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COURSE IN THE THEORY AND DESIGN OF PARTICLE ACCELERATORS - LECTURE IV

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UNIVERSITY OF CALIFORNIA
Radiation Laboratory
Berkeley, California

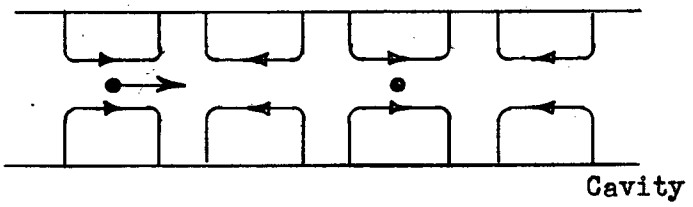
UCRL 2038

Course in the Theory and Design of Particle Accelerators

LECTURE IV
November 26, 1952

W. M. Brobeck
(Notes by: O. Callahan and A. Chesterman)

Standing Wave Electron Linear Accelerator



The machine at Massachusetts Institute of Technology is driven at 3,000 Megacycles frequency and the problem of driving and phasing the cavity has been great.

Alternate Schemes of Building Synchrotrons

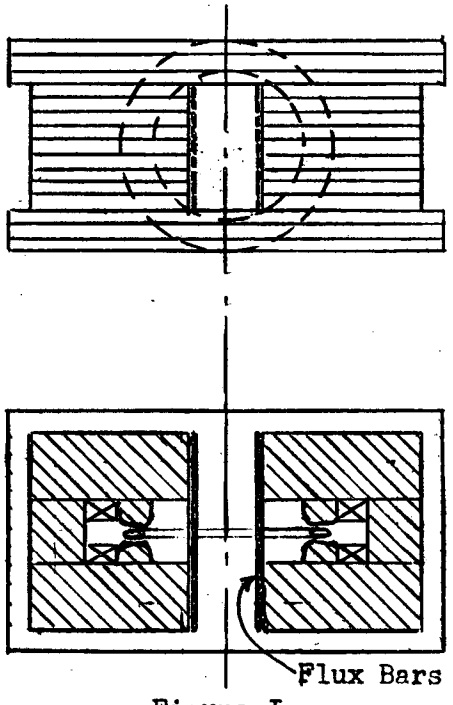


Figure I

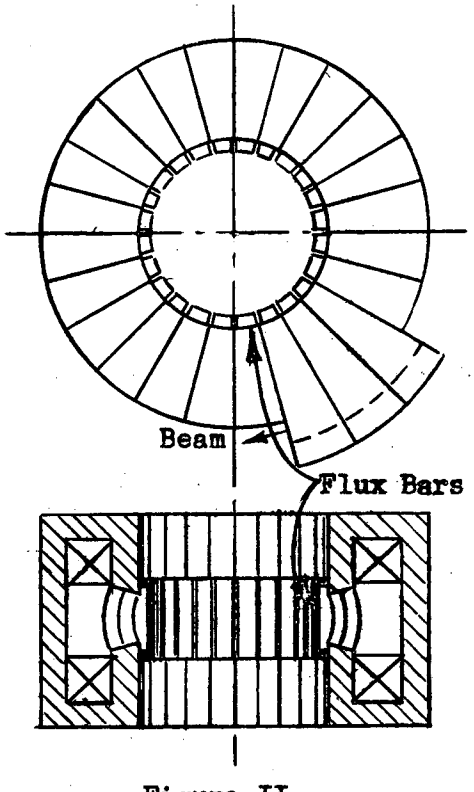
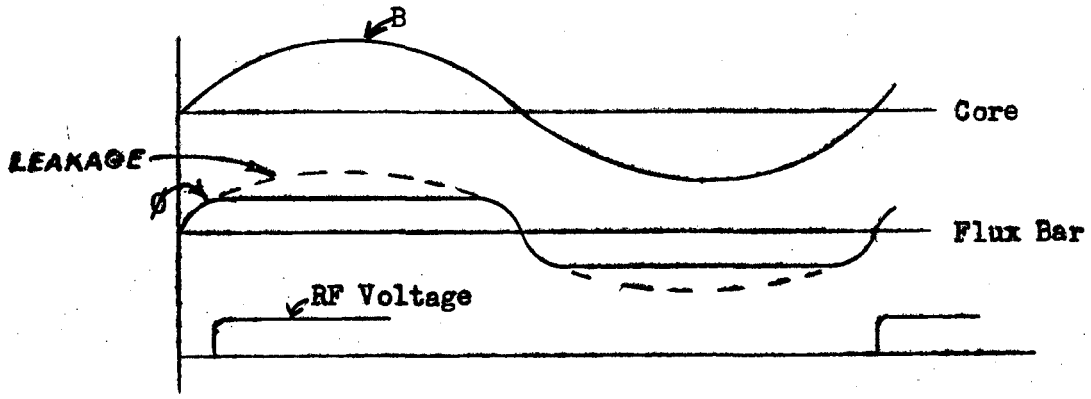


