Karlsruhe Institute of Technology

Introduction to KIT, KARA, and FLUTE

Bastian Härer on behalf of the KIT team

25 April 2022

Welcome to KIT ☺

The Research University in the Helmholtz Association

- ~ 22,000 students
- ~ 10,000 employees
- 5 sites

KIT Campus South

Welcome to KIT ☺

Karlsruhe Institute of Technology

Karlsruhe Palace

Photo: P. Wesolowski, KIT IBPT

KIT Campus South

ARIES

Beam Tests and Commissioning
of Low Emittance Storage Rings

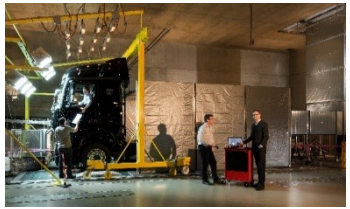
Welcome to KIT ☺

KIT Campus North

~ 10 km north of Karlsruhe
Big research infrastructures

Location of IBPT and
the KIT accelerators

Big Research Infrastructures at KIT



Acoustic Four-wheel Roller Dynamometer

KARA Karlsruhe Research Accelerator

Biomass to Liquid (bioliq®)

EnergyLab 2.0

European Zebrafish Resource Center

High-perfomance Computer for Research

Grid Computing Centre Karlsruhe (GridKa)

Karlsruhe Nano Micro Facility (KNMF)

