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LOS ACELERADORES DE PARTÍCULAS COMO VÍA HACIA LA COLABORACIÓN INTERGUBERNAMENTAL: EL CASO DEL PRIMER COLISIONADOR DE ELECTRONES Y POSITRONES Y EL PODER DE LA FÍSICA TEÓRICA

PARTICLE ACCELERATORS AS A PATH TO INTERGOVERNMENTAL COLLABORATION: THE CASE OF THE FIRST ELECTRON-POSITRON COLLIDER AND THE POWER OF THEORETICAL PHYSICS

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RESUMEN

Repaso la historia del primer colisionador de materia y antimateria, construido en Italia en 1960 y llevado al éxito gracias a una colaboración intereuropea con Francia, para subrayar la necesidad de grandes esfuerzos intergubernamentales en la realización de aceleradores de partículas, como el sincrotrón de electrones propuesto para la región del Gran Caribe. Se recuerda brevemente el papel fundamental del físico teórico de origen austriaco Bruno Touschek y su trayectoria vital por Europa antes y después de la Segunda Guerra Mundial. Se destaca el papel del CERN como institución intergubernamental de la posguerra a la hora de impulsar la colaboración internacional entre los Laboratorios Nacionales de Frascati, en Italia, y el Laboratoire de l'Accélérateur Linéaire d'Orsay, en Francia, a través de documentos históricos y de las aportaciones de entrevistas con los protagonistas de la propuesta revolucionaria de Touschek.

PALABRAS CLAVE

aceleradores de partículas, Bruno Touschek, CERN, colaboración intergubernamental, colisionadores electrón-positrón, historia de la física, partículas elementales

ABSTRACT

I revisit the history of the first matter-antimatter collider, built in Italy in 1960 and carried to success through an inter-European collaboration with France, to underline the need for large intergovernmental efforts in the realization of particle accelerators such as the proposed electron synchrotron in the Greater Caribbean region. The foundational role of the Austrian-born theoretical physicist Bruno Touschek and his life path through Europe before and after World War II is briefly recalled. The role of CERN as a post-war intergovernmental institution in jump-starting the international collaboration between the Frascati National Laboratories in Italy and the Laboratoire de l'Accélérateur Linéaire d'Orsay in France is highlighted through historical documents and contributions from interviews with the protagonists of Touschek's game-changing proposal.

KEYWORDS

Bruno Touschek, CERN, electron-positron colliders, elementary particles, history of physics, intergovernmental collaboration, particle accelerators

1. INTRODUCTION

The effort to promote the construction of an electron synchrotron for the Greater Caribbean region (Castaño et al., 2024; Castaño et al., 2026) highlights the role of particle accelerator facilities not only as fundamental tools for scientific research, but also as infrastructures capable of contributing to political integration and to advances in society along multiple dimensions.[1] This initiative must also be viewed in the broader historical context of Latin America's complex, but ultimately successful, engagement with Big Science. The introduction of large-scale scientific research into the Andean region was neither straightforward nor free of obstacles, yet it produced significant experiences whose impact extended well beyond the scientific community. An early example was the emergence of high-energy physics in the Andean region discussed in a seminal article of more than forty years ago (Cini & Violini, 1983), which contributed to stimulating a debate on the role of advanced science in the region and helped inspire a broader policy approach that would subsequently be led by the Centro Internacional de Física (CIF), making Latin American scientists regular participants in major international facilities.[2]

While history cannot repeat itself, it can be inspirational to revisit the major role played by the science of particle accelerators in the last century, by recounting how the construction of the Frascati electron synchrotron in Italy spear-headed the country scientific recovery after WWII, at the same time underlying the contemporary institution of the intergovernmental Conseil Europeén pour la Recherche Nucléaire (CERN).

Particle accelerators were developed in the first half of the last century to probe the structure of matter. From linear accelerators to synchrotrons, the history of their development and their modern relevance to society's needs is well known, less known is how an electron synchrotron led to the development of a whole new branch of particle physics, when, in Italy, in 1960, the Frascati electron synchrotron was instrumental to the birth of the first ever electron positron collider, named AdA, an Italian acronym for *Anello di Accumulazione*, a Storage Ring in English. To host a large enterprise for a new generation particle accelerator, such as the Frascati synchrotron, a national laboratory, had been built between 1953 and 1959, fostering the gathering of a pool of scientists, technicians and engineers, trained in the post-war electronics and vacuum technology, made possible by the creation

[1]A recent opinion comment highlights how investing in a synchrotron light source means committing to scientific sovereignty, competitiveness, and the region's future, https://acento.com.do/opinion/soberania-cientifica-en-el-gran-caribe-cinco-anos-de-gclsi-9696387.html.

[2]See December 1993 *Report of the Steering Committee for Fundamental Physics*, http://researchgate.net/publication/374730155_Report_of_the_Steering_Committee_for_Fundamental_Physics, DOI:10.13140/RG.2.2.29595.03364, by Aguirre *et al.*, and the 2005 *CERN Courier* article, by L. Maiani, https://cerncourier.com/a/viewpoint-latin-america-comes-to-cern/.

of an intergovernmental institution in Europe such as CERN, and the international transfer of knowledge between Europe and the United States, which fostered the European reconstruction. Thus new ideas, such as the electron-positron collision experiment, which Bruno Touschek (E. Amaldi, 1981) proposed (Bernardini et al., 1960), could arise and their realization was made possible (Bernardini et al., 1963; Bernardini et al., 1964).

Now, more than sixty years since the first laboratory observation of center-of-mass electron positron collisions in AdA the European Strategy Group for particle physics has proposed that the next-generation particle accelerator be a circular collider, FCC-ee, with electron-positron collisions as the starting step for a future hadron-hadron collider.[3] What began as an "experiment worth having", in the words of Bruno Touschek (Pancheri, 2022, p. 319), the Austrian born physicist who proposed it in 1960, has now become the aim of the latest generation of physicists, making worth knowing the story of how that "experiment" (with the Frascati synchrotron) was envisaged and realized. How that happened is an extraordinary combination of circumstances, which includes the reconstruction of European physics through the institution of a regional center such as CERN, and the creation of two national laboratories, the Laboratoire de l'Accélérateur Linéaire d' Orsay, in France, and the Frascati National Laboratories in Italy. But, perhaps, it wouldn't have happened then and there, and it could have happened later and in a different part of the world, for instance in the USSR, in the Nuclear Physics Laboratory of Novosibirsk, beyond the Ural mountains, and who knows how different things would have been. What certainly made the difference were the existence of an intergovernmental collaboration flanked by national laboratories, which harbored and nourished the vision and determination of a theoretical physicist, Bruno Touschek, whose life crossed Europe, in space and time, Fig. 1.

