



ISTITUTO NAZIONALE DI FISICA NUCLEARE

Laboratori Nazionali di Frascati

INFN - 18-05/LNF

25 maggio 2018

Bruno Touschek and AdA: from Frascati to Orsay

Luisa Bonolis¹, Giulia Pancheri²

¹*Max Planck Institute for the History of Science, Boltzmannstraße 22, 14195 Berlin, Germany*

²*INFN, Laboratori Nazionali di Frascati, P.O. Box 13, I-00044 Frascati, Italy*

Abstract

This paper is dedicated to the memory of Bruno Touschek, who passed away forty years ago, in Innsbruck, Austria, on May 25th, 1978. The first electron-positron collisions in a laboratory were observed in 1963-1964 at the Laboratoire de l'Accélérateur Linéaire d'Orsay, in France, with the storage ring AdA, which had been constructed in the Italian National Laboratories of Frascati in 1960, under the guidance of Bruno Touschek. The making of the collaboration between the two laboratories included visits between Orsay and Frascati, letters between Rome and Paris, and culminated with AdA leaving Frascati on July 4th, 1962 to cross the Alps on a truck, with the doughnut degassed to 10^{-9} mmHg through pumps powered by heavy batteries. This epoch-making trip and the exchanges which preceded it are described through unpublished documents and interviews with some of its protagonists, Carlo Bernardini, François Lacoste, Jacques Haïssinski, Maurice Lévy.

PACS: 01.65.+g, 01.60.+q, 29.20.-c, 29.20.db

*Published by
Laboratori Nazionali di Frascati*

Contents

1	Introduction	2
2	The 1961 Geneva Conference	8
3	And then came Pierre Marin and Georges Charpak: <i>Un vrai bijou</i>	11
4	The 1961 Conference at Aix-en-Provence	14
5	Letters and visits	15
6	How AdA left Italy and arrived in France	22
7	What happened in Orsay	27
8	Conclusions	28

1 Introduction

In this paper we describe the making of the Franco-Italian collaboration which brought AdA, the first electron-positron storage ring ever built, from the Italian National Laboratories of Frascati to France, at the Laboratoire de l'Accélérateur Linéaire (LAL) in Orsay, where the linear accelerator could provide AdA with a source of electrons sufficiently intense to offer a good probability to observe collisions. AdA had been the brainchild of the Austrian born theoretical physicist Bruno Touschek, who came to Italy in 1952, and proposed the construction of a colliding beam machine to explore electron-positron annihilations, during an epoch making seminar of March 1960.

There are accomplishments in science which, at first sight, appear to spring from chance or improvisation, but that, once inspected carefully, show the many different threads underlying their development and the conscious decisions taken all along, and which may ultimately lead to transform pure research results into society's gain. Such is the construction and development of particle colliders, which accelerate elementary particles such as electrons or protons, or their anti-particles, making them travel in opposite directions, within the same evacuated ring shaped chamber, called the doughnut because of its shape, and then smash them one against the other, and, through the observation of the debris, probe their internal dynamics or structure. This type of accelerators was envisioned after World War II, in Europe, in the United States, and in the USSR. Their actual realization came through the contribution of different laboratories and scientists from many different countries — Norway, Austria, Germany, Italy, the United States, France, Great Britain, all these pathways eventually converging towards the construction of the first particle-antiparticle collider in 1960 in Italy. A comprehensive description of these various roads is part of a larger work in progress we are preparing. What we shall do in

this paper is to tell the story of how two of these roads came to cross each other, leading to the demonstration of the feasibility of electron-positron colliders.

The first particle collider to enter into operation used electrons and their anti-particles, the positrons, to smash one against the other, after a suitable number of them had accumulated. This first electron-positron collider was called AdA, an Italian acronym for Anello di Accumulazione, storage ring in English. It was built in Italy in 1960, at the Frascati National Laboratories near Rome, and it was made to achieve its potential to collide electrons against positrons three years later in France, at the Laboratoire de l'Accélérateur Linéaire (LAL) in Orsay. Doubts had been raised as to whether it could be possible to build an accelerator where electrons and positrons could be observed to collide in the same ring. However, when the word spread that AdA had started operating and, later on, that collisions had been observed, projects for particle colliders were put in motion in all the main particle laboratories in the world.

AdA was a small machine, little more than 1 meter in diameter, which can still be seen installed under a canopy, in one of the lawns as one enters the Frascati Laboratories. Since AdA's early days, during the last fifty years, scientists have built bigger and more powerful colliders, the biggest of them all being the CERN Large Hadron Collider (LHC). On the long road from AdA to the LHC, particle colliders have provided scientists with the tools to control the dynamics of beams of elementary particles such as electrons, positrons, protons, anti-protons, heavy ions. In the LHC, particles travel in a ring deep under ground, on a 27 km long path, across France and Switzerland, passing along the Cointrin airport of Geneva, in and out of the Jura mountains. With such a powerful machine, in 2012 CERN could announce the discovery of the Higgs boson, the long sought missing link of the Standard Model of Elementary Particles. And, at the same time that colliders contributed to a deep understanding of the structure of matter, it has been possible to exploit this knowledge to build novel accelerators, which would be powerful producers of synchrotron radiation, currently used in a great variety of medical and technological applications.

The events which led to the construction of AdA in Frascati have been described in many publications, starting with Amaldi's biography (Amaldi 1981) of Bruno Touschek—the prime mover and the inspiration for the construction of AdA—to the most recent testimonial of Touschek's life in (Bernardini, Pancheri, and Pellegrini 2015). Edoardo Amaldi, one of the founders of CERN, had invited Bruno Touschek to come to work and do research in Rome in 1952. After Touschek's death in 1978, Amaldi prepared and published an extensive and unsurpassed description of Touschek's life and accomplishments. In Fig. 1, we show him together with Bruno Touschek in the 1960s.

The transport of AdA to Orsay has also been described many times, and a preliminary outline of the exchanges leading to the collaboration between Italian and French scientists was given in (Bonolis and Pancheri 2011). In this paper we shall present a more complete reconstruction, with further details, closing a number of gaps between the



Figure 1: Bruno Touschek, at left, and Edoardo Amaldi at the beginning of the 1960s (Courtesy of Francis Touschek).

various letters and visits and clarifying important events. We shall make use of archival documents from both Sapienza University of Rome and Laboratoire de l'Accélérateur Linéaire, as well of interviews with some of the scientists involved in AdA's adventure. In particular, since 2003, three docu-films have been produced about Bruno Touschek and AdA, namely *Bruno Touschek e l'arte della fisica*¹, *Touschek with AdA in Orsay*² and *60-ans-d'exploration-de-la-matière avec des accélérateurs de particules*³, which describes the impact of AdA on the development of electron-positron colliders in Orsay. Some of the quoted texts included in this paper have been extracted from these docu-films or from their unused parts.

The events of interest we shall describe here took place between June 1961 and July 1962, starting with a Conference in Geneva, where the Frascati team presented their electron-positron projects, up to the time that AdA arrived in Orsay, around July 1962.

As described in (Bernardini 2004), the AdA had been functioning in Frascati since February 27, 1961.

The idea of electron-positron collisions had been suggested by Bruno Touschek in a meeting held to discuss the laboratory future projects on February 17, 1960.⁴ At that time, the electron synchrotron had been in operation at Frascati Laboratory since early 1959 (Alberigi *et al.* 1959) and, in November of the same year, the CERN Proton Synchrotron (PS) had accelerated its first protons. During the meeting, especially devoted to the creation of a theoretical group in Frascati, Touschek suddenly came up with what, at the moment, looked like a strange proposal: transforming the brand new electron synchrotron into an electron-positron storage ring (Amman 1989, 449).⁵ This idea was

¹<https://www.youtube.com/watch?v=ami4kKkxSV8>

²http://www.lnf.infn.it/edu/materiale/video/AdA_in_Orsay.mp4

³<https://webcast.in2p3.fr/video/60-ans-dexploration-de-la-matiere>

⁴ An accelerator in which oppositely charged particles would smash against each other in head-on collisions had been first envisioned by Rolf Widerøe and patented on September 8th, 1943 (Widerøe 1994).

⁵ See report of the meeting (L.N.F., Report N. 62, December 1960). See also B. Touschek, "AdA e

rapidly discouraged. As Touschek later commented:⁶

This proposal was not very tactful in front of a meeting of people who had built the machine and were proud of it and other who had spent years in preparing their experiments and were eager to bring them to a conclusion, to modify them and think of new ones to be carried out with the same machine.

The project was saved by Giorgio Ghigo, Machine Director of the Frascati Laboratories, who suggested to build a smaller ring, dedicated to the storing of electrons and positrons, and authored the blueprints of the magnet, inside which the AdA's doughnut would be placed. With this modification the project was enthusiastically approved by the Laboratory director, Giorgio Salvini. Ghigo's suggestion was followed by a detailed proposal presented by Bruno Touschek two weeks later, on March 7th, and approved shortly after with a 20 Million Lire budget.

In November, it was clear that the ring would function and the first of four articles about the Frascati storage ring was submitted to the *Nuovo Cimento* and published shortly thereafter (Bernardini *et al.* 1960). That same November, Bruno Touschek wrote a memo that envisioned the building of a bigger ring, with a centre of mass (c.m.) energy as high as $\sqrt{s} = 3$ GeV (see Fig. 2).⁷

Following Touschek's memo on ADONE of November 1960, a document was prepared and submitted for approval,⁸ and in February 1961 a study group led by Ferdinando Amman was formally set up with the task of preparing a first estimate of the feasibility and costs of such a project. By that time, a new director had come to the Frascati Laboratories, Italo Federico Quercia, shown in Fig. 3 with Amman, head of the ADONE project, and Ruggero Querczoli, the senior experimentalist for the AdA group.

ADONE, bigger than AdA, and as beautiful as an Adonis, was planned to have such energy to produce the annihilation of the initial electron-positron pair into all the known particle-antiparticle final states, such as pions or muons, i.e. $\pi^+\pi^-$, $\mu^+\mu^-$, including the nucleons and their antiparticles, well above their production threshold.⁹

Adone", manuscript, Edoardo Amaldi Archives, Sapienza University of Rome, Department of Physics, Bruno Touschek Papers (from now on Bruno Touschek Archive), Box 11, Folder 3.92.4, p. 7.

