CE-30 – TOWARD A TRAPPED PARTICLE TARGET

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A magnetic solenoid with a vacuum chamber designed for storage ring use was constructed in 1991/92 and first used to develop a stored beam diagnostic based on measured deflection of a parallel low energy electron beam. This work has been published.[1]

During the summer of 1992, the interior was refitted to serve as a large volume Penning trap for the study of problems in filling, observing and establishing stability limits for a trapped electron cloud. The geometry is shown in Fig. 1. The gradient columns at the trap ends established a "bathtub"-shaped potential which is isochronous for axial motion of single particles near the maximum contained energy. The electron gun is off-axis to keep the trap centerline clear for future passage of a stored ion beam. Initial trap tests were made at a pressure of 1 μPa. The pumping system was augmented in the summer of 1992 so that 0.1 μPa has been obtained after a 180 °C bakeout.

The trapped cloud has been observed by three methods. A collector on the end opposite the gun shows the expected 1.4 MHz axial bounce frequency when 0.1 μs pulses are injected with kinetic energy near the top of the containment potential. An azimuthally-segmented "cage" surrounding the central region of the trap can be connected to a preamplifier to sense a time-dependent line dipole moment of the trapped ion cloud. Under suitable conditions with continuous injection, a strong sustained oscillation of a few kHz is observed, indicating coherent magnetron (diocotron) motion. The minimum period is observed to vary nearly linearly with magnetic field and inversely with trap endcap potential as shown in Fig. 2. This behavior is consistent with the rotation of an ion column driven by an image charge and with the number of trapped electrons limited by axial confinement at 13 V to about 7×10^8 particles.

After filling the trap, one endcap can be ramped to zero potential and the time-dependent current collected on the endcap may be used to measure the number of trapped particles and the energy distribution. The number observed by this method grows to a few times 10^8 over a time of order 0.1 s in a continuous-fill periodic-dump cycle. The filling time indicates an inefficient injection mechanism of unexplained origin. The observed distributions show that the trap may be tuned to contain electrons near the injection energy and/or a component near zero energy as shown in Fig. 3.

Phenomena are observed with a time scale of a few seconds that may be associated with partial neutralization by positive ions created by ionization in the imperfect vacuum. The trap is being modified to allow controlled retention or ejection of positives.

Studies are in progress to elucidate the nature of the filling mechanism, the physics responsible for the redistribution of longitudinal momentum, and to determine the radial and azimuthal distributions of density in the trapped cloud. For use as a target, the cloud must be maneuvered to the trap centerline with the aid of external steering by feedback of the magnetron signal. The number of particles can be increased by operation at higher confinement potential.

The methods developed in this work may be extended to a trap for bare nuclear ions.

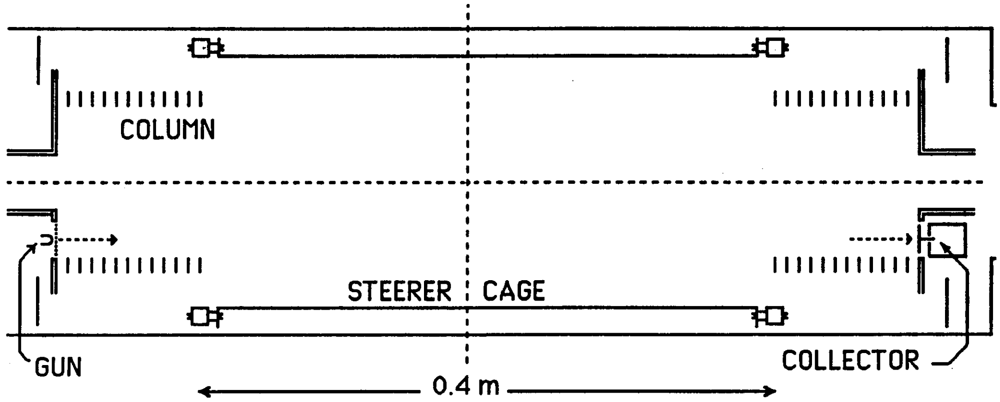

Figure 1. Plan view of bathtub trap. The gradient columns, steerer cage and endcaps have cylindrical symmetry.

