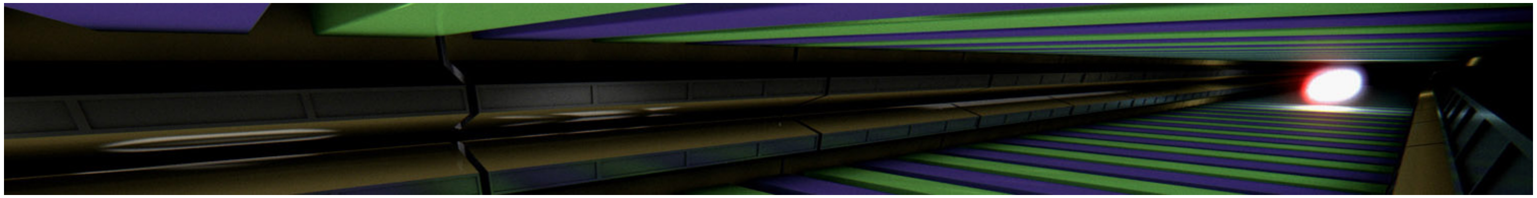


Radiation Safety at the European XFEL

An Overview

Presented at the
Radsynch 2015 Workshop at DESY
June 3, 2015

Norbert Tesch, DESY Hamburg

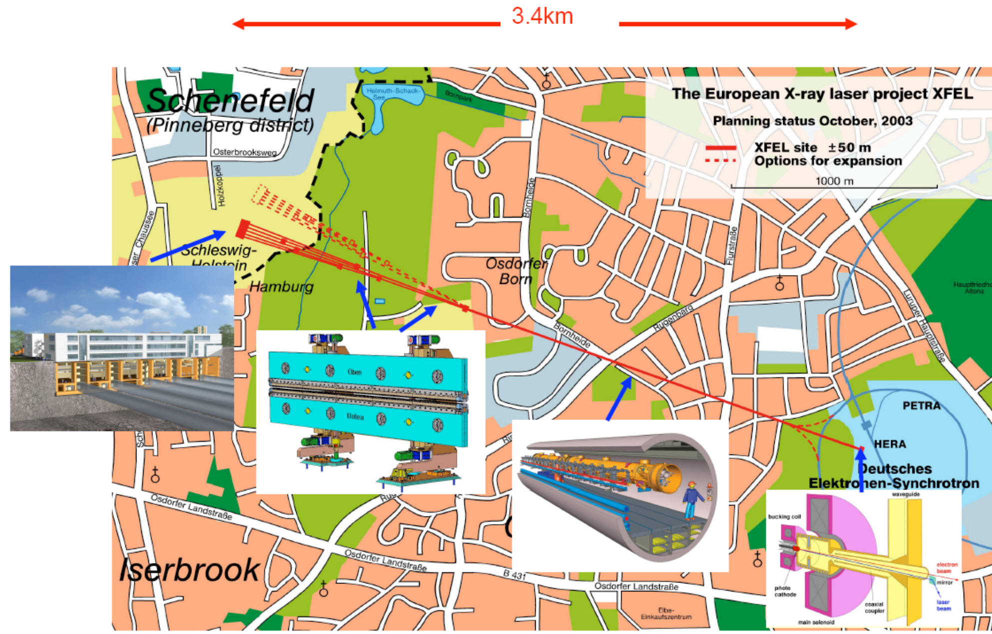
Content

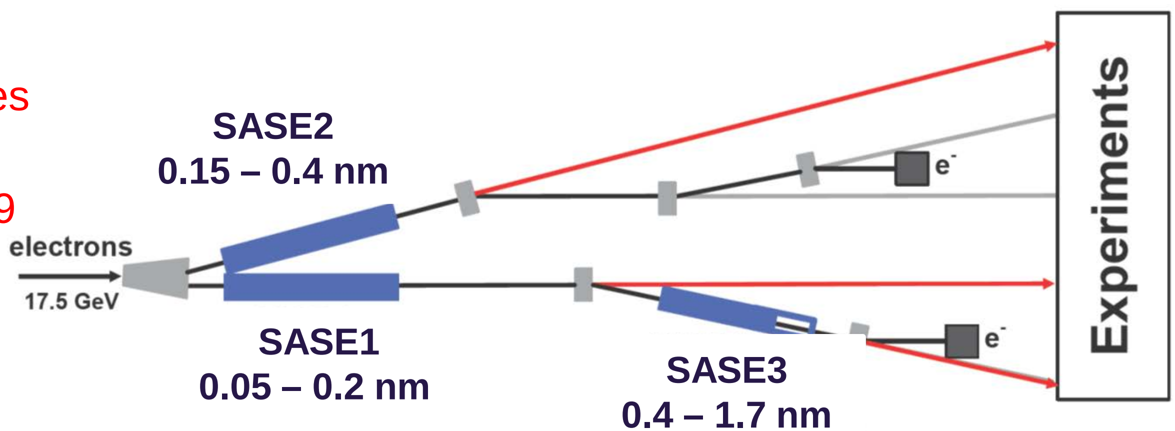
- **Introduction: The European XFEL**
- **Radiation Protection Accelerator**
- **Radiation Protection Beam Dumps**
- **Radiation Protection Experiments**
- **Summary**

