

ΚΟΣΜΙΚΕΣ ΑΚΤΙΝΕΣ

ΕΙΣΑΓΩΓΗ

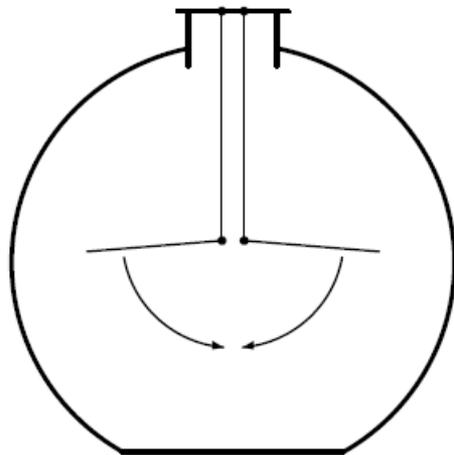
Ιστορική Βιβλιογραφία

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- Cerenkov Radiation and its Applications J.V. Jelley.

ΙΣΤΟΡΙΑ

Πειράματα Hess, Kolhorster 1912 ,
1913, με ηλεκτρόμετρο.

Απόδειξε ότι ο ιονισμός προκύπτει από
ροή ακτίνων που έρχονταν από το
διάστημα.



Απόσπασμα από Rossi.

At six o'clock on the morning of August 7, 1912, a balloon ascended from a field near the town of Aussig, in Austria. In the gondola of the balloon were three men: a navigator, a meteorologist, and a physicist. During the next $2\frac{1}{2}$ hours, the balloon rose to an altitude of 13,000 feet while drifting rapidly northward. For another hour it floated between 13,000 and 16,000 feet. At noon the balloon touched down near the German town of Pieskow, 30 miles east of Berlin and some 125 miles from Aussig.

The physicist and leader of the flight was Victor F. Hess. He had taken with him three electroscopes of the kind then being used to detect and measure the radiation emitted by radium and other radioactive substances. While his companions took care of the navigation and measured altitude and temperature, Hess watched his instruments and recorded their readings. A few months later, after a careful study of the data, he presented to the scientific community a conclusion of far-reaching significance. In the

Απόσπασμα από Rossi.

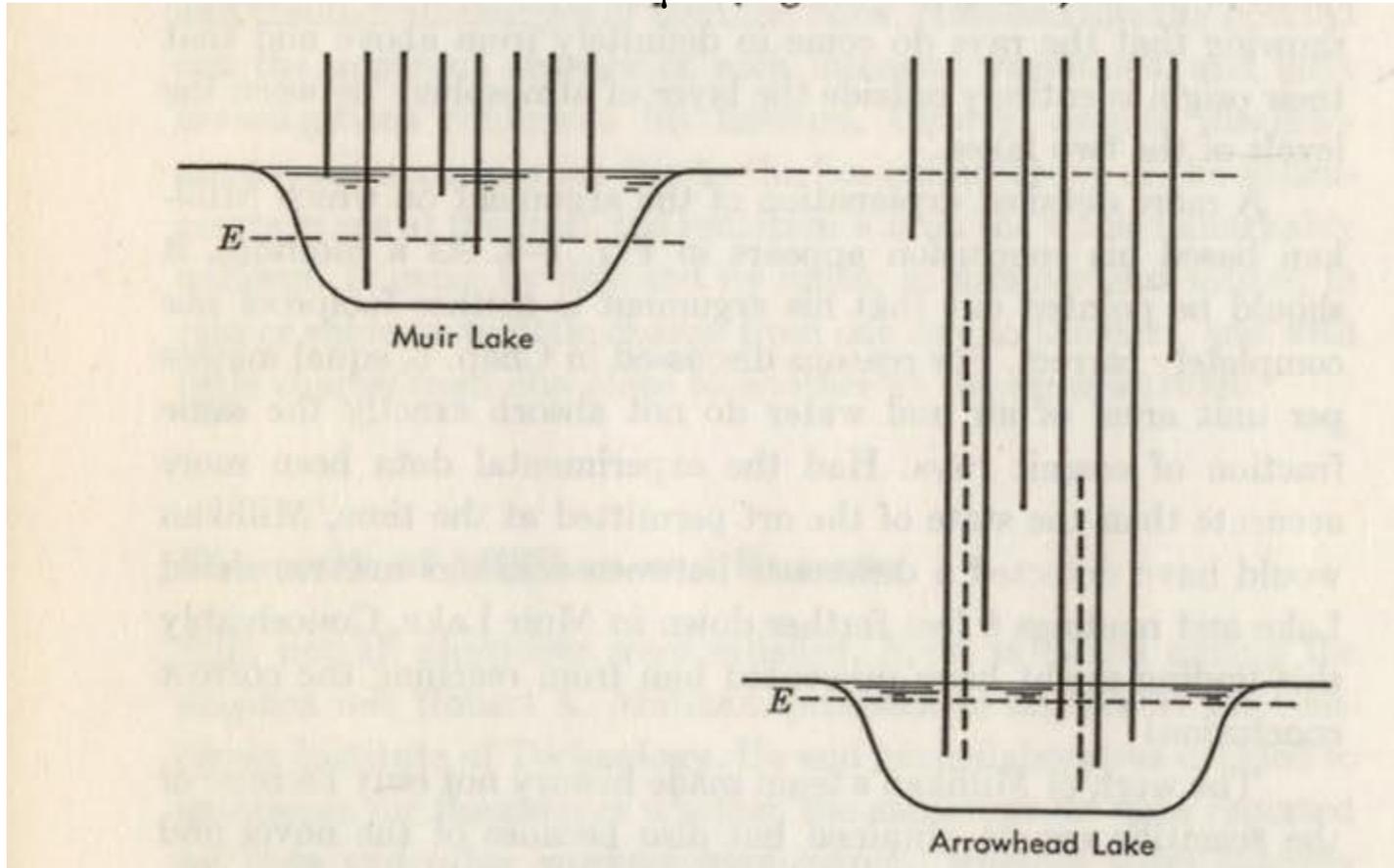
ticularly suitable as a radiation meter was the instrument designed by Wulf in 1909. He replaced the gold leaves with two very thin metal wires held under tension by a light quartz fiber (Fig. 1-3). When charged, the two wires would repel each other, and the separation could be measured by means of a microscope. In 1910 Wulf carried one of his electroscopes to the top of the Eiffel Tower; in 1912 Gockel used a similar instrument in a balloon ascent. Neither found what they had expected. The rate of discharge did not decrease with altitude, or at least did not decrease as fast as they had anticipated.

As the balloon began its ascent through the atmosphere, Hess found that the ionization became somewhat weaker at first, as indicated by a slower rate of electroscopé discharge. Unquestionably, there was a radiation emanating from the earth's crust. But above 2,000 feet the trend reversed itself and the ionization began to increase gradually with altitude, as though the balloon were moving toward the source of the ionizing radiation instead of away from it. Indeed, at 16,000 feet the electroscopes were discharging about *four times faster* than they had at ground level. It was in order to explain this unexpected increase that Hess postulated a radiation falling upon the earth from somewhere beyond the atmosphere.

Απόσπασμα από Rossi.

His assumption was certainly a bold one, and many years were to pass before it became generally accepted. First of all, other experimenters had to check the findings reported by Hess. When they did, they found that the increase of radiation strength with altitude continued well above 16,000 feet. Especially noteworthy were the daring balloon flights carried out by W. Köhlhörster of Germany between 1913 and 1919. In his flights he reached a maximum altitude of about 28,000 feet, where he found an ionizing radiation considerably stronger than that detected by Hess.

Απόσπασμα από Rossi.



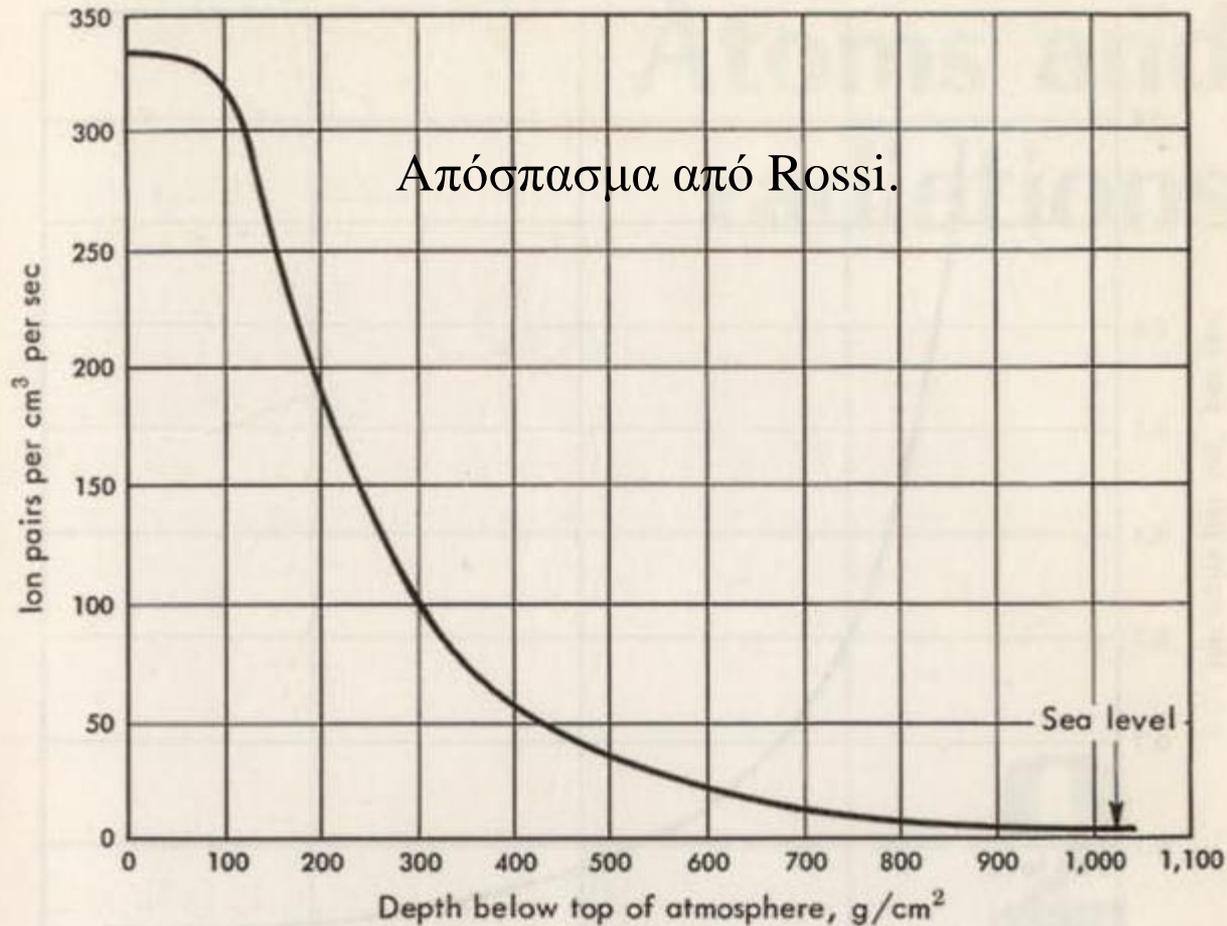


Fig. 1-5 Intensity of cosmic rays as a function of atmospheric depth, as measured by Regener and his group with balloon-borne electroscopes. The atmospheric depth plotted on the horizontal axis is the mass per unit area of the air layer above the electroscope. The vertical scale gives the number of ion pairs produced per second by cosmic rays in 1 cm³ of air at standard temperature and pressure. In these units, the cosmic-ray intensity at sea level is about 2.

