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UNIVERSITY OF MICHIGAN
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PROGRESS REPORT

UNIVERSITY OF MICHIGAN SYNCHROTRON PROJECT

September 1, 1953, to September 1, 1954

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Project 1922

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In June, 1953, five Ph.D. theses describing experimental research done on the synchrotron project were presented, and since that time two theses describing theoretical work done on the project have been completed and presented. In consequence of the completion of so many of the thesis problems which have been under way for two years or more, almost the entire "crop" of Ph.D. students has moved out and a new group of beginners has taken over. For this reason the character of the activity on the synchrotron for the past twelve months has been different from that of the year before, in that most of the problems are in earlier stages. Some of the problems, however, have continued through. A brief description of each activity of the past twelve month period is given below.

Electron Scattering

Experiments on the scattering of electrons by nuclei of heavy and medium atomic number have received the major part of the effort of the group throughout the year. Angular distribution measurements on tungsten at 31, 40, and 60 Mev at angles between 65 and 115 degrees have been completed. In addition, an experiment with the same apparatus and in the same angular range was performed on aluminum at 25 Mev. The latter was a "zero" radius calibration, since the finite-size correction is only a few percent over the whole angular range. The results for the aluminum cross sections check the Feshbach point-charge calculations within the statistical error. The radius found for the tungsten nucleus is larger ($R = 1.2 \times 10^{-13} A^{-1/3} cm$) than previously reported. This difference stems from two sources: (1) the previously reported experimental results were found to be systematically in error by about 10 percent and (2) the prediction of the theory has been changed by more accurate calculations in the period intervening between the two experiments, also about 10 percent.

A manuscript for publication of the above work has been completed, but is being withheld for a month until further checks on the calculations can be made.

During the year a high-resolution (1%) analyzer magnet for the electron-scattering measurements was completed and put into operation. With the improved resolution, electron-scattering work is continuing in the same energy range as has been explored during the past year. In this energy range, the results of Rainwater on mumesic atoms may be directly compared with the result of electron scattering. Superficially, the results are thus far in poor agreement. However, if a shape factor is introduced, i.e., if the uniform density model is abandoned, the experiments can be made to agree. Better accuracy in both sets of experiments will be required before it will be possible to say much about this shape factor.

Preliminary work began this summer on electron-proton scattering at 100 Mev. This experiment will gradually replace the experiments on the high and medium atomic numbered scatterers which have received the principal effort so far. The scattering of electrons against protons is more difficult because of the much lower cross section, but the theoretical interpretation should be of more basic value.

Gyromagnetic Ratio of the Free Electron

This work began about two years ago as a side issue in the synchrotron program and has proved to be so fruitful that it is being continued. The first experiment used the electron-gun system of the synchrotron as a source of 400 Kev electrons; the gyromagnetic ratio work being done during hours when the synchrotron was not in use. Results were obtained giving the gyromagnetic ratio of the free electron to $\pm$ 1/2 percent accuracy. This was the first time that any experiment had given any value at all for this property of the free electron. A reprint of the description of the experiment is enclosed.

From a theoretical point of view, the results will be of a much greater value when an accuracy of 0.1 percent or better is achieved. This is because the "radiative correction", or anomalous part of the moment, is expected to amount to about 0.1 percent of the total moment. Because the first result was already so near to the interesting region, and because there appeared to be ways of making a great jump in the accuracy of the experiment, work was started immediately to rebuild the equipment and at the same time to free it from dependence on the synchrotron-injector system.

The new apparatus has been under construction and test for the past year. At present we have an aluminum vacuum tube 12 inches in diameter and 18 feet long wound on the outside with a single layer of copper

tubing to produce an axial magnetic field, a 150 kv power supply and electron gun, a vacuum pumping system, correction coils for cancelling the earth's magnetic field, and a regulated d-c power supply for the solenoid. Electrons have been sent down the tube for the purpose of aligning the magnetic field and the slits. The most important part which remains to be done on the instrumentation is the detection and counting system. It is expected that attempts can be made to measure the gyromagnetic ratio of the electron during the coming year.

Photodisintegration Experiments

For the past year apparatus has been under construction and preliminary experiments have been run toward a precise measurement of the cross section and angular distribution in the photodisintegration of the deuteron at energies up to 100 Mev. Although the x-ray spectrum from the synchrotron is, of course, not monochromatic, the effect of monochromatic radiation can be achieved by sorting the events with respect to the energy of the ejected proton. A complete system which accomplishes this is now in operation and it is expected that during the coming year the measurements can be made.