To understand how many different stories had to be woven together for a new field of research to be born, such as happened with electron positron physics in the 1960s, I will start, in Sect. 2, with a brief outline of the development of particle accelerators, from the earliest attempts, to synchrotrons and the rise of collider ideas in the USA. In Sect. 3, I will describe how the creation of CERN gave rise to the birth of two national laboratories in Europe and summarize the birth of AdA in Sec. 4. To picture the creation of AdA in the personal and formative experience of its creator, in Sect. 5 I shall give a brief introduction to Bruno Touschek's life after he left his native Vienna in 1942 (E. Amaldi, 1981), (Greco & Pancheri, 2004), (Pancheri, 2022) and (Bonolis et al., 2023), up to when he joined the Physics

[3]For details, such as the 91 Km length, more than ten thousand times longer that AdA, see https://home.cern/the-cern-council-decided-to-update-the-european-strategy-for-particle-physics/ and https://physics.aps.org/articles/v19/127

Institute in the University of Rome in January 1953.

Highlights of the impact of Touschek's talk at the CERN 1961 Conference on Theoretical Physics (Bell et al., 1961) and the international Franco-Italian collaboration which allowed to prove the feasibiity of electron-positron colliders will be presented in Sec. 6.

Sources An extensive list of both primary and secondary sources for the events described in this article can be found in (Pancheri, 2022). Specific events cited here include journal articles and books, in addition to documents deposited in university or research center archives, as well as privately held material such as personal letters. Documents from the following institutional archives have been used: Rome Sapienza University, Physics Department Archives for Edoardo Amaldi and Bruno Touschek papers and photographs, INFN-LNF Library and LNF Images Collection, CERN Documentation Services, Orsay Laboratoire de l'Accélérateur Linéaire Archives, and Vienna Jewish Archives. Copy of letters from Laboratoire de l'Accélérateur Linéaire Archives were sent to this author by e-mail in 2011 by Prof. Jacques Haïssinski, emeritus Professor at Orsay. Among privately acquired document are copies of letters exchanged between Bruno Touschek and his family, photographed with Touschek family permission in 2009 by this author and L. Bonolis, with the original letters privately held by Touschek's son. Interviews used for this text took place in 2003 in Frascati National Laboratories, in Paris in 2013 at the privately held residence of Prof. Maurice Lévy, and in Rome in 2010 and 2013, at Prof. Giorgio Salvini's home, and were partially used in the docu-film *Touschek with AdA in Orsay* by E. Agapito, L. Bonolis and G.P., produced by INFN and Media Scienza. The original reels are with the author Enrico Agapito and one copy with this author. Plans are ongoing to deposit all personal digital material in Rome Sapienza University, Physics Department Archives.

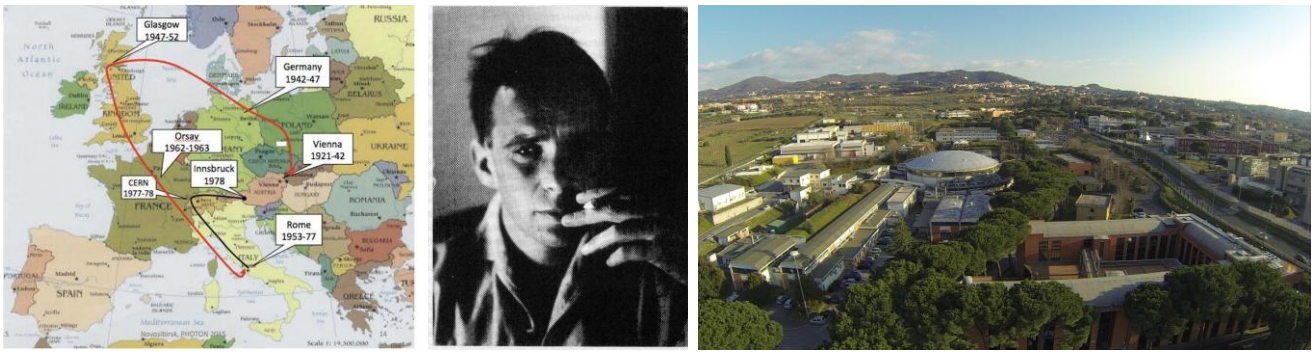


Figure 1. Left panel: image depicting Bruno Touschek's life through Europe in G.P.'s drawing on a 1941 public domain map. Center panel: Bruno Touschek in 1955 in Rome, courtesy of CERN Documentation Services. Right panel: contemporary view of the Frascati National Laboratories with the ADONE building, where electrons and positrons, accelerated to 2.8 GeV center of mass (c.m.) energy, observed an anomalous production of hadronic particles in 1969, with the old synchrotron building, at right across the road, Italy, © INFN-LNF image.

