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ENGINEERING DESIGN
OF NUCLEAR PHYSICAL EQUIPMENT

Scintillation Detector Prototype for a Beam–Beam Counter at NICA SPD

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Abstract—The Beam–Beam Counter of the spin physics detector at NICA is proposed for local polarimetry and luminosity monitoring. The main option of the Beam-Beam Counter is the scintillation tiles with SiPM readout. In this paper, we present the results of studies of a scintillation detector prototype using two types of primary electronics. An estimation of the time resolution using the procedure for correcting the "time-walking" effect is discussed.

Keywords: silicon photomultiplier (SiPM), front-end electronics (FEE), time-over-threshold (ToT), data acquisition system (DAQ), spin physics detector (SPD)

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INTRODUCTION

Owing to the increased interest in studying the properties of dense baryonic matter, the NICA (Nuclotron based Ion Collider fAcility) collider is being created at the Joint Institute for Nuclear Research. One of the points of interaction of the collider is the spin physics detector (SPD), the main purpose of which is to study the spin structure of nucleons in collisions of longitudinally and transversely polarized protons and deuterons with an energy in the center-of-mass system up to 27 GeV and a luminosity up to 10^{32} cm^{-2} s^{-1}.

The SPD is planned as a universal 4π spectrometer with extended capabilities for detecting and identifying particles owing to the wide functionality of its subsystems. The Beam–Beam Counter (BBC) subsystem is being created as a tool for local polarimetry and luminosity control. The feasibility of this type of polarimetry is demonstrated by the correlation between the measurements of the CNI polarimeter and the azimuthal asymmetry of the inclusive charged particle yield in the BBC STAR collaboration.

Two parts of the SPD/BBC, which are planned to be different depending on the intensity of the beam, are proposed. Since the concept of the outer part is highly granular scintillation plates with readout by silicon photomultipliers (SiPM), a scintillation detector prototype was developed (Fig. 1b) with various types of front-end electronics (FEE). Both types are based on readout of Hamamatsu SiPMs (S12572-010P) [1].

DESCRIPTION OF THE PROTOTYPE AND TEST EQUIPMENT

Front-End Electronics with Time-over-Threshold Function

As one of the candidates for the detector prototype, single-channel front-end electronics with SiPM readout was developed. The electronics is made on a 4×2.5-cm^2 printed circuit board (Fig. 2a) and is based on the time-over-threshold (ToT) method. The method itself consists of two measurements of time, the passage of a negative signal below (leading) and return above (trailing) a specified threshold, and makes it possible to measure the charge by the width of the electrical pulse.

In addition, amplifiers that did not change the leading edge of the signal were used. The signal after the amplifier is integrated and transmitted to the comparator, from where it is output to the readout electronics via the LVDS interface. Thus, owing to the developed electronics board, we are able to obtain the time stamp of the event and measure the charge.

A power source (PS) provides power with the ability to simultaneously connect up to eight channels of electronics. The PS contains a push-button interface, display, and built-in voltmeter. The bias voltage con-

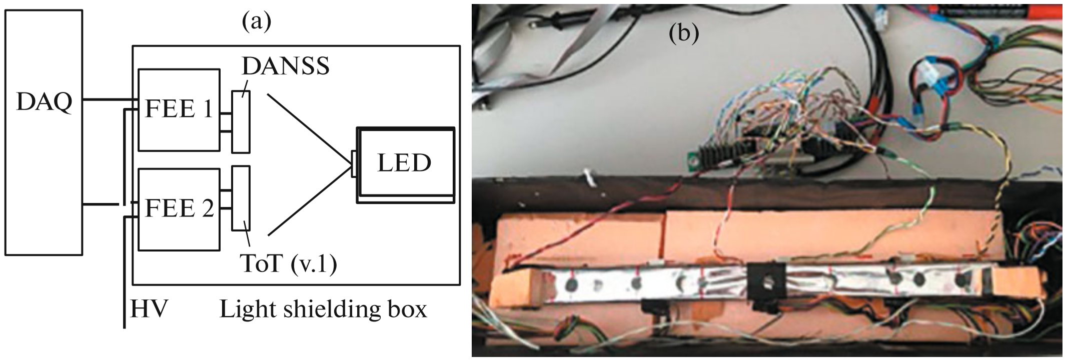

Fig. 1. Schematic appearance of tests without a scintillator (a) and appearance of prototype (b).

