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Bruno Touschek in Glasgow.
The making of a theoretical physicist

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Abstract

In the history of the discovery tools of last century particle physics, central stage is taken by elementary particle accelerators and in particular by colliders. In their start and early development, a major role was played by the Austrian born Bruno Touschek, who proposed and built the first electron positron collider, AdA, in Italy, in 1960. In this note, we present a period of Touschek's life barely explored in the literature, namely the five years he spent at University of Glasgow, first to obtain his doctorate in 1949 and then as a lecturer. We shall highlight his formation as a theoretical physicist, his contacts and correspondence with Werner Heisenberg in Göttingen and Max Born in Edinburgh, as well as his close involvement with colleagues intent on building modern particle accelerators in Glasgow, Malvern, Manchester and Birmingham. We shall discuss how the Fuchs affair, which unraveled in early 1950, may have influenced his decision to leave the UK, and how contacts with the Italian physicist Bruno Ferretti led Touschek to join the Guglielmo Marconi Physics Institute of University of Rome in January 1953.

Ich will ein Physiker werden

I want to become a physicist, Bruno Touschek, 1946

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Premise

This note is part of a project whose aim is to contribute to the knowledge of how present day high energy particle accelerators were conceived and constructed in the second half of the 20th century in Europe, the United States, Japan, the USSR. One of the early protagonists of this story is the Austrian born theoretical physicist Bruno Touschek, who built the first electron positron collider, in Frascati, Italy, in 1960.

As we get close to the hundredth anniversary of his birth on February 3rd, 1921, we are preparing and posting a set of notes, which highlight some of the most important periods in his life. In particular, this note will highlight the period he spent at University of Glasgow, from 1947 to December 1952. We show him in a contemporary photograph with his colleague [Samuel Curran](#), in Fig. 1.

A full length biography, was published three years after Touschek passed away (Amaldi 1981). During the years of his maturity, Touschek was very famous in the particle accelerator community. His work

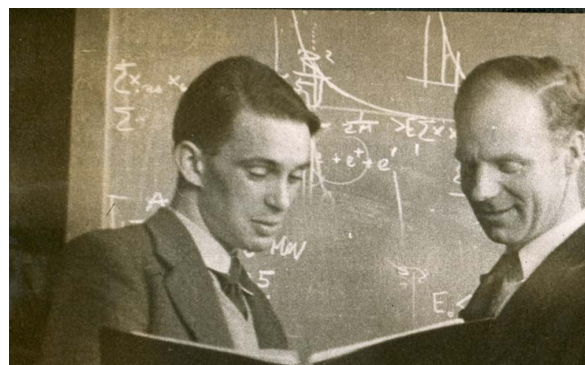


Figure 1: Bruno Touschek with Samuel Curran, at University of Glasgow, around 1948. Photograph courtesy of Mrs. Elspeth Yonge Touschek.

led to the construction of powerful machines, which then opened the way to the formulation of the Standard Model (SM) of elementary particle physics. While Amaldi's biography is unparalleled and constitutes the basis for any more recent work, forty years have passed since its publication. Using newly found material and archival sources, we have started examining Touschek's life in the context of the great scientific developments in the field of particle accelerator physics which took place during last century (Pancheri 2004, Bonolis 2005, Bonolis and Pancheri 2011; 2018, Pancheri and Bonolis 2018). This development has a number of major milestones in particle colliders, marked by the discovery of new particles: the charm quark in 1974, at Brookhaven with a traditional accelerator, but also at the electron-positron collider SPEAR at Stanford and confirmed at the electron-positron collider ADONE in Frascati a few days later, the bottom quark in 1977 at the $\bar{p}p$ Tevatron collider in FermiLab, the W and Z bosons in 1983 at the CERN $S\bar{p}pS$, the top quark in 1989 in FermiLab, the precision measurements of the Z -boson at the CERN Large Electron Positron (LEP) collider through the 1990's, the gluon at the $e - p$ collider HERA in DESY, and finally the Higgs boson in 2012 at the CERN Large Hadron Collider (LHC).

Unfortunately, Bruno died young. His early death, at only 57 years of age, was a deep loss for all who knew him. In 1987, one of his friends said that he had contributed to the *Quattrocento* of particle physics, but could not see the *Rinascimento*, the Renaissance, which was born of it (Salvini 2004).

Bruno Touschek's work and life cross Europe in space and time: from Austria to Germany, United Kingdom, Italy, and France, through World War II and the beginning of the great particle discoveries of the 1970s.

He was born in Vienna, with a mixed heritage: his mother, Camilla Weltmann, who died when Bruno was a young boy, came from a Jewish family immersed in the artistic background of the Vienna Secession movement, his father, Franz Xaver Touschek, was a Staff Officer in the Austrian Army. His studies were disrupted by the annexation of Austria to Germany, the Anschluss, which took place in 1938, and were definitely interrupted in June 1940, when, because of his Jewish origin on the maternal side, he was expelled from the University of Vienna, where he had started physics studies in September 1939. Upon Arnold Sommerfeld's suggestion, his desire to continue studying physics led him to move to Germany, where his paternal name could hide his Jewish origin, and allow him to do some odd jobs, while attending physics classes, held by Sommerfeld's earlier pupils, in Berlin and Hamburg. During the war, he came in contact with Rolf Widerøe, the Norwegian scientist who had built the first linear collider and invented the betatron in 1928. In the last days of the war, he suffered imprisonment and narrowly escaped death.

In our most recent note, we have described Touschek's life after liberation by the Allied Forces in April 1945, and the period of his life until the end of 1946 (Bonolis and Pancheri 2019). In the present note, we shall pick up our story from there.

1 Introduction

In the fall of the academic year 1946-47, the Principal of Glasgow University welcomed a very special student cohort, the one which was returning from the war. As he wrote in the preface to the 1946-47 Student Handbook, he welcomed not only the new first year students, but equally warmly those who would be resuming the course of studies interrupted by the war. “These are sombre and anxious days” he added, “as they must be after the years of loss and destruction”, but the process of recovery had started and, although possibly long and hard and disappointing, he hoped that the new students would set a standard for the future. The Principal’s words are poignantly reflected in the Student Hand book cover in Fig. 2, which shows the transition from the war scenario on the right side, to the purposeful stride of a confident young man at left, under the benign eye of the University tower.

Among this new class, joining in the Spring as a graduate student, there would be Bruno Touschek (Amaldi 1981, Bonolis and Pancheri 2011). He had gone through the disruption of his life, suffered loss and fear, and now he was moving ahead to a new country, a country which had won the war. Unlike Germany, still under the weight of restrictions and lacking resources, the UK was ready to pour energy and money into new roads, which scientists, coming back to basic research after their war engagement, were eager to follow.

When the preface was written on July 19th, 1946, Bruno was still in Göttingen, had just submitted his Diploma thesis and was worrying about the future directions his studies would take. In the meantime, he was working as assistant to Werner Heisenberg, one of the founders of Quantum Mechanics and one of the most illustrious German scientists, a key theoretical figure in the German nuclear project, and, since 1942, official director of the Kaiser Wilhelm Institute for Physics in Berlin-Dahlem (Cassidy 1993; 2017).¹

The year 1946 had been very hard for Bruno, who was torn between a desire to remain to study in Göttingen, under very dire monetary circumstances, and the worry about his parents’ precarious situation in the city of Vienna, under Soviet occupation. His unique expertise in accelerator science, gained working with Rolf Widerøe (Widerøe 1994, Sørheim 2020) during WWII, decided for him. In early January 1946, in fact, the British accelerator program was being defined, and a project for constructing an electron synchrotron at Glasgow University took definite form. Touschek was one of few experts



Figure 2: Front page of University of Glasgow 1946-47 Student Handbook. Courtesy of University of Glasgow Archives & Special Collections, University collection, GB 248 DC 157/18/56.

¹After being taken into custody by the Allied Scientific Intelligence Mission, code-named Alsos, on May 4th, Heisenberg had been kept secluded at the country estate Farm Hall in UK with other key members of the “Uranium Club” and brought back to Göttingen in early spring 1946. In Göttingen, in the years to follow, Heisenberg would devote himself to two large tasks: the reconstruction of the Kaiser Wilhelm Institut für Physik as a center for experimental and theoretical research in physics and the renewal of scientific research in Germany, where, during these early post-war years, research was limited by the directives of the Allied Control Commission.

in the field present in Germany at the time, and his knowledge was prized by the Allied T-force, who had advised for him to be moved to the UK (Bonolis and Pancheri 2019). After interrogations in Wimbledon, Touschek had then been moved from Kellinghusen to Göttingen, where Heisenberg was starting the reconstruction of scientific life in Germany and, on April 1st 1946, had been in Glasgow, where he expected to stay as a research assistant for about a year. However, problems arising from his Austrian citizenship, blocked this appointment, as discussed in (Bonolis and Pancheri 2019). While the paper handling in the UK was being sorted out, he had to go back to Göttingen where he obtained his Physics Diploma in June. He spent the rest of the year as Heisenberg's assistant (Amaldi 1981, Bonolis and Pancheri 2019), worried about his immediate future.

The uncertainty about a future, which was not in his power to direct, and the desire to continue his physics studies made him oscillate between hopes of remaining in Göttingen and obtain a doctorate under Heisenberg or moving to Glasgow, where he would face unknown surroundings and, in some ways, a less prestigious prospect. At the same time, Glasgow would provide a clean break from the past, and be financially more rewarding. It is very likely that, once the decision had been taken (by the T-force), Bruno was happy to leave Germany, which was still under the deprivations and gloom of the war. He had finally made true his old dream of studying in the UK, would have a reasonable salary, and thus could help his family, as he had wanted all along. He would join a great and ancient University, and be part of the British post-war effort focused on bringing to peacetime use the scientific successes and technological innovations which had won the war to the Western Alliance.

In early 1947 Touschek was aware of the approaching engagement with Glasgow University, but was also hoping to continue in Göttingen towards a doctorate under Werner Heisenberg's guidance. This would not happen. Firstly, the financial situation of Heisenberg's Institute was still a difficult one, most probably not allowing the possibility of having PhD students, but mostly, events, which had started early in 1946 and are discussed in Sec. 2, began to unravel. In January 1947, the University of Glasgow Senate submitted to the University Court a proposal for the construction of a synchrotron in the University, whose development, supply and erection would be provided by the Department of Scientific and Industrial Research (DSIR), together with a capital grant of 3,000 pounds towards the provision of a high voltage generator. In Fig. 3 we show the pages from the Minutes of Glasgow University Court stating the decision to build a synchrotron as proposed by DSIR, and appoint the famous Scottish architect Mr. Basil Spence to design the expansion to house the synchrotron. This was part of the project to build an extension to the original Natural Philosophy Building having the purpose to establish the Department of Natural Philosophy "as one of the pre-eminent physics departments in the UK."²

Following this decision, Philip I. Dee, the chair of Department of Natural Philosophy of the University of Glasgow was finally able to carry through the appointment of Bruno, a researcher of exceptional promise, as Dee himself noted in the submission forms a few months later.

²From Minutes of University of Glasgow Court 1946-47, January 23rd 1947. Courtesy of University of Glasgow Archives & Special Collections, University collection, GB 248 DC 157/18/56Archives. News from the Glasgow University Archive Services with a later photo of the Building can be found at <https://www.theglasgowstory.com/image/?inum=TGSD00214>. The first phase was completed around 1954 and consisted of a new lecture room and the purpose built accommodation for the synchrotron. A 2007 journalistic assessment of Spence's work can be found at <https://www.theguardian.com/society/2007/oct/16/communities>.

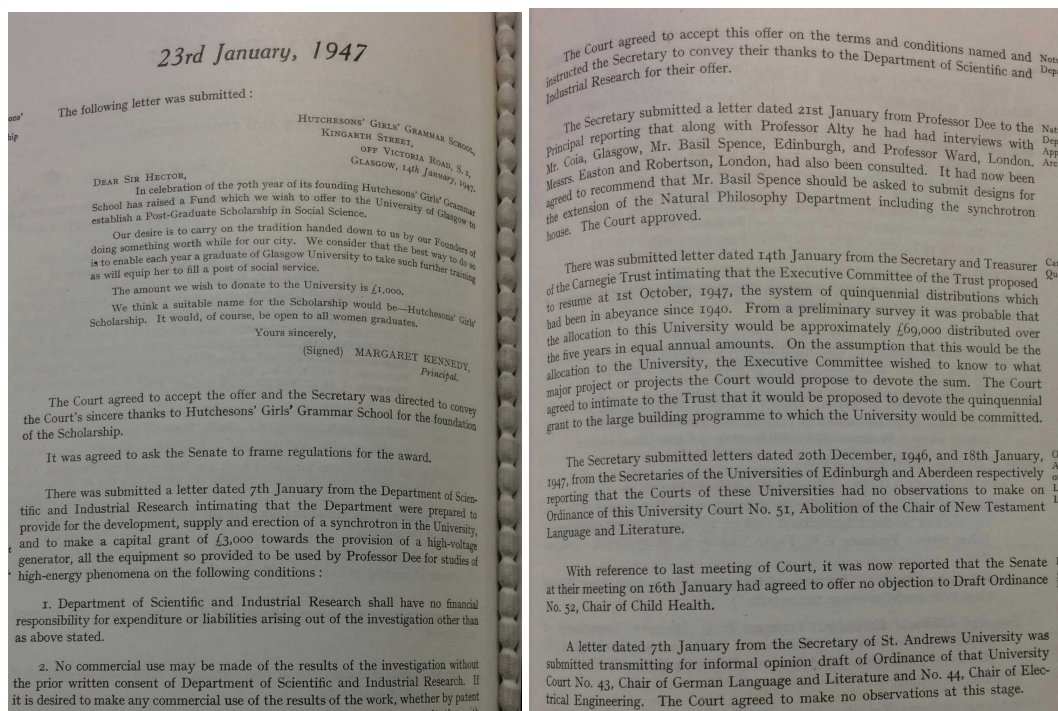


Figure 3: Minutes of University of Glasgow Court 1946-47, January 23rd 1947. Courtesy of University of Glasgow Archives & Special Collections, University collection, GB 248 DC 157/18/56Archives.

Bruno Touschek spent almost 6 years in Glasgow, from April 1947 until December 1952. Little has been known until now about this period of Touschek's life and the crucial influence it had on Touschek's later emerging in Rome as full fledged theoretical physicist, whose exceptional intelligence and sarcastic wit would soon conquer his Roman colleagues, and make him one of the major stars of an Institute bent on taking a central role in the physics scenario of the new Europe. In Edoardo Amaldi's work (Amaldi 1981, 9-12), only a few pages describe the period Bruno Touschek spent in Glasgow. Amaldi cites the copious scientific output, more than 15 published articles with many different co-workers, and, as a personal note, reproduces a long letter by Philip Dee, which describes Bruno as brilliant but temperamental, able to do clean and tidy scientific work, but occasional unrestrained by normal rules of behaviour. This period of Bruno's life seemed almost wasted, or at least irrelevant to his future as the undisputed genius of later years. His scientific work in the Glasgow period appears even forgettable, with the sole exception of the article with Walter Thirring on the Bloch and Nordsieck theorem (Thirring and Touschek 1951). And yet, these are the years when Touschek became a theoretical physicist and met the Italian theorist Bruno Ferretti and, through him, found his way to Rome.

Indeed, as we continued in our search for clues to Touschek's genius and tragic life, and to the genesis of the development of particle beam colliders, we discovered the importance of this period in Touschek's life. In particular, inspection of available archival sources highlighted the relationship Touschek had with Werner Heisenberg and Max Born during his Glasgow years, and revealed the influence these two giants of 20th century physics had on Touschek's formation as a theorist.

Building on this, and placing Touschek in the context of historical events around

him, such as the Fuchs affair, and the effect it had on UK physics, we now present a new insight on Touschek's life in Glasgow, which shows how his destiny became entangled and influenced by his larger surroundings. Far from the image of a studious but nervous and eccentric young man, as described by Philip Dee in the letter to Edoardo Amaldi, we now see him as the young protagonist of a future great adventure, well aware of the mainstream of world events and physics developments, bent on his studies and anxious to recover the years he had lost when he was expelled in June 1940 from the University of Vienna, because of the Jewish origin from his maternal side. These years, lost through the disruptions arising from anti-semitism, had already started in Vienna with the Anschluss in 1938, had then culminated in Germany with his imprisonment in the Fuhlshüttel prison in March 1945, and the improbable escape from death on the way to the Kiel concentration camp (Amaldi 1981, Bonolis and Pancheri 2011).

In what follows, our aim will be to unravel what made Bruno into the scientist who in 1960 merged theory and experimental insight to invent AdA, the first electron-positron collider, have it built and led to success in 1964. We will outline how the theoretical foundations of his later work in Italy were laid during the Glasgow years, and highlight his life-long interest in the radiation electrons emit, when accelerated to very high energies. We shall see the many close exchanges with the UK accelerator scientists during this period, which furthered his deep understanding of how electrons in a beam behave as they move under acceleration, and his personal exchanges with two great theoretical physicists such as Werner Heisenberg and Max Born. All this would come back to him in the 1960s, when AdA was conceived and built, a proof-of-concept leading to the construction of new powerful electron positron colliders in Italy, France, the United States, USSR, and, later, everywhere else in the world.

In order to adequately address Touschek's five years in Glasgow, we shall start with an overview of the UK scientific environment after the war, and contemporary developments in particle physics. It was a time of great discoveries and great advancements in the field of what was then called nuclear or meson physics, and a vast literature about it exists. We have tried to highlight the parts most relevant to the story we want to present. This said, Sec. 2, which follows, implies some pre-existing knowledge of particle physics and its language, and interested readers from other fields may prefer to skip it, except to find in the quoted literature longer and more exhaustive descriptions of the physics of this period.

2 Backstage in UK and crucial particle physics developments elsewhere

Touschek's move to Glasgow can be seen in the context of the extensive program of particle accelerator construction in which the UK had embarked soon after the end of the war. Initially motivated by the possibility of having more powerful machines for investigations at a nuclear level, preliminary plans were further boosted by the discovery of new elementary particles in cosmic ray studies which definitely set the stage for subnuclear physics.

Up to 1945, particle accelerators in use were the van de Graaff, the Cockcroft-Walton, the cyclotron and the betatron. A new era in the field was inaugurated with the principle of phase stability, proposed in 1945 by Edwin W. McMillan in the US and, independently, by Vladimir Veksler in the USSR (McMillan 1945, Veksler 1946). This idea would allow to accelerate particles into the GeV region, which was out of the reach of

cyclotrons. In these machines, which up to that time had been able to produce the highest energies, the relativistic mass increase with high velocities resulted in an energy limit of about 25 MeV for protons. This obstacle was overcome by the new principle, which opened the way to a completely new type of accelerator, the synchrotron, and also allowed to convert cyclotrons into synchro-cyclotrons, operating them at much higher energies. A remarkable advantage of such device was the possibility of accelerating both protons and electrons, and in any case, all the basic knowledge already acquired through betatrons was instrumental for the functioning of electron synchrotrons. All this, combined with the outstanding role of nuclear physics as a research field, achieved during the war, became a powerful trigger for the construction of new accelerators. As we will see, the new type of machine was immediately included in the British nuclear physics program.

By 1945, eight particles were known: the electron, the positron, the proton, the neutron, the photon, the neutrino, and the so called positive and negative mesotron – as it was termed the very penetrating component of local cosmic rays because of its mass of 200 electron masses, intermediate between that of electron and proton – which was wrongly thought at the time to be Hideki Yukawa's meson, the predicted field quantum mediating the strong interaction. As such mesons were believed to be associated with the extraordinary attractive forces binding together the neutrons and protons of the nucleus, the new challenge was to make mesons in the laboratory, and there to study them in the number and the detail which was impossible while their source was still only the cosmic rays. The needed energy was at least 200 MeV, because of their rest energy, known to be 200 times the electron rest energy. But more was of course required to make them in some quantity, and so a popular target for the builders of machines was 300 MeV. As we shall see next, this minimum threshold clarifies the energy choices for the Glasgow and Liverpool synchrotrons which the post-war UK scientists planned to build.

2.1 The UK accelerator program in 1945-46

The UK accelerator program was part of a wider postwar atomic energy program. It was started with the decision in October 1945 to establish the Atomic Energy Research Establishment (AERE), to be built in a site near Harwell, which would become the main center for atomic energy research and development in the UK. At the time, UK was the leading nuclear power in western Europe, having the financial, industrial and technical resources to launch such a large-scale project, which would include also a number of accelerators. Applied nuclear physics was the basic task of the new center at Harwell, directed by Sir John Cockcroft.³ Cockcroft had come back from war work at Chalk River, in Canada, where a heavy-water nuclear reactor to manufacture plutonium and enriched uranium had been built. At AERE, where the first nuclear reactor in western Europe started up in August 1947, Cockcroft supervised the construction of various reactors. But in parallel with nuclear reactors, a variety of accelerators had also been planned to be built there, to be used for more applied tasks of pure nuclear nature, like the production of

³In 1929, John Cockcroft and Ernest Walton, working at Ernest Rutherford's Cavendish Laboratory at Cambridge University, started to build the first 'Cockcroft-Walton accelerator', as it was named since then, a system of capacitors and thermionic rectifiers capable of 600 KV when it was used in 1932 to bombard lithium and beryllium targets with high-energy protons achieving the first artificial disintegration of an atomic nucleus and the first artificial transmutation on one element (lithium) into another (helium) (Cockcroft and Walton 1932). This machine was still used much later to supply voltage in large particle accelerators.

neutrons by photo-disintegration or the determination of cross-section of neutron induced reactions. They were of interest also for radiotherapy and for the study of high energy X-rays.

Between October 1945 and March 1946, the decision was taken to build accelerators in as many UK universities which were chosen as adequately equipped for the task. In early 1946, the Nuclear Physics Committee of the Ministry of Supply sent circulars to thirty universities and other institutions asking about their research programs in nuclear physics (Mersits 1987, Krige 1989). Only five of them replied with requests for large scale equipment, subsequently receiving grants from the DSIR for the construction and maintenance of the following accelerators: a 1.3 GeV proton synchrotron at Birmingham, designed by Mark Oliphant, a 300-400 MeV electron linear accelerator at Cambridge (later abandoned), a 300-MeV electron synchrotron at Glasgow, a 400 MeV proton synchro-cyclotron at Liverpool, a 150 MeV electron synchrotron at Oxford. Actually, all these machines would go into operation between 1953-1954, when the Bevatron and the Cosmotron, accelerators of much higher energies, were already available in the US.

By the end of 1945 the advantage of a synchrotron for the photo-production of mesons had been recognised, and a research program in synchrotron development had been prepared. Philip Dee's idea of building a 200 MeV betatron at Glasgow had been abandoned in favour of the mentioned 300 MeV synchrotron. A working group, under the leadership of Donal Fry, was created in the government center at Malvern, where a top secret radar group had been hosted during the war. Discussions with industrial groups, such as Metropolitan-Vickers, English Electric and British Thomson-Houston, all of which had participated to the war effort, had started (Lawson 1997).⁴

The decision was taken to build a 30-MeV electron synchrotron, which should serve as a prototype for the 300 MeV machine planned by Dee in Glasgow, and at the same time could be used to study nuclear photo-disintegration and gamma-neutron reactions. Following Frank Goward's idea, the first step in this direction was done converting a betatron at the Woolwich Arsenal Research Laboratory (the first in UK during the war) into the world's first electron synchrotron. This prototype, first operated in October 1946 by Goward and D. E. Barnes (Goward and Barnes 1946), established the practicability of the synchrotron acceleration, together with the machine operated by General Electric in US (Elder et al. 1947). The Woolwich synchrotron was then moved to Malvern where it was modified to be used for more general experiments. In providing the premise for the 30-MeV machine, which would go into operation in October 1947 (Fry et al. 1948), the Malvern synchrotron in turn became the hotbed for analyzing the problems of the 300 MeV Glasgow machine. The magnet for the Glasgow electron synchrotron would be built by Metropolitan-Vickers Electrical Co., who were to be responsible for overall design and construction together with the Malvern group and Glasgow University. The Malvern-Harwell group also gave advice to the building of the Oxford electron synchrotron.⁵

This new-generation accelerators were required to provide higher beam currents to make interactions between particles more likely, and provide higher energies to investigate in the laboratory new forms of "nuclear" interactions, previously observed only in cosmic rays experiments. At that time, the adjective "nuclear" referred to the whole research

⁴See also *The CERN Synchrotrons* by Giorgio Brianti in [50 Years of Synchrotrons](#) where Lawson's recollections appear.

⁵See *Metropolitan-Vickers Electrical Co 1899-1949* by John Dummelow: 1939-1949, https://www.gracesguide.co.uk/Metropolitan-Vickers_Electrical_Co_1899-1949_by_John_Dummelow:_1939-1949.

related to the basic structure of matter and the laws behind it, i.e. nuclear forces, mesons, field theory, etc., and its meaning was much broader and quite different from present-day.

2.2 1946: Reaching out to the reconstruction of European science

Alongside the planning for particle accelerators and their transformation as a new tool for exploring particle physics in an unprecedented energy range, the postwar period also brought together many of the prewar European scientists bent on reconstructing their University laboratories and eager to compare each other's ideas about past and present new directions.

The UK was the natural place for such reconstruction to start. English Universities were now seeing many of their scientists coming back from the United States where they had participated to the Manhattan project and the associated Anglo-Canadian Project in Montreal and Chalk River. Among the scientist returning to the UK from the US or from Canada, and of direct interest for Touschek's story, we note Rudolph Peierls, and Hans von Halban. Peierls, who would be Touschek's external PhD examiner in Glasgow, came back from Los Alamos, where he had played a major role in the development of the atomic bomb, and joined the University of Birmingham (Lee 2007).⁶ Von Halban, returning from Canada, was to become the first director of the Laboratoire de l'Accélérateur Linéaire in Orsay (LAL) and oversaw the construction of the linear accelerator which contributed to AdA's success story (Marin 2009, Pancheri and Bonolis 2018).⁷

There were also visitors from continental Europe, in particular from Italy, where the process of reconstruction of scientific institutions was taking place. In Italy, because of Mussolini's 1938 anti-semitic laws, many of the best scientists had moved to the United States, as it had been the case of Enrico Fermi (Bernardini and Bonolis 2004, Pontecorvo 1993), Bruno Rossi (Bonolis 2011), Emilio Segrè (Segrè 1993), Bruno Pontecorvo (Close 2015), and many others. But some of Fermi's students or young collaborators had remained, notably Edoardo Amaldi (Rubbia 1991).⁸ Soon after the war, Italian physicists, in particular from Milan and Rome, in contact with Fermi and Rossi, both in the US, and following their advice, were ready to take up new roads in particle physics. They were restarting from cosmic rays, which in those days, did not need large or costly equipments and could thus be undertaken by many countries, such as Italy, Germany – where other forms of “nuclear” research were initially forbidden – or India, under the leadership of Homi J. Bhabha, who had founded in 1945 the Tata Institute of Fundamental Research, which became a major center of cosmic ray studies (Sreekantan 1998).

In Italy, the great tradition of exploring matter through the particles coming from

⁶An extensive description of Peierls role in the development of the atomic bomb can be found in (Close 2019).

⁷In 1939, at Collège de France in Paris, Hans von Halban had collaborated with Frédéric Joliot and Lew Kowarski in the discovery that several neutrons were emitted in the fission of uranium-235 (von Halban et al. 1939a;b) – a discovery leading to the possibility of a self-sustaining chain reaction. In 1941 von Halban fled to England to subtract the laboratory heavy water equipment from the approaching Germans. He settled in Oxford and then moved to Canada to join the Manhattan project related effort. Back to Oxford, he returned to France in 1954 to become the first director of LAL.