⁶B. Touschek, "A brief outline of the story of AdA", excerpts from a talk delivered by Touschek at the Accademia dei Lincei on May 24, 1974 (manuscript, Bruno Touschek Archive, Box 11, Folder 92.5, pp. 5-6).

⁷B. Touschek, 'ADONE' a Draft proposal for a colliding beam experiment" (typescript, Bruno Touschek Archive, Box 12, Folder 3.95.3, p. 3).

⁸On January 27, 1961, F. Amman, C. Bernardini, R. Gatto, G. Ghigo and B. Touschek presented the Internal Report "Anello di Accumulazione per elettroni e positroni (ADONE)", LNF - 61 / 005, <http://www.lnf.infn.it/sis/preprint/detail-new.php?id=3076>.

⁹This maximum energy for the annihilating electrons and positrons doomed Frascati not to be able to discover the charm-anticharm bound state, the J/Ψ , for which one needed to reach more than of 3.1 GeV in the center of mass (Maiani and Bonolis 2017). Once the discovery was announced (Aubert *et al.* 1974, Augustin *et al.* 1974), the Frascati experimentalists forced ADONE to reach the higher energy value required to observe the new particle, but could only confirm the discovery (Bacci *et al.* 1974), whose credit went to the two American groups, led by Samuel Ting and Burton Richter, respectively. For a description

A D O N E - a Draft Proposal for a
Colliding Beam Experiment.

B. Touschek,
Rome, 9. Nov. 60.

It is proposed to construct a synchrotron like machine capable of accelerating simultaneously electrons and positrons in identical orbits. The suggested maximum energy is 1.5 Gev for the electrons as well as the positrons. This energy allows one to produce pairs of all the so called 'elementary particles' so far known, with the exception of the neutrino, which only becomes accessible via a weak interaction channel.

It is assumed that experiments in which there are only two particles in the final state are most easy to interpret. There are 16 such reactions, namely:

(1) 2γ . This is the only reaction in which the ~~weak~~ intermediate state is 'quasi real' and in which therefore there should be no 'radiative corrections'. This reaction should serve as a 'monitor'. The cross-section is $2.6 \cdot 10^{-31} \text{ cm}^2$.

(2) e^+, e^- . This reaction will show strong angular variations and may require 'good geometry'. It would give information on the breakdown of electrodynamics at distances corresponding to about 1/3 the Comptonwavelength of the proton.

(3) μ^+, μ^- . Test of electrodynamics in 'bad geometry'. May also serve as an indication of the fundamental difference between electrons and muons.

(4) $\pi^+ \pi^-$ reveals the interaction between pions in odd parity states.

(5) $2\pi^0$: charge exchange interaction for pion-pion scattering.

(6) $K^+ K^-$: interaction of K-mesons in odd parity states.

(7) \bar{K}^0, K^0 : Charge exchange interaction between K-mesons.

(8) p, \bar{p} : interaction of proton and antiproton in even parity odd charge parity states.

(9) n, \bar{n} : same as (8) but for the charge exchange reaction.

(10) through (15). Interactions simple or with charge exchange of hyperons.

Figure 2: Bruno Touschek's memo for Adone (Bruno Touschek Archive).

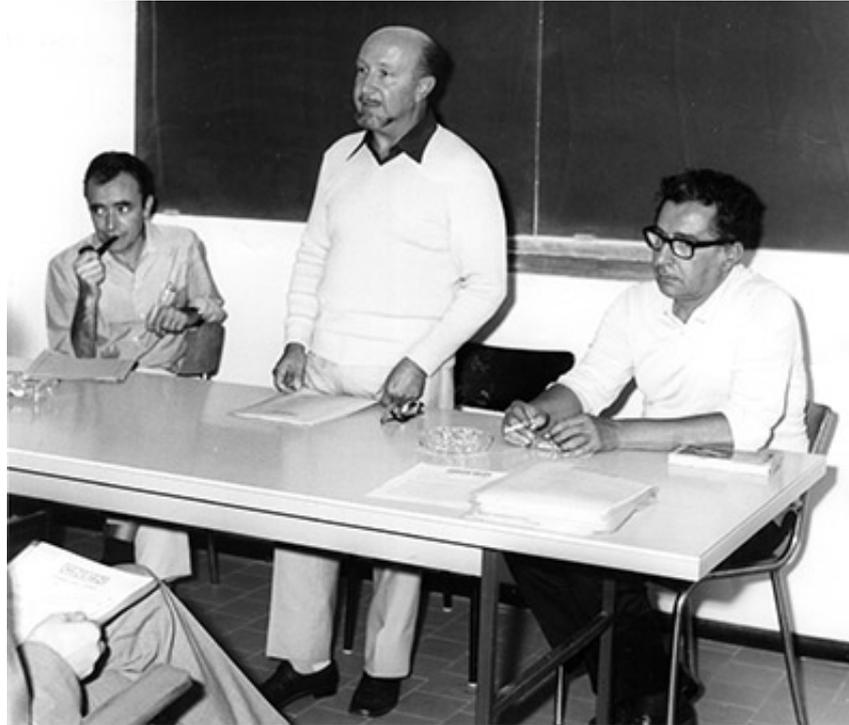


Figure 3: From the left, Fernando Amman, Italo Federico Quercia and Ruggero Querzoli in the 1960s (Courtesy of LNF Archive).

The enthusiasm was high in Frascati, when, in February 1961, the magnet was turned on and, less than a year after the official seminar where Bruno Touschek had presented his proposal, the little ring started functioning: electrons and positrons could be proven to circulate in the doughnut by observing the light signal they emitted, the phenomenon also known as synchrotron light radiation. The number of “electrons” circulating in the machine and the length of time these electrons would “stay alive”, was recorded.¹⁰ Part of the ammeter printout from the phototube record is shown in Fig. 4.

A similar recording was sent by Touschek to Edoardo Amaldi on the morning following the second night of AdA’s operation. During the next night Amaldi went to see with his own eyes something that nobody had ever seen before: the synchrotron light emitted by a *single electron in orbit* which was visible to the naked eye through one of the portholes (Amaldi 1981, 32):

Bruno took an immense pleasure in showing this phenomenon which, to a certain extent, was commonplace, but at first sight appeared incredible. His enthusiasm was extreme [...]

The group was now confident that AdA could lead the way to higher energy physics, and plans were put forward for a bigger and more powerful accelerator, one which would

of the days of the discovery, as seen from Frascati, see M. Greco and G.P., “Frascati e la fisica teorica: da AdA a ADONE” (*Analysis*, issue 2/3 - June/ September 2008), http://www.analysis-online.net/wp-content/uploads/2013/03/greco_pancheri.pdf

¹⁰It was never clear whether the light observed was emitted by an electron or a positron.

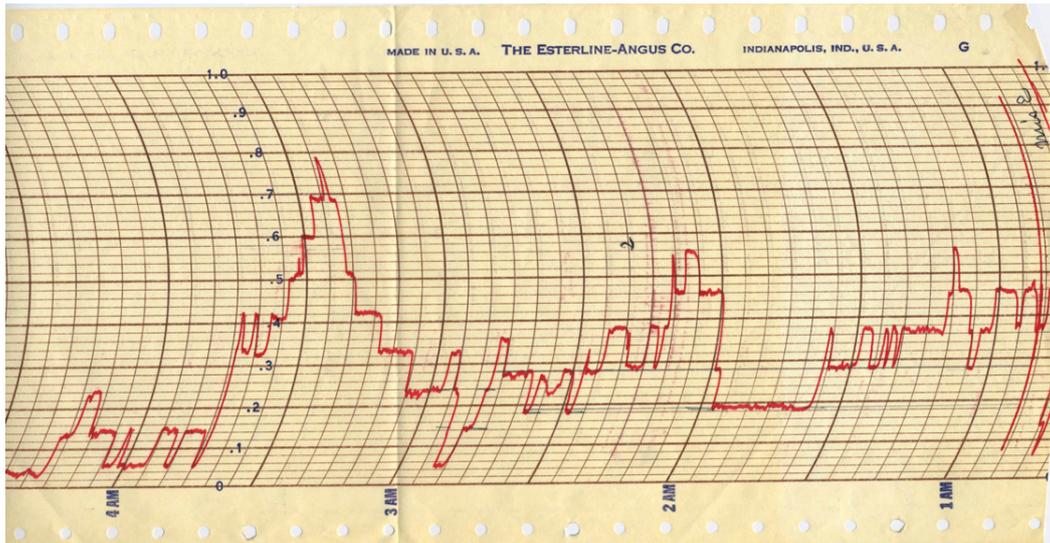


Figure 4: The phototube record of February 27, 1961, showing current versus time steps that correspond to single electrons entering or leaving AdA (courtesy of Carlo Bernardini).

“probe the quantum vacuum”, and discover new particles, through electron-positron annihilation.

Spring 1961 saw more tests and measurements being done with AdA, while more theoretical work was completed by Bruno Touschek’s colleague at University of Rome, Raoul Gatto, in collaboration with Touschek’s former student Nicola Cabibbo. They are both shown in Fig. 5. The first AdA paper had aroused quite some interest and Touschek was invited to present the Frascati work on storage rings to the forthcoming International Conference, to be held in Geneva, June 5th to June 9th, 1961.

Throughout the following months, the AdA team prepared the contributions to the summer conferences, the now customary venue of presentation of the year’s results, the first being the one in Geneva. Our story starts there.

2 The 1961 Geneva Conference

In Frascati, as summer 1961 approached, not everything was working as hoped. The main obstacle appeared to come from the slow injection mechanism of particles from the electron synchrotron, too slow to produce a number of electrons and positrons sufficient to prove that collisions between them were taking place. Still the machine was operating and, in June, Touschek presented these results to the CERN *International Conference on Theoretical Aspects of very high Energy Phenomena* (Bell *et al.* 1961).¹¹ His contribution appeared in the session on *Electromagnetic Interactions* which consisted of three talks, in

¹¹For these Proceedings, see also <https://cds.cern.ch/record/280184>.

