Response of KEK Secondary Emission Chamber to Several GeV Protons and Deuterons

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Abstract

We have investigated the response of KEK secondary emission chamber for protons at 4, 5 and 12 GeV, and for deuterons at 7, 8 and 10 GeV. The response was measured both by the "foil activation" technique and by secondary pions produced from a carbon target.

I. INTRODUCTION

A secondary emission chamber (SEC) is one of useful detectors for the beam intensity in several GeV [1]. In the slow extracted beam lines of 12GeV proton synchrotron at KEK (KEK-PS), SECs are installed at several positions such as just downstream of the extraction from the accelerator and just upstream of the production target stations, in order to monitor primary beam intensity. Each SEC has been calibrated by the "foil activation" method once or twice a year [2].

The KEK-PS has been operated as a proton machine up to 12 GeV for a long time. Recently, however, deuteron can be also accelerated up to 11.2 GeV [3] and the experiments using deuteron beams have been performed [4]. SECs have been calibrated for deuterons as well as protons at several energies.

In this report, the structure and basic characteristics of the KEK SEC are presented in the section II, and the response measurement of the KEK SEC to protons and deuterons is described in the section III. The results and discussion are described in sections IV.

II. KEK SEC

A. Structure

A schematic drawing of the KEK SEC is shown in fig. 1. 5 aluminum foils for signals and 6 aluminum foils for positive high voltages are assembled alternately with 8 mm spacing in a vacuum chamber. Each aluminum foil is 7 μm thick and is plated with 0.1 μm thick silver by a sputtering technique. A chamber is finally evacuated by an ion pump up to about 10^{-7} Torr. Charges from a SEC are collected by a digital current integrator (ORTEC 439) at "1 pulse/10^{-10} Coulomb" mode.

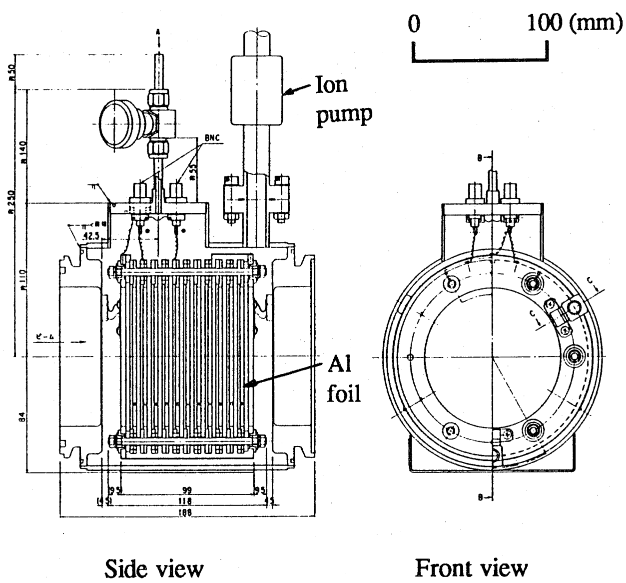

Figure 1. A schematic drawing of the KEK SEC

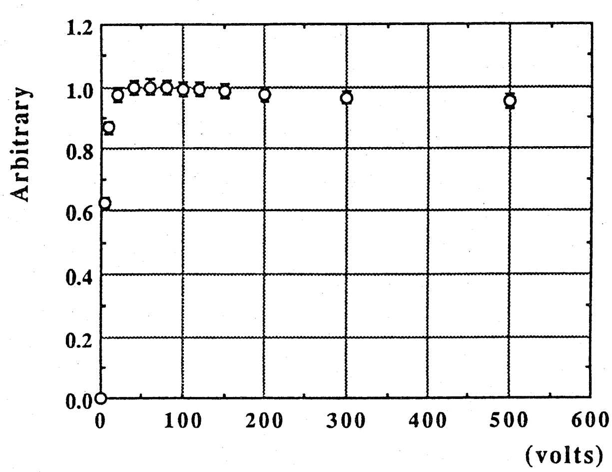

Figure 2. The counting efficiency of the SEC as a function of the supplied voltage.

B. Counting efficiency as a function of the supplied voltage

The counting efficiency of the SEC for 12 GeV protons changes as a function of the voltage supplied between foils as shown in fig. 2. In this measurement, two SECs were installed in the beam line in cascade. Charges from a SEC were measured with changing supplied voltages, whereas another SEC was used as a beam intensity monitor at a fixed voltage. The curve has a peak at around 50 V and shows a same feature as in ref. [5]. The efficiency decreases very slowly as the supplied voltage increases in the region of above 60 V. This slope is small and about 1 %/100 V. In the usual operation, the supplied voltage is set at 100 V.

