The Discovery of the Positron

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PHYS 36300

16 May 2008

Outline

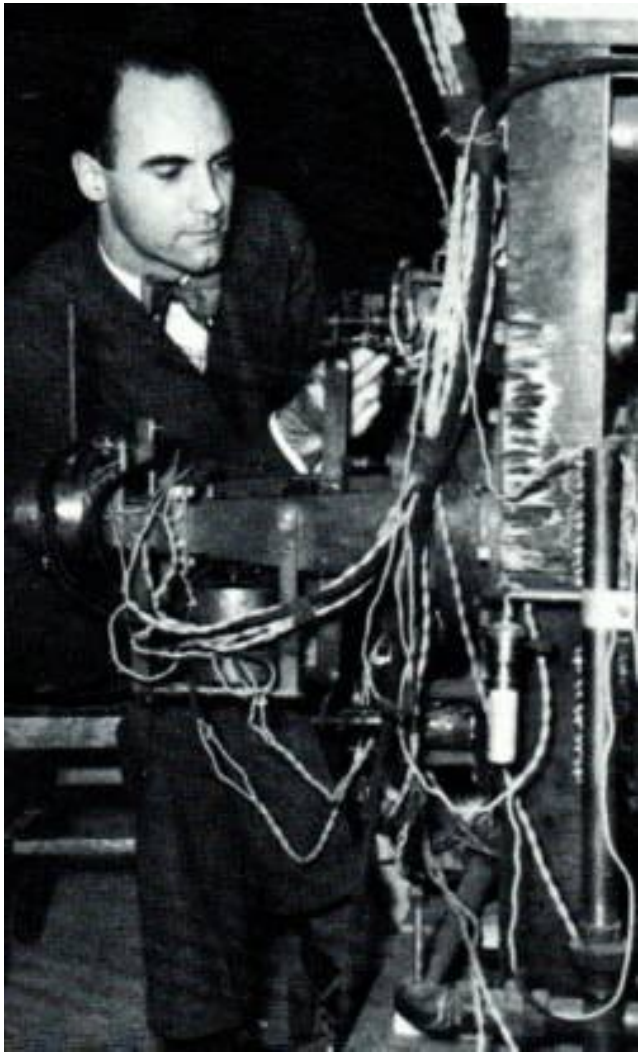
- Dirac's prediction
- Anderson's discovery
- Confirmation by Blackett and Occhialini
- Conclusion

Dirac (1928)

- Predicts the existence of anti-matter
- Relativistic energy: $E^2 = p^2 c^2 + m^2 c^4$
- Positive and negative energy solution: $E = \pm\sqrt{p^2 c^2 + m^2 c^4}$
- Letting $E \to -E$, $t \to -t$, $p \to -p$, and $x \to -x$, we still get an acceptable wavefunction for a free particle.
- Is this simply an unphysical mathematical consequence, or does it have physical meaning?

Carl Anderson

- 1905-1991
- Student of Millikan
- Spent career at Caltech
- Nobel Prize in 1936 for the discovery of the positron



http://en.wikipedia.org/wiki/Carl_David_Anderson

Anderson's paper

- Phys. Rev., vol. 43, 1933
- Observed cosmic-ray tracks in cloud chamber
- Compare tracks to known properties of proton and electron tracks
- 1300 tracks, 15 show evidence of positrons
- No mention of Dirac?

Cloud Chamber – brief review

- Supersaturated water vapor
- Charged particle causes vapor to condense along the particle's path
- Width of track proportional to particle charge
- Magnetic field bends the particle trajectories
- Thin lead plate to determine particle direction

