MULTIPLE TARGET EXTRACTION SHARING SCHEME AT THE CPS

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Abstract

The future CPS slow extraction system will be capable of sharing the beam between internal targets and either of two slow extraction channels. Simultaneous slow extraction sharing is possible when another pair of septa is added. A description of the system and results of tests with an experimental set-up are given.

1. Introduction

During the last years, the intensity of the CPS has increased and a further substantial increase is expected as soon as the CPS booster comes into operation. This will cause problems for counter experiments (counting rate) and especially for internal targets (heating, radiation damage). Moreover there will be from next year on, in addition to the existing slow extraction channel to the East Hall, a second channel feeding the Omega facility[13] in the West Hall. A similar run by run sharing system as it is used till now (one or more fast ejections, followed either by a long spill shared between two internal targets or by slow ejection) would give particles to each of the three counter experiments groups during 1/3 of the CPS operation only.

Experimentally it was shown[1] that a simultaneous target-slow ejection scheme would not be efficient enough with the present integer resonance. As a rule of thumb, the same percentage of the beam as was used on the target was lost somewhere in the machine because of the small momentum acceptance under resonance conditions. This limitation was expected to be less important in the case of a 1/3 integer resonance, which was confirmed by results at the AGS[2] and by tests at the CPS (see 3.2). Therefore, a new scheme employing the Q_R = 6 1/3-resonance, was developed which has the following features :

- Simultaneous sharing of slow ejection with internal targets (T1 or T8) is possible.
- The same set of extraction elements (except, of course, the extractor) can be used alternatively for both extraction channels 16 and 62.
- If a second set of electrostatic and thin magnetic septa is installed, simultaneous sharing between the two slow ejection channels is possible.

2. Lay-Out of the System[6]

Third integer resonances for extraction from synchrotrons usually are excited by several sextupoles suitably distributed around the accelerator[3][4]. Instead of these we will (mainly to save straight sections) use only one non-linear magnet, called semi-quadrupole. A cross-section of this magnet (essentially, it is one half of a Panofsky-quadrupole) is shown on Fig. 1. The main coils create the non-uniform field, dipole coils compensate the dipole component of the field at the center. The field (Fig. 1 bot.) is similar to the 'current strip' or to the perturbation used at the Bevatron[5], the main difference being that our perturbation includes no septum functions. When sharing the beam with an internal target, the particular shape of the perturbation (small field at the inner half of the vacuum chamber aperture) is advantageous.

An interesting property of the resonance excited by semi-quadrupole is the possibility to optimize the jump-spread by adjusting the relative position of the magnet with respect to the asymptotic orbit (Fig. 2).

A certain amount of 'Q-gymnastics' is necessary to prepare the ejection. The beam is first brought to the inside half of the vacuum chamber, then the Q of the machine is increased from its normal value of about 6.25 to about 6.36 by means of an auxiliary quadrupole. Finally the semi-quadrupole is switched on and, after debunching, the particles are spilt by a negative slope on the main field flat-top.

The resonance is created so that at the azimuth of the first septum one of the three groups of separatrices in the radial phase plane is parallel to the x-axis. This group is practically straight and has smaller distance between the separatrices belonging to different stable amplitudes than the other two groups. This not only gives the smallest horizontal emittance of the extracted beam but also minimises the required deflection by the first septum.

A three stage septa system will be used. An electrostatic septum[7] (0.1 mm foil, 80 cm long, $\leq$ 150 kV/cm) is followed by a thin magnetic septum[8] (1.5 mm septum, deflection to the inside $\leq$ 1.5 mrad) and by the extractor magnet - either EM16 (ejection towards the West Hall, 6.3 mm septum) or EM62 (ejection towards the East Hall, 5.8 mm septum).

Complications arise from the condition that it should be possible to fast eject part of the beam towards the West Hall (BEBC) during the same machine pulse immediately before slow ejection through the same channel.

The location of the two extractor magnets in the machine was given by the location of the external beam channels (distance : 2 7/8 betatron wave-lengths). A compromise had to be found for the arrangement of the other components in order to achieve the required high flexibility of the system (Fig. 3; possible locations for the second pair of septa would be straight section 47 (ES) and 49 (TSM)).

The system (as shown on Fig. 3) will be built into the machine at the beginning of next year and will start operation in spring 1972.

