MULTI-BUNCH BEAM DYNAMICS STUDIES IN THE EUROPEAN XFEL

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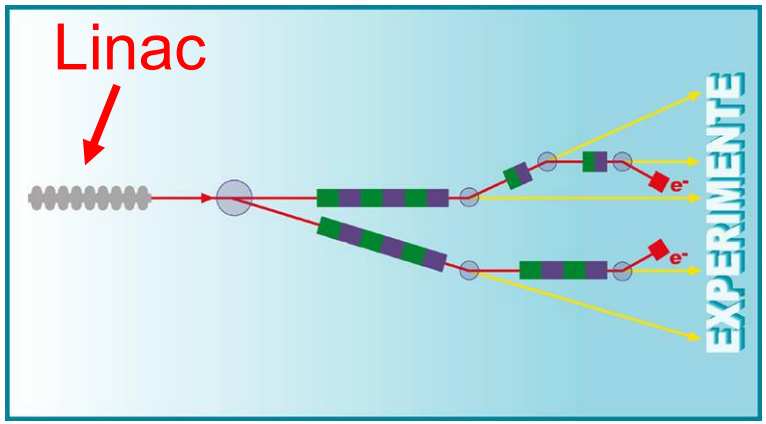
TUP41

Linac for the European XFEL

- X-ray Free Electron Laser
  - MO102 – Reinhard Brinkmann
  - initially developed in conjunction with the TESLA project

TESLA



http://www.desy.de/pr-info/desyhome/gfx/presse/fotos/xfel/300dpi/xfel_schema.jpg

- Linac
  - > 1.5 km, containing almost 1000 TESLA superconducting, 1m long cavities
  - Various beam structure

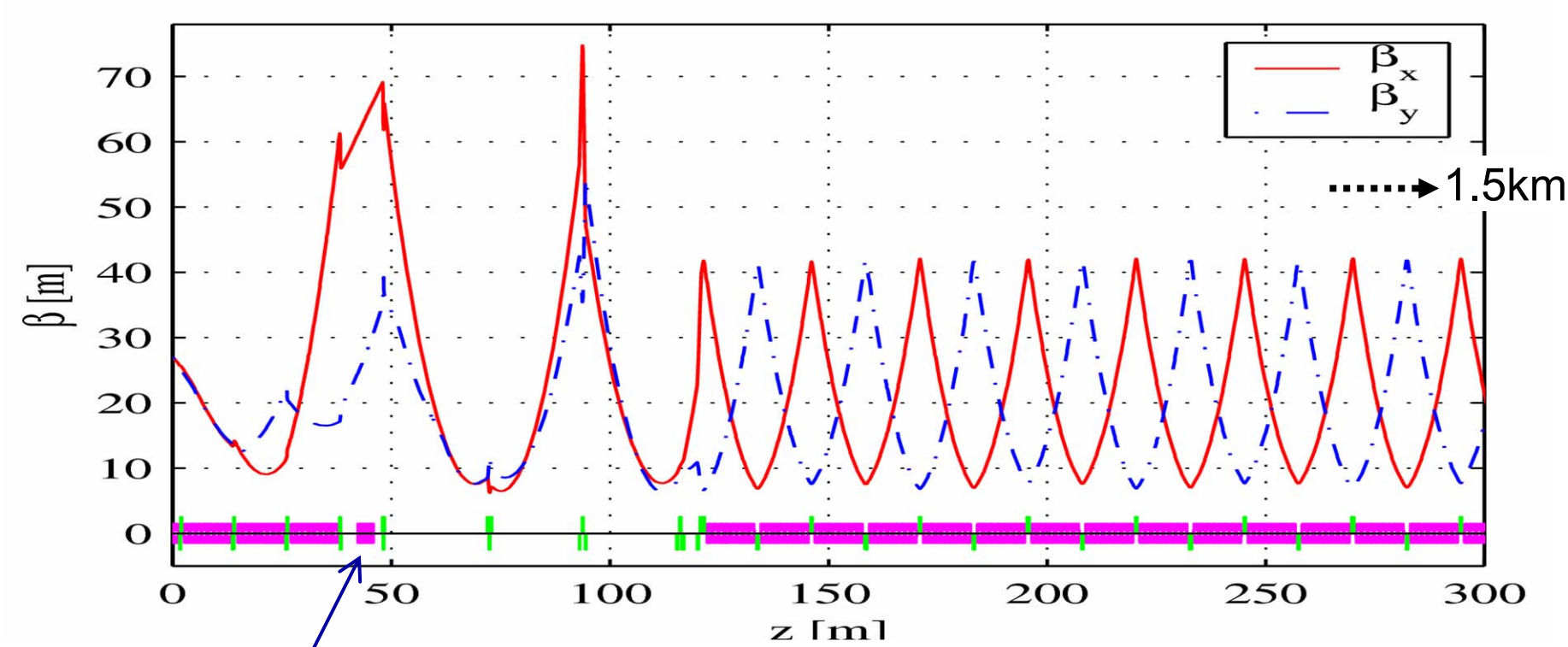
Energy	10-20 GeV
Charge	1 nC
Pulse length	≤ 800 μs
Bunch spacing	≥ 200 ns
Number of bunches per train	≤ 4000

