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DAMPING OF E-BEAM TRANSVERSE ENERGY WITH BUMP COILS

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Introduction

The heating of the transverse temperature of the electron beam arises from several sources, including gun anode effect, (1) and magnetic guide field irregularities. The strongest heating effect is due to the transient gyrocenter drift velocities induced in non-adiabatic radial field bumps (both electric and magnetic). To the extent that the bumps are approximated as linear lenses with radial field amplitudes proportional to radial displacement, induced transverse energies of the beam will be greatest at the beam edge, varying as the square of the radial displacement.

The use of radial electric field bumps in the form of doublet lenses for transverse damping is presently incorporated in the SLAC gun design of the electron cooling system at Fermilab. These damping electrodes are limited to damping out energies of ∿ 50 eV in the transverse plane because of voltage limitations.

A study to use an analogous radial magnetic field bump as a damping element was performed using computer modelling techniques.

Computer Simulation

A computer generated field map of a 4-inch diameter solenoid coil was inputed into the mesh of the electron trajectory program E-gun. The E-gun program at Fermilab has been modified to perform optimization searches, in the case studied here, to minimize the cyclotron component of the transverse energy by varying two independent magnetic field parameters. The specific problem studied was a 2-inch diameter cylindrical 110-kV electron beam carrying a transverse energy of ∿ 200 eV that passed through the bump coil field. The two field parameters searched were:
1) Guide field amplitude, and 2) bump coil amplitude.

Theory

A piecewise linear model of the bump coil is a region of B_r similar to a doublet e-lens. The result of an electron passing through such a region added to a constant guide field B_z is simply a translation of all transverse velocity phase points along the V_r axis by:

$$\Delta V_r = 4.\ \frac{B_r}{B_z} \cdot v_z = 4.\ V_d$$

provided the bump region is one gyrowavelength long!

Thus, a phase point located at $(V_r, V_\phi) = (-4V_d, o)$ will be damped to the origin. However, a quiet beam represented by the origin will be antidamped to a point $(4V_d, o)$. This situation is illustrated in figure 1. To the extent that the bump coil is a linear lens, with $B_r = k.r$ the effect of such a field will be to undo paraxial e-lens effects.

Results

From an initial guess of a 500 amp-turn bump coil immersed in a 1 kG guide field a tune search was performed using a 110 kV x 2-inch diameter electron beam starting with an initial paraxial distribution of transverse energy with a e_t = 200 eV at the beam edge.

A computer search tune of B_z = 840 gauss, and B_{damp} = 80 gauss (NI = 650 amps for the bump coil yielded a damped E_t distribution down to the 1 eV level as shown in figure 2. The non-linear damping effect appears to be present for particles at radii larger than one-half inch, probably because of the small coil diameter relative to the beam diameter.

The modelled beam cyclotron motion is shown in figure 3, with the quiet condition achieved after passage through the damping coil. The corresponding beam-edge particle motion on the $V_r - V_\phi$ plane is shown in figure 4.

Conclusions

By using two solenoidal bump coils in quadrature, i.e. spaced (2n + 1) quarter wavelengths apart, it appears possible to damp out paraxial distributions of transverse energy in the electron beam. For efficient damping the coil diameter should be roughly a gyrowavelength.

The transverse energy that can be removed is given as

$$E_t = \frac{4.B_r}{B_z} \quad . \text{ K.E.}$$

where B_r is the average magnetic radial field of the bump

B_z is the average guide field

K.E. is the beam energy

Such damping coils could be utilized at the gun output instead of resonant electrodes or at the entrance to the cooling solenoid to provide fine tuneout of the electron beam transverse energy for paraxial distributions.

