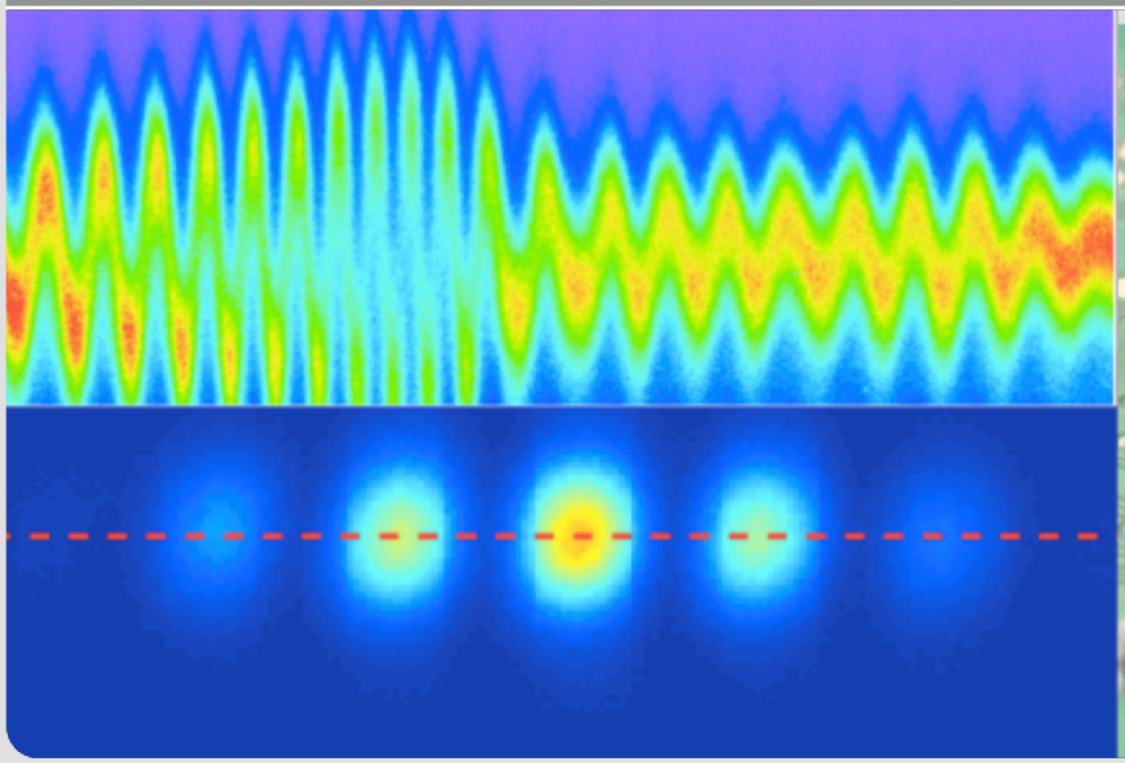
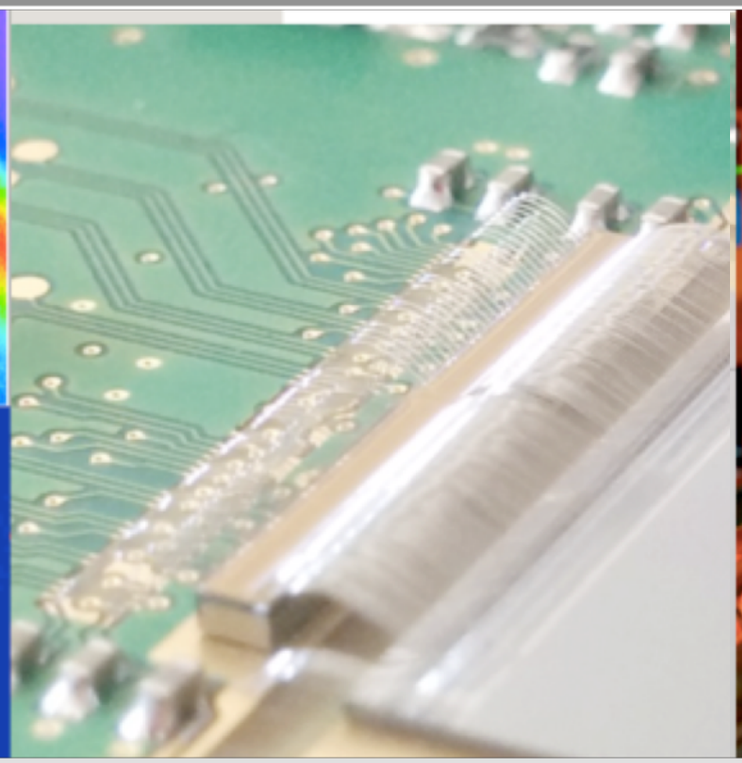
KIT accelerator facility status report

27th ESLS Workshop, Barcelona, Spain 27-29.11.2019

M. Schuh for the accelerator team

Institute for Beam Physics and Technology (IBPT)

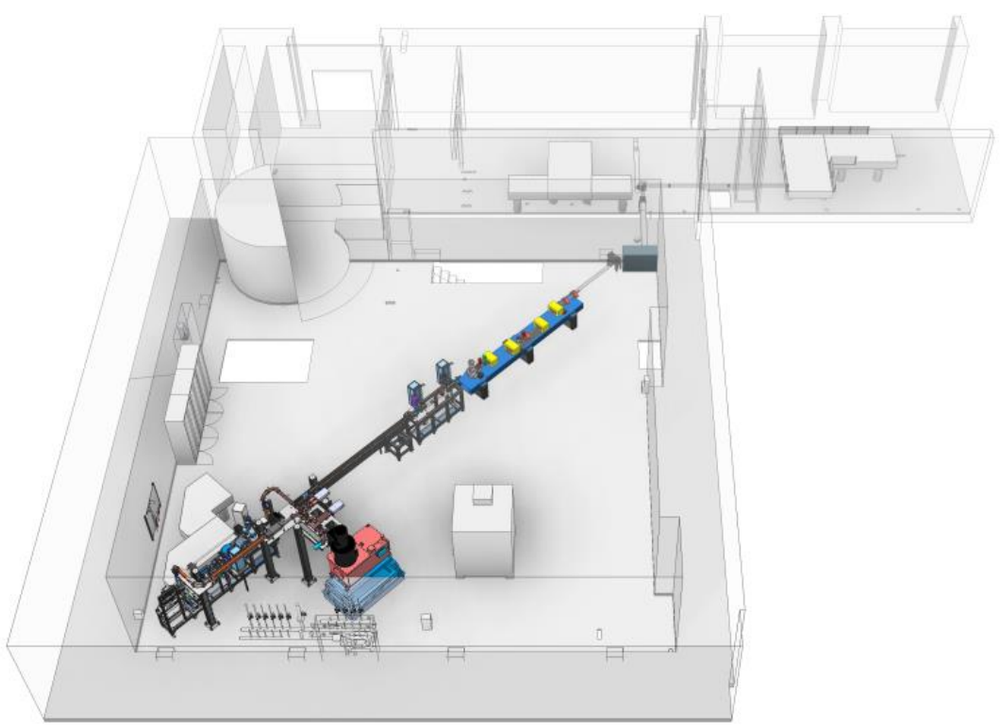




FLUTE: Accelerator test facility at KIT

- 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

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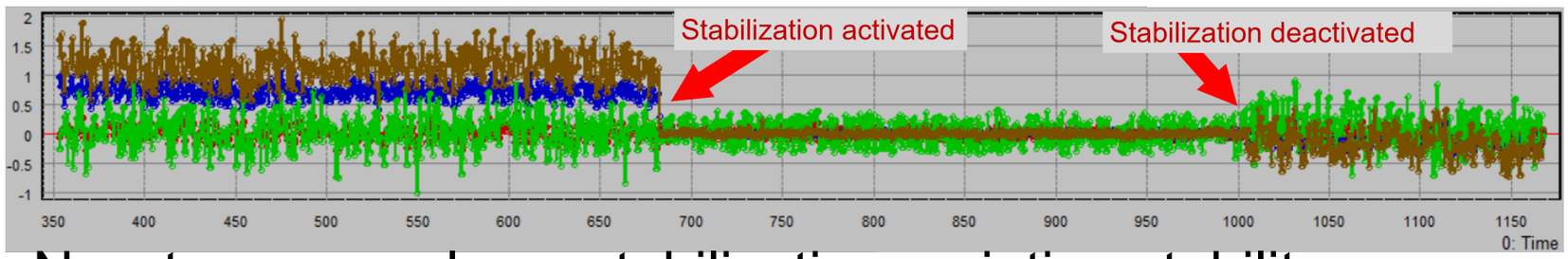
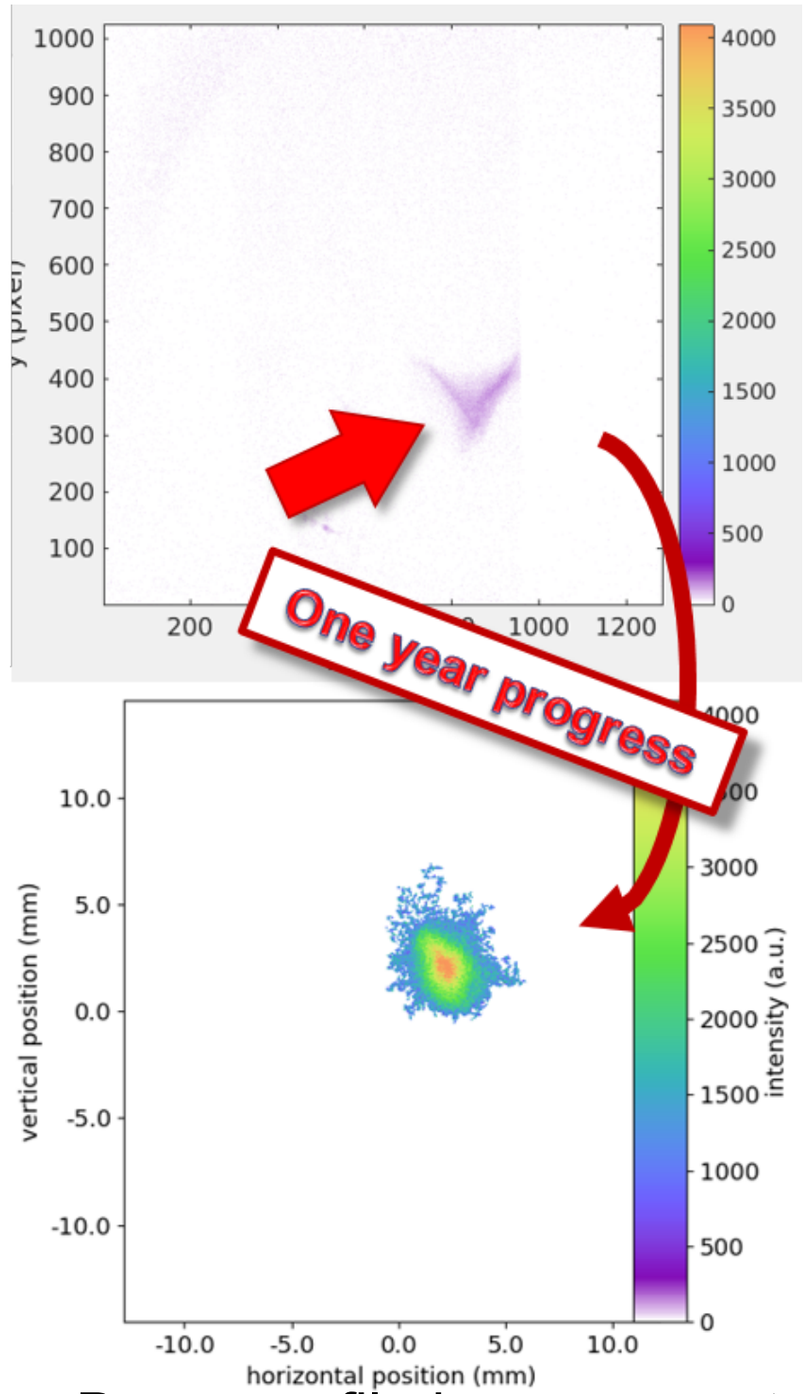
FLUTE status

