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# From Periphery to Center: Synchrotron Radiation at DESY, Part I: 1962–1977


## ABSTRACT

In its fifty-year history, the German national research laboratory DESY (Deutsches Elektronen-Synchrotron, German Electron Synchrotron) has undergone a gradual transformation from a single-mission particle physics laboratory to a multi-mission research center for accelerator physics, particle physics, and photon science. The


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The following abbreviations are used: BAK, Bundesarchiv Koblenz (Federal Archive in Koblenz); CERN, Conseil Européen pour la Recherche Nucléaire (European Organization for Nuclear Research); DESY, Deutsches Elektronen-Synchrotron (German Electron Synchrotron); DFG, Deutsche Forschungsgemeinschaft (German Research Foundation); DIR, Direktorium (Board of Directors); DM, Deutsche Mark (German mark, former official currency of Germany); DORIS, Doppel-Ring-Speicher (double ring storage); EMBL, European Molecular Biology Laboratory; ESRF, European Synchrotron Radiation Facility; EWissR, Erweiterter Wissenschaftlicher Rat (Extended Scientific Council); Fermilab, Fermi National Accelerator Laboratory; FKS, Forschungskollegium für Synchrotronstrahlung (Research Council for Synchrotron Radiation); FLASH, Freie-Elektronen-Laser Hamburg (Free-Electron-Laser Hamburg); FY, fiscal year; GAfSS, Gutachterausschuss für Synchrotronstrahlung (National Expert Committee for Synchrotron Radiation); GeV, Giga electron volts; HASYLAB, Hamburger Synchrotronstrahlungslabor (Hamburg Synchrotron Radiation Laboratory); JB, Jahresbericht (Annual Report); KMK, Kultusministerkonferenz (Standing Conference of the Ministers of Education and Cultural Affairs of the German Länder States); LHC, Large Hadron Collider; PETRA, Positron-Elektron-Tandem-Ring-Anlage (Positron-Electron Tandem-Ring Accelerator); PIA, Positronen-Intensitäts-Akkumulator (Positron Intensity Accumulator); PT-DESY, Projektträger DESY (administrative outpost at DESY); SLAC, Stanford Linear Accelerator Center; SPEAR, Stanford Positron-Electron Accelerator Ring; *SPP*, *Science and Public Policy*; UV, ultraviolet; VR, Verwaltungsrat (Administrative Council); VUV, vacuum ultraviolet; WissR, Wissenschaftlicher Rat (Scientific Council); WJB, Wissenschaftlicher Jahresbericht (Scientific Report); XFEL, X-Ray Free Electron Laser.

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last is an umbrella term for research using synchrotron radiation and, in later years, free-electron laser. Synchrotron radiation emerged initially as a peripheral part of the laboratory activities but grew to become a central experimental activity at DESY via a series of changes in the organizational, scientific, and infrastructural setup of the lab, and in its contextual scientific, political, and societal environment. This article chronicles the first sixteen years (1962–77) of the history of synchrotron radiation at DESY and its gradual transformation from peripheral and parasitic to a regular and recognized research program. The article complements previous writings on DESY history by focusing on synchrotron radiation, and it adds to the body of knowledge about the crucial renewal of Big Science laboratories toward the end of the twentieth century. This renewal culminated in the close-down of several particle physics machines in the early 2000s and their replacement by facilities dedicated to the study of the structure, properties, and dynamics of matter by the interaction with vacuum ultraviolet/X-ray photons. Therefore, this article contributes to the knowledge about the emergence and growth of synchrotron radiation as a laboratory resource, the understanding of processes of renewal in Big Science, and the general history of late-twentieth-century science.

KEY WORDS: synchrotron radiation, DESY, HASYLAB, EMBL, Federal Republic of Germany

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The Deutsches Elektronen-Synchrotron (DESY) is a German national laboratory for particle physics, accelerator physics, and so-called photon science located in the Bahrenfeld area of Hamburg, with an outstation in Zeuthen near Berlin. Although DESY was founded as a single-mission federal research institute for high-energy research with the aid of particle accelerators, it supported research with synchrotron radiation a few years after it was established. Particle physicists viewed synchrotron radiation as an unwanted by-product of particle accelerators built for the exploration of subatomic particles. Synchrotron radiation was initially used in so-called parasitic mode at several accelerators throughout the world but grew to become a big science in its own right with large numbers of dedicated and optimized accelerator laboratories now in operation.[1] Synchrotron radiation has been a feature of laboratory activities at DESY almost since its first machine was operational, which makes this

1. The word "parasitic" means that synchrotron radiation researchers used facilities that were built for other purposes and that their activities depended on particle physicists who defined the performance parameters for the machines used at the facility. "Parasitic" carries possibly negative connotations and is not the preferred expression for all actors and stakeholders at DESY and other accelerator laboratories. Nevertheless, it was used by many people involved at the time, even jokingly; see Olof Hallonsten, "The Parasites: Synchrotron Radiation at SLAC, 1972–1992,"

laboratory a unique case in the global history of synchrotron radiation. Arguably, this factor has also made DESY a forerunner in the gradual technical, scientific, and organizational progress that transformed synchrotron radiation from a peripheral to mainstream experimental resource in the natural sciences.

Synchrotron radiation research at DESY began in the early 1960s with an extramural grant. Step by step, other university groups joined the "bunker," as the very rudimentary experimental facility for synchrotron radiation at DESY was called at the time, and soon the activities moved to more and finally larger buildings. Throughout the 1960s and 1970s, synchrotron radiation research at DESY was "parasitic" in the sense mentioned above. Scientists interested in pursuing a research program using synchrotron radiation at DESY had to take whatever was given to them in terms of basic technical parameters, including energy levels and beam stability, which are both critical factors in the use of synchrotron radiation. This parasitic mode reached its limits at the end of the 1970s, when more and more prospective users from more and more science fields of synchrotron radiation applied for a spot at the DORIS (Doppelring-speicher) facility at DESY and when the science results became more and more novel and important. Developments throughout the 1970s culminated in the foundation of a laboratory coordinating all synchrotron radiation activities at DESY, known as HASYLAB (Hamburger Synchrotronstrahlungslabor). Initially, this new laboratory struggled with resource scarcity, but external (mostly university) research groups invested in equipment and provided, in practice, cofunding and human resources to develop the DESY synchrotron radiation infrastructure.

With new dedicated synchrotron radiation sources being constructed all over the world, the 1980s witnessed a global increase in attention to research with synchrotron radiation, including at DESY, and policymakers both inside and outside DESY became aware of the need to further develop HASYLAB's facilities and staff to seek and maintain a leading global position. In the 1990s, two decisive events happened: research with synchrotron radiation was recognized as a formal organizational goal, and DORIS was fully dedicated to synchrotron radiation research. Then, in the early 1990s, the DESY leadership forged a coalition with the synchrotron radiation researchers to develop a technical design for a new linear collider coupled with an X-ray free-electron laser (XFEL). In the 2000s, synchrotron radiation research achieved a prominent

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*HSNS* 45, no. 2 (2015): 217–72; Park Doing, *Velvet Revolution at the Synchrotron: Biology, Physics, and Change in Science* (Cambridge, MA: MIT Press, 2009).

place in DESY's research strategy; the former parasite had become a partner of particle physics. By the end of the first decade of the twenty-first century, DESY operated three dedicated synchrotron radiation sources, DORIS III, PETRA III, and FLASH, and on its site, the biggest dedicated light source, the XFEL, is currently being built.

This article covers the first sixteen years of synchrotron radiation activities at DESY, ending with the expansion of these activities at DORIS. It is the first of two articles on the history of synchrotron radiation at DESY covering the years 1962–93.[2] DESY's position as one of the leading synchrotron radiation facilities in the world was formed partly in symbiosis and partly in competition with its particle physics program, and with a growing domestic and international synchrotron radiation community and strong support from German science policy. In analyzing the role and status of synchrotron radiation research as a peripheral but gradually growing experimental activity at DESY, this article contributes to understanding DESY's internal transformation and the causes and consequences of this transformation. At the same time, this article details a relevant piece of the history of science and technology in the late twentieth century, highlighting institutional change in large public research organizations.

Existing historical accounts of DESY have focused almost exclusively on its particle physics program, and three books are particularly noteworthy. First, the early history of DESY until 1970 was chronicled by Claus Habfast. This book focuses entirely on DESY's particle physics program.[3] Second, more recently Erich Lohrmann and Paul Söding, both physicists and retired members of the Direktorium (DIR), published a comprehensive account of DESY's history until 2009, including developments in synchrotron radiation research. Their book was also written mainly from the perspective of particle physics.[4] Regarding DESY's synchrotron radiation research program, Christof Kunz, one of the leading synchrotron scientists at DESY, recently provided in his personal memoirs valuable details about the early years of synchrotron

2. The second article will be published as Thomas Heinze, Olof Hallonsten, and Steffi Heinecke, "From Periphery to Center: Sychrotron Radiation at DESY, Part II: 1977–1993," *HSNS* 45, no. 4 (2015).

3. Claus Habfast, *Großforschung mit kleinen Teilchen: DESY 1956–1970* (Heidelberg: Springer-Verlag, 1989).

4. Erich Lohrmann and Paul Söding, *Von schnellen Teilchen und hellem Licht: 50 Jahre Deutsches Elektronen-Synchrotron DESY*, 2nd ed. (Weinheim: Wiley-VCH, 2013); the history of synchrotron radiation is covered on pp. 221–53 and partly on pp. 302–15.

radiation. This book is highly informative but also selective and written as a personal memoir rather than an official historical document.[5]

In addition, this article draws on historical accounts of the foundation and early years of Big Science facilities in Western Germany (*Großforschungseinrichtungen*), first with respect to the re-establishing of nuclear physics after 1955 and second with respect to the funding cycles for Big Science facilities in the context of federal research policy.[6] Furthermore, this article is informed by analyses focusing on similar developments in national laboratories in the United States, first regarding laboratory transformations that followed the conversion of particle accelerators at SLAC, Cornell, and Argonne,[7] and second regarding the changing funding regime for Big Science facilities in the later 1960s and early 1970s, and again in the early 1990s.[8]

Science policy commentators have framed changes in the history of science during the second half of the twentieth century with suggestive labels that

5. Christof Kunz, *Synchrotronstrahlung bei DESY: Anfänge* (Private Print, 2012), available at DESY upon request.

6. Cathryn Carson, "Nuclear Energy Development in Postwar West Germany: Struggles over Cooperation in the Federal Republic's First Reactor Station," *History and Technology* 18 (2002): 233–70; Gerhard A. Ritter, Margit Szöllösi-Janze, and Helmuth Trischler, eds., *Antworten auf die amerikanische Herausforderung. Forschung in der Bundesrepublik und der DDR in den "langen" siebziger Jahren* (Frankfurt am Main: Campus-Verlag, 1999); Peter Fischer, *Atomenergie und staatliches Interesse. Die Anfänge der Atompolitik in der Bundesrepublik Deutschland 1949–1955* (Baden-Baden: Nomos, 1994); Margit Szöllösi-Janze and Helmuth Trischler, eds., *Großforschung in Deutschland* (Frankfurt am Main: Campus-Verlag, 1990); Margit Szöllösi-Janze, *Geschichte der Arbeitsgemeinschaft der Großforschungseinrichtungen: 1958–1980* (Frankfurt am Main: Campus-Verlag, 1990); Wolfgang D. Müller, *Geschichte der Kernenergie in der Bundesrepublik Deutschland. Anfänge und Weichenstellungen* (Stuttgart: Schäffer Verlag, 1990), 304–30; Michael Eckert, "Die Anfänge der Atompolitik in der Bundesrepublik Deutschland," *Vierteljahreshefte für Zeitgeschichte* 37 (1989): 115–43.

7. Olof Hallonsten and Thomas Heinze, "Institutional Persistence through Gradual Adaptation: Analysis of National Laboratories in the USA and Germany," *SPP* 39, no. 4 (2012): 450–63; Olof Hallonsten, "Growing Big Science in a Small Country: MAX-lab and the Swedish Research Policy System," *HSNS* 41, no. 2 (2011): 179–215; Catherine Westfall, "Surviving to Tell the Tale: Argonne's Intense Pulsed Neutron Source from an Ecosystem Perspective," *HSNS* 40, no. 3 (2010): 350–98; Catherine Westfall, "Institutional Persistence and the Material Transformation of the US National Laboratories: the Curious Story of the Advent of the Advanced Photon Source," *SPP* 39, no. 4 (2012): 439–49.

