# **Research Policy Objectives of the Research Field Matter**

# 1. Overarching goals of the Helmholtz Association

* Drive a dynamic development of Program Oriented Funding.
* Promoting thematic profiling and networking in the Research Fields.
* Strengthening research infrastructures by expanding operations for internal and external scientific users.
* Developing a Digitalization Strategy for Helmholtz (Open Science/Open Access/FAIR Data)
* Creating and maintaining attractive research sites
* Strengthening the transfer to business and society
* Building bridges between Research Fields

# 2. Global objectives of the Research Field Matter

## 2.1 Mission and tasks

* Develop the competencies in the research of matter, in the construction and operation of complex large-scale research facilities, as well as in the development of basic technologies such as concepts for new accelerators and detectors.

## 2.2 Priority topics and their objectives

* Develop highly visible profiles at international large-scale facilities for particle, hadron, and astroparticle physics, in particular in the ATLAS, CMS, and ALICE detectors at the LHC, in Belle II, and in CTA, IceCube, and Auger.
* Continue to profile participation in the European X-Ray Free-Electron Laser XFEL, the European Spallation Source ESS, the ESRF, and the ILL as well as in the FAIR (Facility for Antiproton and Ion Research) Facility.
* Clarify the nature of Dark Matter and the properties of neutrinos.
* Develop the understanding of the relationship between the structure and dynamics of matter and its properties.
* Examine the impact of the structure and properties of matter and materials on biological, chemical, and physical processes will be examined.
* Characterize electronic, magnetic, and molecular processes on all relevant length & time scales to develop new materials and active substances in the Helmholtz Research Fields.
* Seek the use of its research infrastructures and competencies for materials research and molecular biology in industry.
* Develop the large-scale facilities of the Research Field to ensure that they remain at the forefront of the world’s facilities.
* Investigate new approaches and develop future technologies, in particular for ultra-compact and cost-efficient accelerators and sources of radiation and particles for science, industry, and medicine, as well as for a prototype of alternative high-brilliance neutron sources.
* Develop novel detectors that meet the requirements at large-scale facilities in terms of high data rates, accuracy, and reliability.
* Develop the Data Management and Analysis (DMA) as a program topic in the Research Field, and cooperate with the Research Field Information.

## 2.3 Structural objectives

* National and international cooperation: Expand the opportunities of operating the Research Field’s large-scale facilities with regard to user groups from science and industry.
* Creating and maintaining attractive scientific environments: Continue to make a special effort when competing for the best minds at the international level.
* Strengthening the transfer of technology and knowledge to economy and society:
* Opening research infrastructures specifically to external users from industry in a targeted way and creating a corresponding business-oriented culture in the Centers.
* Establishing strategic partnerships with industry in order to coordinate goals and research needs at an early stage.
* Creating suitable structures in the Centers in order to make cooperation with industry an integral aspect at the organizational level, e.g., by appointing a chief technology officer.
* Providing targeted support for spin-offs and start-ups in the Centers, e.g., through technology investments or space for high-tech start-ups etc.
* Developing measures to address SMEs in a targeted manner.
* Including regional business enterprises in considerations relating to the development of regional locations, e.g., via networking with the Chamber of Industry and Commerce.
* Developing specific incentive systems in the Research Field Matter, also taking into account the environment of large-scale facilities in particular.
* Report on the Research Field’s industry-related activities midway through the PoF period
* Present a strategy for knowledge transfer and public relations in the Research Field Matter after two years of the PoF term which will be implemented and updated within the funding period.

## 2.4 Further development of research infrastructures:

* Establish a transparent process for developing the portfolio of the Helmholtz research infrastructures, including the participation of potential users. In this process, priorities are to be defined with respect to future research infrastructures of the Research Field Matter, including a strategic classification and integration of these research infrastructures into the international research infrastructure landscape.

## 2.5 Joint initiatives of the Research Field and cross-cutting activities

* Cooperation strategy: Present a cooperation strategy after two years of the PoF period which will be implemented throughout the PoF period.
* Strategy pool: Set up a so-called strategy pool (Matter Forum) to which the participating Helmholtz centers will contribute 1% of their LK I funds in the form of a virtual fund.
* Talent management: Attract the best talents from all over the world, therefore the talent management system of the Research Field Matter must be further developed and expanded at all levels while being embedded in the corresponding Helmholtz strategies.

