MATTER AND TECHNOLOGIES

Matter and Technologies

PoF V Planning for FH

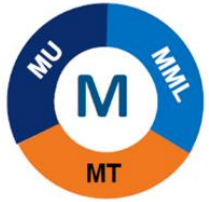
Friederike Januschek

FH Retreat 21.7.25

HELMHOLTZ

Accelerators, Detectors, Data

Helmholtz Matter and Technologies (MT) program (PoF IV)



MATTER AND TECHNOLOGIES M T DESY.

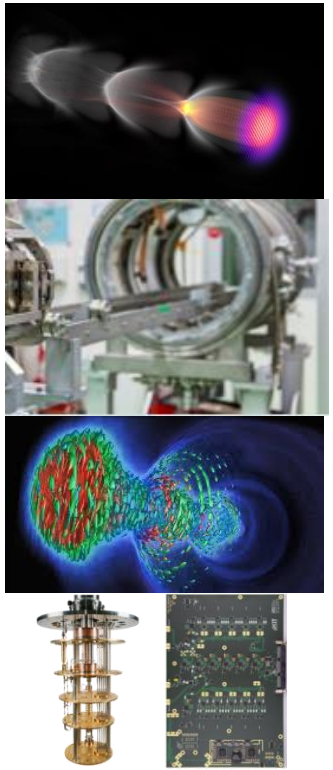
Matter and Technologies

Accelerator Research and Development — DESY, FZJ, GSI, HZB, HZDR, KIT — M T ARD — 75%	Andreas Jankowiak (HZB) Hans Weise (DESY)
Detector Technologies and Systems — DESY, GSI, KIT — M T DTS — 15%	Silvia Masciocchi (GSI) Marc Weber (KIT)
Data Management and Analysis — DESY, FZJ, GSI, HZB, HZDR, Hereon — M T DMA — 10%	Michael Bussmann (HZDR) Philipp Neumann (DESY)

LK II Research Infrastructures

IDAF — DESY — M T IDAF	Yves Kemp (DESY) Christian Voss (DESY)

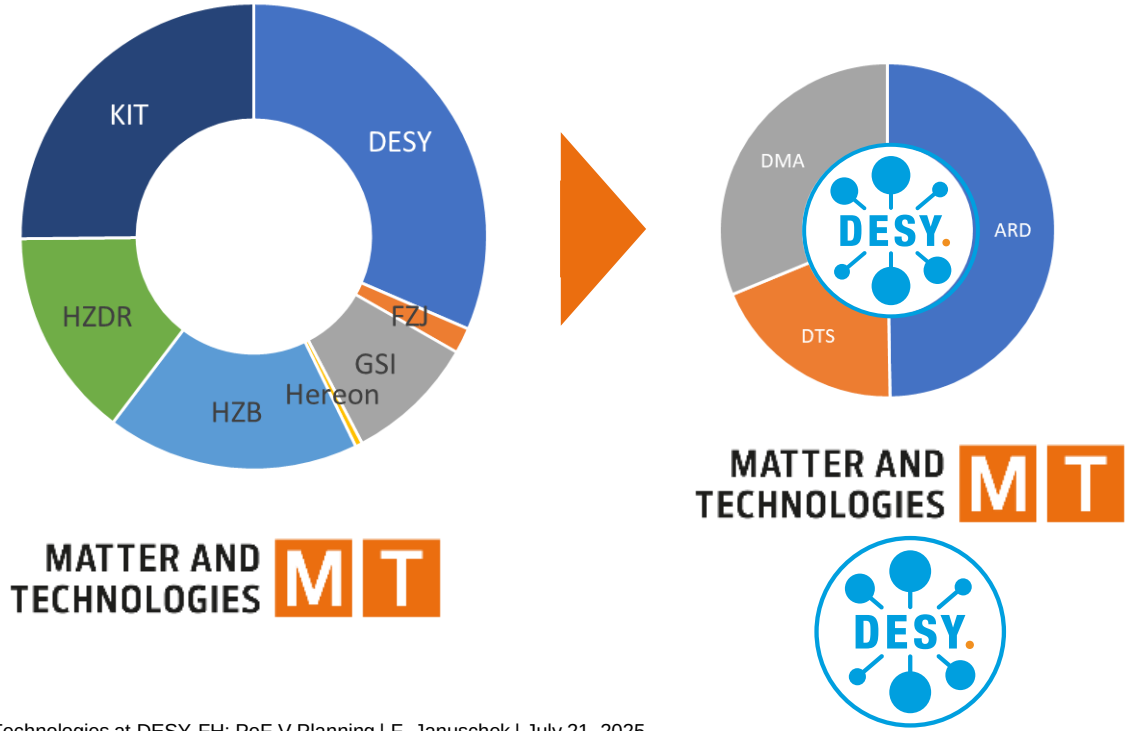
Total Budget
87 Mio EUR in 2024, 300 scientists in 7 centers and 2 Helmholtz institutes



