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Test of the PS new slow extraction scheme

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ABSTRACT

A new scheme for the PS slow extraction was proposed in 1986 and later installed up to a point where the main features of the machine optics could be checked. The operation of the conventional East Hall extraction was stopped during two weeks from May 8 to 19 1989 in order to carry out tests of this first part of the installation. The measurements and tuning performed during this period are described. The performance proves to be as good as that expected from simulation programs, so that we are now quite confident that this new scheme can deliver to the East Area a beam of equivalent quality to the present slow extraction. The advantages are a reduced number of septa, which are shielded from the synchrotron radiation produced during lepton cycles, a reduction of the total straight section space needed and an increase of the extraction spill length.

Introduction

A new scheme for the PS slow extraction was proposed in 1986 [1]. One year later, it was decided to start the installation up to a point where the main features of the machine optics could be checked [2].This includes the quadrupoles, sextupoles, part of the bumpers and the electrostatic septum, but not the thin and extraction septa, This preliminary installation was completed only in February 1989, due to delays in the delivery of vacuum chamber components. In the mean time, a more precise study of the scheme had been performed with the computer simulation program MAD [3]. The operation of the conventional East Hall extraction was stopped during two weeks from May 8 to 19 1989 in order to carry out tests of this first part of the installation. The measurements and tuning performed during this period are described.

Preparation

The power supplies of the conventional extraction were used and connected to the new elements in the ring with the following correspondence table:

Bumps 83-85 (dipoles 80+82+88+90) ---> Bumps 23 (dipoles -19-27)
Bumps 61-62 (dipoles 59-75) ---> Bumps 57 (dipoles -53-61)
Quadrupoles 23+53 ---> Quadrupoles 29+87
Sextupole 53 ---> Sextupoles 7+19

The new electrostatic septum is mounted in S.S.23 towards the inside of the PS. It is fitted with a miniscanner upstream. The standard positions of the anode is just outside the chamber, at -72 mm, the gap being 17 mm and the high voltage 150 kV (same electric field as the present S.S.83 septum).

The rest of the new equipment in the ring consists essentially of a screen and minitoposcope in S.S.57, to observe the extracted beam. The latter was read by a software program specially written [4], and acquisition hardware kindly lent by the SPS division.

We benefitted from a new software [5] running in the console computer and easing dramatically the machine tune, since it calculates the new functions to be sent to the function generators from physical units such as the bumps in mm, Qh and the horizontal chromaticity.

The working point of the machine was then changed to the new requirements:

Qh= 6.20 and Chromh=-1

with the PFW currents on flat top:

Pfwf=176.4 A Pfwd=154.2 A B8=0

Q measurements were done in both planes to check this working point. The results are plotted on figure 1).

The flat top slope had to be changed from a decreasing field to a rising one. A preliminary tuning was made with the values:

C1000	C1200	C1500
11491 G	11535 G	11594 G

The polarities of the 4 auxiliary supplies were checked. The CODD was used to visualize the amplitudes of the bumps and verify the calibration of the local deformations:

BSW 23	-.086 mm / A
BSW 57	-.083 mm / A

The calibrations of the quadrupoles and the sextupoles were verified with the Q-meter. The results are plotted on figure 1). The calculated calibrations of these lenses were verified:

QSE DeltaQh = 2.1* 10 ** -4 / A

XSE DeltaXih = 2.25 * 10 ** -3 /A

Measurements performed

Aperture limitation

All elements were finally turned on (bumps, quadrupoles, sextupoles and electrostatic septum) and the extraction set up. It became soon apparent that the losses in S.S.25 were as high as those in S.S.23, and that very little beam arrived on the screen in S.S.57 with the correct deflection from the electrostatic septum. The simulation program was run and showed that the aperture in S.S.25 was not sufficient (figure 2)). It will have to be enlarged as in S.S.23, with 105 mm chambers in the two preceding and following magnets. In the mean time, it was decided to place the anode of the electrostatic septum at -65 mm from the center of the chamber, and the cathode at -82 mm.

Spill

It was then possible to extract the beam up to S.S.57 where it could be seen on the screen and sampled by the minitoposcope before being lost at the end of the straight section were the chamber gets narrower. The debunching was tuned exactly as for the conventional extraction. The spill could not be measured directly since it was not the purpose of this study. It was observed that the decrease of the intensity during extraction was extremely linear and could be made as long as 450 ms, significantly more than the present absolute maximum of 400 ms. This bonus is due to the fact that we do not have to cross the resonance before starting the extraction, as in the existing scheme. The amount of beam not extracted at the end of the flat top due to the zero width of the third integer resonance is similar to the conventional extraction (figure 3)).

