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CONSIDERATIONS FOR ELECTROMAGNETIC ANTIPROTON TRAPS

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The selection of a Penning ion trap as the capture, storage and launching device for an experiment which will attempt to detect and quantitatively measure the gravitational acceleration of antiprotons is described. Effects due to trap physical parameters, residual vacuum, and rf interrogation of the trapped particle ensemble are considered. Techniques for cooling the trapped particles from approximately 100 eV to near 4 K are discussed. Recent work towards realization of the system is reported.

1. Introduction

A velocity distribution concentrated at extremely low values is essential for keeping the measurement of gravitational acceleration of antiprotons within practical laboratory dimensions. In the experiment PS-200 being prepared for LEAR, Penning ion traps have been chosen to achieve this goal [1]. This type of trap has preferable characteristics over two alternative configurations (see fig. 1) which have been used in conjunction with accelerators: the rf (Paul) trap and the cylindrical electrostatic (Kingdon) trap [2-6]. The rf trap has the often-desirable feature for spectroscopic work of requiring no magnetic field; however, an axial field must already be present for the capture optics from the LEAR-RFQ deceleration and also for the superconducting guide tube in which the gravitational effect on antiprotons will be detected. This suggests directly the use of a Penning trap. The electrostatic trap can store large numbers of ions for long periods of time but would have a large emittance and angular momentum for the released antiprotons which is not at all efficiently matched to the requirements of a Witteborn-Fairbank type of guide tube [7]. As compared to the above, the Penning trap (fig. 1) has the advantage of naturally utilizing the magnetic field [8]. Furthermore there is already an extensive understanding and practical experience available for cooling of ions with these traps [9-12]. This cooling is attainable by a high order of harmonicity in the Z-motion, which also allows a very sensitive external interrogation and control of the ion ensemble [13].

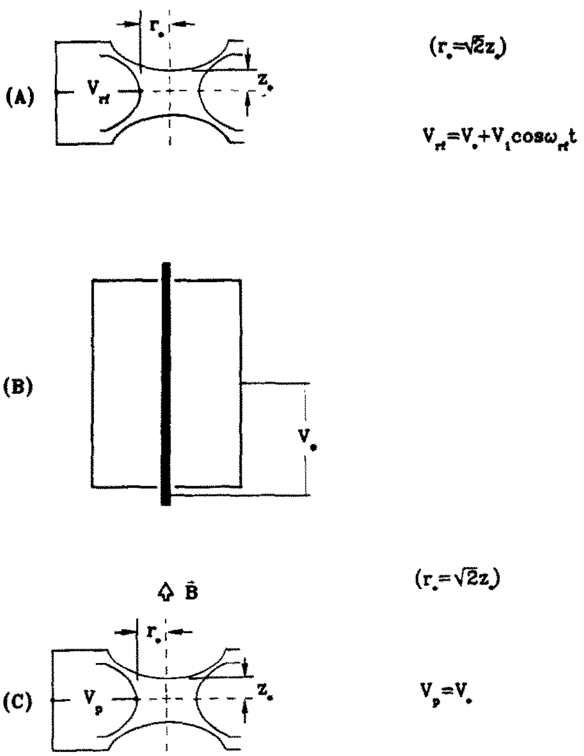

Fig. 1. Three types of trap which have been used for storage of ions produced by accelerators. (a) Rf (Paul) trap. (b) Electrostatic (Kingdon) trap. (c) Penning trap.

A brief summary of the single-particle motion, without including space-charge effects, is helpful in discussion of the operation of the Penning trap. With ideal electrodes which are hyperboloids of revolution about the z axis (magnetic field direction), a particle of mass m and charge q will see a potential

$$\phi=\frac{V_0}{z_0^2}\left(\frac{r^2}{2}-z^2\right),$$

which, in the asymptotically symmetric trap, is generated by electrode surfaces

$$\frac{r^2}{2z_0^2}-\frac{z^2}{z_0^2}=\pm 1,$$

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