The European XFEL Project

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12th International Workshop on RF Superconductivity

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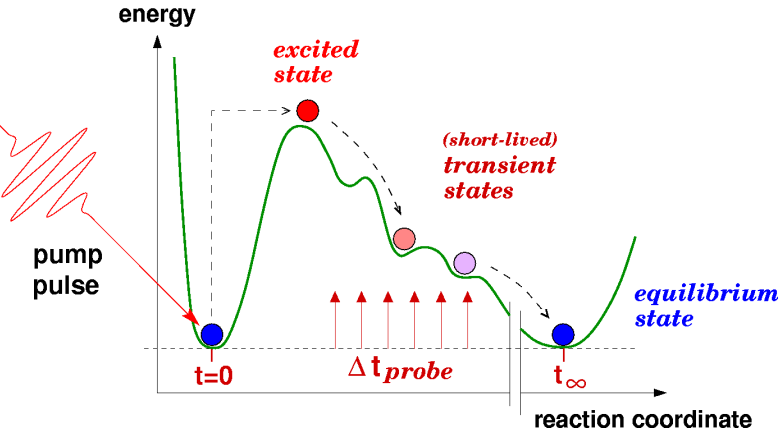
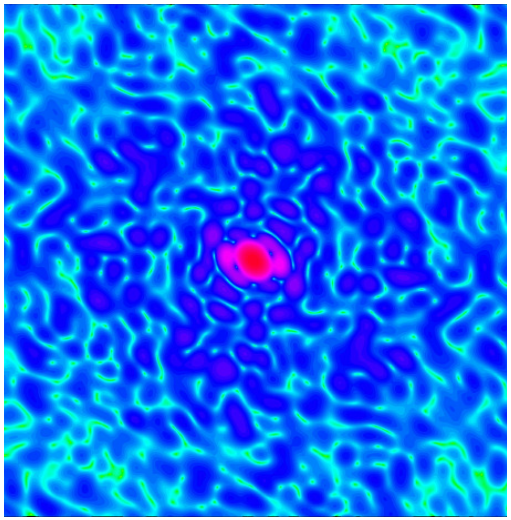
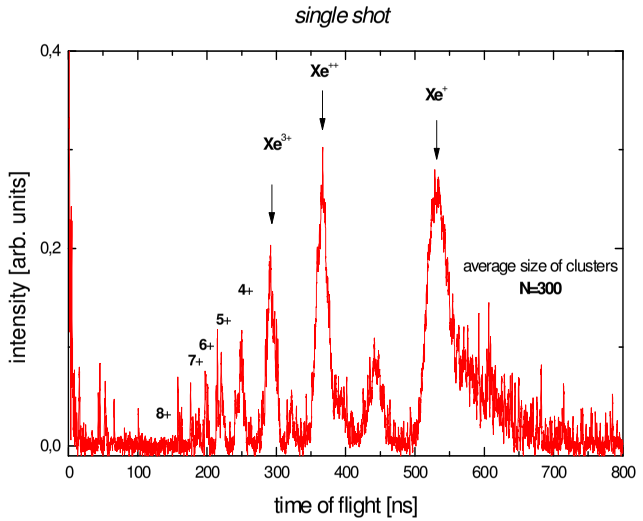
Challenges for Science with X-rays

Real-time observation of atomic motion



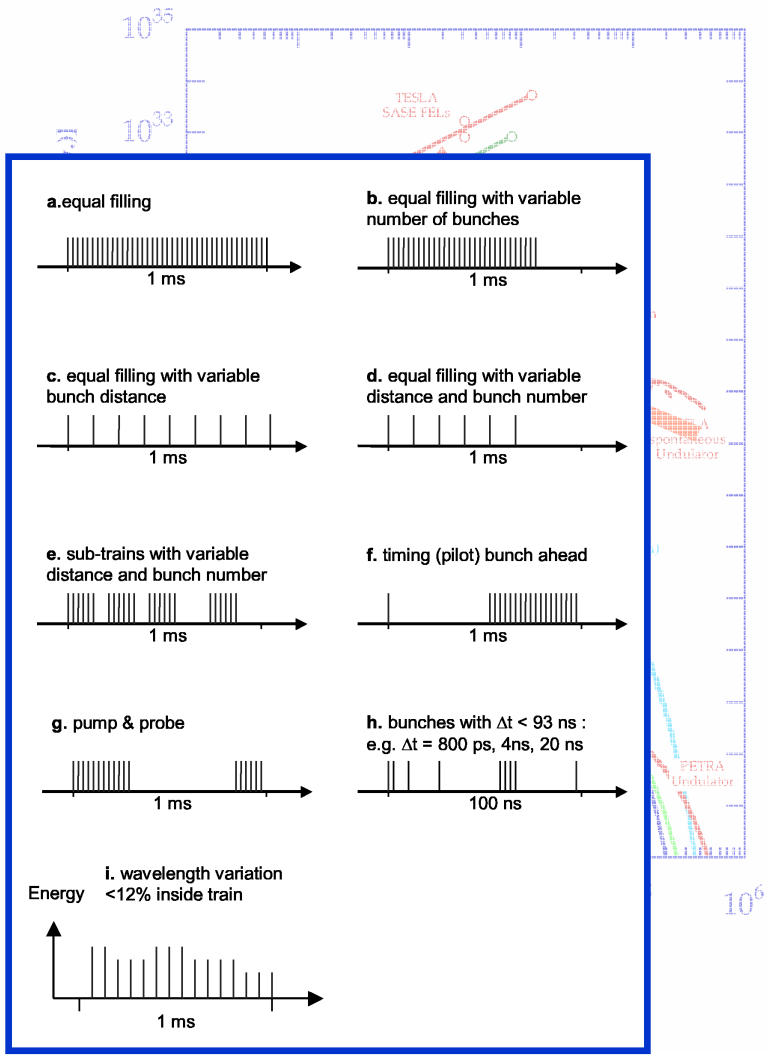


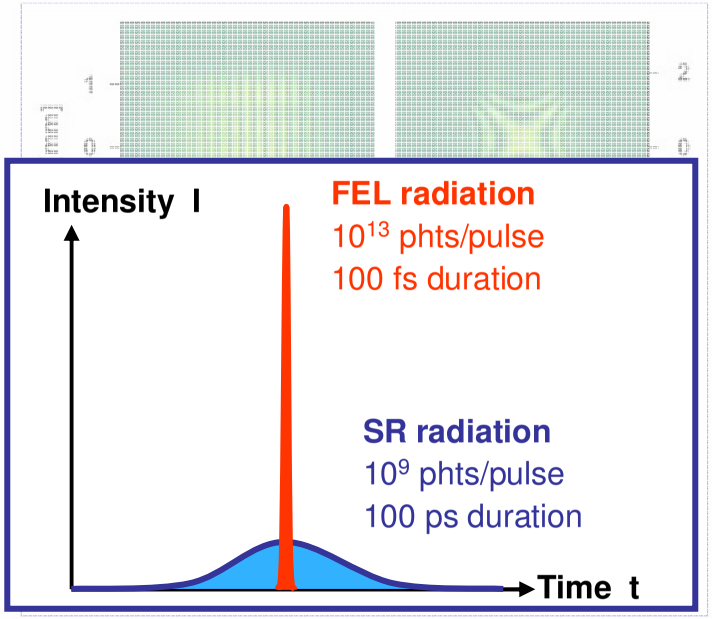
Get structural information out of single bio molecules



