MC 572
5.8
BOX 11 FOLDER 2

HEPAP Correspondence

1968-1969

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APPENDIX B

QUESTIONS RAISED ON THE DESIGN OF THE 200 BEV ACCELERATOR

1. TUNNEL

(a) Will the omission of extensive piles under the tunnel lead to excessive down time for the accelerator? Will it lead to serious inconvenience in the experimental use of the accelerator due to shift of the beam when heavy shielding is moved? Will the adjustments take too long? Are the savings from omitting the piles sufficient to justify the uncertainty as to possible future inconvenience? Is enough money allowed for the adjustment system?

(b) Is the cross-sectional area of the tunnel sufficiently large? Is there excessive reliance on the assumption that most of the radiation will be deposited in a region extending downstream from the target a few hundred feet? Will this requirement cause excessive down time? Is there sufficient room in the tunnel for safe maintenance? Has sufficient space been allowed in the tunnels for the stretched wire polygons that are required for the NAL alignment plan? In particular, is there sufficient room in the tunnel when all the needs are simultaneously met, e.g., when the stretched wire polygons are in place, test and monitoring equipment is in use, and magnets are removed under high radiation conditions? Is there room in the tunnel for a shielded car and a portable crane? Will the tunnel size force an insistence on such low levels of radioactivity that there will be excessive down time or a necessity for operating at excessively low beam intensity? Is it wise to omit overhead crane coverage? What does one do if a shielded car or crane breaks down in the tunnel?

(c) Will the omission of air conditioning in the tunnel lead to difficulties in compensating for changes in the magnet cycle? Will it lead to excessive humidity?

(d) Should there be another beam extraction area which could be activated later without the time delay and additional expense of subsequent tunnel reconstruction? Is there excessive reliance on the concept of the target areas being dominantly along a single long beam line fed from a single extraction point? Will this concept lead to excessive down time when extractors fail or when new extraction techniques are developed?

(e) Are the points of injection and extraction so close together as to interfere with each other and with possible future needed flexibility of each?

2. MAGNETS AND VACUUM CHAMBER

(a) Is there sufficient space between magnets for the magnet coils and for the vacuum and other fittings necessary to provide rapid and efficient removal of a magnet during maintenance?

(b) Is it practical to rely on feeding the magnets directly from the external power? Won't this lead to insufficient flexibility in control of the operations and in chaning the duty cycle?

(c) Would it be wiser to achieve the extendible energy by omitting half of the magnets?

(d) Is excessive reliance placed on new insulators such as alumina-epoxy to avoid radiation damage so the magnet coils can be on the mid-plane? Will injection and tune-up procedures be excessively restricted by the necessity for avoiding radiation damage and hot spots? Can the coils be sufficiently reliable?

(e) Is the radial aperture too restructed to allow for future beam gymnastics associated with targeting and beam extraction or for wandering of the beam orbit due to magnet imperfection? Is the aperture large enough for the extraction system now planned? How will spill be controlled? Is enough money allowed for beam extraction?

(f) Is it wise to combine the magnet and vacuum chamber in such a way that the failure of even a minor part of the magnet requires total replacement?

(g) Doesn't the contemplated quadrupole design throw away the advantages of four-fold symmetry gained from the separated function magnet system?

(h) Has adequate consideration been given to coherent space charge effects? Is the vacuum design adequate to avoid plasma instabilities?

(i) Is the magnet design such that the repetition rate can later be increased? Isn't the machine cycle too slow?

3. BOOSTER

(a) Is enough time and money allowed for developing this design in view of the novel problems it presents?

4. EXPERIMENTAL AND ASSEMBLY AREAS

(a) Is the experimental area sufficiently large? Has adequate space been allocated to staging areas for the assembly of the necessarily large experimental equipment? Is there adequate office and laboratory space near the experimental and assembly areas?

(b) Does the construction of the experimental areas begin early enough for an effective experimental program to be undertaken promptly on accelerator completion?

5. HIGH RISE BUILDING

(a) Is such a building wise and economical? Would a lower height be better? Will the rush hour demands require excessive expenditures on elevators?

(b) Is the high rise building too close to critical portions of the ring? Will the maintenance of adequate radiation levels restrict the accelerator operations. Will the location of the central building restrict future expansion and modification of the facilities?

(c) Are the offices and laboratories for experimental groups in that building too distant from the experimental and assembly areas?

(d) Can the high rise building be suitably and effectively expanded for future growth?

6. COSTS AND TIME SCHEDULE

(a) Are the cost estimates sufficiently conservative? With an initial design that already strongly emphasizes economy there will be less opportunity to compensate for an unexpected increase in the cost of one component by a reduction in the cost of others. Under such circumstances, should the contingency allowance be increased?

(b) Is there enough allowance for conventional materials handling equipment such as fork lift trucks, etc., which came to $0.5 M in the LRL estimate?

(c) Is adequate emphasis being placed on reliability in view of the much larger number of components than in past accelerators with the consequent requirement for greater reliability of each component? Is the budget adequate for this? Is the budget for plant and utilities too austere? Is there enough allowance for miscellaneous items such as motor generators, etc.?

(d) Is there adequate allowance for the cost of constructing or renting the temporary buildings that will be needed by the staff before the final construction is completed?

(e) Is the EDI and A allowance sufficiently large in comparison to SLAC and in view of the contemplated size of the staff? Is enough money allowed for salaries and the expenses of the necessarily large staff?

(f) Will some of the cost savings in the initial construction lead to excessive costs later, either through the need for subsequent construction or through greater costs or reduced efficiencies of operation? For example, will the omission of extensive piles markedly reduce the operating time for the accelerator; will the savings in the reduced tunnel size compensate for possible difficulties in later perhaps having to develop highly compact devices for removing magnets under radiation conditions; and will the subsequent costs and time delays for adding an additional extracted beam area be so great if such an area should be needed that provision should be made now in the tunnel construction for the possible activation of such an area in the future?

(g) Are the cost figures reasonable when compared in detail with those of the LRL study? Are they reasonable in comparison to Brookhaven experience? Can the differences be understood?

(h) Is there adequate allowance for moveable shielding or does this come from separate funding?

(i) Is there enough budget flexibility to be able to respond to detailed studies of orbit dynamics, error analysis, beam extraction, magnet imperfections, etc.?

(j) Is the schedule realistic? Can staff be hired sufficiently rapidly? Is a sufficiently large staff being planned? Can designs be reliably frozen sufficiently early to obligate money so heavily in FY 1969 particularly in view of the necessity for a series of prototypes for many of the components? Are the schedules reasonable in comparison with those achieved at SLAC and Brookhaven? Is allowance made for special procurement difficulties at the present time?

(k) Would it be better to seek construction funds one year later so that more time could be devoted to the design before the Schedule 44's and final proposal are submitted?

7. GENERAL

(a) Is the engineering sufficiently sophisticated? Is sufficient allowance made in the cost estimate for the results of more detailed and sophisticated engineering in subsequent months and years?

(b) Have the interactions between different design decisions been adequately considered? For example, is the selected cross section of the tunnel sufficiently large for the planned alignment procedure with stretched-wire polygons?

(c) Would it be better to spend the money for the 400 BeV option in some other way such as additional experimental area? Should the ultimate energy be expressed as 300 GeV or higher so as to be able to modify the design if unexpected costs arise?

(d) Should the planned initial energy be above 200 BeV?

(e) Will there be sufficient pre-construction accelerator R and D funds? Will there be an adequate operating and capital equipment budget during the construction period so that the accelerator may be effectively utilized when the construction is completed?

(f) Can the wording of Schedule 44 be made more general so that excessive contingency money can be used for other items such as experimental areas? ?

APPENDIX A

The following were sent copies of the Schedule 44 and were invited to the meeting October 8, 1967. Those who attended are indicated with an asterisk (*).

Dr. J. Blewett*
Dr. T. Collins
Dr. R. Cool
Dr. E. Courant*
Dr. G. Danby*
Dr. S. Devons*
Dr. W. Fowler*
Dr. K. Green*
Dr. G. Lambertson*
Dr. E. Lofgren*
Dr. E. McMillan*
Dr. F. Mills*
Dr. W. Panofsky
Dr. R. G. Sachs*
Mr. W. Salsig*
Dr. L. Smith*
Dr. K. Symon*
Dr. V. Weisskopf
Dr. W. Wenzel*
Dr. L. Yuan*

October 8, 1969

Professor Clifford G. Shull
Physics Department
Massachusetts Institute of Technology
13 - 2154

Dear Cliff:

Here is another of those job requests. I have not heard from you as yet in regard to the last one that I sent to you. I wonder whether you have answered that letter? Please let me know if you want me to answer such letters. I will gladly do so if I receive word from you about the matter. Meanwhile, herewith a letter from Christian Nef at CERN.

Sincerely,

Victor F. Weisskopf

Enclosure per above.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

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Memo to Viki Room Ext.

Maybe Jerry would like to see for himself the Bldg 24 & Tech Sq. layouts, so as to know what kinds of operations need homes.

Dave F.

from Room Ext.

MURAN BOSTON

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
LABORATORY FOR NUCLEAR SCIENCE
CAMBRIDGE, MASSACHUSETTS 02139
Room 26-405

12 January 1966

Dr. Rodney L. Cool
Department of Physics
Brookhaven National Laboratory
Upton, L.I., New York

Dear Rod:

Although our write-up contained a section on the physical justification for the experiment we are proposing at the BNL, we thought it might be useful for your Committee to have on hand a brief summary of the aspects of the physics we consider the most important.

The purpose of this experiment is a comprehensive study of photoproduction reactions in the 1-12 BeV range.

In general, such a study is valuable in finding new resonances and studying the energy dependence of the cross sections for their production. As in most studies of this nature, one can study production angular distributions, and polarizations as exhibited by the decay angular distributions of the resonances.

The use of photons as the bombarding particles has some unique differences from conventional beams of charged particles.

The first is that the incoming beam has a (bremsstrahlung) spectrum of energies, so that with a single exposure you are forced to explore all energies at once. From the point of view of investigating the dependence of the cross sections of various processes on the incident energy, this is an advantage in that the entire energy range is simultaneously covered with the same techniques and systematic uncertainties. Thus, resonance peaks in the cross sections, which may be small as compared to the background, are most likely to be observed in this experiment.

The incoming photon spectrum can be determined as well as desired by measuring the electron-positron pairs produced in the hydrogen.

The second feature is that, being neutral, an incoming photon on hydrogen allows the formation of two body final states where only one of the bodies is neutral. In the study of neutral resonances, this is a great advantage as it permits the analysis of the threshold behavior of neutral resonance production much more easily than with charged beams. (Negative projectiles on hydrogen require a neutral companion to be produced with a neutral resonance; positive projectiles require a doubly charged companion, or else a three-body final state.)

Since the neutral beam is not mono-energetic, one constraint on the kinematics is lost. However, as we have shown, this by no means impairs the usefulness of the experiment.

The fact that the beam is electromagnetic in character allows one to study different aspects of the processes of production of strongly interacting particles. For example, the work in the 12-inch chamber at CEA has shown that neutral-rho production is via a "diffraction" rather than a one-pion exchange process.

The use of the neutral photon allows the study of isotopic-spin-zero resonances in the simplest two-body reactions, e.g.,

$$\begin{aligned} \gamma + p \rightarrow\ & \eta^0 + p \\ & \omega^0 + p \\ & \phi^0 + p \\ & f^0 + p \\ & \text{etc.} \end{aligned}$$

In addition, since 12 BeV puts us well into the asymptotic region, we can study the asymptotic behavior of many reactions of interest. For example, the asymptotic behavior of the ρ^0-production, which we have already shown to be related to a diffraction mechanism, can be used to investigate the possible Regge behavior of vector-meson scattering.

The question is: can such a program indeed be achieved?

We have analyzed 8,000 events taken in a 12-inch chamber and the accompanying figures demonstrate that, even with so few events, meaningful results have been derived in the energy interval 1-6 BeV.

Figure 1 shows our invariant mass distribution for the $\pi^+\pi^-$ pairs in the reaction $\gamma + p \rightarrow p + \pi^+ + \pi^-$, in which the existence of appreciable $\gamma + p \rightarrow p + \rho^0$ is clearly demonstrated.

The reactions

$$\begin{aligned} \gamma + p & \rightarrow p + \eta^0 \\ & \rightarrow p + \omega^0 \end{aligned}$$

are also clearly seen in events with a $p + \pi^+ + \pi^- + \pi^0$ final state. These data are shown in Figures 2 and 3.

We enclose 1 dozen copies, which you can distribute among your Committee if you so desire. We also enclose a copy of our recent paper on ρ^0-production, now in process of publication in the Physical Review. We are sending copies of this material to Profs. Low and Weisskopf, since we feel that their experience and knowledge will be most helpful to us all in evaluating this proposal.

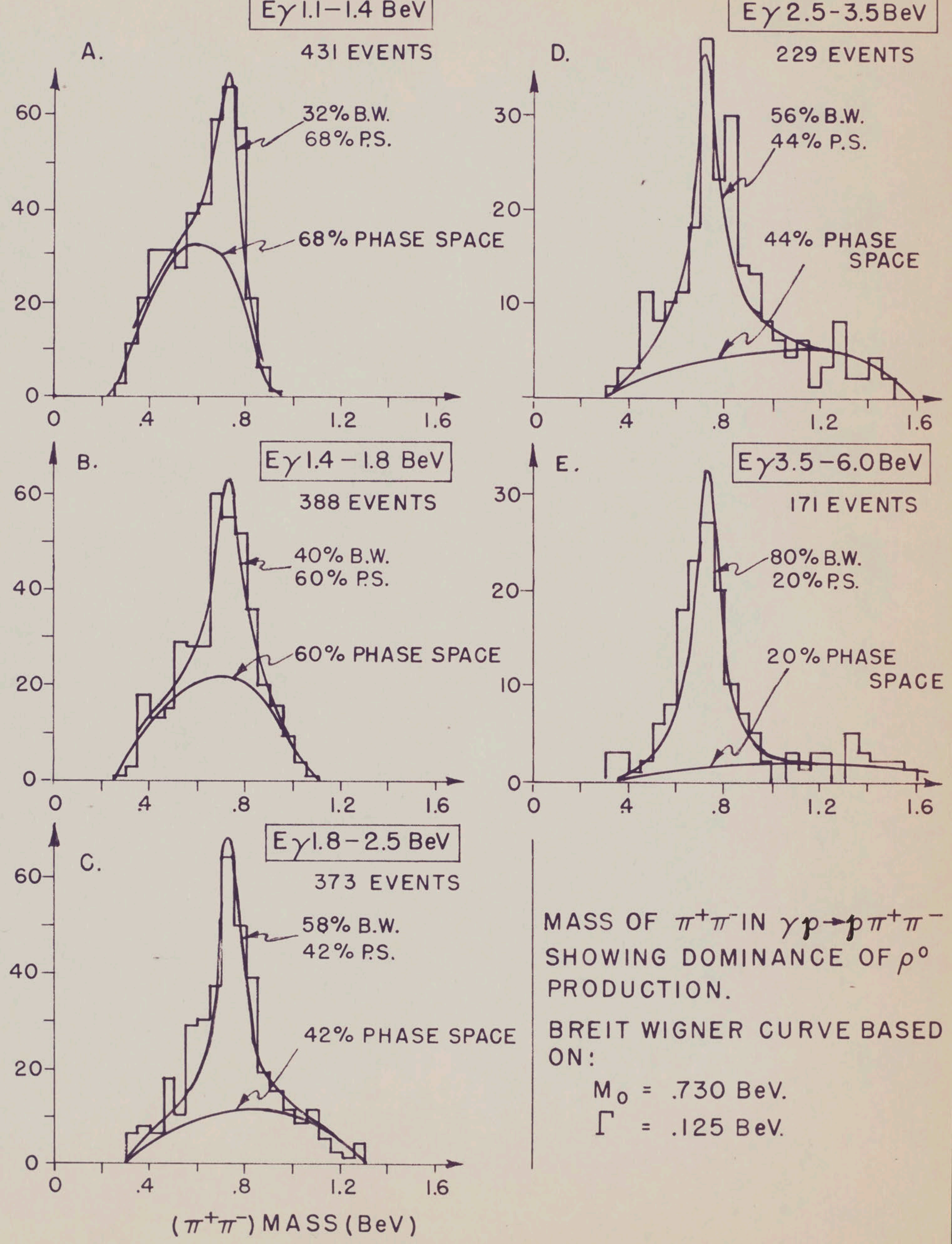
Sincerely yours,

Bernard T. Feld
Bernie

Irwin A. Pless
Irwin Pless/jz

Lawrence Rosenson
Larry Rosenson/jz

cc: F. Low
V. Weisskopf



MASS OF $\pi^+\pi^-$ IN $\gamma p \rightarrow p\pi^+\pi^-$ SHOWING DOMINANCE OF ρ^0 PRODUCTION.

BREIT WIGNER CURVE BASED ON:

M_0 = .730 BeV.

Γ = .125 BeV.

Fig. 1

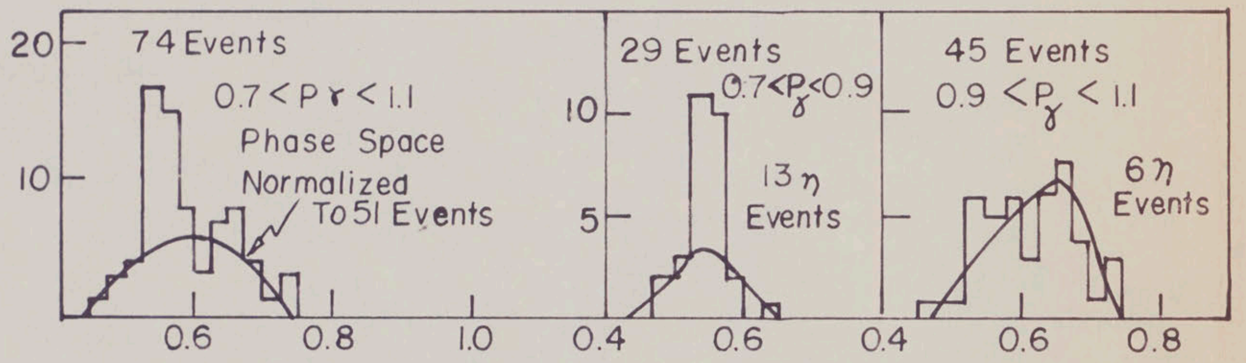


FIGURE 2

η^0 Production in $\gamma p \rightarrow p\pi^+ \pi^- \pi^0$

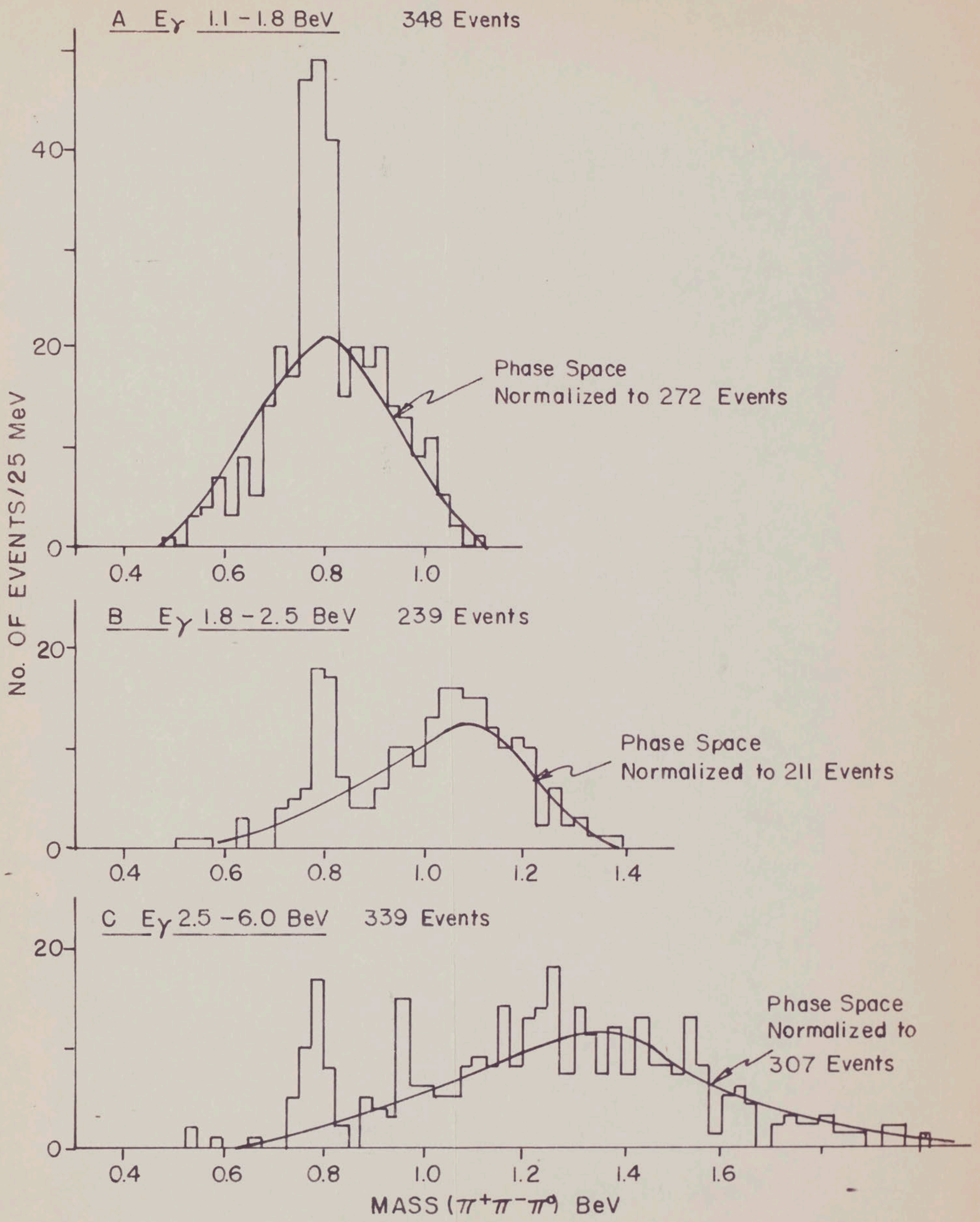


FIGURE 3

ω^0 Production in $\gamma p \longrightarrow p\pi^+\pi^- \pi^0$

STANFORD UNIVERSITY

STANFORD LINEAR ACCELERATOR CENTER

Mail Address
SLAC, P. O. Box 4349
Stanford, California 94305

January 2, 1969

Professor V. F. Weisskopf, Chairman
Department of Physics
Massachusetts Institute of Technology
Cambridge, Mass. 02139

Dear Viki:

I am including a redraft of Chapter VI and of Chapter VII. I have received comments from you and Bernie Hildebrand and these are incorporated to some extent. Bj has sent to you his section on progress "since Ramsey." I personally think this is very good and eloquent but may still need a slight amount of popularization.