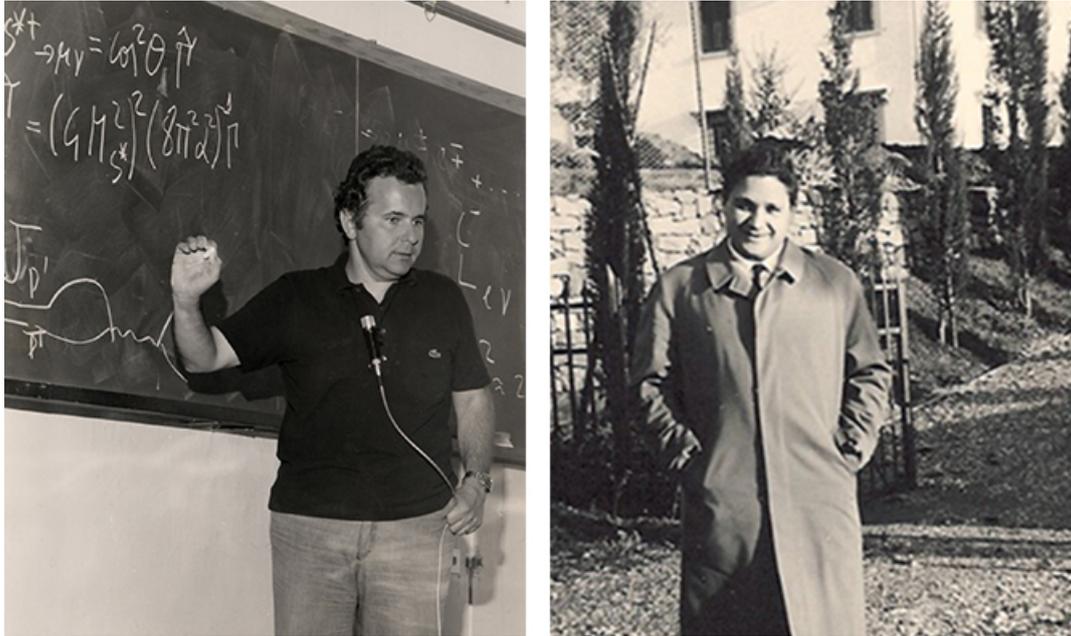


Figure 5: From the left, Nicola Cabibbo and Raoul Gatto in the early 1960s.

the following order: one by Burton Richter,¹² the second by Touschek, the third one by Raoul Gatto.¹³ Gatto's talk was focused on the theoretical aspects of electron-positron physics, presenting two papers authored with Nicola Cabibbo, a short one published in February 1960 (Cabibbo and Gatto 1960) and a lengthier one submitted to *The Physical Review* (recorded submission as of June 8th, 1961), just before leaving for the Conference (Cabibbo and Gatto 1961).

The contrast between the two first talks is striking. Richter seems to justify the choice NOT to start electron-positron experiments, Touschek is announcing they have already built a small prototype and have proposed to build a bigger ring. Let us see the two talks in their most important passages, at a distance of almost 60 years, with what, in Italian, is called *Il senno di poi*.¹⁴

The session started with a talk by Burton Richter, from Stanford University, with the title *COLLIDING BEAMS EXPERIMENT* (Bell *et al.* 1961, 57):

Let me begin by saying that we all hope that this will be the last talk about what we are going to do when the experiment is ready. We hope that next year we can talk about what we have done.

And he then continues by describing the two ring set-up for the proposed electron-electron collision experiment and the hoped for time schedule. Then Richter goes on discussing

¹²In 1976, Burton Richter, from Stanford University, was awarded the Nobel prize for the discovery of a heavy elementary particle of a new kind, the J/Ψ , jointly with Samuel Ting from MIT.

¹³Raoul Gatto was at the time at University of Rome, and, two years later, would become Professor of Theoretical Physics at University of Florence.

¹⁴Wisdom, after the facts.

Positron Experiments, and opens with a denial:

Whenever this subject has been brought up in the past, we have refused to commit ourselves about its prospects. I am not going to change this policy, but I would like to discuss the difficulties of the positron experiments a bit.

Having said this, he adds:

These problems are not the main reason for our long-standing silence on the experiment.

Basically Richter insists that the electron experiments must first be shown to work well, before starting with positrons, namely

Until we know what we can do in storing a beam, we cannot say anything about the positron experiment.

Then Touschek starts, with a simple concise sentence (Bell *et al.* 1961, 67):

Frascati is developing two storage rings.

and then, after rapidly describing the ADONE project, which was still under design, he moves to describe the first project:

The first project - AdA - was started in February 1960. It was clear from the beginning that this project would be a gamble, the calculated intensity of the machine being about a factor 500 less than what was needed for experimentation. It was nevertheless decided to go on with the project, mainly because it was hoped that experience in storage problems could be most rapidly gained in this fashion and that eventually ideas for increasing the intensity might be forthcoming.

Touschek's contribution included many technical drawings, as well as the phototube record of the number of electrons circulating in AdA, shown in Fig. 4. In Fig. 6 we show two photos extracted respectively from Richter's and Touschek's talk. In his talk, Touschek gives one of the clearest expositions of AdA's technical details, listing in his unique, and extraordinarily precise way, all the excellent reasons to start experimentation with electron-positron collisions. To complete this session, Gatto followed with a theoretical talk, where he makes a very prophetic statement (Bell *et al.* 1961, 76):

High Energy electron-positron colliding beam experiments may become a field of spectacular development in high energy physics.



Fig. 4. Finished shells of Y-magnets at each end of interaction region.

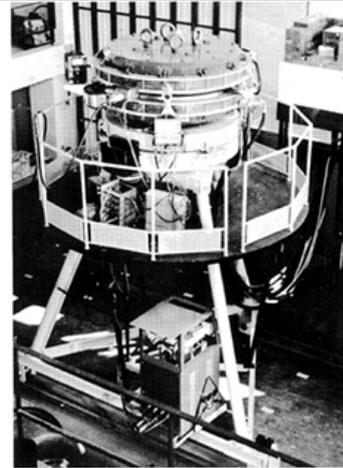


Fig. 5. Tower with storage ring mounted for first test.

Figure 6: Two figures shown at the 1961 Conference, at left the Y magnet at Stanford, with the region where the two electron orbits are tangent to each other to produce electron-electron collisions from B. Richter's talk, at right AdA from Touschek's talk (Bell *et al.* 1961).

3 And then came Pierre Marin and Georges Charpak: *Un vrai bijou*

The conference at CERN, and Touschek's talk, represent a landmark in the development of electron-positron colliders. Word spread that things were happening in the small Laboratory on the Tusculum Hills.

In the far away Russian city of Novosibirsk, beyond the Urals, at the Institute for Nuclear Physics, the scientists understood they were not alone in their work on electron-positron storage rings and increased their efforts (Baier 2006). Closer to Frascati, at CERN itself and in France, at the Laboratoire de l'Accélérateur Linéaire d'Orsay, *le LAL*, interest arose as to what the Italians were doing. France, Italy and Switzerland are close, travel among the Laboratories was frequent, and scientists could easily go and see by themselves what was new. And this is precisely what happened: two French scientists, one from Orsay, the other from CERN, went to Frascati to see with their own eyes. . . .

At the time, in Orsay, a Linear Accelerator had been working since 1959, and the question of how to best exploit its discovery potential was often debated. The team which had built the Linear Accelerator included George Bishop and Pierre Marin, who knew each other from Oxford and had come together to France in 1955, to work on the project. Marin was then 34 years old and would become one of the main artifices of France's accelerator program. In 1961, with the linear accelerator by now successfully built and working, he was wondering which direction his research should take. When Marin asked around for interesting things to do in his research, he was told to go see what was happening in Frascati.

As Pierre Marin later wrote (Marin 2009, 46):

Returning from a stay at CERN, after my thesis, I was searching for my own

research directions, and G. R. Bishop suggested that I go to visit Frascati, where very intriguing things were happening. So, I went there, in the month of August, together with Georges Charpak, who was, at the time, collaborating with both CERN and American physicists on the measurement of the anomalous muon magnetic moment.¹⁵

The visit actually took place in July, as August is unbearably hot in and around the city of Rome.¹⁶ Those who can, escape to the beaches, or go North, to the Dolomites, or, in those days, simply to the nearby hills, the so called Alban hills, from the name of the pre-Roman town of Alba Longa. The Alban Hills, *I colli Albani*, include a half-circle of volcanic hills, which, South East of Rome, limit the plains where the city lies. Among them, and closest to the city, is the Tusculum Hill, sloping down to the Frascati Laboratory mid-way to Rome, cooler and shady in the summer. In a hall next to the synchrotron Marin saw (Marin 2009, 46)

[...] a group of high caliber physicists [...] B. Touschek, C. Bernardini, G. Ghigo, F. Corazza, M. Puglisi, R. Querzoli and G. Di Giugno, [who] showed us with great pride a small machine, AdA, *un vrai bijou*¹⁷ [...]

In Fig. 7 one can see some of the Italian protagonists of the AdA adventure.

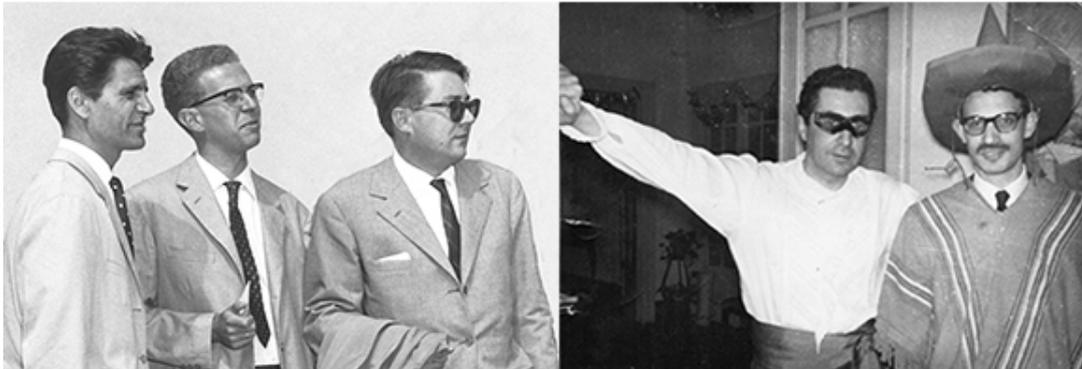


Figure 7: From the left, Gianfranco Corazza, Carlo Bernardini, Giorgio Ghigo, and, in custom party outfits, Ruggero Querzoli and his student, Giuseppe Di Giugno (courtesy of Giuseppe Di Giugno).

