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Proposal for Extinction Measurement of J-PARC Proton Beam at K1.8BR

The COMET collaboration
Primary Beam Group

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Abstract

We request 1 day beam time for COMET extinction study in the 1st period of slow extraction beam in 2009, and further 1 week beam time to finalize this measurement after summer shutdown in 2009.

1 Introduction

COMET would make use of a pulsed proton beam in order to suppress the beam related prompt backgrounds. The number of residual protons between pulses normalized by the number of protons in a pulse is called "extinction". This extinction is one of the most important features of the pulsed proton beam for COMET as described in [1, 2].

The specifications of the pulsed proton beam for COMET are shown in Table 1. It is already mentioned in [2] that the realization of the COMET experiment strongly depends on the intrinsic extinction of J-PARC/MR. For example, if the extinction is 10^{-9} level on a secondary particle production target from the beginning, there will be no need to spare human resources to the extinction developments. If the extinction is

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Table 1: Pulsed Proton Beam for COMET.

Beam Power	> 56 kW
Energy	8 GeV
Average Current	7 μA
Beam Emittance	$< 10\pi$ mm·mrad
Protons per Bunch	$< 10^{11}$
Extinction	$< 10^{-9}$
Bunch Separation	1.2 μsec
Bunch Width	< 100 nsec

much worse than 10^{-9} level, we have to put substantial resources to the development of either or both of a beam line with an external extinction system and/or an in-ring bucket sweeper system. In order to obtain basic information about the order of extinction level of extracted proton beam, we would like to request beam time to study the extinction by using secondary beam. Details of the plan is described in the following sections. This test will be the base of future R&D work to achieve required beam quality of COMET, and in that sense will be very important.

2 Measurement at K1.8BR Beam Line

The best way to study the extinction would be to count directly the number of protons in the MR. However this requires significant technical challenges to use a detector in an extremely wide dynamic range ($\sim 10^9$) with fast response (<100nsec) [1]. Therefore we would like to start our study by adopting a simpler method using secondary beam.

It is expected that secondary particle production reflects the beam structure when proton beam is irradiated on a target. The longitudinal beam structure can be studied by selecting secondary particles directly produced in proton reactions with target material. Various kinds of particles are produced in reactions depending on the proton energy and production angle. In order to view a structure of the primary proton beam, only particles produced in prompt reactions must be utilized. It is better to use charged particles since the measurement is disturbed in case delayed neutrons enter the detection system. Particle identification is necessary because different kinds of particles arrive at the detection system with different time-of flight. It is presumably better to perform particle separation by using a DC separator because the measurement can be biased by decay-in flight of secondary particles like kaons.

Based on this consideration, we would like to request to perform a measurement of the extinction at K1.8BR in the coming period of J-PARC MR operation with slow extraction. The K1.8BR beam line is scheduled to be used by the E17 group during the period of the 1st operation of MR with slow extraction. Our measurement is anticipated not to conflict with E17 (and the consecutive experiment at the same

[1] R&D work of such device is in progress in the COMET collaboration

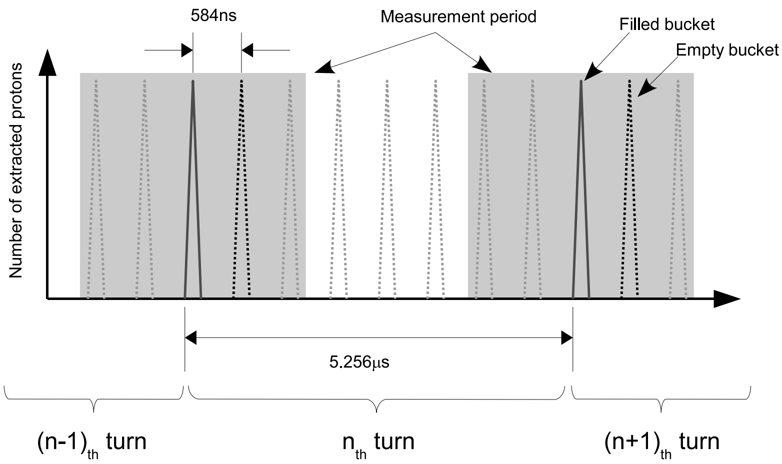

Figure 1: A timing structure of extracted proton beam for the extinction measurement.

place, E15) data acquisition. Schedule and possible setup will be discussed thoroughly with the members of the E17/E15 group.

