UPGRADING OF SLOW EXTRACTION OF KEK-PS

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Abstract

At the extraction line EP2 of KEK 12GeV Proton Synchrotron (KEK-PS), power of slow extraction instruments were improved to realize duty factor upgrading. On the other hand, additional slow extraction system to new counter hall was installed at the other extraction line EP1.

Introduction

Two upgrading projects of KEK PS was completed. One was duty factor upgrading of existing extraction proton line (EP2) and another was construction of new extraction proton line (EP1) in addition to EP2. Two sets of extraction instruments were installed in summer 1990. Powers of EP1 system was higher than old EP2 system but a little bit lower than new EP2 system. Both lines were in principle the same half integer resonant extraction lines.

Duty factor upgrading is elongation of the flat-top from 0.6 sec to 2.1 sec, and the extraction cycle from 2.6 sec to 4.1 sec [1,2]. The flat-top is a portion of the extraction cycle of the magnetic field, during which the field strength is kept maximum and the circulating beam is extracted to the experimental area. The data taking efficiency in physical experiments is expected to be improved with a longer extraction (spill) time.

The beam intensity of KEK-PS is gradually increasing and will reach 10^{13} protons per pulse (ppp) in the future. This intensity can not utilized in the existing counter hall (East Counter Hall, the end of EP2), since the radiation shielding is designed against only 10^{12} ppp. Then the new experimental hall (North Counter Hall), designed for high intensity beam [2], and extraction line (EP1) was constructed.

Extraction system is consist of magnet system, power supplies to these magnets, some monitors and control system. Fig.1 shows the magnet systems installed in the Main Ring tunnel. One system is composed of an electrostatic septum (ESS), five septum magnets (Sep.A, B, C, D and E), four bump magnets (B1, 2, 3 and 4), an octupole magnet (OCT), an extraction quadrupole (EQ) and two ripple compensation quadrupoles (RQ1 and 2). Fig.2 shows septum magnet layout and monitors. There are four single wire profile monitors (SWPM) connected to four beam loss monitors (LM) along the extraction line. In addition we can use secondary emission chambers (SEC), some fluorescent screens (FS) and segmented wire ion chambers (SWIC) along the beam line [3], which are made by beam channel group. Fig.3 shows control system of an extraction line. The main instruments were controlled by microcomputer VME-bus system [4].

There was no instrumental change to Internal Target. It is parallel used with both slow extraction at EP1 or EP2.

Accompanied to the flat-top elongation, we expected the increase of the ratio of spill intensity. We introduced new spill control techniques and reduced the fluctuation ratio to the same level as that was before flat-top elongation. This technique is represented on other report in this symposium [5].

