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SEMI-ANNUAL REPORT

for the period

January 1 through June 30, 1966

AEC Contract AT(30-1)-2076

M. Stanley Livingston

Director

December 6, 1966

RELEASED FOR ANNOUNCEMENT
IN NUCLEAR SCIENCE ABSTRACTS

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
and HARVARD UNIVERSITY

CAMBRIDGE ELECTRON ACCELERATOR

CAMBRIDGE 38, MASSACHUSETTS

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The research work described in this report was performed under Contract AT(30-1)-2076 between the U.S. Atomic Energy Commission and the President and Fellows of Harvard College.

CAMBRIDGE ELECTRON ACCELERATOR

HARVARD UNIVERSITY
42 OXFORD STREET
CAMBRIDGE 38, MASS.

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SUMMARY

Part I indicates the purpose of the contract, which is concerned with the operation of the 6-Gev Cambridge Electron Accelerator. Part II states the general nature of each of the 36 experiments that were in progress or in preparation during the six-month period in question. Part III lists the principal improvements made in the accelerator and the associated facilities. Part IV deals with the routine operation of the accelerator, and indicates that the half-year in question was the most productive such period to date. Part V deals with the safety organization, which has been greatly improved. Part VI summarizes plans and preliminary tests made in preparation for the colliding beam facility BYPASS; crucial tests made to date, including storage of multi-Gev electrons for periods of the order of 10 minutes (limited only by scattering from residual gas) have been successful. Part VII deals with preparations for the Sixth International Conference on High Energy Accelerators, to be held in Cambridge Mass. on Sept. 11 - 15, 1967.

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PART I. INTRODUCTION

This report summarizes the work done under the Harvard-AEC Contract AT(30-1)-2076 during the six-month period from January 1 through June 30, 1966. The contract calls for the operation and maintenance of the CEA 6-billion-electron-volt synchrotron and for designing, procuring, installing, and operating various facilities essential to the experiments to be performed here.

General policies of the Laboratory were determined by a joint M.I.T.-Harvard "Executive Committee of the CEA". During the early part of 1966 this Committee included the following:

from M.I.T.	Dr. Carl F. Floe
	Dr. Bernard T. Feld
	Dr. Francis E. Low
	Dr. Louis S. Osborne
	Dr. Charles H. Townes
from Harvard	Dr. Franklin L. Ford
	Dr. Norman F. Ramsey
	Dr. J. Curry Street
	Dr. L. Gard Wiggins
	Dr. Richard Wilson

Scientific policies were established by a Scientific Committee which included representatives of M.I.T., Harvard, and a few other institutions concerned. During the early part of 1966 this Committee included:

from M.I.T.	Dr. Bernard T. Feld
	Dr. Francis E. Low
	Dr. Louis S. Osborne
from Harvard	Dr. Norman F. Ramsey
	Dr. J. Curry Street
	Dr. Richard Wilson
from Tufts	Dr. Richard H. Milburn
from Yale	Dr. Vernon Hughes

from CEA

Dr. Thomas L. Collins
Mr. Robert E. Cummings (Sec.)
Dr. M. Stanley Livingston
Dr. Gustav A. Voss

More recently the Scientific Committee was reconstituted and includes the following:

from M.I.T.

Dr. Jerome I. Friedman
Dr. Francis E. Low
Dr. Victor F. Weisskopf

from Harvard

Dr. Sheldon L. Glashow
Dr. Francis M. Pipkin
Dr. Karl Strauch

from CEA

Dr. Thomas L. Collins
Mr. Robert E. Cummings (Sec.)
Dr. M. Stanley Livingston
Dr. Gustav A. Voss

from other
institutions

Dr. Robert K. Adair (Yale; Brookhaven)
Dr. Richard H. Milburn (Tufts)

Scheduling of research experiments on a day to day basis was the responsibility of the Director of CEA assisted by a "Scheduling Committee for the CEA". During the half-year in question the Committee members were:

from M.I.T.

Dr. David P. Luckey

from Harvard

Dr. Alfred E. Brenner

PART II. THE EXPERIMENTS

During the six-month period in question there were 36 experiments in progress or in various stages of preparation or completion. These are described briefly below, arranged alphabetically by name of a principal investigator.

