Strategy of the Research Field Matter for PoF V

[Notes: This paper outlines the status of the strategy for PoF V and it will be part of the discussion during the scientific evaluation 2025. It will be included in the status report: the first two sections at the beginning, the remaining sections as the outlook of the research field.

Please follow the corporate design of the Helmholtz Association and use standardized language (see glossary).

The document should not exceed 10 pages

Please use: American English Language, Font Arial 10, Line spacing 13 Pt.; Paragraph spacing 6 Pt. The page margins must be 2.5 cm at the top, left and right, and at least 2.0 cm at the bottom.

If possible, please refrain from using the usual Helmholtz terms and abbreviations in this document. Please write in more general terms for a (scientific specialist) audience that is not necessarily familiar with Helmholtz.

HELMHOLTZ

Content

Excerpt from the Verfahrenspapier:

Die als Ergebnisse des Strategieprozesses vorzulegenden Strategiepapiere sollen der folgenden für alle Forschungsbereiche gemeinsamen Gliederung folgen: Aktuelles Forschungsportfolio

- Einordnung in den nationalen und internationalen Kontext
- Herausforderungen der nächsten 10 Jahre
- Mission und Forschungsziele des Forschungsbereichs
- Zukünftige thematische und programmatische Aufstellung
  - Wissenschaftlich-programmatische Ausrichtung
  - Struktur des Forschungsbereichs
  - Rolle der Infrastrukturen im Forschungsbereich
  - Kooperationsstrategien (intern / extern)
  - Strategien zu programm- und FB-übergreifenden Themen wie z.B. Digitalisierung
  - Strategien zu zentrenbezogenen (forschungs-)politischen und/oder strukturellen Themen wie z.B. Innovation und Transfer / Talentmanagement, Nachhaltigkeit, Parität (Chancengerechtigkeit), Diversität, Digitalisierung
- Die Strategiepapiere sollten einen Umfang von 10 Seiten nicht überschreiten. Das abschließende Strategiepapier wird in die Status Reports für die wissenschaftlichen Begutachtungen und den Programmantrag des Forschungsbereichs für die strategische Bewertung integriert.

1 Research field Matter and its current research portfolio (1)

In the research field Matter, the Helmholtz Centers

DESY, FZJ, GSI (with HIM and HIJ), Hereon, HZB, HZDR and KIT

closely collaborate, exploiting state-of-the-art large-scale research facilities, to explore the structure of matter from sub-atomic to molecular scales and to investigate relevant structural details and processes within new and novel materials and biologically relevant structures. The research field Matter generates in this way new insights into the understanding of the Universe and into the atomic and molecular foundations essential for the development of customized materials and new drugs.

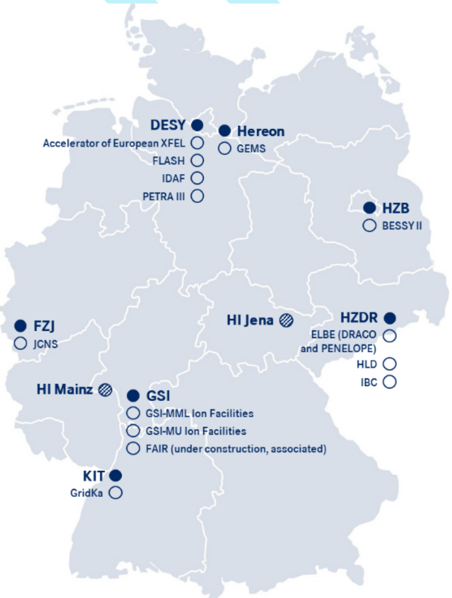
The research field offers a quality-assured access to its cutting-edge large research infrastructures for a large national and international user community from the academic and industrial sectors, in particular to young investigators starting their scientific careers. Another important characteristic of the research field is its strategic cooperation with large international research projects. In this way the interdisciplinary research facilities and international networking in long-term large-scale projects constitute an important pillar of the German science system.

The research field has developed a world-class research program in fundamental and applied science and technology which is largely based on the exploitation of its large-scale research infrastructures which they operate themselves and in which they are participating in international collaborations. This research makes intensive use of the capabilities within Matter to efficiently extract knowledge from the vast amounts of complex data produced by the research infrastructures.

The research field has devised and implemented an efficient interdisciplinary cooperation structure with the aim to create added value in science, technology development and transfer as well as in talent management. The research portfolio is organized into three research programs:

- Matter and the Universe (MU),
- Matter and Technologies (MT), and
- From Matter to Materials and Life (MML).

