



Knowledge and Innovation for Society

Impact analysis of the research light sources
PETRA III and PETRA IV

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PETRA III and PETRA IV

PETRA III went into operation at DESY in 2010; at the time, it was the world's most powerful X-ray source. Since then, it has been generating unique scientific findings and furnishing essential data for innovative developments. More than 3,500 researchers carry out their experiments here every year, somewhat more than half of them from Germany. Converting the facility to become PETRA IV will ensure that it continues to meet the ever higher requirements and growing demand for non-destructive nano-scale analyses in the future. Once completed, it will be the

world's most powerful X-ray source and equipped with specialised AI tools, which will allow the data generated to be widely used in science and industry and to be channelled directly into industrial value chains. This upgrade is essential for Germany and Europe as a centre for science and innovation, in order to be internationally competitive in a wide range of technologies. Time is pressing – similar light sources around the world have long since begun to establish this kind of research infrastructure.

X-ray sources create knowledge and provide an innovative edge

In order to quantify the value of the investment into PETRA III, DESY has collated the following impact parameters together with the Fraunhofer Institute for Systems and Innovation Research (ISI). The added value was calculated on the basis of construction costs, key operating parameters and structural effects. This return on investment for PETRA III forms the basis for determining the expected economic impact of PETRA IV.



The DESY campus in Hamburg with the 2.3-kilometre-long accelerator ring PETRA III (blue). Three experimental halls – in the foreground the long sweeping arc of the “Max von Laue” experimental hall – and numerous laboratory buildings used by some 20 interdisciplinary scientific institutions are clustered around the ring.

DESY's X-ray source PETRA III in numbers:

100,000

hours of research operation per year

3,500

researchers per year

1,700

research projects per year



**Up to 5
billion euros**

Complementary effects

Calculations by DESY show that when third-party spending and the structural effects of PETRA III are taken into account (incl. investments by partner institutes, spending by users, setting up the CSSB on campus and launching start-ups), the economic impact of PETRA III **increases sixfold**.

PETRA III: 2010 to 2022 Total economic value added

DESY has had a considerable economic impact with PETRA III as a major employer and through procurement – in the region, in Germany and in Europe – from the time that construction work began in 2007 and after it went into operation in 2010, through to 2022. At the same time, the knowledge gained through PETRA III has triggered numerous innovations, which have been implemented by industry and commerce in the form of products and processes. These calculations are based on a detailed impact study on PETRA III carried out by the **Fraunhofer Institute for Systems and Innovation Research (ISI)** on behalf of DESY (October 2023, doi:10.24406/publica-1929).

815

million euros

were invested by DESY just on building and operating PETRA III.



up to **x3**

**2.25
billion euros**

billion euros of added value have been created by the X-ray source.

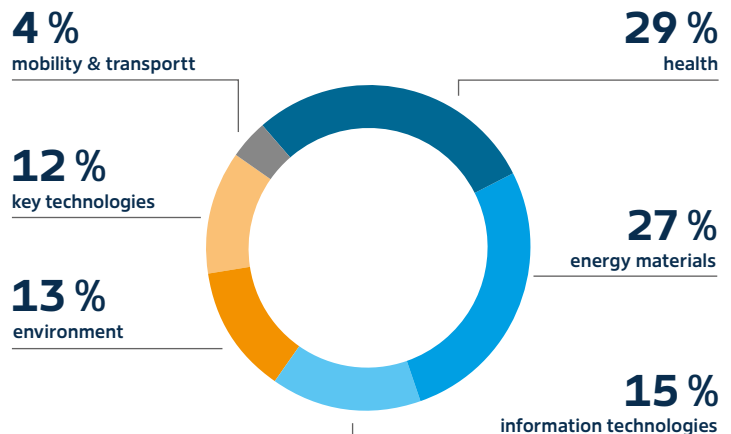


PETRA III: A global magnet for cutting-edge research

The wide variety of research methods available at PETRA III make it a key tool for researchers from a wide range of disciplines seeking tailor-made solutions to the challenges of our time.

The research facility offers experts from all over the world ideal conditions for their research. Young people in particular benefit from the international research environment at DESY in Hamburg, which is centred around PETRA III and offers a large number of unique scientific facilities.

Researchers from all areas of science and technology use PETRA III as a tool for their experiments



13 000
researchers from



60
nations



50 %

Every second publication is the result of global cooperation.

