PH3520 / Particle Physics

Autumn term 2011 – week 5

Royal Holloway University of London

Glen Cowan
Stewart Boogert

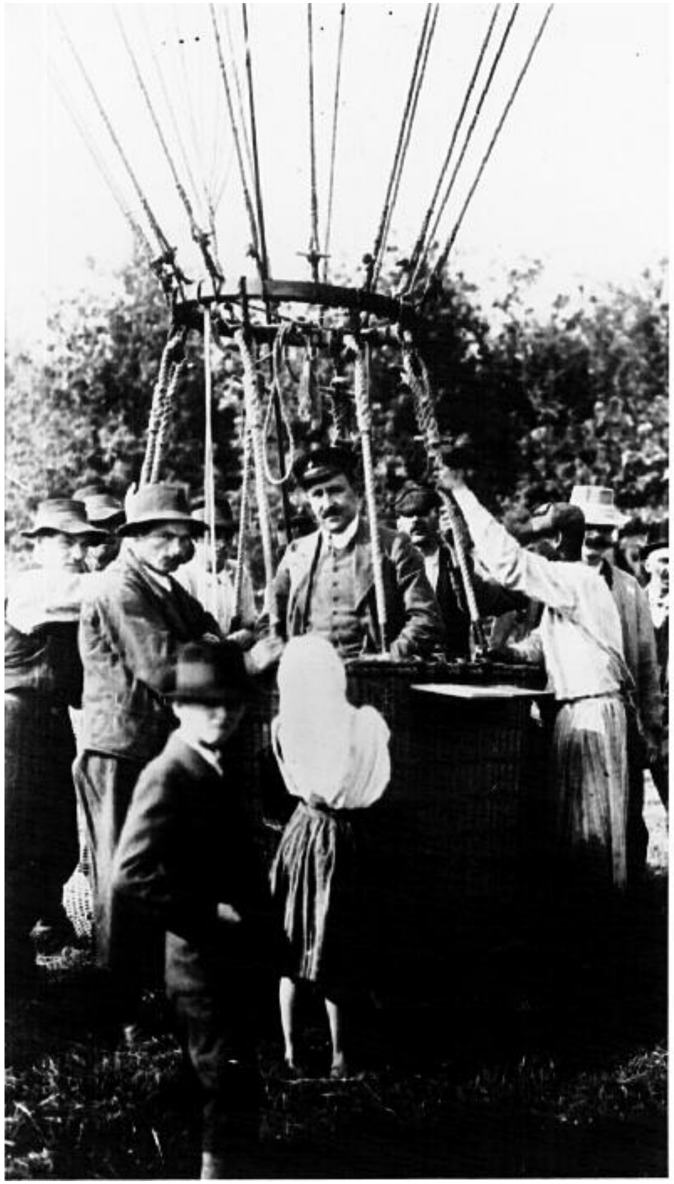
Cosmic rays

V. Hess measures ionizing radiation in balloon flights (1912).

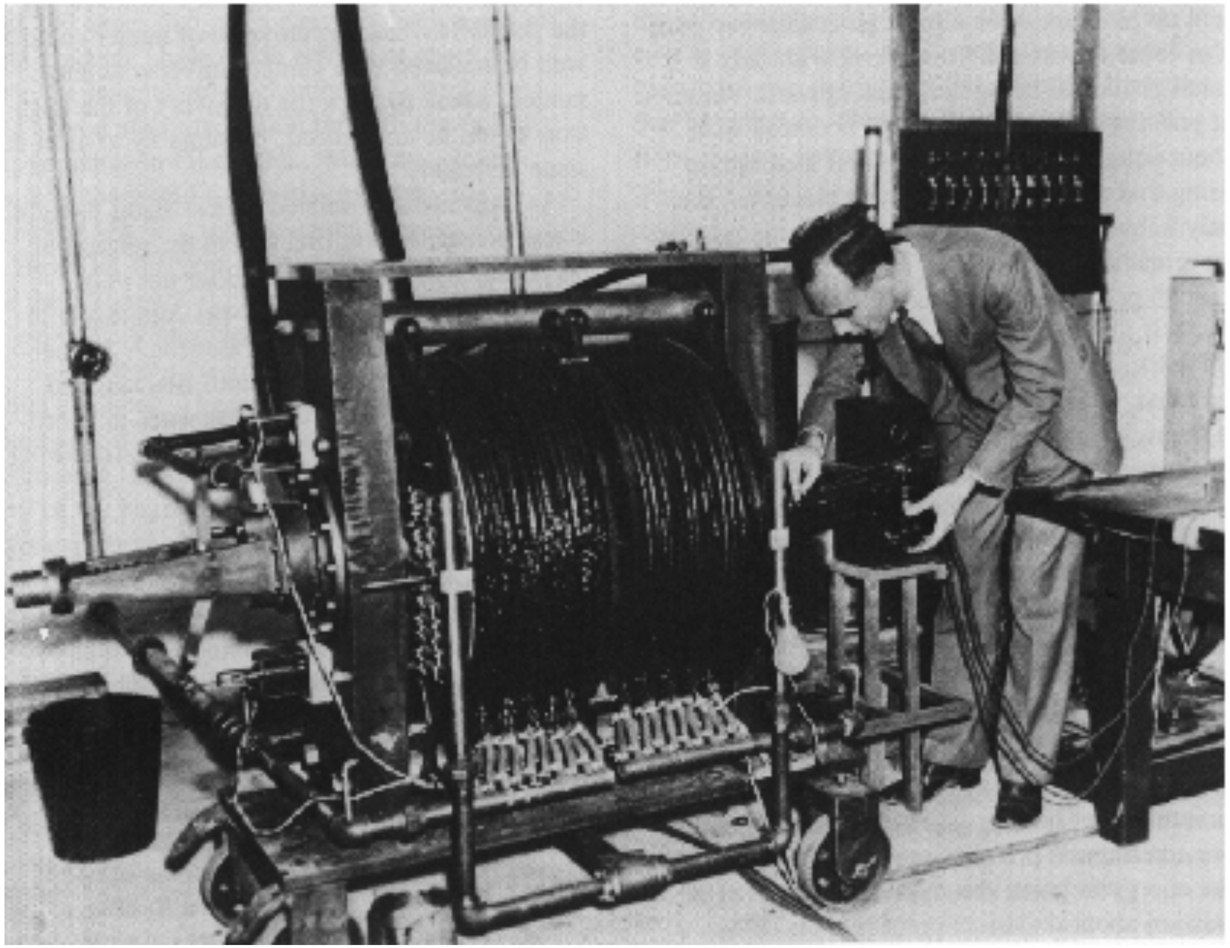
