

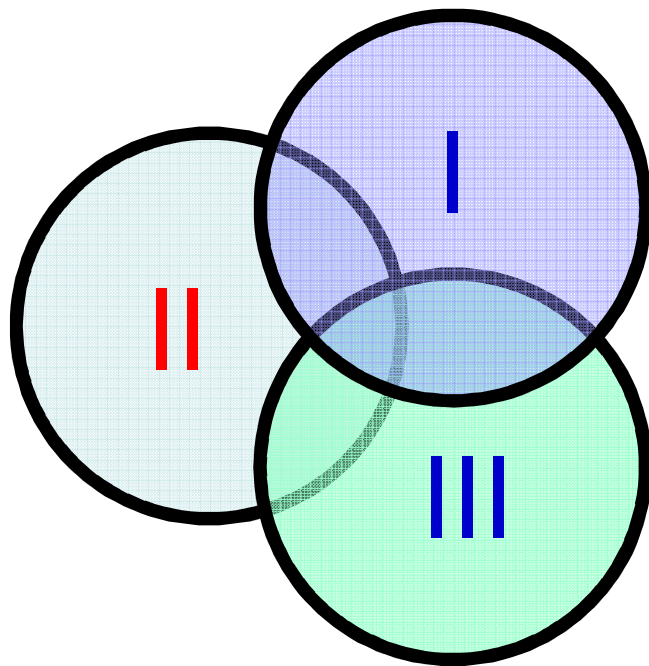
# PT3: ps – fs Electron and Photon beams

## *Subtopic - Ultra fast pulse diagnostic.*

speaker: M. Gensch

AG Coherent THz Radiation

HZDR



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

## II Ultra-fast pulse diagnostics

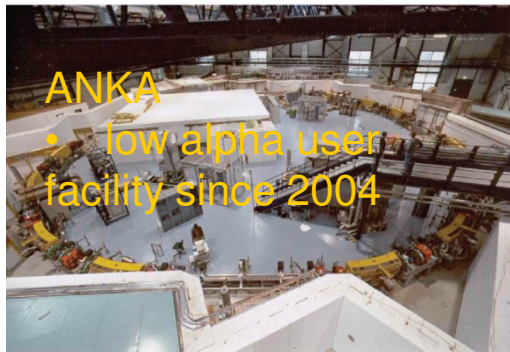
what?	who?	related to
EO techn.	DESY, HZDR, KIT, HZB? (PSI)	
Lasers (EO)	DESY, KIT (PSI)	I
HEBs	KIT, HZB (PTB)	III
Streaking?	DESY, KIT	I
ORS	DESY, KIT, HZB/HZDR (Uppsala, Stockholm, Uppsala)	->PT4
(THz) transport?	all	III
HiRes/fast spectrometers	DESY, HZB, HZDR, KIT	III

**focus on fs diagnostic for future superconducting linacs**

# Focussing within the ARD initiative

- > Improve performance of linac-based photon sources
- > Establish electron bunch diagnostic for future SRF electron accelerators in the HGF (-> PT1)
- > Form collaborations around appropriate “test” facilities for new diagnostic concepts

# existing multi-institutional approach—low alpha storage rings



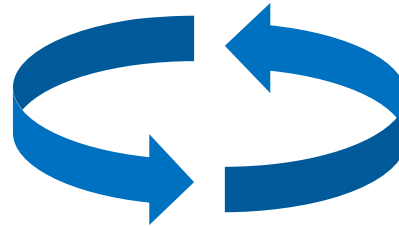
+

potential upgrade with  
*“seeded microstructures”*

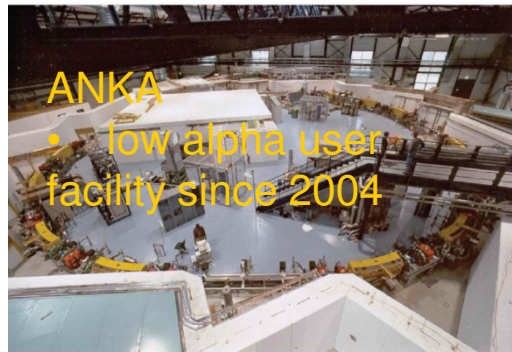


+

potential upgrade to  
*variable pulse length storage ring?*



# existing multi-institutional approach—low alpha storage rings

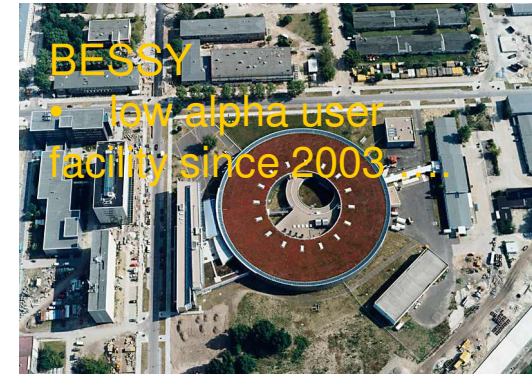


+

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**Goal: optimization of coherent THz radiation from ps – electron bunches for user experiments**



+

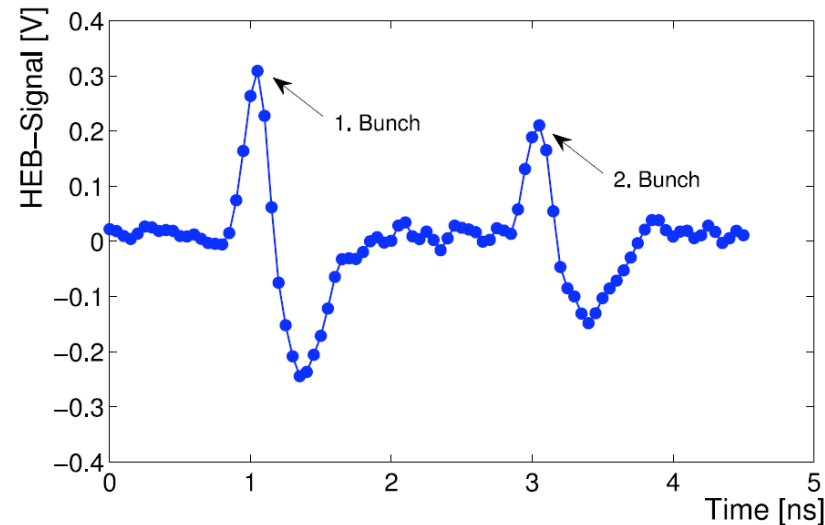
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M. Gensch  
GSI, 21.11.2011

