Karlsruhe Institute of Technology

Status of KIT test facilities and outlook

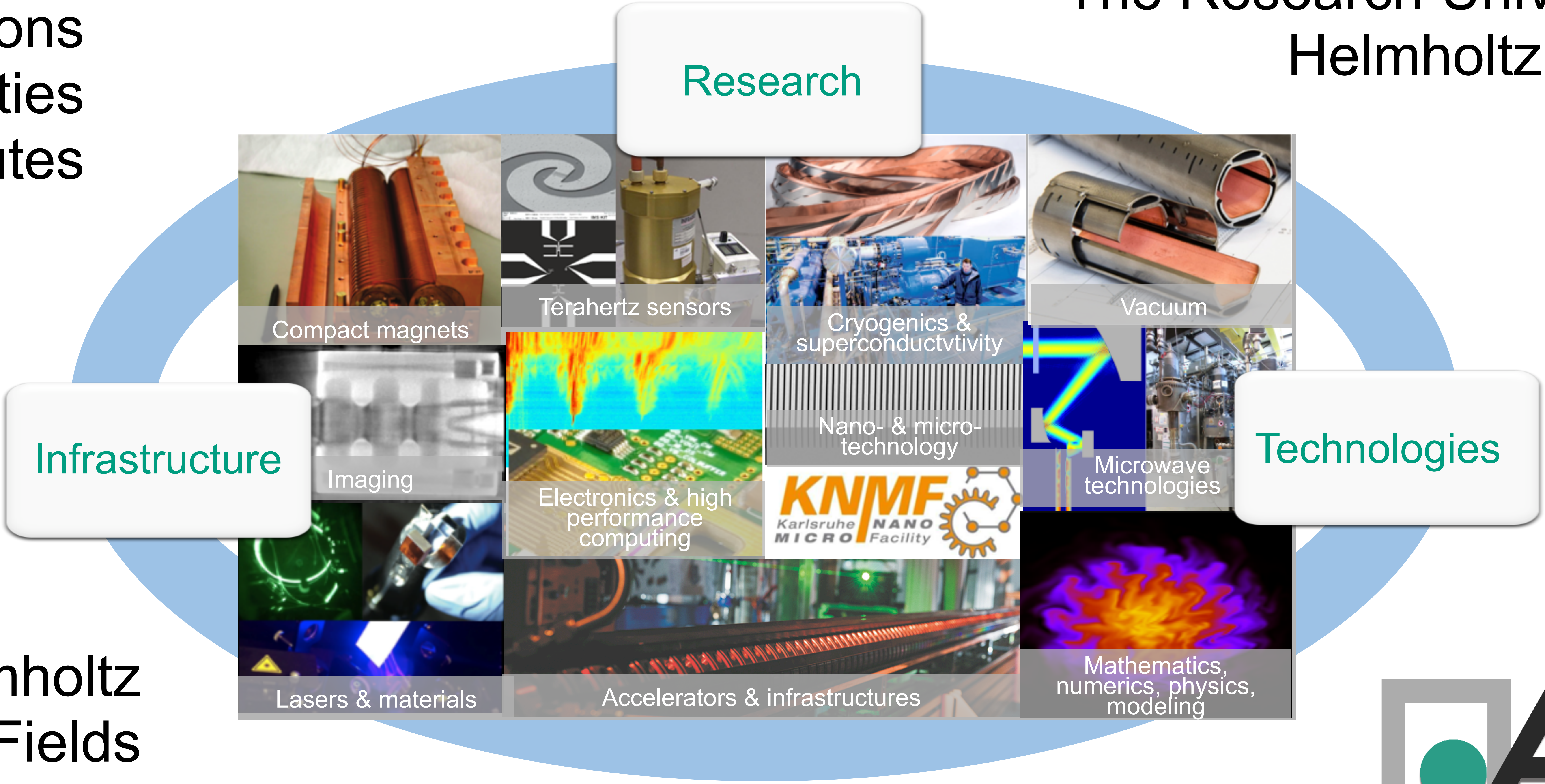
Virtual MT ARD ST3 Meeting 2020 in Karlsruhe
Marcel Schuh for the KIT team

The Accelerator Technology Platform @ KIT (ATP)

