COMPUTER DESIGN OF A HIGH CURRENT, HIGH ENERGY PROTON LINAC

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The accelerator produces enough beam to make the same number of neutrons on the average as 0.5 mA of 800 MeV protons. The beam is delivered to the target in 200 ns pulses at 50 Hz. The results are presented here because some of the problems are similar to HIF problems.

In the Linac discussed here, the current at each point is constant throughout the pulse. Figure 1 demonstrates this scheme: A constant current is extracted from the ion source for a time dT = 2. This beam passes an accelerating gap at D = 0. The velocity profile is adjusted so that the beam is bunched. The time required for the beam to pass a point decreases linearly from dT = 2 to dT = 0 as the distance goes from D = 0 to D = 4.

In the accelerator, all of the acceleration is done by induction cavities. The machine is divided into three sections: a buncher, a debuncher, and a main accelerator. A 7.5A, 2 ms. pulse from a 750 kV preaccelerator is compressed by a factor of 10 in the buncher and debuncher. These 200 ns pulses are then accelerated to 565 MeV.

BUNCHER

In the buncher, the speed of the leading edge of the beam is kept high enough so that the beam current never exceeds 0.2 of the space charge limit. When the beam enters a cavity, it is at 0.2 of the space charge limit. After acceleration, the beam current is the same, but the space charge limit is higher. As the beam drifts to the next cavity, the current increases again to 0.2 of the space charge limit. This process is illustrated in Fig. 2.

The trailing edge of the beam pulse is transported by the same focusing structure as the leading edge. This problem has not been studied, but it seems reasonable to allow the ions in the trailing edge to have twice the momentum of those in the leading edge. This is illustrated in Fig. 3. The factor of two momentum spread is established in the first few accelerating gaps.

A nonrelativistic calculation gives for the length of the buncher after the space charge limit and velocity profile are established.

$$S < \frac{5}{2} T V \frac{M}{M-1}$$

where:

T = the time for the ion source beam to pass a point at the space charge limit (or fraction of the limit to be used),

V = the initial velocity of the leading edge, and

M = the ratio of the trailing edge momentum to the leading edge momentum.

The right-hand side, in the case considered here, is 120 m.

DEBUNCHER

The function of the debuncher is to reduce the momentum spread. This is illustrated in Fig. 3. Bunching continues, but at a reducing rate. The bunch length is shown in Fig. 4. The lower curve is the difference between the arrival time of the leading edge and the center of the beam pulse. The upper curve is the difference between the arrival time of the trailing edge and the center. Note that bunching is almost stopped in the debuncher.