Enter the regime of non-linear interaction of X-rays

Radiation Characteristics

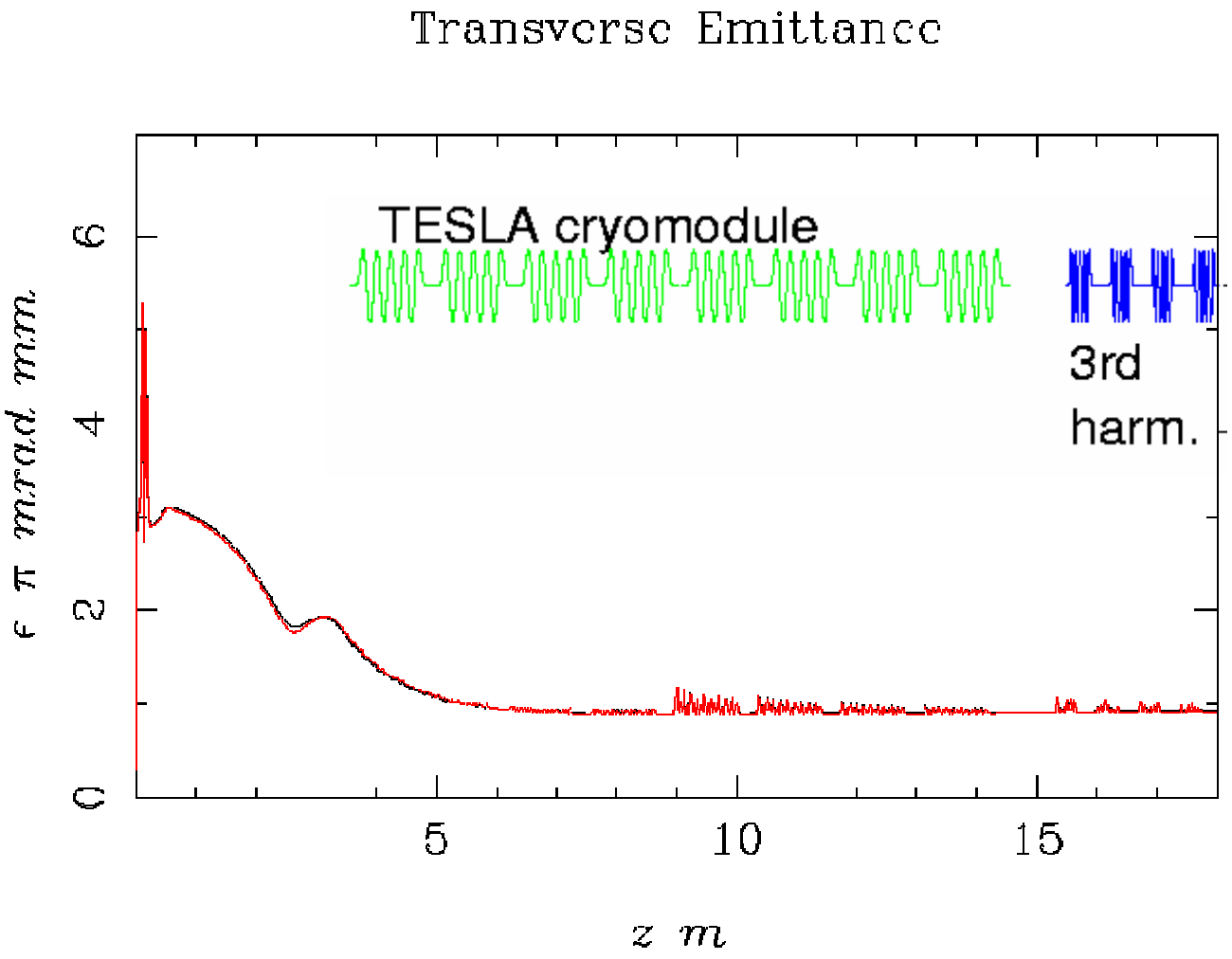




- high brilliance

Choice of the machine parameters

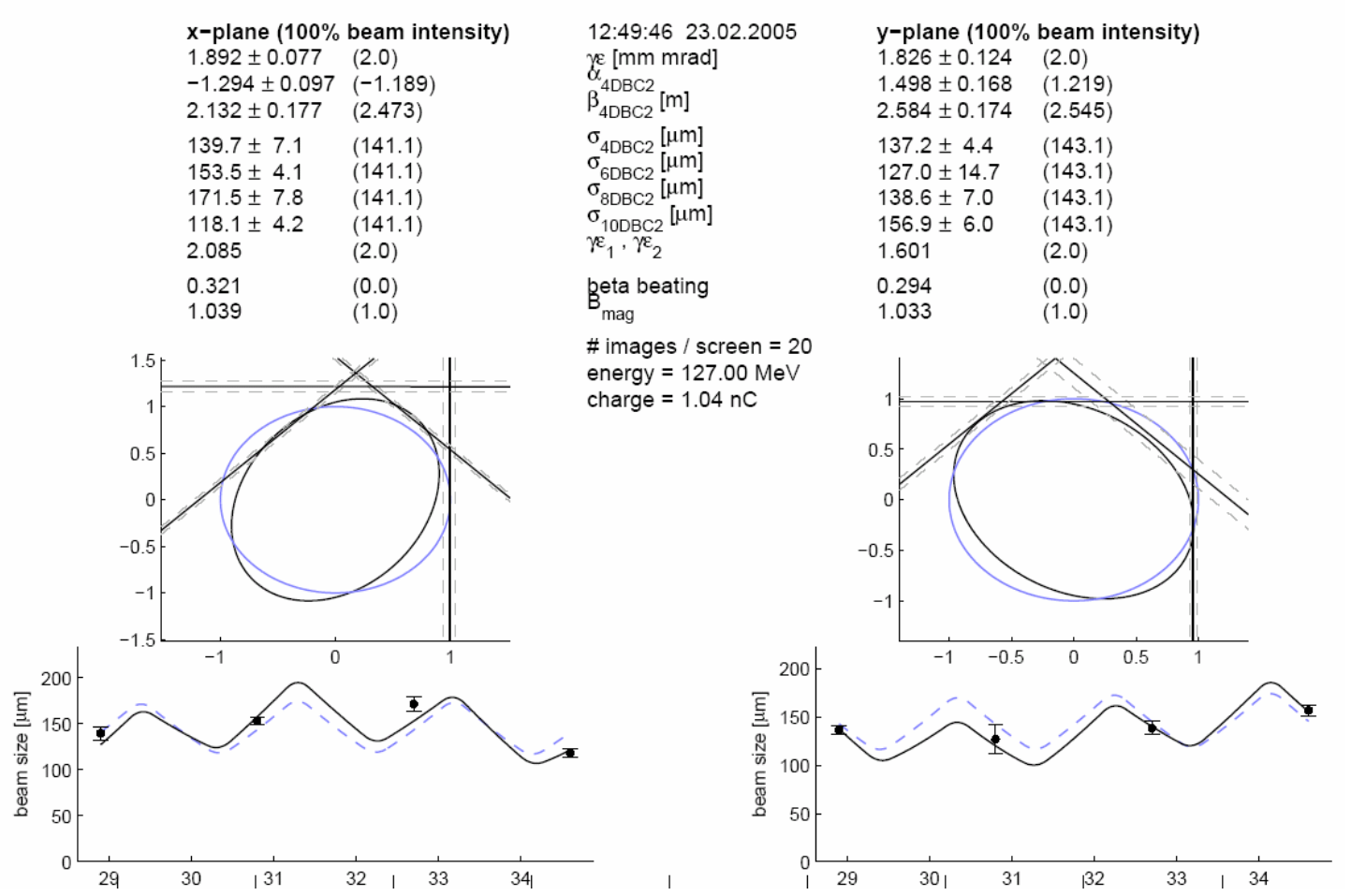
Emittance from photocathode RF gun injector



- 1nC charge
- uniform transverse distribution
- longitudinal flat-top with 2 ps rise time
- incl. thermal emittance

$\varepsilon_n = 0.9\ \mu m$

Emittance Measurement at TTF



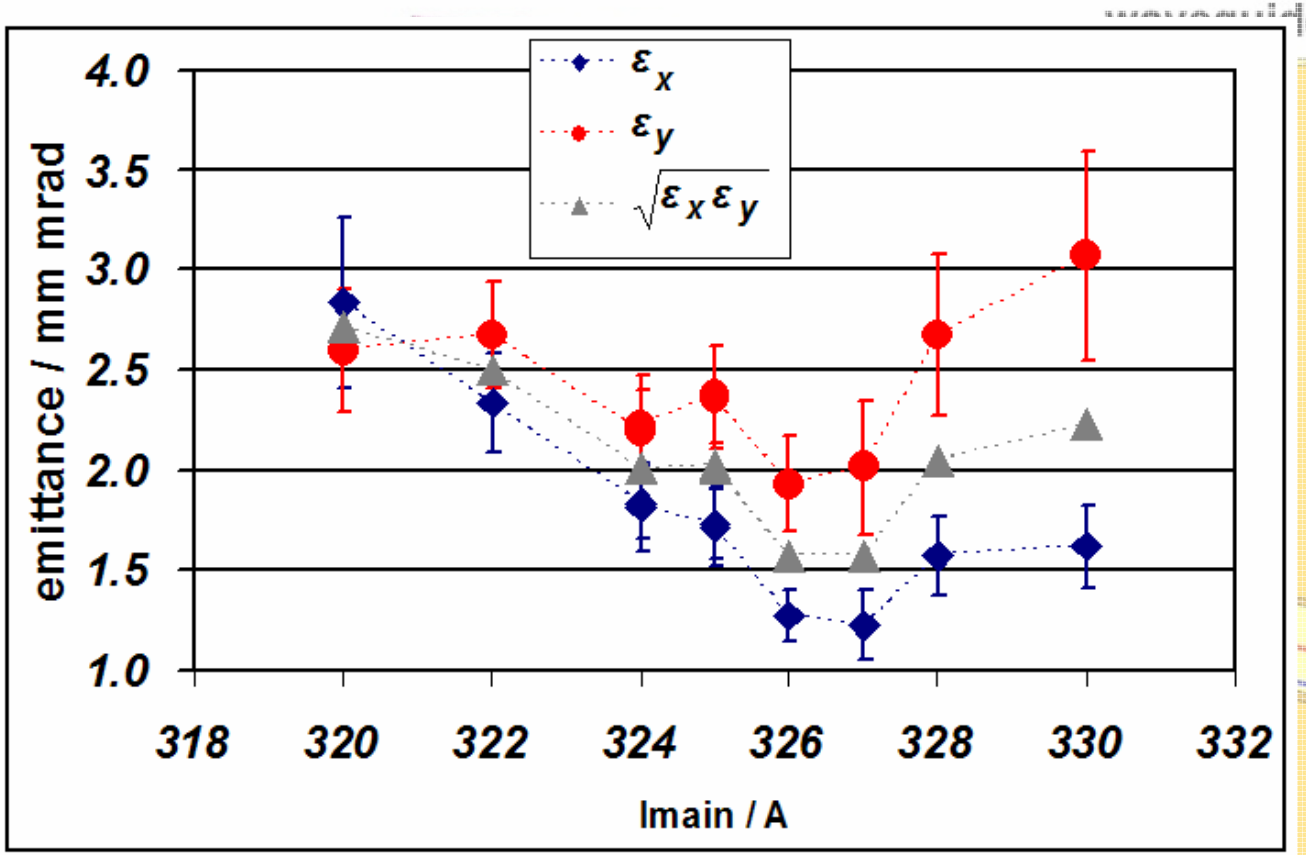
1 nC

measured: 1.9 µm

simulated: 2.1 µm

(w. o. compression)

RF gun development at PITZ in Zeuthen



On-going program:

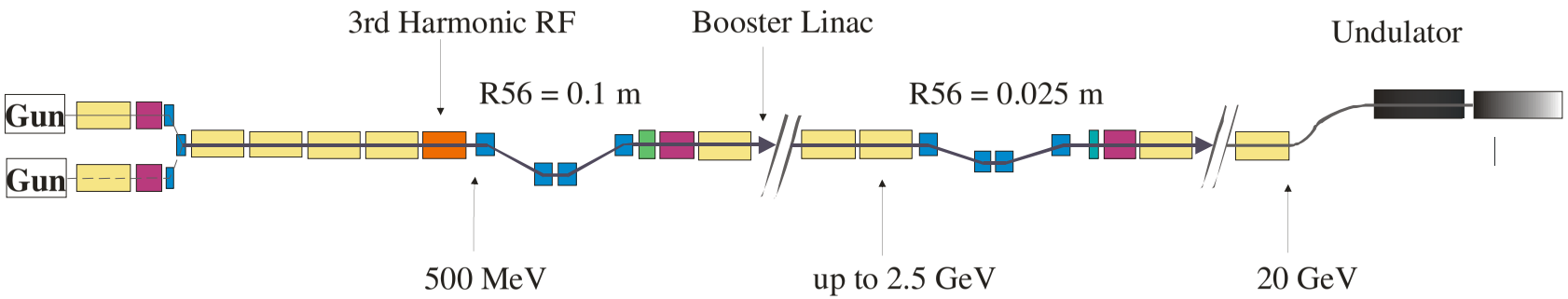
- **increase the gradient on the cathode from 40 MV/m to 60 MV/m**
- **further improve the transverse and longitudinal laser profile (collab. Max-Born Institute, Berlin)**

