This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under GA No 101004730.

AMICI – I.FAST – WP13 – ETIAM

European Technology Infrastructure for Accelerators and Magnets

AMICI – I.FAST Workshop – 12 October 2023, Kraków

Robert Ruprecht on behalf of the ATP members of KIT

Agenda

- **K**arlsruhe **I**nstitute of **T**echnology: **KIT**
  - the Research University within the Helmholtz Association
  - big science institution in Europe
  - research-based study programs
  - prepare **students** for responsible positions in **society, industry, and science**
  - **bridge** between important **scientific findings** and their **application** for benefit of society, economic prosperity, preservation of our natural basis of life

Agenda

- **K**arlsruhe **I**nstitute of **T**echnology: **KIT**
  - **A**ccelerator **T**echnology **P**latform: KIT – **ATP**
    - Numerous **T**echnology **I**nfrastructures **TI** at KIT clustered to diverse **R**esearch **I**nfrastructures **RI** for technology development & testing
    - …will present a few examples related to accelerator research …

Agenda

- **K**arlsruhe **I**nstitute of **T**echnology: **KIT**
  - **A**ccelerator **T**echnology **P**latform: KIT - **ATP**
    - **A**cce**L**erator Test **FA**cilities: KIT – **ALFA**
      - **KA**rlsruhe **R**esearch **A**ccelerator: **KARA**
      - **F**erninfrarot **L**inac **U**nd **T**est **E**xperiment: **FLUTE**
      - **c**ompact **ST**orage ring for **A**ccelerator **R**esearch and **T**echnology: **cSTART**
      - **L**aser **P**lasma **A**ccelerator: **LPA**

Agenda

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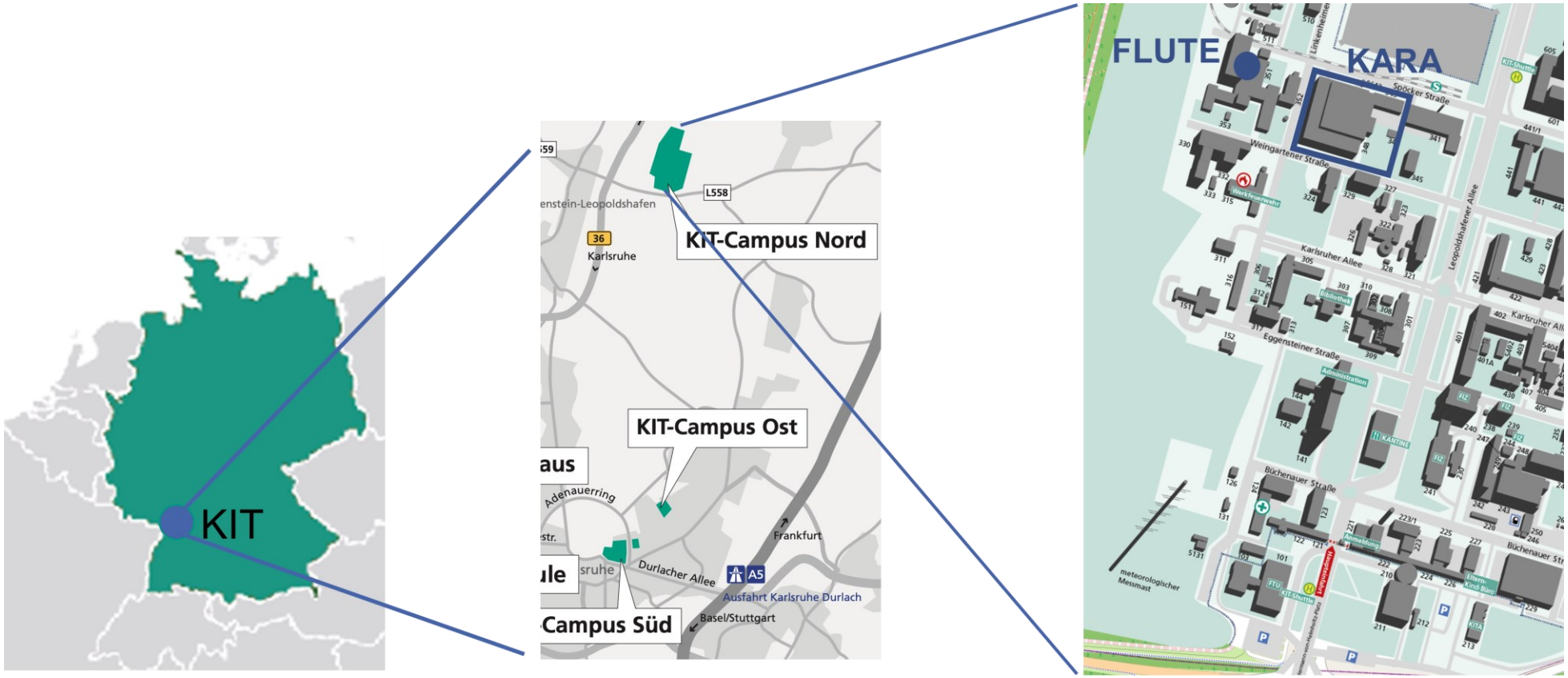
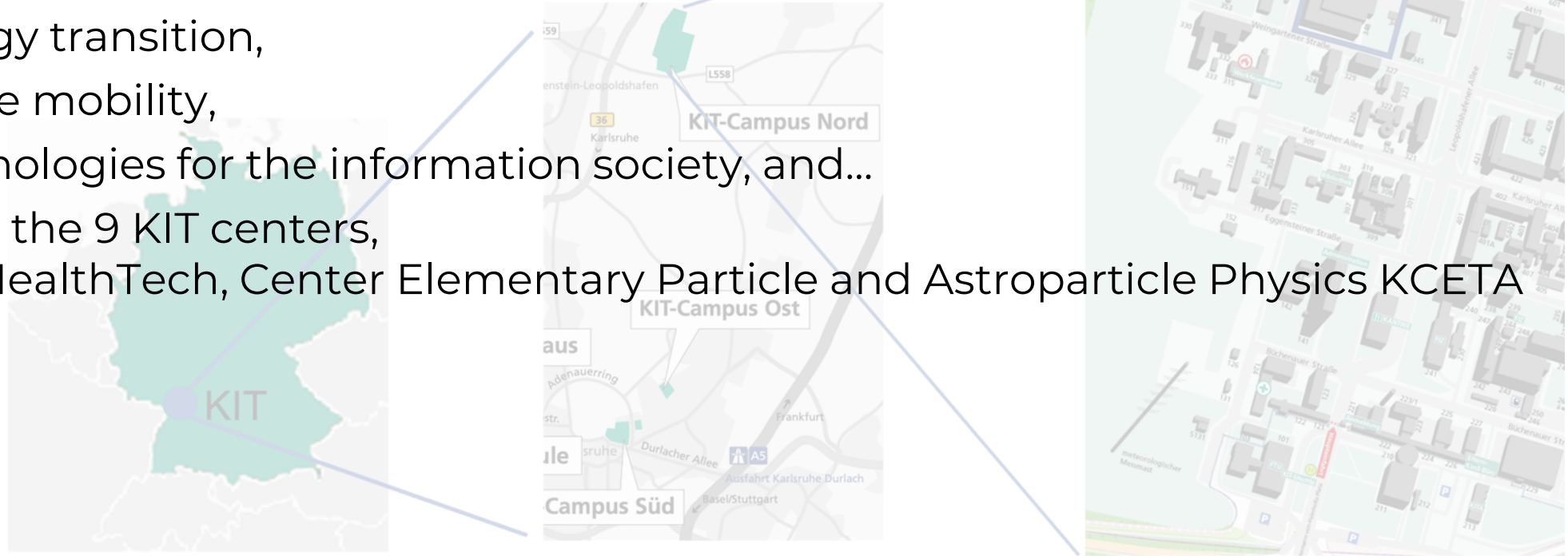
      - **L**aser **P**lasma **A**ccelerator: **LPA**
    - **research, education, training, networking,**
    - **collaboration, transnational access, technology transfer**

KIT – Karlsruhe Institute of Technology



KIT – Karlsruhe Institute of Technology

- **The University in and a Research Center of the Helmholtz Association, Excellence (1 of 11 in GER)**
- **Research, Education, Innovation**
- **Grand Challenges of the Society**
  - energy transition,
  - future mobility,
  - technologies for the information society, and…
  - … see the 9 KIT centers,
    e.g. HealthTech, Center Elementary Particle and Astroparticle Physics KCETA



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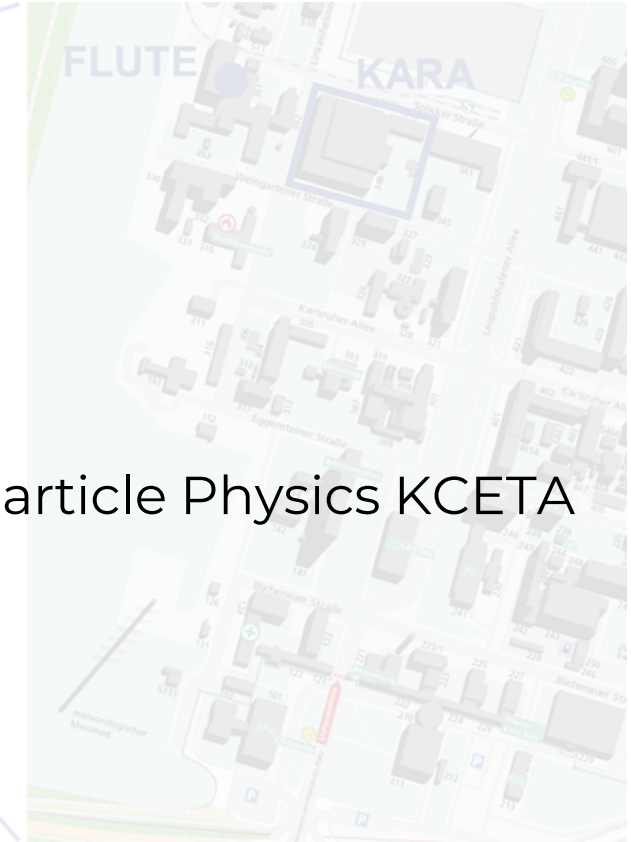
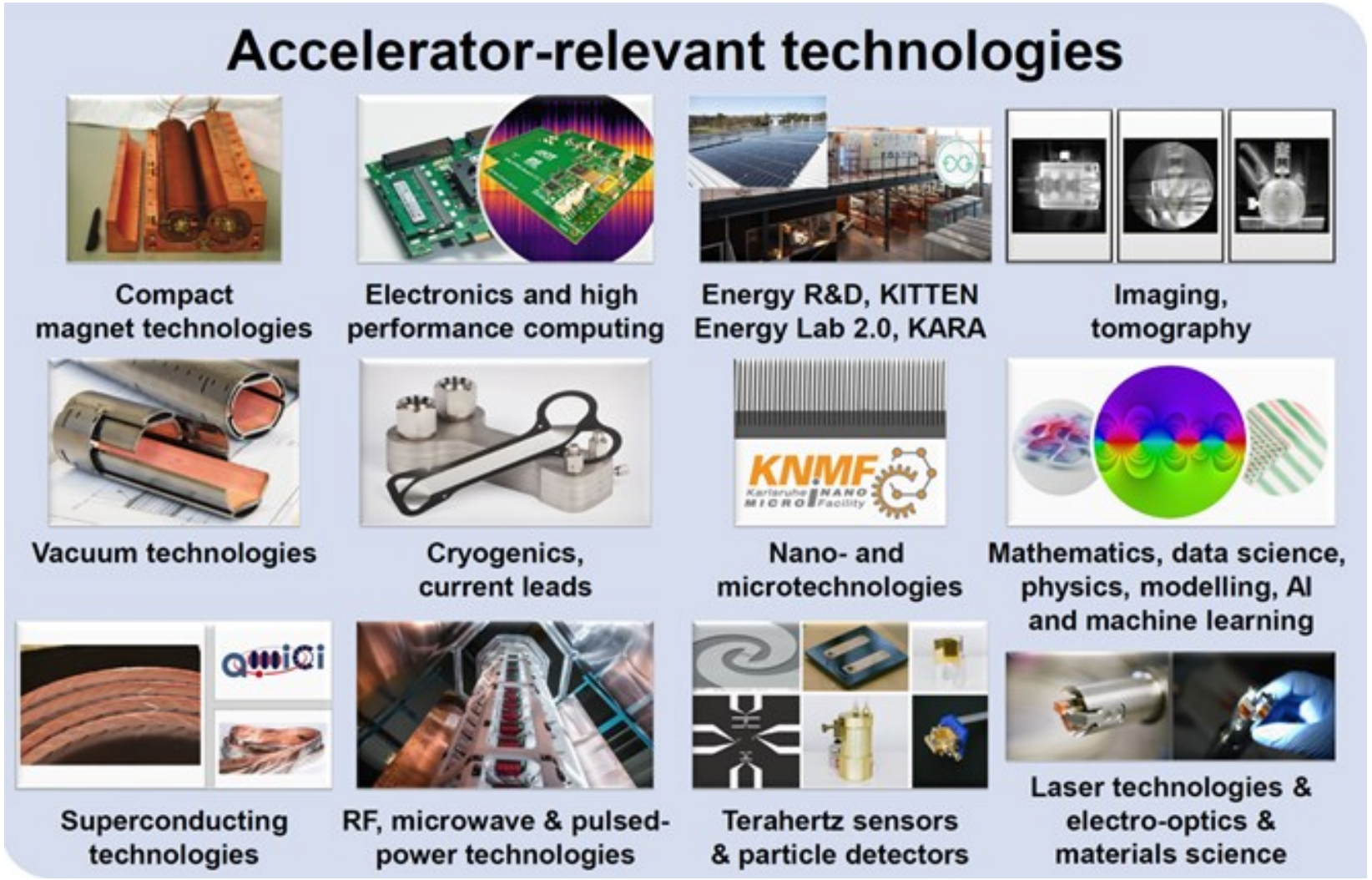
  - … see the 9 KIT centers,
    e.g. HealthTech, Center Elementary Particle and Astroparticle Physics KCETA
- **9 905 employees** *
- **121 institutes in 5 division, 11 faculities**
- **22 373 students**

