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SUPPORT OF RESEARCH ON AND WITH ACCELERATORS

by
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Ever since Cockcroft and Walton accelerated protons to a few hundred KeV over 40 years ago at the Cavendish Laboratory, particle accelerators have been one of the most important tools in nuclear science. Before this time nuclear physicists had only two sources of fast nuclear particles, naturally-occurring alpha emitters and cosmic radiation. Both of these are very limited in intensity and adaptability for experiments, and the need for laboratory-accelerated particles of controllable energy, intensity, and direction was clearly evident even in the 1920's. Certainly, today, little progress could be made in the fundamental fields of nuclear and particle physics without the particle accelerator.

In the intervening years since that first particle accelerator, the diversity, size and complexity of accelerators has grown steadily. The energy frontier has been extended by a full six orders of magnitude to 400 GeV at NAL and the intensity has been extended even more. The cost of accelerator facilities and the number of scientists and engineers involved in the development and use has grown also. Thus, the financial support of research on and with accelerators has become an item of interest in the national budgets of many countries. The intent of this talk is to examine some aspects of that funding in the United States.

The principal justification for the support of accelerator facilities continues to be the conduct of basic research in nuclear science. As is true with any truly basic research, progress in the field requires continually pushing investigative techniques beyond the current state-of-the-art. This, of course, also tends to lead to technological "spin-off," some of which is being discussed at this Conference.

There is a natural relation between the research done with the accelerator facilities, and the research and development activity done on the accelerator facilities. Construction of a new facility typically is followed by exploration of a virgin research frontier. Later research maps the new region more systematically and with greater accuracy and detail. This research usually uncovers areas which cannot be penetrated with available experimental capabilities and points to new capabilities needed to explore these areas. The accelerator and device R&D which has been going on simultaneously with the physics research indicates where the technology frontier can be pushed to obtain the required new capabilities, either by improvements to the existing facilities or by construction of a new facility. It is this kind of growth and natural rhythm that gives the field its vitality and its continued progress.

Support for the development of accelerators and their operation for research is being provided predominantly by the Federal Government. The primary sources of support for this type of effort in the U.S. are the AEC and the NSF. Other substantial sources of support include the NBS, DOD, and NASA. Non-federal support includes a significant university contribution to the support of research done with the accelerators, and a small but real contribution to accelerator development by industry.

Biological and medical applications also have provided impetus for accelerator use. The interactions of accelerated particles with tissue have been of interest to both basic biologists and to clinical physicians. The production of radionuclides has been extremely useful to medicine and to other scientific fields. Recently, interest has been increasing in potential bio-medical uses of particle accelerators; including research on, and possibilities for, cancer therapy. Some support for such studies has been coming from the AEC's Division of Biomedical and Environmental Research, NASA, NSF, and NIH.

The synchrotron radiation from high energy circular electron accelerators and storage rings provides a unique source of well-collimated, intense, polarized photon beams in the far-ultraviolet/x-ray region which are not otherwise available. These are of substantial and increasing interest for materials research, and also biochemical, astrophysics and medical research.

Table I indicates the magnitude of the federal support for research on and with accelerators for FY 1973. The figures include accelerator and facility R&D, construction, equipment, the experimental physics research done using the accelerators and also the theoretical research which complements this experimental research. Facilities which are primarily for medical, educational, materials testing, or other non-research uses are not included.

Table I

Support of Research on and With Accelerators FY 1973

AEC	$254M
NSF	$ 28M
Other (NBS, DOD, NASA, NIH)	$ 10M

The work supported by other agencies would be classified largely as low energy, bio-med and materials research, roughly in the ratio of 6:3:1, respectively. Table II examines the support structure by program for the AEC and the NSF. Within each program construction funding is indicated separately from the operating and equipment. Both FY 1973 and FY 1974 numbers are indicated. The FY 1973 numbers are estimates based on the present funding. The FY 1974 numbers are estimates based on the FY 1974 budget request to Congress.

