SPS/DI/EJNW/bl

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SPS COMMISSIONING REPORT NO. 5

Topic : Correction of Chromaticity and a Cure for the Resistive Wall Instability

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1. Experimental Conditions

A 10 GeV/c beam with 200 MHz structure was injected into the SPS. The r.f. system was switched off to provide the best conditions for beam survival near to betatron resonances. The CPS intensity was 3×10^{12}. Other experimental conditions were similar to those during the first scan of the working diamond (see Commissioning Report No. 3).

2. Measurement of Chromaticity

The main dipole and quadrupole currents were stepped up and down together in 0·1% intervals to simulate changes in injected momentum. With r.f. off the majority of the beam survives anywhere in the working space except close to integer stopbands.

Figure 1 shows the wide range of momenta the SPS will accept under these conditions. The extremity of the acceptance, $\pm 6^{o}/oo$, corresponds to about ±25 mm of horizontal aperture (see Figure 8).

Each point of Figure 1 corresponds to a different momentum offset. Q measurements over 20 pulses established its position. The standard deviations shown were computed on line.

The linearity of this plot and Figures 2 and 3, where Q_H and Q_V are plotted separately versus $\Delta p/p$, indicate that there is little or no systematic magnet imperfection of higher order than sextupole. The sextupole term is much as expected. We deduce $\xi_H = -2{\cdot}03 \pm 0{\cdot}05$, $\xi_V = -0{\cdot}58 \pm 0{\cdot}05$.

3. Correction of Chromaticity

We went on to power the LSF and LSD chromaticity correcting sextupoles for the first time to compensate the slopes of Figures 2 and 3, and in addition provide compensation for the natural chromaticity throughout the ramp.

The extremities of Figures 2 and 3 were remeasured with this correction applied. Compensation is good and ΔQ for a nominal momentum bite of $1^{o}/oo$ must have been only a few parts per thousand.

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4. Observation of the Resistive Wall Effect

As expected, once the chromaticity was corrected, the beam became unstable due to the absence of Landau damping. Figure 4 shows a major fraction of the beam being lost in the first 50 milliseconds accompanied by a peak in the spectrum of frequencies generated at a vertical position pick up at $(28 - Q)\omega_o$. We interpret these pictures as signatures of the resistive wall instability as seen at FNAL (Stiening and Wilson, Nuc.Inst. + Methods 121 (1974)).

5. Correction of the Resistive Wall Instability

The beam was stabilised by powering the Landau damping octupoles, the threshold appeared to be 4.8 amps, corresponding to $\Delta Q_V = 0{\cdot}015$.

In the absence of r.f., which tends to give all protons the same average momentum and Q value over the time scale of the instability, sextupoles equivalent to an additional vertical chromaticity of $\xi > \pm 0{\cdot}3$ also were shown to stabilise the beam. However, since this cure is unlikely to work during acceleration, the LSF, LSD sextupoles were reset to compensate ξ and the amplitude dependence of Q imposed by the octupoles used to keep the beam stable during the acceleration to 50 GeV which followed.

6. Observations of the Effect of Sextupoles and Octupoles during Acceleration

Later, when Q measurements had revealed a slight mistracking of quadrupoles and dipoles and when the power supply regulation had been recalibrated to allow acceleration to 50 GeV, we tried switching off the sextupoles. Figure 6 shows how catastrophic is the effect on beam survival when one does not correct chromaticity and when, Figure 7, in addition octupole damping is removed.

