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PROTONS FOR PREVESSIN

Summary of meeting No. 10 - October 8, 1976

Present

O. Barbalat, R. Billinge, J. Boillot, M. Bouthéon, D. Boussard, B. de Raad, D. Fiander, C. Germain, H. Koziol, A. Krusche, P. Lefèvre, D. Möhl, G. Plass, F. Sacherer, Ch. Steinbach, R. Stiening, E.J.N. Wilson

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1. FAST CYCLING BOOSTER (FCB)

For putting other proposals to increase the performance of the SPS, like multipulsing, in perspective, it had been agreed at a previous meeting, to look again at the initial proposal for the injector of a 300 GeV accelerator, namely the fast cycling Booster.

As far as intensity alone is concerned, it seems difficult to do much better than the CPS, however an other injector might look attractive if it could better preserve the luminosity of Linac beams for colliding beam experiments or if necessary in case of obsolescence or extensive damage to the CPS. The FCB might offer smaller transverse emittances.

The updated parameters of an optimized fast cycling Booster are also useful when considering schemes like cooling rings for anti-protons which might be housed in the same tunnel.

These considerations have led R. Billinge to review the basic design criteria for an SPS Booster (SPS/DI/RB/76-1) which he summarized at the meeting.

The main constraints of the design are :

- the transverse brightness (6 mA/10^{-6} rad.m of Linac normalized emittance) together with a Laslett Q-shift limited to 0.2;
- a peak field of 10 kG with a filling factor ρ/R of 0.6;

- Q_s (number of synchrotron oscillations per turn) restricted to 0.1 to avoid exciting sidebands of the betatron oscillations and a bucket area of 20 mrad;
- a main ring filling time of the order of 2 s with N = 20 batches.

For optimum brightness conservation, one would like to make a bunch to bucket transfer between Booster and Main Ring, this leads to h = 4620/N. D. Boussard pointed out that the limitation on Q_s, together with a bucket area of 20 mrad, leads to a more severe condition on the injection energy than the Laslett Q-shift. This requires either to shift the injection energy to 800 MeV or increase the number of batches to N = 60 with the injection energy kept at 200 MeV. Non sinusoïdal excitation of the magnetic field (3rd harmonic) would not make a significant difference.

This problem has been considered in the design and it is why the harmonic number has been chosen to be equal to 60 which implies a Booster RF frequency of 50 MHz. One can therefore only fill every 4th bucket of the main ring which operates at 200 MHz or debunch and retrap adiabatically at injection in the main ring but the initial brightness is reduced correspondingly. Another solution would of course be to change the frequency of the Main Ring RF system and go to 50 MHz like FNAL.

O. Barbalat made a comparison between the longitudinal phase space densities (an essential parameter for colliding beams or anti-proton production) which could be produced by a fast cycling Booster and the values which could be given by an improved CPS suitably operated to maximize this parameter.

In units of 10^{10} particles per electron-volt second, the fast cycling Booster considered would give in the Main Ring a density of 60 to 70. This figure checks well with the design values for the FNAL machine which turns out to be 64. The present performance of FNAL is 20.10^{10} p/eVs (2.10^{13} protons in $\sim$ 1000 bunches each of an area of 0.1 eVs).

With the present continuous transfer scheme, followed by debunching and retrapping in the SPS, the CPS beam is considerably diluted and gives a density of 3 in the same units as above (10^{13} p in $\sim$ 4000 bunches each of an area of 100 mrad or 0.075 eVs)*.

However, multipulse filling of the SPS would reduce considerably this dilution.

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* In the SPS : $S_{(eVs)} = \frac{R}{h} \frac{m_o c^2}{c} A_{RF}$ (mrad)

i.e. 100 mrad corresponds to 0.075 eVs.

Injection of 5 batches each extracted in 2 turns would allow to gain a factor 5 (with a total filling time of only 2.4 s if the PSB repetition time is reduced as is feasible to 0.6 s). Another factor 3 could be gained by installing in the CPS a 200 MHz accelerating system. The change in harmonic number performed at around 1 GeV in the CPS could be much more efficient than in the SPS at 10 GeV/c. Further improvements each by a factor 2 could be achieved by single turn transfer in the SPS (leaving half the SPS buckets empty) or by vertical recombination of the beams from 2 of the PSB rings with the other two (at the price however of vertical emittance increase).

One obtains thus potential longitudinal densities ranging from 50 to 150.10^{10} part/eVs (including already some safety factor as the present PSB density is 340 in these units).

These parameters were also compared to those of the Serpukhov fast cycling Booster (H. Koziol). The situation in that machine is made easier by the selection of a high number of batches (N = 30) and an harmonic number h = 1.

In the transverse phase plane a fast cycling Booster appears at first sight more attractive as it would have nominal values of $1.2\pi \; 10^{-6}$ rad.m at 10 GeV/c compared with 3π for the CPS vertical emittance.

The magnitude of this discrepancy is however not quite as large as these figures suggest. When comparing transverse emittance figures, one must pay close attention to the definitions.

In the PSB and the CPS emittances are measured with plunging targets and defined as the area containing 95% of the beam. When using profile measuring devices (secondary emission monitors, etc.), one relates the emittance to the standard deviation of the profile distribution. One takes usually 2σ of the distribution which corresponds to 86.5% of the particles and an emittance value 1.5 times smaller than the value which contains 95% of the beam, assuming a Gaussian distribution.

Another aspect is in what direction to go when deciding on future PS improvements. At a previous PFP meeting (Meeting No. 8) one had indicated that the PS intensity limit with the new Linac would be 1.5 to 2.0 10^{13} p/p and present developments are aimed in that direction. One could perfectly well decide instead that it would be better, for the SPS or a downstream colliding beam device, to limit the intensity per pulse to 10^{13} p/p or even 5.10^{12} p/p and concentrate in achieving the minimum vertical emittance compatible with that intensity (say 2π at 10^{13} p/p or 1.5π for 95% of the particles at 5.10^{12} p/p).

<u>In conclusion</u>, it appeared that the possible technical advantages of a fast cycling Booster over a suitably operated CPS are within the error margin of the estimates which can be made today.

Both machines would have a comparable filling time ($\sim$ 2 s) to reach 5.10^{13} p/p. They both require a change in harmonic number of some sort to go from 10 or 50 MHz to 200 MHz. They would yield comparable longitudinal phase space densities. Transverse emittance figures are still debatable. Their definitions should be clarified. An important point would be to determine experimentally what is the maximum beam size which can be practically digested by the SPS. (Theoretically with a vertical aperture of 24 mm, the maximum possible SPS vertical acceptance at β_{max} = 105 m is $\pi(24^2/105) = 5.4\ \pi\ 10^{-6}$rad.m).

It was agreed that in parallel the PS people (O. Barbalat, and al.) would make coherent estimates of possible beam properties as in 1972 (O. Barbalat - MPS/DL/72-42) but taking into account various possible SPS filling schemes and measured SPS acceptance figures.

O. Barbalat

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