Table II

Support of Research on and With Accelerators
FY 1973 & FY 1974 - AEC & NSF

	FY 1973 AEC	FY 1973 NSF	FY 1974 AEC	FY 1974 NSF
High Energy Physics				
Operating and Equip	$148M	$14M	$149M	$14.5M
Construction	45		14	
Medium Energy Physics				
Operating and Equip	19	4	20	4
Construction	2		0.5	
Low Energy Physics				
Operating and Equip	25	7.5	25	8
Construction	0.5		0.5	
Chemistry				
Operating and Equip	7		8	
Other				
Operating and Equip	4.5	2	5.5	2
Construction	2.5			

The High Energy Physics and Medium Energy Physics Programs are almost 100% accelerator related and the numbers in the table represent essentially the full funding for these programs. Low Energy Physics is about two-thirds accelerator oriented. The other programs have a much smaller proportion of their program accelerator oriented. The "other" programs shown in Table II refer to biomedical and materials research.

The AEC Division of Physical Research has four program offices: High Energy Physics, Physics and Mathematics (Low Energy, Medium Energy, Mathematics), Chemistry, and Metallurgy and Materials. Research in Controlled Thermonuclear Reactions, formerly in the division, is now a separate division. The Division of Physical Research, in a sense, serves as an interface between the scientific community and the remainder of the Federal Government. The Division staff, primarily professional scientists, evaluate the research programs being undertaken or proposed, prepare funding requests to AEC management, the OMB and Congress, and then help administer the funds which become available. Since we inevitably fail to obtain as much funding for the programs as either you or we would like, there are always interesting problems with which to contend.

My special interest is High Energy Physics, which is defined somewhat arbitrarily as research with accelerators over 1 GeV, and thereby includes a very large range of energies. In the U.S., there are, as of FY 1974, six high energy accelerators. Some feeling of the range in energy covered by these machines can be obtained by looking at Figure I which shows the relative physical sizes of the five AEC supported machines which range from 38 meters diameter for the Bevatron, through 2000 meters diameter for the NAL, to 3050 meters (or two miles) length for the SLAC linac.

It may be of interest to look at some trends and breakdowns in funding over the past ten years, including the funding for this year, and that requested for next year. The distributions shown are just for the AEC supported High Energy Physics Program.

Figure 2 shows this funding, in terms of constant value dollars, for the period from FY 1963 to FY 1974. The operating funding is in terms of annual costs and represents the funding for accelerator and device R&D, accelerator and facility operations, and theoretical and experimental high energy physics research. The construction, accelerator improvement (AIP) and equipment categories are in terms of annual obligations, where construction includes accelerator laboratories such as the NAL, major modifications such as the AGS Conversion, buildings, etc.; AIP is for accelerator improvements which are required by each laboratory on an annual basis to keep the facility viable and up-to-date, and equipment is for items costing over $100, having a separate existence, and a projected lifetime of over one year in an essentially unaltered form. It is interesting to note that the total funding for the program (in terms of constant value dollars) has been essentially flat over this twelve-year period.

Figure 3 looks by program element at the operating funding indicated in the last figure. This graph gives some indication of the changing character of the program with time. The vertical lines across a program element indicate the time of first beam for that accelerator. It can be seen that there are four accelerators that obtained their first full energy beam during this time period, plus one (CEA) just outside the time period: and four accelerators that have been or will be shut down during this period. (The fourth accelerator shutdown, which is not indicated on the graph, was the Cal Tech 1.5 GeV electron synchrotron which was shut down in FY 1970.) The shutdown accelerators were, in general, much smaller than the new facilities.

It is of interest also to break the program funding down in other ways. Figure 4 shows the total funding broken down into (1) funding for accelerator utilization; i.e., funding for research with the accelerators, for their operation and for equipment for experiments; and (2) funding for the provision of accelerator facilities; i.e., funding for accelerator and facility R&D costs, funds for equipment for R&D, for provision of experimental facilities, accelerator improvement funds, and construction funds. The graph gives a fairly good picture of the relative sizes of the two categories and of trends.