But, as Touschek and Bernardini knew, there were problems with their wonderful little machine. The group of Italian and French scientists started thinking about ways to make AdA produce some physics, beyond the great pride of having succeeded in accumulating electrons and positrons in some number. The estimates which Touschek had

¹⁵In 1992 Georges Charpak was awarded the Nobel Prize in Physics “for his invention and development of particle detectors, in particular the multi-wire proportional chamber”.

¹⁶Marin, in his telling almost forty years later, indicates the month of August for his visit. However from André Blanc-Lapierre’s letter to Italo Federico Quercia in December 1961, we learn that the visit had taken place in July.

¹⁷A real gem.

done in March of the previous year, and which were based on cross-section calculations by his colleagues Nicola Cabibbo and Raoul Gatto, showed that, even if some electrons and positrons were circulating in the ring, luminosity was too low and annihilation could not be proven. To go beyond and demonstrate the feasibility of this type of machines to do physics at high energy, the problem of injection had to first be solved. The Italian team had applied some very ingenious ideas but the rate remained orders of magnitudes smaller than what a successful experiment would require. The problem was always the same: the beam of electrons extracted from the synchrotron was too weak, it could not lead to a photon flux high enough to create enough positron electron pairs in the AdA inner target. Then, Pierre Marin observed that, in Orsay, the Linear Accelerator provided a well focussed 500 MeV electron beam, with an excellent intensity of 1 microampère. Bernardini and Touschek looked at each other, moved slightly aside, talked for a few minutes, and then came back to Marin. The question they posed was (Marin 2009, 47):

“ [...] Do you think that LAL would agree to receive AdA?”

I replied: “A priori, the new director André Blanc-Lapierre would be quite open to welcome this sort of ideas.”

In Fig. 8, we show Bruno Touschek and Pierre Marin in the 1960's.

Hopes were revived and unexpected perspectives opened. Marin and Charpak left. The seed of the future of AdA as a feasible way to high energy colliders had been planted. Marin carried back to Orsay a promise to follow up the idea of a collaboration and perhaps a transfer of people and machinery to France. In the months to follow, steps for a collaboration and the transfer of AdA from Frascati to Orsay were put in motion.



Figure 8: Bruno Touschek, at left, and Pierre Marin, at right, in the early 1960s. Bruno Touschek's photo is courtesy of Giuseppe Di Giugno, Marin's photo is courtesy of Jacques Haïssinski.

The operation was not trivial, as it involved moving a working accelerator, which

was property of a Government institution, across two countries, a trip of about 1500 kilometres, through custom and border controls. We should remember that in 1961, in Europe, there was no free circulation of goods and people and AdA was precious: it had costed some 20 million Lire, at the time a large expenditure for pure research, in a country as poor as post-war Italy. The exchange therefore needed to be approved at the highest level. In addition, as the exchange of letters between the two Laboratories later showed, the collaboration involved a matter of scientific policy in Europe, something to which Edoardo Amaldi, one of CERN's founders, was particularly sensitive.

4 The 1961 Conference at Aix-en-Provence

As soon as the August vacations ended, both in Orsay and Frascati, activities started in earnest: the immediate scope was preparation of talks to present at the imminent conference in Aix-en-Provence, where the community involved in nuclear and particle physics, both experimentalists and theorists, was to gather in mid-September from 14th to 20th . The title of the conference, *The Aix-en-Provence International Conference of Elementary particles*, addressed directly, for the first time, the emergence of the field of elementary particle physics, singling it out from nuclear or accelerator or high energy physics, where it had been so far included. It was mostly a conference where up-to-date theoretical ideas would be debated in the plenary sessions, with experimental talks and other theory papers presented in the parallel sessions. The Italians were presenting results from experimentation with the Frascati electron synchrotron, Ruggero Querzoli being the team leader and giving the talk. From Orsay, Marin was attending, having received instructions from LAL director, André Blanc-Lapierre, to probe the Frascati colleagues about both AdA and ADONE.

The concluding remarks were given by Richard Feynman. It is worth repeating some of them here, applicable as well to what was happening at the Conference (Feynman 1962):

I want to ask what is most characteristic of the meeting — what new positions are we in at the present time — what kind of things do we expect in the future?

At each meeting it always seems to me that very little progress is made. Nevertheless, if you look over any reasonable length of time, a few years say, you find a fantastic progress and it is hard to understand how that can happen at the same time that nothing is happening (Zeno's paradox).

I think it is something like the way clouds change in the sky — They gradually fade out here and build up there and if you look later it is different. What happens in a meeting is that certain things which were brought up in the last meeting as suggestions come into focus as realities. They drag along with them other things about which a great deal is discussed and which will become realities in focus at the next meeting.

Thus, nothing was happening, apparently, as Feynman says, but he was (of course) right, as new realities would soon come into focus and “fantastic progress” would take place in due time.

Among the 90 talks, both plenary and parallel (Crémieu-Alcan, Falk-Vairant, and Lebey 1962), there was one by Raoul Gatto, who had co-signed ADONE’s proposal in the previous month of February. His talk was in one of the parallel sessions and, as he had done in Geneva two months before, it addressed the discovery possibilities of electron-positron physics.

In addition to Gatto’s talk, detailed discussions, about ADONE’s prospects and AdA’s results, took place between Pierre Marin and Ruggero Querzoli from Frascati. Querzoli at the time was working on the synchrotron, but also on AdA, and had been one of the *physiciens du cru*, whom Marin had met in July, when visiting AdA.

Feynman could not have known of such discussions, and no notice was given to Gatto’s talk in his summary. This is partly understandable in light of the fact that the calculations by Cabibbo and Gatto were not using new techniques or envisioning new theoretical scenarios: they actually used the tools of QED and Feynman graphs to calculate the cross-sections of all known processes of interest in electron-positron physics, some of which were already present in the literature. The value of the paper was in the exhaustive study and its completeness. The great novelty of the paper, which had been submitted the previous July to *The Physical Review* (Cabibbo and Gatto 1961), was that it presented realistic calculations for processes that could now be observed and measured in presently foreseeable experimental set-ups, such as ADONE’s.

And so, while “nothing was happening”, our *heroes* were building in the wings and a revolution was being set in motion which would produce new powerful tools of discovery.

5 Letters and visits

On his return to Orsay, Marin prepared a detailed report to his director, accompanying it with a hand written note. The report, *Entrevue avec le Professor Querzoli de Frascati le 19-9-61* is divided into two parts, the first concerns AdA, the second is about ADONE.¹⁸ About AdA, after describing the present state of the machine, successes, and limitations, such as only a moderate vacuum, a slow injection mechanisms etc., Marin listed the expectations of the Frascati group in case that a much better vacuum, i.e. 10^{-9} mmHg vs. the actual 10^{-6} , could be reached. Among these, were the measurement of the annihilation process $e^+e^- \rightarrow 2\gamma$, studying the phenomenon of space charge and the effects of changing the beam energy. But then, at the end of this list of expectations, comes the crucial proposal. We transcribe it here in its original French version:

¹⁸Copies of the report and of the accompanying letter by Pierre Marin were obtained from LAL Archives, courtesy of Jacques Haïssinski.

Si les prévisions de calculs sont exactes, il semble possible de réaliser ce programme à Frascati [...] S'il s'avérait qu'il ne puisse être réalisé à Frascati, A.D.A. serait transporté à Orsay auprès de l'Accélérateur Linéaire.¹⁹

The report then addresses the new Frascati project, ADONE, an electron-positron storage ring, with a beam energy of 1.5 GeV. Marin informs his director that, although the project has not been officially approved, the Italians are rather confident it will be accepted, notwithstanding its much higher cost with respect to AdA. ADONE's budget was 2.5 billion lire, two orders of magnitude costlier than AdA's, with half of it to be spent on a powerful linear accelerator. This was a very ambitious project, which could be started after some further experimentation with AdA. Marin adds that Querzoli is very favourably inclined to have a French scientist visiting with the AdA team, in the coming months.

A STORMY BEGINNING Three months passed however, and no further exchanges seem to have taken place in the immediate period following this report. Then, at the end of December, a letter from André Blanc-Lapierre reached Italo Federico Quercia, then director of the Frascati Laboratories.²⁰ The letter, dated December 22nd, 1961, starts with a rather unexpected sentence: "Dear Professor Quercia, we are starting preliminary studies for a 1.3 GeV storage ring for positrons and electrons in Orsay", and then continues proposing that two or three people from Orsay come to Frascati to discuss some points about storage rings. André Blanc-Lapierre proposed that visits could start any time after the 23rd of January.²¹

This letter is very interesting, as it indicates that a French decision, to start planning for a storage ring at LAL, must have been taken between the time of Marin's report to the Orsay director on September 1962, and the December letter to Frascati, proposing a visit by some French scientists. Edoardo Amaldi answered with a letter which reached Orsay one month later, and which was written in French, which, in those days, was the official language of diplomacy.²² Indeed, André Blanc-Lapierre's letter had ruffled some feathers in Rome, as we shall see next.

André Blanc-Lapierre's letter was probably received in Frascati during the end of the year vacation. As soon as the normal laboratory activities started again, Quercia called a meeting with Fernando Amman, Carlo Bernardini, Gianfranco Corazza and Bruno Touschek for Wednesday January 3rd. He showed them the letter from the French director and the decision was taken to answer positively to the French request, including agreeing

¹⁹If the predictions of the calculation are exact, it seems possible to realise this program in Frascati . . . If it will happen that it cannot be realized in Frascati, A.D.A will be transported to Orsay, next to the Linear Accelerator.

²⁰See also Quercia's biography, *Italo Federico Quercia, note biografiche e documenti*, edited by Ugo Spezia, Collana di Storia della Scienza, Patrocini : SIF, ENEA, INFN, 2007.

²¹LAL Archives, courtesy of Jacques Haïssinski.

