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From Periphery to Center: Synchrotron Radiation at DESY, Part II: 1977–1993

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 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. Together with

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The following abbreviations are used: ARGUS, A Russian–German–United States–Swedish Collaboration; BAK, Bundesarchiv Koblenz (Federal Archive in Koblenz); BESSY, Berliner Elektronen-Speicherring Gesellschaft für Synchrotronstrahlung; BMFT, Bundesministerium für Forschung und Technologie (Federal Ministry of Research and Technology); 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); FBS, Forschungsbeirat Synchrotronstrahlung (Research Council Synchrotron Radiation); FhG-IFT, Fraunhofer-Institut für Festkörper-Technologie (Fraunhofer Research Institution for Modular Solid State Technologies); 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); HERA, Hadron-Elektron-Ringanlage (hadron electron ring

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an earlier publication on the issue in this journal,[1] this article chronicles the first thirty years in the history of synchrotron radiation at DESY. The focus is on the gradual transformation of DESY's research program in synchrotron radiation from peripheral and parasitic into mainstream and mission. We provide insights 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 and X-ray photons. Therefore, we contribute to better understanding the growth of synchrotron radiation as a laboratory resource, and processes of renewal in Big Science as part of the general history of late-twentieth-century science.

KEY WORDS: synchrotron radiation, DESY, HASYLAB, 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. Synchrotron radiation research at DESY began in the early 1960s with Peter Stähelin, DESY's first research director, who understood the scientific potential that synchrotron radiation offered for UV spectroscopy. In 1963, Stähelin obtained a grant from the newly established space research program of the German Research Foundation (DFG) to build an observation bunker at DESY. The bunker consisted of a small building hosting both the final part of a thirty-meter beamline from the synchrotron and a grazing incidence VUV spectrometer. The DFG funding set in motion a gradual transformation 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

accelerator); *HSNS*, *Historical Studies in the Natural Sciences*; JB, Jahresbericht (Annual Report); PETRA, Positron-Elektron-Tandem-Ring-Anlage (Positron-Electron Tandem-Ring Accelerator); PIA, Positronen-Intensitäts-Akkumulator (Positron Intensity Accumulator); SLAC, Stanford Linear Accelerator Center; SPEAR, Stanford Positron-Electron Accelerator Ring; *SPP*, *Science and Public Policy*; SSRL, Stanford Synchrotron Radiation Laboratory; TESLA, TeV-Energy Superconducting Linear Accelerator; UV, ultraviolet; VR, Verwaltungsrat (Administrative Council); VUV, vacuum ultraviolet; VUV-FEL, Vacuum-Ultraviolet Free-Electron Laser; WILMA, Wiggler-Licht-Maschine (Wiggler-Light-Machine); WissR, Wissenschaftlicher Rat (Scientific Council); WJB, Wissenschaftlicher Jahresbericht (Scientific Report); XFEL, X-Ray Free Electron Laser.

1. Thomas Heinze, Olof Hallonsten, and Steffi Heinecke, "From Periphery to Center: Synchrotron Radiation at DESY, Part I: 1962–1977," *HSNS* 45, no. 3 (2015): 447–92.

infrastructure in the late 2000s. In the categories of *historical institutionalism*,[2] the DFG funding initiated a *double layering*: first, new infrastructure, including the observation bunker, its beamline, and various other machinery on top of the existing DESY ring accelerator; and second, a new organizational unit (F41) that was added to the existing research groups in particle physics at DESY's research division. The first experiments with synchrotron radiation started one year later, in parallel with the particle physics program.

In the 1960s, several external research groups from various German universities joined the observation bunker, and soon the activities expanded and became more and more successful. An important year for synchrotron radiation research at DESY was 1968, when the construction of DESY's second machine, the double storage ring DORIS, started. The prospects of this new source attracted scientists from materials science and molecular biology who began to collaborate with F41's synchrotron radiation experimenters. Noteworthy is also the fact that the European Molecular Biology Laboratory (EMBO) established an outstation at DESY in 1971. The expansion into materials science and molecular biology built credibility around the synchrotron radiation activities and demonstrated to the particle physicists in charge of DESY that this research program was important and growing, even in parasitic mode.

The growth of synchrotron radiation activities in number and significance also attracted attention from the funders. In 1973, when DORIS became

2. 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; 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.

operational, the Federal Research Ministry agreed to become the chief sponsor for university groups that wanted to use synchrotron radiation at DESY. Although the possibilities created by DORIS for synchrotron radiation research were very promising, including a stable beam with a hundred-fold greater intensity than the one at the DESY synchrotron, these expectations would soon be disappointed because DORIS suffered severe beam instabilities that prevented the machine from reaching the expected luminosities. Another disappointment came in 1974 with discovery of the J/psi particle by Samuel Ting and Burton Richter, which turned the attention of particle physicists worldwide to a significantly lower energy. Consequently, DORIS produced high-quality UV radiation, but synchrotron radiation experiments in the X-ray spectrum became practically impossible.

This situation at DORIS led several senior synchrotron radiation scientists to consider steps to build a dedicated storage ring for synchrotron radiation research. Although DESY's Board of Directors (DIR) did not support this initiative, in 1976 a proposal was submitted to the Federal Ministry for Education and Research to build a dedicated storage ring. The Ministry set up an ad hoc expert committee, which several months later recommended, among other things, the conversion of DORIS into a dedicated 3.0 GeV synchrotron radiation source. However, the DIR was not convinced that converting DORIS would be the best option. Therefore, another possibility was pursued: the building of a small storage ring (later called the Positron Intensity Accumulator, PIA) that would relieve DORIS from being used as main injector for PETRA. At about the same time, in 1977, stable beams at DORIS became available when it was converted to a single-ring operation. In the categories of *historical institutionalism*, the building of PIA as scientific instrumentation in particle physics made possible *the layering of additional and improved synchrotron radiation research at DESY*. The most important improvement that came with PIA was exclusive beam time for synchrotron radiation experimenters, including the freedom to tune the performance of DORIS to their particular needs.

The parasitic mode of synchrotron radiation research reached its limits in the late 1970s, when more and more prospective users from various scientific fields of synchrotron radiation applied for a spot at DORIS and when the science results became increasingly novel and important. It is this situation that this article begins: 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. In the 1980s, 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: synchrotron radiation was recognized as a formal organizational goal, and DORIS was fully dedicated to synchrotron radiation research.

This article relies 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 (WissR), annual reports from both DESY and HASYLAB, and DESY's annual fiscal plans;[3] (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 books on DESY and Big Science facilities in Germany and the United States.[4]

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

4. Claus Habfast, *Großforschung mit kleinen Teilchen: DESY 1956–1970* (Heidelberg: Springer-Verlag, 1989); Christof Kunz, *Synchrotronstrahlung bei DESY: Anfänge* (Private Print, 2012), available at DESY upon request; Erich Lohrmann and Paul Söding, *Von schnellen Teilchen und hellem Licht: 50 Jahre Deutsches Elektronen-Synchrotron DESY*, 2nd ed. (Weinheim: Wiley-VCH, 2013); 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; 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.

THE CREATION OF HASYLAB, 1977–1981

The considerable expansion of synchrotron radiation research at DESY in the early 1970s came at a time when plans were under way to build a positron-electron storage ring (PETRA) for the particle physics program. Therefore, the increasing demand for more beam time, buildings, and instrumentation space by synchrotron radiation could not be fully satisfied. Building PETRA absorbed much of DESY's technical and scientific infrastructure.[5] In fact, both the DIR and the WissR argued that continued support and an extension of the synchrotron radiation facility to DORIS would require substantial additional funding for DESY.[6] The pressure on the funders to provide substantial additional funding for synchrotron radiation research at DESY was heightened when, in the autumn of 1977, almost fifty user groups signed a memorandum asking for new experimental stations at DORIS,[7] adding momentum to the negotiations between the DIR and the funders.

In December 1977, the Federal Research Ministry and City of Hamburg agreed to provide funding for the first synchrotron radiation laboratory at DORIS, the Hamburg Synchrotron Radiation Laboratory (Hamburger Synchrotronstrahlungslabor, HASYLAB). The agreement covered an initial investment of 14.4 million DM for a new laboratory building, including new office space and new instrumentation and beamlines. HASYLAB was equipped with an annual operating budget of 2.0 million DM and an annual support budget of 2.5 million DM for external user groups. The funders promised up to thirty-three new scientific staff positions and up to twenty-two new positions for support and infrastructure staff.[8]

The substantial investment and the promises for new staff positions from the funders were made at a time when the system of national laboratories in Germany (Großforschungseinrichtungen) had entered a consolidation phase, in terms of both the number of laboratories and budget growth. From the late

5. For PETRA's investment costs, see Table 1 in the Appendix.

6. Board of Directors, "Bericht des Direktoriums über die Zeit von Oct 1977 bis Apr 1978," report of the DIR about the period from Oct 1977 to Apr 1978, 12; 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.

7. This memorandum is mentioned in European Science Foundation, *Synchrotron Radiation: A Perspective View for Europe*, report prepared for ESF (Strasbourg, 1977), 57.