8. Hallam Stevens, "Fundamental Physics and Its Justifications, 1945–1993," *HSPS* 34, no. 1 (2003): 151–97; Lilian Hoddeson, Adrienne Kolb, and Catherine Westfall, *Fermilab: Physics, the Frontier & Megascience* (Chicago: University of Chicago Press, 2008), 93–224, 312–34; Peter Westwick, *The National Laboratories: Science in an American System 1947–1974* (Cambridge, MA: Harvard University Press, 2003), 269–98.

imply grand structural transitions, such as "triple helix," "Mode 1/Mode 2," "post-academic science," or "post-modern science."[9] The nature of these transitions is somewhat controversial because they have not yet been substantiated with much historical evidence. Therefore, there is a clear need to confront claims about major structural changes on the macro-level with conclusive facts and figures. First, such evidence needs to be collated on the micro-level, as was recently demonstrated by a historical account of the proliferation of synchrotron radiation research at SLAC and Cornell.[10] Based on the history of synchrotron radiation at DESY, this article provides additional historical evidence on the micro-level and thereby supports the argument that the worldwide concentration of particle physics at a few large accelerator sites, in particular the Large Hadron Collider (LHC) at CERN, occurred in parallel with the increasing interest in and support of both the life sciences and materials sciences during the second half of the twentieth century.[11]

Second, this article (including Part II)[12] shows how micro-level events in the history of DESY shaped processes by which multidisciplinary photon science research gradually replaced particle physics both as a research program and as a technical infrastructure. Drawing on recent theoretical advances in historical institutionalism, we distinguish among change processes that operate on the levels of laboratory infrastructure, research fields in the laboratory, and formal organizational structure: *layering* means new entities are added on top of existing structures, thus enabling the accommodation of new elements without excessively compromising commitments in the preexisting laboratory; *conversion* refers to when research capacities for one set of goals are redirected to other ends, such as when large technical infrastructures for particle physics are

9. Triple helix: Henry Etzkowitz, *The Triple Helix: University-Government-Industry Innovation in Action* (New York: Routledge, 2008). Mode 1/Mode 2: Michael Gibbons et al., *The New Production of Knowledge: The Dynamics of Science and Research in Contemporary Societies* (London: Sage, 1994). Post-academic: John Ziman, *Real Science: What It Is and What It Means* (Cambridge: Cambridge University Press, 2000). Post-modern: Paul Forman, "The Primacy of Science in Modernity, of Technology in Postmodernity, and of Ideology in the History of Technology," *History and Technology* 23 (2007): 1–152.

10. Hallonsten, "Parasites" (ref. 1); Doing, *Velvet Revolution* (ref. 1).

11. Hallonsten, "Parasites" (ref. 1); Cyrus C.M. Mody, *Instrumental Community: Probe Microscopy and the Path to Nanotechnology* (Cambridge, MA: MIT Press, 2011); Harold Varmus, *The Art and Politics of Science* (New York: W. W. Norton & Co, 2009), 144–45; W. Patrick McCray, "Will Small be Beautiful? Making Policies for our Nanotech Future," *History and Technology* 21 (2005): 177–203; John Sulston and Georgina Ferry, *The Common Thread: A Story of Science, Politics, Ethics and the Human Genome* (Washington, DC: Joseph Henry Press, 2002).

12. Heinze et al., "From Periphery to Center, Part II" (ref. 2).

redeployed for photon science; *displacement* means research capacities are discontinued, and new ones are added in their place; and *dismantling* means technical infrastructures or research units cease to be used without being replaced by new infrastructures or units.[13]

*Layering*, *conversion*, *displacement*, and *dismantling* operate at multiple temporal and spatial scales and mutually influence one another. For example, the *layering* of a new technical infrastructure on top of an existing one may result in a new scientific activity (*layering*) on that piece of infrastructure. The new infrastructure also may lead to the establishment of a new organizational unit (*layering*), but eventually to the takeover of the original research field's use of the infrastructure by the new research field (*displacement*). Simultaneously, the components of the infrastructure itself may be restructured (*conversion*) at various points in time and as part of the overall process of laboratory transformation.

As shown in this paper, the reasons why these processes, or a combination of them, occured, are manifold, depending on actor constellations and contextual factors. According to the historical institutionalism literature, one important contextual factor is resources. For example, if investments in new fields (here, synchrotron radiation research) are sponsored from a growing resource base, then *layering* is likely. In contrast, if investments in new fields are undertaken in a context of stagnation, like in a zero-sum-game, *displacement* is likely. In comparison, *layering* is the least conflict-laden of the four processes because it does not imply direct losses for existing research fields. Hence, *layering* is likely

13. James Mahoney and Kathleen Thelen, "A Theory of Gradual Institutional Change," in *Explaining Institutional Change: Ambiguity, Agency, and Power*, ed. James Mahoney and Kathleen Thelen (Cambridge: Cambridge University Press, 2010), 1–37; Wolfgang Streeck, *Re-Forming Capitalism: Institutional Change in the German Political Economy* (Oxford: Oxford University Press, 2009); Wolfgang Streeck and Kathleen Thelen, "Introduction: Institutional Change in Advanced Political Economies," in *Beyond Continuity: Institutional Change in Advanced Political Economies*, ed. Wolfgang Streeck and Kathleen Thelen (Oxford: Oxford University Press, 2005), 1–39; Kathleen Thelen, "How Institutions Evolve: Insights from Comparative Historical Analysis," in *Comparative Historical Analysis in the Social Sciences*, ed. James Mahoney and Dietrich Rueschemeyer (New York: Cambridge University Press, 2003), 208–40. For a comparison of the four processes, see Thomas Heinze and Richard Münch, "Institutionelle Erneuerung der Forschung. Eine Analyse wissenschaftshistorischer Beispiele zur Transformation von Disziplinen und Forschungsorganisationen," in *Wissenskulturen. Bedingungen wissenschaftlicher Innovation*, ed. Harald Müller and Florian Eßer (Kassel: Kassel University Press, 2012), 19–41; Olof Hallonsten and Thomas Heinze, "From Particle Physics to Photon Science: Multidimensional and Multilevel Renewal at DESY and SLAC," *SPP* 40, no. 5 (2013): 591–603; Hallonsten and Heinze, "Institutional Persistence" (ref. 7).

to get gradual transformation processes started, even if actors in established fields have strong veto power. Both *layering* and *displacement*, in tandem with *conversion* and *dismantling*, occured in the case of DESY and HASYLAB at different levels and at different points in time.

The historical institutionalism perspective improves our understanding of how complex micro-level events result in broader macro-level transformations. It remedies the micro-macro divide in science history in that micro-level events of particular historical cases (here, DESY) are conceptualized as elements in change processes (*layering*, etc.) that in turn constitute the building blocks for broader macro-level transformations (here, the global shift toward using former particle physics laboratories for multidisciplinary photon science research). Using the historical institutionalist perspective allows us to frame the history of one laboratory (here, DESY) in categories that go beyond the particular case and invite comparisons with other laboratories, a prerequisite for the identification of macro-developments in science history.

This article describes step-by-step how DESY gradually transformed, relying on four types of sources: (1) archival material obtained at DESY in Hamburg, including minutes of DESY's Administrative Council (VR), DIR, and Scientific Council (Wissenschaftlicher Rat, WissR), annual reports from both DESY and HASYLAB, and DESY's annual fiscal plans;[14] (2) archival material concerning DESY obtained from other archives, including the European Molecular Biology Laboratory (EMBL) and the Bundesarchiv; (3) personal interviews with key contemporary witnesses; and (4) secondary literature, including the books on DESY and Big Science facilities in Germany and the United States mentioned above.

## PARTICLE PHYSICS, SYNCHROTRON RADIATION, AND LATE 20TH CENTURY BIG SCIENCE

DESY was founded in the midst of the nuclear and particle physics heyday at a time when the governmental budget for science in general—and for accelerator facilities to study subatomic particles and forces in particular—seemed inexhaustible.[15] At that time, few other uses for particle accelerators

14. All archival material quoted in footnotes was retrieved from the DESY archive unless other archives, such as from DFG or BAK, are mentioned.

15. The science budget in Western Germany doubled between 1962 and 1972; see Cathryn Carson, "Beyond Reconstruction: CERN's Second Generation Accelerator Program as an Indicator

were known except on a very abstract and conceptual level: The unavoidable radiation emission by electrons that are accelerated to almost the speed of light and whose trajectories are bent had been known for a while to consist of intense ultraviolet (UV) and X-ray radiation that could, in principle, be of great use in spectroscopic and crystallographic experiments and measurements. However, moving from this rather theoretical realization to actual use of the radiation required a separate effort, and it was not until the early 1960s that some researchers took the opportunity to perform systematic experimental trials. Apart from the technical difficulties involved in extracting useful radiation in a safe and effective way, cultural barriers existed between the particle physics programs and the prospective users of synchrotron radiation. Though the former used accelerators for a single and clearly defined purpose, namely to collide elementary particles and study the results of the collisions, users of synchrotron radiation are typically academic researchers who happen to find use for intense UV or X-ray radiation in their research projects, on a temporary basis; nowadays, they come from disciplines as diverse as solid state physics, materials science, chemistry, biology, the life sciences, medicine, and environmental sciences.[16]

The proof of the usefulness of synchrotron radiation for all of these fields came gradually and in tandem with continuous technological advances in virtually all components of the synchrotron radiation facilities. Most important was the advent of the storage ring concept, which allowed a continuous, well-defined, stable beam of radiation to be extracted, instead of the flickering light of previous synchrotrons.[17] Other significant developments included the introduction of so-called insertion devices, which are arrays of magnets inserted into storage rings and accelerators to allow for higher intensity and eventually the use of hard X-rays (wavelengths <1 Å or 0.1 nm) and of highly brilliant, almost monochromatic photon beams.[18]

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of Shifts in West German Science," in *Physics and Politics: Research and Research Support in Twentieth Century Germany in International Perspective*, ed. Helmuth Trischer and Mark Walker (Stuttgart: Steiner, 2000), 107–30; see also Müller, "Geschichte der Kernenergie" (ref. 6), 315–16.

16. Doing, *Velvet Revolution* (ref. 1); Hallonsten, "The Parasites" (ref. 1); Hallonsten, "Growing Big Science" (ref. 7).

17. Synchrotrons have not been used to produce synchrotron radiation since the storage ring came in existence in the 1970s, and the name "synchrotron radiation" is essentially incorrect, although the original use of synchrotrons for the production of the radiation has made the name stick.

18. Bernd Sonntag, interview by first author, 11 Oct 2012; Gerhard Materlik, interview by first author, 23 Oct 2012.

In parallel with the increased use of synchrotron radiation in several areas and a global increase in synchrotron radiation communities, particle physics experienced a gradual restructuring internally as well as in relation to other rising fields of science. Ever since its emergence, particle physics was inescapably tied to the construction of accelerator machines of higher and higher energies (although in some periods, the optimization of other performance parameters of accelerators was also determinant), which generally meant larger and larger and thus costlier machines. This development made particle physicists used to seeing their machine construction budgets grow, almost as a law of nature, from thousands to millions of dollars in the 1950s, on to hundreds of millions of dollars in the 1960s and 1970s, and finally to several billions of dollars in the 1980s.[19] However, this growth of the machine construction budgets came to a halt in the early 1990s when the Superconducting Super Collider project was cancelled by the U.S. Congress, and for the first time in the United States, there was no "next big machine" that would take the obvious lead in particle physics research worldwide.[20]

Meanwhile, a less abrupt change had occurred in particle physics as a result of the same cost increases, namely the concentration of resources and experiments to a smaller number of labs in both the United States and (Western) Europe, beginning in the 1970s. Some authors have conceptualized this change as taking particle physics from Big Science to "megascience,"[21] and for the discipline it meant that a number of machines and facilities were no longer useful for frontier particle physics research and that the labs running them had to find other ways of justifying their existence. This development meant nationwide prioritization of resource allocation to particle physics laboratories, and the substitution of national programs in favor of globally organized collaborative efforts.[22] Many of the deserted accelerator facilities around the world were eventually converted and taken over by synchrotron radiation

19. Lilian Hoddeson and Adrienne Kolb, "The Superconducting Super Collider's Frontier Outpost, 1983–1988," *Minerva* 38 (2000), 271–310, on 308.

20. Michael Riordan, "The Demise of the Superconducting Super Collider," *Physics in Perspective* 2 (2000): 411–25.

21. Hoddeson et al., *Fermilab* (ref. 8).

22. Catherine Westfall, "Surviving the Squeeze: National Laboratories in the 1970s and 1980s," *HSNS* 38, no. 4 (2008): 475–78; Florian Hars, "Wenn Forschung zu groß wird. Internationalisierung als Strategie nationaler Forschungsplanung am Beispiel der Hochenergiephysik" in Ritter et al., *Antworten* (ref. 6), 286–312.

users, including both DORIS and PETRA, and national workforces of accelerator designers and constructors were also redirected to design and construction of these new "materials science accelerators"[23] that included first synchrotron radiation sources and later spallation neutron sources and free-electron lasers.

The priorities of many national research facilities as well as national science systems were redirected away from particle physics and toward materials and life sciences sustained by these new labs. Later, the resource distribution was fundamentally altered so that most newly built accelerators in the world today are purposefully designed and built for the production of synchrotron radiation (and free-electron laser produced using linear accelerators). For particle physics as a discipline, this of course means a radical difference compared to past times, and a contradictory situation: Progress is evident, as shown by the 2012 discovery of the Higgs boson at Conseil Européen pour la Recherche Nucléaire (European Organization for Nuclear Research; CERN), which was monumental and also led to the awarding of the 2013 Nobel Prize in physics to Peter Higgs and François Englert for the original theoretical prediction of the particle. But CERN is simultaneously the main experimental particle physics laboratory in operation in the world, while former strongholds of experimental particle physics such as the United States, Germany, the United Kingdom, and Russia are without accelerator labs in operation for particle physics research. If CERN is ever succeeded by a "next big machine," this step will very likely be at the expense of the current program because the global particle physics community can no longer afford to run several labs. Relative to the use of major accelerator facilities for materials science and life science research, with new labs emerging every year in new corners of the world, particle physics is thus no longer in a state of scientific growth, although important results are still produced. The shift from particle physics to photon science is profound and has taken place on several levels, reaching from the local use of accelerators for experimental work to national priorities in science. This relation between the two categories of use of major accelerator complexes is the focus for this article because the history of DESY is a case in point for the developments and provides examples of how both micro-level developments in technology and scientific use have resulted in meso-level change processes that are important

23. Westfall, "Surviving" (ref. 22), 478.

for understanding broader shifts in priorities in national (German) and global research policy.