Anderson's Tracks

$$qvBR = mv^2$$

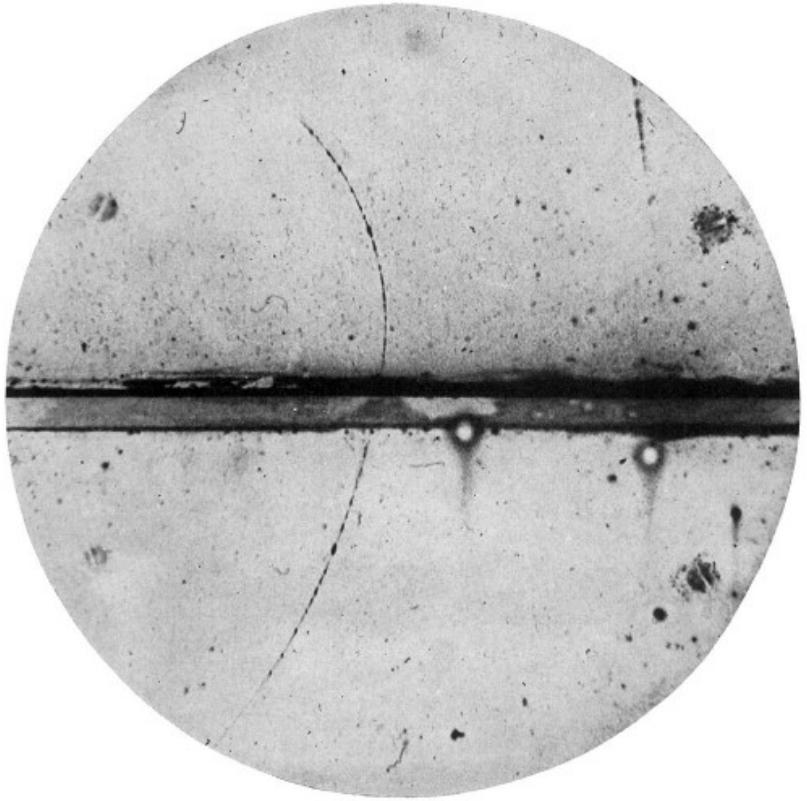


FIG. 1. A 63 million volt positron ($H\rho = 2.1 \times 10^5$ gauss-cm) passing through a 6 mm lead plate and emerging as a 23 million volt positron ($H\rho = 7.5 \times 10^4$ gauss-cm). The length of this latter path is at least ten times greater than the possible length of a proton path of this curvature.

- Harder curvature above plate indicates particle is moving upward
- Track width consistent with charge on the order of electron charge
- Range on the order of cm. If it were a proton the range would be on the order of mm.

Anderson's Tracks (2)

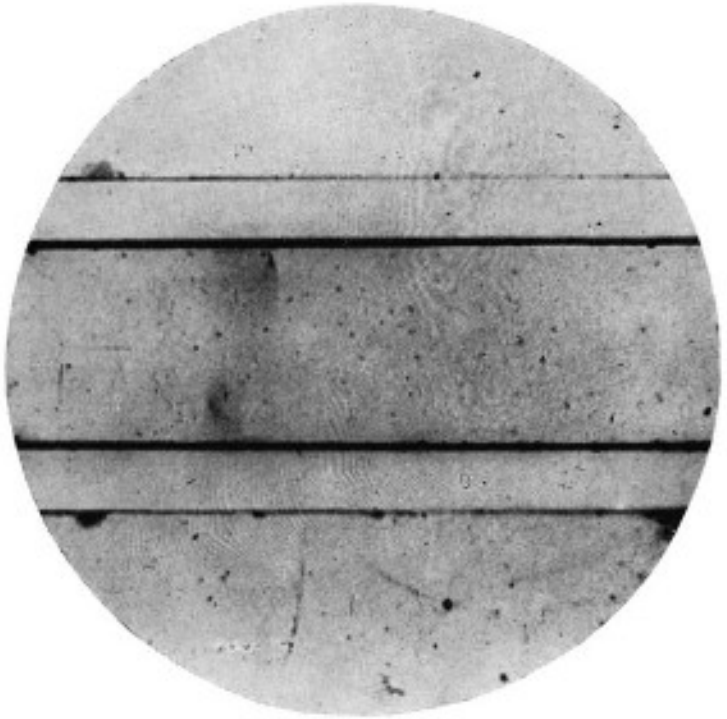


FIG. 2. A positron of 20 million volts energy ($H\rho = 7.1 \times 10^4$ gauss-cm) and a negatron of 30 million volts energy ($H\rho = 10.2 \times 10^4$ gauss-cm) projected from a plate of lead. The range of the positive particle precludes the possibility of ascribing it to a proton of the observed curvature.

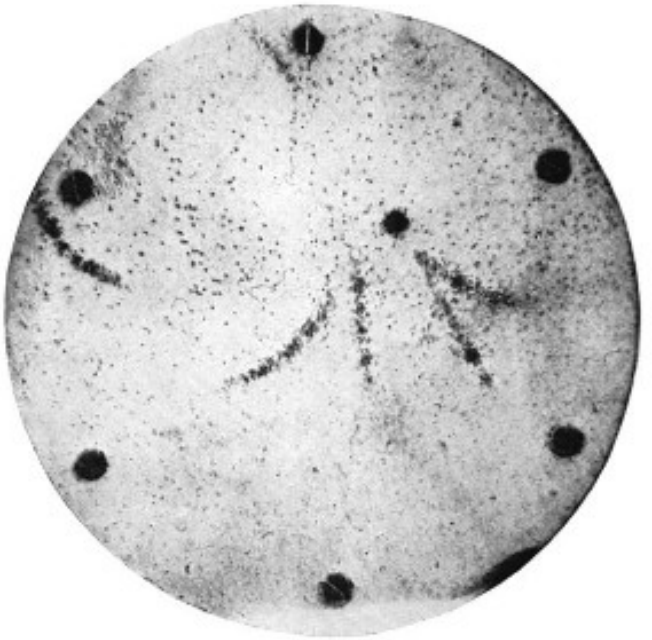


FIG. 3. A group of six particles projected from a region in the wall of the chamber. The track at the left of the central group of four tracks is a negatron of about 18 million volts energy ($H\rho = 6.2 \times 10^4$ gauss-cm) and that at the right a positron of about 20 million volts energy ($H\rho = 7.0 \times 10^4$ gauss-cm). Identification of the two tracks in the center is not possible. A negatron of about 15 million volts is shown at the left. This group represents early tracks which were broadened by the diffusion of the ions. The uniformity of this broadening for all the tracks shows that the particles entered the chamber at the same time.

