University of Zurich[UZH]

Department of Physics

Annual Report and Highlights 2022

Winterthurerstrasse 190, CH-8057 Zurich, Switzerland

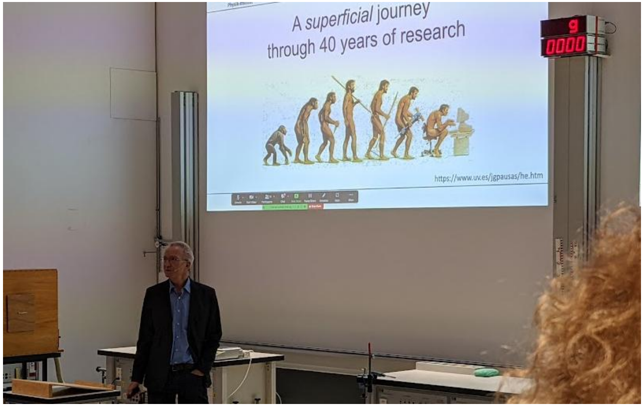
Preface

Thomas Gehrmann, Department Head

With a total of 24 research groups, the Department of Physics of the University of Zurich covers a variety of subfields of physics. Experimental activities include particle and astroparticle physics, hard and soft condensed matter physics, surface physics and nanoscience, as well as the physics of biological systems. Theoretical groups work on precision calculations of processes in quantum chromodynamics and new theories beyond the standard model of particle physics, astrophysics and general relativity, as well as topological concepts in condensed matter physics. Other physics-related groups from within the Faculty of Science and beyond are affiliated to our department, and our home page gives links to their research. Together, we can offer a broad and high quality spectrum of lecture courses as well as Bachelor, Master and semester projects to our students. The infrastructure department consisting of excellent mechanical and electronics workshops. Efficient IT and administrative support teams complete our attractive research environment.
https://www.physik.uzh.ch/en/research.html

The year 2022 marked the successful commissioning of the Xenoscope demonstrator, seen on the report's frontpage. This accomplishment by the experimental astroparticle group of Laura Baudis, with substantial support from our mechanical and electronics workshops, marks an important step towards the DARWIN project, a large-scale detector for dark matter searches at unprecedented sensitivity.

Following almost three decades of world-class research activity in experimental condensed matter and surface physics at our department, our colleague Jürg Osterwalder retired at the end of the spring semester 2022. With a combination of curiosity, common sense, determination and good humour, he shaped and led his thriving research group. The same skills enabled him to successfully manage the Physik-Institut as director from 2016 to 2021 and to guide the Swiss science policy as member of the research council of the Swiss National Science Foundation. His lively lectures were filled with spectacular demonstration experiments, often demanding his all-out involvement, and gaining him a celebrity status especially among the medical students.



Farewell lecture of Jürg Osterwalder.

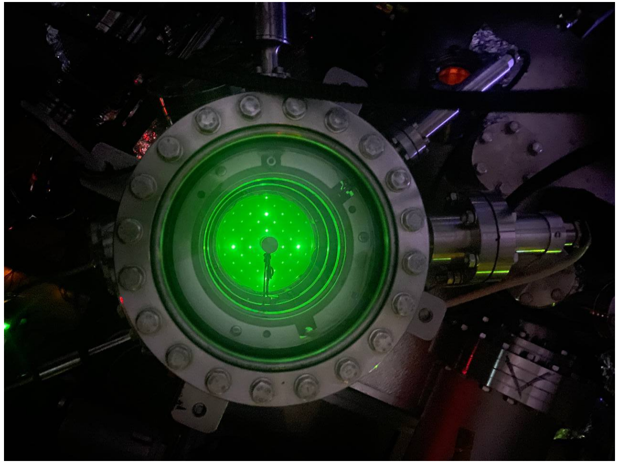
After two years of limited on-site activities due to the Covid-pandemic, our department was very happy to return to normal on-site operations in research, teaching and student supervision in 2022. Many of us gained substantial experience on novel teaching formats and on remote collaborative work during the past years. While parts of these formats were only emergency substitutes for in-person interactions, others proved to be very effective and well-appreciated, leading to innovative improvements especially of teaching methods and student interaction.

