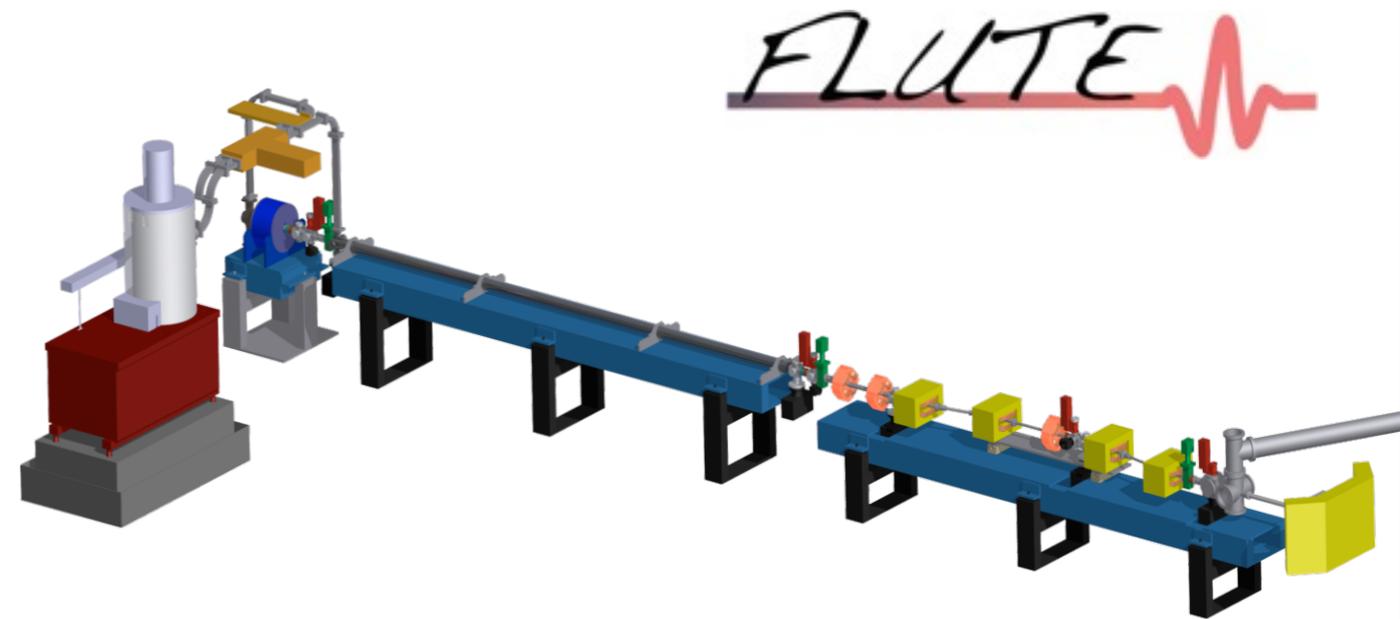


# ANKA, Status and upgrade proposals

23rd ESLS WS 2016, Lund, Sweden

M. Schuh for the accelerator team

Laboratory for Applications of Synchrotron radiation (LAS)  
Institute for Beam Physics and Technology (IBPT)



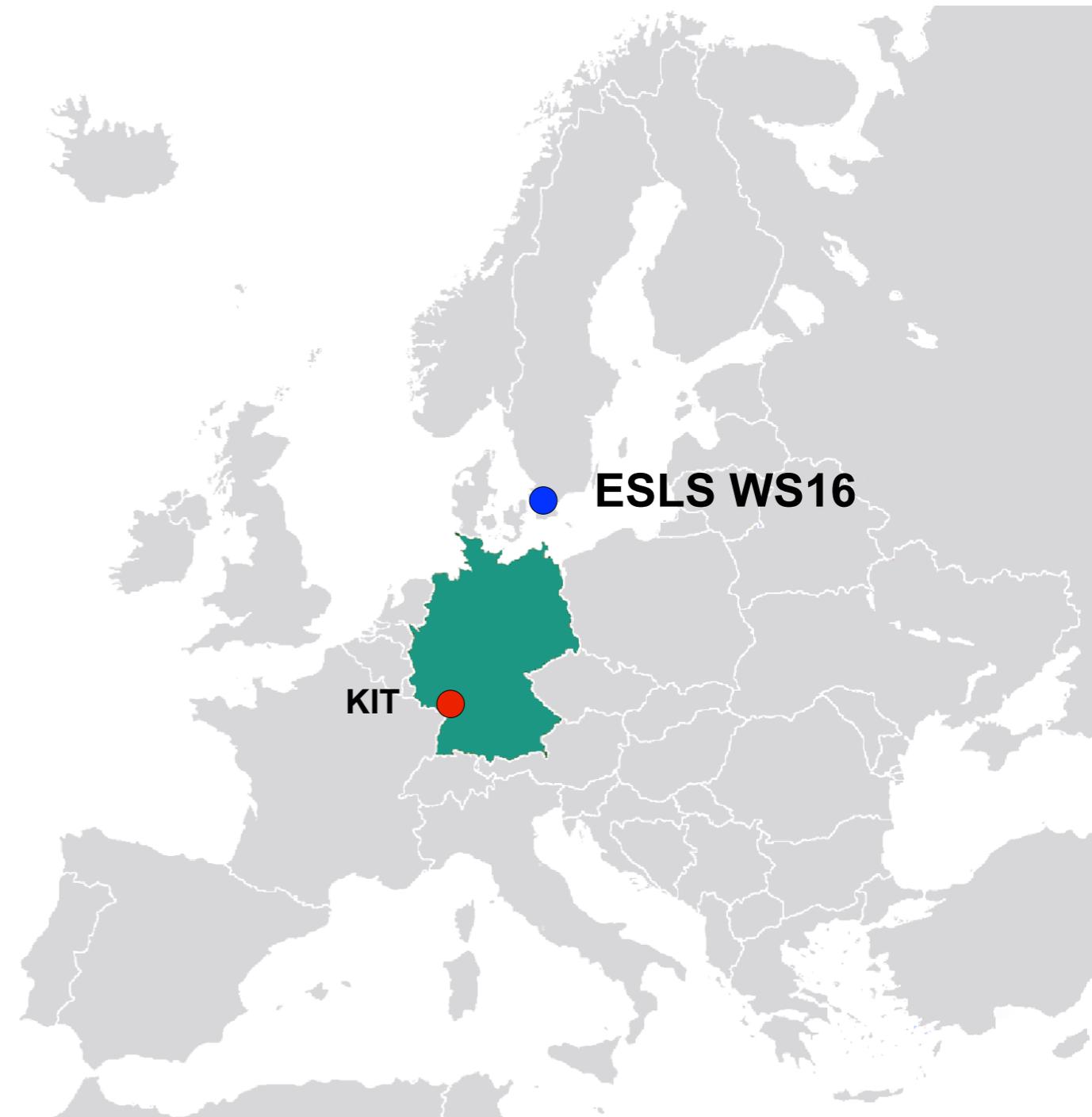
# Acknowledgements

- KIT Team (from IBPT, IMS, IPE, IPS and LAS):  
 M. Balzer, A. Bernhard, E. Blomley, D. Breitmeier, M. Brosi, E. Bründermann, S. Casalbuoni, M. Caselle, A. Grau, S. Funkner, J. Gethmann, B. Härer, N. Hiller, E. Huttel, K.S. Ilin, B. Kehrer, A. Kopmann, S. Marsching, Y.-L. Mathis, W. Mexner, M.J. Nasse, G. Niehues, A. Papash, A. Plech, J. Raasch, L. Rota, R. Ruprecht, D. Saez de Jauregui, M. Schedler, A. Scheuring, P. Schönfeldt, M. Schwarz, M. Siegel, N.J. Smale, J. Steinmann, P. Wesolowski, S. Wuensch, M. Weber, P. Wesolowski, M. Yan, and A.-S. Müller
  
- Collaboration partners



# Outline

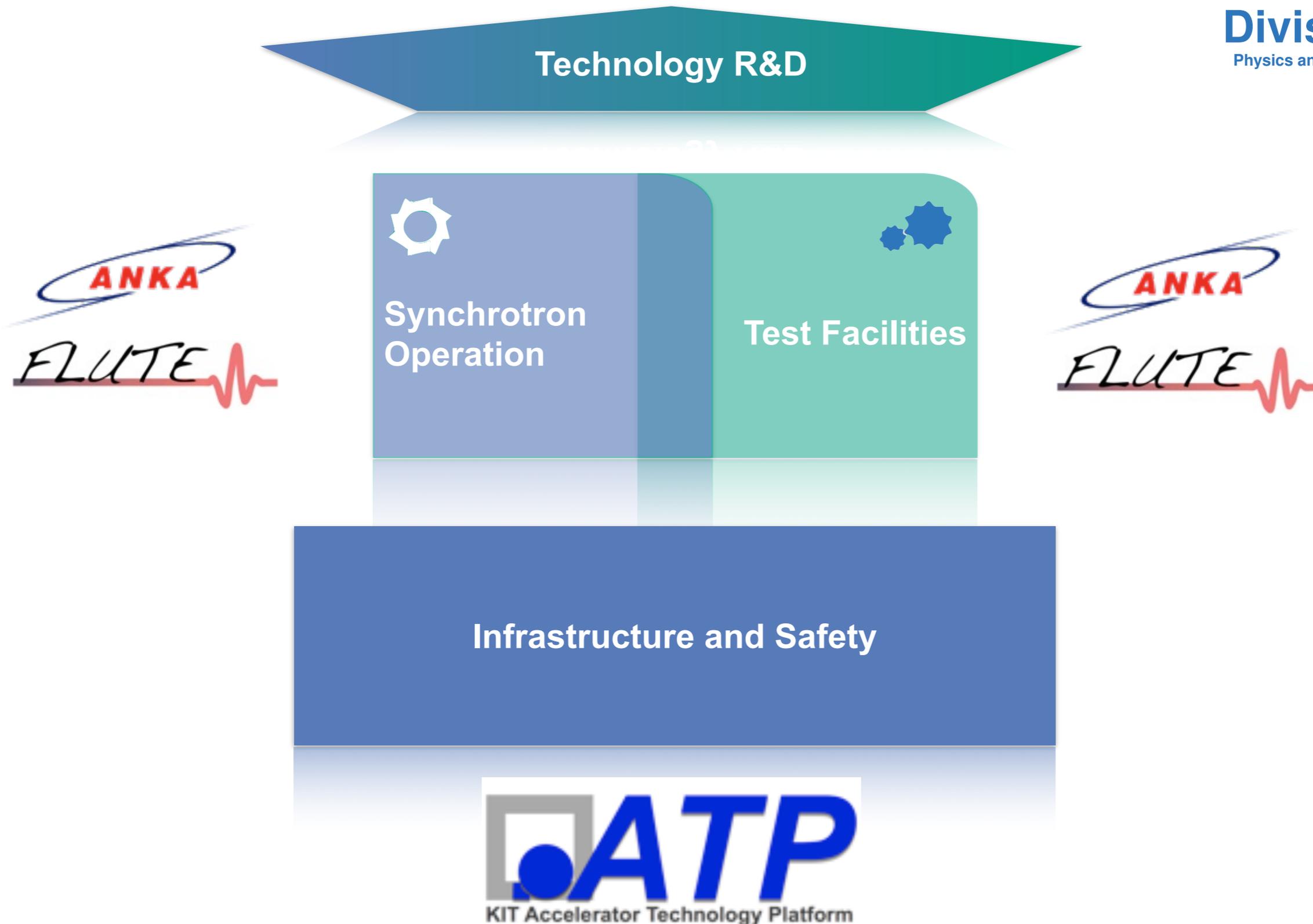
- New mission
- Operation
- Running R&D projects
  - Diagnostic developments
  - THz radiation enhancement
  - CLIC damping ring wiggler
  - EU projects
- Outlook



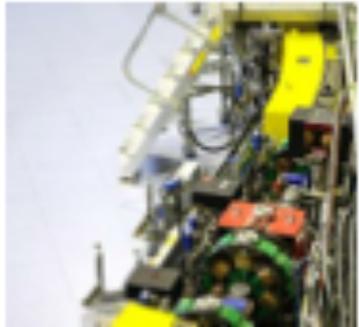
# Institute for Beam Physics and Technology (IBPT)



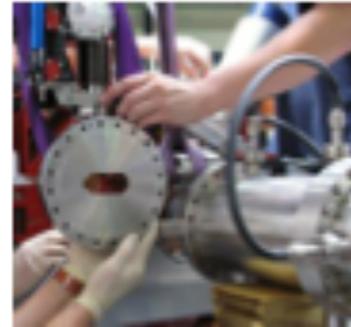
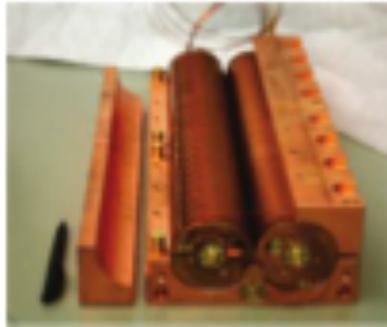
**Division V**  
Physics and Mathematics



