PT3: ps – fs Electron and Photon beams Introduction

speaker: H. Schlarb

Machine Beam Controls

DESY

PT3: ps – fs Electron and Photon beams
Introduction

From reviewer comments & internal discussions:

>Activities within PT3 should **focus** on few goals of **strategic importance**

>Activities **directly supporting** ARD programs **PT1 & PT4**

>**Optimal use** of **exist research infrastructure** to carry out R&D program

>Improved **networking** among HGF accelerator research facilities to **maximize synergies** (exchange of know-how/resource & technologies)

>**Education and training** of young researchers / students / scientists

PT3: ps – fs Electron and Photon beams Introduction

> Categorization of different activities to sub-tasks

> I Laser induced radiation & synchronization

- High power laser play mayor role for the photon radiation generation process
- Precision synchronization is mandatory pre-requisite to carry out experiment

> II Ultra-fast pulse diagnostics

- ps – fs electron bunch profiling
- ps – fs photon pulse profiling
- At low / high charge & low / high repetition rates

> III (Coh.) photon radiation & interaction

- Frontier of photon radiation from electron bunches w.r.t. to user operation
- Self-interaction & dynamics due to coherent radiation (CSR/Micro-bunch inst.)
- Advanced photon radiation source development

> Clearly: overlaps / strong interaction among Sub Topics I,II, III

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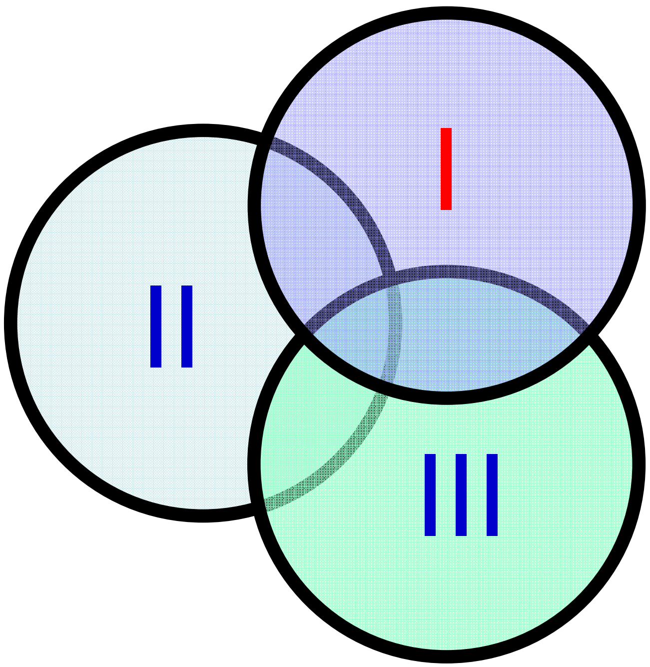


- ➜ I **Laser induced radiation & synchronization**
- ➜ II Ultra-fast pulse diagnostics
- ➜ III (Coh.) photon radiation & interaction

Laser induced radiation & synchronization

> Topics included in TP3-I:

what?	who?	related to
Seeding XUV	DESY, HZB, TU-Do, FZJ	II & III
Synchronization	DESY, HZB, HZDR, KIT	II, TP1/TP4
Slicing Rings	HZB / DESY	II & III
Slicing FELs	DESY	II
Thomson Scattering	HZDR	II
…		

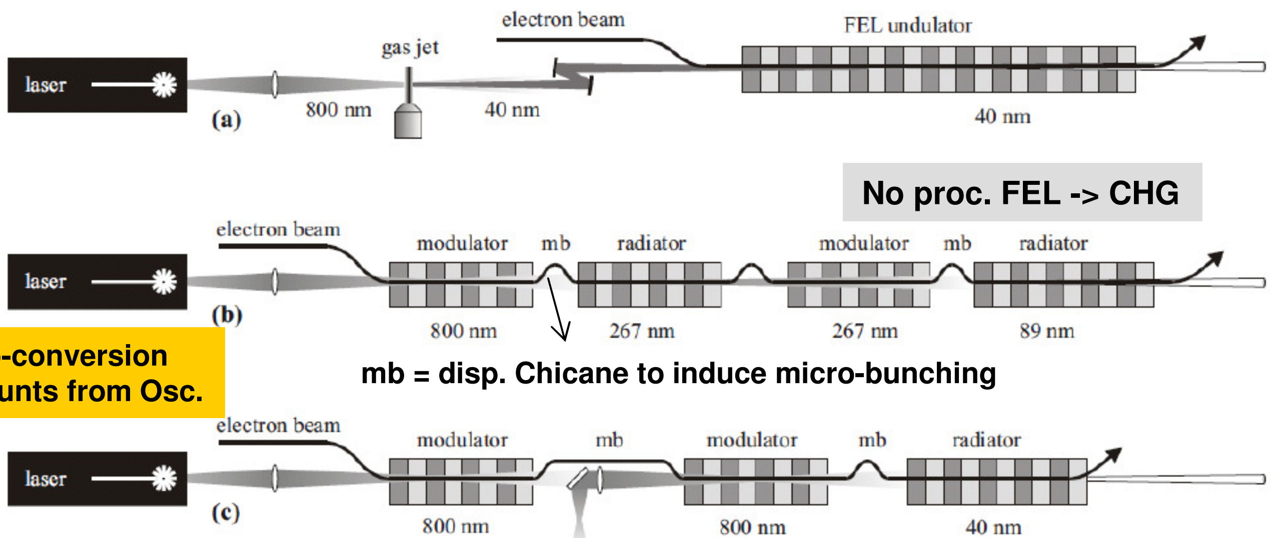
> Concentrate on Short Wavelength Seeding & Synchronization with ARD Program

Laser induced seeding: different schemes

> Goals:

- Long. coherence / improved synchr. / better stability / high control (wave synthesizes)

> Different frequency up-conversion schemes envisioned



No proc. FEL -> CHG

Up-conversion counts from Osc.

mb = disp. Chicane to induce micro-bunching

Courtesy: S.Khan

HHG
High Harmonic Generation
(D. Garzella et al. [2004])

HGHG
High gain Harmonic Generation
(J.Wu et al. [2001])

EEHG
Echo-Enabled Harm. Generation
(E. Stupakov [2009])

> Different Tolerance & Flexibility & Capability depending on schemes

- Discussion within international framework, should have significant contribution

> Fundamental to all: <u>up-conversion limitation</u> (~1-10nm expected)

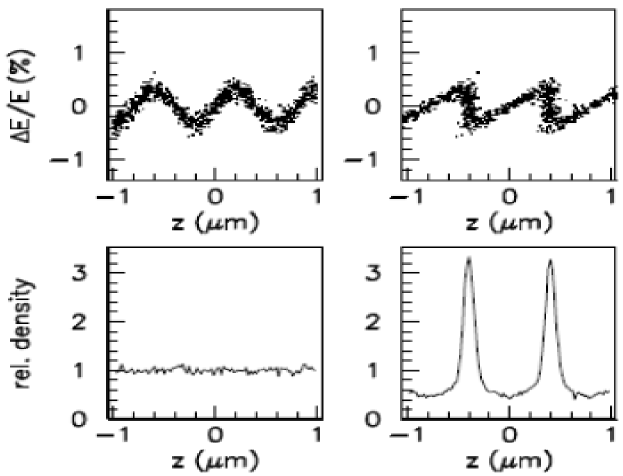
- Problem with phase noise & spatial – frequency errors of laser pulse
- Frontier of laser physics: Diagnostics / Optics / Actuators to level of < 1/10 * λ_{laser} / m

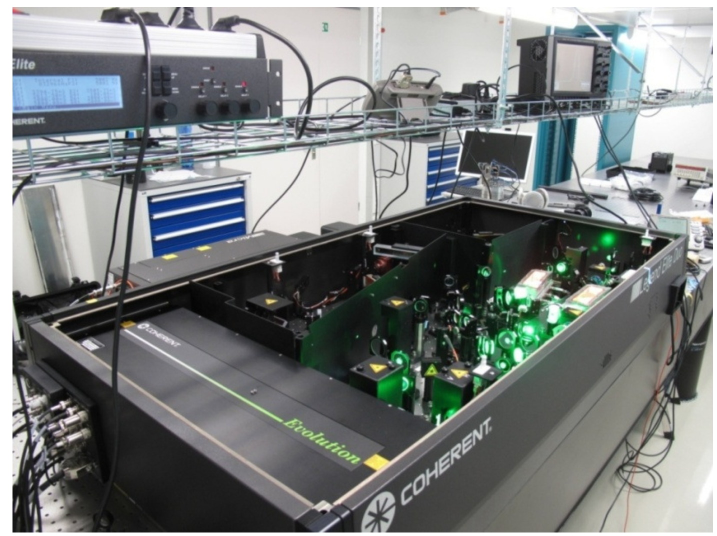
Laser Seeding: CHG @ DELTA (FZJ/TU-Do)