Karlsruhe Institute of Technology

5 Divisions
6 KIT-Faculties
11 Institutes

The Research University in the Helmholtz Association



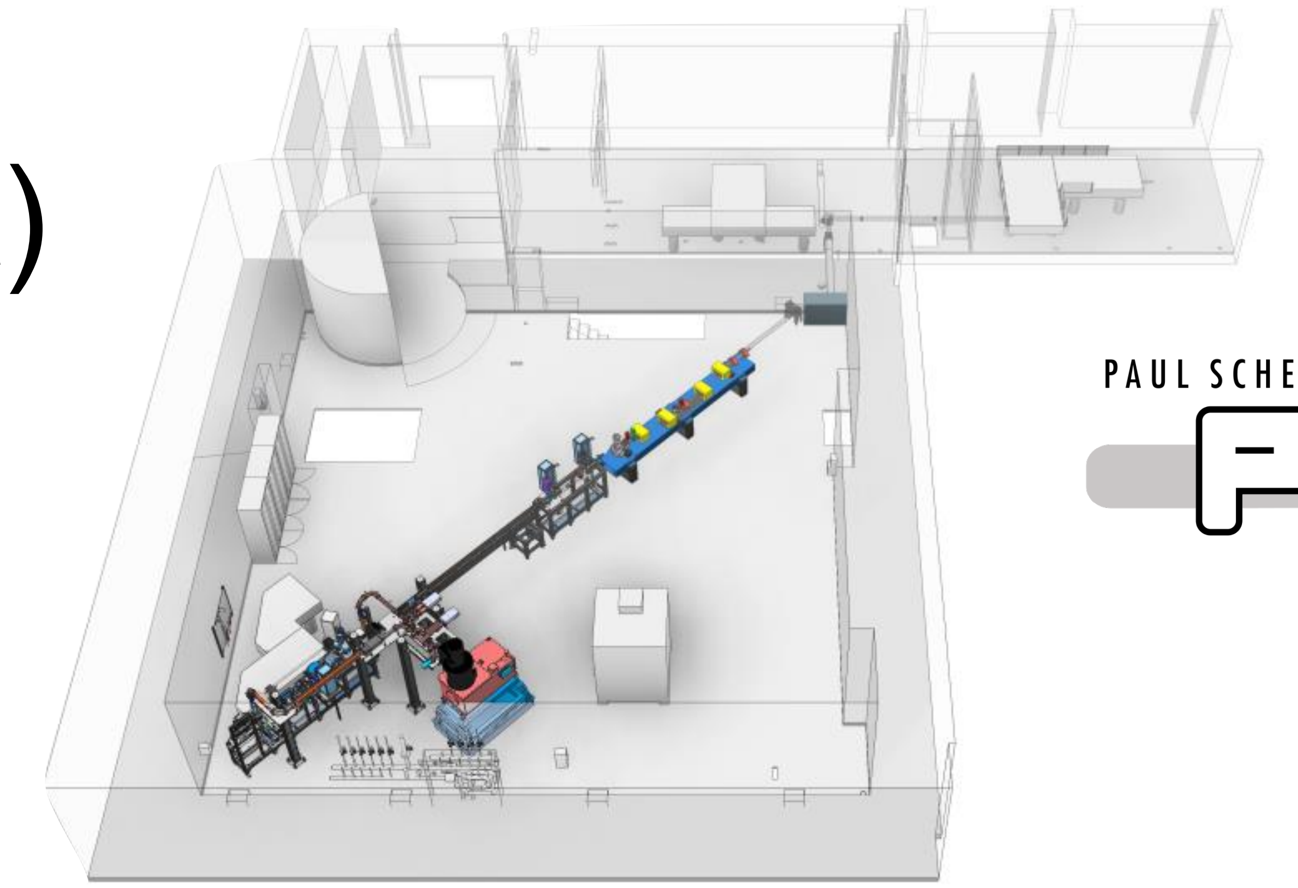
+ strong industrial partners

Helmholtz
3 Research Fields
6 Programmes

Accelerator Technology Platform @ KIT

FLUTE: Accelerator test facility at KIT

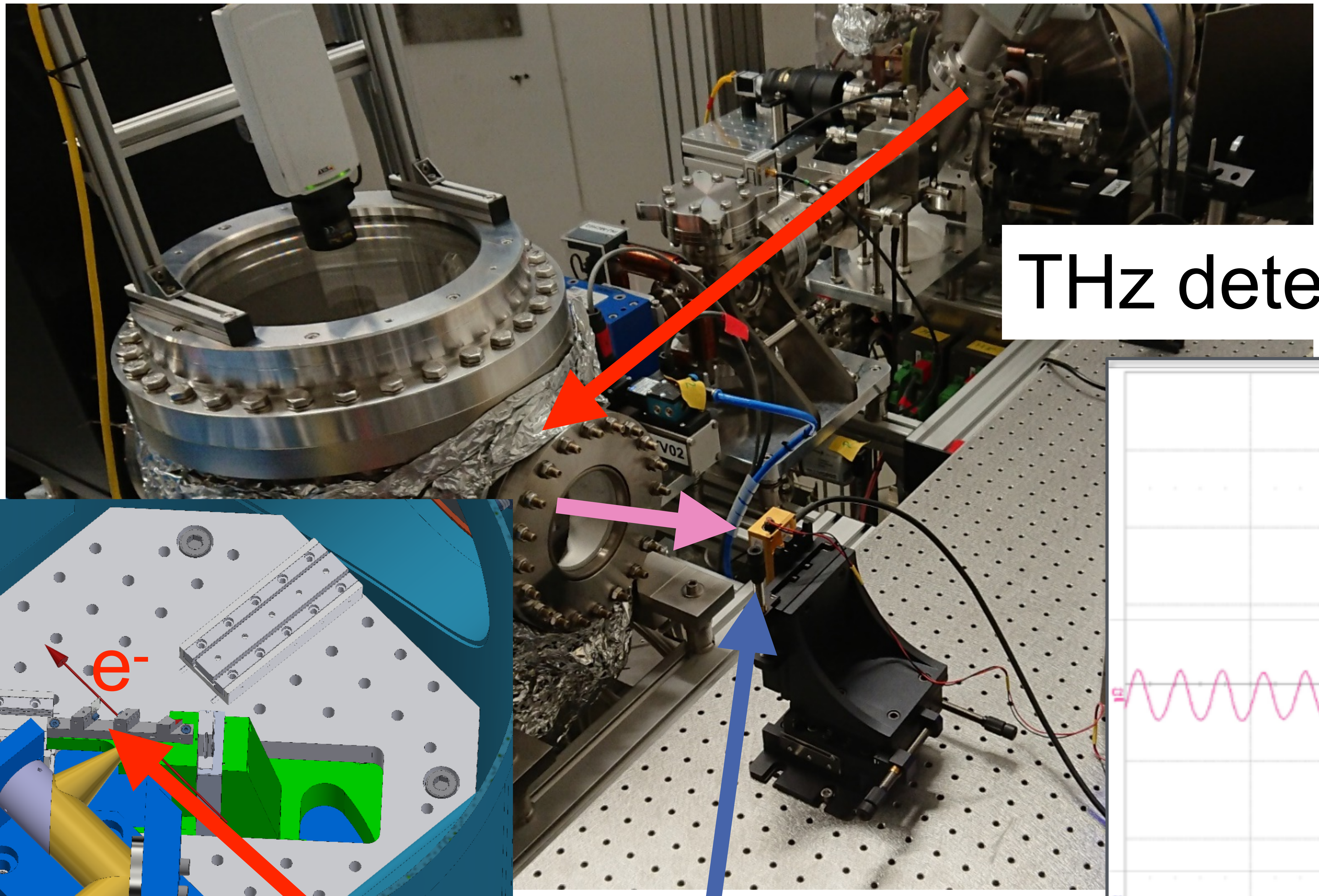
- FLUTE (Ferninfrarot Linac- Und Test-Experiment)
  - Test facility for accelerator physics within ARD
  - Experiments with THz radiation
- R&D topics
  - Serve as a test bench for new beam diagnostic methods and tools
  - Systematic bunch compression and THz generation studies
  - Develop single shot fs diagnostics
  - Synchronization on a femtosecond level

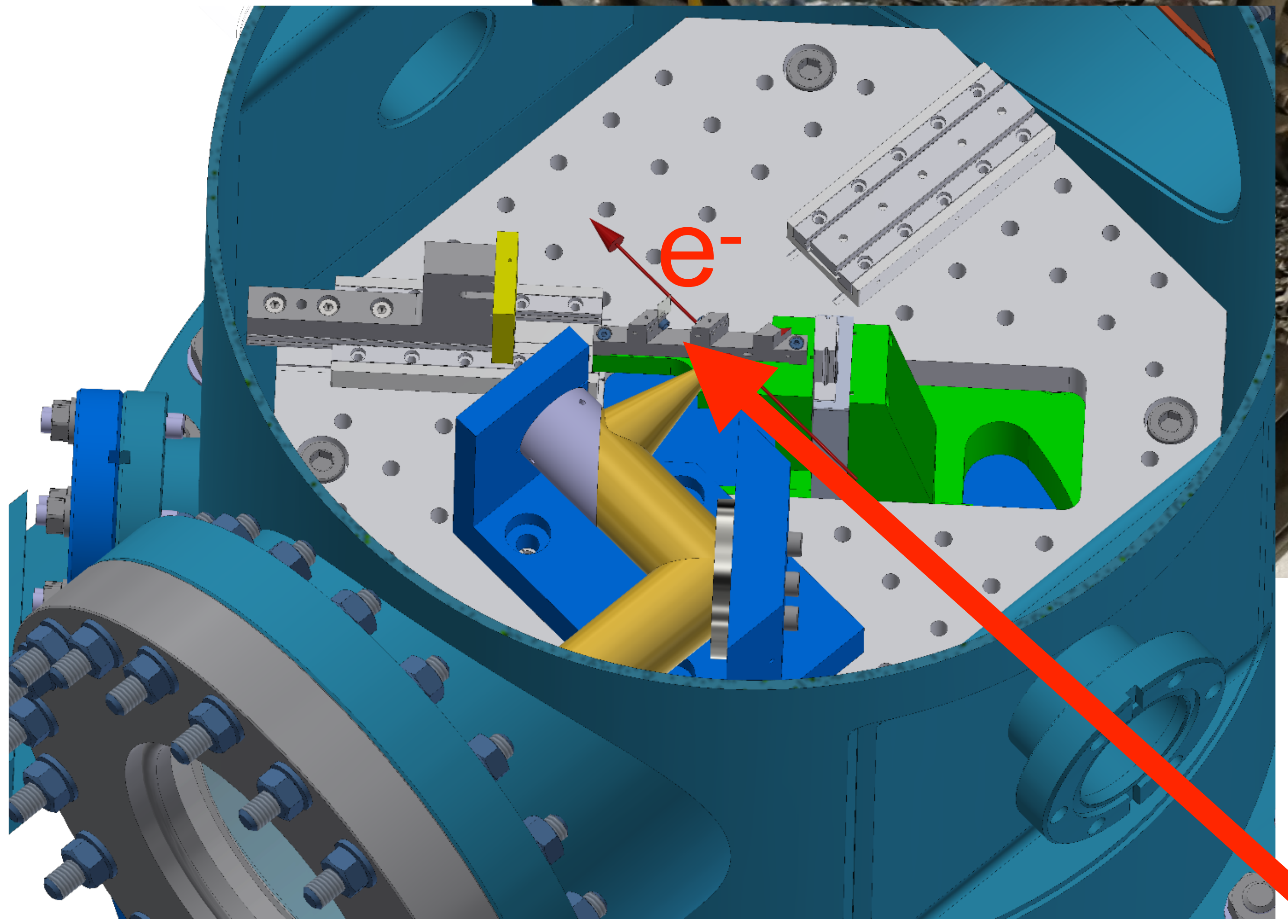


Final electron energy	~ 41	MeV
Electron bunch charge	0.001 - 3	nC
Electron bunch length	1 - 300	fs
Pulse repetition rate	10	Hz
THz E-Field strength	up to 1.2	GV/m

