PRESENT STATUS OF KEK 12 GeV PROTON SYNCHROTRON

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INTRODUCTION

Since 1977, KEK-PS has supplied the proton beams to the various experimental programs for seven years, and shutdown over one year started March this year ('84) due to the tunnel works for TRISTAN project. In the early days of beam utilization ('77 - '79), the beam from the main ring of PS only was provided for the physics experiments, so the booster accelerated and extracted the only nine bunches in the accelerating cycle of the booster. But with completion of Booster Synchrotron Utilization Facility (BSF) in 1980, the booster began to accelerate the beam in all cycles of 20Hz to deliver BSF the surplus bunches other than the above nine bunches.

The beam from the main ring have been used mainly for the experiments of the high energy physics before shutdown, however, after shutdown, the scientists of other regions, the major power of which may be the nuclear physicists, will become the new users of the main ring of KEK-PS besides the high energy physicists. In order to move against this new situation, a working group to suggest the future plan for the studies with 12 GeV PS was organized. A half year deliberation by the working group had the result of settling on the following three targets of the studies, -(1) physics with Kaon beam, (2) physics with polarized beam, (3) physics with light ion beam.

In this report, the present condition of the beam of PS complex, and outline of the progress way of preparation by the accelerator crew for the above future plan are described.

CONDITION OF THE BEAM

Injector (preinjector + linac)

Output intensity of the preinjector consisting of a duoplasmatron type ion source, a 750kV Cockcroft-Walton type high voltage generator and an accelerator column, is 2.3×10^{13} P/P (320mA × 11.5μS) and its normalized emittance is 3mm•mrad. Figure 1 shows output signal of a current detector at the exit of the preinjector. The bunch from the preinjector is chopped to 5μS in the transport line to the linac and its intensity reduces to 4.5×10^{12} P/P at entrance of the linac. The beam accelerated up to 20MeV through the linac has the intensity 3.0×10^{12} P/P (140mA × 3.5μS) in average and 5mm•mrad normalized horizontal and vertical emittance. Figure 2 shows output signal of a current detector at exit of the linac.

Booster

The booster receives the beam of 2.2×10^{11} P/P (100mA × 3.5μS) passing through the 20MeV transport line with 70% transmission efficiency using the method of horizontal multi-turn injection. The beam loses 50% of the injected particles during the process of multi-turn injection. The acceptance of booster is filled up with the beam at the end of the injection process, so addition of synchrotron oscillation to betatron oscillation due to applying of increasing RF voltage brings continuous radial expansion to the beam, as a result, the beam continues to lose the particles until 1ms after injection. This loss is ∿ 40% of the particles survived in the injection process. After all, the injected particles from the linac to the booster lose 70% of them at this stage. These losses are the largest one during the total accelerating process of KEK-PS, and the reason of the loss is an inevitable result of the multi-turn injection method, not the bad condition of equipments nor the unskilled operation. The notable beam loss can not be seen except the above large loss in the booster and a bunch of 80ns long including 5.5×10^{11} particles with 500MeV kinetic tic energy is extracted every 50ms. Figure 3 shows the output signal of a particle number detector of the booster. Normalized horizontal emittance measured at 500MeV transport line is 20mm•mrad and vertical emittance, 15mm•mrad. Cause of threefold blow up of the vertical emittance is not be made clear yet.

Main ring

The nine extracted bunches from the booster are sent to the main ring and thirty eight bunches to BSF in one cycle of the main ring. The transmission efficiency from extraction of the booster to the final point of the injection porch of the main ring is 80 ∿ 90 %, and the efficiency to the final after that - 85 ∿ 90 % in average - depends on mostly the condition of passing through the transition point.

The nine bunches reached 12GeV kinetic energy are debunched by some manipulation of the RF equipments at early stage of the flat top of the magnetic field. A great part of the debunched beam is slowly extracted into the beam channel to the experimental hall by use of half integer resonance, and a small fraction of the beam hits the internal target to generate the secondary particles. Intensity of the circulating beam of 12GeV is 3.5×10^{12} P/P in average and of the slowly extracted beam 3.2×10^{12} P/P, its normalized horizontal emittance is 97mm•mrad, vertical 92mm•mrad and ΔP/P is ± 0.35%. Particles hitting the internal target are ∿ 1.2×10^{12} P/P. Figure 4 shows output signal of a particle number detector in the main ring.

