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Status of the KEK-PS Main Ring

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Abstract

The KEK-PS has been operated successfully to serve an intense proton beam for the past two decades. To meet the need of new physics research, there are several objectives for the PS upgrade, such as, to increase the proton intensity in the main ring, to accelerate the various ions and then the multifunctional operation of PS. Especially, an intensity upgrade is coming to the urgent problem for the long baseline neutrino oscillation experiment and the rare event experiment. Machine study to make clear the machine parameters and to find the curing of the difficulty to increase the beam intensity has been under going. In this article, the brief history of KEK-PS, an operation status and an upgrade subjects will be described.

1. Brief History and an Operation Status

The KEK-PS consists of four accelerator complex, 750KeV Cockcroft Walton pre-injector, 40MeV injector linac, 500MeV booster synchrotron and 12GeV main ring. Brief history of the KEK-PS is shown in Table 1. Counter experiment started on July, 1976 using the secondary beam from an internal target and the fast extraction for bubble chamber experiment[1] and the slow extraction at 12GeV[2] started on January and November, 1977, respectively. Booster Synchrotron Utilization Facility to utilize surplus 500MeV proton beam started on October, 1980. In those days, beam intensity at the booster extraction and in the main ring were 6×10^{11}ppp and 2×10^{12}ppp, respectively. In order to aim the intensity upgrade, booster injection system was changed to H^-injection one[3] from former positive ion multi-turn injection and the linac was subsequently upgraded to 40MeV after the long shut down on 1984. As the results of much effort, the beam intensity was increased to 5.4×10^{12}ppp in the main ring on June 1989 and 2.4×10^{12}ppp for BSF on May 1990. On the other hand, a polarized proton beam acceleration (typically 40% polarization at 3.5GeV) was performed during those days.[4]

Newly second slow extraction line (EP1) and North Counter Hall were established on 1990[5] at the terminated bubble chamber experimental area besides the EP2 line for the East Counter Hall. Since then, the slow beam is extracted to both counter halls independently. Simultaneous extraction has been desired but the feasibility study is still under progress. Figure 1 shows a layout of the KEK-PS complex.

Main ring power supply and equipment for the slow extraction had been upgraded[6] at the same time of the construction of EP1 line, then the main ring operation cycle was elongated up to four seconds and the slow extracted beam spill is 1.7-2.0 seconds. The spill servo controller was improved as a consideration of the frequency response analysis of the slow extraction process using the measured beam transfer function and the frequency response of the servo control devices.[7] This contributed to reduce a spill fluctuation about 10-db and the extracted beam spill efficiency is maintained about 90%. However, the extracted beam spill has been sometimes getting an uncharacteristic frequency due to an incoming disturbance in the commercial AC line.[8]

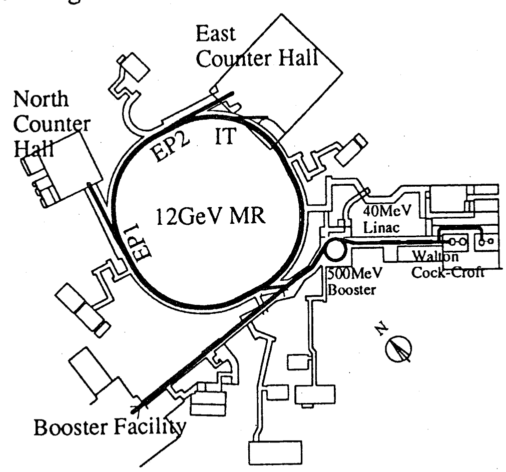

Figure 1. Layout of the KEK-PS Complex.

After successive operation of switching between polarized proton beam acceleration for main ring and high intensity proton beam for BSF, research and development for effective use of PS have been performed, such as deuteron and alpha beam acceleration[9] and also beam was extracted at various energies. Especially, newly developed septum-bump injection system, which is the magnet system available for both negative ion charge exchange injection and positive ion multi-turn injection.[10] This is very noble system and contribute to avoid much troublesome changing the injection system with a large scale evacuating process.

Although the highest beam intensity in the main ring was upgraded to 5.4×10^{12} ppp on 1989 and increased to 5.95×10^{12} ppp on November of 1994, we do not find and fixed yet the machine parameters for reproduction of this condition and an average intensity during operation has been still 3-4 $\times10^{12}$ ppp.

For reliable acceleration of low intensity beam such as alpha beam and polarized beam, high sensitive beam monitors are going to install in the booster and the main ring.

One of the most effective upgrades for stable acceleration of intense beam and ions is an improvement of rf system,[11] such as a voltage-controlled oscillator, phase detectors, function generators, feedback loops and so forth.