⁸In 1938, Fermi was awarded the Nobel Prize in Physics “for his demonstrations of the existence of new radioactive elements produced by neutron irradiation, and for his related discovery of nuclear reactions brought about by slow neutrons.” Fermi's group in Rome included Franco Rasetti, Edoardo Amaldi, Ettore Majorana, Bruno Pontecorvo, and Emilio Segrè, who was awarded the 1959 Nobel prize in Physics for the discovery of the anti-proton.

the sky, the cosmic rays, had continued to be fostered even under the bombing of Rome and despite of the political divisions between South and North, which took place after the 1943 armistice between the Italian Government and the Allies. Now, after the war, an alternative way for exploring nature's atomic scale was available through particle accelerators. As envisioned already before the war in the major European physics laboratories, in particular by both Frédéric Joliot and Fermi, this new road, which required much larger equipments and investments, had been shown to be scientifically viable and could be favoured by postwar reconstruction.

In 1946, a pivotal moment in the scientific reconstruction of Europe had been the international conference on *Fundamental Particles and Low Temperatures*, held from 22 to 27 July 1946 at the Cavendish Laboratory in Cambridge (The Physical Society and Cavendish Laboratory 1947). As recalled by Amaldi, (Amaldi 1979a, 62), “Contacts between physicists in different parts of the world had been impossible for years and this conference provided a welcome opportunity to renew old friendships, and to hear what others had been doing.” Many European states, but not Germany for obvious reasons, as well as other countries like the US, USSR, China and India were represented at the Conference. All of them presented their latest work on cosmic ray physics. Large attention was also given to the theoretical physics side, in particular the last session was entirely devoted to the S-matrix theory proposed by Werner Heisenberg during the war (Heisenberg 1943a;b; 1944). Focusing on observables such as cross-sections or energy levels, Heisenberg's S-matrix theory aimed on building a theory to calculate only observables, such as scattering cross-sections and energy levels. Heisenberg, although released from enforced stay at Farm Hall (Cassidy 2017), was not present as his travels were still restricted, but talks on the subject were presented by Walter Heitler, Christian Møeller, and Carl G. Stueckelberg (Mersits 1987).

Besides the opportunity of scientific exchanges after the forced isolation that many scientists had experienced during the war, the Cambridge conference was also an important occasion to renew the strong pre-war relationships, in particular between physicists from University of Rome, such as Edoardo Amaldi and Gilberto Bernardini,⁹ and Patrick Blackett, then at the University of Manchester, promoting with his group a broadly based cosmic-ray program (Butler 1999, Lovell 1975).¹⁰

Among the speakers at the Cambridge conference of special interest to Touschek's story, there was Bruno Ferretti, a young theoretician in Amaldi's group, who had given a talk on the absorption of slow mesons by atomic nuclei. He was analyzing the problem of nuclear capture (Ferretti 1947), at stake in cosmic-ray experiments being performed in Rome by Marcello Conversi, Ettore Pancini and Oreste Piccioni, which would soon attract attention on both sides of the Atlantic Ocean.

In Rome, cosmic ray research had been initiated in the late 1930's under the leadership of Gilberto Bernardini and had been kept alive through the war with excellent results, continuing a research tradition which would flourish again in the wider framework of reconstruction. In 1937, Bruno Ferretti, born and educated in Bologna, had joined Fermi's group in Rome. Following Fermi's departure for the US in December 1938, he had been appointed to teach his course in Theoretical Physics for the rest of the academic year.

⁹An affectionate and humorous [reminiscence of Gilberto Bernardini](#) by Leon Lederman can be found in (Ledermann 2009). See also [Remembering Gilberto Bernardini](#) in (Ricci 1995).

¹⁰[Patrick Blackett](#) was awarded the Nobel Prize in Physics in 1948 for his discoveries in cosmic rays research.

From 1940, Gian Carlo Wick, who had been closely associated with Fermi, moved on his chair from Padua (Jacob 1999). After the war, when Wick as well emigrated to the US (Jacob 1999), Ferretti remained for a while the only senior theoretician, following in detail nuclear physics and cosmic ray developments and was himself appointed to the chair of theoretical physics in 1947.

During the Cambridge conference, Amaldi saw the opportunity to renew the pre-war exchanges between Italy and the UK, and was able to secure a British Council fellowship for Ferretti to spend ten months at Manchester in 1946, where Ferretti's theoretical experience in the design and analysis of cosmic ray experiments made him more than welcome. Ferretti was thus in Manchester at the time of major cosmic ray discoveries from UK laboratories, and was invited to teach a course on cosmic radiation at University of Birmingham (Amaldi 1979b, 441). There, he established close contacts with Rudolph Peierls, future external examiner of Touschek's PhD. In 1947, Ferretti and Peierls wrote together an article on the quantum theory of radiation damping applied to the problem of propagation of light (Ferretti and Peierls 1947), related to well known divergences in quantum electrodynamics, a highly debated question at the time and a life-long interest of Touschek's. This common interest and shared acquaintances would be instrumental in Touschek's move to Rome in December 1952, as we shall discuss in Sec. 4.3.

2.3 Post war revolutions in particle physics

The Cambridge conference was a major event which re-established collaborations and communication between the UK and the rest of Europe, but in a few months, the new year 1947 would open up completely new perspectives for elementary particle physics.

Based on Yukawa's meson theory, and related theoretical suggestions, slow positive Yukawa mesons, i.e. positive mesotrons of cosmic rays, traversing matter should strongly prefer to decay rather than be absorbed by a nucleus, because of Coulomb repulsion by protons. Negative Yukawa mesons, on the other hand, should strongly prefer absorption to decay. These predictions were blown to bits by a crucial experiment carried out in Rome during the war by Marcello Conversi, Ettore Pancini and Oreste Piccioni. In four consecutive steps they had directly investigated "the fate of mesons coming to rest in matter" (Conversi 1988, p. 11), disclosing that positive cosmic ray mesons behaved as predicted, but a substantial fraction of negative sea-level cosmic ray mesotrons decayed in a carbon plate (Conversi and Piccioni 1944b;a, Conversi et al. 1945, Conversi and Piccioni 1946, Conversi et al. 1947). In Fig. 4 we show a snapshot of Marcello Conversi and Oreste Piccioni, in Rome around the time of the first experiment, and a later (1947) photograph of Ettore Pancini, with Amaldi and G. Bernardini, in the cosmic ray high altitude Testa Grigia Laboratory, near Monte Rosa, in 1947. See (Piccioni 1988) and (Conversi 1988) for a detailed overview of the main steps related to the accomplishment of the four consecutive experiments.¹¹

¹¹As recalled by Piccioni and Conversi, the first experiment was prepared at the Physics Institute in the Rome University campus, the *Città Universitaria*, close to Termini Rail road station. However, on July 19, 1943, Rome was bombed for the first time by the American Air Force and nearly 80 bombs fell within the perimeter of the University campus, which was located near to the main station, an area especially subject to raids. It was thus decided to transport the experiment to a semi-underground class room of the high school Liceo Virgilio, transforming the class into a laboratory. The liceo was located in Via Giulia, near the river Tiber, not far from the Vatican City, and hopefully less in danger of being targeted by American bombs. Work was however interrupted by the Italian armistice (September 8, 1943) and, following it, by



Figure 4: From left: Marcello Conversi and Oreste Piccioni in 1943, Edoardo Amaldi, Gilberto Bernardini and Ettore Pancini in 1947 at the Testa Grigia cosmic ray Observatory, in the Italian Alps, at the southeast limit of the Plateau Rosà glacier. Photographs from “Edoardo Amaldi Archives”, Physics Department, Sapienza University of Rome.

As stressed by Luis W. Alvarez in his Nobel lecture: “[...] modern particle physics started in the last days of World War II, when a group of young Italians, Conversi, Pancini and Piccioni, who were hiding from the German occupying forces, initiated a remarkable experiment...”.¹² The surprising results of the “Rome experiment” showed that negative cosmic-ray mesotrons were almost completely unreactive in a nuclear sense, and provided the first demonstration that this particle was not behaving as it should, if it were the meson predicted by Yukawa as the mediator of nuclear forces (Conversi et al. 1947). The final result of the experiment appeared on February 1st, 1947, but Fermi, who had been already informed by Amaldi in winter 1946, immediately reacted writing an article with Edward Teller and Victor Weisskopf, in which a startling conclusion was reached (Fermi et al. 1947, p. 315): “If the experimental results are correct *they would necessitate a very drastic change in the form of mesotron interactions* [emphasis added].”¹³

The question was definitively resolved through a cosmic ray experiment performed by Cecil F. Powell’s group in Bristol (Lattes et al. 1947). Improved nuclear emulsions, developed following an idea of the Italian physicist Beppo Occhialini, had enabled Powell’s group to establish the existence of a new elementary particle in cosmic rays, the π -meson, a strongly interacting particle of short lifetime, which was identified as the Yukawa meson, the accepted quantum of nuclear forces. The mesotron of cosmic rays,

the occupation of Rome by the German troops. Resumed under very difficult and dramatic conditions, only late in 1943 Conversi and Piccioni finally started to run the first experiment. While they were planning the third experiment, Rome was liberated by the Allied troops (June 5, 1944) and they moved everything back to the Physics Institute at the University. After the liberation of Northern Italy (April 25, 1945), Conversi and Piccioni were joined by Ettore Pancini, a leader in the Partisan movement of the Italian Resistance against German occupation, with whom they performed the third, and then the fourth, decisive, experiment. In this last experiment they replaced the iron with carbon and were able to provide convincing proof that negative mesotrons stopped in carbon did undergo spontaneous decay whereas they did not when stopped in iron. For a reconstruction of these events see also [Le particelle elementari](#) by A. Ereditato, one of Pancini’s students.

¹²L. W. Alvarez, Recent developments in particle physics, Nobel Lecture, December 11, 1968 http://nobelprize.org/nobel_prizes/physics/laureates/1968/alvarez-lecture.html.

¹³See also Ferretti’s publications analyzing results of the Conversi, Pancini and Piccioni experiment (Ferretti 1947; 1948).

now termed the μ -meson, was recognized to be the product of π -meson decay and was clearly a weakly interacting particle, according to the Rome experiment confirmed by Fermi's interpretation.

Meson interactions were still the focus of discussion at the first Shelter Island conference on the Foundations of Quantum Mechanics, held from June 2–4, 1947 in Shelter Island, near New York. It was the first peace time opportunity for the leaders of the American physics community to meet, exchange new ideas and assess the state of the field, after the Manhattan project (Kaiser 2005). At this time, the May 24 issue of *Nature* with the article by Lattes, Occhialini and Powell had not yet reached the United States, but, not long after, in December of 1947, evidence for the existence of new unstable elementary particles detected in cosmic-ray showers – the so called V-particles because of the characteristic tracks they left in the cloud chamber – was announced by Butler and Rochester, members of Blackett's group in Manchester. (Rochester and Butler 1947). Although it took the particle physics community several years to appreciate the importance of the V-particles, the modern day K-mesons, this discovery, together with that of the π -meson, was signalling the existence of a large number of hitherto unsuspected sub-nuclear particles, which would open the new field of particle physics. In parallel with the results of the Conversi, Pancini and Piccioni experiment, these achievements made 1947 a high point in the history of elementary particles, recognized by the Nobel Prize to Blackett, Yukawa and Powell.¹⁴

With the discovery of the π -meson, the energy threshold of meson production would become the frontier of particle physics. "Meson physics" would rapidly develop, while the body of experimental knowledge in the field grew even more rapidly as new meson-producing accelerators began to swing into action. Soon after, in 1948, Eugene Gardner and Cesare Lattes, would be able to artificially produce pions for the first time by bombarding carbon atoms with a 400-MeV proton beam from the 184-in synchrocyclotron at the University of California Radiation Laboratory. For the first time "nuclear physics" was challenging cosmic-ray physics. In the meantime, major proton synchrotron projects were being set up at Brookhaven National Laboratory (BNL) in Long Island, under M. Stanley Livingston, where a 3.3 GeV machine, the Cosmotron, was planned, and with the Bevatron, at Lawrence Berkeley National Laboratory in Berkeley, specifically designed to be energetic enough to create antiprotons. In the early 1950s, these accelerators would definitely mark a new era for particle physics. From then on, cosmic rays would no more be the only tool available for discovering new particles and probing their high energy

¹⁴Blackett was awarded the 1948 Nobel prize in physics for his research on "cosmic rays, using his invention of the counter-controlled cloud chamber." He had actually built this device in the early 1930s in collaboration with Giuseppe Occhialini, who had brought from Florence Bruno Rossi's method of electronic coincidences with which they triggered the expansion of the cloud chamber. Together they were able not only to optimize observation of cosmic rays but were the first to expound the pair formation mechanism, putting the positron – Dirac's hole-theory particle – into theoretical perspective. Since the early 1930s Blackett had very strong ties with the Italian physicists community and in 1938 he had offered Bruno Rossi a position in Manchester, when the latter was forced to leave his chair in Padua because of the 1938 anti-semitic fascist laws (Bonolis 2011). In 1939 Rossi settled in the US helped by Arthur Compton and Hans Bethe. For the discovery of the π -meson and its subsequent decay into a muon and a neutrino, Powell was awarded the 1950 Nobel Prize in Physics "for his development of the photographic method of studying nuclear processes and his discoveries regarding mesons made with this method," while Yukawa had been awarded the 1949 Prize for his theoretical prediction. Occhialini, who had been closely associated with Blackett and Powell in such important discoveries, was awarded jointly with George Uhlenbeck with the prestigious Wolf Prize only in 1982.

regime. Throughout the years to follow, accelerators and the observation of the sky would move together to probe nature at its fundamental level. In the years to follow, a growing interaction between cosmic ray physics, astronomy and astrophysics, cosmology and particle physics would merge the many diverse ways to tackle fundamental questions of the universe under the general field named *astro-particle* physics.

This was the scenario which Bruno Touschek stepped into, as he arrived in Glasgow in April 1947. He had lived in Germany the terrible ‘Hungerwinter’ 1946/1947, noted as the coldest of the 20th century in Europe. The struggle for survival had been extremely painful, and many thousands of people had died because of cold and famine. The winter had severe effects also in the United Kingdom, with fuel and food shortage, and floods caused in March by the thawing snow and heavy rain. Agriculture and breeding were dramatically affected, too, and thousands of British people emigrated, especially to Australia.

At the same time, the initiative of the Marshall Plan, the European Recovery Program, would soon be established by the United States to restart industrial and agricultural production, set up financial stability and expand trade in war-torn Europe.

3 1947-49: Getting a doctorate in Glasgow

Touschek’s time in Glasgow is first presented by Philip Dee in a 1979 letter to Edoardo Amaldi (Amaldi 1981, 9).¹⁵ After Touschek’s early death in 1978, Amaldi had written to all the people who had been friends with Touschek asking for their recollections and memories.¹⁶ The letter describes Bruno’s sparkling intelligence, but also his restlessness and, occasionally, a behaviour outside the accepted norm. On 11th April, 1979, Dee wrote to Amaldi:

Dear Professor Amaldi,

I did not know about Touschek and I am very sad indeed to have your news.

I will write something for you about his life in Glasgow. For quite a while he lived in our house in the University and became in many ways a member of the family [...]

I was quickly impressed by Touschek’s obvious ability, his extensive knowledge of physics, and his enthusiasm and I arranged [...] for him to have a research appointment in the department, which, at that time, had only one staff member on the theoretical side [...]

He was very clever and original, he was also untiringly energetic and extrovert. Bruno led his life to the full extent in all situations and at all times. His

¹⁵One of Glasgow University colleagues, S. Curran, wrote an insightful biography of Philip I. Dee (Curran 1984). Of present note in this biographical sketch are two comments. One, at page 7, about Dee’s publication record, is the fact that machine builders do not have adequate recognition from publication, since during the construction of the machine, their research output in terms of papers is often very poor. This is interesting because the same can be said of Touschek, whose publication output dramatically drops after he started working on AdA. Another interesting comment, in page 5, is that Dee was very kind, and “often he would make ample allowance for illness and the like”. This attitude is confirmed in his communications to Amaldi, after Touschek’s death, as Dee acknowledges Touschek’s original but sometimes unnerving behaviour.

¹⁶The answers he received are kept in Amaldi papers, “Edoardo Amaldi Archives”, Sapienza University of Rome (from now on EAA), Box 205.

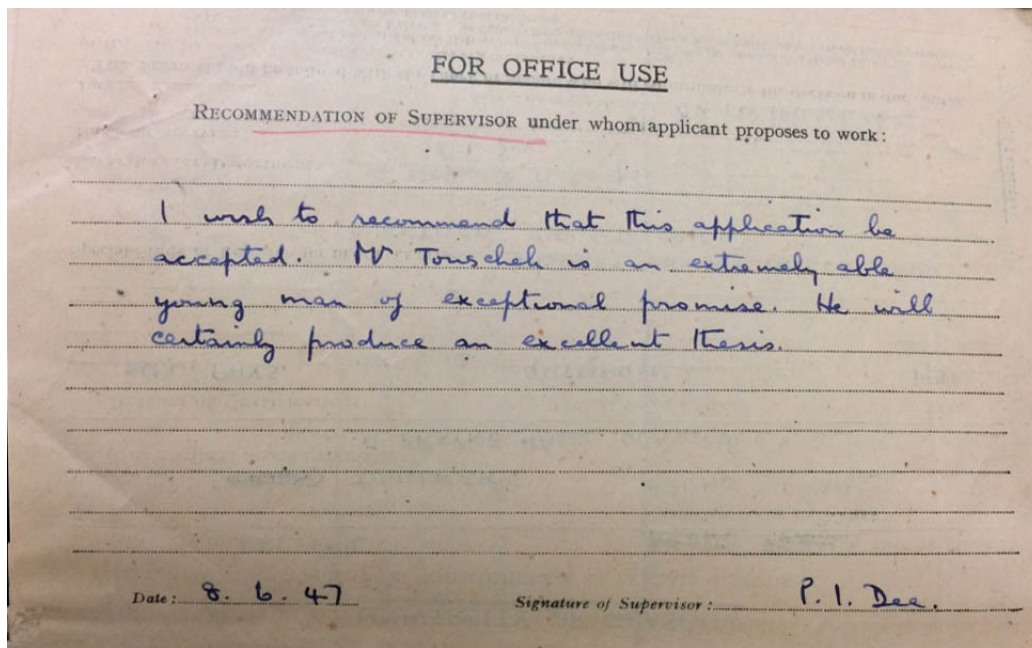


Figure 5: Philip Dee's application to the Senate in favour of a research scholarship for Bruno Touschek. Courtesy of UG's Archives.

enthusiasms were many and, although often brief, were exploited in a manner which most people would have found exhausting.

Dee's high opinion of Bruno is clearly expressed in the application he submitted for a research scholarship for Bruno in June 1947, which is shown in Fig. 5. This probably refers to the renewal of the existing scholarships, since at this time Touschek had already been in Glasgow for two months.

3.1 Arriving in Glasgow accompanied by a guard

When Touschek arrived in Glasgow in April 1947, he was escorted by a guard, as Philip Dee would remember in the letter to Edoardo Amaldi (Amaldi 1981):

My association with Bruno Touschek began in April 1947 when he was brought to my office under guard (!) for an interview. This had been arranged by Dr. Ronald Fraser (a friend of mine) who had met Bruno when serving on a post-war Allied Commission which was visiting laboratories in Germany and elsewhere. Touschek had expressed the wish to work in a British laboratory and Fraser knew that I had recently come to Glasgow to construct a nuclear physics center in the university here.¹⁷

Touschek's duties included teaching, research in theoretical physics, and support to the synchrotron program. He had never lectured in English, and this was a challenge. He started preparing a regular course on selected nuclear physics topics, to be held together

¹⁷Notice that, as we have seen from our previous note, entitled *Bruno Touschek in Germany after the war* and based on Touschek's two letters from Glasgow in April 1946, Dee must have met Touschek already in April 1946 (Bonolis and Pancheri 2019).

with Ian Sneddon, the only other theorist in the department at the time.¹⁸ They outlined the topics, then Sneddon would write down the lectures in “proper english” as Touschek says, and then lectures would be delivered, alternating between the two of them. But his first lecture in English came up as a surprise, as, just on the day before starting his regular course with Sneddon, he was suddenly called to substitute for one of the Professors, who had originally wanted to talk about the synchrotron but had to go to the University Court. Dee asked him to please jump in and Bruno had to rapidly put together a lecture on angular valencies.¹⁹ This was a subject he had studied in depth when in Göttingen, and there would be no problem in preparing the lecture. The well received delivery in English was a confirmation that he could now confidently start teaching his regular course. Years later, in Rome, Touschek became famous for his impeccably clear lectures in Italian, his ability to derive the results as if he had obtained them in that instant, conquering heart and minds of the best students of an already exceptional graduating class.²⁰

Shortly after giving his first lectures, Bruno was also immersed in the vibrant scientific atmosphere which characterised the early British post-war period, with frequent visits from scientists from abroad and a general atmosphere of novel expectations and discoveries, both from an experimental and a theoretical point of view. Bruno and Sneddon, who was only two years older than Bruno and had joined the department just a few months before in 1946, soon became friends and collaborators. They started writing a paper together on meson theory, and, in early May, Sneddon took Bruno to Edinburgh to meet Max Born, the great German born theoretical scientist, one of the fathers of Quantum Mechanics, who had left Germany after Hitler came to power.²¹

Leaving in the early morning from Glasgow, Touschek and Sneddon reached Edinburgh after 1 and 1/2 hour train ride. The train crosses the country side from West to East, until the approaching North Sea signals its presence with a change in the clouds and increasing light in the sky. They had time to be tourists before joining the Colloquium. In Edinburgh Bruno discovered a beautiful city, in stark contrast with Glasgow which in the late 40's was a rather gloomy place.²² He thought Edinburgh most interesting and was en-

¹⁸I. N. Sneddon (1919-2000) was born in Glasgow and became a noted mathematician. After studies in Glasgow and Cambridge, after the war he held a research position in Bristol University, where he worked with N. F. Mott, and authored with him his first book, *Wave Mechanics and its Applications* - which was published in 1948. He returned to Glasgow as a lecturer in physics 1946, or rather natural philosophy as the subject was called in the ancient Scottish Universities at that time. During this period his next major text was the book entitled *Fourier Transforms*, which appeared in 1951, and became such a classic text to be later reissued in 1995. Before the book appeared in print, Sneddon left Glasgow to take up the chair of mathematics at the University College of North Staffordshire (which later became Keele University), and then returned to Glasgow, in 1956 to take up the Simson Chair of Mathematics. Sneddon travelled widely, particularly in North America where he held a number of visiting professorships. From <http://www-history.mcs.st-andrews.ac.uk/Biographies/Sneddon.html>. See also (Chadwick 2002).

¹⁹Letter to parents, April 23rd, 1947.

²⁰See the 2013 interview given by the theoretical physicist Luciano Maiani, 1999-2003 CERN Director General, in the movie *Touschek with AdA in Orsay*. See also (Maiani and Bonolis 2017).

²¹Max Born (1882-1970) had left Germany in 1933 and in 1936 settled in Edinburgh as Tait professor of Applied Mathematics. In 1954 was awarded the Nobel Prize in Physics “for his fundamental research in quantum mechanics, especially for his statistical interpretation of the wavefunction”, sharing it with Walther Bothe “for the coincidence method and his discoveries made therewith”. See also (Kemmer and Schlapp 1971) in *Bibliographical Memoirs of the Fellows of the Royal Society* and a translation of the main part of a Memorial address given by Werner Heisenberg on January 12th, 1971 in Göttingen (Heisenberg 1970).

²²About living conditions in Glasgow, see a recent article in *The Guardian* about the so called ‘Glasgow effect’.

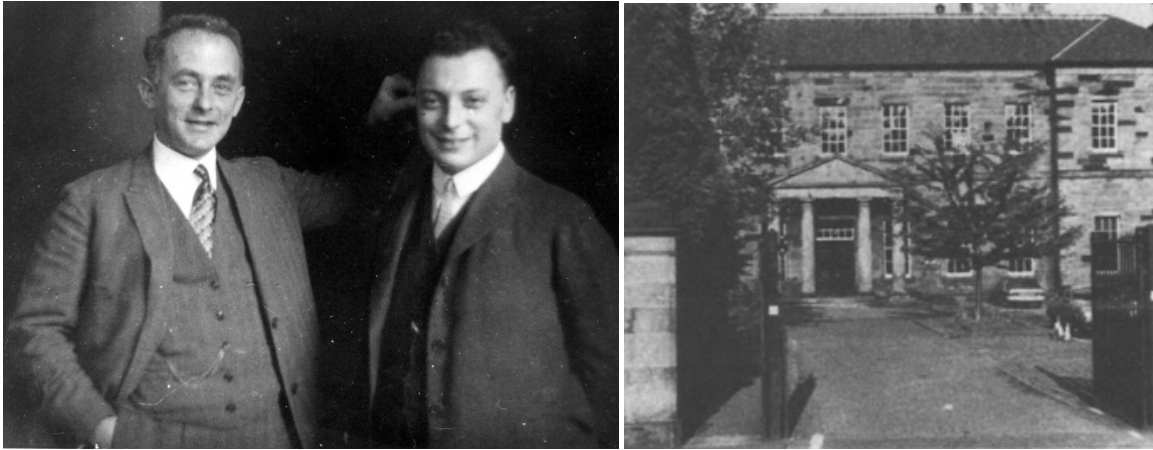


Figure 6: Left panel: Max Born and Wolfgang Pauli (at right), in Hamburg, circa 1925, from CERN archives at <http://cds.cern.ch/record/42702>. This same photograph is also found at <https://calisphere.org/item/ark:/28722/bk0016t4k4m/>, contributed by UC Berkeley, Bancroft Library, has the two scientists mirror inverted. Studying the two photographs, it is likely that the original be the one from UC Berkeley. Right panel: a photograph of the building housing the Applied Mathematics Department in Drummond Street, in Edinburgh, from (Wolf 1995).

chanted with its hilly setting, the medieval streets and old state prisons, or Princes Street, said to be the most beautiful main street in Europe. In the middle of the city, Bruno and Sneddon visited the ancient castle, from which one can see the Firth of Forth and on clear days the sea, and the city Museum, with paintings by Rembrandt and Brueghel. Bruno's artistic disposition had been nourished through pre-war visits to the great European Museums in Rome and Vienna and fostered by a family immersed in the tradition of the Vienna secession movement. After the ravages of the war in Germany, where museums had been bombed, masterpieces hidden or expropriated, walking into a museum was like being reborn. His life was picking up again.

In the afternoon they joined the Colloquium. In Edinburgh Born held a weekly seminar, which he had introduced following the German tradition. In the 1920's in the Institute for theoretical physics at the University of Göttingen, one of prominent weekly events had been the Proseminar, conducted by Max Born and James Franck,²³ in which ideas were debated and young graduate students would present their work. It is remembered that in 1926, at one of these seminars, Werner Heisenberg presented a lecture on the development of Quantum Mechanics, and was enthusiastically applauded by the audience (Amaldi 2012, 14). In Fig. 6, we show a 1925 photograph of Max Born, together with Wolfgang Pauli, who, in later years, became good friend of Touschek. We also show the building housing the Applied Mathematics Department in Drummond Street, in Edinburgh, where Born held the weekly seminar.

