p̄ Note # 473

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DEBUNCHER MOMENTUM COOLING SYSTEM

Debuncher momentum cooling was proposed as an option in the TEV I design, but was never considered very seriously as a part of TEV I. Momentum cooling now appears to be an attractive solution to some of the problems with the anti-proton source. Currently, about 1/2 the beam that is injected into the Debuncher is stacked into the accumulator. The known sources of inefficiency are as follows:

1. With typical running conditions there is perhaps 1500 nA of beam in a Debuncher momentum spread of 2.4% ($\Delta p/p$) after bunch rotation. Roughly 1000 nA of this beam is within the limited momentum spread of 0.2%.

2. About 750 nA of the beam is transferred to the Accumulator injection orbit.

3. Some beam is not stacked from injection to the stacking orbit. The amount may be 10%, but it has not be measured carefully recently.

4. The gain of the stack tail system is limited by betatron heating.

A momentum cooling system can help with all these problems. A 4-8 GHz cooling system can collect particles from a ±.5% $\Delta p/p$ range in the Debuncher. The optimization of the bunch rotation becomes different: one can accept some over-rotation (outside the nominal ±.1%) in order to collect more beam from the tails of the distribution (out to ±.5%). The beam in the D/A line (where $\alpha_p \neq 0$) is smaller; particularly in the Accumulator kicker aperture. The momentum spread on the injection orbit is smaller and the r.f. stacking will be more efficient. Since the momentum spread is smaller, less gain will be required for the stack tail system, reducing betatron heating.

The Debuncher momentum cooling system has the same design considerations as the current betatron cooling systems. Specifically, it is expensive to achieve the optimum cooling gain because of the high power requirements. The power requirement is dominated by thermal (not schottky) noise. Under these circumstance one simply wants:

1. A large number of cryogenically cooled pickups
2. Low noise preamplifiers
3. High power amplifiers
4. A large number of kickers

The one unique feature is the need for a precise notch filter.

A simulation of the cooling process has been made with the same computer program used for the TEV I design calculations. The following parameters were assumed:

Frequency	4-8 GHz
No. of pickups	256
Pickup sensitivity	.75
Pickup impedance	50 Ω
Pickup resistor temperature	80 °K
Preamp noise temperature	200 °K
System gain	140 dB
Total output power	700 W (Thermal)
	100 W (Schottky)
No. of kickers	256

An initial distribution of 2×10^8 particles was assumed with 90% within a parabolic distribution .3% ($\Delta p/p$) wide at the base. The remainder of the particles were within ±.5% of the central momentum. Figure 1 shows the beam profile in energy (ΔE) at .2 sec, .8 sec, 1.4 sec, and 2.0 sec after cooling has begun. The initial rms energy spread is 8.4 MeV; the final rms spread is 1.8 MeV. Of the initial beam 99% is contained in ±.1%; 98% is contained in ±.05%. With 1/2 the gain, 86% of the beam is contained in ±.05% as illustrated in figure 2. Figure 3 shows the result for 2x the nominal gain, and figure 4 shows the result for an error in the initial beam energy of 10 MeV (.1% in $\Delta p/p$). A block diagram of the system is shown in figure 5.

As usual the pickups and kickers are assumed to be electrically identical. A conceptual design of the cross-section is shown in figure 6. The structure consists of two 100 Ω loops side-by-side to yield adequate coverage of the beam image currents on the wall. The two 100 Ω loops effectively add in parallel to give a structure with a sensitivity of .75 and an impedance of 50 Ω. Combiner boards are shown to either side of the loops. A module will be approximately 64 loops long. Two modules will fit between Debuncher quadrupoles. It appears that space can be made for the pickups in D60/D10 and for the kickers in D20/D30 although a substantial rearrangement of diagnostics in D60/D10 will be required. The design of this structure is in progress.

It is assumed that the preamplifiers will be specially designed to be cryogenically cooled to obtain the best noise figure. However, it is worth noting that commercial, room temperature, low noise preamplifiers with noise figures of 2 dB (170 ^{o}K) have recently become available.

