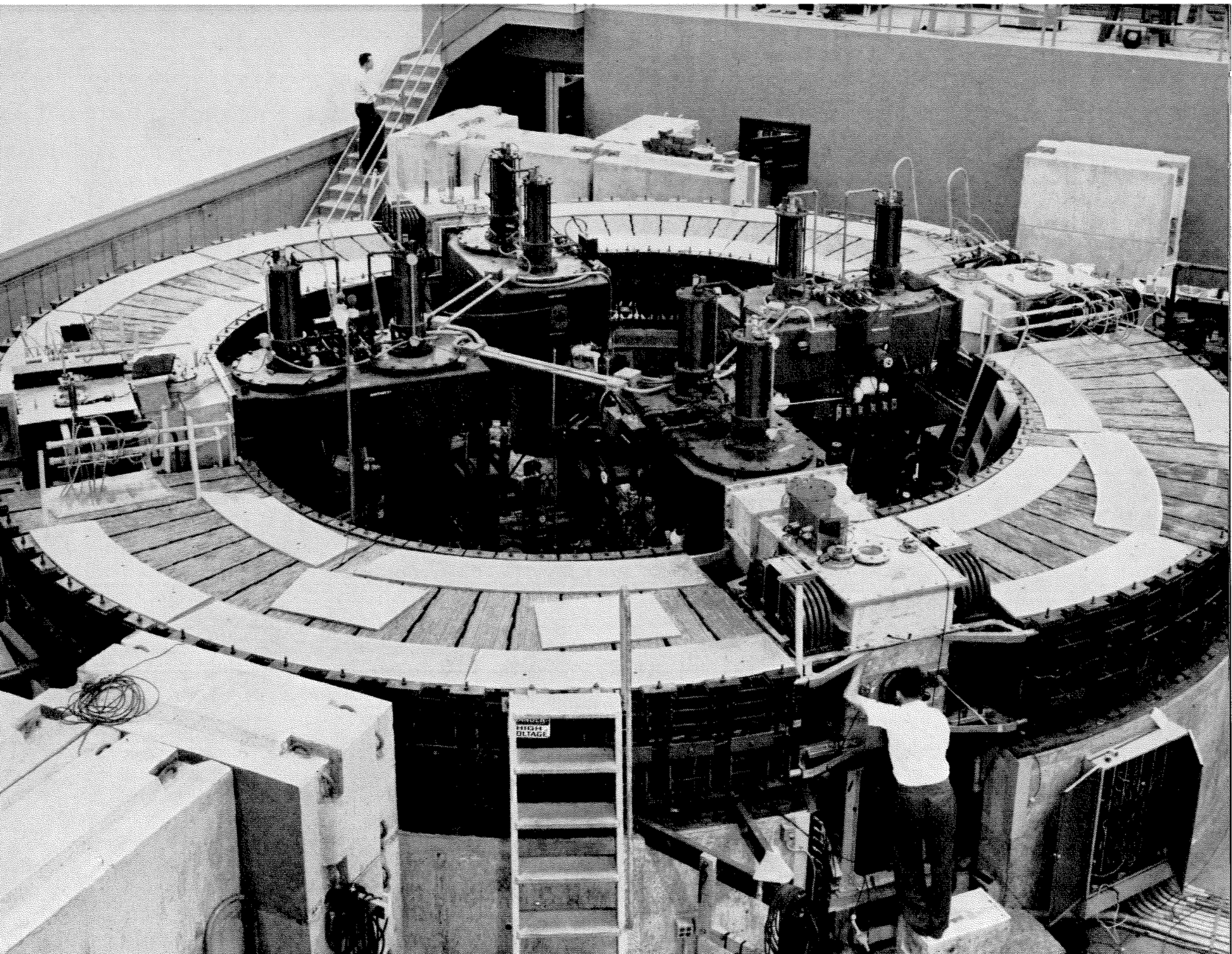


MORE POWER TO THE SYNCHROTRON

Newly-modified Caltech synchrotron is now the most powerful machine of its type in existence