Bunch compressor

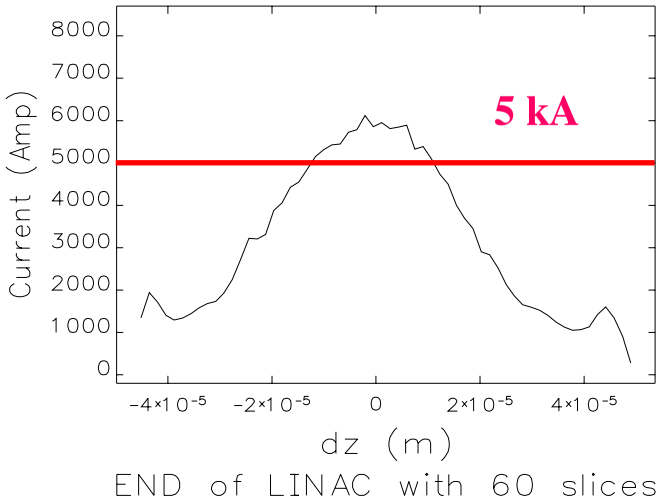
σ_s = 2 mm
I_{peak}: 50 A

σ_s = 0.1 mm
I_{peak}: 1 kA

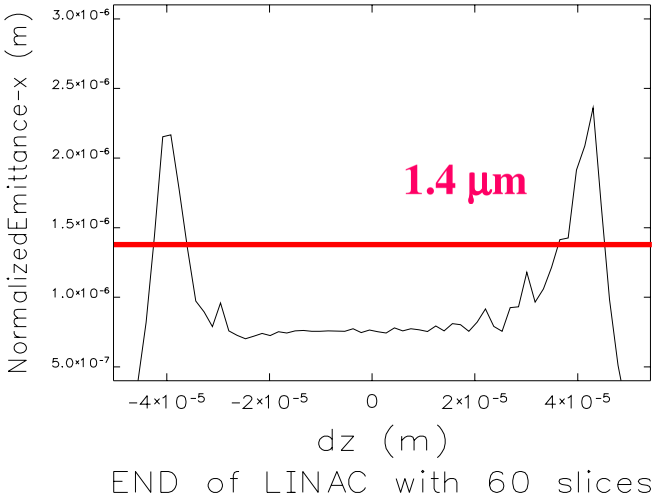
σ_s = 0.02 mm
I_{peak}: 5 kA



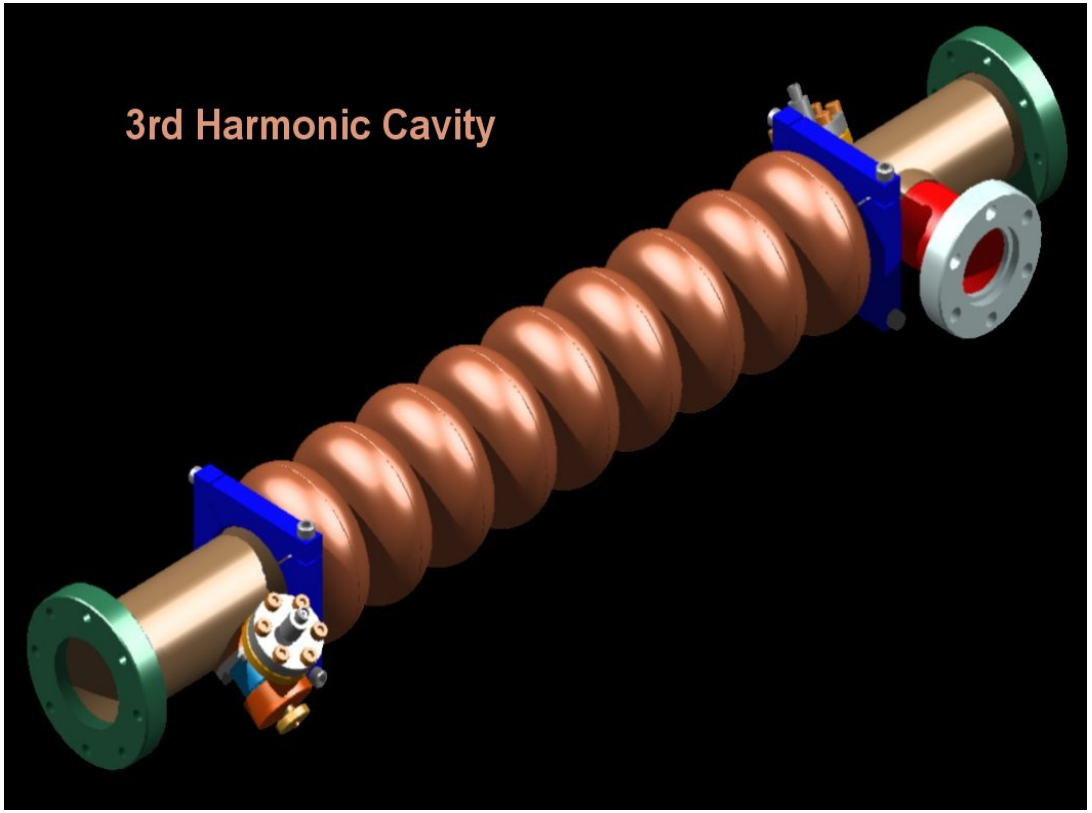
Peak current

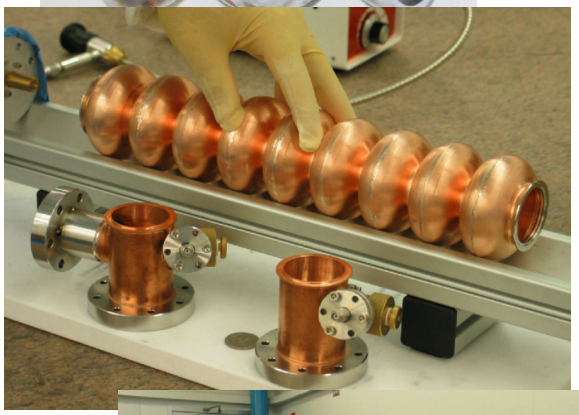


Slice emittance

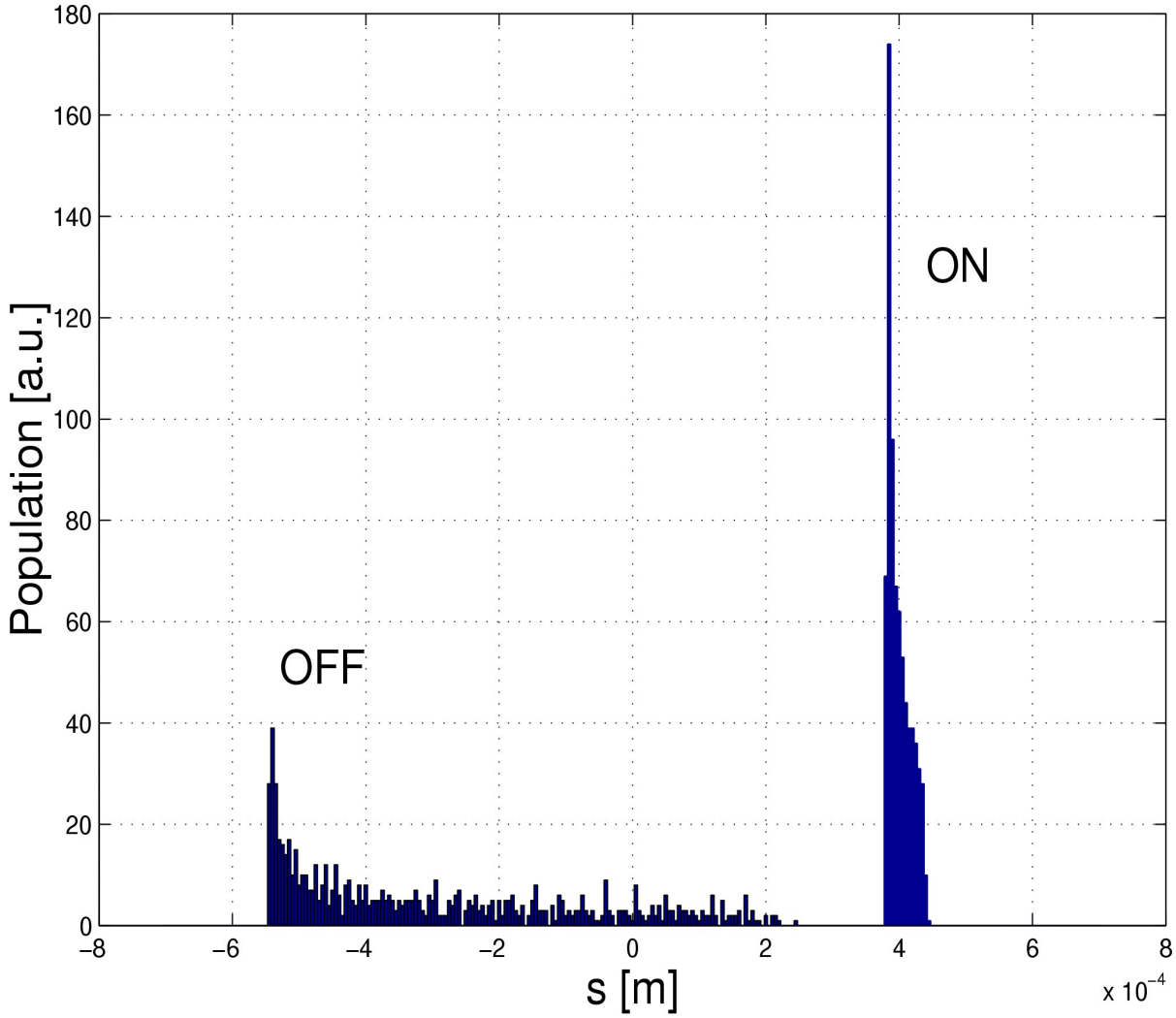


The 3rd harmonic section