- Commissioning progress:
  - New circulator in operation
    ➜ commissioned gun up to 13 MW
  - First energy spectrometer measurements
    ➜ electron beam up to 5.8 MeV
  - New laser transport stabilization system in operation
- Work in progress
  - Optimizing optics on table next to gun
  - Systematic beam characterization
  - Start of first user experiment: SRR



New transverse laser stabilization, pointing stability



Beam profile improvement

M.J. Nasse et al., DOI: 10.18429/JACoW-IPAC2019-MOPTS018

T. Schmelzer et al., DOI: 10.18429/JACoW-IPAC2019-WEPGW010

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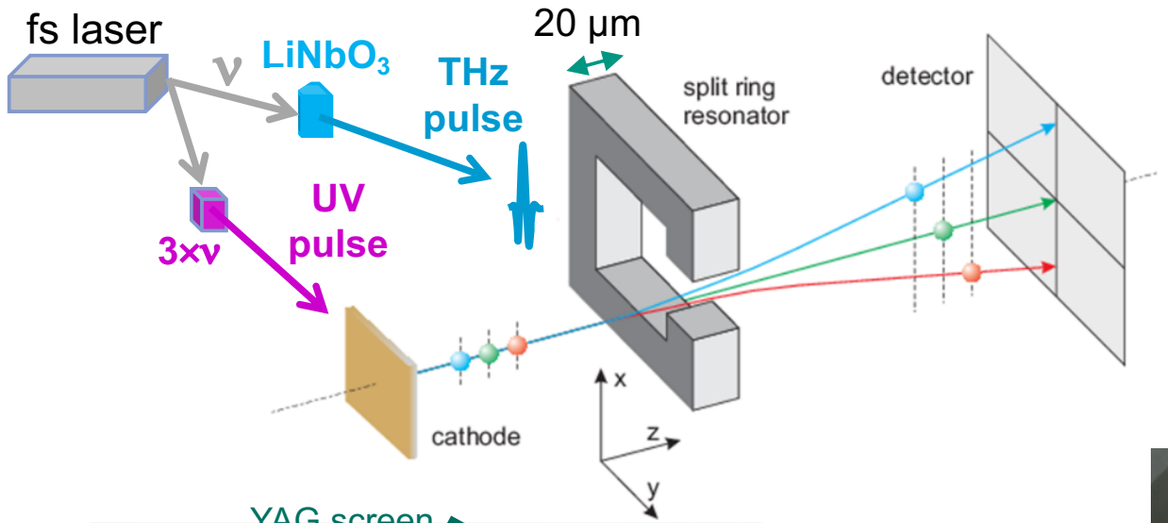
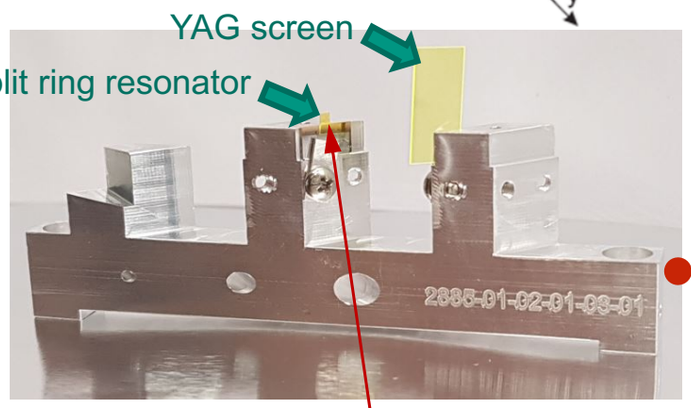
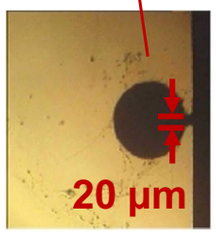
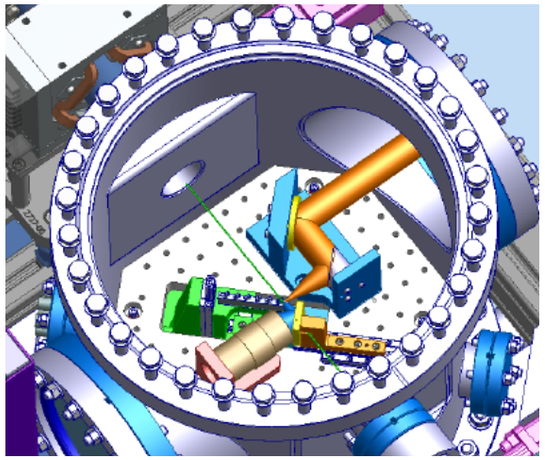
THz streaking using a split ring resonator

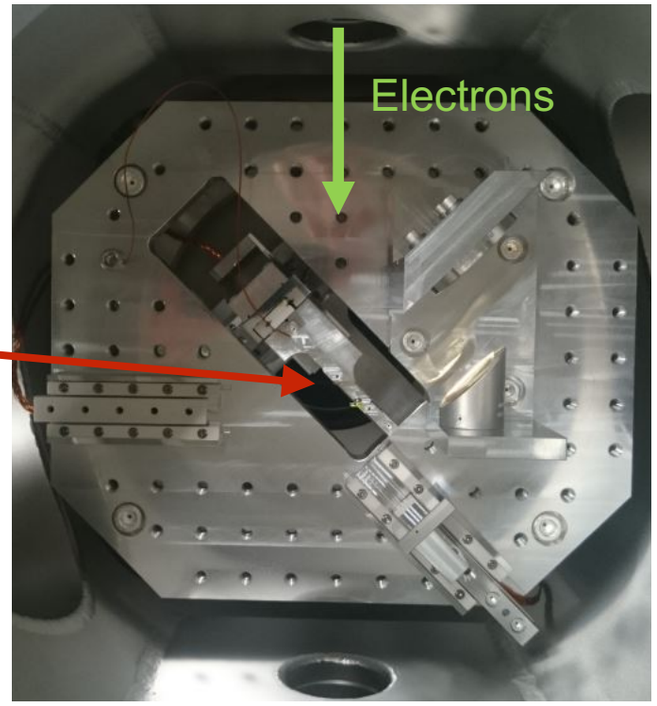
- Split ring resonator and YAG screen mounted in chamber
- First electrons on screen

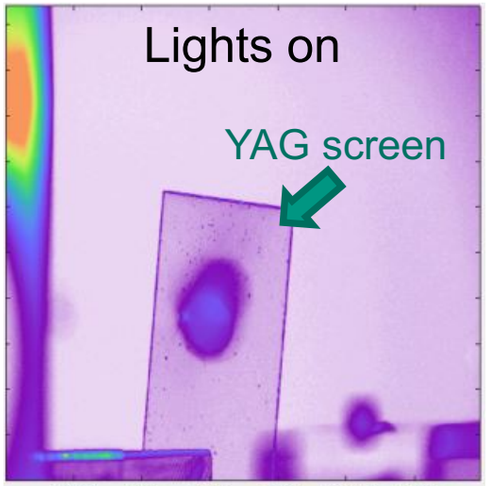


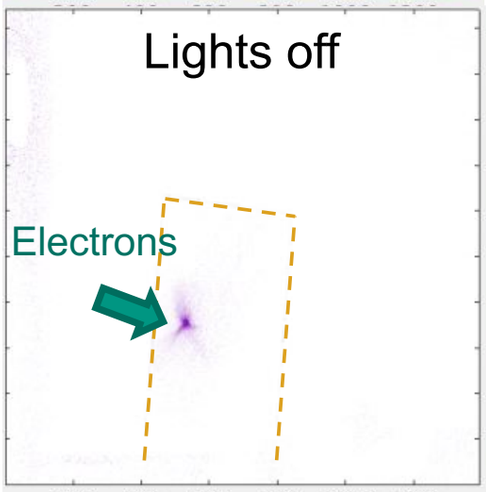












J. Fabiańska et. al., Sci. Rep. 4, 5645 (2014)

M. Yan et. al., IPAC'16, TUPG56 (2016)

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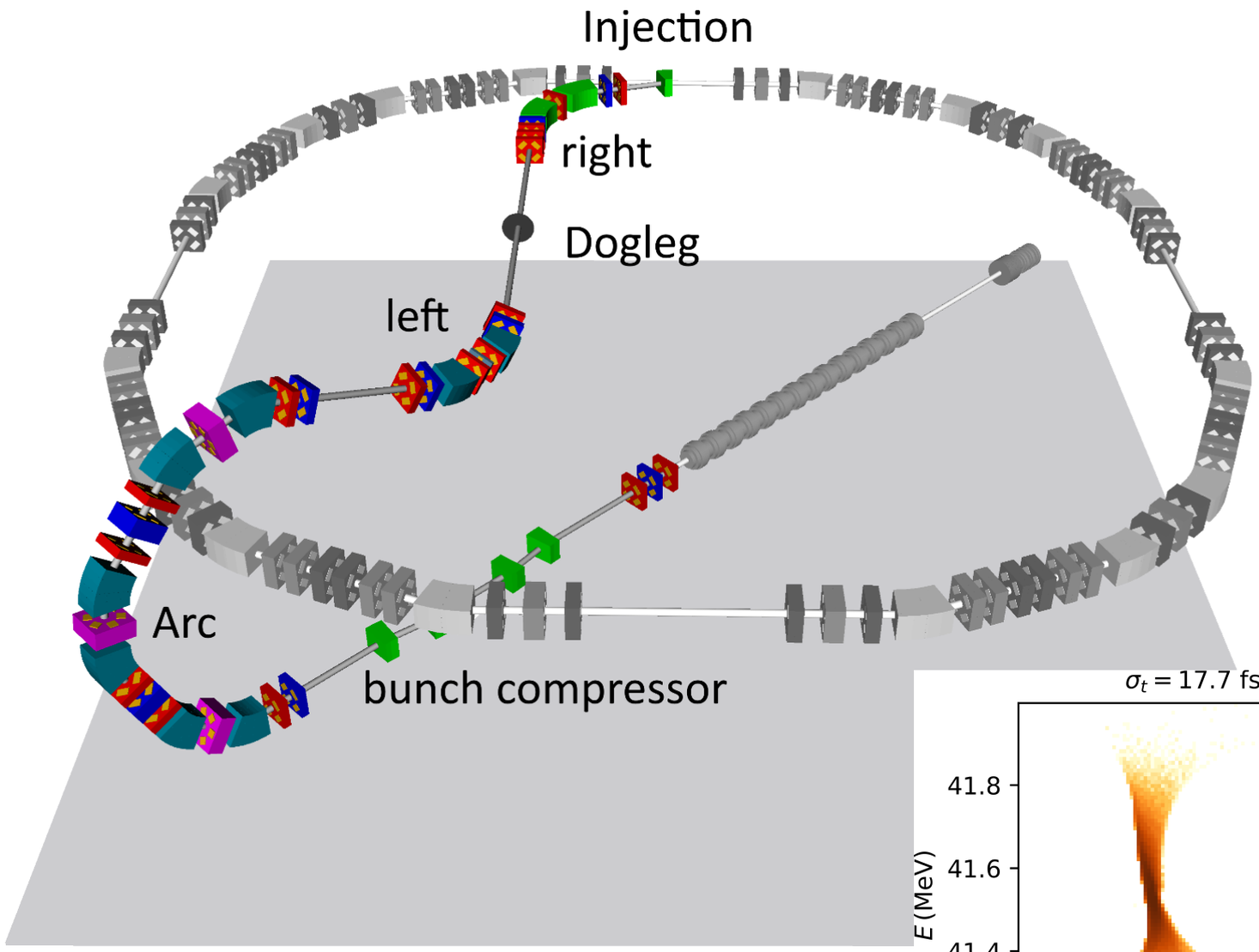
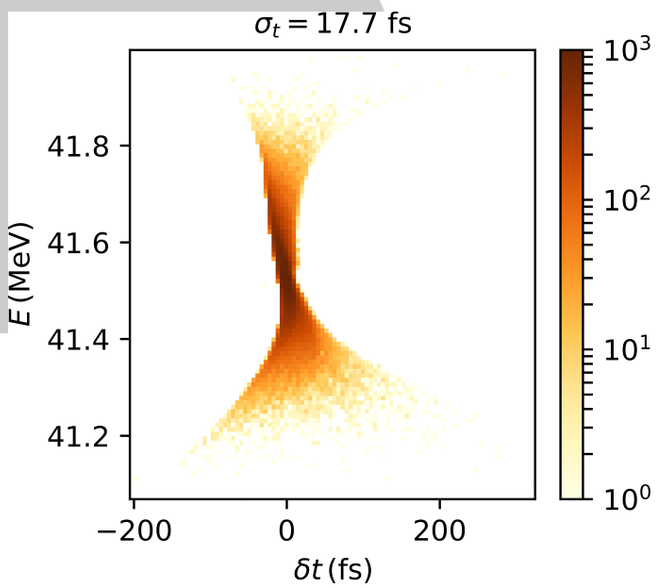
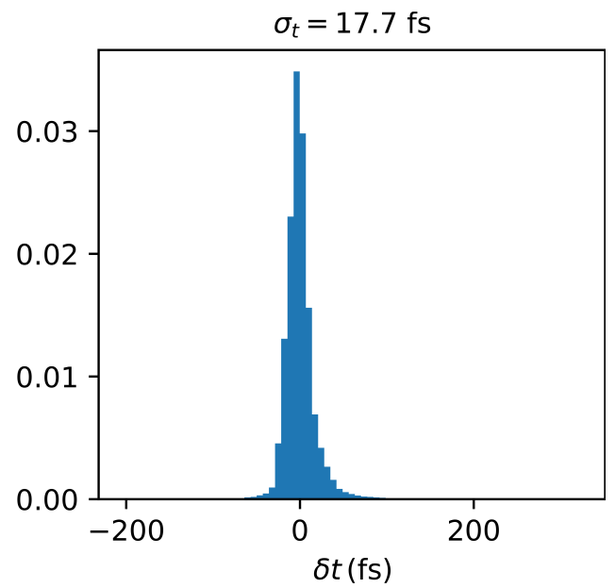
Transfer line FLUTE - cSTART