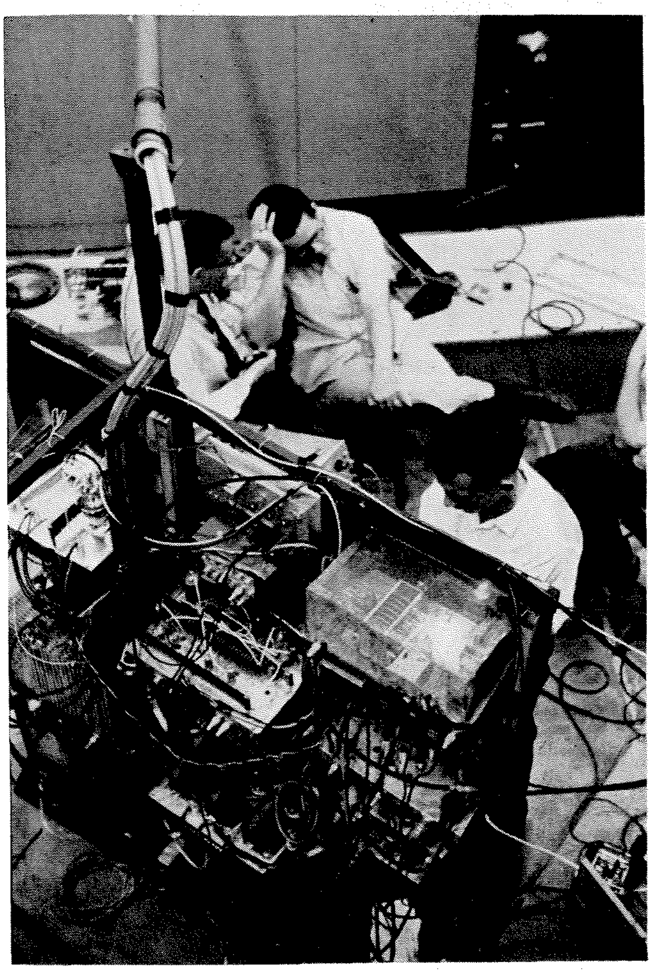
MODIFICATIONS in the Caltech synchrotron, made over a period of two years, have now brought the machine up to such high energy levels that researchers should be able to produce and examine some of the most fundamental particles in nature. The machine, which is now the most powerful of its type in existence, can accelerate electrons to energies of over a billion electron volts, and to speeds never before reached by any man-accelerated particles.

The original synchrotron principle was developed by two men, independently, in 1945—a Caltech alumnus and Nobel prizewinner, Edwin M. McMillan, now at the University of California in Berkeley; and a Russian physicist, V. Veksler. The Caltech synchrotron, installed in 1951, under contract with the Atomic Energy Commission, is of the "race-track" type first suggested by another Caltech alumnus, H. R. Crane of the University of Michigan.

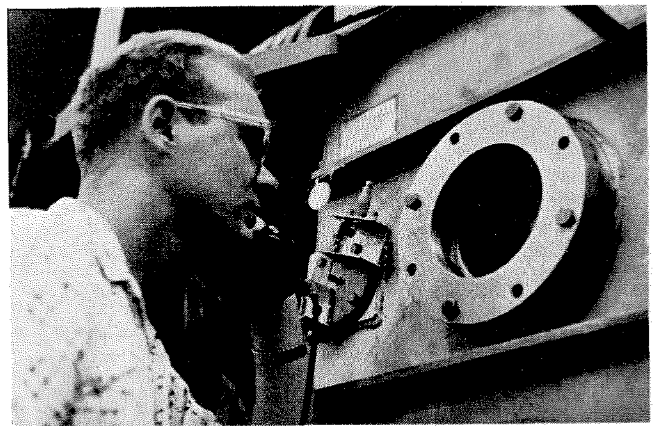
The synchrotron is essentially a machine for the production of X-ray beams of great energy. It does this by directing accelerated electrons against a metal plate or "radiator." The collision generates high-energy X-rays and these, in turn, are used to bombard the nuclei of atoms.

For many years it was believed that the structure of the atom was fairly simple—a nucleus composed of one or more protons and neutrons and, revolving around the nucleus, one or more electrons. But the exploration of atomic nuclei in the past two decades has revealed upwards of 20 other "strange particles" such as mesons, heavy mesons, hyperons, anti-protons and anti-neutrons. The nature of these sub-atomic complexes and of the tremendous forces locking them together presents one of the most formidable mysteries of modern physics.