Touschek and Born shared many common acquaintances, in particular they both knew Fritz Houtermans, who had graduated in Göttingen with James Frank in the 1920's, when Born was holding the chair of theoretical physics before leaving Germany in 1933. Since these Göttingen times, Houtermans had been imprisoned by the Soviets, divorced and remarried (Amaldi 2012). Fritz Houtermans' witty and adventurous personality was an obvious common argument of conversation. Touschek had been close to Houtermans

²³The Nobel Prize in Physics 1925 was jointly awarded to James Franck and Gustav Ludwig Hertz "for their discovery of the laws governing the impact of an electron upon an atom".

when in Göttingen in the previous year, in 1946, in particular sharing evening gatherings and occasional visits to the Observatory to watch the stars and had been talking with Houtermans on the last day of his stay in Göttingen, while waiting for the car to take him away, just a few weeks before. This last meeting with Houtermans in Göttingen belonged to another world now. Sharing memories and anecdotes about their common friend soon put Tauschek and Born on close grounds. Born, appreciative of Tauschek's brilliant intelligence and profound interest in theoretical physics, invited him to the seminars, which were held every week, on Monday and Thursday. Edinburgh, being some 1 and 1/2 hour away by train, biweekly attendance of the Seminar could be difficult, but Bruno decided he would do his best to participate at least once a week.²⁴ Thus they started an acquaintance which later became a true collaboration, with Tauschek giving a contribution to one of the Appendices of a new edition of Born's classic *Atomic Physics* (Born 1951), whose first English edition had already appeared in 1935.²⁵

In early May, Spring was on its way, and the trees were just starting to sprout, but icy winds would whistle through the fireplaces when not burning. It was difficult to believe that summer was just a few weeks away. But it arrived and, early in June, the annual department excursion to the shore took place.²⁶ Two buses were rented to take the 50 students, the research workers and the lecturers, to the Cobbler, a mountain of 884 metres (2,900 ft) height located near the head of Loch Long, a narrow salt water fjord. The trip went past Loch Lomond, where Bruno had already been during a previous outing. They all climbed to the mountain top, including all the girls and Mrs. Dee. Bruno, although he had never climbed in Austria, was confident in his Alpine genes and reached it first. It took more than four hours to be back down. Afterwards, they all lay on the beach along Loch Long, playing ball and throwing stones in the water. Bruno, hot from the climbing and the descent which followed, jumped in the Loch, unknowing of its true nature, getting a good dose of salty water, to everybody's merriment. He could not remember of having had such light hearted fun in a long time. The landscape was astonishingly beautiful, the mood like that of children on some illegal outing, since the trip was not a holiday, but a department yearly date. Bruno could finally appreciate the famed carefree English humour.

In the meantime, Tauschek was working hard on topics which would later become the subject of his PhD dissertation. He had also written an article related to the problem of infinities in quantum field theories in which he was commenting on a work by Walter Heitler's assistant, Huanwu Peng (Tauschek 1948b).²⁷ During the war, a radiation damping theory had been proposed by Heitler and Peng, which gave a procedure to calculate scattering amplitudes and extract empirical predictions. The theory could also be used to calculate the nucleon-meson scattering cross sections, or purely electrodynamic scattering processes. Heitler had presented his damping theory at the 1946 Cambridge conference on fundamental particles (Heitler 1947).²⁸ However, Heitler's program was now being

²⁴Letter to parents, May 3rd, 1947.

²⁵The eighth edition of Born's book was published in 1969, one year before he passed away in Göttingen, on January 5th, 1970. The eighth edition, including revisions by R. J. Blin-Stoyle & J. M. Radcliffe, is available from Dover Publications in paper cover, ISBN 0-486-65984-4.

²⁶Letter to parents, June 7th, 1947.

²⁷Peng had worked since 1938 with Max Born at University of Edinburgh, then recommended by the latter went to Dublin Institute for Advanced Studies as a post doc from 1941 to 1943, and later an assistant professor until 1947, when he returned to China.

²⁸Heitler, who had left Göttingen for the University of Bristol in 1933, had remained there until 1941,

abandoned after renormalized QED was developed in fundamental papers by Tomonaga, Schwinger, Feynman and Dyson (Schweber 1994).²⁹ Tauschek began also to analyze the use of electrons as particles to produce interactions at a nuclear and subnuclear level (Tauschek 1947) (Sneddon and Tauschek 1948a) and, at the same time, worked on theoretical issues related to the nuclear structure (Sneddon and Tauschek 1948c) (Sneddon and Tauschek 1948b), on the eve of the formulation of the nuclear shell model theory.³⁰

In August, he developed an idea for the new synchrotron building and started discussing it with colleagues in the synchrotron group. There were trips to Manchester and Edinburgh, and he was busy moving from the University Halls to private lodgings.³¹ Not all was work, however. He was also frequently bathing in the Loch Lomond and other nearby places, such as Gerloch, the Clyde and even in the Atlantic, getting tanned as he had never been before.³² In Fig. 7 we indicate some of the location Tauschek visited in 1947. Born in a country with no access to the sea, swimming became a long life passion for Tauschek. When, in later years, he would be working in Frascati on the electron positron colliding beam accelerators he proposed and had built, his frequent trips to nearby Lake of Castel Gandolfo were memorable. His maternal aunt Ada had a villa nearby, and bathing and fishing in the lake would be a favourite pastime. He would just leave the laboratories in the early afternoon and escape to Albano. He also loved the sea. After Aunt Ada passed away in 1960, he started spending some time on the south of Rome, in Sperlonga (Amaldi 1981), or on the Amalfi coast (Pancheri 2004), swimming in the crystal clear waters of Positano, which was chosen for family holidays in September, when the vacation crowd has left, the Mediterranean sea is calm, and the water still warm.

The first summer in Glasgow being over, he dutifully kept up the correspondence with his family in Vienna, where life was still difficult, worrying about their well being, proud to help his parents with his earnings, sending both money as well as packages. Then a crack appeared in this otherwise almost idyllic picture. Because of administrative requests, some problems had arisen with the DSIR about his contract after the first six months in Glasgow.³³ As the renewal of his fellowship ran into some delay, he started wishing he could leave the UK.³⁴ He was very annoyed, as he would often be throughout

when he became a professor at the Dublin Institute for Advanced Studies, established by Erwin Schrödinger, Director of the School for Theoretical Physics. In 1946 Heitler became Director of the School for Theoretical Physics after Schrödinger resigned.

²⁹The Nobel Prize in Physics 1965 was awarded jointly to Sin-Itiro Tomonaga, Julian Schwinger and Richard P. Feynman “for their fundamental work in quantum electrodynamics, with deep-ploughing consequences for the physics of elementary particles.” from <https://www.nobelprize.org/prizes/physics/1965/summary/>.

³⁰The nuclear shell model was formulated by Maria Goeppert Mayer and, independently, by Hans Jensen, Otto Haxel and Hans Suess, Tauschek’s good friends since Hamburg and Göttingen times. Goeppert’s first article summarizing the evidence for a shell model of the nucleus appeared in August 1948 (Goeppert Mayer 1948). Her second decisive paper (Goeppert Mayer 1949) was published together with the one by Jensen and colleagues, in June 1949 (Haxel et al. 1949). Goeppert Mayer and Jensen shared the 1963 Nobel Prize in Physics, jointly with Eugene Wigner for unrelated work.

³¹In September his address was c/o Fisher, 16 South Park Ave, Glasgow W2. Letter to parents September 2nd, 1947.

³²Letter to parents, September 2nd, 1947.

³³A copy of his birth certificate, attesting to his Austrian citizenship, was required to renew his contract. The problem was soon solved, though, and the birth certificate received by the DSIR on September 1st, 1947.

³⁴Letter to parents, October 11th, 1947. The letter ends with two verses, paraphrasing a popular song, Sowieso: “Egal was kommt, es wird gut, sowieso/Immer geht ’ne neue Tür auf, irgendwo/Auch wenn’s



Figure 7: A view of places where Touschek moved in 1947: at left for the excursion to the Cobbler, with Loch Lomond in the center, Glasgow -not shown- just outside the lower right hand corner. At right a larger view from Scotland to Manchester, down in the middle of England.

his life when similar impediments forced him to interrupt his work and studies. His expectations had been forever forged by the war experience, first on the betatron project under German military control, and then in Göttingen, under the Allied Forces administration, when civil regulations would be easily overruled by the military. Later in his life, he never understood, nor accepted, the slow methodical process which regulates ordinary dealings of University life.³⁵

All through this first year, Bruno worked hard with the newly established synchrotron group in Glasgow, which included Samuel Curran, Walter Mc Farlane, A. C. Robb and Philip Dee. As one can see from (Curran et al. 1948), where Touschek's collaboration is acknowledged, he worked with Samuel Curran on a problem related to measurements and results obtained with the proportional counter, a new device Curran was developing with his student John Angus (Close 2015, 113-115).³⁶ This work with Cur-

grad nicht so läuft, wie gewohnt/Egal, es wird gut, sowieso [No matter what, it's going to be fine, anyway, a new door always opens, even if it's not going as usual, it's going to be fine, anyway.]” <https://lyricstranslate.com/en/mark-forster-sowieso-lyrics.html>. The letter implies that happiness may be elsewhere.

³⁵See the difficulties he had with applying for professorship in Rome in 1974 as described in (Amaldi 1981).

³⁶Before the war, Samuel Curran (1912-1998) had been at the Cavendish Laboratories with Rutherford in Cambridge. In late 1940, he joined Philip Dee, Bernard Lovell, Alan Hodgkin and others at Worth Matravers, in Dorset. A recollection of this period by Bernard Lovell can be found in the 28th October 1982 issue of the *The New Scientist*, pag. 246. After the invention of the cavity magnetron, Curran's development of spark gap modulators was critical to the success of the magnetron transmitters. In 1944 he went to the United States with a number of other UK other scientists to work on the Manhattan Project, and in 1946 he went to Glasgow University to join Philip Dee. He assisted Dee and McFarlane in the installation of the 300 MeV Glasgow Synchrotron, which became operational in 1954. Later, as Principal and vice chancellor of the University of Strathclyde, he took the lead in developing Britain's first technological university, as from http://www.purbeckradar.org.uk/biography/curran_sam.htm and <https://www.worldchanging.glasgow.ac.uk/article/?id=39>. See also (Fletcher 1999).

ran is also described in the December 1947 research report Touschek submitted to the University.³⁷

The Glasgow group started preparing plans for the synchrotron and meetings were held with other UK groups working on synchrotrons.³⁸ The list of attendees of the 8th Meeting of the Glasgow synchrotron group held on November 4th, 1947 in Manchester, at Trafford Park, on the grounds of the Metropolitan-Vickers company, shows that all the major actors in electron synchrotron preparations in the UK were present, among them Frank Goward, who had succeeded in building the world first electron synchrotron, just over one year before. A copy of the list of participants is shown in Fig. 8.

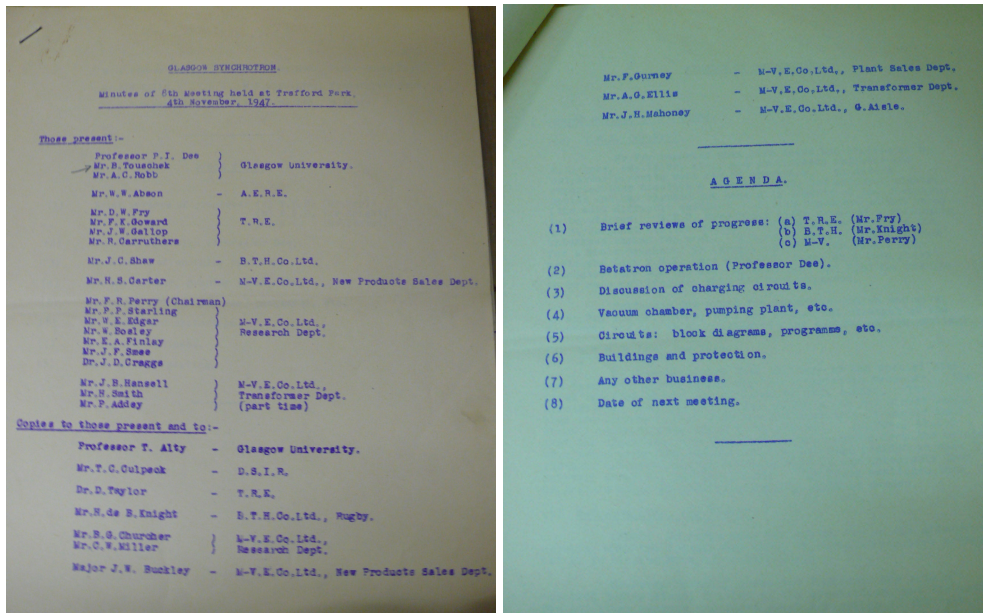


Figure 8: List of attendees and agenda of the 8th meeting of the Glasgow Synchrotron, held in Manchester, at the Metropolitan-Vickers factory in Trafford Park (Bruno Touschek papers, “Edoardo Amaldi Archives”, Physics Department, Sapienza University of Rome, Box 3, Folder 5). The agenda for a previous meeting held on September 7th is also available at same location.

In December Rudolf Kollath and Gerhard Schumann, with whom he had collaborated at the 15 MeV-betatron designed by Widerøe and built in Hamburg, published a review article on the work done during the war and in the early post-war period at Kellinghusen. It included all the important information and many details, making Bruno Touschek’s contribution to the project officially known (Kollath and Schumann 1947).³⁹

As an expert in the field, Touschek continued to be involved with betatrons, as a consultant for the 20 MeV machine operating at the High Voltage Laboratory of the Metropolitan-Vickers at Manchester.⁴⁰ However, his knowledge on accelerators was

³⁷BTA Research Reports (Glasgow), Dic. 1947-Apr. 1948, Box 3, Folder 1.

³⁸He writes about his work on the 300 MeV synchrotron in the October 11th, 1947 letter to his parents.

³⁹Touschek sent his parents a copy of the issue of the Journal of Applied Physics containing the article (letter to parents, October 11th, 1947).

⁴⁰See letter by John D. Craggs of January 27th, 1948: “You may remember that we had a short discussion on the peculiar spectrum we had found for our 20 MeV betatron [...] you may have been able to do some thinking about the problem. We should be most grateful for any light you can throw on the problem.” Bruno Touschek papers, “Edoardo Amaldi Archives”, Physics Department, Sapienza University of Rome (from now on BTA), Box 1, Folder 1. After graduating from King’s College London in 1938, Craggs had

quickly evolving. From his research report on work carried out during the months December 1947–January 1948,⁴¹ we learn that he was preparing a lecture “on the family tree of accelerators (Cyclotron, Betatron, Synchrotron, Synchro-Cyclotron)” as well as a related paper on the synchrotron for the newly founded *Acta Physica Austriaca*, published by the Austrian Academy of Science, of which Hans Thirring was co-director at the time (Touschek 1949).⁴²

Back in Europe, among his mentors and friends, there was appreciation for his achievements, as it appears from a postcard, sent by Arnold Sommerfeld to Paul Urban, on November 2nd: “Touschek has had great success, in Göttingen he passed all his exams one after the other, is now sought after by Hamburg and Hannover and is presently in England [sic!], well paid by the British”.⁴³

3.2 Bruno Touschek and Werner Heisenberg

All along during the doctorate years, Touschek’s published theoretical physics output is remarkable. In what follows, we shall highlight contacts and, so far unpublished, correspondence with Werner Heisenberg, which shed light on his formation as a theoretical physicist. Such scientific correspondence was a natural continuation of the relationship established before Touschek’s arrival in Glasgow, during his stay in Göttingen, while getting his Diploma and afterwards, when he was, for some time, one of Heisenberg’s assistants at the Kaiser Wilhelm Institute (KWI) for Physics.

Touschek had seen Heisenberg for the first time in 1939, giving a public lecture in Vienna, when Heisenberg was already one of the most prominent and influential German physicists. During the war Heisenberg had become director of the Kaiser Wilhelm Institute for Physics in Berlin-Dahlem, leading the German nuclear project and it is in Berlin that Touschek met him for the second time: “[...] hatless hurrying to the KWI & I asked him the way because I wanted to visit him & had not recognised him. He brought me to his office [...]” After the war, in Göttingen, Touschek attended his lectures on quantum field theory, and later commented on them, in the same undated manuscript: “It was not a good course of lectures, but there was one among them, which for me was a complete eye-opener: the harmonic oscillator & its quantization. I had learned Q.T. [Quantum Mechanics] from Sommerfeld’s “wellenmechanisches Ergänzungsband” & I had tried Dirac’s famous book both of which lean heavily on wave mechanics. H.’s lecture opened my understanding to the mechanical approach.”⁴⁴

Among Touschek’s unrecorded work there are his studies of the analyticity properties of Heisenberg’s S-matrix.⁴⁵ Touschek was bent on understanding Heisenberg’s proposed theoretical approach to particle dynamics (Heisenberg 1943b). Heisenberg’s seminal work, *Die ‘beobachtbaren Größen’ in der Theorie der Elementarteilchenphysik*,

joined the staff in the High Voltage Research Laboratories of Metropolitan Vickers Ltd., where – except for a period in Berkeley, California, in 1944-45 – he stayed until moving to Liverpool University in 1946 as a lecturer in Electrical Engineering. His work in Manchester on the neutron generator resulted in the building of the first full-size Van de Graaff in UK (News from the Archive of the University of Liverpool, <http://sca-arch.liv.ac.uk/ead/search?operation=full&recid=gb141unistaffc-d-d835>).

⁴¹BTA, Research Reports (Glasgow), Dic. 1947-Apr. 1948, Box 3, Folder 1.

⁴²See also manuscript “Zur Theorie des Synchrotrons”, BTA, Box 3, Folder 6.

⁴³EAA, Box 205.

⁴⁴Quotations are from manuscript document, courtesy of Mrs. Elspeth Yonge Touschek.

⁴⁵Correspondence with Heisenberg cited here is partly kept in BTA, partly in Touschek’s personal paper, courtesy Mrs. Elspeth Yonge Touschek.

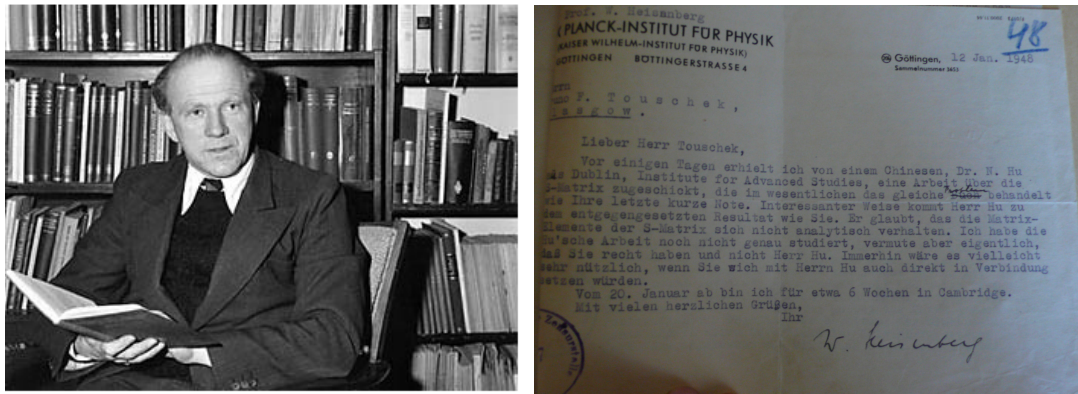


Figure 9: At left, a 1947 photograph of Werner Heisenberg from AP Archives, in Florian Hildebrand's article in https://www.deutschlandfunkkultur.de/heisenbergs-traum.984.de.html?dram:article_id=153450. At right, the January 12th, 1948 Heisenberg's letter to Tauschek, also announcing his forthcoming visit to the UK, from Tauschek's personal papers, courtesy of Mrs. Elspeth Yonge Tauschek.

namely *The 'observable quantities' in the theory of elementary particle physics*, was focused on dealing with observable quantities, rather than order by order perturbation theory calculations, plagued by divergences at a given fixed order.⁴⁶ This work had a profound influence on Tauschek and is echoed in his later work about infra-red Radiative corrections to electron-positron experiments, where Tauschek reflected about the incompatibility between “the picture of an experiment [as] drawn by theory and reality” (Etim et al. 1967).

The analyticity properties of the S-matrix were a strongly debated topic in the theoretical physics community and Tauschek had discussed the argument with Heisenberg when he was still in Göttingen and then again after joining Glasgow. In particular, since fall of 1947, Tauschek exchanged letters with Werner Heisenberg focused on the S-matrix and other theoretical issues which he was studying at the moment.⁴⁷ A contemporary photograph of Werner Heisenberg is shown in Fig. 9 and the January 12th, 1948 letter he wrote to Tauschek from Göttingen.

In January 1948, Heisenberg involved Tauschek in a discussion about a work on the S-matrix, which he had just received from Ning Hu, one of Walter Heitler's collaborators in Dublin, but at the moment in Niels Bohr's Institute in Copenhagen.⁴⁸ Heisenberg wanted Tauschek to look into Ning Hu's work because he thought it to be in some contradiction with Tauschek's unpublished notes.⁴⁹ In asking him to check Hu's calculations, Heisenberg suggested him to directly contact Hu. In the same letter, he also announced

⁴⁶See (Rechenberg 1989) for a historical view of the S-matrix development from 1942 to 1952.

⁴⁷See letters dated October 6th (Tauschek to Heisenberg), October 10th, 1947 (Tauschek to Heisenberg), BTA, Box 1, Folder 1.

⁴⁸After graduation from Tsinghua University in Beijing, Ning Hu had moved to the United States. He had obtained his PhD from Caltech and during 1944-1945 had studied quantum field theory under Wolfgang Pauli at the Institute for Advanced Study in Princeton. During his stay in Europe from 1946 to 1949 he visited Walter Heitler in Dublin and Niels Bohr in Copenhagen. In 1980 he went back to China, and was a long-time professor in the department of physics at Peking University.

⁴⁹The January 12th, 1948 Heisenberg's letter to Tauschek, also announcing his forthcoming visit to the UK, is in Tauschek's personal papers, courtesy of Mrs. Elspeth Yonge Tauschek.

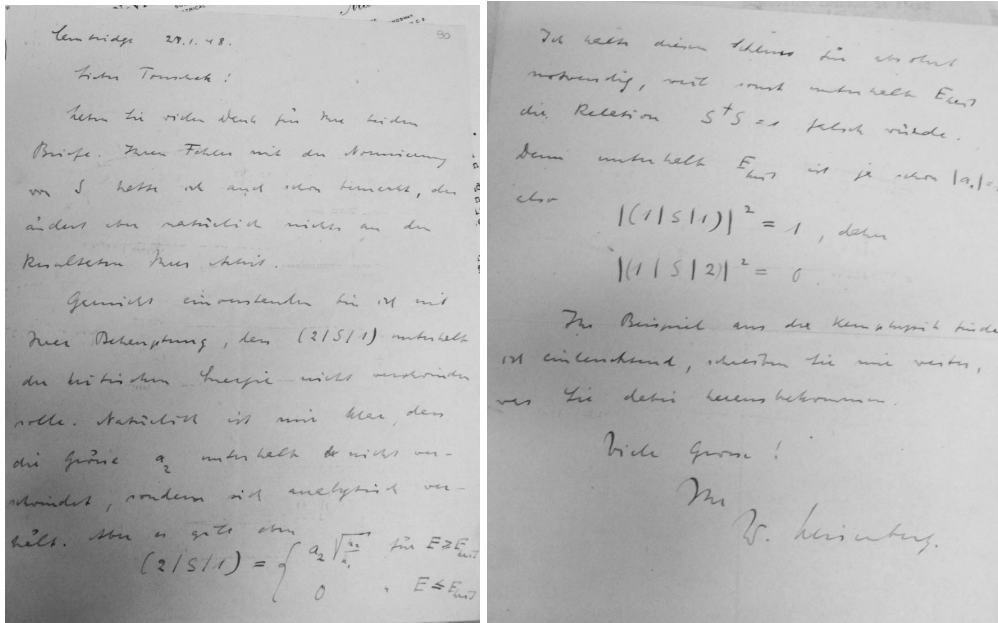


Figure 10: Werner Heisenberg’s January 28th, 1948 letter to Bruno Touschek, from “Edoardo Amaldi Archives”, Physics Department, Sapienza University of Rome.

that he would be in Cambridge for six weeks, starting on January 26th.⁵⁰

The correspondence continued through January, with Heisenberg writing from Cambridge on January 28th, 1948, with the letter shown in Fig. 10, discussing further points about the S-matrix. Other letters followed.⁵¹

The exchanges on the S-matrix properties between Touschek and Heisenberg appear in the research report Touschek submitted to the University of Glasgow, for the periods December 1947 & January 1948, shown in the left panel of Fig. 11. In the report, one of the mentioned items is a ‘triangular discussion’ between Heisenberg, Hu and Touschek, reflecting a correspondence with Hu, mostly lost. A second report was submitted on May 2nd for the period February 1st to April 30th 1948, and is reproduced in the right panel of Fig. 11. From this, we learn that Touschek met Heisenberg in Manchester about the matter.⁵² In the meantime, on April 15, Hu’s article “On the Application of Heisenberg’s

⁵⁰During Heisenberg’s visit to Cambridge, Peierls extended an invitation to Heisenberg to come to Birmingham, letter [445] in (Lee 2009), and discuss the matter of German scientist responsibility and different attitudes towards the Nazi regime. To this Heisenberg replied in letter [447] in (Lee 2009): “Dear Peierls! Thank you very much for your letter. I like to come to Birmingham and I can talk at your seminar about the little thing I think I know about the theory of elementary particles. I also thank you very much for being open to your opinion about a difficult political problem. It is as you suspect: I do not agree with you. But the fact that you wrote to me so openly gives me hope that in a conversation, if not an approximation of the viewpoints so as to understand the other viewpoint, can come. As to the timing: From 10th to 12th I am at Blackett’s [in Manchester] in March; I could come to B[irmingham] on the 12th and stay until the evening of 13. Possibly also March 8 and 9, if from the planned visit to Oxford would come to nothing. Would that be ok for you? Goodbye”.

⁵¹On January 26 and 27 (Touschek to Heisenberg), on January 28 (Heisenberg to Touschek, from Cambridge, UK), on January 31 (Touschek to Heisenberg) on February 29 (Heisenberg to Touschek), on February 23 (Heisenberg to Touschek from Cambridge, Cavendish Lab), on February 29 (Touschek to Heisenberg), on April 20 (Heisenberg to Touschek), on May 2 (Touschek to Heisenberg), BTA, Box 1, Folder 1.

⁵²Touschek’s research reports submitted to University of Glasgow in 1948 are available in BTA, Box 3,

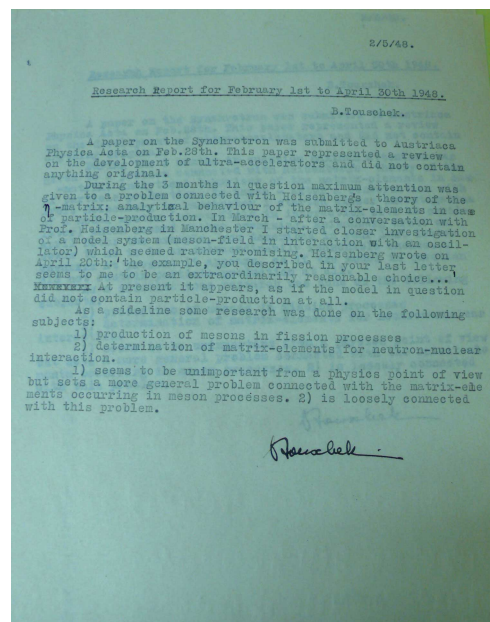
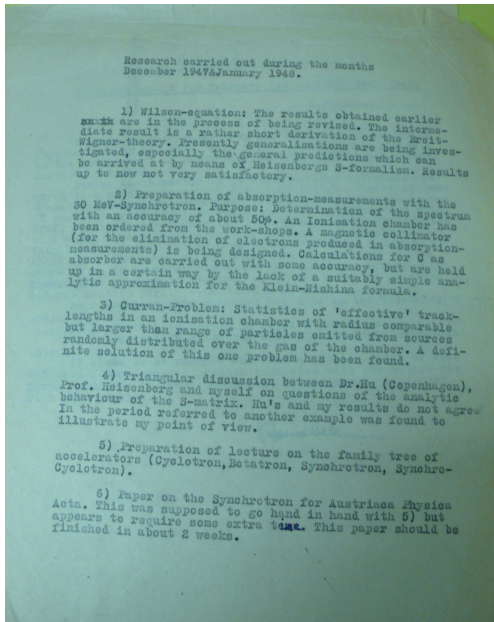


Figure 11: Touschek's research report submitted to University of Glasgow in 1948 (BTA, Box 3, Folder 1).

