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for the period

January 1 through June 30, 1964

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

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Director

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MASSACHUSETTS INSTITUTE OF TECHNOLOGY
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CAMBRIDGE ELECTRON ACCELERATOR

CAMBRIDGE 38, MASSACHUSETTS

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SUMMARY

Part I states the purpose of the contract, which is concerned with operation of the 6-Bev Cambridge Electron Accelerator. Part II indicates the general nature of each of the 15 experiments that were in progress or in advanced stages of preparation during the six-month period in question. Part III lists some of the improvements made in the accelerator and the associated facilities, and Part IV deals with the routine operation of the accelerator.

PART I. INTRODUCTION

This report summarizes the work done under the Harvard-AEC Contract AT(30-1)-2076 during the six-month period January 1 - June 30, 1964. The contract calls for the operation and maintenance of the CEA 6-billion-electron-volt synchrotron and for designing, procuring, installing, and operating various equipments and facilities pertinent to the experiments performed.

Scheduling of research operations is the responsibility of the Director of CEA assisted by a Planning Committee which currently includes Prof. L. Osborne of M.I.T. and Prof. F. Pipkin of Harvard.

PART II. THE EXPERIMENTS

During the six-month period in question there were fifteen experiments in progress or in an advanced stage of preparation. These are described briefly below.

1. Electron Scattering (R. Wilson et al)

Physicists from Harvard obtained much additional data on the scattering of high-energy electrons by nucleons. As in the previous six-month period, the target was mounted directly in the vacuum ring of the synchrotron and the recoiling protons were detected with the aid of a spectrometer situated close beside the ring. In the present period principal attention was given to quasi-elastic scattering by the neutrons in a deuterium target in order to resolve conflicts with results obtained at other laboratories as to the form factor of the neutron. By June 30'th the experimental work was completed and analysis of the data was underway. Preparations for later runs, designed to take advantage of the recently achieved external electron beam of the CEA, are in progress.

2. Bubble Chamber Investigations (Cambridge Bubble Chamber Group)

During March and April 1964 approximately thirty 8-hour shifts of accelerator operation were allocated to the Cambridge Bubble Chamber Group, which obtained of

the order of a half-million photographs of events in its 12-inch-diameter liquid hydrogen bubble chamber. The necessary reduction in intensity of the bremsstrahlung beam from the synchrotron target in Straight Section 4 was accomplished by conversion to positron-electron pairs and reconversion of the positrons. The CEA refrigerator for maintaining the supply of liquid hydrogen performed well. On completion of the run the 12-inch chamber was removed to allow room for final assembly of the 40-inch chamber, to be enclosed in the 300-ton magnet Colossus. It is expected that this latter chamber will be ready for operation early in 1965.

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

Physicists from M.I.T. completed the first phase of their investigation of photoproduction of mesons, i.e., completed their measurements of the cross-sections for production of pions. Two reports on the results were published in the June 22, 1964 issue of Phys. Rev. Letters. More recently the group has been assembling equipment for use in the next phase of the work, which is concerned with photoproduction of pions, η particles, and kaons. Results obtained in this phase will help show whether SU(3) theory is correct in predicting production ratios among these particles. Again Beam 10

is to be used, and the Moby Dick carriage. Data taking is expected to start early in July.

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

Physicists from Northeastern University, M.I.T., and elsewhere completed the analysis of data obtained in earlier months on the wide-angle photoproduction of muon pairs and reported their results in Phys. Rev. Letters; see also a recent issue of the Bulletin of the American Physical Society. By June 30'th the group had nearly finished installing much new equipment in the Beam 11 Area; this equipment is designed to provide results far more accurate than were attainable previously. It is expected that the data to be obtained in the near future will make it possible to demonstrate the validity of quantum electrodynamics at higher momentum transfer and shorter interaction distance than were available previously.

5. Photoproduction of Pairs with Large Momentum Transfer

(V. W. Hughes et al)

In March and April physicists from Yale obtained much data on the cross-sections for photoproduction of wide angle pairs of kaons, pions, and muons (of about 2.5 Bev/c momentum) by 3 to 6-Bev photons as a function of bremsstrahlung endpoint energy, particle momentum,

and production angle. One member of each pair was detected, at angles of 5° , $7\frac{1}{2}^\circ$, and 10° in the lab. system. The equipment included a liquid hydrogen target, the 60-inch pair spectrometer magnet Minerva, two 4-inch-bore focusing magnets, two differential gas Cerenkov counters, and several scintillation counters. The investigations of kaons and pions were especially successful. Analysis of the data is in progress.