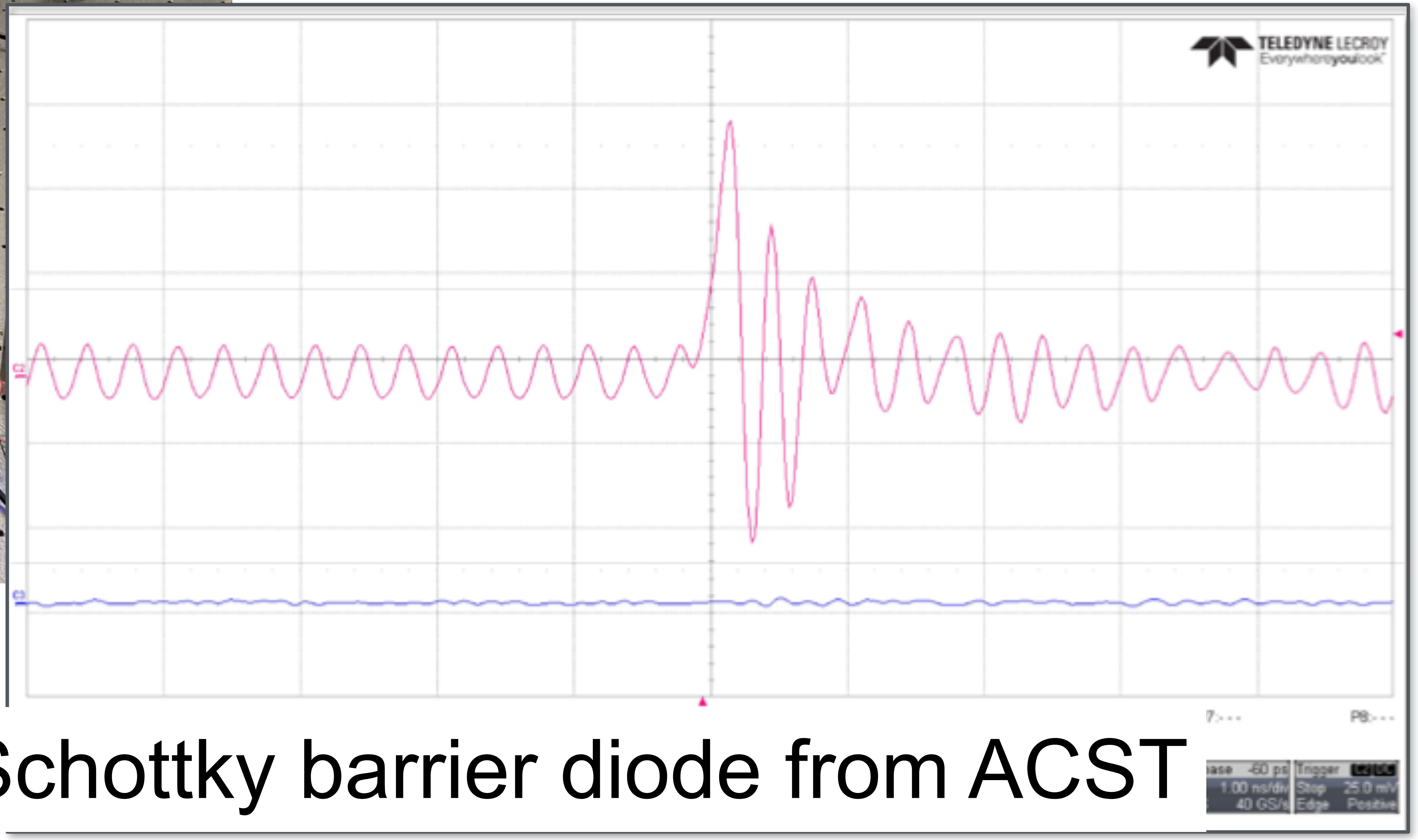
www.ibpt.kit.edu/flute

First electron generated THz signal at FLUTE in February 2020





THz detector signal from transition radiation



broadband Schottky barrier diode from ACST

Courtesy: M. J. Nasse, M. Nabinger

Further FLUTE progress

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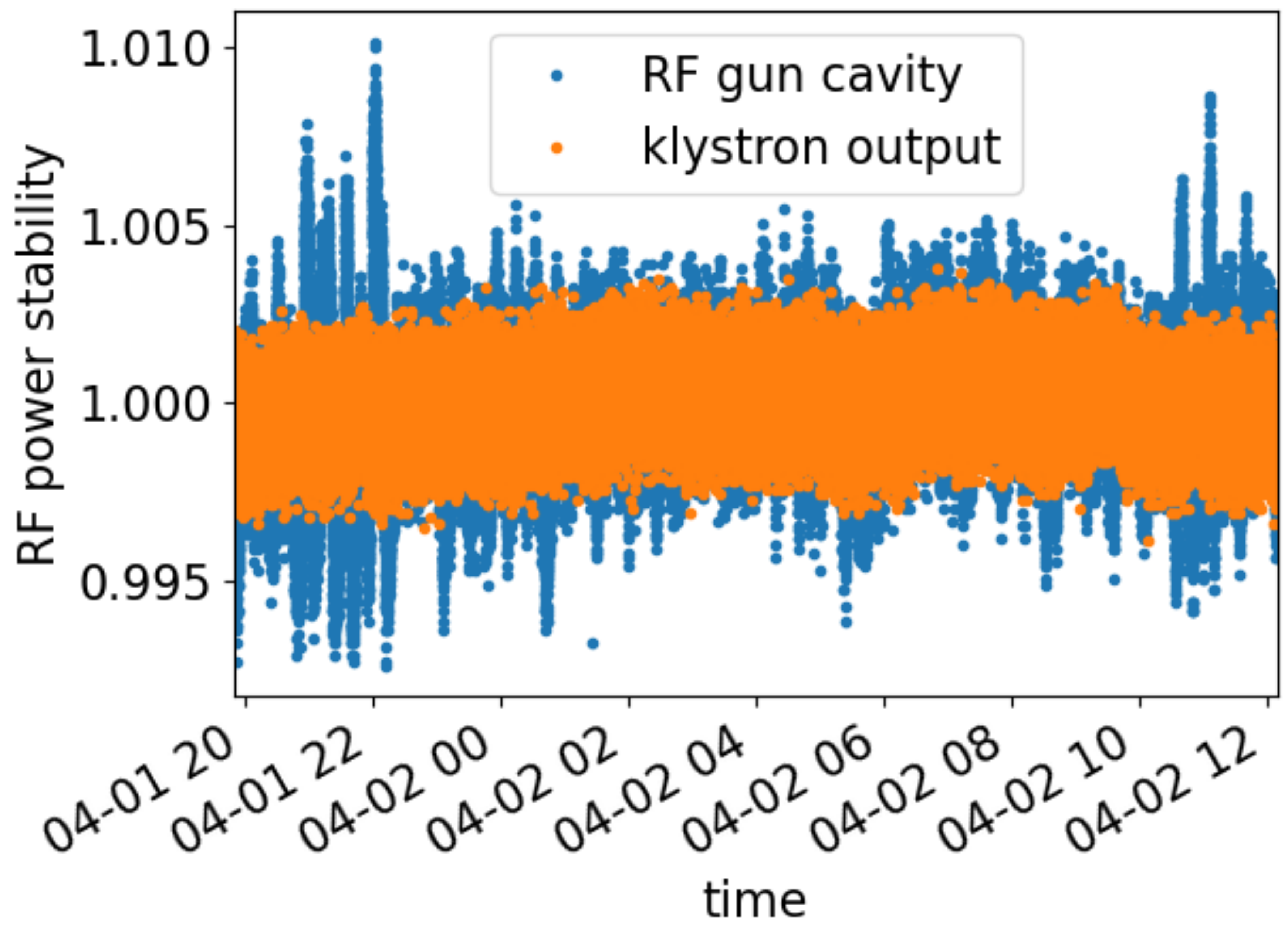
- Gun section fully operational
- Optimized optics setup next to gun in operation
- Longterm stability tests: 2 weeks 24/7 operation
- Closed-loop tuning of the LLRF system in collaboration with DESY
- Improvement of the AC synchronization
- SRR experiment
  - Electron beam focused on SRR
  - Optics for gun & THz generation working
  - THz generation using tilted-pulse-front technique
  - Next: finding temporal and spatial overlap

STalk T. Schmelzer

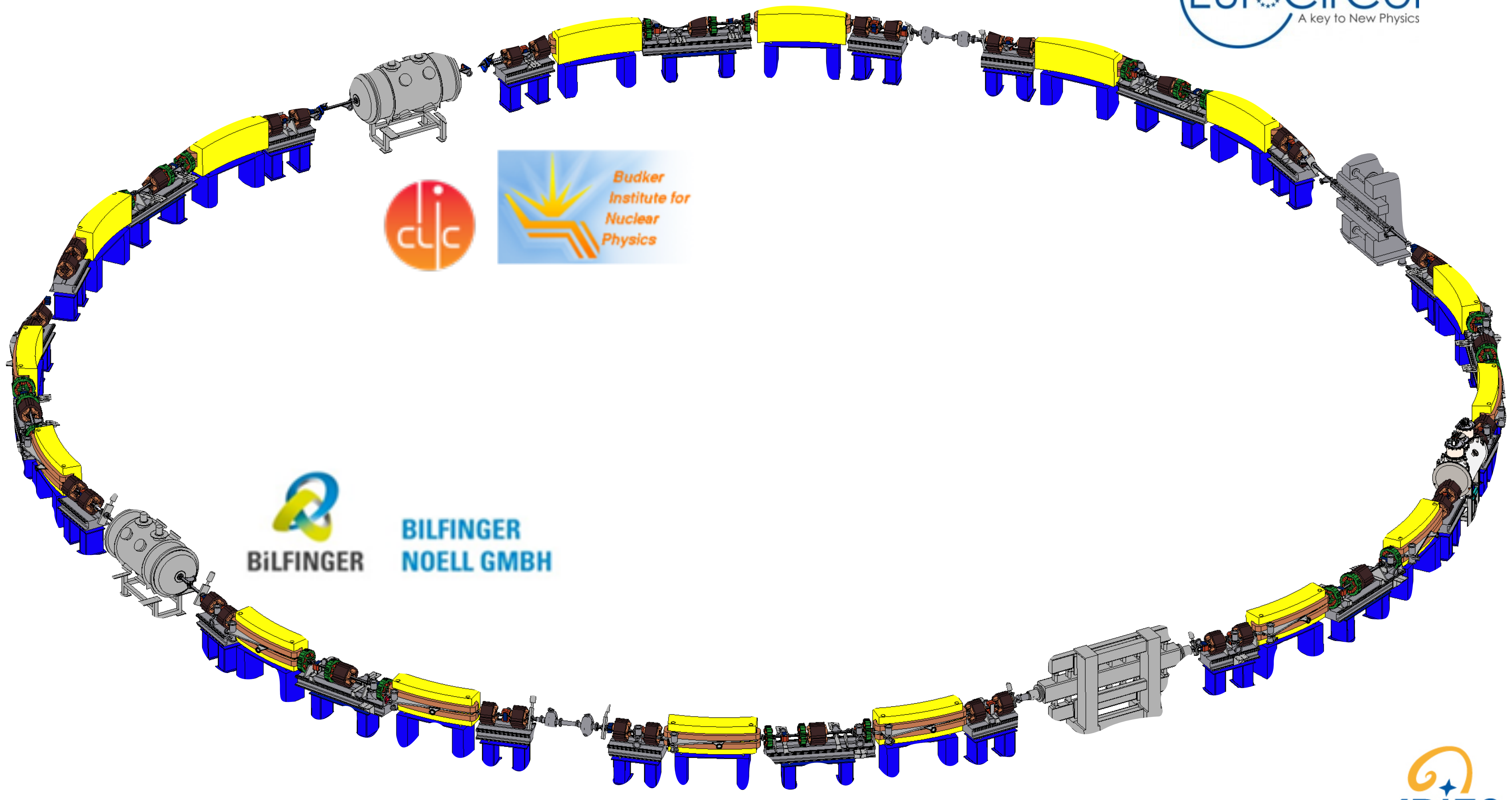
Courtesy: T. Schmelzer



STalk M.J. Nasse

Karlsruhe Research Accelerator (KARA)

- User applications & accelerator test facility
- Key parameters
  - Circumference: 110.4 m
  - Energy range: 0.5 - 2.5 GeV
  - RF frequency: 500 MHz
  - Revolution frequency: 2.715 MHz
  - Beam current up to 200 mA
  - RMS bunch length:
    - 45 ps (for 2.5 GeV)
    - down to a few ps (for 1.3 GeV)

