Particle accelerators

What are particle accelerators used for? A particle accelerator is a device that uses electric fields to propel electrically charged particles in a vacuum, which approach the speed of light, towards each other and collide. The result hopefully being that the kinetic energy in the particles and other energy converted into subatomic particles or various types of nuclear radiation. There is more than one type of particle accelerator; they come in two basic types: •Linear •Circular Linear Accelerators The linear accelerator, or linac, uses microwavetechnologyto accelerate electrons in a part of the accelerator called the " wave guide".

Particles pass through a line of hollow metal tubes enclosed in an evacuated cylinder. Within a hollow conductor there is no electric field so a charged particle travels at constant speed inside each of the tubes. Between one tube and the next there is a potential difference which varies in size and direction as an AC voltage is applied to the series of tubes. Bunches of charged particles are accelerated from tube to tube, moving with the voltage wave as it travels along the linac. The largest linac in the world, at Stanford University, is 3. 2km long.

It is capable of accelerating electrons to an energy of 50 GeV. Stanford’s linac is designed to collide two beams of particles, accelerated in turn by the linac and temporarily kept in storage rings. The two most important problems in the linac design are the accelerator cell voltage flatness and the transverse mode impedance of the cell. Disadvantages •The device length limits the locations where one may be placed. •A great number of driver devices and their associated power supplies is required, increasing the construction and maintenance expense of this portion. If the walls of the accelerating cavities are made of normally conducting material and the accelerating fields are large, the wall resistivity converts electric energy into heat quickly. On the other hand superconductors have various limits and are too expensive for very large accelerators. Cyclotron The cyclotron was the first circular accelerator. A cyclotron is somewhat like a linac wrapped into a tight spiral. Instead of many tubes, the machine has only two hollow vacuum chambers, called dees, that are shaped like capital letter Ds back to back.

A magnetic field, produced by a powerful electromagnet, keeps the particles moving in a curved path. The potential difference between the dees constantly alternates in direction, so that every time the particles reach the gap they experience a forward acceleration. Within each dee the particles travel at constant speed during each half-revolution. As the particles gain energy, they spiral out towards the edge of the accelerator, where finally they exit. Advantages of the Cyclotron •Cyclotrons have a single electrical driver, which saves bothmoneyand power, since more expense may be allocated to increasing efficiency. Cyclotrons produce a continuous stream of particle pulses at the target, so the average power is relatively high. •The compactness of the device reduces other costs, such as its foundations, radiation shielding, and the enclosing building. The world’s most powerful cyclotron, the K1200, is capable of accelerating nuclei to an energy approaching 8 GeV. Synchrotron The synchrotron is the most recent and most powerful member of the acceleratorfamily. It consists of a tube in the shape of a large ring through which the particles travel; the tube is surrounded by magnets that keep the particles moving along the centre of the tube.

The particles enter the tube after already having been accelerated to several million electron volts. They are accelerated at one or more points on the ring each time they make a complete circle around the accelerator. To keep the particles in a rigid orbit, the strengths of the magnets in the ring are increased as the particles gain energy. In a few seconds, the particles reach energies greater than 1 GeV and are ejected, either directly into experiments or towards targets that produce a variety of elementary particles when struck by the accelerated particles.

The synchrotron principle can be applied to either protons or electrons, although most of the large machines are proton-synchrotrons. Differences between Cyclotron and Synchrotron •Synchrotron has a single ring unlike the cyclotron which has two. •Synchrotron is surrounded by magnets, cyclotron has two magnets in all. •Synchrotron accelerates the particles at one or more places as opposed to cyclotron which accelerates the particle with the potential difference between the two dees. •Synchrotron is much cheaper way to achieve high energy particles than the cyclotron and therefore the original cyclotron method is no longer used.

Particle Detectors Particle Detectors are instruments used to detect and study fundamental subatomic particles and are one of the most important pieces of equipment in the particle accelerator. The particle detector sees the particles and the radiation after the collision created by a particle accelerator. Geiger Counter A " Geiger counter" usually contains a metal tube with a thin metal wire along its middle, the space in between them sealed off and filled with a suitable gas, and with the wire at about +1000 volts relative to the tube.

It measures ionizing radiation, and detects photons, alpha, beta, and gamma radiation, but not neutrons. An ion or electron penetrating the tube tears electrons off atoms in the gas, and because of the high positive voltage of the central wire, those electrons are then attracted to it. In doing so they gain energy, collide with atoms and release more electrons, until the process snowballs into an " avalanche" which produces an easily detectable pulse of current. With a suitable filling gas, the flow of electricity stops by itself, or else the electrical circuitry can help stop it.

The instrument was called a " counter" because every particle passing it produced an identical pulse, allowing particles to be counted but not telling anything about their identity or energy. Cloud Chamber The fundamental principle of the cloud chamber was discovered by the British physicist C. T. R. Wilson. The cloud chamber consists of a vessel several centimetres or more in diameter, with a glass window in the top and a movable piston forming the lower side. The piston can be dropped rapidly to expand the volume of the chamber. The chamber is usually filled with dust-free air saturated with water vapour.

Dropping the piston causes the gas to expand rapidly and causes its temperature to fall. The air is now supersaturated with water vapour, but the excess vapour cannot condense unless ions are present. Charged nuclear or atomic particles produce such ions, and any such particles passing through the chamber leave behind them a trail of ionized particles (see Ionization) upon which the excess water vapour will condense. This makes the course of the charged particle visible as a line of tiny water droplets, like the vapour trail left by an aeroplane.

These tracks can be photographed and the photographs then analysed to provide information on the characteristics of the particles. A cloud chamber is often operated within a magnetic field. The tracks of negatively and positively charged particles will curve in opposite directions. By measuring the radius of curvature of each track, its velocity can be determined. Heavy nuclei such as alpha particles form thick and dense tracks, protons form tracks of medium thickness, and electrons form thin and irregular tracks.

Although the cloud chamber has now been supplanted almost entirely by later devices, it was used in making many important discoveries in nuclear physics. Bubble chamber The bubble chamber, is similar in operation to the cloud chamber. In a bubble chamber a liquid under pressure is kept at a temperature just below its boiling point. The pressure is lowered just before subatomic particles pass through the chamber. This lowers the boiling point, but for an instant the liquid will not boil unless some impurity or disturbance is introduced. The high-energy particles provide such a disturbance.

Tiny bubbles form along the tracks as these particles pass through the liquid. If a photograph is taken just after the particles have crossed the chamber, these bubbles will make visible the paths of the particles. As with the cloud chamber, a bubble chamber placed between the poles of a magnet can be used to measure the energies of the particles. Many bubble chambers are equipped with superconducting magnets instead of conventional magnets. Bubble chambers filled with liquid hydrogen allow the study of interactions between the accelerated particles and the hydrogen nuclei.