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Bruno Pontecorvo is an outstanding Italian and Soviet physicist. His life was amazing: the Pisa native became an academician of the USSR Academy of Sciences, invented neutron logging of oil; his remarkable ideas were awarded six Nobel Prizes and formed the basis of modern neutrino physics. This book is a story of his life and scientific discoveries.

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## PREFACE

Bruno Pontecorvo's life story is waiting for its filmmaker. He could make a biographical film about a great scientist, whose ideas have been recognized in the form of six Nobel Prizes. He could make a big family saga about the fate of a wealthy family of textile manufacturers from Pisa during the Mussolini era. A detective story about Bruno's escape with his whole family to the USSR. The drama of a real communist, losing his ideals in the era of glasnost and perestroika.

I am interested in Bruno as a great scholar and a wonderful man. He came into my life with an article in *Yunost* magazine, which I read in eighth grade. The mysterious city of happiness – Dubna, where the celestial physicists and the enigmatic Pontecorvo live – remain clearly in my memory. This article in many ways defined my life. I was very lucky – my childhood dreams had come true. Ten years later, on the bulletin board of the Physics Department at Moscow State University, I saw that Academician Pontecorvo was inviting students to his department and gave a lecture on neutrino physics. At this meeting, I saw Bruno for the first time and I was fascinated; both by what he was saying and by his appearance.

Of course, I chose to work in his department for my diploma, and got to Dubna – where the fantasy went on. My scientific fate was largely related to the verification of Bruno's ideas. I am proud that, together with Leonid Kondratyuk, we introduced into scientific language the term “Pontecorvo reactions” – a special class of annihilation reactions of antiprotons with nuclei, which Pontecorvo predicted six months after the discovery of the antiproton.

A separate big project of my life was my participation in publication of Pontecorvo scholarly writings. At first, a collection of selected articles was published with the help of the Italian Physical Society in English [1]. Then in the publishing house «Fizmatlit», a two-volume collection was published, in which the first volume contained scientific articles, and the second volume contained memoirs of Bruno [2]. Based on the materials of the book, a website <http://pontecorvo.jinr.ru> was created, which also contains a large collection of photographs.

In 2003, I wrote the screenplay for a film about Bruno [3]. During the filming we were able to interview Bruno's brother, the famous director

Gillo Pontecorvo, as well as various people who knew Bruno while he was still living in Pisa.

In 1998, we held the first Pontecorvo International School for Young Scientists at the Joint Institute for Nuclear Research in Dubna. In the course of the school, we recorded several video interviews with colleagues who knew Bruno well – Samoil Bilenky, Semyon Gershtein, Giuseppe Fidecaro, Renato Ricci. A large exhibition of Bruno’s photographs, made by Yury Tumanov, was opened. Up to now it decorates a hall in one of the JINR laboratories [4].

It was quite logical to arrange all the accumulated materials in the form of a book. However, the trigger for me was the book of Frank Close “Half-Life: The Divided Life of Bruno Pontecorvo, Physicist or Spy” [5]. Frank Close is a well-known expert in elementary particle physics, a well-known science writer, has done a lot of work in the archives, interviewed many people who knew Bruno. It’s very interesting research. But, drawn to a simple version – it says Bruno was a spy. The main ‘evidence’ is a Russian swear phrase written in Latin and attributed to Bruno. This ‘proof’ outraged me to the point that working on this book became my daily occupation.

Unfortunately, Close is not alone in his desire to present Bruno’s fate in a style reminiscent of a James Bond epic. The same point of view is held by Simon Turchetti, the author of another book on the fate of Pontecorvo [6]. Of course, for the book’s sales, the taste sensation is necessary, and the spy version is the most profitable. But it’s hard to imagine James Bond making his escape with his wife and three children.

A separate place in the literature on Bruno is occupied by a remarkable book from the famous Italian journalist Miriam Mafai [7]. It is based on a series of interviews with Bruno and can be said to be an authorized biography. But Bruno himself also wrote several autobiographical articles and gave a rather detailed account of various episodes in his life. These formed a separate section in the second volume of his Selected Scientific Works [2] which we published. However, not all the materials from Bruno’s archive were included in the [2]. At one time we wanted to compile the speeches he delivered at various conferences into a separate book, but it did not turn out to be very voluminous. Some of this material will be presented for the first time in this book.