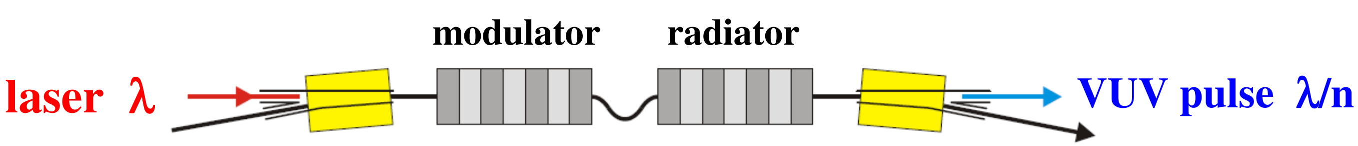
> Laser induced energy modulation + coherent harmonic generation (CHG)

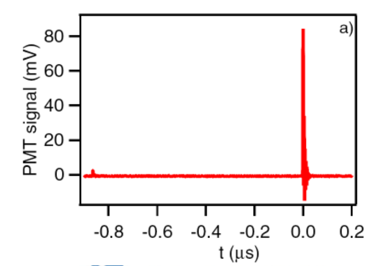
- Wavelength up-conversion n ~ 5
- High intensity
- Ultra-short pulses
- High transverse coherence
- Synchronized to seed laser
- FEL seeding scheme (HGHG) used

ELETTRA: E. Allaria et al., PRL 100 (2008), 174801
UVSOR II: M. Labat et al., PRL 101 (2008), 164803









Laser Seeding: CHG @ DELTA (FZJ/TU-Do)

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- Wavelength up-conversion n ~ 5
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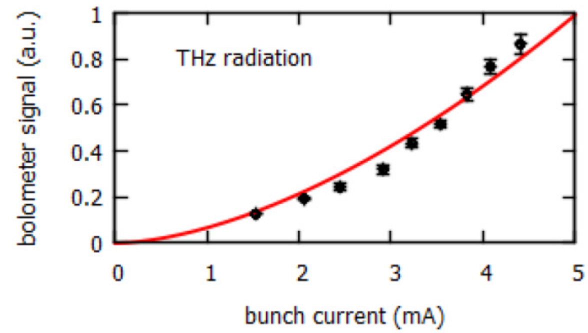
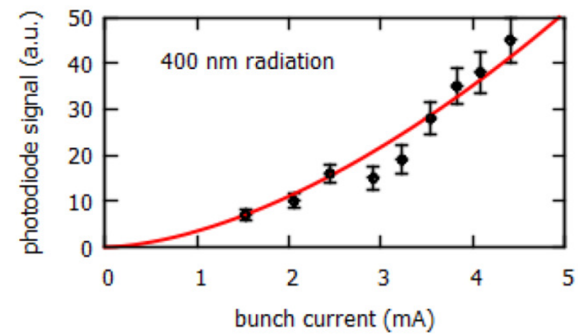
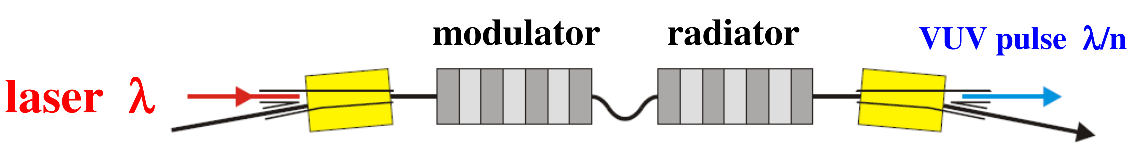
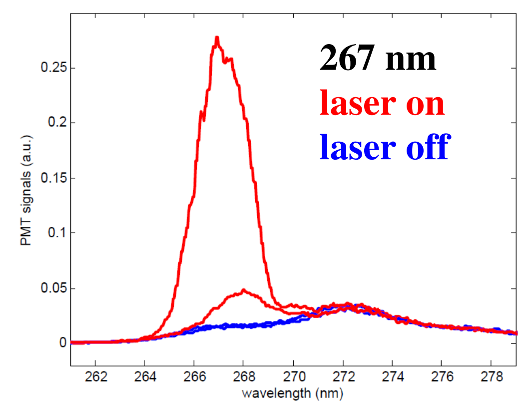
- FEL seeding scheme (HGHG) used

Recent progress
June 29: first coherent THz signal
June 30: first CHG signal at 400 nm
- strong THz signal at 1 kHz
- enhanced signal at 400 nm
- quadratic dependence on bunch current
- small time-bandwidth product
July: THz/CHG in user operation
October 14: first CHG signal at 267 nm









Laser Seeding: EEHG @ DELTA (FZJ/TU-Do)

> Echo-enabled harmonic generation (EEHG)

- 2 x energy modulation + coherent harmonic generation
- Wavelength up-conversion n ~ 30
- High intensity
- Ultra-short pulses
- High transverse coherence
- New FEL seeding scheme used

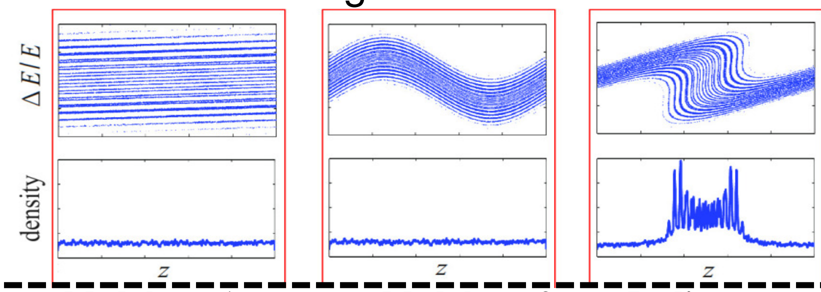
Design study for DELTA, under discussion with FZ Jülich

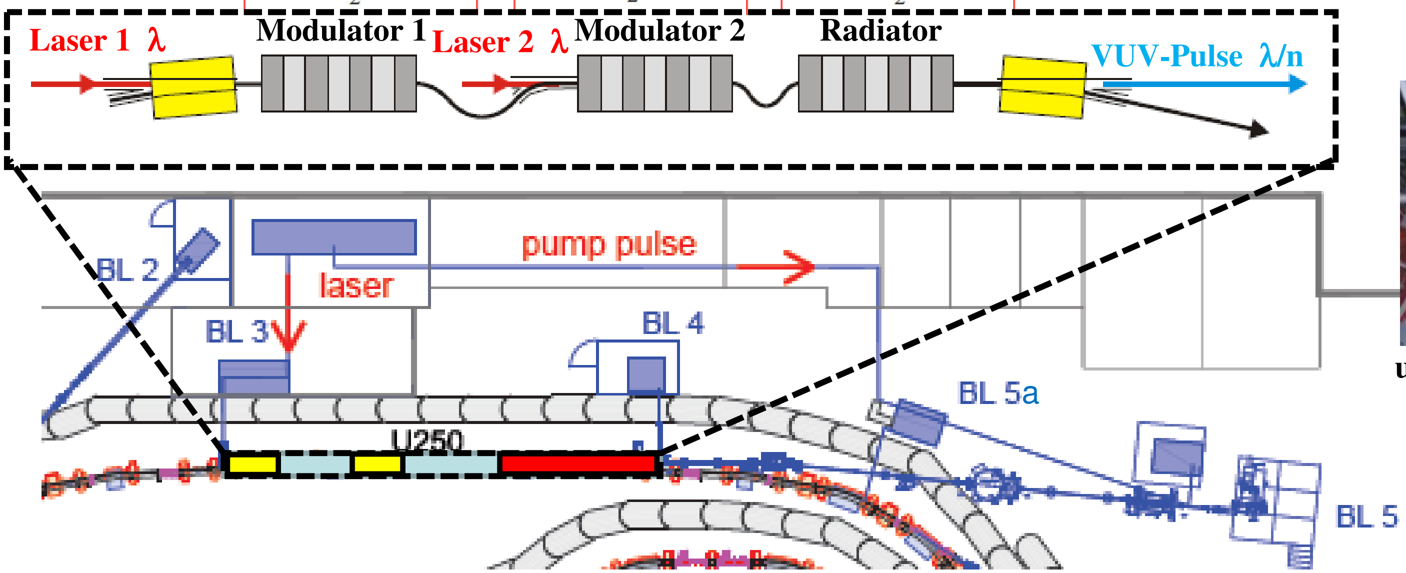
-diploma thesis 2011 (R. Molo),

-bachelor thesis 2011 (T. Büning)

- first storage-ring-based project worldwide

- under study at linacs:
  NLCTA/SLAC: D. Xiang et al., PRL 105 (2010)
  DUV-FEL/SINAP: Z. Zhao, FEL 2011