3. Experiments with a Test Set Up

3.1. Ejection Experiments

In order to check the computer calculations, to gain experience with the electrostatic septum and to prove the possibility of efficient sharing with internal targets, a series of experiments was made, ejecting into the existing channel towards the East Hall. For these tests, no thin magnetic septum was available, but an arrangement of the extraction elements could be found such that the effect of the electrostatic septum was amplified by the auxiliary quadrupole. Still, the septum had to work on the limit of sparking (between 170 kV and 200 kV over 10 mm gap) to obtain useful results. Using the secondary emission chamber (SEC)[9] ejection efficiencies up to 90% could be measured. About 1/3 of the loss was observed at the electrostatic septum, 2/3 on the extractor.

A sensitive property of a resonance ejection is the increase in amplitude over three turns of the particles being spilled. Fig. 4 shows measured and calculated values of the three-turn-jump as a function of the distance from the asymptotic orbit. The measurements were done with a small flag[10] ('Mini-scanner') in front of extractor 62.

In an external test beam we measured the vertical emittance of the beam containing 95% of the particles (similar method as described in Ref.2). We found $\varepsilon = 1.6\ \pi$ mm mrad (the value measured for the integer resonance was $\varepsilon = 1\ \pi$ mm mrad).

3.2. Target Slow Ejection Sharing Tests

The sharing experiments were performed with targets similar to those used in operation (Be, 1 mm Ø, 20 mm long). The sharing ratio was adjusted by changing the radial position of the target in the vacuum chamber. The intensity was between 1 and 1.5 Tp per pulse.

The question of defining sharing efficiency is a delicate problem. We have adopted the following procedure[11] :

- The slow ejection efficiency is measured with a secondary emission chamber (SEC) in the external beam, which has been calibrated by fast ejection. η_s ..efficiency without target, η_{st} ..efficiency with target.
- The target efficiency is measured with the aid of an air ionization chamber[12] (AIC; usually two independent chambers in the straight section of the target). AIC_t ..integrated signal of the AIC when all ejection elements are off (this calibration is of course dependent on target position), AIC_{st} ..integrated signal of the AIC when sharing with slow ejection. Both values are normalized with respect to beam intensity.

The sharing efficiency is then defined as :

$$\eta = \frac{\eta_{st}}{\eta_s} + \frac{AIC_{st}}{AIC_t} .$$

The results of the experiments can be summed up in the following way :

- The 'sharing efficiency' as defined above usually was 100% within the accuracy of the measurements, independent of sharing ratio, type of target support, and type of straight section (radially focusing or defocusing) (see Fig. 5 bot.). The losses on the extractor were increased by a factor 1.3 to 1.5.
- No difficulty was found to have target and ejection bursts at the same time; start and length of the bursts did not depend on the sharing ratio (without any servo system).
- Target and slow ejection bursts have the same low frequency structure (essentially 600 Hz from the provisional power supply of the auxiliary quadrupole). The degree of modulation is substantially smaller for high percentage than for low percentage or nothing on the target.
- Only very preliminary measurements of the vertical emittance of the ejected beam were made up to now. With 34% on the target, an increase by a factor 2 with respect to slow ejection alone was observed.

Using these observations and comparing with estimates on the basis of simplified models[11] we get a qualitative picture of the process :

- Under resonant conditions, the momentum acceptance of the machine is still big enough for the target process.
- The target is hit by unstable particles with jumps in the order of magnitude of the target diameter. This is also confirmed by computer calculations (Fig. 5 top).
- Protons hitting the target without making a nuclear interaction have a rather high chance to be stabilized and to be extracted later on. This explains, at least partially, the increase in emittance.

4. Acknowledgments

Y. Baconnier proposed using in the CPS a single non-linear element to excite the extraction resonance. His continuous interest and advice were a major contribution to the project. I greatly appreciate the support by G. Plass and U. Jacob. It is a pleasure to thank those who helped to prepare and do the experiments, in particular G. Petrucci and G. Pozzo (semi-quadrupole) J.J. Bleeker, C. Germain and R. Tinguely (electostatic septum), O. Barbalat (computer programs), J. Gruber, J. Guillet and F. Rohner (power supplies) and N. Blazianu, A. Millich and N. Rodgers (machine development sessions).