The fluctuation in construction funds from year to year causes significant fluctuations in the overall funding. An examination of operating funds only, which do not have these large year-to-year fluctuations, may be helpful. Figure 5 shows (1) the trend in funding for accelerator and facility R&D, (2) the trend in funding for operation and physics research, and (3) the trend for the total operating funds. R&D funding has remained approximately one-sixth of the total. Figure 6, which indicates R&D funding as a percentage of the total operating funding, shows this more clearly. The projected decrease in this fraction for FY 1974 represents an attempt to place somewhat higher priority on utilization of the existing and new facilities next year.

It is particularly worth noting here that, in spite of the restricted budget climate, the field of research on and with accelerators, is still funded at a very substantial dollar level which permits the continuation of programs of major worldwide significance. It is of interest to consider briefly some of

the impressive new capabilities which are just becoming available in the U.S. accelerator field.

1. NAL -- First 200 GeV beam was obtained just a year ago. 400 GeV has since been achieved and plans are to operate routinely at 300 GeV. Already over 10^{12} protons per pulse has been achieved.

2. LAMPF achieved its first 800 MeV beam last summer, making it the world's largest proton linear accelerator.

3. The BNL AGS which has been in operation for over ten years has just been completely rebuilt to a higher intensity and greater experimental capability. At present, this machine has the highest intensity per pulse of any proton synchrotron, having achieved 7×10^{12} ppp.

The construction costs associated with these three projects are over $350,000,000.

Several projects, smaller by comparison with these just mentioned, are also proceeding well.

1. LBL - Heavy Ions.

   a. The heavy ion linear accelerator, now called the Superhilac, has just been completely rebuilt to yield high intensity beams of any ion up to uranium at about 8 MeV per nucleon.

   b. The Bevatron has had marked success in accelerating heavy ions up to neon to about 2.5 GeV/nucleon.

   c. A project is funded and underway to connect the Superhilac to the Bevatron by a long beam pipe so that the Superhilac can serve as an injector to the Bevatron. The resultant Bevalac will yield 2.5 GeV/nucleon heavy ion beams up to iron.

2. At MIT, the new 400 MeV electron linac has already operated at 125 MeV, and will have the highest duty cycle available among research electron linacs.

3. At Cornell, the electron synchrotron energy has been increased from 10 to 12.5 GeV together with a substantial increase in experimental area.

4. A new titanium vacuum tank has been successfully, and most efficiently, inserted into the ZGS.

5. The SPEAR colliding beams device at SLAC has come into operation during the past year and is now ready to begin experiments. At a luminosity of $1.3 \times 10^{31}/cm^2$ sec and 2.7 x 2.7 GeV, it has achieved the highest luminosity of any storage ring in the world.

Looking more to the future, there are active R&D programs in accelerator research aimed at extensions of capabilities in several areas. There are two projects in particular which are well advanced in design and which are prepared to seek construction funding. At SLAC, the Recirculating Linear Accelerator (RLA) is proposed as an economical method of approximately doubling the energy of SLAC and increasing the duty cycle at the present energy by a factor of over 100. There is also much interest in further extension of capabilities in heavy ion acceleration. Several proposals have been submitted to the AEC for a national heavy ion facility which would have the capability of accelerating any ion species to 10 MeV/nucleon.

Strong interest continues to grow in reaching higher energies for the study of particle physics. It is possible that NAL could reach an energy close to 1000 GeV with the installation of an "energy doubler" which is currently being studied, or that CERN II could do the same with superconducting magnets. However, even with the use of superconducting technology, it does not seem likely that it will be economically feasible to build a synchrotron in the tens of TeV range in the foreseeable future. Thus, the realization of very high center-of-mass energies will probably come through colliding beam devices. Two major studies for such devices are being pursued in this country. At BNL, the study called ISABELLE (Intersecting Storage Accelerator) is considering the design for 200 GeV on 200 GeV protons where the protons would be injected from the AGS into two superconducting rings, then accelerated in these rings to 200 GeV and then permitted to collide with each other. On the West Coast, a joint study by SLAC and LBL called PEP (Positron-Electron-Proton) has a different approach. There, a single ring would store beams of electrons and positrons at 15 GeV which could be used in the manner of SPEAR. However, there would also be a superconducting ring storing protons at about 160 GeV and these would be made to collide with either the electrons or positrons.