- Guidance without particle loss
- Arc with „negative dispersion optics“
- Bunch length compressed to 18 fs





J. Schäfer Master thesis:
Lattice design of a transfer line for ultra-short bunches from FLUTE to cSTART

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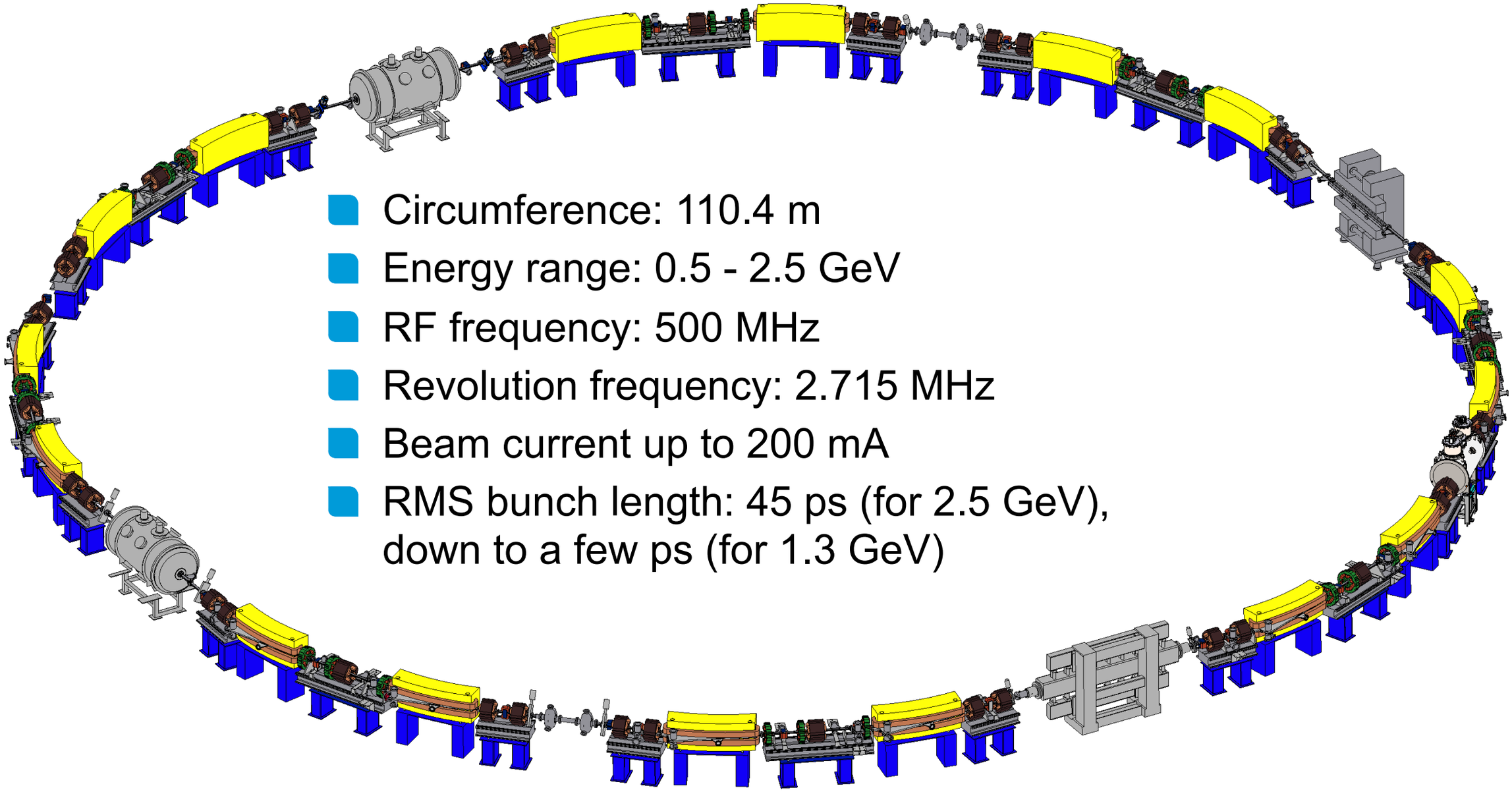
Karlsruhe Research Accelerator (KARA)

- User applications & accelerator test facility



- 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)

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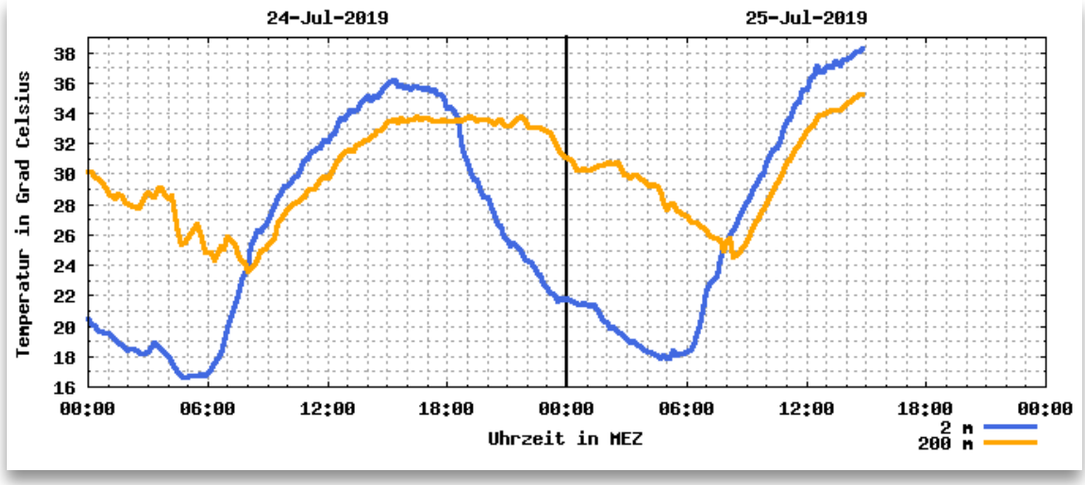
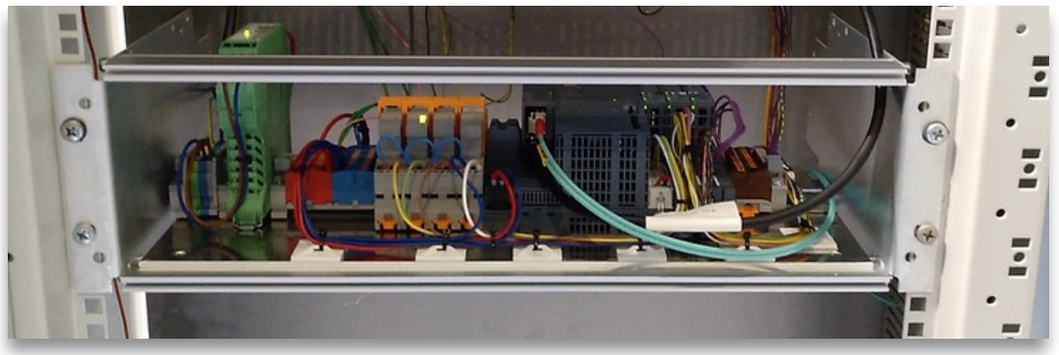
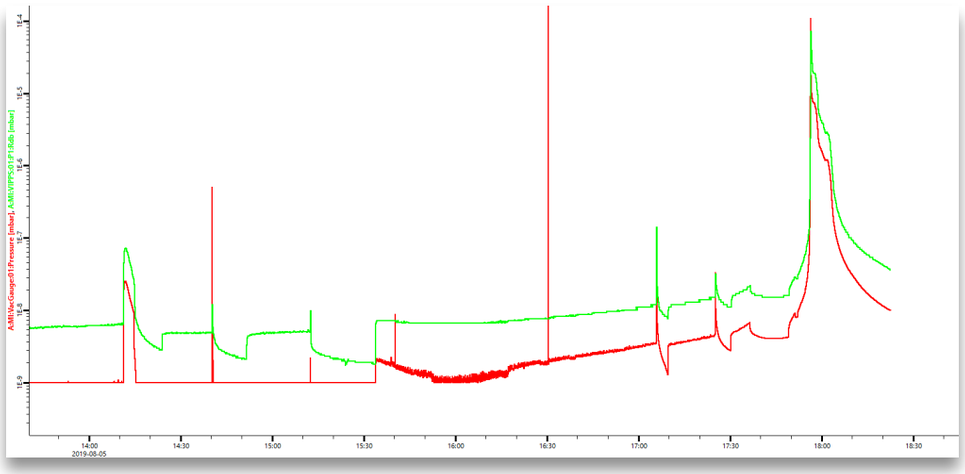
KARA Operation 2019

- 20 days more due to ESRF upgrade
- First time: Two machine shutdowns triggered due to too hot weather. The cooling plant was designed for max temperature of 32°C and it was more than 38°C for several days
- Klystron protection electronics died and was replaced by a PLC with fiber communication
- Vacuum spikes in the E-Gun
  - Bake out helped a bit
  - Service for cathode replacement scheduled for next long shutdown
- 3 GHz Klystron modulator failed after power cut
- Preventive service at LLRF system







