

# Status of DELTA

Shaukat Khan, Zentrum für Synchrotronstrahlung

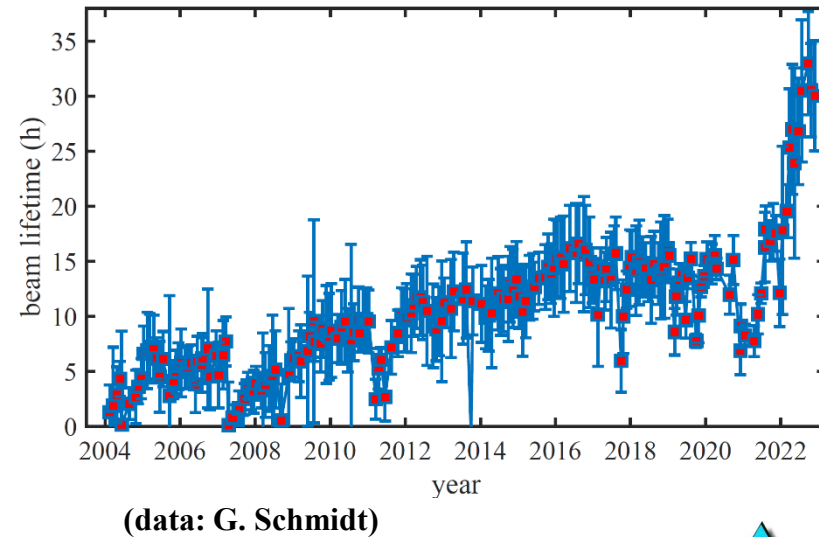
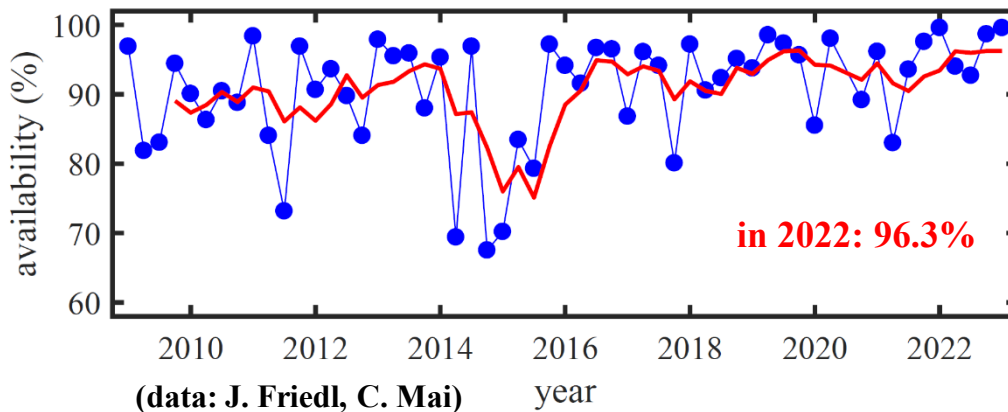
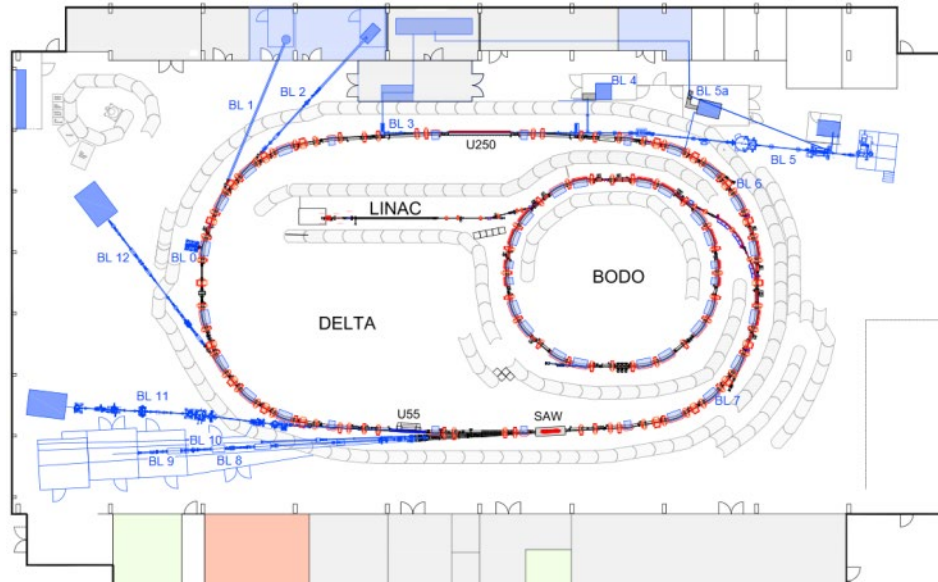
Grenoble, Dec 14, 2022



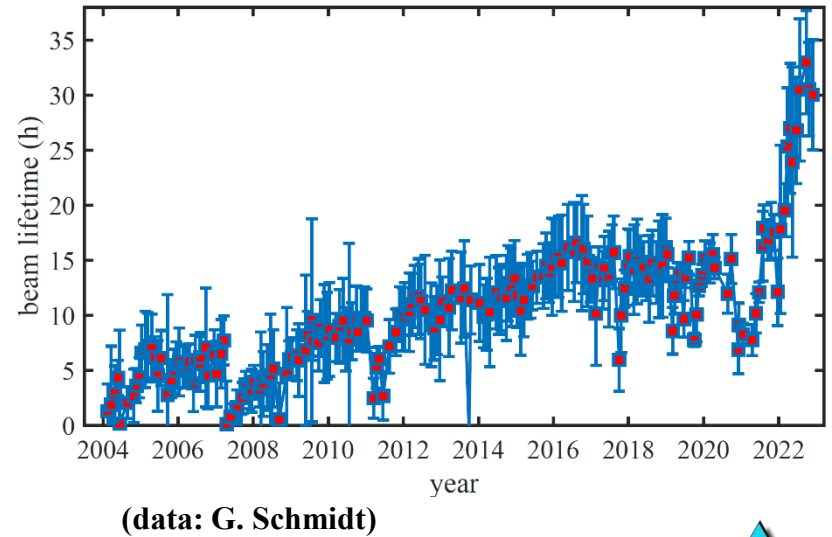
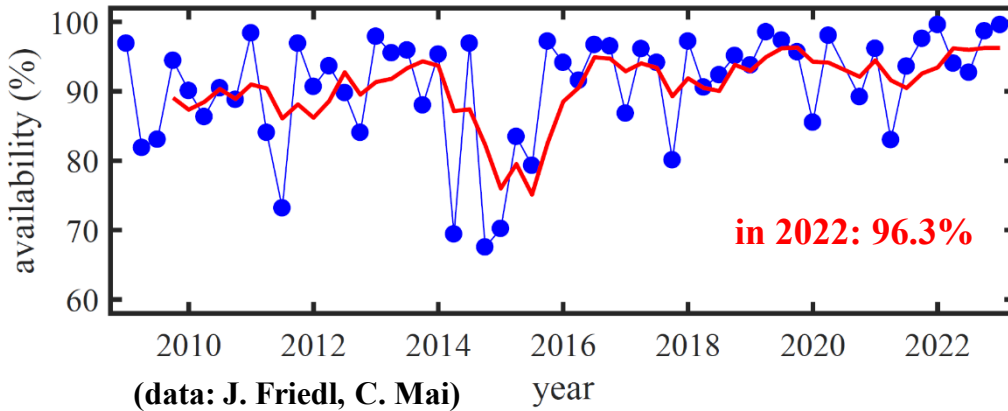
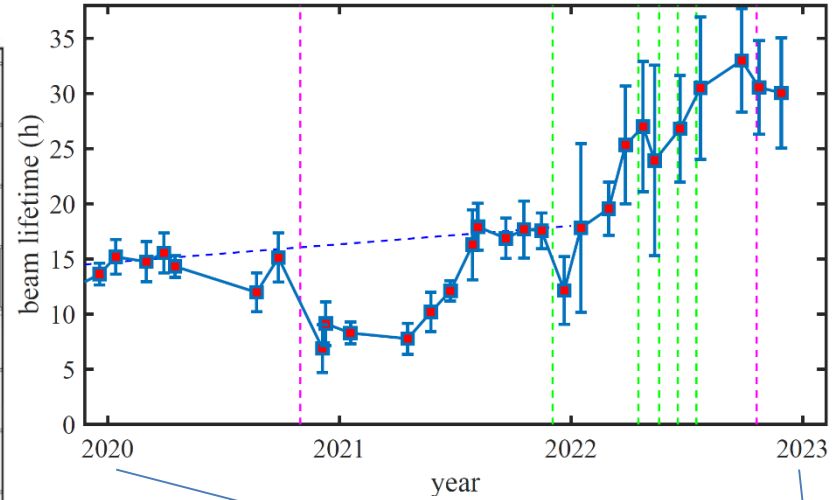
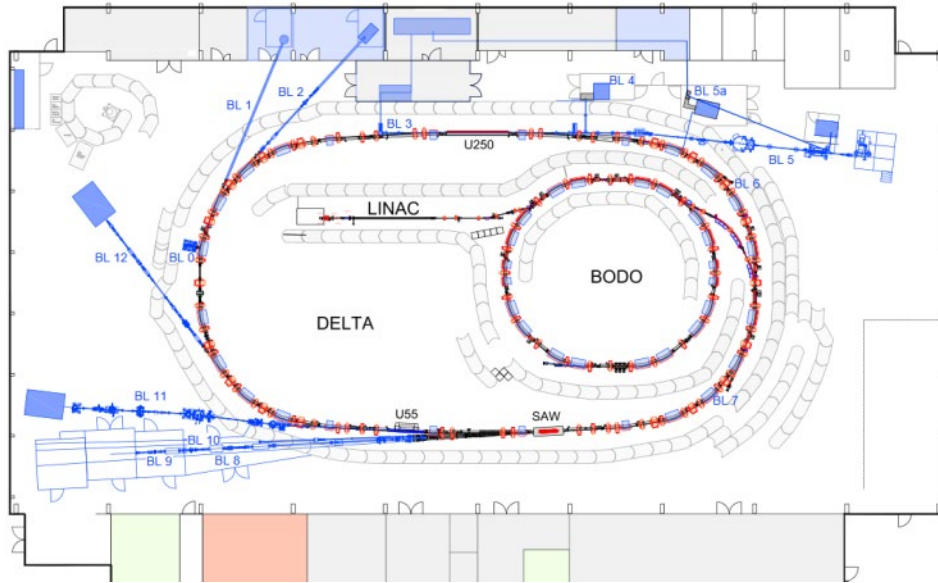
# Parameters and availability