Intro: The XFEL

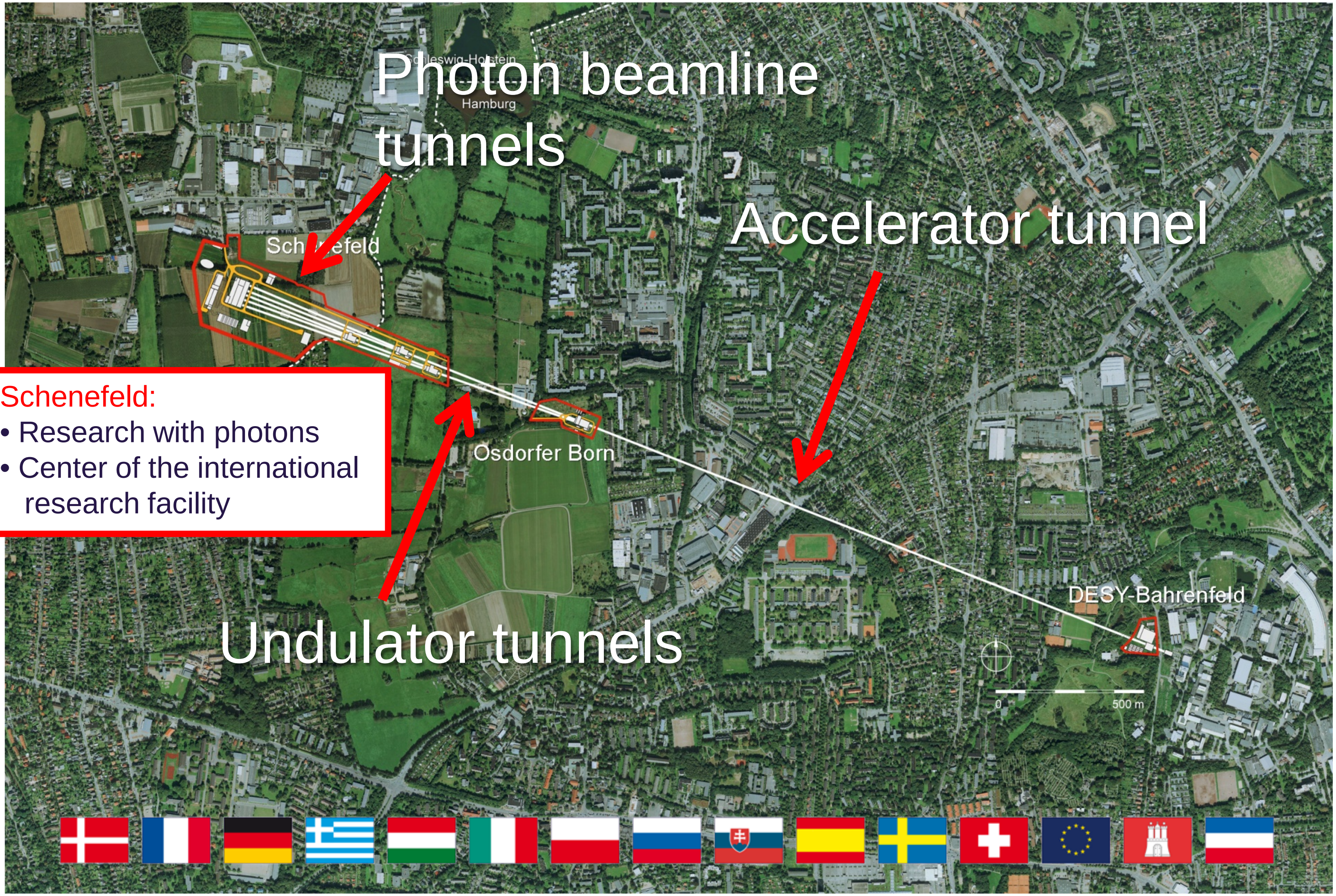
Some specifications

- Length 3.4 km
- Superconducting linac max. 20 GeV
- Max. beam power 1.2 MW
- Max. beam power per dump 0.3 MW
- Max. particles 10^{14} electrons/s
- 10 Hz (27 000 b/s)
- Photon energy 0.3 - 24 keV
- Pulse duration ~ 10 - 100 fs
- Pulse energy few mJ
- 5 beamlines / 10 instruments
  - Start version with 3 beamlines and 6 instruments
- Start of construction begin 2009
- Start of operation begin 2017





Intro: The XFEL



Schenefeld:
- Research with photons
- Center of the international research facility

Intro: The XFEL and Money

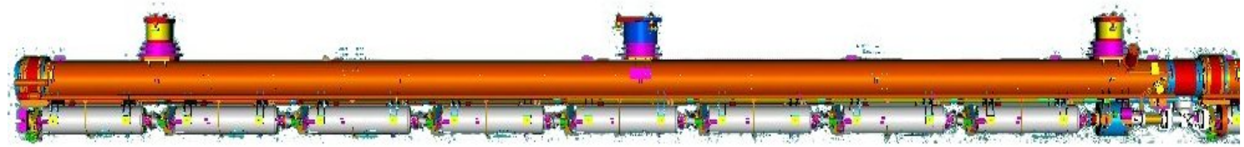
Germany	663 M€*
Russia	306 M€*
France	36 M€
Italy	33 M€
Poland	25 M€*
Sweden	17.5 M€*
Switzerland	17 M€*
Slovakia	12.7 M€*
Hungary, Denmark, Spain	11 M€ each
[Greece	4 M€]

* Increased contribution decided in 2012

Remark: All numbers above are given in “2005 Euro”, total sum will be about 1,5 Billion Euro in “2015 Euro”