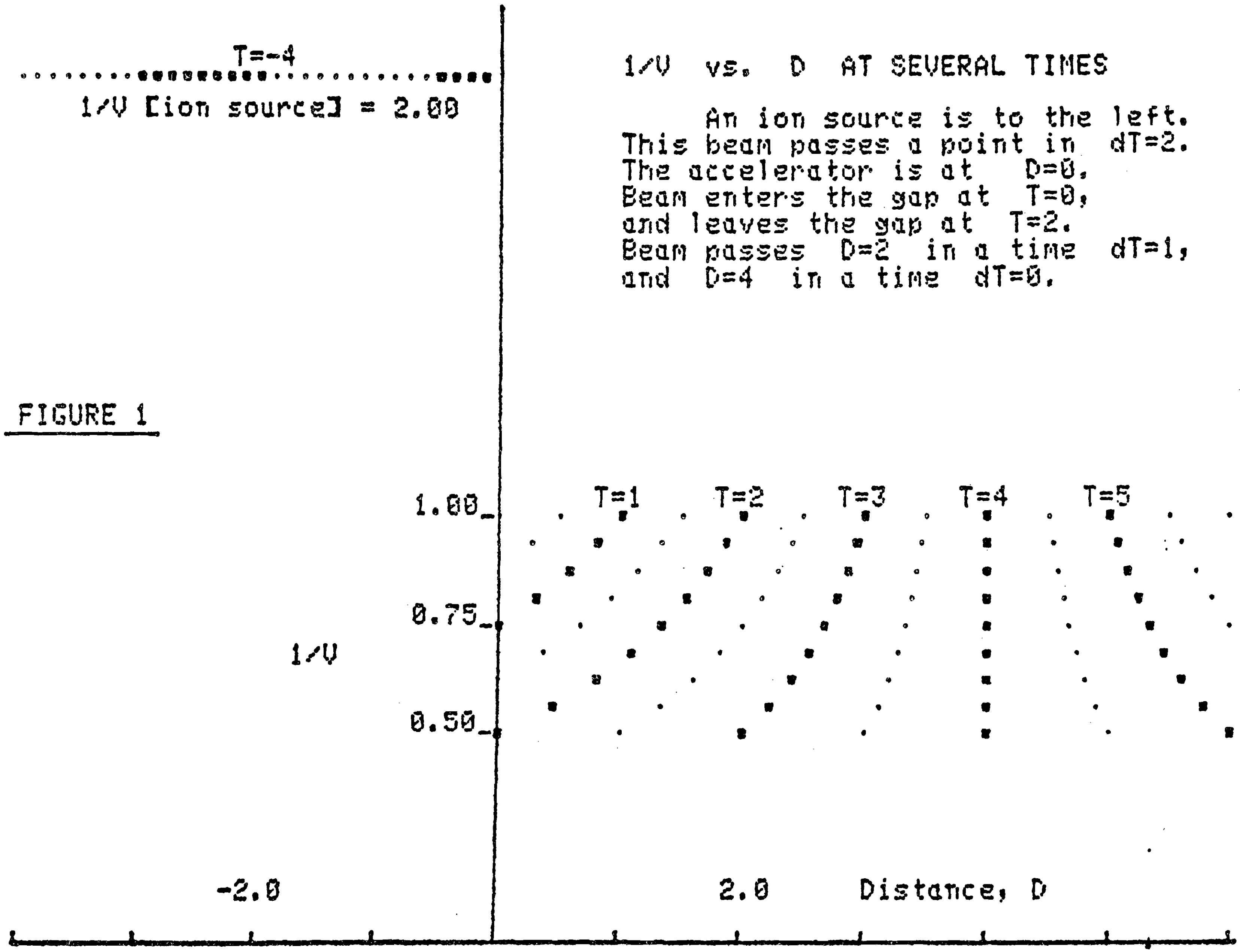
The buncher and debuncher might require hard tube drivers to achieve the desired wave form.

Gap voltage, as a function of distance, is shown in Fig. 5. The voltage vs. time in the buncher and main accelerator is largely determined by the accelerator requirements. However, the debuncher is short and its function can be achieved with a variety of voltage vs. time curves. Keeping this voltage pattern simple is probably an important objective.

Finally, Fig. 6 shows energy vs. distance. Note that the energies in the buncher and debuncher are multiplied by 10. Also, in the first few cavities, where the velocity profile is established, the maximum mVs/m is 435.

CONCLUSION

The induction Linac presents an attractive source of protons for a pulsed neutron target. The performance could be extended by using some of the space charge safety factor in the buncher or by extending the Linac to higher energy, thus getting more neutrons per proton.


T=-4
1/V [ion source] = 2.00
1/V vs. D AT SEVERAL TIMES
An ion source is to the left.
This beam passes a point in dT=2.
The accelerator is at D=0.
Beam enters the gap at T=0,
and leaves the gap at T=2.
Beam passes D=2 in a time dT=1,
and D=4 in a time dT=0.
FIGURE 1
1.00
0.75
0.50
1/V
T=1
T=2
T=3
T=4
T=5
-2.0
2.0
Distance, D