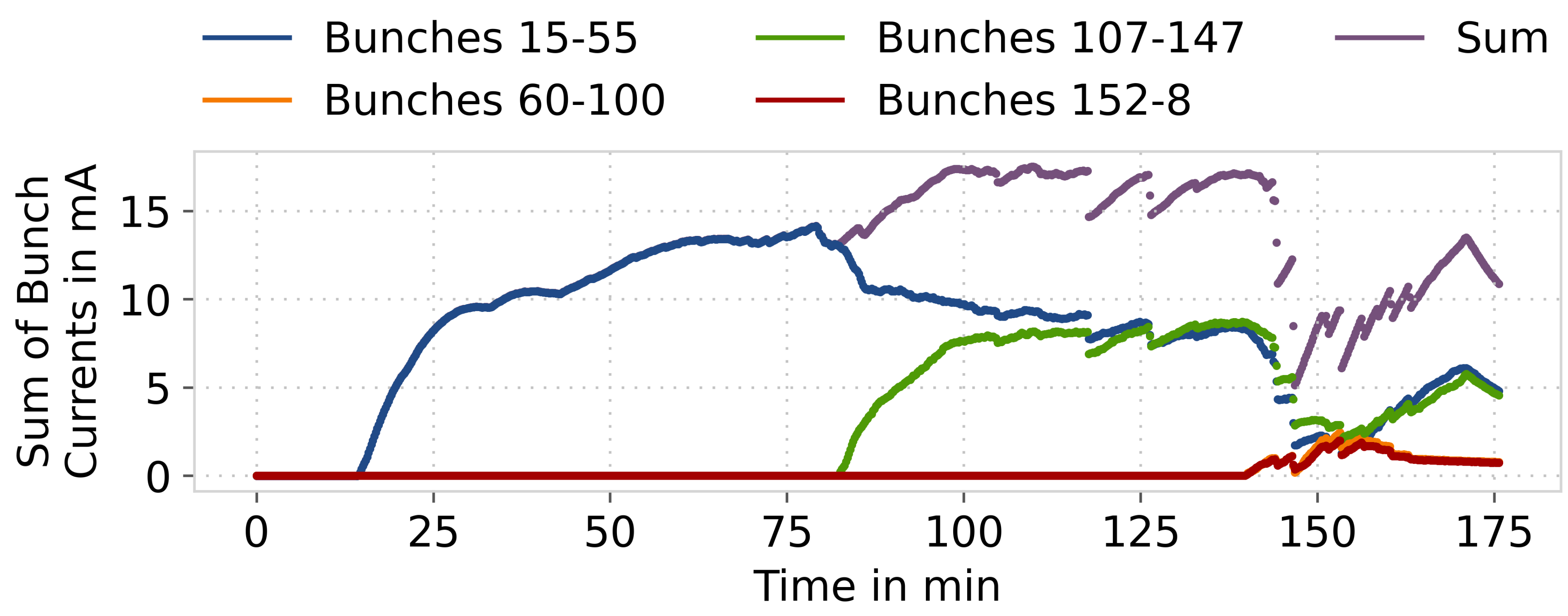


www.ibpt.kit.edu/kara

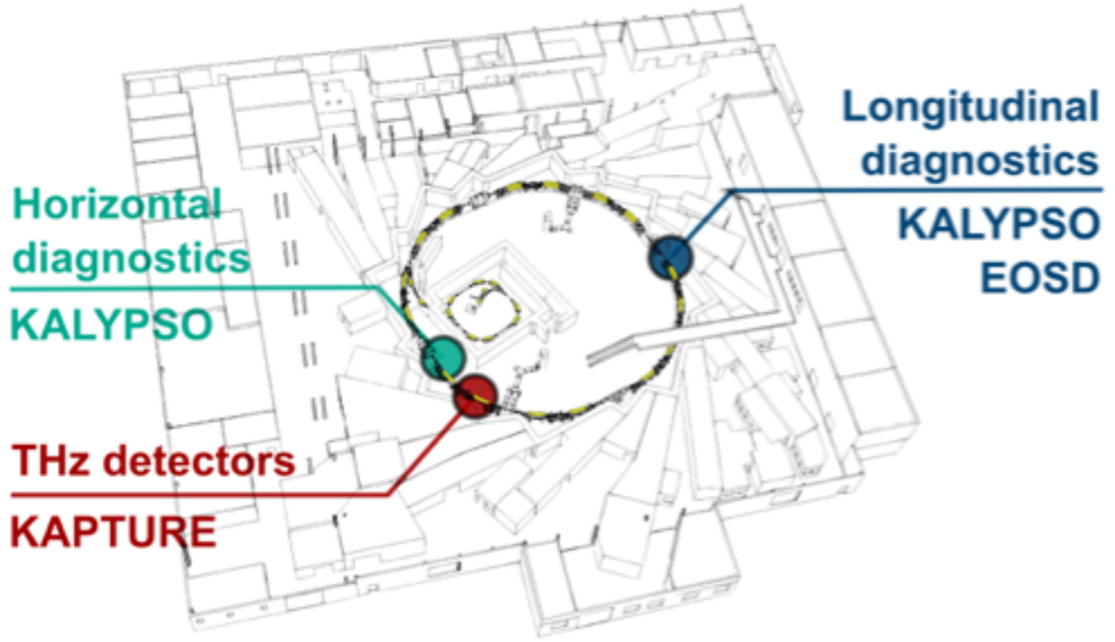
KARA test facility activities

- Probing negative momentum beams
  - Momentum compaction factor α_c
  - Filling pattern
  - Energy (500 - 900 MeV)
  - CSR measurements
- Implementation of an impedance manipulation chamber
  - French-German project supported by ANR & DFG
- KARA Booster as diagnostic test bed for cSTART
  - Similar properties in terms of energy and repetition rate
  - Install new BPM, BLM and BBB electronics

STalk P. Schreiber



KARAs distributed synchronized sensor network



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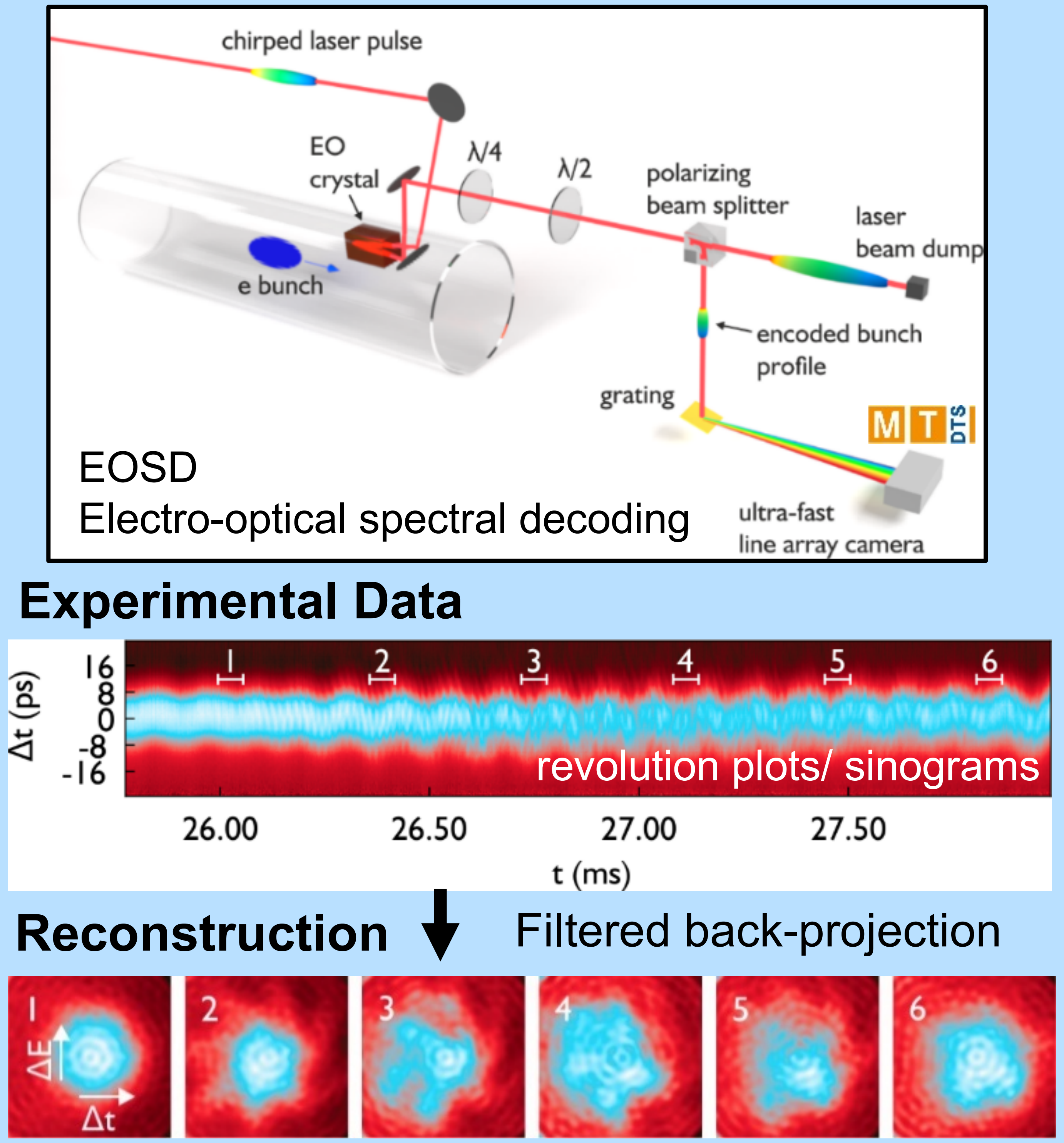
Analyze Longitudinal Phase Space

