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The (re)building work of Italian physics during and after World War II (1940-1965), with analysis of data and original documents

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Abstract. The Italian physics during the XX century passed through different situations: at the beginning of the century there were a lot of problems to make physics in Italy, in particular in the case of modern physics. This situation continued until 1926, when Enrico Fermi won the chair of theoretical physics in Rome. This event started the birth of the School of Physics of Rome (known as "I ragazzi di via Panisperna") where nuclear physics was studied; in the same period there was another important school of physics in Italy: the School of Arcetri (near Florence), where Enrico Persico e Bruno Rossi laid the foundation for the study of cosmic rays. These two topics were, after the end of WWII, the foundation of the Italian modern physics, in particular the Italian particle physics.
This path towards modern physics in Italy was built by many physicists; among them we must remember Edoardo Amaldi, Gilberto Bernardini and Gian Carlo Wick. A special case is that of Giampietro Puppi, a physicist that played a fundamental role in the reconstruction of physics mainly in the city of Bologna.

1. Introduction

A historical work, as this one intends to be, has always to respect some important key-points; in particular a corner stone of the historical work is the use of original documents. But it would be very important to find some methods to determine, in an objective manner, some aspects of the work of a scientific community such were the ones that worked in Italy in the indicated period. It is possible to summarize these two facts as follows:

<u>the use of original sources:</u>
it is impossible to study the history of physics without knowing the events of the period directly from the "voice" of the leading actors

<u>the quantification:</u>
in some cases it could be very useful to quantify some aspects of the topics. For example: how is it possible to evaluate the quality of a school of physics such as the school of physics of Rome or the school of physics of Arcetri? It is a very hard question and it is also very difficult to find a method. My proposal is to use the awards won together with a quantitative analysis of the articles published by the physicists belonging to the two schools.

From these two points of view the case of the Italian physics during the XX century is a vicissitude rich of very interesting ideas, it is a very interesting and articulated history, started with a very local character and arrived to a very high level of internationalization, an inevitable aspect of the modern research. At the same time it is important to remember that each path in the progress of knowledge is the result of a very wide variety of different angles and of different studies. I would like to remember these facts with a quotation:

> *"The history of an idea is, necessarily, the history of many ideas. Ideas, as well as big rivers, never have a single source. Just like a river near the mouth now consists mostly of water of many tributaries, in the same manner an idea in its final formulation is the result of later additions. In light of this, identifying the source of a river is often as difficult as tracing the origin of an idea."*[1]

This paper is divided in three sections. The first one focuses on the analysis of the situation of physics in Italy in the period 1900-1940, with particular attention to the schools of physics and to the awards obtained by Italian physicists in the same period. The second part focuses on the post – war era with the analysis of the articles published, and of the prizes won by Italian physicists. The third and last section outlines a particular case, the case of Giampietro Puppi and of the rebirth of physics in Bologna, begun by the end of the Forties. The final part of my work is composed by a lot of data; some of these data have been elaborated starting from other tables and some have been collected for the first time[2]. In the same section there is a collection of original letters and documents found in Amaldi's archive located in the library of the Department of Physics of the University of Rome.

2. The pre-war period: 1900 – 1940

> *"At the age of twenty-six he obtained the chair of theoretical physics in Rome, created especially for him. Fermi had a chair, had a classroom … and only one student: Edoardo Amaldi. Yet a few years would be enough to form the School of Rome […] which is linked to the name of Rasetti, Amaldi, Segrè, D'Agostino e Pontecorvo."*[3]

The previous quotation gives a real picture of the Italian situation in the field of physics in the studied period. In fact, in the period 1900 – 1925 there was not in Italy a Physics Institute where it was possible to study the modern theories such as Relativity and Quantum Mechanics. In Italy physics was totally centred on experimental work, in particular classical physics. In the first twenty-five years of the XX century the Italian physics was mainly a physics linked to classical topics, reluctant to show interest to the new physics arriving from the other European countries. The main actors of this kind of physics were Guglielmo Marconi (Nobel prize in 1909), Augusto Righi and Quirino Majorana (uncle of the most famous Ettore) in Bologna. Obviously they were not the only ones and also the Institute was not the only one; a lot of other Italian Institutes of Physics were involved in the study of physics. But the distance between Italian physics and modern physics was widespread. Greater force to this idea is provided using the data referred to the articles edited in Il Nuovo Cimento in the period 1900 – 1940. About it the opinion of Mario Ageno was the following:

> *"Segrè accurately highlighted in his writings on the history of sciences how, after the dispersion of the school of Galileo Galilei, unlike what happened in the Northern European Countries, the Italian physics always lacked the physical support of a tradition represented by a big scientific school able to pursue a scientific outlook, also with the contribution of mid-level scientists. So the normal condition of the Italian physics was always of deep coma, sometimes interrupted /from/ by the contribution of some university professors. Alessandro Volta himself represented, after Galilei, a vivid flash block. And he /don't/ didn't have any students."*

Now it's possible to analyze some data referred to the articles published in Il Nuovo Cimento in the period 1900 – 1940; these data are collected by topics, and, inside these topics, will be indicated which of them

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[1] P.Collins, *Al Paese dei libri*, Adelphi, 2010

[2] These data have been obtained from different sources, principally Internet and secondary bibliography.

[3] N.Risi, D.McAdoo, Amaldi's Archivi, Rome

are about modern physics and which are about classical physics. There is an important difference in the picture of the Italian physics at the beginning of the XX century; it is a difference that could mean a possible change in the main topics of study. Let's see4:

MAGAZINE	**TOPIC**	**N° ARTICLES**
Il Nuovo Cimento	Zeeman effect	9
	Cathode rays	10
	Cosmic rays	14
	Relativity	25
	X rays	35
	Radioactivity	42
	Nuclear physics	53
	Quantum physics	90
	Electricity	134
	Electromagnetism	184

It is clear that the main topics of the period were Electricity and Electromagnetism, and it is also clear that the modern physics, such as relativity and quantum mechanics, was, instead, not at the top for the number of articles. Entering more details, it is possible to observe that one topic of modern physics was studied with particular attention; it is the case of quantum physics. On the other side relativity did not receive the same attention. In fact only 25 articles were present in the period. If we sum the number of articles classified as "classical physics" we will obtain 428 articles in the first forty years of the century; at the same time the number of articles classified as "modern physics (relativity and quantum physics) obtains a total sum of 115, which is about ¼ of the previous. A particular mention deserves the topic of Nuclear Physics; it is not a topic of modern physics but it is not a topic of classical physics either. It is a very important topic though, especially in the case of the Italian physics; in fact it was starting from this field of research that Italian physics came back to an important place in the European physics.

It is also possible to view these data in a graphical form; in the left part of Figure 1 it is interesting to note the difference, in per cent, between the number of articles of experimental nature and those of theoretical nature. More interesting is the graph on the right where it is possible to evaluate the difference, in per cent, of various kinds of articles. It is possible to note how, since 1926 there were some big differences: a great increment of Nuclear physics and of Atoms and molecules together with a big decrement of the articles on Classical physics and of Applied physics. The topic calls Quantum and statistical physics during the entire period has, overall, an increase with decrement towards the end of the Thirties.

Having listed the previous data in order of increasing number of articles, it is possible to try to draw some partial considerations; the picture will be more complete and clear after a year by year analysis5.

As first it is possible to see how the previous classification provides two topics of modern physics – let us say "current" (Relativity and Quantum Mechanics) – together with other eight of classical physics; among them it is possible to identify a difference between topics "strictly classical" (Electricity, Electromagnetism e Cathode rays) together with more recent ones, always of classical physics (X rays, Radioactivity e Zeeman effect). For the two remaining items (Nuclear Physics e Cosmic rays) it is possible to think to a separate discussion, to postpone together with the years by years analysis. In other words we may hazard a division between classical physics and new contemporary physics by inserting, in the latter, exclusively the new theory of the XX century (Quantum mechanics e Relativity). According to this division are present 428 articles of all the classical topics and 115 referred to the new theory of the XX century. It is interesting to underline the difference between the two new theories; in the case of Relativity only 24 articles were edited in forty years, while in the case of Quantum Mechanics the number of articles is significantly higher: ninety articles. In the

4 The data contained in the table are concerning to Il Nuovo Cimento and are personal reworking of the data available on the internet site http://fisicavolta.unipv.it/asf/archives.asp managed by prof. G.Giuliani

5 This very careful analysis is not present in this article, but it is possible to ask the author for details.

first case the number of different authors is equal to sixteen, while in the second case the number is about the double: thirty-seven different authors.

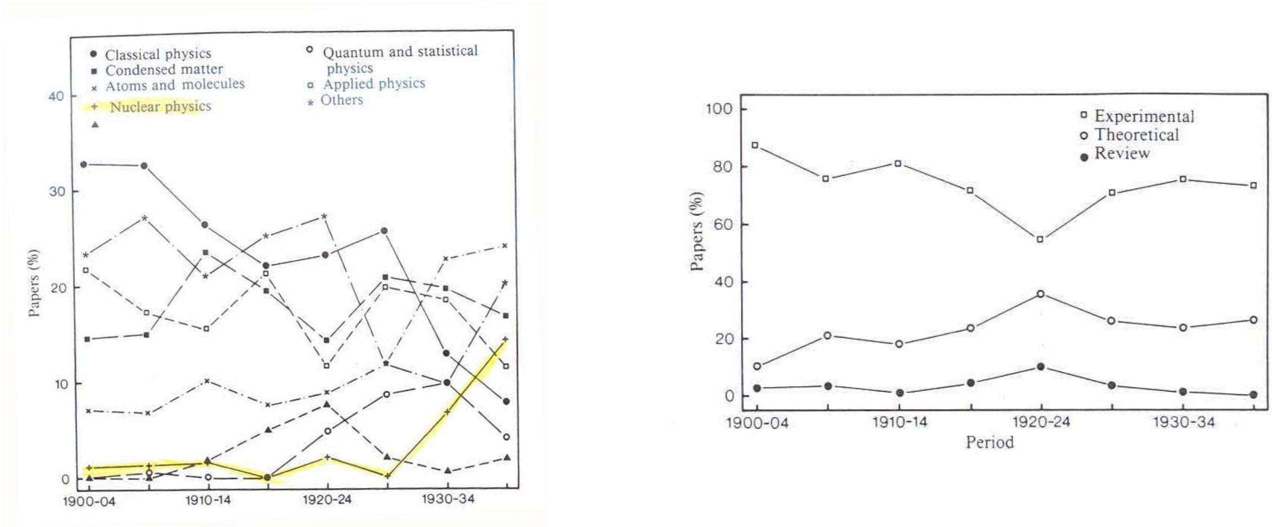

Figure 1

Relativity was studied only by few researchers of the two Italian schools, while in the case of the Quantum Mechanics the number of researchers is higher. In the case of Relativity it is appropriate to distinguish between theoretical and experimental angles; in Italy, apart from few articles centred on the foundation of the theory (authors: Corbino, Crudeli, Garavaldi), most of the articles focused on the experimental verification of the theory. These data were caused also by the mathematical difficulty of the new theory, which was clear mainly to the mathematicians. A lot of these articles were centered on the check of the Michelson-Morley experiment. In 1921, sixteen years after Einstein's annus mirabilis, the physicists Righi edited an article entitled *Sulla teoria della relatività e sopra un progetto di esperienza decisiva per la necessità di ammetterla. Memoria IV (On the theory of Relativity and on a project of a decisive experiment for the need to admit it. Memory IV);* Italian research was still engaged with the experiment for the admission of the Relativity at about fifteen years after the outing of the theory. In the case of Quantum physics there is an important number of articles, even if the first one is dated 1921. Moreover it is possible to see that the physicists of the school of Rome were present in a bigger number of articles than those of the school of Arcetri.

