9th European Particle Accelerator Conference
5 to 9 July, 2004 Lucerne

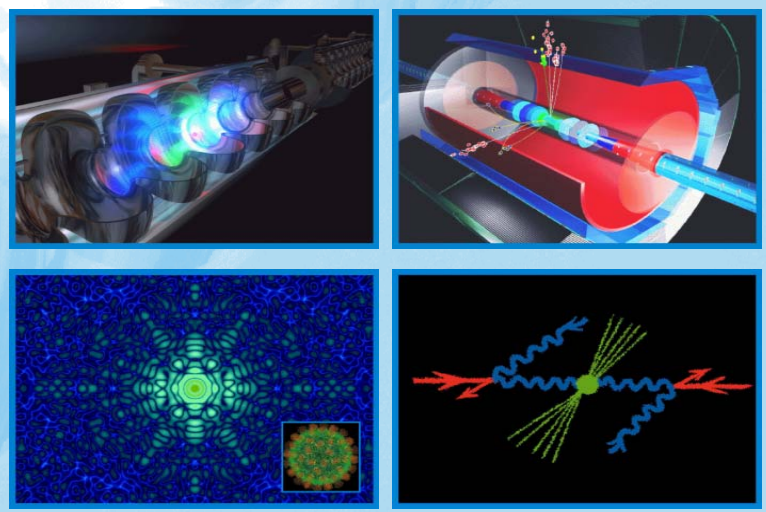
The TESLA XFEL Project

Hans Weise / DESY
for the XFEL Group

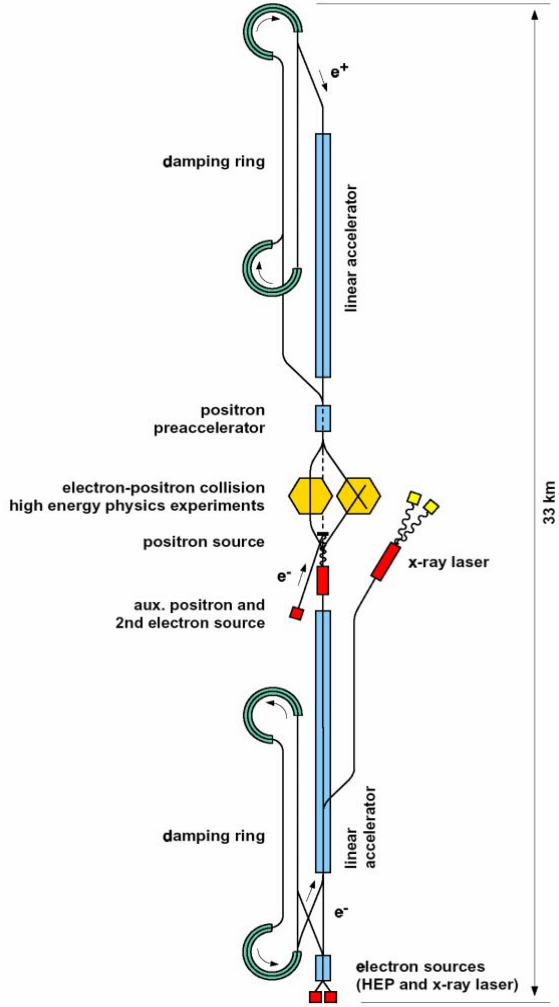
TESLA

The Superconducting Electron-Positron Linear Collider with an Integrated X-Ray Laser Laboratory

Technical Design Report



March 2001



integrated into TESLA LC proposal:

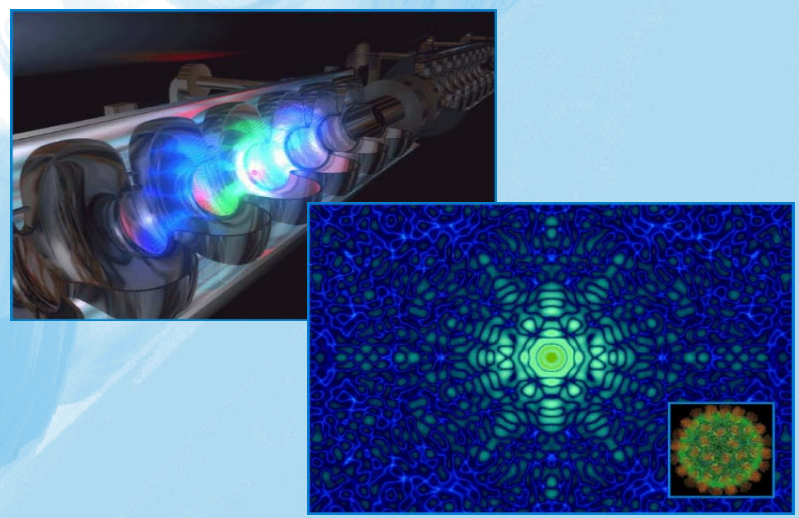
using part of e^- linac, two extraction points, long beam transfer → cost effective but less flexible solution

TESLA XFEL

First Stage of the X-Ray Laser Laboratory

Technical Design Report

Supplement



October 2002

TDR update 2002:

XFEL driver linac separate from LC

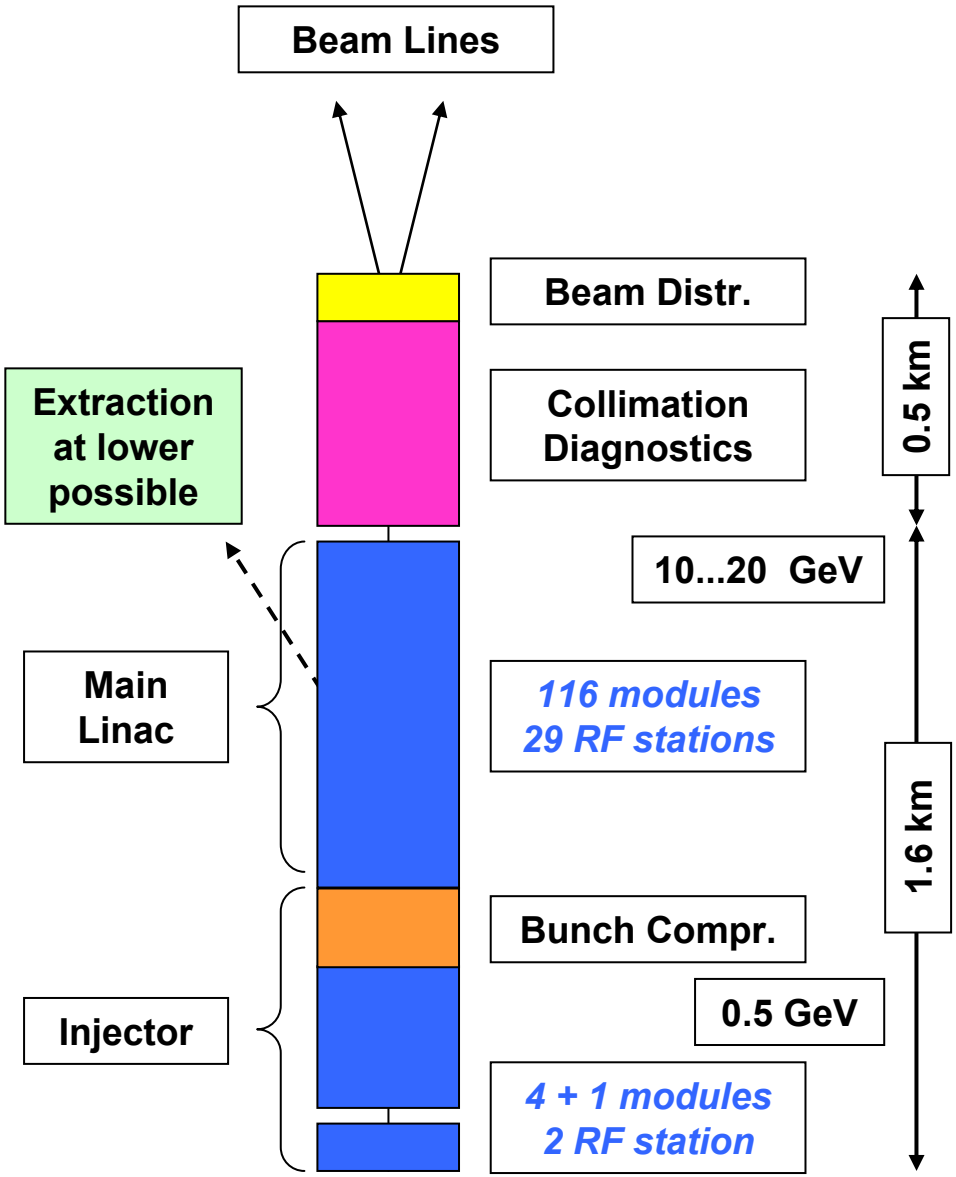
→ de-coupling of the XFEL from the Linear Collider regarding construction & operation (and: *approval*)

- **maintaining common site**
- **identical linac technology**
- **detailed analysis of potential gain in flexibility was not included in the update**

Since then...

