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Oral History Interview

Interview With Nicola Cabibbo

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Abstract After 25 years, this oral history interview with Nicola Cabibbo, recorded in July 2000, is being made available to an international audience. In the interview Cabibbo describes his early years as a student at the Sapienza University of Rome in the 1950s and his collaboration with Raoul Gatto in the pioneering work that launched e^+e^- physics in the early 1960s. The knowledge gained in those years through the systematic application of SU(3) symmetry to particle physics prepared the ground for his greatest achievement: the formulation of the mechanism responsible for quark mixing, which paved the way for the unification of the electromagnetic and weak interactions. Cabibbo's significant influence on the revival of theoretical physics in Italy and his inspiring contribution to the development of a Roman school are also testified, together with his wide interests and lively curiosity which led him to promote the realization of a series of parallel supercomputers for numerical simulations of quantum field theory (the APE line). His extraordinary dedication, rigor and vision in promoting Italian scientific and technological development as President of the National Institute for Nuclear Physics (INFN) and other scientific institutions form a relevant and meaningful part of the narrative, which also includes significant recollections of his role as President of the Pontifical Academy of Sciences. Prominently mentioned are: Guido Altarelli, Edoardo Amaldi, Gilberto Bernardini, Francesco Calogero, Marcello Conversi, Ugo Fano, Enrico Fermi, Bruno Ferretti, Raoul Gatto, Murray Gell-Mann, Makoto Kobayashi, Luciano Maiani, Guido Martinelli, Toshihide Maskawa, Giorgio Parisi, Roberto Petronzio, Giuliano Preparata, Giorgio Salvini, Massimo Testa, Bruno Touschek.

1 Introductory notes

Twenty-five years later, this interview with Nicola Cabibbo, who passed away in 2010, has acquired unquestionable historical value, reinforced by the more general interest in his scientific and human legacy. For this reason, it is appropriate to make it available to a wider audience than was originally intended.[1] The interview was part of a large-scale program sponsored by the Italian Society for Oral History, the aim of which was to collect oral sources on the history of scientific research policy in Italy. In the course of this program, an interest arose in conducting a series of interviews with physicists, highlighting in particular their commitment and passion for research, for the education of young people, and for the strengthening of research institutions and their role in society. The collected material, originally destined to be preserved in the State Archives, has instead been faithfully transcribed and published in a special volume, in order to make it available to a wider audience and, in particular, to make the relevant cultural tradition of the Italian School of Physics more widely known [1].

The series included representatives of the generation of physicists who had trained before and during the war (Giampiero Puppi and Giorgio Salvini) and in the early post-war years (Giorgio Careri, Gianfranco Chiarotti, Carlo Bernardini, Giovanni Jona-Lasinio), through the 1950s (Nicola Cabibbo, Francesco Calogero) and 1960s (Francesco Melchiorri, Luciano Maiani, Giorgio Parisi).

Through the unfolding of personal experiences, the individual stories brought to light the collective memory of a group that was eager to contribute to the reconstruction and relaunch of European physics, to revitalize the field at the national level, as well as to restore and create new links on the international scene. Each of them

[1] The text presented here is the faithful translation of the original transcription of the oral history interview, conducted by L. B. and recorded in the study of Nicola Cabibbo at the Sapienza University of Rome, Italy, on July 12, 2000. The transcription has been edited very slightly to eliminate hesitations and repetitions of the spoken language, and has been approved by Cabibbo. The Italian version was published in the collective volume *Fisici italiani del tempo presente. Storie di vita e di pensiero* [*Italian physicists of the present. Stories of life and thought*] ([1], pp. 45-66) and the original recording is kept in the archives of the Italian Oral History Association.

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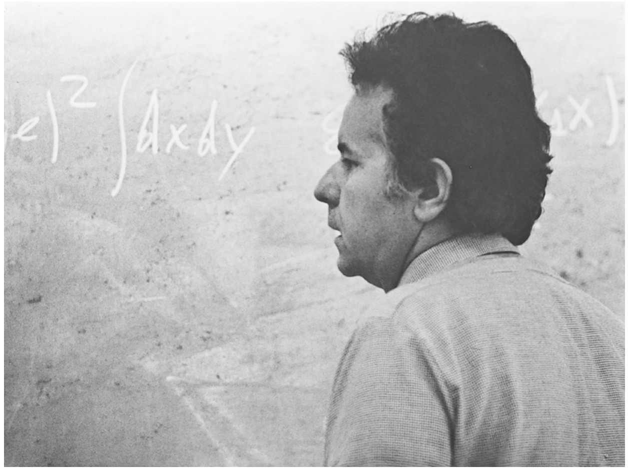

Fig. 1 Nicola Cabibbo in the 1980s. Courtesy of Cabibbo Family, all rights reserved

played a crucial role in different areas of physics research, some of which were developing or receiving new impetus during those years, in the context of the unprecedented perspectives offered to physics, a science that had played a gigantic role during the conflict and had therefore generally enjoyed a huge credit, also in terms of funding and resources available, especially in the United States.

These figures were representative of three important phases in the development of Italian physics, corresponding in a sense to three 'generations' that participated in different ways first in the reconstruction and then in the increasingly explosive development that characterized the 1960s and 1970s, with the emergence of new areas of research and their consolidation within a scientific community that was exceptionally dynamic and integrated at the highest levels in the world scenario.

To better understand the evolution of this community after the Second World War, it's useful to briefly review its roots and early development, to highlight both the continuity with the past and the transition to a new era of Italian physics, and to help situate Nicola Cabibbo's university years of the 1950s and the environment of his early scientific and personal formation.

The journey of modern physics in Italy officially began in 1926, when Enrico Fermi and his close friend Enrico Persico won the competition for the first Chair of Theoretical Physics to be established in the country.[2] In the course of just over a decade, Italy witnessed an unprecedented phenomenon: the rise of modern physics by a small group of brilliant young scientists. In particular, two areas of research were developed: nuclear physics by Fermi and his group in Rome [3], and the study of cosmic rays pioneered by Bruno Rossi in Florence. The development of these skills formed the basis for the birth of one of Italy's most characteristic research traditions still today: elementary particle physics.

In parallel with the establishment of a solid experimental tradition, a small nucleus of young theorists had also emerged around Fermi, like Ettore Majorana, Giovanni Gentile Jr., Gian Carlo Wick, Ugo Fano and Bruno Ferretti. For a variety of reasons, Ferretti was the only member of this group left in Rome after the war. However, his contribution in terms of continuity with the past and the promotion of renewal is relevant to the events surrounding Nicola Cabibbo. Ferretti would not only bring Bruno Touschek (Cabibbo's thesis supervisor) to Rome in the early 1950s, but would also become the thesis supervisor (along with Marcello Conversi) of Raoul Gatto, with whom Cabibbo would later begin his brilliant scientific career.

Needless to say, Fermi's scientific genius exerted a special impetus that remained alive even after his departure from Italy in 1938. The promulgation of the Racial Laws, and Benito Mussolini's alliance with Adolf Hitler, as well as the lack of economic prospects for the development of laboratories equipped with modern research tools such as accelerators, caused a serious diaspora. This led to the catastrophic loss of a large part of the new generation that had been the artifex of the revival of Italian physics on the international scene. Up to that point, Italy had produced outstanding physicists. But they were generally isolated personalities, 'lone wolves', none of whom had ever worked in a 'research group' or created a 'school' as Fermi and Rossi had done in different ways over the course of barely 10 years, in the 1930s.

During the war, the survival of the young community was ensured by the efforts of their direct heirs: Edoardo Amaldi and Gilberto Bernardini, who, supported by their collaborators and other leading physicists in the country, had gathered the remaining forces to keep alive the legacy and also the sense and responsibility of renewal of their

[2] Aldo Pontremoli was the winner of the third chair at the University of Milan, but unfortunately he soon perished in Umberto Nobile's polar expedition in 1928 [2].

young maestros. The strategy adopted by the Roman physicists was applied in the same spirit in other centers such as Turin, Milan, and Padua. The study of nuclear physics, and in particular of cosmic rays, which could be pursued with simple and cheap instruments, had ensured the continuity of research and made it possible to train a new generation of physicists within an established tradition of excellence. Indeed, it produced important scientific results, such as the experiment begun in Rome during the German occupation and completed in 1946 by a team that at the time consisted of Marcello Conversi, Ettore Pancini and Oreste Piccioni [4]. They had shown that the 'cosmic ray mesotron' discovered by Anderson and Neddermeyer in 1936 [5] did not behave as a mediator of the nuclear strong forces as proposed by Hideki Yukawa [6]. Their result had been immediately demonstrated quantitatively by Fermi and co-workers in the United States [7]. In his Nobel Lecture, Luis Alvarez referred to this result as "the beginning of modern elementary particle physics'[8].

At the end of the war, despite the existence of solid roots that had given birth to a new generation capable of producing scientific activity of high quality, Italian physicists were forced to face a harsh reality: the gap with the United States had become insurmountable. Moreover, attracted by better living conditions and research opportunities, many physicists decided to leave the country, mainly for the United States. In 1946, during a trip, Amaldi himself had been offered a position at Chicago University by Fermi, whom he had met for the first time after many years. But moved by a sense of responsibility toward his young collaborators in Rome and the rest of the scientific community, he chose to remain in Italy and to take on the responsibility and burden of rebuilding and revitalizing physics in Italy and in Europe as well [9].