* 402 professors, 5 704 education & research, [end 2022]

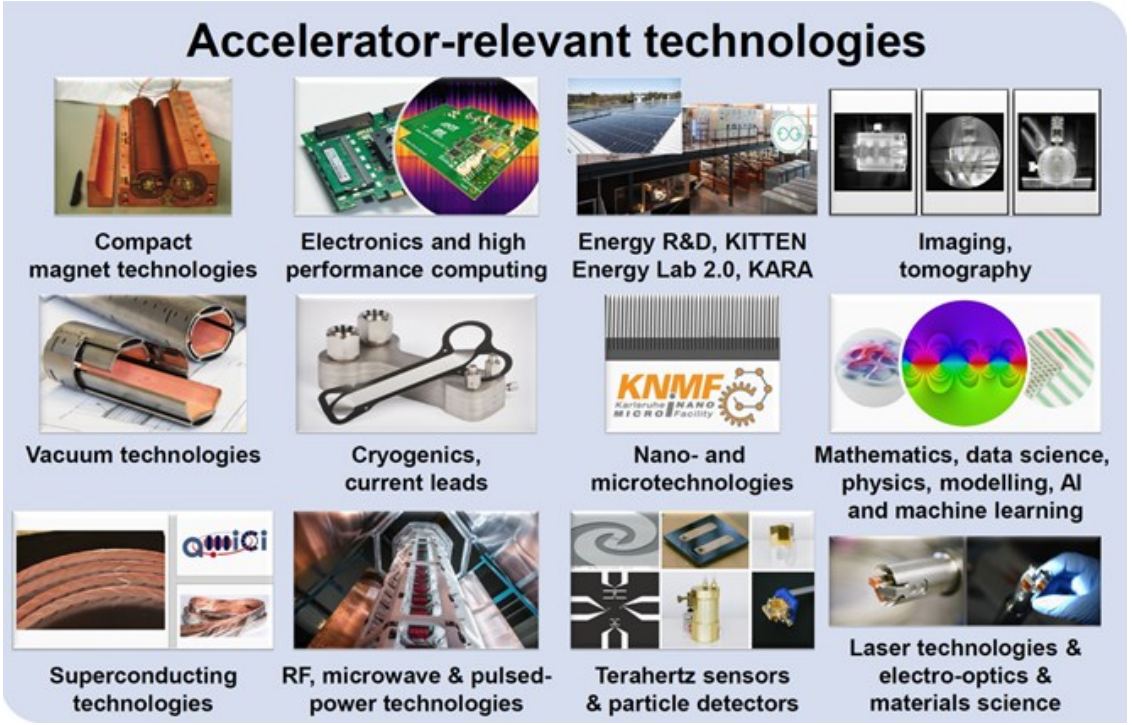


ATP - Accelerator Technology Platform



A T P - Accelerator Technology Platform

- 230 researchers @ KIT
- Large-scale test facilities
- R&D, consulting
- SPOC - single point of contact
- Bridge to companies & laboratories
- Pilot projects, QA
- Successful transfer



Test Facilities like KARA, FLUTE

- At the **Heart of ATP**
- Condensation nucleus
- Connect to KIT's **technology** institutes AIFB, ETP, IBCS, IBPT, IFG, IMS, IPE, IPQ, ITEP, ITTK, SCC, ...

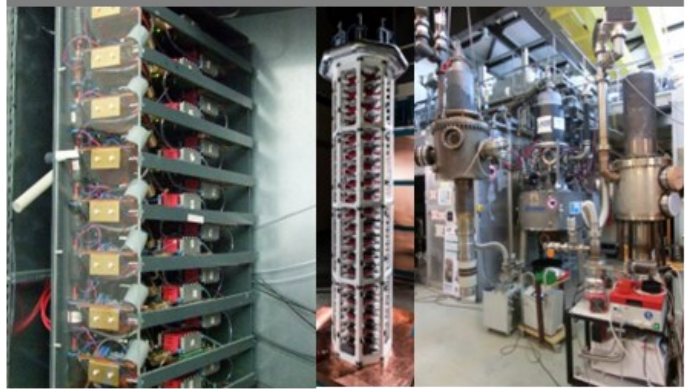
ATP
Accelerator Technology Platform @ KIT