This structure was first introduced in the funding period PoF III and has led to many synergies in the collaboration between the centers. In particular, the program MT has proven to be very successful, as research and development in essential key technologies are carried out in a strategic cooperation between the centers that are highly relevant for research at large-scale research facilities. This includes advanced accelerators and detectors, as well as high performance data and computing systems.



	Leistungskategorie II (LKII)
DESY	Accelerator of European XFEL FLASH IDAF PETRA III
FZJ	JCNS
GSI	GSI-MML Ion Facilities GSI-MU Ion FAIR (under construction, associated)
Hereon	GEMS
HZB	BESSY II
HZDR	ELBE (DRACO and PENELOPE) HLD IBC
KIT	GridKa

Figure 1: Helmholtz Centers, Helmholtz Institutes and research infrastructures (LK II) of the research field Matter

2 National and international context (½ page)

The portfolio of the research field Matter and its close interdisciplinary collaboration across multiple centers are internationally pioneering. With its modern program structure, the research field Matter is an internationally leading concept enabling close cooperation across a wide range of research disciplines, research infrastructures.

National context

At the national level the research field Matter fulfills two strategic tasks: (a) it is responsible for the design, construction and operation of state-of-the-art research infrastructures, notably accelerator-based photon sources (Synchrotron- and X-ray Laser-radiation facilities), neutron and ion facilities as well as of high-field magnet laboratories, including dedicated large-scale computing facilities, and (b) is a key strategic partner in international large-scale research collaborations.

These Matter-operated facilities offer quality-assured open access to research groups from around world. This well-established user operation fulfills a third national strategic role and provides a pivotal model of work sharing between university-based and national lab-based research: experts of the research field Matter offer their competences and assistance to scientists from all sectors of academic research, and especially early-career researchers, to fully exploit the scientific potential available at the research infrastructures. Increasingly, the centers within Matter are also developing more efficient concepts to facilitate access and use of these technologies for industrial research groups.

International context

The research field is very strongly interconnected with leading international large-scale projects in Europe, the US and Japan, especially in the fields of particle and astroparticle physics. These cooperations need to be maintained and further strengthened. In the necessary modernization and upgrades of its research facilities, the research field Matter is moving in a highly competitive international landscape striving for the best technologies and ultimately for the leading research groups, which are attracted by the best research opportunities. Currently, this particularly concerns photon sources and radioactive beam facilities, which are being upgraded worldwide with new transformative technologies.

3 Challenges for the next ten years (1 page)

Due to the very fundamental nature of its research program, the research field Matter naturally has a rather long-time horizon for its research objectives. The research field is however increasingly focusing on solutions to the pressing societal challenges of today and tomorrow in its strategic considerations. Matter will make essential contributions to many of the European Commission's strategic development goals and will support high-tech and deep-tech companies in accelerating their value chains.

In a new challenging geopolitical world, the research field also sees itself responsible for contributing to the country's technology sovereignty and for strengthening the national science and innovation ecosystem through providing cutting-edge technologies. At the same time, the research field and its endeavors are based on long-term international collaborations, and thus contribute to a stable communication channel across borders also in difficult geopolitical times as we see today.

The research field Matter has cast its ambitions into a list of grand challenges, structured along the programs of the research field.

Matter and the Universe

- Understanding of the nature of dark matter, the origin of the matter-antimatter asymmetry in the universe, and the properties of neutrinos
- Studying hadronic matter under extreme conditions in the laboratory, which is essential for unraveling the origin of heavy elements in the universe

- Understanding the connection of particle physics with the processes in the universe and how the most extreme events shape our universe

Matter and Technologies

- Meeting the demands for ever more powerful accelerators and detectors, generated within the research in Matter, including the strategic development of potentially disruptive technologies, the exploration of new and emergent ideas, and moving them from the realm of pure research into the application in Matter.
- Answering to the enormous increase in data recorded in Matter and, more generally, in research, and developing efficient ways to turn data into knowledge
- Making fundamental research technologically viable in times of energy and climate crisis.

From Matter to Materials and Life

- Understanding of matter under extreme conditions: (1) strong-field processes from the THz to the X-ray range both in vacuum and matter with applications to imaging, and (2) the warm dense matter state that is central to inertial confinement fusion and to astrophysical objects and processes.
- Tailoring and optimization of materials for quantum technology, sustainable energy, and engineering processes.
- Science-driven drug development supported by structural biology and AI-facilitated generation of new compounds and macro-molecules.

4 Mission and research objectives **(1 page)**

The mission of the research field is to explore the structure and properties of matter and the universe as well as the data-based molecular design of new material functions and biological systems, utilizing large-scale research facilities for investigations across all relevant length and time scales.