Karlsruhe Tritium Neutrino Experiment

Theodor Rehbock River Engineering Laboratory

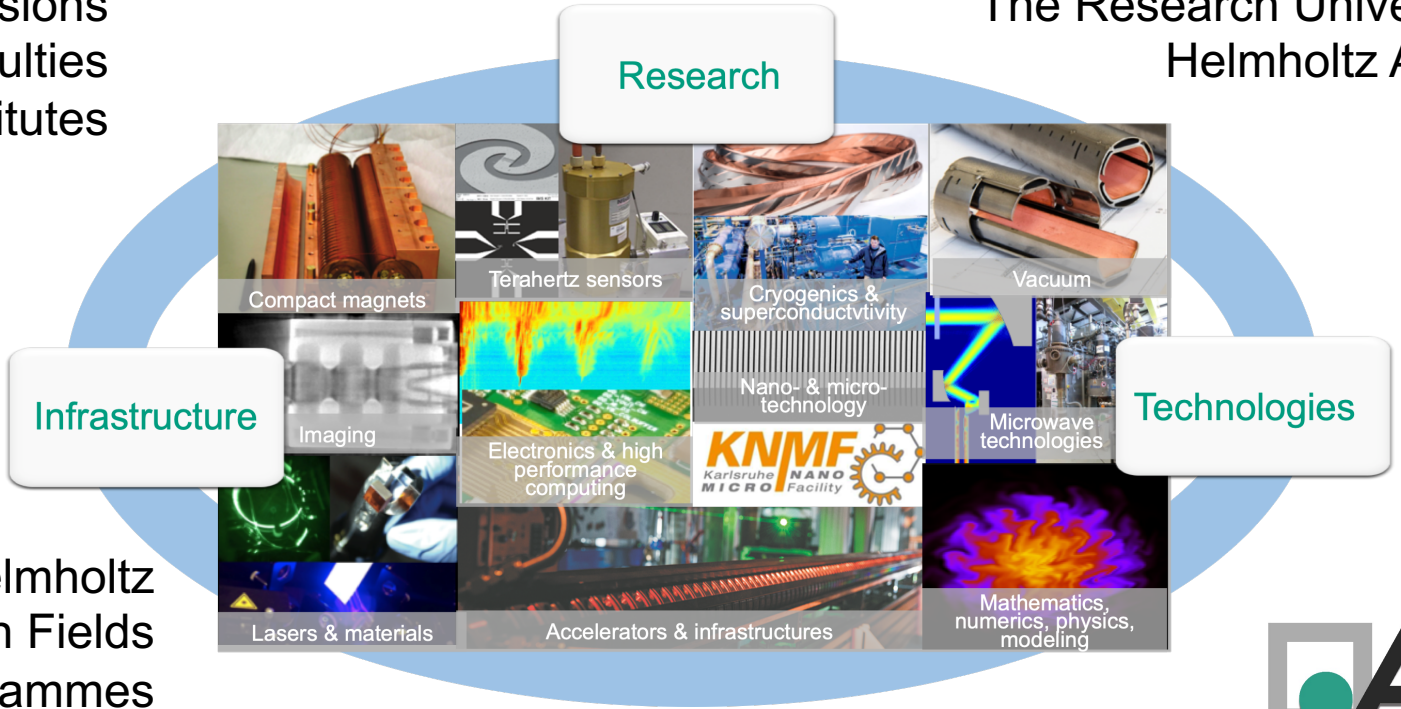
Vehicle Efficiency Laboratory

AIDA Cloud Chamber

The Accelerator Technology Platform @ KIT (ATP)

5 Divisions
6 KIT-Faculties
11 Institutes

The Research University in the Helmholtz Association



Helmholtz
3 Research Fields
6 Programmes

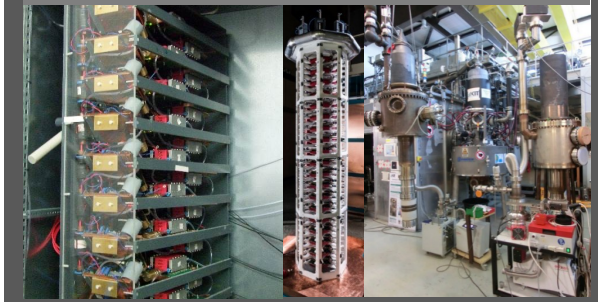
+ strong industrial partners

ATP
Accelerator Technology Platform @ KIT

Test facilities & technologies - examples

ATP Accelerator Technology Platform @ KIT
KIT Karlsruhe Institute of Technology

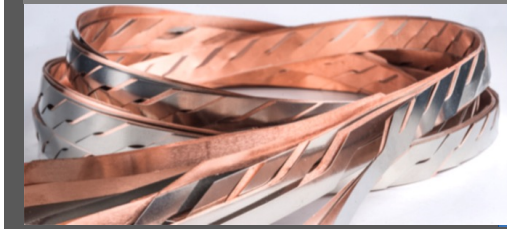
Pulse power technology *Gyrotrons*

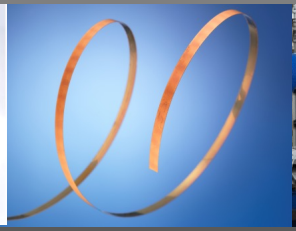


Winding technologies

Magnet test facilities

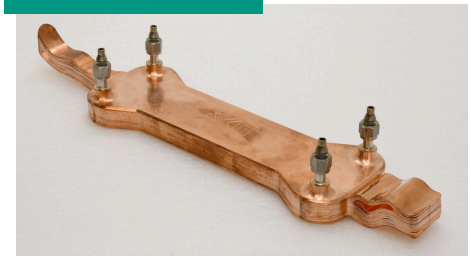
Cable technologies *High temperature superconductors*



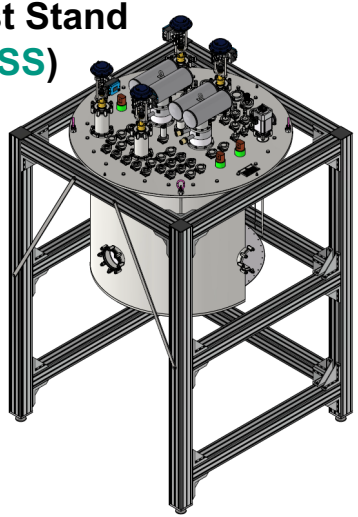


Accelerator & Energy Systems Test Field KITTEN

Design
I < 10 kA



Compact Accelerator Systems Test Stand (COMPASS)



