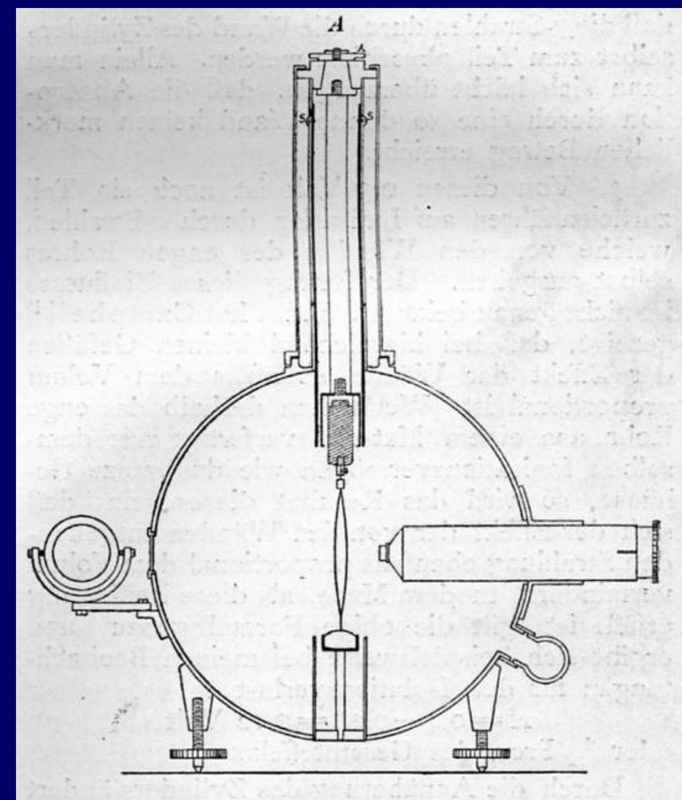
Colloque “Victor Hess: Rayons cosmiques, 100 ans d’une réalité insoupçonnée”
Collège de France, 26 juin 2012

Des électromètres aux émulsions nucléaires

Au cœur du *premier âge d’or* de la recherche sur les rayons cosmiques

Sofia Talas
Musée d’Histoire de la Physique, Université de Padoue, Italie

Electromètres à feuilles métalliques



"… appareils pour radiation de Wulf..."
(Victor F. Hess, 1912)

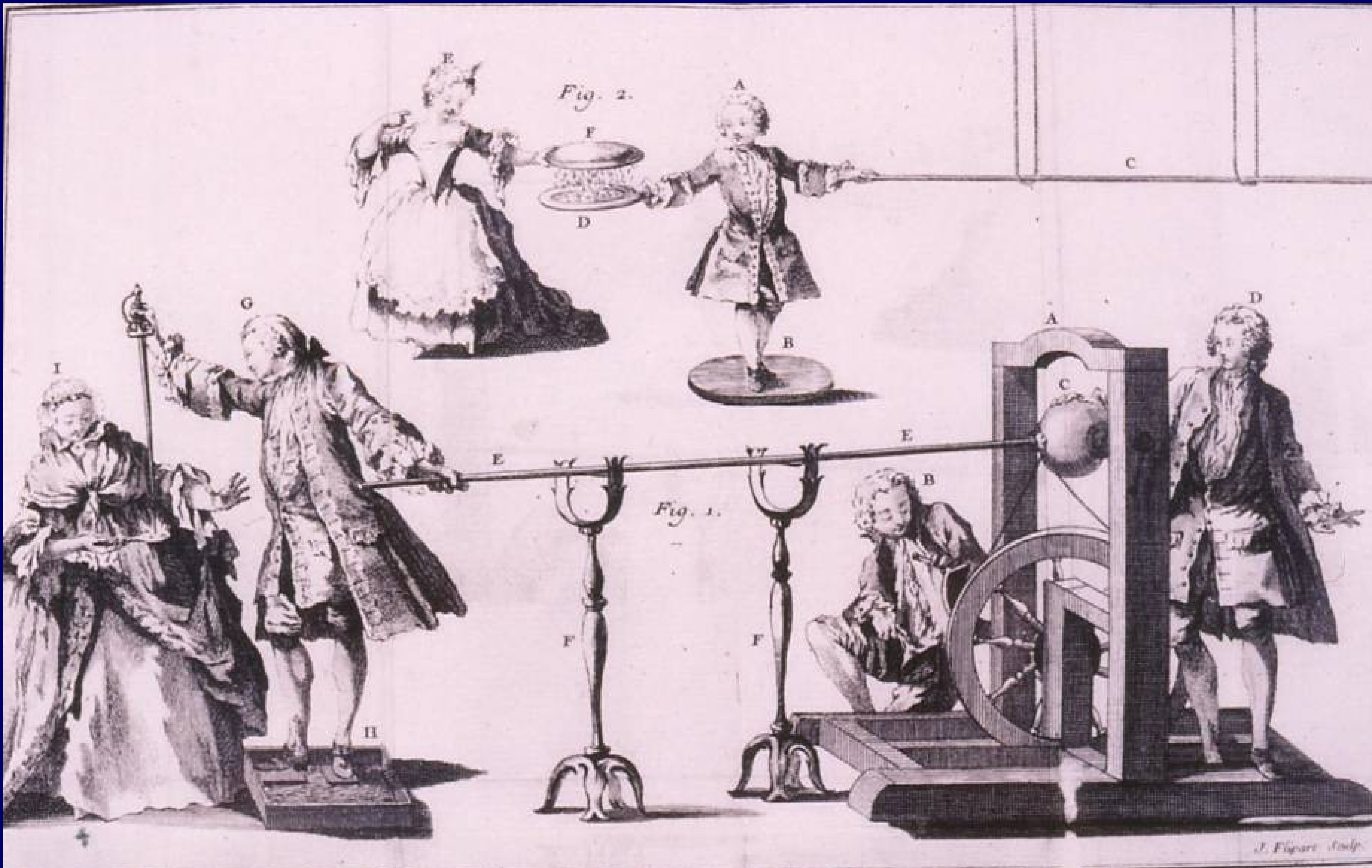


Fig. 2.
Fig. 1.
E
F
D
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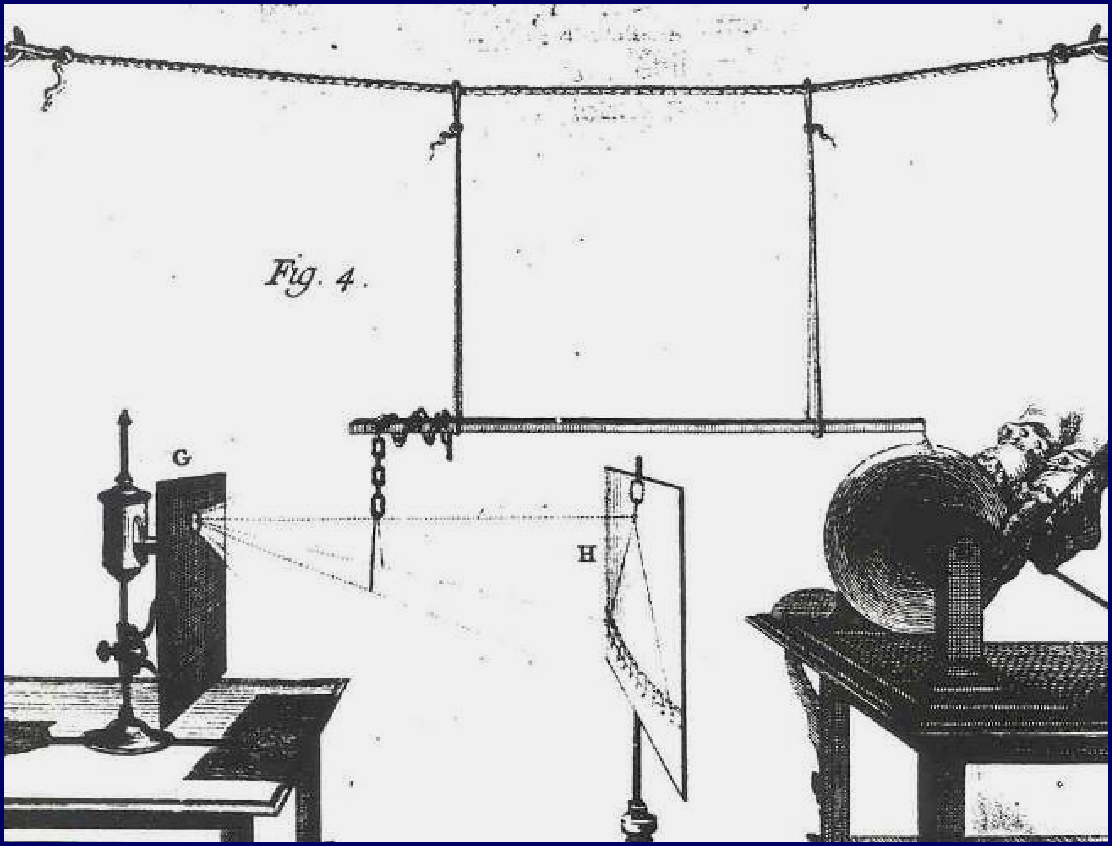
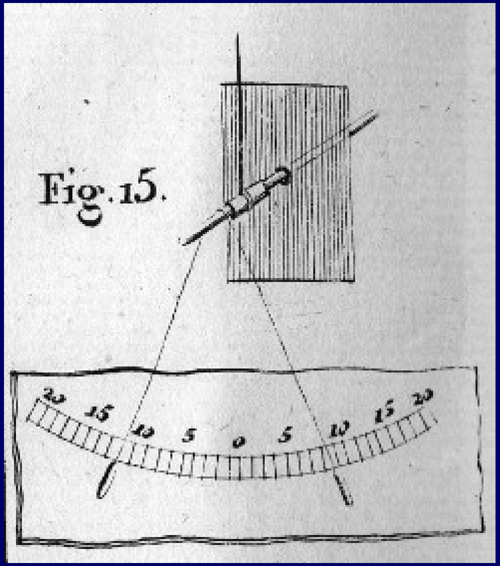
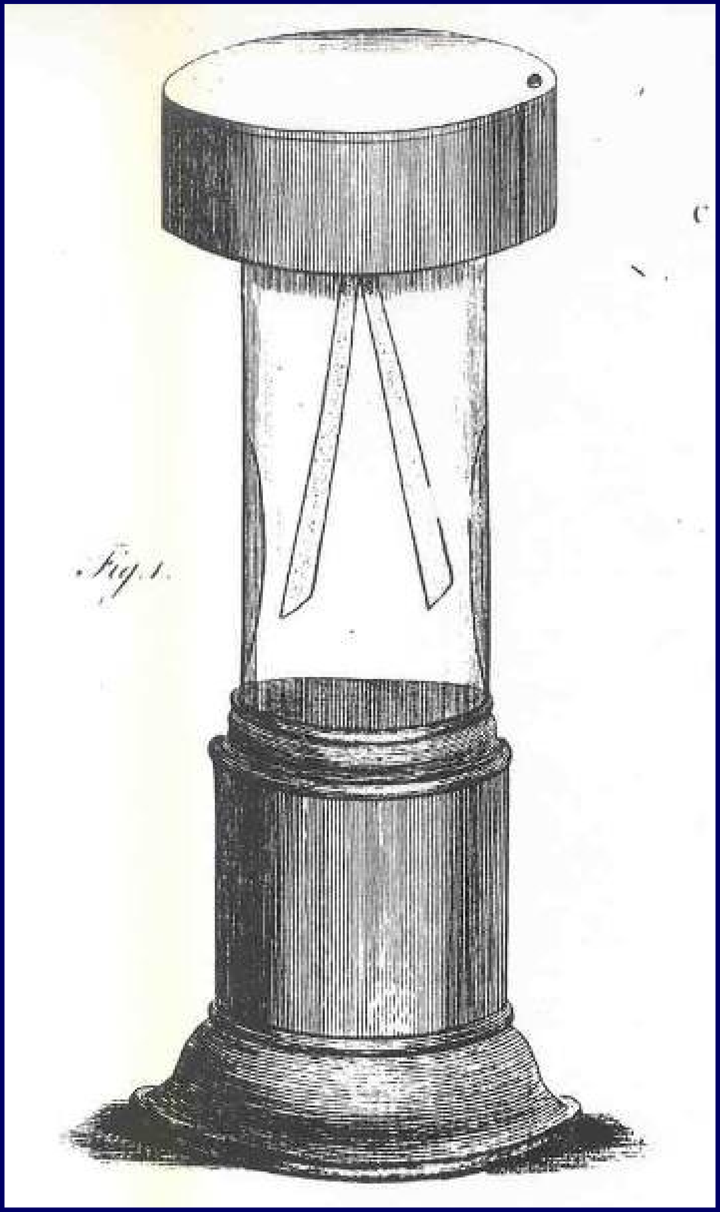
J. Flipart Sculp.