A key part of its mission is to make the unique analytical potentials of its infrastructures accessible to a wide range of users from the academic and industrial sectors.

Through its contribution to the national technological sovereignty and the broad participation in cutting-edge technology for science and society, the research field significantly strengthens Germany's position as “Wissenschafts- und Innovationsstandorts”.

The research field Matter stands in for a world-open international and diverse research environment.

Matter and the Universe

Our mission is to understand the Universe on all energy, length and time scales, and to connect the evolution of the cosmos and its phenomena to the fundamental physics of the microcosmos and the basic constituents of matter.

We strive to enable an optimal knowledge gain through the development, construction, operation, and efficient utilization of cutting-edge research and computing infrastructures in an international environment. These encompass world-leading high-energy accelerator experiments and large-scale particle astrophysics observatories. Furthermore, we develop theoretical foundations and analytical methods employing modern computing technologies like Artificial Intelligence. We will ensure that Germany will benefit in the long term from this knowledge gain, fostering the education of young high-potentials and advancing sustainable practices, particularly in fields such as computing.

Matter and Technologies

Our mission is to conceive enabling research technologies which are “driven by science and driving science”.

We leverage emergent and sustainable technologies in an integrative approach in accelerator, detector and data sciences to create new opportunities for sustainable cutting-edge research in Matter and beyond. We push technologies for accelerators and detectors and we develop schemes to efficiently and safely store data and make them accessible to science and to provide low-carbon footprint and resource responsible systems.

We strengthen research in technology as a field, train the next generation of engineers and scientists in our field and link into areas such as energy-, information-, and health-science, and society at large.

From Matter to Materials and Life

Our mission is to elucidate the molecular and electronic structures and processes within condensed matter, materials and biological structures with utmost precision and in relevant environments, thus laying the groundwork for the development of better materials for future eco-friendly technologies and a circular economy, as well as the data-based design of new pharmaceuticals.

To this end, we operate world-leading research infrastructures, which we make available to both German and international research groups. We recognize our responsibility to contribute essential solutions to the major societal challenges of today and tomorrow.

5 Future thematic and programmatic positioning

The future research program is being developed based on the scientific and technological knowledge and successes achieved during the current funding period. Specifically, the program structure, which has proven to be exceptionally effective, will be maintained (see section 5.2).

In terms of programmatic positioning, the research field recognizes a new responsibility to stronger contribute targeted solutions to current societal challenges, especially in combating climate change.

5.1 Scientific positioning **(1 page each program)**

Matter and the Universe

Exploring the structure and the properties of the microcosm, we strive to identify the most fundamental matter constituents, to study the interactions between them at the highest possible precision, and to understand the influence of these fundamental building blocks on the evolution and the fate of our Universe.

- We study the electroweak and strong interactions at the LHC, with Belle II, and at smaller experiments located at Helmholtz centers and elsewhere.
- We investigate in detail the Higgs boson and the top quark at the LHC – using them as precision tools and portals for searches for physics beyond the standard model – and precision flavor physics with tau leptons and B mesons with the Belle II experiment, addressing important questions like CP violation or lepton flavor universality
- Bundling theoretical and experimental efforts we work towards identifying dark matter particles and other hypothetical particles like axions and understanding their influence on the development and the evolution of the Universe.

Focusing on studying hadronic processes in dense environments at GSI/FAIR and LHC, we strive to understand how the properties and dynamics of matter and antimatter arise from strong interactions and how they determine the evolution of stars and shape nucleosynthesis.

- We determine the phase structure and the equation of state of QCD matter at extreme values of density, temperature and isospin as are existent in neutron star merger events employing modern detector and computing technologies.
- We identify of the most important nuclear properties and mechanisms that determine the production of elements in the Universe and understand how nuclei emerge from the fundamental building blocks.

- We decipher the origin of matter-antimatter symmetry and test the fundamental symmetries.

Combining observations of the cosmos with our own experiments, we seek to understand the nature of dark matter, determine the properties of neutrinos and their role in the Universe, and study processes that govern the Universe at high energies.

- We build and operate detectors for the direct detection of dark matter in the laboratory. The flagship project will be DARWIN/XLZD[*], the successor to XENONnT.
- We develop and use novel technologies to unravel the mystery of neutrino mass and pave the ground for a new generation neutrino mass experiment as successor to KATRIN.
- We combine astrophysical observations in a multi-messenger approach to decipher the high-energy Universe. The flagship projects will be CTA, IceCube, and the Auger Observatory, with an extension of IceCube to IceCube-Gen2[*] being planned. We will work towards completing this portfolio with gravitational wave astronomy (Einstein Telescope[*]).

