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SPS IMPROVEMENT REPORT NO. 147The Working Point $Q_H = 15.38$, $Q_V = 15.42$ and Single Bunch Acceleration

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1. Introduction

Previous work (IP n^o 127) has clarified various mechanisms, notably negative mass and head-tail instabilities, which are responsible for large beam loss when intense single bunches are accelerated through transition. For the p-p̄ project, both protons and antiprotons will be accelerated to 26 GeV/c in the CPS before injection above transition ($p_{tr} = 21.8$ GeV/c for $Q = 26.6$). However, until the injection beam line TT10 is upgraded to 26 GeV/c there remains the problem of accelerating intense single bunches to high energy so that storage experiments can proceed. The aim of the present experiment was to avoid transition crossing by dropping the transition momentum to below the present maximum injection momentum (16 GeV/c). To achieve this the machine was tuned to the new working point $Q_H = 15.38$, $Q_V = 15.42$, giving a transition momentum of 13.5 GeV/c. Intense bunches were then injected on the rising slope of the SPS magnetic field at 15.8 GeV/c and intensities of $4 - 5 \times 10^{10}$ protons per bunch were successfully accelerated.

2. The choice of working point

Figure 1 shows the lattice functions α_{pmax} , γ_T , β_{max} and β_{min} over a wide range of Q . The α_p function becomes infinite at integral multiples of the superperiodicity of 6. Between these there are minima at around 27, 21 and 15. The minimum around 27 is the normal working point of the machine, and the region around 21 will be used for acceleration to 500 GeV/c when the quadrupoles can no longer achieve the required gradient at the normal working point. The third region is attractive for the present study, since the transition momentum is about 13.5 GeV/c.

Although the αp function has a maximum of 11.7 m compared with only 4.5 m for normal operation, this is offset by the fact that one avoids transition where $\Delta p/p$ is large. Figure 2 shows the pattern of αp around the ring.

The maximum of the beta function is not much different from that for normal operation (114 m compared with 107 m) although the minimum is considerably increased (48.3 m instead of 19.5 m). The pattern of resonance lines is similar to that for the normal working point and suggests that 15.4 would be better than 15.6, which is a 5th order structure resonance.

3. Cycle optimisation

The cycle was a normal SPS 9.6 sec cycle with flat tops at 210 GeV/c and 400 GeV/c and with a flat bottom at 10 GeV/c. The first step was to optimise this cycle as far as possible with a normal 10-turn continuous transfer at 10 GeV/c. It was hoped that sufficient beam would be transmitted through transition to tune the whole cycle before moving to fast-extracted beam at 15.8 GeV/c for single bunch studies. All correction elements except the chromaticity sextupoles were switched off. The constants for the contribution of B_{inj}/B and \dot{B}/B to the chromaticity correction were set to values which were expected to be about 5 times higher than normal because of the much higher αp at this working point. After adjusting the Q-values to the correct half-integer square and correcting the closed orbit at injection, some beam was accelerated to top energy although, as expected, there were large losses at transition. Nevertheless, this allowed Q and chromaticity to be corrected later in the cycle. The chromaticity was first corrected at high energy to give the constant term, then on the flat bottom to give the B_{inj}/B term. It was not possible to make good measurements at maximum \dot{B} to optimise the \dot{B}/B term, so this parameter was adjusted by maximising the transmission through transition. The values found in this way are shown in Table 1.

Table 1 - Empirically determined values of the chromaticity constants

<u>Term.</u>	<u>Horizontal</u>	<u>Vertical</u>
Constant	.501	1.43
B_{inj}/B	5.166	-5.7
\dot{B}/B	-2.251	2.157

The closed orbit at high energy (Figure 3) showed a strong perturbation in sextant 6 which is not understood for the moment.

4. Injection at 15.8 GeV/c

The TT10 transfer line can be operated up to 16 GeV/c provided that the power supply driving the main vertical bends MBIV1003 is modified for pulsed operation. Consequently an injection momentum of 15.8 GeV/c was chosen in order to give a small reserve whilst still being sufficiently far from transition to allow reasonable matching of the short bunches to the SPS buckets. The settings of the four main bends in TT10 were as follows:

<u>Magnet</u>	<u>Current (amps)</u>
MBIH 1001	474.6
MBIV 1003	534.8 (pulsed)
MBIS 1029	905.7
MSI 118	1147.8

Table 2 - Settings of TT10 bends

The CPS was set up for a special cycle with a long flat top at 15.8 GeV/c and could provide a fast extracted beam of 1 to 20 bunches with or without bunch rotation. The bunch rotation was adjusted to give bunches of 3 nanoseconds duration and with approximately 1.5×10^{11} protons per bunch. The Laslett incoherent Q-shift in the SPS at 10^{11} p/bunch is about -0.09 but the Q of the machine was not adjusted to compensate.

