Discovery of the Pion

Anton Kapliy
April 30, 2008

Cecil Frank Powell

- 1903 - 1969
- Wilson, Rutherford
- University of Bristol
- First pions in 1947
- Nobel in 1950
- Russel-Einstein msto
- CERN

Scanned at the American
Institute of Physics

Scientist in the making

- 12 yo — first chemistry book

  "Found it full of romance"

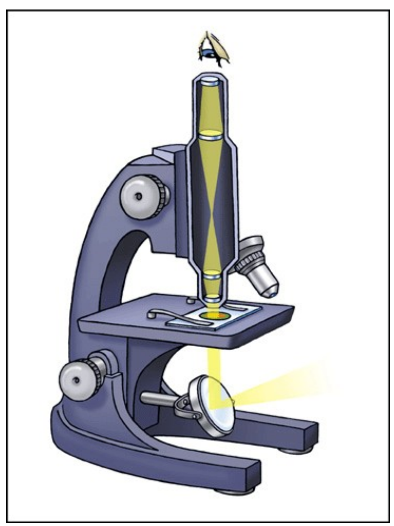
- 14 yo — first big experiment
  - generated hydrogen "by the action of granulated dilute sulphuric on granulated zinc"

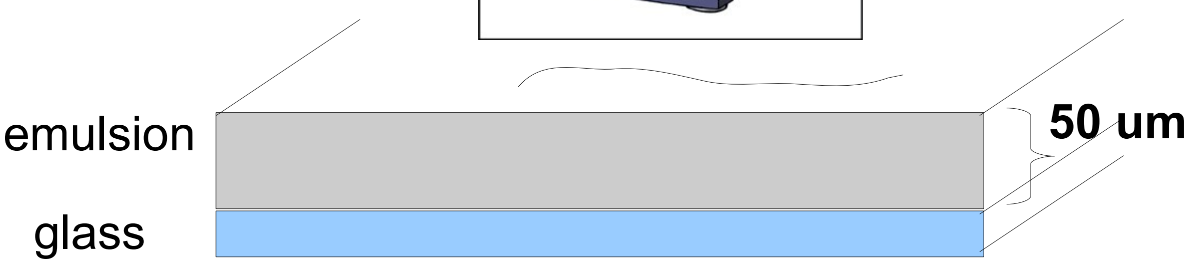
Early life

- 1920's — Cavendish Labs
- 1932 — wedding, industry temptation
- 1930's-1940's — Bristol, British atomic project
  - Starts experiments with photoemulsions

Photographic emulsions

- Grains of silver-halide
- Suspended in gelatin
- Ionizing particles create Ag grains
- Develop a photograph





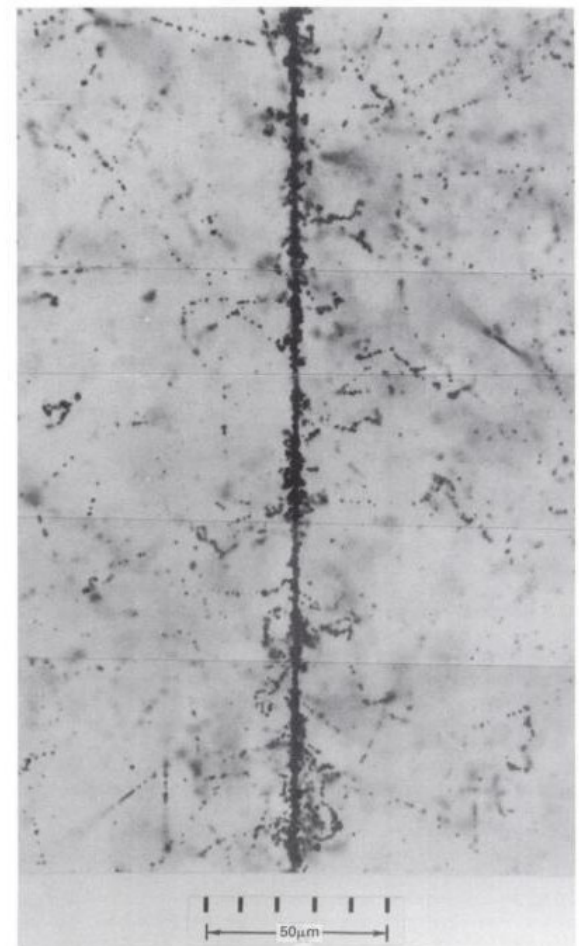


Fig. 5.1 Track of a highly ionizing nucleus in a photographic emulsion. The shor tracks produced by δ electrons may be clearly seen surrounding the track. Figur courtesy of P. H. Fowler.