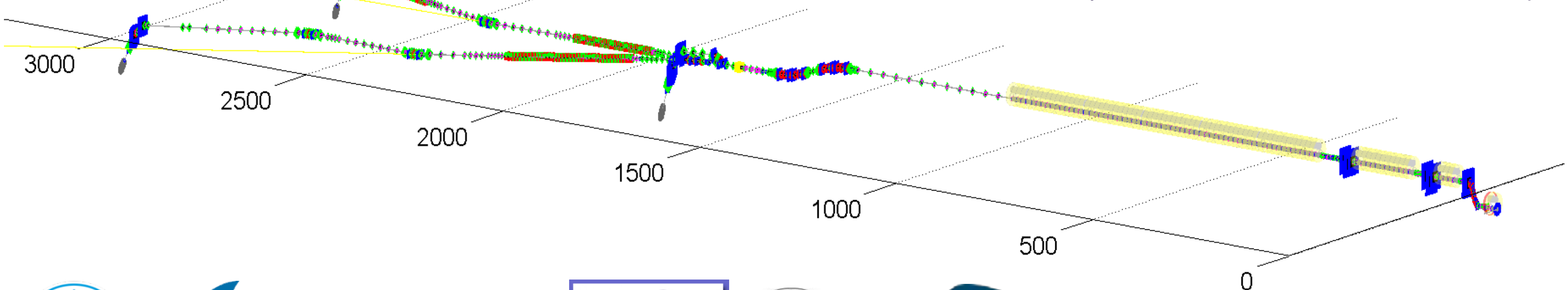
Intro: Challenges

100 accelerator modules

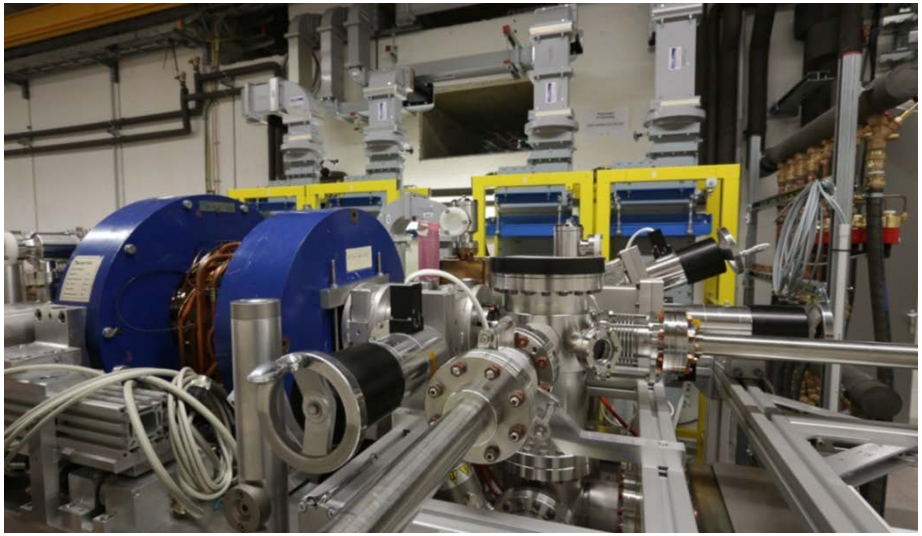
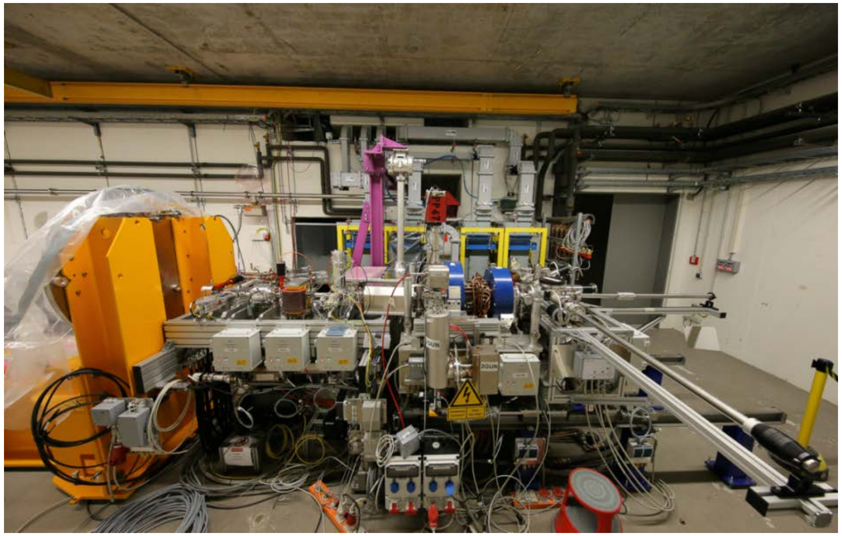
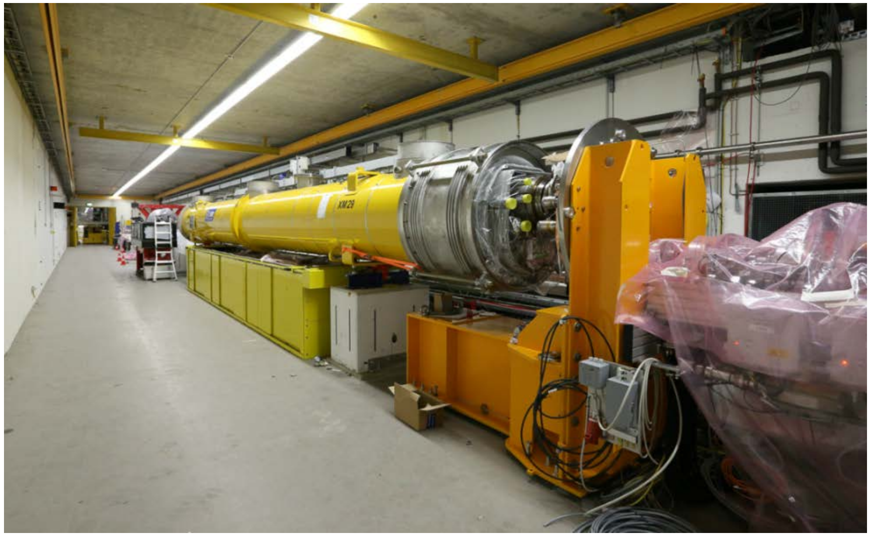


