



DEDICATORY ADDRESS

By Leland J. Haworth

ON both general and highly personal grounds it is a privilege for me to dedicate this great new scientific resource and thereby to honor the many individuals whose energy and skill and great devotion have brought it into being.

As you will understand, it seems very strange to be here as a guest.* Of the many facets of the strangeness, I shall mention only one. During my last weeks at Brookhaven I had persuaded Professor Rabi to give this dedicatory talk and had expected to introduce him. By a strange quirk of fate, our roles have been reversed. I feel somewhat as might the father of a newborn child who suddenly finds that the minister has possession of the baby, and that he, the father, has been asked to do the christening.

The great machine that lies next door is the most recent, though certainly not the final, consequence of a series of notable scientific and technical advances over a period of thirty years. The remarkable success of quantum mechanics in the 1920's brought to climax an era in which physicists had devoted their maximum efforts toward understanding the outer structure of the

atom. By the early 1930's attention was turning to the next logical step, intensive exploration of the nucleus. It was realized that detailed knowledge of its structure, the forces between the elementary particles, the internal energy states, and other nuclear properties could best be studied by methods in which nuclei were disturbed internally, either spontaneously or by bombardment with energetic particles. Indeed, some progress had been made. Detailed observations had been made of the various radioactive chains of the heavy elements by

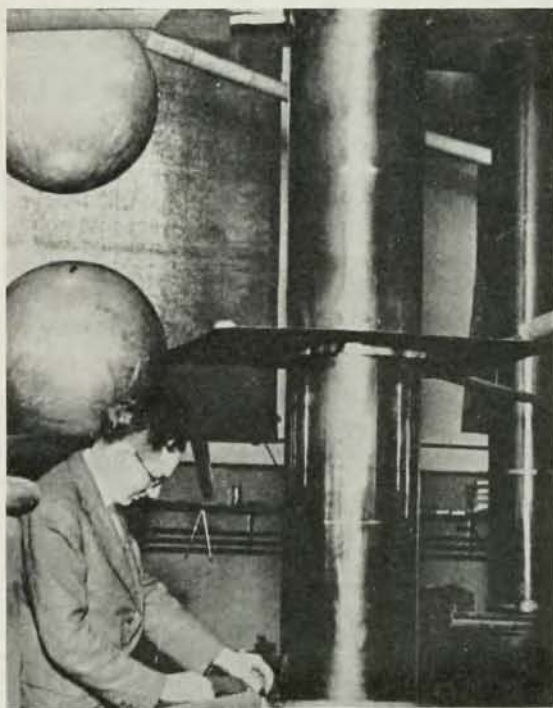


BNL's former director, Leland J. Haworth, under whose guidance and encouragement the alternating-gradient synchrotron was successfully built.

* Dr. Haworth was director of Brookhaven National Laboratory and president of Associated Universities Inc. (AUI) until he was appointed Atomic Energy Commissioner in April 1961. Prof. I. I. Rabi is the present president of AUI.



Ernest Rutherford, a pioneer in the early period of nuclear exploration before the era of big machines.



E. T. S. Walton and 600-keV generator with which he and John Cockcroft accelerated protons in 1932.

Becquerel, the Curies, Rutherford, and many others. Energetic particles derived from radioactive sources had also been used to study interactions, notably in Rutherford's scattering experiments leading to the Bohr theory of the atom, and in the artificial transmutation of elements first accomplished also by Rutherford in 1919. A mass of observational data had been acquired through cosmic rays, but they are few in number, complex in composition, and uncontrollable.