A T P - Accelerator Technology Platform

Karlsruhe Institute of Technology

test facilities & technologies – KIT examples

Pulse power technology *Gyrotrons*

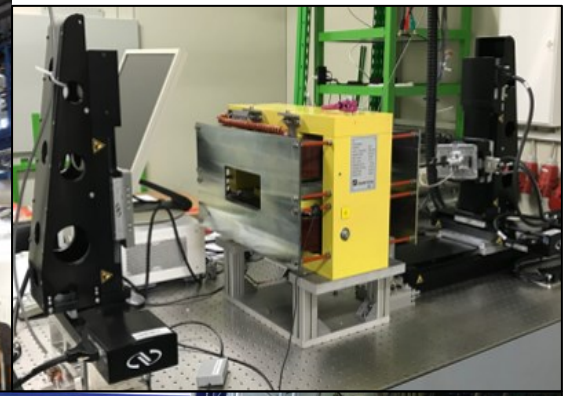


Winding technologies

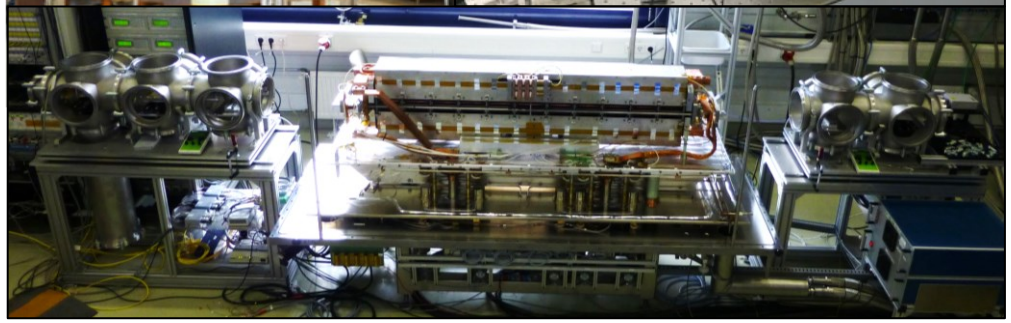
Magnet test facilities

ATP

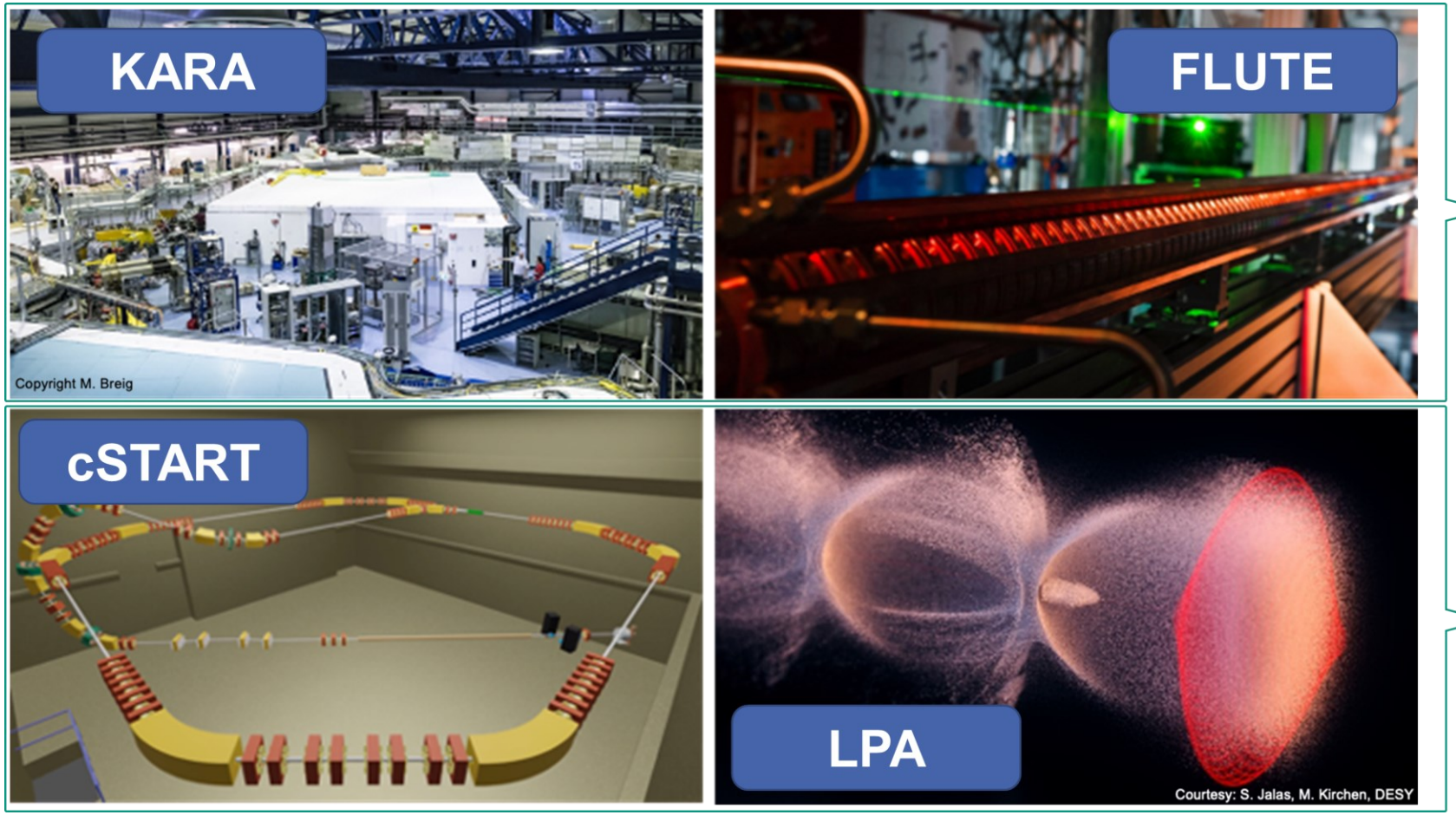
Accelerator Technology Platform @ KIT



Cable technologies *High temperature superconductors*



ALFA - AcceLerator test Facilities

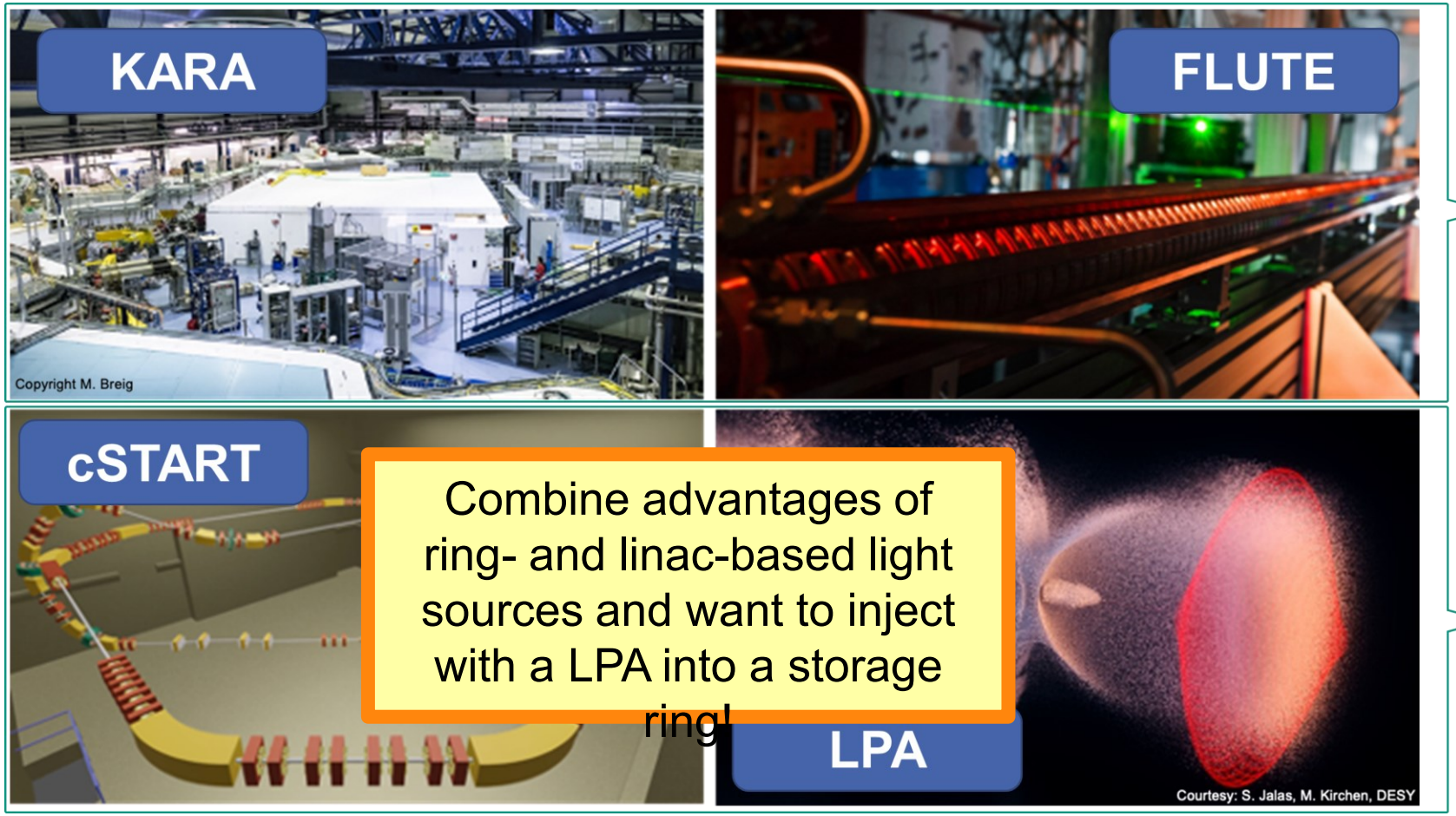


in operation

under construction

LPA

ALFA - AcceLerator test Facilities



in operation

under construction

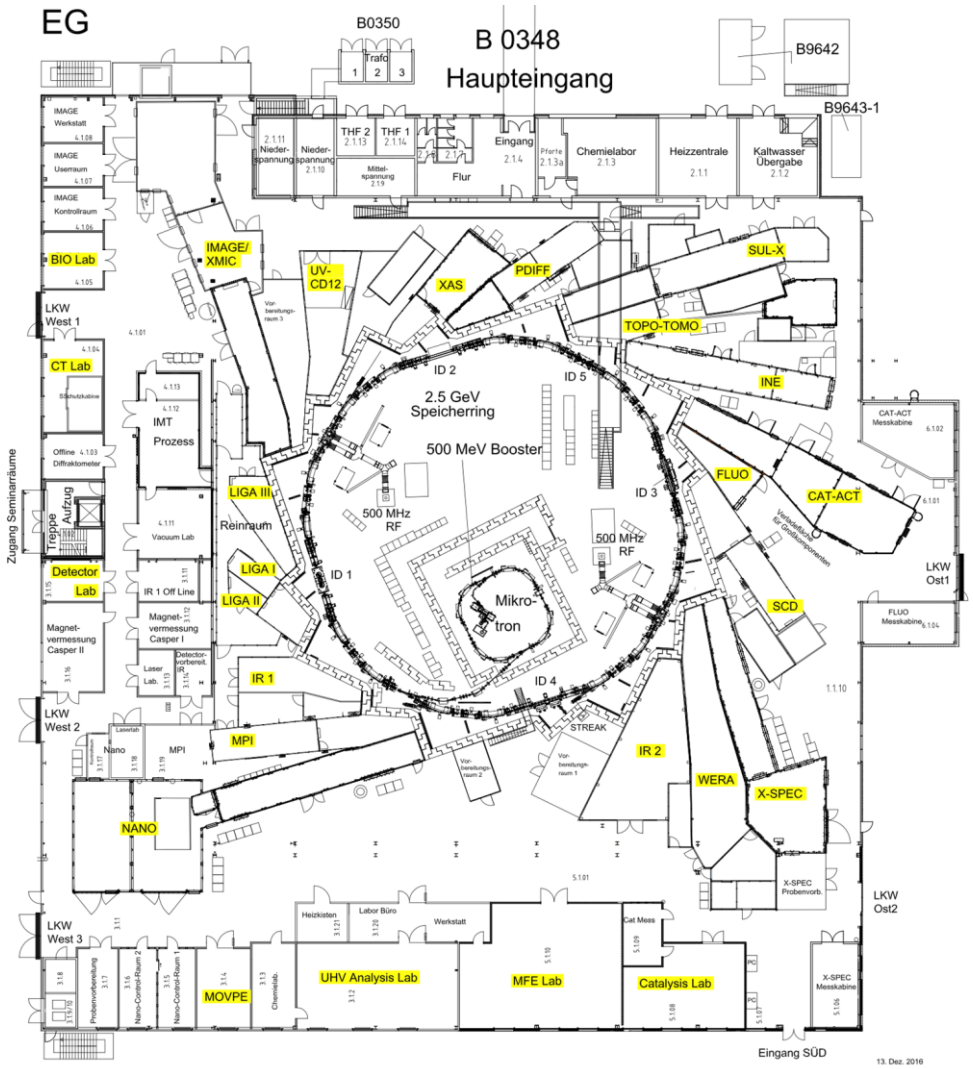
LPA

KARA – KArlsruhe Research Accelerator

electron, synchrotron radiation facility
+ storage ring of the KIT light source

- Circular accelerator with tangential beamlines
- Associated laboratories for sample preparation
- Building approx. 80 m x 90 m
- 20 Beamlines

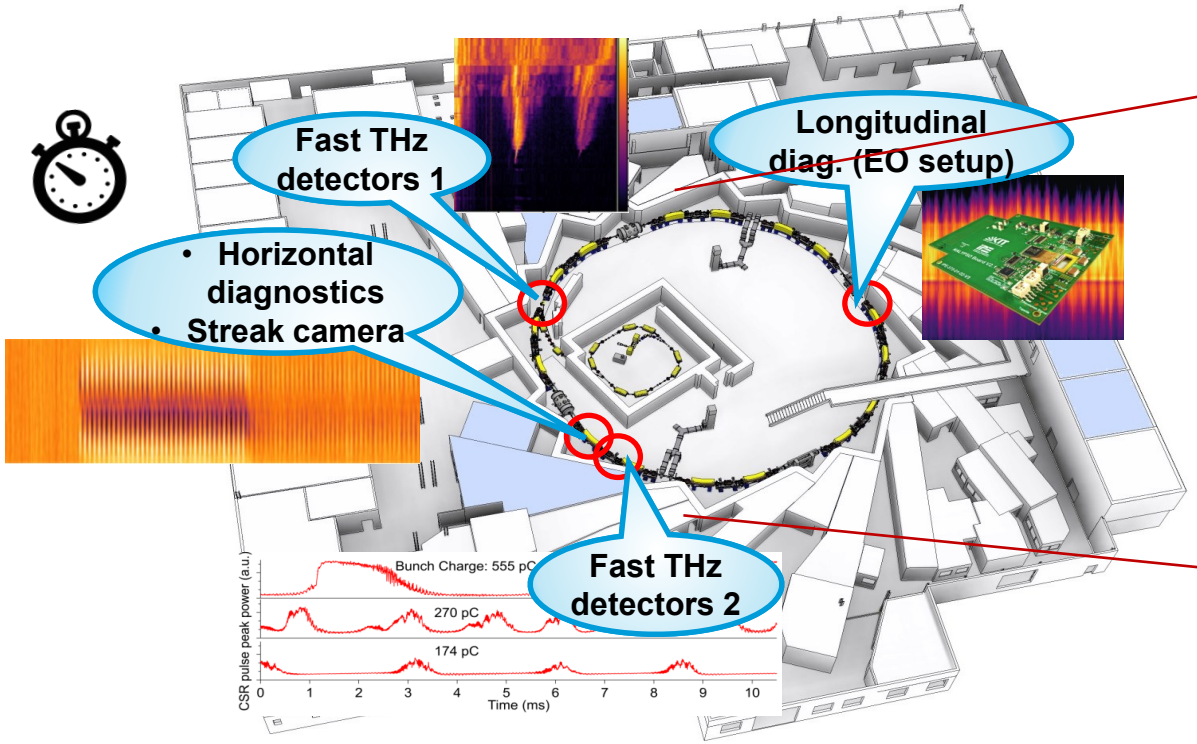
Electron energy	0.5 – 2.5	GeV
Beam current	180	mA
Bunch length	1 – 45	ps
Revolution frequency	2.71	MHz
Circumference	110	m