REFERENCES

1. L. Oleksiuk,"Gun Anode Lens Effects on Beam Transverse Temperature," TM. 996, (Sept. 1980).

MAGNETIC RESONANT Field Bumps

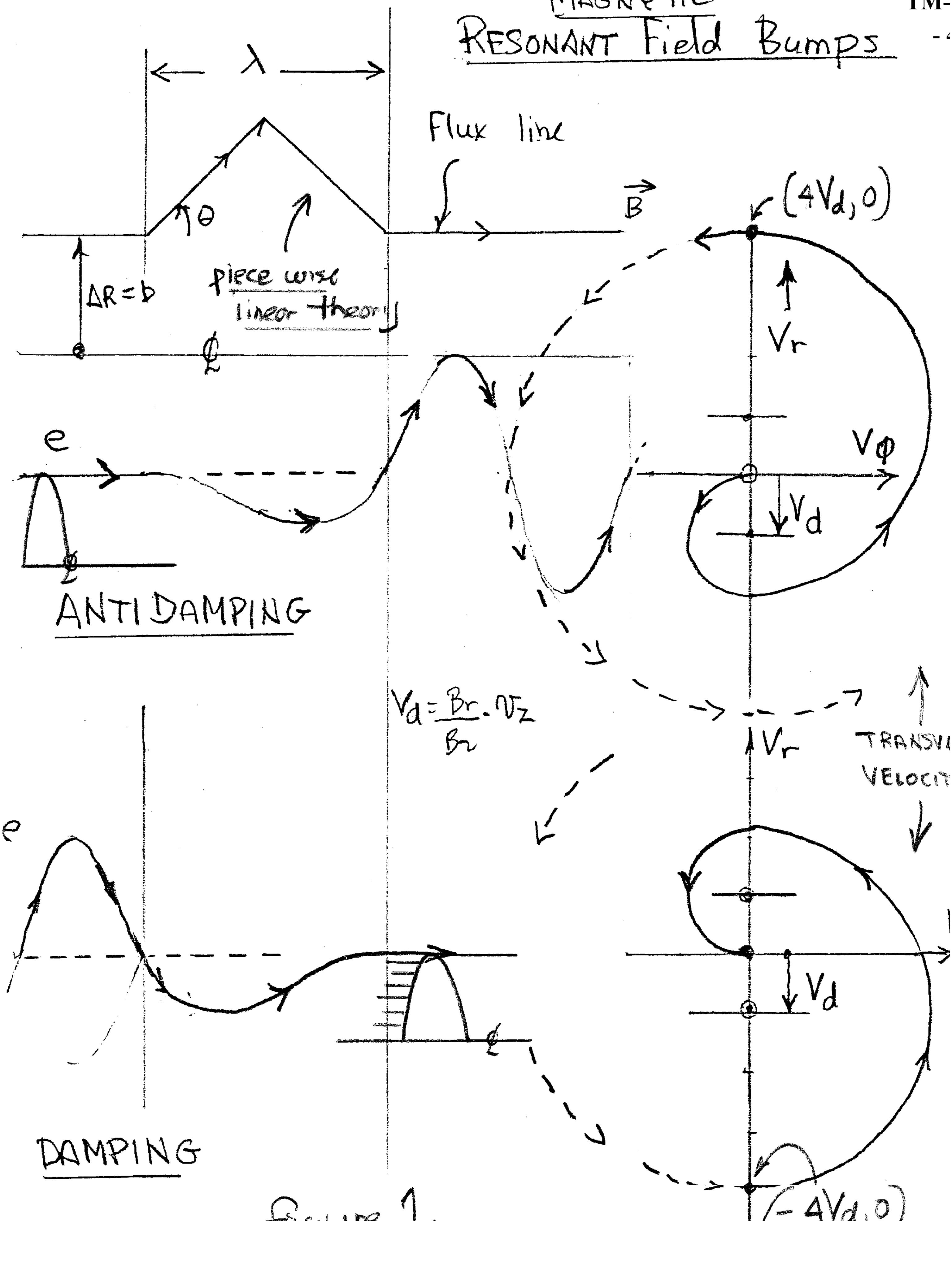

Figure 1.

