ISSN 1547-4771, Physics of Particles and Nuclei Letters, 2026, Vol. 23, No. 5, pp. 645–648. © Pleiades Publishing, Ltd., 2026.

PHYSICS AND TECHNIQUE OF ACCELERATORS

Study of the Characteristics of the BBC Detector Prototype

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Received December 5, 2025; revised March 20, 2026; accepted April 20, 2026

Abstract—One of the subsystems of the SPD experiment (phase I) is the Beam Counter (BBC), designed as high-granularity scintillation detector with a segmented structure of ~800 channels. To ensure its reliability, a quick tool to check entire optoelectronic path is needed. We present an optical diagnostic method alternative to the use of ionizing radiation sources. The method, which is based on the use of side-glow fiber (SGF), allows for channel-by-channel testing. Results of research on the choice of interface configuration, optimization of light collection using reflective substrates, and testing of a multichannel optical cable prototype are presented. The developed approach is recommended for use in the BBC subsystem.

DOI: 10.1134/S1547477126700639

INTRODUCTION

The BBC beam counter in the SPD experiment is a complex system, where each of its ~800 channels includes a scintillator plate with a wavelength-shifting fiber (WLS), optical connections, photosensors (SiPM), and readout electronics. The operability of such a detector to be ensured requires effective methods of acceptance control and diagnostics of the state of each element of the path [1–2].

In this study, a method has been developed and tested that allows for such diagnostics to be carried out without the use of ionizing radiation. It is based on the use of side glow fiber (SGF) and a stable light-emitting diode (LED) source to simulate the illumination of scintillator elements. Presented below are the results of experiments on selecting the optimal fiber coupling, optimizing light collection, and testing a prototype multi-channel optical cable.

DESCRIPTION OF THE METHOD

The method is based on the use of SGF with an MMA core and a Teflon shell. Breakdown of total internal reflection in SGF ensures uniform light scattering along its length. This allows the light from the LED propagating along the SGF to effectively illuminate the WLS fibers at their interfaces.

The method solves two main problems:

(1) Rapidly diagnose channels with abnormally low response to identify defects (connectors, fibers, SiPMs or read channels).

(2) Check the linearity of the response of the entire electronic circuit with SiPM by varying the LED intensity.

A promising direction is the use of this method for diagnosing collected sectors, which requires separate research.

EXPERIMENTAL STAND AND EQUIPMENT

The tests were carried out on a light-protected stand assembled for the study of:

(I) methods of coupling SGF with WLS; and (II) prototype of an optical cable based on transparent Kuraray fiber.

A single scintillator plate with a glued-in WLS BCF92S (emission peak 492 nm, Saint-Gobain Crystals) corresponding to the “phase 0” configuration was used as the base sample. The WLS was connected to the Onsemi SiPM (SensL) via the DT5202 primary electronics module (CAEN FERS-5200 system) [3].

For illumination, SOF solid type SGF fibers (wavelength range 350–780 nm) were used. SGF-2 and SGF-3 with diameters of 2 and 3mm, respectively, were employed. Each 250-cm fiber section was alternately rigidly connected to the LED (wavelength 470 nm).

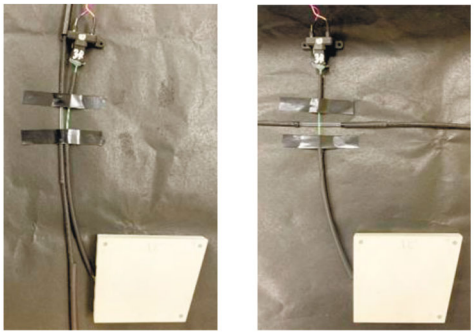


Fig. 1. Methods of coupling WLS with SGF-2: (left panel) parallel, (right panel) perpendicular.

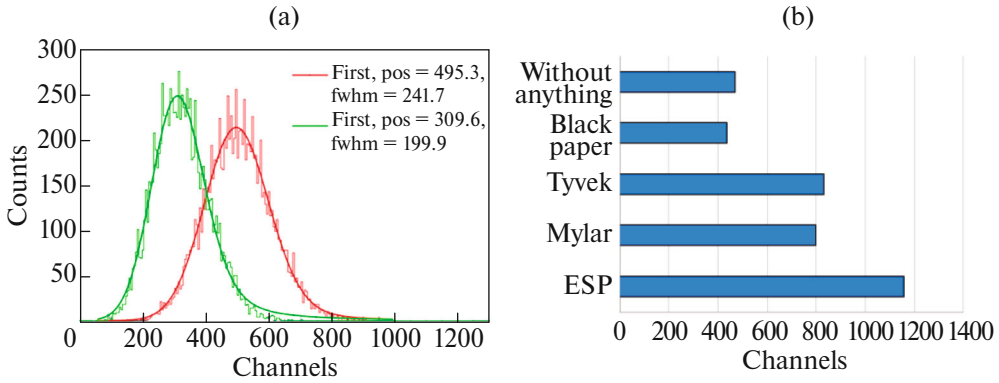


Fig. 2. Signal amplitudes for various coupling methods (left panel). Comparison of reflective substrates (right panel).

