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UNITED STATES
ATOMIC ENERGY COMMISSION
Washington 25, D. C.

May 18, 1961

Dear Jerry:

I enclose the promised documents on possible international projects. As you know, these are not official proposals. The document on the Bio-Medical accelerator was prepared by John Hall with help from the AEC Division of Biology and Medicine. That on the High-Flux Research Reactor was prepared by members of the Division of Research and the Division of Reactor Development with help from me; Dr. Seaborg has read it and concurred. I prepared the document on Accelerators; Paul McDaniel helped refine it.

Since the various documents are written by different people, a relative assessment by one person might be useful. All three projects have appeal from the political standpoint. This is perhaps the most attractive feature of the Bio-Medical Accelerator; indeed, Chuck Dunham doubts that such a machine should be built as a purely national facility. The very high energy accelerator would, of course, be scientifically desirable on any basis. From the pure standpoint of American scientists, it may well be that a given amount of money would be better spent for a very high energy national accelerator, rather than to pool it with funds from other countries to build a still larger machine. The political considerations are, however, very appealing. In addition to the obvious ones, is the fact that Soviet scientists (especially Veksler) have indicated that should such a project be embarked upon, they would give serious consideration to significant opening up with respect to their technology and industrial practices relating to such things as steel and copper.

The High-Flux Reactor Center has appeal from both the economic and the political standpoint. Furthermore, in the opinion of some of our reactor technologists,

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real advantages might be gained pooling scientific and technical manpower on such a project. They doubt that this country alone would embark on a project of this magnitude.

Perhaps one of the most important aspects of any such international projects would be the fact that influential intellectual leaders from the East and the West would be thrown into intimate contact for long periods of time.

Sincerely yours,

Leland J. Haworth
Commissioner

Dr. Jerome B. Wiesner
Special Assistant to the President
for Science and Technology
The White House

Enclosures

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MODERATELY HIGH-ENERGY (500 MEV) AND HIGH INTENSITY ACCELERATOR FOR BIO-MEDICAL RESEARCH

1. Need for bio-medical synchrotron

Use of the Berkeley cyclotrons has demonstrated the usefulness of heavy particles in dealing with diseases associated with pituitary function, conditions such as acromegaly, malignant diabetes, and cancers dependent in some degree on the production of pituitary sex hormones. Other work in a still more experimental phase shows that good cerebral lobotomies and laminectomies can be achieved and the technique promises to be a new "bloodless" technique for the neurosurgeon. Much of the most significant work going on today in molecular biophysics is being done with the existing Berkeley Linac. A new and more flexible machine would permit greatly expanded studies in this field. Finally there is an over-riding need to learn everything possible about protons and heavier charged particles if man is to go into space, because such radiation appears to be the biological and hence engineering limiting factor.

A recent review at Berkeley (2/5/61) concluded that a weak focusing, high reception rate synchrotron would be the instrument of choice. It would provide the flexibility necessary to take care of these research needs. Briefly a machine providing a proton energy of 1 Bev, or 125 Mev per nucleon for heavy ions with an 800 Kv Cockcroft-Walton injector was specified. It can be used for both biophysical and medical, theoretical as well as practical, purposes on a 168-hour per week basis.

The problem is not that there are no machines producing such particles, but that ordinarily the physicists and chemists have priority on the machines and keep them almost continually occupied.

2. Technical Description

The accelerator would comprise a weak-focusing high repetition rate synchrotron with an injector consisting of an 800 KV Cockcroft-Walton machine, a linear accelerator, and a stripper. The Cockcroft-Walton would have two ion sources, one for heavy ions and one for protons.

Two separated external beam areas would be provided; one for medical purposes, and one for bio-physical experiments.

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In the interests of low background radiation the entire machine should be underground.