In an Italy devastated by the conflict and in dire economic straits, with the community of physicists severely thinned out, they had to rebuild what had been destroyed, but above all they had to build a new reality in accordance with the profound changes in the scientific and geopolitical landscape and in the light of the extraordinary developments that had characterized physics—and nuclear physics in particular—in the 1940s. The lack of resources and institutional support contrasted sharply with the increased funding that U.S. physicists enjoyed at the time. The vicissitudes of Italian physics during the ten years following the end of the war have been recounted by Edoardo Amaldi himself in a paper entitled precisely "The Years of Reconstruction", which highlights the efforts made by the physics community during this difficult period, which was nevertheless characterized by great enthusiasm and dynamism [10].

In the midst of the early revitalization process, some key figures who had emigrated abroad before or in the early post-war period were encouraged to return. Meanwhile, a first step toward the creation of a national institute for fundamental research, which Fermi had dreamed of in the 1930s but had been unable to realize for lack of funds, was the construction of the 'Testa Grigia' National Cosmic Ray Laboratory. It was built at Pian Rosà (3500 m above sea level) under the direction of Gilberto Bernardini, assisted by Conversi and Pancini, and thanks to the financial support of some northern Italian industries. This laboratory immediately became a place of national and international collaboration and scientific exchange. This initiative was followed by the creation of a second high-altitude laboratory on the Marmolada, at Pian di Fedaia, by a group of researchers from Padua, and of other research centers in Turin and Milan. Together with the Center for Nuclear Physics created by Amaldi in Rome, these centers became the first four sections of a National Institute for Nuclear Physics (INFN) founded in 1951 [11].

At the same time, Amaldi and Bernardini finally realized Fermi's dream by launching the project for a national accelerator and a laboratory to house it. At Bernardini's suggestion, the decision to build an electron accelerator—to complement CERN's planned Proton synchrotron—was taken by the Board of Directors in February 1953. The 33-year-old Giorgio Salvini was put in charge of the project, while Enrico Persico, Fermi's old schoolmate and a great friend, was entrusted with the theoretical group. Italy thus embarked on such an ambitious project with absolutely no experience of building large accelerators.

In 1952–1954, during the start-up phase of this national project, which involved the recruitment of bright and promising, albeit inexperienced young people, the INFN participated in some large international collaborations for the study of cosmic rays with high-altitude balloons [12]. These campaigns were promoted by the nascent CERN—established as a permanent body in 1954—in the context of the great transition from particle physics based exclusively on cosmic ray particles to the study of subnuclear physics pursued with a new generation of high-energy accelerators, such as the Cosmotron and the Bevatron in the USA. Amaldi was one of the great promoters of the idea of an international laboratory as an expression of the revival of European physics through fundamental research, far from any use of nuclear energy for military purposes [13]. He would also later come to advocate a European Space Agency [14].

In 1954, Frascati, a town in the hills south of Rome, was chosen as the site of the National Laboratory that would house the 1.1 GeV electron synchrotron, and in 1957 the group responsible for building the accelerator moved in and began assembling the machine [15].

It was at this time that Nicola Cabibbo completed his undergraduate studies at the Sapienza University. Born in Rome in 1935, he graduated in the academic year 1956-1957 with a thesis on "Pauli invariants in the decay of the μ meson" ["Invarianti di Pauli nel decadimento del mesone μ"].[3] The topic was part of a wider dissertation

[3] Archives of the Physics Department, Sapienza University of Rome, Nicola Cabibbo papers, Box 16, Folder 108.

project on the weak interaction, studied from different angles by Cabibbo, Francesco Calogero and Paolo Guidoni. These were the times when parity violation, seriously questioned by Tsung-Dao Lee and Chen Ning Yang after the 1956 Rochester Conference [16], had also been experimentally established by Chien Shung Wu and collaborators [17], and confirmed in further experiments by Lederman and Garwin [18] and by Friedman and Telegdi [19]. Their supervisor was Bruno Touschek, who had a deep interest in symmetries and in weak interactions, topics he used to discuss in particular with Wolfgang Pauli.[4]

Touschek's life had been very difficult and complicated: having been forced to leave his native Vienna after the *Anschluss* and having survived difficult years in Germany during the war, he had moved from Glasgow (where the Allies had taken him after the war) to the Sapienza University of Rome, attracted by common research interests with Bruno Ferretti, one of Fermi's last assistants, and invited by Amaldi with an INFN contract [20,21]. Touschek was a fascinating personality, both as a person and as a scientist; Cabibbo always regarded him as his mentor.

After graduating, Cabibbo was offered a position as a researcher at the INFN and immediately began working between the University of Rome and the Frascati Labs, where the 1.1 GeV electron synchrotron was being completed [22], and while CERN's first accelerator, the 600-MeV Synchrocyclotron, was coming into operation. Cabibbo immediately began to collaborate with Raoul Gatto, a brilliant young theorist who was five years older and had just returned from Berkeley, where his scientific value had been fully recognized [23–25].

During the 1960s, the scientific and intellectual synergy between Touschek and Gatto was instrumental in shaping a new generation of theorists in Italy, and in establishing electron-positron colliders as a fundamental discovery tool in particle physics [26]. Following Touschek's proposal in February 1960 to build the electron-positron ring AdA [27], the world's first matter–antimatter collider (500 MeV c.m. energy), at the INFN Frascati National Laboratory, Gatto and Cabibbo were the first to systematically study e^+e^- physics [28]. In later years, Gatto still well remembered that they sent this work to the *Physical Review Letters* with "a very faint hope that the paper would be accepted".[5]

The following year, they discussed possible experiments with high-energy colliding beams of electrons and positrons [29], presented in a more detailed and systematic way in a famous paper that became known as 'the Bible' in Frascati circles [30]. In later years Cabibbo recalled that "The result of our explorative work confirmed beyond the wildest dreams the intuitions of Bruno Touschek [...] The net result of this work was the conclusion that e^+e^- machines opened up an entire world of physics to be explored" ([31], pp. 221–223). At that time, just one year after Touschek's proposal to study e^+e^- collisions, AdA stored its first beams at the Frascati National Laboratory, heralding a new era in high-energy particle physics [32].

Cabibbo himself recalled his early collaboration with Gatto in these terms: "While we were doing this work we had the exhilarating experience of expanding into a vacuum: for a few years the only theoretical papers on the physics of e^+e^- were those coming out of Rome or Frascati" ([31], p. 223).[6]

In parallel, Cabibbo continued to study the weak interaction, that had been the subject of his thesis. In this regard, he emphasized in the interview how, having studied in detail with Gatto the weak interactions of hadrons in the framework of the newly discovered SU(3) symmetry of Gell-Mann and Ne'eman [33], he "*had all the mathematics of group theory at hand that was needed*" to tackle the problem of a striking anomaly in the weak decays of strange particles. While at CERN, in 1963 he solved the puzzle of how to reconcile such decays with the universality of the weak interaction [34].[7]

The 'Cabibbo angle' is the first example of a new class of fundamental constants related to discrete C, P and T symmetries (later generalized to the elements of the Kobayashi-Maskawa matrix). This work not only contributed to the understanding of the relationships between different quark species, but also provided the basis for the development of a unified theory of the electroweak interactions [35–37]. In particular, as Parisi points out, "Cabibbo's theory relied heavily on SU(3) symmetries, which became extremely popular and universally accepted partly as a result of the success of this theory" [38].

Cabibbo's legacy in particle physics will remain "recorded in the Cabibbo-Kobayashi-Maskawa (CKM) matrix and the Cabibbo angle" [39], although his name was not included in the list of winners of the 2008 Nobel Prize in Physics, awarded to Makoto Kobayashi and Toshihide Maskawa *for the discovery of the origin of the broken symmetry which predicts the existence of at least three families of quarks in nature.*[8]

[4] See related correspondence in the Bruno Touschek Papers, Archives of the Physics Department, Sapienza University of Rome.

[5] Raoul Gatto, personal communication to L.B., 24 November, 2003.

[6] Cabibbo's recollections on the developments of e^+e^- physics in the 1960s between Rome and Frascati can be found in a volume dedicated to the collider ADONE [31].

[7] See Maiani's detailed discussion on the origin of Cabibbo theory and its role in the discovery of the unified Electroweak Theory [35].