## PREHISTORY: THE CREATION OF DESY, 1955–1959

After the end of World War II, all nuclear physics research in Western Germany remained under embargo for ten years, including six years during the existence of the Federal Republic founded in 1949 by the union of the British, French, and American occupation zones. When these allied forces lifted the ban on nuclear energy in 1955, a new Federal Ministry for Atomic Matters (Bundesministerium für Atomfragen) was swiftly founded on October 15, a mere five months after the ban was lifted, indicating that the German Federal Government had a strong interest in re-establishing Germany's position as a global leader in nuclear physics.[24] Political interest converged with the ambitions of many German physicists, including Werner Heisenberg and Otto Hahn, who wanted the fields of nuclear physics and particle physics to flourish as they did before and during the war.[25] CERN, the European Organization for Nuclear Research, was founded in 1954 without formal participation by Western Germany due to the ban on nuclear energy, but several prominent German nuclear physicists were present as observers at meetings and conferences leading to the launch of the organization.[26] This postwar mobilization of physics research in Germany, despite the nuclear interdiction, was testimony to the ambitions of Western Germany and paved the way for the creation of a domestic laboratory after the legal barriers were removed.

Indicative of these attempts to put Germany on the international map of particle physics was the recruitment of Willibald Jentschke to the Faculty of Physics at Hamburg University. After World War II, Jentschke had moved to the United States, where he served as the director of the Cyclotron Laboratory at the University of Illinois at Urbana-Champaign from 1950. Reportedly

24. Armin Hermann, John Krige, Ulrike Mersits, and Dominique Pestre, eds., *History of CERN: Volume I—Launching the European Organization for Nuclear Research* (Amsterdam: Elsevier Science, 1987), 388; Habfast, *Großforschung* (ref. 3), 2; Lohrmann and Söding, *Von schnellen Teilchen* (ref. 4), 3–8; Carson, "Nuclear Energy" (ref. 6); Ritter et al., *Antworten* (ref. 6); Fischer, *Atomenergie* (ref. 6); Müller, *Geschichte der Kernenergie* (ref. 6); Eckert, "Die Anfänge der Atompolitik" (ref. 6).

25. Cathryn Carson, "Heisenberg and the Framework of Science Policy," *Fortschritte der Physik* 50 (2002): 432–36.

26. Carson, "Beyond Reconstruction" (ref. 15); Hermann et al., *History of CERN* (ref. 24).

determined to bring "Big Physics" to Hamburg, Jentschke accepted the position of professor at the University of Hamburg in October 1955, after the City of Hamburg and the Federal Ministry for Atomic Matters assured him that an investment of 7.35 million Deutsche Mark (DM)—an enormous sum at the time—would be made available for a new physics institute with a new nuclear machine (Kernmaschine), a 6.0 GeV (Giga electron volts) electron synchrotron, as the centerpiece. Initially, Jentschke preferred a 2.0 GeV proton synchrotron, but he changed his mind when Cornell built and successfully operated an electron synchrotron in 1954.[27]

The form and structure of this new institute was negotiated among Jentschke, the Faculty of Physics at Hamburg University, the Senate of Hamburg City, and the new Federal Ministry for Atomic Matters from 1956, when Jentschke assumed the position of full professor at the Faculty of Physics, to 1959, the year DESY was founded. These negotiations were complex, involving not only funding questions but also structural issues regarding the internal organization of the Faculty of Physics and the relationships between the eventual 6.0 GeV synchrotron laboratory and Hamburg University. However, in June 1956, the International Symposium on High Energy Particle Accelerators at CERN recommended, in its so-called Geneva Memorandum, the building of an electron synchrotron under Jentschke's leadership.[28] In addition, in July 1956, Jentschke was supported by a joint effort of German nuclear physicists at the German Physics Society (Deutsche Physikalische Gesellschaft), who endorsed his leadership of the new synchrotron facility.[29]

In October 1956, the Standing Conference of the Ministers of Education and Cultural Affairs of the German Länder States (Kultusministerkonferenz, KMK) generally approved the plans for a particle accelerator in Hamburg.[30] However, between 1957 and 1958, neither the KMK nor the Standing Conference of the Ministers of Finance (Finanzministerkonferenz) would agree to contribute to the construction costs of DESY.[31] Therefore, the Federal Ministry

27. Habfast, *Großforschung* (ref. 3), 3–8. GeV is the abbreviation of Giga electron volt, which is the unit for energy level in a particle accelerator. The energy level has some importance for the performance of accelerators for both particle physics and synchrotron radiation research, although several other parameters also affect the performance in both realms.

28. Habfast, *Großforschung* (ref. 3), 8–14; Lohrmann and Söding, *Von schnellen Teilchen* (ref. 4), 3–4;

29. Ibid., 20–21.

30. Ibid., 24.

31. Ibid., 66–68.

for Atomic Matters and Water Policy (Bundesministerium für Atomfragen und Wasserwirtschaft)[32] and the City of Hamburg had to pay the construction costs of DESY, which had increased to 60 million DM. The Federal Ministry agreed to fund 85 percent of DESY's construction costs, with the other 15 percent funded by the City of Hamburg. The official agreement to build a 7.4 GeV synchrotron, which at that time would have been the biggest facility of its kind in the world, was signed on December 18, 1959, by Siegfried Balke, the Federal Minister for Nuclear Matters and Water Policy, and Max Brauer, the mayor of Hamburg.[33] Jentschke became the first DESY director and remained in that position until 1970.[34]

After DESY was founded, construction of the synchrotron started immediately. However, the initial 52.4 million Euro was soon exceeded, and drawn-out funding negotiations ensued among Jentschke, the Federal Ministry, the City of Hamburg, and the German Länder States.[35] In 1962, the Administrative Council of DESY (Verwaltungsrat, VR), in which the Federal Ministry and the City of Hamburg held equal voting rights, managed to mediate a solution: The Federal Ministry for Scientific Research (Bundesministerium für wissenschaftliche Forschung) approved an additional 32 million DM, the City of Hamburg another 8 million DM, and the Volkswagen Foundation added another 10 million DM.[36] In sum, the total construction costs of DESY amounted to approximately 109 million DM.[37] In February 1964, the Länder States agreed to sponsor 50 percent of the operational costs of DESY if the annual budget did not exceed 30 million DM.[38] In the same month, the first electrons were accelerated in the synchrotron, and research on subnuclear particles started. When DESY ceremonially opened in November 1964, the first experiments with synchrotron radiation had already been conducted.

32. The Federal Ministry for Atomic Matters had been renamed the Federal Ministry for Atomic Matters and Water Policy in October 1957.

33. Habfast, *Großforschung* (ref. 3), 37–41.

34. The VR convened for the first time on 11 Apr 1960 and declared the acting DIR (including Willibald Jentschke), which had been already set up in Dec 1959, as formally established. Board of Directors, "Tätigkeitsbericht des Direktoriums DESY für die Rechnungsjahre 1960 und 1961," report prepared by the DIR for the FY 1960 and FY 1961, 3.

35. Board of Directors, "Tätigkeitsbericht" (ref. 34), 8; Habfast, *Großforschung* (ref. 3), 57–66.

36. The Federal Ministry for Atomic Matters and Water Policy was renamed the Federal Ministry for Scientific Research in December 1962.

37. Board of Directors, "Bericht des Direktoriums für die Geschäftsjahre 1962 bis 1963," report prepared by the DIR for the FY 1962 and FY 1963, 9; see Table 1 in the Appendix.

38. Habfast, *Großforschung* (ref. 3), 181–85.

The founding of DESY is a peculiar tale in organizational terms. When Willibald Jentschke was recruited to the Faculty of Physics of Hamburg University, he became director of the Physikalisches Staatsinstitut, which had existed since 1885 and had a longer tradition than the university itself, which was founded in 1919. The decision to establish DESY in 1959 meant a restructuring of the Physikalisches Staatsinstitut, and it was split into two separate university institutes: the I. Institut für Experimentalphysik, and the II. Institut für Experimentalphysik, located in Hamburg-Bahrenfeld. After the split of the Physikalisches Staatsinstitut, Jentschke became director of the II. Institut.[39] Subsequent DESY directors would become professors at the II. Institut, and many leading and senior scientists at DESY, including the synchrotron radiation research program, would also become faculty members there. This close connection between DESY scientists and the II. Institut is one of the reasons that physics-oriented synchrotron radiation research became established as HASYLAB inside the formal organizational structure of DESY in the late 1970s rather than as an independent research laboratory at Hamburg University.[40]

## BEGINNINGS OF SYNCHROTRON RADIATION AT DESY, 1960–1967

Synchrotron radiation research at DESY essentially began with Peter Stähelin, who became professor of physics at the University of Hamburg in 1960, after having spent most of his previous career at the Swiss Federal Institute of Technology (Eidgenössische Technische Hochschule, ETH) in Zurich, and then at the Cyclotron Laboratory at the University of Illinois at Urbana-Champaign between 1954 and 1960, partly (until 1955) under the directorship of Willibald Jentschke. Stähelin's field of specialization at that time included the theory and construction of cyclotron accelerators,[41] and the position offered to Stähelin was one of the two new professorships established at the II. Institut to build up new research capacity in particle physics, as was the position of research division head at DESY.[42] The intellectual and organizational connection

39. Karl Witte, "Zur Geschichte des Physikalischen Staatsinstituts und der Physik in Hamburg," in *100 Jahre Physik in Hamburg*, ed. Klaus Tornier (Hamburg: Universität Hamburg, 1985), 22–23.

40. See "The Creation of Hasylab, 1977–1981" in Heinze et al., "From Periphery to Center, Part II" (ref. 2).

41. Gustav Weber, "Peter Stähelin 65 Jahre alt," *Physikalische Blätter* 46, no. 1 (1990): 25.

42. Witte, "Zur Geschichte" (ref. 39), 24; Board of Directors, "Bericht des Direktoriums" (ref. 37), 7.

between DESY and the University of Illinois at Urbana-Champaign did not cease after Jentschke and Stähelin moved to Hamburg. Bernd Sonntag, one of the early PhD students of the F41 synchrotron research group (see below), worked as a visiting assistant professor at the University of Illinois from 1972 to 1973.[43]

As the first research director at DESY, Peter Stähelin was one of the five members of the DIR responsible for planning and preparing particle physics experiments.[44] Although he specialized in nuclear physics, Stähelin reportedly understood the scientific potential that synchrotron radiation offered for UV spectroscopy. Some exploratory use of synchrotron radiation had occurred at Cornell University in the mid-1950s and at the National Bureau of Standards in Washington in the early 1960s. Although it led to little in the way of significant results and thus attracted limited international interest, a small network of enthusiasts started to form at these labs and in university departments in the United States.[45] It is likely that Stähelin, having spent several years at the University of Illinois, knew about these activities.

The solid state physics professors in the University of Hamburg's Faculty of Physics, however, showed little or no interest in setting up a new spectroscopy group to take advantage of the opportunities offered by the DESY synchrotron machine. For example, Heinz Raether (1909–86), who held a chair in applied physics and played an important role in recruiting Willibald Jentschke to Hamburg, studied the structure and growth of crystals, electron plasma, and electric discharge in gases, but was, according to Bernd Sonntag and Christof Kunz, not very interested in using a big machine for UV or vacuum UV (VUV) spectroscopy. Kunz, a former PhD student of Heinz Raether, argues: "Raether would have had the best possible conditions to enter the field of synchrotron radiation. . . . Not only was Raether working in the field of solid state physics, he also studied spark discharges in gas, which extends through the ionization with UV and VUV radiation."[46] In this context of comparable

43. The title of Sonntag's PhD thesis is "Photoabsorption der Metalle Ti bis Cu für Phtotonenenergien zwischen 40 eV und 300 eV." Kunz, *Synchrotronstrahlung bei DESY* (ref. 5), 154.

44. DESY had three divisions in 1962–1963: Technische Leitung (Teucher), Verwaltung (Berghaus), and Experimente (Stähelin). Board of Directors, *Bericht des Direktoriums* (ref. 37); Lohrmann and Söding, *Von schnellen Teilchen* (ref. 4), 324.

45. Keith Codling, "Atomic and Molecular Physics Using Synchrotron Radiation. The Early Years," *Journal of Synchrotron Radiation* 4 (1997): 316–33; David W. Lynch, "Tantalus, a 240 MeV Dedicated Source of Synchrotron Radiation, 1968–1986," *Journal of Synchrotron Radiation* 4 (1997): 334–43.

46. Kunz, *Synchrotronstrahlung bei DESY* (ref. 5), 10–11.

disinterest in new spectroscopy opportunities from solid state physicists at the Faculty of Physics, Stähelin took the initiative himself and submitted a proposal to the newly established space research program of the German Research Foundation (Deutsche Forschungsgemeinschaft, DFG) to build a beam observation bunker (Strahlbeobachtungsbunker) at DESY. Stähelin requested 0.537 million DM for two years, including 0.150 million DM for the observation bunker.[47] Following the DFG's grant approval, DESY's administrative director, Heinz Berghaus, submitted a request to the City of Hamburg for building the observation bunker, which was approved in May 1963.[48] Stähelin submitted three follow-up applications to the DFG in 1964, 1965, and 1968, which were all approved by the DFG.[49] In total, the DFG provided funding of 0.859 million DM, and for a total duration of nine years (1963–71). With the help of this funding, Stähelin established both the bunker and a new research group. The bunker consisted of a small building hosting both the final part of a 30-meter beamline from the synchrotron and a grazing incidence VUV spectrometer.[50] The new research group was located at DESY, and it was mentioned in DESY's 1964 annual report under the name "F41."[51]

In terms of the categories of change processes introduced above,[52] the DFG funding for Stähelin set in motion a *layering process* that had far-reaching consequences for DESY from the 1970s onward, finally leading to the displacement of particle physics both as a research program and scientific infrastructure in the late 2000s. The DFG funding constitutes both a layering of new infrastructure, including the observation bunker, its beamline, and various other machinery on top of the existing DESY ring accelerator, and an *organizational*

47. Peter Stähelin, "Antrag auf Gewährung von Mitteln aus der Schwerpunktförderung der Weltraumforschung bei der Deutschen Forschungsgemeinschaft," 17 Sep 1962, German Research Foundation, grant proposal within the core area of the space research program.

