DEVELOPMENT OF A NEW BEAM POSITION DETECTOR FOR NA61/SHINE EXPERIMENT*

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New beam position monitors were developed for the NA61/SHINE experiment. Detectors are based on the single-sided silicon strip detector produced by Hamamatsu (S13804). The detector's readout allows for saving waveform for each strip, and it is based on DRS4 chips. The main goals required from the designed detectors are: they should work efficiently with proton and lead beams with beam intensity on the level of 100 kHz, the detectors' material on the beamline should be minimized, the detectors should be able to determine the position of X and Y hit of each beam particle with maximum possible accuracy. In this contribution, detector design and construction will be presented. The developed procedure of the signal and position reconstruction will also be shown. Finally, detector performance during measurement will be discussed.

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1. Introduction

NA61/SHINE is a fixed-target experiment located in the North Area of the CERN Super Proton Synchrotron (SPS) [1]. Developing a new Beam Position Detector (BPD) was part of the upgrade of the detection system of the experiment during Long Shutdown 2.

NA61/SHINE detector system includes the 8 Time Projection Chambers (TPCs), Time of Flight detectors (ToF), and Vertex Detector (VD) downstream of the target. The system's primary goal is to measure the particles produced in the interaction of the beam particles with the target. The schematic layout of the detector system is shown in Fig. 1. Additionally, upstream of the target there is located a set of beam detectors that provide the identification, timing references, and beam position measurements. The layout of the beam detectors is shown in Fig. 2.

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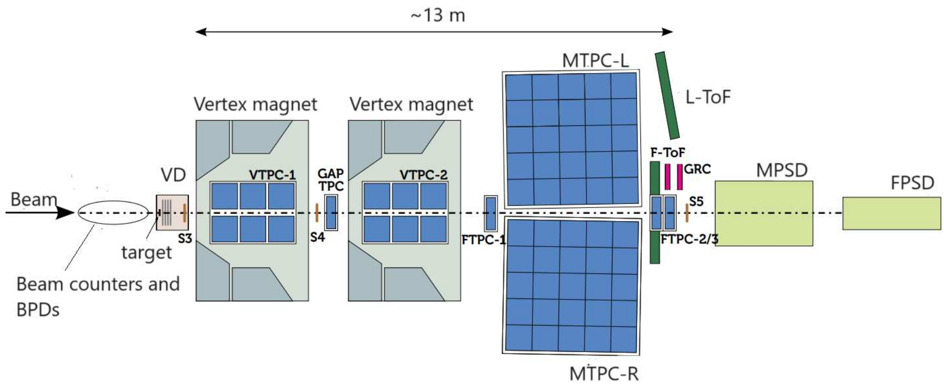

Fig. 1. Schematic layout of the NA61/SHINE experiment after the LS2 upgrade.

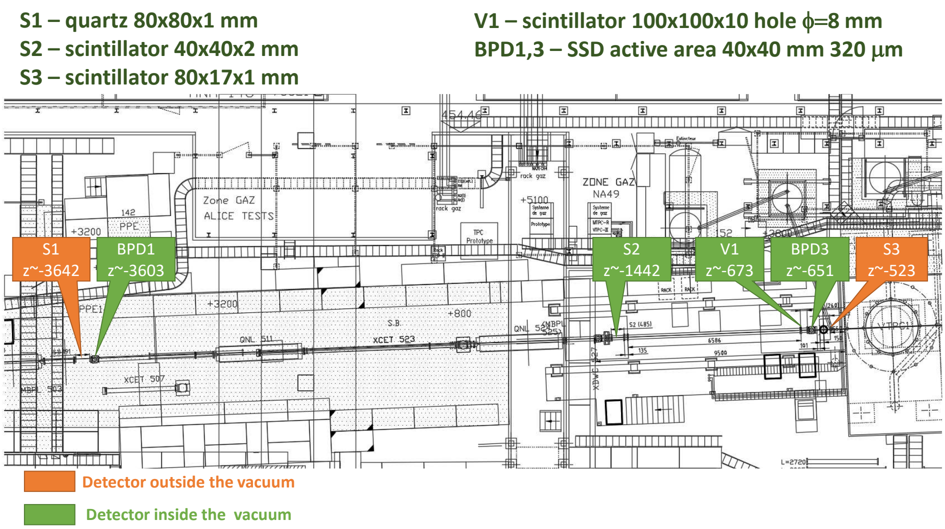

Fig. 2. Schematic layout of the beam detectors located upstream of the target along the beam line.

Beam position detectors (BPD) are used to calculate the trajectory of the incoming beam particle based on its measurement in X and Y planes along the beamline. The new beam position detectors should allow for the measurement of the trajectory of each proton or lead beam particle separately with intensities on the level of 100 kHz with maximum possible accuracy. Additionally, the detector should operate in a vacuum. New beam position detectors based on single-sided silicon strip matrices (SSD) have been manufactured, tested, and successfully used during two measurement campaigns with lead ion beams.