By analogy with the extra-nuclear case, and from past nuclear observations, it was recognized that a source of controlled high-energy particles in sufficient quantities would be extremely useful in nuclear experiments. From theoretical considerations, heavy nuclear particles, especially protons, gave most promise of results. At first sight, very high energies seemed essential to surmount the Coulomb barrier presented by the repulsive forces between like charges. Numerous workers were endeavoring in various ways to achieve the required energies, believed to lie in the millions of electron volts. Fortunately, however, as a result of a nuclear model due primarily to Condon, it was suddenly realized that in accordance with principles of quantum mechanics there is a finite probability that the Coulomb barrier will be penetrated by a particle with insufficient energy to surmount that barrier. Taking advantage of this fact, Cockcroft and Walton at the Cavendish Laboratory constructed a high-voltage source which accelerated protons to a few hundred thousand volts and thereby achieved, in 1932, the first transmutation using accelerator particles. At about the same time, Van de Graaff at Princeton devised the electrostatic generator which now bears his name, and Ernest Lawrence at the University of California originated the cyclotron, the ancestor of all modern magnetic machines. The age of high-energy accelerators was born.

Phenomenal advances have occurred in the intervening three decades. Particle energies have increased in almost exponential fashion from a few hundred thousand to thirty billion electron volts, or tenfold every six or seven years. The list of elementary particles has grown from a very few to more than thirty. The wonderland of nuclear and elementary-particle structure has rapidly unfolded, enriching our knowledge, though only partially our understanding.

LET us review briefly a few important milestones. The cyclotron development of Lawrence applied successfully the principle of resonance acceleration not previously practical for linear devices. This technique was rapidly exploited. Energies increased by an order of magnitude within the next few years. Cyclotrons were built at laboratories throughout the world. The Van de Graaff generator also played a vital role. The scientific potentialities of the field were enriched by such discoveries as that of the neutron by Chadwick and of artificial radioactivity by Curie and Joliot.

Each advance in energy opened up additional fields, but, as the decade ended and scientists turned their attention to wartime work, energy limits seemed in



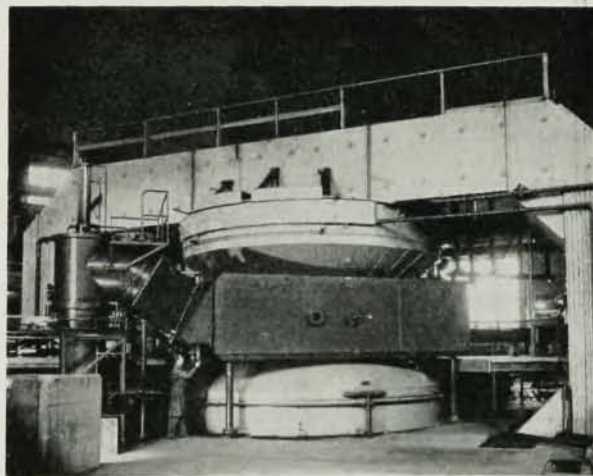
Ernest Lawrence at the controls of the Berkeley sixty-inch cyclotron in 1939.

sight. Electrostatic devices had definite voltage limitations; the cyclotron seemed up against a fundamental barrier because of the relativistic change in mass. Fortunately, physicists rose to the occasion with a second great advance, the betatron of Kerst and Serber. This device, itself, made possible electron energies in the hundreds of millions of electron volts. More importantly, its focusing principle permitted the use of ring-shaped magnets without which our present energy attainments in magnetic accelerators would be economically absurd.