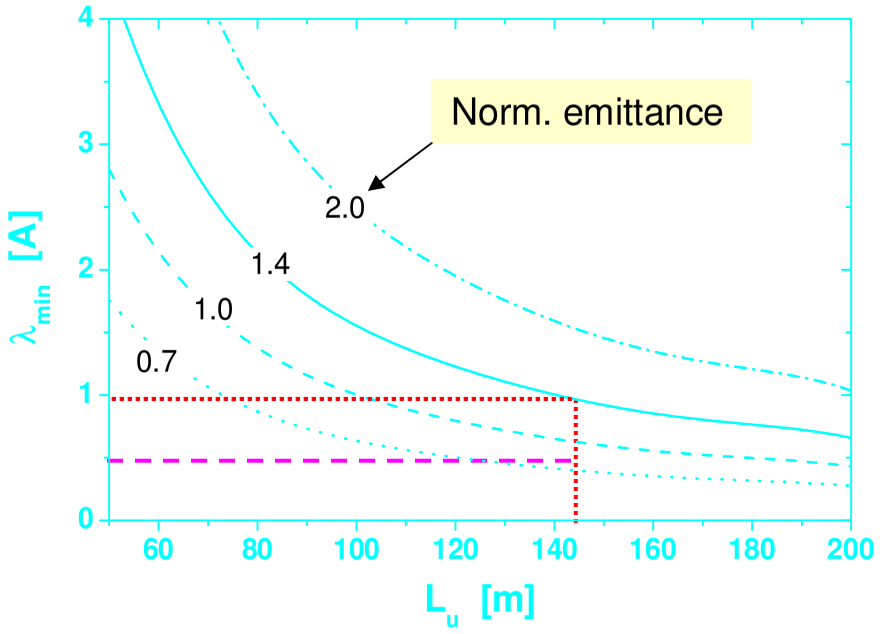
The longitudinal phase space

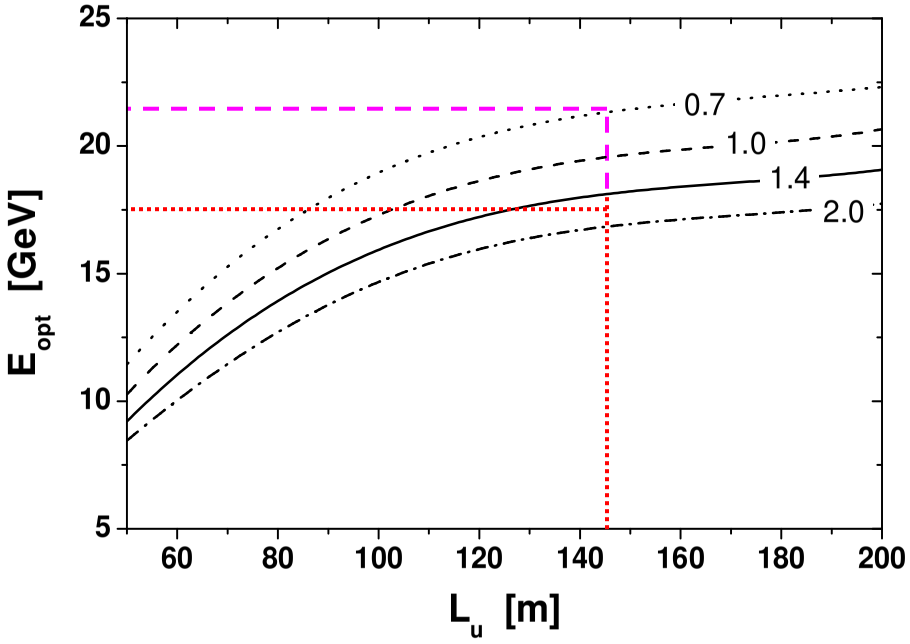


Longitudinal particle distribution behind bunch compressor with and without the 3rd harmonic system.

Choice of the Beam Energy

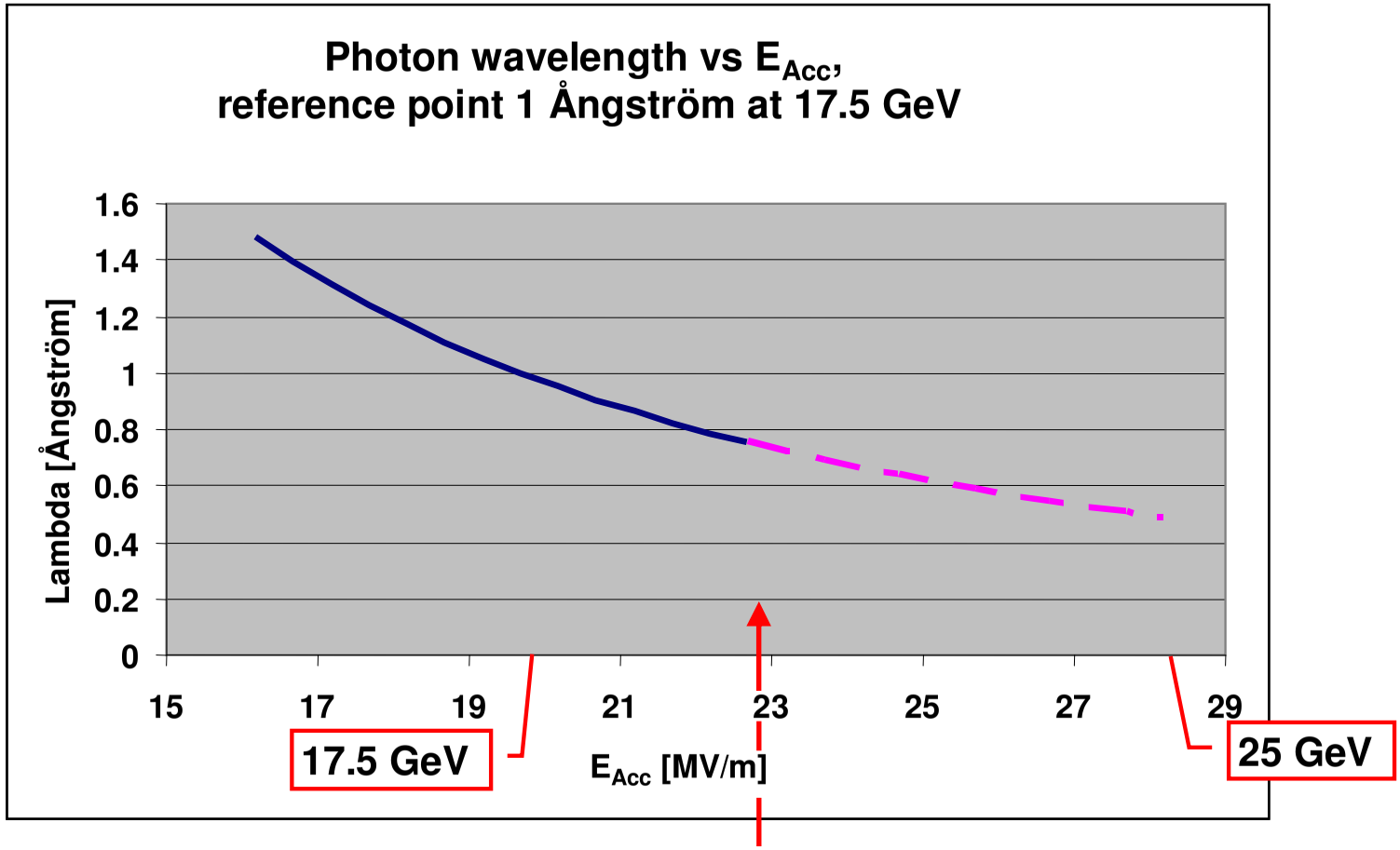
Emittanz [mrad mm]	0.7 – 2.0
I_{peak} [kA]	5.0
ΔE [MeV]	2.5
Undulator gap [mm]	10