3. Tentative Specifications

PROTON ENERGY	1.0 Bev
HEAVY ION ENERGY	125 Mev/Nucleon
REPETITION RATE	15 Cycles per second
MAGNET APERTURE	3 x 11 Inches
MAXIMUM FIELD	13 Kilogauss
FIELD AT INJECTION, PROTONS	300 Gauss
FIELD AT INJECTION, HEAVY IONS	1000 Gauss
ORBIT RADIUS IN MAGNET	14 Feet
OVERALL "DIAMETER"	46 Feet
WEIGHT OF IRON	170 Tons
WEIGHT OF COPPER	13 Tons
DC MAGNET POWER	350 Kilowatts
AC MAGNET POWER	325 Kilowatts
INJECTION ENERGY	0.8 Mev/Nucleon
ORBITAL FREQUENCY AT INJECTION	0.3 MC/second
MAXIMUM ORBITAL FREQUENCY (PROTONS)	6.3 MC/second

4. Time for Construction

It is estimated that it would take 3 to 4 years to construct the proposed bio-medical synchrotron and associate laboratory.

5. Cost

It is estimated that the machine would cost in the neighborhood of $10 to $15 million and the associate laboratory and medical facilities would probably cost at least another $5 million.

6. Location

A bio-medical facility such as that proposed should be constructed in an area where there is engineering competence in the synchrotron field such as at Berkeley. In this connection the University has already offered to make land available for such a facility. In view of U.S. pre-eminence in this field it would make the most sense to locate the facility in the U. S. and probably in the area of Berkeley.

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7. International Cooperation

The capital outlay as noted would be approximately $20 million. Internationalizing the project would enable the U. S. to affect some economies. A machine of this type would be highly useful to any highly-sophisticated radio-biologist. An international biomedical CERN would be consistent with the policy leading to the development of CERN itself.

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INTERNATIONAL HIGH-FLUX RESEARCH REACTOR CENTER

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INTERNATIONAL HIGH-FLUX RESEARCH REACTOR CENTER

I. INTRODUCTION

This paper will consider two possible proposals for international research centers related to heavy element research and high-flux reactors: (1) a transplutonium element production and research center, containing a high-flux reactor and research facilities designed to produce and conduct basic research on heavy isotopes; and (2) a broader research complex containing, in addition to the capabilities described in (1), high-flux reactor facilities suitable for research in reactor and solid-state physics and for development of fast fuels for fast breeder reactors.

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II. CONCLUSIONS

An International High-Flux Reactor Center combining the provision of high neutron fluxes for heavy element production and for research in heavy element chemistry, nuclear, solid-state and reactor physics and fast reactor fuels research is considered desirable. Such a center would be of primary value to the international scientific community in the advancement of new scientific frontiers and in particular to the U.S. in providing scientific information and technical developments applicable to our fast breeder reactor program.

An International Center for Transplutonium Production and Research would duplicate facilities now planned or in progress in the U.S. and is therefore less desirable to this country. It would, of course, provide facilities for heavy element production and research to other countries not now possessing such capabilities.

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III. HEAVY ELEMENT RESEARCH CENTER

A. BACKGROUND

1. U. S. Program

The U. S. Atomic Energy Commission is undertaking a program for the production of research quantities of transplutonium elements. Kilogram quantities of Pu-239 are being irradiated in reactors at the Commission's Savannah River Plant which will subsequently yield over a thousand grams of Pu-242 plus hundreds of grams of Americium-243 and Curium-244. After processing, the Pu-242 and americium and curium will be further irradiated in a high-flux isotope reactor now under construction at the Oak Ridge National Laboratory. This reactor, which will have a power level of 100 MW and a thermal flux of about 5×10^{15} n/cm^2/sec, will permit the production of milligram amounts of californium and other heavy elements by 1965 and gram amounts by several years later. The processing of the recycle americium, curium, and heavier elements and the handling of the large quantities of product californium and other heavy elements which undergo spontaneous fission require a very highly shielded hot cell facility. Such a special transuranium facility (TRU) is being planned for the Oak Ridge National Laboratory. Heavy element hot laboratories designed for research programs utilizing the heavy nuclide products of this program are being constructed or planned for at several of the National Laboratories.