8. Administrative Council, "Niederschrift über die 46. Sitzung des Verwaltungsrates am 25 Nov 1977," minutes of the 46th meeting of the VR, 7–8.

1970s until the mid-1980s, the budget for all national laboratories declined and grew only moderately afterward, compared to the high growth rates in the 1960s and early 1970s.[9] In this context of federal fiscal constraints, the DIR demanded a complete separation of the HASYLAB budget from the DESY budget to ensure that, if additional funds were not provided as promised, the new laboratory could not draw on general DESY funds: "There was agreement among the members of the Board of Directors that the new synchrotron radiation activities should be realized as a DESY research group with a special status, which consists in the fact that this group is displayed separately in the organizational chart and that the funds for synchrotron radiation are assessed separately in the fiscal plan."[10] The funders agreed that HASYLAB's budget and staff were separately mentioned in DESY's annual fiscal plan; yet they demanded that DESY submit one fiscal plan for both DESY and HASYLAB, so a complete budget separation would not be possible.[11] In this way, the funders wanted to make sure, given the fiscal constraints, that if additional funds could not be fully provided, then DESY had to use resources from the particle physics budget for HASYLAB's operations. As explained below, this scenario is what ultimately unfolded during the 1980s.

In addition to financial questions, several organizational issues had to be addressed. In October 1978, the WissR proposed a new statute for HASYLAB.[12] It included the position of HASYLAB director, who served a (renewable) term of four years and had to be approved by both the WissR and the DIR; and it included the new Research Council Synchrotron Radiation (Forschungsbeirat Synchrotronstrahlung, FBS), which assumed the responsibilities of its predecessor (FKS), including the review of research proposals submitted to HASYLAB and the allocation of beam time and budget, but which also assumed new responsibilities, such as proposing candidates for the position of

9. 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), 259–95; Hallonsten and Heinze, "Institutional Persistence" (ref. 2), 453–56, 463.

10. Board of Directors, "Bericht des Direktoriums über die Zeit von Nov 1977 bis Apr 1978," report of the DIR about the period from Nov 1977 to Apr 1978, 10; Lohrmann and Söding, *Von schnellen Teilchen* (ref. 4), 230.

11. Administrative Council, "Protokoll über die zweite Sitzung der vom Verwaltungsrat eingesetzten Arbeitsgruppe 'HASYLAB' am 30 Sep 1980," minutes of the 2nd meeting of the working group HASYLAB, founded by the VR, on 3.

12. Scientific Council, "Niederschrift der 50. Geschäftssitzung des Wissenschaftlichen Rates am 10 Oct 1978," minutes of the 50th meeting of the Scientific Council, TOP 5.

HASYLAB director and plans for HASYLAB's future development.[13] The DIR approved HASYLAB's statutes in October 1978 and named Christof Kunz its first director (until 1985).[14] Kunz became a physics professor at Hamburg University in 1978, whereupon he was no longer a DESY employee.

The most important organizational issue was how independent the new laboratory should be from DESY. The Cardona Report had suggested four alternative organizational models: (1) a scientifically and administratively independent laboratory with contractual relations to DESY; (2) an institute at the Kernforschungsanlage in Jülich; (3) a Max Planck Institute; or (4) a university institute in Bonn or Hamburg.[15] Although none of these models were ever realized, the Cardona Report was accurate in its conclusion that an international organization would take too long to satisfy the urgent needs of many synchrotron radiation users. The European Science Foundation Report on synchrotron radiation sources in Europe, published some months after the Cardona Report, recommended that "an interdisciplinary working group be constituted with the task of studying the possibility of building a new European X-ray synchrotron radiation laboratory starting in the 1980s."[16] This working group issued its report in 1979, but it would take another fifteen years of political maneuvering and intergovernmental negotiation until the European Synchrotron Radiation Facility (ESRF) opened to users in 1994.[17]

13. The new FBS had the following members in 1979: Ulrich Bonse, Manuel Cardona, Otfried Madelung, Wulf Steinmann, and Helmut Baumgärtel (external members); Ernst E. Koch, Christof Kunz, and Erich Lohrmann (DESY members). The following guests were regularly invited: Ruprecht Haensel, Heinz Raether (external guests), and Herwig Schopper (DESY director). Research Council Synchrotron Radiation, minutes of the second FBS meeting, 26 Feb 1979.

14. Board of Directors, "Niederschrift über die Beschlussfassungen des Direktoriums am 12 Oct 1978," minutes of the resolutions taken by the DIR, TOP 8; Board of Directors, "Bericht des Direktoriums über die Zeit von Oct 1978 bis Apr 1979," report of the DIR about the period from Oct 1978 to Apr 1979, Anlage 3.

15. 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), 37.

16. European Science Foundation, *Synchrotron Radiation* (ref. 7), 70.

17. European Science Foundation, *Synchrotron Radiation: The Feasibility Study*, report prepared for ESF (Strasbourg, 1979). For details of the history of the ESRF, see: Vincent Simoulin, *Sociologie d'un grand équipement scientifique: Le premier synchrotron de troisième generation* (Lyon: ENS Éditions, 2012), 87–146.

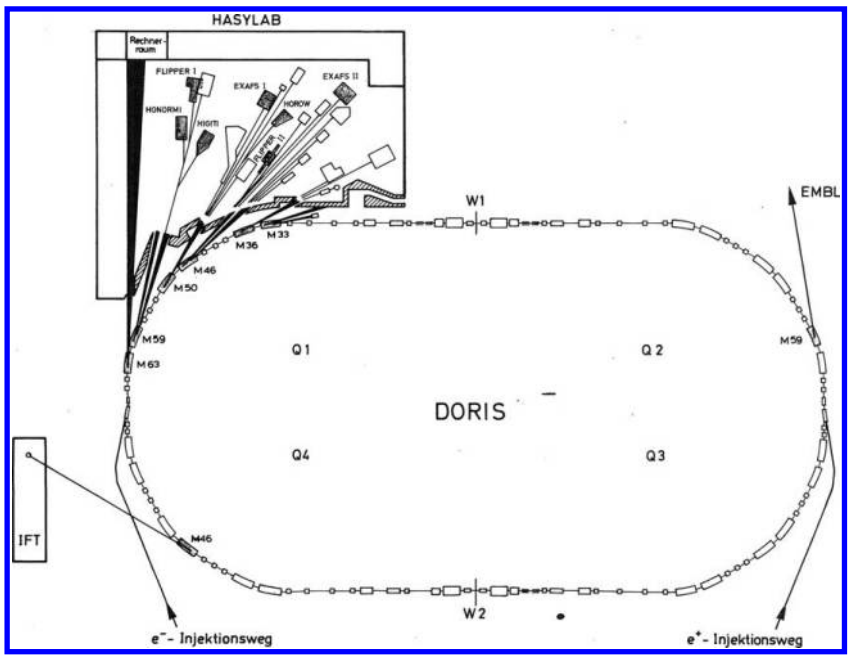

FIG. 1. HASYLAB–DORIS, floorplan, 1980. *Source*: JB DESY, 1980, p. 92.

In July 1980, the Administrative Council considered two organizational models for HASYLAB. The first model took into account the status quo by adding a new unit to DESY and keeping the budgets of DESY and HASYLAB separate. The second model included an organizational separation from DESY in which HASYLAB would enter into contracts with DESY concerning services and beam time, as well as their prices, and thus was similar to the EMBL contract.[18] After long discussions, the VR established a working group on this issue, indicating that the opinions about how HASYLAB should be organized differed. The funders, particularly the Federal Research Ministry, preferred the first model for two reasons. First, the funders wanted the DIR to sponsor HASYLAB, at least partially, from the annual DESY budget. Second, the Federal Research Ministry had already made a considerable commitment to building a dedicated 750 MeV storage ring hosted by a new laboratory in Berlin (BESSY).[19] Under these circumstances, the Federal Research Ministry

18. Administrative Council, "Vorlage für die Beschlussfassung des Verwaltungsrates am 11 Jul 1980," draft for the VR resolutions, 1–2; Administrative Council, "Protokoll" (ref. 11).

19. The Berliner Elektronen-Speicherring Gesellschaft für Synchrotronstrahlung (BESSY) was founded in March 1979 and became operative in 1981. Despite Cardona et al.'s recommendation

preferred HASYLAB to remain under the organizational umbrella of DESY.[20] The DIR, although it actively resisted any cross-funding from the particle physics budget, also favored the first model because the second model would have substantially changed the established relationship between DESY and F41, resulting in much less coordination and control regarding synchrotron radiation research at DESY. Nevertheless, the DIR considered the second model, in principle, as a possible solution for HASYLAB.[21] Inside HASYLAB, however, there was some controversy regarding the two models because several scientists favored the second model.[22] The working group delivered its report in December 1980, recommending that HASYLAB be organized as a legally dependent entity of DESY until a final decision regarding the European Synchrotron Radiation Facility had been reached.[23] The VR approved the working group's recommendation,[24] and the status quo was maintained, but there was also an option for a more independent organizational future for HASYLAB. Following this decision, HASYLAB's official opening ceremony was held in January 1981.[25]

Even before HASYLAB officially opened, DESY entered into contracts with outside research organizations regarding DORIS. In 1975, DESY had established contractual relations with EMBL; in 1978, the DIR signed a contract with the Fraunhofer Society in Munich, whose Institut für Festkörpertechnologie (Fraunhofer Institute for Solid State Technology, FhG-IFT) was active in X-ray beam lithography, and established an outstation at DORIS the following

for Hamburg (ref. 15), the 750 MeV, dedicated second-generation synchrotron radiation source in the ultraviolet and soft X-ray region was built in West Berlin. In October 1977, it was even considered to run HASYLAB as an outstation of BESSY; 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), BAK 196/34435, III/1.