L'électroscope de Jean Antoine Nollet,1747

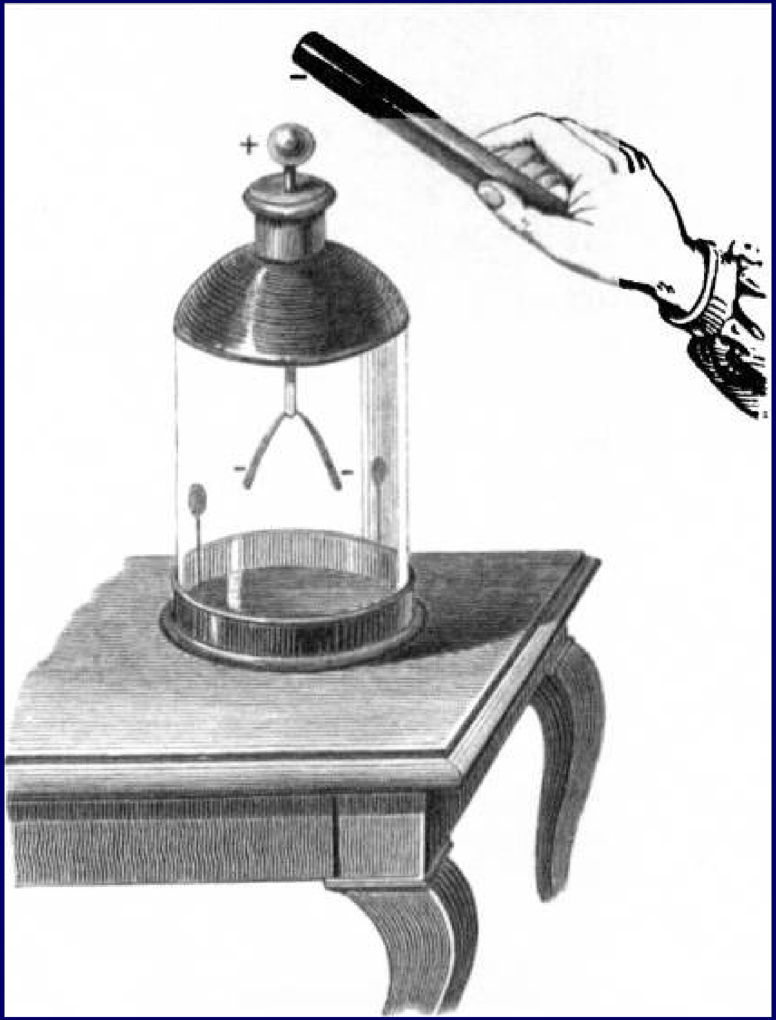




"je me suis servi, pour connoître les progrès de l'électricité, d'un moyen assez simple…"
(Jean-Antoine Nollet, 1747)

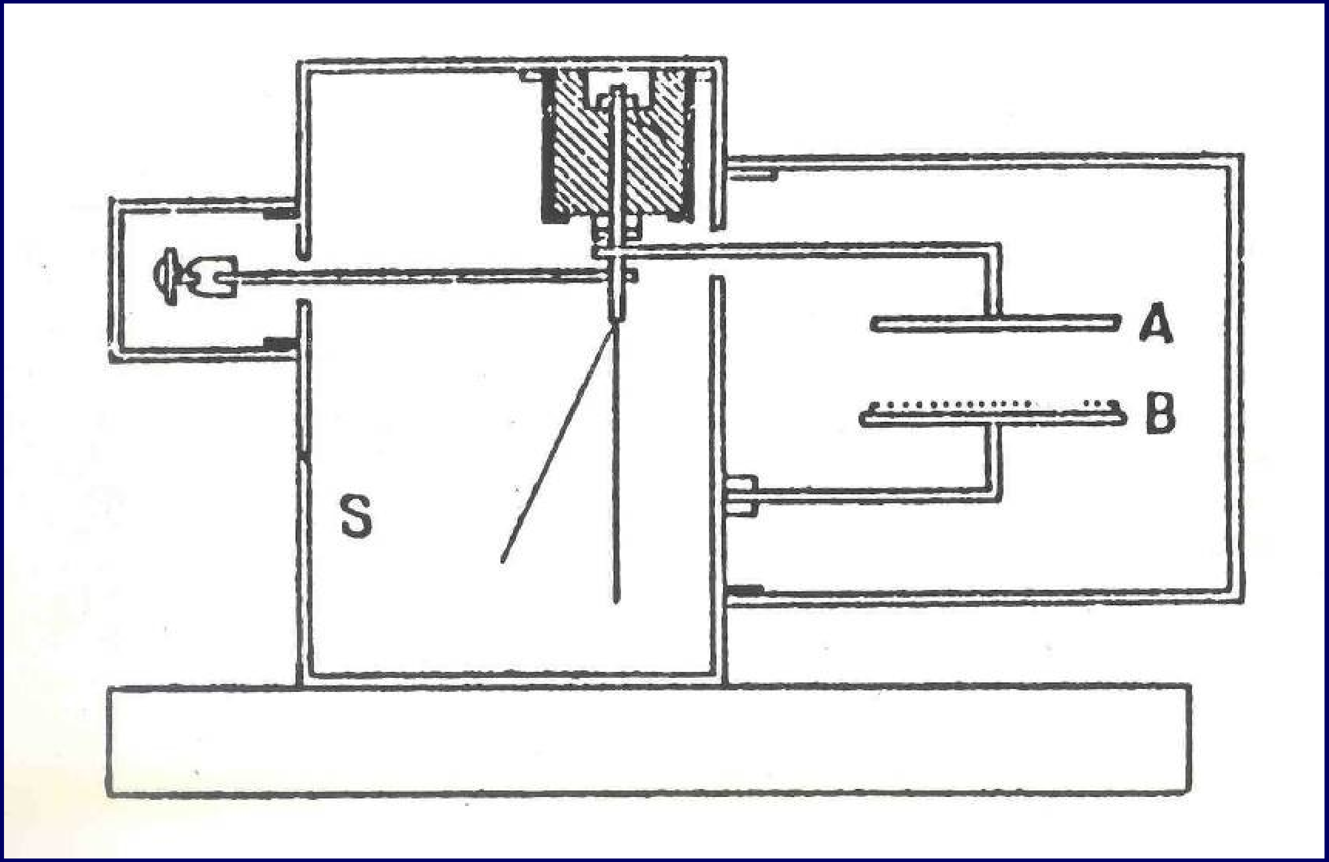


L’électromètre à feuilles d’or
d’Abraham Bennett, 1787



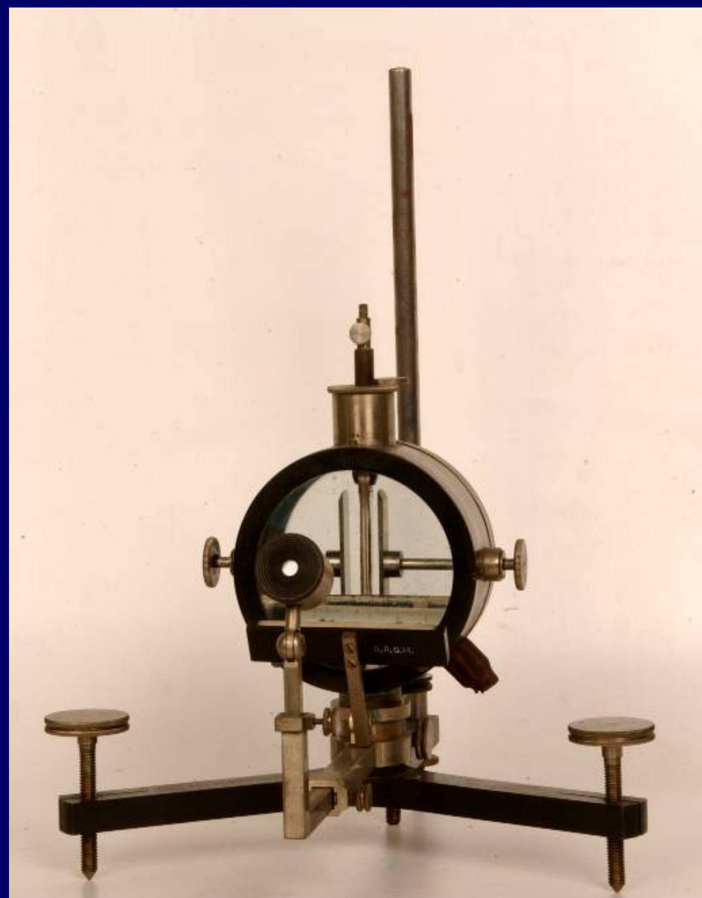
Adolphe Ganot, *Cours de Physique purement expérimentale*, Paris 1859

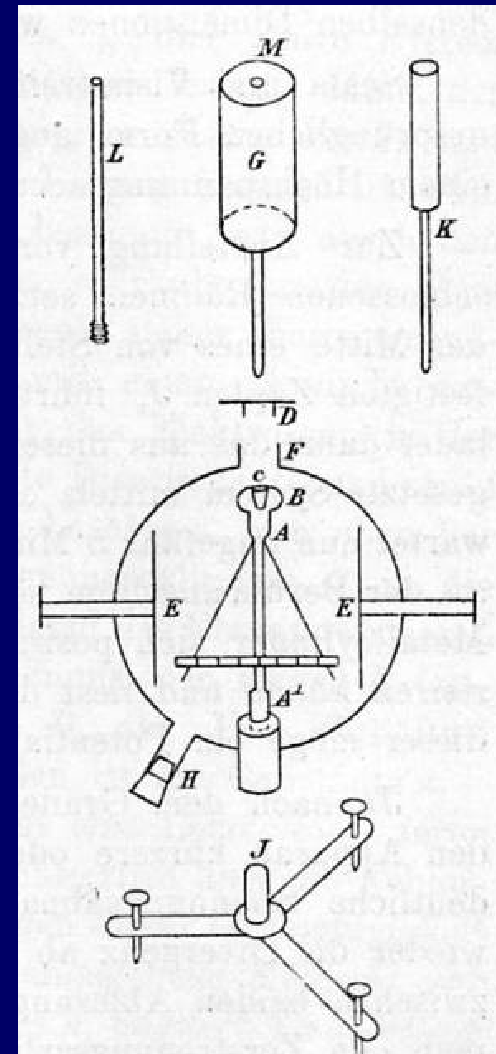
L'électromètre de Pierre Curie



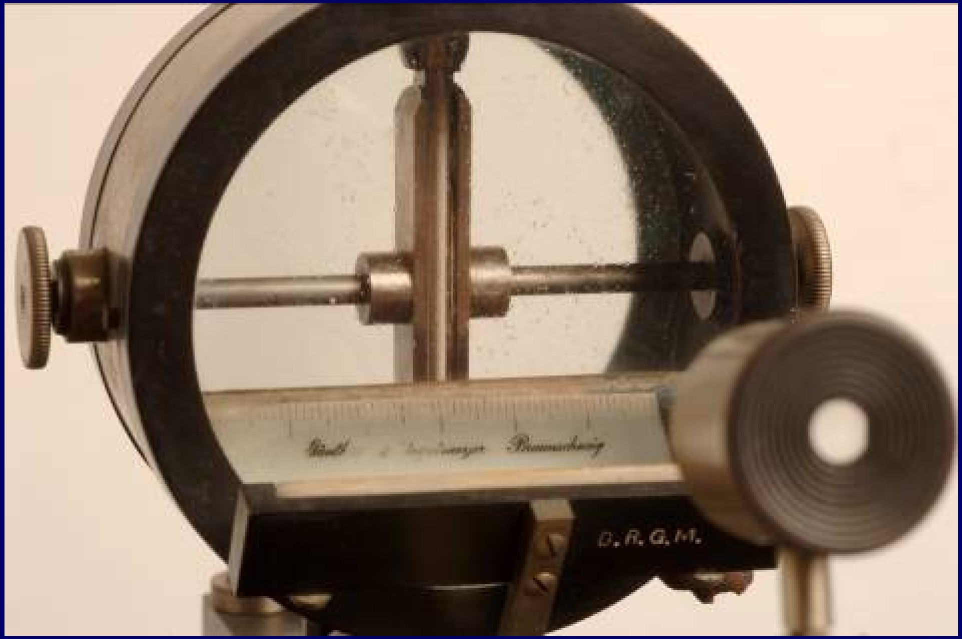
Marie Curie, *Traité de radioactivité*, Paris 1910