48. DFG to Stähelin, 1 Feb 1963; Heinz Berghaus to Oberfinanzdirektion Hamburg, Bundesvermögens- und Bauabteilung, 29 Apr 1963; Oberfinanzdirektion Hamburg to Heinz Berghaus, 27 May 1963.

49. The first follow-up proposal was submitted on 25 Nov 1964, and granted approval by DFG on 23 Jun 1964; the second follow-up proposal was submitted on 4 Jun 1965, and granted approval by DFG on 1 Aug 1965. The third follow-up proposal was not submitted to the Space Research Program but to the Solid State Physics program on 9 Oct 1968, and granted approval by DFG on 31 May 1969. All documents were provided by Dr. Pietrusziak, archivist at the DFG archive in Bonn.

50. Jahresbericht (JB) DESY 1964, Annual Report DESY FY 1964, 3-16–3-18.

51. Ibid., 3-2, 3-16–3-18.

52. Mahoney and Thelen, *Theory of Gradual Institutional Change* (ref. 13); Streeck and Thelen, *Beyond Continuity* (ref. 13); Heinze and Münch, "Institutionelle Erneuerung" (ref. 13).

*layering*: the new F41 group that was added to the existing research groups in particle physics at DESY's research division. Therefore, we observe a double layering process: instrumentation and formal organization.

This *double layering process* was possible because Stähelin won several DFG grants, recruited Ruprecht Haensel as a PhD student to organize the installation of the bunker and its experimental equipment,[53] and held the role of research director at DESY. When the bunker's construction turned out to be more time consuming and expensive than expected, being research director of DESY gave Stähelin some discretion over the allocation of funds and human resources. Although there is no evidence that Stähelin channeled money away from the regular, mainstream particle physics activities of DESY into the significantly more peripheral synchrotron radiation activities, the overall technical infrastructure and scientific staff over which he had decision-making power were vital to ensuring that the synchrotron radiation activities, which were primarily funded by DFG money, received much-needed technical and scientific support.[54]

The first experiments with synchrotron radiation started in parallel with the particle physics program in 1964 and constitute another dimension in the layering process: a new research activity. One year later, in 1965, this *layering of a new research field* was deepened when the grazing incidence spectrometer was installed, allowing experiments in the VUV (photon energies from 30 eV to 400 eV).[55] This installation attracted several external scientists, including Robert Paul Godwin, who obtained his PhD under Hans Frauenfelder at the University of Illinois at Urbana-Champaign, the same department from which Willibald Jentschke and Peter Stähelin were recruited, and Michael Skibowski and Wulf Steinmann, two members of Walter Rollwagen's group at LMU Munich, the same group from which Ruprecht Haensel was recruited.[56] Therefore, F41 had four members, three of whom were external researchers. One year later, in 1966, F41 included seven members; the new members were Bernd Sonntag (II. Institut), Christof Kunz (DESY), and Taizo Sasaki (guest

53. Lohrmann and Söding, *Von schnellen Teilchen* (ref. 4), 29. Before he joined Stähelin's group, Haensel had completed his diploma thesis in the group of Walter Rollwagen at LMU Munich. The bunker was soon informally called the "Haensel-Bunker"; Kunz, *Synchrotronstrahlung bei DESY* (ref. 5), 15–16.

54. The building of the "observation bunker" was first mentioned in 1963. Board of Directors, "Bericht des Direktoriums" (ref. 37), 39.

55. Jahresbericht DESY 1965, Annual Report DESY FY 1965, 3-28–3-29.

56. Ibid., 3-2.

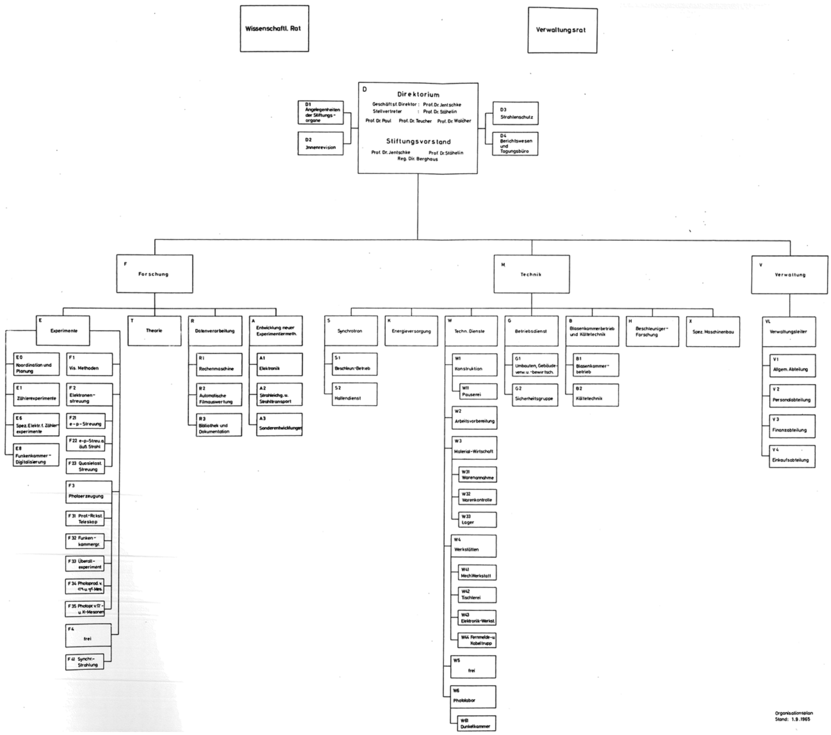


**FIG. 1.** Organizational Chart, DESY 1965. *Source*: JB DESY, 1965, p. 85.

at the II. Institut). Thus, within three years, F41 had emerged as a small and peripheral activity alongside the main particle physics program at DESY, which employed 150 scientists and almost 600 nonscientific staff in 1967.[57]

Though F41 had several guests and collaborators in its early years, its initial collaborators came from Walter Rollwagen's group at the Faculty of Physics at the University of Munich. Members of the Rollwagen group built their own instrumentation, partly with DFG money, and conducted their own experiments at the DESY site. In 1966, they installed a normal incidence grating monochromator for photon energies between 10 eV and 40 eV and published several papers and reports from experiments with this new device.[58] Their

57. See Table 2 in the Appendix.

58. Jahresbericht DESY 1967, Annual Report DESY FY 1967, 4-13–4-14. A monochromator is a device that narrows the wavelength span of the synchrotron radiation. Different experiments typically require different wavelengths.

research was highly complementary to that of the core F41 team in Hamburg, which conducted studies in higher energy regions.[59] At the same time, however, F41 was clearly dependent on the particle physicists. Christof Kunz argued that "the particle physicists were the masters of events"[60] and that the synchrotron radiation team members "were the users of an unwanted by-product, so-called parasitic users, sometimes even called parasites as a joke."[61] Thus, the situation was similar to most early synchrotron radiation laboratories and very similar to early work with synchrotron radiation at SLAC, where the word "parasites" was also used, both descriptively and jokingly, for the status of the synchrotron radiation program on site.[62]

When Peter Stähelin stepped down as head of DESY's research division in 1967,[63] he was succeeded by Erich Lohrmann, a particle physicist who stayed in office until 1972 and who became DESY's research director again from 1979 to 1981.[64] Lohrmann held the chair of particle physics at the II. Institut since 1976; this chair was the second DESY-funded professorial position in the Faculty of Physics, in return for the fact that several members of the physics professoriate were actively engaged in DESY leadership.[65] Stähelin has been described by some as a "pioneer" and the "father" of synchrotron radiation at DESY, and Lohrmann continued to be supportive in practical and administrative matters after the intellectual and physical expansion of synchrotron radiation research was established,[66] yet the interest in synchrotron radiation from the professoriate of the Physics Faculty at Hamburg University was still very low. Therefore, Stähelin had no direct successor in his role as promoter of synchrotron radiation in Hamburg.

59. Kunz, *Synchrotronstrahlung bei DESY* (ref. 5), 57.

60. Ibid., 28.

61. Ibid., 20.

62. Hallonsten, "Parasites" (ref. 1).

63. After 1967, Stähelin was involved in the foundation of a new faculty of computer sciences at Hamburg University, and later on he was also involved in the establishment of the Technical University of Hamburg-Harburg, the second university in Hamburg. Kunz, *Synchrotronstrahlung bei DESY* (ref. 5), 21.

64. Lohrmann and Söding, *Von schnellen Teilchen* (ref. 4), xv.

65. The first professorial position that had been funded by DESY since 1966 was that of Gustav Weber. Witte, "Zur Geschichte" (ref. 39), 24.

66. Sonntag, interview (ref. 18); Materlik, interview (ref. 18).

## INTELLECTUAL AND PHYSICAL EXPANSION, 1968–1974

In 1968, DESY started building DORIS, the double storage ring that became operational in 1973 and would be of vital importance for the future of synchrotron radiation research at DESY in the late 1970s, 1980s, and particularly in the 1990s. Internationally, the storage ring design concept would become the breakthrough technology for synchrotron radiation and eventually enable its full transformation from small laboratory curiosity to mainstream experimental technique in many fields. Seven years after DESY was founded and two years after the DESY synchrotron was operational, in 1966, the DIR and WissR started discussing an extension of the particle physics research program at DESY. At the center of this discussion was the proposal to build a 3.0 GeV electron-positron double storage ring (i.e., DORIS) to study collisions between electrons and positrons. DESY's 1966 annual report stated: "The discussion about an expansion of the experimental facilities at DESY was invigorated by the proposal to build an electron-positron storage ring in 1966. This proposal was extensively discussed by the Board of Directors [DIR] and by the subcommittee of the Scientific Council [WissR], which investigates the possibilities for future development of DESY."[67] The DORIS proposal was submitted formally to the WissR by a group of sixteen particle physicists and machine scientists (Gruppe H);[68] it was ambitious, both scientifically and technically. A storage ring with electron energy levels of several GeV had never been built, and the technical design of the double rings was novel—early work with double rings at Stanford had featured two intersecting rings in the same plane,[69] but the DORIS design placed one ring on top of the other, which was unprecedented. From a scientific point of view, DESY physicists were confident about gaining new insights into quantum electrodynamics by colliding electrons with positrons and by studying their annihilation into hadrons.[70]

67. Jahresbericht DESY 1966, Annual Report DESY FY 1966, 1-1; Habfast, *Großforschung* (ref. 3), 227–39.

68. DESY, *Vorschlag zum Bau eines 3 GeV Elektron-Positron-Speicherringes für das Deutsche Elektronen-Synchrotron*, proposal to construct a 3 GeV electron-positron storage ring at DESY, Sep 1966 (Hamburg).

69. Andrew Sessler and Edmund Wilson, *Engines of Discovery: A Century of Particle Accelerators* (New York: World Scientific Pub. Co., 2007), 81–83.

70. Lohrmann and Söding, *Von schnellen Teilchen* (ref. 4), 61–62.

Jentschke, who had started consulting on this proposal both inside and outside DESY, received many positive responses, particularly from physicists in the United States,[71] but the most detailed reviews of the proposal were negative. Hans Joos from DESY and Harry Lehmann from the University of Hamburg, both theoretical physicists, argued that the new double ring would not deliver what it promised and that DORIS would not achieve a luminosity high enough to accomplish its scientific goals. Therefore, they stated that the existing synchrotron would be sufficient for the next ten years and that another machine was not needed.[72] After a request from DESY's Scientific Council the same year,[73] Gruppe H submitted a revised proposal to the WissR in the autumn of 1967; in this proposal, the construction costs of the new machine were estimated at approximately 74.4 million DM and the annual operating costs at 10 million DM.[74] An ad hoc committee of the German Nuclear Commission (Atomkommission), which was responsible for reviewing proposals of this size, was asked to review the proposal.[75] Following the commission's positive review, the VR approved the revised proposal in 1968 and decided to build the new machine.[76] The construction of DORIS became part of a larger upgrade of the laboratory, which cost almost as much as the initial construction of the DESY synchrotron: approximately 85 million DM for the construction of DORIS and a 15 million DM upgrade to DESY's other infrastructure.[77] When DORIS became operational in 1973, Willibald Jentschke had already left DESY to become Director General of CERN.

