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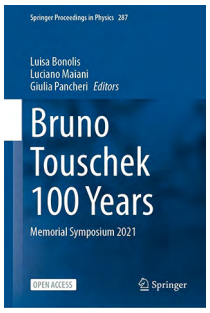

Luisa Bonolis, Luciano Maiani,
Giulia Pancheri (Editors)

Bruno Touschek 100 Years
Memorial Symposium 2021

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The 100th anniversary of the birth of Bruno Touschek (Vienna 1921, Innsbruck 1978) provided an opportunity to recall the immense contribution made by the great Viennese physicist to the development of particle accelerators and thus to fundamental physics during his last years in Italy. It is also about 70 years since Bruno Touschek arrived in Italy and sixty since his creature AdA, the first particle-antiparticle collider, became operational in Frascati. The incalculable progress in elementary particle physics that arose from Bruno Touschek's visionary work is now recalled in this beautiful book, edited for Springer by Luisa Bonolis, Luciano Maiani and Giulia Pancheri, which collects the papers presented in December 2021 at three different conferences at La Sapienza University of Rome, at the INFN National Laboratories in Frascati, where Ada saw the light, and at the Accademia dei Lincei.

Giulia Pancheri and Luisa Bonolis initiated the centenary celebrations with some historical articles on Bruno Touschek's (hereafter BT) training period in postwar Germany [1] and Glasgow [2], and on his great scientific legacy [3]. Also to be associated with the present collection of celebratory articles is the book that Giulia Pancheri has written under the evocative title "*Bruno Touschek's Extraordinary Journey - From Death Rays to Antimatter*" [4]. An extraordinary and adventurous journey was indeed the life, personal and scientific, of BT, which ended prematurely at only 57 years of age.

Opening our book and series of talks at La Sapienza is Francis Touschek's tale (Ch. 1), which recalls dad Bruno (aka Burl) in several episodes of family life and with the same sense of humor peculiar of certain Austro-Hungarian Jewish ancestry. In particular, Francis mentions that Viennese cultural milieu of Grandma Camilla Weltmann, where dad grew up. That world populated by extraordinary names in the sciences and the arts, but troubled by the growing anti-Semitism, which came between the end of the empire and the Anschluss: what remained of "*Die Welt von Gestern*" narrated by Stefan Zweig.

BT's extraordinary scientific adventure is recounted by Luisa Bonolis (Ch.2): his adolescence, the difficult university years, the protection of Sommerfeld, the dramatic, miraculous survival from Gestapo imprisonment, the immediate postwar period in Göttingen with Heisenberg and other members of the Uranverein, returning from the British imprisonment at Farm Hall. Then the five years in Glasgow, and the arrival in Italy at the end of 1952, immediately after the birth of the INFN, to participate in the work of reconstruction of Italian physics with the great survivors and heirs of Fermi's school: the ideal conditions to realize in Frascati AdA, the first particle-antiparticle (e^- - e^+) collider, later transferred to the LAL in Orsay. And it was at Orsay, as Jacques Haïssinski tells (Ch. 3), that the first evidence of the Touschek effect and of collisions between counter-rotating particles was obtained in 1963. Then ADONE in Frascati and the birth of a theoretical school in Rome, and finally BT at CERN to participate in the proton-antiproton collider project of Carlo Rubbia and Simon van der Meer, just before his untimely death in Innsbruck.

Bruno Touschek belonged to that generation of great physicists who knew how to be both experimentalist and theoretician at the same time. Giancarlo Rossi, who was his student and graduate student, tells in Ch. 4 how highly Touschek was appreciated as a lecturer in the course of statistical mechanics. Together they wrote the textbook "*Meccanica statistica*" (Boringhieri, 1970), so innovative in its choice and presentation of topics to definitely deserve a reprint.

CPT invariance was the theoretical basis of AdA, but the parity violation of weak interactions, discovered a few years earlier by Chien-Shiung Wu in beta decay, opened great horizons not only to leptonic colliders but to all physics where chirality plays a fundamental role. The fact foreseen by Pasteur that living matter also has definite chirality led Abdus Salam and Jona-Lasinio, among others, to think that the remote origin of such dissymmetry is precisely the chirality of weak interactions. Unfortunately, BT could not learn about the discoveries of Carlo Rubbia and van der Meer, thus joining the club of missed Nobel laureates, along with Wu and others. Carlo Rubbia, in his paper (Ch. 5) recalls BT's great role in the realization of particle-antiparticle colliders and concludes "I have learned from Bruno to love matter-antimatter reactions. Without this fact my own scientific career would certainly have been very different! So, I believe it has been the case for many others of us."

