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Bruno Touschek in Germany after the War: 1945-46

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Abstract

Bruno Touschek was an Austrian born theoretical physicist, who proposed and built the first electron-positron collider in 1960 in the Frascati National Laboratories in Italy. In this note we reconstruct a crucial period of Bruno Touschek's life so far scarcely explored, which runs from Summer 1945 to the end of 1946. We shall describe his university studies in Göttingen, placing them in the context of the reconstruction of German science after 1945. The influence of Werner Heisenberg and other prominent German physicists will be highlighted. In parallel, we shall show how the decisions of the Allied powers, towards restructuring science and technology in the UK after the war effort, determined Touschek's move to the University of Glasgow in 1947.

Make it a story of distances and starlight

Robert Penn Warren, 1905-1989, ©1985 Robert Penn Warren

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Contents

Premise

The present note forms part of a project that aims to tell the story of Bruno Touschek, the maker of the first electron-positron collider, named AdA, Anello di Accumulazione[1], a type of elementary particle accelerator that opened the way to present-day machines, such as the CERN Large Hadron Collider.

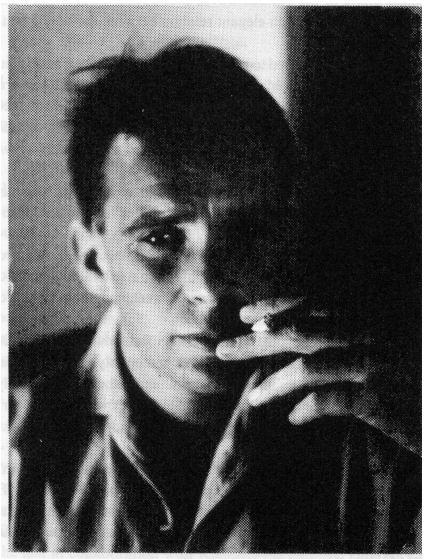

Figure 1: Bruno Touschek in 1955 from (Amaldi 1981).

Bruno Touschek, shown here at right in a 1955 photograph, Fig. 1, was born in Vienna, on February 7th 1921. In view of the approaching hundredth anniversary of his birth, we have already posted two notes which are part of this project (Bonolis and Pancheri 2018, Pancheri and Bonolis 2018). These notes cover the years 1961-1964, during which experimentation with AdA, built in Italy at the Frascati National Laboratories, took place, first in Frascati and then at Laboratoire de l'Accélérateur Linéaire d'Orsay, in France. In what follows we go back to an earlier period of Touschek's life, the one immediately following the end of World War II. This was a crucial transition time – for all of Europe. During these months, Touschek moved away from a war-related scientific activity, spent in semi-hiding in Germany because of his Jewish origin, and went on to become a physicist, under the guidance of the great German scientists assembled in Göttingen by the Western Allied Forces to support the reconstruction of European science. In a parallel move, the British scientists, who had actively participated in the war effort and had now engaged in the conversion of UK physics from a

[1] Storage ring in English

war context to new research and civil society applications, were instrumental in favouring Touschek's move to the University of Glasgow in 1947. Touschek's formation as a theoretical physicist was completed in Glasgow, later enabling his deep understanding of the symmetries of nature, which would lead to the AdA project in 1960. This period in Touschek's life will be narrated in another forthcoming note.

1 Introduction

On May 7th, 1945, with the official surrender of Germany, World War II came to its end in Europe.[2] The immense bloodshed and destruction that had overcome Europe were over.

Amid the million Europeans starting on a new road to peace and collaboration, there are the early protagonists of the story of electron-positron colliders, the Austrian Bruno Touschek and the Norwegian Rolf Widerøe. Bruno and Rolf had come together in 1943, during the darkest times of World War II and worked for two years on the 15-MeV German betatron, commissioned to Widerøe by the Reichsluftfahrtministerium (Reich Air Ministry) for, allegedly, war purposes (Amaldi 1981, Widerøe 1994, Bonolis and Pancheri 2011b).

Before, during and after the war, many pathways criss-crossed Europe to ultimately lead to the construction of AdA, the first ever electron-positron collider, built in Italy in 1960. Brought to Orsay in 1961, a Franco-Italian team under Touschek's guidance proved its feasibility as a major tool to explore the world of elementary particles.When Bruno and Rolf met, two of these pathways came together. One road came from Norway, the other from Central Europe, Austria and Germany. Then, after the war, the destinies of the two scientists took different ways. Between March and April 1945, as described in (Widerøe 1984), (Brustad 2009), and more in depth in (Sørheim 2015), Rolf Widerøe returned to Norway, where, in May, shortly after the German surrender, he was arrested and accused of having worked on the development of V2 rockets.[3] He wrote an extensive report on his work on the betatron construction in Hamburg and was released in July, but only in February 1946 it was clarified that his work had not been of any military value to Nazi Germany. However, he was burdened with financial penalties and was eventually allowed to move to Switzerland, where he took up a leading position at Brown Boveri & Co and applied his knowledge of accelerator science to medical developments.

As for Touschek, his mind and heart were now bent on regaining the lost years and finishing the studies he had started at the University of Rome in Spring 1939, after passing his high school exam, the *matura*, at the Staatsgymnasium I in Vienna in February 1939 (Amaldi 1981). In those years, after the *Anschluss*, namely the annexation of Austria to Germany, and the promulgation of the Nüremberg laws, his Jewish origin on the maternal

[2]The official date for the end of the war is different from country to country. In Italy for instance, the *Giorno della Liberazione*, the day of Liberation of Italy, is celebrated on April 25, which is the day the freedom fighters, *i partigiani* in Italian, entered Milan, whereas in Paris *la Libération de Paris* falls on 25 August 1944, which is the day the German command in France surrendered. In Asia, the war ended only after the second atomic bomb was dropped on Nagasaki, with Japanese forces surrendering on August 15th 1945.

[3]See letter from Widerøe to Ernst Sommerfeld from Baden, dated April 12, 1946. Deutsches Museum Archive, NL 089, box 014: "My question whirled up naturally a lot of dust and quite fantastic things were hypotesized (for example, I was supposed to have invented the V2)" (Meine Sache wirbelte natürlich sehr viel Staub auf und man vermutete ganz phantastische Sachen (beispielweise sollte ich angeblich die V2 erfunden haben)).

side had derailed his life and studies.[4] After an attempt to emigrate to England and study chemistry at the University of Manchester,[5] he had enrolled in physics at the University of Vienna in fall 1939, but, at the end of the academic year, he had been expelled from the University because of his Jewish origin. To continue his studies, as other possibilities were now closed to him, he moved out of Vienna, to Germany, where his (non-Jewish) last name could allow him to move around, *incognito*. There, in Hamburg and Berlin, from 1942 until 1945, he attended physics lectures, leading the life of a student without being one, trying not to be noticed by the omnipresent Gestapo. Once the war was over, at the end of 1945, he finally could try to fulfill his dream to become a physicist. After one year in Göttingen, Touschek went to Glasgow for 5 years, for his doctorate and three years of lecturing and research, and then moved to Rome, hired by Edoardo Amaldi, one of CERN's founding fathers, to do research in cosmic rays, theoretical physics and assist experimentalists in accelerator activities. When he arrived in Italy, in 1952, he joined the road of postwar reconstruction of Italian physics. This road, and the synchrotron, which would be built on the gentle slopes of the ancient hills overlooking Rome from the South-east, in the newly founded National Laboratories in Frascati, would bring him to propose the construction of AdA, the first ever accelerator for electron-positron collisions, an experiment, he said, "really worth doing".[6]

In what follows, we shall tell the story of Touschek in the transition period in Göttingen, from the end of the war in 1945 through 1946, when he was getting ready to join the University of Glasgow as a doctoral student. The present note focuses on a period of Touschek's life, so far not much explored. Starting with Bruno in Wrist in 1945 soon after the war ended, we shall go beyond what is known from (Amaldi 1981) and highlight the relevance of this early post-war period in Touschek's formation as physicist, through the impact of the German experience, first as a Diploma student and then as a researcher in Göttingen.

We shall start by recalling Touschek's life during the last months of the war, relying on the two letters, sent by Bruno Touschek to his parents in 1945, already published in (Bonolis and Pancheri 2011b), and which are part of a copious correspondence Touschek kept up with his family throughout his life. For the period to follow, our reconstruction is mainly based on documents from a number of public archives, such as, in particular, Edoardo Amaldi and Bruno Touschek Archives in Rome University, Arnold and Ernst Sommerfeld Archives at the Deutsches Museum in Munich, and Werner Heisenberg's papers at the Archives of the Max Planck Society in Berlin. In addition, we have consulted family documents to which we were given access by Bruno Touschek's widow, the late Elspeth Yonge Touschek, during a series of encounters between 2003 and 2011.

We had both been acquainted with Elspeth for quite some time. In 1966 and 1967, one of us, G.P., had been a researcher with Touschek's group at Frascati National Laboratories and had occasion to meet her, first in Rome, and later during a vacation in Positano. It was September 1966, and Bruno had invited the young researchers from his theory group, Paolo Di Vecchia, Giancarlo Rossi and G.P., to join him and the family for a few days of sun and swimming on the Amalfi coast (Greco and Pancheri 2005).

[4] On March 12th 1938, Austria was annexed to Germany, and on May 25th the German Nüremberg laws, affecting citizens of Jewish origin, were applied to Austrian citizens as well. These laws distinguished between various degrees of Jewish parentage. For a poignant memory of Vienna during the Anschluss, see (De Waal 2012).

[5] Letter to parents (father and stepmother), 20 March 1939, from Rome.

[6] See Minutes of Frascati Laboratories Meeting of Febuary 17, 1960 in (Pancheri and Bonolis 2018).

In May 1978, Touschek passed away. A few years later, G.P. had met again Elspeth and her son Francis in 1987, during the first edition of the Bruno Touschek Memorial Lectures, held in the INFN National Laboratories in Frascati. Later on, the other author of this note, L.B., interested in preparing a docu-film about Touschek on the occasion of 25 years since his death, started visiting Elspeth, who had now left the city to live in the countryside. Elspeth showed to L.B. letters, photographs and other documents, ranging from *circa* 1936 to 1971, and which were used in part for the docu-film *Bruno Touschek and the art of physics*, authored by E. Agapito and L. Bonolis in 2003, and in (Bonolis 2005).

In 2008, the two of us started preparing an article about Touschek's life and accomplishments (Bonolis and Pancheri 2011b), which could update Amaldi's biographical work (Amaldi 1981). We went to visit Elspeth together, and she shared with us some of her memories as well as additional letters and documents about Touschek's life, which were on her possession and which she had carefully organized in chronological ordering. The present narration, if not otherwise indicated, is based on our conversations with her and the material to which she gave us access. Before starting our narration, we wish to express our deep gratitude to Elspeth for bestowing on us her friendship.

2 Hamburg 1945: from death rays to post-war science

Widerøe's betatron had been built in Hamburg, at the C.H.F. Müller factory. But as the war entered into its final months, it became clear that it could be destroyed by the Allied heavy bombing or captured by advancing enemy troops, either the Western Alliance or the Soviet Army.

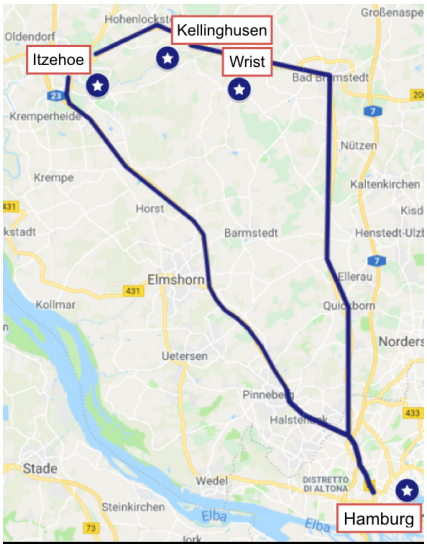

Figure 2: Touschek's movements in March 1945.

In March, the German Aviation Ministry ordered the betatron group to bring it to a safer location. A disused factory in Kellinghusen, in the surroundings of Wrist, a few kilometers north of Hamburg, was found, and the transport was over by mid-March. In Fig. 2 we show a map locating Touschek's movements in March 1945, as described in the October and November letters to his parents (Bonolis and Pancheri 2011b).

Immediately after the betatron was away and safe, Touschek was arrested by the Gestapo. This is what he had feared already two years before, when, in fall 1943, he had joined Widerøe's classified betatron project. Touschek saw that such involvement would expose him to the Gestapo, who would make inquiries and thus learn of his Jewish origin.[7] What he had feared was now happening: his usefulness over, the Gestapo was ready to arrest him, eventually sending him later to a concentration camp, as had happened to many technical or scientific employees in similar condition.[8] The events of his impris-

[7] Letter to parents, 29th October 1943, from Berlin.