²²LAL Archives, courtesy of Jacques Haïssinski.

to the proposed date of January 23rd for the visit to start.²³ Hopes for a collaboration which could solve AdA's injection problem and open the way to prove full feasibility of electron-positron storage rings, were renewed. Touschek, among the AdA team, was particularly anxious that a positive answer be sent immediately to the French colleagues. A letter by Quercia to Touschek, dated January 12th, less than 10 days after the meeting, implies some tension between Quercia and Touschek on this issue, since Quercia mentions a telephone call by Touschek "this morning", whose reason he "could not understand well".²⁴ We can only imagine that Touschek, when he saw that no letter to LAL had been sent after almost ten days from the meeting and more than two weeks from André Blanc-Lapierre's letter had passed, became upset, fearing that the French would be moving ahead with their proposed plan (for ACO, Anneau de Collisions d'Orsay), and that the visit would be delayed. He must have pressed the Laboratory director for an answer, in not too diplomatic terms. This is quite understandable, since he certainly knew that the future of AdA rested on the collaboration with LAL scientists and the use of their Linear Accelerator.

Touschek's phone call to Quercia did produce a reaction, and, on January 16th, Amaldi, then director of the Physics Institute of University of Rome, and INFN president, answered to André Blanc-Lapierre.²⁵ The matter, indeed, did not simply involve a friendly agreement among scientists and two laboratories, as Touschek may have thought. Its complexity can be glimpsed from the fact that Quercia had sent a formal letter to answer Touschek's phone call. Since the University of Rome and the Frascati Laboratory were connected by a direct shuttle bus, which used to leave from the University of Rome every hour, it would have been simpler for Touschek and Quercia to just talk to each other: instead we have a formal letter, from the Laboratory director, in Frascati, to Touschek, in Rome. In fact, as one can see from the correspondence which followed, the matter needed to be thought over, with adequate consideration of scientific priority.

The reason for the delay in answering André Blanc-Lapierre's letter is apparent in the response which Edoardo Amaldi sent to André Blanc-Lapierre, four days later, on January 16. Amaldi starts his letter with the acknowledgment of the proposed collaboration, referring to Amman and Touschek for its implementation, but then he addresses the point of major interest for him, that of European accelerator strategy and Italian scientific priority. Unlike the previous one by André Blanc-Lapierre or anyone of successive exchanges, this is a formal letter, as proven by the fact that it was written in French, the language of diplomatic exchanges, not in English. We quote here from the letter:²⁶

²³I. F. Quercia to B. Touschek, January 12th, 1962, Bruno Touschek Archive, Series 1, Folder. 4, Box 1, 1962-67 Correspondence.

²⁴I. F. Quercia to B. Touschek, January 12th, 1962, Bruno Touschek Archive, Series 1, Folder. 4, Box 1, 1962-67 Correspondence.

²⁵For a list of INFN Presidents, see <https://www.presid.infn.it/index.php/it/10-articoli-del-sito/73-presidenti-dal-1954>.

²⁶LAL Archives, courtesy of Jacques Haissinski.

[...] Pour ce qui concerne la construction d'un Accélérateur qui accumule dans le même anneau électrons et positrons, je désire vous faire savoir que le group dirigé par l'Ing. Amman est déjà arrivé à un degré plutôt avancé dans le projet d'une machine de ce genre pour 1,5 + 1,5 GeV [...] et que cet appareil constituera la partie essentielle de notre Second Plan Quinquennal [...].

Nous croyons, pourtant, qu'il faudrait, en préparant des autres programmes, considérer tout cela, afin d'éviter des redoublements [...] Ceci est un cas particulier du problème plus général de la coordination [...] des plans de recherche de divers groupes nationaux surtout entre deux pays déjà si liés par des intérêt[s] communs, comme la France et l'Italie.²⁷

Amaldi then continues with the authority given to him as one of the founders of CERN and protagonist of the European scientific reconstruction after the war:

Un premier pas, dans ce sens, a été déjà fait avec la construction de l'European Accelerator Study Group, aux réunions duquel on a présenté le project italien dès Decembre 1960.²⁸

This letter was received in Orsay, on January 24, and was followed by another letter by Amaldi to André Blanc-Lapierre, in which, having clearly stated Italy's priority, Amaldi welcomed the start of the collaboration. In this second letter, dated January 23rd, the exchanges between the two laboratories were blessed and specific plans for visits could start. Amaldi invited André Blanc-Lapierre to come to Frascati "accompanied, eventually, by another Member of your Group". The occasion was going to be an informal meeting held on the dates 7-8-9 of February, to discuss present results from the electron synchrotron, work at CERN by Italian groups, and, last but certainly not the least in Amaldi's priorities, reports on the ADONE project. This second letter reached Orsay on January 29th.²⁹ At his end, after his December letter, André Blanc-Lapierre had not remained idle: even before receiving the Italians' answer to his query, he had contacted the French Atomic Energy Commission, *Commissariat à l'Énergie Atomique (CEA)*, probably in the person of its President, Francis Perrin.³⁰ We learn that, on January 16th, André Blanc-Lapierre

²⁷Concerning the construction of an Accelerator that can store in the same ring electrons and positrons, I wish to let you know that the group directed by Eng. Amman has already reached an advanced stage in planning such machine with [energy] 1,5 + 1,5 GeV [...] and this apparatus will constitute the main part of our Second Five-Year Plan [...]. We believe, therefore, that, in starting other programs, one should consider all this, in order to avoid duplications [...] This is a particular case of the more general problem of coordination [...] of the research plans of different national groups, especially between two countries already so closely connected by common interests such as France and Italy.

²⁸A first step in this direction has already been taken with the establishment of the European Accelerator Study Group, where the Italian project has been presented since December 1960.

²⁹LAL Archives, courtesy of Jacques Haïssinski.

³⁰Amaldi's letter reached Orsay only on January 24th, but the French Atomic Energy Commission, is mentioned in a 16th January letter written from Orsay to Quercia (on the same day as Amaldi's positive answer for a collaboration left Rome). We have not located this letter, but its existence is acknowledged, and its content described, in a January 23rd letter by Quercia to André Blanck-Lapierre — director to director.

had proposed the new date of February 5th for a visit by three French scientists, F. Fer, Marin and Boris Milman, adding that one or two people from the French Atomic Energy Commission could be part of the expedition.³¹ The inclusion of official visitors, not just scientists, indicates the importance the French scientific establishment attributed to the storage ring projects.

VISITS AND ENCOUNTERS: TOWARDS THE TRANSFER OF ADA From February through June 1962, the collaboration was put in motion, resulting in reciprocal visits and (at least) one meeting in Geneva.

The first visit took place, as proposed by Amaldi, on the occasion of the Frascati *Congressino* held from 7th to 9th February 1962. Amaldi's introductory talk was dedicated for the major part to the ADONE project, which he clearly saw as crucial for the future of Italian and European high energy physics. André Blanc-Lapierre did not come, but four French scientists were welcomed by Amaldi in his opening address to the participants, H. Bruck, F. Fer, F. Guerin (M.le Guerin, in fact, offers a welcome appearance of a woman in this story) and P. Marin.³² In addition, the non Italian participants included F. Lefrançois, also from Orsay and Richard Wilson from Cornell. We notice a UK scientist from Harwell, P.G. Murphy from Rutherford Laboratory, attending the meeting. This may have created an opportunity for Touschek to visit the UK, later in February.³³ A thank you note from F. Fer to Touschek is shown in Fig. 9, together with a letter from Touschek to E.R. Rae from Harwell.

By the end of February, Touschek was already confident that AdA would go to Orsay, at the same time he was also actively pursuing approval for the bigger ADONE project. Now that the "ice had been broken", as Touschek wrote in April to Blanc-Lapierre (see Fig. 10), more visits and exchanges between Frascati and Orsay soon followed. The letters which passed between the two Laboratories during this period are very warm and friendly, as both sides were now eager to pursue the possible transfer of AdA and discuss the practical implications.

Interest in the Frascati projects was not limited to the French Laboratory. In February, Touschek was invited to attend a meeting at CERN organized by Kjell Johnsen, to examine large accelerator projects for the future of high energy physics.³⁴ Since 1961, a special Study Group on New Accelerators led by Johnsen had been established to work out the design study of the Intersecting Storage Rings, a proton-proton collider which

³¹Marin and Milman had been part of the team which came from Oxford in 1955. F. Fer is among the participants to the Geneva 1961 Conference.

³²The Report of the Meeting is available at <http://www.lnf.infn.it/sis/preprint/detail-new.php?id=2980>, as LNF-62 / 037.

³³This visit is mentioned in a letter from Touschek to Ernest Rae, at Harwell. For this and other earlier contacts, such as a letter from O'Neill dated February 8th, 1962, see Edoardo Amaldi Archive, Sapienza University of Rome, Bruno Touschek Archive, Series 1, Folder. 4, Box 1, 1962-67 Correspondence.

³⁴The subject of the meeting appears in the April 4th letter by André Blanc-Lapierre mentioned later in the text. For info about Johnsen, see <http://cerncourier.com/cws/article/cern/31195>.