The topic of Nuclear Physics deserves special attention; the atomic and Nuclear physics are topics born in a classical era for physics (end of the XIX and beginning of the XX century); starting from 1933 some articles were published in Il Nuovo Cimento. The year of the first publication means that it was thanks to the work of the Ragazzi di via Panisperna that nuclear physics became an important topic of research.

Summarizing, Electricity and Electromagnetism were the must of the study in the first thirty years of the Italian physics. In the Italian physics of the XIX century there was an attitude deriving from the preference for the French experimental physics at the expense of the German or English theoretical physics. Quoting Maiocchi:

> *" […] after the Unity of Italy (1861) [was prevalent] a physics strictly connected to the observation, free from hypothesis not totally supported by the facts, a physics very reluctant to trust the powers of abstraction of maths. This attitude created an environment unsuitable to a theory like Relativity, that broke with the "common sense", that deeply cracked the faith that knowledge was always founded on the hypothesis, that did arise the truth from the intellectual critic and from the use of the most refined maths rather than from the senses.*

> *[…]*
> *Augusto Righi rose against the excessively abstract power of the new theory, against its lack of experimental foundations. His example was immediately followed by a large number of researchers: Cantone, Quadrelli, Gianfranceschi, Somigliana, Quirino Majorana, Timpanaro, La Rosa, and so on."*[6]

In the same period also the ministerial indications, while reaffirming the importance of the scientific culture, claimed:

> *" […] Science is a product of the man and for this it is true; the scientific activity is moral and therefore it is to be seen as a duty, not as enjoyment, whose responsibility falls on men, a big responsibility, not only human, but universal, of the historical or natural universe."*[7]

Always according to Maiocchi's thought: *"In this thesis is held all the fascist idea of science: very useful activity to develop for the economic and political need of the Country."* It is clear how the classical physics could give, immediately, answers to the needs of the Country, unlike relativity and quantum mechanics.

To this Italian feature contributed, certainly, also the ideological orientation derived from fascism, not for the rejection of theory nonconforming to the ideology, but rather as a consequence of the wrong interpretation caused by confused ideas. On the magazine Gerarchia, edited by Benito Mussolini, in an article dated 1922, the famous philosopher Ardengo Soffici stated:

> *"I speak of the introduction which has been made between us and of the rapid spread that we are seeing of the doctrine called relativism founded by a group of German and Jews, or German Jews headed by Einstein."*[8]

After this introduction with a first analysis of some of the problems connected to the research of physics in Italy at the beginning of the XX century, it is time to introduce two very key people for the change in the address of research of the Italian physics. These two are Orso Mario Corbino and Antonio Garbasso. They were two very different people but united by the same goal: to create the right condition to permit to the modern physics to take place also in Italy. Each of them had trained in physics during the university period, but they were fundamental for the Italian physics due to their political office. In fact the first of them held very important political posts in the central government, while the second one was the Major of the city of Florence in the period of the school of Arcetri. These two played a double political role: to create the good condition to make research in physics they helped the two school both from an economic and from an institutional point of view. It is possible to sum up their political careers as follows:

Orso Mario Corbino
Senator from 1920
Ministery of Education (1921-1922)
Minisery of Economic (1923-24)
Director of the Institute of via Panisperna

Antonio Garbasso
Major of the city of Florence (1924-1928)
Senator from 1926

The first twenty years of the XX century were very important for the future of physics in Italy. In fact, in this period the majority of the physicists that played an important role in this story were born. In particular we should remember among them:

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[6] R.Maiocchi, pag. 937
[7] G,Gentile, *La moralità della scienza*, in R.Maiocchi, *Il ruolo delle scienze nello sviluppo industriale Italiano*, Storia d'Italia, Annali 3, EInaudi, pag. 935
[8] A. Soffici, *Relativismo e politica*, Gerarchia, 1922

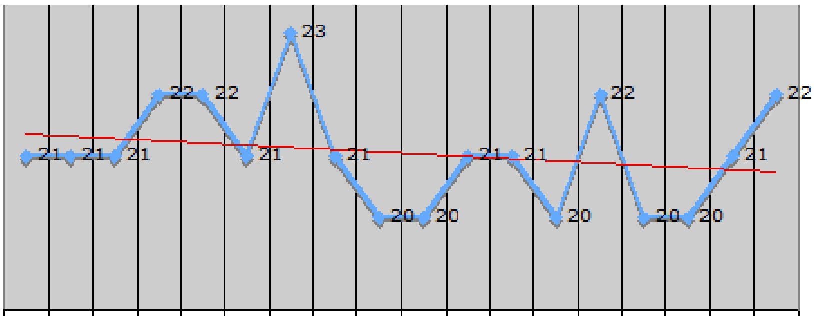
ANNO	NASCITA	NASCITA	NASCITA
1900	Persico Enrico		
1901	Fermi Enrico	Rasetti Franco	
1905	Rossi Bruno	Segrè Emilio	
1906	Bernardini Gilberto	Majorana Ettore	
1907	Occhialini Giuseppe		
1908	Amaldi Edoardo		
1909	Wick Giancarlo	Racah Giulio	
1910	Bocciarelli Daria		
1913	Pontecorvo Bruno		
1915	Pancini Ettore	Ageno Mario	Piccioni Oreste
1917	Puppi Giampietro	Conversi Marcello	

In this table are indicated only the physicists that took part in the foundation work of the Italian new physics and that took part in one of the two Italian schools of physics, Rome or Arcetri. Following different paths these people arrived to study physics and to graduate at about the same time:

	BORN	DEGREE	Δ
Persico	1900	1921	21
Fermi	1901	1922	21
Rasetti	1901	1922	21
Rossi Bruno	1905	1927	22
Segrè	1905	1927	22
Bernardini	1906	1927	21
Majorana	1906	1929	23
Occhialini	1907	1928	21
Amaldi	1908	1928	20

	BORN	DEGREE	Δ
Wick	1909	1929	20
Racah	1909	1930	21
Bocciarelli	1910	1931	21
Pontecorvo	1913	1933	20
Pancini	1915	1937	22
Ageno	1915	1935	20
Piccioni	1915	1935	20
Puppi	1917	1938	21
Conversi	1917	1939	22

It is interesting to note how all these physicists spent about the same number of years to achieve the degree. And, after this result they took place in one of the two schools, in many cases thanks to the work of Corbino and Garbasso.



Before passing to the study of the two Italian schools I would like to devote a little time to a very important person in the Italian situation, with particular influence in the history of the school of Arcetri: Enrico Persico. His work in training the group of Arcetri was fundamental; in particular it is important to pay attention to his method of work. Persico was a very good teacher, a teacher who gave much attention to the preparation of his lessons. His lessons were collected by some of his students in a book entitled "Lezioni di Meccanica Ondulatoria" ("Lessons of wave mechanics"), edited by CEDAM in 1935.

Reading the index of this book it is possible to extract some information about the physical ideas on the modern physics taught in Arcetri. The text is divided in three parts, entitled:

PARTE I - "Concetti fondamentali e prime applicazioni"
(PART I – "Fundamental concepts and first applications")

PARTE II - "Generalizzazioni"
(PART II – "Generalizations")

PARTE III - "Reazioni fra atomi e radiazione"
(PART III – "Reactions between atoms and radiation")

E. PERSICO

LEZIONI

DI

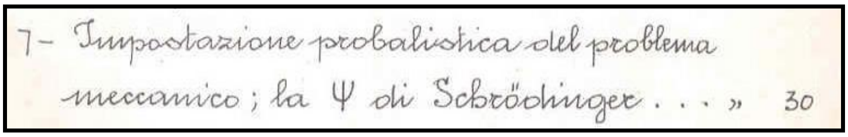
MECCANICA ONDULATORIA

Redatte dal Dott. B. ROSSI e da G. RACAH

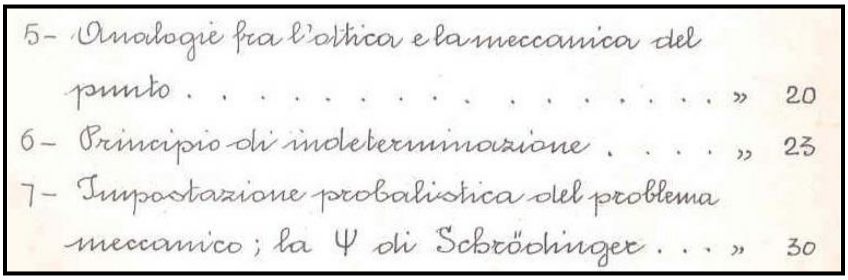
TERZA EDIZIONE RIVEDUTA

CEDAM

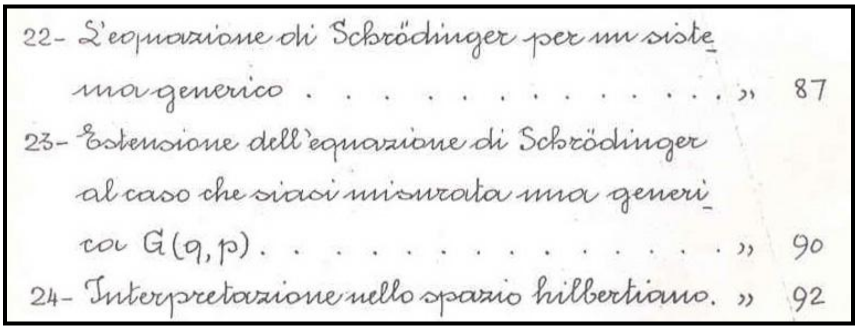
Before the printed version came out the lessons had been collected in a handout version; these notes dated towards the end of the twenties, just after the introduction of the new quantum theory of matter. Despite this fact the notes had filled of quantum mechanics both in the wave formulation, both in matrix formulation it is a clear indication of the ability to update and to keep pace. Now an indication of the main passages of the index:



PART I



PART I



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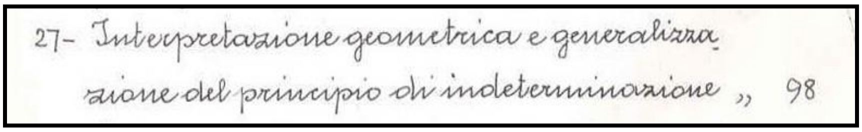

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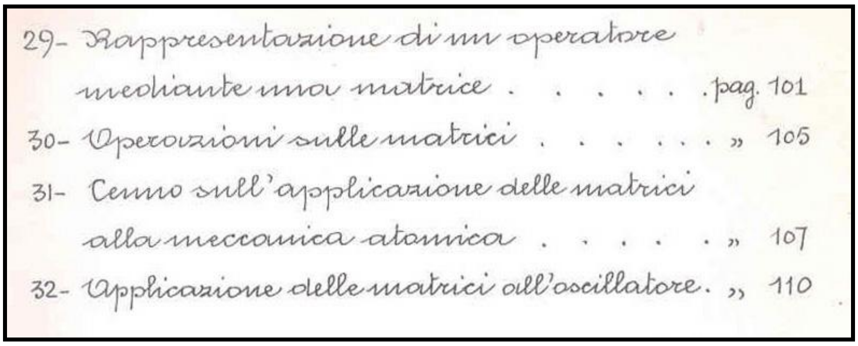
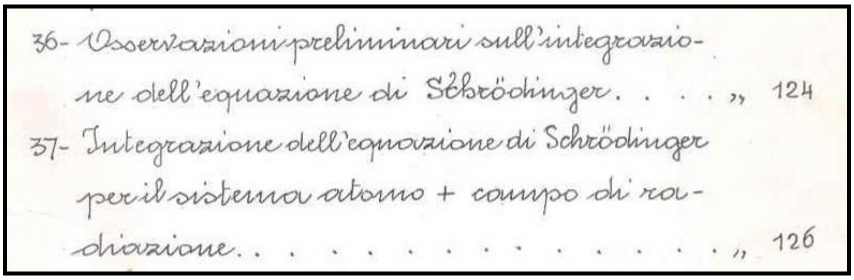


PART III



PART III

The Italian school of physics

Arcetri

Bruno Rossi was born in Venice in 1905. He studied at the University of Padua and, subsequently, of Bologna, he took his degree in 1927; after that he was designated assistant to the chair of Experimental physics at the University of Florence, under the guidance of Antonio Garbasso, eclectic person with many interests, able to sum up in his person the spirit of the researcher with the administrative tasks due to his political appointments.