Study of the Oscillation Frequencies of the Electrons in the Synchrotron Orbits

Some years ago a purturbation method for determining the oscillation frequencies in the orbits was proposed and tried. This consisted of applying a very weak, transverse r.f. field across the donut, either vertically or radially, and of simply observing the frequencies which caused the beam to "blow up". The experiment was taken up again during the past year with the object of investigating more carefully the question as to whether the existing orbit oscillation frequencies were missing, with sufficient margin of safety, the blow-up frequencies in the racetrack which are theoretically expected to be present because of the four straight sections. (Actually, no such resonant blow up has ever been reported in connection with any existing racetrack synchrotron, but there is no doubt, theoretically, as to the possibility.)

Two results were obtained from the experiments: First, the desired information on the nearness of the oscillation frequencies to the racetrack resonances was found, and it pointed to a possible improvement through a change in the fall-off index. Second, a new phenomenon was observed. Each orbit oscillation frequency was found to have a fine structure consisting of a band of evenly spaced, sharp lines. This type of spectrum was identified as one arising from frequency modulation. The synchrotron phase oscillations cause a modulation in radius, which in turn gives a

modulation in the fundamental frequency. This, then, modulates the betatron type oscillations; splitting each of the latter into a band of evenly spaced lines. A new piece of information is immediately derived from the spacing in the bands, namely, the synchrotron oscillation frequency. This was verified by changing the power in the r.f. accelerator cavity, thereby changing the synchrotron oscillation frequency. The details of the experiment and theory have been prepared for publication.

Injector Research

One of the fertile fields for improvement in all synchrotrons is beam intensity. Toward this end, in the past year experiments have been conducted with systems for focusing the electrons from the filament into the inflector plates and with the pulse transformer which produces the high-injection voltage. The oil-immersed transformer feeding a single gap accelerator at 420 kv, which is still being used, has caused a total of several weeks of shut-down time during the past year, and consequently, it is felt that it would not be wise to try to push this system to a higher voltage.

A design using freon gas insulation instead of oil has been tried and its performance at atmospheric pressure has equaled that of the present oil-filled system. Therefore, an injector which will be insulated with freon under pressure, and which should bring about a considerable increase in voltage, is being constructed. The injection voltage is, incidentally, the only parameter which has been found that has a really important effect on beam current, and therefore, it is expected that the new injector system will bring about a substantial improvement.

Installation of Ignitron-Magnet Pulser

The ignitrons which had been on order for more than a year arrived and were put into place. Some work remains to be done on the water system and the electrical control system before operation can begin. The present energy of the synchrotron is 100 Mev. With the ignitron-pulse system it should be possible to move up to the full design energy of the magnet, 300 Mev.

SCIENTIFIC PERSONNEL

H. R. Crane (Professor)
R. W. Pidd (Associate Professor)
L. W. Jones (Instructor)
K. M. Terwilliger (Instructor)
C. L. Hammer (Instructor)
A. A. Shoupp (Ph.D. thesis student)
D. A. Naymik (Ph.D. thesis student)
D. F. Nelson (Ph.D. thesis student)
J. C. Van der Velde (Pre-thesis graduate student)
H. W. Hilsinger (Pre-thesis graduate student)
G. P. Kenfield (Pre-thesis graduate student)

PROFESSIONAL PERSONNEL

A. B. Miller (Full-time synchrotron operator)
H. A. Westrick (Instrument maker)
O. W. Haas (Machinist)
W. A. Miller (Assistant machinist)
G. M. Edict (In charge of electronics shop)

STUDENT HELPERS

Part-time student helpers are not listed by name. They are used in the work to the extent of about four at any given time.

THESES PRESENTED

"Some Contributions to the Theory of Scattering from a Many-body System, with Application to the Scattering of Electrons from Nuclei", by Robert Lewis.

"Theory of an Electron in a Magnetic Field, with Application to the Measurement of the Gyromagnetic Ratio of the Free Electron", by H. Mendlowitz.

PAPERS AND ABSTRACTS PUBLISHED

"An Experimental Measurement of the Gyromagnetic Ratio of the Free Electron", W. H. Douisell, R. W. Pidd, and H. R. Crane, Phys Rev 94, 7 (1954).

"High Energy Electron Scattering by Nuclei", R. W. Pidd, C. L. Hammer, and E. C. Raka, Phys Rev 92, 436 (1953).

"High Energy Electron Scattering", R. W. Pidd, Minneapolis Meeting, APS, June 28-30, 1954 (invited paper).

PAPERS IN PREPARATION

"The Frequency Spectrum of Orbital Oscillations in the Synchrotron", K. M. Terwilliger and R. W. Pidd (for Rev Sci Instruments).

"High Energy Electron Scattering", D. A. Naymik and R. W. Pidd (for Phys Rev).

"The Gyromagnetic Ratio of the Free Electron", H. R. Crane (for Am J Phys).