Accelerators Made Simple

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Accelerators Made Simple is intended to be an introductory primer to provide a background of nomenclature, units, uses, and first principles of accelerator construction and operation. It also provides the reader a background of the kinds of accelerators that are used at Brookhaven National Laboratory (BNL) and specifically some details of the NASA Space Radiation Laboratory (NSRL) at BNL.

We begin with some definitions of units for energy and mass in the context of the theory of Special Relativity. This leads to an explanation of the basic principles of a particle accelerator. This includes the process of forming the initial beam, the acceleration process and the process of guiding the beam to the desired location. A brief introduction to magnet types, dipoles to steer beams and quadrupoles to focus and defocus beams to contain the particles in the accelerator vacuum envelope, are discussed.

We then provide a brief description of basic accelerator types; linear and circular accelerators. Linear accelerators come basically in two types. There is the electrostatic based device where particles are accelerated via a fixed high voltage electrical field. The Tandem accelerators, which are electrostatic machines, provide the first stage of acceleration for the NSRL facility. The second variety of linear machines (linac) use a traveling wave radio frequency electric field to accelerate particles, like riding a surfer wave. The BNL proton linac provides protons for NSRL.

A circular machine, the Booster synchrotron, is the next machine to take the beam from either the Tandem or Linac, and accelerate it to the final energy before delivery to the experimental target station. The basic principles of circular machines are then presented. Cyclotrons, which are one type of a circular machine, are based on a fixed magnetic field and a varying acceleration field frequency. The cyclotron rapidly becomes prohibitively large and expensive when you desire beam energies of the order of 600 MeV or greater. This difficulty is overcome with synchrotrons, reaching energies greater than a million million electron volts (TeV), by varying the magnetic field strength and the accelerating field frequency together during the acceleration cycle. A brief description of a synchrotron, the physics of steering of and acceleration is presented.

A brief discussion of typical uses of accelerators is presented. The 24 accelerators at BNL supply photons, electrons, protons and ions for basic research in nuclear and particle physics, material science, energy research and life science research.. The Relativistic Heavy Ion Collider is the largest, 4 km circumference, and highest energy, 250 GeV polarized protons and 100 GeV / nucleon gold ions at BNL. A brief discussion of hadron therapy beam specifications and typical material science specifications are described.

The final topic presented is the beam specifications of the NSRL facility and how it is operated. Of particular interest for the summer school students is the physics of energy loss and dose for various ion species as a function of energy and depth of beam penetration. The concept of a Bragg curve is elucidated with an example of a typical irradiation of a liquid filled flask and the radiograph images produced as a function of beam energy.

The final slide is a sample homework to reinforce the most important points to be absorbed by the student.

Keywords:

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Ions, protons, linear energy transfer, LET, Bragg curve, accelerator basics