The numerical and tabular material in the charts should now be accurate, thanks mainly to Hildebrand's comments, and the figure showing intensity and energies of present accelerators represents the current situation. I have been trying to react to your comments as they relate to recommendations but have succeeded only partially. I still think it is a good idea to specifically flag recommendations in the main text, even though they are repeated verbatim in the summary of recommendations. However I have not specifically identified "Conclusions" but simply preserved any conclusions as part of the general narrative.

The tables and figures have simply been put on to the end of the chapter; there may be some virtue in distributing them.

I have carefully reread Chapter VII in relation to your criticism that it has an anti-HBC bias and have tried to redress this balance conscientiously. I hope that the presentation now is a fairly balanced one among the various detection techniques giving both their pros and cons and also identifying the specialized opportunities. I have also tried to introduce a little bit more material emphasizing our present ignorance in the computer situation and flagging this as a potential problem.

I have read Earle Fowler's Chapter VIII. I have no particular disagreement with anything which he says but there simply is not very much there. As a matter of fact almost the entire material of Chapter VIII could be substituted for some of the bubble chamber material I have written in Chapter VII without very much shift in emphasis. This, however, still means that we have a big gap in terms of a critical discussion in the entire data analysis field which I hoped Chapter VIII would constitute. To fill this gap during the drafting sessions may be very difficult.

I believe you now have all the material I owe you: You have received Appendix I and I sent you a suggestion for presentation of the graphic material for the chapter on financial implications; I have also sent you comments on the poetry chapter.

I had one thought about an omission in the introductory material and that deals with the definitions of high energy physics, intermediate energy physics and low energy physics, on the one hand, and elementary particle physics and nuclear structure physics, on the other. Fundamentally we are dealing with a matrix of energy regions, on the one hand, and fields of interest on the other. This should somehow be explained because otherwise our arguments on shutdowns become very weak (as pointed out by Bernie Hildebrand), and also our graphs on the growth of high energy physics financing are harder to explain.

Please let me know whether there is anything further I should do. I am very worried whether the material which we have sent you is adequate, and we are certainly indebted that you are willing to try.

Happy New Year.

Best regards,

W. K. H. Panofsky
Director

cc: B. Hildebrand w/encs.

University Participation in Research in High-Energy Physics.

Research in high-energy physics has always been chiefly based in the universities, the logical place for the pursuit of basic knowledge and the drive to satisfy man's curiosity concerning his surroundings. The early accelerators, together with the devices for studying the reactions produced by them, were built at the universities. Some of the smaller high-energy accelerators are still located at universities and their advantages are obvious, both with respect to their close proximity to the campus and their role in the training of students. But these have become relatively less important as emphasis has shifted to experiments utilizing the higher energies, greater intensities, and the more sophisticated equipment available at the national accelerator laboratories. However, the research continues to be mainly carried out by the faculty and students of the universities, in spite of the effort, the strains of working at a distance from the campus, and the inevitable concentration of the major research tools at a few large centers. At the national laboratories, internal research groups play a specialized role that has grown to be an important part of the general research pattern but their numbers are far less than the university-based groups.

slac

University participation is of great benefit to the field of elementary-particle physics, to the universities themselves, and to the national laboratories. Any research program needs the vitality that comes from a continuing supply of young people with fresh ideas, with stimulating and enquiring minds, and with the enthusiasm for innovation needed to counteract the pressures for conservatism that tend to creep into a more static environment. These young people must come, primarily, from the universities -- the students and the recent doctorate recipients. At the same time, the universities must fulfill their traditional dual role of educational institution and center for scholarly research leading to new knowledge. This duality rests on the need for continuous enquiry into the validity of that which is taught and the need for synthesis and organization to elucidate what should be sought. These needs are intimately coupled and a separation into teaching academy and research institute would be disastrous. As for the national laboratories, a close relationship with the universities is vital. In a recent assessment of relationships between Federal Laboratories and Universities, the Federal Council for Science and Technology concluded that *

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* Education and the Federal Laboratories. The Federal Council for Science and Technology, March 1968.

a different atmosphere existed in laboratories where this relationship was close.

> " In talking with persons in these laboratories, one senses a purpose, an alertness, an enthusiasm, a striving for excellence, a dedication, a feeling of accomplishment, ... an excitement, a sense of life and involvement. This atmosphere, fostered by close association with the academic world, highly desirable and not easily attained, was seldom transmitted ... (by) the laboratories lacking close university relationships. "

It is indeed fortunate that high-energy physics is a field where this close relationship exists and it is extremely important that it be maintained.

This relationship is the foundation of the high-energy-physics program with its two-fold purpose of research and education. The research brings knowledge about one of the most fundamental aspects of nature with the motivation in part to pave the way for future technology and in part, equally important, to enrich all human knowledge. The educational role is fulfilled, in the more limited sense, through the teaching of students, to give them the benefit of learning from, and being stimulated by, work on problems that are exciting, sophisticated, and of fundamental importance. High-energy physics is certainly not the only field with these characteristics but it does attract many brilliant students who are drawn by the challenge it presents. These two purposes of the program should be kept in balance with neither being carried to such an extreme as to be detrimental. For example, the most efficient short-range procedure, from the research aspect, might be to have all experiments carried out at two or three national laboratories. But, as already mentioned, a healthy long-range program depends upon the influx of young people with the viewpoints mainly acquired at the universities. For this purpose, it might be sufficient for 10 or 20 universities, with large and active groups, to work together with the national laboratories. However, such a system would not be adequate to support the educational objectives (not to mention the political and sociological problems that it would create). The large number of relatively small university groups contribute in an important way to the educational side as well as to the overall research effort. On the other hand, too great an increase in the number of these small groups, with the present limitations on funds, would dilute the support to all, would result in diminished accomplishment, and the entire program would suffer.

At the present time, there are approximately 50 universities fairly seriously involved in research in elementary-particle physics with an additional large number engaged in research at a low level or with hopes of entering the field. The total number of institutions already participating in some degree is about 125, of which some 90 receive direct federal support. It is estimated that the number will probably grow to more than 150 in the next five years, although there are severe limitations on how many of these can be supported in the near future.

A university may carry out research in high-energy physics in one or a combination of the following ways: by an experimental program based on a local "university accelerator" and the advantages of this have been mentioned; by one, or more, "user-groups" who carry out experiments at the large accelerator centers; and by a theoretical program. At present, a majority of the university user-groups, that are involved with experimental research at the large accelerator centers, utilize the bubble-chamber technique with the required particle beams, the bubble-chamber facility, and the film development, all provided by the accelerator laboratory. Enormous contributions to our knowledge of elementary particles have been made through work with bubble chambers and this technique has the special advantage for a university group that most of the work can be performed at home with but a few weeks, or less, spent at the accelerator to obtain the photographs. Another advantage, from the point of view of the laboratory, is that many groups, in sequence, can use a given beam and bubble-chamber facility to obtain many sets of pictures, without major changes in the installation. Also, with one set of pictures (usually several hundred thousand), the university group can frequently obtain more than one type of result and several publications -- an advantage for graduate-students' theses. An average university bubble-chamber group may consist of about three senior physicists, two younger Ph. D.'s and six to eight graduate students. In addition, the scanning and measuring effort required to extract data from the photographs will need further personnel so that a total of more than thirty people may be involved and the average yearly budget for the group can be well over $ 300,000. A crucial requirement for the groups is the availability of adequate computer facilities. There are large variations in size among the groups engaged in this type of research and recent years have brought considerable change in the methodology and requirements. More detail concerning research connected with the bubble-chamber technique and its problems is given in Chapter - -.

The other common technique employed by university groups involves the use of counters, spark chambers, and complex electronic systems to obtain the experimental data. Usually the array of equipment, some of which may be provided by the accelerator laboratory, is set up in a beam from the accelerator that has been specially designed for the one specific experiment to be performed by the group. Another group, with a different experiment, may be able to use part of the beam-transport equipment (magnets, vacuum pipe, etc.) but usually requires considerable rearrangement and a completely different array of detecting apparatus. Although much of the preparation for experiments of this type can be carried out at the university, various components being constructed there, a more or less extended stay at the laboratory is required, not only during the data-taking stage but during a prior period of installation and testing. The total time for such an experiment, from initial proposal to publication of results, frequently amounts to two or three years during which attendance at the laboratory by some of the group will be needed for perhaps one quarter to one third of the time. While the overall group may be larger, the active participants in a given experiment are, on the average, five physicists, two graduate students, one engineer, and two technicians. Again, there are wide variations in the size of groups. Back-up support at the university will include a machine shop, electronics shop, computer services to analyze data, and perhaps scanning and measuring equipment to reduce data from spark-chamber photographs. An active group may have a yearly budget of $ 500,000 or more, although a minimal program can be pursued for much less.

Since theorists do not need expensive equipment, a theoretical group can be supported on a relatively small budget. However, the theoretical and experimental groups complement and support each other so that most successful university programs include both. It is not easy to establish a good theoretical group in high-energy physics in the absence of an experimental program but, with a small budget, a university can make a start in the field with only theoretical staff who, at the same time, make a large contribution to the educational effort.

Collaborative experiments offer another mode of participation for university user-groups, either through two (or more) university groups making a joint undertaking or by a university group collaborating with a research group at a national laboratory. There are decided advantages to these arrangements that provide ~~the~~ opportunit~~y~~ies ~~to~~ for a group to increase the number of experiments it can undertake (with given funds and manpower), to broaden the types of physics it can investigate and widen the experience of both professors and students. It allows the members of the collaboration to benefit from certain specialties in which a given group may have strength, such as advanced techniques in electronics, detector design, data analysis, computer skills, or beam design. Collaboration is especially appropriate between a newly formed group and a more established one. The new group can become involved in substantial experiments more quickly and the established group, whose resources may be heavily committed, can find that a relatively modest increase in manpower and funds from the new group helps to support an experiment that might otherwise have had to be deferred. With the increasing complexity and cost of modern experiments in high-energy physics, and as the field progresses to higher energies, it is ~~expected~~ probable that collaborations will increase for reasons of both economy and productivity.

Collab with Natl groups

Since a successful program of research in high-energy physics makes a valuable contribution to the educational side of a university's activities, all good universities should want to participate to some extent in this field. At present, the number of groups which can be supported is limited by the available funds and somewhat by the amount of time available at the accelerators. These limitations mean that not all universities that want to enter the field will be able to, at least in the foreseeable future. During the past year (FY 1968), approximately 120 new proposals (not renewals) for work in high-energy physics, requesting some $ 25 million, were under consideration by the federal agencies. In this period, federal funds were used to initiate research in only seven institutions which previously had no program in the field, at a cost of $ 0.5 million.

An estimate of the minimum requirements for a new experimental group indicates that it should contain not less than one senior and two junior Ph.D. physicists with experience in high-energy physics, two graduate students, one technician and access to some engineering support together with shop and computer facilities. Preferably, there should be at least one resident particle theorist. Space needs will be not less than 5000 sq. ft. Funds required will be of the order of $ 100,000 per year, in addition to academic salaries, at the start and increasing to something like $ 300,000 per year if the group ¶ is to be productive. Universities should be aware that these represent necessary, but not sufficient, conditions for entry into the field; since not many new groups can be started under present fiscal conditions, competition is very severe. When funds are sought by a new group, "seed money" provided by the university is likely to be important; it can be taken as evidence of the seriousness with which the university wishes to establish this new activity. A possible method for starting a new group can be found when one (or more) member of an established strong group moves to a university where he begins research by continuing his association with the parent group, working in collaboration until the staff for ~~a~~ this new group is built up and has sufficient support and experience finally to become independent.

The problems and needs of university groups in high-energy physics are not all fiscal ones. Obviously, there are many difficulties in attempting to carry out a research program at a location far distant from both campus and home. In general, high-energy-physics professors are conscientious teachers and believe that the non-teaching "research star" does not belong in the field. But it is almost impossible to predict, very far ahead, the exact time when an experiment can be scheduled at an accelerator; the previously scheduled experiments may need extra time to follow up some unexpected results or, rarely, may obtain data in a shorter time than anticipated. Thus, teaching schedules must be flexible and adaptable at short notice, something not always easy to arrange with current university policies. At the same time, experiments are becoming increasingly complex, require more data and take longer to perform, so that the time away from the campus may involve a large fraction of a year together with brief shorter stays at the accelerator for testing and debugging the apparatus. Another problem connected with the long duration of present experiments is that, after a major experiment's completion, most of the junior members of the team will leave the university and the one or two senior investigators are faced with forming an entirely, or almost new group for the next experiment. This lack of continuity and experience in a team may lead to inefficiency but is usually compensated by the fresh viewpoints and vigor of the newcomers. A fairly serious problem has arisen in recent years with the increased needs for computing time to process the larger quantities of data now required. These problems are discussed more fully in Chapter -- . ¶ A problem that is not unique to university research groups but that may affect all research workers in the field, could be called "creeping conservatism". With the increase in complexity, cost, and time-scale of all experiments, and with limited funds, there can be a tendency toward overcaution. There is great competition for the time available at the accelerators and a group, particularly with graduate students desirous of thesis material, may be tempted to design an experiment that is sure to yield publishable results x rather than risk the effort for a bold and exciting, but possibly unproductive one. This problem requires vigilance on the part of all workers in the field.

A close relationship between and the research workers from the universities ~~and~~ the national laboratories is essential for a healthy and vigorous program in high-energy physics. As in all human relationships, there are many problems but the productivity of the field is sufficient evidence that they have been solved fairly satisfactorily through a continual learning and adapting process. Each national laboratory has its own pattern for furthering this relationship but a general framework has evolved that is more or less common to all. The National Accelerator Laboratory, with the 200-Gev accelerator, is in the process of setting up such a relationship and its pattern, although having some of the same general features, will probably include ~~develop~~ new procedures that cannot now be foreseen, due to the higher energy, the larger and more complex subsidiary apparatus, and ~~perhaps~~ new methods of experimentation.

At a national laboratory, besides the accelerator and its operating xxxxx staff, there are usually research groups whose members also have the responsibility for many of the services and facilities available within the laboratory. The major facilities, such as large bubble chambers, particle velocity analyzers, spectrometers, etc., are integral with the entire accelerator complex and their design requires familiarity with xxx all aspects of this complex. Since the resident staff has this familiarity together with knowledge of the engineering and technological specialists of the laboratory, it is more feasible, as a rule, that such devices be built and operated by the laboratory's personnel. On the other hand, the designers of such facilities must be active in research in order to determine what is most suitable and desirable. Although some of these facilities have been built by university users, usually in collaboration with ~~the~~ a laboratory's staff, the prevailing tendency is to make them the solely the responsibility of the laboratory. Because of their proximity and their close association with the total program of the laboratory, the in-house research groups can contribute greatly to keeping the laboratory's technological resources at optimum level. It is important that the research effort of these groups be kept ~~at a~~ reasonably productive, ~~level~~; probably the use of about 25 percent of the accelerator's research time is about right with a somewhat higher figure if collaborative experiments are undertaken with university groups. The present ratios vary from laboratory to laboratory but are not far different from this. As new accelerators come into operation and more of the research equipment is concentrated at the national laboratories, care should be taken to maintain this balance of use between the university and laboratory research groups. mixed groups

Unfortunate pressures on a laboratory's management occur if there is a general feeling that the laboratory is judged primarily on the output of its internal research groups rather than on all the work carried out at the accelerator. These pressures are not entirely psychological, since funding may depend on a laboratory's reputation. Credit for work at a national laboratory should accrue from all the work done there, whether by university users or by internal groups, in order to encourage the entire community to strive for the best overall program. To help in this problem, and also for general interest, it would be a good idea if all authors would acknowledge (perhaps by a footnote on the title page of their papers) which accelerator and which pieces of major equipment, if any, were used in the performance of the experiment.

University groups need access to the unique engineering, computing, and shop facilities at the national laboratories. Sometimes there is the feeling that the in-house research groups have unfair advantage in the use of these services. Clearly there is need for some control in such usage and, in general, the university groups should expect to pay for these services. Many of these services are already available to the university users but special efforts should be made to ensure that they and the internal research groups are on an approximately equal footing with respect to all the specialized facilities and technical services involving unusual technology that are available only at the national laboratory.

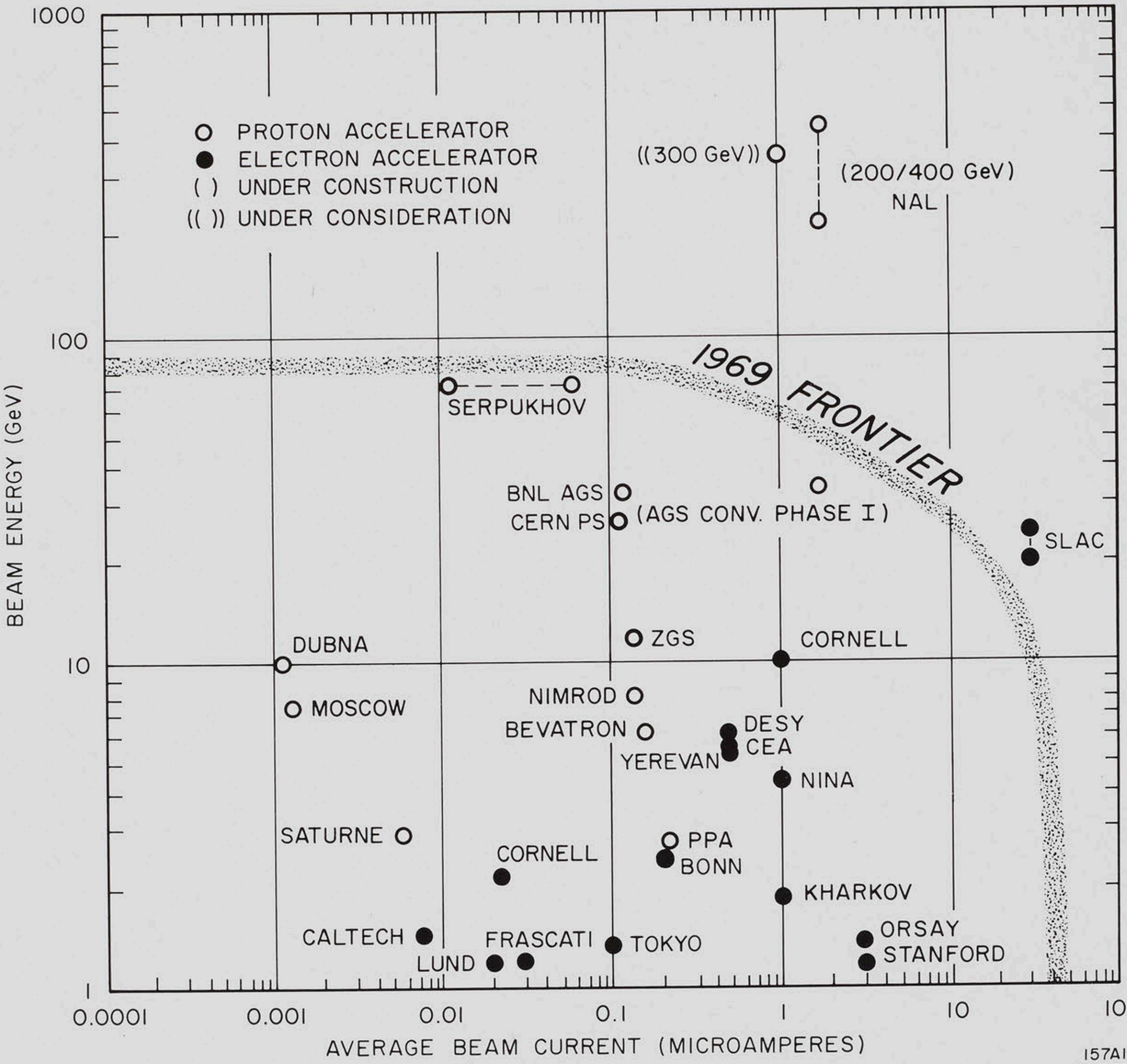
While both the university groups and the accelerator laboratories suffer, at present, from insufficient funds, it is the accelerator laboratory that must carry the larger fraction of the experimental cost. A rough estimate shows that, of the entire budget for high-energy physics, about three-sevenths represents the cost of the research effort and four-sevenths is the cost of the support for the research, i.e., for operation of the accelerator, for the facilities, and for equipment and services. It may be fairly easy to arrange for two experiments, rather than one, to be operated simultaneously at an accelerator's target station but it is not trivial to duplicate the equipment and services required for two experiments and, at the same time, to maintain high quality with maximum efficiency in operations. This aspect must be borne in mind when increases in the number of research groups are contemplated. Although the direct costs of ~~the~~ a group may be only two to three hundred thousand dollars, the total cost of a "typical" major experiment may be well over one million dollars. These costs will probably increase with the higher-energy experiments at the 200-GeV accelerator.