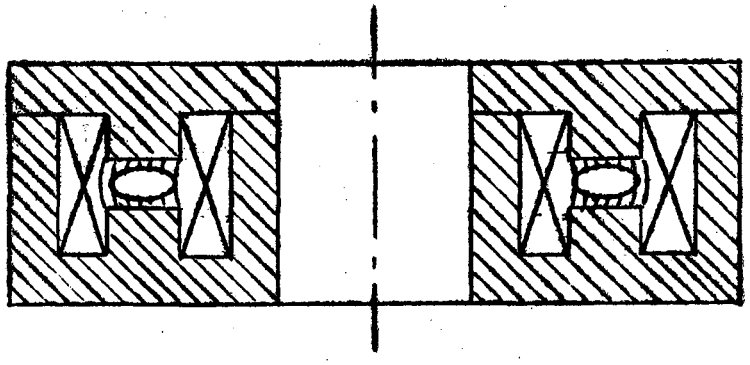
Figure II

The synchrotron at Berkeley is as shown in Figure 1, and although less economical to build than the one of Figure 2, it does present less of a problem of getting out the beam since the sides are open. Lengthening some segments of the magnet in Figure 2 leaves a gap through which the beam could be fed. This type being used at M.I.T., Cornell, and Purdue University.

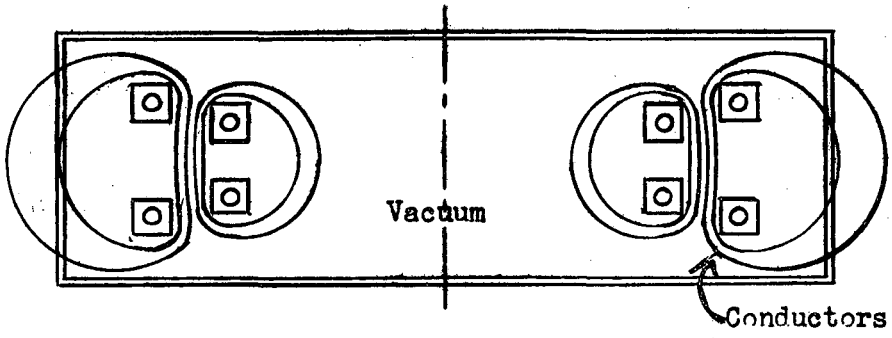
Betatron Injection into Synchrotron is generally used to accelerate from 100 KV to 2 MEV energy. The flux through the flux bars must be in the same direction as that through the core.



Frequency Modulated Synchrotron at University of Michigan



Synchrotron withou Iron Core. General Electric Company.

