Proposal of a test experiment for a test beam line at the K1.8 BR area

Y. Enari[A], M. Friend[A], R. Honda[A], Y. Horii[B], K. Inami[B], J. Maeda[C], I. Nakamura[A], T. Nanamura[D] Y. Okazaki[A], H. Otono[E], K. Ozawa[A], K. Sakashita[A], M. Tomoto[A], J. Tojo[E]
KEK-IPNS[A], Nagoya University[B] Kobe University[C], Riken[D], Kyushu University[E]

Contact person: Y. Enari (*yuji.enari@kek.jp*)

Exclusive summary

This is a proposal of a test experiment to measure the charged pion rate for a test beam line at the K1.8 BR area. There is a particle transfer pipe from the primary target at a angle of 50 degree towards K1.8 BR area. There are preliminary measurement and simulation study which provide consistent total particle rates and predict decent rate of charged pion as a hadron test beam line. However, given total rate seems to be dominated by low energy electron. We are going to make a measurement for charged pion rate to verify past studies as a step towards realization of hadron test beam line at J-PARC. This measurement can be performed at the slow extraction without disturbing other experiment after installing the test setup during shutdown period in 2024. We do not require any special machine time.

Introduction

In the J-PARC hadron hall, there is a particle transfer pipe from the production target at a angle of 50 degree, towards K1.8 BR area as shown in Fig 1. This pipe line can be used as a hadron test beam line. To make a solid proposal for the hadron test beam line (hadron TBL), the particle rate from the pipe needs to be understood. Currently, the end point of the pipe line is shield by concrete blocks with a space of 2 m (length) $\times$ 1 m (width)$\times$ 2 m (height). The target monitor counter (so-called TM) and an ion-chamber are located in the space and measured the hit rates of (charged) particles. A simulation study is carried out for the hadron TBL with MARS. The measured and expected rate of the charged particles are matched in same order. However, according to the simulation, the main component of the in-coming particle is low energy (MeV level) electron. In addition, neutron background seems to be also significant. The largest component of the charged particle is proton, then charged pion.

In this test measurement, the charged pion rate will be measured by excluding low energy electron with vetoing the proton component. The purpose of this measurement is to measure characteristic of the beam line, therefore no need to have special beam condition.

The expected rate and the past measurement on the particle rate

The simulation study is carried out with MARS simulation. The primary purpose of this study was radiation safety, to verify the amount of shield after modifying the K1.8 BR line with the Hadron Test beam line. The MARS simulates the interaction of the primary proton (30 GeV) on the production target, and transfers particles through the pipe in the concrete shield towards the Hadron test beam area (This turned out that the radiation level is low enough after placing concrete shield with 2 m thickness). The diameter of the pipe is changed at the middle of the pipe. The first section of the pipe which is up to 9.5 m from the target has the diameter of 6.5 cm. The diameter of the

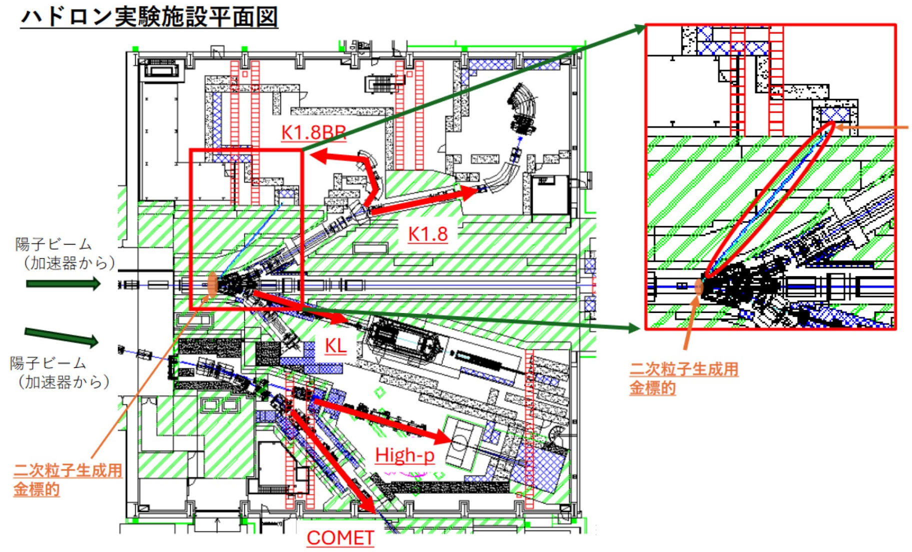

Figure 1: Floor map of the hadron hall. The zoom up box on the right shows the pipe location from the primary target to the test beam line.