By operating large-scale accelerator and computing facilities for an international user community, we will enable groundbreaking insights into the understanding of the processes of the micro- and macro-cosmos.

- We provide hadron beams of the highest intensity and quality.
- We produce exotic secondary beams of high energy with excellent properties.
- We ensure optimal scientific return and data dissemination by providing large-scale and sustainably operated computing facilities (GridKa and Green IT Cube) and developing and implementing innovative simulation and analysis methods.

Matter and Technologies

Accelerator development is a core subject of MT. Scientists are active on a broad range of topics, which are highly relevant for the development of the infrastructures within Helmholtz and beyond, and future new facilities.

- We unlock the full potential of intrinsically energy-efficient superconducting RF systems for operational flexibility and tailored beam properties for optimal exploitation of multi-user facilities and compact SRF accelerators in a highly energy-, resource-, and cost-efficient way.
- We accomplish ultimate intensities and stability of hadron and electron beams and needs-based beams in resource-responsible accelerator facilities by developing new concepts and technologies from the component to the system level.
- We advance beam control, diagnostics and dynamics to enable the next revolution in accelerator science using the suite of our test facilities.
- We develop reliable laser-plasma accelerators, accelerating both electrons and ions, to enable first pilot application in the area of fundamental research, life science, health and industry.

Detectors are an integral part of the strategy of Matter and Technologies. Ever more powerful facilities need ever more powerful detectors, to record the science. New developments in detectors feed back onto the design of accelerator facilities, by challenging the accelerator scientists to deliver beams of ever better quality and intensity.

- We perform fundamental research to push the limits of performance in detection systems. We realize intelligent and compact granular detectors with high space and time resolution. We establish highly pixelated quantum sensors with ultimate energy resolution.
- We build sustainable detector systems and cope with dramatically increasing data rates. We closely collaborate with industry – e.g. the microelectronics industry – and ensure technological sovereignty in key technologies.

[*] Subject to pending international and national funding decisions.

- We conceive novel detection principles and systems and thus enable current and future experimental facilities in Matter and best exploitation of their science potential.
- We rely on and develop sophisticated infrastructures for fabrication, characterization and integration of detector components and systems and make them accessible for our partners.

Data are produced by science in enormous quantities. Turning data into knowledge requires our capability to handle data, make them accessible, develop algorithms to analyse them and have the means to understand them.

- We establish cross-center, cross-community F.A.I.R. data lifecycle management solutions at Matter research infrastructures for intelligent, scalable data reduction methods at extreme rates, volumes and complexity.
- We roll out novel, intelligent algorithms for data management and analysis in the post-Exascale era into efficient, sustainable, scalable production-ready research software leveraging the power of AI, foundation models, quantum computing, heterogeneous architectures and non-von Neumann compute paradigms.
- We establish digital twins for detectors, accelerators, beamlines, instrumentation and experiments across Matter and integrating them into autonomous, intelligent facilities to realize data-driven science and intelligent discovery across all Matter.
- We enable autonomous operation of research facilities with new human-machine interfaces with our solutions for intelligent operation, optimization, and knowledge extraction informed by real world and simulation data. We make these solutions available in a F.A.I.R., sustainable and workable manner on Matter infrastructures to accelerate research outcomes across the whole research field of Matter.

To address the increasing role optical technologies play in our research, most notably in the form of high power high performance laser systems, we will establish a new platform “frontiers of optical technologies”. This platform, embedded within the research field, and managed by the program MT, will bring together all players of this field in Matter, and also connect to activities outside of the research field.

From Matter to Materials and Life

The program "From Matter to Materials and Life" pursues research with the goal to gain unique insights into the properties of matter, materials, and life to contribute significantly in solving the major challenges of our society. This is achieved through facility-oriented research that spans a large range of lengths, times, energies, and electromagnetic fields which is not accessible to conventional laboratory investigations.

Our research explores fundamental aspects of the dynamics of matter, identifies the underlying mechanisms, and pursues microscopic control strategies. In this way, the conceptual and methodological backbone is provided for all scientific activities employing cutting-edge large-scale infrastructures involving photons, neutrons, ions, and high fields and cutting-edge data-science methods. These infrastructures are developed and operated by the program, and comprise a unique portfolio of facilities with a complementary set of beam parameters. Currently, it consists of the synchrotron sources BESSY II, PETRA III, and the free-electron lasers FLASH and European XFEL for photons research, the FRM II reactor at JCNS for neutrons, the IBC ion source laboratory and synchrotrons and storage rings SIS18, ESR and CRYRING for ions, as well as the free-electron laser ELBE and the HLD laboratory for high electro-magnetic fields.