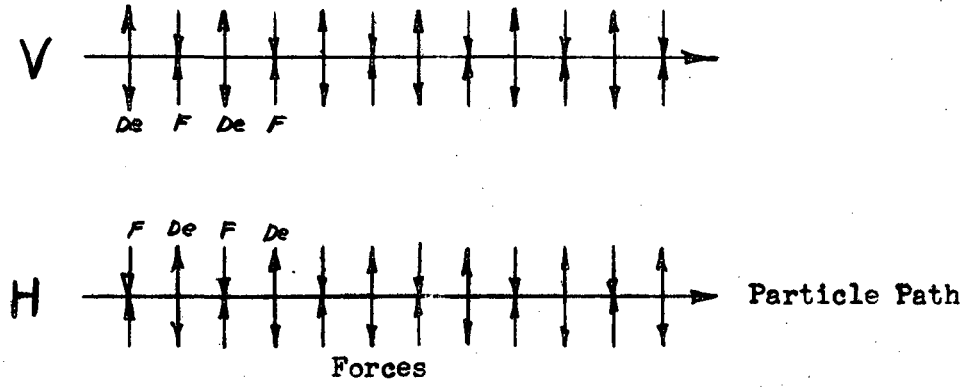


Chief difficulty with this type is that the mechanical forces on the conductors are high and present a problem in supporting them.

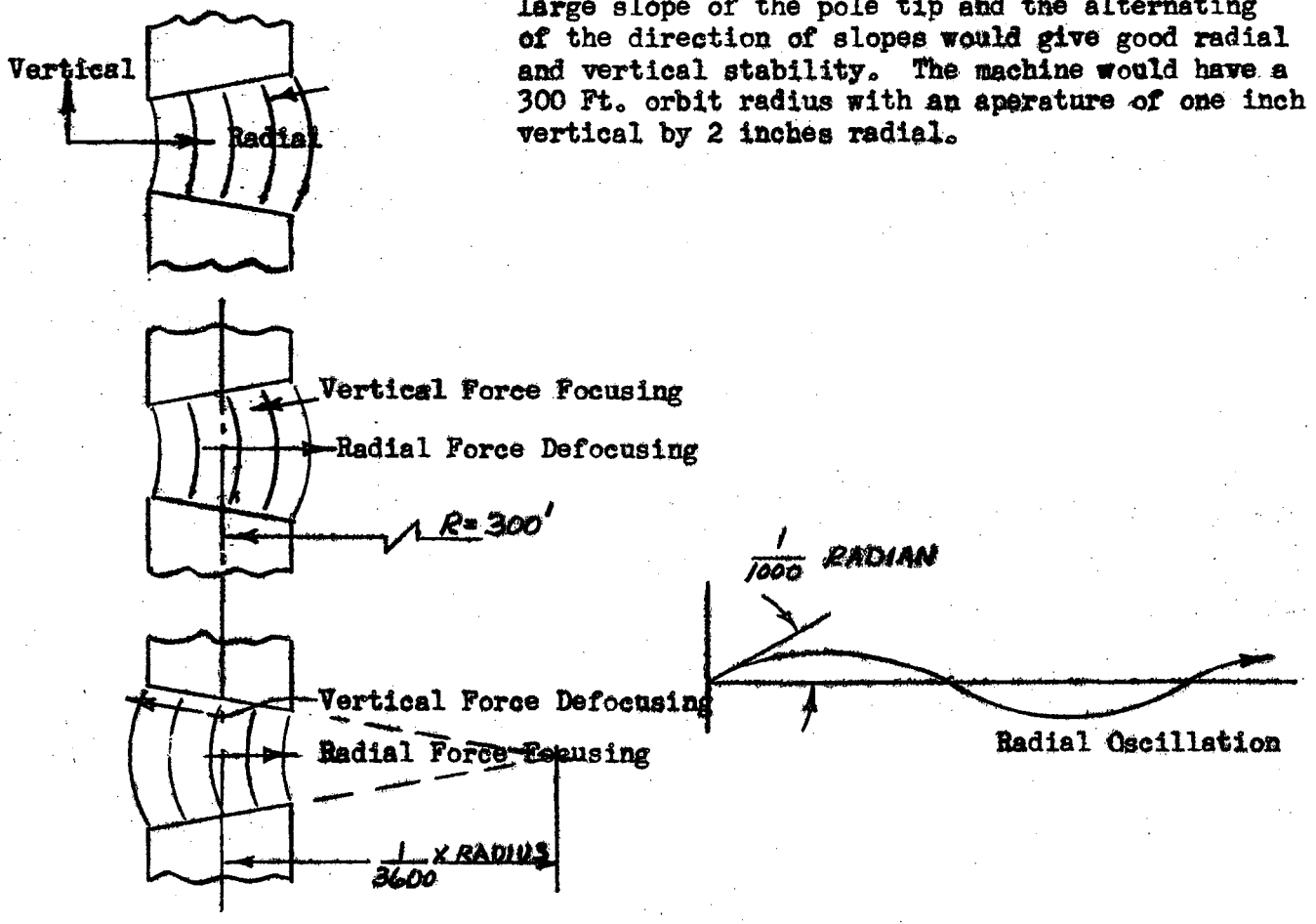
Strong Focusing Synchrotron as proposed by Brookhaven Institute.

