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* SPS COMMISSIONING REPORT No. 19

Topic : Further Study of Q-Dependent Beam Loss and High Intensity Instabilities

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In the SPS a beam intensity of 3×10^{12} appears to be the dividing line between the low intensity regime where single particle phenomena are sufficient to account for the observed beam loss and the regime where collective instability is dominant. The first part of this report describes experiments relating to single particle instability which were made with a beam intensity of 2×10^{12} protons/pulse. In the second part we describe experiments made to study collective instability at an intensity of 4.5×10^{12} protons/pulse.

Part I: Low Intensity Runs

In a previous report (No. 18) we showed that the transmission efficiency of various steps in the SPS injection sequence was strongly tune dependent. In particular there was evidence for 5th order structure resonances at $Q = 27.6$. Since no magnets have been installed to correct these resonances, we thought it important to see if the region around $Q = 27.4$ was a better operating point. The resonances at 27.4 are due to random fluctuations only.

A 200 GeV cycle was established with a 1.5 second long 10 GeV/c flat bottom. Prior to the experiment all extraction elements were demagnetized and the harmonic correctors were all off except the skew quadrupoles which were set to cancel the coupling at $Q_H - Q_V = 0$. Beam dampers were off and a small current (4.7 amps) excited the Landau damping octupoles. The sextupoles were set for zero vertical and horizontal chromaticity. We measured the beam survival with RF off as a function of Q .

The results of this experiment are shown in Figure 1 where we show both short term $[I(50 \text{ ms})/I(\text{TT10})]$ and long term $[I(1300 \text{ ms})/I(\text{TT10})]$ beam survival as a function of tune along the diagonal trajectory $Q_H = Q_V$. The data show that the 27.6 structure resonance is stronger than the 27.4 fluctuation resonance. A third curve in Figure 1 shows the long term transmission $[I(1300)/I(\text{TT10})]$ with RF on. The resonances appear to be wider because of the tune spread due to synchrotron motion. Evidently, the chromaticity was not set exactly to zero.

Since the width of the resonances was greater than expected, we looked for sources of tune modulation. The largest effect seems to be a drift in the main power supply. We injected a beam, and with RF off, measured the tune as a function of time on the 1300 ms flat bottom. The results are shown in Figure 2.

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The large drift (.03) accounts for a substantial part of the measured resonance width. The fact that the data of Figure 1 are somewhat inconsistent with a earlier experiment (Commissioning Report No. 3) in which the 200 ms RF off transmission was measured may be accounted for by a much reduced power supply drift since only a 50 GeV ramp was used in that experiment. This suggestion has not been checked by an experiment.

Part II: High Intensity Runs $(4.5 \times 10^{12}) \epsilon_H = 1.8 \pi, \epsilon_V = 1.2 \pi$ in LSS5 .

The beam with RF off is unstable at this intensity without Landau or electronic feedback damping. With feedback damping alone the beam is stable with about a 6 dB gain margin in the vertical feedback system. Since octupole stabilization may be required for single bunch effects with RF on, we measured the 1300 ms transmission of the beam as a function of octupole current with beam dampers on. Thus we could determine the harmful effects of the octupoles without needing them for stabilization. The Q was near 27.6 in this experiment. The results are shown in Figure 3. Evidently, up to about 5 amps may be used without ill effect. Without feedback damping 10 to 15 amps were required to stabilize the beam. Since the octupole current required for stabilization is proportional to beam intensity, it is clear that about 4.5×10^{12} is the useful limit for stabilization by this method alone.

At the end of the above experiment we tuned the octupoles off and retuned the machine to the vicinity of $Q = 27.4$. We are able to report a 90% transmission of the TT10 beam to 1300 ms at this operating point with RF off. We then tuned RF on and within a 100-300 ms interval after the beam was bunched it became unstable. This is shown in Figure 4. A photograph of the bucket by bucket surviving intensity shows a wide variation. This indicates that the instability is a single bunch effect. A quick experiment showed that this instability could be suppressed with a non-zero chromaticity setting. This will be the subject of a future experiment.

It should be noted that the instability thresholds are similar to those in the Batavia accelerator. This is to be expected since the dominant factors are the size of the vertical aperture and the vacuum chamber conductivity. Both of these parameters are similar in the two machines.