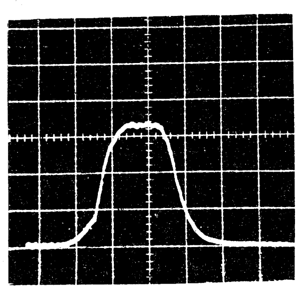

Fig. 1 Signal of current detector at exit of preinjector.
H; 5μs/div. V; 100mA/div.

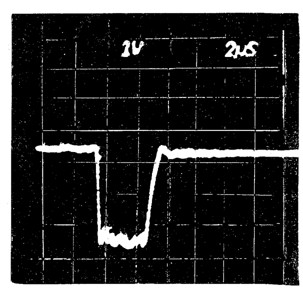

Fig. 2 Signal of current detector at exit of linac.
H; 2μs/div. V; 50mA/div.

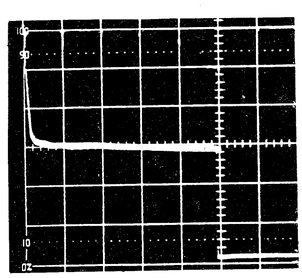

Fig. 3 Signal of particle number detector in the booster
H; 5ms/div. V; 2×10^{11} p/div.

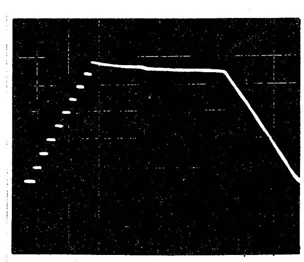

Fig. 4 Signal of particle number detector in the main ring.
H; 200ms/div. V; 1×10^{12} p/div.

CONDITION OF OPERATION

Operation of eight hours is a minimum unit of the operation schedule called "shift", and thirty shifts form one "cylce" which is operation term of ten days from Wednesday morning to next Saturday morning. The fourteen or fifteen cycles of operation are consumed in a year. Seven laboratory staffs and four temporary employees per day attend to oeration of the accelerator.

Operation hours of PS in a year are 3600 hours in average, 70% of which are spent by the various experiments, 20%, study of the accelerators, 3% are failure time of the accelerator and 7% others. Figure 5 shows the failure statistics of each part of the accelerator in last year ('83) and Fig. 6 operation hour statistics from 1977 to 1983.

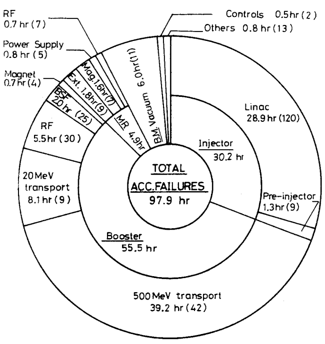

Fig. 5 Failure statistics of accelerator in '83.

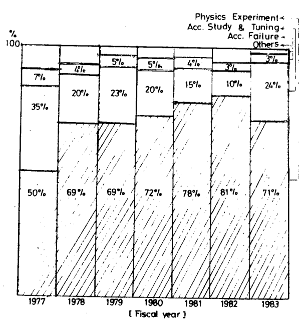

Fig. 6 Operation statistics of accelerator since '77 to '83.

PREPARATION FOR FUTURE PLAN

As stated before, the three themes for the future plan -(1) physics with Kaon beam (2) physics with polarized beam(3) physics with light ion beam- were suggested as the targets of studies with KEK-PS. PS crew is carring out the preparation works for these plans besides operating PS.

Increase of intensity of protons as the primary particles by adoption of charge exchange injection to the booster and extention of the linac energy to 40MeV were attemped for the plan (1).

A high current polarized ion source was already constructed and measures for depolarization resonance occurring in acceleration of the polarized proton beam are studying now for the plan (2).

For the plan (3), an idea of the light ion acceleration by means of a just few modification of the present PS system was found and investigation of the various kind of light ion sources are in progress.