20. Gerhard Materlik, interview by first author, 29 Apr 2014; Herwig Schopper, interview by first author, 20 Feb 2014. Several leading scientists and administrative staff moved from Hamburg to Berlin when BESSY was built, including Gottfried Mülhaupt, Ernst-Eckhard Koch, and Heinz Berghaus.

21. "Vermerk" (ref. 19), III/3; Materlik, interview (ref. 20); Schopper, interview (ref. 20); Christoph Kunz, interview by first author, 2 May 2014.

22. Materlik, interview (ref. 20).

23. Arbeitsgruppe HASYLAB, "Organisations- und Finanzierungsform von HASYLAB in der Betriebsphase: Empfehlung der vom Verwaltungsrat in seiner Sitzung vom 11 Jul 1980 eingesetzten Arbeitsgruppe," report prepared by HASYLAB Working Group, 1–3.

24. Administrative Council, "Niederschrift über die 51. Sitzung des Verwaltungsrates am 12 Dec 1980," minutes of the 51th meeting of the VR, TOP 9.

25. Wissenschaftlicher Jahresbericht DESY 1981, Scientific Report DESY FY 1981, 83.

year.[26] The two contracts with EMBL and FhG-IFT involved a mutually beneficial exchange. On the one hand, both EMBL and FhG-IFT provided HASYLAB with valuable funds and human resources to build and maintain its synchrotron radiation research program at a time when HASYLAB had limited basic funding and only a few staff members. On the other hand, both EMBL and FhG-IFT had exclusive access to beamlines at a time when there was greater demand than supply for vacuum ultraviolet and soft/hard X-ray spectroscopy. The EMBL outstation had its own proposal selection procedure for (biology-related) synchrotron radiation projects. Therefore, it was independent both of the FBS and the GAfSS, which were responsible for proposal selection at HASYLAB.[27]

HASYLAB was built in 1979–1980, and comprised a new laboratory building (1,000 square meters) in the northwestern area of DORIS, including new instrumentation and additional beamlines, as well as more office space to host scientists and technicians.[28] The building effort was led by Ernst-Eckhard Koch and Christof Kunz from DESY and Bernd Sonntag from the II. Institut für Experimentalphysik at the University of Hamburg.[29] Nine employees were hired from project funds, and four people were borrowed from other DESY divisions, adding up to seventeen HASYLAB employees in the founding years.[30] In 1981, of the twenty-four planned stations, nineteen were fully operational, covering the whole energy spectrum well into the hard X-ray regions. That same year, HASYLAB hosted 189 scientists from forty-five different institutes.[31]

In 1980, the second world energy crisis had some unintended positive consequences for HASYLAB. Because of considerable inflation and budget cuts at all national laboratories in Germany, the Federal Research Ministry determined

26. "Vereinbarung zwischen dem Europäischen Laboratorium für Molekularbiologie EMBL und dem Deutschen Elektronen-Synchrotron DESY," 21 Apr 1975, agreement between EMBL and DESY (Hamburg); DESY, "Kooperationsvereinbarung zwischen der Fraunhofer-Gesellschaft und der Stiftung DESY," collaboration agreement/contract between Fraunhofer Society and DESY (Hamburg, 30 Jan 1978). First contacts between the FhG and DESY were established in July 1977; Board of Directors, "Niederschrift über die Beschlussfassungen des Direktoriums am 21 Jul 1977," minutes of the resolutions by the DIR, TOP 1.

27. Materlik, interview (ref. 20).

28. Wissenschaftlicher Jahresbericht DESY 1978, Scientific Report DESY FY 1978, 108; Wissenschaftlicher Jahresbericht DESY 1979, Scientific Report DESY FY 1979, 118–20, 145.

29. Kunz, *Synchrotronstrahlung bei DESY* (ref. 4), 120.

30. DESY, "DESY Programmbudget 1981/1982: Planperiode 1979–1985," DESY budget 1981/82, 43; these 17 employees were temporary and not equivalent to staff positions—see Table 2 in the Appendix and "Expansion and Dedication of DORIS, 1982–1993" below.

31. See Table 3 in the Appendix.

that it was too expensive to run full-scale particle physics experiments at DESY, and DESY's 1980 budget was cut by 6.5 million DM.[32] One immediate effect was that in March 1980, DORIS temporarily ceased operation for particle physics, which meant that large shares of new beam time became available for the synchrotron radiation users.[33] In 1981, DORIS was run only for synchrotron radiation experiments,[34] which consumed considerably less energy than the particle physics operation and was much cheaper. Using DORIS as a dedicated storage ring for synchrotron radiation experiments had been a long-time dream of synchrotron radiation scientists, at least since the Cardona Report in 1977. Therefore, the new situation led to a lively discussion about the future of DORIS, a debate dominated by the energy crisis and the need to reduce electricity costs.[35]

A first result of that debate was that Klaus Wille, a DESY accelerator physicist, proposed reducing power consumption by making some technical adjustments to the DORIS ring.[36] The estimated costs of making these adjustments, at 2.0 million DM, were expected to be redeemed by energy savings within two or three years.[37] Following this proposal, in November 1981, DORIS was shut down and transformed into DORIS II within six months. When DORIS II became operational in June 1982, it was advertised as one of the most brilliant X-ray sources in Europe.[38] A second result was that the DIR decided to allocate a third of the total beam time at DORIS to the synchrotron radiation user community.[39] However, this decision did not come

32. Board of Directors, "Bericht des Direktoriums über den Fortgang der Arbeit bei DESY Nov 1979 bis May 1980," report of the DIR about the period from Nov 1979 to May 1980, 9.

33. In 1980, 42.5 percent of DORIS's beam time was allocated to synchrotron radiation research. This high share was available also because PIA had become operative and released DORIS from its function as injector for PETRA. Wissenschaftlicher Jahresbericht DESY 1980, Scientific Report DESY FY 1980, 121–25.

34. Board of Directors, "Bericht des Direktoriums über die Zeit vom Nov 1980–May 1981," report of the DIR about the period from Nov 1980 to May 1981, 1; Board of Directors, "Bericht des Direktoriums über die Zeit vom Dec 1981–May 1982," report of the DIR about the period from Dec 1981 to May 1982, 9; WJB DESY 1981 (ref. 25), XII; see Table 3 in the Appendix.

35. Lohrmann and Söding, *Von schnellen Teilchen* (ref. 4), 82.

36. H. Nesemann, J. Susta, F. Wettstein, and K. Wille, "DORIS II, an e+e- storage ring with mini beta sections," 7–11 Jul 1980, in *11th International Conference on High-Energy Accelerators* (Geneva, Switzerland), 315–19.

37. Board of Directors, "Bericht Dec 1981–May 1982" (ref. 34), 10.

38. WJB DESY 1981 (ref. 25), 113; Wissenschaftlicher Jahresbericht DESY 1982, Scientific Report DESY FY 1982, 6.

39. Board of Directors, "Bericht Nov 1980–May 1981" (ref. 34), 11.

out of the blue; it was informed by the recommendation of the Brix commission in 1977[40] and influenced by Erich Lohrmann, who was research director at DESY at that time and had been a long-time supporter of synchrotron radiation research.[41] Lohrmann recalled, "I had made a wise decision, because I was declared as the enemy by both communities."[42]

To summarize, by 1981, the double-ring concept of DORIS had been abandoned in favor of a single-ring operation, two major synchrotron radiation users (EMBL and FhG-IFT) had established their outstations, a third of DORIS II's beam time had been allocated to synchrotron radiation users, and HASYLAB had opened its doors, with many more experimental stations than ever before. Even though the DIR had not followed Cardona et al.'s recommendation to fully dedicate DORIS to synchrotron radiation and instead given its highest priority to PETRA, the synchrotron radiation community had gained substantial ground. In terms of the categories of *historical institutionalism*,[43] the founding of HASYLAB and the two new outstations from EMBL and FhG-IFT are important elements in the *layering of new organizational units for synchrotron radiation research*. It is noteworthy that both *internal* (HASYLAB) and *external* (EMBL, FhG-IFT) *organizational layering* took place at DESY. In comparison to EMBL and FhG-IFT, HASYLAB as a DESY unit was clearly more dependent on the DIR in terms of both administration and research programming. In comparison to the Stanford Synchrotron Radiation Laboratory (SSRL) at SLAC, an independent laboratory at Stanford University in the 1970s and 1980s,[44] synchrotron radiation research at DESY appeared more fragmented, particularly along disciplinary boundaries: HASYLAB had a research focus on solid-state physics, EMBL on molecular and structural biology, and FhG-IFT on materials science and engineering. Both the fragmentation of synchrotron radiation and HASYLAB's role as a dependent laboratory meant that in the early 1980s, synchrotron radiation research, from

40. DESY's EWissR 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. The Brix commission submitted its report in June 1977; Scientific Council, "Niederschrift der 47. Geschäftssitzung des Wissenschaftlichen Rates am 12 Dec 1977," minutes of the 47th meeting of the WissR.