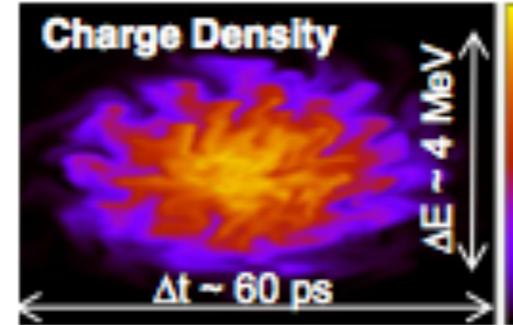
# Accelerator Technology Platform @ KIT



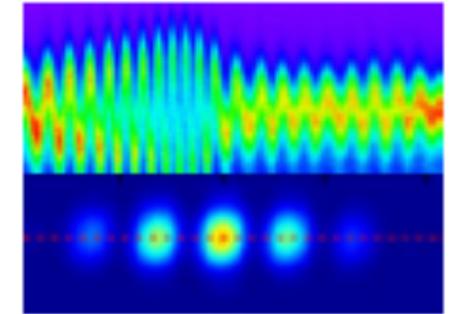
Compact Magnet Technology



Vacuum Technology



Multi-dimensional Spectroscopy & Imaging  
Big Data, Data Science



Simulations  
Mathematics  
Theory



Femtosecond Lasers



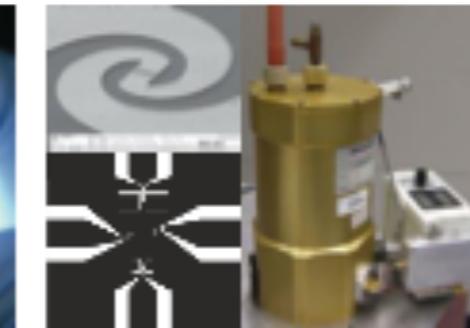
THz & IR &  
VIS & UV Laser



Fibers  
Adv. ICT



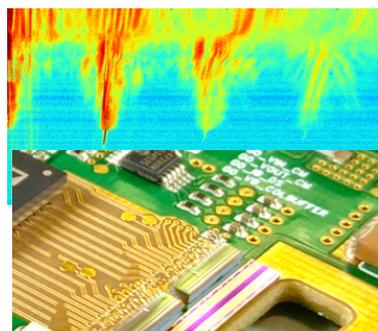
Electro-Optics  
Materials Science



Ultra-Fast  
THz Detectors



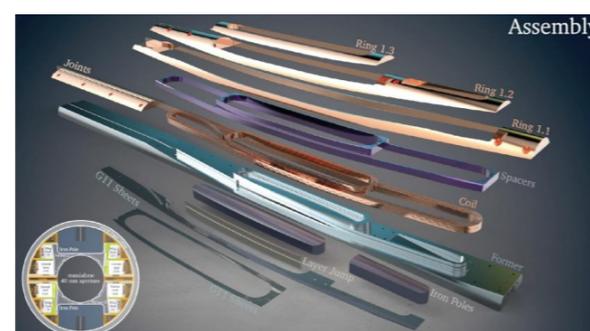
Nanotechnology



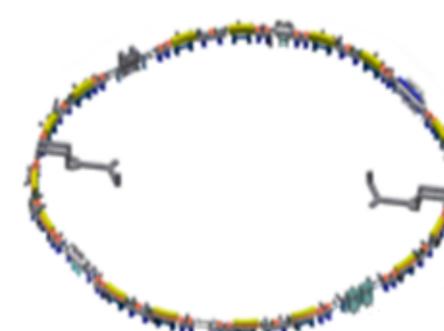
Electronics



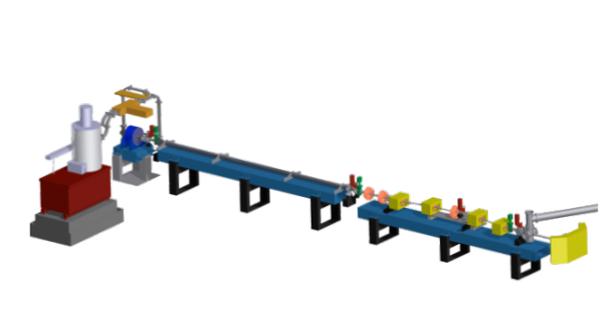
Cryogenics



Superconductivity &  
HTS developments



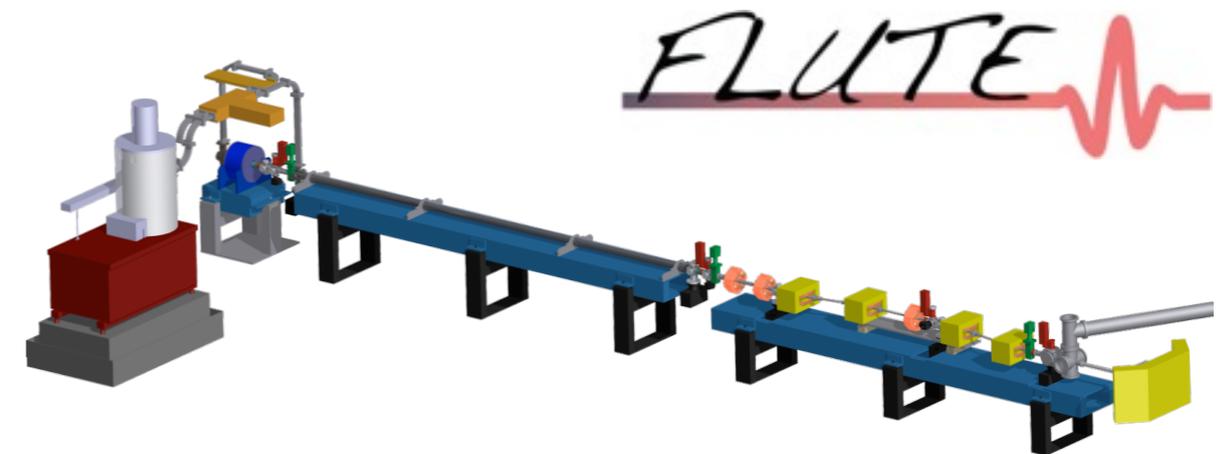
Storage Ring  
Test Facility



Short-Pulse Linac  
Test Facility

# Accelerators @ KIT

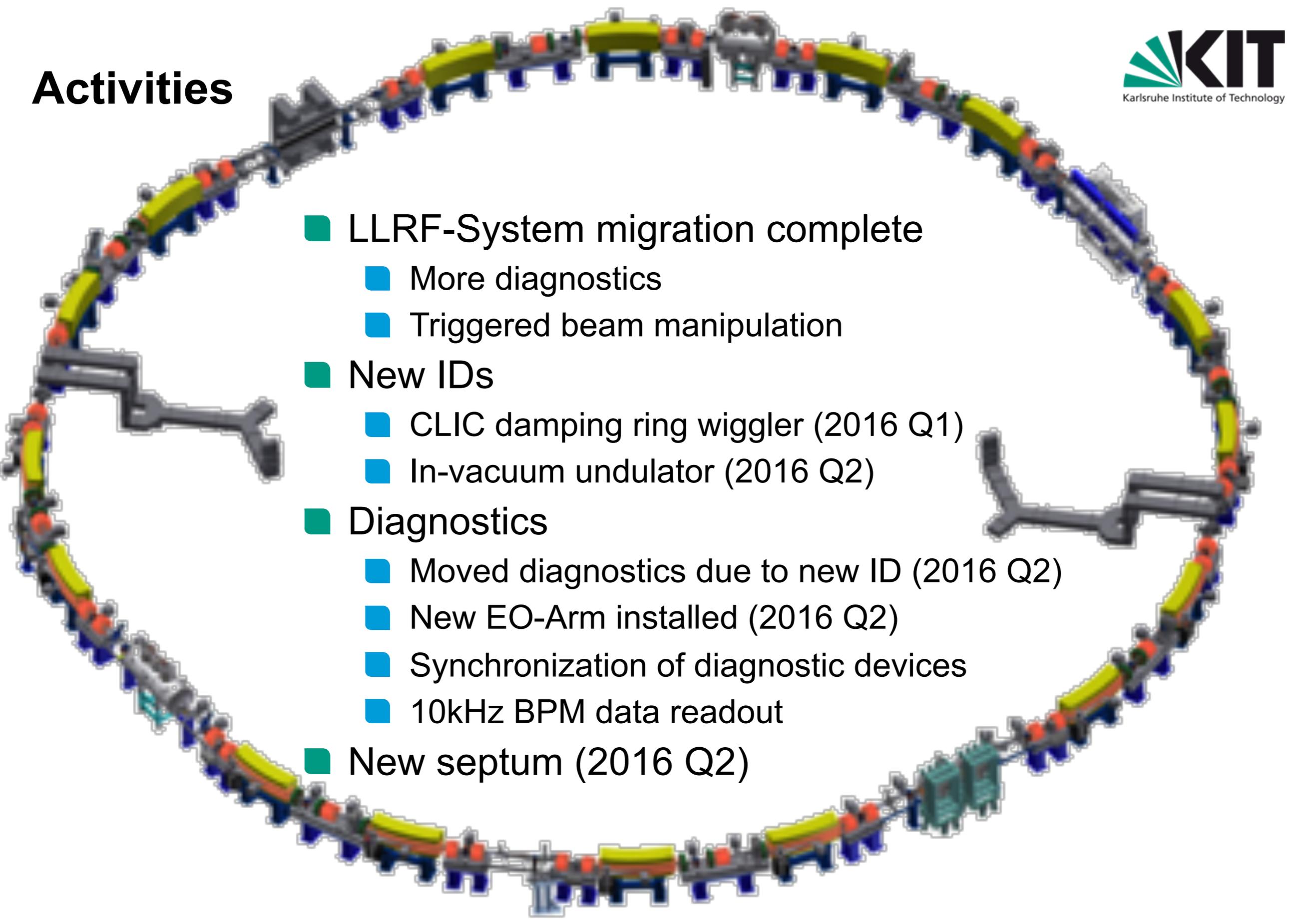
## ■ User applications & accelerator test facilities



- 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)

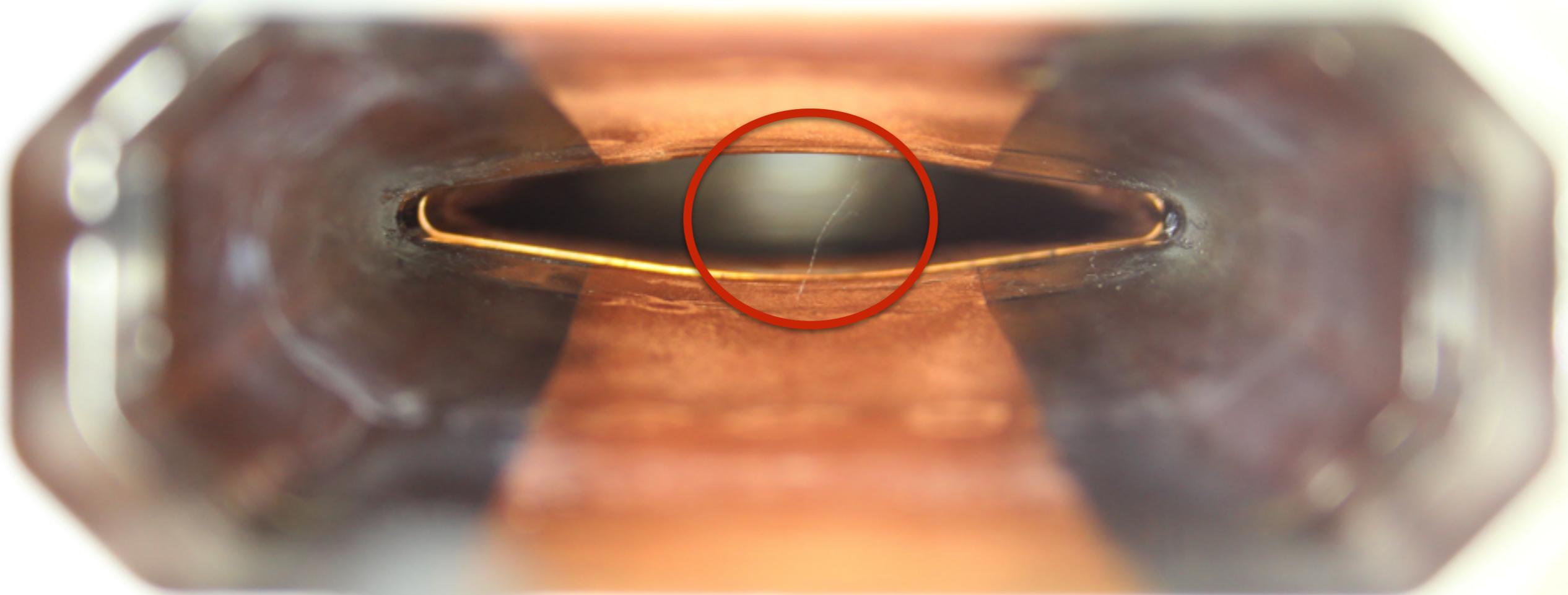
- Length: < 20 m
- Energy: ~ 41 MeV
- RF frequency: 3 GHz
- Pulse repetition rate: 10 Hz
- Electron bunch charge: 0.001 - 3 nC
- RMS bunch length: 1 - 300 fs
- THz E-Field strength: up to 1 GV/m

# Activities

- 
- LLRF-System migration complete
    - More diagnostics
    - Triggered beam manipulation
  - New IDs
    - CLIC damping ring wiggler (2016 Q1)
    - In-vacuum undulator (2016 Q2)
  - Diagnostics
    - Moved diagnostics due to new ID (2016 Q2)
    - New EO-Arm installed (2016 Q2)
    - Synchronization of diagnostic devices
    - 10kHz BPM data readout
  - New septum (2016 Q2)