The preparation work for the plan (3) is in the stage of the desk work yet, but they for the plan (1), (2) are in the stage of the practical work and the first experiments on charge exchange injection to the booster and acceleration of the polarized protons were tried last autumn. As the details of the experiments are reported in each session of this symposium, only their outline are described here.

Charge exchange injection

As stated before, the highest beam loss exists in the injection stage and early stage of acceleration of the booster. The purpose of adoption of the charge exchange injection method is to reduce this beam loss as much as possible to increase the output intensity of PS. Charge exchange injection makes superposition of the beams in the phase space possible by releasing the beam from the restriction of Liouville's theorem, and this can clear the limitation for acceptable particle number with the present multi-turn injection method.

The preinjector including a multicusp ion source extracted 20mA H^- ion beam with 100μS duration each pulse and 8mA with 100μS duration (5×10^{12} particles) was injected to the booster and converted to the proton beam by passing through a carbon stripping foil placed at the injection point of the booster. Accumulated protons at final of injection process are 2.1×10^{12} per pulse, whereas the maximum accumulated protons by the multi-turn injection are 1.2×10^{12} per pulse, that is, improvement of 75% increase of intensity was seen in this stage in the booster with the new injection method. The normalized emittance of H^- beam measured at 20MeV transport line was 2mm•mrad and 40% of the present emittance of proton beam. The beam intensity reduced to 9×10^{11} P/P during 1 ms after the accumulation final, its authentic reason is not obvious at present. There was further 20% beam loss over 8ms after that, therefore the final intensity was $\sim 7 \times 10^{11}$ P/P, however, this last beam loss was temporary one coming from a sudden trouble of the high power part in the RF system. Then a guarantee value of intensity of the booster after shutdown will be 9×10^{11} P/P.

The only one problem in the charge exchange injection to KEK booster is that multiple scattering and energy loss of the circulating beam by a stripping foil is larger because of the lower injection beam energy.

Energy extension of the linac will be expected to reduce above disadvantage, besides it will contract the emittance of the linac beam and raise the space charge limit of the booster. In the routine operation after shutdown, H^- beam instead of proton beam will be emitted from the ion source and injected to the booster.

Acceleration of polarized protons

The main tasks for acceleration of polarized particles are construction of a high current polarized ion source and skillful avoidance of the depolarization resonances. In PS division, a high current polarized ion source using optical pumping with dye laser was constructed already and various measures are being taken to avoid the one intrinsic and one imperfection resonance in the booster, and the eleven intrinsic and twenty two imperfection resonances in the main ring.

A term of the test experiment for acceleration of the polarized protons was so short, only three weeks, that there was no time to try to accelerate the polarized beam in the main ring, however, depolarizations in the booster were studied enough and the hopeful results were obtained.

The ion source emitted the polarized H^- ions instead of the polarized protons for charge exchange injection to the booster, and the polarized protons were accelerated up to 500MeV in the booster, then injected to the main ring. The polarizations of the beam were measured at the 20 MeV transport line and in the main ring.

Intensities of polarized beam at each position in PS were as follows.

ion source	(H^- , 750keV)	$\sim 4.5 \times 10^9$ P/P
linac	(H^- , 20MeV)	$\sim 4.5 \times 10^8$ P/P
booster	(P , 500MeV)	$\sim 3 \times 10^8$ P/P
main ring	(p , 500MeV)	$\sim 2 \times 10^8$ P/P

The measurements show that spin was almost completely flipped by two strong depolarization resonances in the booster as expected, but there was a weak resonance causing the large depolarization. Fortunately, this depolarization was reduced enough by excitation of a correction quadrupole magnet.

The polarizations of the beam measured at each polarimeter were

$\sim$ 50%,	20MeV transport line
$\sim$ 13% (500 MeV),	main ring

Excitation of the above correction quadrupole magnet could increase 13% polarization up to 20%, so the remained polarization (polarization in the main ring/ polarization in the linac) became finally 40%.

The trial of acceleration of the polarized beam in the main ring will begin soon after shutdown.