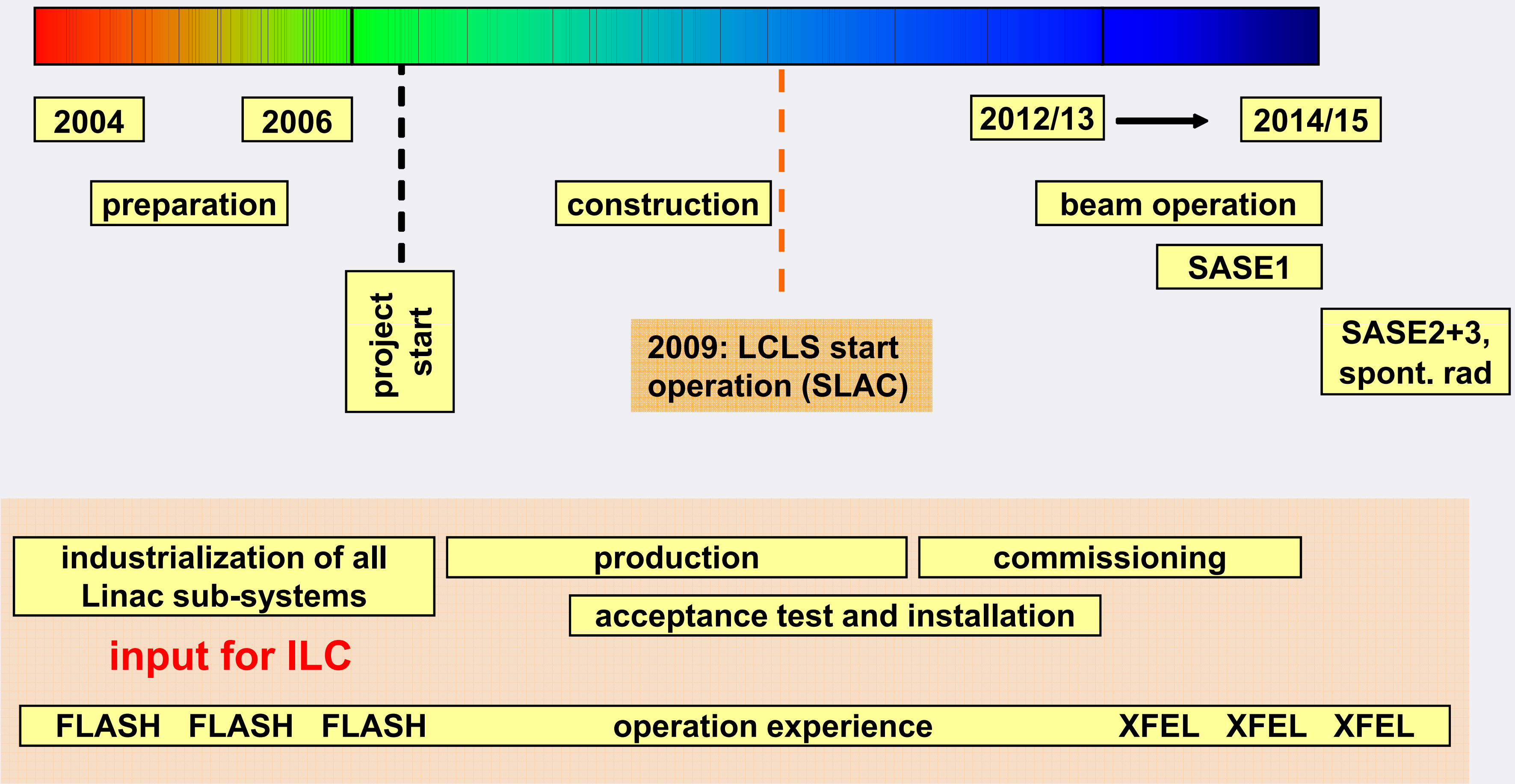
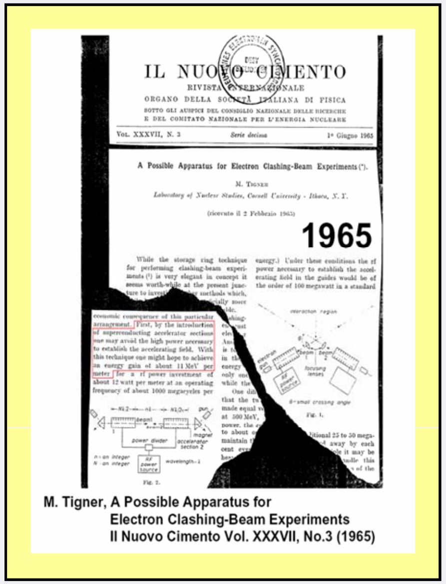
XFEL: which ILC questions are answered?

H. Weise, for the XFEL Project Team

XFEL Principle Schedule



From the Idea to the TDR, and to the Project Start


IL NUOVO CIMENTO
RIVISTA INTERNAZIONALE
A Possible Apparatus for Electron Clashing-Beam Experiments
M. Tigner
Laboratory of Nuclear Studies, Cornell University - Ithaca, N. Y.
1965

M. Tigner, A Possible Apparatus for
Electron Clashing-Beam Experiments
Il Nuovo Cimento Vol. XXXVII, No.3 (1965)

sc linac

2001 XFEL Proposal

2002 XFEL Supplement

2006 XFEL Final TDR

1997 1st electron beam accelerated at TTF
2000 1st lasing at TTF-FEL (80-120 nm)
2005 1st lasing at TTF (VUV-FEL) 30 nm
2006 13 nm and saturation
many happy photon beam users
2007 energy upgrade to 1 GeV,
i.e. 6 nm in reach

FLASH

2003 German Science Council recommends building the XFEL
2004 Project Preparation Phase
MoU between European Partners
(project preparation)
2006 Final TDR incl. detailed technical layout and experiments
Planning Approval

XFEL

XFEL International Project Organization

XFEL Steering Committee ISC (Chair: H. Schunck, Germany)

- Representatives of all countries intending to contribute to the XFEL facility
- *13 countries have signed MoU (project preparation phase) in 2004*

CH	CN	DE	DK	ES	FR	GB	GR	HU	IT	PL	RU	SE

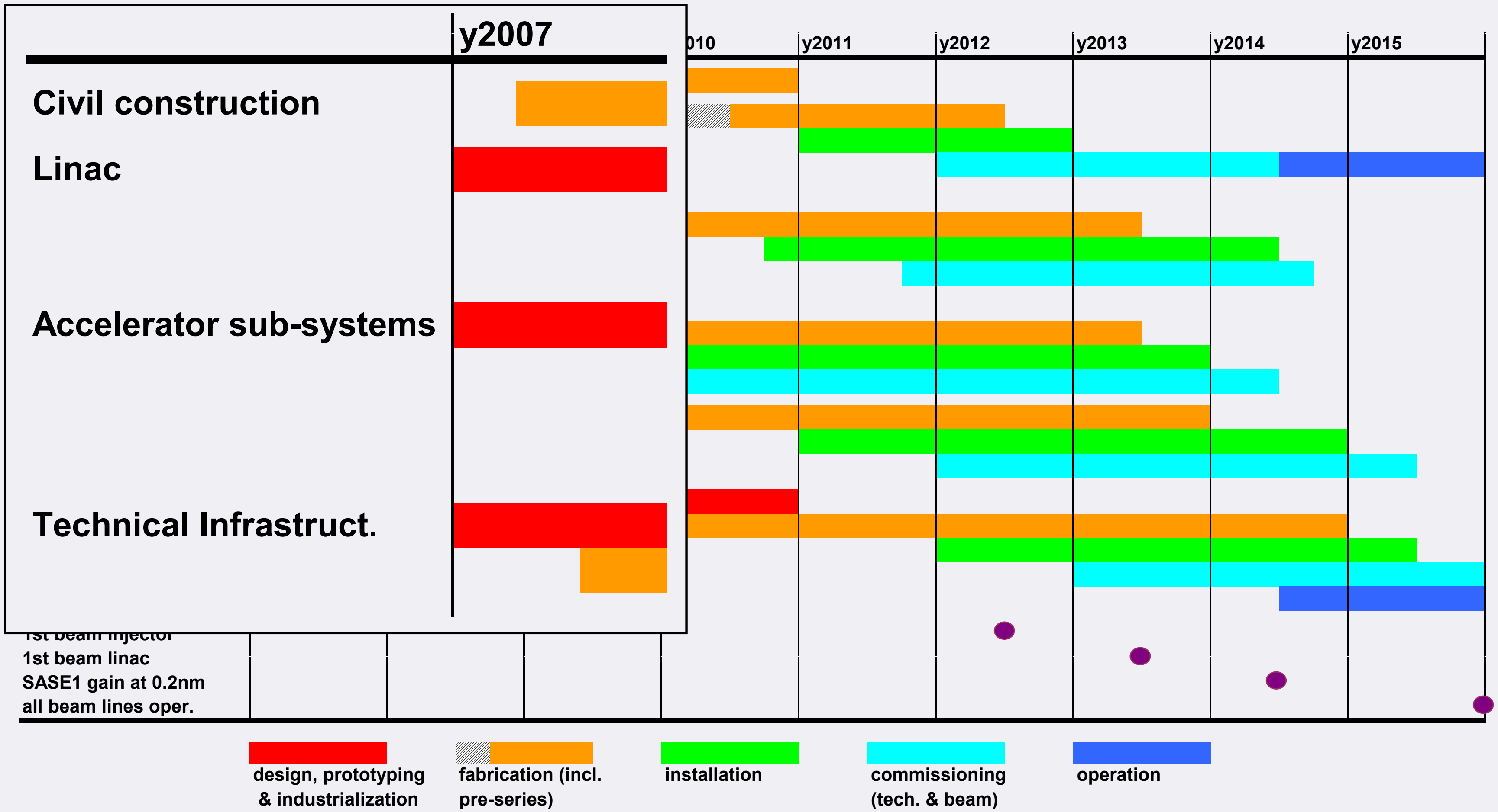
- *Nomination of European Project Team (Leader: Massimo Altarelli)*

WG on Scientific and Technical issues STI (chair: F. Sette, ESRF)

WG on Administrative and Funding issues AFI (chair: H.F. Wagner, Germany)

Bi-lateral negotiations between Germany and signature countries on funding contributions are ongoing

XFEL Schedule



XFEL Civil Construction

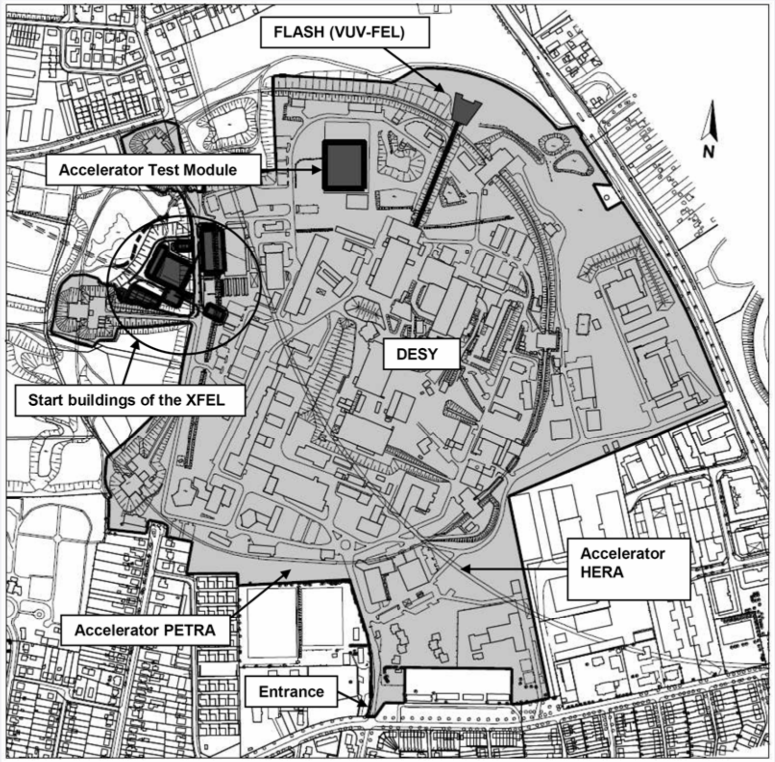
The requirements for all **XFEL buildings were specified** on the basis of several iterations with all involved technical groups. The process,