Problems with emulsions

- Low sensitivity to ionization (before 1947)
- Fading over time
- Non-uniformity of active material
- Hard to observe the tracks (too small)

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Powell's response:

- Collaboration with the industry: Kodak, Ilford
- New sensitizing methods
- State of the art microscopes

More problems

- Unable to use B-field to bend trajectories
  - Compare with Wilson (aka cloud) chambers!
- Cavendish dis-endorsement:
  - *incapable of "reliable and reproducible precision measurments"*

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Powell's response:

20000 stereoscopic photos => 1600 usable traces
3000 traces on a 3 cm^2 photographic plate

- But photoplates have continuous uptime
- Can deduce a lot about nature of particles
- Powell's determination
  - *"The right man pushing exactly the right experimental technique at the right time"*

Q: Where do we look for Yukawa mesons?
A: <u>Cosmic rays</u>!

Mt. Pic Du Midi, 10000 ft

Flying baloons, >10000 ft

First pion

Nuclear capture of pion

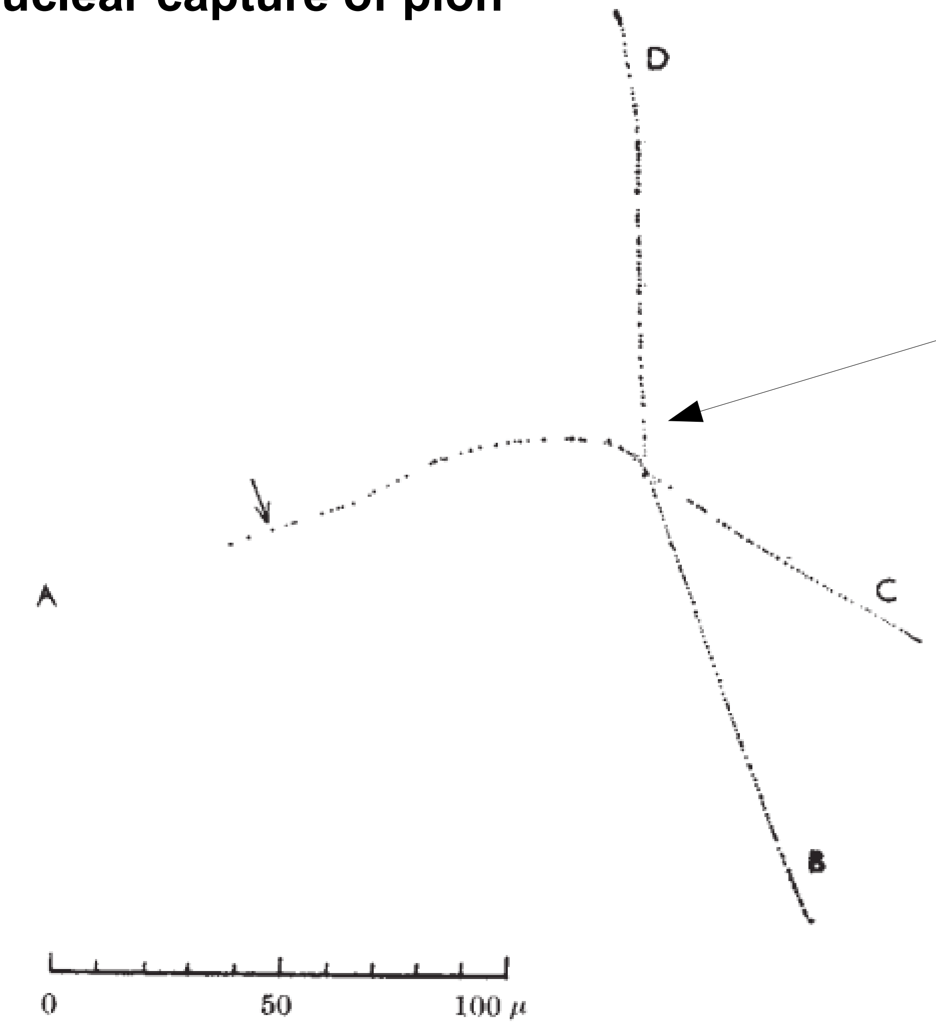
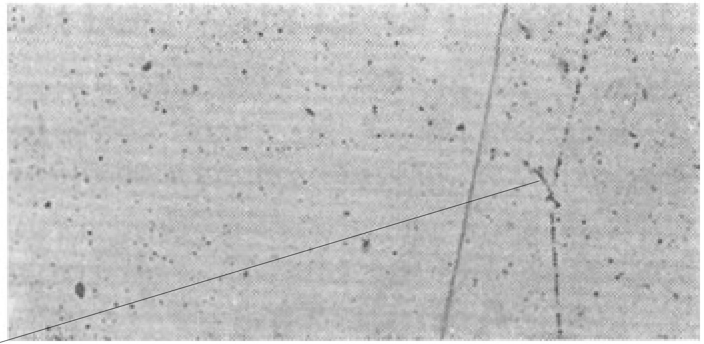