41. Kunz, *Synchrotronstrahlung bei DESY* (ref. 4), 52.

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

43. Mahoney and Thelen, "Theory of Gradual Institutional Change" (ref. 2); Streeck and Thelen, *Beyond Continuity* (ref. 2); Heinze and Münch, "Institutionelle Erneuerung" (ref. 2).

44. Olof Hallonsten, "The Parasites: Synchrotron Radiation at SLAC, 1972–1992," *HSNS* 45, no. 1 (2015).

an organizational point of view, was relatively weak despite its considerable expansion of research activities.

EXPANSION AND DEDICATION OF DORIS, 1982–1993

Shortly after HASYLAB was founded, DESY entered a ten-year tug-of-war with the Federal Research Ministry about the fifty-five new positions promised for HASYLAB.[45] In 1980, the Federal Research Ministry had allocated eight temporary new positions to DESY, three of which were positions for scientists and five for support staff. However, one year later, as mentioned above, it cut DESY's annual budget by 6.5 million DM, a much larger amount than the new positions cost. Between 1980 and 1984, the DIR regularly reminded the funders that too few positions had been allocated and that HASYLAB was operating at a suboptimal level. Therefore, in September 1981, Volker Soergel, the new DESY director (until 1993) urged Günther Lehr, the representative for the Federal Research Ministry and chairman of the VR (1972–82), to allocate the positions promised in 1977, otherwise HASYLAB's operations would be in jeopardy: "I would like to sincerely ask you to commit yourself to grant project funds for HASYLAB from 1982 onward without the declared obligation and for further granting of new personnel positions in the framework of future fiscal plans of DESY. A disapproval of these grants and positions would put the operation of HASYLAB seriously into question."[46] In December 1981, the head of the WissR, Klaus Lübelsmeyer, professor at the University of Aachen, sent a letter to Lehr with the same argument and tone of urgency.[47]

The shortage of positions for HASYLAB led to a situation that the DIR had anticipated several years in advance: to save HASYLAB's operations, the DIR had to allocate positions from DESY's particle physics program to HASYLAB. At the same time, there were plans on behalf of HASYLAB scientists to substantially extend the laboratory after all of the new buildings were finished.[48] The pressure on the DIR was high because both the number of external institutes and number of external synchrotron radiation users had doubled by

45. Lohrmann and Söding, *Von schnellen Teilchen* (ref. 4), 230.

46. Volker Soergel to Günther Lehr, letter 30 Sep 1981, 4. The DIR complained about too few positions for HASYLAB in its biennial reports and the annual budgets as well. Board of Directors, "Bericht" (ref. 32), 14; Wirtschaftsplan DESY 1984, Budget Plan DESY FY 1984, 33.

47. Klaus Lübelsmeyer to Günther Lehr, letter 1 Dec 1981.

48. Jahresbericht HASYLAB 1982, Annual Report HASYLAB FY 1982, 7–14.

1983 compared to 1981, when HASYLAB opened.[49] In June 1983, Josef Rembser, the representative for the Federal Research Ministry, was under the impression that "DESY does not make sufficient provisions for the optimal realization of HASYLAB's possibilities."[50] Following the discussion in the VR, the WissR requested that the DIR set up a working group to make suggestions for the improved and extended use of DORIS II for synchrotron radiation experiments.[51] In November 1983, the working group concluded that HASYLAB needed fifty-eight positions and that the synchrotron laboratory should be substantially extended in 1984–85 to host more synchrotron radiation users and to install so-called wigglers that would yield higher quality synchrotron radiation from electron beams.[52]

Wigglers are an alternative method of producing synchrotron radiation by inserting arrays of magnets in the straight sections of the accelerators, which significantly improve the brilliance of the radiation produced. Wigglers had already been proposed as a technical concept in the early 1970s but were not tried until the late 1970s, at SLAC, where the first wiggler was proposed, designed, implemented, and used in direct response to their "X-ray drought." As it turned out, not only was the use of wigglers harmless to the experimental particle physics program on the Stanford Positron-Electron Accelerator Ring (SPEAR) accelerator, they actually improved it by compressing the accelerator bunch, which increased luminosity.[53] Wiggler technology and the subsequent innovation known as the "undulator" were key pieces in the vast technological improvement in the 1980s and 1990s of accelerator systems used for producing synchrotron radiation. They boosted the general scientific performance of synchrotron radiation facilities and led to wide expansions in areas of use, as well as to further optimization of experimental and measurement technologies that made synchrotron radiation a cutting-edge tool for several specializations in the life sciences and materials science.

49. See Table 3 in the Appendix.

50. Scientific Council, "Niederschrift der 68. Sitzung des Wissenschaftlichen Rates von DESY am 14 Jun 1983," minutes of the 68th meeting of the Scientific Council.

51. Scientific Council, "Niederschrift" (ref. 50), TOP VII; Wissenschaftlicher Jahresbericht DESY 1983, Scientific Report DESY FY 1983, 165.

52. Working Group, "Bericht einer ad hoc Arbeitsgruppe zur verbesserten und erweiterten Nutzung des Speicherrings DORIS für Experimente mit Synchrotronstrahlung," report prepared by an ad-hoc working group on the improved and extended use of DORIS for experiments with synchrotron radiation, 29 Nov 1983, 7–10.

53. Hallonsten, "Parasites" (ref. 44).

In January 1984, the DIR agreed with the conclusions of the working group and added that further extension of HASYLAB would not be possible if the promised positions were not allocated soon: "The most important point—an improved staff situation at HASYLAB—is a condition for the realization of those plans and shall now be implemented through the allocation of new personnel positions in the next three years. To the extent that the personnel problem is solved, the establishment [of HASYLAB] can be continued and the support to experimenters can also gradually be improved."[54] The DIR also stated that it would not be prepared to allocate positions from the general DESY (particle physics) program to HASYLAB: "Without additional staff, DESY does not see itself in the position to implement the extension of synchrotron radiation experiments and to operate them. . . . In the face of the very tense staff situation, positions for it from other DESY divisions are not available."[55] In addition, the WissR and VR approved the working group's conclusions, and HASYLAB was allowed to embark on a considerable upgrade between 1985 and 1988.[56] DORIS's first wiggler was already installed in 1984,[57] and according to DESY's annual scientific report in 1985, the wiggler beam met all expectations and had already produced interesting scientific results.[58] In 1986, a second wiggler was installed for the soft X-ray region, and in 1987, a third wiggler for the hard X-ray region was installed in a separate building and successfully tested.[59] In 1988, the upgrade was finished at a cost of 18.3 million DM, surpassing the initial HASYLAB investment.[60] In the same

54. Wissenschaftlicher Jahresbericht DESY 1984, Scientific Report DESY FY 1984, 135.

55. Board of Directors, "Stellungnahme und Schlussfolgerungen des Direktoriums zur Verbesserung und erweiterten Nutzung von DORIS für Experimente mit der Synchrotronstrahlung," position paper on the improvement and the extended use of DORIS for experiments with synchrotron radiation, prepared by the DIR, 5 Jan 1984, 2.

56. Scientific Council, "Niederschrift der 71. Sitzung des Wissenschaftlichen Rates von DESY am 12 Mar 1984," minutes of the 71st meeting of the Scientific Council, TOP 7; Administrative Council, "Niederschrift über die 58. Sitzung des Verwaltungsrates am 10 Jan 1984," minutes of the 58th meeting of the VR, TOP 6; WJB DESY 1984 (ref. 54), 135.

57. WJB DESY 1984 (ref. 54), 137; Jahresbericht HASYLAB 1984, Annual Report HASYLAB FY 1984, 3.

58. Wissenschaftlicher Jahresbericht DESY 1985, Scientific Report DESY FY 1985, 10.

59. Wissenschaftlicher Jahresbericht DESY 1986, Scientific Report DESY FY 1986, 10, 32, 127; Wissenschaftlicher Jahresbericht DESY 1987, Scientific Report DESY FY 1987, 36–37; Board of Directors, "Bericht des Direktoriums über die Zeit vom Nov 1987 bis May 1988," report prepared by the DIR about the period from Nov 1987 to May 1988, 5.

