Accelerator Layout and Parameters

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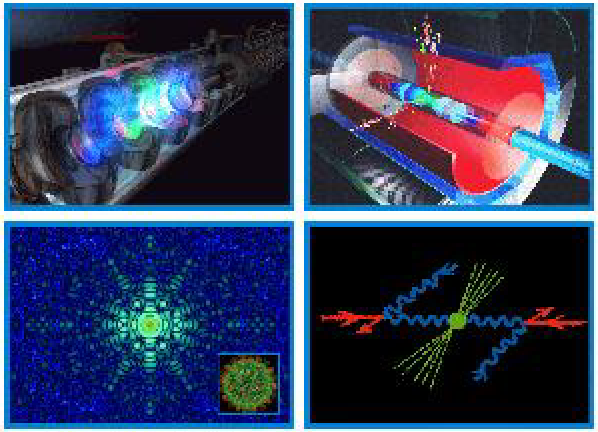
TESLA TDR March 2001: *integrated* XFEL

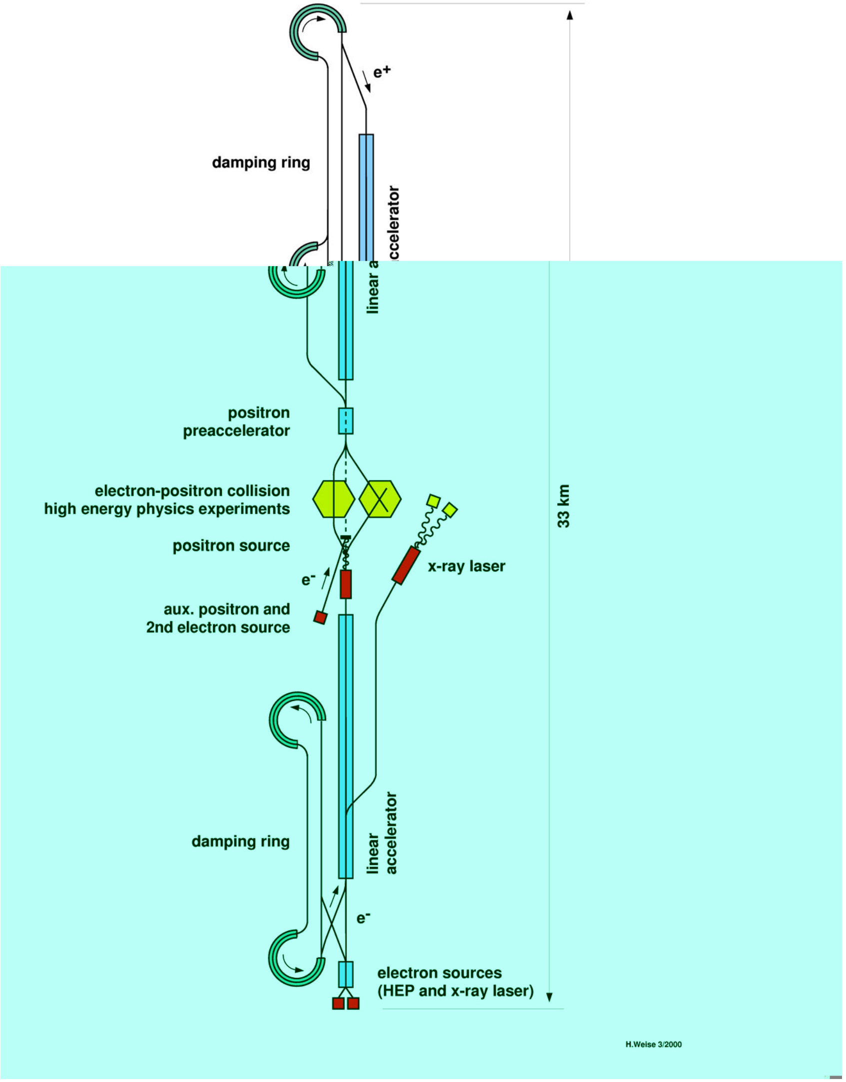
TESLA

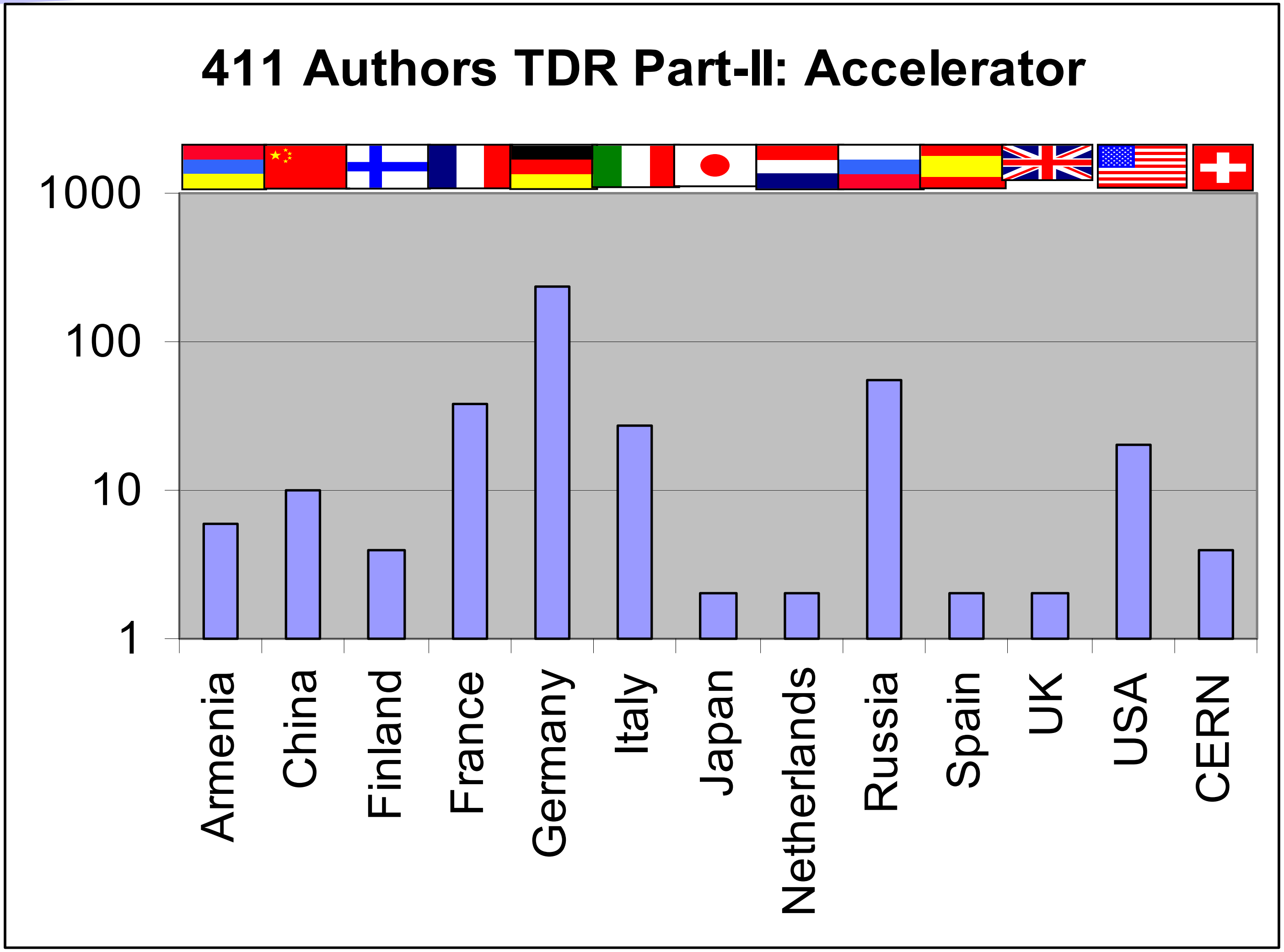
The Superconducting Electron-Positron Linear Collider

