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THE POST-WAR RECONSTRUCTION OF PHYSICS IN MILAN: CLOUD CHAMBER AND COSMIC RAYS (1945-1960)

VALERIA BERETTA, LEONARDO GARIBOLDI
Università degli Studi di Milano
Istituto di Fisica Generale Applicata

The aim of this communication is to discuss the role played in the post-war reconstruction of physics in Milan by the studies on cosmic rays made by Milan physicists between 1945 and 1960 with the cloud chamber experimental technique. The main sources of this historical analysis comprise the reminiscences on cloud chamber physics made by John G. Wilson[1], Patrick M.S. Blackett[2], Lajos Jánossy[3], and Antonio Mura[4], and those on the history of physics in Milan made by historians of physics: P. Tucci, Lanfranco Belloni[5], Guido Tagliaferri[6], and Giovanni Polvani. A fundamental contribution to this work was given by the oral history with interviews to the physicists Guido Vegni and Ettore Fiorini.

This communication is divided into two main parts. In the first one, we offer a short history of the device, the cloud chamber, and of the main discoveries made with it. In the second one, we study the use of the four cloud chambers built at the Institute of Physics of Milan. We analysis the situation of physics in Milan in the years under discussion, the experiments made with the cloud chamber and the obtained results. We conclude with a note on the importance of these studies in the reconstruction of physics in post-war Milan and their developments.

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[1] Wilson, John G. (1951). *The Principles of Cloud Chamber Technique* (Cambridge: Cambridge University Press, 1951).
[2] Blackett, Patrick Maynard Stuart (1948). "Cloud chamber researches in nuclear physics and cosmic radiation" *Nobel Lectures, Physics 1942-1962* (New York: Elsevier, 1964): 97-119.
[3] Jánossy, Lajos (1948). *Cosmic Rays* (Oxford: Oxford University Press, 1948).
[4] Mura, Antonio (1951). "Il metodo della camera di Wilson" in: Società Italiana di Fisica, Sezione Lombarda (*ed.*) (1951). *Conferenze di Fisica* (Milano: Editrice Viscontea, 1951): 311-325.
[5] Belloni, Lanfranco (1988). "Giovanni Polvani e l'Istituto di Milano" *Il Nuovo Saggiatore* 1988, *4*, *3*: 35-49.
[6] Tagliaferri, Guido (1989). "Post War Restarting of Cosmic Ray Research at Milan University" in: De Maria, Michelangelo; Grilli, Mario; Sebastiani, Fabio (*eds*.). *The Restructuring of Physical Sciences in Europe and the United States 1945-1960* (Singapore: World Scientific, 1989): 716-731. Tagliaferri, Guido (1993). "Ricordo di Giovanni Polvani (1892-1970)" *Giornale di Fisica* 1993, *34*, *1*: 3-7. Tagliaferri, Guido (1995). "Le Scienze Esatte all'Università di Milano" *Storia di Milano* (Roma: Istituto della Enciclopedia Italiana, 1995) *18*, *3*: 660-677.

1. Cloud Chambers

The first cloud chamber was built by Charles Wilson[7] in 1911. This device is composed by a rigid, transparent container with, inside it, a mix of gas and water vapour next to saturation, and by a moving piston. If the cloud chamber is adiabatically compressed when an ionizing particles goes through it, the vapour condenses around the ions created in the gas mix and cloud drops are formed. The drops evidence the track of the particle.

The efficiency of the cloud chamber was greatly increased when, in Cambridge 1931, Blackett and Occhialini connected the device with a system of coincidences made by a series of Geiger-Müller counters. The system of coincidences was developed by Bruno Rossi a few years before in Florence.

With the cloud chamber, physicists can measure momentum, ionisation, range and mass. Some of the main discoveries in cosmic and particles physics in the 30's-40's were actually made with the cloud chamber. We remind the discovery of the positron (Anderson 1932), of the pair production (Blackett and Occhialini, 1933), of the muon (Anderson and Neddermeyer, 1936) and of the strange particles (Butler and Rochester, 1946-47).