- **Emitted CSR**
  - THz Detector
  - KAPTURE
- **Energy Spread**
  - Horizontal bunch profile in dispersive section
  - KALYPSO
- **Bunch Profile**
  - Electro-optical spectral decoding
  - KALYPSO

Phase Space Tomography during MBI



phase space density
S. Funkner (KIT) et al.,arXiv:1912.01323

Talk S. Funkner

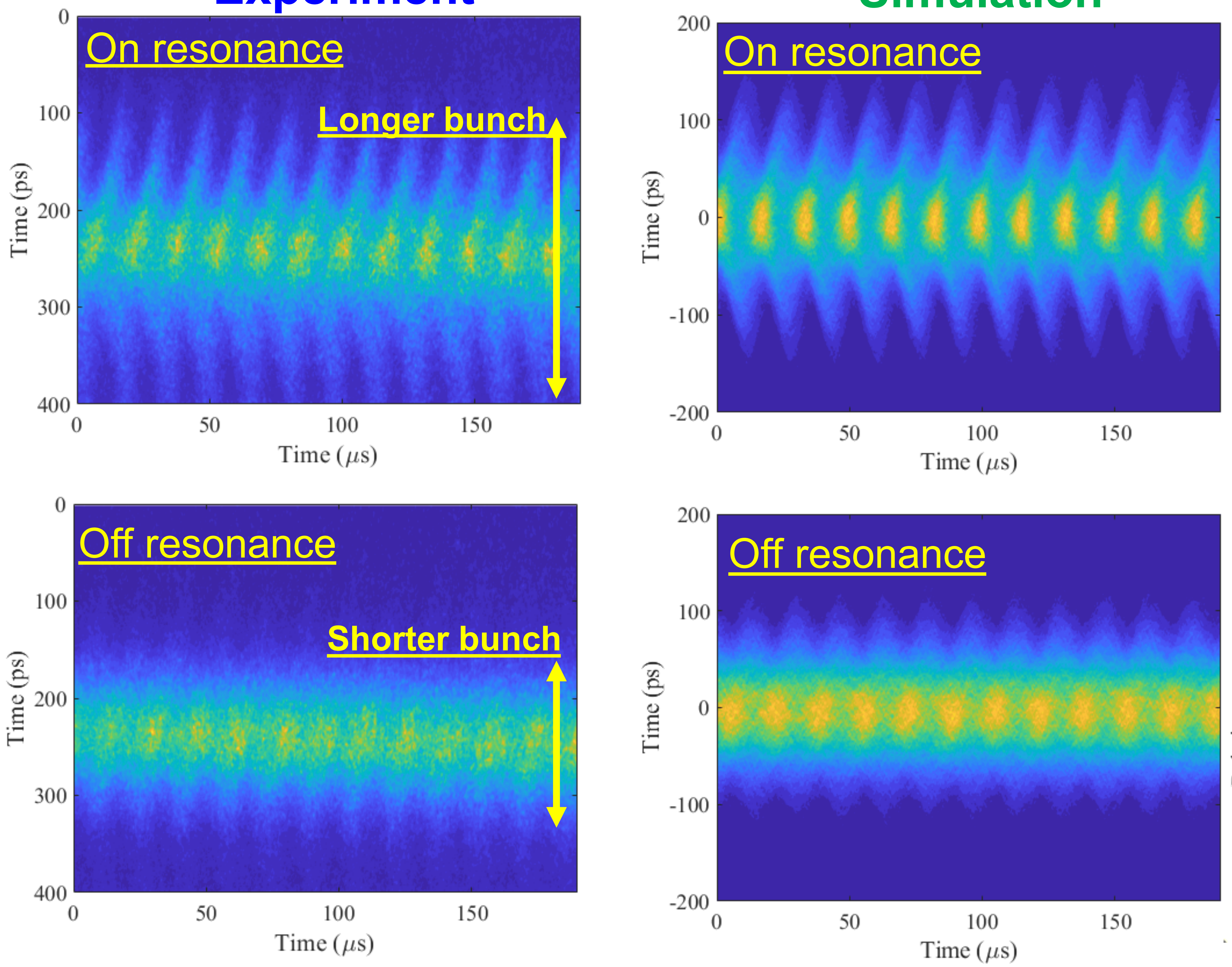
EPS-AG Frank Sacherer Prize 2020 (J.L. Steinmann)

B. Kehrer: Time-resolved studies of the micro-bunching instability at KARA, PhD dissertation
M. Brosi: In-Depth Analysis of the Micro-Bunching Characteristics in Single and Multi-Bunch Operation at KARA, PhD dissertation.

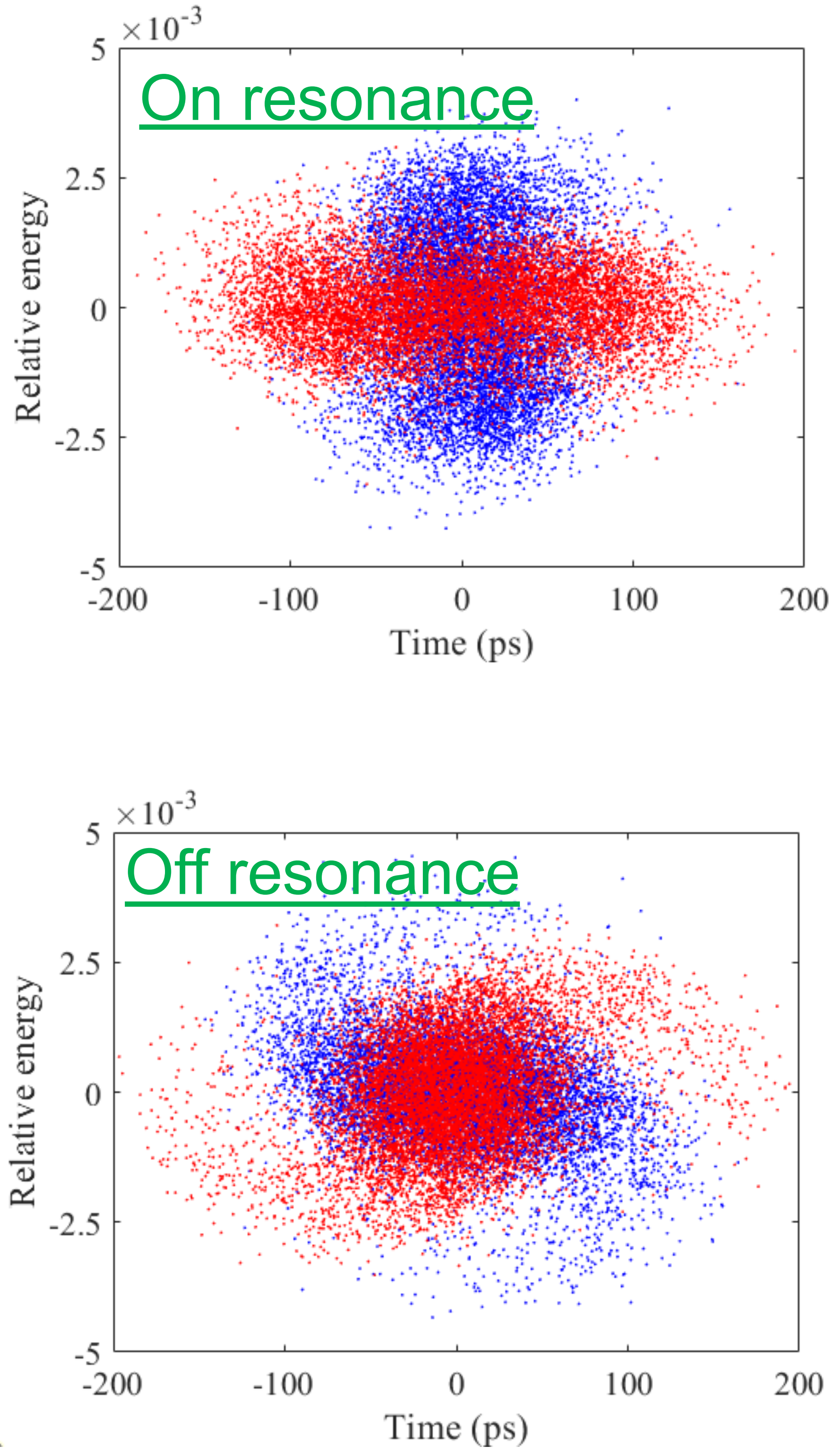
Beam manipulation on longitudinal phase space by RF phase modulation with $2f_s$