with an Integrated X-Ray Laser Laboratory

Technical Design Report






411 Authors TDR Part-II: Accelerator
1000
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Armenia
China
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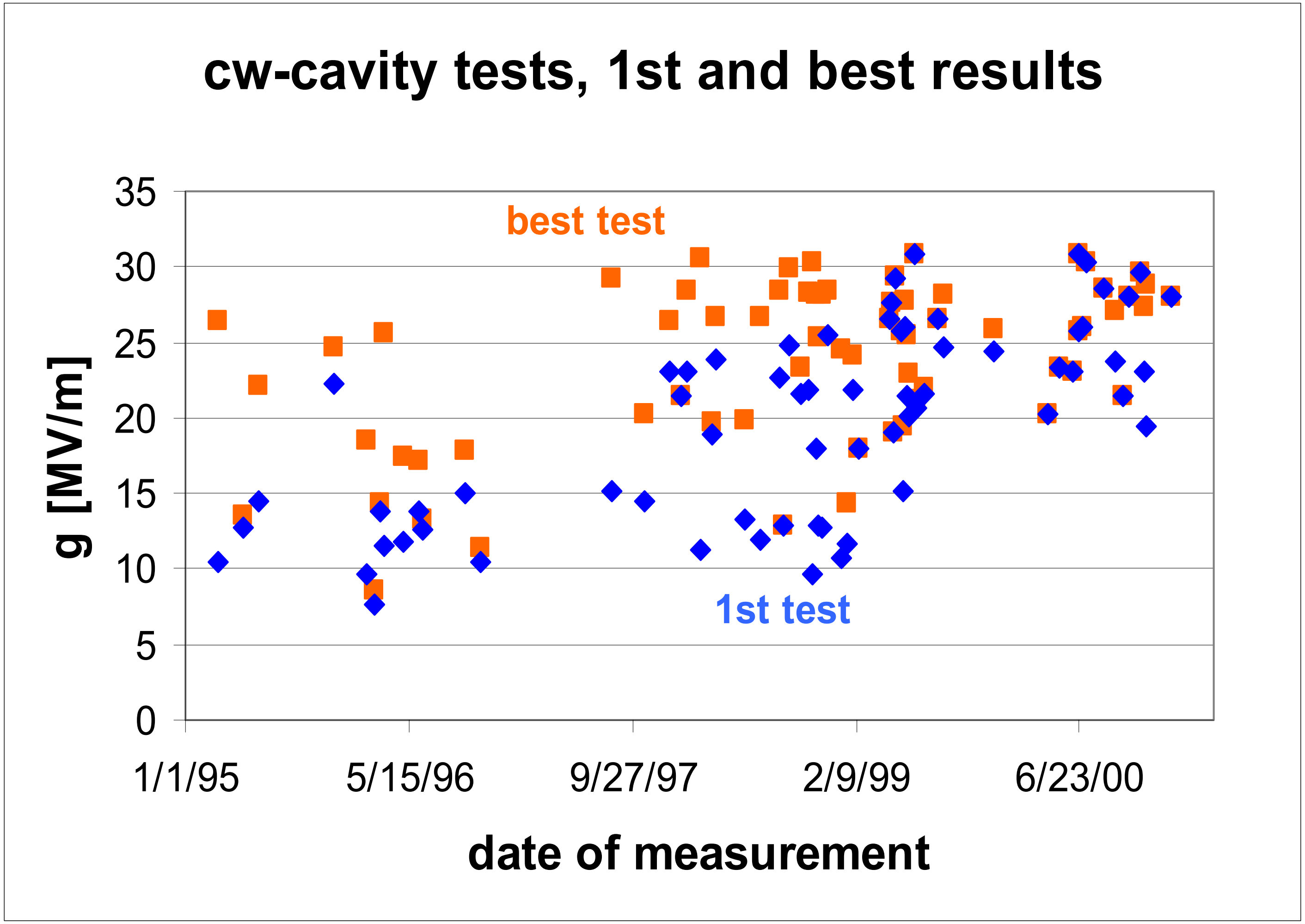
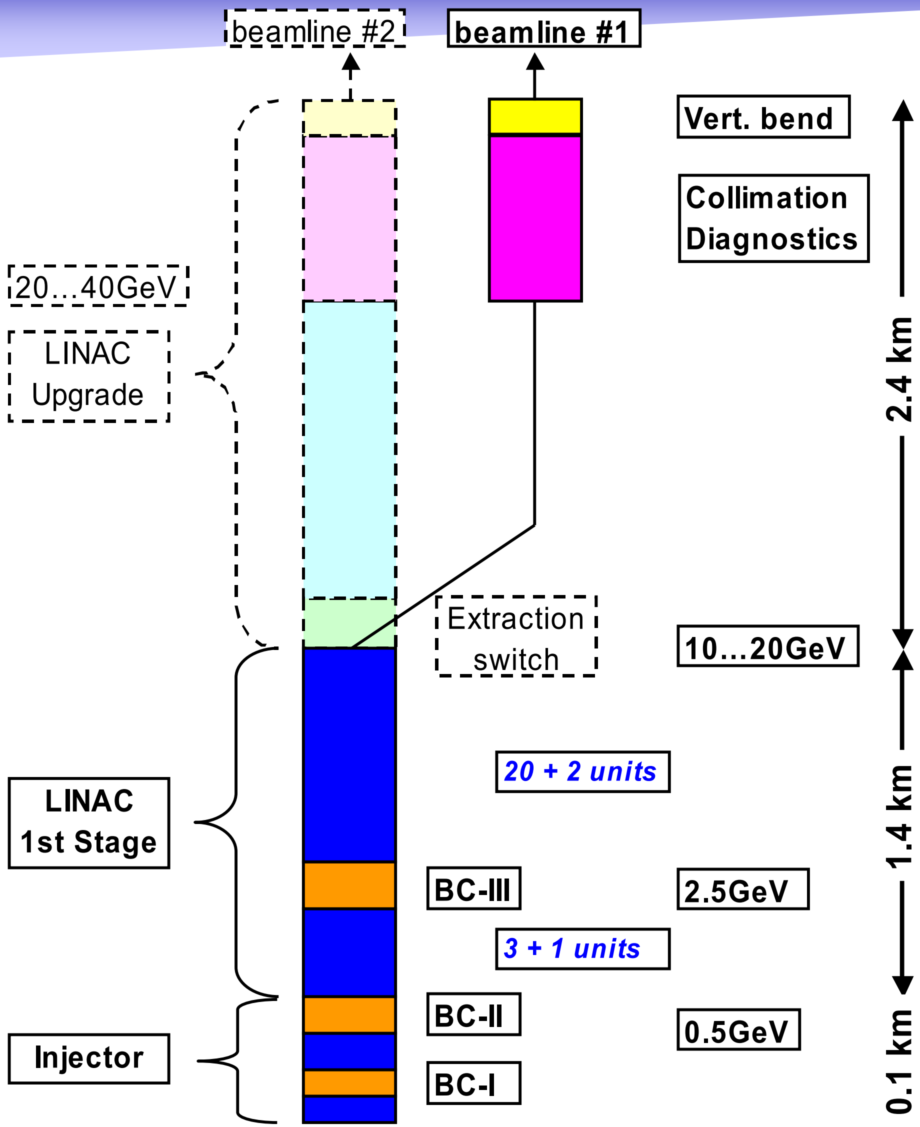
USA
CERN

