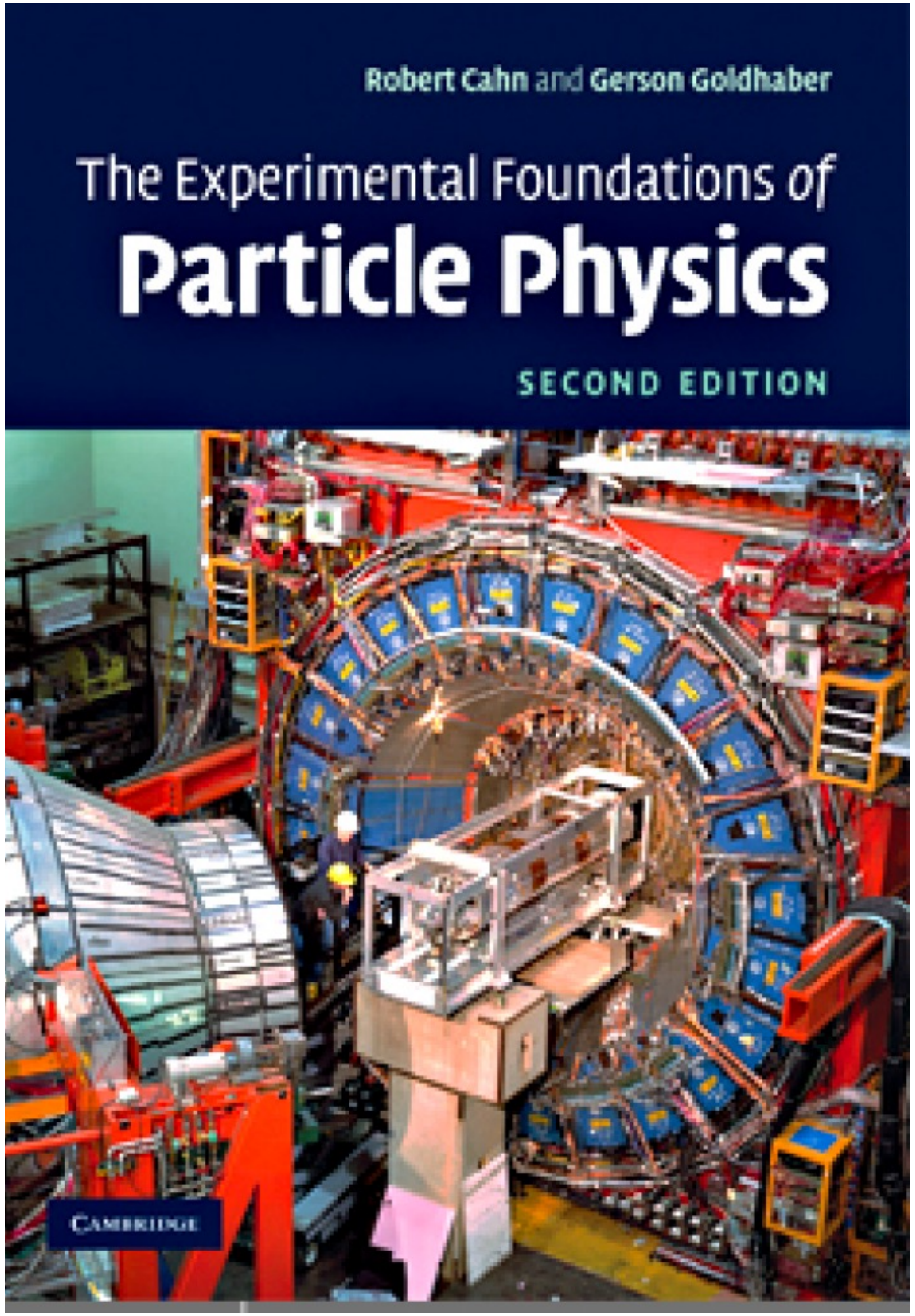
History of particle physics experiments

- Idea to present every two weeks(?) one experiment of particle physics + an overview on the scientific background & ideas which contributed to that experiment
- The Cahn-Goldhaber book would be a guide which we can follow
- On the other week we could discuss one experimental problem/excercise
- The meeting should last 1—1:30h from 9:30am-11:00am
- The first meeting could be on October 2 or 9 with a presentation


Robert Cahn and Gerson Goldhaber
The Experimental Foundations of
Particle Physics
SECOND EDITION
CAMBRIDGE

Overview

1

The Atom Completed and a New Particle

The origins of particle physics: The atom, radioactivity, and the discovery of the neutron and the positron, 1895–1933.

The fundamental achievement of physical science is the atomic model of matter. That model is simplicity itself. All matter is composed of atoms, which themselves form aggregates called molecules. An atom contains a positive nucleus very much smaller than the full atom. A nucleus with atomic mass A contains Z protons and $A - Z$ neutrons. The neutral atom has, as well, Z electrons, each with a mass only 1/1836 that of a proton. The chemical properties of the atom are determined by Z; atoms with equal Z but differing A have the same chemistry and are known as isotopes.

