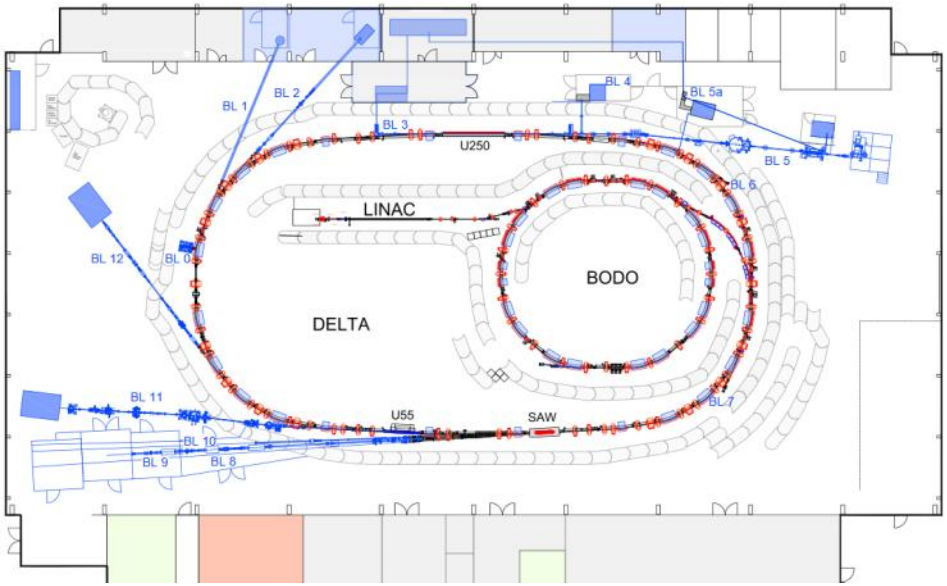
DELTA: Status and future plans

Shaukat Khan, Zentrum für Synchrotronstrahlung

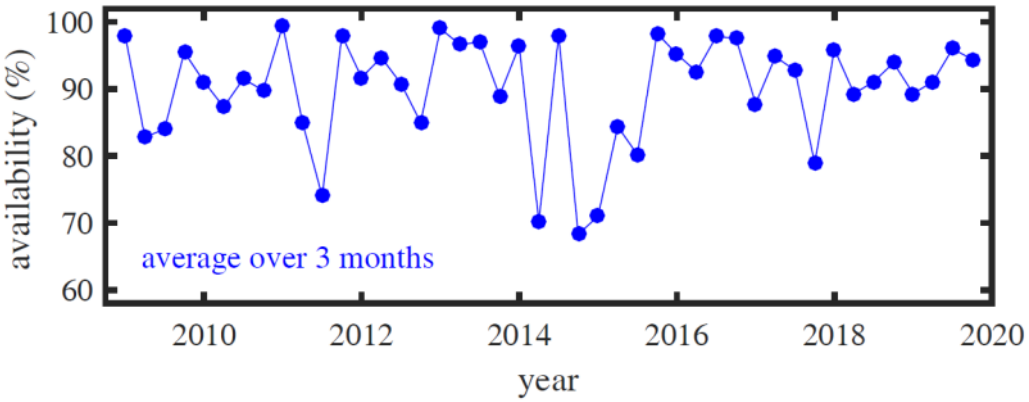
Cerdanyola del Vallès, Nov 28, 2019

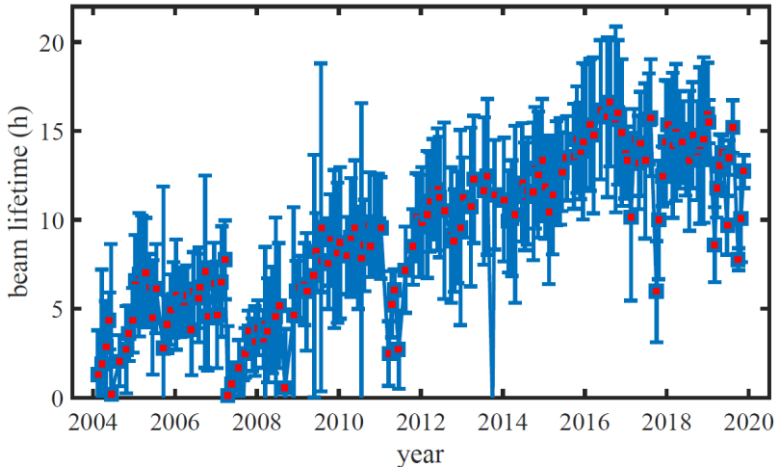
Parameters and availability



Parameters

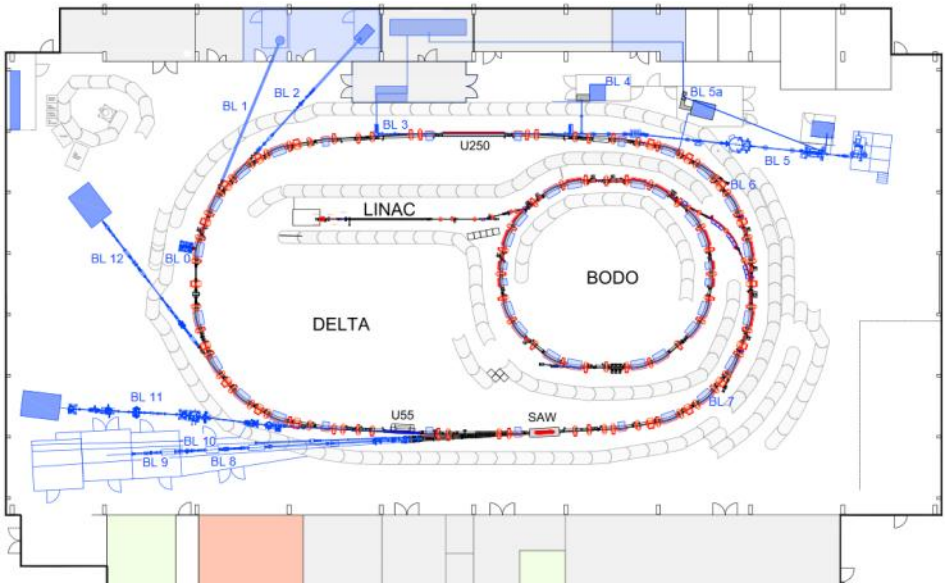
circumference	**115.2 m**
beam energy	**1.5 GeV**
beam current	**130 mA multi-bunch**
beam current	**20 mA single bunch**
beam lifetime	**~13 h at 100 mA**
hor. emittance	**~16 nm rad**
bunch length	**35 ps rms**
user operation	**2000 h/y (20 weeks/y)**
machine studies	**1000 h/y (10 weeks/y)**





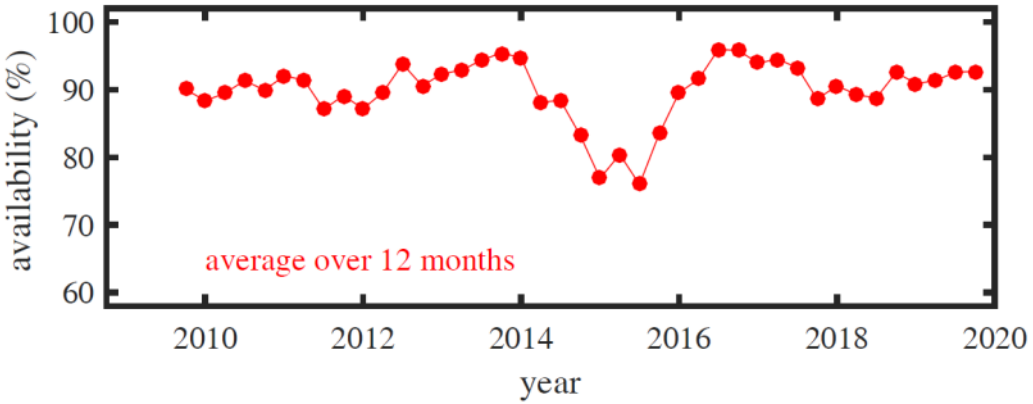
(J. Friedl, G. Schmidt)

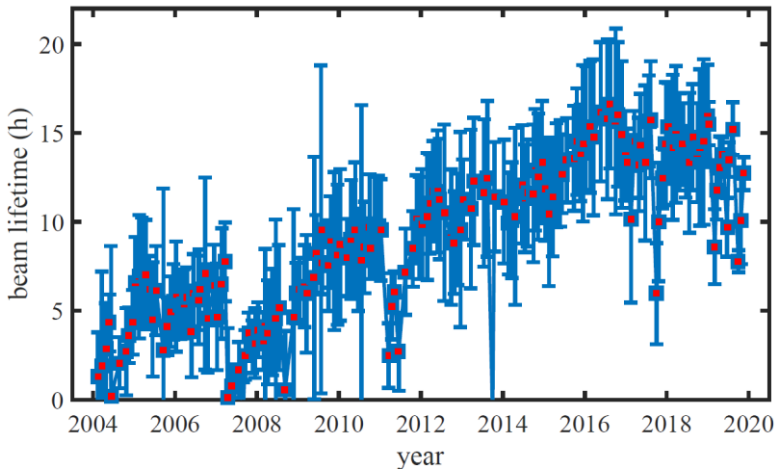
Parameters and availability



Parameters

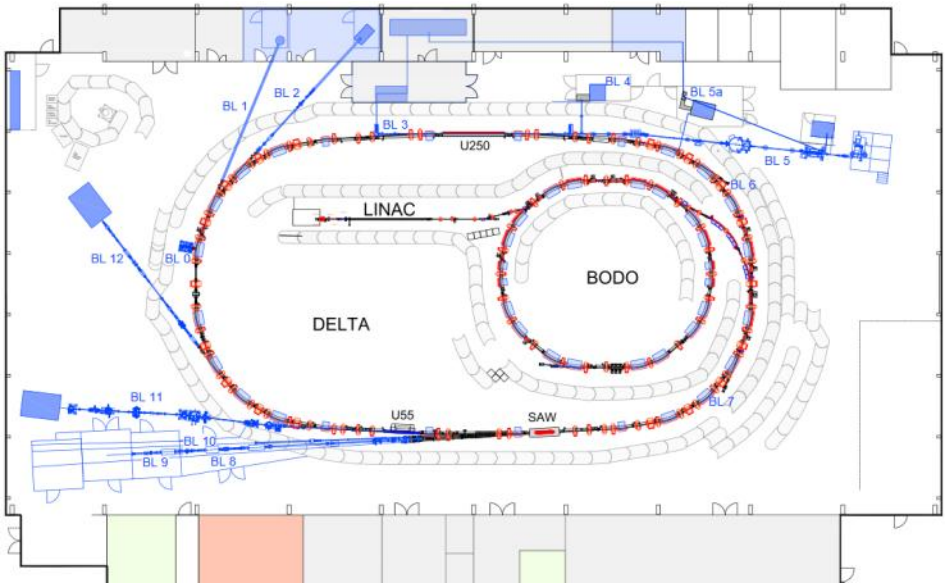
circumference	115.2 m
beam energy	1.5 GeV
beam current	130 mA multi-bunch
beam current	20 mA single bunch
beam lifetime	~13 h at 100 mA
hor. emittance	~16 nm rad
bunch length	35 ps rms
user operation	2000 h/y (20 weeks/y)
machine studies	1000 h/y (10 weeks/y)