1. Photoproduction of π^+ and k^+ at Large Angles and Study of Angular Distributions and Spins (R.A. Alvarez et al). Physicists from M.I.T. have continued their preparations for studying the photoproduction of positive pions and kaons by means of a 1 to 3 Gev photon beam that strikes a liquid hydrogen target. They will use a large deflecting magnet, spark chambers, and other detectors. Data-taking runs began late in 1966.
2. Single Pion Photoproduction on Deuterium (Bar Yam et al). Physicists from Southeastern Massachusetts Technological Institute have nearly completed preparations for the study of single pion photoproduction on deuterium. They will use the Moby Dick spectrometer and special hodoscopes. Data taking began in mid-summer of 1966.
3. Proton Compton Effect (Deutsch et al). Physicists from M.I.T. are continuing the study of gamma proton scattering, undertaken earlier at CEA. The experimental conditions will be extended to photon energies of 2.5 Gev and to center-of-mass angles of 65 to 120°. Detection equipment will include a magnetic spectrometer, spark chambers, and a shower counter.

The data will be analyzed with the aid of the SPASS computer program. Runs are expected to start by the end of 1966.

4. Determination of the Polarization of Lambda Particles Jointly Photoproduced with Kaons (Deutsch et al). Physicists from M.I.T. are planning to direct a 1.5 to 3.0 Gev photon beam at a liquid hydrogen target and study the polarization of the lambda particle found in the photoproduction of the (Λ , K) final state. They will use a magnetic spectrometer, four spark chambers, and a gas-filled Cerenkov counter. Runs are to begin near the end of 1966.

5. Photoproduction of K^0 (Engels et al) Physicists from Harvard and elsewhere are preparing to measure the cross section of photoproduction of the neutral kaon. They will use a metallic target (e.g., aluminum), spark chambers, scintillation counters, and Plexiglass Cerenkov counters (but no magnet). They will employ a tungsten block to regenerate K_1^0 particles from K_2^0 particles, and will detect the pions produced by the K_1^0 particles. Runs may start in 1967.

6. Photon Energy Determination (Fessel et al). CEA physicists have completed preparations for the rapid and accurate determination of the spectral energy distribution of a multi-GeV bremsstrahlung beam. The individual photon strikes a thin foil just upstream from a pair spectrometer magnet, and the energies of the resulting electron and positron are

determined with the aid of two banks of scintillation counters and two banks of glass Cerenkov counters. The equipment was operated successfully in October 1966.

7. Production of Quasi-Monochromatic, Linearly Polarized Photon Beam with the Aid of a Crystal (Fessel et al). CEA physicists have been completing preparations for inserting a diamond in an electron beam of 1 to 6 Gev energy and orienting the diamond accurately so as to produce a bremsstrahlung beam which, after collimation, will be quasi-monochromatic and will have a degree of linear polarization of 10 to 90%. A remote-controlled, in-vacuum goniometer has been designed and constructed, and trial runs were made in November 1966. The resulting polarized beam can be analyzed with the aid of the pair spectrometer mentioned in the previous paragraph, or may be used in photoproduction experiments of especially significant type.

8. Internal Beam Tagging Facility (Frisch et al). M.I.T. physicists, with assistance from CEA engineers, have been preparing to try out a scheme of producing tagged, multi-GeV photons by causing the internal electron beam of the CEA to strike an exceedingly fine wire situated within the vacuum chamber in Magnet 12. The energy of the individual, spent electron is to be determined with the aid of the magnetic field of this magnet (used as an analyzing magnet) and a bank of 30 detectors situated near the downstream end of the magnet. The tagged photon, with energy known

to within about 2%, will enter the Experimental Hall and strike a target there, and the resulting event will be analyzed with the aid of a spark chamber. Trials should begin late in 1966 or early in 1967.

9. Study of Wide-Angle Electron Pairs and Muon Pairs with the Aid of an Internal Beam Tagging Facility and a Large Spark Chamber (Frisch et al). Physicists from M.I.T. and Northeastern University have continued preparations for employing the internal beam-tagging facility (discussed in the previous paragraph) in the study of the photoproduction, by means of photons of accurately known energy, of electron pairs and perhaps muon pairs also. Each pair will be analyzed with the aid of a large spark chamber situated within the field of a large magnet, and with the aid of shower counters and range counters.