L'électromètre de Julius Elster et Hans Geitel





J. Elster et H. Geitel, *Annalen der Physik,* 1900

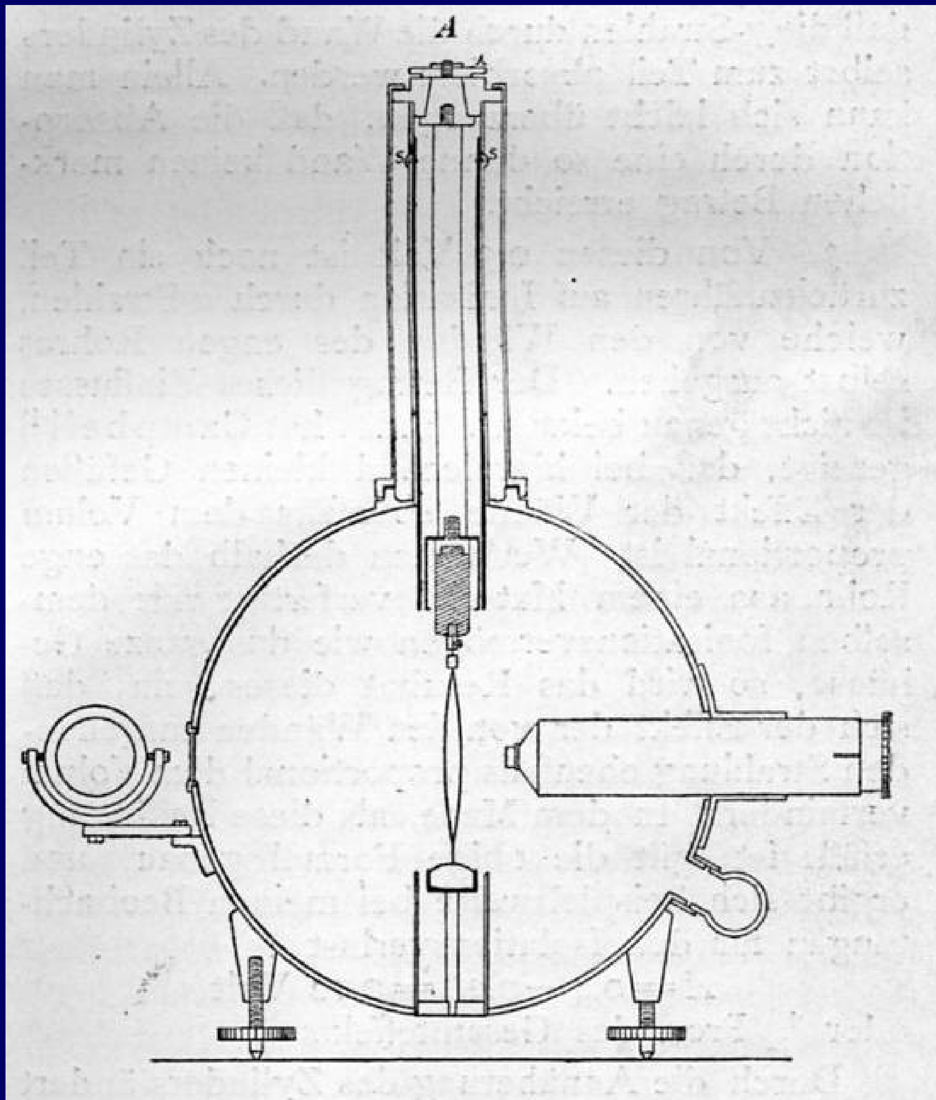


Electromètres de Elster-Geitel et de Exner, signés “Günther & Tegetmeyer Braunschweig”

Piles sèches

Modèle de Dolezalek et Nernst, 1896

Modèle de Giuseppe Zamboni 1812

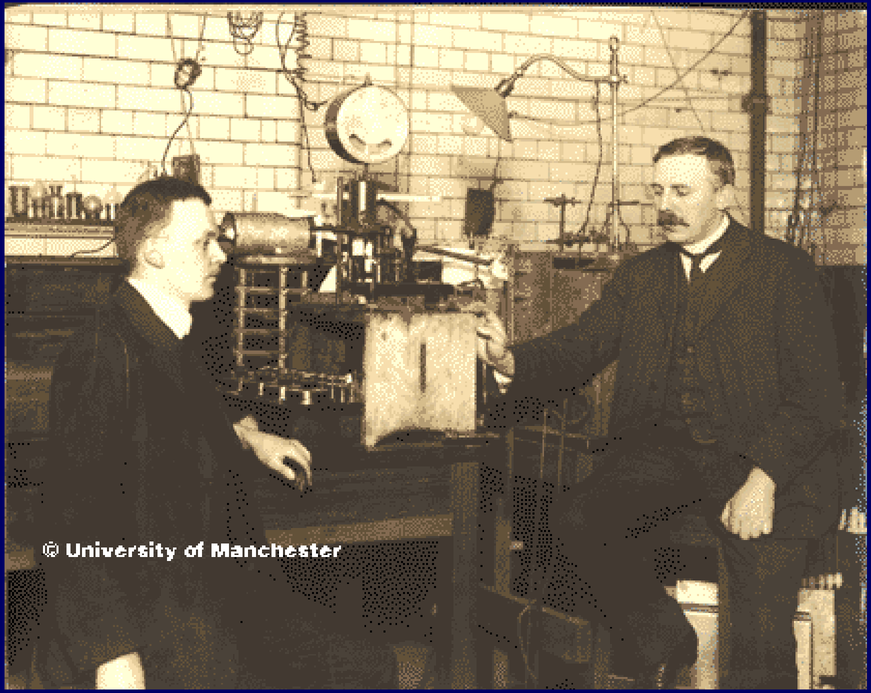


L'électromètre de

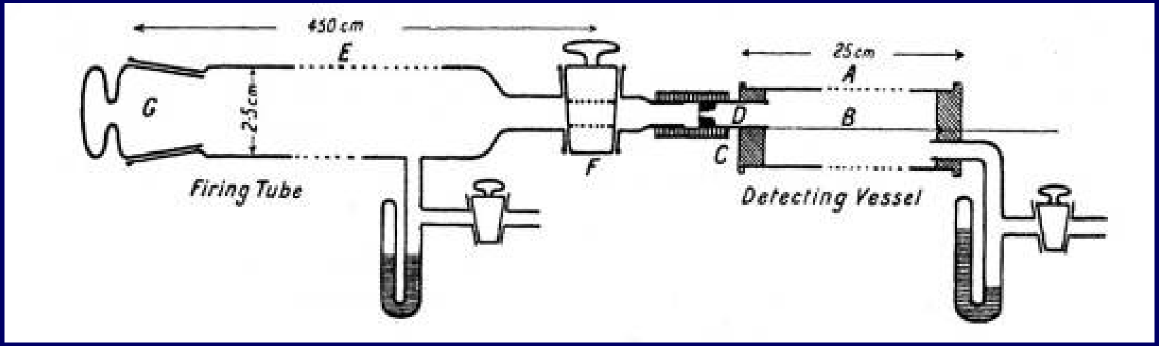
Theodor Wulf, 1909

Th. Wulf, "Über die in der Atmosphäre vorhandene Strahlung von hoher Durchdringungsfähigkeit", *Physikalische Zeitschrift*, 1909.