2. WHAT IS A COLLIDER AND WHY ANTIMATTER

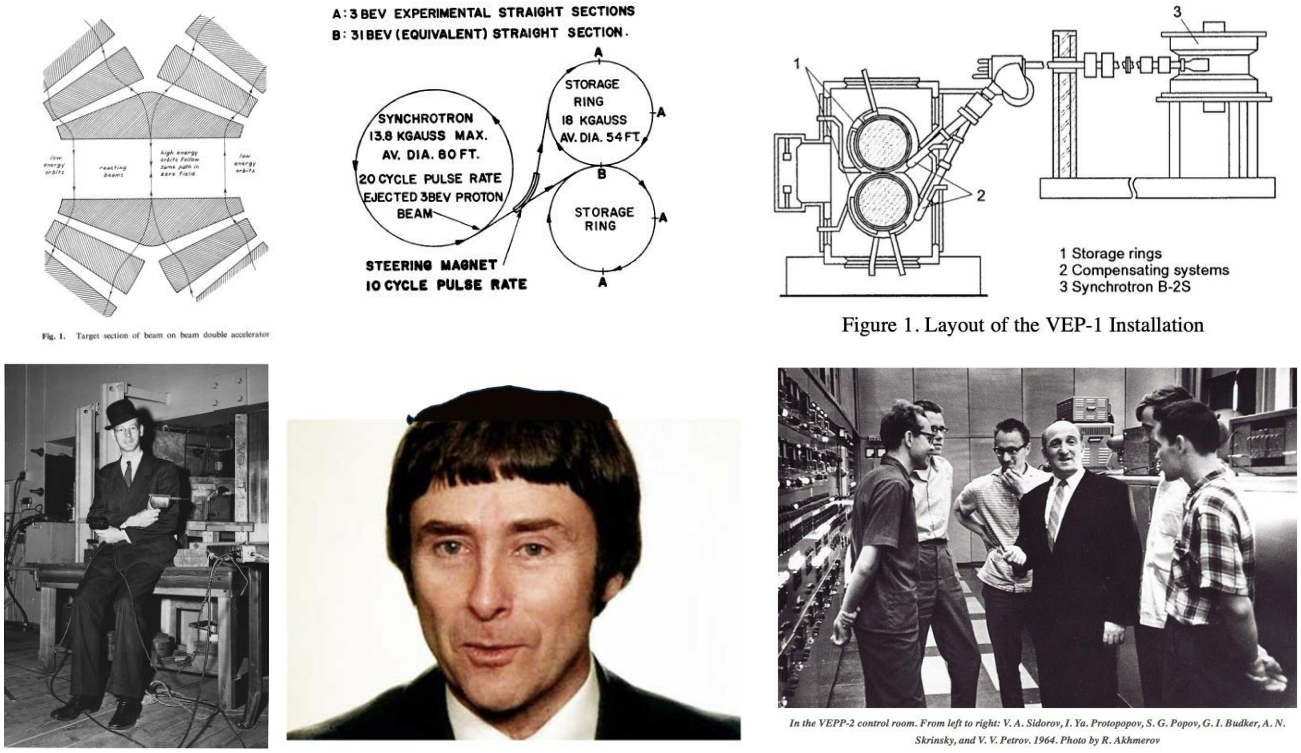


Figure 1. Layout of the VEP-1 Installation

Figure 2. Top level: at left the schemes for electron-electron or proton-proton collisions proposed by D. Kerst (left), by G. O'Neill at center, from the Proceedings of the *1956 CERN Symposium on High-Energy Accelerators and Pion Physics*, Geneva, CDS, and, at right, the scheme for VEP-1, built by G.I. Budker, from a recollection by A. Skrinsky in 1996. Bottom panel: the respective proposers of the above schemes, D. Kerst (left), photograph courtesy of University of Illinois, G. O'Neill (center), public domain, and G.I. Budker and his collaborators (right) in the VEPP-2 control room, from A. Skrinsky's contribution, to the centenary volume *Budker in Four Perspectives* https://scfh.ru/en/papers/budker-in-four-perspectives/.

A particle collider realizes the intuitive idea of center of mass collisions as a means of reaching higher energies and make easier to break up nuclei and their components, to access their inner structure.

The science of particle accelerators was developed in the last century, starting with a linear accelerator for electrons (Ising, 1924; Widerøe, 1928) then moving to circular structures, such as cyclotrons (Lawrence & Livingston, 1931), betatrons (Kerst, 1941; Kerst & Serber, 1941) and synchrotrons (McMillan, 1945; Veksler, 1946) all of them consisting of accelerating a single beam of charged elementary particles, such as electrons or protons, impinging on a target of nuclear material and observing the scattered broken content. Large laboratories were built to house the accelerator facilities, which became bigger and bigger to allow for higher particle accelerations and higher energies hitting the target.

In the mid 1950s the idea of exploiting the kinematic advantage of center of mass collisions, first suggested by Rolf Widerøe during WW-II (Widerøe, 1994), inspired US (Kerst et al., 1956; O'Neill, 1956) and USSR (Baier, 2006) scientists to develop accelerators where beams of electrons or protons moving at the same speed in opposite directions would clash against each other. Projects with electrons against electrons started in the USA, at SLAC, the Stanford Linear Accelerator Center (Barber et al., 1959), and in the USSR between Moscow and the new laboratory of the Siberian Branch of the Russian Academy, in Novosibirsk (Skrinsky, 1996), at the end of the 1950s, Fig. 2.

But, as described next, it was in Europe that the spark of future accelerators was ignited, as post-war reconciliation had spurred new collaborations fostered by intergovernment exchanges.

3. CERN AND THE CREATION OF NATIONAL LABORATORIES IN EUROPE



Figure 3. Left panel: Maurice Lévy, from May 2013 interview for the docu-film *Touschek with AdA in Orsay*, © E. Agapito and INFN. Center panel: Giorgio Salvini, 2010 in the video *Salvini Giorgio, Considerazioni a 90 anni*, © E. Agapito and INFN. Right panel: extract from a group photo with Matthew Sands at left, next to B. Touschek, G. O'Neill, J. Haïssinski and V.N. Baier, from the 46th International School of Physics "Enrico Fermi": Physics with Intersecting Storage Rings, 16–26 June 1969, Varenna, Italy, © Società Italiana di Fisica, reproduced with permission.

The series of events sketched in this article is based on oral and written contributions, photographic and video recordings, which started with Amaldi's biography of Touschek (E. Amaldi, 1981) and continued in 1987 with the *Bruno Touschek Memorial Lectures*, held in Frascati to commemorate Bruno Touschek's untimely demise in 1978 (Greco & Pancheri, 2004). Among the testimonies gathered since then, there are video interviews taken for educational purposes in 2003, 2010 and 2013, realized with the support of INFN, the Frascati National Laboratories, and Orsay Laboratoire de l'Accélérateur Linéaire. Complementing these interviews with the 1987 AIP interview with the American physicist Matthew Sands, allows a clear picture to emerge about the post-war rise of particle accelerators in Europe.

The birth of national laboratories in Europe in the 1950s was a natural consequence of the creation of CERN, as recalled below in excerpts transcribed from video interviews taken in 2013, in Paris with the eminent French theoretical physicist Maurice Lévy, at left in Fig. 3, and in Rome with the first director of the Frascati Laboratories, Giorgio Salvini, *ibidem* at center, for the docu-film *Touschek with AdA in Orsay* by E. Agapito, L. Bonolis and G.P., https://w3.lnf.infn.it/ada-anello-di-accumulazione/, © Agapito Mediascienza.

