matched to the wavelength of the plasma waves. Joshi showed results of an experiment in which a carbon dioxide laser was run at two frequencies to create the beat wave and the presence of the plasma wave was verified by Thompson scattering of laser light. Sullivan showed a movie of a simulation of that mechanism in which accelerating gradients of 50 GV/m were developed. The physics of these processes is interesting but it obviously remains to be demonstrated that plasmas can be sufficiently well controlled.

The 'near-field' type of laser accelerator can be typified by acceleration using the longitudinal field associated with evanescent waves near a grating. A simple wave would have accelerating gradients falling towards zero as the velocity approaches that of light but a substantial accelerating field could be retained between two gratings a fraction of a wavelength apart or by a single-grating illuminated by composite laser waves. R. Palmer put forward this latter possibility which might result in accelerating gradients of 1 GeV/m. However the accelerated currents are likely to be small (perhaps only 10^4 particles per bunch) compared to the conventional linac.

The similarity between a grating and a linac was explored. This led to consideration of an optimum wavelength — longer wavelengths allow higher currents but the breakdown fields associated with longer pulselengths is lower. M. Tigner worked out that the optimum may lie in the 1 to 10 mm region. Suitable high power lasers have not been developed in this region but this could change with the advent of, for example, the free electron laser.

The working groups urged that the limits on acceleration in gas in grating structures be measured as a function of wavelength and that further experiments on accelerating gradients in plasmas be carried out. The Workshop summary was presented by J. Lawson and the proceedings will appear in about six months.

There are some topics of basic physics concerning the interactions of laser fields with particles, plasmas and materials which clearly need further study and the road to realizing the great potential of laser accelerators is sure to be a hard one. Nevertheless emerging from the Workshop was a recognition of the great potential which exists and the identification of laser-driven accelerators as a specific field for investigation and systematic development. These matters, among others, will be reviewed in the ECFA Conference on novel particle acceleration techniques at Oxford in September.

(We are grateful to John Lawson, Andy Sessler and Bill Willis for providing us with information from which this article is drawn.)

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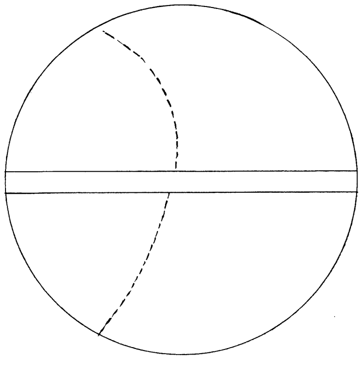
50 years of positrons

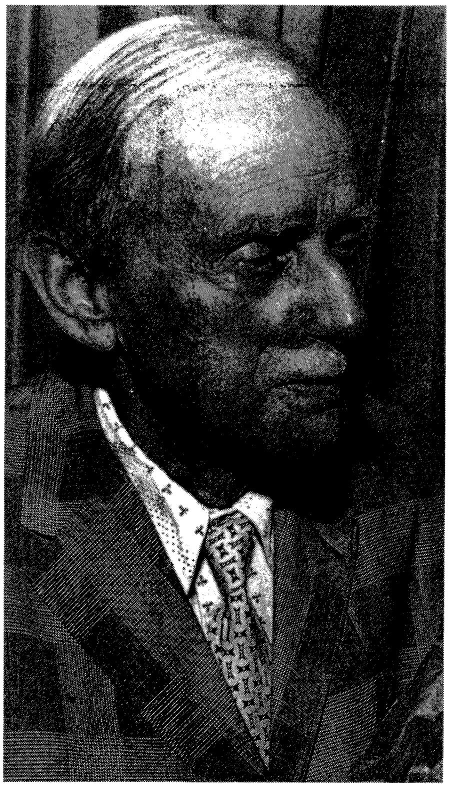
This year marks the 50th anniversary of one of the major landmarks of modern physics — the discovery of the positron, the antimatter counterpart of the electron. This provided the first evidence for antimatter, and it was also unprecedented for the existence of a new particle to have been predicted by theory. The positron and the concepts behind it were to radically change our picture of Nature. It led to the rapid advancement of our understanding, culminating some fifteen years later with the formulation of quantum electrodynamics as we now know it.