Beam stability at the thin septum

During the spill, one could observe the beam moving on the screen of S.S.57, as in the conventional extraction. This is due to the variation of the average particle momentum during the extraction. It can be cured in three different ways: with a slope on the quadrupole, on the pole face winding, or on the S.S.57 bumps currents. All three methods were tested successively and successfully.

In the first case, a rising ramp from 5900 A to 6670 A during the 600 ms flat top of the quadrupole current was used. In the second case, the slope was positive (rising) for the focussing PFWF current with +4.8 A at the end of the 621 ms flat top, and negative (falling) for the defocussing PFWD current with -7.8 A. This method is better because it allows working with a constant and maximum kick enhancement. However, it turns out that the spill suffers from the insufficient resolution of the pole face winding function generators. Small steps appear in the current and produce discontinuities in the low frequency components of the spill. The new function generators foreseen will avoid this problem. The third method requires a slope of 90 A (the absolute value of the current is decreased in the bumpers) and works without any problem. The question of the choice between these three methods will have to be reconsidered anyway when the rest of the extraction is completed, since the beam stability is to be achieved at the extraction septum and not at the thin one.

Extracted beam edges

The effect of the electrostatic septum in S.S.57 was observed on the TV screen and measured with the minitoposcope. The strips are mounted 1.5 mm apart, so that it is not possible to know the width of the "hole" in S.S.57 with a good precision.

The edges of the circulating and extracted beams were quite steep right at the beginning. This means that the predetermined values of parameters from the simulations were close to the optimum. A last trimming was made with the chromaticity adjustment using the pole face winding currents as foreseen in [1].

Spiral pitch

The spiral pitch could not be measured with the miniscanner in front of the electrostatic septum because the noise level was too high at the low intensity used. But it can be derived from the minitoscope in S.S.57, knowing from [1] that a 11.5 mm wide beam in S.S.57 corresponds to a 10 mm one in S.S.23. One could change the spiral pitch using the Bumps 23 or the sextupole strength, as expected. We were limited by the acceptance in S.S.25, and had to limit ourselves to a 6 to 7 mm spiral pitch. Nothing should prevent to go up to 10 mm when this restriction disappears.

Vertical instability

The appearance of a vertical instability was noted for certain values of machine tune. A typical case was when the sextupole current was set to 260 A. Though precise Q-measurements could not be done, it is almost sure that the beam was sitting on the 6.25 resonance, enlarged by the octupolar components of the magnet fringe field in the local bumps. For reduced values of the sextupoles (207 A), the horizontal chromaticity must be increased to compensate. This is done with the pole face windings and moves away Qv from the resonance. This explains why the vertical blow up disappears. The effect of the 19 th harmonic of sextupole component on the spiral pitch can be compensated with the bump amplitude at the electrostatic septum, so that the quarter integer vertical resonance was avoided for the rest of the study.

Separation between circulating and extracted beam

Estimations from the printed output of the minitoposcope (figure 4)) give a maximum hole of 8 to 9 mm with the quadrupole current set to the maximum value possible with the Tekelec power supply. This agrees reasonably well with the expectations of [1] and [3], the first one being optimistic with a result of 8 mm for a quadrupole current of 650 A, and the second pessimistic with a result of 6.7 mm for 610 A in the quadrupoles.

The main parameters used after optimization of the machine to get these results were:

PFWF: 162.0 A   PFWD: 160.4 A   PFWB8: 0 A
Bumps 23: -546 A   Bumps 57: -692 A to -605 A
QSE: 650 A   XSE: 206 A   SES23: 150 kV

Next step

These results are all fairly consistent with the predictions from the previous studies. We are therefore ready to start with the detailed design of the remaining elements. These have been listed in [6] except that one item must be added to the equipment already foreseen: the enlargement of S.S.25 towards the inside. This is evaluated at a price of 45 kF [7], which brings the cost of the completion of the installation to a price of 1165 kF, if one retains the cheapest solution which consists in duplicating existing septa.

The planing has obviously to be actualized, since no fund is foreseen this year. All that can be said now is that two years of design and fabrication are necessary before the long shut down chosen for the installation.

Conclusion

A thorough study of the beam behaviour during the extraction was performed during this two weeks test. The machine optics could be experimentally observed up to the future location of the thin magnetic septum. The performance proves to be as good as that expected from simulation programs. We learned that an extra vacuum chamber enlargement has to be provided around S.S. 25, that vertical instabilities could appear but were easily avoided and that the future function generators of the pole face windings would be welcomed. Besides, we experimented a new operation assistance software which will soon be introduced for the conventional extraction.