60. Wissenschaftlicher Jahresbericht DESY 1988, Scientific Report DESY FY 1988, 33; see Table 1 in the Appendix.

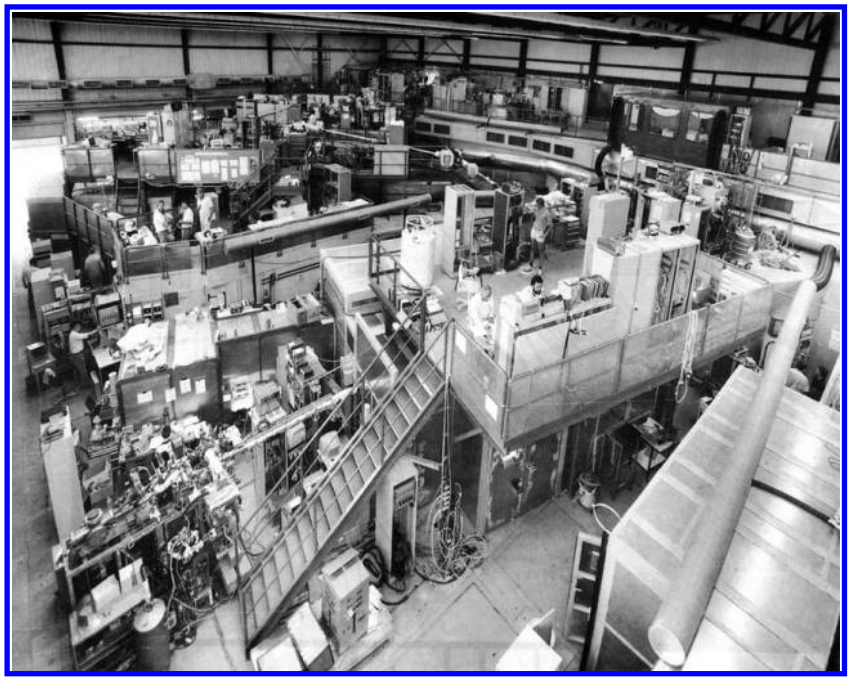

FIG. 2. HASYLAB Experimental Hall, 1988. *Source*: JB HASYLAB, 1988, p. 9.

year, the number of synchrotron radiation users reached 750 scientists from 115 institutes.[61]

Despite the technical upgrades and new infrastructure at HASYLAB, all of which can be regarded as *instrumentation and infrastructure layering* for synchrotron radiation research, new positions came only gradually; six new positions were allocated to HASYLAB in 1985, and again in 1986. Therefore, HASYLAB staff increased from seventeen to twenty-three, and from twenty-three to twenty-nine, but it took another two years until HASYLAB's staff was what had been promised in the late 1970s, from twenty-nine to forty-eight positions in 1987, and to fifty-five staff positions in 1988.[62] However, many of these positions could be allocated to the synchrotron radiation program only because the funders took positions from the DESY particle physics program. That the funders sponsored HASYLAB's growth by using the particle physics program is demonstrated by the fact that Josef Rembser, the representative for the Federal Research Ministry in the VR, asked DESY in January 1984 to

61. See Table 3 in the Appendix.
62. See Table 2 in the Appendix.

permanently allocate the nine positions temporarily borrowed from DESY's particle physics program in 1980 to HASYLAB.[63] Therefore, we observe a *displacement process in the organizational structure* over several years. Hence, in 1986, the DIR complained that, until the mid-1980s, forty staff positions had been moved from the particle physics program to the synchrotron radiation program.[64] However, the number seems to be closer to thirty based on the annual fiscal plans from 1979 to 1987; the number of nonscientific positions at DESY (excluding HASYLAB) declined from 830 to 778, and the number of scientific positions fell from 205 to 196. Including HASYLAB, the numbers stood at 799 nonscientific positions and 204 scientific positions. Therefore, twenty-nine out of forty-eight HASYLAB positions (nonscientific and scientific) had effectively been created by shrinking the particle physics program. The fact that the synchrotron radiation program was sponsored considerably by DESY's particle physics program shows that the lack of additional resources led to *displacement*—a change process that is more prone to conflict and typically takes longer than *layering*.[65]

In November 1984, the same working group that had proposed a substantial upgrade of HASYLAB issued a second report on HASYLAB's future, particularly with regard to the foreseeable discontinuation of the particle physics program at DORIS.[66] In this report, a new Wiggler Light Machine (Wiggler Licht Maschine, WILMA) was proposed based on a study by Werner Brefeld and Peter Gürtler. WILMA was meant to be installed in the DORIS tunnel but with many more straight sections for wigglers and undulators than DORIS II.[67] However, this machine was never built because it was proposed at a time when DESY had already started building its new particle physics machine, the

63. Administrative Council, "Niederschrift über die 58. Sitzung des Verwaltungsrates am 10 Jan 1984," minutes of the 58th meeting of the VR, TOP 6.

64. Board of Directors, "Bericht des Direktoriums über die Zeit von Jun bis Oct 1986," report prepared by the DIR about the period from Jun 1986 to Oct 1986, 9.

65. Wilson, Duncan, *Reconfiguring Biological Sciences in the Late Twentieth Century: A Study of the University of Manchester* (Manchester: University of Manchester, 2008).

66. Working Group, "Bericht einer ad-hoc Arbeitsgruppe zur verbesserten und erweiterten Nutzung des Speicherrings DORIS für Experimente mit Synchrotronstrahlung," report prepared by an ad hoc working group on the improved and extended use of DORIS for experiments with synchrotron radiation (Part 2), 1 Nov 1984.

67. Werner Brefeld and Peter Gürtler, "Vorstudie für einen Speicherring für Synchrotronstrahlung WILMA (Wiggler-Licht-Maschine)," pre-study of a storage ring for synchrotron radiation WILMA (wiggler-light-machine), Techn. Notiz HASYLAB/F41 84–02 (Hamburg, 1984), 2–4.

large hadron electron ring accelerator (Hadron-Elektron-Ringanlage, HERA).[68] Similar to the situation in the mid-1970s when PETRA was the top priority of DESY leadership, HERA absorbed all available resources and staff, particularly accelerator scientists. Therefore, new projects in the synchrotron radiation program that would go beyond the ongoing extension of HASYLAB could not be started. In the words of DESY's annual report: "The approval of the HERA project in April 1984 naturally had a considerable impact on the operation and development programs of all existing accelerators and storage rings at DESY, as well as on the organization of the laboratory as a whole. . . . Scientists from the accelerator division were deployed not only for tasks at the HERA electron ring but also for solving problems of proton acceleration and were therefore no longer available for physical measurement programs at accelerators or the support of the ongoing operations of PETRA and DORIS."[69]

The new HERA project also meant that DESY would not submit a proposal to become the host of the ESRF, despite the logic of making such a bid, the strong position of DESY in synchrotron radiation in Europe, and the likelihood that Germany would be one of the major contributors of funding to ESRF. Since 1979, the FBS repeatedly recommended Hamburg as a location for a European synchrotron radiation source.[70] However, in 1982, in a meeting of the FBS, DESY director Volker Soergel (1982–93) made clear that "DESY . . . will not submit a [ESRF] proposal for Hamburg."[71] Also, during a discussion about the dedicated use of DORIS for synchrotron radiation, Soergel stated that "the interest of high-energy physics in experiments at DORIS will continue to exist unchanged in the foreseeable future and that a more detailed discussion of this point would be premature."[72] In the same

68. WJB DESY 1984 (ref. 54), 7, 32, 159.

69. WJB DESY 1984 (ref. 54), 173.

70. Research Council Synchrotron Radiation, "Protokoll der 3. Sitzung des Forschungsbeirats Synchrotronstrahlung vom 8 Oct 1979," minutes of the 3rd meeting of the FBS, TOP 8; "Protokoll der 5. Sitzung des Forschungsbeirats Synchrotronstrahlung vom 27 Jun 1980," minutes of the 5th meeting of the FBS, TOP 5; "Protokoll der 6. Sitzung des Forschungsbeirats Synchrotronstrahlung vom 8 Oct 1980," minutes of the 6th meeting of the FBS, TOP 4.

71. Research Council Synchrotron Radiation, "Protokoll der 12. Sitzung des Forschungsbeirats Synchrotronstrahlung am 24 May 1982," minutes of the 12th meeting of the FBS, 4; for further reading on ESRF and its history: Olof Hallonsten, "The Politics of European Collaboration in Big Science," in *The Global Politics of Science and Technology*, Vol. 2, ed. Maximilian Mayer, Mariana Carpes, and Ruth Knoblich (Heidelberg: Springer, 2014), 38–39.

72. Research Council Synchrotron Radiation, "Protokoll der 19. Sitzung des Forschungsbeirats Synchrotronstrahlung am 17 Sep 1984," minutes of the 19th meeting of the FBS, TOP 2.

meeting, Soergel added that "further experiments are planned for the next three years with the detectors ARGUS and CRYSTAL BALL in the t-resonance spectrum. New proposals are expected in the near future. Therefore, it is not possible at this moment to specify a fixed date for the termination of high-energy experiments at DORIS."[73] Similar to the situation in the early 1970s, DESY pursued its long-term scientific agenda in which synchrotron radiation was still a peripheral activity. Soergel, like his predecessor Schopper, had shaped this long-term agenda as a member of the WissR from 1964 to 1967 and later as its deputy chairman (1974–75) and chairman (1976–80), before he became DESY's director in 1981.[74] Therefore, in the early 1980s, the DIR did not consider that DESY's synchrotron radiation program could be on par with its particle physics program.[75]

In 1985, the DIR signed a contract with the Max Planck Society in Munich and EMBL regarding the establishment of three research groups for structural biology at HASYLAB under the leadership of Hans-Dieter Bartunik, Eckhard Mandelkow, and Ada Yonath.[76] These life science groups eventually became world leaders in their respective fields. Ada Yonath, an Israeli crystallographer who continued working at HASYLAB until 2004, received the 2009 Nobel Prize in Chemistry for her work on ribosomes using synchrotron radiation at DESY (and later also at other facilities).[77] In the same year, 1985, the DIR deepened the ties between DESY and the Faculty of Physics at Hamburg University with a formal contract, particularly with regard to supporting doctoral students, the share of facilities, and regular meetings between the

73. Scientific Council, "Protokoll der 99. Sitzung des Wissenschaftlichen Ausschusses am 21 Jun 1983," minutes of the 99th meeting of the Scientific Council, TOP 1.