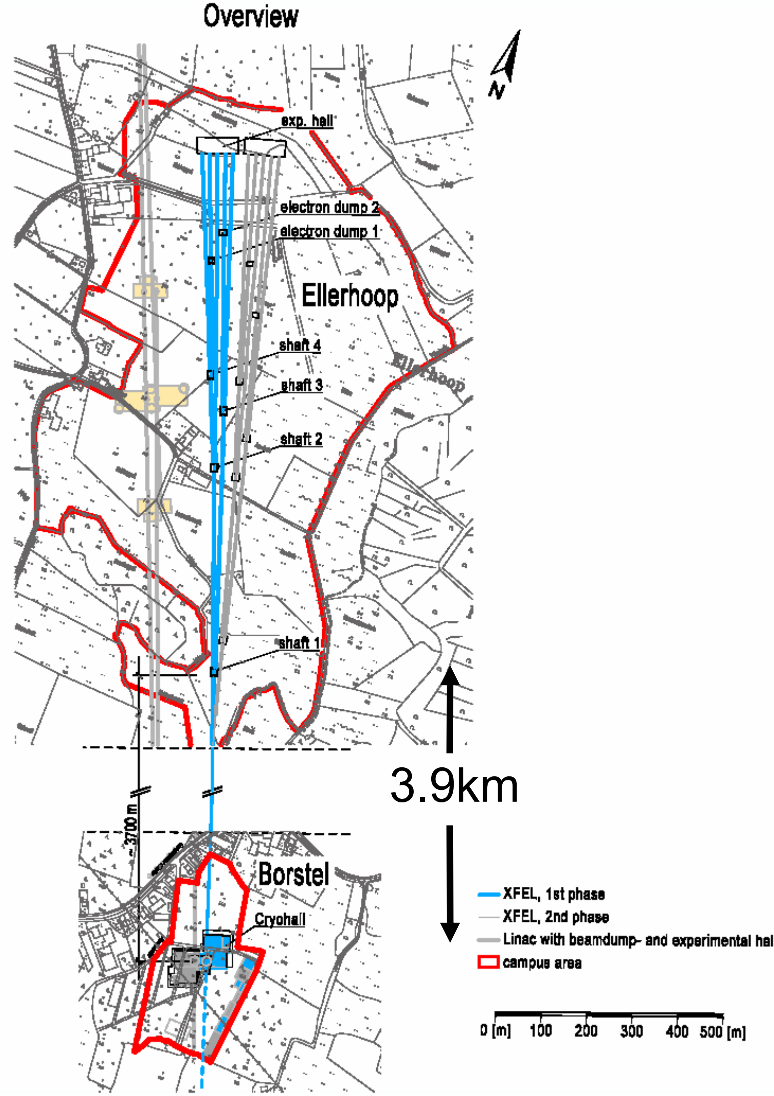
Basis for TDR: high-performance sc cavities

(→ Talk H. Weise & poster session)



Update 2002: *separate* XFEL linac





Update 2002 cont'd

- de-coupling LC - XFEL regarding construction & operation (and: ***approval***), maintaining common site; keep cost close to TDR2001 figure by reduction of (1st stage) energy to 20 GeV, # of beam lines 10 → 5

Parameters 1Å SASE, fixed gap undulator:

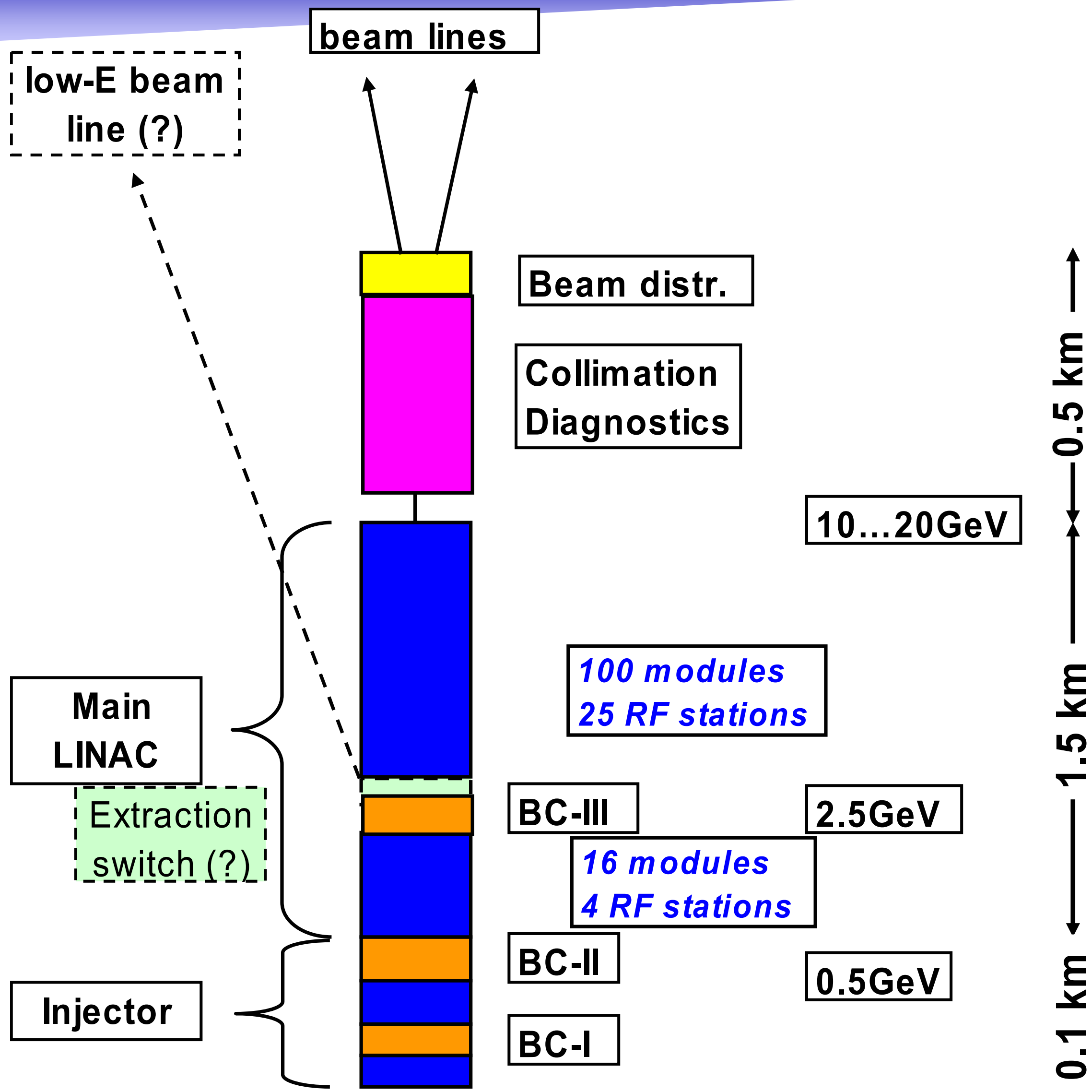
	E_b [GeV]	ε [10^{-6}m]	σ_E [MeV]	I_{pk} [kA]	λ_U [mm]	K_U	gap [mm]	L_{sat} [m]	L_{tot} [m]
TDR2001	25	1.6	2.5	5	45	4	12	210	311
Update02	20	1.4	2.5	5	38	3.8	10	145	213

(FEL process & parameters: → talk by M. Yurkov)

Present: detailed project preparation for construction start in ~2 years

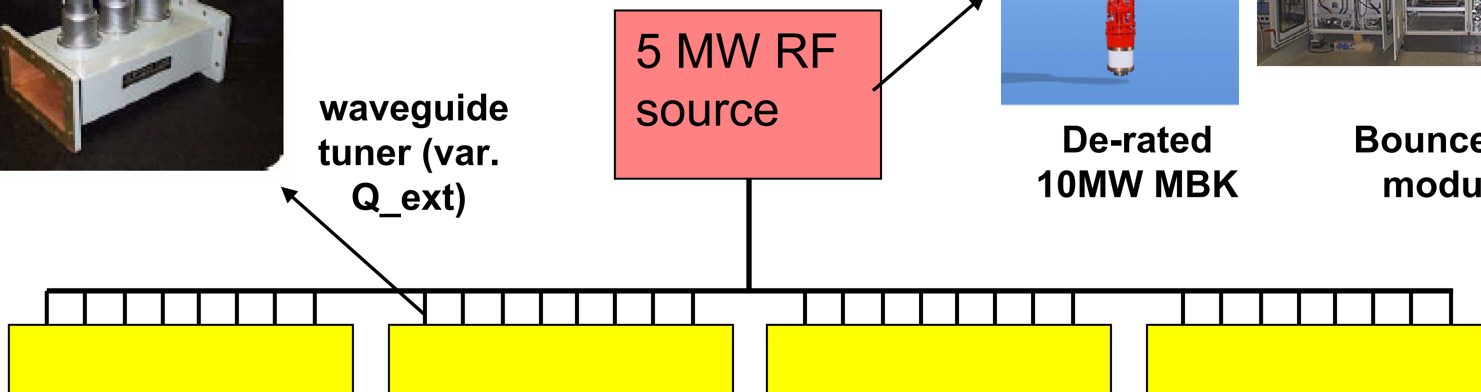
- Choice of DESY-near site de-coupled from TESLA LC
- Linac in TTF-like technology, 20 GeV at 23 MV/m, abandon length reserve, optional higher energy from improved cavity performance
- Investigation of operating parameter flexibility, in particular regarding duty cycle / repetition rate

