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EXPERIMENT : Stochastic Betatron Cooling on a Betatron Coupling Resonance

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EXPERIMENTER : Rol Johnson

Goal of the Experiment

Demonstrate that one can cool in both transverse planes with only one cooling system by using the natural coupling of the AA with equal horizontal and vertical tunes.

Description of the Experiment

The 1-2 GHz cooling systems (H±) were used to cool a beam of $\sim 1.7 \times 10^{11}$ protons. First the protons were well cooled longitudinally using the HF Δp system. All subsequent measurements described below were made using only the HF vertical betatron stochastic cooling system.

The tunes and cooling rates were measured as during normal operation. See Fig. 1 where the vertical cooling time at a momentum corresponding to $f_{rev} = 1.855$ MHz is found to be $\tau_{vertical} = 87$ m and $\tau_{horizontal} = 918$ m. The ordinate of Fig. 1 is the average of the peak amplitudes of the upper and lower betatron sidebands at the 44th revolution harmonic as measured with the resonant Schottky pick-ups.

Next, the vertical tune at the center of the (narrow) stack was changed using the AA quads until $Q_V = Q_H$ as measured by the Schottky pick-ups. At this point one could see "instantaneous" horizontal cooling as the coupling on the main diagonal of the working diagram caused the horizontal and vertical betatron emittances to come to equilibrium. See Fig. 2, which shows the horizontal betatron sidebands before and after moving to the main diagonal. Since the vertical plane was well-cooled, after equilibrium the vertical emittance grew while the horizontal emittance diminished.

The next step was to use the vertical beam damper, fed with an appropriate oscillator signal, to blow up the beam. Being still on the coupling resonance, this blew up the vertical and horizontal emittances equally. Fig. 3 shows the increase in betatron amplitude as a function of time of vertical excitation.

Finally, the cooling times and tunes were measured as the HF vertical betatron cooling was used while on the coupling resonance. See Fig. 4. The horizontal and vertical cooling rates were measured to be 237 m and 182 m, respectively.

Analysis

The measurement of the cooling rates seemed to be entirely dominated by systematic errors. Looking at Fig. 4, for example, one can see the correlation between the data points for horizontal and vertical amplitudes taken at the same time. One could define a ratio of Amp_{vert}/Amp_{horiz} which would remove the error due to this correlation, but I prefer to repeat the measurement at a time when the data and errors can be studied in more detail.

Nevertheless, the qualitative agreement between the data and naīve expectations is quite good. Namely the coupling causes the cooling rates to become equal in the two planes with cooling times which are twice the original V_β cooling time.

Conclusions

Simultaneous cooling of both transverse planes by means of one transverse stochastic cooling system and operating on a coupling resonance works as expected. This only assumes that the resonance coupling time is short compared to the cooling time, as seen in Fig. 3.

Comments

For practical operation of the AA this experiment probably has implications for the unlikely case of one of the transverse cooling systems dying with a stack of $\bar{p}$'s in the machine.

For new systems now being designed where the cooling in one plane is much easier, for geometrical considerations, for example, one could consider using coupling resonances to cool in two planes with one cooling system. As a cute aside, one could pick a non-diagonal coupling resonance to enhance the relative cooling in one plane vs. another (e.g. $Q_V - 2\ Q_H = n$, where some artificial coupling may have to be introduced into the lattice).

Another possibility would be the use of synchro-betatron coupling resonances to allow the cooling of bunched beams circulating in a $p\bar{p}$ collider.