The notch filter was assumed to be perfect in the simulations, i.e., no dispersion. More careful calculations will need to be made, but one can estimate the required notch precision by equating the rms notch dispersion to one half the beam width (σ). One finds that:

$$\Delta f/f \leq 5 \times 10^{-7}$$

i.e., five times better than the TEV I superconducting notch filters.

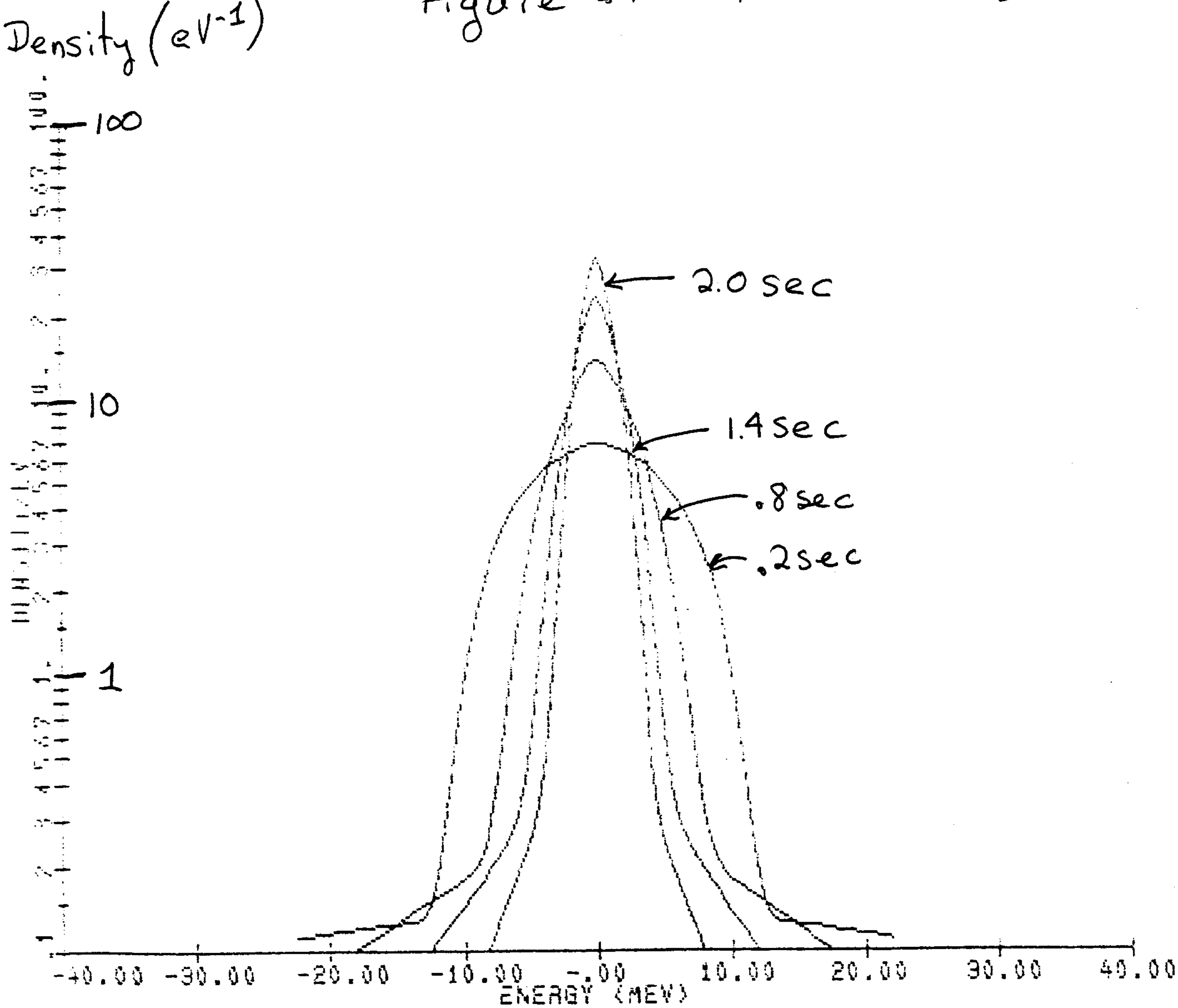
The total output power assumed in the parameter list is the power delivered to the kicker plates. To account for losses between the power amplifiers and the loops one should multiply the required power by two. If one uses 200 W (nominal) travelling wave tubes, then 16 tubes with a nominal output power of 100 W each would be adequate.