- **SASE FELs in operation**
- **LCLS project**
- **XFEL is a European project**
- **new site close to DESY**
- **TESLA linac technology**
- **detailed analysis of flexibility with respect to photon beam time structure**
- **detailed planning started**

Basic Accelerator Layout

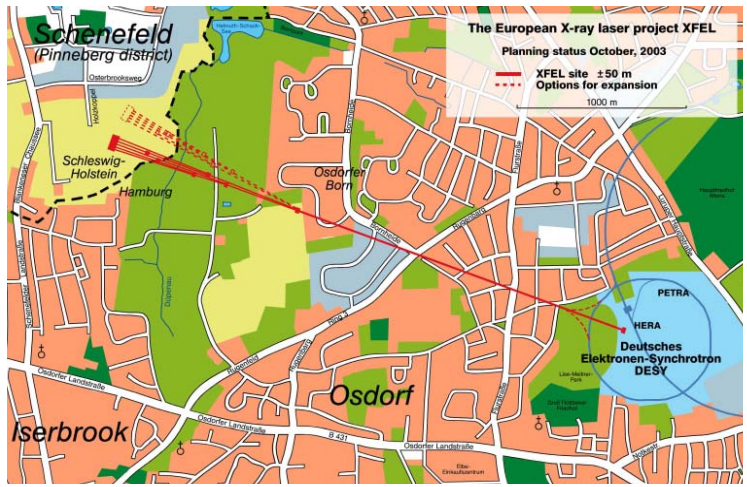


The XFEL starts on the DESY site.

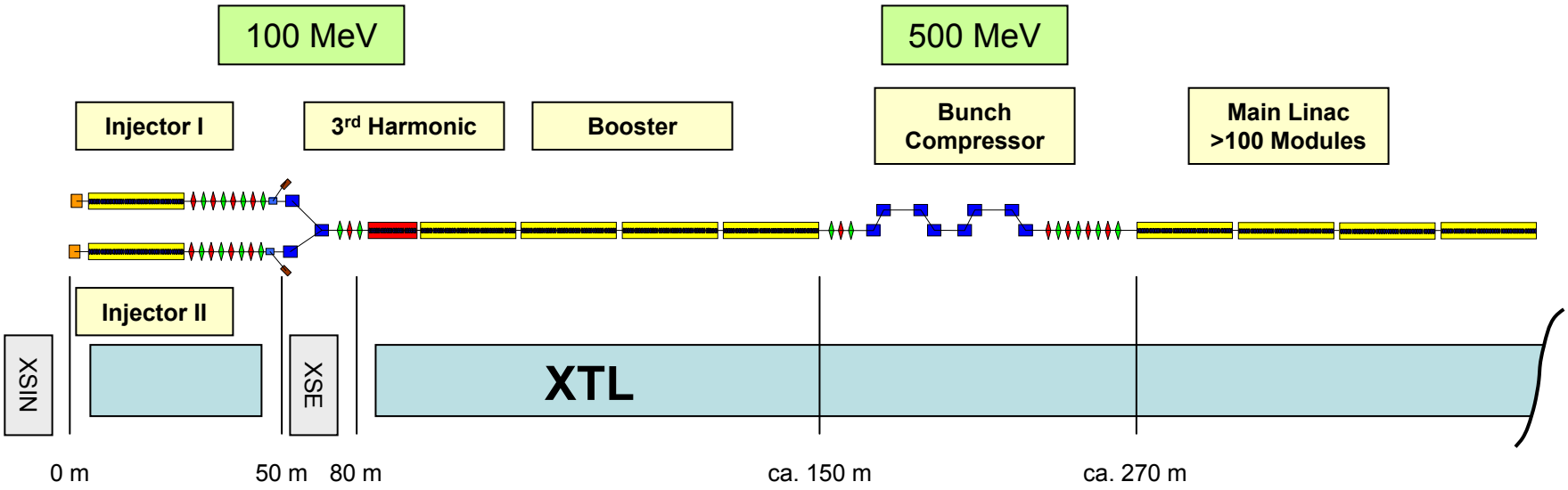
The tunnel is approx. 15 to 30 m deep underground.

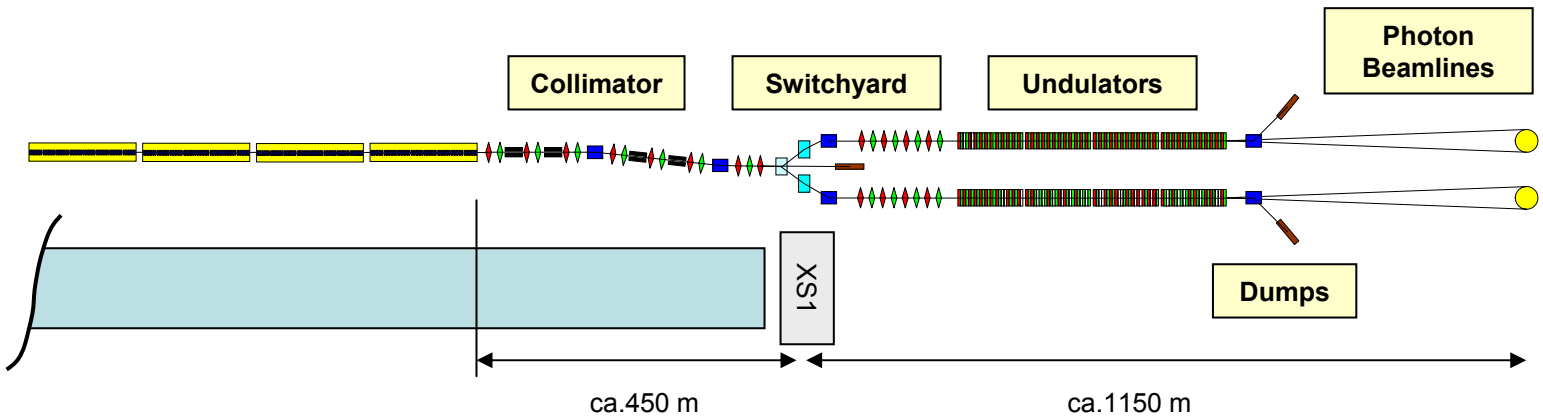
The linac is below an urban area.

An almost rural area offers sufficient space for the experiments hall.



XFEL Linac Layout



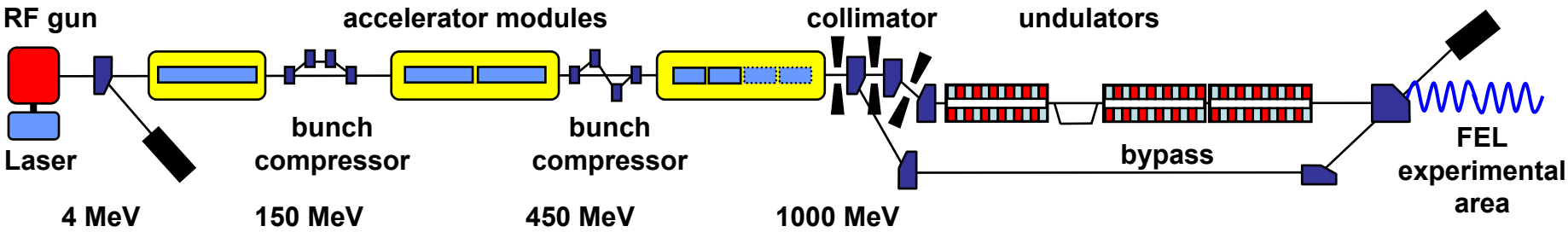


Reference Parameters

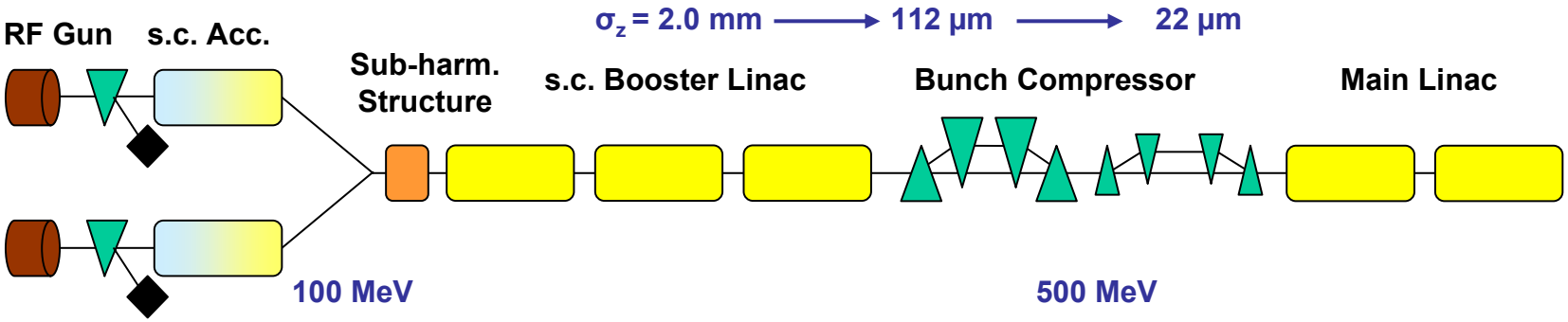
Main linac	
Energy gain	0.5 → 20 GeV
# installed modules	116
# active modules	104
acc gradient	22.9 MV/m
# installed klystrons	29
Bunch spacing	200 ns
beam current	5 mA
power→beam p. klystron	3.8 MW
incl. 10% + 15% overhead	4.8 MW
matched Q_{ext}	$4.6 \cdot 10^6$
RF pulse	1.37 ms
Beam pulse	0.65 ms
Rep.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

