Development of an aerogel Čerenkov counter for the Σp scattering experiment

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We are planning to the Σp scattering experiments in J-PARC (J-PARC E40 experiment). The purpose of this experiment is to measure the differential cross sections of $\Sigma^+ p$ and $\Sigma^- p$ elastic scattering and $\Sigma^- p \to \Lambda n$ inelastic scattering by detecting more than 10,000 scattering events. In $\Sigma^+ p$ channel, we aim to verify a large repulsive core which is expected due to the Pauli repulsive principle in the quark level. In other channels, we aim to investigate the ΣN interaction systematically. In J-PARC E40 experiment, Σ will be generated by $p + \pi^{\pm} \to \Sigma^{\pm} + K^+$ reaction with π beam. To tag Σ generation, π and K^+ are detected with K1.8 beamline spectrometer and KURAMA spectrometer. By the measurement of momentum vector of π and K^+ and kinematic energy and track of scattered p, the Σp scattering event is detected.

Aerogel Čerenkov (AC) counter will be installed in the downstream of the target, to identify scattered π and K^+, a trigger detector to remove scattered π events on online revel. Since using 20 MHz high intensity π beam in this experiment, it is important to suppress the trigger rate by AC counter. This counter is required to have a π detection efficiency of 98 % or more.

I decided the basic design of AC counter. The size of this counter is 480 mm $\times$ 400 mm $\times$ 80 mm and this counter is divided into 4 segments (Room1, Room2, Room3, Room4). Čerenkov light read out with 12 fine mesh Photomultiplier Tubes (PMT). As a radiator, we use a silica aerogel having refractive index of 1.10.The assumed rates in E40 experiment for Room1, Room2, Room3 and Room4 are 300 kHz, 300 kHz, 250 kHz and 40 kHz.

I made two prototype AC counter (diffuse and specular reflection type) to decide detail design and did the test experiment with e^+ beam at Research Center for Electron Photon Science (ELPH) Tohoku University. As result, the prototype of diffuse reflection has high performance (over 20 p.e. and 99.9% efficiency) at low beam rate. However, PMT gain decreased at high beam rate due to the increased current between the dynodes.

I made AC counter for J-PARC E40 experiment and did the test experiment with e^+ beam at ELPH. In order to avoid gain decrease, the voltage applied to the PMT was set low and the signal was amplified by PMT AMP. As a result, the detection efficiency of positrons at a rate of 300 kHz was over 98% when the threshold value was 6 p.e. or less.

The particle detected by AC counter is π. Therefore, I estimated the detection efficiency of π by Monte Carlo simulation with Geant4. As a result, it was estimated that the detection efficiency of π is over 98% when the threshold value is 6 p.e. or less.

Finally, I considered the setting of AC counter in the J-PARC E40 experiment. As a result, it is considered that the optimum PMT gain is 60 ch/p.e. and the threshold is 4 p.e..