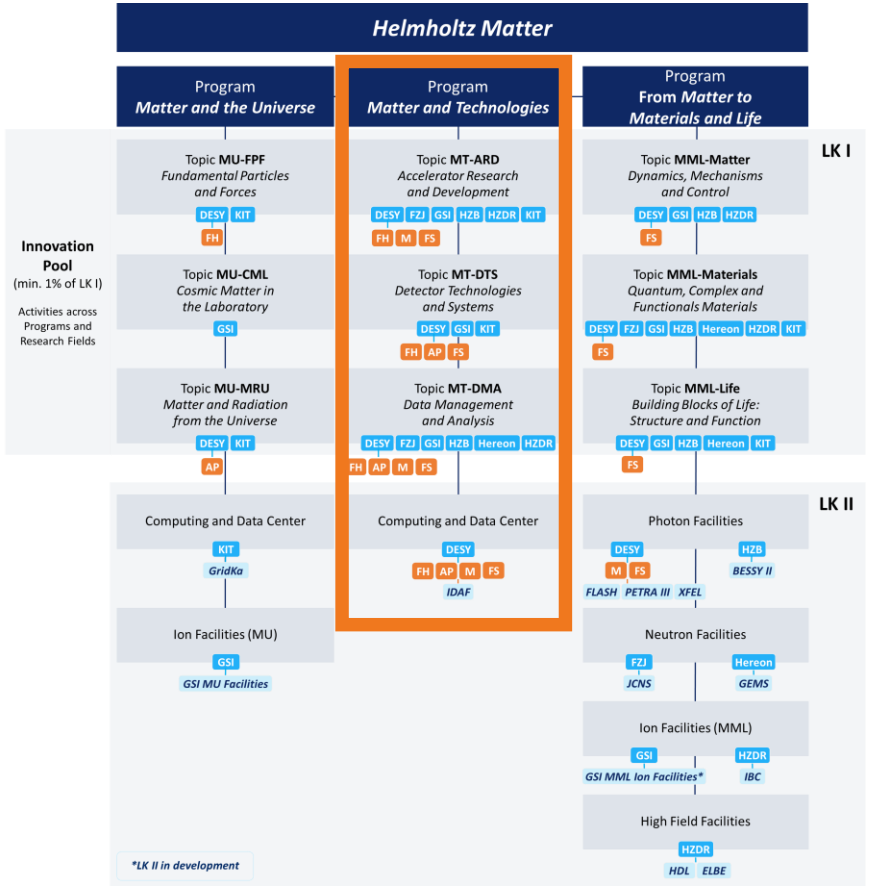
Driven by science and driving science.