→ **17.5 GeV for 1Å**

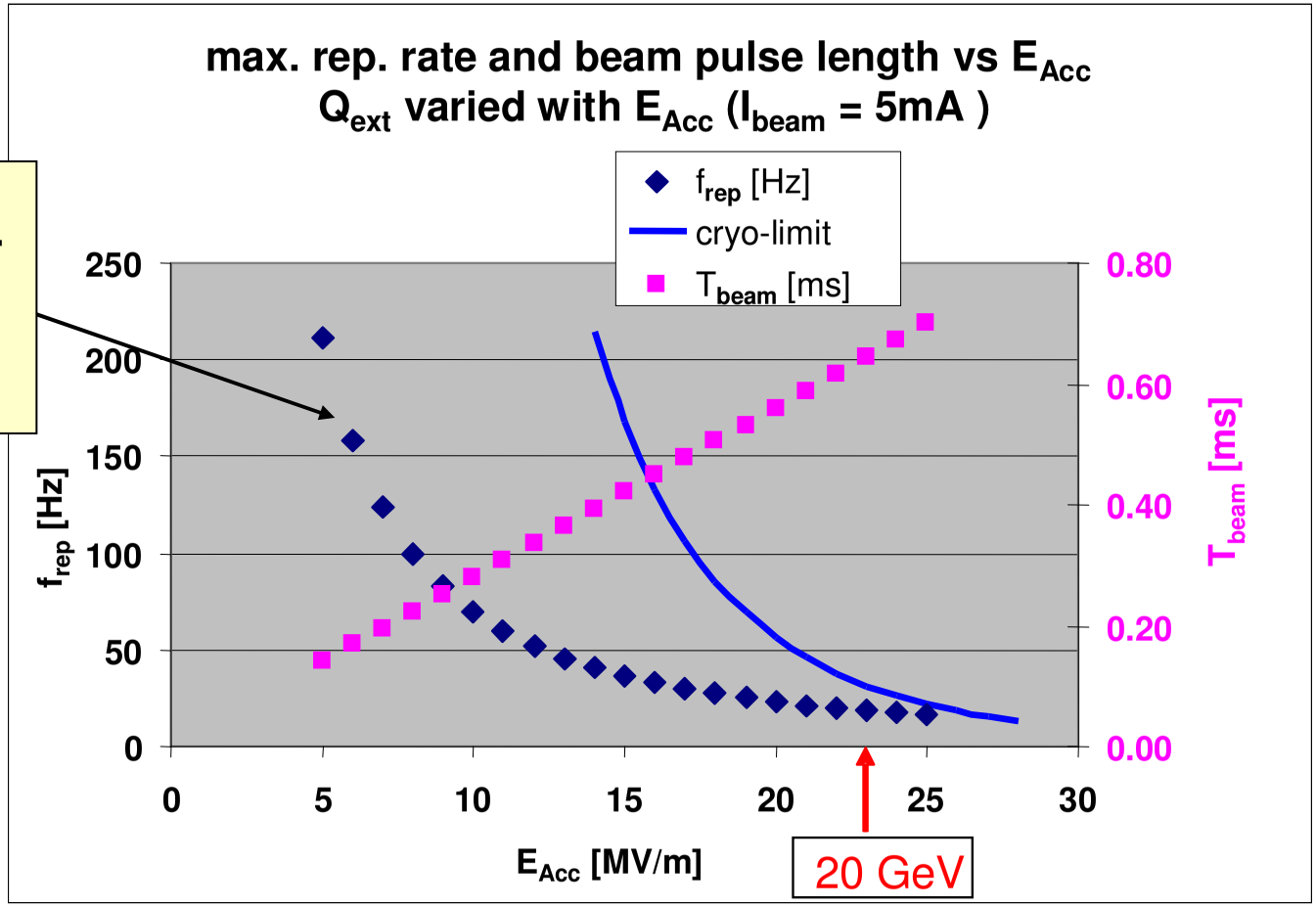
Wavelength vs Accelerating Gradient



Nominal linac energy 20 GeV, includes ^{57}Fe line @ 0.8Å

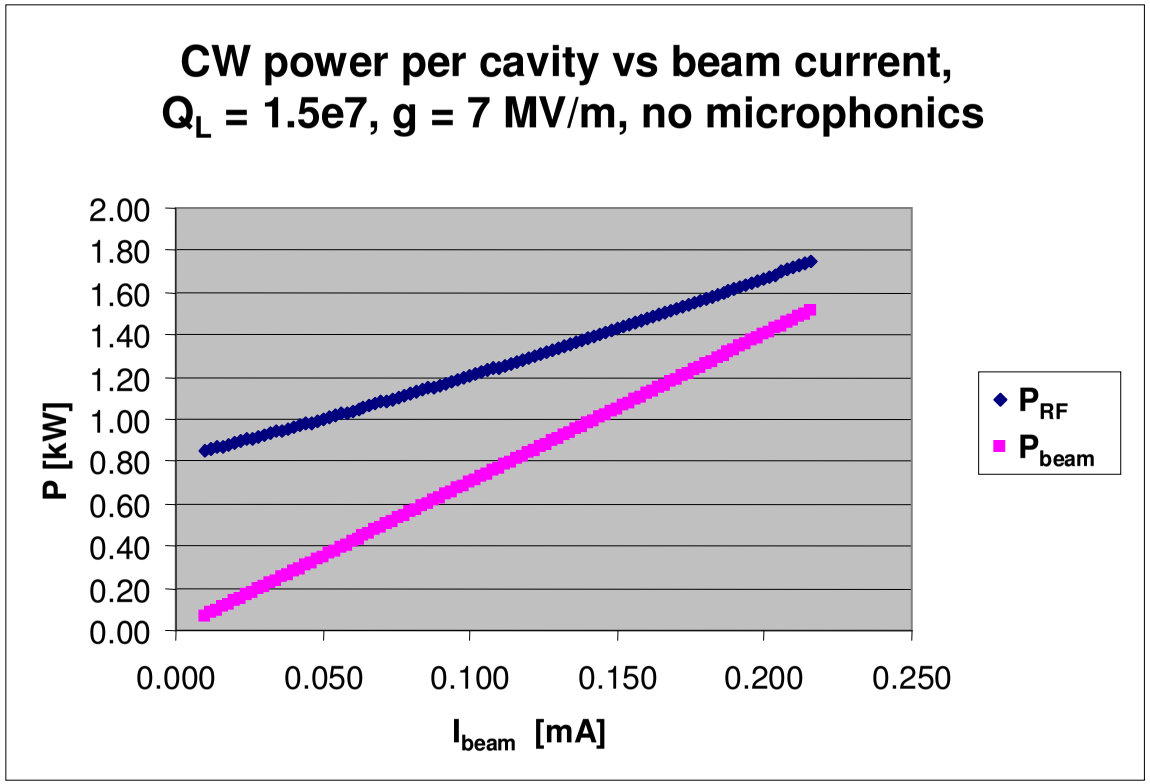
Operational flexibility – duty cycle

Decreasing T_{beam} at higher f_{rep} helps, but injector is an issue!



Sketch of Possible Future CW Operation Mode

If Å FEL radiation at lower beam energy comes in reach (better injector/beam quality, advanced FEL concepts, …) → high duty cycle, up to CW, can become an attractive option



Sketch of Future CW Operation Mode cont'd

Linac layout & cryogenics consistent with this option (at E_{Acc} = 7…8 MV/m), different RF system has to be added

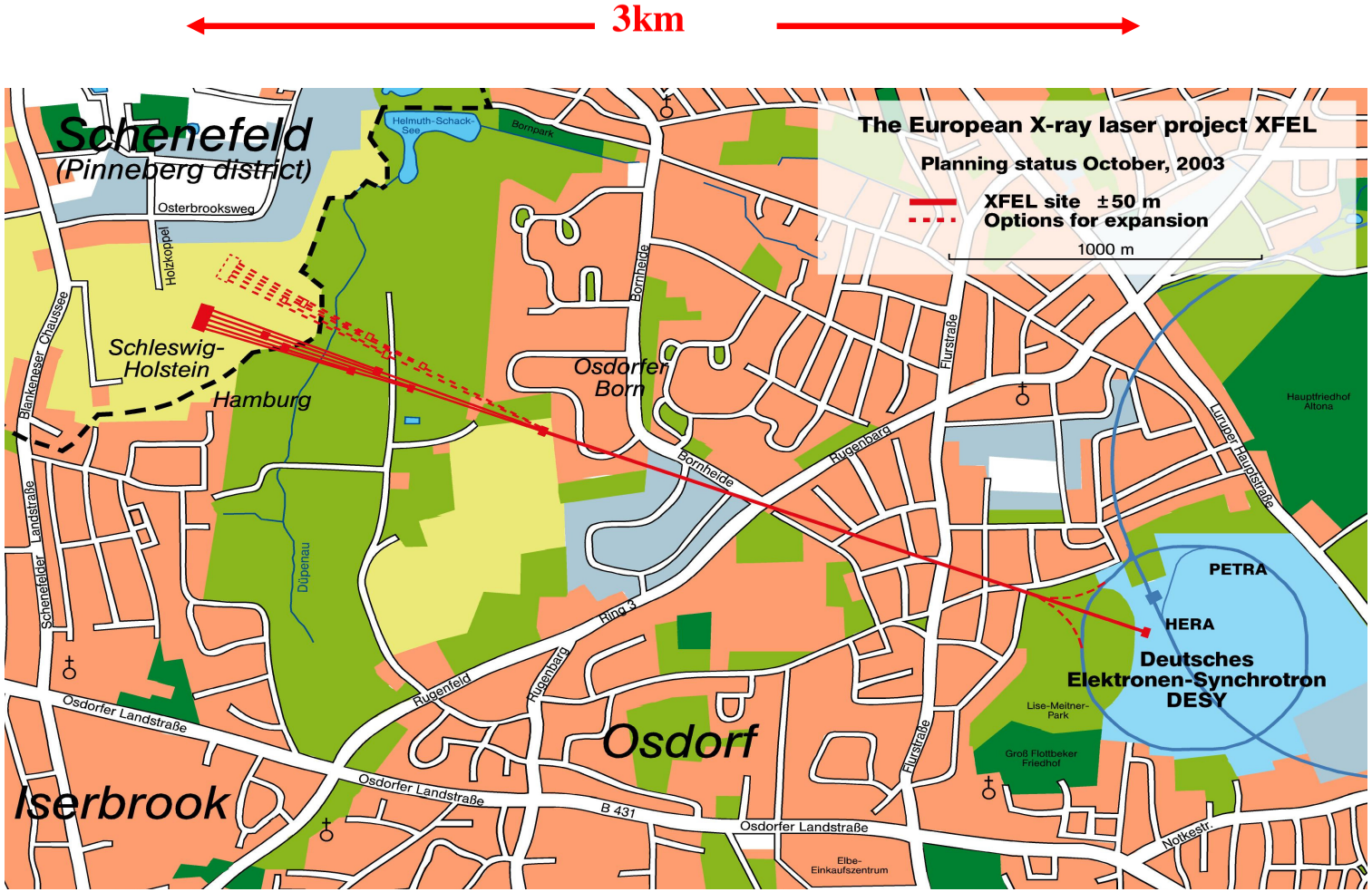
Beam Energy [GeV]	6.5
Acc. Gradient [MV/m]	7
Beam Current* [mA]	0.18
Bunch Spacing [μs]	5.5
RF power / module [kW] (incl. overhead)	~ 20
Dynamic cryo. load 2 K [kW]	~ 2.4

* total beam power of 1.2 MW sufficient to operate simultaneously 4 undulator beam lines at the dump limit of 300 kW

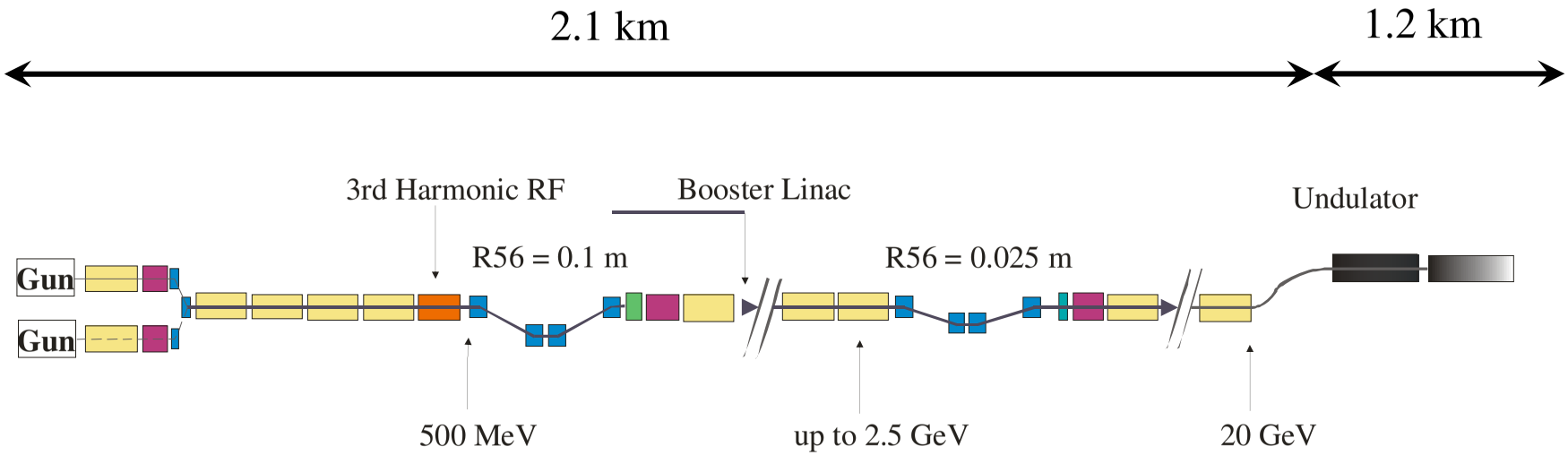
If user demand very high average power, ERL option is conceivable