> **Maurice Lévy (Paris, May 2013) —** I came from the United States in 1952 at the École Normale Supérieure [in Paris] that at the time was directed by Yves Rocard, the father of the well known politician Michel Rocard, and he asked me to start a group of theoretical physicists. [...] In 1953, we started to have a discussion about the creation of particle machines. The reason was that the decision to create CERN was taken in 1952. It was a group of physicist, Pierre Auger from France, Edoardo Amaldi from Italy, Harry Massey from England, Heisenberg from Germany, they decided to create CERN, the Laboratory, which was approved by the governments, and this created immediately a problem, for us and I believe for the rest of Europe, in the sense that we did not have enough experimentalists to work both at CERN and in Paris, in France, in general. So it was decided by discussions with Francis Perrin, who was at the time the Haut Commissaire pour l'Énergie Atomique, and Yves Rocard, to start the building of two machines, one was a proton circular machine to be built in Saclay by the Atomic Energy Commission, and it was called Saturne, and the second one was supposed to be an electron machine. For the electron machine there were two possibilities, one was to create a circular machine of the type Bob Wilson had built in Cornell University, the other was to build a linear accelerator of the type at the [Stanford] Linear [Accelerator] Center. [...The] final decision was taken to build a linear accelerator in Paris. [...] In Paris the question was we could not build a linear accelerator at the École Normale which did not have the space and because of that, between '55 and '60, we were developing an new campus in Orsay, where we had all the space we needed and, because of that, the building of the LAL [Laboratoire de l'Accélérateur Linéaire] and building of Orsay went together.

In Italy, the decision to build a large laboratory outside Rome was taken in 1952 by Edoardo Amaldi, CERN first Secretary General, and INFN president Gilberto Bernardini (Battimelli et al., 2001). The task of building the laboratory and the machine went to Giorgio Salvini, who had done his physics dissertation on the betatron in 1942 and, after the war, had spent two years at Princeton, doing cosmic ray detector research, returning to Italy, in 1952. The development of decisions in Italy is discussed by Giorgio Salvini, in a June 2013 video-interview.

> **Giorgio Salvini (Rome, June 2013, in Italian, author's translation) —** In '47-'48 Edoardo Amaldi, Gilberto Bernardini and others were asking what could they do for Italy's renaissance. These great personalities got the idea to build a new laboratory and to place there an accelerator. In the meanwhile the decision for a French machine had been taken, and in Germany, which had been totally destroyed, the [industrial and scientific] machine was restarting. [...] In 1952, back to Italy from the United States, the prospect to build a new laboratory arose, and I was asked to be the director of the new laboratory. From what and

> where? At the end the choice fell to Frascati.[4] Frascati? I had never heard of it. [...] A friend warned me of the risk to be stuck all my life in a nowhere land.

In an AIP interview by Finn Aaserud,[5] the American physicist Mathew Sands, in the right panel of Fig. 3, described how the building of the Frascati synchrotron changed Italy's prospects from those of a country which had lost the war into the successful protagonist of a new scientific renaissance:

> **Matthew Sands (May 4 and 5, 1987) —** [In 1952, I went for sabbatical from Caltech to Europe, to Paris and Rome, where ...] Oh, it was postwar poverty. I mean, they had no money. They still had no money for research. They had managed to scrounge a few microscopes to work with emulsions. They would get surplus electronic radio gear from the army to steal parts from to make counting circuits for cosmic rays. However, it seemed to be the breaking point, I mean the transition point. It was 1952, and this was the time when things were going to change. CERN was just getting organized. The government was proposing that it could find money to support research.

In April of 1968 Sands returned to work for six months in Italy, where he found Italian physicists to now be in the forefront of accelerator science, indeed, as he said in the AIP interview,

> **Matthew Sands (May 4 and 5, 1987) —** ...they were now the world leaders in this field.

The transformation, which would make Italy a major player in accelerator physics development, had taken place with a new transition point easily identified at the end of 1959, when the Frascati laboratories had been built and an electron synchrotron had started operating, prompting the search for new ideas, as we shall see next.

Sand's words are echoed by Giorgio Salvini, interviewed in 2010, in preparation of celebrations for the 150 years since Italy's unification in 1870.[6] Ninety year old at the time, he had been Professor of Experimental Physics at the University of Rome for almost sixty years, President of the National Accademia dei Lincei and Italian Minister for University and Scientific and Technological Research.

> **Giorgio Salvini (Rome, May 2010, in Italian, author's translation) —** It is now 150 years [since the unification of Italy] of which i have only lived through 70 of them. I can testify to the enormous contribution to Italy's unification brought by science and, in particular, by the science in which I had the good luck to operate.

4. THE BIRTH OF ELECTRON-POSITRON COLLIDERS

As 1959 ended, seven years after the events recollected by Lèvy and Salvini, in Europe there were three new laboratories, and three new elementary particle accelerators, a new

[4]The choice of location came from the government, and through connections between the Ministry of Industry, the mayor of Frascati and other locally important political players (Valente, 2007, p. 39).

[5]Santa Cruz, California Transcript version date: December 18, 2024 https://doi.org/10.1063/nbla.lhoa.awxy May 4 and 5, 1987.

[6]The video-interviews was taken in G. Salvini personal residence in Rome, by E. Agapito, on the occasion of Salvini's 90th birthday, https://lamediateca.infn.it/mediateca/view.php?v=213.

generation proton synchrotron, the PS at CERN (Brianti, 1997), a powerful linear accelerator at the Laboratoire de l'Accélérateur Linéaire in Orsay (Marin, 2009) in France, and an electron synchrotron at Frascati (Salvini, 1962) in Italy, which, for a while, had the highest energy ever reached in a laboratory. European physicists were discussing and meeting, travelling to conferences, and exchanging ideas with both Russian and American counterparts, often at CERN, where accelerator physicists were looking for new ways to reach even higher energies and plans, for a conference to discuss the future of particle physics, were being laid by a group of four theoretical physicists. It was at such a conference, held in June 1961 (Bell et al., 1961), that colliding beam physics came to the fore, when Touschek announced that Frascati had built an electron positron storage ring, where matter would clash against anti-matter. But how did the idea to use matter-antimatter arise? And how feasible could it be? The turn is now for theoretical physics to join the field, as a powerful concept, invariance of an elementary particle state under transformations of Charge, Parity reflection and Time reversal (CPT), was formulated into a theorem between 1953 and 1958 by a number of scientists (Blum & Martínez de Velasco, 2022), among whom there was Wolfgang Pauli, the discoverer of the exclusion principle.[7] During these years, there were frequent exchanges between Pauli and Bruno Touschek who had joined the Institute of Physics in Rome in 1953, after having held a Nuffield Lecturer position at the University of Glasgow (Pancheri, 2022, 7). Thus Touschek learned about the CPT theorem, while it was in the making,[8] and, when the time came, he proposed to the Frascati scientists to realize it in a laboratory, by making matter-antimatter collisions, with particles of opposite charge, moving in opposite directions.