I would like to be able to give specific timetables for proceeding with these new projects. However, since even the FY 1974 budget is still tentative, I can only give some very general indications. The Atomic Energy Commission certainly intends to maintain its support of a vigorous program of research on and with accelerators, and the importance of new facilities to the continued viability of the program is recognized. Although there appears to be little real prospect for major changes in total support levels, I personally have high expectations that the next decade will include work on major new facilities, such as high energy colliding beams.

It is most difficult to make projections into the future; however, the overall outlook appears bright. A number of new areas of research are ripe for exploitation with the new facilities which have recently come into operation. These new opportunities portend a vigorous decade ahead - perhaps with more restrictive boundary conditions than in recent years - but nevertheless exciting for research both in basic physics and in accelerator physics and technology.

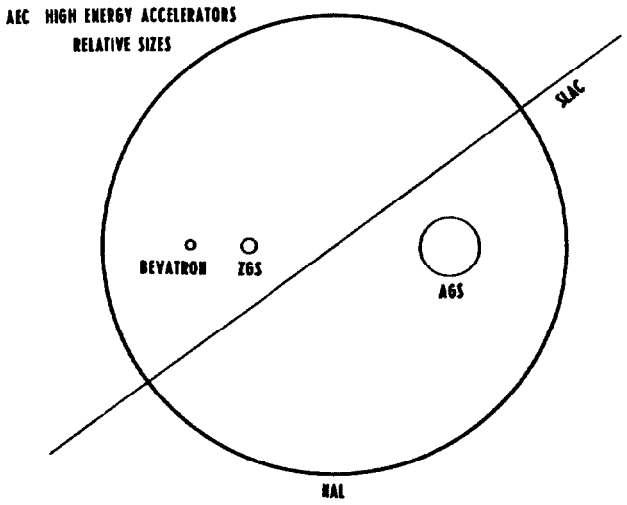


Figure 1.

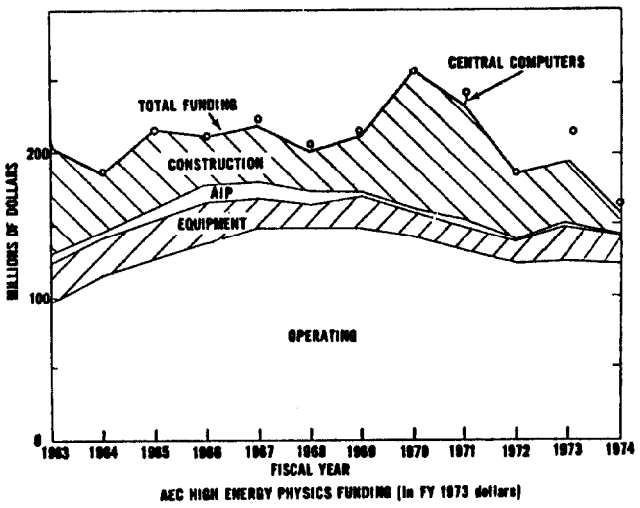


Figure 2.