74. Jahresbericht DESY 1965, Annual Report DESY FY 1965, 1–4; Jahresbericht DESY 1966, Annual Report DESY FY 1966, 1–4; Jahresbericht DESY 1967, Annual Report DESY FY 1967, 1–3; Wissenschaftlicher Jahresbericht DESY 1974, Scientific Report DESY FY 1974, 2; Wissenschaftlicher Jahresbericht DESY 1975, Scientific Report DESY FY 1975, 16; Wissenschaftlicher Jahresbericht DESY 1976, Scientific Report 1976, 16; Wissenschaftlicher Jahresbericht DESY 1977, Scientific Report DESY FY 1977, 16; Wissenschaftlicher Jahresbericht DESY 1978, Scientific Report DESY FY 1978, 14; Wissenschaftlicher Jahresbericht DESY 1979, Scientific Report DESY FY 1979, XVII; WJB DESY 1980 (ref. 33), XVIII.

75. WJB DESY 1987 (ref. 59) 13; Wissenschaftlicher Jahresbericht DESY 2003, Scientific Report DESY FY 2003, 13; Hermann Schunck, interview by first author, 10 Oct 2012.

76. WJB DESY 1985 (ref. 58), 33, 137; Jahresbericht HASYLAB 1985, Annual Report HASYLAB FY 1985, 6.

77. Ada Yonath, "Hibernating Bears, Antibiotics and the Evolving Ribosome," Nobel Lecture in *Angewandte Chemie International Edition* 49, no. 26 (2010): 4340–54; see also Wissenschaftlicher Jahresbericht DESY 2010, Scientific Report DESY FY 2010, 7, 24–25.

president of Hamburg University and the DESY leadership.[78] This contract was considerably extended in 2011, when DESY signed a new partnership with Hamburg University that includes not only physics but also research areas in which DESY and Hamburg University share interests, including biology, materials sciences, physics, and chemistry.[79]

The discussion about HASYLAB's future was fueled again when, in 1986, Gerhard Materlik followed Christof Kunz as HASYLAB director (serving until 1993).[80] In close consultation with Werner Brefeld, HASYLAB's machine scientist, Materlik started discussions about replacing one of DORIS II's long, straight sections with a slightly curved section consisting of several shorter straight sections in which relatively long wigglers and undulators could be inserted. This new technical design, later called DORIS III, would considerably improve beam intensity and beam quality for synchrotron radiation experiments.[81] The FBS issued a strong recommendation: "The FBS attributes priority to the creation of additional measurement stations at the wigglers and undulators and the study of such 'insertion devices'. For that reason, the FBS welcomes the proposal and recommends investigating all options for preferably early implementation."[82] In December 1986, the WissR also endorsed the project.[83] However, it took another two years for the technical details of the

78. DESY, "Vertrag über die Zusammenarbeit zwischen der Universität Hamburg und dem Deutschen Elektronen-Synchrotron DESY," contract between Hamburg University and DESY (Hamburg, 9 Sept 1985).

79. DESY, "Vereinbarung über die Einrichtung von PIER (Partnership for Innovation, Education, and Research) zwischen dem Deutschen Elektronen-Synchrotron, vertreten durch das Direktorium und der Universität Hamburg, vertreten durch den Präsidenten (Hamburg, 8 Feb 2011).

80. Materlik was a former PhD student of Ulrich Bonse. He received his PhD in 1975 on "Interferometric Measurement of the Real Part of the Coherent Forward Scattering Amplitude across the Nickel K-Absorption Edge with Synchrotron Radiation" at the University of Dortmund, WJB DESY 1975 (ref. 74), 169. Then he moved to Cornell as a post-doctoral researcher where he was involved in building up a synchrotron radiation source, which would later become the Cornell High Energy Synchrotron Source. In 1978, he joined the synchrotron radiation team at DESY but returned to the United States for extensive research stays, including Bell Labs in 1979 and SSRL from 1993 to 1994. In 2001, he accepted the position of Chief Executive Officer of the Diamond Light Source. He led its construction in Oxfordshire, UK, to the opening in 2007 and brought it into full user operation until 2013; Materlik, interview (ref. 20).

81. WJB DESY 1985 (ref. 58), 132–33.

82. Research Council Synchrotron Radiation, "Protokoll der 24. Sitzung des Forschungsbeirates Synchrotronstrahlung am 28 May 1986," minutes of the 24th meeting of the FBS 3; see also WJB DESY 1985 (ref. 58), 133.

83. WJB DESY 1985 (ref. 58), 133.

project to be fully worked out,[84] mostly because the new branch would bypass the site of the former Crystal Ball detector, which had ceased operation. If the straight old branch were taken out, the symmetry of the DORIS lattice would be reduced, and it could not be ruled out that this change would negatively influence the operation in a particle physics run. ARGUS, installed in the opposite straight section, was a highly successful installation of the particle physics program and crucial to an important discovery made in 1987, particle/antiparticle transitions with b-mesons.[85] The ARGUS team feared that DORIS III would not be able to deliver stable beams for particle collisions. Consequently, Materlik suggested building the bypass around the existing straight section without dismantling it.[86] However, DESY's leading machine scientist, Gustav-Adolf Voss, in consultation with Werner Brefeld, was confident that a curved section with the same performance as the straight one could be built; therefore, the old straight section of DORIS II was dismantled when the construction started on DORIS III in July 1990.[87] Crystal Ball was dismounted, transferred to SLAC, and never returned to DESY.

In June 1991, the first electrons were being stored at 3.7 GeV, and by December 1992, all new wigglers were installed and tested.[88] The official opening ceremony for DORIS III was held in February 1992.[89] DORIS III had a circumference of 289 meters, allowing the storage of positrons or electrons at an energy level of 5.6 GeV. In general, five bunches were stored, but single-bunch operation was also possible, which allowed for some time-resolved studies. The spectrum of DORIS III radiation ranged from infrared to hard X-rays.[90] Unfortunately, DORIS III created severe instabilities and decreased luminosity for the ARGUS detector, just as feared.[91] The DIR, after consulting with the WissR, decided that the particle physics program should be dismantled at DORIS III if the previously achieved luminosities could not

84. Werner Brefeld, H. Nesemann, and J. Roßbach, "The Bypass Project at DORIS II," DESY Report M-88-04 (Hamburg, 1988).

85. WJB DESY 1987 (ref. 59), 37, 92–101.

86. Materlik, interview (ref. 20).

87. WJB DESY 1988 (ref. 60), 142–43; Wissenschaftlicher Jahresbericht DESY 1990, Scientific Report DESY FY 1990, 115–23, 150–52; Jahresbericht HASYLAB 1990, Annual Report HASYLAB FY 1990, 6.

88. Wissenschaftlicher Jahresbericht DESY 1991, Scientific Report DESY FY 1991, 103–12; Wissenschaftlicher Jahresbericht DESY 1992, Scientific Report DESY FY 1992, 33, 231.

89. WJB DESY 1992 (ref. 88), 91.

90. WJB DESY 1992 (ref. 88), 193.

91. WJB DESY 1992 (ref. 88), 197.

be reproduced.[92] After failed attempts to reproduce the luminosity, the DIR, under the leadership of new director Björn Wiik (1993–99), decided to discontinue the ARGUS experiment at DORIS III.[93] The ARGUS group continued their project at the HERA-B facility,[94] and in June 1993, DORIS III became a dedicated synchrotron radiation source.

The decision to dedicate DORIS III to the synchrotron radiation community was influenced by severe instabilities and decreased luminosity for the ARGUS detector. At about the same time, Jochen Schneider and Gerhard Materlik, two prominent synchrotron scientists at DESY, were offered prestigious professor positions abroad. The DIR responded by offering both the position of Leading Senior Scientist.[95] Two years later, in 1992, Schneider received another job offer from a prestigious university in Switzerland. It seems that the job offers for Materlik and Schneider convinced the DIR that synchrotron radiation research would play a stronger role in DESY's future. In 1993, the DIR decided to discontinue ARGUS and to convert DORIS III into a dedicated synchrotron source.[96]

With regard to the analytical categories of historical institutionalism,[97] DORIS III is an example of *conversion of technical infrastructure* by which an existing particle physics machine, after being used in parallel for particle physics and synchrotron radiation research for many years, is finally switched into a synchrotron radiation source. Because DORIS as a machine remained intact and has only partially been rebuilt, the category of *infrastructure conversion* is most appropriate.[98] It is noteworthy that the conversion of DORIS into a dedicated synchrotron radiation source had already been proposed in the late 1970s, but this proposal finally led to the construction of PIA, a particle physics

92. Scientific Council, "Niederschrift der 100. Sitzung des Wissenschaftlichen Rates von DESY am 23 Apr 1993," minutes of the 100th meeting of the Scientific Council, TOP 6.