In addition, the past half century has seen positrons develop from a curiosity into one of the major tools — in electron-positron colliders — for today's particle physics research. If the list of proposed new high energy projects is anything to go by, they will continue to be exploited for a long time to come.

(Oddly enough, this year is also the fiftieth anniversary of another major milestone in particle physics — the discovery of the neutron. This we shall be returning to later this year. But it is clear that in view of these two major advances, 1932 could

Sketch of the first positron event, seen by Carl Anderson in 1932 in his cloud chamber exposed to a magnetic field of 15 kilogauss. A 63 MeV cosmic ray positron entered the chamber from below, lost energy in the central lead plate, and emerged again in the top half of the chamber. The difference in track curvature between the two halves of the chamber showed that the particle was definitely moving upwards.





Paul Dirac, whose theory of the electron set the scene for the discovery of the positron 50 years ago.

well be cited as the dawn of particle physics.)

It was on 2 August 1932 that Carl Anderson, working at California Institute of Technology, saw a cosmic ray event in his detector that he dared to propose as being due to a positively charged electron. In fact this was not the first time that anyone had seen such effects — tantalizing hints of positive electrons had been glimpsed up to seven years before by Skobeltzyn, Rochester, Feather, Meitner, the Joliot-Curies, Millikan and others, including Anderson himself. Although positive electron tracks had probably been encountered, nobody had ever identified one as such.

On the theoretical side, the positron story unfolded largely through the genius of Paul Dirac. Not content with his beautiful new formulation of non-relativistic quantum mechanics, Dirac had begun to grapple with the challenge of electrodynamics and special relativity. In 1928 he published the electron equation which now bears his name.

As well as reproducing all that had gone before, the new equation had something else. It appeared to say that electrons could have negative, as well as positive kinetic energy. Dirac argued that this 'sea' of negative energy electrons is normally full except for occasional unoccupied states, or 'holes'. In an electromagnetic field, such a hole would act as though it has opposite electric charge to a normal electron. At first, Dirac proposed that these positive charges were the protons of atomic nuclei, much heavier than the electrons. However this appeared to bother him, as the symmetry of the theory suggested strongly that the two solutions of the equation should have the same mass.

When the proton dropped out of the running, Dirac in 1931 boldly postulated the existence of an as yet unseen 'antielectron'. Because of its affinity for ordinary electrons, this would be difficult to find in ordinary matter, but could perhaps be produced in interactions involving hard gamma rays. The stage was set for Anderson's discovery.

For some time Anderson thought that he had been seeing positive electrons, but had no proof. The vital ingredient in his new experiment was a lead plate, slightly more than a centimetre thick, mounted across his cloud chamber. This was subjected to a magnetic field of 15 kilogauss. Cosmic ray particles passing through the metal plate would lose energy, leaving the plate in a tighter curve than they went in. This gave the direction of motion of a charged particle in the magnetic field. Previously it had not been clear whether electron-type tracks were due to an ordinary electron going one way or a positive electron moving in the reverse direction.

After painstaking work, Anderson found an event which he proposed as a 'positron' candidate (the name was Anderson's own contraction for 'positive electron'). This was a bold move since the positively charged track involved was due to a stray cosmic particle which in fact had entered the chamber from below!

This was indeed a courageous step to take at the time, as although the particle had been predicted by Dirac, this theoretical work was not yet universally known and many contemporary authorities did not subscribe to these ideas anyway.

Soon Anderson had obtained many more positron tracks, and supporting evidence came from P.M.S. Blackett and G.P. Occhialini working with their newly-developed Geiger counter-triggered cloud chamber, who showed that the positron was indeed the Dirac antielectron.

Antimatter had been discovered, but physics had to wait until 1955, with the sighting of the antiproton (also predicted by Dirac) at the Berkeley Bevatron, for a glimpse of another antiparticle.