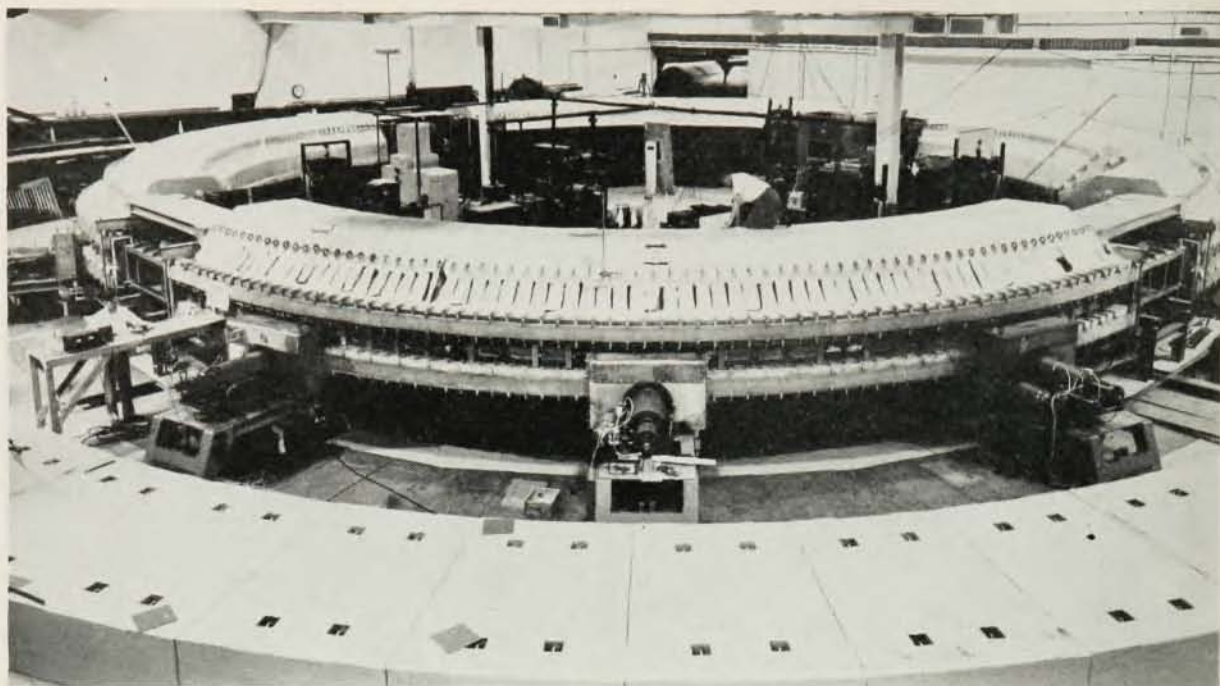
As the war ended, Veksler and McMillan independently brought forward a third great accelerator principle, the theory of phase stability. It made feasible the use of frequency modulation to overcome the relativistic difficulty of the cyclotron, and it had important implications in linear accelerators. Even more importantly, it led to the marriage of the ring-shaped magnet of the betatron with the radio-frequency acceleration of the cyclotron to produce their progeny, the synchrotron. The first postwar crop of accelerators featured synchrocyclotrons and electron synchrotrons accelerating particles to a few hundred-million volts.

By now, emphasis at the higher energies was turning from studies of the complex nucleus as a whole to investigations of the nature of the fundamental particles themselves. The potentialities of the newer accelerators gave physicists the hope of furthering their understanding by producing in the laboratory the mesotron postulated by Yukawa as an important key to nuclear forces. This was for a time assumed to be the particle of 200 electron masses observed in cosmic rays; its production was an early goal for the crop of new machines. But,

as these machines were underway, a major discrepancy was found. The penetrating power of the cosmic-ray mesotron, as observed in deep-mine experiments, indicated an interaction cross section many orders of magnitude too small to be consistent with the theories of Yukawa or any mechanism of production that anyone could visualize. This difficulty was resolved when, in 1947, Marshak postulated, and Powell and Ochilini observed in cosmic rays, a somewhat heavier, strongly interacting transient particle that decays to form the lighter one. About that time semantics changed to give the name of meson to such intermediate particles; the



One of the early postwar machines, the 184-inch cyclotron at Berkeley, a product of the phase-stability concept.



The 3-Bev cosmotron at Brookhaven was completed in 1952. Compared with the half-mile circumference of the underground magnet tunnel of the new AGS, the cosmotron, once a giant among accelerators, now seems modestly proportioned.

heavier was called the pi meson, the lighter the mu meson. Later, at Fermi's suggestion, these were dubbed the pion and the muon.

Fortunately, the accelerators underway had energy sufficient to produce the pion, even with its greater mass. It was first observably produced at the Berkeley synchrocyclotron by Lattice and Gardiner in 1948. Innumerable revealing experiments involving pions have been performed with all of these machines in the intervening years.