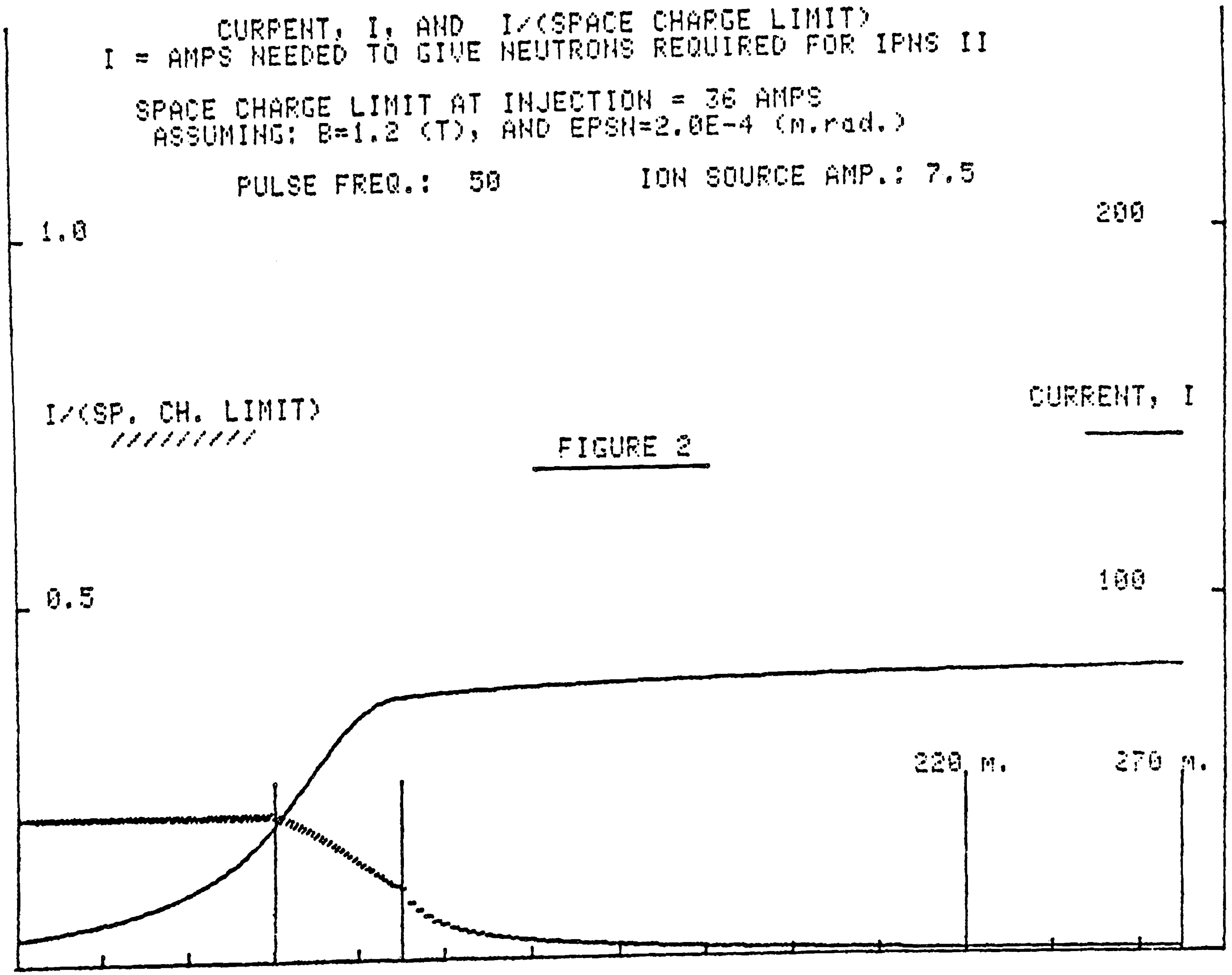