Present accelerator layout



Accelerator layout cont'd

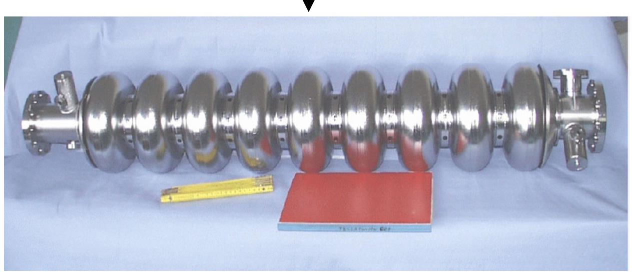
waveguide tuner (var. Q_ext)



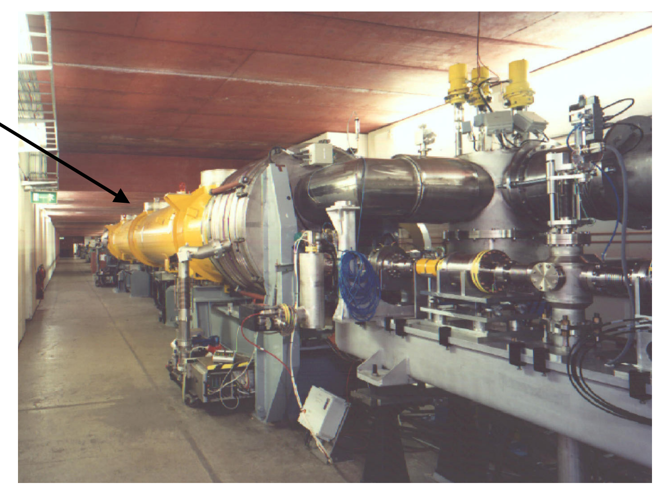
De-rated 10MW MBK

Bouncer-type modulator

eight 9-cell Nb cavities at 2K, $Q_0=10^{10}$



12m TTF-like acc. modules

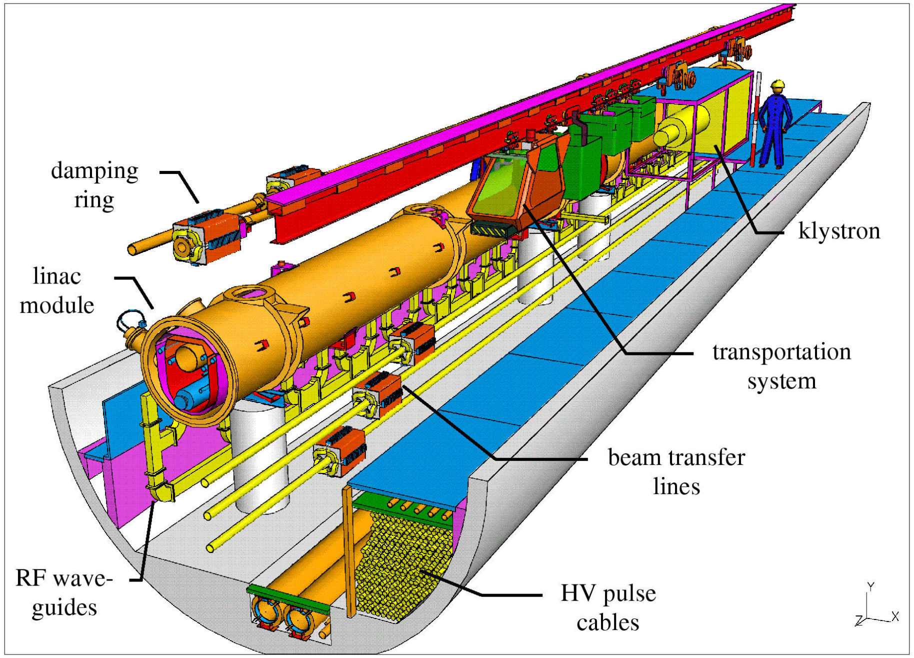


Linac tunnel layout

Accelerator housed in a ~5m diameter tunnel ~12m underground

Klystron in tunnel are connected to modulators in external hall by 10kV pulse cables