KARA – KArlsruhe Research Accelerator

distributed synchronized sensor network

emitted CSR, energy spread, bunch profile, phase space tomography in MBI*,
in parallel: simulation of MBI* by OCELOT, INOVESA



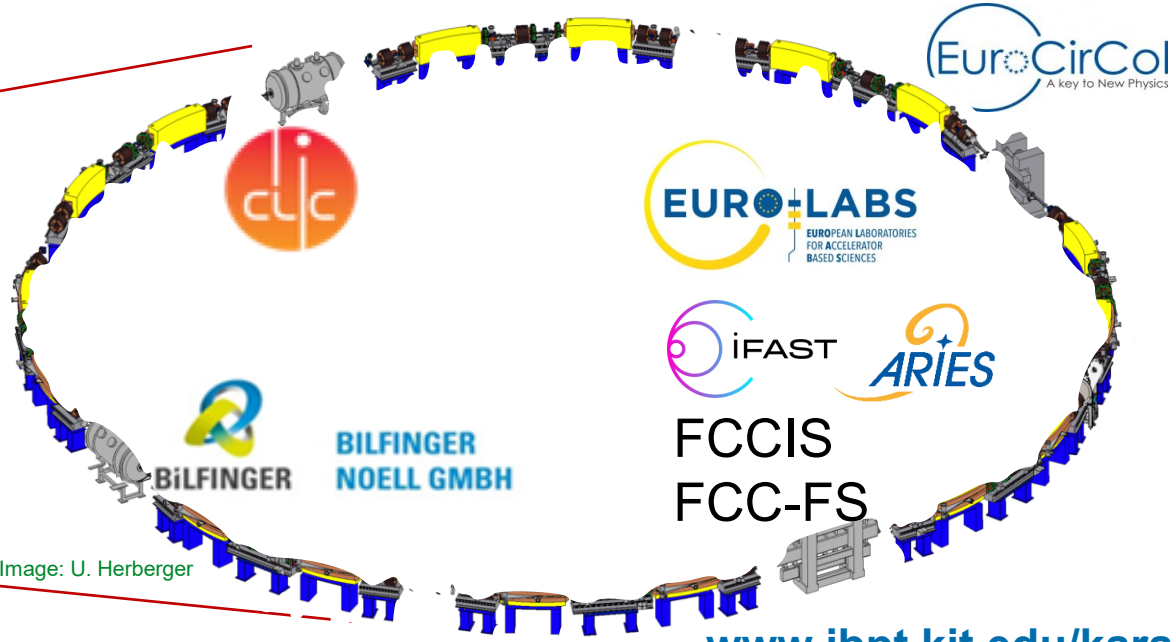


Image: U. Herberger

www.ibpt.kit.edu/kara

- Operation (22-)23h/5d/30w/y
- Single or multi-bunch mode

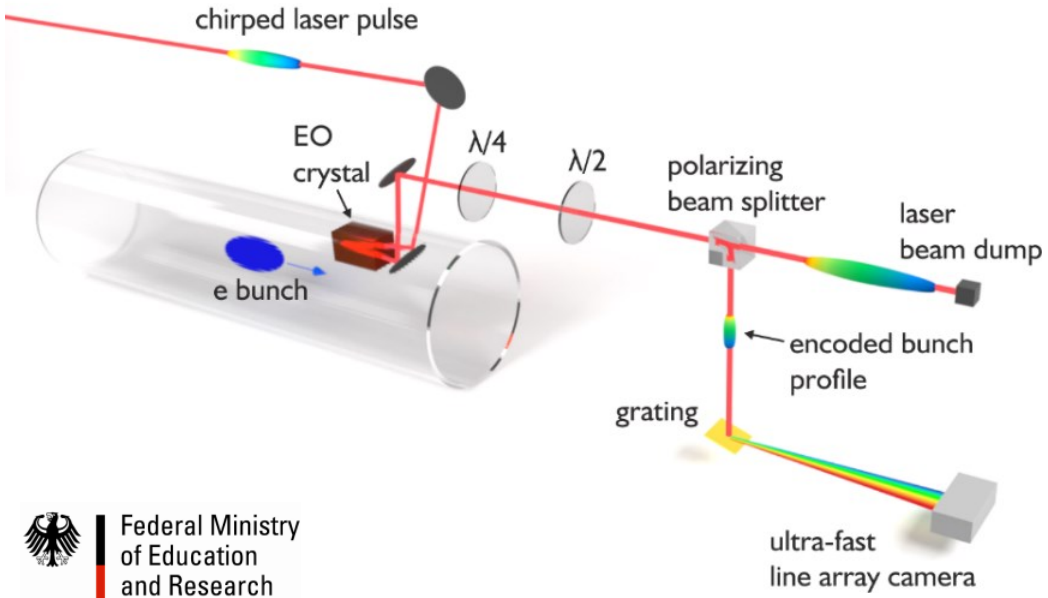
Short bunch mode
- Lower momentum compaction factor
  → Bunch length: 45 ps ↘ few ps
- Coherent synchrotron radiation (CSR) in THz range

Negative momentum compaction factor

MBI* = Micro-Bunching Instabilities

EO Near-Field: Phase Space Tomography

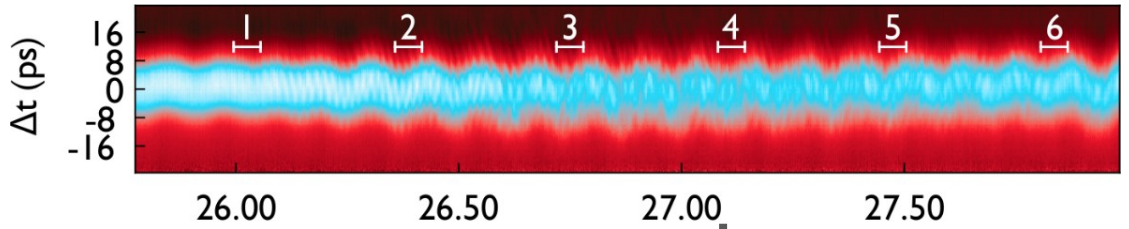
- single-bunch @ 2.7 MHz



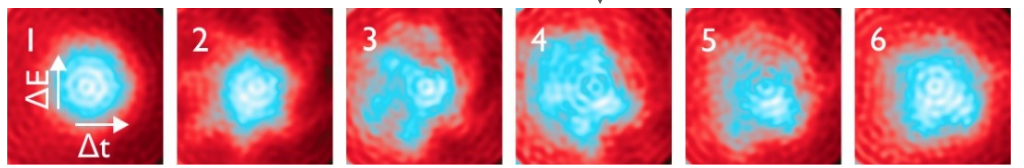
Federal Ministry
of Education
and Research
05K22VKB
05K19VKD

S. Funkner et al., Sci Rep, March 2023, Vol. 13.1, pp. 1-11.
doi:10.1038/s41598-023-31196-5

revolution plots/ sinograms

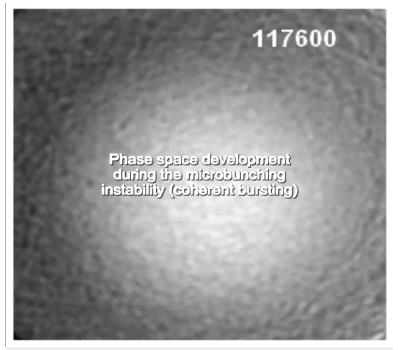


phase space density



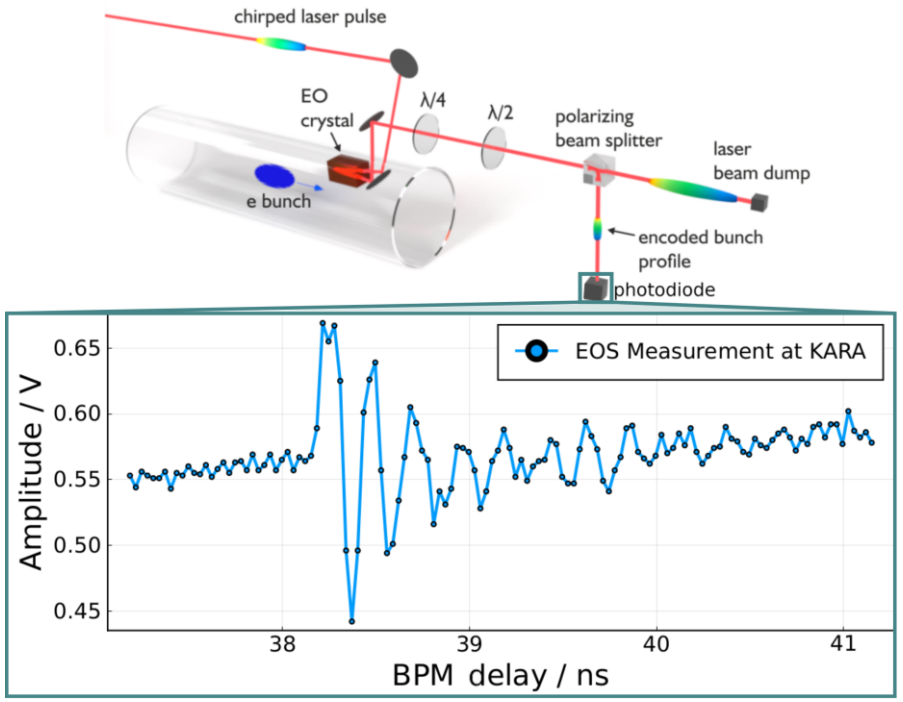
Phase space tomography

- Complete phase space image reconstructed from time interval of 61 µs
- “Randon morphing“ between independent measurements

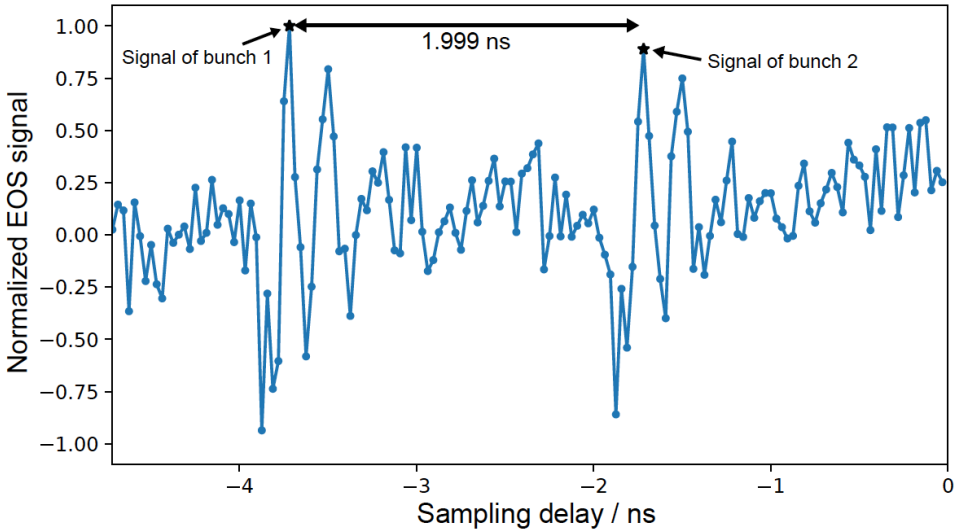


EO Near-Field: Phase Space Tomography

Single-Bunch towards Multi-Bunch Measurements

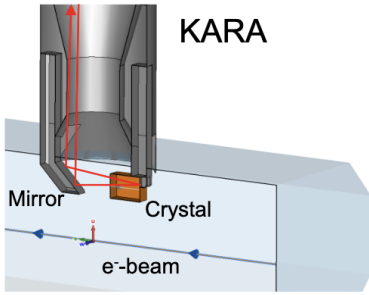


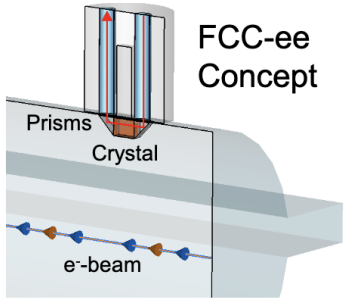
First 2 bunch EOS measurements @ KARA



- Compensation for signal drift (heating?)
- Two bunches are clearly visible in the measurement