Project Overview & Status

XFEL Site in Hamburg



Injector & Bunch compressor



XFEL-Cryomodule Design

based on the TESLA/TTF –type III design

8 TESLA Type Cavities

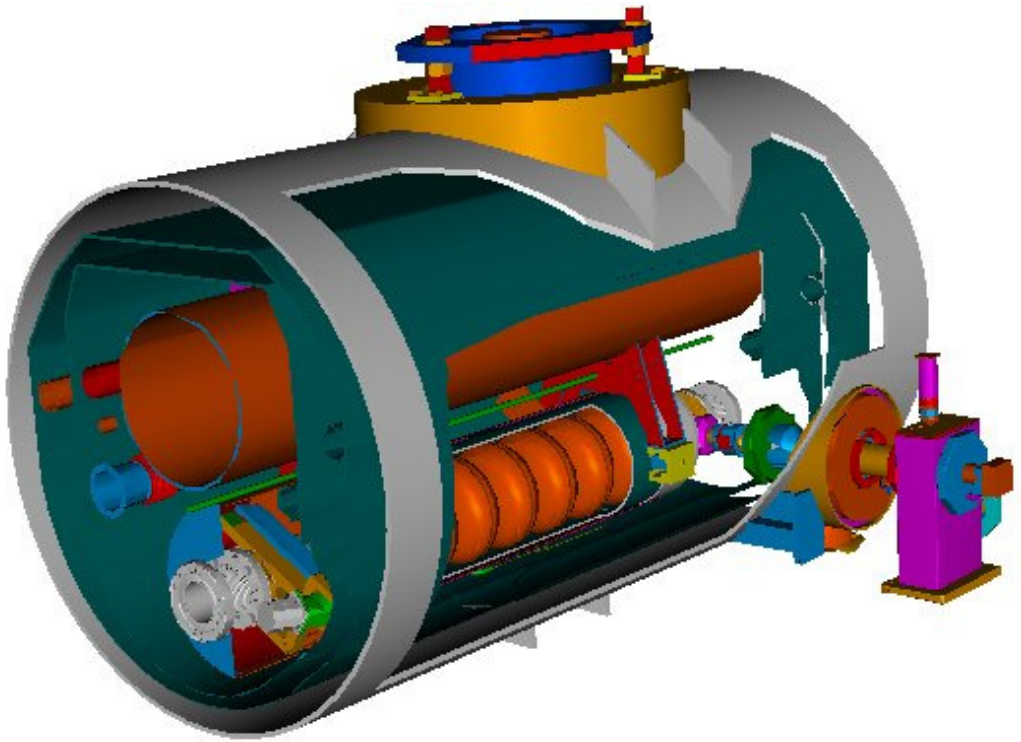
1 magnet package

Spec: 28 MV/m operable

23 MV/m needed for 20 GeV operation

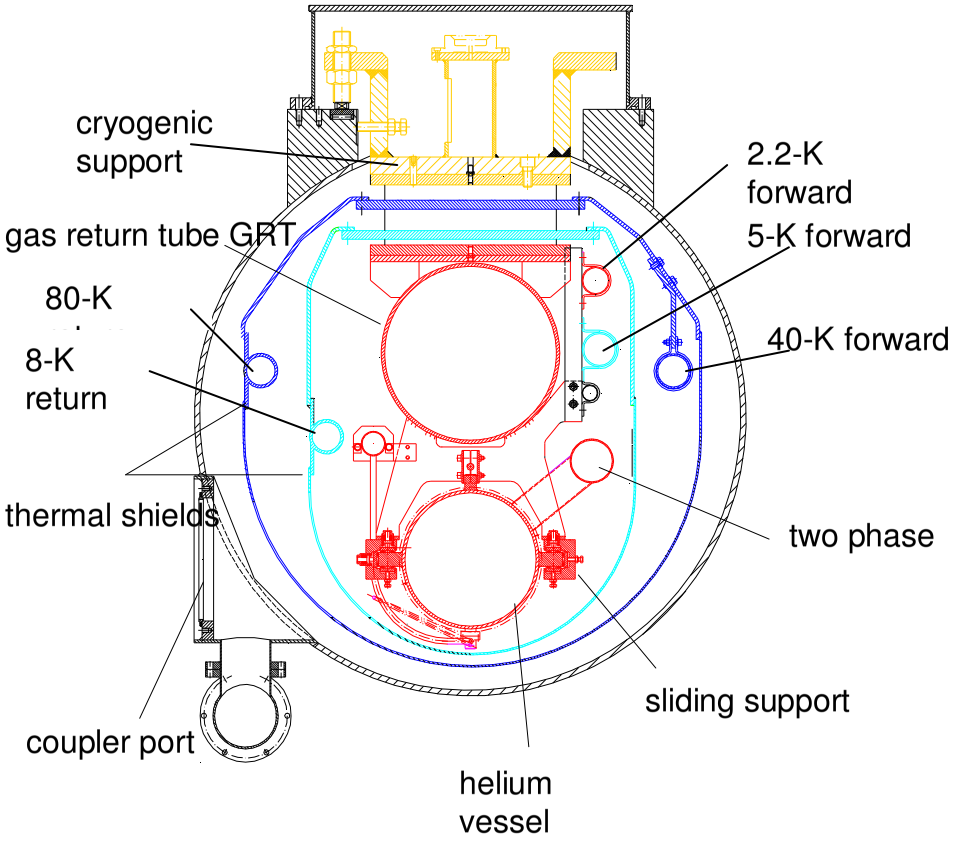
116 Modules

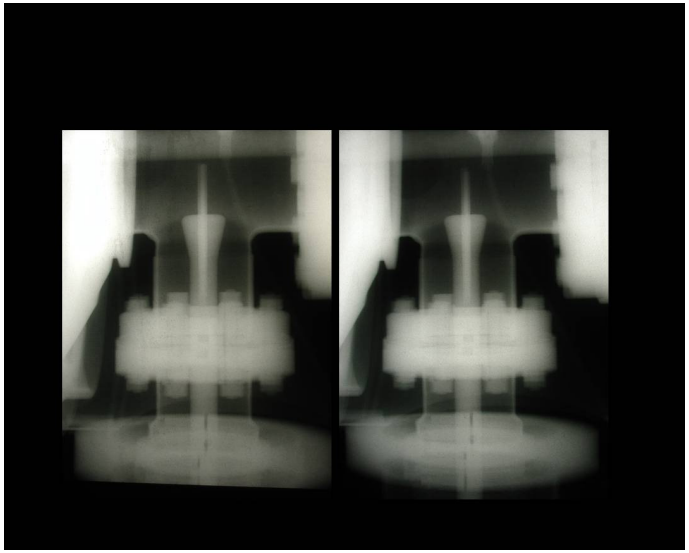
928 Cavities



Cryomodule cross-section

XFEL-Cryomodule Design





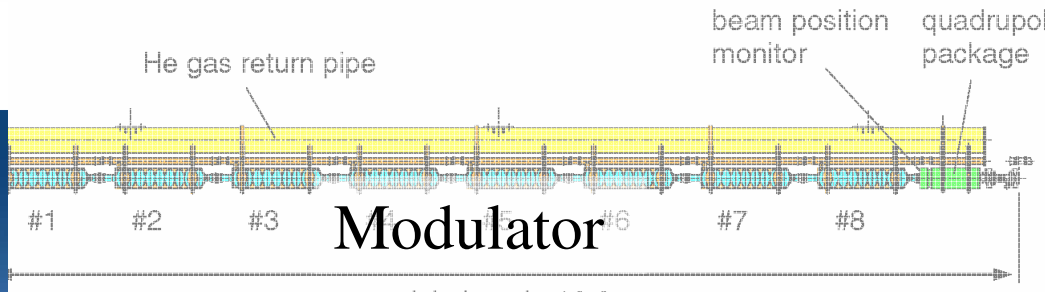
300 K and 2K

Module 5 coupler 2

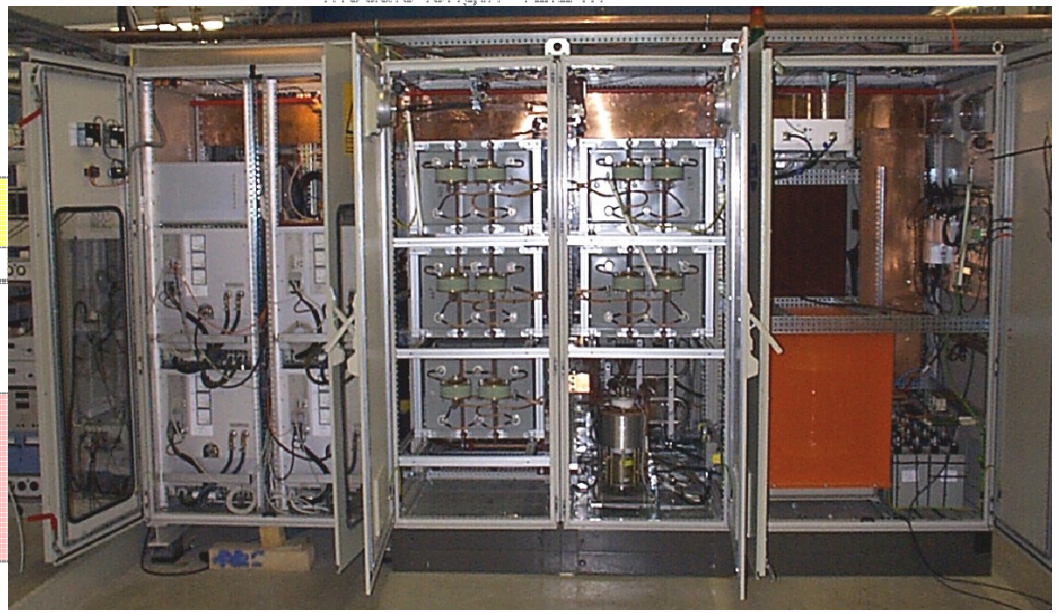
Cavity chain is fixed to an invar rod – couplers keep position

