History of the Muon

Physics 290e Spring 2020

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Particle Physics in 1930’s

1897 - J.J. Thomson discovers the **electron**

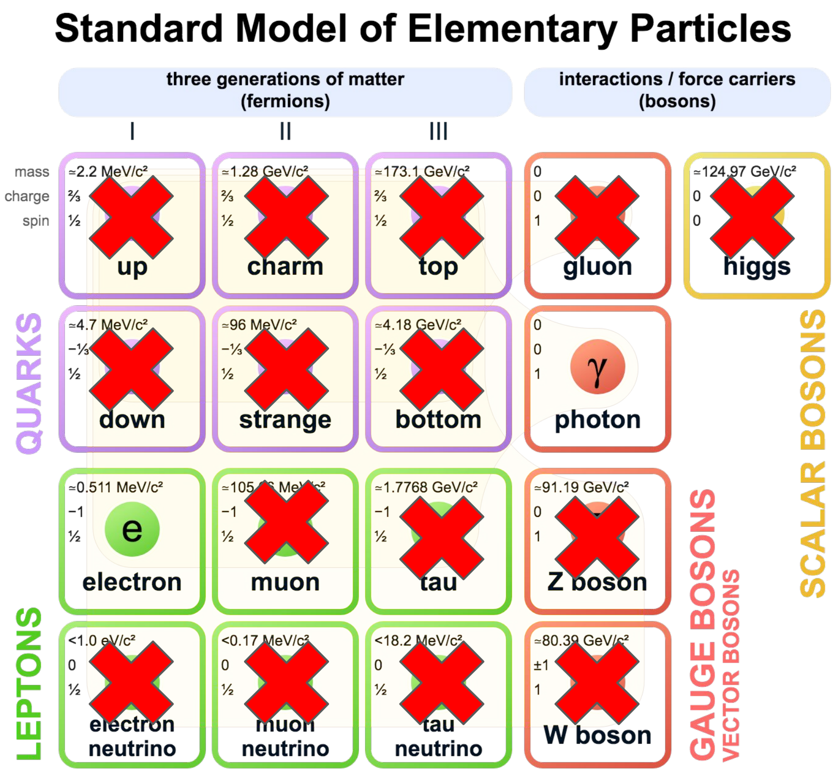
1900 - P. Villard discovers gamma rays

1912 - Victor Hess discovers cosmic rays

1917 - E. Rutherford discovers the **proton**

1932 - J. Chadwick discovers the **neutron**

1932 - Carl Anderson discovers the positron

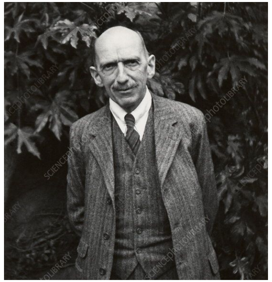


Cosmic Rays

- Discovered by Victor Hess in 1912
- Believed to be primarily photons until...
- Jacob Clay finds evidence that cosmic rays are deflected by geomagnetic field (1927)

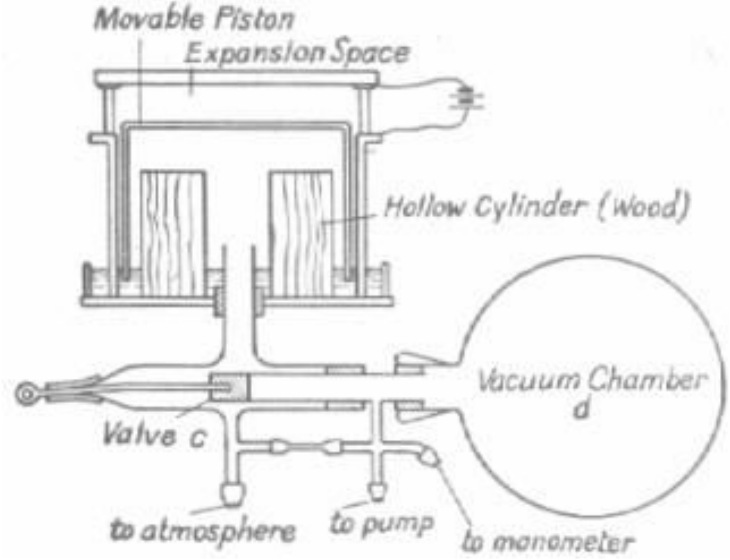
-> Cosmic rays are primarily composed of charged particles

Wilson Cloud Chambers

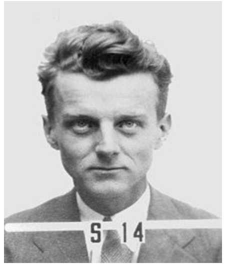


Cloud Chamber: ionizing particles pass through a gas, leaving a trial of ionized gas particles. Water vapor condenses on the ion trail