Since the mass of the machine varies approximately as the cube of the radius of particle orbit and the energy varies approximately with the radius, it becomes apparent that a machine in the Billion Electron Volt range will be quite large. One method of reducing its cost would be to use a small apertur . The machine at Berkeley has a 1' x 4' aperture because of the weakness of foc sing. A smaller aperture would reduce the amount of iron in the magnet. The aperture size is some percent of the wave length of lateral oscillations, and by reducing the amplitude and wave length of these oscillations, the aperture can be reduced. This is accomplished by use of strong focusing.

Strong focusing is accomplised by alternating forces of the magnetic field due to alternating slopes of the pole tips.

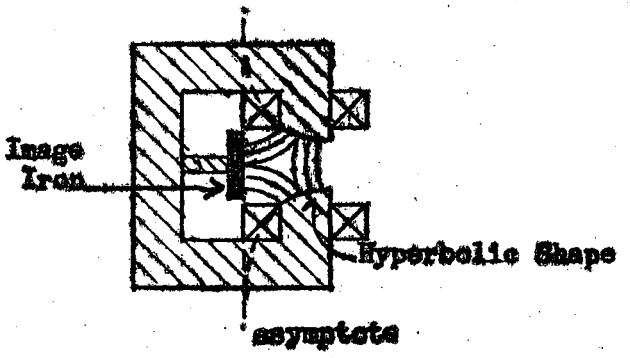


Limit of pole tip slope in an ordinary synchrotron is when the magnetic lines start to become spherical. At this point, the field starts to drop off too fast radially. This results in good vertical stability but poor radial stability. The proposed strong focus machine would require a large slope of the pole tip and the alternating of the direction of slopes would give good radial and vertical stability. The machine would have a 300 Ft. orbit radius with an aperature of one inch vertical by 2 inches radial.