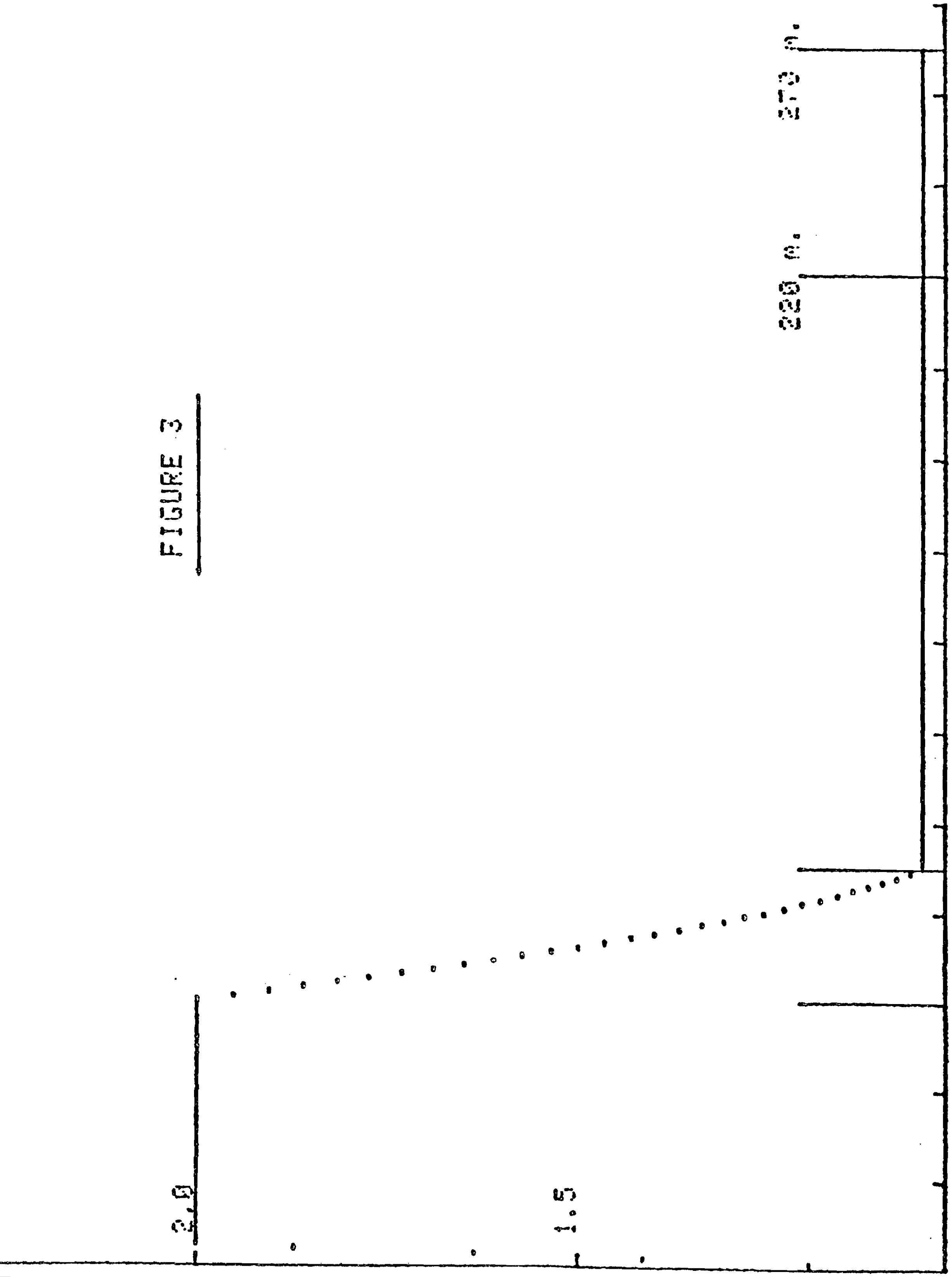