RF System

Klystron

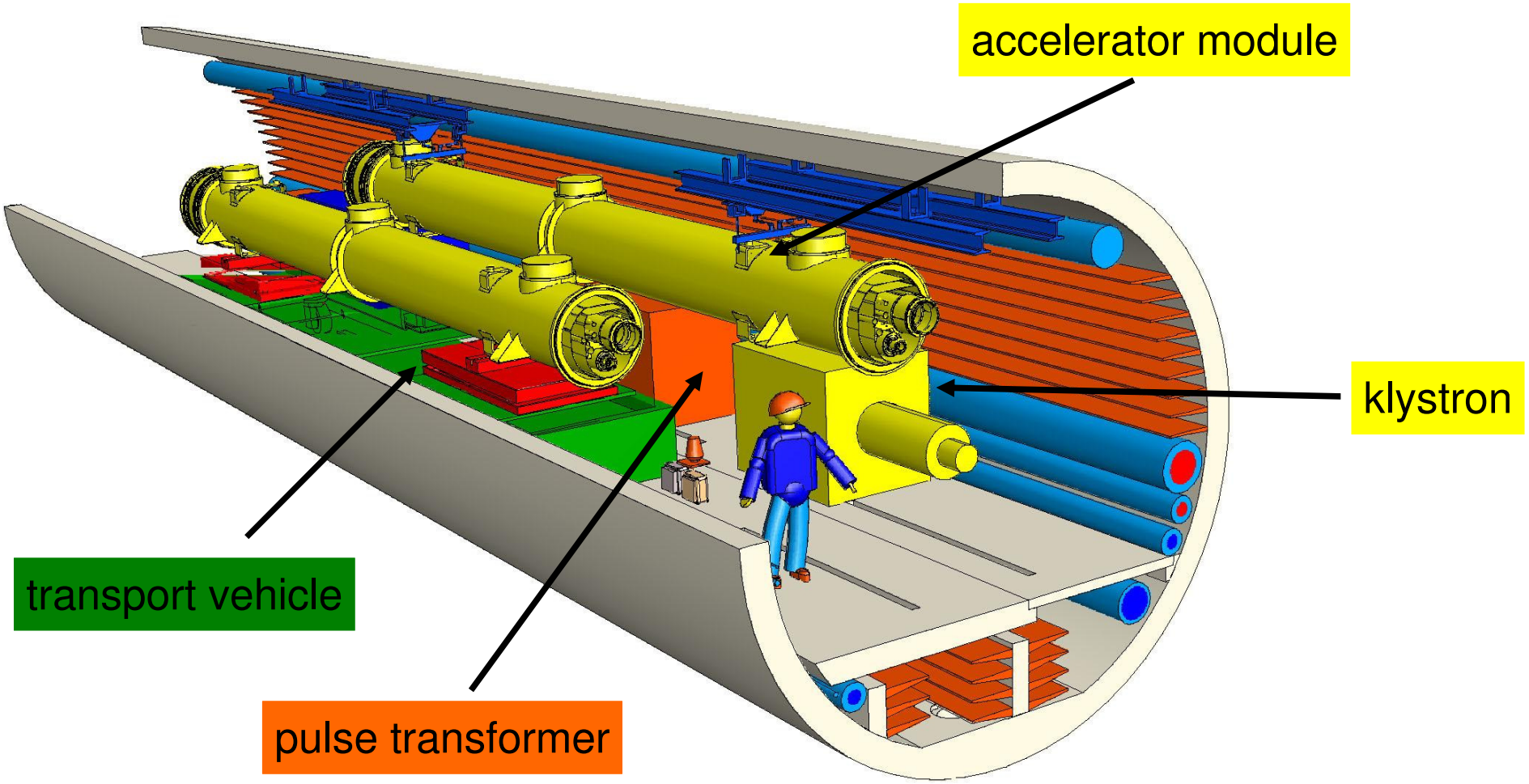


Modulator



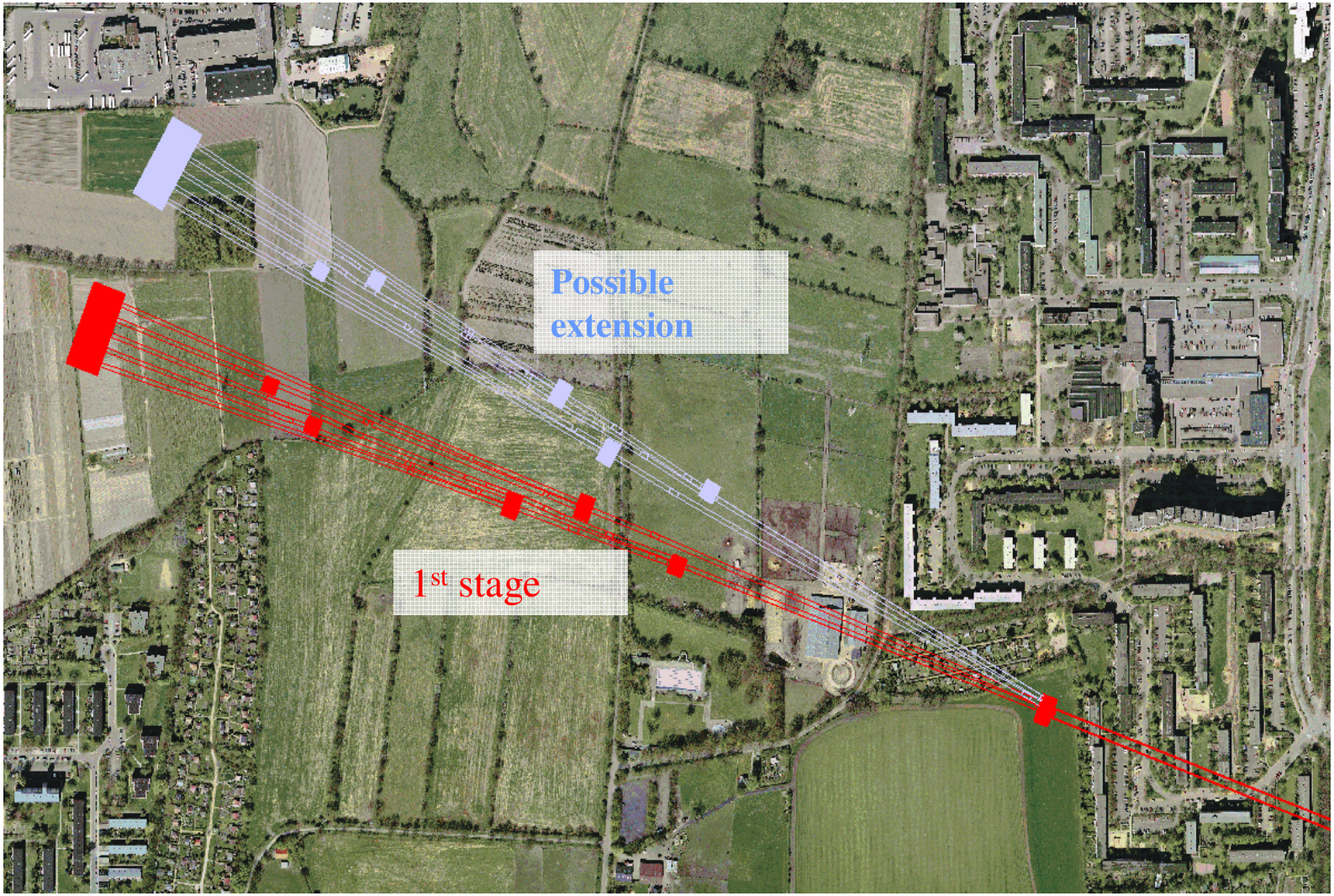
29 RF Stations

XFEL Tunnel Layout

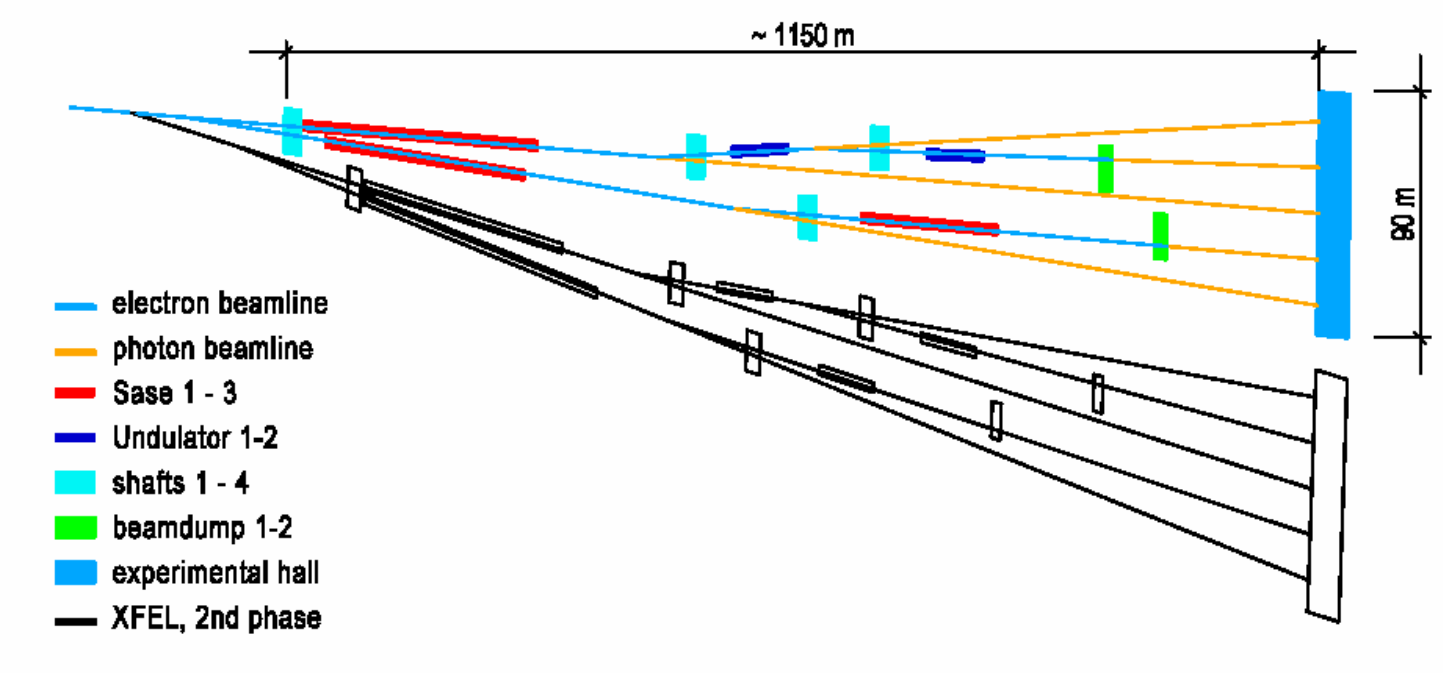


Linac tunnel 15 – 30m underground in urban area

Distribution Fan



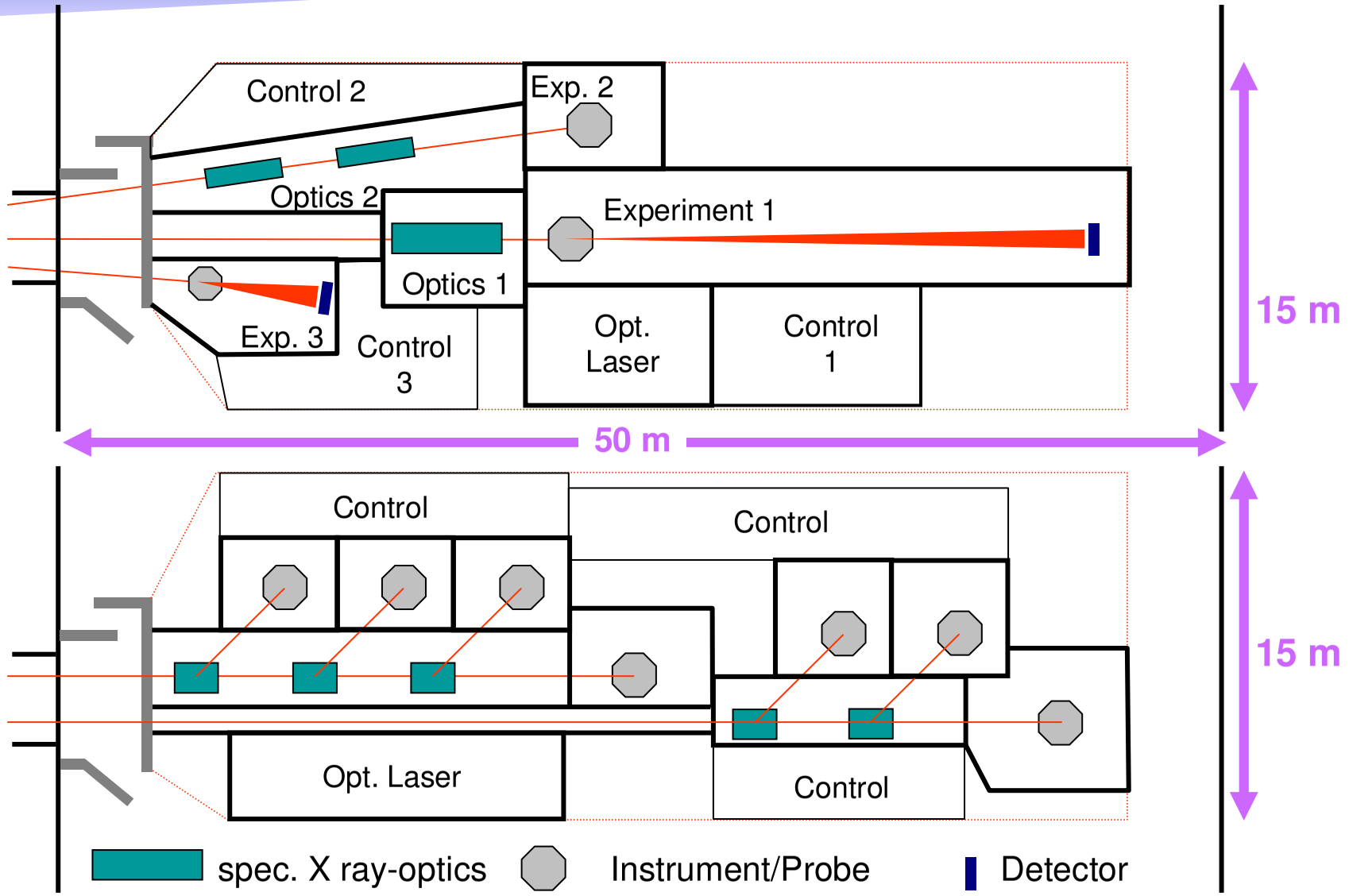
User facility - Beam lines



SASE undulators 0.1 – 6 nm, magn. Length 150 – 80 m

Variable gap (min. 10 mm) → independent λ-tuning

2 Examples for Experiments Installation



Schenefeld Site

Schenefeld Site

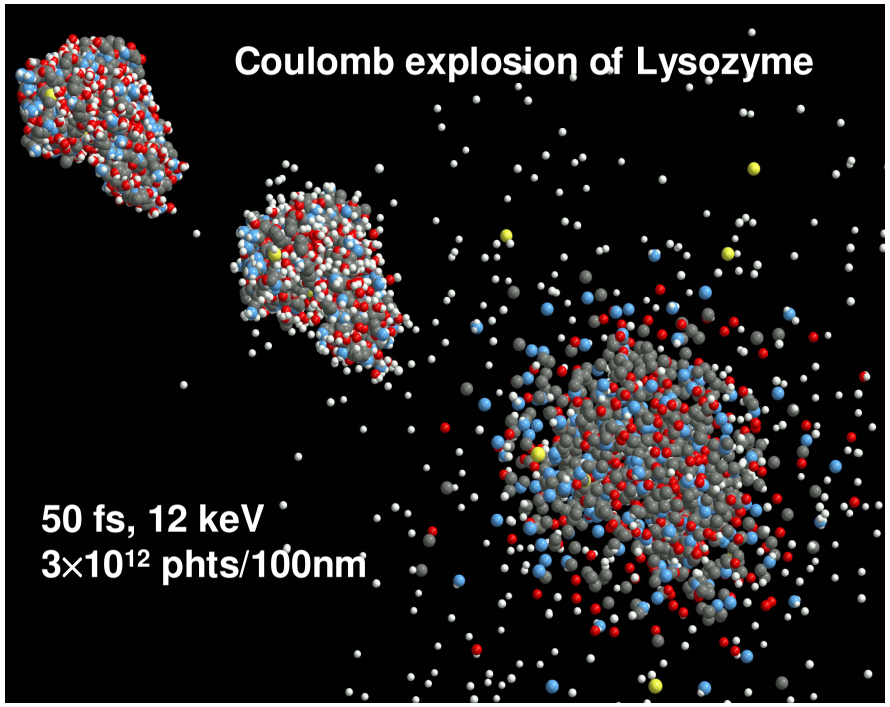
Schenefeld Site

Challenges for the Machine

- Generation and Transport of High Brightness Electron Beams