Magnet system

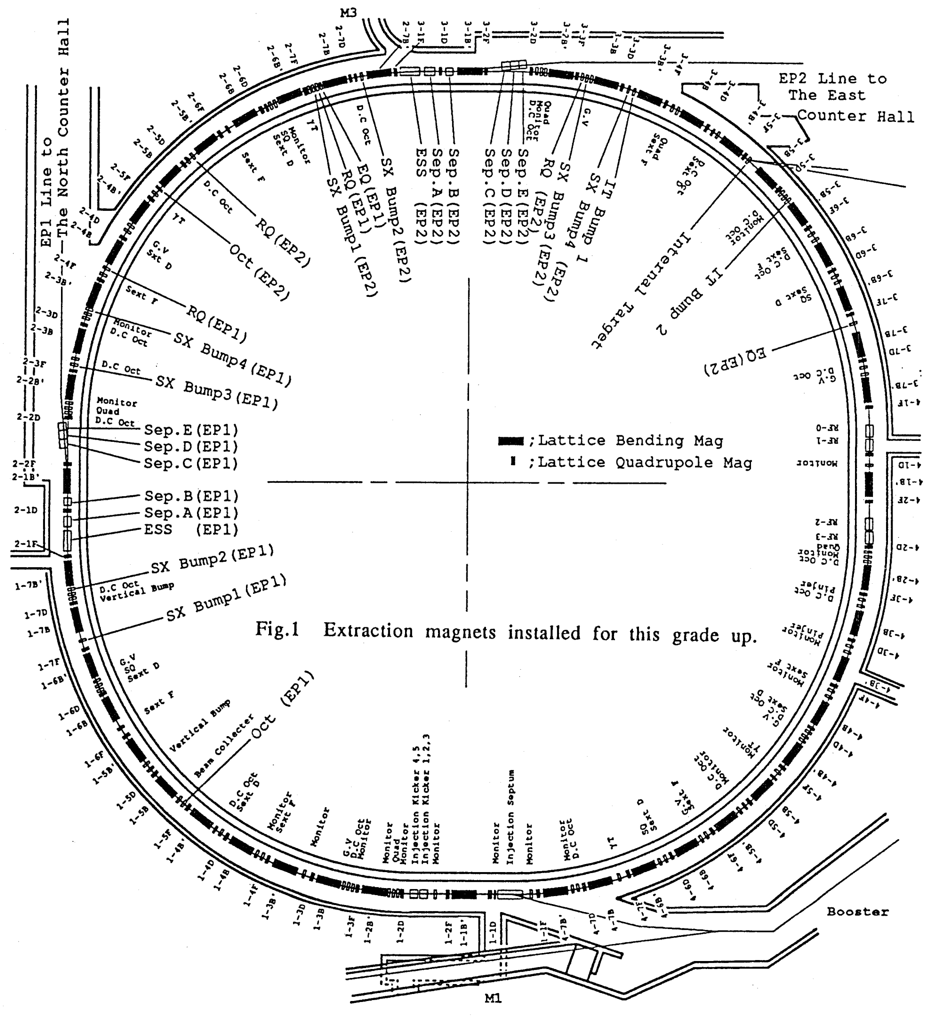

Fig.1 Extraction magnets installed for this grade up.

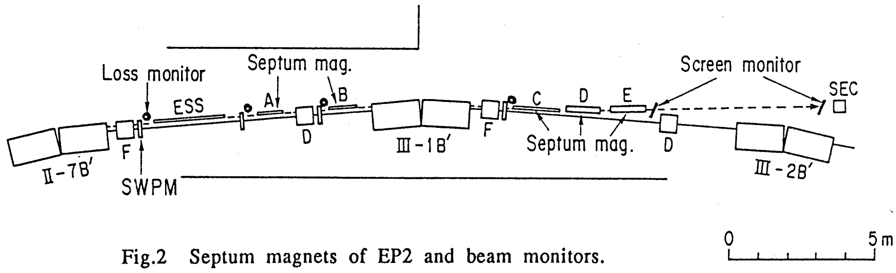

Fig.2 Septum magnets of EP2 and beam monitors.

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Parameters of septums are listed in Table 1. ESS, Sep.A and Sep.B are almost the same types as old types. Sep.C, D and E are upgraded. B1-4 ,OCT and EQ are replaced by new ones. Old air core RQs are used for EP2, but new RQs for EP1 are thin iron core magnets. All magnets had low hysterisis laminated iron cores.

The most serious limit on flat top elongation was heat problem of Sep.D and E (They were the same type magnets). Their thin coils curved suddenly at the both ends of septums. Because thin pipes for water cooling could not curve such suddenly, there were small part where coils were not cooled. We managed to minimize such uncooled part. Then we got enough heat tolerance for our purpose. The thickness of the septums were 32 mm, which were made of 8 turn 3.2 mm thick coils. Each coils were insulated by 0.6 mm ceramic coating, and were cooled by two water cooling pipes with inner diameters of 2.3mm. There were 16 water cooling circuits for one septum. Septum D and E works with mean current of more than 3000 A, with the water pressure loss of 6 kg/cm^2.

