Proceedings of the 1963 Conference on Proton Linear Accelerators, New Haven, Connecticut, USA

October 23, 1963

HARMONIC BUNCHING*

R. Perry
Argonne National Laboratory

I should like to give a summary of the results of computations which I have made on the use of a multiple harmonic buncher. The ideal buncher would be one in which the buncher voltage varied linearly with time or with buncher phase, ψ_b.

$$V_b = \frac{\psi_b}{\pi} A \qquad (1)$$

This voltage can be approximated by combining the first few terms of a Fourier series of the form

$$V = \sum_{1}^{K} \frac{(-1)^{n-1}}{n} \sin n\psi \qquad (2)$$

which converges to (1) as K becomes very large (see Fig. 1).

The sinusoidal buncher, n = 1, gives a theoretical capture efficiency of about 69%. By combining with this a second harmonic cavity (K = 2) and separated from the first cavity by a distance which is small compared to the distance to the linac (see Fig. 2), the capture efficiency is about 81%. Three harmonics give about 86%, and four harmonics give about 90% capture efficiency, for ANL parameters. The second harmonic cavity has been built at ANL and is awaiting completion of tests of a frequency doubler and rf amplifier

* This material has appeared as ANLAD-74 Feb. 22, 1963 (ED).

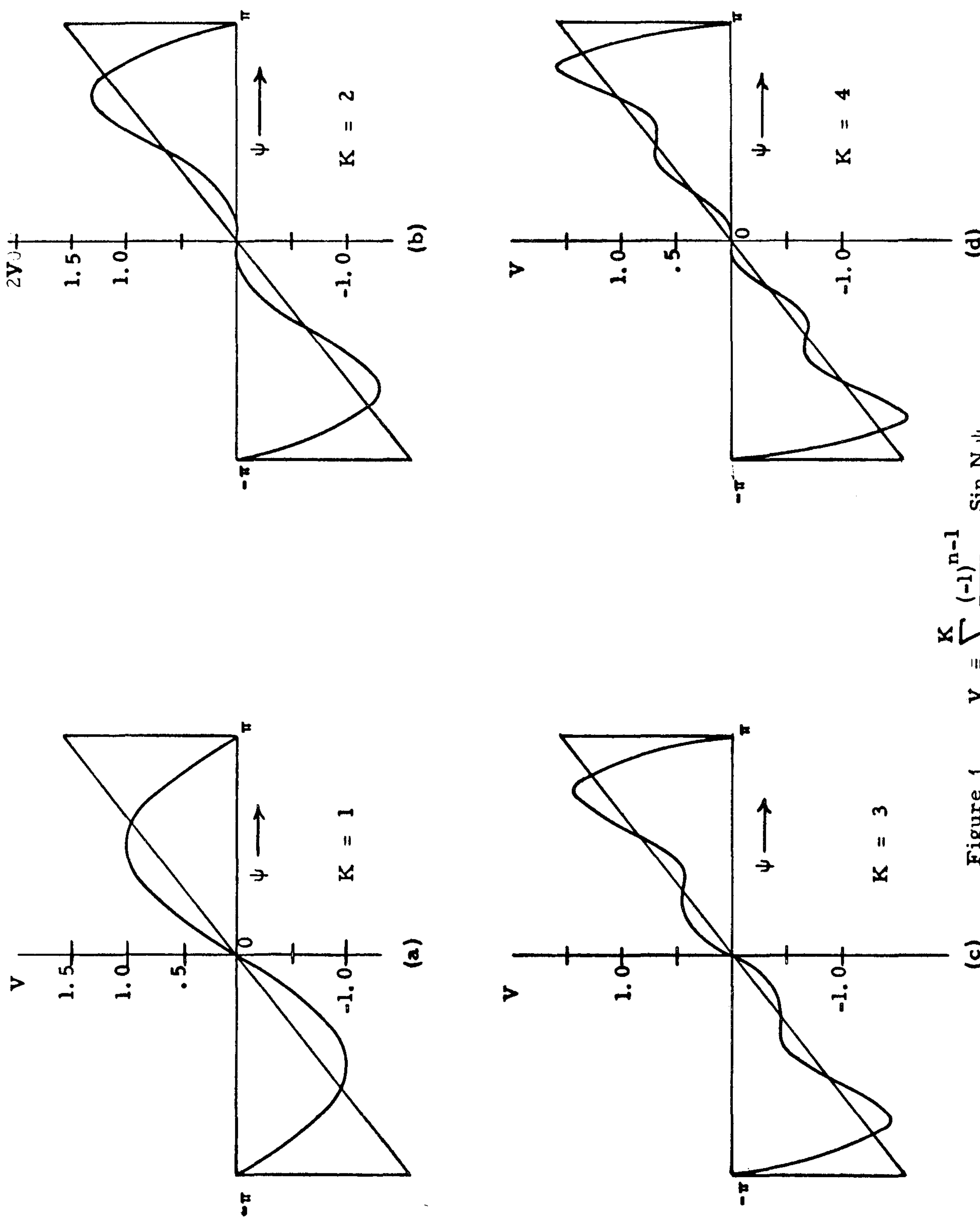

Figure 1 $V = \sum_{1}^{K} \frac{(-1)^{n-1}}{N} \text{Sin } N\psi$

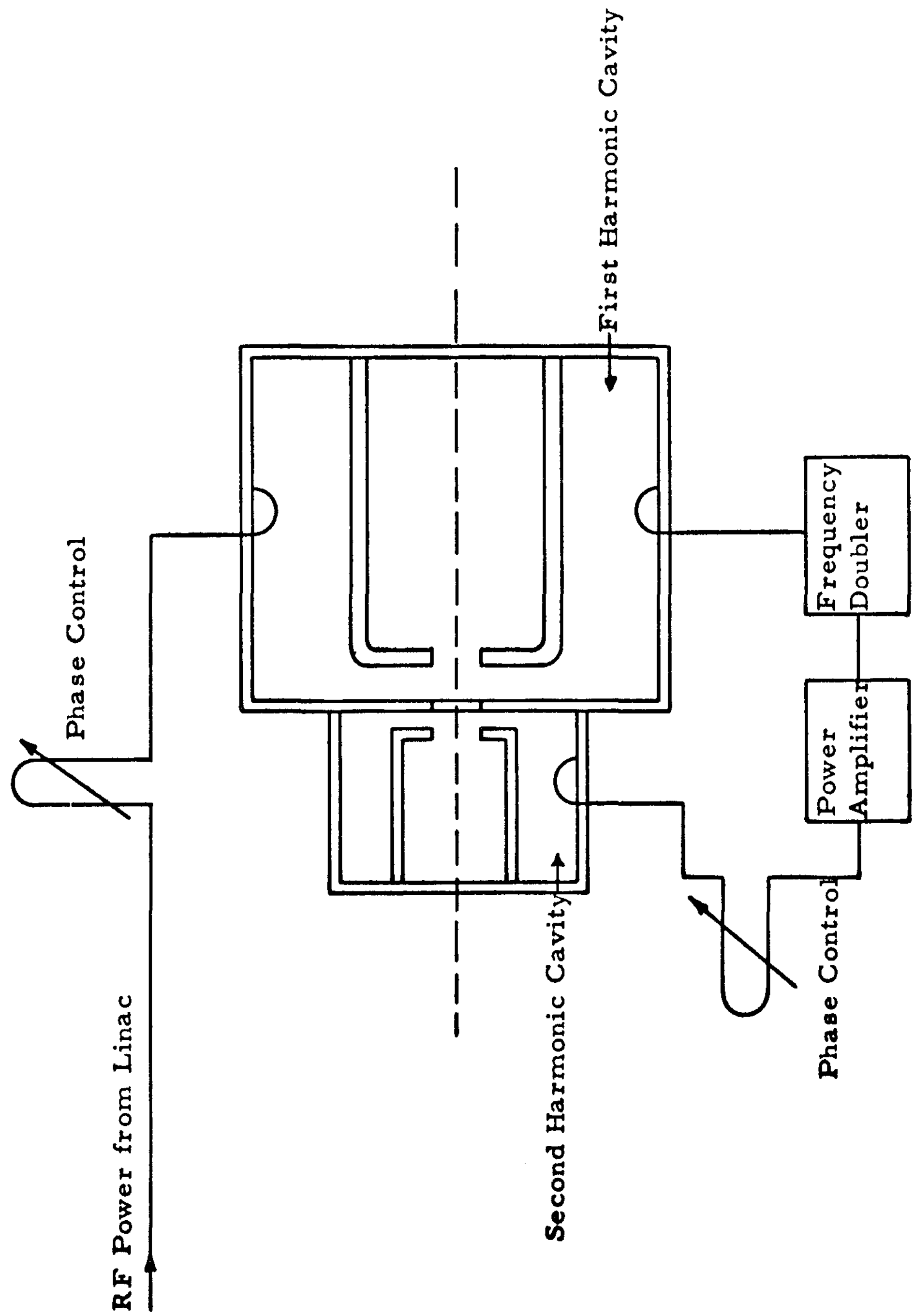

Figure 2 Schematic of Two-Harmonic Buncher

