Development of a Compact Silica Aerogel Čerenkov Counter

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A compact silica aerogel Čerenkov counter with fine-mesh type photo-multiplier tubes has been developed to reject e^+e^- pair created events at a trigger level. The silica aerogel is covered with a highly reflective material to lead emitted Čerenkov photons into the photo-cathodes. The efficiency of e^+e^- event identification is obtained to be more than 97%.

§1. Introduction

A magnetic spectrometer has been constructed in the 2nd experimental hall at Laboratory of Nuclear Science (LNS) to study photo-production of the K^0 meson [1], $\pi^+\pi^-$ mesons [2], and the Θ^+ baryon [3]. Many electrons and positrons are generated by the electro-magnetic interaction in a target. To keep the data taking efficiency at a realistic level for a high intensity photon beam, it is important to veto e^+e^- events at a trigger level.

An e^+e^- veto counter should be placed just behind the target to response the e^+e^- event efficiently since electrons and positrons are bent inside a space with high magnetic flux density. One of $\pi^+\pi^-$ mesons to which a K^0 meson decays has a momentum of 1 GeV/c at maximum. It is necessary that the refractive index should be 1.01 or less so that 1 GeV/c π mesons can not emit Čerenkov photons. It should consist of low amounts of substance so that the emitted particles are not much influenced with them, due to the energy loss and multiple scattering.

The available space for the counter thickness is limited and is about 50 mm. To construct the counter in a compact size with a few materials, silica aerogel has been selected. Diffuse reflectors have been also selected to let the Čerenkov photons reach a photon detecting device. Fine-mesh type photo-multiplier tubes (PMT) are employed since the magnetic flux density measures 0.4 T near the target. We have selected the PMT with a quartz window, Hamamatsu H8409-70QB , because the most Čerenkov photons have a short wave length.

§2. Aerogel Čerenkov counter

The size of each silica aerogel piece is 132 (H) × 132 (W) × 22 (T) mm^3 and its refractive index is 1.01. Two pieces are stacked to generate Čerenkov photons enough to get a high efficiency of e^+e^- veto. Four PMTs are coupled to the aerogel in such a way that most of the charged particles produced at the target can not go through the PMT materials. The two of them are located on the top of it, and the others are on the bottom. Aerogel pieces are covered with a diffuse reflector to make the emitted Čerenkov photons go into photo-cathodes of PMTs.

We have tested two types of diffuse reflectors. One is a Millipole membrane filter, HAWP00010, with a thickness of 150 μm, a pore size of 0.45 μm, and a porosity of 79%. The other is a GORE-TEX DRP backlight reflector sheet with a thickness of 500 μm. The whole counter is wrapped with a sheet of 150 μm thick black paper [4]. Figure 1 shows the aerogel Čerenkov counter we made.
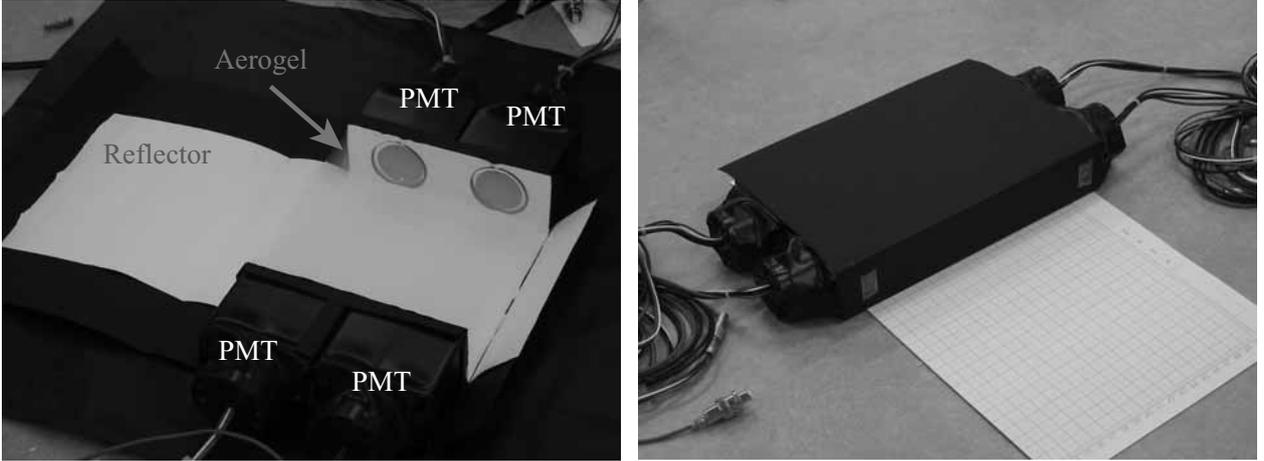

Fig.1. The silica aerogel Čerenkov counter. The left and right panels show the counter before and after assembly, respectively.

§3. Experiment

The detection efficiency for the counter has been measured by using a 457 MeV electron beam [5], at LNS, which is able to produce Čerenkov photons. Two experimental sets, with aerogel and without aerogel, have been performed. The experimental setup is shown in Fig. 2. We have detected small amounts of Čerenkov photons without aerogel because Čerenkov photons are also generated in the air [6]. Another experiment has been carried out with a 80 MeV proton beam at Cyclotron Radio Isotope Center (CYRIC), Tohoku University [7], to confirm no detection of Čerenkov photons due to low energy protons.

We have used two scintillating fiber hodoscopes, x and y, to make a trigger signal, which is a coincidence signal between x and y as

$$(x \text{ fiber OR}) \otimes (y \text{ fiber OR}). \tag{1}$$

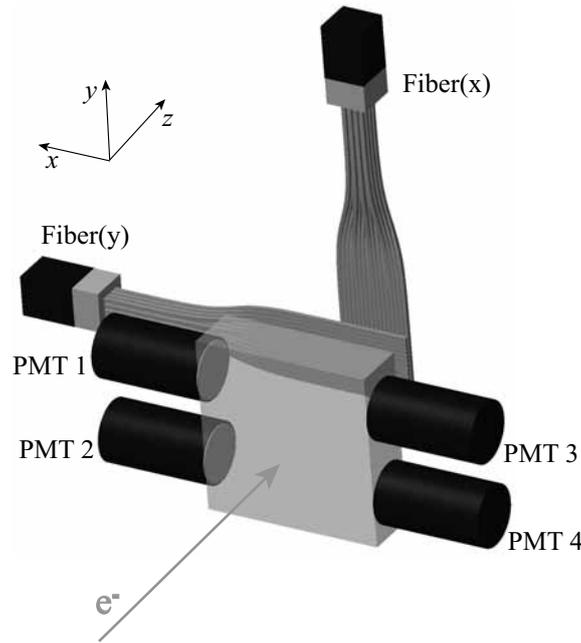The pedestal data have been also taken by a clock trigger.

Fig.2. Experimental setup at LNS. Two scintillating fiber hodoscopes are used for a trigger counter. The silica aerogel Čerenkov counter is located in front of the two hodoscopes.

§4. Data analysis

ADC data of four PMTs have been obtained under every experimental setup. Figure 3 shows ADC distributions for electrons with a GORE-TEX sheet where aerogel is placed in the counter.
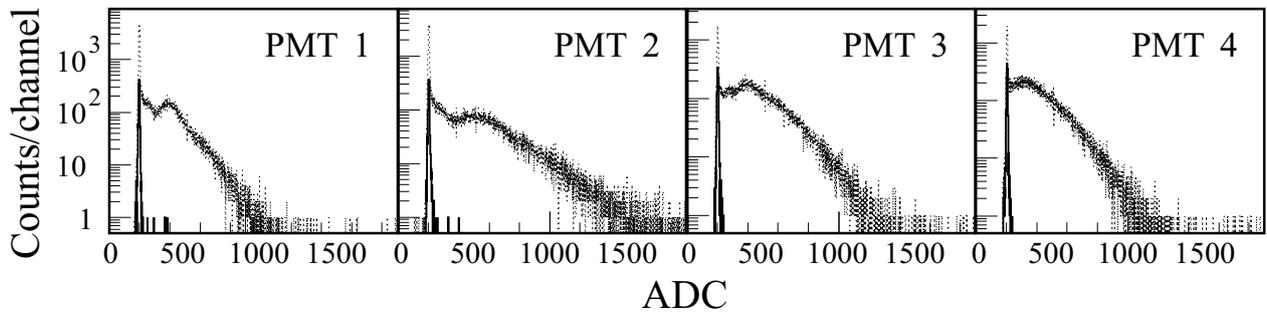

Fig.3. ADC distributions for electrons with a GORE-TEX sheet where aerogel is placed in the counter. The dotted histograms show ADC distributions with the fiber trigger, and the solid histograms below 300 show the distributions with the clock trigger.

Each peak of pedestals corresponding to solid histograms has been fitted by a gauss function. The peak value μ and standard deviation σ of the fitting function have been determined. Two counting ratios are defined as

$$R_1 = \frac{N_{\mathrm{ADC}>\mu+3\sigma}}{N_{\mathrm{Trig}}} \times 100, \text{ and} \tag{2}$$

$$R_2 = \frac{N^{\mathrm{multi}}_{\mathrm{ADC}>\mu+3\sigma}}{N_{\mathrm{Trig}}} \times 100. \tag{3}$$

N_{Trig} is the total number of taken events. $N_{\mathrm{ADC}>\mu+3\sigma}$ or $N^{\mathrm{multi}}_{\mathrm{ADC}>\mu+3\sigma}$ is the number of events of which

"one" or "more than one" ADC value exceeds $\mu + 3\sigma$. In Table 1, the counting ratios R_1 and R_2 are summarized.

Table 1. The counting ratio R_1 and R_2 for the electron and proton beams.

		for electrons		for protons	
		Millipole filter	GORE-TEX sheet	Millipole filter	GORE-TEX sheet
R_1	w/ aerogel	97.9±0.3	99.1±0.3	13.0±0.1	—
	w/o aerogel	30.9±0.2	74.5±0.2	15.5±0.1	—
R_2	w/ aerogel	82.6±0.3	90.7±0.3	0.7±0.0	—
	w/o aerogel	4.4±0.1	33.0±0.1	1.0±0.0	—

The ratio R_2 with aerogel and the Millipole filter gives the lowest efficiency 0.7% for the proton beam, and 82.6% for the electron beam. In the planned experiments, e^+e^- pairs pass through the Čerenkov counter even in the magnetic field, since it is placed just downstream of the target. Therefore the e^+e^- detection efficiency would be about 97% for the counter with the Millipole filter and 99% with the GORE-TEX sheet. The determination method R_2, in which multiple response events are used, is suitable for rejecting e^+e^- events without rejecting proton events.

§5. Conclusion

The detection efficiency for one electron is 82.3% for the counter with the Millipole filter and 90.7% with the GORE-TEX sheet. The fraction of which protons are mistaken for electrons is 0.7% with the Millipole filter. The efficiency for e^+e^- events would be 97% with the Millipole filter and 99% with the GORE-TEX sheet.

Acknowledgments

References

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