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

TESLA Test Facility as Prototype for the XFEL



TESLA Test Facility as Prototype for the XFEL Injector

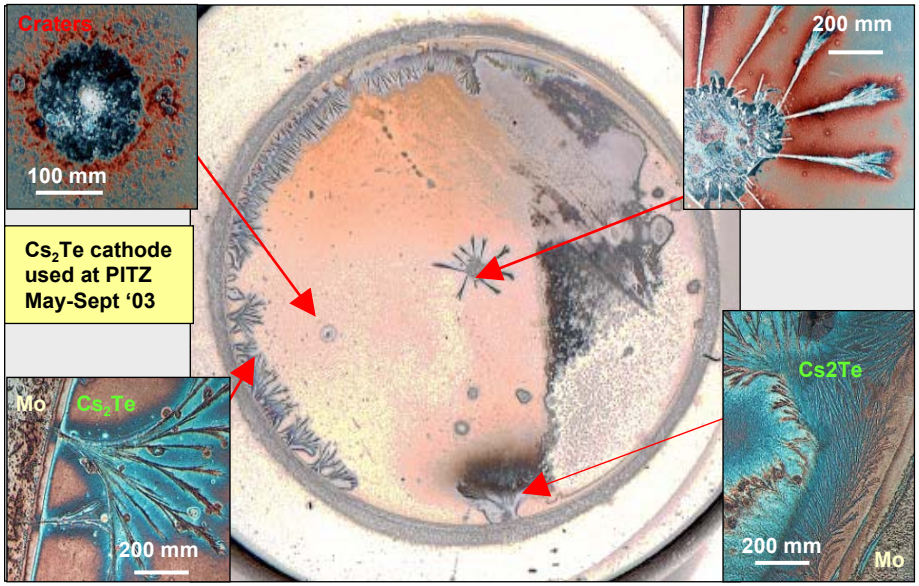


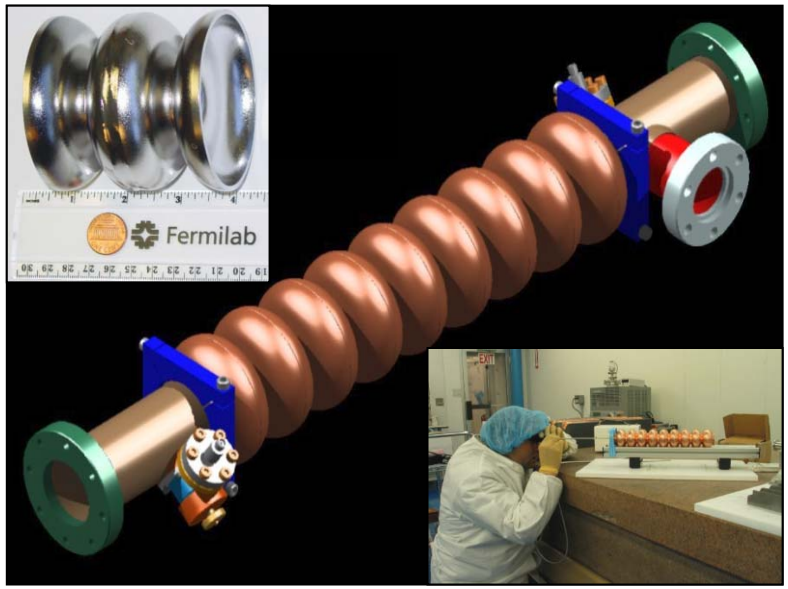
The goal for the XFEL:

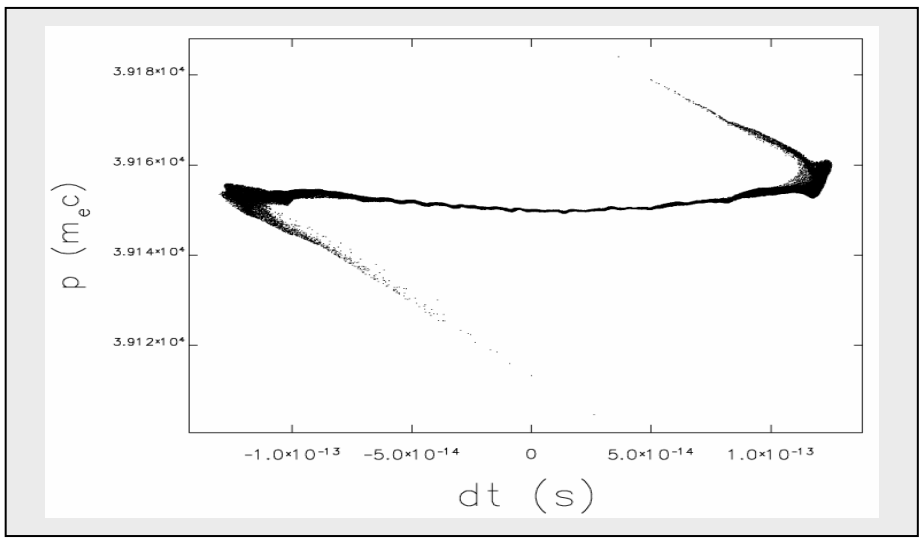
charge	1nC
$\varepsilon_{x,y}$	1.4 µm
σ_z	~ 20 µm (80 fs)
$\sigma_{E,\,uncorr}$	< 2.5 MeV

At TTF and PITZ (DESY) we are already close to these parameters.

Injector R&D in the TESLA Collaboration

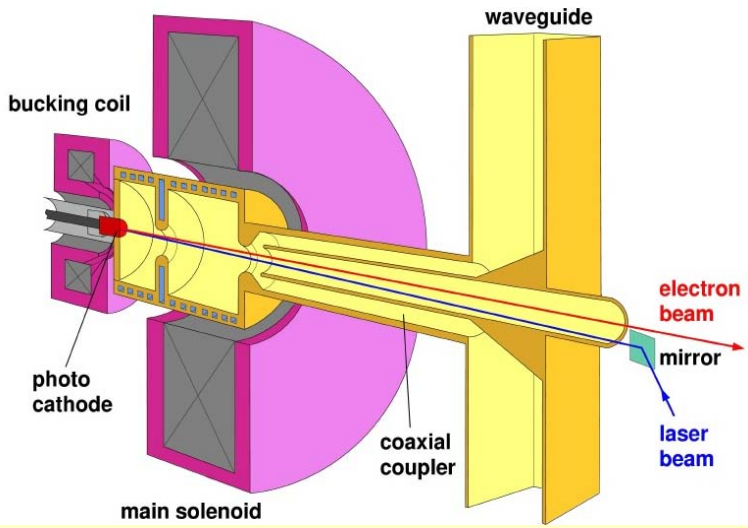






- **Cathode development** at INFN Milano.
- **Simulation code development** at DESY and FNAL.
- **3rd harmonic cavities** at FNAL.
- Experimental investigations at the **A0 Photo injector** at FNAL.
- Injector operation at **TTF I and TTF II**.
- Experimental investigations at the Photo Injector Test stand in Zeuthen **PITZ**.