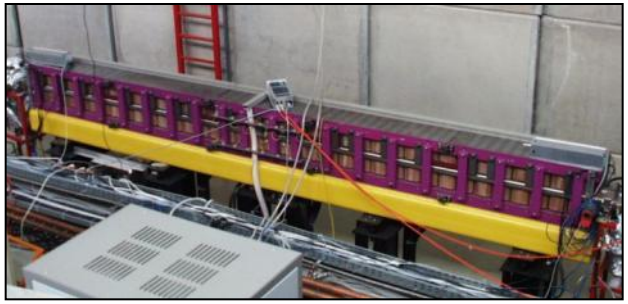




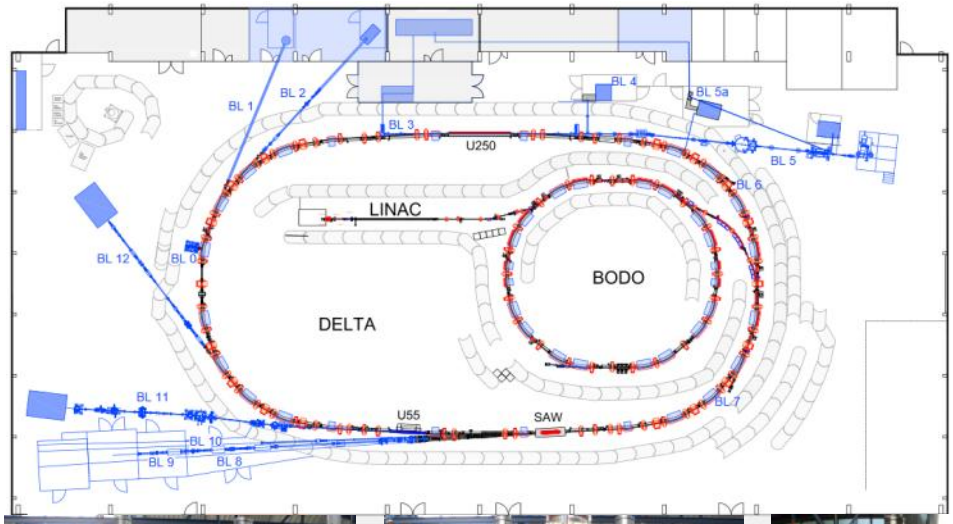
(J. Friedl, G. Schmidt)

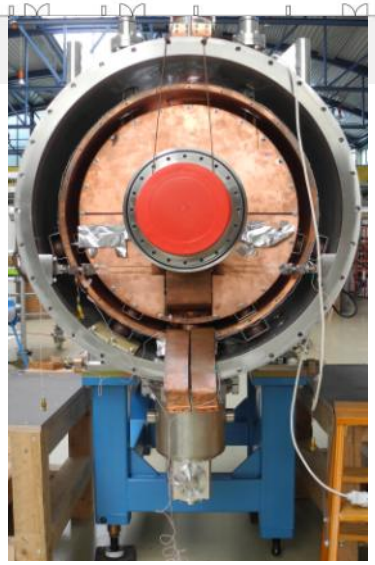
Insertion devices

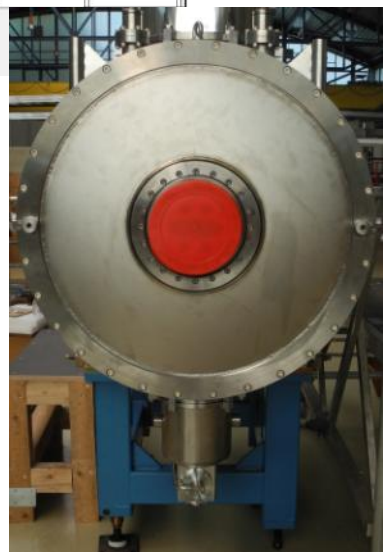




Insertion devices







New superconducting wiggler delivered in July 2018

configuration:
asymmetric → symmetric

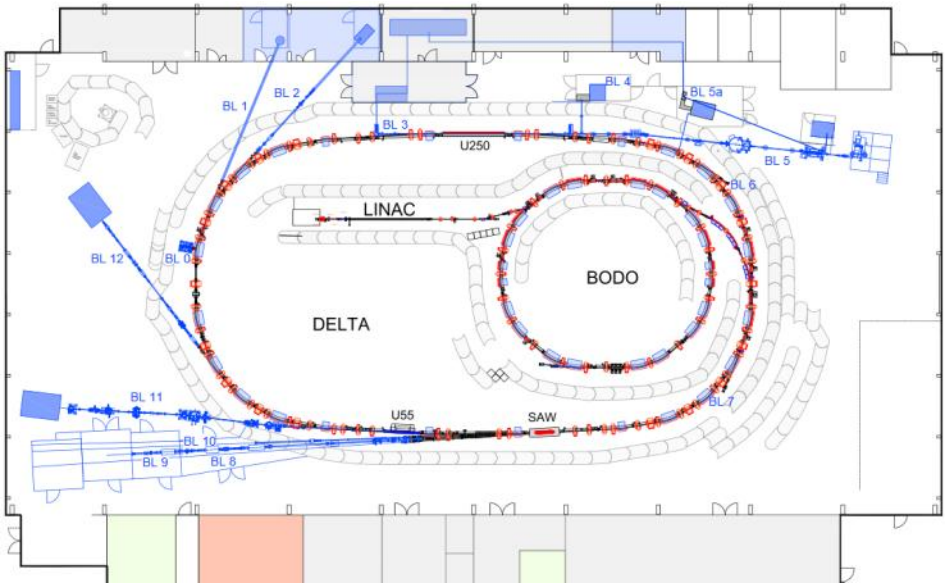
magnetic field
5.3 T → 7 T

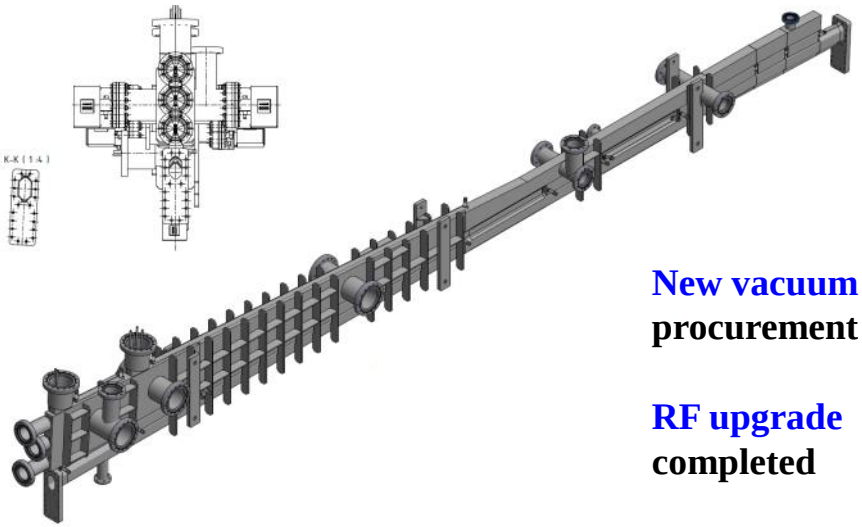
periods
5 → 9

He consumption
130 l/week → none)

(B. Beyer, W. Brembt, P. Hartmann, B. Hippert, S. Khan, V. Kniss, P. Kortmann, M. Paulus, D. Schirmer, G. Schmidt, C. Sternemann, M. Tolan + BINP team)

Insertion devices: Superconducting wiggler





New vacuum chambers
procurement

RF upgrade
completed

RF upgrade

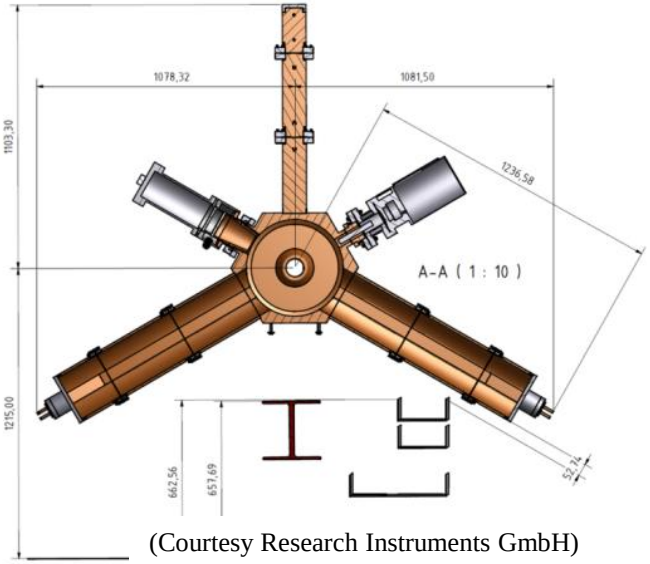
(W. Brembt, P. Hartmann, A. Leinweber, V. Kniss, T. Weis)

500 MHz European HOM-damped cavity

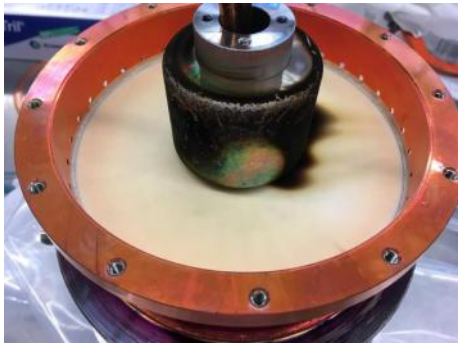
delivered and conditioned in 2018, problem with coupler
installed in April 2019
operated since August 2019 after problem with probe window