More ionizing particles found as balloon ascends to 5 km.

Hess: Particles coming from space.

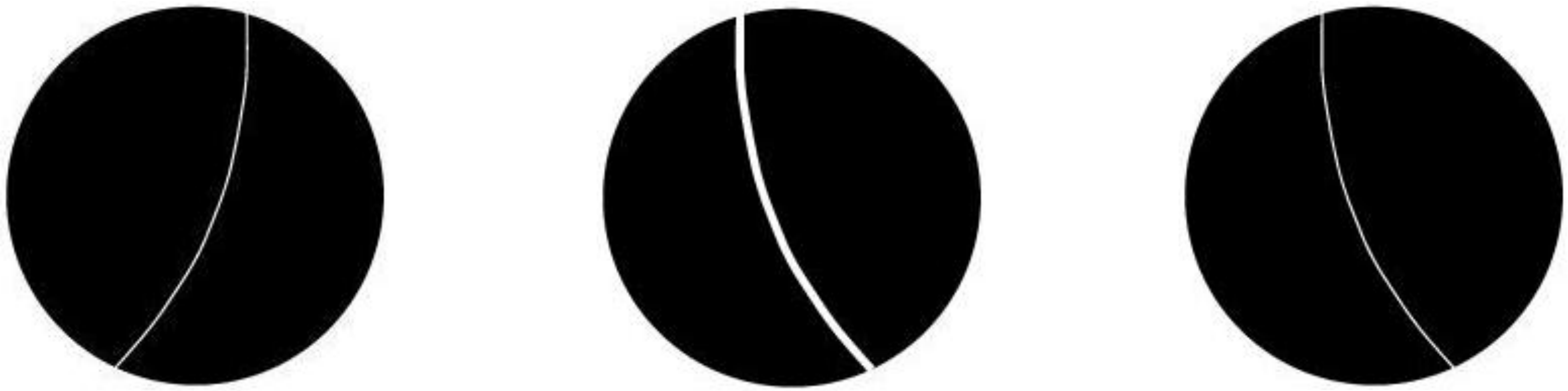
'Shower' of secondary particles mostly absorbed in atmosphere, some make it down to Earth's surface.



