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Modular Detector with Picosecond Time Resolution

Nowadays the TOF measurement with picosecond time resolution is important feature in high-energy physics experiments and the detectors solving this task are important part of experimental setups.
The initial point of our activity in this direction was a proposal of Fast Forward Detector (FFD) for MPD/NICA project [1]. The detector concept and results obtained with the first version of detector modules were published in [2]. Another considerable application is developing a modular array for BMN project [3]. Both these cases were studied by MC simulation and some the results are presented here.
Application in experiments with rather low energy of heavy ions, sNN1/2 ˜ a few GeV, is the most difficult case because in such collisions the produced particles have the smallest multiplicity and mostly their velocities β are essentially less of 1. The examples are novel experiments CBM at SIS-100, BMN at Nuclotron, and MPD/NICA which are in preparation stage.
In this report the experience in developing and testing modules for detector arrays with picosecond time resolution based on registration of Cherenkov radiation induced by relativistic charged particles and high-energy photons is described. The important point for ps-timing and operation in magnetic field is application of MCP-PMTs XP85012/A1-Q from Photonis. The main idea of the detector concept is registration of ultrarelativistic charged particles and high-energy photons by conversion to electrons in lead layer in front of quartz radiator. The total active area of the module is 59 × 59 mm with zero dead space (only module housing defines the dead area). It is very important point because it allows designing detector arrays without any dead space. The module has four independent cells/channels. The quartz radiator has 15-mm thickness and it is segmented into four bars. The radiator is optically coupled with MCP-PMT which has 8 × 8 anode pads transformed into 2 × 2 cells by merging 4 × 4 pads of each cell into a single channel. The FEE is carried out amplification and formation of output analog and LVDS signals.
The performance of detector modules and modular arrays proposed for start signal generation in TOF measurements and triggering Au + Au collisions in MPD/NICA and BMN was studied by MC simulation and in tests with GeV single-charged ions of Nuclotron beam and cosmic rays. In the experimental tests three different types of readout electronics were used: (i) measurement of time and amplitude with TAC and ADC, (ii) determination of time and pulse width for LVDS signals, and (iii) analysis of pulse shape by digitizing with 200-ps/bin time scale.
For single-charged particles with β ≈ 1 producing about 1800 Cherenkov photons in quartz, the module channel generated the pulses with pulse height of ˜ 300 mV, rise time of 1.2 ns, pulse width of 5 ns at noise level of a few mV. The time resolution obtained in the measurements with two modules is ˜ 30 ps (sigma) per module cell. It means that one may hope to get an excellent time resolution better than 10 ps in a real experiment where registration of a large number of charged particles and photons by modular array occurs in single events.

1. Kh. U. Abraamyan et al. Nucl. Instr. Meth. A. 628, 2011, 99.
2. V. I. Yurevich et al. Physics of Particles and Nuclei Letters. 10 (3), 2013, 258.
3. http://nica.jinr.ru/files/BM@N/BMN_CDR.pdf

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