> *"The laboratory was always behind in paying the electric bills, and the only reason for which our electricity was not cut off altogether was that the director of the laboratory was also major of the city."*[9]

The knowledge of the young physicists was, first of all, in mathematical physics, and not in experimental physics. His arrival in Florence was followed by the arrival of Gilberto Bernardini, coming from Pisa, where he had studied. Other important people, regular researchers of the laboratory were Giuseppe (Beppo) Occhialini, Daria Bocciarelli, Guglielmo Righini, Beatrice Crinò, Giulio Racah, and Lorenzo Emo Capodilista. All these young physicists had as a reference point the figure of Enrico Persico, first mentor of the school, always present with the aim to introduce the young physicists to the study of wave mechanics; for this goal Persico organized weekly visits, readings with commentary of original articles and seminars, his famous seminar, from which the book previously mentioned was edited. In the introduction of the book Persico himself remembers that *"I had tried to avoid the excessive analytical developments that, sometimes, could cover the physical meaning of the questions."*. Persico thought it was important to share the notes for the following reason:

> *"The idea was to guide the student to the new points of view of physics, along the path that I though to be more natural (even if it does not match to the historical development of the new theories); i.e. putting in the foreground the uncertainty principle of Heisenberg obtained by induction from the observation of some elementary cases, and extracting from it the need for a probabilistic interpretation of the me-*

[9] B.Rossi, 1981

> *chanics: interpretation that it will be develop under the guide of the optical analogy."*[10]

Another important person in Arcetri was Giorgio Abetti, assistant of Garbasso: he regularly updated the young researchers with a "Seminar of Physics". With the arrival of Bernardini the school of Arcetri begun; one of the first and most important works of the young Rossi was performed together with Bernardini, and it gave good results. In 1929 Bothe and Kohlhörster published an articled entitled "*Das Wesen der Höhenstrahlung*"; it was the turning point for the group. The hypothesis of the two German scientists captured the attention of Rossi (and also of the young Beppo Occhialini): from the study of the cosmic radiation it was possible to extract a very high number of information, even if the precision of the German experimentalists was not so refined. It was believed that the cosmic rays detected on the Earth's surface were ▯ rays with very high energy, but the remembered experiment of Bothe and Kohlhörster did not give the expected results.

> *"For me, the turning point in the search came in the Fall of 1929 with the apparence - in "Zeitschrift fur Physik" of the historical paper "Das Wesen der Höhenstrahlung" by W. Bothe and W. Kohlhörster."*[11]

Rossi's interest in cosmic rays produced, as first result, the improving of the accuracy of the experiment of one order of magnitude, due to the introduction of the coincidence circuit; it was very important and prolific news. Rossi remembers:

> *"I felt that the power of the coincidence method would be greatly enhanced if one could devise a method for recording coincidences that would be less cumbersome than that used by Bothe and Kohlhörster, and would provide a better time resolution."*[12]

Bruno Rossi made a second very important introduction after the coincidence circuit; to detect a possible deflection of the arriving particles he inserted an improvement suggested by Luigi Puccianti (from Pisa)

> *"In another experiment I had tried to detect a deflection of the penetrating particles in their passage through a bar of magnetized iron. Not having obtained any significant result from this experiment, I later tried to observe the deflection of cosmic-ray particles in magnetized iron, using a different and more sensitive arrangement suggested by Professor Puccianti of Pisa. This arrangement, which one could describe as a magnetic lens, consisted in a closed-circuit magnet formed by two oppositely magnetized iron bars that were arranged next to one another."*[13]

The following year the first defection inside the young group of physicists occurred; in fact Enrico Persico moved to Turin. Together with his unquestionable scientific value the young group lost the principal teacher. But, as the protagonist always remembers:

> *"The group I found in Arcetri was quite small, but quality made up for the size."*[14]

The following year, 1930, was very important for the young Rossi; in fact, thanks to an initiative of Garbasso, he obtained a scholarship to go abroad. It was one of the first cases in Italy, and the scholarship

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[10] E.Persico, 1935, pag. 1
[11] B.Rossi, 1981, pag. 35
[12] ibid, pag. 35-36
[13] ibid, pag. 36
[14] ibid, pag. 35

was granted to Rossi for his recognized leadership in the young group of Arcetri. So Rossi could go to Berlin to Bothe at the Reichsanstadt of Charlottenburg. For the young physicists the period in Germany was extremely stimulating as these words clearly show:

> *"The memory of that summer is still vivid in my mind. Berlin was, at that time, the very heart of contemporary physics. There I met Max Plank, Albert Einstein, Otto Hahn, Lise Meitner, Max von Laue, Walther Nernst, and Werner Heisenberg, to name just few. (...) At that time I also began my friendship with Patrick Blackett, who was also visiting there from England."*[15]

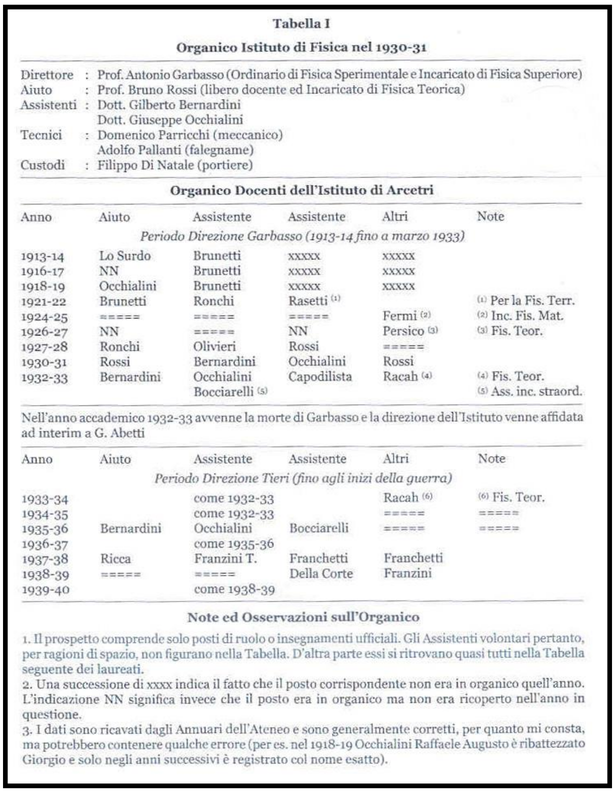


Tabella I

Organico Istituto di Fisica nel 1930-31

Direttore : Prof. Antonio Garbasso (Ordinario di Fisica Sperimentale e Incaricato di Fisica Superiore)
Aiuto : Prof. Bruno Rossi (libero docente ed Incaricato di Fisica Teorica)
Assistenti : Dott. Gilberto Bernardini
Dott. Giuseppe Occhialini
Tecnici : Domenico Parricchi (meccanico)
Adolfo Pallanti (falegname)
Custodi : Filippo Di Natale (portiere)

Organico Docenti dell'Istituto di Arcetri

Anno	Aiuto	Assistente	Assistente	Altri	Note
Periodo Direzione Garbasso (1913-14 fino a marzo 1933)					
1913-14	Lo Surdo	Brunetti	xxxxx	xxxxx	
1916-17	NN	Brunetti	xxxxx	xxxxx	
1918-19	Occhialini	Brunetti	xxxxx	xxxxx	
1921-22	Brunetti	Ronchi	Rasetti (1)		(1) Per la Fis. Terr.
1924-25	=====	=====	=====	Fermi (2)	(2) Inc. Fis. Mat.
1926-27	NN	=====	NN	Persico (3)	(3) Fis. Teor.
1927-28	Ronchi	Olivieri	Rossi	=====	
1930-31	Rossi	Bernardini	Occhialini	Rossi	
1932-33	Bernardini	Occhialini Bocciarelli (5)	Capodilista	Racah (4)	(4) Fis. Teor. (5) Ass. inc. straord.

Nell'anno accademico 1932-33 avvenne la morte di Garbasso e la direzione dell'Istituto venne affidata ad interim a G. Abetti

Anno	Aiuto	Assistente	Assistente	Altri	Note
Periodo Direzione Tieri (fino agli inizi della guerra)					
1933-34		come 1932-33		Racah (6)	(6) Fis. Teor.
1934-35		come 1932-33		=====	=====
1935-36	Bernardini	Occhialini	Bocciarelli	=====	=====
1936-37		come 1935-36			
1937-38	Ricca	Franzini T.	Franchetti	Franchetti	
1938-39	=====	=====	Della Corte	Franzini	
1939-40		come 1938-39			

Note ed Osservazioni sull'Organico

1. Il prospetto comprende solo posti di ruolo o insegnamenti ufficiali. Gli Assistenti volontari pertanto, per ragioni di spazio, non figurano nella Tabella. D'altra parte essi si ritrovano quasi tutti nella Tabella seguente dei laureati.
2. Una successione di xxxx indica il fatto che il posto corrispondente non era in organico quell'anno. L'indicazione NN significa invece che il posto era in organico ma non era ricoperto nell'anno in questione.
3. I dati sono ricavati dagli Annuari dell'Ateneo e sono generalmente corretti, per quanto mi consta, ma potrebbero contenere qualche errore (per es. nel 1918-19 Occhialini Raffaele Augusto è ribattezzato Giorgio e solo negli anni successivi è registrato col nome esatto).

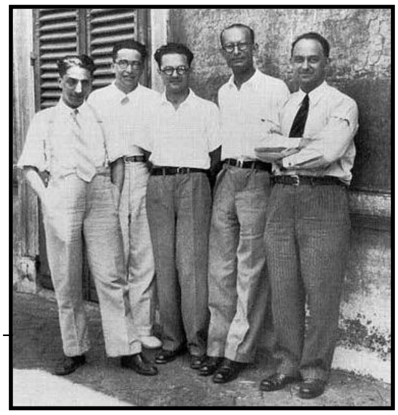
The new friendship with Blackett proved very important for the future; not for Rossi directly, but rather, for another member of the group of Arcetri: Giuseppe Occhialini. The pair Blackett-Occhialini wrote some of the most important pages of physics, even if the awards were won only by the English physics.

Rossi's work continued along the same direction providing another important contribution to the understanding of the cosmic rays. In fact, starting from Stormer's work on aurora borealis and adjusting this idea to the cosmic rays, in 1933 after a lot of difficulties Rossi verified the correctness of the East-West hypothesis carrying out measures in Asmara (Ethiopia), a very suitable site for its geographical position (near the equator and at good altitude).

