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Topic : The Effect of Betatron Resonances on the Injection Process

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The injection process in the SPS is divided into three steps. In the first step, a bunched beam from the PS is allowed to coast and debunch for 100 ms with the SPS RF off. In the second step, the beam is trapped into 200 MHz buckets and the RF level is raised to 2×10^6 volts. The final step is the acceleration of the beam. In the experiment reported here, this final step has been replaced by a one second RF-on constant guide field coasting time to eliminate many other effects which would make the results difficult to interpret.

We have measured the beam survival during each of the steps described above as a function of tune along the trajectory $Q_H - Q_V = 0.04$. This trajectory is shown in figure 1. The entire experiment took place at a constant momentum of 10 GeV/c. The RF program during the cycle is shown in figure 2. We measured three quantities: injection efficiency, trapping efficiency, and coasting efficiency. These are defined in figure 3 which also shows the results. It is clear that betatron resonances are a dominant factor in the losses associated with all three steps. Strong quadrupole, sextupole, and octupole resonances are seen. There may be evidence for a 5th order resonance at Q = 0.6. Since 5 x 27.6 = 138, and 138/6 = 23, this is a resonance which is amplified by the 6-fold symmetry of the SPS. There is a shift in the position of the resonances between figure 3 B and 3 C which is probably due to a drift in the power supply current during the flat-bottom.

Since betatron resonances above second order preferentially extract particles with large oscillation amplitudes, it is essential that care be taken to ensure that the PS emittance be kept as low as possible and that no mismatch be allowed to occur in the transfer line. The emittance as measured in LSS-5, which was characteristic of the beam during this experiment was $\varepsilon_H = 1.8\,\pi$, $\varepsilon_V = 1.6\,\pi$.

Some other observations made during this run are as follows. Initially, we attempted to make this experiment with an injected beam of 6×10^{12} protons. Immediately after bunching, this beam became unstable and the intensity dropped to 10^{12} or less. A later observation made with a lower beam intensity showed the magnitude of the loss was sensitive to the sign of the vertical chromaticity. This suggests head-to-tail effect as an explanation for the loss. High mode number vertical and lowest mode number horizontal resistive wall instabilities were also observed. Finally, we measured the linear coupling in the SPS by exciting a radial oscillation with the Q-kicker and by observing the resulting growth in the vertical oscillation amplitude. The coupling could be suppressed by a small current (- 0.55 A) in the six correction skew quadrupoles.

Reported by:

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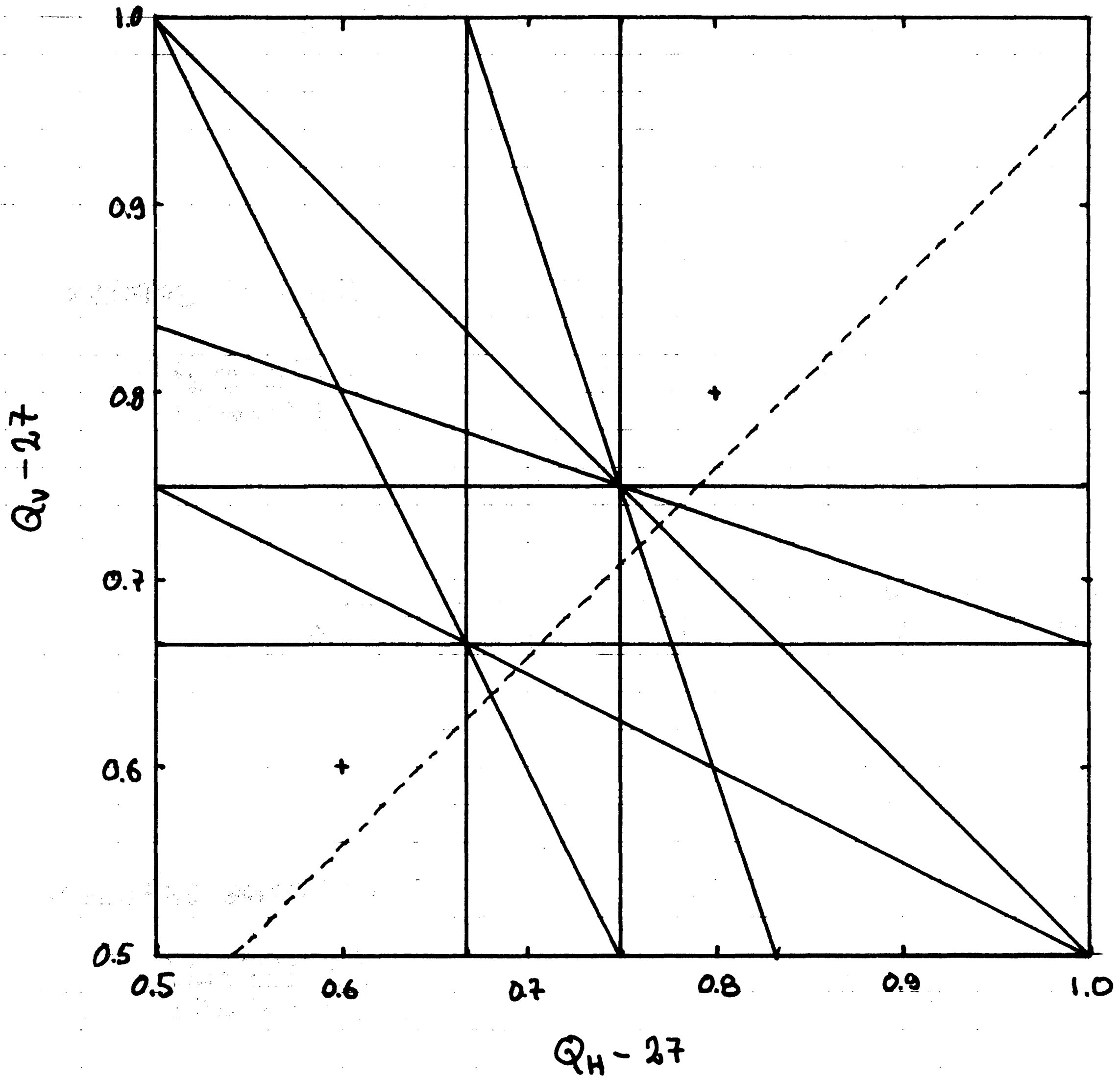