to drive it.

One effect of the ideal or linear buncher voltage is that all ions would be bunched at the same phase in the linac bucket. By using buncher voltages smaller than the value required for maximum capture efficiency (with either a single or a multiple harmonic system) the particles in the highest phase density regions can be placed well inside the phase limits of the phase space envelope (see Figs. 3 and 5) while only those in the low phase density regions will fall outside the bucket. With excessive buncher voltage amplitude, the regions of highest phase density will be pushed out of the bucket and be lost (see Figs. 4 and 6). It should be pointed out that for a high energy linac where there is concern over radiation from particles which are outside the phase bucket and which, therefore, are not accelerated to full energy, such particles will most likely become lost in the low energy end of the linac, probably before the 10 MeV region and certainly before 50 MeV. (The ANL linac has scarcely any neutron yield from beam losses on drift tubes.) It would, therefore, seem that the concern over radiation from loss at high energy due to lack of bunching should not be great. Moreover, any particles which might otherwise drift through at less than full energy would certainly be removed by strong focussing lenses before reaching a dangerous energy.

LIVDAHL: I mentioned the high voltage regulation problem earlier. One of our people redid the regulation system. His measurements of the regulation, both pulse to pulse and during the pulse, is 0.05% (or possibly even a little bit better) at 60 mA of beam in the column.

BLEWETT: I think we approach that value too.

BITTNER: Our regulation is better than one kilovolt at 750 keV.

BERINGER: I wonder if anyone has tried to decide in the Fourier sense of this problem, on the basis of the acceptance of what they would like to have and then construct a time-dependent wave-form that will do it. Even though it may look difficult on the surface, for either meson factories or injectors, it would be quite worth doing.

BLEWETT: Just assume the shape of bunch you would like to get and simply work back and see what that is?

BERINGER: Yes.

LEISS: When handling the order of 60 mA to 100 mA of positive ion beams, how much total current do you find yourself handling? I presume there are quite a few electrons flowing back up the column that increase the loading, and this is probably variable depending on the vacuum and operating conditions in general. Is it the same order of magnitude as the proton current?

LIVDAHL: I'm not sure you can tell the difference.

LEISS: In other words, it adds a very small amount to the total load.

SWENSON: I gather from the discussion that, maintaining a correct phase relationship between various buncher gaps at these frequencies is difficult.

PERRY: It is something of a problem.

