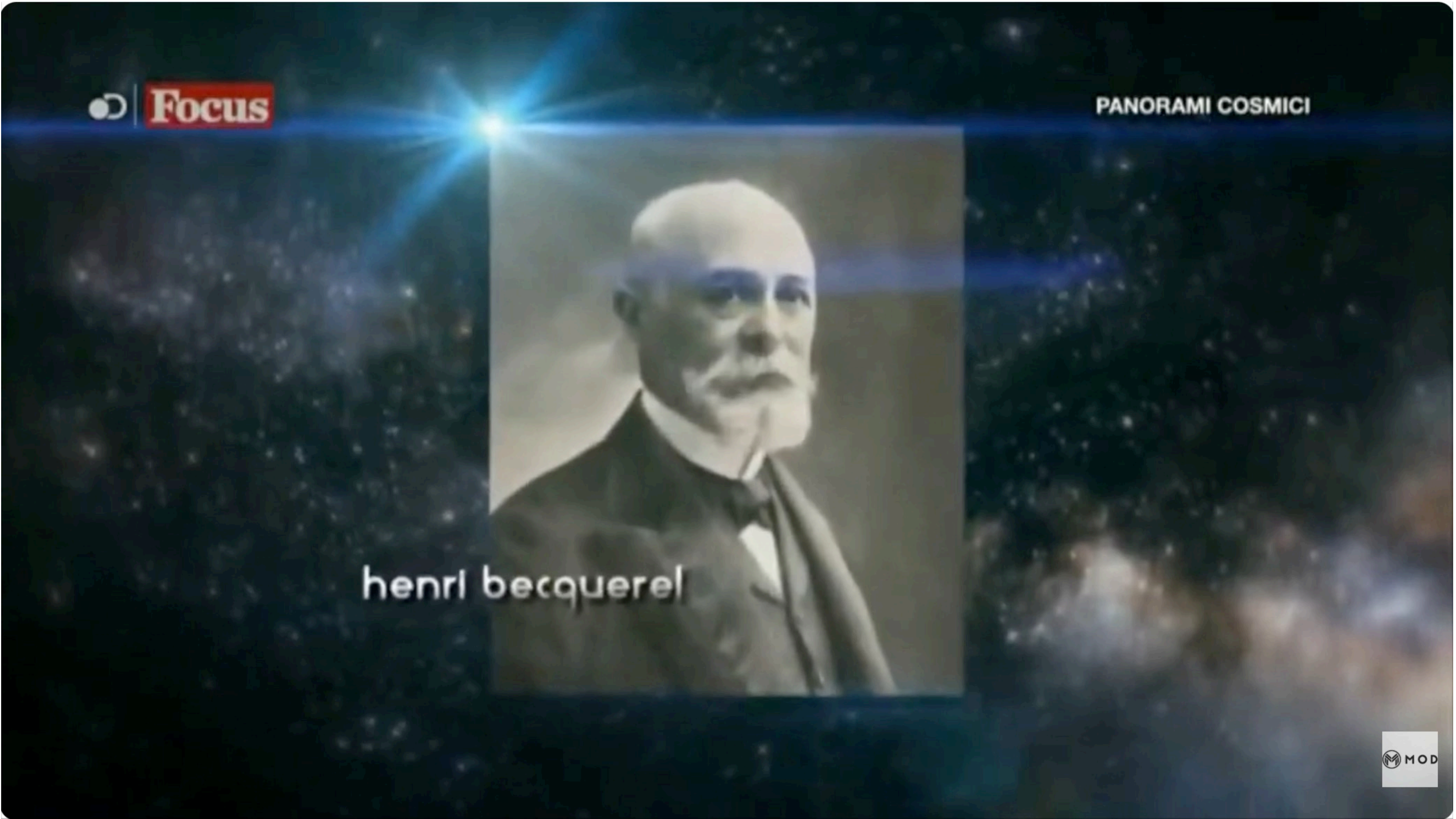
I primi esperimenti con i raggi cosmici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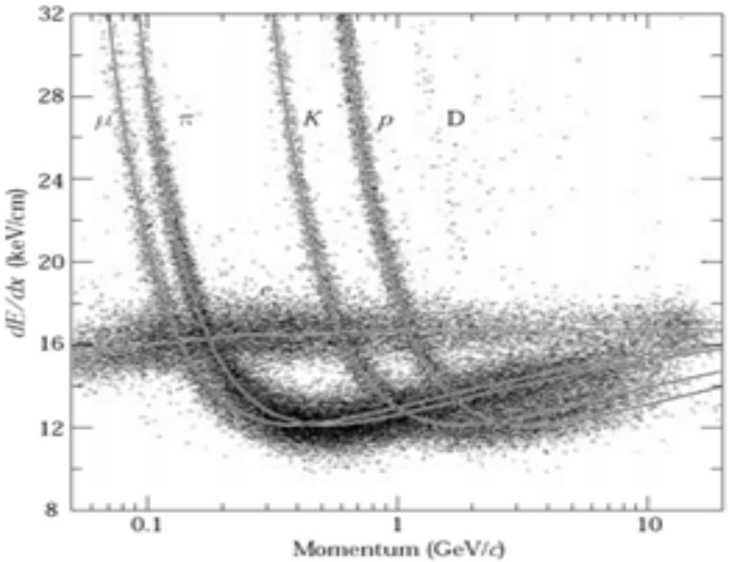
Discoveries in cosmic-rays researches versus experimental techniques