Table 1 Parameters of extraction septums.

septum	ESS	Sep.A	Sep.B	Sep.C	Sep.D	Sep.E
thickness(mm)	0.1	1.0	2.0	16.0	32.0	32.0
length(m)	1.5 X 2	0.9	0.7	1,5	1.3	1.3
field strength	6MV/m	0.08T	0.16T	0.8T	1.6T	1.6T
deflection angle(mr)	1.4	1.6	2.5	28	49	49
environment	vacuum	vac.	vac.	air	air	air
max. current (A)	0.003 X 2	3500		6000		

Power supplies

All of power supplies for EP2 was replaced by new ones, except for 200kV DC power supplies for ESS. All of power supplies for EP1 were the same type as those for EP2. Auxiliary power supply room M2 is extended to install EP1 power supplies (we refer nM2 to this room).

Power supplies for Bumps, EQ and OCT are Transistor regulated power supplies. Power supplies for Sep.A,B and Sep.C,D,E have achieved stability of 10^{-4} including both reproducibility and ripple. They are thyrister regulated power supplies, which have 50 Hz and 100 Hz ripple reduction feed back system with narrow band pass filters. Power supplies for RQs are DC power amplifiers commercially available.

Control system

Fig.3 shows the control system of magnets. VME crates are set at each power supply room (M3, A47 and nM2) and central control room (CCR). All crates and graphic consoles are connected with VME-bus MAP system. On VME crates Digital Delay boards set extraction timings, DA boards produce reference pattern signals of magnet excitations, Relay boards control ON/OFF and RESET of power supplies, Digital input boards and AD boards

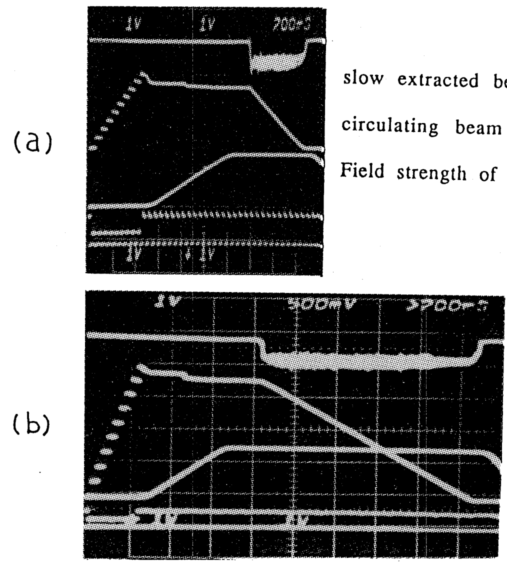

Fig.4 Slow extraction beam spill of EP2, beam intensity and bending magnet current (a) before and (a) after flat-top elongation. Horizontal = time scales are the same for both (a) and (b).