800 accelerating cavities

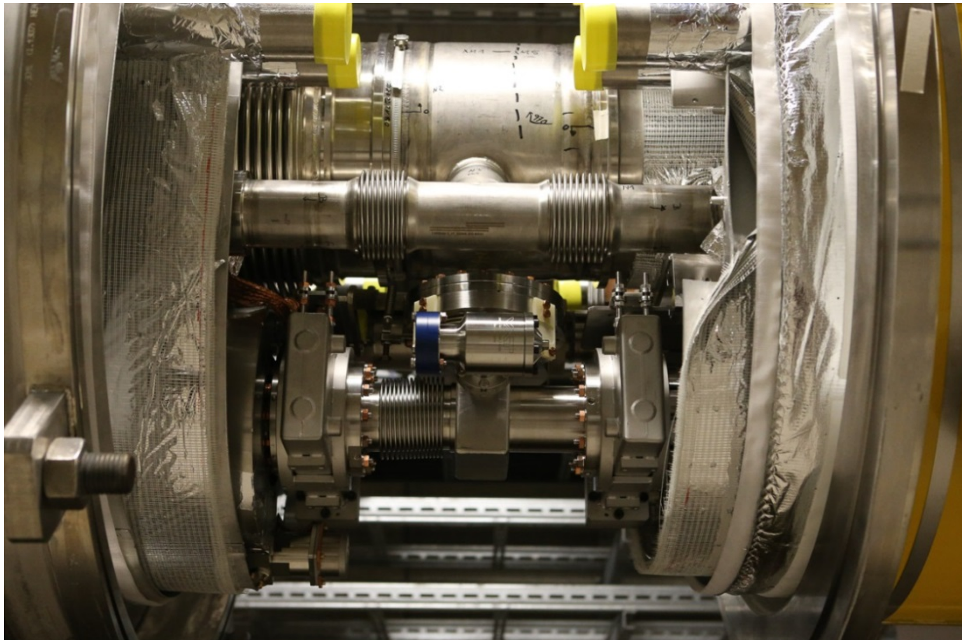
1.3 GHz / 23.6 MV/m



Intro: The Injector


Intro: The Main Linac



Intro: The Main Linac

Intro: The Main Linac

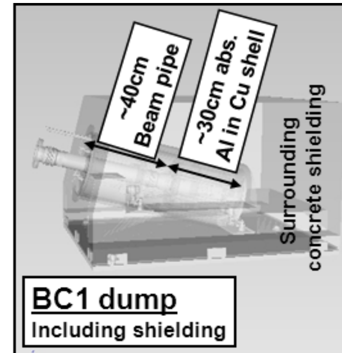
Intro: The Beam Dumps

Beam dumps will be installed here:

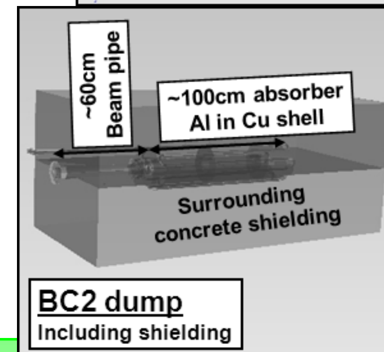
- 2 (1 for the beginning) injector dump(s)
- 1 BC1 (bunch compressor) dump
- 1 BC2 (bunch compressor) dump
- 1 main dump at XS1
- 2 main dumps at XSDU1 and XSDU2

Intro: The Beam Dumps

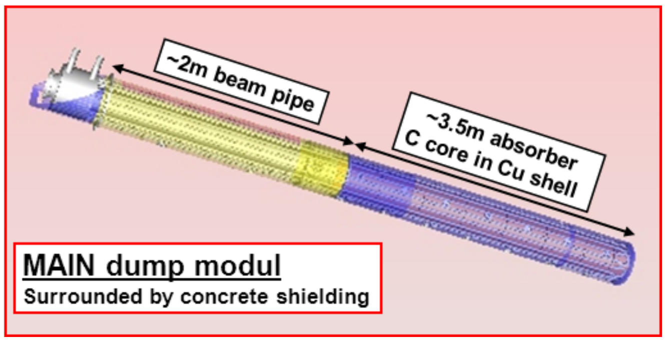
Number and Typ	3x MAIN	1x BC 2	1x BC 1	2x INJ
Purpose	**XSDU1/2**: end e-beams **XS1**: Linac Tuning	BC2 Tuning	BC1 Tuning	Injector Tuning
Construction (see below)	C core, Cu shell With beam window	Al core, Cu shell Without beam window		
Limits of operation				
E_0 , beam energy	≤ 25GeV	≤ 2.5GeV	≤ 500MeV	≤ 300MeV
q_t , charge in bunch train	≤ 4000nC		≤ 40nC	≤ 4000nC
I_{ave} , average current	≤ 40μA	≤ 4μA	≤ 0.4μA	≤ 40μA
P_{ave} , ave. beam power	≤ 300kW	≤ 10kW [1)]	≤ 200W	≤ 12kW
Beam properties				
$\sigma_{x,y}$, size @ dump	≥ 2mm	≥ 3-4mm	≥ 0.2mm	≥ 2-3mm
Slow Sweep	Yes with R_s = 5cm	No		
Fast (intra train) Sweep	No if minimum size is guarenteed			
[1)] Thermal limit, radiation protection limit is 500W				