Reported by Rol Johnson

$Q_H = 2.2660$

$Q_V = 2.2600$

1.855 MHz

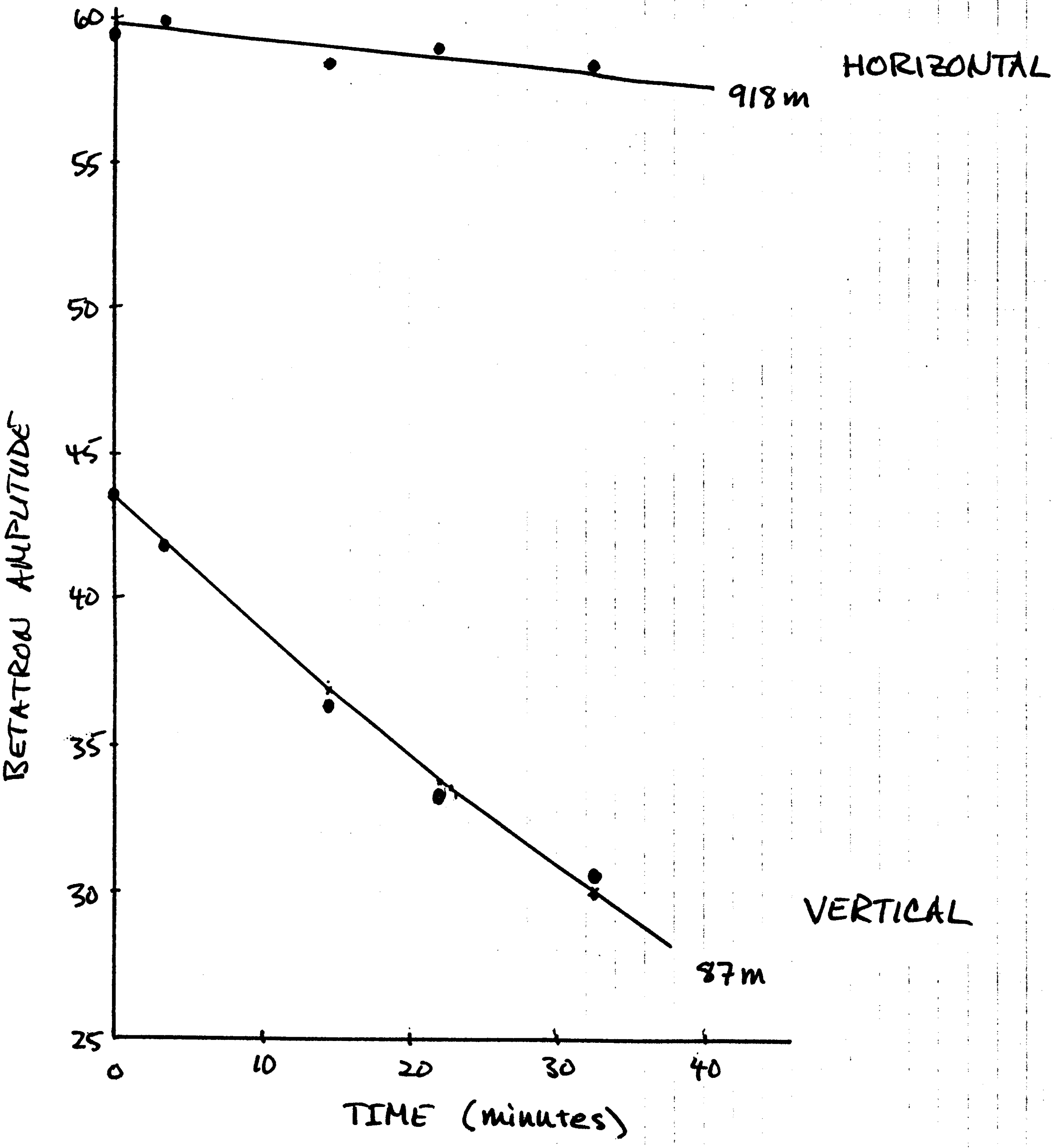
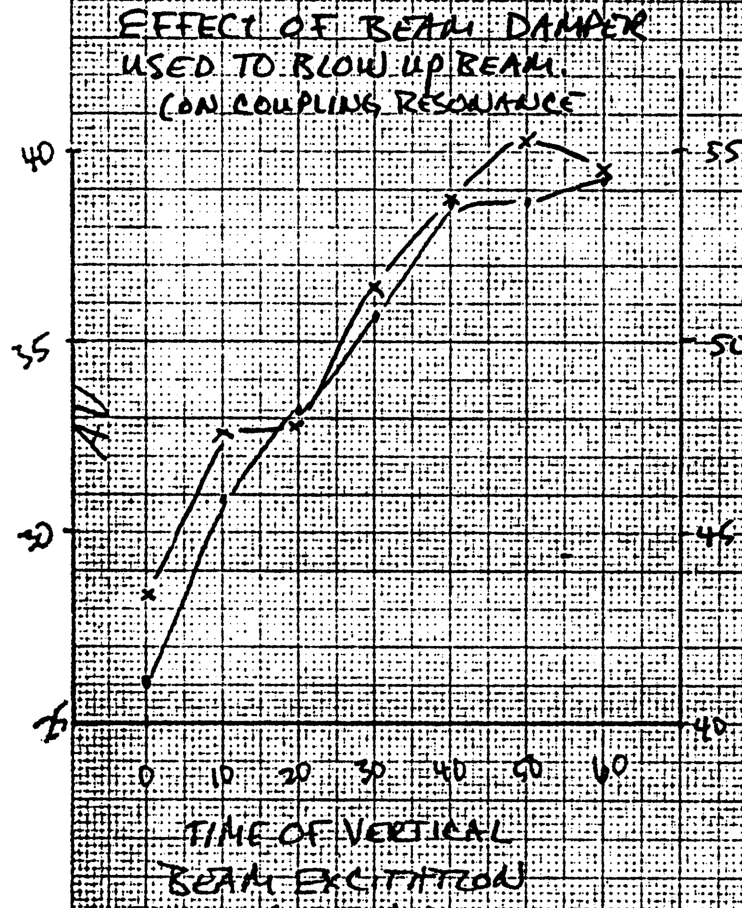