- Invented in 1911 by Charles Wilson
- Adiabatic expansion causes condensation
- Geiger-Mueller counter triggers

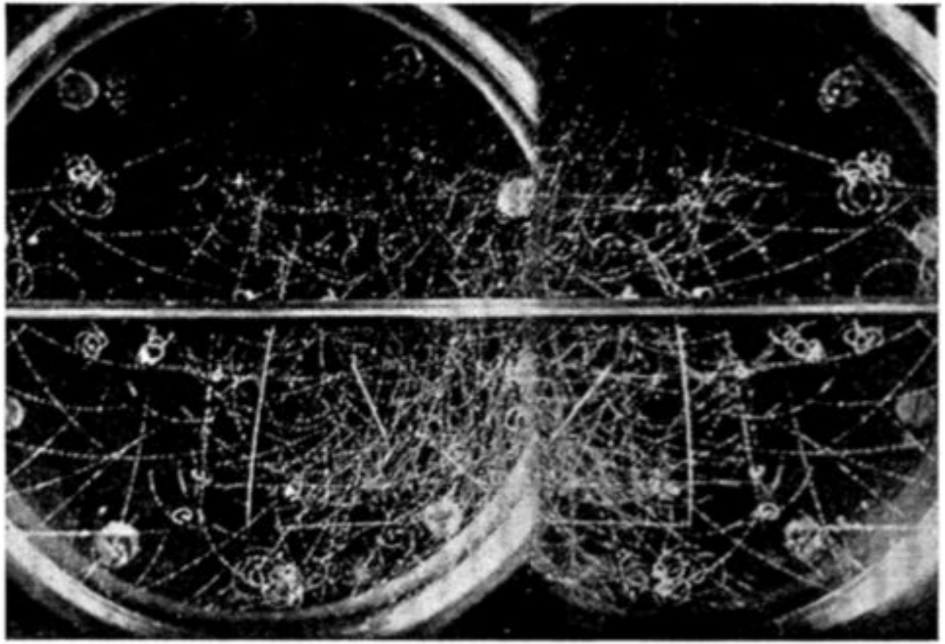


Early Evidence of Muons (1936)



S. Neddermeyer & C. Anderson

Cloud chamber observations of cosmic rays



Charged particle moving in B-field:

$$R = mv / qB$$

- Measure range and radius
- Infer value of m / q

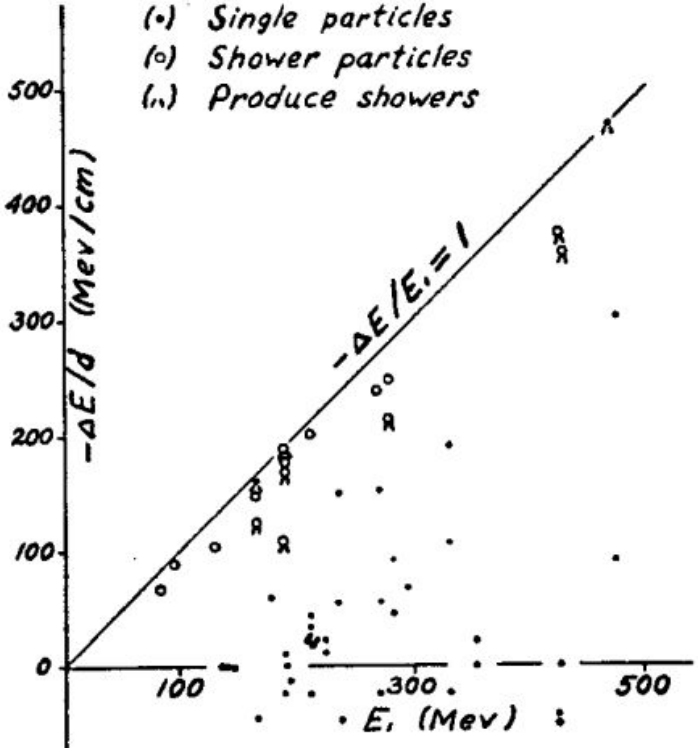
Found events with range and R values that did not match m / q for the electron or the proton

Further Evidence (1937)

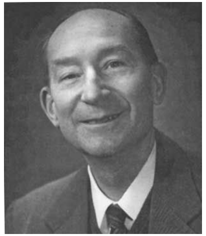
"Red" and "Green" Electrons?

- Showering particles well described by Bethe & Heitler's theory of electron radiation
- Single, penetrating particles: very mysterious…..