Streak Camera Image

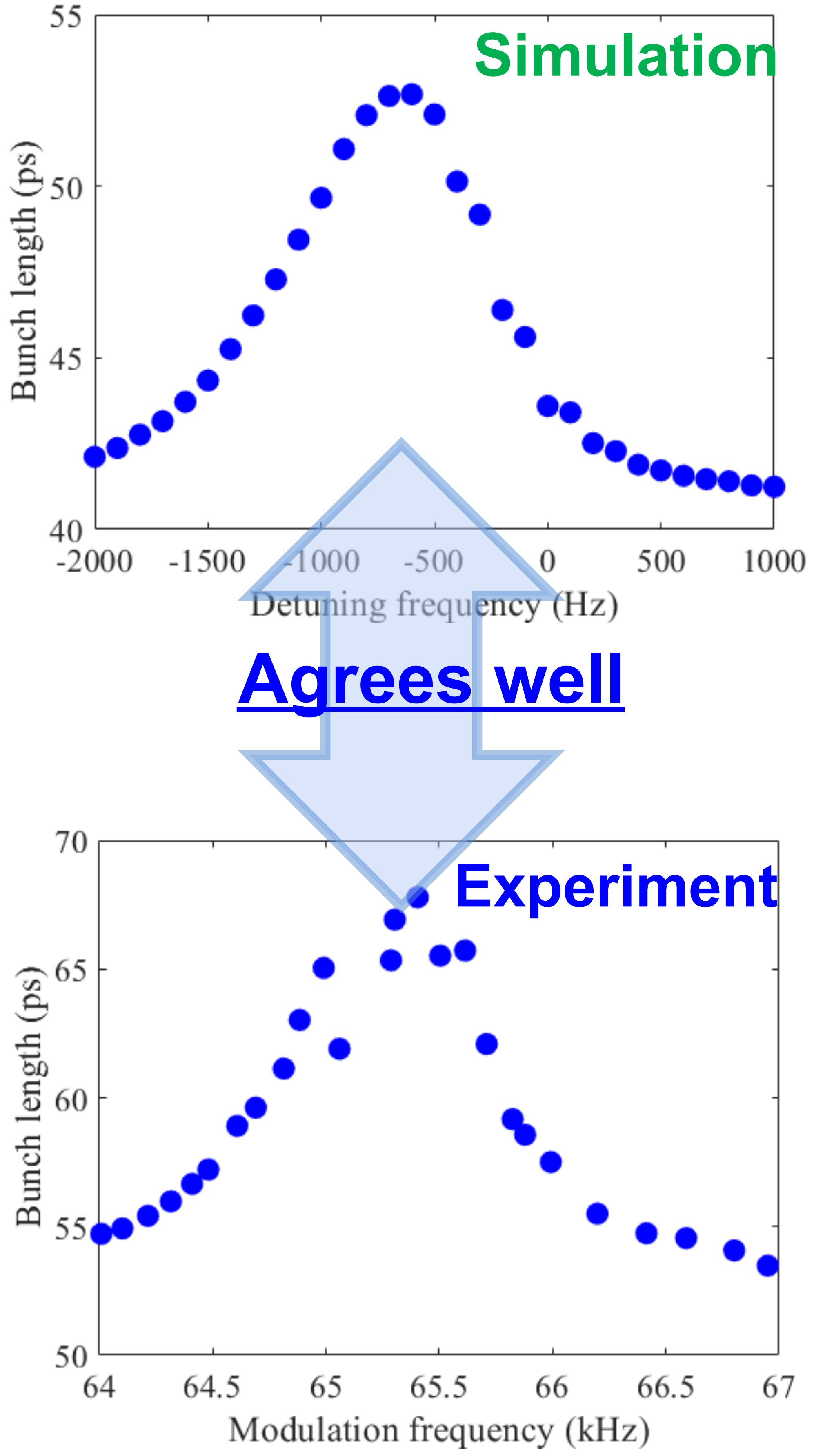
Experiment — **Simulation**



Phase space Simulation



Detuning property

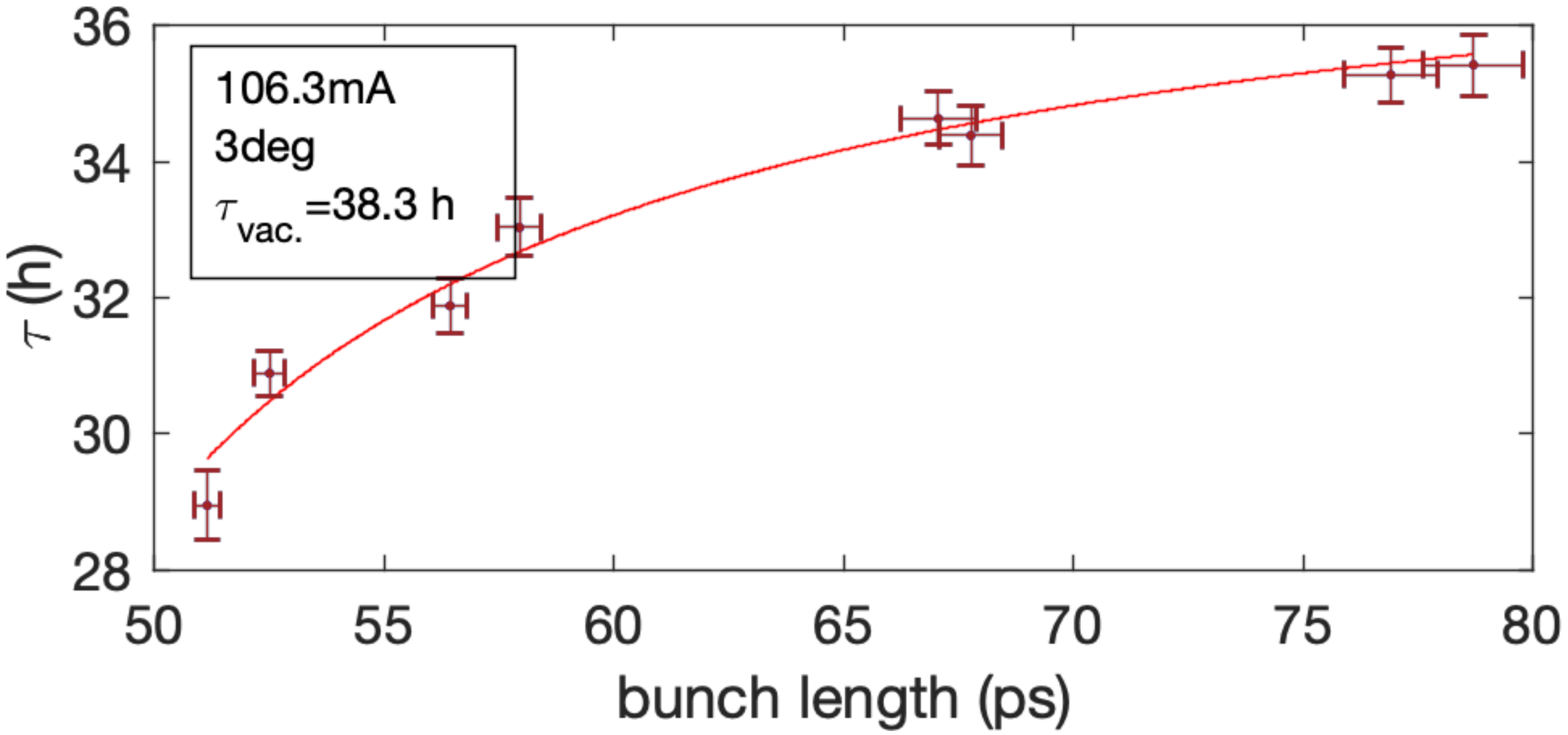


Article in preparation

Courtesy: A. Mochihashi, S. Maier

Systematic studies of RF phase modulation at KARA

- With the RF phase modulation the bunch length can be influenced
- Life time improvement as function of the bunch length



S. Maier, Systematic studies of RF phase modulation at KARA, Master thesis, to be published

Courtesy: S. Maier

Talk A. Santamaria Garcia

AI/ML assistants and RL agents tailor beams

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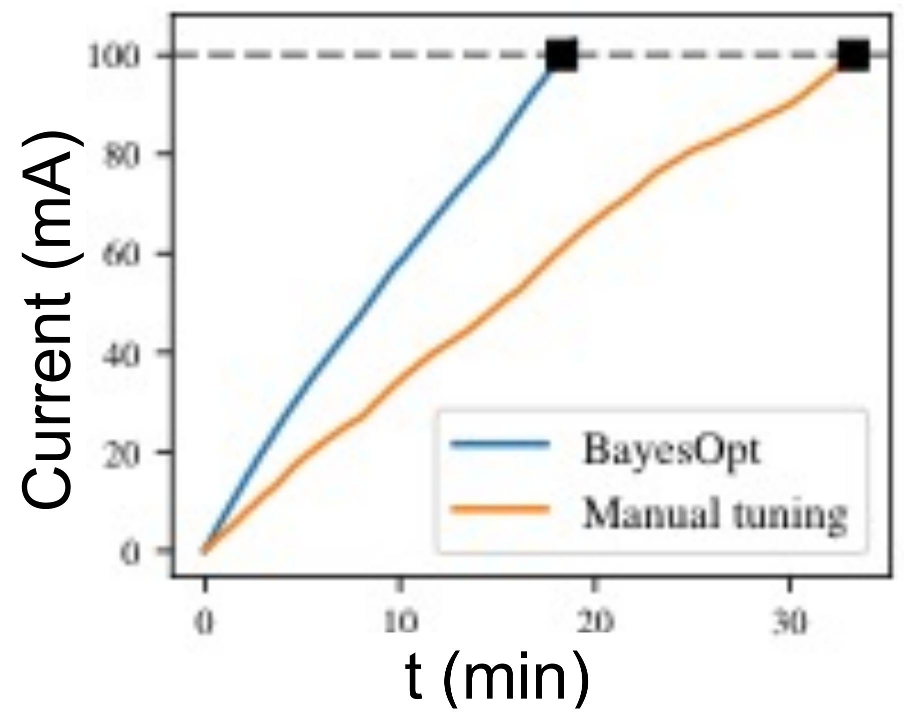
- Collaboration with High Performance Humanoid Technologies Lab at KIT (Institute for Anthropomatics and Robotics, Dept. of Informatics)
- RL-based stabilization of THz power achieved in simulation; continue with beam tests & FPGA implementation (with MT-DTS)
- Very successful injection-optimization with Bayesian optimization demonstrated - 2 times faster injection than manually
- Application to
  - Rings: Innovationspool AMALEA (with MT-DTS, 2019-20)
  - Linacs: ML toward Autonomous Accelerators (A. Eichler DESY, E. Bründermann KIT)
  - Plasma accelerators/high-power lasers: Innovationspool ACCLAIM (planned to start 2021)