Theory of S-Matrix to the Problems of Resonance Scattering and Reactions in Nuclear Physics" was submitted to the *Physical Review* and appeared in the July 15 issue of the journal (Hu 1948). On May 25 Touschek thanked Hu for his manuscript, that he was carefully reading, also mentioning previous letters they had exchanged (but which are not present in Touschek's papers in Rome). Finally, on July 27, Touschek wrote to Heisenberg that he had a rather lengthy correspondence with Hu and at the moment he did not think that Hu's work was correct.⁵³ From the available documents, we see that the exchanges on this subject between Touschek and Heisenberg continued through part of the summer 1948. His closeness to Heisenberg is also seen in a sequence of letters between Touschek and a colleague, B.J. Warren, about a position in Vancouver offered to Dr. H. Koppe, a member of Heisenberg's group in Göttingen. However, after July 27th, 1948, no letters are present in Bruno Touschek Archives in Rome up to 1958, when correspondence with Heisenberg started again.

The correspondence is proof of how the young theoretician was trusted by Heisenberg, how much Bruno would be learning from this exchange of ideas, and how much he was deeply involved in strongly debated theoretical questions of his time. The available documents indicate that the exchanges with Heisenberg during the Glasgow period lasted about 2 years. There is no doubt they had a profound influence on Touschek. The direct confrontation with one of the proponents of Quantum Mechanics, a scientist of great intellectual and scientific stature, did influence his formation. He could not avoid feeling proud of Heisenberg's clearly good opinion, and his own self-esteem could now be enforced. He would still make mistakes, as we shall see from his correspondence with Born or with Neville Mott (Pippard 1998), but, encouraged by his exchanges with Heisenberg,

Folder 1.

⁵³BTA, Box 1, Folder 1. Touschek's work remained unpublished, but it is a very interesting result quoted by the noted theoretical physicist R. J. Eden in a Royal Society communication presented by Dirac (Eden 1949).

he had no reasons to doubt anymore his capacity to do physics.

We shall now step back, to see how Bruno's other physics interests and personal life unravelled during 1948, the first complete year he spent in Glasgow.

3.3 1948: Settling in Glasgow

At end of 1947, Bruno was finally able to travel to Vienna and see his parents, probably for the first time after the end of the war. He left London on December 16th, spent Christmas and New Year with them, and was back to Glasgow on January 6th 1948. In between, combining work and family, on his way back from Vienna in early January, Touschek passed through Malvern, to see the synchrotron with Donald Fry.⁵⁴ The trip to London is also mentioned in letter to parents on January 28th, 1948.

The long sought reunion with his parents fortified his spirits and carried him through the harshness of the Glasgow winter and his frequent travels to England or to Edinburgh. His research report for December 1947 and January 1948 describes many different physics projects, about accelerator physics and possible experiments, and, of course, theoretical physics. In addition to giving lectures and working with the Glasgow group on designing and planning the 300 MeV synchrotron, he was involved with the operation of the 30 MeV electron synchrotron in Manchester, and giving support to the group taking measurements with the 20 MeV betatron, as also seen by the intense exchange of letters between Touschek and the colleagues in Manchester, which took place through the first months of the year.⁵⁵ Both Bosley and Cragg from Metropolitan-Vickers in Manchester came up to Glasgow to discuss with him about their results on X-radiation from the 20 MeV betatron.⁵⁶ Touschek's contribution was later acknowledged by the authors as their being "greatly indebted to Mr. B. Touschek" (and F. K. Goward) for "instructive discussions on the work" (Bosley et al. 1948). He also was in correspondence with Goward in Malvern.⁵⁷

But he was keen to continue on with theoretical physics. In January he submitted a paper on the double β -decay to the *Zeitschrift für Physik* for a special issue prepared to celebrate Lenz' 60th birthday (Touschek 1948a).⁵⁸ Touschek had been very close to

⁵⁴An expense note to the DSIR on January 7th, 1948 mentions travelling through to London onto Malvern.

⁵⁵Letter to F.K. Goward January 8th, 1948, and exchanges with Bosley in February, BTA, Box 1, Folder 1.

⁵⁶In Manchester, the Metropolitan-Vickers Electrical Company had participated intensively to the war effort, including having some of its scientists released to work in the United States for the atomic bomb effort. The company was also active in the field of nuclear physics, and a High Voltage (HV) laboratory had been opened in 1930 by Ernest Rutherford, director of Cavendish laboratory at the time, who had been professor in Victoria University in Manchester from 1907 until 1917. At the HV laboratory, cyclotrons had been constructed in 1938, one with Cockcroft for the Cavendish Laboratory, one to be installed at Liverpool for James Chadwick, the discoverer of the neutron. After the war, a research group, finalised to work on accelerators, was started in 1946, and a 20 MeV betatron, the first in the country, was designed and built. A collaboration, also involving the Telecommunication Research Establishment (TRE) in Malvern, was started with Philip Dee in the design of the 300 MeV synchrotron in Glasgow, as described by John Dummelow in the section about *Nuclear Physics* in [Metropolitan-Vickers Electrical Co 1899-1949](#). The British industrial enterprise as a M-V E. also provided diffusion pumps for the Malvern synchrotron.

⁵⁷The extraordinary history of the contribution to science and technology from Malvern is kept alive by the Malvern Radar and Technology History Society (MRATHS), a registered charity No 1183001.

⁵⁸Letter to parents, January 28th, 1948. Already in November 1946, Touschek had announced to his parents, that he had come back from one of his preliminary travels to UK with an article on such topic "in his pocket". However he also told having found an error and that it took him a couple of months

Lenz during the war period, attending his lectures in Hamburg as an unregistered student, and also living with him for a period of time (Amaldi 1981, 4).⁵⁹ His contribution had been asked by Hans Thirring, the former professor of Theoretical physics at University of Vienna until 1938, later reinstated to his position after the war.⁶⁰ Touschek had been in touch with Hans Thirring during the war years, whenever he could go to Vienna. In particular, we note that sometime, late 1942 or early 1943, Bruno had been part of a discussion held with Hans Thirring and Hans Suess about relativistic effects when electrons reach high energies. This discussion is mentioned in a letter to his parents, and was the problem which Touschek had noted in Widerøe's article (about a 15 MeV betatron), which he was reviewing for the *Archiv für Elektrotechnik* (Bonolis and Pancheri 2011, 26).⁶¹ This paper, accepted but never published, started the secret betatron project financed by the Reichsluftfahrtministerium, the Aviation Ministry of the Reich (Bernardini et al. 2015).

Notwithstanding occasional bouts of annoyance, such as we mentioned at the end of 1947, towards a world which, to him, appeared to be moving too slowly, he was not only working on his doctorate, but also enjoying the new environment.

His involvement with the social life of the department is aptly described by Philip Dee in a letter he sent to Touschek's step mother, Rosa Touschek. Busy between lecturing and doing synchrotron work in Glasgow, traveling to Manchester, Malvern and Birmingham, attending Born's Seminar in Edinburgh, meeting and writing to Heisenberg, it is no wonder that Bruno may have neglected to write to his parents as frequently as had been his custom since his young age, when away from home. Thus, one day, on April 7th, 1948, his step mother took the extraordinary step to write to Dee and inquire about Bruno's well being. Dee's answer is reproduced in Fig 12. In this letter, Bruno is described by Dee as "perfectly well and happy", adding how glad he is to have him there, "not only because of his value to the department, but also because his attractive personality makes him a welcome addition to the social activities of our group." This comment by Dee is confirmed by a snapshot taken during a later excursion which we show in the right hand panel of Fig. 12. The group is identified by Touschek in the back of the photo, the young woman in the center of the photograph being Miss Merriç, a graduate student from University of

to set the problem and that it would appear in the *Zeitschrift für Physik*, but further problems must have hindered publication, probably also a normal delay as it happened for all scientific journals at the end of the war. The submission date is marked December 1946, but the article appeared only in early 1948 and was included in the issue dedicated to Lenz. In a later manuscript note, Touschek wrote: "The problem which bothered H. [Heisenberg] & which he asked me to unravel was 'double β -decay'. Haxel felt he could just do it (experimentally) & I ran into the difficulty of distinguishing what was arbitrary & what was sound in Fermi's theory of 'weak interactions.' I saw that clearly in 1947, but what I wrote then was riddled by stupid mistakes, which H. Did not – or did not want to – see" (manuscript, courtesy of Mrs. Elspeth Yonge Touschek). It even appears that this research argument had been already suggested by Paul Urban when Touschek moved from Vienna to Hamburg during the war, as claimed by the former in a letter written much later to Amaldi, who was writing Touschek's biography (Urban to Amaldi, June 3rd, 1980, EAA, Box 205, Folder 4).

⁵⁹Wilhelm Lenz (1888-1957) was Professor of Theoretical Physics at University of Hamburg, since 1921. His major scientific accomplishment is the formulation of the Ising model (Brush 1967). He was a student of Arnold Sommerfeld, and protected Touschek during the war years. Rolf Widerøe mentions to Amaldi after Touschek's death: "Touschek lived in the flat of Professor Lenz in Hamburg [...] and he had considerable difficulty bringing the old and often sick man to the cellar when the bombers came". We notice that Lenz was not that old at the time, being only 55, but may very well have been weak or sick.

⁶⁰After the end of the war, Hans Thirring (1888-1976) became dean of the Philosophical Faculty at University of Vienna in 1946-47, and a member of the Socialist Party of Austria.

⁶¹Letter to parents, February 15th, 1943.

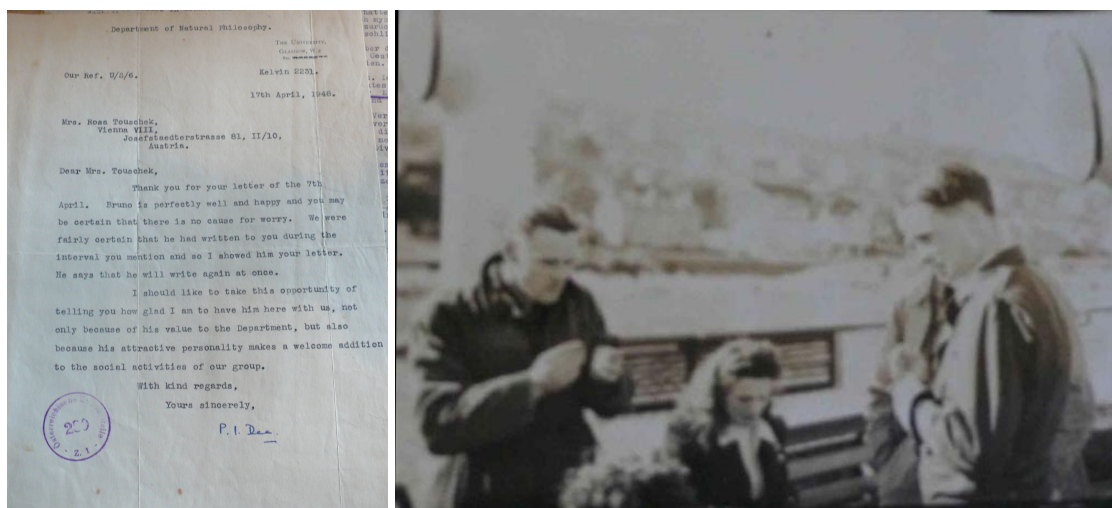


Figure 12: The letter which Philip Dee wrote to Rosa Touschek reassuring her that Bruno was fine and striving. At right, a snapshot taken on board returning from an excursion to Rothsay, with Walter MacFarlane at left and Touschek at right. Samuel Curran was also part of the same excursion, but is hidden behind Touschek, and Miss Meriç is at the center. Courtesy of the late Mrs. Elspeth Yonge Touschek.

Istanbul, who received her PhD in physics in November 1949, in the same session as did Touschek.⁶²

As the work on the Glasgow synchrotron progressed, rumors spread through the town and the countryside about University professors planning to build some ‘atomic’ project. To reassure the public of lack of any danger, Philip Dee had to give an interview to the Glasgow Herald, as we can see from a contemporary newspaper cutting shown in Fig. 13. The date of this article is not known, but it is likely to have been published in mid 1948, when Touschek was still strongly involved in the synchrotron project.⁶³ Part of his activity includes exchanges with Emlyn Rhoderick, who was working on the Cavendish cyclotron in Cambridge at the time, and would join Glasgow University, shortly later.⁶⁴ Bruno was concerned about the treatment of Coulomb interaction in meson scattering, and the related divergences. This problem was strongly debated, and of interest also to Rudolph Peierls, who visited the Cambridge group in August, as we learn from Rhoderick’s August letter to Touschek.⁶⁵ Physics was not all encompassing, however. Always a lover of nature, Bruno joined his colleagues in excursions to the islands, to Rothsay as we have seen, and, in summer 1948, went harvesting to Wick, a town in Caithness county, very far up North. In Fig. 14 we show the letter from the D.S.I.R. allowing him to take leave to participate to the harvest in Northern Scotland (BTA, Box 1, Folder 1), and, to the right, a notice from the Glasgow Herald, which mentions these activities.

Bruno’s spirits in this period were high, and he started including little drawings in the letters to his parents, as he had done since he was a little boy, and had continued do-

⁶²Courtesy of University of Glasgow Archives & Special Collections, University collection, GB 248 DC 157/18/56.

⁶³Letter to parents, July 3rd, 1948.

⁶⁴Emlyn H. Rodherick (1920–2007) worked at the Royal Signals and Radar Establishment during the Second World War on coastal defence radar, and studied physics at Trinity College, Cambridge. He then taught at Glasgow University, and went on to become professor of solid-state electronics at Manchester.

⁶⁵BTA, Box 1, Folder 1.

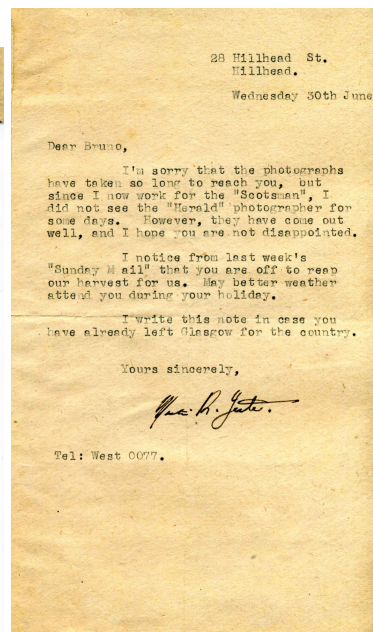


Figure 13: At left we show a cutting of an article in the local Glasgow daily. The photograph is likely to have been among those included by a journalist from the 'Scotsman', in a June 30th, 1948 letter, shown at right, where Touschek's harvesting in Northern Scotland is also mentioned. Courtesy of the late Mrs. Elspeth Yonge Touschek.

ing through the war years until September 1944. Since then, however, no drawings are present in the home letters until summer 1948, when he related to his parents some adventures of the summer harvest, humorously drawing his engagement in potato picking.⁶⁶ We reproduce them in Fig. 15.⁶⁷ The reappearance of his drawings and the humorous nature of their content signal a renewed confidence in his abilities. After the traumas of imprisonment, the tragedy of immediate post-war months in Hamburg, the displacement to Göttingen, and the move to Glasgow, he was relaxing, engaging with fellow harvesters, and enjoying, it seems, the company of a painter, something to which he had been very much exposed in Vienna.⁶⁸

Returning from the harvest, he found an unpleasant surprise. In his recollections to Amaldi, Dee related the incident, writing (Amaldi 1981, 9):

Naturally, after this early period he gave me many problems! The first was his housing. A small lodging house seemed satisfactory for a while, but after a short 'holiday', which he spent potato picking in the north of Scotland, under spartan conditions, but fortified by the prospect of an early return to his comfortable room in Glasgow, this arrangement came to an abrupt end. On his return he found that the landlady had changed his curtains without prior

⁶⁶One can find some anguished scribbles or doodles on the back of 1947 or 1948 letters he kept in his office at University of Rome and presently in BTA, folder 1, Box 1, *Corrispondenza varia, anni 1947-1949*.

⁶⁷Letter to parents, September 3rd 1948 [our dating], with written date 3/8/48, probably but a typo, in place of 3/9/48.

⁶⁸Touschek's mother was rather good at drawing and his maternal uncle Oskar Weltmann was a painter of some renown in Vienna (Amaldi 1981, 81), and one of Touschek's maternal aunts had married an architect, Emmanuel Joseph Margold, assistant to Joseph Hoffmann, co-founder of the Vienna Workshop. The family artistic bend is witnessed by one of Touschek's war time letters to parents, where he asks they send him a picture by Egon Schiele, which used to hang in his own room in Vienna (Bernardini et al. 2015).

DEPARTMENT OF SCIENTIFIC & INDUSTRIAL RESEARCH

PARK HOUSE,
24 RUTLAND GATE,
LONDON, S.W. 7.
Telephone: Kensington 9022.

9th August, 1948.

Dear Mr. Touschek,

You asked me some time ago whether it would be possible for you to take your leave from September 4th - 18th and to spend it at a harvesting camp in Scotland. You will, of course, realise that according to the terms of your contract you are entitled to one week's leave only. However, we are prepared to allow you a second week's paid leave, provided that the two weeks are taken consecutively and are both spent at the harvesting camp. I understand that volunteer agricultural workers are paid at standard rates; the amount which you earn in this way will not be deducted from your salary from this Department. On your return from Wick, perhaps you would be good enough to let me have a certificate of service from the camp.

Yours sincerely,
J. Thomson

B. Touschek Esq.,
Hillhead Hotel,
51 Ashton Road,
GLASGOW.

HL.

A Scientist "Pitches" In

SCIENCE will wait while an Austrian atomic researcher of Glasgow University pushes a pitchfork for a few weeks. Mr. B. Touschek has decided to help gather the Scottish harvest.

His companions include a lawyer, a fireman, and a shell-shocked ex-Serviceman.

They signed on at the Harvest Helpers' recruiting office at Central Station, Glasgow.

Scots farmers expect to grow 100,000 more acres of cereals, 13,000 more acres of potatoes than last year.

MORE WANTED

Already 4500 people have volunteered to help gather the crops. Two thousand more are still wanted, otherwise food will go to waste.

Pay is £3 8s for men, £2 16s for women, for a 48-hour week. Fares to the farms are refunded. Accommodation and food is provided at 90 first-class hostels, some situated in Scotland's famous beauty spots.

Figure 14: At left, copy of the DSIR letter of August 9th, 1948, granting Touschek leave to participate to the harvest. At right a newspaper article about Touschek's participation to the summer harvest in Northern Scotland. Courtesy of Mrs. Elspeth Yonge Touschek.

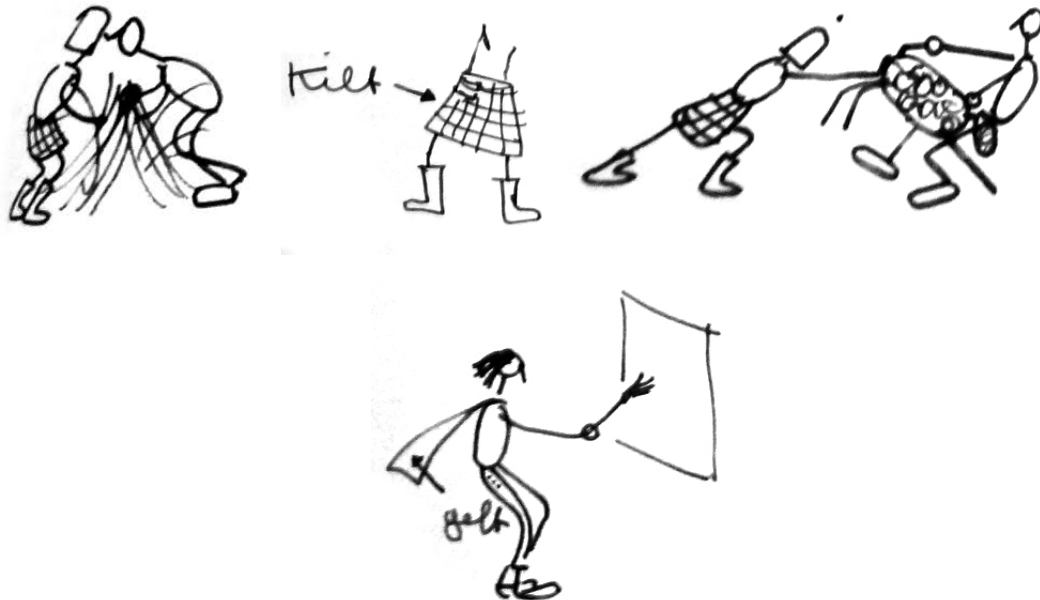


Figure 15: Drawings included by Touschek in one of his letters home, describing his harvesting time in Northern Scotland in summer 1948, graphics by A. Ianiro. Courtesy of Mrs. Elspeth Yonge Touschek.

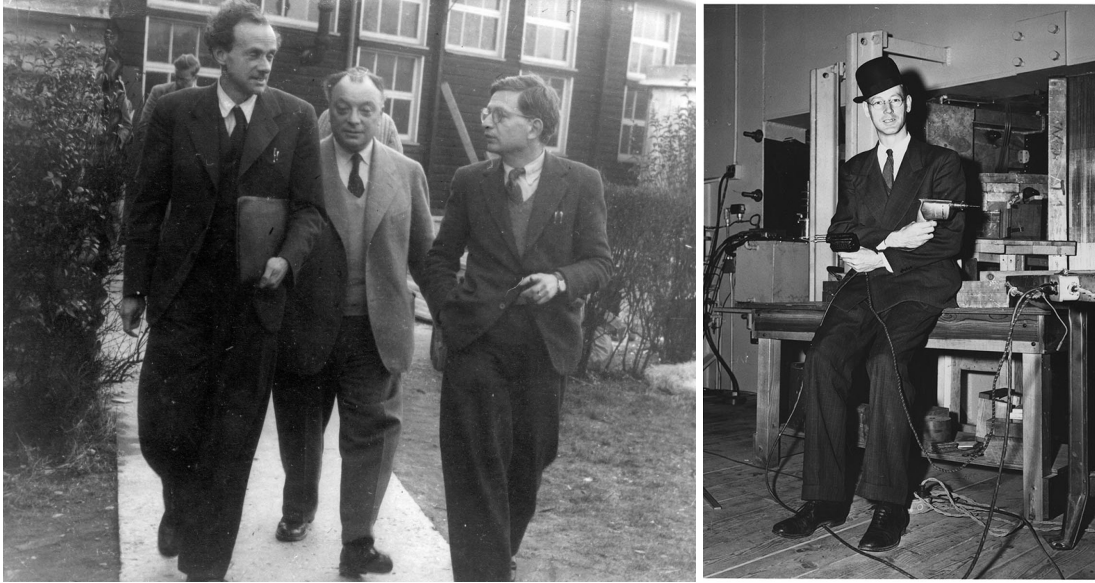


Figure 16: Left panel: Rudolf E. Peierls, at right, with Paul A.M. Dirac, at left, and Wolfgang Pauli, at the 1948 International Conference on Nuclear Physics, in Birmingham, from <https://cds.cern.ch/record/42760>. See also CERN Courier vol 42 no 7: September 2002 (P.A.M. Dirac's obituary). Right panel: Donald Kerst around 1950 wielding a soldering gun and drill, from <https://www.aip.org/file/donald-w-kerst>.

consultation and, enraged by this destruction of his anticipated homecoming, he immediately returned the curtains to the manageress with a demand for instant restoration of the original ones.

This request was obviously refused, and one more attempt to find a suitable lodging took Bruno from 51 Ashton Road to Kew terrace.⁶⁹

Shortly after the harvesting holiday, physics was once more at the center of Tousek's life. Between 14th and 18th September, a conference was organized in Birmingham by Rudolph Peierls.⁷⁰ In Fig. 16 see Rudolf E. Peierls with Paul A.M. Dirac, at left, and Wolfgang Pauli, at the 1948 International Conference on Nuclear Physics, in Birmingham. Tousek participated to the conference, where he met Donald Kerst, shown in the r.h. panel in Fig. 16.

In Birmingham, he might have discussed his ongoing work with Rudolph Peierls, external examiner of his 1949 PhD dissertation, and met Maurice Pryce, a mathematician and theoretical physicist from Oxford University, and, at the time, Max Born son-in-law (Elliott and Sanders 2005).⁷¹ In those days, Tousek was working with Sneddon on meson production with electrons and after the conference sent to Donald Kerst a preliminary version of the paper, as possible example of meson (particle) experiments one could do with 300 MeV. At Kerst's Institute at University of Illinois, they worked on the same problem (electron excitation), but Tousek thought they were about one year behind.⁷² The

⁶⁹ Adresses given in May 23rd, 1948 letter to parents and c/o Mrs. Boyle in October 29th, 1948 letter.

⁷⁰ See Peierls' letter to Hans Bethe [448], in (Lee 2007).

⁷¹ Letter to parents on October 10th, 1948 from Birmingham, September 28th, 1948 letter to Kerst, September 27th, 1948 to Pryce and (undated) reply from Pryce (BTA, Box 1, Folder 1).

⁷² Kerst was constructing such a betatron in the United States, which became operational in 1950. See also Kerst memoir in <http://www.nasonline.org/publications/biographical-memoirs/memoir-pdfs/>

paper was later submitted and published. He also had news of his friend Fritz Houtermans coming to England, with whom he had quarrelled for no reason Touschek could remember. It was a silly thing, and Bruno sent him a postcard with a view of the place he had been in Caithness county and a short amicable message. This restored them to the past friendship, and Houtermans, who was at the time in England, proposed to visit Bruno in Glasgow. Bruno was elated at the idea and telegraphed back “By all means come!”.⁷³ But the encounter fell through and they do not seem to have met in this occasion.

In October as the summer fun was over and the days shortened in the approach to winter, Touschek was once again feeling restless and unhappy. He was holding a Nuffield fellowship, his previous contract having expired, and he inquired from Dee what could come next. Dee’s frank answer includes the possibility of a professorship in two years after the doctorate, but with some *caveat*: Bruno needed to accept life in the UK, and feel more at ease, as he was into discussing and quarrelling too often for his comfort. The real point is that he was anxious to progress, to be closer to the places where theoretical physics was taking giant steps forward, such as indeed was happening in particular in the United States. He feared remaining isolated in Glasgow, without being able to keep the needed intellectual connection to other theorists. He felt that perhaps he should be moving out again, and that he may have been wasting his time. It should be added that he may very well have been going through some exhaustion and its consequent depression state. He was in fact still continuously travelling, like having to be in Malvern on Monday and back to Glasgow on the Tuesday.⁷⁴

In December, painful memories were coming back, as a new movie from Germany was released and shown in Glasgow’s Cosmo theatre to a packed audience. *Die Mörder sind unter uns*,⁷⁵ was shown in various countries around the world, and was seen by Touschek together with the whole physics department. The action of the film, by the German director Wolfgang Staudte, took place in allied-occupied Berlin, where Touschek had lived during the war. It was one of the first post WWII German films, the first to use as setting for the story the consequences of the bombings, with piles of rubble and destroyed buildings. It was produced by a company, DEFA, established in the Soviet occupied zone. Its aim was to urge the public to see and judge those responsible for the atrocities committed during the war.⁷⁶

None of this could be soothing Bruno’s anxiety and possibly incoming depression. In addition, as the year 1948 drove to its end, Touschek went through one more change of lodgings. The occasion amounts to an almost comic story, with a landlady quarrelling with her landlord husband, the husband hitting the wife, Touschek trying to defend the wife and being hit by the husband, who finally called the police. The story is related by Bruno in a letter to his parents, but in later years he narrated it to his friends in Rome, who picked it up to become an often relished anecdote about Touschek’s life in the UK

sessler-andrew.pdf.

