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Development of the Fast Plastic Scintillation Detector for High-Resolution Velocity β Measurements in a Short Flight Path

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Improving the resolution of particle identification is a crucial challenge in nuclear physics experiments using heavy ion beams. Among the important parameters for particle identification is the particle velocity, which is generally determined by measuring the time of flight (TOF) of charged particles. Enhancing the resolution of TOF measurements can be achieved by either extending the flight path or improving the time resolution of the timing detector. In particular, improving the time resolution allows for a more compact experimental setup, making it applicable to a wide range of nuclear experiments.
In this study, we developed a plastic scintillation counter with excellent time resolution by combining a fast plastic scintillator with newly developed high-speed photomultiplier tubes (PMTs). Recently, HAMAMATSU PHOTONICS K.K. developed a new series of ultra-fast PMTs that place the anode potential near the first dynode. On the other hand, ELIJEN TECHNOLOGY also developed ultra-fast scintillators by adding trace amounts of benzophenone as a quenching agent. We assembled a detector by mounting two of these PMTs on either side of the rectangular ultra-fast scintillator.
We evaluated the performance of the detector using a ^{132}Xe primary beam at 420 AMeV at the HIMAC synchrotron accelerator facility at the National Institutes for Quantum Science and Technology. Measurements were performed by varying parameters such as the scintillator size, the applied high voltage to the PMTs, and the discriminator threshold to determine the optimal conditions. As a result, we achieved a time resolution of approximately $\sigma \sim 5$ ps. In this study, we discuss the final results of the time resolution of the developed fast plastic scintillation detector and how it can be applied to physical experiments.

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