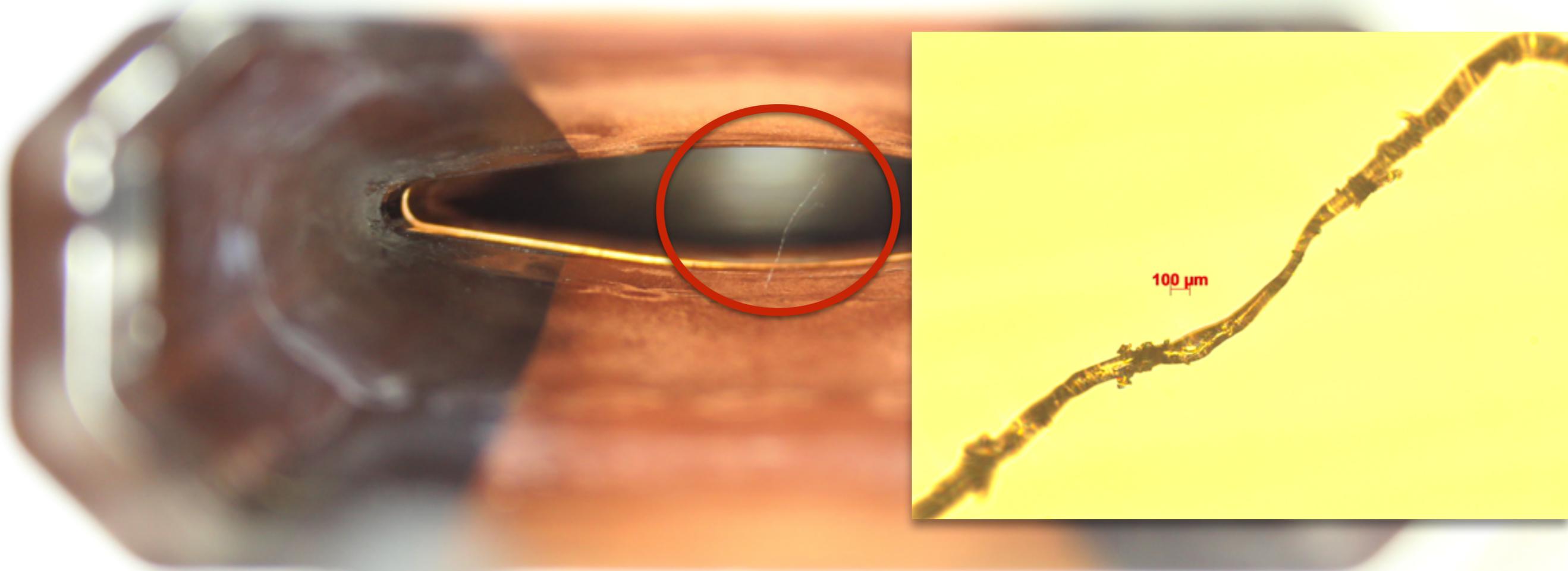
## Operation issues - Q1

- No injection after winter shutdown
- Found fibers inside ID beam pipe



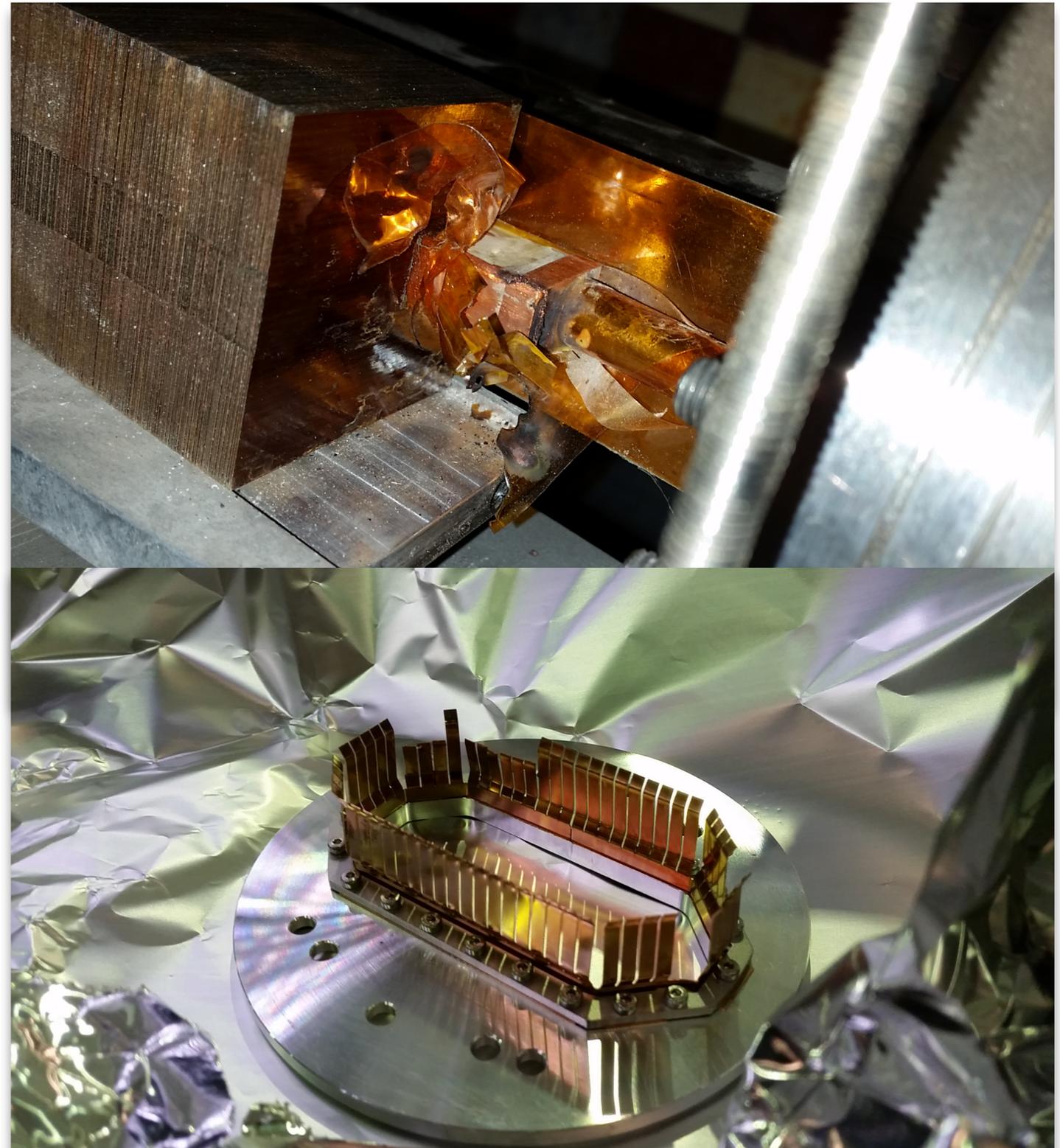
# Operation issues - Q1

- No injection after winter shutdown
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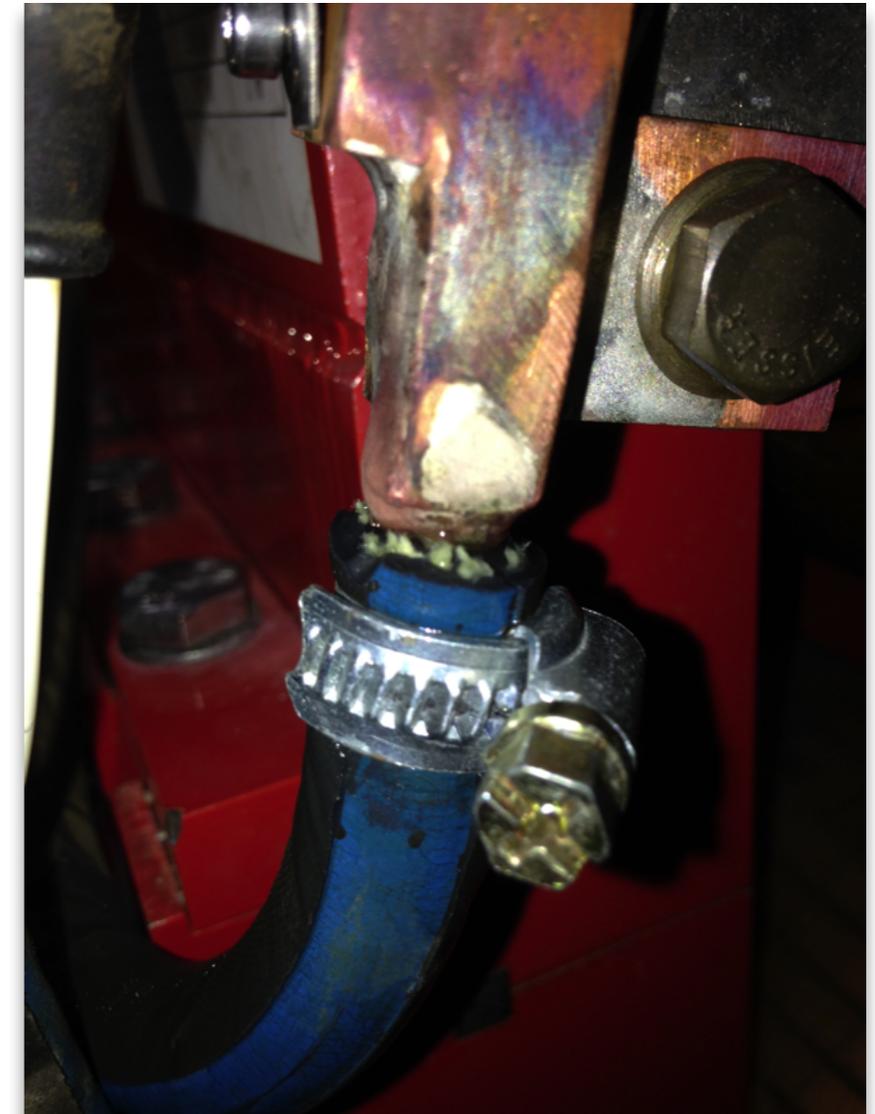
# Operation Issues - Q2

- Storage ring septum failed
  - Replaces with spare septum
  - Redesign of septum in progress
- Found broken rf fingers in bellow
- Bunch by Bunch feedback
  - Amplifier broken
  - HDD crashed
- Two out of the three cooling plants failed
  - One system repaired
  - New cooling plant in progress



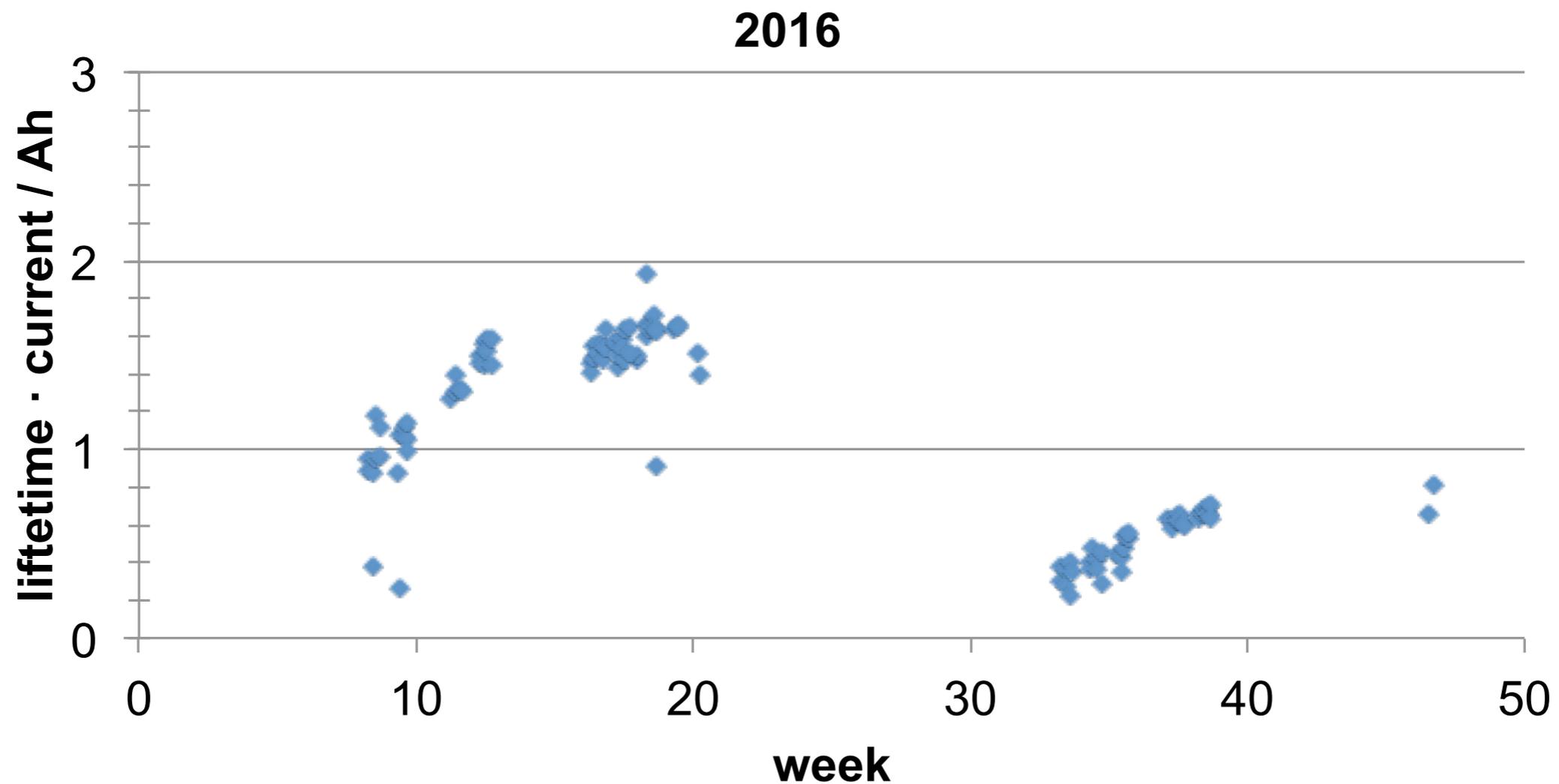
# Operation issues Q3

- Cavity motors failed due to broken clutch to encoder
  - Replaced with other clutch
  - New motors and gears planned
- Water interlocks
  - PLC failed, replaced with new PLC and integrated in control system
  - Frequent water interlocks
    - Cleaned flow monitors
    - Installed flow meters to improve diagnostics
    - Analysis running
- Libera unit failed (first one)
- Water leak in Quadrupole coil
- Lifetime and current limitations due to bad vacuum (4 sections vented)



