

RESEARCH FACILITIES AND PROGRAMS

Particle physics

"In 1961 the federal government spent \$87 million for research, construction, and equipment in the field of high-energy physics. In the current fiscal year, government expenditures for high-energy physics are estimated to total \$173 million. Studies have indicated that by 1975 the federal government may be spending nearly one-half billion dollars per year to support this program. The burden, therefore, rests with the scientists in this field to communicate to the Congress and the public, the objectives, the needs, and the social benefits of high-energy physics research."

The speaker was Congressman Melvin Price of Illinois, chairman of the Subcommittee on Research, Development, and Radiation of the Joint Congressional Committee on Atomic Energy; the occasion, the opening of public hearings on high-energy physics early in March. A select gathering of some three dozen scientists, including several Nobel laureates, science administrators and advisers, and specialists in particle-physics research, had been called to explain to Congress and the public why it is important to spend some hundreds of millions of federal dollars annually for bigger and more intense multi-BeV probes to deal with the exceedingly small distances involved in exploring the nature of subnuclear particles.

"Scientists should not forget," Congressman Price warned, "that if society pays for the research, there must be adequate repayment to society. This can take the form of increased national security or economic well being, as well as other national or international benefits. . . . I cannot emphasize too strongly that since your support depends on public funds, the public must be able to understand the purpose of high-energy physics research and the reasons why expensive tools are required in this research."

During the ensuing four days of well-organized testimony, the history, status, and objectives of particle physics were thoroughly reviewed and ex-

planations were offered of its significance as a frontier science devoted to understanding the most fundamental problems in physics. Discussions of the possible benefits to society of research in particle physics were generally concerned with long-range effects. W.K.H. Panofsky of Stanford went perhaps further than most in declaring that all other physical sciences, and probably all life sciences as well, must ultimately rest on the findings of elementary-particle physics. It would violate our past experience in the progress of science, he suggested, to find that nature had created a family of phenomena to govern the behavior of elementary particles without at the same time establishing any links between these phenomena and the large-scale world which is built from those very particles. In another vein, there was the unsettling conjecture by Luke C. L. Yuan of Brookhaven, who speculated that if quarks (the postulated but as yet undiscovered heavy triplets) should turn out to be stable, then both charged quarks and antiquarks might "easily" be separately stored and then brought together to annihilate with an energy release of the order of 20 BeV, about a thousand times greater than in the thermonuclear conversion of hydrogen to helium. In terms of more immediate practical dividends from the field of particle physics, references were made to various byproducts of accelerator technology, including high-power transmitting tubes, better vacuum pumps, improved electronics systems, and on-line computing techniques. It was also argued (by Panofsky) that high-energy physics has produced more well-trained students at the doctorate level than it has absorbed, and thus has been a net producer of such talent for industry, education, and government.

The fear that particle physics may receive more support than it deserves was expressed by two of those who made statements at the hearings. Eugene Wigner did not doubt that high-energy phenomena are worth explor-

ing or that they should and will be explored. "If there is a question in my mind," he said, "it concerns the rate of exploration, that is, whether or not the proposed rate is so fast that it entails a less effective use of the expenditures and scientific manpower than could be attained in other areas. If that should be the case, progress in other areas, which are also important because of their interactions with our general body of knowledge, or because of their practical or defense applications, would be unnecessarily hampered." Philip H. Abelson, director of the Carnegie Institution's Geophysical Laboratory and editor of *Science*, said that an improved method of allocating the nation's research resources more effectively can be arrived at "through application of intelligence." To illustrate, he stated that he had compared the relative merits of high-energy physics, materials science, unmanned space exploration, and molecular biology by employing a rating scale ranging from 0 (for none) to 5 (for very important). He found that high-energy physics trails the other three fields, even though he rated it very important to practitioners, significant to scientists in other fields, very important in its intellectual values, of significant interest to nonscientists, and important for international prestige. He found, however, that high-energy physics makes only moderate contributions to defense, slight contributions to health, and no contributions at all to the international trade balance of payments or to such needs of society as energy, food, clothing, shelter, or transportation. "For reasons of its importance to science and because of philosophical values," he concluded, "high-energy physics should be supported. However, the highest priorities should be assigned elsewhere."

