EXPERIMENT : Stack tail Δp cooling system influence on the core.

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Goal of the Experiment: Study the mechanism which causes the core to become wider under the influence of the stack tail Δp stochastic cooling system.

Description of the Experiment:

A small beam of antiprotons (6.3×10^9) which had been cooled with the HF systems was subjected to additional cooling by the stack tail Δp system. Various parameters of the S.T. Δp system were changed and the variations in the core momentum distribution were recorded.

The HF system had the following parameters:

	Δp	V	H	
Attenuator	4	8	8	dB
Delay	2.158	1.982	2.371	ns
Power (typical)	.8	.3	.2	W

1. The first experiment was to turn on the S.T. Δp system in the same condition it had been in during stacking but with 3 dB more attenuation.
2. The second experiment was to change the relays to disconnect the S.T. Δp pick-ups and terminate the preamp inputs on resistors. The

subsequent experiments are all with the pick-ups off (i.e. preamp inputs terminated).

3. The third experiment was to increase the gains of each of the two S.T. Δp subsystems S1 and S2, by 3 dB. This corresponds to the normal working level during stacking.

4. The fourth experiment was to turn off ½ of all the 32 final stage amplifiers in the S.T. system and take out all attenuation to bring the cooling power to the level of experiment 3. (Since each amplifier is connected to its own kicker, turning off half the amplifiers reduces the number of kickers by one half. Thus, to get the same cooling power with ½ the kickers and ½ the amplifiers, the gain must be increased by 6 dB. The total output power is then increased by a factor of 2 over experiment 3.) The total output power increased 678 W instead of the expected 780 W when the attenuation was reduced. This is partially because one of the 18 amplifiers tripped off.

After the fourth experiment the S.T. conditions were returned to those of experiment 3, then 2, to see if the widths returned to earlier values. Lack of time prevented measuring the reversability of the core growth with any accuracy.

Analysis:

Figure 1 shows the time variation of the r.m.s. core width and 3rd moment during the course of the experiments. The 3rd moment is mostly interesting in that it shows that the distributions are still evolving even when it seems that the core width has reached an asymptotic value. Perhaps this represents the subtle cold war between the HF and S.T. systems.

Experiments 1-3 show the effects of thermal noise on the core distributions. The comparison between P.U. on/off shows no change in the core momentum distribution, indicating that the core broadening can be explained entirely by thermal noise at the input of the S.T. Δp preamplifiers. At nominal operating S.T. power levels the core of the stack of 6.3×10^9 is doubled in width in $\sim 1\frac{1}{2}$ hours.

Experiment 4 shows the effect of non-linearities in the stack tail amplifiers. By making the amplifiers work at 4 times the normal power level, the intermodulation distortions are greatly enhanced. The 3rd order intermodulation products are, in principle, the only likely offenders and a factor of 3.5 in power should increase the 3rd order distortions by a factor of $\sim$ 43. The core width increased by $\sim$ 17 % when the power amplifier was increased by a factor

$$\frac{2(678)}{437} = 3.1$$

measured by the power meter or $5\frac{1}{2}$ dB = 3.5 by the attenuators.

The intermodulation distortions could be seen more directly by comparing the depths of the filter notches in the spectrum of the S.T. Δp power sum signal. Figure 2 shows such a spectrum at the 200th revolution harmonic for the conditions of experiments 3 and 4. The two traces have been aligned to overlap outside the notch region. Thus, the light trace which corresponds to the conditions of experiment 4 is seen to have a notch some 5 dB shallower than the heavy trace of experiment 3.

Another possible explanation for the results of experiment 4 is that the HF Δp preamp somehow was able to see the higher power of the S.T. Δp system. For example, intermodulation distortion in the HF preamp could have caused the increased core width in the conditions of experiment 4 compared to experiment 3. In fact, at the normal power levels, the HF Δp power spectrum between 1 and 2 GHz is not affected by turning the S.T. Δp systems on or off. Thus this mechanism is excluded.

One might ask whether the Schottky spectrum in the S.T. Δp system can cause core widening when the design $\bar{p}$ accumulation rate is reached. Most of the Schottky power in the S.T. Δp system is concentrated in the tail region because of the filters and compensation electrodes. This can be seen to a certain extent on Figure 3 where the bright trace is the S.T. Δp S2 pick-up signal in conditions of $\sim 2.5 \times 10^9$ $\bar{p}$/h accumulation and 7.5×10^{10} $\bar{p}$ in the stack. The small bump to the left of centre is the Schottky signal, the flat portions represent the normal thermal noise. One can see that most of the Schottky power does not overlap the core region.