C.D. Anderson and cloud chamber



C.D. Anderson observations of cosmic ray tracks



Thin, curved to left, $m \approx m_e$ and $q = -e$ (if from above).

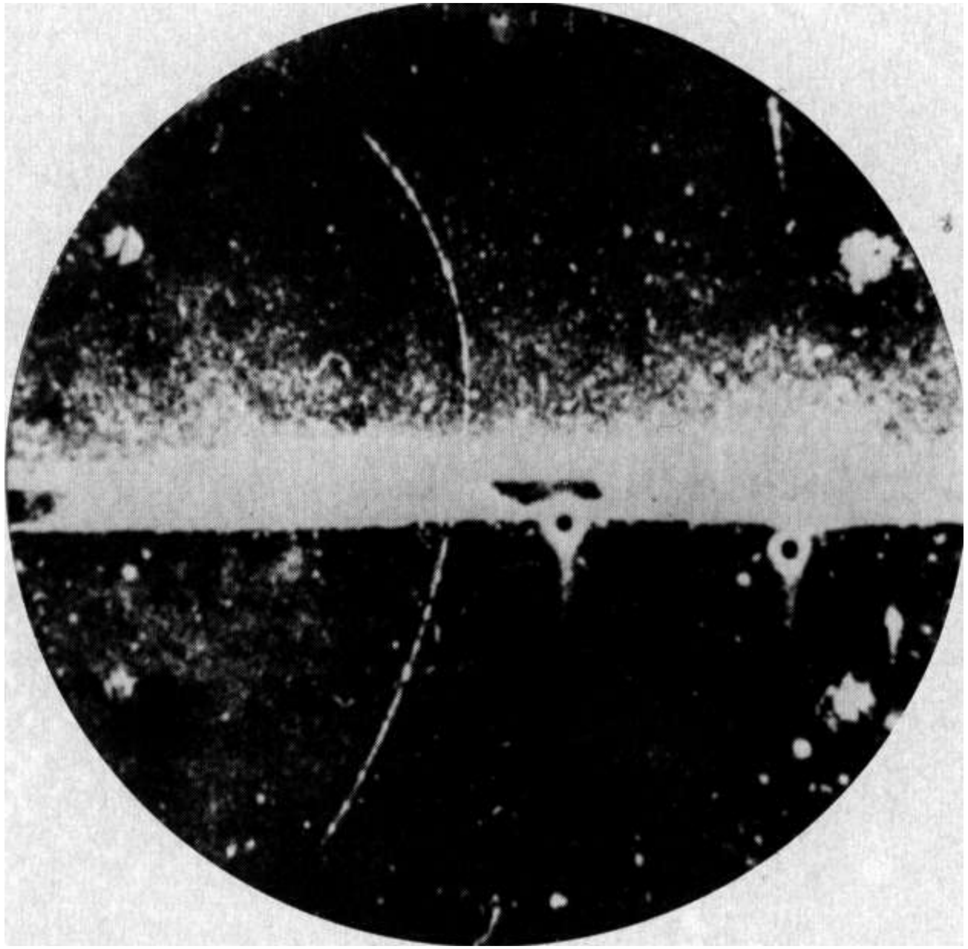
Thick, curved to right, $m \approx m_p$ and $q = +e$ (if from above).

Thin, curved to right, $m \approx m_e$, $q = ?$ What direction???

Millikan − "Cosmic rays only come from above! Your mass measurement must be wrong."