Starting from 1930 with the transfer of Persico to Turin, the permanence of Occhialini in Cambridge for three years (and not three mouths as initially decided), the death of Garbasso (1933) and Rossi's transfer to Padua in 1932, the suitable condition to keep a school of physics rapidly finished. But the seed planted gave a lot of fruits in Italy and all around the world.

Rome

Only for alphabetical order, the second school of physics in Italy, was, certainly, the school of Rome, began by Enrico Fermi. It is a well known and studied case. Due to the wide and deep bibliography, in this article I will restrict to a systematic analysis of the main features of the school, returning for further information to the existing bibliography.



It is well known what the significance of the birth of the group of Via Panisperna was, inside and outside Italy. It was a group, perhaps unrepeatable, not only for the people (Enrico Fermi, Franco Rasetti, Emilio Segrè, Edoardo Amaldi, and, in a second moment Oscar D'Agostino, Bruno Pontecorvo and Ettore Majorana), but also for the state boundary (the remembered role of Orso Mario Corbino). It was a change in the method of research and in the attention to the other groups of research from foreign Countries.

It will be interesting, in this framework to remember a lone voice, not so known but expressed by one of the most important Italian scientists, Mario Ageno. He remembered:

> *"The students were only two: Alfonso Barone from Rome and myself who had come from the province after I had attended two years at the University of Genoa. I remember that we were conducted into a dark and half-empty room, at the ground floor, on the right side of the hall; after a short delay we were joined by two young men older than us, wearing white coats, who stared at us with a very critical and annoyed attitude."*[16]

Also in Fermi's biography written by Emilio Segrè we can read:

> *"Despite spectacularly successful the research on neutron had also negative consequences on the method of work and on the spirit of the Institute of Rome. The work was so hard that a very sustained effort that totally changed our scientific habit was necessary. Fermi had no longer time to deal with students and with visitors, nor to follow the development of physics outside the field of our immediate interest […]. The seminars and the restricted conferences from which we had learned in the previous years were abandoned. The study of physics became more restricted and assumed an utilitarian feature; to conserve the primacy in the study on the neutron we had to work as rapidly and efficiently as possible."*[17]

Ageno remembers as well:

> *"Alfonso Barone and I made our exercises of the 2nd biennium left to ourselves, but also very busy and happy for the almost complete autonomy: only Edoardo, who played the role of the friendly teacher with us, sometimes went to meet us to give some suggestions […].*
>
> *At the same time I attended, as single student, also a course of Exercises of Physics taught in the classroom by Basilisco (i.e. Segrè); I uncovered the humanity and the great willingness to teach when he thought it was worth it."*[18]

Again Ageno on Fermi:

> *"I attended Fermi's I learned from Fermi a lot of things, both from academic lessons and observing how Fermi was moving in the laboratory, how he solved the problems, how he carried foreword day by day the research and how he answered /the questions of its collaborators, reformulated always in a clearer manner; I learned a lot of things in this manner."*[19]

In Ageno's words we find an indication of a particular and interesting teaching method based on the importance of the example. We are talking about very particular years, with a social, economic and political situation with strong specificity: a marked social conflict with the provision (in same cases also the physical elimination, such in the Matteotti's case, 1924) of who was thinking in a different manner, or, simply, of who was "different"; an economic bankruptcy and the perspective of a wide war. The concerns were present and influenced the daily work, also of those who tried to stay away from the political discussion. Perhaps also for these facts the group of Rome, starting from a certain data was mainly concerned to defend itself .

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[16] L.Bonolis, 2008, pag. 3
[17] E.Segrè, 1971, pagg. 94, 95
[18] L.Bonolis, 2008, pag. 4-5
[19] ibid, pag. 8 (in a footnote)

In this particular condition the group left an important methodological indication: the possibility to see, to touch, to ear and to live with the main researchers is the framework to build groups of research with a good probability to obtain significant results.

Analogy and difference

We are in front of two very similar cases, but with, also, some differences. From a historical point of view it would be interesting to discover the analogies and the differences between the two adventures. In the Italian case this fact is very important; in fact the renaissance of the Italian physics after WWII will find the foundations in the convergence of the heredity of the two schools. The analogies and the differences between them created the (new) Italian physics.

The end of the school of Arcetri[20] had some causes. In 1933 together with the leaving of some of the main physicists, such as Occhialini, Persico and Rossi, the political father of the school, Antonio Garbasso died. The loss of the political and economic help was a very hard fight for the school. Moreover Arcetri changed its category from Institute to University, but always in the second category, that is to say with the budget partially supplied by the central Government and partially by the local Government. The University classified in the first category received all the budget from the central State. In Amaldi's[21] thought this fact had an important influence, for example, on the decision of Enrico Persico to move to Turin, first category University.

Maiocchi remembers:

> *"University's laws, CNR's activity and, particular but very important element, the rhetoric on the imperial fate that brought fascism to prefer the University of Rome to all the others, were the factors that caused a high concentration of opportunities in the physical Institute in Rome, despite all the others; without this concentration also Fermi's researches would not have been possible."*[22]

The follower of Garbasso, despite all the indications that Segrè gave, was Laureto Tieri, an experimental physics of the school of Pietro Blaserna; he was a very good physicist but totally out with respect to the new physics theory.

Despite all these advantages the Institute of Rome was hard struck by unexpected events. From this point of view the opinion of Franco Rasetti is very important:

> *"I have to declare, with pain but with duty frankly, that now it seems to be difficult to preserve to Italy the predominant position that had in recent years. The fundamental researches of Fermi would be done with infinitesimal amounts of radioactive substances ... so different are the quantities of radioactive substances to pass to the applications ... are needful new and most powerful devices, devices that already been brought higher levels of improvement, especially in the United States ... Fermi's discoveries have been made with simply means: receiving in four years less than 1500 thousand lira. But now, in this and in many other fields of physics, the initial period in which, only with the genius helped by almost primitive means, it was possible to revolutionize science is gone forever. To progress now it is necessary the collabora-*

[20] It is important to pay attention to the fact that now we are talking about the school of Arcetri and not of the Institute, until now in activity and famous.

[21] E.Amaldi, F.Rasetti, 1979, pag.9

[22] R.Maiocchi, op.cit., pag. 949

> *tion of many researchers together with a powerful organization of laboratory […]."*[23]

Rasetti's words seem to picture a very lucid analysis of the Italian situation: these are loving and clear words. It seems to understand that, even if Fermi stayed in Italy, the situation was so critical to have no solution. Another important indication present in the previous words is referred to the physics of the future; it will be a Big Science, a field of research where, to obtain important results it will be needed to assembly a very large group of people, also to be able to use the big laboratory built in the meantime. At the same time Rasetti expressed strong opposition to the Big Science, as it is possible to read in the following quotation:

> *"The scientific and technological progress is going to fast because all could proceed in the better way. To put in the hands of men all these devices without a right moral development is, almost I think it could be, very dangerous. Why is no one asking himself how the scientific progress could be a good thing for humanity […]?"*[24]

Also from a historical point of view it is clear how there were a lot of contemporary causes which took the gold period of Italian physics to an end. In their work Cavallo and Messina[25] indicated three different causes for the end of the school of physics in Rome:

- the leaving of some members of the group
- Corbino's death; none of the members of the group was able to get the heredity (*"No one is able to get the heredity in this field: Rasetti due to his cultural background is totally stranger to this kind of problem; Fermi, due to the nomination to Accademico d'Italia is too busy with research; Segrè and Amaldi too young"*)
- The degeneration of the political situation in Italy

Although it goes beyond the subject of this article, it is interesting to give attention to the case of the school of Padua. In fact this school was a fruit born from the school of Arcetri, thanks to the work of Bruno Rossi. But the effects of the historical period arrived also in Padua and a lot of young physicists were forced to leave Italy. Only Pancini remained there.

Ugo Bordoni, President of the Committee for Physics of C.N.R. in 1938, after he had talked about other two similar cases, referred to the political problem connected to the research:

> *"The third example, the "institute for radioactivity" proposed by Fermi in 1938, aimed to promote high-level on nuclear physics and chemistry, "the facilities of a university institute being insufficient for the purpose". Emilio Segrè has described the next steps: "Fermi himself went to Mussolini and tried to get more money for science, to make a modern institute. Mussolini received him, approved the idea, requested a memorandum which was left with him, and said it would be done-and nothing happened. The memorandum was pigeonholed." After the war Segrè found a file on Fermi in the archives of the fascist secret police, with critical reports about his tepid attitude towards the regime. The file also held the Fermi's memorandum to Mussolini and the letter of the Minister of Education, Balbino Giuliano, "who opposed Fermi's idea of a physics institute. He said it would arouse strong jealousies*

[23] F.Rasetti, 1937
[24] Buttaro, Rossi, 2007, pag. 238
[25] Cavallo-Messina, pag. 1133-1134

among all other physicists in Italy. That was the reason why the project was pigeon-holed.”[26]

It can be clear now how the problem arose inside the Institute of Physics after Corbino’s death, had a political imprinting. It was certainly another important reason that oriented the choice to stay or to go of the physicists.

The Congress of Rome, 1931

A first important indication of the high level reached by the Italian physics starting from 1926 was represented by the organization of an International Congress on Nuclear Physics. It was a very important Congress, as the list of the participants shows clearly. It was organized by the Royal Academy of Italy and it was hosted in a Farnesina’s palace. The Presidency of the Congress was assigned to two Nobel Prizes; besides it presented fifteen other Nobel Prizes (some of them had already won the prize others would be future winners) and a lot of other very important physicists, such as Lise Meitner and George Gamow.

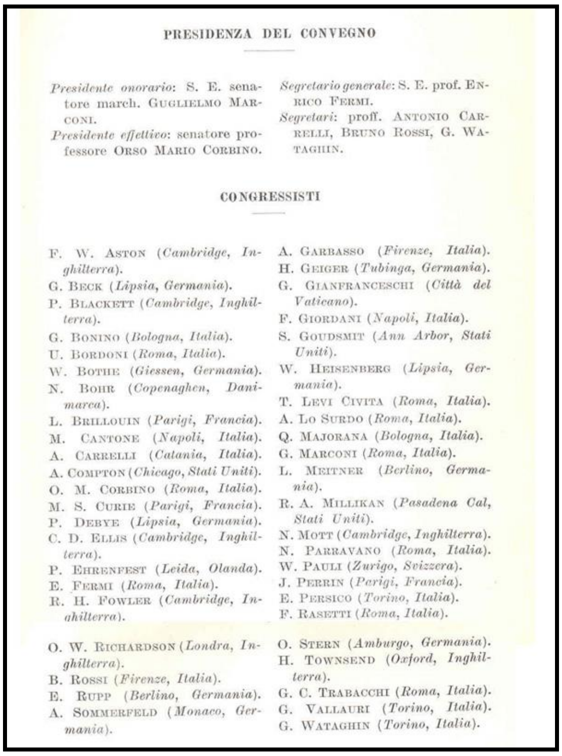
REALE ACCADEMIA D’ITALIA
FONDAZIONE ALESSANDRO VOLTA
ATTI DEI CONVEGNI
I

CONVEGNO
DI
FISICA NUCLEARE

OTTOBRE 1931-IX

ROMA
REALE ACCADEMIA D’ITALIA
[illegible]

Photo of the group



PRESIDENZA DEL CONVEGNO

Presidente onorario: S. E. senatore march. GUGLIELMO MARCONI.
Presidente effettivo: senatore professore ORSO MARIO CORBINO.
Segretario generale: S. E. prof. ENRICO FERMI.
Segretari: proff. ANTONIO CARRELLI, BRUNO ROSSI, G. WATAGHIN.