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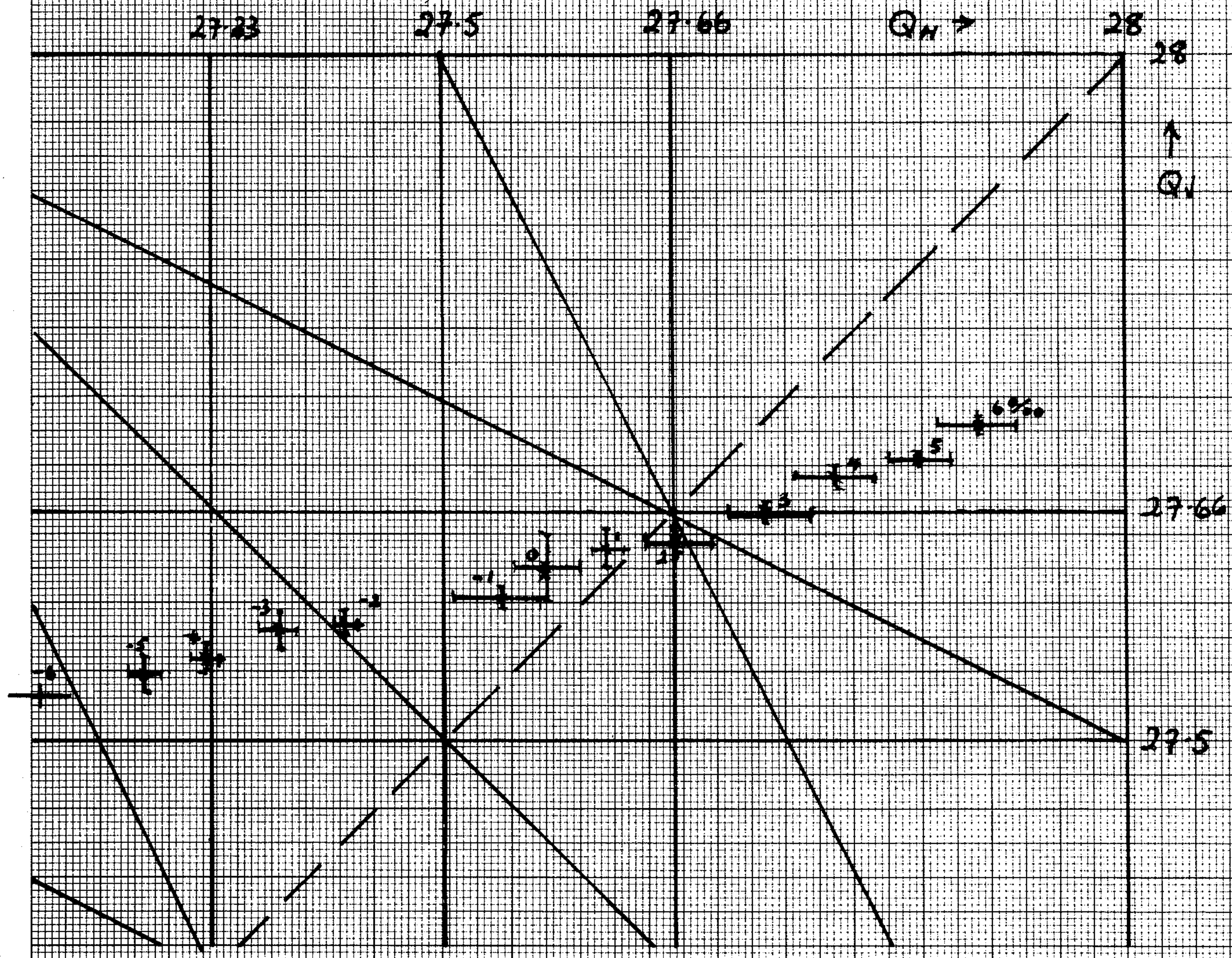


SPS CHROMATICITY BEFORE CORRECTION AT 10GeV/c

Each point is mean of 20 measurements made with r.f off

Label: e.g 6‰ is a 6‰ increase in dipole and quadrupole currents equivalent to −6‰ change in $\Delta p/p$.

Fig 1.