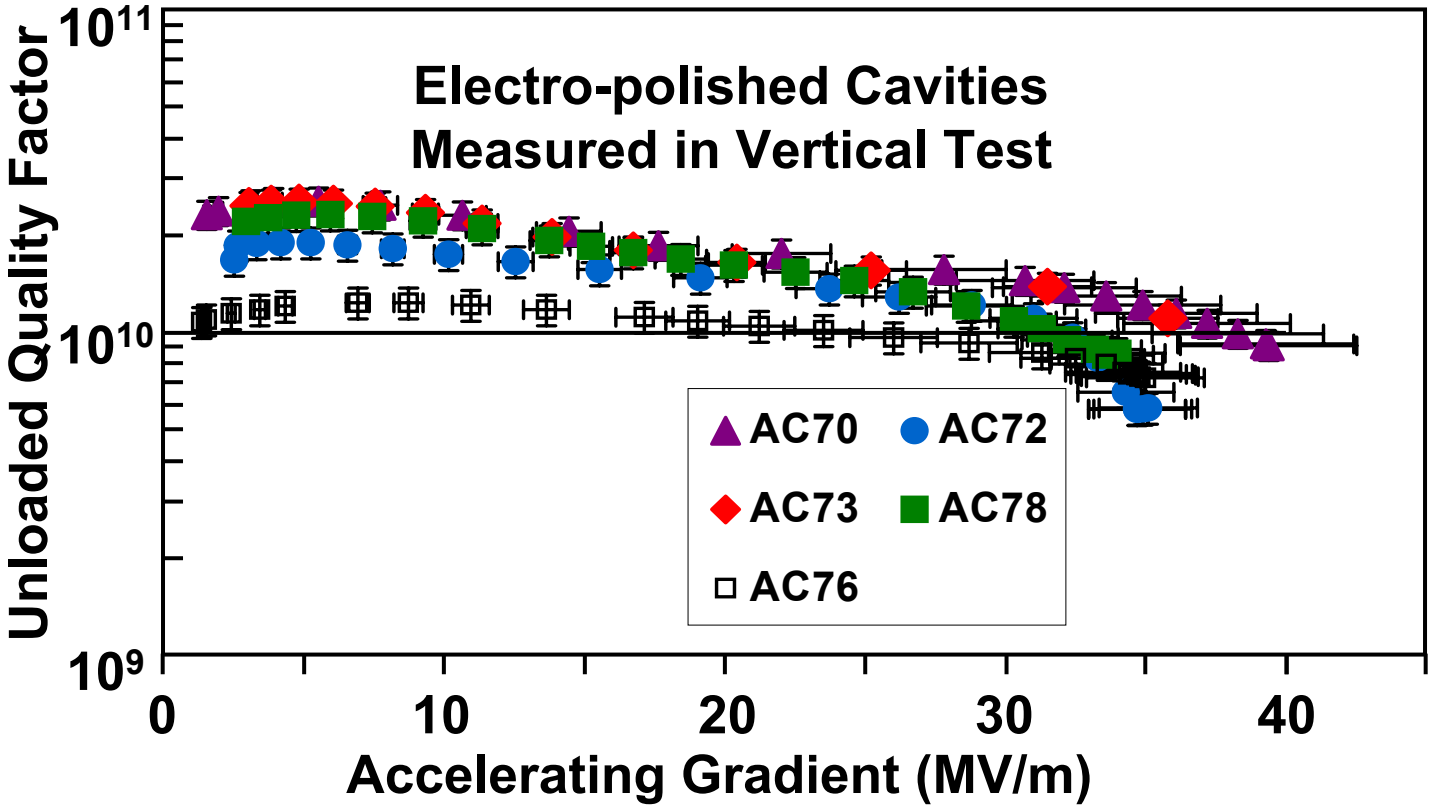
From TTF II to the XFEL Injector



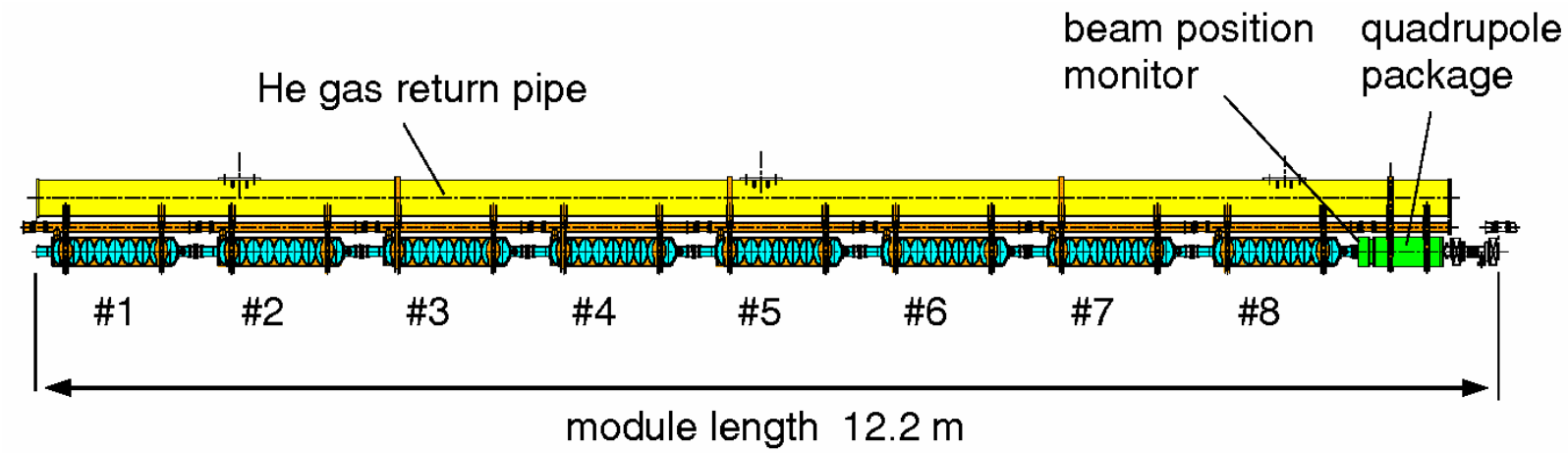
TTF II parameters have been achieved at PITZ (DESY Zeuthen).
In order to reach the XFEL parameters we have to:

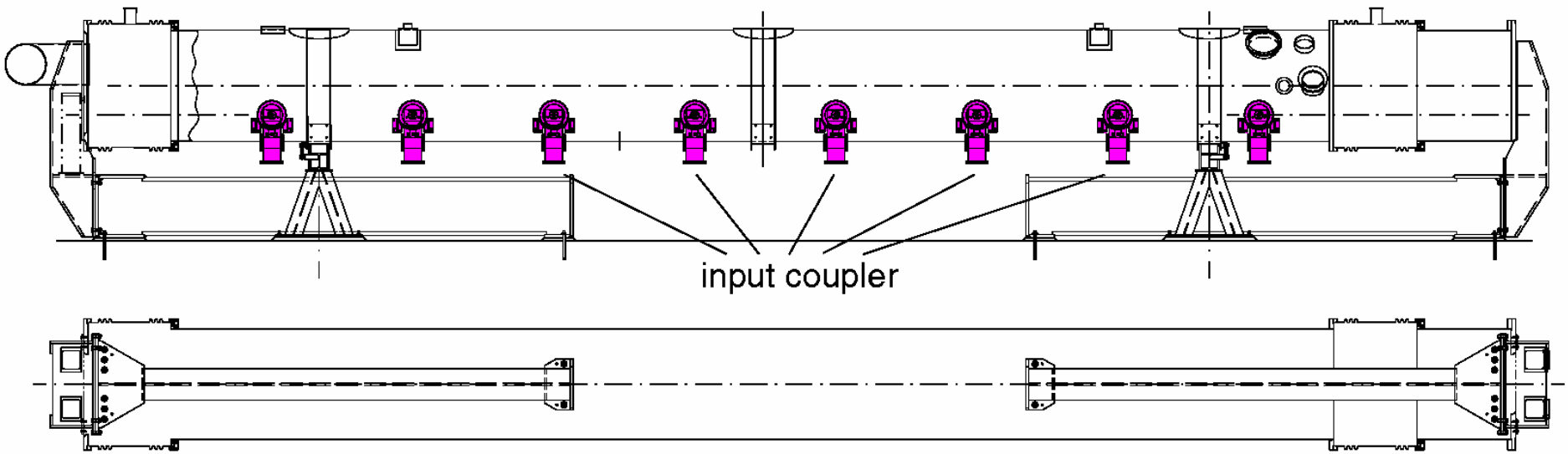
- **increase the gradient on the cathode from 40 MV/m to 60 MV/m**
  this is scheduled for the next running period at PITZ
- **further improve the transverse and longitudinal laser profile**
  an on-going program in collaboration with the Max-Born Institute

Electro-Polishing becomes State-of-the-Art Surface Preparation Technique



TTF Accelerator Modules





Cavity String Assembly

The assembly of an 8 cavity string

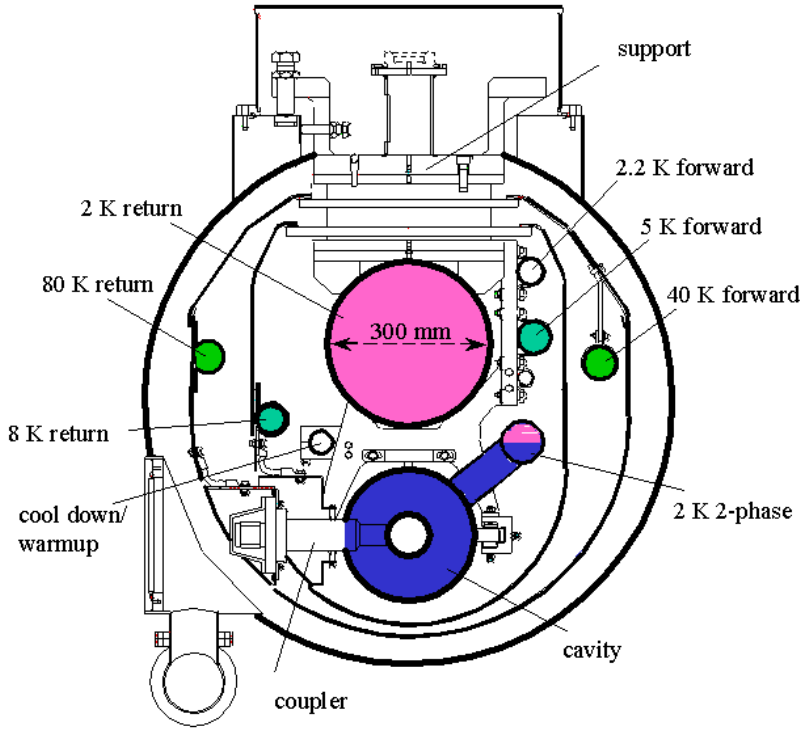
- is a standard procedure
- is done by technicians from the TESLA Collaboration
- is well documented using the cavity database as well as an Engineering Data Management System
- was the basis for two industrial studies.