[8] Amaldi, probably quoting Touschek, mentions his reading foreign papers in a public library, as the reason for his imprisonment (Amaldi 1981). A slightly different story comes from Carlo Bernardini, Tou-

onment and those immediately following it, have been part of Touschek's legend. Their general outline was presented by Edoardo Amaldi, who heard the story from Touschek himself, and included it in (Amaldi 1981). The details are now known from two letters he wrote to his parents, the first on June 22nd and the second on November 17th 1945, published in English translation in (Bonolis and Pancheri 2011b). From these, one learns, first hand and just as memories were still vivid and precise, the sequence of almost miraculous events which allowed Touschek to escape death and which we summarize below for convenience of the reader.[9]

In the October and November letters, Touschek recounts how he was held in the infamous Fuhlsbüttel prison near Hamburg from March 15th until mid April 1945. After a first week of hardship and despair, during which he even considered suicide, he was able to receive visits from Rolf Widerøe, who was still in Germany.[10] Bruno was reassured he could soon be free, as it was being clarified that his work was very important for the betatron project. On the contrary April came, and he was still held prisoner. Then, as the Allied forces were approaching Hamburg, orders came for the 200 prisoners from Fuhslbüttel to be moved out towards the Kiel concentration camp, ~ 100 km North. Touschek was one of them.

On the way to Kiel, Touschek, who was ill and carried a heavy package of books, fell to the ground. As he wrote to his parents (Bonolis and Pancheri 2011a):

> ...I definitely broke down in Langenhorn.

He was then shot by one of the SS guards escorting the prisoners, and left for dead. The forced march from Fuhlsbüttel to Kiel is described in (Fentsahm 2004), where one can also find the map shown in Fig. 3.

As he regained consciousness, he was first brought to a hospital and then through "all kind of prisons", the last being in Altona, in the surroundings of Hamburg (Amaldi 1981, 5,7) (Bonolis and Pancheri 2011b, 45).

Those were the final days of the war in Europe, indeed the last hours, during which prisoners risked being killed, often to prevent witnesses from surviving. Touschek was lucky, or perhaps, and more likely, the tight grip held by the Nazis was at its end. On April 30th, Theodore Hollnack, the administrator of Widerøe's betatron project, eventually came to free Touschek.[11]

Two days earlier, the British army had started the final assault on the city of Hamburg, where the German command was holding against the Allied invasion, and the fight moved from block to block through the city. The city surrendered on May 3rd.[12]

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schek's closest friend in Rome. According to him, Touschek was seen drawing gyroscopes in some public place, and since gyroscopes could be related to rockets (V-2) control system, he was accused of espionage. Both stories could come from Touschek himself, either reading of foreign magazines and drawing of gyroscopes could be true, but the explanations seem contrived. Touschek's letters of the Fall 1943 suggest a much darker and dramatic explanation: when Touschek signed his contract to work on the betatron project, under the Reichsluftfahrtministerium's control, his life was obviously investigated and his Jewish origin became known.

[9] A full description of Touschek's whereabouts from mid March to November 1945, are to be found in the two letters first published in their entirety in (Bonolis and Pancheri 2011b). Quoted remarks in this section refer to these letters.

[10] For Rolf Widerøe's movements after he left Germany sometimes in April 1945, see (Widerøe 1994).

[11] In a letter to his friend Ernst Sommerfeld describing all this, Touschek wrote that he was angry because Hollnack had waited too much: "He then explained to me – after having done nothing for three weeks –

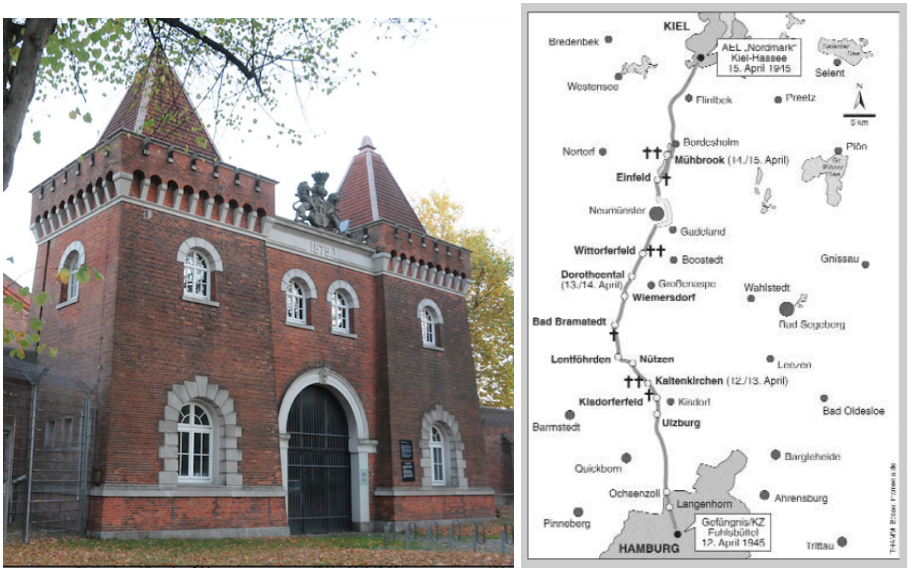

Figure 3: At left, a contemporary photo of the entrance to the Fuhlsbüttel prison in Hamburg where Touschek was held for about 6 weeks in Spring 1945. At right, a map of the forced march from Fuhlsbüttel to Kiel, which brought the 200 prisoners from Hamburg to Kiel, between 12-14 April 1945, from (Fentsahm 2004). Langenhorn, where Touschek was shot and fell to the ground, while the column continued towards Kiel without him, is seen at bottom, within the Hamburg region. The crosses indicate prisoners' deaths.

3 German science and the mission of the T-force

The last year of the war saw not only the heavy bombing of German cities and installations, but also planning for the future of the Western world, as it came to be called. The position of eminence of Germany in science and all fields of technology in Europe had been such that, as the various Allied armies progressed through Germany, they raced to secure what would be the most prized booty, depending on the stage of scientific and technological advancement of the different countries. What the Germans had achieved in science and technology since the late 1930's, would be important to know and to acquire in view of the new world political assessment after the war. To this end, the Western Alliance set in motion a number of different operations which would lead to the capture of a vast amount of German industrial, scientific and technical equipment as well as of the most prominent German scientists, who were quickly transported to the United States and to England.[13]

All along, even before the final surrender of Germany, a special task force under joint American-British command, named the T-Force, had been scouting Germany for its industrial and scientific resources, racing to reach Germany's top scientists before the arrival of the Russian Army (Bernstein 2001) (Longden 2009). One of the key actions of T-Force units was the Allied Scientific Intelligence Mission, code-named "Alsos", brain-

that without him I would have definitely been shot." Deutsches Museum Archive, NL 089, box 014.

[12] An eerily silent footage about the entrance of the Allied troops in Hamburg can be found in https://www.youtube.com/watch?v=en3hkuc1QoM. See also details about the Battle of Hamburg-1945.

[13] For a good journalistic overview, see https://www.theguardian.com/science/2007/aug/29/sciencenews.secondworldwar.

Figure 4: At left, an image of the battle for Hamburg, May 1945, from https://en.wikipedia.org/wiki/Battle_of_Hamburg_(1945). At right, Farm Hall in Godmanchester, England, where the Uranium scientists were held *incommunicado* for 7 months, from https://en.wikipedia.org/wiki/Operation_Epsilon#/media/File:FarmHallLarge.jpg.

child of Colonel Leslie Groves, the military head of the Manhattan Project.[14] The Alsos Mission, headed by U.S. Army Lieutenant Colonel Boris T. Pash, was set up to seize key elements of the German nuclear energy project working at Hechingen, in southwest Germany, where the Kaiser Wilhelm Institute for Physics had been evacuated from Berlin-Dahlem (Pash 1969) (Goudsmit 1996) (Cassidy 2017).[15] Other actions concerned the rocket scientists, as well as biological and chemical warfare experts (Jacobsen 2014).[16] And, as we shall see in 3.2, particle accelerators as well would be a target of interest.

3.1 Operation Epsilon

Operation Epsilon was the codename of the program in which the main protagonists of the German nuclear program – the Uranium Club – were flown to England at the beginning of July and held in secrecy at the country estate Farm Hall, near Cambridge. A primary aim of the program was to understand how close Nazi Germany had been to building a nuclear bomb by listening to their conversations through hidden microphones (Bernstein 2001, Cassidy 2017, McPartland 2013).[17]

[14] "Alsos" is also the Greek word for 'grove'.

[15] Efforts in Hechingen had been concentrated on trying to achieve criticality in a primitive research reactor they had assembled within a cave in the nearby town of Haigerloch.

[16] For the Americans a major target became the rocket scientists, foremost among them Wernher von Braun, who had been in charge of the nazi V-2 program in Peenemunde, and would later bring the US to land on the Moon.

[17] The 10 leading German nuclear scientists brought to Farm Hall were Erich Bagge, Kurt Diebner, Horst Korsching, Walter Gerlach, Otto Hahn, Paul Harteck, Werner Heisenberg, Max von Laue, Carl F. von Weizsäcker, and Karl Wirtz. The American officers in command wanted to keep them under constant guard, as prisoners, but the British captain in charge explained there would be no need for this, if the scientists could be convinced to give their word of honour not to escape. The transcript of these conversation were held classified until 1992, when they were released following a request addressed to the House of Lords by the President of the Royal Society in London. In the letter, to whose draft contributed Rudolf Peierls, later external PhD supervisor of Touschek in Glasgow, the following 1985 words by the German President Richard von Weizsac̈ker, are quoted: "We need and we have the strength to look truth straight in the eye

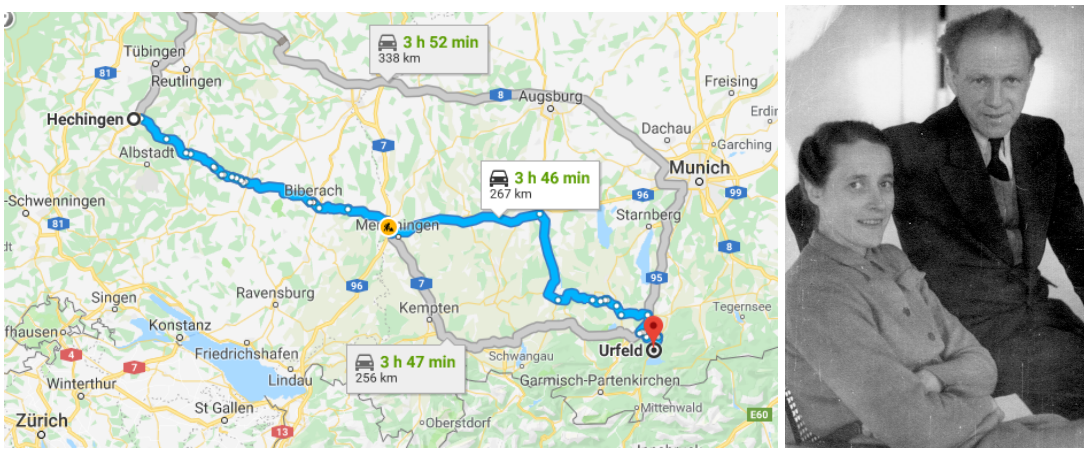

Figure 5: At left, a contemporary map showing the long trip Heisenberg took to reach his family, as the Allied forces were progressing through Germany, from Hechingen to Urfeld, where he was taken charge by the ALSOS mission on May 4th 1945. At right, a (circa) 1946 photograph of Werner and Elizabeth Heisenberg, Heisenberg Family Archives.

Among the Farm Hall detainees, there was 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).[18] He was taken into custody by Alsos on May 4th, in the little village of Urfeld, where he had arrived after a desperate bicycle ride across war-torn southern Germany to reach his family, as soon as news of the French advance had reached Hechingen.

In Heisenberg's own words (Heisenberg 1971, 190-192):

> In the middle of April [1945], the last German stragglers passed through Hechingen heading East. One afternoon we could hear the first enemy tanks. In the South, the French had probably advanced well past Hechingen, as far as the ridge of the Rauhe Alb. It was high time I was gone. Toward midnight, Carl Frederick [von Weizsäcker] returned from a bicycle reconnaissance tour of Reutlingen. We held a small farewell celebration in the air raid shelter of the institute and at about 3 a.m. I set off in the direction of Urfeld [...]
>
> [...] it was not until three days after I had set out that I reached Urfeld and found my family well and unharmed [...]
>
> On May 4th, when Colonel Pash, leading a small US detachment, came to take me prisoner, I felt like an utterly exhausted swimmer setting foot on firm land.