But even as the synchrotron and synchrocyclotron were underway, further goals were within sight. At energies within reach, one might hope to perturb the nucleon. The discovery of the positron had long since helped clarify the Dirac theory to include the antinucleon; its production seemed attainable. Furthermore, the realm of higher energies surely held innumerable unknown riches.

Radiation losses in the electron-synchrotron would rapidly increase its problems and multiply its cost; the proton seemed preferable in any case. But the synchrocyclotron had economic limits at something like a Bev. The proton-synchrotron seemed the obvious answer. Though ingenuity and skill and massive effort were required, the principles were all in hand. Machines were planned at Birmingham, at Brookhaven, and at Berkeley; their energies were one, three, and six Bev respectively, the last deliberately above the antinucleon threshold. In 1952, the Brookhaven cosmotron reached its multi-Bev goal, followed later by the others. Still later came the ten-Bev synchrophasotron at Dubna in the Soviet Union.

HARD upon the heels of the completion of the cosmotron came a new development. The group in Western Europe forming CERN was engaged in studies of an appropriate accelerator which they naturally hoped would increase the energy ceiling. Simultaneously, the Brookhaven group was beginning to consider what further steps might be taken there. Mutual discussions sought to find improvements and economies that might permit extension of the cosmotron technique. Clearly economic considerations would be the limiting factor, since costs would rise much more than linearly with energy. Fifteen Bev seemed a likely upper limit, and even this would cost a princely sum.

Happily, during these deliberations, certain theoretical studies of particle orbits led to a fourth great discovery, the principle of alternating-gradient focusing, by Courant, Livingston, and Snyder. It was quickly learned that Christofilos, working alone in Athens, had independently evolved the principle even earlier but had not published it. Though not all of its potentialities were then realized, one fact was obvious; the reduction in amplitude of orbital oscillations would correspondingly reduce the required cross section of the vacuum chamber and hence of the ring-shaped magnet. The energy ceiling imposed by economics would be raised substantially. Both CERN and Brookhaven seized on the opportunity. Though there were no obvious scientific landmarks by which to set the energy, an order of magnitude above that of the cosmotron seemed generally desirable and not too unreasonable in the scientific economics of that time. Accordingly, 25 to 30 Bev was set as a goal for each machine, the one here being

slightly larger, and work began in earnest in 1953 and 1954. Each has, of course, exceeded its original goal in energy and, even more significantly, in intensity.

The wisdom of embarking on these projects expeditiously has been well demonstrated by scientific developments in the intervening years. The results flowing from the cosmotron, the bevatron, and others have exceeded expectations and opened up further promising fields at still higher energies. The *V*-particles first observed in cosmic rays proved to be members of whole families of the new particles, *K*-mesons and hyperons, whose behavior is so "strange" that that adjective itself has been incorporated in their collective name. Their properties, as well as those of antinucleons, have been studied in detail within the limits of the energies and intensities available. The phenomenon of associated production has helped point out the new property of "strangeness". In a different area, certain experimental anomalies led Yang and Lee to discover the non-conservation of parity in weakly coupled interactions. The list is almost endless.

But there was definite need for higher energies for many purposes. Numerous phenomena should be extended in their range. The heaviest antiparticles could be produced only indirectly, if at all. There was urgent need for increased yield at higher energies for nearly all the manufactured particles in order to observe their interactions with the nucleons in secondary targets.

The CPS at CERN and the AGS at Brookhaven have nicely met the present need. Indeed, it would be difficult to find a more propitious matching of a scientific need with a newly available tool. It has been thus throughout the history of the field. The impedance match has been phenomenal. Successive needs for higher energy have been met with timeliness. Contrariwise, advances in accelerators have always found immediate and effective application in research. Some human phase stability may underlie these facts.

I have spoken briefly of the scientific and technical advances of which the AGS is the present culmination. They have been accompanied by many drastic changes in our methods of approach. High-energy groups have grown from handfuls to hundreds of people. Budgets have grown a thousandfold. The efforts of enormous laboratories are engaged within this single field.

This is clearly "big" science, something that scientists have traditionally viewed with suspicion.