## Interfaces to other Helmholtz Research Fields

* Materials research: Enhance the cooperation in the context of materials research with other Helmholtz Research Fields. The main aim is to develop a deeper microscopic understanding of matter, materials, and biological systems, as well as applied materials research on the basis of concrete problems from the other Research Fields, which are solved through the use of large-scale facilities.
* Digital transformation:
* Participate in the Helmholtz Digital Transformation Strategy and integrate previous and potential future activities of the Research Field relating to the Helmholtz Data Federation (HDF) and the Helmholtz Information & Data Science Incubator.
* Continue the integration and exchange with national expert committees and the involvement in relevant topics in the BMBF’s ErUM-Data action plan in connection with related activities of the Federal Government.
* Work on an Open Access, Open Data and Open Science Strategy, which it will implement together with the other Research Fields.
* Structural biology and biological processes and radiation research:
* Develop and tap the research into existing experimental possibilities to search for new active substances in close coordination with the Research Fields Health and Information.
* Radiation research: Use the unique possibilities offered by the Research Field’s radiation sources in order to yield new insights in the area of structural biology & biological processes; and focus on the fields of radiation biology and radiation therapy as well as molecular imaging for biomedical applications; explore potential synergies with the Research Field Energy.
* Quantum technologies: Participate within the strategy process and its implementation for quantum technologies in the Helmholtz Association.

# 3. The Programs

## 3.1 Research objectives of “Matter and the Universe” (MU)

* Identify the fundamental particles and their interactions as well as to obtain an exact understanding of the structure of the vacuum.
* Understand the structure and dynamics of hadrons, nuclei and nuclear matter and their role in the astrophysical formation of chemical elements.
* Understand the nature of Dark Matter and Dark Energy and of the universe at high energies.

#### Specific objectives of Topic: “Fundamental particles and forces”:

* Accurate measurements of the properties of the Higgs boson will be carried out at LHC/HL-LHC, as well as high-precision investigations of the electroweak and strong interaction at LHC/HL-LHC and at Belle II. Search with these experiment for new particles and phenomena, either by direct observation or by deviations between theory and precision measurements.
* Search for axions and similar hypothetical particles with the ALPS II experiment at DESY. In addition, the technical and financial feasibility of the possible follow-up projects, MADMAX and IAXO, will be worked out and possibly lead to first demonstrators.
* Advance the understanding of cosmology, illuminate the so-to-speak “dark side” of the universe, and are complementary to astroparticle physics activities in the topic “Matter and radiation from the universe”.

#### Specific objectives of Topic: “Cosmic matter in the laboratory”:

* Investigate the phase diagram of hot and dense nuclear matter with their effect on the equation of state of astrophysical objects such as supernovae, neutron stars, and merging neutron stars. This may also lead to new insights into gravitational wave signals.
* Investigate the nuclear structure and the reaction phenomena far away from the so-called valley of stability. In particular, a better understanding of the element formation in the universe in supernovae and neutron star fusions should follow from the study of the r-process, e.g., the element abundances of the elements gold, platinum, and beyond.
* Test QCD predictions for exotic particle states via precision measurements of proton-antiproton collisions.

#### Specific objectives of Topic: “Matter and radiation from the universe”:

* Gain a comprehensive understanding of the structure of the universe as a whole, derived from the observations of the various complementary messengers (gamma radiation, neutrinos, particles and nuclei, and gravitational waves). The Research Field will strengthen this so-called multi-messenger approach significantly during the PoF IV period.
* Integrate existing and future observatory data into a data and analysis center for high-energy astroparticle physics.
* Measure the mass or the most stringent limitation of the mass of the electron neutrinos with the KATRIN experiment by the end of the PoF IV period. Investigate the feasibility of a corresponding campaign to search for Dark Matter with KATRIN.

#### Specific objectives for the User facilities:

* Provide large-scale research facilities for users at GSI/FAIR affiliated with the MU program including the UNILAC, SIS18, and FSR accelerator facilities as well as the FAIR Green IT Cube.
* Operate the German Tier data centers for the LHC experiments, for Belle, and other consortia in particle and astroparticle physics (see the program MT).
* In particular, develop GridKa to be able to cope with the significantly higher data flows from the HL-LHC.
* Address additional challenges for the large-scale research infrastructures used within the program, e. g. the high luminosity upgrade of the LHC, novel sensors and detector systems, the Gamma Observatory at CTA, the IAXO experiment, the IceCube-Gen2 interdisciplinary neutrino observatory, the GCOS Global Cosmic Ray Observatory, the AugerPrime upgrade, and the DARWIN project.

## 3.2 Research objectives of “From Matter to Material and Life” (MML)

* Research on the relationship between structure and dynamics and the resulting properties and functions of matter, even under extreme conditions.
* Elucidate the properties of materials and their interaction with biological, chemical, and physical processes.
* Conduct in-situ and in-operando investigations under real conditions with a view to develop new materials and agents in a targeted way.
* Elucidate the structure and function of the building blocks of life and related biological processes and reactions to external stressors.
* Provide novel analytical methods and services to industrial companies and supporting their application, together with appropriate technology transfer.

#### Specific objectives of Topic: “Matter - dynamics, mechanisms, and control”:

* Investigate new insights into processes in strong fields and promote the observation and use of nonlinear X-ray processes.
* Investigate observation and control of real-time dynamical processes of molecular interactions.
* Provide new insights into matter under extreme conditions; therefore generate and investigate extreme states of matter with ion beams, intense laser pulses, and X-rays.

