SILICA AEROGEL ČERENKOV COUNTER IN A MISSING-MASS EXPERIMENT

$K^-d \rightarrow K^+ + X$ AT 1.4 GeV/c

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ABSTRACT

Two Čerenkov counters, $\check{C}_0$ and $\check{C}_1$, are being used in an experiment to search for dibaryon candidates in the reaction $K^-d \rightarrow K^+ + X$ at 1.4 GeV/c. They have useful cross-sections of $10 \times 8 \text{ cm}^2$ and $30 \times 15 \text{ cm}^2$, respectively. Each counter is a diffusing box surrounding the aerogel sample and seen by two photomultipliers. The mean number of photoelectrons collected is equal to 17 in $\check{C}_0$ and 21 in $\check{C}_1$ for $\beta = 1$ incident particles. Below threshold, the residual scintillation corresponds to 0.12 photoelectron. The role of each counter in the trigger logic for the $K^-d \rightarrow K^+ + X$ experiment is carefully studied.

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1. INTRODUCTION

We have decided to use two silica aerogel Čerenkov counters, $\check{C}_0$ and $\check{C}_1$, in an experiment to search for dibaryon candidates in the reaction $K^-d \rightarrow K^+ + X$ at 1.4 GeV/c. This experiment is taking data at the CERN Proton Synchrotron (PS 159).

The $\check{C}_0$ counter selects the kaons in the beam by rejecting the pions. The $\check{C}_1$ counter, installed after the target, rejects the pions above 400 MeV/c with a very good efficiency and identifies the kaons below 1100 MeV/c.

These counters considerably reduce the spurious trigger rate given by the fast logic and therefore enrich the $K^-d \rightarrow K^+ + X$ sample on the on-line tape. The off-line time-of-flight analysis of the incident and scattered particles gives a full identification of the reaction.

2. DESCRIPTION OF THE COUNTERS

Counters $\check{C}_0$ and $\check{C}_1$ are two diffusing boxes partially filled with silica aerogel; they are each viewed by two photomultipliers.

The box of counter $\check{C}_0$ has a volume of $10 \times 8 \times 8 \text{ cm}^3$. It is coated with two layers of millipore*), and is viewed by two XP 2020 photomultipliers with a photocathode diameter of 44 mm. The box contains three aerogel blocks with a measured optical index $n = 1.05$. The radiation thickness along the beam axis is 7.5 cm.

The box of counter $\check{C}_1$ has a volume of $30 \times 15 \times 15 \text{ cm}^3$. It is also coated with millipore, and is viewed by two XP 2041 photomultipliers with a photocathode diameter of 110 mm. It is filled along the beam axis with 12 aerogel blocks of refractive index $n = 1.094$, and around these there are 12 blocks with $n = 1.06$. The particles normal to the counter cross 9 cm of aerogel.

The photomultipliers for both of these boxes are each coupled to a separate cylindrical light-guide made of aluminized glass. The length of each light-guide is equal to the photocathode diameter; their transmission is of the order of 50%.

*) Filter paper from Millipore S.A., Malakoff (92), France.

3. THE AEROGEL BLOCKS

The blocks were made at CEN-Saclay (DPhPE-STIPE), where the aerogel Čerenkov counters have previously been studied¹⁾.

Careful investigations were carried out to improve the optical quality of the manufactured blocks. It was found that optical transmission is improved by heating the block in an oxygen atmosphere at 450 °C for at least 48 hours. This treatment reduces the weight of the aerogel by about 5%, since volatile products are evacuated but the volume remains constant. As the index is proportional to the density ($n - 1 = 0.23 d$), it is also smaller after treatment. The light transmitted through a sample of thickness x is equal to $\exp(-\mu x)$, where μ is the transmission coefficient. The transmission coefficients before and after treatment are shown in table 1. These values are the mean values from measurements done on 10 aerogel blocks with a spectrophotometer. At 350 nm, the transmission of a 2 cm aerogel sample varies from 3.5% to 8.5% after treatment.

Refractive indices have been measured with the prism method at the wavelength of the He-Ne laser beam. The indices of the blocks contained in $\check{C}_0$ and $\check{C}_1$ are shown in table 2.

As it is impossible to obtain aerogel blocks directly with indices greater than 1.06, the blocks with a mean measured index 1.094 are obtained by very carefully baking in air, at a temperature of about 900 °C, those blocks with index 1.06. At this temperature we get blocks with greater density as their volume decreases. The measurement of indices by the prism method is not very accurate because of the surface imperfections, giving a higher Δn value for this set of blocks ($n = 1.094$, see table 2).