TM

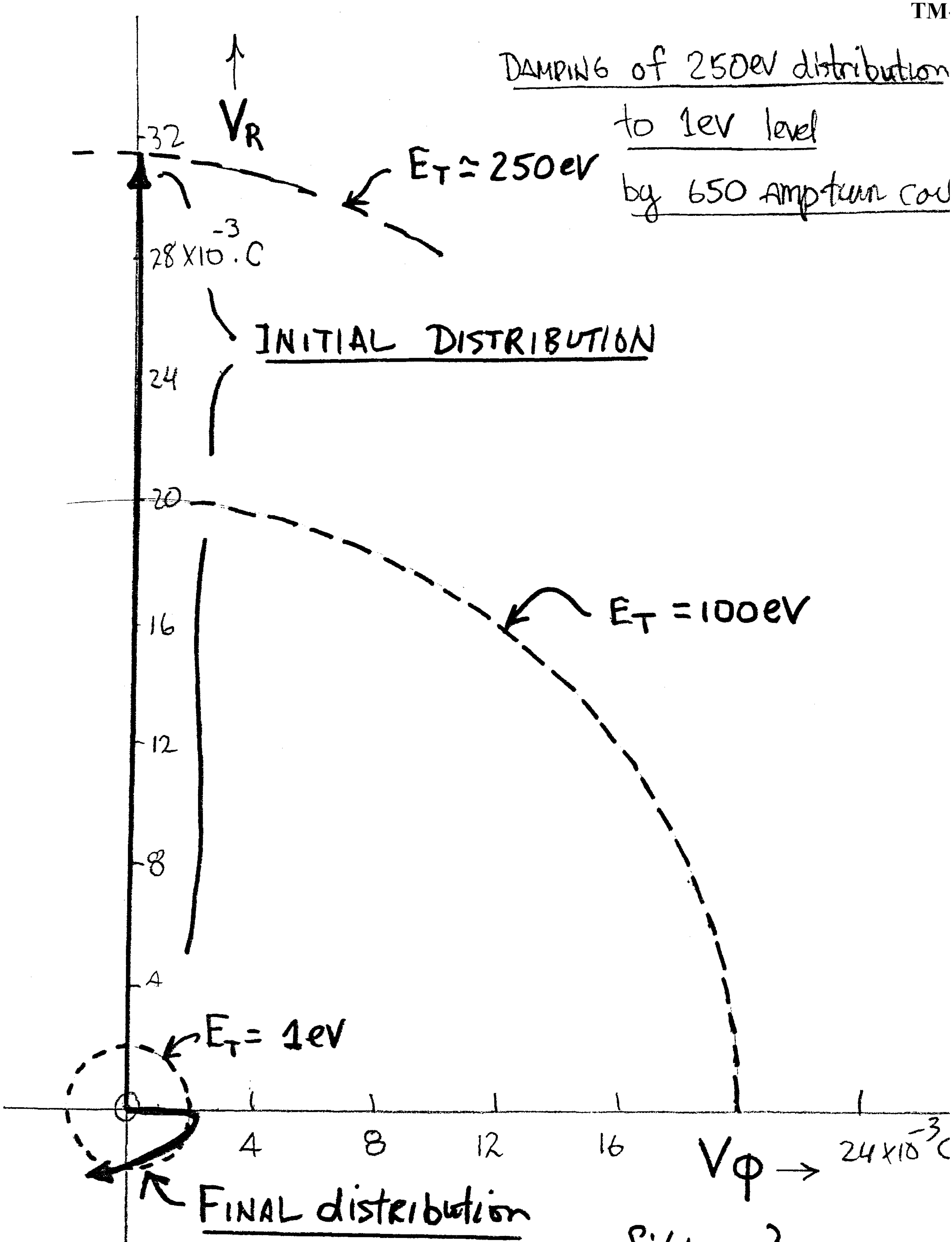
DAMPING of 250ev distribution to 1ev level by 650 Amp-turn coil
V_R
32
28 X 10^{-3} C
24
20
16
12
8
4
$E_T \simeq 250$ eV
INITIAL DISTRIBUTION
$E_T = 100$ eV
$E_T = 1$ eV
FINAL distribution
4
8
12
16
24 X 10^{-3} C
V_ϕ →