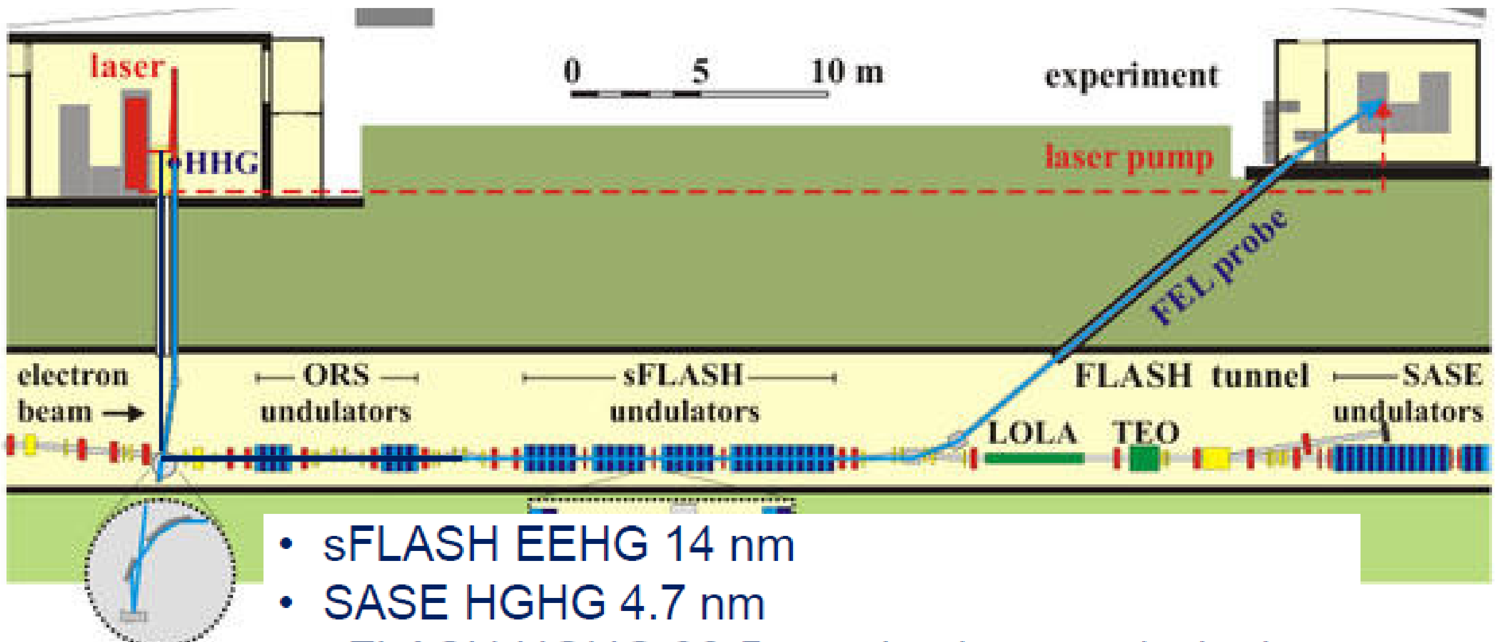
undulator with 5 periods at FLASH

HELMHOLTZ GEMEINSCHAFT

Seeding XUV: HHG / EEHG @ sFLASH

- sFLASH : HHG source at 38.5 nm (Uni-HH/Uni-D./DESY)
- sFLASH extension: EEHG (ARD supported) (Uni-Do. + Uppsala/Uni-Stockholm)
  - International collaboration
  - Uses 95% of sFLASH hardware
  - Critical issues can be address already 2012
  - High up-conversion from 800nm (x21 / x57 / x171)
  - Photon experiments prepared!

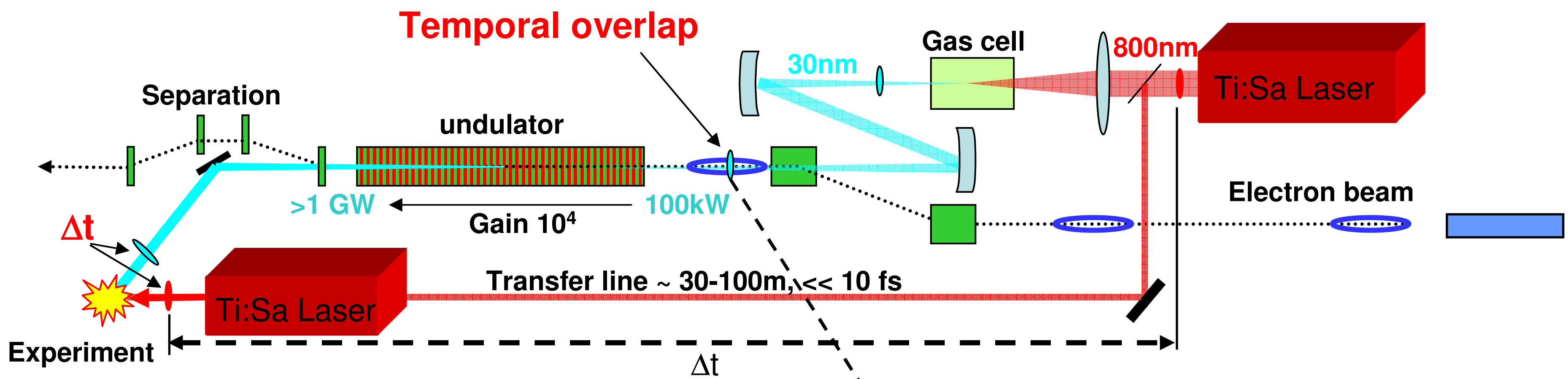
Kirsten Hacker*, Shaukat Khan, TU Dortmund
Gergana Angelova Hamberg, Volker Ziemann, Uppsala University
Peter Salen, Peter Van der Meulen, University of Stockholm
Armin Azima, University of Hamburg
Holger Schlarb, DESY



- sFLASH EEHG 14 nm
- SASE HGHG 4.7 nm
- sFLASH HGHG 38.5 nm simple commissioning

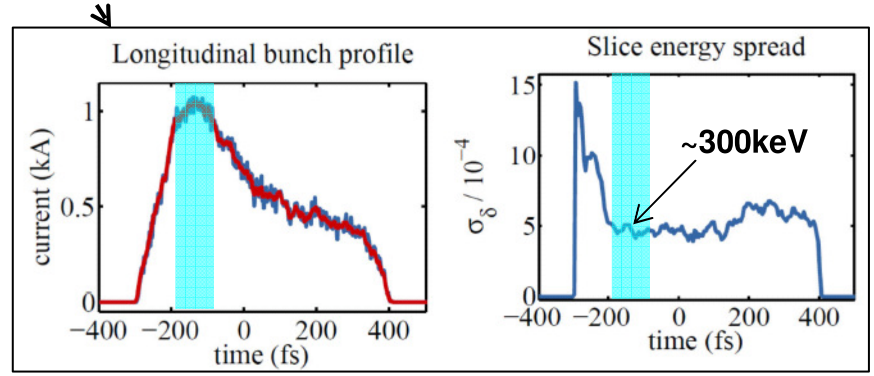
Synchronization demands: Seeding XUV

> Temporal overlap between electron beam and seed



Access to new class of experiments:

- Stable seeding / manipulation of electron beam using external laser
- Photon pulse arrival now defined by external laser ⇒ ~ fs feasible



Requirements:

- Temporal overlap between electron bunch & seed pulse essential ~ 10-50 fs
- Requirements on synchronization between pump & probe laser ~ 1 fs

Synchronization demands: Seeding XUV

> Temporal overlap between electron beam and seed

Temporal overlap

Gas cell 800nm Ti:Sa Laser

Δt

Experim

Acce

- Sta elec
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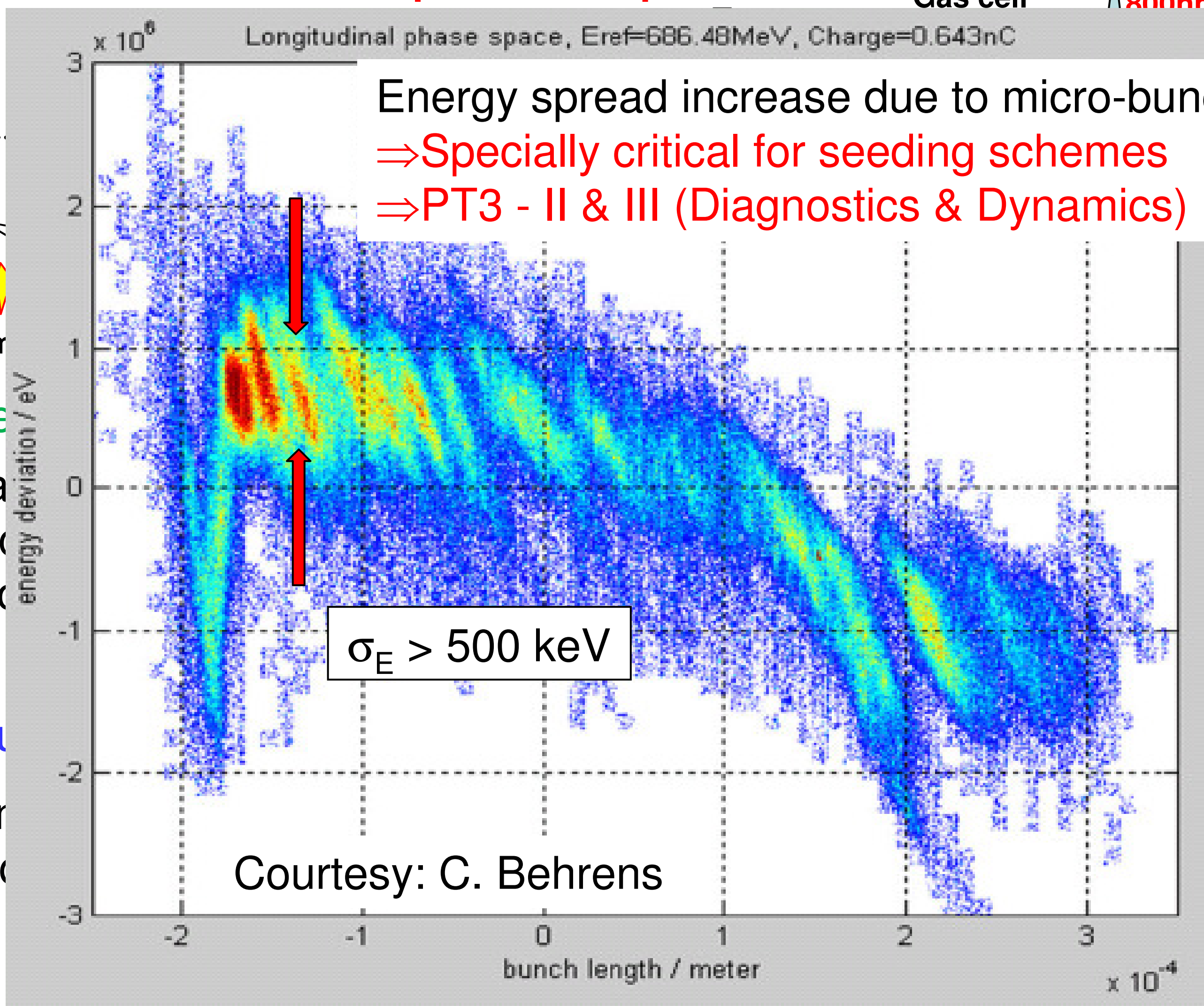
Requ