Two options for tunnel layout being reviewed



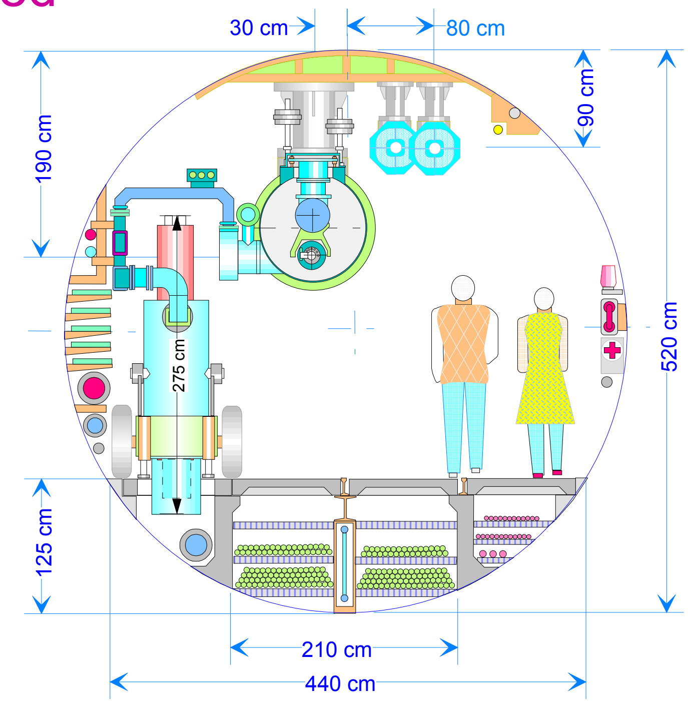


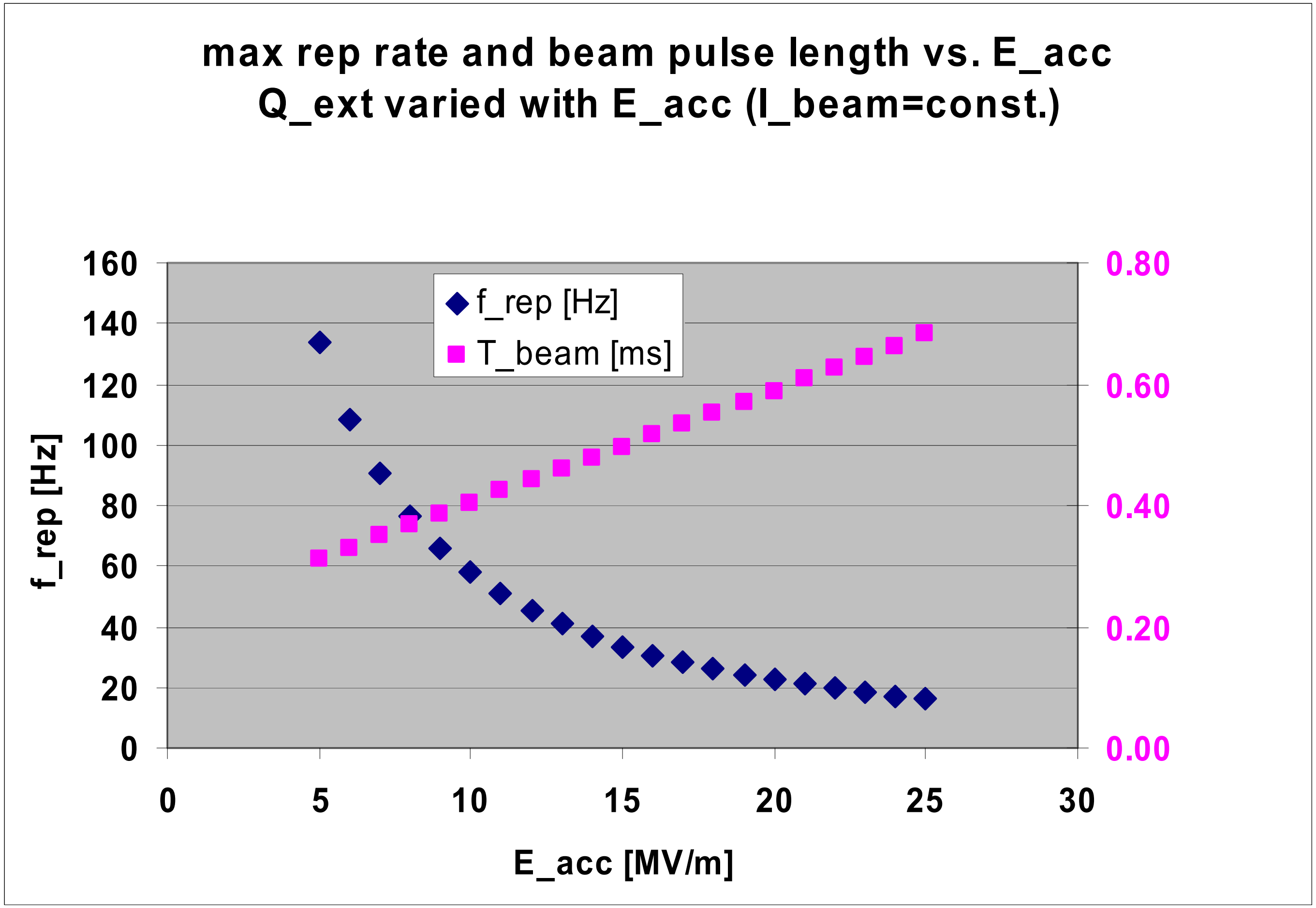
Figure 3. Main LINAC, Damping Ring & Klystron Station

Reference parameters

Main linac	
Energy gain	0.5 → 20 GeV
# installed modules	116
# active modules	104
acc gradient	22.9 MV/m
# installed klystrons	29
Bunch spacing	200 ns
beam current	5 mA
power→beam p. klystron	3.8 MW
incl. 10% + 15% overhead	4.8 MW
matched Q_{ext}	$4.6 \cdot 10^6$
RF pulse	1.37 ms
Beam pulse	0.65 ms
Rep. rate	10 Hz
Av. Beam power *	650 kW
Total AC power	≈ 9 MW

* Power limitation to ~300kW per beamline → solid beam dump possible

Parameter flexibility: rep rate



Longer term perspective: CW an option??

- At 20 GeV: cryogenic plant 3 times capacity of 500 GeV TESLA LC… unreasonable!
- At lower energy: worth a serious thought…consider following option for low-current, CW-mode (e.g. 1nC bunches at 10kHz):
  - At 23MV/m power per cavity is 30kW at ~zero beam current
  - Energy/sqrt(10) (because of cryogenics) → power per cavity 3kW
  - Increase Q_ext ~ factor 3 → power <1kW (+regulation reserve)
  - **→ linac can deliver ~6GeV CW beam without modifications – except for (of course) additional RF system with ~50kW CW klystrons (or: IOTs)**
- careful: we don't have a suitable injector yet!

- No need to rule out ERL-type of operation in further distant future – except for few basic considerations, can't be focus of attention for next years