## Parameters

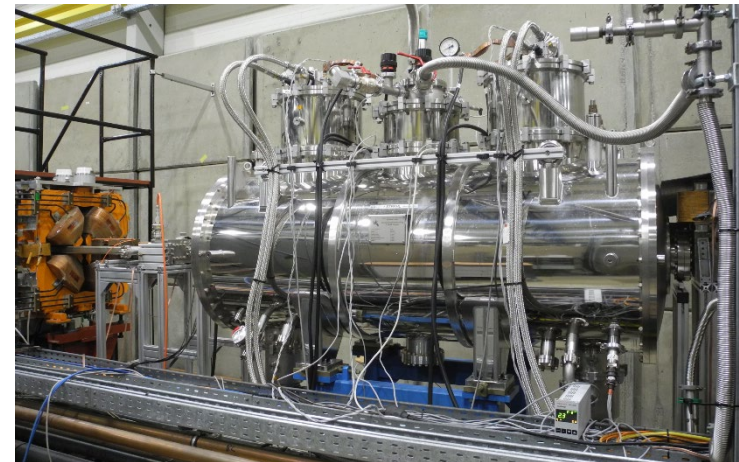
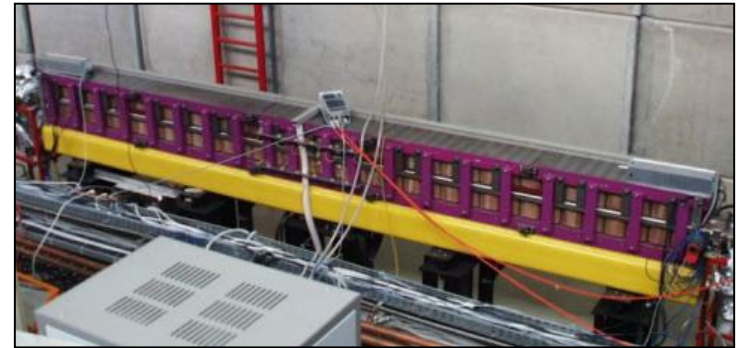
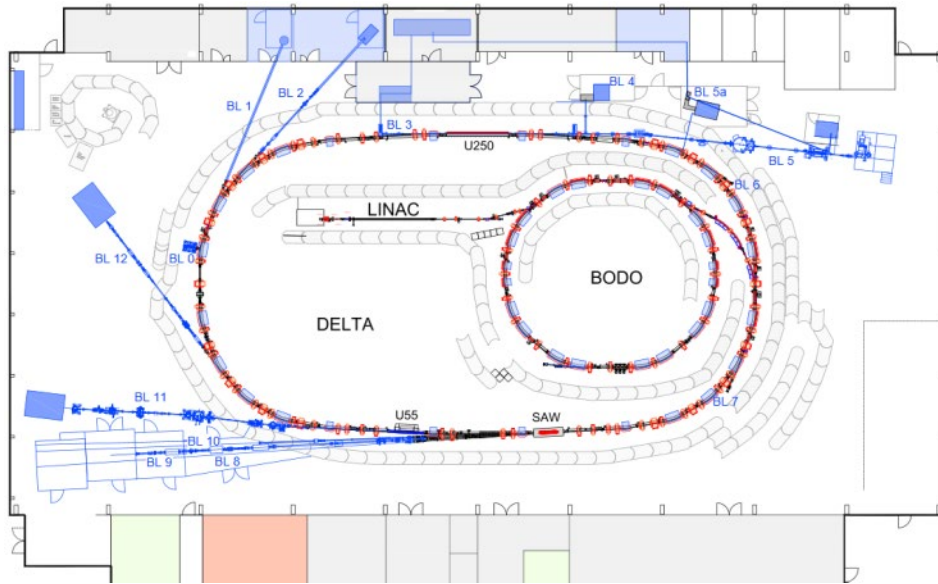
circumference	115.2 m
beam energy	1.5 GeV
beam current	130 mA multi-bunch
beam current	20 mA single bunch
beam lifetime	>30 h at 100 mA
hor. emittance	~16 nm rad
bunch length	40 ps rms
user operation	2000 h/y (20 weeks/y)
machine studies	1000 h/y (10 weeks/y)



# Parameters and availability



# Insertion devices



## New superconducting wiggler installed in 2020

A. Althaus, B. Beyer, B. Büsing, G. Dahlmann, S. Khan, V. Kniss, M. Paulus, B. Sawadski,  
D. Schirmer, G. Schmidt, T. Schulte-Eickhoff, C. Sternemann, T. Dybiona, M. Tolan + BINP team

**Magnetic field: 5.3 T  $\rightarrow$  7 T**

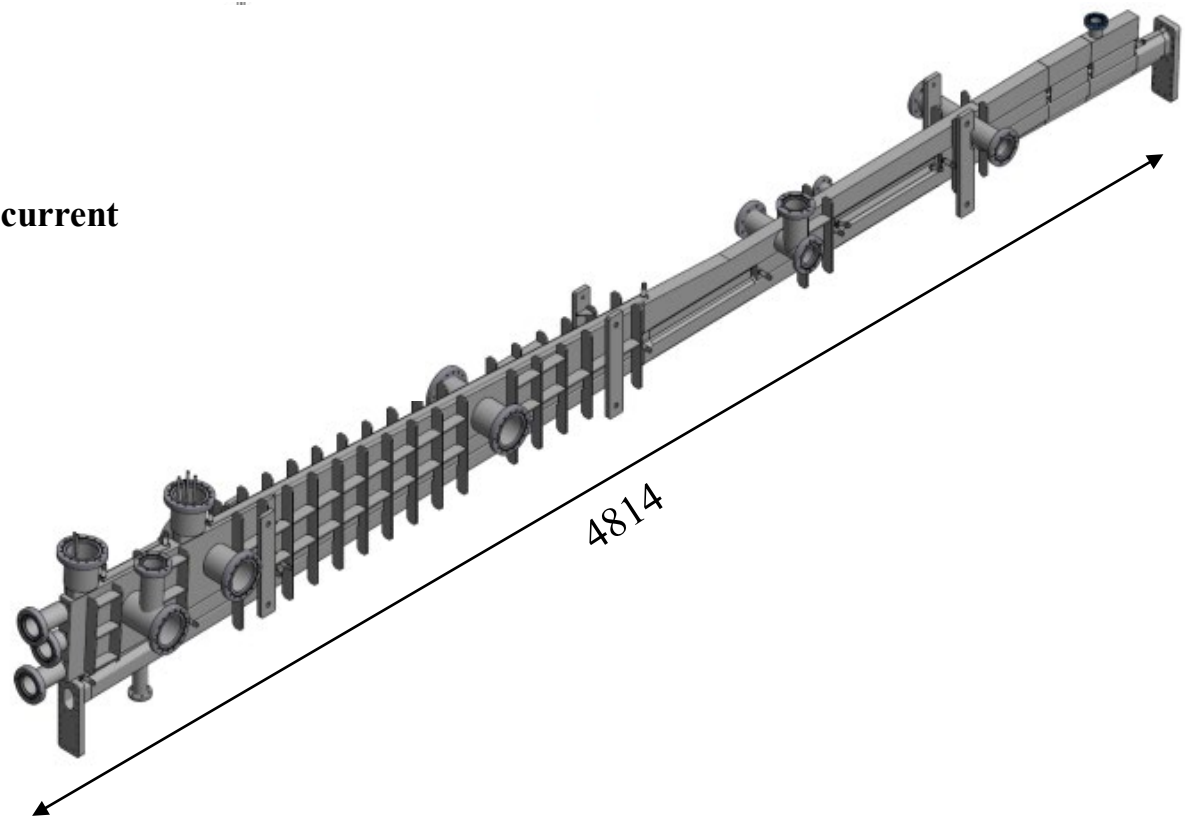
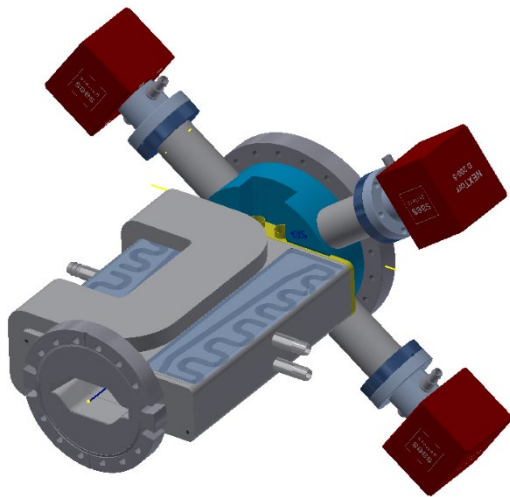
**Number of periods: 5  $\rightarrow$  9**