Nobel laureate Edwin M. McMillan suggested that particle physics should not be considered as a new and isolated field of inquiry but rather as the latest chapter in the ancient

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search for an understanding of the ultimate forces and structures of the universe—a search that has been and continues to be the spearhead of all science. For particle physics to continue its exploration of the far frontier, he said, the step to the next energy range must be taken; otherwise, we will eliminate the frontier and kill the field, or badly cripple it. Failure to proceed to higher energy, in McMillan's view, would have these long-range results:

1. The discouragement of advances in particle physics would put boundaries around the central search for knowledge for the first time in United States history. We would lock the door on future discoveries at the heart of matter.

2. The vitality and dynamism that have characterized American science in the last thirty years would be adversely affected. The long-range feedback from this kind of frontier research will cease. The other sciences have much to explore. There is much to do in expanding understanding of the phenomena at the nuclear, atomic, and molecular level. But the important facts will gradually become known, and the present sciences would grow increasingly technological. There will be no prospect of going deeper; of understanding phenomena in fundamental terms, unless we get our feedback from Europe or Russia. There is also an intangible factor in this effect on American science. Even though he may not have a present awareness of its significance, every good scientist must be affected by the knowledge that someone is asking the ultimate questions of nature. We have never had a closed horizon in science in this country. We cannot measure the potential effect of the elimination of the horizon, but I am convinced it will be important.

3. The impact on technology is potentially disastrous. We cannot predict what, if any, new technologies may arise from particle physics, but we can look at the past and the present to see how our present technology has derived from the basic research of the past.

4. Closing the horizon would affect American prestige. Particle physics is a field in which the United States has had a clear world leadership. For thirty-five years this country has attracted some of the world's best scientists through its strength in the search for an understanding of matter, and this immigration has greatly strengthened American science and education.

5. Europe presently has under study a machine of 300 BeV. Russia is building an accelerator of 70 BeV. In view of these projects American leadership could not be expected to continue. We might expect an exodus of some of our best brains to Europe.

6. American science might be expected to return, over a period of time, to the secondary position it occupied until the late 1920's, when a vigorous broadly based American science began to develop. Until that time, the United States relied primarily on Europe for new knowledge from the frontiers of science. In today's world, when scientific discoveries are sometimes quickly translated into technology, this could have tragic consequences.

McMillan's views concerning the urgency of the situation are widely shared. Just two years ago, the report of the Panel on High-Energy Accelerator Physics of the President's Science Advisory Committee and the AEC's General Advisory Committee, under the chairmanship of Norman Ramsey, listed as its foremost recommendation that the construction of a proton accelerator with an energy of approximately 200 BeV be authorized "at the earliest possible date." The Ramsey report further recommended that intensive design studies be conducted for an accelerator in the range of 600 to 1000 BeV. Design studies for both machines have been in progress, and specifications for the 200-BeV accelerator are expected to be submitted to the AEC early this summer by the Lawrence Radiation Laboratory, where a preliminary study was carried out. Edward J. Lofgren of LRL, at the time of the hearings, estimated that the accelerator could be turned on six years after its authorization and that its experimental program could be started in the following year. Thus, if authorization were given in the fiscal year 1968, the machine could be placed in operation in fiscal 1974, fourteen years after the completion of the 33-BeV alternating gradient synchrotron at Brookhaven.

The lead time required for the 600- to 1000-BeV machine would be appreciably longer. The design study is currently being carried out at Brookhaven in the expectation that the accelerator can be authorized for construction in fiscal 1971 and placed in full operation in fiscal 1980.

