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MASTER

SEMI-ANNUAL REPORT for the period

January 1 to June 30, 1963

A.E.C. Contract AT(30-1)-2076

M. Stanley Livingston
Director

July 18, 1963

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MASSACHUSETTS INSTITUTE OF TECHNOLOGY
and HARVARD UNIVERSITY

CAMBRIDGE ELECTRON ACCELERATOR

CAMBRIDGE 38, MASSACHUSETTS

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SUMMARY

During the six-month period from Jan. 1, 1963, through June 30, 1963, the 6-Bev strong-focusing electron synchrotron continued to run well. In June, three-shift operation was begun, one shift being devoted to machine maintenance and improvement and two shifts being devoted to serving the various groups of experimentalists. Nine experimental projects have made substantial use of the accelerator to date, and several others are in advanced stages of preparation. Brief descriptions of the experiments are presented in Part II. The first phases of three experiments were completed, and one of these has already been reported in the literature.

Supporting activity continued at a high level. Much new equipment was obtained, an external positron beam (10^6 particles/sec.) was established, and preparations for trial production of an external electron beam were completed.

The task of fitting out the new Control Room is underway, and construction of a new Counting Room has begun. To permit work on these new rooms the synchrotron will remain off from July 15th until early in September. The backlog of requests by experimentalists for machine time in September and subsequent months is very large.

A request has been made to the AEC for funds to obtain a new linac, -- one having greater stability, greater reliability, and a higher energy (about 70 Mev). If such

a linac were installed, machine down-time could be reduced and the intensity and reliability of the circulating beam could be increased considerably.

PART I. INTRODUCTION

This report summarizes the work done under the Harvard-AEC Contract AT(30-1)-2076 during the period Jan. 1 - June 30, 1963. The contract calls for the operation and maintenance of the CEA 6-billion-electron-volt synchrotron of strong focusing type, and for designing, procuring, installing, and operating various equipments and facilities pertinent to the experiments to be performed.

The construction of the accelerator has been described in the final report on Harvard-AEC Contract AT(30-1)-1909.

As in earlier periods, policies governing the use of the laboratory and its facilities by the various groups of experimentalists have been established by an Executive Committee of the CEA, which includes five representatives of Massachusetts Institute of Technology and five representatives of Harvard University. Scheduling of research operations is the responsibility of the Director of CEA assisted by a Planning Committee, which includes one representative each from MIT and Harvard. Until June 1, 1963 the respective representatives were Prof. M. Deutsch and Prof. R. Wilson; after that date they were Prof. L. Osborne and Prof. F. Pipkin.

PART II. THE EXPERIMENTS

During the first six months of 1963 there were thirteen experiments in progress or in advanced stages of preparation. Eleven of these were described in the previous semi-annual report, and are described very briefly below.

* * *

1. Electron Scattering (R. Wilson et al)

Physicists from Harvard and CEA are investigating the form factors of the proton and neutron by means of the elastic scattering of high energy electrons. During the first four months of 1963 much data was obtained at 1 Bev and 4 Bev, and the first phase of the experimental work was completed; see Phys. Rev. Letters 10, 500, (1963). The target (polyethylene) was mounted in Straight Section 14 of the synchrotron, and the recoil protons were detected with the aid of a large spectrometer employing a 12-inch-bore quadrupole focusing magnet and an array of scintillation counters located in the target area. A quantameter and other detectors were used as beam monitors. By June 30, 1963, the next phase of the experiment (involving detecting the scattered electrons) was already well underway. Some preliminary results were presented at the June 24 - 27 International Conference on Nucleon Structure at Stanford University.

2. Bubble Chamber Investigations (Cambridge Bubble Chamber Group)

Physicists from M.I.T., Harvard, and several other New England universities have made preparations for exploring a variety of particle interactions by means of 12-inch and 40-inch liquid-hydrogen-filled bubble chambers. The 40-inch chamber, to be enclosed in the 300-ton magnet Colossus, has sufficient length and breadth to permit high-resolution examination of the entire group of tracks produced in most types of interactions. The group will study the photoproduction of light and heavy mesons and also strange particles. In addition it will study various electromagnetic interactions. By June 30, 1963, the 12-inch chamber had been assembled, tested, and made ready for operation in Beam 4 1/2. (On July 6th many thousands of successful photographs were obtained.) The enormous task of readying the 40-inch chamber and the associated cryogenic equipment progressed well. Present expectations are that this chamber will be ready for use early in 1964.