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

Physicists from Tufts explored the photoproduction of sigma particles by a highly collimated beam of 3-Bev photons aimed at a small target of liquid hydrogen. The paths of the sigma particles and other charged particles were recorded by nuclear emulsions situated in a magnetic field within 1 or 2 inches of the target and of the axis of the photon beam. Analysis of the emulsions is in progress.

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

Physicists from M.I.T. and elsewhere studied the production, by 2 to 5 Bev photons of accurately known energy, of single pions that travel in almost-straight-ahead directions. The purpose was to find the nature of the virtual particle involved in such a photoproduction process. To obtain individual photons of accurately

known energy the investigators employed a convertor to produce electron-positron pairs (from the bremsstrahlung beam from the synchrotron), and directed the resulting electrons at a thin copper target. When such an electron interacted with the target, a high-energy photon was emitted in forward direction. By determining the energy loss of the electron by means of a bending magnet and a 20-channel scintillation hodoscope the investigators were able to compute the energy of the photon. The direction and momentum of the pion produced when the photon struck the liquid hydrogen target was evaluated with the aid of four spark chambers, a Scylla-type 48-ton bending magnet, a differential gas-filled Cerenkov counter, and a shower detector. More than 50,000 successful sparkchamber photographs were obtained and are now being analyzed.

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

Physicists from Harvard obtained much data on the photoproduction of symmetric, wide-angle electron pairs, for the purpose of seeing whether quantum electrodynamics is still valid at very high momentum transfer and very small interaction distance, i.e., to see whether predictions based on the Bethe-Heitler equations are valid. Electron-positron pairs produced by 5-Bev photons in a carbon target were analyzed with the aid of a two-arm

spectrometer each arm of which employed a 7-ton focusing magnet of half-quadrupole type, an array of scintillation counters, a $3\frac{1}{2}$ -ton threshold-type gas Cerenkov counter, and other discriminating and detecting devices. The results are now being analyzed. Meanwhile a new series of runs, designed to shed light on the photoproduction of pion pairs via resonances, is getting underway.

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

Physicists from M.I.T. have been preparing to study a wide variety of photoproduction processes with the aid of a large " L_{π} " spark chamber situated in the field of a specially designed 130-ton magnet Mascot. The (1 to 5 Bev) photons employed will originate in a fine wire mounted directly in the path of the orbiting electrons at the center of Magnet 12. By measuring the individual photon in coincidence with the recoil electron responsible, and finding the change in energy of this electron, the investigators will be able to compute the energy of the photon. Assembly of the frame of the magnet is complete and other components of the magnet are scheduled to be delivered soon.

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

Physicists from M.I.T. continued their studies of the elastic scattering of 1 to 3 Bev photons by protons.

The results obtained in the earlier runs were analyzed, and at the same time the experimental equipment was augmented by an analyzing magnet for determining the energy of the recoil proton more accurately. A large quantity of data was obtained in May and June, and the results are being analyzed.

11. Elastic Scattering of Electrons by Deuterons

(J.I. Friedman et al)

Physicists from M.I.T. have nearly completed preparations for studying the rare events in which a high-energy electron strikes a heavy-hydrogen target and is elastically scattered by a deuteron, rather than by a single nucleon. The detection equipment will include three large banks of scintillation counters and an array of 20 Cerenkov counters capable of discriminating between deuterons and nucleons. This equipment, together with a focusing magnet and a special planar array of spark-forming wires, is to be assembled on the large spectrometer platform that has been in use adjacent to Straight Section 14. It is expected that the equipment will be ready for preliminary trial within two months.

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

Physicists from Harvard are completing the assembly of apparatus for studying the scattering of positrons by protons. The positrons, produced by a double

conversion process, are directed at a liquid hydrogen target. Scattering events in which the scattered positron and recoiling proton are coplanar with the incident positron are to be analyzed with the aid of four large spark chambers.

