

# Scintillation fiber detector of relativistic particles.

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## *Abstract*

At present the development of a silicon photomultiplier (SiPM), being a microcell photodiode with Geiger amplification, is going on [1]. Such devices are capable of registering faint light bursts, what, in aggregate with their small dimensions, makes them highly promising for application as photoreceivers in scintillation fiber detectors. Relying on the studies of the latter and those of SiPM, a bread-board model of a tracking detector of relativistic particles, containing 16 channels, has been designed and created. The characteristics of SiPM have been studied with a beta-source.

A read-out electronic unit, containing preamps, shapers, discriminators, has been designed to collect the signals of SiPM. The characteristics of this unit are presented and the prospects of its application in experimental physics are discussed.

## I. INTRODUCTION

The scintillation fiber detector is one of the promising devices for relativistic particle detection, however its wide application is hindered by the absence of compact, cheap and easy for service photoreceivers.

At present the development of a silicon photomultiplier (SiPM), being a microcell photodiode with Geiger amplification [1], is going on. Such devices have high gain ( $>1\ 000\ 000$ ), efficiency at the level of vacuum PMTs (10...20%), with help of these photoreceivers it is possible to detect light in a dynamic range of  $\sim 1000$ , beginning from solitary photons. Simultaneously they are capable of operation in magnetic field and require low supply voltage, what makes them fairly promising for application in tracking scintillation detectors.

## II. GENERAL STRUCTURE OF PROTOTYPE TRACKER

The tracker for registering  $\beta$ -particles is being an assembly of a 16-channel optical unit and corresponding read-out electronics (see block-diagram of fig.1). The photograph of this set-up is shown in fig.2.

## III. OPTICAL UNIT

The optical unit consist of: collimator, scintillation fiber detector, the unit of SiPM and coax cable fixation. Its design is presented in fig. 3. Under the influence of  $\beta$ -particles the scintillation fiber detectors produce optical signals, which are fed to the optical inputs of SiPMs. Much attention was paid to the matters of choosing the SiPM cases and connecting them with plastic fibers. Since one of the main applications of SiPM in nuclear physics consists in using it as a radiation detector, its case should meet a number of requirements, following from the modes of its operation. Therefore the case should:

- provide the connection of SiPM with optical scintillation fibers at a minimum loss level;
- have sufficiently small dimensions in order to make possible the design of an assembly of several tens of SiPMs;
- have leads, not hindering the achievement of a bandwidth, sufficient to transfer subnanosecond pulses;
- provide the possibility to cool the SiPM chip with a thermoelectric element.

The above-adduced requirements caused the SiPM case to be designed as a pigtail one of cylindrical shape, widespread in optical fiber technology. The main advantage of this case is its manufacturability, the accuracies of adjustment and of

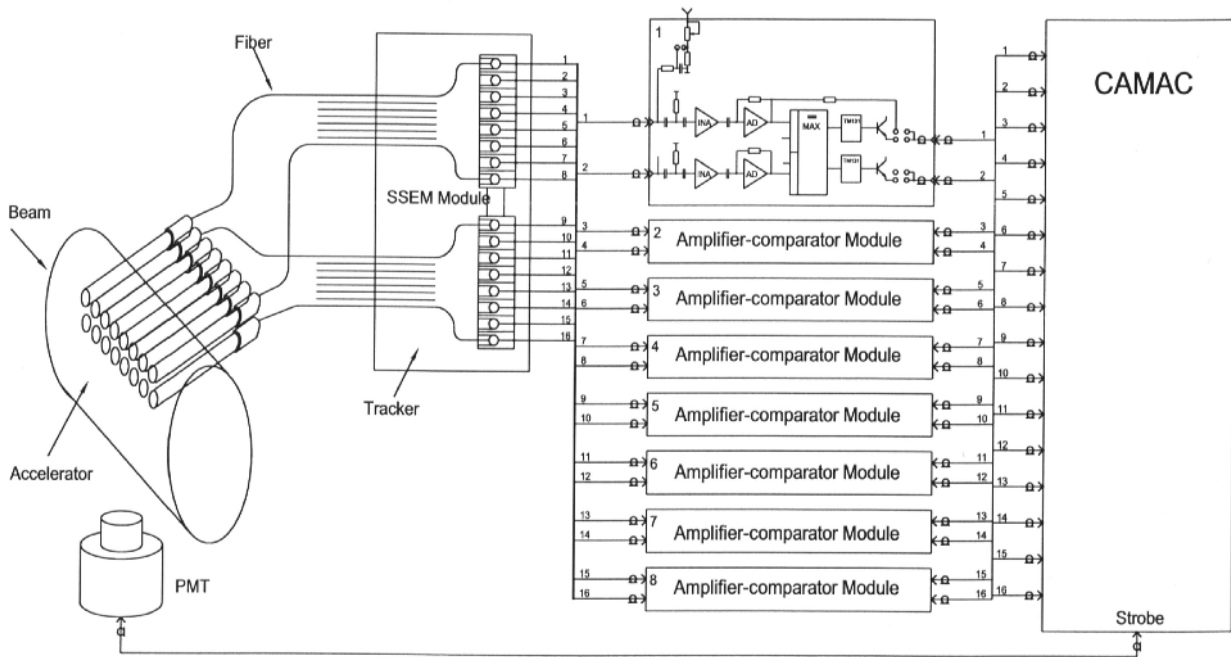


Figure 1: General structure of prototype tracker

bonding the optical fiber in it. The chip of SiPMs is thereat mounted most often in a transistor case of the TO-3 (KT-1) type, the leads of which provide an effective signal transfer in the frequency range up to 1.5 GHz.