The imprisonment of the German "atomic scientists"[19] marked the "zero hour" of

without embellishment and without distortions [...] anyone who closes his eyes to the past is blind to the present". The British version of the transcripts is now available for free download at http://discovery.nationalarchives.gov.uk/SearchUI/Details?uri=C4414534. For the US copy, see NARA, RG 77.11.1 (Office of the Commanding General), entry 22, Box 163, in (Cassidy 2017). An Italian translation was published in 1994 (Frank 1994).

[18] For an extensive bibliography of Heisenberg's work, see http://www.netlib.org/bibnet/authors/h/heisenberg-werner.html. For the collected works see as well (Heisenberg 1984-1989).

[19] What is now called *nuclear physics*, and which includes studies for nuclear energy uses, both civilian

the post-war future of German science. During their seclusion in Farm Hall which lasted 6 months, the Western Alliance debated and planned the reconstruction of Europe. In particular, a major interest to the British political establishment was the reconstruction of Germany on its industrial and technological aspects, all of which had to start with rebuilding a strong scientific terrain.

3.2 The T-Force and Widerøe's betatron

Widerøe's betatron was also one of the targets of the T-Force. Particle accelerators had now morphed from the planning and invention stage into the most prominent research tool in atomic and nuclear physics, and would become of future strategic interest, in the mind of politicians and the military.[20] As the war started, a major advancement in the field had taken place in the United States, with the successful operation of a betatron, announced by Kerst in 1941 (Kerst 1940; 1941, Kerst and Serber 1941).[21] This series of articles revived the interest in betatrons and new projects were submitted to the German military, which saw them as possible sources of deadly X-rays (Waloschek 2012). Among them, there was Rolf Widerøe's proposal (Widerøe 1994) for the construction of a 15-MeV betatron – the first at this energy in Germany – and a parallel proposal for a much more powerful 100-MeV machine which was never built.[22] It is therefore quite understandable that, as the war ended, the German knowledge in accelerator science became of possible interest to the Allied nations, and in particular to the British, less so to the Americans, whose expertise and dominance were not lacking in this field. The German work on betatrons, which had been going on through the war, became part of the British war spoils (Hall 2019).

After Hollnack freed Touschek from prison, they went back to Kellinghusen, near Wrist, where, in mid March, a time which now seemed like centuries ago, Touschek and Rolf Widerøe had brought the 15-MeV betatron. In Kellinghusen, Hollnack had immediately put himself at the disposal of the British authorities, and reorganized activities around the betatron creating a small enterprise called the MegaVolt Forschung Laboratorium, MV-Research Association (MVRA), which gathered all the key members of the

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and military, was then called *atomic physics*, hence the still used term *atomic bomb* and, in the context of German scientists at Farm Hall, *atomic scientists*.

[20] The field of particle accelerators had initially developed through electrostatic accelerators, most prominent of them the one by Van de Graaff in the United States (1929-30), followed by the British developments by J.D. Cockcroft and E.T.S. Walton in 1932. See original papers in https://royalsocietypublishing.org/doi/pdf/10.1098/rspa.1932.0107 and https://royalsocietypublishing.org/doi/pdf/10.1098/rspa.1932.0133. New directions had also arisen through the seminal work by Rolf Widerøe, first by proposing the induction accelerator, an accelerator for electrons (beta rays) later to be called the *betatron*, and then with the construction of the first linear accelerator, the result of his doctoral dissertation in Aachen, completed in 1927 (Widerøe 1928). While Widerøe had not succeeded in making his betatron work, his linear accelerator inspired E.O. Lawrence to build the first cyclotron, an accelerator of protons, at the University of California in 1930, as Lawrence himself recalled in his Nobel Lecture (https://www.nobelprize.org/prizes/physics/1939/lawrence/lecture/). See also P.F. Dahl in (Dahl 1992) at lss.fnal.gov/archive/other/ssc/sscl-sr-1186.pdf. In 1933, a patent for a betatron was filed in Germany by Max Steenbeck. Later, in the 1930's, cyclotrons were also built in Europe: among them, and of later relevance to our story, the one at the Collège de France in Paris, by Frédéric Joliot and one in Germany by Walther Bothe and Wolfgang Gentner.

[21] In his first article, Kerst cited Rolf Widerøe's seminal paper (Widerøe 1928), but with a wrong year, 1938.

[22] For a T-force report on history of betatron development, see B.I.O.S. Report n. 77 in http://www.cdvandt.org/fiat-cios-bios.htm.

betatron group – previously working under the guidance of Widerøe (the Megavolt Versuchsanstalt) – and others.[23] Hollnack asked Touschek to join in. Everybody was trying to survive and, for some, as in Hollnack's case, even to strive. At that moment Touschek had no alternative and accepted the offer; he had been freed by Hollnack, thus avoiding being killed in the last days of fights around the city. While still trying to recover from the painful memories of his losses and the trauma of imprisonment, Bruno immediately made plans for a doctorate, as he told his parents in his first letters written in June, where he recounted the whole story of his arrest. In the meantime, thanks to his knowledge of English,[24] he acted as interpreter and was then able to negotiate with the T-Force and have the MVRA "occupied" by them, mainly meaning being protected by the British troops against looting and other killings.

However, he was soon out of empathy with the group. He did not like Hollnack, nor 'his grandiose ambitions', and was also eager to return to the theoretical physics studies he had started during his last two years in Vienna, in 1940-41, fostered by his physics mentor, Paul Urban, a young assistant professor at the University of Vienna.[25] His dream of becoming a physicist had then been reinforced by the correspondence with Arnold Sommerfeld in 1941 and the lectures by prominent scientists he had attended during the war at Hamburg and Berlin Universities.[26]

By end of June Touschek asked his colleagues in the MVRA to put an end to his collaboration. They agreed that he would have a three-months leave and in late August, as he wrote in a letter to Arnold Sommerfeld dated 28 September, he went to visit some of the scientists whose lectures he had attended *incognito* during the war: Hans D. Jensen – one of the members of the Uranium Club, now in Hannover – and Hans Süss in Göttingen, who had participated in German nuclear research activities during the war, and whom he knew since his Hamburg days, as well.[27] In Göttingen, Touschek also saw Friederich Georg Houtermans, or Fritz, or Fissel, as he was also known, with whom he would remain friends until Houtermans' death in 1966.[28]

[23] November 17th, 1945, letter by Bruno Touschek to his parents in (Bonolis and Pancheri 2011b).

[24] Touschek had learned English when in Rome, in Spring 1939, when he was applying for a Visa to go to England and study at the University of Manchester.

[25] Paul Urban (1905-1955) assisted Bruno Touschek to continue his studies at the University of Vienna, after June 1940, when, because of his Jewish origin, Bruno was not allowed to follow courses anymore nor to borrow books from the library. Later Urban was instrumental in introducing Touschek to Arnold Sommerfeld (Amaldi 1981). For Urban's life and scientific accomplishments, see also (Guardiola 1996).

[26] Sommerfeld's correspondence with Touschek referred to in this note is kept in the Archives of the Deutsches Museum in Munich, Arnold Sommerfeld Papers, folder NL 089,013.

[27] At that time, both collaborated on the nuclear shell model, for which Jensen would later be awarded one half of the 1963 Nobel Prize jointly with Maria Goeppert-Mayer (the other half was awarded to Eugene Wigner for his fundamental work on symmetry principles).

[28] Fritz Houtermans had arrived in Göttingen in spring 1945, after a tortuous trajectory of persecution by both Nazis and Communists. Fritz Houterman's life was the subject of various books, in particular of an unpublished manuscript on which Edoardo Amaldi was working before his sudden death in 1989. In 2010, the manuscript was donated by Amaldi's family to the Bern University Laboratory for High Energy Physics. It was then edited by S. Braccini, S. Ereditato and P. Scampoli, three researchers from the University of Bern, in recognition of Houtermans' contribution to the development of particle physics in Bern, and in Switzerland (Amaldi 2012). In the Preamble to the unfinished book, Amaldi writes : 'When in 1937 my friend George Placzek arrived in Rome from U.S.S.R, he had mentioned Houtermans as one of the young physicists gone to Karkhov to participate in the construction of a socialist society and recently in serious political troubles. I received a letter from him, from Berlin in 1942, after, as I learned late, he had succeeded in getting out of a prison to which he had been transferred from the Lubyanka in Moscow."

Touschek's principal worry now was to formally complete his studies, first by obtaining a degree in Physics, namely the title of Diplom-Physiker, and then continue with a doctoral thesis. During the visit, Jensen promised Touschek he would arrange for a PhD work and a position as assistant and he also received a similar offer from Hamburg, where Wilhelm Lenz, director of the Institute of Theoretical Physics, who had always protected him during the war, could now openly support him to complete his university studies and continue with a PhD dissertation.

A way to proceed was in sight, and, returning to Kellinghusen, Touschek was now eager to start writing a dissertation on the betatron. However, this could not happen. As he would later write to his parents in the already mentioned November 17th letter (Bonolis and Pancheri 2011b):

> A reunion with the T-Force has decided that things should remain a state secret so that its use for a thesis is out of the question. I will be able to leave Kellinghusen only after an Allied Commission has decided in regard to the betatron.

Writing to Sommerfeld in September, Touschek says that he "felt like a T-Force prisoner".[29] Indeed, he was. In this second half of the year 1945, the Allies were making a thorough survey of the scientific achievements of German science and technology, and nothing could really start in Germany until the decisions had been taken as to Germany's future. Not unlike the members of the Uranverein (the Uranium Club), who were held in England in Farm Hall, so was Touschek held in Germany. Unlike them, however, he was free to move within the British zone, still he could not go to Austria or publish anything about the betatron. In the meantime he continued his work on different theoretical topics related to the betatron, in particular on radiation damping, but also on neutrino theory.

In October, following British-American careful investigations held on various German Science and Industrial Institutions, "investigators" from the British Intelligence Objective Sub-Committee (B.I.O.S.) visited the C.H.F. Müller factory in Hamburg, where the 15-MeV betatron had been built, and where Touschek had worked with Widerøe and his group. A photo of the betatron, from a postwar publication by two members of the group, is shown on the left panel of Fig. 6.[30] The right panel shows the first page of a report on radiation damping in the betatron, where we see what would become Touschek's lifelong interest in the question of how radiation from a moving charge affects the operation of electron accelerators. This report is likely to include the work Touschek was working on during his imprisonment, and which Amaldi mentions as having been written in invisible ink (Amaldi 1981, 5) on Heitler's book on the quantum theory of radiation (Heitler 1984).[31]

[29] Touschek to A. Sommerfeld, 28 September 1945 from Kellinghusen, Deutsches Museum Archive, Arnold Sommerfeld papers, folder NL 089,013.

[30] In B.I.O.S. Final Report No. 201, Item No. 1,7, 21, dated 8.10.1945, "Visit to C.H.C. Müller, A.G. Röntgenstrasse 24, Bahrenfeld, Hamburg, reported by C.G. LLoyd and G. J. Thiessen, http://www.cdvandt.org/BIOS-201.pdf, on p. 3 it was further specified that "Dr. Fehr [assistant to Manager] stated that the project had been experimented for the Luftwaffe with the hope (?) of obtaining a death ray for anti-aircraft work." These reports covered a wide variety of German scientific and industrial Institutions, and were authored by officers from B.I.O.S., C.I.O.S. (Combined Intelligence Objectives Sub-Committee) and F.I.A.T (Field Information Agency Technical, United States Group Control for Germany).

[31] A different version of this work, entitled "The effect of Radiation-Damping and the Betatron", undated but bearing an address in Göttingen – and apparently submitted to the *Physical Review* (according to the

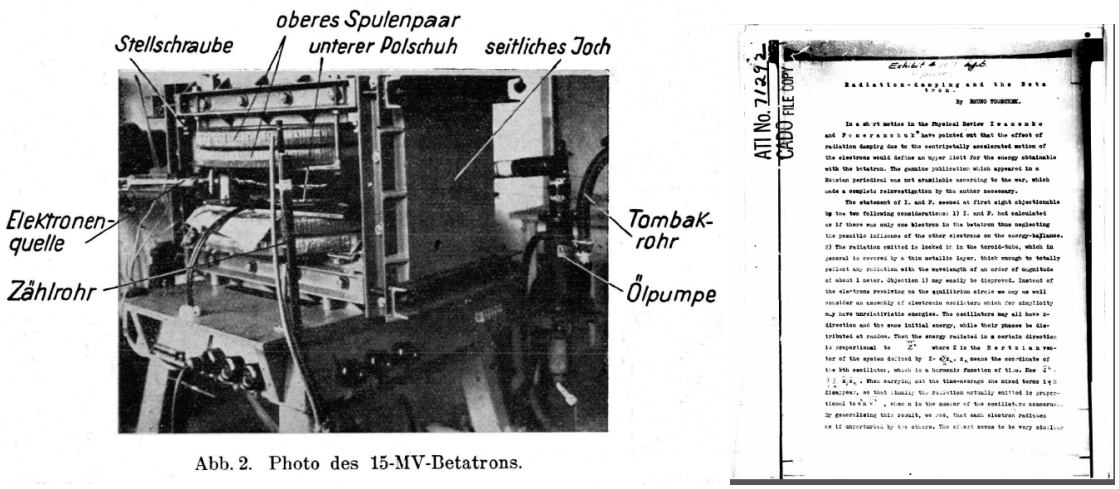

Figure 6: At left, Photo of the 15-MeV betatron mounted on a big table as shown in (Kollath and Schumann 1947, 635). At right, we show the first page of Touschek's 1945 report on Radiation damping in a betatron, unpublished report for the US Armed Forces, part of the Air Technical Index [ATI] collection available at https://apps.dtic.mil/dtic/tr/fulltext/u2/a801166.pdf. Signed by Bruno Touschek at the end of the note, the handwritten date reads as to be 28.9.45.

The investigation continued with a visit to Wrist, the town near Kellinghusen, where the betatron had been kept since Touschek and Widerøe had brought it in March 1945. The British officers were in the Wrist Laboratory, on October 23rd.[32] In their report it was mentioned that they had received a series of reports written by Bruno Touschek.[33]

Touschek's contribution is clearly acknowledged also in another detailed B.I.O.S report on *European Induction Accelerators* prepared in October 1945 by the U.S. Naval Technical Mission in Europe: "In collaboration with the design work of Widerøe, a considerable amount of work was carried out by Touschek. This is known to have been of invaluable aid in the development of the 15-MeV accelerator. Further theoretical work has also been done by Touschek in the starting of electrons in the accelerator. Some of the work is along the lines initiated by Kerst and Serber which were known to Touschek." It is also specified that "Widerøe and the group that came to be associated with him in the war-time German betatron work were not in sympathy with the Nazi-cause, and were persuaded to continue their work for purely scientific considerations."[34]

The activities of the Megavolt Research Association in Wrist are examined in detail in the second part of report No. 148. The British investigators specified in particular that "The experimental work at Wrist should close down at once" and that "The complete apparatus should be sent to UK". They finally specified that "Mr. Touschek is recommended

first line of the document) where it was never published – is preserved in Bruno Touschek Archive, Box 4, Folder 15.

[32] A.T. Starr, K.J.R. Wilkinson, J.D. Craggs, L.W. Mussel, "German Betatrons", BIOS, Final Report No. 148, Item No. 1, dated 24.10.1945.

[33] Copies of such reports on the theory of the betatron written by Touschek (Zur Theorie d Strahlentransformators. Typoskr.-Kopie, o.D. 10 Bl.+ Beil.; On the Starting of Electrons in the Betatron. Kopie, o.D. 11 Bl.; Die magnetische Linsenstrasse und ihre Anwendung auf den Strahlen-Transformator. Typoskr.kopie, 10 Bl., 1945; Zur Frage der Strahlungsdmpfung im Betatron. Typoskr.- kopie, 7 Bl., 1945) can be found in Rolf Widerøe's papers at the Eidgenossischen technischen Hochscule (ETH) in Zurich (see finding aids at https://www.research-collection.ethz.ch/bitstream/handle/20.500.11850/140811/eth-22301-01.pdf).

[34] B.I.O.S MISC.77, p. 6.

to be taken to UK for work on theoretical physics".[35] This recommendation sheds light on all of Touschek's whereabouts in the year to follow. As we shall see, starting in the early months of 1946, Touschek would go back and forth between Germany and the UK, Göttingen and London, or Glasgow, until he would finally settle in Glasgow, in spring 1947, remaining there for 5 years.

In November, writing to his parents, Touschek was still hoping he would soon be allowed to visit his family in Vienna, in the Soviet occupied zone. But this could not happen yet. The T-force had other plans for him.

In December,[36] working on his research on radiation damping in the Wrist office, from 10 in the morning until 10 in the evening in the only warm room in the area, the uncertainty of the situation was becoming unbearable. The Western Alliance were making preparations for the reconstruction of Europe, but in the meanwhile, living conditions were dramatic. Winter was coming, there was scarcity of food, hardly any winter clothing, heating was a luxury.

As the year was coming to an end, it was clear that the *limbo* in which the German scientists were kept by T-Force could not go on forever, and some decision would and should be taken. Exacerbated, Bruno wrote to the officers of the T-Force, but no immediate answer came about the decisions yet to take. However, a rumor, eventually originated by the T-Force, gave him the hope that he would be brought to England. The probability could be low, but the prospect made the situation more tolerable. Europe, at that time, pillaged of its scientists and infrastructures, was not appealing for his future as a physicist, and, financially, England would likely be a much better prospect, given that he wanted to help his parents, his father being retired from the Austrian Army, and living under difficult conditions in Vienna, under Soviet occupation. Another reason, the main one perhaps, was that going to England would make a plan he had envisioned before the war come true. In spring 1939, after the Anschluss of Austria shattered the regular course of his life and studies, while in Rome visiting his maternal aunt AdA Weltmann, he had decided to go and study in England. Actual plans had been drafted and he had applied for a Visa to the British consulate in Rome, but these plans never materialized.

During these last few months of 1945, the reconstruction of German science was being discussed and planned by the occupying forces: how, how much, where, and under whose direction, these were the questions to pose and solve. Finally, the decision was taken that post-war German science would be mainly rebuilt in the University town of Göttingen, which had been relatively untouched by Allied bombing. This decision had a wide impact: the Farm Hall detainees could be allowed to return home, to their families and institutes, and Werner Heisenberg would be one of the key figures in the revival of scientific research in Western Germany, and especially in German science policy. Once this path was clear, also other decisions came along and the restrictions imposed by the T-Force on the betatron group were lifted.

In December 1945, work with Wideroøe's 15-MeV betatron had been completed at Wrist and the machine was transported to the Woolwich Arsenal near London, where it was used for some time with the help of Rudolph Kollath, one of the members of Widerøe's betatron group.[37] As for Bruno, he could be free to leave Kellinghusen and go

[35] See reference in footnote 32.

[36] Letter to his parents, December 13th, 1945 from Kellinghusen.

[37] Rudolf Kollath wrote a five-pages long report on their results ("Bericht von Ing. R. Kollath, 11.12.1945, über die Arbeiten am Betatron in Wrist", see copy in Widerøe's archive in Zurich). Kollath and Schumann,

back to his studies, the first thing being to obtain his diploma in physics.

Bruno had to now start his life anew. As a 17 year old youth he had gone through the Anschluss, and then the loss of his identity as a rightful Viennese citizen and promising physics student, who had been following courses during Spring 1939 in the University of Rome and, in 1939-1940, at the University of Vienna. He had been living in Germany through four years of semi-hiding, with little food, scarcely any heat, both in Berlin and Hamburg with daily bombs devastating the cities, away from his beloved family, the grandmother, his father, his stepmother, the aunts and uncles from his large maternal family. At some time, he had learnt that his grandmother Weltmann had never returned from Theresienstadt, the concentration camp 20 kilometers from Prague. The world of his youth was definitely over. He now had to go on with life. How? Not unlike many scientists in those days, he could do this only by fulfilling his dreams. For Bruno, they were the ones he had pursued through his correspondence with Arnold Sommerfeld in 1941 and which has prompted him to move to Germany in 1942. He had dreamed of studying and becoming a physicist. This is what he was now anxious to do and was the only way he could overcome the grief for the lost past. As we shall see, he was not yet free to decide his destiny, and had only a partial notion of which decisions were taken about the rebuilding of universities in Germany. Likewise, whether he could eventually end up studying in the UK was also rather nebulous. As things unraveled, his first return to normality was to be at the University of Göttingen.

In the section to follow we shall temporarily leave the story of Bruno Touschek, and give a brief overview of what had been happening in Germany and what Touschek found when he joined the University, in spring 1946.

4 From destruction to reconstruction: Starting anew in Göttingen

Touschek would not be alone in rebuilding his hopes and dreams. As 1946 started, all around him the titanic effort of the reconstruction of Europe was already taking place, coordinated by the American military, with the UK command on its side. The reconstruction of science in postwar western Germany – and German political revival – is to be framed within the broad contexts of the Allied occupation (Cassidy 1994; 1996, Berghahn 1996, Ash 1996, Gimbel 1990b). As described in Krige's *American Hegemony and the Postwar Reconstruction of Science in Europe*, "The immense scientific and technological achievements in the United States during the war and the ongoing support for research in the country after 1945 contrasted sharply with the situation in postwar Europe. There, laboratories were ill-equipped, destroyed, pillaged, and (in the case of Germany) strictly controlled; researchers were poor, cold, hungry, and demoralized; and national governments had far more pressing concerns than scientific (and technological) reconstruction." (Krige 2006, 1). However, after the war, "science had become an affair of state", strongly intertwined with the re-shaping of socio-economic relations in the wider context of Cold War relations between the United States, the Soviet Union, and the countries of war-ravaged Western Europe. As stressed by Krige, "Combining scientific advantage with

who had operated the betatron up to the end of 1945, wrote together an extensive report on the performance of the betatron and on tests in Wrist which was published only about two years later (Kollath and Schumann 1947). A detailed outline of the 15-MeV betatron and related work carried out by the group, including studies for a large 200-MeV betatron, were reviewed by Herman F. Kaiser in early 1947, also specifying different aspects of Touschek's involvement as a theorist (Kaiser 1947).

economic and political leverage, scientific statesmen, officials in the U.S. administration, and officers in organizations like the Ford and Rockefeller foundations did more than simply 'share' science or 'promote' American values abroad; they tried to to *reconfigure* the European scientific landscape, and to build an Atlantic community with common practices and values under U.S. leadership" (Krige 2006, 3).

During the immediate post-war years Germany was facing devastation, poverty, enormous loss of lives, and the collapse of economic and political organization with the country divided into four occupation zones. Among the many challenges, the reconstruction of research in Germany was extremely difficult, as German science had to rebuild itself practically from the ground up and, at the same time, needed to be reintegrated into the international community. Moreover, Allied restrictions specifically forbade applied nuclear physics and in particular also commercial production of betatrons, synchrotrons and all particle accelerators over 1 MeV, including many sorts of equipment. The conditions were perhaps most favorable in the British Zone, where the authorities, especially the liaison officer Colonel Bertie Blount, appeared quite open to a dialogue with German scientists.

In the British zone, the city of Göttingen had survived World War II without major damage, which meant an invaluable starting advantage for the town and the famous university, the oldest in Germany.[38] With the permission and the encouragement of the British, Göttingen grew into one of the main scientific centers of the Western occupation zones.

The Georgia Augusta was the first German university to resume teaching already in September 1945. It had lost its excellence after the great purge of 1933, because of the expulsion from the University or flight abroad of leading Jewish physicists and mathematicians, among them Max Born, James Franck, Edward Teller, Leo Szilard, Eugene Wigner, Richard Courant, Edmund Landau, and Emmy Noether.[39]

In the early 1930's, the University included Institutes for experimental and theoretical physics. The Institute in Experimental physics was directed by James Frank, the one in theoretical physics by Max Born. Both had arrived to Göttingen as Professors in 1921, and, in due time, both were to win the Nobel Prize.[40] In 1933 the National Socialists' rise to power and the contempt for modern "Jewish" physics, which included Quantum mechanics and Einstein's theory of relativity, forced them to emigrate. James Franck, by then a Nobel laureate, went to the United States. Max Born, one of the founders of quantum mechanics, went to Italy, then Cambridge and, in 1936, to Scotland, at the University of Edinburgh. Born's chair at the Institute for Theoretical Physics was then occupied in 1936 by Richard Becker, who had been transferred to Göttingen by order of the Reich Ministry for Education (Hentschel and Rammer 2001). Becker and Born had an influence on Touschek's development as a theoretical physicist, as Becker was Touschek's professor when Bruno studied in Göttingen in 1946. As for Born, Touschek first met him in

[38] Named after its founder, George II, King of Great Britain and Elector of Hanover, the Georg-August University of Göttingen was founded in 1734 with starting classes in 1737.