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Figure 1

The working diamond. The dotted line is the Q-trajectory followed in the experiment. All sum resonances through fourth order are shown in the figure. Crosses mark the location of the intersection of fifth order sum resonances.

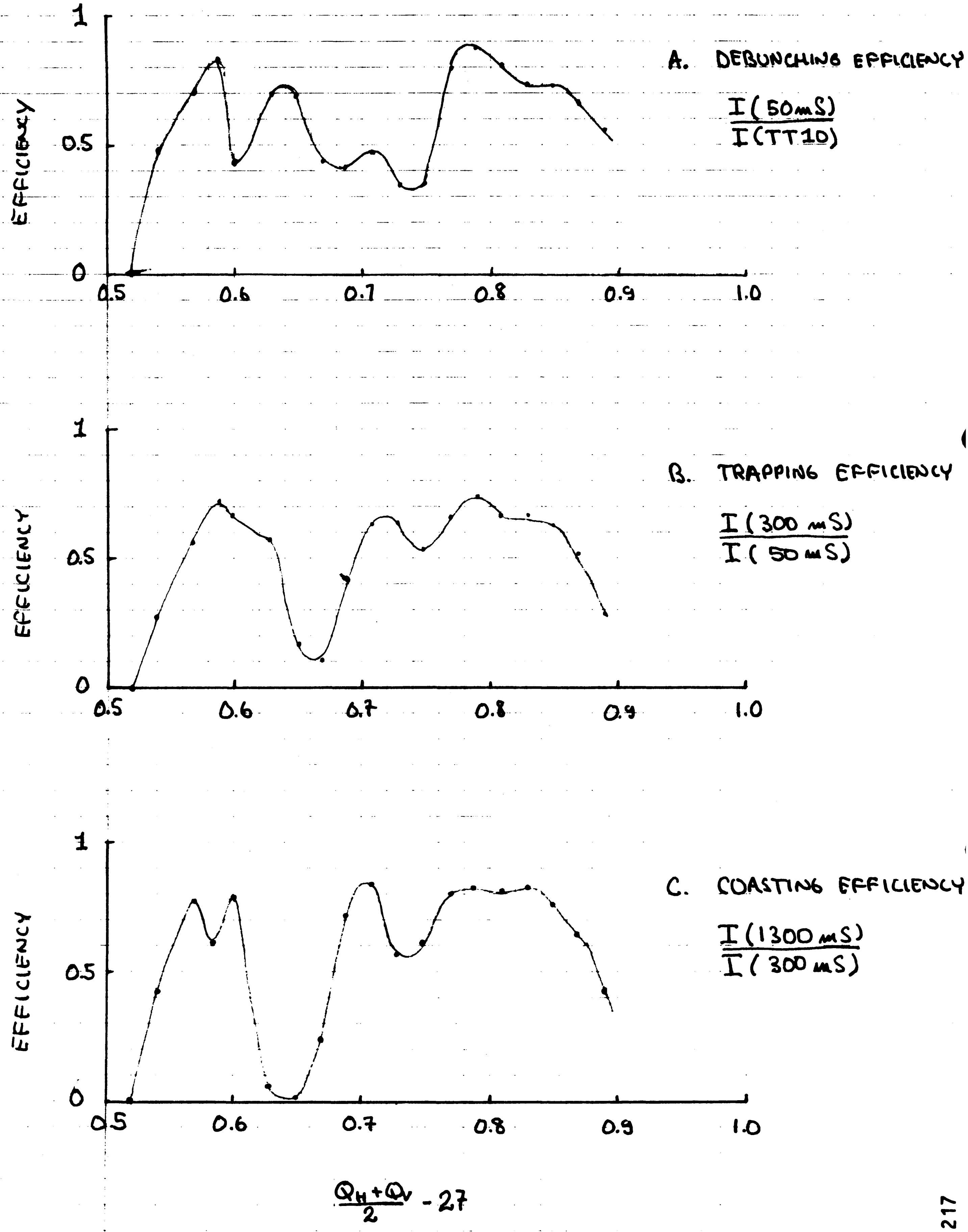

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Figure 2