C. Position dependence

The curve in fig. 3 shows the SEC counting dependence on the incident position of 12 GeV protons. Response of a SEC was measured with changing beam position by using a steering magnet. The beam spot was smaller than 10 mm in diameter. Incident beam position and size were monitored by a segmented parallel-plate ion chamber (SPIC) [6]. Another SEC installed upstream of a steering magnet monitored a beam intensity. The response of SEC is found to be almost flat within the area of 80 mm in diameter. The beam sizes at any places where SECs locate are sufficiently small comparing with this effective area (80 mm in dia.) of the SEC.

III. RESPONSE MEASUREMENT OF SEC

A. calibration by foil activation

In order to get the absolute response for protons and deuterons, the calibration by the "foil activation" method has been performed for the B3-SEC which locates just upstream of the target station of the T3 beam line in fig. 4.

A stack of aluminum foils, which area was 10×10 cm^2, was attached to the SEC and exposed to primary beams. A sample aluminum foil of 25 μm thick was sandwiched by the same aluminum foils in order to compensate the loss of produced radioactive nuclei. A "rad color" was also stacked together with aluminum foils to monitor an integrated beam size at exposure. Exposure times were ranged from 7 min. to 37 min. depending on primary beam intensity. The calibration was performed at 4, 5 and 12 GeV for protons and 7, 8 and 10 GeV for deuterons. Counts of a current integrator connected to the SEC were accumulated during the exposure.

After the exposure, a stack of foils was punched together with an attached "rad color" which changed its color at around beam exposed area. To determine punched sizes, three different areas were punched and measured its activities for both ^{24}Na and ^{7}Be. The first area (A) was 1 mm larger than a discolored ellipse of the "rad color", the second area was 40 mm in diameter of the remaining foil and the third was the remaining. About 98 % of produced activities were found in the area A, and more than 99 % were observed within the area of 40 mm in diameter. A punched size was thus determined so as to cover the exposed area.

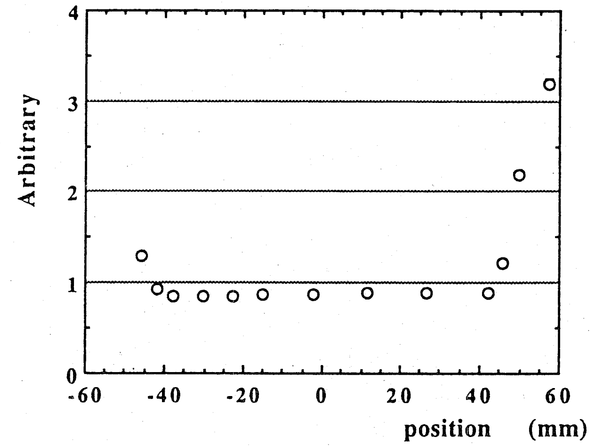

Figure 3. SEC response dependence on incident beam position

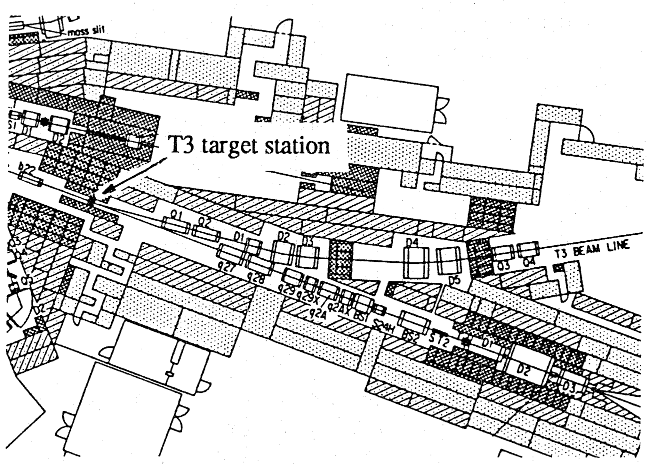

Figure 4. A layout around the T3 beam line

The ^{24}Na activities were determined by assaying the intensity of the 1368 keV γ-ray with a pure Ge detector. The results obtained are shown in table 1. Errors indicated include the counting efficiency of a pure Ge detector (<5%), statistical errors (<1%) and uncertainty of an aluminum foil thickness (<1%). The cross sections used for the activities ^{24}Na via ^{27}Al(p,3pn) or ^{27}Al(d,3p2n) reactions are listed in table 2 [7]. The sensitivity of the KEK SEC to deuteron seems to be 40-50 % higher than to protons.