10. Photo-Induced Spallation Study Involving Foils (Fulmer, Handley and Williams). Physicists from Oak Ridge National Laboratory are studying the production of spallation (in foils) of nuclei of uranium and other elements by means of multi-Gev photons. Exposures were made during the summer of 1966.

11. Search for Quarks (Garelick et al). Physicists from M.I.T. searched for quarks that might originate in a large block of carbon struck by multi-Gev photons. Thick attenuators of iron and lead were used. The detectors consisted of scintillation counters. Runs were made in the summer and autumn of 1966.

12. Electroproduction of Wide-Angle Muon Pairs (Gettner et al).

Physicists from Northeastern University initiated a study of production of wide-angle muon pairs by means of multi-Gev electrons, with a view to exploring the time-like form factor of the (e, μ) scattering process and providing an additional test of the validity of quantum electrodynamics. Runs began late in 1966.

13. Photoproduction of Kaons and Y^* Resonances (Hughes et al).

Physicists from Yale University continued their preparations for measuring, with greater precision than has been achieved previously, the production of positive kaons by a 3 to 6 Gev photon beam incident on a liquid hydrogen target, with the purpose of finding the cross section for the production (with the kaons) of Y^* resonances as a function of energy. Several large analyzing magnets are employed, and a large variety of counters. Data taking runs were made in the summer and autumn of 1966.

14. Elastic Scattering of Electrons by Deuterons (Kendall et al).

MIT physicists completed the data taking phase of this investigation of the elastic scattering of electrons by deuterons. They are currently analyzing the results.

15. Search for e' Particle (Kendall et al). M.I.T. physicists completed a brief search for the e' particle in 1965. A report on the (negative) outcome is in preparation.

16. Inelastic Scattering of Electrons by Deuterons (Kendall et al). Physicists from M.I.T. have been preparing to study the inelastic scattering of electron by deuterons, and thus explore the electrodisintegration of the deuteron near threshold and explore the short-range structure of the (n,p) interaction at low energy in the (n,p) c.o.m. system. They employ an external, multi-Gev electron beam, a liquid deuterium target, and several arrays of scintillation counters. It is hoped that data-taking runs will start in 1967.

17. Elastic Scattering of Electrons by Alpha Particles (Kendall et al). M.I.T. physicists have been preparing to study the scattering of electrons by alpha particles, with a view to determining the short-range structure (form factor) of the alpha particle -- a spin-zero particle. They plan to use an external electron beam and a liquid helium target; also scintillation counters. It is hoped that runs will begin in 1967.

18. Coherent π^0 Photoproduction from the Deuteron (Kendall et al). M.I.T. physicists hope that, by detecting the recoil deuteron in coincidence with the shower generated by a photon from the π^0 decay, they can study the photoproduction of neutral pions and obtain information as to the relative phases of the amplitudes for the production of neutral pions from the neutron and proton. They expect to take data late in 1967.

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19. Photoproduction of π^0 and n^0 at Forward Angles (Luckey et al). Physicists from M.I.T. are planning an experiment on the photoproduction of π^0 and n^0 that will supplement the investigations made by them in 1964 and 1965. Specifically, they will study production at forward angles; and, being unable to measure protons that are scattered almost straight backward, they will concentrate on measuring the directions and energies of the photons resulting from the decay of the neutral particle in question. They will use a liquid hydrogen target and two large arrays of glass Cerenkov-type shower detectors. Data taking is to start in 1967.

20. Production of Polarized Photons with the Aid of a Lazer (Milburn et al). Physicists from Tufts are preparing to exploit the method of producing polarized high-energy photon beams demonstrated on a token scale in 1964 and 1965. The method entails directing a very intense beam of polarized photons head-on at the electrons in orbit in the synchrotron; the photons recoil with energies as great as 800 Mev, and retain their original polarization. The group is preparing a laser of 100-fold greater power and greater repetition rate, and will use a lead-glass Cerenkov counter as shower detector. It is hoped that runs will be made in 1967.