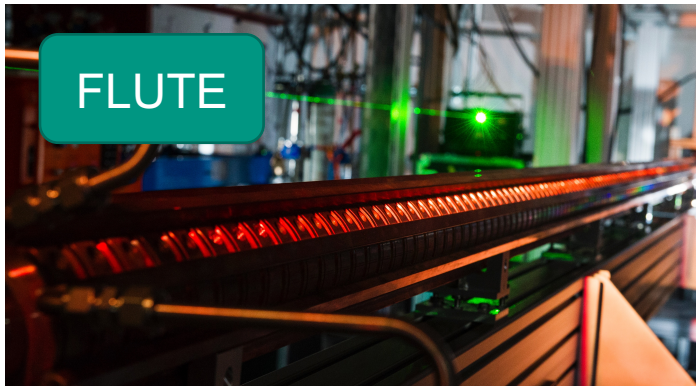
InnovEEA
Innovation pool project for Energy Efficient Accelerators

- Load Management (network stability)
- Ultra compact accelerator technology

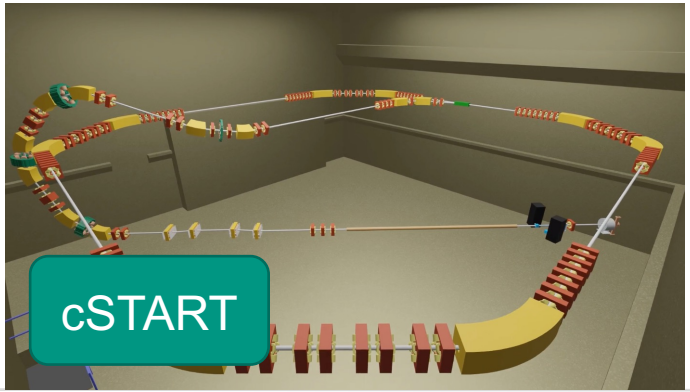
J. Arnsberg, S. Grohmann, Innovationspool III. InnovEEA Meeting 30.03.2022 - https://indico.scc.kit.edu/event/2646/

- Digital Twin of KARA
  - analyzing, developing and testing future energy solutions for accelerators

Accelerator test facilities at KIT



in operation



in procurement

Karlsruhe Research Accelerator (KARA)

- KIT synchrotron lightsource & 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)