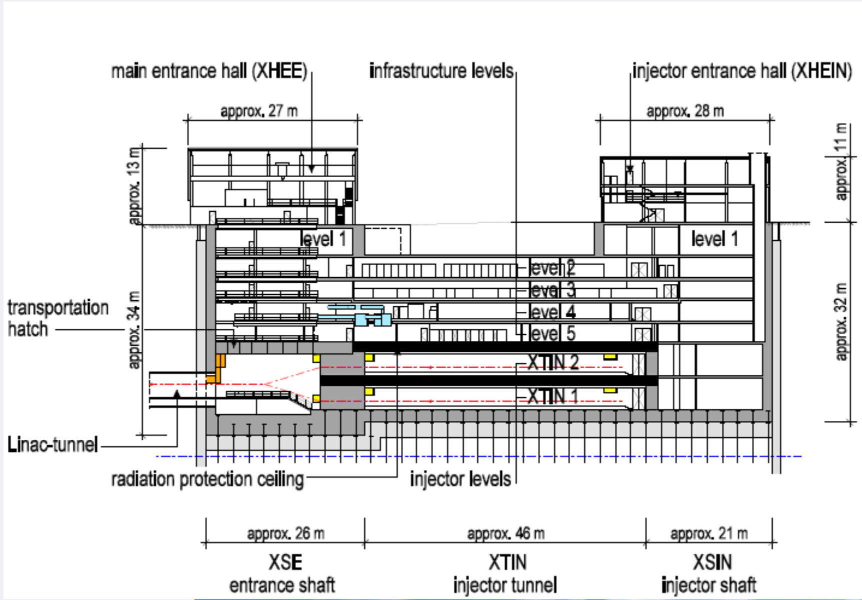
- starting with simple brainstorming,
- followed by detailed discussions about TTF experience,
- a long discussion about the accelerator tunnel layout
- close collaboration with professional civil engineers specialized on underground buildings

now ends in the **call for tender procedure** (June 6th, 2007) for the civil construction, and was strongly supported by Engineering Data Management tools.

A side remark / experience:
Scientists liked the good old paper (pdf files), while engineers took quite some advantage of EDMS

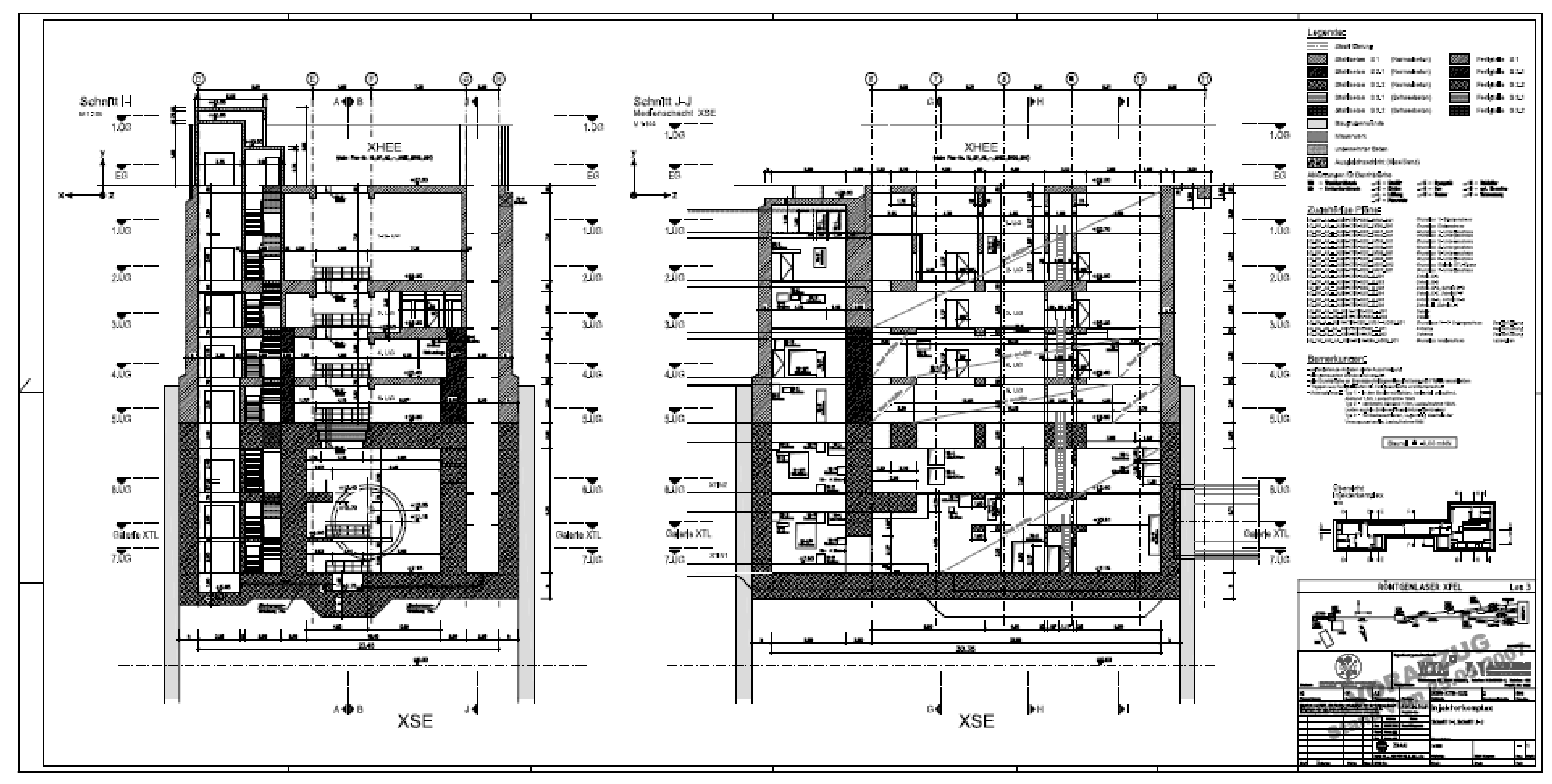
XFEL Buildings





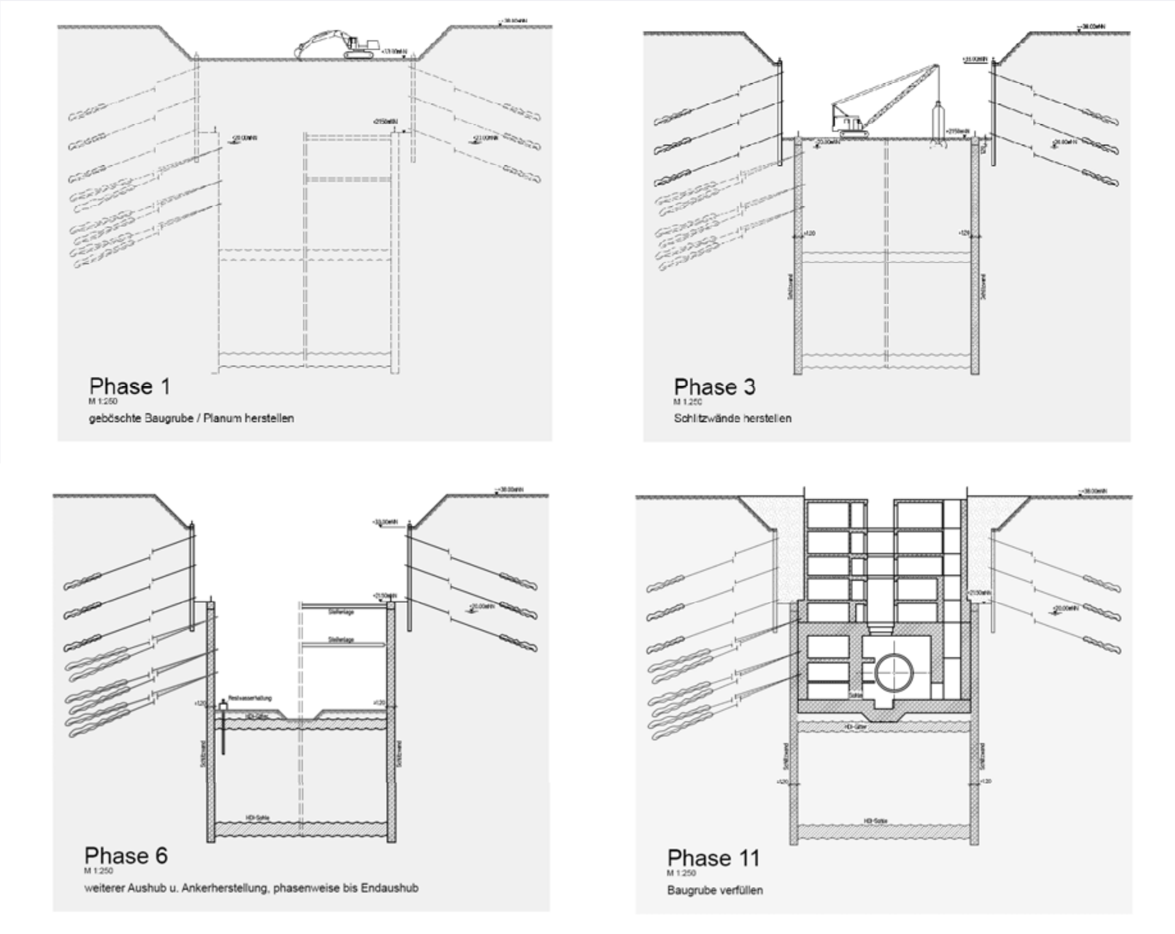
A great help: The **XFEL injector is basically a copy of the TTF Linac**. All the experience wrt. the technical infrastructure was an excellent starting point.

Construction Documents for XFEL Buildings



Detailed specifications allow the beginning of construction work for all XFEL buildings. The work is completely secured by the official **Planning Approval**.

XFEL Ground Breaking



Ground-breaking is expected for early spring 2008.

The tunnel and shaft buildings will be realized in a depth from 12 m up to 44 m below the surface. The **foundation** of the buildings will thus be situated **below the groundwater table** and the buildings will lie up to 20 m inside the groundwater.

