INTENSITY ASYMMETRIC MULTIPLE SLOW EXTRACTION AT THE KEK-PS

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Abstract

Intensity asymmetric simultaneous extraction to multiple beam lines at the KEK 12GeV Proton Synchrotron has been performed for physics experiments since the end of 1995. The exctracted beam to one beam line is about 1/100 lower intensity than another. This weak beam has been utilized for the primary beam experiments with stable spill quality.

1 INTRODUCTION

Resonant slow extraction is widely used in existing synchrotrons. Some of them have two extraction lines and simultaneous beam extraction for multiple beam lines are carrying out in order to save the operation time. They are symmetric in resonant phase.

Fig.1 is a schematic drawing of the KEK-PS. The KEK-PS has three beam lines which consist of two slow extraction beam lines (called EP1 and EP2) and one secondary beam line of the internal target (IT). In usual, we extract the beam only to either EP1 or EP2 beam line with parasitic IT beam. Since the EP1 and EP2 beam lines have their own independent extraction system designed for single extraction, they are not symmetric in resonant phase.

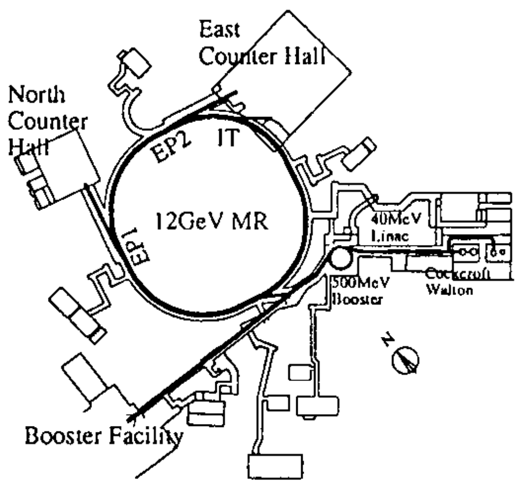

Figure 1: Schematic drawings of the KEK-PS.

The test operation for the double slow extraction was started in 1992, the basic design work was performed[1]. In this case, though much efforts was spent to guarantee the same intensity on the extracted beam both EP1 and EP2 beam lines, it found difficult to utilize them for the physics experiments due to their unstability and large beam losses without building a new extraction system. However the physics committee proposed the intensity asymmetric multiple extraction in late 1995 accompanied with the build of the new branch of the beam line called EP1-B. The EP1-B was designed for very low intensity beam of under 5×10^{10} [ppp]. This new offering required the intensities of EP1, EP2 and IT of about 1:100:10, respectively. The very weak extracted beam is utilized for the experiments on the primary proton beam.

The test operation of the simultaneous multiple beam extraction began to start again with largely asymmetric beam intensity.

Table 1: Expected beam losses.

case 1	case 2	case 3
4 %	5 %	22 %

case 1: EQ1 for EP1 or EQ2 for EP2
case 2: EQ1 for EP2 extraction
case 3: EQ2 for EP1 extraction

2 EXTRACTION SCHEME

2.1 Double Slow Extraction

The extraction system of the KEK-PS is designed to utilize the $2\nu_h = 15$ half-integer resonance[2]. The EP1 and EP2 extraction system are almost same. The slow extraction system consists of one perturbing quadrupole magnet called "EQ", one octupole magnet called "OCT" and two electrostatic septa "ESS" and five magnetic septa "septum A to E". The "EQ" is installed in order to produce a half-integer stopband and the "OCT" is to separate unstable phase space region. On the horizontal tune getting closer to the half-integer, the stable region in phase space becomes smaller and beam particles begin to spill out of the accelerator. The beam particles spilled out are consequently shaved by "ESS" and deflected to the beam line by magnetic septa. The extracted beam is controlled by the spill-servo system feeding back the spill intensity[3][4]. The spill-servo system has two inputs. One is the circulating beam intensity just before extraction process and the other is the realtime spill intensity. The spill-servo system controlls the purturbation quadrupole based on these signals in order to keep the spill intensity to the constant.