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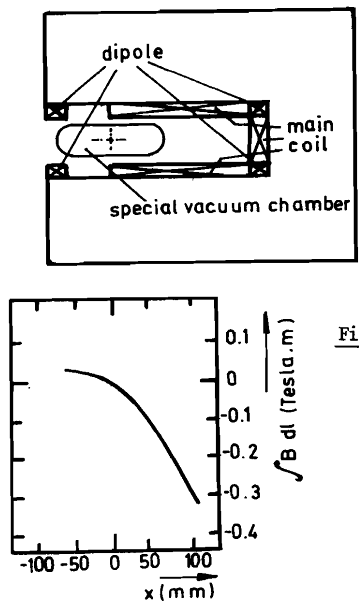


Fig. 1 Semi-quadrupole

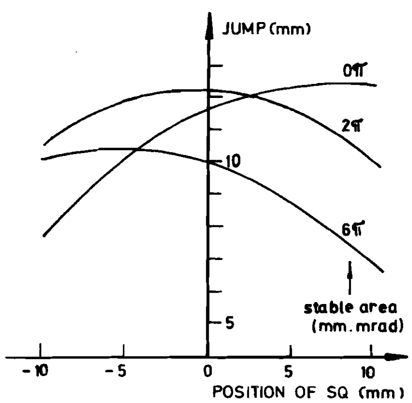
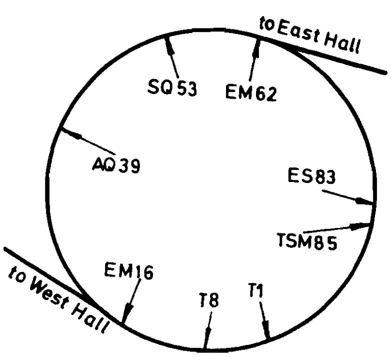


Fig. 2 Three-turn jumps as function of position of semi-quadrupole



SQ : semi-quadrupole
AQ : auxiliary quadrupole
ES : electrostatic septum
TSM: thin septum magnet
EM : extractor magnet
T : internal target

(orbit bumps are omitted for the sake of simplicity)

Fig. 3 Lay-out of the system

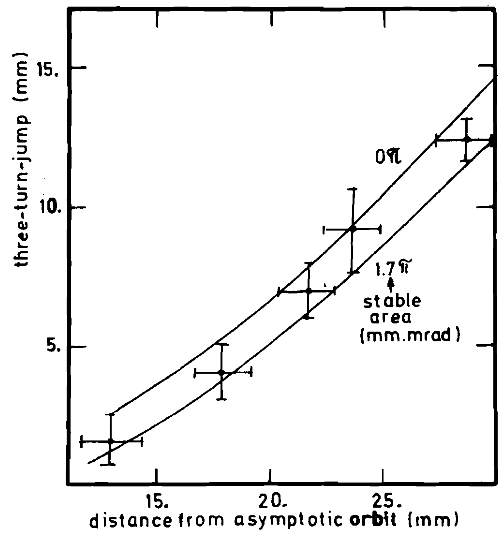


Fig. 4 Measured and calculated values of the three-turn jumps.

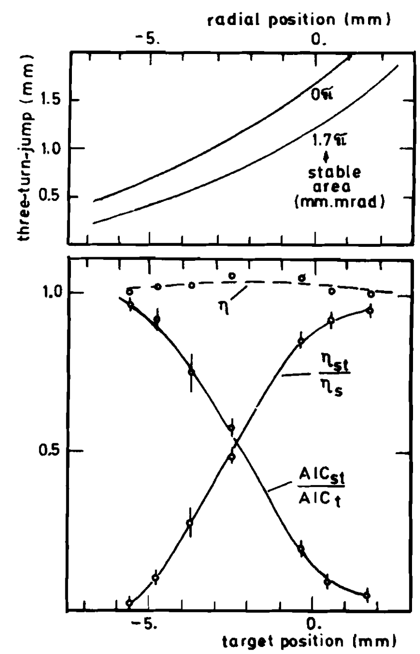


Fig. 5 Efficiency of the sharing process (bottom); calculated three-turn-jumps (top). (There is an uncertainty of about 2 mm in the relative position of the two diagrams).