While DORIS was under construction, F41 attracted more and more users from different disciplines and fields. In 1969, materials sciences became a part of F41 when Manuel Cardona from Brown University started using synchrotron radiation at DESY. Cardona, who was one of the founding directors at the Max Planck Institute for Solid State Research in Stuttgart in 1971, was not only a frequent user in the early 1970s but also an important supporter of synchrotron radiation research at DESY in the late 1970s. Cardona was a member of

71. Habfast, *Großforschung* (ref. 3), 246.

72. Ibid., 245.

73. Ibid., 241.

74. DESY, *Vorschlag zum Bau* (ref. 68), 124–25, 143.

75. Habfast, *Großforschung* (ref. 3), 248.

76. Jahresbericht DESY 1968, Annual Report DESY FY 1968, 1-1.

77. Habfast, *Großforschung* (ref. 3), 251–53; JB DESY 1968 (ref. 76), 1-1; and Table 1 in the Appendix.

the WissR and the Research Council for Synchrotron Radiation[78] and later the chairman of the "Cardona Commission."[79] His close collaboration with members of F41 is demonstrated in the more than ten co-authored papers and reports between 1969 and 1972 that dealt mostly with the optical properties of semiconductors.[80] In 1969, members of another physics group from the University of Munich (led by A. Faessler) joined F41; they installed a new spectrometer and conducted studies on ultra-soft X-ray emission spectra, resulting in several publications and presentations.[81]

One year later, in 1970, molecular biology became a part of F41 when Gerd Rosenbaum, a former graduate student from Rollwagen's group in Munich who had finished his diploma thesis in 1968 at DESY, returned to F41 as a PhD student enrolled at the University of Heidelberg, where his PhD advisor, biophysicist Kenneth Holmes, was director of the Max Planck Institute for Medical Research. Holmes and Rosenbaum performed muscle X-ray diffraction on beetles (*Lethocerus maximus*) and applied this method to various biological research questions.[82] They "initiated a scientific collaboration . . . that resulted in the first use of synchrotron radiation for diffraction at low angle with biological samples. . . . [T]he measured radiation intensity emanating from DESY was consistent with previous calculations and amounted to about 300 times the intensity produced by the most powerful fine-focus X-ray tubes of the time."[83]

Holmes, who had long been interested in using intense radiation sources for X-ray diffraction on biological samples, moved to Heidelberg in 1968. He quickly understood the potential of synchrotron radiation for molecular biology and managed to capture the attention of John Kendrew, the 1962 Nobel

78. Wissenschaftlicher Jahresbericht DESY 1976, Scientific Report DESY FY 1976, 16–17.

79. Manuel Cardona, Ulrich Bonse, Ruprecht Haensel, Gottfried Mülhaupt, Gerhard Noldeke, Hermann Pfisterer, Edward Schlag, and Wulf Steinmann, "Speicherringe für Synchrotronstrahlung," report on storage rings for synchrotron radiation, prepared for DESY (Hamburg, Jan 1977)

80. Wissenschaftlicher Jahresbericht DESY 1969, Scientific Report DESY FY 1969, 58; Wissenschaftlicher Jahresbericht DESY 1970, Scientific Report DESY FY 1970, 150–53; Wissenschaftlicher Jahresbericht DESY 1971, Scientific Report DESY FY 1971, 120; Wissenschaftlicher Jahresbericht DESY 1972, Scientific Report DESY FY 1972, 128.

81. WJB DESY 1970 (ref. 80), 152–57; WJB DESY 1971 (ref. 80), 119–20; WJB DESY 1972 (ref. 80), 127–29.

82. WJB DESY 1971 (ref. 80), 119; WJB DESY 1972 (ref. 80), 130.

83. Cele Abad-Zapatero, "Notes of a Protein Crystallographer: Our Unsung Heroes," *Structure* 12, no. 4 (2004): 523–27, on 524 and 526.

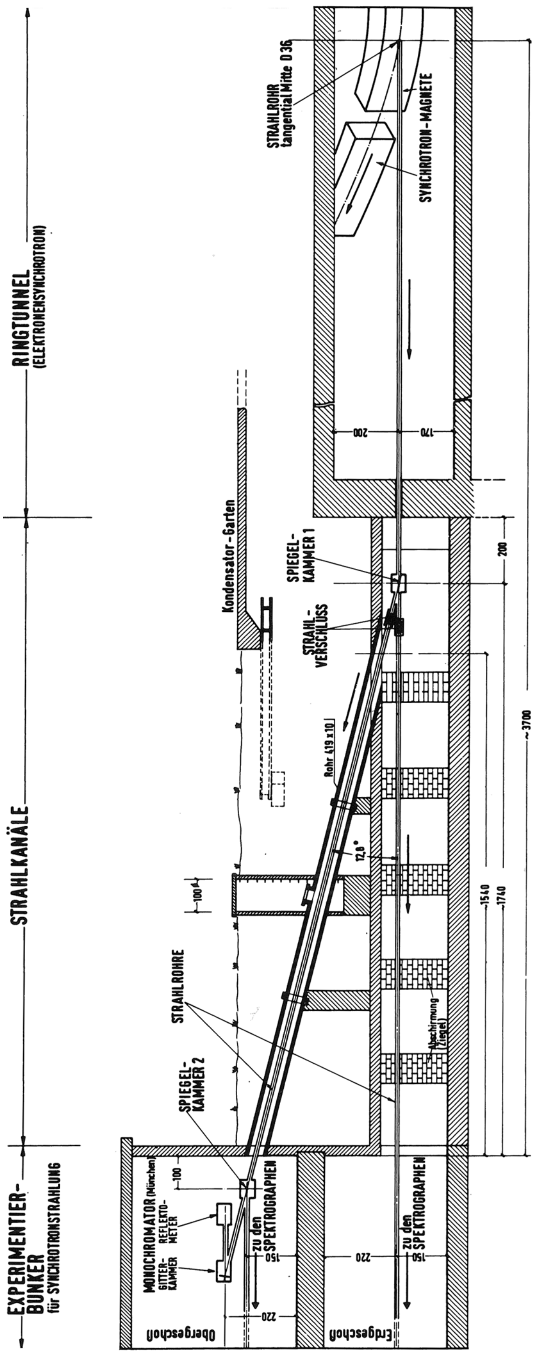


**FIG. 2.** Vertical Cross-Section of Bunker 1, DESY 1970. *Source*: JB DESY, 1970, p. 65.

laureate in chemistry who was to become the first director of EMBL, also located in Heidelberg. The scientific mission of EMBL, an intergovernmental organization currently funded by twenty member states, was (and still is) basic research in molecular biology, and the successful experiments conducted by Holmes and Rosenbaum and published in *Nature* (in 1971) convinced Kendrew that synchrotron radiation would offer enormous possibilities for EMBL research.[84] Three years before the official opening of EMBL, which happened in 1975, Kendrew, in consultation with Holmes and Rosenbaum, established an EMBL outpost called Bunker 2 at the DESY synchrotron.[85] The design of the new bunker and its beamline were provided by Rosenbaum.[86] DESY built the bunker at a cost of 0.450 million DM and was reimbursed when EMBL entered into a formal contract with them in 1975.[87] The beamline equipment was jointly funded by DESY, EMBL, and the Max Planck Institute for Medical Research in Heidelberg.[88]

The *layering of new research fields*, materials science and molecular biology, and the subsequent *layering of a new organizational unit*, the EMBL outstation, at the DESY site were possible because the general conditions for the synchrotron radiation research program at DESY had improved compared to the situation in the mid-1960s. In 1969, a second floor was built on the Haensel-Bunker that provided more space for research instrumentation.[89] In 1970, two new monochromators for the UV region were installed.[90] In 1972, a new monochromator for the X-ray region was installed.[91] In the same year, a new building, Bunker 2, for EMBL was opened.[92] All of these events were elements in the layering process by which new instrumentation and scientific infrastructure were added to the existing facilities at DESY. The enlarged and

84. John Krige, "The Birth of EMBO and the Difficult Road to EMBL," *Studies in the History and Philosophy of Biological and Biomedical Sciences* 33 (2002): 547–64; Abad-Zapatero, "Notes" (ref. 83), 525.

85. WJB DESY 1972 (ref. 80), 9.

86. Abad-Zapatero, "Notes" (ref. 83), 525.

87. "Vereinbarung zwischen dem Europäischen Laboratorium für Molekularbiologie EMBL und dem Deutschen Elektronen-Synchrotron DESY," 21 Apr 1975, agreement between EMBL and DESY (Hamburg), Art. 1 (2), (4).

88. John Barrington Leigh and Gerd Rosenbaum, "A Proposal for the EMBO Synchrotron Radiation Bunker at DESY Hamburg," 6 Oct 1971 (Heidelberg), Table 2.

89. WJB DESY 1969 (ref. 80), 10.

90. Ibid., 72.

91. WJB DESY 1972 (ref. 80), 60.

92. Ibid., 9.

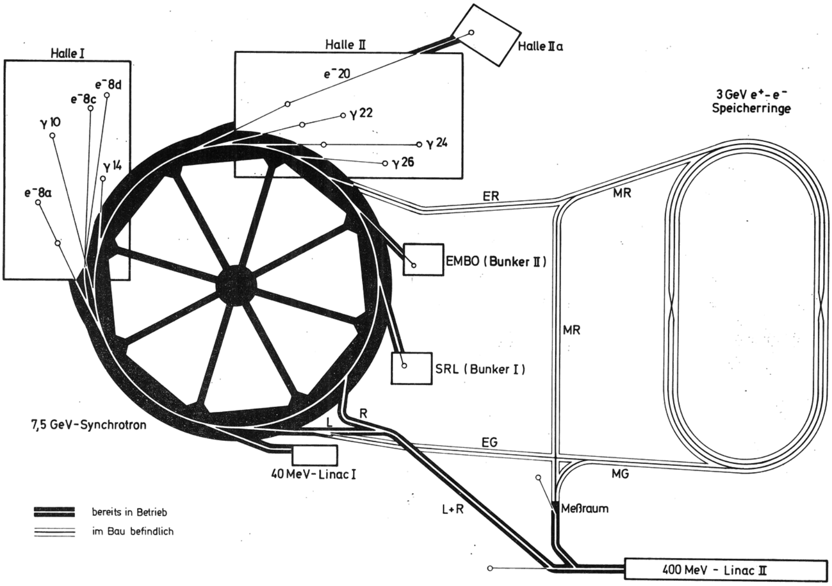


**FIG. 3.** Beamlines between DESY and DORIS (under construction), 1972. *Source*: JB DESY, 1972, p. 9.

improved instrumentation and infrastructure paved the way for establishing new research fields and one major external research unit (the EMBL outstation).

This expansion into materials science and molecular biology (via layering of new infrastructure, organizational units, and research activities) was important for building credibility around the synchrotron radiation activities and to show the particle physicists in charge of DESY that this research program was important and growing, even in parasitic mode. In 1972, DESY's annual report acknowledged that the research from F41 had achieved scientific recognition worldwide: "Since its beginnings, DESY has had a synchrotron radiation group, which by now has earned international recognition."[93]

Over time, the number of users and research publications grew. In 1968, thirty publications, diploma theses, and conference presentations were attributable to synchrotron radiation activities; in 1970, the annual number had grown to sixty-eight, and in 1975, it reached eighty.[94] Despite the building of

93. Jahresbericht DESY 1972, Annual Report DESY FY 1972, 5.

94. JB DESY 1968 (ref. 76), 5-16–5-20; Jahresbericht DESY 1970, Annual Report DESY FY 1970, 151–58; Jahresbericht DESY 1975, Annual Report DESY FY 1975, 166–72.

a second floor on the Haensel-Bunker and the new EMBL buildings that opened in 1972, the demand for synchrotron radiation in the mid-1970s was much higher than the capacity offered by the facility. Several external groups are said to have been turned away simply because there was not enough DESY support staff to accommodate their scientific needs, and many had to turn to other, less powerful synchrotron radiation sources in operation at the time, such as the 500 MeV machine at the University of Bonn.[95]

The growing synchrotron radiation user base was discussed at DESY's DIR, and in 1972, when Erich Lohrmann was still head of DESY's research division, a Research Council for Synchrotron Radiation (Forschungskollegium für Synchrotronstrahlung, FKS), consisting of internal and external researchers, was established to advise and report to the DIR.[96] The FKS's responsibilities were also to oversee the synchrotron radiation unit and, if necessary, to mediate conflicts between users or between users and DESY staff.[97] Setting up the FKS was an important step toward recognizing synchrotron radiation as a regular research program at DESY and toward acceptance from particle physicists. In terms of the *layering process* by which synchrotron radiation became established at DESY, the FKS represents yet another organizational unit added on top of existing scientific advisory bodies in particle physics.

The growth of synchrotron radiation activities in number and significance at DESY also attracted attention from the funders. Over the years, German research groups had submitted more and more applications to the DFG requesting funding of projects that would make use of synchrotron radiation at DESY, but these applications had simply outstripped the funding agency's budget. Therefore, the DFG turned to the Federal Ministry for Scientific Research and asked the Federal Ministry to take over the responsibility of funding this new and growing research area. In 1973, the Federal Research Ministry agreed to become the chief sponsor, taking over from DFG the funding responsibility for university groups that wanted to use synchrotron

95. European Science Foundation, *Synchrotron Radiation: A Perspective View for Europe*, report prepared for ESF (Strasbourg, 1977), 43; Cardona et al., "Speicherringe für Synchrotronstrahlung," (ref. 79), 15–18; Sonntag, interview (ref. 18).

96. The first meeting of the FKS took place on October 26, 1972. Board of Directors, "Beschlussfassungen des Direktoriums vom, 25 Oct 1972," resolutions of the DIR, TOP 9a. In 1973, the FKS had the following members: Manuel Cardona, Otfried Madelung (chairman), Gustav Weber, Rupprecht Haensel, Christof Kunz, and Michael Skibowski. Research Council for Synchrotron Radiation, "Protokoll 2. Sitzung des Forschungskollegiums für Synchrotronstrahlung am 15. Februar 1973," minutes of the 2nd meeting of the FKS.