# existing multi-institutional approach—low alpha storage rings

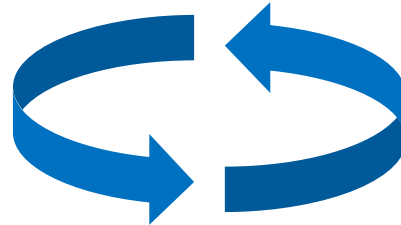
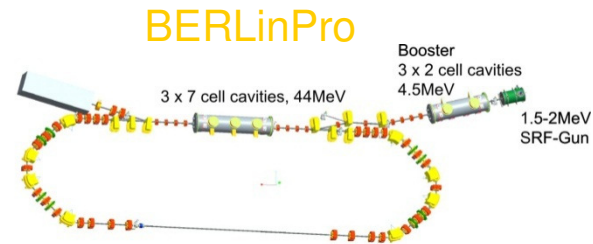
## Hot electron bolometer, electronics and diagnostic methods (KIT, HZB, PTB, DLR, TUDo, TUB, UBo)



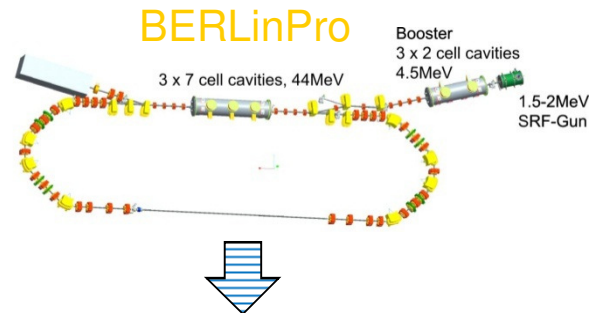
- > FIR detector system with sub 100 ps rise time has been developed
- > allows to resolve individual bunches in multi bunch filling
- ➔ influence of filling pattern can be studied



# challenges and strategic goals - linacs



# challenges and strategic goals - linacs



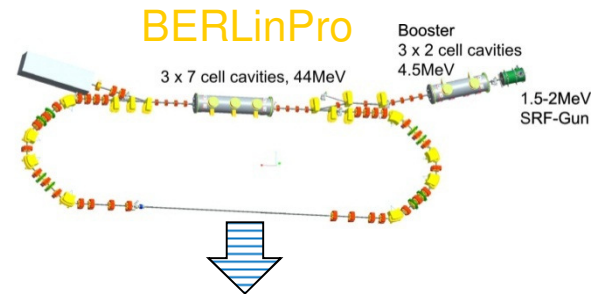
**Goal: improvement  
of photon source properties  
(beyond original design)**

**-> diagnostic & feedbacks  
essential!**





# challenges and strategic goals - linacs

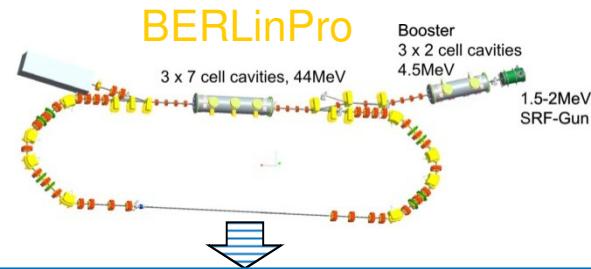


**fs diagnostic of:**

- Electron bunch form
  - Electron bunch arrival time
  - X-ray/THz pulse form
  - X-ray/THz arrival time
- > preferable non invasive and suitable for feedbacks**



# challenges and strategic goals - linacs



## Techniques for fs diagnostic:

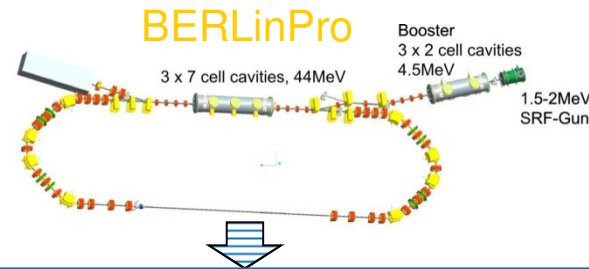
**electrons:** *transverse deflecting cavity, BAM, BCM, electro-optic sampling, THz frequency analysis, optical replica synthesizer,....*

**THz:** *spectroscopy (FTIR, grating & time-domain), electro-optic sampling*

**X-rays:** *autocorrelators, crosscorelators, photoelectron streaking, optical afterburner..*



# challenges and strategic goals - linacs



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## X-ray FELs/coherent THz source

*userfacility*

- advanced single pulse/high charge diagnostic in routine operation
- primarily high charge (> 100 pC)
- interested in long pulse train/low charge diagnostic

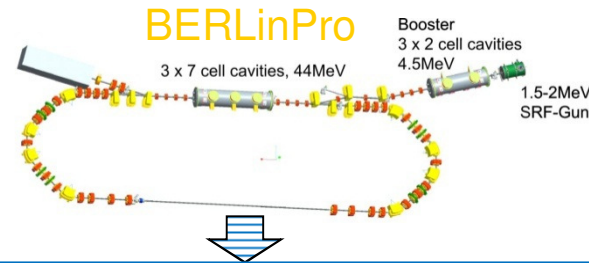


## ELBE:

- low charge/long pulse train
- ps diagnostic in operation (ELBE)
- interested in fs diagnostic for low and high charge + interest in advanced diagnostic for long pulse trains/cw