Experimental confirmation of antimatter

(C.D. Anderson, 1932)



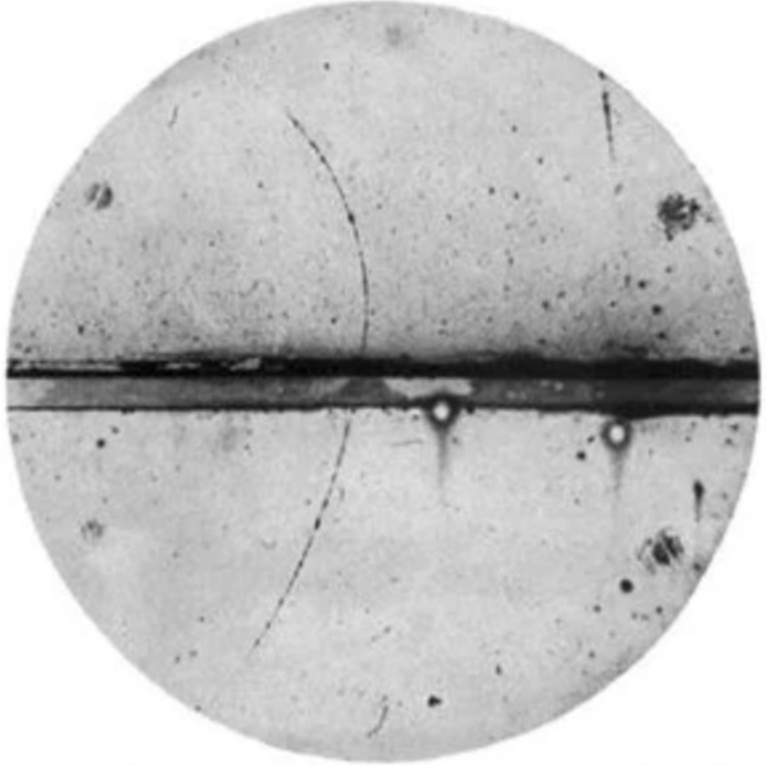
Detector: a Wilson cloud – chamber (visual detector based on a gas volume containing vapour close to saturation) in a magnetic field, exposed to cosmic rays

Measure particle momentum and sign of electric charge from magnetic curvature

Lorentz force $\vec{f} = e\vec{v} \times \vec{B}$ ⟹ projection of the particle trajectory in a plane perpendicular to $\vec{B}$ is a circle

Circle radius for electric charge $|e|$: $$R\,[\mathrm{m}] = \frac{10\,p_{\perp}[\mathrm{GeV/c}]}{3B\,[\mathrm{T}]}$$