Multi-Bunch Beam Dynamics

- Electron beam quality is important
- Long-range wakefield effects
  - may dilute beam quality
  - **how critical are wakefield effects for the XFEL?**
- From the extensive simulations made for the TESLA linear collider

  $\Rightarrow$ many conclusions on the XFEL dynamics
  - relaxed beam and requirements, e.g.
    - smaller bunch charge
    - higher design normalized emittance ($1.4 \cdot 10^{-6}$ vs. $3 \cdot 10^{-8}$ m·rad)
  - however, there are significant differences, e.g.
    - low energy of the beam – stronger kicks from wakes
    - different bunch train structure
- Therefore simulations for the XFEL were desirable

XFEL Linac Layout



module with eight
3.9 GHz cavities

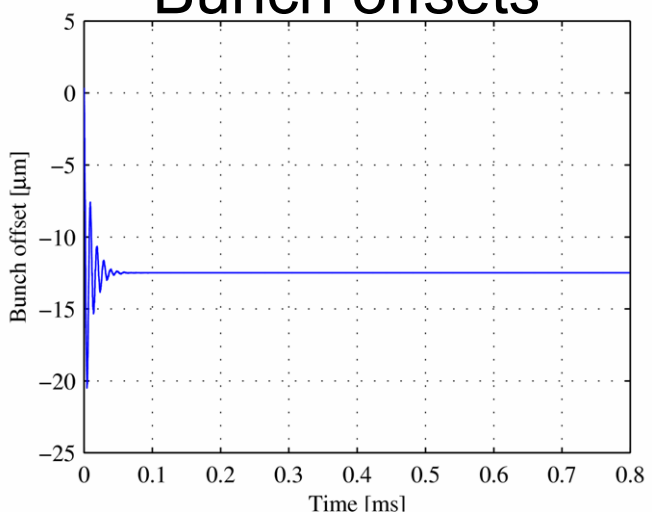
2 bunch
compressors

FODO cells:
2 cryo-modules
8 cavities / module

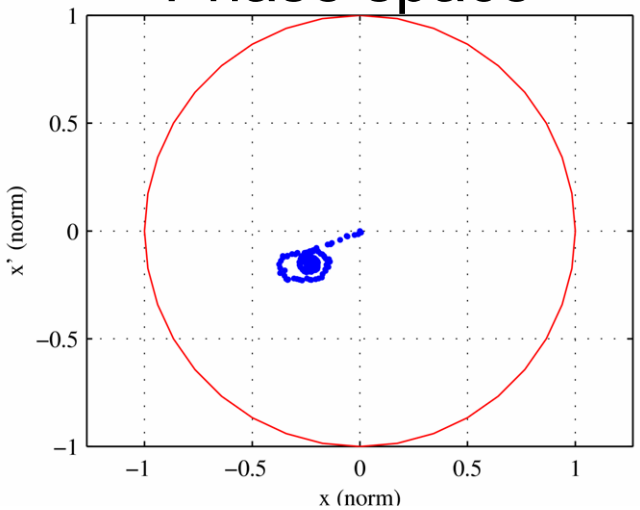
Simulations

- Specifications
  - cavity misalign. 500 μm rms
  - HOM detuning 0.1% rms
- Dip. passbands 1-3
- 200 ns bunch spacing (min)
- 800 μs length (max)
- energy 20 GeV (max)