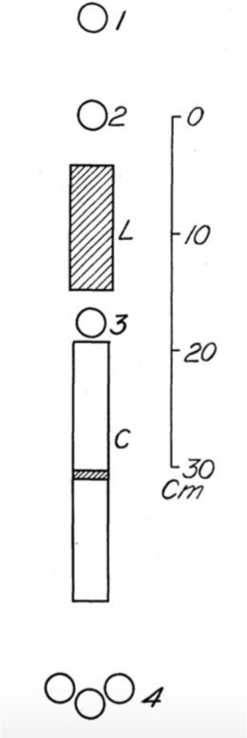
"We should like to suggest, merely as a possibility, that the strongly ionizing particles of the type of Fig. 13, although they occur predominantly with positive charge, may be related with the penetrating group above."



“Smoking Gun” detection (1937)




J.C Street & E.C. Stevenson



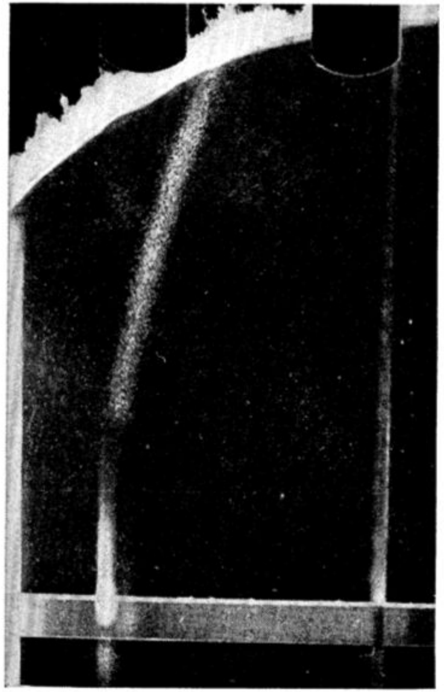


FIG. 3. Track B.

Measure ionization density and radius at end of particle range, infer rest mass of the particle

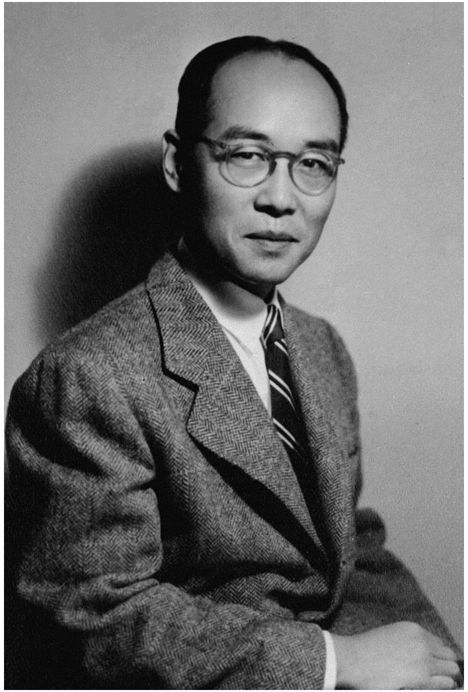
Particle with 130 times the electron mass (real mass of the muon is 207 times, uncertainty due to ion count)

So, what is it?

H. Yukawa: meson theory of strong nuclear forces (1935)

- Predicts particle of unit charge with mass in between electron and proton
- Seemed promising that this new “mesotron” particle could be Yukawa’s missing meson

(it wasn’t)




~ Intermission for WWII ~

Identity crisis of the “mesotron”

Experiments done by Conversi, Pancini, and Piccioni observe muons coming to rest in carbon (1946)

- Yukawa’s predicted meson should be absorbed by the carbon nuclei, and no decay should be observed
- But… CPP found their negative “mesotrons” decaying in carbon

A possible strong force interaction with carbon nuclei was weaker than theoretical predictions by 12 orders of magnitude

Discovery of the pion (1947)

Crisis resolved by the discovery of the pion by Lattes, Murihead, Occhialini and Powell (and “Mrs. I. Roberts”?)