We prefer to perform the measurement at the proton energy of 8GeV, but 30GeV operation can also be acceptable since there is no transition in proton acceleration in the MR and thus there will be no significant difference of the longitudinal proton beam structure between 8GeV and 30GeV. We expect "single bunch" operation of the MR with low proton intensity (4×10^{11} proton per bunch) and harmonics number of 9. RCS is necessary to be operated by filling only one bucket with the operation harmonics number of 2 in order to follow the proposed beam acceleration scheme of COMET [1]. Extraction of the proton beam is necessary to be done in the "slow-extraction" mode without switching off the acceleration RF voltage to realize the condition for the COMET experiment (bunched slow extraction). The maximum duty factor of the RF system is designed to be 60%. We think that this is achievable by reducing the RF voltage during extraction. Details of the extraction technique need to be discussed with experts of the accelerator groups.

Figure 1 shows a time structure expected by above mentioned acceleration and extraction. Our extinction measurement is focused in the area as indicated in Figure 1. If there is any particle leakage during injection from the LINAC to RCS, acceleration in RCS, injection to the MR, acceleration in the MR, and/or extraction from the MR, we would see particles in other regions than the peak. The ultimate goal of the COMET beam requirement is to realize a beam extinction level of 10^{-9}. Since it is not possible to confirm this level in a single measurement of secondary particles, we will integrate our measurement in 1k to 50k proton accelerations (spills) depending on the extinction level and secondary beam intensity.

The proton beam structure can be investigated by measuring time difference between the time of the secondary particles arriving at the detection system and that of the reference signal provided from the accelerator. We are planning to use an RF reference signal for this purpose but a further detailed study is necessary to obtain a precise (a few nsec) reference signal in the experimental area.

The secondary particle arrival time is measured by using a set of plastic scintillation counters located in the area. We need at least two counters to perform particle identification using time-of-flight, although we will prepare more than two for advancing reliability of the measurement. Actually there will be three sets of hodoscope counters for the E17 experiment placed before the final focusing point (FF) where the stopping target of E17 will be located [4]. The first counter will be located in front of the 1st dipole magnet behind the beam sweeping magnet for K1.8BR and K1.8 beam lines. The second counter will be located behind the 1st dipole magnet, and the 3rd one will be behind the 2nd dipole magnet. We expect counter signal from these can be provided for our study without disturbing E17/E15 data acquisition. Another hodoscope counter will possibly located by ourselves 10 m downstream of the last beam line hodoscope counter in order to obtain reliability of the measurement, which is expected to be very effective to reduce accidental overlap, and to perform particle identification using time-of flight.

Figure 2 shows a layout of the K1.8BR beam line. The beam line will be tuned to transport 1.0GeV/c secondary particles. We are planning to use pions since time-of flight of pions is less affected by momentum dispersion of the secondary beam line and the number of produced particles is expected to be large even with lower proton intensity. Time-of flight of pions from the T1 target to the FF points is estimated to be 91nsec. Kaons (β=0.90) and protons (β=0.73) will arrive at the FF about 9.5 nsec and 33 nsec later respectively than pions, which are not negligibly small compared to the size of time structure of the proton beam. As already mentioned, we are planning to locate a hodoscope counter at an order of 10m distance downstream of the other for particle identification using time-of flight (37.2nsec for pions and 45.8nsec for kaons). It is not difficult to achieve a few hundred psec time resolution using recent technology, thus we expect particle separation of pions from kaons and protons with sufficient purity.

The expected number of pions for 4×10^{11} protons is estimated to be 50k for one acceleration cycle. This is evaluated from the number of expected kaons described in [3] for the case when the ratio of the production cross sections of pions to kaons is 50 at 30GeV. The signals from the counters will be recorded in a conventional DAQ system including TDC, ADC and scalers. Counting coincidence rate between the counter and reference signals (RF) with different delays can provide sufficient information about the proton beam timing structure without suffering from the DAQ dead time. It is also considered to sample waveforms of the counters in order to gain the reliability of the measurement.

3 Measurement Plan and Cost

Before starting the measurement it is necessary to perform beam line tuning for 1.0GeV/c pions at K1.8BR. In fact the E17 group will also need beam line parameters for 1.0GeV/c pions in their studies, thus we can collaborate for this purpose.