DESY plays a central part in MT: PoF IV status

MT is a strong team with DESY an integral part



MT: A cross-divisional activity



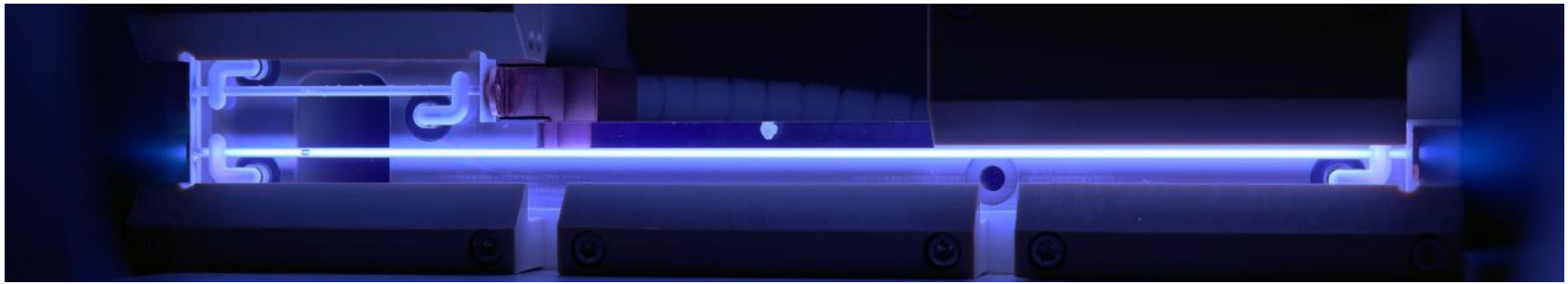
Mapping to DESY divisions

	Accelerator	Photon	Particle	Astroparticle	Core-funded (DESY)
ARD	■	■	■		19.7 Mio, 39.1 FTE
DTS		■	■	■	7.3 Mio, 18.3 FTE
DMA	■	■	■	■	9.9 Mio, 32.6 FTE

DESY-FH has large contributions in MT-DTS and MT-DMA and a smaller, but important contribution in ARD.

MT-ARD @ DESY

- MT-ARD @ DESY is a common effort of M, FH and FS, with M being the largest contributor
- Key aims for DESY:
  - Proof of concept of efficient HDC/CW SRF (XFEL upgrade)
  - Developing reliable plasma accelerators
- FH contribution (about 9 FTE) within FTX-AST:
  - FLASH-FORWARD ➔ Beam-driven plasma wakefield research, together with M



MT-ARD @ DESY-FH

FLASHForward Goals: Mid-term future

Matthew Wing
Stephan Wesch

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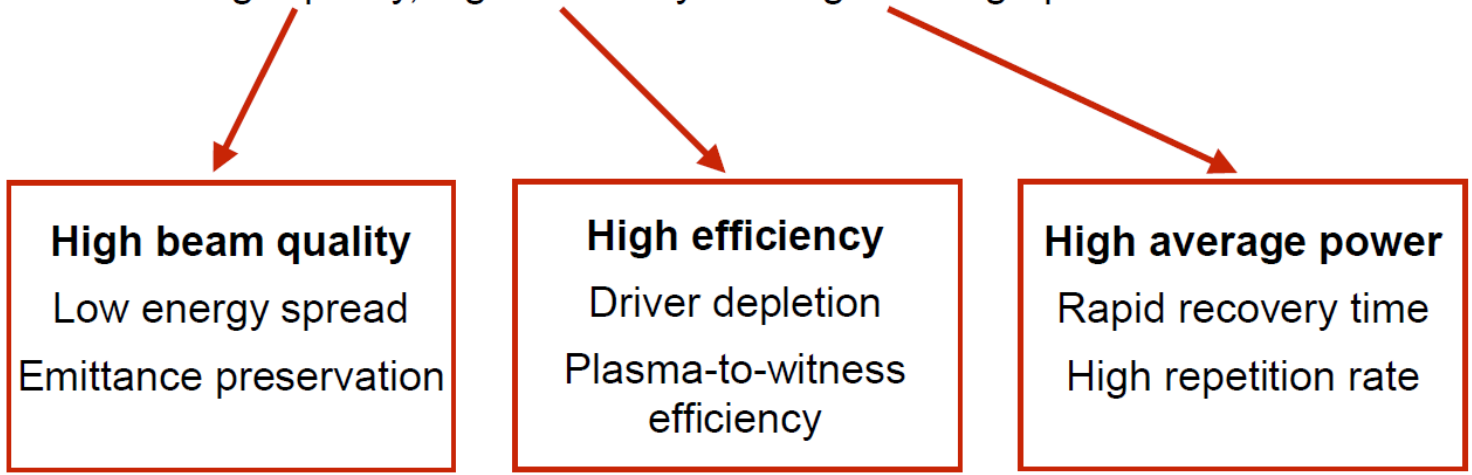
Develop a self-consistent plasma-accelerator stage
with high quality, high efficiency and high average power at 1 GV/m