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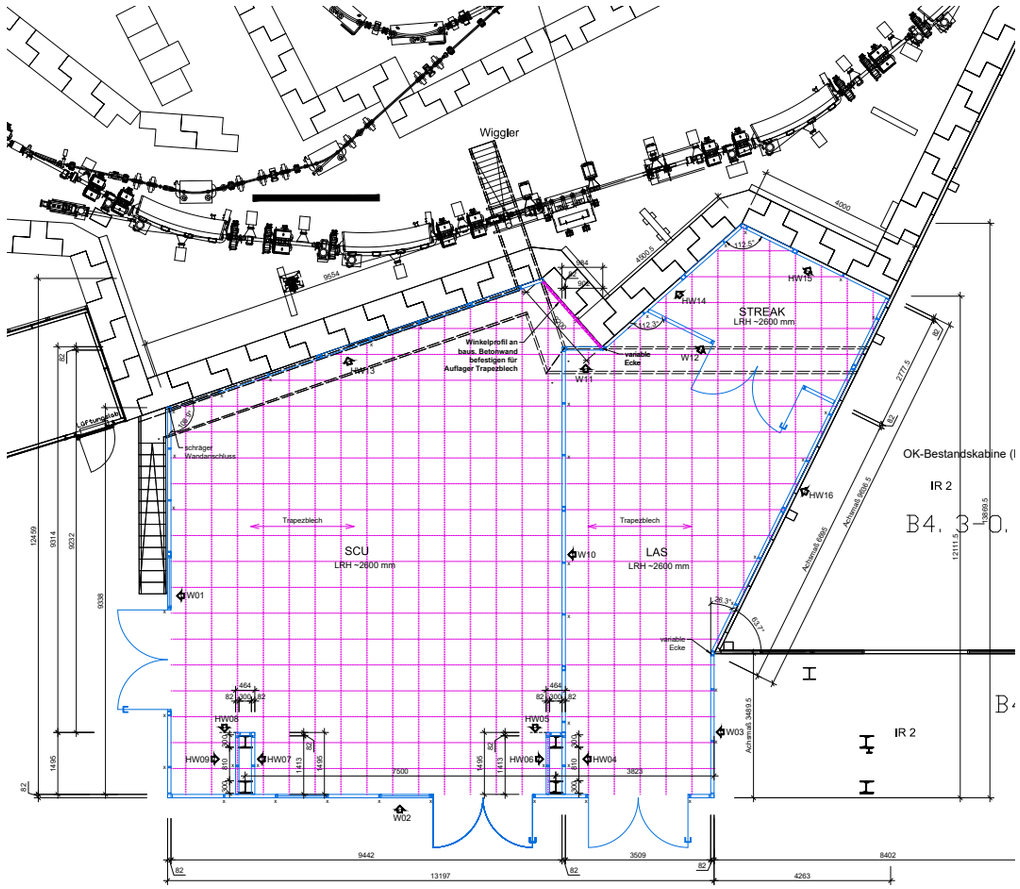
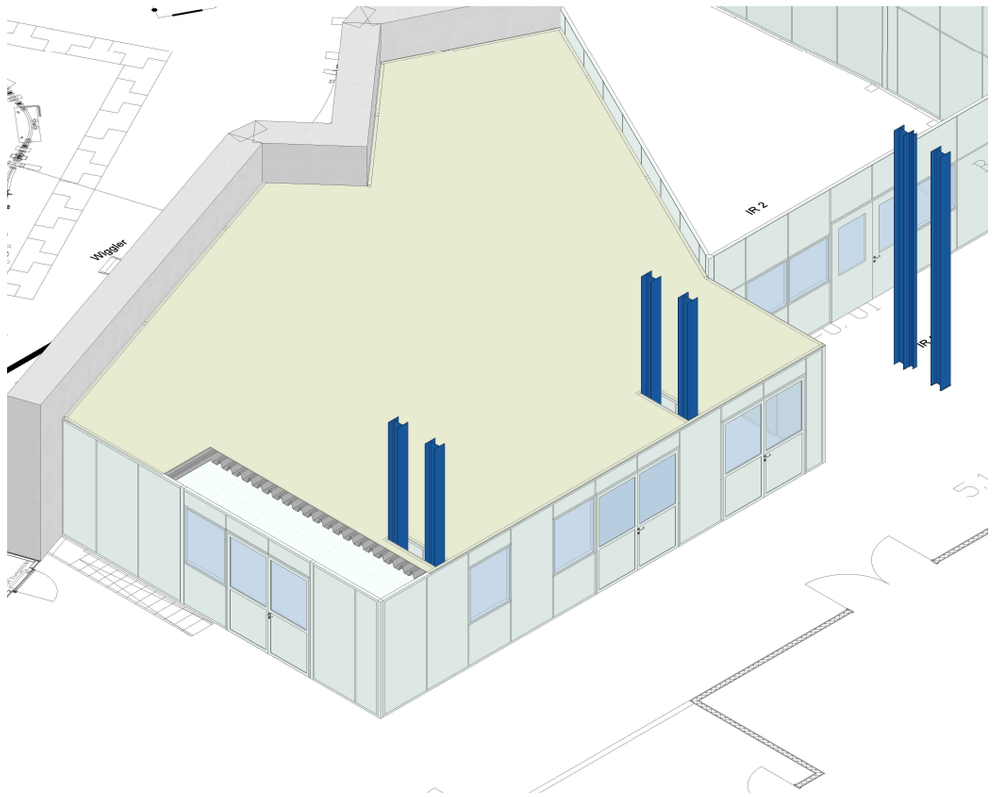
KARA refurbishment

- Replaced the storage ring corrector power supplies
- New controllers for the quadrupole and sextupole power supplies
- New hutch for the visible light diagnostic port and lab space
- New personal safety system (PSS) under design

M. Hagelstein et al., RadSynch2019





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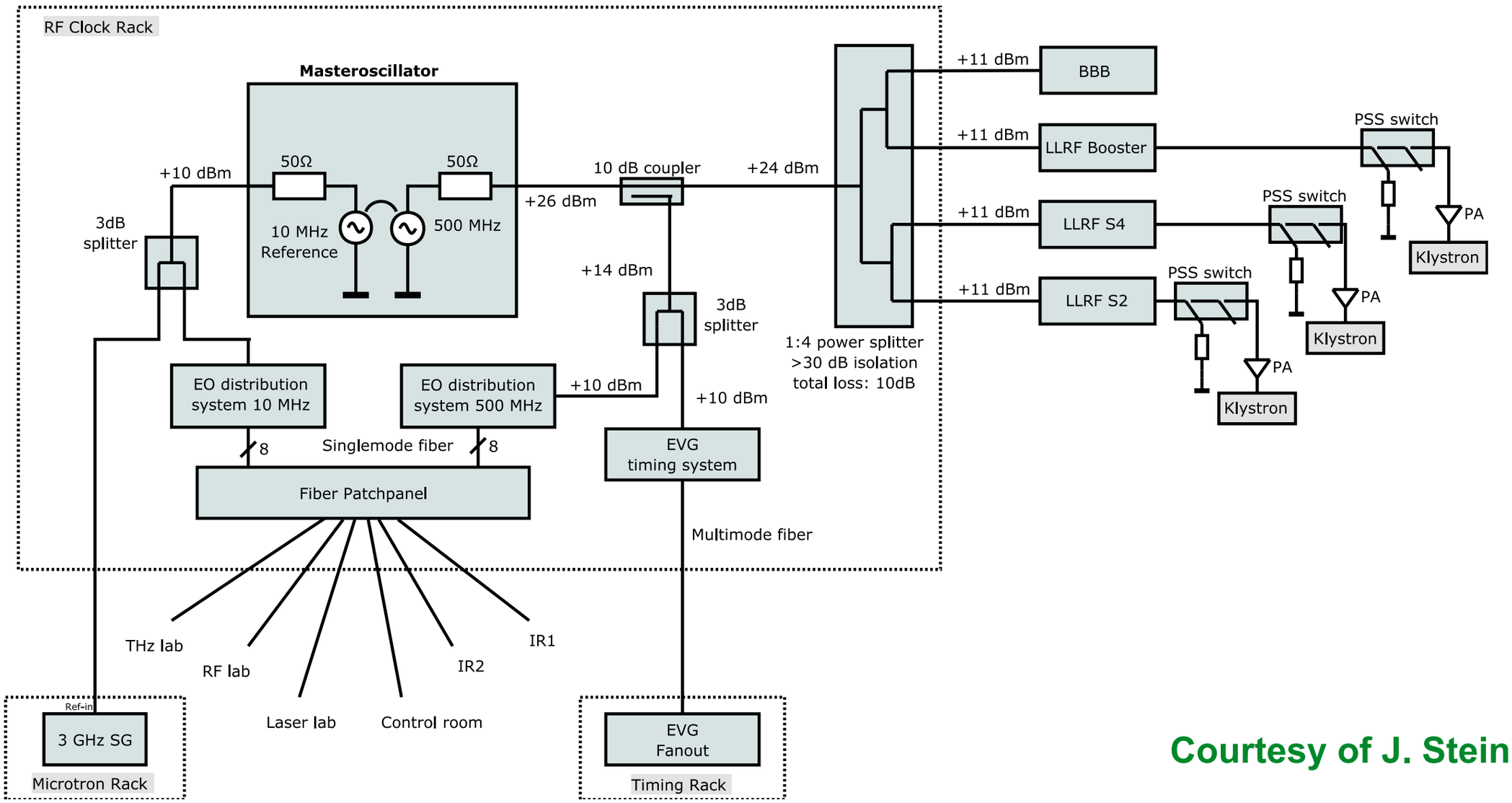
New reference clock distribution

- New master oscillator installed and testing started
- Installation of fiber-based reference clock distribution system in progress
- Required changes in the interfacing to the PSS under discussion



Courtesy of J. Steinmann

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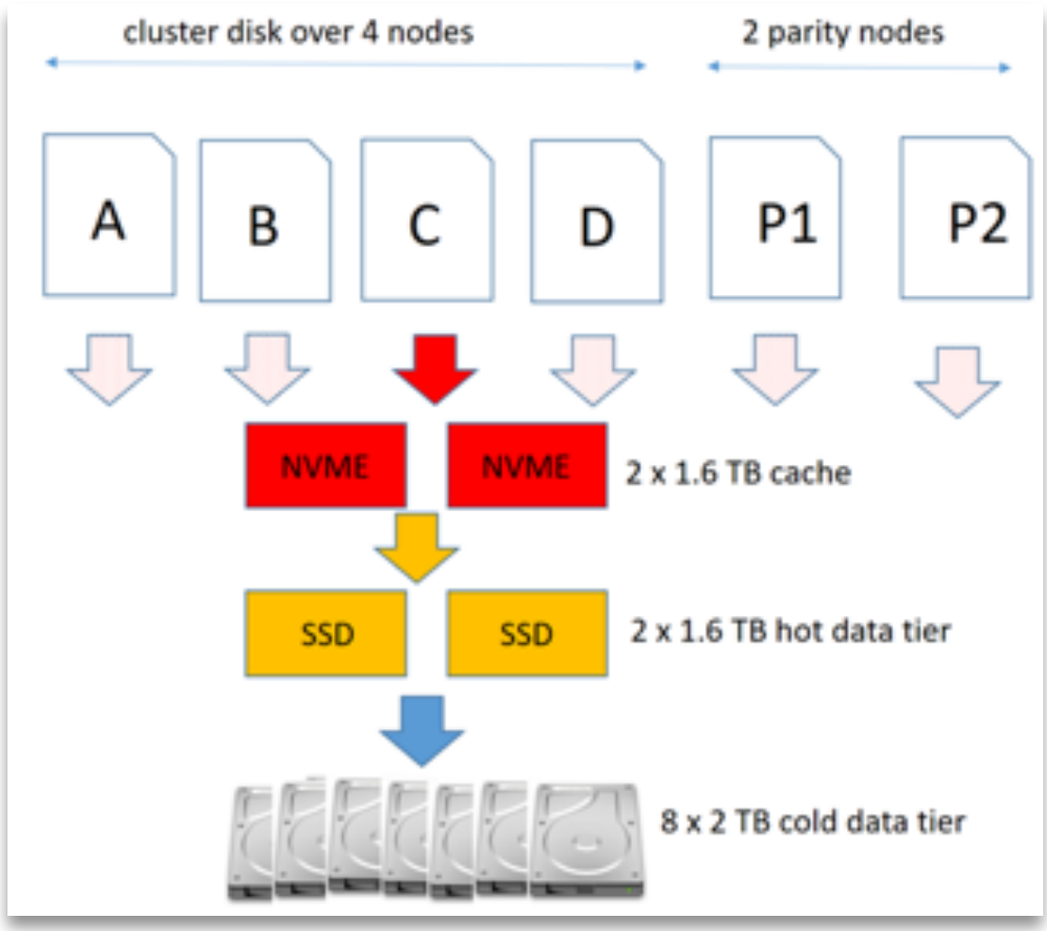
KARA Control System Virtualization