⁷³Houtermans’ letter to Touschek is kept in Bruno Touschek papers in Rome, dated October 25th, 1948. On the top of this letter Touschek scribbled “By all means come! Wire date!” Then adds his address and the word “sent” pointing to Houtermans’ address. The letter and Touschek’s added words suggest the text of a telegram he sent to Houtermans.

⁷⁴Letter to parents, October 5th, 1948, also about meeting Kerst in Birmingham.

⁷⁵The title of the movie, *The murderers are among us* in English, recalls the title of the 1921 Fritz Lang’s movie *M*, originally *Mörder unter uns*.

⁷⁶The movie is available through YouTube. Another, almost contemporary, movie on the same subject is Roberto Rossellini’s 1948 movie *Germania Anno Zero*.

In Carlo Bernardini's version, Touschek described Mrs. Boyle's house in Ashton Road as *una casa piena di generali*, a house full of generals.⁷⁷ In his letter to Amaldi in 1981, Dee describes the episode as follows:

[...] on a Sunday morning [...] during my lunch, I answered the door to find Bruno on the doorsteps, very dishevelled and agitated and exhibiting a severely bruised eye. It transpired that during lunch his host had spoken very rudely to his wife and Bruno's attempts to teach him marital civility had ended in a violent physical encounter.

It is at this point that Professor Dee and his wife, always very kind and affectionate as Curran says in Dee's biography (Curran 1984), offered Touschek to move in their house. And this is why the end of the year 1948 finds Touschek settled into the top floor of Dee's home, 11 University Square.⁷⁸

Dee and his family lived in one of the 13 townhouses built for the University Professors by the famed architect George Gilbert Scott. Scott built a large number of institutional and domestic buildings in the *gothic revival* style, such as The Midland Hotel near St. Pancras Station in London. Number 11 was especially reserved for the Professors of Natural Philosophy. Its first occupant was William Thomson, Lord Kelvin, who lived in the house from 1870 until 1899, when he retired. It was entirely lit by electricity, probably the first in the world to have such futuristic installation. It still houses a clock, especially designed by Kelvin, which spans two floors.⁷⁹ Philip Dee was the fifth resident in the house, from 1943 to 1972, when he retired. In Fig. 17 we show a front view of Dee's house and, at right, the plaque commemorating Lord Kelvin's residency.

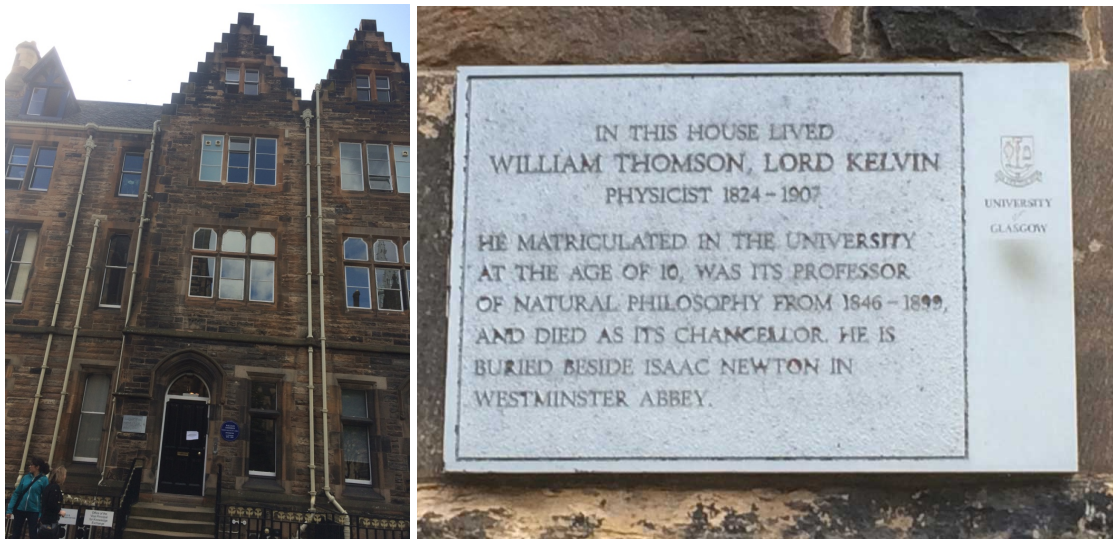


Figure 17: The Square, 11 University: left photo shows a front view of the house, where Bruno Touschek lived in the top floor with Prof. and Mrs. Dee, at right the plaque commemorating Lord Kelvin.

⁷⁷Personal communication by Carlo Bernardini (1931-2018), Professor of Physics in Rome Sapienza University, close friend and collaborator of Bruno in the AdA adventure.

⁷⁸Letter to parents from Glasgow, 6th December, 1948.

⁷⁹See <https://universitystory.gla.ac.uk/building/?id=85>.

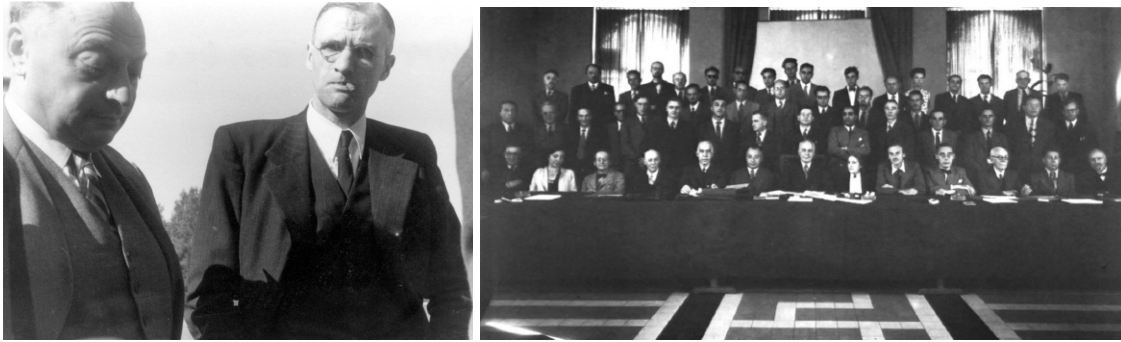


Figure 18: Left panel: Wolfgang Pauli, at left, and Philip Dee at the 1948 Solvay Congress in Brussels, from <https://cds.cern.ch/record/42755>. Right panel: The 1948 Solvay Conference photograph showing participants. Philip Dee, Rudolph Peierls and Homi Bhabha are shown in second row, fifth, ninth and tenth from left respectively, Bruno Ferretti in third row, behind Peierls and Bhabha. Photograph from https://upload.wikimedia.org/wikipedia/commons/8/82/Solvay_conference_1948.g.jpg.

Touschek lived with the Dees for almost two years in the top floor of their house.⁸⁰ Professor and Mrs. Dee were remembered by Bruno as well as by many other colleagues as exceptionally kind. As soon as Bruno moved in their house, Mrs. Dee took care of buying proper furniture for his room, treating him almost like a son. In his 1979 letter to Amaldi, Dee remembers:

Our house in the University was an old one on five floors, with rather steep communicating stairways. During the year or two which followed, I never met Bruno on these stairs. His transit time from top to bottom and in reverse were always so short that there was negligible probability for an encounter.

Dee remembers warmly Touschek's period and Touschek found a family atmosphere in Mrs. Dee's kind attentions to his needs. In the left panel of Fig. 18, we show a contemporary photograph of Philip Dee together with Wolfgang Pauli, taken at the 1948 Solvay Conference with the official photo of the Conference also shown in the right panel.⁸¹

The wounds of the past could start to mend. The more stable situation brought by comfortable lodgings, more akin to the well-to-do Vienna homes, with his parents or his grandmother's, or in Rome with aunt Ada in the '30s, would now help him to recover from the traumas of his past.

⁸⁰Letter to parents, December 6th, 1948: "At the Dees I live now in top-flat [of their house]", letter to Max Born from Oakfield Avenue on October 26th and November 1950 to parents with description of moving and room plan.

⁸¹The 1948 Solvay Conference took place after a hiatus of 15 years, the longest interval since its beginning in 1911. Through WWI, the conference series had also seen a long interruption, from the second Solvay conference in 1913 until the third in 1921. Thus the eighth Solvay conference, held in Bruxelles on October 28th, saw gathered together all the protagonists of modern physics before the war and some new entries as well. The 1948 conference followed two important meetings held in the United States a few months before in the same year, the Annual APS meeting in New York in January, and the Pocono Manor meeting, April 30- May 2nd, in Pennsylvania. At these two meetings, there are some of the first public appearances of what we now call QED, Quantum Electrodynamics, with Julian Schwinger, at both the APS and the Pocono Manor meeting, giving lectures on the new method to solve and calculate problems in particle scattering (Kaiser 2005).

3.4 1949: Getting the Doctorate

1949 was a very important year in Tauschek's progression towards becoming a *true blood* theoretical physicist. As we shall see, he started to work with Born on the new (fifth) edition of his *Atomic Physics* book, travelling often to Edinburgh and writing the appendix on β -decay, a subject Tauschek knew well from his Göttingen days and also including some nuclear physics.⁸² Then, at the end of the year, he obtained his Doctorate and became Nuffield Lecturer.

As the new year started, Tauschek was still involved in collaborations with experimentalists, but was more and more turning to theoretical physics, where his output is quite intense, mostly in collaboration with Ian Sneddon. In addition to the papers published with Sneddon more directly focused on nuclear physics proper (Sneddon and Tauschek 1948b;c) as well as on the "excitation of nuclei by electrons" (Sneddon and Tauschek 1948a, Tauschek 1950), they wrote a preliminary short note on the interaction between electrons and mesons submitted in October 1947 and published in April 1949 (Sneddon and Tauschek 1949), and soon after, on January 20, submitted a more complete paper on the results of their investigations on the "probability of producing mesons by electron bombardment", a very important question in view of the recent developments in the design of synchrotrons expected to produce high-energy electrons. These results were presented by Bruno in February 1949 at the Annual meeting of the Physical Society, held that year at the University of Edinburgh, where he gave a paper "on electrons as nuclear projectiles", while Curran presented work "on the use of proportional counters to investigate β -disintegration" (Unknown 1949).

All this was at the core of Tauschek's PhD dissertation, which he submitted in May, and whose title was *Collisions between electrons and nuclei*, and represented "a review of the work on electron excitation carried out in collaboration with Sneddon during the period 1947-1949".⁸³

In March he was still living with the Dees, not having yet found suitable accommodations elsewhere, partly because of the cost of a reasonable serviced lodging, but very likely because Dee's hospitality was providing him with a very comfortable home and had a calming effect on him, which he appreciated. He continued travelling to Edinburgh, where he was an active participant to Born's Seminar. Max Born was fond of Bruno and appreciated his presentations, even when not all of his ideas would turn out to be correct. In one occasion, Bruno gave there a lecture, and two days later, to his great embarrassment, discovered that part of the arguments he had presented was wrong. But Born knew how to encourage students whose capacities he valued (he had been one of Heisenberg's teachers, the other had been Sommerfeld) and kindly told Bruno that he had really liked the other part (which was correct).

As he started feeling more at ease with his research, and confident of being able to keep ahead with the requirements for the PhD, he decided to have a real summer vacation. The Dees were going to spend their holidays on the island of Skye and the department would accordingly enter into some lethargic state. Bruno's summer plans were to be with his parents. As a Nuffield research fellow, he could take a full month vacation, quite enough for relaxing in a place nice and warm before returning to Glasgow and the

⁸²For this see the Appendix on meson physics, as it called at the time, pag. 415 of the 1962 Edition (Born 1962).

⁸³A copy of the dissertation was kindly provided by Prof. D. H. Saxon to one of us (L.B.) in 2010.

Scottish winter. The plan was to be near some mountain lake or pool in the Austrian Tyrol, where he could find a place to swim, as he loved, and take excursions, walking through the woods and mountains of famous Alpine resorts, such as Kitzbühel, usual vacation site for the Thirring family, or Alpbach. He started proposing the idea to his parents in March, since restrictions still applied for Visas to enter Austria from abroad and travelling documents would take time, not to mention planning for the money to finance the trip.⁸⁴

A month later the question of the summer stay was becoming a full-blown problem. One month vacation in Tyrol would not come cheap of course. His parents in fact, did not think such vacation could be afforded. But Bruno felt confident it could be handled, even recurring to a loan from his bank if needed. He also considered the possibility to go further South, and visit his maternal aunt Ada and her husband, the Italian industrialist Gaetano Vannini. Aunt Ada and her husband were the only ones in the family who were in good financial conditions. They had no children and were very attached to Bruno, who had often spent his school vacation with them, in Rome, before the war. More recently, he had written to aunt Ada from an airplane, probably while going to Vienna a year before at Christmas time, and she had been duly impressed by the fact that he was an air traveller. In a letter to his parents, Bruno, jokingly, muses that his work with pump equipments (for the planned synchrotrons) may have contributed to impress his aunt, who ran a pumping business with her husband. Aunt Ada and her husband had also started building a house near Lake Albano. If the house were finished, visiting them would be an attractive, inexpensive prospect and he wrote her a letter.⁸⁵

Summer plans remained undefined until late May, but after debating whether to go to St. Ulrich or to St. Johann or some similar place, and whether to rent a house or stay in a hotel, he finally convinced his parents and decided on Flecken, a small village with the attraction to be near swimming possibilities, such as the Pillersee could offer, in addition to being close to the Thirring family, also holidaying near by, in Kitzbühel some 20-30 kilometers away.

During this first part of the year, he was also working hard, travelling, occasionally racing all over England. In April he had to go to Oxford and then to Harwell where he met Richard Becker, his professor from Göttingen. Becker was quite optimistic about the situation in Germany and inquired if Bruno would have liked to go back. The idea was appealing, but Bruno did not come to a definite conclusion, perhaps for the poorer financial prospects which Germany still offered, and the occasion to return to Germany slipped away. Later, he regretted not to have come to the opposite decision, but subsequent events in his life may indicate otherwise: Italy, where he settled in January 1953, offered him the way to combine theoretical physics with his knowledge of particle accelerators, and thus build the world's first ever electron-positron collider, AdA, in 1960.

After the intense travelling to all the places in England where synchrotrons were being built, and the hard focusing on his theoretical work for the approaching dissertation, the long sought summer vacation in Tyrol finally came. August went by and Bruno enjoyed his parents company. In Fig. 19 we show one of Touschek's companions during the Tyrol vacation, the Oxford physicist and mathematician Maurice Pryce, and a drawing with the silhouette of two figures, an older one with a plume in the hat (a characteristic Tyrolean headgear), and a younger slim one, which may be a sketch of Bruno and his father, during the Tyrol vacation. After his parents left, he remained in Tyrol for an extra

⁸⁴Letter to parents, March 9th, 1949.

⁸⁵Letter to parents, April 23rd, 1949.

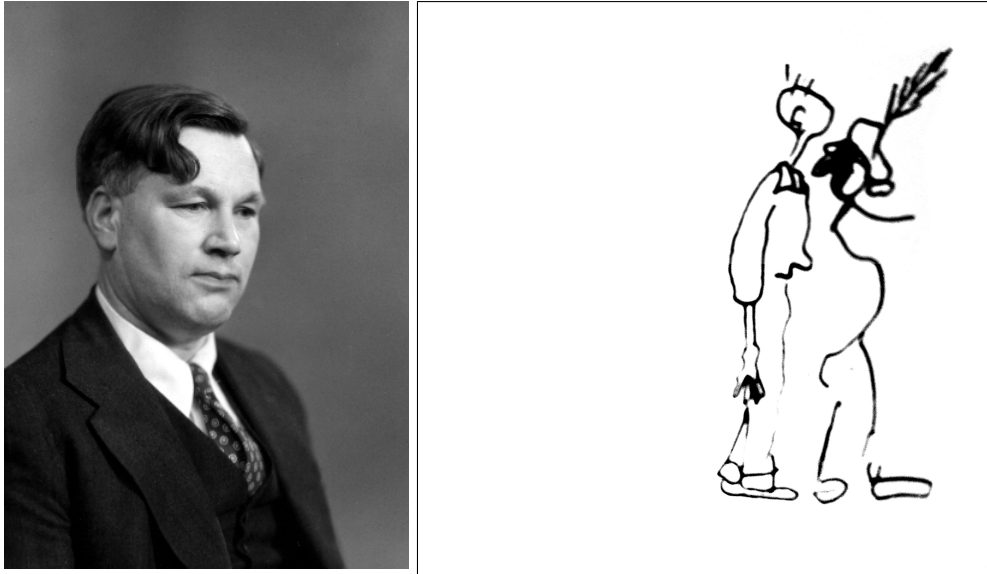


Figure 19: Left panel: Maurice Pryce, with whom Touschek shared a mountain excursion in Tyrol during summer 1949, from (Elliott and Sanders 2005). Right panel: One of Touschek's drawings placed together with fall 1948 letters, but possibly referring to 1949 Tyrol vacation with his father (from "Edoardo Amaldi Archives", Physics Department, Sapienza University of Rome, BTA, Box 1, Folder 1). Graphics by A.Ianiri.

5 days in the company of other physicists, among them Pryce, with whom he had a very pleasant mountain tour, and Léon Rosenfeld,⁸⁶ with whom he shared his return home through Switzerland.⁸⁷

Back to the UK, there came both the return to physics and the shocking news of devaluation of the pound! On September 19th, the pound sterling was devalued from 4,03 dollars to 2,80 dollars. This was announced by the Chancellor of the Exchequer, Sir Stafford Cripps, in a broadcast to the nation. The devaluation was enormous, almost 30%, resulting in increasing costs for everything imported from abroad. For Bruno this meant that whatever money he could send to his parents would be decreased by almost a third through the new exchange rate. He was very upset and felt he had been betrayed by the country he was now living in. He felt insecure about future prospects, while the devaluation was also threatening his commitment to his parents financial comfort. Thoughts of going abroad, in the United States or Canada, for 1 or 2 years crossed his mind. Or, since preparations for such move could take time, other possibilities in England or, more likely, in Ireland could be explored. He had a year-long invitation by Janossy in Dublin, which had graduated from the same high school in Vienna as Bruno, the Schottengymnasium, but four years before him. Visiting Dublin was an attractive possibility, also because Walter Thirring, Hans Thirring's son, whom Touschek knew well, and considered an outstanding young theorist, was also going to be there in 1950.

All these plans of course would have to wait until Bruno received his PhD, but in fact this was going to happen soon. In mid September he was informally told that

⁸⁶Léon Rosenfeld was a Belgian physicist born into a secular Jewish family. He was a polyglot who knew eight or nine languages and was fluent in at least five of them. Rosenfeld obtained a PhD at the University of Liège in 1926, and was a close collaborator of Niels Bohr.

⁸⁷Letter to parents on September 20th, 1949.

the dissertation he had submitted in May had come back with a very good rating from Rudolph Peierls (the external examiner in Birmingham).⁸⁸ The graduation ceremony was going to be held in early November, and he expected to receive a new contract with an increased salary, which might offset the pound devaluation.

While pleased with looking forward to receive finally his official entry pass into being a theoretical physicist, Bruno could not avoid feeling that Glasgow was as dirty as ever, looking even blander and dirtier after a summer break. The prospect of intensified austerity did not make things any more pleasant, but he hesitated in running away, yet. He had done this all his life, and thus escaped stagnation and probably death. But now, he had gone far, beyond his early dreams, and the next move needed to be carefully thought out. It is quite possible that similar considerations were in his mind when, earlier in the year in Harwell with Becker, he did not follow up with the Göttingen offer.

In October, he received an official letter informing him that his thesis has been approved and no corrections were requested, intimating that he would receive his Doctorate in the coming session, the letter also including the address of the robe-makers, in case he planned to be present at the official Graduation Ceremony (which he did). He also received the assurance that he could continue staying in Glasgow as “Official Lecturer in Natural Philosophy” (Amaldi 1981, 12). With the salary coming with his prospect of improved status as a Lecturer, he could feel financially more secure. Emboldened by the official confirmation that his application for doctorate had been approved, he sought to buy a car, even though he still had neither a driving license, nor the money. Indeed his impatience with the slow process of learning to drive, led him to potential troubles, as he related his first driving attempt, with the car to be purchased, in a humorous letter to his parents. Fig. 20 reproduces a small drawing included in the letter, showing the effect of his driving the B.S.A. - sport - (170 pounds), as he was rushing out of the shop and trying it.⁸⁹ We show Tauschek’s description of this adventure in the left panel of Fig. 20, and, at right, the Senate letter he had received just a few days before.

As we have seen, Tauschek’s doctoral thesis was on the interaction of electrons with mesons, a topic on which he wrote several papers with Sneddon. John C. Gunn, who held the newly established Chair of theoretical physics, was his internal examiner.⁹⁰ The external examiner was Rudolf Peierls, from University of Birmingham, with whom Tauschek shared his life-long interest in the problem of *Radiation Damping*.⁹¹ A 1944 photograph of Tauschek’s internal examiner appears in Fig. 21. The official record of awarding of Tauschek’s PhD is shown in the right panel.

Tauschek received his degree on November 5th, 1949. We show in Fig. 22 the certificate by the Academic Senate and Tauschek’s official photograph on the occasion of the

⁸⁸Letters to parents on September 20th, 1949.

⁸⁹Letter to parents, October 24th, 1949.

⁹⁰John C. Gunn was a Professor of Natural Philosophy at University of Glasgow. He was born in Glasgow, and studied at St. John’s College in Cambridge. After the war he was lecturer in Applied Mathematics at the University of Manchester and then started research in nuclear and particle physics at University College in London, as from <https://www.universitystory.gla.ac.uk/biography/?id=WH1433&type=P>. In London, Gunn published a paper on “Interaction of Mesons with a potential field” (Gunn and Massey 1948). The paper, published by the Royal Society, was presented by Harrie Massey, one of the active supporters of CERN from the UK side. Gunn was appointed to the Chair of Theoretical Physics in University of Glasgow in 1949. See also <https://www.universitystory.gla.ac.uk/biography/?id=WH1433&type=P>.

⁹¹We know that, according to what Rolf Widerøe wrote to Amaldi, Tauschek had worked on radiation damping during his prison days, even writing a paper, ‘in invisible ink’ on the copy of Heitler’s book *Theory of Radiation*.

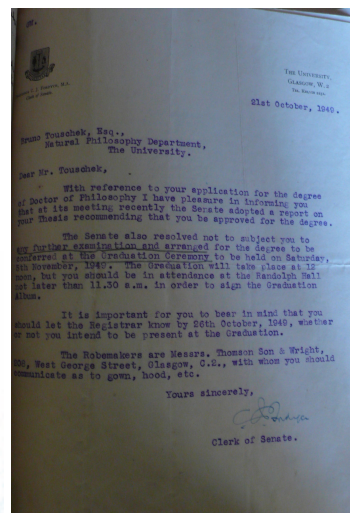
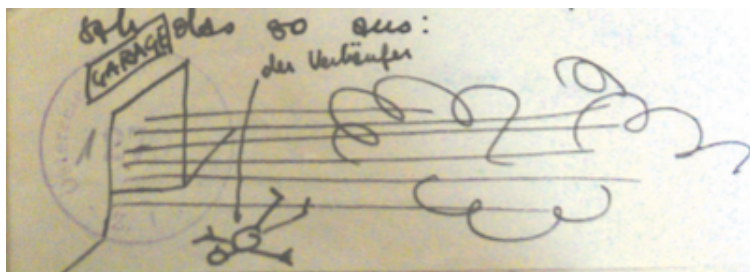


Figure 20: At left: Touschek’s drawing about leaving the garage where he had just wanted to buy a car, and almost crushed the attendant seller. At right, the Senate letter informing Touschek that his application for PhD had been accepted, October 21st, 1949. Courtesy of Mrs. Elspeth Yonge Touschek.

doctorate. Amaldi writes that, immediately after his doctorate, Touschek was appointed ‘Official Lecturer in Natural Philosophy’ at University of Glasgow (Amaldi 1981, 12), a position he held for three years.

Shortly after Touschek’s doctorate ceremony, a conference was organized by Max Born at the University of Edinburgh on November 14-17 (Anonymous 1950). Through the year, Bruno had often visited Max Born in Edinburgh and, at some time, started working on an Appendix to the new edition of Born’s famous *Atomic Physics* book with a contribution on the process of β -decay. The subject had interested Touschek since his Göttingen days. It was now understood that the underlying mechanism could be used to distinguish the so-called μ -meson, discovered in 1936 in cosmic rays, from the proposed carrier of nuclear forces (successively named the π meson). The subject of particle decays was at the center of debates, as one can see from the Conference preliminary program shown in Fig. 23, with cosmic rays results still the winner of the day in terms of experimental high energy particle physics. One notices that among the speakers there was Bruno Pontecorvo, who presented a talk on *The decay products of the μ -Meson*. He had spent the war years mostly in Canada, and was then based at AERE.

The conference had been organized by University of Edinburgh to take advantage of the presence in Scotland of Niels Bohr, who gave that year’s [Gifford Lectures](#), held bi-annually in Scottish Universities (Anonymous 1950).⁹² The Glasgow particle physics group, including Dee, Touschek and students, drove everyday to Edinburgh, with Bruno holding the wheel of Dee’s car, and the students huddled in the back of the car, frozen with fright at every turn of the road, since Bruno was still a rather inexperienced driver. After the Conference, the big event of the year in the Glasgow Physics Department took

⁹²Niels Bohr gave the 1949 Gifford Lectures at the University of Edinburgh under the title *Causality and Complementarity*. The lectures remain unpublished, but the audio recordings of 9 of the 10 lectures [lecture 2 is unfortunately missing] are maintained at the Niels Bohr Archive (<http://nbarchive.dk>). A manuscript entitled “Summary of Gifford Lectures is reproduced in *Niels Bohr Collected Works*, vol. 10, *Complementarity beyond Physics (1928-1962)*; edited by David Favrholdt.

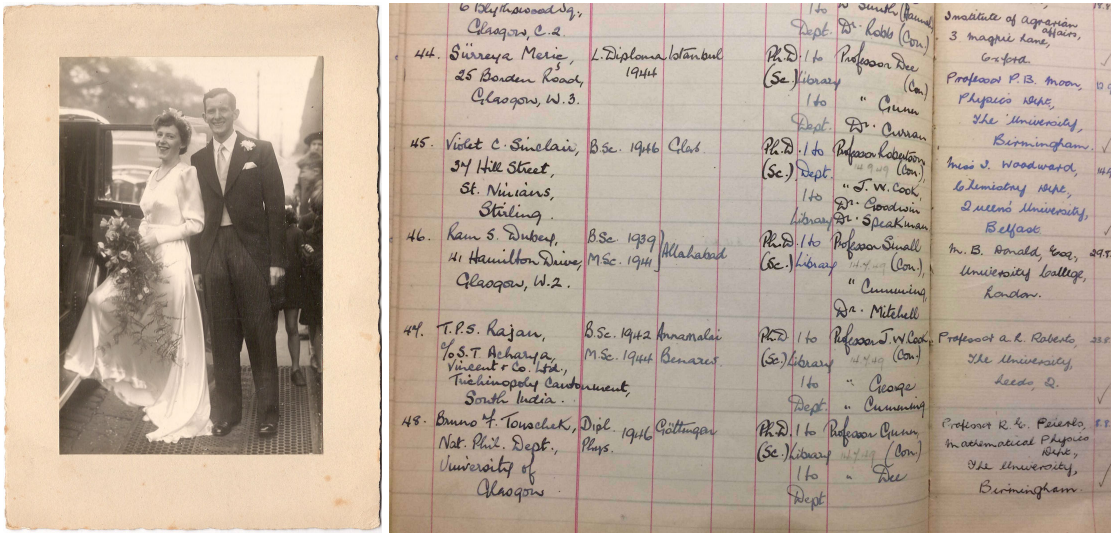


Figure 21: At left, we show a photograph of John C. Gunn and his new bride on their wedding day, 1944, courtesy of Prof. J.M.F. Gunn, from Birmingham University. At right, pages from Touschek's official PhD record from Glasgow University Record of Higher Degrees, courtesy of University of Glasgow Archives & Special Collections, University collection, GB 248 DC 157/18/56.