During the first phase of its operation, over a period of three years, the Caltech synchrotron operated at an energy level of 500 million electron volts, and succeeded in producing relatively lightweight mesons from the bombardment of hydrogen and deuterium atoms. Careful measurements showed that the production of mesons was increased greatly as X-ray energies increased, but



Drs. Langmuir, Teem and Clegg tackle the problem of tuning up the radio frequency acceleration system.



Dr. Vincent Peterson watches electrons hit a fluorescent screen through a window in the machine.

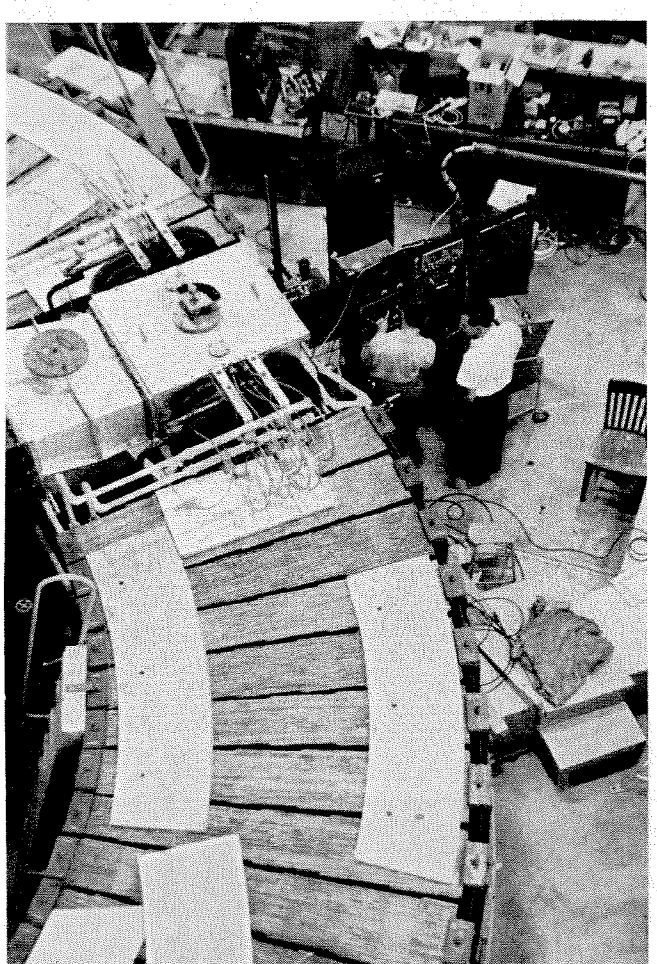
that beyond a certain energy level (about 300 million electron volts) the production of mesons fell off sharply. This enhanced response at a particular energy level is known as "resonance"—analogous to the resonant frequency of a piano string. It means that there is an excited state, or state of preferred energy, in which the proton-meson system exists. Investigation of the properties of this state gives physicists further insight into the nature of forces operating between protons and mesons and brings them a step closer to an understanding of the atomic nucleus.

Now, with much higher energies available, it will be interesting to see whether the synchrotron can produce other particles, such as heavy mesons and hyperons. They have been produced elsewhere as the by-products of proton-proton collisions, but it is not known whether high-energy X-rays can tear them out of the atomic core. If they can, it will be by a quite different production system. And it may be that the characteristics of this new system will shed more light on our understanding of nuclear forces.