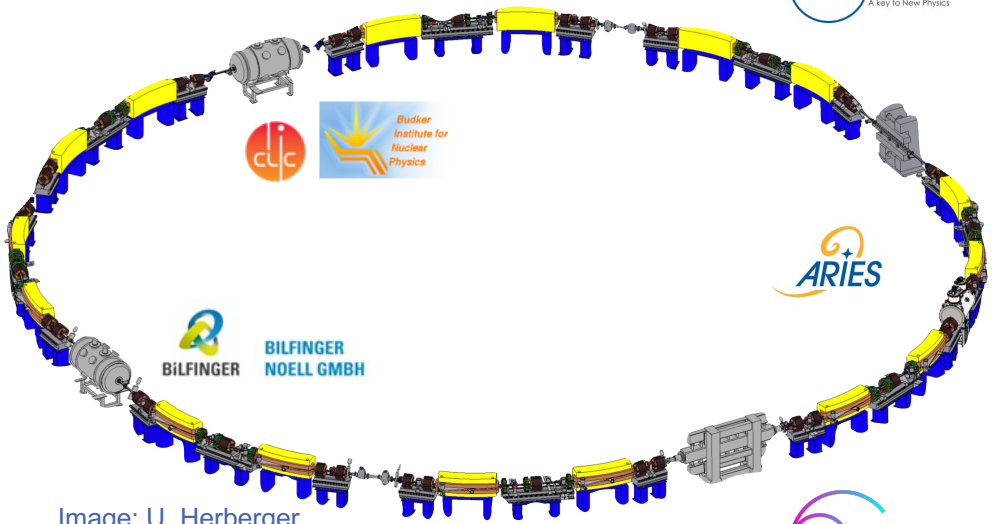


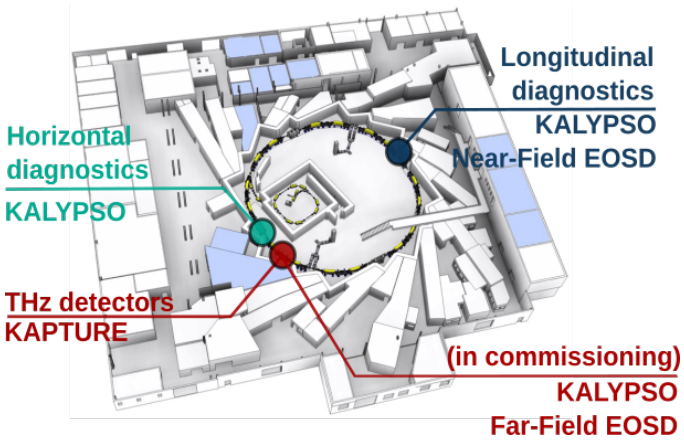
Image: U. Herberger

www.ibpt.kit.edu/kara

Longitudinal Beam Dynamics

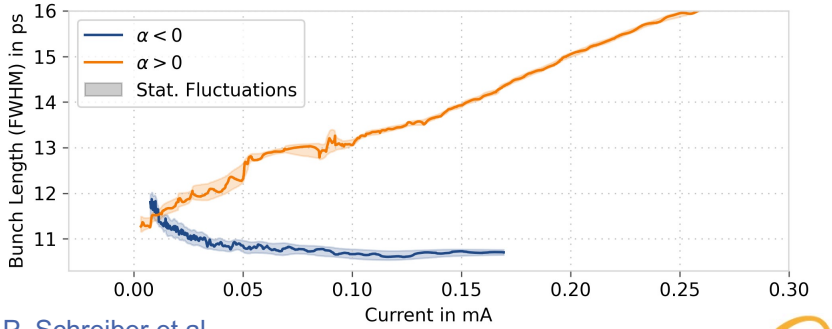
Interesting for high brilliant lightsources and low-emittance rings:

- Turn-by-turn and bunch-by-bunch diagnostics @KARA



talk J.L. Steinmann

- Effect of negative momentum compaction operation on the current-dependent bunch length

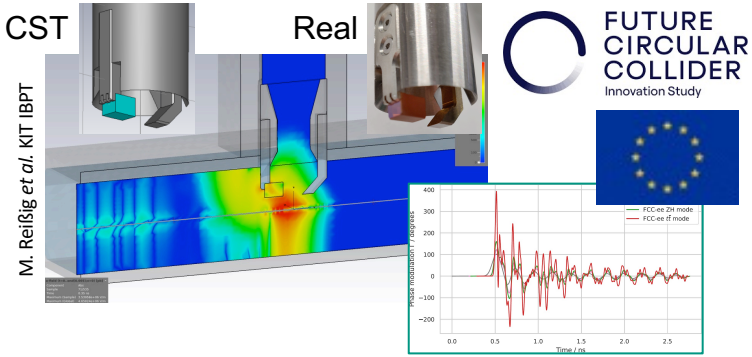


P. Schreiber et al.
https://doi.org/10.18429/JACoW-IPAC2021-WEPAB083

talk P. Schreiber

Highlights

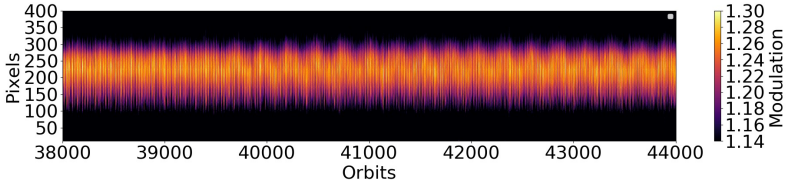
Beam diagnostics for 100-km FCC



One-fits-all: EO setup for 3 FCC-ee modes

Z, WW and ZH mode similar signal strength

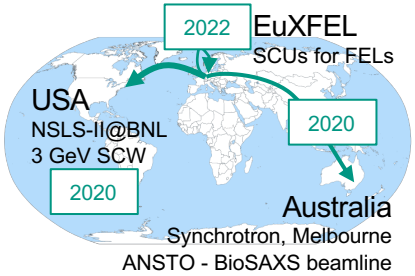
Extra adjustment for $t\bar{t}$ due to 3x/4x signal strength