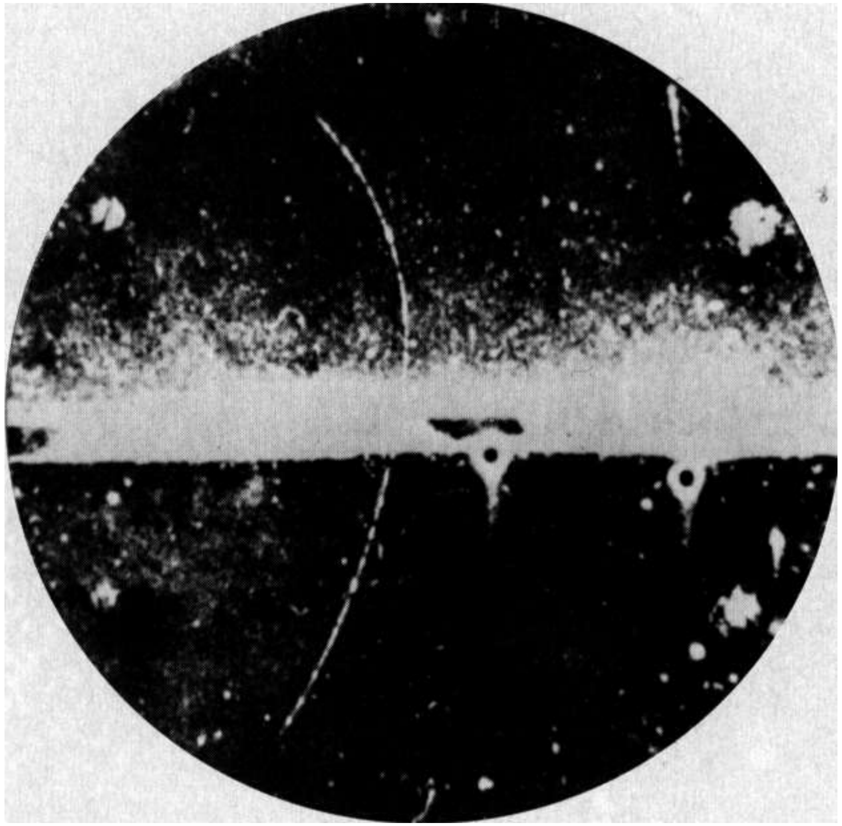
Anderson − "The mass measurement is reliable: $m \ll m_p$"