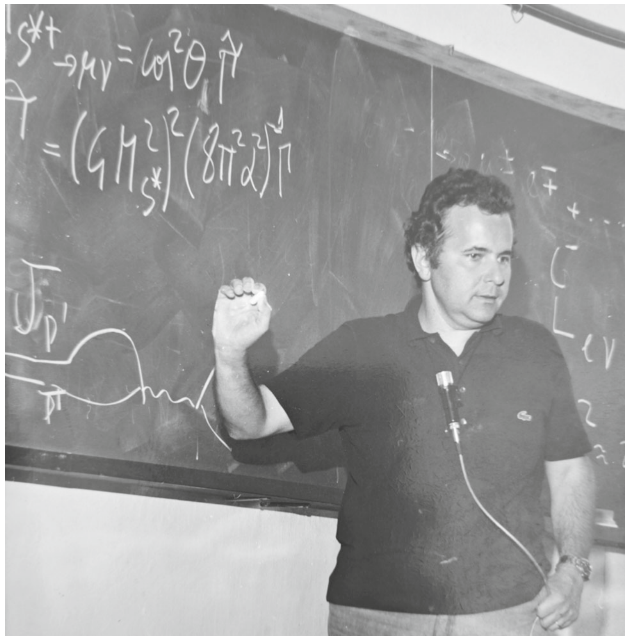

Fig. 2 Nicola Cabibbo in the 1970s. Courtesy of Cabibbo Family, all rights reserved

Between 1963 and 1966 Cabibbo was in Berkeley and at CERN. After a short stay at the University of L'Aquila as full professor, he returned to the Sapienza University in 1966. Meanwhile, the larger e^+e^- collider, named ADONE (3 GeV c.m. energy), which had been planned since 1960, was being built and became operational in 1969 at the Frascati Laboratories [42]. As Cabibbo later recalled, the first results from preliminary measurements with ADONE showed the surprising and unexpected phenomenon of "an abundant production of hadronic events [which] was something qualitatively different from the world dominated by form factors that we were expecting [...] but we soon saw that this behaviour fitted well with Feynman's interpretation of the deep inelastic scattering experiments at SLAC" ([31], pp. 223–224). Maiani ([43], p. 635) emphasized how Cabibbo was the first to study the total cross section of e^+e^- annihilations into hadrons discussing the parton model in an article written with Massimo Testa and Giorgio Parisi [44], where they obtained "a precise and quantitative description of hadron production in electron-positron collisions" [38]. In the following years Cabibbo continued a remarkable collaboration with Maiani, Guido Altarelli, Parisi, Roberto Petronzio, Giuliano Preparata and Guido Martinelli, and others that he himself mentioned in the interview. His scientific and human qualities made him become a new pole of attraction in Rome for a younger generation of brilliant theoretical physicists, some of whom had already shown remarkable qualities working with Gatto in Florence.

Cabibbo's proverbial courtesy and kindness manifested itself in his ability to put at ease anyone who came into contact with him, as witnessed by the experience of Yogendra Srivastava, who considers "Cabibbo, Gatto & Touschek" his own "three Roman Maestros": "I had met Cabibbo at Berkeley, and he invited me—an unknown Indian physicist—to Rome in 1967 to give 10 lectures on the S-matrix theory (this led Gatto to invite me to Florence as well). Despite a persistent rumor about Nicola being a cold person, Nicola was extremely warm and kind to me and treated me handsomely".[9]

In the years 1981–1994, Cabibbo held the Chair of Theoretical Physics at the University of Tor Vergata in Rome, and despite his great commitment as President of INFN, he devoted much of his time to the ambitious project of building from scratch a parallel supercomputer that would allow the study of lattice gauge theories, which required massive computational resources, far beyond those available at the time. APE, which had a gigabyte of memory and could perform one billion calculations per second, became operational in 1986. For a short time it was the fastest in the world, and was the forerunner of several generations of supercomputers [45–50]. Its impact extended

[8] Half of the 2008 Prize was awarded to Yoichiro Nambu "for the discovery of the mechanism of spontaneous broken symmetry in subatomic physics". Nambu was unable to attend the ceremony and his Nobel Lecture was delivered by Giovanni Jona-Lasinio (Sapienza University of Rome), who had been coauthor of the Nambu–Jona-Lasinio model, published in 1961 [40] and who pioneered with Carlo Di Castro in showing that the renormalization group could be used to understand the critical behavior near second phase transitions. See Jona-Lasinios' oral history interview in [1] and Di Castro's interview with memories on the beginnings of theoretical condensed matter physics in Rome [41].

[9] Srivastava also recalls how generous Cabibbo always was with valuable advice and encouragement, the influence and impact of which persisted over the years. Y. Srivastava to L. B., 20 January 2025.

Fig. 3 Chania, Crete, July 1969, workshop organized by Antonis Verganelakis. In the first row, from left: Massimo Testa, Giorgio Parisi and Carlo Rubbia. Nicola Cabibbo is in the back row, on the right. Courtesy of Giorgio Parisi, all rights reserved

Fig. 4 Nicola Cabibbo with the students of his course in Elementary Particle Physics (Department of Physics of the Sapienza University of Rome, c. 2008). Courtesy of Guido Martinelli, all rights reserved

to the training of brilliant young people who applied this technology to activities outside fundamental research. Of those years, Giorgio Parisi cherishes "[...] the Saturday morning meetings in Cabibbo's large, sunny office, where in front of a blackboard he would assess the situation, analyze the difficulties we were encountering, and often suggest the best solutions" [51].

In 1994 Cabibbo returned to the Sapienza University, where he taught the course on Elementary Particle Physics. Thanks to his charismatic personality, to his physical intuition and his mathematical skills, Cabibbo's influence on the revival of theoretical physics in Italy and as a mentor to renowned younger physicists has been enormous, in particular his inspiring contribution to the development of a Roman school of theoretical physics that "significantly contributed to establishing what we call today the Standard Theory of particle physics" [35].[10]

As Parisi emphasized: "Cabibbo had an infectious enthusiasm for physics. He was a born problem solver; to him, physics was a kind of play, like putting together the pieces of a puzzle to form a meaningful pattern from an incoherent data set. I will always remember him saying, 'Why should we study this problem if we do not amuse ourselves in solving it?"' [51].

In 1983, Cabibbo was elected President of the National Institute for Nuclear Physics, and until 1992 he devoted himself to the management of the institution, with relevant scientific initiatives and, among other things, by ensur-

[10] For details of the group's main achievements in those years, see in particular Section 15 (Cabibbo: Leading the Roma School) of Maiani's paper [35].

ing that its organizational structure—considered by all to be exemplary—was not distorted by changes imposed by the bureaucratic mentality of government control bodies. It was during his presidency that the underground Gran Sasso National Laboratories were inaugurated. As Till Kirsten, the project leader of the GALLEX experiment testifies, Cabibbo's far-sighted intervention was instrumental in supporting the idea of hosting at Gran Sasso the solar neutrino experiment, which made a significant contribution with the first observation of the primary *pp* neutrinos, which make up almost the entire solar neutrino flux, and confirmed beyond doubt the electron neutrino deficit, a result which, combined with data derived from other experiments, paved the way for the discovery of neutrino oscillations.[11]

His scientific vision and exploratory spirit extended to fostering new avenues and new research projects in fields other than those at the core of the INFN'S traditional mission. A striking example of his cultural openness is his decisive action as President when the proposal led by Adalberto Giazotto for an Italian interferometric antenna was included in the INFN five-year funding plan 1988–1993, at a time of widespread perplexity and disbelief toward the 'gravitational waves' enterprise. Pio Pistilli has stressed how "Cabibbo's support and firm belief in the importance of pursuing this field was absolutely crucial at the INFN Council Board meeting, where the 5-year funding plan was discussed.[12] Luciano Maiani, Cabibbo's successor as President of the INFN from 1993 to 1998, and also a supporter of the project to build an interferometer in Pisa, signed the final agreement with the French CNRS for the construction of Virgo. The first direct observation of gravitational waves announced by the LIGO and Virgo collaborations on February 11, 2016 inaugurated the era of gravitational wave detection—as well as multi-messenger astronomy [54]. Such an event can, with good reason, be considered part of Cabibbo's scientific and cultural legacy.

In 1993, at the end of his second term as President of the INFN, he was appointed President of the Ente Nazionale Energia e Ambiente (ENEA), to which he tried to give impetus as a dynamo of Italian technological development, encountering not a few difficulties in arousing the interest of politicians and, in particular, of the Ministry of Industry.

Twenty-five years later, the parts of the interview devoted to his activities as president of these important Italian scientific institutions are still of great value, both in terms of the history of the institutions themselves and of their relations with the scientific community, and in particular for Cabibbo's own reflections on the role they play—or should play—in society.

Unfortunately, due to Cabibbo's numerous commitments, it was not possible at that time to hold further meetings dedicated to an in-depth exploration of his relevant research activities.

Nicola Cabibbo passed away in Rome on 16 August, 2010, a few days after being awarded the prestigious Dirac Medal and the International Centre for Theoretical Physics (ICTP) Prize for his major contributions to the understanding of the weak interaction and other fundamental aspects of theoretical physics.

In his obituary, Raoul Gatto commented on Cabibbo's 'style' as President of the Pontifical Academy of Sciences, a position he held from 1995 [55]:

"In his delicate role as President of the Pontifical Academy of Sciences, he had never hesitated to take a firm stand in favour of scientific correctness and objectivity. In particular, his role in the debate on creationist theories was admirable, all the more so given his prestigious position in the Catholic world. In all his activities he had always shown an unquestionable scientific objectivity, a sense of balance and thoughtfulness that had always been part of his style and character".

