

Second Test of Aerogel Cherenkov counter for the J-PARC E36 experiment

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Introduction

The J-PARC E36 experiment aims to measure the ratio of the decay rate $\Gamma(\text{Ke}2)$ to $\Gamma(\text{K}\mu2)$ with 0.25% accuracy. One of the most important issues of this experiment is the particle identification (PID) of the decay products, positrons and muons. We plan to prepare three kinds of PID detectors such as an Aerogel Cherenkov (AC) counter, a time-of-flight (TOF) counter, and a lead-glass counter. The required performance for the AC counter is the muon mis-ID rate as low as 3% and the positron efficiency as high as 98%.

In this test experiment, we will measure the dependence of the positron efficiency and the muon mis-ID rate of the AC counter on the beam incident angle and position with four kinds of the Aerogel material and twelve types of the main mirrors to maximize the performance. We plan to do experiment at the K1.1BR beamline. We will use positrons and muons whose momentum is 250 MeV/c.

We request 168 hours for the beamtime. We expect that our test experiment will be performed from 14th May 2013 to 31st May 2013. We prefer to do experiment every 12 hours.

AC counter

Figure 1 shows an AC counter schematically. The AC counter surrounding the target is divided into 12 sectors. This AC counter is a threshold type Aerogel counter. A kaon beam is injected into the target, and the decay products pass through the Aerogel counter. The Aerogel index is chosen so that only positrons emit Cherenkov light. The Cherenkov light is detected by two side photomultipliers (PMT) via a main mirror and the Winston cone. The Aerogel size, the counter size, the main mirror parameters, and the Winston cone parameters are optimized by simulation.

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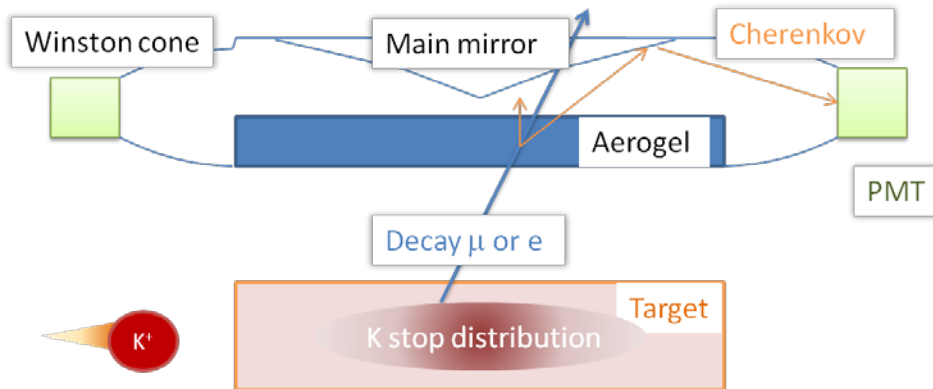


Figure 1: Schematic figure of the AC counter.

Figure 2 shows the second prototype AC counter. To measure the dependence of the efficiency and muon mis-ID rate on the incident angle and position, the AC counter is set up on a rotational stage and a linear stage.

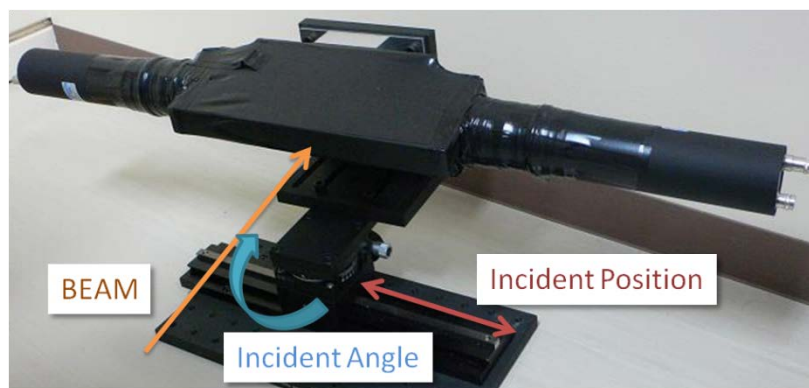


Figure 2: Second prototype AC counter

Experimental setup

Figure 3 shows the K1.1BR area setup for the AC counter test. We will prepare two gas Cherenkov counters and TOF counters with flight length of 5 m to define a muon beam with a purity greater than 99.9%. The beam is focused onto the beam defining counter (BDC). The finger counters (FCs) placed in front of the AC counter limit the beam size to horizontally 10 mm x vertically 5 mm. The BDC2 is to ensure that the beam passes through the two gas Cherenkov counters. The BDC3 is newly installed to suppress the beam positron escape effect which causes underestimation of the AC counter efficiency.