University research

- BMBF research grants (including joint funding) totalling around **120 million euros** have been secured for the instrumentation of the experimental facilities. The aim is to bolster university research, which will be utilised by subsequent researchers.
- PETRA III is an essential research tool for the **Hamburg Clusters of Excellence** "Understanding Written Artefacts" and "CUI: Advanced Imaging of Matter"

Research excellence

Researchers from all areas of science and technology use PETRA III as a tool for their experiments. This has led to excellent work which has been published in leading journals.



Its **participation in top-class research projects** is further proof of its excellence:

In 2021 alone, 59 papers were published by **39 ERC-funded researchers** using PETRA III data.*

5200

papers
published altogether

> 650

publications ranked among the
10 most cited papers worldwide

260

publications
in Science and Nature

Promoting young scientists and networking

- DESY runs no less than **three graduate schools** on campus with different research partners.
- Every year, **120 PhD students** complete their doctoral theses at PETRA III.**
- Once a year, DESY in Hamburg hosts the world's largest user meeting with more than **1,000 participants**.
- More than **30,000 participants** attended workshops or conferences at DESY.
- **30 percent** of the researchers registered with PETRA III are students.

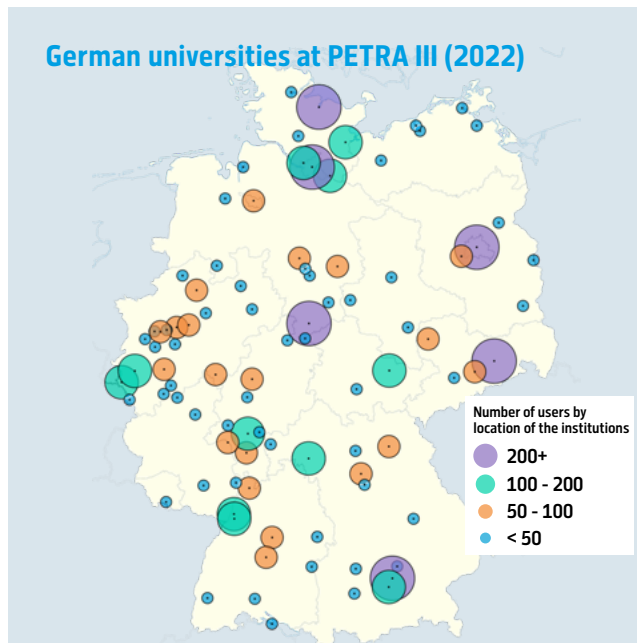
*The European Research Council grants (ERC grants) of up to 3.5 million euros support scientists recognised for their successful research.

** Estimated by the Photon Science Division.

X-ray sources are indispensable for a centre of science and innovation

PETRA III continues to provide important infrastructure for many research disciplines, especially in the natural sciences and engineering. The facility encourages collaboration between universities and research institutions. Around 52 percent of the researchers are from Germany. The high-brilliance radiation ensures that German researchers remain internationally competitive.

German scientific institutions and universities at PETRA III



1870
Scientists from German institutions conducted research on PETRA III (2022).

27 %
of the German **Clusters of Excellence** conducted research at PETRA III.

PETRA III: Research for sustainability

Most of the scientists conducting experiments at PETRA III do so with a view to a better and more sustainable future.

80 %
of PETRA III publications contribute to topics that are directly **relevant to society**

PETRA III's contribution to the UN Sustainable Development Goals



PETRA III: Insights for industrial innovation

251

PETRA III publications
with industry involvement

140

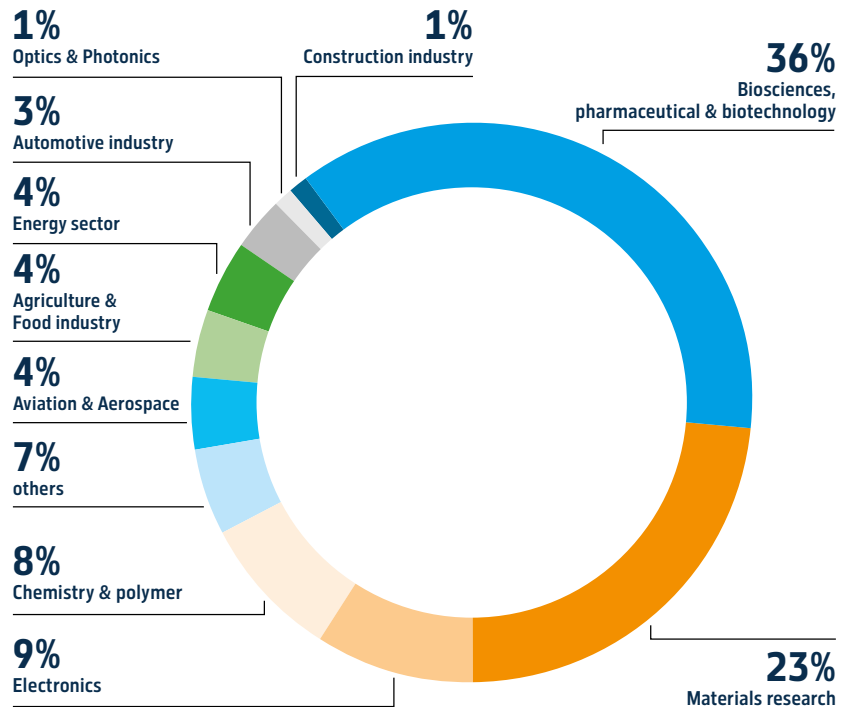
companies
have used PETRA III since 2010