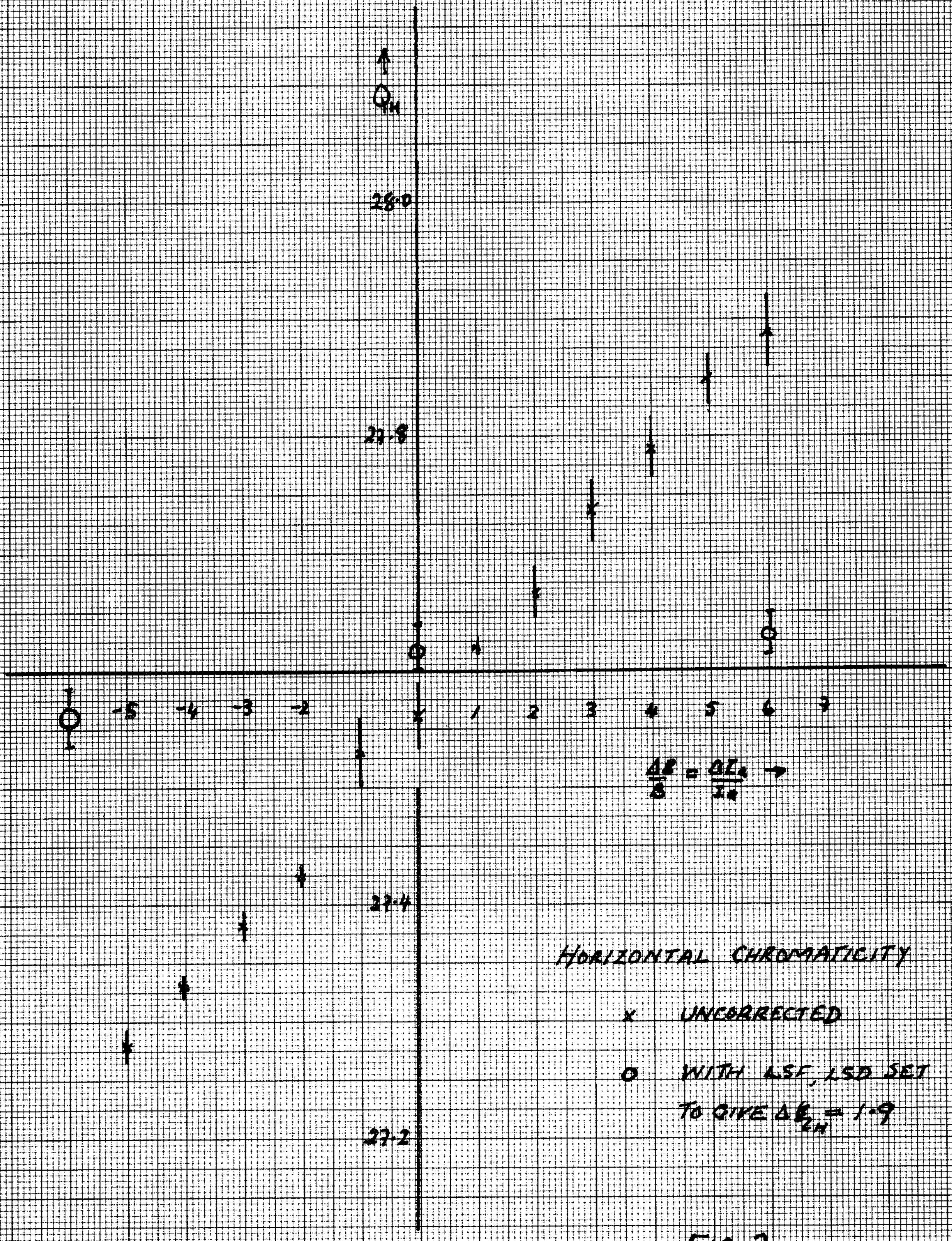
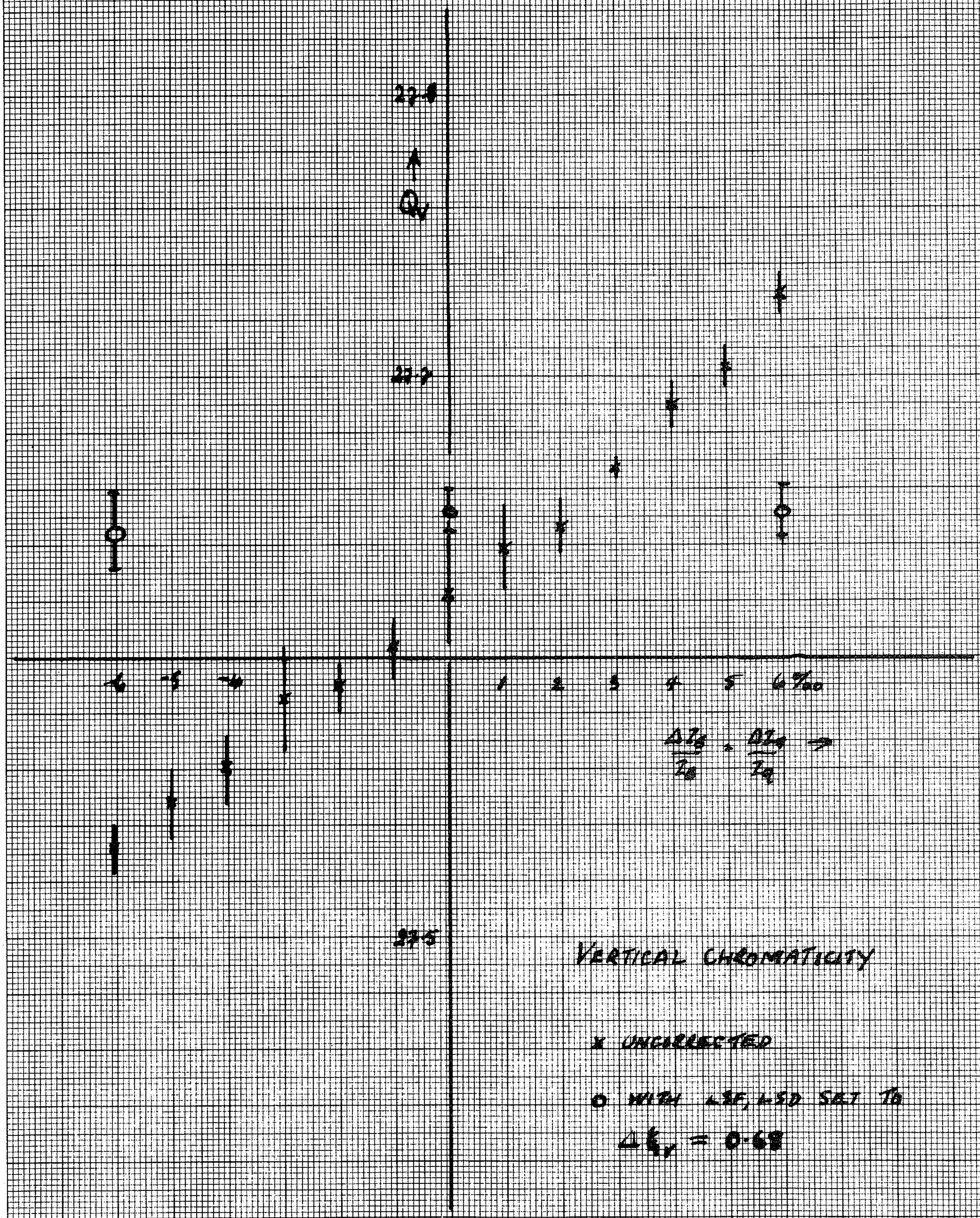