second section is 11.4 cm, which is up to 13.6 m. The MARS follows all particles generated at the production target, computes all interaction with materials and outputs the particles reached at the end of the secondary pipe.

The simulation for a 4.2×10^9 proton on target is performed. Figure 2 shows the particles reached and end of the pipe. The charged particles, which are proton, charged pions, Kaons and muon, in total 476 particles, are reached to the end of the pipe. And three times more electron are reached. Thoese momentum distributions are shown in Figs 3. This is equivalent with 8.4 MHz at 115 kW operation of the J-PARC main ring. In terms of the charged pion rate, about 150 k hits per spill at the range of 0.9 GeV to 1.0 GeV is expected which is enough high as a test beam line.

On the measurement, the TM consists with three scintillation counters which scintillator size of 1 cm $\times$ 1 cm $\times$ 2 mm thick. Ion-chamber of 15 cm $\times$ 15 cm. The measured rate of charged particle is 10 M $\sim$ 40 M hits per spill.

These particle rate measurements and expectation based on MARS simulation are in same order. However, the dominant contribution of the rate seems to be low energy electron. Also simulation result shows dominant charged particle at high energy is proton. It's important to measure the particle rate with higher energy, i.e. more than 0.5 GeV of charged pion, which can be used for the test beam.

Setup of the charged pion rate

The target of the measurement is estimation of particle rate as test beam line, with functionality to apply veto on proton. Need to take into account that the space to place experimental setup is limited. Requirements on the setup are listed below.

A Charged particle detector which can cover an area of 8 cm x 8 cm.
The coverage of the detector is given by size of the pipe, which diameter of 11.4 cm. The spread of the particle is 3.56×10^{-5} sr, which is determined by the geometry of the production target and pipe. The coverage should be enough at the end of space.

B Exclude low energy electron and photon.

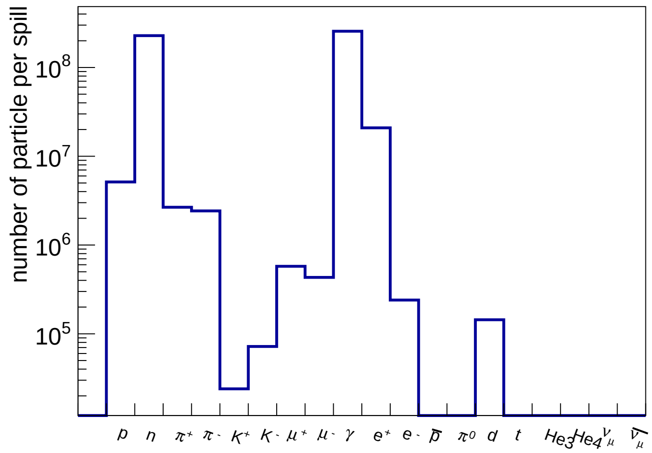

Figure 2: Expected distribution of particle species at the hadron test beam line in the K1.8 BR area (by the MARS simulation). Scale of y-axis is number of particle per spill at 115 kW operation.