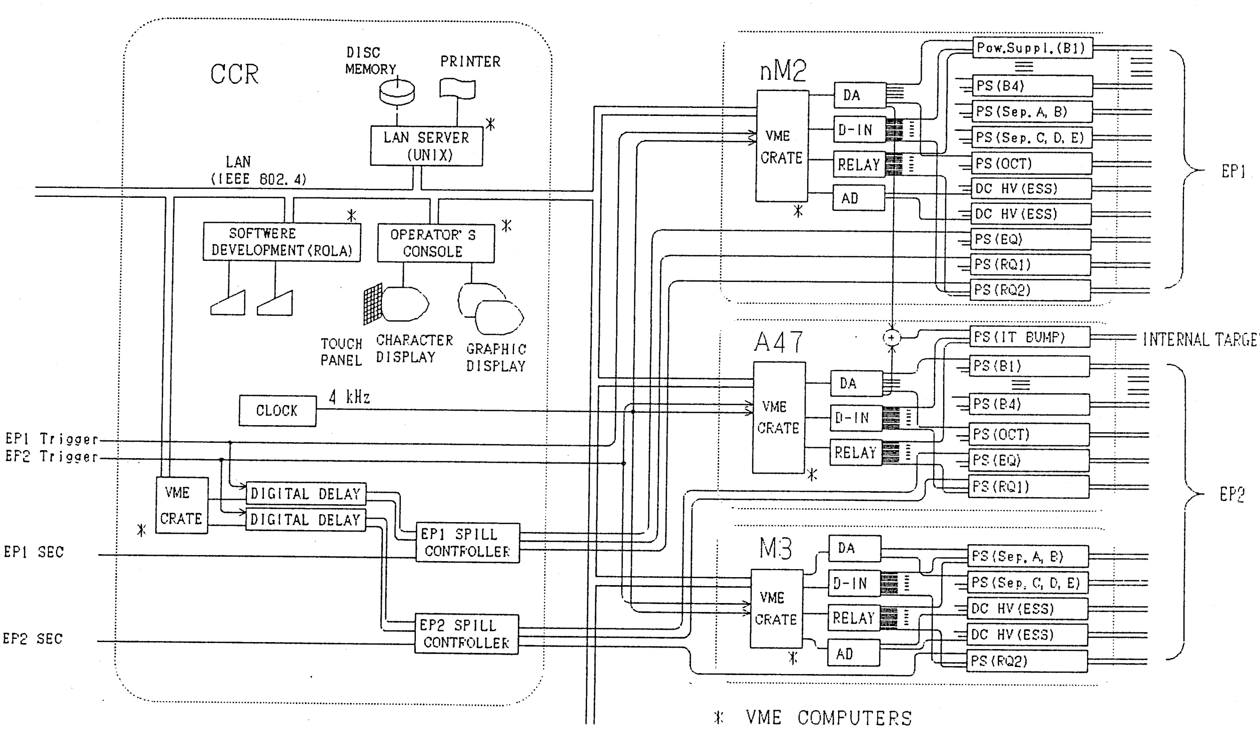

Fig.3 Control system of extraction magnets.

set extraction timings, DA boards produce reference pattern signals of magnet excitations, Relay boards control ON/OFF and RESET of power supplies, Digital input boards and AD boards monitor status of power supplies. Safety signal stops power supplies of Sep.A,B and Sep.C,D,E. This works independent to VME computer [4]. Positions of ESS and Sep.A,B and SWPM will be controlled with VME in the future. Basically the real time feedback for the beam spill control was not changed, and is now separated from VME.

Status of extraction

Flat Top Elongation

In October 1990 the proton beam was successfully extracted with the long spill time of about 2 sec. as shown in Fig.4. The proton beam was extracted to the East Counter Hall through EP2 with an efficiency of more than 90%. After this success of the beam extraction, the long spill beams have been supplied as a routine operation of the KEK PS for high-energy physics experiment.

The spill length for North Counter Hall through EP1 was 1.5 sec, a shorter than EP2 due to the heat problem. Internal Target spill length was the same as that of main slow extraction.

Extraction to North Counter Hall

In January 1991 the proton beam was first extracted to North Counter Hall. The routine operation started in June 1991 with beam intensity of 3×10^{12} ppp.

The system is basically the same as that of EP2, except for heat tolerance, but the extraction efficiency is about 85%. At present we have not investigated exactly why the efficiency of EP1 is worse than that of EP2. In Fig.5 shows beam size of extracted beam. The thin solid lines were calculated trajectories and the shadows represent horizontal beam profile measured by SWPM. We represent principle of SWPM and example of data in Fig.6 The beam was normally extracted with an sufficient turn separation.

Extraction to Both of Counter Halls

Pulse to pulse alternating extraction to East Counter Hall and North Counter Hall was succeeded in May 1991. The parallel run with Internal Target will be possible in this autumn.

Simultaneous extraction to two lines was not succeeded yet. We extracted 2×10^{12}ppp to North Counter Hall and 1×10^{11}ppp to East Counter Hall simultaneously. But we couldn't increase the extraction rate to East Counter Hall without serious beam loss. The study will be going on.