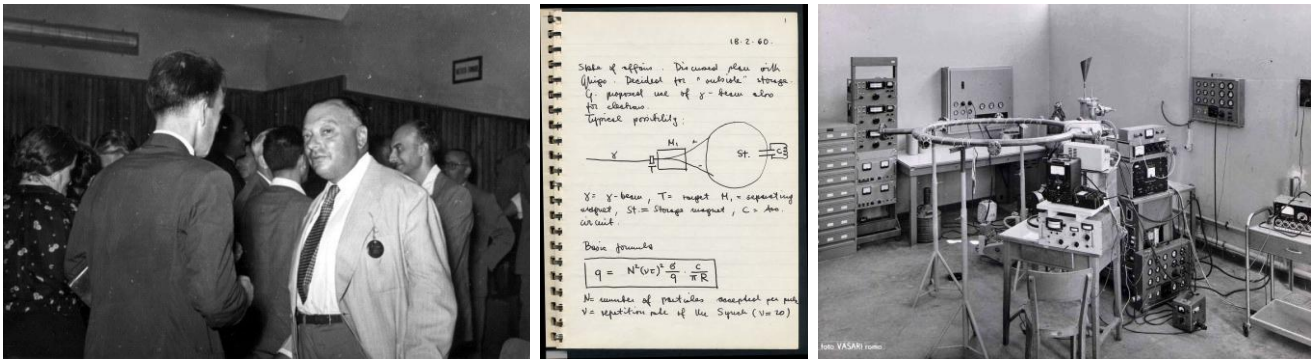


Figure 4. Left panel: Bruno Touschek (back to the camera) with Wolfgang Pauli, in 1953 in Cagliari, during the National Congress of the Italian Physical Society, courtesy of CERN Documentation Service. Center panel: the first draft of AdA's scheme

[7]W. Pauli was recipient of the 1945 Nobel Prize in Physics "for the discovery of the Exclusion Principle, also called the Pauli Principle", https://www.nobelprize.org/prizes/physics/1945/summary/. Pauli's contribution to the formulation of the CPT theorem is included in W. Pauli, *Exclusion principle, Lorentz group and reflection of space-time and charge*, in: *Niels Bohr and the Development of Physics*, pp. 30–51 (1955), https://cds.cern.ch/record/96173/files/CERN-ARCH-PMC-05-029.pdf.

[8]Exchange of letters between Bruno Touschek and other proposers of the CPT theorem, such as Gerhard Lüders, are held in Touschek Papers in Rome Sapienza University, Physics Department Archives.

prepared in February 1960 by Bruno Touschek, © Touschek family, on the day which followed his proposal for an experiment with the Frascati synchrotron. Right panel: the steel doughnut for electrons and positrons to circulate together, under preparation at the Frascati Laboratory in 1960, © LNF-INF images.

Rolf Widerøe (Widerøe, 1994, pp. 81–82): *An important event in my Hamburg period happened during the Autumn 1943 […] which started me thinking that […] when a target particle (at rest) is bombarded, […] only a relatively small portion of the accelerated particle's energy is used to actually split or destroy the colliding particles. However when the collision is frontal most of the available …energy can be exploited. […] I spoke with Touschek about my ideas and he said they were rather obvious* … Bruno Touschek (February 1960):[9]

> *The first suggestion to use crossed beams I have heard during the war [was] from Widerøe…*

Nicola Cabibbo (Cabibbo, 1997): *I still recall vividly the seminar in Rome in late '59 by [W.] R. Panofsky. It was after the seminar that Bruno Touschek come up with the remark that an e^+e^- machine could be realized in a single ring, "because of the CPT theorem"*. Bruno Touschek (1974):[10]

> *The challenge of course consists in having the first machine in which particles which do not naturally live in the world which surround us can be kept and conserved.*

The path to realize such an innovative idea as matter-antimatter collisions in a laboratory setting, can be traced to the extraordinary, and often tragic, life of Bruno Touschek, the scientist who proposed AdA in February 1960, and proved its feasibility.

5. BRUNO TOUSCHEK (1921-1978) FROM VIENNA TO ROME

Bruno Touschek[11] was born in Vienna in 1921, in a family immersed in the artistic movement of the Viennese Secession movement. His mother was Jewish, his father a catholic and a Major in the Austrian Army. As a young boy, Bruno suffered two successive tragic losses, his mother in 1931, and his maternal uncle, Oskar Weltmann, a doctor and a painter he very much admired, by suicide in 1934. After losing two of her children, his maternal grand mother, Josephine Weltmann, decided to move to Rome and live with her only surviving daughter, Adele, nicknamed Ada, who was married to an Italian industrialist. Thus, when the annexation of Austria to Germany in March 1938 destroyed the life and well being of Vienna Jews, Bruno's father thought wise to send Bruno to study in Rome, where anti-semitism, as

[9]Bruno Touschek, *On the Storage Ring*, incomplete typescript, Rome Sapienza University, Physics Department Archives, Touschek Papers, 3.86.1 in (Battimelli et al., 1989).

[10]Bruno Touschek, *A brief outline of the story of AdA*, excerpts from a talk delivered at the Italian Accademia dei Lincei 24-05-74, Rome Sapienza University, Physics Department Archives, Touschek Papers 3.92.5 in (Battimelli et al., 1989).

[11]The biographical material in this section was first collected by E. Amaldi directly from Bruno Touschek in February 1978, and was complemented by archival documents received by this author from the Vienna Jewish Archives. Of particular interest for the period covered in this section, have also been the letters sent by Touschek to his father from 1939 to 1953, so far unpublished, with excerpts in (Pancheri, 2022).

perceived from Vienna, was not yet rampant and he could attend engineering courses at the University, while living with his maternal aunt and grandmother. In Rome, one of the courses he attended was on mathematical physics, taught to both physics and engineering students, by a famous professor, Francesco Severi. Bruno had not yet passed his final high school exams, the so called *Matura*, and the course was probably more advanced than what Bruno, only 17 years old, could successfully study, but his fascination with theoretical physics may have started here, as he later wrote to have attended Severi's course with

"more enthusiasm than success".[12]

The project to stay in Rome did not materialize, since the life of Italian Jews under Mussolini's government, took a turn for the worst after Hitler's visit to Rome, followed by anti-semitic laws promulgated in October and signed by the King of Italy in December 1938 (Violini, 2006). Bruno returned to Vienna, as did his grandmother.