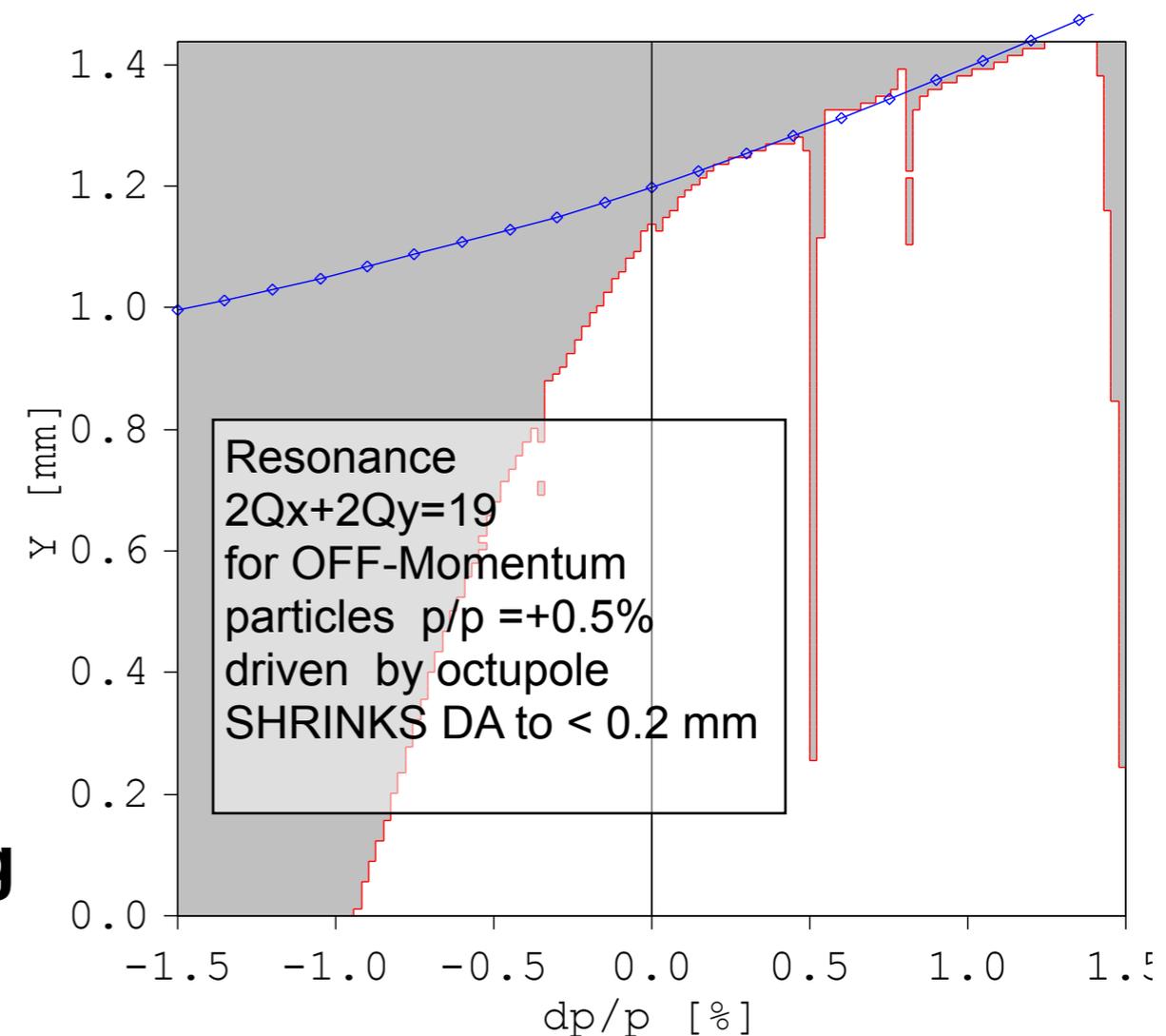
# Operation issues Q4

- Twisted copper plate in ID bellow prevented injection
  - Vented section
  - Adjusted plate
- Still recovering from bad vacuum



# Lifetime reduction due to octupole resonance

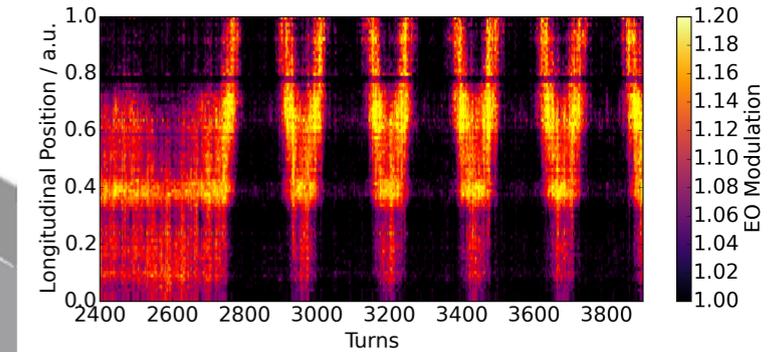
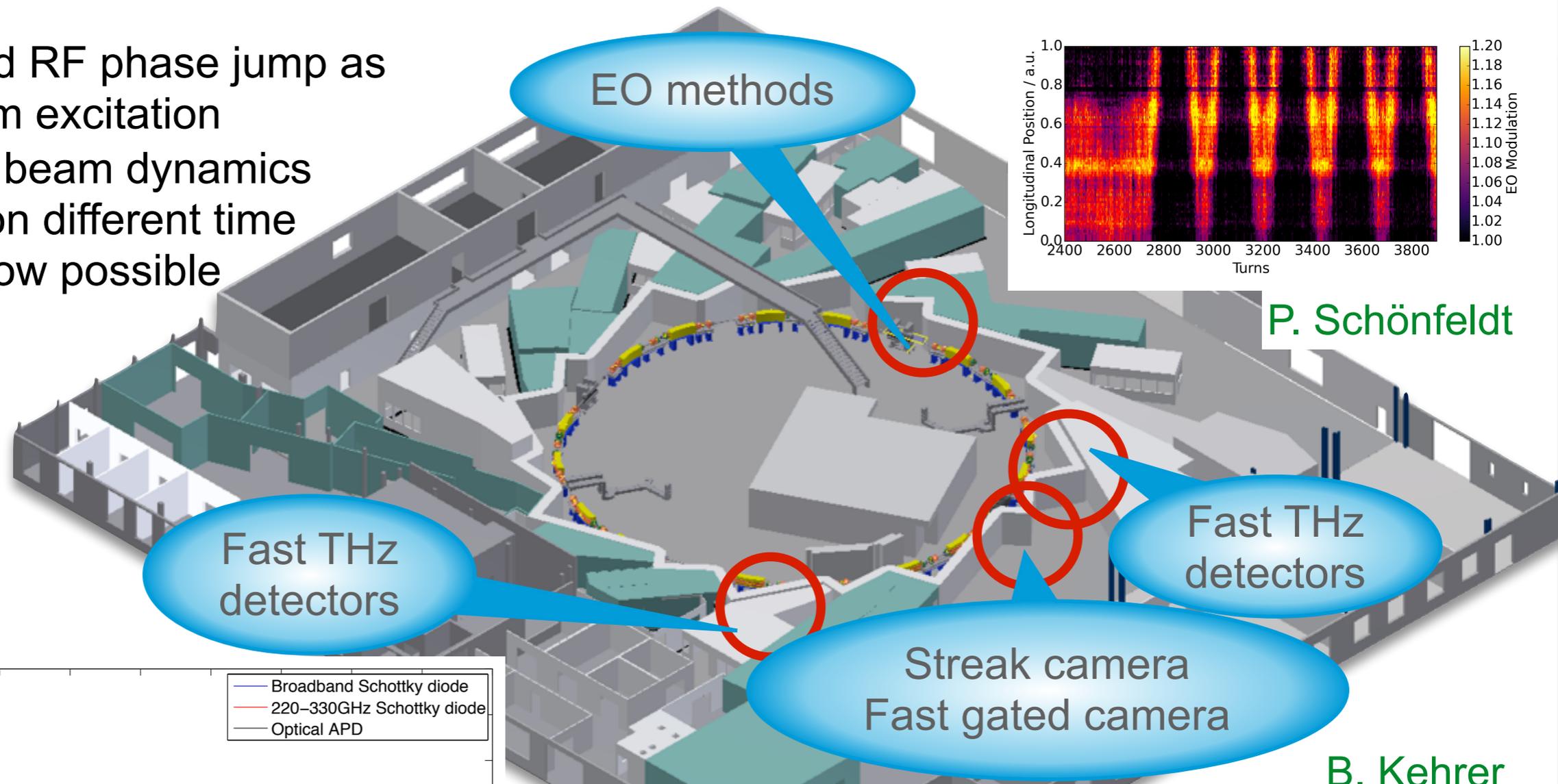
- Reduction of life time from 15 to 12 h has been observed while CAT-ACT wiggler was in operation at high field level ( $B = 2.2 - 2.5$  T)
- ID is installed in short straight section with large vertical beta function (13 m)
- Coherent shift of vertical tune is compensated locally
- Strong sextupoles at positive chromaticity +2,+6
- Dynamic aperture studies show losses for off-momentum particles
- Successful test with other working point
- **Next step: Implement new working point**



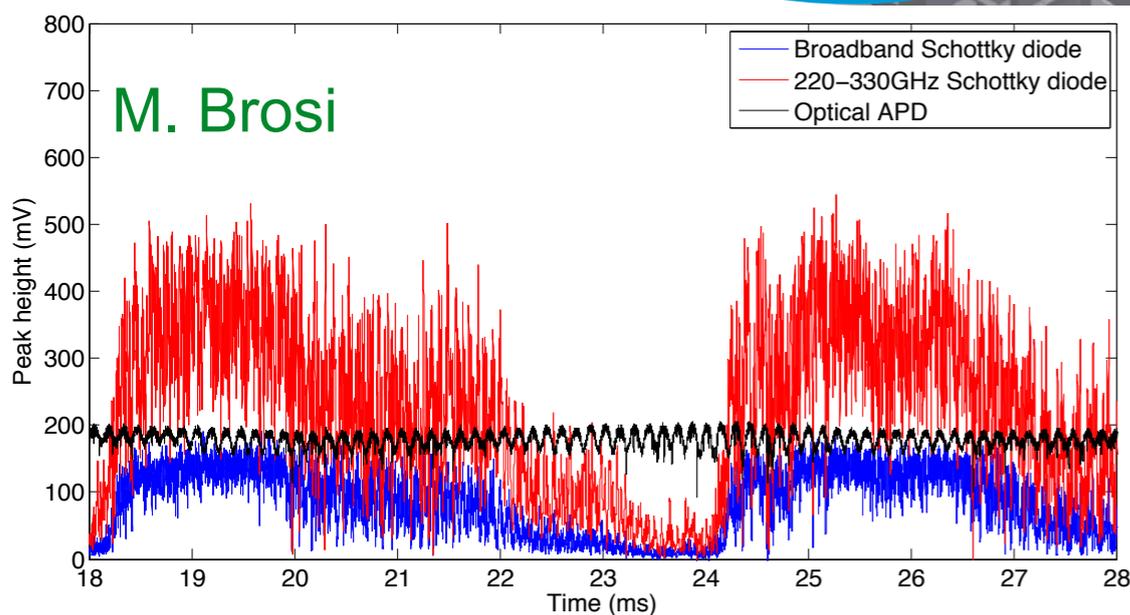
A. Papash

# Synchronized single shot beam diagnostics

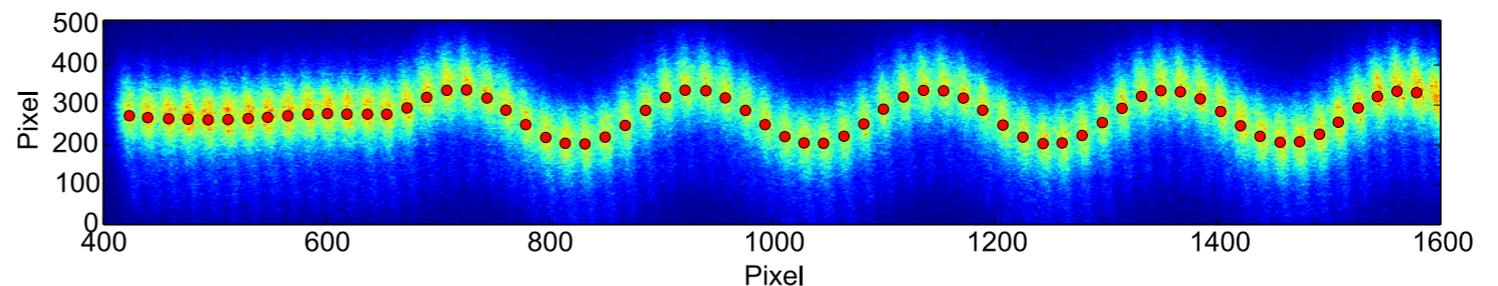
- Triggered RF phase jump as fast beam excitation
- Detailed beam dynamics studies on different time scales now possible