Απόσπασμα από Rossi.

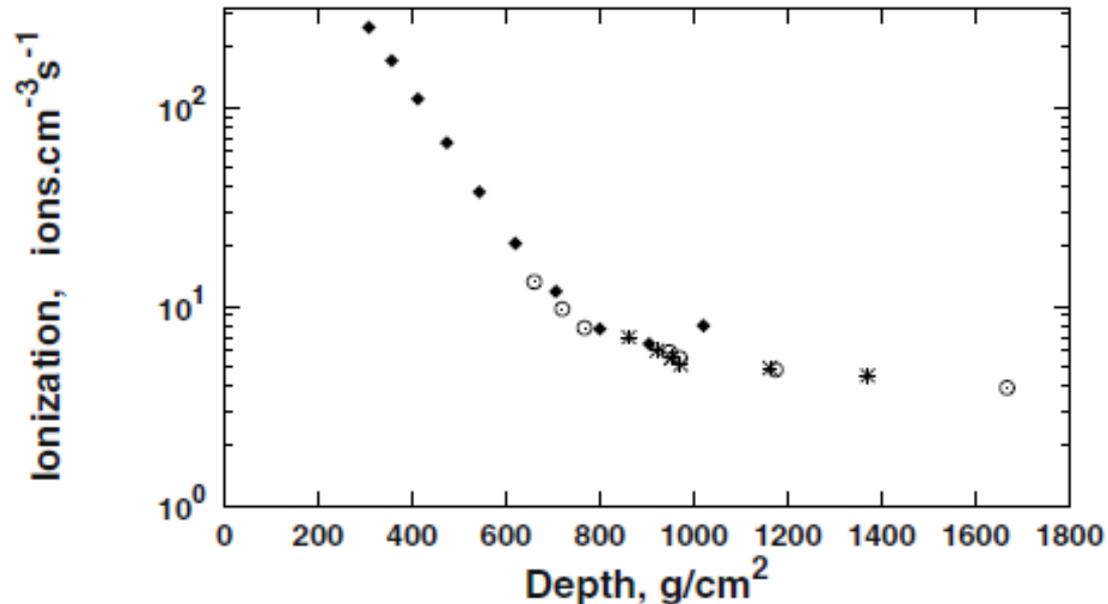
Now, absorption measurements in the atmosphere and under water by Hess, Kohlhörster, Millikan, Regener, and others had shown the cosmic radiation to be more penetrating than any other (see Figs. 1-5 and 1-6). It was thus natural to think that cosmic rays were of greater energy than the most energetic photons found among γ rays. Some physicists, willing to trust the theory of the Compton effect in a range of energies where it had not yet been tested experimentally, estimated the energies of the hypothetical cosmic-ray photons from the shape of their absorption curve. Cosmic rays, they concluded, were a mixture of photons with energies ranging from 20 or 30 to several hundred MeV. This estimate was the basis of a most provocative suggestion put forward by Millikan in 1928. According to Millikan, cosmic rays were born of the energy released during the synthesis of heavier elements from primordial hydrogen spread throughout the universe.

Απόσπασμα από Rossi.

Millikan noted that the actual absorption curve of cosmic rays did not correspond to any single curve thus computed. However, it could be represented by the *sum* of the absorption curves of three groups of photons with mean free paths of 300, 1,250, and 2,500 g/cm². Using Dirac's theory of the Compton effect (Klein and Nishina had not yet published theirs), Millikan arrived at energies of about 26, 110, and 220 MeV for the three respective groups of photons. He therefore concluded that cosmic radiation was for the most part a mixture of photons with those energies.

While searching for clues to the origin of the photons, which appeared to come in equal numbers from every region of the sky, Millikan was led to the following speculation: Interstellar space is filled with very dilute hydrogen gas. Conceivably, out of this gas the atoms of the heavier elements might continuously evolve by a spontaneous process of *fusion*. Once in a while, for example, four hydrogen atoms might meet and fuse to form a helium atom.

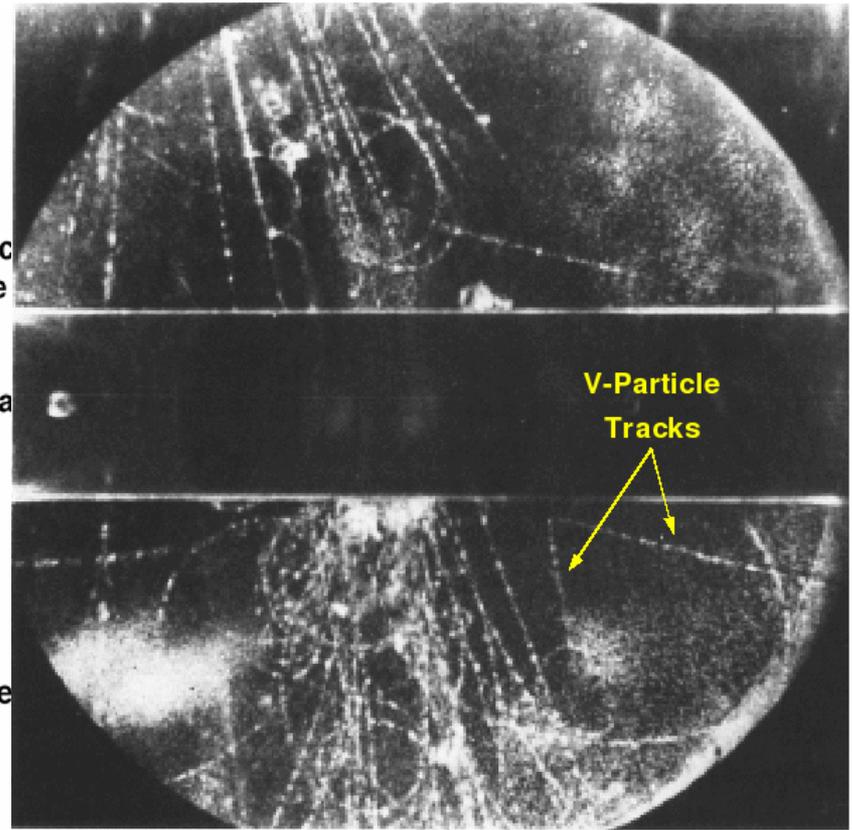
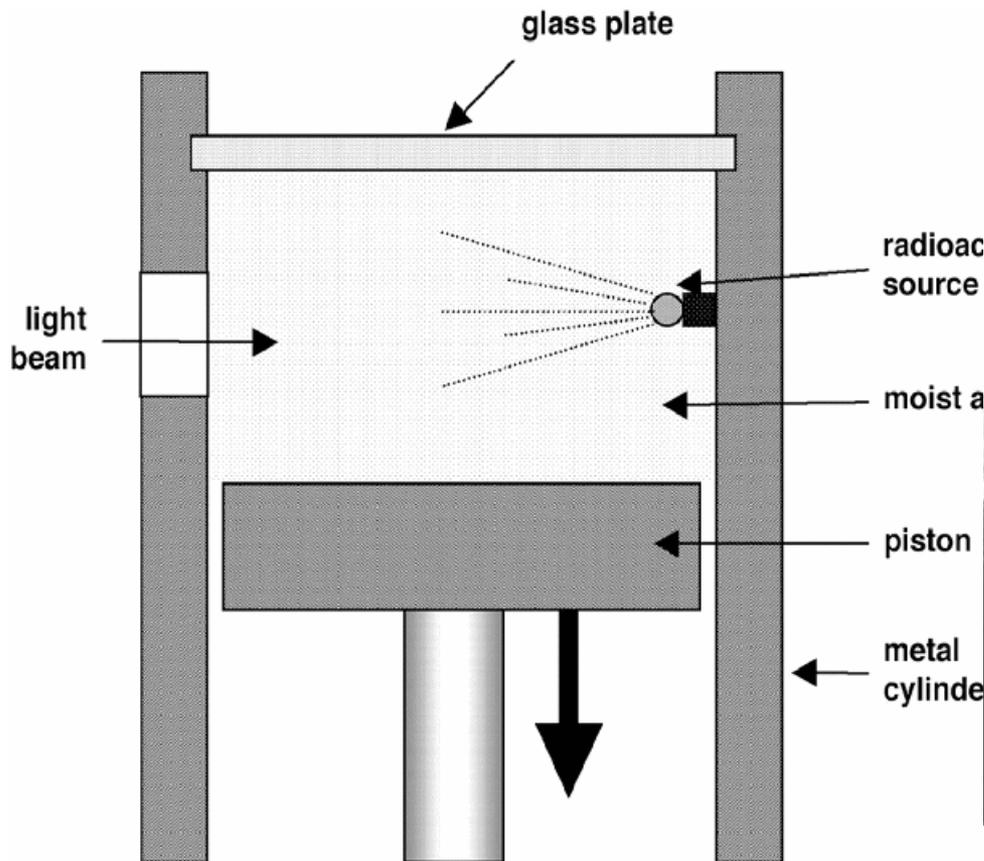
Πόσο καλές ήταν οι μετρήσεις των Hess, Kolhorster και Millikan:



Ο T. Stanev τοποθέτησε σε ένα διάγραμμα τις μετρήσεις με το ηλεκτρόμετρο των Kolhorster και Millikan , αντικατέστησε το ύψος με την μάζα που διασχίζουν τα σωματίδια.