↑
Q_H
28·0
27·8
27·4
27·2
-5
-4
-3
-2
1
2
3
4
5
6
7
$\frac{\Delta p}{p} = \frac{\Delta I_M}{I_M}$ →
HORIZONTAL CHROMATICITY
x UNCORRECTED
O WITH LSF, LSD SET
TO GIVE $\Delta\xi_H = 1\cdot9$

FIG 2



VERTICAL CHROMATICITY

FIG 3

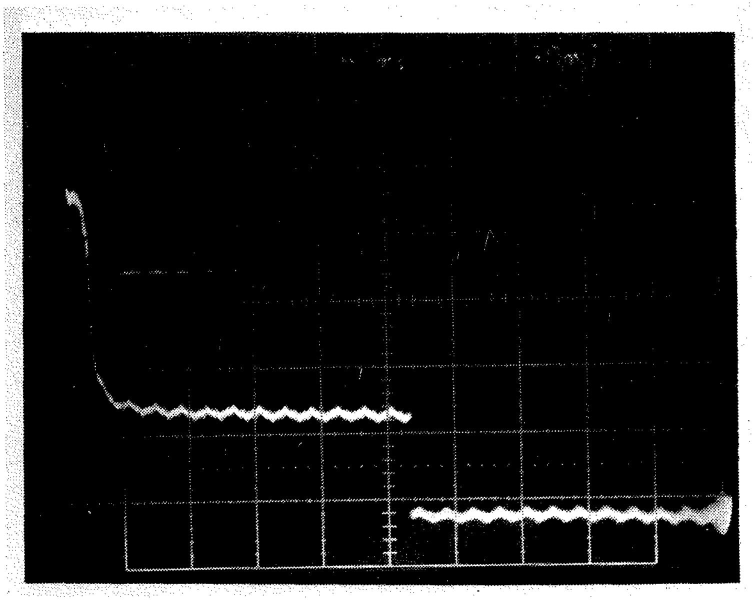


Fig. 4 Beam current transformer shows loss in the first 5 milliseconds due to resistive wall instability (50 ms/div.)