The various intensity measurement times are shown with the RF voltage program. The injection magnet field value was held throughout the duration of the cycle shown in the figure.

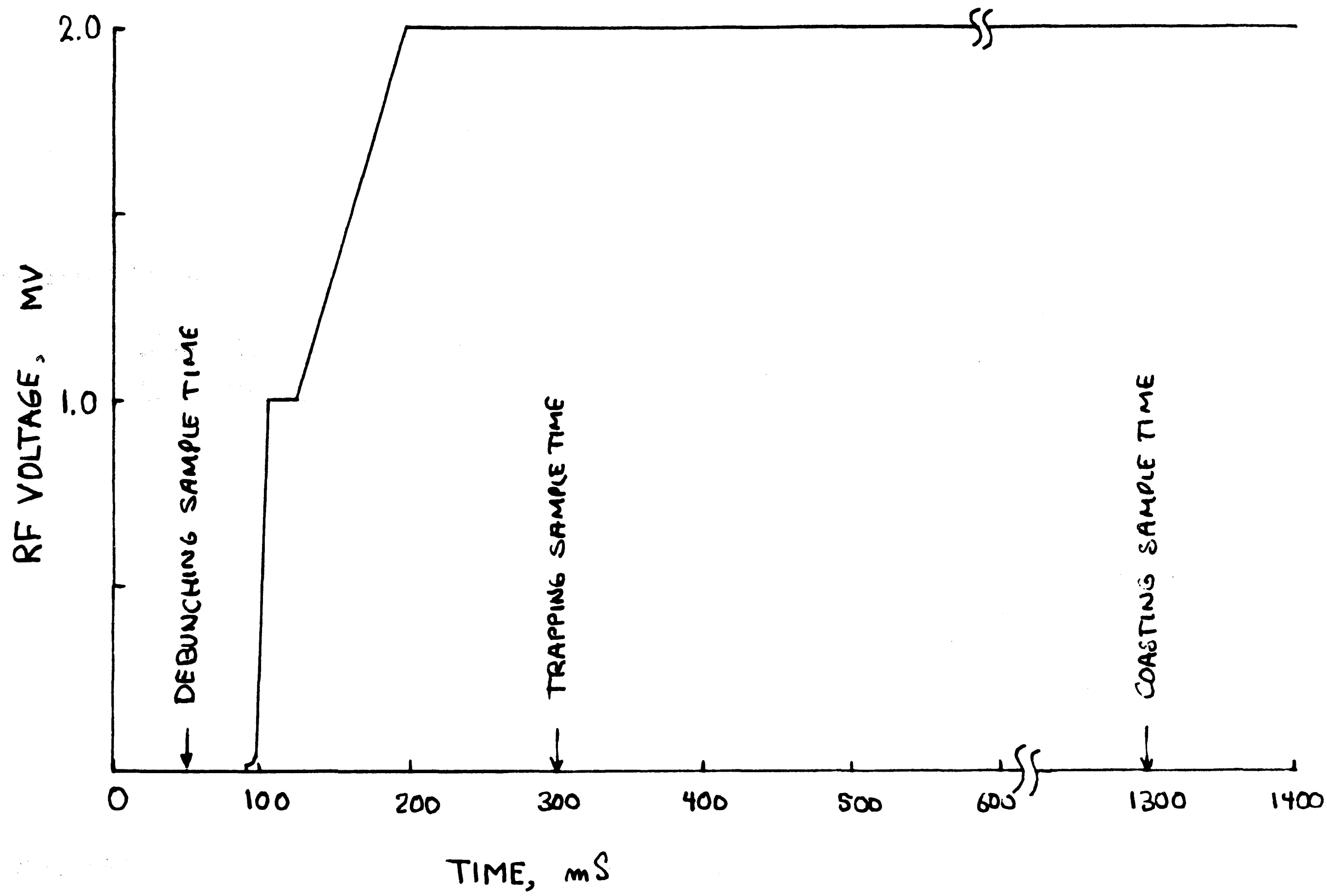

Figure 3

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The efficiency of the three steps in the SPS injection sequence. The quantities of Q_H and Q_V are power supply settings. The actual tune appears to drift during the injection sequence.