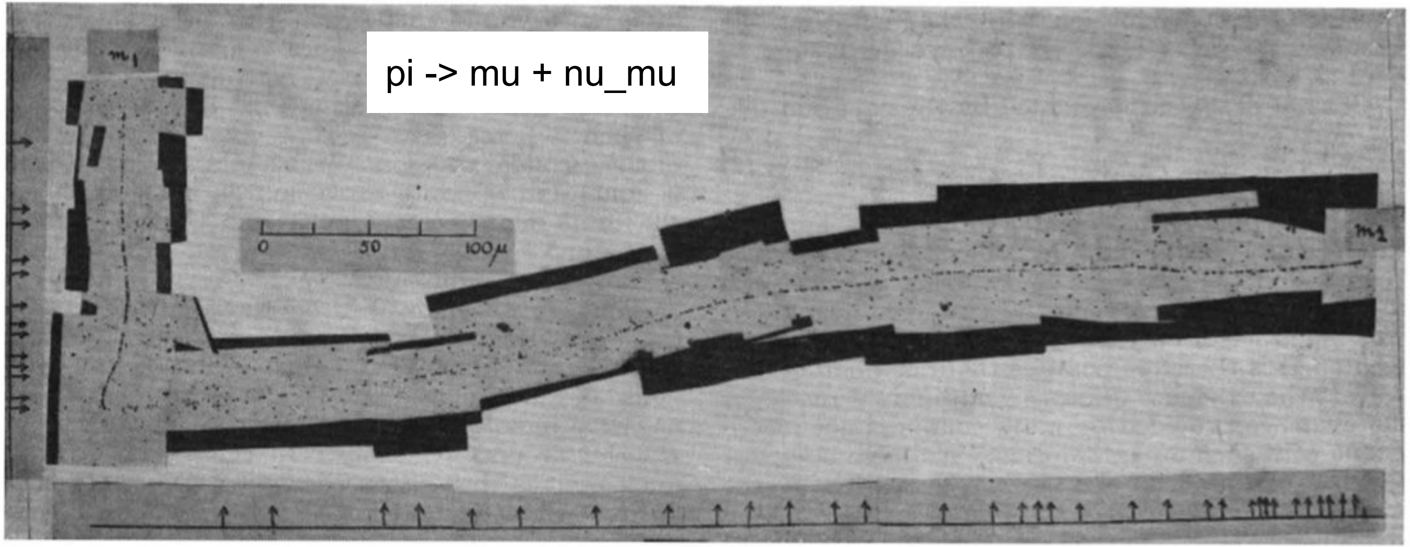


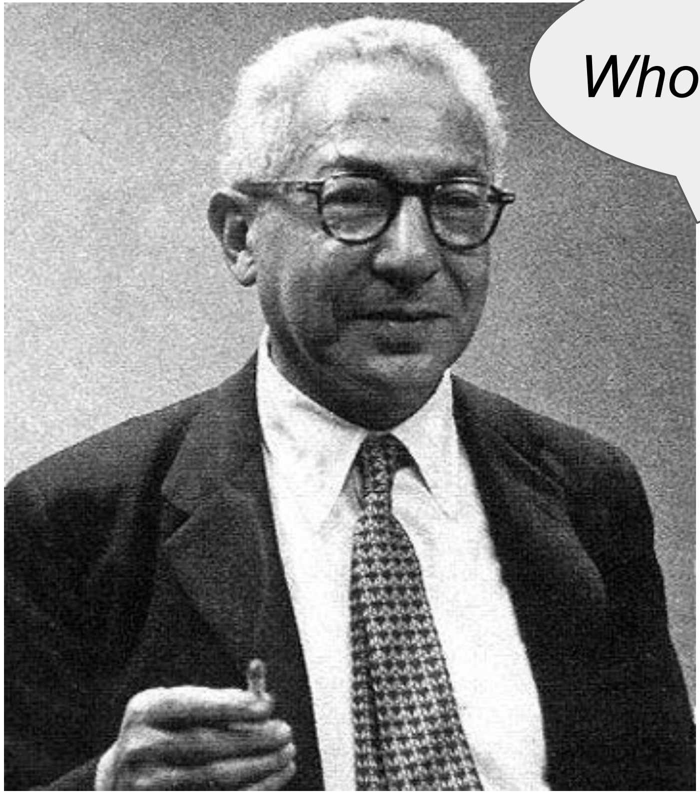
Fig. 1. Observation by Mrs. I. Roberts. Photomicrograph with Cooke × 45 ‘Fluorite’ objective. Ilford ‘Nuclear Research’, boron-loaded C2 emulsion. m_1 is the primary and m_2 the secondary meson. The arrows, in this and the following photographs, indicate points where changes in direction greater than 2° occur, as observed under the microscope. All the photographs are completely unretouched

“Mu - meson” to Muon

Discovery of the mu-meson and the pi-meson leads to new category of “meson” particles -- particles with intermediate mass (mes = mid)

Later, the quark model is discovered and it’s understood that the “mu meson” differs from other mesons...

- Mesons are redefined as hadrons composed of two quarks, categorized by composition rather than mass
- The “mu meson” becomes the “muon,” simply a larger electron, grouped in the lepton family



Who ordered that?

I. Rabi

https://link-springer-com.libproxy.berkeley.edu/content/pdf/10.1007/BF02068933.pdf

https://journals-aps-org.libproxy.berkeley.edu/pr/pdf/10.1103/PhysRev.50.263

"New Evidence for the Existence of a Particle Intermediate Between the Proton and Electron", Phys. Rev. 52, 1003 (1937).

https://www.nature.com/articles/159694a0

http://web.ihep.su/dbserv/compas/src/neddermeyer37/eng.pdf