- 22 virtualized servers
- EPICS 7.0 with
  - > 100 IOCs
  - > 70,000 PVs
- Automatic server deployment with VINEGAR
- Automatic server configuration with SALTSTACK



Hyper V Storage Spaces Direct Cluster

- 1,152 GB RAM
- 120 VMs
- 72 Cores

W. Mexner et al., ICALEPS 2019

Vinegar: https://github.com/KIT-IBPT/vinegar/

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KARA distributed sensor network

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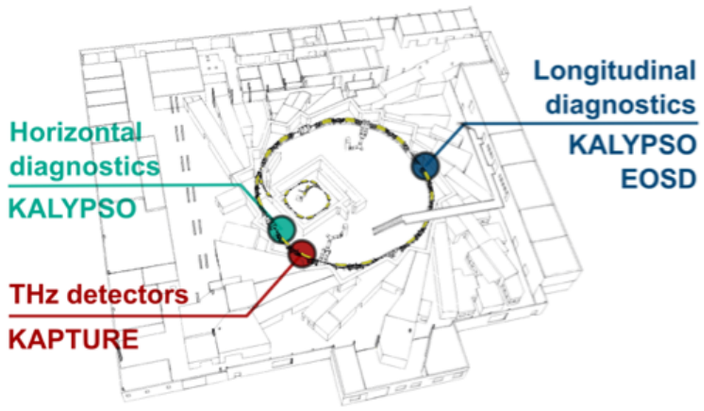
05K19PEC



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

M. Brosi et al., DOI: 10.18429/JACoW-IPAC2019-WEPTS015
B. Kehrer et al., DOI: 10.1103/PhysRevAccelBeams.21.102803
S. Funkner et al., DOI: 10.1103/PhysRevAccelBeams.22.022801

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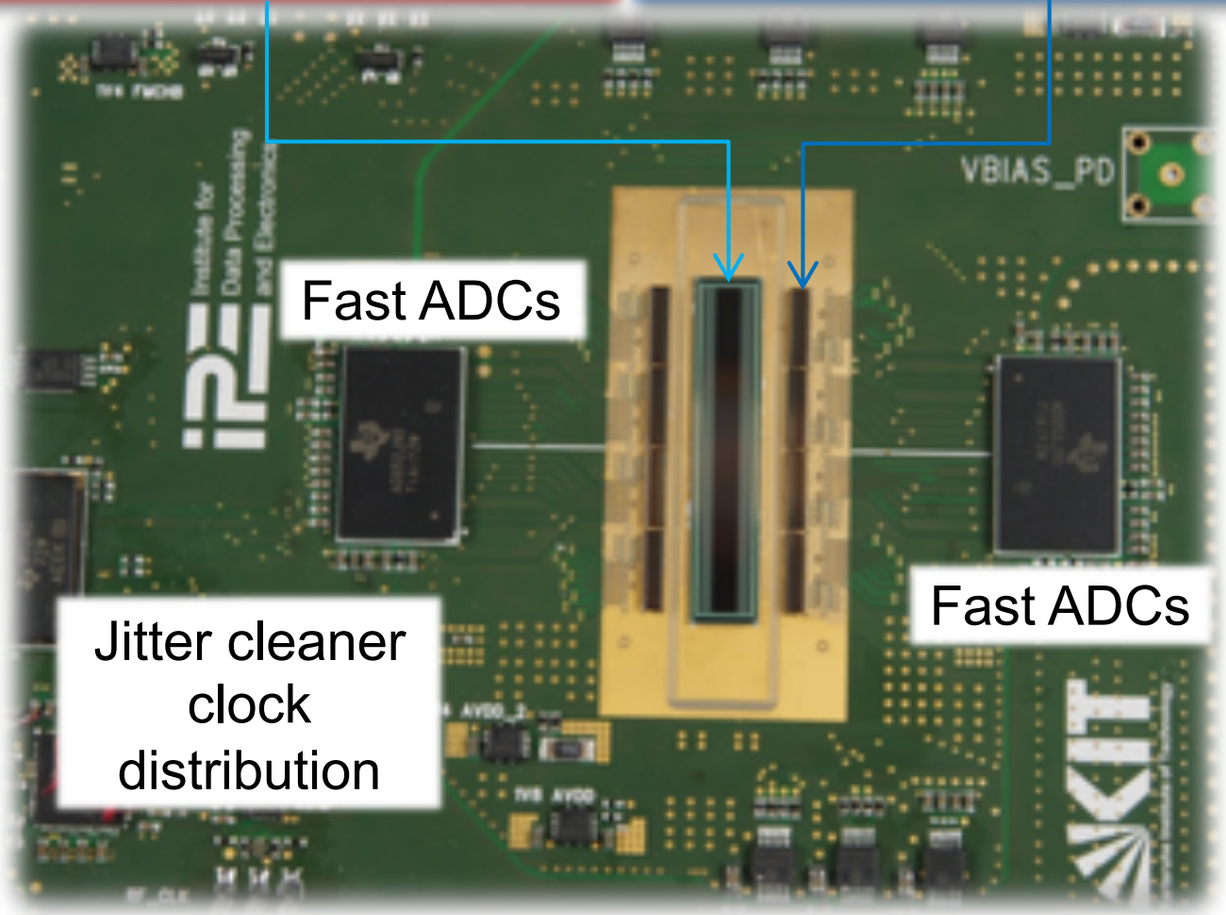
KALYPSO V2.5 detector board

Towards single-pulse spectral analysis of MHz-repetition rate with wide line array



- Line array sensor up to 2048 channels (near-UV, VIS, near-IR)
- Up to 8 parallel low-noise front-end Gotthard-HR (KIT, PSI)
- Fast ADCs, 10/12 and 14 bit

ADC Conversion Rate	1024 channels	512 channels
100 MSPS (10 bit)	up to 3.1 Mfps	up to 6.25 Mfps
80 MSPS (12 bit)	up to 2.5 Mfps	up to 5 Mfps
65 MSPS (14 bit)	up to 2 Mfps	**up to 3 Mfps**

- External clocks and trigger synchronizations (option.)

L. Rota, M. Caselle et al., DOI: 10.1016/j.nima.2018.10.093

M. Patil et al., DOI: 10.22323/1.343.0045

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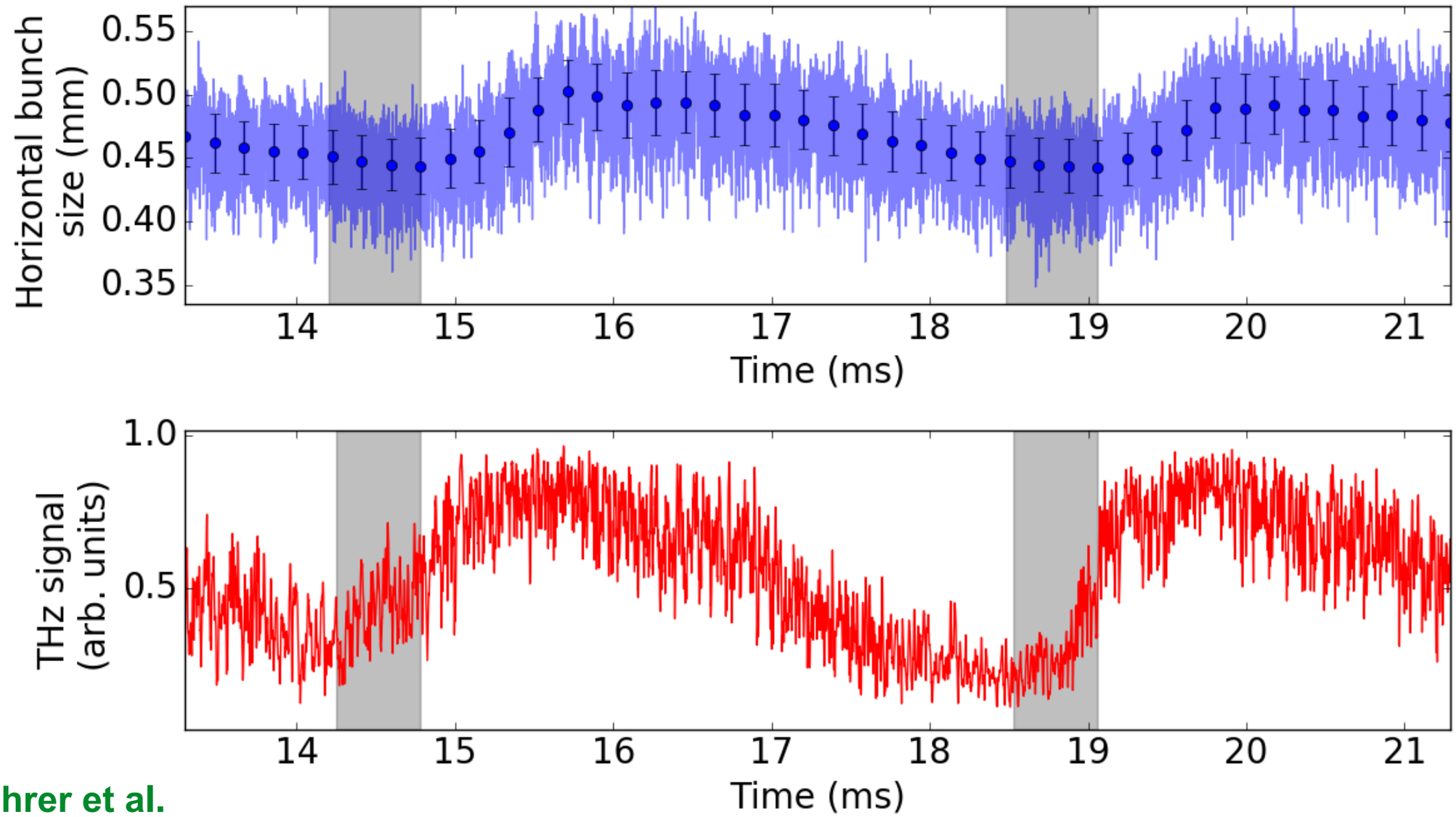
Synchronous measurements