In addition to the Russian edition of the book, I started a telegram channel [https://t.me/bruno\\_pontecorvo](https://t.me/bruno_pontecorvo) , which contains video interviews and various materials used in the book.

Bruno Pontecorvo is a great physicist. And the first thing I wanted to talk is about the originality and depth of his physical ideas. That's why this book will have formulas and graphs, without which the beauty of an experiment or a theoretical proposal is hard to explain.

Bruno's fate speaks for itself.

# 1.

## PONTECORVO FAMILY

When I first went to Pisa, I wanted to find the house where the family of Pontecorvo lived. Gil Pontecorvo, son of Bruno Maximovich, did not remember the exact address, but he gave me a clue: the house is near Piazza dei Miracoli, the main square of Pisa, where the magnificent cathedral baptistery and the famous falling tower are situated.

I passed Piazza dei Miracoli, went out into the next street, and approached the first carabinieri I saw, asking him if he knew where Pontecorvo's house was. He directed me to a tourist information agency. The girl at the agency shrugged and sent me to the nearest hotel. The porter was at a loss – he hadn't heard. Then I saw two old men drinking coffee on the hotel terrace and asked them: "Do you know where Pontecorvo's house is?" "The director?" – one asked. "The physicist?" – another asked.

This involuntary opinion poll revealed that it was the filmmaker Gillo Pontecorvo and the physicist Bruno Pontecorvo, better than all the glorious members of the Pontecorvo family are the ones who have been recorded in the mass consciousness of Italians (at least, visitors to the local cafe). In the end, it took 10 minutes to find Pontecorvo's house. It stands on Via Bonanno Pisano, 111, now home to the Hotel Roma (Fig. 1-1).



**Fig. 1-1.** Pontecorvo family home (author's photo).

However, there are other places in Pisa connected with the Pontecorvo family. For example, Pellegrino Pontecorvo Street, named after Bruno's grandfather. He's revered as an outstanding entrepreneur who created several textile factories in Pisa. In 1915 the Pontecorvo Company had about 2,000 workers, 1,250 looms, 3,000 rotating spindles, and two workshops for dyeing raw cotton [8].

Now in one of the buildings of the Pontecorvo factory is the physics department of the University of Pisa. In the foyer of this building stands a bust of Pellegrino Pontecorvo, I took a picture next to it of Gil Pontecorvo, Pellegrino's great-grandson (Fig. 1-2).



**Fig. 1-2.** Bruno's son, Gil Pontecorvo next to a bust of his great-grandfather Pellegrino Pontecorvo (photo by the author).

We have Bruno Pontecorvo Street in Dubna. This stimulated the idea of asking the city of Pisa to name one of its streets after him. From the Joint Institute of Nuclear Research in Dubna, where Bruno had worked all his life in Russia, a letter with this proposal was sent to the Pisa City Hall. They received a very warm response; the initiative was supported. A small square near the physics department building was named after Bruno (Fig. 1-3). The nice thing is that now its official mailing address is Largo Bruno Pontecorvo 3.



**Fig. 1-3.** A rally marking the opening of the Bruno Pontecorvo Square in Pisa (photo by the author).

Bruno was born on August 22, 1913, in the spa town of Marina di Pisa, where the family kept a summer vacation villa. His mother, Maria Maroni, was the daughter of a famous Milanese physician and hospital director. Bruno recalled how his mother told him not only about Milan's social life, the great stores, performances at La Scala, but also about the production of Chekhov's "Three Sisters".



**Fig. 1-4.** Bruno's parents (photo from <http://pontecorvo.jinr.ru>).

His father, Massimo, one of Pellegrino Pontecorvo's ten children, continued the family textile business with his brother Otilio. Their houses on via Bonnano Pisano faced each other.

Miriam Mafai recorded [7] Bruno's impressions of his little one being frightened by crowds of young workers walking down the street and singing: "Here Lenin will come, here Lenin will come, he will make everyone work, and he will not give them bread! And Pontecorvo will also work without food!"

Bruno's fears ended when he heard his father humming that song, too, beating a rhythm on the table. Bruno's father was very good to his workers. When Mussolini came to power, Massimo refused to join the Fascist Party, and when the Fascist leader of Pisa, one Buffarini Guidi, offered Massimo to give out the names of the workers-organisers of a major textile strike, Bruno's father gave the Fascist boss such a scolding that the case almost ended in a duel. Buffarini Guidi subsequently made a career and becoming Minister of the Interior in Mussolini's government.