Resolving electron bunch profile in every turn @ 2.7 MHz

Technology transfer from KARA to the world

Superconducting Undulators – **The future is now**



Citation: "**Superconducting undulators … most powerful light source for any experiment**"

Project BRIGHT | Australian Synchrotron | ANSTO

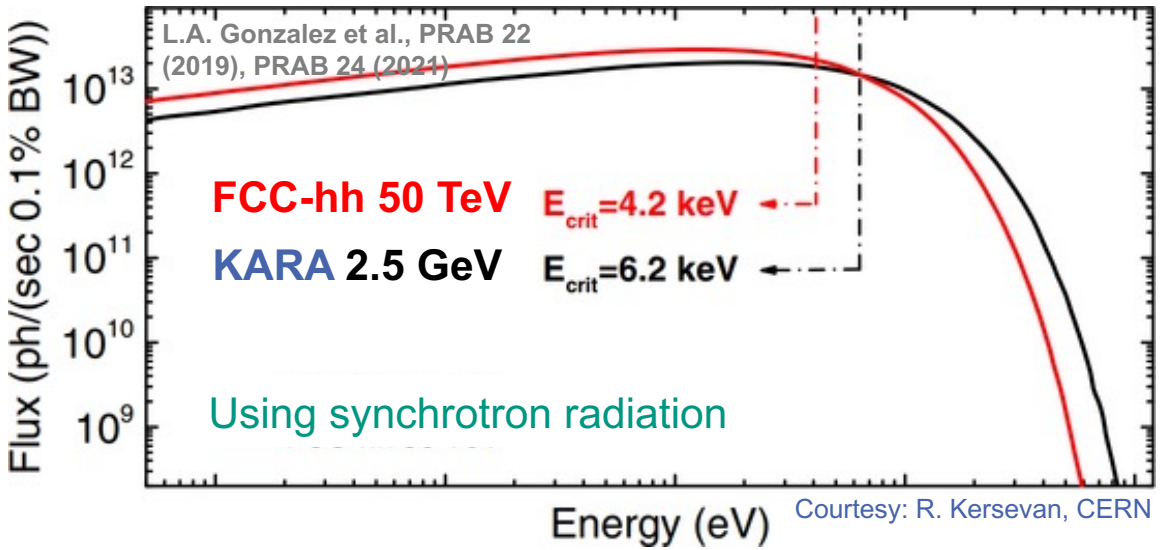
Accelerator R&D
Beam technologies

FCCIS I.FAST

ATP Accelerator Technology Platform @ KIT

KIT Karlsruhe Institute of Technology

- Push intensity, quality and efficiency frontier with prototypes & experiments
  - BESTEX (CERN experiment & **(rapid) prototyping** at **KARA**)
  - Future Circular Collider Innovation Study (FCCIS): diagnostics



Courtesy: R. Kersevan, CERN

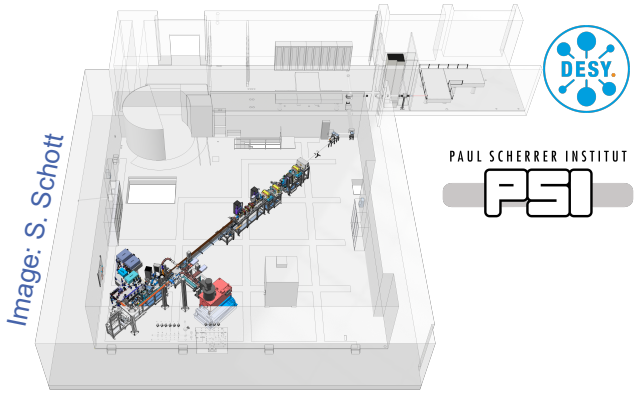
Several prototype vacuum chambers tested at KARA

Courtesy: L.A. González, CERN

FLUTE: Accelerator test facility at KIT

- FLUTE (Ferninfrarot Linac- Und Test-Experiment)
  - Linac-based test facility for accelerator physics
  - Experiments with THz radiation