Total operation time was more than 4500 hours per year for a recent few years, and 70-77% was dedicated to physics experiment and about 15% was used for accelerator study and tuning. The accelerator was operated in fairly good condition with less than 5% machine failure.

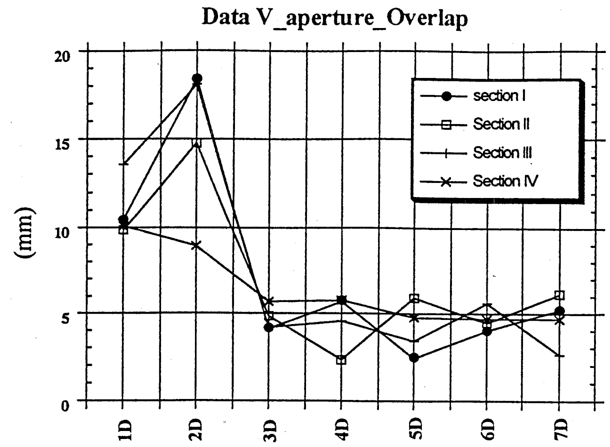

Figure 2. Results of the local aperture survey using local bump method. First and second cells are missing bend ones.

2. Intensive Machine Study for the Main Ring Intensity Upgrade

As described above, every effort to realize the upgrade of KEK-PS have been devoted. Booster synchrotron accelerates 1-2 x 10^{12} ppp for Booster Synchrotron Facility. If the main ring can accept and accelerates the beam of this intensity with no beam loss, 10^{13} ppp beams could be expected for main ring utility. However, the circulating beam intensity is limited to about 6 x 10^{12} ppp for some reasons which is not still understood. An intensive machine study has been performed to make clear the machine parameters and to find the cause and curing of the difficulty in order to realize the beam intensity upgrade.

First of all, several tools for the machine study were developed, such as an upgraded injection error monitor, a fast beam loss monitor which can observe it turn by turn using computer workstations and so forth.[12)]

After several times brain storming, the aim of the first study was decided to concentrate the main ring beam injection problem. The local aperture measurements of the main ring were performed to make clear the real orbit center in the vacuum chamber using a small size beam scraped in the booster synchrotron. The twenty eight steering dipoles were excited independently to make a local bump orbit at each section in the main ring. The vertical aperture seems to be determined by the diameter of the vacuum chamber in the bending magnet as shown in Figure 2.

The orbit was set to the center of the vacuum chamber as decided above, then the beam survival were measured to make clear and maximize the acceptance with dependence on the injection error made by injection kicker and septum magnet for the horizontal plane and by steering magnet in the transport line for the vertical plane. Data analysis is under consideration since there are some problems to make sure the systematic errors of twiss parameters and beam position monitors.

The usual operating point of PS main ring is at around ν_x=7.12 and ν_y=7.25 and the average beam intensity from the booster is 4-5 x 10^{11}ppp. In order to avoid beam loss due to the space charge detuning for a high intensity beam, it should be select rather higher operating point. However, a third order resonance, $\nu_x + 2\nu_y = 22$, and fourth order resonances, particularly $4\nu_y=29$ and $2\nu_x + 2\nu_y = 29$ seem to be obstacles. After these resonances were corrected as established using rather low intensity beam, high intensity beam, 1.3 x 10^{12}ppp, were injected from booster and measured the tune mapping of beam survival as shown in Figure 3. There is no region where more than 70% of the beam survives. A fast beam loss is brought at around an operating point with smaller tunes, on the other hand a slowly beam loss is brought at around an operating point with larger tunes. Further studies should be necessary to make clear these effect and how to cure.

Summary of the spring studies, which includes also some results at the studies performed before summer shut down, will be reported soon in KEK Report.

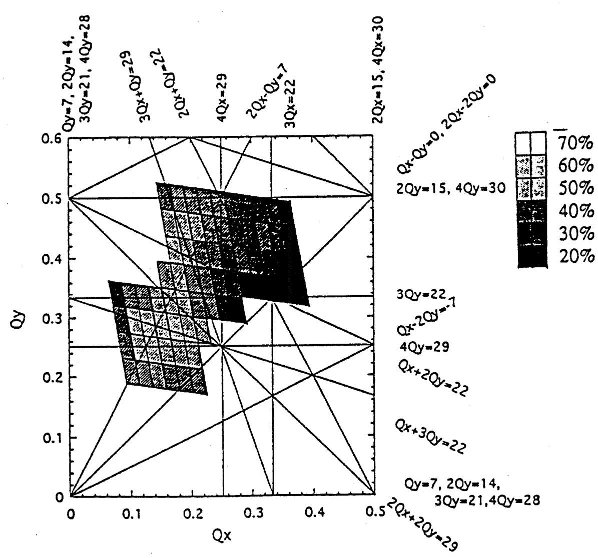

Figure 3. Tune mapping of the beam survival injected the intensity of 1.3 x 10^{12}ppp from booster. Intensity ratio of the beam survival until 350ms after injection to that from the booster.