# challenges and strategic goals - linacs



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**HZDR**

**GSI**

**HZB** Helmholtz  
Zentrum Berlin



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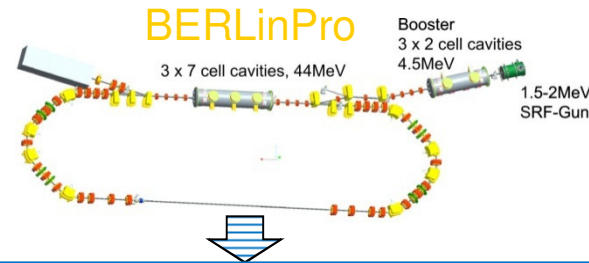
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focus on noninvasive techniques  
suitable for „quasi“ cw SRF accelerators



**HELMHOLTZ**  
GEMEINSCHAFT

# fs diagnostic in electron linacs: - multi institutional approach



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## X-ray FELs/coherent THz source userfacility

- advanced single pulse diagnostic in routine operation
- primarily high charge (> 100 pC)
- interested in long pulse train/low charge diagnostic



## FLUTE

*ideal „test“ bed for high charge single bunch diagnostic*

## ELBE/TELBE:

*ideal „test“ bed for low-high charge, single – macrobunch – cw bunch train diagnostic*

focus on noninvasive techniques  
suitable for „quasi“ cw SRF accelerators

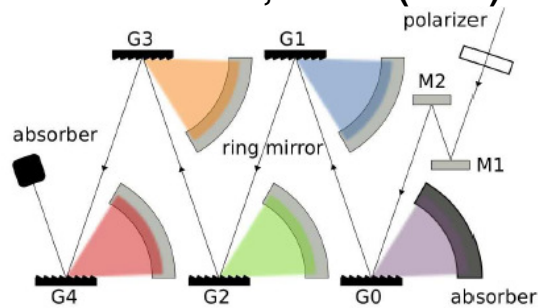


# fs e-bunch diagnostic: coherent THz frequency analysis

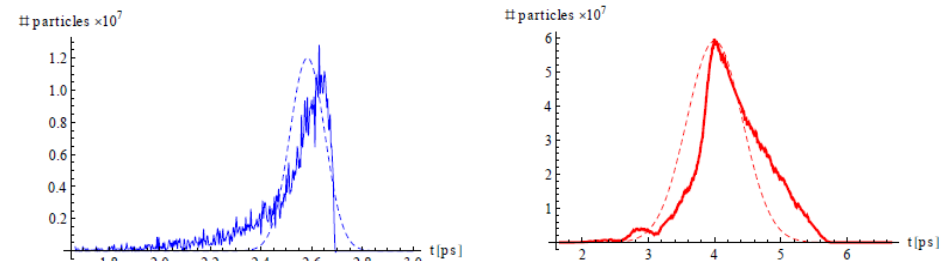
## Example: Multi-channel THz and IR spectrometer (DESY)

-> transfer to other interested facilities (e.g. HZDR, KIT, ...)

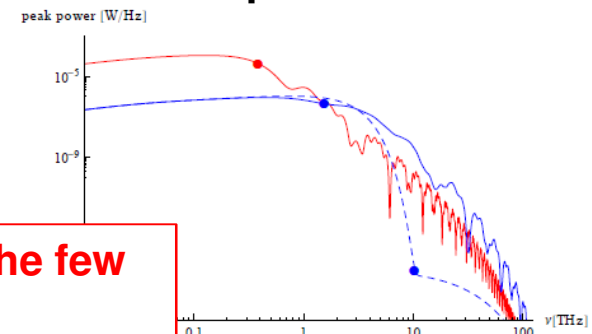
### Design and Performance S. Wesch et. al., NIM A (2011).



### longitudinal electron bunch form (simul. for FLUTE, S. Naiknaimueang et. al., IPAC.Proc 2011)



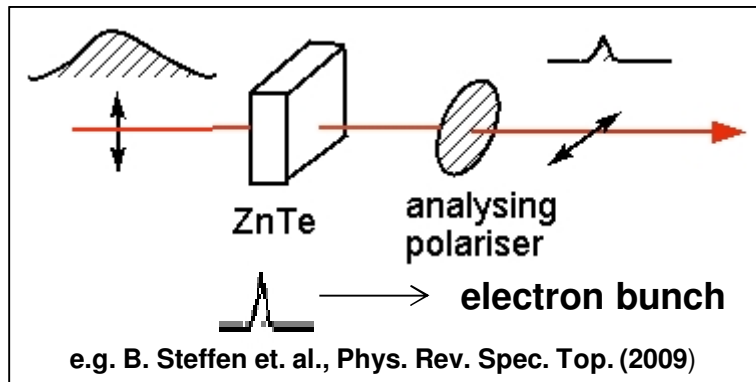
### THz spectra



**allows to resolve structures on the few femtosecond timescale!**

# fs e-bunch diagnostic: current ARD focus e/o monitors

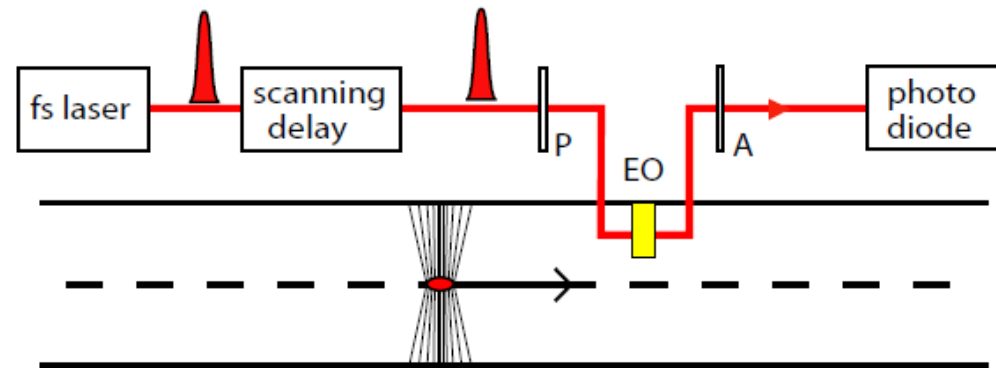
## principle:



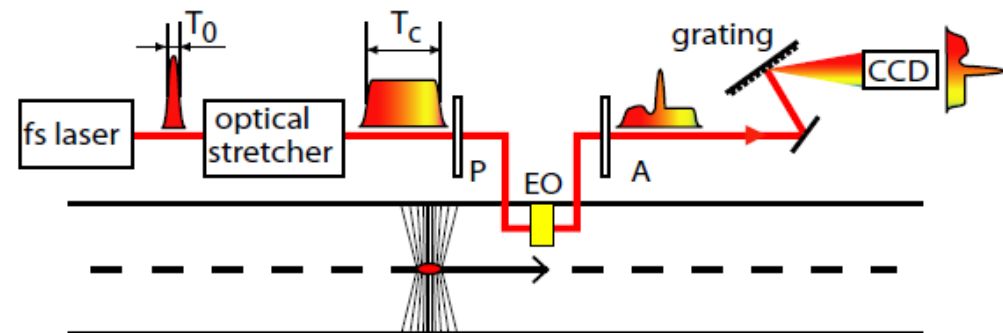
## future developments:

- > design more robust monitors
- > optimize time resolution
- > increase sensitivity for low charge diagnostic
- > utilize for feedbacks (slow & fast)

## using variable delay -> mean bunch properties:

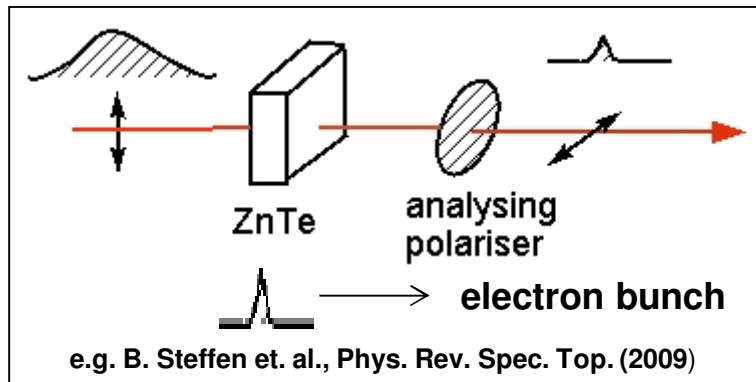


## single pulse diagnostic: e.g. spectral decoding



# fs e-bunch diagnostic: current ARD focus e/o monitors

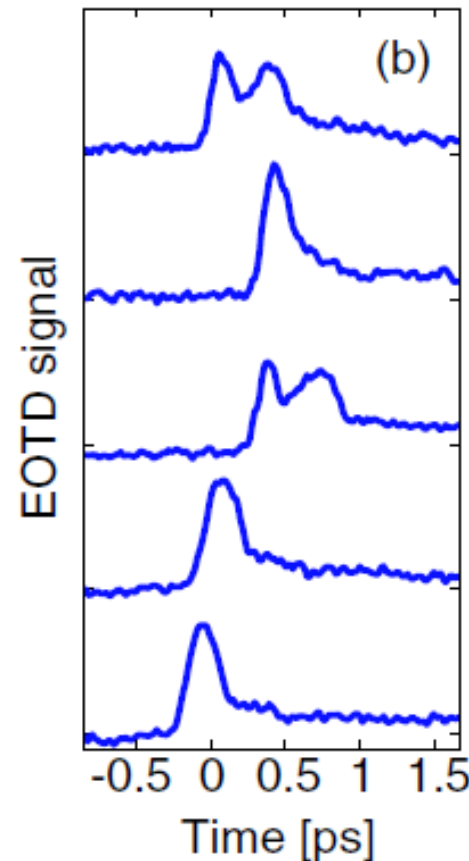
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## future developments:

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can serve as monitor for electron bunch form & arrival time (DESY, FOM, Daresbury + Univ.)



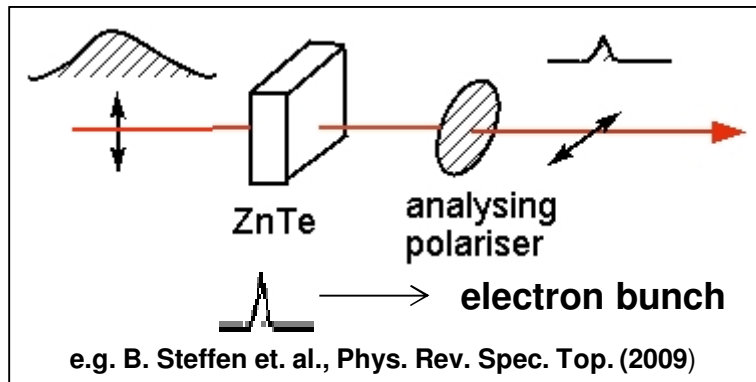
State of the art:

>  $\sim 60$  fs resolution  
(BW:  $< 8$  THz)