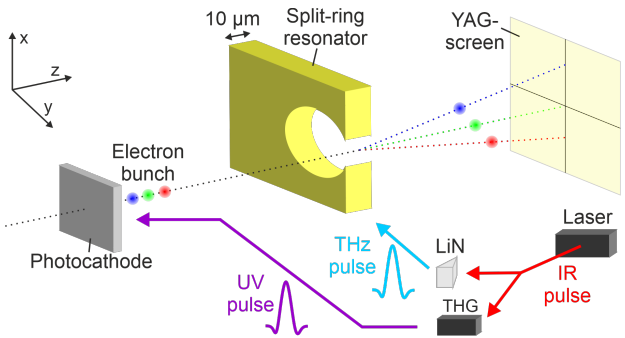
- R&D topics
  - Serve as a test bench for new beam diagnostic methods and tools
  - Systematic bunch compression and THz generation studies
  - Develop single shot fs diagnostics
  - Synchronization on a femtosecond level



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

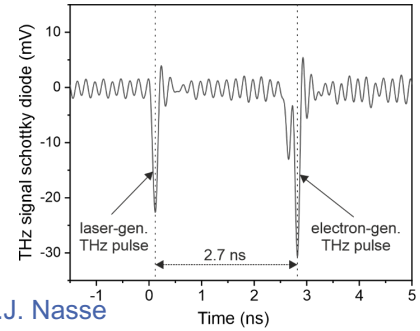
www.ibpt.kit.edu/flute

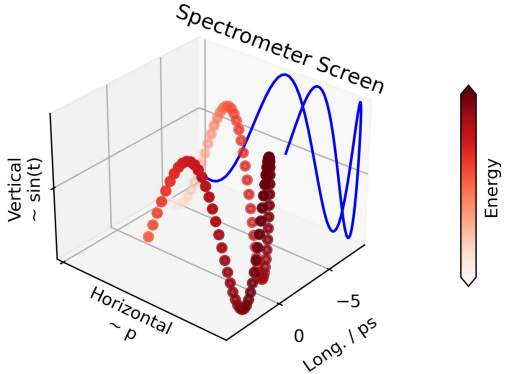
Split Ring Resonator Experiment

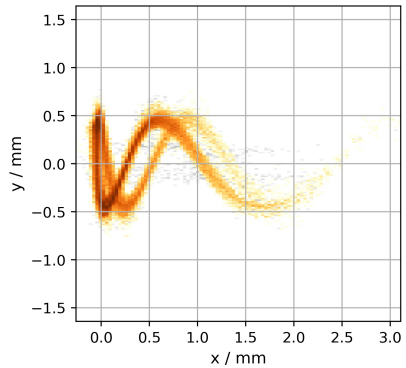


Courtesy: M. Nabinger, M.J. Nasse

Temporal overlap experimentally pre-adjusted!