In double slow extraction, we have two purturbation quadrupoles. Table 1 shows the predicted beam loss during the extraction period in three cases.

Obviously the case 1 which is the ordinary extraction

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scheme shows the best extraction performance. Though the case 2 is acceptable, the case 3 is not. This results determines that the using EQ1 is the unique solution for the double slow extraction. In case of the EP2 main channel mode, the EP2 spill intensity feeds back to the EQ1 through the spill-servo system.

2.2 Internal Target

The Internal Target(IT) is the oldest system which was applied for the physics experiments in the KEK-PS. The IT system consists of the two bump magnets called "IT-bump", and two target arms including a spare arm. The circulating beam is bended out by IT bump magnets and one target arm is inserted into the beam line during the extraction period. The secondary beam intensity produced through the target is about 1/10 of the primary extracted beam in usual. Unfortunatery, because the IT bump cannot be completely closed due to their series cabling, it can largely affect on the intensity of the weakest beam in case of the multiple extraction.

3 RESULTS

3.1 Beam Intensity and Spill

The intensity asymmetric multiple extraction has started in extracting the weak beam to the EP1-B line which is referred as the EP2 main channel mode. The EP1 main channel mode is expected to run in this autumn.

In both cases, multiple extraction has to start the single extraction (very often with IT) using EQ1 purturbation quadrupole magnet. The EP1 main channel mode starts the ordinary EP1 extraction operation. Then turning on the EP2 extraction system with guradually raised bump magnets. Fig.2 shows the extracted beam spills, circulating beam intensity and current of EQ1 magnet of the EP1 main channel mode. Table 2 shows the intensities of extracted beams. In case of the EP1 main channel mode, the interfere on the main spill from the multiple extraction is very small.

Table 2: Beam intensities in [ppp] of each extraction modes.

Timing	EP1 main	EP2 main
P3	2.9e+12	2.8e+12
EP1	2.4e+12	2.0e+10
EP2	2.4e+10	2.0e+12
IT	1.0e+11	3.3e+11

P3: acceleration end corresponding to just before the extraction.

Fig.3 shows those of the EP2 main channel mode. In case of the EP2 main channel mode, firstly the EP2 single extraction tuning utilizing EQ1 is performed and then turning on the EP1 extraction system. The EP2 extracted beam

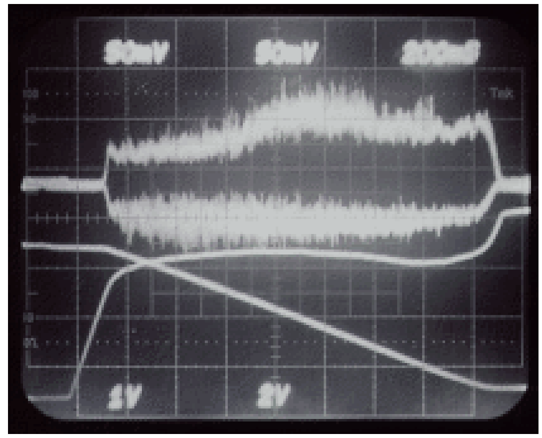

Figure 2: EP1 main mode. Extracted beam spills (EP2 was reversed), circulating beam intensity and EQ1 current.

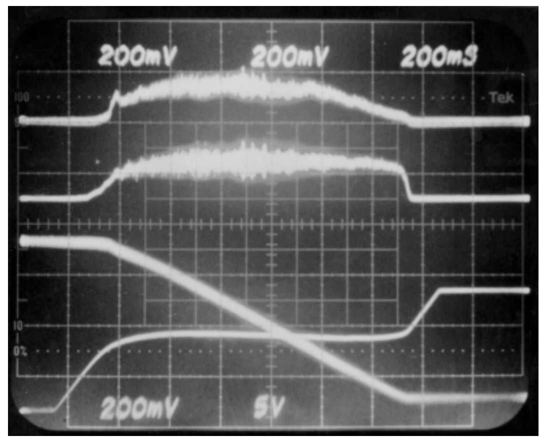

Figure 3: EP2 main mode. Extracted beam spills, circulating beam intensity and EQ1 current.