Our research lays a robust foundation for the scientific and technological breakthroughs needed for solving grand challenges faced by society.

- We advance our understanding of strong field processes from the THz to the x-ray region to access the structure of the vacuum, the warm-dense-matter state and astrophysical objects and processes.
- We strive to understand and steer fundamental processes in chemistry and physics at their natural picosecond to attosecond time scales by developing super-slow-motion imaging and advanced molecular-scale control.

- We advance our analytic capabilities at large scale facilities with compact light sources and enable photonic quantum technologies thereby contributing to shaping the second quantum revolution.

The development of tailored advanced materials is key to the solution of many of the grand challenges of society, starting from renewable-energy concepts over quantum materials for information technologies to biocompatible materials for medical applications. By concentrating on the large portfolio of large-scale research infrastructures:

- We strive to understand the dynamics of electronic, magnetic, and topological states in such detail that we can use and control them for new quantum and information technologies.
- We explore chemical reactions under industrially relevant conditions to improve catalytic and other chemical processes in energy conversion and storage, as well as chemical processing.
- We aim to understand and control macromolecular materials for active biocompatible substances, sensing and organic electronics.
- We push for novel analysis techniques at our large-scale infrastructures to identify and optimize new materials for sustainable energy concepts and engineering processes.

At the next higher level of complexity, we focus on a deeper understanding of living systems. In combination with innovative technical and methodological developments, the large-scale Helmholtz x-ray and particle beams facilities offer unique opportunities to study the structure and dynamics of everything from fundamental molecular processes, e.g., the dynamics of water to macromolecules and their interactions in atomistic detail.

- We develop and integrate accelerator-based X-ray analysis methods and multimodal imaging to delineate the molecular basis for biological function and to efficiently perform time-resolved studies of macromolecules as well as targeted compound screening.
- We push for AI-supported design and tailoring of new enzymes and molecules for technological applications and new drugs.
- We develop & apply AI-driven high-throughput techniques for correlating morphology with genetics and ecology to understand evolution & biodiversity as well as genetic diseases.
- We explore the response and interaction of biomolecules, tissues and organisms to external stressors and stimuli for organoids & tissue engineering, for an understanding of the effects of climate and environmental change on biodiversity as well as for application in cancer treatments and in infectious disease.
- We concentrate on improvements of radiotherapy in oncology and aim to develop solutions to protect astronauts during space travel.

As novel tools, at MML we will employ ML and AI to push the frontiers of our research, most prominently towards automated data collection and analysis, resolution improvement for photon imaging across all wavelengths, simulation of extreme matter states, as well as search for novel materials ("digital twin").

5.2 Structure of the research field **(½ page)**

In 2012-2013, the research field "Structure of Matter" embarked on an intensive strategic process to develop a completely new program structure that more efficiently utilizes the potentials within the research field and promotes closer and deeper cooperation between the centers.

Moreover, this strategic process took a visionary step by developing a program (Matter and Technologies) in 2015 (PoF III), dedicated to technology development in areas highly relevant to the research field, i.e. accelerators, detectors, and (later complemented by) data systems. This globally leading technology program plays a key role in the development of new technologies at the research infrastructures operated by the research field in user-service modes.

The newly structured research field (renamed "Matter") for the first time consolidated the very fundamental research areas of particle and astroparticle physics, and hadron physics into a common program (Matter and the Universe) and reorganized materials research using accelerator-based research facilities. This program structure has proven to be exceptionally effective and is therefore intended to be maintained further.

Matter views the research areas of "Optical Technologies" and "Laser Development" as important future competence fields of the research field. These will be more effectively consolidated in a new structure within the research field in the future ("Matter Competence Teams", see section 5.5).

Further changes in research field Matter relate to the neutron facilities, which will in future be linked to material development in the research field Information. The same applies to material research at KIT, which will be connected to the material research program of the research field Information in the future.