[39] A good source of biographical data on eminent mathematicians can be consulted at the site http://www-history.mcs.st-and.ac.uk/ maintained by St. Andrews University.

[40] The 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". Born was awarded the 1954 Nobel Prize in Physics "for his fundamental research in quantum mechanics, especially for his statistical interpretation of the wavefunction", sharing it with Walther Bothe, as from https://www.nobelprize.org/prizes/physics/1954/born/facts/.

Edinburgh, in May 1947, while in Glasgow as a doctoral student. Bruno became a regular attendee of Born's weekly seminars, and, later on, prepared the Appendix on the theory of neutrinos in Born's new edition of his famous *Atomic Physics*.[41]

After the war, the First Institute for Experimental Physics was headed by Robert Richard Pohl, whose research constituted one of the foundations of solid-state physics. The direction of the Second Physics Institute between 1942 and 1953 was in the hands of a former student of James Franck, Hans Kopfermann (Weisskopf 1964), who initiated and supported nuclear physics in Germany together with his assistant Wolfgang Paul.[42] During the war, Kopferman and Paul learned of Kerst's success in constructing and operating the first betatron, and decided to build such an accelerator as soon as possible. The project was put aside as they heard that Konrad Gund had built a 6-MeV betatron at Siemens-Reiniger Company in Erlangen (Waloschek 2012) and Paul started taking measurements on the machine in Erlangen. After the war, Paul and Kopferman, with the help of Ronald Fraser, Scientific Advisor of the Research Branch of the British military, were able to transfer this betatron to Göttingen. Together with Becker, Kopferman was Touschek's advisor for his 1946 Physik-Diploma dissertation about the betatron, from the University of Göttingen (Amaldi 1981, 7).

In early October 1945, while the University of Göttingen was resuming academic activities, Heisenberg, Hahn and von Laue, while still held in Britain, had met their British colleagues at the Royal Society in London to discuss the rebuilding of German science.[43] On 3 January 1946, the ten German nuclear scientists, among them by now three Nobel Prize laureates, were finally released from Farm Hall and brought back to Western Germany by Colonel Bertie Blount, who had studied in Germany.[44] With the British officials Bertie Blount and Ronald G. J. Fraser, himself a physicist as well as Scientific Advisor of the British military, the group of German physicists started to forge working relationships. It was the beginning of a long collaboration which had a great importance for the future of the Federal Republic.

On January 12 Hahn and Heisenberg visited Göttingen with Col. Blount, where they found Max Planck, who had arrived there as a refugee seeking shelter with relatives.[45] Since 1930, Planck was President of the Kaiser Wilhelm Society, a non-university science organization founded in 1911 to conduct specialized basic research in its own Institutes,

[41] This book had several English editions starting from 1935, the last one in 1969.

[42] W. Paul shared with Hans G. Dehmelt one half of the 1989 Nobel Prize in physics "for the development of the ion trap technique", the other half was awarded to Norman F. Ramsey "for the invention of the separated oscillatory fields method and its use in the hydrogen maser and other atomic clocks".

[43] In this meeting, two of the German physicists had been Nobel prize winners, Max von Laue in 1914 and Werner Heisenberg in 1932. The third, Otto Hahn, would be awarded the prize a few months later, while still under imprisonment at Farm Hall. On the British side, the meeting included Patrick Blackett, who would be later awarded the 1948 Nobel Prize in physics, for his work on cosmic rays. In early September, Blackett and Heisenberg had held a long conversation in Farm Hall. This encounter had then been followed by a letter addressed to Blackett by Heisenberg, on behalf of the other scientists. In this letter, the conversations and the position of Heisenberg and the other Farm Hall detainees was summarized. (Bernstein 2001).

[44] At his arrival, on January 3, 1946, Heisenberg immediately wrote to his wife Elisabeth from the small village Alswede: "My dear Li! This is the first evening back in Germany since the end of the war. This long time of captivity seemed to us only bearable through the scientific work. How it's going to be here, we do not know yet. The purpose of our being here is as follows: The highest authorities have decided that we all should in the future have our workplaces in the British occupation zone." (Heisenberg and Heisenberg 2016).

[45] Max Planck had been awarded the 1918 Nobel Prize "in recognition of the services he rendered to the advancement of Physics by his discovery of energy quanta."

predominantly in the natural sciences. The Kaiser Wilhelm Society (Kaiser-Wilhelm-Gesellschaft) had quickly established itself nationally and internationally thanks to its outstanding scientific achievements, but during the 1930s-1940s, the Society's leadership and many of its scientists had become supporters of Hitler's regime, or had been involved in armament research. The Allies were thus urging that the Society should be dissolved. However, with the support of Nobel Prize Laureate Max Planck, who was unanimously regarded as an outstanding scientist with an impeccable international reputation, Otto Hahn's efforts succeeded in gaining British approval for the revival of the Kaiser William Society and on 26 February 1948 the Max Planck Society was eventually founded in Göttingen as successor organisation.[46]

Seven of the ten physicists kept at Farm Hall, were now members of the Kaiser Wilhelm Institute for Physics in Göttingen: Werner Heisenberg, Max von Laue, Carl Friedrich von Weizsäcker, Karl Wirtz, Horst Korsching, Otto Hahn and Erich Bagge. The first four were also given positions as professors at the University. But towards the end of February1946, they had discovered that the Institute would be hosted in the empty rooms of the former Aerodynamics Research Institute (Aerodynamische Versuchsanstalt, AVA) which had been denuded of all its war-related equipment: its large wind tunnels had in fact been partly destroyed and partly dismantled and transported to England.[47] All of the scientific machinery and commodities, with which they had hoped to be able to start anew, had been carried away. Moreover, they had no access to all their instruments and equipment left in Heisenberg's Institute in Hechingen after the scientists fled as the Allied army was proceeding through Germany. The Institute was now located in the French occupation zone, and could not be reached anymore.[48]

In Fig. 7, we show a map of how Austria and Germany were divided among the four powers which had won the war, with Göttingen being in the British zone, some 200 kms North of Cologne.[49]

In Göttingen, in the years to follow, Heisenberg devoted 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.

Heisenberg's efforts took large part of his energies, but he was successful and, during the years of the reconstruction, the Max Planck Institute for Physics gained a growing reputation as a leading representative of German physics in the international arena after so many years of isolation during the Third Reich and World War II. As he wrote to his wife in the early days of his Göttingen's stay, on February 28: "What our future will look like in all its reality, I cannot yet tell at all. In spite of it, I have the clear sense that it will not really be all that bad, if only we are patient." (Heisenberg and Heisenberg 2016).

[46] Its first president was the Nobel Prize laureate Otto Hahn. The Max Planck Society then evolved into one of the mainstays of the science landscape of the Federal Republic of Germany, which was founded in 1949 (Walsh 1968) (Dickson 1986).

[47] On the race to take possession of the German aircrafts as well as research and production facilities see (Christopher 2013).

[48] On February 28, Heisenberg wrote his wife: "Well, here in Göttingen things are limping along, more or less. Our rooms in the AVA, at this point, are ugly, some basic office space devoid of any hint of warmth, but useful enough as temporary campsites in the crusade of life." (Heisenberg and Heisenberg 2016).

[49] A day by day account of how the final agreement about the division among the four powers, can be found at https://berlinexperiences.com/potsdam-conference-1945/.

Figure 7: At left, we show the four zones into which Germany and Austria were divided and became occupied by the winning powers, following the accords which took place in Potsdam, a small city located in occupied Germany, from 17 July to 2 August 1945, map is from https://estonianworld.com/life/remembering-estonias-wwii-refugees/. At right an image of the location of the town of Göttingen in relation to the places in UK through which Touschek would later move.

5 1946: Touschek between Göttingen and Glasgow

As 1946 started, Touschek was anxious to have a clear idea of how and where to continue and complete his studies. As we shall see, this was not so obvious, and through the whole of 1946 he moved back and forth between the United Kingdom, travelling to London and Glasgow, and Germany, following courses in Göttingen.

In 1946, the decisions leading to the reconstruction of Europe were being put in action. Many European scientists, who had left to join the Manhattan project, returned to Europe. Together with those who had remained in Europe, they could resume visiting each other's laboratories and universities and restart pre-war exchanges. The first international conferences since he beginning of the war were held. Everything was slowly starting anew.

In Germany, science was to be rebuilt starting from Göttingen, but all equipment of technical or scientific interest had been taken to England or to the US (as in the case of the already mentioned wind tunnels, as also discussed in (Jacobsen 2014)). Among them, was Widerøe's betatron. As Widerøe writes in his biography: "In December 1945, the British authorities decided to take the betatron, as part of the booty of war, from Kellinghusen to the Woolwich Arsenal near London. Apparently, Rudolf Kollath later on took charge of its operation in Woolwich where it was used for non-destructive X-ray inspection of steel plates and such like. The machine has since disappeared without a trace. Many, including myself, later attempted to find it, but with no success. It was most probably scrapped." (Widerøe 1994, 87).

In 1945, to the officers of the T-Force reporting on Widerøe's betatron, Touschek had expressed the desire to go the UK, and such had been the recommendation in the BIOS report. This had been also the plan he had pursued just before the war broke out in Europe. At the same time, he was also part of the "war booty", to be interrogated on 'German science', but in particular on the betatron, and, sometime in January or February

1946, he was taken to England.[50] During this first visit, plans for Touschek's move to study in a university in the UK were put in motion. The English officer in charge of the German scientists in Göttingen was Ronald Fraser, whom Heisenberg remembers as a friendly British officer in his memoirs of the period.[51] Fraser sought to have Touschek to go to the University of Glasgow, where plans for 300-MeV electron synchrotron, to be built under the direction of Philip I. Dee, were considered, together with a smaller, preliminary 30-MeV machine.[52]

Philip Dee had arrived in Glasgow in 1945 to occupy the long established Chair of Natural Philosophy, which had been offered to him already during the war, while he was involved in radar work and other leading war activities (Curran 1984). He had immediately set up major plans for relaunching physics, which included the building of an electron synchrotron, based on the new revolutionary principle of phase stability just discovered, simultaneously, both in the USSR (Veksler 1946) and US (McMillan 1945).[53] At that time, the only European country, whose scientific and technical evolution in nuclear and atomic physics could be compared to that of the US, was Great Britain, as underlined by John Krige (Krige 1989, 488): "[...] as the leading nuclear power in (western) Europe at the time, Britain alone amongst European countries had the human and financial resources, and the political will, to launch a major accelerator construction programme immediately after the war."

The foundation of Britain's post-war accelerator construction program were laid out, immediately after Japan's surrender in August 1945, through a government committee (Cabinet Advisory Committee on Atomic Energy) which should advise the new Labour Prime Minister Clement Attlee on general policy for Britain's postwar atomic

[50] This early visit to London is glimpsed from a letter he sent to his parents on April 8th, from Glasgow, where he mentions that his entrance to the U.K. had been again refused, an indication that he had already been in the UK, but that refusal of entry did not prevent him to enter the country. The apparent contradiction between immigration authorities and the military, which were accompanying Touschek as an 'enemy alien', is similar to the long drawn fight between the US Immigration and Naturalization Service and military authorities over allowing entry or residence rights to German scientists, who could have been involved in war crimes, as seen in (Jacobsen 2014).

[51] Ronald Fraser was a research physical chemist at Cambridge University, where he worked for a few years after having been a lecturer at Aberdeen University, as from footnote (50) in (Amaldi 1981).

[52] Fraser knew Dee from the University of Cambridge, where Dee had graduated in 1926, later working at Cavendish Laboratory.