*comparison BAM:*  
-> BW:  $\sim 40$  GHz

# fs e-bunch diagnostic: current ARD focus e/o monitors

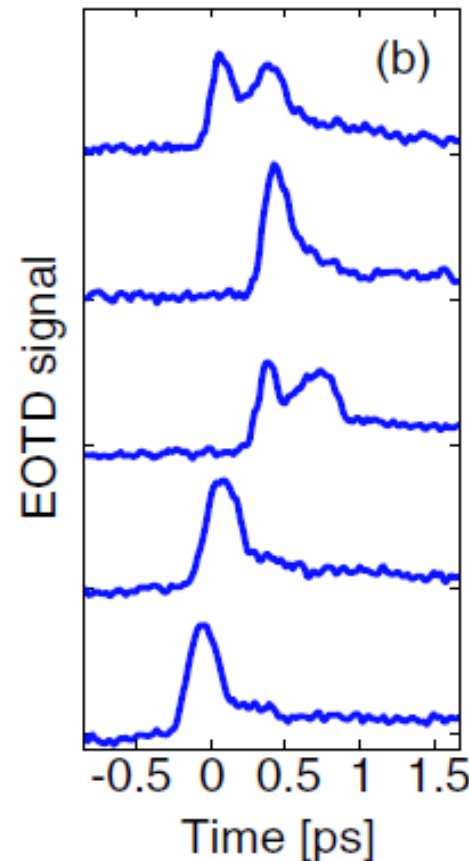
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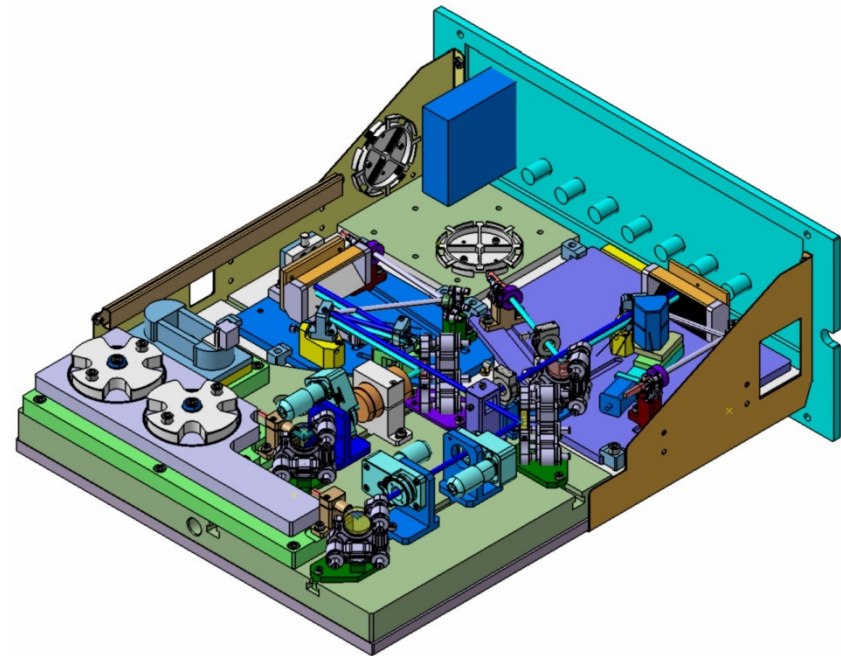
> ~ 60 fs resolution  
(BW: < 8 THz)

*comparison BAM:*  
-> BW: ~40 GHz

# fs e-bunch diagnostic: current ARD focus e/o monitors

## custom made Yb-Fiber laser system for EO monitors (DESY, KIT, PSI) -> transfer to HZDR/HZB

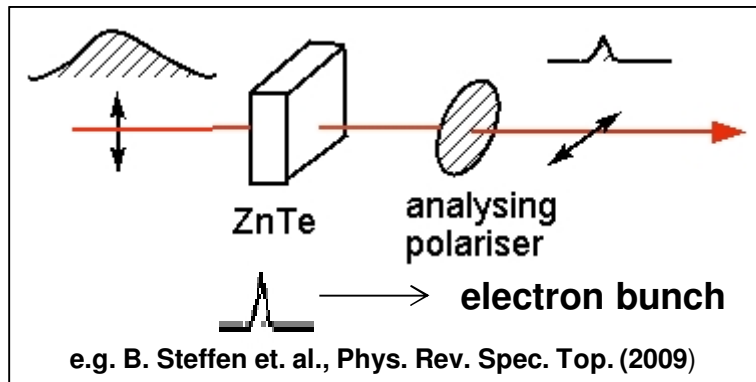
- > Oscillator with free space dispersion compensation
- > Breathing system → pulse duration > fourier limit
- > Non-linear amplifier to increase pulse power and bandwidth





# fs e-bunch diagnostic: current ARD focus e/o monitors

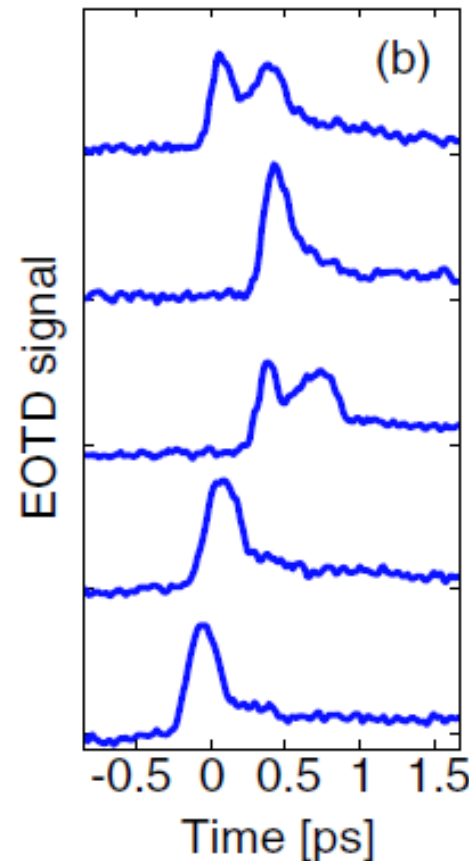
## principle:



## existing challenges:

- > design more robust monitors
- > optimize time resolution
- > increase sensitivity for low charge diagnostic
- > utilize for feedbacks (slow & fast)

can serve as monitor for electron bunch form & arrival time (DESY, FOM, Daresbury + Univ.)



State of the art:

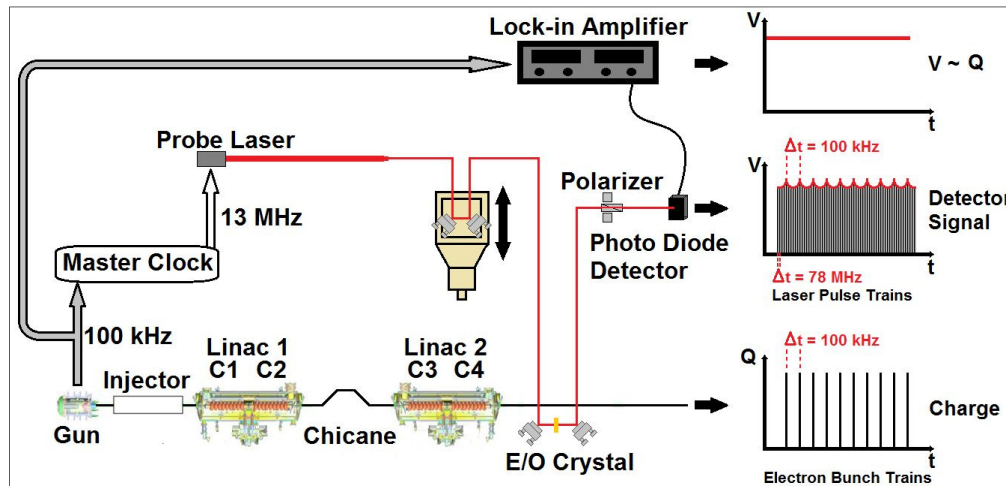
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(BW: < 8 THz)