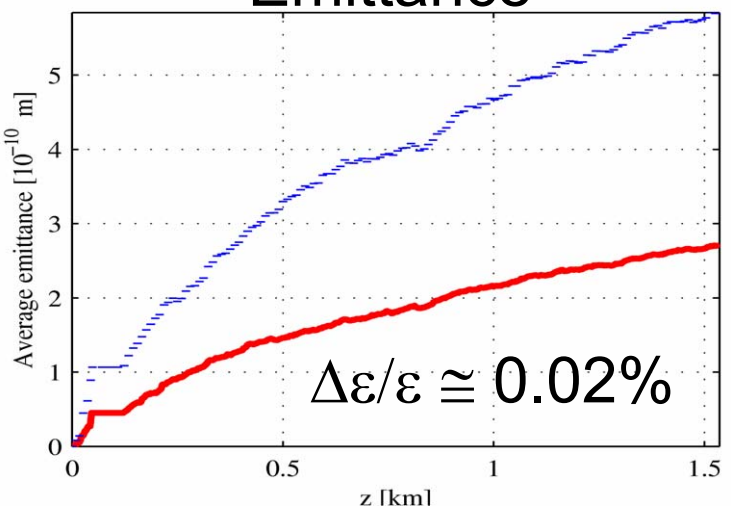
Bunch offsets



Phase space



Emittance



Simulations (2)

- Higher emittance for short bunch trains, low spacing and low energy
- Energy spread
  - 5.15 MeV rms for 20 ns pulse
  - 17 MeV peak-to-peak

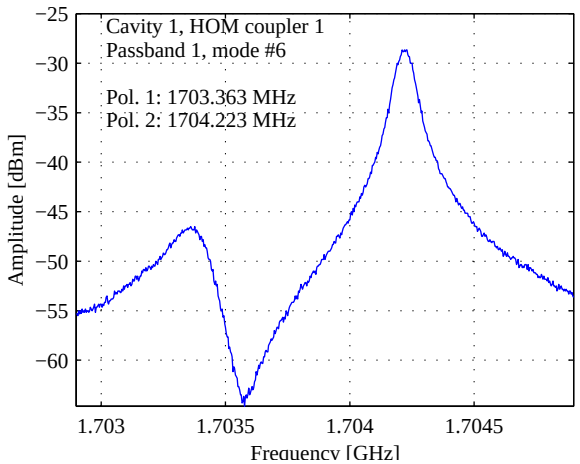
Emittance growth (%)

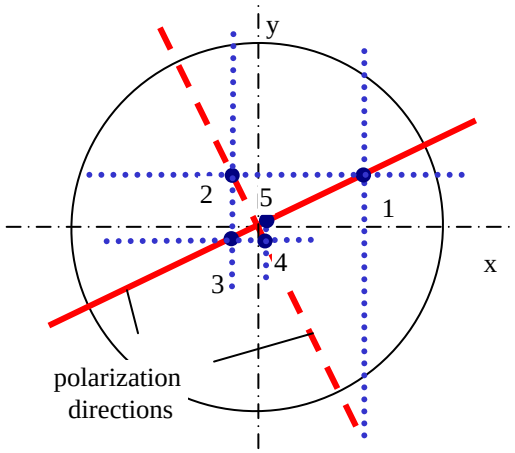
Spacing [ns]	Bunch train length [μs]		
	800	120	20
200	0.017	0.11	0.62
400	0.003	0.022	0.11
337	0.0005	0.003	0.016

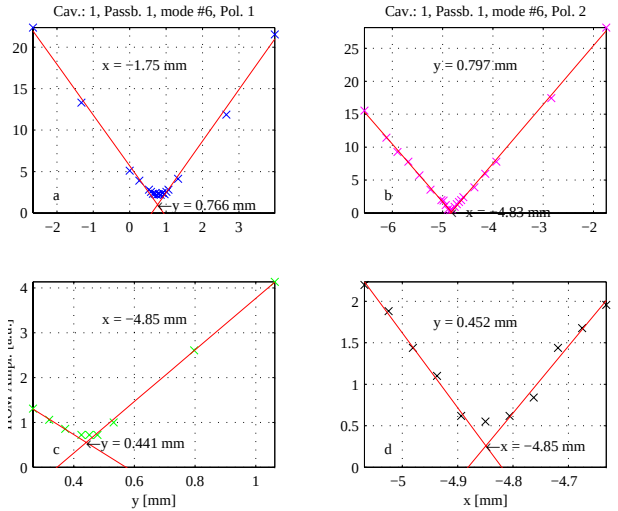
- If concern for users with some pulse structures
  - can kick away the first part of the train
  - due to the static nature of the multi-bunch effects, as shown for TESLA $\rightarrow$ can compensate with feedback system