Our department made substantial contributions to community-building and outreach events. Researchers from our department initiated and co-organised the "Women in Physics Career Symposium" as a satellite event to the annual meeting of the Swiss Physical Society (SPS) in Fribourg. The symposium attracted 75 participants from all career stages and launched a mentoring program for early-career female physicists in Switzerland. The tenth anniversary of the discovery of the Higgs boson was celebrated with an informative walk through the Irchelpark. Marking the 100th anniversary of the award of the Physics Nobel Prize to UZH-alumnus Albert Einstein, we organised an exhibition in the Irchel Lichthof. Highlighting the stages of Einstein's career and explaining his major scientific accomplishments, the display was very well received by students and academics from all faculties. A new exhibition on the LHCb experiment was opened in the Science Pavilion UZH, joining the already present three exhibits from our institute on superconductors, search for Dark Matter and the CMS experiment. Finally, our institute organised an open day and contributed to the Long Night of the Museums and the Science & Nature Festival.

This booklet aims to give a broad idea of the wide range of research pursued in our department and refers the more interested reader to the research websites. Presenting individual highlights with pride, we thankfully acknowledge the continued support from the Kanton Zürich, the Swiss National Science Foundation, the European Commission, and others who have made this fundamental research possible.

Retirement - Jürg Osterwalder, Emeritus since August 2022

Ask which instrument you play, and I tell you who you are. This mantra of Katrina Krimsky reminds of approaches to personalities like graphology or astrology – Jürg is a fish – still, it might contain a grain or two of truth. Besides the question of which instrument you play, it is also important how good you play it, whether you like solos or whether you are part of an orchestra or a band. As we know, at least since June 3, Jürg plays banjo, an instrument where you pluck mostly five strings that are resonating via a membrane spanned across a cavity. The origins of the banjo are in the United States of America, a country that Jürg likes a lot, where he spent his time as a postdoc, his two sabbaticals and where he became a fellow of the American Physical Society. Plucking persons and then letting them evolve is one of his ways to manage, where he likes to listen to the tones that evolve from the resonator that makes the triggered vibrations audible, even if they are gentle. With this attitude he led and shaped the surface physics group from 1994 to 2022, and the Physik-Institut as a director from 2016 to 2021. Sixteen semesters he served as a member of the research council division II of the Swiss National Science Foundation and five of those as the president. Physics for medical students was one of his favorite lectures that he liked to give, condense and perfect to high standards. His science was based on the detection of electrons and learning from them all they can tell if they are excited in condensed matter: energy, momentum and spin. His way of recording and displaying photoelectron diffraction data in two dimensional maps was eye-opening and as well applied for the direct measurement and visualisation of Fermi surfaces. His development of methods around the photoelectric effect was coupled with his will to contribute step by step to the solution of problems such as the storage of hydrogen in metals or the conversion of light energy into chemical bonds. When we asked him on what he will do after emeritation, he smiled and said more will come, may be, I will program an app on a mobile phone. Such down to earth projects are typical for him, he makes use of his skills and insights and likes to see his work to work.



A low-energy electron diffraction (LEED) image taken at 60 eV on a freshly prepared $Fe_3O_4(001)$ surface represents the diffraction spots of the $(\sqrt{2}) \times \sqrt{2})$-R45 reconstruction. Image: Mert Taskin, 2021.

Prof. em. Ernst Brun, 1927 – 2022

Prof. em. Dr. Ernst Brun was Professor for Experimental Physics at our institute from 1958 until his retirement in 1992.

Ernst Brun studied physics at the University of Zurich and received his doctorate in 1954 under Professor H.H. Staub with a thesis on magnetic nuclear moments using nuclear magnetic resonance. He developed new experimental methods - dynamic nuclear polarization - to amplify nuclear magnetic resonance signals and thus was able to detect very weak signals. After a research stay in the USA, he was appointed associate professor of experimental physics at the University of Zurich in 1958. In 1963 he was promoted to full professor.