has a different angle with respect to the ordinary extraction which is achieved by EQ2. Fig.4 and Fig.5 show the beam profile at EP2 after the ESS measured by a single wire profile monitor. The single wire profile monitor consists of the scattering wire and loss monitors. A number of particles corresponding to the beam profile scattered by a wire are detected by a loss monitor placed just behind the wire. Fig.4 is in the normal extraction by EQ2. The island of the center is of the extracted beam profile and the right continent is the coast of the circulating beam. Fig.5 is of the multiple extraction by EQ1. The beam profiles are shifted to the inner of the ring and close each other. The septum A and B have to be moved to the appropriate position on the multiple extraction.

As mentioned in Table 1, the amount of the beam loss with respect to the EP2 extraction utilizing EQ1 is expected to be almost the same as that under the normal operation. However the extraction ratio of the EP2 main channel mode is under 80%. In actual, the beam loss at the EP2 during extraction period became above twice, especially on ESS and Septum A which were the upstream of the extraction

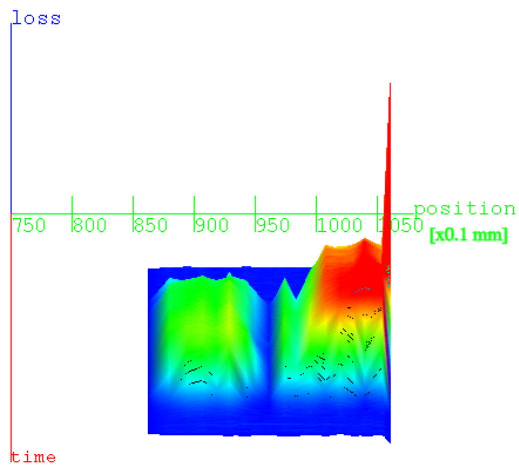

Figure 4: Ordinary extracted beam profile after ESS.

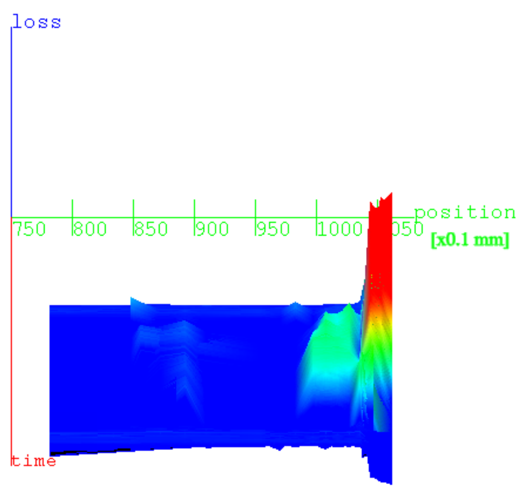

Figure 5: Beam profile of the EP2 main mode after ESS.

septa, according to turning on the EP1 extraction. This comes from the unseperation between shaved beam by ESS and circulating beam as shown in Fig.5. Moreover the inscrutable islands were found in the profile measurements in later runs. This problem has not been solved yet even in the simulation.

3.2 Stability

In the case of the EP2 main channel mode, the stability of the beam intensity and spill structure were monitored.

- December 1995, 2 days (the first try)
- January 1996, 6 days
- February 1996, 8 days
- April 1996, 14 days
- May 1996, 6 days
- October 1996, 8 days

  including no IT extraction period

Although the weakest EP1 beam intensity varied in 1.7 to 3.4×10^{10} [ppp] during above period, it could be corrected very easily. Any serious changes on the spill structure did not observed. The multiple extraction has enough stability.

On April 1997, the first try of the EP1 main channel mode has done. Though this test ended in half a day, it seemed to be also very stable.

4 CONCLUSION

The intensity asymmetric multiple beam extraction of 100:10:1 was successed and being applied for physics experiments nowadays as the usual operation. Over the 3 experiments goes at the same time on our three beam lines. This intensity asymmetric multiple beam extraction is our answer to the strong requirements to get more machine time for the physics experiments.

5 REFERENCES

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