Anderson's Conclusions

- Positron charge “less than twice, and is probably equal to, that of the proton.”
- Upper bound on mass: “If these particles carry unit positive charge the curvatures and ionizations produced require the mass to be less than twenty times the electron mass.”

Blackett and Occhialini Paper

- Proc. of the Roy. Soc. of London, vol. 139 (1933)
- Confirm Anderson's findings
- Draw connection to Dirac's theory
- Some consideration of the origin of the particles is given

Blackett and Occhialini (contd.)

- More elaborate appartus – two Geiger-Müller counters for coincidence
- Only photograph events
- See evidence of showers
- No better bound on the charge or mass than Anderson: positron mass and charge are shown to be “comparable” to those of the electron.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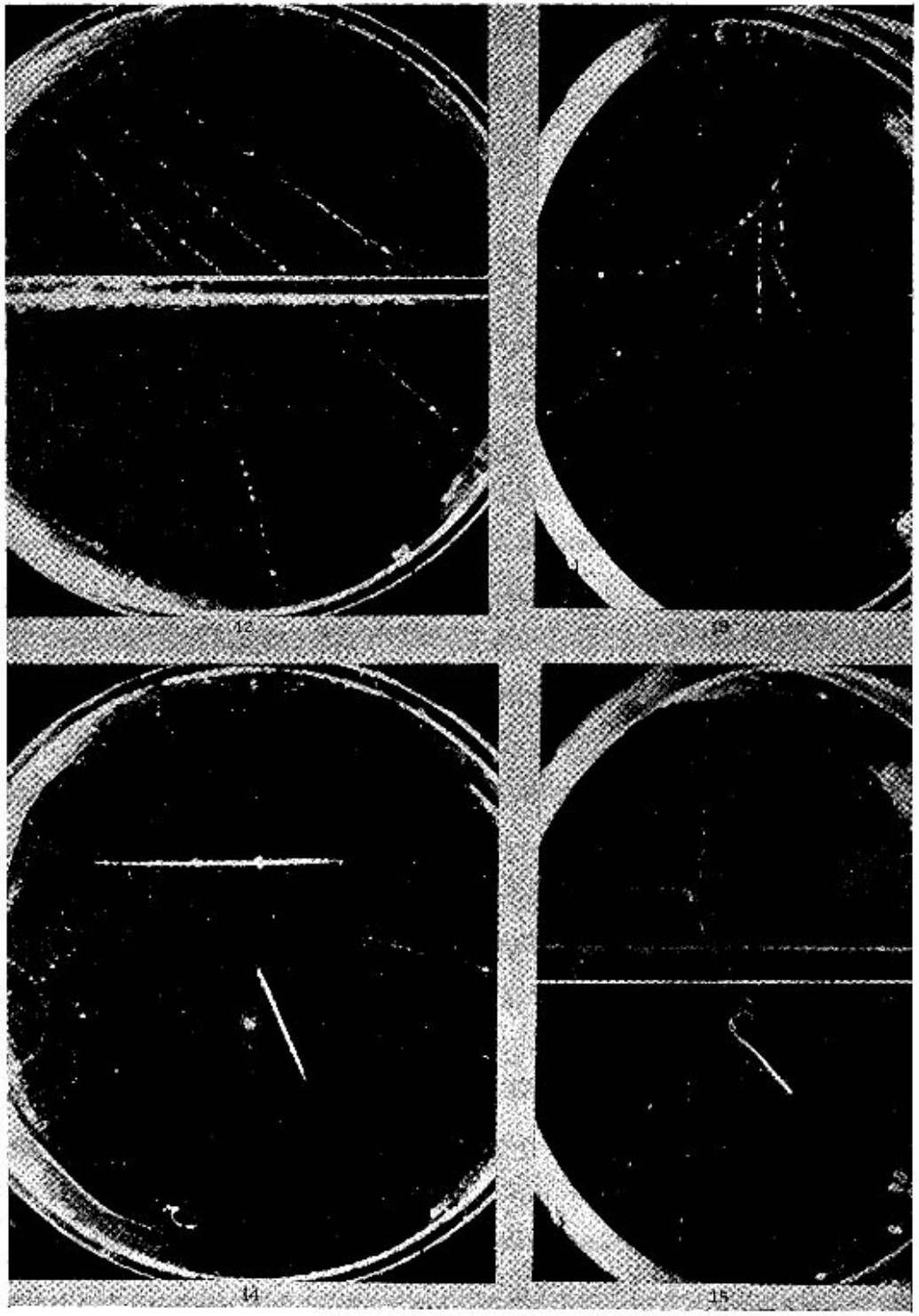
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Conclusion

- Positrons predicted by Dirac, observed by Anderson, confirmed by Blackett and Occhialini
- First observation of anti-matter
- In this instance, the “Who ordered that?” question has an answer: Dirac.
- First instance where theory indicates the existence of a new particle that is subsequently found.

Questions

- What was the actual nature of Dirac's prediction?
- Why didn't Anderson mention the connection to Dirac's work in his paper?