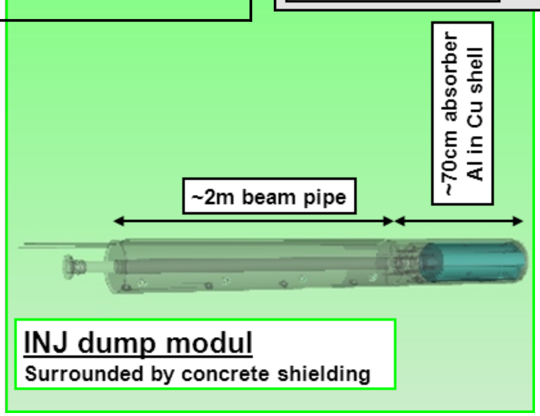
BC1 dump
Including shielding



BC2 dump
Including shielding

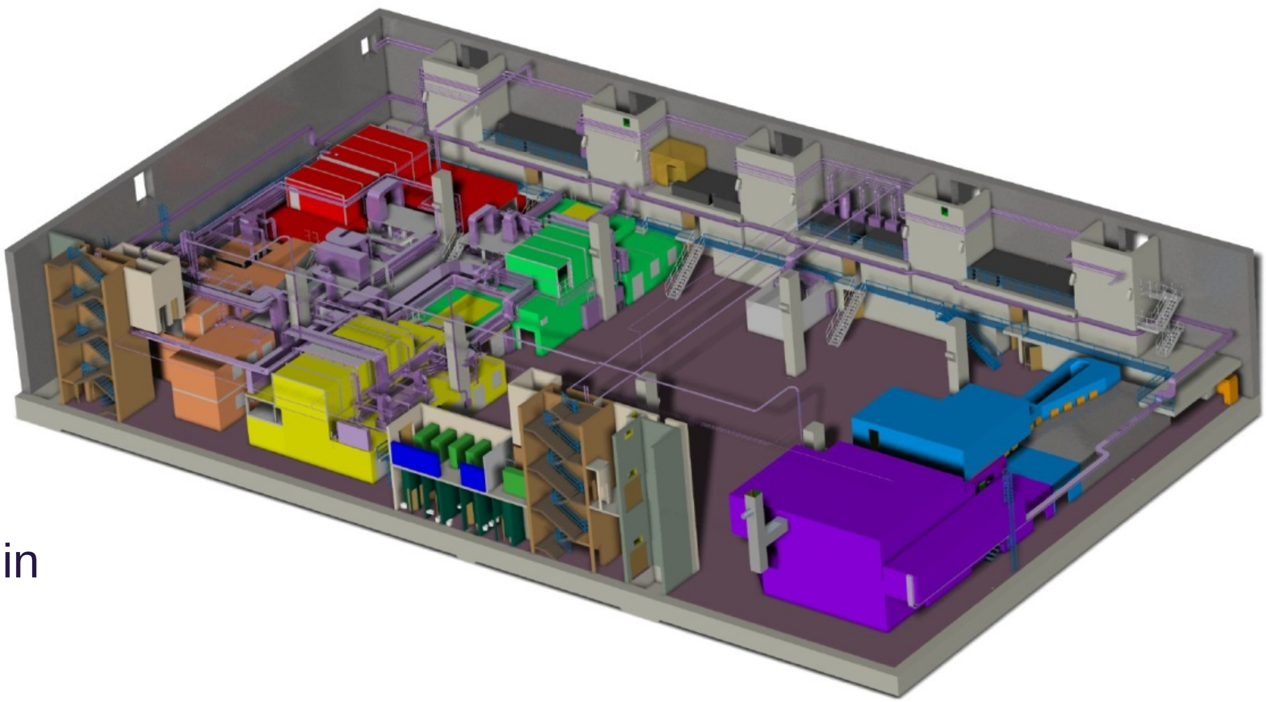


MAIN dump modul
Surrounded by concrete shielding



INJ dump modul
Surrounded by concrete shielding

Intro: The Experiments



Talks by Tschentscher, Sinn and Boyd in later sessions

Intro: The Time Table

2016 Initial commissioning of linac, to bring electron beam in first undulator (SASE1). Enable first lasing.

2017 Bring X-ray FEL beam to XHEXP.

Continue commissioning of accelerator.

Initial commissioning of X-ray beam transports and instruments.

Start “early user experiment” programme (peer-reviewed).

2018 Reach full performance of accelerator.

Development of X-ray beam transports and instruments towards full performance.

Continue “early user experiment” programme (peer-reviewed).

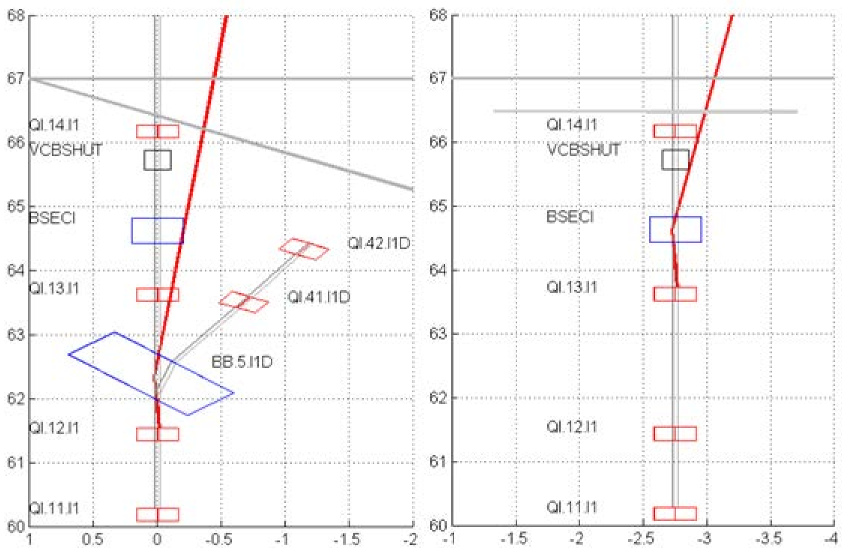
During 2nd half 2018 start full scope user programme (peer-reviewed).