*comparison BAM:*  
-> BW: 40 GHz

# fs e-bunch diagnostic: current ARD focus e/o monitors

## Development of concepts for E/O based feedback at high rep rate accelerators (DESY, HZDR) -> transfer to HZB, KIT

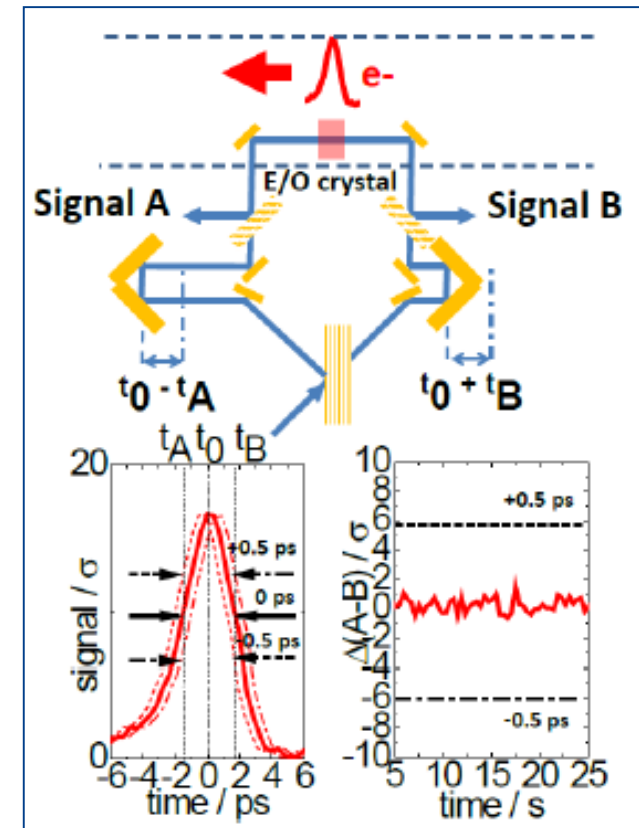
example: concept for cw e/o monitor



> measurement of sub pico-coulomb charges

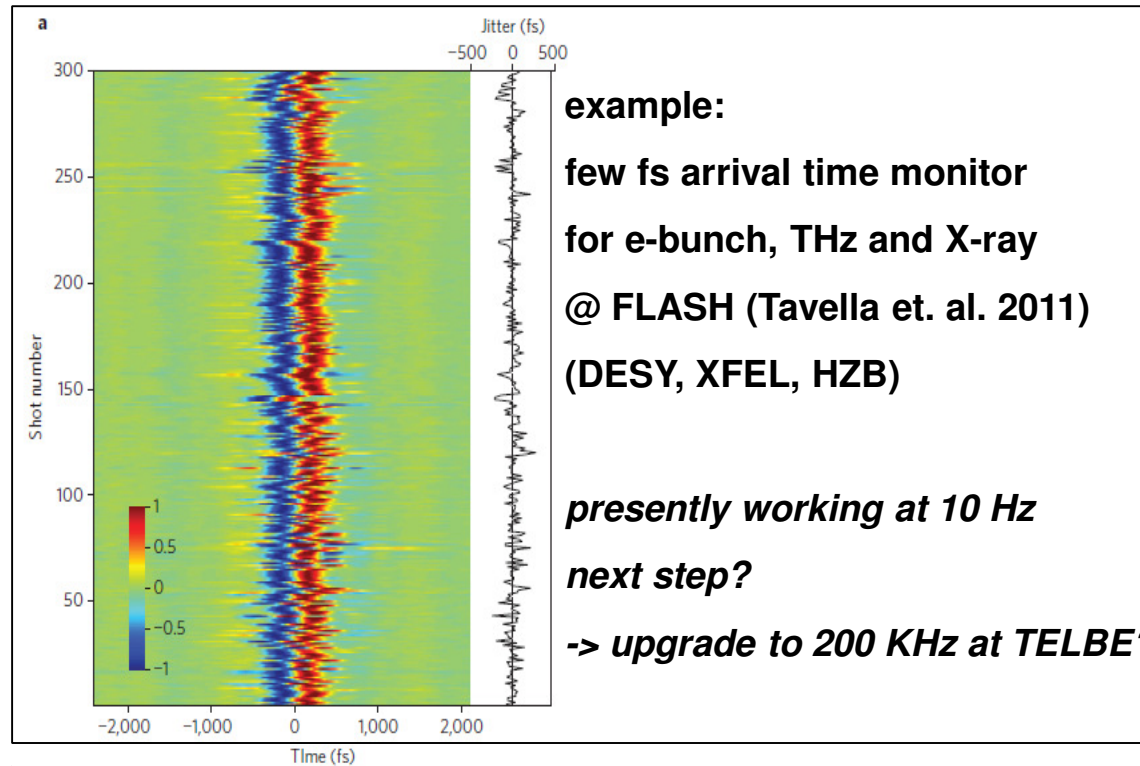
> suitable for slow feedback

➡ *far goal is fast feedback and single bunch /pulse diagnostic at high rep rates (KHz – MHz)*