Fig. 1 *b*. TRACE OF COMPLETE STAR ON SCREEN OF PROJECTION MICROSCOPE, SHOWING PROJECTION OF THE TRACKS IN THE PLANE OF THE EMULSION. TRACK *A* CANNOT BE TRACED WITH CERTAINTY BEYOND THE ARROW



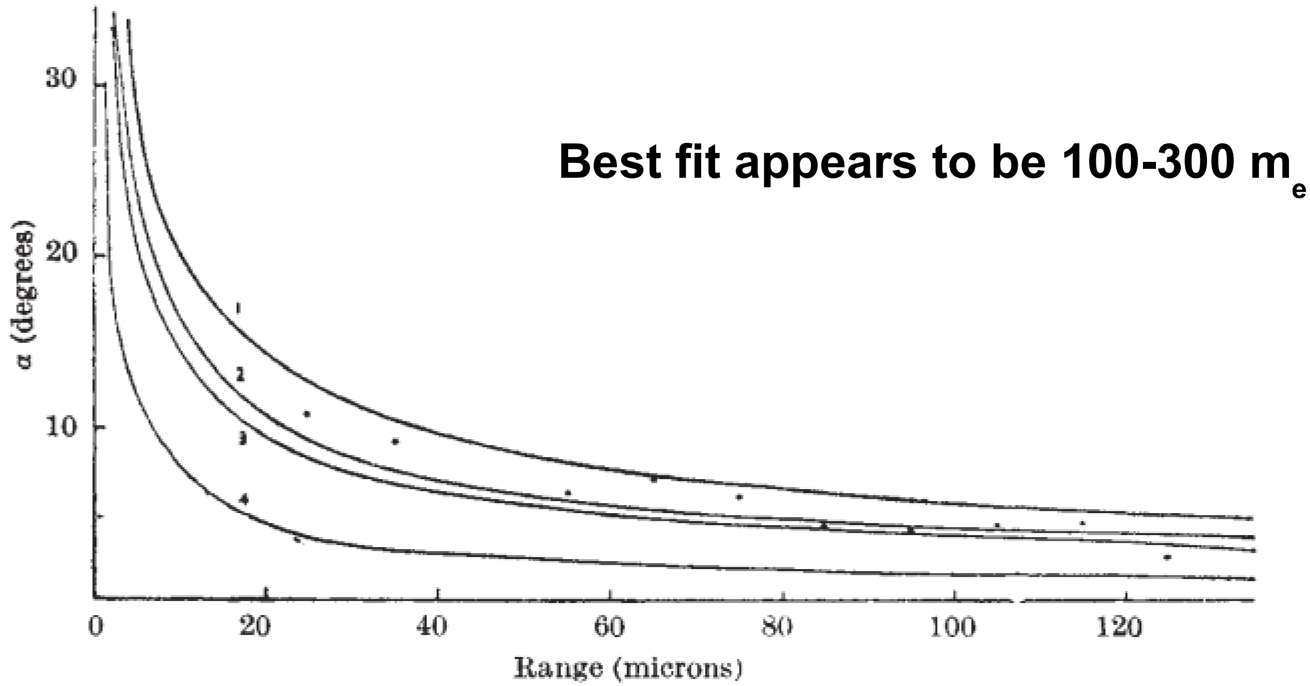
g. 1 *a*. PHOTOMICROGRAPH OF CENTRE OF STAR, SHOWING TRACK OF ESON PRODUCING DISINTEGRATION. (LEITZ 2 MM. OIL-IMMERSION OBJECTIVE. × 500)