Acknowledgement

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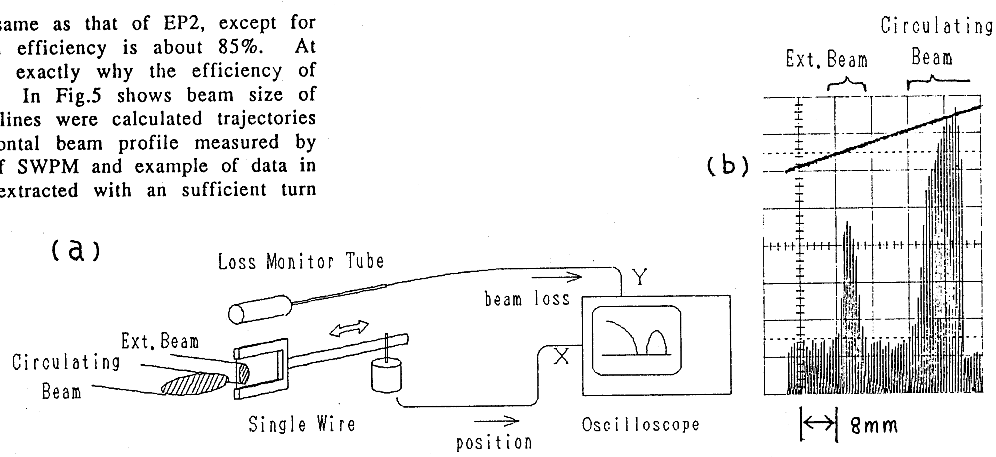

Fig.6 (a) Principal of SWPM. (c) Beam profile at the upstream end of Sep.B. Circulating beam and extracted beam are separated enough.

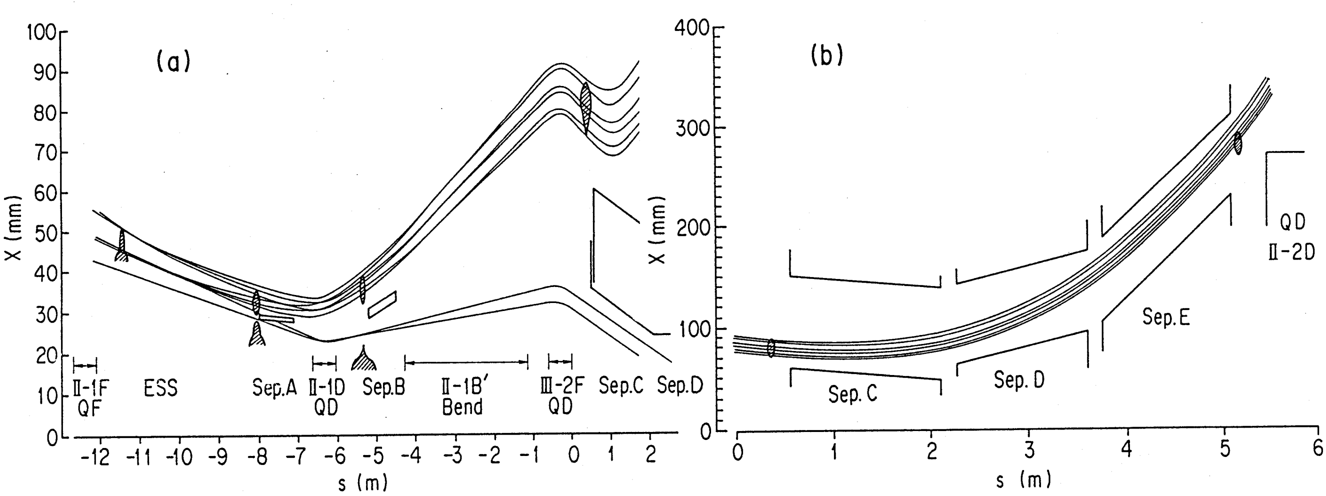

Fig.5 Beam size and trajectories of EP1 extracted beam (a): from ESS to Sep.C and (b): from Sep.C to Sep.E. The shaded features represent measured beam size. They are measured with SWPM except one at downstream end of Sep.E, which is measured with Fluorescent Screen. Solid lines are particle trajectories calculated from the strength of septums.