ELECTROSTATIC SEPARATOR AND K1.8 SECONDARY BEAMLINE AT THE J-PARC HADRON-HALL

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Abstract

The secondary beam line with two electrostatic (ES) separators to deliver 1-2GeV/c kaon beams has been constructed at the high intensity proton accelerator facility (J-PARC). The ES separator is designed so as to be radiation-proof and to lower spark rate. The K^-/π^- ratio of the line is designed to have a larger value than 1. The basic performance as a separating beam line has been checked by mass separation curves.

INTRODUCTION

The secondary beam line K1.8 has been constructed in Hadron Experimental Hall at the 50-GeV Proton Synchrotron (PS) of J-PARC (Fig. 1). The K1.8 line has two ES separators to deliver 1-2 GeV/c kaon beams with less contamination of pions to the K1.8 experimental area. This line branches off for the left to provide secondary beams to the K1.8BR experimental area, so as to deal with the various experimental subjects.

An electrostatic (ES) separator is one of key elements of a secondary beam line, which generates a transverse electric field along the beam axis to separate particles by their mass differences. ES separators were used for a long time at KEK 12GeV-PS [1], however, the first stage separator in the K1.8 beam line has been incorporated with the following improvements:

- Organic parts should be replaced by inorganic material or metal, since the radiation level at J-PARC will be higher by several hundreds times than at KEK-PS due to high intensity of primary proton beams.
- Shapes of electrodes and high-voltage feeders are designed to mitigate high electric fields.

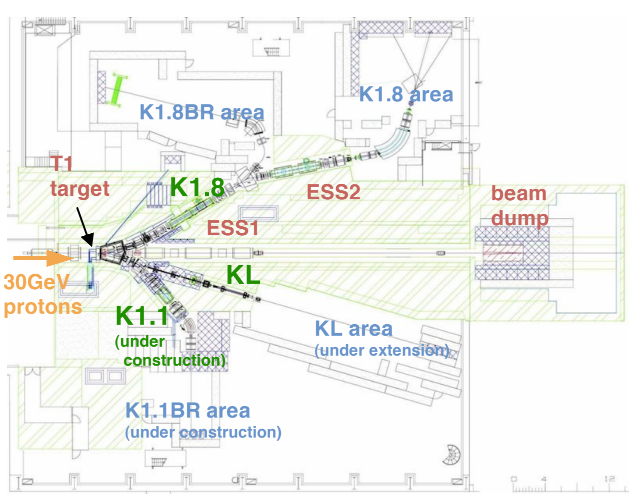

Figure 1: Layout of the Hadron Experimental Hall.

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K1.8 BEAM LINE

With primary protons of 15μA at 50GeV, K^- intensity of 10^7 per spill will be delivered to the K1.8 experimental area. The maximum central momentum of the K1.8 beam line is 2GeV/c, to cover a peak of the elementary cross section of Ξ^- production via p(K^-, K^+) reaction at P_{K^-}=1.8GeV/c. The production ratio of π^- to K^- around 1.8GeV/c is about 500, so unwanted π^-s should be taken away from the wanted K^- beam trajectory to perform an experiment with secondary K^- beams efficiently. The design optics of the K1.8 line is shown in Figure 2. The intermediate focus [2] and the double stage of separation [3] are employed to realize the K^-/π^- ratio better than 1. Tertiary π^-s produced around the production target such as from K^0_s decay or from reactions of secondary particles at materials close to the target will be reduced by the slits at the intermediate focal point (IF) in the vertical direction. Secondary π^-s from the production target in the same momentum region of K^-s will be filtered by two sets of a combination of magnetic and electrostatic fields. A set of dipoles for horizontal magnetic fields is placed just upstream and downstream of the ES separators for vertical electrostatic fields. The ES separators of K1.8 will generate 75kV/cm electrostatic field between parallel electrodes of 10 cm gap with the area of 40 cm in width and 6m in length.

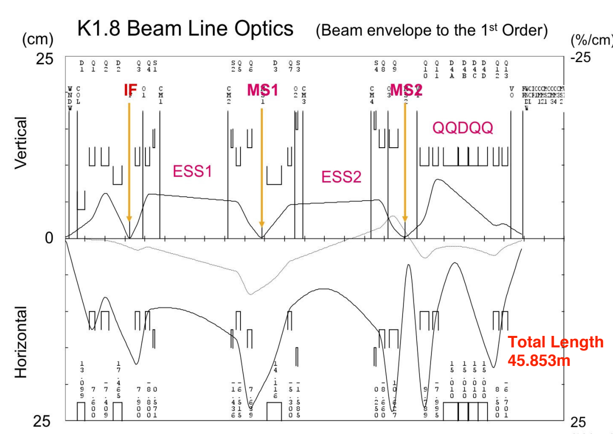

Figure 2: First order TRANSPORT beam envelope of the K1.8 beam line. The positions of an intermediate focal point and mass slits are denoted as IF and MS1, 2.

The first ES separator (ESS1) has to be radiation-proof, since it is installed rather close to the production target that will be exposed to radiation caused by intense proton beams. The present KEK-PS type separators is used as the second ES separator (ESS2) of the K1.8 beam line, since the radiation level there is not so high. Unwanted π^-s are deflected by the ExB fields and filtered by the two mass slits, MS1 and MS2, downstream of the ESS1 and ESS2 respectively.

By changing the polarity of the D3 magnet, secondary beams are delivered to the K1.8BR area. K1.8BR beam line with the single stage separator has shorter length for kaons up to 1GeV/c.

ES SEPARATOR

Radiation-proof

The positive and negative high voltage generators of Cockcroft- Walton type are mounted on the stainless steel vacuum chamber of the ES separator, and directly connected to the electrodes inside the chamber. The sheath of the plug-shaped high-voltage feedthrough of the KEK-PS type separator was made of fiber reinforced plastic (FRP), and was immersed in insulation-oil with a ceramic container. FRP and insulation oil should be refrained under high radiation circumstances, therefore, we substitute ceramic for FRP to prolong the lifetime of separators for the J-PARC type. Since outer oil layer is no longer needed, assembling and maintenance become extremely simpler. For ESS1, the vacuum seals are metal gaskets and a radiation resistant turbo-molecular pump and an oil-free scroll pump are used.

Mitigation of electric fields

Several windows are arranged on the main vacuum chamber to mount high voltage generators and supports of electrodes, and to put vacuum ports and viewing ports. Pipes were welded directly to the window-halls on the main chamber, and these unavoidable corners at these welding supposed to be sources of sparks. For the J-PARC type, unwanted welding corners at these joints between the main chamber and branch pipes are removed by forming flared opening in the main chamber. Since outer pipes are welded at the neck where it is flat and well apart from the electrodes inside the main chamber, unexpected electric discharges will be reduced (Fig. 3).

Electro-chemical polishing is performed at the final stage of manufacturing. "Mean deviation of the profile" and "maximum height of the profile" are expected to be 0.05µm and 0.2 µm, respectively.

The smaller diameter of the vacuum chamber, as compared to the KEK-PS type, is adopted to reduce collision probability of ions during their drift. Since cathode (anodized aluminum) is more prone to emit electrons than anode (stainless steel), the width of the cathode is slightly wider than the anode to form a moderate electric field at the surface of cathode. Electric fields are calculated for the new size of the chamber and shape of electrodes, and no significant difference between the new separator and the KEK-PS type. The corner of the anode, however, is found to have high electric fields compared with other places. The corner radius of anode is changed to 8mm from 3mm (the KEK-PS design), to lower the electric field by 23%.

Figure 3: The main vacuum chamber with flared opening windows. This is just after electro-chemical polishing.

Figure 4: ESS1 installed on the K1.8 beam line from upstream. The top of the line has been covered by concrete shields.

CHECKOUT OF THE BEAM LINE WITH ES SEPARATOR

On January 27, 2009, protons were accelerated up to 30 GeV at the main ring, then successfully extracted to Hadron Experimental Hall and transported to the beam dump.

The secondary particles are produced when the extracted protons hit a nickel or platinum metal target (T1 target in Fig. 1), and particles within the selected momentum range by magnetic fields are transported along the K1.8 beam line. Particle separation curves at the K1.8BR experimental area are measured at ±200kV of the first ES separator by changing field strength of the correction dipole magnets (CM1 & CM2) as shown in Figure 5. At each 'CM1&CM2' settings, particles of 0.75GeV/c, which pass through the MS1, are counted by detectors in the K1.8BR area. Counts of secondary particles are normalized to primary protons measured by secondary emission chamber (SEC)[4]. Peaks of $\pi^{\pm}$, $K^{\pm}$ and p (p-bar) are well separated.

As a trial of a density increase of kaons at 1.8GeV/c in the secondary beams at the K1.8 experimental area, two ES separators are activated. Figure 6 is obtained by excitation of four correction magnets at the calculated values fitting for ±200kV of two ES separators. Enhancements of kaons in the secondary beams are clearly seen by "on" and "off" of ESS1 and/or ESS2 from (a) to (c) recorded in 'Kaon' trigger mode of the detectors. Since a ratio of kaons in the secondary beams are still 8% as shown in (d) with both separators, the optimal operation of beam line parameters have to be surveyed further for the secondary pion and kaon beams to realize the designed K^{-}/π^{-} ratio.

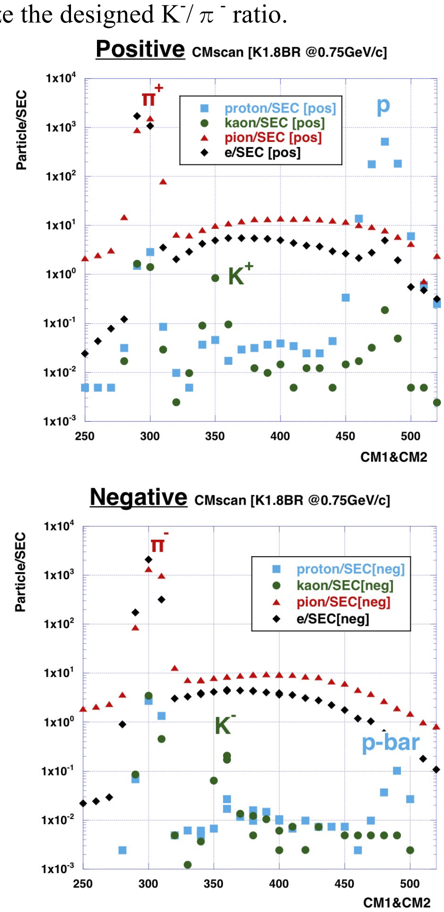

Figure 5: Particle separation curves at the K1.8BR experimental area are measured at ±200kV of the first ES separator by changing field strength of the correction dipole magnets (CM1 & CM2) for the electrostatic fields

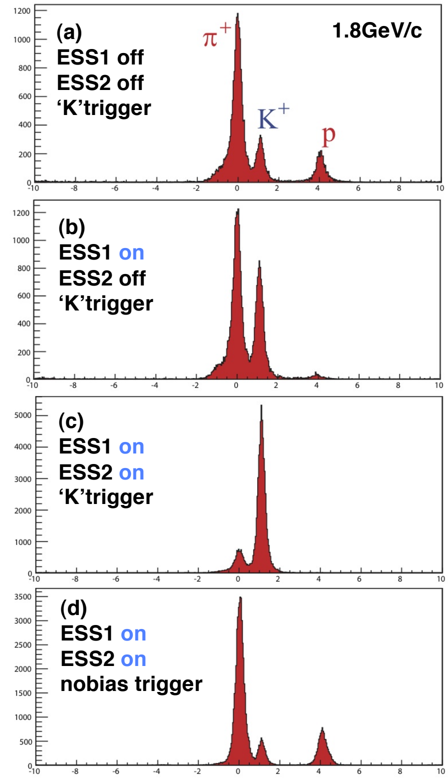

Figure 6: Trial of a density increase of kaons at 1.8GeV/c in the secondary beams at the K1.8 experimental area. Two ES separators are activated at ±200kV. For (a), (b), (c), 'kaon' is selected by triggering detectors in the K1.8 area. For (d), all secondary particles through MS2 are displayed.

ACKNOWLEDGEMENT

The authors are grateful to Prof. A. Yamamoto of KEK for his important advices and useful discussions. Measurement of separation curves at K1.8BR area was performed with J-PARC E15 and E17 experimental group. A trial of kaon enhancement at K1.8 area with two ES separators was done with J-PARC SKS experimental group.

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