3. Photoproduction of Mesons (L. Osborne et al)

Physicists from M.I.T. and neighboring universities are engaged in measuring the cross-sections of photoproduction of positive, negative, and neutral pions by photons have energies from 1 to 6 Bev. Later they will study the photoproduction of kaons. The experimental

equipment, located in the Beam 10 area, includes the 40-ft-spectrometer carriage Moby Dick, two 12-inch quadrupole magnets, a gas-filled Cerenkov counter, two analyzing magnets Scylla and Charybdis, an array of scintillation counters, various hydrocarbon targets and (late in the spring) a liquid hydrogen target. The first successful runs (1 to 2.3 Bev) were made during the spring, and the results are now being analyzed. Runs at higher energies will be undertaken when synchrotron operation is resumed in September.

4. Wide-Angle Muon Pair Production (R. Weinstein et al)

Physicists from Northeastern University, M.I.T., and elsewhere completed the task of installing equipment for studying the photoproduction of muon pairs by 1 to 5 Bev photons. The detection equipment is of wide-angle type, suitable for analyzing pairs having paths at large angles to the axis of the photon beam, and thus implying short inter-particle distance. A two-arm spectrometer of fixed type is used. Each arm consists of a fixed train of thick iron plates for transmitting muons but stopping other kinds of particles. A three-dimensional array of several hundred scintillation counters mounted between the successive iron plates indicates the directions and ranges of the muons. The pulse height analyzers and scalers associated with the hodoscope are situated in a data-recording house located

only 20 ft. away, behind a shielding wall. A digital device for storing the data in IBM magnetic tape format is also used. On January 18, 1963 the equipment was operated successfully for the first time. In subsequent months much data of high quality was obtained. The analysis of results is underway.

5. Photoproduction of Pairs with Large Momentum Transfers

(V. W. Hughes et al)

Physicists from Yale have set up equipment for measuring the ratio of the cross-sections for photoproduction of electron and muon pairs with similar momentum transfer to the nucleus, by detecting one member of each pair at large angle (10° to 15°) to the photon beam direction. The dependence of the cross-section on angle and energy will be evaluated. High energy (4 to 6 Bev) photon beams are used. The equipment, set up in the Beam 7 area, includes a 38-ton pair spectrometer magnet, a pair of 4-inch-bore quadrupole magnets, and an 8-ft high-pressure gas differential Cerenkov counter for identifying electrons, muons, and pions. The equipment is capable of detecting particles that make small angles with the photon beam, and since such particles are especially abundant, good statistics are obtainable.

6. Photoproduction of Sigma Particles (R. H. Milburn et al)

Physicists from Tufts have been preparing to study the photoproduction of sigma particles by a high-energy photon

beam that is sufficiently slender and clean that photographic emulsions situated only one inch from the beam axis may be used as detectors. The equipment includes a lithium hardener, an especially slender and accurately aligned collimation system, a liquid hydrogen target, and a magnet for deflecting Compton electrons away from the emulsions. On May 6, 1963 the effectiveness of the collimation system was explored using a 3-Bev beam and found to be excellent. Preparations for full-scale runs are expected to be complete by October.

7. Pion Production in Peripheral Processes (D. O. Caldwell et al)

Physicists from M.I.T. and Hamburg, Germany will study the production, by 2- to 5-Bev photons of accurately known energy, of single pions that travel in almost-straight-ahead directions. The purpose is to find the nature of the virtual particle involved in such photoproduction process. To provide individual photons of accurately known energy, a 5.5-Bev positron beam is produced by placing a converter in the bremsstrahlung beam from a target in Straight Section 4. The individual positron, on striking a very thin target in the gap in a large magnet, is deflected and at the same time may emit one photon in a forward direction. By measuring the resulting direction and momentum of the positron (by means of a 20-channel hodoscope) the investigators will be able to compute the energy of the photon with an accuracy of $\pm 2 \frac{1}{2}\%$. To find the direction and

momentum of the pion produced by such photons, they will employ several spark chambers, a bending magnet, and other detectors. The determinations of momentum transfer and missing mass may then be made. In June a beam of 5.5-Bev positrons was established, and the hodoscope was operated successfully. Collection of data is expected to start early in the fall.