97. Erich Lohrmann, interview by all authors, 31 May 2012.

radiation. In exchange, the DFG became a sponsor of other physics instrumentation at universities that were previously funded by the Federal Research Ministry.[98] As the new sponsor for university groups using synchrotron radiation at DESY, the Federal Research Ministry took several administrative measures. In 1973, it established a national Program for Synchrotron Radiation Research (Verbundforschung Synchrotronstrahlung). This program became operational in 1974 and has since been the main funding vehicle for synchrotron radiation research in Germany. In the period 1974–93, approximately 208 million DM were allocated to synchrotron radiation projects.[99] In addition, the Federal Research Ministry set up a national Expert Committee for Synchrotron Radiation (Gutachterausschuss für Synchrotronstrahlung, GAfSS) with Otfried Madelung, a highly respected solid state physicist from the University of Marburg, as chairman.[100] The GAfSS, together with the FKS, considered applications for experiments with respect to their technical feasibility, beam time, and scientific value. Projects were then ranked to make a priority list.[101] Finally, in 1974, the Federal Research Ministry established an administrative outpost at DESY (Projektträger DESY, PT-DESY) that was, and still is, responsible for project administration for both particle physics and synchrotron radiation research.[102]

The new sponsorship of the Federal Research Ministry and its administrative support was an important step in the upgrading of synchrotron radiation at DESY from being merely peripheral and parasitic to a more regular and recognized activity. However, it also fitted the increased ambitions of science policy during the social-liberal coalition in Western Germany toward more environmental, biological, and health-related research that would deliver applied technologies to improve economic welfare and social cohesion. These political ambitions remained on the political agenda even when, in the 1970s, Big Science facilities for the first time had to accept a funding regime with

98. Klein, Kirste, and Küllmer, meeting, 26 Jul 1973, "Vermerk betreffend die Neuabgrenzung der Förderungszuständigkeit zwischen BMFT und DFG, hier auf dem Gebiet der Niederenergie-Kernphysik und Plasmaphysik," memo on the reassignment of funding responsibilities between the BMFT and DFG, here in the field of low energy nuclear physics and plasma physics, 22 Aug 1973 (Bonn-Bad Godesberg); Kunz, *Synchrotronstrahlung bei DESY* (ref. 5), 75.

99. See Table 3 in the Appendix.

100. Kunz, *Synchrotronstrahlung bei DESY* (ref. 5), 76.

101. European Science Foundation, *Synchrotron Radiation* (ref. 95), 44.

102. Jahresbericht DESY 1974, Annual Report DESY FY 1974, 1; Board of Directors, "Bericht des Direktoriums über die Zeit von Januar bis Mai 1974," report of the DIR about the period from Jan to May 1974, 16; PT-DESY, "Projektträger DESY," pt.desy.de/ (accessed 19 Mar 2015).

lower growth and even stagnation compared to the situation in the 1950s and the 1960s.[103]

By the early 1970s, DESY's synchrotron radiation activities had gained recognition and structural importance that went well beyond the series of DFG grants that Stähelin had brought to DESY. The increasing importance of synchrotron radiation at DESY was also clear when the 4th International Conference on VUV Radiation Physics was held in Hamburg in 1974. This conference, and the publication following it, raised awareness in the synchrotron radiation community and attracted many new users to DESY.[104]

## STRUGGLES AND ACHIEVEMENTS WITH DORIS, 1974–1977

The growth, and thus layering, of synchrotron radiation research at the Haensel-Bunker continued well into the mid-1970s. In 1975, nine external research groups were stationed at the Bunker, and seven short-term experiments were conducted at this site, four of which involved collaboration with the "core F41 team"[105] in Hamburg. Two years later, fourteen external research groups were

103. Hans-Willy Hohn and Uwe Schimank, *Konflikte und Gleichgewichte im Forschungssystem: Akteurkonstellationen und Entwicklungspfade in der staatlich finanzierten außeruniversitären Forschung* (Frankfurt am Main: Campus, 1990), 252–72; Ingrid von Stumm, *Kernfusionsforschung, politische Steuerung und internationale Kooperation. Das Max-Planck-Institut für Plasmaphysik (IPP) 1969–1981* (Frankfurt/New York: Campus, 1999), 118–64; Helmuth Trischler, "Die 'amerikanische Herausforderung' in den 'langen' siebziger Jahren: Konzeptionelle Überlegungen," in Ritter et al., *Antworten* (ref. 6), 11–18; Hallonsten and Heinze, "Institutional Persistence" (ref. 7), 453–56, 463.

104. Ernst E. Koch, Ruprecht Haensel, and Christof Kunz, "Proceedings of the IVth International Conference on Vacuum Ultraviolet Radiation Physics," 22–26 Jul 1974, in *Fourth International Conference on Vacuum Ultraviolet Radiation Physics* (Braunschweig: Pergamon-Vieweg); Kunz, *Synchrotronstrahlung bei DESY* (ref. 5), 84–86. In the same year, Ruprecht Haensel, the group leader of F41, who had coordinated the construction of the first beam observation bunker and its gradual extension, left DESY and became a professor in the Faculty of Physics at the University of Kiel. He was replaced by his deputy Christof Kunz. At the same time, Ernst-Eckard Koch assumed the new position of coordinator for synchrotron radiation experiments; see Board of Directors, "Beschlussfassungen des Direktoriums vom 25 Apr 1974," resolutions of the DIR, TOP 4. Haensel later became the founding director of the European Synchrotron Radiation Facility (ESRF) in Grenoble in 1986 (serving until 1992), which is still the largest and most successful dedicated synchrotron source in Europe.

105. Wissenschaftlicher Jahresbericht DESY 1975, Scientific Report DESY FY 1975, 84–86. The "core F41 team" formally consisted of members of two separate organizational units: the II. Institut für Experimentalphysik at Hamburg University and DESY employees working at the Haensel-Bunker, but *de facto*, it was one team. It operated three experimental stations in 1975.

stationed at the Haensel-Bunker, and thirteen short-term experiments were conducted at the site, five of which involved collaboration with the core F41 team.[106] These external groups were typically funded by DFG grants and grants from the national Program for Synchrotron Radiation Research; therefore, these grants were vitally important for building up experimental stations at DESY. The core F41 team could not possibly design, build, and maintain all of the installations that the external groups needed for their research projects; thus, the PhD students and post-docs from external university groups were indispensable.[107] The increasing number of collaborations between the F41 team and external groups is a testament to the fact that strong and fruitful relationships developed between them. One example is Ulrich Bonse's group from the Faculty of Physics at the University of Dortmund. He and his PhD student Gerhard Materlik worked in the X-ray energy region, particularly on X-ray interferometry. Materlik joined DESY as staff scientist in 1977 and became the second director of HASYLAB in 1986.[108]

Things at the new double storage ring were different, however. In principle, the possibilities created by DORIS for synchrotron radiation research were very promising: a stable beam with a hundred-fold greater intensity than the one at the DESY synchrotron. Yet, these expectations would soon be disappointed. DORIS had been constructed using an innovative but somewhat risky design that utilized two separate intersecting rings for electrons and positrons, which was supposed to significantly increase the amount of particles that could be injected into the rings, thereby increasing the luminosity (the number of collisions per second) in the particle physics experiments. However, the design did not deliver what it promised, and the beam instabilities caused by the two beams "talking to each other" (in the words of Björn Wiik) not only prevented the machine from reaching the expected luminosities but also shortened the lifetime of the beams to a degree that significantly hindered productive experimentation.[109] The only way to reduce the instability was to reduce

106. The "core F41 team" operated nine experimental stations in 1977. Wissenschaftlicher Jahresbericht DESY 1977, Scientific Report DESY FY 1977, 93–95.

107. Sonntag, interview (ref. 18); Materlik, interview (ref. 18).

108. Board of Directors, "Niederschrift über die Beschlussfassungen des Direktoriums am 7 Nov 1977," minutes of the DIR resolutions; Jahresbericht DESY 1986, Annual Report DESY FY 1986, 13. On Materlik, see also Heinze et al., "From Periphery to Center, Part II" (ref. 2), FN 81.

109. Björn Wiik, quoted in Michael Riordan, *The Hunting of the Quark: A True Story of Modern Physics* (New York: Touchstone Books, 1987), 308; Lohrmann and Söding, *Von schnellen Teilchen* (ref. 4), 69.

the currents, which unfortunately also led to less synchrotron radiation. The energies of the particles were determined by the particle physics program. The instabilities were drastically reduced when DORIS was converted to a single ring operation in 1977.[110]

Yet another disappointment for the synchrotron radiation scientists hoping to make use of the potential of DORIS came when the "November revolution" of 1974 unsettled the field of particle physics. Within weeks of each other, two independent teams at Brookhaven National Laboratory in New York and SLAC at Stanford in California discovered a new particle that would later be called the J/psi, earning team leaders Samuel Ting and Burton Richter the 1976 Nobel Prize in physics. The discovery largely affirmed the quark hypothesis and was a momentous step in establishing the "Standard Model" for particles and their interactions, which still dominates subatomic physics today.[111] The impact of the "November revolution" was quite different for the particle physics and synchrotron radiation communities at DESY. DORIS was constructed to produce energies up to 3.0 GeV, where synchrotron radiation in the X-ray range would be produced, but the discovery of J/psi turned the attention of particle physicists throughout the world, including at DESY, to a significantly lower energy (1.5 to 2.0 GeV), where new discoveries were expected to be made. At the lower energy, DORIS would in principle still emit high-quality ultraviolet radiation, and for those using radiation at those wavelengths, the reorientation did not lead to any disturbances, but experiments in the X-ray spectrum became practically impossible. Therefore, Bernd Sonntag, one of the members of the synchrotron radiation group, remembers the months following the November revolution as a truly difficult time, demonstrating the low priority of synchrotron radiation at DESY.[112]

This situation at DORIS led synchrotron radiation scientists, including Christof Kunz, Gottfried Mülhaupt, and Ernst-Eckhard Koch, to consider steps that would generally improve the situation of synchrotron radiation

110. Extended Scientific Council, "Niederschrift der 44. Geschäftssitzung des Erweiterten Wissenschaftlichen Rates am 1 Mar 1977," minutes of the 44th meeting of the EWissR, TOP 2; Scientific Council, "Niederschrift der 47. Geschäftssitzung des Wissenschaftlichen Rates am 12 Dec 1977," minutes of the 47th meeting of the WissR, TOP 4.

111. Riordan, *Hunting* (ref. 109), 268–92; Peter Galison, *Image & Logic: A Material Culture of Microphysics* (Chicago: University of Chicago Press, 1997), 538.

112. Sonntag, interview (ref. 18).

researchers at DESY,[113] making plans for the first dedicated synchrotron radiation source at the facility. Already in the spring of 1975, they considered the possibility of building a dedicated storage ring in the vacuum ultraviolet region. Because the machine would not be able to produce X-rays, it was not proposed to alleviate the X-ray drought but to make synchrotron radiation researchers independent from particle physics. However, when they presented their plan informally to DESY's director, Herwig Schopper (in office between 1973 and 1981), he rejected it right away.[114] This rejection might be regarded as surprising given the fact that in the same year, 1975, the DIR had signed a contract with EMBL that formally dedicated two synchrotron radiation bunkers, Bunker 2 at the DESY synchrotron and Bunker 4 at DORIS, to EMBL.[115] The contract with EMBL meant a stronger involvement of DESY in synchrotron radiation. However, Schopper's rejection is quite understandable. First, he considered a proposal from internal DESY scientists as much less effective in garnering support from the Federal Research Ministry for Education and Research compared to a proposal from a group of external users, including influential chairholders from the universities in Munich, Heidelberg, or Dortmund. Hence, from a strategic point of view, Schopper favored an external request from synchrotron radiation users. Second, at that time, the funding decision for PETRA was pending, which is the reason why the synchrotron radiation community had to wait.[116]

The formal request for a small dedicated storage ring for synchrotron radiation research (500 MeV) at DESY was issued to the WissR and DIR one year later, in 1976, by internal DESY scientists (led by Kunz, Mülhaupt, and Koch), with support from several external synchrotron radiation users.[117] Synchrotron radiation scientists at DESY, in particular Kunz, Mülhaupt, and Koch, were in a dilemma. Although they understood the strategic advantage that an external

113. The term the "X-ray drought" was used to describe the very same situation at SLAC, where the SPEAR storage ring also had been designed to run at higher energies and produce radiation in the X-ray spectrum, which the Stanford Synchrotron Radiation project (SSRP) scientists desired to make use of, but where priorities also were reoriented to lower energies. See Hallonsten, "Parasites" (ref. 1).

114. Kunz, *Synchrotronstrahlung bei DESY* (ref. 5), 91–92.

115. DESY and EMBL, contract (ref. 87).

116. Herwig Schopper, interview by first author, 20 Feb 2014; Kunz, *Synchrotronstrahlung bei DESY* (ref. 5), 92–94.

117. Hans-Joachim Behrend, Ernst E. Koch, Christof Kunz, and Gottfried Mülhaupt, "Studie über die Verbesserung der experimentellen Möglichkeiten für Synchrotronstrahlungsexperimente am Deutschen Elektronen-Synchrotron," Internal DESY Report, Hamburg, 1976.

proposal from influential university chairholders would have in mobilizing support from the funders, Kunz and colleagues feared that if the proposal were issued from outside, their low organizational status as research group F41 at DESY would have excluded them from direct negotiations with the funders, the DIR, and the external users. Therefore, they wanted to be involved in these negotiations and thus took initiative and submitted the 500 MeV machine proposal.[118]

Eventually, the proposal was forwarded to the GAfSS at the Federal Ministry for Education and Research. The GAfSS set up an ad hoc expert committee to explore the possibility of building a dedicated synchrotron radiation source in Germany. The committee consisted of DESY outsiders only, although many of them had been and still were users, including Manuel Cardona, the committee's chairman.[119] Setting up the committee was timely because the National Academy of Sciences in the United States had already issued a report on synchrotron radiation facilities in 1976 that listed the existing and planned synchrotron radiation sources in that country and worldwide, with a general strategy for the future of the field in the United States, including the construction of new dedicated synchrotron radiation machines.[120]

The Cardona Report, as it was called in the community, was submitted to the Federal Research Ministry in January 1977, and stated the necessity of building two dedicated synchrotron radiation sources in Germany. The report listed all planned synchrotron radiation facilities in the United States and worldwide, arguing that the German government needed to act, otherwise the hegemonic position of the United States in synchrotron radiation research would be fortified.[121] The report emphasized that the parasitic operations at DORIS were ill-equipped for the expected expansion of synchrotron radiation research in the future. It stated the need for two machines: a smaller 0.7 GeV

118. Christoph Kunz, interview by first author, 2 May 2014.

119. National Expert Committee for Synchrotron Radiation, "Protokoll der 6. Sitzung des Gutachterausschusses für Experimente mit der Synchrotronstrahlung (GAfSS) am 22.10.1976," minutes of the 6th meeting of the GAfSS from 22 Oct 1976, 2; Kunz, *Synchrotronstrahlung bei DESY* (ref. 5), 106–7.