**He consumption: 130 l/week  $\rightarrow$  none**

**Still missing:**

- dipole chamber + absorbers
- up/downstream taper
- enclosure

**Wiggler presently operated at 5 T,  
commisioned to 7 T with low beam current**



# Radiofrequency

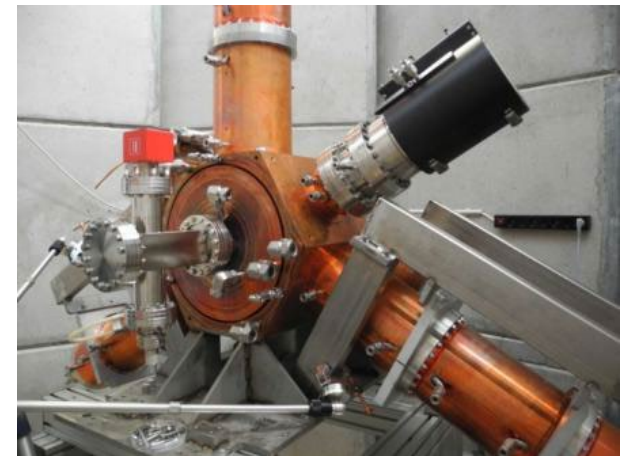
P. Hartmann, A. Leinweber, V. Kniss

## RF upgrade in 2019

- 500 MHz EU HOM-damped cavity
- solid-state amplifiers for booster and storage ring
- digital low-level RF system

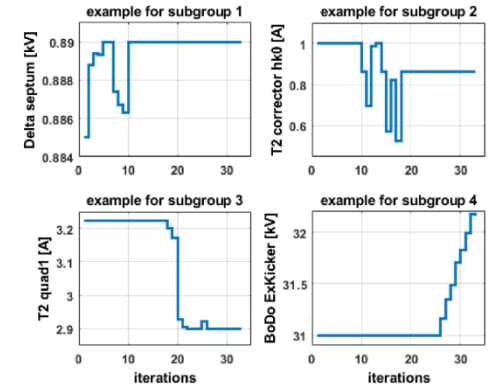
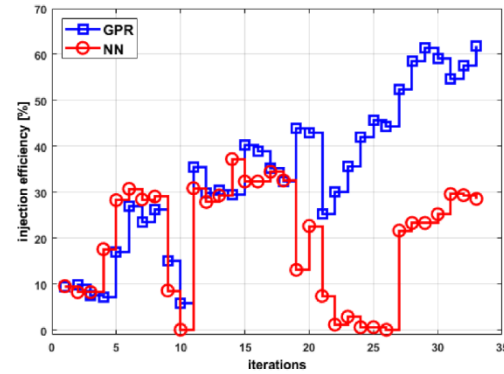
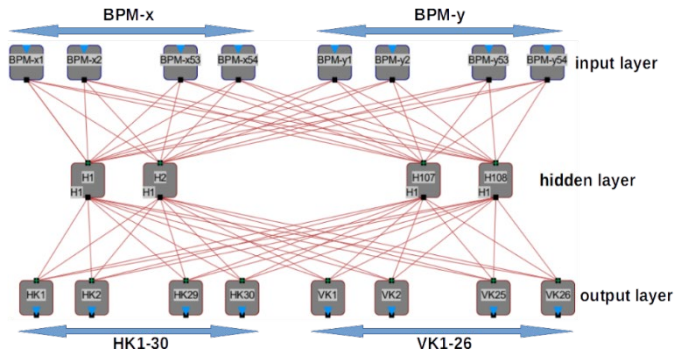
## Saving energy

- goal: 25-30% reduction
- measures:
  - 20% less operation in 2023 (-4 user weeks, -2 machine weeks)
  - RF power reduced or single-cavity operation (wiggler at 5 T)
  - RF power and magnet current reduced if not needed
  - ...



# Machine learning applications

D. Schirmer, S. Hüser, T. Schüngel



**Injection:** T. Schüngel, Master's thesis, TU Dortmund (2022)

## Orbit and tune feedback (NN)

- successfully operated

## Chromaticity control (NN)

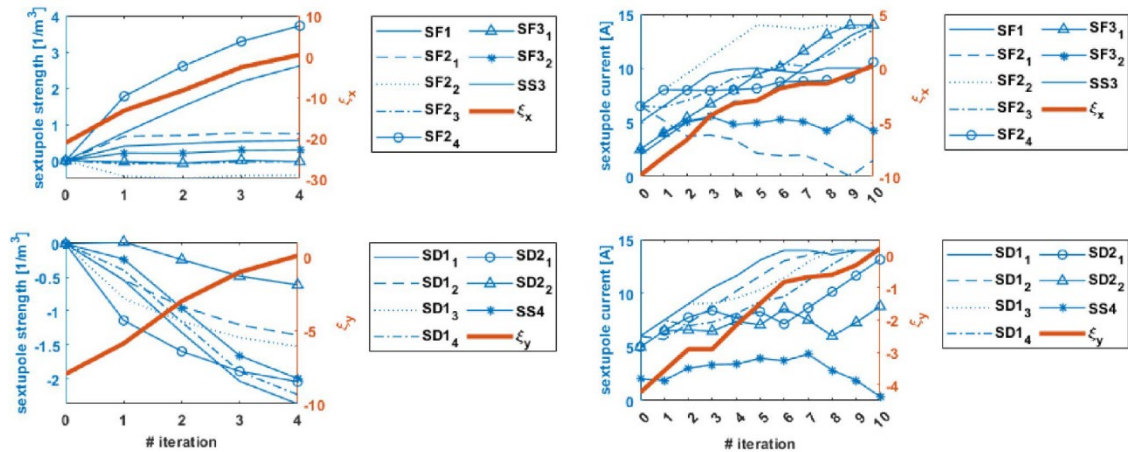
- simulation study  
- experimental demonstration

## Injection efficiency (NN and GPR\*)

- ongoing work

\* NN: neural network

GPR: Gaussian process regression



**Chromaticity:** D. Schirmer, A. Althaus, T. Schüngel,

IPAC 2022, Bangkok, Thailand, p. 1141



# Split beams

scientific reports 12, 18383 (2022)

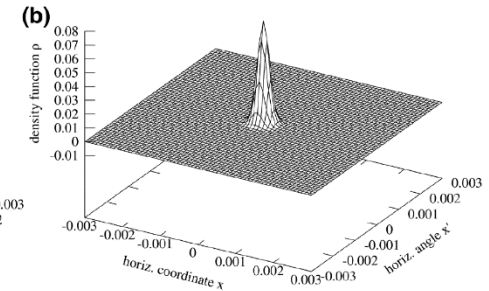
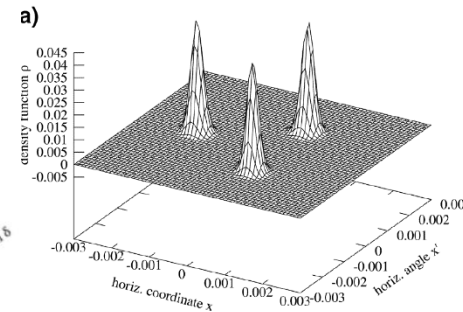
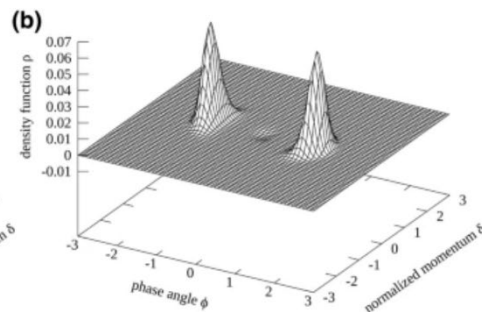
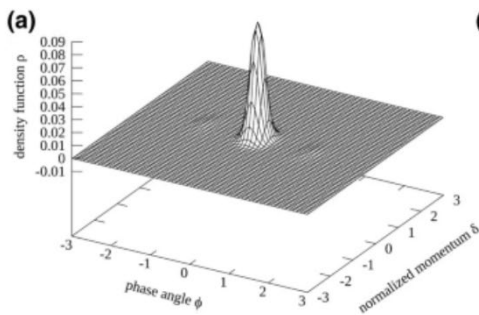
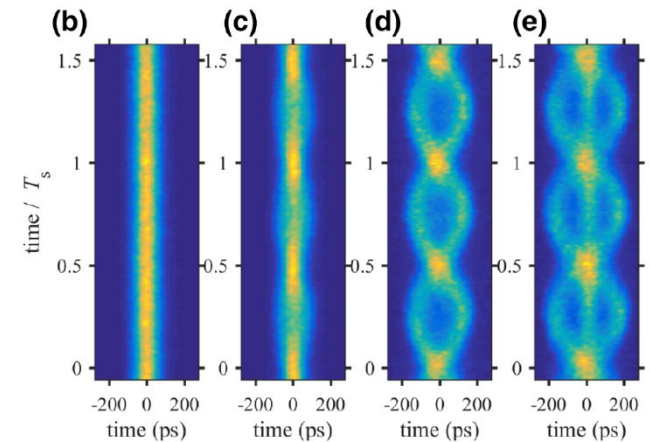
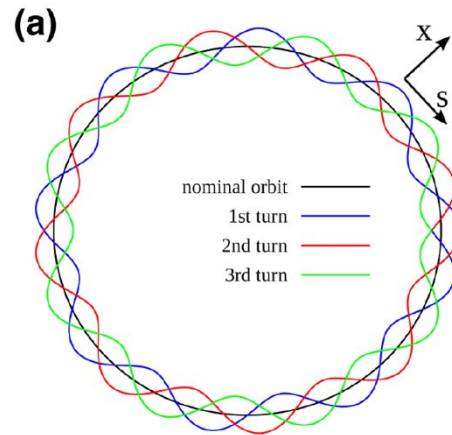
M. Jebramcik, A. Glassl, W. Helml, S. Khan ...