- Innovation: Technology - Transfer to CERN
- KIT prototype **EO Bunch Profile Monitor for FCC-ee**
- **1st test on air at CLEAR@CERN in July 2023**

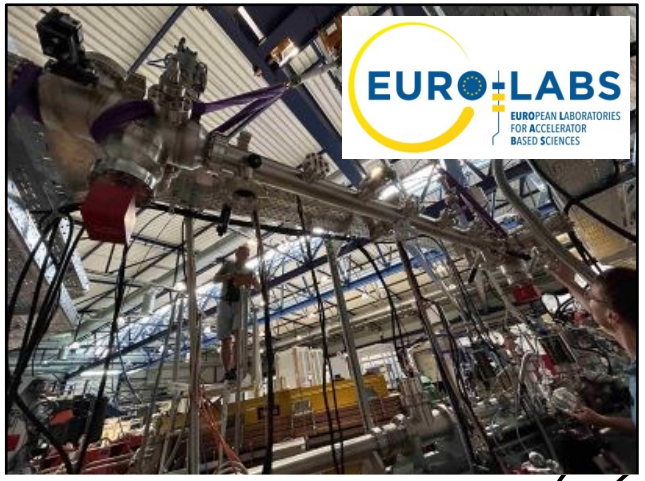


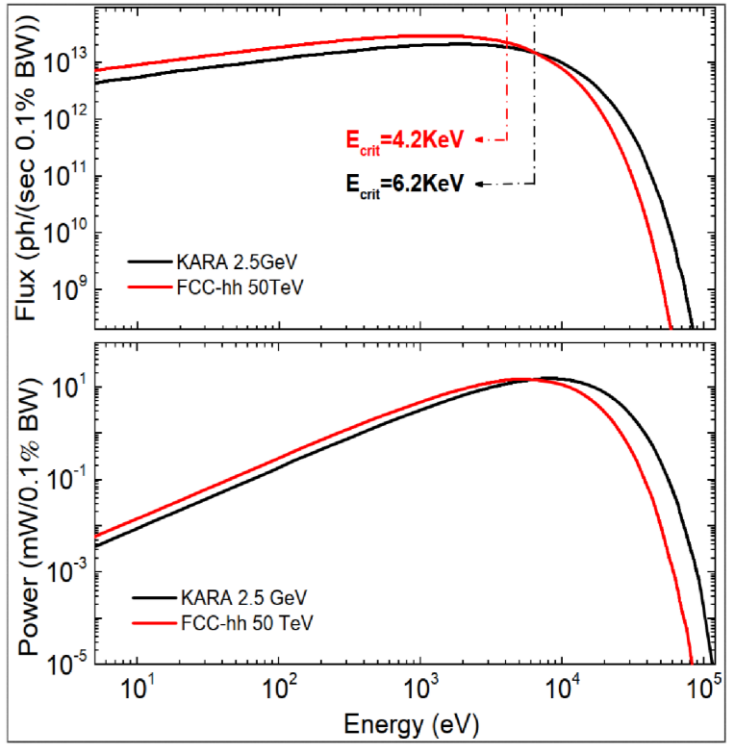


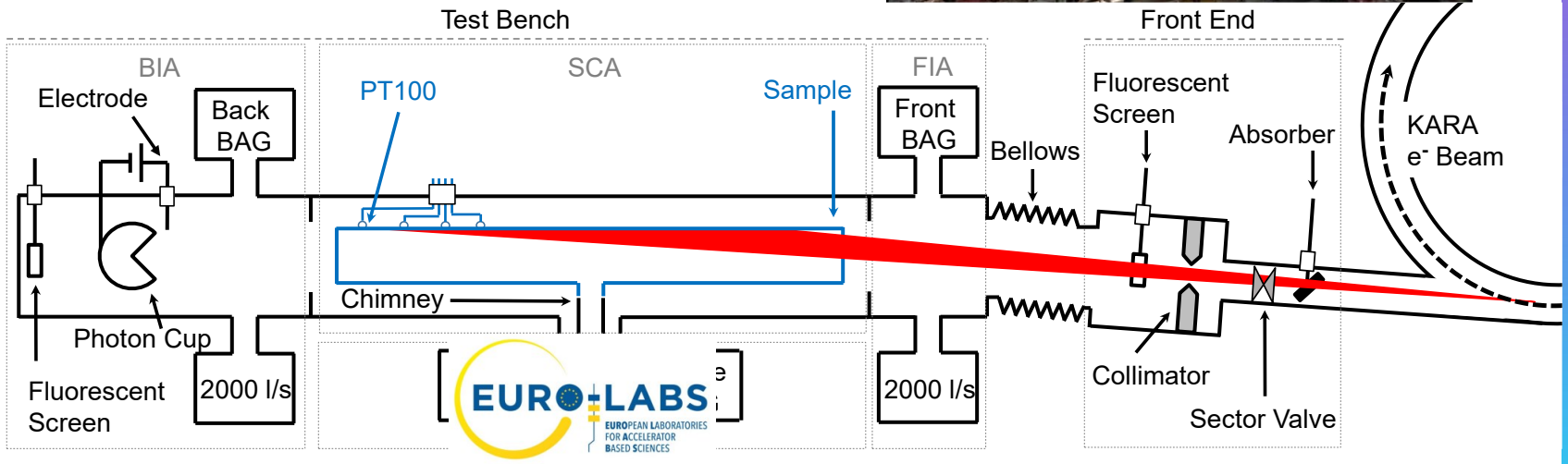
FCCIS, task 2.2

BESTEX beamline @ KARA: 1st TA* in EURO-LABS

- The FCC-hh's photon spectrum and linear power are reasonably reproduced in KARA, even at nominal beam energy.
- **Beam Screen prototype No. 5 with sawtooth profile** tested at CERN's BESTEX beamline at KARA
- heat load and photon-stimulated desorption was measured under cryogenic conditions (liquid N_2 cooling)







TA* = Transnational Access: https://web.infn.it/EURO-LABS/transnational-access/

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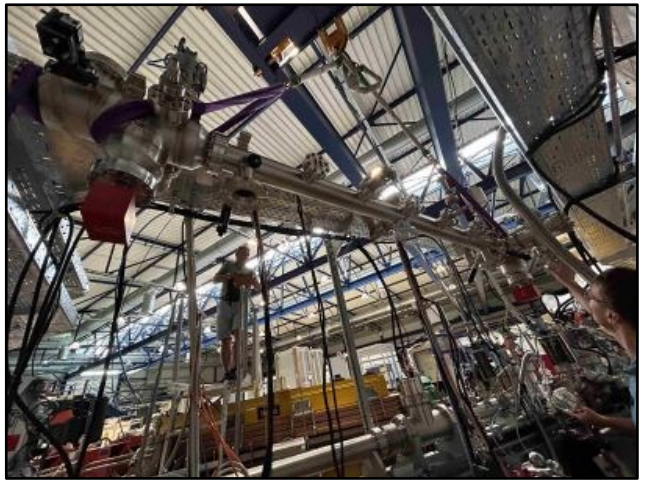
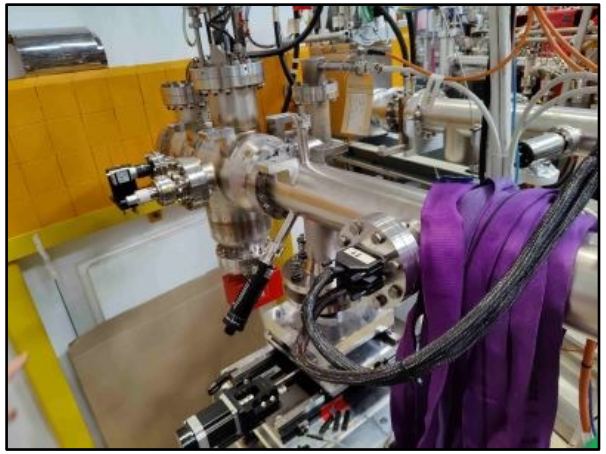
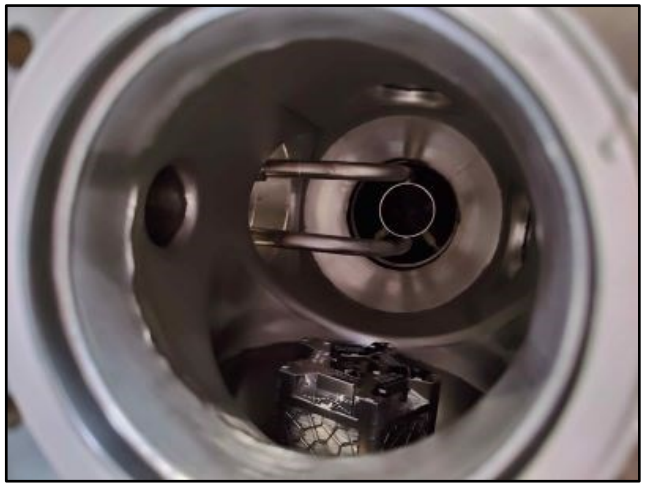






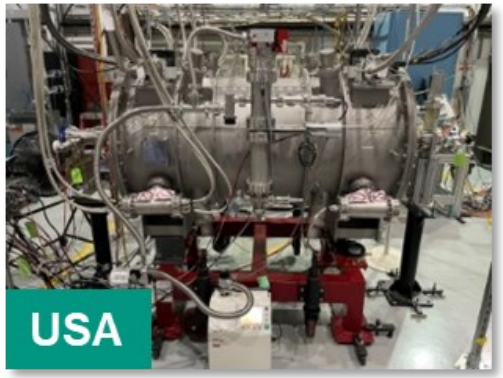
Peter Lindquist Henriksen, Marton Ady, Roberto Kersevan, FCCweek 2023; https://indico.cern.ch/event/1202105/contributions/5380087/

TA* = Transnational Access: https://web.infn.it/EURO-LABS/transnational-access/

Super-conducting Insertion Devices @ KARA

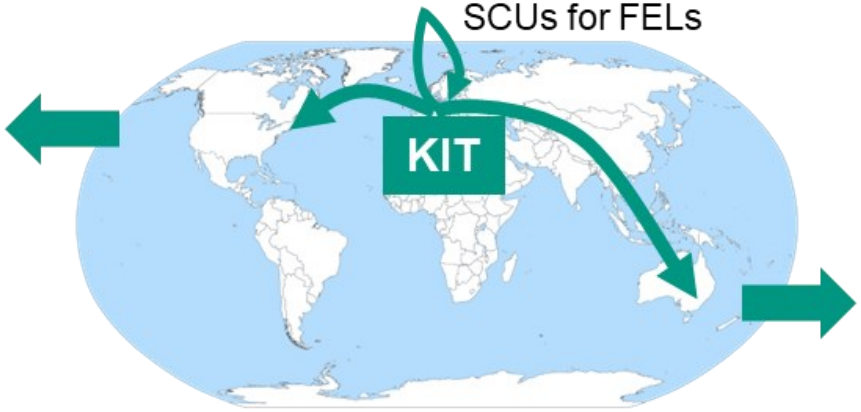
- Collaboration between **KIT and Bilfinger Noell GmbH (BNG)**
- BNG receives further orders for insertion devices from Light Sources and strengthens its world leading position in the supply of SCU und SCW.
- Brilliant light from in-series produced superconducting undulators
- **2 deliveries (!) and “First Light” in November 2022**
- **KIT developed mobile diagnostic system, on-site quality assurance,** QA by KIT experts