2. Silicon strip detector

The new beam position detector is based on the Hamamatsu S13804 Silicon Strip Matrix [2]. It is a silicon wafer with p–n junctions arranged in a stripe formation. The active area is 97×97 mm^2 in size and 320 μm in thickness. The detector has 1024 stripes arranged in two rows. The pitch between the strips is 190 μm.

Two detectors are placed in the 6-way vacuum fitting in the final design. One determines the position in the X-plane, and the other, rotated by 90°, determines the position in the Y-plane. The distance in Z-direction between the two planes is 5 cm. The schematic layout of the detector placed in the vacuum fitting and the photo of the detector are shown in Fig. 3. Detectors are placed on aluminum plates, which stabilize them and ensure they are in the correct position for the beam. The signal is extracted through ISO-K vacuum flanges with two high-density vacuum feedthrough connectors connected to the detectors by flexible PCB.

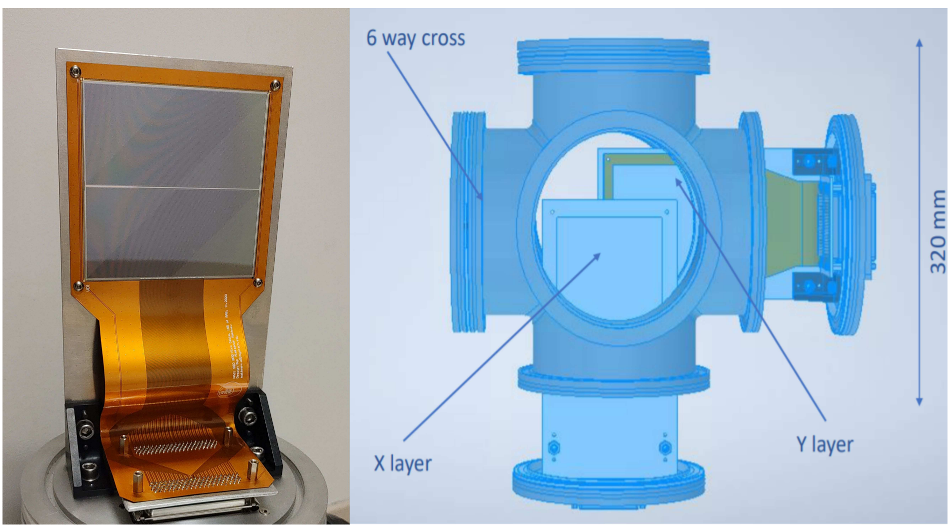

Fig. 3. Silicon strip detector in 6-way vacuum fitting.

A dedicated read-out hardware has been manufactured for the detector. It consists of charge-sensitive amplifiers, intermediate amplifiers, and read-out buffers. The charge-sensitive amplifier is mounted directly on the vacuum cross. Its differential output signal is transmitted to the buffer through HDMI cables and an intermediate amplifier, which is an interface for the linear input of the buffer (DRS4 chip). A DRS4 chip converts the analog signal to digital data. It was chosen because it has a high sampling speed and allows for saving waveform for each strip.

2.1. Reconstruction of beam position algorithm

Each BPD measures the position of the trigger-selected beam particle in two orthogonal directions independently. During measurements with a lead-ion beam in each strip plane, a charge distribution is induced with a width of about 10 strips.

The reconstruction algorithm first searches for a cluster in each plane. The cluster is defined as a set of adjacent strips with signal amplitudes above a threshold value. Then, an average of the strip positions weighted with the signal amplitudes on the strips is calculated for the cluster to estimate the position of the beam particle (the so-called centroid method). A 3-dimensional point measured by a given BPD is built from two transverse coordinates measured by the two-strip planes and the position of the BPD along the beamline. In order to reconstruct a beam particle track, least squares fit of straight lines is performed to the positions measured by the three BPDs in X–Z, and Y–Z planes independently.

An example of cluster and saturated and unsaturated (red) signal on Silicon Strip Detector induced by 150 A GeV/c lead ion is shown in Fig. 4.

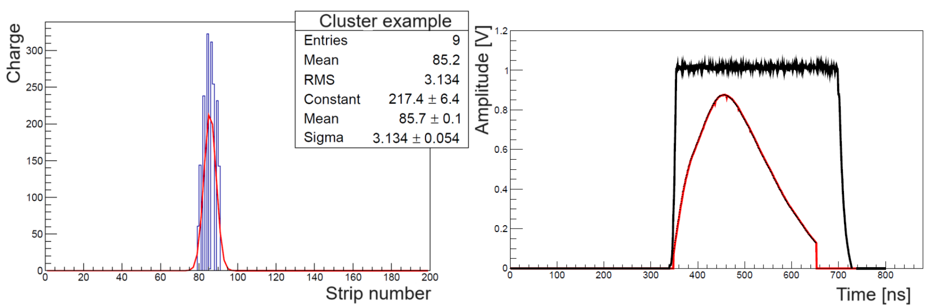

Fig. 4. (Color online) Example of cluster and saturated and unsaturated (red) signal on Silicon Strip Detector induced by 150 A GeV/c lead ion.