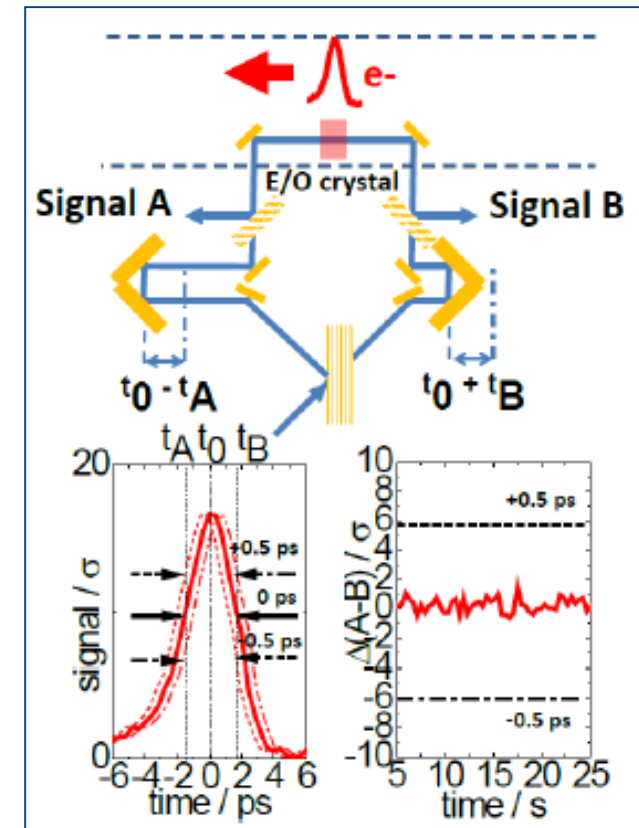


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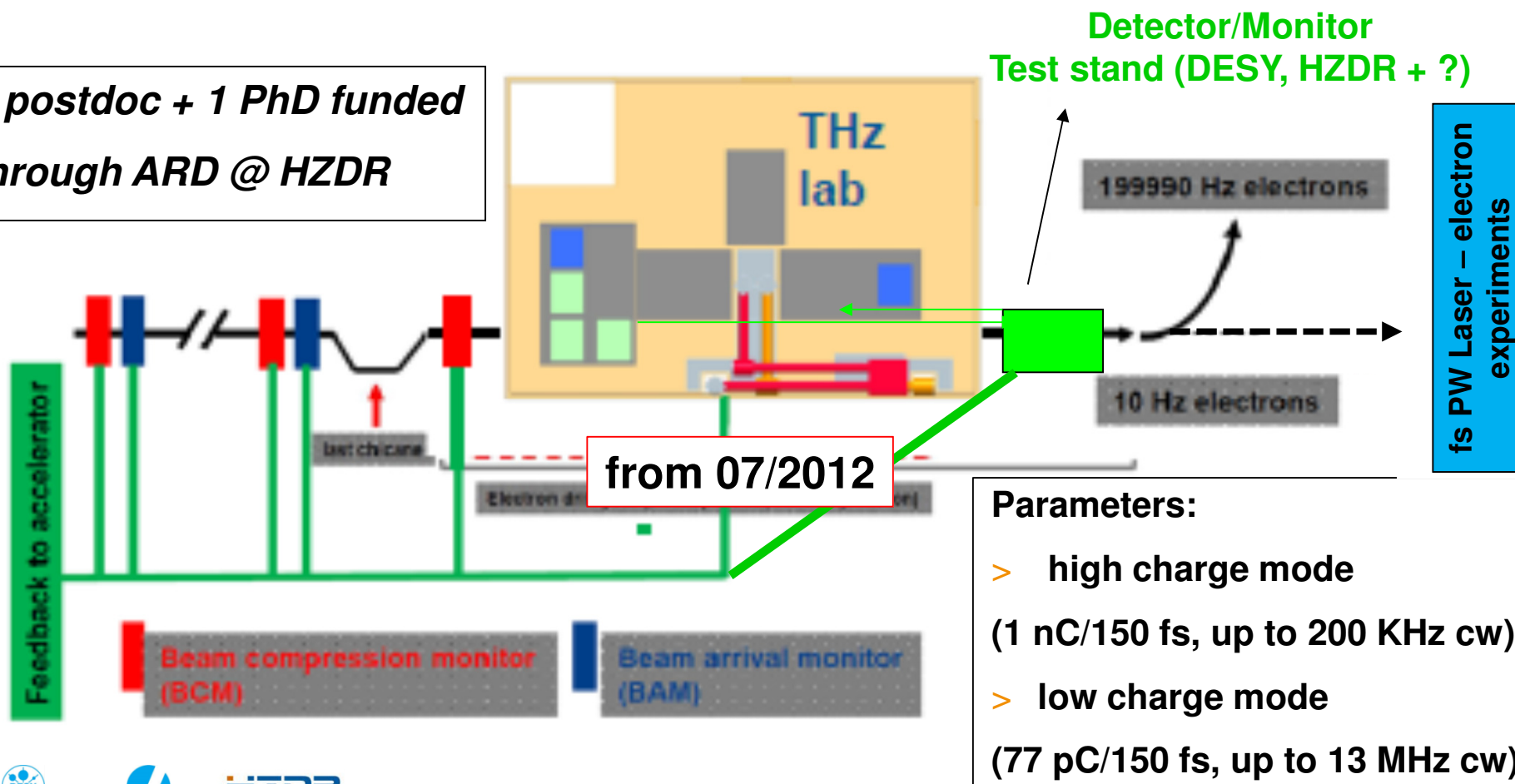
➡ far goal is fast feedback and single bunch /pulse diagnostic at high rep rates (KHz – MHz)



# fs e-bunch diagnostic: current ARD focus e/o monitors

Test beam for high rep-rate fs – electron bunch trains @ HZDR  
-> open for interested HGF institutes