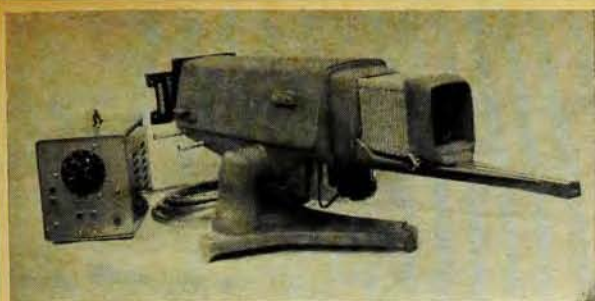
The costs of construction alone have been estimated at \$240 million for the 200-BeV machine and \$800 million for the larger accelerator. During last year's AEC authorization hearings, the Joint Congressional Committee on Atomic Energy took note of the rapid

rise in the Commission's expenditures for high-energy physics and went on record as saying that it did not feel that it should approve, or participate in setting the stage for, such massive increases in spending without a clearly defined national policy on high-energy physics research. At the specific request of the Joint Committee, the AEC then tackled the problem of formulating a long-range policy statement.

The resulting document, which coincides closely with the recommendations contained in the 1963 Ramsey report, was reviewed in draft form by the Commission's General Advisory Committee, the President's Science Advisory Committee, and the Technical Committee on High-Energy Physics of the Federal Council of Science and Technology. The final report, entitled "Policy for National Action in the Field of High-Energy Physics," was sent to the Joint Congressional Committee late in January. It was promptly published, together with other pertinent material, as a Joint Committee print* and thus was available for distribution and discussion at the time of the high-energy physics hearings in March. In addition to the AEC's new policy report, the publication contains the texts of the Bacher Panel report of 1954, the Haworth Panel reports of 1956 and 1958, the Piore Panel reports of 1958 and 1960, and the Ramsey Panel report of 1963. It also includes a 1964 letter to the Joint Committee in which Donald F. Hornig, director of the Office of Science and Technology, stated his views concerning the formulation of a long-range policy.

In discussing future needs in particle-physics research, the Commission's statement of policy singles out proton energy as being the most important parameter to be extended, and much of the report is devoted to a review of questions that can be answered only by going to higher accelerating energies than are provided

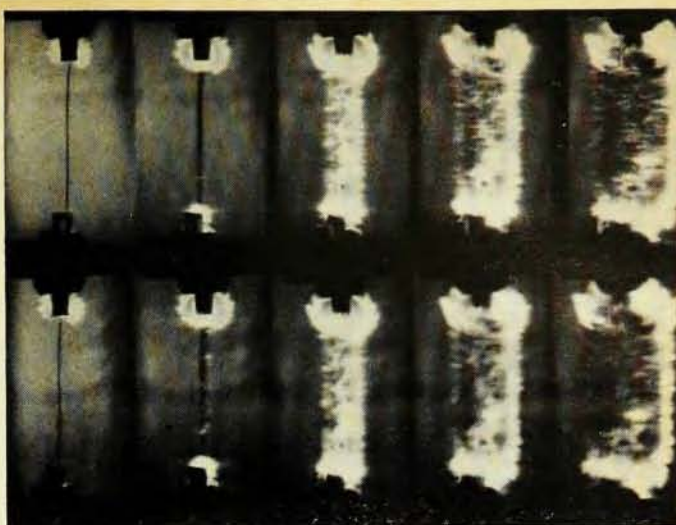
**High Energy Physics Program: Report on National Policy and Background Information.* Joint Committee on Atomic Energy, February 1965, 175 pp. For sale by the Superintendent of Documents, US Government Printing Office, Washington, D. C. 20402. Price, 55¢