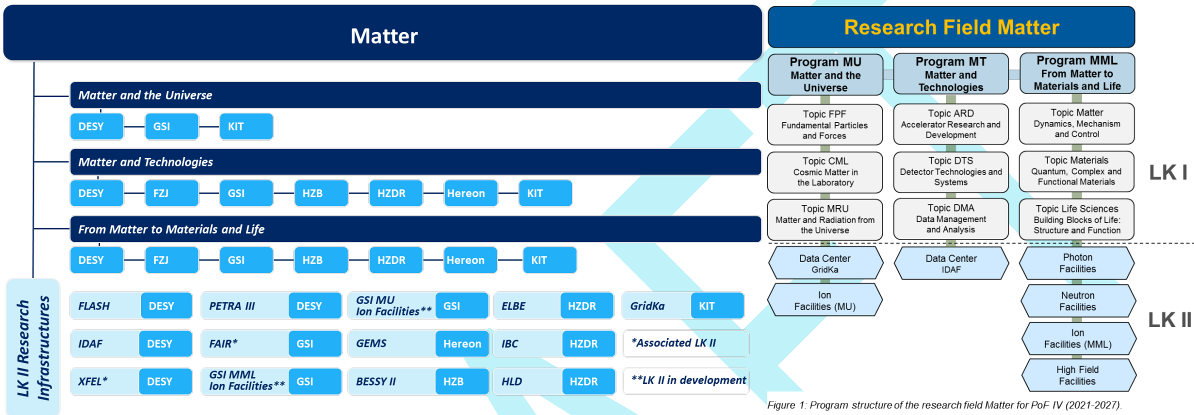


Figure 2: Schematic Overview of the research field Matter with its programs, topics and LK II (update following)

5.3 Role and Impact of infrastructures **(½ page)**

The research field Matter and its mission are inconceivable without large-scale research infrastructures which work as super-microscopes and -telescopes for the world of the invisibly small and inconceivably large.

The interdisciplinary and cross-sectoral research at its large-scale research facilities is the salient feature of Matter and the paradigm of a highly efficient research strategy in the cooperation between universities, non-university research institutes and industry. This strategy is essentially dependent on the core competence of the research field Matter in the design, construction, and operation of complex large-scale research facilities. To strengthen this competence, the program Matter and Technologies takes up requests and needs from the researchers and users for improved accelerators, detectors and data management systems. Another important point is the necessary modernization of research facilities, which the research field is facing in an international environment that is competitive in terms of talent and technology.

The large-scale research facilities of the research field are research and technology platforms that play an indispensable role in projects of all disciplines ranging from physicists, chemists, biologists to geo- and materials scientists and medical experts, as well as in many other disciplines of societal relevance. They offer unique research opportunities, especially to our early career scientists at universities. The research field operates a number of mid-sized infrastructures, which offer access to a broad range of users including Universities and industry. In particular, the program MT depends on these infrastructures to develop technologies and concepts as well as, or to test and commission them.

The potential of non-destructive *in-situ*, *in-vivo*, and *operando* analytics are increasingly being recognized and utilized in industry-related research. In the future, the access of the industry to large-scale research facilities is to be focused on more and more, thereby making a significant contribution to the country's technology sovereignty.

A significant part of the international research network is supported by large long-term collaborations in particle and astroparticle physics. The scientists of the program MU are key partners at major research infrastructures and large observatories.

5.4 Internal and external cooperation (½ page)

To fulfill its mission and set research objectives, the research field Matter relies on the cooperation with partners with complementary skills. This will continue to be an essential part of the research strategy in the future.

Within the research field, the three programs are set up in such a way that a maximum degree of cooperation between the centers and the Helmholtz research groups is promoted (see also 5.5. “Cross cutting topics”).

A decisive factor in its national role are the large research facilities, which the research field operates as user facilities, thus providing access annually to more than 10,000 users from the entire scientific system to the complex and dedicated experimental stations and equipment.

Collaboration with universities plays a prominent role. It primarily occurs through scientific collaborations and user operations, as well as through joint appointments of leading scientists and education of doctoral students. Helmholtz Institutes (like HI Mainz and HI Jena) are acting as an interface between centers and universities. Another highlight of this cooperation strategy is the visible success in the Excellence Initiative. An important tool is the BMBF “Verbundförderung” program, which enables university groups to contribute to the portfolio of instrumentation at research infrastructures.

The research field of Matter is deeply interconnected on an international scale through its large-scale projects, actively seeking strategic partners worldwide to boost its research objectives. The dramatically changed geopolitical situation requires a critical analysis of cooperations with countries where scientific freedom is threatened or not intact. The research field is currently very active in seeking to achieve greater robustness in the interaction with international partners in the future, with the goal of maintaining targeted win-win cooperations.

5.5 Cross-cutting topics (½ page)

As a core aspect of its mission, the research field delves into fundamental investigations of the structure and function of matter, utilizing advanced large-scale research facilities. The expertise within this research field holds significant importance not only for all research areas within the Helmholtz Association but also for the broader scientific community.