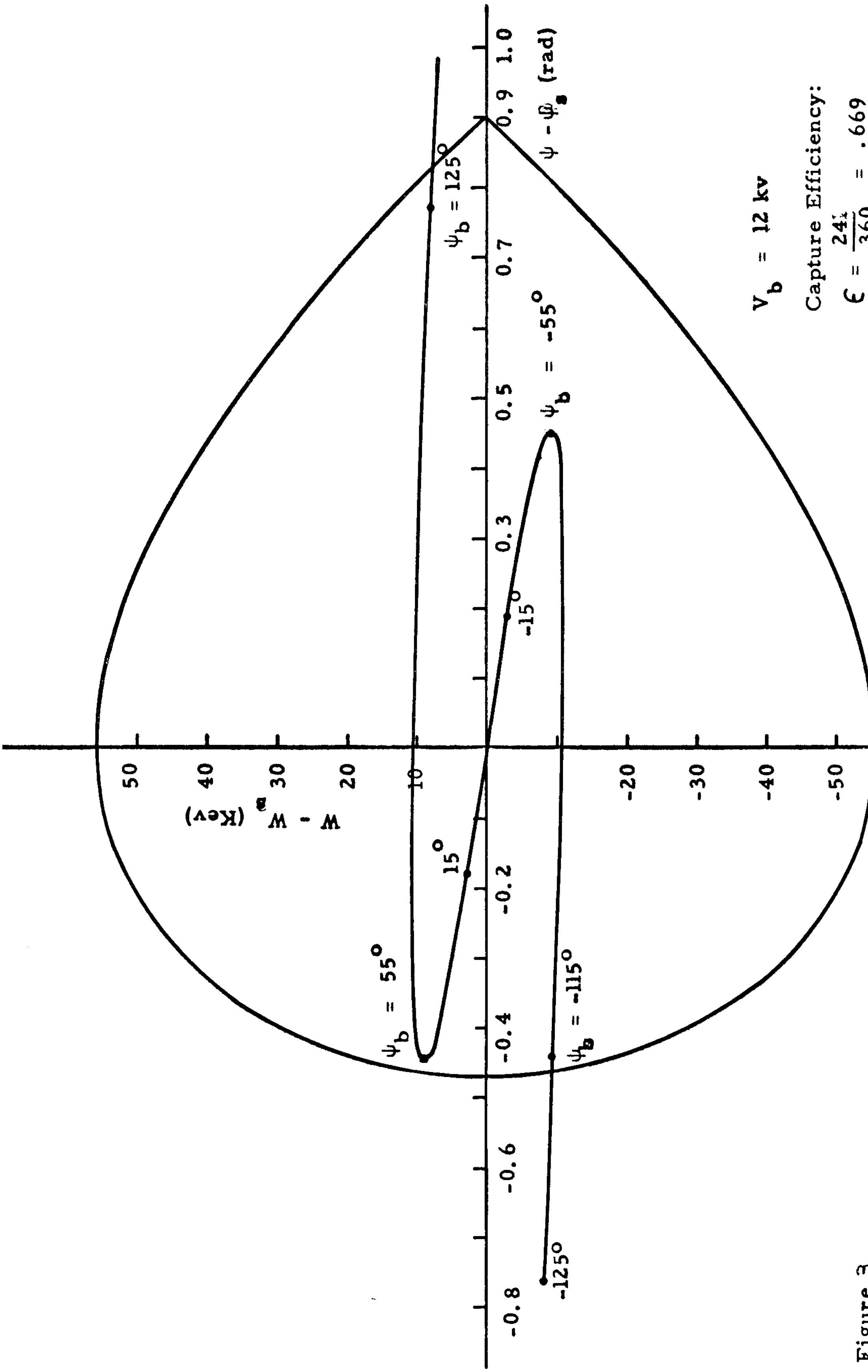

Figure 3
Phase-Energy Distribution at Linac
for Protons from Sinusoidal Buncher