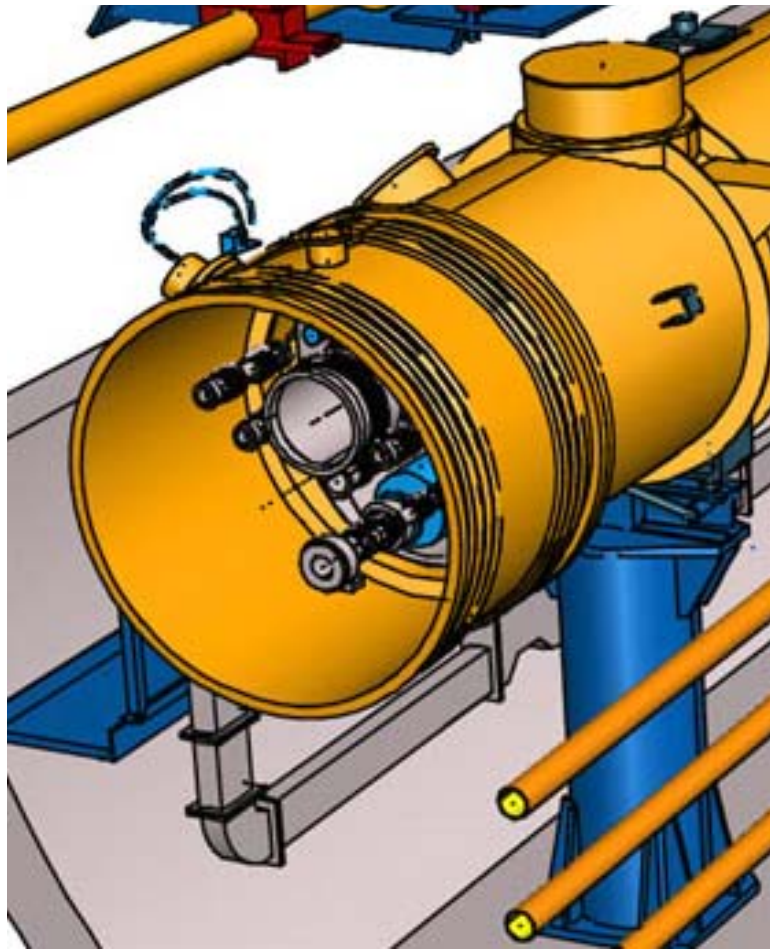
We are ready to transfer this well known and complete procedure to industry.

The inter-cavity connection is done in class 10 clean rooms

TTF Linac Accelerator Modules

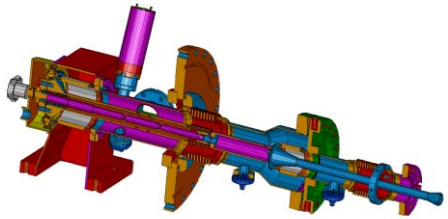
New Generation as XFEL Prototype





- **Reduced diameter**
- **New concepts accommodate for lon-gitudinal shrinkage during cool down**

RF Unit of the XFEL (32 cavities)