Reported by

R. Stiening

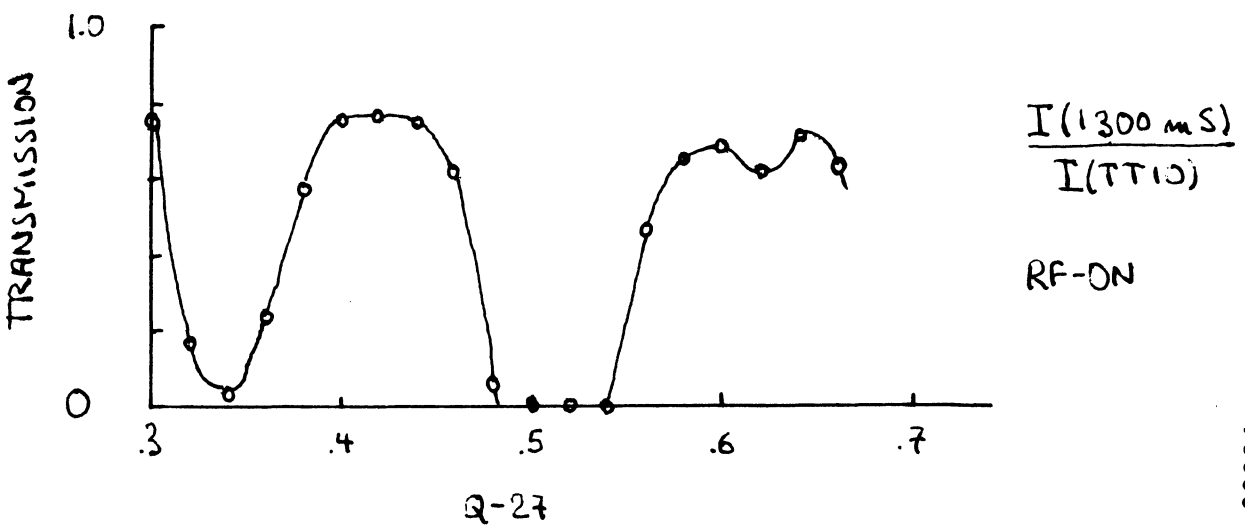
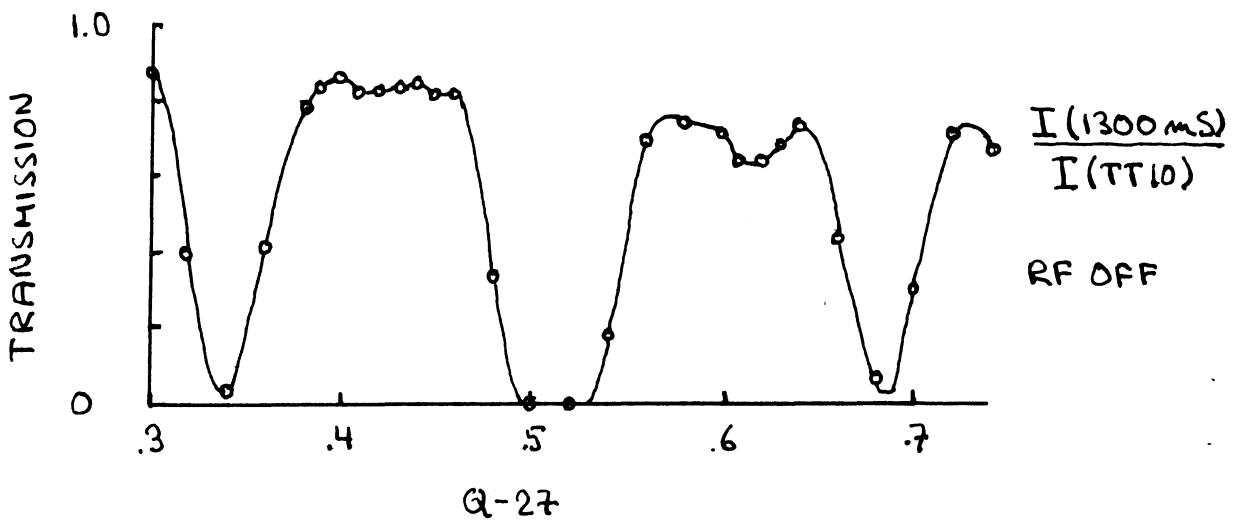
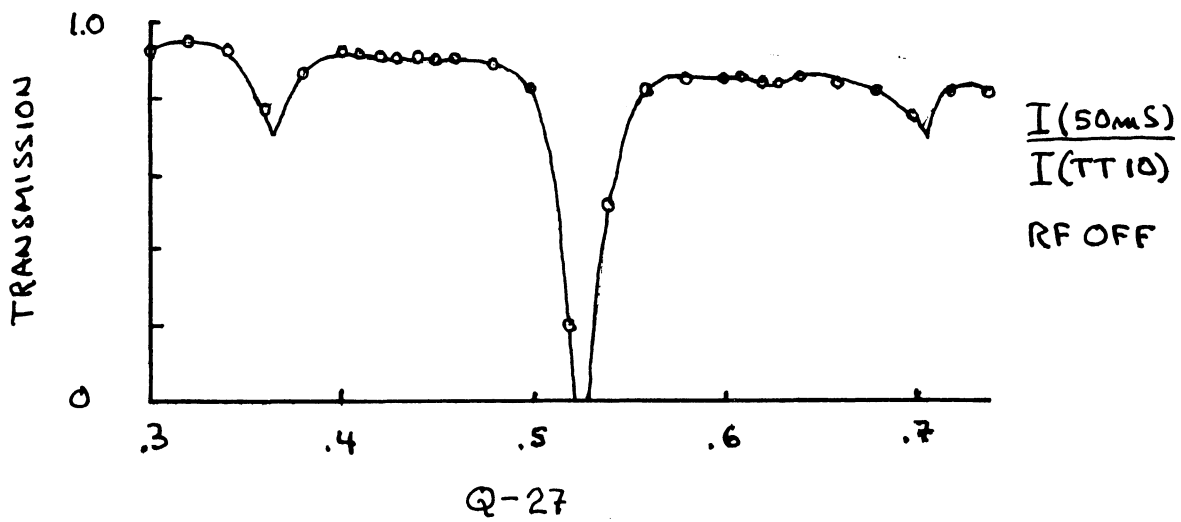