In 1939, as the position of Jews in Vienna was further deteriorating, Bruno made an attempt to emigrate to the UK, and study Chemistry at the University of Manchester, a city where a substantial Jewish community had been established since the previous century. For reasons unknown, Bruno did not succeed in going to the UK, and in September 1939 enrolled to study physics at the University of Vienna, where a great school in mathematical physics included such professors as Hans Thirring, later a friend and mentor of Touschek's. Following a suggestion by another of his teachers, Bruno's road as a theoretical physicist took its definitive direction when he was encouraged to read Arnold Sommerfeld's treatise *Atombau und Spektrallinien* and follow this up with a correspondence with the great scientist in late December 1941 (Pancheri, 2022, pp. 36–37). Sommerfeld encouraged Touschek to move to Germany in order to continue his studies and gave Bruno access to his vast network of former students and pupils, many of them professors in the German universities, such as Paul Harteck in Hamburg, Max von Laue and Werner Heisenberg in Berlin.[13] In Germany for 5 years, from 1942 to March 1947, Bruno learnt theoretical physics from some of the scientists who had developed it during the pre-war years or were still developing it, as was the case with Heisenberg. After the war, Touschek become his assistant, in Göttingen, where German science was being reconstructed under Heisenberg's direction.

[12]See the draft of Touschek's last CV, undated, but probably prepared in late February 1978, Amaldi Papers in Rome Sapienza University, Physics Department Archives.

[13]Von Laue and Heisenberg were both Nobel Prize recipients, Von Laue in 1914 "for his discovery of the diffraction of X-rays by crystals" and Heisenberg in 1932 "for the creation of quantum mechanics, the application of which has, inter alia, led to the discovery of the allotropic forms of hydrogen", https://www.nobelprize.org.

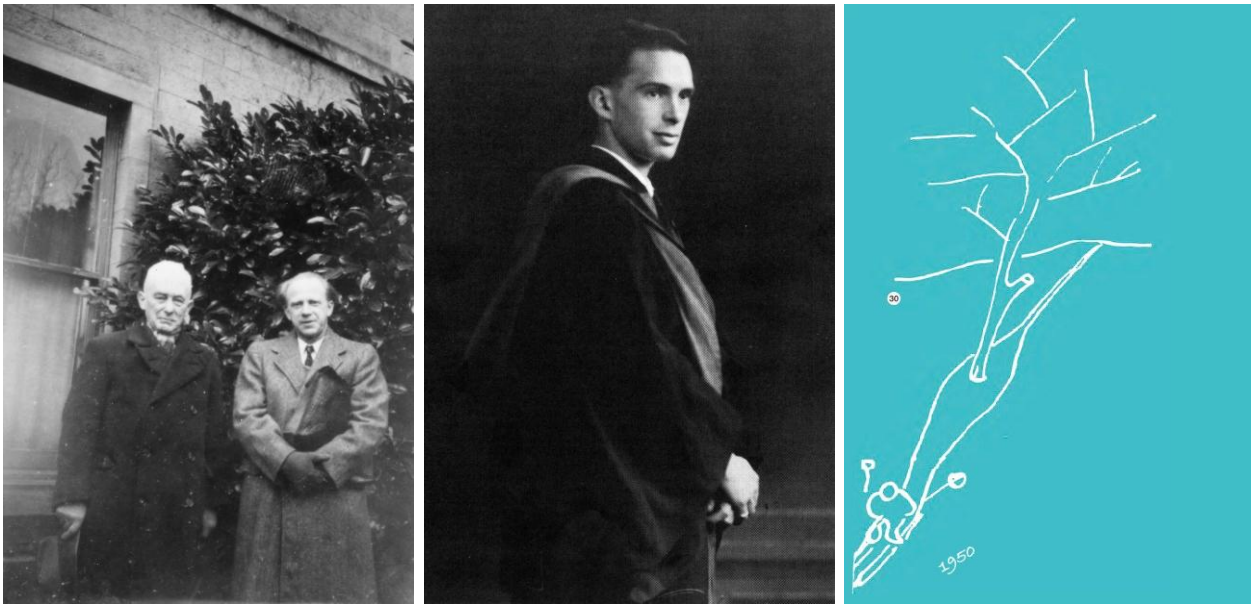


Figure 5. Left panel: Max Born and Werner Heisenberg, in Glasgow, 1947, courtesy of CERN Documentation Service. Center panel: Bruno Touschek's 1949 D.Phil. official photograph from University of Glasgow, from the Bruno Touschek papers at Rome Sapienza University, Physics Department Archives. Right panel: a drawing by Bruno Touschek in a 1952 letter to his father from Glasgow, ©Touschek Family, rendering by A. Ianiro, no reproduction allowed.

Bruno's formation as a theoretical physicist was completed in Scotland, where he earned his D.Phil. in 1949 from the University of Glasgow, and became a collaborator of another theorist who had shaped pre-war nuclear science, Max Born, then Tait Professor in the University of Edinburgh, seen in the left panel in Fig. 5.[14] For Born, Bruno curated the proofs of his book *Atomic Physics* and prepared an appendix to it (Pancheri, 2022, pp. 218–222). Shortly after his doctorate, Fig. 5, Bruno also wrote a remarkable paper with Walter Thirring (Thirring & Touschek, 1951) about the infrared catastrophe and the covariant formulation of the Bloch and Nordsieck theorem (Bloch & Nordsieck, 1937), a life-long interest of Touschek's (Etim et al., 1967). He remained in Glasgow until December 1952, and joined the Physics Institute of the University of Rome in January 1953.

I have gone through the list of some great scientists which contributed to Touschek's formation as a theoretical physicist, to contrast the view, commonly held after his death, that his proposal to build a new type of accelerator had come almost casually after a seminar by Wolfgang Panofsky, the director of the Stanford Linear Accelerator Center. While this was a moment in time when things were set in motion as detailed in (Bonolis et al., 2024), it was Bruno's theoretical physics knowledge that gave him the vision and determination to pursue the idea of what could and should be done to further probe nature's

[14]Max Born was the 1954 Nobel Prize recipient "for his fundamental research in quantum mechanics, especially for his statistical interpretation of the wavefunction", https://www.nobelprize.org/prizes/physics/1954/born/facts/.

deeper world. Of course, as often repeated, he also had first-hand knowledge of the mathematics involved in building an electron accelerator (E. Amaldi, 1981) and when he proposed to build AdA, he needed to convince his fellow scientists in the Frascati National Laboratories that it would be worth doing, investing money and people, engineers and physicists, the director of the Laboratory and the President of the National Institute for Nuclear Physics (INFN), who had to approve the budget and present the request to the Ministry of Industry for providing the funds. His success in this first phase between February and March 1960 came from his deep conviction that the machine he proposed to build was the future of particle physics. This same deep faith carried him and his team through the three years that it took to prove the feasibility of electron positron collisions.