P. Schönfeldt



M. Brosi

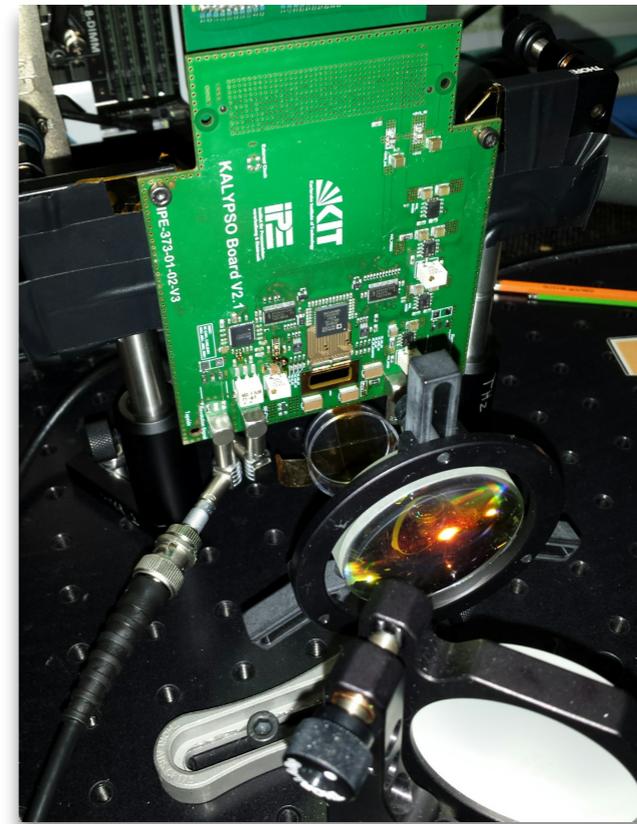


B. Kehrer

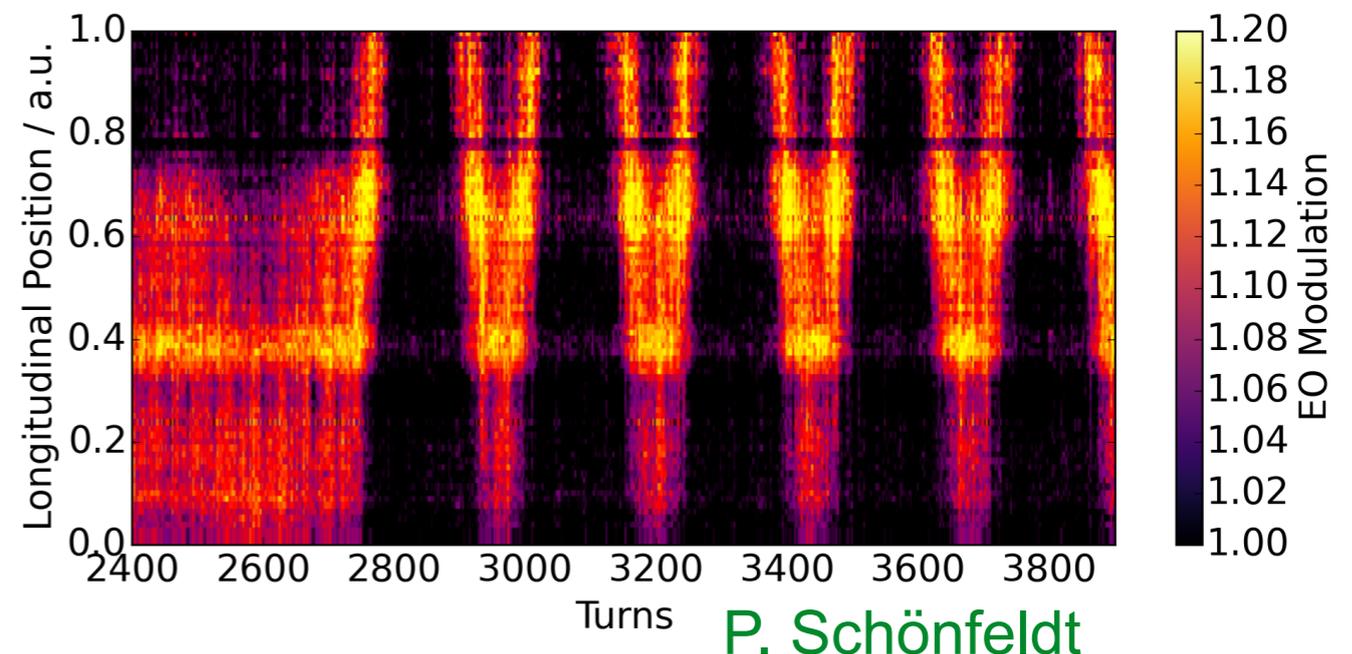
B. Kehrer et al., IPAC16, MOPMB014

# EO based longitudinal diagnostics

- Fast spectrometer readout
  - 2015-09: KALYPSO I (0.9 MHz)
  - 2016-04: KALYPSO II (2.7 MHz)
- Redesign of the ANKA EO-Arm
  - Reduce the impact of wake fields
  - Installed in June
  - In commissioning
- Two new EO Laser systems assembled together with DESY