120. National Academy of Science, "An Assessment of the National Need for Facilities Dedicated to the Production of Synchrotron Radiation," report prepared by the National Academy of Science (Washington, DC: National Science Foundation, 1976).

121. Cardona et al., "Speicherringe" (ref. 79), 5–7. A very similar position regarding the hegemonic position of the United States can be found in a report published by the European Science Foundation in the same year, European Science Foundation, *Synchrotron Radiation* (ref. 95), 68–70; Kunz, *Synchrotronstrahlung bei DESY* (ref. 5), 107–11.

machine as a source of VUV, and a 3.0 GeV machine as an X-ray source.[122] An important question discussed at length was whether the bigger machine would be built on a green field site or whether DORIS should be converted into a 3.0 GeV synchrotron radiation source. Based on an extrapolation of costs and pressing needs from synchrotron radiation users, the report concluded that converting DORIS into a dedicated synchrotron radiation source would be the preferable option. The DORIS conversion was estimated to cost 20.15 million DM, compared to at least 72.1 million DM for a new facility. The report also recommended building the 0.7 GeV machine in Bonn and the 3.0 GeV machine in Hamburg.[123]

Given the substantial costs of a new synchrotron radiation facility, the Federal Research Ministry, represented at DESY's VR, preferred the conversion of DORIS into a dedicated synchrotron radiation facility. In addition, the VR acknowledged that DESY had outstanding technical expertise and a well-functioning scientific infrastructure and organization, which meant that the conversion of DORIS would be easier to achieve than building a completely new synchrotron radiation lab: "In order . . . to provide the necessary capacity in the X-ray field in Germany, either the construction of a new storage ring is to be considered . . . or the establishment of a significantly enlarged laboratory at DORIS in connection with main user time. The second option offers two main advantages: 1. investment costs are at least five times lower and 2. it could be realized in significantly shorter time."[124]

DESY's DIR was not convinced, however, that conversion of DORIS would be the best solution, not least because the DIR had other priorities than synchrotron radiation. In August 1976, members of the WissR actively debated whether PETRA should be used for synchrotron radiation experiments. In that meeting, DESY's director Schopper argued that "at present, no plans to conduct synchrotron radiation experiments at PETRA are known and hence currently no plans for new buildings have been taken into consideration."[125] In March 1977, in a meeting of the Extended Scientific Council (Erweiterter Wissenschaftlicher Rat, EWissR), Schopper argued that "a dedicated source

122. Cardona et al., "Speicherringe" (ref. 79), 17–19.

123. Cardona et al., "Speicherringe" (ref. 79), 25–36. The 0.7 GeV machine was later built in West Berlin as BESSY; see Heinze et al., "From Periphery to Center, Part II" (ref. 2), FN 19.

124. Administrative Council, "Vorlage für die Sitzung des Verwaltungsrates am 25 Nov 1977," draft for the VR meeting, TOP 5.

125. Scientific Council, "Niederschrift der 42. Geschäftssitzung des Wissenschaftlichen Rates am 31 Aug 1976," minutes of the 42nd meeting of the WissR, TOP 1.

could not be operated by DESY."[126] Thus, the conversion of DORIS into a dedicated synchrotron radiation source was not an option for the DIR in the late 1970s. However, the DIR did not openly reject Cardona et al.'s recommendations, but argued that any extension of the synchrotron radiation facility would require additional staff and money: "The Board of Directors points out that DESY will not be able to deliver the desired support without additional staff."[127] In this way, the DIR clearly stated that synchrotron radiation research would need additional investments from the federal funder.

In the meantime, however, another option came under discussion. Gottfried Mülhaupt, a leading synchrotron radiation scientist, proposed building a small storage ring (later called the Positron Intensity Accumulator, PIA) that could function as an injector for PETRA.[128] If this option were realized, DORIS would be free from injection into PETRA and could be used for both particle physics and synchrotron radiation experiments, which would mean substantially more beam time for synchrotron radiation. DESY's EWissR picked up this idea and asked a commission headed by Peter Brix, the director at the Max Planck Institute for Nuclear Physics in Heidelberg, to develop a plan outlining the future contribution of DORIS to synchrotron radiation research.[129] The Brix commission submitted its report in June 1977, suggesting 50 percent beam time for the synchrotron radiation research program, and for the first time at DESY, 10 percent exclusive beam time: "The commission recommends DORIS should be used on equal terms for high-energy physics and for synchrotron radiation. The aim should be to make 50 percent of beam time available for synchrotron radiation, including approximately 10 percent of beam time for 'dedicated' operation. If the definition of operations of DORIS on the part of high-energy physics leads to unfavorable working conditions for synchrotron radiation physics, the portion of dedicated time would have to be increased. The commission does not give a final recommendation on the maximum share of 'dedicated' beam time; approximately 33 percent should be the basis for further discussion."[130] The EWissR endorsed the commission's

126. Extended Scientific Council, "Niederschrift" (ref. 110), TOP 2.

127. Board of Directors, "Bericht des Direktoriums über die Zeit von Mai bis Oktober 1977," report of the DIR about the period from May to Oct 1977, 17.

128. Gottfried Mülhaupt, "Ein Kleinspeicherring als Zwischenspeicher für die Positronen Injektion nach PETRA," DESY Report H2-77/11 (Hamburg: DESY, 1977).

129. Extended Scientific Council, "Niederschrift" (ref. 110), TOP 5.

130. National Expert Committee for Synchrotron Radiation, "Protokoll" (ref. 119), 7–8.

recommendations in June 1977.[131] In December 1977, PIA was approved by the DIR, and it became operational in July 1979.[132] Stable beams at DORIS had already become available when it was converted to a single ring in December 1977.[133] Therefore, the single ring operation of DORIS, together with the new PIA injector, was a real improvement for all synchrotron radiation users.

To understand why PIA was built when neither a small, dedicated, 500 MeV synchrotron radiation machine (proposal by Kunz, Mülhaupt, and Koch in 1975–1976) nor the conversion of DORIS (proposal by Cardona et al. in 1977) seemed possible, one has to consider first that DESY had a long-term scientific agenda in particle physics into which a dedicated synchrotron radiation machine did not (yet) fit, whether small (the 500 MeV machine) or large (e.g., the converted DORIS). Long before his tenure as DESY's director, Schopper had shaped this scientific agenda both as a member of the WissR (1960–70) and as chairman of a WissR committee that was responsible for the future development of DESY (1966).[134] According to DESY's statutes, the WissR is an important advisory committee to the DIR in programmatic scientific issues.[135] Second, although the Federal Research Ministry, which held a majority in the VR, had a clear preference for the conversion of DORIS into a dedicated synchrotron radiation source, according to DESY's statutes, the VR has an advisory function to the DIR, whereas the DIR, together with the WissR (and to some extent also the Wissenschaftlicher Ausschuss, Scientific Committee), is responsible for DESY's scientific program. Trute emphasizes the strong position of the DIR regarding the scientific program: "Decisions concerning the scientific program are concentrated in the hands of the Board of Directors whose members are predominantly scientists" and

131. Extended Scientific Council, "Niederschrift" (ref. 110), TOP 7. It is noteworthy that half a year later, the Scientific Council (not the Extended Scientific Council) revised this decision and recommended dedicated beam time only if experiments for the particle physics program would not be affected. Scientific Council, "Niederschrift der 47. Geschäftssitzung des Wissenschaftlichen Rates am 12 Dec 1977," minutes of the 47th meeting of the WissR, TOP 7.

132. Wissenschaftlicher Jahresbericht DESY 1979, Scientific Report DESY FY 1979, 10, 128, 144.

133. JB DESY 1975 (ref. 94), 84, 168–69.

134. Board of Directors, "Tätigkeitsbericht" (ref. 34), 4; Board of Directors, "Bericht des Direktoriums" (ref. 37), 5; JB DESY 1964 (ref. 50), 4; JB DESY 1965 (ref. 55), 5; JB DESY 1966 (ref. 67), 4; JB DESY 1967 (ref. 58), 3; JB DESY 1968 (ref. 76), 4; WJB DESY 1970 (ref. 80), 5.

135. §7, §10 Satzung DESY; §7, §10 Statutes of DESY; Hans-Heinrich Trute, *Die Forschung zwischen grundrechtlicher Freiheit und staatlicher Institutionalisierung. Das Wissenschaftsrecht als Recht korporativer Verwaltungsvorgänge* (Tübingen: J.C.B. Mohr, 1994), 545–47.

"fundamental decision-making lies in the hands of the Board of Directors."[136] Therefore, both the DIR and the WissR were responsible for steering DESY's scientific program. Ultimately, of course, the Federal Research Ministry, together with the City of Hamburg, had to take funding decisions, and thus shaped the scientific program as well.[137]

With respect to the categories of institutional change introduced above, the building of PIA is equivalent to a new layer of scientific instrumentation in particle physics. Most interesting, however, is the fact that this *particle physics layering of instrumentation* made possible *the layering of additional and improved synchrotron radiation research at DESY*. For synchrotron radiation scientists, the most important improvement of PIA was exclusive beam time, which included freedom to tune the performance of DORIS to the exact needs of the synchrotron radiation experimenters rather than having to accept whatever was given to them by the particle physicists.[138] In this way, we observe yet another element in the *layering process* of synchrotron radiation research that had started in the early 1960s.

In 1973, a group of particle physicists at DESY submitted an internal memorandum that proposed a new proton electron storage ring (Proton-Elektron Tandem Ringanlage).[139] However, this proposal was not pursued further because a proton-electron collider would have required two storage rings, which was too expensive. In contrast, a positron-electron collider required only one storage ring and was thus much cheaper.[140] Therefore, a revised proposal was submitted to the WissR in June 1974 for a positron-electron storage ring, which eventually became PETRA.[141] The WissR recommended PETRA in November 1974, and in December 1974, the VR asked the DIR to prepare a construction plan.[142] The funding decision was made by the VR in

136. Trute, *Die Forschung* (ref. 135), 575–76.

137. The Federal Research Ministry played a much more active role in other Big Science facilities, in particular the nuclear research centers in Karlsruhe and Jülich. However, since the 1970s, the Federal Research Ministry pulled out of directly steering these centers; this phenomenon is called *Globalsteuerung* (indirect control) in the science history literature on Big Science facilities in Western Germany; see Hohn and Schimank, *Konflikte* (ref. 103), 260–62; Szöllösi-Janze, *Geschichte der Arbeitsgemeinschaft* (ref. 6), 15, 88–94; Stumm, *Kernfusionsforschung* (ref. 103), 124–35.

138. Materlik, interview (ref. 18).

139. H. Gerke, H. Wiedemann, Björn Wiik, and Günter Wolf, "Ein Vorschlag, DORIS als ep Speicherring zu benutzen," proposal to use DORIS as an ep-storage ring, H-72/22 (Hamburg, 1972).

140. Lohrmann and Söding, *Von schnellen Teilchen* (ref. 4), 87.

141. WJB DESY 1975 (ref. 105), 111.

142. Wissenschaftlicher Jahresbericht DESY 1974, Scientific Report DESY FY 1974, 1–3.

October 1975 and construction began in 1976; the first beams were stored in 1978.[143]

Regarding PETRA, Herwig Schopper was under pressure for two reasons in particular. First, he had promised the funders (the Federal Ministry for Research and Technology[144] and the City of Hamburg) that PETRA would be constructed without any additional staff. Therefore, all efforts and all staff in the second half of the 1970s were prioritized for completing PETRA on time. In 1976, DESY's annual report stated: "This year the accelerator division was dominated by work for the construction of the new 19.0 GeV storage ring PETRA. As there are no additional personal capacities available for this project, all the work has to be done by project groups formed of staff from existing DESY groups. The additional workload for these DESY groups is extraordinarily high and severely restricts normal development work outside the PETRA project. . . . Major new projects besides PETRA could not be started."[145] Second, DESY was involved in fierce competition with laboratories in the United States, where scientists had discovered three elementary particles within a few years: J/psi in 1974 by Richter (SLAC) and Ting (Brookhaven/Cornell), the "tau-Lepton" in 1976 by Martin Perl (SLAC), and the "b-quark" in 1977 by Leon Lederman (Fermi National Accelerator Laboratory; Fermilab).[146] Any other major project, especially if it involved the synchrotron radiation facility, would potentially draw resources (and attention) from PETRA and thus could not receive support from the DIR and the WissR.

With respect to the increasing demand for more beam time, buildings, and instrumentation space by synchrotron radiation, the VR and the DIR were divided. On the one hand, the Federal Research Ministry had launched its synchrotron radiation funding program in 1974 and expected the DIR to continue its general support for F41. In one of its meetings, the VR urged the DIR "to examine all appropriate steps to overcome the accrued personal problems. . . . The already commenced work of planning and preparatory construction shall be continued as far as DESY infrastructure allows."[147] On the other hand,

143. WJB DESY 1975 (ref. 105), 9, 103, 111; WJB DESY 1976 (ref. 78), 14; Wissenschaftlicher Jahresbericht DESY 1978, Scientific Report DESY FY 1978, 7.