Compteurs Geiger-Müller

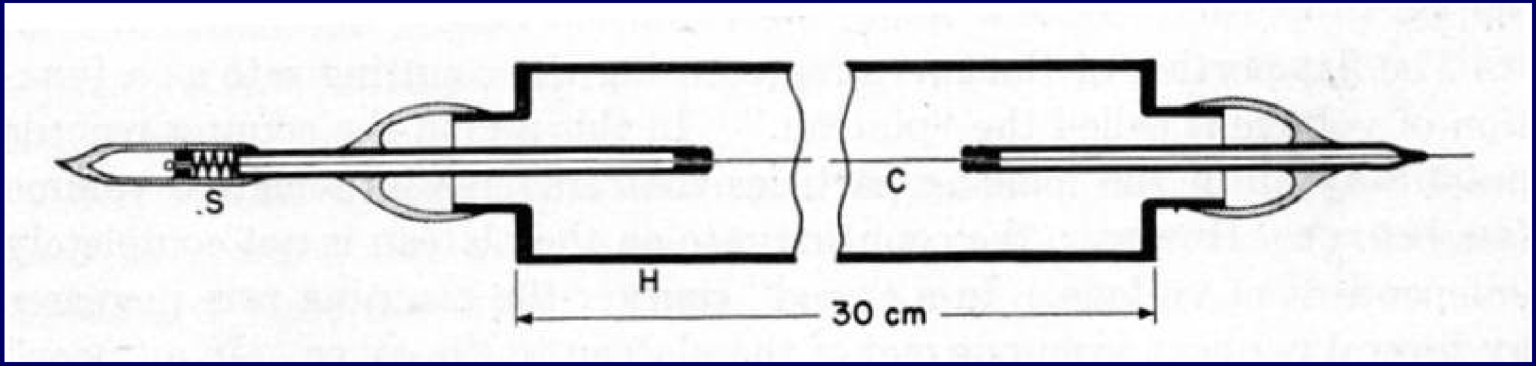


Ernest Rutherford et Hans Geiger, 1908

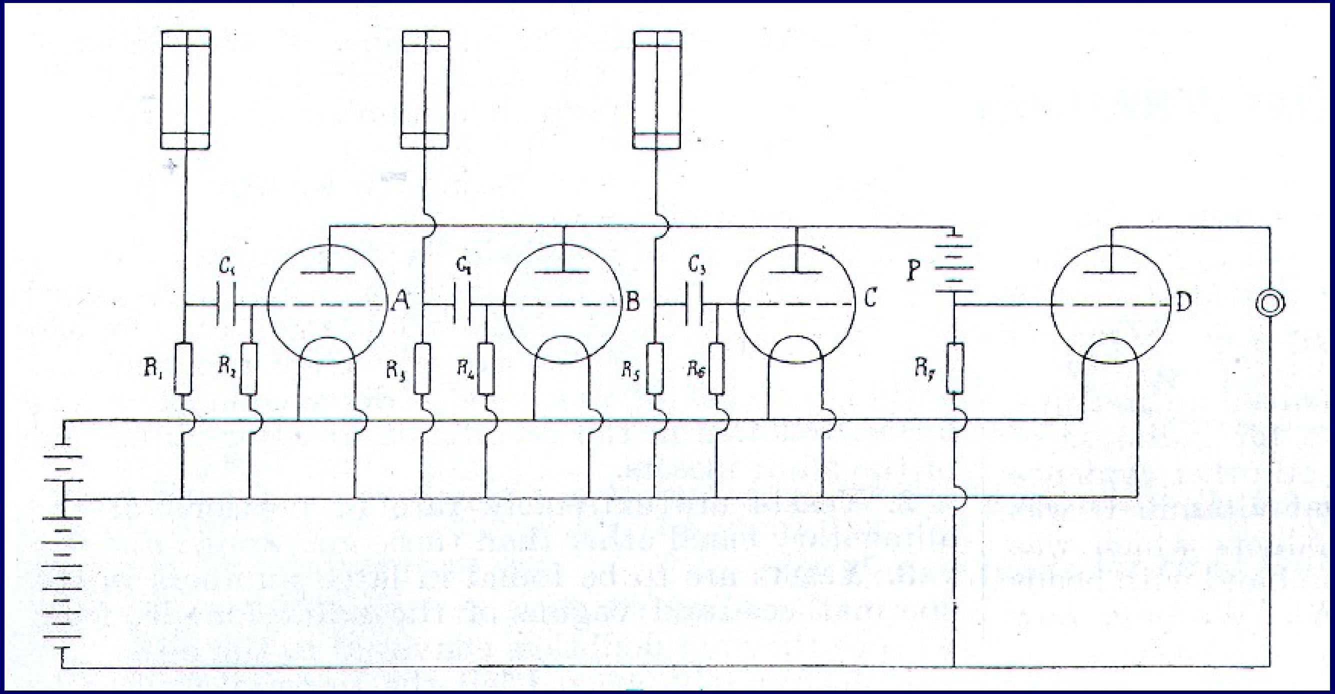


E. Rutherford and H. Geiger, "An Electrical Method of Counting the Number of α-Particles from Radio-active Substances", *Proc. R. Soc. London,* 1908.

Hans Geiger et Walther Muller, 1928



Circuit à coïncidences de Bruno Rossi, 1930



B. Rossi, "Method of Registering Multiple Simultaneous Impulses of Several Geiger's Counters", *Nature* **125** (1930).

Dispositif alt-azimuthal utilisé par Bruno Rossi pour les mesures de distribution angulaire des rayons cosmiques, 1933-34

Etude de l'effet est-ouest

- Arthur Compton, 1933
- Thomas Johnson, 1933
- Bruno Rossi, 1934

La découverte des grandes gerbes atmosphériques

Pierre Auger – Roland Maze (1938)

	3 compteurs				4 compteurs	Δ
d	$E = 0{,}2$	5	10	15		
2 m	1,7	0,86	0,2	$<0{,}1$	0,8	40
5 m	1,4	0,7	-	-	-	-
20 m	0,9	0,4	0,1	$<0{,}1$	0,45	30

P. Auger e R. Maze, “Extension et pouvoir pénétrant des grandes gerbes de rayons cosmiques”, *Comptes Rendus Académie des Sciences,* **208** (1939)

Compteurs Geiger-Müller

REVIEWS OF MODERN PHYSICS VOLUME 21, NUMBER 1 JANUARY, 1949

Extensive and Penetrating Atmospheric Showers

R. Maze, A. Fréon, J. Daudin, and P. Auger
Ecole Normale Supérieure, Paris, France

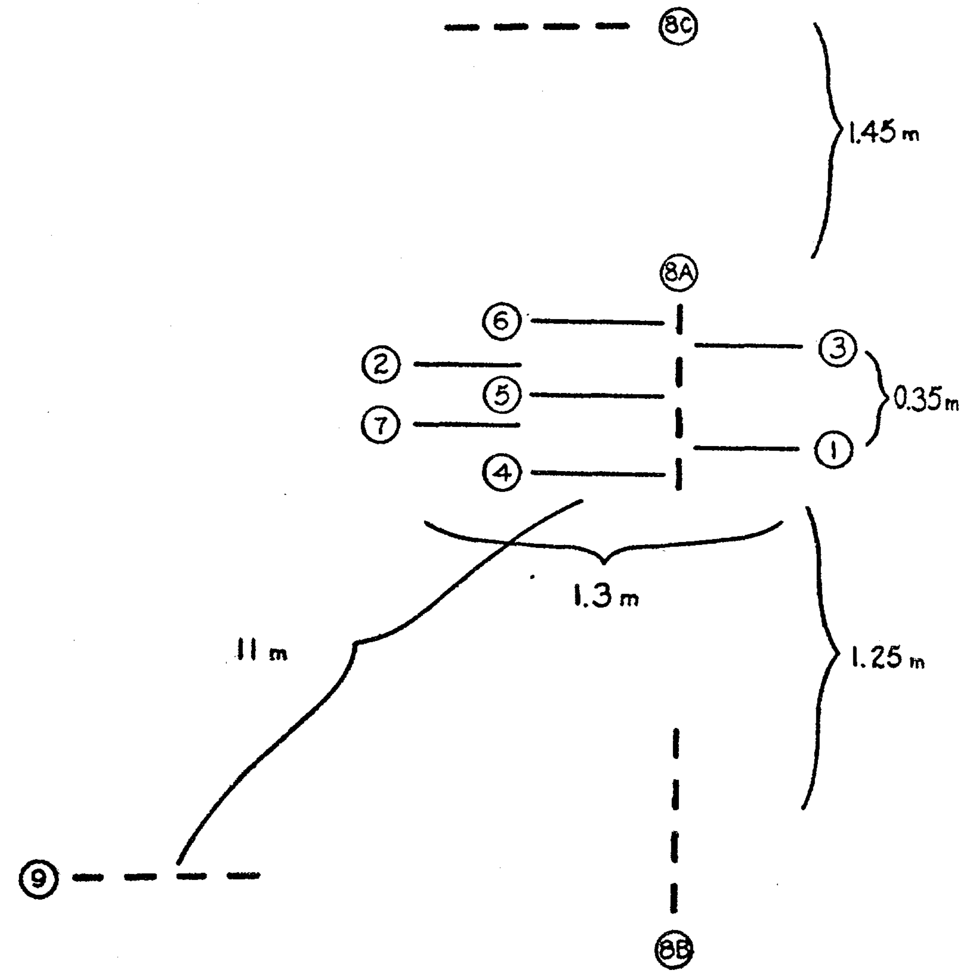


Fig. 1. Arrangement and spacing of counters.

Conversi-Pancini-Piccioni's experiment, 1945

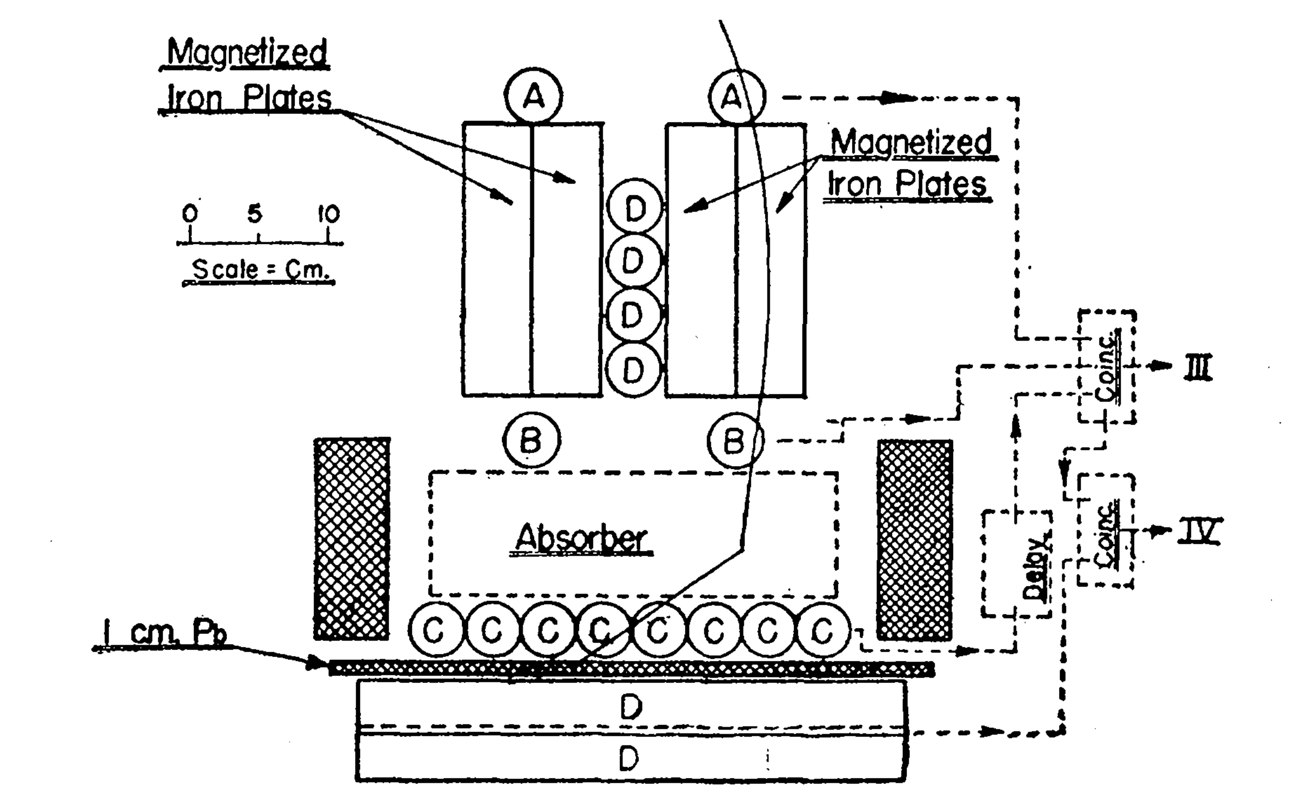


FIG. 1. Disposition of counters, absorber, and magnetized iron plates. All counters "D" are connected in parallel.

"As a personal opinion, I would suggest that modern particle physics started in the last days of WWII, when a group of young Italians, Conversi, Pancini and Piccioni, who were hiding from the German occupying forces, initiated a remarkable experiment"

Luis Alvarez, *Nobel Lecture*, décembre 1968

Chambres à brouillard

- Charles T. R. Wilson - 1897
- C.T.R. Wilson - Application pour la visualisation de particules - 1911

Chambres à brouillard

C.T.R. Wilson, “On an Expansion Apparatus for Making Visible the Tracks of Ionising Particles in Gases and Some Results Obtained by its Use”, *Proceedings of the Royal Society of London*, 1912