While this large scale program is underway, a smaller interim program is currently being carried out with irradiations in the MTR and ETR which are producing microgram quantities of californium and other heavy elements.

For the preparation of the very heaviest nuclides, the Commission's Lawrence Radiation Laboratory at the University of California, Berkeley, has a heavy ion linear accelerator in which the heaviest nuclides are used as targets for heavy ion bombardment. In addition, variable energy cyclotrons, suitable for heavy element bombardment, are being made available at several of the Commission's laboratories.

2. Programs in other Countries

Several other countries are interested in heavy element research and some have started small transplutonium production programs of their own. The Euratom nations are currently

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planning a program which will involve irradiations of plutonium or americium in the BR-2 reactor at Mol. A Transplutonium Research Center is being constructed for Euratom at Karlsruhe and will be completed after July, 1962. Professor Feenberg of the USSR reported at the 1958 Geneva Conference on the design of high-flux (about 2×10^{15} n/cm^2/sec) reactor, but little information on the status of this proposed reactor is available at this time. The Canadians had expressed an interest in converting the NRU reactor at Chalk River into a high-flux isotope reactor, but found it too expensive. Several other countries are engaged in heavy element research programs and we have supplied or plan to make available to them small research quantities of some heavy elements.

B. INTERNATIONAL FACILITY

An international center for heavy element research would have to provide for the production of significant amounts of the transplutonium isotopes, for the carrying out of the required chemical and mechanical operations in direct support of the production effort, and facilities for the conduct of research utilizing the isotopes which are produced. As a minimum, the following facilities would be required:

a. High-flux isotopes reactor, with thermal flux of at least 5×10^{15} n/cm^2/sec.

b. Heavily shielded facility for preparing targets for, and processing materials from, the high-flux reactor.

c. Well-equipped nuclear chemistry research laboratories.

d. Heavy-ion linear accelerator or variable-energy cyclotron.

The capital cost of such a complex would be in the neighborhood of $50,000,000. The feed for the high-flux reactor would be the products of lengthy reactor irradiation of kilogram amounts of plutonium. This feed (Pu-242, Am-243, Cm-244) should be contributed by the major participating countries. The fuel for the high-flux reactor, and its reprocessing, would also be contributed by the participating countries.

C. CONCLUSION

An international center as described above would allow any country possessing the interest and capability to conduct research

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on the transplutonium isotopes. Many countries have shown interest in this field but do not have, and probably could not support purely national efforts, for acquiring the necessary facilities. It would not, however, offer to the U.S. any scientific capability that we do not now possess or are planning.

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IV. HIGH-FLUX RESEARCH REACTORS

A. BACKGROUND

Since the start of operation of the MTR as the first high-flux research reactor (5×10^{14} n/cm^2/sec, thermal) in the world, advancements in technology have led to the next generation of high-flux reactors (thermal neutron fluxes from 2-5 x 10^{15} n/cm^2/sec) now planned or under construction in the U.S., namely the Brookhaven Beam Research Reactor, the Oak Ridge High-Flux Isotope Reactor and the NRTS Advanced Test Reactor, and the USSR High-Flux Reactor reported at the 1958 Geneva Conference by Feenberg.

The need for research reactors capable of producing usable thermal and/or fast neutron fluxes greater than 10^{16} n/cm^2/sec has been expressed by power reactor developers, for the fast breeder reactor program. The satisfaction of this need has not been undertaken by any one country primarily because of (a) the necessity of extensive research and development required by this advancement for producing higher neutron fluxes and (b) the high capital and operating costs for these reactors.

A high-flux research reactor center offers a number of attractive features for an international cooperative venture. Some features are:

(a) A substantial research and development effort would be required in reactor physics, chemistry, heat transfer, fluid flow, coolants, fuel and structural materials, metallurgy, radiation induced corrosion.