To fully unlock this Helmholtz potential, the research field is setting up so-called Matter Competence Teams (MCTs) in selected research areas that are distinguished by both a high interdisciplinary character and significant relevance. The tasks of the MCTs are:

(a) organizing an interdisciplinary Matter platform for the research field (“Matter-driven Cross cutting Topics”) and for the Helmholtz association (“Helmholtz-driven Cross cutting Topics”)

(b) serving as competent contact points both Helmholtz-internally and externally

(c) identifying so far unexplored cross-cutting projects. A selected part of the funding could be sourced from the Innopool funding corridor, specifically earmarked for 3-years "pathfinder projects.

The MCTs, lead by a speaker and co-speaker, will have a lean governance structure.

Table 1: The following MCTs will be established with a streamlined governance structure

Matter-driven Cross Cutting Topics	Coordinated by	Cooperation	Comments
- AMD: Advanced Materials Design	MML	all fields	Focus on safe and sustainable materials
- OPT: Frontiers of Optical Technologies	MT	Information AST, Energy	Focus on large and fast laser systems/ sources, X-ray optics
- SRB: Structural and Radiation Biology	MML	Health	
Helmholtz-driven Cross Cutting Topics	**Coordinated by**	**Comments**	
- CR: Matter for Climate Research	E&U	Matter Competence Teams to connect to the overall Helmholtz Cross Cutting Topics	
- QT: Matter for Quantum Technology	Information		
- BE: Matter for Biomedical Engineering	Health		

5.6 Commitment to strengthening and advancing our workforce and infrastructures **(1,5 pages)**

Description: Strategies on center-related (research) policy and/or structural topics such as innovation and transfer, talent management, sustainability, parity (equal opportunities), diversity, digitalization, etc.
A list of all centers and their activities should be avoided. Rather general (and research field-wide) aspects should be described first, which are then substantiated with one or two best-practice examples.
The centers should be in close exchange to fine-tune the examples and ensure that a diverse picture of the activities of the centers of the research field is be shown here. In addition, the overarching Matter-perspective should always be considered (and could at best relate to the "grand challenges" of the research field Matter in a way).

Missing: "advancing infrastructures": Photon Science Roadmap, see annex !!!

Input, unsorted:

Research in the research field Matter is highly characterized by international cooperation between different research institutions and almost always takes place in large international collaborations. These collaborations and the international environment in our research facilities have an integrative effect on our society and can be seeds of far-reaching scientific and economic collaborations. Our research facilities and infrastructures are currently undergoing a transformation to sustainable operation, so that we assume our global responsibility with individual action as research institutions, but also as individual employees.

- Digitalization: Open community software (CORSIKA, GammaPy, AMPEL, AM3, ...)
- Our worldwide collaborations promote diversity, including partners and host sites in South America (CTA, Auger) and Africa (H.E.S.S.)
- Sustainability: Construction and operation of facilities focus on minimizing environmental impact
- Talent management: Graduate schools (Multi-messenger school, HGSHire, etc.), Junior research groups and dedicated preparation programs (e.g. YIG Prep Pro at KIT and Young Investigator Networks at KIT and DESY and the tenure track program at GSI); DESY international / Ukraine summer school
- training of early-career researchers in our groups leads to innovation in industry
- our scientific infrastructures enable unique technological development which are of use for national and societal challenges like a sustainable use of new energy sources

- our international project foster partnerships and communication between countries and cultures and are seed points for economic cooperations; (“Anti Anti-globalization” argument), not only in science but also in society
- Excellence through highest level of education, training, and quality of research to maintain a world-wide leadership role in research and innovation (“Made in Germany” quality argument)
- Societal argument: development of a modern perspective on work-life-balance and efficiency for the next-generation work force (radiating outside science) in direct competition and comparison with the international context (“German efficiency argument”)
- our research activities and infrastructures provide an international context also at our host institutions and create a modern, open-minded, inspiring atmosphere for the societiy by the participating scientists, students, technical and administrative support personnel
- Our modern research infrastructure together with our ambitious research program attracts the young, international scientists, and provide an effective gate to the German society.

Knowledge transfer:

Long-term basic research is necessary in order to find targeted and short-term solutions to urgent social challenges, for example. The large infrastructures we operate are drivers of innovation for the economy and society. By developing and operating the infrastructures, the research field Matter ensures that numerous scientists, engineers, technicians and other specialist personnel in many areas in the infrastructures themselves, but also in the technological and economic environment of these infrastructures, have the expertise they need for the future. Our infrastructures serve to gain knowledge and further technological development and they offer platforms for prototype developments. The international cooperation and the international environment in our research facilities have an integrative effect on our society and can prepare the ground for far-reaching scientific and economic cooperation. Our research facilities and infrastructures are currently undergoing a transformation towards sustainable operation, so that we are assuming our global responsibility with individual action as research facilities, but also as individual employees.

Participation in research and research dialogs is possible via publicly available research data and results.