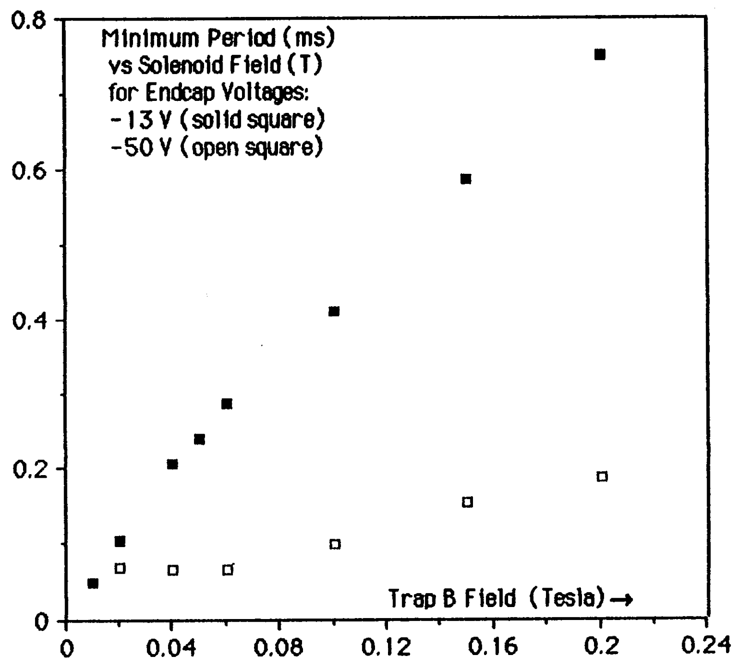

Figure 2. Dependence of minimum period of observed magnetron motion on the applied magnetic field for two values of confinement implies that the number of trapped electrons N is independent of the magnetic field. The data at 50 eV appear to indicate an increase of N with magnetic field below 0.08 T and a linear increase of N with confinement potential above this threshold.

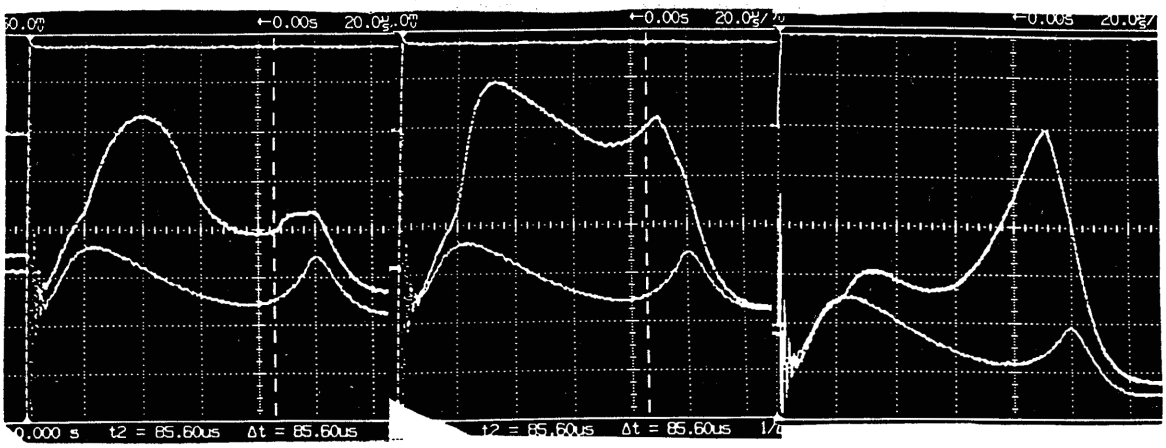

Figure 3. Representative oscilloscope photos of the time distribution of electron current collected on the gun endcap when the potential on this end of the bathtub is lowered linearly past zero. The lower trace in each case is the collector response with the trap empty. The amplifier inverts the negative current signal. Current collected early (as at left) is indicative of higher longitudinal energy in the trapped distribution. The peak near 80 μs (as at right) is a low energy component. The central picture is an example of a nearly uniform distribution.

A higher field solenoid must be employed for construction of a large-capacity heavy-particle trap.

1. R.E. Pollock, *et al.*, Nucl. Instrum. Methods **A330**, 27 (1993).