Many of you will remember a postwar ballad in which there is proposed

...
At an ancient army base
The best electro-nuclear
Machine at any place

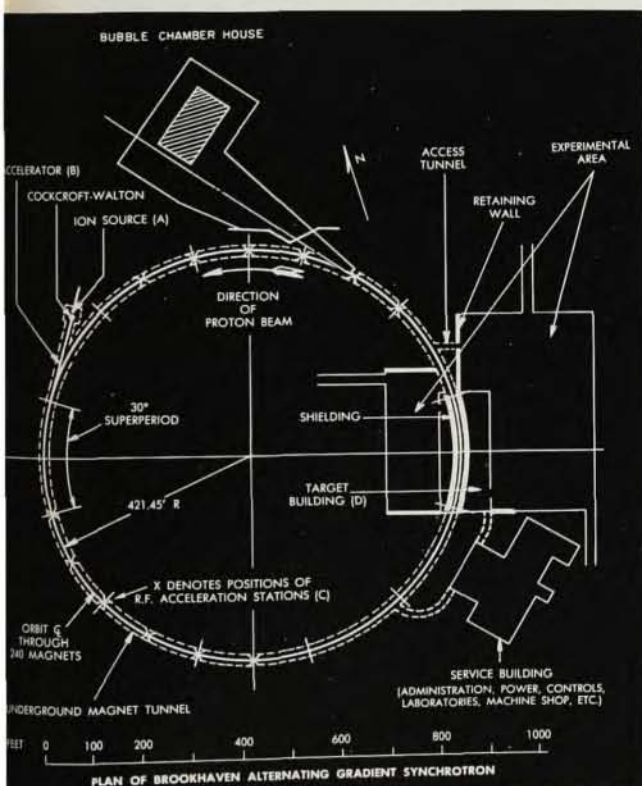
It will cost a billion dollars
Ten billion volts 'twill give
It will take ten thousand scholars
Seven years to make it live
This machine is just a model
For a bigger one, of course
That's the future course of physics
As I'm sure you'll all endorse