- Ter ial ~ 10-50 fs
- Rec ~ 1 fs



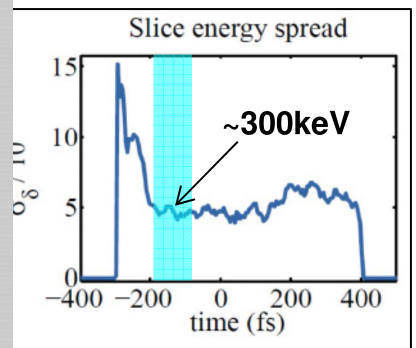
Energy spread increase due to micro-bunch instabilities

⇒Specially critical for seeding schemes

⇒PT3 - II & III (Diagnostics & Dynamics)

σ_E > 500 keV

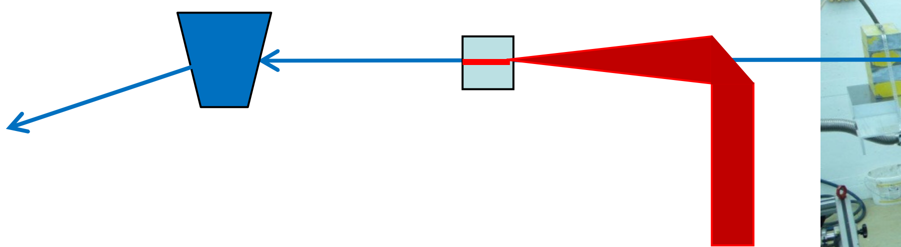
Courtesy: C. Behrens

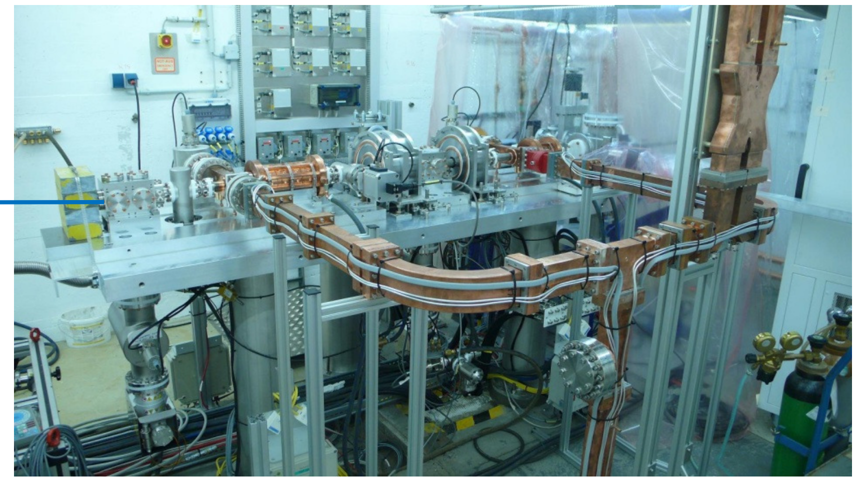


Synchronization demands: DESY / HZB / HZDR / KIT

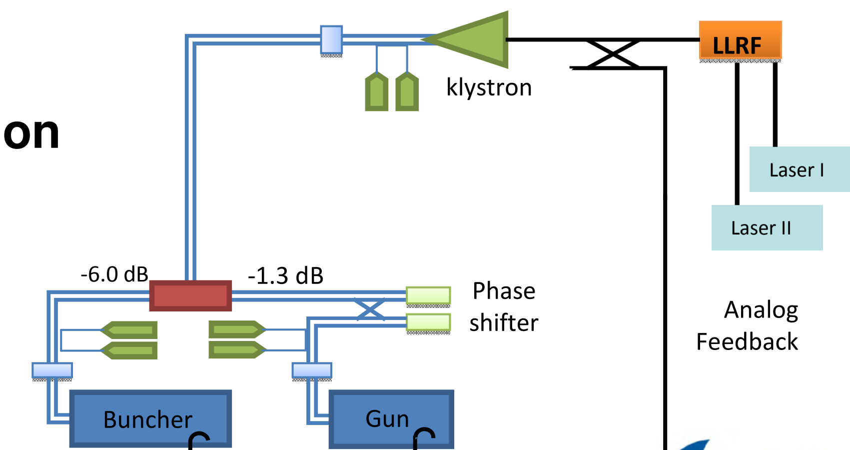
Precise synchronization: pre-requisite for many accelerators & experiments

>Laser plasma acceleration @REGAE and @FLASH III





- **Synchronization demand < 10fs**
- **LLRF** regulation for **NRF @3GHz** with **integrated laser synchronization**
  - Down converter calibration
  - Cable reflectrometry
  - High speed cav. temp regulation
  - Low latency analog addition
  - Sagnac loop TiSa ↔ RF conversion



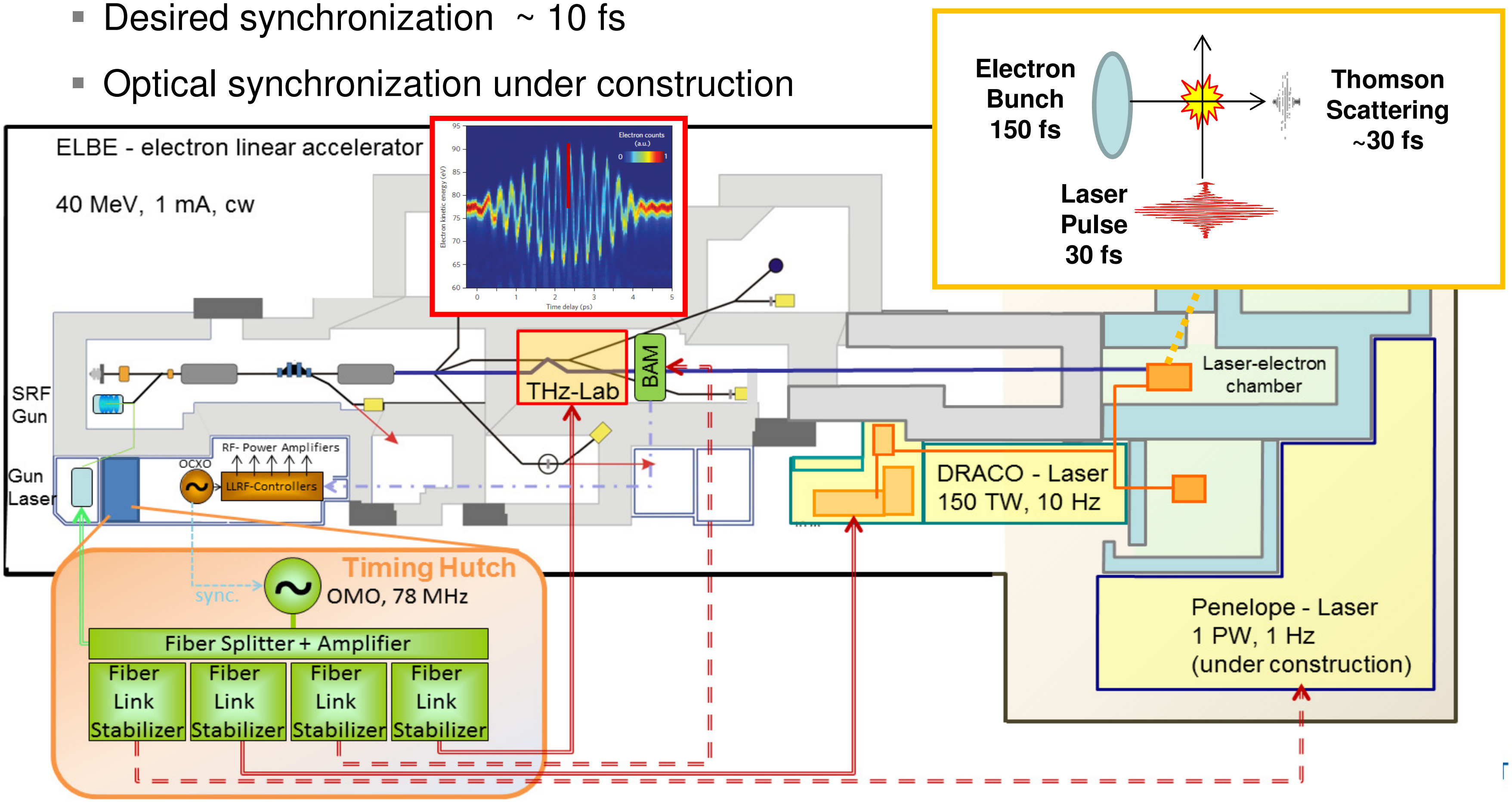
Synchronization demands: DESY / HZB / HZDR / KIT