Πρώτοι ανιχνευτές

Θάλαμος νέφωσης (cloud Chamber).



Πρώτοι ανιχνευτές GM

The answer to the needs of cosmic-ray physicists came in 1929 with the invention, by Geiger and one of his students, W. Müller,

In their experiments, Bothe and Kohlhörster had set up two G-M counters, each connected to an electroscope, in order to observe cosmic rays. They noticed that the counters, when placed one above the other a small distance apart (Fig. 3-3), often dis-

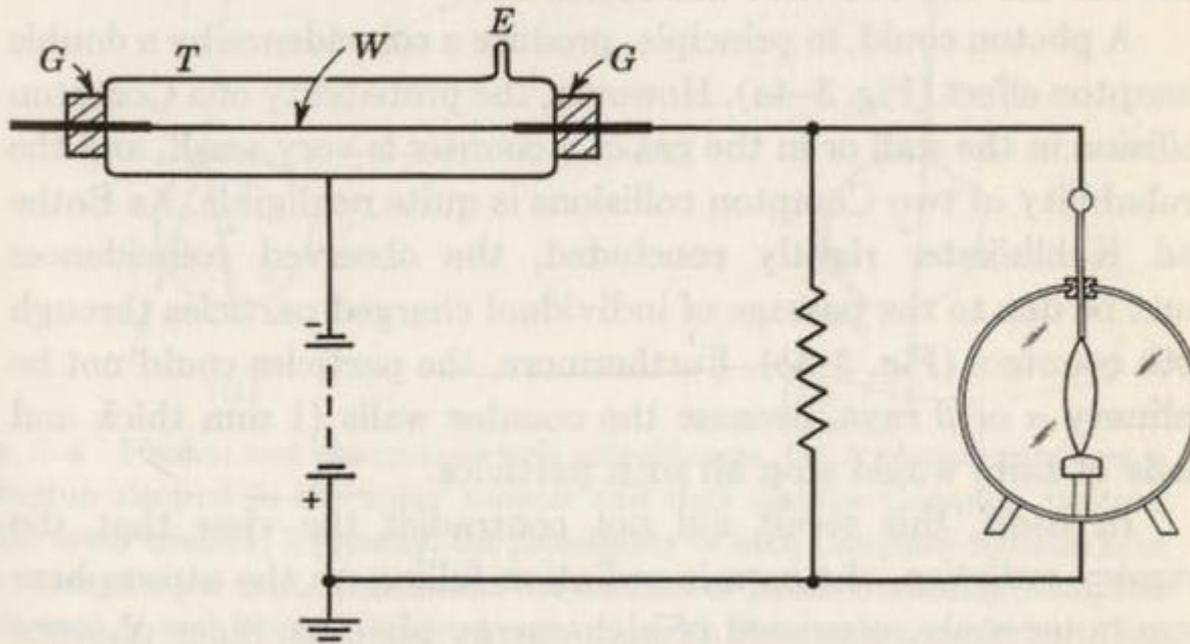
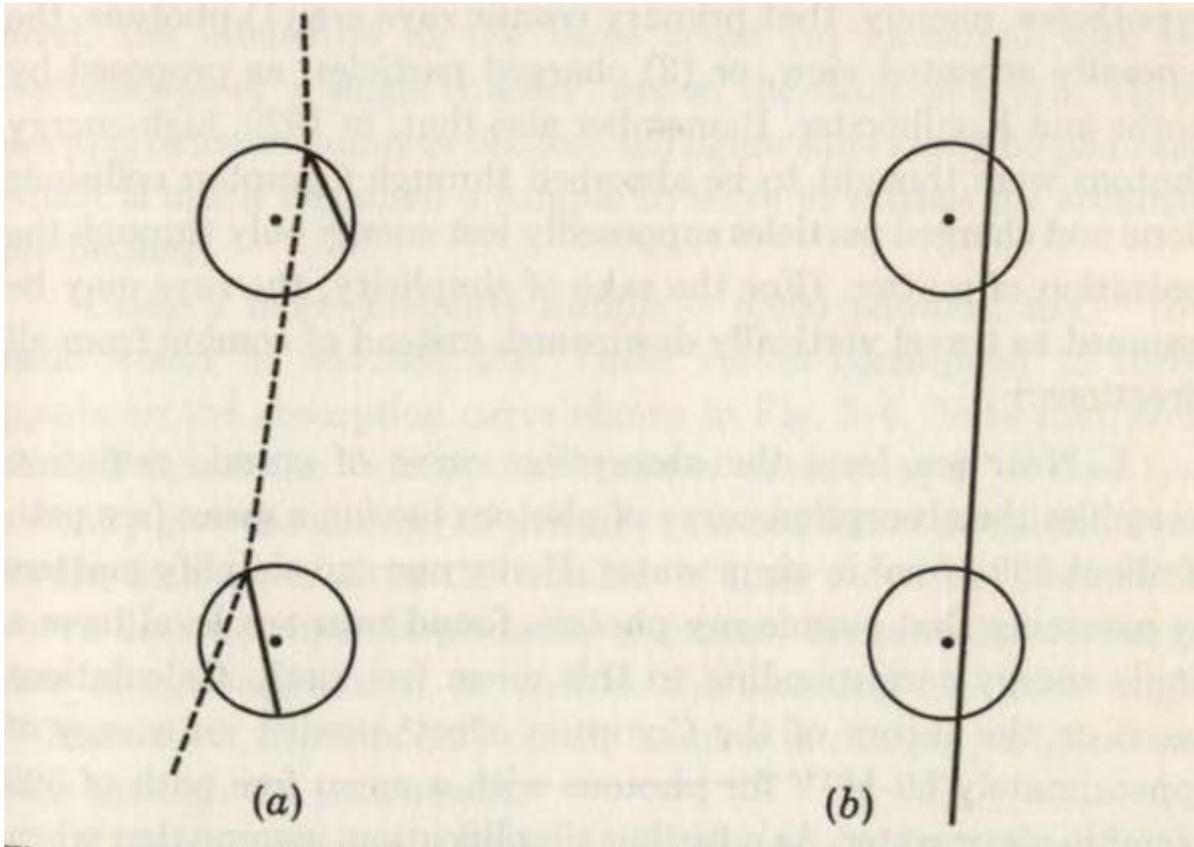


Fig. 3-2 The Geiger-Müller counter: metal tube *T*; glass insulators *G*; thin wire *W*; tube for evacuating and filling the tube *E*. Electrical connections are similar to those shown in Fig. 3-1.

Σύμπτωση με ανιχνευτές GM



Πρώτοι ανιχνευτές GM

significant observations were those made in 1929 by the Russian physicist D. Skobeltzyn. Working with a cloud chamber placed in a magnetic field, Skobeltzyn had photographed the tracks of unusually energetic negative particles passing through the chamber. The curvatures of the tracks (Chap. 5) indicated particle energies much greater than those of ordinary β rays. Skobeltzyn suggested that the tracks were probably left by electrons recoiling from Compton collisions with the hypothetical cosmic-ray photons.

Skobeltzyn also pointed out the occasional appearance, in his pictures of high-energy particles, of two and in one case, three tracks in the same picture. It was possible to explain the multiple tracks by assuming that a recoil electron had undergone one or more collisions somewhere near the cloud chamber and in these collisions had ejected secondary particles of sufficient energy to penetrate the chamber wall.