500 MHz solid-state amplifiers

installed in 2017
- 75 kW for the storage ring
- 20 kW for the booster



(Courtesy Research Instruments GmbH)



coupler with defective window

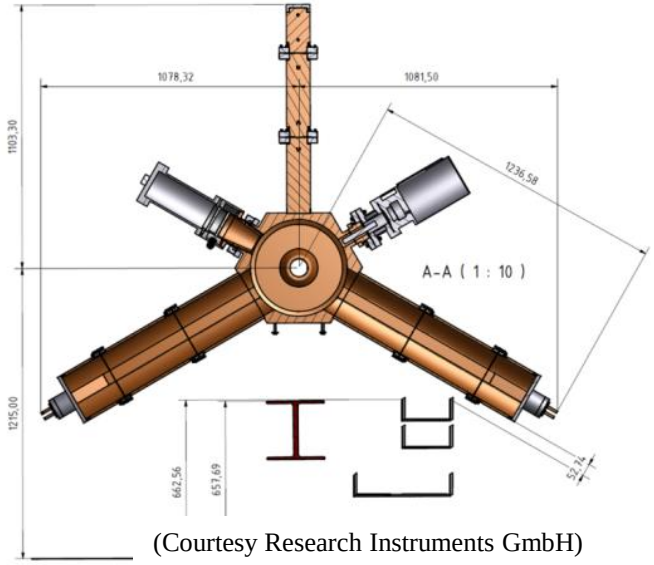
75 kW solid-state amplifier

cavity probe: old design (left) and new ALBA design (right)

EU cavity prototype tested at DELTA > 10 years ago

RF upgrade

(W. Brembt, P. Hartmann, A. Leinweber, V. Kniss, T. Weis)



(Courtesy Research Instruments GmbH)

500 MHz European HOM-damped cavity

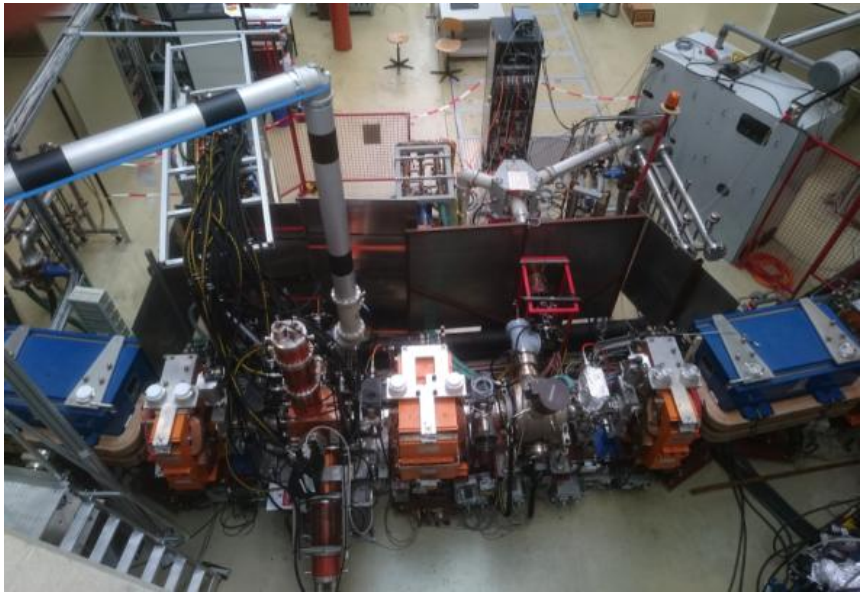
delivered and conditioned in 2018, problem with coupler
installed in April 2019
operated since August 2019 after problem with probe window

500 MHz solid-state amplifiers

installed in 2017
- 75 kW for the storage ring
- 20 kW for the booster

Digital low-level RF system

delivered in 2018
operated since August 2019
failure in October, bug fixed in November
spare provided by KARA/KIT !



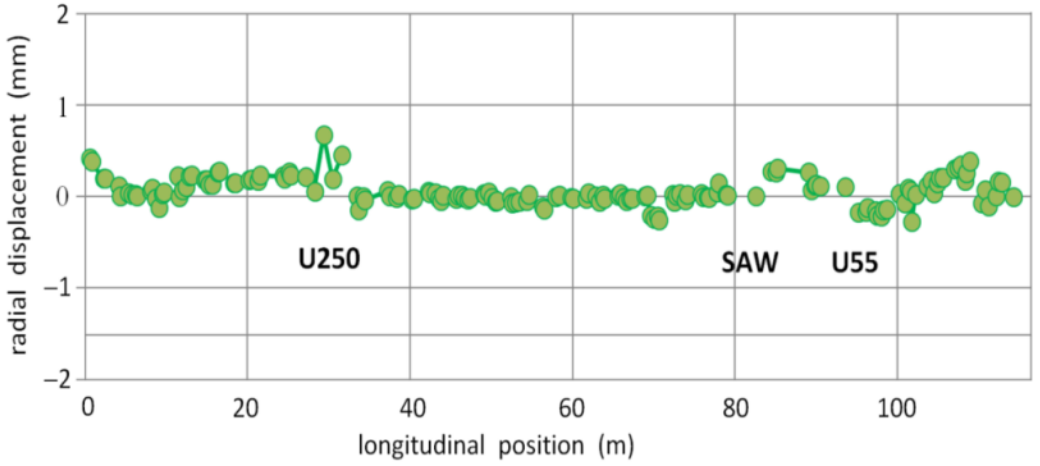
EU and DORIS cavity installed in the ring

Alignment of the storage ring

(U. Berges, G. Dahlmann, T. Dybiona, B. Isbarn, B. Hippert, P. Kortmann, G. Pike,
H. Rast, G. Schmidt, T. Schulte-Eickhoff; **Faculty of Physics, TU Dortmund)**

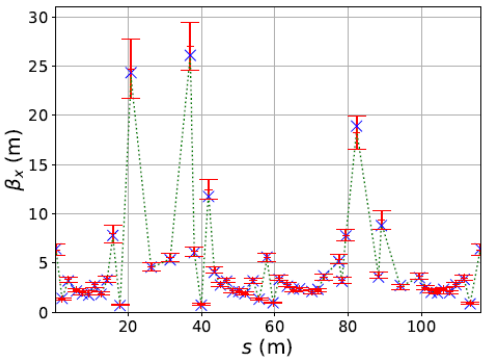
Vertical alignment
- **completed in 2013**
- **significant improvement**

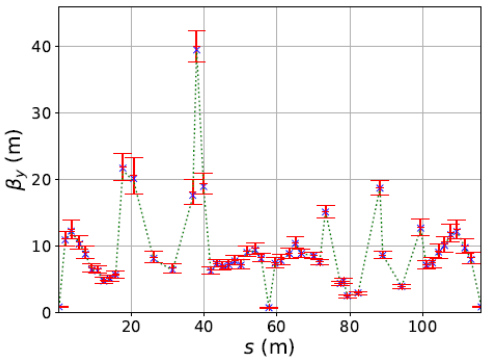
Horizontal alignment
- **completed in 2018**
- **further corrections**

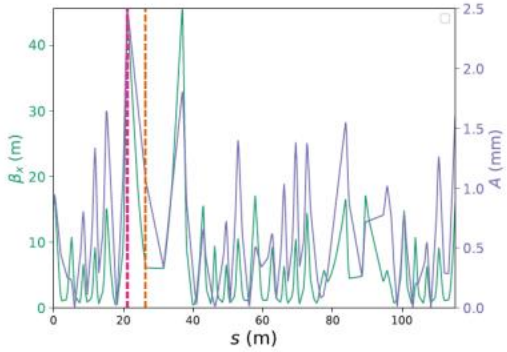


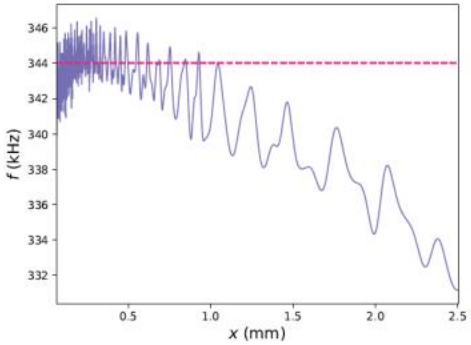
Orbit correction etc.

(A. Glassl, W. Helml, M. Jebramcik, S. Kötter, B. Riemann**, T. Weis; **now at SLS)









New orbit correction underway

- **improved algorithm**
- **up-to-date software**
- **currently under test**
- **plan to integrate BE+d model (biliniear exponential + dispersion)**

Tune shift with amplitude

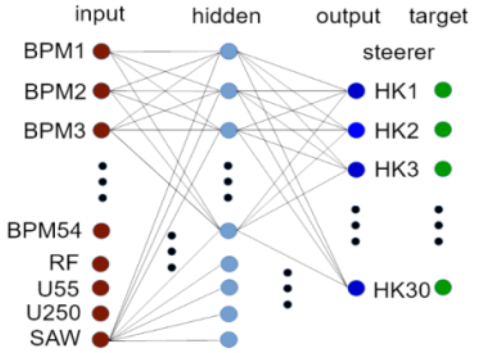
- **measurements in view of transverse resonant island buckets (TRIBs)**

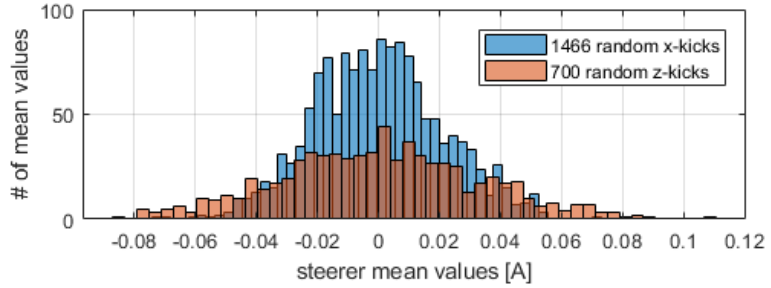
TRIBs control room workshop at BESSY Nov 10, 2019

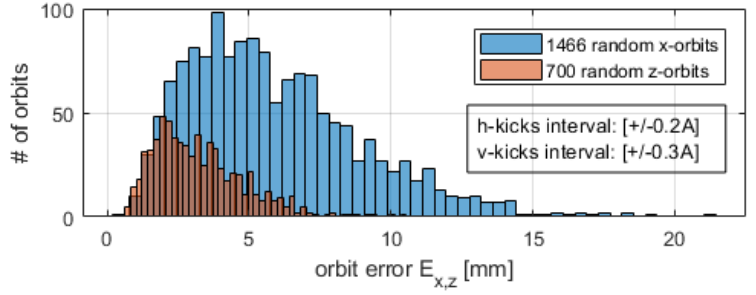
Orbit correction with artificial intelligence