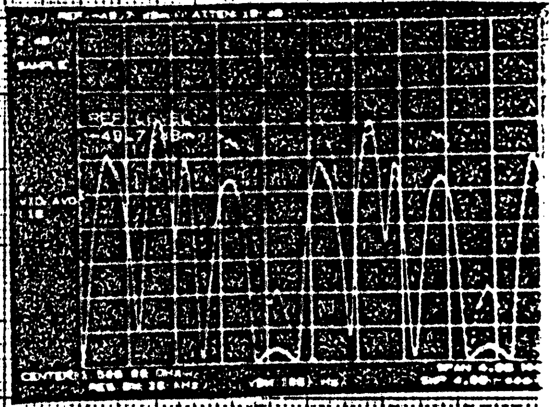
figure 1



EFFECT OF BEAM DAMPER USED TO BLOW UP BEAM.
(ON COUPLING RESONANCE

FIG 3

EFFECT OF MOVING TUNES TO MAIN DIAGONAL ON H_β AMPLITUD



LIGHT TRACE: H_β signal befo

i.e. $Q_H, Q_V = 2.266, 2.2$

BRIGHT TRACE:

$Q_H = Q_V = 2.266$

"INSTANTANEOUS CHANGE".

NOTE THAT V_β WAS WELL

FIG 2

1.855 MHz

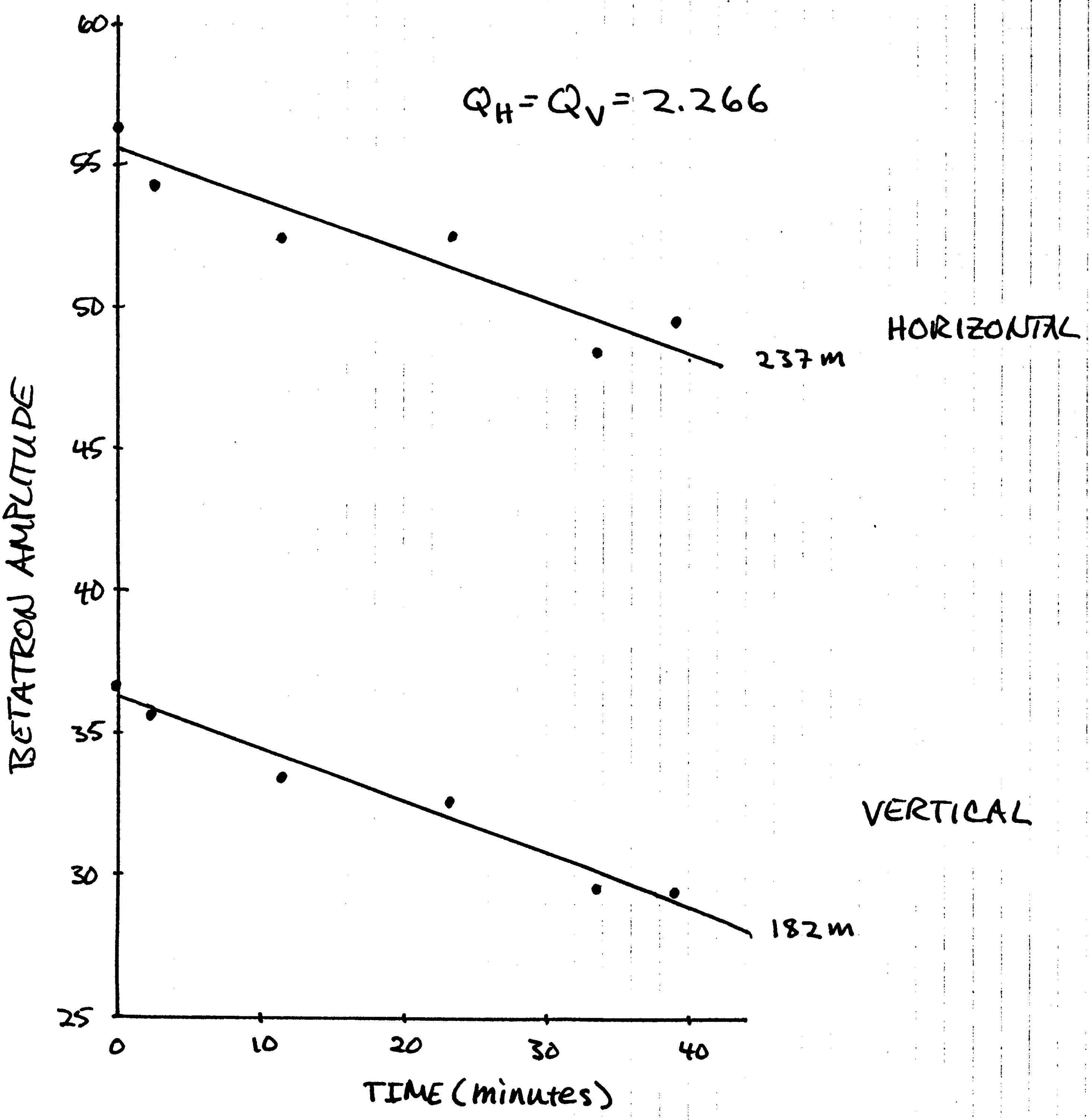


Fig. 4.