NSLS-II, HEX beamline
Brookhaven National Lab



© Bilfinger Noell GmbH

3rd order in 2022
by EuXFEL
SCUs for FELs



The Australian Synchrotron
Melbourne, ANSTO, BioSAXS beamline

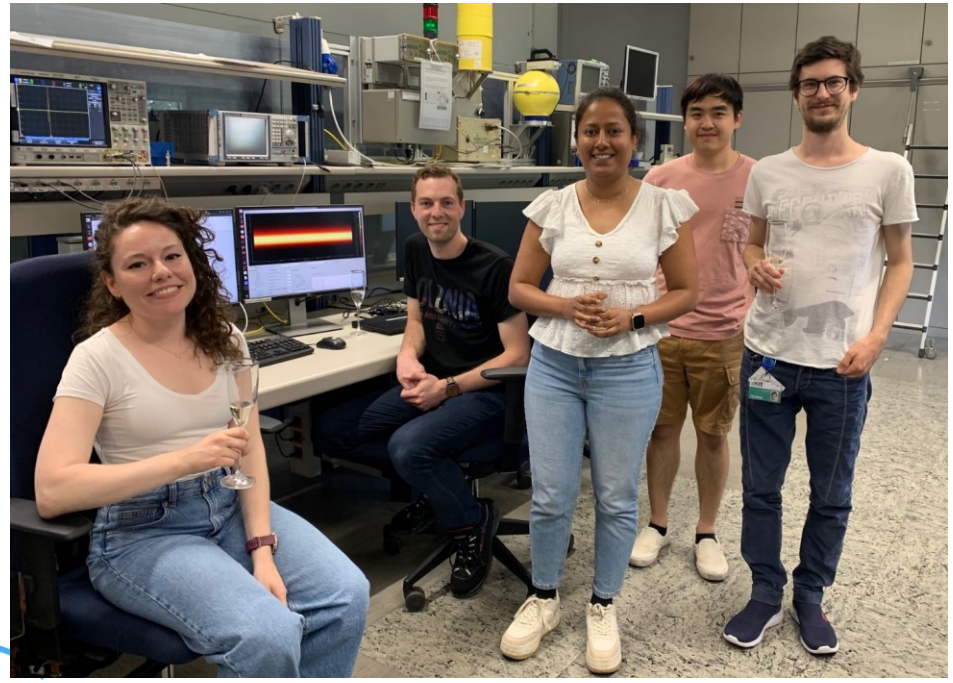
© KIT & Bilfinger Noell GmbH

Photo: A. W. Grau, KIT

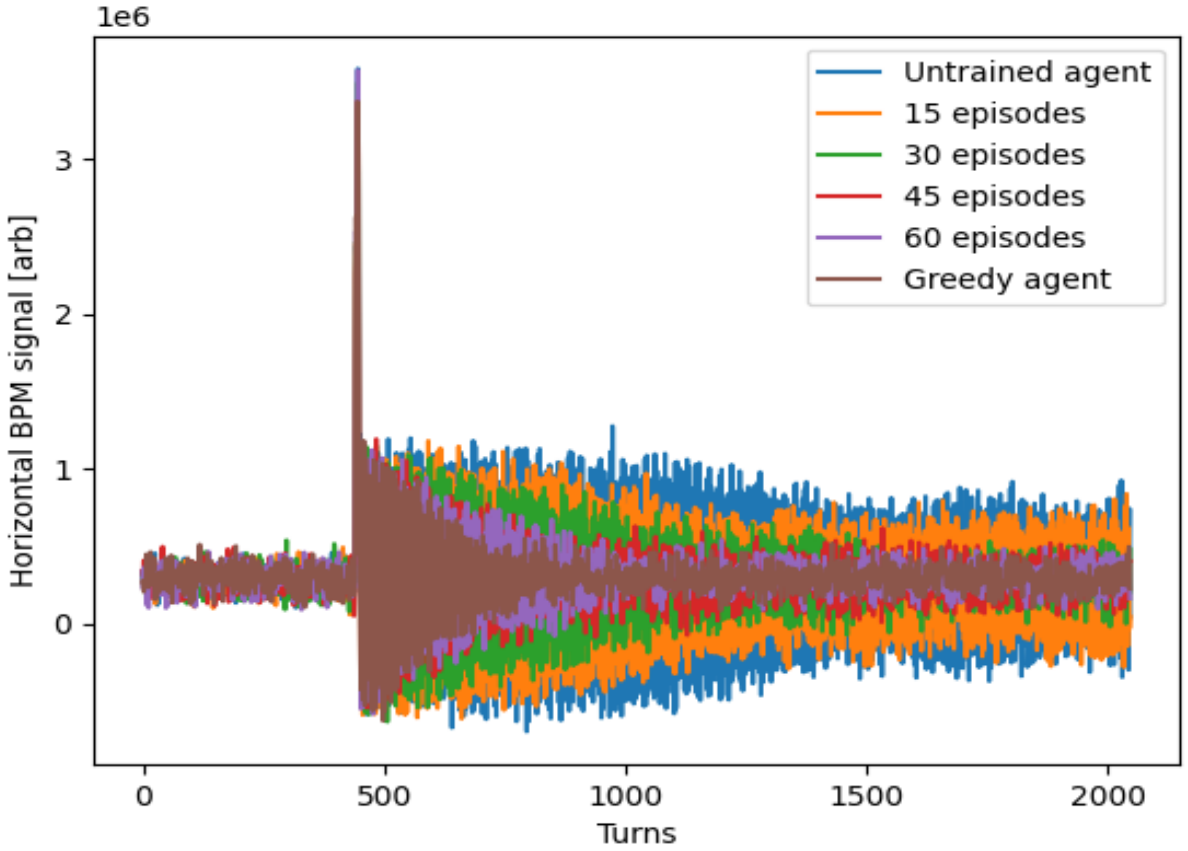
1st demo. of AI-on-hardware for accelerator control

- **ML***: Rapid prototyping of **accelerator R&D & detector R&D at KIT**

- **Reinforcement Learning (RL) implemented on hardware @ KARA**
  - Unprecedented speed and control
  - Developed by young researchers



Hot of the press in June 2023

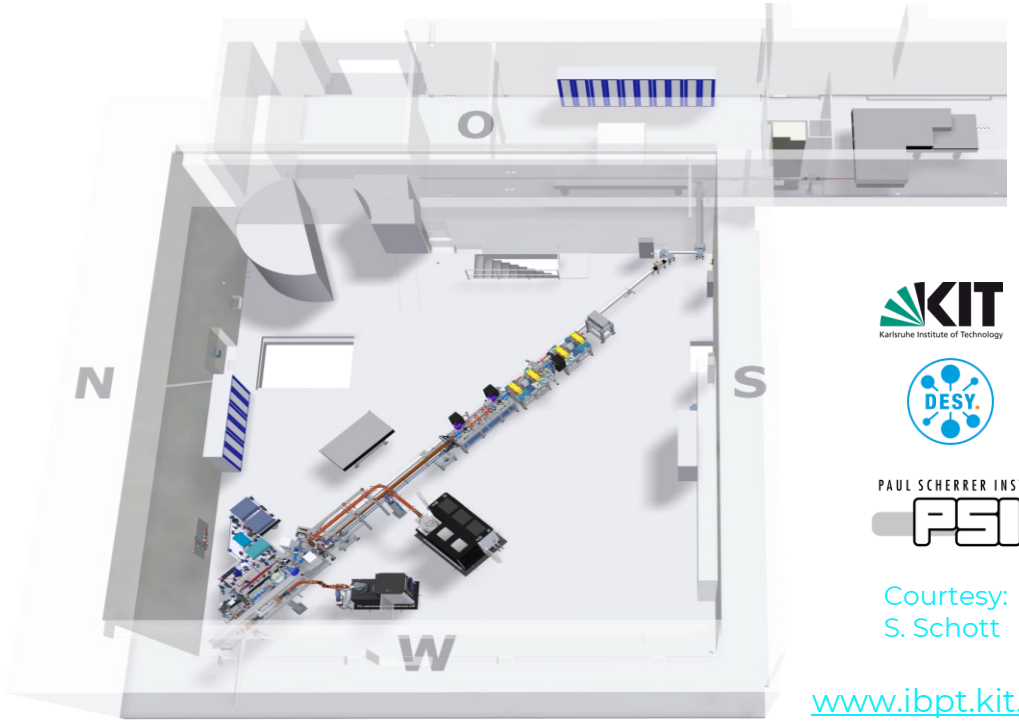


AI * = Artificial intelligence, ML* = Machine Learning

FLUTE - Ferninfrarot Linac Und Test Experiment

- Compact test facility for **accelerator physics within ARD*** at KIT
- Experiments with electrons & THz radiation, e.g. experiments towards FLASH therapy
  - R&D Topics
- Systematic bunch compression and THz generation studies
- Serve as a test bench for new beam diagnostic methods and tools
- Develop single shot fs diagnostics
- Synchronization on a femto-second level

Final electron energy	5 to 50 (41)	MeV
Electron bunch charge	0.001 - 1 (3)	nC
Electron bunch length	1 - 300	fs
Pulse repetition rate	up to 10	Hz
THz E-Field strength	up to 1.2	GV/m

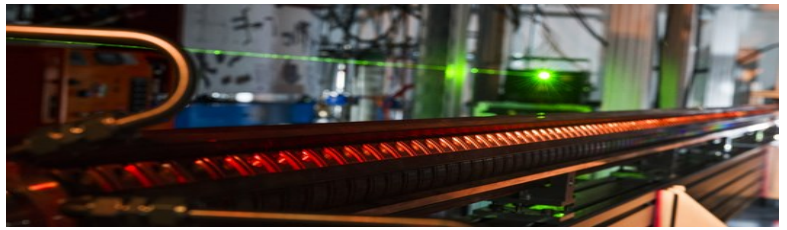


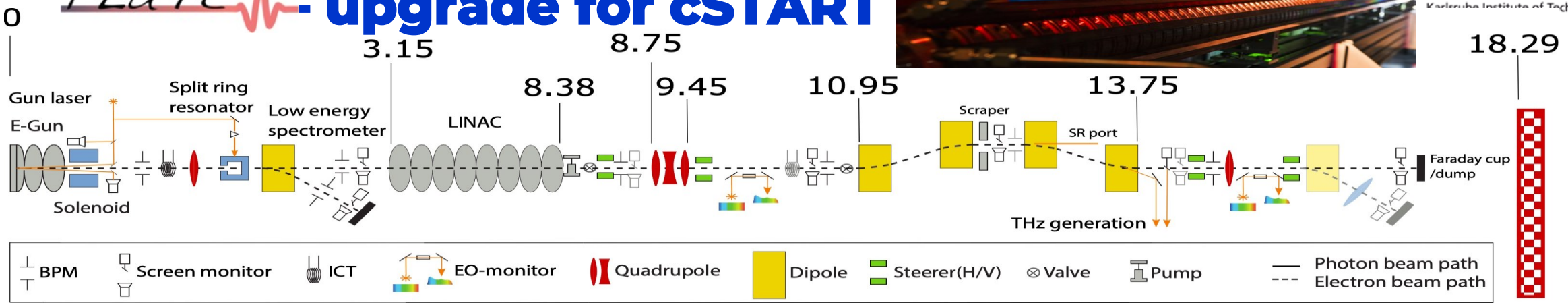
Courtesy:
S. Schott

www.ibpt.kit.edu/flute

ARD* = Accelerator Research & Development

FLUTE - upgrade for cSTART





1st stage

(in commissioning)