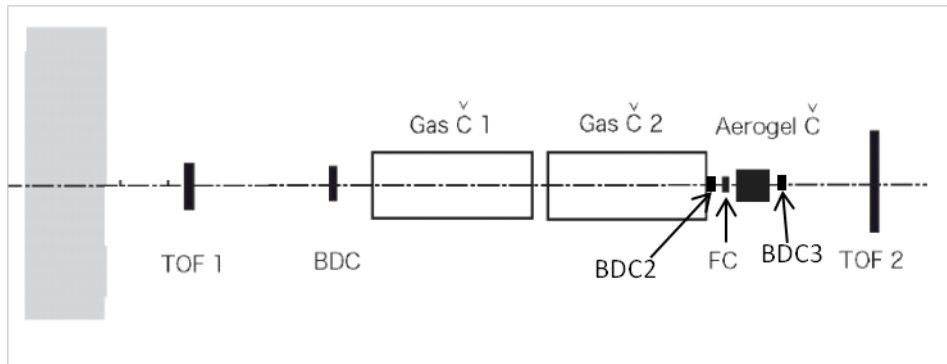


Figure 3: K1.1BR area setup for AC counter test.

AC counter test

We plan to measure the data set of 6 combinations of beam incident angle and position as shown in Figure 4.

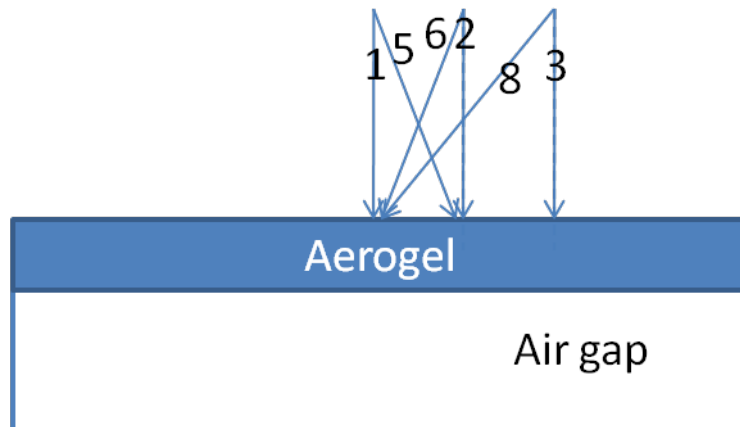


Figure 4: Data set of beam incident angle and position

We have prepared 12 types of the main mirror such as a polygonal flat mirror 1 (PF1), a polygonal flat mirror 2 (PF2), a polygonal flat mirror 3 (PF3), a polygonal flat mirror 4 (PF4), a polygonal flat mirror 5 (PF5), a polygonal flat mirror 6 (PF6), polygonal flat mirror 7 (PF7), a polygonal flat mirror 8 (PF8), a polygonal diffused mirror 1 (PD1), a polygonal diffused mirror 2 (PD2), a diffused mirror (D), and a flat mirror (F). The flat mirror is prepared to calibrate the simulation. The other mirrors are optimized by the simulation.

We also have prepared 4 types of the Aerogel material such as the Aerogel with index (n) of 1.05 and a transmission length (TL) of 40 mm, the Aerogel with $n=1.035$ and TL=50 mm, the Aerogel with $n=1.08$ and TL=40 mm, and the Aerogel with $n=1.08$ and TL=20 mm. The first, second, and third ones are measured for the index dependence, and the last one is for the TL dependence measurement.

The previous experimental result

The previous beam time result is as follows.

- The Winston cone version 3 (WC3) which has an Al mylar reflective surface marked the best performance.
- The scattering effect at the FCs caused the underestimation of the AC efficiency by about 3-4%.
- The PF1 mirror marked the best efficiency of PF1, PF2, PD1, PD2, D, and F on the condition of $n=1.05$, $TL=40$, and 20 mm thickness, but the position dependence is large.
- The diffused mirror had the lowest angle and position dependence, but the efficiency is relatively low.
- The best Aerogel thickness on the condition of $n=1.05$, $TL=40$ mm, and D mirror was 40 mm, not 20 mm which is expected by the simulation estimation. This means that the surface reflectivity is higher than expected.