XFEL Buildings

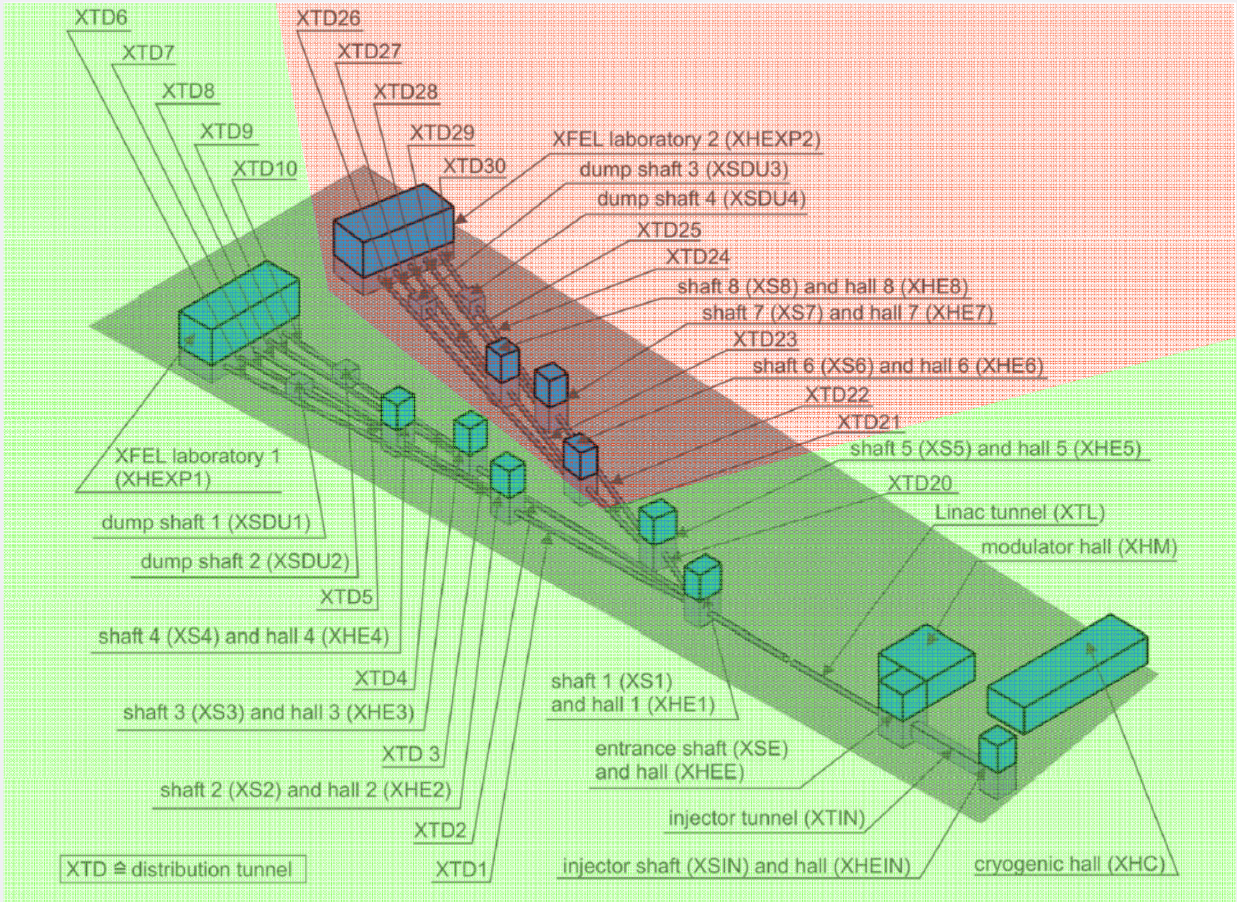


Figure 7.1.3: *Nomenclature for the main buildings of the XFEL facility for the two building phases, both above and below surface.*

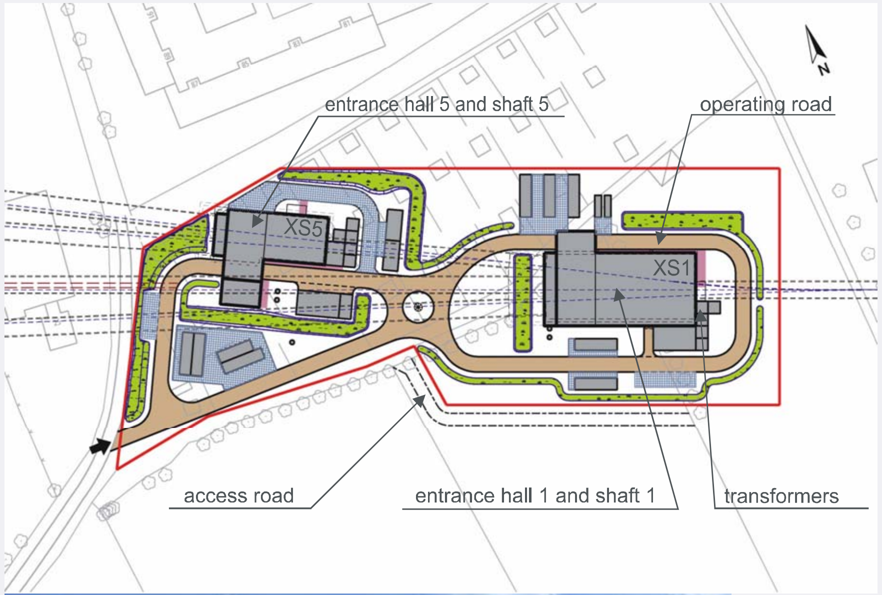
2000 m accelerator tunnel

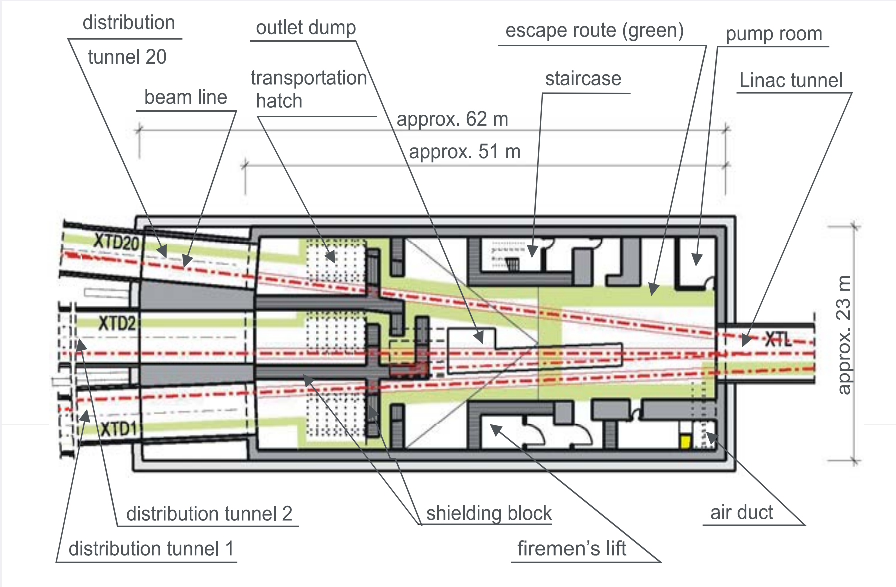
3850 m electron and photon beam transport

10 halls / 9 shafts including so-called distribution shafts, i.e. the splitting of tunnels

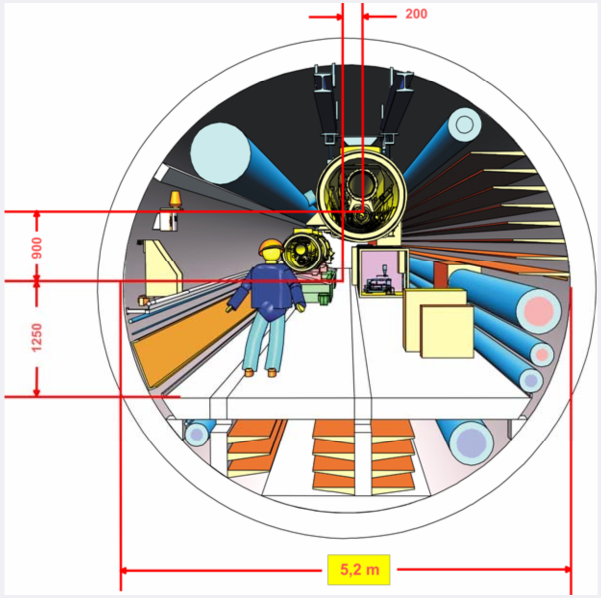
Approx. **12-15% of ILC effort** (site depending)

XFEL Distribution Shaft (XSE)





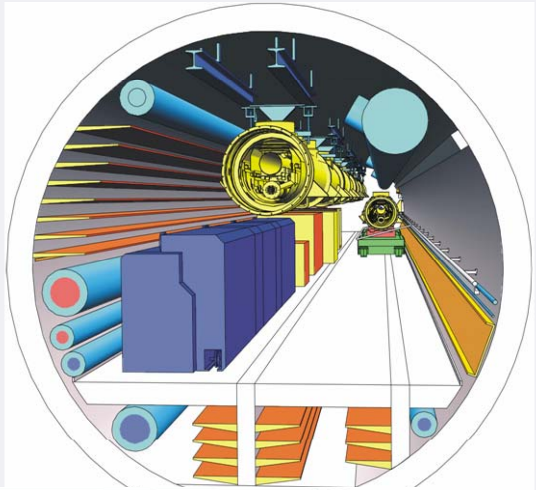
XFEL Tunnel

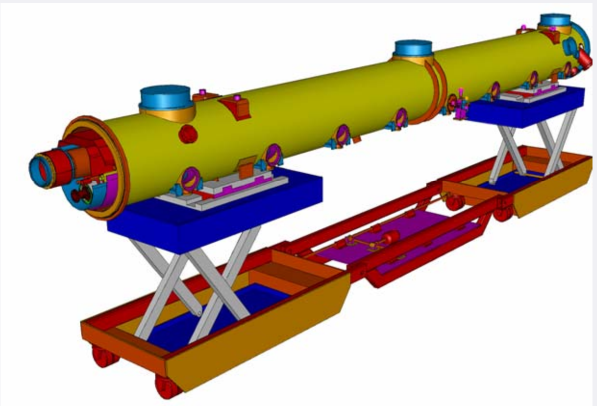


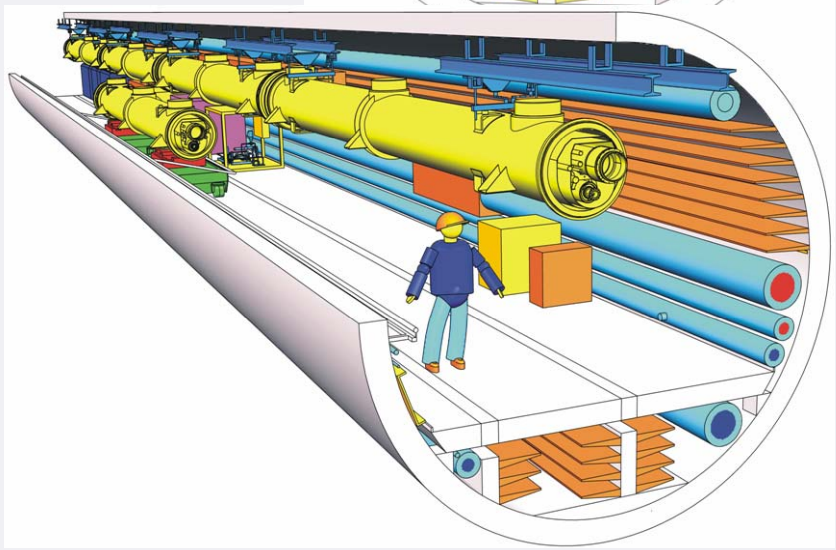
The **XFEL tunnel layout** was developed in several iterations.

A **mockup** is currently under construction.

Installation procedures are under study.