All combined with >1 GV/m with energy gain as large as possible and as stable as possible.

MT-ARD @ DESY-FH

Longer-term goals

Matthew Wing
Stephan Wesch

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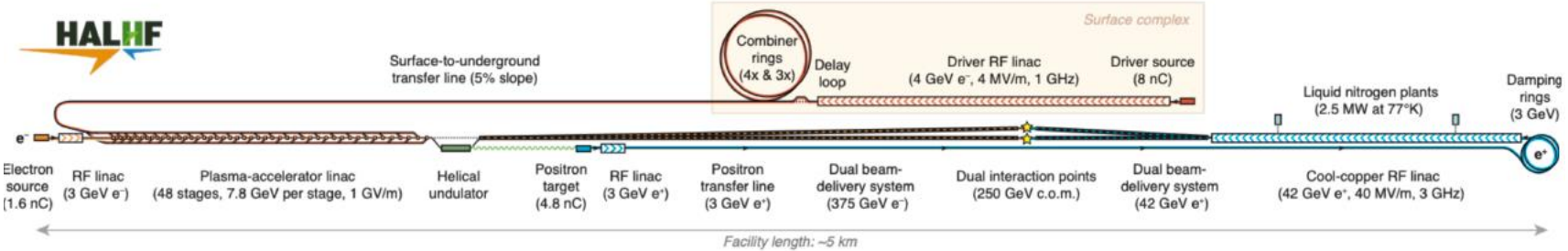
- Going to higher energies:
  - ELBEX / EuXFEL booster for high energy?
  - HALHF demonstrator?



MT-ARD

MATTER AND TECHNOLOGIES MT

Continuous development of the very successful ARD sub-topic structure

	2021 – 2027 PoF IV	2028 – 2034 PoF V
ST1	Advanced CW SRF-Systems	SRF systems for sustainable applications
ST2	New Concepts and Prototypes for Maximizing the Performance of Hadron & Electron Accelerators	Efficient and High-Performance Hadron & Electron Accelerators
ST3	Advanced Beam Control, Diagnostics and Dynamics	Tailored 6D Beam Dynamics, Diagnostics, and Intelligent *(Beam)* Control
ST4	Ultra Compact, Novel Accelerators and their Applications	Plasma Accelerators and their Applications

5 centres & 2 Institutes

DESY. GSI HI JENA HIM HZB Helmholtz Zentrum Berlin HZDR KIT

R&D for outstanding science & technologies

& disruption

Within PoF V DESY will contribute to all subtopics, with a clear focus on ST3 (Beam Control) and ST4 (Plasma)

Contribution to Competence Team Optical Technologies (OPT)

MT-DTS @ DESY

- MT-DTS @ DESY is a common effort of FH, FS and AP.
- Main drivers @DESY are and will be **systems** for experiments in MU and MML
- FH contributes about half of the FTE in MT-DTS, FS about a third.
- FH DTS FTEs (around 30 in PoF V) are distributed amongst the FH groups (FTX, ATLAS, CMS, BELLE, ALPS, FE), with many people contributing to both MT-DTS and MU-FPF.
  - Detector activities in FH are formally part of **MT-DTS** (R&D) as well as **MU-FPF** (construction).
- Infrastructures are key for our activities: in particular DESY testbeam (MT) and DAF (currently MU)
- Key **recommendations** from scientific review:
  - *„ DESY would benefit from a dedicated, more centrally coordinated, detector development group“*
  - *“The proposed Distributed Detector Laboratory (DDL) would offer a tremendous opportunity“*