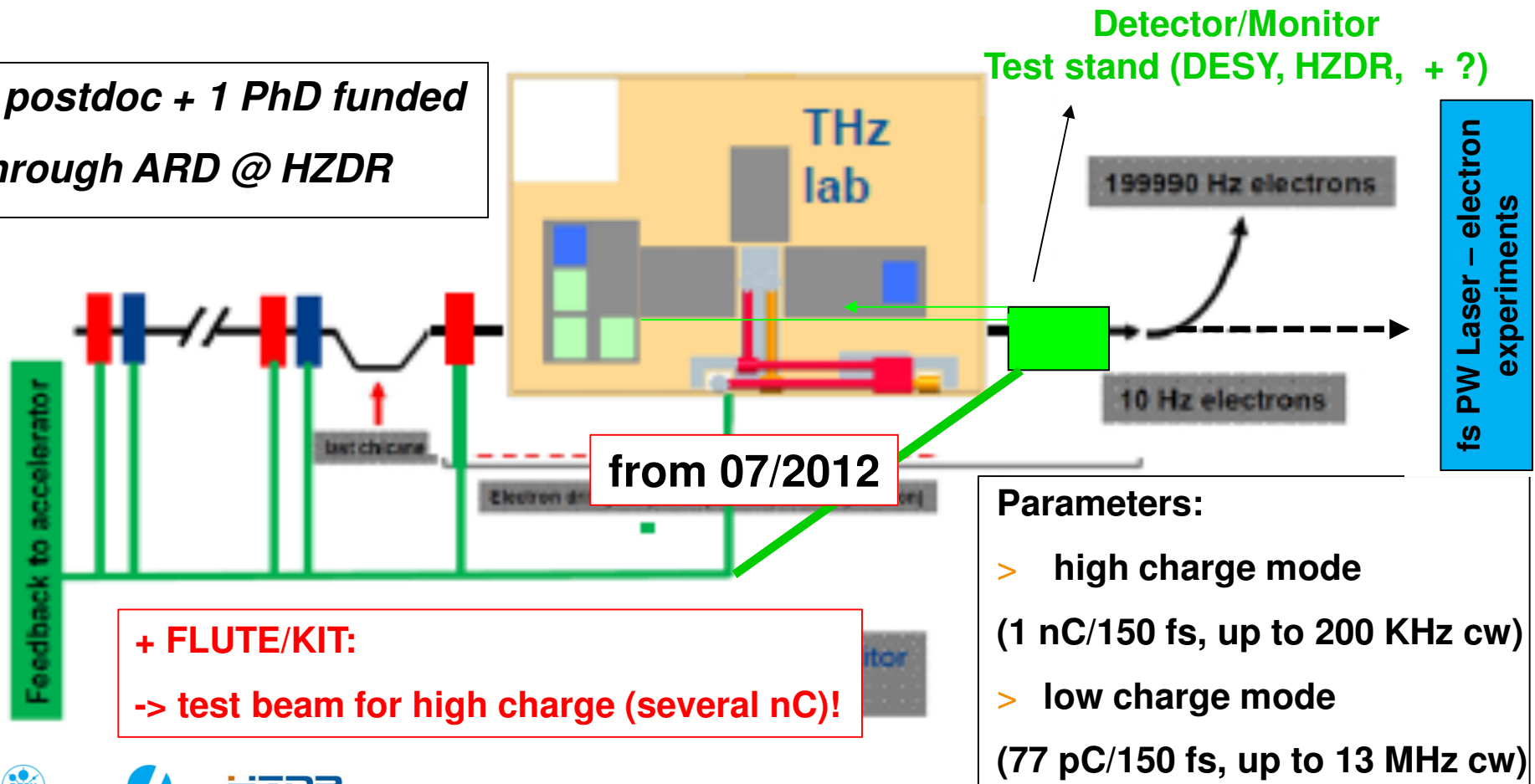
*1 postdoc + 1 PhD funded  
through ARD @ HZDR*



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# Focussing within the ARD initiative

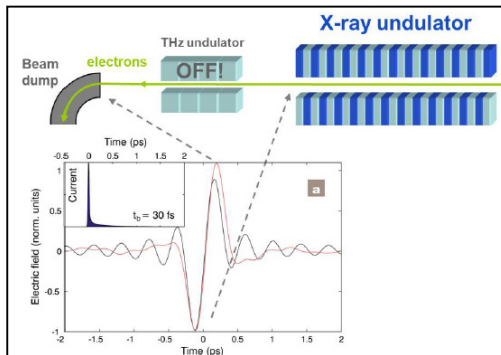
- > Improve performance of linac-based photon sources
- > Establish electron bunch diagnostic for future high rep-rate SRF accelerators in the HGF (PT1)
- > Form collaborations around appropriate test facilities for new diagnostic concepts

# fs diagnostic in electron linacs: - multi institutional approach

## first hand experience & exchange of expertise example: DESY & HZDR

### Topics:

- electron beam dynamics
- electron bunch diagnostics
- THz pulse diagnostic
- X-ray pulse diagnostic
- *synchronization/timing*

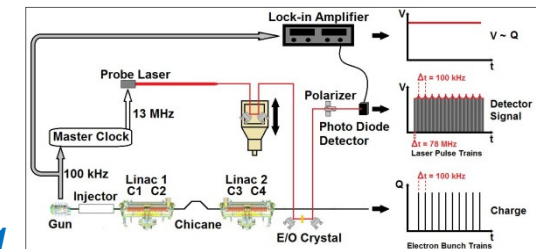


prototype monitors for arrival  
time + form of X-rays and e- bunches

01/2011 – 11/2011:

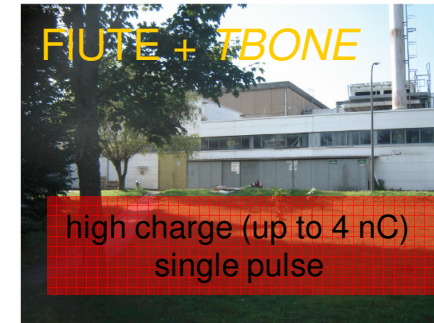
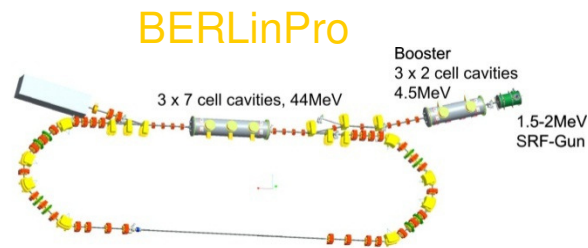
- participation in more than 25 shifts  
@ ELBE and FLASH
- several joint publications &  
conf. contribut.

Cooperation agreement: *will be signed in 2011*



prototype monitor for electron  
bunch form and arrival time in  
cw linacs

# fs diagnostic in electron linacs: - multi institutional approach



Thank You for  
the attention