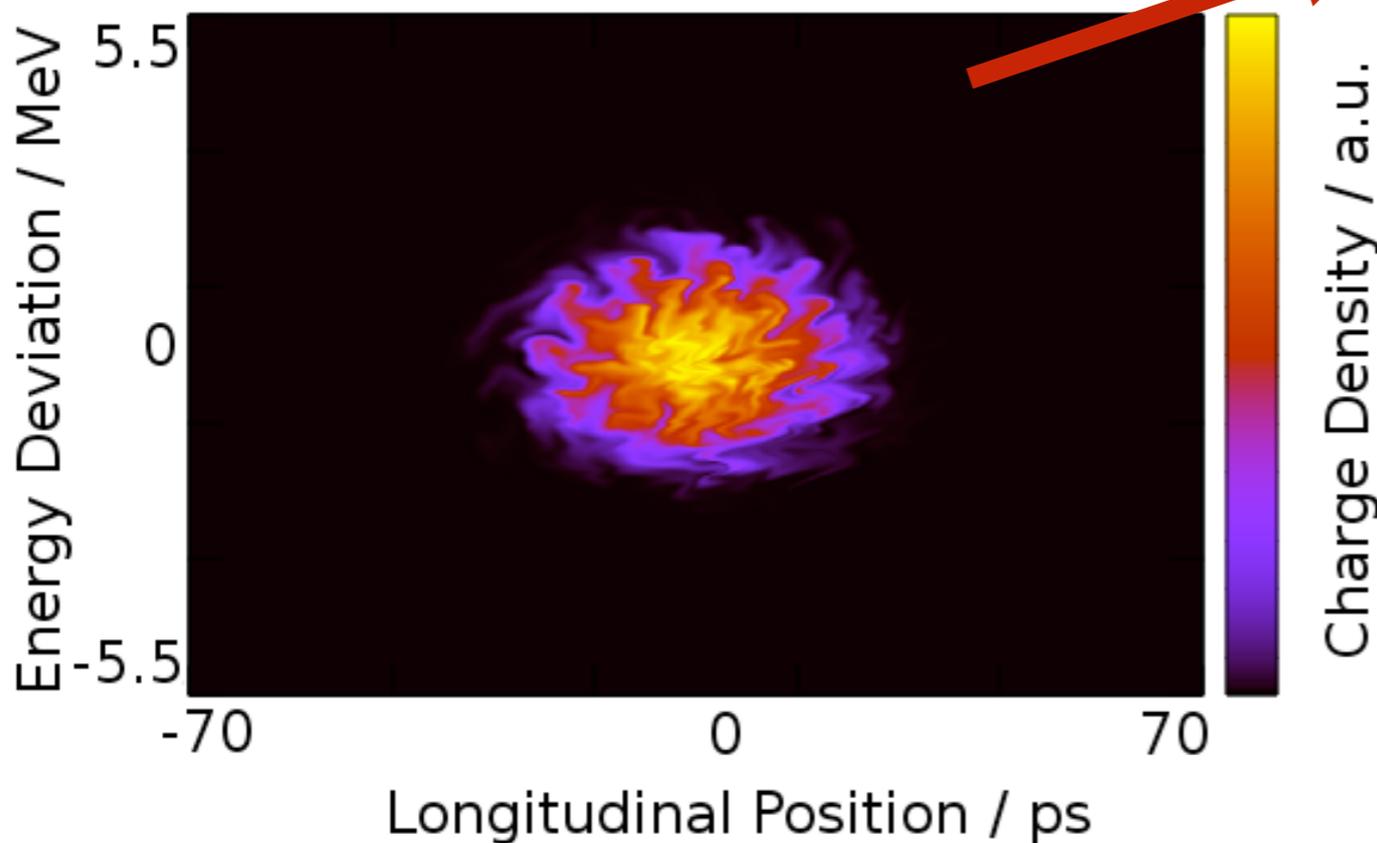
L. Rota et al., IBIC16, WEPG46



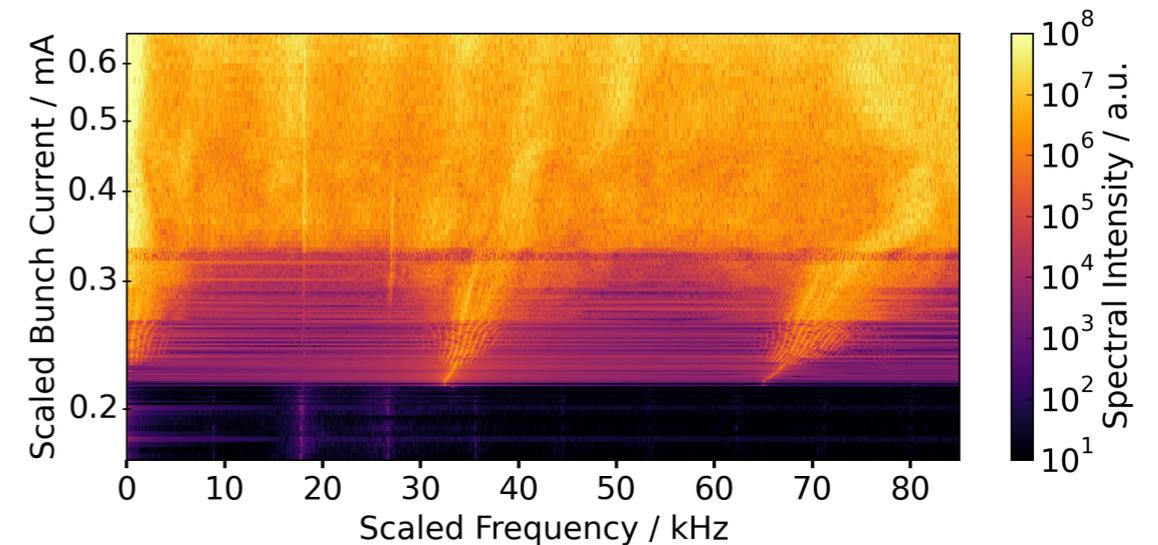
# Inovesa

## ■ A Parallelized Vlasov-Fokker-Planck-Solver for Desktop PCs

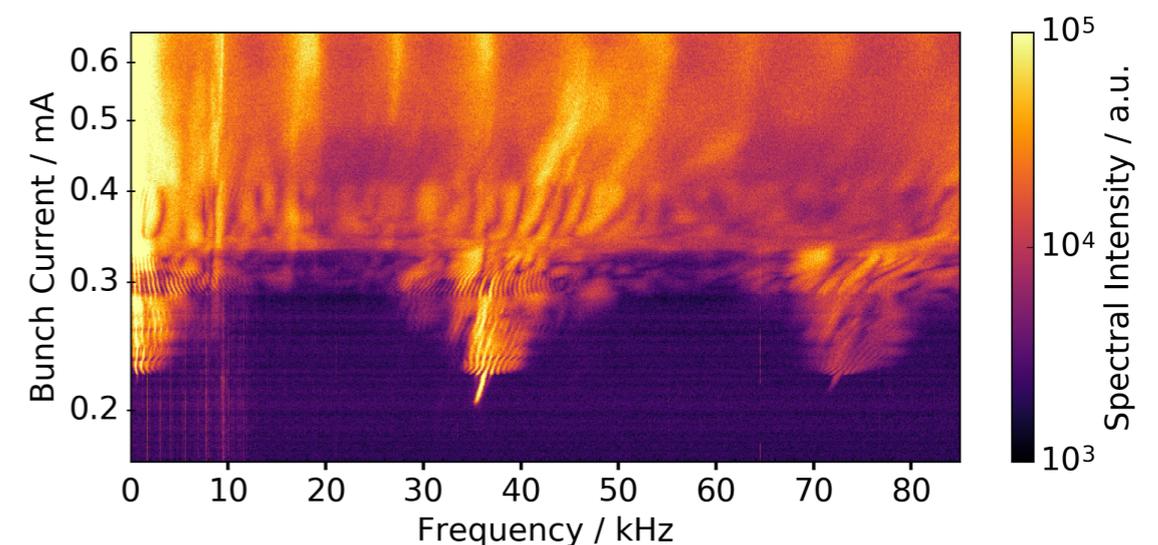
Simulated phase space



Simulated



Measured

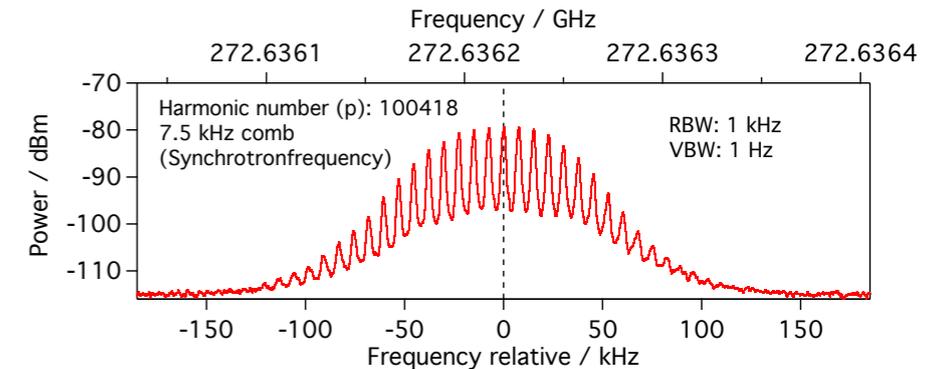
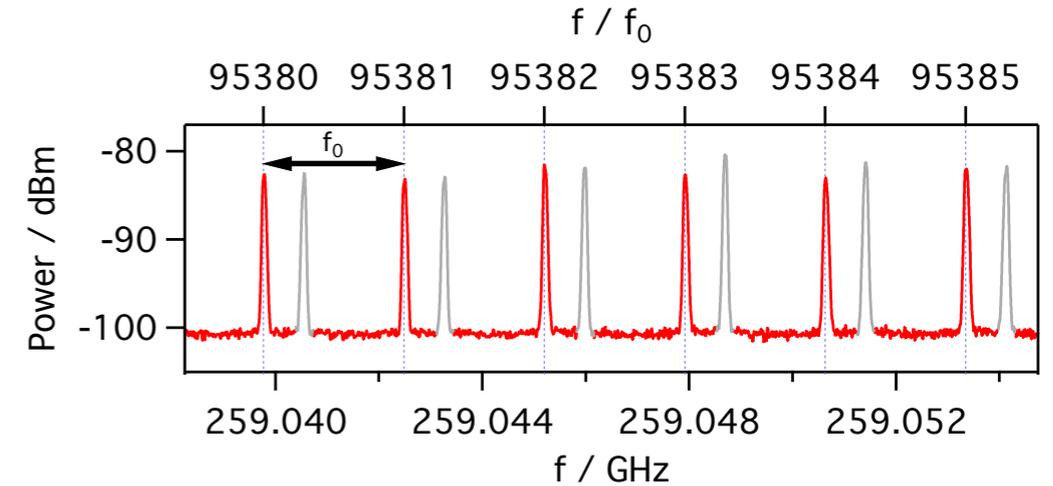
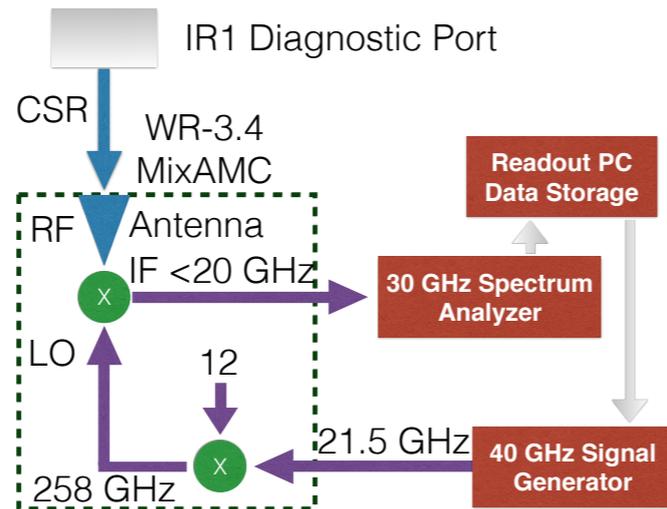
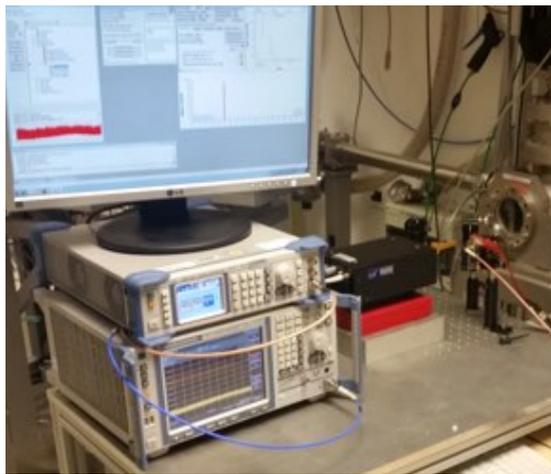


P. Schönfeldt et al., IPAC16, TUPOR005  
 P. Schönfeldt et al, submitted to PR-AB  
<http://arxiv.org/abs/1611.05293>

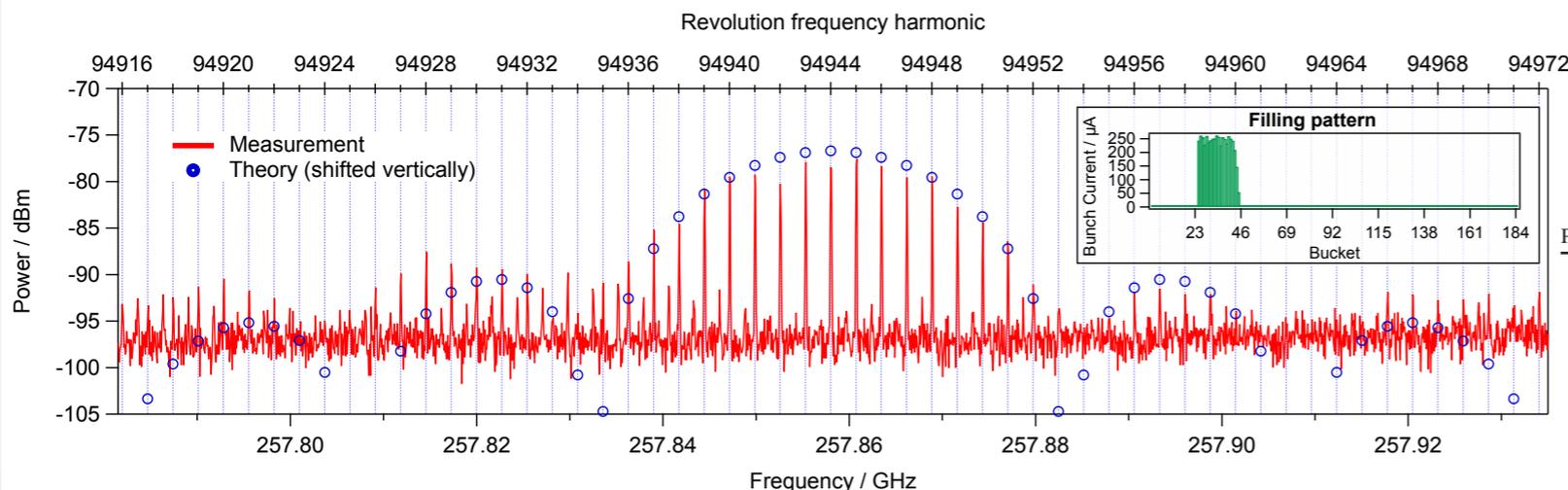
**CODE:** <https://github.com/Inovesa/Inovesa>

M. Brosi

# Influence of filling pattern on THz spectrum



- By the use of a heterodyne mixing setup, the discrete revolution frequency harmonics and even synchrotron frequency modulation can be observed
- The intensity of the harmonics is dependent on the discrete Fourier transformation of the filling pattern
- Frequency-Comp spectrum



$$|S(f)|^2 = \underbrace{\frac{1}{T_0} \text{III}_{\frac{1}{T_0}}(f)}_{f_0 \text{ frequency comb}} \times \underbrace{\left| \sum_{k=1}^h V_k e^{-i2\pi f k T_{rf}} \right|^2}_{\text{filling pattern}} \times \underbrace{[N_e + N_e(N_e - 1)F(f)]}_{\text{CSR enhancement}} \times \underbrace{|S_p(f)|^2}_{\text{SR spectrum}}$$

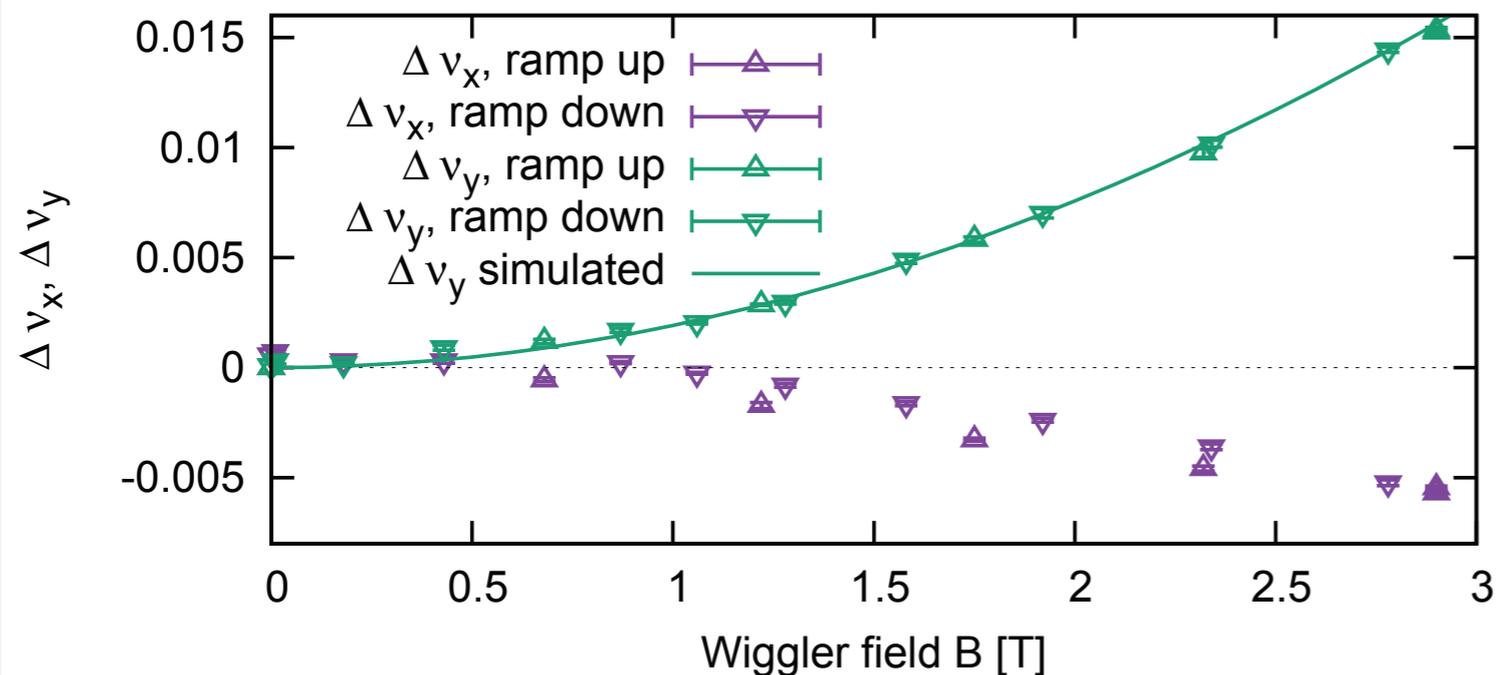
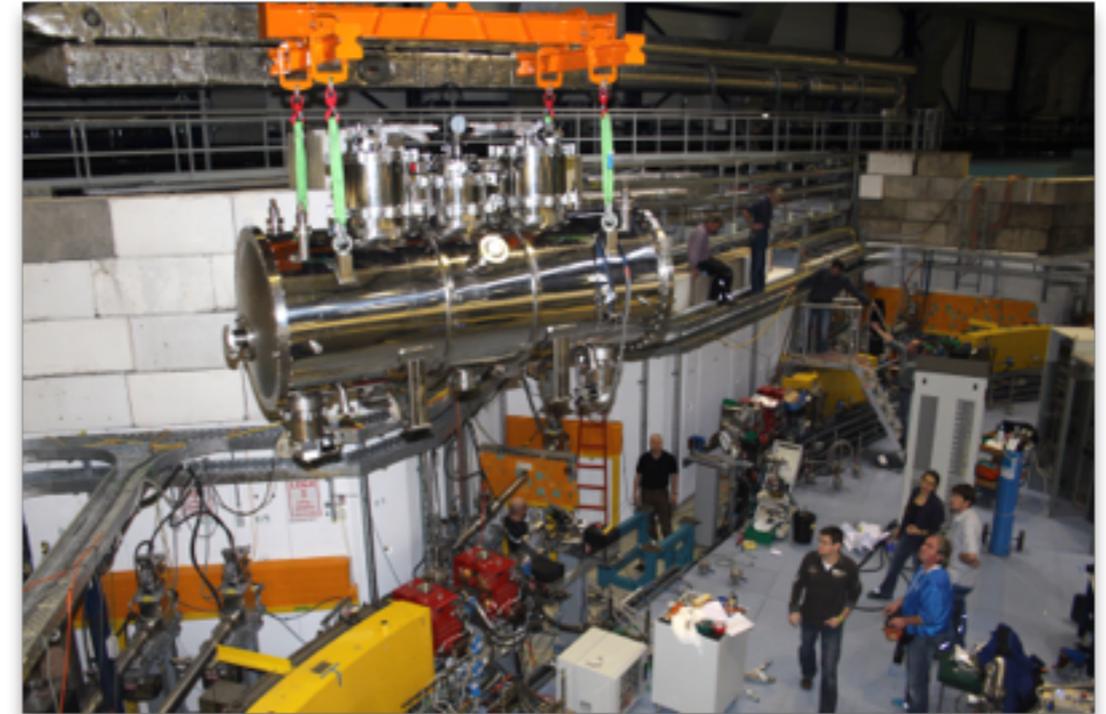
PRL 117, 174802 (2016) PHYSICAL REVIEW LETTERS week ending 21 OCTOBER 2016

## Frequency-Comb Spectrum of Periodic-Patterned Signals

Johannes L. Steinmann,<sup>1,\*</sup> Edmund Blomley,<sup>2</sup> Miriam Brosi,<sup>1</sup> Erik Bründermann,<sup>2</sup> Michele Caselle,<sup>3</sup> Jeffrey L. Hesler,<sup>4</sup> Nicole Hiller,<sup>2</sup> Benjamin Kehrer,<sup>1</sup> Yves-Laurent Mathis,<sup>2</sup> Michael J. Nasse,<sup>2</sup> Juliane Raasch,<sup>5</sup> Manuel Schedler,<sup>1</sup> Patrik Schönfeldt,<sup>2</sup> Marcel Schuh,<sup>1</sup> Markus Schwarz,<sup>1</sup> Michael Siegel,<sup>5</sup> Nigel Smale,<sup>2</sup> Marc Weber,<sup>3</sup> and Anke-Susanne Müller<sup>2</sup>

# CLIC damping ring wiggler

- ANKA has similar properties as the damping rings proposed for CLIC
- Design and construction of a SC wiggler according CLIC-damping ring specifications (CERN, BINP) ✓
- Test and beam dynamics studies at ANKA in progress
- Modeling low alpha lattice with IDs