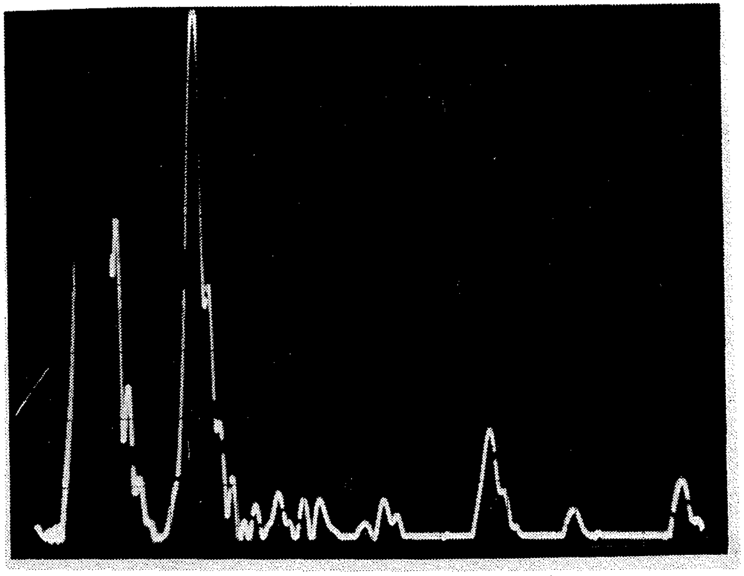


Fig. 5 Spectrum analyser shows $(n - Q)\omega_o$ peak-signature of resistive wall (10 kHz/div.)

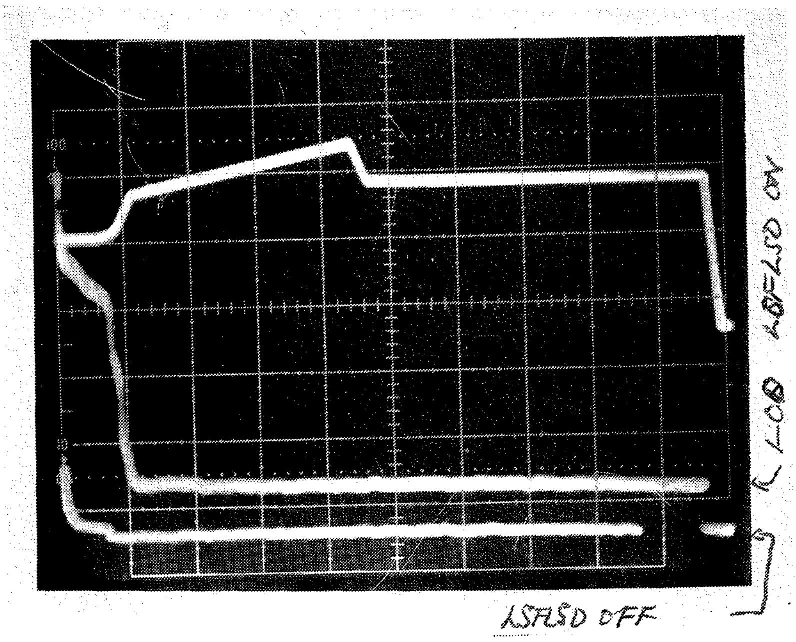


Fig. 6 Middle track is BCT during 50 GeV cycle - lower trace shows how switching of LSF and LSD kills the beam (500 ms/div.)

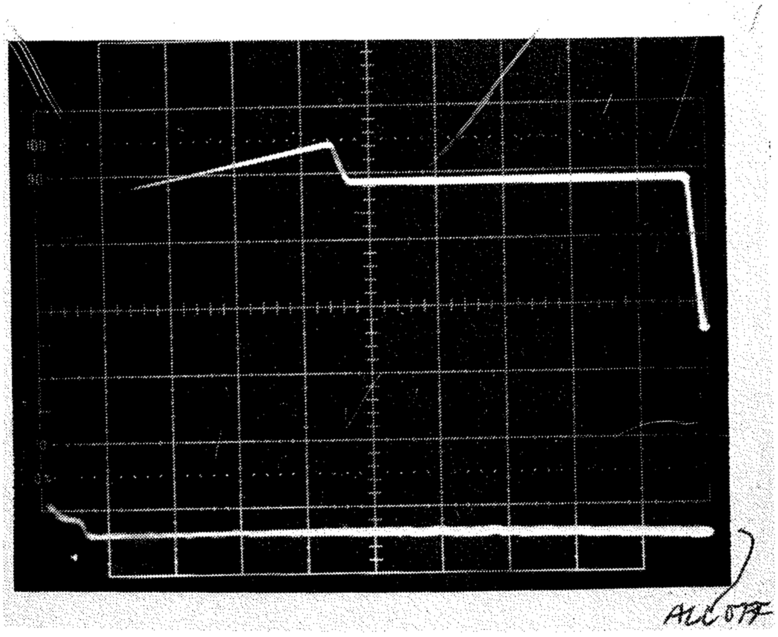


Fig. 7 Lower trace shows no beam survival after 300 milliseconds when LOD's are off as well as LSF LSD (500 ms/div.)