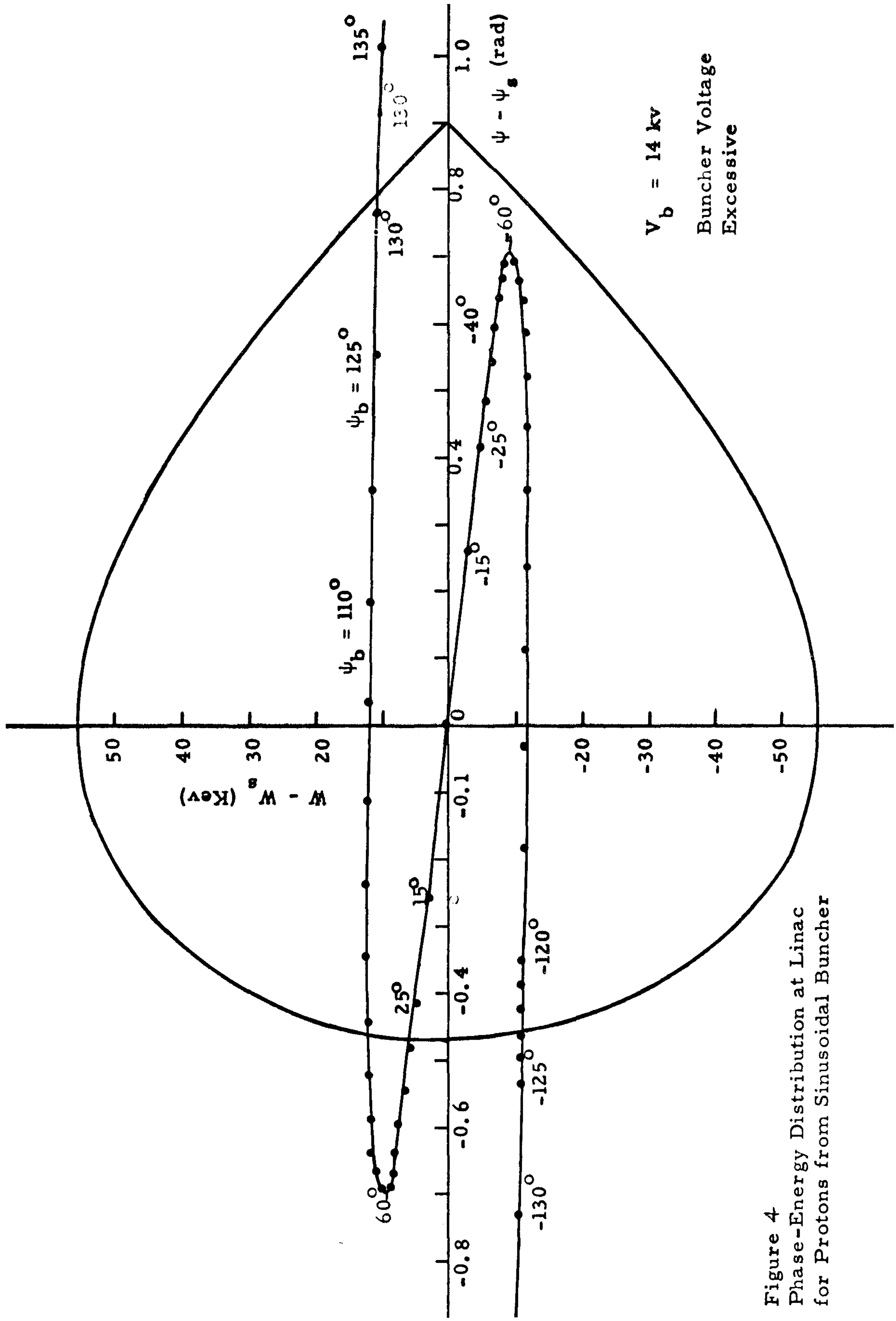

Figure 4
Phase-Energy Distribution at Linac
for Protons from Sinusoidal Buncher