This school-level description did not exist at all in 1895. Atoms were the creation of chemists and were still distrusted by many physicists. Electrons, protons, and neutrons were yet to be discovered. Atomic spectra were well studied, but presented a bewildering catalog of lines connected, at best, by empirical rules like the Balmer formula for the hydrogen atom. Cathode rays had been studied, but many regarded them as uncharged, electromagnetic waves. Chemists had determined the atomic weights of the known elements and Mendeleev had produced the periodic table, but the concept of atomic number had not yet been developed.

The discovery of X-rays by W. C. Röntgen in 1895 began the revolution that was to produce atomic physics. Röntgen found that cathode-ray tubes generate penetrating, invisible rays that can be observed with fluorescent screens or photographic film. This discovery caused a sensation. Royalty vied for the opportunity to have their hands X-rayed, and soon X-rays were put to less frivolous uses in medical diagnosis.

The next year, Henri Becquerel discovered that uranium emitted radiation that could darken photographic film. While not creating such a public stir as did X-rays, within two years radioactivity had led to remarkable new results. In 1898, Marie Curie, in collaboration with her husband, Pierre, began her monumental work, which resulted in the discovery of two new elements, polonium and radium, whose level of activity far exceeded that of uranium. This made them invaluable sources for further experiments.

A contemporaneous achievement was the demonstration by J. J. Thomson that cathode rays were composed of particles whose ratio of charge to mass was very much greater

Experiment

MARCH 15, 1933 PHYSICAL REVIEW VOLUME 43

The Positive Electron

Carl D. Anderson, *California Institute of Technology, Pasadena, California*

(Received February 28, 1933)

Out of a group of 1300 photographs of cosmic-ray tracks in a vertical Wilson chamber 15 tracks were of positive particles which could not have a mass as great as that of the proton. From an examination of the energy-loss and ionization produced it is concluded that the charge is less than twice, and is probably exactly equal to, that of the proton. If these particles carry unit positive charge the curvatures and ionizations produced require the mass to be less than twenty times the electron mass. These particles will be called positrons. Because they occur in groups associated with other tracks it is concluded that they must be secondary particles ejected from atomic nuclei.

Editor

On August 2, 1932, during the course of photographing cosmic-ray tracks produced in a vertical Wilson chamber (magnetic field of 15,000 gauss) designed in the summer of 1930 by Professor R. A. Millikan and the writer, the tracks shown in Fig. 1 were obtained, which seemed to be interpretable only on the basis of the existence in this case of a particle carrying a positive charge but having a mass of the same order of magnitude as that normally possessed by a free negative electron. Later study of the photograph by a whole group of men of the Norman Bridge Laboratory only tended to strengthen this view. The reason that this interpretation seemed so inevitable is that the track appearing on the upper half of the figure cannot possibly have a mass as large as that of a proton for as soon as the mass is fixed the energy is at once fixed by the curvature. The energy of a proton of that curvature comes out 300,000 volts, but a proton of that energy according to well established and universally accepted determinations[1] has a total range of about 5 mm in air while that portion of the range actually visible in this case exceeds 5 cm without a noticeable change in curvature. The only escape from this conclusion would be to assume that at exactly the same instant (and the sharpness of the tracks determines that instant to within about a fiftieth of a second) two independent electrons happened to produce two tracks so placed as to give the impression of a single particle shooting through the lead plate. This assumption was dismissed on a probability basis, since a sharp track of this order of curvature under the experimental conditions prevailing occurred in the chamber only once in some 500 exposures, and since there was practically no chance at all that two such tracks should line up in this way. We also discarded as completely untenable the assumption of an electron of 20 million volts entering the lead on one side and coming out with an energy of 60 million volts on the other side. A fourth possibility is that a photon, entering the lead from above, knocked out of the nucleus of a lead atom two particles, one of which shot upward and the other downward. But in this case the upward moving one would be a positive of small mass so that either of the two possibilities leads to the existence of the positive electron.

In the course of the next few weeks other photographs were obtained which could be interpreted logically only on the positive-electron basis, and a brief report was then published[2] with due reserve in interpretation in view of the importance and striking nature of the announcement.

Magnitude of Charge and Mass

It is possible with the present experimental data only to assign rather wide limits to the

[1] Rutherford, Chadwick and Ellis, *Radiations from Radioactive Substances*, p. 294. Assuming $R \propto v^3$ and using data there given the range of a 300,000 volt proton in air S.T.P. is about 5 mm.

[2] C. D. Anderson, Science **76**, 238 (1932).

Guidelines for the presentation

- Scientific background
- Description of the experiment (quantitative considerations)
  - innovative characters
  - result
  - Impact
  - In case: how you would do it today?

Guidelines for participants

- Informal discussion
- You shouldn't be afraid to ask questions
- The final aim is the scientific growth of young people (and review some experiments for the seniors)

Program

- We can start on October 9 with Section 1:
- Possible experiments:
  - Discovery of the neutron
  - Positron
  - …

Program

- We can continue on October 23 with Section 2:
- Possible experiments:
  - Discovery of the muon
  - Conversi, Pancini, Piccioni
  - Discovery of the charged/neutral pion and determination of its spin

- Who wants to start?

Experimental Problem/Exercise

- Usual a problem of Particle physics (like the determination of some quantities in a scattering of particles or detector considerations)
- We could have a first introduction on Relativistic kinematics (GV)
- Detectors (FI?)
- …