Conclusions:

1. The core width growth seen under $\bar{p}$ stacking conditions seems to be due to thermal noise in the Δp stack tail stochastic cooling system.

2. Intermodulation distortions of the stack tail amplifiers have been measured to be reasonably small for the anticipated power demands of the AA design.

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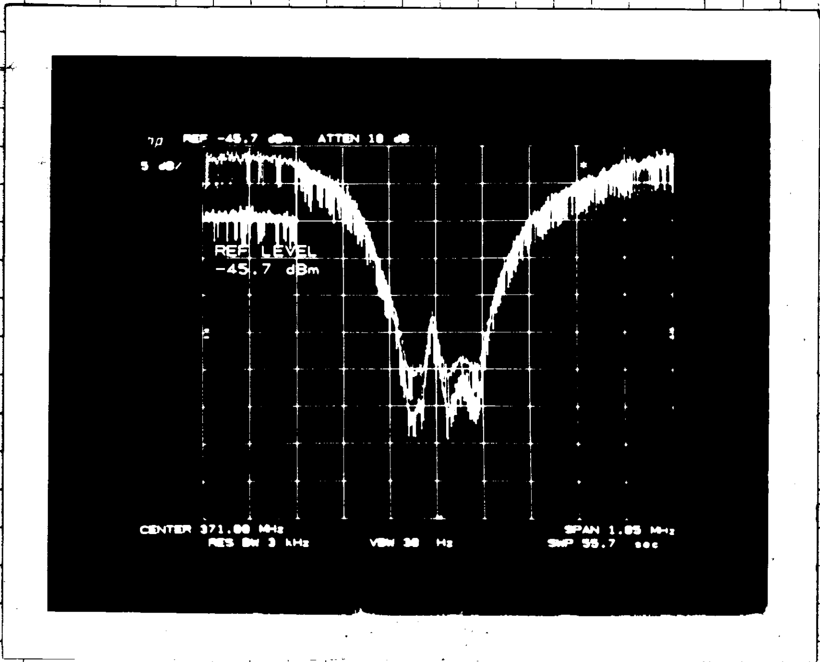

FIG. 2. Notch depth comparison of Experiment 3 vs Experiment 4. Signal is S.T. Δp power sum.

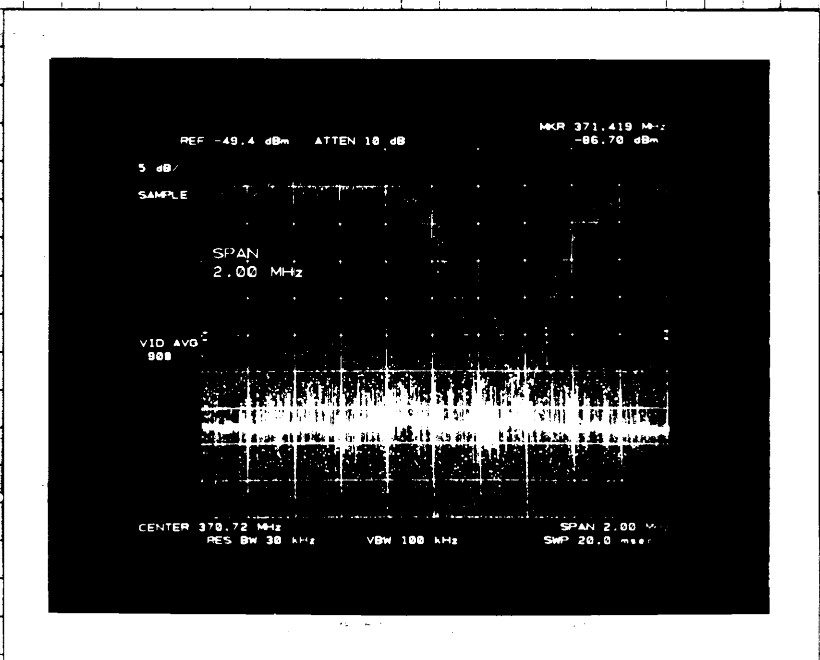

FIG. 3. S.T. PICKUP SIGNAL UNDER $\bar{P}$ STACKING CONDITIONS COMPARED TO NOTCH PLACEMENT.