  - Coherent Synchrotron Radiation
  - Surface Roughness Wakefields
- Stability
- Synchronization
- …

Challenges for the Users

Users have to be very fast



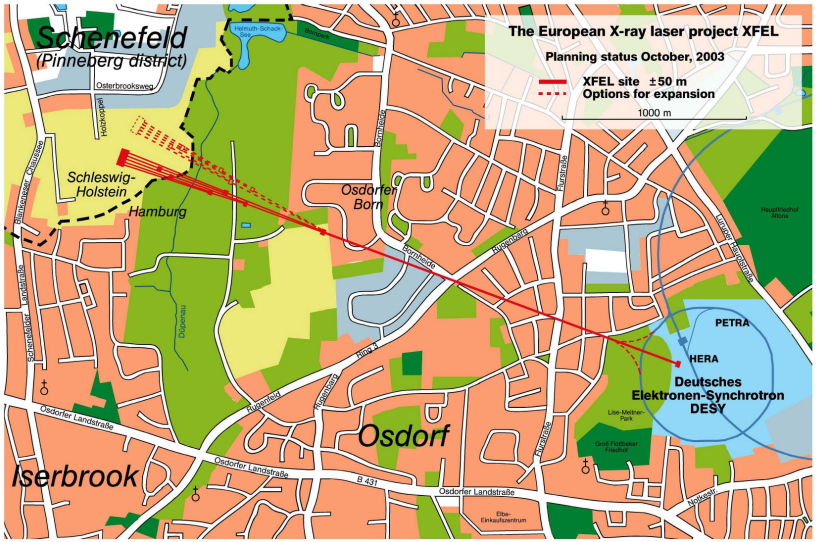
New experimental techniques and fast detectors have to be developed !

XFEL schedule:

Memorandum of Understanding: to date, 11 countries have decided to sign

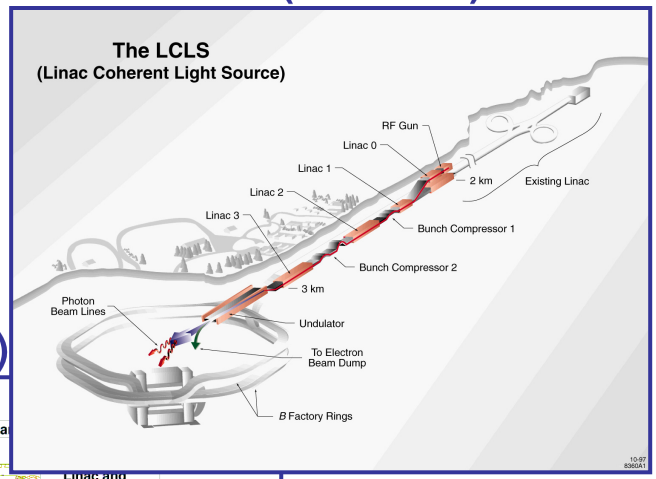
Assume final project approval & funding at European level in ~mid 2006

Status of X-ray FEL projects

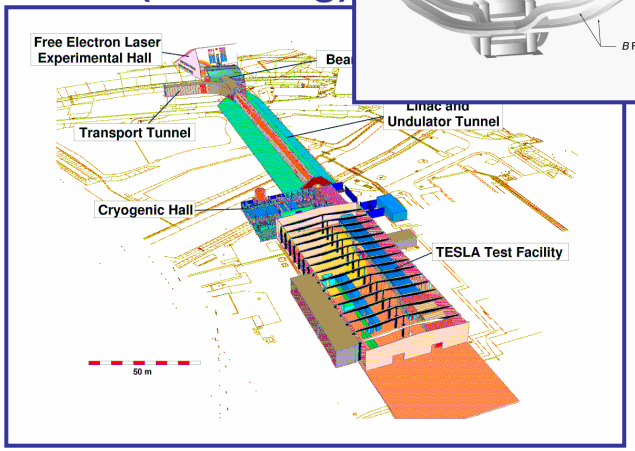


2012 European XFEL (Hamburg)

2008 LCLS (Stanford)



2004 VUV-FEL (Hamburg)



2000-2002 TTF-1 (Hamburg)

2000-2001 LEUTL (Argonne)