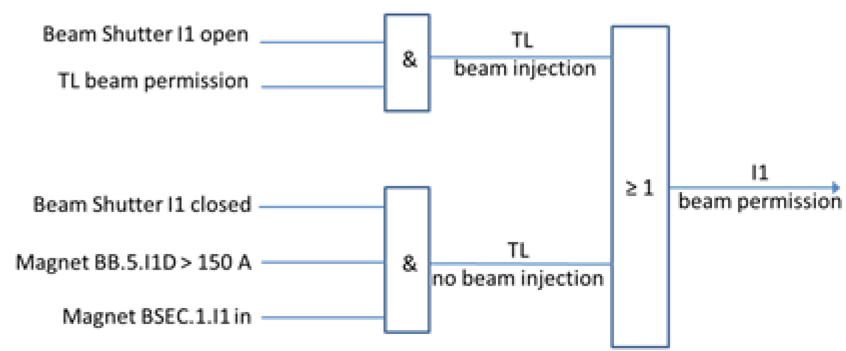
2019 Regular operation (4000 hrs for user programme).

Accelerator: Concept of Electron Enclosure

All measures preventing primary electrons to fly along the (photon) beam line and reach the experimental hall (accessible tunnel).

1. Active: Watching the electric current through the separation dipole.
2. Passive: There is a permanent magnet in the first part of the (photon) beam line. In case the active system fails (magnet shortage) the primary electrons will enter the (photon) beam line but will be bent sideward towards the wall.





Example for injector operation (local mode) and main tunnel accessible with movable permanent magnet BSEC1

Accelerator: Radiation Protection Calculations

Most of the calculations to verify the protection of the public had been carried out with the FLUKA program tools, as there are the following topics:

- Direct radiation from warm sections
- Direct radiation from beam dump sections
- Direct radiation due to muons
- Activation of soil
- Activation of ground water
- Activation of tunnel air

All these calculation showed that we are well below our planning goal of using not more than 10% of the legal dose limits for protection of the public

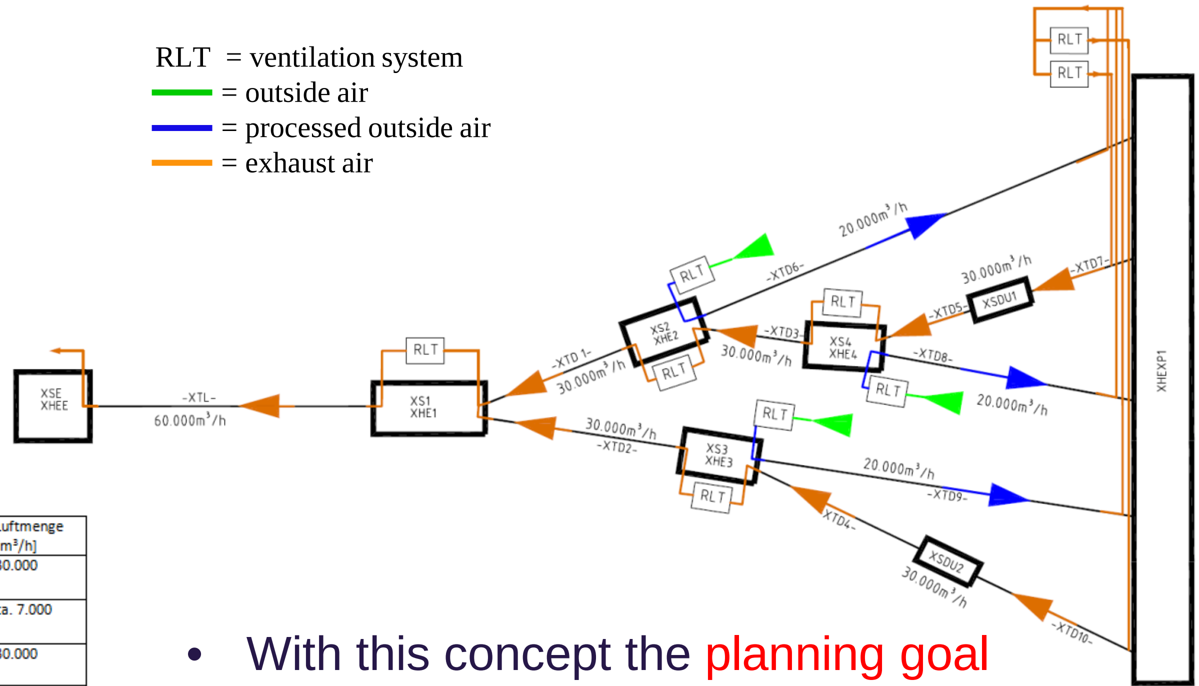
A second set of calculations had been done to check the internal radiation level at critical locations, as there are the following topics:

- Direct radiation from the beam dump sections in the shafts
- Activation of beam dump and collimator components (to design beam dumps)
- Air activation inside the beam dump cavern
- Activation of cooling water
- Activation of concrete (to select optimal mixture already at construction phase)

Accelerator: Air Activation / Ventilation Scheme

Concept of ventilation

- 3 inputs: fresh air input only at 3 shafts
- 1 output: push all air from hot regions (dumps) through the whole tunnel



	Überwachter Kanal	Ort	Größe [mm*mm]	Luftmenge [m³/h]
1	XHE4 Tunnelluft XTD5	XHE4/ 2. OG	800*500	30.000
2	XHE4 Schacht-Fortluft	XHE4/ 1. OG	800*600	ca. 7.000
3	XHE3 Tunnelluft XTD4	XHE3/ 2. OG	2100*800	30.000
4	XHE3 Schacht-Fortluft	XHE3/ 1. OG	800*600	ca. 7.000
5	XHE2 Tunnelluft XTD3	XHE2/ 2. OG	800*500	30.000
6	XHE2 Schacht-Fortluft	XHE2/ 1. OG	800*600	ca. 7.000
7	XHE1 Tunnelluft XTD1	XHE1/ 1. OG	1800*750	30.000
8	XHE1 Tunnelluft XTD2	XHE1/ 1. OG	1800*750	30.000
9	XHEE Tunnel-Fortluft XTL	XHEE/ 2. OG	1500*2500	60.000
10	XHEE Schacht-Fortluft	XHEE/ 2. OG	800*600	ca. 7.000
11	XHEIN Tunnel-Fortluft Injektor UG6	XHEIN/ EG	800*450	5.000
12	XHEIN Tunnel-Fortluft Injektor UG7	XHEIN/ EG	800*450	5.000

- With this concept the planning goal of using only 10% of the legal limit can be reached (FLUKA simulations folded with ventilation concept)
- In addition there will be 12 air monitoring systems distributed over the whole facility

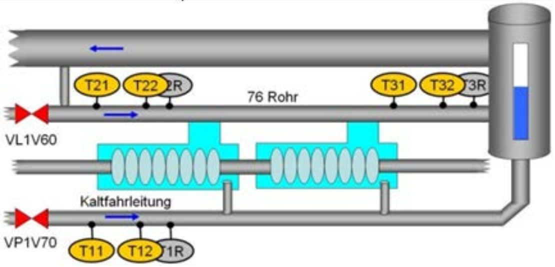
Accelerator: AMTF and Warm Conditioning

AMTF = "Accelerator Module Test Facility"
to test cavities and modules for XFEL

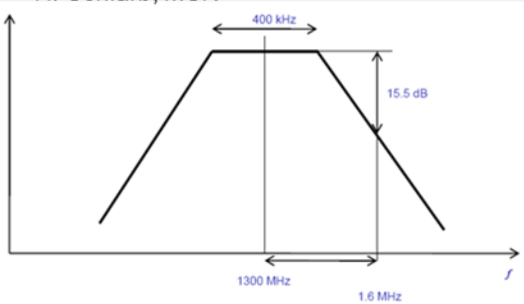
Requirement: Conditioning of RF power couplers in warm accelerator modules with access to the tunnel @ AMTF and XFEL (operate and work at the same time!)

- Modules must be warm (T>200 K)!
  - RF cannot generate dark current on cold resonance frequency
  - Safety signal: temperature threshold
- RF not on warm resonance frequency!
  - Narrow RF band filters in RF drive of klystron (LLRF controls)
  - Safety signal: contact of filter position