**OPEN** Steady-state solutions of split beams in electron storage rings

Marc Andre Jebramcik<sup>✉</sup>, Shaukat Khan & Wolfram Helml

## Common Vlasov-Fokker-Planck description

- RF phase modulation  
regular operation
- transverse island buckets  
experimentally not achieved

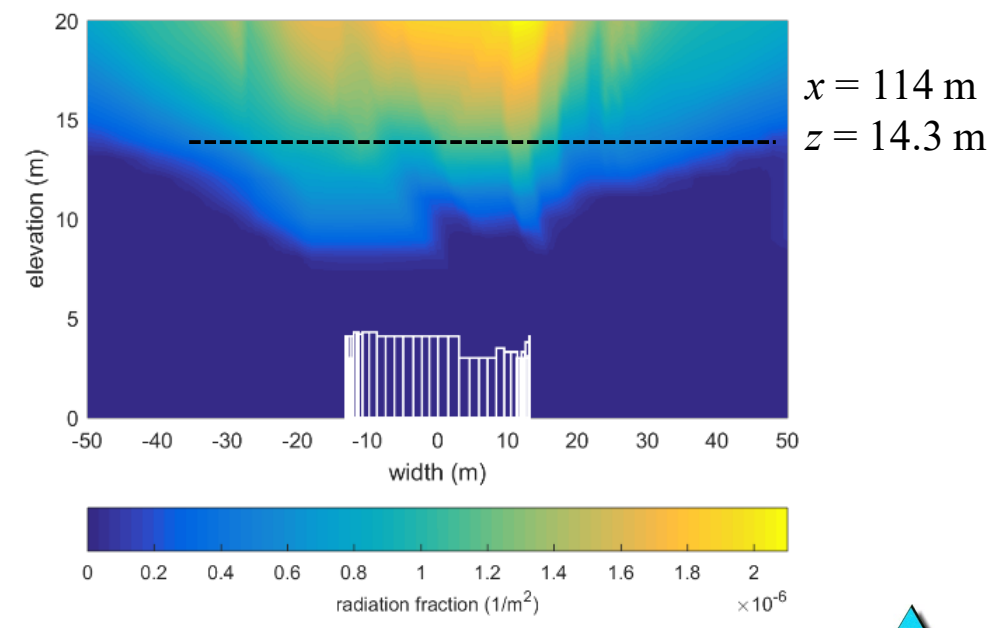
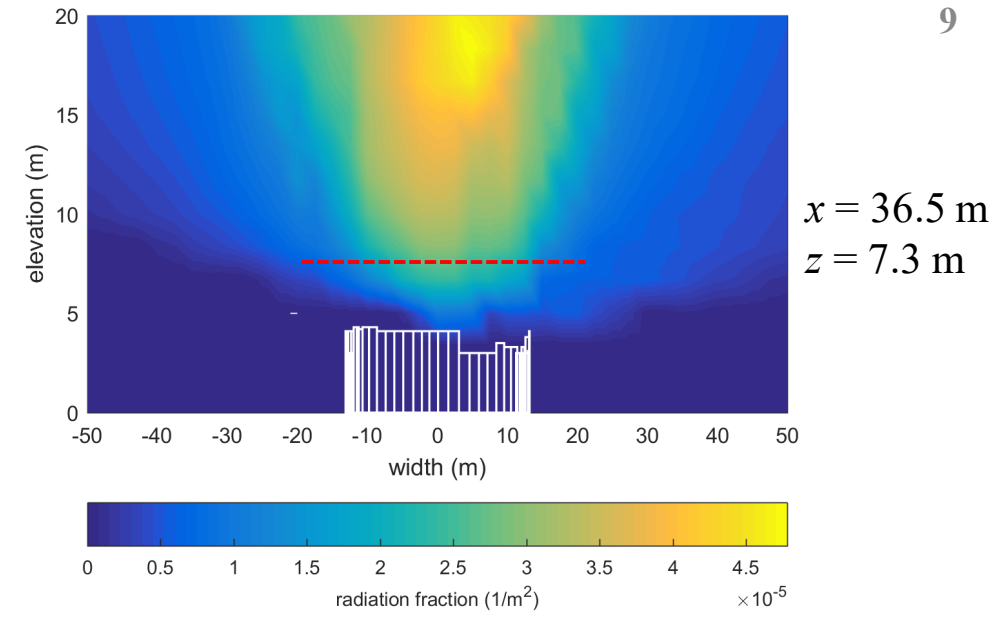
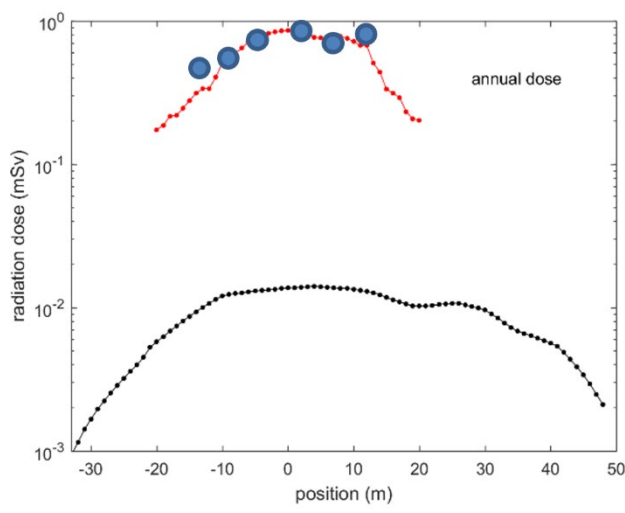
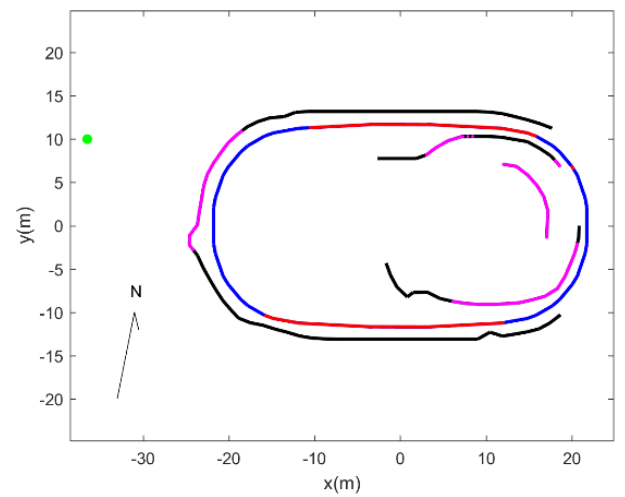




# Radiation protection

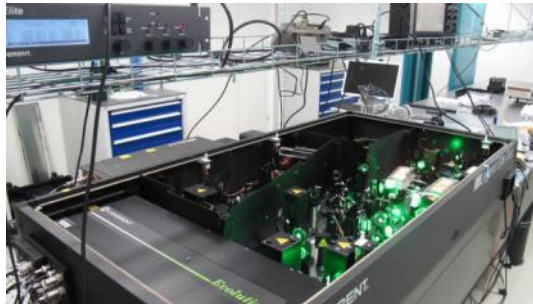
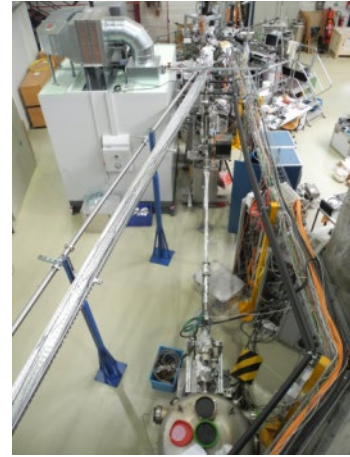
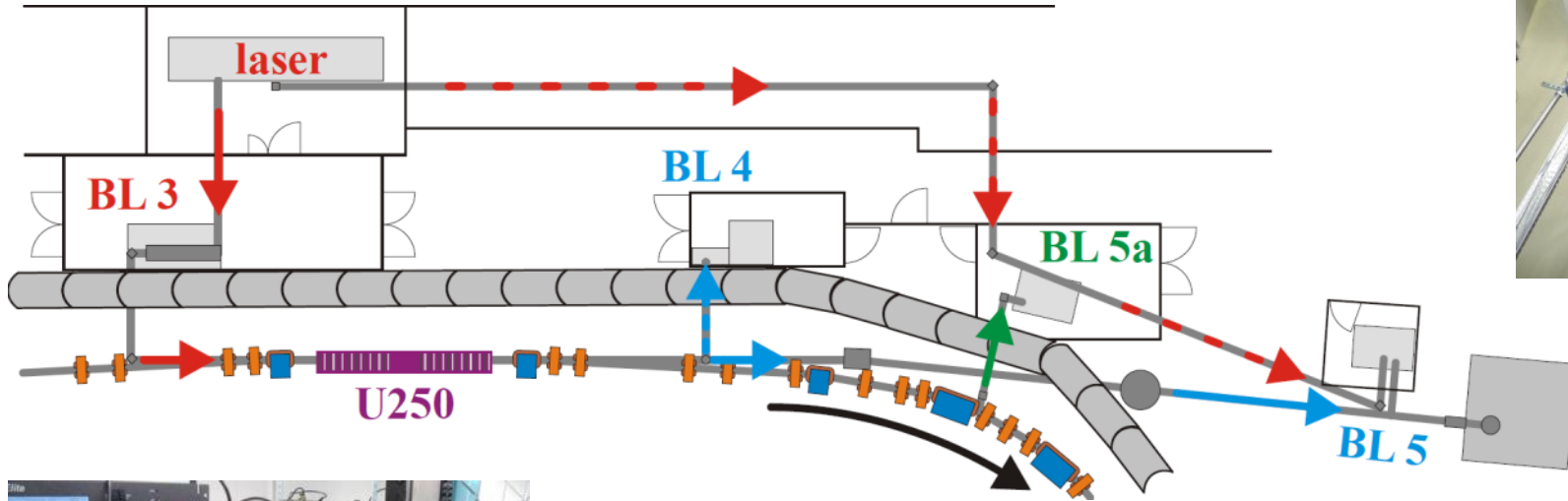
J. Friedl, S. Khan, C. Mai