It has been traditional in research in the physical sciences for the serious investigator to build ~~his~~ all of the apparatus for his experiments and such construction has often been a major part of the effort and has contributed to the total experience. In high-energy physics, today, this is rarely the case although many of the strong university laboratories started in the field through the construction of an accelerator. Once founded, these laboratories became independent of the character of their specific accelerator but benefited from the ~~inherent~~ remaining structure of experienced engineers, ~~space,~~ designers and technicians. Some universities have, in recent times, participated in the construction of bubble chambers and special magnets but the trend is toward making the construction of any of the major devices almost entirely the province of the national laboratories. Nevertheless, important long-range advantages can accrue to a university which becomes involved in the development of a new technology. Even if such ventures are now beyond the capabilities of most universities (but perhaps they should be ebcouraged to attempt them) and full responsibility cannot be taken, the individual university research workers can provide much in the way of ideas for design and ultimate use. Frequently, it is the enthusiasm of the university user that initiates the planning for some piece of new apparatus. One way that has been found successful has been for such an interested university physicist to work with and at the laboratory as a part-or full-time employee (temporary). There must, of course, be a very clear understanding of the mutual authorities and responsibilities in such cases. If the device is to become a facility at the laboratory, the final responsibility for its working condition and operation ~~must~~ will rest with the laboratory and the laboratory's management must have the authority to make decisions connected with this responsibility.

The plans for new major facilities at a laboratory, for increasing the scope of the research program through expansion of the accelerator or other major projects, require projections very far into the future (several years) in order to obtain the funding, to carry out the design and complete the construction. Decisions on these matters need strong input from those most interested in the future research, namely, all of the laboratory's users ~~especially~~ including those from the universities. But university physicists are usually highly involved in their immediate research problems and it is not easy to persuade them to devote sufficient attention to the long-range needs of a laboratory. In general, it is the laboratory that presses the user for advice and each laboratory has different mechanisms, committees and users' associations whereby it obtains this advice. But, although the users' community may have an enormous influence, it cannot have the authority to make decisions for the laboratory; the final authority and responsibility for the decisions must rest with the laboratory's director. It is good if the director has such close communication with the users that they realize the bases for his decisions, but there are many subtle factors involved and, often, there are critical questions of timing that cannot be resolved by committee.

The major accelerator laboratories have ~~a~~ program, or scheduling, committees that advise~~s~~ the laboratory's director concerning the approval of the proposed experiments and the requests for extensions ~~to~~ for operating experiments. A typical program committee consists of 8 - 10 research physicists, including one or more theor some of whom may be associated with the laboratory and some ~~of the more senior~~ with university ~~users~~ groups, together with appropriate ex-officio operational personnel. Such a committee usually meets frequently and questions of long-range policy are often discussed with this group.

More general communication between the laboratory and the users occurs through the users' associations that are usually composed of all those interested in the high-energy-physics program of the laboratory. There is considerable overlap in membership between the various associations of users at the different laboratories but this can be advantageous. Comparisons of various procedures and services at the different laboratories can result in improvement to all. The users are also likely to know what experiments are planned, and the state of progress of those under way, at other laboratories and this information can be of great value in planning a program. However, in order to develop strong support from ~~the~~ a user-community, it is important that ~~xxx~~ it has some feeling of proprietary interest in the laboratory. At the same time, the user groups should have, in their association, a sense of autonomy and independence of the laboratory management in order that the advice offerred be a true reflection of the users' needs, opinions, and plans. Therefore, an organization that is self-generating would seem best, even though the laboratory may have to initiate the process. Meetings of the entire user-community with the laboratory's management and personnel are a very necessary part of the relationship but enthusiastic participation at more than a few meetings a year is improbable. Close communication on such a large scale is usually not feasible and a smaller representative group has proved successful in some cases. An example is the Technical Advisory Panel (TAP), a subgroup of the Argonne Users' Group; the officers or executive committee of a users' association can also serve the same purpose. In all arrangements, it is important that the relationship between the leaders of the users' group and the laboratory management be one of mutual confidence. The subgroup should be made up of ~~xxxxxxxxxxxxxxxx~~ active research workers who are willing to meet frequently enough to be able to contribute to the continual progress of the laboratory. A Users' Group has already been formed in connection with the National Accelerator Laboratory's research planning and its executive committee is working with the laboratory's staff on some of the matters concerned with future experimentation. Undoubtedly, the development of this users' organization will result in new types of relationships, in order to meet the future needs of both the univeristy users and the labroatory.



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COMPARATIVE GRAPH OF VARIOUS ACCELERATORS

STANFORD UNIVERSITY

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December 31, 1968

JAN 2 1969

Professor V. F. Weisskopf
Department of Physics
Massachusetts Institute of Technology
Cambridge, Massachusetts 02139

Dear Viki:

Here at long last is my propaganda piece (Pief has the original). I am very sorry for the long delay, and hope that it did not hurt.

I have tried not to hide my prejudiced outlook on things, and trust that you and the committee will remedy that problem.

Best regards, and a Happy New Year.
Sincerely yours,

bj

J. Bjorken

JB-sj
enclosure

Not enough <u>exp.</u> discoveries
the page

Chapter VI, VII,
Earl Fowler's chapter

Recent Progress in High Energy Physics

Since the Ramsey-panel report in 1963, high-energy physics has continued to make rapid advances. The general picture of that time was the existence of four highly distinguishable, but relatively unrelated classes of phenomena: strong, electromagnetic, weak, and gravitational, the latter not even observed at the level of particle interactions. While this picture remains, with possibly one exception, unchanged in form, the clarity of our view of the picture has increased enormously.

What has changed in the realm of strong-interaction phenomena is the development of a rich spectroscopy involving hundreds of new states of strongly interaction matter, a spectroscopy similar in many ways to that of atoms and nuclei. In parallel with this vast accumulation of data there has developed highly successful classification schemes which correlate large bodies of these data. In the field of electromagnetic interactions, confidence in the beautiful, precise theory governing such phenomena has continued to increase upon conclusion of several successful, highly accurate, and incisive tests of the theory, sensitive to its small-distance structure. In studies of weak interactions, a quantitative theoretical description has been successfully compared with accurate data on the decays of unstable particles, leading to a confidence in the theory of some kinds of weak phenomena rivalling that given to the theory of electromagnetic phenomena.

While the main thrust of the recent research has been to bring into sharper focus the nature of these three kinds of phenomena, a new and generally unexpected phenomenon, nature's violation of the combined symmetry operation (CP) of replacing particle by antiparticle (C) and of mirror reflection (P) has been discovered. Violation of C and P separately (with no apparent violation of CP) was identified in 1957 as an important intrinsic property of weak interactions. The new violation has not been so identified and may be related to a part of any of the three known interactions or quite possibly to an entirely new one. Clarification of this phenomenon is one of the great challenges facing particle physics.

I. The Structure of Nucleons and Mesons

The study of the structure and the properties of hadrons (the strongly interacting particles, including the proton and neutron, π-mesons, and strange particles) has, especially in the last few years, been strikingly parallel to the study of atoms by means of spectroscopy in the 1920's prior to the golden age of quantum mechanics. In analogy to the resonant atomic states responsible for the spectral lines, there exist a large number of resonant states of hadronic matter. The evidence for these resonant states has largely come from the painstaking analysis of hundreds of thousands of bubble-chamber photographs. During this period, it was noticed that patterns began to emerge, and that the observed states could be classified into families, whose members possess similar properties, such as nearly equal mass and the same spin angular momentum. These family-relationships are quantitatively described by a theory of symmetry labelled SU(3) by the mathematicians. Even the deviations of the masses of family members from the average value are simply and accurately described by this picture. The most convincing evidence for the SU(3) classification scheme came after the discovery and identification of nine different resonance states, all in the same family. There was one missing member, whose properties could be predicted from those of the other nine. This missing particle, the Ω^-, was subsequently discovered; it indeed has the precise mass, the charge, and the strangeness which was predicted. Since that time the SU(3) classification scheme has continued to be successful, and attention has centered on ways of enlarging it further. One avenue has been the identification of sequences of resonance-states whose members differ only in the value of their spin angular momentum. These are the "Regge-trajectories" or rotational bands. Another direction taken has been a model based on the idea that mesons and nucleons are composites of two or three fractionally charged objects, the quarks. This model, which owes much to similar models of the atom and the nucleus, has found success in correlating properties of a great number of meson and nucleon resonance states. As yet, the full significance of this result is not clear, owing both to the relative crudity of the theoretical models and to the absence of any experimental evidence for quarks, despite searches for them in everything from the cosmic ray to oysters.

Complementary to the spectroscopic studies of hadron states are the structural studies of the proton using high-energy leptons (electrons, μ-mesons, and neutrinos) as convenient, approximately structureless, weakly interacting probes. In this way the average distribution of electromagnetic current inside the proton has been accurately measured by colliding high energy electrons with protons. New data from very violent electron-proton collisions, collisions in which the proton is broken up, in particular holds great promise for learning more details of proton substructure. In addition to production of various resonance-states, a component is observed in these experiments which decreases relatively slowly with increase of the transverse momentum transferred by the electron to the proton, as if the scattering were from point-like objects within the proton. One is inevitably reminded of the similar experiment on atoms by Rutherford in 1911 which revealed the existence of the atomic nucleus, using α-particles as the probes. It is not expected that history should repeat. If anything, the data would suggest a nucleon model more analogous to the Thomson-model of the atom; if history repeats, it probably will be that the Thomson-model fails again. Nevertheless, on the basis of the data alone, one can expect a broad class of similar phenomena will also be characterized by large mean transverse momenta[†], and will be distinguishable, despite smaller reaction rates, from the more typical strong-interaction phenomena characterized almost entirely by small transverse-momentum. The connection between large transverse momentum and small distances is a direct consequence of quantum theory, and suggests that all such studies of lepton-hadron interactions with high transverse momentum will be sensitive to the structure of the proton at distances small compared to its spatial extent.

Similar experiments using protons or π-mesons as probes have been carried out, yielding a wealth of detailed information. While the theoretical interpretation of these experiments is more difficult, the richness of the data is considerable compensation. At present, there is the possibility of a connection between elastic proton-proton and electron-proton collisions, a point which should be clarified at higher energies.

[†] We mean, for example, μ, e, and γ-ray inelastic scattering, electromagnetic and proton-induced μ-pair production, and especially neutrino-production of μ-mesons and electrons.

II. Current Algebra

Intimately connected with the last topic and with SU(3) is the development of "current algebra" in the last few years by Gell-Mann and many others. It bears a close parallel to Heisenberg's contribution of "matrix-mechanics" to the development of the theory of the atom and of quantum mechanics. The basic ingredients for Heisenberg's theory were the observable probabilities for light to be absorbed and to produce the resonance-states of atoms. Heisenberg studied the mathematical relationships of these observable quantities, which turned out to be simple, elegant, and useful. In current algebra the atom is replaced by the hadron. The external probes, analogous to light in the case of atoms, become the leptons (as well as light), which couple to the hadrons via both the weak and electromagnetic forces. Again, the mathematical relationships among these observable quantities, such as the probabilities that lepton-pairs be absorbed by hadrons, are simple and elegant and provide a precise foundation for the theory of the approximate SU(3) symmetry observed in the spectroscopic data on the resonances. Current algebra has done more: it helps to reveal and exploit an additional, more subtle, approximate symmetry-property of strong interactions called chiral symmetry. The application of these concepts has produced many useful relations between measured quantities, perhaps the most impressive being a relation between the weak β-decays of neutron and π-meson and the probabilities that energetic π-mesons interact with protons. The identification of the basic observable quantities of current algebra and of the simple properties these quantities possess is a cornerstone with firm foundations upon which future theories will build.

The analogy of the present status of hadron physics with that of atomic physics at the dawn of the quantum era is so close that great efforts have been made to try to fill the remaining gaps. Despite some heroic tries, there is as yet no analogue to Schrodinger's equation, which opened the way to the great advances in understanding the atom. Indeed, there is no basis for confidence in expecting a description of the nucleon, and hadrons in general, in terms of simpler constitutents, although the successes of the quark model might possibly point in that direction. There is as yet no parallel to the contribution of Bohr, who first linked the spectroscopic data with the structural information on the atom obtained by Rutherford. But the status of all these questions is undergoing rapid change, and the answers must await the future.

III. Interactions of the Fundamental Particles

The different interactions, or forces, between the fundamental particles — strong, electromagnetic, and weak — remain at present three rather distinct subjects, with little unity between them. Within each of these classes, however, there has been considerable progress in elucidating the nature of the forces.

A. Strong Interactions: Recent progress in the study of the nature of strong interactions has been concentrated on high-energy collision processes, for which a large body of accurate data has been accumulated. General relations, the "dispersion relations", for π-proton collisions based upon (hopefully) well-founded principles of relativity and causality have been tested by precise experiments. The results of these experiments verify the dispersion relations and indicate that while the total reaction cross-sections at high energies have become nearly independent of the energy of the incident π-meson, there remains a small component with a fairly slow energy-variation which will still be measurable at much higher energies than at present. Considerable evidence exists that this energy-variation, as well as stronger energy-dependences found in other reactions, is connected with a reaction mechanism involving exchange of a particle (or rotational "Regge" series of particles) between the projectile and target particle. This exchange can change the charge, spin, strangeness, and other attributes of the target and projectile. New data on photon-initiated reactions supports this same general picture, and is providing a powerful constraint on detailed theoretical models of these processes. The relation between photon-induced and hadron-induced reactions may be even more closely related: evidence is accumulating that suggests a proportionality between the properties of photon-initiated reactions and those initiated by ρ, ω, and ϕ mesons, resonance-states which have the same spin angular momentum as the photon. These mesons, discovered originally in bubble-chamber experiments, have recently been produced from colliding beams of high-energy electrons and positrons in storage rings built in France and in Russia; these results herald a promising future for these remarkable instruments.

B. Electromagnetic Interactions: The theory of strong interaction processes is at present almost wholly descriptive: it attempts to reduce the great volume of existing data to a small number of general principles. For processes involving the electromagnetic force (and where the strong interactions can be eliminated or kept under control), just the opposite is the case. Here there is a theory, virtually complete in its predictive powers. It emerged from the work of 19th century physicists such as Maxwell, was adapted to the laws of quantum mechanics, and was made workable after the second world war by Tomonaga, Feynman, Schwinger, and many others. This theory, while falling short of being perfect, is rivalled only by the theory of gravitation in its predictive power. It is believed that almost all of the everyday phenomena around us (excluding the falling apple) are controlled by the laws of quantum electrodynamics. The remaining flaws in the theory appear to lie in its structure at small distances; here it is of interest and of importance to make experimental tests to verify that the theory works at ever smaller distances.

There recently have been more incisive tests of this nature, probing the theory at distances of less than 10^{-14} cm. These have included measurement of the "electrostatic" force between electrons at such distances, and measurement of the magnetic moment of the μ-meson to an accuracy of better than one half part per million. Evanescent discrepancies between the theory and other such experiments have largely disappeared, although some remain. There is at present no incontrovertible evidence against the validity of quantum electrodynamics.

As the experiments continue to increase in precision, the theoretical calculations necessary to compare with the measurements increase rapidly in difficulty. The theoretical physicist and computer scientist have joined forces in developing sophisticated techniques for carrying through the difficult algebraic calculations and multiple integrations needed in this field.

C. Weak Interactions: That part of the weak interactions which involve leptons has undergone great progress in the last few years. In this area there exists, at low energies, a satisfactory theoretical description, closely linked to current algebra. It generally accounts for a large amount of remarkably accurate data on the weak decays of unstable particles, as well as the important recent data on neutrino-induced reactions. The part of weak interactions involving weak decay of strange particles (K, Λ, Σ, Ξ) into π mesons and nucleons alone (the nonleptonic decays), despite considerably more accurate and complete data, continues to resist a completely satisfactory description. However, important new successful results, especially among the K-meson decays, have been found by means of current algebra ideas.

The status of weak-interaction theory is far inferior to that of quantum electrodynamics, but much more predictive than strong-interaction theory. While many perplexing questions remain in the realm of low-energy weak phenomena, the great frontier lies at higher energies, where it is known that the existing description _must_ fail. Most attempts to remedy the inconsistencies include the introduction of new kinds of heavy particles, the most celebrated being the W-meson, which is supposed to be carrier of the weak force, much as the photon mediates the electromagnetic force. To study such questions, experiments with high-energy neutrino beams will be extremely important; they promise the most direct way to study the weak force at high energy.

IV. CP Violation

In the face of the general improvement in understanding has come the important, surprising discovery that the combined symmetry operation of replacing particle by antiparticle (C) and of mirror reflection (P) is not a symmetry of nature. This has been established by the observation that the K_L^0 meson decays into two charged π-mesons, a reaction forbidden were CP an exact symmetry. A subsequent measurement of the K_L^0 decays into $\pi^+ + \mu^- + \bar{\nu}_\mu$ (and $\pi^+ + e^- + \bar{\nu}_e$) and into the antiparticles $\pi^- + \mu^+ + \bar{\nu}_\mu$ (and $\pi^- + e^+ + \bar{\nu}_e$) shows a small (~ 0.3%) preference for the K_L^0 to choose the π^+ modes over the π^- modes, providing a graphic example of the lack of particle-antiparticle symmetry in a process symmetric under mirror reflection. The interpretation of these experiments is at present totally confused. The strength of the interaction responsible has been estimated to be anywhere between 10^{-2} and 10^{-17} of the strength of strong interactions. Many searches for CP-violating effects in strong, weak and especially electromagnetic phenomena have given negative or inconclusive results. Several extremely difficult experiments are in progress in an attempt to improve this appalling situation. It is without question that the pursuit of this problem is of the greatest importance for particle physics.

V. Other Unresolved Questions

The status of many old, extremely fundamental questions has been improved hardly at all. It is important to say this, because much of the slow, painstaking work of the present points toward the lofty goal of finding answers to them. Despite the distinct separation between the properties of hadron and lepton, and between the (at least) four different forces, there are some similarities linking them. Protons and electrons have the same charge, to an incredible accuracy. No one knows why, or why charge only comes in units. The weak interactions of hadrons and of leptons have the same strength, a statement which can be formulated precisely using the language of current-algebra. But no one knows why. The not quite exact SU(3) symmetry of the hadrons has its analogue in the not quite exact symmetry between μ-meson and electron: almost all of the properties of μ and electron are identical. This has recently been tested with greater precision and sensitivity, e.g. by the magnetic-moment measurement on μ and electron, by the comparison of μ-proton and electron-proton collision processes, and by the establishing the existence of two neutrinos, one associated with the μ and the other with the electron. The only known fundamental distinction between μ and electron is that the mass of the μ is 200 times that of the electron. This way in which the μ-electron symmetry is broken is qualitatively similar to how the strong-interaction SU(3) symmetry and chiral symmetry is broken. All this evidence points in the same direction as one's aesthetic sense: in the future a more unified picture of the world of fundamental particles will emerge.

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DEC 17 1968

December 13, 1968

Professor Victor F. Weisskopf, Chairman
Department of Physics
Massachusetts Institute of Technology
Cambridge, Mass. 02139

Dear Viki:

I am including two highly preliminary drafts of Chapter VII for your comments; the text is still fairly rough and I will go over it again but I was wondering whether you agree with the general format and in particular with the way in which the conclusions and recommendations reached have been incorporated in the text.

The tabular and graphical material is still out of date and I am working on getting it updated.

With best regards,

Pief

W. K. H. Panofsky
Director

cc: addressee at Biltmore Hotel, N.Y. w/enc.
Dr. B. Hildebrand w/enc.

enc.

p. 17

saving by new technology

Preliminary

Privileged

Privileged

CHAPTER VI

Accelerator Construction and Accelerator Technology

A. Current Status. All accelerators currently operating in the region above 1 BeV are either proton or electron synchrotrons employing copper conductors or electron linear accelerators employing microwave structures; these accelerators operate somewhat above room temperature. We will designate accelerators operating on these principles as employing "conventional" technology. In contrast, Appendix I discusses "advanced" accelerator technologies applicable to the next generation of machines.

Since the AEC's report on National Policy for High Energy Physics in 1965 several major changes in the U.S. accelerator facilities have occurred.

1. The ZGS has reached full operation.
2. SLAC was completed and is now in full operation up to 21 GeV electron energy.
3. The Cornell 10 GeV Electron Synchrotron was constructed and has commenced operation for research.
4. The 3 GeV Cosmotron has been shut down.

As a result of these U.S. developments, combined with advances in the rest of the world, the list of accelerators is now as shown in Table 1. This table presents two primary parameters: The type of particle accelerated and the energy achieved. Of course other quantities are of importance such as the beam intensity which controls the attainable data rate and various beam quality factors such as duty cycle and beam geometry which relate to the experimental techniques which can be used.

Figure 1 gives a world-wide plot of energy and intensity of the world's accelerators and indicates what might be called "The 1969 Frontier."

During the past decade another type of high energy beam device has demonstrated its usefulness in physics; this is the "storage ring," a device which confines beams in circular orbits permitting them to undergo "colliding beam" collisions, in contrast to the "beam target collisions" exploited in conventional accelerators. Table 2 gives the world's status in storage ring exploitations. Important experiments (See Section V) using these techniques have been carried out at the Princeton-Stanford (now shut down), Novosibirsk and Orsay storage rings.

Storage ring technology and the type of physics it can provide is discussed more fully in Appendix I. Suffice it to say here that these new techniques give access to new realms of particle physics at relatively moderate cost.