The CPS extraction timing was adjusted in small steps along the flat top until the beam was seen to circulate in the SPS. Since there was insufficient 200 MHz component on the beam spectrum, the closed orbit at injection could not be measured so the only instrumentation available to tune injection were TV screens for the first turn and beam loss monitors ! Nevertheless, as soon as the SPS r.f. system was adjusted some beam was accelerated to top energy. At this point, the CPS was asked to send only a single booster batch of 5 bunches and without any further adjustment, intensities of 2 to 2.5×10^{11} ppp were accelerated. This proved to be above the threshold for a head-tail instability which resulted in the loss of a large fraction of the beam. It was stabilized by making the vertical chromaticity more positive.

Finally, a single bunch was demanded from the CPS. Unfortunately, the experiment came to an abrupt end after only a few injections of a single bunch due to a magnet fault in TT10 which could not be repaired in the short time left. Nevertheless, a bunch of 5×10^{10} protons had been accelerated to high energy, that is twice the value achieved up to now.

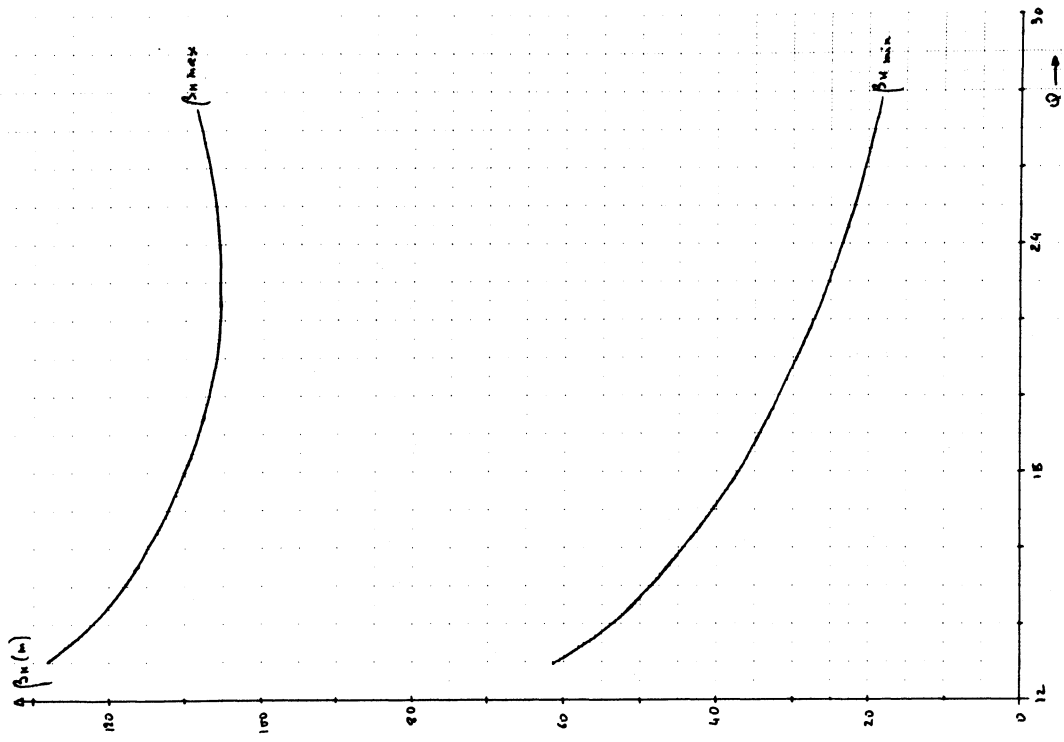
Conclusions

The working point at $Q = 15.4$ has proved to be an interesting way to avoid transition crossing and to allow intense bunches to be accelerated.