Precise synchronization: pre-requisite for many accelerators & experiments

>Laser plasma acceleration @REGAE and @FLASH III

>90deg Thomson & THz-Laser PP-experiments @TELBE

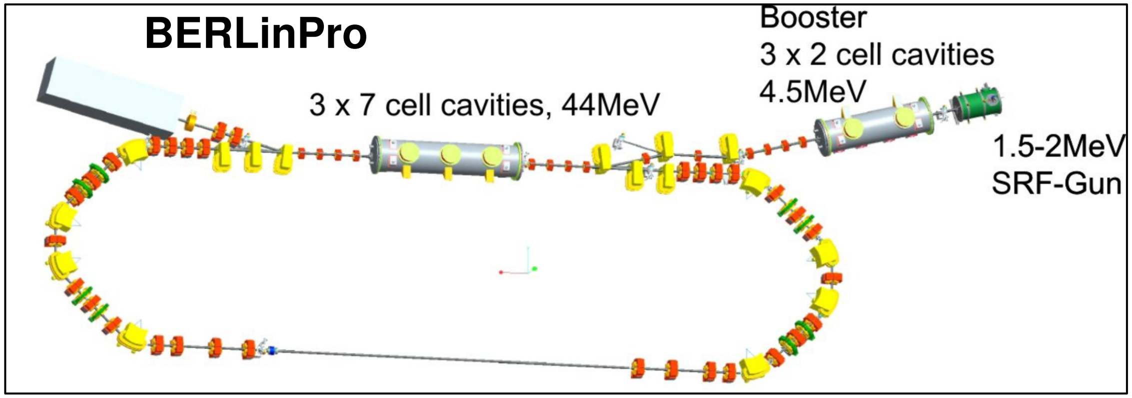
- Desired synchronization ~ 10 fs
- Optical synchronization under construction

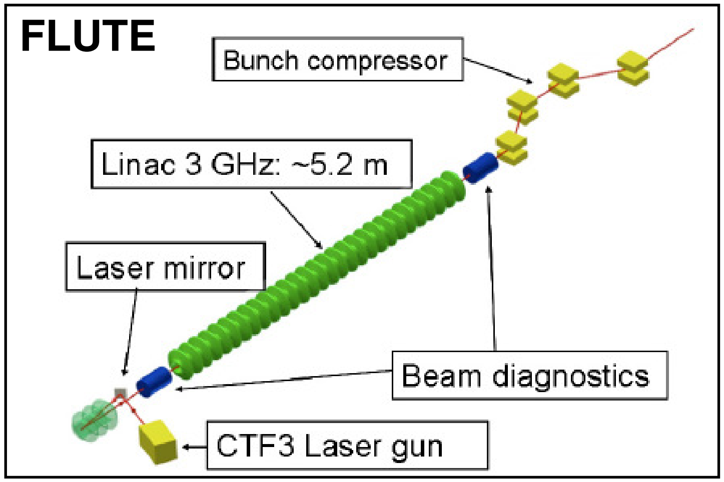


Synchronization demands: DESY / HZB / HZDR / KIT

Precise synchronization: pre-requisite for many accelerators & experiments

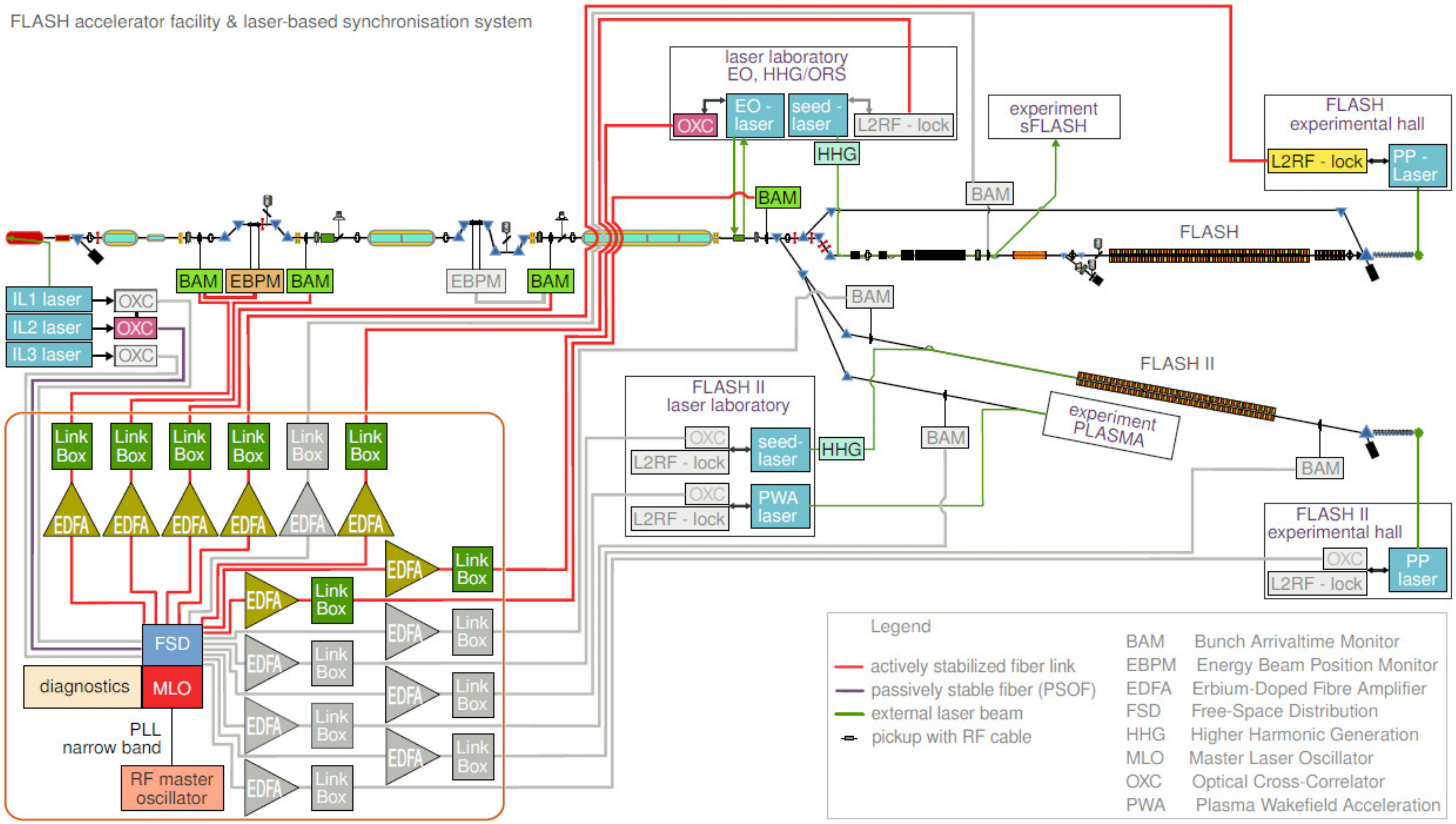
- Laser plasma acceleration @REGAE and @FLASH III
- 90deg Thomson & THz-Laser PP-experiments @TELBE
- Accelerator stability and control (BERLinPro/FLUTE/TBONE)
  - RF Synchronization (Interferometric RF distribution for XFEL)
  - LLRF @ 1.3GHz / 3GHz (CW test CMTB/REGAE)
  - Photon-injector laser synchronization





Synchronization developments @ FLASH

> Optical synchronization system FLASH / II / III



> Synchronization tap points increased from 12 → 22

Synchronization developments @ FLASH

Synchronization reach into many different physics/engineering disciplines and requires wide range of technologies

Radio Frequency:

different types of oscillators (quartz, SAW, dielectric)
phase detectors / mixer / multiplier /divider
low noise amplifier / limiting amplifier / filters / direction couplers
cables / connectors / PCB design / waveguides / RF structure / LLRF / HLRF

Optics & Lasers:

laser oscillator/pulse shaping/amplification/wavelength conversion
fiber optics / fiber optics devices / opto-electronic devices / photo-detection
laser sources (DFB/harmonic mode-lock/passive & active mode)
non-linear optics / opto-mechanics / free-space optics / pump-modules