CONGRESSISTI

F. W. ASTON (*Cambridge, Inghilterra*).
G. BECK (*Lipsia, Germania*).
P. BLACKETT (*Cambridge, Inghilterra*).
G. BONINO (*Bologna, Italia*).
U. BORDONI (*Roma, Italia*).
W. BOTHE (*Giessen, Germania*).
N. BOHR (*Copenaghen, Danimarca*).
L. BRILLOUIN (*Parigi, Francia*).
M. CANTONE (*Napoli, Italia*).
A. CARRELLI (*Catania, Italia*).
A. COMPTON (*Chicago, Stati Uniti*).
O. M. CORBINO (*Roma, Italia*).
M. S. CURIE (*Parigi, Francia*).
P. DEBYE (*Lipsia, Germania*).
C. D. ELLIS (*Cambridge, Inghilterra*).
P. EHRENFEST (*Leida, Olanda*).
E. FERMI (*Roma, Italia*).
R. H. FOWLER (*Cambridge, Inghilterra*).
A. GARBASSO (*Firenze, Italia*).
H. GEIGER (*Tubinga, Germania*).
G. GIANFRANCESCHI (*Città del Vaticano*).
F. GIORDANI (*Napoli, Italia*).
S. GOUDSMIT (*Ann Arbor, Stati Uniti*).
W. HEISENBERG (*Lipsia, Germania*).
T. LEVI CIVITA (*Roma, Italia*).
A. LO SURDO (*Roma, Italia*).
Q. MAJORANA (*Bologna, Italia*).
G. MARCONI (*Roma, Italia*).
L. MEITNER (*Berlino, Germania*).
R. A. MILLIKAN (*Pasadena Cal, Stati Uniti*).
N. MOTT (*Cambridge, Inghilterra*).
N. PARRAVANO (*Roma, Italia*).
W. PAULI (*Zurigo, Svizzera*).
J. PERRIN (*Parigi, Francia*).
E. PERSICO (*Torino, Italia*).
F. RASETTI (*Roma, Italia*).
O. W. RICHARDSON (*Londra, Inghilterra*).
B. ROSSI (*Firenze, Italia*).
E. RUPP (*Berlino, Germania*).
A. SOMMERFELD (*Monaco, Germania*).
O. STERN (*Amburgo, Germania*).
H. TOWNSEND (*Oxford, Inghilterra*).
G. C. TRABACCHI (*Roma, Italia*).
G. VALLAURI (*Torino, Italia*).
G. WATAGHIN (*Torino, Italia*).

List of the participants

[26] A.Russo, 1986, pag. 305. The articles cited in Russo’s work are: Bordoni, Report, 10 marzo 1938 (CNRP, file 208); E.Segrè, Nuclear Physics in Rome, in R.H.Stuewer, ed., *Nuclear Physics in retrospect* (Minneapolis, 1979), 35-62, on 55

Photo of the group with didascalia:

1) Richardson; 2) Millikan; 3) Marconi; 4) Bothe; 5) Rossi; 6) L.Meitner; 7) Goudsmit; 8) Stern; 9) Debye; 10) Compton; 11) Curie; 12) Bohr; 13) Aston; 14) Ellis; 15) Sommerfeld; 16) Wataghin; 17) Perrin; 18) Corbino; 19) Trabacchi; 20) Cantone; 21) Parravano; 22) Rasetti; 23) Heisenberg; 24) Brillouin; 25) Townsend; 26) Ehrenfest; 27) Fermi; 28) Beck; 29) Persico; 30) Vallauri; 31) Giordani; 32) Bonino; 33) Mott; 34) Rupp; 35) Majorana Q.; 36) Garbasso; 37) Lo Surdo; 38) Carrelli

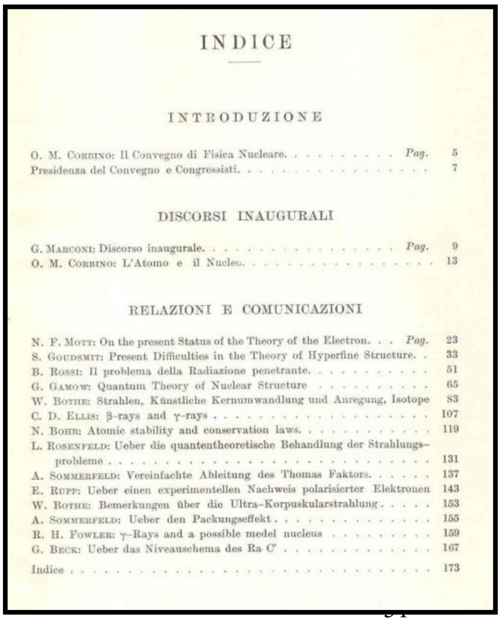
YEAR	WINNER	SUBJECT	YEAR	WINNER	SUBJECT
1948	Blackett	Physics	1923	Millikan	Physics
1954	Bothe	Physics	1945	Pauli	Physics
1922	Bohr	Physics	1926	Perrin	Physics
1927	Compton	Physics	1943	Stern	Physics
1903	M.Curie	Physics	1922	Aston	Chemistry
1938	Fermi	Physics	1911	M.Curie	Chemistry
1932	Heisenberg	Physics	1936	Debye	Chemistry
1909	Marconi	Physics			

The opening relation of the Congress was read by Orso Mario Corbino; among his words it is important to remember the following ones:

> *"If Science is far from a revolutionary innovation, it is possible, otherwise, to see a wide conceptual and experimental attention towards atomic physics; at the moment this is far from a rapid possibility of utilization, but it seems to have perspectives of very wide importance, due to the already known transformation of the elements and the existence of a big amount of energy that could be released during this changing. So there are a lot of reasons to choose the physics of the nucleus as subject of this Volta's Congress, that is collecting the main researches on this big problem."*[27]

The structure of atomic nucleus is not so definite at the time of the Congress, as it seems clear from the initial speech of Marconi; even if there was the suspect of the existence of a massive and neutral particle inside the nucleus, only one year later Chadwick experimentally confirmed it. To the ones that were concerned with the problems of nuclear physics the presence of very strong forces insides the nucleus began to be clear. Corbino himself was concerned in this kind of problem, and he, contemporarily, was proud of the works carried on by the group of Rome, especially for the capacity to understand the right moment and the right topics on which to work, both experimentally and theoretically.

Also from Corbino's talk:



INDICE

INTRODUZIONE

DISCORSI INAUGURALI

RELAZIONI E COMUNICAZIONI

[27] O.M.Corbino, 1931, pag. 14

> *"In the game of the forces that the electrons undergo from the middle and for those that the electrons practice each other, the group arises a stable configuration that was established exactly for all the elements. To reach this goal a new mechanics was needed, called Quantum Mechanics, that was rising because it became clear that the laws and the methods of classical physics became insufficient inside the atom. It was obtained a theory perfectly agree with the known facts and that gave the possibility to introduce a lot of news, sacrificing the old concepts of Mechanics and Electrodynamics and revolutionizing a lot of the ideas that had been used to talk about the phenomenon of the microscopic world"*[28]

At the Congress Bruno Rossi, gave a report on his works on cosmic radiation; it was the deserved recognition to the introduction of Rossi's "coincidence circuit". He remembered:

> *"Thanks to the improvement of the devices already used and to the making of a new method to investigate, our experimental knowledge of the phenomenon has been gradually expanding and specifying; so, if until some years ago it could be possible to have some doubts on the existence of the penetrating radiation, we now possess sufficiently precise notions on the absolute value of its intensity, on the dependence of its from the altitude of the place to observe, on the geographical sites, etc …"*[29]

In the conclusion of his work Rossi stated:

> *"The phenomenon attributed to the penetrating radiation took their origin from the presence, in the atmosphere, of a radiation whose primary ionizing powerful is much greater than that of the common γ rays, and, even more, of γ rays with hardness equal to the hardness of the penetrating rays. Until proven otherwise it has to be considered a corpuscular radiation."*[30]

Articles published on Il Nuovo Cimento, 1900 – 1940

It is possible to find a good indication on the validity of a school of physics analyzing the articles published by the researchers group, using some clear parameters to evaluate it. In the case of the physics in Italy in the period 1900-1940 the majority of the articles were published in Il Nuovo Cimento; it is true that a lot of articles were published in other magazines, in some cases foreign magazines; inside the thesis from which this article has been extracted there is a complete analysis of the situation.

The data have been divided in some topics to help the reading; to the same goal the period has been divided in two equal periods (1900-1920 and 1921-1940), each one twenty years long. This last division is based on an important fact; at about the middle of the Twenties on the Italian picture there was big news: Enrico Fermi in 1926 obtained the first chair of theoretical physics, in Rome. It was a fundamental event with a lot of consequences. But it is also important to have two periods of the same length; so the choice to divide the period in two parts of twenty years each one.

Together with the numerical analysis it is useful to have also the relative graphs; In these two graphs the same colour corresponds to the same topic.

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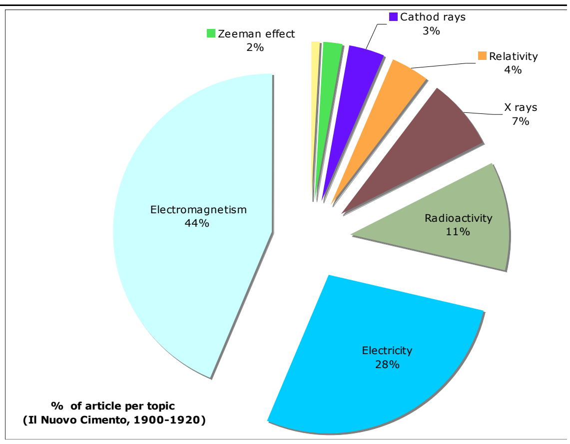
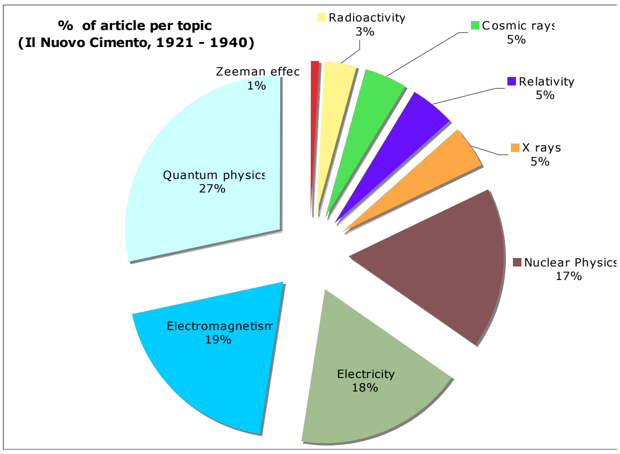
[28] ibid, pag. 14
[29] B.Rossi, 1931, pag. 51
[30] ibid, pag. 64