But of course, theoretical physics is not sufficient. As the case of electron positron physics shows, it is not enough to know the physics potential, which Touschek did, as one must also know that it can be done, which he did as well, having learnt the ways electrons in a magnetic field can be controlled when he was in Germany, during the war, earning his living by assisting the Norwegian scientist Rolf Widerøe to build a 15 MeV betatron for military uses (Pancheri, 2022, 5). And yet, to reach deeper into the structure of matter, as electron-positron colliders aimed to do, a single European country on its own, even if equipped with a national laboratory as Frascati was, could not overcome the limitations of space, financial investments, human resources and up-to-date transfer of knowledge. How post-war Europe provided all this and gave birth to electron positron colliders will be highlighted in the next section.

6. THE MAKING OF ADA AND THE EUROPEAN DIMENSION

AdA was observing electrons or positrons circulate in the same magnetic ring in February 1961 (Bernardini et al., 1962), but it took three more years before the definite proof of the feasibility of electron positron colliders as an effective tool for high energy physics experiments.

The result was obtained through both theoretical work in the University of Rome (Altarelli & Buccella, 1964; Cabibbo & Gatto, 1960) and the joint experimental effort (Haïssinski, 1965; Haïssinski, 2023) between the Frascati National Laboratories and the Laboratoire de l'Accélérateur Linéaire in Orsay, where AdA was taken to improve its performance, thanks to the higher photon yield of the LINAC (Pancheri & Bonolis, 2018). It is part of AdA's legend that since strict custom regulations between Italy and France did not allow for free movement of goods or people, it took the intervention of Francis Perrin, *Haut Commissaire à l'Energie Atomique au CEA*, one of the founders of CERN who had worked with Frédéric Joliot on nuclear chain reactions and was very influential, before the truck carrying AdA and all its working vacuum pumps, could enter France. As Carlo

Bernardini recalls, in July 1962, a direct telephone consultation between ministers in France and Italy, became necessary in order for the newly constructed storage ring AdA, to cross the existing custom barriers (Bonolis & Pancheri, 2018). [15]

The transfer had been envisaged during Marin and Charpak's visit to Frascati in July 1961, and was discussed in encounters and letters exchanged by the two laboratories, between September 1961 and July 1962.[16] This international transfer of people and machinery had its origin through the special role of CERN for Europe's scientific exchanges.

The starting point for the transfer had taken place in Geneva, at the CERN 1961 Conference on Theoretical aspects in High Energy Physics, during the session on Electromagnetic Processes (Bell et al., 1961, p. 57), where Touschek presented the Frascati electron-positron storage ring under construction, AdA, and the ADONE project for a much more powerful collider, proposed in (Amman et al., 1961), which he had dreamed could reach an unthinkable energy, $E_{\text{c.m.}}$ = 3.0 GeV.[17] ADONE became reality operating with two beams in 1969, right away observing an anomalous production of hadronic particles (Lubkin, 1973).

Following and complementing Touschek's talk at the CERN 1961 Conference, was his colleague Raoul Gatto, (Bonolis et al., 2024), another first class theorist from the University of Rome, who gave a talk about the physics prospects at such machine. In the CERN audience, the idea sparked interest while news of Frascati's bold step forward reached both the USSR and France.

In France, Pierre Marin, Fig. 6, from the Orsay Laboratoire de l'Accélérateur Linéaire was looking for new research directions and went to Frascati to see what was happening (Marin, 2009, p. 46). This visit started the international collaboration which one year later, brought AdA to be transported to Orsay, where collisions were observed within less than two years. The laboratory work and the details of this ground-breaking observation were described in his *Thèse d'État* by Jacques Haïssinski, Fig. 6, later to be one of the protagonists of the construction of the French collider ACO, *Anneau de Collisions d'Orsay*, which started operations in 1968 (Augustin et al., 1968).

[15]The episode is also recalled by the French physicist François Lacoste, in a 2013 interview, at Orsay, for the docu-film *Touschek with AdA in Orsay*.

[16]In 2011, copies of letters and other supporting material describing these exchanges were sent by e-mail to this author by the late Jacques Haïssinski, who had digitalized them from the Archives in Orsay Laboratoire de l'Accélérateur Linéaire. Details of their content appeared in (Bonolis & Pancheri, 2011), (Bonolis & Pancheri, 2018) and (Pancheri, 2022).

[17]Touschek proposed to build ADONE in a memo dated November 9th, 1960, (Pancheri, 2022, p. 397). In February the proposal was formally prepared as LNF note (Amman et al., 1961).

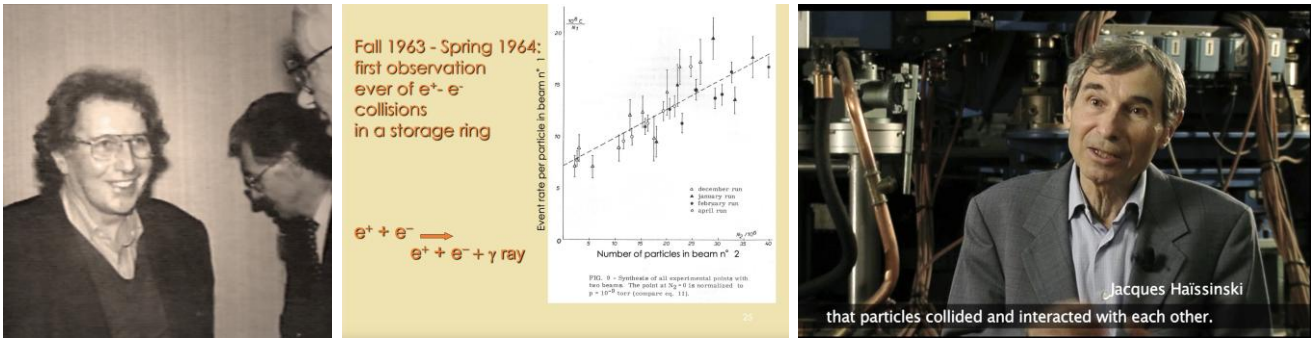


Figure 6. Left panel: Pierre Marin with Georges Charpak (barely seen at right in the first panel) in the late '70s, photo courtesy of Jacques Haïssinski. Center panel: transparency presented by Jacques Haïssinski in 2020 in Rome (Bonolis et al., 2023), with the plot proving that AdA had observed collisions during four runs in the Laboratoire de l'Accélérateur Linéaire d'Orsay, now IJC-Lab, from Carlo Bernardini's Papers in Rome Sapienza University, Physics Department Archives. Right panel: still shot of Jacques Haïssinski in the docu-film *Touschek with AdA in Orsay*, ©E. Agapito and INFN.