MT-DTS @ FH

Key components for PoF V activities

Moritz Guthoff
Katja Krüger

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- Next generation **trackers** and **calorimeters** are required to provide **high resolution**, additional measurements such as **timing** and **energy**, while consuming **little power** at **reduced non-detection related mass**.
- Maximising **data processing on the detector** is paramount to achieve performance targets and to keep the needed data transfer under control.
- Strategy:
  - High level of integration allows for scalability while keeping system complexity under control
  - High bandwidth data transfer at low power consumption
- Key technologies to address these challenges
  - CMOS based sensors
  - Photonic transceivers
  - Advanced interconnects and wafer bonding
  - Advanced cooling techniques

MT-DTS @ PoF V

Preliminary structure

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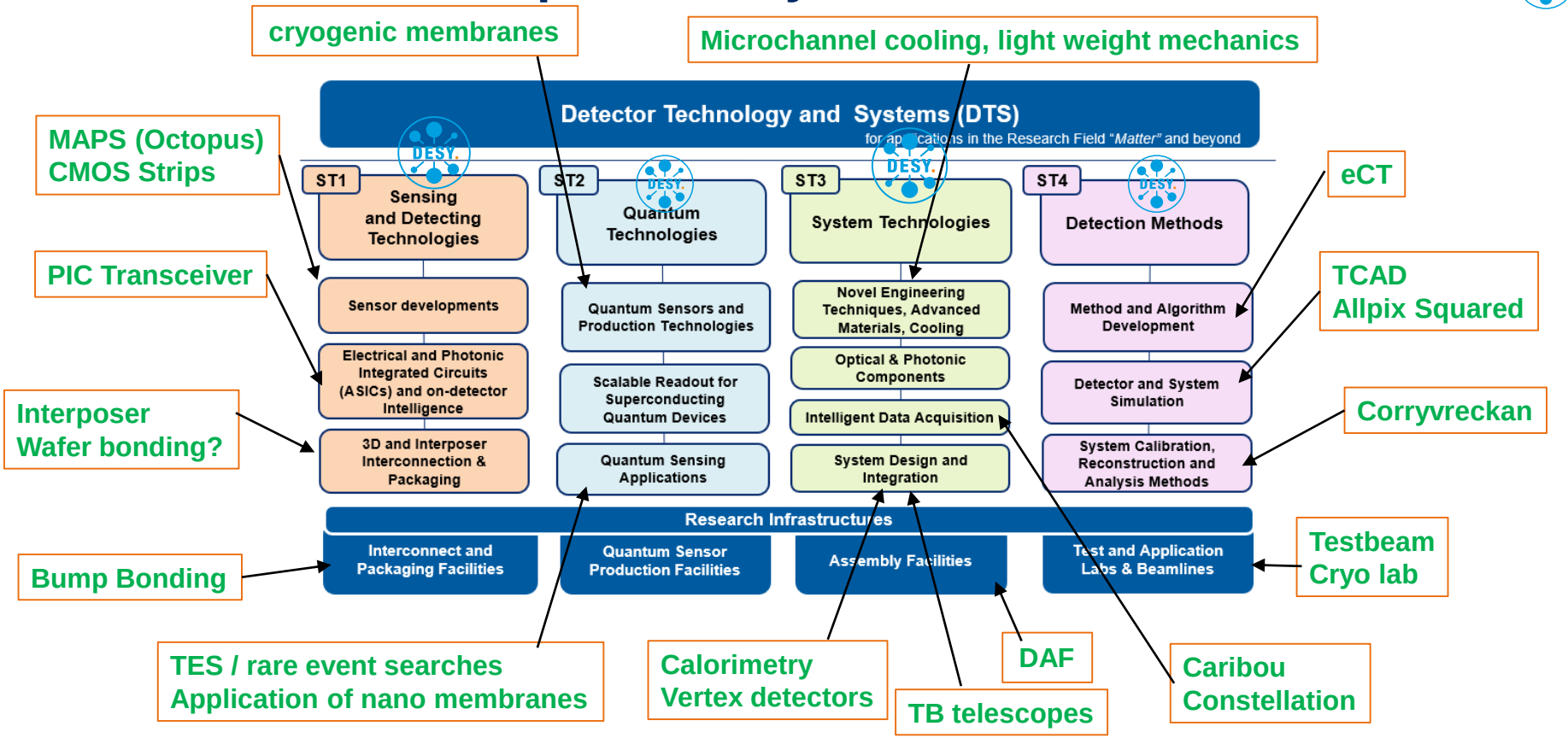
Detector Technology and Systems (DTS)