## Simulation study + dosimeter tests



# Facility for ultrashort VUV and THz pulses

B. Büsing, A. Held, S. Khan, C. Mai, A. Radha Krishnan, W. Salah\*, Z. Usfoor, V. Vijayan  
 \* on leave from The Hashemite University, Zarqa, Jordan



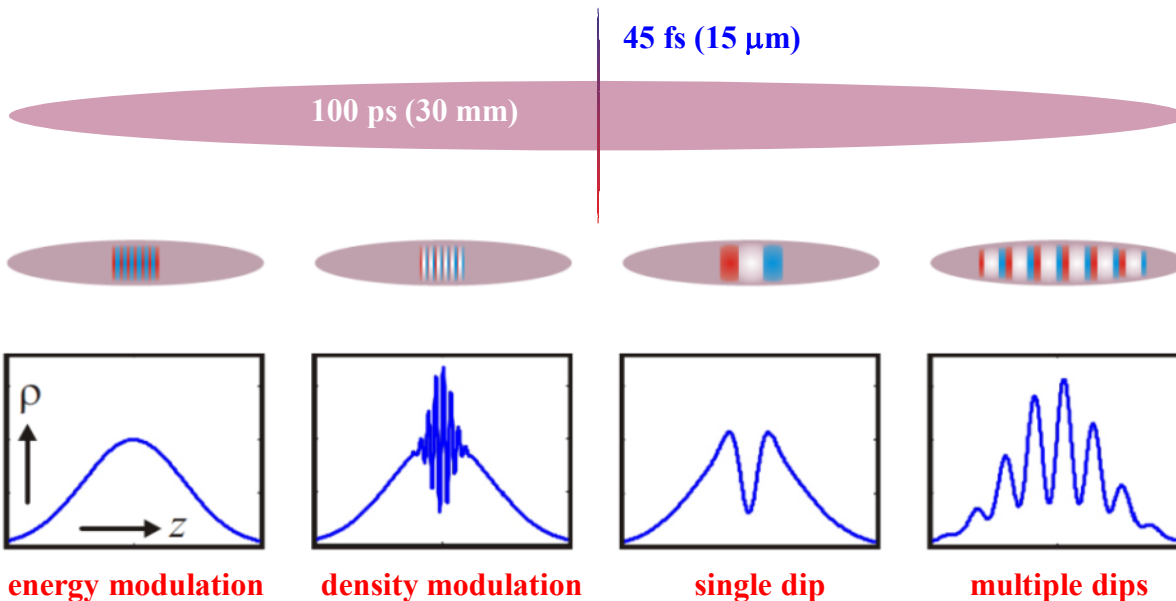
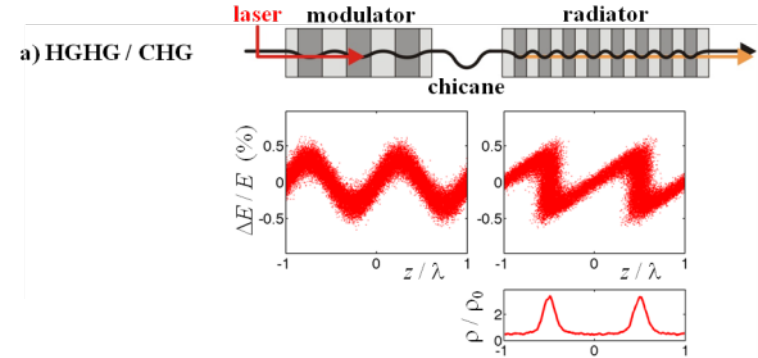
# Facility for ultrashort VUV and THz pulses

## Coherent harmonic generation (CHG)

- laser-induced energy modulation within a bunch "slice"
- density modulation in a magnetic chicane
- coherent radiation at harmonics of the laser wavelength (so far, 80 nm)

## Coherent terahertz (THz) emission

- short "dip" due to energy-dependent path length
- broadband coherent THz radiation
- narrowband coherent THz radiation from multiple dips



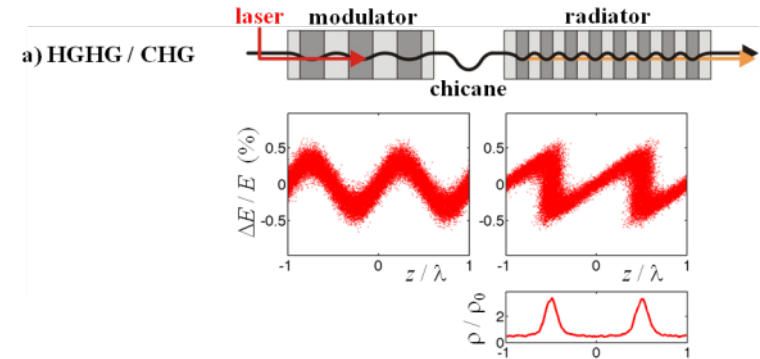
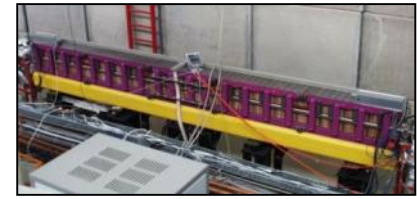
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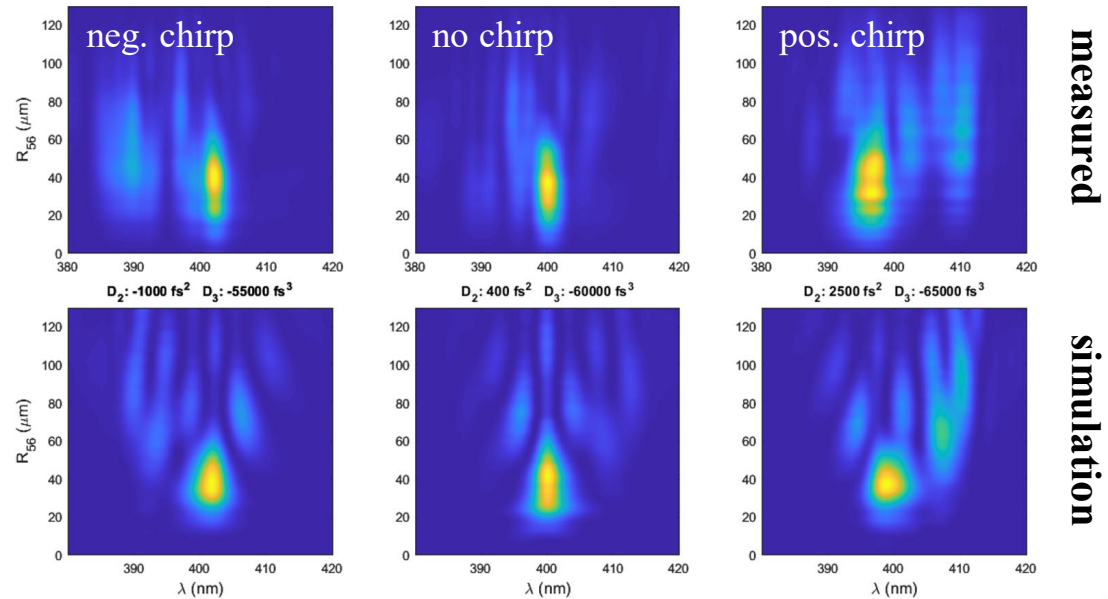
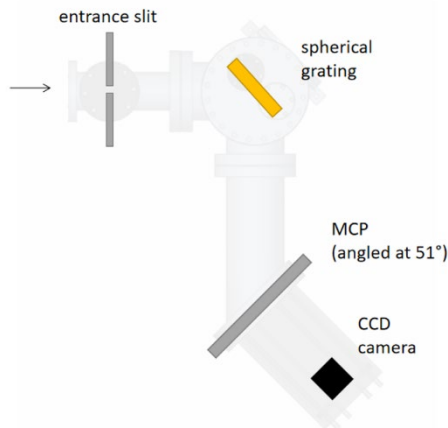
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## CHG spectra und variation of $R_{56}$