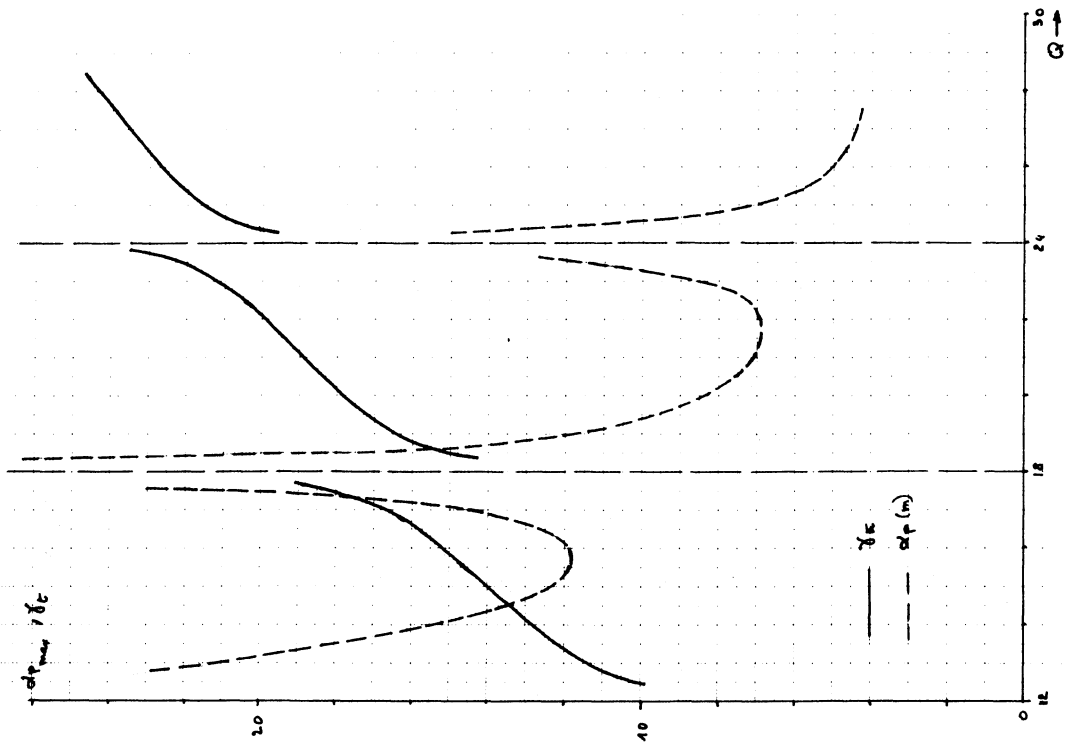
Acknowledgements

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Reported by L.R. Evans



b) β_{max} and β_{min}



a) $\alpha_{p_{max}}$ and γ_T

Figure 1 - Variation of some lattice parameters over a wide range of Q_H

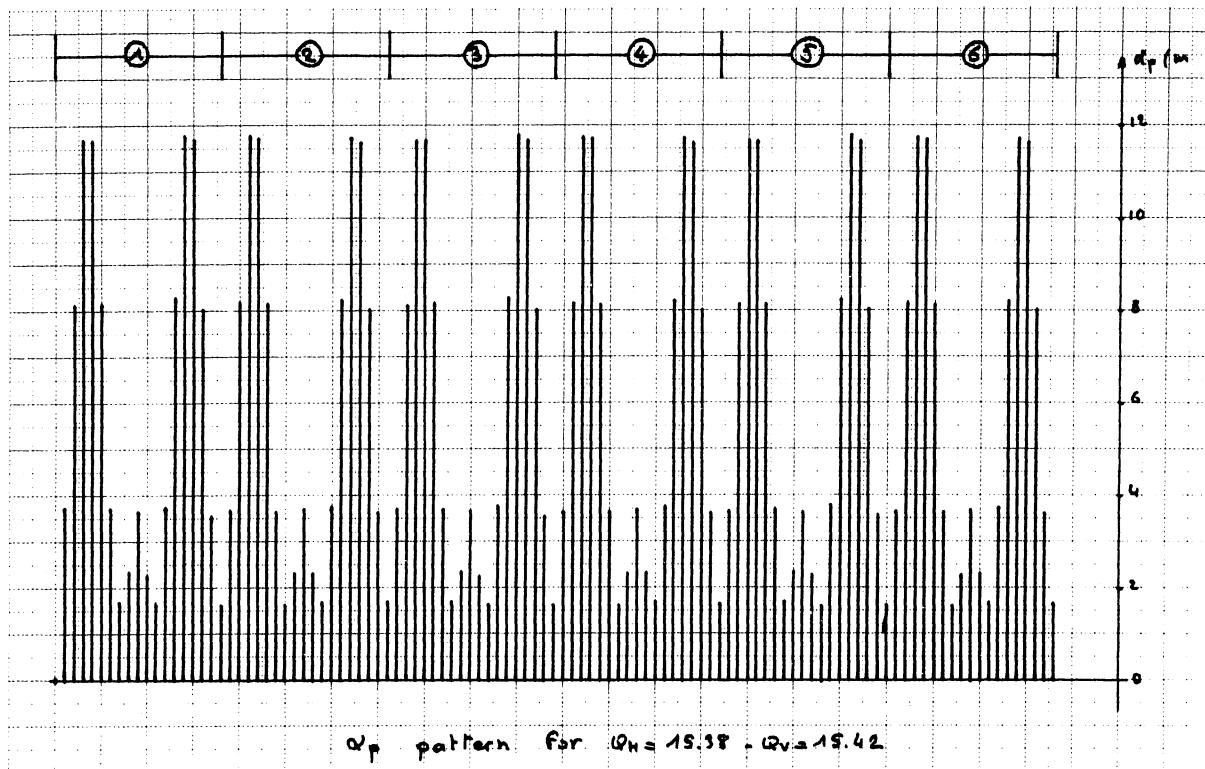


Figure 2 - α_p pattern around the ring

SPS BP DISPLAY #30 T3=5600 10 NOV 78 17: 3: 3

1 2 3 4 5 6

MOY= 5.340 SIG= 5.833 MIN -1.892 MAX 27.388

HOR



MOY= .083 SIG= 2.598 MIN -8.104 MAX 6.838

VER



Figure 3 - Closed orbit at 400 GeV/c

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