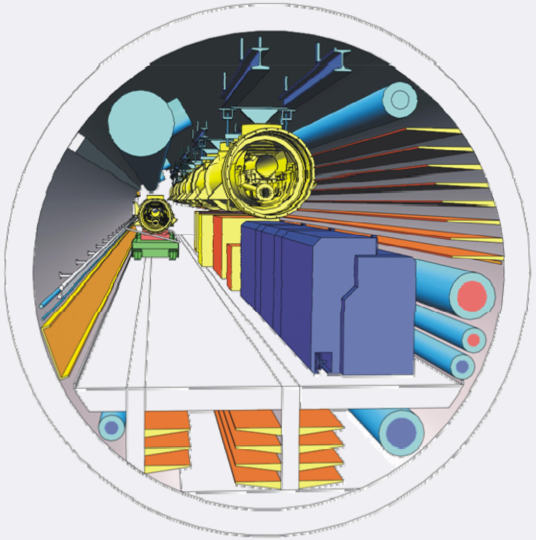
XFEL Tunnel Mockup

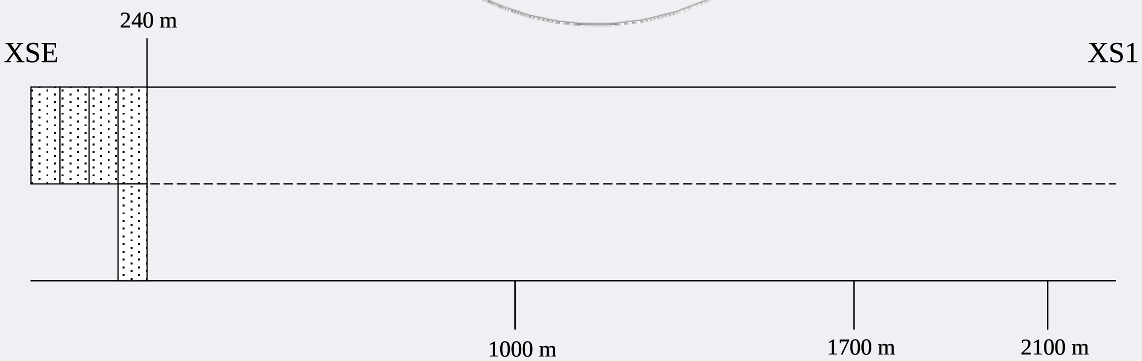
XFEL Tunnel – Draft Installation Schedule

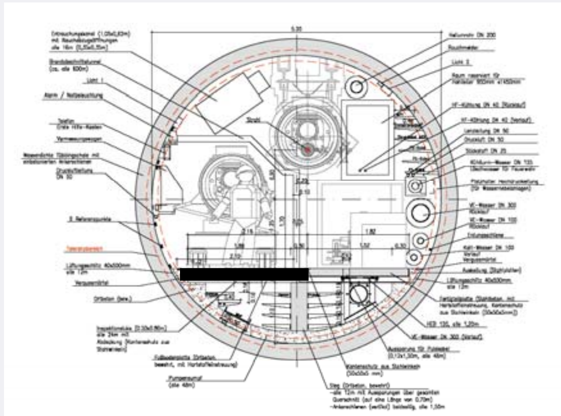
1st beam in Injector	**-> mid 2012**
1st beam in Linac	**-> mid 2013**
1st SASE(1) at 0. 2 nm	**-> mid 2014**
All beam lines oper.	**-> end 2015**

Week 1

Start laying left floor lane: 240 m/w
-> 40 slabs/d = 48 m/d, ≈ 1750 slabs in total ≈ 44 d in total
-> Set up storage areas (e.g. each 80 slabs -> ≈ each 100 m)







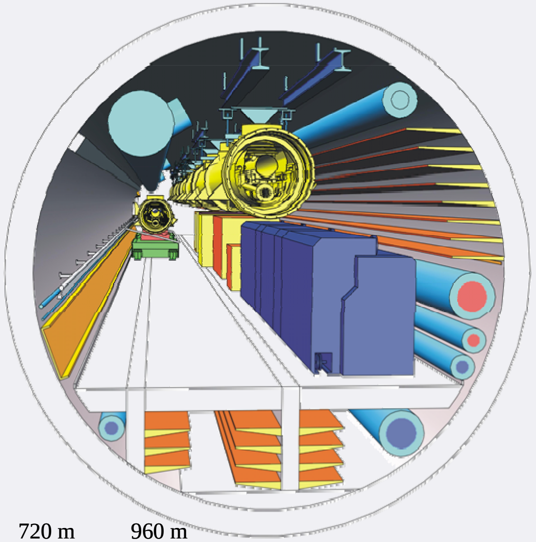
XFEL Tunnel – Draft Installation Schedule

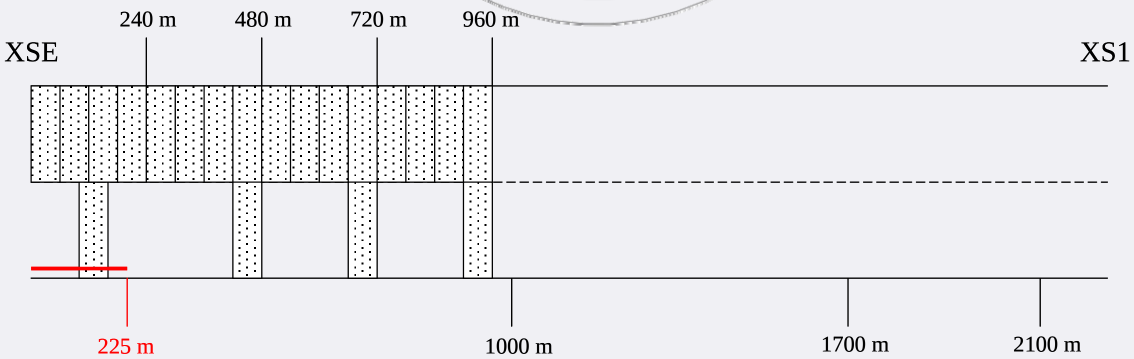
1st beam in Injector	**-> mid 2012**
1st beam in Linac	**-> mid 2013**
1st SASE(1) at 0. 2 nm	**-> mid 2014**
All beam lines oper.	**-> end 2015**

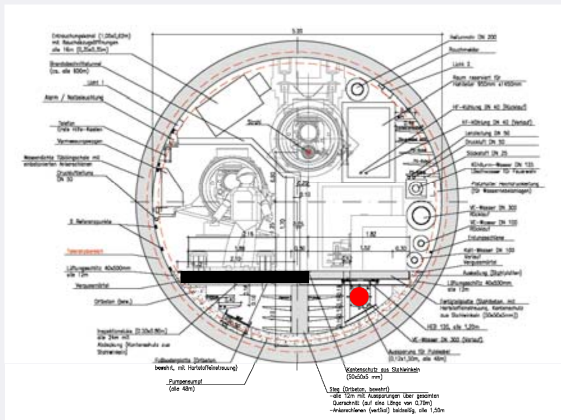
Week 4

Continue laying left floor lane: 240 m/w (40 slabs/d = 48 m/d) - Arrange storage areas

Continue installing DN 300 cooling water supply line (underfloor): 75 m/w (15 m/d)

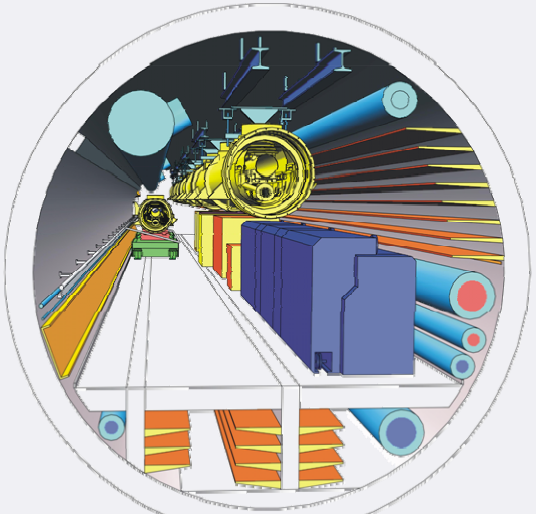






XFEL Tunnel – Draft Installation Schedule

1st beam in Injector	-> mid 2012
1st beam in Linac	-> mid 2013
1st SASE(1) at 0. 2 nm	-> mid 2014
All beam lines oper.	-> end 2015



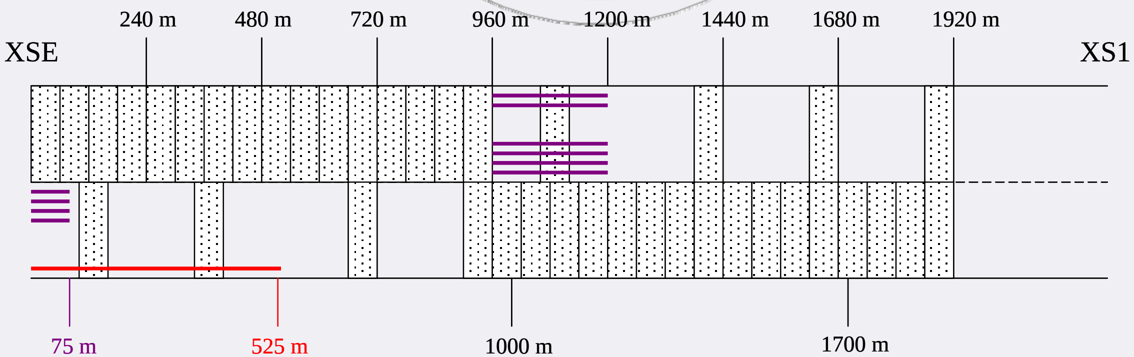
Week 8

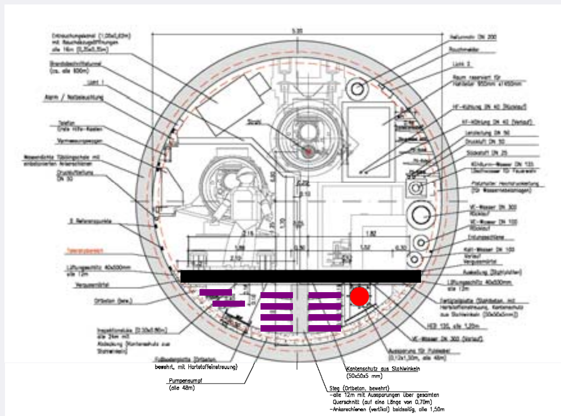
Continue laying right floor lane: 240 m/w (40 slabs/d = 48 m/d) - Arrange storage areas

Continue installing DN 300 cooling water supply line (underfloor): 75 m/w (15 m/d)

Continue installing 6 underfloor cable trays on left side: ≈ 72 rm/d -> ≈ 360 rm/w

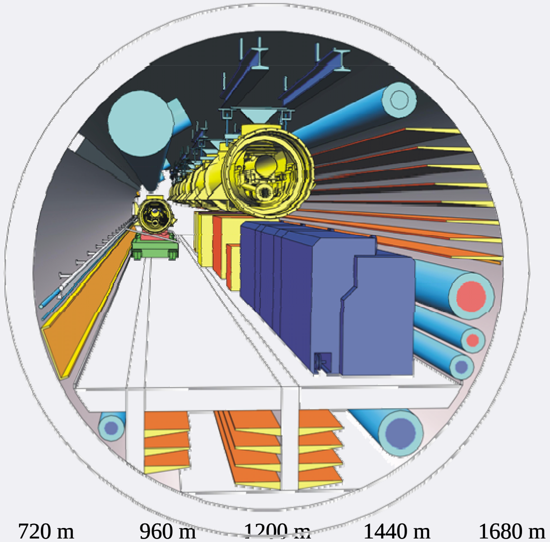
Start installing 4 underfloor cable trays on right side: ≈ 72 rm/d -> ≈ 360 rm/d





XFEL Tunnel – Draft Installation Schedule

1st beam in Injector	-> mid 2012
1st beam in Linac	-> mid 2013
1st SASE(1) at 0. 2 nm	-> mid 2014
All beam lines oper.	-> end 2015



Week 52

Arrange storage areas

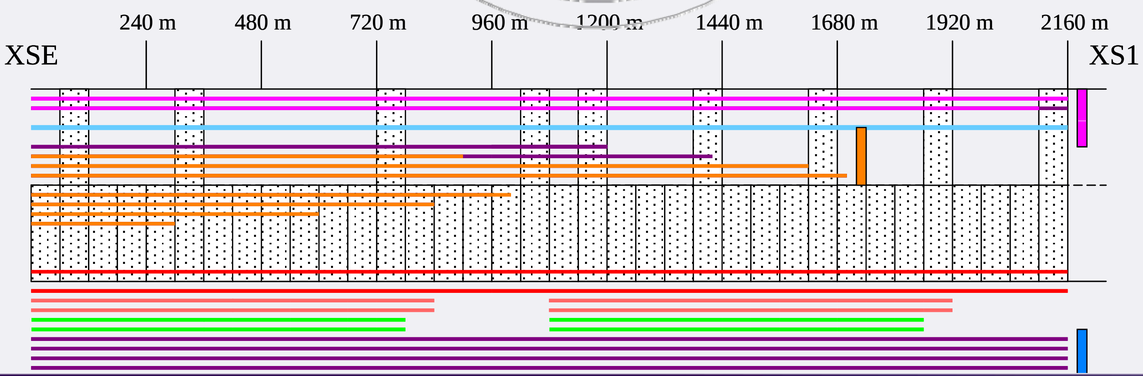
Continue installing 2 DN 100 cold water lines (supply & return): 60 m/w (12 m/d)