28 %

About a third of these companies
are based in Germany, including
DAX-listed companies and SMEs

110

additional beamtime contracts
with companies that are subject
to a non-disclosure agreement
(2018 – 2022)



PETRA III accelerated research into Covid-19

BioNTech used PETRA III to study how the lipid envelopes for its mRNA vaccines work. The direct benefit of this rapid vaccine development led to 4.7 billion euros in income tax in 2021, which would have been impossible without fundamental research.

Reducing costs through swift insights:

The federal government spent 150 billion euros a year to mitigate the impact of the pandemic. In this context, averting a potential lockdown by rapidly developing a vaccine was of huge economic importance.

PETRA III is supporting the energy transition

Trumpf SE has optimised a resource-efficient commercial laser system for laser welding high-performance electronics used in electromobility applications.

Bosch AG has investigated laser welding technologies for lightweight construction techniques and developed benefits for manufacturing.

Research using PETRA III will ultimately benefit current and future products made by German manufacturers. In order to achieve large-scale and low-cost production, industry needs reliable laser techniques, which can be analysed particularly effectively using X-rays.

X-rays for drug development

Bayer AG has used PETRA III to study a promising cancer drug, which has already been cited in 20 other patent applications.

Companies working in the life sciences use synchrotron radiation sources to determine the structure of proteins at the molecular level and thereby improve or develop new drugs. Studies like this stimulate growth, particularly in the European pharmaceutical industry, which itself employs 840,000 people and 125,000 in research and development.

Developing innovative materials

Bioplastics and spray-coated solar cells:

A material made from cellulose nanofibres, which was developed at PETRA III, could be used as an alternative to plastic in vehicles, furniture or packaging. Even biomedical applications are conceivable since cellulose is biocompatible.

This material can also serve as a substrate for polymer solar cells. The prototype of a solar sun blind has been developed in collaboration with **KTH** in Stockholm and the start-up **CelluXtreme**, co-funded by the Federal Ministry of the Interior and Community (**BMI**).

Culture of innovation: Fuelled by X-rays

DESY has created a fertile environment
for spin-offs and start-ups

350 More than seven percent of all publications based on PETRA III research are cited in patents or patent applications.

152 DESY holds **152 current (know-how) licences**, 91 of them with industry and 61 with scientific players.

17 Start-ups are located on the DESY campus.

14 million euros in turnover were generated by the start-ups. They currently provide jobs for **137 employees**. The number continues to rise: in 2021, there were 106 employees.



Examples:

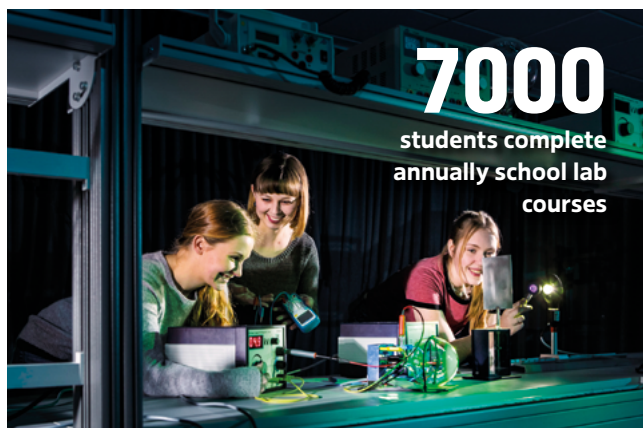
Wired Sense: Designs and manufactures extremely sensitive detectors for use in materials testing and analysis.

Haystack Oncology: Develops personalised tests for cancer diagnostics.