We are now quite confident that this new scheme can deliver to the East Area a beam of equivalent quality to the present slow extraction. The advantages are a reduced number of septa which are shielded from the synchrotron radiation produced during lepton cycles, a reduction of the total straight section space needed and an increase of the extraction spill length.

To complete the installation, we must now build the three septum magnets for S.S. 57 (in vacuum), and S.S. 61 (both outside vacuum), the tank for S.S. 57 and the vacuum vessels for S.S. 61 and the enlarged chambers. The price estimate has been given in [6], to which a sum of 45 kF must be added for the extra enlarged chamber in S.S. 25, so that the total amount needed is 1165 kF.

References

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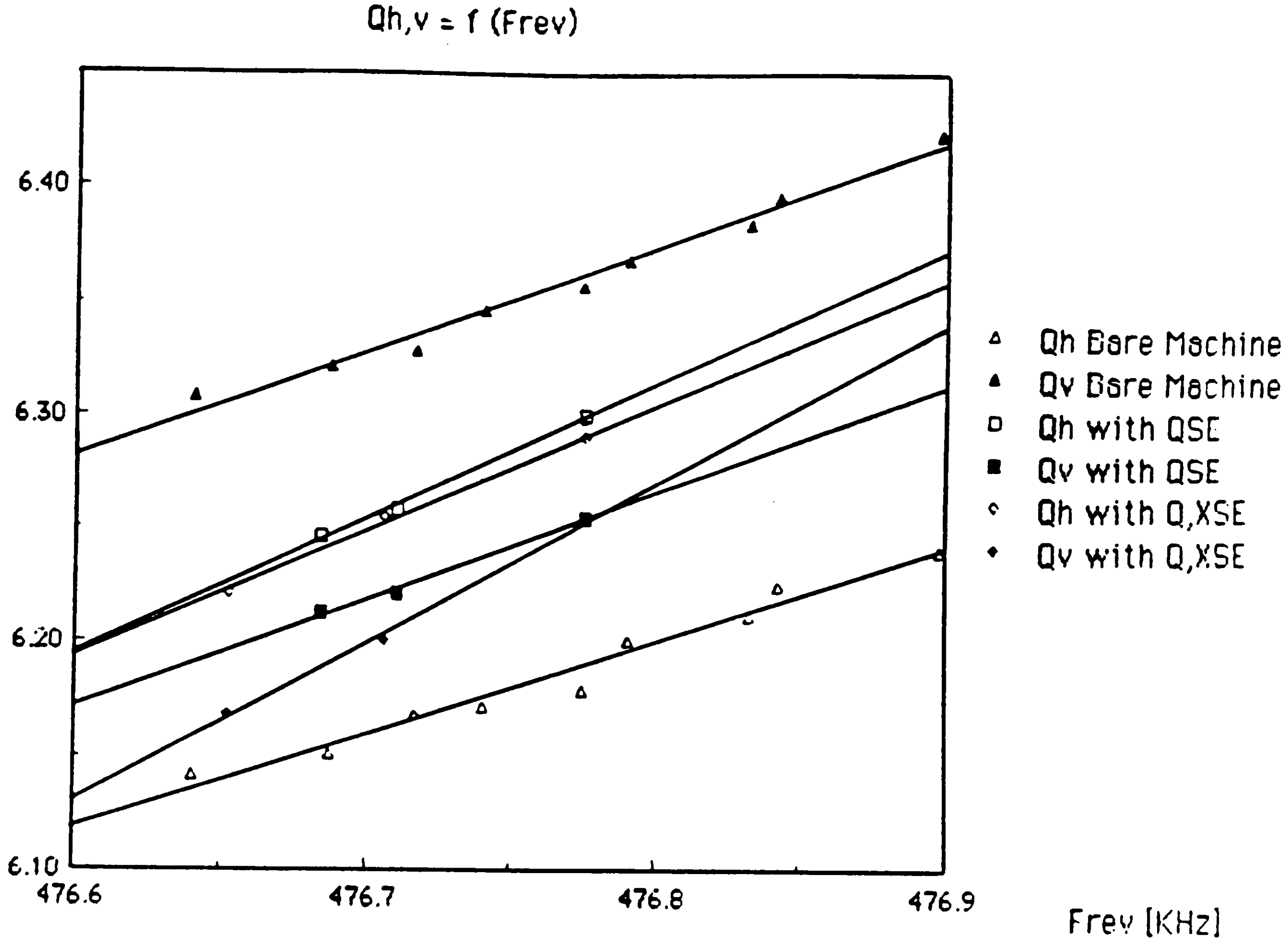