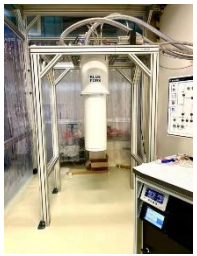
ST1	ST2	ST3	ST4
Sensing and Detecting Technologies	**Quantum Technologies**	**System Technologies**	**Detection Methods**
"Realize intelligent and compact granular detectors with high space and time resolution"	"Establish highly pixelated quantum sensors with ultimate energy resolution"	*"Build sustainable detector systems and cope with drastically increasing data rates"*	"Integrate advanced detector systems into multidimensional modalities for scientific discovery"

DTS FH activities in preliminary PoF V structure



Infrastructure for Detector R&D

- Test beam: Essential work horse for detector development in particle and nuclear physics.
  - Currently available test beams: 1-6 GeV electrons. 3 beam lines
  - With PETRA IV, a new test beam facility is needed, concepts are being developed
  - New beam telescopes: synergy with detector technology development
- Detector Assembly facility (DAF)
  - Currently fully in use for LHC upgrades (expected until 2027)
  - Large clean rooms with equipment for detector assembly, testing, mechanical integration, cooling tests, metrology etc.
  - Formally belongs to MU-FPF
- Smaller detector labs
  - e.g. Cryogenic detector labs
- Workshops



MT-DMA @ DESY

- MT-DMA @ DESY is a common effort of FH, FS, AP and M
  - FH and FS about equally contributing, AP and M smaller
- Vision for DESY:
  - Be at the forefront of computational and data science for the research field Matter, jointly and sustainably addressing the complex challenges of big data, simulation, and scientific computing.
- FH DMA FTEs (around 27 in PoF V) are distributed amongst the FH groups including IT, with many people contributing to MT-DMA and MU-FPF in parallel.
- IDAF as infrastructure associated to MT with a clear connection to DMA
- Key **recommendations** from scientific review:
  - *„While there is expertise in AI/ML distributed around the DMA effort, there seems to be no dedicated person or organizational structure specifically responsible for developing or coordinating a strategic vision for AI/ML and data science.“*
  - *“There are multiple examples of excellent software development practices leading to impactful cyberinfrastructure. There is an opportunity to build on this success and continue spreading these best practices to other parts of the lab.”*

MT-DMA @ DESY-FH

Philipp Neumann

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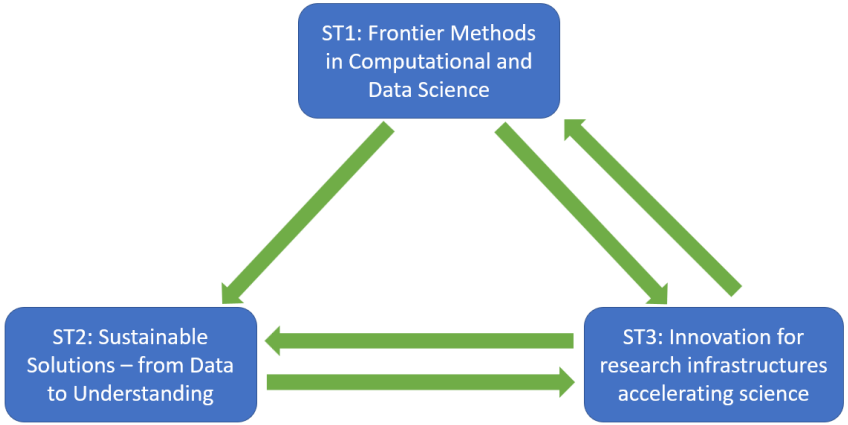
- Key DESY-FH topics:
  - Artificial Intelligence
  - Data- and Metadata storage (e.g. dCache, MDC for on-site)
  - Research software engineering hub (e.g. key4HEP)
  - Autonomous experiments (autonomous beamlines a key topic within DESY, might profit)
  - Sustainable dynamic energy use and resource provision for large infrastructures
  - AI-based procedures for monitoring and digital twin technology for distributed computing infrastructures (IDAF)
  - Quantum computing applications