144. The Federal Ministry for Education and Research was split into two ministries in 1972. The new Federal Ministry for Research and Technology became responsible for DESY.

145. WJB DESY 1976 (ref. 78), 109.

146. Riordan, *Hunting* (ref. 109), 268–92; Hoddeson et al., *Fermilab* (ref. 8), 232.

147. Administrative Council, "Niederschrift über die 46. Sitzung des Verwaltungsrates am 15 Jun 1978," minutes of the 46th meeting of the VR, 10.

the general line of reasoning of both the WissR and the DIR was that continued support and an extension of the synchrotron radiation facility to DORIS would require substantial additional funding for DESY, putting pressure back on the funders.[148] Therefore, the situation was very different from ten years earlier when the day-to-day activities of the new synchrotron radiation facility were generously supported by DESY's technical and scientific infrastructure. Since the mid-1970s, DESY's technical and scientific infrastructure had been almost completely absorbed by the particle physics program, especially PETRA.[149]

## CONCLUSIONS

This article provides the first part in the thirty-year history of synchrotron radiation at DESY and has shown how a laboratory founded as a resource for particle physics started to invest considerably into synchrotron radiation research between 1962 and 1977. We have demonstrated how many incremental yet interconnected steps started the renewal of DESY's research program. These events are important elements in change processes that operate at the levels of technical infrastructure, research fields, and formal organization. As shown above, most events are elements in a *layering process* in which new pieces of technical infrastructure (Strahlbeobachtungsbunker), new research fields (molecular biology, materials sciences), and new organizational units (F41, EMBL outstation) were added on top of preexisting units invested in particle physics. These new elements were incorporated at DESY without challenging existing commitments in particle physics.

However, as will be shown in the second part of the history of synchrotron radiation research at DESY,[150] this layering process triggered several other

148. Scientific Council, "Stellungnahme des Wissenschaftlichen Rates vom 4 Apr 1978 zum Entwurf des Wirtschaftsplans 1979," position paper on the draft of the budget plan 1979 by the WissR, 3.

149. The fact that PETRA was a top priority in the late 1970s and that synchrotron radiation research had a low priority for the DIR is validated in several documents that are part of the so-called "Sonderakte Synchrotronstrahlung," special folder synchrotron radiation, available in the BAK 196/34435; see "Vermerk über meinen Informationsbesuch in Hamburg bei F41, 2 Aug 1978 (Dr. Möckel, BMFT)," minutes of site visit at F41 in Hamburg (Dr. Möckel, BMFT), 2; "Ergebnisvermerk über die Besprechung zwischen Vertretern Hamburgs, des Bundes und DESY über den weiteren Ausbau der Synchrotronstrahlung bei DESY, minutes of the meeting between representatives of the City of Hamburg, the Federal Research Ministry, and DESY regarding the expansion of synchrotron radiation at DESY, III/1.

150. Heinze et al., "From Periphery to Center, Part II" (ref. 2).

change processes, including the *conversion* of major pieces of technical infrastructure and the gradual *displacement* of particle physics by solid state physics, biology, materials sciences, and chemistry both at the synchrotron DESY and the storage rings DORIS and PETRA. Therefore, although layering seems to dominate the initial phase of DESY's transformation, the other three processes are quite important as well.

The fact that a *layering process*, in combination with *conversion and displacement processes*, has been underway since the 1960s shows a general pattern of incremental yet cumulative institutional change that is the building block of the larger macro-level transformation from particle physics to photon science. It is very likely that similar processes can be observed at other research laboratories that have undergone a similar transition in their mission and research activities, although these processes might take shorter or longer depending on the particular circumstances of the laboratories under study.

The macro-level change this article describes is that of the beginning of a major transformation in science and technology in the late twentieth century by which the dominance of high-energy physics in national and international science budgets was weakened and eventually displaced by the rise of life sciences and materials sciences, with applications of similarly tremendous impact. As will be shown in the second part of the history of synchrotron radiation research at DESY, synchrotron radiation took a leading position on the side of experimentation in these growing fields of research and development and became a new form of Big Science, generously funded by national governments and with user communities expanding across academia as well as industry.

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## APPENDIX

**TABLE 1.** Annual Capital Investments at DESY.

| | ***DESY*** | ***Linear accelerator*** | ***DORIS*** | ***PETRA*** | ***HASYLAB*** | ***DORIS II*** | ***HERA*** | ***PETRA III*** | ***FEL/TESLA/ XFEL*** | ***DESY Infrastructure*** |
|---|---|---|---|---|---|---|---|---|---|---|
| 1957 | 1.922 | | | | | | | | | |
| 1958 | 3.844 | | | | | | | | | |
| 1959 | 5.766 | | | | | | | | | |
| 1960 | 7.688 | | | | | | | | | |
| 1961 | 18.367 | | | | | | | | | |
| 1962 | 20.545 | | | | | | | | | |
| 1963 | 24.676 | | | | | | | | | |
| 1964 | 10.791 | | | | | | | | | |
| 1965 | 7.051 | | | | | | | | | |
| 1966 | 4.134 | | | | | | | | | |
| 1967 | 4.155 | 6.081 | | | | | | | | |
| 1968 | | 15.354 | | | | | | | | |
| 1969 | | 1.564 | 5.620 | | | | | | | |
| 1970 | | | 12.166 | | | | | | | |
| 1971 | | | 20.262 | | | | | | | |
| 1972 | | | 30.663 | | | | | | | |
| 1973 | | | 32.021 | | | | | | | |
| 1974 | | | 15.425 | | | | | | | |

*(continued)*

TABLE 1. *(continued)*

| | **DESY** | **Linear accelerator** | **DORIS** | **PETRA** | **HASYLAB** | **DORIS II** | **HERA** | **PETRA III** | **FEL/TESLA/ XFEL** | **DESY Infrastructure** |
|---|---|---|---|---|---|---|---|---|---|---|
| 1975 | | | | | | | | | | |
| 1976 | | | | 40.651 | | | | | | |
| 1977 | | | | 46.068 | | | | | | |
| 1978 | | | | 33.854 | 624 | | | | | |
| 1979 | | | | 17.278 | 5.022 | | | | | |
| 1980 | | | | 9.022 | 8.696 | | | | | |
| 1981 | | | | 1.269 | | 14.146 | | | | |
| 1982 | | | | 1.187 | | 11.134 | | | | |
| 1983 | | | | 164 | | 7.802 | | | | |
| 1984 | | | | 561 | | | 56.497 | | | |
| 1985 | | | | | 2.477 | | 118.377 | | | |
| 1986 | | | | | 4.905 | | 197.573 | | | |
| 1987 | | | | | 4.761 | | 220.126 | | | 1.450 |
| 1988 | | | | | 4.480 | 36 | 174.842 | | | 1.913 |
| 1989 | | | | | 1.696 | 688 | 111.271 | | | 5.004 |
| 1990 | | | | | | 7.960 | 113.753 | | | 1.666 |
| 1991 | | | | | | 7.136 | 29.549 | | | 258 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 1992 | | | 5.444 | | | 257 |
| 1993 | 464 | 417 | 637 | | | 1.893 |
| 1994 | 1.062 | 3.746 | | | | |
| 1995 | 2.108 | 2.783 | | | | |
| 1996 | 202 | 1.024 | | | | |
| 1997 | | | | | 618 | |
| 1998 | | | | | 3.046 | 99 |
| 1999 | | | | | 12.559 | 274 |
| 2000 | | | | | 5.220 | 99 |
| 2001 | | | | | 9.584 | 157 |
| 2002 | | | | | 11.820 | 273 |
| 2003 | | | | | | 273 |
| 2004 | | | | 2.222 | 2.222 | 273 |
| 2005 | | | | 6.933 | 5.009 | 3.084 |
| 2006 | | | | 5.000 | 11.100 | 5.424 |
| 2007 | | | | 10.000 | 11.400 | 5.424 |
| 2008 | | | | 10.013 | 15.072 | 65 |
| 2009 | | | | 14.087 | 22.884 | 522 |

*Source*: WP DESY 1963–2009, in 1.000 DM. Since 2002, numbers are provided in 1.000 Euro.

**TABLE 2.** Non-Scientific and Scientific Staff at DESY, HASYLAB, and EMBL.

| | *Non-scientific DESY staff* | *Scientific DESY staff* | *Non-scientific HASYLAB staff* | *Scientific HASYLAB staff* | *Non-scientific EMBL staff* | *Scientific EMBL staff* |
|---|---|---|---|---|---|---|
| 1961 | 243 | 4 | | | | |
| 1962 | 285 | 6 | | | | |
| 1963 | 266 | 6 | | | | |
| 1964 | 388 | 16 | | | | |
| 1965 | 544 | 25 | | | | |
| 1966 | 665 | 28 | | | | |
| 1967 | 597 | 150 | | | | |
| 1968 | 626 | 142 | | | | |
| 1969 | 641 | 143 | | | | |
| 1970 | 654 | 144 | | | | |
| 1971 | 684 | 151 | | | | |
| 1972 | 719 | 160 | | | | |
| 1973 | 748 | 157 | | | | |
| 1974 | 805 | 176 | | | 2 | 2 |
| 1975 | 832 | 199 | | | 4 | 2 |
| 1976 | 832 | 208 | | | 11 | 5 |
| 1977 | 834 | 206 | | | 11 | 5 |
| 1978 | 830 | 205 | | | 11 | 7 |
| 1979 | 830 | 205 | | | 12 | 9 |
| 1980 | 836 | 201 | 5 | 3 | 12 | 6 |
| 1981 | 837 | 205 | 5 | 3 | 11 | 7 |
| 1982 | 833 | 204 | 5 | 3 | 12 | 10 |
| 1983 | 819 | 201 | 6 | 4 | 14 | 9 |
| 1984 | 813 | 199 | 11 | 6 | 13 | 12 |
| 1985 | 808 | 199 | 17 | 6 | 15 | 14 |
| 1986 | 799 | 196 | 21 | 8 | 12 | 18 |
| 1987 | 855 | 201 | 33 | 15 | 13 | 19 |
| 1988 | 856 | 203 | 35 | 20 | 13 | 20 |
| 1989 | 861 | 206 | 36 | 20 | 15 | 19 |
| 1990 | 877 | 210 | 36 | 21 | 15 | 18 |
| 1991 | 879 | 216 | 36 | 21 | 17 | 21 |
| 1992 | 877 | 212 | 34 | 20 | 15 | 17 |
| 1993 | 881 | 218 | 36 | 21 | 15 | 16 |

*(continued)*

TABLE 2. *(continued)*

| | Non-scientific DESY staff | Scientific DESY staff | Non-scientific HASYLAB staff | Scientific HASYLAB staff | Non-scientific EMBL staff | Scientific EMBL staff |
|---|---|---|---|---|---|---|
| 1994 | 880 | 216 | 36 | 21 | 15 | 21 |
| 1995 | 874 | 217 | 36 | 21 | 14 | 24 |
| 1996 | 854 | 214 | 35 | 20 | 15 | 21 |
| 1997 | 846 | 210 | 36 | 20 | 16 | 28 |
| 1998 | 840 | 204 | 36 | 20 | 16 | 26 |
| 1999 | 819 | 195 | 32 | 19 | 18 | 23 |
| 2000 | 800 | 186 | 33 | 20 | 18 | 23 |
| 2001 | 795 | 196 | 33 | 20 | 24 | 28 |
| 2002 | 803 | 364 | 41 | 56 | 25 | 29 |
| 2003 | 825 | 385 | 40 | 50 | 28 | 35 |
| 2004 | 816 | 409 | 50 | 62 | 32 | 45 |
| 2005 | 900 | 443 | 26 | 80 | 31 | 50 |
| 2006 | 908 | 464 | 31 | 89 | 31 | 51 |
| 2007 | 928 | 491 | 28 | 93 | 31 | 54 |

*Sources*: WP DESY 1963–2009, in FTE (not including DESY Zeuthen), EMBL: Office of Administrative Director.

**TABLE 3.** Annual Expenditures in the Federal Synchrotron Radiation Funding Program.

| Fiscal year | Annual expenditure |
|---|---|
| 1974 | 665 |
| 1975 | 117 |
| 1977 | 199 |
| 1978 | 199 |
| 1979 | 3.494 |
| 1980 | 6.294 |
| 1981 | 6.830 |
| 1982 | 9.193 |
| 1983 | 11.417 |
| 1984 | 10.841 |
| 1985 | 14.196 |
| 1986 | 16.361 |

*(continued)*

TABLE 3. *(continued)*

| ***Fiscal year*** | ***Annual expenditure*** |
|---|---|
| 1987 | 17.234 |
| 1988 | 16.162 |
| 1989 | 17.750 |
| 1990 | 20.014 |
| 1991 | 17.909 |
| 1992 | 19.637 |
| 1993 | 19855 |
| 1994 | 20.054 |
| 1995 | 17.353 |
| 1996 | 16.182 |
| 1997 | 15.527 |
| 1998 | 13.760 |
| 1999 | 13.918 |
| 2000 | 14.971 |
| 2001 | 14.157 |
| 2002 | 8.000 |
| 2003 | 8.500 |
| 2004 | 5.360 |
| 2005 | 8.520 |
| 2006 | 8.390 |
| 2007 | 19.030 |
| 2008 | 16.750 |
| 2009 | 15.950 |
| 2010 | 20.710 |
| 2011 | 17.390 |
| 2012 | 19.920 |

*Source*: PT-DESY Hamburg (courtesy of Dr. Olaf Kühnholz), in 1.000 DM. Since 2002, numbers are provided in 1.000 Euro.