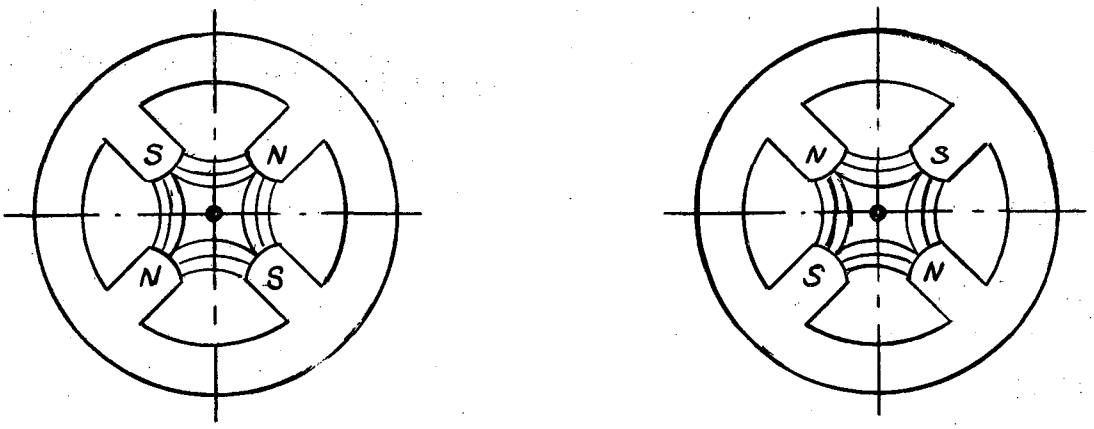


With such a small aperture, the acceleration must occur during the linear accelerator phase stable region at low energy and the synchrotron phase stable region at high energy.

The magnet would use image iron to give a constant field with approximately 20,00 gauss at minimum gap and approximately 11,000 gauss average field.

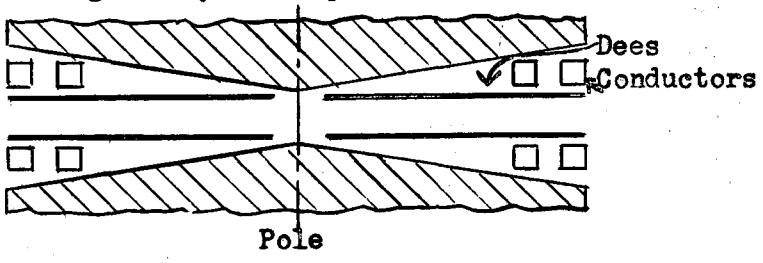


A scheme has been proposed for using separate focusing magnets for passing through the critical energy at which phase stability transition occurs, i.e., from linear accelerator to synchrotron phase stability. The focusing magnets would give on the average a zero field and the turning of the particle would have to be done with another field between the focusing magnets. When the unstable energy is nearly reached, the focusing magnet strength would be reduced while the turning magnet field was held constant. This would reduce the unstable energy below the particle energy and acceleration could continue in the synchrotron phase stable region.

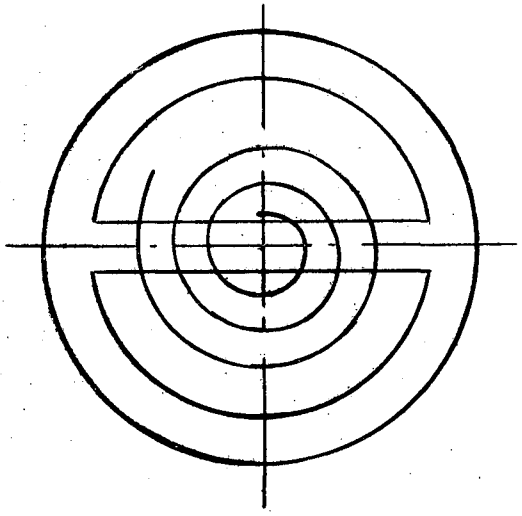


Cyclo Synchrotron--Australian

This machine uses a Cyclotron Magnet and Dees but has a pulsed magnetic field at outer radius. The pulsed magnetic field comes from pulsed current in large circumferential conductors energized by a Homopolar Generator.