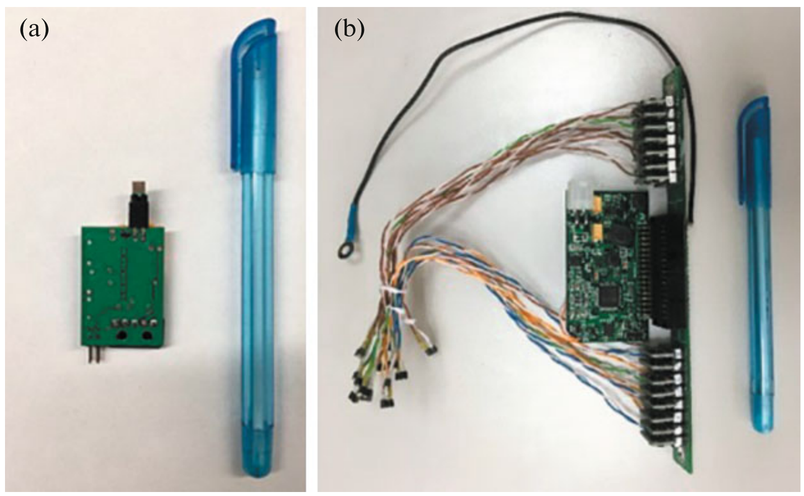

Fig. 2. Schematic view of the electronics: with the ToT function (a) and of DANSS experiment (b).

sists of constant (38/52/67 V) and adjustable parts for each channel (in the range from 0 to +10 V).

Front-End Electronics of the DANSS Experiment

Another candidate for a detector prototype was the electronics produced by the ITEP group (Fig. 2b). This electronics is used, for example, for the DANSS experiment [2] and has a multichannel platform created from several printed circuit boards. The first board provides power and communication with a PC via RS-232 and is connected via IDC34 to a common board, on which 15 front-end electronics boards are installed. The power is produced in a wider range and consists of constant (10–65 V) and adjustable (±10 V) bias voltages for each channel. Each 1.7×1.9-cm^2 board contains a bias voltage output for SiPM and a signal input. The signal passes through the amplifier and is then output through the IDC34 connector to the readout electronics.

Scintillation Detector Prototype

The initial version of the detector prototype includes a 40-cm plastic scintillator and ten channels of electronics (Fig. 1b). The scintillator is wrapped in a Mylar to increase the light collection. In the Mylar on the upper face of the scintillator, there are holes for studies related to the position of the source of calibrated light pulses (LED): at the center; with a 5-cm step in both directions; and a few extra holes on each side. Along the lateral face, there is the same type of electronics with SiPM in the holes: at the center and with a 10-cm step in both directions. One channel of each version of the electronics was located at the ends of the scintillator. In the case of electronics with the ToT function, the third version of the boards was used. This version features comparator stability and an extended operating range.

Test Equipment

The electronics (Fig. 1a) and the detector prototype were tested in a the light shielding box, where the

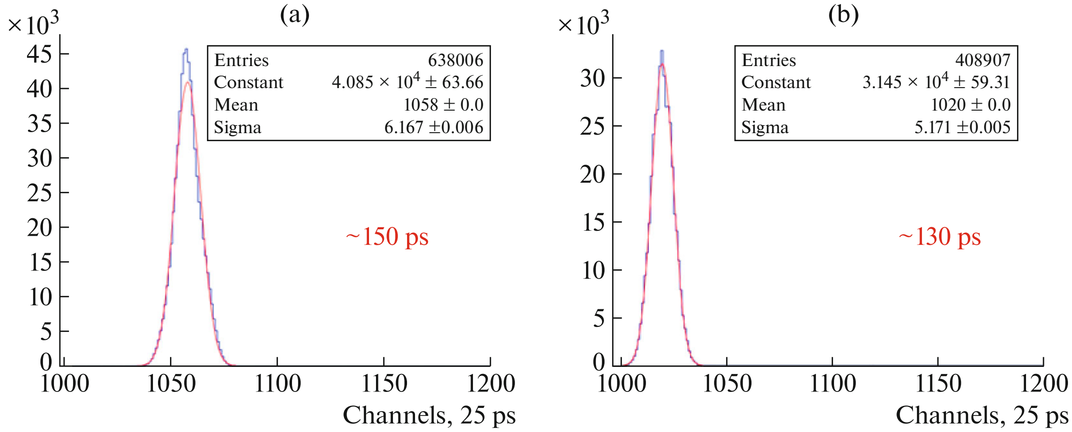

Fig. 3. Histogram of $T_{SiPM1}-T_{SiPM2}$ after correction for tests of the electronics with the ToT function in the case of no scintillator (a) and the presence of a scintillator (b).