[53] After the war, four types of accelerators were in use: Van de Graaff, Cockcroft-Walton, cyclotron, and betatron. The cyclotrons, which were able to produce the highest energies, had reached their energy limit due to the relativistic mass increase at very high particle velocities, laying at roughly 25 MeV for protons. The principle of phase stability came as a solution to this problem, making it possible to accelerate particles into the GeV region compensating for the relativistic mass increase either by changing the accelerating high-frequency voltage or the magnetic field strength during the acceleration of the particles. Not only cyclotrons could be operated at higher energies converting them into synchro-cyclotrons, but it was also possible to build a completely new type of accelerator, the *synchrotron*. This new machine could keep the particles on a path of constant radius by varying both the magnetic field strength and the frequency of the accelerating voltage with increasing particle energy. Last but not least, this kind of accelerator could be used for accelerating *both protons and electrons*. Machines based on this principle promised to displace betatrons as accelerators of high-energy electrons: indeed further developments of the betatron mostly took place for medical uses. In US, the leading country in the field, accelerator programs for nuclear physics research were being carried out at Brookhaven and Berkeley, two Laboratories which played a role as models for European physicists. In fall 1946 Lawrence's 184-inch synchro-cyclotron was producing its first beam at Berkeley's Radiation Laboratory and new machines were being planned, notably a 10 GeV proton synchrotron.

program. A Nuclear Physics Subcommittee was created on October 4, 1945. It was chaired by James Chadwick and was composed of leading nuclear physicists such as Patrick Blackett, John Cockcroft, Charles G. Darwin, Philip Dee, Norman Feather, Mark Oliphant and George Thomson. One of its first recommendations had been that "immediate support be given to Oliphant's and Dee's proposals to build accelerators at Birmingham and Glasgow universities, respectively." (Krige 1989, 488-490).[54] Dee's plans were thus part of larger program launched in UK universities between October 1945 and March 1946 which included the building of big accelerators in five universities: 1.3 GeV proton synchrotron (Birmingham), a 400-MeV synchrocyclotron (Liverpool), the 300-MeV electron synchrotron in Glasgow, as well as two less powerful machines in Oxford and Cambridge.

In this perspective, Touschek's experience with Widerøe's betatron would be an important asset for Dee's department and the foreseen project. As mentioned, there is some evidence that Touschek was brought to the UK in the early months of the year 1946, probably to be further interrogated about the German betatron and start negotiations for a move to Glasgow. A suitable salary from the Darwin Panel Scheme, under which German scientists and technicians could be employed in UK, may have been discussed at the time.[55]

To finalize such an appointment, it was necessary to wait for the UK government's final approval of the Committee recommendations about the construction of new accelerators. In the meanwhile, Touschek, still under the 'protection' of the T-Force, was brought back to Germany, firstly to Kellinghusen, to take leave of his apartment and pack his few things. As for the next step, while waiting for the Glasgow situation to become definite, the natural choice was for him to go to Göttingen, where the University was restarting in the British occupied zone. Of interest to Bruno, was also that Wolfgang Paul, Kopfermann's assistant at the Institute for Physics of the University, was working with the betatron built by Konrad Gund for Siemens in Erlangen (Waloschek 2012) and which later was brought to Göttingen. This would give Bruno a good opportunity for discussions with Paul and Kopfermann while he was completing his dissertation to earn his Diploma in physics, the pre-requisite for any further studies.

Sometime in early March, Bruno moved to Göttingen from Kellinghusen.[56] The three Nobel Prize laureates from Farm Hall, Werner Heisenberg, Max von Laue and Otto Hahn were already there, having arrived since January. We show them in Fig. 8 together

[54]For a discussion of the British projects on accelerators see (Mersits 1987), especially Section 1.3.3. As part of the British nuclear-physics program, a variety of different types of accelerators was being also planned at Harwell, the site chosen for the Atomic Energy Research Establishment to cover all aspects of the use of atomic energy, but this program was more oriented towards nuclear physics rather than "meson physics", as nuclear and particle physics was called at the time. When the 400-MeV synchrotron Liverpool machine went into operation in 1954, it was Europe's biggest synchro-cyclotron until 1957, when the CERN 600-MeV synchro-cyclotron was completed. Three of these UK university accelerators under construction would allow to do meson physics. Even if in the meantime higher energies had become available in US, they were a good basis for launching a research program in particle physics.

[55]Information about the Darwin fellowships, and the scientists whose work in the UK was sponsored through the Scheme, is available at the UK National Archives, https://discovery.nationalarchives.gov.uk/details/r/C258396.

[56]Bruno Touschek's letter, in which he describes his first impressions of Göttingen, is dated 12.4.1946, but the month, as written, is likely to be an error, with Touschek typing a 4 (April) instead of 3 (March). All evidence from the letters of this period, in particular two letters from Glasgow, respectively on April 8th and 12th, points to the date "12.4.1946" to be "12.3.1946".

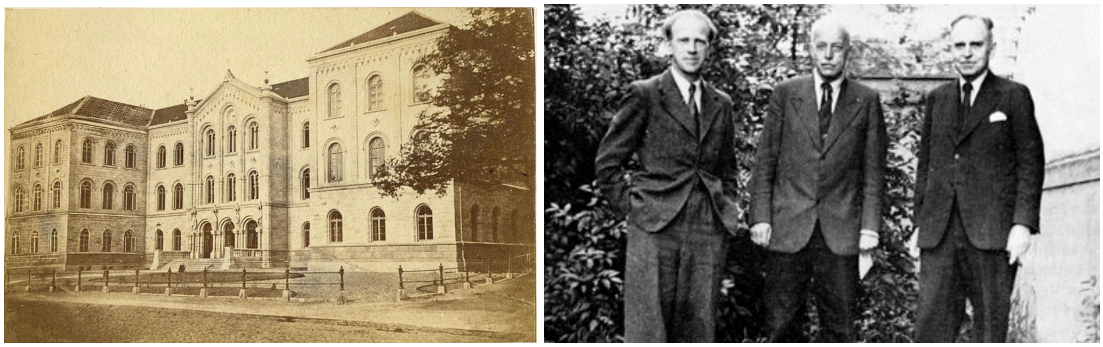

Figure 8: At left, an image of Göttingen University. At right, Werner Heisenberg, Max von Laue and Otto Hahn in Göttingen, Germany, in 1946. Image: INTERFOTO/AKG-IMAGES, from https://www.nature.com/articles/503466a.

with an old image of the University, which had been left almost untouched by the war.

Touschek knew the group of German physicists he saw as he arrived in Göttingen, since his Berlin days.

Touschek also renewed his acquaintance with Fritz Houtermans, who was planning to go to Vienna in the summer, raising Bruno's hopes to go with him and finally be re-united with his family. But he was not yet free to do as he wished. Unbeknownst to him, the British plans for post-war accelerator physics development were being finalized, with approval of the construction of the 300-MeV synchrotron in Glasgow. The plan to bring Touschek to the UK had also been carried through, with arrangements with Philip Dee, and a suitable salary higher than could be expected in Germany or Austria. A contract was prepared for a six month position under the Darwin Scheme and in April 1st Touschek was brought to Glasgow, and housed in MacBrayne Hall of the University of Glasgow, which we show in two contemporary photographs in Fig. 9.[57] The accomodation in the old Scottish University was very different from what he had seen in Göttingen, where he had been housed in the buildings of the AVA (the Aviation Institute), which had been deprived of its instrumentation, but had been newly refurbished, all shiny and polished. In McBrayne Hall, his rooms were small and ancient looking, only 1.80 meters high, with beam ceilings running as if towards some distant adventure, one room filled with lumber and a bookshelf, crossed by the tubes of all bathrooms, which Bruno decided, right away, to paint pink as soon as possible. He expected to be there for half a year, at least, and had brought his books and few things, which he immediately arranged around the room. Lack of proper clothing was still a worry, but Bruno had an uncle from the maternal side, Alfred Weltmann, who lived in Birmingham, and whom he was planning to apply to in case of need.

However, once more, things were not to go on as he had expected. A week since his arrival, a complication arose.[58] As it turned out, this was not a small mishap, instead it was a tough obstacle to overcome. This was so because the Department for Scientific and Industrial Research (D.S.I.R.) had suddenly found out that he was Austrian, whereas the Darwin panel, from which Touschek's salary should come, only applied to Germans. Although this had been clearly stated by Bruno in the many questionnaires which he had filled in the intervening months, this 'detail' had obviously escaped the attention of

[57] April 8th, 1946, letter to parents from Glasgow.
[58] April 12th, 1946, letter to parents, from Glasgow.

Figure 9: Two contemporary photographs of McBrayne Hall of the University of Glasgow, a front view in left panel, and a side view in the right panel, courtesy of Dr. Robert McLaughlan.

whoever had prepared the contract.

This was an unexpected drawback. Once more Bruno's path had to be changed. Somewhat used to skirt administrative regulations, Touschek at first thought the objections could be of minor import and underestimated the difficulty of overcoming the D.S.I.R. objections. Since leaving Austria as a twenty one year old, Bruno had either been in semi-hiding or under the control of military authorities, while working in Widerøe's group during the war, or under T-Force authority afterwards. Thus, he did not understand that, outside the control of the military, civilian life was quite differently regulated and administrative obstacles were not so easily overcome. All his life, Touschek would have little tolerance for this type of delays and encumbrances, also a remnant of how, in the war years, he had to find alternative solutions to survive. As ultimate instance, one can remember that, towards the end of his life, he refused to prepare and submit his scientific credentials for promotion to Professor of Physics at the University of Rome (Amaldi 1981). His friends had to do it for him.

5.1 Getting a Diploma in Göttingen

The D.S.I.R. proved to be a hard contender and very soon Touschek left to return to Göttingen, to prepare for the physics exams and presentations leading to his Physics Diploma, while, in Glasgow, Dee would continue his efforts to have him join the University.

Touschek was not disappointed about having to return to Göttingen. He was very resilient: a life of losses and changes, starting with losing his mother when in his early teens, then the expulsion from Vienna University and the years in Germany spent almost in hiding, up to miraculously escaping death during the final days of the war, all this had hardened his resolve to survive and bounce back. He was still young and confident in his future.

Back in Göttingen, he was pleased to be with familiar faces and have nice arrangements for housing in the countryside.[59] He had immersed himself in his studies, to prepare the exams for the Physics Diploma at Göttingen. He passed his pre-diploma exam very well on May 8th. There also appeared a thrilling prospect, namely that, after the exam, he could remain, for a while at least, as a research assistant with Heisenberg's group in particle theory. This was a chance like he had never encountered before and could not be missed, after almost seven years of disrupted life. Thus, the plan to go to Vienna in the summer had to be postponed, notwithstanding his parents' pressing for his return there.

In fact, having seen Bruno return to Germany from Glasgow, his parents had started hoping he would come back to Vienna. Earlier he had also received an offer for a lectureship in Berlin, and similar chances could possibly exist in Vienna, as well, but none of this was in Bruno's plans. He refused the Berlin offer to lecture in electricity and theoretical nuclear physics, because, at that point in his life, the priority for him was to become *a physicist*. A precarious and temporary position in a University, which at the time was completely empty, had no interest for him now that physicists such as von Laue and Heisenberg were no more teaching there.

About his return to Vienna, this had to be postponed at least by another year, as he could not see himself going back without having first gotten his degree and become Heisenberg's assistant in Göttingen, an extraordinary opportunity opening up for him in the coming months.

Now that he was engaged in a clear path for his Diploma, Bruno could enjoy the friendship of other Viennese physicists or professors he had seen in Berlin or Hamburg during the war. One such occasion was on May 10th, when there was an evening at the Houtermans' to celebrate Touschek's pre-diploma exam, with three Generations of Viennese scientists: the 75 year old mathematician Gustav Herglotz, Fritz Houtermans, then 50 year old, and Touschek himself, at 25. During these months in Göttingen Touschek became close to Fritz Houtermans. They had both been born in Vienna, came from similarly assimilated Jewish families, and had both experienced a skirmish with death, to which they had come close but from which both had luckily escaped from. In Fig. 10, we show two photographs of Fritz Houtermans, with the one in the left panel from the time when he was held prisoner at the Lubyanka in Moskow, in 1937. In the right panel, Fritz Houtermans is second from the right.

This time of Touschek's life reflects a close camaraderie with other German or Viennese physicists, who had all lived through the hardship of war.

On June 9th, 1946, Pentecost, also known as Whitsunday in the English world and an important Christian festivity, took place.[60] The first Pentecost after the war had ended, it held a special importance in Europe. After the carnage, divisions and conflicts of WWII, survivors and warring armies were sharing the hopes and burden of reconstruction, in a kind of suspended peace, which would soon be shattered by new divisions brought about by the *cold* war. But on that Pentecost Sunday, it was a good moment, for all, to celebrate the peace, no matter what their religion was.

Touschek, while studying hard for his exams and presentations, and basically on the eve of his diploma preparations, was one of many other Europeans who shared this holiday with friends, taking a small break from everyday occupations.

The week-end was quite exhausting. On the Friday before Pentecost, Houtermans

[59] May 9th, 1946 letter to parents from Göttingen.

[60] June 14th, 1946, letter to parents from Göttingen.