- spectrometer + gated iCCD camera
- in-vacuum grating spectrometer



# Echo-enabled harmonic generation at DELTA

Proposed 2009 as FEL seeding scheme\*

- demonstrated at NLCTA, SDUV-FEL, FERMI\*\*

Since 2011 plan to create a 21 m long straight section

- modulators: 2 short undulators

- radiator: present U250 undulator

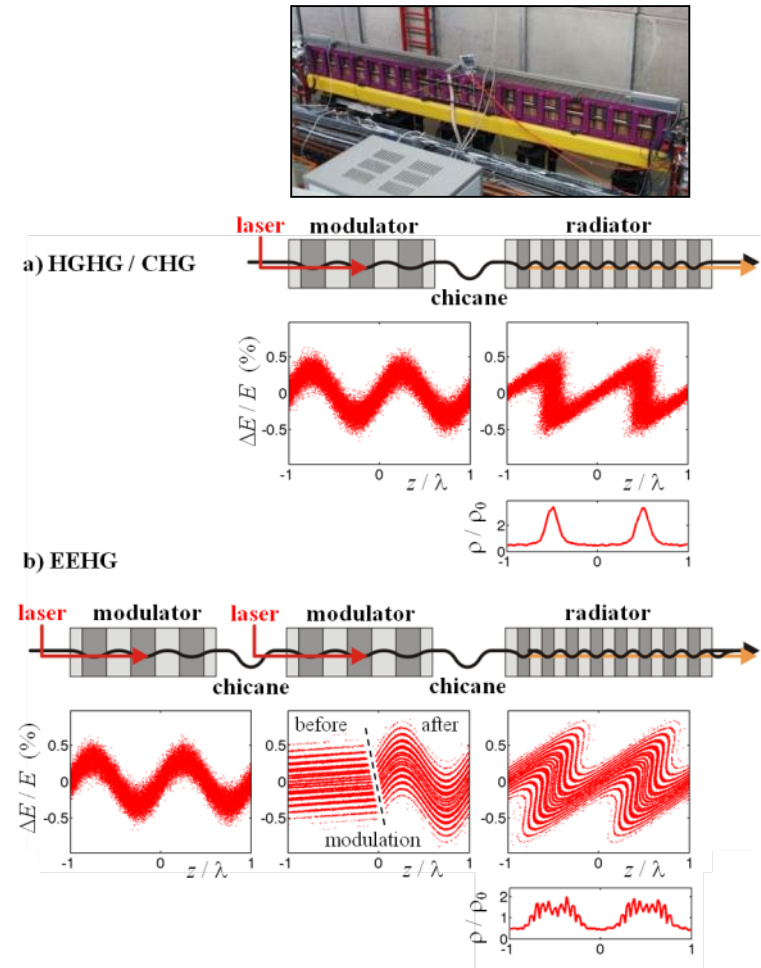
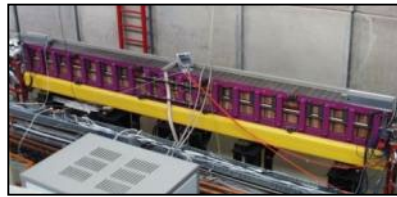
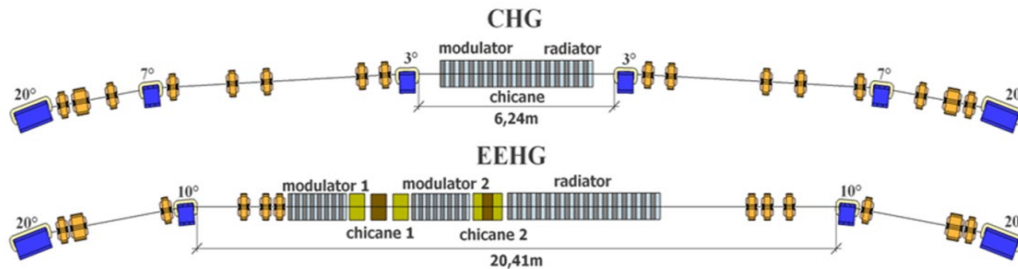
\* G. Stupakov, Phys. Rev. Lett. 102, 074801 (2009)

\*\* D. Xiang et al., Phys. Rev. Lett. 105, 114801 (2010)

Z. T. Zhao et al., Nature Photonics 6, 360 (2012)

E. Hemsing et al., Nature Photonics 10, 512 (2016)

P. R. Ribič et al., Nature Photonics 13, 555 (2019)



# The SPEED project (Short-Pulse Emission via Echo at DELTA)

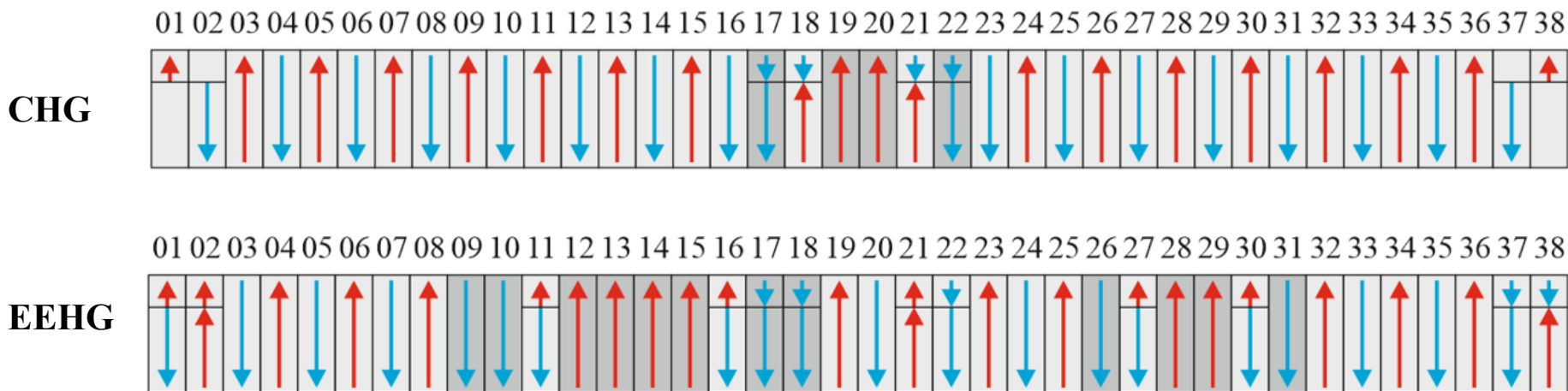
B. Büsing, A. Held, S. Khan, C. Mai, A. Radha Krishnan, W. Salah, Z. Usfoor, V. Vijayan

## Faster than the "big" project

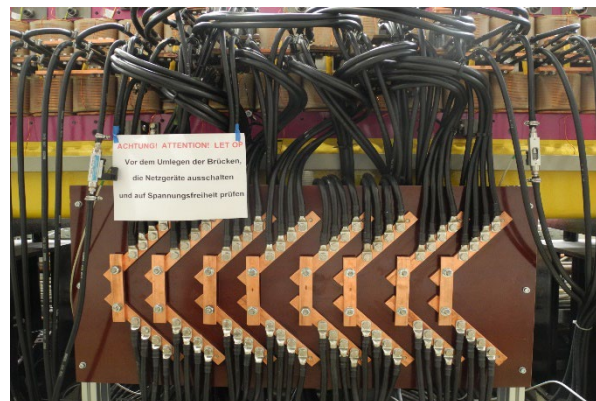
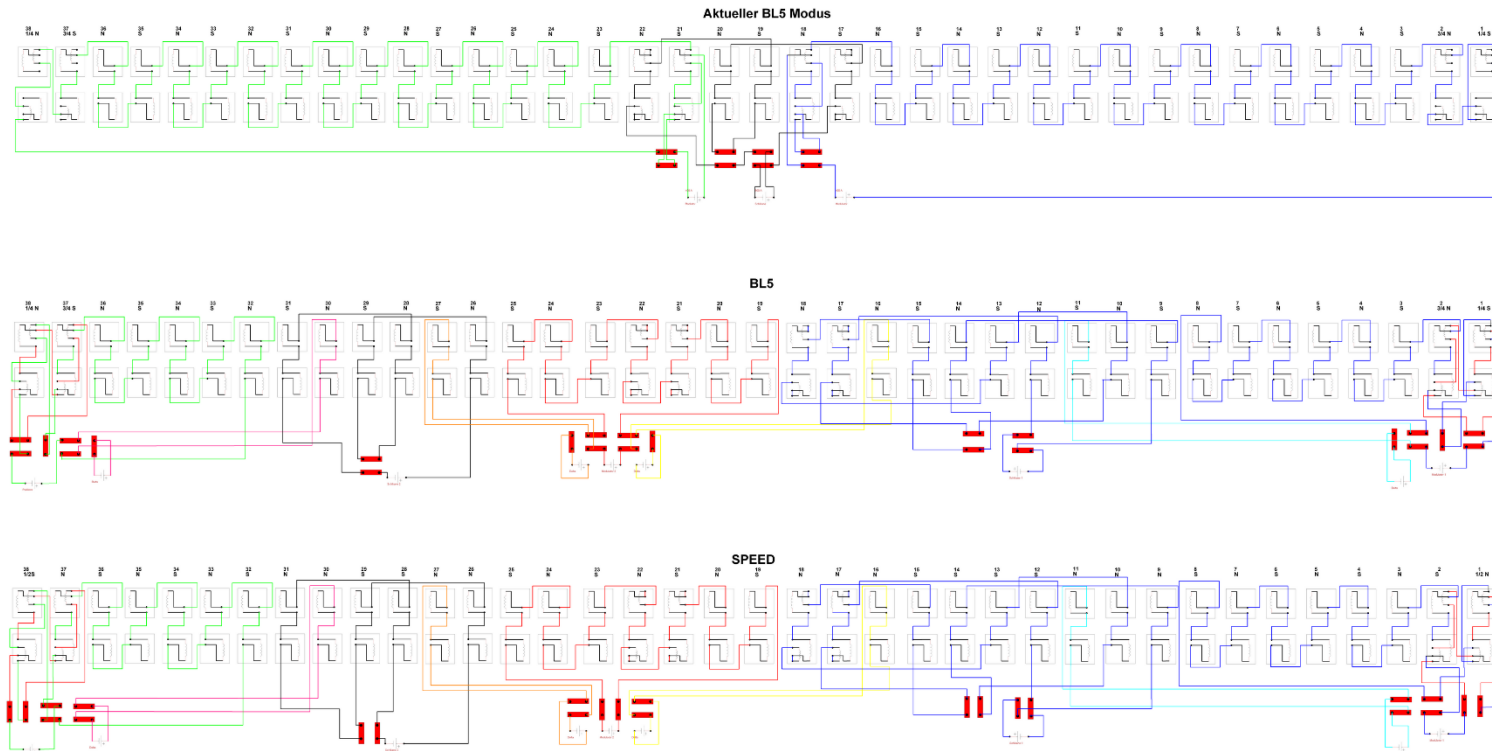
- started April 2022
- first signal September 2022