- KALYPSO for horizontal bunch size
- KAPTURE with Schottky diode for CSR



B. Kehrer et al.

DOI: 10.5445/IR/1000098584 DOI: 10.18429/JACoW-IPAC2019-WEPGW016

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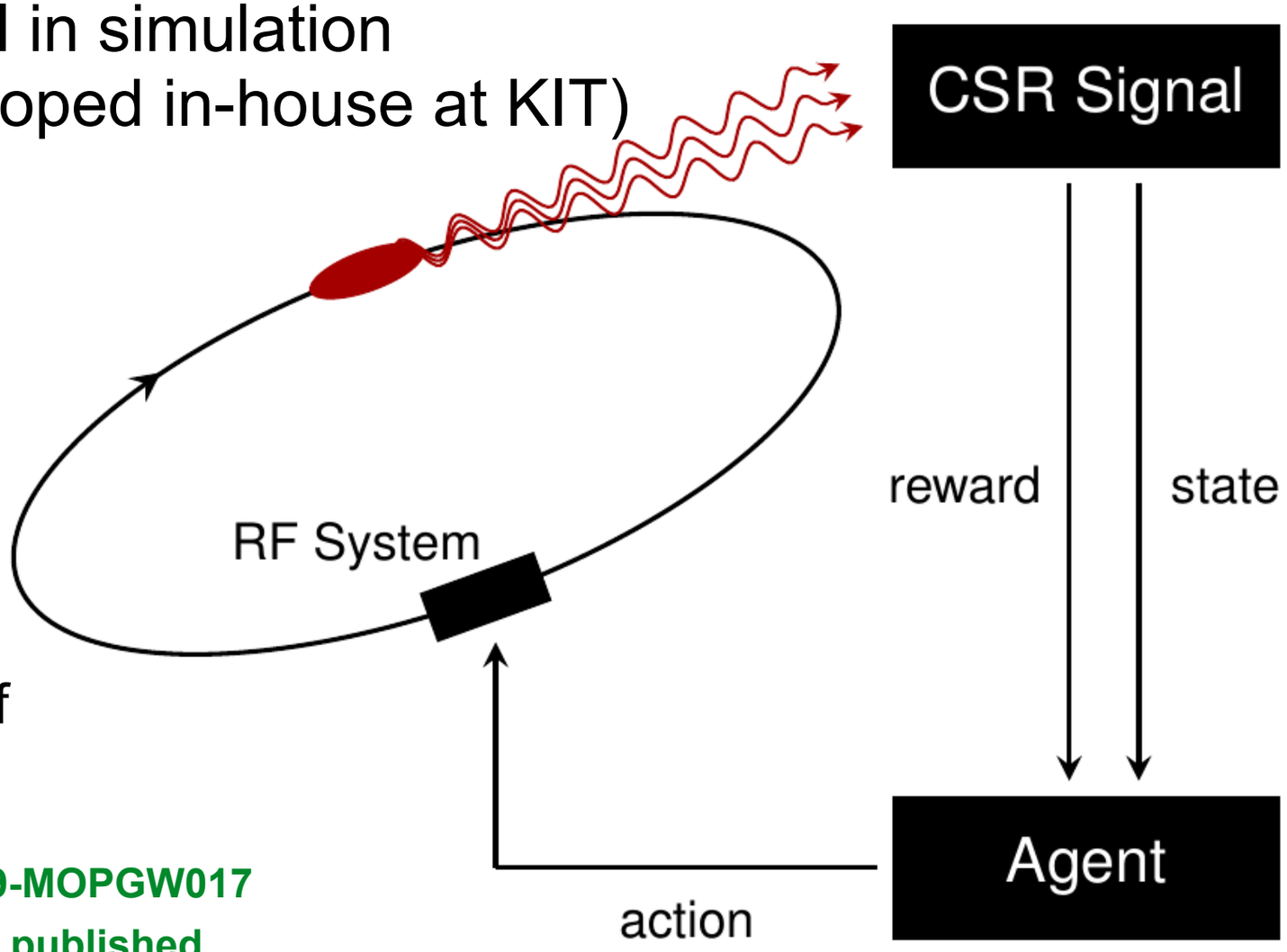
Micro-Bunching Control with Reinforcement Learning

- **Goal:** Longitudinal feedback to control micro-bunching dynamics
  ➜ optimize emitted CSR (high average, low variance)

- **Proof of principle:** Control in simulation
  (VFP solver Inovesa, developed in-house at KIT)
  – ongoing work

- **Implementation:**
  - Connection of THz diagnostics (KAPTURE) with KARA RF system
  - Machine learning on FPGA to match time constraints of kHz repetition rate



T. Boltz et al., DOI: 10.18429/JACoW-IPAC2019-MOPGW017

W. Wang et al., ICALEPCS'19, TUCPL06, to be published

Inovesa (https://github.com/Inovesa/Inovesa), P. Schönfeldt et al., DOI: 10.1103/PhysRevAccelBeams.20.030704

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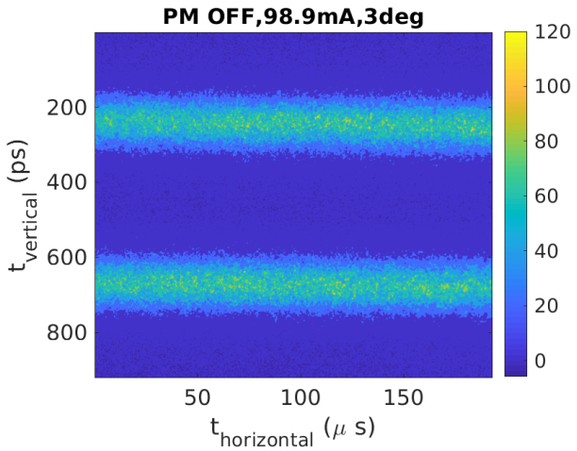
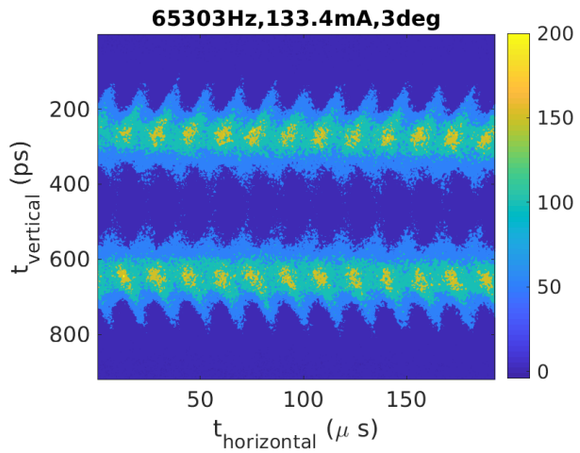
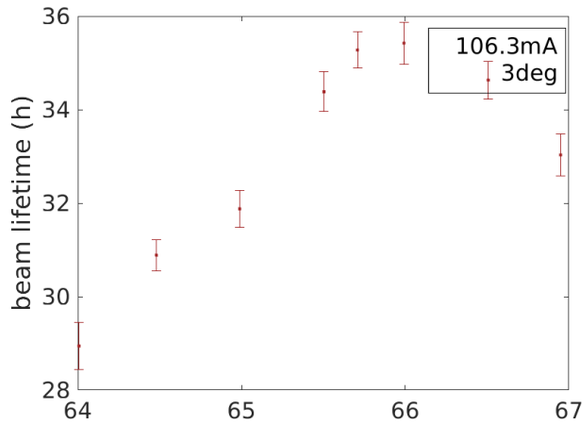
RF phase modulation

Talk A. Mochihashi

- Increase the bunch length to increase the beam life time
- Excite the beam using phase modulation in the LLRF system



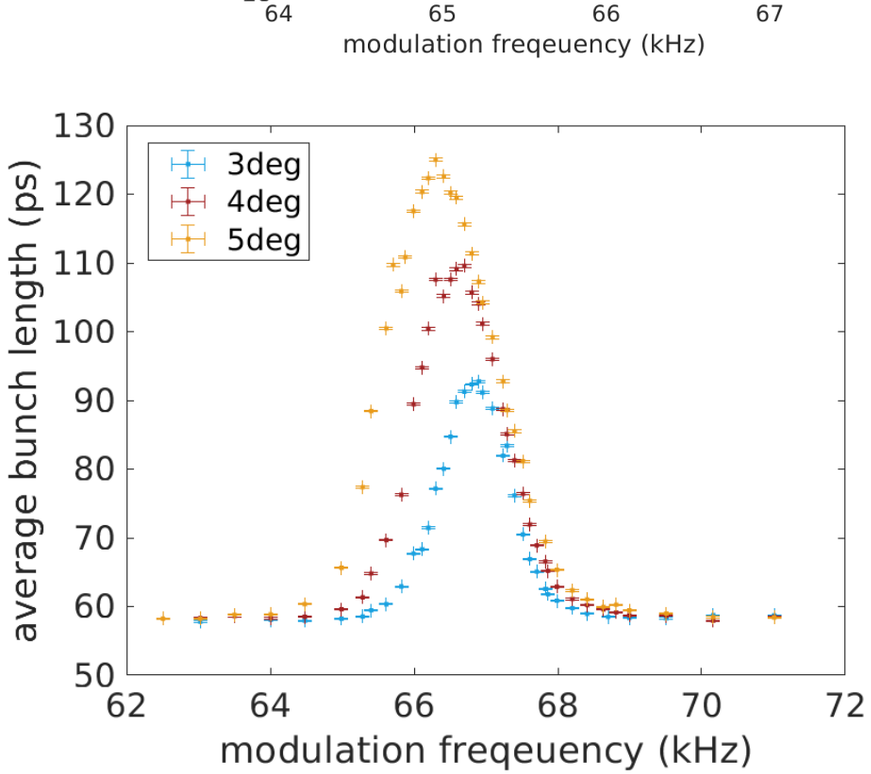




- Systematic studies
  - Analyze the bunch lengthening using a Streak camera
  - Scan the excitation frequency
  - Phase modulation amplitude

S. Maier and A. Mochihashi

DOI: 10.18429/JACoW-IPAC2019-WEPTS016



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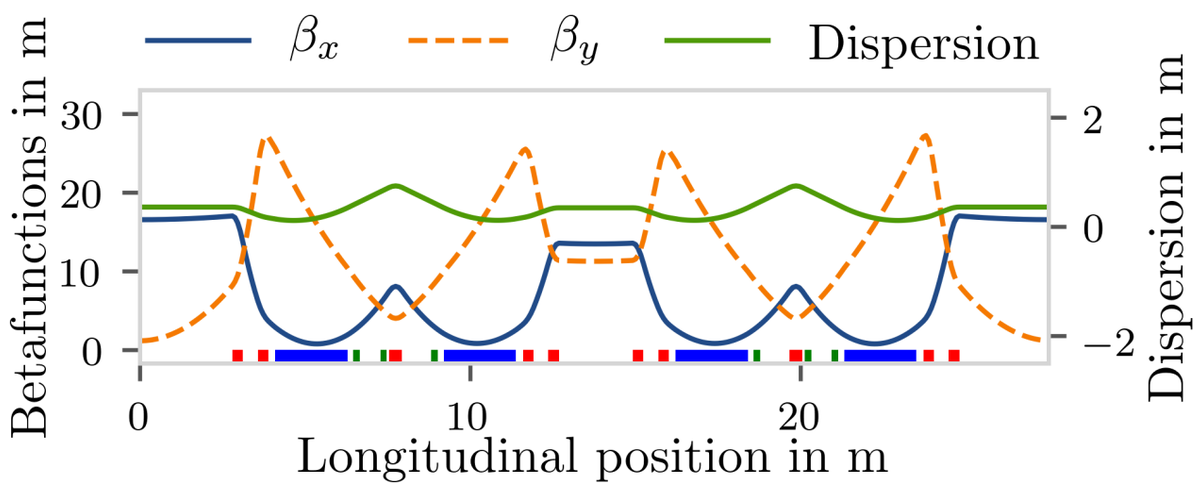
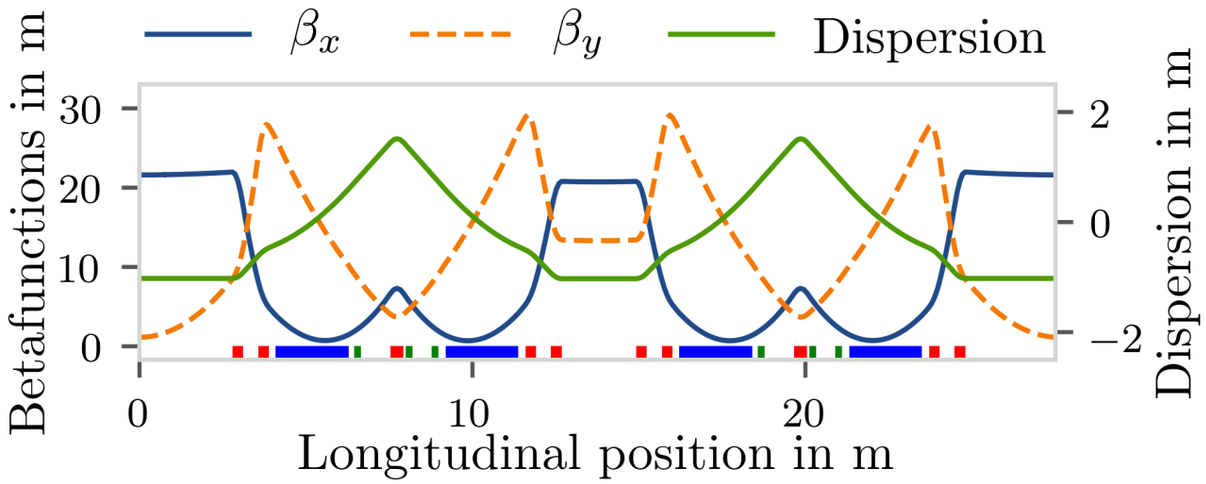
Low and negative α_c optics at 500 MeV