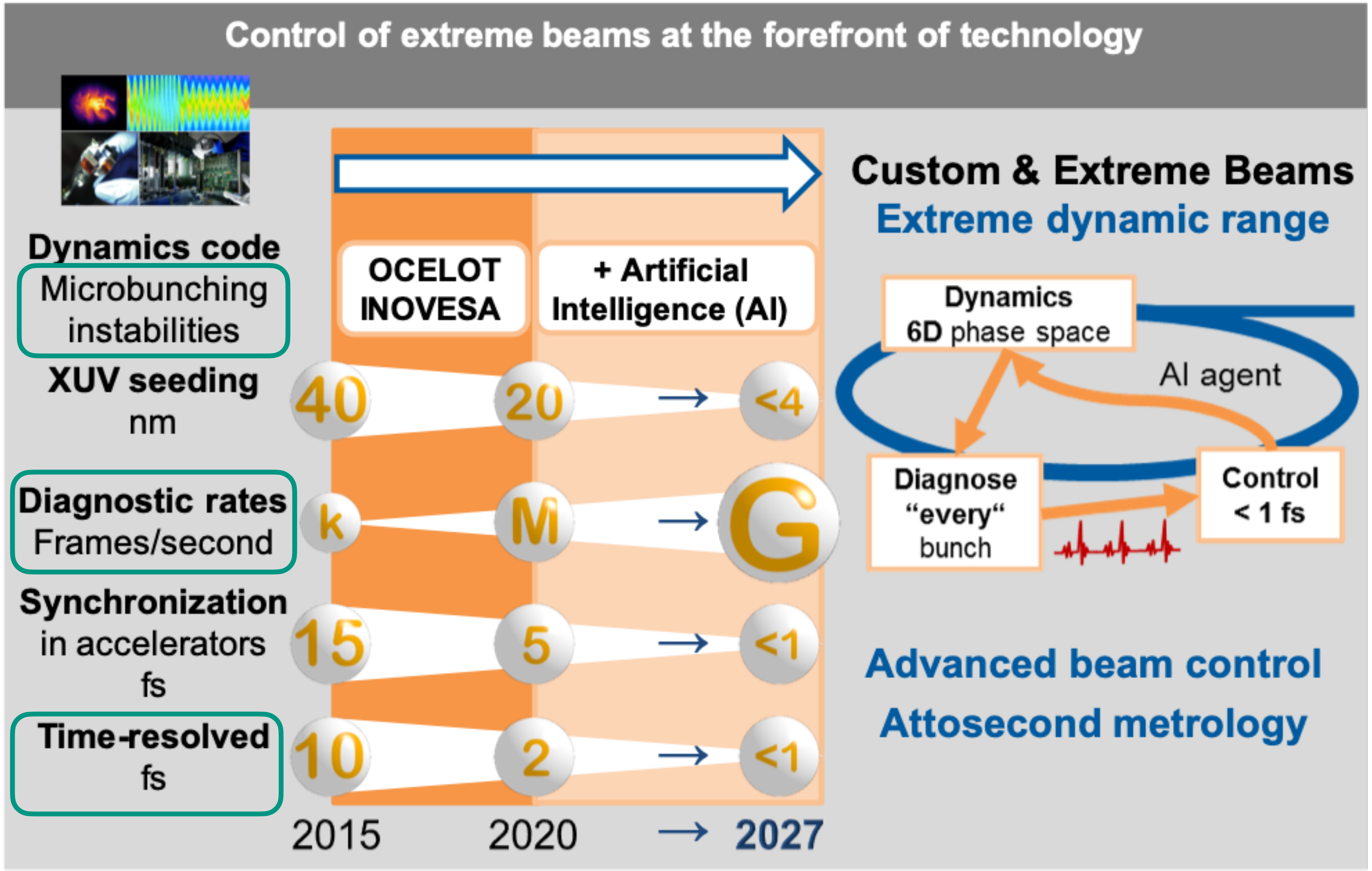
HELMHOLTZ AI | ARTIFICIAL INTELLIGENCE COOPERATION UNIT

Courtesy: C. Xu



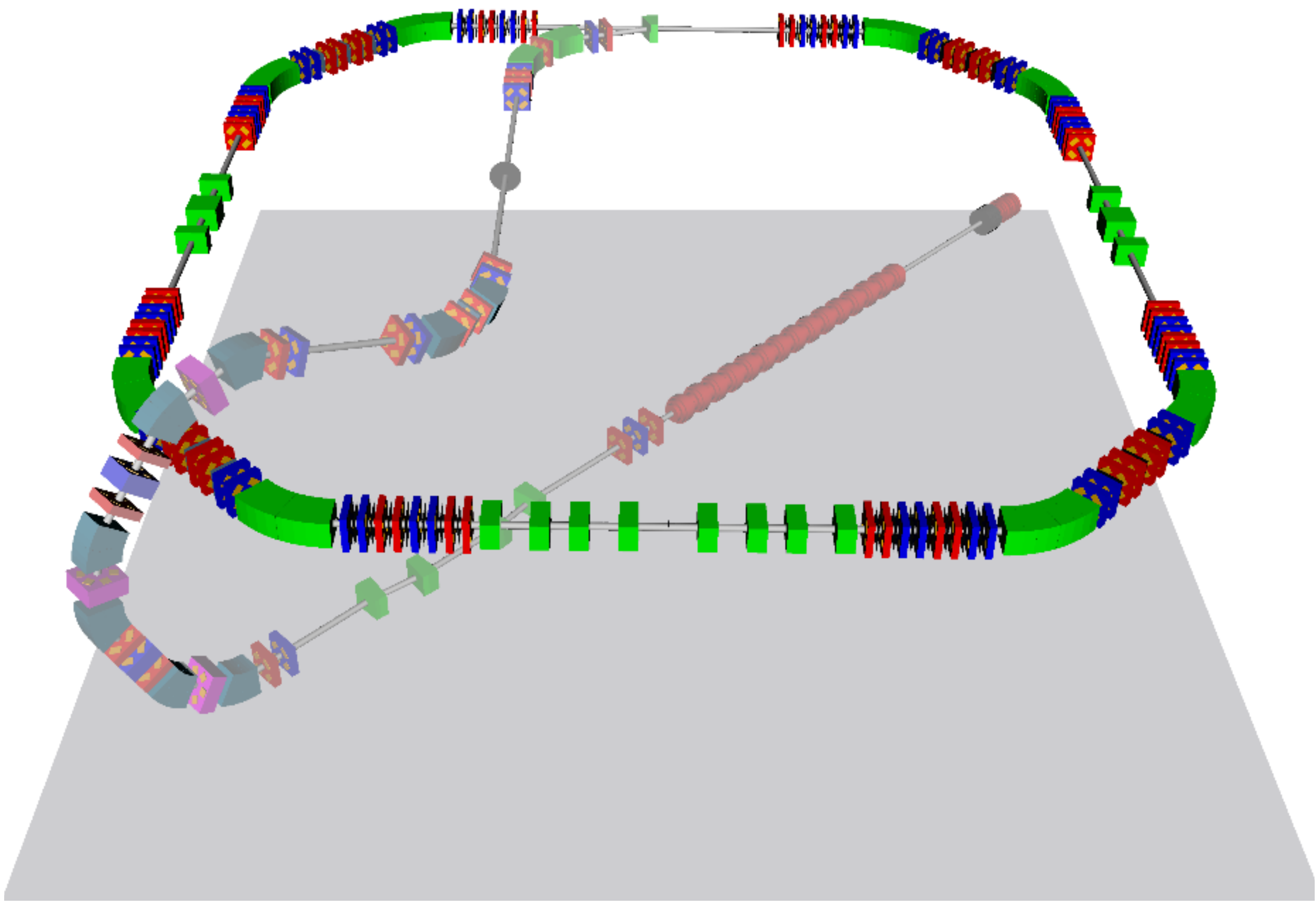
C. Xu, Bayesian Optimization of Injection Efficiency at KARA using Gaussian Processes, Master thesis, to be published

ST3 – Advanced beam control, diagnostics & dynamics
Heart beat of Matter – Faster, more throughput, at highest precision



cSTART

- Goal: demonstration and examination of the injection and the storage of a laser wakefield accelerated (LWFA) like electron beam
- The Very Large Acceptance compact Storage Ring (VLA-cSR)
- Utilize FLUTE with transfer line as injector
- Status
  - Finalizing lattice design
  - Optimizing parameters to match with LWFA
  - Layout of diagnostics