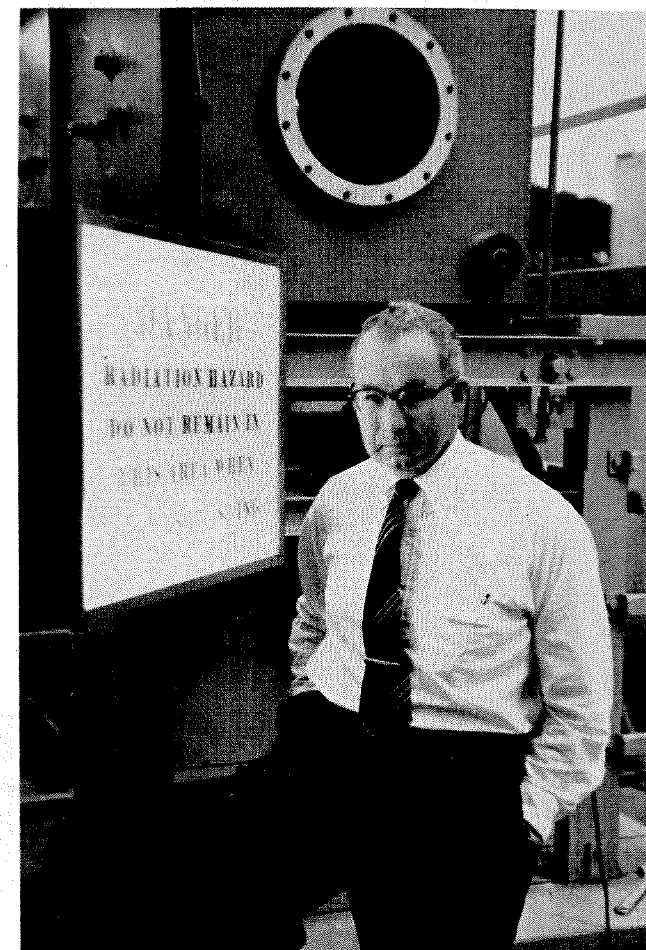
Research with the synchrotron begins when an "electron gun" driven by a million-volt pulse transformer shoots bursts of several billion electrons into a tube where they are accelerated to approximately 94 percent of the speed of light, then bent through 90 degrees to enter a tunnel-like vacuum chamber. This chamber, evacuated to within a few billionths of an atmosphere, runs around the inside of the 140-ton electromagnet which is the main body of the synchrotron. The chamber provides the path along which the electrons travel. The vacuum serves to minimize air resistance to them. The electromagnet holds them to their path.

The magnet is divided into four quadrants separated by five-foot straight sections. Each of these sections houses a unit of the vacuum pumping system, and two of them also house radio frequency cavities, or booster units.

Each time the electrons circle the chamber, they get a 600-volt kick from the first radio frequency cavity. As they are accelerated—and in accordance with Einstein's relativity principle—they gain mass, actually at a billion



View of magnet which bends particles into circular orbit. Radio frequency cavity is inside rectangular box.



Dr. Robert F. Bacher, chairman of the Physics Division, and director of the synchrotron project.

volts becoming heavier than protons. (Normally, the electron's mass is only 1/1840 that of the proton.) However, during acceleration, the electrons lose a certain amount of energy by radiating light. In order to make up for the lost energy, the electrons require greater energy boosts, and these, steadily increasing up to more than 50,000 volts per rotation, are provided by the second radio frequency cavity.

Meanwhile, to keep the electrons from flying out of their orbits, the strength of the magnetic force holding them must be steadily increased. This increasing force is produced by a current that rises from zero at the moment of electron injection to 3,000 amperes a quarter of a second later, and then falls back to zero in preparation for the next cycle. The power for the electromagnet is drawn from a large motor generator set, and when the synchrotron is in use, each burst of electrons is accompanied by a heavy pulsing sound occurring at almost exactly the same rate as that of the normal human heartbeat.

Before reaching their peak energy, the electrons travel around the vacuum chamber two million times, receiving a total of two million boosts and covering a distance of 37,000 miles. All this takes time—in fact, one-fifth of a second. At peak energy, the radio frequency cavity is turned off, the electrons leave their orbits and, at a "muzzle-velocity" within about one ten-millionth of the speed of light, strike a small piece of a heavy metal, tantalum. It is this collision that produces the 1.2 billion volt X-rays. The X-rays, directed at such targets as liquid hydrogen and liquid deuterium, produce sub-atomic particles such as mesons.

What happens during these secondary collisions is instantly registered either on photographic plates or on scintillation counters that produce electrical signals corresponding to the sizes, courses and decay modes of the particles.

In particular, researchers will try to find out what particles are created when nuclei are bombarded with the increased power of these very high energy X-rays.

Members of the synchrotron team are: Dr. Robert F. Bacher, chairman of Caltech's Physics Division; Dr. Arthur B. Clegg, research fellow in physics; Dr. Robert V. Langmuir, associate professor of electrical engineering; Dr. Vincent Z. Peterson, senior research fellow in physics; Bruce Rule, chief engineer; Dr. Matthew L. Sands, associate professor of physics; Dr. John G. Teasdale, senior research fellow in physics; Dr. John M. Teem, senior research fellow in physics; Dr. Alvin V. Tollestrup, assistant professor of physics; Dr. Robert L. Walker, associate professor of physics; and a number of graduate students.