Διεισδυτικές ακτίνες, Bothe και Kolhorster

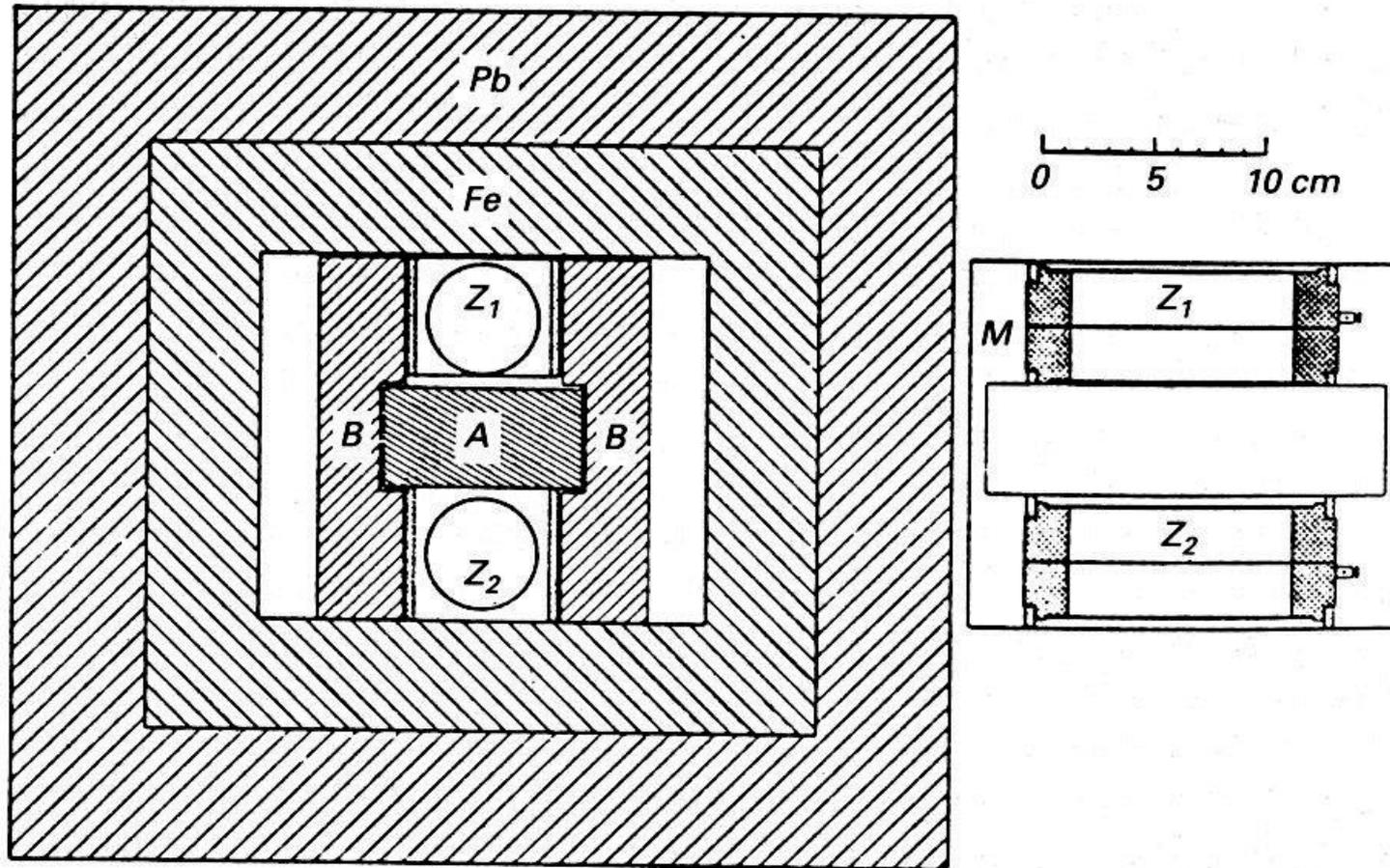


Figure 1.5. The experimental arrangement used by Bothe and Kolhörster to demonstrate that cosmic rays are charged particles and not high energy γ -rays. Z_1 and Z_2 are Geiger-Müller detectors and A is the absorbing slab – lead and gold were used in the key experiments. (W. Bothe and W. Kolhörster (1929). *Zeitschrift für Physik*, **56**,

Ανίχνευση πολλαπλών τροχιών Rossi.

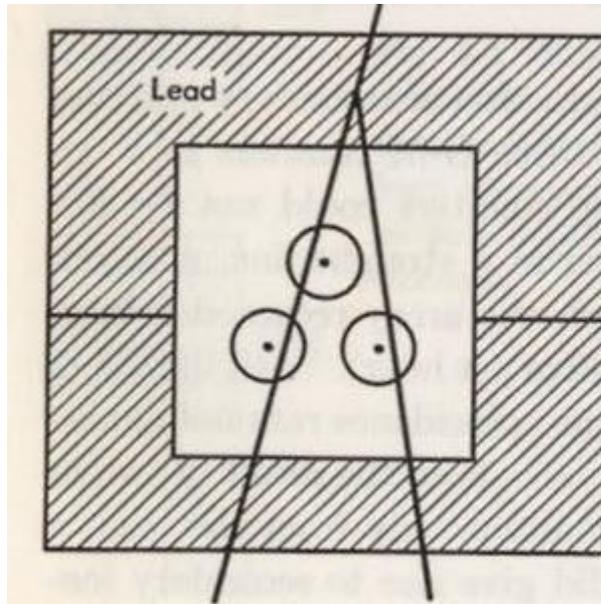


Fig. 4-3 Triangular array of G-M counters used in the first experiment demonstrating the production of secondary particles by cosmic rays. At least two charged particles emerging simultaneously from the lead are needed to produce a coincidence. One of them may be a primary particle, but the other must have been produced in the lead. (If the upper section of the lead shielding is removed, the coincidence rate falls nearly to zero.)

Obviously, the yield of useful pictures would be increased enormously if the chamber expanded at the right time — immediately after a particle had passed through. It turns out that this timely expansion can be brought about by means of the coincidence technique. One can, for example, place single G-M counters above

¹ Some years after, in the late 1930s, cloud chambers capable of continuous

Πρώτοι καταιονισμοί Blackett Occhialini

The 1933 paper in which Blackett and Occhialini described their first observations with the counter-controlled chamber marked another milestone in the history of cosmic-ray research. I shall come back to it in a later chapter. Here I wish to mention only one result. A number of pictures showed the tracks of many particles that clearly resulted from the interaction of a single high-energy cosmic ray somewhere in the vicinity of the chamber (Fig. 4-5). These groups of particles, or *showers*, were unquestionably the cause of the coincidences between counters out of line that I had observed previously.

Σωλήνες Geiger-Muller, Κύκλωμα Σύμπτωσης

66

B. ROSSI AND N. NERESON

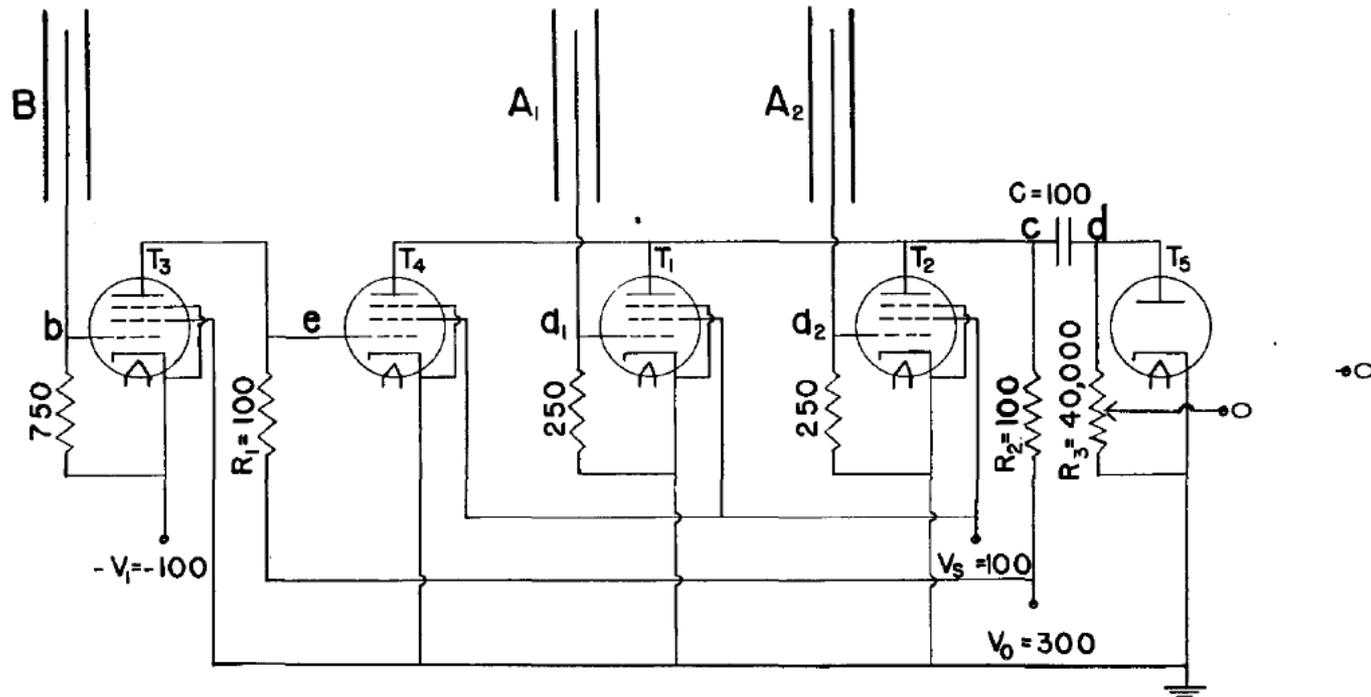


FIG. 1. "Time circuit." T_1, T_2, T_3, T_4 are 6J7 tubes. Resistances are measured in 10^3 ohms, capacities in μmf , potentials in volts.

The discovery of the positron

Even before the discovery of showers, Carl D. Anderson, in Millikan's laboratory at the California Institute of Technology, had started an experimental program that, together with the one begun a little later by Blackett and Occhialini, was to provide a partial answer to our questions. The major result of this work was the discovery of the *positive electron*, or *positron*, and of the strange circumstances attending its birth and its disappearance.

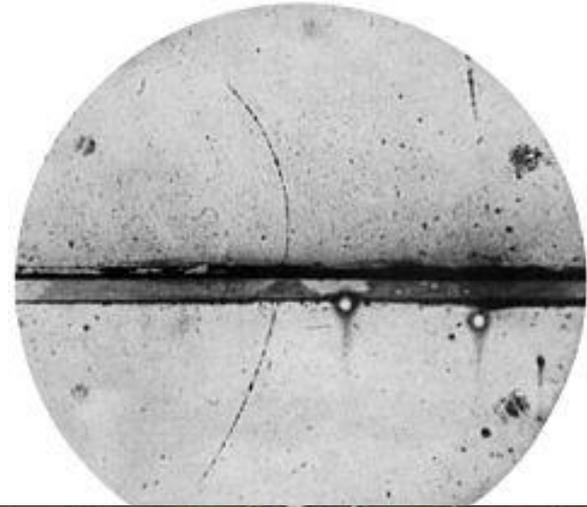
In his experiments Anderson used a cloud chamber placed in the field of a powerful electromagnet. At a maximum field strength of 24,000 gauss he was able to measure the magnetic deflection of tracks whose radius of curvature was as great as 7 meters and whose magnetic rigidity was therefore roughly 1.7×10^7 gauss·cm (that is, 24,000 gauss \times 700 cm). The corresponding kinetic energies — about 5 BeV for particles with the mass of an electron and about 4 BeV for particles with the mass of a proton (Fig. 5-3) — were several hundred times greater than any energy that previous instruments had been capable of measuring. It soon became apparent that the particles of the local cosmic radiation had a wide range of energies extending well beyond 1 BeV. In addition, about half their trajectories bent to the right and half to the left. Assuming the direction of travel to be downward in every case, Anderson concluded that positively and negatively charged particles were about equally abundant in the local cosmic radiation.

Ανακαλύψεις σωματιδίων

1932 Anderson και Millikan
Ποζιτρόνιο.

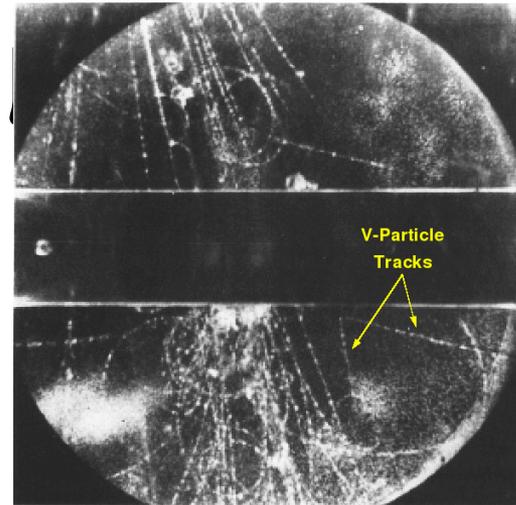
1933 ο Ochialini
καταιονισμοί, $e^+ e^-$.