2 Family origins and cultural influences. The choice of physics

L. B. You were born in Rome on April 10, 1935. Would you like to tell something about your parents?

N. C. My parents were Sicilians. My father came to Rome after the First World War. I am the second son, my older brother was born in 1924. We have always lived in Rome. My father was a lawyer and a magistrate before the war. He was a great lover of philosophy and had a beautiful library: all the old Laterza books, especially Plato and Gentile. He was part of a small group of friends who used to visit the philosopher Giovanni Gentile.

L. B. Did your father's interests have an influence on you?

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[11] Till Kirsten, personal communication to the author. For a broad overview of the history of the GALLEX experiment see ([52], pp. 459–489) and references therein.

[12] Pio Pistilli, personal communication to L. B., February 2025. For details on Cabibbo's enthusiastic endorsement of an Italian-French antenna see Adele La Rana's article analyzing the causes of the failure of a collaborative project for the construction of a European Interferometric Gravitational Wave Observatory, which gives an account of the circumstances that led to the approval of the Italian Virgo project ([53], pp. 3–4). The fundamental importance of Cabibbo and his favorable role are confirmed by interviews with protagonists of the time, such as Giazotto and Paolo Strolin. I am very grateful to Adele La Rana, for providing such relevant connections with the Italian path to gravitational wave research.

N. C. I don't think I was aware of it at the time, but I was certainly left with an interest in philosophy. My mother, on the other hand, was basically what you would call a housewife today. She had always lived in the family and then married my father, who was from Ragusa, while she was from a town near Catania, Riposto.

L. B. What do you remember about your first school experiences?

N. C. I really liked school at the time of elementary school; I remember little of middle school, and I basically hated high school. I was not interested in it, although I did quite well in all subjects without having any preferences.

L. B. What were the reasons that made you choose to study physics?

N. C. I had a general scientific curiosity and read popular books. I also read science fiction books.

L. B. Someone—perhaps Isaac Asimov himself—has said that science fiction, rather than some kind of popularization, can create a strong suggestion, the first stimulus, in people who later become involved in science...

N. C. I suppose so, in my case. I used to be very interested in adventure, then I became a theorist, which is not so adventurous... Another of my father's passions was having all sorts of books written about polar exploration. These were subjects that were very exciting to me, so I was very attracted by the desire to go to the North Pole, to go to the Moon... A few years ago, I had the chance to go to Antarctica, but it was too late. Then I ended up in physics...

3 The institute of physics in Rome in the 1950s

L. B. Did you make your choice of physics on the basis of a particular stimulus?

N. C. In the years 1952-53, physics became very fashionable: it was the era of great progress, of nuclear power, of electronics... The attraction was strong, but the number of physicists in general was very small. There were only 10 or 15 of us enrolled in the physics course.

L. B. Which teachers have influenced you the most?

N. C. Undoubtedly Edoardo Amaldi, and Enrico Persico, who was still active and a great champion of clarity. Gaetano Fichera, the mathematician, was an outstanding teacher, he was a 'showman', his lectures were lively and very interesting.

L. B. There was a special atmosphere at the Institute of Physics in Rome in the 1950s. These were the years of enthusiasm for the revival of Italian physics, with the construction of the Frascati National Laboratories on the outskirts of Rome and the planned electron synchrotron, which would make Italy competitive again with other centers at world level. Although cosmic ray research, which had helped Italian research to survive during the difficult war years, was still an excellent local resource for training young physicists...

N. C. Yes, of course, and cosmic ray research was still in full bloom... But when I was about to write my thesis, parity violation was discovered, which had a big impact. Then I wrote a thesis on the weak interaction...

L. B. Bruno Touschek was your supervisor. He was a fascinating figure both as a human being and as a physicist...

N. C. Touschek was an extraordinary person, a man of extreme clarity. He had all the charm of someone who had studied with the greats, like Arnold Sommerfeld. He had a great style. I also remember that one of the things I liked most about that period was the mentoring, especially the figure of Gherardo Stoppini. He was great, he was passionate, he would bring up all kinds of problems. Some problems, like the one about the carpet unrolling on an inclined plane, were never satisfactorily solved! Of course, tutoring worked because there were so few of us... Later Stoppini dropped particle physics, too bad! There was a small group that started to be interested in statistical mechanics when very little was being done at the institute. I remember that we had a kind of seminar with Giancarlo Moneti, who is now a professor at Syracuse, I also remember Alessandro Vaciago, a very nice chemist. At that time, chemists were not highly esteemed at the Physics Institute. He was a physics enthusiast, and I remember we had a seminar where we studied Boltzmann's H-theorem. It was a very nice environment, very lively. There were the young people from Amaldi's group: Lucio Mezzetti, Carlo Franzinetti—very good—Carlo Castagnoli... They were all very young, 'fired up', full of energy, very attractive, even as people. I remember a very good chemist, Paolo Silvestroni. He was at the beginning, a very brilliant character.

L. B. Apparently, your relations with chemistry were not as bad as they traditionally are for physicists...

N. C. No, although there were some rather 'sad' characters. Physical chemistry was a disaster; now it has become a leading subject, but back then they were essentially studying batteries, accumulators...

L. B. What made you decide to do your thesis under the supervision of Bruno Touschek?

N. C. I had decided to do my thesis in theoretical physics, together with Francesco Calogero and Paolo Guidoni. There was a strong tradition there, going back to Enrico Fermi, but Bruno Ferretti, who was sort of Fermi's successor in Rome, had moved to Bologna University. There was no professor of theoretical physics, and so Touschek, who was also not a professor—I think he had some kind of contract with the INFN—was the leading person there. We formed a small group where we would study a particular topic involving the weak interactions, each from a different point of view. All three of us wanted to do a theoretical paper, and the topic was fashionable at the time, but it passed quickly. It was a paper by Wolfgang Pauli that had identified certain invariances of weak interactions, and Touschek took on the task of cleaning up the topic by applying it to different cases, such as μ

Fig. 5 The 9th "Enrico Fermi" Summer School on "Pion physics", organized and directed by Bruno Touschek (Varenna, 18-30 August 1958). Nicola Cabibbo, a recent graduate (wearing a tie and a dark V-neck sweater), is in the second row, center, to the right of Touschek, who is in the first row (see arrows). Francesco Calogero (who, like Cabibbo, wrote his thesis under Touschek in 1956-1957) is the last person standing on the right. © Società Italiana di Fisica

capture and β decay. I remember that I was working on μ decay and Calogero was working on β decay. This was in 1958.

4 The Frascati National Laboratories. The e^+e^- colliders AdA and ADONE. The interplay between theory and experiment

L. B. How was your existence channeled after graduation? It was the beginning of the great adventure of the Frascati National Laboratories... The 1.1 GeV electron synchrotron was being put into operation and Italy was once again competitive at the world level, as it had been in the 1930s with Fermi and his group on atomic and nuclear physics and with Bruno Rossi's frontier research on the nature and behavior of cosmic rays...

N. C. Yes, in fact I remember that by the time I graduated, Touschek was no longer working on weak interactions and was somehow involved with the electron synchrotron. When he was in Germany during the war, Touschek had worked on the construction of the first betatrons, and he had also done some theoretical work on the circulating beams. When he arrived in Rome in the early 1950s, he had also written a paper with Matthew Sands on the stability of orbits in a circular machine [56].[13] At this point I began to work with a young assistant, Raoul Gatto, who became a professor in Rome and then in Florence and Geneva and is now retired. I worked with him continuously until 1963, first in Rome and then in Frascati. It was a long and very beautiful period.

L. B. What do you remember about the beginning of e^+e^- physics in Frascati?

N. C. I remember very well that Wolfgang Panofski came to Rome in the fall of 1959 to give a seminar and told us what they were doing at Stanford and talked—among other things—about the design of an e^-e^- machine. On that occasion Touschek came up with the idea of an e^+e^- machine instead, an electron-positron collider. We went wild and did some calculations on cross sections. There was also work done by Calogero with Laurie Brown [57], an American—there were a lot of Americans at that time—while I was doing a little different work with Gatto [33].

L. B. It was the time of the famous 'Bible', the article you published with Raoul Gatto in 1961 summarizing the theory of high-energy e^+e^- collisions...

N. C. We began to realize that this would be a very nice machine to study the properties of hadrons, especially pions, and so we began to study the pion form factors [28]. Then Gatto said: "You have to make a complete list of everything you can do with this machine...". It took us several months for that. It was an interesting time, we did a lot of work and also proposed experiments... [29,30].

We also did one of the first works on neutrino experiments, I think in 1960 [58],[14] and some more theoretical work, on some particular symmetry laws between the electron and the muon [61]. We also tried to do something on dispersion relations.

[13] Where Cabibbo mentions specific works, references have generally been added.

[14] Among Cabibbo's early articles on neutrino see also [59] and a slightly later article with Giuseppe Da Prato evaluating the cross-sections for inelastic high-energy neutrino-nucleon interactions [60].

L. B. At that time, the Frascati National Laboratories were beginning to operate at full capacity; it was a completely new situation and opportunity for the Italian scientific community. How did the interplay between theory and experiment work?