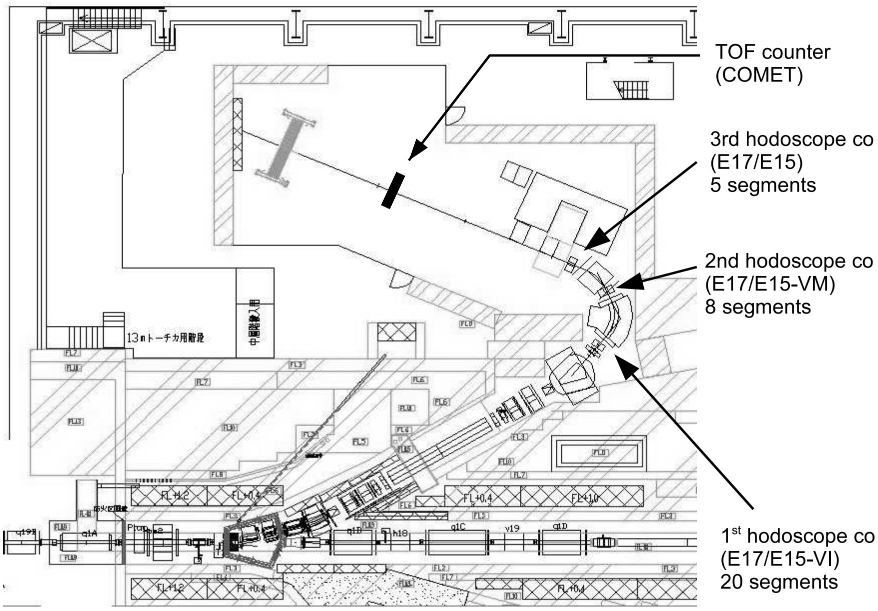

Figure 2: Layout of the K1.8BR beam line.

According to the E17 group, they will continue their beam line studies before staring physics data acquisition in autumn 2009 for about 40 days between January and March in 2009. We would like to request 1 day beam time, dedicated to COMET extinction study, at the end of their beam line study period. We plan to perform beam related background study (counting rate of each hodoscope counter, possible contribution by slow component like neutrons, and so on) that must be understood before performing further measurement.

The extinction measurement itself at K1.8BR can be finished within a few days with sufficient statistics. We plan to perform this measurement after the E17 group finishes their physics data acquisition in October 2009. We request 1 week beam time for this purpose including accelerator study period for preparing slowly extracted proton beam with pulsed time structure. We would like to discuss details with accelerator and beam channel groups based on the result of the first measurement including a possibility of MR operation at 8GeV.

A rough cost estimation is made as summarized in Table 2. We expect that we can utilize beam line counter signal provided by the E17/E15 group. We need to construct a time-of-flight hodoscope counter to be located 10m downstream of the last beam line hodoscope counter. For data acquisition and data analysis, we can employ equipments used in our R&D works and do not need to newly invest a lot.

Table 2: Rough cost estimation of the extinction study at K1.8BR

Item	Cost (kJPY)
TOF hodoscope	
Scintillator	200
Photomultiplier	1,800
Cables	300
Supporting frame	150
Electronics parts	200
Articles of consumption	200
Total	2,850

4 Summary

We would like to propose an experiment to study the proton beam extinction by using secondary particles.

The measurement will be done at the K1.8BR beam line where the E17/E15 group is launching experiments. We have discussed and (will continue to) how to share the the location and equipments in order to minimize the impact and to perform data acquisition efficiently. Our measurement consists of two parts. The first one is for understanding beam line background during the phase of E17/E15 beam line study which is scheduled between January and March in 2009. The second part will be realized after the E17 group finishes there physics data acquisition in October 2009. We plan to perform extinction measurement using secondary beam in this period.

Our beam time request is summarized in Table 3.

Table 3: Beam request for the extinction study at K1.8BR

	1st measurement	2nd measurement
date	2009/3	2009/10
beam time	1 day	1 week
beam energy	30GeV	8GeV or 30GeV
beam time structure	bunched slow extraction	bunched slow extraction
Number of filled buckets	1 out of h=9	1 out of h=9
secondary beam	pion 1.0GeV/c	pion 1.0GeV/c
secondary beam rate	50kHz	$>$ 50kHz

We would like to request also strong support for providing a reference signal of beam timing from the accelerator to the counting room.

To ensure success of the COMET experiment, it is necessary to obtain sophisticated proton beam with very small extinction level. We would need extra-extinction device(s) to realize such beam. This measurement can provide basic and important information for defining the direction of future R&D works of the COMET experiment.

References

[1] Propsal to J-PARC 2007, The COMET collaboration. available at http://comet.phys.sci.osaka-u.ac.jp

[2] COMET Report submitted to the 5th J-PARC PAC meeting. available at http://research.kek.jp/people/mihara/COMET/PAC-2008/pac-2008.pdf

[3] KEK Internal 2007-1, August 2007

[4] H.Outa and the E17 group, private communication