$p_{\perp}$: momentum component perpendicular to magnetic field direction

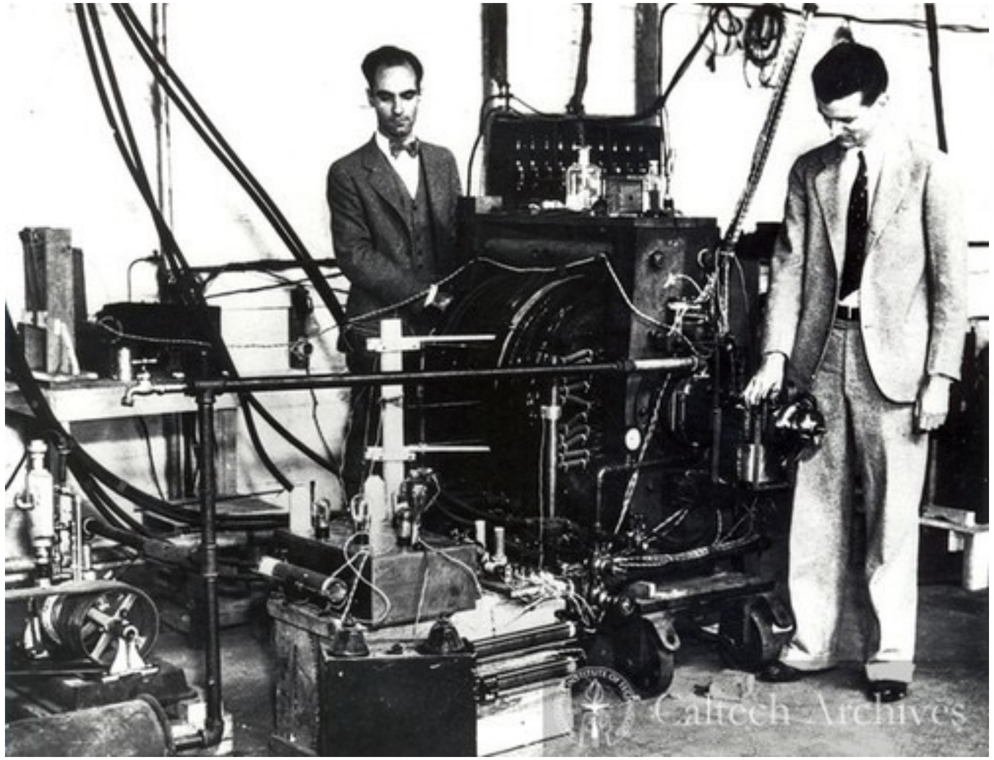


NOTE: impossible to distinguish between positively and negatively charged particles going in opposite directio

⇒ need an independent determination of the particle direction of motion

Muon Discovery

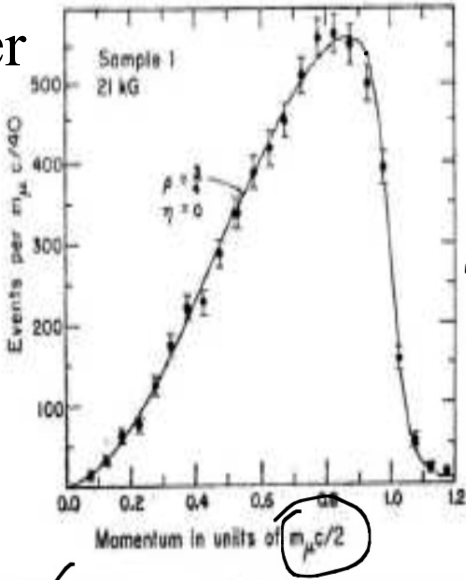
Carl D. Anderson and Seth Neddermeyer discovered muons at Caltech in 1936