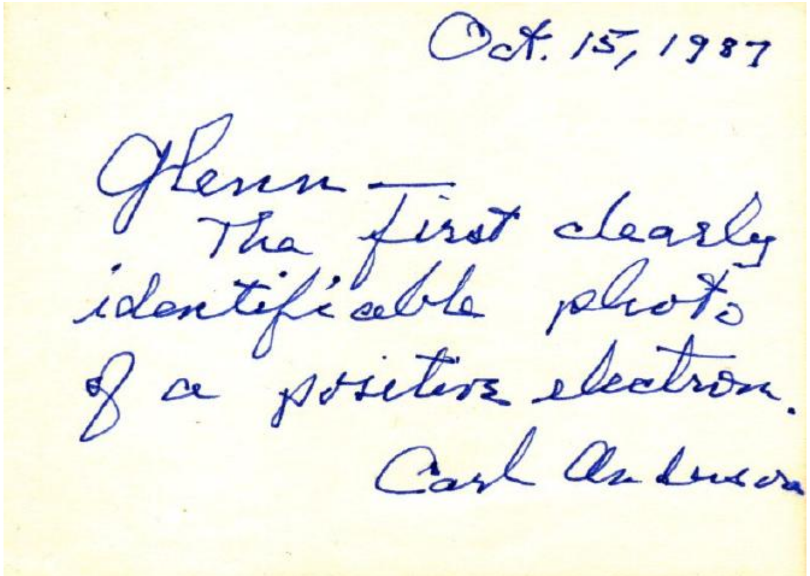
The first positron



C.D. Anderson
2 August, 1932

The first positron

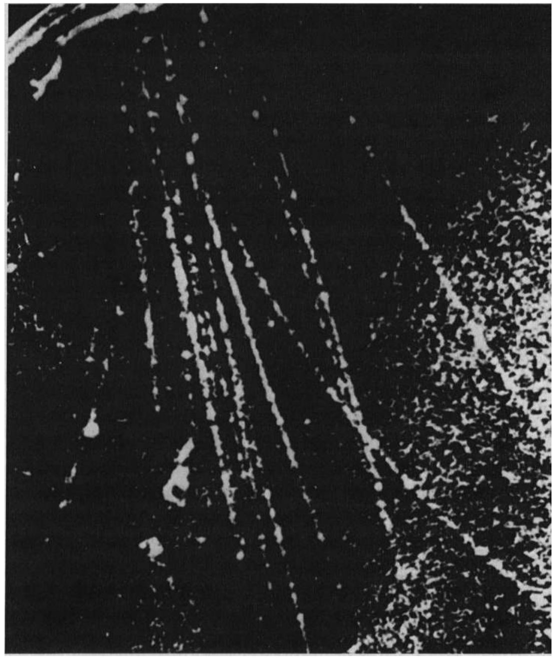




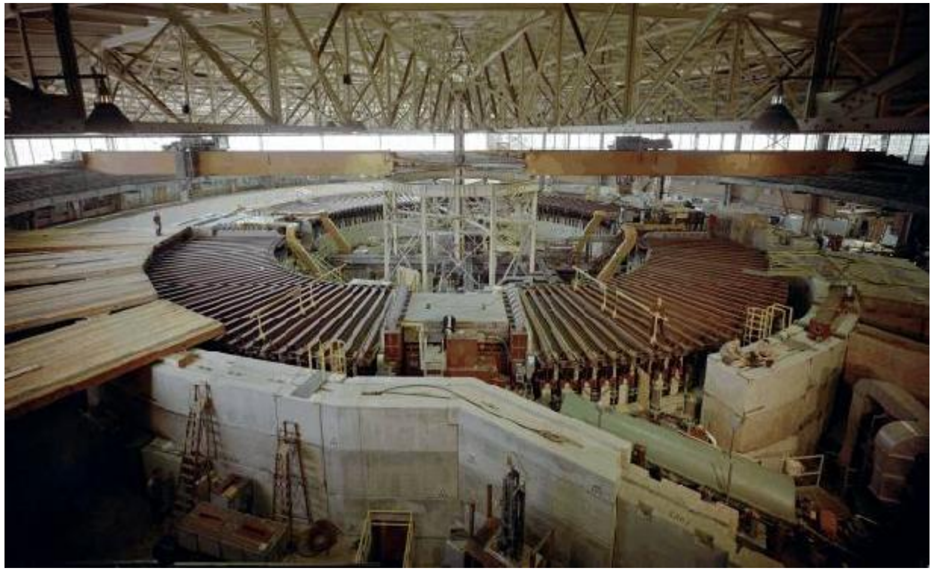
Oct. 15, 1987

Glenn —
The first clearly identifiable photo of a positive electron.
Carl Anderson

More antimatter



Electron-positron shower seen by Blackett and Occhialini, 1933.



Antiproton discovered by Segrè, Chamberlin et al., 1955.

MAY 15, 1937 PHYSICAL REVIEW VOLUME 51

Note on the Nature of Cosmic-Ray Particles

SETH H. NEDDERMEYER AND CARL D. ANDERSON
California Institute of Technology, Pasadena, California

little energy loss (muons)

large energy loss (electrons)

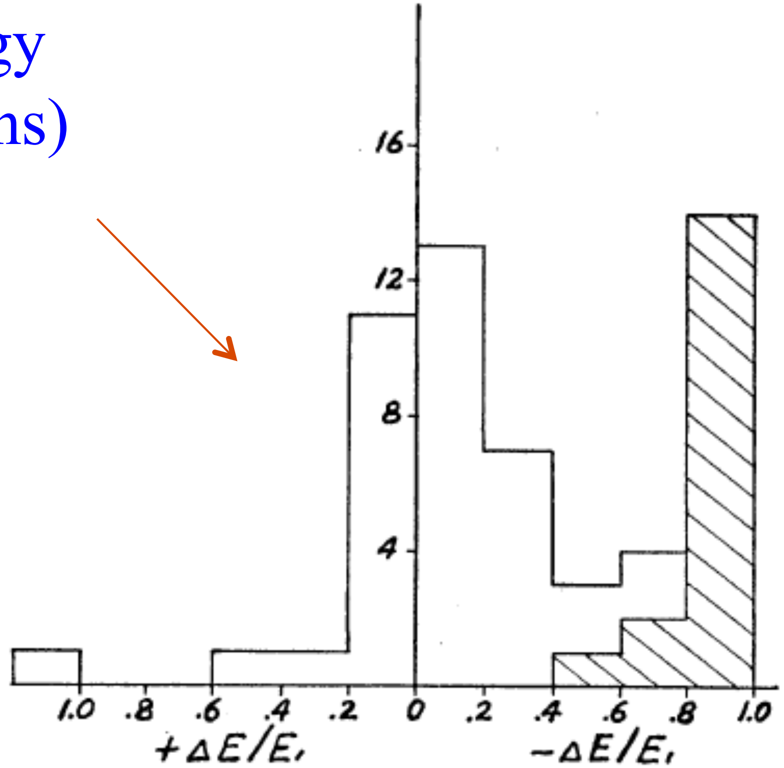


FIG. 2. Distribution of fractional losses in 1 cm of platinum.