In making projections and recommendations for future accelerator construction (or terminations of facilities) we are mindful of a number of facts relating to the current program. Predominant among these are the following:

1. The current program is operating under serious fiscal stringencies. Inspection of Table 1 combined with the fiscal data given in Chapter IV indicates that the United States is operating two additional large high energy installations relative to Western Europe, while the support levels of the United States and Western Europe are essentially the same, and in terms of available manpower the Western European levels are considerably higher. All U.S. accelerators are substantially underutilized; a relatively small increase in operating funding would yield a disproportionately large increase in scientific output. On this basis we recommend:

TABLE 1

Operating Accelerators Above 1.5 GeV

Accelerated Particle	U. S.		Western Europe		USSR	
Proton	PPA	3 GeV	Saturne	3 GeV		
Proton	Bevatron	6 GeV	Nimrod	7 GeV	ITEP	7 GeV
Proton	ZGS	12.5 GeV			JINR	10 GeV
Proton	AGS	32 GeV	PS	30 GeV	Serpukhov	76 GeV
Electron	CEA	6 GeV	DESY	6 GeV	Yerevan	6 GeV
Electron	Cornell	10 GeV	NINA	4 GeV	Kharkov*	2 GeV
Electron	SLAC*	21 GeV				

All accelerators are synchrotrons excepting those marked * which are linear accelerators.

Table 2

STORAGE RING PROJECTS

Designed Primarily for Elementary Particle Physics Experiments
Now Operating, Under Construction, or Committed*

Preliminary

AREA	STATUS 1968			
	LOCATION	ENERGY AND PARTICLE TYPE	BEAM CURRENT (AMPERES) IN EACH BEAM	COMMENT
U. S. A.	CEA	3 GeV e^+e^-	0.1	Exper. study of feasibility of using a synchrotron as a storage ring; operating facility at medium intensity; suitable for QED experiments.
WESTERN EUROPE	Orsay (France)	450 MeV e^+e^-	0.1	Exper. program in progress.
	Frascati (Italy)	1.5 GeV e^+e^-	0.1	Injection studies in progress. Low intensity facility for QED experiments.
	Hamburg (Germany)	3.0 GeV e^+e^-	1 - 25	Very high current, designed to permit both strong interaction and precision QED experiments; follows SLAC design.
	CERN (Switzerland)	30 GeV pp	40	Operation expected in 1972. Under construction.
U. S. S. R.	Novosibirsk	700 MeV e^+e^-	0.025 e^+ 0.100 e^-	Physics experiments in progress.
	Novosibirsk	3.0 GeV e^+e^-	0.25	Construction of physical plant is complete. Ring components under construction. Due to be operational in 1969. Machine will also be used as part of the 25 GeV proton-antiproton machine.
	Novosibirsk	25 GeV $\overline{p}p$	20 p 0.002 $\overline{p}$	Ring tunnel complete. The project involves use of a new technique of proton damping.
	Lebedev Inst.	1.5 GeV e^+e^-	not known accurately	High intensity Microtron injector

*Other projects, designed primarily for beam dynamics studies, include MURA (USA), ADA (Italy), Kharkov (USSR).

> That presently existing facilities be exploited commensurate with their scientific potential. To this end appropriate increases in operating budgets should be sought with very high priority.

2. A second problem relates to equipment needs and construction modifications at existing installations. The experimentation carried out with modern high energy accelerators involves consistently evolving technology and changing requirements as to services such as power, water, etc. feeding such equipment. Moreover, new data analysis methods are constantly being developed. For this reason a substantial fraction of those funds now earmarked in the Equipment and Accelerator Improvement (construction) categories are required for the maintenance of the vitality of the regular ongoing research program associated with high energy accelerator facilities. Such funds,which under current AEC procedures are budgeted as capital equipment and construction funds, do not represent capital expansion of facilities. This fact appears not to have been clearly understood and therefore recent budget cuts have fallen disproportionately heavily on these categories under the erroneous assumption that such cuts are related to control of expansion of capital plant. We therefore recommend:

> That equipment needs be met by existing experimental programs and newly constructed facilities in balance with the operational research levels. We note that a large fraction of these needs is essential for efficient operation and does not represent expansion.

3. The initial leadership in storage ring physics of the United States has now been totally lost in favor of the vigorous program in Western Europe and the USSR.

Storage ring experiments involve either electron-positron collisions or proton-proton collisions. Electron-positron collisions offer answers to basic physics questions which cannot be obtained any other way. The major opportunities will be lost unless both the CEA colliding beam bypass project is supported both in its development and utilization phases, and unless a major expansion of electron-positron colliding beam experimentation in a separate storage ring installation is supported. We therefore recommend:

A major expansion of electron-positron colliding beam experimentation.

4. Proton-proton colliding beam opportunities were discussed in the Ramsey Panel Report as a possible addition to the Brookhaven National Laboratory; the decision was, however, reached not to go forward with such activities. In contrast work on the 30 BeV intersecting storage ring (ISR) at CERN is going forward with operation expected in 1971. We conclude:

> That proton colliding beam construction activities should now be deferred until NAL has reached the operating stage, but then the addition of storage rings to NAL may well be the next logical step to higher center of mass energies.

We will discuss this matter further in a later section.

5. The performance of an accelerator must not be static. There are continuously changing demands in accelerator performance imposed by new types of experiments; there is continuous pressure for increasing beam intensity and for increasing reliability and flexibility of operation. Although the performance of U.S. accelerators in general has been excellent from the reliability point of view, the high operating costs of accelerators places

a strong economic incentive for continuous upgrading of reliability using modern components. We therefore recommend that:

> Support be given to continuing programs for improving performance, reliability and efficiency of existing accelerators.

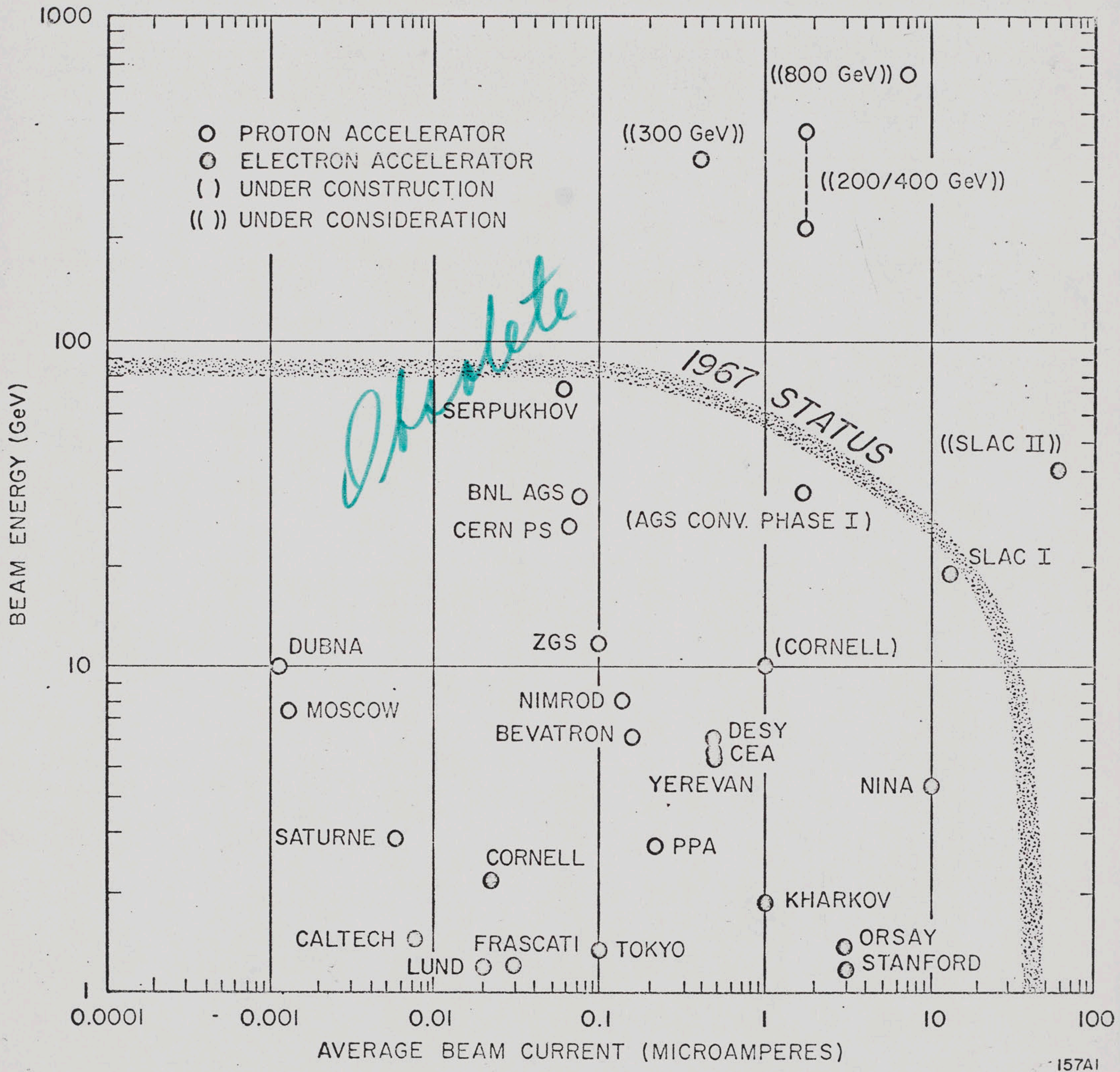
We recognize that some existing U.S. accelerators not operating near the "1969 Frontier" (see Fig. 1) will be phased out during the next decade. For such accelerators major improvement programs which would involve costs comparable to the original cost of the facility itself (such as new injectors or major target area expansions) appear at present difficult to justify.

B. General Planning Factors. We recognize that the future program of construction of new accelerator facilities will in fact pace the entire growth of the field and will in the long run control both the scientific opportunities and the requirements for support. For this reason we would like to enumerate here various factors which affect the specific conclusions of this report.

It would be foolish to ignore the existence of a number of very fundamental problems which call for a large amount of judgment and compromise among conflicting requirements. The components of this conflict are the following:

1. The insufficient level of funding of already existing facilities.
2. The increasing cost per experiment.
3. The importance of values other than those of short-range research productivity. Among such factors are: The educational involvement of the program, international relations, minority training and pressures for geographical diversity.

Figure 1



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COMPARATIVE GRAPH OF VARIOUS ACCELERATORS

4. The increasing community of high energy physics experimentalists combined with the continued open endedness and the challenge of the field with its very fundamental results.

5. There is an unavoidable contraction of accelerators operating at the frontier of energy and intensity, while there is an expansion of new "centers of excellence" which demand access to high energy facilities.

6. New research results and new accelerator technologies evolve rapidly as documented in previous chapters, yet there is a time interval of generally at least ten years between the development of initial plans for an accelerator project and its first impact on research.

7. A large part of the intellectual leadership of high energy physics has originated from the universities and high energy physics has remained an essential part of our educational enterprise. Yet the evolution of experimental techniques and the progressive concentration of the "frontier facilities" force deviations from traditional academic patterns. Planning of new accelerator facilities must, from the outset, be mindful of the university-laboratory relationships.

We do not pretend to know what the ideal compromise is among the set of partially conflicting factors enumerated above. Yet we would like to state the ground rules on which our recommendations for future accelerator considerations are based. These are:

1. We will expect a growth rate of the support for high energy physics greater than the static level experienced during the last four years, and we will assume that new construction activities and their consequent need for operating, equipment and construction funds will receive consideration on their own merits and will not have to be absorbed by the ongoing programs as long as those remain fully productive.

2. We will anticipate shutdowns of old accelerator facilities but we will not accelerate by fiscal considerations shutdowns of fully productive accelerators beyond the rate set by natural decrease of interest. We note that cost savings originating from shutdowns are not large considering the shift of interest by the accelerator users to the use of other accelerators. We would like to emphasize that the community of high energy physicists in conjunction with the supporting agencies have in the past been willing and able to shut down accelerator facilities as the frontier of interest advanced. Table 3 shows a list of those accelerators operating above 100 MeV which have been shut down since World War II as the frontier of elementary particle physics has moved to higher energies.

3. We will anticipate a program considerably smaller than that proposed by the Ramsey Panel and by the National Policy Paper on High Energy Physics. On the other hand we will anticipate a program which is commensurate in growth rate on the average with such indices as graduate enrollments, the over-all research support for basic research at the universities, as well as the basic productivity of the field.

4. We will propose a program <u>in toto</u> fully competitive and even superior to that of Western Europe and the USSR, but which does not aim to be superior in <u>all</u> the subfields of high energy physics.

5. We will maintain the progressiveness of the field by placing an emphasis on advanced technology.

6. We will be selective in terms of the number of constructive steps taken to attain a given goal. Under this criterion and the fiscal guidelines a program will evolve which will <u>not</u> satisfy total user demand.

TABLE 3

Preliminary

Lab	Dead or Doomed Machine	Successor
Berkeley	37" cyclotron	
	60" cyclotron	
	40 MeV linac	184" cyclotron
	300 MeV synchrotron	Bevatron
Stanford	MII	
	III	What is it called? SLAC
Caltech	1.2 BeV synchrotron (1969)	SLAC
Carnegie Tech	380 MeV cyclotron (1969)	
Rochester	? MeV cyclotron (1969)	
Chicago	100 MeV B-tron	450 MeV cyclotron
	450 MeV cyclotron (1972?)	ZGS
Harvard	240 MeV cyclotron (1969)	CEA
MIT	300 MeV Synchrotron	CEA
Purdue	300 MeV synchrotron	ZGS
Cornell	300 MeV synchrotron	
	1 GeV synchrotron	
	2 GeV synchrotron	10 GeV synchrotron
BNL	cosmostron	AGS

7. We recognize that the implementation of these criteria means that only a decreasing fraction of those physicists trained in high energy physics can stay in the field. Under the limited program outlined here only about one-half of the Ph.D.'s trained in high energy physics can continue in the field.

C. Future Program. I. In consonance with the conclusions of former panels we consider the highest priority construction item to be the step toward higher energy as now implemented through the authorization of the 200 BeV accelerator facility at Batavia, Illinois. Initial design and planning of this accelerator are very encouraging and we urge that the momentum and efficiency of this operation be maintained. A large construction project of this kind will suffer cost increases, managerial inefficiencies, morale problems and delay of its final usefulness if funding is being controlled on a year-by-year authorization basis rather than permitting laboratory management to control construction in the most efficient manner. For these reasons we recommend:

> That the rate of expenditure for the construction of the 200 BeV accelerator be left to the discretion of the machine builders, subject only to the normal AEC supervisory role.

II. New Technology. At this juncture new accelerator technology is in an exceedingly promising state. However we estimate that a time interval of about two years will be required before definitive conclusions as to the advisability of going forward with "new technology accelerators" in the energy region above 1 BeV will result. Nevertheless, we consider the promise of the new technologies to be so high that we can see no valid motive at this time for the construction of new accelerators beyond 1 BeV using conventional technology, nor do we have in view any major improvement programs which would not envision new technology.

Appendix I gives a detailed description of the competing new accelerator technologies; we will only give an outline here. The promising methods are the following:

1. Superconducting Alternating Gradient Synchrotron. The "conventional" alternating gradient synchrotron on which the AGS at Brookhaven, the PS at CERN, and the NAL accelerator at Batavia are based are limited by the maximum field strength which can be produced by conventional magnets. Superconductivity has shown the path towards higher magnetic fields for magnets producing steady magnetic fields but thus far superconducting magnets producing time-varying magnetic fields have excessive power loss. There is expectation that developments of highly stranded conductors may break this barrier and that economically competitive designs making higher energies possible within smaller radius accelerators may be developed.

2. Cryogenic Alternating Gradient Synchrotron. An alternate approach toward improving the economics of design of a very high field alternating field magnet is through use of cryogenic (not superconducting) conductors; such conductors will operate at somewhat higher temperatures than those required for superconducting magnets with a consequent lessening of refrigeration requirements. The possible success of such a system depends on the use of extremely pure metals (aluminum is a primary candidate) for the windings; success depends on complete control of the various effects (such as stress,

radiation damage, impurities) which might be deleterious to the low temperature resistance of such materials.

3. Fixed Field Synchrotrons. As mentioned above fixed field magnets for beam transport and other applications have been developed successfully but the adaptation of superconducting techniques to accelerators using time-varying fields is not fully solved. A possible alternative is to apply superconducting techniques to the fixed field alternating gradient synchrotron (FFAG) which, however, requires fairly large field volumes and an alternate solution may be to rotate fixed field superconducting magnets mechanically, thus effectively producing alternating field effects. These two approaches are under study.

4. The Superconducting Microwave Linear Accelerator. At present electron linear accelerators are limited by the high power dissipation in the walls of the accelerating structure. This limitation manifests itself in short duty cycle of the resulting beam, which in turn limits the range of experimentation which is possible; moreover expensive radiofrequency power sources are required. Accelerating structures for use at temperatures below the point at which the walls are superconducting could constitute an electron linear accelerator which gives a nearly continuous beam and which would reach considerably higher energies in a given length. Such an accelerator might well combine the advantages of the conventional linear and circular accelerators.

Tests of single, microwave cavities employing niobium walls are most encouraging; however no definitive fabrication process has as yet been developed; moreover problems of field emission, damage to surface by vacuum accident, and control problems require further study and experimentation.

5. The Electron Ring Accelerator (ERA). It has been recognized for a long time that if protons were captured in a cloud of electrons which is then accelerated to high energy, then the captured protons would attain an even greater energy than that given to the electrons; accordingly one could build an accelerator for protons to extremely high energies in a machine of moderate length. A promising practical approach to this problem is the Electron Ring Accelerator in which the capturing electron cloud is in the form of a ring made up of high speed electrons. Initial success in producing and compressing such a ring and capturing protons has been attained, both in the Soviet Union and in the USA. Many problems concerning the transfer of such a ring into an accelerating structure and the associated problems of stability and ultimately of economics are under investigation.

It is a fair summary of all these methods (which are discussed in considerably more detail in Appendix I) that they all appear promising as far as technical feasibility is concerned, but one has to recognize that the principal incentive for pursuing them is economic: All these methods lead to accelerator parameters which are in principle attainable by conventional technology; however one hopes that a given goal can be reached at a cost several times lower, or that energies several times higher can be obtained at a given cost. Specifically one might expect that using one of these techniques an accelerator reaching perhaps 2,000 GeV might be designed at a cost which at the time of the Ramsey Panel Report was visualized for an 800-1000 GeV accelerator.

We note that the cost of a new accelerator facility is controlled only partially by the cost of the accelerator itself; as an example the total cost of creating the BNL and SLAC high energy facilities is roughly three times the amount one would ordinarily identify with the technical components of the accelerator itself; the balance covers items such as site development, shielding, laboratories, target area facilities and initial research equipment. Hence one should not expect that the new accelerator technology will generate spectacular changes in the over-all costs of operational accelerator installations.

Since the date of establishing the over-all feasibility of these methods (both in the technical and economic sense) is still two to three years hence, our recommendations for future accelerators must be considered to be planning assumptions rather than specific recommendations.

Considering the crucial importance of these new technologies to the future of high energy physics we recommend:

That Research and Development in new accelerator technology be supported vigorously.

Application of the new accelerator techniques appears to us to be logical in three connections:

1. As a means for upgrading the performance of those accelerator laboratories in the United States in which there exist large investments in site, ancillary equipment and experienced personnel; such laboratories could thus enter a new realm of energy and intensity.

2. To provide a new accelerator which would meet the frequently expressed need for a regional facility not operating at the frontiers of energy and intensity, while at the same time being a pilot operation for gaining experience with new accelerator technology on a moderate scale.

3. Eventually the actual construction of an accelerator extending the energy frontier beyond that of the Batavia 200-400 GeV accelerator.

D. Specific Planning Projections and Recommendations. Proposals for new accelerator facilities of energies above those of the CERN and Brookhaven accelerators, but below the frontier energies of NAL, have frequently been discussed. It is clear that NAL will support only a fraction, well under one-half, of U.S. high energy physics; moreover, concentration of effort on to a single laboratory would run counter to the pluralistic tradition of American science which has drawn much strength from the diversity of its style and approach. The total volume of unanswered problems in high energy physics which can be covered by an accelerator in the 30-100 GeV range is enormous. In addition to the obvious scientific merit of an intermediate range accelerator we also note that even with the strongest of management effort to make each of the large U.S. accelerators nationally available they still retain some regional character: The home-base of the users of such national accelerator facilities, including the AGS, the ZGS and SLAC, tends to exhibit a regional concentration. Since NAL will be constructed in the Midwest there is clearly a valid incentive for a regional upgrading to intermediate energies on the East and West Coasts.

In the face of these positive arguments for constructing a "sub-frontier" accelerator there remains the hard fact that the time interval between initiation of plans for construction of such a facility and its initial impact on physics is apt to be as much as 10 years, and by that time the frontier will have advanced further than it has today. In addition we have to consider that as a result of fiscal restrictions NAL will be developed much more slowly than its scientific and technical potential permit. Increasing the target areas and other associated facilities of our "leading" facility will presumably receive very high priority in the future, in competition with lower energy machines.

Considering these facts the panel concludes that:

> It would be difficult to justify the construction of new accelerator facilities employing conventional technology in the energy range below that of NAL.

On the other hand, we come to the opposite conclusion when considering the implication of the new technologies: In that case it appears that we have the objective of providing additional scientific tools in the intermediate energy range, preventing the over-concentration of facilities, maintaining the vitality of the existing nationally available high energy physics laboratories, and providing a pilot operation of the new accelerator technologies. These combined reasons would give ample justification for the construction of possibly two accelerators in the sub-frontier range.