21. Spark Chamber Analysis of Photoproduced Polarized Protons (Milburn et al). Using much of the equipment employed by Deutsch et al in the proton Compton-effect experiment, and also a

large spark chamber containing 60 plates of graphite, the Tufts group hopes to evaluate the polarization of recoil protons produced during the photoproduction of pions in a liquid hydrogen target. It is hoped that runs will begin in 1967.

22. Comparison of Rates of Photoproduction of Kaons and Pions (Osborne et al). M.I.T. physicists made runs supplementary to the investigation conducted in 1965 on the rates of photoproduction of positively charged kaons and pions. A brief report of the work has been published and a more detailed report is in preparation.

23. Exploration of Some Simple (γ +p) Reactions at Many Angles (Osborne et al). This group of M.I.T. physicists has been studying some of the simpler reactions that occur when photons of 2 to 3 Gev energy strike liquid hydrogen. They use a two-arm spectrometer: one arm (Moby Dick) measures recoil protons, and the other (Remora) analyzes the decay products of the neutral pions. Various supplementary runs were finished in August 1966, and a detailed report is being written.

24. Study of Large-Angle Electron-Positron Pairs Produced in a Carbon Target (Osborne et al). Physicists from M.I.T. have used the Moby Dick spectrometer in a search for possible breakdown of quantum electrodynamics when electron-positron pairs are produced by high-energy photons that strike a carbon target. Data taking runs were completed during the summer of 1966 and the results are now being analyzed.)

25. Exploratory Survey of Neutral Pion Photoproduction (Osborne et al). M.I.T. physicists have been preparing to explore the broad features of π^0 photoproduction under a wide variety of conditions. Data taking runs were made during the summer of 1966.

26. Small Angle Scattering of Electrons by Carbon (Pipkin, Faissler, et al). Harvard physicists investigated the small-angle scattering of electrons by a carbon target in order to obtain additional information on the form factor of the carbon nucleus. They employed an external electron beam and a single-arm spectrometer that detected and analyzed the electrons scattered by the target. Data taking was completed in September 1966 and the spectrometer was then dismantled.

27. Photoproduction of Charged Kaons (Pipkin, Joseph, et al). Physicists from Harvard determined the number of charged kaons that are emitted from a target of carbon or liquid hydrogen as a function of photon energy and direction of emitted kaon, with the purpose of discovering the dominant characteristics of the kaon photoproduction process. They employed photons of 3 to 5 Gev energy, and a single-arm spectrometer capable of distinguishing kaons from the (much more numerous) pions and muons; the spectrometer included focusing magnets, scintillation counters, and two gas-filled Cerenkov counters. Data taking runs were completed in the summer of 1966.

28. Wide-Angle Electron Pair Production (Pipkin et al).

Harvard physicists are preparing to study wide-angle electron-positron pair production with greater accuracy than was achievable earlier. An especially sturdy two-arm spectrometer is to be used. Data taking will start in the spring of 1967.

29. Wide-Angle Electron Pair Study with Tagged Photons and a Wide-Gap Spark-Chamber (Strauch et al). Harvard physicists have been completing preparations for a new and ambitious approach to the study of possible breakdown of quantum electrodynamics at large four-momentum transfer. The method involves use of tagged photons produced with the aid of momentum-analyzed positrons; the individual positron (of known energy) strikes a thin target and radiates by bremsstrahlung process; an open-sided tagging magnet (momentum analyzing magnet) and an array of scintillation counters permits determination of the energy of the spent positron and, by subtraction, the energy of the bremsstrahlung photon. This tagged photon is put to use as follows: it is caused to strike a target of carbon or liquid hydrogen and produces here an electron-positron pair; an adjacent spark chamber shows the initial directions of these two particles, and a second spark chamber, situated within the large gap of a 200-ton H-type magnet permits determination of the momentum of each particle; 14-ft-long spark chambers and high-Z plates permit distinguishing electrons from pions. Preliminary runs were begun late in 1966.