- **A is the new meson**
- **B,D,C are likely protons**
- **Track C goes into the page**

Why A is a new meson:
electron: range too large
proton: scattering too large
muon: frequent nuclear interaction

(Jan 1947, observed by D. Perkins)

First pion — mass via scattering



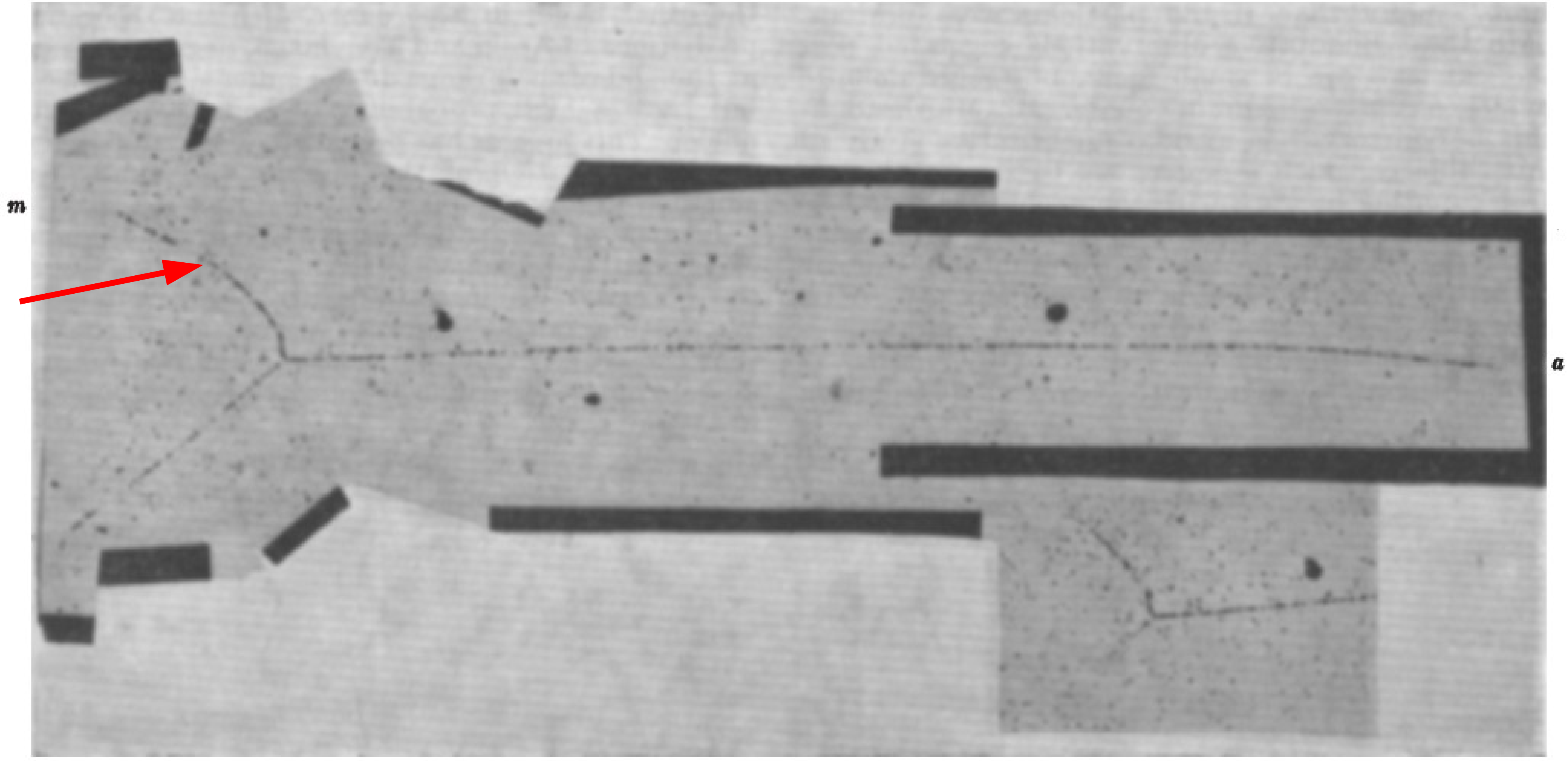
Curve 1: $M = 100\ m_e$; curve 2: $M = 200\ m_e$; curve 3: $M = 300\ m_e$; curve 4: $M = 1{,}800\ m_e$