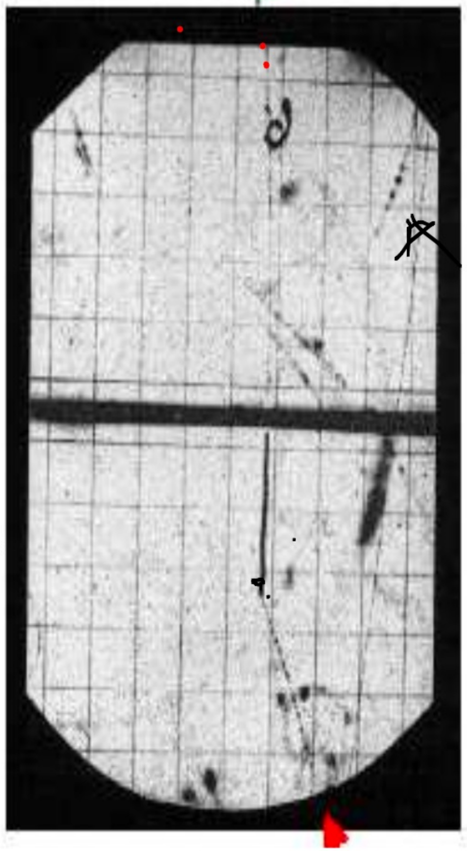
Muon decay

$\mu^{\pm} \rightarrow e^{\pm} + \nu + \bar{\nu}$

Decay electron momentum distribution



Cosmic ray muon stopping in a cloud chamber and decaying to an electron



Muon spin = ½

p_e $p_{\nu_1} + p_{\nu_2}$

$E^2 = p^2c^2 + m^2c^4$

$m_\mu c^2 = (\sum E_i) \approx (\sum p_i c)$

$m_\mu c^2 = p_e c + (p_{\nu_1} c + p_{\nu_2} c)$

$m_\mu c^2 \geq 2 p_e c$ $\quad p_e c$

$p_{e_{MAX}} \simeq \frac{m_\mu c}{2}$

valore max se emesso back to back con i 2 neutrini

$(p_{\nu_1} c + p_{\nu_2} c)$

$\frac{m_\mu c}{2} \sim 53$ MeV/c

$m_\mu c^2 \sim 105$ MeV

NUCLEAR EMULSION

- Photographic emulsions were key to the discovery of the pion. Previously the tools available were Geiger Counters and Cloud Chambers

Discovery of radioactivity and alpa rays using photographic emulsion
1896

First ever observation of proton tracks in nuclear emulsion using alpha rays in paraffin wax - Marietta Blau

First ever observation of neutrons in nuclear emulsion through proton recoil - Marietta Blau

Marietta Blau and Hertha Wambacher first observed the disintegration of the nuclei through smaller particles at 2,300 m *

First ever detection of muons through photographic emulsion - Bibha Chowdry

Kodak and Ilford produce photographic emulsions to record nuclear particles

Cecil Powell was told of and reproduced Blau's work in nuclear emulsion on Jungfraujoch 3,500 meters. Method was so simple that 'even a theoretician might be able also to do it'

Observation of pion using emulsion plates exposed to cosmic rays in the pyrenees - Powell et al
1947

Observation of kaon using emulsion plates exposed to cosmic rays on Jungfraujoch- Rosmary Brown

1947: Discovery of the π - meson

(by Cecil Powell, Cesare Lattes, Giuseppe Occhialini, and Marietta Kurz

Observation of the $\pi^+ \to \mu^+ \to e^+$ decay chain in nuclear emulsion exposed to cosmic rays at high altitudes

Nuclear emulsion: a detector sensitive to ionization with ~1 μm space resolution (AgBr microcrystals suspended in gelatin)

In all events the muon has a fixed kinetic energy (4.1 MeV, corresponding to a range of ~ 600 μm in nuclear emulsion) $\Rightarrow$ two-body decay