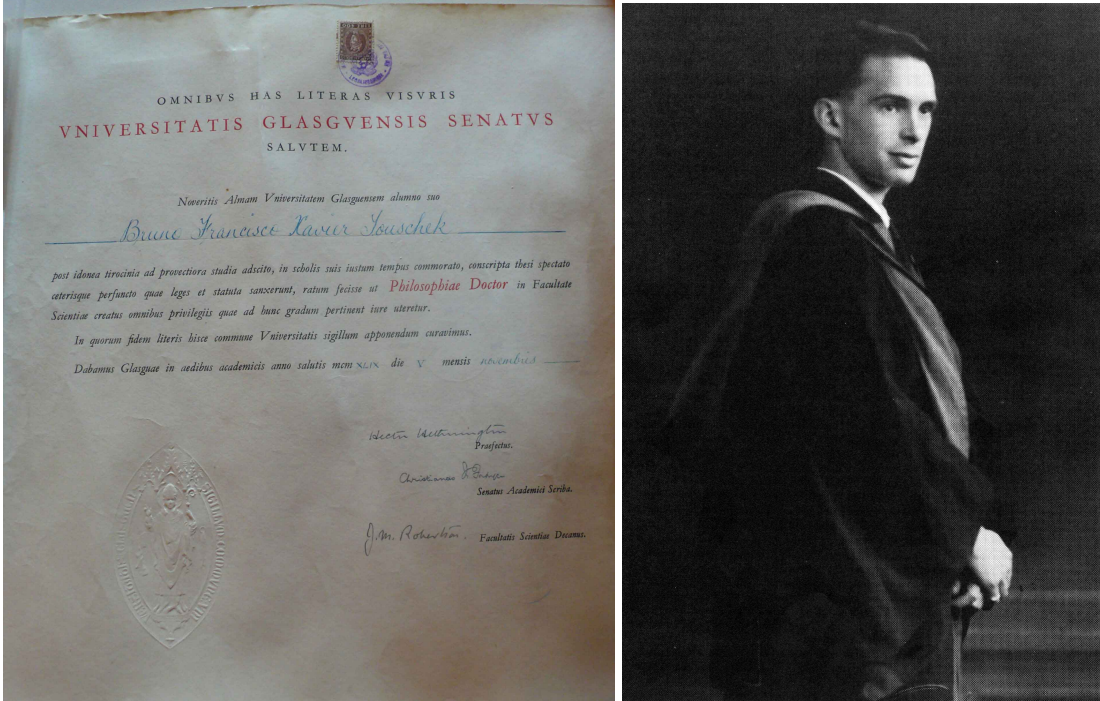


Figure 22: Touschek's certificate of award of Doctor of Philosophy from University of Glasgow and his official Graduation photograph (Amaldi 1981). Courtesy of Mrs. Elspeth Yonge Touschek.

UNIVERSITY OF EDINBURGH
CONFERENCE ON ELEMENTARY PARTICLES.
in the Natural Philosophy Buildings, Drummond Street, Edinburgh.

MONDAY, 14th November:

Professdr W. Feather : Experimental Evidence concerning the possible existence of the Negative Proton and the Di-Neutron.

Dr. D.H. Perkins : The Mechanism of Emission of Heavily-Charged Fragments in Nuclear Explosions.

Prof. L. LePrince-Ringuet : Effets Nucleaire de grand Energie dans le Rayonnement Cosmique.

Dr. J.G. Wilson : Some new measurements on the Nature of the Vertical Cosmic Ray Beam at Sea Level.

TUESDAY, 15th November:

Prof. W. Heisenberg : Die Erzeugung von Mesonen in Vielfachprozessen.

Prof. L. Janossy : On the Production of Mesons by Nucleons.

Dr. B. Pontecorvo : On the Decay Products of the μ -Meson.

Prof. C.P. Powell : Observation bearing on the question of the existence of heavy charged mesons.

WEDNESDAY, 16th November:

Prof. P. Bopp : Title not fixed. Subject probably "Generalised Field Theories."

Prof. M. Born : General Theory of Elementary Particles.

Dr. K.C. Cheng : Reciprocity Theory of Electrodynamics

Prof. M. Fierz : Pauli's "Regularisation."

Prof. H.A. Kramers : Quantum Electrodynamics and Correspondence-Principle.
Born - Rosenfeld
Fierz

Fierz
cosmic distribution

The above is subject to additions. Detailed programmes for each day will be decided later.

Figure 23: Preliminary program of the 1949 Conference on Elementary Particles, held in Edinburgh 14-16 November 1949, from Bruno Pontecorvo papers at Churchill Archives, Cambridge University.

place on Thursday and Friday, 17 and 18th November: Niels Bohr came visiting on his Gifford Lecture tour. The highlight of Bohr's visit was an inaudible lecture at the physical institute during which Bohr moved from the lectern to the blackboard, to clarify a point which nobody could follow anyway.⁹³ The talk was given to a packed audience of students and professors alike, who had all come to listen and see the *der Physik papst*, the pope of physics, as he was called. A visit from the King of England would not have given half as much trouble. Bohr was accompanied by his assistant Stefan Rozenthal and his long-time collaborator Léon Rosenfeld, whom Tauschek knew from Birmingham and Alpbach. Tauschek drily reflected that Bohr's esthetically supreme choice in his adept's name allowed no choice for someone with a non-descript name such as his own. But while Bohr could neither catch nor pay attention to Tauschek's name, he must have been sufficiently impressed by the young man's intelligence that he invited him to come to Copenhagen on his next trip. This was an invitation which Tauschek was glad to accept for the next fall. Heisenberg, Bohr, Heitler and Rosenfeld are shown in Fig. 24, from around 1934.



Figure 24: From left: Werner Heisenberg and Niels Bohr, Walter Heitler and Léon Rosenfeld, in photos of the mid 1930s (Wolfgang Pauli's Archive at CERN, <https://cds.cern.ch/record/42960> and <https://cds.cern.ch/record/42896>). For other photos of interest see <https://cds.cern.ch/search?cc=Pauli+Archive+Photos&ln=en>. Photograph at right is also to be found in <https://calisphere.org/item/ark:/28722/bk0016t4h8s/> where it is indicated as around 1934, Copenhagen conference.

Bohr and his wife arrived with something like 71 pieces of baggage which Dee personally brought down from the third floor into his car, when they left. At the train station, Dee was having great difficulty keeping track of all the porters running in different directions with that much luggage, not to mention the enormous tip to give them after the Bohrs left. All through this, Bohr very quietly and steadily was clarifying the subtleties

⁹³Bohr's lectures were famously long and often not understandable. One such reaction is reported from the Pocono Manor meeting, March 30–April 2nd, 1948, in Pennsylvania. At this conference, Feynman gave the first public introduction to his method, since then referred to as *Feynman diagrams* and universally used to calculate particle interactions. An interesting article related to [The unveiling of Feynman diagrams at the Pocono Manor Conference](#) tells how Feynman's talk, presented at the end of the day, was poorly received. In particular, 'Bohr leapt to the mistaken conclusion that they represented a violation of Pauli's exclusion principle.' and after more questions were asked which Feynman appeared unprepared to answer, 'Bohr rose and approached the blackboard where he delivered a long speech on the Pauli exclusion principle'. At the end of the session, it seems that almost nobody had understood what Feynman's method could do. See also a 2018 article by Ashutosh Jogalekar on [The Birth of a New Theory: Richard Feynman and His Adversaries](#), in *3 Quarks Daily on-line magazine*.



Figure 25: The places Bruno Touschek toured during his Xmas vacation in 1949.

of the uncertainty principle.⁹⁴

For Xmas, Touschek decided he had had enough of Glasgow and took a break to the North of Scotland, planning to go to Glencoe and Fort William in Inverness-shire, climb Ben Nevis and visit the island of Skye, enjoying the North in the heart of winter. In Fig. 25, we show the sites he visited during this Christmas vacation.⁹⁵

As the year was coming to an end, from the wilderness of the North, he was thinking of his future, facing possible new research directions or places to go and his thought wandered to Rome and aunt Ada. The idea of a summer vacation with a trip to Italy and to the South started appealing to him once more. He thought of writing to her, but did not have her address and postponed.

4 Lecturer in Glasgow: 1950-1952

While Bruno in Glasgow had been working on his doctorate and, afterwards, continuing as “Official Lecturer in Natural Philosophy”, in continental Europe the massive process of reconstructing European science was undertaken. In France, in Italy, in Germany, in all the universities which the war and fascism had decimated of its scientists and laboratory equipment, younger scientists joined forces with the few who had remained and had started to rebuild Europe. Such massive effort, which culminated with the foundation of CERN, but also with the launch of national laboratories and research institutions such as the Laboratoire de l’Accélérateur Linéaire in Orsay or the National Institute for Nuclear Physics (INFN) in Italy, led to the construction of new powerful particle accelerators, which, unexpectedly, could compete with the American ones. Indeed at the end

⁹⁴Letter to parents, November 21st, 1949

⁹⁵Letter to parents, December 25th, 1949.

of the 1950s, a proton synchrotron was working at CERN, a linear electron accelerator in Orsay, an electron synchrotron in Frascati. While all this was in the future, the year 1950 saw Europe on the stepping stone of an epochal change, which was only partly reflected in the UK. Britain had won the war, and throughout it had maintained – indeed fostered and increased – its intellectual and technological power, but the drive to start anew in a joint effort, as the continental nations were doing, was not as strong. One recalls that Britain itself criticized the project of a European laboratory, even considering it a crazy idea (Hermann et al. 1987, 114), and hesitated in joining CERN at the beginning. Only in 1954 did Britain become one of CERN member states, after its scientists fully endorsed the idea and lobbied the government (Amaldi 1979a).

Only part of this was resonating in Glasgow, as the world entered into the 1950s. At this time, Glasgow appeared stagnant to the young Touschek and he began actively looking for a place to go and continue his path in theoretical physics. And then, as 1949 ended and 1950 took over, there unfolded events which would affect nuclear physics in the UK, and, with it, Touschek's life. These events were the consequence of actions which had started 8 or 10 years before, and had been known only to a handful of people, from both sides of the Atlantic. In February 1950 they became public, after having been brought to the attention of the US and UK highest political and scientific authorities in January. The knowledge of what had happened shook the world and changed the course of many people's lives, as well as the direction of nuclear physics research in UK. We refer here to so called *Fuchs affair*. Rudolf Peierls, Touschek's external PhD examiner, was most directly affected, but Bruno's life as well was indirectly influenced by it.

4.1 Fallout from the Fuchs affair

In early 1950, the British scientific community was shaken by the discovery that the theoretical physicist in charge of the Nuclear Physics program at Harwell, Klaus Fuchs, was, and had been, a spy, who had passed crucial information about the making of the atomic bomb to the Soviet Union (Close 2019). Fuchs was German born, and had left Germany for the UK before the war. After getting his PhD at the University of Bristol in 1937, he went to Edinburgh, where he worked with Max Born and was awarded a Doctor of Science degree. He was interned as an enemy alien at the start of World War II, but was soon released as his known enmity to the nazi regime cleared his political allegiance. His importance as a theoretical physicist was underlined by Max Born, who wrote that Fuchs “was the soul of my research group [...] He is in the small group of theoretical physicists in this country.” (Close 2019, 45). He was also highly considered by Peierls and in May 1941 he became Rudolph Peierl's assistant in Birmingham, working with him on “Tube Alloys”, the British atomic bomb project, beginning to pass information to the Soviets. In 1942 he became a British citizen, and could thus move with Peierls to work on the Manhattan Project, later joining the Los Alamos top secret laboratory in New Mexico.⁹⁶ After the war, Fuchs returned to England, and went to the nuclear research centre at Harwell.

When Fuch's betrayal become public, suddenly, in the UK, all foreign born scientists came under suspicion. As [Richard Wilson](#) remembers in his memoirs: “The problem

⁹⁶From <https://www.britannica.com/biography/Klaus-Fuchs>: “Klaus Fuchs, in full Emil Klaus Julius Fuchs, (born December 29, 1911, Rüsselsheim, Germany, died January 28, 1988, East Germany), German-born physicist and spy who was arrested and convicted (1950) for giving vital American and British atomic-research secrets to the Soviet Union.”

began in December 1949 when the nuclear physicist Alan Nunn May was arrested as a spy at McGill University in Canada just after a lecture. He had been working on the atomic bomb project and was accused of giving information to the USSR some five years before. The USA panicked. All foreign [born] nuclear physicists were suspect.” (Wilson 2011, 111).⁹⁷ Fuchs was one of them. His espionage activities were detected, and he was arrested on February 2nd 1950, upon which he admitted passing information to the Soviet Union since 1943.⁹⁸ We show a photograph of Karl Fuchs in the left panel of Fig. 26.

Rudolf Peierls, Tauschek’s external examiner, was particularly shaken by the uncover of Fuchs as a Soviet spy. Peierls, also German born, had supported Fuchs’ eligibility for the Manhattan project. The two scientists were very close friends, having shared the experience of leaving Germany as Hitler came to power, and gone to the UK to continue their work. Peierls may have felt not only betrayed, but also himself in danger.⁹⁹ Peierls’ wife was Russian, and he had frequently visited the USSR before the war, also had collaborated and would do more so later, with prominent Russian scientists such as Lev Landau. In the witch hunt atmosphere which would soon engulf the United States with the rise of McCarthyism, German scientists in the UK would also feel insecure. Peierls himself was the target of suspicions and criticism (Close 2019, 392-401).¹⁰⁰

Everywhere in Europe and the US, the fear of a communist threat to Western society led to major changes to some scientists life. One can remember that on April 26th, 1950, Frédéric Joliot (Pinault 2000) was made to resign from the Chairmanship of the French Atomic Energy Commission for his sympathies for the Communist Party and activities in favour of an international ban on nuclear weapons (Close 2015, 157). And, in early September 1950, the Italian physicist Bruno Pontecorvo, shown in the right panel of Fig. 26, one of Fermi’s collaborators before the war, suddenly disappeared from Italy with his wife and children, joining the Soviet Union, as it became known only five years later (Turchetti 2012, Close 2015).¹⁰¹

The cold war had started. This atmosphere weighted heavily on the morale of UK scientists, and had strong impact on career prospects for non-British citizens working in the UK

The impression from the Fuchs affaire is present in Tauschek’s letters in early 1950. Fuch’s trial started on February 12th, very soon after he had been arrested, only one week after he had confessed (Close 2019, 334). Tauschek mused on the prosecutor’s description of Klaus Fuchs as Dr. Jekyll and Mr. Hyde’s personality, and drily observes that a double

⁹⁷Richard Wilson (1926-2017) was an English born experimental physicist, who was Professor of Physics at Harvard University, USA, and designed, constructed, and used the Cambridge Electron Accelerator 6 GeV synchrotron, which, from 1962 on, further probed nucleonic structure.

⁹⁸He was sentenced to 14 years in prison. After his release in 1959 for good behaviour, he went to East Germany, where he was granted citizenship and was appointed deputy director of the Central Institute for Nuclear Reactions.

⁹⁹In his memoirs *Birds of Passage* (Peierls 1985, 223) Peierls recalls: “Our most dramatic experience was the Fuchs case. [...] On the day I heard of his imprisonment under the spy charges I went on to Brixton prison to see Fuchs. We had a long talk. Yes, he had given secret information to Soviet contacts.”

¹⁰⁰As Close writes: “With his phone and mail continually monitored, Rudolph Peierls became part of the communist witch-hunt until 1954” when the British security closed their file on him. But the United States did not relent and in 1957 asked the British Department of Atomic Energy that Peierls be given no access to American secret documents. At which point, Peierls decided to resign from his consultancy at Harwell.

¹⁰¹Pontecorvo was born in Pisa in 1913 from a prominent Jewish family. He moved to the USSR in 1950, returning to Italy for the first time only 28 years later, in 1978, on the occasion of Edoardo Amaldi’s seventieth birthday celebrations. He died in Dubna in 1993. See also (Mafai 1992, Turchetti 2007).



Figure 26: Left panel: Klaus Fuchs, at the time of his arrest for espionage in favour of the Soviet Union, ©ImperialWarMuseum, from <https://history.blog.gov.uk/2020/03/02/whats-the-context-sentencing-of-atomic-spy-klaus-fuchs-1-march-1950/>. Right panel: Bruno Pontecorvo with Enrico Fermi, shown at right, in a photograph taken on occasion of the International Conference on Nuclear Physics, Quantum Electrodynamics and Cosmic Rays held in Basel, CH, and Como, Italy, in September 1949, from a contemporary newspaper.

personality has nothing to do with nuclear secrets. He did not sympathize with the Soviet Union, but felt that the prosecutor’s hype was excessive.¹⁰²

Unfortunately, the Fuchs affair was not a passing episode.

4.2 Bruno Touschek and Max Born – 1950-52

During his stay in Scotland, Bruno exchanged letters with Max Born in Edinburgh and frequently visited him. From this correspondence, one can see that Touschek’s formation into a theoretical physicist owes much to the relationship with the great scientist. The letters often include questions of theoretical physics, articles to be discussed, even some fatherly advice, such as we glimpse from a letter where Touschek acknowledges some errors he had made and accepts Born’s suggestion that ‘a little Puritan classical electrostatics would do me no harm’.¹⁰³

Most of Born’s correspondence with Touschek is kept in the Churchill Archives Centre, in Churchill College, Cambridge, UK.¹⁰⁴ The sequence of letters kept in Churchill Archives Center starts with May 18th, 1950, with Born informing Touschek that he had just come back from Cairo finding the galley proofs of his book *Atomic Physics*. He could not yet work on them, because of a commitment to write an article on the physics of the last 50 years for the *Scientific American*, and asked Bruno to help him with the proofs, a copy of which he should have received as well, and invited him to come over for a day to Edinburgh. Bruno replied ten days later, sending the corrected proofs. After mentioning

¹⁰²Letter to parents, February 14th, 1950.

¹⁰³Touschek to Born, September 25th, 1950, Churchill Archives Center.

¹⁰⁴We were made aware of this correspondence by Ms. Antonella Cotugno, from Rome University Library, and the quoted text comes from 23 letters she copied with the kind permission of Churchill Archives Centre, Churchill College, Cambridge University, UK, where the original letters are kept and are available in the [Cambridge University, Churchill Archives Centre, The Papers of Professor Max Born](#). These copies are kept in Bruno Touschek papers at Sapienza University in Rome.

an interesting effect observed by his experimentalist colleagues and for which he was trying to find a theoretical explanation, he inquired about a position in Cairo: “On Monday you mentioned a possible vacancy in Cairo and I could not help thinking about it”. As we know, since passing his doctorate in November, Touschek had been looking for a way out of Glasgow, and started some fantasy about such position. Uncertain about writing directly to the Physics Department in Cairo, he mused whether this would be a form of ‘escapism’, born from growing doubts about his future in the UK. He had loved Scotland, but not anymore now that he had gotten used to it. This is an interesting observation, since it reflects an internal pervasive restlessness, which may have had a remote origin, probably when his mother died and, as a young boy before the war, he would leave Vienna for periods of time to stay with aunt Ada, in Rome.

In any case, he reassured Born that he won’t want to leave for another year, because of work he had started and wanted to finish. He closed the letter, asking Born if he would be angry at him if he applied for the position in Cairo. Shortly after, on May 31st, Born thanked for the proofs, hoping to see him before Bruno leave for Germany, and promising to inquire about the position in Egypt.

After the summer, and visits to Göttingen, Copenhagen and Austria (vacationing in Tyrol), Touschek picked up again the correspondence on September 29th, apologizing for some mistake in a paper he had been working on, and informed Born of a pending visit by Walter Thirring in October-November. During the summer Touschek had attended a small private conference organized in Kitzbühel, at Hans Thirring’s house. This may have prompted plans for a visit to Glasgow by Thirring’s son, Walter, in the coming fall. In Thirring’s autobiography, the tour which he took in fall 1950, first to Dublin invited by Schrödinger and then to Glasgow, is seen as an apprenticeship and travel tour (Thirring 2008), before Thirring would go back to Göttingen for the rest of the academic year. In this letter, Touschek proposes to take Thirring with him to Edinburgh, upon his arrival in Glasgow.

When Touschek wrote next, on October 26th, he apologized for the silence, partly due to have been very busy leaving Dee’s house to move to his own place in Oakfield Avenue, and mentioned work he had started with Thirring. At the time of this visit, Walter Thirring was interested in going through electrodynamics with the covariant formalism of Schwinger and Feynman, in particular doing so through Heitler’s book, Touschek’s *bible* during the war years. From this letter, the why and when of Touschek and Thirring’s paper (Thirring and Touschek 1951) on the Bloch and Nordsieck (BN) problem (Bloch and Nordsieck 1937), first appears. Born welcomed the idea of Thirring coming to Edinburgh and on November 10th invited both Touschek and Thirring to come on the following Thursday for discussions, ‘high tea’, or possibly for lunch. During November, Touschek and Thirring wrote the paper on the covariant formalism of the BN problem and then, after having submitted it to the *Philosophical Magazine* Touschek sent a copy of the manuscript to Born on December 18th. By that time, in early December, Thirring had gone back to Göttingen. There is no mention of this paper in Thirring’s memoirs, whereas for Touschek it would later become a milestone in his formulation of infra-red radiative corrections to electron positron experiments (Etim et al. 1967).

The next letter in the Churchill Centre Archives is dated April 3rd, 1951. Touschek apologizes for the silence, and, implicitly, for lack of visits to Edinburgh during these 4 months, informs Born of his recent theoretical physics output and asks him for a referral for a position in Oxford as Senior Lecturer. He had written to Maurice Pryce, Born’s

former student in the 1930s and his son in law, having married one of Born's daughters, but apparently Pryce was in Princeton, according to Sneddon, and there was no reaction. Born replied immediately, after a couple of days, that he was happy to give a referral and thought that Pryce, who should come back from Princeton next July, should be delighted to have Touschek in Oxford. He was happy to have heard from Touschek, inviting him to come again over to Edinburgh.

As of May 28th, Touschek had not received any reply from Oxford, neither from Pryce nor from the University Registrar, and became worried that there would not be enough time to give notice to Glasgow University, in case of a positive answer from there. One reason for this could be that Pryce, after a one-year sabbatical leave at Princeton, on his return would become head of the theoretical physics division at the Atomic Energy Research Establishment at Harwell, (Elliott and Sanders 2005), replacing Klaus Fuchs who had been arrested on February 2nd 1950 and convicted, on March 1, on a charge of spying (Close 2019). In the same letter, Touschek mentions his latest physics paper, a work which he calls 'no more than a patent application', meaning that he had an idea and wanted to have it down in print, to establish his priority. We know from correspondence with his family that he felt he often worked out results which were developed around the same time by other physicists, but which did not get attention because he had not published them, or, more likely, did not propagate outside his own restricted circle. In a later CV, Touschek mentions one such case concerning the Appendix about meson theory he wrote for Born's book. In the appendix, he anticipated the universality of weak interactions, but had not published his intuition about the subject, having discovered that it had been developed elsewhere, in particular by G. Puppi (Puppi 1948).¹⁰⁵

The preoccupation to establish a priority explains the term 'a patent application' for the paper he submitted on May 3rd, 1951. This paper (Touschek 1951) is of note because it includes citation of article by the Italian theorist Bruno Ferretti, submitted from Rome and published in February 1951 (Ferretti 1951), which may have attracted Bruno's attention to the Physics Institute in University of Rome.

In the May 28th, 1951 letter, Touschek also informed Born of his summer plans, which included driving the motor cycle he had just bought, and travelling with a companion, Dr. Rae, through the continent. But Born had also already left for the Continent, and would only be returning at the beginning of August. The department, in Edinburgh, offered to forward Touschek's letter to Born in Göttingen.

No more letters are recorded until the next year. What prompted such long silence? Letters between September 1951 and January 1952, when Touschek was back in Glasgow after the summer leave, may have been lost. But it is just as likely that Touschek, after unsuccessful attempts to find an alternative position in Oxford, or Germany, turned his attention to Italy, starting his contacts during summer 1951, as we shall see later. This preoccupation would engulf him. Back to Glasgow, he was also very busy with teaching, working with his research students, and worrying about a (never published) book with Ian Sneddon.

The next group of letters starts in January 1952, but they are less frequent. From January through March, there are various exchanges about slides and photographs of no-

¹⁰⁵Puppi is credited for having been the first to discuss the muon-electron universality, which actually had been already mentioned by Bruno Pontecorvo (Pontecorvo 1947), but seldom recognized. Oskar Klein, too, had realized that all weak processes investigated thus far seemed to be due to the same universal Fermi interaction (Klein 1948), as did Tiomno and Wheeler (Tiomno and Wheeler 1949).

25th March, 1952.

Dear Tousehek,

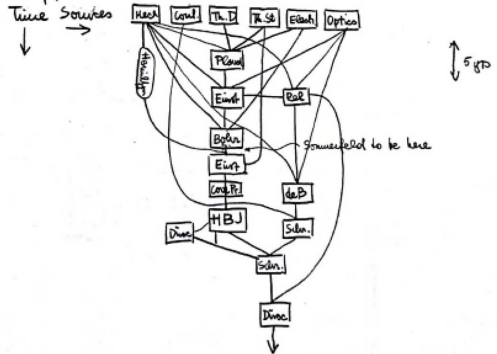
Thank you very much for your kind letter with the account of your lecture and the newspaper cutting. I think that your diagram is indeed very helpful.

With kind regards,
Yours sincerely,

Dear Professor Born,
Enclosed a cutting from the Glasgow Herald. During the time I was running out I actually only got to 1925 & had to cut very roughly on the wave-mechanical side.
Many thanks for the great help in letters & slides

Yours sincerely
B. Touschek

P.S.: I found the following very helpful



Development of Quantum Mechanics

The fact that quantum theory became established by utilising ideas and facts from nearly every branch of physics was emphasised in a lecture given in Glasgow by Dr B. Tousehek on the historical development of quantum mechanics. The lecture was the seventh in the series arranged by the Scottish branch of the Institute of Physics to explain the fundamental concepts of science.

Quantum theory has as its birthday October 19, 1900, when Max Planck in Berlin proposed an empirical formula to explain the distribution of energy with wavelength in the radiation from a hot body. The classical theory of statistical mechanics had failed to explain this distribution, which had been very carefully measured in a number of experiments, and the Planck formula could be interpreted as stating that only certain values of the energy of an oscillating charge could be permitted. These values were integral amounts of the frequency of the radiation multiplied by a constant now known universally as "Planck's constant."

In 1905 Einstein realised that if the radiation, after leaving the source, could

be supposed to retain the nature of a packet of energy, the radiation would behave like particles and their action on matter would explain the phenomenon of the photo-electric effect; the latter was quite inexplicable using the electromagnetic concept of Maxwell.