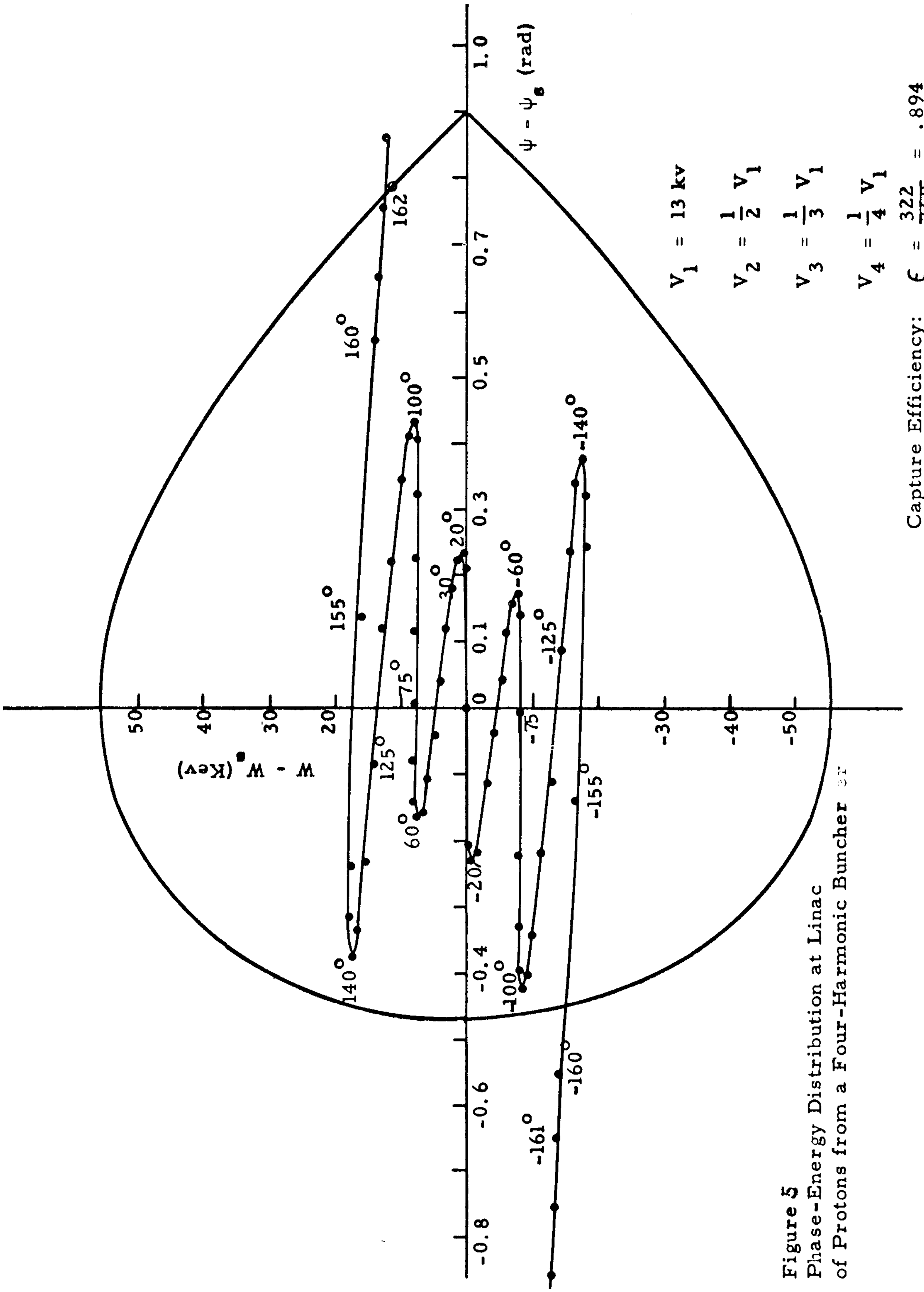

Figure 5
Phase-Energy Distribution at Linac
of Protons from a Four-Harmonic Buncher