var. Q_ext with adjustable coupler and/or waveguide tuner

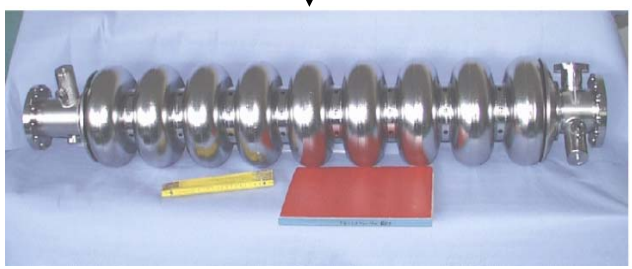
5 MW RF source

De-rated 10MW MBK

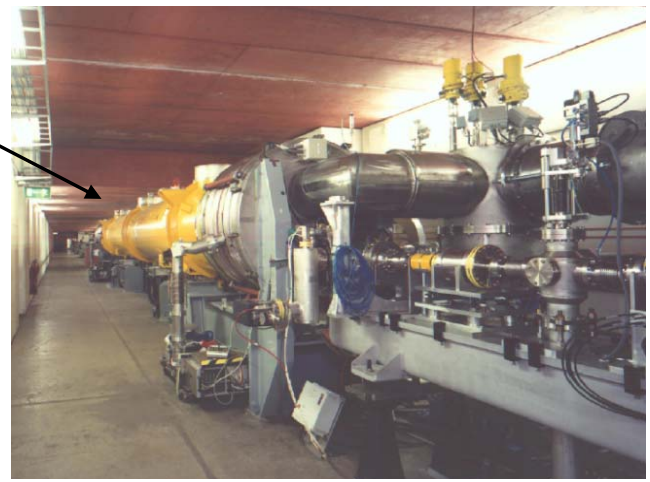
Bouncer-type modulator

Acc 1 | Acc 2 | Acc 3 | Acc 4

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

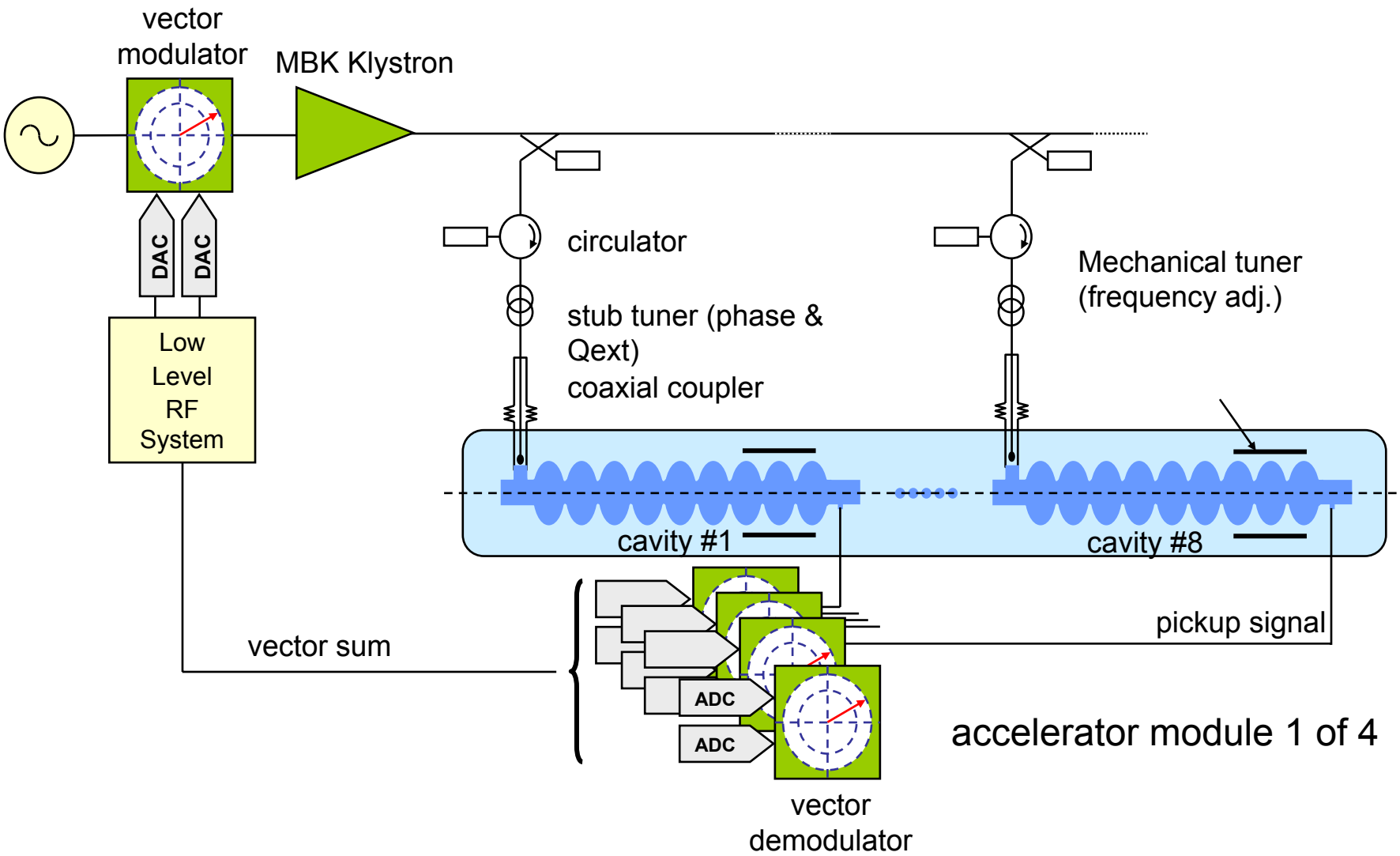


12m TTF-like acc. modules

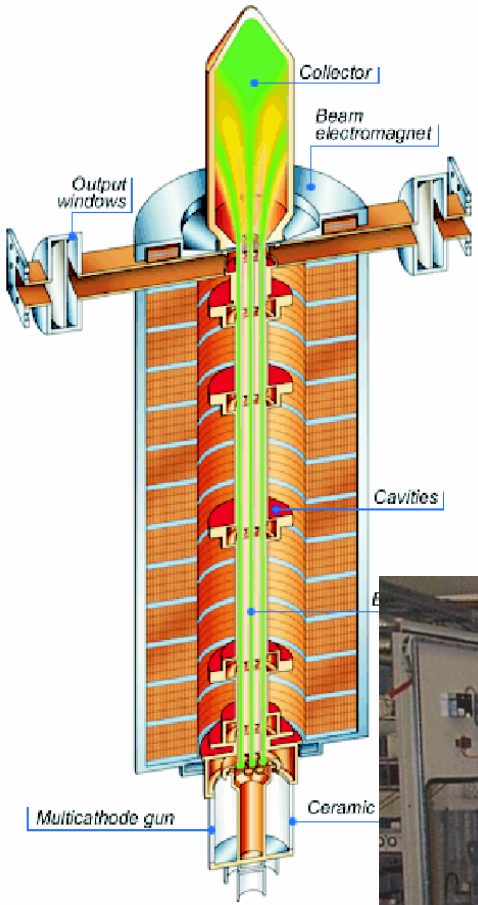


XFEL RF Unit

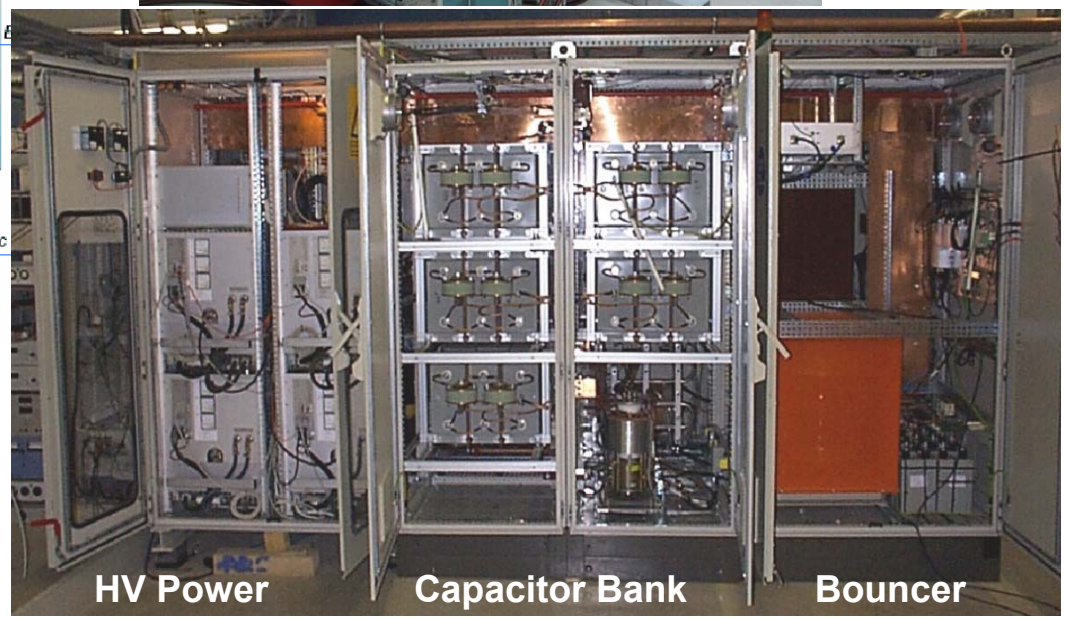
1 klystron for 4 accelerating modules, 8 nine-cell cavities each



TTF High Power RF



IGCT Stack



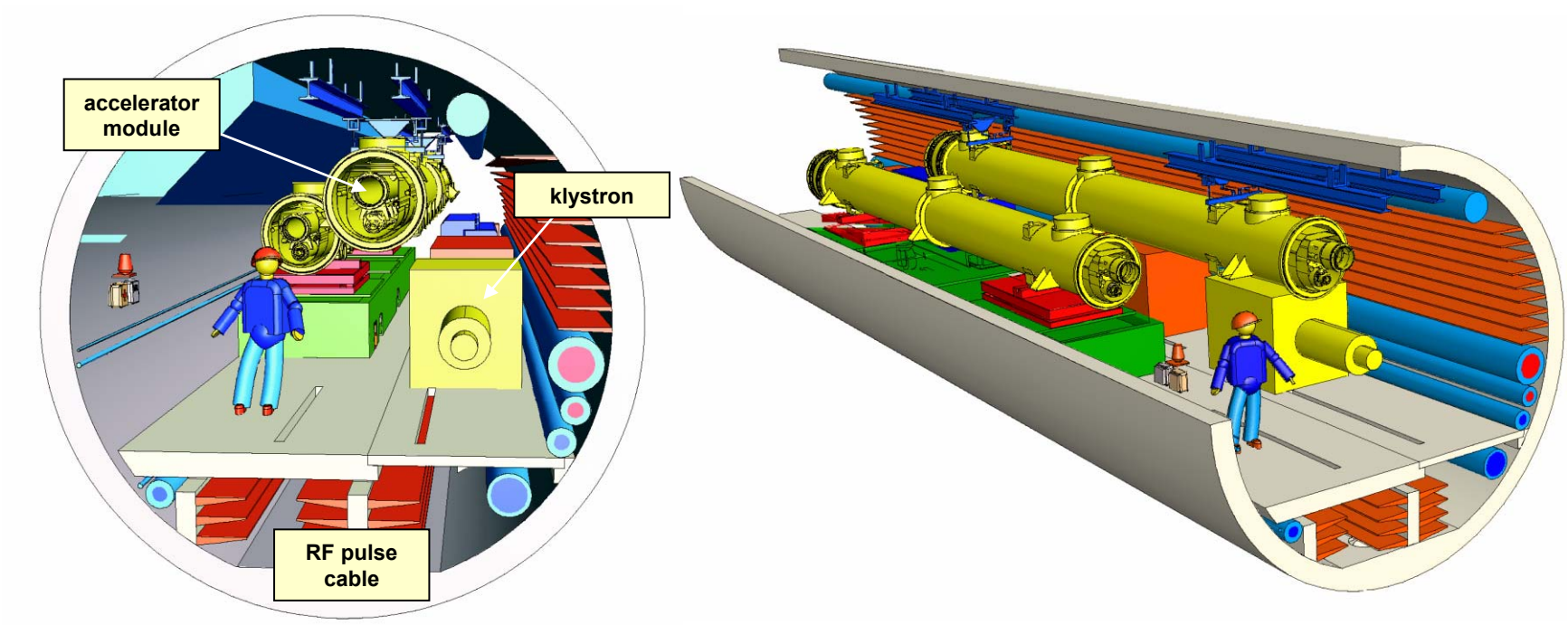
TH1801
Multi-Beam
Klystron

XFEL Linac Tunnel Layout

Accelerator is housed in a 5.2 m diameter tunnel ~ 15 - 30 m underground.

Klystrons in tunnel are connected to modulators in an external hall by 10kV pulse cables.

Preferred installation concept is suspension from tunnel ceiling



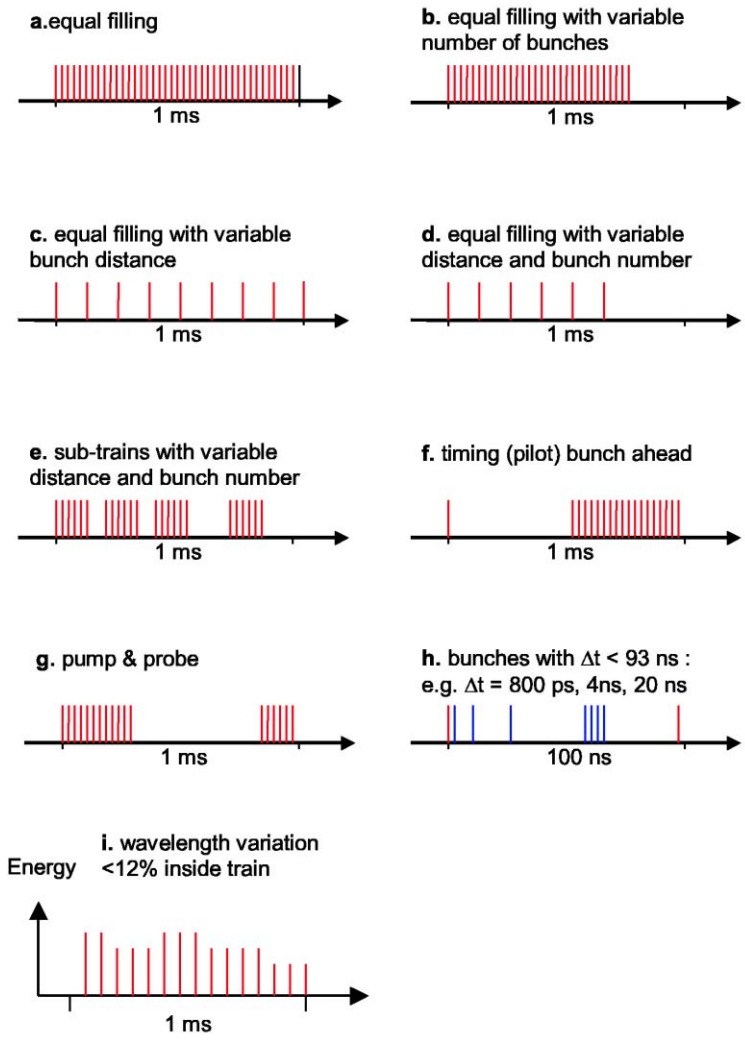
Photon Pulse Time Structure

Future users ask for:

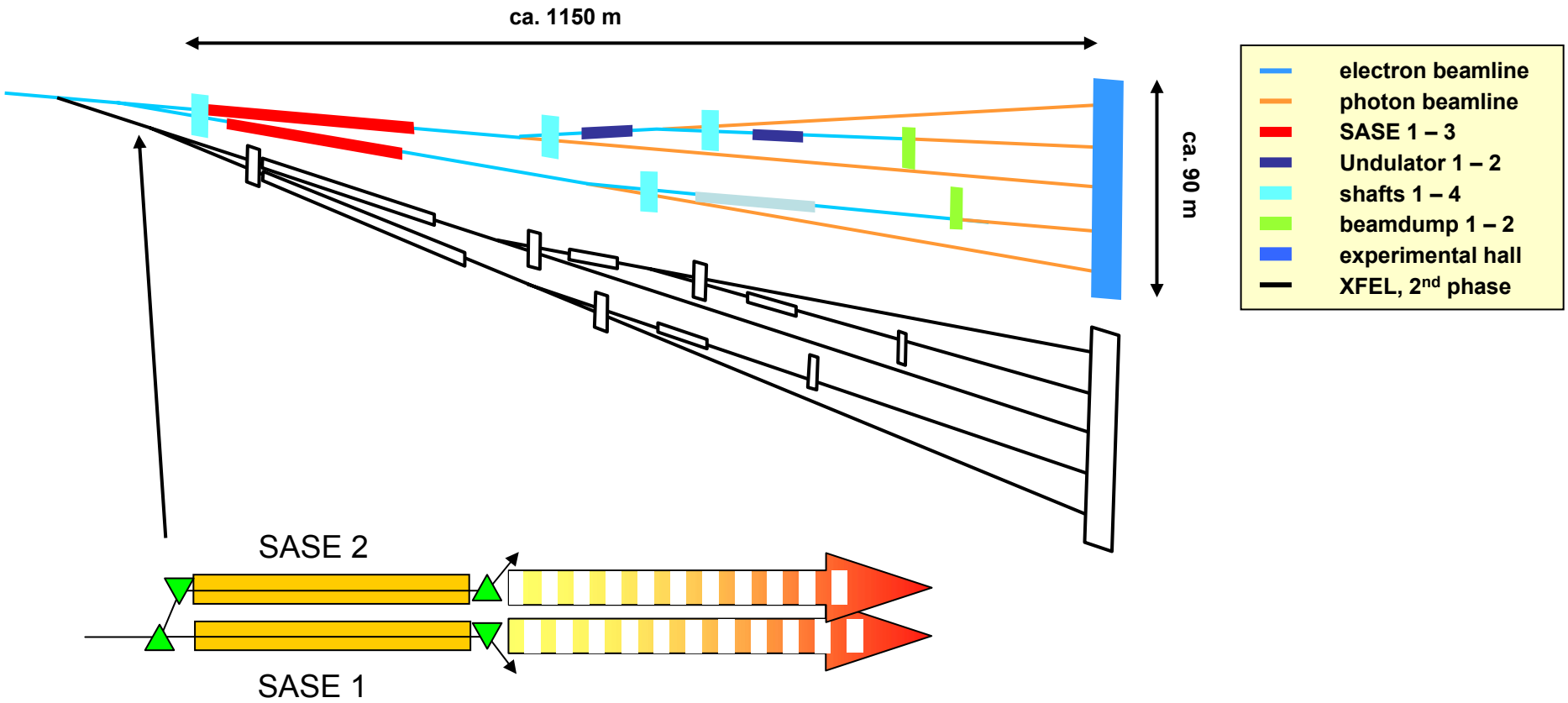
- **Homogenous filling**
- **Homogenous filling with variable bunch distance**
- **Homogenous filling with variable bunch distance and bunch number**
- **Sub-trains with variable distance and bunch number**
- **Pilot bunches ahead**
- **Pump and probe (two bunches spaced by one / a few RF buckets)**
- **Wavelength variation of a few percent inside a bunch train,**
  i.e. energy variation