Table 1 Results of the foil activation method

Incident Particle	Energy [GeV]	Exposure Date	(in 1992) Time	Number of incident particle by ^{24}Na [×10^{14}]	Integrated charge from SEC [μC]	SEC charge per 10^{14} particles [μC]
d	10	10-APR	10:47-11:18	1.21±0.06	4.75	3.93
d	8	15-APR	10:54-11:10	1.48±0.08	5.36	3.62
d	7	21-APR	10:37-10:48	0.93±0.05	3.63	3.90
p	4	19-MAY	11:05-11:25	1.73±0.09	4.57	2.64
p	5	21-MAY	10:43-11:20	1.41±0.07	3.62	2.57
p	12	9-JUN	10:55-11:02	1.49±0.08	4.22	2.83

Table 2 Cross sections for ^{24}Na production

Particle	Energy [GeV]	Cross sections used for ^{24}Na [mb]
d	7,8,10	15.
p	4	9.0
p	5	8.8
p	12	7.92

B. calibration by secondary pions

Secondary produced pions ($\pi^{\pm}$) for a carbon target of 40 mm thick, which locates just downstream of the B3-SEC, were measured during E257 experiment at the T3 beam line. Preliminary values of pion yields normalized to 100 counts of the B3-SEC (10^{-8} Coulomb) are listed in table 3. In this measurement and analysis, there were no large uncertainties in absolute values to extract pion yields between protons and deuterons. On the assumption that a proton and a neutron in a deuteron of several GeV react with target nuclei independently, sum of π^+ and π^- yield by incident protons should be equal to π^+ or π^- yield by incident deuterons at the same incident energy per nucleon. The energy in several GeV region would be high enough above the pion production threshold, and the deuteron binding energy is negligibly small compared to this energy region. The numbers in the next columns of π^+ or π^- yields by deuteron are the deduced incident deuteron intensity normalized proton intensity obtained from the sum of π^+ and π^- yield by protons at the same incident energy under the above assumption. For this measurement, the response of SEC is almost the same for proton and for deuteron.

IV. Results and Discussion

By the foil activation method, the KEK SEC seems to have 40 – 50 % higher sensitivity to deuteron than to protons, however, there are no such large difference between responses to proton and deuteron from the consideration of secondary pion yields. The response of the SEC should be originated from the atomic process and should be a function of velocity (β) of incident particles. Since βs of proton and deuteron are almost the same in this energy region, the response for deuterons is likely to be the same as for protons.

As for proton induced reactions, there are several independent measurement for the ^{24}Na activities in GeV region, however, only two data for ^{24}Na at 2.33 GeV and 7.3 GeV are available for deuteron [8]. If a SEC's response for deuterons is the same as for protons, cross section of the $^{27}Al(d,3p2n)^{24}Na$ reaction should be about 11 mb in this energy region. Further investigations of this monitor reaction for deuteron would be awaited.

For data of secondary pions, we would like to express our thanks to the E257 experimental group for their kind cooperation. We are also grateful to the KEK-PS accelerator group for their support to the measurement.

V. References

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Table 3 Yields of pions normalized to 10^{-8} Coulomb of SEC (Preliminary)

Incident Energy [GeV/u]	Momentum of produced π [GeV/c]	Number of produced π by proton			Number of produced π by deuteron			
		π^+ [$\times 10^3$]	π^- [$\times 10^3$]	sum [$\times 10^3$]	π^+ [$\times 10^3$]	d–intensity	π^- [$\times 10^3$]	d–intensity
5.0	1.0	196	107	303	294	0.97	296	0.97
	1.5	442	170	612	585	0.96	625	1.02
	2.0	438	143	581	571	0.98	580	1.00
	2.5	309	110	419	389	0.93	400	0.95
4.0	1.0	(173)	76	250	213	0.85	205	0.82
	1.5	(347)	101	449	351	0.78	353	0.79
	2.0	212	71	283	250	0.88	265	0.94
3.5	1.0	137	48	185	206	1.11	189	1.02
	1.5	210	53	264	288	1.09	283	1.07