2. The First Cloud Chamber in Milan

The studies on cosmic rays in Milan began in 1938 with Giuseppe Cocconi and Vanna Tongiorgi, and also A. Loverdo who joined them later. The first cloud chamber had a circular section, whose dimensions were typical of the period (30 cm diameter and 5 cm depth). It was a controlled cloud chamber: when a comic particle went through the system of GM counters places above and below the chamber, the Rossi circuit detected a coincidence and opened a valve. The valve connected a tank with the back of a light piston, which went back and made the chamber expand. The gas was a mix of air saturated with water and alcohol. Later, air would be substituted with argon, permitting a lower expansion rate. The experiments made by this group took place in Milan and at the Passo Sella, before and during WWII. Our research evidenced the studies made on the determination of the mean life-time of the muon[8], the analysis of the hard component and the dependence of its intensity on the zenithal angle[9], the study on the nature of the primary and secondary components[10], and the study on air extensive showers[11]. In these experiments, they used the first Milan cloud chamber built by Cocconi and Mazzon in 1941.

This very cloud chamber was used again in a series of measurements made at the Lago Inferno, after WWII, by a new group of cosmic ray physicists of Milan composed by Guido Tagliaferri, Antonio Mura, and Giorgio Salvini. Their research mainly concerned the analysis of air extensive showers. With their experiments, they confirmed the presence of a penetrating component in the showers processes (1946) and studied their characteristics (1947)[12]. They furthermore evaluated the density

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[7] Wilson, Charles Thomas Rees (1912). "On an Expansion Apparatus for making Visible the Tracks of Ionising Particles in gases and some Results obtained by its Use" *Proceeding of the Royal Society* 1912, *A 87*: 277-292.

[8] Cocconi, Giuseppe (1939). "Una nuova prova dell'instabilità del mesotrone" *La Ricerca Scientifica* 1939, *10*: 958-961.

[9] Tongiorgi, Vanna (1943). " Sulla struttura fine delle curve zenitali della radiazione cosmica" *Il Nuovo Cimento* 1943, *1,2*: 96-100.

[10] Cocconi, Giuseppe; Tongiorgi, Vanna (1941). "Sulla natura della componente elettronica della radiazione cosmica a 120 e a 2200 metri sul livello del mare" *La Ricerca Scientifica* 1941, *12,2*: 144-166.

[11] Cocconi, Giuseppe; Tongiorgi, Vanna (1940c). "Misure sugli sciami estesi di raggi cosmici a 2200 metri sul livello del mare" *La Ricerca Scientifica* 1940, *11*: 788-790.

[12] Mura, Antonio; Salvini, Giorgio; Tagliaferri, Guido (1947a). "Sulla presenza di una componente penetrante negli sciami estesi dell'aria" *Il Nuovo Cimento* 1947, *4,1-2*: 10-23.

spectrum of the particles composing a shower and the lateral development of the electromagnetic component.

3. The Second Cloud Chamber in Milan

The attention of the Milan physicists working with the cloud chamber turned to the study of the nuclear interactions that could happen when cosmic radiation went through the plates inserted inside the device. With this aim, Mura and Lovati built the second Milan cloud chamber. This chamber also worked with a controlled expansion. It was cylindrical in shape and was deeper than the first one (15 cm), in order to study the whole development of possible nuclear showers. The light piston was substituted with a rubber membrane, to make the expansion smoother and faster. The chamber was always used at a pressure a bit higher than the atmospheric one (15-20 cm_{Hg} higher). In 1948, the chamber was brought to and used in the Testa Grigia Laboratory on the Alps. The main results of these experiences were: the verification that penetrating particles strongly interacted with nuclei[13]; the evaluation of the mean cross section of production of nuclear explosions by penetrating particles in lead[14] (it resulted of the magnitude order of the geometrical one), and the determination of the mean free path of nuclear interaction in lead[15].