30. Photoproduction of Baryon-Antibaryon Pairs (Von Goeler et al). Physicists from Northeastern University, using photons of 4 to 6 Gev energy, have studied the photoproduction of baryon-antibaryon pairs by the reaction: $\gamma + p \rightarrow \bar{n} + d$. The deuteron was detected by the Moby Dick spectrometer and the decay products of the antineutron were detected by six scintillation counters surrounding an iron absorber. The experimental work was finished in September 1966 and the results are being analyzed.
31. Photoproduction of Antiprotons (Von Goeler et al). Physicists from Northeastern University have begun a brief, exploratory experiment on the photoproduction of antiprotons, using a variety of target materials. A central problem was how to achieve adequate discrimination against pions. Data taking began in August 1966.
32. Total Cross-Section for Photoproduction of Electron-Positron Pair (Walker, Knasel, et al). Harvard physicists are preparing to measure with 20-fold improved precision the total cross-section of photoproduction of electron-positron pairs, to see whether any disagreement with predictions based on quantum electrodynamics can be found. Tagged photons will be used. Runs are to begin early in 1967.
33. Precise Elastic (e, p) Scattering (Wilson, Goitein, et al). Harvard physicists have been obtaining absolute cross-sections (and additional, more precise information as to the form factors)

of the proton at very high four-momentum transfers. An external beam of 5.5 to 6.0 Gev electrons is used. Principal attention is given to electrons scattered at forward angles. A half-quadrupole spectrometer (with scintillation counters, a shower counter, and a Cerenkov counter) identifies the electron and measures its momentum. A satellite spectrometer detects the proton in coincidence. Runs should be complete by December 1966.

34. Precise Quasi-Elastic (e,d) Scattering Study Involving a Coincidence Method (Wilson, Budnitz, et al). Physicists from Harvard have been engaged in making a five-fold increase in the accuracy of the determination of the two electromagnetic form factors of the neutron by measuring the quasi-elastic scattering reaction $e + d \rightarrow e + p + n$ with the aid of an external electron beam, a liquid deuterium target, and a coincidence method of detection and analysis. A checkerboard array of 144 scintillation counters permits determination of the polar and azimuthal angles of the resulting proton; the electron is detected by means of a spectrometer including a threshold-type Cerenkov counter and a lead-scintillator-sandwich shower counter. Data are analyzed by an on-line computer. The experimental work was completed in July 1966 and the results are now being interpreted.

35. Determination of the Pion Form Factor through Study of Inelastic (e,p) Scattering Near the First Pion-Nucleon Resonance (Wilson, Mistretta, et al). Harvard physicists have

begun a more accurate determination of the form factor of the charged pion. They employ an external electron beam, a liquid hydrogen target, and a two-arm spectrometer. One arm (Kontiki), which includes a focusing magnet, arrays of scintillation counters, a gas-filled Cerenkov counter and a shower counter, detects the electron. The other arm, employing a sweeping magnet, a 144-element scintillation counter, and a Lucite Cerenkov counter, detects the pion in coincidence with the electron. By September 1966 the equipment was nearly ready for trial operation.

36. Search for Violation of Time-Reversal-Invariance in Electromagnetic Interactions, with the Aid of a Polarized Target (Wilson, J. Chen, et al). Harvard physicists are preparing to find whether, in electromagnetic interactions among strongly interacting particles, any violation of time-reversal invariance occurs. They will analyze events in which electrons are scattered by protons inelastically. The polarized target, being developed by Pound and others at Harvard, will consist of toluene in which 30 to 40% of the effective protons will be polarized (with the aid of a magnet of a 26 kilogauss intensity and an rf field). Just the (inelastically scattered) electrons will be detected, with the aid of a single-arm spectrometer. Runs are to begin early in 1967.

PART III. EQUIPMENT AND FACILITIES

During the half-year in question many improvements were made in the accelerator and in the facilities provided for use by experimenters.

By January 16, 1966, the necessary repairs to the Experimental Hall (consequent to the explosion and fire of July 5, 1965) had been made and the Hall again became available to the CEA staff and to experimenters. The shielding walls and beam catcher huts were rearranged to accommodate the forthcoming experiments. New gates, radiation interlock systems, and warning lights were installed. Spectrometer platforms were reconditioned, and focusing magnets, analyzing magnets, and detector arrays were mounted on them. New cables for transmission of power and signals were installed. By the latter part of February 1966 the accelerator itself and several of the experimental installations were ready to be operated routinely.