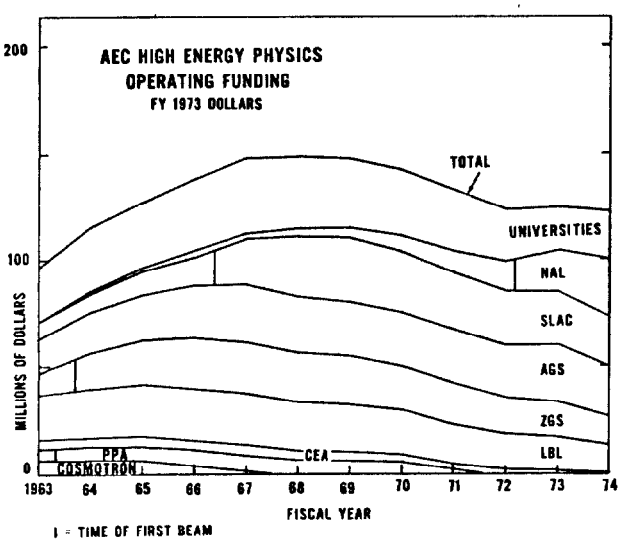


Figure 3.

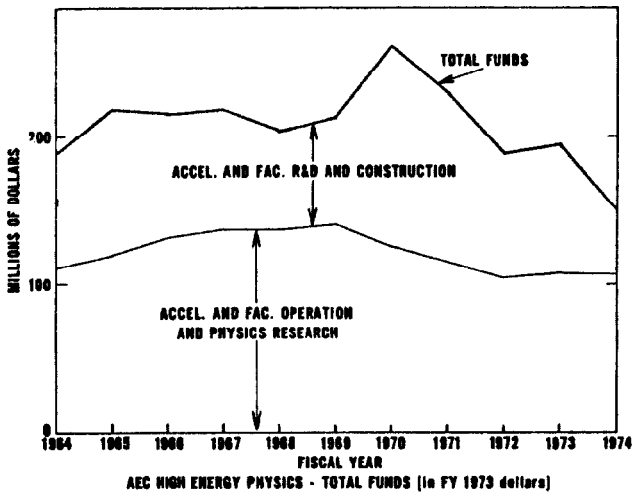


Figure 4.

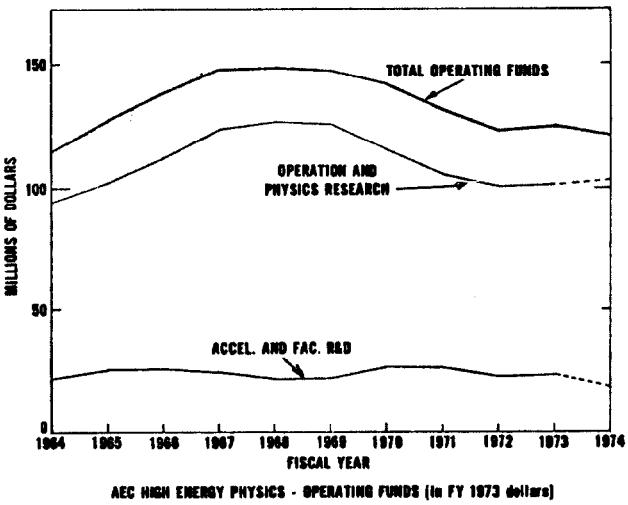


Figure 5.

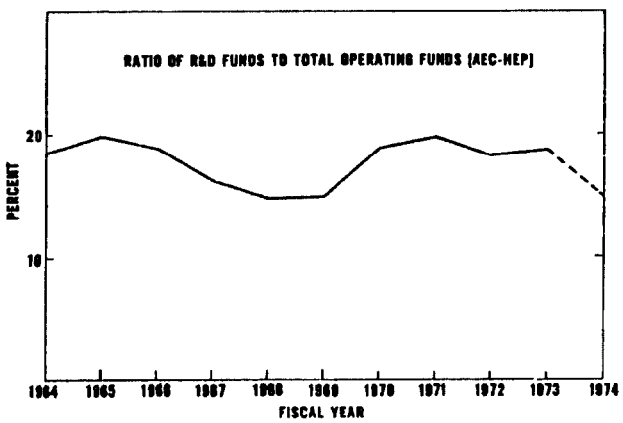


Figure 6.