Conclusion:

A 4-8 GHz momentum cooling system for the Debuncher appears to be feasible and would be an effective early component of an anti-proton source upgrade.

Normal gain

Figure 1. Nominal System



$\frac{1}{2}$ gain

Figure 2. $\frac{1}{2}$x nominal gain

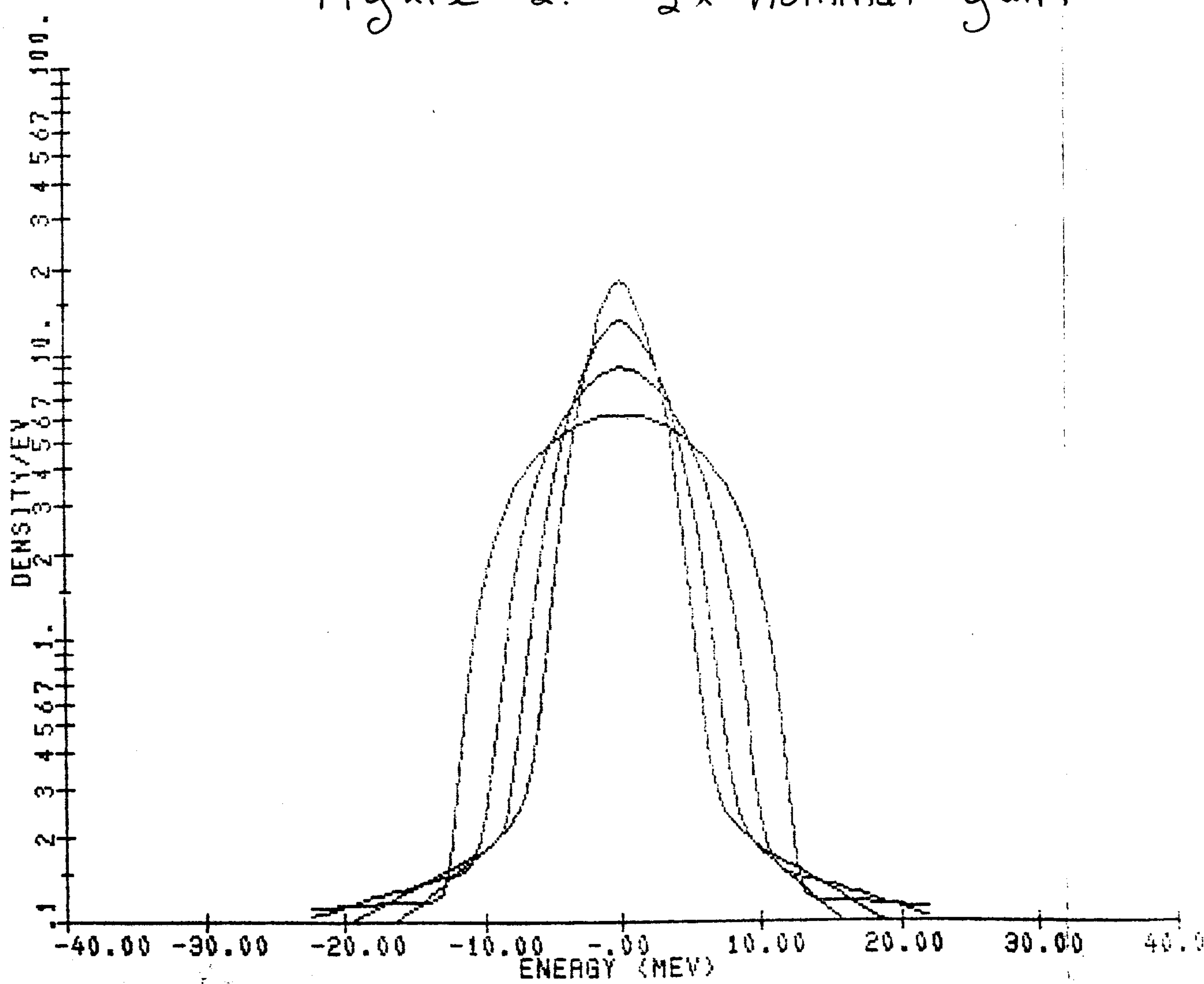
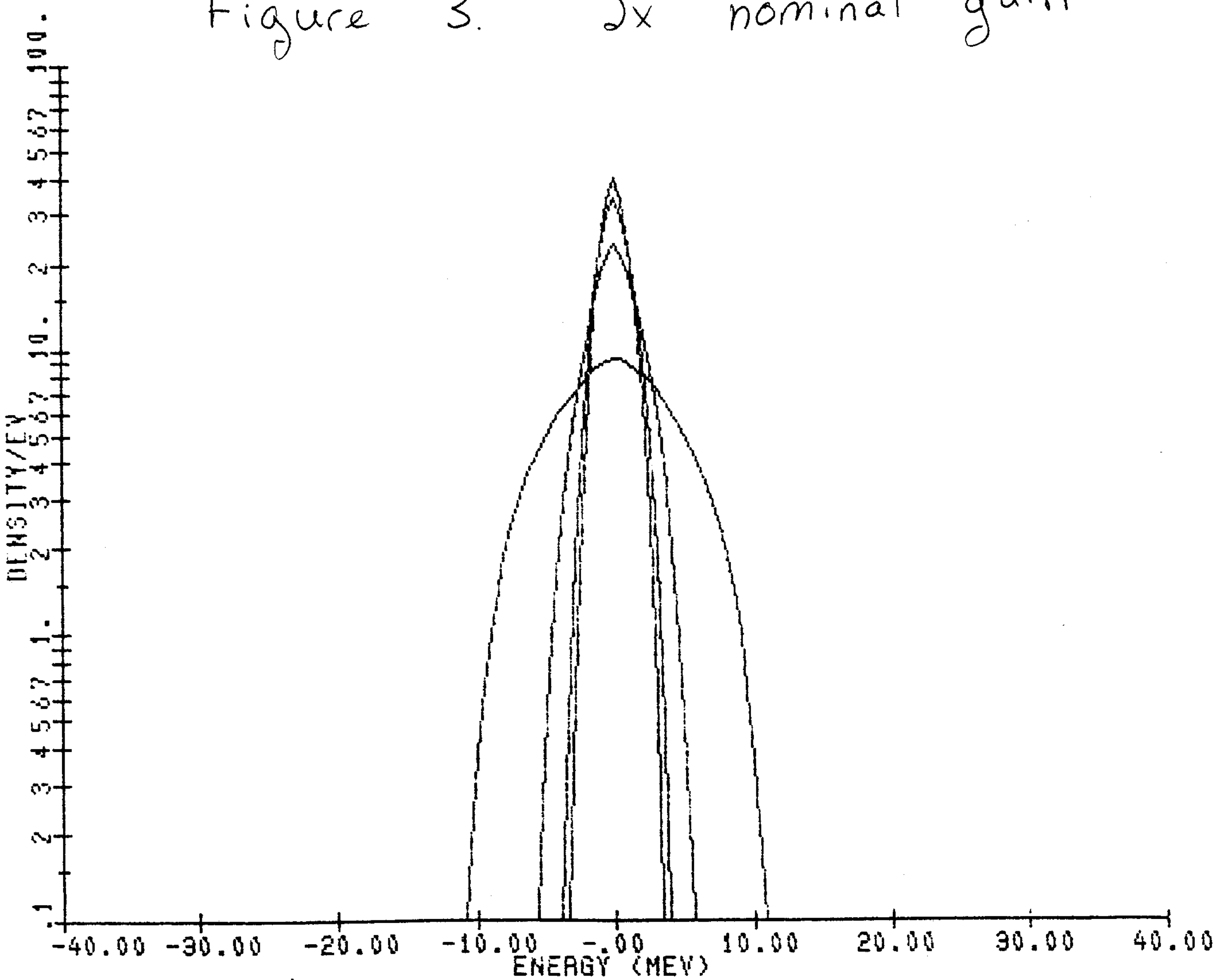