MT IDAF

Yves Kemp
Christian Voss

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Interdisciplinary → Photon science MML Accelerator R&D MT
(Astro-)particle physics MU

Data and → Data centric concepts and implementation

Analysis → Designed for the diversity of analyses

Facility. → Supporting the complete data lifecycle

- Key goals for PoF V
  - Enabling the large, PoF V data sources (HL-LHC, PETRA IV, BELLE, CTAO, XFEL)
  - Serving the smaller onsite experiments
  - Digital twin for sustainable data center
  - Integration of AI at all levels of user interaction
  - Support novel analysis techniques (e.g. columnar analysis): Interplay Users<==>IDAF
- TIER Upgrade

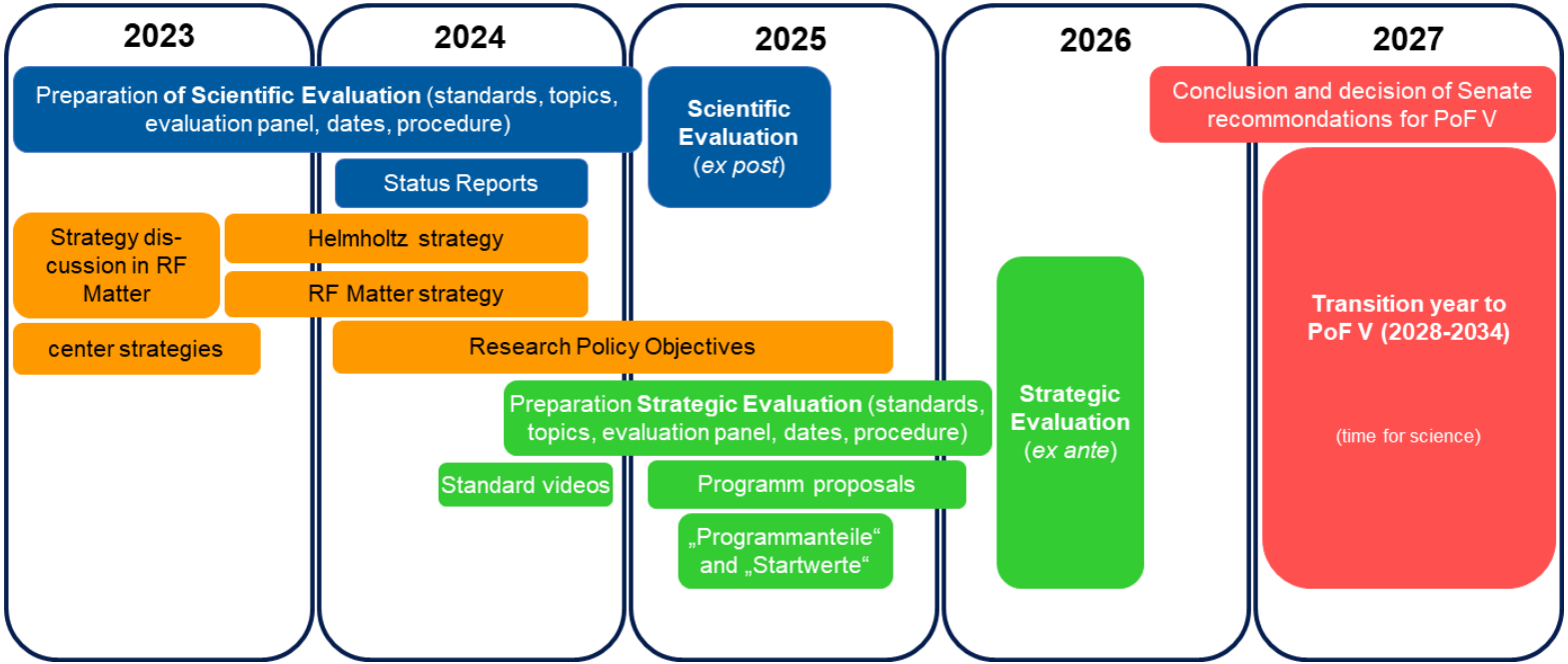
Summary: MT @ DESY-FH

- Planning for MT in PoF V is in full swing
  - Three topic structure ARD, DMA, DTS remains unchanged
  - Smaller changes including more weight to sustainability, optical technologies, quantum
- MT at DESY-FH very well positioned, key partner in all topics
  - Focus ARD: Plasma (FLASHForward)
  - Focus DTS: Systems, Pixel detectors, Data
  - Focus DMA: AI methods, Sustainability, Infrastructures
- Points under discussion for MT@DESY-FH
  - How to strengthen cross-divisional coherence and cooperation?
    - Data, in particular AI
    - Detectors
    - Synergies with PETRA IV
  - Infrastructure development: Test beam in times of PETRA IV, future of DAF, „DDL“-like project?

Backup

Timeline for PoF V

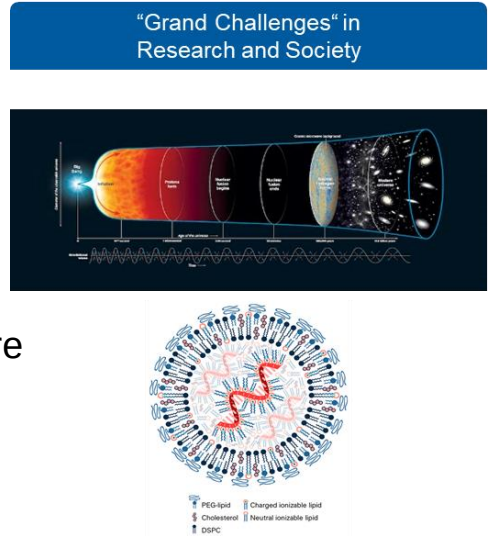
Preparations for PoF V in full swing