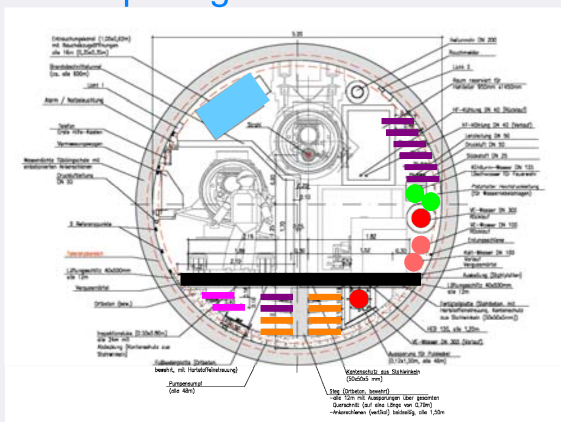
Continue installing cooling tower & high pressure water lines: 60 m/w (12 m/d)

Continue pulling 10 kV cables on left side: 210 rm/w

Continue pulling pulse cables on left side: 210 rm/w

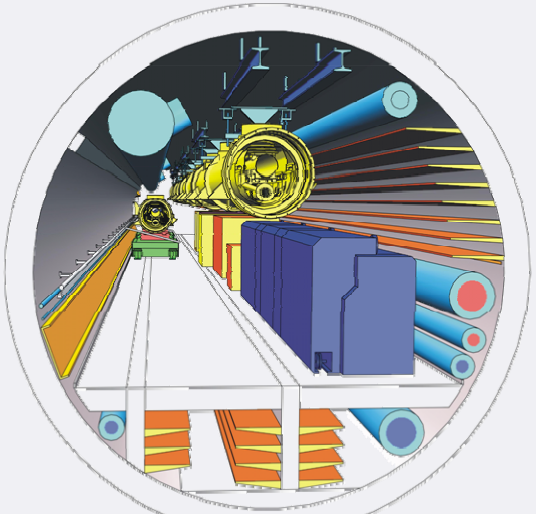
Continue pulling cables

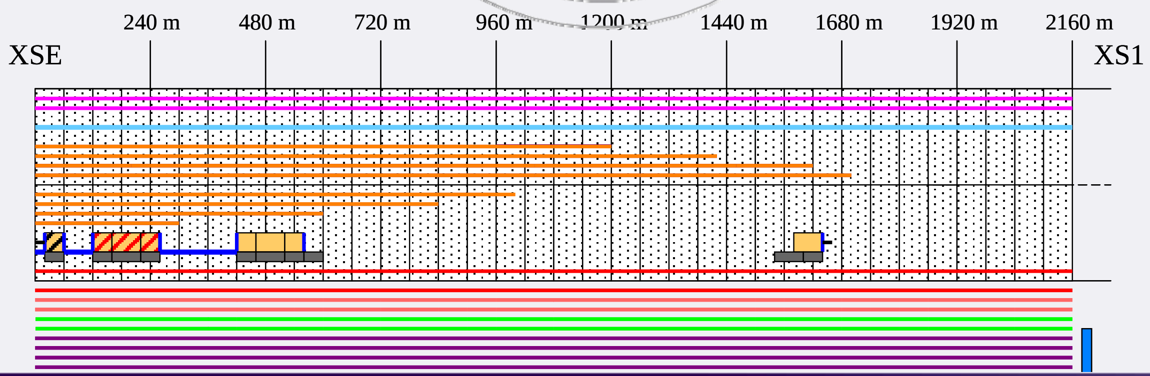




XFEL Tunnel – Draft Installation Schedule

1st beam in Injector	**-> mid 2012**
1st beam in Linac	**-> mid 2013**
1st SASE(1) at 0. 2 nm	**-> mid 2014**
All beam lines oper.	**-> end 2015**





Week 63

Continue completing left floor lane: 240 m/w (40 slabs/d = 48 m/d)

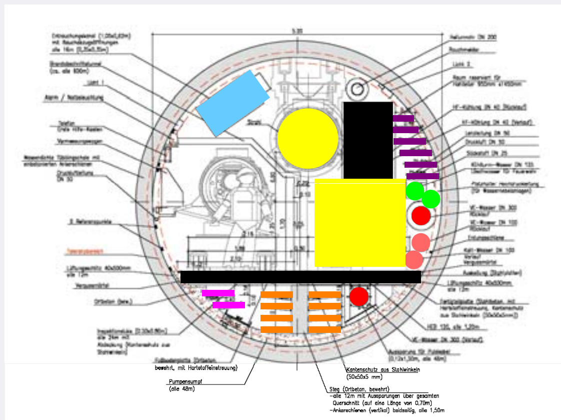
Continue Installing (&Commissioning) Wave Guide Distributions: 1 unit/d

Continue Installing Cold Boxes: 1 unit/d

Continue Installing Modules: 1 unit/d

Continue Connecting Modules

Installing Warm Sections 30 m/w



XFEL Tunnel – Draft Installation Schedule

1st beam in Injector	-> mid 2012
1st beam in Linac	-> mid 2013
1st SASE(1) at 0. 2 nm	-> mid 2014
All beam lines oper.	-> end 2015

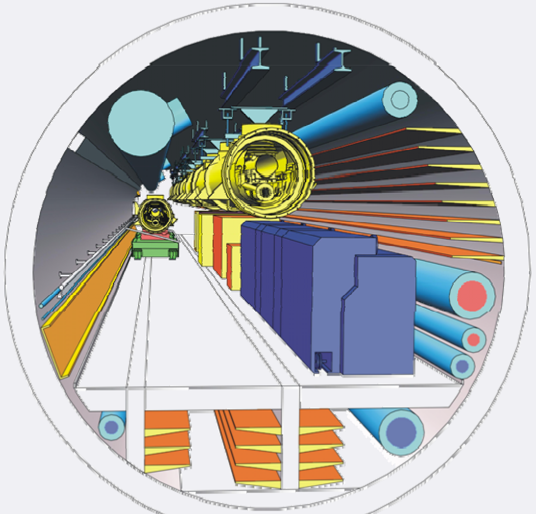
Week 103 (46)

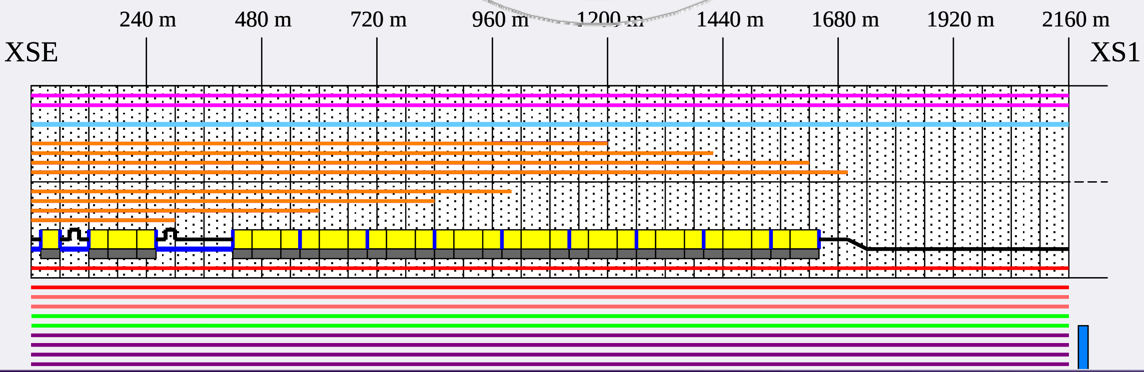
Continue Commissioning Wave Guide Distributions: 1 unit/d

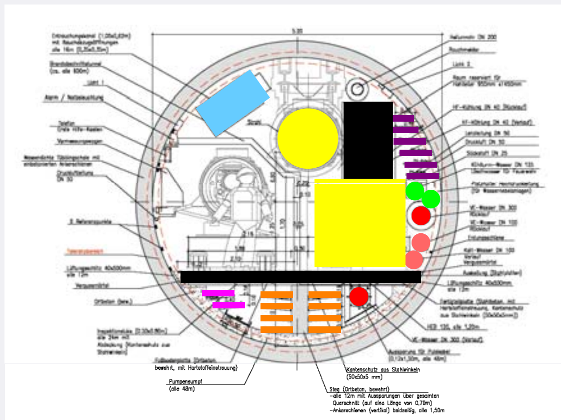
Continue Commissioning Cryo System

Continue Commissioning Warm Sections: 30 m/w

Continue Module Commissioning







XFEL Accelerator Components

Rapid start-up scenario for 17.5 GeV

101 Accelerator Modules

RF Gun + 1 single acc.module

25 units (4 acc. modules each)

(1) x 4 x 8 x 23.6 = 500 MeV

(2+1) x 4 x 8 x 23.6 = 1.5 + spare -> 2 GeV

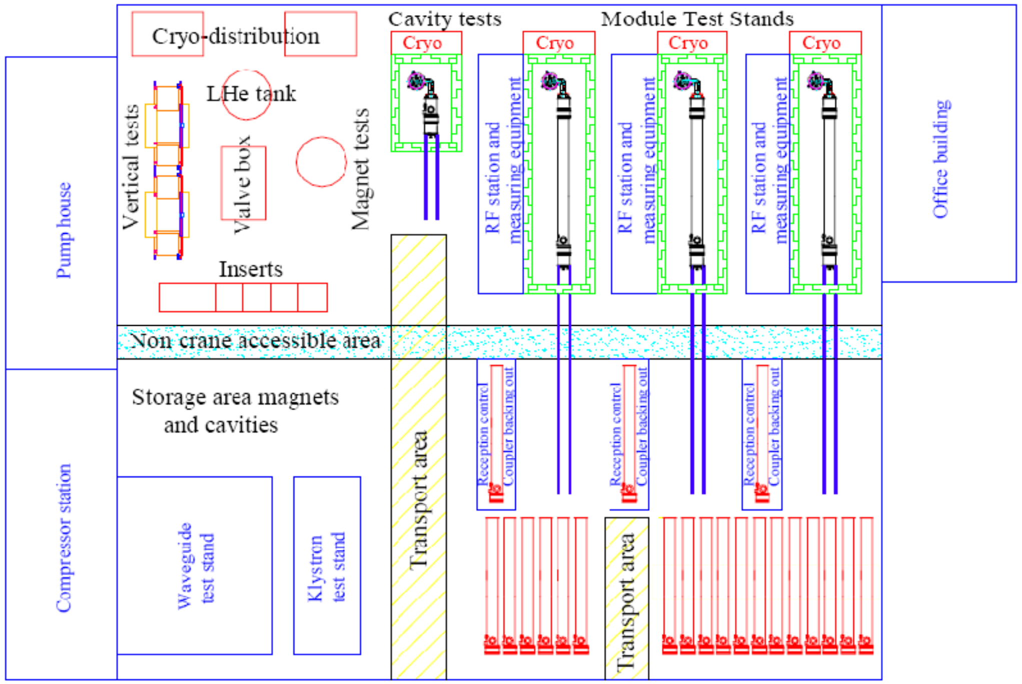
(20+1) x 4 x 8 x 23.6 = 15.1 + spare -> 17.5 GeV

---

module installation from 3/2012 until 7/2012 **at a rate of 1 unit / day**
all modules to be tested at AMTF between mid 2010 and mid 2012

cold-mass delivery at a rate of 1/week; 1st cold-mass delivered Q3/2009
1st cavity string components Q3/2009
1st module spring 2010
i.e. **all accelerator components ready to order end of 2008**; actual R&D status supports this

XFEL Accelerator Module Test Facility

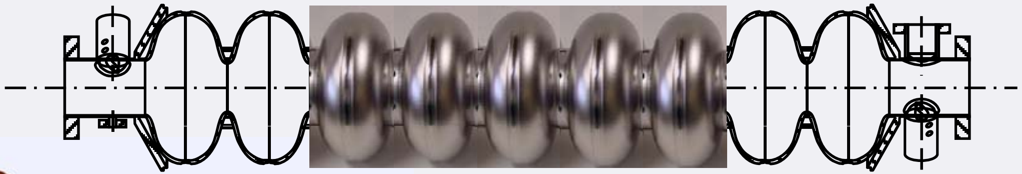


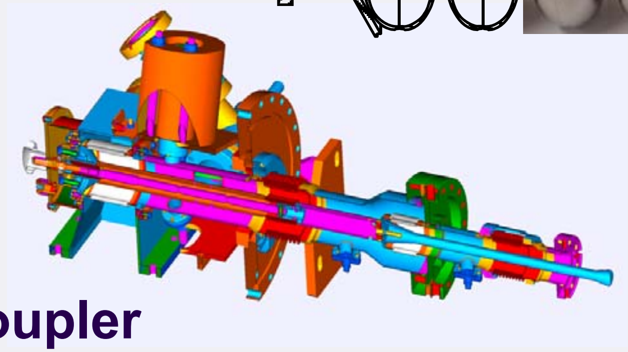
TDR version of the AMTF. After some iterations (costs, practicability) the final version to be built until 2009 will look slightly different.