Figure 1. Beam survival as a function of tune along the trajectory $Q_H = Q_V$

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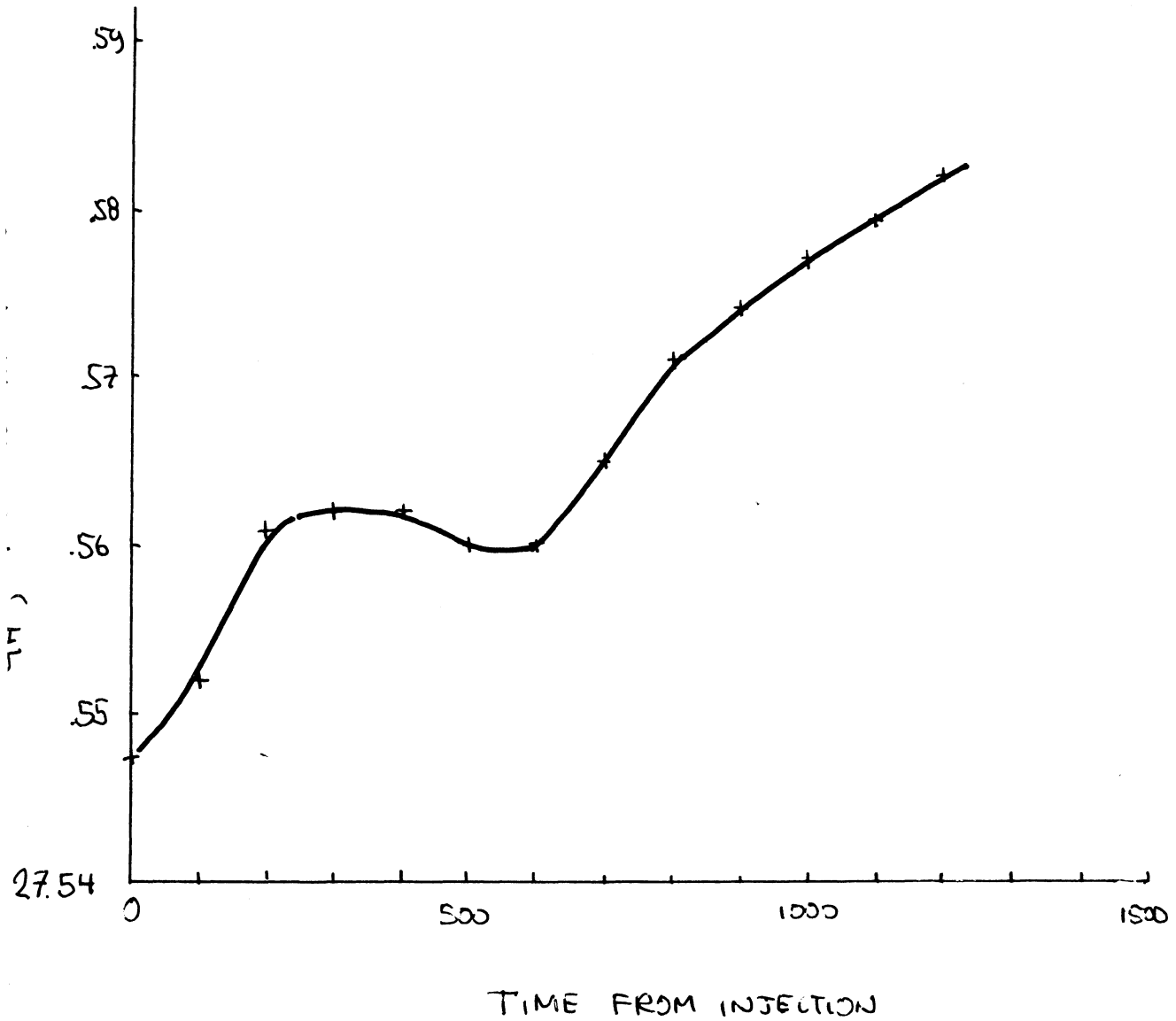