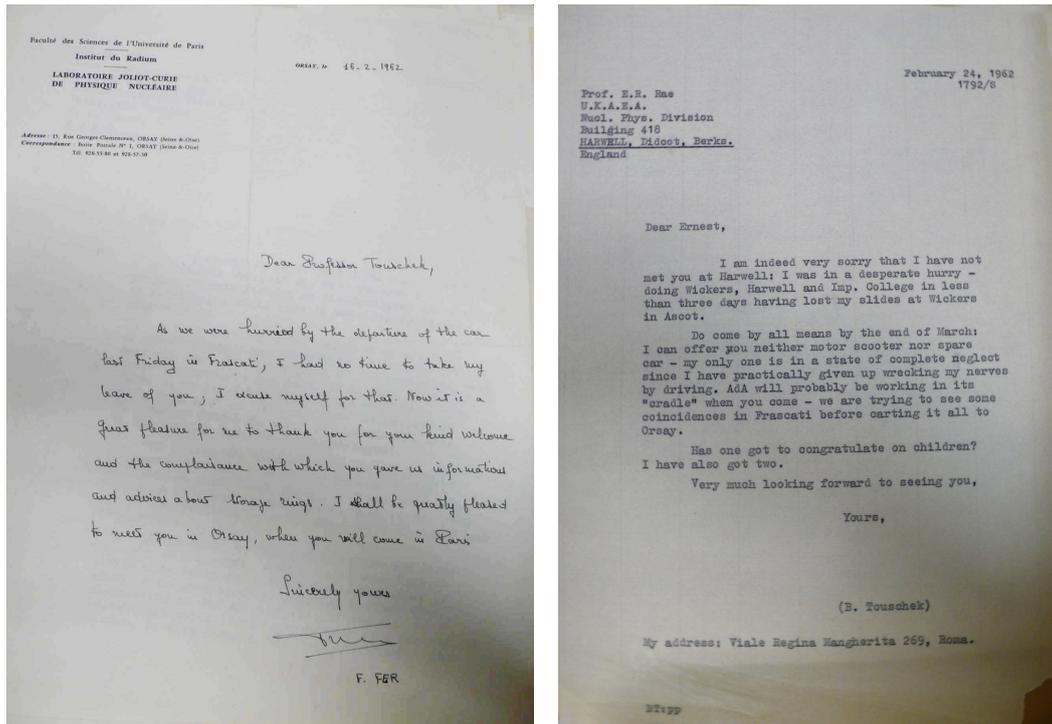


Figure 9: February 16th, 1962 letter from F. Fer to Bruno Touschek thanking him after visiting Frascati at left, and February 24th, 1962 letter from Touschek to E. R. Rae, at the United Kingdom Atomic Energy Authority, indicating a visit to Harwell by Touschek (Bruno Touschek Archive).

would be the second large CERN machine (Russo 1996). Johnsen was clearly quite interested in Touschek's participation to the meeting. The invitation was very pressing, as we can see from Touschek's answer:³⁵

Dear Dr. Johnsen,
 your threat of ringing me has been transmitted by Amman and I am looking forward to its execution.
 I shall certainly come for 3 or 4 days to participate at the enthusiast's meeting
 ...
 With many greetings and looking forward to your call ...

André Blanc-Lapierre had been looking ahead to a possible encounter with Touschek in Geneva at the end of March, in the context of this meeting organized by Kjell Johnsen. However, notwithstanding his earlier positive response, for some reasons, Touschek did not attend the meeting. But Carlo Bernardini and Amman were there and the practical details of AdA's transfer to Orsay started to be discussed. André Blanc-Lapierre was sorry not to have met Touschek, and pressed him, on an April 4th letter, to come to Orsay

³⁵B.T. to K. Johnsen, 21 February 1962, Bruno Touschek Archive, Series 1, Folder. 4, Box 1, 1962-67 Correspondence.

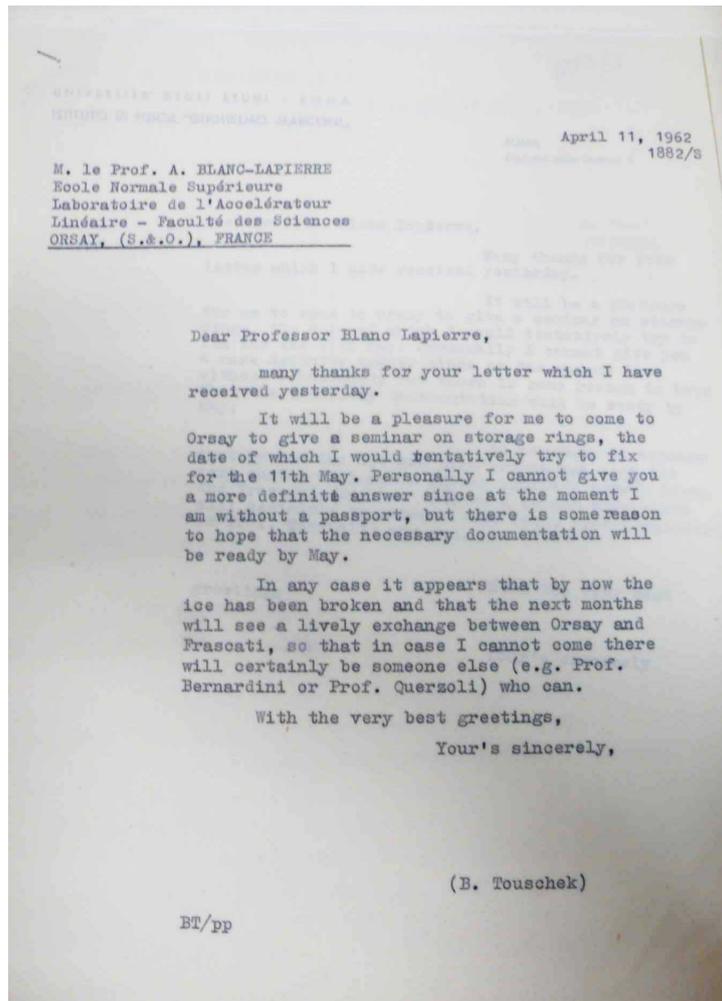


Figure 10: Copy of the letter from Bruno Touschek to André Blanc-Lapierre (Bruno Touschek Archive).

and give a seminar.³⁶ Bruno Touschek welcomed the invitation, but had no passport at the time. Hoping to receive it in time, he chose the date of May 11th for his visit.³⁷

It is uncertain whether Touschek was able to go to Paris and Orsay for the promised seminar. However, there exists a testimony of Touschek's visiting Paris and giving a seminar, from the theoretical physicist Maurice Lévy, professor at École Normale Supérieure who had been instrumental in calling André Blanc-Lapierre from Algiers to France in 1961. In telling the episode, Lévy is uncertain about the precise dating, tentatively placing it in the 1950's.³⁸ It is tempting to place the visit in May 1962, and because Lévy's anecdote brings Bruno's personality into a vivid light, this is what happened:

I knew Touschek by reputation and I had met him at several conferences.
In Paris in the framework of our theory group, we had a weekly seminar

³⁶Bruno Touschek Archive, Series 1, Folder. 4, Box 1, 1962-67 Correspondence.

³⁷Bruno Touschek Archive, Series 1, Folder. 4, Box 1, 1962-67 Correspondence.

³⁸This anecdote is reported in (Bernardini, Pancheri, and Pellegrini 2015), and was originally told to one of us, G.P., by Maurice Lévy during a interview in Paris, on May 24th, 2013.

where we invited people from all over and on several occasions we invited Touschek, who came and talked to us. Unfortunately I do not remember on which subject he talked. In fact he came at least two or three times. . . . I have a small anecdote. In one of the visits, we had put him up in a small hotel on Boulevard Saint Michel and before retiring at night, he had put his shoes outside the door of his room, and when he opened the door on the next day, the shoes had disappeared. So, he had a problem, the owner of the hotel kept saying “this is a small hotel sir, we don’t make shoes” and so on. Finally the proprietor of the hotel lent him a pair of shoes, which were much too big for him, two or three sizes too big, and he went to a shop, at nine o’clock when the shops open, to get another pair of shoes for himself. He told us the story later on, [when he came to the Laboratory,] with great sense of humour, Touschek was well known for his sense of humour.

The months to follow saw many lively exchanges, and detailed plans for AdA’s transfer were made. One of the members of the team of the Linear Accelerator, François Lacoste, remembers visiting Frascati in the Spring of 1962:³⁹

I was witness to some initial contacts between Frascati and Orsay in ’62 and I had occasion of one visit to Frascati with Boris Milman, where I met Bernardini and Touschek and we looked at some details about how it would be possible to bring AdA to Orsay.

6 How AdA left Italy and arrived in France

The transfer posed many technical problems, such as maintaining the vacuum in the doughnut as AdA would travel across the 1500 kilometres and more between Frascati and Orsay. A major challenge in the storing of positrons was in fact the requirement of an extreme vacuum in the doughnut, to prevent scattering with the residual gas. To this aim, a legendary vacuum as low as 5×10^{-10} mmHg was reached in Frascati by Gianfranco Corazza, one of the physicists in the AdA team, together with Angelo Vitale, a technician who specialized in outgassing in very low pressure vessels. Reaching such a low level vacuum required two or three months, and it was essential not to lose it during the transfer. As the vacuum was maintained by powerful devices constantly pumping residual gas from the doughnut, batteries would be needed to keep the pumps working and accompany AdA through Italy and the Alps into France and on to Orsay. Two trucks were hired for the transfer: a bigger one with AdA, sealed with its vacuum, with pumps and batteries, and a smaller one for other heavy equipment. Other lighter components could follow by plane.

There were also problems of a different nature: the head of the Italian National Committee for Nuclear Energy (CNEN), a government agency owning and overseeing

³⁹From an interview with François Lacoste on May 2013, in Orsay.

the Frascati Laboratories, needed to be contacted and his agreement for AdA to leave Italy had to be obtained. Touschek, advised by Amaldi, wrote a letter and AdA was granted permission to go. Another possible problem involved the crossing of the border between Italy and France. The chosen route was across the Alps and the custom station was at Modane, near the Frejus.⁴⁰ Passing the French customs could be tricky, and had to be prepared in advance. Both Italian and French officers in the foreign ministries needed to be informed so as to act in case of difficulties.

When the time for the transfer came near, Touschek sent a letter to Francis Perrin, Haut Commissaire à l'Énergie Atomique au CEA, who had worked with Frédéric Joliot on nuclear chain reactions, and was very powerful and influential on all science matters in France. Perrin had been one of the founders of CERN, and knew Amaldi very well. Informal exchanges between them started as the date of transfer drew close. At the end of June, everything was finally ready.

In Fig. 11 we show Touschek's letter of June 28th, 1962,⁴¹ which reads:

Dear Professor Perrin,

I enclose a list of material for the second convoy Frascati-Orsay, which will presumably leave Rome on the 4th of July and should arrive in Paris on the 7th.

We very much hope that there will be no difficulties at the customs but, in case of emergency, we would much appreciate the help so kindly offered by you to Prof. E. Amaldi.

[...] it contains the vacuum chamber at 5×10^{-10} mm ... The ideal solution would be if some competent official at the Modane customs office could be informed before hand.

I will take the liberty of wiring you the exact (as near as possible) time at which the convoy can be expected to pass the frontier [...]