13. Analysis of Bremsstrahlung Beam (CEA Physicists)

CEA physicists have continued assembling equipment needed for determining the spectral energy distribution of a multi-Bev photon beam. A 20-ton Orpheus-type pair-spectrometer magnet will be used to divert the positron and electron (produced by the given in a converter) toward two symmetrically arranged arrays of scintillation counters backed up by glass Cerenkov counters. It is estimated that an accuracy of $\frac{1}{2}$ to 1% in energy of the individual photon will be achieved. The equipment is expected to be ready for use within a few months.

14. Production of Polarized High-Energy Photons

(R.H. Milburn et al)

Physicists from Tufts and CEA continued preparations for exploring the feasibility of producing polarized high-energy photons by means of collisions between polarized low-energy photons and high-energy electrons of the CEA circulating beam. Linearly polarized photons of red light (about 2 ev) from a ruby laser are aimed

head-on at a beam of 5 or 6-Bev electrons in Straight Section 10, with the expectation that a small but appreciable fraction of the photons will be scattered almost straight backward with greatly increased energy and with retention of a high degree of linear polarization. Estimates suggest that about 100 linearly polarized photons having 400 to 850 Mev energy will be produced per pulse of the laser. Most of the necessary equipment was procured and installed in the Target Area, and, in preliminary trials, backward-scattered high-energy photons were detected.

15. Study of Polarization of Recoil Proton in Neutral Pion

Photoproduction at 1.5 Bev (R. H. Milburn et al)

Physicists from Tufts are preparing to determine the degree of polarization of the recoil proton produced when a 1.5 Bev photon strikes a liquid hydrogen target and produces a neutral pion. Such a determination would assist in interpreting the process underlying the recently observed "fourth resonance". The first phase of the work is the experimental determination of the feasibility of moderating protons recoiling at 90° in the c.o.m. system to energies at which the polarization can be analyzed efficiently. The equipment to be used will include a special spark chamber that contains carbon plates, and also an analyzing magnet and a Cerenkov counter. A small spark chamber was built and tried out successfully in the Beam 10 Bremsstrahlung beam.

PART III. EQUIPMENT AND FACILITIES

Many improvements in equipment and facilities were made during the current six-month period. A prebuncher for the linac was built and put into operation, a set of coils of improved type was received and installed on the 60-ton inductor of the magnet power supply, vacuum chambers of new (solid side-wall) type were received and installed and additional quantities of such chambers were ordered.

The versatility of the beam-bump system was improved to the extent that bremsstrahlung beams could be directed into either of two experimental areas with virtually any desired sequential sharing schedule, and with spill times as long as three milliseconds.

The CEA electron beam was successfully ejected and directed across the Target Area. The linear and angular widths of the ejected beam were measured and found to be satisfactorily small, for all machine energies from 1 Bev to 6 Bev. Construction of a versatile transport system is underway.

Extensive rearrangement of Experimental Hall shielding walls, interlock systems, cables, etc., was accomplished to serve new groups of experiments. Large numbers of cables serving the New Counting Room were installed. Several new coolers for liquid hydrogen targets were completed and put into use. Four new focusing magnets of special oblong-aperture type were obtained, and

likewise a 130-ton magnet Mascot for use in forthcoming spark-chamber experiments. A new spectrometer carriage "Kontiki" was received. New equipment for power factor correction was installed, and new circuit breakers were received.

Several new quantimeters were received, and construction of a Faraday cup for monitoring the external electron beam was completed. A set of 10 additional monitors of fast neutrons was purchased. A 245-page report CEAL-1000 on the accelerator and its facilities was issued.

In mid-April 1964 a 33-page "Proposal for a Storage Ring at the Cambridge Electron Accelerator" was submitted to the Atomic Energy Commission, and on May 23rd the proposal was discussed with the AEC Storage Ring Evaluation Committee.

PART IV ACCELERATOR OPERATION

During this 6-month period the accelerator ran well. In February, during operation at 5.5 Bev energy, a circulating current of 8.3 milliamperes was achieved. Gradual improvement in reliability of operation has been made also.

From December 14, 1963, until January 6, 1964, the accelerator was shut down to permit various repairs and improvements to be made. Another three-week shutdown occurred from April 27 through May 18, 1964.

In all, eleven groups of experimenters (listed in Part II) enjoyed use of the high-energy beam.

The practice of operating the synchrotron continuously throughout the weekend was adopted in March and April. Preparations are being made for operating three shifts per day, 7 days per week following the proposed three-week shutdown to begin early in September. A formal training program for operators is underway.

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