Figure 2. Tune drift with RF off. The curve represents the average behaviour of the power supply. Pulse to pulse instability was about 0.01 in time.

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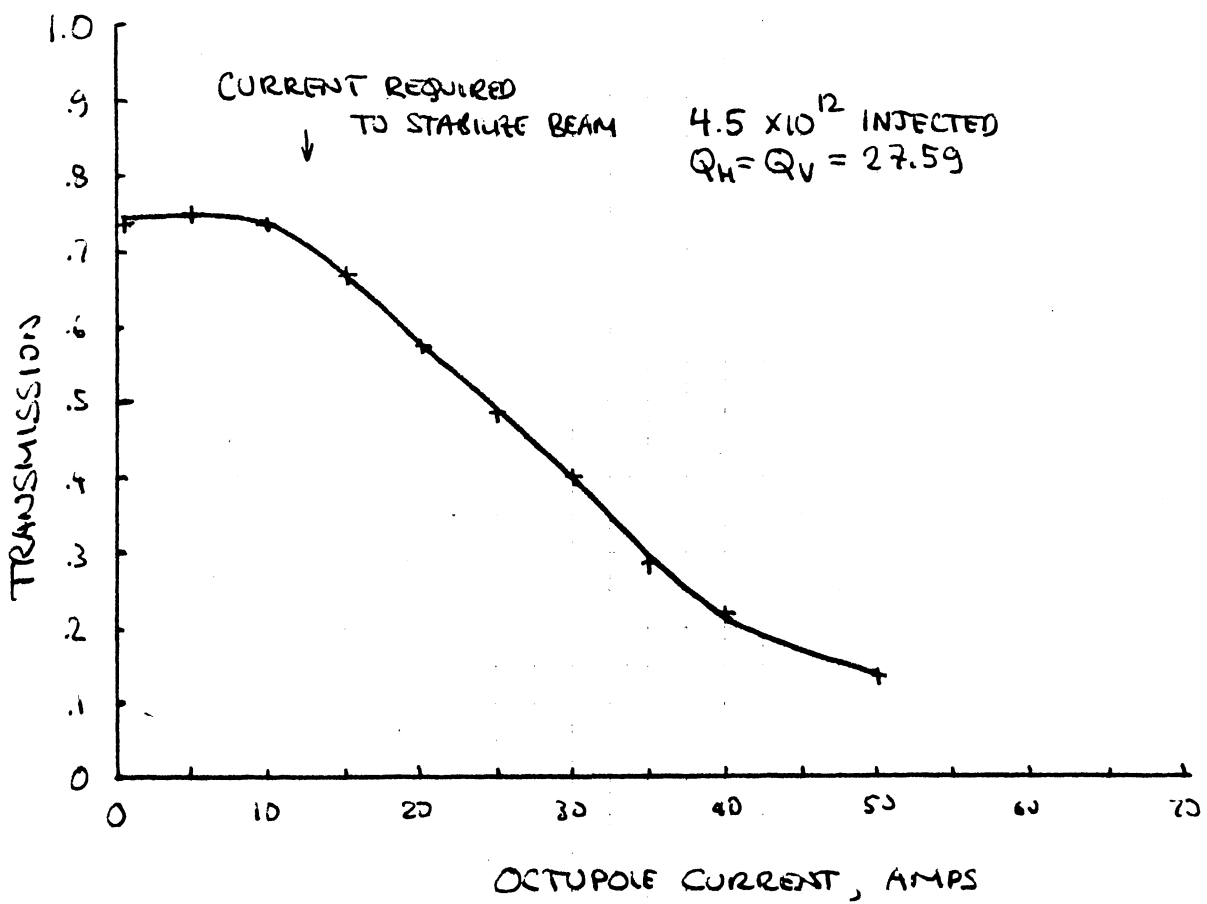
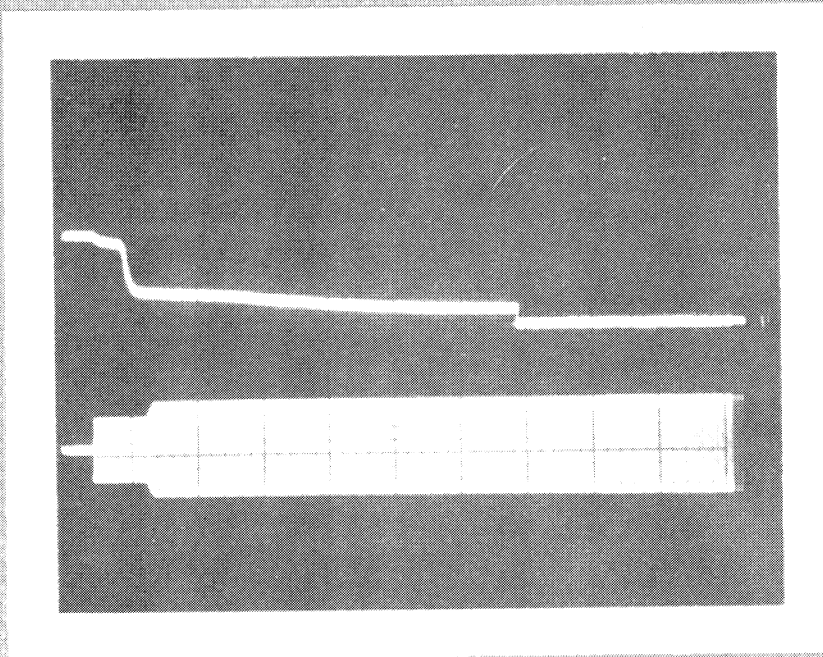