Figure 10: A 1937 photo of Fritz Houtermans while imprisoned by the Secret Police of the Soviets, from (Frenkel 2011). At right, from left, Wolfgang Pauli, Pasqual Jordan, Fritz Houtermans and the well known relativist Peter G. Bergmann during the conference held in Bern in 1955 to celebrate the 50th anniversary of the formulation of special relativity by Einstein, photo property of the University of Bern collection, courtesy of S. Braccini.

had to go to the observatory, and asked Touschek to follow him there with Fritz's wife, promising visions of a comet. But, first they failed to find the observatory, wandering around until 11 in the surrounding forest, and then, when they finally got there, there was no sign of the promised comet, and they had to content themselves with a flickering Jupiter. At 2 o'clock they were not yet back home and the night was lost.

On Saturday, Jensen from Hanover appeared and they went together to Houtermans' home, to find Heisenberg, a Military Government official, and Süss, with whom Bruno had often come together in his small apartment in Hamburg, during the war.[61] Saturday night was spent at Touschek's place, with a 'little night physics' ('eine Kleine Nachtphysik'), in a typical Jensen-Houtermans' meeting.[62] The rest of the night was not much fun, given the rather crampled accomodation in Touschek's place (such as just one bed and both Touschek and Jensen having to share it). In Fig. 11 we show two (later times) photographs of both Jensen and Süss.

On Sunday morning, they were again all together at Houtermans and Heisenberg was there as well, but apart from Heisenberg, they were all quite sleepy. The conversation must have been sleepy as well, given that, for some of them, the hours from 1 to 5 in the morning had gone by with the 'kleine Nachtphysik'.

While all this happened, Touschek was very worried about preparing a lecture he was to hold at Heisenberg's seminar, and, in the same days, completing the submission of his diploma thesis. He was able to bring both to a successful completion, not without obvious effort and strain, and he submitted the thesis on June 14th, as he proudly announced

[61] Hans Süss studied physical chemistry at the University of Vienna, receiving his Ph.D. in 1936. He was in Hamburg at the Institute for Physical Chemistry, since 1938. He had a wide range of interests, and becamed an expert in heavy water, becoming a scientific advisor to NorskHydro, the Norwegian plant in Vemork. After the war, in 1950 he moved to the US. For details see (Waenke 2005).

[62] Houtermans was famous for his hospitality. In (Amaldi 2012, 27), Houtermans' first wife, Charlotte Riefenstahl, is quoted as remembering that in Berlin, around 1930, their "...small house and the tiny garden were always bursting with guests. It was not unusual to have 35 people dropping in for tea". One evening almost every week, the Houtermans invited their colleagues and friends to what Fissel called 'Eine kleine Nachtphysik' paraphrasing Mozart's 'Eine kleine Nachtmusik'. During these evening get-togethers, discussions around physics often lasted for hours and until late into the night. See also preface in (Rößler 2007).

Figure 11: Left panel: a photograph of Hans Jensen, at right, with Wolfgang Pauli, center, and Markus Fierz (Pauli Archive Photos, CERN, https://cds.cern.ch/record/42961?ln=en). Right panel: Hans Süss from the Biographical Memoirs of the US National Academy of Sciences (Waenke 2005).

to his parents.[63] The diploma thesis on the theory of the betatron had been done under the joint supervision of Richard Becker and Hans Kopferman and was most likely based on the work he had done during the war and the reports he had prepared afterwards for the T-Force. As for the lecture, it was received well and Bruno could rest and relax for a few days.

In the meanwhile, two weeks before, the possibility of going to England had come up again. He had to fill a rather long questionnaire with an English officer (taking him well of two hours), about a still rather uncertain stay for a six month period. Among a number of different opportunities, the UK option was still appealing to him, partly as he felt he owed the British a lot. There were also an invitation from Rolf Widerøe to visit Switzerland for a three week period, and the offer for a lectureship position at the Berlin University, which he had already decided to refuse. In any case, nothing could be decided until his diploma had been granted.

His gymnasium papers, testifying that he had passed the *matura* in Vienna in 1939 at the Staattsymnasium, were requested and received, and he passed his Colloquium with full honors on June 26th.[64] At this point, after six months of having gone back and forth between London, Göttingen and Glasgow, he started asking what could he do next, or, rather, where would he go. Beyond the six-month position under Heisenberg, the plans for the future included the project in Scotland, the Swiss offer, or remaining in Göttingen and starve. Each of the plans had its own attraction, and staying in Göttingen with Heisenberg was most appealing to him scientifically. Financially, however it was the least secure, because of the lack of research funds available in Germany at the time. Touschek wanted to help his parents in Vienna, where conditions under the Soviet occupation were very harsh, and the difficulty of doing this, as a poorly rewarded Heisenberg's assistant, were scarce. Waiting for the work at the Heisenberg institute to start in August, he envisioned to take a small break, such as driving around the countryside, something he would enjoy, but seemed frivolous. As a matter of fact, the decisions he was agonizing about were not

[63] June 14th, 1946, letter to parents from Göttingen.

[64] June 28th, 1946, letter to parents from Göttingen.

in his power to take.

The British in fact had been preparing his next visits to London, the first of which took place in early July, but in June he would not know about this, and became restless. One night, in late June, after his diploma, he read a book which drove him to reconsider what had happened in Germany. The book was *Darkness at Noon* by Arthur Koestler.[65] It dealt with the fate of a People's Commissar during one of the Russian purges, started in 1933-34, and leads the reader from the arrest to the hanging. Apart from leaving him quite depressed, he was led to consider the difference between what had happened in Germany and the Soviet still ongoing brutality. He could clearly see how things had now changed in Germany, at least in the English zone. He also saw that people around him did not realize this change, neither the British, nor the Germans, who had not seen evil when it was in front of their eyes during the Nazi regime, and could now hardly wait for it to become history.

5.2 Doubts and uncertainty

Shortly after receiving his Diploma, Bruno was taken to England.[66] In Wimbledon, at Beltane School in Queensmere Road, there was an internment camp, where German scientists and technologists were held in order to obtain information and expertise by interrogating them about techniques in which Germany was ahead of Britain (Gimbel 1990a).[67] Unlike others, Touschek was actually free to move in and out of the Beltane school and was even financially compensated. By July 19th, he was back in Göttingen, although not for long.[68] The frequent moves between the UK and Germany, which appear to have taken place between July and September, compounded Touschek's feelings of displacement, even affecting the research he was engaging in. We see that, for Touschek, the period after his diploma became a period of great uncertainty.

After the diploma, Touschek was offered a six month assistantship in Göttingen and he seems to have entertained various possibilities for his future studies, including to remain in Germany, perhaps doing his doctorate with Heisenberg. Envisaging the possibility of a doctorate under Heisenberg was shaking his original desire to go to England. In any case, he now faced two possible pathways to follow, whether to remain in Germany for his doctorate, either in Göttingen or perhaps in Berlin, or pursue the UK road, to Glasgow, where Philip Dee was continuing his efforts to obtain for him a doctoral stipend. Both personal and financial reasons weighted in, pulling him in one or the other direction, and would make Bruno alternate between different routes.

It was an extremely difficult choice. In Germany, he could have the chance to work with Heisenberg, and be surrounded by the top German physicists, eager to rebuild the pre-war eminence of German science. From a strictly scientific point of view, however,

[65] Arthur Koestler (1906-1983) was born in Budapest, from Jewish parents, who left Hungary for Vienna in the 1920's. He became a member of the German Communist party in 1931 and traveled to Russia. He was disillusioned by what he saw, and, after many perilous adventures which included Spanish prisons in 1937 and a stint with the French Foreign Legion, he went to England, and was later naturalized a British citizen. *Darkness at noon* was published in 1940.

[66] July 3rd, 1946 letter to parents from London-Wimbledon.

[67] 'Once the Germans [scientists] had been located by the search teams, escorting officers were detailed to accompany them to London where they were taken to an interrogation center in Wimbledon, based at the premises of the Beltane school.', in (Longden 2009). The center was removed to Hampstead in 1947.

[68] July 19th, 1946, letter to parents from Göttingen.

there were strong restrictions by the part of the occupying forces on the research topics which could be pursued by German physicists. Certainly no accelerator could be built in Germany, for quite some time. And, soon to happen, as we know now, *a posteriori*, the greatest advantages in theoretical physics, the development of relativistic quantum field theories and Quantum Electrodynamics, would in fact take place away from Europe (Schweber 1994).[69] On a personal basis, while he had known many of the Göttigen professors, who held him in good consideration, he was an Austrian, would still be partly an outsider, and his Jewish heritage clashed with remaining in Germany. He would of course be even more of an outsider in the UK, where he would be an ex-enemy alien, but he also had family in Birmingham, a maternal uncle, Alfred Weltmann, with whom he could relate. Ultimately, Touschek always remained an outsider, and this may have been both the source of his genius, and his demise.

However, it is not clear at this point how and why he followed the original plan and left Germany for Glasgow. As we shall see, at the end, after literally going back and forth between the UK and Göttingen from July to December, in April 1947 he moved to Glasgow. And from Glasgow, to Rome, where he would be the moving force for the early development of particle colliders: *a posteriori* one can say that this turned out to be the right choice.

In the uncertainty, he went back to physics, to a neutrino physics problem he had worked on before. Having lost all his notes because of his many moves, and not able to reconstruct right away the arguments and the calculations, he felt like an old man, losing his capacities. He even doubted of losing his talent.

As for his future, conversations with Ronald Fraser did not help to clarify his mind or what could he expect to happen. Fraser wanted to know about possible work and publications on the betatron, but Touschek was now almost totally disinterested in anything connected with that work. Albeit late at this point, Fraser also gave him a gratifying information, namely that things were no longer secret and that the whole secrecy about the betatron, as it was in the previous November and December, was an invention of subaltern officials.

In the second part of July, while in Göttingen, discussing with Fraser whether Touschek were free to accept a possible offer to go to Glasgow, a British corporal appeared with a telegram from England requesting once more the completion of yet another questionnaire. All this was still non-committal, and Bruno was feeling more and more displaced and without a safe direction to go. Memories of his family were coming back to him more often, and, at times, he dreamed of taking a vacation, three years from now, after his doctorate, and go back to the 'Colle d'oro', the golden hill near Rome, where his aunt Ada had a summer house and where she had taken him, during his visits before the war.[70]

Between August and December, Touschek was in the UK at least one more time.[71] In August he may also have been again in Scotland, where the position in Glasgow University, in the department where Lord Kelvin had held a chair, was appealing and definite

[69] In 1965, the Nobel Prize in physics was assigned to Richard Feynman, Julian Schwinger and Sin-Itiro Tomonaga for 'their fundamental work in quantum electrodynamics, with deep-ploughing consequences for the physics of elementary particles.'

[70] The 'Colle d'oro' is a location near Velletri, one of the many small towns dotting the vulcanic hills South-East of Rome.

[71] August 18th, 1946, letter to parents from Wimbledon.

enough that he gave up his room in Göttingen.[72] As it turned out, more time was needed before the offer could be approved by the University administration, and in late September he was back in Göttingen, where the landlady refused to let him back to his room, and he had to sleep on hard pavement, until, presumably, rescued by his friends.

During the summer and the months to follow, Bruno worked hard on double beta decay.[73] In those months, traveling between different places and countries did not permit easy concentration on physics. Still, he worked on the problem while in the UK and started writing a paper, which was then submitted for publication. Upon his return to Göttingen, focusing better on his physics, he found there was a mistake in his conclusions, and had to chase the error to correct it before the paper would be published (Touschek 1948).[74] The anxiety about correcting an error, trace its origin, and rushing to have it corrected while the article was under publication, took most of his energies in October and November. In addition he had to move away from the betatron affairs, where some British officers were still keen on obtaining work or informations from him.

Not receiving news from Glasgow, the uncertainty about where he would be in the next year became a pressing concern and, on November 5th, Touschek solicited Philip Dee for an answer about the Glasgow position.[75] During these months, Philip Dee, who was keen on having Touschek come to Glasgow, had continued his efforts on Touschek's behalf, for him to come to Glasgow, and enter the University Doctoral program. In Fig. 12 we show two images from the 1946-47 Student Handbook of the University of Glasgow.

The solution was near, but it would take another four months before Touschek could take on his research fellowship in Glasgow.

Touschek's anxiety about his future was also entangled with a degree of uncertainty about the direction his research should take. He saw that purely theoretical problems were not interesting him any more, and felt he perhaps lacked the enthusiasm to persevere and solve them. He went to Heisenberg for advice, but could still not see his way out. Various other difficulties piled up, including financial ones. At the end of November, after Dee's letter, the only strategy for Bruno appeared to let the British authorities take care of his next move, although it was clear to him that no solution would be the perfect one. Behind uncertainty and doubts, there looms large the presence of Werner Heisenberg, who befriended Touschek, and may have been his inner mentor throughout his life.