CrystalsFirst: This spin-off from the University of Marburg offers its customers services and solutions for drug development, for which it uses PETRA III.

Training powerhouse

DESY provides extensive educational and training resources. The research centre also offers a wide range of career opportunities and a comprehensive professional development programme, as well as knowledge transfer activities.



PETRA IV.

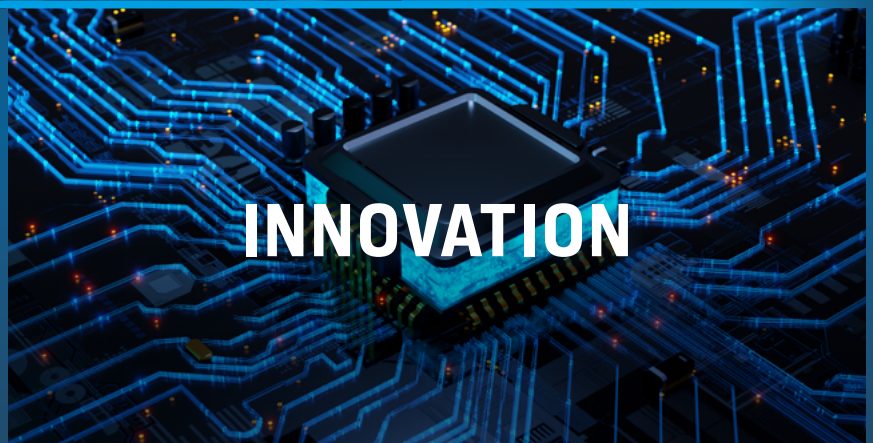
DESY's project to secure Germany's future
as a centre for science and business



INSIGHT

PETRA IV will revolutionise
our view of the molecular world

PETRA IV will accelerate the
development of technologies
that will change the world



INNOVATION



TRANSFORMATION

PETRA IV will open up
research at large facilities
to brilliant ideas everywhere
in the world

PETRA IV: Generating insights and creating value for society, science and business

PETRA IV will ensure technological and process independence as well as sustainable solutions in many areas by enhancing the scientific and technological capabilities and the associated data pool. The advantages of PETRA IV over PETRA III in terms of efficiency presented here have been scaled accordingly.

DESY plans to operate the world's most powerful X-ray source

- The power of PETRA IV will exceed that of PETRA III by a factor of 500 to 1000
- This will make X-ray analyses up to **500 times faster**: analytical problems that are too time-consuming to solve using current technologies can be solved using PETRA IV
- The **image resolution** will improve dramatically, providing insights at the nanoscale with unprecedented precision
- Innovative, high-speed access model and services, including **preparing data for extended user groups** (hospitals, SMEs, etc.)



View of the DESY campus including the planned new large experimental hall (left). The existing accelerator ring PETRA III will be thoroughly modernised.

PETRA IV: Ten-year horizon

Total economic value added

Based on calculations similar to those performed in the study by the **Fraunhofer Institute for Systems and Innovation Research (ISI)** for PETRA III, the investment into PETRA IV will generate additional benefits of more than seven billion euros, even when only considered as a classical piece of research infrastructure.

2.45
billion euros

Construction costs are expected to come to 1.54 billion euros and operating costs for the first ten years to 910 million euros.



7.35
billion euros

added value can be generated by the X-ray source.



More added value as an innovation driver

DESY plans to establish PETRA IV as a driver for data and solutions that serves the scientific community, companies, start-ups and hospitals. In other words, the X-ray source will be more than just a piece of scientific infrastructure: PETRA IV will be a key tool for innovation across all industries.

Taking into account the complementary effects, and especially the transformative character in terms of industry support, data generation and advances in AI, as well as the estimated influence on deep-tech start-ups, the economic footprint could be ten times higher, according to DESY's internal extrapolations. In short, the added value will lie between seven and up to 24 billion euros.

Up to 24
billion euros

PETRA IV will provide high-precision data for innovation and find smart solutions to research questions

The state-of-the-art infrastructure surrounding PETRA IV has been rigorously designed for digitalisation, transfer, and the promotion of ideas and talent. The aim is to drastically accelerate the development of new technologies and materials, also by simplifying access and creating the optimal ecosystem for innovation. As a unique, world-class large facility, PETRA IV will strengthen the technological independence of Germany and Europe. The facility will be open to the international scientific community and attract experts in key technologies.