3. Design status for the fast extraction system

Fast extraction had been operated until July, 1981, for the bubble chamber experiment as a shaving extraction.[1)] At this time, full beam which is circulating in the main ring, should be extracted instantaneously for the neutrino oscillation experiment. Then, several research and development have been done.

Construction of 12.5Ω kicker magnet and Blumlein system are advantage from the view point of economy and saving the space of magnet setting. Prototype one has just constructed and is facing on the exciting test.

Orbit analysis for the feasibility using existing slow extraction devices, such as bump and septum magnets system is under consideration. This is important for the switching the fast extraction and the slow extraction for multi user request. We are considering now the changeable system of the extraction kicker and electro-static septum in the vacuum chamber. A large orbit excursion is the problem since the extracted beam passes through non linear magnetic field region of both bending and quadrupole magnets. In order to construct economically, reconstruction of these magnets should be avoided. Detailed analysis of the magnetic field and orbit calculation using this data are under going.

4. Summary

Acceleration of 5.95×10^{12} ppp intense beam has achieved, however, an average intensity during normal operation has been still 3-4 $\times 10^{12}$ ppp.

Although the spring studies were concentrated to the problem during injection period, the reason of the beam loss was not still understood yet . Further we should make clear the problems at acceleration start and transition crossing to realize the beam intensity upgrade.

Twenty years has passed since the KEK-PS constructed, then several equipments and parts become decrepit, then taking into consideration for this problem is also important subject for the reliability of machine operation.

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References

1) J. McCARTHY and Y.Kimura KEK-74-16
2) K.Endo and C.Steinbach KEK-77-13
3) T.Kawakubo, Nucl.Instrum.& Methods, A265(1988)351
4) H.Sato et al., Nucl.Instrum.& Methods, A272(1988)617
5) K.H.Tanaka, Proc. of the workshop on Science at the Kaon Factory, Vancouver, 1990, p.1
6) H.Sato et al., Proc.of the 1991 IEEE Part. Accel. Conf., 1991, p.908
Y.Shoji et al., KEK-93-10
7) H.Sato et al., 9th Sym. on Accel. Sci. & Tech., 1993, p.376
T.Toyama et al., 9th Sym. on Accel. Sci. & Tech., 1993, p.404 and to be presented in this Symposium
8) H.Sato et al., Proceedings of the 1st Symposium on Power Supply Tech. for Acc., KEK Proceedings 95-3, p.60
9) Y.Mori et al., Proceedings of the 1993 IEEE Part. Accel. Conf. , p.3754
I.Sakai et al., Presented at the IEEE Part. Accel. Conf. , Dallas,1995 and to be presented in this Symposium
10) I.Sakai, Presented at the 14th Int.Conf.on Magnet Tech., Tampere, Finland,1995
11) S.Ninomiya et al., KEK-93-4
12) M.Shirakata et al., to be presented at the ICALEPCS 95, Chicago, Oct. 1985

Table 1. History of KEK Proton Synchrotron

April	1971	Construction started
June	1974	Pre-injector accelerated protons to 750 KeV
August	1974	Injector linac accelerated protons to 20 MeV
December	1974	Booster synchrotron accelerated protons to 500 MeV
December	1975	Commissioning of main ring operation
March	1976	Main ring accelerated protons to 8 GeV
December	1976	Main ring accelerated protons to 12 GeV
May	1977	Bubble chamber experiment started
June	1977	Beam intensity of booster was 6×10^{11} ppp
November	1977	Counter experiments with slow extracted beam started
July	1978	Beam intensity of main ring was 2×10^{12} ppp
June	1980	Experiment with Booster Synchrotron Utilization Facility started
July	1981	Babble chamber experiment was terminated
May	1984	Pre-injector acceleration duct was renewed
[Long shut down during TRISTAN tunnel construction]		
June	1985	Booster injection system was changed to H- injection
November	1985	Linac upgraded to 40 MeV
May	1987	Experiment using polarized proton beam started
May	1988	Accelerator control was upgraded to MAP
June	1989	Beam intensity of main ring upgraded to 5.4×10^{12} ppp
May	1990	Beam intensity of booster upgraded to 2.4×10^{12} ppp
August	1990	Main ring power supply was upgraded
January	1991	Counter experiment at the North counter hall started
February	1992	Deuteron beam was accelerated to 11.2 GeV
April	1992	Experiment with deuteron beam started
April	1994	Septum-bump injection system was developed
April	1994	Alpha beam accelerated to 23 GeV and experiment started
August	1994	Realignment of the booster magnets