CURRENT, I, AND I/(SPACE CHARGE LIMIT)
I = AMPS NEEDED TO GIVE NEUTRONS REQUIRED FOR IPNS II
SPACE CHARGE LIMIT AT INJECTION = 36 AMPS
ASSUMING: B=1.2 (T), AND EPSN=2.0E-4 (m.rad.)
PULSE FREQ.: 50
ION SOURCE AMP.: 7.5
1.0
0.5
200
100
I/(SP. CH. LIMIT)
//////////
CURRENT, I
220 m.
270 m.

FIGURE 2

MOMENTUM RATIO: TRAILING TO LEADING EDGE

FIGURE 3



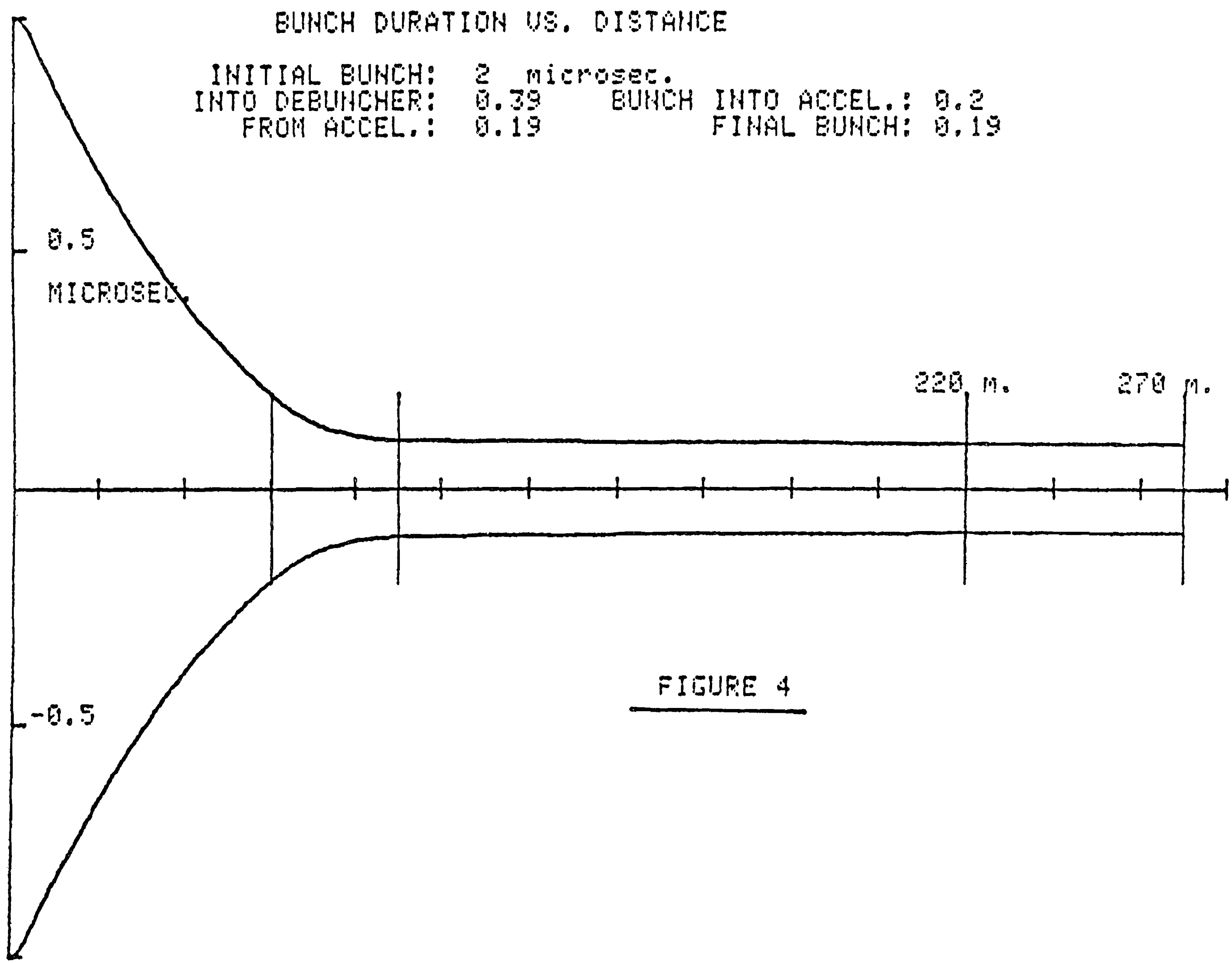

BUNCH DURATION VS. DISTANCE
INITIAL BUNCH: 2 microsec.
INTO DEBUNCHER: 0.39 BUNCH INTO ACCEL.: 0.2
FROM ACCEL.: 0.19 FINAL BUNCH: 0.19
0.5
MICROSEC.
-0.5
220 m.
270 m.