The simulation work using this experimental result shows that the mirror shape parameters have the index dependence. Thus we are now preparing the new mirrors (PF3, PF4, PF5, PF6, PF7, and PF8) for the Aerogel material with 40 mm thickness. The PF3 and PF4 are for $n=1.035$, the PF5 and PF6 are for $n=1.05$, and the PF7 and PF8 are for $n=1.08$.

Beam time request

We need 3 hours beam time for each data set (6 angle-and-position conditions) to achieve the 1% positron efficiency uncertainty according to the previous beam time measurement.

- $n=1.05$, $TL=40$ mm, 20 mm^t thickness, PF1 mirror (Check the BDC3 effect)
- $n=1.05$, $TL=40$ mm, 20 mm^t, F mirror (Simulation calibration)
- $n=1.05$, $TL=40$ mm, 20 mm^t, D mirror (Check the reproducibility)
- $n=1.05$, $TL=40$ mm, 20 mm^t, PF2 mirror
- $n=1.05$, $TL=40$ mm, 20 mm^t, PD1 mirror
- $n=1.05$, $TL=40$ mm, 20 mm^t, PD2 mirror
- $n=1.035$, $TL=50$ mm, 40 mm^t, PF3 mirror (Check index dependence)
- $n=1.035$, $TL=50$ mm, 40 mm^t, PF4 mirror
- $n=1.035$, $TL=50$ mm, 40 mm^t, D mirror
- $n=1.035$, $TL=50$ mm, 60 mm^t, D mirror
- $n=1.035$, $TL=50$ mm, 60 mm^t, F mirror
- $n=1.035$, $TL=50$ mm, 20 mm^t, D mirror
- $n=1.035$, $TL=50$ mm, 20 mm^t, PF1 mirror

- $n=1.035$, TL=50 mm, 20 mm^t, PF2 mirror
- $n=1.035$, TL=50 mm, 20 mm^t, PD1 mirror
- $n=1.035$, TL=50 mm, 20 mm^t, PD2 mirror
- $n=1.035$, TL=50 mm, 20 mm^t, F mirror
- $n=1.05$, TL=40 mm, 40 mm^t, PF5 mirror (Check index dependence)
- $n=1.05$, TL=40 mm, 40 mm^t, PF6 mirror
- $n=1.05$, TL=40 mm, 40 mm^t, D mirror
- $n=1.05$, TL=40 mm, 70 mm^t, D mirror
- $n=1.05$, TL=40 mm, 70 mm^t, F mirror (Check the simplest system)
- $n=1.05$, TL=40 mm, 50 mm^t, D mirror
- $n=1.05$, TL=40 mm, 50 mm^t, F mirror
- $n=1.05$, TL=40 mm, 30 mm^t, D mirror
- $n=1.05$, TL=40 mm, 30 mm^t, F mirror
- $n=1.08$, TL=20 mm, 40 mm^t, PF7 mirror (Check the TL effect)
- $n=1.08$, TL=40 mm, 40 mm^t, PF7 mirror (Check index dependence)
- $n=1.08$, TL=40 mm, 40 mm^t, PF8 mirror
- $n=1.08$, TL=40 mm, 40 mm^t, D mirror
- $n=1.08$, TL=40 mm, 20 mm^t, PF1 mirror
- $n=1.08$, TL=40 mm, 20 mm^t, PF2 mirror
- $n=1.08$, TL=40 mm, 20 mm^t, D mirror
- $n=1.08$, TL=40 mm, 20 mm^t, PD1 mirror
- $n=1.08$, TL=40 mm, 20 mm^t, PD2 mirror
- $n=1.08$, TL=40 mm, 20 mm^t, F mirror
- $n=1.08$, TL=40 mm, 60 mm^t, D mirror
- $n=1.08$, TL=40 mm, 60 mm^t, F mirror
- Aerogel change time (2.5 hours x 11 = 27.5 hours. 2.5 hours are based on the previous record)
- Mirror change time (1 hour x (38-11) = 27 hours. 1 hour is based on the previous record)

Total beam time is $3 \times 38 + 27.5 + 27 = 168.5$ hours. We request 168 hours in total for the beam time. Man power is expected to be limited, thus we prefer to do experiment every 12 hours. There is also a possibility to reduce the Aerogel change down-time to some extent by this schedule.