- New E- gun
- New RF system
- 1st diagnostics section improved after 5 years in operation

2nd stage

(RF commissioning)

- Linac baked out
- 2nd diagnostics section built
- K300 for RF in commissioning

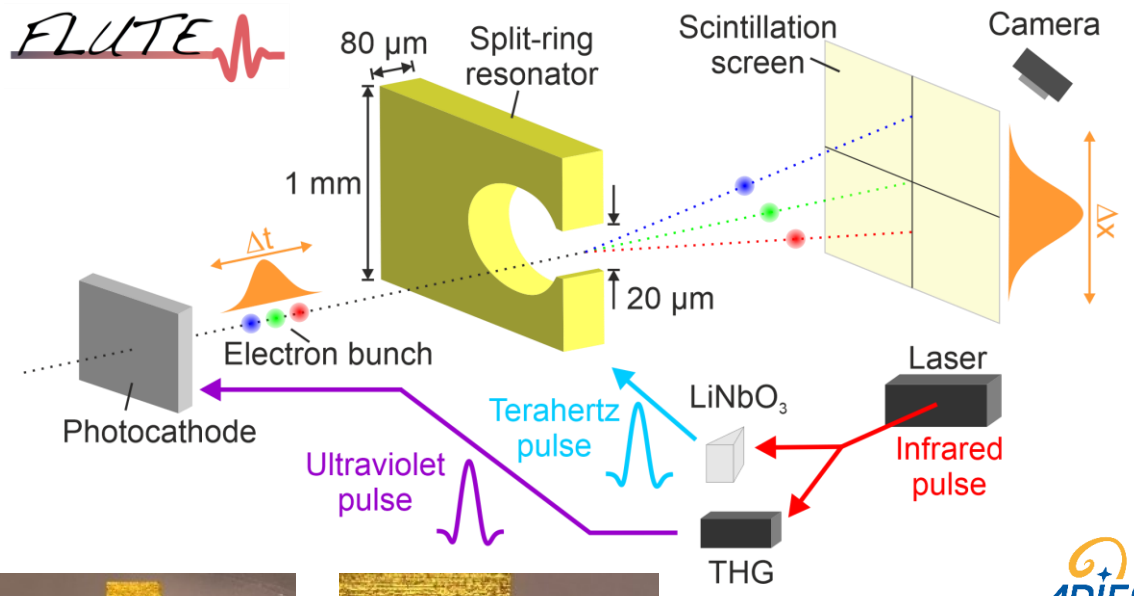
3rd stage

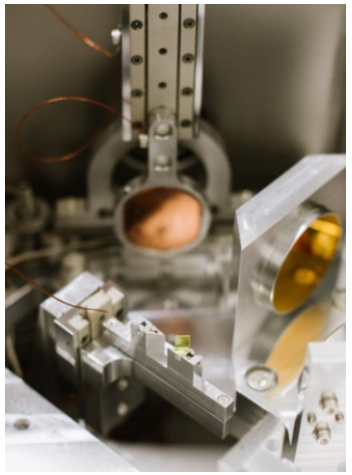
(assembly in finalization)

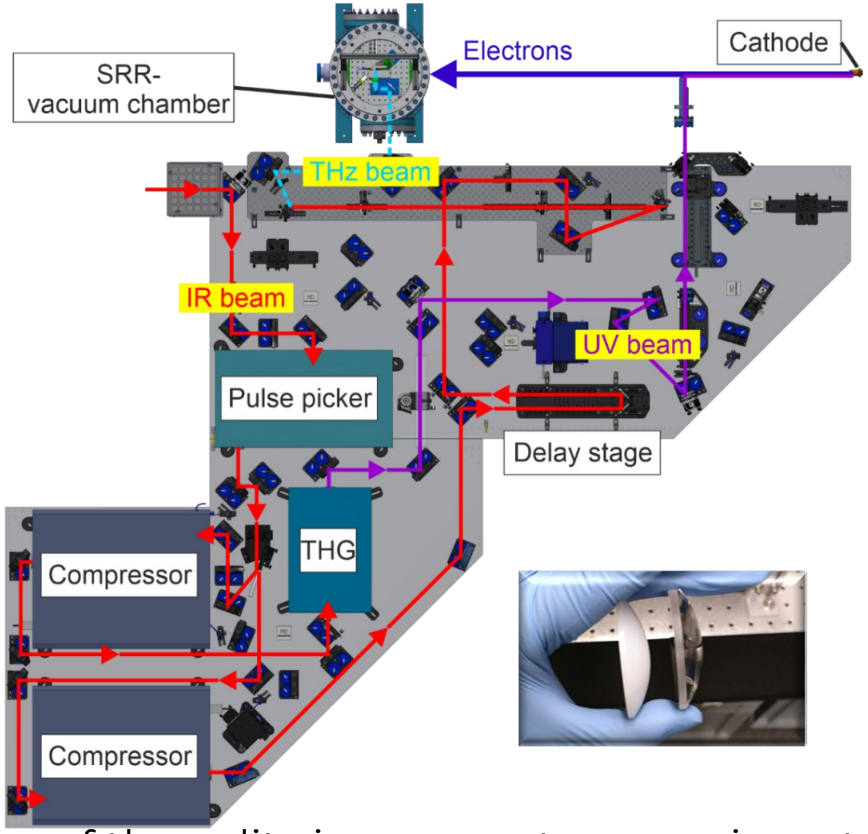
- Bunch compressor
- e^- diagnostics
- THz diagnostics in manufacturing

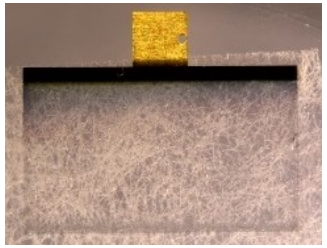
FLUTE - Ferninfrarot Linac Und Test Experiment

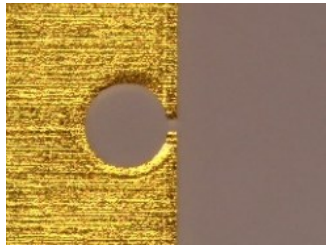
- **Split-Ring Resonator** SRR for **longitudinal electron bunch profile** measurements











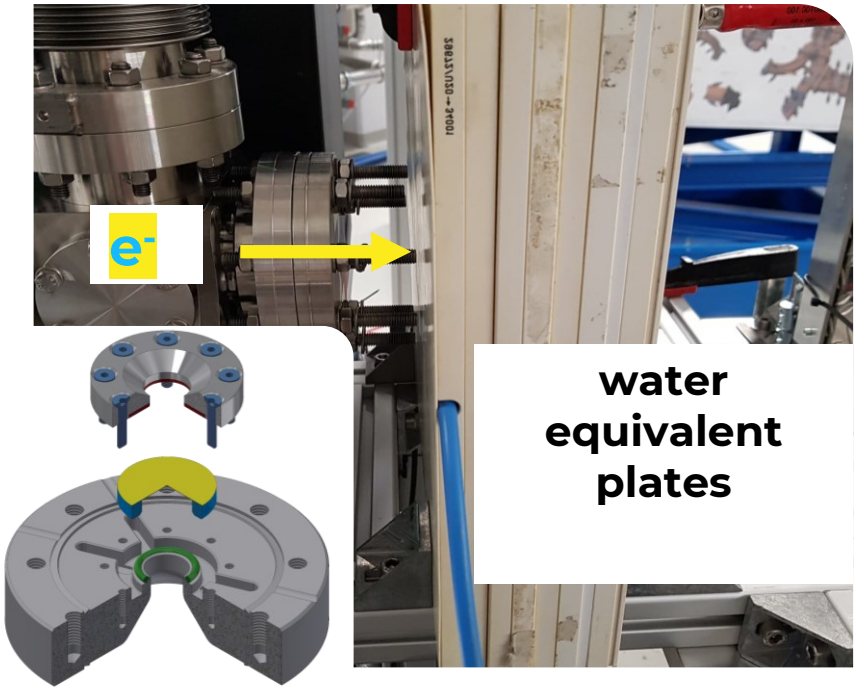
J. Schäfer et al.
https://doi.org/10.18429/JACoW-IPAC-23-THPL122
M. Nabinger et al.
https://doi.org/10.18429/JACoW-IPAC-23-THPA079

Streaking with THz radiation and amplifying the electric field with a **20 µm gap split-ring resonator**

Setup of the split-ring resonator experiment in the low energy section at FLUTE
Improvement: self-made lenses and study of water vapor impact

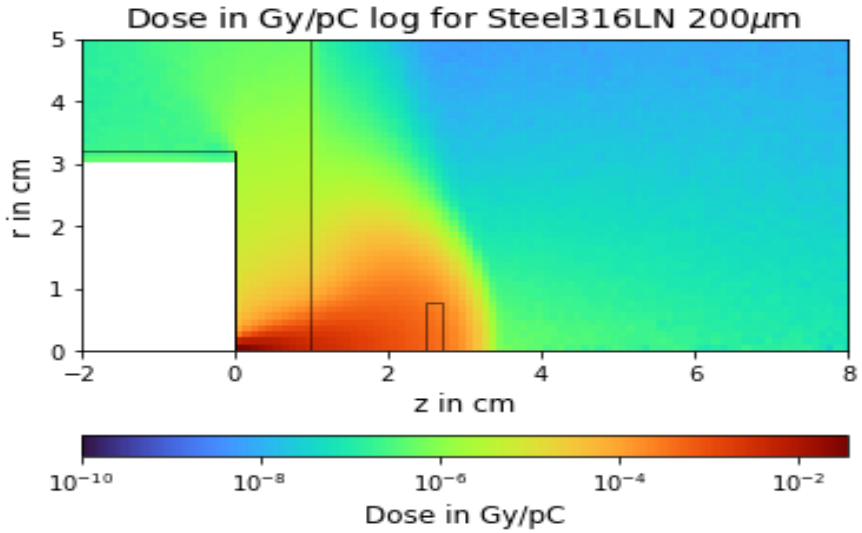
FLUTE - Ferninfrarot Linac Und Test Experiment

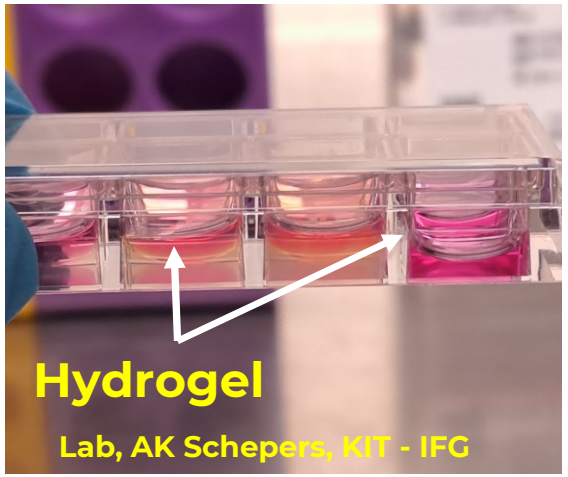
- Accelerator technology for precision medicine within **KIT Center HealthTech**
- Development and implementation of innovative technologies (e.g. FLASH) leading to the transformation of health technologies into future healthcare.