The trigger signal from the LED was used for DT5202. Data was collected using the DAQ "Janus" provided by CAEN. The data obtained were processed using the FersRun framework [3].

EVALUATION OF THE EFFICIENCY OF SGF CONJUGATION METHODS

Two methods of coupling WLS with SGF-2 were examined (Fig. 1 left, right panel):

- Parallel: The WLS was located along the SGF-2 at a fixed distance (~0.5 m) from the LED. Working area is 10 mm.
- Perpendicular: The WLS was located across SGF-2. The working area of each fiber is 10 mm.

For each method, a series of measurements of the output signal amplitude were carried out from the same SiPM (SMTPA FC-10035). The results (Fig. 2, left panel) show a difference in peak positions of 40% on average. From the point of view of simplicity and technological efficiency of installation, the perpendicular method is preferable. In this regard, optimization of light collection is required to improve detection efficiency.

OPTIMIZING EFFICIENCY

To optimize light collection, the SGF-3 in combination with reflective substrates (Tyvek, Mylar, ESR [4], 50 × 50 mm) and a control substrate made of black paper was investigated. The substrates were placed one by one on the fibers for comparative analysis.

The transition from SGF-2 (∅2 mm) to SGF-3 (∅3 mm) increases the signal amplitude (Fig. 2, left, right panels). The average SGF-3/SGF-2 light yield ratio was 1.50 ± 0.09, yielding an increase of ~50%.

The influence of reflective substrates on light output has also been confirmed experimentally. Tyvek and Mylar substrates exhibit comparable performance, increasing the signal on average by a factor of 2 compared to the control measurement. Moreover, the ESR substrate showed an advantage of 25–30% compared to Tyvek and Mylar.

TESTING A PROTOTYPE OPTICAL CABLE

Testing was carried out on a sample with a perpendicular coupling of WLS and SGF-3 without reflective substrates (Fig. 3) in combination with a prototype optical cable. Measurements were conducted on chan-

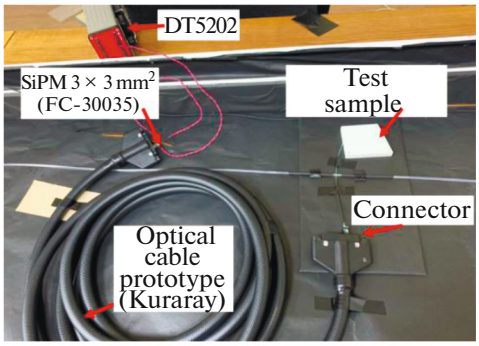


Fig. 3. Optical cable prototype testing scheme.

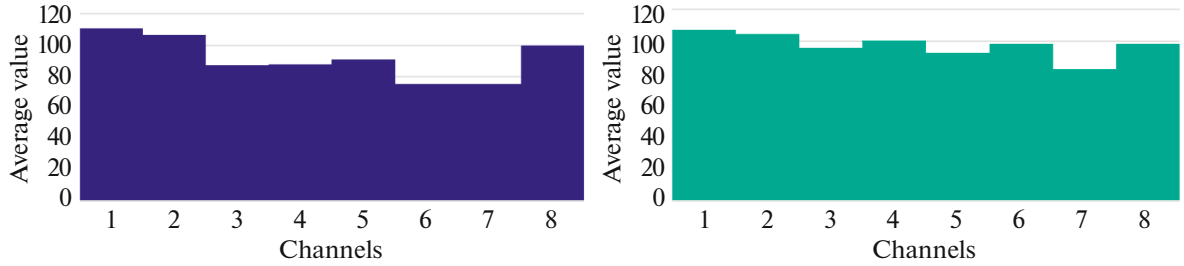


Fig. 4. Results of testing optical cable before (left panel) and after (right panel) connector adjustments.

nels (1–8) with alternating switching at both ends of the cable. On the sample side, a centering connector was used, and on the opposite side, a developed connector with SiPM 3 × 3 mm (FC-30035) was employed to ensure identical switching conditions.

The results of channel-by-channel measurements before (Fig. 4; left panel) and after (Fig. 4; right panel) the connector adjustment are shown. For channels 3–6, an increase in the average peak amplitude is observed. A constant signal on channel 7 may indicate a possible defect in the transparent fiber.

CONCLUSIONS

An optical method for elementwise diagnostics of optoelectronic channels without the use of ionizing radiation has been developed and successfully tested.

The choice of perpendicular fiber coupling was experimentally substantiated, and the configuration was optimized for maximum light collection: using SGF-3 with a diameter of 3 mm instead of 2 mm increases the signal by ~50%, and the reflective ESR substrate provides a total gain of more than 3.5.

The method has proven its effectiveness in detecting defects using channel-by-channel testing of an eight-channel optical cable based on transparent Kuraray fiber. A potential defect in one of the fibers was identified and localized, and the effectiveness of the connector adjustment for other channels was confirmed. Overall, the nature of the signal indicates the need to improve the connector end-face processing procedure. The obtained results allow this approach to be recommended for acceptance control and monitoring of the state of the BBC detector channels.

FUNDING

This work was supported by ongoing institutional funding. No additional grants to carry out or direct this particular research were obtained.

CONFLICT OF INTEREST

The authors of this work declare that they have no conflicts of interest.

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