1936 Anderson και
Neddermeyer μιονίο.



Ανακαλύψεις σω

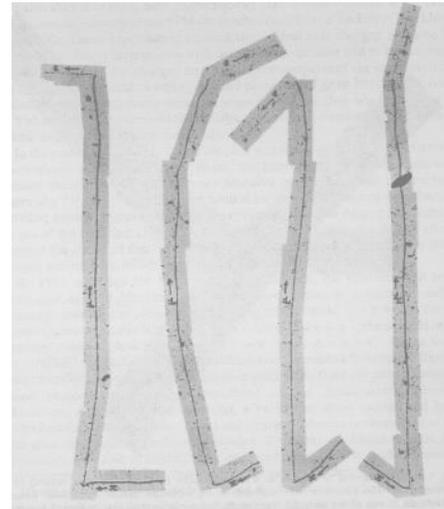
1947 Blackett K^+ , K^- , K^0 Λ



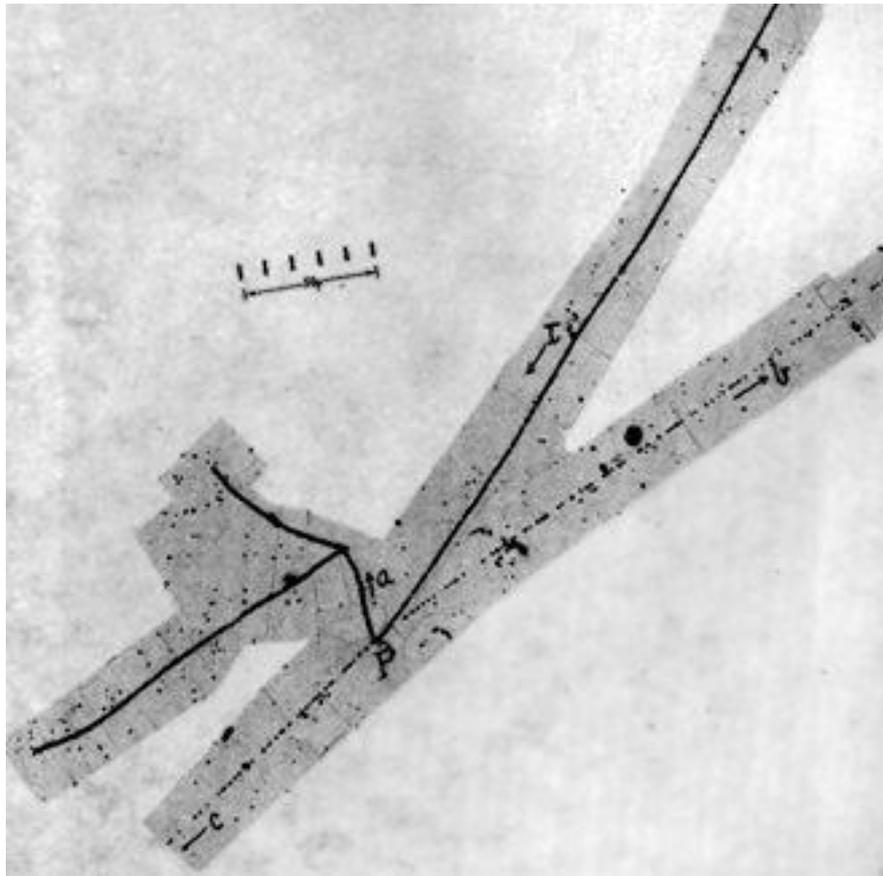
1947 Powell

φορτισμένα πιόνια π^+
και π^-

1947 Occhialini Conversi
Διάσπαση πιονίου.

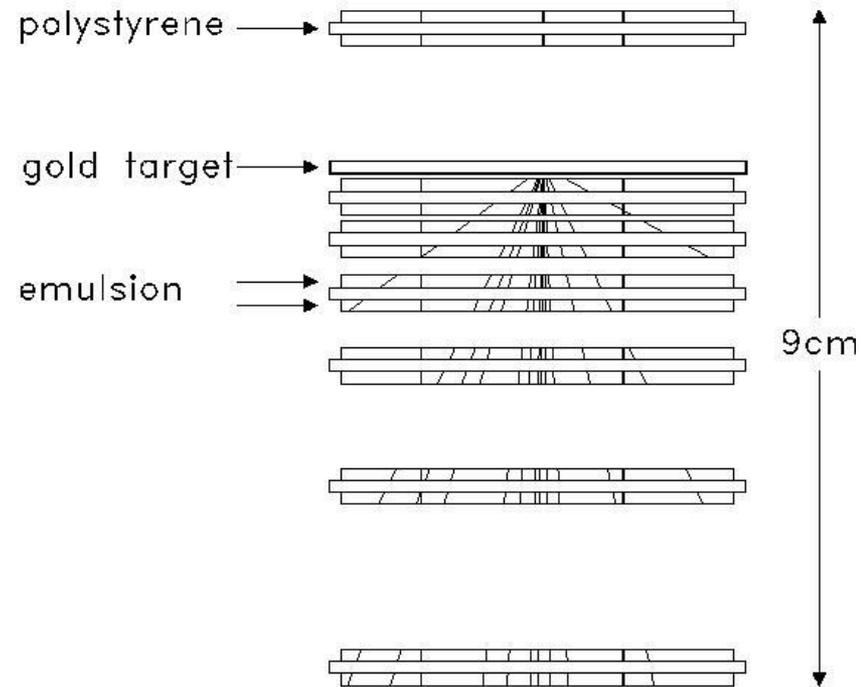


Φιλμ (nuclear emulsion).



Ένα K^+ διασπάται σε $\pi^+ \pi^+ \pi^-$

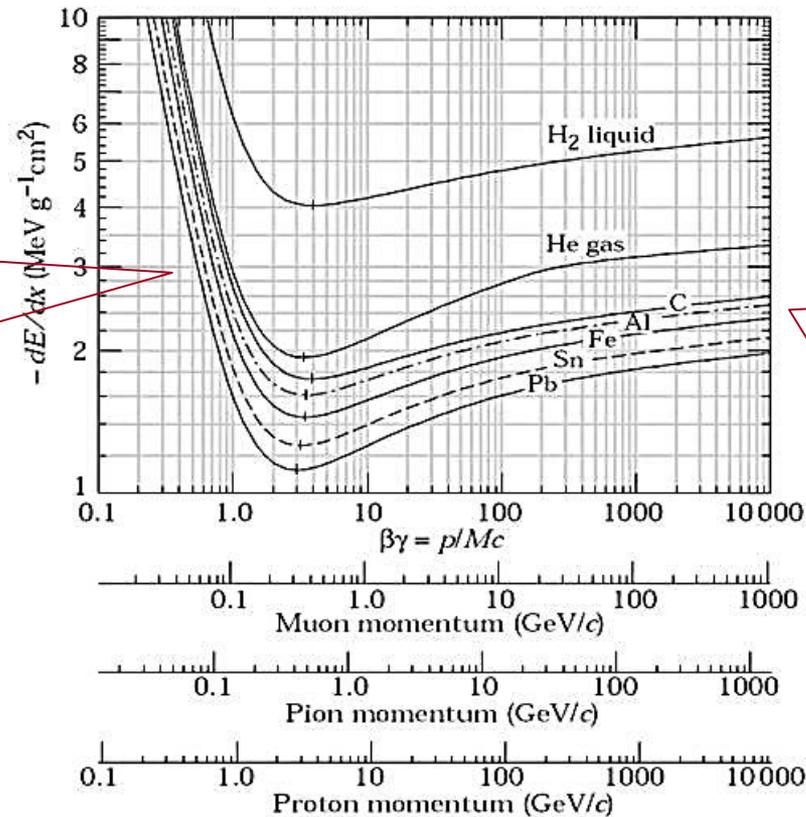
EMU01 Chamber Design



Νεώτερη κατασκευή

Απώλειες Ενέργειας

Bethe-Bloch for Different Materials



Η απώλεια λόγω ιονισμού
ελαττώνεται όσο
αυξάνεται η ταχύτητα

Οι βαρύτεροι
πυρήνες
ιονίζουν
περισσότερο

The Σωματίδια που βρέθηκαν με emulsion stack

The Discovery of new particles by using Nuclear Emulsions

- In 1947, π^+ and π^- were discovered by Powell.
- In 1947, K^+ and K^- were discovered.
- In 1953, Σ^+ was discovered by A. Bonetti.
- In 1958, Anti Λ^0 was discovered by Baldo Ceolin.
- In 2001, ν_τ was discovered by DONut collaboration.