(b) Critical experiments would be required to assume uniform fluxes and provide the desired fast to thermal neutron ratios.

(c) Research and development would be required in the non-uniform distribution of fuel within fuel elements and the use of burnable poisons to maximize the time between reloading of fuel.

(d) The research and development work required for these high-flux reactors is such that it should prove challenging to experts from the participating countries in the various scientific and technical fields involved and should attract them to participate in such an international venture.

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(e) A research reactor center supplying neutron fluxes greater than 10^{16} n/cm^2/sec, while considered technically feasible, exceeds the technical capabilities of any one country at this time.

(f) The high capital costs and high annual operating and fuel costs will probably prevent any one country from undertaking such a venture, but may serve to encourage a cooperative effort and a sharing of costs.

(g) France, U.K., USSR and the U.S. have fast breeder reactor programs, thus an interest motive in fast reactors exists in a number of countries and could serve to crystallize into a cooperative venture.

(h) The fast breeder program requires extensive and expensive research in the field of fuel materials and in the achievement of high fuel burnup.

(i) No fast fuel research reactor exists at the present time in free world countries nor to our knowledge anywhere else. The availability of such a research reactor should advance timewise the fast breeder program.

B. INTERNATIONAL HIGH-FLUX RESEARCH REACTOR CENTER

An international high-flux research reactor center could provide a variety of neutron fluxes which are not attainable in existing research reactors. These neutron fluxes would be characterized by high intensity (greater than 10^{16} neutrons per cm^2/sec. In the thermal energy region and a similar intensity of higher energy), by the ability to vary the fast to thermal flux ratio over wide ranges, adaptability to specialized isotope production, and suitability for performance of fast breeder reactor fuel experiments.

Two types of reactors are proposed: (a) research reactors designed for research in solid-state physics, radiation effects, radiation induced corrosion, special isotope and transplutonium element production; and (b) a reactor suitable for fuel research in a fast breeder reactor program. Consideration could be given to combining both reactor types into a single "all-purpose" reactor.

C. CONCLUSION

A High-Flux Reactor Center is desirable

(a) To provide research scientists with the most intense source of reactor-produced neutrons in the world.

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(b) To provide a research reactor for the fast fuels research required for fast breeder reactor programs.

(c) Because of the advancements in general nuclear technology that would result from the design and development of the high-flux reactors.

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V. SUMMARY

Either of the above concepts could be suggested and supported. The strongest overall scientific justification, however, would be possible for an international center combining the facilities and capabilities of both concepts. Such a broad "International High-Flux Reactor Center" would provide facilities for participating countries to conduct basic research in nuclear chemistry, solid-state physics, and nuclear physics, and applied research and development in reactor engineering and design. No one country, including the U.S., has such capabilities (or is planning for them) at the present time. The facilities would include:

(a) One or two reactors providing fast and thermal fluxes on the order of 10^{16} n/cm^2/sec and adequate capacities for isotope irradiations, in-pile test space for reactor development work, beam holes for nuclear and solid-state physics research, etc.

(b) Heavily shielded facilities for handling the extremely radioactive materials produced in the reactor.

(c) Well-equipped research and engineering laboratories with supporting shop and service facilities.

(d) Heavy-ion linear accelerator or variable energy cyclotron, for heavy element research.

The capital cost of such a center would be in the range of $150,000,000 - $250,000,000. It would not be completely self sufficient, and would require contributions from participating countries in terms of reactor fuel, fuel reprocessing service, and feeds for heavy element production.

The primary value of such a combined center to the international scientific community would be the provision of high neutron fluxes for research in heavy element chemistry, nuclear, solid-state and reactor physics, and advances in reactor technology. The primary value to the U.S. would consist of the scientific information and technical developments applicable to our fast breeder reactor program.

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VERY HIGH ENERGY ACCELERATORS

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VERY HIGH ENERGY ACCELERATORS

SUMMARY

1. Cooperation with the USSR in the design, construction and use of very high energy accelerators has been the subject of numerous fruitful exchanges between representatives of the two countries.