93. Wissenschaftlicher Jahresbericht DESY 1993, Scientific Report DESY FY 1993, 29–32.

94. Jochen Schneider, interviews by first author, 25 Apr 2012, 7 May 2014; Lohrmann and Söding, *Von schnellen Teilchen* (ref. 4), 240–41, 273.

95. Materlik, interview (ref. 20).

96. Scientific Council, "Niederschrift der 103. Sitzung des Wissenschaftlichen Rates bei DESY am 15 Mar 1994," minutes of the 103rd meeting of the WissR, TOP 4; Schneider, interviews (ref. 94); Materlik, interview (ref. 20); Albrecht Wagner, interviews by first author, 31 Oct 2012 and 28 Jan 2014.

97. Mahoney and Thelen, "Theory of Gradual Institutional Change" (ref. 2); Streeck and Thelen, *Beyond Continuity* (ref. 2); Heinze and Münch, "Institutionelle Erneuerung" (ref. 2).

98. If DORIS had been completely dismantled and a new machine built instead, this would be equivalent to *infrastructure displacement*.

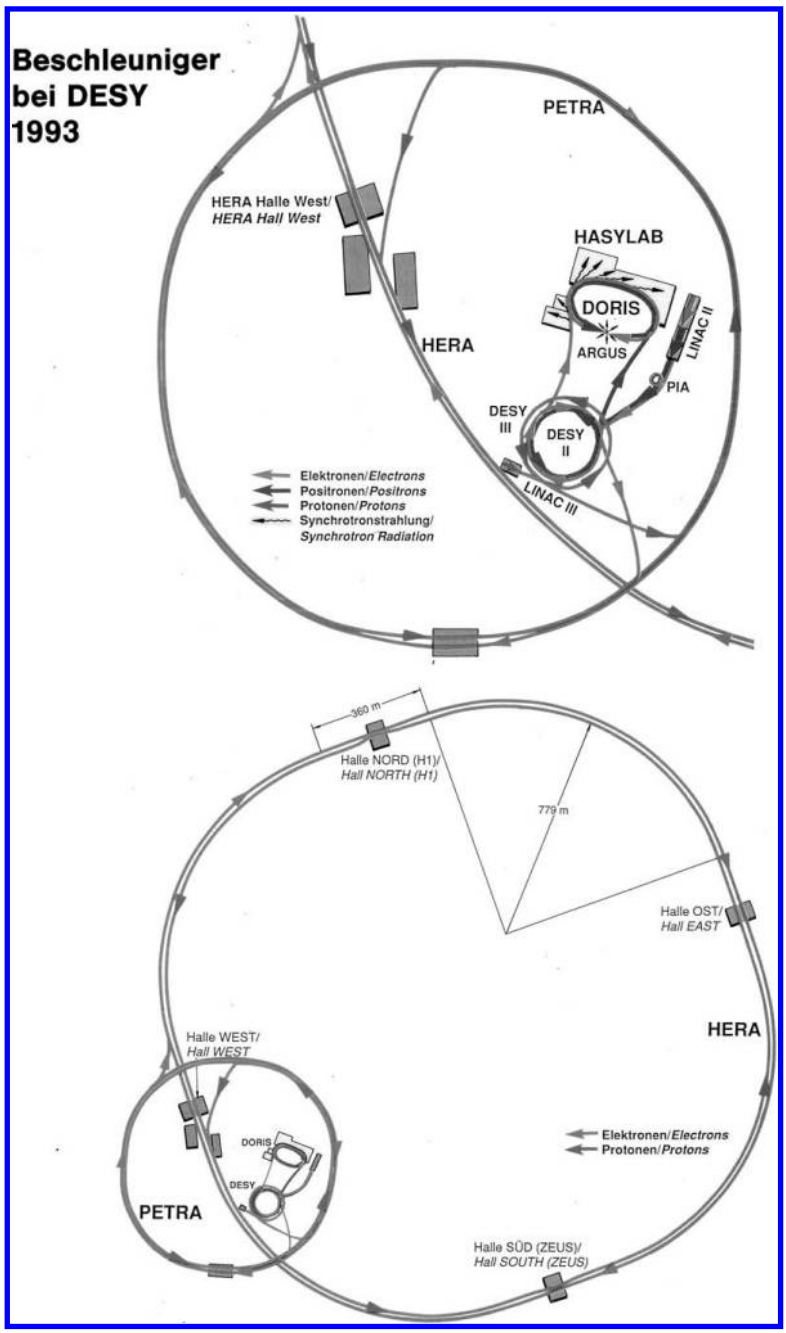

FIG. 3. DESY Accelerators (scheme), 1993. *Source*: JB DESY, 1993, p. 320.

infrastructure that relieved DORIS from being an injector to PETRA, thus improving opportunities for conducting synchrotron radiation experiments at DORIS (as described previously).

With DORIS III being operative, the synchrotron radiation community, after almost thirty years, had emancipated itself from its former parasitic status; it controlled the energy stored in particles at DORIS and all other technical parameters, allowing them to achieve extremely high reliability and brilliance.[99] This new situation attracted many new synchrotron radiation users, in particular from biology and materials science. The reason that HASYLAB could host many new synchrotron radiation users was that it was relatively well equipped with support staff by that time. HASYLAB could provide the maintenance and service that many synchrotron radiation users had been missing during their work in the 1970s and 1980s. When the originally promised fifty-five new positions had been allocated to HASYLAB in 1988 (as noted above), the overall efficiency and user support of the laboratory started to increase considerably. External users could focus more on their research as HASYLAB staff performed service tasks.[100] The increased demand, exemplified by a new record of external users (1,066 scientists from 180 institutes in 1993),[101] called for yet another extension of the HASYLAB buildings.[102] The new buildings opened in 1995, offering 1,800 square meters of additional space.[103] By that time, the number of external synchrotron radiation users had risen to 1,709 scientists from 246 institutes.[104] Hence, the conversion of DORIS into a dedicated synchrotron radiation source in fact strengthened the *layering process* by adding new infrastructure, including buildings, office space, and experimental stations, and new research opportunities for external users provided by this infrastructure.

Before DORIS III was dedicated to HASYLAB, another important decision helped emancipate the synchrotron radiation program from its operation in parasitic mode. After the reunification of Germany in 1990, DESY integrated one of the former GDR Academy institutes, the Institute for High Energy Physics ("Institut für Hochenergiephysik") in Berlin-Zeuthen. Therefore,

99. Materlik, interview (ref. 20).

100. Bernd Sonntag, interview by first author, 11 Oct 2012.

101. See Table 3 in the Appendix.

102. Wirtschaftsplan DESY 1992, Budget Plan DESY FY 1992, 108; Wissenschaftlicher Jahresbericht DESY 1994, Scientific Report DESY FY 1994, 234; see also Table 1 in the Appendix.

103. Wissenschaftlicher Jahresbericht DESY 1995, Scientific Report DESY FY 1995, 237.

104. See Table 3 in the Appendix.

since January 1992, DESY has had an outpost in Zeuthen,[105] and DESY's statutes had to be adapted to the new situation. Although the Zeuthen institute conducted predominantly particle physics research, the organizational change provided the funders with the opportunity to include the synchrotron radiation program in the statutes.[106] Thus, parasitic mode was also formally abolished. Including synchrotron radiation as a formal organizational goal at DESY can be regarded as yet another element of *organizational layering*.

In 1993, sixteen years after its establishment and twelve years after its official opening, HASYLAB could look back on a series of important improvements: It was well equipped with support staff; an outstation for the Max Planck Society had opened; DORIS had successfully been transformed into a fully dedicated synchrotron radiation machine; and the synchrotron radiation program had been integrated into DESY's statutes. Also, in 1993, Jochen Schneider followed Gerhard Materlik as HASYLAB director, and Björn Wiik followed Volker Soergel as DESY director. Both Schneider and Materlik became leading figures in the final transformation of DESY into a dedicated synchrotron radiation laboratory in the 2000s.

DISCUSSION AND CONCLUSION[107]

We have shown how a laboratory once founded as a resource for particle physics managed to shift priorities considerably toward synchrotron radiation research. Therefore, although the single-mission status of laboratories like DESY carries enormous institutional weight, scientific development eventually turned the tables. In the early 1990s, Schneider, Wiik, and Materlik forged a partnership between the particle physics program and the synchrotron radiation program that culminated in the TeV-Energy Superconducting Linear Accelerator (known as TESLA) proposal, and eventually in the building of the XFEL. By the late 2000s, all of DESY's large machines were dedicated to photon science. DORIS III was operated until 2012, a highly reliable and popular machine in the synchrotron radiation community, as indicated by its

105. WJB DESY 1991 (ref. 88), 10–12.

106. Administrative Council, "Niederschrift über die 74. Sitzung des Verwaltungsrates am 13 Jun 1991," minutes of the 74th meeting of the VR, TOP 6.

