Development of Plastic Scintillator Barrel for WASA at GSI

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We plan to conduct new experiments for hypernuclear spectroscopy1) and η'-mesic nuclei exploration2) using the WASA central detector3,4) and the fragment separator (FRS) at GSI. The WASA central detector consists of a superconducting solenoid magnet, a plastic scintillator barrel (PSB), and a cylindrical drift chamber for charged particle measurement and CsI calorimeters for gamma-ray measurement.

We are upgrading the cylindrical part of PSB to achieve 100 ps in time resolution based on the experimental requirement. In the old configuration, we had only one photomultiplier tube with a light guide for each scintillator slat of PSB. We improved the time resolution by detecting photons on both sides using multi-pixel-photon counters (MPPCs). Since the PSB will be located inside the superconducting solenoid magnet, we chose detectors that can be operated under a magnetic field. MPPC satisfies this requirement.

We made a single slat of PSB as schematically shown in Fig. 1. The size of the plastic scintillator is $550 \times 38 \times 8$ mm^3. We adopted Eljen EJ-230, which has an attenuation length of 120 cm. We attached four MPPCs (Hamamatsu Photonics S13360-6050CS) on each side of the plastic scintillator and electrically connected them in series. The effective area of the MPPC is 6×6 mm^2. The MPPCs were then connected to amplifiers developed in Ref. 5). The amplified signals were recorded by a waveform digitizer (CAEN V1742) with a sampling frequency of 2.5 GHz.

In order to evaluate the time resolution, we irradiated the plastic scintillator with electrons from a ^{90}Sr source with an endpoint energy of 2.28 MeV. A slit with a gap of 2 mm was inserted between the plastic scintillator and the ^{90}Sr source. We performed mesurements by changing the position of the source to investigate the hit position dependence. The overvoltage was also changed to 4, 6, and 8 V.

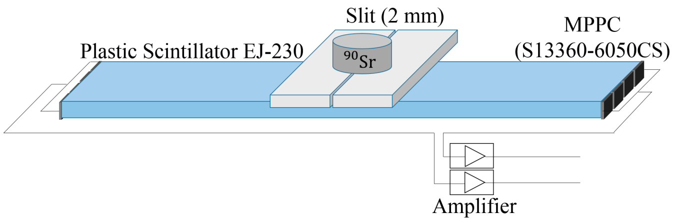

Fig. 1. Schematic configuration of a single slat of PSB.

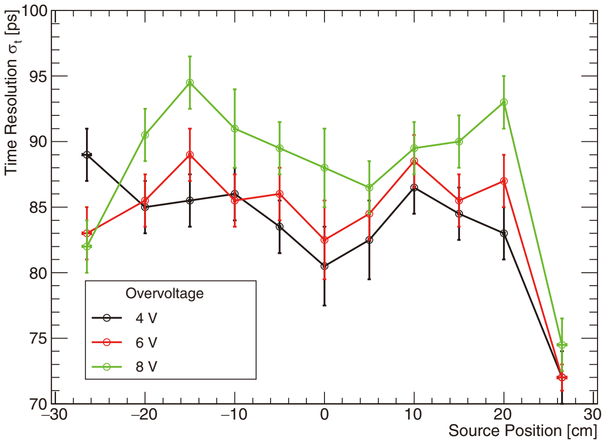

Fig. 2. The dependence of the time resolution σ_t on source positions and applied bias voltages.

We evaluated the time resolution of the plastic scintillator by analyzing the waveform data. In the analysis, we simulated a function of constant fraction discriminators by using a software to obtain the precision arrival time of signals at the right and left ends of the plastic scintillator (T^{R} and T^{L}). The time resolution of this single slat of PSB (σ_t) can be estimated by fitting a $(T^{\mathrm{R}} - T^{\mathrm{L}})/2$ histogram with a Gaussian function and taking its standard deviation, neglecting the hit position distribution of the electrons.

Figure 2 shows the time resolution σ_t as a function of the source positions. Different colors correspond to different bias voltages. We achieved a time resolution better than 100 ps for all the tested conditions. We also found that the time resolutions become better as the overvoltage is decreased.

Based on the measurements described above, we confirmed that a single slat of PSB achieves the required time resoution. We are planning a more systematic evaluation of the PSB performance by using mono-energetic proton beams.

References

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