Environmental control:

temperature / humidity / air pressure / vibration / ground motion / EMI / EMC

Controls & control theory:

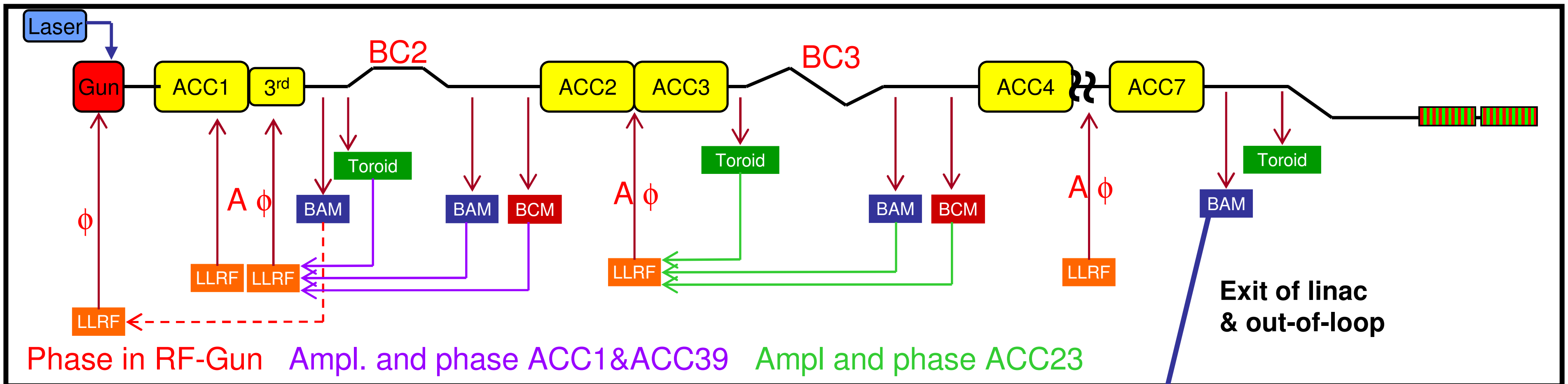
multiple feedbacks / PLL theory / automation / SISO / MIMO / …

Longitudinal electron beam dynamics

Synchronization: Ultimately use Fast Beam Based FBs

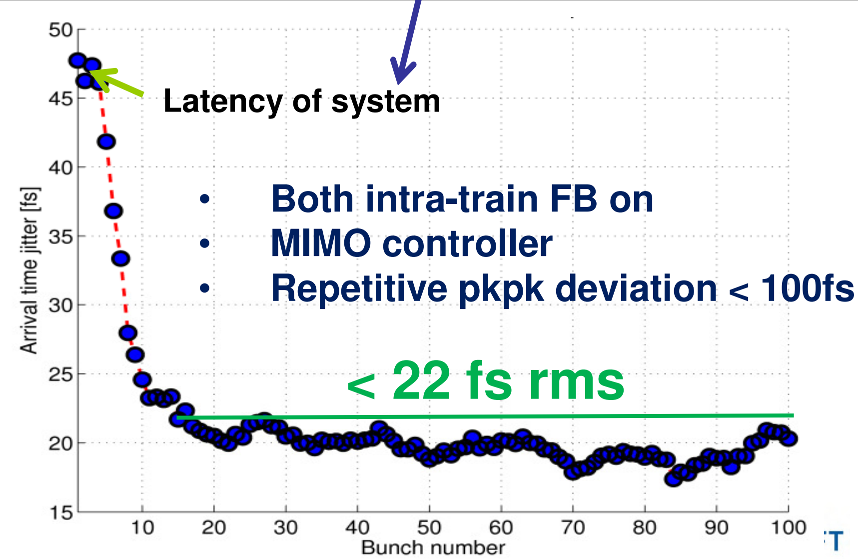
> Fast beam feedbacks for arrival stabilization (~usec bunch spacing)

$\Rightarrow$ **key feature of all SRF accelerators (TP1)**



> FEL Users: 10 fs **FWHM**

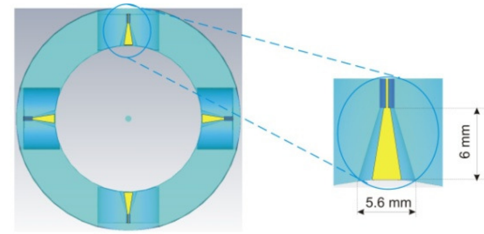
> Short pulse operation: 1nC $\Rightarrow$ 20pC

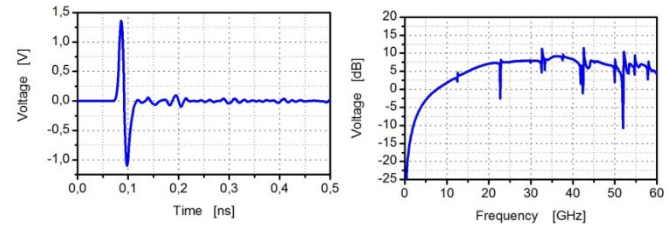


Synchronization: Example for collaboration / cooperation

> Beam arrival time monitor (1nC → 20 pC)

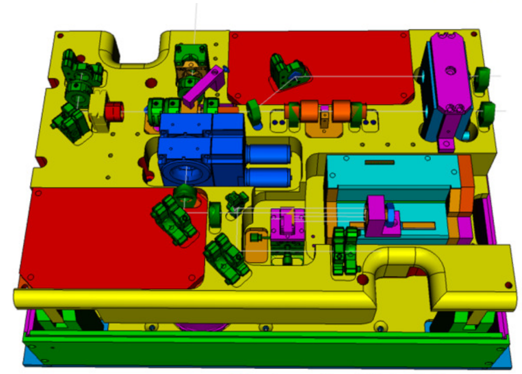
- BMBF Verbundantrag (TEMF/IMP/DESY)
- Increase bandwidth from 10GHz → 40 GHz
- Contract with two companies: 40GHz feed-through
- Vacuum capable prototype on the way
- Construct modified version for ELBE (2xBAMs)





> Construction of optical links (ARD)

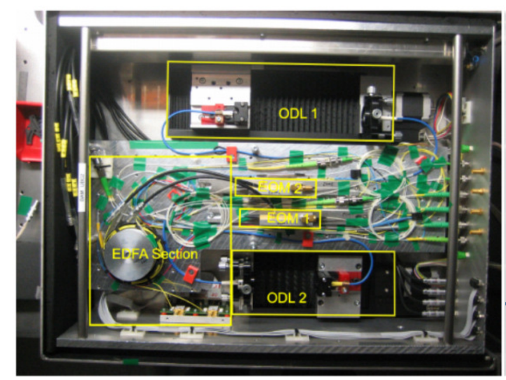
- Exchange of personnel: HZDR ↔ DESY
- Evaluation of sub-components
- Training how to build link + construction documentation
- Purchase link mechanics together (price reduction)



Courtesy: Bock/Schultz/Lamb

> Revision BAM frontend electronics (ARD 2012)

- Collaboration TU-Darmstadt / HZDR /DESY
- Better thermal / opto-mechanics stability / 40GHz EOMs



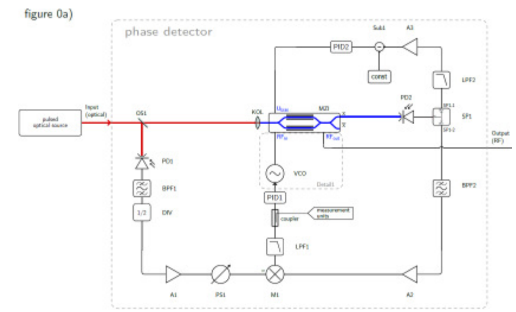
Synchronization: Program & goals within the ARD Program

> Technology transfer to HGF centers by
  - Commercialize synchronization (sub-)components
  - Exchange of personnel (both directions) for training & common improvements / consultancy
  - Provide assembly and commissioning instructions of devices
  - Reduce complexity of system

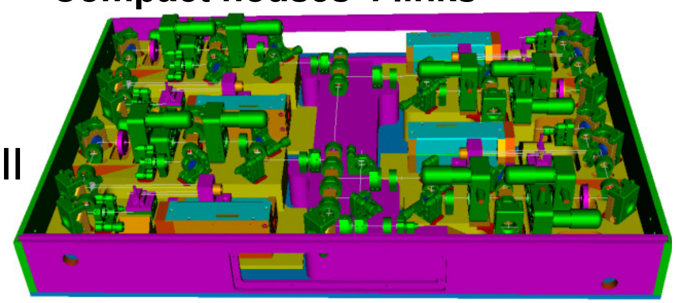
> Support of PT1 activities
  - Precision synchronization for REGAE / PITZ / FLASH III
  - LLRF developments beyond SRF controls
  - Laser to RF conversion with fs long term stability (Sagnac loop with 3GHz EOM)

> Expand application range of opt. synchr. System
  - Compact and low-cost femtosecond photon arrival time monitor