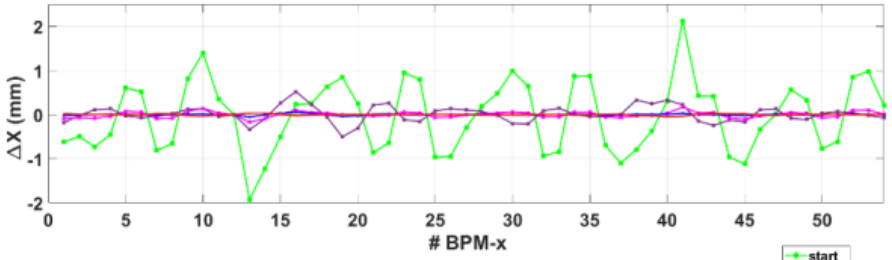
(D. Schirmer)

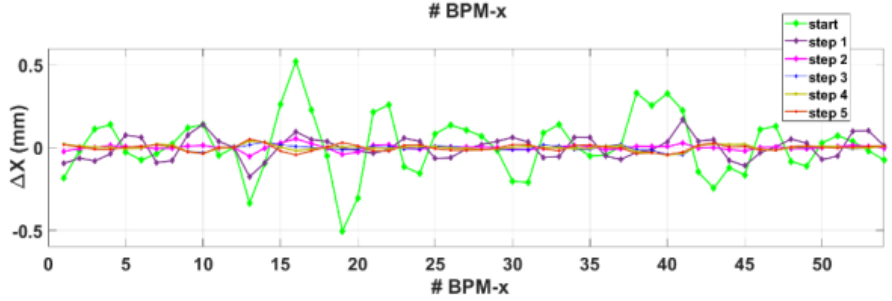
Feedforward neural net (FFNN)
trained with random steerer settings
orbit correction converges faster than SVD etc.

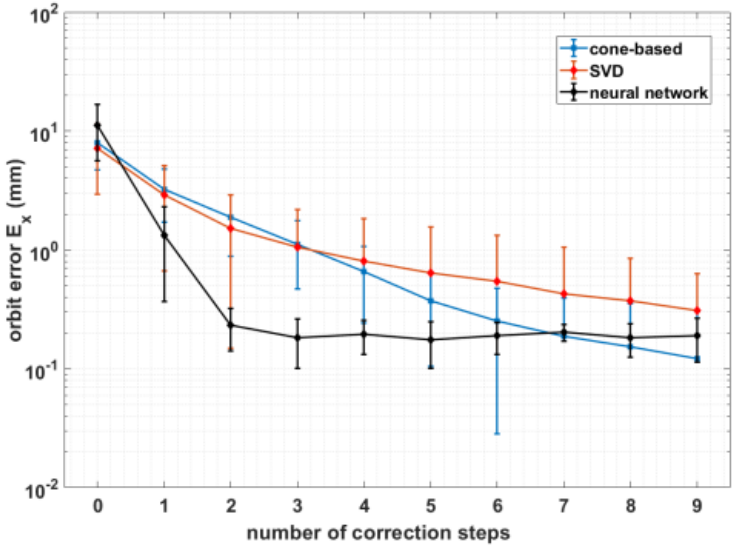










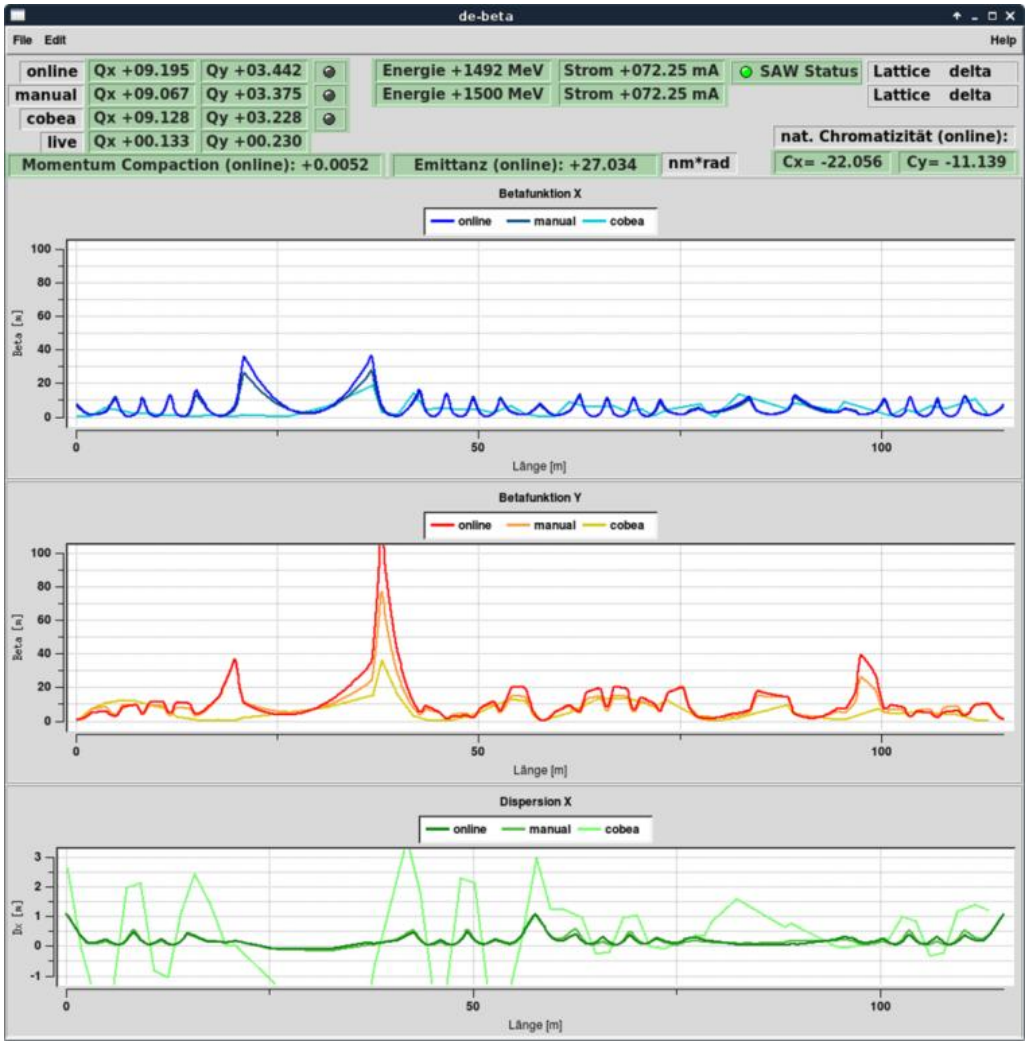


Model server

(A. Althaus, D. Schirmer)

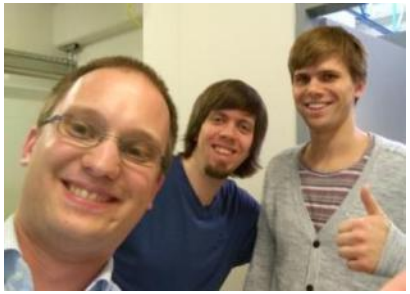
Integrated into EPICS-based control system
- python-based
- using OCELOT, COBEA
- all parameters available as EPICS PVs
- GUI to visualize and set parameters

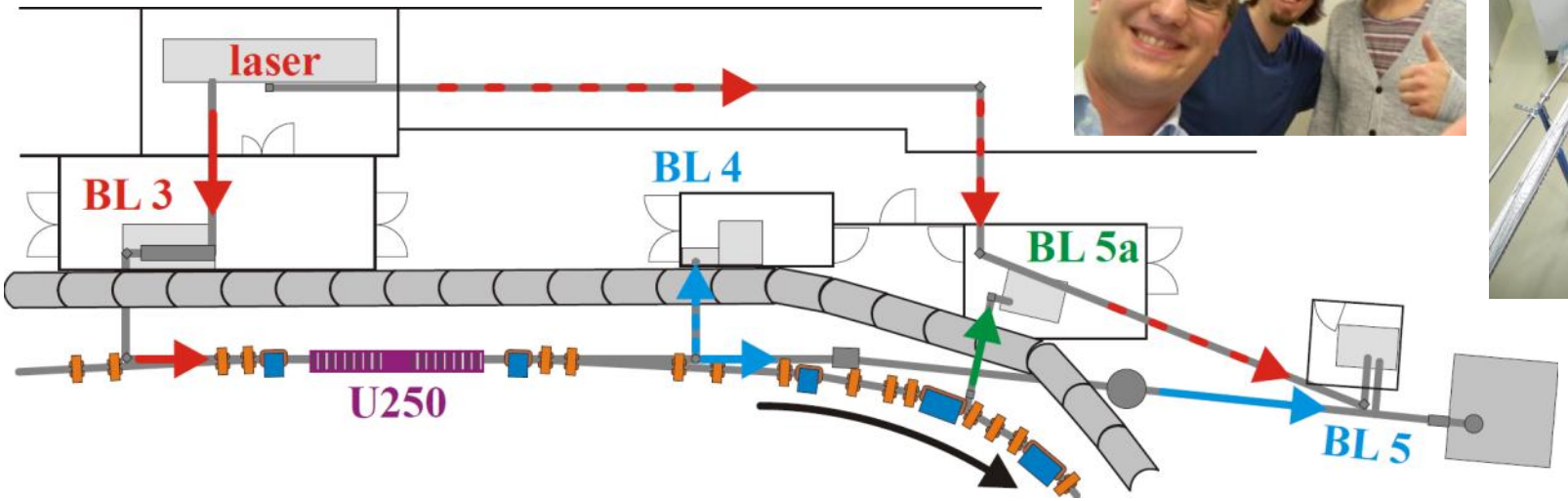
Different simulation modes using
- model parameters
- setup files
- real settings

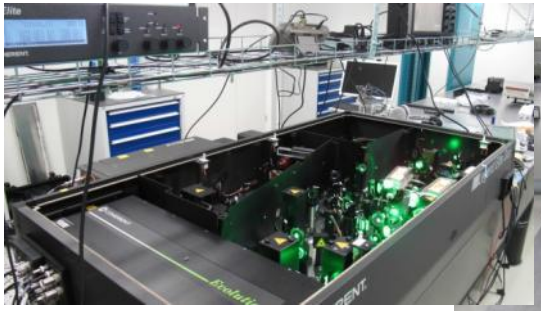


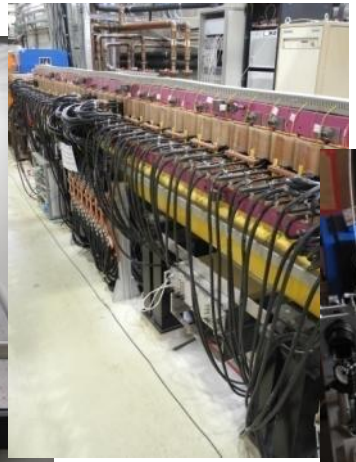
Facility for ultrashort VUV and THz pulses