Heisenberg was one of the great scientists who constructed the theoretical framework sustaining particle physics, a concerned observer of the influence of science and philosophy, and a controversial protagonist of the debate about the moral imperative of a scientist facing political power. He was also a major influence on Touschek's development as a physicist. Touschek and Heisenberg never collaborated on an actual paper, nor was Touschek to be his doctoral student. However, they often discussed physics together and Bruno Touschek occasionally worked on some problems of interest to Heisenberg: when a scientist of Heisenberg's stature makes himself available to intellectual and physics discussions, as in Touschek's case, the effect will last forever.[76] The influence of Werner

[72] Bruno Touschek's November 24th, 1946 letter to his parents.

[73] November 24th, 1946, letter to parents from Göttingen.

[74] The paper, submitted to *Zeitschrift für Physik* (now the *European Physical Journal*), on December 2nd, 1946, was published in 1948. In this article Touschek thanks Heisenberg for suggesting the problem and for advice.

[75] November 14th, 1946, Philip Dee's letter to Bruno Touschek, Bruno Touschek Archive, Box 1.

[76] See the extensive correspondence between Heisenberg and Touschek preserved in Bruno Touschek's papers in Rome and in Heisenberg's papers at the Archive of the Max Planck Society in Berlin.

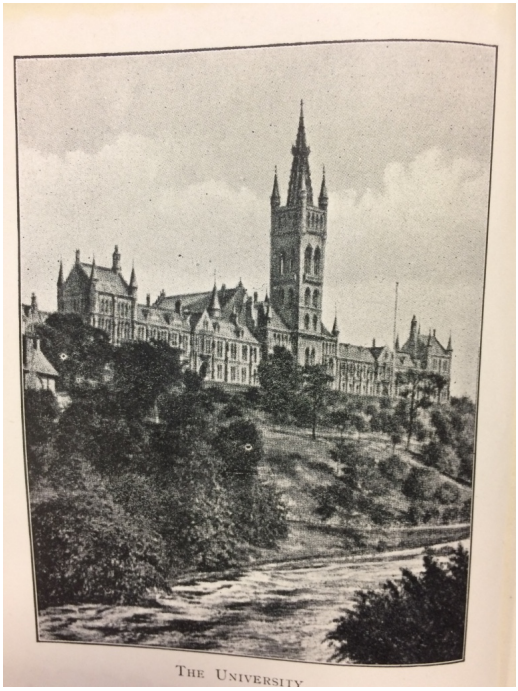

Figure 12: Left and right panels reproduce two pages from the University of Glasgow 1946-47 Student Handbook, an image of the University and the front page, photographed from the original booklet, University of Glasgow Archives & Special Collections, University collection, GB 248 DC 157/18/56. Reproduced with permission from University of Glasgow Archives.

Heisenberg on Touschek runs deep through Bruno's work with Walter Thirring (Thirring and Touschek 1951) on the Bloch and Nordsieck theorem (Bloch and Nordsieck 1937) and in statistical mechanics (Touschek and Rossi 1970). No matter how short, six months or one year, the contact with genius, when the latter allows it, touches one's mind and heart.

By mid December,[77] Dee clarified that the 'unfortunate delay' was that all those involved in the affair had forgotten that difficulties could arise at the University level – not just at the D.S.I.R. Once this was understood, it had then been necessary to wait for the rectorate decision. This having been favourable to Touschek's hiring, it was now mostly a question for the appointment to go through the usual official channels. This would naturally take some time, but it was now only a matter of few months. This delay would suit Bruno, who was keen on attending a lecture by Heisenberg, to be held in January.

Once the Glasgow position had a definite starting date, April 1st, 1947, Touschek could see a clear way ahead of him, and could make closure with some of his past. In particular, he had to put an end to his parents' pressure to go back to Vienna. He had to definitely let his parents know that he would not look for a position there, as they were rather naturally asking of him. Going to Glasgow was a clean break from the past. The lost time was his to reclaim, he hoped: the five years spent in semi-hiding in Germany, the two years between the Anschluss and the expulsion from the University of Vienna in June 1940, studying at Urban's home with borrowed books in 1941, all that lost time could be retrieved. He was going to begin a new life, and could not afford to make any more mistakes. He would not go back to Vienna, at least not until he had his Doctorate.

[77] December 18th, 1946, letter to parents from Göttingen.

He saw that the first mistake had been not to leave Austria in 1938 or 1939, when, from Rome, he had applied for a *visa* to go England. Waiting for it to arrive any day, ultimately he had returned to Vienna. Did he receive the *visa* but lacked the courage to go, or, perhaps, was the family support not forthcoming? It is quite possible that the difficulty may have been on missing family support. In Vienna, they were still hopeful for the worst not to happen. But it was not going to be, as we know. Bruno's grandmother Weltmann, who had moved to Rome to stay with her daughter Ada in 1938, had later returned to Vienna, after Vittorio Emanuele III, King of Italy, had signed into law the anti-semitic regulations declared by Mussolini's regime in October 1938. But once in Vienna, around 1941 she had been taken to Theresienstadt, and never came back (Amaldi 1981, 13).

In December 1946, when Bruno's diploma thesis was in print and the Glasgow situation was clearly in sight, Bruno could sever the bond with his native city. He saw that offers for a position in Vienna were not forthcoming: if he were to go back, he would be one of the clamoring many, and would need to enter into the typical academic squabbling and competition, something he did not, and would never have, appetite for. As for his next move, he had no doubt that, from the scientific and intellectual point of view, remaining in Göttingen would be the most favourable way to go ahead towards a doctorate, but this was not to be taken for granted, not to mention the poor financial prospects. In fact the financial situation of Heisenberg's Institute was still a difficult one, with scarce possibilites to support PhD students.

The problem of money was a natural consequence of Touschek's rather desperate economic situation for a number of years. From a rather affluent pre-war, pre-Anschluss life, he had been thrown into the need to support himself when semi-hiding in Germany. The war over, one can see the emergence of a moral imperative to support his parents in Vienna, under Soviet occupation. Touschek's father had been a major in the Austrian Army and was now retired, and Touschek believed that his father had perhaps left the Army under pressure because of him, his Jewish son, from his first marriage. In later conversations, with Edoardo Amaldi and Carlo Bernardini, his closest friends during the twenty five years he lived in Italy, Touschek let transpire a feeling of guilt in this respect (Amaldi 1981). None of this can obviously be found in Touschek's writings, but the *leit motif* of financial concern, and how much he could help his father and his step mother is omnipresent.

Thus, in April 1947, Touschek joined the Physics Department of the second most ancient of Scottish Universities, as a doctoral student in Glasgow. In later years, Touschek regretted not having remained in Germany, but the history of science tells us that this was the right decision. In Glasgow, Touschek would develop into a full fledged theoretical physicist, and establish contact with the young Italian theorist Bruno Ferretti, who would bring him to Rome in December 1952, where one of the great adventures of particle physics were to begin a few years later. There, in the nearby hills overlooking the city spreading down to the Thyrrenian Sea, a new laboratory would be conceived in 1954 and built, and an electron synchrotron constructed and made to operate in 1959. In this laboratory, on February 17th, 1960, Touschek proposed to construct AdA, an electron-positron collider, the first storage ring of matter-antimatter particles in a laboratory (Amaldi 1981, Bonolis and Pancheri 2011b). Through AdA's operation and first successes, there came the development of a new type of accelerator, which, in the fifty years to follow, would unravel many of the mysteries of the world of particle physics.

6 Who made the decision for Touschek's move to Glasgow in 1947: T-Force, Touschek or Heisenberg himself?

The sudden change of plans in April 1946, when Touschek first went to Glasgow and, one week later, left and went back to Göttingen to get his diploma, can be understood if we place Touschek's personal story in the wider context of how the Allies were planning for the scientific and technological future of the Western world, in a race against the Russians. We have seen the development of Operation Epsilon, through which the German nuclear scientists were chased and brought to England, to be kept without any contact with family and colleagues for six months. In January 1946 they were released to return to Germany, where they would rebuild German science in its less war related aspects, namely no applied nuclear physics, no new accelerators, and other restrictions. Much more sinister, and better known in its general lines, was Operation Paperclip, which brought to the United States many scientists involved in rocket building, in chemical and biological warfare as detailed in (Jacobsen 2014).[78]

In the context of our story, we should recall that the October 1945 B.I.O.S. report about Widerøe's betatron had recommended that Bruno Touschek be brought to the UK.[79] This was also what he mostly wished to happen at the time. As 1946 rolled in, we have also seen that in January a program for constructing new particle accelerators was proposed by the UK Nuclear Physics subcommittee of the Government Advisory Committee on Atomic Energy. This program was then endorsed by the Committee on March 28th, 1946, and, shortly after, approved by the UK government (Krige 1989, 491). This is why Ronald Fraser was able to carry through Touschek's proposed hiring in Glasgow, where he would complete his studies and eventually get his doctorate. No time seems to have been wasted after the UK Government approved the construction of the new accelerators, and in April Touschek was brought in the UK by the military to start his work in Glasgow. Apparently, the immigration authorities, at Harwich, had some objections and officially refused landing rights. However, this did not stop Touschek from entering the UK, something which had also happened before, during a first visit in January or February, but the military was able to override the civil authorities. However, when the Darwin fellowship could not be approved because of him being Austrian rather than German, nothing could be done, and he went back to Göttingen, to continue his studies there.

On June 26th Touschek obtained his diploma, which had been a great success as Sommerfeld wrote in a letter to Paul Urban.[80] We can now see various parallel actions being set in motion. While Dee and Fraser were trying to get him to join Glasgow, Touschek, emboldened by his diploma, was now hopeful to remain in Göttigen and do his

[78] Chief among the German scientists brought to the US was Wernher von Braun. Main scientist of the Nazi rocket program, including the V-2, he became the main artifex of the American space program, as director of NASA's Marshall Space Flight Center and chief architect of the Saturn V launch vehicle which propelled the US to the Moon (see biography of Wernher von Braun at https://history.msfc.nasa.gov/vonbraun/bio.html). Bringing a number of German scientists, some of whom turned out to have been directly involved with slave labor in the concentration camps during the war, often gave rise to contrasts between the military and the US Immigration and Naturalization Service, most of the times resolved in favor of the military by higher political decisions.

[79] B.I.O.S. Miscellaneous Report No. 77, Technical Report No. 331-45, European Electron Induction Accelerators.

[80] Postcard from Sommerfeld to Urban, in Amaldi Archive, Sapienza University of Rome, Box 524, Folder 4, Subfolder 4. It was probably a document sent by Urban to Amaldi, when the latter was preparing his biography of Touschek (Amaldi 1981).

doctorate with Heisenberg. Other options were also open, but the most coveted would obviously be to remain and work with Heisenberg. It did not happen. He did receive a six month position, but that was all. We have no hints regarding Heisenberg's intentions about keeping Touschek at his institute, but at the end of 1946/early 1947, the Kaiser Wilhelm Institute for Physics was still in a very difficult phase, most probably not yet in the position of funding PhD students. Touschek discussed his prospects at length with Fraser, who would assure him things would be OK if he, Bruno, would remain in Germany. Was this all as straightforward as it appears? Or did the T-Force decision that Bruno was needed in Glasgow influence Heisenberg so that Touschek's only way forward was to go to Scotland? Did Bruno ever have a different choice? We may never know, but the background story is so much larger than what Touschek could see, that various possibilities co-exist. Once the accelerator program was approved by the UK government in March 1946, his move to Glasgow had to take place one way or the other. Dee (and Fraser) could not immediately overcome the obstacles posed by the civil authorities, but eventually they did, and Touschek (and his professors in Göttingen) had no choice. Namely, from the very beginning, it is very likely Touschek was meant to take the Glasgow way, because his expertise was of interest to the British scientists planning for the future of particle physics in the UK.

It may appear that we are assigning too much importance to Touschek in this context, but one cannot forget the exceptional intellectual qualities that he possessed and were clearly seen by his peers, Arnold Sommerfeld, or Max Born, among them: coupled with the unique experience with Widerøe, this combination is what ultimately led to the success of AdA. In Touschek, one finds the potential for innovation and disruption: he was a theoretical physicist who had learnt the ways of electrons, during the dark days of World War II, under the guidance of Rolf Widerøe, the European authority on electron accelerators at the time. Thanks to such combination, of theory and practical expertise, in due time, Bruno Touschek could envisage and build a new type of accelerator, a matter-antimatter collider.

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