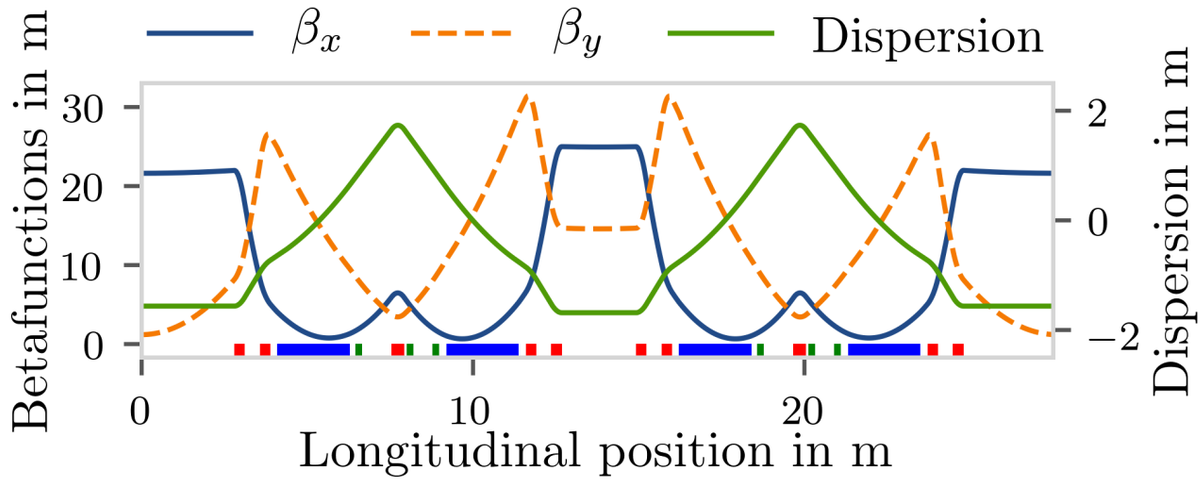
$\alpha_c = 9 \times 10^{-3}$



$\alpha_c = 1 \times 10^{-4}$



$\alpha_c = -8 \times 10^{-3}$



A. Papash et al. DOI: 10.18429/JACoW-IPAC2019-TUPGW016

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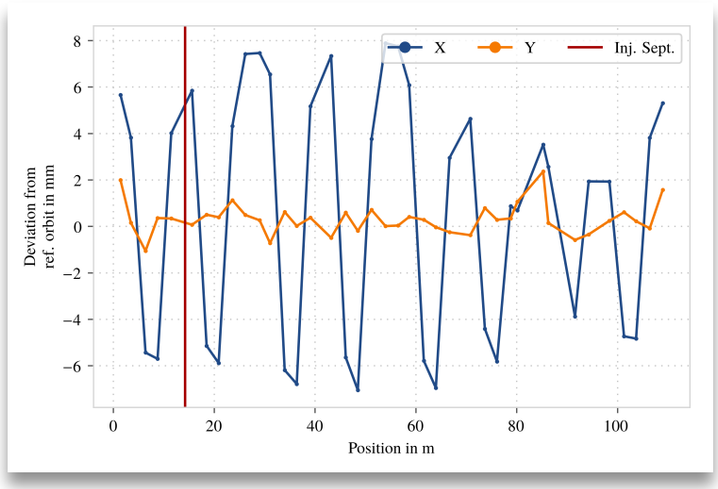
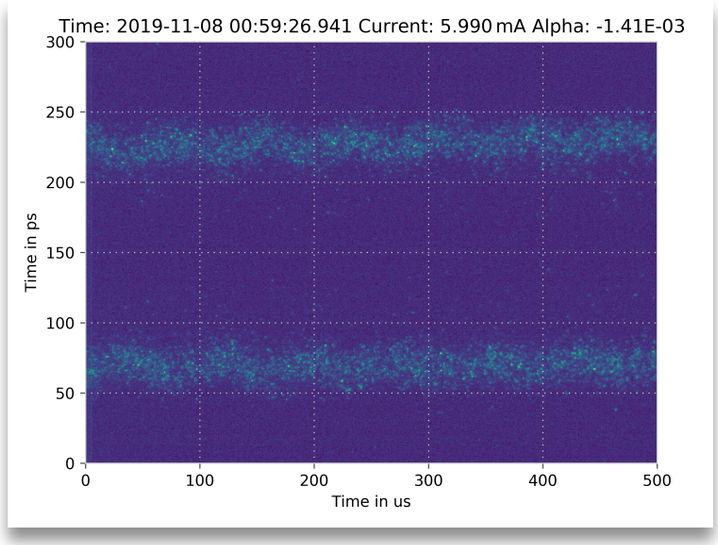
Low and negative α_c operation at 500 MeV

- Identified potential working points with different α_C
- Established tune and chroma measurement
- Large horizontal orbit oscillation required for injection
- One MD week in the frame of ARIES with the colleagues from Soleil
- First bunch length studies with streak camera
- Next step - characterize working points
  - Bunch length
  - Thz emission
  - Identify contributions of different collective effects





P. Schreiber et al., DOI: 10.18429/JACoW-IPAC2019-MOPTS017

P. Schreiber et al., MCBI 2019, https://indico.cern.ch/event/775147/

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement No 730871.

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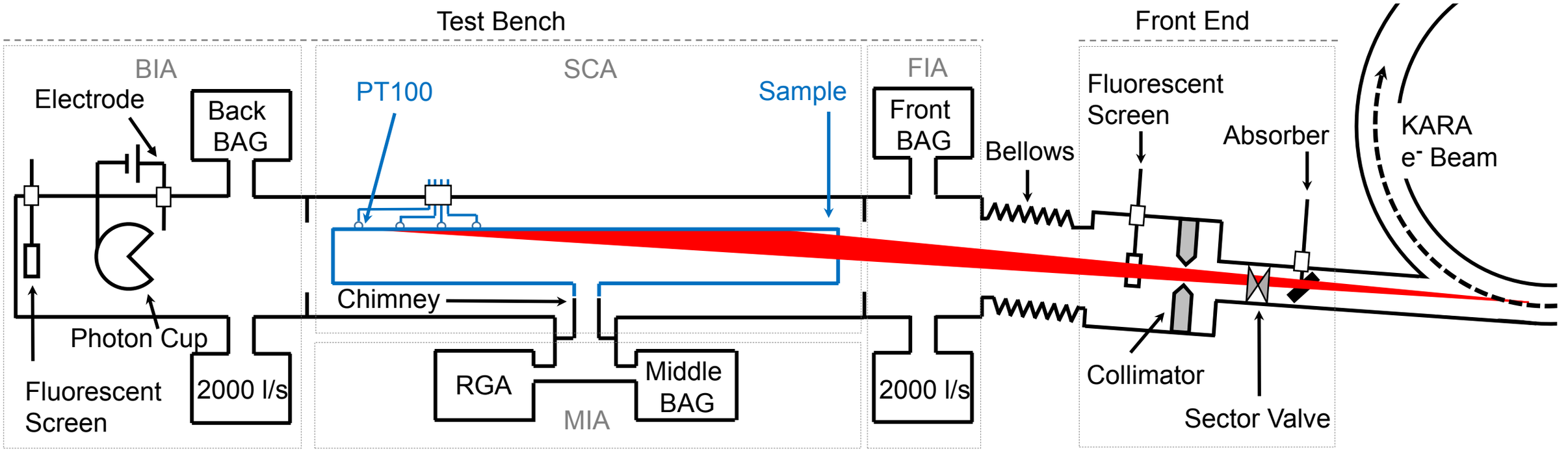
BESTEX

- Three FCC-hh Beam Screen prototypes including the baseline design have been tested so far at BESTEX
- Upgrade: Implement liquid Nitrogen cooling to test under cryogenic conditions in the future



L. A. González et al,

DOI: 10.1103/PhysRevAccelBeams.22.083201

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SCID: superconducting undulator with switchable period length

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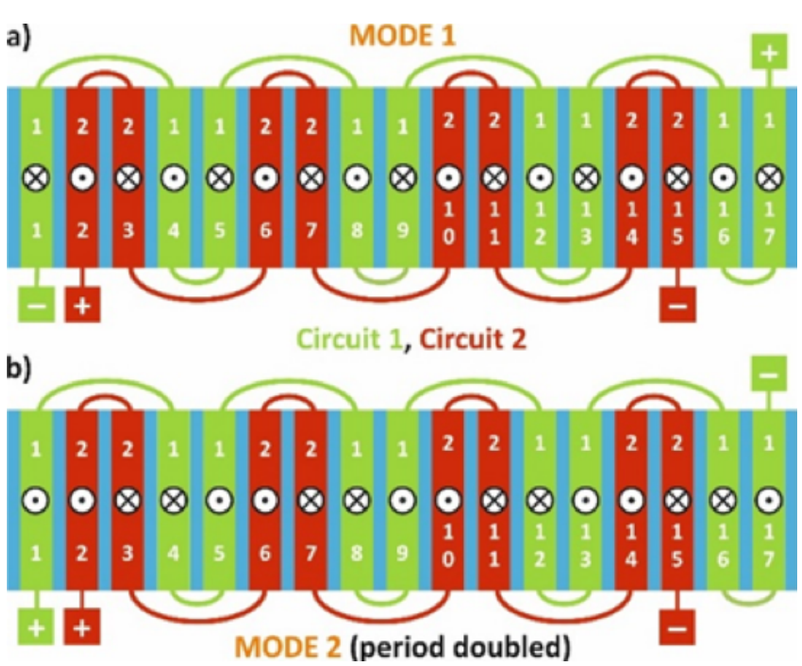
Idea: switchable period length → increase of photon energy range
Concept: changing the current in one circuit
Fabrication of a SCID with 17 mm and 34 mm period at IBPT

- reach full tunability with 17 mm
- high brilliance in the soft X-ray regime with the 1st harmonic of 34 mm:
  - to measure M-absorption edges of metals like V, Cr, Mn and Fe
  - going as low as few tens of eV (low emittance light source with 3 GeV)



