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**CHALLENGES OF THE COMING 5 – 10 YEARS 2**

The mission of our Research Field is the investigation of matter ranging from the elementary building blocks of matter and their interaction up to the appearance of complexity at all length scales, from the mysteries of the universe as the origin of dark matter up to understanding and developing new materials and drugs. Examples for the central questions we pursue in the Research Field Matter are:

• How has the universe developed from the big bang to our days – what are the building blocks of matter and what is the origin of the elements in the universe?

• How can we understand and control electronic, atomic and molecular processes to be able to design new functional materials and active agents?

• How can we devise novel high-gradient particle accelerators? For this aim, we address and resolve scientific and technical challenges, and we construct and operate large-scale facilities.

**2.1 Scientific goals**The scientific goals of the next decade are the following:

• **We explore the limits of the Standard Model of particle physics**The Higgs boson discovered at the LHC opened up completely new perspectives for testing the Standard Model and for the search for physics beyond the Standard Model. The LHC is the on-ly facility worldwide for such studies at highest energies and smallest length

• **We explore the physical limits of particle acceleration**We must further optimize accelerator technology in order to keep the existing and future user facilities as European XFEL and FAIR at the top of global research. For future experiments, we will generate and characterize particle beams of highest density, highest performance, highest brilliance and ultra-short pulse length in the attosecond range. The further development of the superconducting accelerator technology continues to be a central challenge.

• **We are analyzing the physical mechanisms of plasma acceleration**The acceleration of charged particles opens the way to novel ultra-compact accelerators. Much progress in the understanding of accelerator mechanisms and physics of plasma is necessary to bring this revolutionary technology to application maturity.

• **We are investigating novel sensor materials**Sensors are the central part of our detectors. We will advance the development of innovative sensors and complete detector systems which will make possible the ultimate energy and spa-tial resolution near the quantum noise. We will individually tailor the properties in particular of semiconductor sensors according to the particular experimental requirements.

• **We push the limits of knowledge extraction**Our Facilities and experiments provide high quality data – both real and model based - of un-precedented complexity and volume at ever increasing rates. We will heavily invest in people and in developing advanced methods for extracting the scientific knowledge from these re-sources while providing software and hardware infrastructure that will enable scientists to optimally deal with the future volume, variety, velocity and veracity of scientific data in Matter.

**2.2 Technological challenges**

To achieve our goals we must create the necessary technological preconditions. This generally involves pushing the limits of the technically feasible. In the coming years, we will address the following challenges:

• **Construction and implementation of the experiments for the HL-LHC**The planned high luminosity operation at the LHC confronts the detectors with enormous challenges. Construction and commissioning of the detectors is a central goal of the coming years. Here, DESY will assume a central role in Germany and worldwide.

• **Development of novel sensors and detector systems for future experiments of particle, hadron and astroparticle physics, and FELs**

With the rapidly increasing performance of accelerators and radiation sources and with large new observatories, detector systems and the gain of knowledge from data must keep pace.

The number of pixels and the integration density of particles and X-ray detectors massively in-crease and this allows us to develop detectors of so far unrivalled capacity.

• **Technology development for the advancement of accelerator facilities**

To adapt the accelerator facilities of our Research Field to the ever increasing user requirements regarding the performance parameters, we develop the superconducting radio frequency technology for the efficient CW operation and new concepts and technologies to fulfill the in-creasing demands concerning beam intensity, stability and quality. We further advance our methods and techniques for the diagnosis and control of particle beams.

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**3.2 Positioning of the Programs**

**Program *Matter and Technologies*(MT)**Accelerators, detectors and data are the basis for experimental research in the Research Field Matter and they define the three central topics of the Matter and Technologies program. With the MT program, the centers DESY, FZJ, GSI, HZB, HZDR and KIT – through intensive and coordinat-ed cooperation between the centers participating in MT and with other programs of the Research Field Matter – laid the foundation for speeding up and optimally use the technological progress. This procedure attracted interest and imitation worldwide. In the new funding period we will bundle the efforts in the field of data – data taking, recording and processing – in a new topic. This topic as well as the remaining part of MT is closely networked with the two other Matter programs.

**Topic *Detectors (DTS)*(DESY, GSI, KIT)**We see a great potential in the development in the field of highly granular, pixelated detector sys-tems. The main challenge will be to keep pace with the developments with regard to readout and detector integration. Therefore, we will set a focus on the development of intelligent sensors and detector modules, in which part of the data processing is already carried out in the detector. Nevertheless, data transfer is still a challenging task. Here, we see a major opportunity in the intensive development of mixed optical and electronic systems. But we also see important applications for other technologies as semiconductor detectors. Gas filled detectors for example are a cost-efficient and flexible way to instrument large volumes. Here, we approach new concepts to combine high rates and high accuracies. More strongly than hitherto we will focus on the development and operation of cryogenic detectors. These systems have a perfect energy resolution and are unrivalled for numerous applications which require an extremely low noise level. For the development of modern detectors, test facilities are essential. Thus, the DESY test beam plays an important role.

**Ideas for strategy paper PoF V**

**Chapter 3 Challenges PoF V**

* Total length for all of Matter: 1 page
* General introduction of the Research Field: 1/3 page
* Then approx. **9** major scientific challenges & technological questions
* Also relate to societal challenges and grand challenges of RF matter
* The challenges may not directly relate to DTS or ARD, etc. only, etc.
* If they do: **we need to suggest ~ 1 challenge/question for DTS**
* Which one??
1. How can we increase space, time and energy resolution of detectors by orders of magnitudes to exploit the science potential of current and future experiments and facilities?
2. How can we exploit the opportunities of quantum computing and artificial intelligence in real-time data analysis and minimize data volumes?
3. How can we cope with dramatically increasing data rates in a sustainable way?

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**Chapter 4 Mission and research objectives**

**Chapter 5.1 Scientific positioning**

* Total length for all of Matter: 3 pages
* 1 page for all of MT
* Max. 1/3 of a page for DTS
* What is the essence of our DTS message??

1. We explore novel and innovative technologes and make them fit for applications in detector systems of Matter

2. In doing so we closely collaborate with industry – e.g. the microelectronics industry –

and ensure technological sovereignty of key technologies in Matter

3. We conceive novel detection principles and systems and thus enable future experimental facilities and best exploitation of their science potential

4. Sustainability is a major concern of DTS. We try to minimize our ecological footprint in our research and provide climate-friendly detector systems. We e.g. minimize power consumption by design and technology choice. We explore innovative, sustainable materials. We minimize data values and throughput by intelligent online analysis and reconstruction methods. We thus enable maximum science output at reduced power and CO2 budget.

5. We rely on and develop sophisticated infrastructures for fabrication and characterization of detector components and systems, like test beams, cleanrooms, ….

and make them accessible for our partners

6. We consider application of our research beyond Matter and make your technologies available to interested partners