DESY marks 50 years of accelerator research

When DESY was founded in December 1959 as a German national laboratory for high-energy physics, it was far from obvious that it would develop from its modest beginnings into a research centre with an international reputation that now extends beyond particle physics to photon science.

The first five chairmen of the DESY directorate, photographed in 1993. From left: Herwig Schopper (1973–80), Wolfgang Paul (1971–73), Willibald Jentschke (1959–70), Volker Soergel (1981–93) and Bjørn Wiik (1993–99). (Courtesy DESY.)

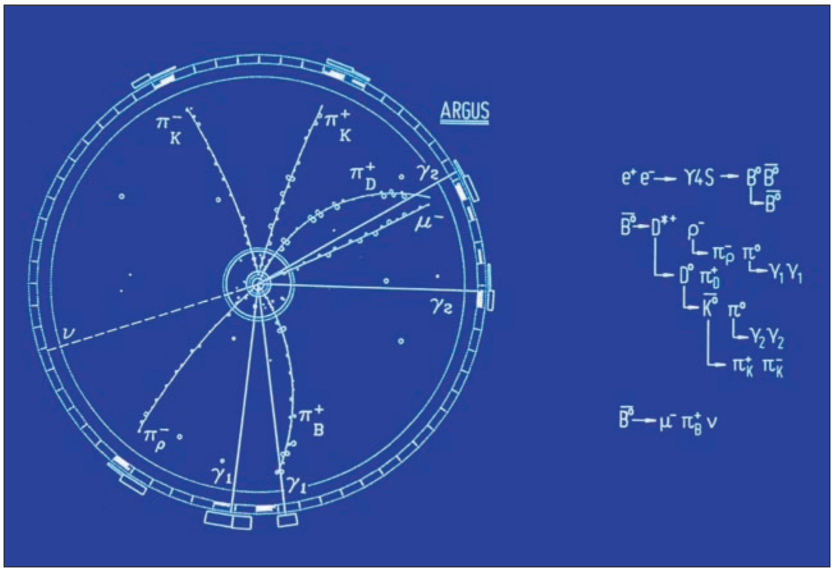
The founding father of DESY, Willibald Jentschke, was a Viennese nuclear physicist who had built a successful career in the US by the time he accepted a professorship at Hamburg University in 1955. He arrived with a plan to build a substantial laboratory for which he managed to secure unprecedented start-up funding worth about €25 million in today's money. Jentschke discussed his ideas with leading German nuclear physicists, including Wolfgang Gentner, Wolfgang Paul and Wilhelm Walcher, at the 1956 Conference on High-Energy Particle Accelerators at CERN. Together they conceived the idea to create a laboratory serving all German universities, thus making good use of Jentschke's "seed money". This would enable German physicists to participate in the emerging field of high-energy physics where similar laboratories were planned or already in existence in other European countries. With the backing of influential personalities such as Werner Heisenberg and the firm support of the authorities of the City of Hamburg, the plan eventually materialized and Jentschke became the first director of the Deutsches Elektronen-Synchrotron, DESY, which came into being in December 1959.

DESY's founders wisely opted for a 6 GeV electron synchrotron – the highest electron energy they could expect to reach with contemporary technology. In this way the machine would be complementary to CERN's proton accelerators, the Synchrocyclotron and the Proton Synchrotron. The DESY synchrotron started operations in 1964. At the time, physics with electron and photon beams was considered a niche activity, but under Jentschke's direction DESY managed to perform new and beautiful measurements of the nucleon form factors and the photoproduction of hadrons. It also earned renown for having "saved QED", with an experiment led by Sam Ting that corrected earlier results from the US on wide-angle electron-pair production.

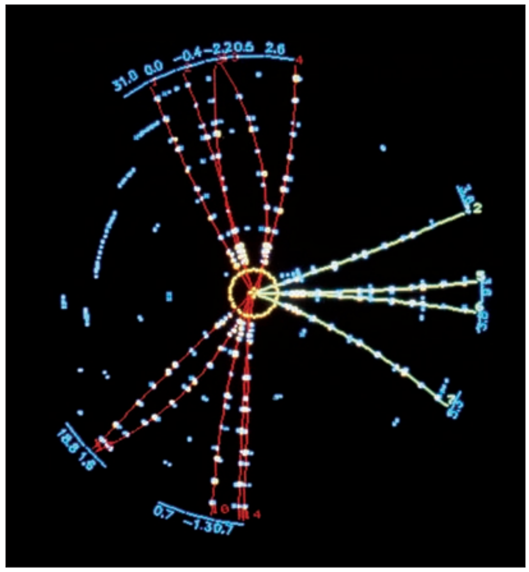
In the early 1960s, the laboratory developed plans to build a large electron–positron storage ring. The motivation was to try something new, but the physics prospects did not appear exciting. Few people at the time took quarks seriously, so the physics community expected hadron production to be dominated by time-like form factors and to decrease dramatically with energy. It was a bold move to base the future of DESY on electron storage rings as the main facility to follow the synchrotron. After controversial discussions, the laboratory nevertheless took the step towards an uncertain future: the construction of DORIS, a two-ring electron–positron collider with 3 GeV beam energy, began in 1969.