Horizontal axis: range of travel in microns

Vertical axis: <u>mean scattering angle</u>

Theory curves: Williams's multiple scattering formula

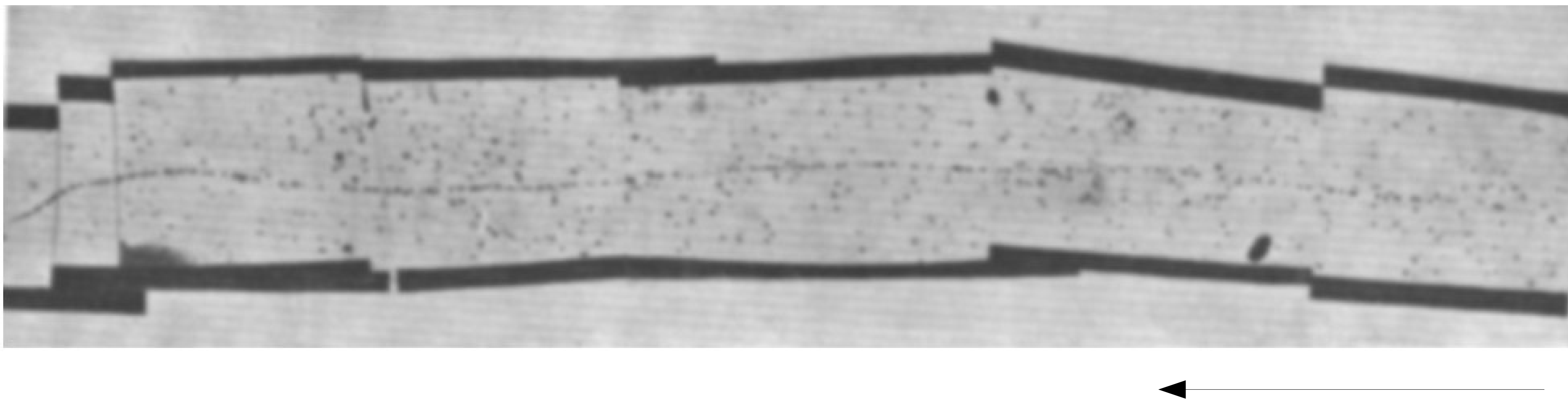
Another pion capture: π^-



According to predictions of Araki and Tomonaga, **negative mesons** are usually captured by nucleus at the end of their range

(Feb 1947, observed by Powell, Occhialini)

Event suspected to be π^+



Apparently, no nuclear capture. Comes to rest at the very end of range. A muon probably escaped the emulsion and wasn't detected.