The XFEL requires an **Accelerator Module Test** of all 101 individual modules. The test rate is 1 module/week corresponding to the envisaged assembly rate. In order to be most efficient, the **vertical test** of bunches of cavities is integrated. Othee issues are **waveguides and cold magnets**.

XFEL Accelerator Components

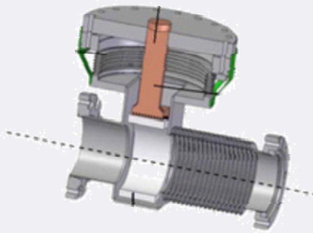
cavities





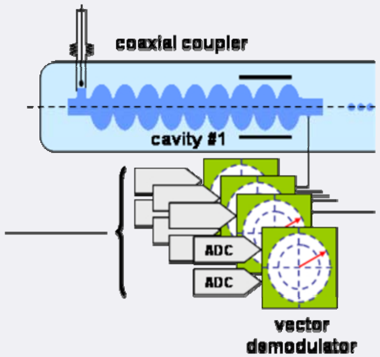
coupler

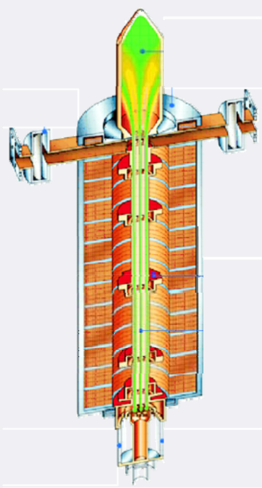
TESLA Technology



HOMs

LLRF

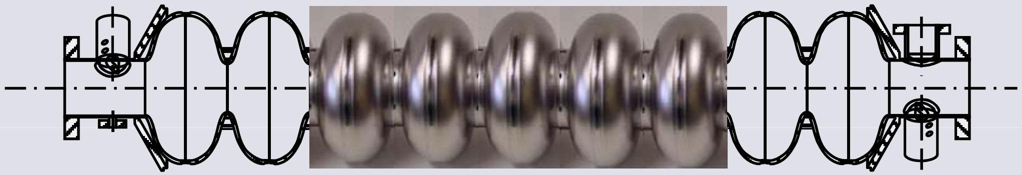




RF

XFEL Cavities

The XFEL will use 800 accelerating cavities (rapid start-up scenario)



which is approx 5% of the ILC design.

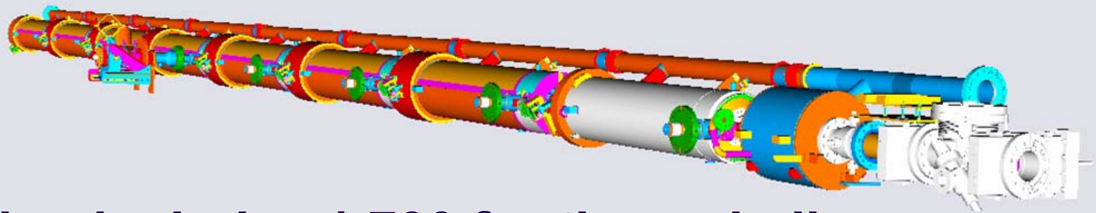
There are at least two well established ‘sources’ for an **industrial cavity production** guaranteeing the required rate of 8 to 10 cavities per week over two years. **At the companies, new infrastructure is required** but the effort is well understood.

Cavity treatment will be done in industry. In order to prepare this, two companies will do the first electro-polishing of 12 9-cell cavities each in 2007.

The **quality check** will be done in terms of a vertical test on the XFEL/DESY site. The **tested cavities will be given to industry** for string/module assembly.

Cavity Strings

While the XFEL will use 100 cavity strings of 8 cavities each,



the ILC design includes 1,700 for the main linac.

The **technology transfer** to industry is done for the XFEL.

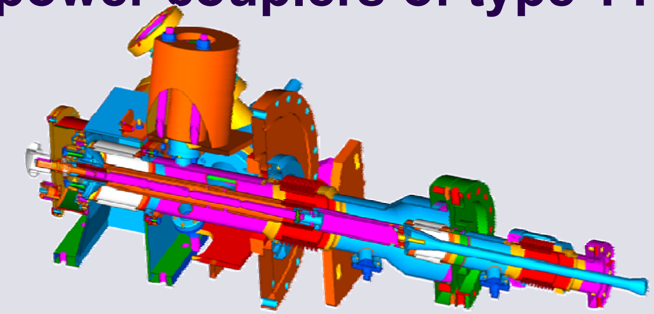
Minor differences in the module design have basically no impact.

The XFEL foresees two parallel lines (companies) for string assembly.

RF Main Power Couplers

While the XFEL will use 800 RF main power couplers of type TTF III,

the ILC design is based on
the same coupler type,
but needs 15,000.



Also here the **technology transfer** to industry is done for the XFEL (LAL Orsay).

At the end, **several companies** should be qualified to build a larger number of couplers.

The XFEL foresees at least two parallel lines (companies) for coupler production.

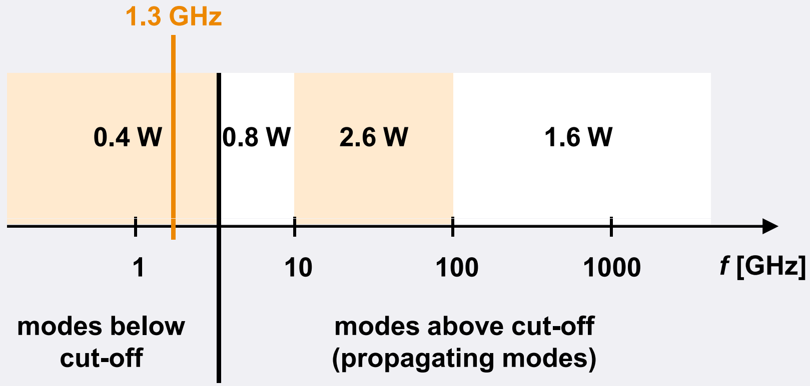
Coupler conditioning might be still done at the labs, the transfer to industry requires setting-up complete RF stations. Not a principle problem….

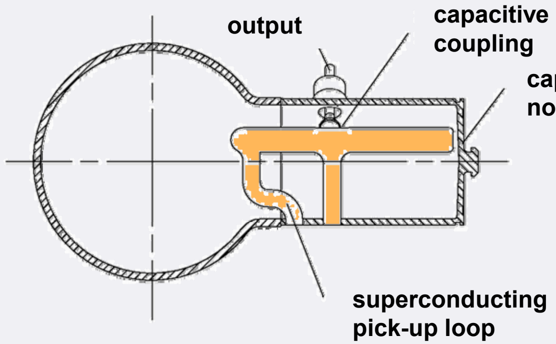
Damping of Higher Order Modes (HOMs)

The spectrum of the XFEL electron bunch (σ_z = 25 µm) reaches high frequencies up to 5 THz.

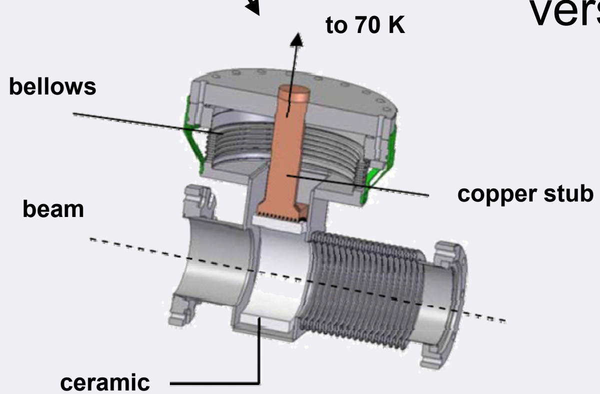
The standard accelerator module has an integrated loss factor of 135 V/pC.

The total power deposited by the nominal beam is 5.4 W per module.





HOM coupler

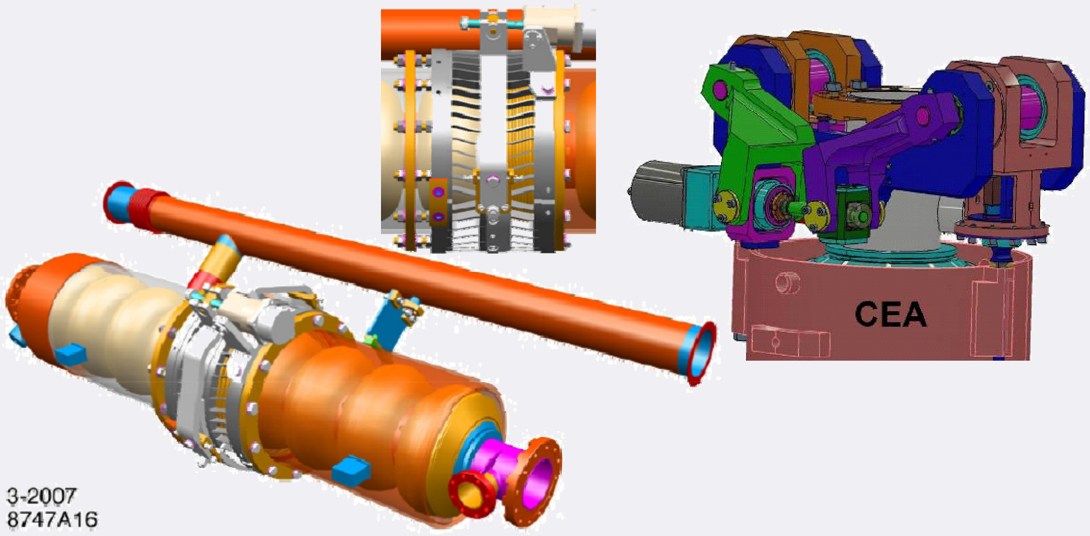


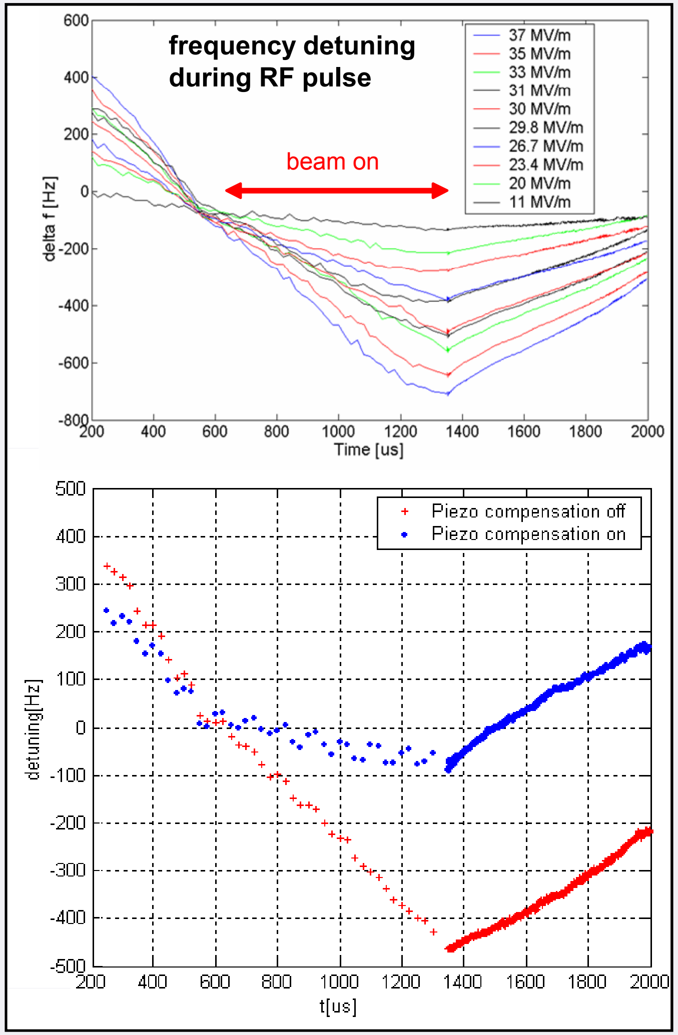
beam pipe absorber

The ILC should have a little less HOM power at high frequencies.