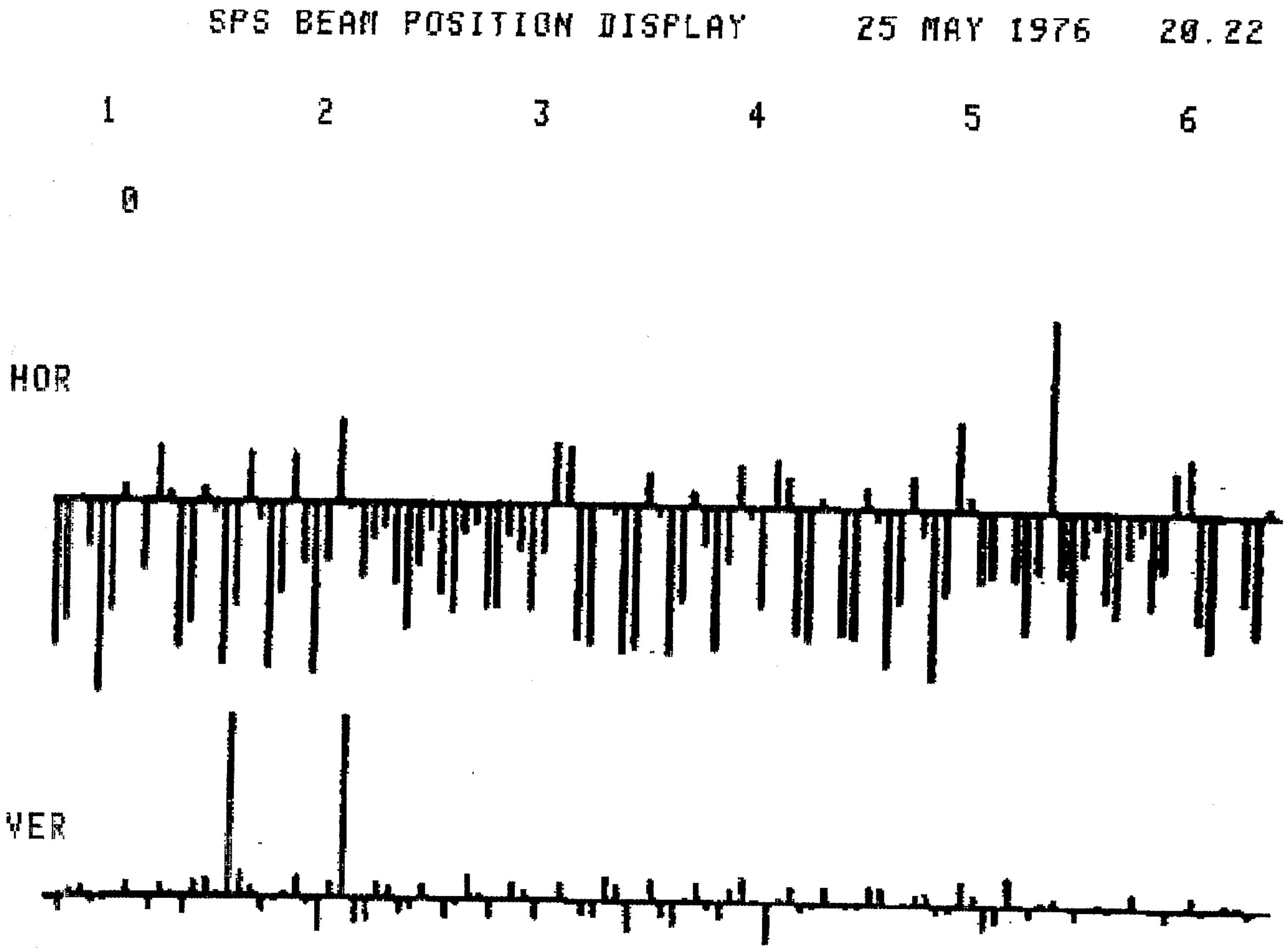


FIG 8

WITH $\Delta I/I = +6$‰ IN DIPOLES + QUADS