In line with these considerations we recommend that:

> Budgetary projections permit the realization of one proton machine and one electron machine, each employing new accelerator technology, in the region near 100 GeV. These machines should, if at all possible, be sited to preserve the vitality of existing national high energy facilities.

In conjunction with recommendations originating from the potentials of new accelerator technology one also wishes to consider the logical upgrading of the Batavia NAL facility which, for reasons of fiscal stringency, was originally authorized at a reduced scope. The Batavia facility permits substantial upgrading of energy (from 200-400 GeV energy) at moderate cost, and permits considerable increases in its target areas, thus leading to support of a larger community of high energy physicists. For these reasons we recommend that:

a) The NAL accelerator be upgraded to its final design energy of 400 GeV once it has been operated successfully at 200 GeV and when some experience in research in these energies has been gained.

and

b) Further experimental facilities and target areas be authorized at NAL as the demand for experimental use at NAL expands and after the success of the initial experimental program has been demonstrated.

A thorough study has been carried out on the technical feasibility of adding a colliding beam storage ring facility to NAL; the study showed that this not only is a technically feasible step but also identified a large number of singular experiments which could be carried out at such a facility. Specifically this panel concludes that:

> A colliding beam facility at the NAL accelerator deserves serious consideration as a next step in extending the high energy frontier; however the construction of a storage ring at NAL should be dependent on the experience gathered by the experiments on the ISR at CERN which is expected to be in operation by 1971.

This conclusion is based on our conviction that a proton-proton colliding beam facility may not only be a "window into the future" as far as high energy experimentation is concerned (a 100 GeV colliding beam facility at NAL would be equivalent to a 20,000 GeV conventional accelerator in terms of center of mass reaction energy), but may in fact be in the long run the only avenue now open to extending physics into the extremely high energy domain.

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APPENDIX B

HIGH ENERGY PHYSICS MANPOWER SURVEY

I. INTRODUCTION

The High Energy Physics Advisory Panel, through one of its sub-panels, examined various aspects of the population of scientists engaged in High Energy Physics, both as they relate to the production of new scientists and to the pursuit of the science by established investigators. HEPAP feels that it has obtained a more accurate picture on the recent activities of the scientists (i.e., elementary particle physicists) produced in this field in the U. S. over the last ten years as well as a more complete description of the activities of scientists and graduate students presently working in the field, than has hitherto been available. As is the case with the most recent studies on the same subject [the Walker Panel Report (1966), the AEC Policy for National Action in the Field of High Energy Physics (1965), and the Ramsey Panel (1963)], emphasis was placed on the PhD scientists because of their key role in the field.

The information presented in this study was principally obtained from five sources which are continuously available should any future manpower studies requiring new or additional statistical material be undertaken. These were the following:

Source (1)	The Doctorate Records File compiled by the National Academy of Sciences, 1958 to 1967.
Source (2)	The 1966 National Register of Scientific and Technical Personnel assembled by the National Science Foundation.
Source (3)	The High Energy Physics Manpower Census started in 1966 by the Division of Research of the Atomic Energy Commission. Latest issue: May, 1968. Attachment I.
Source (4)	The American Institute of Physics.
Source (5)	Doctorate Recipients from United States Universities 1958-1966. National Academy of Sciences.

The National Academy of Sciences, the National Science Foundation and the Atomic Energy Commission are the sources of the basic data, and the appreciation and the thanks of HEPAP are extended to all of the individuals in these organizations who assisted in any way. By their excellent cooperation and through their compilation of material of this nature surveys such as this one are possible.

Dr. Fred Boercker of the National Academy provided the names of the PhD graduates from the Doctorate Records file. In addition, Mr. Tom Mills and Dr. Milton Levine of the National Science Foundation assisted the Atomic Energy Commission personnel in using the computerized information from their 1966 Register. Dr. Lewis Slack of the American Institute of Physics was consulted on various questions relating mostly to student enrollment. All the work involved in extracting the statistical information from the various sources was accomplished by members of the Division of Research of the Atomic Energy Commission. In particular, without the efforts of Dr. Arthur Greene and the staff of the High Energy Physics Section, this survey could not have been done.

II. BASIC TABLES

1. Description of Table 1

The AEC has compiled the most comprehensive list of scientists presently engaged in High Energy Physics and supported in whole or in part by Federal funds through one of the several Agencies with programs in that field. It is believed that this total is accurate to about 5%, the error being due to insufficient information from certain sources. For the purposes of this survey, it is believed that the summary is accurate enough. The AEC list does not include scientists engaged in High Energy Physics who are supported wholly by their universities or private funds or who are directly or indirectly supported by Federal funds not identified specifically for High Energy Physics.

The breakdown was designed to illustrate the composition of the present population of scientists in the field so that the sub-group composed of those scientists who received degrees in Elementary Particle Physics in the last ten years could be compared more readily with the whole population. In this connection, it is interesting to note that nearly 20% of the scientists currently active received their PhD degrees from foreign institutions and that, quite unexpectedly, nearly 15% of those now active received their PhD degree in the last ten years in fields other than Elementary Particle Physics as listed by the National Academy of Sciences. There is some evidence that would indicate that this is, in some instances, a matter of some PhD degree granting institutions preferring to grant more general degrees but it also represents some bonafide transfers of scientists from other branches of physics into High Energy Physics.

TABLE 1

Scientists Presently Supported by Federal High Energy Physics Funds

1.	Number of scientists who received PhD degrees prior to Fy 1958.	357
2.	Number of scientists who received PhD degrees from foreign institutions.	271
3.	Number of scientists who received PhD degrees in Elementary Particle Physics from U.S. institutions during the period Fy 58 through Fy 67 as defined by the NAS Survey. [Source (1)]	531
4.	Number of physicists who received PhD degrees in fields other than Elementary Particle Physics (as described by the NAS Survey) during the period Fy 58 through Fy 67. [Source (1)]	172
5.	Number of scientists who received PhD degrees since Fy 67 and are not yet covered by the NAS Survey.	104
6.	Number of scientists with degrees other than the PhD.	33
7.	Number of scientists who supplied incomplete information.	27
	TOTAL	1495

Source (3)

2. Description of Table 2

The main reasons for compiling the information in this table were to examine the current activities of physicists who received PhD degrees in Elementary Particle Physics over the last ten years both with respect to those still engaged in the science and to those who have left the field. The information available in the 1966 Register for the 1965, 1966 and 1967 graduates (total of 562 physicists) is rather poor and about half of the 265 unknowns in the next to last column in the table received their degrees in those years. As a result of these unknowns, the overall situation is not clear, and no strong statement can be made about physicists who have left the field. By the time the 1968 register is available at the end of the year, the group of graduates from 1965, 1966, and 1967 will be considerably more settled than they were at the end of 1966 and much better information should thus be available on the current activities of graduates of the years 1958-1967. It will probably be possible then to draw more meaningful conclusions from such information and HEPAP intends to up-date this survey when the 1968 Register is available.

The number of theorists listed for the fiscal years 1958 through 1962 was obtained by going through the records of all the theorists produced in those years since prior to Fy 1963 theorists in all fields of physics were lumped together. The number of theorists listed therefore for Fy 58 through Fy 63 is an interpolation, the basis being that if a theorist claimed to have one of his four listed scientific specialities in elementary particle physics he was assumed to be equivalent to one who from Fy 63 on was designated as having received his degree in elementary particle physics. In all other cases, i.e., for all of the experimentalists and all of the theorists from Fy 63 on the designation was made to the NAS by the individual scientist or his degree granting institution.

A large number of the scientists who are listed under the category of not being recently federally supported in HEP still listed their chief specialty and employment as elementary particle physics. In the case of those involved in education, many were both teaching elementary particle physics and doing some research with funds provided by their universities, or other sources. In fact, many not currently supported by a Federal Agency have active proposals under consideration. Some of the few who are now involved in industry also indicated continued involvement in elementary particle physics.

Those listed under government and non-profit laboratories include scientists in the Armed Services, the National Laboratories, NASA, NRL, and other government laboratories and at non-profit making private laboratories, but not supported by High Energy Physics Funds. The category headed other largely consists of people who are still active in HEP but who are employed in a foreign laboratory or who have returned to their native country. The unknown category includes, for the most part, people who did not fill out the register form but also includes many of those who returned to their native country after receiving their degree here and those who are deceased.

Of interest in a future study would be to determine the number of PhD graduates who earned their bachelor degrees in foreign countries and, in addition, the number of those returning to their native land after receiving their PhD degree. A more detailed analysis of what those people are doing who still claim to be active in elementary particle physics but who are not now supported by federal funds may also be of interest.

TABLE 2

Summary of Recent Activities of PhD Graduates in Elementary Particle Physics During the Period Fy 58 through Fy 67

Fiscal Year	-A- PhD Graduates in HEP[1]			-B- Present Activities of PhD Graduates Federally Supported in HEP[2]							-C- Recent Activities of HEP PhD Graduates Not Now Federally Supported in HEP[3]						TOTAL
				University[4]			National Lab[5]										
	Th	Exp	Total	Th	Exp[6]	Sub Tot	Th	Exp[6]	Sub Tot	Total	Ind.	Edu.	Govt. non-profit Labs	Other	Unknown	Subtotal	
1958	19	38	57	13	7	20	1	3	4	24	6	11	3	0	13	33	57
1959	18	49	67	8	12	20	5	8	13	33	7	8	6	0	13	34	67
1960	20	49	69	11	18	29	0	5	5	34	6	12	10	1	6	35	69
1961	31	66	97	18	17	35	0	4	4	39	10	18	10	2	18	58	97
1962	31	94	125	11	23	34	1	12	13	47	6	32	9	1	30	78	125
1963	72	83	155	20	20	40	1	12	13	53	16	40	12	0	34	102	155
1964	66	81	147	23	35	58	0	10	10	68	9	42	7	4	17	79	147
1965	76	104	180	16	30	46	3	8	11	57	16	51	13	7	36	123	180
1966	61	100	161	24	40	64	6	11	17	81	7	34	6	6	27	80	161
1967	83	138	221	29	47	76	5	14	19	95	10	27	9	9	71	126	221
TOTAL	477	802	1279	172	247	422	22	87	109	531	93	275	85	30	265	748	1279

[1] Source (1) and Source (5)

[2] Source (3)

[3] Source (2)

[4] Includes CEA, PPA, Cornell Research Staff.

[5] Mostly ANL, BNL, LRL and SLAC.

[6] Experimental Physicists are approximately divided evenly between Spark Chamber-Counters and Bubble Chambers.

3. Description of Tables 3, 4, 5, 6

Table 3 gives the area of speciality of recently PhD physicists so that the elementary particles group may be compared with the whole. These data are also plotted in Figure 1.

PhD's in the various physical sciences and engineering are listed in Table 4, and plotted in Figure 2.

Table 5 was supplied by Dr. Lewis Slack, Associate Director of the American Institute of Physics. It gives information about enrollments and degrees granted during the last eight years. It is based on a survey made yearly by the AIP.

Table 6 gives the amount of Federal support in High Energy Physics. The figures were supplied by the AEC.

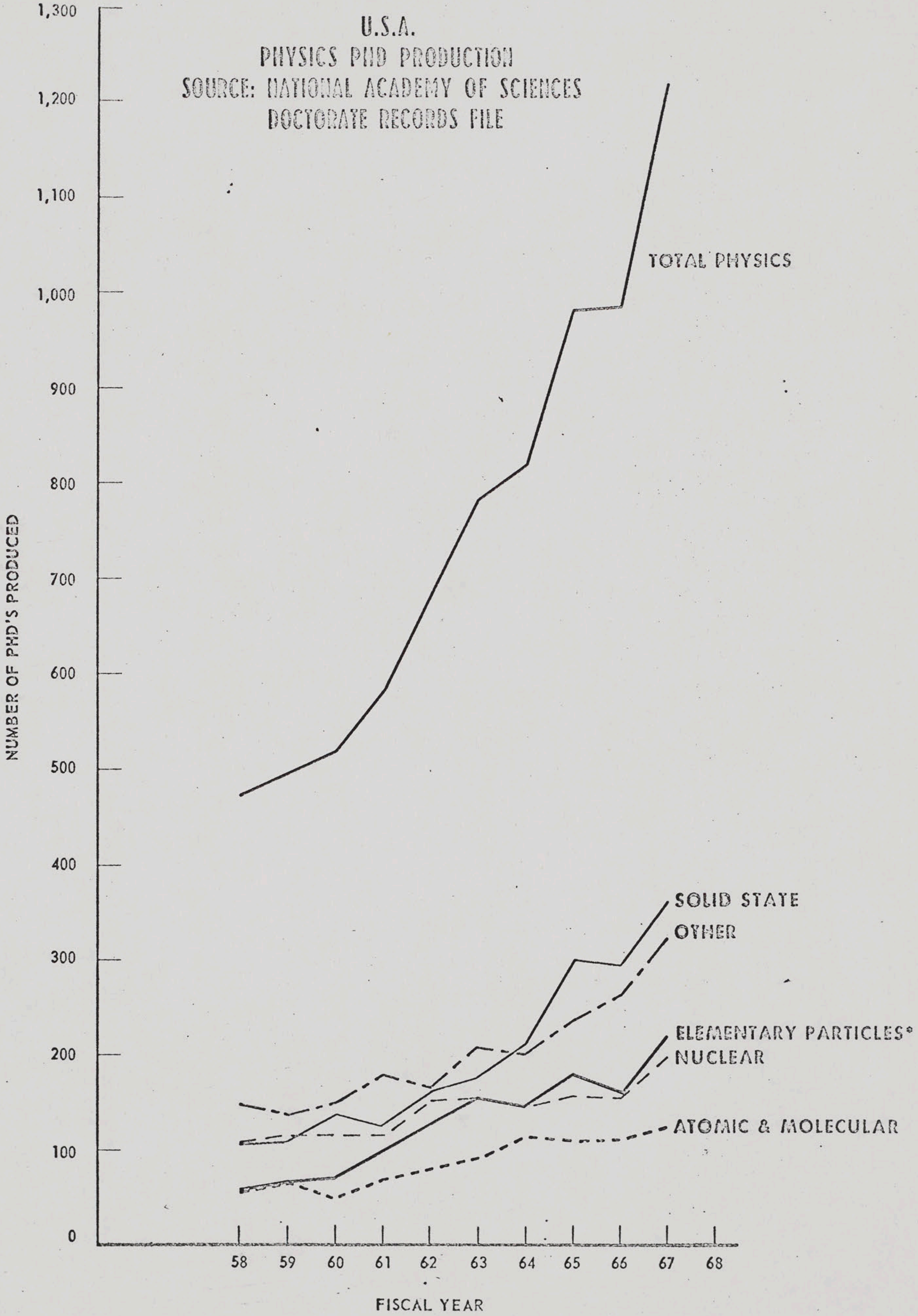
TABLE 3

Physics PhD, Field of Speciality[1]

Fiscal Year	Elementary Particles	Nuclear Structure Physics	Solid State	Atomic & Molec.	Fluids	Other[2]	Total
1958	57	108	107	57		147	476
1959	67	115	110	66	1	136	495
1960	69	117	136	49	4	145	520
1961	97	115	123	68	19	159	581
1962	125	151	161	81	30	134	682
1963	155	155	175	90	22	187	784
1964	147	147	211	114	14	186	819
1965	180	158	299	110	32	203	982
1966	161	154	295	111	28	234	983
1967	221	198	365	125	45	280	1,234
TOTALS	1,279	1,418	1,982	871	195	1,811	7,556

[1] Source (5)

[2] Includes Theorists in 1958-1963 who did not have a specialty in Elementary Particle Physics.



U.S.A.
PHYSICS PHD PRODUCTION
SOURCE: NATIONAL ACADEMY OF SCIENCES
DOCTORATE RECORDS FILE

*Includes portion of theory

FIGURE I

TABLE 4

Physical Sciences and Engineering PhD[1]

Fiscal Year	Physics	Math	Chemistry	Earth Science	Engineering	Astronomy	Total Phys. Sci. & Engr.	Other	Total PhD's All Fields
1958	479	238	964	190	629	20	2,517	6,253	8,770
1959	495	289	1,054	232	699	20	2,789	6,423	9,212
1960	520	291	1,077	253	792	11	2,944	6,790	9,734
1961	581	332	1,150	246	940	16	3,265	7,146	10,411
1962	682	388	1,137	249	1,215	28	3,699	7,808	11,507
1963	784	484	1,288	322	1,357	34	4,269	8,451	12,720
1964	819	590	1,351	312	1,662	45	4,739	9,585	14,324
1965	982	684	1,439	374	2,068	64	5,611	10,691	16,302
1966	983	766	1,580	399	2,273	66	6,067	11,798	17,865
1967	1,234	828	1,764	419	2,581	61	6,887	13,408	20,295
TOTALS	7,556	4,890	12,804	2,996	14,216	365	42,787	88,353	131,140

[1] Source (5).

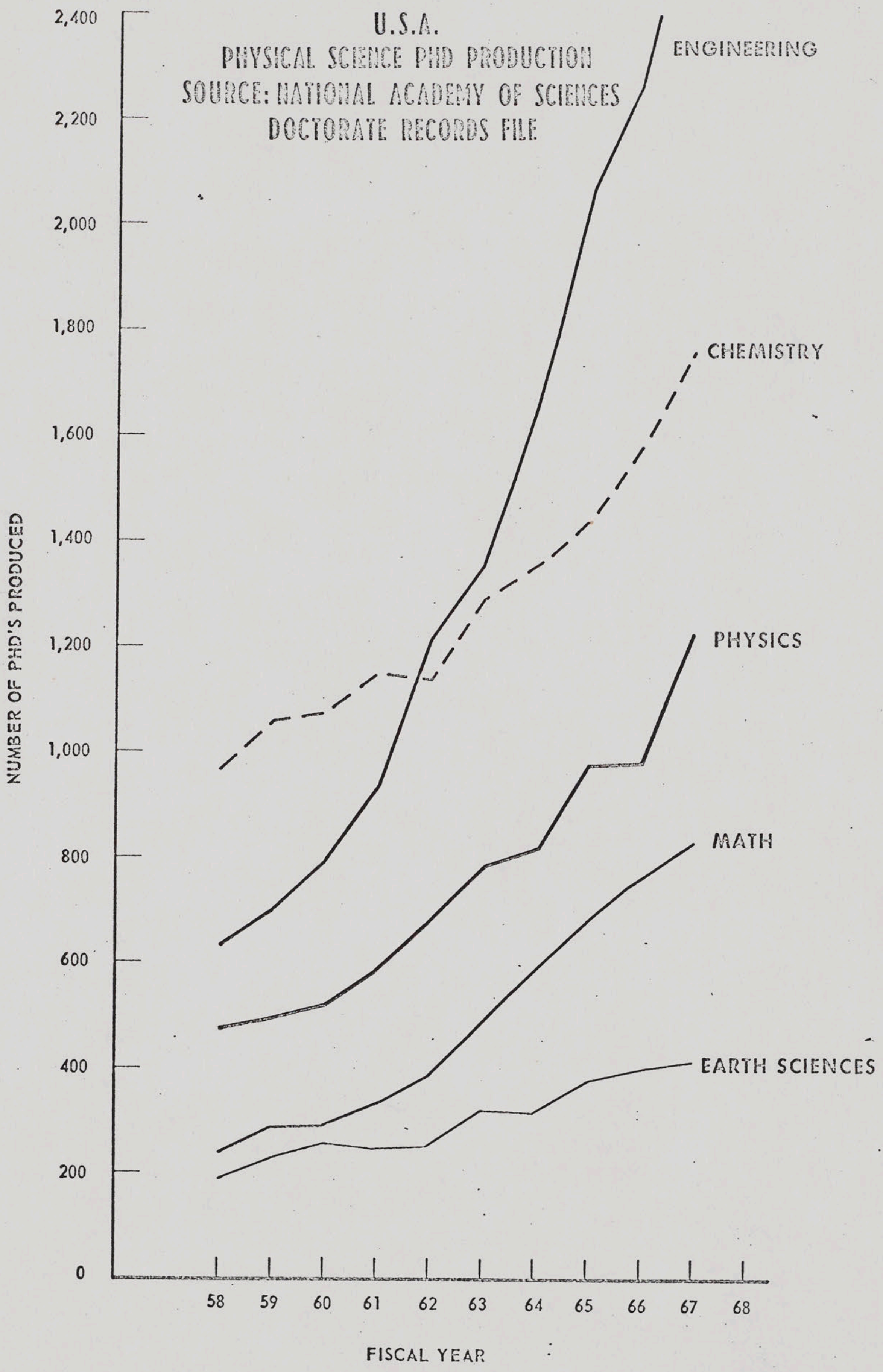

U.S.A.
PHYSICAL SCIENCE PHD PRODUCTION
SOURCE: NATIONAL ACADEMY OF SCIENCES
DOCTORATE RECORDS FILE
NUMBER OF PHD'S PRODUCED
2,400
2,200
2,000
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
58
59
60
61
62
63
64
65
66
67
68
FISCAL YEAR
ENGINEERING
CHEMISTRY
PHYSICS
MATH
EARTH SCIENCES

FIGURE II

TABLE 5

AMERICAN INSTITUTE OF PHYSICS

335 EAST 45 STREET, NEW YORK, NEW YORK 10017 • (212) 685-1940

ACADEMIC YEAR (July 1 to June 30)	PHYSICS DEGREES GRANTED			UNDERGRADUATE PHYSICS MAJORS ENROLLED		GRADUATE STUDENTS ENROLLED	
	Bachelor's	Master's	Doctorate	Jr. year	Sr. year	Total	1st year
1960-61	5293	1321	615	8264			
1961-62	5622	1431	699	7934	6633	11 308	
1962-63	5452	1850	858	7873	6386	12 265	
1963-64	5611	1907	792	7520	6676	13 046	4061
1964-65	5517	2045	983	7132	6514	13 629	4167
1965-66	5037	2050	948	7014	6296	14 876	4358
1966-67	5236	2193	1233	7345	5992	15 504	4162
1967-68				7822	6704	15 305	4010

TYPE OF INSTITUTION		1966-67 PHYSICS DEGREES GRANTED			1967-68 PHYSICS ENROLLMENT UNDERGRADUATE		GRADUATE	
		Bachelor's	Master's	Doctorate	Jr. yr. Majors	Sr. yr. Majors	Total	1st yr.
Type III - Grants Doctorate in Physics	N	2630	1689	1233	3982	3322	13 505	3251
	%	50	77	100	51	50	88	81
Type II - Grants Master's in Physics	N	911	504		1411	1239	1800	759
	%	18	23		18	18	12	19
Type I - Grants Bachelor's in Physics	N	1695			2429	2143		
	%	32			31	32		

Area of Concentration for 1966-67 Degree Candidates

The estimated number of graduate physics degrees awarded in 1966-67 was 2,200 master's degrees and 1,000 doctorates.

for Master's candidates Physics Specialty	% Students
Solid state physics	22%
Nuclear physics	10
Atomic & molec. physics	5
Optics	5
	42%

for Ph. D. candidates Physics Specialty	% Students
Solid state physics	28%
Nuclear physics	19
Atomic & molec. physics	9
Elementary particles	18
	74%

TABLE 6

Federal Agency Support of High Energy Physics

Actual

Fiscal Year	AEC	NSF	Other	Total
1964	124.9	3,940	5,080	133.9
1965	149.8	3,794	5,040	158.6
1966	159.4	9,700	7,600	176.7
1967	151.1	11,641	7,873	170.6
1968	151.7	9,271	5,550	166.5

Source: High Energy Physics Section, Division of Research U.S. Atomic Energy Commission.