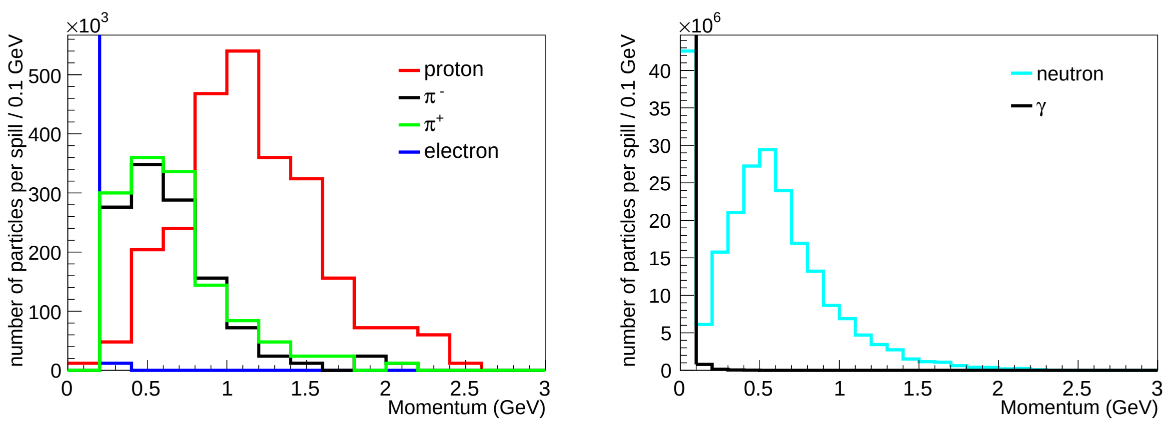

Figure 3: Expected momentum distribution for charged particles at the hadron test beam line in the K1.8 BR area (by the MARS simulation). Scale of y-axis is scaled for 115 kW operation.

There are photon not only electron. Just placing lead plate would not be enough, because of pair creation of electron and positron. Therefore, plan to place dipole magnet to bend out low energy charged particles. Here, the steering magnet from KEKB can be used which can generate magnetic field of 0.05 T, which is enough high field to exclude up to a few MeV charged particles with 10 cm. Need to check effect of the magnetic field for the TM.

C Possible to veto on the proton.
After excluding low energy electron, next dominant particle is proton. To measure charged pion rate, these proton need to be vetoed. We plan to set the aerogel Cherenkov counter based on the Belle-II aerogel plates, which refractive index is 1.045. With this configuration, charged pion which has more than 0.4 GeV emits the Cherenkov light while proton which has below 3 GeV does not.

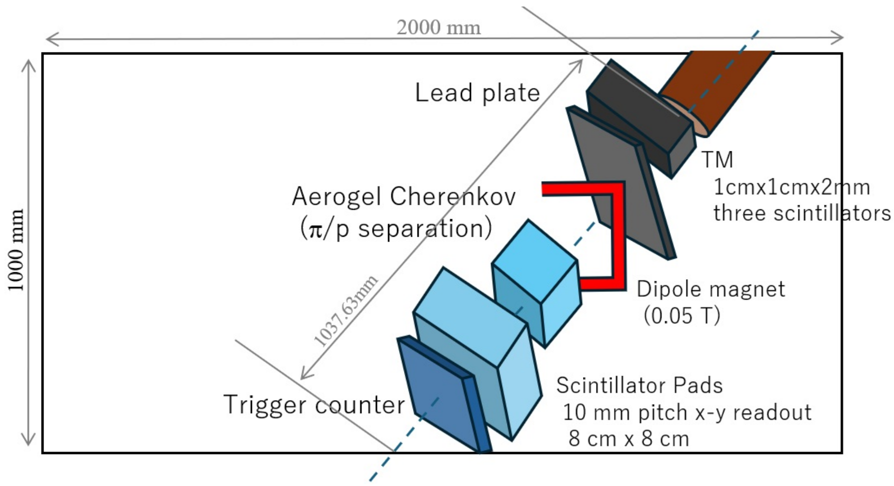

Figure 4: Expected setup to measure charged pion rate at the hadron test beam line in the K1.8 BR area.

D Setup needs to be fit in the space.
The space is surrounded by concrete shield, there is only about 1 m from end of the pipe to the wall. The height of the pipe is 2 m from the ground level. There are 4.5 cm spacer and 1.5 m thick concrete shield on the ground, therefore the height of the center of pipe is 45.5 cm from the shield.

E Coarse position resolution would be preferable.
Expected beam profile is uniform with given spread by geometry. Therefore, this is not requirement. But it would be good to have coarse position resolution in 2-dimension. Possible choice is wire chamber with 8 mm pitch and / or scintillation tile with 1 cm pitch. This can realize by reading out 10 channels for each direction, in total 20 channels.