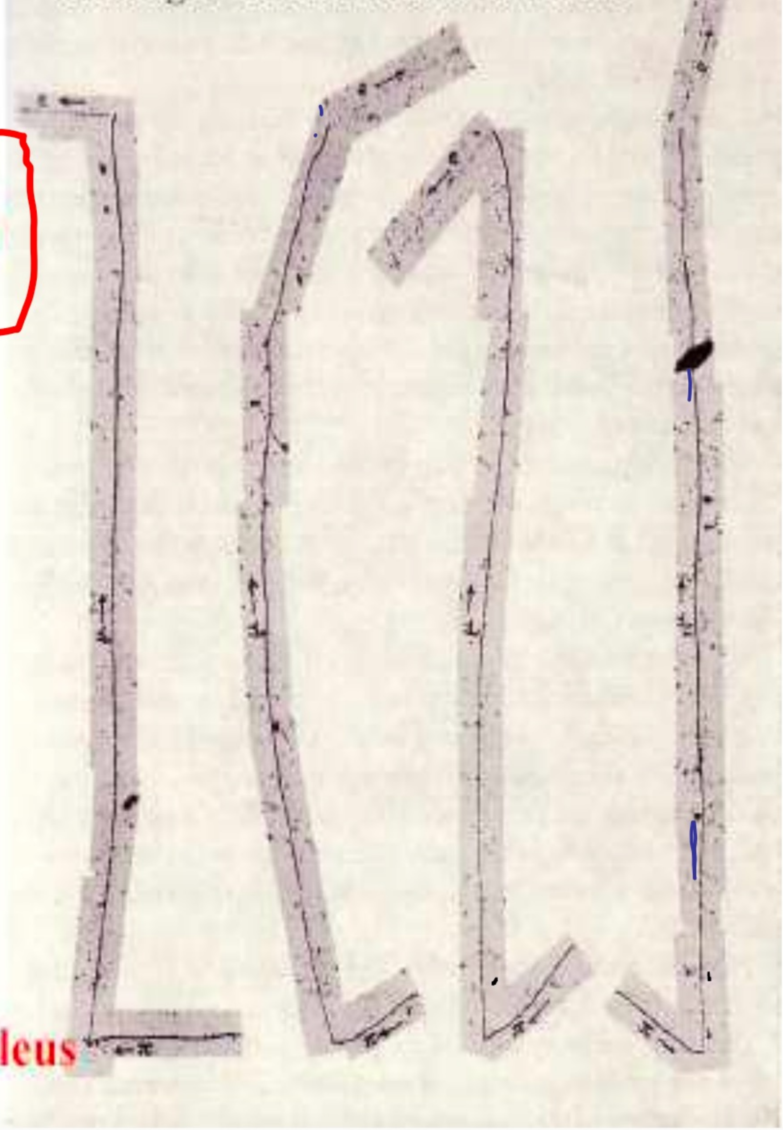
$m_\pi = 139.57$ MeV/c^2 ; spin = 0

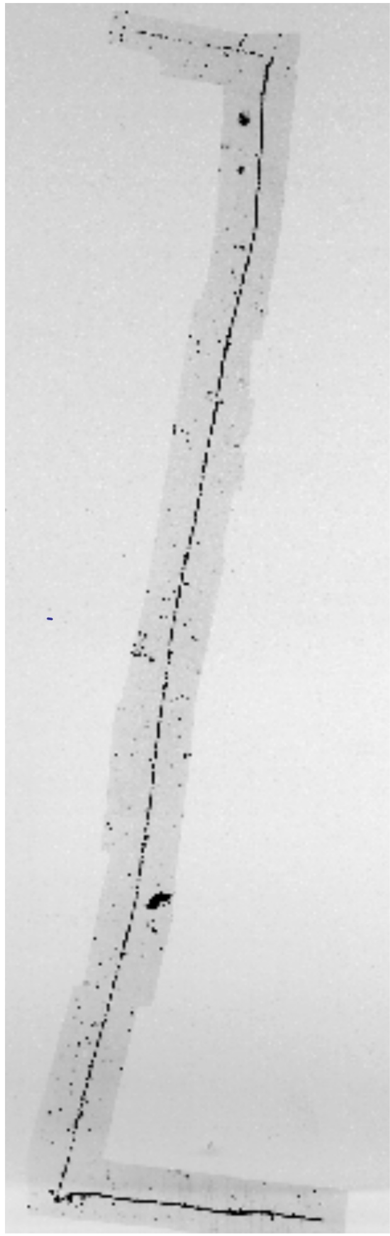
Dominant decay mode: $\pi^+ \to \mu^+ + \nu$