PETRA IV will create the analytical preconditions for new, urgently needed materials, active compounds and future technologies:

- Secure microelectronics
- Concepts for renewable energy sources
- Personalised medical drugs and treatments
- Resource-efficient chemicals and precursors
- Sustainable industrial processes and consumer products

A flexible access system tailored to the needs of industry and an extensive range of services (including data analysis and interpretation) ensure that enquiries to DESY can be processed quickly and in a solutions-oriented manner. DESY plans to reserve around 20 percent of the beamtime for industry-related projects, adjusting this in line with demand.

Technology development in critical industries

From digitalisation and European security policy to the pharmaceutical industry and pandemic defences: X-ray analysis is a fundamental tool when manufacturing semiconductors and microchips, developing and validating quantum, energy-generating and catalytic materials, as well as developing drugs and medical treatments. PETRA IV will ensure that the results can be directly translated into product developments and process optimisations in critical industries, in Germany and in Europe as a whole.

PETRA IV: Reinforcing technological security in microelectronics

1000 times more powerful X-rays will allow the non-destructive quality control of entire microchips.



PETRA IV technologies will allow the detailed structures of 3D-integrated nanoelectronics to be imaged in their entirety. For the first time in the history of X-ray analysis, it will be possible to image a semiconductor chip in all necessary detail within a matter of days. Today, this would take three years. This will safeguard the quality and integrity of the circuits used in advanced computer and communication technologies.

Advantage for Germany as a business location:

Through the European Chips Act, the EU is aiming to double its current global market share to reach 20 percent by 2030. To achieve this goal, production needs to increase by a factor of four.

Great hopes are being placed in the joint venture between the chip manufacturers Bosch, Infineon, NXP and TSMC, with a volume of up to 10 billion euros. PETRA IV could provide the basis for standardised quality controls of microchips "Made in Europe".

PETRA IV: Stimulating the biotechnology and pharmaceutical industries

Measurements can be carried out 1000 times faster while increasing their sensitivity 25-fold, allowing new drugs to be developed that specifically target the causes of a disease.



Reducing the time needed for experiments – while further automating the measurement and analysis process – could revolutionise the systematic search for new drugs. High-resolution 3D imaging of large tissue samples down to the molecular level will open up entirely new ways of observing and studying diseases such as Alzheimer's or cancer.

Pharmaceutical companies around the world are working to bring mRNA-based cancer vaccines to the market. BioNTech too will expand its research into mRNA technologies at DESY. PETRA IV could offer a decisive advantage by providing high-resolution, high-contrast images for systematic studies.

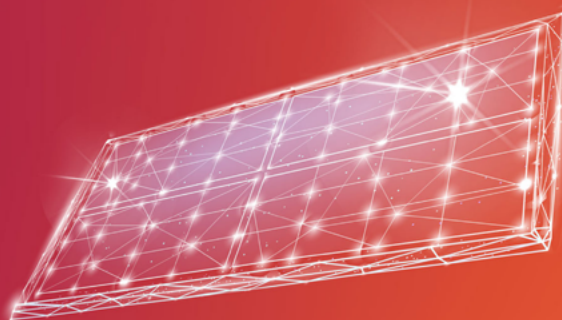
Advantage for Germany as a business location:

The global market for mRNA vaccines is worth around USD 34.7 billion. This volume is expected to exceed USD 68.1 billion by 2030.

The potential of mRNA therapeutics is also reflected by the number of companies investing in this technology: at the moment, around 420 programmes are testing mRNA for more than 120 different diseases, including a large number of cancers and rare diseases.

PETRA IV: Sustainable pathways with new and better materials

Upgrading PETRA III to PETRA IV will make it possible to image different materials in real time, at high resolution and in 3D



New materials and active compounds are vital in order to solve the pressing issues of the future. They need to be more intelligent and far more efficient than today's materials. One vision for the future involves synthesising the function of new materials at a molecular level using AI. PETRA IV can take the decisive step of not simply analysing such nano-scale processes, but specifically controlling them as well. This is not possible with today's instruments.

PETRA IV will draw widely on AI-driven analytical techniques: virtual models based on simulations and training data (digital twins) will support and speed up the development of customised functional materials.

Systemically relevant insights will be generated:

- New types of solar cells with longer lifetimes
- Significantly improved battery systems
- Biodegradable plastics
- Catalysts for green chemistry and hydrogen technology
- Sustainable industrial processes and consumer goods

Advantage for Germany as a business location:

The demand for batteries for electric vehicles and resource-efficient processes is increasing worldwide. Protagonists who not only develop new technologies quickly, but who are able to implement them in practical applications, can become market leaders. This will also support the European Green Deal.



HELMHOLTZ

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DESY is a member of the Helmholtz Association,
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