in region around beam, the cell size of 4x4 cm² in central region was chosen. In total the detector has 252 tiles of 12x12 cm² size and 32 tiles of 4x4 cm² size around the beam hole.

The design based on plastic scintillator pads with light read-out through the WLS fibers is chosen as good compromise between requirements and cost. The choice of detector technique was based on our experience with construction of LHCb [2] preshower detector. The scintillating light is collected from the tile by 3.5 coils of WLS fiber of 1mm diameter glued inside the circular groove of 4.1 mm depth. The thickness of tile is 15 mm. We use Y11-250 J-type fiber produced by Kuraray (JP) because of its mechanical durability against of bending required for inner cells. The measured light signal from minimum ionizing particle at the output of fiber at 15 cm distance from the tile was equal to 600 photons at 520 nm wave length in case of 12x12 cm² and about 1.5 times larger in 4x4 cm² tiles.

The advantage of multi-pixel avalanche photodiodes operating in Geiger mode against conventional multi-anode PMT R5900 (Hamamatsu, JP) is listed bellow:

1. Due to small size and material budget APD can be placed near the tile with short fiber. The PMT has to be moved out of acceptance of the detector, and therefore the part of light will be attenuated in the fiber.
2. The quantum efficiency of APD is higher more than 2 times, than with PMT.
3. The optical cross-talk between neighboring pixels in PMT could be significant. With individual APD per tile there is no such effect.
4. The operation voltage and current are significantly smaller for APD, which has an impact on the detector cost.
5. The time of signal transition in PMT is larger than in APD.

After tests of samples and comparison of few types of APD we chose the MRS APD produced by CPTA, Moscow [3]. The geometry of APD has a hexagonal shape of sensitive area with 556 pixels of 1.1 mm² total surface. There two types of APD used, which differs mostly by operation voltage of 60 and 20 Volts. The other characteristics are rather close. The details of this comparison can be found in [4].

Before the installation of APD on the tiles, we measure for each APD the noise-voltage characteristics. It was

important to group the APD by 16 pieces in order to have close operation voltage values inside each group connected to one front-end board. The operation voltage is chosen to provide good quantum efficiency of APD but to set noise count not larger than 1 kHz with threshold of electronics around 5 photo-electrons. Some of APD (<10%) have been sorted out by higher noise and poor stability.
The pad detector was tested with muons from K decays in 2009 experimental run in order to study main detector performance. The preliminary results show the average detection efficiency larger than 95%, time resolution better 2 nsec (σ). The further tests and implementation of trigger electronics is under way.

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