## U250 with 38 poles (17 periods + 4 endpoles) reconfigured

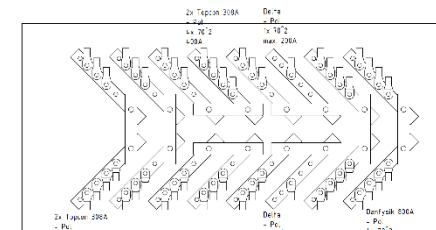
- 2 modulators (8 poles each)
- 2 chicanes (8 and 4 poles)
- radiator (8 poles)
- endpoles (2 poles)



A. Althaus, B. Büsing, T. Dybiona, C. Mai, H.-P. Ruhl, B. Sawadski, D. Schirmer, G. Schmidt, T. Schulte-Eickhoff et al.

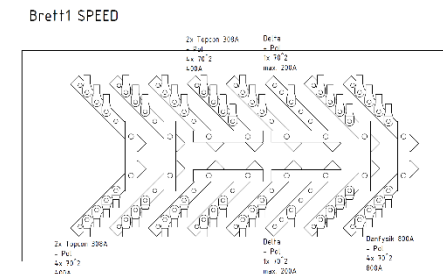
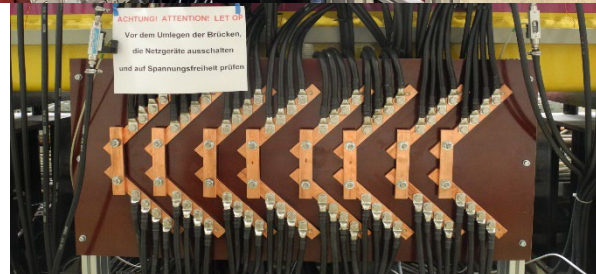


Brett11 SPEED



A. Althaus, B. Büsing, T. Dybiona, C. Mai, H.-P. Ruhl, B. Sawadski, D. Schirmer, G. Schmidt, T. Schulte-Eickhoff et al.

13 power supplies  
190 new cables  
12 m copper bars





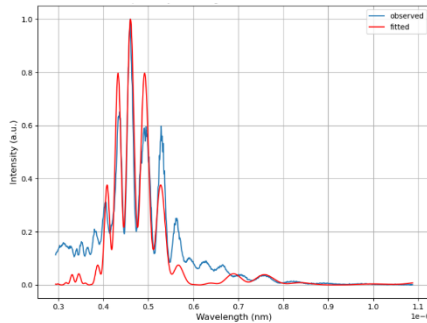
## Worldwide first EEHG implementation at a storage ring

### Three short undulators

- four periods each

### Two magnetic chicanes

- 530 and 105  $\mu\text{m}$   
from measured spectra

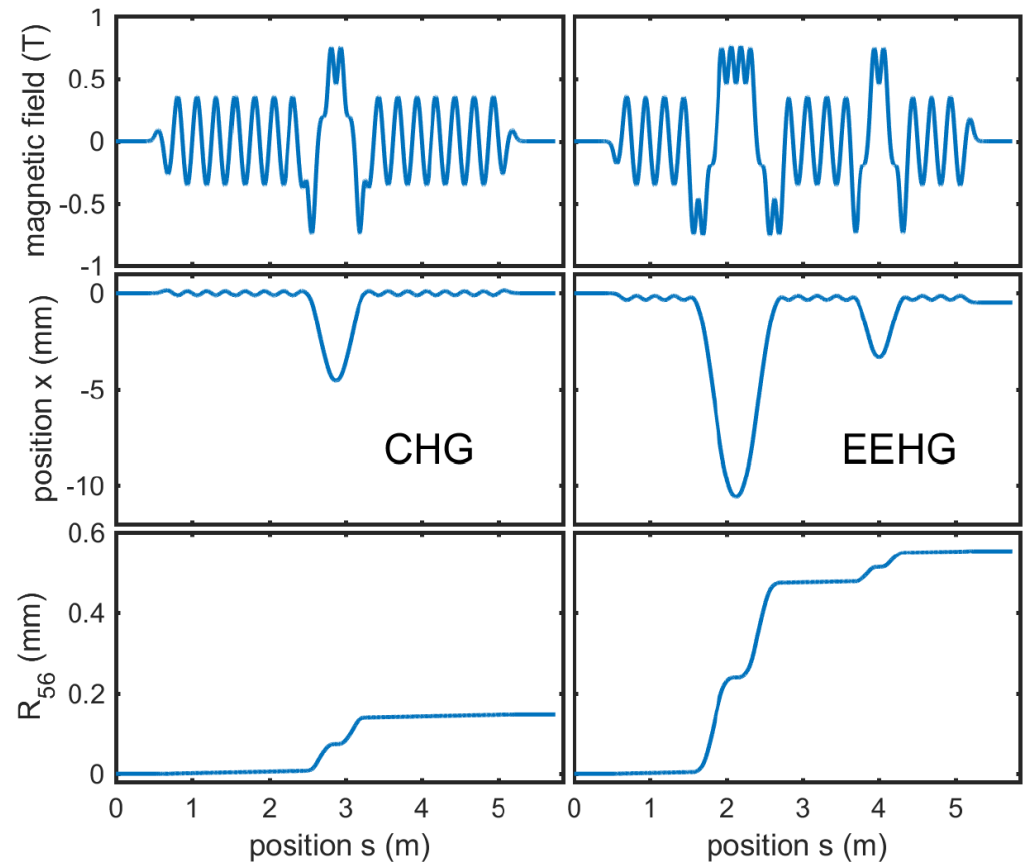
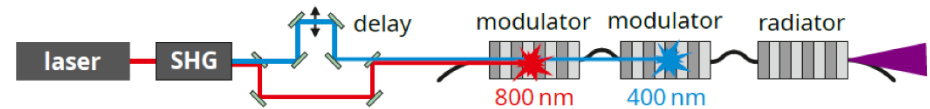


### Two femtosecond laser pulses

- 400 nm from SHG
- 800 nm residual pulse

### Diagnostics

- Czerny-Turner monochromator  
+ APD or iCCG camera
- in-vacuum grating spectrometer + MCP



## First results

### September/October 2022

- signal at 267 nm
- depends on 400/800 nm timing
- non-linear chirp

### November/December 2022

- recommissioning of the in-vacuum spectrometer
- 160 nm accessible

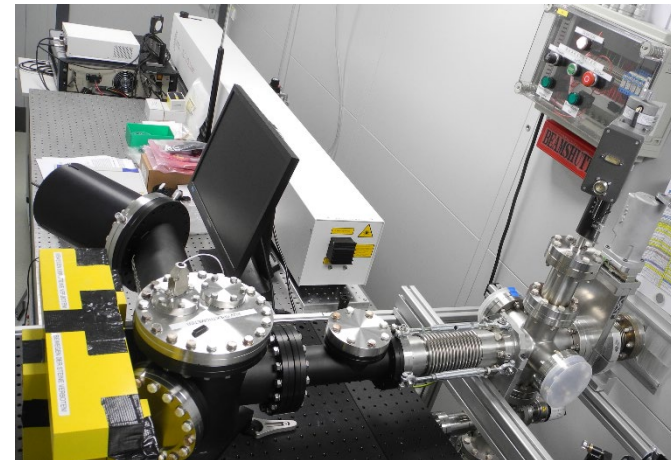
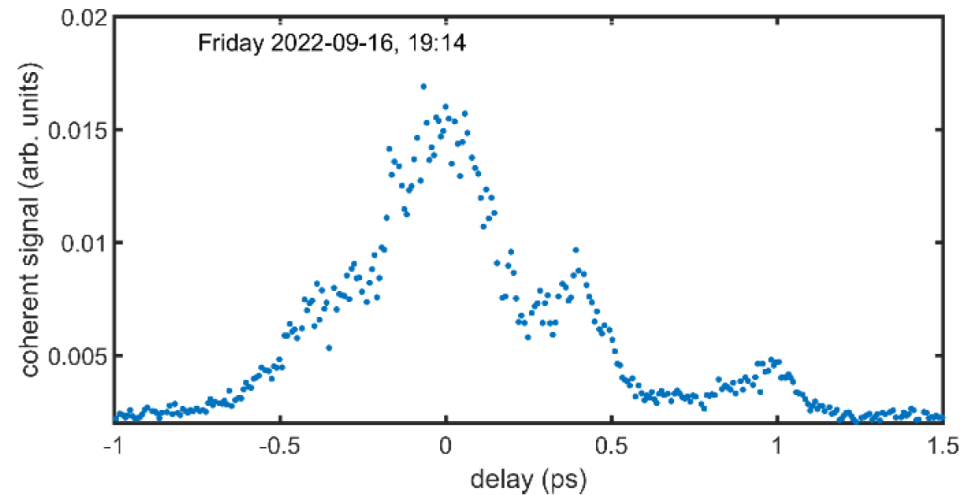
### Near future

- removal of a MgF vacuum window
- shorter wavelengths

## Outlook

### EEHG in storage rings with single insertion device

- previous proposals:
  - ... long straight section (DELTA [1])
  - ... two straight sections (SOLEIL [2], BESSY [3])
  - ... whole ring as chicane (HLS [4])
- optimized device
  - ... permanent magnets
  - ... smaller gap, shorter periods