The international collaborations and the international environment at our research institutions make it clear that the major issues and challenges facing society must be considered and tackled globally. At the same time, however, each research institution and its individual employees assume global responsibility with sustainable, responsible action.

6 Annex

Table 2: LK II research infrastructures (user facilities) of the research field Matter

Acronym	Program	Type	Centers	Annual operating costs (€)	Thereof: base-funded scientific/technical staff (FTE)
GridKa	MU	Data	KIT		
Grid Computing Centre Karlsruhe, Tier-1 center at KIT, LK II facility of the Program MU					
GSI-MU Ion Facilities	MU	Ion	GSI		
UNILAC, SIS18, ESR and FRS with respective experimental sites, delivering ion beams from protons to uranium at up to 4 GeV (p) and 2 GeV/u (U) respectively; facility for production of high intensity radioactive beams and injector for the FAIR accelerators including an IT Compute Facility (Green IT Cube) for data acquisition and analysis					
IDAF	MT	Data	DESY		
Interdisciplinary Data and Analysis Facility for Matter Research, LK II facility					
BESSY II	MML	Photon	HZB		
Third-generation soft X-ray user facility (MML) utilized for accelerator R&D, LK II facility					
FLASH	MML	Photon	DESY		
XUV and soft X-ray free-electron laser, 10% of beam time dedicated to accelerator R&D					
PETRA III	MML	Photon	DESY		
Third-generation synchrotron radiation source with high brilliance, mainly for experiments in the hard and high-energy X-ray range					
GEMS	MML	Photon & Neutron	Hereon		
German Engineering Materials Science Centre with outstations and instrumentation at DESY (PETRA III) and MLZ (FRM II), including complementary engineering materials science laboratories					
Accelerator of European XFEL	MML	Photon	DESY		
GSI-MML Ion Facilities	MML	Ion	GSI		
HITRAP (currently put into operation), CRYRING (2019), ESR for storage and cooling of highly-charged ions (1990); KJ/PW laser PHELIX (2008); various experimental areas for atomic, plasma and biophysics and materials research					
IBC	MML	Ion	HZDR		
Ion beam facility for materials and interdisciplinary research					
ELBE (DRACO and PENELOPE)	MML	High-Field	HZDR		

Multiple radiation source powered by superconducting (SC) CW electron LINAC, LK II facility					
HLD	MML	High-Field	HZDR		
High-magnetic-field facility generating highest possible non-destructive pulsed magnetic fields					

Table 3: Proposed LK II research infrastructures (user facilities) of the research field Matter (Helmholtz Roadmap)

Acronym	Program	Type	Centers	Category	Time period	Total invest in Mio. €	Year of planning
TIER-Upgrade			KIT, DESY, GSI	A	2027 - 2030	33	Hier bitte das Jahr angeben, in dem die Kosten berechnet wurden
*Upgrade of the Grid Computing Centres for the HL-LHC***							
PETRA IV			DESY, Hereon	B	2024 - 2031ff	1.400	
*Upgrade der Synchtrotron-strahlungsquelle PETRA III***							
DALI			HZDR	B	2024 - 2030	200	
*Dresden Advanced Light Infra-structure***							
BESSY III			HZB	B	2029 - 2031ff	980	
*Berliner Elektronenspeicherring für Synchrotronstrahlung III***							
IceCube-Gen2			DESY, KIT	C	2024 - 2031	292,2	
*IceCube-Generation 2***							
DARWIN			KIT	C	2025 - 2030	175	
Dark Matter WIMP Search with Liquid Xenon							
ET			DESY, HZDR, KIT	C	2026-2031ff	1736	
Einstein Telescope, a 3rd Generation Gravitational Wave Detector							
GCOS			KIT	C	2028 - 2031ff	390	
Global Cosmic Ray Observatory							
HIBEF 2.0			HZDR, GSI	A*	2024 - 2026	28	
*Helmholtz International Beamline for Extreme Fields 2.0**							

Category A – Helmholtz projects financed through the Helmholtz Association's competitive procedure for strategic expansion investments (€15 to €50 million).

Category B – Large national projects of the Helmholtz Association that are included on the national roadmap and funded with additional project funding (> €50 million).

Category C – Helmholtz participation in international research infrastructures that are transferred to the ESFRI list via the national roadmap, via the national representatives,

or include other international participation.

A – The construction of HIBEF 1.0 at the European XFEL is almost complete, but the withdrawal of the Chinese cooperation partner means a replacement investment is necessary.*

**) New strategic expansion projects already underway before 2021 or approved since 2021 are not listed here.*

***) Update compared to the 2021 planning proposal.*