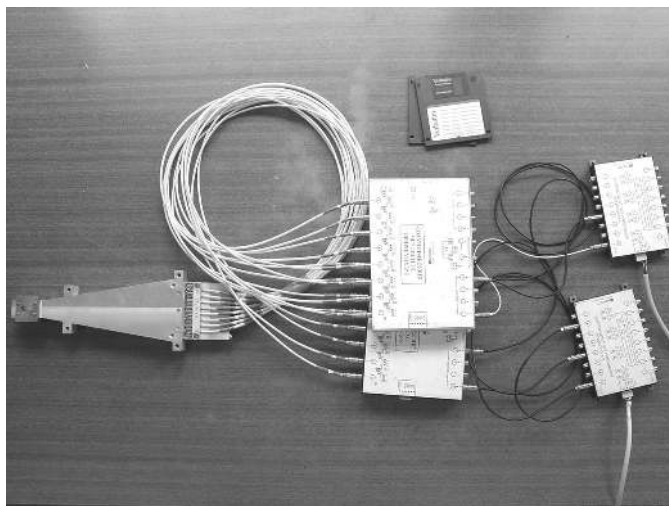


Figure 2: The photograph of tracker

The connection of plastic fibers with SiPM is made in the form of a cylindrical pipe, at one end of which the SiPM chip in a TO-3 case is bonded in. At the other end a plastic fiber, 1 mm in diameter, is bonded in. The gap between the face of the optical fiber and the SiPM chip's surface does not exceed 50  $\mu\text{m}$ . After adjustment and fixation of the fiber's tip the whole design is covered by a protective cylindrical shield and soldered in a dehumidified atmosphere.

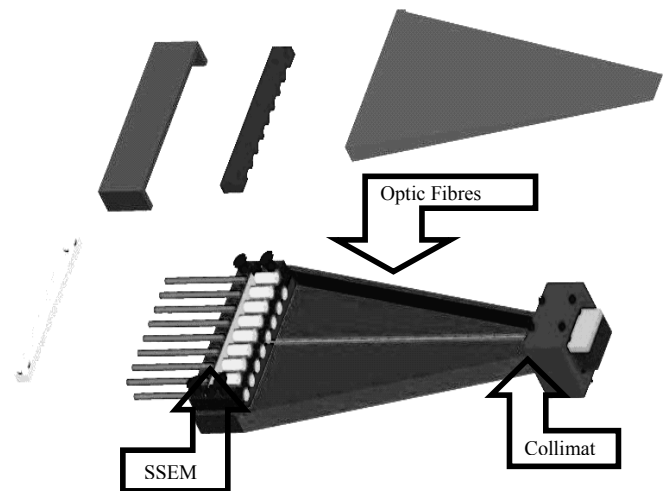


Figure 3: The optical unit

The direct connection of scintillation fiber with SiPM ensures minimal losses of light, but, due to the large fading in scintillation fibers (200-300 dB/km), the length of such a pigtail may not exceed (20...30) cm and forces the SiPM to be placed close to the radiation source.

The collimator unit serves to fix the assembly of 16 scintillation fibers and adjust them relative to a point radiation source. The fiber assembly has a rectangular cross-section measuring 2.8\*6 mm<sup>2</sup>. A collimator slit, 0.4 mm wide, provides the adjustment of a beta-particle beam, running from a point source to scintillation fibers. Micrometric screws

provide a fluent transposition of the slit relative to the fiber assembly.

The SiPM fixation unit ensures the mechanical strength of fixing the 16 SiPMs in cases. The signal leads of SiPM are soldered to the interconnection board. The latter serves to feed the bias voltage and provides the mechanical fixation of signal leads and central conductors of coax cables. The SiPM signals are brought out by standard coax cables PK-50-2-21 and “Lemo” connectors. The length of cable in each of 16 measuring channels makes up 1 m. The housing ensures the protection of scintillation fibers against external exposure.

#### IV. ELECTRONIC UNIT.

The electric output signals of SiPMs travel through coax cables to electronic 16-channel pre-processing units and further to CAMAC.

The 16-channel front-end electronics has been built with 2 printed circuit units. The photo of one such unit is shown in fig.4. It was implemented with 4-layer printed circuit boards by SMT. 4-channel preamp-shaper-comparator ICs are being the core of it [2].