Figure 3. 2x nominal gain



10 MeV offset

Figure 4. 10 MeV offset in initial distribution

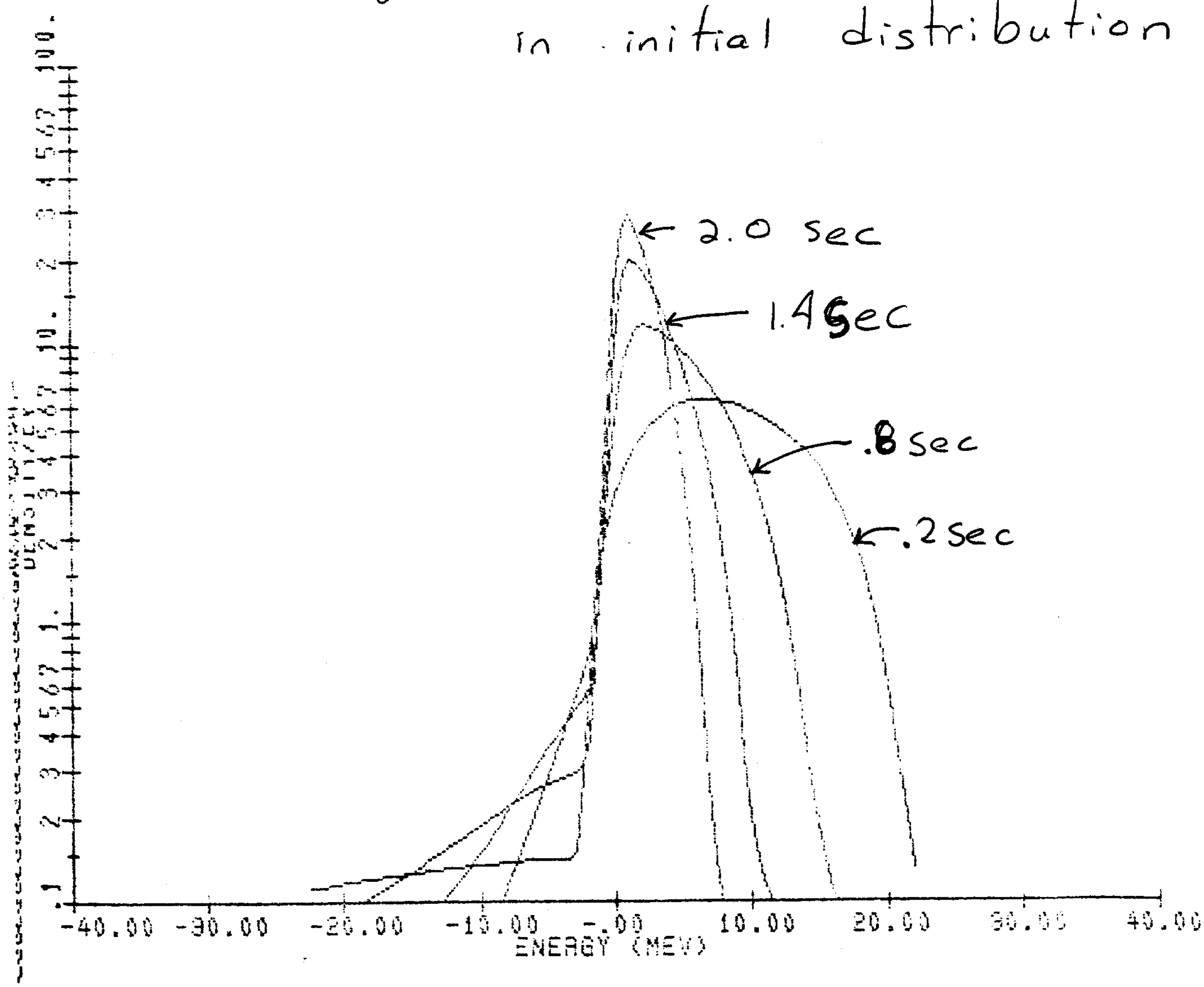