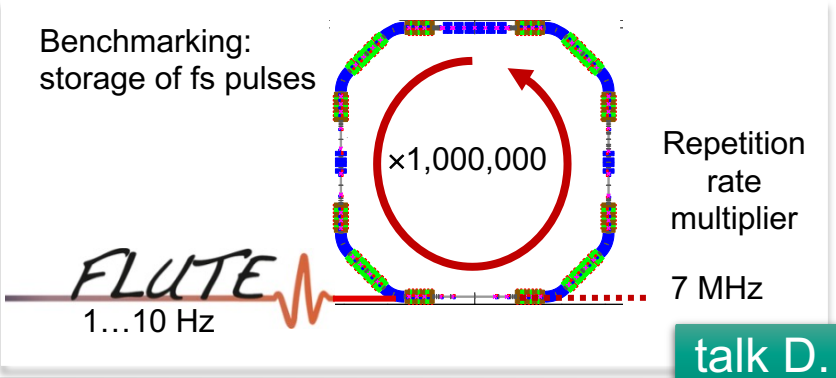
Courtesy: J. Schäfer

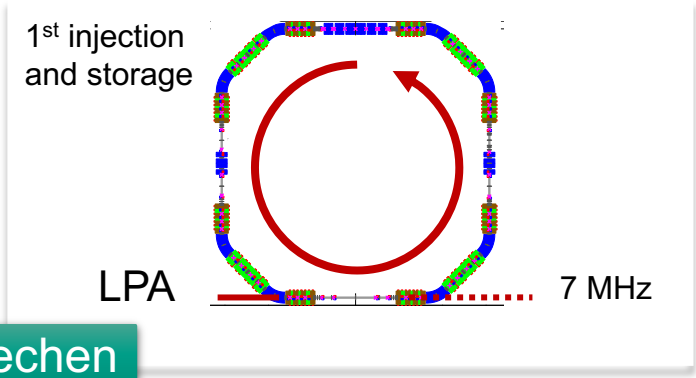
- Novel streaking device for bunches down to fs length
- Simulations finished
  - Matching simulation, machine settings and measurements
  - Prediction of optimal machine settings for split ring resonator experiment
- Experiment currently in commissioning for long bunches

cSTART – the new KIT accelerator project

*compact **St**orage Ring for **A**ccelerator **R**easearch and **T**echnology*

- Motivation: Storage of ultra-short (fs) electron bunches with high repetition rate
- Goal: **injection & storage** of a Laser Plasma Accelerator beam in a storage ring
- **1st study: LPA injection in ring-based light sources**
- Unique design: non-equilibrium ring with **very large momentum acceptance**

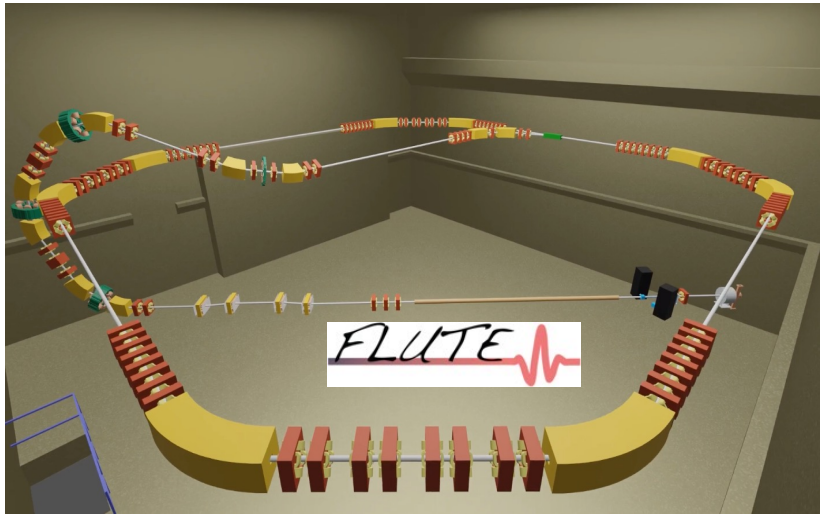




talk D. El Khechen

The two injectors

FLUTE



Courtesy: J. Schäfer

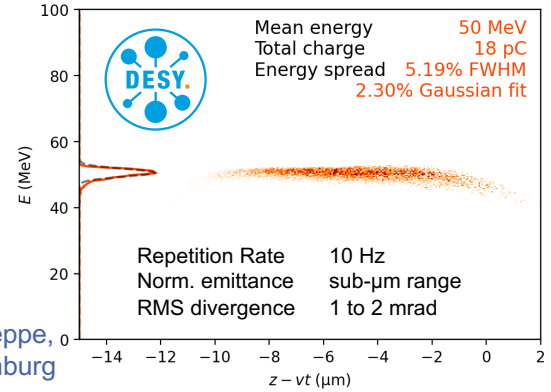
Laser plasma accelerator

Commercial Laser System

- For laser plasma accelerator (LPA) injector
- Parameters: > 1.5 J, < 25 fs, > 60 TW, 10 Hz
  - In production, commissioning at KIT in 2022

LPA design by DESY

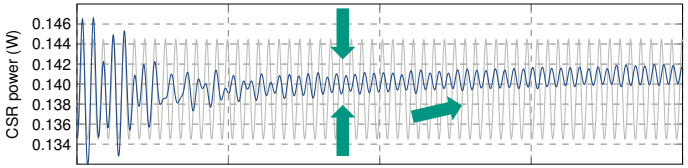
- Cooperation within ATHENA project
- Target based on LUX design