4. USE OF THE AEROGEL COUNTERS IN $K^-d \rightarrow K^+ + X$ EXPERIMENT

The aim of the experiment is to measure the missing mass X to K^+ in the reaction $K^-d \rightarrow K^+ + X$ at 1.4 GeV/c. The incident beam is a separated kaon beam with about 15% kaons. It contains about 18,000 K^- per burst with a momentum dispersion $\Delta p/p = \pm 2.5\%$, and is defined by the scintillation counters S_1 and S_2 .

A spectrometer, consisting of a magnet and multiwire proportional chambers, is installed after the deuterium target (fig. 1). After the last wire chamber, there are the hodoscope H consisting of 9 scintillation counters, and the water Čerenkov counter $\check{C}_2$, which is a diffusing box viewed by 14 photomultipliers XP 2041.

Counters $\check{C}_0$ and $\check{C}_1$ are shown in fig. 2. The central region of $\check{C}_1$ (R_1) on the incident beam axis contains aerogel blocks with index 1.094, and the surrounding aerogel blocks have index 1.06 (R_2).

The purpose of the Čerenkov counters $\check{C}_1$ and $\check{C}_2$ is to reduce the number of triggers defined by the coincidence $T = S_1 S_2 \check{C}_0 H$. The major part of this trigger rate is due to pions below 1 GeV/c, protons below 1.6 GeV/c scattered off the target, and also pions from the beam K^- decays ($K^- \rightarrow \pi^+ \pi^- \pi^-$) after the Čerenkov counter $\check{C}_1$.

Protons below 1.08 GeV/c are rejected by the coincidence of the $\check{C}_2$ signals with the trigger signal T.

The pions are rejected by the anticoincidence of $\check{C}_1$ in the central region (R_1) below 320 MeV/c and in the surrounding regions (R_2) below 400 MeV/c.

The special purpose of the central region of counter $\check{C}_1$ with index 1.094 (table 2) is to reject the incident kaons at 1.4 GeV/c which have not interacted in the target. The triggers due to the following kaon decays in the spectrometer are then reduced by a factor of 10.

The number of triggers defined by $T\check{C}_2$ equals 120 per burst and by $T\check{C}_2\check{C}_1$ only 16 per burst. An on-line analysis of these events on a NORD-10 computer reduces the number of events, which are being written on tape at a rate of 0.8 per burst. The rejected events are mainly spurious events and protons with momentum greater than 1.08 GeV/c coming from the reaction $K^- d \rightarrow p X n_s$ with a spectator neutron.

In the off-line analysis, the kaons are well separated from the pions and protons in the spectrum of the particle masses calculated from the momentum through the spectrometer and the time of flight between the counter S_2 and the counters of the hodoscope H.

5. MEASUREMENT OF THE EFFICIENCY OF COUNTERS $\check{C}_0$ AND $\check{C}_1$

To evaluate the counter efficiency, we have measured the amplitude spectra of the signals from each photomultiplier of $\check{C}_0$ and $\check{C}_1$.

The beam particles crossing $\check{C}_0$ and $\check{C}_1$, defined by the $S_1 S_2 H_1$ coincidence, are identified as pions or kaons by the time-of-flight measurements between S_1 and S_2 and also between S_2 and H_1 . The NORD-10 computer rejects the particles whose trajectory is not a straight line through the five wire chambers CH_{12} , CH_{14} , CH_1 , CH_2 , CH_4 .

The normalization of the spectrum of one photoelectron is made with a light diode and a diaphragm which gives the correct light flux. When the detection efficiency of each light pulse emitted by the diode is smaller than 10%, the amplitude spectrum is the one-photoelectron amplitude.

The amplitude spectra relative to a given mean number of photoelectrons are calculated with a Monte Carlo program from the one-photoelectron spectrum, and are compared with the measured spectrum. There is a good agreement between the measured and the calculated spectra, as shown in figs. 3 and 4.

Table 3 is a summary of the measurements done with incident pions of 1.4 GeV/c. These results show that the efficiency of counters $\check{C}_0$ and $\check{C}_1$ for $\beta = 1$ particles is very good.

The spectrum of 1.4 GeV/c kaons in counter $\check{C}_0$ is a one-photoelectron spectrum (table 2) and corresponds to a mean number of photoelectrons equal to 0.06. In order not to lose incident kaons, it is possible to increase the detection efficiency of the kaons by increasing the discriminator level of the logical channels of the two photomultipliers of $\check{C}_0$ ($\check{C}_0$ is in anticoincidence). Then the number of pions accepted by the trigger is bigger, but they are easily rejected in the off-line analysis with the time-of-flight measurement between S_1 and S_2 .

We have measured the efficiency of the $\check{C}_1$ central region (R_1) for the pions and the kaons as a function of the momentum. When we apply the same method described above, we obtain the collected mean number of photoelectrons. The results are shown in table 4 for kaons and in table 5 for pions.

In order to reduce the loss of the good K^+ events between 0.4 and 1.1 GeV/c ($\check{C}_1$ in anticoincidence), one could also (as is done for $\check{C}_0$) increase the discriminator level of the two logical channels of the two $\check{C}_1$ photomultipliers. In this case, the efficiency for the 1.4 GeV/c incident kaons decreases rapidly since their momentum is not too far from the Čerenkov threshold in R_1 (1.12 GeV/c in table 2). The number of triggers due to the incident kaons decaying into three pions after $\check{C}_1$ would be unacceptable. The best solution is to work with a discriminator level at minimum, in order to obtain the best ratio between the K^+ and the pions detected in the spectrometer.

6. CONCLUSIONS

The use of the two silica aerogel counters in the missing-mass experiment $K^-d \rightarrow K^+ + X$ at 1.4 GeV/c is very efficient for reducing the trigger rate at the fast logic level. We obtain 16 triggers per burst, and this is low enough to permit the use of a sophisticated on-line data reduction program.

These two counters have been working for one year without any problem. The material has been produced at CEN-Saclay (DPhPE-STIPE), where efforts are continuing to be made to obtain blocks with indices between 1.025 and 1.06 which have a good transmission at 350 nm, and to produce aerogel with indices between 1.06 and 1.15 by baking, in air, blocks with index 1.06.

REFERENCE

- 1) M. Bourdinaud, J.B. Chèze and J.C. Thevenin, Nucl. Instrum. Methods 136 (1976) 99.

Table 1

Measurements of μ_1 and μ_2 ;
 μ_1 is the transmission coefficient before treatment,
and μ_2 is the same coefficient after the O_2 treatment.

λ (nm)	μ_1 (cm^{-1})	μ_2 (cm^{-1})
700	0.11	0.09
600	0.19	0.15
500	0.37	0.29
400	0.95	0.71
350	1.66	1.23
300	3	2.25

Table 2

n is the mean refractive index of the blocks used in the experiment. The index of each block is between the two limits $n \pm \Delta n$.
 P_π , P_K , P_p are the thresholds for π , K, p, respectively.

n	Δn	P_π (GeV/c)	P_K (GeV/c)	P_p (GeV/c)
1.05	0.003	0.44	1.54	2.93
1.06	0.003	0.40	1.40	2.67
1.094	0.010	0.32	1.12	2.13

Table 3

N and N' are the mean number of photoelectrons collected by the two photomultipliers of $\check{C}_0$ and $\check{C}_1$. The incident particles are 1.4 GeV/c pions.

	$\check{C}_0$	$\check{C}_1$
N	9.4	12.8
N'	7.6	9

Table 4

The mean number of photoelectrons collected by the two photomultipliers of $\check{C}_1$ for different kaon momenta p_K

p_K (GeV/c)	0.8	0.9	1	1.1	1.2	1.3	1.4
Mean number of photoelectrons							
N	0.07	0.10	0.14	0.17	0.9	2	4.2
N'	0.06	0.08	0.10	0.14	0.72	1.7	3

Table 5

The mean number of photoelectrons collected by the two photomultipliers of $\check{C}_1$ for different pion momenta p_π

p_π (GeV/c)	0.9	1	1.2	1.4
Mean number of photoelectrons				
N	11.4	12.6	12.5	12.8
N'	7.9	8	8.6	9

Figure captions

- Fig. 1 : Layout of the experimental apparatus. S_1, S_2 are scintillation counters. H is a hodoscope consisting of nine scintillation counters. $\check{C}_0, \check{C}_1$ are the aerogel Čerenkov counters. $\check{C}_2$ is the water Čerenkov counter. $CH_{11}, CH_{12}, CH_{13}, CH_{14}, CH_{15}, CH_1, CH_2, CH_3, CH_4$ are wire proportional chambers.
- Fig. 2 : Counters $\check{C}_0$ and $\check{C}_1$ are represented with the same scale. The aerogels are indicated by hatched marks, and the photomultipliers are indicated by P.M. In the $\check{C}_1$ counter, there are two regions of different indices of refraction: R_1 ($n = 1.094$) and R_2 ($n = 1.06$).
- Fig. 3 : Comparison of the measured amplitude spectrum ($\bullet$) with a Monte Carlo calculation (---) for 1.4 GeV/c incident kaons in the R_1 region. The mean number of photoelectrons collected by one photomultiplier of the $\check{C}_1$ counter equals 4.2. The hatched area shows the measured amplitude spectrum corresponding to a one photoelectron spectrum.
- Fig. 4 : Comparison of the measured amplitude spectrum ($\bullet$) with a Monte Carlo calculation (---) for 1.4 GeV/c incident pions in the R_1 region. The mean number of photoelectrons collected by one photomultiplier of the $\check{C}_1$ counter equals 12.8. The hatched area shows the measured amplitude spectrum corresponding to a one photoelectron spectrum.

Fig. 1

Fig. 2

Fig. 3

Fig. 4