107. The conclusion covers the first 30 years of synchrotron radiation research at DESY, 1962–93, including Heinze et al., "From periphery to center, Part I" (ref. 1).

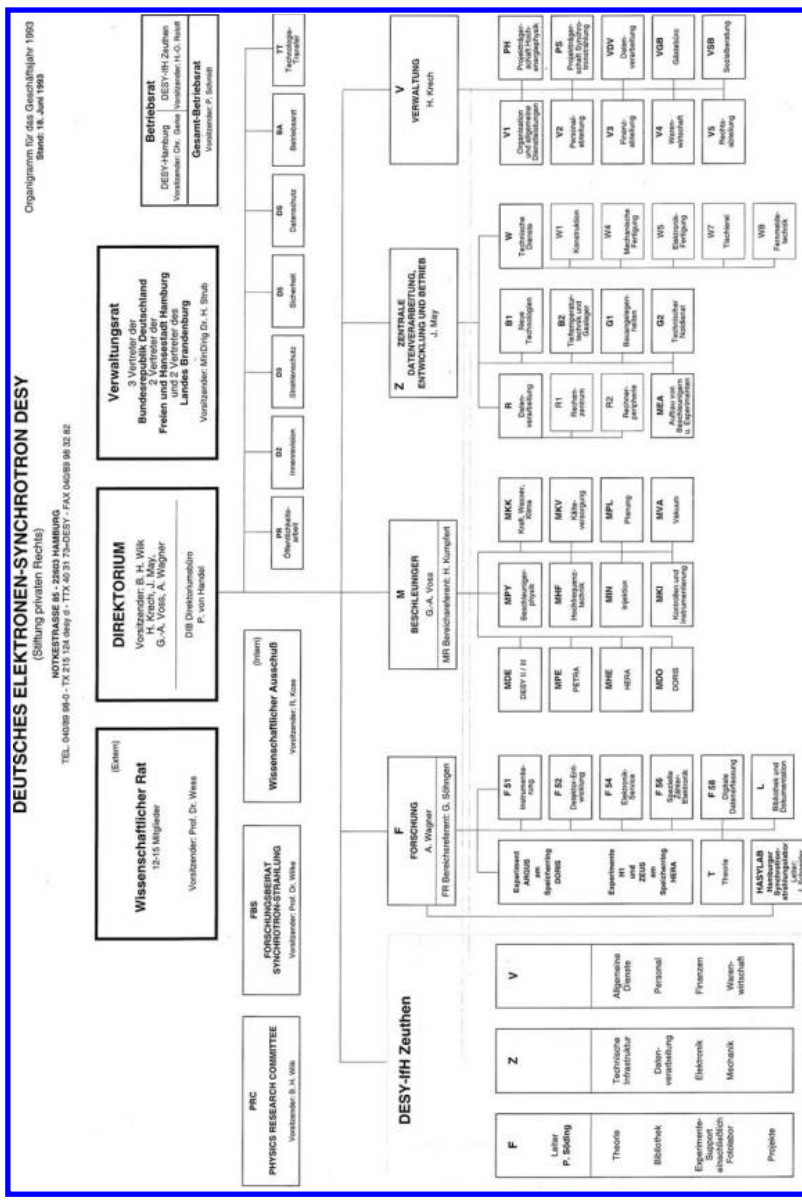

FIG. 4. Organizational Chart, DESY, 1993. *Source*: JB DESY, 1993, p. 10.

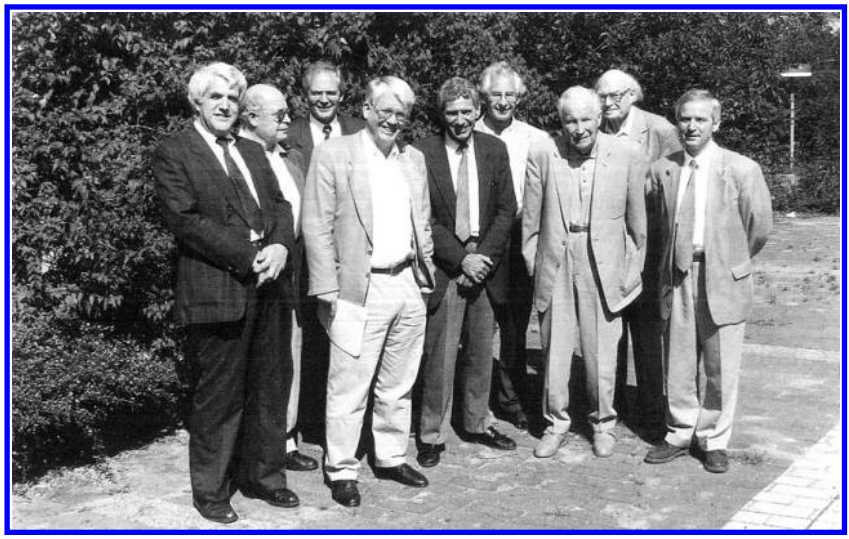

FIG. 5. Celebrating 30 Years of Synchrotron Radiation at DESY, 1993. From left to right: Ruprecht Haensel, Peter Stähelin, Jochen Schneider, Björn Wiik, Kenneth Holmes, Christoph Kunz, Wolfgang Jentschke, Heinz Berghaus, and Gerd Materlik. *Source*: JB DESY, 1994, p. 6.

substantial oversubscription.[108] In 2004, the VUV-FEL user facility opened (since 2006, under the name FLASH), providing a highly brilliant photon beam between 6 and 120 nm.[109] In 2009, PETRA III opened, and regular operations started in spring 2010.[110] Today, DESY operates two major photon science machines but no particle physics machines, and its future photon science machine, the XFEL, is under construction by an international consortium. In organizational terms, DESY runs a fully fledged research division for synchrotron radiation research, on par with the particle physics research division, as displayed in DESY's organization chart.[111]

The history of synchrotron radiation at DESY demonstrates how many incremental yet interconnected steps cumulated in the overall renewal of a large national laboratory's research program. These micro-level events constitute more than the material for the narrative about how and when DESY shifted

108. Wissenschaftlicher Jahresbericht DESY 2006, Scientific Report DESY FY 2006, 9.

109. Wissenschaftlicher Jahresbericht DESY 2004, Scientific Report DESY FY 2004, 8, 125, 130; Wissenschaftlicher Jahresbericht DESY 2005, Scientific Report DESY FY 2005, 8.

110. Wissenschaftlicher Jahresbericht DESY 2009, Scientific Report DESY FY 2009, 7; WJB DESY 2010 (ref. 77), 28.

111. WJB DESY 2005 (ref. 109), 30.

its mission toward photon science. 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 (observation bunker, HASYLAB building), new research fields (biology, chemistry, materials sciences), and new organizational units (F41, HASYLAB, EMBL outstation, FhG-IFT outstation, MPG outstation) were added on top of existing units invested in particle physics. These new elements were incorporated at DESY without excessively challenging existing commitments in particle physics. Sometimes, these events resulted directly in new layers of infrastructure, research activities, and organizational units, but sometimes—as becomes obvious when considering a long-term perspective—these events initiated changes that led to the *conversion of technical infrastructure* (DORIS III) and to the *displacement of existing by new research fields* (particle physics displaced by solid-state physics, biology, materials sciences, and chemistry). The full scale of *conversion*, *displacement*, and *dismantling* becomes visible when viewed from today: HERA, DESY's largest accelerator, was dismantled as a technical infrastructure in 2007; in-house, accelerator-based particle physics research was dismantled at DESY with the shut-down of HERA in 2007; and PETRA III was opened as a fully converted photon science facility in 2009.

Analyzing micro-events with the help of categories developed by *historical institutionalism* advances our understanding (and appreciation) of DESY's transformation as a story of *cumulative gradualism* in at least two ways. First, there is no evidence of external shocks or internal disruptions that suddenly altered DESY's infrastructure, research fields, or formal structure between 1962 and 1993. Therefore, in line with *historical institutionalism*, DESY's history of synchrotron radiation is not a story of transformative change initiated or explained by a series of discontinuous events. Second, DESY's transformation contains more than an array of complex micro-events and actor-constellations that somehow interacted with and influenced each other. Rather, this article argues that significant events in DESY's history of synchrotron radiation are elements in meso-level processes that contribute to larger trends in science history.

Therefore, 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. From a methodological point of view, the process perspective of this article invites comparisons with other laboratories. Such comparisons would help in validating the theoretical claim of *historical institutionalism* that macro-level changes indeed result from a combination of several meso-level processes that operate across particular cases.[112] The decreasing dominance of high-energy physics in national and international science budgets and the concurrent rise of life sciences and materials sciences constitute a macro-level transformation in science and technology in the late twentieth century. Synchrotron radiation took a lead 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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112. For example, see Hallonsten and Heinze, "From Particle Physics" (ref. 2).

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

Source: 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.