Measuring the muon's mass

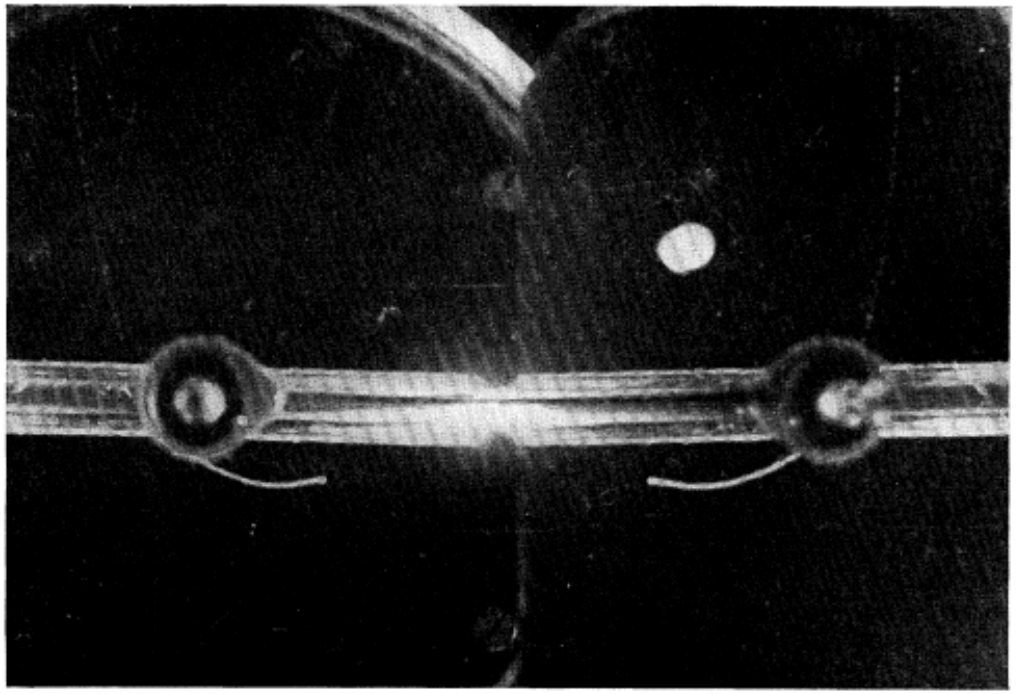


FIG. 1. A positively charged particle of about 240 electron-masses and 10 Mev energy passes through the glass walls and copper cylinder of a tube-counter and emerges with an energy of about 0.21 Mev. The magnetic field is 7900 gauss. The residual range of the particle after it emerges from the counter is 2.9 cm in the chamber (equivalent to a range of 1.5 cm in standard air). It comes to rest in the gas and may disintegrate by the emission of a positive electron not clearly shown in the photograph. It is clear from the following considerations that the track cannot possibly be due to a particle of either electronic or protonic mass. Above the counter the specific ionization of the particle is too great to permit ascribing it to an electron of the curvature shown. The curvature of the particle above the counter would correspond to that of a proton of 1.4 Mev and specific ionization about 7000 ion-pairs/cm, which is at least 30 times greater than the specific ionization exhibited in the photograph. The curvature ($\rho \cong 3$ cm) of the portion of the track below the counter would correspond to an energy of 7 Mev if the track were due to an electron. An electron of this energy would have a specific ionization imperceptibly different from that of a usual high energy particle which produces a thin track, and in addition it would have a range of at least 3000 cm in standard air instead of the 1.5 cm actually observed. Moreover if the particle had electronic mass and emerged from the counter with a velocity such that its specific ionization were great enough to correspond to that exhibited on the photograph, its residual range (in standard air) would be less than 0.05 cm instead of the 1.5 cm observed. A proton of the curvature of the track below the counter would have an energy of only 25,000 ev and a range in standard air of less than 0.02 cm.

Anderson and Neddermeyer, Phys. Rev. 54 (1938) 88.

p from curvature,

E from range,

$$m = \sqrt{E^2 - p^2}$$

$$= (220 \pm 35)\, m_e$$

Current estimate:

$$105.658389 \pm 0.000034 \text{ MeV}$$