In 1913 Bohr applied this concept of "quantised" energy values to the Rutherford atom and showed that it gave an immediate explanation of the spectrum of hydrogen, which consists of discrete wavelength values, which again was impossible to appreciate from a classical viewpoint. The Bohr concept suggested the existence of orbits in which electrons revolved around the nucleus without radiating energy; the idea was extended by Sommerfeld, who introduced further quantum numbers to allow a more general expression of quantum conditions.

In 1925 the work of the Göttingen physicists under Professor Born, on dispersion theory, led his team to question the physical reality of orbits and culminated in the revolutionary idea proposed by Heisenberg in which the orbit concept completely disappears and is replaced by matrices derived from the Fourier amplitudes of the motion. This allowed, for the first time, accurate predictions concerning the lifetime of the Bohr quantum states to be made.

In parallel with this work the development of a wave-mechanical theory of matter was carried out by Schrodinger on the analogue between optics and mechanics, and this new concept was joined to that of relativity by Dirac's theory of the spinning electron.

Figure 27: Tousehek's handwritten letter to Max Born, and a Glasgow Herald article about the lecture he held at the Glasgow Physics Institute. Courtesy of Churchill Archives Center of Churchill College, Cambridge University.

table scientists in Born's possession which Tousehek wished to use for 'a chatty talk' on the historical development of quantum mechanics he had been asked to give at the Glasgow Physics Institute. In Fig. 27 we show the scheme he sent to Born, together with a Glasgow Herald cutting about the talk. A long silence follows after this, as no other letters appears to have been exchanged.

On November 6th, Tousehek writes that he is moving to Rome shortly, and would like to visit Born and his wife, once more. To which Born replies on November 10th, in a somewhat reproachful way, that he had heard of Tousehek's move, and congratulates him for the new position. Adding his hope that Tousehek will be happy there, he also comments that 'to live in Rome, alone, is a great privilege'. He will try to find a time to see him, among all his engagements, such as the Gifford lectures taking place in Edinburgh. Born's letter ends by saying that they (himself and Mrs. Born) are 'quite well, apart from getting old and always being tired'. Then, in a last letter written just on the following day, concerned that his previous message had not been sufficiently welcoming, he urges Tousehek to come, adding, as an inducement, that he would like Tousehek to explain him a recently published paper by Heisenberg (Heisenberg 1952). Born was going to give a lecture on Heisenberg's work in the coming month of December, in London, and since Heisenberg referred to Born's old non-linear electrodynamics, he wished to mention something about it. Born confesses that despite his efforts he has not been able to understand Heisenberg's work, but hopes Tousehek knows something about the matter. It is amusing to compare Born's comments with the interest these papers have generated through the years: Heisenberg's paper has received continuous attention since the time

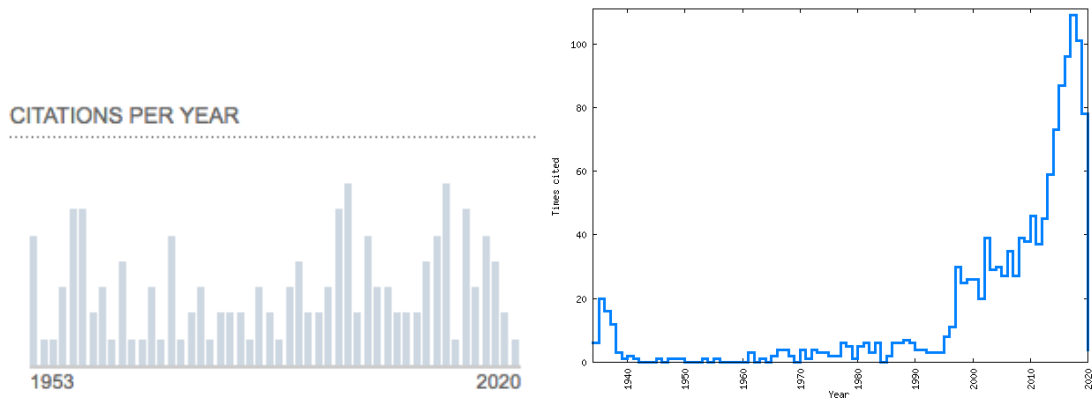


Figure 28: The figure shows, at left, the impact of Heisenberg’s 1952 paper (Heisenberg 1952) mentioned by Max Born in the 11th November, 1952 letter to Bruno Touschek, and, at right, the impact of Born and Infeld’s article (Born and Infeld 1935), cited by Heisenberg. The plots are a 2020 citation analysis from the repository <http://inspirehep.net>.

of his publication, and Born’s non linear electrodynamics work (Born and Infeld 1934; 1935), has recently been subject of growing interest, as one can see from the 2020 citation results for Heisenberg and Born’s papers in Fig. 28.

In conclusion, as we shall see in detail in the following pages, the long intervals in the Born-Touschek correspondence both in the summer of 1951 and more so in summer 1952, may have been related to Touschek reluctance to tell his friend and mentor that he was going away, abandoning Scotland, the frequent visits to Edinburgh, the warm friendship between them, the train rides through the countryside from West to East and back, afternoon ‘high tea’ at the Borns’ home, the intellectual stimulus of Born’s genius and his Seminar. He was focusing to find a position in Italy and leave Glasgow. As he wrote to his parents, he was planning ‘betrayal’ and could not face to tell his mentor. The Oxford option had not worked out, and possibilities to go to Germany had either dried out or were not sufficiently appealing. For reasons which included both his physics interests and personal story, it was to Italy that he chose to go. In the sections to come, we shall try to unravel the motivations and the possibilities which made him decide to go South.

4.3 Planning betrayal

In this section we shall return to 1950, and to the three full years Touschek spent in Glasgow after his doctorate and how his decision to leave the UK matured.

Indeed, only a few months into his position as Lecturer, Bruno was finding the atmosphere in Glasgow rather stifling and was trying to see how to escape from it. His physics interests were also leading him more and more into theoretical particle physics, and Glasgow was not offering sufficient stimulus. He had slowly lost interest in the Glasgow synchrotron program, which was stagnating. The building was growing and growing, but Touschek had no more interest in just having the synchrotron built, probably for lack of enthusiasm in the physics program. He could envisage the synchrotron to be finished in one or, rather, two more years, and then what? What to look for? Which new programs could be seen as natural follow-up to the 300 MeV synchrotron? In Glasgow, Touschek mused, only Dee was still interested in the project, everybody else was reading Nature’s jobs openings and looking for positions elsewhere.



Figure 29: Ian Sneddon being presented to H.M. Queen Elizabeth by the Principal, Lord Lindsay, at the formal opening of the University College of North Staffordshire, later to become the University of Keele, on 17 April 1951 from (Chadwick 2002).

Touschek was right in feeling that the UK was not offering him much of a way forward. In two years, by 1952, when the Glasgow synchrotron could be close to start operating, European physicists in the continent would be ready for the challenge of building a large international laboratory, such that it could possibly house much more powerful accelerators. In the department in Glasgow, the atmosphere was changing as well. Touschek's friend and collaborator Ian Sneddon was leaving, first for the United States, then for a new position in Staffordshire. We show a photograph of Ian Sneddon in 1951 in Fig. 29. Mostly because of the Fuchs affair, this road was hardly open to Bruno. He regretted to have refused a position in Göttingen the previous year, but he now decided he did want to leave and would use the summer to look for a job in the Continent. The winter climate did not help, of course, nor did the town, which did not offer much entertainment, the only exception being the occasional evening at the cinema, and this as well was often depressing if not making him dizzy with boredom.¹⁰⁶

To get over his low spirits, Bruno started a detailed planning for the summer, something which always helps to overcome winter blues. In 1947, he had stayed around Glasgow for his first summer (occasionally swimming in Loch Lomond and nearby places), in 1948 he had gone harvesting to the Northernmost part of Scotland, while in 1949, as travel restrictions to Austria were eased, he spent a full month in Tyrol with his parents. Now it was the time for his first vacation as a Lecturer, and not as a research student. The plan was to be again in Tyrol, even organize a stay for Professor and Mrs. Gunn, but not only. He was really planning betrayal.¹⁰⁷ Soon after obtaining his doctorate he had already started thinking about looking for a position in the continent, now he was going to work on it. In June the summer program was completed: 20.6–9.7 in Göttingen; 10.7–18.8: Ty-

¹⁰⁶Letter to parents March 21st, 1950. He also mentions having been rather annoyed by the movie *Gioventù perduta*, by Pietro Germi (1947).

¹⁰⁷Letter to parents on March 21st, 1950.

rol and surroundings; 18.8–25.8: Hamburg and surroundings [Umbegeung]; 26.9–18.9: Copenhagen.¹⁰⁸

The 1950 summer plans included, for the first time, a very long absence from Glasgow, a three months leave, of which almost one month to be spent in Göttingen, and then visiting Hamburg and Denmark, following Bohr's invitation in November 1949. In Tyrol he was with his family, but was also part to a small private conference in Hans Thirring's house in Kitzbühel, as mentioned in one of Touschek's letters to Born.¹⁰⁹

The Gunns' planned vacation in Tyrol took place during this extended visit as well.¹¹⁰ M. J. Gunn, Gunn's son born in 1954, remembers his father often talking about Touschek: "– it was clear he liked Bruno and he had been a lively figure in the department in Glasgow. I heard the story about his escape from the Gestapo (or SS?) during that period. I [also] remember hearing about the Tyrol trip. It was my mother's first trip abroad. My father was more adventurous than sensible – so one of their walks was on their hands and knees across a glacier".¹¹¹

Bruno arrived in Copenhagen on August 31.¹¹² But he was unwell, having caught a very annoying ear infection, and could hardly enjoy his visit. Notwithstanding the rain and himself being sick, he liked very much the city and was anxious for a bit of good weather to tour around. Unfortunately the language was a hard barrier to overcome, as neither his native German nor his quite good English could help.¹¹³ During all this time, Touschek was also keeping a close correspondence with Arnold Sommerfeld. He had planned to visit him in Munich, on his way back from the Austrian vacation, but it did not happen, and Touschek apologized to him in letter on October 5th.¹¹⁴

While planning betrayal, Touschek had also decided it was time to move out of Dee's house and find his own home. Since he was leaving for the entire summer, this was particularly easy. Thus, back from his extended leave, while he is still writing to Max Born from 11, The University, on September 29th, we find him writing from 51 Oakfield Avenue on October 26, announcing Thirring's presence and his house move. A detailed drawing of his room is shown in Fig. 30, together with a contemporary view of 61 Oakfield Avenue, the residence listed in the University records for the 1950-51 academic year.

4.4 A visit from Walter Thirring

In Fall 1950, an important development in Touschek's theoretical works, took place. Such development was stimulated by a visit by the young theorist, Walter Thirring.

Since his arrival, Touschek's scientific interests had shifted from accelerator physics towards particle physics, where a new world was opening through the experiments made possible by post-war accelerators, such as synchrotrons. The new experiments allowed to observe particle interactions in laboratory settings. Unlike the case of cosmic rays

¹⁰⁸Handwritten letter to parents June 23rd, 1950.

¹⁰⁹Letter to Born, September 29th, 1950. Courtesy of the Churchill Archives Center, Cambridge, UK.

¹¹⁰In November 1950 letter to his parents, Touschek mentions that the Gunns had very much enjoyed the visit.

¹¹¹Private e-mail communication to G. P. by Prof. M.J. Gunn, February 17th, 2020.

¹¹²See letter to parents from Copenhagen, with handwritten date hard to read, 1950, September or October 6th, likely to be September 6th, since he writes to Born from Glasgow at the end of September.

¹¹³Letter to parents from Copenhagen, September 6th, 1950, as discussed in previous note.

¹¹⁴Bruno Touschek to Arnold Sommerfeld, October 5th, 1950 Deutsches Museum Archiv, NL 089, 013

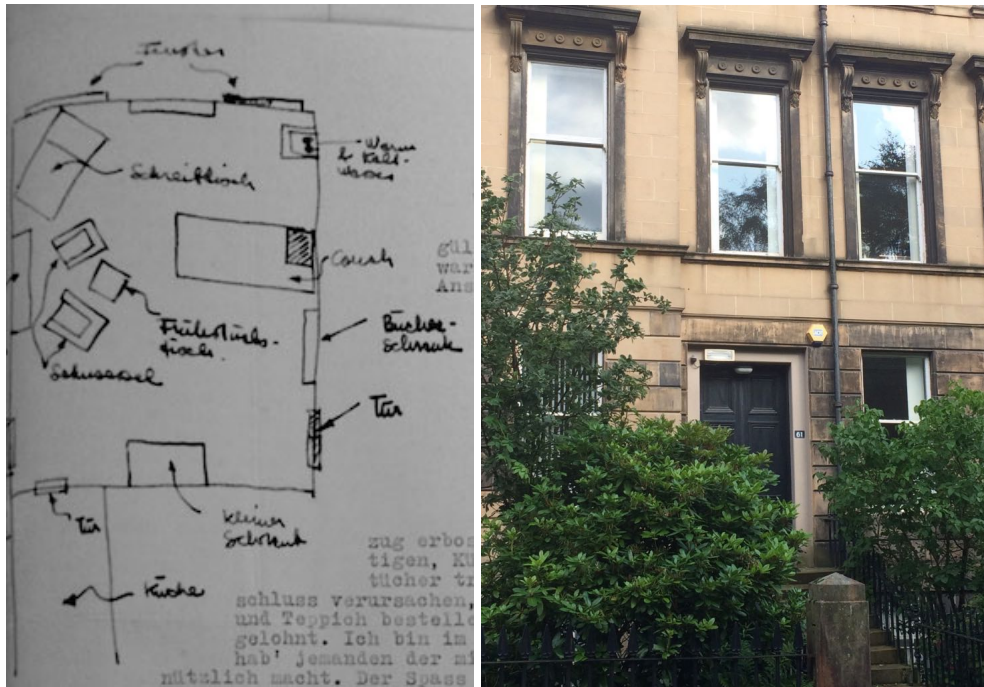


Figure 30: At left we show a drawing by Bruno Touschek which describes the layout of his new lodging at 61 Oakfield Avenue, in Glasgow, extracted from a November 1950 letter to his parents. Courtesy of Mrs. Elspeth Yonge Touschek. The right panel shows a contemporary view of 61 Oakfield Avenue, photograph by G.P. August 8th, 2019.

physics, where particles come from the sky and their origin is outside the experimenter's control, accelerators allowed a choice of projectile and target, electrons or protons, and their energies could be controlled. As physicists say, the initial state is known, and the observation of the scattered particles (the final state), can give precise information on what happened during the transition. Thus, the interactions among elementary particles in the newly opened high energy regime could be studied with greater accuracies. New theoretical formulations and techniques were developed, and took central stage, as infinities plaguing the calculation of scattering processes were being cured by including virtual scattering processes in the calculation, in a combination of relativistic field theory and perturbation theory.¹¹⁵ The covariant formalism, in which relativity is formulated, made calculations more transparent and became the new language of particle physics.

It is in this scenario, that Touschek started looking again at an old problem, the so called "infrared catastrophe", discussed in a seminal paper by Felix Bloch and Arnold Nordsieck, in 1937. This problem needed to be reformulated in modern language, namely through the new covariant formulation, and the occasion to do so was the visit of Walther Thirring from Vienna, with a Nuffield Fellowship. Walther Thirring was the son of Hans Thirring, whose lectures Touschek had attended during the war, in occasion of his visits to Vienna.¹¹⁶ During the summer, Bruno had learnt of the young man's travels from Vienna, first to Dublin with Schrödinger, and then to Glasgow. He held him in great consideration, as the most brilliant young theoretician in all of Europe, and had been looking forward to

¹¹⁵See also David Kaiser's *Drawing Theories Apart: The Dispersion of Feynman Diagrams in Postwar Physics* (Kaiser 2005, 53).

¹¹⁶For Walther Thirring's comments about Touschek, see Thirring's autobiography (Thirring 2008).

welcome him in Glasgow.¹¹⁷

Walter Thirring arrived in October 1950.¹¹⁸ It was an extremely busy time for Bruno. He had never before taken full responsibility for his lodgings, the furnishing, the cleaning, procurement of food. The many house caring activities engulfed him during October and November. All this had to be done in addition to looking after his research student, going to Edinburgh with Thirring, and, most of all, working with Thirring on the problem of the Bloch and Nordsieck method, writing the paper. They submitted it on November 29th to the *Philosophical Magazine*, where it was published in March 1951 (Thirring and Touschek 1951). This paper is very important in Touschek's future thinking about electron accelerators: after AdA's proof of feasibility in 1961, Touschek planned the construction of a much more powerful electron positron accelerator, ADONE. Because of the much higher energy range of the new machine, the extraction of physics results was connected to the Bloch and Nordsieck theorem, and, in 1964, Touschek started on the problem of summing the infinite number of soft photons emitted before and after the collisions.¹¹⁹

Thirring left in early December 1950, barely after only 2 months, and Touschek started again feeling that Glasgow could not offer the type of environment he sought. The joys and pains of teaching were also hitting him. Students sometimes complained about difficulties in his course, or he felt that his research students were too slow and lazy to carry through some new research lead he gave them. In February, he observed with some amusement the frolics on the occasion of the 500th anniversary of the University of Glasgow foundation, when the students behaved 'pleasantly ghastly' and threw eggs and rolls of toilet paper at the Senate.¹²⁰

4.5 The Southern way

After Thirring left, Touschek started looking for a position elsewhere, in Switzerland, with a new institution created by UNO – CERN, perhaps – or in Germany, in Munich, but only if Heisenberg were to move there. He expressed all these hopes and plans in his letters home. The stays in Europe during the summer made winters in Glasgow harder to bear. Max Born was going to retire in one or two years and planned to go back to Germany, so did many others. As we have seen from the correspondence with Born, in the spring, Touschek aimed for a Senior Lectureship position in Oxford, but nothing came of it. The solution were to come from a different direction, through the Italian theorist Bruno Ferretti, who, at the turn of the 1950s, was already deeply involved together with Edoardo Amaldi in discussions about the foundation of CERN (Hermann et al. 1987, 67).

The association between Touschek and Ferretti follows rather standard research channels. It is possible that the two of them met in 1947 in Birmingham, where Ferretti was giving a course and working with Peierls.

Bruno spoke Italian, an easy way to start talking to Ferretti. The occasion could have been the fact that Ferretti and Peierls were working on radiation damping, the phenomenon by which an accelerated electron loses energy by radiation (Ferretti and Peierls

¹¹⁷Letter to parents, November 1950.

¹¹⁸See Born-Touschek correspondence vs September or October, according to Amaldi.

¹¹⁹This problem led Touschek to train a group of young theoretical physicists recently graduated from University of Rome, as described (in Italian) in [Frascati e la fisica teorica](#).

¹²⁰The letter to parents is dated February 12th, without the year, but mentions the 500 year anniversary of the university, which was founded in 1451.



Figure 31: From left, Felix Bloch, Bruno Ferretti, Homi J. Bhabha, Wolfgang Pauli, at the 1948 Solvay Congress. CERN Pauli-Archive-Photos PHO-063-1 <https://cds.cern.ch/record/42752/files/063.jpg?subformat=icon-1440>.

1947), and a problem which had interested Touschek since the war days. Bruno may have read and studied Ferretti and Peierls' paper and approached them about the article. However in summer 1947, when the article had appeared, Touschek may not have been thinking much about Italy, and he was still a first year research student, hardly in confidence with a well known senior scientist such as Rudolf Peierls, later his PhD external examiner, or his guest Bruno Ferretti. Ferretti appears in Fig. 31, a photograph taken at the 1948 Solvay Congress, attended by all the best theoretical physicists of the time.

The connection between Touschek and Ferretti was certainly established or enforced in spring 1951, when Touschek saw one of Ferretti's papers in *The Nuovo Cimento* (Ferretti 1951), which particularly interested him. Soon after, he wrote, and submitted for publication, his own article citing Ferretti's (Touschek 1951). From this to start writing to Ferretti about physics is just an obvious step, and either before or after Touschek's article, the possibility of meeting Ferretti in Rome during the upcoming summer vacation for a scientific discussion, arose. A visit to University of Rome was likely included in his summer plans. At the same time, independently of physics interests, the visit to Rome would allow to resume contact with his aunt Ada, as he had been thinking of Italy and the holidays spent in Rome before the war, at her beautiful apartment in the Parioli neighbourhood.

The visit to Rome took place in mid July 1951,¹²¹ and it is conceivable that a meeting between Touschek and Ferretti in the Physics Institute in Rome had been foreseen to discuss physics questions. A description of their first meeting in Rome is given in (Amaldi 1981, 13): “[In September 1952] Touschek went to visit Ferretti at University of Rome. A few hours after their first meeting, spent discussing mutual scientific questions, they established such marked professional respect and personal attachment for each other that

¹²¹Letter to parents, June 25th, 1951.

Touschek decided to remain permanently in Rome.” These lines give a very vivid picture of Touschek and Ferretti’s encounter, except that Amaldi places it in September 1952. However, from Touschek’s accurate descriptions of the 1951 and 1952 summer travels in letters to his parents, a visit to Rome in 1952 is unlikely, whereas he was certainly planning to be in Rome in July 1951. Our conclusion is that Touschek and Ferretti met in Rome in July 1951, discussed physics together and the idea of applying for a position in Rome came up. As recalled by Amaldi, “It was mainly Ferretti’s personality that, in 1952, attracted and permanently fixed in Rome an occasional visitor, Bruno Touschek [...] (Amaldi 1979b, 441). Following the extended European tour, a correspondence took place between the two of them about such possibility, but the thing needed time to be perfected.¹²² There was in fact the question of giving notice to University of Glasgow, and properly tie the end of Touschek’s commitment to Glasgow with the new position he was hoping to have in Rome. The details were probably worked out through such correspondence, mentioned in Touschek’s letters home, but with no other records.

Christmas and New Year came, and brought very cold days. In January 1952 it was so cold that the water in the bathroom would freeze.

His unhappiness about the weather was not made better by his getting a cold around Christmas time. It forced him to stay home, and not be able to attend the Dees’ party. Christmas and New Year Day were thus terribly boring, and many small problems aggravated his spirit. Taxes to prepare, rations to obtain, writing a chapter of a book with Gunn he could not really enjoy doing, and again the cold, made him unhappy and discontent. In between, always a keen sportsman, he would not neglect some winter outing, such as going to ski with Mrs. Gunn. Fig. 32 shows his visual commentary of the snowy winter.

He went on with his teaching, and caring for his students, but as the spring came he knew he would be going away, either to Italy or somewhere else. In late August, possibly after the usual vacation in Tyrol, Touschek went down to Milan from Austria, through the Brenner pass. The program, included a visit to University of Milan. No explanation is given as to the reason for such visit, however, some physicists of that University had established a laboratory devoted to the development of applied nuclear physics, CISE (Centro Informazioni, Studi ed Esperienze), in which Ferretti and other physicists from University of Rome, where he was a Professor, were also involved (Amaldi 1979a, 58). Thus, Touschek’s visit appears to have been planned to take advantage of Ferretti’s presence in Milan at this time, and to discuss the details of the planned engagement with the University of Rome. Touschek had not yet decided whether to get one year unpaid leave from Glasgow, or resign from his Lecturer position and he needed to clarify salary questions related to either option. After a couple of days in Milan, he crossed into Switzerland through the Gotthard Pass, and reached Bern, where he received a letter from Ferretti who wrote he would agree to the postponement demanded by Glasgow until the first of January.¹²³ In the meanwhile, Touschek was also seeking some other possibility, like a fellowship with UNESCO, which Heisenberg could try to get for him in case of need, or a Lectureship in Bonn, which Wolfgang Paul could support.

On September 15th, the situation cleared up when Amaldi, then head of the Rome branch of the National Institute for Nuclear Physics (INFN), wrote officially to Bruno offering a one year (renewable) position, adding that in case of need, one month salary

¹²²Letter to parents, November 8th, 1951

¹²³Letter to parents, September 10th, 1952.



Figure 32: A drawing from a January 27th, 1952 letter. Graphics by A. Ianiro. Courtesy of Mrs. Elspeth Yonge Touschek.

could be advanced to him.¹²⁴ It is of interest to see Amaldi's list of Touschek's expected duties, namely: a) research work in theoretical physics, b) discussions and advice to experimental physicists working on cosmic rays and possibly accelerators; c) not more than two hours per week of teaching to advanced students in theoretical physics.

Touschek in the meanwhile had decided to resign from Glasgow, thus solving the problem of missing salary and, on September 23rd, 1952, Touschek replied to Amaldi accepting the offer. The final exchange of letters put Bruno on his way to Rome, sealing his future and leading him to conceive AdA less than 10 years later. Bruno's future was now traced. He would be immersed in a unique moment of hopes and dreams, when all seemed possible, and when much was indeed accomplished. In the 1950's Italy, which had been unified from North to South only in 1870, which had given access to vote to every citizen, women and men, only in 1946, entered into a period of great cultural, economic and political development, which led to what was later known as the *Miracolo italiano* of the 1960's.¹²⁵

As one leaves this part of Touschek's life, which represents one of the many roads ultimately leading to particle colliders, the UK road, we show a 1952 photo of the Physics Faculty from the Department of Natural Philosophy of University of Glasgow, with Bruno

¹²⁴The newly founded institute was bypassing some of the bureaucracy inherent at the time in University administration. Such possibilities, one month advanced salary, would in fact be unheard of in the regular university administration. For the history of INFN see (Battimelli et al. 2001).

¹²⁵Italy had been unified into a political entity from North to South in 1870, Rome becoming the capital city of the new Italian state on February 3rd, 1871. The Italian Miracle, as it was called, signalled the full transformation of Italy into a modern state, economically competing with other European nations.



Figure 33: The physics faculty at University of Glasgow in 1952, with Philip Dee at the center, and Bruno Touschek seated at right, from <https://universitystory.gla.ac.uk/images/UGSP01004.jpg>.

Touschek at right in the front row, in Fig. 33. A few months later, he left.

When Bruno Touschek arrived in Rome, it was the end of the year. He had left Glasgow where winter brought early darkness and freezing cold, and after a brief stay in Bern, crossed the Alps through Switzerland, and was charmed by warmer weather and the Roman food. As it often happens to travellers from Northern lands, he found he did not need to walk fast to keep warm, rather he needed to slow down his nordic walking, and must have welcomed the lighter days of the Rome winter. On his arrival he dutifully visited his aunt Ada, and was housed in a nice family pension near the University, booked for him through the Physics Institute. He found the Institute really excellent, with no feeling of estrangement, as he met there Patrick Blackett whom he knew from Glasgow and Wolfgang Pauli whom he knew from Göttingen. He also found the colleagues from the Institute very interesting and welcoming.¹²⁶

Bruno's life had been broken, but it was now being pieced together again. Physics in Italy was fully flourishing and the future there looked really exciting. He felt ready for a great adventure.

5 Sources and acknowledgements

Since 2002, a main primary source has been the Bruno Touschek papers kept at the “Edoardo Amaldi Archives” of the Physics Department at Sapienza University in Rome as well as contacts with Bruno Touschek's widow, Mrs. Elspeth Yonge Touschek, who gave us access to important personal material in her possession about Touschek's life. In particular, until 2013, when she unfortunately passed away, Elspeth shared with us many of the letters Touschek wrote to his parents during most of his life. L.B. had been visiting

¹²⁶Letter to parents, December 30th, 1952.

her and discussing a project for a docu-film [Bruno Touschek and the Art of Physics](#) about Bruno's life since 2003, one of us, G.P., had known her since 1966.