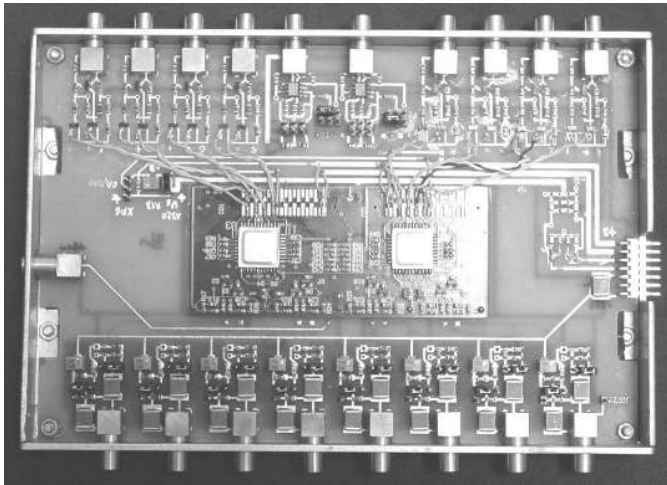


Figure 4: 8-channel front-end PCB unit

High-speed printed circuit units, based on INA-51063 solid-state wide-band amplifiers, were designed for a detailed research of SiPM temporal characteristics. A rise-time of 300ps was thereat observed.

For collecting tracker signals a double-channel amplifier-discriminator was designed, the photo of which is given in fig.5. At its input there were also used the INA-51063 wide-band amplifier ICs at a gain of 10. The following AD8009 op amp, which determines the speed, provides an additional gain of 3 or 10 (chosen by jumper). The typical signal after amplification at the analog output is shown in fig.6 at 3 different time-bases (2...200 ns/div). Thereat the rise-time makes up about 3ns.

Signals from analog outputs also travel to a shaper, a following discriminator with an AD96687 IC and a circuit,

shaping the output logic signal by duration (between 5 and 20 ns), built with 100TM131.

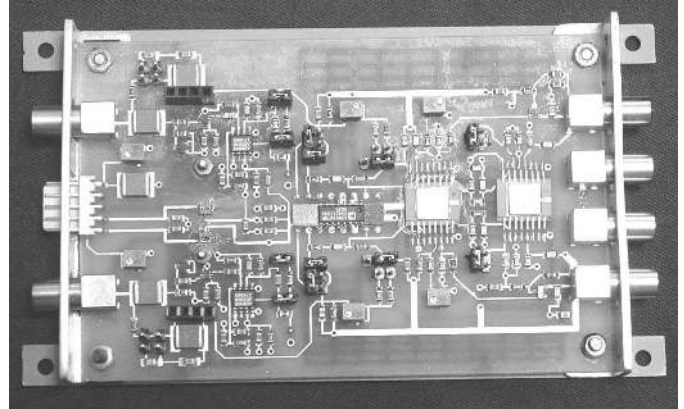


Figure 5: High-speed 2-channel amplifier-discriminator PCB

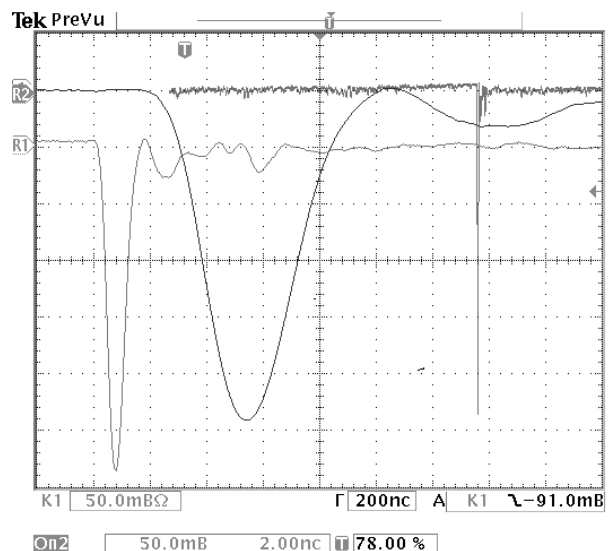


Figure 6: Typical SiPM signal at analog output

#### V. LAB TESTS AND CONCLUSIONS

Proceeding from the results of studying the SiPMs and scintillation fibers, there was designed and created a 16-channel bread-board model of a tracking detector. The read-out electronics has been described in section IV.

Scintillation fiber detector was studied with help of multi-clad scintillation fibers SCSF-3HF (1500)M of Kuraray Co., 1 mm in diameter, and an SiPM with a sensitive area of 1 mm.sq. The separation of  $\beta$ -particles, passing through the studied fiber, was carried out by using a collimator and two additional scintillators. The mean number of detected photoelectrons amounted to  $\sim 5$ , what allowed to reach a registration efficiency of  $\beta$ -particles close to 100% at room temperature. However the high rate of noise pulses at room temperature ( $\sim 1$ MHz for amplitudes, corresponding to 1 photoelectron and more) required a refrigeration of SiPM down to  $-(20..60)^{\circ}\text{C}$ , whereat the probability of false

switchover did not exceed (1...2)%. For lowering the temperature there were studied the possibilities of forced cooling, based on Peltier elements.

Currently the work is going on. The last samples of SiPM with different types of electronics are under tests.

The given work was supported by the International Science and Technology Center (ISTC).

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