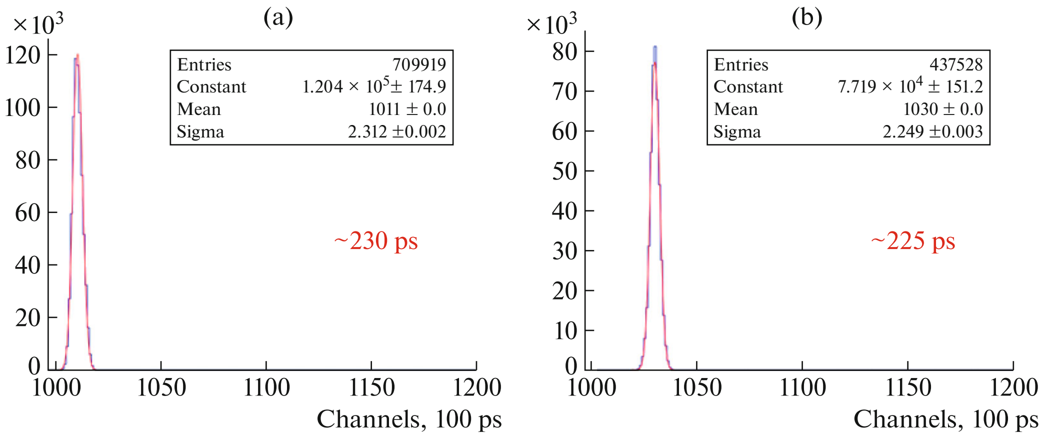

Fig. 4. Histogram of $T_{SiPM1}-T_{SiPM2}$ after correction for tests of the electronics of the DANSS experiment in the case of: no scintillator (a) and the presence of a scintillator (b).

temperature during measurements was 27.1 ± 0.4°C. An LED in the form of a separate board with a clock pulse from the LEMO output was used as a light source [3]. This sync pulse was used as a trigger for the VME-based data acquisition system [4]. The system included an FVME-V2.0 controller, TQDC16 and TDC32 digitizing modules, and a TMWR trigger module [5]. The collected data were processed in the ROOT software package.

TEST RESULTS

The SiPM response from a light source with two types of electronics was studied in the presence and absence of a scintillator. Histograms of the time difference at various LED amplitudes were obtained and analyzed.

Earlier, when testing the first version of electronics with the ToT function [6], it was found that the signal in the region of small amplitudes arrives later in time. This is due to the signal delay often called the "time-walking" effect. This effect occurs because of the difference in time when a photon or charged particle passes through the detecting element and the time when the electronics registers this signal. This results in worse time resolution. In this regard, a method for correcting time spectra described in [7] was proposed.

The proposed correction is relevant when comparing time spectra in the presence and absence of a scintillator. Figures 3 and 4 show the histograms of the difference $T_{SiPM1}-T_{SiPM2}$ in the arrival times of the signals for the end channels of the electronics after applying the correction. The histograms were fitted with a Gaussian function, and the time resolution was determined as the sigma (σ) parameter of the Gaussian function. As can be seen in the figures, the temporal resolution is almost unchanged in the presence or absence of plastic scintillator for the two types of front-end electronics.

When comparing the front-end electronics with the ToT function and the DANSS experiment, the time resolution was approximately 130 and 225 ps, respectively.

CONCLUSIONS

The second version of the front-end electronics with the ToT function was developed.

We tested the front-end electronics with the ToT function and the electronics of the DANSS experiment with Hamamatsu (S12572-010P) SiPM readout.

A scintillation detector prototype was tested. The difference in time resolution was ~40%.

The proposed prototype is an important part for the development of the BBC subsystem. Given the suboptimality of SiPMs used for accurate timing measurements, the result is promising.

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CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

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