A number of significant improvements were made in the linac and also in the synchrotron vacuum system. Procedures for cleaning and baking-out existing vacuum chambers, rf cavities, and straight section tanks were greatly improved, and the resulting pressure was found to be reduced by an order of magnitude -- to about 2×10^{-8} torr under favorable circumstances. The first of several all-ceramic vacuum chambers, expected to have especially long life and high-vacuum capability, arrived and was made ready for use. Pressure gages of improved type were installed; likewise internal-electron-beam monitors of more sensitive, yet more compact, type were installed.

Additional monitors of external bremsstrahlung beams and external electron beams were constructed, calibrated, and put to use; we now have five gas-filled quantimeters, three secondary-emission monitors, and two Faraday cups. Additional coolers for liquid hydrogen targets were completed, and as many as three were operated simultaneously in support of experiments running simultaneously. We purchased a cryogenics refrigerator for producing liquid hydrogen without the intermediary of low-temperature helium.

Two especially large spectrometer platforms were ordered, and also a pneumatic lift system for raising and positioning them. The assembly and testing of a 200-ton, wide-angle, H-type analyzing magnet was completed, and the same applies to a 72-inch C-type tagging magnet to be used in conjunction with it. Twenty additional concrete shielding blocks were purchased. In May we constructed a new beampath, called #9, through the Main Shielding Wall in order to make it possible for an additional experimentation area to be established in the Experimental Hall. Much progress was made on the design, construction, and testing of computer interface equipment for connecting experimenters' data handling systems to the Harvard Computation Center IBM 360/50 computer.

Construction of the new 100 Mev linac by Varian Associates, although a few weeks behind schedule, proceeded satisfactorily; CEA engineers made several visits to the Varian plant to inspect components and discuss time schedules. Delivery is now expected to occur early in 1967.

Excavation for the tunnel to house this linac (adjacent to Radial Tunnel 26) was started in May, and by June 30 the construction of the tunnel itself was well underway.

Orders for quadrupole triplet magnets for the new linac beam run were placed in April, and orders for power supplies for these magnets and for the septum magnet to be used in inflection were placed in June.

PART IV. OPERATION

On February 25, 1966, we received permission from the New York Office of the Atomic Energy Commission to resume normal operation of the synchrotron in support of the several experimental installations that were ready to run. Among the first of these were the installations of Osborne et al, Wilson et al, Pipkin et al. (The natures of these experiments are indicated in PART II.) In preparing for routine operation we expanded our Operations Division activity to provide three-shift operation starting February 21, arranged a number of operator training sessions, and made extensive improvements in the Operations Procedure Manual. On March 26 we started seven-days-a-week operation of the accelerator.

The total number of hours of use of the accelerator by visiting experimenters and CEA experimenters (including prime time and parasite time) was as follows:

January	0 hours
February	0 hours
March	440 hours
April	716 hours
May	626 hours
June	694 hours

In general, this period was the most productive one to date, despite the fact that, in May and June, daytime operation of the accelerator on week-days had to be curtailed because of excavation work in connection with the new linac tunnel.

On March 24 we achieved a beam current of 22 milliamperes. This is the highest intensity achieved to date in this accelerator and slightly exceeds the original design intensity.

PART V. SAFETY

During January and February the CEA Safety Committee continued the formulation of safety standards and regulations. It prepared a comprehensive safety manual and distributed copies to key CEA persons and principal experimenters.

In February the centering of responsibility for safety in the CEA Director was clarified by President N. M. Pusey, and in February and March the Director issued directives indicating the detailed delegations of responsibility to the Safety Committee, Safety Committee Chairman, Safety Office, Radiation Safety Officer, and other groups concerned with safety.

AEC officials visited the Laboratory, reviewed the safety organization and procedures, and, on February 25, authorized resumption of operations.

In the following months regulations concerning liquid hydrogen targets, pressure vessels, flammable gases, and thin windows were further revised. Also, the Safety Committee spent much time devising a scheme that would make it possible to increase the number of experimental installations in the Experimental Hall without entailing dangerous crowding.