Exciting times

Good news followed with the discovery at the storage rings Adone in Frascati and the low-beta bypass of the Cambridge Electron Accelerator in Massachusetts that cross-sections for electron–positron collisions decrease only mildly with increasing energy. This was finally interpreted as evidence for quark–antiquark pair production and went a long way in establishing the quark model. The bad news was that beam instabilities, in particular in two-ring storage machines, were much stronger than expected; moreover, SPEAR, the simpler one-ring machine at Stanford, had started up some years before DORIS. So the J/Ψ and the τ-lepton were found at SPEAR. The experiments at DORIS were nevertheless able to contribute substantially towards charm spectroscopy, for example by discovering the P-wave states of charmonium and finding evidence for leptonic charm decays. The real opportunity for DORIS came later, however, after the discovery of the b quark in 1977. DESY ▷



An event recorded by the ARGUS detector at the DORIS storage ring shows the decay of the Υ(4S) resonance into a pair of B mesons, identified by their decay. This is evidence of B–$\bar{B}$ mixing. (Courtesy DESY.)



A three-jet event, registered at the PETRA storage ring; such events were a direct evidence for the existence of gluons. (Courtesy DESY.)

made a big effort to upgrade DORIS in energy so that B mesons could be pair produced. The experimenters were able to perform a rich programme on the physics of the B particles, culminating in 1987 in the discovery of the mixing of neutral B mesons.

Plans for a bigger ring surrounding the whole DESY site were already under discussion during the construction of DORIS, and the discovery of the J/ψ in November 1974 provided the final impetus. Under the guidance of the director at the time, Herwig Schopper, and an energetic accelerator division leader, Gustav-Adolf Voss, PETRA – an electron–positron collider with an initial centre-of-mass energy of 30 GeV – was completed in 1978, far ahead of schedule and below budget. PETRA was later upgraded to 46 GeV and, for the eight years of its lifetime, was the highest-energy electron–positron collider in the world. The year 1979 saw the first observation of three-jet events at PETRA, leading to the discovery of the gluon and a measurement of its spin. Other important results concerned the comparison of the production of quark and gluon jets with the predictions of QCD perturbation theory to second order, leading to a measurement of the strong coupling constant α_S and the first measurements of electroweak interference in muon- and τ-pair production.

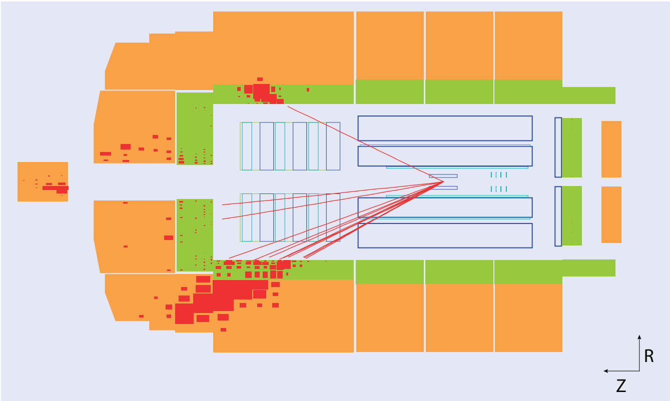
It was an exciting time in which experimenters and theorists worked together closely on the new fields that PETRA had opened up. By the time the experiments were completed in 1986, they had contributed greatly to establishing the Standard Model as a generally accepted theory. With PETRA, DESY had grown into a leading centre for particle physics, reflected by the international nature of its user community, with as many as 50% of the visiting scientists coming from outside Germany.