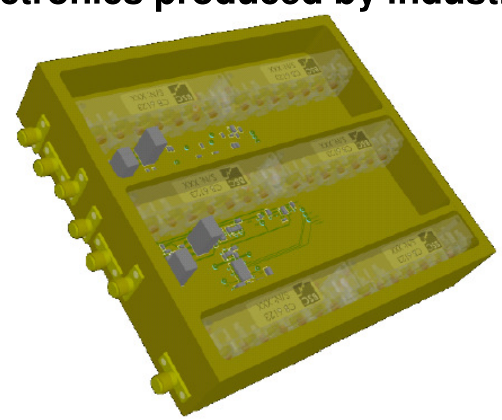
RF @ 1.3 GHz lock to laser (~3fs)



New RF Link stabilization scheme: Compact houses 4 links



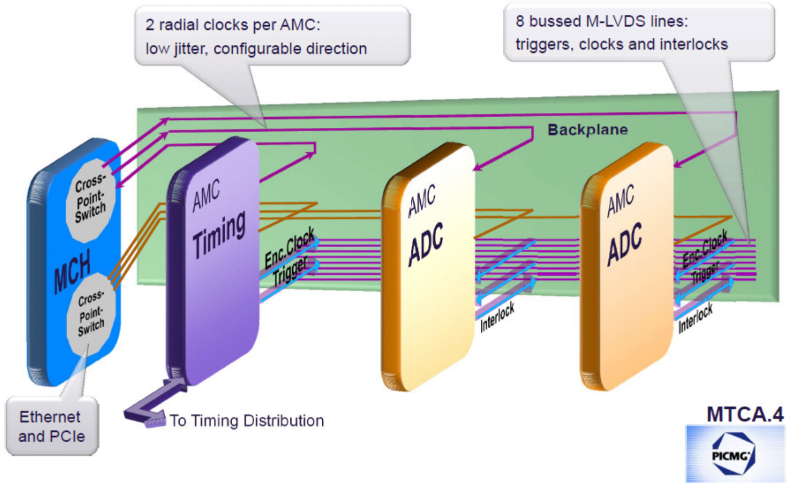
Electronics produced by industry



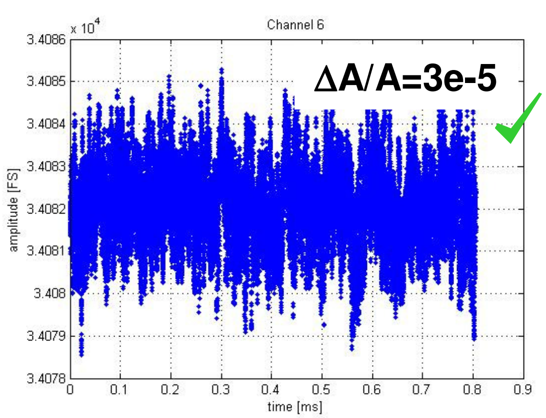
H. Schlarb
GSI, 21.11.2011

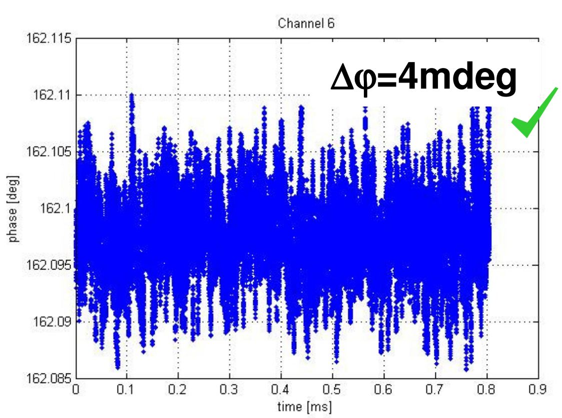
uTCA electronics / innovation / industry

- New Crate standard **MTCA.4** (available since Oct. 2011) was defined by
  - Acc. Labs: IHEP, Fermilab, SLAC, DESY
  - > 30 industrial partners
  - Clock, trigger & interlock distribution
  - Front/rear boards (digital/analog)
  - Fully compatible with old standard MTCA

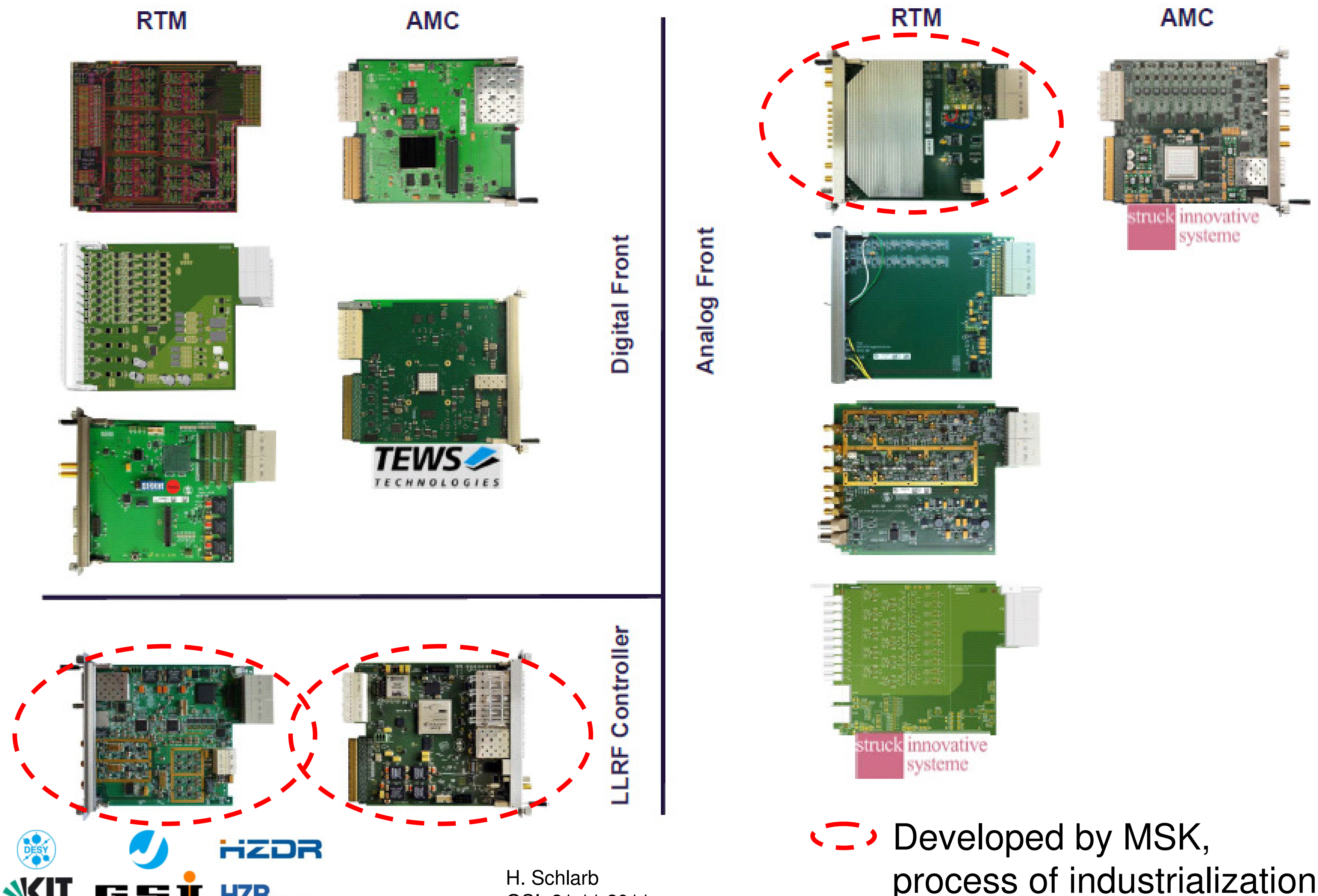


- Currently: **DESY drives development**
- Combines: **Telecommunication** (Digital) hardware & **high precision analog** needs for accelerators (Instrumentation/LLRF)





uTCA electronics / innovation / industry



uTCA electronics / innovation / industry

> Strong cooperation with industry on MTCA.4 electronics

TEWS TECHNOLOGIES
ILFA Feinstleitertechnik
ERICSSON
N.A.T.
PCI INDUSTRIAL PICMG COMPUTERS
Instrumentation Technologies
Cryoelectra
uBLADE
struck innovative systeme
ELMA Your Solution Partner
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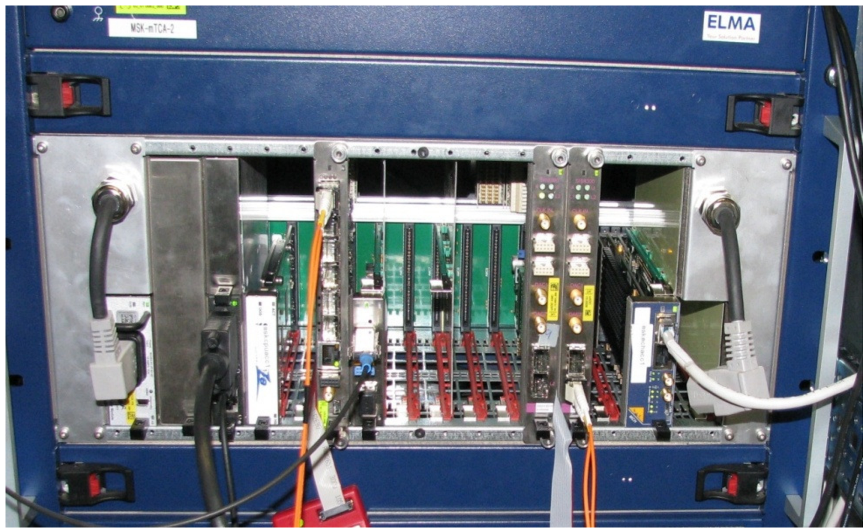