The story of AdA's transfer from Italy to France has been told on various occasions by its protagonists, Carlo Bernardini, who saw the convoy leave Frascati, and François Lacoste, who saw it arrive in Orsay.⁴²

When the time came for the transfer, the Frascati Laboratories called a trusted moving firm, in the person of the legendary Signor Grossi, as Bernardini calls him, who was often employed by the Laboratories for moving equipment to and from University of Rome or others.⁴³ The 8 ton iron magnet inside which AdA's doughnut was placed, was

⁴⁰As the Frejus road tunnel did not yet exist, roads would go through the Moncenisio Pass.

⁴¹Bruno Touschek Archive, Series 1, Folder. 4, Box 1, 1962-67 Correspondence.

⁴²Carlo Bernardini, *Fisica vissuta*, 2006 Codice Edizioni, Torino, and François Lacoste interviewed by GP, May 2013, Orsay.

⁴³*Il mitico signor Grossi*, in Bernardini's words.

June 28th, 1962
2015/S

Prof. F. PERRIN
Haute Commissaire à
l'Energie Atomique
69, rue de Varenne
P A R I S

Dear Professor Perrin,

I enclose a list of material for the second
convoy Frascati-Orsay, which will presumably leave
Rome on the 4th of July and should arrive in Paris
on the 7th.

We very much hope that there will no difficult-
ies at the customs but, in case of emergency, we would
much appreciate the help so kindly offered by you
to Prof. E. Amaldi.

The present operation is most critical since
it contains the vacuum chamber at 5×10^{-10} mm. The
ideal solution would be if some competent official
at the Modane customs office could be informed before
hand.

I will take the liberty of wiring you the exact
(as near as possible) time at which the convoy can
be expected to pass the frontier.

With best thanks for your kindness and interest,

Yours sincerely,

(B. Touschek)

BT:pp

Figure 11: Copy of the letter from Bruno Touschek to Francis Perrin about the transfer of AdA to Orsay (Bruno Touschek Archive).

put on the truck, with its set of batteries to keep the pumps working, and maintain the vacuum. Any mishap, namely any air that got into the doughnut would have meant months of extra work in Orsay to clean the chamber. The batteries had to be able to provide power for two, maximum three days, enough to cover the trip from Frascati to Orsay.

There was some worry that such weight could unbalance the truck and make it difficult to keep control. Signor Grossi did not think so, but Touschek was very concerned. So he jumped on the driver's seat and started driving the truck around the large square in front of the synchrotron building. Perhaps he just wished to try the driving, the result instead was to destroy a lamp post. Properly subdued, he let Signor Grossi take over and finally AdA left.

Finally the truck reached the state border between Italy and France, in Modane, on the French side of the Alps. Angelo Vitale, the specialist of the vacuum, was travelling with the convoy. Customs checks were a very serious business at the time, so the customs officer asked: "What's inside?", meaning inside the bulky green round object, out of which

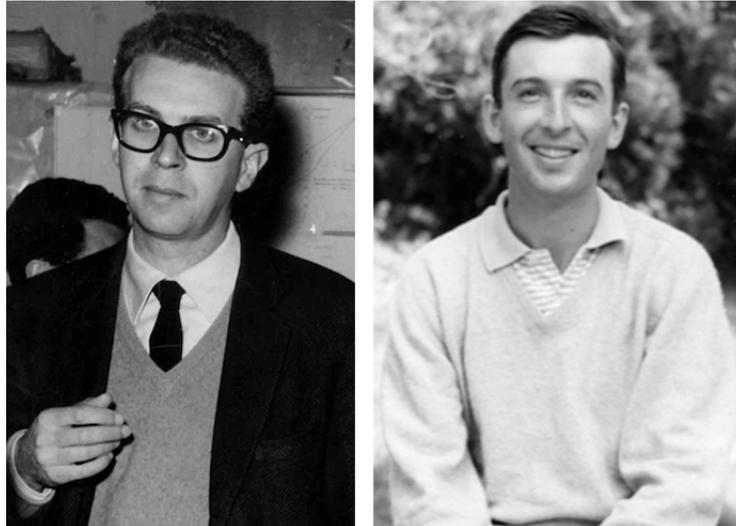


Figure 12: Carlo Bernardini at left, in the 1960's. At right a photo of François Lacoste, taken in St Jean de Luz, during August 1962, the month just following AdA's arrival in Orsay. Photos courtesy of Carlo Bernardini and François Lacoste.

protruded a short tube with a small round glass window. This was the window through which scientists and their visitors in Frascati could see the synchrotron light emitted by the circulating electrons. What could Vitale say? The legend goes that he answered “There is nothing, just nothing”, which was indeed the truth. But this was not sufficient to let AdA pass. So the help which Touschek had asked for, in his letter to Perrin, became necessary. Vitale called Corazza, who called Amaldi, who called Perrin, who called the French Minister of Interior, and from there, down the line of command to the customs officer, until finally AdA was allowed to enter France.

The story as told by Lacoste is very similar:

The transfer of AdA to Orsay came during the summer of 1962 and I remember waiting for AdA and witnessing the arrival of AdA in Orsay.

We had to wait a bit longer than we thought because AdA was stopped at the *frontière* by the French customs, who wanted to understand what they were bringing, what the team from Frascati was bringing and they were especially suspicious of what was inside AdA, and they wanted to look into, perhaps thinking that it could be drugs or whatever, into the vacuum ring, which was pumped during the trip because they had made the degassing, and so on, and it was vacuum of 10^{-8} and at that time good vacuum was very difficult to bring, so they had the pump working during the transit. So the customs wanted to open it and they only had a small window to ask [to be opened]. So they asked what the window was, and the Frascati people answered “It is in sapphire” , which didn't improve the situation because sapphire is a jewel,

for customs.⁴⁴ They had to wait and find a solution and, luckily, we had the intervention of Francis Perrin. . . .

AdA and the two trucks arrived in Orsay, and the empty trucks left, to go back to Italy. The image is still vividly recalled in Lacoste's words:

I remember the trucks going back and, as the small truck was empty and the big truck also, they decided that it was easier for the driver of the truck to put the small truck on the big truck and I remember seeing them travel back that way.

AdA's "wedding trousseau", i.e. *il corredo*, as Carlo Bernardini used to call it in Italian, was completed a few days later with the remaining equipment being sent by plane. The list, detailed in a July 6th letter by Carlo Bernardini to François Lacoste, reads like a nursery rhyme:⁴⁵

Two Cherenkov glass counters . . .

one oscillograph . . .

one Movie camera . . .

12 power supplies . . .

30 modular units . . .

6 scintillation counters

. . .

And then, after AdA and its outfits had arrived, the scientists and the technicians came. AdA was installed in Salle 500 next to the Linear Accelerator, and a new team, now composed of French and Italian scientists, moved on to the last leg of AdA's great adventure.⁴⁶ In Orsay, the Italian team joined forces with François Lacoste, Pierre Marin and a young graduate, Jacques Haïssinski, who would prepare his *Thèse d'État* on AdA, completed three years later, under the guidance of André Blanc-Lapierre. In Fig. 13 we show a photo of Jacques Haïssinski with Pierre Marin, taken in the early 1960s.

Thus the adventure of AdA in Orsay started.

⁴⁴Carlo Bernardini, one of the physicists who built AdA, says the window was not made of sapphire, but of quartz. Private communication to the authors.

⁴⁵Copy of this letter is courtesy of Mario Fascetti, the AdA technician who had built AdA's radiofrequency system, under Mario Puglisi's supervision.

⁴⁶"Salle 500" means Salle 500 MeV, 500 MeV being the electron beam energy which was delivered by the Linac in this experimental hall.



Figure 13: Jacques Haïssinski (at left) and Pierre Marin in the early 1960s (courtesy of Jacques Haïssinski).

7 What happened in Orsay

In Orsay, the Italian scientists found the ideal conditions to successfully show the feasibility of electron-positron colliders as best suited to probe the structure and dynamics of the world of elementary particles.⁴⁷ Ada allowed to discover unsuspected collective effects between colliding bunches of particles, and, measuring them, to anticipate how future machines should be constructed to exploit the potential of colliding beam physics for future discoveries. The main observations from AdA's experimentation concern collective effects about life time and beam size in storage rings, such as the so-called *Touschek effect* (Bernardini *et al.* 1963). The Touschek effect, discovered in 1963, is still relevant in planning today's colliders, notwithstanding the enormous magnification in size and energy of present day colliders with respect to little AdA.

The discovery of the Touschek effect led to understand the correct size of the volume occupied by the particles when the two bunches of oppositely charged particles met, and allowed the Franco-Italian team to establish that collisions among electrons and positrons had taken place (Haïssinski 1998). It is appropriate to quote here Jacques Haïssinski, from an interview which took place in May 2013, at Laboratoire de l'Accélérateur Linéaire, in Orsay:

Les mesures finales qui ont été faites ont porté sur le nombre de collisions

⁴⁷Carlo Bernardini used to say that they soon understood they had been dealt a very good deal, *un buon affare*, in Italian.

par seconde entre les électrons et les positrons. C'était la première fois au monde que l'on montrait que les particules, effectivement, interagissaient et entraient en collision les unes avec les autres et donc, ça montrait que, on peut dire, que ces machines étaient utilisables pour faire de la physique des très hautes énergies, et l'essentiel, pas tout, bien sûr, on a fait d'autres découvertes par la suite, mais l'essentiel, quand même, des caractéristiques de ce type de machines était validé et permettait de penser que les générations ultérieures seraient utilisables pour faire de la physique des particules à très haute énergie.⁴⁸

Thus AdA and its team of Franco-Italian scientists laid the grounds for the “fantastic progress” which Richard Feynman had unknowingly divined in his address at the Aix-en-Provence conference only ten months before AdA reached Orsay.⁴⁹

8 Conclusions

In this paper we have described how French and Italian scientists in the early 1960's created a collaboration which brought the first electron-positron particle collider AdA, Anello di Accumulazione, storage ring in English, from Frascati to Orsay, a transfer crucial to the success of AdA as a precursor of future colliders. The events which we have described are part of a larger historical scenario, in which different European countries, following separate ways before, through, and after World War II, prepared the scientific and technological conditions for AdA to be built in Frascati and collisions between electrons and positrons to be observed in Orsay (Bernardini *et al.* 1964).