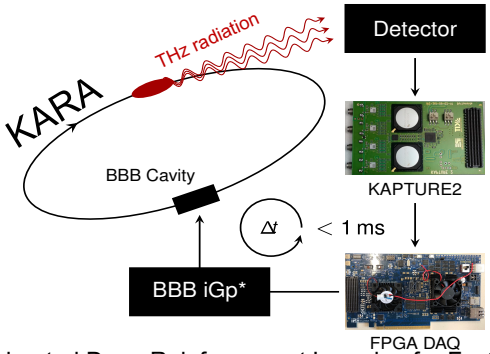


Courtesy: L. Jeppe, University Hamburg

Machine Learning Activities

First steps at real-time control of physical processes with Reinforcement Learning





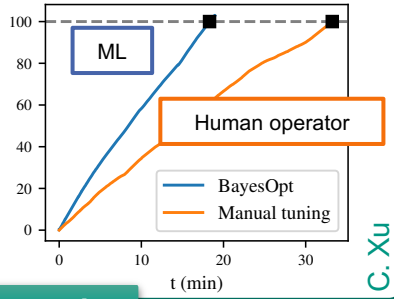
talk A. Santamaria

In house framework for ML deployment on hardware

T. Boltz

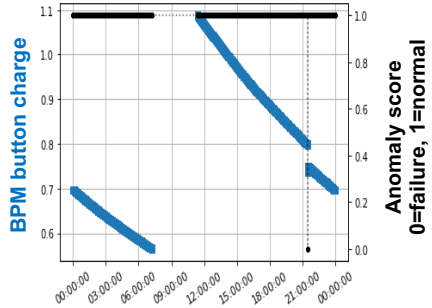
"Accelerated Deep Reinforcement Learning for Fast Feedback of Beam Dynamics at KARA" (IEEE 10.1109/TNS.2021.3084515)

Bayesian Optimization of injection efficiency



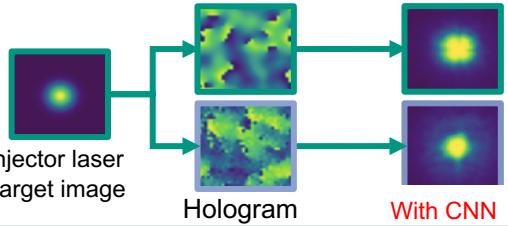
C. Xu

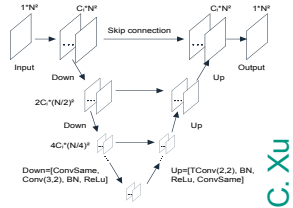
BPM anomaly detection with autoencoders



N. Bruchon

First steps at beam shape control





C. Xu

C. Xu et al. https://doi.org/10.18429/JACoW-IPAC2021-WEPAB289

Acknowledgements

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- The accelerator team:
  Axel Bernhard, Edmund Blomley, Tobias Boltz, Nicky Bruchon, Miriam Brosi, Erik Bründermann, Hyuk Jin Cha, Kantaphon Damminsek, Samira Fatehi, Stefan Funkner, Julian Gethmann, Andreas Grau, Steffen Grohmann, Dima El Khechen, Michael Hagelstein, Bastian Härer, Erhard Huttel, Stephan-Robert Kötter, Igor Kriznar, Artem Kuzmin, Sebastian Maier, Anton Malygin, Sebastian Marsching, Yves-Laurent Mathis, Wolfgang Mexner, Akira Mochihashi, David Moss, Matthias Nabinger, Michael J. Nasse, Gudrun Niehues, Meghana Patil, Alexander Papash, Micha Reißig, Robert Ruprecht, David Saez de Jauregui, Andrea Santamaria Garcia, Jens Schäfer, Thiemo Schmelzer, Patrick Schreiber, Nigel J. Smale, Johannes L. Steinmann, Pawel Wesolowski, Christina Widmann, Chenran Xu, and Anke-Susanne Müller
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