N. C. It was very intense. At Frascati, Giordano Diambrini carried out a series of experiments on coherent effects in crystals.[15] Normally, the interaction of electrons or gamma rays with matter had always been considered as an interaction with a single nucleus. In fact, when we are in a crystal—an ordered system of nuclei forming a lattice—some reactions can take place in a coherent way, as if you were superimposing the collision with a whole series of nuclei to get a coherent result. But these are extremely directional effects: for this to happen, the direction of the gamma ray has to be very much aligned with one of the lattice directions. We did some of the first theoretical work on this. I discovered that, starting from these Frascati experiments, we arrived at the very strange fact that crystals have optical properties typical of normal optics, even for gamma rays. There is a linear polarization analyzing power, similar to that of polaroids, and also a rotational power. Crystals can therefore be used to produce linearly or circularly polarized gamma rays [63–65]. At that time there were no applications of this kind of work—which I did in '61/'62—because in fact the effect increases as the energy increases, and it was only many years later that there was a group at Stanford using this method at energies that were by then about twenty times higher than those available at Frascati.

Frascati was also the site of the first experiment to detect the decay of the η meson into two γ rays, and one of the things we did with Gatto was actually to predict the rate of this decay using SU(3) symmetry. One of the big events in 1961 was indeed the discovery of SU(3) symmetry by Murray Gell-Mann and Yuval Ne'eman, and so we started working with Gatto looking for some interesting applications. One of them was the η meson, which was being studied at Frascati at the time. In fact, perhaps what I enjoyed most in those years, and then in my years at CERN, was the interaction between theory and experiment. The theorist also has the task of proposing experiments...

L. B. Indeed, a true symbiosis between theory and experiment has become one of the hallmarks of the Frascati Labs! What was Italy's position in the world at that time? Was it competitive?

N. C. Yes, it was very competitive. The work done with the electron-positron collider AdA, and later with ADONE, was the seed for everything that was done later at CERN, but also in the United States. The LEP and the LHC are in a way the children of the physics that was done at Frascati, no doubt. Stanford itself had started with a linear accelerator, and they had also started with storage rings, but of the electron–electron type, a very sterile system, because when two electrons collide, the most they do is deflect, they can emit a photon, but it is not very interesting, apart from verifying quantum electrodynamics; whereas the electron-positron collision is a real mine... Stanford immediately realized the importance of this line and accelerated the construction of the SPEAR collider, which had about twice the power of ADONE and was able to reach the J/Ψ resonance.

L. B. On the one hand, e^+e^- collisions at ADONE had provided the first indications of the existence of the multihadron production in the early 1970s, but later the existence of the J/Ψ, a resonance at an energy slightly above 3 GeV, was a snub for ADONE—and for Bruno Touschek. Only by forcing the machine slightly beyond the maximum energy for which it was designed was it possible to verify the existence of the resonance. Too bad... Then, in 1962 you moved to CERN...

N. C. I spent a year at CERN from '62 to '63. I got married in '63, and in the summer of that year I went to Berkeley and stayed there for a year. Then I came back and stayed in Geneva for two more years. Then I got a professorship, and since then, after the first year of teaching in L'Aquila, I have been in Rome pretty much on a permanent basis.

5 Quark mixing and the universality of weak interactions

L. B. What is the origin of what has become known as the 'Cabibbo angle'? How does it relate to the phenomenon of quark mixing in the weak interactions?

N. C. It just came up in '63 when I was at CERN. The seed had been planted at Frascati. In a way it is a child of SU(3) symmetry, in the sense that before SU(3) was discovered it was not clear that there was a serious problem to be solved underneath.

There is a difference between the β-decay rates of the neutron and the so-called hyperons—'strange' particles (now we know why: they consist of two normal quarks and one 'strange' quark). Of course, the decay rates depend on the available energy, but it is a rather trivial dependence.

But when this aspect was removed from the data, a discrepancy remained: the decays of the 'strange' particles were about twenty times slower. Before SU(3), it was not clear that this was a problem; one might have thought that these particles were very different from the others, and it was not so obvious that they should have the same properties. With SU(3) it quickly became a 'scandal'. It took a year from the time the problem was raised in all

[15] On these experiments see Diambrini's recollections in [62].

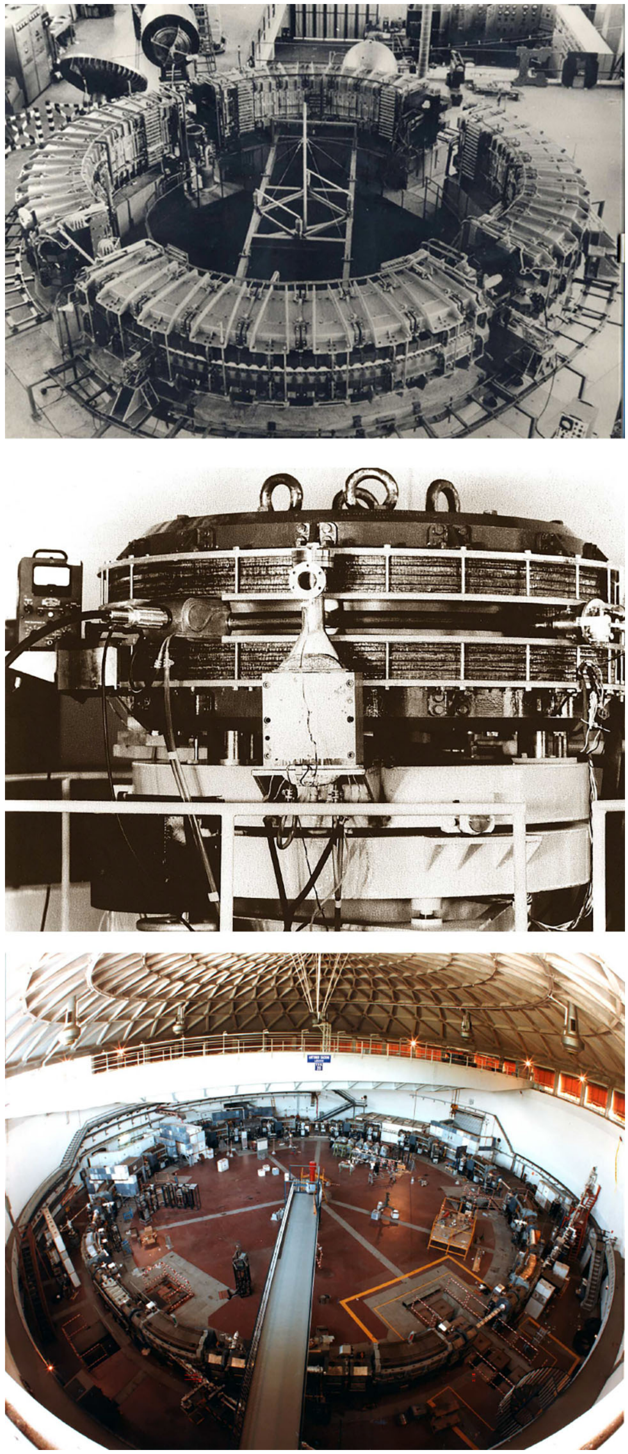

Fig. 6 Three generations of accelerators at Frascati Laboratories: the Electron Synchrotron (1959), AdA (1960), ADONE (1969). © INFN-LNF

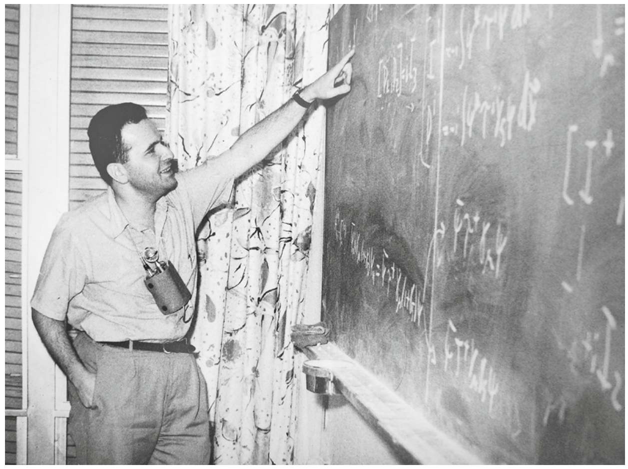

Fig. 7 Nicola Cabibbo at CERN, between 1962 and 1963, lecturing at the time he had just formulated the theory that reconciled the observed decays of strange particles with the universality of the weak interactions. Courtesy of Cabibbo family,

its seriousness to the time I solved it. After working with Gatto on SU(3), I had all the mathematics of group theory at hand that was needed to think about such things.

The solution was interesting because this effect is of a quantum nature: what was expected—perhaps naively—was that these decays would have the same strength. In reality, however, these decays divide a given total force into proportions given by the sine and cosine of a given angle. This is a quantum phenomenon, because the non-strange particles must be seen as a superposition (sum between two coherent lights) between two waves, one of which has the weak decay and the other does not, while the strange particles have the opposite superposition (with coefficients—and thus the proportions/probabilities—swapped). From this it turned out that everything was explained by saying that in these two mixed states in the case of the non-strange particles the beta decay was preponderant, while in the case of the 'strange' particles the different type was preponderant. A typical quantum phenomenon.