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**

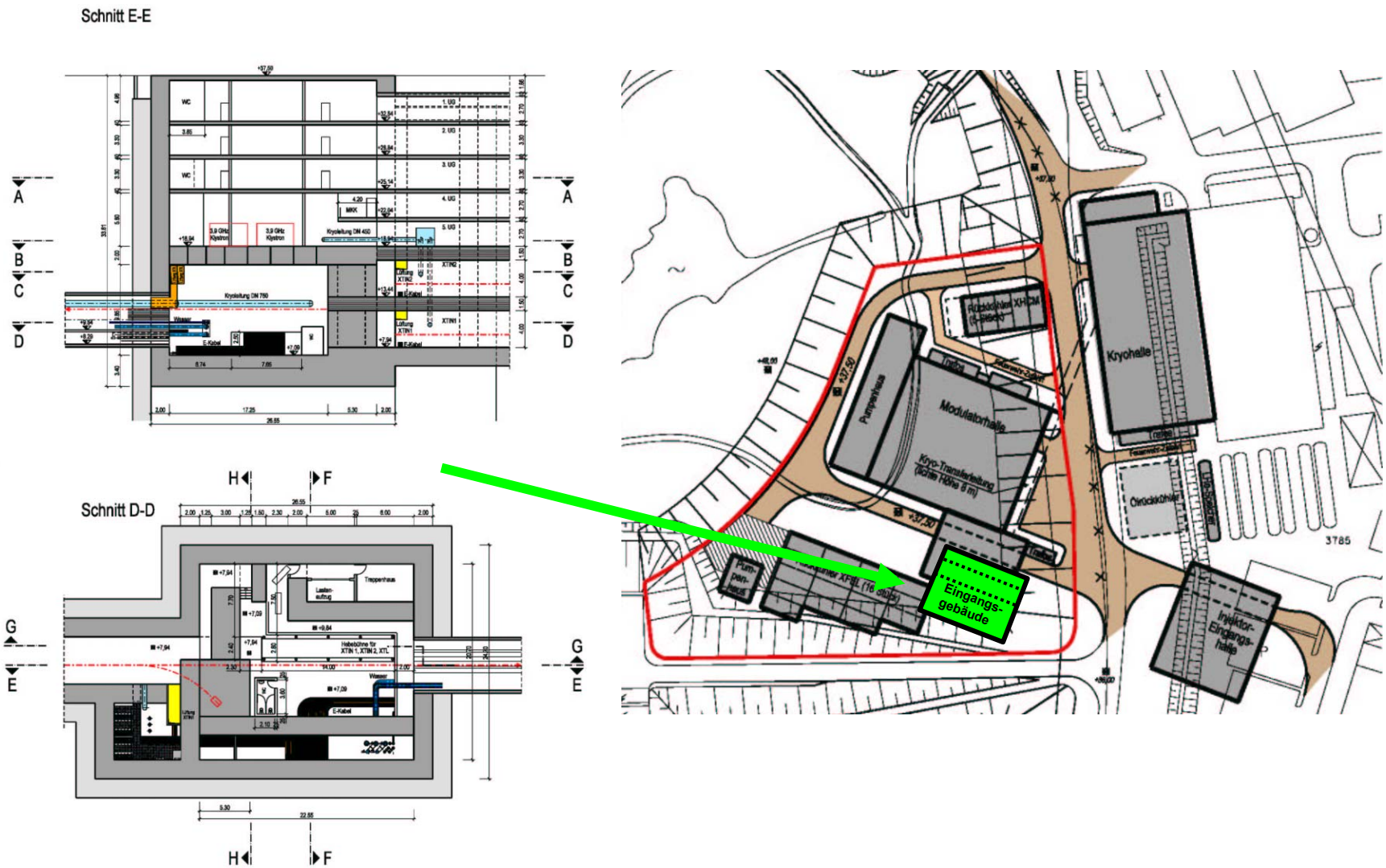


Electron Beam Distribution

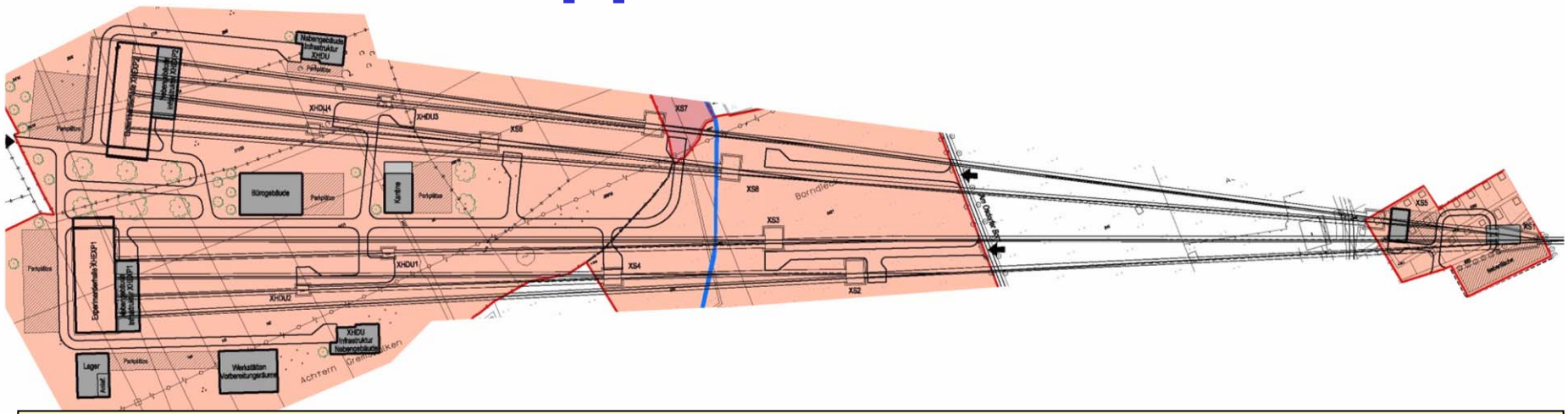


DC Magnet	Slow switch pulse to pulse	High Q Resonator	Programmable fast kicker for individual bunches
One beamline only Commissioning option	Duty cycle reduced by number of beamlines TDR option	Fixed bunch pattern, full duty cycle	Flexible

The First Detailed Site Drawings



Plan Approval Procedure



The plan approval procedure requires a detailed site layout.

At present the preparation of this legal procedure is done on the basis of the knowledge we have.

In order to detail the different sections of the XFEL installation, a number of accelerator experts and future users, nominated by their home institutes and the corresponding national funding agencies, are discussing the final layout in two groups:

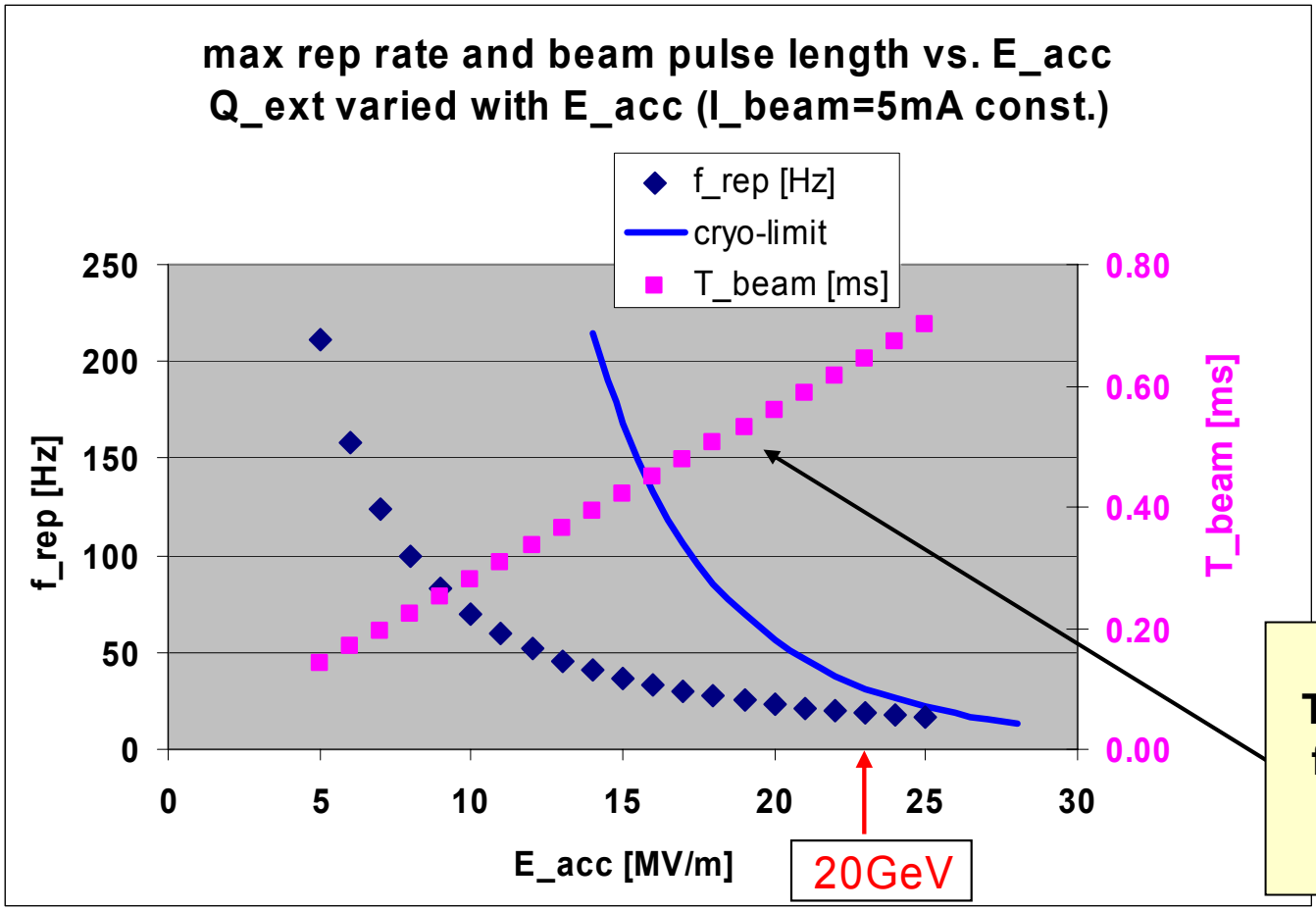
- **Science and Technology Issues (STI) as well as**
- **Administrative and Funding Issues (AFI).**

Both groups are going to come up with a common proposal and a memorandum of understanding by 2005.

Sketch of a Possible Future CW Operation Mode

- **Assume that as a result of longer term developments the possibility of Ångstroem FEL radiation at lower beam energy comes in reach, by:**
  - **Improved beam quality (lower emittance)**
  - **Shorter period undulators**
  - **Advanced FEL concepts, etc.**
  - **Last, not least: experience gained during 1st stage of the facility**
- **→ high duty cycle (up to CW) operation mode may become an attractive future option and should not be excluded in the design**

Repetition Rate for Bunch Trains



If you are ~~curious~~ please check http://xfel.desy.de

want to participate

The European X-Ray Laser Project XFEL - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Back Search Favorites Media

Address http://xfel.desy.de Go Links

MySearch Search Smiley Central My Info Customize My Button 1 Highlight

XFEL
X-Ray Free-Electron Laser

The European X-Ray Laser Project XFEL

DESY

XFEL Homepage | Organization | Technical Information | Science | Project Group

XFEL » XFEL Homepage

- XFEL Homepage
- Facts & Figures

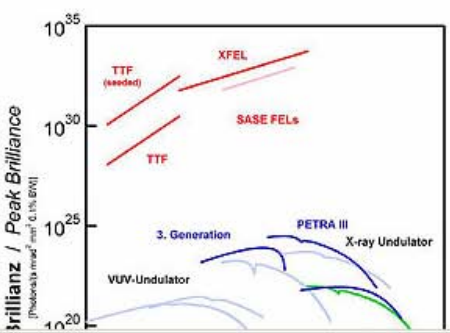
Website Hosted by DESY

Deutsch

The European X-Ray Laser Project XFEL

The X-Ray Free-Electron Laser—A Light Source of Superlatives

In February 2003, the German Federal Ministry of Education and Research gave the green light for the X-ray laser. Together with European partners, the project is to be further developed in such a way that a decision to begin construction can be made at the end of 2004. After a construction period lasting about six years, the commissioning of the facility could start in 2012. An international research team—the TESLA collaboration—is currently trying out the facility's pioneering technology at a test facility in Hamburg—and it has already achieved the key milestones it has been aiming for. The free-electron X-ray laser will make it possible to do leading-edge research in Europe and will guarantee a major role for Germany as a location for research and industry.



Brilliance in comparison
This comparison of the peak brilliance of synchrotron radiation sources with free-electron lasers (FELs, red lines) shows the great leap in brilliance offered by the FELs. (Source: DESY Hamburg)

External Links

- XFEL News
- xfel-wissen.desy.de
  What is worth knowing about the European X-ray laser project XFEL - project, application, light source, accelerator
  In German

Internet

Conclusions

- The 20 GeV s.c. linac based on the technology developed by the TESLA collaboration and successfully demonstrated at TTF / VUV-FEL is an ideal driver for the Free Electron Laser facility, offering a broad range of operating parameters in its baseline design. Future upgrade options can be included.

- With the R&D work towards industrial production of major components and the preparations for the site and the legal procedure (plan approval procedure) well under way, we should be ready to go into construction phase in ~2 years from now.