The Discovery of new particles by using Various Detectors

Particle	Instrument
π^+ and π^-	Nuclear Emulsion
π^0	Counters and Emulsion
Λ	Cloud Chamber
K^+ and K^-	Nuclear Emulsion
K^0	Cloud Chamber
Σ^+	Nuclear Emulsion
Σ^-	Cloud Chamber
Σ^0	Bubble chamber
Ξ^-	Cloud Chamber
Ξ^0	Bubble Chamber
Anti Λ^0	Nuclear Emulsion

Πειράματα με αερόστατα. BESS

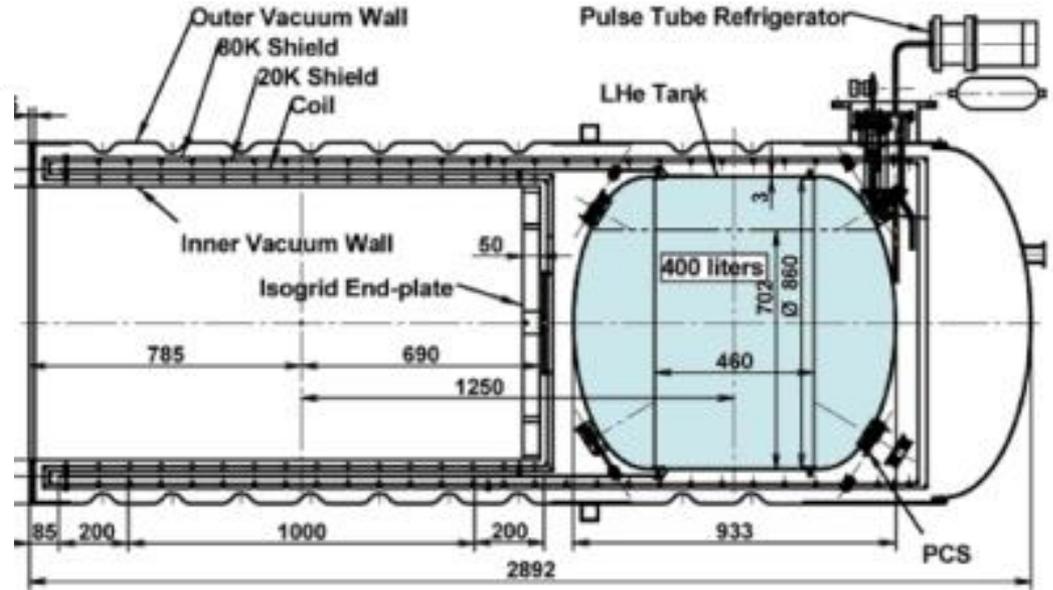
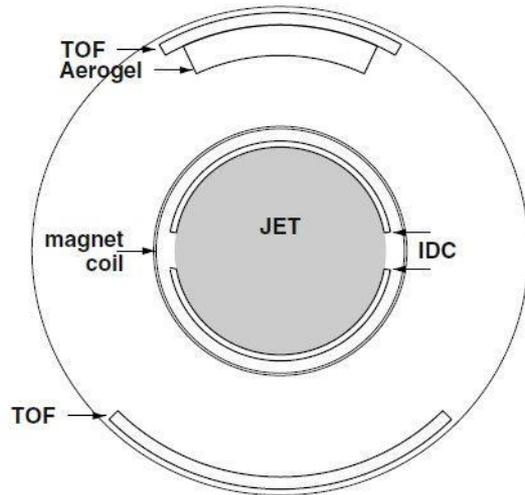
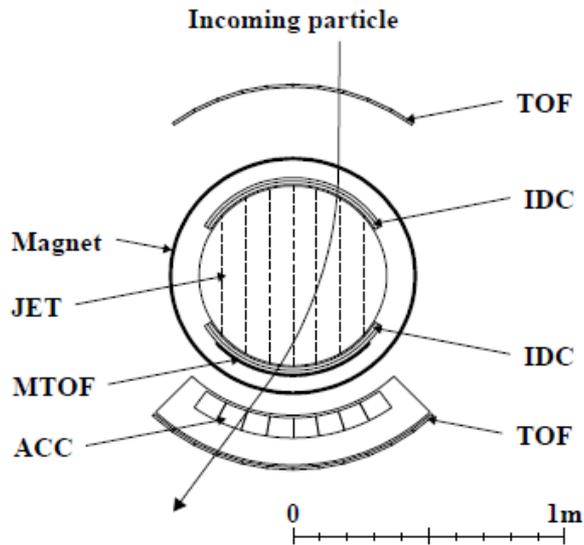


Fig. 5.3. The BESS detector (not to scale).
Εξωτερικοί σπινθηριστές μετρούν χρόνο πτήσης, θάλαμοι ολίσθησης μετρούν την τροχία, ελαφρύ υπεραγωγίμο πηνίο δημιουργεί μαγνητικό πεδίο, εσωτερικοί θάλαμοι ολίσθησης για τον υπολογισμό της ορμής.



Διατομή ανιχνευτή BESS



TOF scintillator hodoscope

Supeconductive coil

IDC inner drift chamber

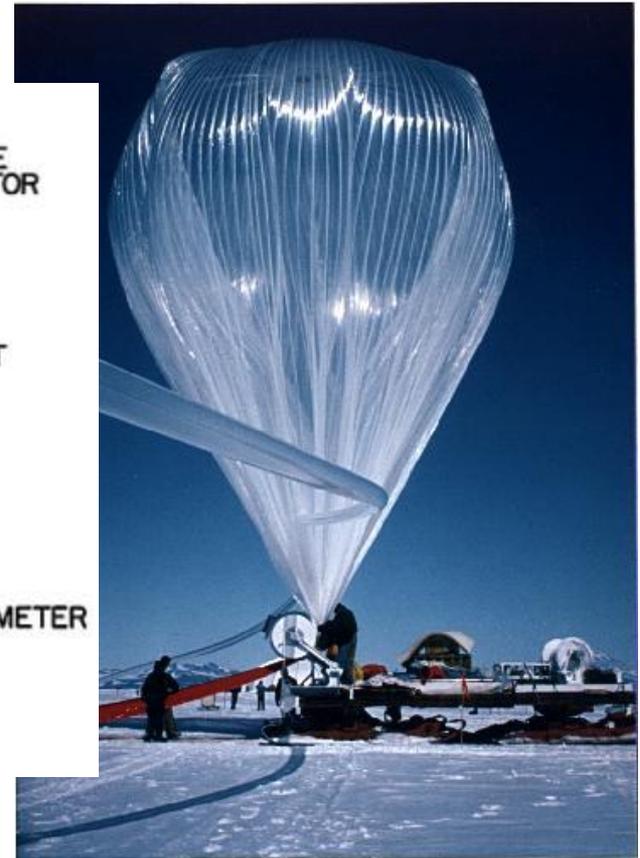
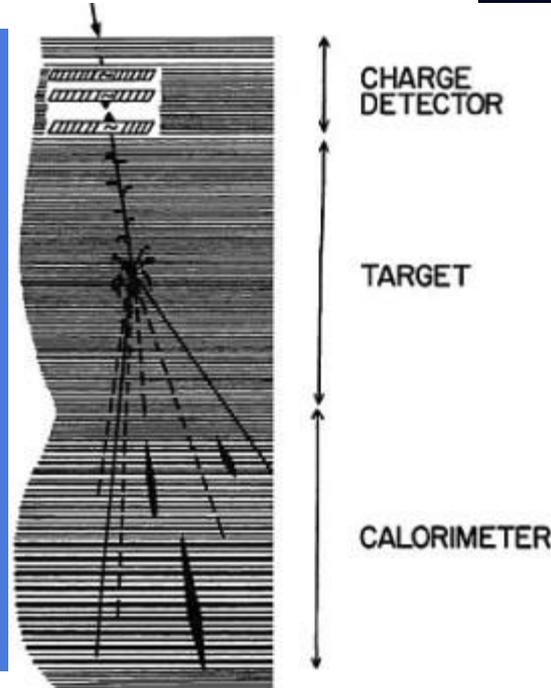
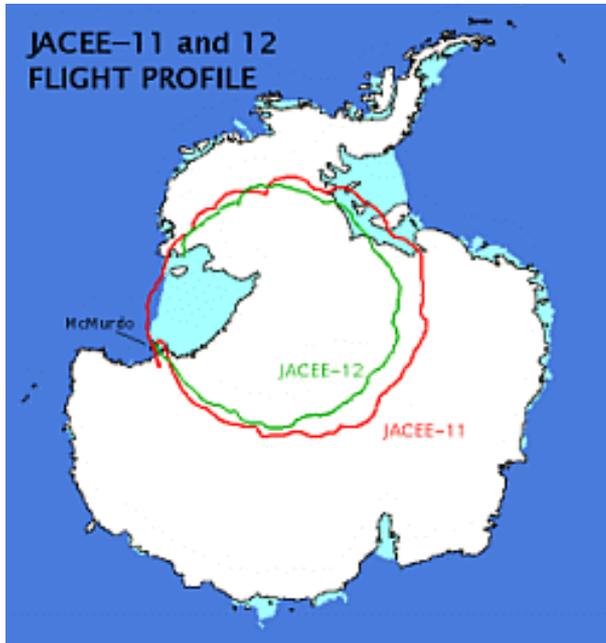
MTOF middle time of flight
(hodoscope)

ACC aerogel cerencov counter

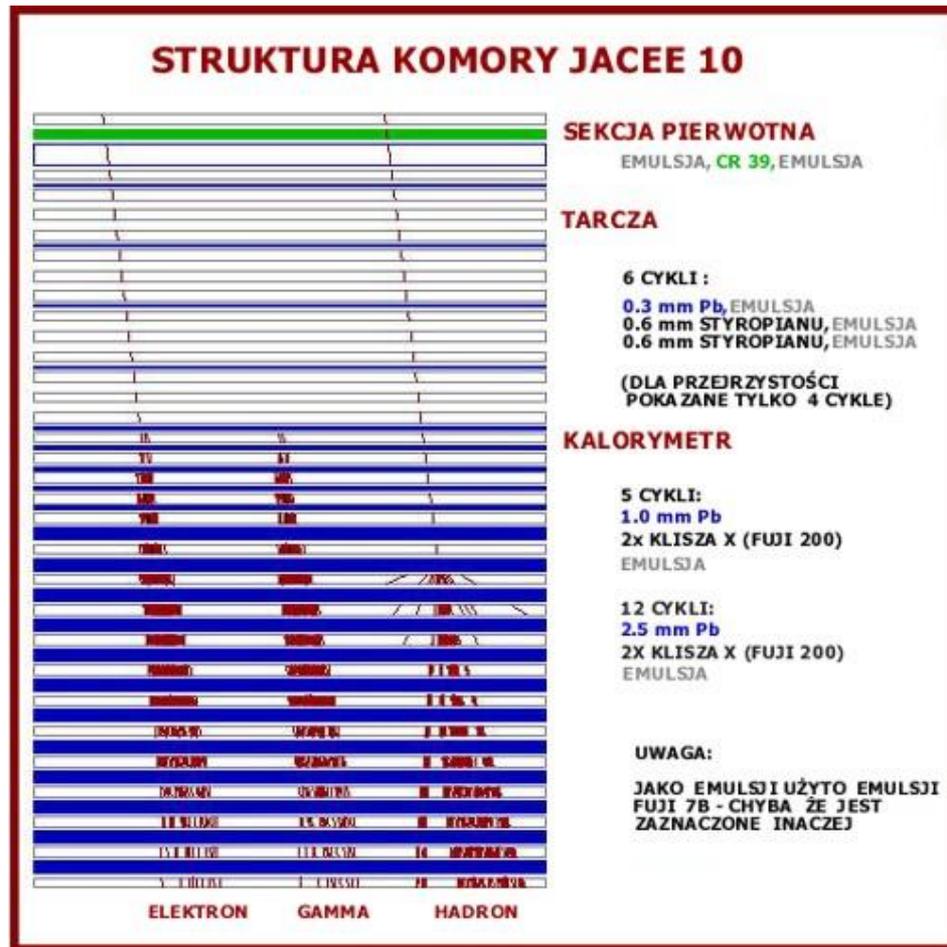
Fig. 1. Cross-sectional view of the BESS-Polar spectrometer.