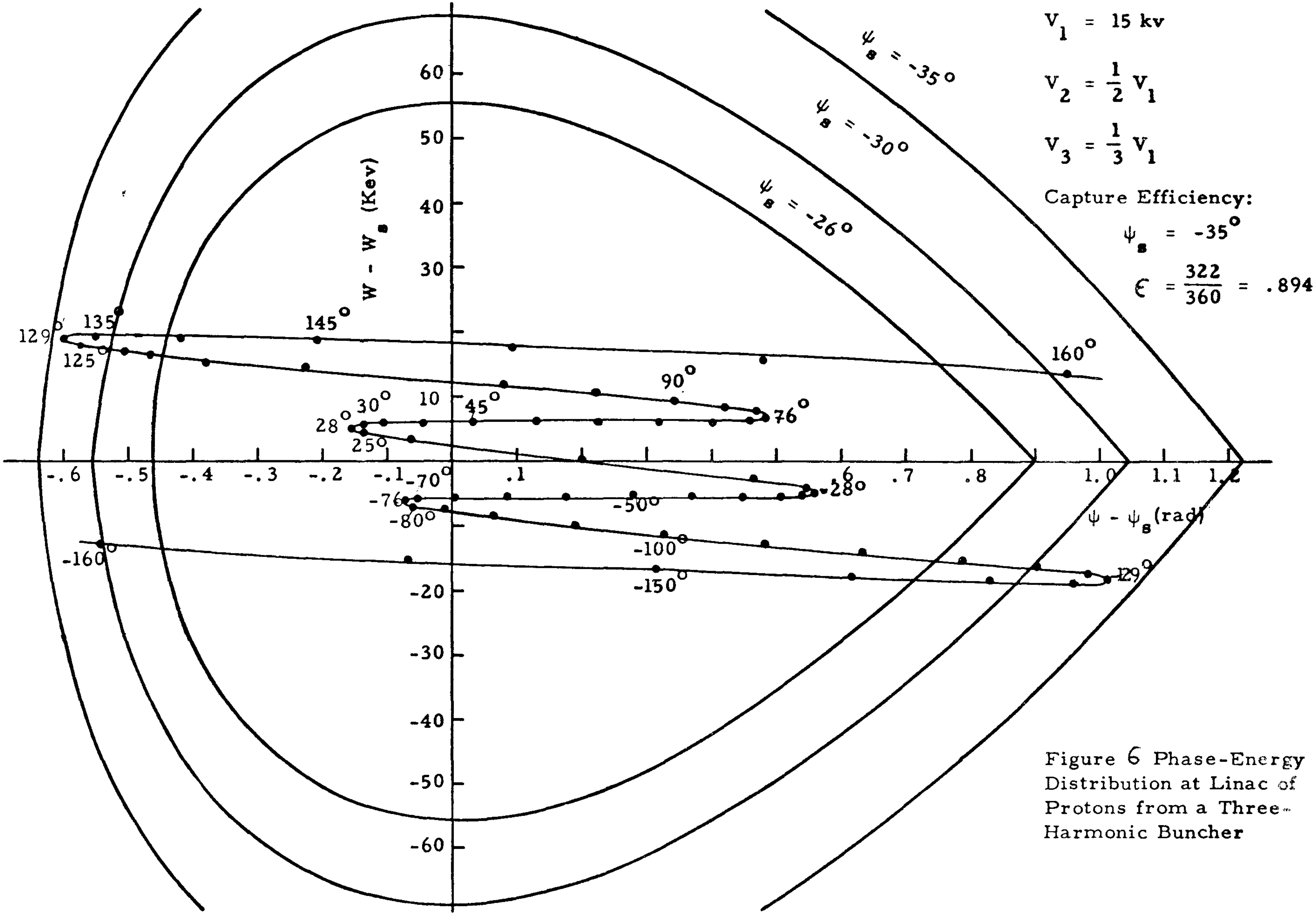

Figure 6 Phase-Energy Distribution at Linac of Protons from a Three-Harmonic Buncher