Fig. 2

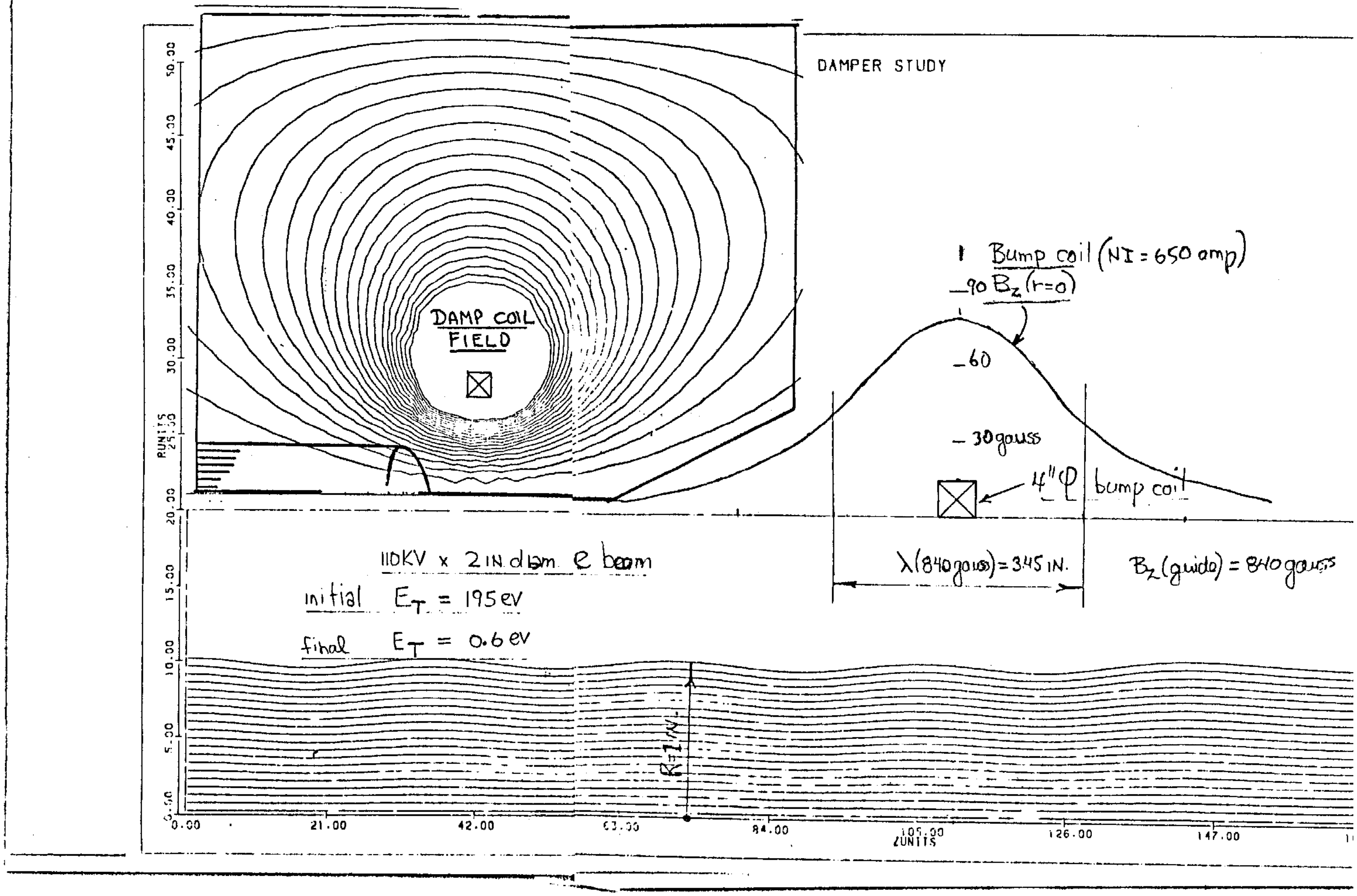

Figure 3. Electron beam trajectory showing damping of motion by 4 in. diameter solenoid bump coil

Vr-Vφ plot of beam edge electron showing damping from bump coil.