Ανιχνευτές σε αερόστατα και δορυφόρους

Πείραμα JACEE



Jacee



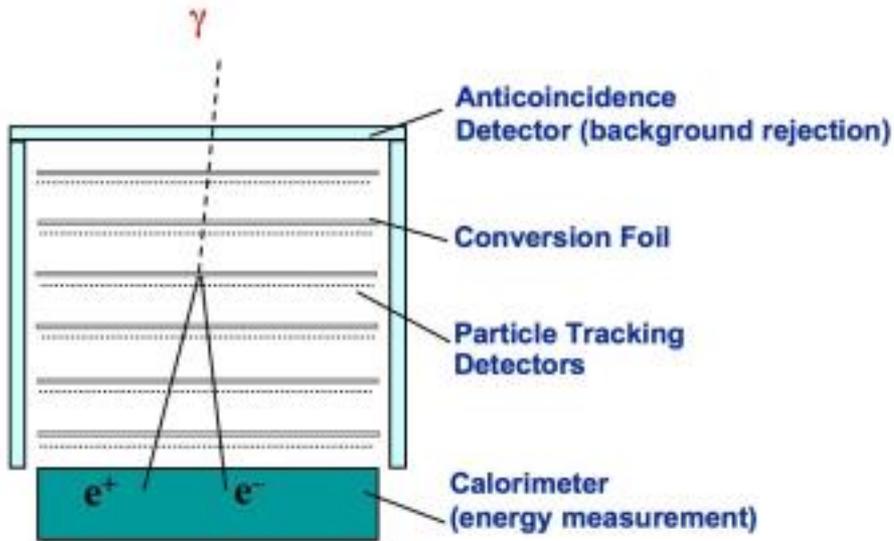
Ανιχνευτής
τροχιάς.

Καλορίμετρο.

Ένα είδος καλορίμετρου, που ανάμεσα στις πλάκες μολύβδου τοποθετείται φιλμ ακτίνων X. Από τον ιονισμό στο φιλμ προσδιορίζουν το είδος του πυρήνα. Από το προφίλ του καταιονισμού που δημιουργούνται, υπολογίζουν την ενέργεια του σωματιδίου. Έχει μετρήσει ενέργεια πύρήνων μέχρι 100 TeV.

Δορυφορικά Πειράματα

Ανιχνευτής ακτίνων γάμμα GLAST



Διαδοχικά επίπεδα silicon strip μετρούν τη θέση των φορτισμένων σωματιδίων ανιχνευτής CsI, μετρά την ολική ενέργεια του φωτονίου.



PAMELA

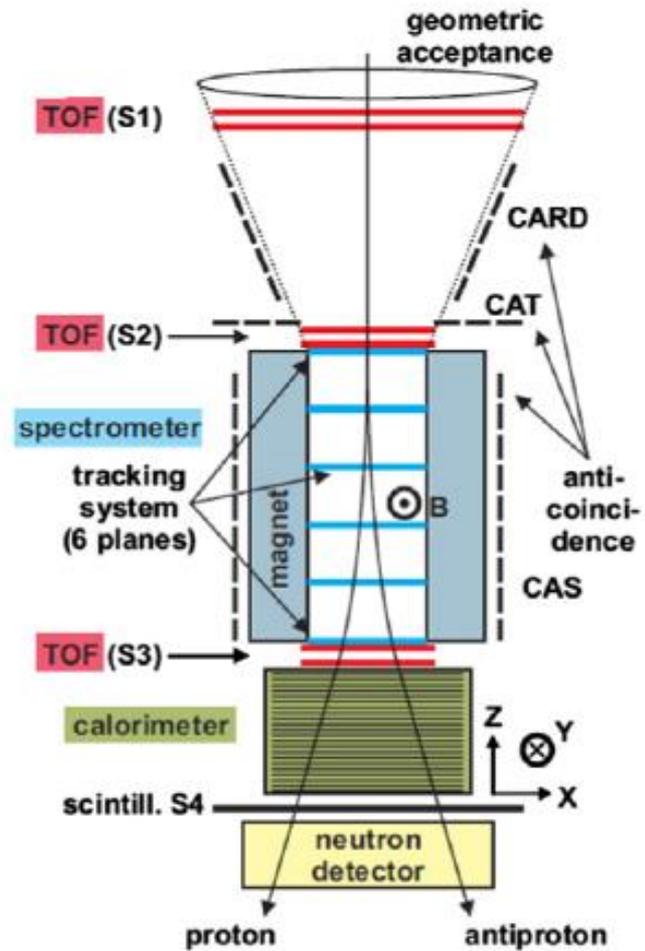
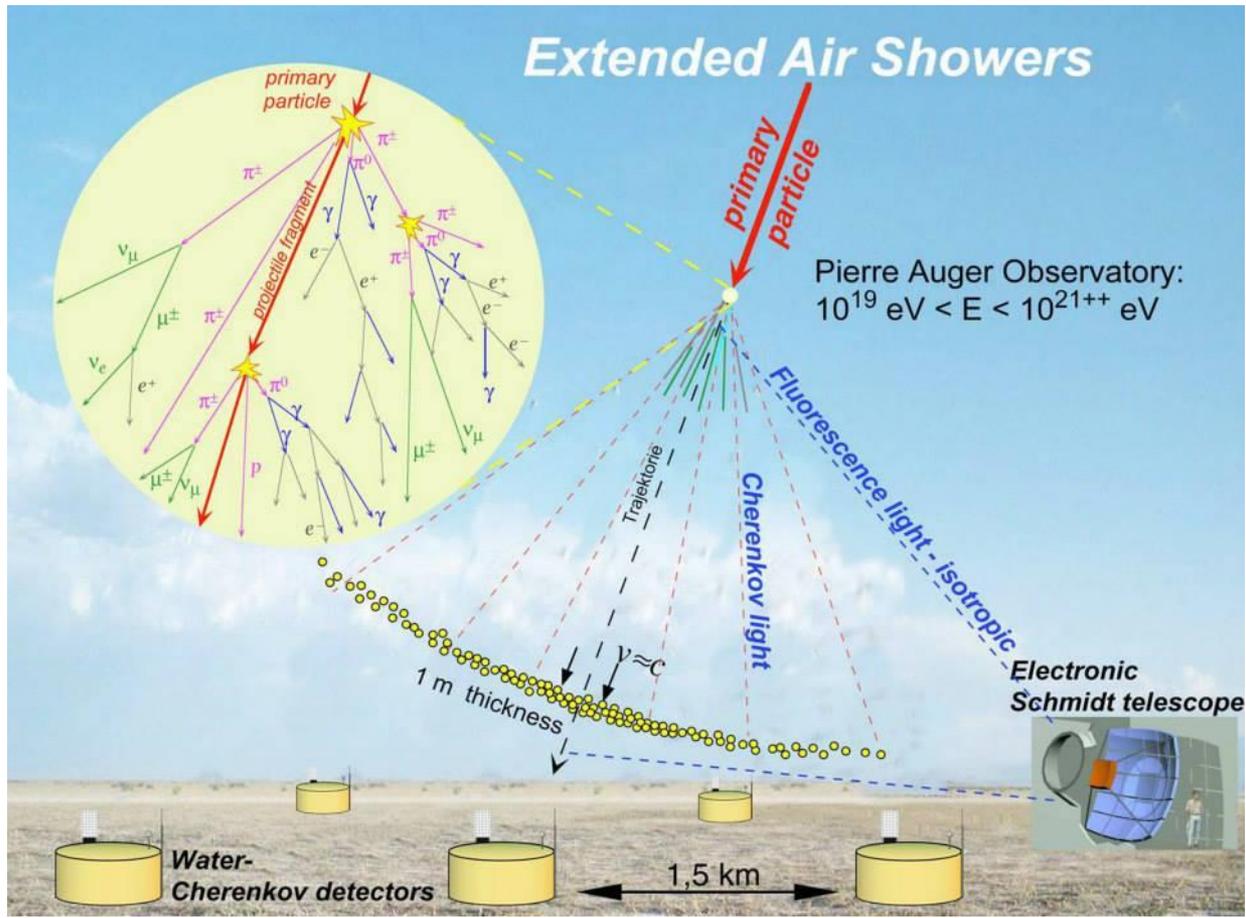


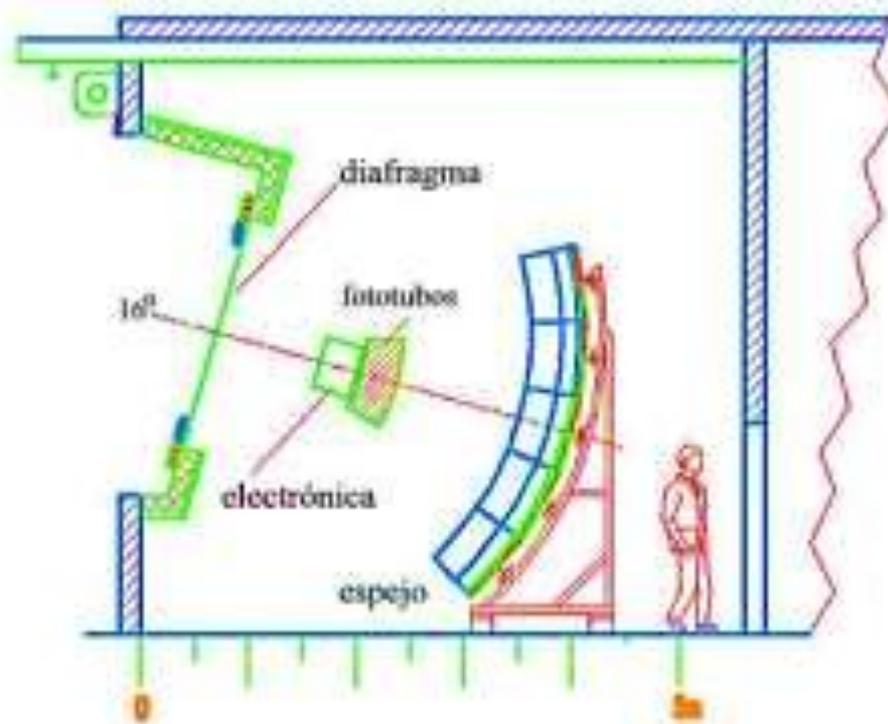
Fig. 1. A sketch of the PAMELA telescope. The method of discrimination between particle and antiparticle with the magnetic spectrometer is illustrated. The main direction of the magnetic field B inside the spectrometer is also shown.