III. OBSERVATIONS

1. Present Supply of Scientists

HEPAP concludes that there is not now and in the near future there will not be a shortage of physicists in the High Energy Physics program and that the program is in fact highly successful as a producer of trained scientists who go into teaching and various other services. As shown in Table 1 there are about 1500 PhD's associated with Federally Supported High Energy Physics programs and in Table 2 about 750 recent PhD's not in Federally Supported High Energy Physics programs. Since most of the research in this field is supported by the Government it may be concluded that a substantial but not definitely known fraction of the 750 represent scientists who although they were trained in high energy physics and still maintain an interest in the field, actually have as their main occupation teaching, government service, industry or research other than high energy physics.

2. Future Supply of Scientists, Near term

There are approximately 1100 graduate students in High Energy Physics beyond their second graduate year. It is believed that this large number indicates a continued up trend in the number of PhD graduates per year indicated in Table 2 and will be about 300 in 1968 and 1969. Only a small fraction of these scientists will find positions in High Energy Physics programs because of the present very stringent budgets.

3. Future Supply of Scientists, Long term

The longer range supply of scientists trained in the field may be affected by several factors. Dr. Lewis Slack, Associate Director of the American Institute of Physics, in response to inquiries by HEPAP commented on some of these factors:

> "To turn to the effect of the draft - our own data indicates that it will not be nearly so drastic as predicted last April; the situation in physics, therefore, is consistent with that reported in the Times last Sunday (Sept. 15, 1968) for all fields of graduate study. Eighty-eight chairmen of departments offering the PhD departments which had 1992 first year students last year, reported 1922 acceptances

> for fall admission in 1968. Some --- anticipate that strictures in support of research will have a more noticeable impact than the draft, at least for the fall term. These same chairmen anticipate an appreciable drop (about 20%) in the proportion of their own graduating seniors with graduate school plans."
>
> "Superimposed on all of these effects on the numbers of students in the pipeline, is the matter of the steady drop in the relative number of students in physics. It remains to be seen whether this reflects a real disenchantment with physics as it well may be in the case of undergraduate majors who fail to go on to graduate work. Alternatively, it may be a matter, in the case of the decline of the number of undergraduate majors, of greater choice of fields available (oceanography, etc.). Perhaps the answer will come out of the attrition study for which questionnaire returns are just coming in. I understand a graduate student of Merton's in the department of Sociology at Colombia is working on a problem involving disenchantment of good students with physics arising from feeling it has no social relevance or use."

Further information on physics graduate students has also been supplied by Dr. Slack and is given in Attachment II.

4. Supply of Engineering Support Manpower

An attempt was made to estimate the number of engineers working in support of the High Energy Physics Program by examining the Form 189 records at the AEC. There seems to be such wide divergencies in these figures that we believe the lack of an accepted common system of defining and reporting these activities makes it impossible to compile reliable totals. However, the consensus of the Sub-Panel based on their own experience is that the number of engineers in support of High Energy Physics is not greater than the number of physicists. That number, 1500, is sufficiently small compared with the number of engineers in the country that there can be no problem with supply. (There may at times be a problem in making positions sufficiently attractive to compete with industry for the best engineers.) Should a future accurate estimate of supporting staff be required, the AEC or some other agency would have to undertake a detailed survey similar to that made by the AEC as the basis for Source (3).

5. Cost of Graduate Training

HEPAP has not undertaken to estimate the cost of graduate education per PhD student in High Energy Physics. Although the number of PhD degrees awarded annually in High Energy Physics are listed in Table 2, and Table 5 gives the amount of Federal support provided in these years for High Energy Physics, HEPAP believes that these data cannot be meaningfully combined for the purpose mentioned.

As one reason for this view, we note that any distinction between National Laboratory funds expended for "in-house" research and funds devoted to the support of university-based programs would be difficult to draw with precision, and in practice is based on criteria that differs materially from laboratory to laboratory. Secondly, although High Energy Physics has proven to be an excellent field for attracting and training innovative scientists, neither the university-based programs nor the national laboratory programs have graduate education as their only justification and objective.

6. Comparison of 1963 Predictions and Current (1968) Realizations

The projection of manpower engaged in high energy physics and the funding of the program in future years is subject to many inaccuracies, and it is well to realize the limitations of such predictions. These limitations are evident in comparing the predictions of the Ramsey Panel, which when made in 1963 were as good an estimate as anyone knew how to make, with the realities of five years later.

	Ramsey Report		This Report
	1963	1968	1968
Manpower	800-900 (est)	1200 (prediction)	1500 (est)
Federal Support of Program	$\$143 \times 10^6$ (actual)	$\$317 \times 10^6$ (prediction)	$\$166.5 \times 10^6$ (actual)

The first observation is that the actual manpower associated with the program is significantly higher than the predictions. One possible reason for this is that in 1963 there was no good survey of the then current situation; the 800-900 estimate was low, and this led to consistently low estimates for future programs. The present estimate is based on the AEC survey [Source (3)] and is certainly much more accurate.

The second observation is that the actual funding represents an average growth rate of 3% per annum while the predicted figure corresponded to a 15% increase per annum. The major difference here is in the construction items. The FFAG was not authorized, the AGS program was reduced, and the 200 BeV program delayed by three years. If high energy physics had been funded at the rate predicted there would have been an even greater discrepancy in the manpower projections.

HEPAP concludes, therefore, that if future predictions are to have a reasonable reliability, it is essential that they be based upon very accurate current information and that they be subject to continuous corrections as each year's statistics unfold. In order to achieve better reliability in predictions, HEPAP recommends that a continuous program rather than a one-shot effort be undertaken, particularly as they relate to manpower studies.

AIP Pub. No. R207

ATTACHMENT II

AMERICAN INSTITUTE OF PHYSICS

335 EAST 45 STREET, NEW YORK, NEW YORK 10017 • (212) 685-1940

1966 - 67 GRADUATE STUDENT SURVEY

The Survey: During the academic year 1966-67 an estimated 15,500 students were enrolled in graduate physics departments in the United States. About 9,300 students (60%) returned usable questionnaires. This 60% sample approximates the distribution of the total graduate physics student population with respect to geographic location.

I. Summary of statistics on background information:

Total population = 15,500 students

Age distribution:

years	% students	years	% students
21	0.6%	26	12.4%
22	3.2	27	10.1
23	12.6	28	7.2
24	15.4	29	22.5
25	14.7	no report	1.2

Citizenship: 86% of the estimated 15,500 students are U.S. citizens. This distribution remains the same when we examine only those who expect the Ph.D. in 1966-67.

Sex: 3.3% are women.

State of high school: Over 50% of the graduate students (excluding foreign students) took high school physics in one of the following nine states:

California
Illinois
Massachusetts
Michigan
New Mexico
New York
Ohio
Pennsylvania
Texas

High school physics: 94% of the students took some physics in high school.

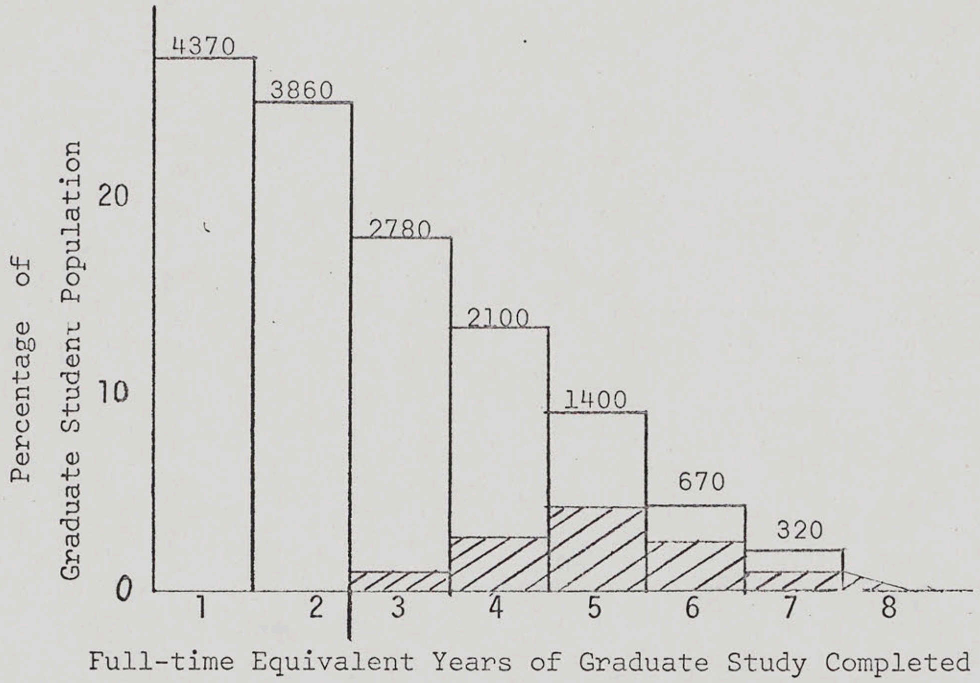
II. Graduate education:

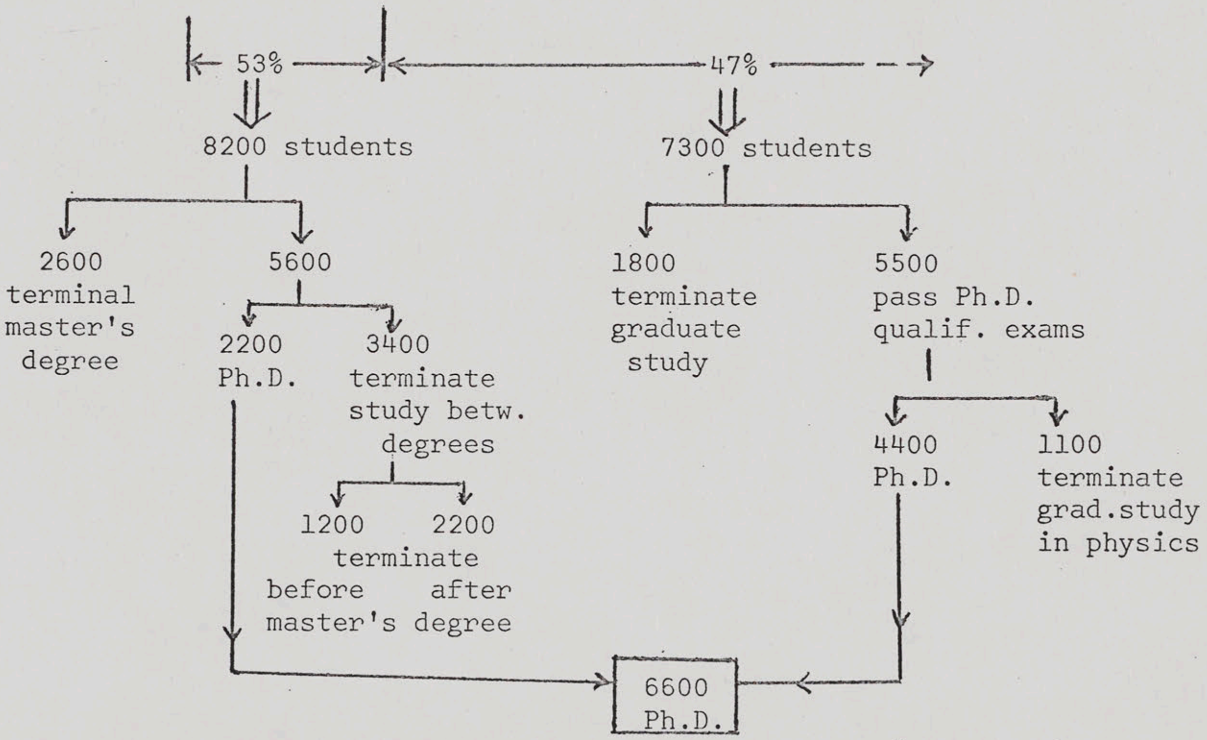
Student status: 83% are full-time students.

Baccalaureate origin of graduate students

Type of Institution Attended	% Graduate Students	Nonphysics Baccalaureates [2,500 students]
Doctorate-granting	56.3%	61.3%
Master's-granting	11.7	12.0
Bachelor's-granting	20.7	15.0
Foreign	11.3	11.7

1966-67 Distribution and Plans of 15,500 Graduate Physics Students





Undergraduate Major and Type of Baccalaureate Degree

Major	Distribution of Graduate students		
	Total	B.S. Recipients	B.A. Recipients
Physics	83.4%	74%	26%
Engineering	6.9	99	1
Mathematics	3.8	61	39
Physical Science	3.8	61	39
Chemistry	0.6	67	33
Education	0.4	*	*
Astronomy	0.2	*	*
Other fields	0.9	*	*
	100.0%		

* fewer than 50 respondents

Distribution of Students who Completed 3 or more Years of Graduate Study in Physics

Type of Bachelor's Institution	Total No. of Students	Ph.D. Qualifying Examination Status		
		Passed	Will Retake	Not Taken
Ph.D.-granting	4,400	80%	3%	17%
Master's-granting	650	68	5	28
Bachelor's-granting	1,400	73	6	21
Foreign	850	71	4	25

Geographic Mobility Of the 13,300 graduate students who received their bachelor's degrees in the U.S. 45% are attending graduate schools in geographic regions different from those in which they received their bachelor's degrees.

Geographic Mobility of Physics Students* between Receipt of their Baccalaureates and their Entrance into Graduate Schools

Geographic Region	Distr.of all Students by Bach. Inst. Col. 1	% of Students in Col.1 leaving Region Col. 2	Distr.of all Students by Grad. Inst. Col. 3	% of Students in Col.3 entering Region Col. 4	Net change **
New England	11.4%	60%	11.0%	59%	-3.6%
Middle Atlantic	22.8	45	19.0	34	-16.6
E. N. Central	19.0	41	19.7	43	+3.3
W. N. Central	8.6	55	7.0	45	-18.4
South Atlantic	8.6	42	12.0	58	+39.3
E. S. Central	4.2	49	3.8	44	-9.7
W. S. Central	7.9	37	6.7	26	-14.8
Mountain	3.5	48	4.7	61	+33.7
Pacific	13.9	35	16.1	43	+15.4
	99.9%		100.0%		

* Foreign graduate students are excluded from this analysis. Total = 13,300 students.

** Net change = $\frac{(\text{Column 3} - \text{Column 1})}{\text{Column 1}} \times 100$

Area of Concentration for 1966-67 Degree Candidates

The estimated number of graduate physics degrees awarded in 1966-67 was 2,200 master's degrees and 1,000 doctorates.

for Master's candidates Physics Specialty	% Students	for Ph. D. candidates Physics Specialty	% Students
Solid state physics	22%	Solid state physics	28%
Nuclear physics	10	Nuclear physics	19
Atomic & molec. physics	5	Atomic & molec. physics	9
Optics	5	Elementary particles	18
	42%		74%

Graduate Institutions Enrolling large Numbers of 1966-67 Graduate Students
(Frequency measured by the respondents to this survey)

Doctorate-Granting Institutions

Rank	Name	No. of Students
1	U. of Ill.	236
2	U.C.-Berkeley	234
3	Harvard U.	230
4	N.Y.U.	202
5	Purdue U.	197
6	M. I. T.	196
7	U. of Maryland	194
8	U. of Wisconsin	168
9.	Stanford U.	162
10.	Cornell U.	153
10.	U.C.L.A.	153
		2,125

Master's-Granting Institutions

Rank	Name	No.of Students
1	San Diego St. Col.	44
2	San Jose St. Col	35
3	Trinity Col.(Conn.)	31
4	Cal.St.Col.(Long Beach)	29
5	Cal. St. Col. (L.A.)	28
5	Fairleigh Dickinson U.	28
6	Franklin & Marshall Col.	26
7	San Fernando Valley St.C.	22
8	Texas Western Col.	21
8	La. St. U. New Orleans	21
9	John Carroll U.	20
10	De Paul U.	19
		324

Baccalaureate Sources of Graduate Physics Students
(measured by the respondents to this survey)

Doctorate-Granting Institutions

Rank	Name	No.of Students
1	M. I. T.	314
2	U.C.- Berkeley	183
3	CCNY - CUNY	174
4	Cal. Inst.of Tech.	127
5	R. P. I.	112
6	Harvard U.	111
7	U. of Illinois	109
8	U.C.L.A.	107
9	Cornell U.	100
10	U. of Michigan	96
		1,433

Master's-Granting Institutions

1	San Diego St. Col.	47
2	Fairleigh Dickinson U.	34
3	Texas Western Col.	30
4	Union Col. N.Y.	29
5	Cal.St.C.-Long Beach	25
5	Miami U. - Ohio	25

Bachelor's-Granting Institutions

Rank	Name	No.of Students
1	St.Joseph's Col.	35
2	Pomona Col.	32
3	Reed Col.	31
4	Manhattan Col.	30
5	Carleton Col.	24
5	Oberlin Col.	24
7	Amherst Col.	23
7	St. Procopius Col.	23
9	U.of Scranton	21
9	Valparaiso U.	21
11	Swarthmore Col.	20
12	Harvey Mudd Col.	19
13	Grinnell Col.	18
13	Le Moyne Col.	18
13	Occidental Col.	18
13	St. Olaf Col.	18

III. Employment of New Master's Degree Recipients Est. Total = 900

An estimated 900 new master's degree holders are planning immediate employment. Of this group, 73% had accepted positions by August 1967. An average of 1.3 job offers were made to those who accepted employment.

New Master's Degree Recipients (Cont.)

Type of Employer	Distr. of new Physics Masters	Median Monthly Starting Salary	Starting Salary Chemistry Masters [1]
Coll.or Univ.	19%	$ 710	$ 660
High School	9	550	*
Industry	48	865	790
Government	21	740	*
Other	3	-	
TOTAL	100%	$ 825	

1 Chemical & Engineering News (Oct.23, 1967, 1.93

* Insufficient data.

IV Employment of New Doctorate Recipients Est. Total = 1000

885 new physics doctorate-holders reported that they received job offers from different employers. Of this group 54% received one offer, 26% received 2 offers, and 20% received three or more offers. 55% of the new doctorate recipients had accepted positions by August 1967.

Type of Employer	Distr. of new Ph.D.-holders	Median Monthly Starting Salary	Starting Salary for PhD Chemists [1]
Coll. or Univ.	62%	$ 800	$ 890
Industry	22	1250	1100
Government	12	950	940
Other	4	--	--
TOTAL	100%	$ 950	

Work Activity

The median monthly starting salary for new physics doctorate recipients engaged in research was $840.- The median monthly salary for those engaged in teaching and research was$920.- All other categories of work activities had fewer than 50 respondents in the survey.

Trends

An increasing proportion of new Ph.D. recipients are employed by educational institutions.

Type of Employer	Distribution of new doctorate recipients in:			
	1963-64	1964-65	1965-66	1966-67
Industry	15%	17%	22%	22%
Educational Inst.	57	56	60	62
Government	12	11	12	12
Other	16	16	6	4

Prepared by the Project for
the Analysis of Educational
and Manpower Data in Physics
January,1968

May 27, 1968

ATTACHMENT I

SPECIALTIES OF HIGH ENERGY PHYSICISTS
PHD's AND GRADUATE STUDENTS
BY LOCATION

From January 1968 Updating of
High Energy Physicist Listings.