FIGURE 4

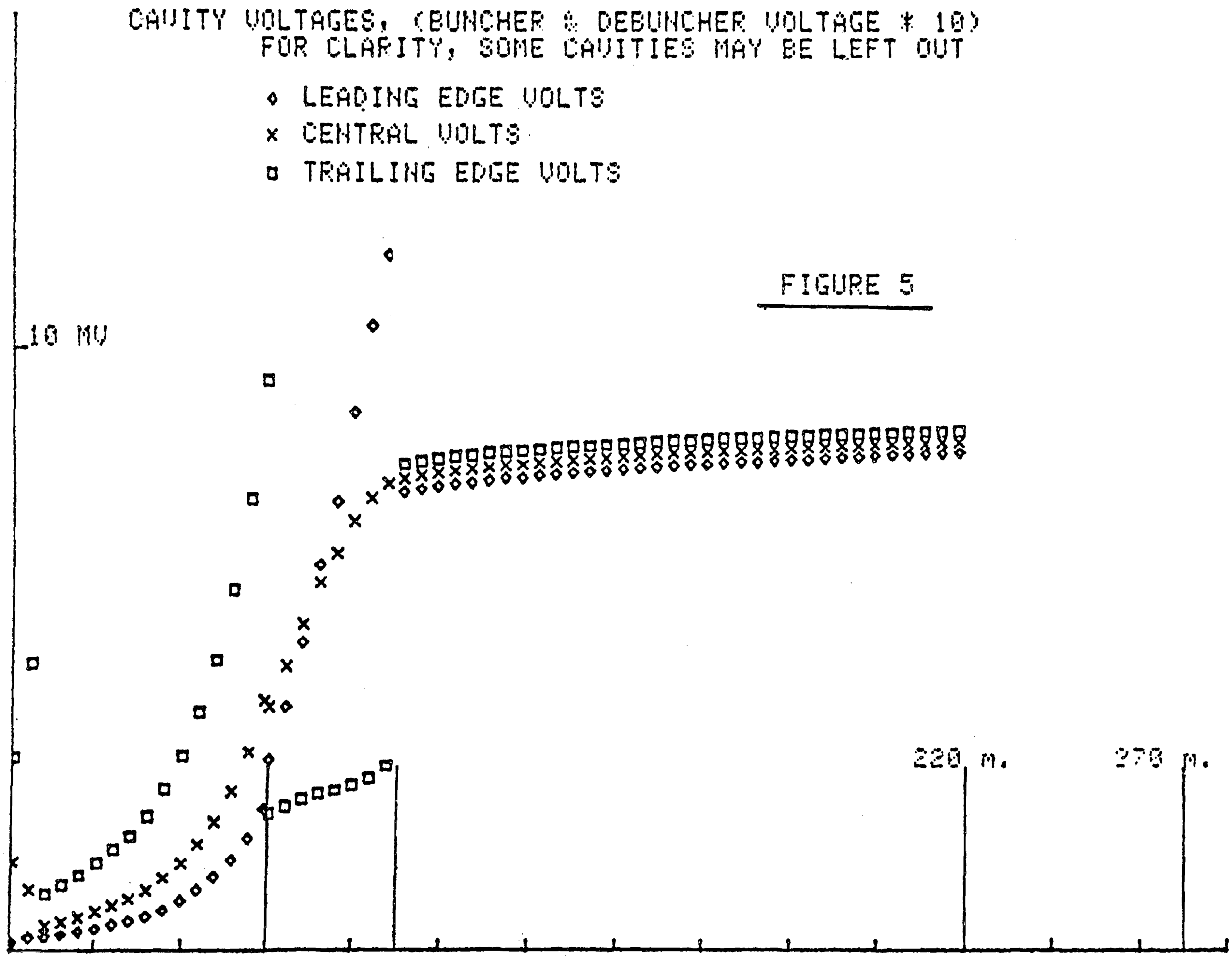

CAVITY VOLTAGES, (BUNCHER & DEBUNCHER VOLTAGE * 10)
FOR CLARITY, SOME CAVITIES MAY BE LEFT OUT
◇ LEADING EDGE VOLTS
× CENTRAL VOLTS
□ TRAILING EDGE VOLTS
10 MV
220 m.
270 m.