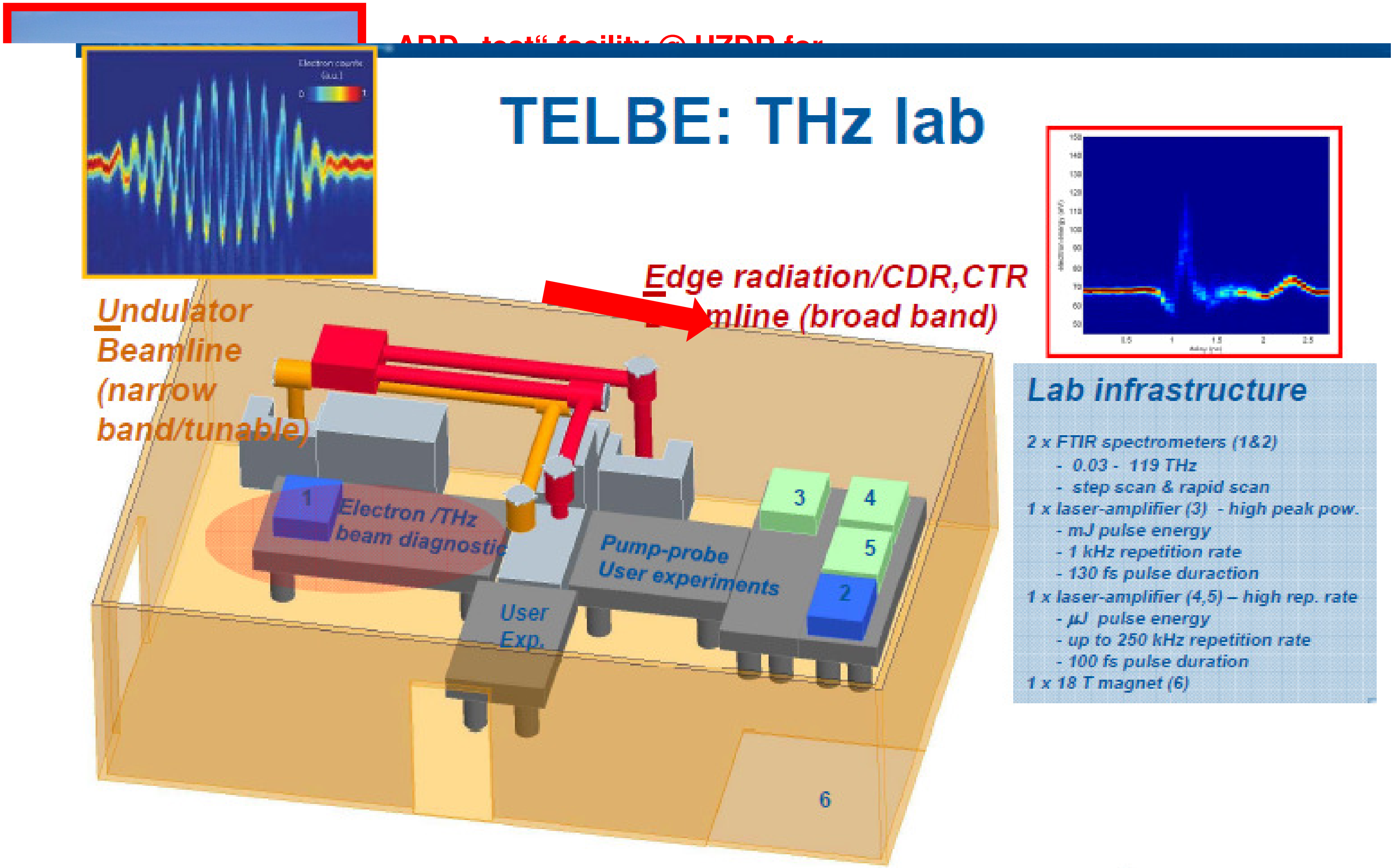
> Developments for FLASH/XFEL: license to industry for production

> Available for any laboratory (up to certain extend support by DESY)

> Other instruments considered to push MTCA.4 standard (validation fond)

Thanks for attention

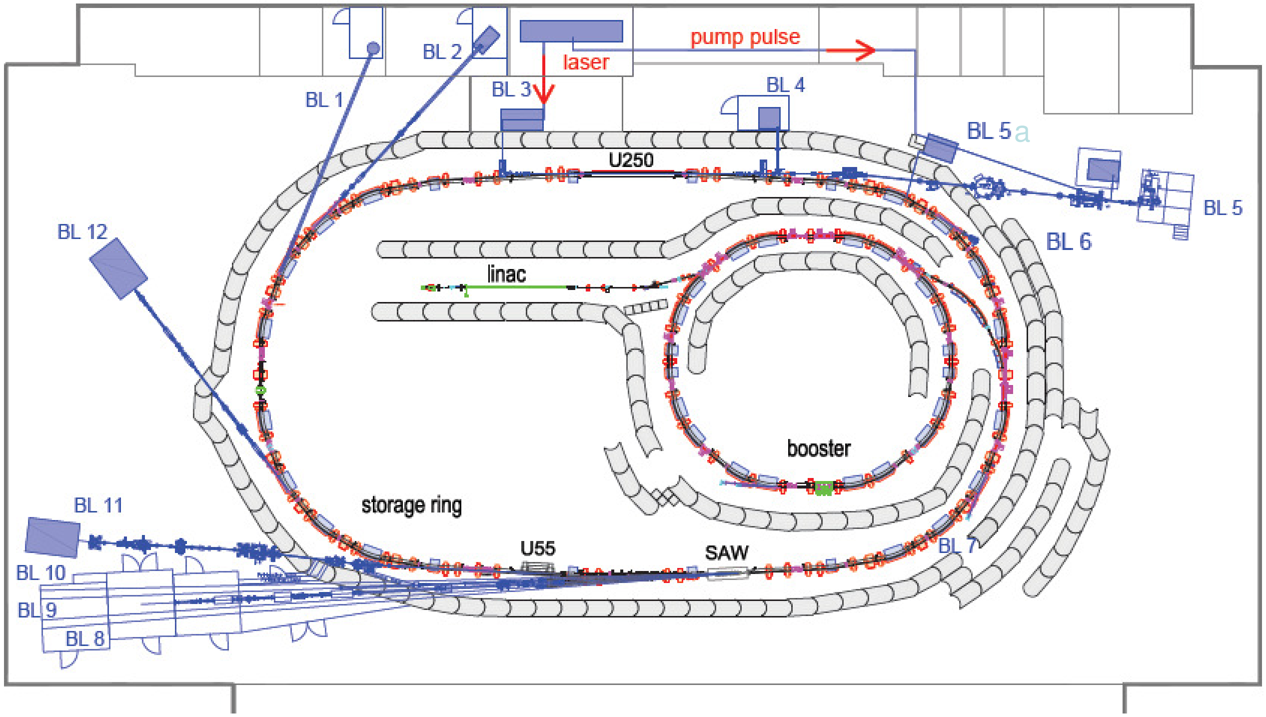
Collaborations: 1. „cw“ electron bunch diagnostic



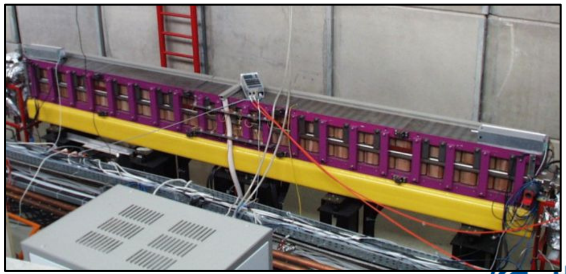
Seeding: EEHG @ DELTA (FZJ & TU-Dortmund)

4. application: "echo-enabled harmonic generation" (EEHG)

2 x energy modulation + coherent harmonic generation



circumference	115.2 m
beam energy	1 GeV
beam current	130 mA
user operation	2000 h/a
machine studies	1000 h/a



PT3: ps – fs Electron and Photon beams
Introduction

From reviewer comments & internal discussions:

>Activities within PT3 should be **reduce** and **focus** to few critical goals of **strategic importance**

- Significant improvement of photon source for user experiments (CW operation, longitudinal coherence, photon pulse stabilization, source characterization)
- Critical technology for long term accelerator development (HTC)
- Substantial visibility within scientific community (X-UV seeding/

>Preferred activities: **directly supporting** ARD programs **PT1/PT2&PT4**

- SRF development => non-interseptive , high rep. rate short pulse diagnostics

>**Optimal use** of **exist research infrastructure** to carry out R&D program (HGF Uebergreifened including Universities)

>High ranking for methodes with industrialization and innovative potential

>Improved **networking** among HGF accelerator research facilities to