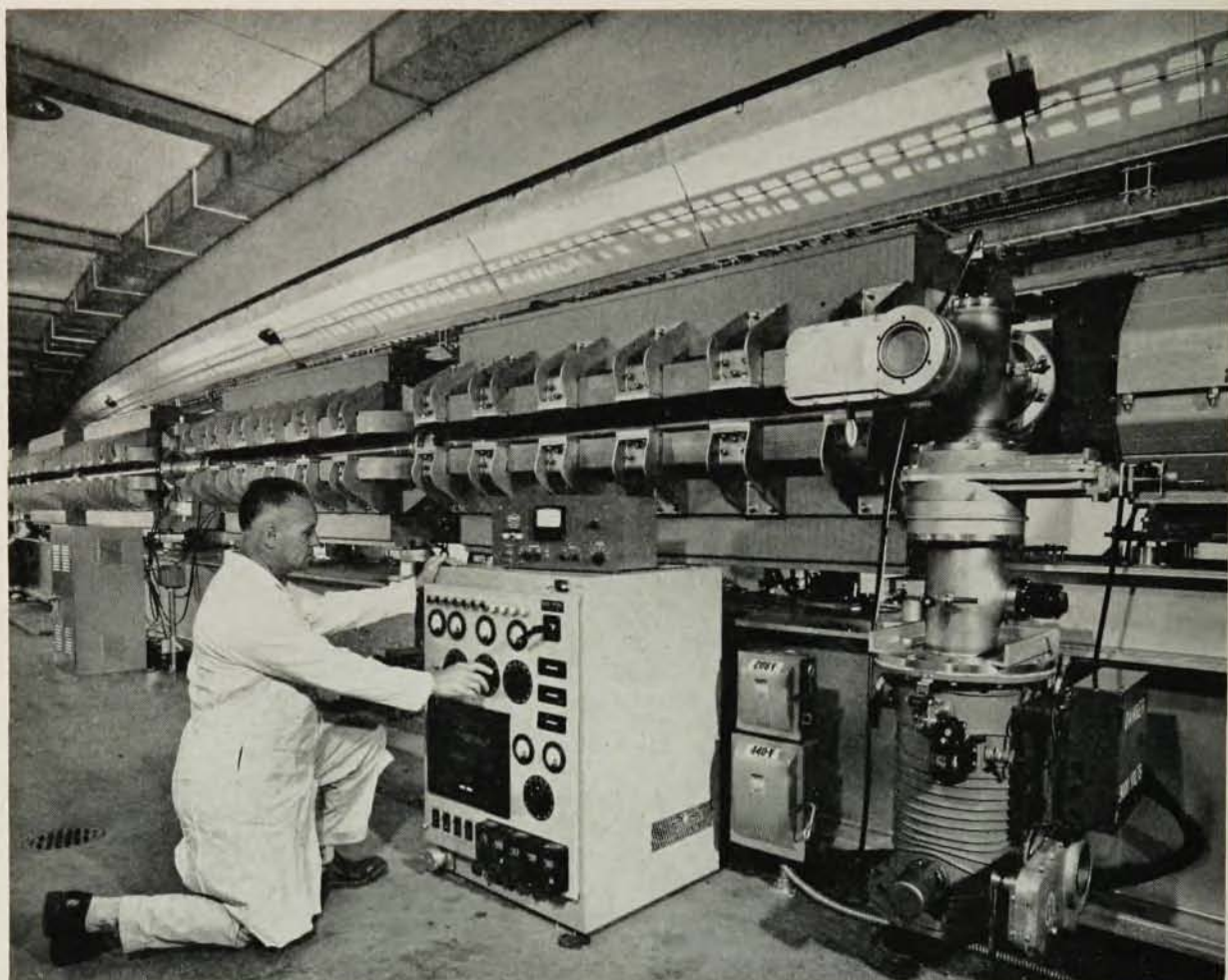
Perhaps because the proposer was guilty of accelerator history's only over-estimation of cost and manpower, the idea was scornfully rejected by the hero of the ballad.

Take away your billion dollars
Take away your tainted gold
...
Take, oh take your billion dollars
Let's be physicists again

It is a long time since I have heard a high-energy physicist sing that ballad. Indeed, many of its most gleeful renderers of fifteen years ago, including the composer, are earnest practitioners in the field who find budgets far too tight. But there are others who long for "the good old days" in unchanged form. They argue that intensive, highly organized research results in intellectual sterility, that large-scale programs demand so much of scientists in the way of management and administration as largely to prevent the quiet contemplation conducive to great scientific achievement.

No one would claim that, like virtue, "bigness" is its own reward. But sometimes bigness is essential. It





The piece of equipment in right foreground, above, is one of 48 titanium evaporation pumps located in underground ring of the AGS; white box is its control console. The pumps are used to maintain a high vacuum in accelerating tube.