Bruno repeatedly emphasized that it was his father's desire for justice that played a key role in his destiny. Bruno had four brothers, Guido (1907–1999), Paolo (1909–2004), Gillo (1919–2006), Giovanni (1926–2006) and three sisters, Giuliana (1911–1994), Laura (1921–2011), Anna (1924–1986).

The greatest prominence in the mass Italian consciousness, as we have seen from my survey in Pisa, was Bruno's younger brother, the filmmaker Gillo Pontecorvo. I highly recommend watching his wonderful film, *The Battle of Algiers* awarded the Golden Lion of St. Mark at the Venice Film Festival. Filmed in 1966 it still amazes with its modern approach to the problem of the perception of terrorism. He was president of the Venice Film Festival for a long time.

Bruno's older brother, Guido, was also very well known, though not in such wide circles. He worked at the University of Edinburgh, worked in genetics, and was a Fellow of the Royal Society of England.

Brother Paolo chose engineering, in 1938 he moved to the United States. He was involved in the development of radar. Giovanni lived in England and was involved in small business. Sister Giuliana, married to Duccio Tabet, became a journalist and held Communist views. She and her husband played a prominent role in the Italian Communist Party. Anna was a teacher, and Laura, who became a nurse, emigrated to England.

As a child, Bruno had an unpleasant experience which he even saw fit to mention in his autobiography [9]:

“ My parents, conservative people, were quite demanding and had each of us a certain opinion, which they did not show. We were familiar with this opinion, being willing or unwilling listeners to their conversations. Here it is: Guido was the smartest of the brothers, Paolo was the most serious, Giuliana was the most educated, Bruno was the kindest, but the most limited (this was evidenced by his eyes – kind but not clever). I owe this opinion to my shyness and of inferiority, which have hung over me almost all my life.

Just think about it – by the time he wrote his autobiography, Bruno was a successful, respected man, an academician, a laureate, a father of three children. And here, in the second paragraph of his biography, he writes about his parents’ opinions that made him shy and insecure! This is doubly surprising to people who knew Bruno through the life – he was always a bright, cheerful, charming, easy-going man. If you imagine this picture-a child who unwittingly heard from his parents their judgments about his own character and then got a complex for life – I wish no one would repeat Bruno’s parents’ mistakes.

The family loved music. They organized family concerts. Bruno, at the age of eight learned to play the violin and he loved it. Gillo Pontecorvo said [10] that when Bruno was ten years old his parents asked him which instrument to buy – a piano or a violin, he immediately said the violin.

But most of all he loved tennis. His aunt Clara Colony had her own tennis court on which fierce battles were fought. According to Gillo Pontecorvo [10], Bruno won the Italian doubles championship in the second division. At the age of 16 he was invited to join the Italian junior tennis team and was supposed to go to a training camp in France, but his parents wouldn’t let him. Even many years later Bruno talked about this episode with great bitterness.

Pontecorvo graduated from the R. Ginnasio Galilei Lyceum. His class register from 1920 is still kept at the Lyceum and bears witness to his successes. Bruno was brilliant at school. He jumped three grades

in one year. But that also created the obvious problems that all young prodigies face. Gillo Pontecorvo told us [10] that when 12-year-old Bruno found himself in an exam with adolescents aged 16 or 17, he felt very uncomfortable and became very anxious. He knew one subject well and behold, it was the topic that fell to him in the exam! It would seem that he should only rejoice. But the nervous stress was so great, he was so worried that he cried from unexpected happiness. The examiner looked at the crying baby and said sternly: “Well, what kind of sentiments! We don’t have babysitters here!”

Gillo Pontecorvo said that as a child Bruno was unusually modest: “We never heard him say ‘I’. It was as if this pronoun was absent from his vocabulary. His complete modesty was accompanied by a lively interest for other people” [10].

## 2.

# IN THE FERMI GROUP

One day Guido's friend, the physics student Franco Rasetti, brought his classmate, a certain Enrico Fermi, to Pontecorvo's house. Rasetti claimed that his comrade was a real genius. Bruno was ten years old at the time, but he remembered the reaction of his parents and brothers: "Isn't Rasetti exaggerating? Who can believe that such a shy and silent young man is a genius!" [11].

Eight years later, Bruno had his next meeting with Professor Fermi.