		1900-1920		1921-1940		
JOURNAL	**TOPIC**	**N art.**	**%**	**N art.**	**%**	**Δ (%)**
Il Nuovo Cimento	Zeeman effect	6	2,1	3	1	**-1**
	Cathode rays	10	3,5	0	0	**-3**
	Cosmic rays	0	0,0	14	5	**5**
	Relativity	11	3,8	14	5	**1**
	X rays	21	7,3	14	5	**-3**
	Radioactivity	32	11,2	10	3	**-8**
	Nuclear Physics	0	0,0	53	17	**17**
	Quantum physics	2	0,7	88	28	**28**
	Electricity	79	27,6	55	18	**-10**
	Electromagnetism	125	43,7	59	19	**-25**
		286	**100**	**310**	**100**	

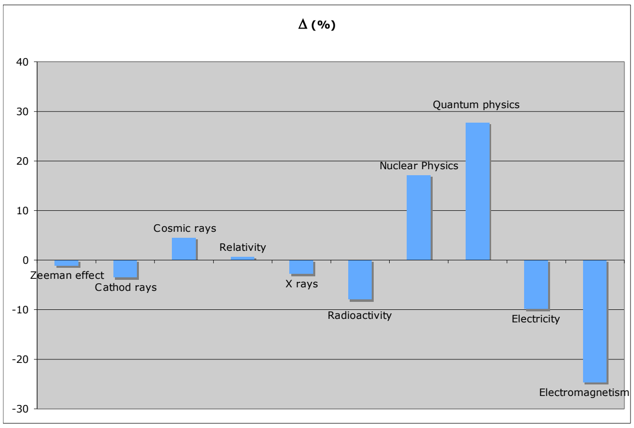
1900 - 1920



1921 - 1940



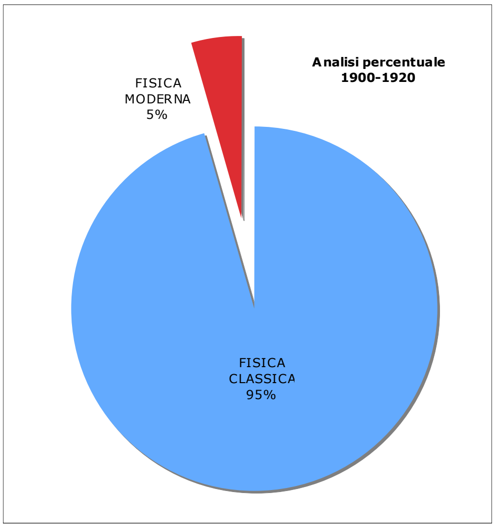
Reading the data and the graphs it is possible to obtain some indications and also to underline some particular characteristics. Passing from the first twenty years to the second period it is possible to see some big differences: in particular there is a clear decrement of the number of articles classified as Electromagnetism and Electricity; at the same time the increasing of the number of articles referred to Quantum Physics and Nuclear Physics is evident. The other topics present some differences, but not as evident as these last ones. For this reading the use of the graphical indication is useful:

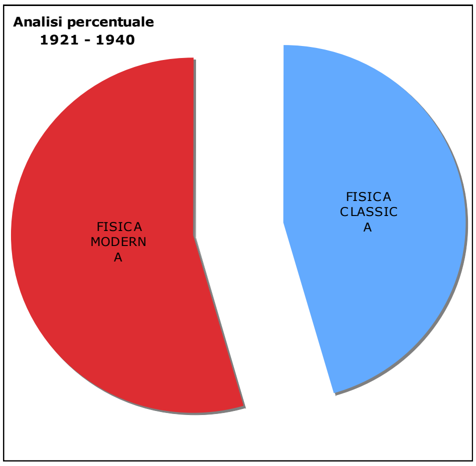


To complete this part it would be useful to supply a reading of the data of all the period. In the last column of the following table is indicated the type of topic, such as to say if the topic has a classical (C) or a modern (M) characteristic.

JOURNAL	TOPIC	N art.	%	Class/Mod
Il Nuovo Cimento	Zeeman effect	9	2	C
	Cathode rays	10	2	C
	Cosmic rays	14	2	M
	Relativity	25	4	M
	X rays	35	6	C
	Radioactivity	42	7	C
	Nuclear Physics	53	9	M
	Quantum physics	90	15	M
	Electricity	134	22	C
	Electromagnetism	184	31	C
		414	69	TOT C
		182	31	TOT M

It would be interesting to read these data from the point of view of the two periods indicated previously; the evident increasing of the number of articles on Modern physics is equal to 41%. It is a big variation, clear consequence of the new orientation of the research in Physics in Italy.

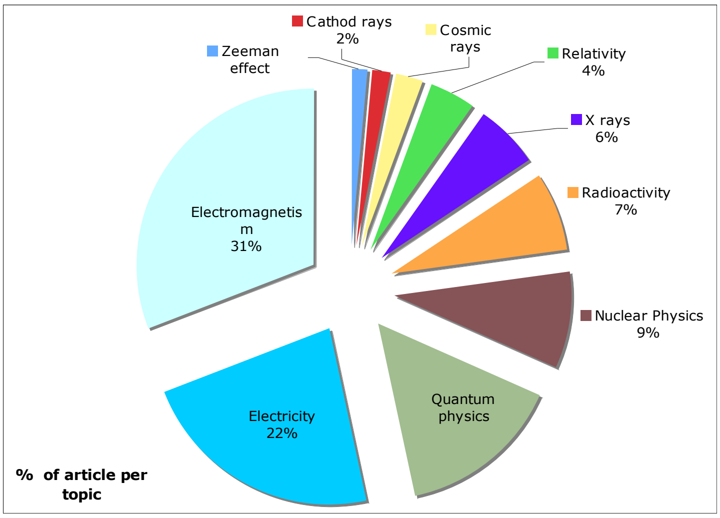




MODERN PHYSICS	4,55%
CLASSICAL PHYSICS	95,45%
	100,00 %

MODERN PHYSICS	45,48%
CLASSICAL PHYSICS	54,52%
	100,00 %

In the longer period it becomes evident that the articles on Classical Physics prevailed over the ones on Modern Physics (69% the first one; 31% the second one). In the next graph the data of the complete period divided per topic have been reported. The total data confirm the change in the orientation of the research with a prevalence of the articles with classical subject, with Electromagnetism and Electricity at the top (in per cent).

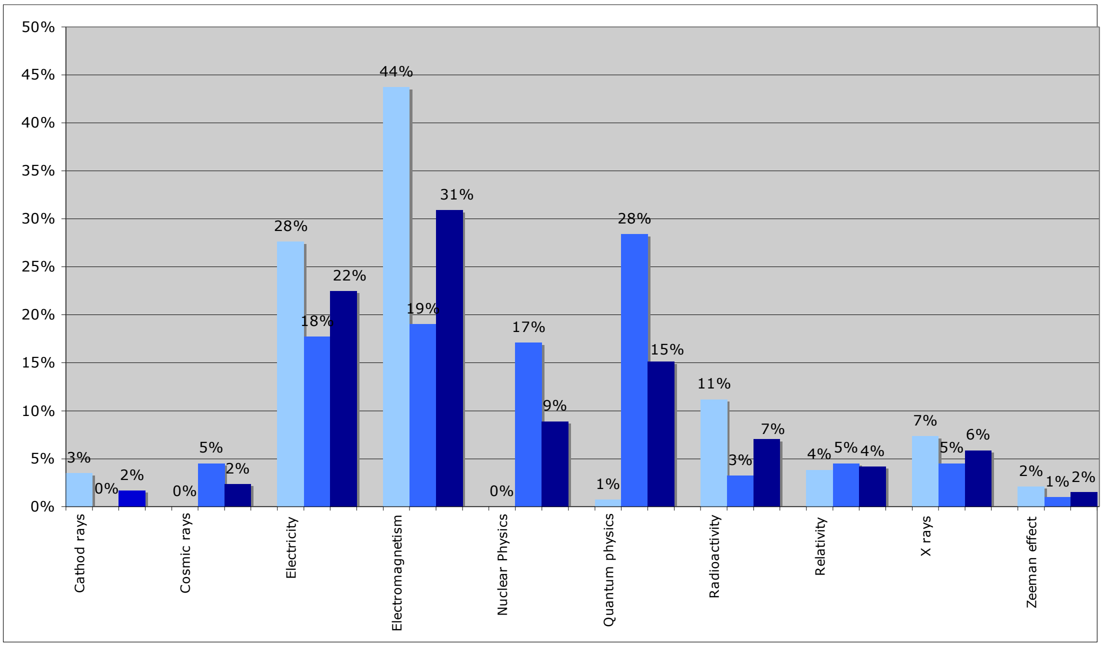


To finish this analysis in the next table and graph have been reported the data divided per topic and per period, as indicated in the lower table. This is a complete reading of all the possible data.

TOPIC	N art.	%	PERIOD	TOPIC	N art.	%	PERIOD
Cathode rays	10	3	1	Quantum physics	2	1	1
	0	0	2		88	28	2
	10	2	3		90	15	3
Cosmic rays	0	0	1	Radioactivity	32	11	1
	14	5	2		10	3	2
	14	2	3		42	7	3
Electricity	79	28	1	Relativity	11	4	1
	55	18	2		14	5	2
	134	22	3		25	4	3
Electromagnetism	125	44	1	X rays	21	7	1
	59	19	2		14	5	2
	184	31	3		35	6	3
Nuclear Physics	0	0	1	Zeeman effect	6	2	1
	53	17	2		3	1	2
	53	9	3		9	2	3

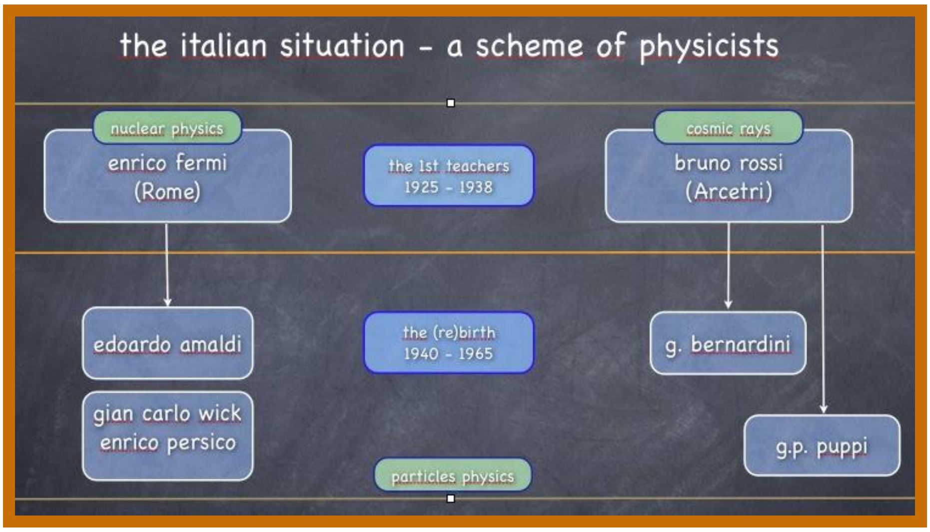
reading	1900 – 1920	1921 – 1940	1900 – 1940
	Period 1	Period 2	Period 3
	Art. = 286	Art. = 310	Art.. = 596

The last data are reported in the next graph, where light blue corresponds to Period 1; blue corresponds to Period 2 and dark blue corresponds to Period 3.