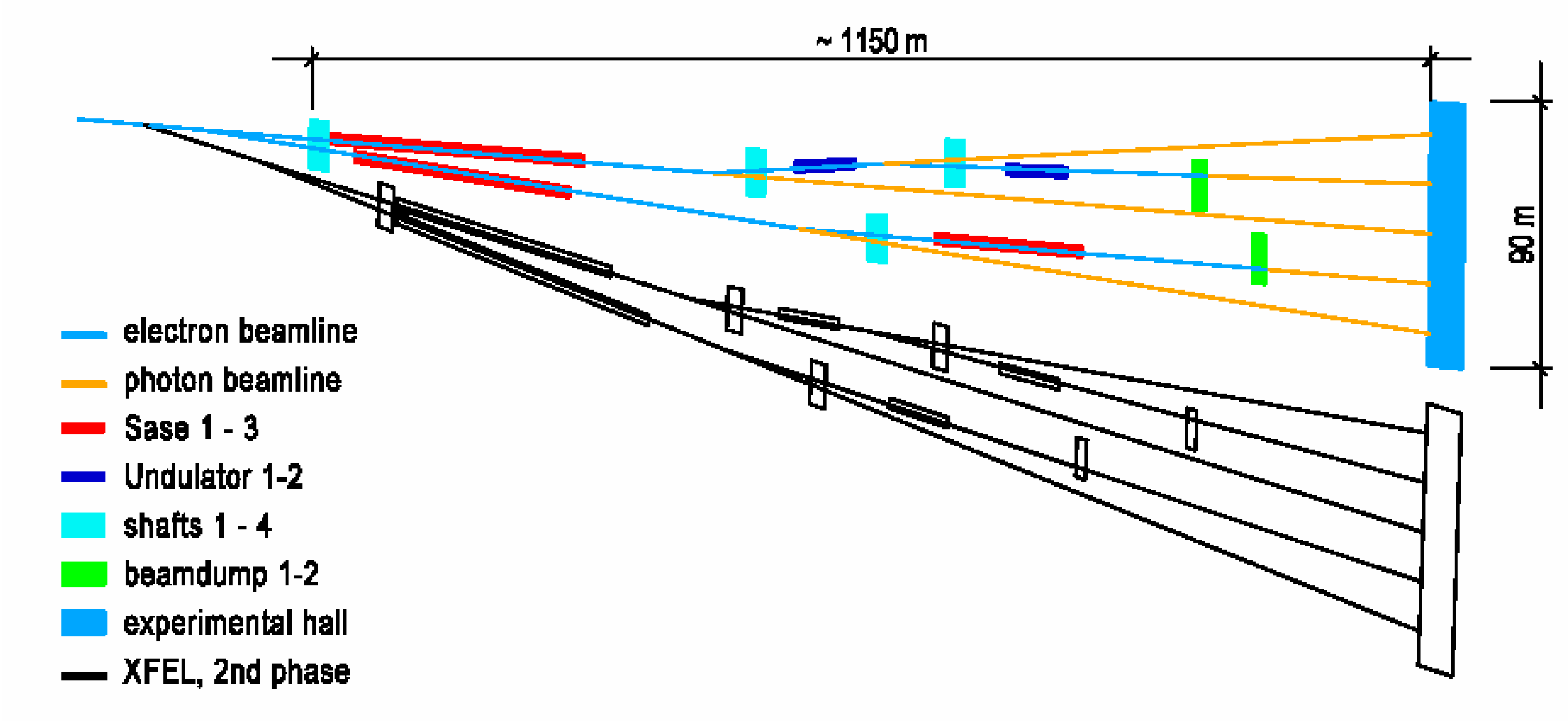
(some of the) Accelerator sub-systems

- Photocathode RF gun and bunch compressors: generate and preserve excellent beam quality (peak current 5kA, normalised transverse emittance 1.4 mrad*mm) (→ talks by K. Flöttmann, W. Sandner, poster session)

- Beam delivery system: (→ poster session)
  - Beam collimation: protect undulators from halo and mis-steered beams
  - Diagnostics: determination of beam properties in 6D phase space with complex structure
  - Beam distribution: slow and fast devices for multi-user operation
  - Feedback systems: intra-train stabilisation (position, energy, timing, …) using "pilot bunches"

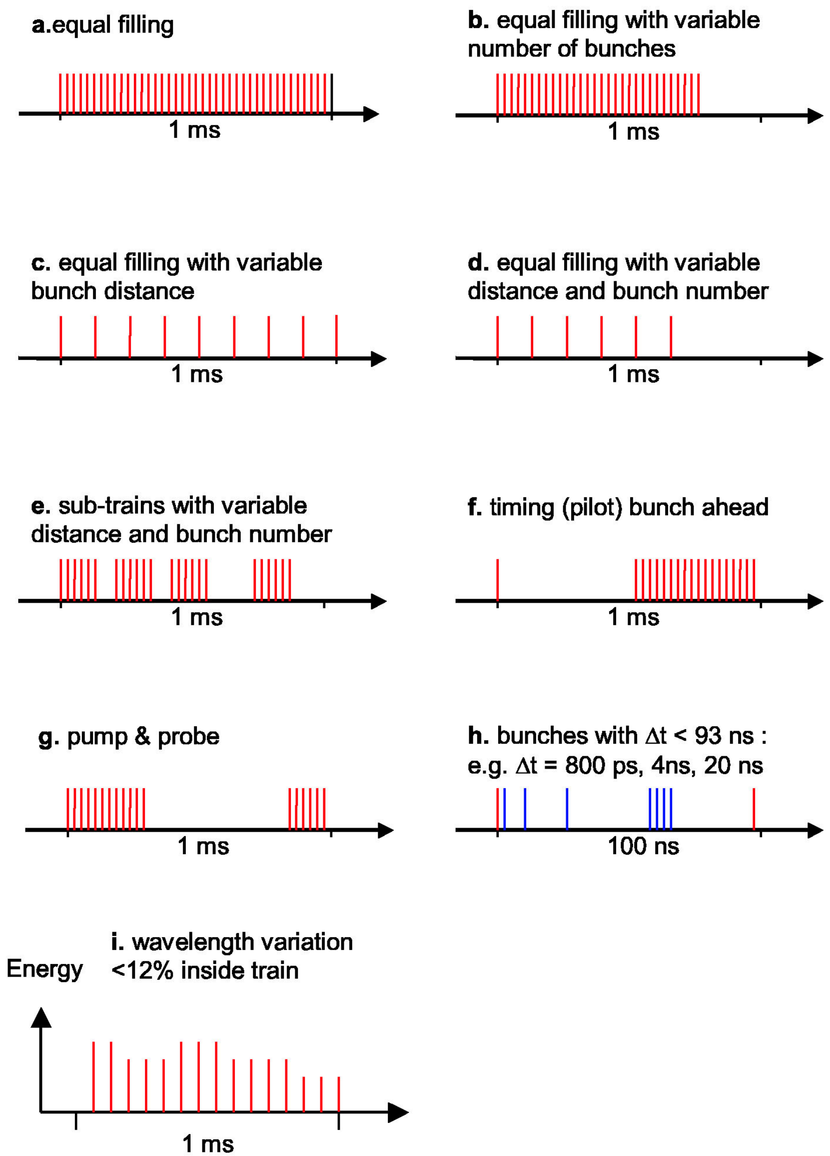
Beam distribution options

- Straight forward and simple: pulse-to-pulse switch magnet
- Much better, but more challenging: fast (intra-train) kickers

