Particle beams are also used for purposes besides cancer therapy. Treatment of growth disorders due to hyperactive pituitary glands with protons and heavy ions was first achieved at Lawrence Berkeley Laboratory using its synchrocyclotron. In 85 percent of the cases, patients returned to normal growth rates with far less risk than in other treatments. This procedure has since become a standard clinical procedure that can be performed routinely at facilities like Harvard's 160 MeV cyclotron.

Other medical applications of high-energy physics involve diagnosis rather than therapy. Computed Axial Tomography (CAT scanners) and Magnetic Resonance Imaging devices (MRI scanners) have revolutionized diagnosis of disorders of soft tissues, especially disorders of the head and brain. Rare is the shock-trauma unit or major neurological clinic that does not have one of these machines on-site or at its immediate disposal. The sophisticated mathematical techniques used to reconstruct the images of organs and tissues that doctors see with these amazing diagnostic instruments—as well as in positron emission tomographs discussed below—originated in particle detection methods developed by high-energy physicists.

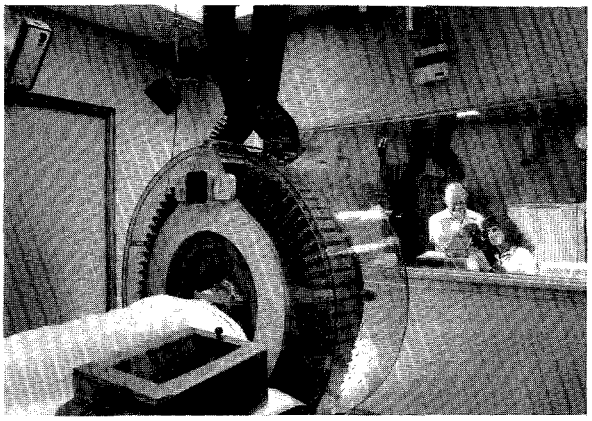

Figure 24. Brookhaven's facility for positron emission tomography.

Allan Cormack, a high-energy physicist at Tufts University, shared the 1979 Nobel prize in physiology and medicine for his key work in developing these methods for CAT scanners which are widely regarded as the most significant advance in medical radiography since the 1895 discovery of x-rays. His physics research was directed towards replacing bubble chambers and similar particle detectors with digital electronic instruments.

In positron emission tomography or PET, as with the other scanners, doctors see a precise image of a cross section of the tissue and can detect any change or abnormality that has occurred. A radioactive isotope that decays by emitting positrons is administered to the patient and collects in tissues. Two energetic gamma rays shoot out back-to-back when a nucleus of these isotopes decays. Crystals of bismuth germinate, first developed for high-energy physics particle detectors, are used to detect these photons, and a computer helps to reconstruct the image.

In medical scanners and some particle detectors, photons or particles moving in different directions pass through a target volume and are received by an array of surrounding detectors. The detector measurements tell how much of the original radiation was absorbed during the passage. The computer uses this information, together with data on how materials absorb radiation, to reconstruct an image of an interior slice of the target.

Positron emission tomography has provided physicians a new and powerful tool. It has proved to be a non-invasive way to observe changes as they are occurring in the body. This kind of imaging is important for the study, diagnosis, and treatment of brain tumors, strokes, Alzheimer's disease, schizophrenia, and heart disease. PET scans are also being used to distinguish the two major types of breast cancer. Since one type requires early, aggressive treatment, learning the distinction is vital.

Integrated circuit technology has provided yet another channel through which particle physics research affects commercial technologies. One of the most important of these has been ion implantation. In this technique, particle beams are used to embed a thin layer of ions near the surface of a semiconductor material to alter its chemical structure. According to the National Research Council, "Every IC [integrated circuit] now made employs ion implantation .... the remarkable growth in integrated circuit technology is difficult to envision without ion implantation." Ion implantation also has been used to reduce the wear of artificial hip joints by 400 times, saving replacement operations.

One of the most promising technologies for the analysis and creation of new integrated circuit chips is synchrotron radiation—energetic photons spun off tangentially by electrons as they whip around inside a storage ring. Physicists first viewed synchrotron radiation as an undesirable but una-