- KARA → **photon irradiation**
- FLUTE → **electron irradiation**
- First tests in cooperation with **DKFZ**

K. Mayer, Master thesis 2023

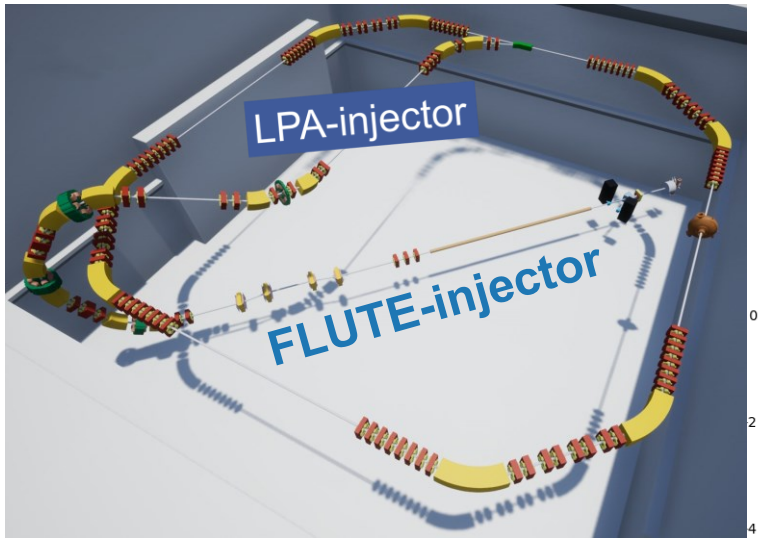




KIT 2030 in Accelarator Research & Development

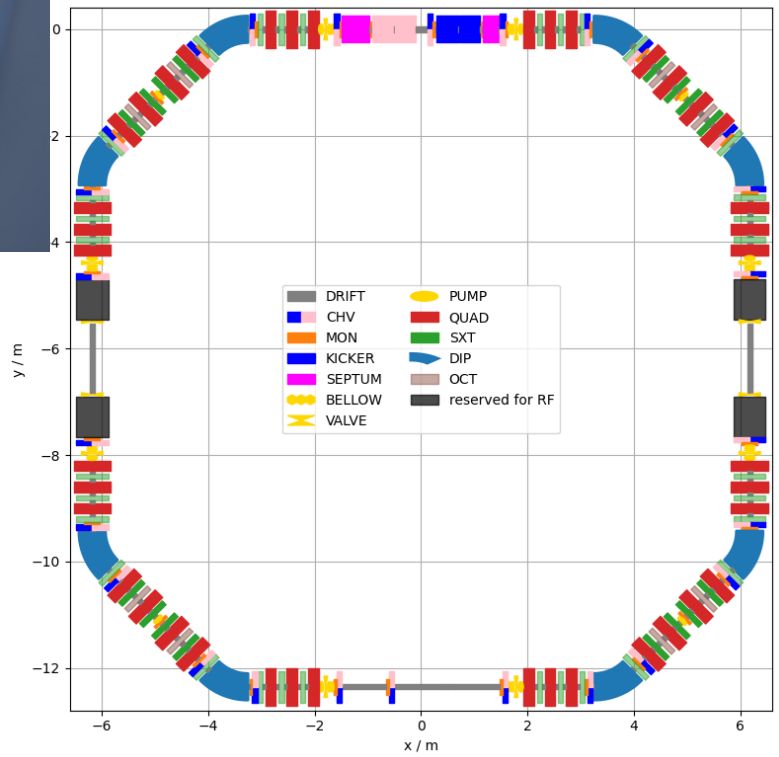
- Motivation**:** Storage of **ultra-short (fs) electron bunches** with high repetition rate

- Compact storage ring with very large momentum acceptance and dynamic aperture for LPA-like electron beams



- Injector: FLUTE with new transfer-line

- Status:
  - Conceptual design and specification: finished
  - Transfer line: first magnets delivered
  - Test of diagnostics at KARA booster: ongoing
  - Technical Design Report ordered in 9/2023



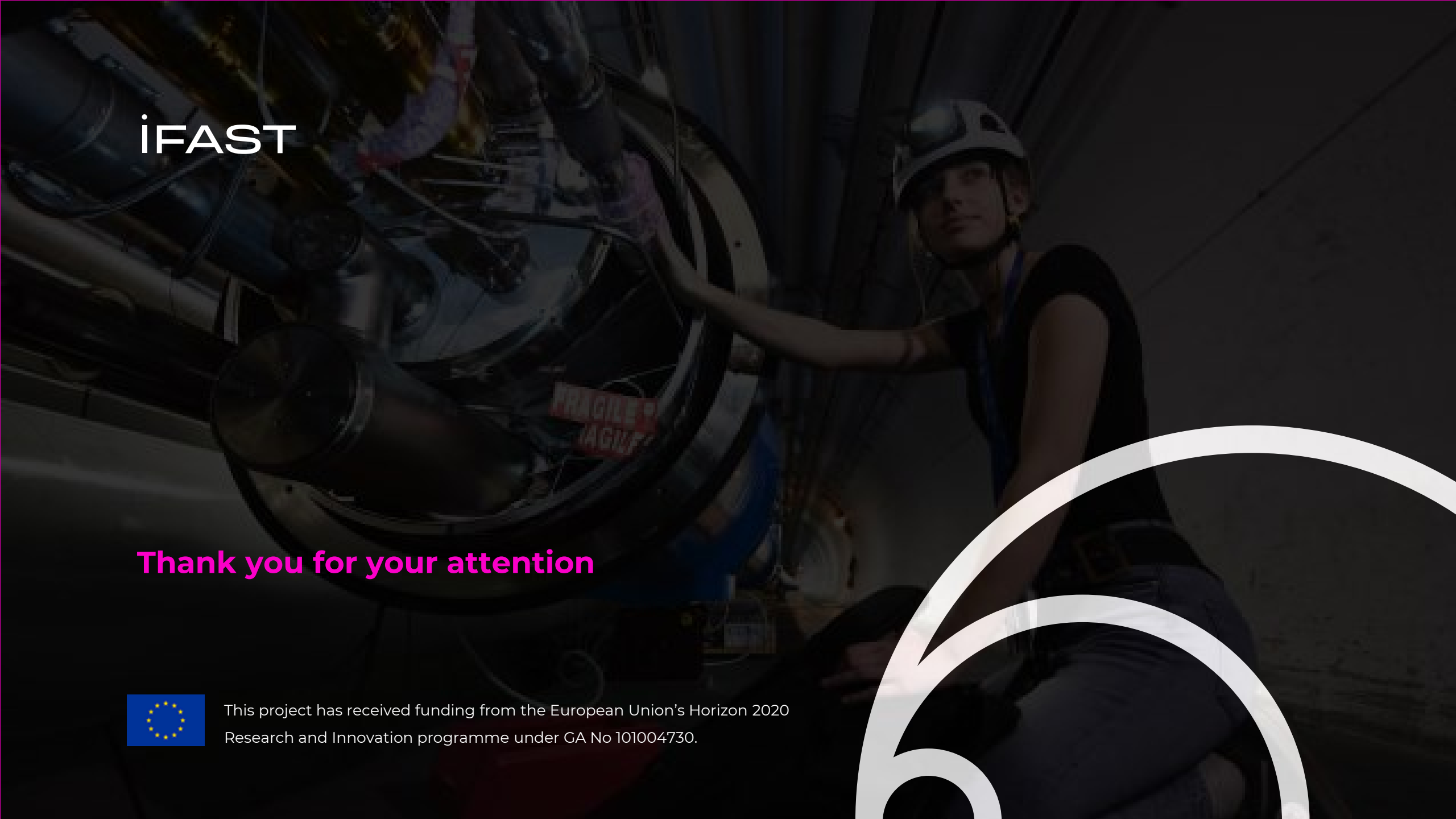
TFs* = Technology Platforms

KIT is Partner 18 in I.FAST on WP 5, 7, 13

- Task 5.1: **MUon colliders ST**rategy network (MUST)
  platform to discuss the plans for key R&D and test facilities,
  disseminate the information on muon colliders activities
  contains the muon source (positron and proton driven) and the overall collider design

- Task 7.2, KIT-Task-leader: Enabling **technologies for ultra-low emittance rings**
  Experimental tests (KIT, CERN) on the major technical challenges: e.g. NEG characterization
  organize general and topical workshops on the specific technical challenges and support exchange of staff for visits and common experiments:
- Workshop at KIT: April 2022: Beam Diagnostics & Dynamics in Ultra-Low Emittance Rings
- Workshop at KIT: Nov 2023: Bunch-by-Bunch Feedback Systems & Related Beam Dynamics
- Networking, sharing experience and training: EURO-LABS-TA experiments at KARA in 11/2023

- Task 13.1: **Developing and promoting services to industry** in AMICI TFs
  Organization and operation of a central information and contact point for industry and other external partners to access TPs with the aim to ensure the dissemination of information, analysis of requests and contacts to the appropriate TP. The central contact point will be managed by CEA assisted by a network of contacts at each AMICI TF.



iFAST

Thank you for your attention

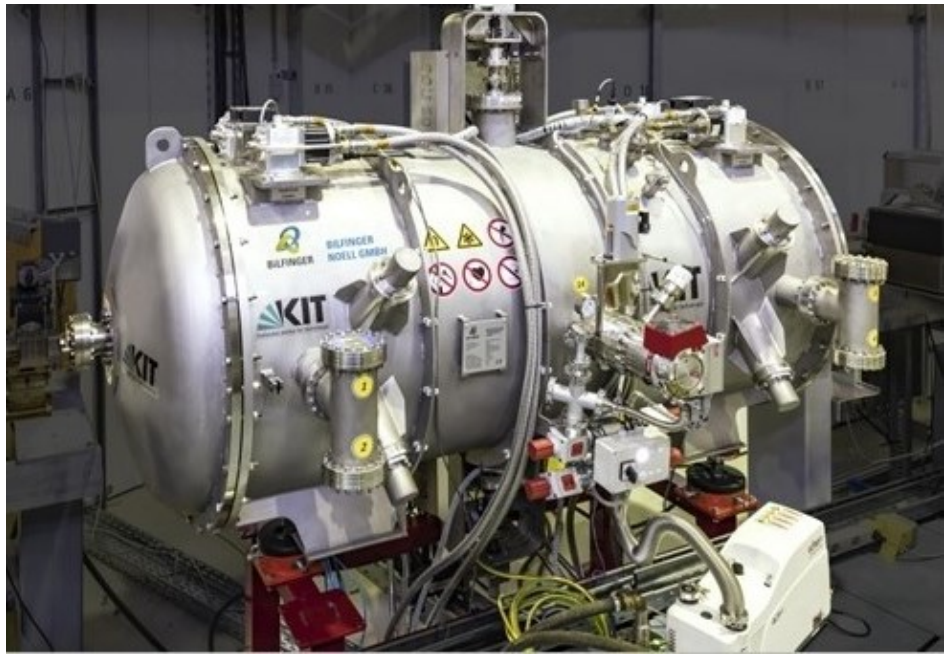
This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under GA No 101004730.

Super-conducting Insertion Devices @ KARA

- Collaboration between KIT and Bilfinger Noell GmbH (BNG)

- BNG receives further orders for insertion devices from Light Sources and strengthens its world leading position in the supply of SCU und SCW.

- The insertion devices are the result of the 15 years collaboration with KIT-IBPT, which will also carry out the cold test of the units.



view in the KARA hall