PART VI. STUDY OF BEAM STORAGE

During the six-month period in question the CEA staff made good progress in trial storage of multi-Gev electrons. The study is a part of our "Project Bypass" effort to plan a colliding beam facility that does not require construction of an entire new ring and does not involve the many years of work that such construction would entail. Rather, a short "bypass" beam-run would be arranged, detouring a portion of the existing ring and providing the especially fine focusing ("low beta"), ultra-high vacuum, and long straight section essential to efficient use of colliding beams.

The plan is to inject electrons into the existing synchrotron, accelerate them and damp their oscillations, then decelerate them to permit injection of additional electrons into unoccupied phase space. This process is repeated again and again until perhaps a 50-ma circulating beam of electrons is achieved. Then the alternating-current component of the magnet-ring excitation is turned off (gradually, over several seconds) and the level of d.c. excitation is gradually increased until the desired energy, such as 1.5 Gev or 3.0 Gev, is reached.

If a positron source were available, a large beam of counter-traveling positrons could be achieved in the same ring, again by employment of multi-cycle injection, and both beams could be raised to high energy by turning off the a.c. component of magnet excitation and increasing the d.c. component suitably.

High-speed switching magnets could then be brought into play to switch both kinds of circulating particles into the bypass, where they would be subjected to very fine focusing and then, in a long straight section maintained under extremely high vacuum, would collide head-on. Because the beam cross-sections will be so very small here (thanks to the low-beta feature invented by K. W. Robinson and G. A. Voss in 1965, and described in report CEAL-TM-149) exceptionally high luminosity will be achieved.

The feasibility of retaining high-energy electrons in orbit while the a.c. component of magnet excitation is being turned off was demonstrated in December 1965. However, no special damping was provided and the beam lasted only a few seconds after a.c. turn-off. In March 1966 we received a special damping magnet -- designed to damp horizontal betatron oscillations; we tested it in April and installed it in the synchrotron ring in May. On June 29 we used it successfully in the first long-term storage of multi-GeV electrons: we succeeded in storing a small current of 1.8 GeV electrons for $2\frac{1}{2}$ minutes. The damping of the horizontal betatron oscillations, which normally limit beam-life to about $\frac{1}{4}$ second, was entirely successful.

In order to remove the beam-life limitation of about 2 minutes, we must reduce the pressure of residual gas in the vacuum ring by about two orders of magnitude. We devoted much effort to finding how to improve the vacuum attainable

with our present vacuum chambers (of epoxy resin and other materials), and in fact made considerable gains by means of better cleaning and bake-out procedures, better pumps, etc. More recently we tried out new all-ceramic chambers, with complete success; additional chambers of this type are on order.

Because the damping magnets alter the ν -values of the magnet ring slightly, hence could pose a threat of beam blow-up at certain fractional-integer stop-bands, we made several studies of the ν -values that actually pertain under various typical sets of operating conditions and tried various schemes for controlling the values. Also, we developed several schemes for studying the cross-section of the circulating beam as evidenced by the synchrotron radiation emitted; these monitoring schemes have been found to be very helpful.

At present (November 1966), using two damping magnets, we are able to store a beam of 3-Gev electrons for a period of the order of $\frac{1}{2}$ hour, which we believe to be a world record. When the new linac comes into operation and additional all-ceramic vacuum chambers are available, we expect to store higher intensity beams for longer times and expect to try out multi-cycle injection. We will then be most anxious to obtain a positron source in order that we may prepare to accelerate electrons and positrons in the same ring, simultaneously and countercurrently.

PART VII. PLANNING FOR THE SIXTH INTERNATIONAL
CONFERENCE ON HIGH ENERGY ACCELERATORS

In November the president of the International Union of Pure and Applied Physics designated the CEA as host agency for the Sixth International Conference on High Energy Accelerators. The Planning Committee created to advise on policies concerning this Conference met at the CEA on April 23, 1966, and decided that the Conference should be held on September 11 through 15, 1967.

Various preliminary arrangements have been made, and it now appears likely that the Conference will be attended by about 40 men from USSR, 75 from various European countries, at least 100 from the USA, and about 20 from other countries. Invitations are to be issued in January 1967.

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