An infrastructure proposal to make a difference for Matter

DDL: current status and prospectives

- DDL: a key strategic initiative to make cutting edge detector infrastructure available to Matter
- All participating centers got recommendations to try again for a DDL like structure



We should think carefully how a new Ansatz for a central DTS activity can be defined and – eventually - funded

Topics of Interest & Connections to DRDs

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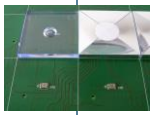
Silicon detector development is a strong focus of our interest

- Monolithic CMOS
- Novel sensors (ELAD, digital SiPM, …)
- Software tool developments
- Involvement in DRD3 (Silicon)

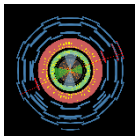
Calorimeter developments

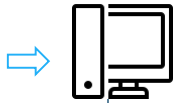
- Highly granular SiPM on tile calorimeter
- Involvement in DRD6 (Calo)



Data transfer

- Silicon photonics
- Advanced interconnects
- Involvement in DRD7 (Electronics)



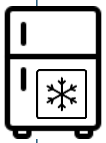


Integration

- Detector integration center
- R&D on light weight mechanics, local cooling and cooling systems
- Involvement in DRD8 (Integration)

Cryogenic detectors

- Transition Edge Sensors
- Developments for axion/dark matter experiments
- Involvement in DRD5 (Quantum sensors)



Infrastructure

- Detector Assembly Facility
- Test beam

Cross topic goal: Build a demonstrator vertex detector based on CMOS technologies

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