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Bruno Touschek and the birth of electron-positron Collisions

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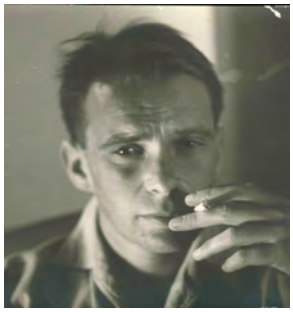
B. Touschek

On November 11th, 1974 the simultaneous announcement of the discovery of the J/Psi by Burt Richter and Sam Ting [1], confirmed three days later by the Italian physicists in Frascati, signaled the beginning of a new era in particle physics. The discovery, at a traditional proton machine in Brookhaven National Laboratory and at two electron-positron colliders, SPEAR in SLAC and ADONE in Italy, showed that matter-antimatter collisions in a laboratory setting could compete with the traditional proton machines and were a formidable tool to probe the quantum vacuum and discover new particles.

The road to matter-antimatter collisions in the Laboratory had started thirty years earlier, when two European scientists, the Norwegian Rolf Wideroe and the Austrian born Bruno Touschek, had met in war ravaged Germany, and had exchanged ideas and books about the theory of the betatron. It is Wideröe [2], who first thought of having two beams of particles collide head-on and even patented his idea in later years. He discussed the matter with Touschek, during one of their meetings, but it was Touschek who, after moving to Italy at the beginning of the 1950s, applied the idea of the kinematic advantage to beams of particles of opposite charges, and actually proposed and built, in Frascati, the first electron-positron storage ring, named AdA, the Italian acronym for Anello di Accumulazione. The story of this achievement is a good illustration of how physics ideas start and develop, and Touschek's survival in Germany during the war is one more tale of courage deserving to be known.

Bruno Touschek was born in Vienna, in 1921 from Franz Joseph, an officer in the Austrian army, and Camilla Weltmann, who belonged to a Viennese Jewish family prominent in artistic and intellectual circles like the Vienna Secession and the Wiener Werkstätte. Camilla Weltmann died young, but Bruno kept frequent and intense relations with his maternal family, in particular with one aunt who lived in Italy and had a villa on the Alban hills southeast of Rome. In the fall of 1938, Touschek's life was shattered, when he was expelled by all Viennese Lyceums, together with every other young persons of Jewish origin. But, like most of them, he still took his final exams privately and in fall 1939 registered to study philosophy, i.e. physics, at the University of Vienna. Not for long though, since, in June 1940, also university life closed for him. He continued his studies, at the home of Paul Urban, then a young assistant professor, with books borrowed from the university library, and read Arnold Sommerfeld treatise on "Atombaum und Spektrallinien". It is through this book that Touschek came to first learn electrodynamics and then to know Arnold Sommerfeld, whose protection allowed him to move to Germany, in early 1942, when life for Vienna Jews became too dangerous.

In Germany he moved between Berlin and Hamburg, attending classes at the University without being registered, and keeping some odd jobs. One of them was with a small electronic devices firm, whose director was also editor of a scientific journal, Arkiv fur Electrotechnik. Through him, Touschek heard of Rolf Wideröe's proposal to construct a 15 MeV betatron. At that time, D. W. Kerst and R. Serber had already put into operation a 2.3 MeV betatron at the University of Illinois, so that Wideröe was to build for the German authorities the first European betatron, later appropriated by the Allied forces and somehow lost. Thus Bruno Touschek and Wideröe met and when Touschek was finally discovered by the Gestapo and put to jail as a spy, Wideröe would go to visit him, bring him books and

continue discussing about the physics and their ideas. Wideröe, in his biography, remembers bringing food and cigarettes and a copy of Heitler's "Theory of Radiation". On such book, it is said that Touschek wrote, with invisible ink, a short note on "Radiation damping in betatrons" [3]. These short notes indicate clearly the intellectual developments and studies which would lead later to the proposal to build an electron-positron collider and to a program of administering radiative corrections to high energy electron positron scattering. But all this was yet to come. In early 1945, while the Allied were progressing through Europe, Touschek met the most dramatic point of his life. We have his direct account of a famous incident in a letter he wrote to his father shortly after the war ended. We have extracted some details, as follows.*

"1945, June 22nd
Dear parents, … I have not received any news from you for a very long time…[I shall now give you] a brief update about what happened to me… After 3 weeks in prison in Hamburg, where I was because of suspected espionage, the prison was evacuated …[and] all the (200) prisoners were put in a long line towards Kiel [concentration camp]. In front of us, behind, and on the sides, marched the SS guards. Near Hamburg… I fell to the ground … and the guards pushed me in the gutter, near the
*A full translation of the letter, which is in German, will be published elsewhere.
road, and shot me. One shot went through my left ear, the other through the lining of my coat. …[After they left me for dead] I went to the hospital, and was again made a prisoner and sent to Hamburg from prison to prison. This lasted about four weeks."