FIGURE 5

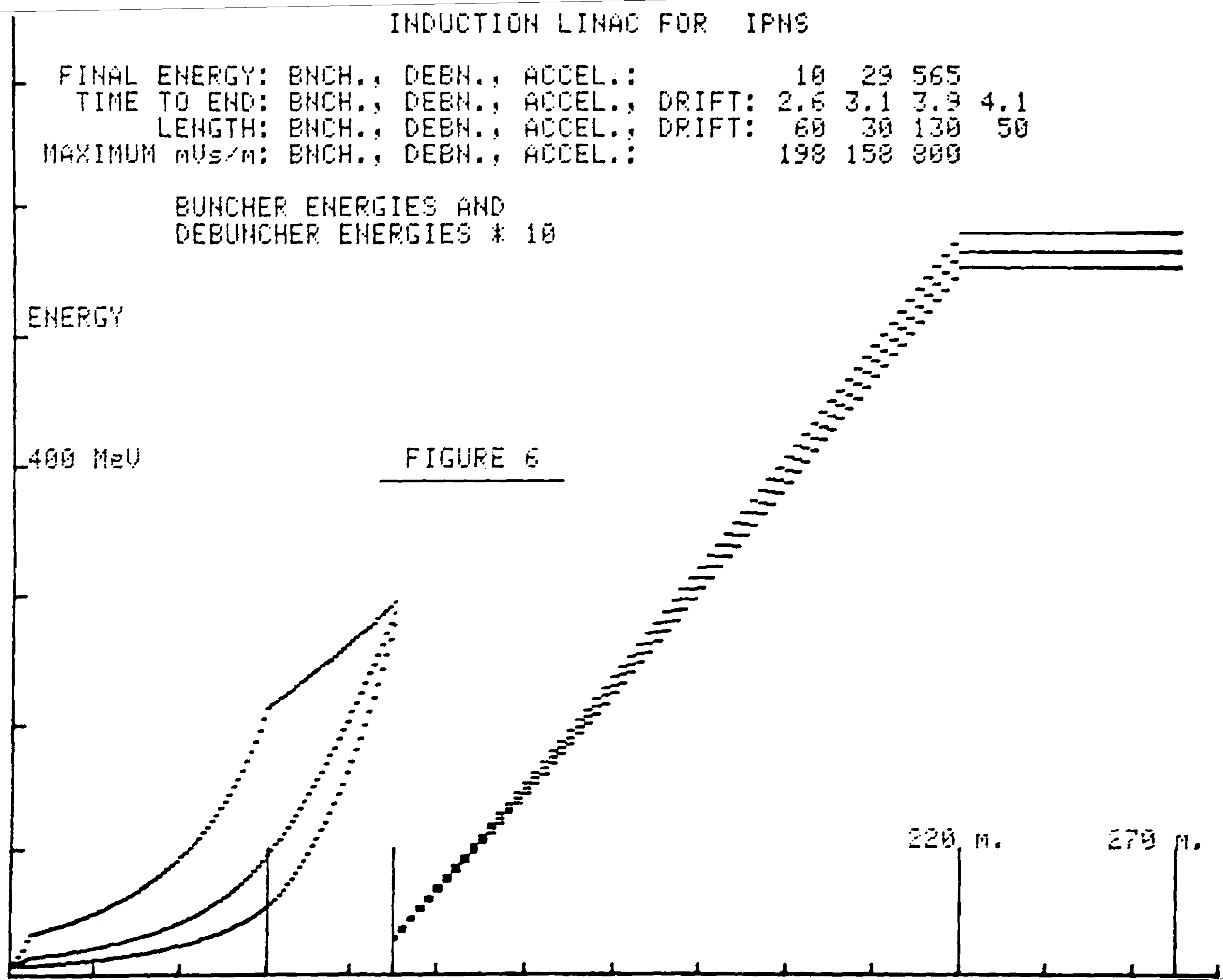

INDUCTION LINAC FOR IPNS
FINAL ENERGY: BNCH., DEBN., ACCEL.: 10 29 565
TIME TO END: BNCH., DEBN., ACCEL., DRIFT: 2.6 3.1 3.9 4.1
LENGTH: BNCH., DEBN., ACCEL., DRIFT: 60 30 130 50
MAXIMUM mVs/m: BNCH., DEBN., ACCEL.: 198 158 800
BUNCHER ENERGIES AND
DEBUNCHER ENERGIES * 10
ENERGY
400 MeV
220 m.
270 m.

FIGURE 6