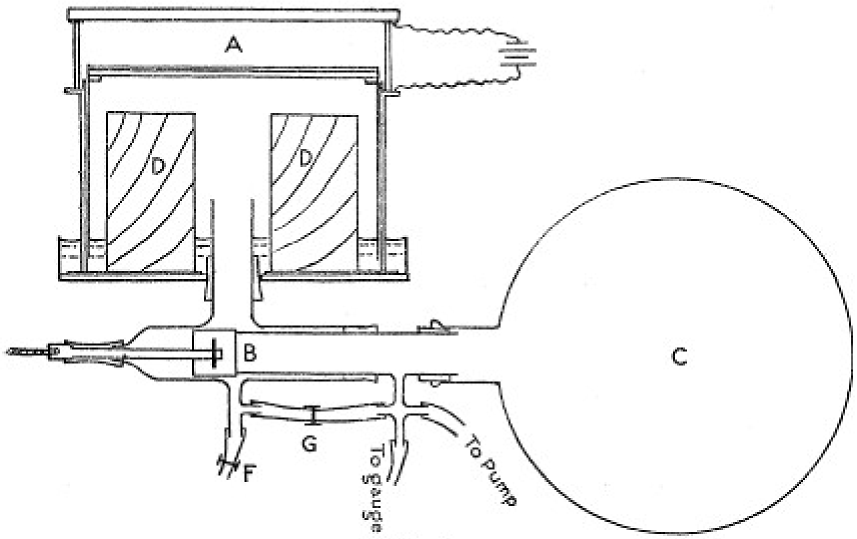
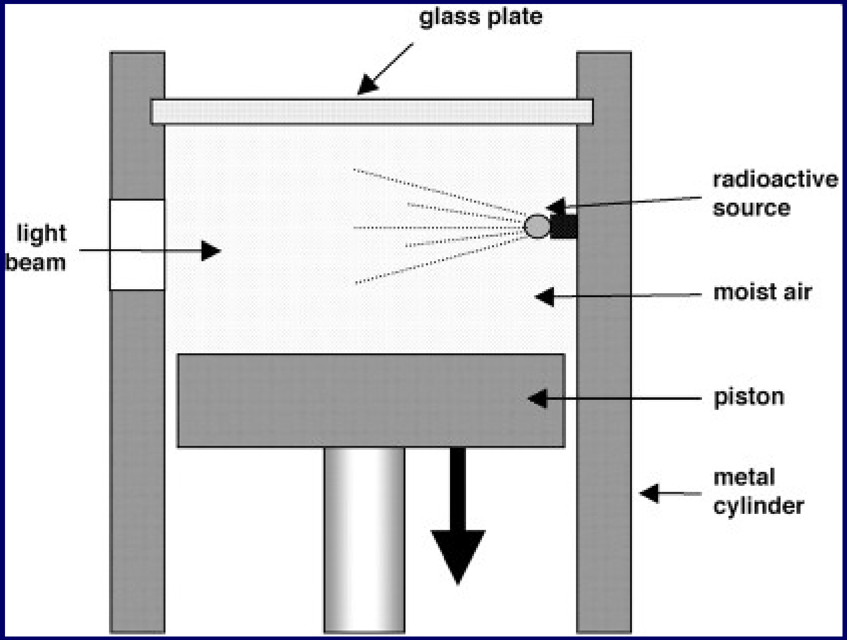
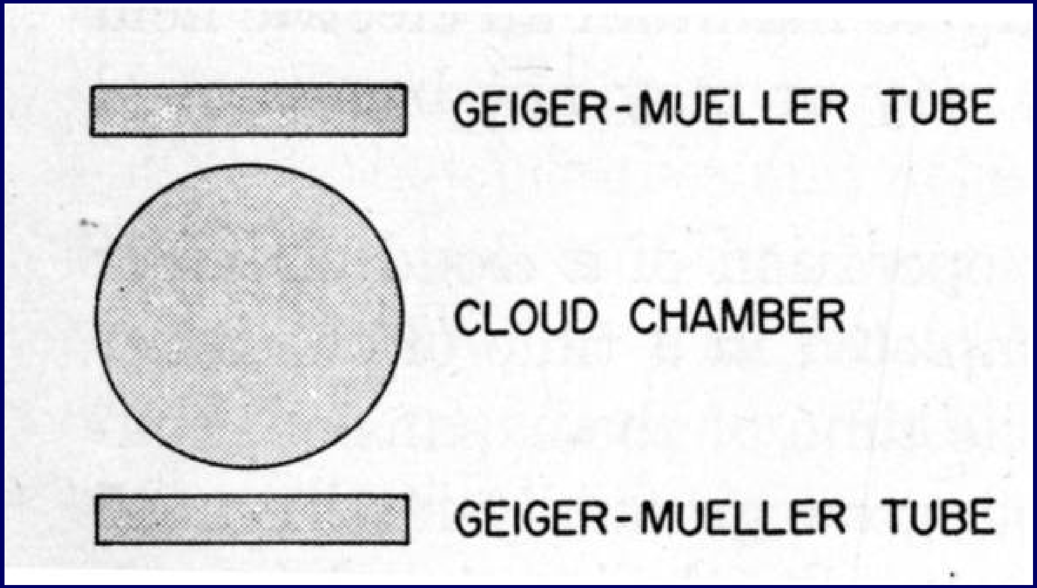


FIG. 1.

Fonctionnement



C.T.R. Wilson, “On an Expansion Apparatus for Making Visible the Tracks of Ionising Particles in Gases and Some Results Obtained by its Use”, *Proceedings of the Royal Society of London*, 1912

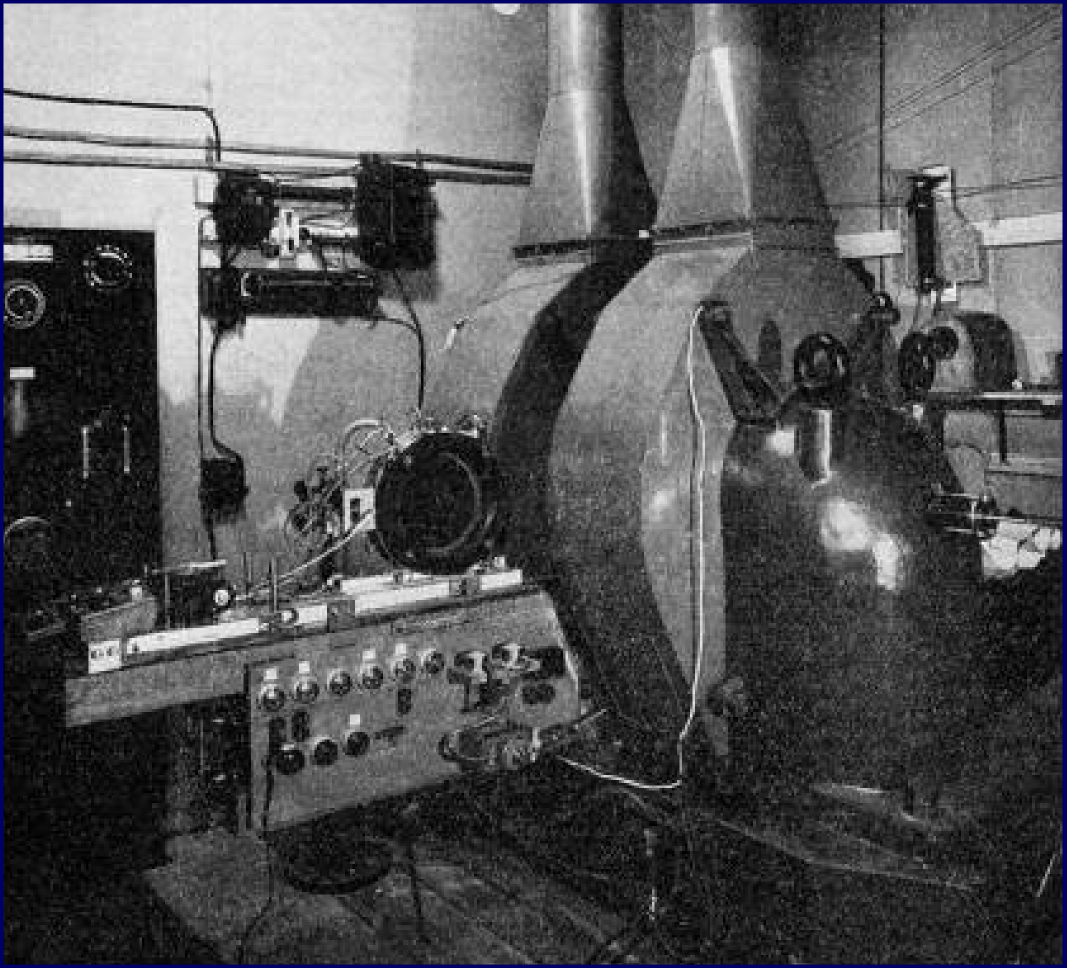


Les chambres controllées par compteurs

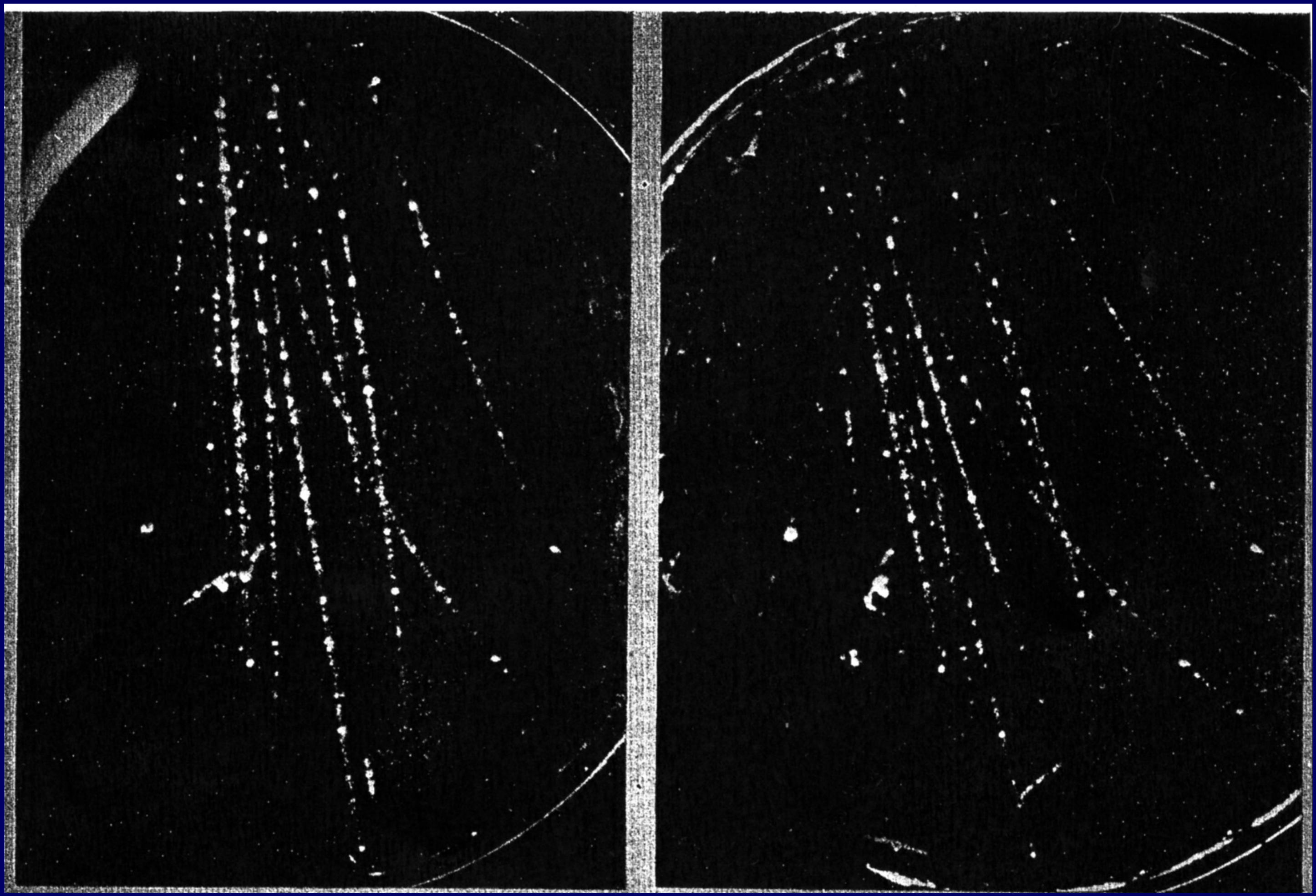
Patrick Blackett et Giuseppe Occhialini, 1933

“We have recently developed a method by which the high speed particles associated with penetrating radiation can be made to take their own cloud photographs.”