B. Büsing, S. Khan, D. Krieg, C. Mai, A. Meyer auf der Heide, B. Riemann, B. Sawadski, F. Teutenberg [TU Dortmund]
S. Cramm, L. Plucinski, C. Schneider [FZ Jülich and U Duisburg-Essen]
M. Cinchetti, S. Ponzoni [TU Dortmund]

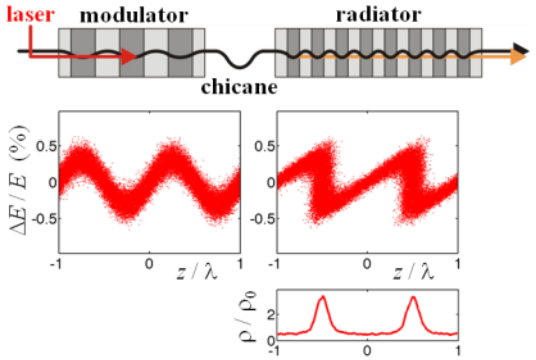








Facility for ultrashort VUV and THz pulses

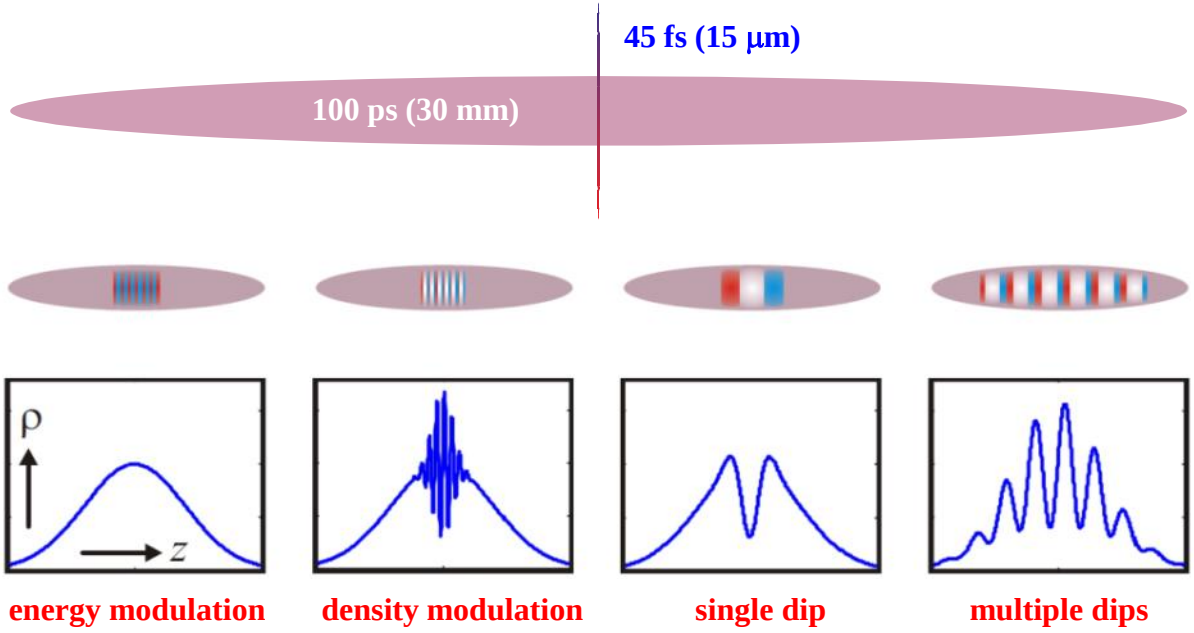


Coherent harmonic generation (CHG)

- 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) radiation

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

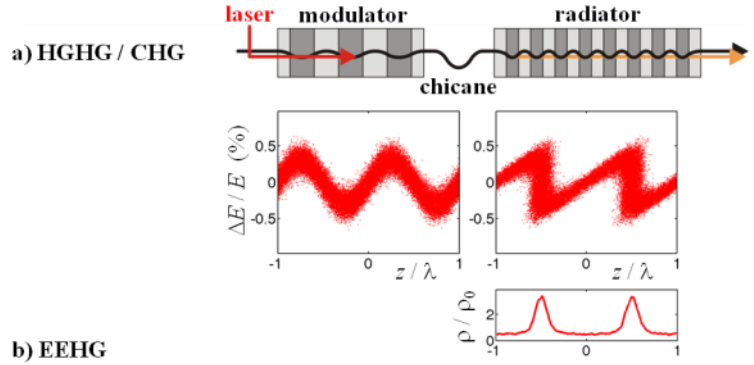


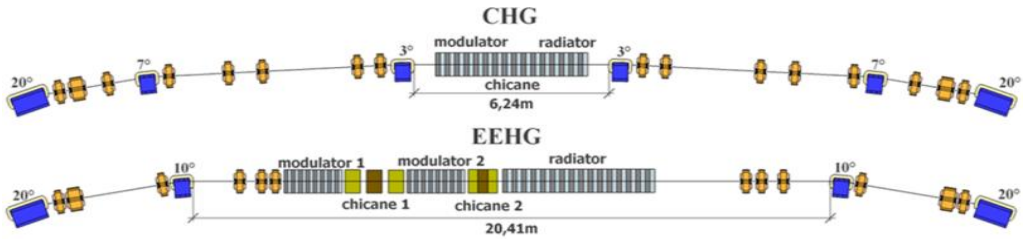
Echo-enabled harmonic generation at DELTA

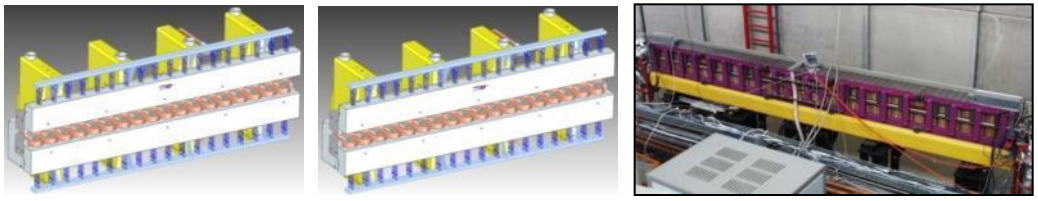
Supported by Helmholtz ARD initiative (FZ Jülich)

- **modulators: 2 short undulators**
- **radiator: present U250 undulator**
- **requires 20 m long straight section**
- **modified storage ring optics**
- **additional undulator for "femtoslicing"**

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)





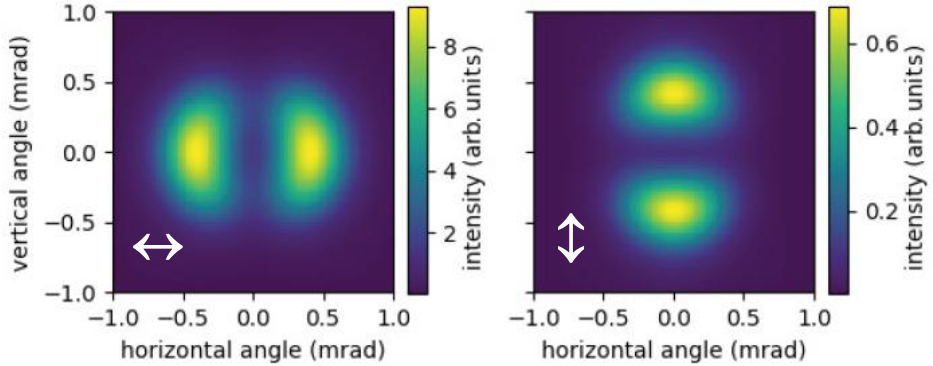


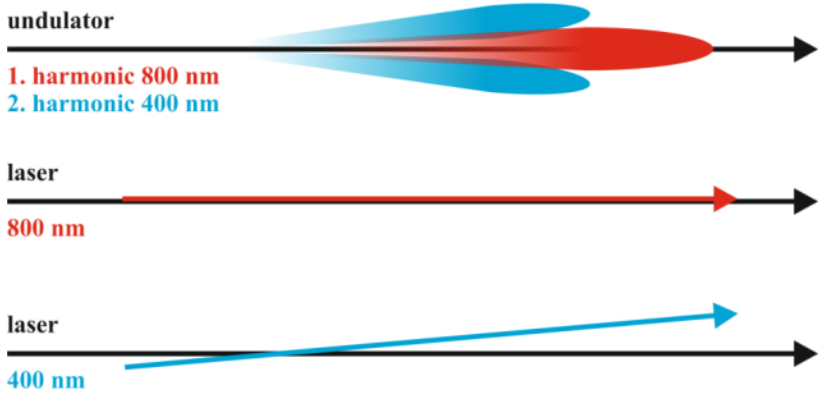
Courtesy Scanditronix AB

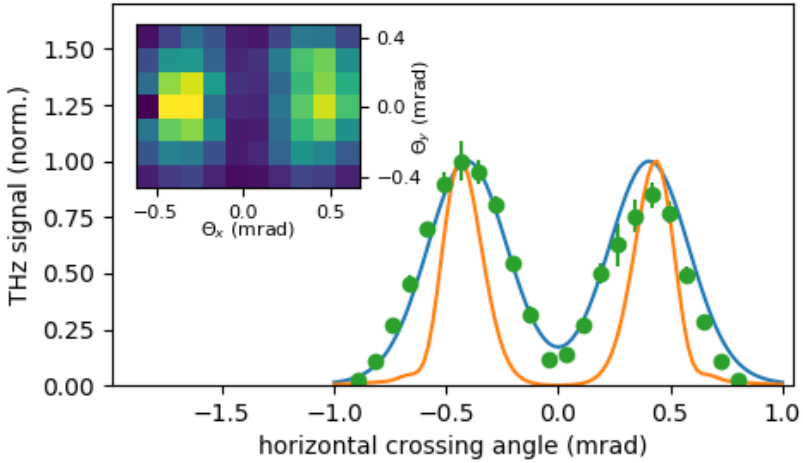
Facility for ultrashort VUV and THz pulses

Off-axis seeding at the second undulator harmonic
- laser-induced energy modulation follows spontaneous undulator radiation

angular distribution at 400 nm, folded with laser divergence







calculations using SPECTRA
H. Tanaka and H. Kitamura,
Journal of Sync. Radiation 8, 1221 (2001)