F Access to the detector is very limited.
The space is shielded by concrete blocks, which access is established only maintenance period by request. Once the area is closed, next opportunity to access is next shutdown period, i.e. six month later.

Expected setup for pion rate measurement is shown in Fig. 4. Setup consists six components, from up stream, TM which is pre-placed beam monitor, lead plate, dipole magnet, aerogel cherenkov counter, scintillation pad 2D counters, and trigger counter. The trigger counter is scintillation counter, may be added at the upstream of the lead plate. Aerogel counter will be read by two photo tubes. In total, number of channel to readout is expected to be about 30 channels.

Analog cable will be placed to extract signal to the shielded space. Primary readout will be based on digital scalar. Outputs of discriminators will be connected to the HUL (Hadron Universal Logic Module) which can handle basic logic to make coincidence up to 64 channels. The number of output logical signal will be sent to AMANEQ, which has functionalities of scalar and TDC with precision of 1 ns. Based on this system, particle hits rate will be extracted, and it is possible to store all hits information with trigger less readout functionality of the AMANEQ for further studies. Proposed place for the readout DAQ is shown in Fig. 5. To minimize the length of analog cable, a rack is required to be close to the space. Basically these detector components are already available

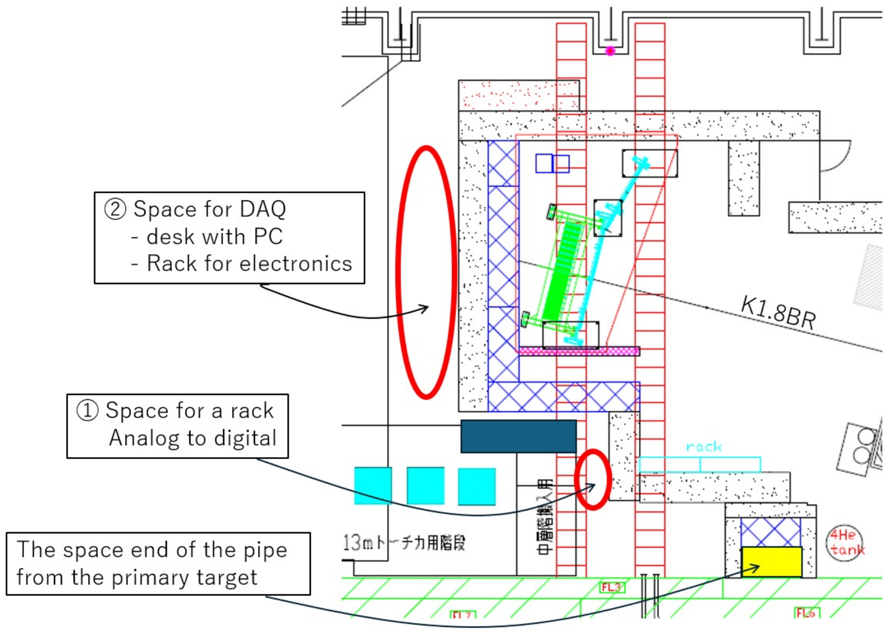

Figure 5: Location of readout DAQ at the hadron test beam line in the K1.8 BR area. It's good to have a rack close to the space to set module for analog signal treatment and discriminators. Rest of DAQ system will be placed on the behind of K1.8 BR line.

or easy to assemble. Cost estimation to prepare setup is 2,000,000 yen including PC for the DAQ. The setup needs to be installed and tested before starting beam time of entire hadron hall, and the space must be shielded by concrete blocks. We need to support from J-PARC Hadron group for this installation. The preparation of installation has started in order to finish installation and commissioning before starting the beam time of FY 2024 at the J-PARC Hadron hall.

Summary

We propose a test measurement on the particle rate for a test beam line at the K1.8 BR area. From this measurement, integrated rate of charged pion with momentum grater than 0.5 GeV will be extracted. This measurement can be made at the slow extraction without disturbing other experiment. We do not require any special machine time.