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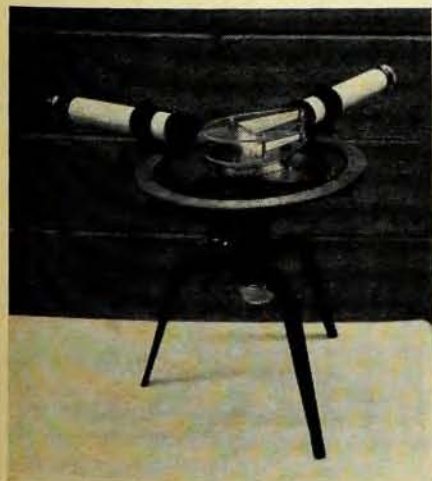
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by the 30-BeV machines at Brookhaven and CERN. Strong-interaction probabilities, the report emphasizes, vary rather slowly with proton energy, and there is only a slow rise in the energy available for secondary-particle production (and in the energy of the secondary particles themselves) as the primary proton energy is increased. The Commission thus feels that accelerator energies must be extended substantially beyond even the 70 BeV expected from the Soviet accelerator at Serpukhov, which is now under construction and is expected to be in operation next year. In addition, the report stressed the importance of extremely high proton intensity in accelerators operating in the energy region from 10 to 30 BeV. First of all, the report said, such high-intensity machines will make available neutrino, muon, and strange-particle beams of considerably higher intensity than ever before. Second, the higher intensity will support more experiments running in parallel and sharing the intensity of each machine pulse.

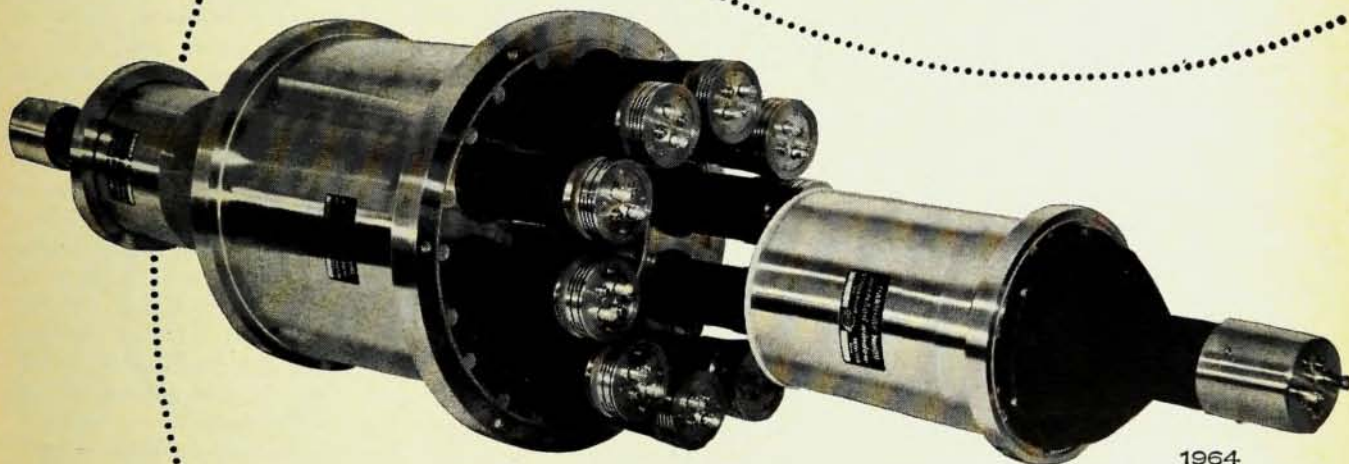
In summary, the following specific long-range plans were spelled out in the Commission's report:

1. Construction of a high-energy proton accelerator of approximately 200 BeV, in accordance with technical specifications developed by Lawrence Radiation Laboratory, to be operated as a national facility. This machine should be authorized for design in fiscal 1967, and for construction in fiscal 1968.
2. Conversion of the Brookhaven AGS to a high-intensity facility. Phase I of this conversion should be authorized for design in fiscal year 1966; and for construction in fiscal year 1967.
3. Upgrading of the Argonne ZGS by an improvements program which will include a new experimental area, a large bubble chamber, and a higher-energy injector. The large bubble chamber and experimental area should be authorized in fiscal year 1966. The high-energy injector should be authorized in fiscal year 1967.
4. Construction of a high-energy electron-positron storage-ring facility as an adjunct to the Stanford Linear Accelerator. This should be authorized in fiscal year 1967.
5. Support of the study of new accelerator principles and techniques. In particular, support should be provided for intensive design studies aimed primarily toward a future na-

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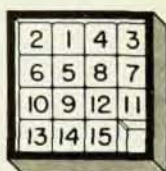
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tional accelerator in the range of 600 to 1000 BeV. Support and encouragement should be given to these studies for the pursuit of new ideas which could lead to a more capable and efficient machine at lower cost. It is anticipated that these studies would lead to a request for authorization of construction in fiscal year 1971 of a 600- to 1000-BeV-class proton accelerator which would be available for experimentation in fiscal year 1980. Consideration of high-energy storage rings for possible future addition should be included in these design studies.

6. Support for the development and utilization of new and improved techniques and methods of particle detection and data reduction and analysis, including the strong need for advanced computational facilities.
7. Continued and increased support of the productive accelerators at present in operation or under construction and their associated research programs, without neglecting the need for new facilities. This includes taking steps to increase their scientific value and productivity where needed to maintain a sound scientific program. It also includes recognition of the special need for substantial operating and research budgets for the newest accelerator laboratories before they come into full operation.
8. Construction of large bubble chambers and other accelerator-associated facilities when justifiable needs arise. It is anticipated that two to three large hydrogen bubble chambers should be started within the next 1 to 3 years.
9. Increased support of university high-energy user groups including buildings, major equipment, and particularly data-handling and analysis facilities. The user group concept has proven to be both feasible and highly productive and is essential to the future of the national program.
10. Close down or reduce the level of operation of those accelerators which become relatively unproductive. The prime considerations involved in continuing an accelerator program are its scientific significance, and the capacity of the associated research group to carry out a worthwhile and significant program. Additional factors, such as the educational function served by the accelerator and its use in preparing experiments for more costly facilities, are also important considerations in assessing the value of a machine.
11. Provide for an overall review and reassessment of the high-energy physics programs at suitable intervals.

Whether or not the time schedules called for by the Commission can be

met will depend upon many factors, one of which will be the rate of increase of appropriations approved by Congress for the support of particle-physics research. The AEC now supports about ninety percent of the costs of such research in the United States. Since 1960, the total annual budget of the AEC has remained relatively constant, but in the same period the amount spent annually on high-energy physics has tripled, and the current level of spending is expected to double in the next five years. According to AEC estimates, annual expenditures for the proposed program would reach a peak of \$490 million in 1978, three times as much as in 1965.

In its statement of policy, the Commission emphasized that it is in the national interest to support vigorous advancement of high-energy physics as a fundamental field of science, but that the research should be carried out under a national program not related solely to the mission of any one agency. The report held that the AEC's role as executive agent is appropriate, but stated that participation by the National Science Foundation and other agencies of the government is important for the maintenance of a truly national program. It added: "The level and character of support for high-energy physics should be determined and periodically reassessed in the context of the overall national science program (rather than in relation to the applied research and development programs of the AEC), advances and promises of advances in the field itself, and the then existing fiscal situation."

No precise limits have been set to govern the ratio of an agency's basic research expenditures to the costs of its mission-related research and development programs. The rapid growth of high-energy research as an item in the AEC budget, however, has thoroughly upset tradition and this has been a cause for concern both in the Administration and in Congress. The result has been a penetrating re-examination of science policy that has added strength to the arguments for expanding the role of the National Science Foundation in supporting basic research in the sciences, which is a vital part of its primary mission.