New information came from recent searches, and we acknowledge the courtesy of reproduction or consultation of the Archives of the Physics Department of Sapienza University in Rome (SUA), in particular Edoardo Amaldi (EAA) and Bruno Touschek (BTA) papers, and copies of Max Born correspondence with Bruno Touschek from [Churchill Archives Centre, The Papers of Professor Max Born](#) of Churchill College, Cambridge University (CHA), the Archives of the Deutsches Museum, Munich, Arnold Sommerfeld papers, the University of Glasgow Archives & Special Collections, University collection, GB 248 DC 157/18/56 (UGA) and Special Collections, and the Archives of Keele University Library.

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References

- E. Amaldi. The Years of Reconstruction. Part I. *Scientia*, 114:51–68, 1979a.
- E. Amaldi. The Years of Reconstruction. Part II. *Scientia*, 114:439–451, 1979b.
- E. Amaldi. *The Bruno Touschek legacy (Vienna 1921 - Innsbruck 1978)*. Number 81-19 in CERN Yellow Reports: Monographs. CERN, Geneva, 1981. doi: 10.5170/CERN-1981-019. URL <https://cds.cern.ch/record/135949/files/CERN-81-19.pdf>.
- E. Amaldi. *The Adventurous Life of Friedrich Georg Houtermans, Physicist (1903-*

- 1966). Springer-Verlag, Berlin Heidelberg, 2012. URL <https://doi.org/10.1007/978-3-642-32855-8>.
- Anonymous. Edinburgh Conference on Elementary Particles. *Nature*, 165(4185):54–56, 1950. doi: 10.1038/165054a0. URL <https://doi.org/10.1038/165054a0>.
- G. Battimelli, M. De Maria, and G. Paoloni. *L'Istituto Nazionale di Fisica Nucleare Storia di una Comunità di Ricerca*. Laterza, 2001.
- C. Bernardini and L. Bonolis, editors. *Enrico Fermi. His Work and Legacy*. Springer-Verlag, Berlin Heidelberg, 2004. URL <https://www.springer.com/de/book/9783540221418>.
- C. Bernardini, G. Pancheri, and C. Pellegrini. Bruno Touschek: From Betatrons to Electron-Positron Colliders. *Reviews of Accelerator Science and Technology*, 08:269–290, 2015. doi: 10.1142/S1793626815300133.
- F. Bloch and A. Nordsieck. Note on the Radiation Field of the Electron. *Physical Review*, 52(2):54–59, 1937. doi: 10.1103/PhysRev.52.54.
- L. Bonolis. Bruno Touschek vs. Machine Builders: AdA, the first Matter-Antimatter Collider. *La Rivista del Nuovo Cimento*, 28(11):1–60, 2005. doi: 10.1393/ncr/i2005-10006-x. URL <https://doi.org/10.1393/ncr/i2005-10006-x>.
- L. Bonolis. Bruno Rossi and the Racial Laws of Fascist Italy. *Physics in Perspective*, 13(1):58–90, 2011. doi: 10.1007/s00016-010-0035-4. URL <https://doi.org/10.1007/s00016-010-0035-4>.
- L. Bonolis and G. Pancheri. Bruno Touschek: Particle physicist and father of the e^+e^- collider. *European Physical Journal H*, 36:1–61, 2011. doi: 10.1140/epjh/e2011-10044-1.
- L. Bonolis and G. Pancheri. Bruno Touschek and AdA: from Frascati to Orsay. *arXiv e-prints*, arXiv: 1805.09434, May 2018. URL <https://arxiv.org/abs/1805.09434>.
- L. Bonolis and G. Pancheri. Bruno Touschek in Germany after the War: 1945-46. *arXiv e-prints*, arXiv:1910.09075, October 2019. URL <https://arxiv.org/abs/1910.09075>.
- M. Born. *Atomic Physics, 5th edition*. Blackie & Sons, Glasgow, UK, 1951.
- M. Born. *Atomic Physics, 7th edition*. Hafner Publishing Company - New York, 1962.
- M. Born and L. Infeld. Foundations of the new field theory. *Proceedings of the Royal Society London*, A144(852):425–451, 1934. doi: 10.1098/rspa.1934.0059.
- M. Born and L. Infeld. On the Quantization of the new Field Equations. II. *Proceedings of the Royal Society London*, A150(869):141–166, 1935. doi: 10.1098/rspa.1935.0093.
- W. Bosley, J. D. Craggs, W. F. Nash, and R. M. Payne. X-Radiation from a 20-Mev. Betatron. *Nature*, 161(4104):1022–1023, 1948. doi: 10.1038/1611022a0. URL <https://doi.org/10.1038/1611022a0>.

- S. G. Brush. History of the Lenz-Ising Model. *Reviews of Modern Physics*, 39(4):883–893, October 1967. doi: 10.1103/RevModPhys.39.883.
- C. C. Butler. Recollections of Patrick Blackett 1945-70. *Notes and Records of the Royal Society of London*, 53(1):143–156, 2020/03/04/ 1999. URL www.jstor.org/stable/531934.
- D. Cassidy. *Uncertainty. The Life and Science of Werner Heisenberg*. W. H. Freeman, 1993.
- D. Cassidy. *Farm Hall and the German Atomic Project of World War II*. Springer International Publishing, 2017. doi: 10.1007/978-3-319-59578-8.
- P. Chadwick. Ian Naismith Sneddon, O.B.E. 8 December 1919 – 4 November 2000. *Biographical Memoirs of Fellows of the Royal Society*, 48:417–437, 2002. URL www.jstor.org/stable/3650270.
- F. Close. *Half-Life: The Divided Life of Bruno Pontecorvo, Physicist or Spy*. Basic Books, New York, 2015.
- F. Close. *Trinity. The Treachery and Pursuit of the Most Dangerous Spy in History*. Penguin Random House UK, 2019.
- J. D. Cockcroft and E. T. S. Walton. Disintegration of Lithium by Swift Protons. *Nature*, 129(3261):649–649, 1932. doi: 10.1038/129649a0. URL <https://doi.org/10.1038/129649a0>.
- M. Conversi. From the Discovery of the Mesotron to that of its Leptonic Nature. In B. Foster and P. H. Fowler, editors, *40 Years of Particle Physics. Proceedings of the International Conference to Celebrate the 40th Anniversary of the Discoveries of the π - and V -particles, held at the University of Bristol, 22–24 July 1987*, pages 1–20, Bristol and Philadelphia, 1988. Adam Hilger.
- M. Conversi and O. Piccioni. Sulla disintegrazione dei mesoni lenti. *Il Nuovo Cimento (1943-1954)*, 2(1):71, 1944a. doi: 10.1007/BF02903046. URL <https://doi.org/10.1007/BF02903046>.
- M. Conversi and O. Piccioni. Misura diretta della vita media dei mesoni frenati. *Nuovo Cimento*, 2:40–70, 1944b. URL <https://doi.org/10.1007/BF02903045>.
- M. Conversi and O. Piccioni. On the Mean Life of Slow Mesons. *Physical Review*, 70 (11-12):859–873, December 1946. URL <https://doi.org/10.1103/PhysRev.70.859>.
- M. Conversi, E. Pancini, and O. Piccioni. On the Decay Process of Positive and Negative Mesons. *Physical Review*, 68(9-10):232–232, Nov 1945. doi: 10.1103/PhysRev.68.232. URL <https://link.aps.org/doi/10.1103/PhysRev.68.232>.
- M. Conversi, E. Pancini, and O. Piccioni. On the disintegration of negative mesons. *Physical Review*, 71(3):209–210, 02 1947. doi: 10.1103/PhysRev.71.209. URL <https://link.aps.org/doi/10.1103/PhysRev.71.209>.

- S. C. Curran. Philip Ivor Dee. 8 April 1904 – 17 April 1983. *Biographical Memoirs of Fellows of the Royal Society*, 30:140–166, 1984. URL <https://www.jstor.org/stable/769823>.
- S. C. Curran, J. Angus, and A. L. Cockcroft. Beta spectrum of tritium. *Nature*, 162(4112): 302–303, 1948. doi: 10.1038/162302a0. URL <https://doi.org/10.1038/162302a0>.
- R. J. Eden. The analytic behaviour of Heisenberg's S matrix. *Nature*, 165(4185):54–56, October 1949. doi: 10.1038/165054a0. URL <https://doi.org/10.1038/165054a0>.
- F. R. Elder, A. M. Gurewitsch, R. V. Langmuir, and H. C. Pollock. A 70Mev Synchrotron. *Journal of Applied Physics*, 18(9):810–818, 2020/03/05 1947. doi: 10.1063/1.1697845. URL <https://doi.org/10.1063/1.1697845>.
- R. Elliott and J. H. Sanders. Maurice Henry Lecorney Pryce. 24 January 1913 - 24 July 2003. *Biographical Memoirs of Fellows of the Royal Society*, 51:355–366, 2005. doi: 10.1098/rsbm.2005.0023. URL <https://doi.org/10.1098/rsbm.2005.0023>.
- E. Etim, G. Pancheri, and B. Touschek. The infra-red radiative corrections for colliding beam (electrons and positrons) experiments. *Il Nuovo Cimento B*, 51(2):276–302, 1967. URL <https://link.springer.com/article/10.1007%2FBF02712050>.
- E. Fermi, E. Teller, and V. Weisskopf. The Decay of Negative Mesotrons in Matter. *Physical Review*, 71(5):314–315, Mar 1947. doi: 10.1103/PhysRev.71.314. URL <https://doi.org/10.1103/PhysRev.71.314>.
- B. Ferretti. The Absorption of Slow Mesons by an Atomic Nucleus. In *Report of an International Conference on Fundamental Particles and Low Temperatures, held at the Cavendish Laboratory, Cambridge, on 22 /27 July 1946*, volume 1 . Fundamental Particles, pages 75–77, London, 1947.
- B. Ferretti. Sulla cattura atomica dei mesoni lenti. *Il Nuovo Cimento (1943-1954)*, 5(4):325–365, 1948. doi: 10.1007/BF02784466. URL <https://doi.org/10.1007/BF02784466>.
- B. Ferretti. Sulla diagonalizzazione della hamiltoniana nella teoria dei campi d'onda e sulla teoria dei sistemi chiusi. *Il Nuovo Cimento (1943-1954)*, 8(2):108–131, 1951. doi: 10.1007/BF02773048. URL <https://doi.org/10.1007/BF02773048>.
- B. Ferretti and R.E. Peierls. Radiation Damping Theory and the Propagation of Light. *Nature*, 160(4068):531–532, 1947. doi: 10.1038/160531a0. URL <https://doi.org/10.1038/160531a0>.
- W. Fletcher. Sir Samuel Crowe Curran. 23 May 1912 – 25 February 1998. *Biographical Memoirs of Fellows of the Royal Society*, 45:95–109, 1999. doi: 10.1098/rsbm.1999.0008. URL <https://royalsocietypublishing.org/doi/abs/10.1098/rsbm.1999.0008>.
- D. W. Fry, J. W. Gallop, F. K. Goward, and J. Dain. 30-Mev. Electron Synchrotron. *Nature*, 161(4092):504–506, 1948. doi: 10.1038/161504a0. URL <https://doi.org/10.1038/161504a0>.

- M. Goeppert Mayer. On Closed Shells in Nuclei. *Physical Review*, 74:235–239, Aug 1948. doi: 10.1103/PhysRev.74.235. URL <https://link.aps.org/doi/10.1103/PhysRev.74.235>.
- M. Goeppert Mayer. On Closed Shells in Nuclei. II. *Physical Review*, 75(12):1969–1970, 06 1949. doi: 10.1103/PhysRev.75.1969. URL <https://link.aps.org/doi/10.1103/PhysRev.75.1969>.
- F.K. Goward and D.E Barnes. Experimental 8 Mev. Synchrotron for Electron Acceleration. *Nature*, 158, 1946. URL <https://doi.org/10.1038/158413a0>.
- J. C. Gunn and H. S. W. Massey. Interaction of Mesons with a Potential Field. *Proceedings of the Royal Society of London. Series A. Mathematical and Physical Sciences*, 193(1035):559–579, 1948. doi: 10.1098/rspa.1948.0062. URL <https://royalsocietypublishing.org/doi/abs/10.1098/rspa.1948.0062>.
- O. Haxel, J. H. D. Jensen, and H. E. Suess. On the "magic numbers" in nuclear structure. *Physical Review*, 75(11):1766–1766, 06 1949. doi: 10.1103/PhysRev.75.1766.2. URL <https://link.aps.org/doi/10.1103/PhysRev.75.1766.2>.
- W. Heisenberg. Die "beobachtbaren Größen" in der Theorie der Elementarteilchen. *Zeitschrift für Physik*, 120(7):513–538, 1943a. doi: 10.1007/BF01329800. URL <https://doi.org/10.1007/BF01329800>.
- W. Heisenberg. Die beobachtbaren Größen in der Theorie der Elementarteilchen. II. *Zeitschrift für Physik*, 120:673–702, 1943b. doi: 10.1007/BF01336936. URL <https://doi.org/10.1007/BF01336936>.
- W. Heisenberg. Die beobachtbaren Größen in der Theorie der Elementarteilchen. III. *Zeitschrift für Physik*, 123(1):93–112, 1944. doi: 10.1007/BF01375146. URL <https://doi.org/10.1007/BF01375146>.
- W. Heisenberg. Mesonenerzeugung als Stosswellenproblem. *Z. Phys.*, 133:65, 1952. doi: 10.1007/BF01948683.
- W. Heisenberg. Professor Max Born. *Nature*, 225(5233):669–671, 1970. doi: 10.1038/225669a0. URL <https://doi.org/10.1038/225669a0>.
- W. Heitler. The Quantum Theory of Damping as a Proposal for Heisenberg's S-Matrix. In The Physical Society, editor, *Report on an International Conference on Fundamental Particles and Low Temperatures, held at the Cavendish Laboratory, Cambridge, on 22-27 July 1946*, volume 1. Fundamental Particles, pages 189–194. Taylor & Francis, 1947.
- A. Hermann, L. Belloni, J. Krige, U. Mersits, and D. Pestre. *History of CERN. Launching the European Organization for Nuclear Research*, volume 1. North-Holland, 1987.
- N. Hu. On the Application of Heisenberg's Theory of S-Matrix to the Problems of Resonance Scattering and Reactions in Nuclear Physics. *Physical Review*, 74(2):131–140, 07 1948. doi: 10.1103/PhysRev.74.131. URL <https://link.aps.org/doi/10.1103/PhysRev.74.131>.

- M. Jacob. Gian-Carlo Wick. October 15, 1909–April 20, 1992. In *Biographical Memoirs*, volume 77, pages 333–349. The National Academies Press, Washington, DC, 1999. URL <https://www.nap.edu/catalog/9681/biographical-memoirs-v77>.
- D. Kaiser. *Drawing Theories Apart: The Dispersion of Feynman Diagrams in Postwar Physics*. The University of Chicago Press, Chicago and London, 2005.
- N. Kemmer and R. Schlapp. Max Born, 1882–1970. In *Biographical Memoirs of Fellows of the Royal Society*, volume 17, pages 17–52. Royal Society, 1971. URL <http://doi.org/10.1098/rsbm.1971.0002>.
- O. Klein. Mesons and Nucleons. *Nature*, 161(4101):897–899, 1948. doi: 10.1038/161897a0. URL <https://doi.org/10.1038/161897a0>.
- R. Kollath and G. Schumann. Untersuchungen an einem 15-MV-Betatron. *Zeitschrift für Naturforschung A*, 2(11-12):634–642, December 1947. doi: 10.1515/zna-1947-11-1205. URL <https://doi.org/10.1515/zna-1947-11-1205>.
- J. Krige. The Installation of High-Energy Accelerators in Britain after the War. Big Equipment but not “Big Science”. In M. De Maria, M. Grilli, and F. Sebastiani, editors, *The Restructuring of Physical Sciences in Europe and the United States, 1945–1960*, pages 488–497, Singapore, 1989. World Scientific.
- C. M. G. Lattes, H. Muirhead, G. P. S. Occhialini, and C. F. Powell. Processes Involving Charged Mesons. *Nature*, 159(4047):694–697, 24 May 1947. URL <https://doi.org/10.1038/159694a0>.
- J. D. Lawson. Early Synchrotrons in Britain, and Early Work for CERN. Technical report, CERN, 1997. URL <http://cds.cern.ch/record/340513>.
- L. Ledermann. Life in physics and the crucial sense of wonder. *CERN Courier*, 49(8): 22–24, 2009. URL <https://cds.cern.ch/record/1734431>.
- S. Lee. *Sir Rudolf Peierls. Selected Private and Scientific Correspondence. Vol. 1-2*. World Scientific, Singapore, 2007. doi: <https://doi.org/10.1142/5941>.
- S. Lee, editor. *Sir Rudolf Peierls. Selected Private and Scientific Correspondence*, volume 2. World Scientific, Singapore, 2009.
- B. A. C. Lovell. Patrick Maynard Stuart Blackett, Baron Blackett, of Chelsea, 18 November 1897–13 July 1974. *Biographical Memoirs of Fellows of the Royal Society*, 21: 1–115, 1975. doi: 10.1098/rsbm.1975.0001. URL <https://doi.org/10.1098/rsbm.1975.0001>.
- M. Mafai. *Il lungo freddo: storia di Bruno Pontecorvo, lo scienziato che scelse l'URSS*. Milan, Arnoldo Mondadori Editori, 1992.
- L. Maiani and L. Bonolis. The Charm of Theoretical Physics (1958–1993). *Eur. Phys. J. H*, 42(4-5):611–661, 2017. doi: 10.1140/epjh/e2017-80040-9.
- P. Marin. *Un demi-siècle d'accélérateurs de particules*. Éditions du Dauphin, Paris, 2009.

- E. M. McMillan. The Synchrotron—A Proposed High Energy Particle Accelerator. *Physical Review*, 68(5-6):143–144, 09 1945. doi: 10.1103/PhysRev.68.143. URL <https://link.aps.org/doi/10.1103/PhysRev.68.143>.
- U. Mersits. From Cosmic-Ray and Nuclear Physics to High-Energy Physics. In A. Hermann, J. Krige, U. Mersits, and D. Pestre, editors, *History of CERN. Launching the European Organization for Nuclear Research*, volume 1, pages 3–52. North-Holland, Amsterdam, 1987.
- G. Pancheri. Bruno Touschek and the Frascati Theory Group. In M. Greco and G. Pancheri, editors, *Bruno Touschek Memorial Lectures*, volume 33 of *Frascati Physics Series*, pages 101–103. INFN-Laboratori Nazionali di Frascati, 2004. URL <http://www.lnf.infn.it/sis/frascatiseries/Volume33/volume33.pdf>.
- G. Pancheri and L. Bonolis. Touschek with AdA in Orsay and the first direct observation of electron-positron collisions. *arXiv e-prints*, arXiv:1910.09075, December 2018. URL <https://arxiv.org/abs/1812.11847>.
- R. E. Peierls. *Birds of Passage. Recollections of a Physicist*. Princeton University Press, 1985.
- O. Piccioni. The Discovery of the Leptonic Property. In G. Baroni, L. Maiani, and G. Salvini, editors, *Present Trends, Concepts and Instruments of Particle Physics. Symposium in Honour of Marcello Conversi's 70th Birthday (Roma, 3-4 November 1987)*, volume 15, pages 171–193, Bologna, 1988. Italian Physical Society.
- M. Pinault. *Frédéric Joliot-Curie*. Odile Jacob, Paris, 2000.
- B. Pippard. Sir Nevill Francis Mott, C. H. 30 September 1905 – 8 August 1996. *Biographical Memoirs of Fellows of the Royal Society*, 44, 1998. doi: <https://doi.org/10.1098/rsbm.1998.0021>. URL <https://royalsocietypublishing.org/doi/10.1098/rsbm.1998.0021>.
- B. Pontecorvo. Nuclear Capture of Mesons and the Meson Decay. *Physical Review*, 72: 246–247, Aug 1947. doi: 10.1103/PhysRev.72.246. URL <https://link.aps.org/doi/10.1103/PhysRev.72.246>.
- B. Pontecorvo. *Enrico Fermi : ricordi di allievi ed amici*. Edizioni Studio Tesi, 1993.
- G. Puppi. Sui mesoni dei raggi cosmici. *Il Nuovo Cimento*, 5(6):587–588, 1948. doi: 10.1007/BF02780913. URL <https://doi.org/10.1007/BF02780913>.
- H. Rechenberg. The Early S-Matrix Theory and its propagation (1942-1952). In L.M. Brown, M. Dresden, and L. Hoddeson, editors, *Pions to Quarks. Particle Physics in the 1950s.*, pages 551–570. Cambridge University Press, Cambridge, 1989.
- R. A. Ricci. Remembering Gilberto Bernardini. *Europhysics News*, 26: 117–117, 1995. URL <https://www.europhysicsnews.org/articles/e pn/pdf/1995/05/e pn19952605p117.pdf>.

- G. D. Rochester and C. C. Butler. Evidence for the Existence of New Unstable Elementary Particles. *Nature*, 160(4077):855–857, 1947. doi: 10.1038/160855a0. URL <https://doi.org/10.1038/160855a0>.
- C. Rubbia. Edoardo Amaldi, 5 September 1908 – 5 December 1989. *Biographical Memoirs of Fellows of the Royal Society*, 37:1–31, 1991. doi: 10.1098/rsbm.1991.0001. URL <https://royalsocietypublishing.org/doi/abs/10.1098/rsbm.1991.0001>.
- G. Salvini. The role of Bruno Touschek in the Realization of the Proton Antiproton Collider. In M. Greco and G. Pancheri, editors, *Bruno Touschek Memorial Lectures*, volume 33 of *Frascati Physics Series*, pages 61–68. INFN-Laboratori Nazionali di Frascati, 2004. URL <http://www.lnf.infn.it/sis/frascatiseries/Volume33/volume33.pdf>.
- S. S. Schweber. *QED and the Men Who Made It: Dyson, Feynman, Schwinger, and Tomonaga*. Princeton University Press, 1994.
- E. Segrè. *A Mind Always in Motion. The Autobiography of Emilio Segrè*. University of California Press, Berkeley, 1993. URL <https://publishing.cdlib.org/ucpressebooks/view?docId=ft700007rb;query=;brand=ucpress>.
- I. N. Sneddon and B. F. Touschek. The Excitation of Nuclei by Electrons. *Proceedings of the Royal Society of London. Series A. Mathematical and Physical Sciences*, 193(1034):344–356, 2019/04/04 1948a. doi: 10.1098/rspa.1948.0050. URL <https://doi.org/10.1098/rspa.1948.0050>.
- I. N. Sneddon and B. F. Touschek. A Note on the Calculation of the Spacing of Energy Levels in a Heavy Nucleus. *Mathematical Proceedings of the Cambridge Philosophical Society*, 44(3):391–403, 1948b. doi: DOI:10.1017/S0305004100024397. URL <https://doi.org/10.1017/S0305004100024397>.
- I. N. Sneddon and B. F. Touschek. Nuclear Models. *Nature*, 161(4080):61–61, 1948c. doi: 10.1038/161061a0. URL <https://doi.org/10.1038/161061a0>.
- I. N. Sneddon and B. F. Touschek. Production of mesons by electrons. *Nature*, 163(4144):524–524, 1949. doi: 10.1038/163524a0. URL <https://doi.org/10.1038/163524a0>.
- A. Sørheim. *Obsessed by a dream. The Physicist Rolf Widerøe – a Giant in the History of Accelerators*. Springer, Cham, 2020. doi: 10.1007/978-3-030-26338-6. URL <https://doi.org/10.1007/978-3-030-26338-6>.
- B. V. Sreekantan. Homi Bhabha and Cosmic Ray Research in India. *Resonance*, 3(7):18–27, 1998. doi: 10.1007/BF02837309. URL <https://doi.org/10.1007/BF02837309>.
- The Physical Society and Cavendish Laboratory, editors. *Report of an International Conference on Fundamental Particles and Low Temperatures, held at the Cavendish Laboratory, Cambridge, UK, on 22-27 Jul 1946*, London, 1947. Physical Society and Cavendish Laboratory, Cambridge, England, The Physical Society.
- W. Thirring. *Lust am Forschen*. Seifert Verlag GmbH, Wien, 2008.

- W. E. Thirring and B. Touschek. A covariant Formulation of the Bloch-Nordsieck Method. *Philosophical Magazine*, 42(326):244–249, 1951. URL <https://doi.org/10.1080/14786445108561260>.
- J. Tiomno and J. A. Wheeler. Energy spectrum of electrons from meson decay. *Rev. Mod. Phys.*, 21:144–152, Jan 1949. doi: 10.1103/RevModPhys.21.144. URL <https://link.aps.org/doi/10.1103/RevModPhys.21.144>.
- B. Touschek. Excitation of Nuclei by Electrons. *Nature*, 160(4067):500–500, 1947. doi: 10.1038/160500a0. URL <https://doi.org/10.1038/160500a0>.
- B. Touschek. Zum analytischen Verhalten Schrödinger'scher Wellenfunktionen. *Zeitschrift für Physik*, 125(4-6):293–297, Apr 1948a. URL <https://doi.org/10.1007/BF01454900>.
- B. Touschek. Note on Peng's Treatment of the Divergency Difficulties in Quantized Field Theories. *Mathematical Proceedings of the Cambridge Philosophical Society*, 44(2): 301–303, 1948b. doi: DOI:10.1017/S0305004100024294. URL <https://doi.org/10.1017/S0305004100024294>.
- B. Touschek. Das Synchrotron. *Acta Physica Austriaca*, 3:146–155, 1949.
- B. Touschek. CXVIII. A Perturbation Treatment of Closed States in Quantized Field Theories. *The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science*, 42(333):1178–1184, 1951. doi: 10.1080/14786445108561363. URL <https://doi.org/10.1080/14786445108561363>.
- B. F. Touschek. An Estimate for the Position of the Lowest Dipole-Level of a Nucleus. *The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science*, 41(319):849–851, 08 1950. doi: 10.1080/14786445008561016. URL <https://doi.org/10.1080/14786445008561016>.
- S. Turchetti. *Il caso Pontecorvo*. Sironi Editore, 2007.
- S. Turchetti. *The Pontecorvo Affair: A Cold War Defection and Nuclear Physics*. Chicago:University of Chicago Press, 2012.
- Unknown. Physical Society : Meeting at Edinburgh. *Nature*, 163(4134):127–127, 1949. doi: 10.1038/163127c0. URL <https://doi.org/10.1038/163127c0>.
- V. Veksler. Concerning Some New Methods of Acceleration of Relativistic Particles. *Physical Review*, 69(5-6):244–244, 03 1946. doi: 10.1103/PhysRev.69.244. URL <https://link.aps.org/doi/10.1103/PhysRev.69.244>.
- H. von Halban, F. Joliot, and L. Kowarski. Liberation of Neutrons in the Nuclear Explosion of Uranium. *Nature*, 143(3620):470–471, 1939a. doi: 10.1038/143470a0.
- H. von Halban, F. Joliot, and L. Kowarski. Number of Neutrons Liberated in the Nuclear Fission of Uranium. *Nature*, 143(3625):680–680, 1939b. doi: 10.1038/143680a0. URL <http://dx.doi.org/10.1038/143680a0>.

- R. Widerøe. *The Infancy of Particle Accelerators. Life and work of Rolf Widerøe (edited by P. Waloschek)*. Vieweg +Teubner Verlag, Braunschweig, Germany, 1994. URL <https://doi.org/10.1007/978-3-663-05244-9>.
- R. Wilson. *Physics is Fun. Memoirs of a Life in Physics*. Richard Wilson, Department of Physics, Harvard University, 2011.
- E. Wolf. Recollections of Max Born. *Astrophysical Space Science*, 227, 1995. doi: <https://doi.org/10.1007/BF00678085>. URL <https://doi.org/10.1007/BF00678085>.