#### Specific objectives of Topic: “Materials - quantum, complex, and functional materials”

* Investigate the structure and properties of materials for the development of novel, complex materials.
* Investigate functionalities at the nanoscale and develop quantum materials.
* Strengthening the search for functional materials for new devices and applications.

#### Specific objectives of Topic: “Life sciences - building blocks of life: structure and function”

* Investigate the structure and interaction of subcellular and molecular components.
* Explore the Morphology and function of biological systems in the field of tension between genetics and environment.
* Examine the effects of radiation (ions, photons) and external stressors.
* Strengthening the specific research on applications in the areas of medical physics and therapy, but also in Aeronautics, Space, & Transport.

#### Specific objectives for the User facilities for the research with photons

* Operate the facilities BESSY II and PETRA III, as well as at the free-electron laser facilities FLASH and European XFEL including HIBEF at the highest international level with highest priority for the national and international user community.
* CDRs (conceptual design reports) and TDRs (technical design reports) for PETRA IV and DALI should be available in the first year of the PoF IV period with the aim of placing these projects on Germany’s National Roadmap. In the case of BESSY III, a CDR is to be completed by the middle of the PoF IV period at the latest and a corresponding TDR in the second half of the PoF IV period.
* FLASH2020+ is to be realized and user operation will begin in the first part of the PoF IV period. In the case of BESSY VSR, these goals are to be achieved within the PoF IV period.
* Scenarios for the development of the European XFEL towards a continuous pulse sequence and a second set of further beamlines are also to be worked out during the PoF IV period in close coordination with the European XFEL Company, the European XFEL Council, and within the framework of LEAPS at the European level.

#### Specific objectives for the User facilities for the research with neutrons

* Expand the MLZ at FRM II for neutronic connection and commissioning of the instruments in the Neutron Guide Hall East, to transfer the instruments of the BERII reactor, and to realize new instruments for the development of further scientific fields.
* Follow the seven instrumentation projects of the German partners in ESS in order to take them into user operation in the middle of the PoF IV period.
* Develop and realize a compact accelerator-driven neutron source, which will allow complementary experiments to the ESS through their optimization for brilliance. A CDR and TDR for the construction of a prototype based on this novel concept is to be submitted by the middle of the PoF IV period.

#### Specific objectives for the User facilities for the research with ions

* Provide the Ion Beam Center (IBC) for application in materials research, in interdisciplinary Research Fields (resource technology, geomorphology, environmental and climate research), and as an ion beam service for industrial partners. Establish a low-energy ion laboratory for modifying and analyzing 2D materials and significantly expanding AMS operations.
* Develop a novel FAIR instrumentation for the experiments at the current accelerator and storage ring facilities UNILAC, SIS18, ESR, and HITRAP. Start regular operation of the newly installed storage ring CRYRING to make highly charged, decelerated ions available for the experiments. Starting in 2024/2025, the first experiments will also be possible with the new FAIR facilities (e.g. High Energy Storage Ring).

#### Specific objectives for the User facilities for research in highest electromagnetic fields

* Operate HLD for fundamental investigations, especially in the area of solid-state physics and material sciences in ultra-high magnetic fields.
* Use the high-power laser systems DRACO and PENELOPE as well as PHELIX for investigating states of matter and the physics of strong fields.
* Objectives on ELBE and HIBEF see research with photons above.

## 3.3 “Matter and Technologies” (MT)

* Develop accelerator technologies with a focus on delivering highest brilliance, luminosity, compactness, and stability.
* Investigate the physics of radiation detection to advance and deepen the understanding in concrete detector systems.
* Drive forward the digitization in all scientific areas in the Research Field Matter using newest methods and innovative technologies.

#### Specific objectives of Topic: “Accelerator research and development”:

* Develop a reliable continuous wave operation of SCRF accelerators.
* Optimizing accelerator parameters for hadrons and electrons to achieve ultimate intensities and stability.
* Developing advanced concepts for beam control, dynamics, and diagnosis.
* Developing concepts for compact accelerators up to applicability.

#### Specific objectives of Topic: “Detector technologies and systems”

* Optimizing the sensitivity, the time, space, and energy resolution of sensors needed in the context of novel accelerators and extreme sources.
* Developing novel detector and readout concepts for extreme data rates and environments.
* Consolidating technologies into application-driven, integrated detector systems.
* A further goal of the program is to improve the infrastructure by establishing a distributed detector laboratory (DDL).

#### Specific objectives of Topic: “Data management and analysis”

* Develop and apply innovative digital solutions for the handling and analysis of the extreme quantities and rates of complex data generated in large-scale research infrastructures in the Research Field Matter.
* Develop and provide novel digital methods for knowledge extraction from experiments and digital models in Matter.
* Develop and integrate cutting-edge state-of-the-art digital methods to exploit data from experiments and facilities in the Research Field Matter.

#### Specific objectives for the User facilities of the MT program

* Operate the Tier-2 computing center IDAF within the existing commitments to the LHC or European XFEL. This Interdisciplinary Data and Analysis Facility should play a central role in the implementation of the DMA strategy.