P. M. S. Blackett; G. P. S. Occhialini, “Some Photographs of the Tracks of Penetrating Radiation”, *Proceedings of the Royal Society of London.* Vol. 139 (1933)



P.M.S. Blackett, "The Measurement of the Energy of Cosmic Rays",
Proceedings of the Royal Society of London, 1936



P.M.S. Blackett, G.P.S. Occhialini, “Some Photographs of the Tracks of penetrating Radiation”, *Proceedings of the Royal Society of London*, 1933

Quelques-unes des difficultés techniques

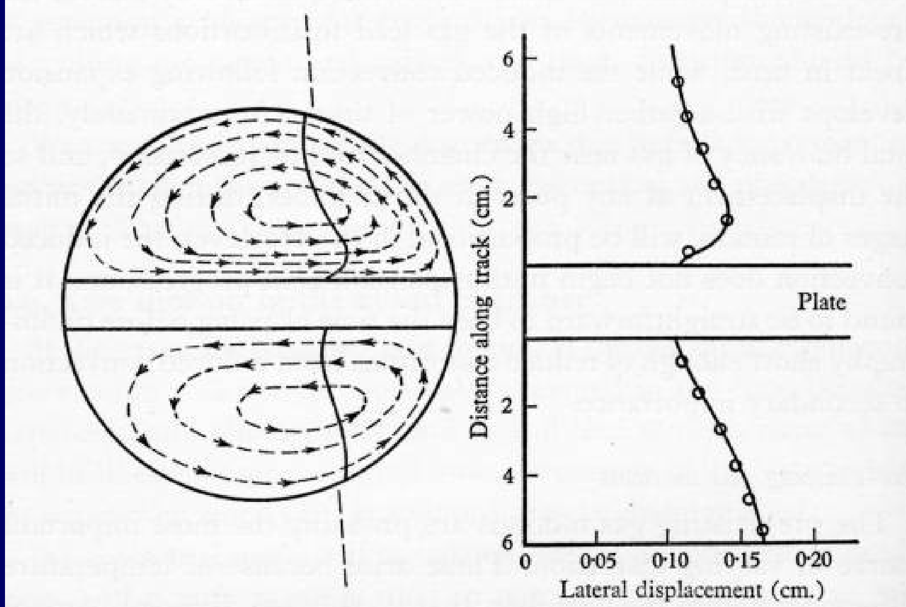


Fig. 19. Distortion of a counter-controlled cloud track by convective drift. Left, schematic; right, measurements on an actual track.

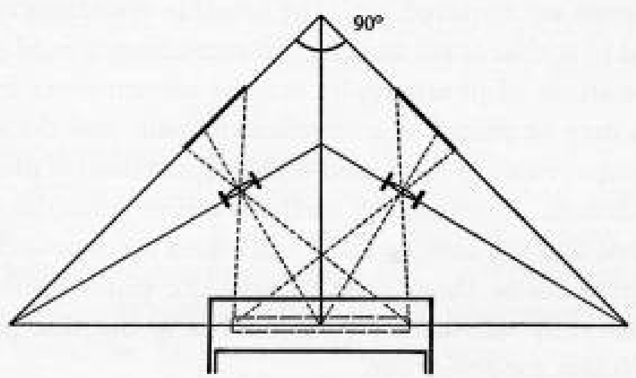
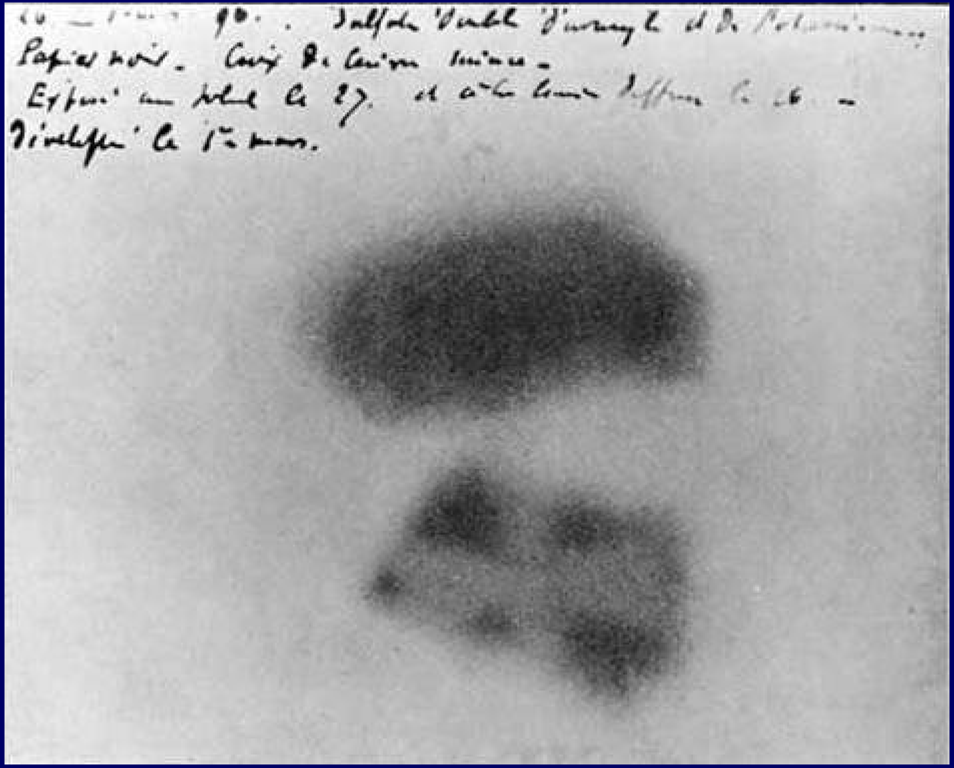


Fig. 28. Photography of tracks on planes at right angles. (Blackett.)

Emulsions photographiques

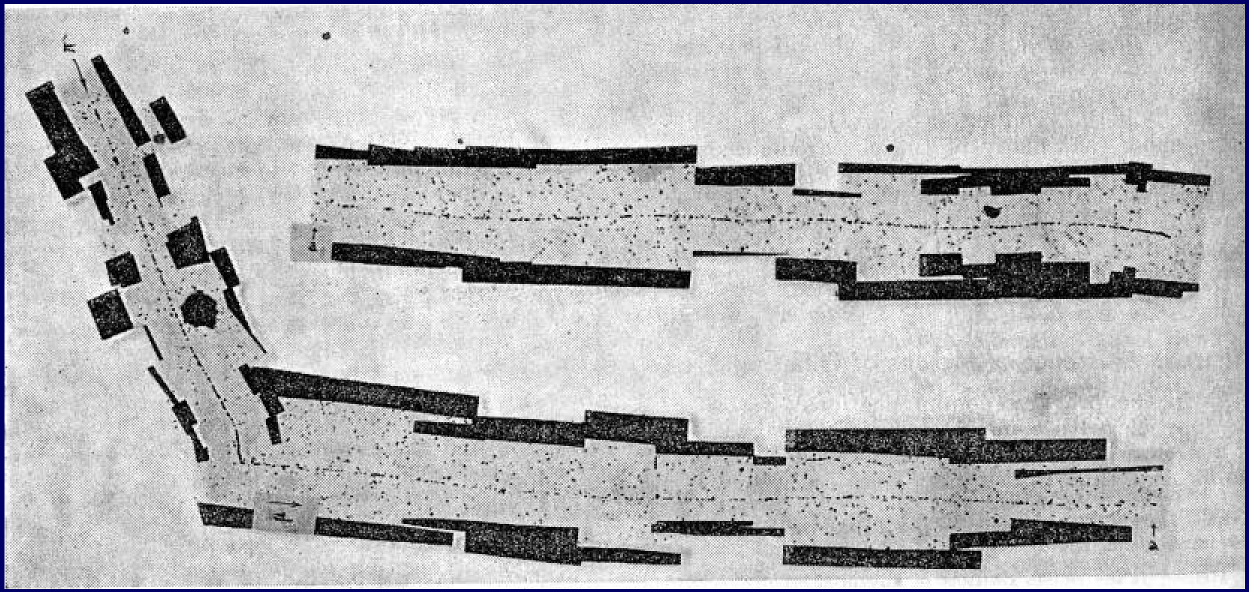


On radioactvity, a new property of matter, *Nobel Lecture*, décembre 1903

Henri Becquerel, 1896

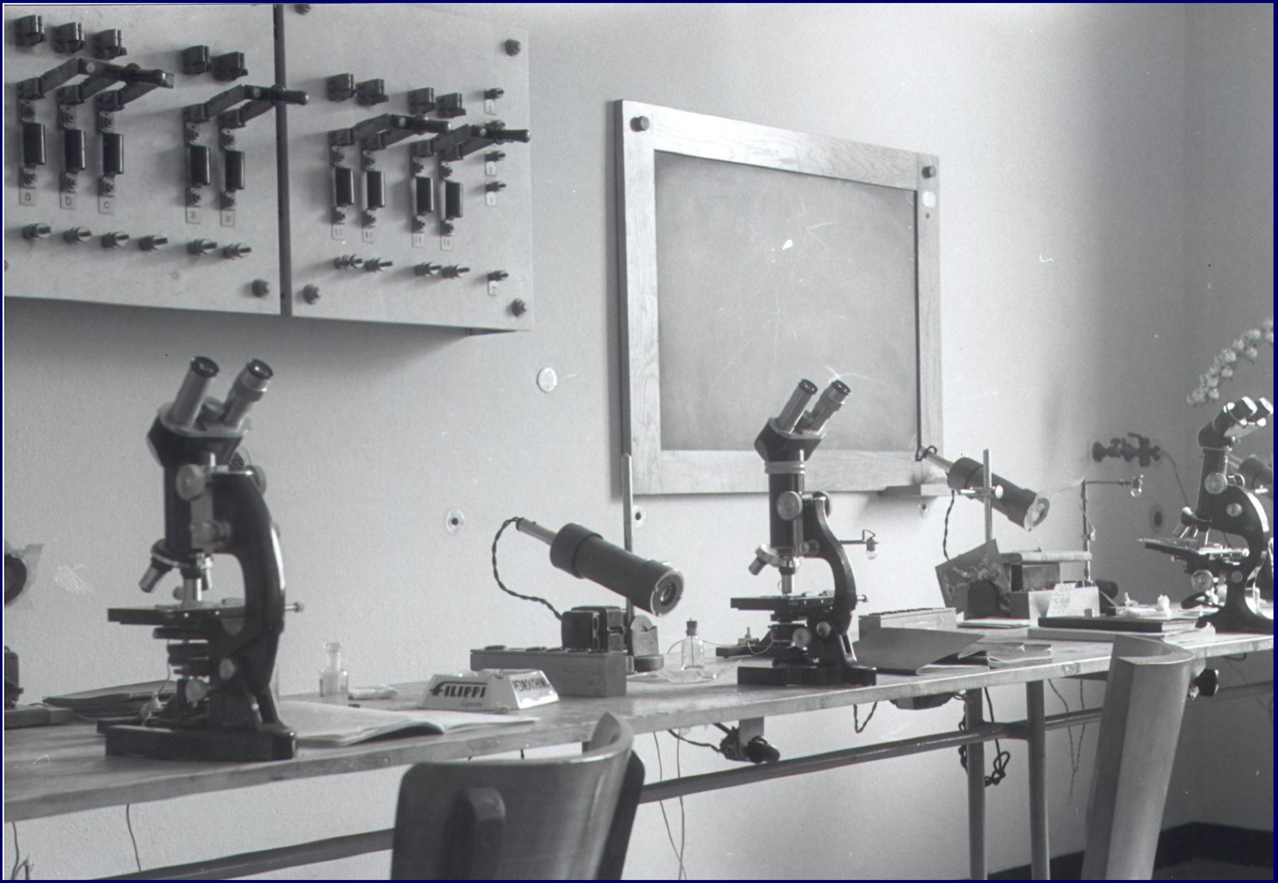
"Sur les radiations émises par phosphorescence", *Comptes Rendus de l'Académie des Sciences, vol.* 122

Les perfectionnements et les découvertes de Cecil F.Powell et de ses collaborateurs



Lattes, Occhialini, Powell, "Observations on the tracks of slow mesons in photographic emulsions", *Nature*, 1947

Microscopes utilisés pour l’analyse des émulsions photographiques,
Université de Padoue, 1953-55