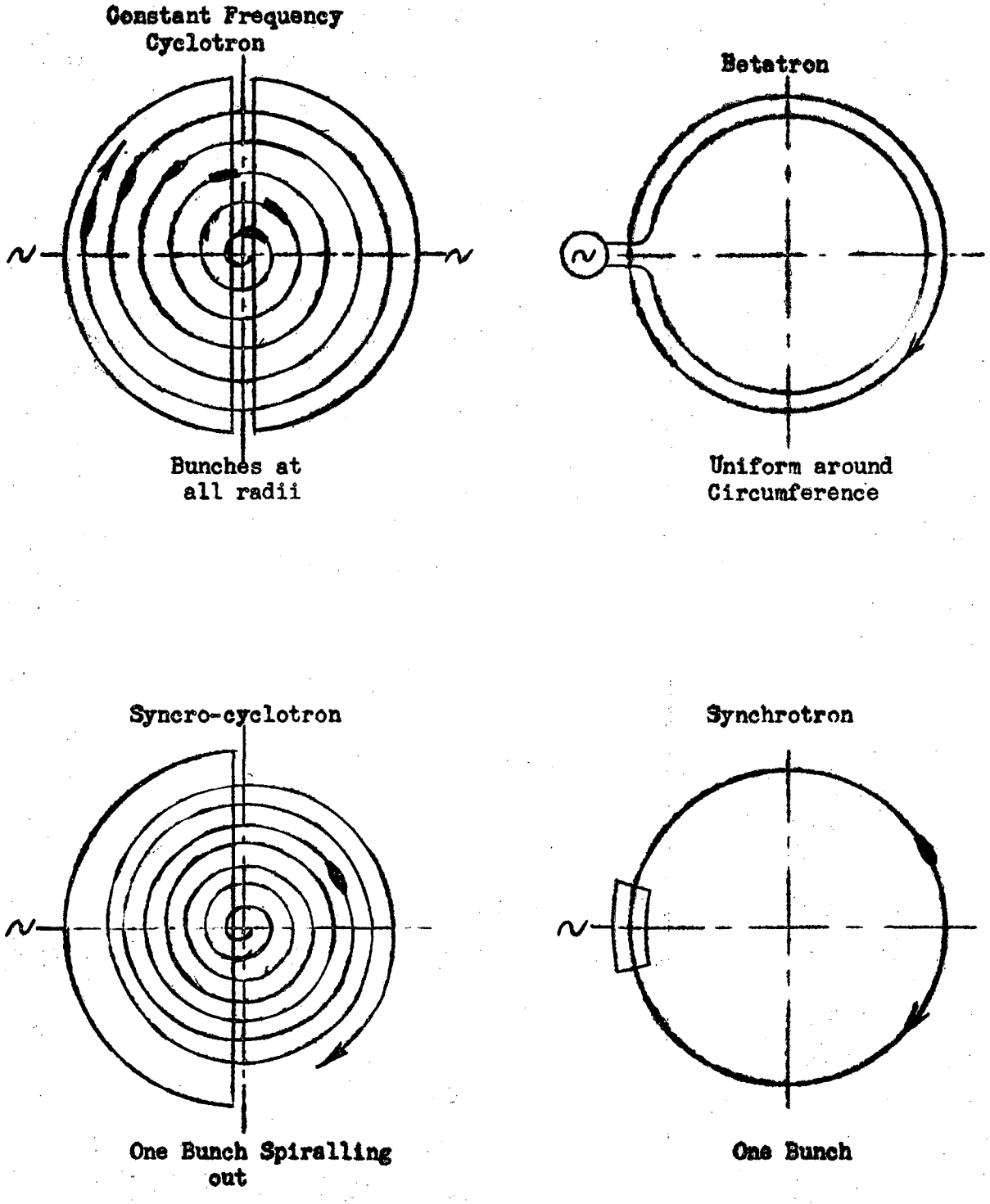


Microtron (Electron Cyclotron)--Canada



The rotation time increases one cycle for each half turn of the particle. This machine operates at very high frequency and in the relativistic region only. No electron source is needed other than discharge from the Dees.

Drawing showing particle distribution at any instant in the various machines.



Below is the first of several problems which will be given for outside study. Anyone who wishes to have his solutions to the problems corrected, may turn them into the Engineering Dept. Office where they will be corrected and returned.

Problem 1.

Prepare a table listing all the types of accelerators discussed and comparing them according to the following characteristics:

Path shape--straight, circle or spiral
Accelerating force--electric or magnetic
Guiding force--electric or magnetic
Accelerating field, DC, RF or AC (low frequency)
Quantities varying during acceleration,
Radius, Guide field, Frequency
Approximate energy range
Particles accelerated
Velocity range as non-relativistic--constant mass
relativistic--changing mass and velocity, or
relativistic--constant velocity.

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