2.2. Beam monitoring during measurements

The new beam position detectors were successfully used to monitor beam parameters during two measurement campaigns, both with 150 A GeV/c lead-ion beam. During measurements, the main beam parameters that are monitored are position, width, emittance, and the reconstructed main interaction vertex. All of these measurements are also saved and used during the reconstruction and analysis of the collected data after the measurement campaign is completed. The plots of the beam profiles are presented in Fig. 5. The reconstructed beam tracks in XZ and YZ planes are shown in Fig. 6 and Fig. 7.

After the November measurement campaign, an inspection of the detectors is planned for radiation and mechanical damage. A few missing strips were recorded during the measurements, which may indicate mechanical or radiation damage to the strip.

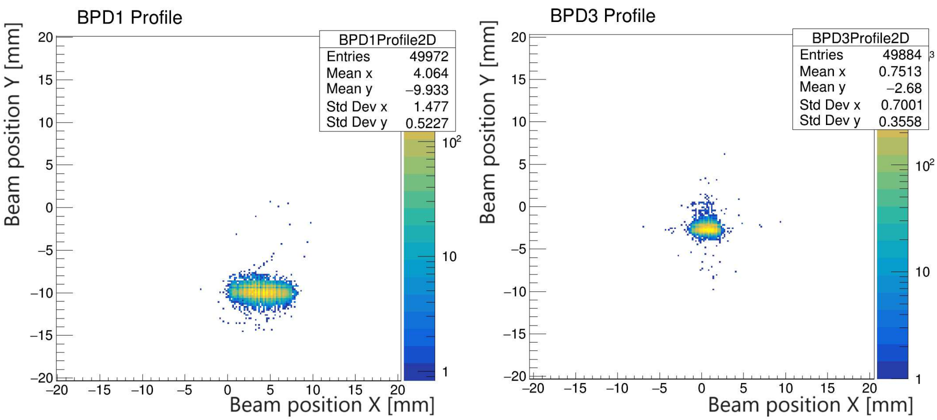

Fig. 5. Histogram of beam position on BPD1 and BPD3.

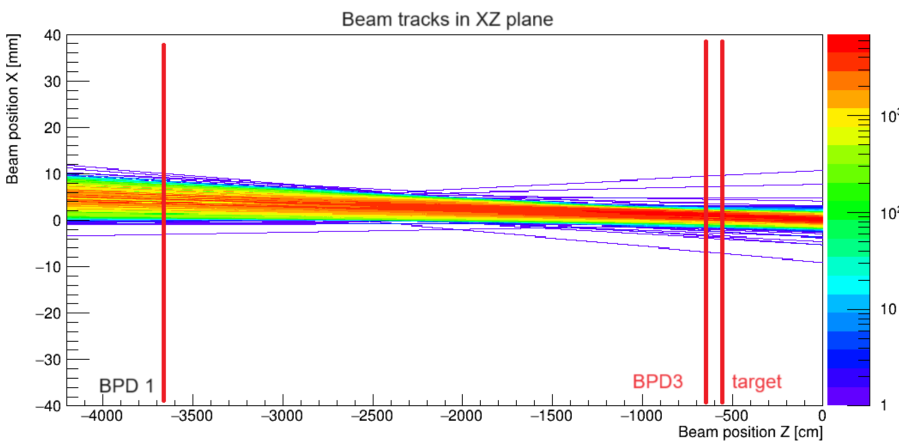

Fig. 6. Reconstructed beam track in XZ plane.

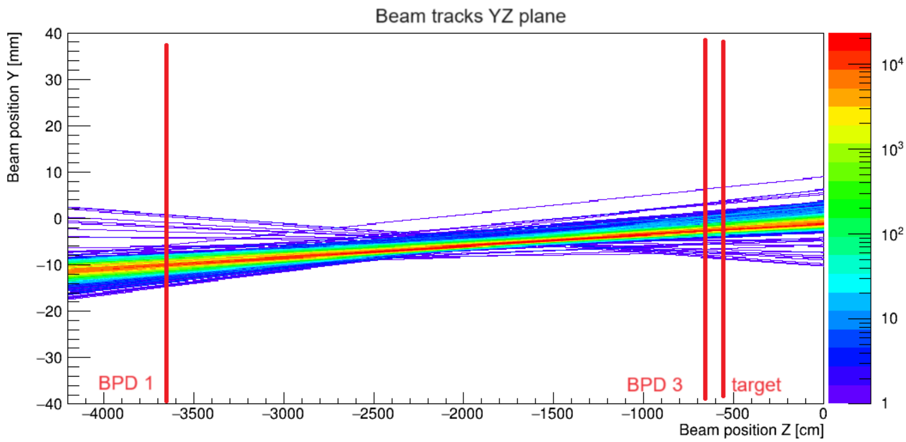

Fig. 7. Reconstructed beam track in YZ plane.

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