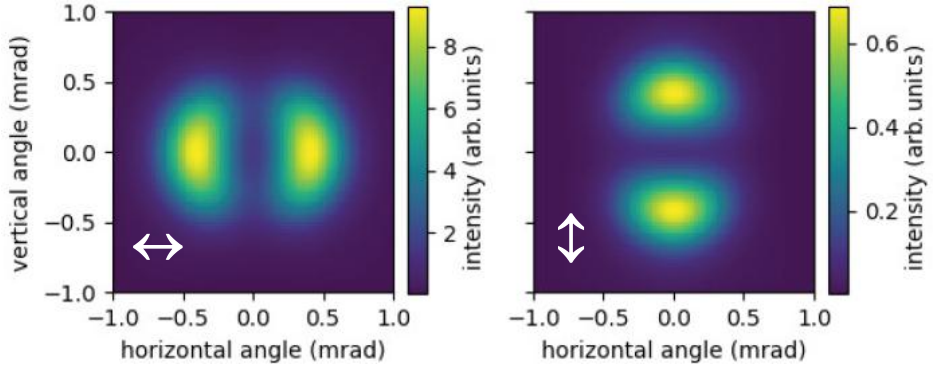
A. Meyer auf der Heide et al.,
Proc. FEL 2019, Hamburg,
paper TUP080

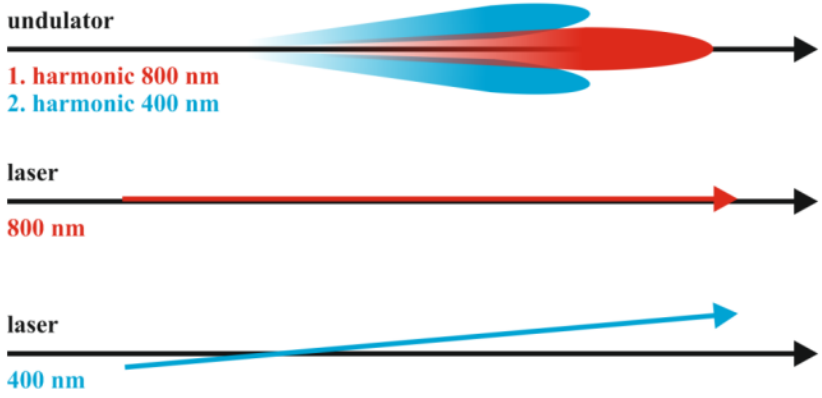
Facility for ultrashort VUV and THz pulses

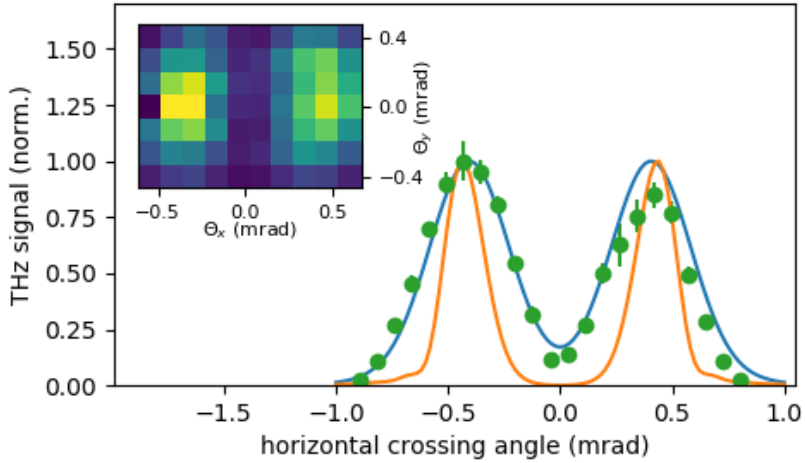
Off-axis seeding at the second undulator harmonic

- laser-induced energy modulation follows spontaneous undulator radiation

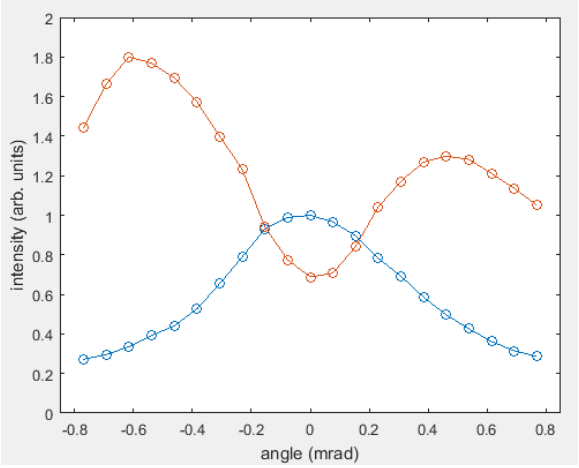
angular distribution at 400 nm, folded with laser divergence







spontaneous undulator radiation



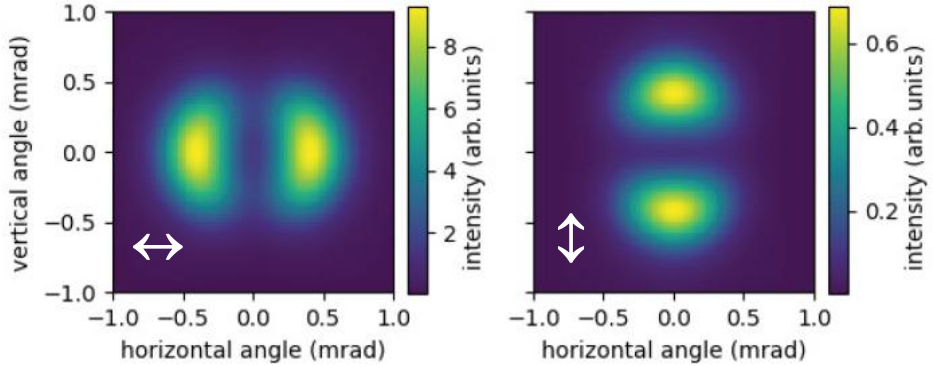
first and **second** harmonic (K = 10.2)

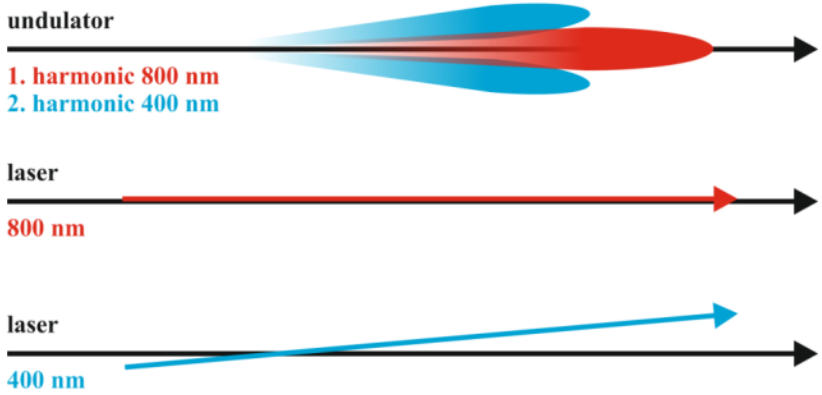
Facility for ultrashort VUV and THz pulses

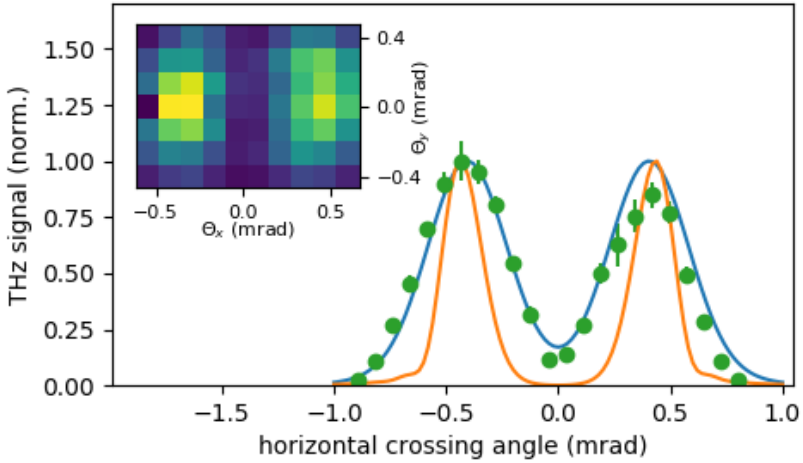
Off-axis seeding at the second undulator harmonic

- laser-induced energy modulation follows spontaneous undulator radiation

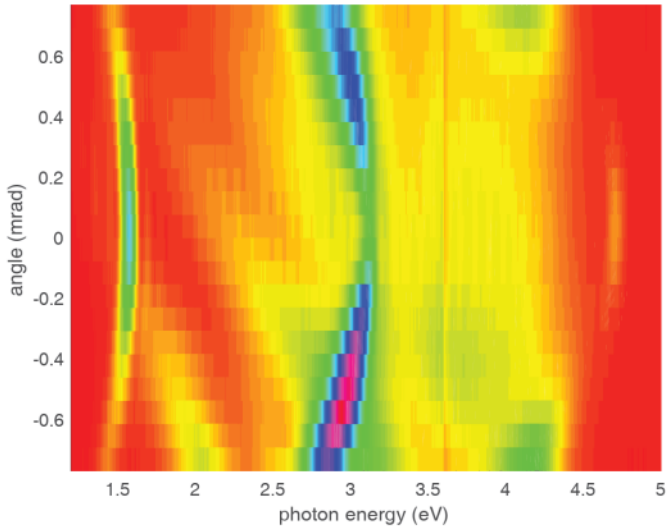
angular distribution at 400 nm, folded with laser divergence







angle by moving the electron beam, detector fixed

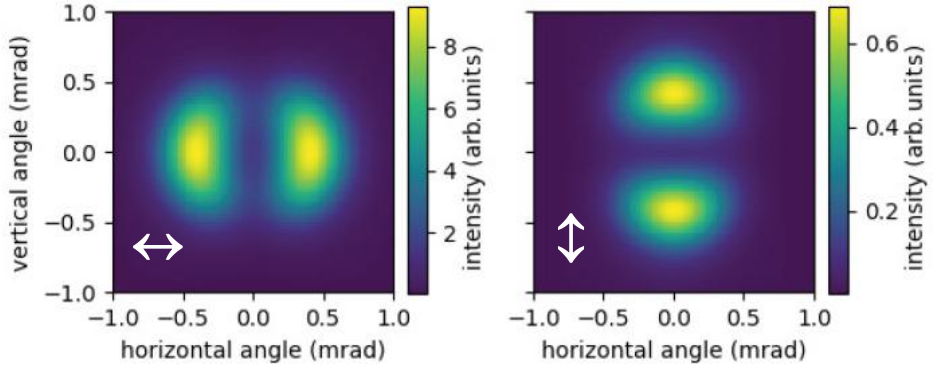


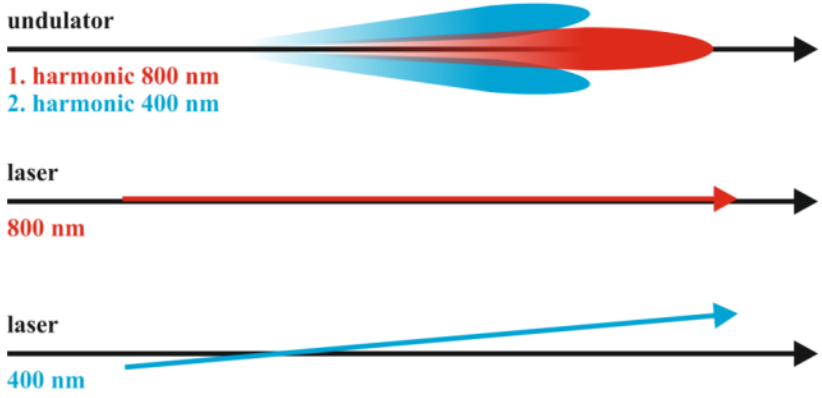
Facility for ultrashort VUV and THz pulses