The fact is that at the age of 16 Bruno enrolled in engineering at the University of Pisa, where he studied for two years. But he didn't like drawing and wanted to study physics. Naturally, when Guido learned of his brother's wish, he immediately advised him to move to Rome, to his friend Franco Rasetti, who was already working in the group of physicists led by Professor Enrico Fermi.

It was a life-changing choice that not only shaped Bruno's professional life, but also gave him the unique opportunity to work alongside a great scientist, and participate in a landmark discovery.

In one of his interviews [12] Bruno said that meeting Fermi was pure happiness, at the time he was not interested in anything but tennis. Fermi was an example of a scientist to him. In Bruno's study in Dubna, two portraits hung, Fermi and Joliot-Curie.

Fermi's laboratory, as Bruno recalled [13], was

“ first-class, but rather small. It employed no more than ten scientists and technicians. The physics department at the time had one or two students. The means for experimental research were literally negligible. I remember, for example. Once, in order to save money for scientific research, Fermi decided to make ordinary electrical plugs in his laboratory.

Rasetti and Fermi put the young man to some test. Bruno recounted [9] how at the end of the interview Fermi summarized:

“ Unfortunately, physicists today are divided into two categories-theorists and experimentalists. The requirements for

theoreticians are very high. If the theoretical physicist is not at a very high level, his work is meaningless. In this respect there is an analogy, say, between the profession of the theoretical physicist and the profession of the scientist-egyptologist. If the Egyptologist did not turn out to be an exceptionally bright scientist, it means that he simply made a mistake in his choice of profession. As for experimental physicists, even for person of average ability, there is always the possibility of being useful. An experimenter can, say, measure the density of different substances. This would be very necessary work, though it does not require much intelligence.

Bruno was assigned to the experimenters. He probably didn't look very bright at the exam. Nevertheless, Bruno entered the third year of the physics department in Rome and managed to defend his diploma brilliantly, getting 110 points out of a possible 110, at the age of 20 [14,15]. This was a rare exception at the time, and even nowadays very few people successfully receive university education at the age of 20.

The supervisor of the thesis was Franco Rasetti. He had a rare device at the time – an electron microscope. At the defense, he said that the main merit of the diplomate was that he survived well without suffering from electric shock [12].

Bruno's first work was on optical spectroscopy, and he happily finished it in the summer of 1934. After the summer break, Bruno was assigned to help another member of the Fermi group, Edoardo Amaldi, with a promising new topic: research into artificial radioactivity.

### 3.

## SLOW NEUTRONS

In 1934, Fermi and his group were actively studying a recently discovered interesting phenomenon, artificial radioactivity. Natural radioactivity consists of elements which can spontaneously, without any external influence, emit helium nuclei ( $\alpha$ -decay), electrons ( $\beta^-$ -decay), positrons ( $\beta^+$ -decay) or gamma quanta. A typical example of a radioactive element is uranium. However, the question of whether an ordinary substance, for instance aluminum, could be made to emit radiation, remained unanswered until Frederic and Irene Joliot-Curie carried out their experiments in the beginning of 1934. They irradiated light elements (boron, beryllium, aluminum) with helium nuclei ( $\alpha$ -particles) and found that after this exposure, the samples began to emit positrons.

Fermi decided to repeat the experiments of Joliot-Curie's, but to irradiate the samples with neutrons. The logic was simple – positively charged  $\alpha$ -particles to interact with the nucleus had to overcome the Coulomb repulsion of the positively charged protons in the nucleus. Whereas the neutron has no electric charge and should easily enter nuclear reactions.

The experiments were also very simple: a test tube with a radon-beryllium source was held up to a sample of neutrons. It was irradiated for a certain amount of time, and then the sample was brought to a Geiger counter to see if there was any induced activity – whether it was radiating, and if so, what was the intensity of the radiation.

However, there were details: radon is a radioactive gas, which is released from radium, and has a half-life of 3.82 days. That is, it is necessary to have a constant source of radon for days-long experiments, which is far from easy. Fortunately, already at that time, medics were using radon as a means to fight cancerous tumors. In the basement of the Fermi Institute, there was a medical school laboratory that had several radium sources. Its director, Giulio Trabacchi, set up an apparatus for extracting radioactive radon, which was used to fill small (about 10 mm) glass ampoules with radon. Radon is a powerful source of alpha particles, and if beryllium powder is placed in the ampoule with the gas, the reaction will produce a source of neutrons.