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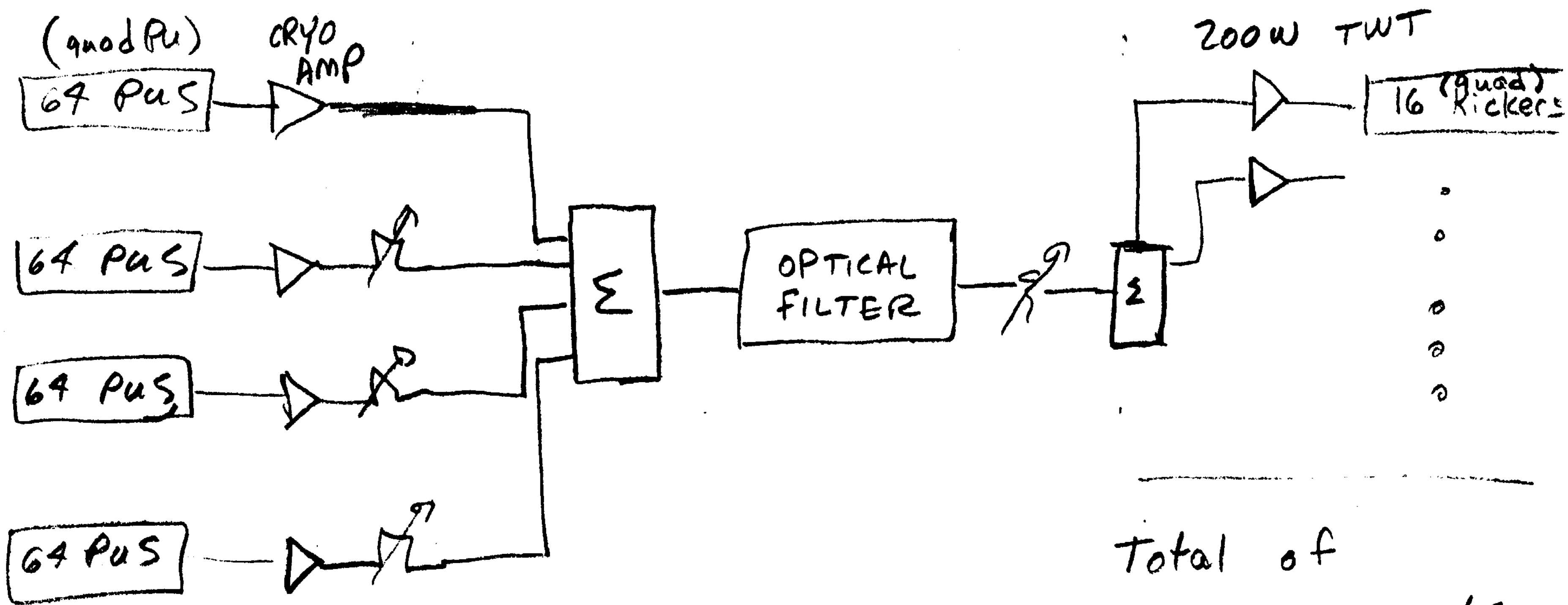
Figure 5.