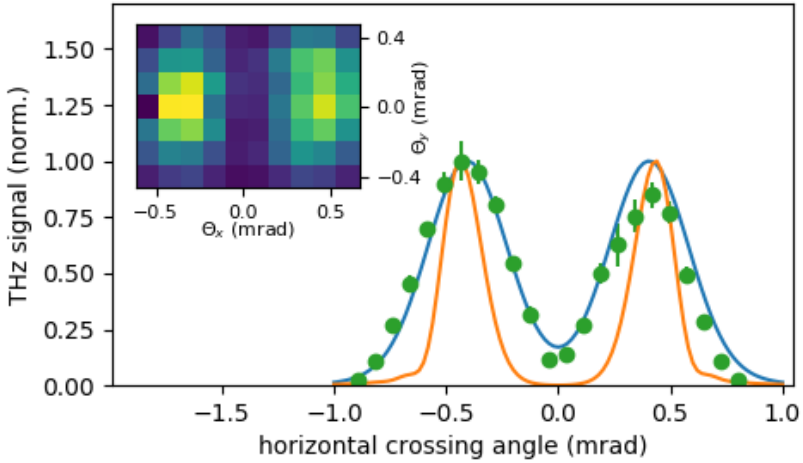
Off-axis seeding at the second undulator harmonic

- laser-induced energy modulation follows spontaneous undulator radiation

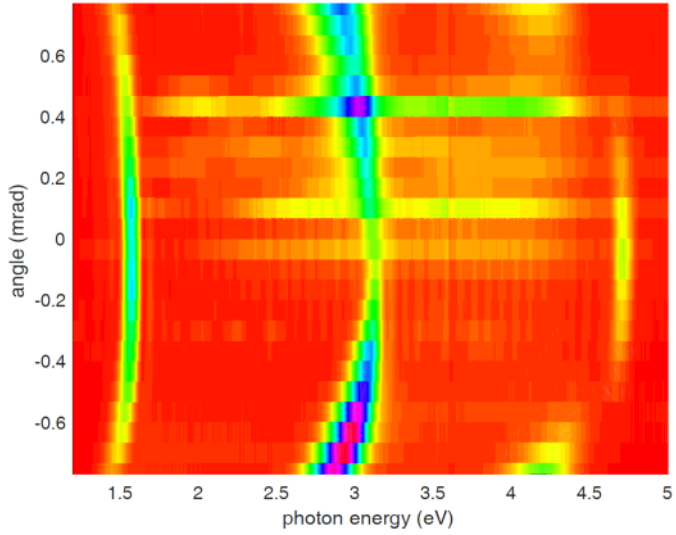
angular distribution at 400 nm, folded with laser divergence







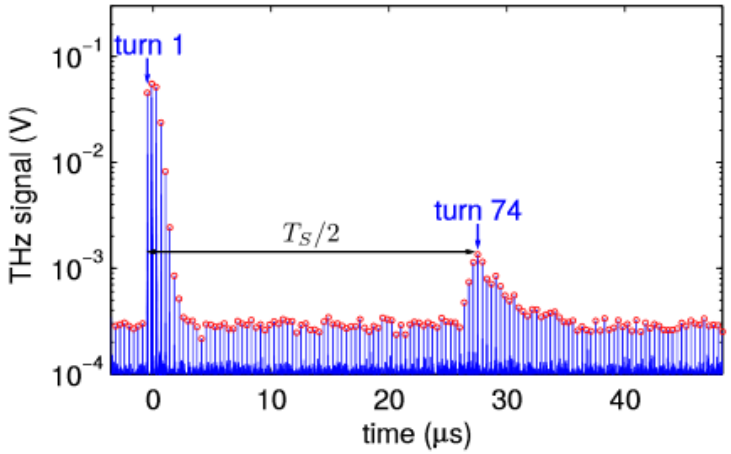
angle by moving the detector, electron beam fixed



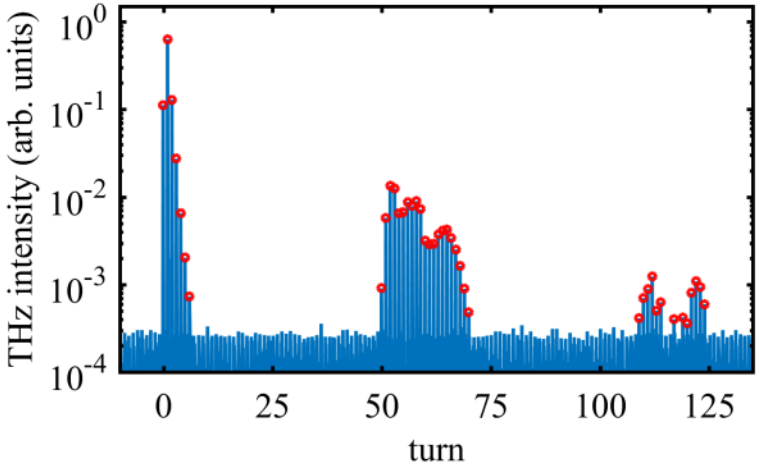
Facility for ultrashort VUV and THz pulses

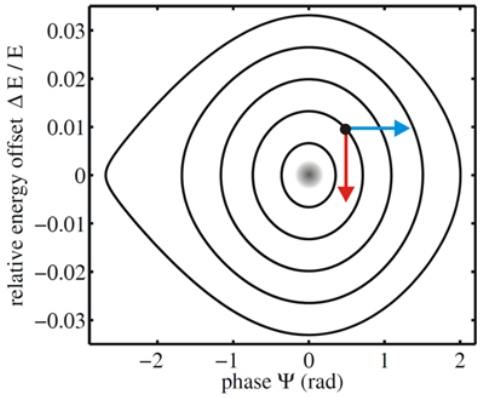
Coherent emission of Terahertz radiation

- **diagnostics of laser-electron interaction**
- **short laser pulse: broadband THz radiation**
- **long modulated pulse: narrowband THz radiation**
- **sub-THz signal after 1/2 and 1/1 synchrotron period**



C. Mai et al., Proc IPAC 2015, Richmond/USA, 823



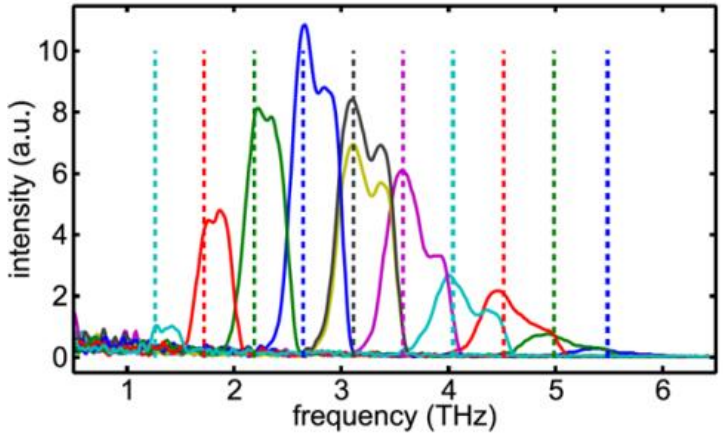


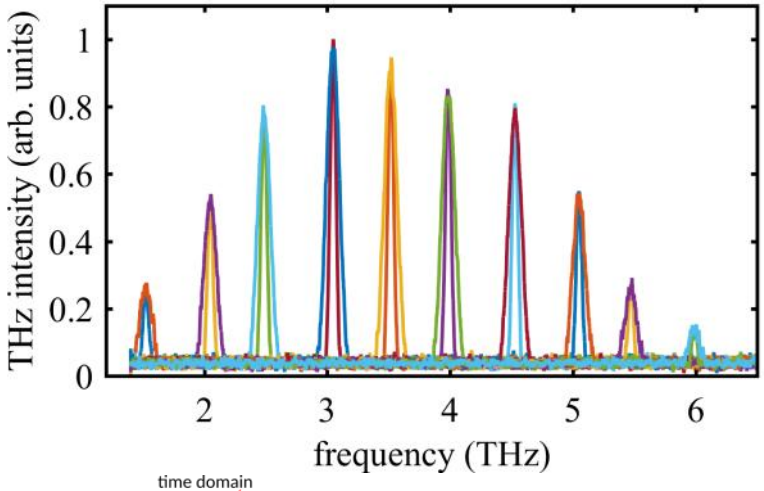
Facility for ultrashort VUV and THz pulses

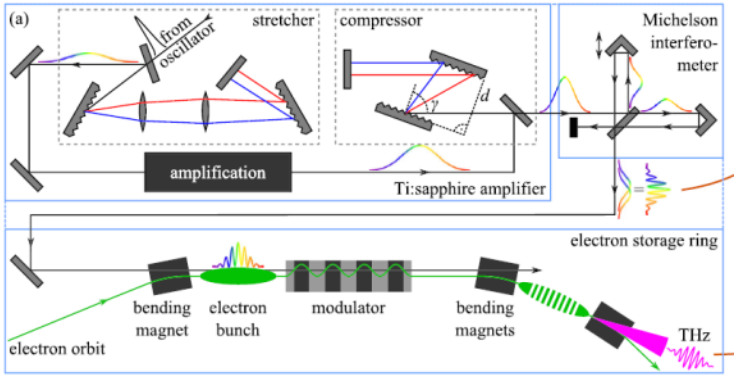
Coherent emission of Terahertz radiation