Emulsions photographiques

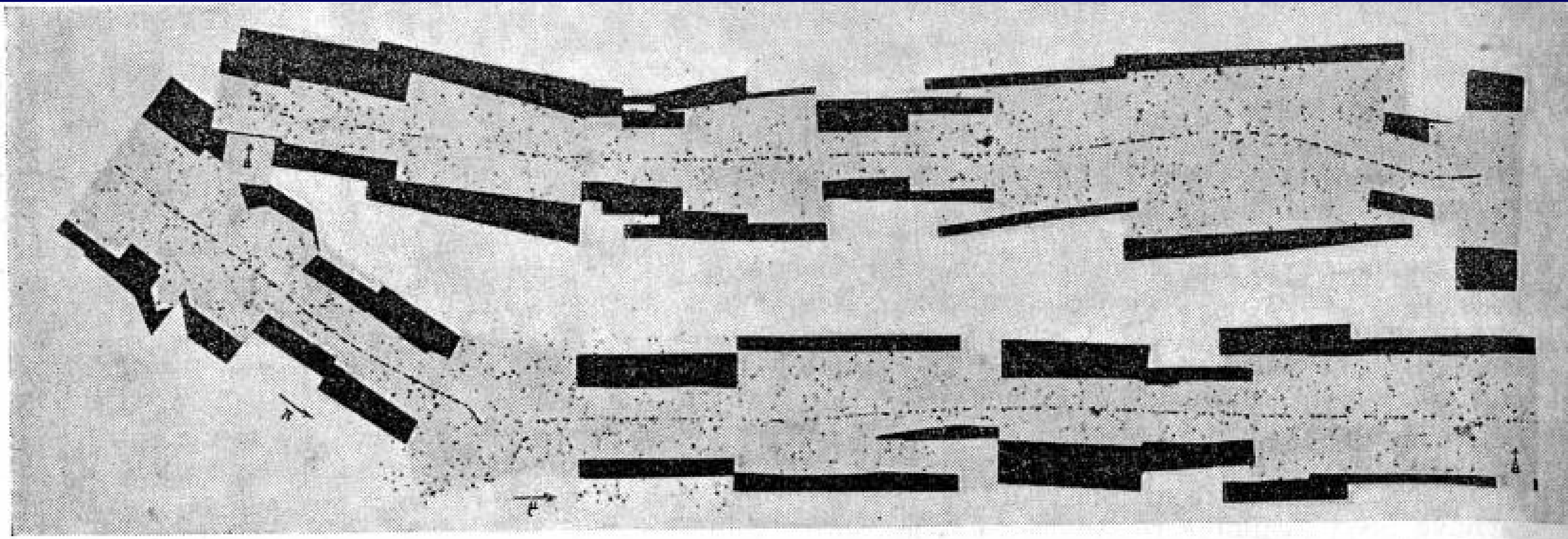


Fig. 1. OBSERVATION BY MRS. I. POWELL. COOKE × 95 ACHROMATIC OBJECTIVE; $C2$ ILFORD NUCLEAR RESEARCH EMULSION LOADED WITH BORON. THE TRACK OF THE μ-MESON IS GIVEN IN TWO PARTS, THE POINT OF JUNCTION BEING INDICATED BY a AND AN ARROW

Lattes, Occhialini, Powell, “Observations on the tracks of slow mesons in photographic emulsions”, *Nature*, 1947

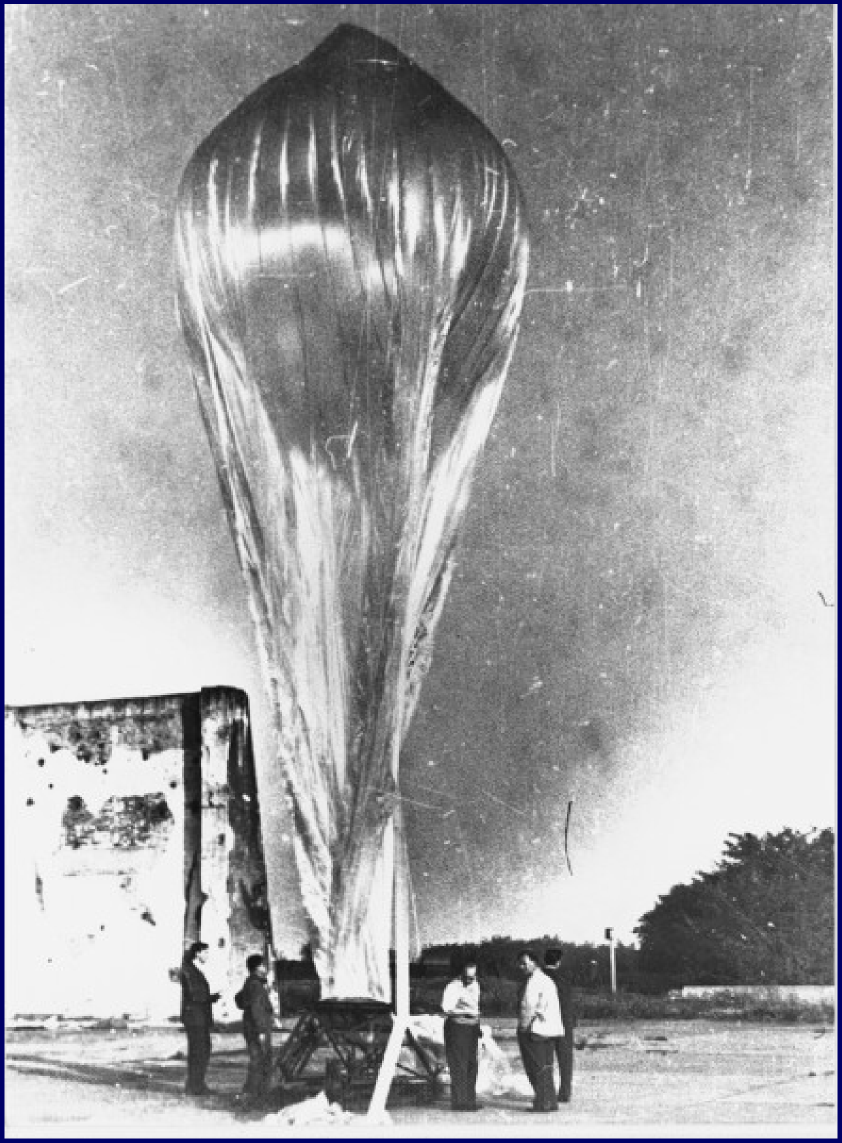
Ultérieurs perfectionnements

- La méthode “Temperature Development” pour émulsions épaisses
- Les “stripped emulsions”

Developpement des émulsions épaisses, Michelangelo Merlin, Institut de Physique de Padoue, 1953

Institut de physique de Padoue, 1953

Les premières grandes collaborations internationales (Sardaigne, 1952-53)



Le G-Stack ou Stack Géant,
1954

Le G-Stack ou Stack Géant,
1954

represent the ladder approximation is to include an infinite set of radiative corrections to each nucleon line corresponding to the successive emission and reabsorption one at a time of any number of mesons. The properties of these modified propagation functions have already been discussed in I; they differ little from the original functions if particles (1) and (2) are moving as nearly free particles. If however pair formation has occurred as is characteristic of the pseudoscalar theory even when the nucleons are interacting rather weakly, then the modification of the propagation functions is very large. Accordingly the effect will be small only if an adiabatic approximation[2,3] is made to the integral equation which does not involve pair formation. The next contributions to the adiabatic approximation to the equation involve the formation of zero, one, or two nucleon pairs, as is shown in Fig. 2, which will be decreased

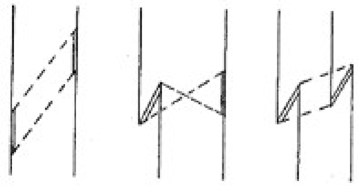


FIG. 2. g^4 contributions to the potential in the adiabatic approximation. The doubled nucleon lines represent propagation functions modified by radiative corrections.

in the nonrelativistic region by factors of approximately one, $(1+3g^2/16\pi^2)$ and $(1+3g^2/8\pi^2)$, respectively. More generally, the radiative effects tend to prevent inversion of the nucleon line in time, i.e., pair formation, which is similar to the result already discussed in I.

Similar comments also apply to the formulation of the relativistic integral equation[4] describing meson-nucleon scattering. In that problem the g^2 kernel includes not only the two usual Compton contributions but also radiative terms for both the meson and nucleon which lead to replacement of S_F and D_F by S_F' and D_F' which differ by damping radiative terms similar to those discussed above.

Finally it may be remarked that while the treatment of the radiative terms in the g^2 kernel as suggested here is fairly non-ambiguous, the method of inclusion of radiative effects in higher-order terms in the kernel of Eq. (1) still remains somewhat arbitrary.

The author is indebted to Professor H. Bethe for interesting discussions of this and related problems.

* Supported by a grant from the National Science Foundation.

1 Brueckner, Gell-Mann, and Goldberger, Phys. Rev. **90**, 476 (1953).
2 E. E. Salpeter and H. A. Bethe, Phys. Rev. **84**, 1232 (1951).
3 M. Lévy, Phys. Rev. **88**, 72 (1952).
4 Compare, for example, Karplus, Kivelson, and Martin, Phys. Rev. **90**, 1072 (1953).

Bubble Chamber Tracks of Penetrating Cosmic-Ray Particles*

DONALD A. GLASER
Harrison M. Randall Laboratory of Physics, University of Michigan, Ann Arbor, Michigan
(Received May 20, 1953)

TRACKS of penetrating cosmic-ray particles passing through an ether-filled bubble chamber under 10 cm of lead have been recorded by flash photography triggered by a twofold vertical coincidence telescope. The bubble chamber consisted of a heavy-walled cylindrical Pyrex bulb 3 cm long and 1 cm inside diameter, which communicates with a pressure-regulating device by means of a Pyrex capillary tube 45 cm long. A thermostated temperature bath of mineral oil surrounded the bulb, maintaining

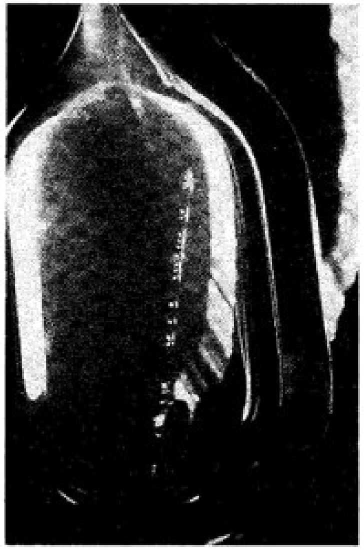


FIG. 1. Flash duration 20 microseconds, no deliberate delay, temperature 140°C.

the temperature constant within 0.5°C in the range 138°C to 143°C. The pressure-regulating device consisted of a brass cylinder of length 2 cm and inside diameter 3 cm. One end of the cylinder was sealed with a flexible diaphragm of $\frac{1}{8}$-in. Neoprene faced with Teflon to confine the ether and permit variation of its pressure by controlling the pressure of compressed gas on the outside of the diaphragm.