Once this was clarified, very specific predictions could be made. What is decaying is not the particle that we see, but it is a component of it that is the same in both cases so this allows you to say that apart from the different intensity, the characteristics of the decay must be in a sense the same. We were able to obtain very detailed predictions of all the decays. At that time three or four strange particle decays were known, whereas the possible number is about ten, and each of them is characterized by a couple of numbers that could be predicted starting from the beta decay. There are many different ways to check this mixing angle, and they all give the same result. This theory explained what was happening. The latest result came a couple of years ago from the FermiLab in Chicago.

The other interesting thing about this work is that it laid the foundation for understanding that weak interactions have their own universal force, such as electromagnetic interactions, which at the elementary level have a force that is the charge of the electron. All elementary particles have a charge, which is either the charge of the electron, or zero, or a multiple of that. The electron charge is thus a parameter that determines the strength of all electromagnetic interactions. The same is also true in the case of the weak interaction, and this could be understood after solving this puzzle. It was possible to state that the weak interactions are as universal in strength and intensity as the electromagnetic interactions. After a few years it became clear that this was due to some underlying reality represented by the unified model.

L. B. The implications of his work therefore went far beyond the discussion concerning the decay modes of these particles...

N. C. There was a direct discourse that was related to understanding a certain situation, but it was actually an indication of much deeper issues...

L. B. In what sense did this discovery establish the existence of a new class of physical constants, the prime example of which is precisely the 'Cabibbo angle' which determines the mixing of 'strange' quarks with 'non-strange' quarks?

N. C. There are six types of quarks, and the mixings are between three of them. These angles are now three plus one phase, an extension due to the Japanese Makoto Kobayashi and Toshihide Maskawa (incidentally, Luciano Maiani had found the same thing independently, but later, and so the whole thing is attributed to the Japanese physicists). Since we have six types of quarks that are divided into two groups—those with charge 2/3 and those with charge 1/3—in the weak interactions each of those with charge 2/3 corresponds to some superposition of

Fig. 8 Erice (Sicily), 1–14 July, 1967, 5th Course of the International School of Physics "Ettore Majorana". A famous historical photograph showing from left to right: Bruno Zumino, Sidney Coleman, Antonino Zichichi, Nicola Cabibbo, Sheldon Glashow and Murray Gell-Mann [CERN Courier 7(8), 1967, p. 148]. Cabibbo discussed recent work on radiative corrections to $\beta-$decay that he had done in collaboration with Luciano Maiani and Giuliano Preparata [66,67]

Fig. 9 Nicola Cabibbo with Makoto Kobayashi at the CKM Workshop in Nagoya, Japan, 15 December 2006. Courtesy of Marcella Bona, all rights reserved

those with charge 1/3, I have three possible mixings between three types of quarks, and it can be shown that this is defined by four parameters that generalize the concept of angle. When I introduced the 'angle' there were only three quarks, so there was only one mixing between two, one going into a linear combination of the other two, so only one angle was needed. Related to a similar phenomenon of mixing is a major development of these years, namely, the discovery of neutrino oscillations, a phenomenon first predicted by Bruno Pontecorvo, in the 1950s-1960s. It is another example of mixing, which in principle depends on four parameters—there are three neutrinos that mix with each other—and can only occur if the neutrinos have a non-zero mass, and the fact that an oscillation has been observed tells us, on the one hand, that the neutrinos have a non-zero mass, on the other hand, that there is mixing. At present, of the twenty or so known physical constants that determine the entire structure of matter, eight are represented by mixing constants.

L. B. Later on, you also became interested in neutrinos. This was indeed a natural extension of your previous work on the weak interaction, and a subject that continued to fascinate you over the years, including the problem of neutrino oscillations...

N. C. Yes, I actually wrote the first paper suggesting that neutrinos might show CP symmetry violation. It is actually something very difficult to observe; each experiment has to be designed *ad hoc*. An experiment is currently being designed that will send a neutrino beam from Geneva to Gran Sasso, which will in principle determine only one of these parameters. But it will be a long time before the whole neutrino tangle is unraveled...

Fig. 10 From left to right: Enzo Marinari, Pier Stanislao Paolucci, Gaetano Salina and Nicola Cabibbo. Courtesy of Enzo Marinari

6 The APE family of parallel supercomputers

L. B. Later, in the 1980s, you have been involved in the APE parallel computer project. How did this experience come about and how did it evolve?

N. C. Giorgio Parisi and I started it together with Roberto Petronzio, Enzo Marinari, etc., because we needed a computer to perform simulations on particle problems. I was particularly interested in simulating the weak interaction. There are some things related to the so-called Standard Model of weak and electromagnetic interactions that you cannot calculate with normal analytical methods and therefore you have to resort to computer simulation. APE grew out of that, but of course there was also a passion for electronics, on my part, a youthful passion that had gone unexpressed in the sense that I had not been involved in it for many years, but in the second half of the 1970s, when microprocessors appeared, I built myself a couple of computers...

L. B. In short, it was almost like a 'hobby'...!

N. C. Yes, among theoretical physicists... Even Giorgio Parisi, who is a theoretician, was very interested in the problem. We worked on the project and it was a wonderful experience, interesting also because we came into contact with a type of guys that you don't usually see among theoretical physics students: they are less attracted to pure research and more attracted to technology and applications... They are often very nice and very good, and many of them have come through the APE group. Many of them have gone on to become entrepreneurs, great at all sorts of different things, and some of them are still working with us in the business of online hotel reservations; they have set up a business that provides them with a good living. At first, only the physicists knew the Web well, a field that is now well developed and known to everyone, on the other hand the Web was invented at CERN. Another one of these guys, a computer genius, has founded an important company in the field of comics, they produce software to draw cartoons. They seem to be the leading company in this field; at one point they were bought by Microsoft.

The interesting thing was that we were at the frontier in this field, we were among the best for a great many years; now the Americans are investing a lot in it, the competition is tougher, but the whole thing is still interesting. It is still true that we can build our own computers at an extremely lower cost than what they would cost (a few tens of billions) if we had to buy them. Building them ourselves is also an experience that teaches us a lot and serves to prepare young people for quite interesting careers; and in the end, it is also cheap and efficient.

L. B. How did this experience fit into the world scene at the time it began? In what sense were you innovative?

N. C. The type of design was totally innovative. There was a collaboration/competition with a group at Columbia University, which is the other university group that builds computers to do these simulations. Over the years we took turns in being more advanced. However, there was a difference: after the first project, which was a hand-built prototype, we realized that we needed to have a more industrial method; in fact, APE100 and APE1000, and the

Fig. 11 From left to right: Cecilia Tarantino, Nicola Cabibbo, Guido Martinelli and Vittorio Lubicz. Courtesy of Guido Martinelli, all rights reserved

next one as well, make very heavy use of industry. We do the detailed design of everything and then the industry does the manufacturing.

7 President of the National Institute for Nuclear Physics (INFN)

L. B. As president of the INFN (National Institute for Nuclear Physics), do you feel that you have somehow renewed the institution, which already had a very strong and well-defined structure?

N. C. When I was president (1984-1993) I did not make any real structural innovations. In the previous years there had been Claudio Villi, who had done some fundamental things, including national committees. The uniqueness of INFN in the Italian picture is that it is run by scientists; it is probably the only non-university research organization that really works well. This is largely due to the founding fathers, such as Edoardo Amaldi, but also to Villi, who had the very strong idea of democratizing the institute by creating this dual system of the Governing Board and the Commissions. The Governing Board came naturally, because in the beginning INFN was a kind of 'club' of some Physics Institutes and so it was practically run by the directors of the respective institutes—such as Edoardo Amaldi and Antonio Rostagni. This mechanism remained when INFN was transformed into a real institution, and it was a huge advantage. To all of this Villi added the National Commissions, which are basically committees that deal with the different topics INFN works on, for example, elementary particles, experiments with and without accelerators, such as astrophysics, neutrinos, and everything that is done at the underground Gran Sasso National Laboratories. The third group is nuclear physics, the fourth group is theoretical physics, and the fifth group is what is called interdisciplinary physics, which is a smaller set of projects, such as the development of instrumentation or the application of physics instrumentation to subjects such as cultural heritage preservation, medicine. Each of these groups consists of one representative from each Section, so the Rome Section has its own representative who is elected to each of these five groups; and these groups are very heated discussion groups because they are the ones who, in a sense, outline the research program. So there is a kind of dialectic between the Board of Directors, which gives the general guidelines of how the budget is to be divided among the various groups, and the groups themselves, which, once they have taken note of how much of the budget INFN can devote to a certain class of experiments or theoretical activities, discuss how to divide it among the various experiments, especially which experiments to approve. So every experiment that is funded is hotly debated in these committees. It is also an internal evaluation system that is very effective. I found this situation and I defended it. From a structural point of view, I defended what already existed, because there were strong temptations from the political world to change it and to introduce an external board. These 'attacks' were repeated several times during my presidency.

L. B. During your presidency you also experienced the excitement of inaugurating the Gran Sasso underground Laboratories, which became the largest underground laboratories in the world and a real success for Italy...

C. B. I managed the whole very interesting phase of the creation of the Gran Sasso Laboratories: the experimental program, the first experiments, the completion of the Laboratories. There was also the beginning of the experiments at LEP and the beginning of the construction of HERA and DESY, in which we participated, the development of the Catania Laboratory with the superconducting cyclotron...