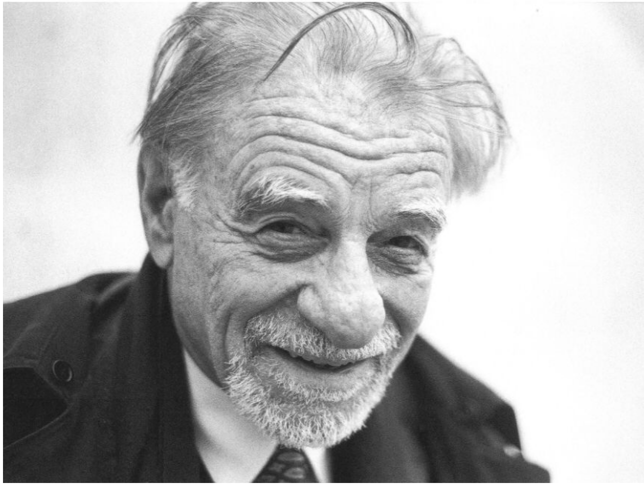
Brun initially worked on nuclear magnetic resonance (NMR) and its applications to the structural analysis of minerals. His close collaboration with crystallographers in Switzerland and abroad stemmed from this period. Later, he focused his diverse scientific activities on the study of complex nonlinear systems using NMR and laser methods, which led to the discovery of the NMR laser (Raser) in his research group. He also made increasing use of extensive simulation calculations based on spin dynamics and spin thermodynamics, as exemplified by the development of the Raser: It started with the observation of non-linearities in the signal strengths of the nuclei at strong negative polarization. Based on model calculations with extended Bloch equations, he postulated that a nuclear spin system should spontaneously emit coherent radio frequency radiation when the degree of polarization reaches a certain threshold. Following extensive experiments, he finally succeeded in realising experimentally this nuclear resonance laser or Raser. He interpreted the spontaneous transitions of the disordered system to a coherently radiating highly ordered state and the complex transient processes occurring in the process with theories of phase transitions and with chaos theoretical principles (chaos and order). The insights gained were often of a very general nature and can be applied to many areas of the natural sciences.

Ernst Brun's research was characterized by curiosity and enthusiasm. He successfully transferred this permanently to his colleagues. He was open to many new ideas, which he discussed critically, thus pursuing new paths with conviction, both mentally and materially.

In addition to his profound special lectures, Ernst Brun taught medical students for many years as a great and dedicated teacher in lectures that remained in the memory of many former students. In doing so, he succeeded in conveying to his audience the fascination of researching fundamental physical questions, and in introducing physics as a basic subject to the future natural scientists.

Ernst Brun served as Dean of the Philosophical Faculty II (today Faculty of Mathematics and Natural Sciences) from 1970 to 1972 and as Director of the Physik-Institut of the University of Zurich from 1972 to 1992. He was a charismatic and very people-oriented institute director who emphasised a collaborative management style. Important decisions were taken together with the people concerned and were presented and discussed at institute meetings. In this way, he made a significant impact in ensuring that no one felt advantaged or disadvantaged and that a good atmosphere was created throughout the institute. The welfare of all was always more important to him than personal success or honours. The Physics Institute under the leadership of Ernst Brun was marked by unity with a sense of community, which was shaped and fostered by his extraordinary personality.

Prof. em. K. Alex Müller, 1927 - 2023



Prof. Dr. Dr. h.c. mult. K. Alex Müller,
IBM Fellow, Nobel Prize Winner in Physics 1987, was Professor for Experimental Physics at our institute from 1970 until his retirement in 1994.
K. Alex Müller's scientific career path started with the studies of physics at ETH Zurich where he was intensely influenced by Prof. Wolfgang Pauli. His diploma work was supervised by Prof. G. Busch, who was also the supervisor of his PhD thesis which dealt with the paramagnetic resonance in the newly synthesized double perovskite $SrTiO_3$.

K. Alex Müller started his professional life as head of the magnetic resonance group at the Battelle Memorial Institute in Geneva. Upon the recommendation of Prof. E. Brun he did his habilitation at the University of Zurich in 1962. In view of his high scientific impact, the IBM Zurich Research Laboratory offered him in 1963 the position of a researcher where he was promoted to a group leader of the physics department in 1971, a position that he held until 1985. During this time his research focused on $SrTiO_3$ and related perovskites with emphasis on their chemical binding, their ferroelectric and soft-mode properties, and later on their critical and multicritical phenomena at their phase transitions. His enormous successes in this field made him to one of the world leading experts in the research on ferroelectricity and structural phase transitions. In addition, his intimate knowledge of perovskites paved his way to superconductivity in this material class. In 1970 he was appointed as titular professor of the University of Zurich. A decisive moment in his career occurred in 1982 when he was nominated as IBM fellow. This enabled him to decide freely and independently about his further research areas - a milestone on his way to the Nobel prize.