Courtesy: J. Schäfer

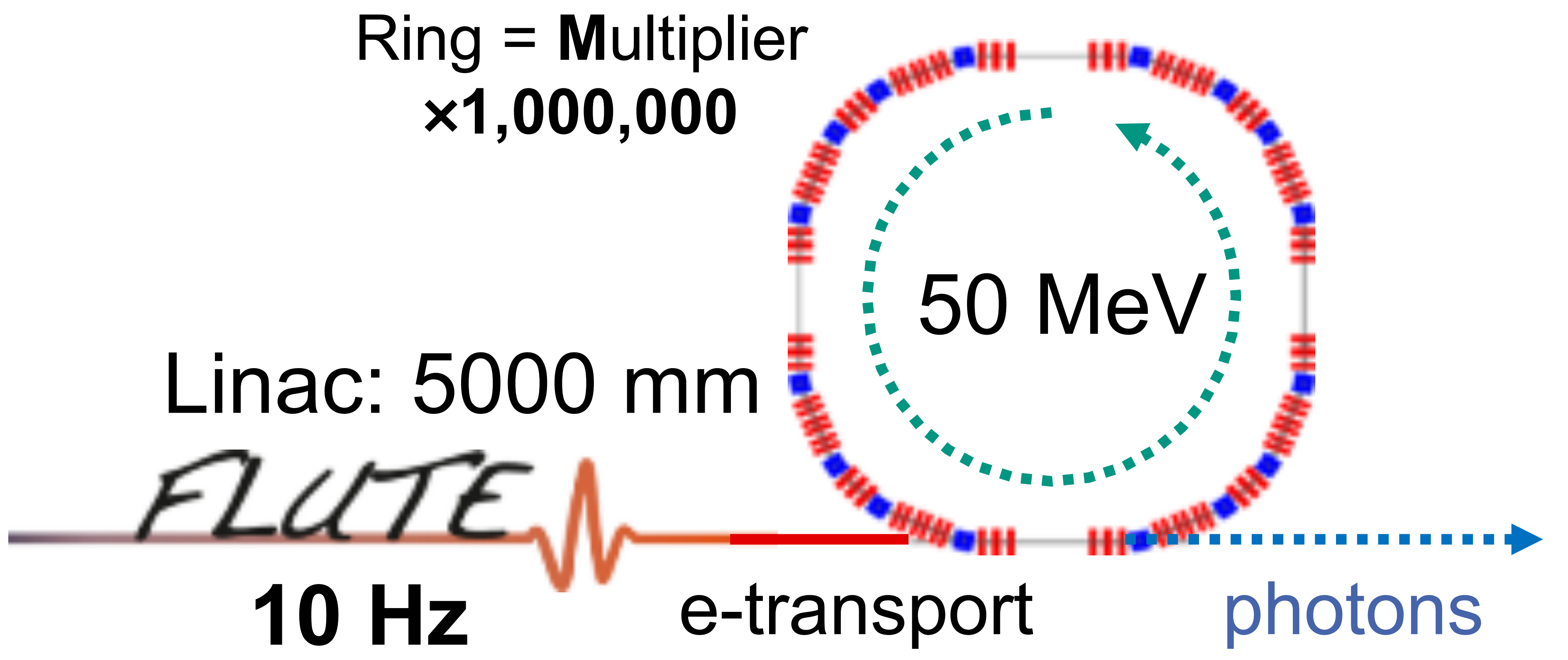
STalk D. El Khechen

B. Haerer et al., proceedings of IPAC2019, TUPGW020

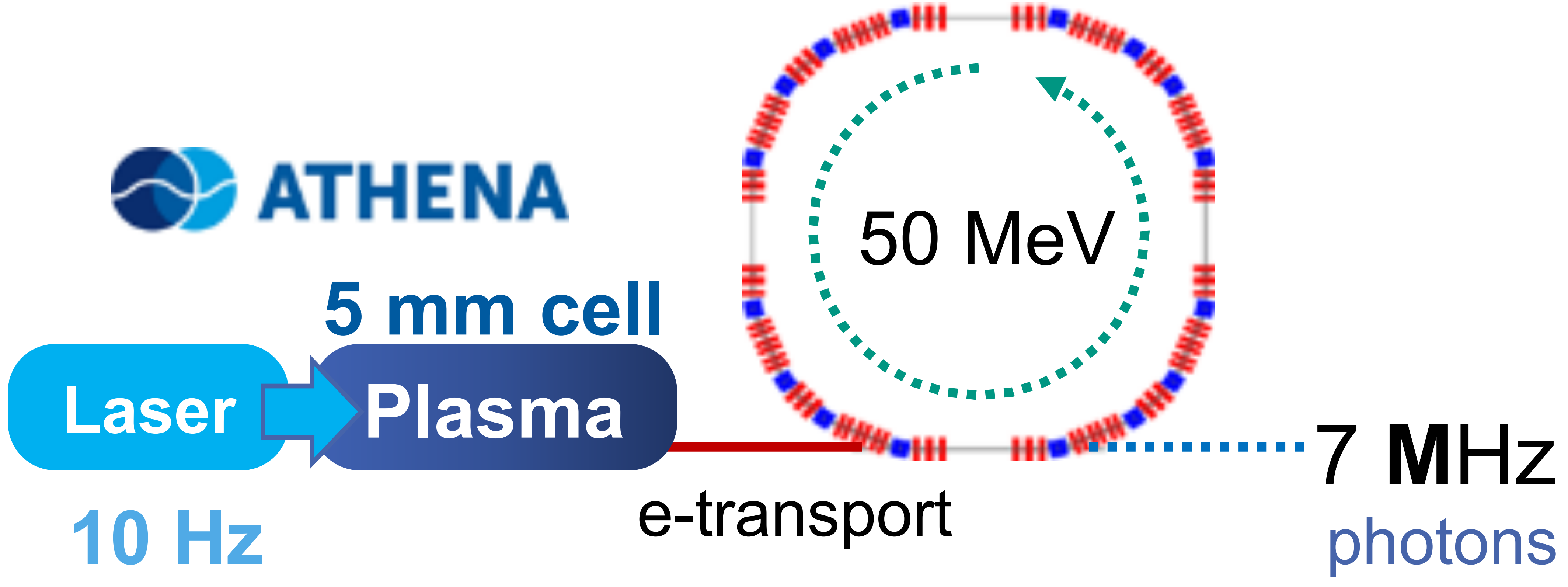
Connecting ST3 to ST4 at KIT
Compact novel accelerators and their applications

- Bring plasma acceleration to applications and compact accelerator technology
  - **„from acceleration to accelerators“**
  - Well-defined **transport of electrons originating from a plasma** to an application point

Goal: Storage of fs-long electron bunches
Solution: unique storage ring design



Goal: efficient storage of injected plasma electrons
Cooperation with DESY and HI Jena
Goal TMed: Terahertz medical imaging
Cooperation and R&D in MT-ARD-ST3 & MT-DTS

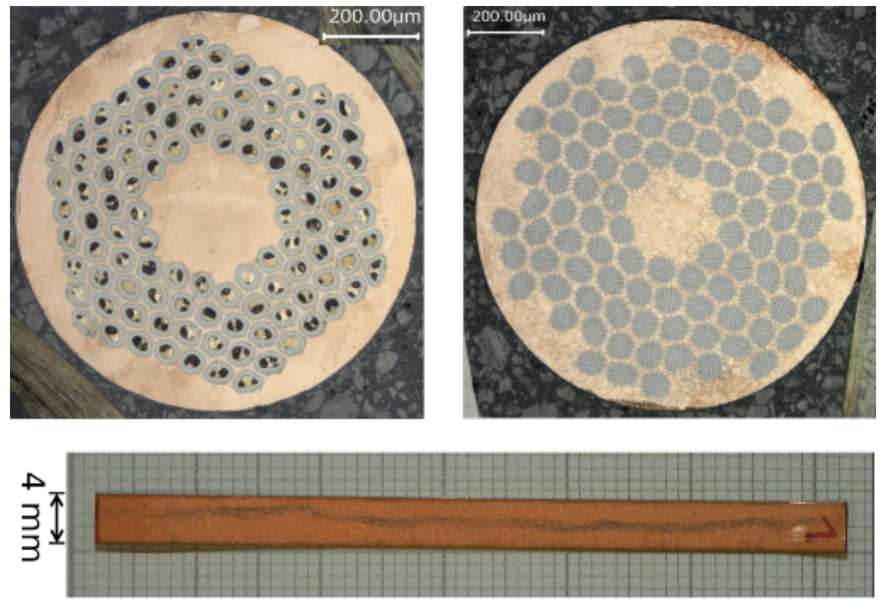


B. Haerer et al., proceedings of IPAC2019, TUPGW020

Professor for Laser-based Accelerators @ KIT

ST2 – Concepts & Prototypes for maximum performance
Enhanced beam intensities, beam qualities and efficiency

- **Develop superconducting fast-ramped, low-loss magnets and cable technologies for highest efficiencies**
  - Radiation hardness, HTS cables and IDs
- Push intensity, quality and efficiency frontier with prototypes & experiments
  - BESTEX
  - Future Circular Collider Innovation Study (FCCIS)
- **Enable novel, efficient, and new operation modes for storage rings**
- **Optimal energy management in Accelerator Facilities**
  - Sustainable, energy efficient applications
  - **Energy Lab 2.0 at KIT:** simulation and experimental area
    - Energy storage, power transmission lines
    - Load management
    - Reduced environmental footprint
- **Innovationspool project for energy efficient accelerators**
  - InnovEEA planned to start in 2021, project led by KIT



Courtesy: A. Will

Power Hardware in the Loop (PHIL)

Energy Lab 2.0 at KIT

Courtesy: L. A. González

together with RF *ENERGY*
Helmholtz programs ESD + MTET

Where we come from and where we are going follows function – A straight path into the future

ARD – implemented as a research topic of its own

- builds on existing competences
- shapes the future of Matter
- driven by the goal to lead the field

	2015 – 2020 PoF III	2021 – 2027 PoF IV
ST1	SCRF Science and Technology	Advanced CW SRF-Systems
ST2	Concepts and Technologies for Hadron Accelerators	New Concepts and Prototypes for Maximizing the Performance of Hadron & Electron Accelerators
ST3	Picosecond and Femtosecond Electron and Photon Beams	Advanced Beam Control, Diagnostics and Dynamics
ST4	Novel Acceleration Concepts	Ultra Compact, Novel Accelerators and their Applications

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- KIT Institutes (ETP, IHM, IMS, IPE, IPS, LAS, IAR, IPQ)

STalk B. Scheible

- Collaboration partners: