

# Commissioning of the J-PARC K1.8 beamline and the beam spectrometer

**Tomonori Takahashi**  
**for J-PARC K1.8 Collaboration and Hadron beam line group**

University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo, Japan

E-mail: tomonori@post.kek.jp

**Abstract.** The K1.8 beam line of the J-PARC Hadron facility has been constructed for the experimental activities on hadrons and nuclei using secondary particles, especially kaon. On October 22nd 2009, the first beam was successfully extracted and the commissioning of the beam line and the experimental apparatus was started. Although the beam line was not tuned optimally, the yields of the beam kaon were measured to be at least 40 k for  $K^+$  and 5.1 k for  $K^-$ , respectively, with the primary intensity of  $2.5 \times 10^{12}$  protons. These values agreed with the designed ones within a few factors and will be improved after the fine tune. The momentum resolution of the beam spectrometer was estimated to be  $\delta p/p < 2.1 \times 10^{-3}$  by the beam through run. Though it includes contributions from the spectrometers for scattered particles, it is satisfactory for the experiment.

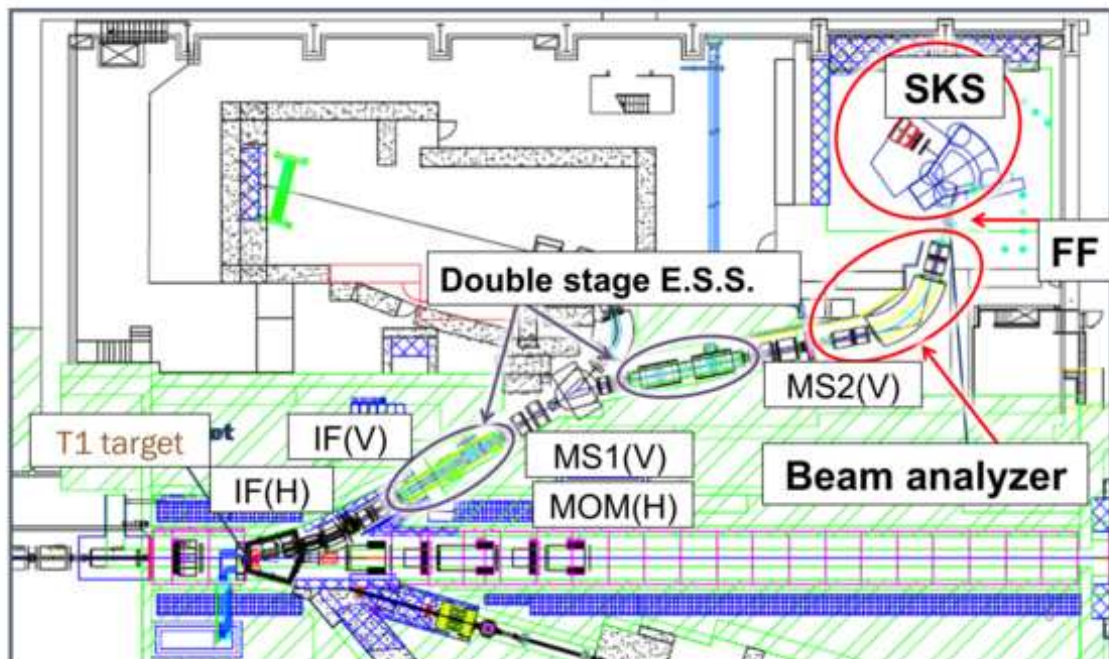
## 1. Introduction

Various types of experiments related to strangeness nuclear physics are planned at the J-PARC [1]. In particular, the experimental studies of strangeness  $S = -2$  system, such as  $H$  dibaryon search, double  $\Lambda$  hypernuclear spectroscopy and  $\Xi$  hypernuclear spectroscopy, are important to investigate less known channel in Baryon-Baryon interaction based on  $SU(3)_{flavor}$ . In order to create the  $S = -2$  system, the  $\Xi$  production via the  $(K^-, K^+)$  reaction is one of the suitable way. Thus, the K1.8 beam line was designed and has been constructed to provide high intensity of larger than  $10^6/\text{sec}$  and high purity of  $K/\pi$  of more than unity.

## 2. K1.8 beam line and beam spectrometer

The K1.8 beam line is located at the north-side of the J-PARC Hadron facility. The layout of the K1.8 is shown in Figure 1 and the design parameters are listed in Table 1. This beam line has two sets of electrostatic separators [2], which lead to a high purity  $K^-$  beam with a  $K^-/(\pi^- + \mu^-)$  ratio of 3.5. A high intensity  $K^-$  of  $1.4 \times 10^6$  ppp can be obtained on the reaction target with a primary beam of  $2.0 \times 10^{14}$  ppp and 54 mm long Ni production target. While the main purpose of the K1.8 is to provide 1.8 GeV/c  $K^-$  beam, this beam line can deliver charged particles of up to 2.0 GeV/c.

At the most downstream part of the beam line, a high resolution beam spectrometer is located. Figure 2 shows a schematic view of the K1.8 beam spectrometer. It is comprised  $QQDQQ$  magnets, 4 sets of wire chambers and trigger counters. Optics of the beam analyzer was calculated to utilize point-to-point focus condition so as to reduce multiple scattering effects.

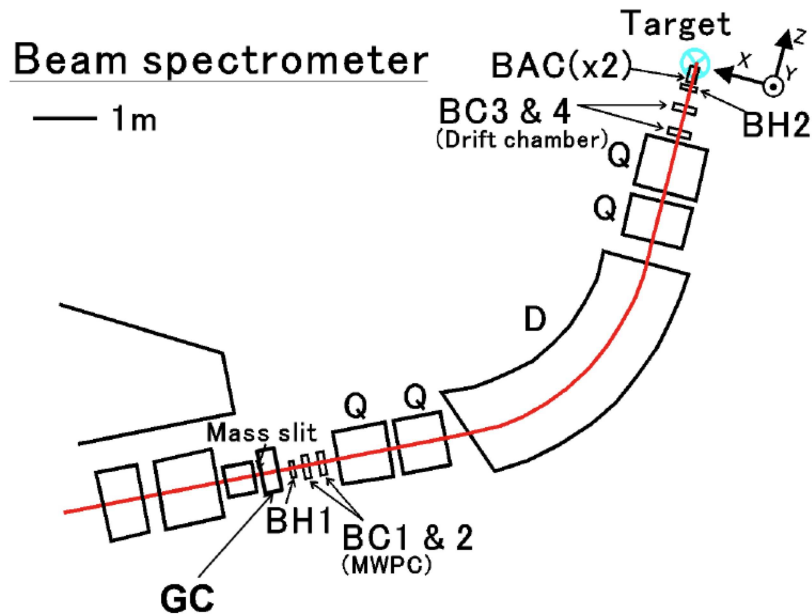


**Figure 1.** K1.8 beam line in the J-PARC Hadron facility.

In addition, the wire chambers were made as thin as possible in substance. The momentum resolution expected from the 1st order optics is  $1.4 \times 10^{-4}$  (RMS) when the position resolution of the trackers is  $200 \mu\text{m}$ . Considering the singles rate more than 8 MHz at the upstream part of the spectrometer, we adopted two sets of a multi-wire proportional chamber (MWPC) with 1 mm wire pitch. As for the downstream part, the two sets of a multi-wire drift chamber (MWDC) with 3 mm anode-anode spacing are prepared. Design parameters of wire chambers are shown in Table 2. Segmented plastic scintillator hodoscopes, BH1 at the entrance and BH2 at the exit of  $QQDQQ$ , respectively, are used for both the trigger and the time of flight for offline particle identification. A gas Čerenkov counter to reject electrons (or positrons) is inserted into between the second mass slit (MS2) and BH1. An aerogel Čerenkov counters with the refractive index of 1.03 are employed to veto pions in the kaon beam. Specifications of trigger counters are given in Table 3. As for the spectrometer for the scattered particles, the Superconducting Kaon Spectrometer system (SKS) is used. The detail of the SKS and the commissioning run with some reactions are described in Ref.[3].

**Table 1.** Design specifications of the K1.8 beamline at Phase-1 (30 GeV, 9  $\mu$ A).

Primary proton beam	$2.0 \times 10^{14}$ ppp
Length	45.97 m
Acceptance	1.4 msr %
Maximum momentum	2.0 GeV/c
Electrostatic separators	750 kV /10 cm, 6 m $\times$ 2
$K^-$ intensity	
@FF 1.8 GeV/c	$1.4 \times 10^6$ ppp
Singles rate	
@MS2 1.8 GeV/c	$> 8.0 \times 10^6$ ppp
$K^- / (\pi^- + \mu^-)$ @ FF	3.5
$X_{\text{rms}}/Y_{\text{rms}}$ size @ FF	19.8 mm /3.2 mm



**Figure 2.** Schematice view of the K1.8 beam spectrometer.

### 3. Commissioning status

On October 22nd 2009, the first beam was extracted to the K1.8 beam line. In order to evaluate the performance of the beam line,  $K^+$  and  $K^-$  counts in the beam were measured, respectively. In those measurement, the two electrostatic separators (ESS1, ESS2) were in operation with the electric field strength of 40 kV/cm. The kaon beam trigger condition is defined as follows:

$$\text{BEAM}_K = \text{BH1} \otimes \text{BH2} \otimes \overline{\text{BGC}} \otimes \overline{\text{BAC}}.$$

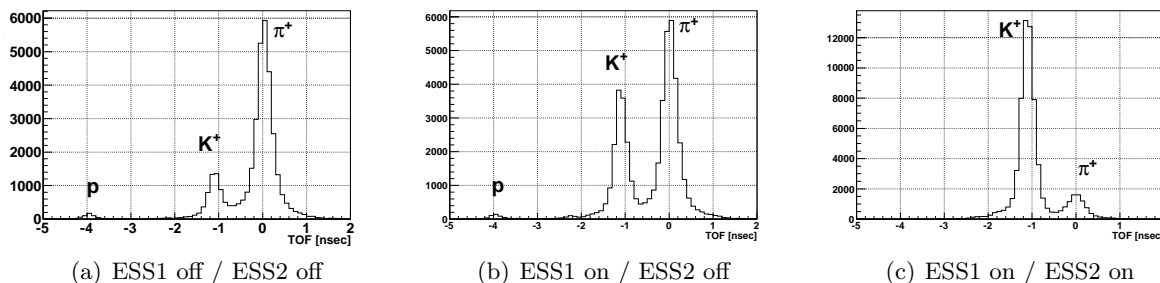
In November 2009, the  $K^+$  beam yield was measured with the primary proton intensity of  $1.18 \times 10^{11}$  ppp. Figure 3 shows the Time-Of-Flight spectra of 1.8 GeV/c beam with the  $K^+$  triggered events. An enhancement of the kaon component can clearly be seen as the separators

**Table 2.** Design specifications of the beam line trackers. Wires in the  $x$ ,  $u$  and  $v$  plane are tilted from the vertical direction by  $0^\circ$ ,  $-15^\circ$  and  $+15^\circ$ , respectively. The primed planes are displaced by a half-cell.

name	sensitive area [mm]	sense wire spacing [mm]	wires	gas mixture
MWPC				
BC1	$256^W \times 100^H$	1	$xuvxuv$	Ar 77%, $iC_4H_{10}$ 19% , Methylal 4%
BC2	$256^W \times 100^H$	1	$uvxuvx$	Ar 77%, $iC_4H_{10}$ 19% , Methylal 4%
MWDC				
BC3	$192^W \times 150^H$	3	$xx'uu'vv'$	Ar 77%, $iC_4H_{10}$ 19% , Methylal 4%
BC4	$192^W \times 150^H$	3	$uu'vv'xx'$	Ar 77%, $iC_4H_{10}$ 19% , Methylal 4%

**Table 3.** Specification of trigger counters in the K1.8 beam spectrometer.

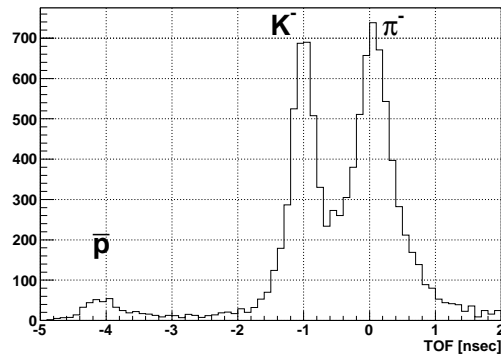
name	sensitive area [mm]	PMT	notes
BH1	$170^W \times 66^H \times 5^T$	R1450 $\times$ 22	11 segments, 3-stage booster
BH2	$133^W \times 66^H \times 5^T$	R1450 $\times$ 14	7 segments, 3-stage booster
BGC	$\phi 300 \times 210^T$	R1250-03 $\times$ 1	$i-C_4H_{10}$ ( $\sim 0.15$ MPa), $n = 1.002$
BAC	$160^W \times 60^H \times 66^T$	H6614-70UV $\times$ 4	silica aerogel, 2 layers, $n = 1.03$



**Figure 3.** Time of flight spectra of 1.8 GeV/c beam with " $K^+$  triggered events".  $\pi^+$  peak is set to be zero. Peaks around -1 nsec and -4 nsec correspond to  $K^+$  and proton, respectively.

were applied. The number of  $K^+$  per spill was estimated by fitting with 2 gaussians in  $K$ ,  $\pi$  region of each spectrum; 0.74 k/spill for "ESS1/ESS2 = off/off", 0.71 k/spill for "ESS1/ESS2 = on/off" and 0.61 k/spill for "ESS1/ESS2 = on/on", respectively. In February 2010, the  $K^-$  amount was counted with the primary proton intensity of  $2.5 \times 10^{12}$  ppp. In this measurement, horizontal slits were fully opened. Figure 4 shows the measured TOF spectrum with the aerogel Čerenkov cut in offline analysis. From this data,  $K^-$  yield was computed as 5.1 k/spill.

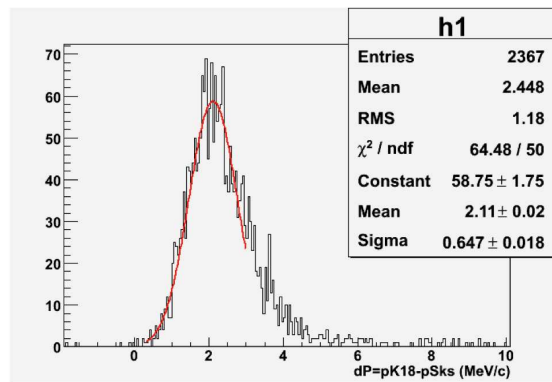
Table 4 shows the comparison of the measured kaon yields and the calculated ones. In this comparison, the numbers were normalized to the beam condition in Feb. 2010. The measured  $K^+$  yield was not only scaled with the primary beam intensity but also multiplied by a factor of around 3 which came from the difference of the opening in the horizontal slits. The result was well reproduced within a few factors with the values calculated by the Sanford-Wang's empirical formula and an optics simulation by Decay-TURTLE.



**Figure 4.** Time of flight spectrum of 1.8 GeV/c beam with "K<sup>-</sup> triggered events". π<sup>-</sup> peak is set to be zero. Peaks around -1 nsec and -4 nsec correspond to K<sup>-</sup> and anti-proton, respectively.

**Table 4.** Comparison of the kaon yield per spill.

	1.18 × 10 <sup>11</sup>	2.5 × 10 <sup>12</sup>	
		full open	simulation
K <sup>+</sup>	0.61 k (measured)	40 k	62 k
K <sup>-</sup>		5.1 k (measured)	17.5 k



**Figure 5.** Momentum difference between the beam spectrometer and the SKS.

The momentum resolution of the beam spectrometer was evaluated by the beam through data, in which a beam with the momentum of around 0.75 GeV/c had passed through both the beam spectrometer and the SKS. For the beam spectrometer, third order transfer matrix parametrization was used to calculate the beam momentum. As for the SKS, tracks were reconstructed by the Runge-Kutta method and fitted. The momentum difference measured by both spectrometers is shown in Figure 5. The width of 1.6 MeV/c (FWHM), which corresponds to  $\delta p/p = 2.1 \times 10^{-3}$ , was obtained. This result is satisfactory for the experimental requirement and is thought to be mainly determined by the SKS.

#### 4. Summary

The K1.8 beam line will provide high intensity and purity  $K^-$  beam for the hypernuclear studies, especially on  $S = -2$  system. The commissioning of the J-PARC K1.8 beam line and the beam spectrometer was performed. When the double stage electrostatic separators were turned on, kaon enhancement was confirmed in the  $K$  trigger events. We can obtain at least 40 k/spill for  $K^+$  and 5.1 k/spill for  $K^-$ , respectively, with the primary beam intensity of  $2.5 \times 10^{12}$ /spill which is 1/100 of the Phase-1 goal. It is important to note that this is the very preliminary result. The kaon yield will be improved after the fine tune of the beam line magnets. The momentum resolution was estimated by the beam through data. The obtained width of the momentum difference between the beam spectrometer and the SKS was  $\delta p/p = 2.1 \times 10^{-3}$  (FWHM), which satisfied the experimental requirement.

#### References

- [1] Nagae T *in this proceedings*
- [2] Ieiri M *et al.* 2008 *Nucl. Instr. Meth. B* **266** 4205
- [3] Shirotori K *in this proceedings*