(and $\pi^- \to \mu^- + \overline{\nu}$)

Mean life at rest: $\tau_\pi = 2.6 \times 10^{-8}$ s = 26 ns

Four events showing the decay of a π^+ coming to rest in nuclear emulsion





A neutral π – meson (π°) also exists:

m (π°) = 134.98 MeV /c^2

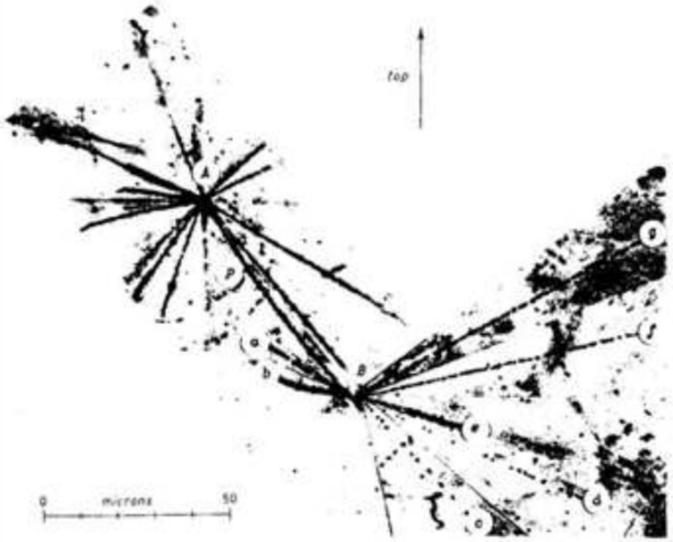
Decay: $\pi^\circ \to \gamma + \gamma$, mean life = 8.4×10^{-17} s

π – mesons are the most copiously produced particles in proton – proton and proton – nucleus collisions at high energies

The antiproton balloon event

"Unusual Event Produced by a Heavy Particle at Rest"

"Unusual Event Produced by Cosmic Rays"



"... the interpretation of this track in terms of a high energy fragment... is very improbable. Such a conclusion is definitely confirmed by the fact that the deflection of a fast fragment through an angle of 90° should be associated with a rather long recoil track, even in the case of a target nucleus as heavy as silver. No recoil is observed in the present case.... the track is due to a low energy particle.

... the event could also be due to an accidental coincidence in space. Therefore we have evaluated the probability for such a coincidence... the value is sufficiently small to entitle us to look for an interpretation of the observed event in terms of a physical process... We are left to consider the star B as produced by the track p. Then the corresponding particle either has rest energy of the order of 1.5 $\div$ 2 GeV, or, being an antiproton, it has been annihilated by a nucleon, releasing 2 $m_p c^2$ = 1876 MeV.

One can conclude that the probability of an accidental coincidence can not be disregarded although it is rather small. If one excludes this possibility the more likely interpretation seems to be that of an annihilation process of a heavy particle... the many questions raised by the discussion of this event will obviously find their final answer only if other similar events will be observed."

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Unusual Event Produced by Cosmic Rays.

