**ALICE Photon Spectrometer Upgrade R&D project**

**(JINR Participation)**

**ABSTRACT**

ALICE is the dedicated heavy ions experiment running at Large Hadron Collider (LHC) since 2009. The central part of the ALICE detector includes PHOS, the photon spectrometer, designed to detect, identify and measure with high resolution the 4-momenta of photons. The main physics measurements with PHOS spectrometer are the detection of direct thermal photons. This is the only way to determine initial temperature of the hot fireball created in high energy heavy-ion collisions at LHC. The measurement of the thermal photons is a quite difficult and challenging task, since their expected signal is rather weak (a few per cent) as compared to a high physical background of decay photons from hadrons produced in the same collision.

The goals of proposed ALICE ***Photon Spectrometer Upgrade R&D*** project are to improve such base detector characteristics as dynamic range of direct photon detection, energy resolution, discrimination power against charged hadrons, neutrons and anti-neutrons.

Each PHOS channel consists of PWO crystal in the size 22х22х180 mm3, the avalanche silicon photo diode (APD), a preamplifier, and shaping amplifier. The measured pulse after shaper has width about 1 µs. For increase of dynamic range the amplification channel split out on two amplifiers with a different amplification factors. Now the spectrometer PHOS for digitizing uses the same electronics as TPC that is 10-bit ALTRO ADC with 10 MHz sampling. For each channel sixty 40-bit words are read. The amplitude and time values are extracted after fitting sample values with function describing the form of a slow microsecond pulse. The time resolution at measured energy of 1 GeV is about 3-4 nanoseconds. Current design of the PHOS Front End Electronics (FEE) was based on assumption of the luminosity of pp collisions L= 1030 cm-2s-1.

Actuality of the PHOS readout upgrade project concerned first of all with planned increase of the LHC collision energy to 14 TeV and in luminosity by a factor of 10. It is shown, with Monte-Carlo calculations for upgraded PHOS and LHC, that with instantaneous luminosity *L*=3x1031 cm-2s-1 and integrated luminosity 100 pb-1, one can expect to detect a non-negligible number of direct photons in the range PT<200 GeV/c. It defines a required dynamic range of the upgraded PHOS detector by the upper limit of detected energies 200 GeV. The second conclusion from the calculations is requirement of improvement PHOS discrimination power against charged hadrons, neutrons and **anti-neutrons**. For such an improvement a time of flight (TOF) discrimination with the timing resolution of 0.5ns was proposed in the original upgrade project, in such a case contamination from neutrons and antineutrons will be reduced below 1%, which is of the order of 1/3 of the direct photon signal. This requires development and production of a new PHOS electronics, since, with the existing electronics, the PHOS timing resolution is about 5 times worse.

Further improvement of TOF measurements with PHOS can be researched with using silicon photo multipliers (SiPM) or large area avalanche device (APD) as photo detector. The silicon photomultiplier is the avalanche photo diode consisting of a considerable quantity of pixels (several thousand per mm2). Pixels work in limited Geiger mode with amplification up to 106. The signal output from the SiPM is the total sum of the outputs from all pixels. The advantage of the silicon photomultiplier is the big amplification, good (it is about 100 psec) the time resolution, low, is less 100 V bias voltages, tolerance to a magnetic field, small thickness. For PHOS upgrade the most attractive feature of silicon photo multipliers is the good time resolution.

A number of tests performed on the electron beams at CERN with different SiPM’s have shown that the time resolution better 500 ps are possible to reach at working temperatures booth as Т=-25 0С and Т=+18 0С.

At the usage of the 10x10 mm APD instead of 5x5 mm APD at working temperature Т=+18 0С , the energy resolution is not get worse. So, it feasible to exploit PHOS under room temperature without deterioration of the energy resolution and improved very much the time resolution. The exploitation costs will be much cheaper, also.

The prototype of the 8 channel readout card (FEC-8) developed and tested in the beam during 2017-2018.

During 2019-2020 it is planned to develop the prototype of the 32-channel readout card (FEC-32) compatible with the ALICE detector control system and data acquisition system, test it and then develop the pre-production sample with the complete documentation for the mass production.

The continuation of the project is necessary to finalize the proposed configuration of the new readout scheme of the PHOS detector.