Nevertheless, **HOM couples and absorbers are required.** The XFEL version is available.

Slow and Fast Frequency Tuner



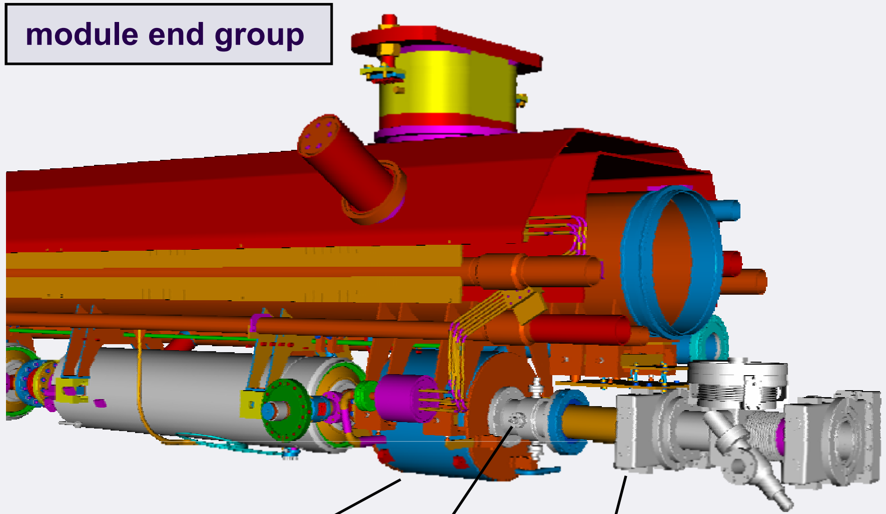


On the first glance XFEL and ILC tuner look completely different. But **critical parts** like motor, gear box, and eventually piezos (fast tuner) **can be identical**.

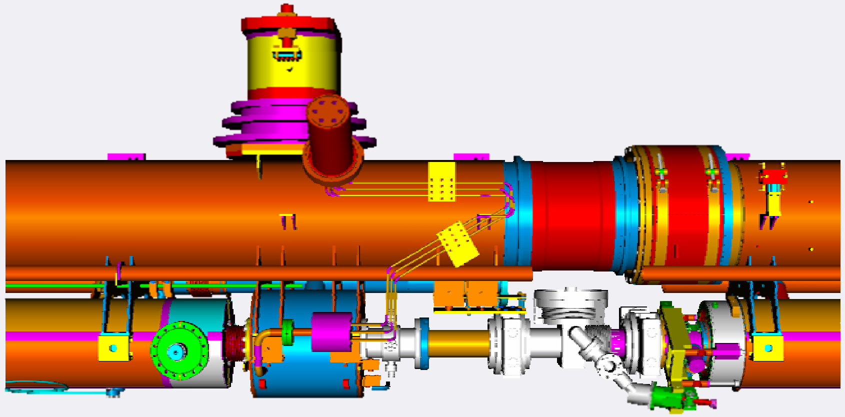
- The slow tuner compensates for drifts; 400 kHz range, 1 Hz resolution.
- The fast tuner compensates the Lorentz-Force detuning during the RF pulse.

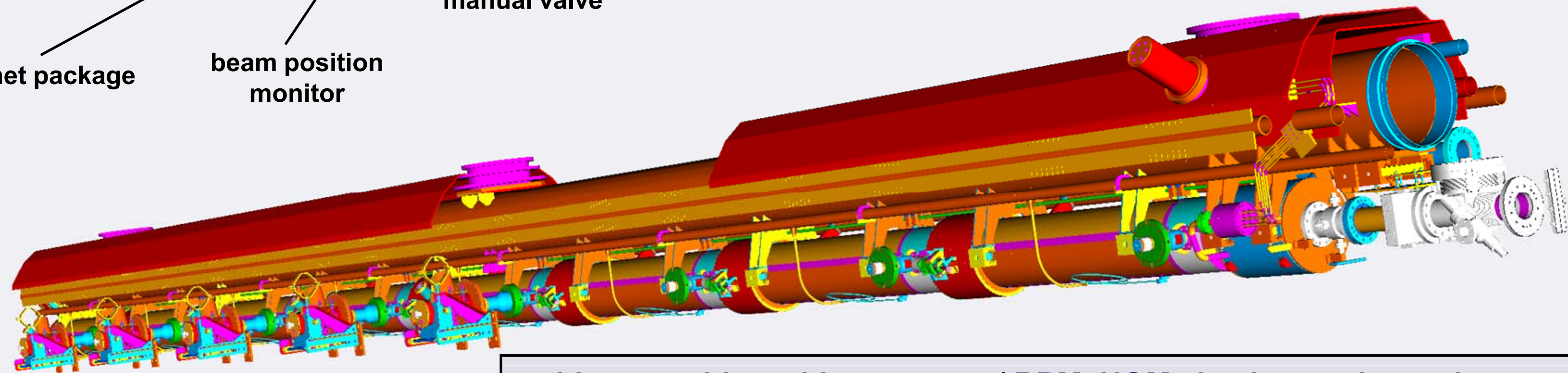
Accelerator Module (Cryomodule)

module end group



module to module connection





cold mass with cavities, magnet / BPM, HOM abs. beam pipe, valve

Accelerator Module (Cryomodule)

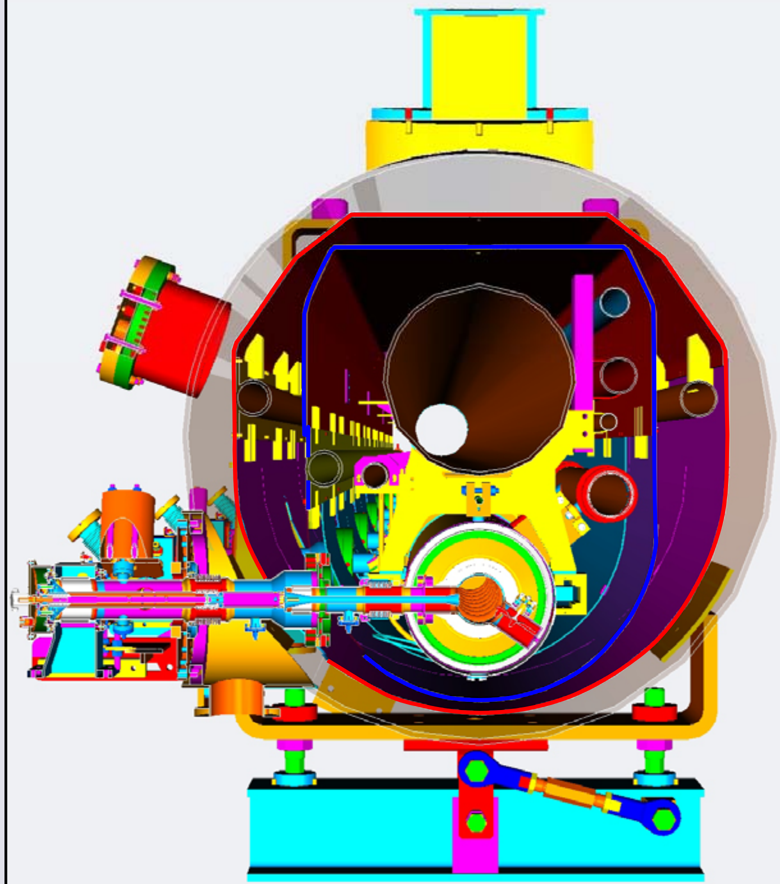
The XFEL accelerator module is based on the 3rd cryomodule generation tested at the TESLA Test Facility and designed by INFN.

Already 10 cryomodules have been built and commissioned for the TTF Linac.

Module 6 and Module 7 (repl. ACC3) were just recently installed at TTF/FLASH.

Additional cryostats will be available end of this year:

- Module 8 (most likely ACC7)
- Module 9 (FNAL ass. kit)
- Module 3** (spare ACC1, sched. 2008)
- 2-3 cold masses in 2008

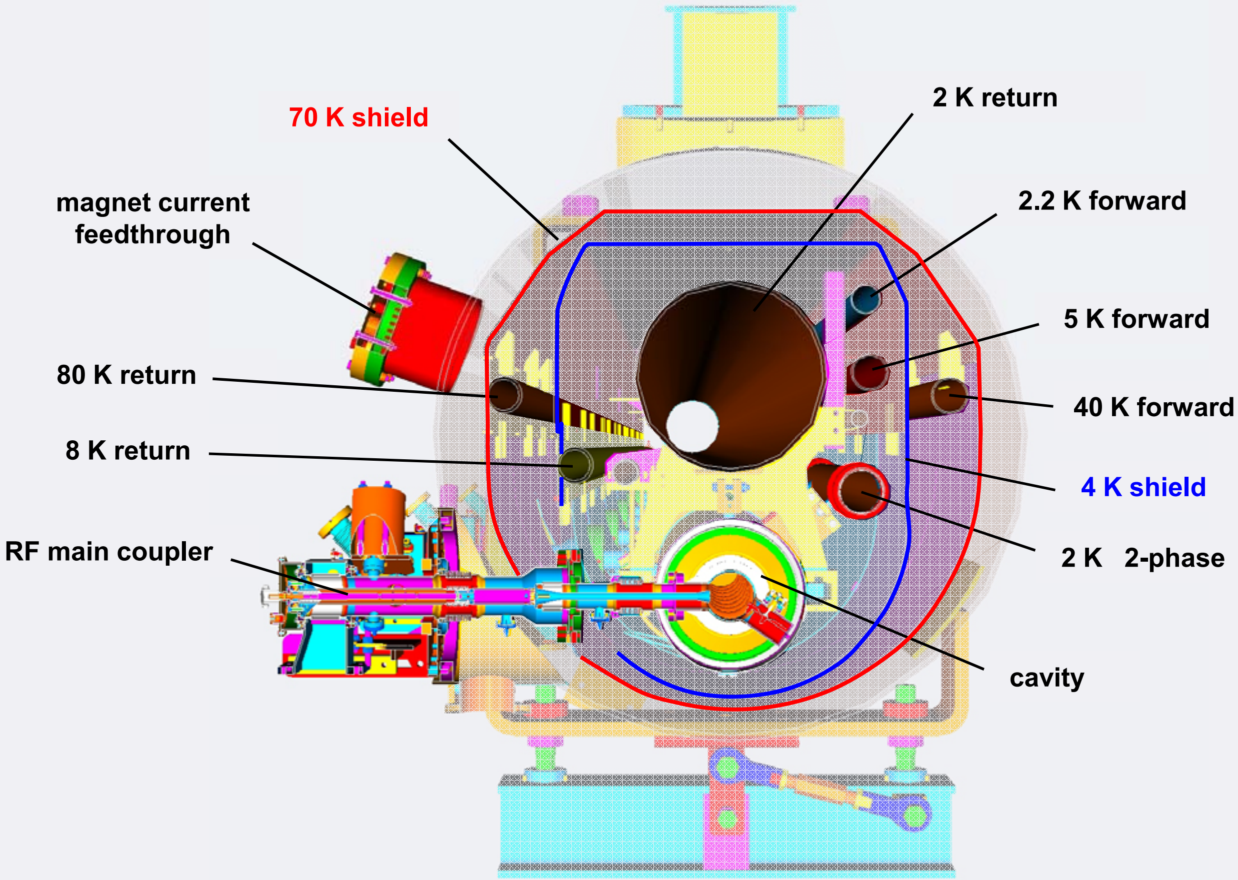


The **same principle design** is used for XFEL and ILC.