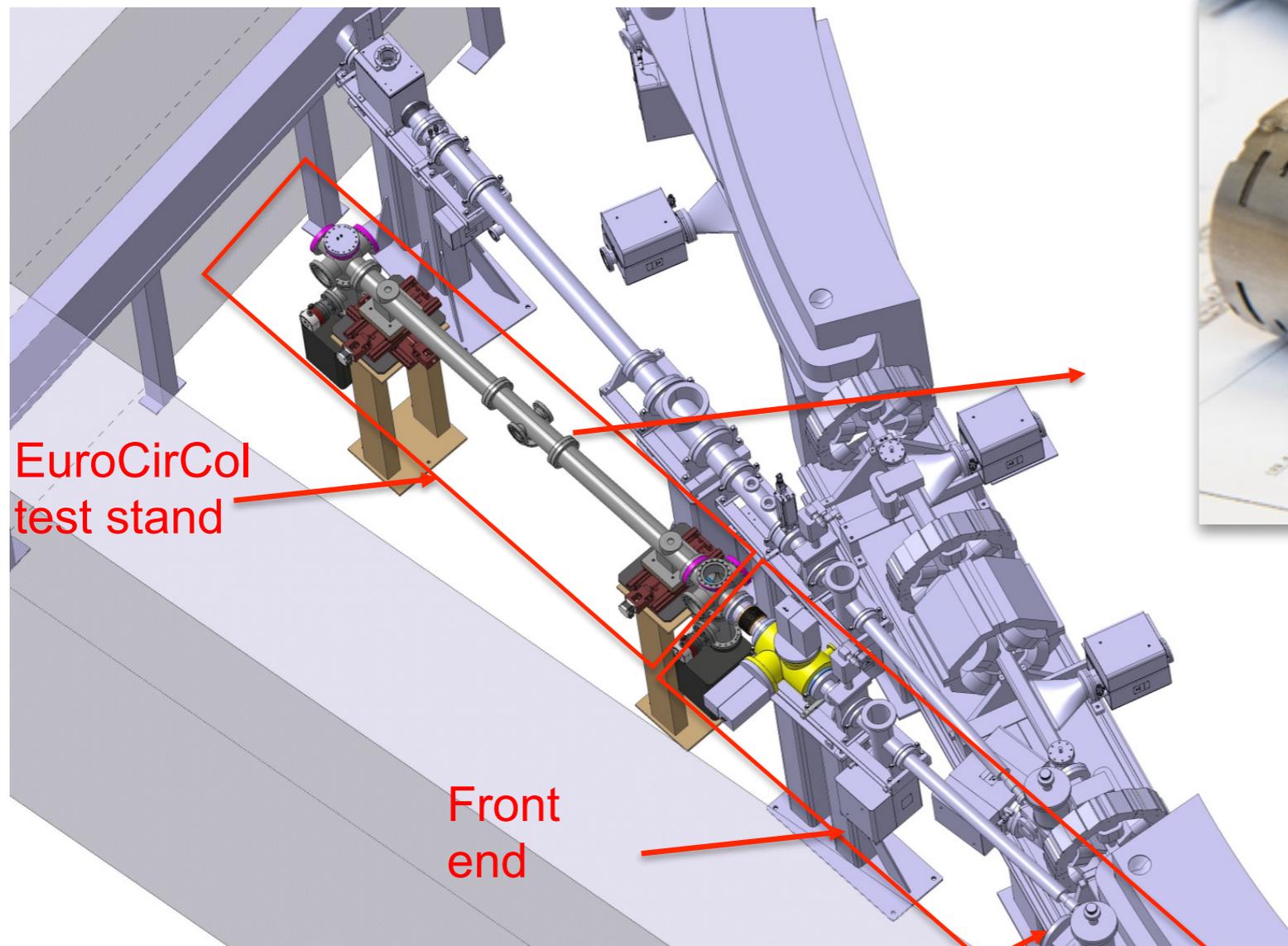
A. Bernhard et al., IPAC16, WEPMW002



# EuroCirCol

## ■ FCC H2020 Project - The European Circular Energy-Frontier Collider Study

FCC-hh beam screen prototype



S. Casalbuoni et al.

Crotch absorber



# EU accelerator test facilities



- ARIES - Accelerator Research and Innovation for European Science and Society
- 42 beneficiaries from 18 European countries
- Transnational Access to 14 European accelerator test facilities
- KIT will be active in:
  - WP2: Training, Communication and Outreach for Accelerator Science in Europe: Tasks 2.2 to 2.4: Contributing information/media to the e-learning project. Students will serve as representative test groups to benchmark e-learning components.
  - WP6: Accelerator / Beam Control, Design & Coordination Task 6.3: Facilitate exchange information and accelerator operation experience.
  - WP7: Beam tests and commissioning of ultra-low emittance rings: Task 7.4: Facilitate exchange of information on beam dynamics and ultra-low emittance source technology.
  - WP11: Electron and proton beam testing: ANKA and FLUTE will provide a unique test environment as part of a transnational access program.

# Outlook

- Continue refurbishment program for ANKA
  - Finish construction and continue commissioning of FLUTE
  - Active R&D programme
    - Diagnostics
    - THz
    - SC-IDs
  - To master all these tasks we have / will open new positions
    - RF expert
    - Machine operation
    - Department head
    - ...
- } **contact: [anne.stoesser@kit.edu](mailto:anne.stoesser@kit.edu)**

# Outlook

- Continue refurbishment program for ANKA
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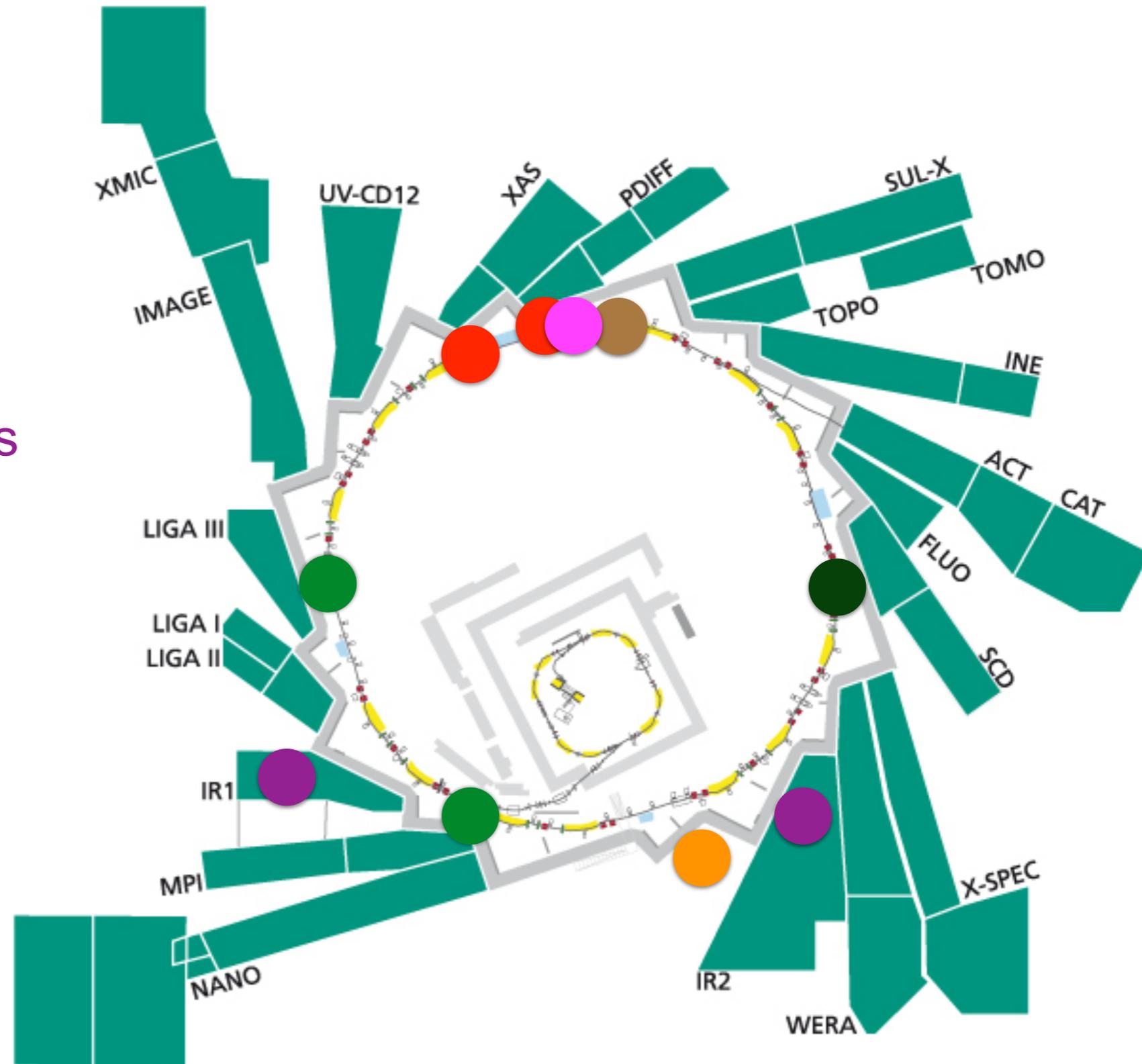
contact: [anne.stoesser@kit.edu](mailto:anne.stoesser@kit.edu)

**Thank you for your attention and the KIT team for their support!**

# Backup slides

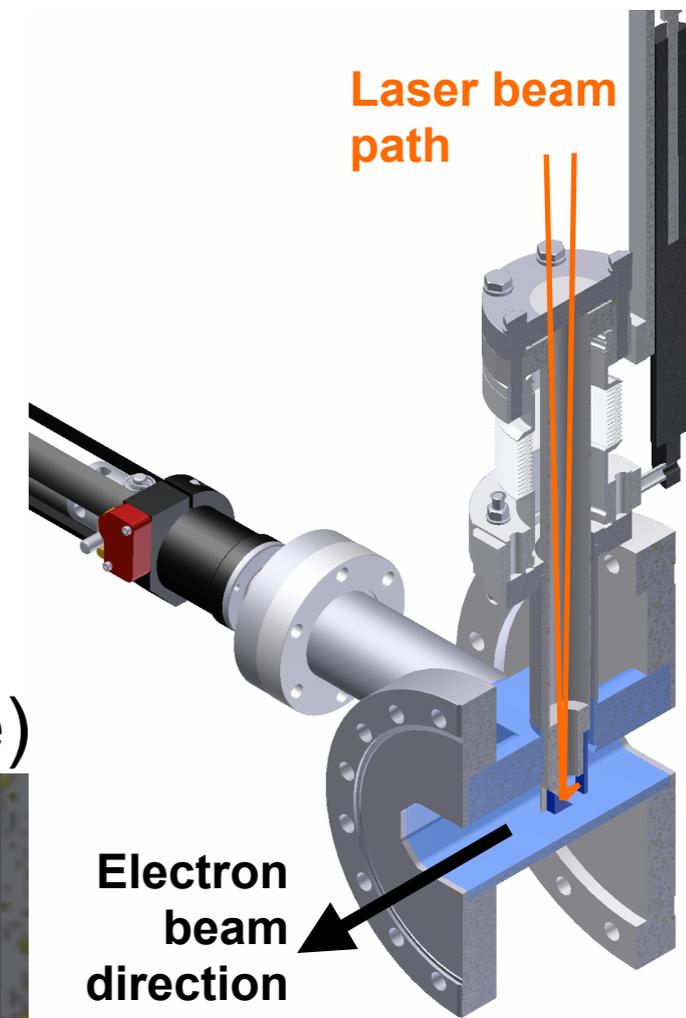
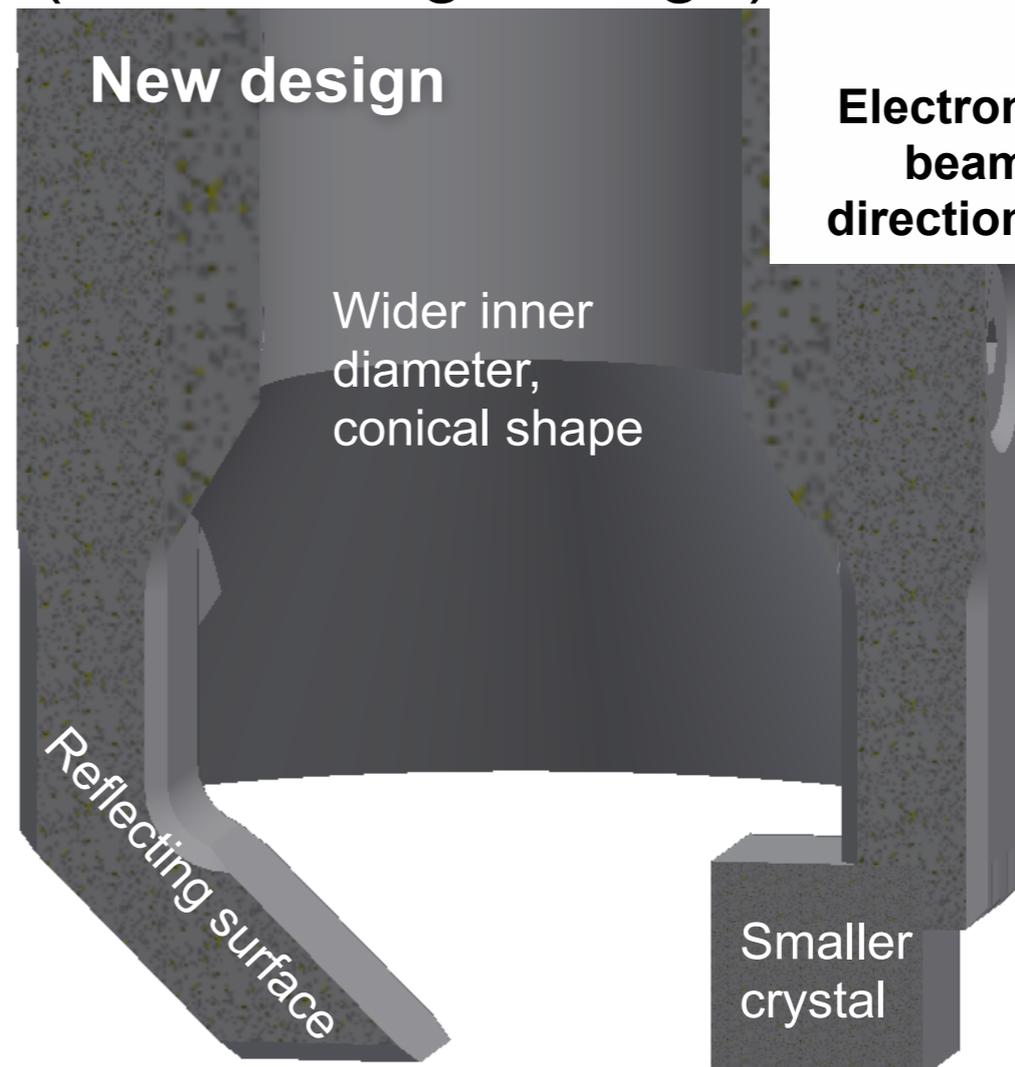
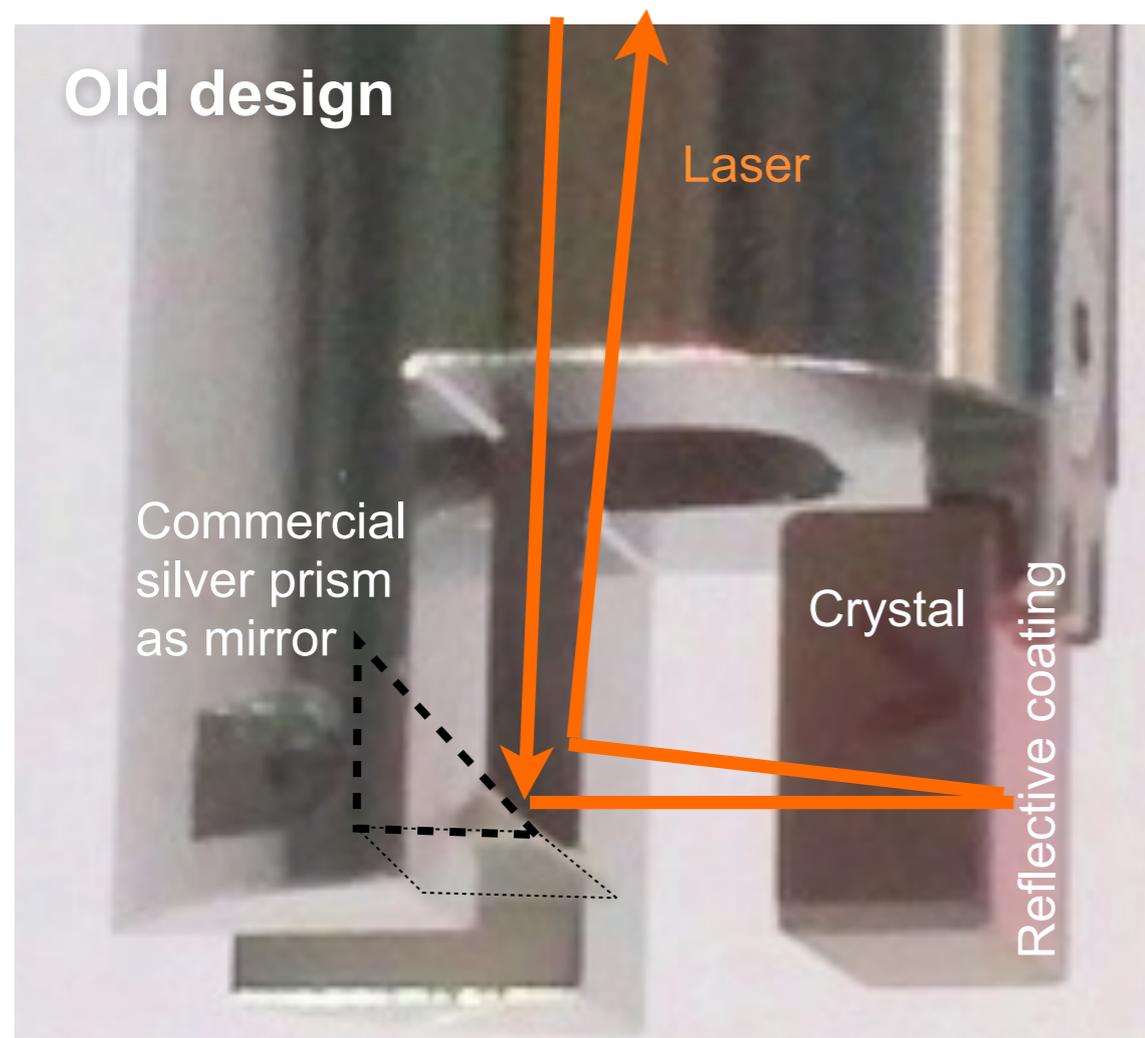
# Diagnostics at ANKA