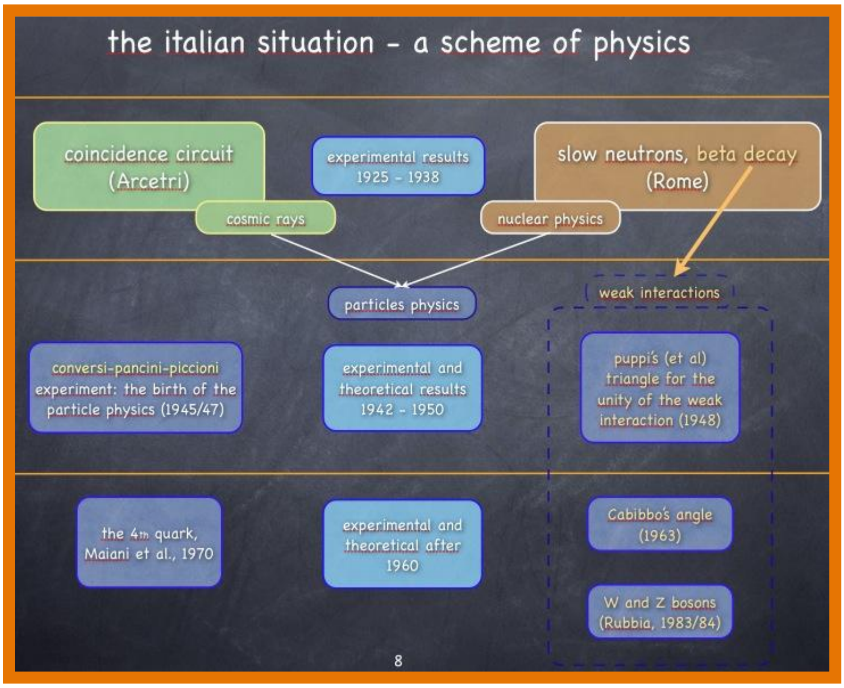
The background idea

Behind each work there is a strong idea that guides the path. In this case my idea is to look for some guidelines along which the Italian physics has been developing during the indicated years. I have tried to sum up these guidelines in two schemes; the first one is about the Italian situation in terms of people whose work concurred to the (re)birth of physics. The second one is about the main topics that were developed and that contributed to the change from classical to modern physics, with its consequences.



As it always happens every time you resort to patterns, some simplifications have been introduced and some aspects have been forgotten. In the previous scheme are taken into account only the physicists that studied the topics connected to the two main Italian schools, such as cosmic rays physics and nuclear physics, before WWII. After WWII the two previous topics formed the elementary particle physics, a fields of research in which Italian physics obtained a lot of very important awards.

In the last scheme with the wording "the 1st teachers" I have indicated a first level from which starting to go towards the "new physics". In the lower part of the scheme I have indicated other two fundamental teachers such as Edoardo Amaldi and Gilberto Bernardini. These two people made the main work necessary to allow the "new start" of physics, even in the very difficult conditions of Italy after the end of WWII. At the same time it is important to remember some of the other physicists that worked for the same goal, although with different importance, for many different reasons. In fact Gian Carlo Wick and Enrico Persico spent a lot of years outside Italy, meanwhile Giampietro Puppi played a fundamental role in a particular case, the one of the University of Bologna. There was, obviously, a lot of other important physicists, but for many reasons these were not involved in the same topics and in the same works.



Another scheme is the one called "The Italian situation – a scheme of physics". In this case it indicates some of the main guidelines of the research in physics in Italy. As in the previous case these are not the only possible paths of research, but are some of the most important of them, as for topics, as for the award obtained. In the upper part of the scheme it the two main topics developed in the period 1925-1938 are indicated; in the middle part of the scheme it indicates the new topic that summarized the previous two. Together with the new topic – elementary particle physics – it also indicates one of the most important experiments: the Conversi-Pancini-Piccioni experiment that has usually been considered the starting point of the elementary particle physics. In the lower part of the scheme it shows some of the main results obtained in the field of elementary particle physics after 1960. Particular attention must be given to a specific topic of research in which Italian physics has always played a guide role; I am talking about the weak interaction that, started with Fermi's work in the Thirties, continued until 1984 when Carlo Rubbia won Nobel Prize for his discovery of $W^{\pm}$ and Z_0 bosons.

To finish I would like to remember Occhialini's words:

> *"I have always wished to leave to History a geometrical picture as in the case of Feynman, Puppi and some other; probably this is, for me, the last occasion. The shape is the triangle: an equilateral triangle that represents the situation here, from my point of view. [...] We call "the mystic triangle" or, for practical reason, the stool with three legs. Here we put Garbasso (the upper vertex), here we put Persico (in the lower vertex in the right) and here we put Abetti (lower vertex in the left) [...]. The triangle that says the total weight is positive, which totally changes the relation is the presence in this laboratory of three people called Garbasso, Persico and Abetti. They were the three legs of the stool and they created all the difference in a situation otherwise unsustainable."*[31]

3. After WWII

[31] G. Occhialini, 2007, pag.75, 76.

Until now the article has talked about what the situation of physics in Italy was before WWII. In this period was placed the basis for the "new start" of Italian physics; it has been defined a "new start" to distinguish it from a re-start or a second start to underline the fact that there was a clear cut in the physics before and after WWII. Towards the end of the Thirties the majority of the physicists of the two initial groups (Arcetri and Rome) were abroad due to a lot of motivations. First of all the problem caused by the odious racial laws, promulgated by the Italian fascist regime in 1938; these laws forced a lot of physicists with their families to go abroad to save their life. From the point of view of the research, the consequences of these laws were very heavy because only few physicists could choose to stay in Italy. Let's see the various situations in the main Institutes of physics in Italy.

Institute of Arcetri	• The majority of the physicists of the school changed Institute • The Institute passed from class A to class B losing importance
Institute of Rome	• It lost a lot of physicists, first of all Fermi • It remained the most important Institute in Italy • During the war it carried on a very important experiment, the Conversi-Pancini-Piccioni experiment
Institute of Milan	• In Milan the war ended later than in Rome and in southern Italy, so the situation of isolation was longer. • There were a lot of problems to publish articles
Institute of Padua	• The majority of the physicists went abroad • A lot of young physicists stayed here • The Institute began to study cosmic rays
Institute of Bologna	• It was an Institute strongly linked to the classical and experimental physics • There was a very small number of students • The situation changed with the arrival of Puppi (near the end of the Forties)
Institute of Turin	• Persico went abroad due to the racial laws • Only after the end of the war there was a restart with Gleb Wataghin

In the previous part of this article it is nominated an experiment, the Conversi-Pancini-Piccioni experiment; it was a very important experiment for physics, but it was also a clear indication of the strong will of the Italian physicists to cross over the terrible period of the war to go towards better times. The experiment was realized in very difficult conditions: together with the problems of each war, such as finding something to eat or to drink, fear of dying, starting from 1943 all Italian regions were subject to frequent and very hard bombing. To be able to realize an experiment in these conditions was very hard; for these motivations this experiment showed the evidence of the desire of the Italian physicists to look ahead, to think how to (re)build the right environment to do what they were able to do: the modern physics. It is possible to find trace of this will also in the letters that a lot of the physicists were used to exchange. At the library of the Department of Physics of the University of Rome "La Sapienza" is located the archive of Amaldi's letters[32], a real treasure

[32] For completeness: at Amaldi's archive are located also some other very important archives, such as a part of Persico's archive and Conversi's archive.

for the history of physics. For my PhD thesis I examined Amaldi's archive and I found a lot of very interesting letters. In particular I read these letters:

n. of letters	sender	recipient
39	Amaldi	Puppi
30	Puppi	Amaldi
116	Amaldi	G.Bernardini
148	G.Bernardini	Amaldi
16	Amaldi	Wick
12	Wick	Amaldi
1	Amaldi	Persico
1	Persico	Amaldi
2	Cacciapuoti	Amaldi

It is a very high number of letters (365 letters in total) and with a lot of very interesting particulars. All these letters were written in a period between 1940 and 1965. The topics covered by the letters are different; some letters are about the economic situation in Italy, some others are about the problems encountered to guarantee the right funds for economic support of the research, some other are about the wrong Italian habits to find the right recommendation. Let's see one of these letters about the economic situation; it is a letter written at the beginning of 1949 by Amaldi to G.Bernardini:

> *" Dear Gilberto, I'm writing to you only a few lines to add to the letter of Cortini. You ask me, in your last letter, if it would be possible to allocate 500 dollars to build a device that you would bring here. I agree with you in principle, but remember the economic situation: before the end of 1948 we have already spent the first rate of the budget of 1949, that would be enough until July; a few million of debt that I don't know how to pay; the salaries of these and of the following months to pay without having the right budget. Debts in dollars of the Institute: to me starting from 1946 at about $400 and to you at about $250 of which only one half guaranteed by an anticipation that you have received before starting. […] The possibility to find money … only few Italian lire by Consiglio della Valle."*[33]

In the next communication, dated the 5th of June of 1950, in a letter from Bernardini to Amaldi, it is possible to read:

> *"You say to me that the economic situation is not so bad, and that you are without debts. I see the work of a new Quintino Sella and I tribute it to you, together with my congratulations, too interesting to be genuine."*[34]

Another very important point of view on which I worked during the composition of my PhD thesis is the research of a quantitative system to evaluate the goodness of the results produced by a school of physics. In particular, for this goal, it suggested the idea to use the results obtained by a school of physics. With the term "result obtained" I mean both the number of prizes awarded to the people that studied in a school, and the "number of significant articles" published. With the word "prizes" I mean the Nobel Prize together with some other very important and international prizes such as the Dirac Medal, for example. At the same time with the words "number of significant articles" I mean the results of the statistic investigation executed on

[33] Letter from E.Amaldi to G.Benardini, 20/1/1949
[34] letter from G.Bernardini to E.Amaldi, del 5/6/1950

the article published by The Physical Review and The Physical Review Letters during its first one hundred years of activity. These results were published on a special number of the Review.

Let’s start with The Physical Review Letters:

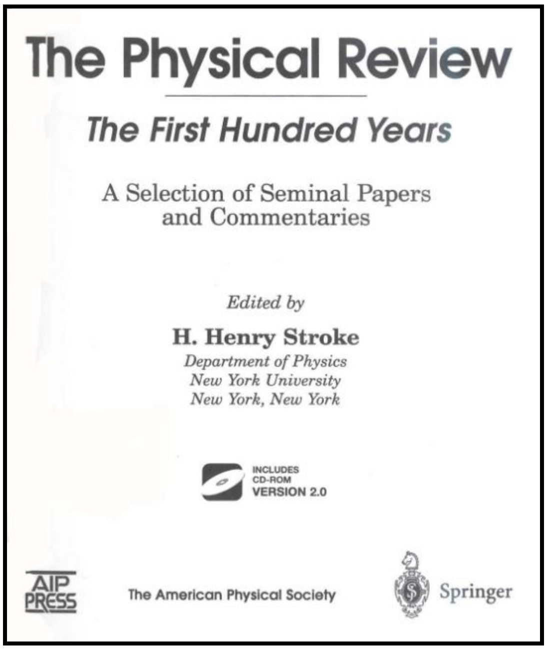
> *“The Physical Review-The First Hundred Years is a selection of seminal papers and commentaries highlighting the developments in physics and their applications presented in printed and electronic form.*
> *The publication of this collection is sponsored jointly by the American Physical Society and the American Institute of Physics in celebration of the 100th anniversary of The Physical Review”.*[35]

The book is divided in eleven different topics of physics; inside each one of these chapters are indicated the best articles edited in the review in the last hundred years. It is important, for the Italian case, to note that this book was edited in 1995; therefore, the period under observation for the analysis starts in 1895. As shown in the previous part of this work, the Italian physics underwent a significant change in its subject of research in the Thirties: it will be interesting to observe the influence of this change in a period of time so long.