Institution	#PhD Theory	#PhD BC	#PhD SC-C	Both BC&SC-C	#PhD Other or Unknown	Total PhD	G.S. Theory	G.S. Exp.	G.S. Unknown	G.S.* Total	Known Federal Contract Supp
Ames Laboratory, Iowa State University	11	4	1		2	18	15	4		19	AEC
Argonne National Laboratory	9	14	15		14	52	4	12		16	AEC
Arizona, University of			5			5					NSF
Arizona State University	1					1	1			1	OSR
AEC Headquarters		2			4	6					AEC
Boston University	5					5	7			7	OSR
Brandeis University	7	3			1	11	8	2		10	AEC,NSF,OSR
Brookhaven National Laboratory	11	38	26	1	41	117		2		2	AEC
Brown University	11	1		4		16	7	6		13	AEC,NSF
California, Univ. of, Berkeley	7	2	1		3	13	3			3	NSF,OSR, ONR
California, Univ. of, Irvine	5	4	5			14	2	7		9	AEC,NSF
California Institute of Technology	12		12		2	26	19	23		42	AEC,ONR
California, Univ. of, La Jolla	10	3	9	2		24	12	11		23	AEC
California, Univ. of, Los Angeles	16	5	5		2	28	13	10	1	24	AEC,NSF
California, Univ. of, Riverside	6	5	1			12	8	7		15	AEC
California, Univ. of, Santa Barbara	9		4		1	14	4	1		5	AEC,NSF
California, Univ. of, Santa Cruz	1					1					NSF
Cambridge Electron Accelerator					14	14					AEC
Carnegie-Mellon University	8	8	4			20	1	6	6	13	AEC
Case Western Reserve University	7	5	10			22	8	14	2	24	AEC,NSF,ONR
Catholic University	1		2			3		9		9	NSF,ONR
Chicago, University of	7	5	16	1	2	31	18	24	2	44	AEC,NSF,OSR,NASA
New York, City University of (City College)		4				4					NSF
Colorado, University of	11	3		2		16	8	13		21	AEC,NSF,ONR,OSR
Columbia University	13	3	15	1	4	36	17	32		49	AEC,NSF
Cornell University	14		26		5	45	16	27	4	47	AEC,NSF,ONR
Duke University	7	4				11	3	1		4	AEC,NSF
Florida State University	3	5				8		2		2	AEC
Georgia Institute of Technology	1					1					NSF
Harvard University	16	5	16	1	5	43	10	34	4	48	AEC,ONR,OSR
Hawaii, University of	3	1	3	2		9		8		8	AEC
Idaho State University					1	1					NSF
Illinois, University of, Urbana	10	12	8	1	3	34	10	31	1	42	AEC,NSF,ONR
Illinois, University of, Chicago Circle	1					1					NSF
Illinois Institute of Technology	1	3				4					NSF

SPECIALTIES

Institution	#PhD Theory	#PhD BC	#PhD SC-C	Both BC&SC-C	#PhD Other or Unknown	Total PhD	G.S. Theory	G.S. Exp.	G.S. Unknown	G.S. Total	Known Federal Contract Supp
Indiana, University of	4	6	1			11					NSF
Institute for Advanced Studies	4					4					OSR,NSF
Johns Hopkins University	3	6		2		11		4		4	NSF
Kansas, University of		3				3					NSF
Lawrence Radiation Laboratory	17	29	28	7	22	103	19	74	1	94	AEC, NASA,OSR
Louisiana State University			6		1	7					NASA,NSF
Loyola University, Louisiana	1					1					NSF
Maryland, University of	16	8	3		1	28	9	12		21	AEC,NSF,OSR
Massachusetts, University of, Amherst	7	5	1		1	14	7	5		12	AEC,NSF
Massachusetts, University of, Boston	1					1					NSF
Massachusetts Institute of Technology	26	7	7		20	60	49	45		94	AEC,OSR
Miami, University of	4					4					OSR
Michigan State University	3					3			5	5	AEC,NSF
Michigan, University of	7	6	14		1	28	8	30		38	AEC,NSF,ONR,OSR
Minnesota, University of	13		3	4	1	21	6	10		16	AEC
National Accelerator Laboratory			2		20	22					AEC
National Bureau of Standards	5					5					ONR, AEC
Naval Research Laboratory			5		3	8					NSF,ONR,NASA
Nebraska, University of	3					3					NSF
New York University	8					8					NSF
SUNY, Stony Brook	25	3	6			34	8	6		14	AEC,OSR
Northeastern University	5		9			14					NSF
Northwestern University	3	7	1		3	14		2		2	NSF,ONR
Notre Dame University	6	6			1	13					NSF
Oak Ridge National Laboratory		1	1		5	7	1			1	AEC,NASA
Ohio University	1	5				6					
Ohio State University	6		4	2		12	3	6		9	AEC
Oregon, University of	5					5	5			5	AEC,OSR
Pennsylvania, University of	10	3	18	5	1	37	6	24	2	32	AEC,NSF
Pittsburgh, University of	11					11	3			3	AEC
Princeton University/PPA	15	4	13	1	7	40	2	28	2	32	AEC,ONR,OSR
Purdue University	13	13		2	3	31	3	8		11	AEC,NASA
Rochester, University of	9	3	12	2		26	13	16		29	AEC,NSF
Rutgers, The State University	3	3				6					NSF
Southeastern Massachusetts Tech. Inst.	1					1					NSF
Southwest Center for Advanced Studies			1			1		2		2	OSR
Stanford University/SLAC	24	11	43	4	19	101	13	31	17	61	AEC,ONR,OSR
Stevens Institute of Technology					2	2					NSF

Institution	#PhD Theory	#PhD BC	#PhD SC-C	Both BC&SC-C	#PhD Other or Unknown	Total PhD	G.S. Theory	G.S. Exp.	G.S. Unknown	G.S. Total	Known Federal Contract Supp
Syracuse University	15	2		2		19	13	11	1	25	AEC,NSF,ONR
Tennessee, University of		2				2					
Texas A & M			3			3		4		4	NASA,OSR
Tufts University	3	4	4	1	2	14	3	6		9	AEC
Utah, University of			6			6					NSF
Utah State University		1				1					NSF
Vanderbilt University	1	4				5					NSF
Washington, University of			9		1	10					NSF
Washington University, St. Louis	1					1					NSF
Wayne State University	3					3					NSF
Wisconsin, University of	10	12	4			26	10	27		37	AEC,NSF
Yale University	9	5	8	2	1	25	17	15		32	AEC,NSF
Yeshiva University	2					2	2			2	NSF,OSR
TOTALS	527	298	396	49	219	1,489	394	652	48	1,094 *	

NOTES:

1) The PhD classification includes physicists who hold PhD degrees and/or are working at a PhD level.

2) Included in the graduate student classification are students possessing an MS degree or equivalent training and who:

a. Have passed preliminary examinations or their equivalent and
b. Are planning or engaging in research in high energy physics suitable for a PhD thesis.

3) The Other or Unknown column includes physicists indicating solely the following specialties or combinations of them:

a. Emulsion experiments
b. Computer employment in research
c. Accelerator design and development
d. Accelerator operation
e. Device design and development
f. Administration

*Due to limited response from several of the Federal agencies the statistics on graduate students are lacking considerably.

Dec. 24

Dear Pief,

A quick note before I leave regarding

Chapter Drafts VI and VII.

VI: Content O.K. but the form worries me.
It contains the same recommendations (word for word)
as the "recommendations", with a little more 'conclusions'.
I believe that we should rewrite VI such that
it is ~~supplementary~~ supporting material for
Recommendations 1, 2, 3, 7, 9, 10, 11, 12, 13.
Some of your phrases may be used to strengthen
the conclusion + recommendations.

VII. This chapter seems unbalanced. It is mostly
against bubble chambers. We must be careful
here: We propose full exploitation of 72", 7', 12'

new construction of 25'. So we must be circumspect when saying "B.C. technique has passed its prime". (Special position? Why phase out 300 l. which is more modern and bigger than the other ANL chambers except the 12').

Too specific in respect to B.C., not enough
specific
in respect to the other items

No reasons given for endorsing or not endorsing new Beam Facilities (p. 11)

We are too vague in regard to new items (p 12), and too explicit in the negative aspects of B C.

I remember our talk on Stanford Campus about this. But that chapter does not convince. It must be right for five years.

Cost Projections should include a 2000 machine and its facilities.

Excuse the scribble!

Happy new Year

V.W.

Duke University
DURHAM
NORTH CAROLINA

DEPARTMENT OF PHYSICS

POSTAL CODE 27706
TELEPHONE 919-684-8111

January 3, 1969

Professor Victor Weisskopf
Physics Department
Massachusetts Institute of Technology
Cambridge, Massachusetts

Dear Viki:

Here is another version of Chapter XII. I have not been able to talk with Kent Curtis about it yet, but have sent him a copy and will try to get with him on Monday. I have had a good letter from Aihud Pevsner and Dick Zdanis on the computer in the university and have used some of Zdanis' words.

Best regards,

Earle

Earle C. Fowler

ECF:mm

STANFORD UNIVERSITY

STANFORD LINEAR ACCELERATOR CENTER

Mail Address
SLAC, P. O. Box 4349
Stanford, California 94305

January 8, 1969

Professor V. F. Weisskopf, Chairman
Department of Physics
Massachusetts Institute of Technology
Cambridge, Mass. 02139

Dear Viki:

As promised I have made some revisions in Bj's chapter but I am very unsure whether the revisions are an improvement. Since, as we agreed, the purely instrumental innovations "since Ramsey" are now incorporated in another chapter all I could really add were occasional references to specific experimental progress, and I also tried to eliminate some of the more technical theoretical language.

I think in general this chapter reads quite well, thanks to Bj, but I think unavoidably it is addressed to a relatively small audience.

Best regards,

Pief.

W. K. H. Panofsky
Director

cc: Dr. B. Hildebrand w/enc.
Dr. J. Bjorken w/enc.

THE UNIVERSITY OF WISCONSIN
MADISON 53706

DEPARTMENT OF PHYSICS
475 NORTH CHARTER STREET

Jan.2, 1969 JAN 7 1969

Professor Victor F. Weisskopf
Dept. of Physics
Massachusetts Institute of Technology
Cambridge, Mass. 02139

Dear Viki:

On reading over the Conclusions and Recommendations section, I have two general comments. First, it seems to me we have to avoid both the accusation that we have our heads in the sand regarding the fiscal situation, and we have to avoid any appearance of saying that inadequate budgets have resulted in inadequate second-rate research programs. Any request for an increase in funding under present conditions seems to me to justify the charge that we are unaware of what is going on around us. We can properly say that existing facilities are underutilized, but we should also say that to the extent they are used, their output is of the highest quality. I tried to meet the problem by saying that the high quality of recent research output in spite of budget limitations which allow only partial utilization of our capital investment emphasizes the relatively large return per additional research dollar which could be realized if more funds were available. We can then logically recommend increases in funding whenever budgetary limitations will allow it. If we imply that we cannot mount a productive research effort with present funds, then the conclusion is either that the budget must be increased which most people think is at present unrealistic or that the funds might as well be cut back if they are unproductive anyway. The point of view which I think we were trying to get across does not seem to me to come through in the final draft circulated. I am not satisfied in particular with the first sentence in the last paragraph on page 1, and I think it is very bad on page two to say for several years existing facilities have not been effectively utilized.

My second general comment is that we have ended up doing what most such committees do, that is removing specific recommendations (about which there is nearly always some controversy and therefore on which the government agencies most need advice) and leaving only generalities which really do not say anything or say only what is obvious. For example, at the end of conclusion 1, we recommend a funding level appropriate to maintain high energy physics at a vigorous level. But what level is that? We don't even say whether it is more or less than at present. Who is to tell the government what funding level is appropriate to maintain HEP at a vigorous level? HEPAP, I should think. I would like to be more specific about the level of support we think would allow full utilization of present facilities, and desirable future rates of growth, but show that we are realistic by recommending an attempt to reach such levels whenever it becomes fiscally feasible.

Under 5, we have again removed a specific recommendation against starting new small bubble chamber groups and substituted a recommendation which not only says nothing specific, but seems to imply that the considerations that are relevant are purely financial, whereas my understanding was that there are technical reasons why a small bubble chamber group will find it hard to compete with the large established outfits.

Why are we so cagy about what we recommend under 12 in the way of further electron-positron colliding-beam facilities? We surely mean specifically at SLAC. It is only at SLAC that beams are available which allow a greater potential than at CEA. I should think in fact that at the present time we would definitely not recommend construction of further such facilities anywhere else.

Now a few detailed comments. Under 8, I had the impression that there was agreement that the decision to move the ANL chamber to NAL need not and shouldnot be made at this time. Certainly I did not feel we had the technical information needed to make that judgement now. What we should recommend is that the technical and budgetary flexibility be preserved in planning for the next few years so that the option to move it remains open.

Under 10, I do not understand the reason for the different recommendation regarding electron ring and superconducting or cryogenic accelerators, unless it is political. Either type, if it turns out to be feasible, could be built either at a new installation or at an existing laboratory using perhaps some existing facilities or buildings. I doubt that the word "conversion" is strictly applicable in either case, although it has political advantages; if it is used it could be equally applicable to either of the new techniques.

I have also read the latest edition of poetry and liked it generally, so I will make only a few detailed suggestions for changes. In the third paragraph, I think the first sentence is too strong, as it implies that other sciences have had no important impact. We should make the point that physics is the most advanced of the sciences and must be included in any discussion of the impact of science upon society without implying that the discussion should be based just upon physics.

The first paragraph on page 3 is strongly overstated and should be omitted or at least rewritten. Power production, electronics, metallurgy, and environmental control, and I suspect also development of plastics existed and reached an important level of advancement without utilizing quantum mechanics. Understanding of quantum processes has however permitted astonishing new advances in these areas.

The middle paragraph on page 9 makes an important point, but it is a very touchy one and must be carefully phrased if it is not to antagonize those in other areas. A comment about international aspects might also be fitted in here. The last paragraph on page 8 is also a very touchy one which has to be carefully worded.

The statement on page 11 that federal support of high energy physics has not increased since 1966 will be difficult to believe in view of the approval of NAL; at least people will not believe that support has levelled off. With tight budgets all around, and with our big pet project virtually the only new one to be authorized, with all the attendant publicity, I think we will leave a bad taste in people's mouths if we loudly complain that we are not getting enough money. It is all right to make the point that HEP has not been growing relatively to other areas and relatively to the growth of higher education. Some people seem to think we have been getting more than our share, and we should make it clear that we have not and that we are as hard pressed by the budgets as the next man. We should also make it clear that continuing at present budget levels involves a deliberate decision to slow down the advance of American science generally. But I don't think we should make a special plea for a bigger share of the budget for HEP or predict dire consequences if we don't get it. I don't think we will get more at least until the war is over, and I hope and believe that we will continue to do worthwhile and exciting physics anyway, although we will be less productive than we might have been.

Sincerely yours,

Keith

Keith Symon

STANFORD UNIVERSITY

Stanford Linear Accelerator Center

Mail Address
SLAC, P. O. Box 4349
Stanford, California 94305

December 19, 1968

Professor V. F. Weisskopf, Chairman
Department of Physics
Massachusetts Institute of Technology
Cambridge, Mass. 02138

Dear Viki:

I have had a chance to read your poetry chapter and would like to give preliminary comments.

In general I am very enthusiastic about the approach: The whole story about evolution of the basic assault from atomic through nuclear to elementary particle physics comes through very well. Also the last part which relates the spirit of basic research to the actual accomplishment of applied tasks should work well. I have some comments in detail, mainly aimed at avoiding irritations among our friends and non-friends in other sciences.

I think that one cannot quite state that our present civilization is based on the achievement of the physical sciences. Political scientists would argue that such aspects as political organization and social customs carried over from Europe have much to do with the current aspects of our civilization, possibly as much as does its technical base. I suspect that if you say that our present standard of living, rather than our present civilization, is based on the physical sciences few people would object.

I think you might also draw some criticism in calling physics the most advanced of the sciences (bottom of page 1) just because that term is so ill-defined. If by advanced one means basic understanding this may well be true; but on the other hand some biologist might argue that some physical ideas have had their origin in biological problems. For instance, the law of conservation of energy, I believe, originates from Helmholtz's work on biological systems. Somehow or other one might try to substitute for the concept of "most advanced" the concept of having been most successful in reducing questions to simpler forms which at least might be tractable in giving specific answers. Another approach might be to point out that results in physics have been irreversable, that is new advances have limited the range of validity to older concepts but have not reversed them. In contrast this has not been true at all in the social sciences, and to some extent has not been true in biological sciences where theories and concepts have undergone cyclic variations. Somehow one should make the point here that once a physical discovery has been made the world is never the same again, and that unless one participates in a direct way in this process the rest of the world will overtake one's society.

On page 2 there are some problems of definition: You say we have divided the development of atomic research into 3 parts, but then later you use the term "atomic science" for just the first part. Somehow one has to invent a better term than "atomic research" for the advances in science from atomic through nuclear to particle physics.

On page 4 the fact that the nuclear force is stronger but of shorter range than the "atomic force" which you identify as being electrical does not quite come through.

The top of page 5 - people might disagree that the study of nuclear processes led to an understanding of the history of the universe; critics might say that things are not as clear as all that and will point to many of the outstanding unknowns. It might be wise to weaken this phrase slightly.

It might be worthwhile to point out in the second paragraph of page 5 that in the long run nuclear energy in its various forms is one of the strongest conservation forces we have. We will run into serious limitations of fossil fuels in 50 to 100 years and limitations of fissionable material in 100 to 200 years, and therefore new approaches, be they fusion or something else, are eventually needed. Moreover, if intelligently managed and if not controlled by short-range economic pressures, nuclear type energy sources will give considerably less problems with pollution than do fossil fuels.

In the second paragraph on page 6 you are saying that we are at the beginning of the period of research into the "third stage," that is - elementary particle physics. I think this slightly belittles the accomplishments to date and it may also scare the reader unduly in terms of financial implications; if 400 BeV machines are just the beginning then what are we talking about? Actually I think one can be somewhat prouder of the actual achievements in this third stage by stating that we are in the middle of understanding. In a similar vein I think that the statement "We cannot assess their full scientific and practical significance" might be split in terms of saying that we are in the middle of understanding the scientific significance but only at the beginning of understanding the practical significance. It would be better in this part of the story to again emphasize the time lag between scientific and practical understanding rather than pulling them together into a single sentence.

There is some editorial difficulty on the bottom of page 6 because you are describing anti-matter as being "in complete symmetry" with ordinary matter while a few lines below you indicate the violation of this symmetry.

I think this can be fixed by saying in line 8 from the bottom, "The existence of anti-matter in apparent symmetry with ordinary matter,".

The material on page 7 is extremely eloquent in presenting the great open questions. The only additional comment which might be worth adding has to do with the open question of a fundamental length. You pointed out in the beginning of the section that one of the really surprising but unappreciated factors in nuclear physics was the fact that quantum mechanics survived the transition from atomic to nuclear scale. Nobody really quite knows whether this is still true if we go to extremely small dimensions since none of the fundamental constants involve a characteristic length, and one might interpret the QED violation experiments in this more fundamental light.

I am glad that you put your intensive vs. extensive argument into pages 7 and 8. I would tend to be slightly more biased than your statement, "A healthy development of science requires that both tendencies are pursued with equal strength and vigor." Somehow the thought has to come through that if the spearhead (to use your term) fails to penetrate further, then in the long run the extensive efforts will degenerate into organized mediocrity and to prevent this from happening the intensive activities may need more or less support than the extensive activities. The important thing is that there is enough support for the intensive activities to progress at a reasonable rate and equality may not be the right criterion.

I think that the point on page 10, second paragraph, could be made stronger concerning the usefulness of students trained in high energy physics. It is a combination of the fact that students trained in high energy physics have worked in large research groups with complex machinery and in teams and the fact that they have participated in truly exciting new and basic things which makes them such useful citizens in other activities also. By emphasizing the former but not the latter one might gather the impression that one talks primarily about training of super-technicians.

I hope you will find these comments useful. In general I think this piece is really a very excellent approach.

We are gathering some pictures which Mr. Blumberg will have available which could be introduced as illustrations into Chapters VI and VII to make them somewhat more lively. We are also working on updating the figure on accelerator status in Chapter VI, and hopefully Bernie Hildebrand is critically going over the tabular material in Chapters VI and VII.

With best regards,

Pief

W. K. H. Panofsky
Director

CALIFORNIA INSTITUTE OF TECHNOLOGY
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PASADENA, CALIFORNIA 91109
PHYSICS

December 20, 1968

Professor V. F. Weisskopf
Physics Department
Massachusetts Institute of Technology
Cambridge, Massachusetts 02139

Dear Viki:

I am returning your draft No. 1 of the Introduction to the HEPAP Report with a few editorial-type changes indicated in red pencil.

With the exception of the first page and a half, I like your draft very much. The first page continuing through the first paragraph on page 2, I do not like and hope that a better introduction to the introduction can be composed. One objection is that if I were antagonistic toward high energy physics, after reading the first sentence and the first paragraph I would say, "Aha, just as I expected. They are going to claim that science is great and that high energy physics is the greatest science." Another comment is that I doubt if the statements made on the first page will convince anybody of anything.

I would prefer to see the report begin with a factual description of what high energy physics is all about and postpone the statements which are laden with value judgments. It might start, for example, "High energy physics is . . . . ". Most of your draft beginning just above the middle of page 2 is of this nature and I think it is very well done.

I intended to try my hand at a new introduction to the introduction and may do so yet. However, to avoid a delay in the return of your manuscript, I am sending it back with these comments.

I know that I also owe you a statement on the "panelization of high energy physics" and the need to encourage individual initiative. I have not forgotten, but since returning from the HEPAP meetings, I seem to have spent all my time doing one thing after another, all of which had to be done "right now". It is frustrating.

With best regards,

Sincerely yours,

Bob

Robert L. Walker

RLW:jc

12-10-68
DRAFT #1

I. INTRODUCTION

Our present civilization is based upon the achievements of the physical sciences in the last two centuries. Our daily life, our industrial production, our thinking and planning, our vision of the future, are all derived from our growing insight into nature. Consistent rational investigation of nature led to an ever widening understanding of natural phenomena. The gradually discovered facts and laws of nature changed the attitudes of man ~~versus~~ towards his environment. Fear and superstition gave way to rational knowledge which was used to manipulate nature and to serve man's purpose.