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

This group is studying the wide-angle, 6-Bev, photo-production of electron-positron pairs, with the object of finding whether the laws of quantum electrodynamics continue to hold at the high energies and short distances involved. Particles produced in a thin beryllium target are analyzed with the aid of a two-arm spectrometer. Each arm employs a focusing magnet of half-quadrupole type, an array of scintillation counters, a 3 1/2-ton threshold-type gas Cerenkov counter, and other discriminating and detecting devices. Data collection is expected to start early in the fall.

In April the group cooperated with representatives of the Stanford University SLAC project in making a series of measurements at CEA relating to the Drell process of photo-production of pions, to provide a firmer basis for decisions and plans being made at Stanford. The runs were successful and the results are now being written up for publication.

9. Study of Shielding (M. S. Livingston et al)

The goal of this project, carried out by physicists from CEA, was the determination of the effectiveness of iron-loaded concrete in attenuating radiation proceeding forward and transversely from a target struck by a 4-Bev beam, to help high-energy physicists planning shielding for personnel or detection equipment. During the current six-months period, the experimental results (obtained in October 1962) were analyzed and a report was drafted. The report is to be issued soon.

10. Spark Chamber Studies of Photoproduction (D. H. Frisch et al)

In this experiment a variety of photoproduction processes will be studied with the aid of a large spark chamber situated between the poles of a specially designed 150 ton magnet. The (1 to 5 Bev) photons employed will originate in a very fine wire target situated near the center of a straight section of the synchrotron. By measuring the individual photon in coincidence with the responsible electron and finding the change in energy of this electron, the investigators can compute the energy of the photon. Tests made in June demonstrated that the "tagging" is successful and the presence of the wire in the center of the straight section does not interfere appreciably with concurrent use of the synchrotron in other experiments.

11. Proton-Compton Effect at 1 to 3 Bev (M. Deutsch et al)

This group is studying the elastic scattering of photons by protons in an energy range (1 to 3 Bev) not available elsewhere. In May and June the group set up, in Beam 10, a train of spark chambers, scintillation counters, and attenuation plates of aluminum for measuring the direction and energy of the recoil proton and a train containing a scintillation counter and a glass Cerenkov counter for measuring the scattered photon. (On July 9, 1963, about 30,000 spark chamber photographs were obtained in a successful run at 1 Bev.)

* * * * *

During the six-month period in question, plans for several additional experiments were accepted, as follows:

12. Elastic Scattering of Electrons by Deuterons (J. I. Friedman et al)

This group plans to use a liquid heavy hydrogen target situated in a straight section of the synchrotron, and will employ focusing magnets, scintillation counters and glass Cerenkov counters to detect the recoil deuterons and distinguish them from protons. The experiment is still in an early stage.

13. Positron Scattering Experiment (L. Hand et al)

This group will investigate the elastic scattering of positrons by protons, and will compare positron scattering with electron scattering. The work is still in an early stage.

PART III. EQUIPMENT AND FACILITIES

In the current six-months period the equipments and facilities for experiments were extended and improved. A 35-ton vertical deflecting magnet was received; four 8-inch-bore quadrupole magnets, two lozenge-type quadrupole magnets, four 3-inch clearing magnets, and a 150-ton magnet for the Frisch spark chamber were designed and ordered.

Additional photon-ejection-type vacuum chambers were built and put into use, and likewise a chamber designed for use with the external electron beam (discussed below). Several of the standard vacuum chambers that were in use for many months just downstream from the linac or at other locations where the radiation levels are particularly high were found to have developed leaks, and were removed from the synchrotron and repaired.

The radiation damage to these chambers requires the prompt development of an alternative type of chamber free from this limitation. A new type of chamber with all-metal side walls has been designed and a model tested; an order

for 4 full-length units has been placed, for detailed testing and study.

Beam Runs 7 and 10 were provided with better collimators and were aligned more carefully. A within-vacuum shutter, remotely controlled and suitably interlocked, was installed in the Beam 10 run; additional shutters were purchased and will be installed. The available quantimeters were improved. The Beam 7 and Beam 10 beam-catcher huts were altered so as to produce much additional attenuation of radiation reaching nearby areas. Adjustable fences of improved type (for excluding people from high-level-radiation areas and yet allowing closely adjacent areas to be used safely as work areas) were obtained and installed.