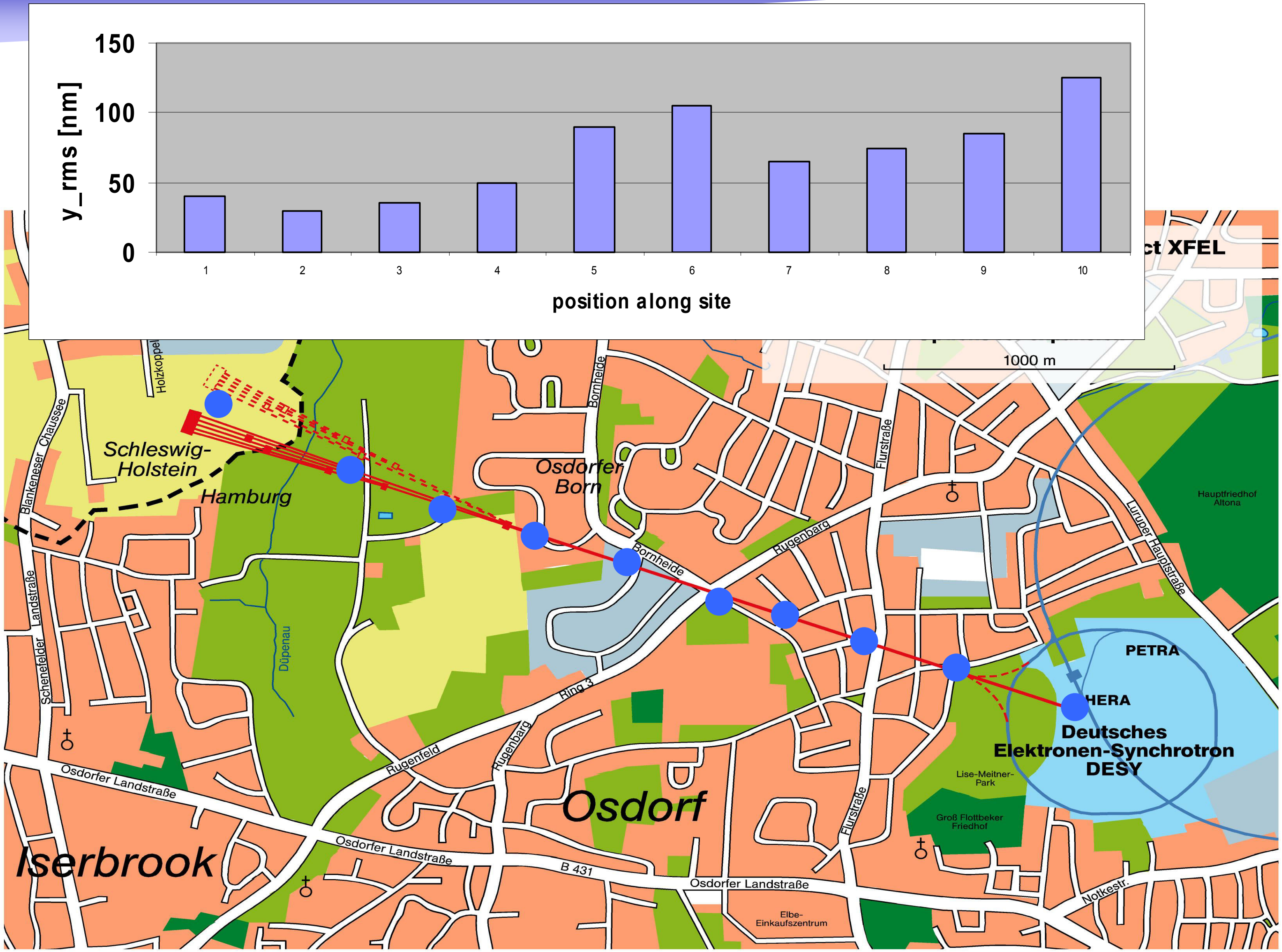


Different users – different time structures

- Generation of bunch train patterns:
  - At the source → varying transient effects in the entire accelerator (handled e.g. by the LLRF system)
  - At the beam delivery/distribution system → more challenging kicker devices

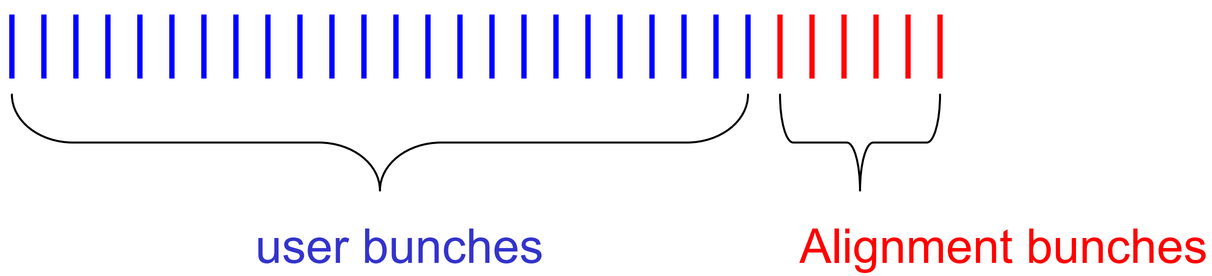


One source of jitter: ground motion



Intra-train beam stabilisation

- From ground vibration: jitter ~ 0.1σ at end of linac
  - Can be enhanced during "single events" e.g. heavy traffic, and by quad support eigenmodes
  - Other effects: stray fields, HOMs, …
- → feedback system between linac and distribution to undulators



Also active stabilisation of energy and possibly other beam parameters

Conclusions

- The 20 GeV s.c. linac based on the technology developed by the TESLA collaboration and successfully demonstrated at TTF is an ideal driver for the Free Electron Laser facility – offering a broad range of operating parameters in its baseline design *and* with future upgrade options
- Experience at test facilities creates a solid ground also for the design of other accelerator sub-systems (injector, bunch compressors, diagnostics, feedback systems, …) of the XFEL

- The project preparation is well under way and will lead into the construction phase in ~ two years from now