Fig. 12 Herwig Schopper shows the Golden Book to Gordon Munday (left) and Nicola Cabibbo (right) during the 75th CERN Council Session in December 1983. © CERN Documentation Service

Fig. 13 L-R: Nicola Cabibbo, Giulia Pancheri and Giorgio Salvini at the "Bruno Touschek" Scientific Lyceum in Frascati in 2006. © INFN-LNF

It was a good time, a fairly orderly period of development. The central problem of the management of the INFN is that the physicists just want to do their experiments, while the institution also has to take care of the facilities. Gran Sasso, for example, is an important facility with relevant regional spin-offs, as in the case of the Catania Laboratory or the Legnaro Laboratory near Padua. These are laboratories that have great local spillovers and, therefore, contribute to the popularity of the INFN in the local world, in the political world. It is important for an institute run by scientists to be very careful to frame its activities in a broader interest than just science. This is quite a difficult task.

L. B. What were the main spillovers in your view?

N. C. The Catania Laboratory strengthened the whole scientific area of the city, which is now becoming important industrially. As a result of the proximity of the Laboratory with a range of expertise, of people working on accelerators, SGS Thompson—which is now called ST Microelectronics—also located in Catania. This experience was transferable to ion implanters or other machines used for silicon processing. The APE project itself had subsequent spin-offs through the creation of a number of small companies that are now standing on their own. This is a not insignificant effect. It was a very interesting time, although a bit stressful...

8 President of the National Agency for Energy and new Technologies (ENEA)

L. B. Still as president, from 1993 to 1998, you were also involved with ENEA, the National Agency for Energy and New Technologies...[16]

N. C. I was invited to become the president of ENEA a few months after my INFN presidency ended. It was a completely different matter. There are some similarities in the sense that ENEA also has some pretty good research groups. Also, INFN and CNEN (the National Committee for Nuclear Energy) originally had a common history: some of the Frascati groups were initially undivided, the Laboratories in the 1960s belonged to CNEN. Unfortunately, ENEA was very badly affected by the end of nuclear energy in Italy. It was born for it and had really good international expertise, but after Chernobyl everything was over, practically overnight. A whole range of activities that were not strictly nuclear continued normally, but at the same time ENEA had to create new fields of activity for itself: the environment, cultural heritage, alternative energies, fields that were somehow new to ENEA. As an institution, it suffers from not being seen as a research institution, which it is. The best it does is research, then it does some project management that anybody else could do. In terms of research, on some issues like alternative energy, on solar, on alternative fuels like hydrogen, it still has some very good skills of its own. On certain types of lasers for industrial use, it has absolutely excellent scientific research capabilities. It also has an excellent group working on nuclear fusion. On the one hand, it suffers precisely from the fact that it is not considered a research organization, but rather is dependent on the Ministry of Industry, because it was originally set up to develop nuclear energy and was therefore part of the Ministry of Industry. Now that nuclear energy has been abandoned, the Ministry of Industry is not interested in research activities of practically any kind, except for those within ENEA, which have nothing to do with the interests of the Ministry. So, it is very difficult to be understood by the Ministry, there is almost no dialogue, and on the other hand the structure imposed on the Agency, in particular the politically appointed Board of Directors, makes the management of this institution very difficult. In general, the Presidents are of a certain level—there was Umberto Colombo, who was unquestionable, now there is Carlo Rubbia, who is also unquestionable—but apart from the Presidents the Board is made up of people who are in one way or another sympathetic to this or that minister of the day, almost regardless of their professional skills, which are often present, but not in the field of research. In the first board, under my presidency, there was Maurizio Cumo, an expert in nuclear research, who had a good technical background, but the bulk of the board was made up of people who you wondered why they should be in charge of a research organization. This was a very unpleasant kind of problem; another one—which will be resolved over the years and the process is already under way—concerns all the old nuclear managers, some of whom, a few, had really great technical skills and went on to do interesting things in neighboring fields or in what little remains of nuclear issues, such as the radioactive waste problem, which requires constant attention. There is a very good quality group dealing with these issues. But many of the senior managers were essentially managing laboratory or large apparatus construction projects, they were more like industrial contract managers, and the new ENEA does not have all these contracts to manage, so the body at the high levels is burdened with people who basically no longer have much to do with what they were hired to do at the time. At the lower levels, fortunately, ENEA has very good young people—because I personally have followed this policy as much as possible—to keep hiring young people. I brought my experience from the APE group to ENEA and created a group dealing with numerical simulations—I created a group dealing with climate and energy simulations. It is a very interesting area that lends itself very well to this kind of application and has worked well. I fished out some of the older people who were very good from a technical point of view and helped out. Some things worked better, some things worked less well: the working conditions were absolutely terrible and got worse over the years.

9 Reflections on science and technology research policy in Italy

L. B. More generally, what is your opinion on Italian energy policy?

N. C. I'm not an expert, but I have a rather different opinion from my colleagues: I think the nuclear shutdown was a good thing because Italy was essentially incapable, system-wide, of running nuclear power. In order to run a serious nuclear program, one that makes a serious contribution to solving energy problems, the program has to be large, and Italy, in the midst of political uncertainties of various kinds, had positioned itself on a reduced nuclear program, consisting of two/three reactors, which basically solved nothing, while the reduction did not silence the political contrasts. It is one of the cases that has suffered most from Italy's political instability. If someone has

[16] Initially, ENEA was an acronym that stood for Energia Nucleare ed Energie Alternative (Nuclear Energy and Alternative Energies), but after the referendum against the production of nuclear energy in Italy, which took place after the Chernobyl disaster in 1986, the name was changed into Ente per le nuove tecnologie, l'energia e l'ambiente (Agency for New Technologies, Energy and the Environment). The current name is Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile (National Agency for New Technologies, Energy and Sustainable Economic Development).

Fig. 14 Nicola Cabibbo (left) with Melvin Schwartz and Martinus Veltman at Veltman's 60th birthday symposium in Ann Arbor, Michigan, 16-18 May, 1991. © AIP Emilio Segrè Visual Archives

even one per cent of the vote, they have unlimited ban power. In this situation, it was quite reasonable to stop nuclear power; I am sorry to say it, but it is so. In any case, energy policy is made by the market: energy is bought. The great energy policy is mainly made by the United States, including with its military presence in the Mediterranean area, where oil is produced; France can do it with its nuclear program; everyone else basically buys and sells; we buy energy in the form of oil or electricity from France.

L. B. However, the fact remains that we are completely dependent on those who own the energy sources...

N. C. Yes, but in the context of an ever-increasing development of European integration, it may at most be of little concern. In the energy sector, we have to buy, but it is not the only case. It is just a question of price. The European Community more or less guarantees us access to markets on an equal basis with other European countries. The energy problem is at the European level, the perspective is European, fortunately. In the 1960s and '70s there was the idea that it could be solved at the national level; France succeeded and we did not: they are better at it.

L. B. What are the spillovers effects in terms of overall research done in the country?

N. C. The spillover is very considerable in the sense that many of the technical skills that exist in Italy are born in research institutions: the ability to train young people who have technical skills that are then eventually needed by industry are 80 to 90 percent born in research institutions and universities. This is all happening through a thousand channels, bearing in mind that we are now talking about a knowledge society: for example, today it is no longer energy that counts, which we were talking about earlier, but the ability to manage knowledge, to have knowledge, to generate knowledge. The main product today is knowledge, know-how. One of the most dynamic sectors in Italy is the goldsmith industry, which relies entirely on local know-how, but the same is true, to take a more technically interesting example, for the tool machine industry, which requires a great deal of technological knowledge that must be developed over time, which is exactly what has happened. We went from purely mechanical machines to electronically controlled machines and then to computer-controlled machines. Somewhere along the way, the knowledge came in order to keep itself sufficiently advanced.

L. B. All this despite the fact that in Italy, especially at the political level, the concept of "let's invest in research" has no citizenship...

N. C. Yes, indeed! Very little is being done about it, partly because there is little understanding at a general cultural level, and that in turn is reflected in the world of politics, which is based on what people think. It seems to me that there are some signs of improvement due to new technologies, in the sense that people are beginning to realize that they are using new technologies and are therefore starting to understand the importance of the problem; whereas the technologies that were being used in the 1970s and '80s were not so different from those that were being used in the 1950s, such as the automobile and so on. The visibility of the technology is very high. Something is changing at the industrial level, and at the level of Confindustria in particular, just look at the articles you read in the newspaper *Sole 24 Ore*: there are articles talking about the importance of research, of innovation. The President Luigi Abete, and more recently Antonio D'Amato, raised the issue of research in their inaugural speeches. The industrial world seems to realize that it cannot get by without producing knowledge, or having access to locally produced knowledge. The illusion that research can only be bought from outside is only to some extent true. In the field of computers, the interesting technologies, those of Apple, of Microsoft, are not

Fig. 15 From left to right: Luciano Maiani, Nicola Cabibbo and Carlo Rubbia at the opening ceremony of the 50th anniversary of INFN in 2001. At the time Maiani was Director-General of CERN. © INFN

for sale, you can only buy the finished product. The really cutting-edge technologies you have to make yourself, you cannot buy them.

L. B. The fact remains, however, that science in general, and the products of research activity in particular, are not generally regarded as cultural heritage...