Ionization (distance between grains) suggests a meson of mass **100-230 m_e**

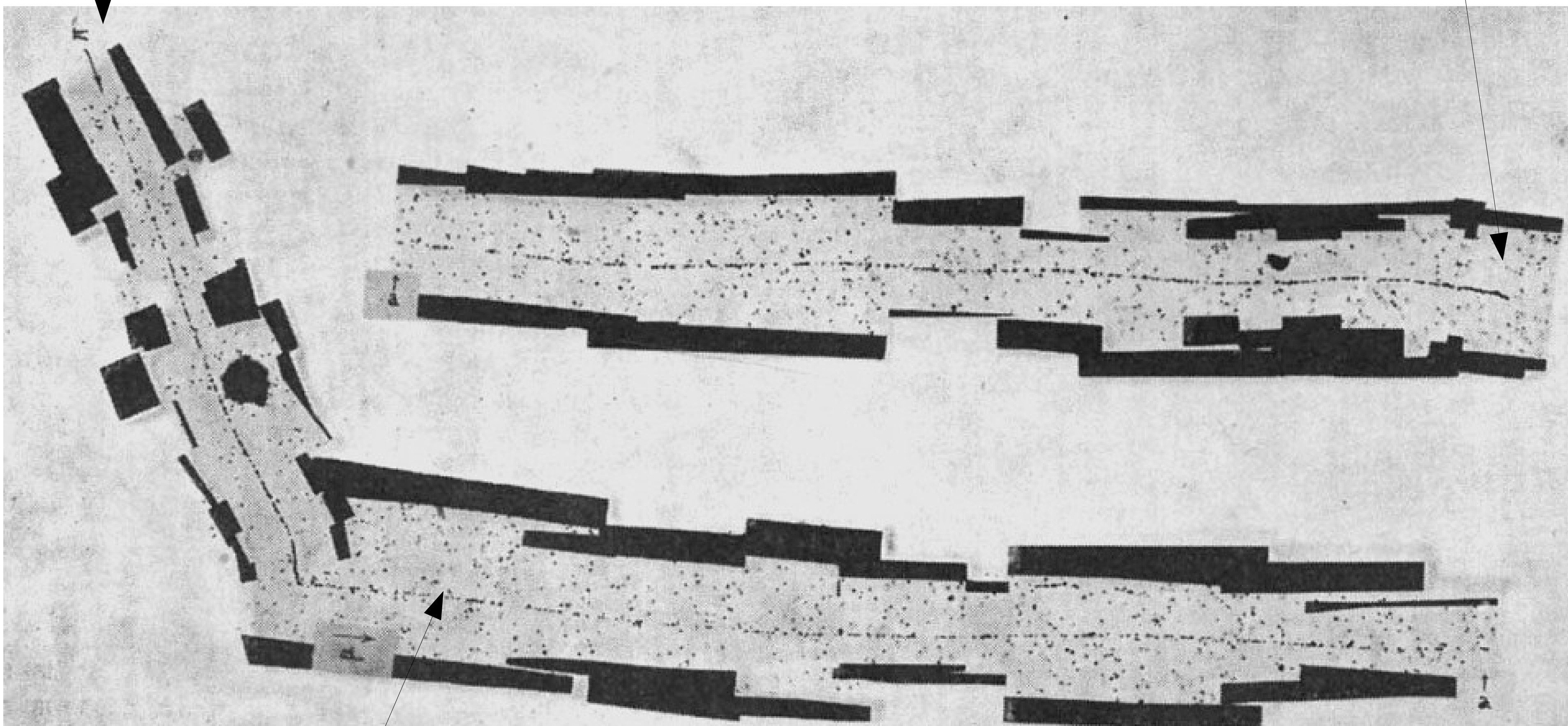
Mean scattering angle suggests a meson of mass **250-350 m_e**

(Feb 1947, observed by Powell, Occhialini)

π→μ event

π

μ stops in emulsion



μ (estimated mass = 100-300m_e)

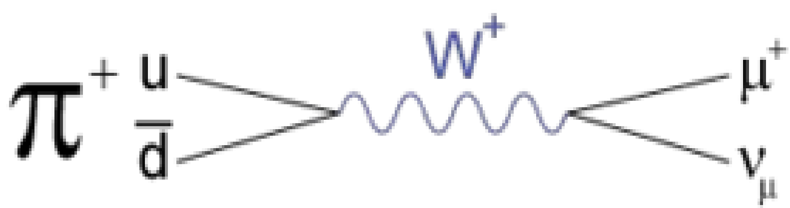
(Oct 1947, observed by Powell, Occhialini, Lattes)

Range of muons

Event No.	Range in emulsion in microns of Primary meson	Secondary meson
I	133	613
II	84	565
III	1040	621
IV	133	591
V	117	638
VI	49	595
VII	460	616
VIII	900	610
IX	239	666
X	256	637
XI	81	590

Mean range $614 \pm 8\,\mu$. Straggling coefficient $\sqrt{\Sigma \Delta_i^2/n} = 4{\cdot}3$ per cent, where $\Delta_i = R_i - \bar{R}$, R_i being the range of a secondary meson, and $\bar{R}$ the mean value for n particles of this type.

- Note <u>constant range</u> of muons
- Muons have constant kinetic energy!
- Produced in a 2-body decay of the pion



Consequences

- Cheap, fast-to-start method to study particles
- Quick adoption by university groups
- Detailed cosmic ray studies
- Particles with strangeness (V-shaped tracks)
  - Kaons, hyperons (sigmas, lambdas, xis)
- Gell-Mann et al use the data for their models
- Still used today! E.g., medicine

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