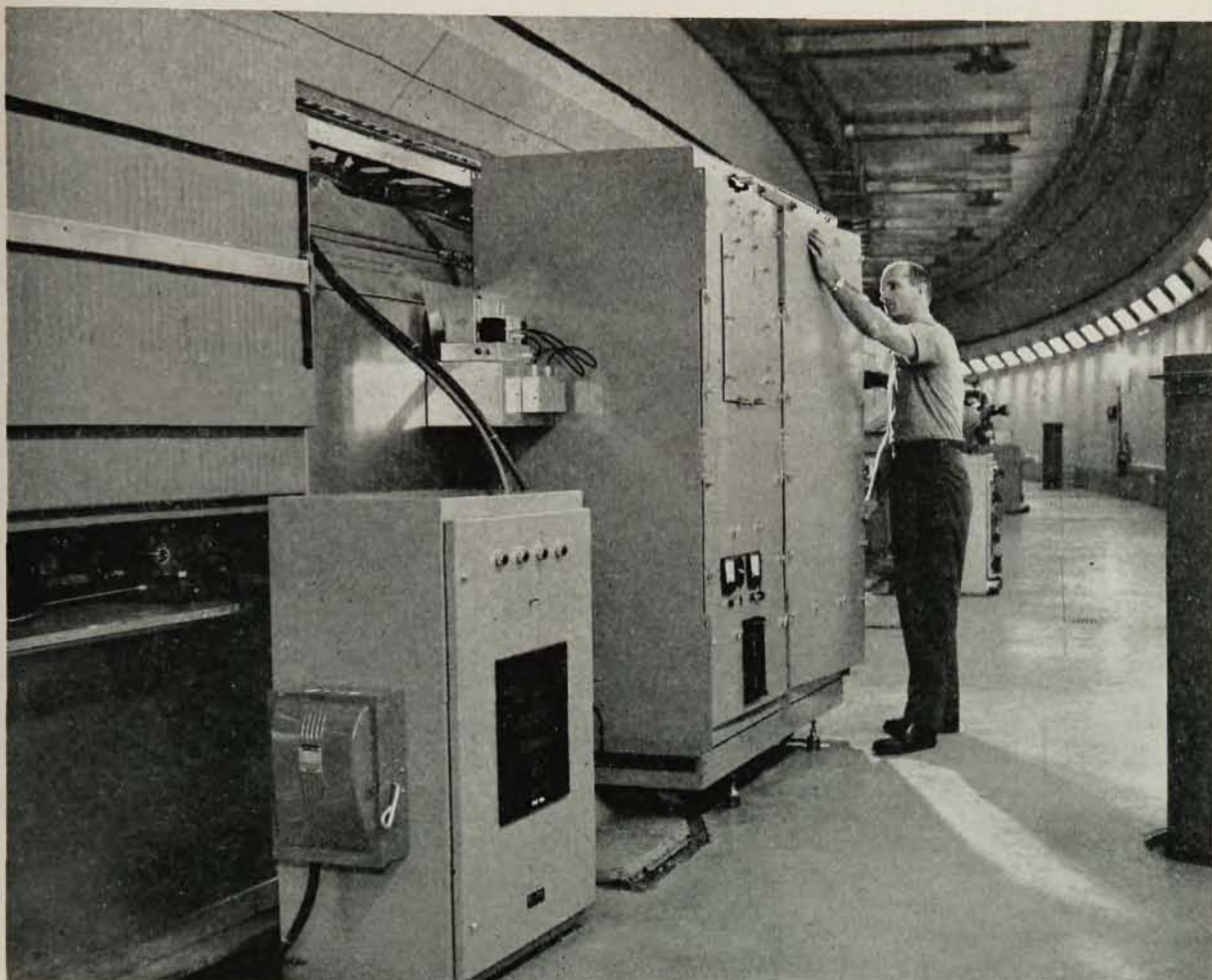
has been ever thus, even in the field of science. Galileo used the Leaning Tower; Darwin used the good ship Beagle; Kepler and Newton used the solar system not only to describe it but also as a tool for finding universal laws. The essential difference in the present situation is that in many fields the tools required must be specially created at great effort and great cost. Because they must be few in number, they must be shared by many scientists. Bigness is the price we pay to have the opportunity of making progress in the field.

Nor need bigness be a bar to individual effort or even quiet contemplation. To be sure, the tools are large and their operation needs large groups; but the experiment itself, its purpose and its planning, its interpretation and evaluation, can still be a highly individual matter. The achievements of Van Allen and Christofilos in the upper atmosphere were clearly so, though massive efforts were required to give them opportunity.

So it is around the big accelerators. The research groups are highly individualized. Strenuous efforts have

been made to keep them so. The very organization which is decried by some, places the heavy burdens of general administration on the shoulders of a few, leaving the many in the laboratories free to devote themselves to science. Generous support makes it possible to provide adequate numbers of technical assistants, and thus relieve the scientists themselves of many time-consuming manual chores that old-timers used to do.