So what was to come after PETRA? As a guiding principle, complementarity with the programme at CERN had always been central to DESY's strategy. So, when CERN opted for the Large Electron–Positron (LEP) collider, the next big project for DESY became HERA – the world's only electron–proton collider. Bjørn Wiik had been pursuing plans for such a machine for years and these gathered full momentum when Volker Soergel became DESY's director in 1981. Together, Wiik and Soergel succeeded in convincing colleagues and funding agencies in Canada, France, Israel, Italy and the Netherlands to contribute to HERA as a joint project through the provision of machine components to be manufactured by the respective home industries or laboratories. In addition, physicists and technicians from universities and institutes not only in Germany but in many other countries, foremost China and Poland, came to DESY to participate in the construction of the machine. Eventually almost half of the manpower used to build HERA was from outside DESY. This "HERA model" of how to realize a big accelerator facility became an outstanding success. HERA was also unique in being situated underground in a residential area, but it took little more than six years from the start of construction to obtain the first electron–proton collisions at the full centre-of-mass energy of 300 GeV, in 1991. Two big detectors, H1 and ZEUS, started taking data immediately; HERMES and HERA-B followed a few years later.

Further expansion

HERA was operated successfully until 2007. While spectacular "new physics" failed to appear, the experiments revealed the structure of the proton with unprecedented beauty. Their results will define our knowledge of the nucleon for the foreseeable future and will be invaluable for interpreting the data from the LHC experiments (*CERN Courier* January/February 2008 p30 and p34); they also offer some of the most precise tests yet of QCD and of the electroweak interaction.

Wiik succeeded Soergel as DESY's director in 1993 and he soon initiated another vision: TESLA, a linear electron–positron collider of 500 GeV centre-of-mass energy employing superconducting accelerating cavities. It would, at the same time, provide the beam for an X-ray free-electron laser. An international collaboration was formed to develop the project and it had made substantial progress when, in 2003, a decision by the German government forced a drastic change of plan. While the government agreed to the realization of the X-ray free-electron laser part of the project within an international framework, it did not at the time support building the high-energy



A deep inelastic electron–proton scattering event, recorded by the H1 detector at HERA. The proton beam comes from the right, the electron beam from the left. The electron is back-scattered off a quark inside the proton and emerges to the left upwards. The quark is knocked out of the proton and produces a shower at the lower left. (Courtesy H1/DESY.)

A view inside the 6.3 km tunnel of HERA shows the superconducting magnets – used to guide the proton beam – installed above the normally conducting magnets of the electron ring. (Courtesy DESY.)

Measuring station in the experimental hall of the new PETRA III synchrotron radiation source at DESY – one of the most brilliant storage-ring-based X-ray sources in the world. (Courtesy Dominik Reipka, Hamburg.)

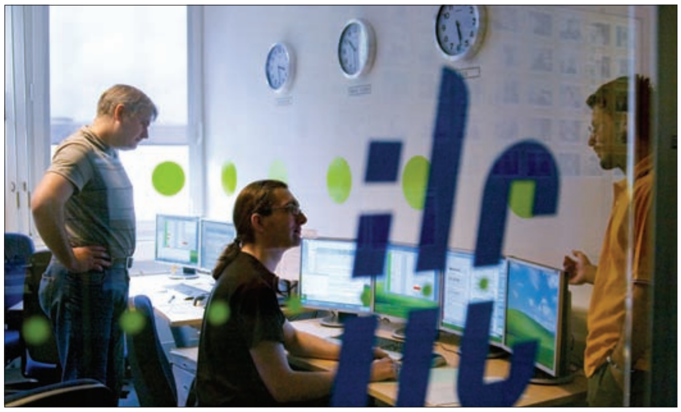
collider in Hamburg and decided to await the course of international developments before recommending a site for the collider. The German government did, however, renew its support for R&D work for a linear collider, which enabled DESY to proceed with this and maintain its involvement in the international co-ordination and decision process. By endorsing the realization of one of the world's most powerful X-ray lasers in the Hamburg area, this decision in effect contributed to strengthening the second "pillar" of DESY's research: photon science.

Photon science – a modern term for research with synchrotron and free-electron laser radiation – was not new to DESY. On the initiative of research director Peter Stähelin, DESY had already built laboratories and instruments for utilizing synchrotron radiation at the original synchrotron and had made them available to a wide community of users in the 1960s. Later, the storage ring DORIS offered a continuous beam with much improved conditions, in particular for X-rays. The quality was enhanced further by insertion devices such as wigglers and undulators. In 1980 DESY created HASYLAB, a big laboratory to provide the growing community of users with all of the facilities they required. The research spanned a wide area, from materials science, physics, chemistry and geology to molecular biology and medical applications. Among the most active users were the European Molecular Biology Laboratory (EMBL) – which operated its own outstation at DESY – and special groups that the Max Planck Society established for applying the synchrotron radiation at DESY to research in structural biology. One prominent Max Planck group was led by Ada Yonath from the Weizmann Institute in Israel, who won the 2009 Nobel Prize in Chemistry for unravelling the structure of the ribosome. Part of this work was done with the help of synchrotron radiation from DORIS.