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



# ANKA EO Arm Redesign

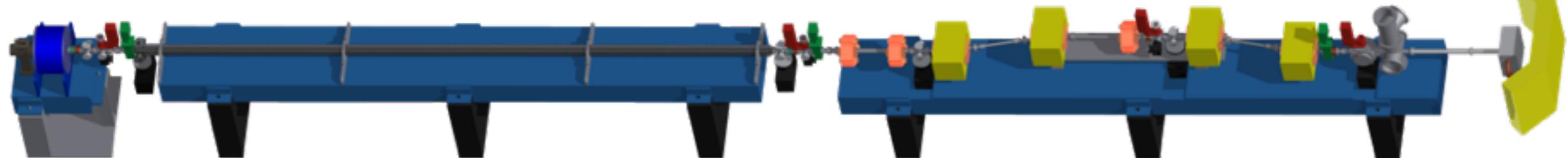
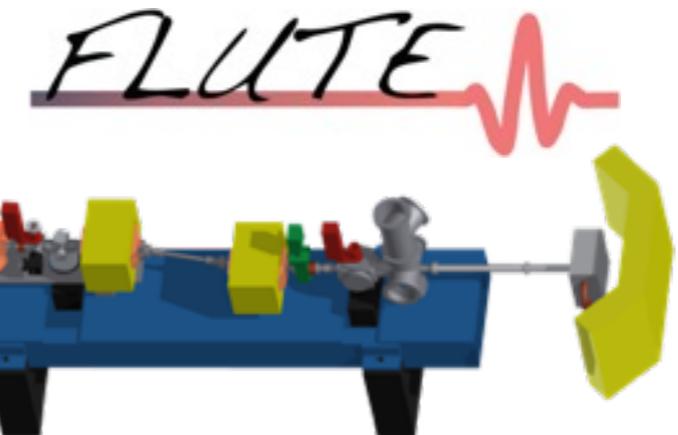
- Change in geometry to reduce wake-fields & heat load which limit multi-bunch operation
  - Reduce wake-fields & heat load which limit use in multi-bunch operation
- Maintain compactness of setup (12 cm flange-flange)



Courtesy of  
P. Schönfeldt  
& Steffen Schott

# FLUTE: Accelerator test facility at KIT

- FLUTE (Ferninfrarot Linac- Und Test-Experiment)
  - Test facility for **accelerator physics within ARD**
  - **Experiments** with THz radiation



- Serve as a test bench for new beam diagnostic methods and tools
- Develop single shot fs diagnostics
- Synchronization on a femtosecond level
- Systematic bunch compression studies
- Generate intense THz radiation
- Compare different coherent THz radiation generation schemes in simulation and experiment

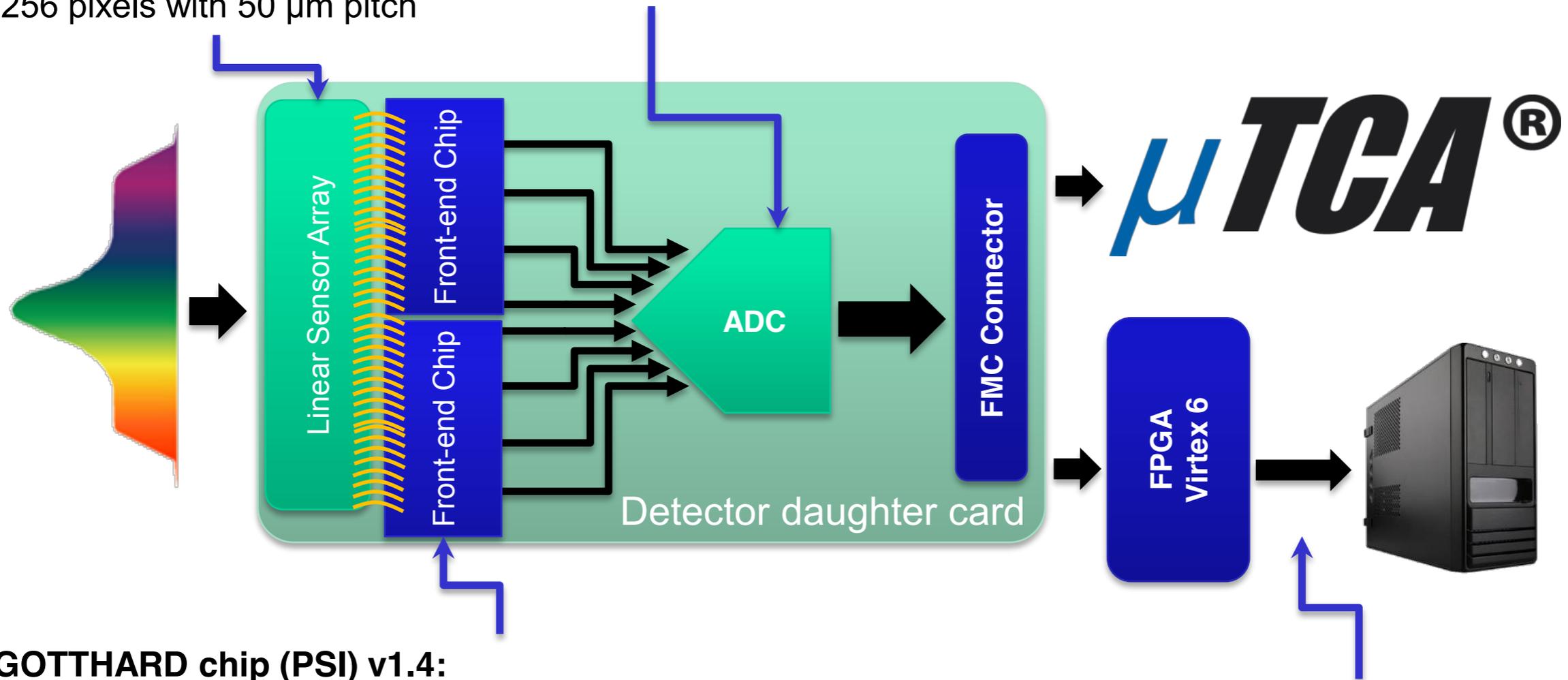
Final electron energy	~ 41	MeV
Electron bunch charge	0.001 - 3	nC
Electron bunch length	1 - 300	fs
Pulse repetition rate	10	Hz
THz E-Field strength	up to 1.2	GV/m

M. Nasse et al. , Rev. Sci. Instrum. 84, 022705 (2013)

# KARlsruhe Linear arraY detector for MHz-rePetition rate SpectrOscopy

**InGaAs (Xenics) / Si (PSI):**  
256 pixels with 50  $\mu\text{m}$  pitch

**ADC9252: 8 channels @ 14-bit, 50 MSPS**



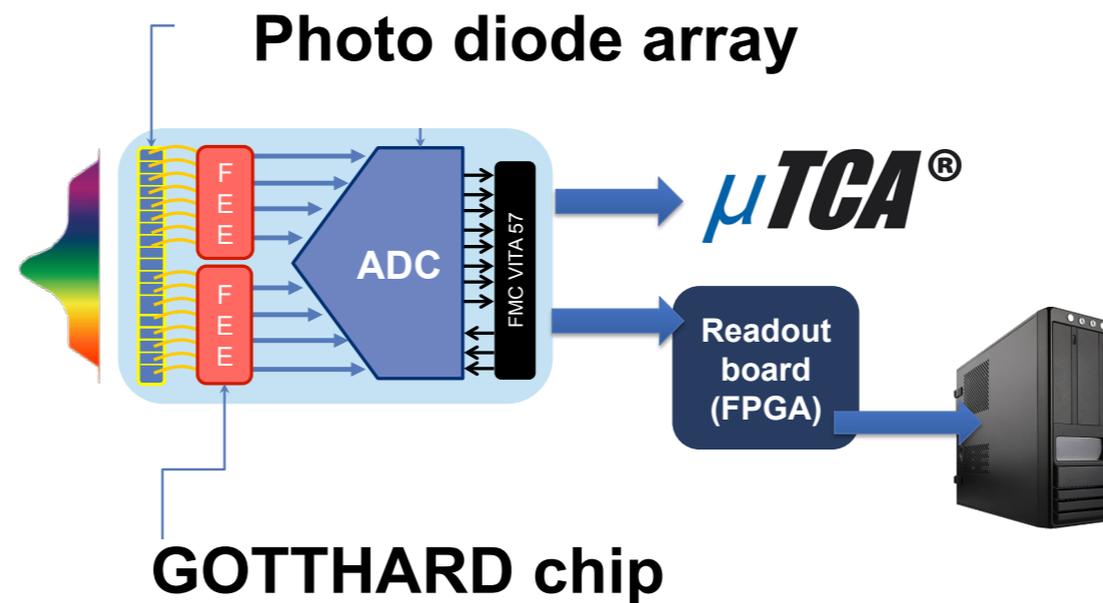
**GOTTHARD chip (PSI) v1.4:**

Gain Optimizing microSTrip system with Analog Readout  
Charge Integrating readout for XFEL strip-detector - IBM 0.13 $\mu\text{m}$   
128 inputs, 4 analog outputs operating at 32 MHz  
Max. read-out rate: 1 Mfps

**Fast KIT-DAQ:**  
Based on PCIe/DMA

# KALYPSO collaboration

## Scientific collaboration:



- Hardware & partly software implementation of daughter card
- Fast readout based on PCIe/DMA
- Real-time GPU data evaluation



- GOTTHARD front end development
- Si arrays



Lodz University of Technology

- Firmware for daughter card control
- $\mu$ TCA integration