- diagnostics of laser-electron interaction
- short laser pulse: broadband THz radiation
- long modulated pulse: narrowband THz radiation
- sub-THz signal after 1/2 and 1/1 synchrotron period

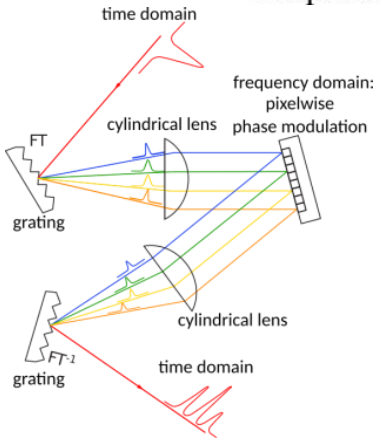
S. Bielawski et al., Nature Physics 4, 390 (2008)
C. Evain et al., PRST-AB 13, 090703 (2010)
P. Ungelenk et al., PRAB 20, 020706 (2015)







chirped-pulse beating



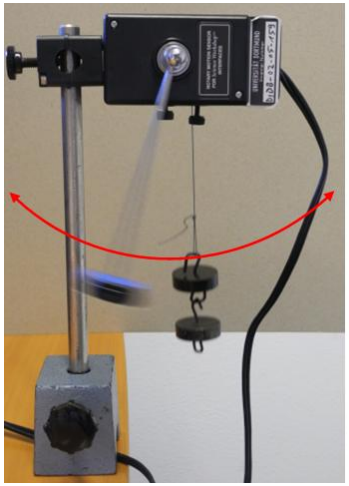
spatial modulator

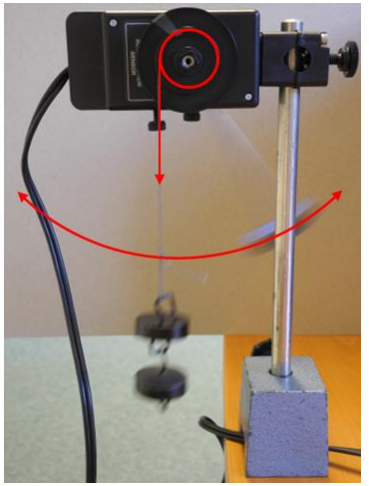
Accelerator physics in the bachelor and master curriculum

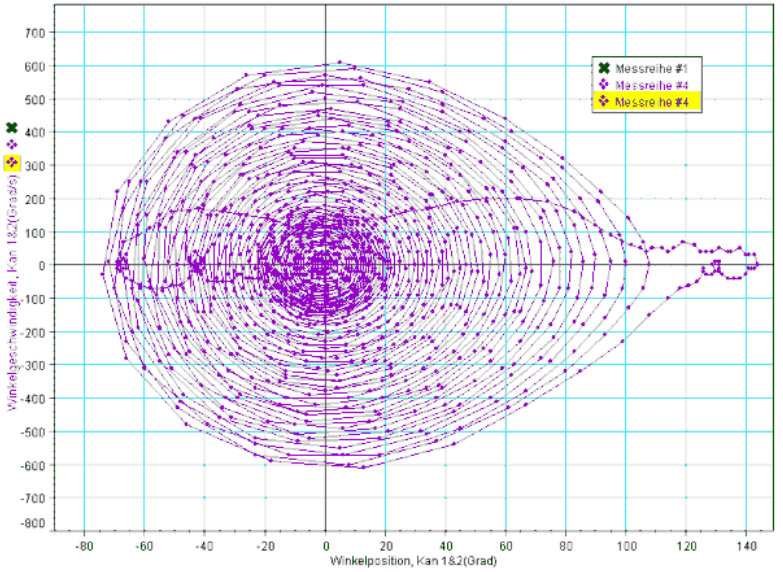
Bachelor, master, docorate theses

One-semester course on instruments (lasers, accelerators, detectors ...)
- 2 hrs lecture
- 1 hr exercises

Two-semester accelerator course
- 2 hrs lecture
- 1 hr exercises
- 1 hr seminar
- field trips
  (Berlin, Hamburg, ...)





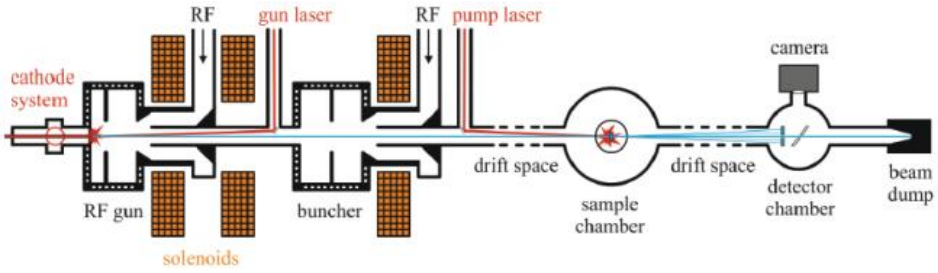


The Future of DELTA

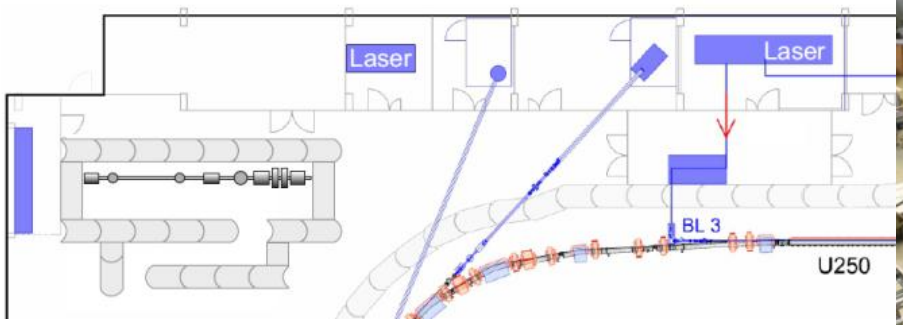
Last workshop on February 20, 2018

The next 10 years

- **consolidation and improvement**
- **7-T wiggler and RF upgrade**
- **EEHG short-pulse source**



MERCUR grant to develop an electron source for ultrafast electron diffraction (UED@DELTA)
- 2 PhD positions (Dortmund and Duisburg-Essen)



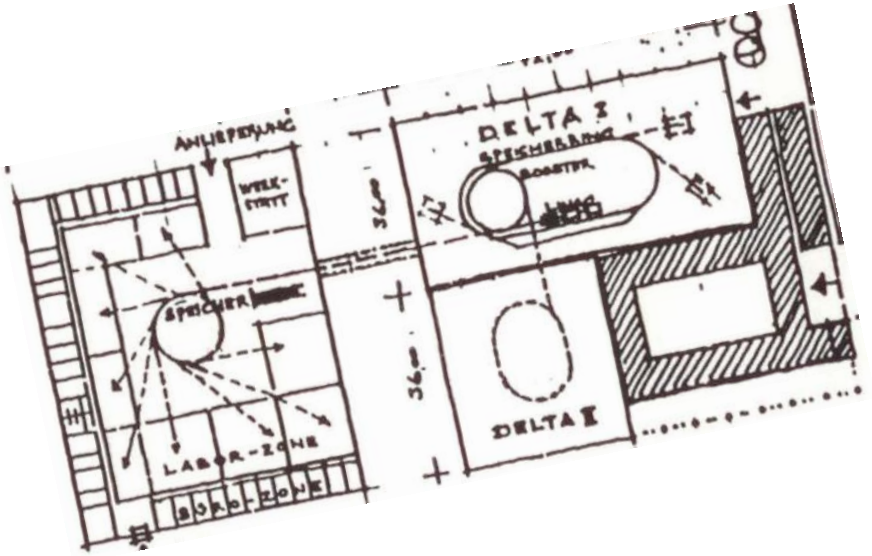
The Future of DELTA

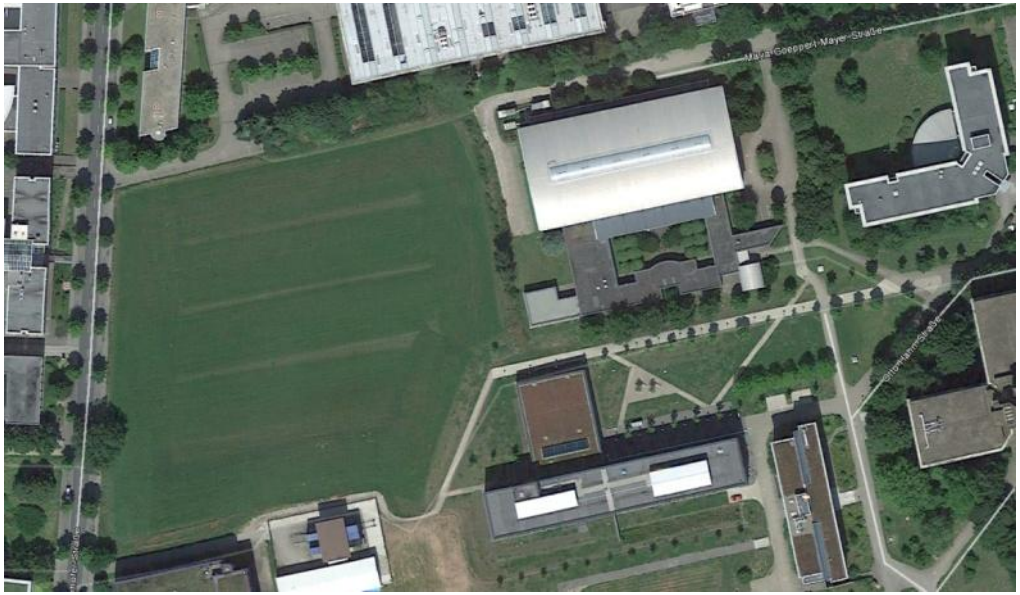
Last workshop on February 20, 2018

The next 10 years

- **consolidation and improvement**
- **7-T wiggler and RF upgrade**
- **EEHG short-pulse source**

... and beyond





Thank you very much / Moltes gràcies

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

DFG Deutsche Forschungsgemeinschaft

Mercator Research Center Ruhr
Eine Initiative der Stiftung Mercator
und der Universitätsallianz Ruhr

Bundesministerium
für Bildung
und Forschung