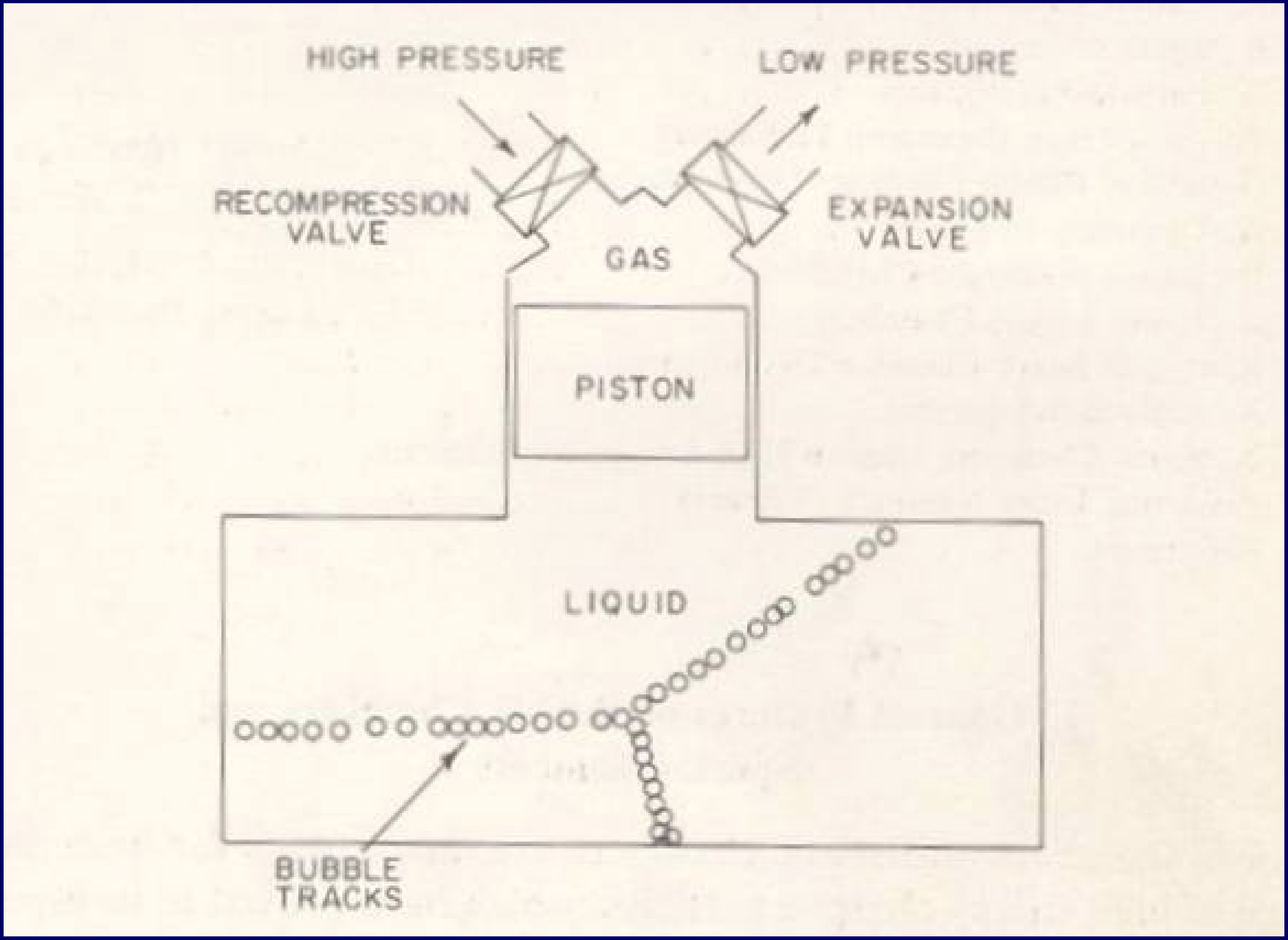
To prepare for taking a picture of a track, the ether was compressed by admitting compressed nitrogen to the pressure regulator at a pressure of 300 pounds per square inch so that no vapor bubbles remained in the system. Then the gas was allowed to escape, so that the ether suddenly became highly superheated at atmospheric pressure. On the average the liquid remained quietly in this unstable condition for several seconds until a violent eruptive boiling occurred. If a coincidence of the vertical counter telescope occurred during this waiting time, a picture was taken by means of a xenon discharge flashlamp. About 5 seconds were required to recompress the ether in preparation for the next event.

Figure 1 shows a track obtained at a temperature of 140°C with a flash duration estimated to be 20 microseconds. In Fig. 2 the duration was reduced to about 5 microseconds, the temperature 141°C. Here one sees a scattering of about 2°.

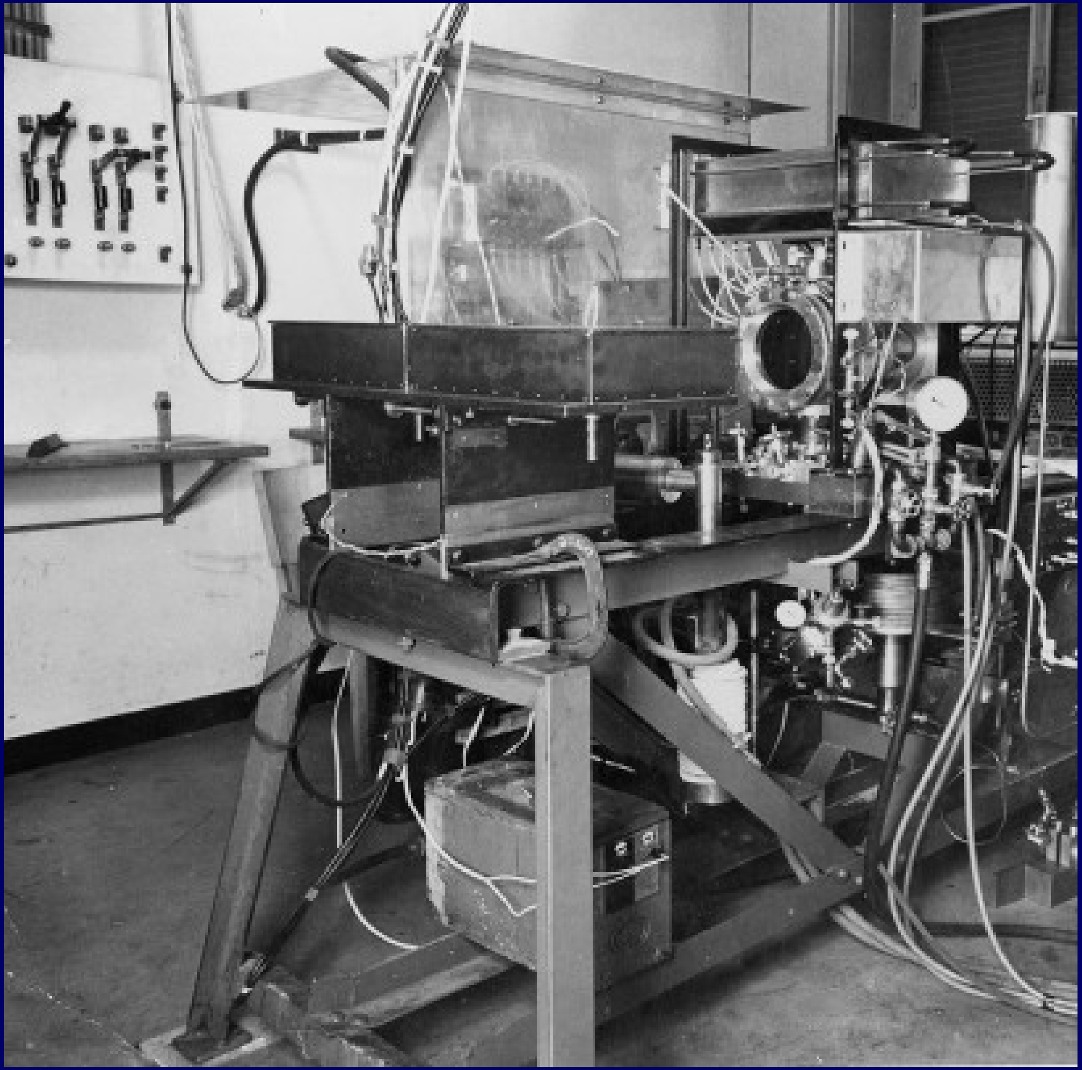
From these sample pictures several characteristics of bubble chambers and their possible applications to high-energy nuclear physics can be inferred. Because of the relatively high density of the sensitive medium (about 0.5 g/cc under these conditions), there is a good chance of seeing an interesting event occurring in the liquid where most of the secondaries would be visible. Since the particles recorded here are almost certainly fast mu mesons, one concludes that the bubble chamber is sensitive to minimum ionizing particles. Since the bubbles grow so extremely rapidly, there are virtually no distortions of the tracks due to convection

Chambres à bulles

Donald A. Glaser, 1952


HIGH PRESSURE
LOW PRESSURE
RECOMPRESSION VALVE
EXPANSION VALVE
GAS
PISTON
LIQUID
BUBBLE TRACKS

Pietro Bassi et collaborateurs, 1955



Le piston de BEBC

BEBC (Big European Bubble Chamber), 1966

30.000 litres d'hydrogène liquide – Utilisée jusqu'en 1984

Chambre à bulles Gargamelle
Diamètre 2 mètres; longueur 4,8 mètres
Environ 12 mètres cubes de freon.
Construite en France, opérative de 1970 à 1978.

Rayons cosmiques, instruments et prix Nobels

Charles T.R. Wilson – 1927 – “pour sa méthode de rendre visibles les trajectoires de particules chargées électriquement par condensation de vapeur”

Patrick M.S. Blackett – 1948 – “pour avoir développé la méthode de la chambre à brouillard de Wilson, et les découvertes qu’il a pu en tirer dans les secteurs de la physique nucléaire et de la radiation cosmique”.

Cecil F. Powell – 1950 – “pour le fait d’avoir développé la méthode photographique pour l’étude des processus nucléaires et ses découvertes sur les mésons faites avec cette méthode”.

Donald A. Glaser – 1960 – “pour l’invention de la chambre à bulles”

NUCLEAR PHYSICS IN PHOTOGRAPHS

TRACKS OF CHARGED PARTICLES IN PHOTOGRAPHIC EMULSIONS

BY

C. F. POWELL

AND

G. P. S. OCCHIALINI

THE H. H. WILLS PHYSICAL LABORATORY
UNIVERSITY OF BRISTOL

OXFORD
AT THE CLARENDON PRESS
1947

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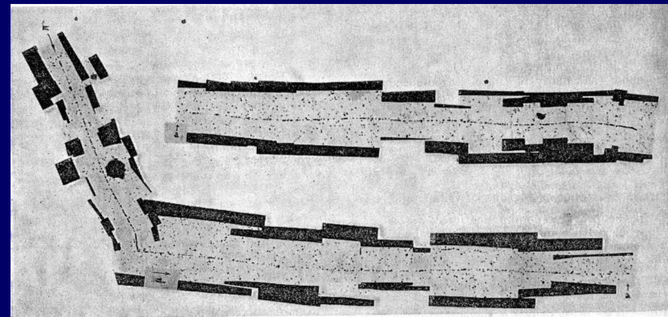
UNIVERSITY OF BRISTOL



There are, as I have said, some minds which can go on contemplating with satisfaction pure quantities presented to the eye by symbols, and to the mind in a form which none but mathematicians can conceive.

There are others who feel more enjoyment in following geometrical forms, which they draw on paper, or build up in the empty space before them.

Others, again, are not content unless they can project their whole physical energies into the scene which they conjure up. They learn at what a rate the planets rush through space, and they experience a delightful feeling of exhilaration. They calculate the forces with which the heavenly bodies pull at one another, and they feel their own muscles straining with the effort.

To such men momentum, energy, mass are not mere abstract expressions of the results of scientific inquiry. They are words of power, which stir their souls like the memories of childhood.

For the sake of persons of these different types, scientific truth should be presented in different forms, and should be regarded as equally scientific, whether it appears in the robust form and the vivid colouring of a physical illustration, or in the tenuity and paleness of a symbolical expression.

James Clerk Maxwell, 1870

For whatever may be said about the importance of aiming at depth rather than width in our studies, and however strong the demand of the present age may be for specialists, there will always be work, not only for those who build up particular sciences and write monographs on them, but for those who open up such communications between the different groups of builders as will facilitate a healthy interaction between them […] I suppose that when the bees crowd round the flowers it is or the sake of the honey that they do so, never thinking that it is the dust which they are carrying from flower to flower which is to render possible a more splendid array of flowers, and a busier crowd of bees, in the years to come. We cannot, therefore, do better than improve the shining hour in helping forward the cross-fertilisation of the sciences".

J.Clerk Maxwell, "The Telephone", *Nature*, vol. XVIII