4. The Third Cloud Chamber in Milan

In the early Fifties, cosmic radiation was still the main source of new particles. The Milan group of cosmic ray physicists decided to build a third cloud chamber based on their solid experience on the field. The chamber was built by A. Lovati, A. Mura, G. Tagliaferri, and L. Terra in 1951, and was used in the Testa Grigia Laboratory and, later, in a railway tunnel near Verbania. The third cloud chamber has a rectangular section and has large greater dimensions: 50x60x15 cm^3. Thanks to its dimensions, they were able to insert a larger number of metallic plates and to make also a series of random expansions since they were able to collect a sufficient quantity of useful data. The group was led by Tagliaferri and Succi. Their studies concerned the production of π^0-mesons[16] and the detection of some strange particles[17], the V-particles.

5. The Fourth Cloud Chamber in Milan

The fourth cloud chamber was built in 1956 by Succi's group, which comprised also, as young students, Ettore Fiorini and Riccardo Giacconi. This cloud chamber had noteworthy dimensions: 156x156x98 cm^3. The main structure of this last chamber is conserved in the main hall of the Department of Physics in Milan. This group of cosmic ray physicists worked from 1952 alongside with a new staff of *cosmiciens*, led by Giuseppe Occhialini, who used the nuclear emulsions technique to study the

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[13] Lovati, Antonio; Mura, Antonio; Salvini, Giorgio; Tagliaferri, Guido (1949c). "Nuclear Interactions of the Particles Produced in Cosmic Ray Bursts" *Nature* 1949, *163*: 1004-1006.

[14] Lovati, Antonio; Mura; Antonio; Salvini, Giorgio; Tagliaferri; Guido (1950c). "Mean Free Path of the Particles Produced in Nuclear Explosions and Comparison Between Explosions in C and Pb" *Physical Review* 1950, *77*: 284-285.

[15] Lovati, Antonio; Mura, Antonio; Succi, Carlo; Tagliaferri, Guido (1951). "Interaction Mean Free Path of the Particles Emitted in Cosmic Ray Nuclear Explosions" *Il Nuovo Cimento* 1951, *8*, *4*: 271-278.

[16] Lovati, Antonio; Mura, Antonio; Tagliaferri, Guido; Terrani, S. (1952). "A Cloud Chamber Analysis of Cosmic Rays at 3500 Metres. Part. A: The Electronic Component from Nuclear Disintegrations in Lead" *Il Nuovo Cimento* 1952, *9*: 946-958.

[17] Giacconi, Riccardo; Lovati, Antonio; Mura, Antonio; Succi, Carlo (1956b). "High Energy Nuclear Interactions in Lead by Cosmic Ray Protons at 3500 m" *Il Nuovo Cimento* 1956, *4*: 826-833.

production of the newly discovered particles (mainly strange mesons) by flying emulsions on balloons. The experiments made with the fourth cloud chamber were made at the Sabbione Dam in Val Formazza with the collaboration of a group of physicists of the Pisa University. They concerned the search of a new particle, with a $550m_e$ mass, whose existence had been hypothesised by a group of Soviet physicists, led by Alikhanian[18]. Their studies ended in 1959 with the result of the non-existence of Alikhanian's particle[19].

CONCLUSIONS

The studies of the Milan physicists with the cloud chamber played a fundamental role in the development of physics in Milan in the immediate post-war period. In particular, the researches made by Tagliaferri's group with the second cloud chamber – with the detection in extensive showers of penetrating particles (later identified as protons, mesons and nucleons) able to produce and to be produced in nuclear interactions – contributed to put cosmic ray researches in Milan on an international level.

The evolution of the cloud chamber group of physicists happened in two important fields of research: nuclear physics (Tagliaferri and Succi) and particle and high energy physics (Fiorini and Salvini) together with Occhialini's nuclear emulsions group.

[18] Alikhanian, A.I.; Shostakovich, N.V.; Dadaian, A.T.; Fedorov, V.N.; Deriagin, B.N. (1957). "On the Mass Spectrum of Charged Cosmic Ray Particles" *Soviet Journal JETP* 1957, *4,6*: 817-830.

[19] Conversi, Marcello; De Munari, G.M.; Egidi, A.; Fiorini, Ettore; Ratti, S.; Rubbia, Carlo; Succi, Carlo; Torelli, G. (1959). "Ricerca sulla esistenza di particelle di massa intorno a 550 m_e nella radiazione cosmica" *Il Nuovo Cimento* 1959, *XII*, 2: 148-155.