During a sabbatical leave starting in 1979 at IBM Yorktown Height (USA) K. Alex Müller paid for the first time attention to superconductivity and gained profound knowledge in this field. He was especially interested in oxide superconductors which were rare at that time. Theoretical ideas as developed by Prof. Harry Thomas and his group at the University of Basel gave him the impulse to concentrate on complex oxides with Jahn-Teller centers. Such ions provide a source of strong and unconventional electron-phonon interactions including polaron and bipolaron formation. Together with J. Georg Bednorz he started in 1983 a new research project concentrating on superconductivity in oxide Jahn-Teller systems. In 1986 they achieved the breakthrough with the discovery of cuprate high-temperature superconductors (HTSs), which only a year later in 1987 was honored with the Nobel prize in physics for both. In the same year, but before their nomination, K. Alex Müller was promoted to a full professor at the University of Zurich.

After the Nobel prize K. Alex Müller continued his work on cuprate HTSs by focusing on their pairing mechanism. Since his original concept for the discovery was based on a polaronic or bipolaronic mechanism, he initiated a project on isotope effects in cuprate HTSs where novel and unexpected isotope effects were discovered which confirmed his starting concept that the charge carriers in these superconductors are strongly coupled to the lattice, *i.e.* that local lattice effects and inhomogeneity are relevant for superconductivity in cuprates. This notion is and was in strong contrast to the widely accepted conviction that the paring mechanism in the cuprates is of purely electronic origin.

Besides of his ingenious scientific achievements and engagements he was also a dedicated and inspiring teacher with profound interest in the students and their life. He attended the seminars at the Physik-Institut with deep scientific interest and was known for his perceptive and subtle questions and contributions. Up to an old age he stayed in close contact with the Physik-Institut and vividly took part in the social life.

Statistical Data

202
personnel

professors: 25
affiliated professors: 10
senior researchers: 17
postdoctoral researchers: 46
PhD students: 75
engineers and technicians: 22
administration: 8
+ research assistants

420
students

~80
new students

220 bachelor	31 BSc degrees
98 master	18 MSc degrees
97 PhD	18 PhD degrees

11
SNF prof. and ERC grants

35	SNF or EU research grants
7	fellowships
45	UZH and other grants

304
publications

282	peer reviewed papers
19	conference proceedings
3	books & others

433
conference and workshop contributions

207	talks at conferences
123	seminar and other talks
66	posters
37	outreach

Outreach

Awards

- Jens Oppliger: Dectris prize
- David Urwyler: Soluyanov prize
- Yuta Takahashi: CMS young researcher prize
- Sevda Esen: LHCb early career award
- Michael Denner: SPS General Physics Award
- Laura Baudis: Charpak Ritz Prize

Events

- Connecting Women in Physics
- Open Day of the Institute
- Long Night of Museums
- Science & Nature Festival
- Exhibition: 100 years nobel prize of Albert Einstein
- Higgs@10: educative walk through the Irchel park

Others

- New exhibition on LHCb in the Science Pavilion UZH

Dance your Science: illustrating proton-proton collisions in the Science Pavilion UZH.

Teaching

bachelor **3** major options	180 ECTS physics 150 ECTS physics/30 ECTS minor 120 ECTS physics/60 ECTS minor
4 master programs	particle physics condensed matter astro(particle) & cosmology bio- & medical physics

service lectures **1457** students		
	550	medicine
	650	biology & biomedicine
	160	chemistry
	70	teacher
	27	minors

A practical demonstration of the lens-maker equation by simple means

Describing the combined influence of refractive index contrast and boundary curvature on the properties of a lens is demonstrated by a glass inside a rectangular container that both can be filled with water. If both the glass and the container are empty (left most picture), the arrows behind the glass are undisturbed. If the glass is filled with water, it acts as a focusing lens and creates an inverted, real image of the arrow. Filling the container as well removes the curved interface, such that again an undisturbed image is obtained. Finally, filling the container, while leaving the glass empty results in the glass acting as a defocusing lens, producing a reduced, virtual image of the arrow.