After the war, Touschek went to University of Göttingen to obtain his diploma, and then, for his final education, to Glasgow, where he obtained his doctorate in 1947. In Glasgow there was active work in designing and constructing a synchrotron, as shown in the accompanying cutting from a local Glasgow newspaper. This experience established Touschek's subsequent and seminal work of all the subsequent years.

The Home Of The Synchrotron

Prof. Philip Dee (extreme right) pointing out to fellow research workers features on a model of the new synchrotron block to be built at Glasgow University. Others are (left to right) Mr. A. C. Robb, Dr. S. C. Curran and Mr. B. Touschek.

NO DANGER TO CITY FROM A-PLANT

"THERE will not be the slightest danger to anybody in the neighbourhood of this machine. I want to make that clear because I know there are a lot of stories going around."

Thus Professor Philip Dee, leader of the research team which will probe atom secrets at Glasgow University, yesterday scotched alarmist rumours which have sprung up following the announcement that a giant 300-million volt synchrotron producing 30 million volt X-rays is to be installed there.

The tall, dark, sparely-built Professor added: "Long before anybody outside would be affected in the slightest degree, those inside would be dying like rats. So people outside are certainly very safe—we are not going to kill ourselves, and we are going to be up against the thing."

The Professor was showing reporters a model of the new building which will house Britain's biggest synchrotron.

The machine will be sunk in a basement 20ft. below ground level, with 5ft. concrete slabs separating it from a main hall and research rooms above.

More important to the physicists than the synchrotron itself will be the beam produced, which will travel through a tube to a beam room into which targets will be shot through slits to test matter's reaction to 30-million volt X-rays.

BENEFITS

What are likely to be the benefits to society and medical science? His answer:

"It would be a very bold person who said what would be the consequences of understanding the structure of the nucleus.

"We physicists are not indifferent to what comes out of it. But it is best that things should be allowed to grow out of it naturally, rather than that we direct our efforts to a specific end."

When in the early 1950's in Frascati, near Rome, an electron synchrotron was designed and finally commissioned a few years later, Touschek, who had moved to Rome in 1953 with a University position, was ready and prepared to join the work taking place in the newly built National Laboratory. The Frascati Synchrotron started to work in the fall of 1959, and it is at this point that Touschek put forward an "unthinkable idea", namely to forget the electron synchrotron, one of the most powerful of its kind in the world (the other two being at Cornell and at Caltech), and transform it in a single ring for observing collisions between electrons and positrons. The concept of center-of-mass collisions had been pursued by the American and Soviet counterparts all throughout the late 1950's, but the concept was applied to beams of protons circulating in two different rings or two electrons againts electrons, as in the case of the Princeton group, who, with Gerald O'Neill, was building an electron-electron two-ring collider. Touschek's speculations emerged during discussions following a seminar delivered at the Physics Department in Rome in the fall of 1959 by Wolfgang Panofsky, at the time the Director of HEPL at Stanford. Touschek's outstanding idea was that, because of symmetry, opposite charges can be stored in one single ring, and made to collide head-on, provided that their masses are equal. Touschek's also favored electrons over protons, as the first appeared to him as "gentle probes" opposed to the "messy physics" generated by protons. Thus one needed positrons to collide with electrons. "*The challenge of course"* as Touschek writes in one of his notebooks,"*consists in having the first machine in which particles which do not naturally live in the world that surround us can be kept and conserved* ".

Touschek presented his ideas at a Laboratory meeting in February 1960. His proposal of converting the synchrotron was obviously rejected, but a decision was taken for the construction of a small storage ring to prove the feasibility of electron-positron collisions, and, at the end of 1960, AdA had been built. The small AdA had a 65 cm radius and a beam energy of 250 MeV. A first stored beam of few electrons was obtained at the end of May 1961, using the Frascati Electron Synchrotron as an injector, while electron-positron collisions were actually only observed at the beginning of 1964 when AdA was shipped to France at the "Laboratoire de l'Accelerateur Lineaire" of Orsay, near Paris, where a high intensity linear accelerator was available.

AdA showed the feasibility of electron-positron collisions, and opened the way to higher energy and luminosity. Soon after it was built, in the USA, Soviet Union and Europe, proposals to built more powerful colliders, with higher energy and higher luminosity were put forward. The road which led to some of the most important discoveries of the Standard model had been opened.

[1] Samuel C.C. Ting, From Nobel Lectures, Physics 1971-1980, Editor Stig Lundqvist, World Scientific Publishing Co., Singapore, 1992.
http://nobelprize.org/nobel_prizes/physics/laureates/1976/ting-lecture.pdf
[2] The life of Rolf Wideroe, 1994, DESY, Edited by Pedro Waloschek.
[3] E. Amaldi, The Bruno Touschek Legacy, CERN 81-19, 23 Decembre 1981 and L'eredita' di Bruno Touschek, Quaderni del Nuovo Cimento, SIF, Vol. V, 1982.