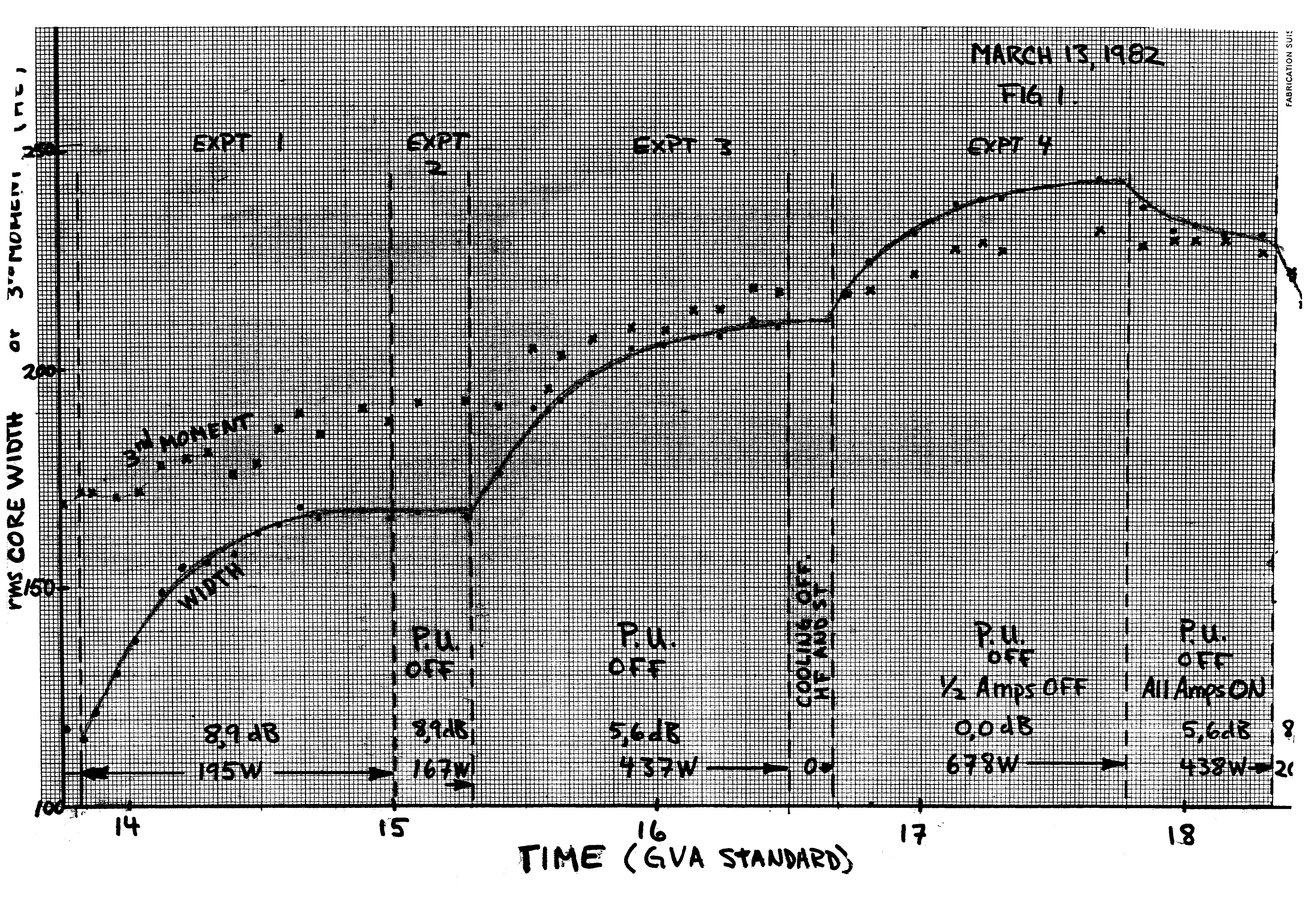

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FIG 1.
EXPT 1
EXPT 2
EXPT 3
EXPT 4
rms CORE WIDTH or 3rd MOMENT
3rd MOMENT
WIDTH
250
200
150
100
P.U. OFF
P.U. OFF
COOLING OFF. HF AND ST
P.U. OFF
½ Amps OFF
P.U. OFF
All Amps ON
8,9 dB
8,9dB
5,6dB
0,0dB
5,6dB
195W
167W
437W
0
678W
438W
14
15
16
17
18
TIME (GVA STANDARD)