So, let’s start with the analysis of the results extracted from The Physical Review and referred to the Italian case.

- (The Physical Review then and now)
- (One hundred years of the Physical Review)
- (The early years)

- Atomic physics
- Nuclear physics
- Statistical physics
- Gravity physics and cosmology
- Cosmic radiation
- Condensed matter
- Plasma physics
- Elementary particle physics experiments
- Particle theory
- Science and technology
- Quantum mechanics



In this review are collected a lot of articles of physicists from all over the world. To place these statistical data inside this work it is interesting to extract the data referred only to the Italian physicists. The results of this partial analysis are reported in the following table

35 The Physical Review. The first hundred years, pag V. *“Our journals in the main are nothing more, or less, than the combined efforts of our past and present colleagues, American mainly in the early days but recently more and more representing international physics (well over 50% of our 1993-1994 submission are from non-U.S. sources).”*[35]

subject	**articles**	**%**
atomic physics	6	17
nuclear physics	4	11
statistical physics	1	3
cosmic radiation	4	11
elementary particle physics experiments	10	29
particle theory	5	14
science & technology	4	11
quantum mechanics	1	3
TOTALE	**35**	**100**

The percentages indicated in the last table were calculated for only the Italian articles.

For Italian physics there is another important note in The Physical Review Letters; in one of the chapters of the book, the one titled "Elementary particle physics experiments", the first article present is "On the disintegration of negative mesons" written by Conversi, Pancini and Piccioni. It is just the article written after the famous experiment executed by the three Italian physicists during the war. It is a very important acknowledgment for the physicists and for the Italian physics. It is a clear indication of the high quality of the work made in Italy in the period after WWII.

To complete the analysis were used other data available on Internet in some specialized sites. This further study allowed to pick up the data of a lot of other reviews to have a full picture of the articles published by the Italian physicists during the chosen period. The data referred to the articles edited on Italian reviews were extracted form the site http://fisicavolta.unipv.it/asf/archives.asp; the other data, referred to the articles published on foreign reviews were extracted from the following sites:

http://www.springerlink.com/
http://scitation.aip.org/
http://publish.aps.org/[36]

For example, in the case of Gilberto Bernardini using the previous system for the analysis of his data it is possible to find the following further information:

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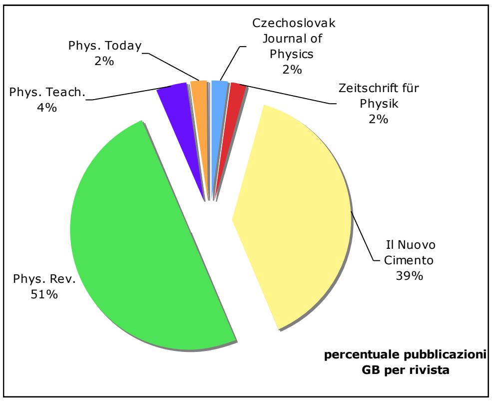
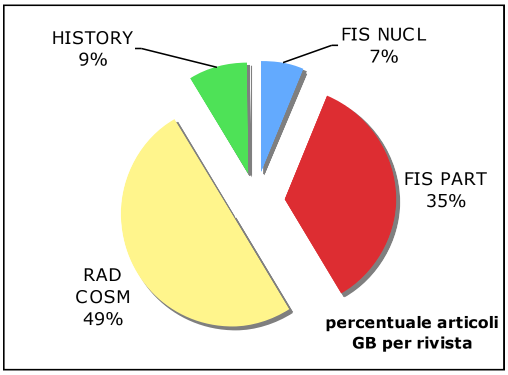
36 The reviews analysed are: *Il Nuovo Cimento, Zeitschrift für Physik* (Springerlink); *Physical Review Letters*, *Review of Modern Physics*, *Physical Review A – E* (APS); using Scitation it is browsing through hundreds of different reviews such as *Physics Today*, *Physics Review*, *AIP Conferences Proceedings*, *Review of Scientific Instruments*. To these has to be added a specific research in *Proceedings of the Royal Society of London* made to check some articles written by Amaldi at the beginning of his scientific career.

Journal	Pap.	%
Czechoslovak Journ. Physics	1	2,2
Zeitschrift für Physik	1	2,2
Il Nuovo Cimento	18	39,1
Phys. Rev	23	50,0
Phys. Teach.	2	4,3
Phys. Today	1	2,2
	46	**100,0**



Subject	Q.ty	%
FIS NUCL	3	6,5
FIS PART	16	34,8
RAD COSM	23	50,0
HISTORY	4	8,7
	46	**100,0**



These data are resulting from previous elaborations of the results obtained by the analysis of the specified review. In this case some interesting data are emerging. In particular it is possible to confirm the prevalence in Bernardini's work of the research on Cosmic rays physics and Elementary particle physics, so it is clear the predominance of two reviews on which editing the articles (Il Nuovo Cimento and Physical Review). Through a deeper analysis, not possible in this context, it should be possible to underline how Bernardini edited his articles on the various reviews in a uniform ways during the years of his scientific activity. In other words, there isn't a predominance of a specific review in a period of time in Bernardini's case, such as it was, instead, in the case of other physicists in the same period.

Another characteristic that rises from the previous analysis is connected to the topics of Bernardini's researches. In all this scientific career the physicists studied, with a clear prevalence, the problem connected to Elementary particles and Cosmic rays physics. Only towards the end of his scientific career he gave attentions to other topics; in particular, together with others, he started to study the history of physics and to deepen the problems linked to the education in physics of the young students. In this effort one of his colleagues was Laura Fermi, the wife of Enrico Fermi.

The International awards

To end this work I would like to underline a last point of my research. I think it is important to find an objective method to determine if the work of the schools of physics has given good results. Together with the analysis of the articles published in the reviews, another, complementary method consists of a research on the awards won by the physicists of the country. In particular I have chosen the International Prizes meaning, with this term, the Prizes that are placed at physicists' disposal International Associations such as the Swedish Academy for Sciences for the Nobel Prize, the Dirac Medal from the International Centre for Theoretical Physics of Trieste (Italy), the Boltzmann Medal from International Union of Pure and Applied Physics, and so on.

Among all these prizes I have analysed in a deeper manner only the case of the Nobel Prize, for two reasons: it is the most important scientific prize of the world (and also the most known also by people) and it presents a very particular method of decision, long and complex. What's more, for this prize are available also the data relative to the practice of the decision; it is a very interesting procedure; from which it is possible to extract other interesting readings of the facts. It is important to remember that the data of the choice of the Nobel's winner are available only Fifty years after the year under analysis. At the moment the only publication on this subject is dated 1992; it means that the data are available from 1900 to 1951.

In this article I report only some cases among all the ones that I have studied. In particular I would like to talk about a specific point of view of the Nobel Prize together with the analysis of the Wolf Prize in Physics. It is only a subjective (personal) choice.

The Italian winners of the Nobel Prize are known; more interesting is to analyse the nominations (i.e. the number of times that a physicists /has/ was indicated as possible winner of the prize) received by the Italian physicists in the available period (1900-1951):

name	Nomin.	Nomin.	Nomin.
Casalis	1	Pavia	1
Fermi	35	Righi	40
Marconi	15	Rossi	6
Occhialini	7	Vallauri	4
Total nomin.	**109**		

In the previous table there are a lot of interesting indications; let's start. The total number of nominations is high; among them the highest number was obtained by Righi, and the lowest by Canalis; none of these two ever won the Prize. Also Fermi had obtained a very high number of nominations, but he won the Prize. The data referred to Occhialini is very intersting; as it is said he was one of the most important physicists of his period, and played a fundamental role in the discovery of the positron in the cosmic rays (with Blackett) and in the discovery of the pion (with Lattes and Powell). Even if he never won the Nobel Prize these data say that he came very close to win it.

To deepen the analysis it is possible to specify also the year in which a physicists received the nominations. From the following table it is possible to see the year of each nominations together with the number of nominations.

name	year	num	name	year	num	name	year	num
Canalis	1915	1	Marconi	1933	1	Righi	1913	5
						Righi	1914	4
Fermi	1935	3	Occhialini	1936	1	Righi	1915	1
Fermi	1936	4	Occhialini	1949	4	Righi	1916	2
Fermi	1937	13	Occhialini	1950	2	Righi	1917	2
Fermi	1938	11				Righi	1918	1
Fermi	1939	2	Pavia	1915	1	Righi	1919	3
Fermi	1947	1				Righi	1920	4
Fermi	1948	1	Righi	1905	1			
			Righi	1906	1	Rossi	1947	2
Marconi	1901	1	Righi	1907	2	Rossi	1948	1
Marconi	1902	2	Righi	1908	4	Rossi	1949	3
Marconi	1903	6	Righi	1909	1			
Marconi	1908	2	Righi	1910	5	Vallauri	1934	1
Marconi	1909	2	Righi	1911	1	Vallauri	1935	1
Marconi	1929	1	Righi	1912	3	Vallauri	1941	2

The complete analysis of these data is available in my thesis and it is completed with the reading of these data from almost all the possible points of view. He same work could be done also on the nominators, the physicists called to decide the winner.

Another very important prize that is available every year for physicists is the Wolf Prize in Physics. I have chosen this prize because it is full of significance for the development of physics in Italy after WWII. As it is said in the introduction to the prize:

> "*The prize will normally be awarded for theoretical contributions made at an early stage of the recipients research career.*".

Among all the winners there were three Italian physicists: Bruno Rossi, Riccardo Giacconi and Giuseppe Occhialini: it seems the logical conclusion of this article. Rossi and Occhialini were two of the main physicists of the period analyzed in this article and were also two of the teachers of the Italian school, even if Occhialini stayed abroad for long years. Besides the association of Rossi with Giacconi is very right, because the last one is the "scientific son" of the first, and the first is one of the fathers of the (new) physics in Italy after WWII. It is a clear indication of an important continuity between the first teachers and their followers.

YEAR / SCIENTIST	MOTIVATION
1987 Bruno Rossi, Riccardo Giacconi (con Herbert Friedman)	*for the discovery of extra-solar X-ray sources and the elucidation of their physical processes.*
1979 Giuseppe Occhialini (with GE.Uhlenbeck)	*for his contributions to the discovery of electron pair production and of the charged pion.* *Professor Giuseppe Occhialini has contributed to the discovery of electron pair production, jointly with P.M.S. Blackett and J. Chadwick, and to the discovery of the charged pion, jointly with C.M.G. Lattes, H. Murihead and C.F. Powell. Giuseppe Occhialini has also contributed to major research techniques including cloud chambers triggered by counters and the use of special photographic emulsions to study cosmic rays.*

To finish this part I would like to report the complete motivation associated with Rossi's Wolf Prize (the bold is mine):

> *"Professor Bruno B. Rossi initiated in 1959 research aimed at utilizing the burgeoning space technologies in a search for extra-solar X-ray sources.* ***Motivated by a lifelong interest in the nature and origins of cosmic radiations, a field of study to which he had been making major contributions since the early 1930´s****, Rossi persuaded the management and scientists at American Science and Engineering, Inc, to undertake a study of the theoretical and experimental prospects for X-ray astronomy. This study, carried out under the leadership of Riccardo Giacconi, led to proposals for new forms of X-ray optics utilizing grazing incidence reflection, and exploratory rocket experiments to scan the sky with X-ray detectors of much greater sensitivity than had previously been used. […]*

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Amaldi’s archive

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