PROPOSED 4-8 GHz ΔP COOLING FOR DEBUNCHER



Total of
16 200 W TWT'S

[8 200W TWT'S
feeding 32 (quad)
Kickers is OK]

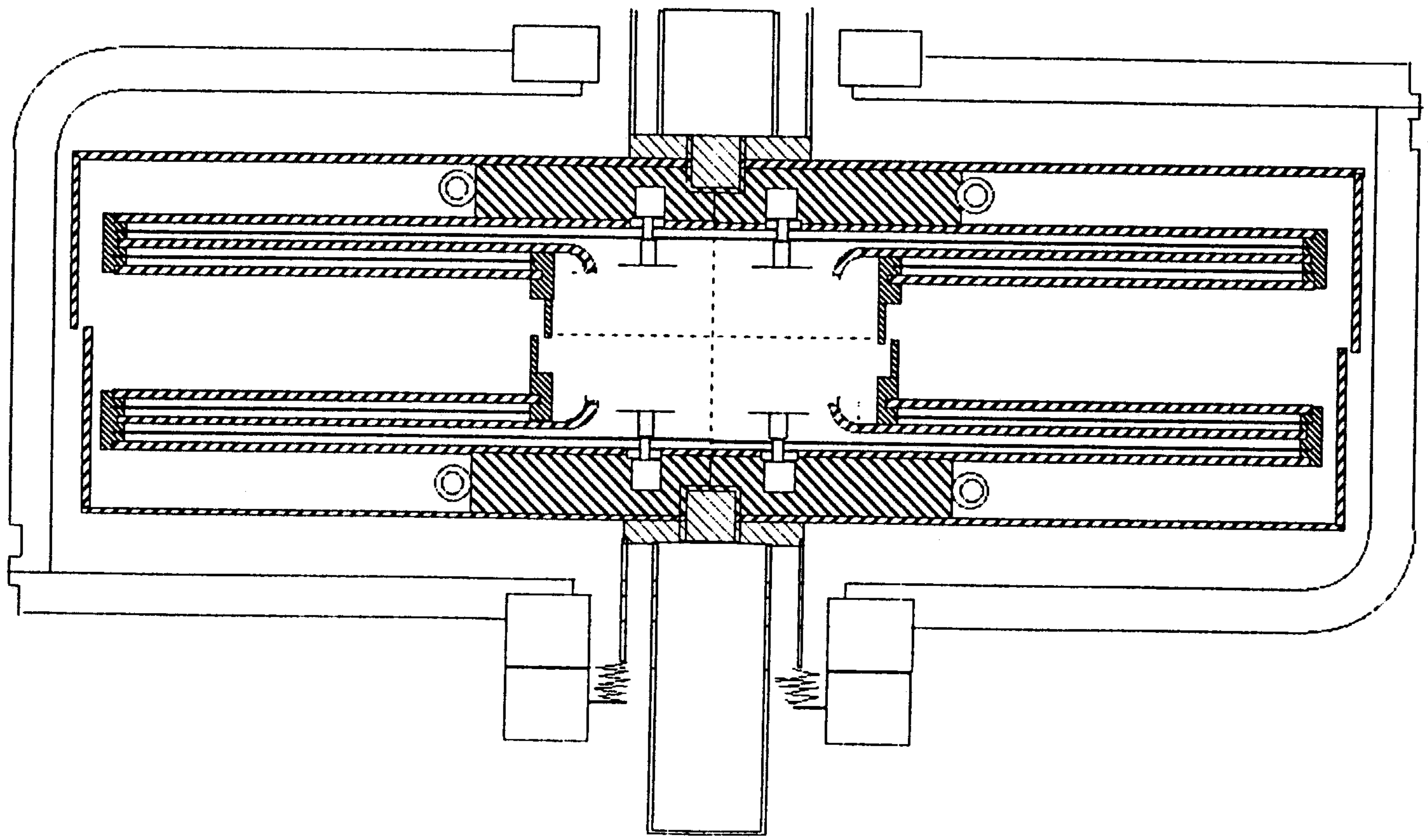


Figure 6. Pickup Cross-section