Perhaps most importantly of all, the evolution of the large devices has been accompanied by an evolution in their creators. In the very early days, each accelerator was brought to being by research physicists who needed such a tool and, of necessity, removed themselves, sometimes for many years, from research itself in order to construct it. As time went on some individuals began to specialize in the accelerator art and devote substantial fractions of their time to furthering its progress. The process has become complete. A new professional group has risen, called by our Russian colleagues "accelerator specialists". Some are physicists and some



There are twelve radiofrequency accelerating stations like the one shown above distributed within the synchrotron tunnel. Each station is complete with controls for accurate application of accelerating voltage to the orbiting protons.

are engineers. All are devoted to advancing the machines themselves. Their effective work permits the research physicists to devote all their efforts to experimental work. Even while a new machine is being built, the researcher can continue with the old. Such a group of specialists has built the AGS.

In recent times, this trend has been extended to include the largest instruments. Large groups spend years of effort to design and build big bubble chambers which they then operate for the benefit of all. In such ways the onerousness of bigness can be largely mitigated.

I should further like to make the claim that bigness itself has some positive rewards. The rapport between scientists and engineers has benefited both. The essential contributions made by the engineers have been repaid by their opportunity for increased understanding and appreciation of science and of its values.

In a different plane, the large accelerator centers have brought about close cooperation between physicists from many institutions. They live and work together for a

time, sharing their ideas and inspirations. Distillations of their thoughts are rapidly available to all. Their motion back and forth between the various institutions imparts a broadening and a vigor that helps science as a whole.

These benefits transcend even national boundaries. The great CERN Laboratory in Geneva, created through the need for bigness, has reaped rewards far beyond its immediate scientific goals. Its unity of purpose and close cooperation have helped to draw together many lands.

The spirit of cooperation has even bridged the oceans. The CPS at CERN and AGS at Brookhaven have brought about, and profited from, the very close relations between these institutions. Indeed, they have been almost sister projects. Similar relationships exist in many other cases. Scores of people in this room count among their very closest friends their fellow workers from across the sea.

Less close but very real relationships have been established with our colleagues from the Soviet Union.



Original target area for the AGS, shown here filled with concrete shielding blocks, focusing magnets, and experimental equipment, now has ample additional space for experiments in area behind the walls to the right and in the right rear.

Information and visits have been increasingly exchanged. Possible cooperation has been informally discussed. One hopes that these relationships can help toward the understanding needed to ease the problems of the world.

To sum it up, the bigness of the programs, though presenting problems, has also brought rewards. Despite the doubts of many, phenomenal progress has been made toward ultimate understanding in the most fundamental science of them all. Many of our greatest minds have been given maximum opportunity to exercise their fullest scope. We can view results with quiet satisfaction.

NOW, what about the future? At Stanford University a parallel development will hopefully result in an electron linear accelerator in this general energy range. Its fate lies with the Congress. Within the Soviet Union, designs are underway for an alternating synchrotron of some 70 Bev. Each will help extend the field.

But the end is not in sight. The great success of the alternating-gradient synchrotrons has shown that their principle can be extended almost indefinitely. In contrast to all previous circular devices, higher-energy machines can be devised by increasing only the circumference. Indeed, by injecting sufficiently energetic particles, the cross section of the magnet can even be decreased. Physicists are talking of machines of many

hundred billion volts. The injector would be an AGS or linear accelerator, itself delivering ten Bev or more.

The all-out proposer of today might sing:

It will cost a billion dollars
A trillion volts 'twill give
It will take three hundred scholars
'Leven years to make it live
This machine is just a model . . .

But why go on?

One could wish that the suggested costs are as grossly overestimated as those of long ago; but I fear it is not so. Even much more modest machines will require such huge outlays of money and manpower as to require concerted, all-out efforts on a national or even on an international scale. Effective resolution of the many problems raised is an important task for all of us.

I have wandered far astray from the purpose of this meeting. We are gathered here today in recognition of a recent great achievement; to dedicate the AGS. Its success will always be remembered as a bright landmark in progress in this field.

We are really here to honor the group of imaginative, skilled, and devoted men and women who brought about this triumph. Theirs is a fine achievement. In their honor I dedicate this alternating-gradient synchrotron to the world community of science.