S. Casalbuoni, N. Glamann, A.W. Grau, T. Holubek, D. Saez de Jauregui
DOI: 10.18429/JACoW-IPAC2019-TUPGW017

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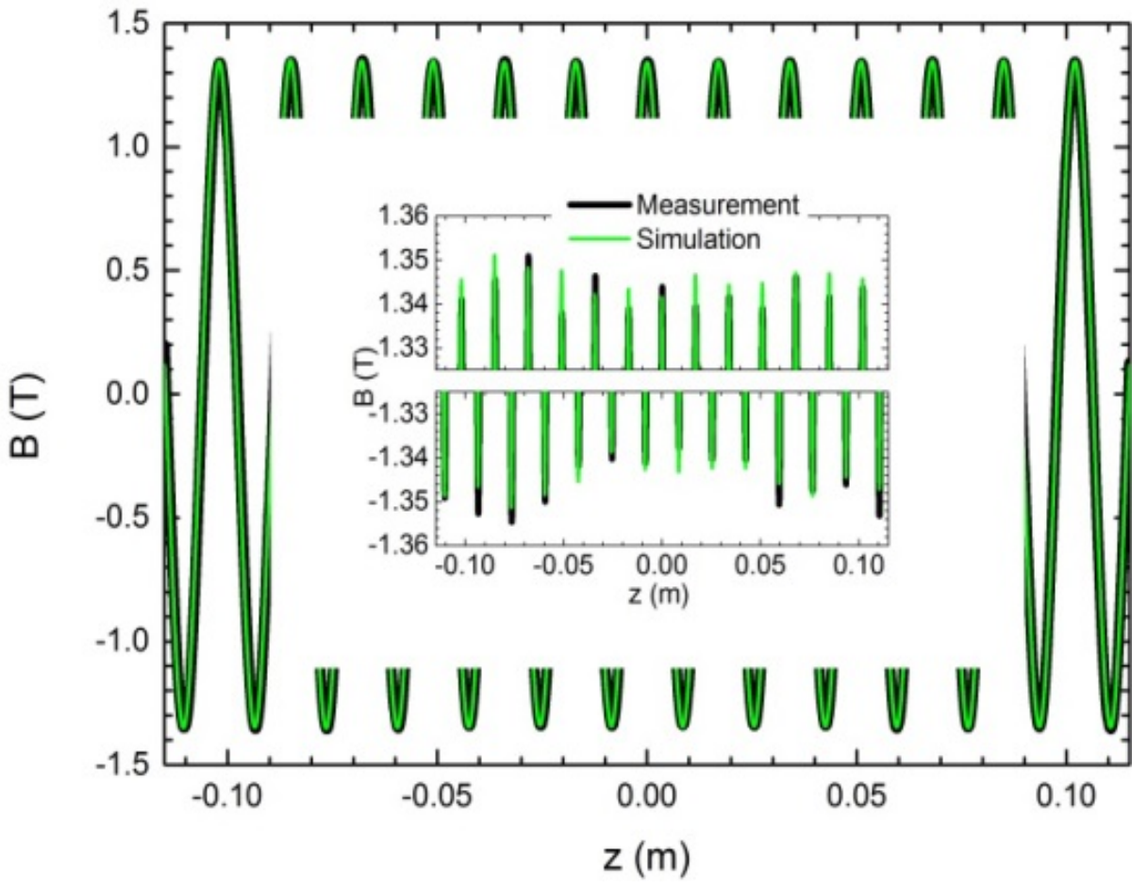
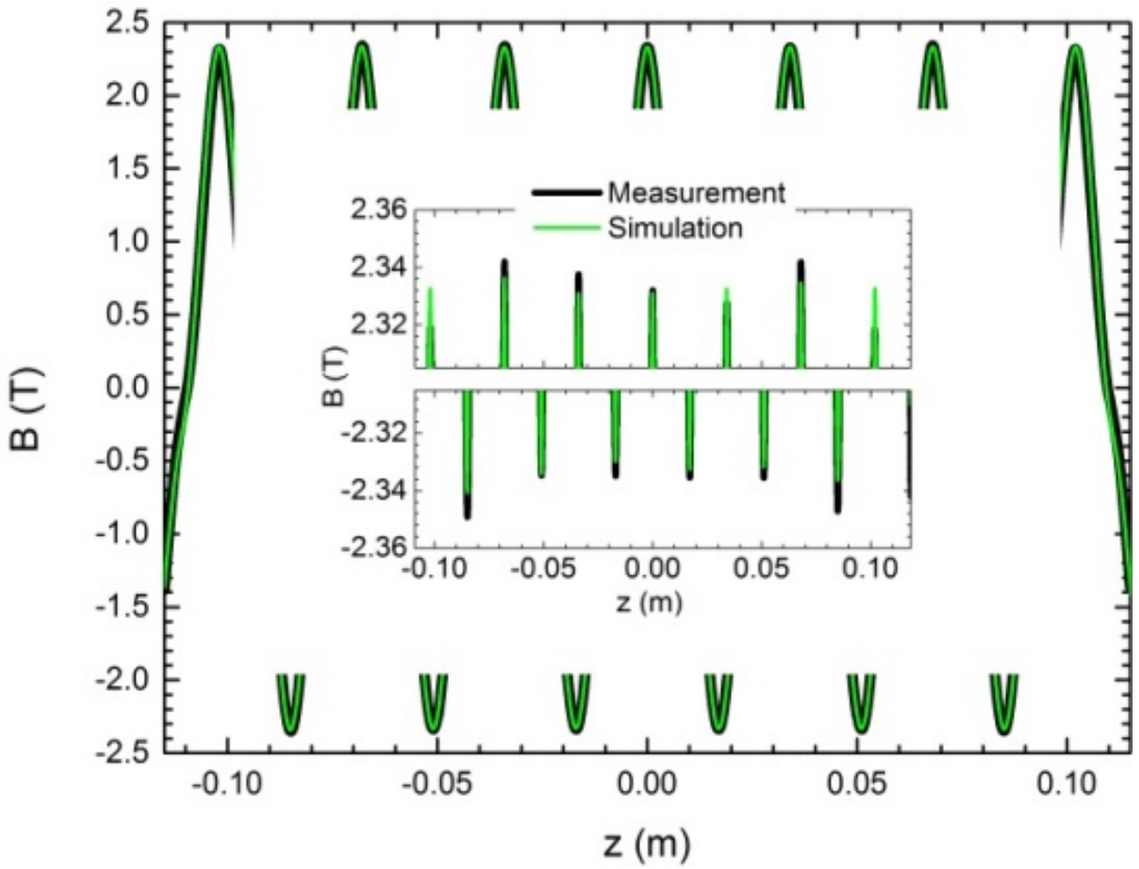
SCID: superconducting undulator with switchable period length

Field measurement results

@17 mm period length 500A



@34 mm period length 370A



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- The accelerator team:
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- Collaboration partners

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Backup slides

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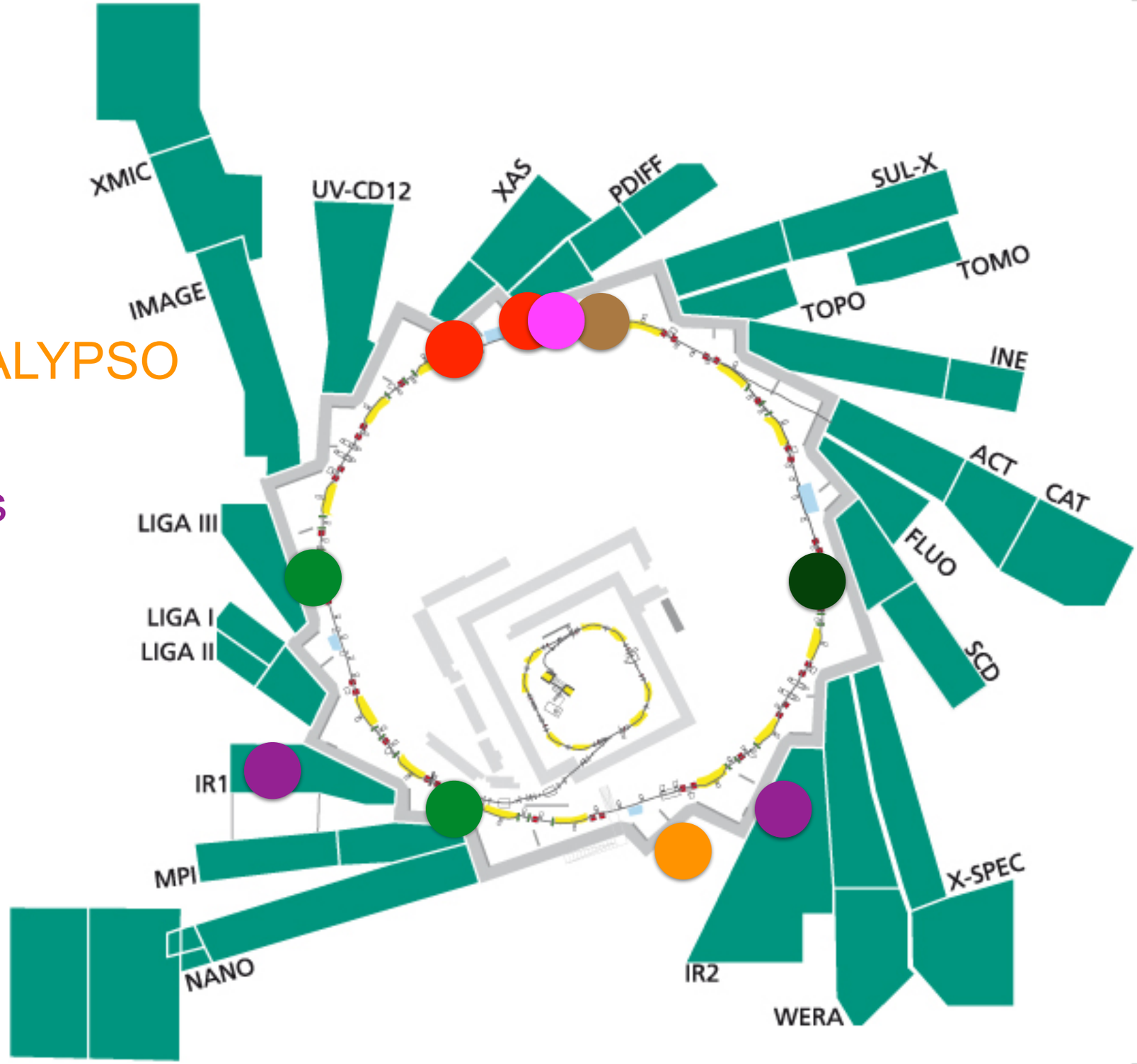
Diagnostics at KARA

- SR light monitor
- In-Air X-ray detector
- EO-Nearfield setup
- Streak camera
- Fast-gated camera / KALYPSO
- BBB feedback system
- Ultra fast THz detectors
- Lead glass detector
- BPMs
- BLMs
- …



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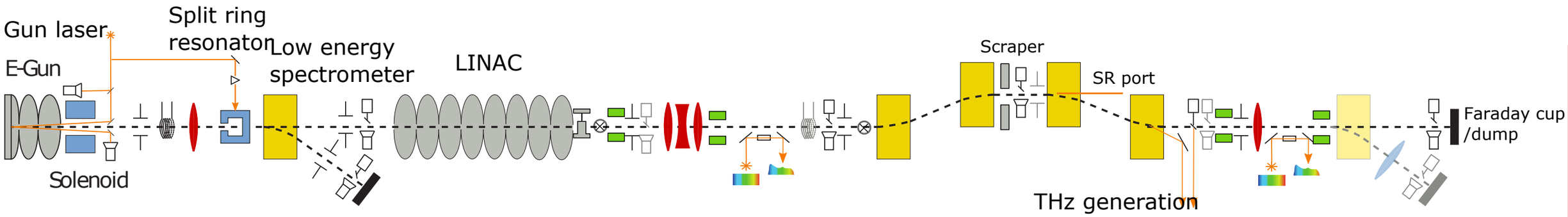
FLUTE diagnostics



- **Large dynamic range:**
  - **Charge: 1 pC - 3 nC**
  - **Energy: 7 - 42 MeV**
  - **Bunch length: 2-3 ps (after gun), few fs (after chicane)**
  - **Transverse bunch size: 20 µm - 4 mm**
- Charge, position, size:
  - Integrating current transformer
  - Faraday cup
  - 7-8 cavity BPMs (XFEL, SwissFEL)
  - 5-8 movable screens (PSI)
- Energy:
  - 2 spectrometers (7 & 42 MeV)
- Bunch length:
  - 2 electro-optical monitors (PSI / DESY)
  - Split ring resonator
- Laser-Diagnostic:
  - Virtual cathode
  - Cathode imaging
  - Auto-Correlator / Grennouille
- THz-Diagnostic:
  - Fast THz-detectors (e.g. HEB, Schottky Diodes)
  - Interferometer: Martin-Puplett, Michelson
  - Electro-optical methods (far-field)

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