2. The McCone-Emelyanov Agreement, signed in November 1959, provided that the U.S. and the USSR would "examine separately the feasibility of engaging in joint projects....," including "the design and construction of an accelerator of large and novel type." It further provided that "representatives of the U.S. Atomic Energy Commission and the USSR Main Administration of the Utilization of Atomic Energy will meet in the first half of 1960 to consider what enterprises merit further study and will request the International Atomic Energy Agency to assist in arranging such meetings."

3. In May, 1960, Professor Emelyanov proposed a joint accelerator project in a discussion with an official group of American physicists then inspecting Soviet high energy facilities. He suggested that formal discussions of such a project be held at the time of an International High Energy Physics Conference at the University of Rochester in August, 1960.

4. In response to a written request by Emelyanov, the topic was officially discussed at a meeting between U.S. and USSR scientists in New York City on September 16, 1960. In a joint memorandum to the two governments (copy attached), they concluded that accelerators of several hundred Bev are scientifically desirable and appear to be technically feasible. They recommended that officially appointed groups in each country study accelerators in the range from 300 to 1000 Bev and that further mutual discussions be held in conjunction with the International Accelerator Conference to be held at Brookhaven in September, 1961. The group recognized that any project should be multilateral but no such recommendation was made in deference to the Soviets' formalistic position that the group must stay within the bilateral framework of the McCone-Emelyanov Agreement. No formal action on the recommendations has been taken by the U. S. Government nor, so far as we know, by the USSR.

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5. Interest in a project of this nature has been expressed by scientists from many countries in Western Europe and the Far East.

6. Studies of accelerators above 100 Bev are proceeding at the Lawrence Radiation Laboratory, at the California Institute of Technology and at Brookhaven National Laboratory. The last is specifically responsive to the recommendations of the New York meeting.

7. These studies have verified the conclusion that accelerators of several hundred Bev are both scientifically desirable and technically feasible. Indeed, the feasible energy limit seems to be set by economics. The cost of complete installations is estimated to range from $150 - $250 million at three hundred Bev to $500 - $750 million at one thousand Bev.

8. From the sole standpoint of American scientific progress, a given national accelerator would be preferable to an equivalent international one. This factor may well be outweighed by economic and political considerations.

9. Political advantages of East-West cooperation in such a project would include increased exchange of scientific and technical information, contributions toward international understanding and, hopefully, insight into Soviet technology, including manufacturing procedures. It is important that cooperation on this type of project would bring together intellectual leaders from the East and the West.

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BACKGROUND

So far as the writer is aware, the first formal suggestion that consideration be given to East-West cooperation in the construction and use of very high energy particle accelerators was made in the 1958 Report of the Special Panel on High Energy Accelerator Physics, appointed by the PSAC and the GAC. This report recommended, among other things, that the Federal Government:

> "(m) Encourage international collaboration and cooperation in the planning for and design of future machines and the increased use of facilities.
>
> "(n) Request the National Academy of Sciences to study and advise the Government on the best method for proceeding with international cooperative research on new accelerator concepts, such cooperative activity to include the Soviet Union."

In response to the above, the National Academy of Sciences approached members of the U.S. National Committee for the International Union of Pure and Applied Physics (IUPAP) through whom the subject was placed on the agenda of the High Energy Commission of IUPAP at its meeting in Kiev in July 1959. An attempt by that Commission to establish an international study committee on the subject failed through lack of Soviet participation. However, at an informal discussion during an accelerator conference at Geneva in September 1959, representatives of the U.S., of Western Europe and of the USSR agreed upon the desirability of international cooperation in this field.[1/] The Soviet representatives expressed fear that the purpose of the U.S. was to control national programs through the mechanism of large international accelerator projects. They were disabused of this thought.

The McCone-Emelyanov Agreement for Cooperation in Nuclear Science and Atomic Energy, which was signed in November, 1959, provided for exchange visits and exchanges of information, and in addition included, under the heading "Joint Enterprises" the following statements:

> "The parties agree initially to examine separately the feasibility of engaging in joint projects in various unclassified areas.

1/ Note that the Bronk-Nesmyanoff Agreement, which was formally signed in July, 1959, did not include high energy physics as a subject for exchange.

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"Included in the initial exploration are joint facilities and undertakings in....; the design and construction of an accelerator of large and novel type; ....

"Representatives of the U.S. Atomic Energy Commission and the USSR Main Administration of the Utilization of Atomic Energy will meet in the first half of 1960 to consider what enterprises merit further study and will request the International Atomic Energy Agency to assist in arranging such meetings."

The possibility of seriously considering cooperation in the design and construction of a large accelerator was mentioned from time to time in various East-West contacts over the next few months. For example, Professor Emelyanov proposed such a venture in a discussion in Moscow on May 28, 1960 with the official U.S. High Energy Physics Group then inspecting Soviet High Energy installations. He specifically suggested that discussions of such a project take place at the time of the High Energy Physics Conference to be held at the University of Rochester in August and September, 1960.

Taking a cue from that discussion, Professor Marschak invited approximately 25 physicists from a large number of countries--both East and West--to attend an informal meeting in Rochester on August 28, 1960, to discuss the scientific desirability and technical feasibility of very high energy accelerators. The discussion was entirely technical and although many of the participants were aware of the possible international implications, those implications were not discussed in the meeting. The meeting concluded that accelerators in the range of 100-300 Bev, or even higher, would be very useful scientifically and that their design and construction is technically feasible, although expensive.

Meanwhile, Professor Emelyanov wrote to Chairman McCone urging that a formal meeting be held, after the Rochester Conference, between representatives of the USSR and the U.S. to discuss in a preliminary way the desirability and feasibility of a joint project. Such a meeting was held in New York City on September 16, 1960.

By agreement early in the meeting, the discussion was confined to accelerators in the energy region between 300 and 1000 Bev. The group agreed upon the scientific desirability and the apparent technical feasibility of such accelerators. A memorandum was prepared incorporating these conclusions and a series of recommendations to be submitted to the two governments. (A copy is attached). Briefly, the memorandum recommended that "officially appointed" technical

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groups in each country should study the scientific desirability and technical and economic feasibility of particle accelerators in the energy range between 300 and 1000 Bev. It was also recommended that reports of these studies be made at a second meeting at the time of the International Accelerator Conference at Brookhaven National Laboratory in September, 1961.

Although the recommendations of the memorandum have never been formally acted upon by the American Government (nor, so far as we know, by the Soviet Government) a study group was established at Brookhaven National Laboratory early in 1961. Scientists and engineers from many institutions have participated on a part-time basis, both at their home institutions and during short visits to BNL. Close cooperation has been maintained with high energy accelerator studies being carried out at the Lawrence Radiation Laboratory and at the California Institute of Technology.

In parallel with these technical studies theoretical and experimental physicists have been considering, on the one hand the scientific usefulness of results that might be achieved through the use of such ultra-high energy protons, and on the other the instrumental and other problems involved in experimenting with such particles.

All of these studies have strengthened the belief that accelerators in the energy range in question are both scientifically desirable and technically feasible, and that the costs would probably not be excessive in the context of a large scale international effort.

SCIENTIFIC AND TECHNICAL CONSIDERATIONS

Scientific Desirability of an Ultra High Energy Accelerator:

A marked extension in the available particle energies would serve two general purposes; it would make possible refinements and extensions to higher energy, of the class of experiments already underway; more importantly, it would undoubtedly reveal a whole field of new phenomena and areas for investigation.

In the past such new phenomena have been discovered whenever a substantial increase in energy has been achieved. These discoveries have been such that it is not an overstatement to claim that our concepts of the most intimate structure of basic physical principles have undergone a profound change during the last decades. Although no one can foretell whether the next increase in energy will be equally productive, promising areas are apparent. These include:

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(1) The information which can be gathered from neutrino experiments will continue to increase with energy.

(2) New particles and, in particular, new particle "states" may develop.

(3) Experiments in which secondary particles are scattered by stationary electrons, leading to "knock-on" electrons will reveal the structure of the new, unstable particles.[2/]

(4) Cosmic ray events at very high energies have exhibited certain purling features which it is essentially hopeless to explore further without the controlled conditions of accelerator experiments. Detailed exploration of such high energy "jet" events may give crucial data on the problem of fundamental interparticle forces.

The present class of experiments can be extended in several important ways:

(1) The study of production processes for secondary particles can be extended to much higher energies, thereby increasing the understanding of these processes. In particular, the great increase in multiple production of secondaries would yield essential information concerning interparticle forces.

(2) The energy range of available secondary particles will be greatly extended, correspondingly increasing the energies at which interactions of these particles with stationary nucleons can be observed.

(3) The increased multiplicity of production of secondary particles of lower energy will be equivalent to a corresponding increase in intensity from a lower energy accelerator. For example, a 300 Bev accelerator of given intensity is expected to produce between 50 and 100 times as many secondary particles of a few Bev energy than would a 15 Bev accelerator having the same primary beam intensity.

2/ Since such secondary particles cannot be made available in targets, it is necessary in studying their structure to reverse the usual procedure and bombard stationary electrons with the unstable particles. Unfortunately, the very low mass of the electron requires that the oncoming particles have very high energy in order to provide sufficient momentum transfer for the studies to be revealing.

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Hence a multi-100 Bev accelerator is basically a dual purpose device: an exploratory tool to study new phenomena at ultra-high energy and a highly competitive source of secondary particles of lower energies.

Technical Feasibility

Accelerator studies carried out to date have yielded increasingly promising results. An important conceptual basis for these studies has been the idea of using a high energy (10-15 Bev) accelerator as an injector for a very high energy alternating gradient synchrotron. This concept offers great advantages. The correspondingly high magnetic field at injection, the large reduction in space charge effects and the virtual elimination of gas scattering would permit the use of far smaller magnet apertures, and hence lighter weight and less costly magnets, vacuum tubes, etc., than would be the case at low injection energies. Indeed, careful orbit studies have shown that the linear dimensions of the aperture can be comparable to or less than the present AGS machines[3/] and need not increase with the energy of the accelerator. An equally important benefit is that the reduction in space charge effects permits very high intensities before reaching the space charge limit. Indeed, the injector would undoubtedly be the limiting factor governing intensity. Furthermore, the requirements of alignment precision are apparently not more rigorous than those already successfully achieved at CERN and at Brookhaven.

Both linear accelerators and synchrotrons are being considered as injectors. Injection from a linear accelerator is more straightforward since a well-focussed external beam is automatically provided by such a machine. However, careful calculations based in part on experimental evidence at CERN and BNL have indicated that the transfer problem between two synchrotrons is also solvable. In favor of the synchrotron injector is the fact that at first sight it seems to be cheaper. However, to realize the full single pulse intensity of the large accelerator at repetition rates sufficient to give reasonable average intensities requires that the synchrotron injector be pulsed at a very rapid rate, greatly increasing its technical complexity and cost. The relative merits of the two systems is under careful study, taking into account the above and other factors.

In summary, one can predict with reasonable assurance that proton synchrotrons of many hundred Bev can be designed and built and

3/ Note that the concept of multi-Bev injection is meaningful only for a very high energy accelerator. Clearly a 10 Bev injector would not be logical for, say, a 30 Bev final one.

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operated with difficulties not qualitatively different from those originally faced in the last generation of accelerators.

The magnitude of effort that would be involved is clearly much greater. The quantities of each component, the level of the RF power, the complexity of the controls, etc., would rise in keeping with the size.

The personnel requirements would, of course, be large. Fortunately, however, the number of experienced personnel would not increase proportionately with the total effort. The largest relative increase would be in the requirements for technical and skilled assistants.

Economic Feasibility

Although it is not yet at this stage possible to make accurate estimates of the cost of accelerators in the energy range under discussion, some rough estimates are available. It is believed, however, that the cost would be roughly linear with energy and that it might range from $150 - $250 million at three hundred Bev, to $500 - $750 million at one thousand Bev.

GENERAL CONSIDERATIONS

The desirability of undertaking a cooperative project of this nature is influenced by many factors. Omitting for the moment the political factors, the advantages would include the sharing of costs, the larger pool of scientific and technical manpower, and the scientific stimulation to be derived from the mutual contacts and cooperation between the scientists of many countries. The disadvantages as compared to a national accelerator would include the probable remoteness of the site, the administrative cumbersomeness and resultant slowing down, and the reduced availability of the machine for use by American scientists. On balance it is generally believed by American scientists that from these standpoints alone, a national accelerator of equivalent performance would be preferable. It is important, however, that the very large investments involved might well make it possible to construct a higher energy, more costly accelerator, if international resources were pooled.

The political factors are, of course, numerous and of great importance. Among them are the possible contributions toward international understanding and good will, the breaking down of communication barriers, resulting in increased information in both the

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technical and the general sense. An especially interesting possibility is that of acquiring knowledge of technological and industrial practices in the USSR. Indeed, informal conversations with responsible Soviet scientists have indicated that for this purpose they would seriously consider making available manufacturing techniques in fields required by principal accelerator components such as steel and copper. Clearly, such information would be of great value.

It is important that cooperation on this type of project would bring intellectual leaders from the East and the West into intimate contact for long periods of time.

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DESIRABILITY AND FEASIBILITY OF NEW ACCELERATORS OF LARGE AND NOVEL TYPE

Report to

U.S. AND SOVIET ATOMIC ENERGY AUTHORITIES
by
Officially - Designated Scientific Group

A meeting was held at the American Institute of Physics, New York City, on September 16, 1960, to consider the scientific desirability and feasibility of new accelerators. Participating in this meeting were V. I. Veksler, D. I. Blokhintsev, S. Y. Nikitin, V. P. Dzhelepov and N. N. Bogolyubov from the Union of Soviet Socialist Republics and L. J. Haworth, R. R. Wilson, G. F. Chew, K. R. Symon, P. W. McDaniel and G. A. Kolstad from the United States. This meeting was arranged by the State Committee of the Council of Ministers of the USSR for the Utilization of Atomic Energy and the U. S. Atomic Energy Commission.

In arriving at the following conclusions and recommendations it was agreed that the discussion be limited to accelerators of a scope beyond presently envisioned national accelerators. Energies above 300 Bev were adjudged to fulfill this criterion.

CONCLUSIONS

1. That an accelerator in the energy region above 300 Bev is desirable.

2. That a strong focusing proton synchrotron in this energy region appears to be feasible and that other types might also be feasible.

3. That thorough technical study of such machines is essential.

4. That thorough study of the experimental use of such machines is also essential.

5. That participation in these studies by scientists of other countries would be desirable.

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RECOMMENDATIONS

1. That study groups be officially appointed in each of the two countries to examine the technical and scientific problems.

* 2. That encouragement be given to other countries or areas to form similar groups or to participate in the work of the USSR and US groups.

3. That the groups be encouraged to cooperate in their studies.

4. That plans be made for a comprehensive intergroup discussion at the time of the 1961 International Accelerator Conference and that further steps be considered at that time.

5. That the studies include:

   a. Scientific justification

   b. Technical aspects of accelerators of energies between 300 Bev and 1000 Bev

   c. Beam handling and experimental techniques

   d. Technical effort, cost and probable time scale.

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* Not included as jointly recommended by US/USSR group. Recommended separately by U.S. group. USSR group personally in agreement and indicated their intention to make the same recommendation to their government separately but felt that such a recommendation should not be included in a joint document.

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