Figure 3. Experiment to determine how much octupole current can be used without beam loss. The beam has been stabilized with feedback.

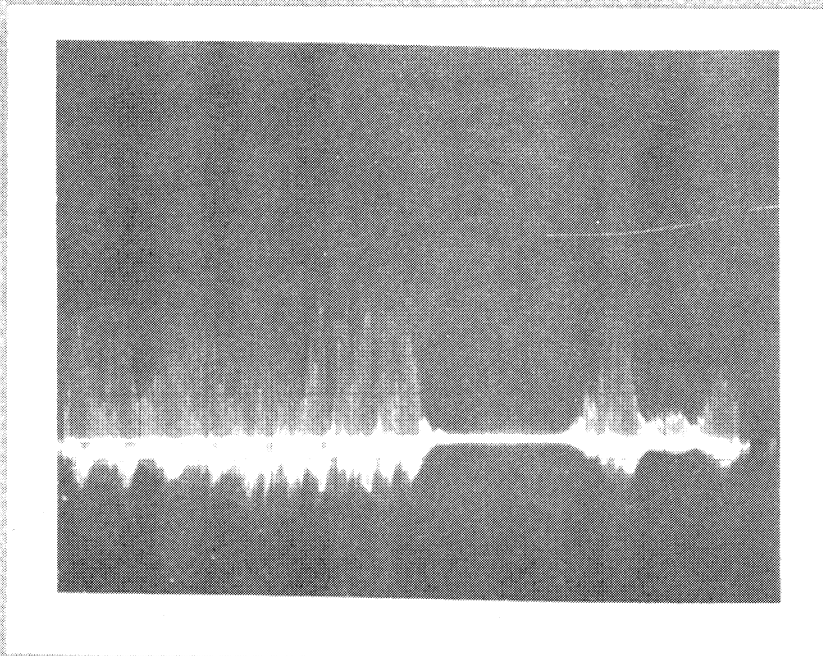
BEAM
CURRENT

RF
VOLTAGE



TIME, 100 nS / DIVISION

BEAM
CURRENT



BUNCH NUMBER

Figure 4. Beam loss caused by "head to tail" instability. Current surviving after instability varies from bunch to bunch. This fact establishes the effect as primarily an individual bunch instability.