In Novosibirsk, the theorist V.N. Baier, in late October 1959, had convinced the laboratory director, G. Budker, of the advantage in building an electron positron collider (Baier, 2006), but progress had been slow because of inherent difficulties and the isolation of the Russian scientists. The news from Frascati encouraged them, and their electron-positron collider, VEPP-II, could be seen to be in advanced state of preparation in 1963 (Marin, 2009), (Pancheri, 2022, pp. 381–383). By this time, new collider projects had been approved, in Italy with ADONE, in France with ACO, at CERN with the ISR, Intersecting Storage Rings, while in the USA the electron-electron project was already in construction.

The impact of Touschek and Gatto's talks at CERN in June 1961 is not limited to the interest it generated in Orsay. The Italian-French collaboration, which demonstrated the feasibility of electron positron colliders, was started by a visit to Frascati, one month after the June 1961 meeting at CERN (Bonolis & Pancheri, 2018), but Pierre Marin did not go alone. He went there, he writes, with Georges Charpak, Fig. 6, who had joined CERN in 1959, where discussions about future programs had started since the PS had began operations. Storage rings were part of on-going discussions and the two presentations by the Italian scientists, followed by Charpak's visit to Frascati, signalled the beginning of a new era.

CERN had experience with accelerating proton beams. It is therefore no accident that while Frascati and the Laboratoire de l'Accélérateur Linéaire pursued a collaboration about electron positron colliders, at CERN the interest in storage rings veered to *pp* collisions (Hereward et al., 1960), and the ideas of what would become the Intersecting Storage Rings would be studied by a group of "enthusiasts" (Hereward et al., 1962) led by Kjell Johnsen, who invited Touschek to join them (Bonolis &

Pancheri, 2018).[18] Touschek accepted the invitation but he was very busy with planning for AdA's transfer to Orsay, and there is no information about his going to CERN in Spring 1962.

AdA arrived in Orsay in July 1962, to be installed in Hall-500 of the Laboratoire de l'Accélérateur Linéaire in November. Less than two years later, the proof of feasibility of Touschek's electron-positron experiment was submitted for publication (Bernardini et al., 1964). By this time, news about Frascati's results had led to proposal and approval of projects for electron-positron colliders such as the Anneau de Collisions d'Orsay (ACO) in France, ADONE in Italy, VEPP-2 in the USSR. In the 1970s, the traditional way of accelerating particles to hit a fixed target was slowly abandoned in favor of collisions between moving beams and, in the second part of last century, different types of particle colliders were designed and built. New facilities hosted new accelerators (U. Amaldi & La Rana, 2015) for electrons clashing against positrons, protons against other protons or against anti-protons, positrons against protons, heavy ions against protons, or other heavy ions. Reaching higher and higher energies allowed the experimental discovery of particles which had been proposed by the theoretical physics community to be the building bricks of the Standard model of elementary particles (Treille & Pauss, 2025).

Thus, in a joint march toward the unknown, sponsored and encouraged by international and intergovernmental exchanges, theorist and experimentalists led and followed the development of ever more powerful particle accelerators, until the LHC, in 2012, closed the first chapter of the Standard Model of Elementary Particles, with the discovery of the Higgs boson, born as a theoretical physics mechanism proposed in 1964 and searched for, in its particle form, through many decades. Such is the power of theoretical physics.

7. CONCLUSION

The story I outline in this article captures the making of a revolution in particle accelerator physics in the second half of last century. Such a revolution made particle colliders the major discovery tool in high energy physics, and was made possible by international collaboration, interregional and intergovernmental treaties and exchanges.

The vision which guided scientists in 1950 led the European governments to establish an organization such as CERN, the Conseil Éuropeèn pour la Rechèrche Nucléaire which would reunite and guide European scientists towards post-war reconstruction. The substantial costs carried by

[18]K. Johnson solicited Touschek to join the next meeting of the group through Fernando Amman, who was in charge of the nascent ADONE project, as we learn from Touschek's letter to Johnsen on February 21st, 1962, Touschek Papers in Rome Sapienza University, Physics Department Archives.

competing scientifically with the US was provided jointly by the Member States, in proportional to national budgets. Italy and France were founding members, but on opposite sides, as France was among the WWII victors, and Italy on the losing side.

CERN's scientific project was the study of nuclear physics, to probe interactions among matter constituents. Around such a vision, European scientists built a powerful proton accelerator, and, in parallel, two national laboratories and two modern type accelerators. For Italy, which the war had tragically divided into two parts in 1943, the Frascati synchrotron became a symbol of unity and exceptional progress, led by Edoardo Amaldi, one of the founders of CERN, and President of a newly born National Institute for Nuclear Physics in 1952. The next step, in developing the extraordinary discovery tool of particle colliders, came from the vision of theoretical physicists. Central to the new step was the CPT theorem and Touschek's unshakeable faith in its validity which led to the birth of electron positron physics. A new field of physics was thus born through the 1960s in Europe, the USSR and the USA, where both electron-electron and electron-positron colliders were built (Paris, 2001). The scientific revolution brought by elementary particle accelerators is now returning its due to society, as seen in the pervasive usage of particle beams for medical and industrial purposes, which are presently routinely performing in most advanced countries with beneficial political and societal effects. Such benefits must be extended to other, less developed, regions and the story told in this article could provide inspiration for the scientific community in the greater Caribbean region to carry their voice to the governments for the creation of a regional alliance towards a large project such as the Greater Caribbean Synchrotron, in a guiding vision to include both the scientists and the political world and their interaction.

Scientists, and, in particular theoretical scientists, are used to work on a mental scale beyond their life-time, thus their vision may overtake present tragedies and conflicts, and may be the ideal conveyors for carrying their projects to government attention. If the political world, with its different vision can rise to the challenge, great steps to society's benefit can occur.

While it is true that history does not repeat itself, it can teach and encourage to dream and to plan and make things, otherwise and apparently impossible, to become reality, as in cases such as the one recollected here. If this article can provide inspiration to pursue the construction of the Greater Caribbean Light Source Project, the story of Touschek's small machine and the Frascati synchrotron will return to life and be of use to future generations.

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[19]See https://www.sfphysique.fr/evenement/colloque-jacques-haissinski/.

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