Related Posters – Beam alignment in TESLA Cavities

- Beam alignment
  - Studies on alignment in the TESLA cavities based on the signals from the HOM couplers started at TTF2 @ DESY
  - Should improve further the beam quality
  - **MOP36**
    - O. Napoly, M. Wendt – present at the conference

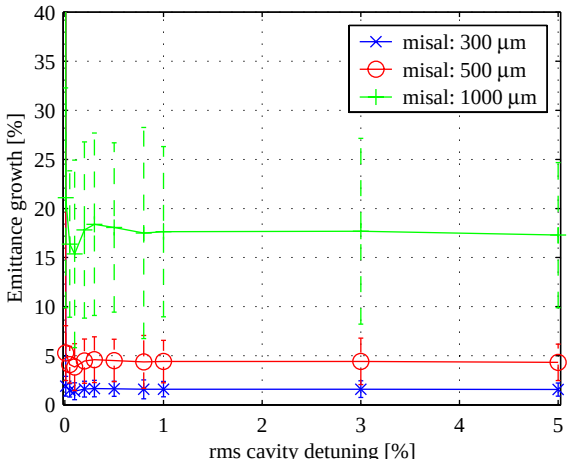


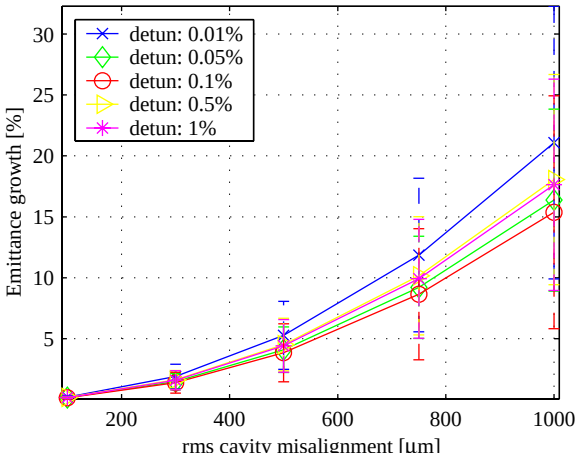




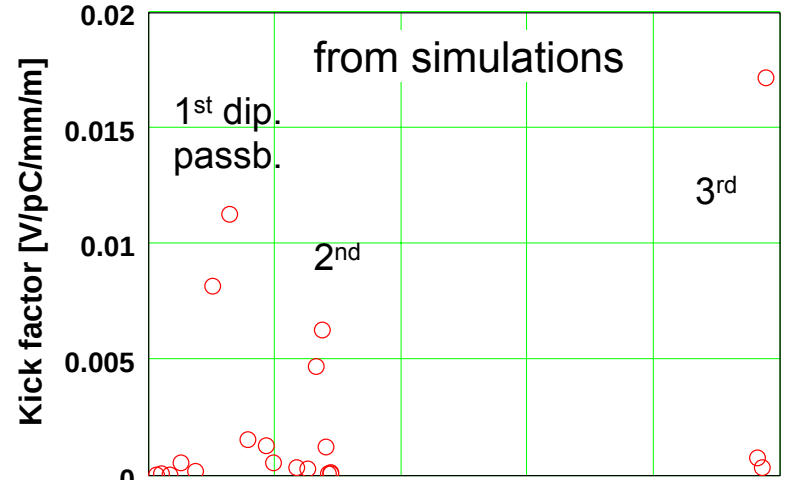
Related Posters – Tolerances in TESLA (and XFEL)

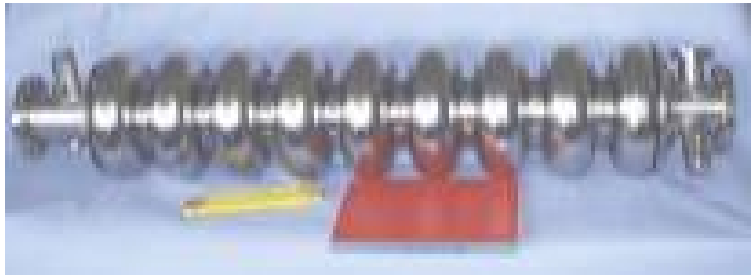
- Specification: misalign. 500 μm rms; detuning 0.1% rms
- Frequency spread measured in TTF cavities
  - 0.05…0.45% rms, depending on the mode
- Study of sensitivity to tolerances
- **MOP41**
  - R.M. Jones – present at the conference





Wakefields and Higher Order Modes (HOM) in the TESLA Cavities





TESLA Cavity