E. Amaldi, C. Castagnoli, G. Cortini, C. Franzinetti and A. Manfredini

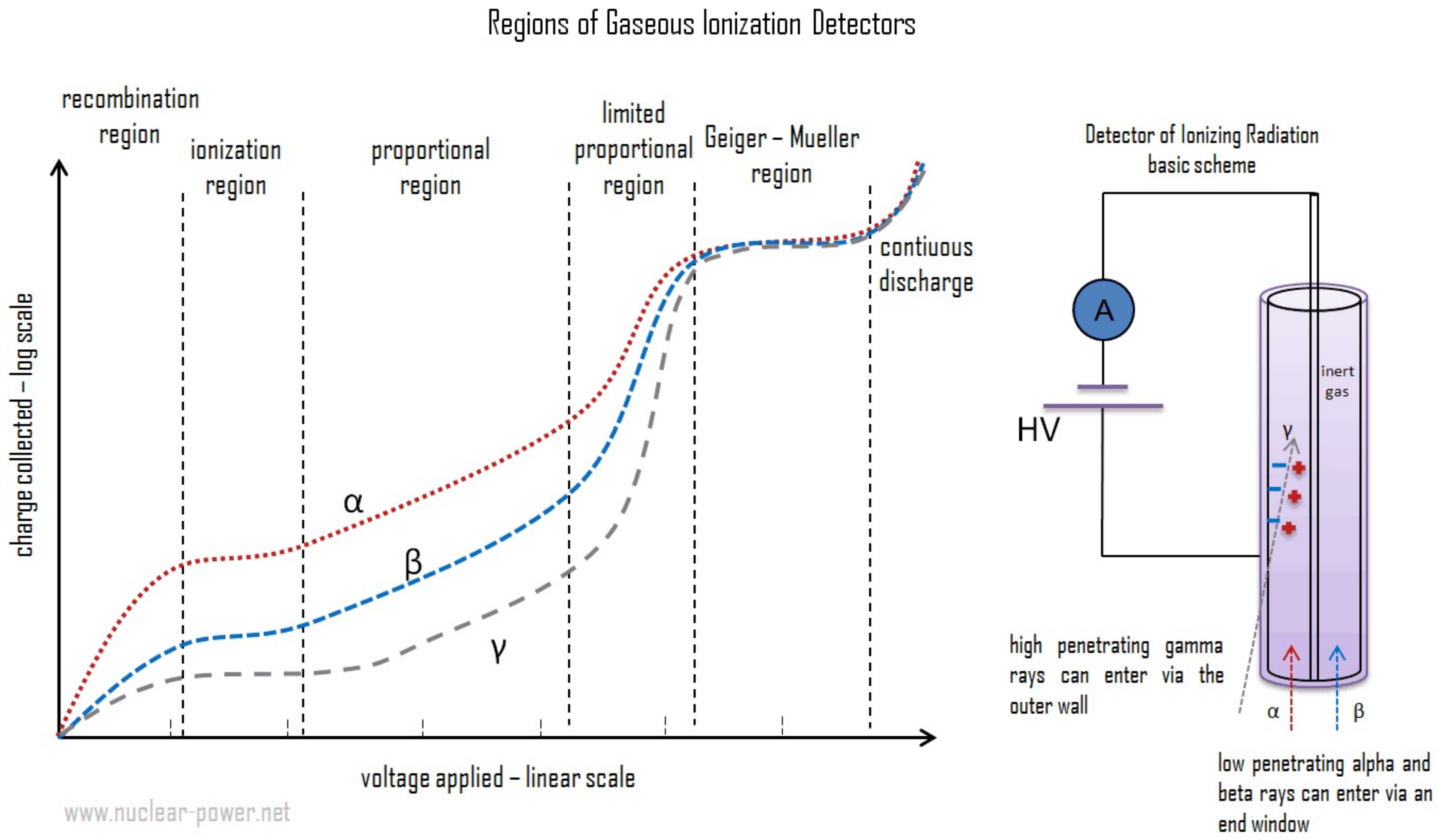
Istituto di Fisica dell'Università - Roma
Istituto Nazionale di Fisica Nucleare - Sezione di Roma

(ricevuto il 18 Febbraio 1955)

Summary. – The authors describe an event consisting of two stars respectively of about 5 and 1-2 GeV energy. The probable value of the number of accidental space coincidences that one expects to observe in the scanned volume, is about $4\cdot10^{-4}$. This value, although it does not allow us to exclude an accidental process, justifies the consideration of interpretations in terms of some physical process. Special attention is devoted to the production, capture and annihilation of a negative proton.

"Faustina", l'evento "strano" rintracciato all'inizio del 1955 dal gruppo di Roma nelle lastre esposte alla radiazione cosmica durante la spedizione di Sardegna del 1953

Il contatore Geiger-Muller (1928)

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