In 1993, after an upgrade with additional insertion devices, DORIS became entirely dedicated to the generation of synchrotron radiation and, with more than 40 beamlines, became a leading X-ray facility. By 1995 PETRA's performance as a pre-accelerator for HERA was so smooth that this machine could also be used as a source for hard X-rays. The rising demand for such beams led to the rebuilding of PETRA as a dedicated synchrotron-radiation source, once the operation of HERA ceased in 2007. PETRA III was completed in 2009 together with a large new experimental hall (*CERN Courier* September 2008 p19). As one of the most brilliant light sources of its kind, it will be a world-leading facility for research with hard X-rays and provide high intensity for very small probes.

The big challenge for the DESY accelerator experts in the forthcoming years will be the construction of the X-ray free-electron ▷

The 30 m-long undulator of the FLASH free-electron laser at DESY, the only such facility to produce high-intensity, ultrashort radiation pulses in the vacuum ultraviolet and soft X-ray wavelength range down to 6.5 nm. (Courtesy Manfred Schulze-Alex, Hamburg.)



The new CMS and ILC control rooms at DESY allow the operation and data-taking of CMS to be monitored as well as ILC test experiments at CERN and Fermilab to be run remotely from Hamburg. (Courtesy Barbara Warmbein, DESY.)

laser, the European XFEL. Having grown out of the TESLA project, this 3 km-long facility will be equipped with superconducting accelerating cavities and precision undulators. It will allow users to study dynamic processes with atomic-scale resolution in space and time, opening exciting research opportunities. A similar but smaller self-amplifying spontaneous-emission laser, FLASH, has already been operating at DESY for a few years. It generates ultrashort laser pulses of vacuum-ultraviolet and soft X-ray radiation and is in high demand by experimenters because of its unique properties (*CERN Courier* January/February 2007 p8).

With around 2000 users, photon science is now a major activity at DESY. No longer having a high-energy accelerator on site, DESY's particle physicists have turned to the LHC and become partners in the ATLAS and CMS collaborations. This revives a tradition, as in past decades, of DESY physicists participating strongly in experiments at CERN, such as with bubble chambers and muon beams. DESY is also setting up a National Analysis Facility – a computing and analysis platform for LHC experiments. Studies relating to a possible International Linear Collider (ILC), which will make use of superconducting cavities as developed for TESLA, also remain on the agenda. DESY has formed a close relationship with the German universities and institutes that are involved in the LHC or the ILC studies within the national Helmholtz Association alliance, "Physics at the Terascale", which extends to theoretical particle physics and cosmology (*CERN Courier* May 2008 p11). The DESY theory group is also strongly engaged in lattice calculations.

In 1992 the Institute of High-Energy Physics of former East Germany, in Zeuthen near Berlin, became part of DESY. Besides its involvement in high-energy-physics experiments, particle theory and the development of electron guns for free-electron lasers, the institute brought astroparticle physics into DESY's programme. DESY Zeuthen is currently a strong partner in the construction of the 1 km^3 IceCube neutrino telescope at the South Pole, which should soon deliver results (*CERN Courier* March 2008 p9).

In its 50th year, with the prospect of photon sources of unprecedented quality, an active role in particle and astroparticle physics and the involvement of a wide international scientist community, DESY is looking forward to a continuing bright future.

Further reading

For more about the 50 years of DESY, see Erich Lohrmann and Paul Söding *Von schnellen Teilchen und hellem Licht, 50 Jahre Deutsches Elektronen-Synchrotron DESY*, Wiley-VCH Weinheim (2009).

Résumé

DESY : cinquante ans de recherche sur les accélérateurs

DESY, fondé en 1959, est un laboratoire allemand de physique des hautes énergies, devenu un centre de recherche de réputation internationale. Son domaine ne se limite pas à la physique des particules, puisqu'il travaille aussi sur la « science des photons » – des recherches pour lesquelles il utilise des rayonnements produits par les synchrotrons et les lasers à électrons libres. Au fil des années, les recherches en physique des particules sont passées du synchrotron initial de 6 GeV au collisionneur électron–positon PETRA, et enfin au collisionneur électron–proton HERA. Pour l'avenir, le grand défi pour les experts des accélérateurs de DESY sera la construction de l'installation européenne XFEL, un laser à électrons libres à rayons X, de 3 km de long, exploitant la technologie supraconductrice.

Erich Lohrmann *and* **Paul Söding**, *DESY.*