The present paper is part of a work in progress for a project, in which the various European roads to particle colliders will be described in detail. This project will include an account of the circumstances which brought Bruno Touschek and the Norwegian Rolf Widerøe to work together in Germany, during WWII, on a secret project for the construction of a betatron, financed by the Ministry of Aviation of the Third Reich. It is during this period that Rolf Widerøe envisaged the possibility to construct an accelerator able to make collisions between particles of opposite signs, an idea he shared with Bruno Touschek, and later patented (Widerøe 1994). As Touschek himself always acknowledged, this was the first time he had ever heard of such idea. When the times became ripe for transforming Widerøe's idea into a working machine, twenty years later, Touschek remembered the long ago conversations he had with Rolf Widerøe in Berlin, as they were

⁴⁸The final measurements relied on the rate of collisions among electrons and positrons. It was the first time in the world that one could show that the particles effectively interacted and collided against each other, and this allowed to think that these machines could be used to do [experiments] in high energy physics. There were other discoveries, of course, but the essential point was that the characteristics of this type of machines were validated and that successive generations [of these machines] could be used for very high energy physics.

⁴⁹In 1965 Richard Feynman was awarded the Nobel Prize in Physics for the “fundamental work in quantum electrodynamics, with deep-ploughing consequences for the physics of elementary particles”, jointly to Sin-Itiro Tomonaga and Julian Schwinger.

planning the betatron and the war was entering its darkest period, and together with his collaborators proposed and started to build AdA. Of course, to transform the idea into reality, many things had to happen, among them the construction of the Orsay Linear Accelerator and the Frascati electron synchrotron, both of which will be described in the project under preparation.

We are now posting this part of the AdA story in memory of Bruno Touschek, the Austrian born theoretical physicist who was the prime mover behind AdA and who passed away, 40 years ago, on May 25th, 1978, in Innsbruck, Austria. We close this preliminary presentation of our work in progress with Fig. 14, a photograph of Bruno Touschek taken in the University of Rome, around 1960.

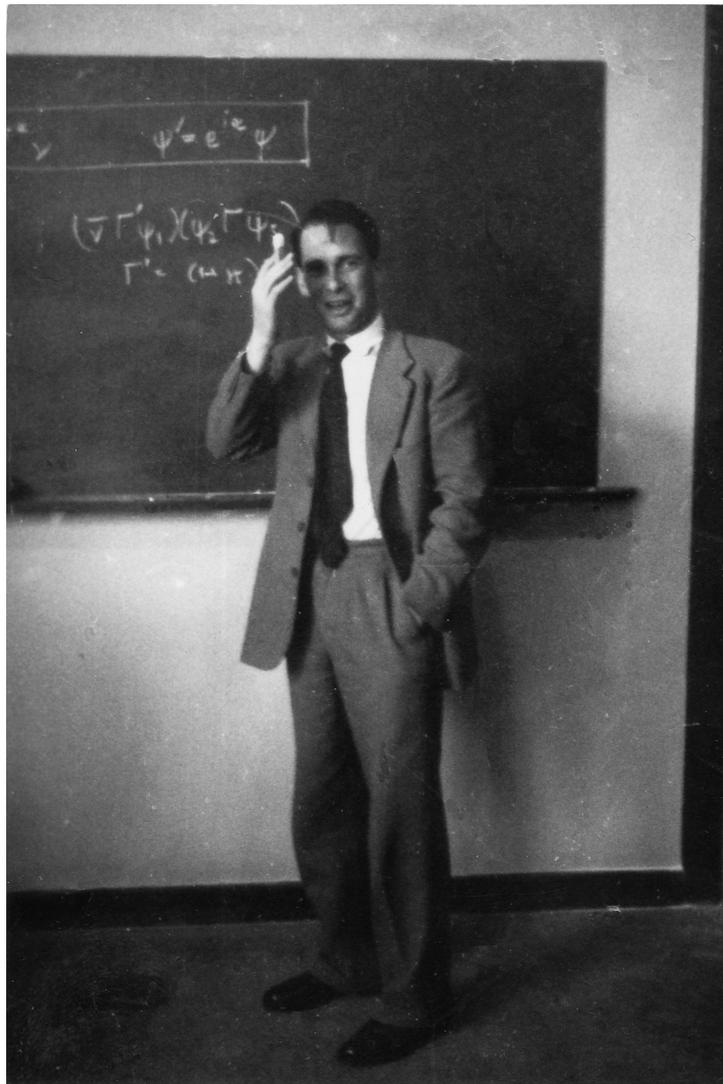


Figure 14: Bruno Touschek at University of Rome, around 1960 (courtesy of Francis Touschek).

Acknowledgements

We thank Jacques Haïssinski for invaluable advice on the early AdA history and a critical reading of the manuscript. We gratefully acknowledge his many useful suggestions and help in providing archival documents on the exchanges between Rome and Paris, which were to lead to AdA's transfer to France. One of us, G.P., is grateful to Earle Lomon for encouragement and criticisms, and gratefully acknowledges hospitality at the MIT Center for Theoretical Physics, while this article was completed. We thank the Laboratoire de l'Accélérateur Linéaire for hospitality during the May 2013 interviews quoted here. We thank Orlando Ciaffoni, Antonio Cupellini and Claudio Federici, from INFN Frascati National Laboratories, for providing support, library assistance and access to photographs. We also thank Giovanni Battimelli and the Sapienza University of Rome for access to the Edoardo Amaldi Archives of the Department of Physics and for allowing reproduction of documents from Bruno Touschek Papers. We thank Francis Touschek for kind permission to use Bruno Touschek's photos.

References

- Alberigi, A., Amman, F., Bernardini, C., Bizzarri, U., Bologna, G., Corazza, G., Diambrini, G., Ghigo, G., Massarotti, A., Murtas, G. P., Puglisi, M., Quercia, I. F., Querzoli, R., Sacerdoti, G., Salvini, G., Sanna, G., Sona, P. G., Toschi, R., Turrin, A., Ageno, M., and Persico, E., [Il Nuovo Cimento **11**, 311 \(1959\)](#).
- Amaldi, E., *The Bruno Touschek legacy (Vienna 1921 - Innsbruck 1978)*, CERN Yellow Reports: Monographs No. 81-19 (CERN, Geneva, 1981).
- Amman, F., in *The Restructuring of Physical Sciences in Europe and the United States, 1945-1960*, edited by G. M. De Maria M. and S. F. (World Scientific, Singapore, 1989) pp. 449–476.
- Aubert, J. J. *et al.* (E598), [Phys. Rev. Lett. **33**, 1404 \(1974\)](#).
- Augustin, J. E. *et al.* (SLAC-SP-017), [Phys. Rev. Lett. **33**, 1406 \(1974\)](#), [Adv. Exp. Phys.5,141(1976)].
- Bacci, C. *et al.*, [Phys. Rev. Lett. **33**, 1408 \(1974\)](#), [Erratum: *Phys. Rev. Lett.* **33**: 1649 (1974)].
- Baier, V. N., [arXiv:hep-ph/0611201 \(2006\)](#), [hep-ph/0611201](#) .
- Bell, J. S., Cerulus, F., Ericson, T., Nilsson, J., and Rollnik, H., eds., *Proceedings, International Conference on Theoretical Aspects of Very High-Energy Phenomena*, CERN (CERN, Geneva, 1961).
- Bernardini, C., [Physics in Perspective **6**, 156 \(2004\)](#).

- Bernardini, C., Corazza, G., Giugno, G., Haissinski, J., Marin, P., *et al.*, [Il Nuovo Cimento **34**, 1473 \(1964\)](#).
- Bernardini, C., Corazza, G. F., Di Giugno, G., Ghigo, G., Querzoli, R., Haissinski, J., Marin, P., and Touschek, B., [Phys. Rev. Lett. **10**, 407 \(1963\)](#).
- Bernardini, C., Corazza, G. F., Ghigo, G., and Touschek, B., [Il Nuovo Cimento **18**, 1293 \(1960\)](#).
- Bernardini, C., Pancheri, G., and Pellegrini, C., [Rev. Accel. Sci. Tech. **08**, 269 \(2015\)](#), [arXiv:1510.00933 \[physics.hist-ph\]](#) .
- Bonolis, L. and Pancheri, G., [Eur. Phys. J. **H36**, 1 \(2011\)](#), [arXiv:1103.2727 \[physics.hist-ph\]](#) .
- Cabibbo, N. and Gatto, R., [Phys. Rev. Lett. **4**, 313 \(1960\)](#).
- Cabibbo, N. and Gatto, R., *Meeting of the Italian School of Physics and Weak Interactions Bologna, Italy, April 26-28, 1984*, [Phys. Rev. **124**, 1577 \(1961\)](#).
- Crémieu-Alcan, E., Falk-Vairant, P., and Lebey, O., eds., *Proceedings, Conférence Internationale d'Aix-en-Provence sur les Particules Élémentaires*, Vol. 2, CEN (CEN, Gif-sur-Yvette, France, 1962).
- Feynman, R. P., in *Proceedings, Conférence Internationale d'Aix-en-Provence sur les Particules Élémentaires: Aix-en-Provence, France, Sep 14-20, 1961*, Vol. Vol. 2, edited by E. Crémieu-Alcan, P. Falk-Vairant, and O. Lebey (CEN, Gif-sur-Yvette, France, 1962) pp. 205–210.
- Haissinski, J., in *Bruno Touschek and the birth of e^+e^- physics*, Frascati Physics Series, Vol. XIII, edited by G. Isidori (Laboratori Nazionali di Frascati, 1998) pp. 17–31.
- Maiani, L. and Bonolis, L., [European Physical Journal H **42**, 475 \(2017\)](#).
- Marin, P., *Un demi-siècle d'accélérateurs de particules* (Editions du Dauphin, 2009).
- Russo, A., in *History of CERN*, Vol. III, edited by J. Krige (Elsevier, 1996) pp. 97–170.
- Widerøe, R., *The Infancy of particle accelerators. Life and work of Rolf Widerøe*, edited by P. Waloschek (Vieweg +Teubner Verlag, Braunschweig, Germany, 1994).