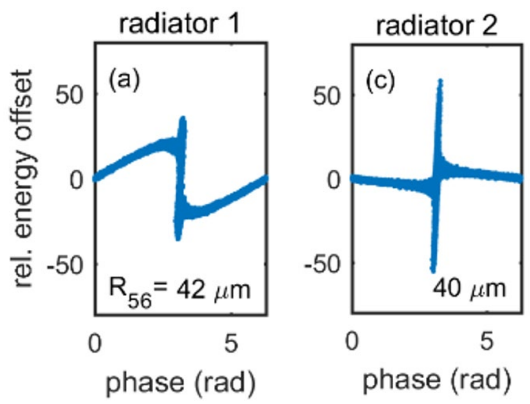
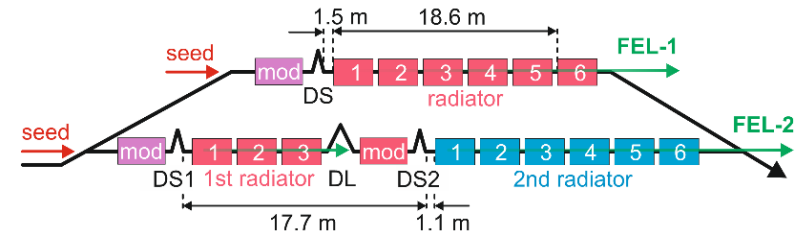
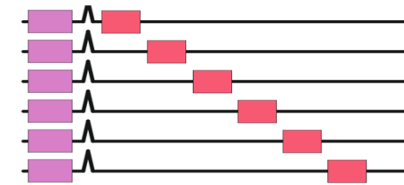


- [1] S. Khan et al., Sync. Rad. News 26:3, p. 25 (2013)  
 [2] C. Evain et al., New J. Phys. 14, p. 023003 (2012)  
 [3] J.-G. Hwang et al., Scient. Reports 10, p. 10093 (2020)  
 [4] H. Li et al., IPAC'13, Shanghai, China, p. 1208 (2013)

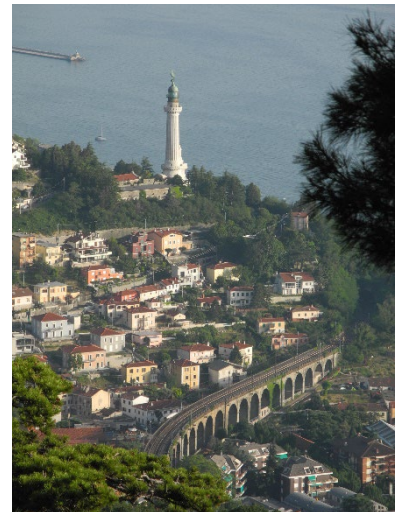
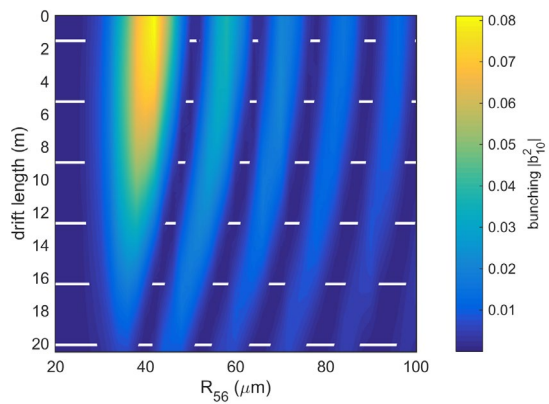
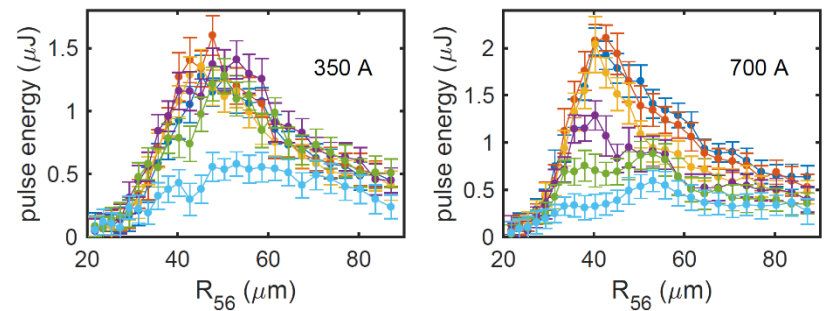
# External activity: FERMI at Sincrotrone Trieste

## Effect of space charge on microbunches (S. Khan)

- experiments at FEL-1 with variable drift and current
- well reproduced by 1-dimensional model



S. Khan et al.,  
FEL 2022,  
Trieste, Italy,  
MOP01.

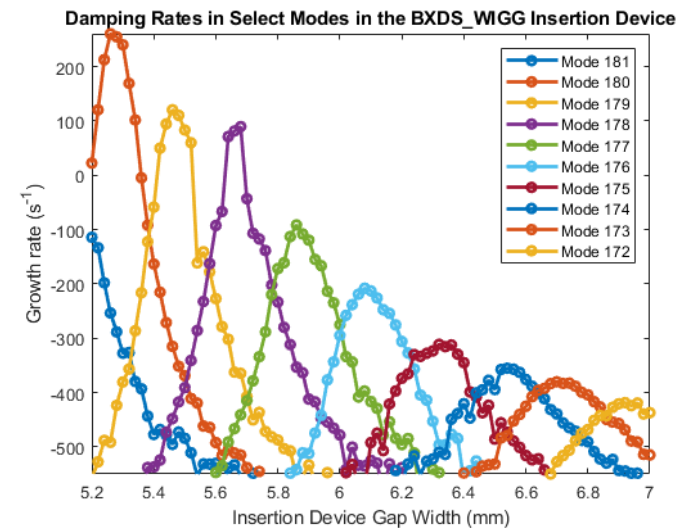
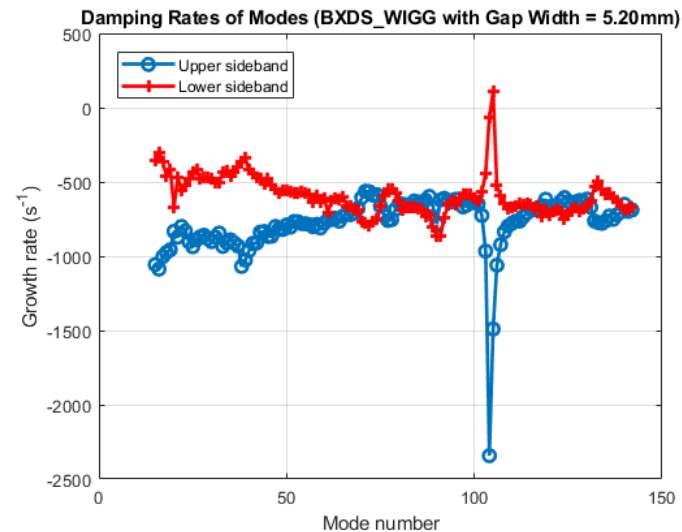
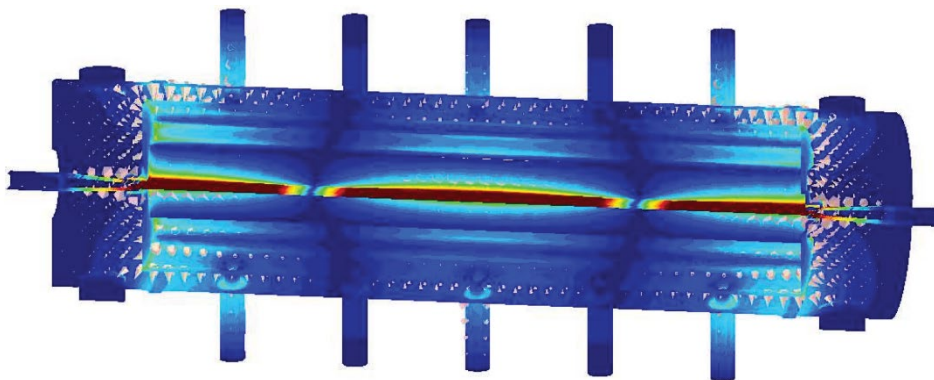


# External activity: Canadian Light Source in Saskatoon

## Studies of instabilities in the storage ring and energy spread of the linac (P. Hartmann)

### - variation of in-vacuum undulator gap

S. Martens, ..., P. Hartmann,  
IPAC 2022, Bangkok, Thailand, p. 230.



## Further external activities: BMBF collaborative research

### Single-bunch beam diagnostics (S. Khan et al.)

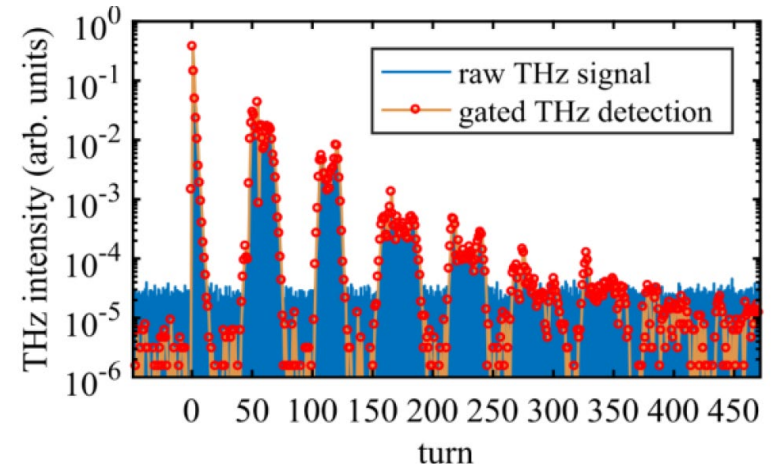
EVEBUD, together with KIT Karlsruhe

### Shaping of electron bunches (S. Khan et al.)

FLARE, at FLASH/DESY Hamburg

### Sub-fs time-resolved spectroscopy (W. Helml et al.)

TRANSALP, with U Kassel at the European XFEL





Thank you for your attention

Ministerium für Innovation,  
Wissenschaft und Forschung  
des Landes Nordrhein-Westfalen



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