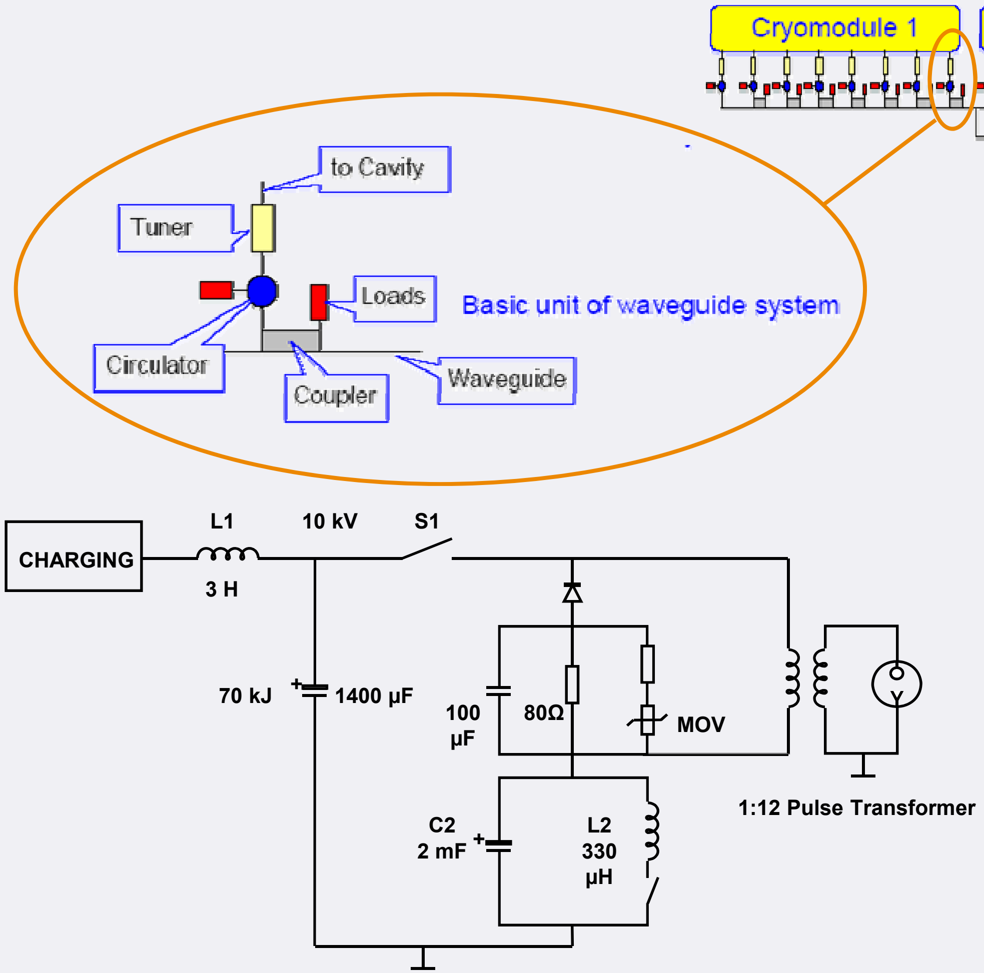
Minor modifications (quads, BPM, nbr. of cavities, overall length) should have almost no impact on industrialization.

Open issue: **vibration sensitivity** in the ILC case. The XFEL requirements are fulfilled.

Accelerator Module (Cryomodule)



High Power RF System



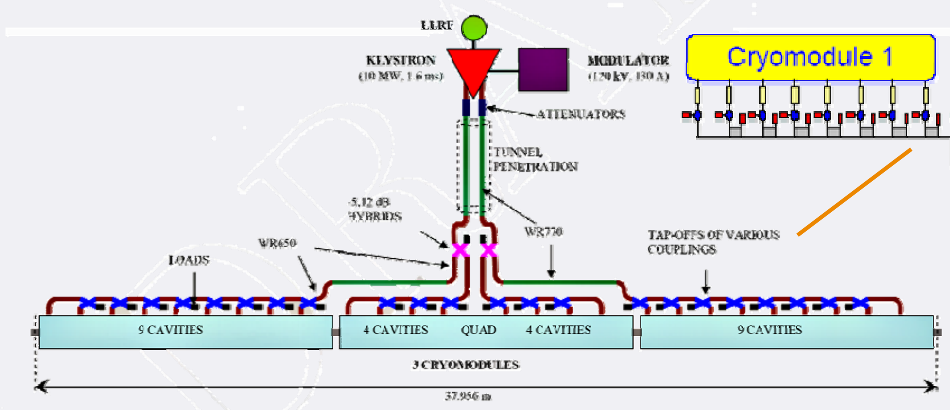

Toshiba E3736

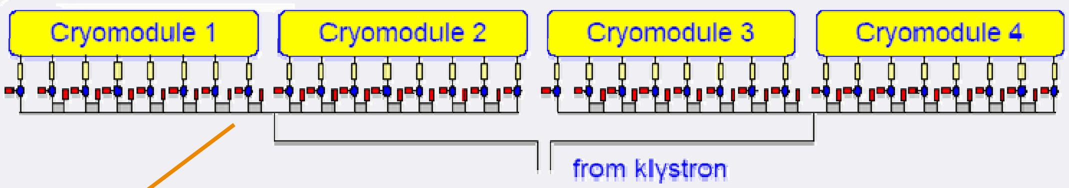
31 RF stations provide **10 MW peak** and **150 kW average**.

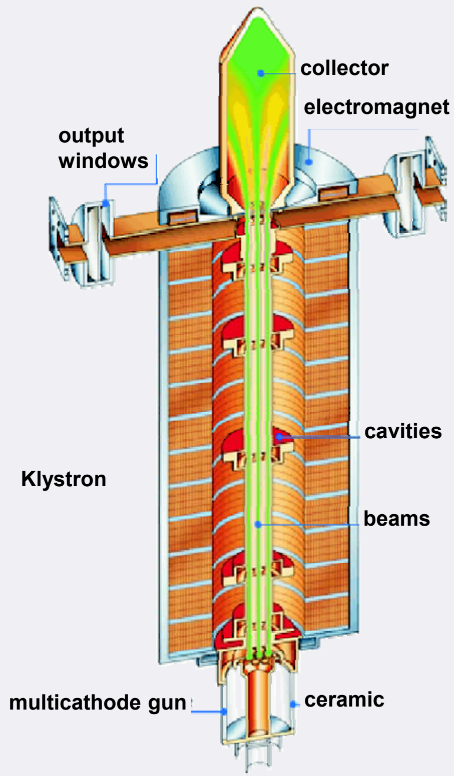
3.9 MW are required at nominal beam parameters and 20 GeV.

Incl. waveguide losses (6%) and regulation reserve (15%) **5.2 MW**.

High Power RF System







XFEL has **32 cav. per klystron**, ILC 26.

Due to the higher gradient, the 3.9 MW for the XFEL at the cavities becomes 7.6 MW. This leaves approx. 15% each for **wave guide losses and regulation reserve.**

The XFEL will install 25 klystrons in the tunnel while ILC wants to put the klystrons & modulators in the **2nd tunnel.**

31 RF stations provide 10 MW peak and 150 kW average.

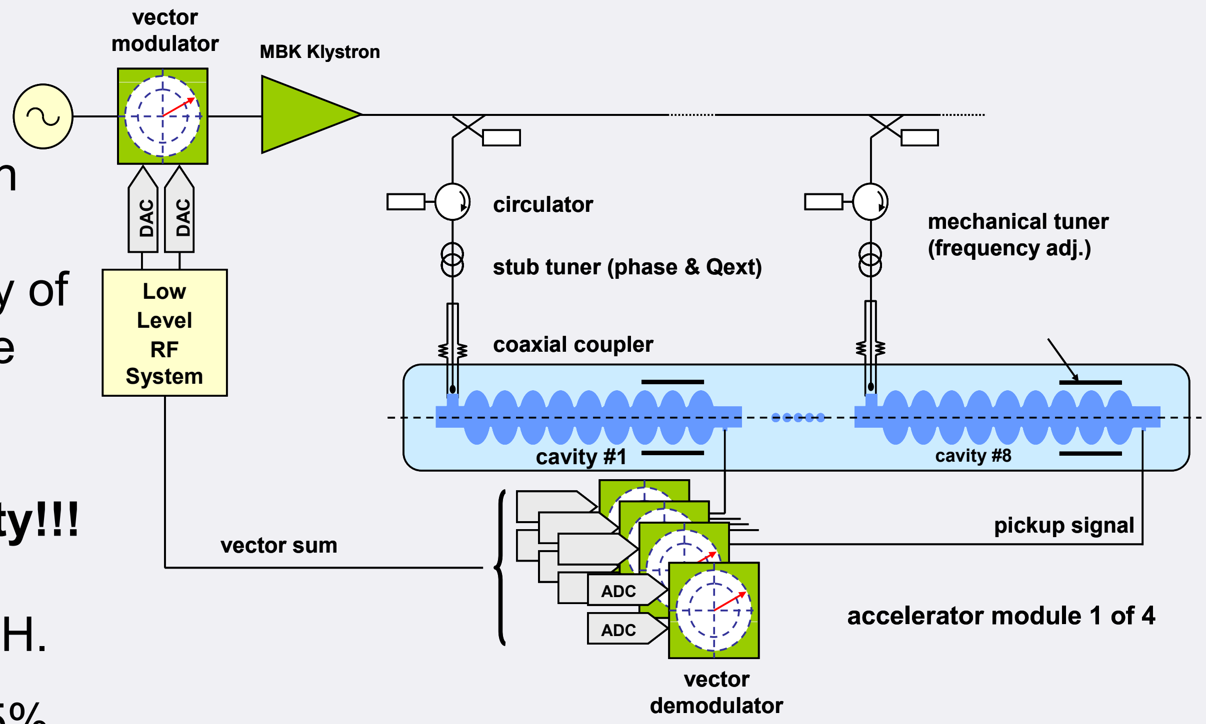
3.9 MW are required at nominal beam parameters and 20 GeV.

Incl. waveguide losses (6%) and regulation reserve (15%) 5.2 MW.

Low Level RF Control

The XFEL LLRF requirements are driven by the injector, its' bunch compressors, and the demand for high stability of the photon intensity. The RF system needs **0.01% amplitude and 0.01 deg phase stability!!!** Successful tests were performed at TTF/FLASH.

The **ILC numbers:** 0.35% amplitude and 0.07 deg phase stability (correlated).



The **operational requirements** are probably different but similar to handle. Here the number of spare RF stations as well as the aimed up-time defines the 'rules of the game'.

XFEL: which ILC questions are answered?

- how to build a 100 accelerator module linac using TESLA Technology
- how to industrialize the SCRF on a 5% ILC scale
- how to extrapolate from TTF / FLASH by a factor of 20
  Remark: ILC eq. 20 XFEL
- how to start and organize an international project based on in-kind contributions