Fig. 1: Tune as a function of Revolution Frequency

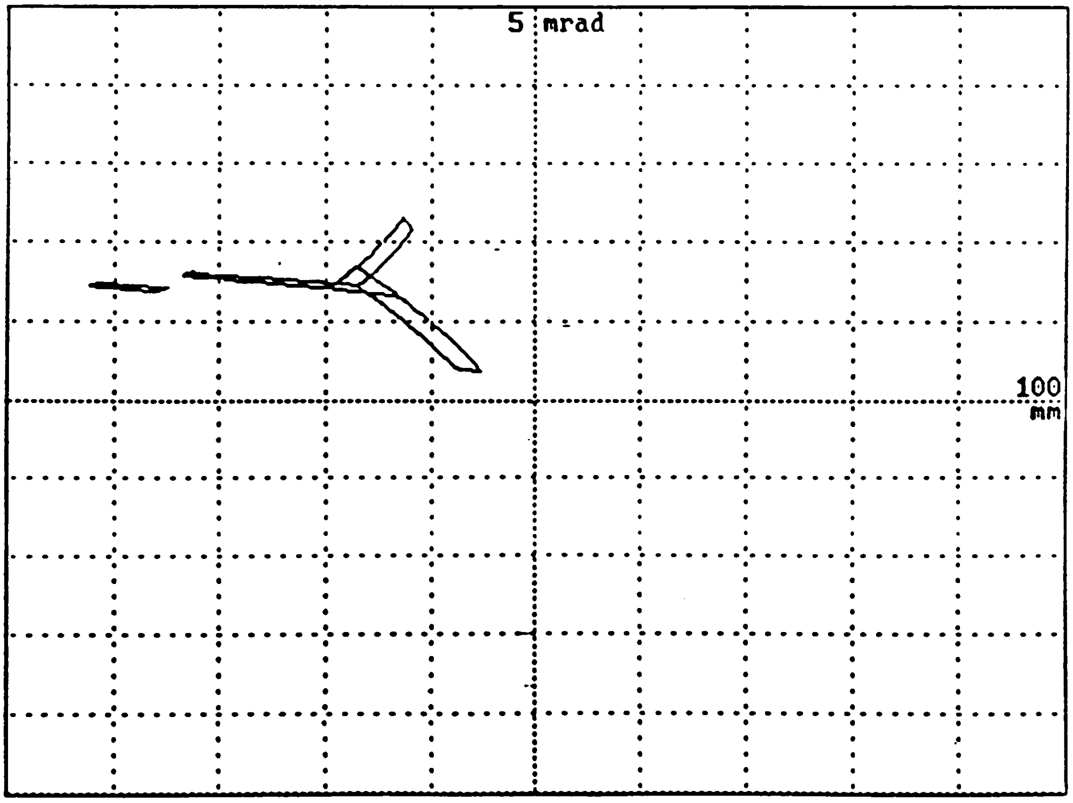
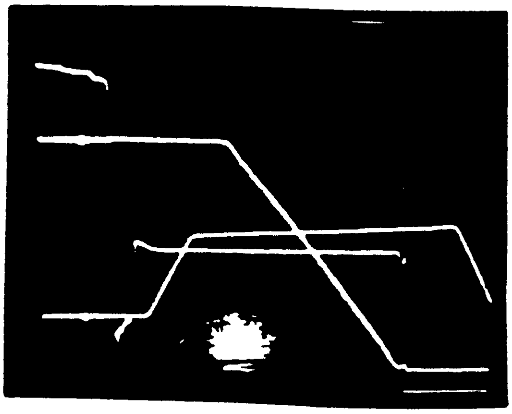


Fig. 2: Phase plane at S.S.25



Beam current Ip

QSE current

dB/dt

100 ms/div

Fig. 3: Circulating Beam Current, dB/dt, Quadrupoles Current vs time

```
100 I
    I
    I
    I
    I
    I
 75 I                     ***
    I                     ***
    I                     ***
    I                  ******
    I                  ******
    I                  ******
 50 I                  ******
    I                  ******
    I                  ******
    I                  ******
    I                  ******
    I                  ******
 25 I                  ******
    I                  ******
    I                  ******
    I***            *********
    I***            ************
    I***            ************
  0 I-+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+->
    0    3     6     9    12    15    18    21    24    mm

                BEAM PROFILE ON PR.MSG57

    MEASUREMENT NUMBER         :         36

    DELAYED MEASUREMENT TIME   :       1300 mSec.

    INTEGRATION TIME           :        100 mSec.
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Fig. 4: Beam Profile at Thin Septum Location

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