Cyclotron Accelerators

The cyclotron principle involves using an electric field to accelerate charged particles across a gap between two "D-shaped" magnetic field regions. The magnetic field accelerates the particles in a semicircle, during which time the electric field is reversed in polarity to accelerate the charge particle again as it moves across the gap in the opposite direction. In this way a moderate electric field can accelerate charges to a high energy. This overcame the difficulty of electric discharge caused by the high DC voltages in the Cockroft-Walton and van de Graaf accelerators.

In 1930, Earnest O. Lawrence operated the first successful cyclotron, accelerating protons with a radio frequency (RF) voltage applied across the gap between the two "Dee" magnetic field regions. The first model was only 10 cm in diameter. A larger unit built with the assistance of M. Stanley Livingston was about 25 cm in diameter and accelerated protons to about 1 MeV of energy.

The upper bound on energy obtainable from the cyclotron is set by relativistic effects. Since the cyclotron frequency of the RF accelerating voltage depends upon the particle mass, the effects of relativistic mass cause the particle to get progressively more out of step with the accelerating voltage as its speed increases. This problem is addressed in the synchrocyclotron by varying the frequency of the accelerating voltage to track the relativistic effects.

Types of Accelerators

Index

Particle concepts

Search for elementary particles

HyperPhysics***** Quantum Physics

R Nave

Go Back

Synchrocyclotron

Since the cyclotron frequency depends upon the relativistic energy of the particles being accelerated, the cyclotron with its fixed-frequency accelerating voltage gets progressivley out of synchronization with the motion of the particles as they reach relativistic speed. In 1945 the technology was developed to vary the frequency of the accelerating voltage to track the change in relativistic energy of the particles. This device is called a synchrocyclotron and has been used to accelerate particles to around 700 MeV of energy. That is about 100 times the energy obtainable from natural radioactivity.

Since the accelerating frequency is variable, it is no longer necessary to use the high accelerating voltages of the cylotrons which needed to get the largest possible energy in a few cycles. Accelerating voltages in the synchrocyclotron are typically about 10 kV, and the limitation on maximum particle energy is set by the size of the device (i.e., the radius of the magnetic field region).

Types of Accelerators

Index

Particle concepts

Search for elementary particles

HyperPhysics***** Quantum Physics

R Nave

Go Back

Betatron

Invented in 1940 by D. W. Kerst, the betatron is a circular accelerator for electrons. It differs from the cyclotron in that the acceleration of the electrons is achieved by increasing the magnetic flux through the orbit of the electrons. The electrons travel in an orbit of fixed radius, and are accelerated by the magnetic field which also keeps them in the orbit.

In the betatron, one must deal with the relativistic effects on the electron as well as the loss of energy from radiation. All accelerated charges radiate electromagnetic energy, and accelerated electrons radiate more energy in a given kinetic energy range than would protons. This radiative energy loss, called synchrotron radiation, limits the maximum energy from the betatron to a few hundred MeV. The acceleration program for the increasing of the magnetic flux to keep the electron accelerating in a fixed-radius orbit must account for the change in the relativistic particle energy gmc^2.

Types of Accelerators

Index

Particle concepts

Search for elementary particles

Reference Rohlf Ch. 16

HyperPhysics***** Quantum Physics

R Nave

Go Back