A positron beam, for use by Caldwell et al and also by the Bubble Chamber Group, was established along Beam-path 4 1/2. Suitable focusing and clearing magnets were provided, and a beam of 10^6 positrons/sec. was introduced and put to use in the Experimental Hall.

Work on equipment for producing an external electron beam progressed well. On April 5, 1963 the feasibility of deflecting the electrons out of the orbit (to the extent of 1 inch in a run of 16 ft.) by means of a pulsed current strip ("Magnet E-1") mounted in a straight section tank was demonstrated successfully. By June 30, 1963 Magnet E-2 was in place in the following straight section ready for ejecting the deflected beam entirely out of the synchrotron

and toward the Experimental Hall. (This goal was accomplished a few days later, on July 2, 1963, using improvised power supplies.) It is expected that the equipment will be ready for routine use early in 1964.

The first semi-portable unit for cooling liquid hydrogen targets was completed and put into routine operation. Four more such devices were ordered.

The large liquid-hydrogen refrigerator to be used in conjunction with the 40-inch bubble chamber was assembled and tested. The tests showed that the poly-concentric tubes of the heat interchanger performed considerably less efficiently than the manufacturer had indicated; improved tubes are being obtained. Meanwhile the refrigerator was put into successful use serving the smaller, 12-inch chamber.

The radiation safety equipment continued to perform well and showed that no appreciable amounts of radiation were reaching work areas within CEA or parking areas, etc., outside. Improved monitors of fast neutrons were obtained.

PART IV. ACCELERATOR OPERATION

The accelerator performed well throughout the six-month period in question. Despite numerous delays on account of leaks in certain vacuum chambers, various difficulties with the linac, and occasional troubles of other kinds, the accelerator was operated acceptably on the great majority

of week-days. Starting in June, three-shift operation was inaugurated. One shift was used for servicing, repairing, and improving the accelerator. The other two shifts were devoted to runs on behalf of experimentalists. The number of hours of operation per month are indicated in the monthly reports.

Although the trend in operation has been toward greater reliability and higher intensity, many difficulties have been apparent. A number of improvements have been made. For example, the cause of the "rainy day effect" (leakage currents in the outdoor capacitor yard caused by rain) was determined and improved insulators were installed, greatly improving the situation. We plan to correct many of the other difficulties during the period from July 15 through Sept. 2 when the machine will be out of operation. It has become clear, however, that many of the problems will remain until an improved linac is obtained; the present linac was not designed to provide the reliability or uniformity of output that now appears necessary, and in any event its maximum energy (28 Mev) is insufficient and permits remanence effects in the 48 magnets and stray fields of various kinds to distort the orbit to an important extent. Advances in the linac art now make it possible to procure a linac providing much higher energy (about 70 Mev) and greater stability, and we have asked the AEC for funds to purchase such a linac in FY 65.

PART V. MAJOR IMPROVEMENTS MADE

A new room situated in the SW portion of the Power Building ground floor was completed and made ready for fitting out as Main Control Room. The old Main Control Room, in Room 103 of the Laboratory Building, was undesirably remote from the subsidiary control rooms, i.e., linac control room, magnet power control area, rf control room. In any event, the consoles and cabling provided there were informal and not suited to permanent use. The new room is acoustically isolated from the adjacent power supplies, and has floor panels providing short, easily serviced runs of cables from the synchrotron to the various consoles. By June 30th the console frames were in place and plans for installing the necessary meters, controls, etc., were well advanced. When the machine starts operating again in September, it will be controlled from this room.

Plans for constructing a new Counting Room directly above the Target Area were completed, the necessary contract has been let, and excavation is already (July 18, 1963) underway. The new room is to be ready for occupancy early in 1964.

Plans for building a retaining wall along the Hammond Street and Gorham Street boundaries of the property, and raising the level of earth fill in order to provide a greater attenuation of radiation from scrapers etc. within the Circular Tunnel, were completed, and orders placed.

A new locker room and wash room for technical staff on the second floor of the Power Building was nearly complete by June 30th.

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