Giorgio Parisi, who became interested in ADONE's physics in 1970, also explains (Ch. 6) how important that physics was for his great theoretical achievements on partons and asymptotic freedom, and how the Frascati data confirmed Gell-Mann's QCD at a famous seminar of his in Rome. As Luciano Maiani tells in Ch. 7, the Constituent Quark Model for hadrons, *vs*. the so-called "nuclear democracy," and the formidable theoretical school of great "constituent" physicists at Sapienza and Frascati were born at that time. "Our generation has been very lucky to be there, at the right place and the right time, and it all has been, indeed, a great fun", Maiani concludes.

The next three chapters completing the Sapienza talks, written by Ugo Amaldi, Gabriele Veneziano and Guido Martinelli, illustrate how far BT's work has taken fundamental physics. On the experimental side, the Laboratory for Electro-Strong Physics, the large LEP detectors and from the LEP to the LHC are born at CERN. The Standard Model and Quantum Chromodynamics are consolidated, the hunt for the Higgs boson begins (Ch. 8). Theory aspires to unification of forces: Hadron Strings, D-branes, Quantum Gravity (Ch. 9). Supercomputers needed to address new problems and theoretical methods, such as Lattice QCD, are needed and developed (Ch. 10).

The four papers given at Frascati (Ch. 11-14) delve into the role of BT at that historic site. Mario Greco, who came to Frascati in 1965 and stayed there for 25 years, is a magnificent witness to the new physics that was being realized there with AdA and ADONE. The follow-up at the Frascati National Laboratory (LNF) from ADONE to the present day is

found in Andrea Ghigo's account, while the development at the IJCLab in Orsay is illustrated by Achille Stocchi. The technical challenges that lie ahead for future accelerators are discussed by Lucio Rossi. Prominent among these are the development of superconducting magnets for accelerators, and the prospects opened by high-temperature superconductors.

The papers presented at the Lincei give an idea of how far BT's work has taken it. Giulia Pancheri (Ch. 15) takes up the theme of BT's extraordinary journey from Widerøe's to storage rings, *i.e.*, the realization of AdA, while that of ADONE is recounted by Claudio Pellegrini, who at the LNF contributed to greatly increase the luminosity of the colliders. Exciting is the reproduction of the draft proposal written by BT to build an electron-positron collider dated November 9, 1960! On the theoretical level, who better than Giovanni Jona-Lasinio could speak about Touschek chiral transformation with respect to which the Nambu - Jona-Lasinio model of fermionic mass generation is invariant? It was Jona-Lasinio who presented Yoichiro Nambu's Nobel Lecture on spontaneous symmetry breaking on December 8, 2008, and he rightly talks about this in his tribute to BT, expanding the discussion also to condensed matter. Paolo Di Vecchia, a distinguished string theorist, also fondly recalls BT's famous Statistical Mechanics lectures before delving into the salient aspects of the theory.

Too young the great astrophysicist Marica Branchesi to have known BT: she was born when BT was at CERN, a year before he passed away. Now she tells us (Ch. 19) about multi-messenger astronomy, which began with the first observation of gravitational waves by the LIGO and Virgo networks, where Marica Branchesi has been a leader. Rightly so, because the multi-messenger astronomer starts obtaining information about a wealth of fundamental processes occurring in the cosmos as well as in large colliders. How much this new synergy will materialize in future major European projects, specifically in the European Strategy for Particle Physics, is explained by Gian Francesco Giudice (Ch. 20), who works on the two fronts at CERN. In the meantime, large circular colliders are being planned in China, see Yifang Wang's presentation (Ch. 21), and linear colliders at CERN (CLIC) and in Japan (ILC), as illustrated by Steiner Stapnes (Ch. 22) in the last Lincei talk. The final chorus (Ch. 23) closes the opera, with personal recollections of distinguished colleagues who participated in the Lincei session: Giovanni Battimelli, Franco Buccella, Luisa Cifarelli, Carlo di Castro, Giovanni Gallavotti and Luciano Pietronero. I cannot find any better conclusion that would translate the meaning of this book than the one placed by Luciano Maiani at the close of his talk: "Our generation has been very lucky to be there, at the right place and the right time, and it all has been, indeed, a great fun."

Giorgio Benedek
Università di Milano-Bicocca

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