Science is a continuous process. It is the essence of science to proceed from one problem to the next and to admit no limits of knowledge. This constant strive for deeper insight is part of the drive of our civilization, to improve conditions of life and to change society into a better one. The dynamics of this process is intimately connected with the evolution of scientific knowledge -- in many instances it is based upon it.

non-physicists won't like it.

Any discussion of the impact of science upon our society must be based upon ~~knowledge of~~ the development of physics, the most advanced of the sciences. Broadly speaking, physics in the eighteenth century dealt with mechanics and heat. It produced the steam engine, and other mechanical devices.

The nineteenth century was the age of electricity and its well-known technical applications. The twentieth century is the age of atomic research. The development of this research has been so rapid that it is often difficult to see the whole picture in perspective. This lack of perspective explains perhaps why high-energy physics is often misunderstood. Omit. In order to try to see the problem more clearly, we shall divide the development of atomic research into three parts.

Today everyone knows that the atom consists of a very small but ~~solid~~ dense atomic nucleus with electrons revolving around it. The first step in atomic research was to recognize the existence of the outer electron shell and to study its laws. The essential advance which made this possible was the conception of quantum theory. It was the key to the understanding of most of the phenomena which surround us in our terrestrial environment. One cannot exaggerate the importance of the quantum theory and of the discoveries to which it led. The knowledge of what goes on in the electron shell of the atom gave us a basis for the understanding of the constitution of all the substances which make up the world around us -- metals, solid bodies, gases, fluids and chemical compounds. It has also enabled us to understand electrical phenomena, the relation of matter with light, and the emission and absorption of radiation. It led to an understanding of production of energy by fire, electricity and by chemical processes. We believe ~~It is probable~~ that the problems of biology, such as heredity, differentiation and evolution are all connected with the question of the quantum nature of molecular structure.

Every industrial activity today is affected in one way or another by atomic science; modern production of power is based on a thorough analysis of the underlying atomic processes. Electronics, and the science of communication~~,~~ could not exist without a knowledge of the quantum nature of electron motion. Modern metallurgy makes use of the quantum structure of metals and the production of plastic materials would be impossible without modern quantum chemistry. The understanding of the electron structure of the atom gave us the means of control of our terrestrial environment.

The basic force which keeps the electrons together in the atom -- and which, therefore, is responsible for the atom's quantum structure -- is ~~of~~ electrical in nature. ~~It is the power of attraction between the atomic nucleus and the electrons which surround it.~~ The atomic nucleus plays the part of a ~~solid~~ fixed charged core at the centre of the atom. The internal properties of the atomic nucleus are not relevant for the atomic phenomena which we have mentioned so far.

The second phase of atomic research, concerns the structure of the nucleus. To understand the significance of this second step, it is necessary to keep in mind a basic law of nature, a quantum law, which states that the smaller the object being studied, the higher must be the energy used to penetrate into the object. Hence, the investigation of the structure of the nucleus required much higher energies than those usually available on earth. Such energies, ~~with~~ ranging from a hundred thousand to millions of electron volts, became available in the early thirties when ~~artificial~~ particle accelerators ~~of~~ in this energy ~~level~~ region could be built. It then became possible to ~~discover~~ investigate the structure of the nucleus and it was found that nuclei are composed of protons and neutrons. What was even more important was the fact that there exists a nuclear force keeping these ~~two~~ constituent parts together. A new physical force was thus identified. It became clear that the laws of quantum mechanics which govern the electron shell are also the laws of nuclear structure, if allowance is made for the fact that the motion is governed by the nuclear force instead of electric forces. It was a great success for quantum theory that it should also be applicable to the newly discovered nuclear phenomena. They include nuclear reactions, the transmutation of a nucleus of one element into one of another, the excited states of a nucleus whose study has led to nuclear spectroscopy analogous to atomic spectroscopy. It also includes radioactive phenomena, artificial radioactivity, fission and fusion, and, recently, the production of a variety of short lived transuranic nuclei, new man made elements. Furthermore, it was found that nuclear processes are responsible for the energy production in the sun and in the stars. Moreover, the study of nuclear processes led to an understanding of the history of the universe. It could be shown that the elements were formed in the centre of stars and in star explosions. The history of matter could be traced from an original hydrogen cloud to its present forms.

Good. - No Bombs.

The practical side of all this is well known. ~~We know that~~, Contrary to all expectations, nuclear physics has not remained an esoteric pure science but ~~that it~~ has eminently practical applications. In nuclear reactors, the fission of the nucleus has been turned into an outstandingly productive source of energy. ~~It warrants the~~ There is hope that the nuclear fusion process will also some day find a practical application as a steady energy source and not only as an explosive. Furthermore, artificial radioactivity has opened up new fields of research in medicine and in science as a whole, from biology to metallurgy.

The third stage of development deals with the protons and neutrons. What do these elementary particles consist of? What is their structure? Because of the law already mentioned above, substantially higher energies are required in order to penetrate into the structure of these particles. One can get a glimpse of the structure of these particles only if energies a thousand times higher than those required in the second stage are available. There is a natural source of energy of this order of magnitude --

cosmic radiation. But cosmic radiation, like natural radioactivity in earlier days, is too dispersed and too difficult to control to be useful as a systematic tool of research. Accelerator techniques, on the other hand, have been developed to such an extent that they can provide up to hundreds of billions of electronvolts. Cosmic rays may still be of importance for a look at energies much higher than our present accelerators can attain.

What ~~was~~ is the outcome of the third stage of research? At this time no systematic account can be given because we still are at the beginning of this period. As yet, we are unable to formulate the results in a simple way; we cannot assess their full scientific and practical significance. Nevertheless, it is obvious that great perspectives are opening up. We are beginning to understand the real nature of the nuclear force. We are faced with a world of entirely new phenomena such as the existence of many excited states of the proton, the emission and absorption of a large number of different mesons, the existence of anti-matter in complete symmetry with ordinary matter, the phenomena of weak interaction characterized by the appearance of neutrinos, and the mysterious heavy electrons. The weak interactions have been of special interest because some long cherished laws seem to be violated, such as the left-right symmetry of natural laws and the symmetry between world and anti-world.

When we observe matter exposed to high energy beams, we face a strange new ~~and unusual~~ world of phenomena, new particles, new reactions, new forms, a new behavior of matter, much richer in its features than anyone would have guessed. Moreover, the study of these events is bound to lead us closer to an understanding ~~the problem~~ of the fundamental structure of matter. We may yet find that protons and neutrons are composite systems of even more fundamental particles. We are approaching what might be called the primeval history of matter. Perhaps such research will produce answers to some major questions that are still unanswered: The nature of electric charge, the connection between the different forces of nature, gravity, electricity, nuclear forces and weak interactions, the expansion of the universe, the origin of matter. We cannot, at this stage, speak of practical applications; they are still remote. All we can offer at the moment is a description of a wealth of new phenomena -- a systematic classification and formulation, but not yet an explanation.

The development of atomic and nuclear physics is not exclusively directed towards higher energy and smaller units. The physics of the electron shell and nuclear structure physics are constantly developing further and gain in breadth every year. Broadly speaking, the evolution of science goes into two directions: The "intensive" direction towards new and unknown realms; the "extensive" direction towards more breadth, inter-connection and completeness. The development from the electron shell to the nucleus and then twoards subnuclear phenomena is an "intensive" one. The recent astrophysical research, in particular the discoveries of radioastronomy, belong in the same category. On the other hand, we observe today a continuous development and expansion of atomic physics into new fields, such as laser physics, low temperature physics, solid state physics, material sciences, plasma physics and biology. These are developments of the "extensive" kind. A healthy development of science requires that both ~~tendencies~~ categories ~~are~~ be pursued with equal strength and vigor. High energy physics is an essential part of the *intensive* activities. It is the spearhead of science into the innermost structure of matter.

The value of fundamental research does not lie only in the ideas and results it produces. The spirit that prevails in the basic sciences affects the whole scientific and technological life because it determines the way of thinking and the standards by which its creations are judged. An atmosphere of creativity is established that penetrates to every frontier. The applied sciences and technology adjust to the intellectual standards that are developed in the basic sciences. This influence works in many ways: A good ~~part~~ proportion of fundamental-research students go into industry; the techniques that have been applied to meet the stringent requirements of fundamental research, serve to create new technological methods. ~~We quote~~ Two examples coming from high energy physics: are ~~T~~he techniques of measuring very short time intervals, and the development of the computer for pattern recognition. ~~Altogether,~~ T the style and the level of scientific and technical work are determined primarily in pure research. This is one of the important social functions of pure science; it establishes the climate in which all scientific and technological activities flourish: it pumps the life-blood of ideas and inventiveness into laboratories and factories.

There is another point which must be considered here: It is the spirit of idealsm and determination directed towards the exploration of nature, which pervades the centers of pure research. The people working in them are less prone to the feeling of aimlessness of our civilization which is observed in too many segments of our society. It may be of great import to our present situation, that there exist strong centers of activity in our society with goals beyond mere increase of wealth and comfort. The idealistic orientation of these groups also produces an atmosphere which is conducive to easier solutions of problems in regard to social and racial differences among their numbers.

Good

One of the most important influences of basic science on society comes from its role in higher education. Here the "intensive" frontier of science is of particular significance. When students are introduced to the workings of nature, the open frontiers and the unsolved fundamental problems are bound to be the center of interest. There is more to it than just the teaching of science. There is no scientific education without the active pursuit of research. The young men who will shape our future must be immersed in the spirit of inquiry, they must be faced with the basic problems and unsolved mysteries of nature, they should share the joy of new understanding. They must have been exposed to the atmosphere of research at the frontiers of knowledge with its continuous questioning of routine methods and the need of finding new ways to accomplish things, in order to be effective in the face of any problem, be it one of science or otherwise. Basic research, therefore, must be an essential part of higher education.

High energy physics research plays a special role in the educational process. It is strongly tied to the universities, most of its practitioners are university professors; furthermore the national high energy laboratories have very close relations to academic research. It should be emphasized that a number of factors such as the relatively large size of research groups, the necessity of team work, the exploitation of complex machinery, are helpful in preparing the students for work in large, modern ~~industrial~~ technical enterprises.

Viewed in this frame, it becomes obvious that pure scientific research fulfills an important social role and should be supported in such a way that it is able to continue to do so in the future. Up to about 1966, the support of basic science and science education in the U.S.A. was generous and this growth was commensurate to our student population and gave rise to the outstanding position of this country in almost all scientific fields. A natural equilibrium resulted between the different basic sciences, which properly reflected the basic relative needs and opportunities of different fields. In 1966 high energy physics was supported at about 5.5 percent of the total of $3.2 billion for basic science. We believe that this percentage is still a reasonable one. Since 1966, however, federal support of academic science increased at a much slower rate than before; and the support of high energy physics stayed constant in dollar value, corresponding to a decrease in actual effort. Hence, the pursuit of basic science has been seriously slowed. The American Scien~~ce~~tific enterprise ~~establishment~~ may be able to sustain such a slowdown for a year or two, but serious consequences will show up if this condition is not soon remedied.

The present slowdown of scientific activity coincides with an unusual increase in higher education. New universities are founded, more students are seeking education. The number of graduate students increases today at a rate of almost 10 percent, much higher than the birth rate or the increase in the GNP. Should the new generation get less scientific training than the previous one, at a time when science becomes an ever increasing factor in our lives? The future position of the U.S.A. in the world, in industry and culture, may be threatened.

It therefore, seems imperative to adjust the support of basic science to the growth of higher education. This was not done in the last few years: In particular HEP was kept at a level which did not correspond to the growth of higher education in the USA and to the vast opportunities of this fundamental field. ~~of science.~~

# # #

THE UNIVERSITY OF MICHIGAN
ANN ARBOR

THE HARRISON M. RANDALL LABORATORY
OF PHYSICS

TEL. NO. 313-764-4437

January 2, 1969

JAN 6 1969

Professor V. F. Weisskopf
Department of Physics
Massachusetts Institute of Technology
Cambridge, Massachusetts

Dear Viki:

I like your new version of the introduction. It is enthusiastic and compelling. Very nice! Suggestions: p. 9, middle paragraph will unnecessarily irritate non scientists. Perhaps corrected by changing 'too many' to 'some' line 15, eliminating 'mere' line 17.

p. 10: next to last line. Eliminate 'properly'. Understood, better left unsaid.

p. 11: The ending is strongest if you finish at 'lives?', line 19. The rest is clearly implied.

The conclusions and recommendations section is also getting in good shape. The new format is a big improvement over the previous seperated sections.

Suggestions:

C. and R. 1 and 2 read quite redundantly -similar statements appear in both. I understand the idea is to make #1 the general recommendation and #2 the specific but the distinction should be sharpened up or the two combined. Shouldn't #7, the paragraph on equipment, be included here too since we maintain it is as important as operating?

C. and R. 3. I still feel that more emphasis should be given to the 200 GeV - it is <u>the</u> most critical item for H.E.P.; significant funding must be approved by Congress this year - and it would be a mistake to assume it is completely in the bag.

You know, shouldn't we somewhere in this document express our appreciation of the support the country is giving to this project, rather than just appearing annoyed at how slowly the money is coming?

In R.3.2 we should also include experimental facilities to properly exploit the 200 GeV - the present budget for this is just a starter.

C 5. The emphasis seems to have switched to examination of finances, rather than analysis of technologies and their potential. I think both should be included.

C.R. 8. The new bubble chambers are as yet unproven. So I would change the next to last line p. 6 to "... chambers can be expected to be useful for such ..." In the recommendation the 25' should be mentioned - as it stands we are not commenting on it.

C.13. A misprint. The single beam would have to have 22,000 GeV, not 28,000 GeV.

Best regards,

Kent

Kent M. Terwilliger

KMT:aa

Dec 22, 1968

Dear Viki,

Your introduction is an excellent job. The tone, I think is about right. I agree that the justification should be as broad as possible. Our paper goes to a wide audience and different arguments appeal to different people. To that end I would add, in a brief mention, bombs and plowshare as practical aspects on page 5. Also because of its prominence I would make a specific example of C-14 application to photosynthesis and genetics. A few other minor points are indicated by red pen on the copy enclosed.

I am not sure that it is suitable, but do you think that something like the enclosed paragraph might be useful as a transition between stage 1 and 2 in your story.

Possible transition
between phases of atomic science
narrative ??

The structure of man, body and mind, is made of atoms and molecules and ~~its~~ in its functions is ultimately governed by the laws that govern these particles. It is a wonder that the mind so constituted has been able to reflect upon its surroundings and itself and to understand these laws. More wonderful still is the quest to understand the deeper layers - the nuclear and sub nuclear domains of matter and energy

The present format of conclusions and recommendations is much better than our old format. I have only a few comments.

The first is that recommendations 1 and 2 are very similiar, in fact one has to read carefully to get the difference. Would it be better to put both recommendations in one section — we recommend -- and furthermore we recommend -- as in section 3.

The second refers to section 6 ~~on page 5~~ second paragraph, page 5. Following the sentence about university users and graduate students bringing ideas etc. to the national laboratories, the inverse should also be noted:- Similiarly university science is stimulated and graduate student experience is enriched by contact with the advanced professional science at the National Laboratories.

The third refers to section 10, last recommendation, page 9. I think that the implication regarding the time of the new technology accelerator is to late. We should say: in a few years, or early in the coming decade, or somthing to prepare the AEC for the real possibility that it may be very soon.

Best Wishes for a Merry
Christmas and New Year

Ed.

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THE ENRICO FERMI INSTITUTE
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Office of the Director

December 20, 1968

JAN 2 1969

Professor V.F. Weisskopf
Massachusetts Institute of Technology
Department of Physics
Cambridge, Massachusetss 02139

Dear Viki:

I liked the first draft dated December 10th of your poetic document very much. Of course, each of us would go about writing such a document in his own way and if I were to start from scratch, the result would probably be quite different, but probably no better. Therefore, I think I shall limit myself to a few specific comments.

First of all the selection of material you have used and the general organizing seemed to me to be vastly superior for our purpose to the review of Greenberg's book that you sent to us. That review seemed to me to suffer from the limitation that far too many arguments at too many different levels were presented. Your present effort is much more clearly on the target.

My other comments concern simply the selection of a few words, which may possibly antagonize our friends in other scientific fields. The very first sentence seems to me to bring too much credit to the physical sciences. There certainly is more basis to our present civilization than the achievements of physical sciences. I, for one, would be willing to give Picasso and James Joyce some credit. I would suggest that the statement be somewhat softened. Incidently, the phrase "based upon" appears three times on the first page.

Again on the first page in the third line from the bottom, it is stated that physics is "the most advanced of the sciences". I can imagine that not everyone would agree with that. My own view is that Physics is the most elementary of the sciences, but I do not recommend your using that phrase because it can be easily misunderstood. In a certain sense, physics is the most successful of the sciences because it s laws are most comprehensive. After all of this philosophical discourse, I see no need to say that it is the most anything in order to put across the point in your sentence. The necessity for basing a discussion of the impact of science on our society on the development of physics is simply that physics has had an enormous influence on the development of other sciences and society.

Finally, I suspect that a Congressman might be irrated by the wording at the beginning of the second paragraph on page 2. It is probably not true that "everyone knows" what you say they know.

With these small exceptions, I am quite satisfied with what you have written. I hope that everything is going as well with regard to the other material you have been collecting together. I trust that you and Hildred had a good time putting together the conclusions and recommendations. Season's Greetings!

Sincerely,

Bob

Robert G. Sachs

RGS:lb

D?

U of C-AUA-USAEC

ARGONNE NATIONAL LABORATORY

May 22, 1968

Professor Victor F. Weisskopf
Department of Physics
Massachusetts Institute of Technology
Cambridge, Massachusetts 02139

Dear Viki:

I want to register a strong protest concerning the wording of your letter of May 17 to Paul McDaniel concerning HEPAP's views on the bubble chamber situation. My primary concern relates to the second sentence of the second paragraph on the second page of your letter, which states in part that "The expected neutrino interaction rates in the 12-foot chamber are too small to permit quantitative measurements of unknown parameters ...." In our telephone conversation of May 8, I understood that you had agreed to change that to read "...some of the relevant parameters..." in place of "unknown parameters." This appears to me to be a significant change since there are certainly some unknown parameters that can be determined in the 12-foot chamber, just as there is useful work that can be done at Brookhaven with the 7-foot chamber.

The fact that the change was not made relates, I believe, to the other aspects of that paragraph that we discussed, but which I agreed to leave for further discussion between you and other members of the Panel. After thinking over the matter and after seeing the outcome of your discussions with other members of the Panel, I have come to the conclusion that the decision to include the entire paragraph was a serious mistake.

It seems to me that a determination of the expected neutrino physics in the 12-foot chamber is a technical matter requiring careful technical evaluation. It certainly would have been perfectly proper for HEPAP to have undertaken such an evaluation and made the judgment set forth in your letter, but at no time has HEPAP been presented with a substantial part of the available information required for making the judgment.

The formal presentation of a technical judgment without careful examination of the facts is bound to damage the credibility of all decisions made by HEPAP.

9700 South Cass Avenue, Argonne, Illinois 60439 · Telephone 312-739-7711 · TWX 910-258-3282 · WUX LB, Argonne, Illinois

I do not know whether there is anything that can be done about this now, but I should like to encourage the Panel to examine its methods and procedures in regard to technical judgments much more carefully.

Sincerely,

Bob

Robert G. Sachs

RGS:mc

cc: Dr. Paul W. McDaniel
Members of HEPAP

UNIVERSITY OF CALIFORNIA

LAWRENCE RADIATION LABORATORY
BERKELEY, CALIFORNIA 94720

April 30, 1968

Professor Victor F. Weisskopf
Massachusetts Institute of Technology
Department of Physics
Cambridge, Massachusetts 02138

Dear Viki,

The Bevatron Experimental Facility was cut back after the Berkeley HEPAP meeting to $\$3.9 \cdot 10^6$ for FY 1969. For some reason that I have not traced down, the old figure was used in a five-year projection. This project is now being re-submitted for FY 1970 at $\$4.1 \cdot 10^6$. The increase from 3.9 to 4.1 is escalation. The AEC had the lower figure and knew that it was the correct one. Your letters to McDaniel about the bubble chambers and equipment funds appear all right to me.

I shall be at BNL Thursday and Friday, May 2-3, and then on Monday to Rutherford and CERN.

Sincerely,

Ed.

E. J. Lofgren

EJL:amn

HIGH ENERGY PHYSICS CONSTRUCTION PROJECTS

	FY 1969	FY 1970
200 Bev Accelerator	230.0	
14' Bubble Chamber, BNL	~~16.9~~ 17.5	
Electron-Positron Storage Ring, SLAC	17.65	
Bevatron Experimental Facility, LRL	6.85	
HEP Building, University of Pennsylvania	2.3	
Technical Services Building, BNL	2.4	
PPA Research Building		1.7
Bevatron Staging Building, LRL		1.1
Engineering Service Building, CEA		0.7
Addition to Assembly Area, ANL		1.0
Computer Building, SLAC		2.2
Experimental Equipment Fabrication Facility, BNL		2.5
Research Laboratory, SLAC		2.7
HEP Building, Columbia University		1.6
HEP Building, University of Wisconsin		1.5
HEP Building, University of Rochester		2.0
New Injector, ZGS, ANL (AE only)		2.0
Physics Building, Phase III, BNL		3.0
40" Bubble Chamber Facility, ANL		1.0
ZGS Control Computer, ANL		1.0
$9M^3$ Bubble Chamber Facility, ANL		0.8
Physics Building Addition, LRL		2.1

	FY 1969	FY 1970
HEP Building, Mass. Inst. of Tech.		5.0
HEP Laboratory and Office Additions, ANL		4.0
SLAC - Modification to 30 Bev		20.4