N. C. This is the general problem in Italy, at the level of the intellectual class, which is accustomed to reading the philosophers [Benedetto] Croce and [Giovanni] Gentile and deriving from them a definite anti-scientific position, whether on the Right or on the Left. The only good news is that we are forgetting Croce, which is not a bad thing.

L. B. However there is still a more insidious aspect, which concerns the total lack of awareness that doing science is also doing culture. In this respect, I think we are still far behind.

N. C. That is why, I would say, the interest of the industrial world is very important, as well as the interest of the trade union world, both of which actually determine the political lines.

L. B. Unfortunately, the world of industry is also the world that deals with information, so there is still a threat that we will remain on a superficial level.

N. C. Yes. I think they are better off in the UK. I have no idea about France....

L. B. In England there is a tradition, a habit of outreach, of lectures that goes back at least to the nineteenth century. It has always been a point of honor for great scientists to talk about the results of their work. Even within the scientific community, I think it's fair to say, there is certainly a very different sense of responsibility in this regard.

N. C. Certainly, there is a tradition in Britain of an educated audience, whereas we have little culture in general...

10 The 'Roman School'

L. B. How much of a 'son' of Edoardo Amaldi and 'grandson' of Enrico Fermi do you feel? In what sense do you feel a continuity with this tradition?

N. C. When I was a student, I remember very well that the very few physics students had a class where they went to the workshop and we learned how to use the lathe, and it was there that we came into contact with the technicians who had worked with Fermi. They were very proud of the lathe that "Professor Fermi" had ordered. There were still traces... At that time Fermi had left fifteen years earlier and at that time Majorana had disappeared less than twenty years before; and now another forty years have passed, and yet they hover around here. In any case I think there is a very strong continuity. I never knew Fermi, but Amaldi was a kind of 'high priest' of Enrico Fermi. I can't express it, but there is certainly a school. However, I wouldn't 'sanctify' it too much, there are other good schools. I think the most interesting thing about Fermi was that he did not want to distinguish between

Fig. 16 Edoardo Amaldi and Nicola Cabibbo in 1987 in the large lecture hall of the Physics Department of the Sapienza University of Rome, now called 'Amaldi Hall'. ©Edoardo Amaldi Archive, Department of Physics, Sapienza University of Rome

theory and experiment. In that sense he was one of the last universal 'greats'; slowly we moved towards a very strong specialization.

L. B. In your opinion, can this attitude still be viable today? Even though the way science is done has inevitably changed?

N. C. In my own small way, I have been involved in a few experiments, more by suggesting the experimental method than as a hands-on participant. Occasionally, when I have to justify APE to more theoretical colleagues, I say that Fermi would have done it...

L. B. It is extremely plausible... Fermi was immediately very excited by the possibilities offered by computers, which had originally been developed in the USA to tackle the difficult calculations involved in the thermonuclear bomb project led by Edward Teller. When the MANIAC was built at Los Alamos, he immediately used it, together with John Pasta and Stanislaw Ulam, to simulate non-linear systems and to analyze data collected by his group at the synchrocyclotron in Chicago...

N. C. And, in fact it is said that he was the one who suggested to Marcello Conversi that they should start a computer program at the University of Pisa, which led to the creation of a whole school. This is the origin of Italian computer science. Richard Feynman himself participated in the study of one of the first parallel computers, the Connection Machine; he was a consultant to the company that built it. He also wrote a very nice book about computers. So that sort of influence is certainly there. Fermi, like Amaldi, was very particular, characterized by an infinite and, moreover, inimitable regularity in his work. He was a tireless worker who approached everything with a continuous, constant method. I interacted a lot with Amaldi: we wrote a paper on monopoles together, we discussed gravitational waves together, and in several cases I supported his group by providing calculations.[17] I always admired his inexhaustibility. He was also a very energetic person when he was young, up until the 1960s; his outbursts were famous, you could hear him all the way down the corridor outside his studio... He was very rigorous and his tirades were mythical and very violent.

L. B. What other people have you felt particularly close to while working together?

[17] Cabibbo's article on monopoles was actually written with Ezio Ferrari [68], but they thanked Amaldi for stimulating their interest in the subject. And actually at the time Amaldi was searching for Dirac monopoles at the CERN PS [69] and, as recalled by Cabibbo, was also beginning to be interested in gravitation experiments and gravitational wave detection [70].

Fig. 17 Cabibbo in the late 1970s. Courtesy of INFN-Presidenza, all rights reserved

N. C. I worked with Raoul Gatto for a long time, from ’58 to about ’63. We had a very good relationship, he was ‘the older brother’... And then at some point I went to CERN and the relationship ended. I started working with younger people; on the other hand, there is a time when collaborations end, somehow you can’t stand each other anymore... We remained quite friendly. I worked a lot with a group where there was Luciano Maiani, Giuliano Preparata, Guido Altarelli; that was my basic group until the ’70s, then I worked a little bit with Giorgio Parisi and Massimo Testa. Later, in ’84, the APE [Array Processor with Emulator] project started, in the meantime I had started my involvement as president of INFN, so I didn’t have much time.

L. B. The collaboration with Parisi began prior to the start of the APE project...

N. C. Yes, Parisi graduated with me. In the first paper we wrote together, we proposed that quarks escape confinement at very high temperatures: i.e. the existence of a new phase of matter, the quark plasma phase [71]. We approached it in a slightly different way because quantum chromodynamics was not established at that time. It was a good paper; I consider it one of my best. Later we worked together on APE and the physics projects around APE. Then he got into the very interesting line of spin glasses and worked with a lot of students. Giorgio was very good, you could see he had a sparkling intelligence; and then he was always very generous, one of his characteristics was always to work with so many people, to give ideas; that’s a great strength of his. At a certain point, after graduating, he went to France, I think to avoid military service. Basically, we wrote two papers together; one is the one I mentioned, and the other is the one with Luciano Maiani and Roberto Petronzio [72]. It is the one where we found limits on the masses of certain new particles, in particular the top quark and the Higgs boson. When they later discovered the top, it was right at the limit of our prediction. The Higgs boson hasn’t been discovered yet; it’s all still to be verified.

11 Experience as President of the Pontifical Academy of Sciences

L. B. You are the President of the Pontifical Academy of Sciences. What does it mean to you to be part of such an institution?

N. C. I was invited to join the Academy in 1992; after a while, in 1995, I became its president. The Academy is small, we are only eighty people from all over the world, and there are very few Italians. Franco Rasetti is also a member of the Academy, he is still alive and will be 100 years old next year. Rasetti has been a member since it was

Fig. 18 Portrait of Nicola Cabibbo taken in 2007 by his son Andrea, all rights reserved

founded in 1936. The Pontifical Academy is not Catholic, it is very diverse as a presence from a religious point of view: there are Muslims, Jews, etc. Recently, Ahmed Zewail, the Egyptian Nobel Prize winner, became a member: he is the first Arab to be a member. I think it is a very interesting institution. The Pope is very interested in the problems that scientists are dealing with and on which they are often not heard. Problems of the environment, of poor countries, of science in poor countries, of war, of the dangers of armament; the Academy is very much heard, in fact much more than the Lincei. We see the Pope two or three times a year, and I have the distinct impression that he is interested in what we do. And I think what we do is useful. For example, there was the problem of some scientists who were imprisoned in Cuba, and the Academy brought the problem to the attention of the Holy Father, and when he was in Cuba he was able to get them released. The role of the Academy is essentially to maintain contact between the Church and the world of science. Some of the questions it has dealt with concern classical areas, such as cosmology... After being burned by the Galilei affair, the Church is very attentive to these things! Even in biology we have done interesting activities: in '95 we organized one of the first conferences on the genome, on the ethical implications of the genome. Then we had a series of meetings on the problems of the Third World, to which the Church is very sensitive. There is a very strong interest in studying these issues. The Academy is an institution that plays a very positive role and can also say uncomfortable things. In '92 there was a congress on resources and population; now the problem seems to be less serious, but the problem of megacities still exists. It is not a heavy activity for me, and I find it very positive and useful. About 20 Nobel laureates are members of the Academy, people are at a very high level, and humanly it is very interesting to meet very valuable people. Everyone cooperates very willingly. In 1991, for example, Max Ferdinand Perutz participated in the "Resources and Population" Conference and delivered a paper on motherhood, breastfeeding, and women's education as an important element in dealing with these problems. For the Church, this is a very good thing, and so the fact that the Popes, starting with Pius XI, who founded the Academy in '36, wanted to have this channel of communication is a very interesting aspect. Of course, we try to keep an open mind on the subjects of cosmology, for which there is a historical interest. In November we will have three days of meetings on the latest cosmologies, "The Future Universe: From a Cosmic Perspective". The other big topics are Third World countries and the environment.

L. B. Finally, I would like to ask you whether you think that the history of science, and in particular the history of one's own discipline, should be part of a scientist's education?

N. C. I think it should play a role already in high school, as a part of history, which is not only about battles and kings, but also about scientists! We study the history of literature, the history of philosophy, the history of art, but in school, which is a natural context, there is no place for the history of science. To do the history of science, you have to have a scientific background; it is clear that this gap cannot be filled without the input of scientists...

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