The PAMELA apparatus, shown in Fig. 1, is composed of several sub-detectors: TOF system, anticoincidence system (CARD, CAS, CAT), magnetic spectrometer with microstrip silicon tracking system, W/Si electromagnetic imaging calorimeter, shower-tail-catcher scintillator (S4) and neutron detector.

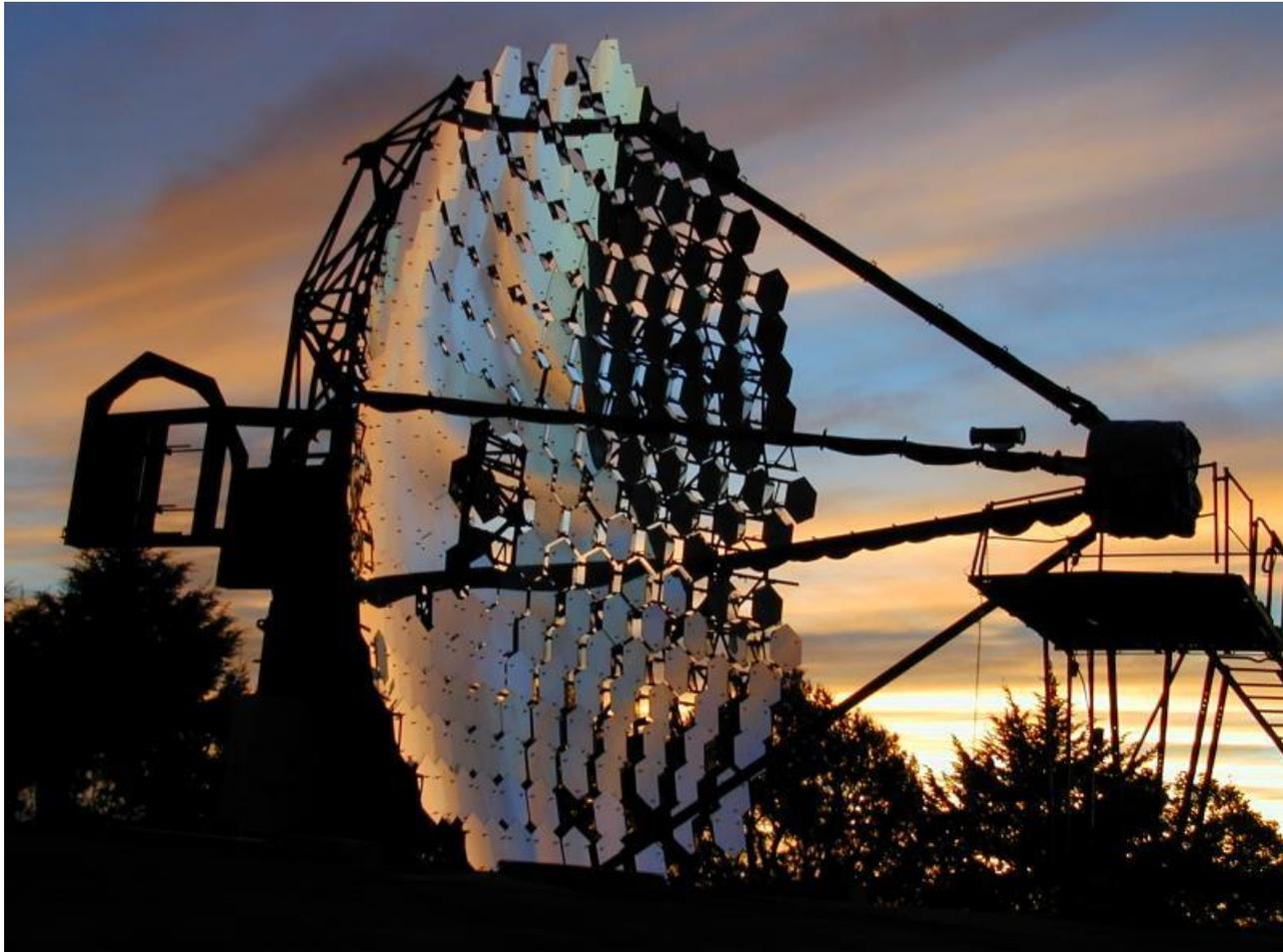
Πειράματα Καταιονισμών Υψηλής Ενέργειας



Auger unit



Καταιονισμοί Ακτίνων γ Υψηλής Ενέργειας

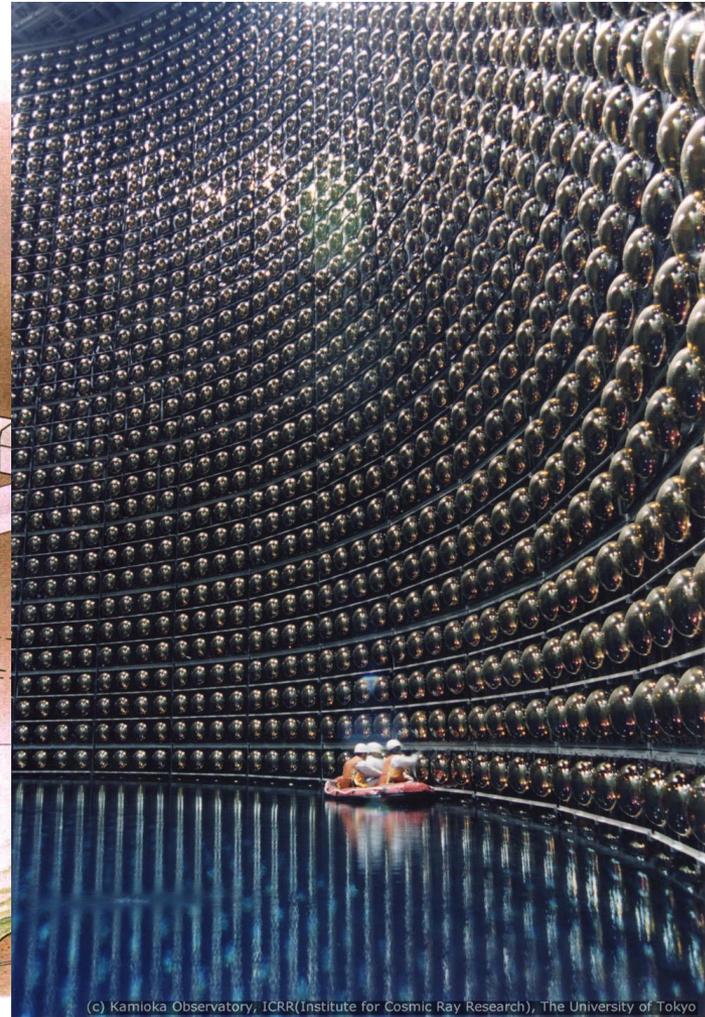
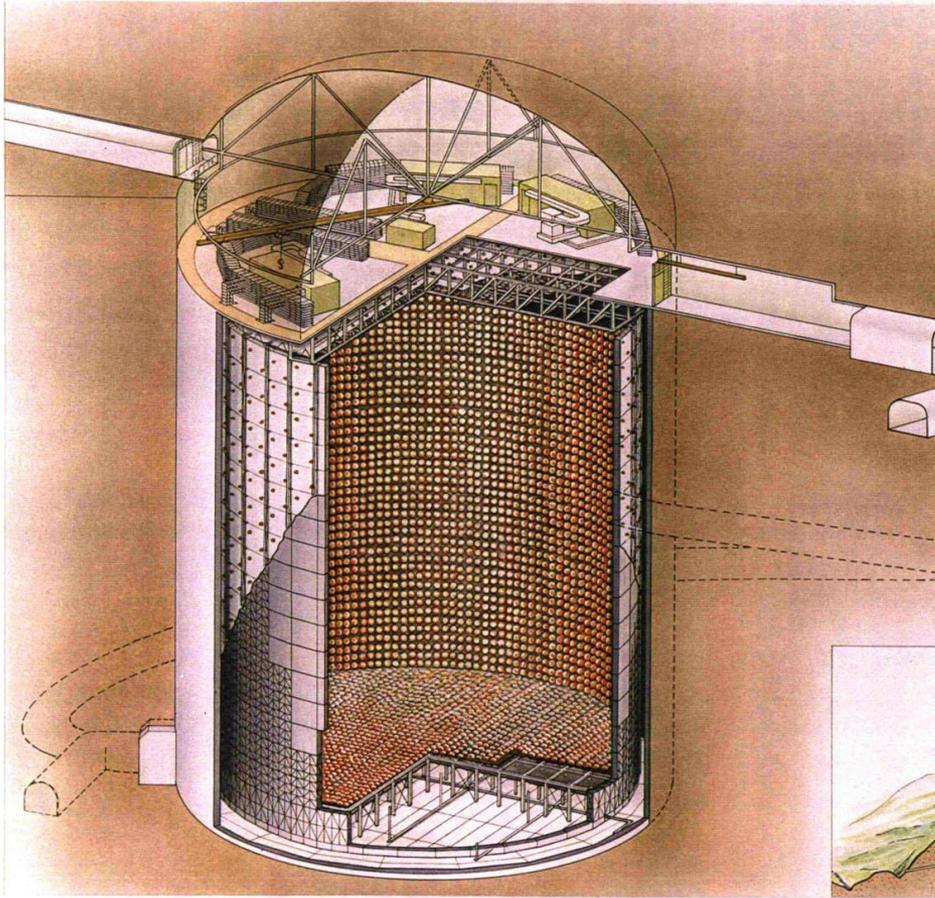


VERITAS



Πειράματα Νετρίνων

SUPER KAMIOKANDE



(c) Kamioka Observatory, ICRR(Institute for Cosmic Ray Research), The University of Tokyo

ICE CUBE