T. Böckmann, MKS2



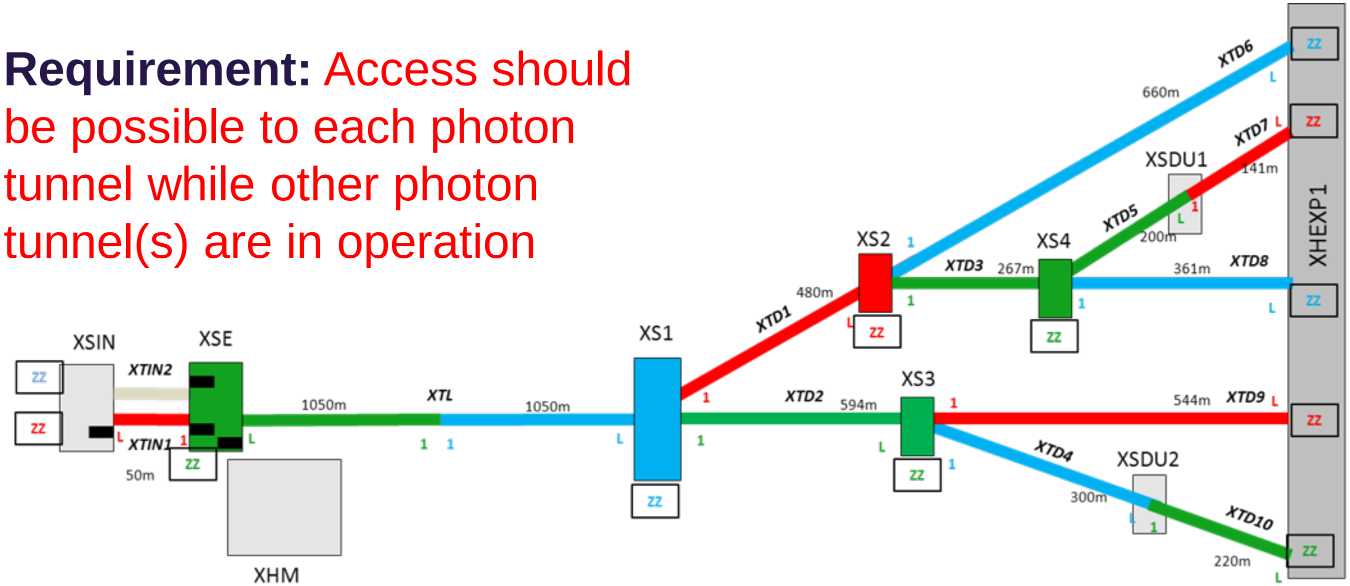
H. Schlarb, MSK



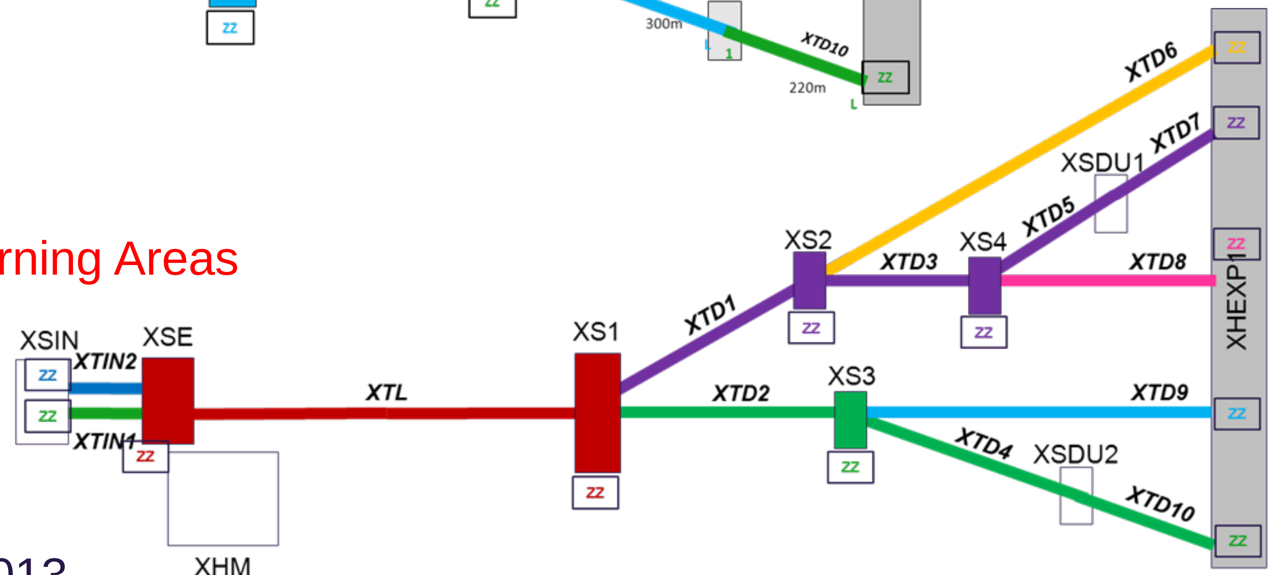
Accelerator: Interlock Concepts

Requirement: Access should be possible to each photon tunnel while other photon tunnel(s) are in operation

Interlock Areas

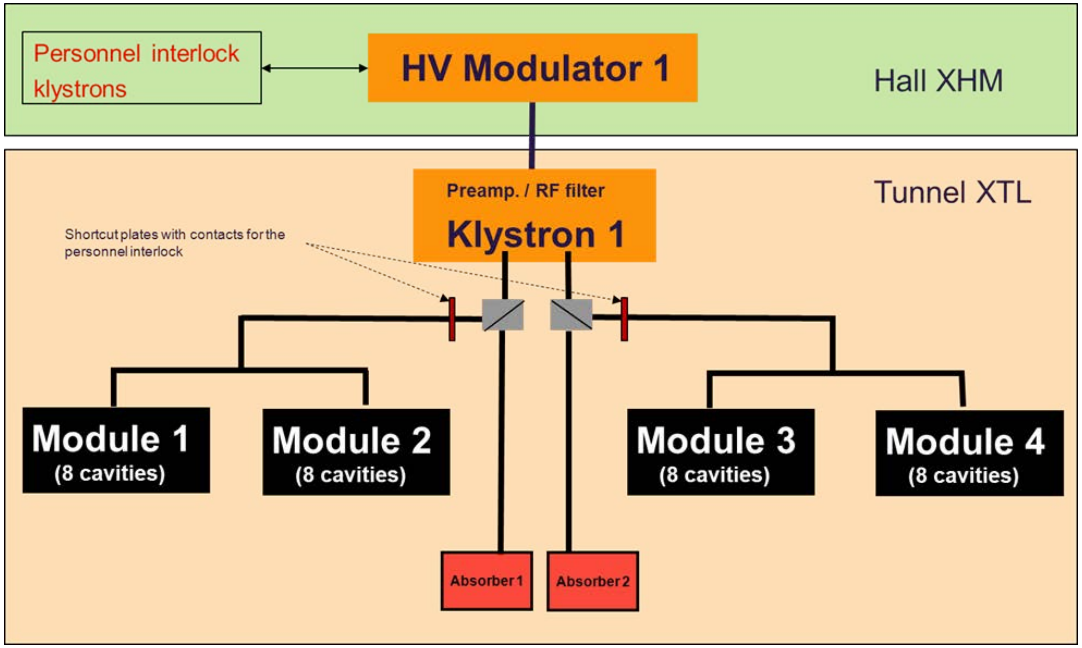


Warning Areas



For details see talk of
B. Racky / Radsynch 2013

Accelerator: Interlock Concepts

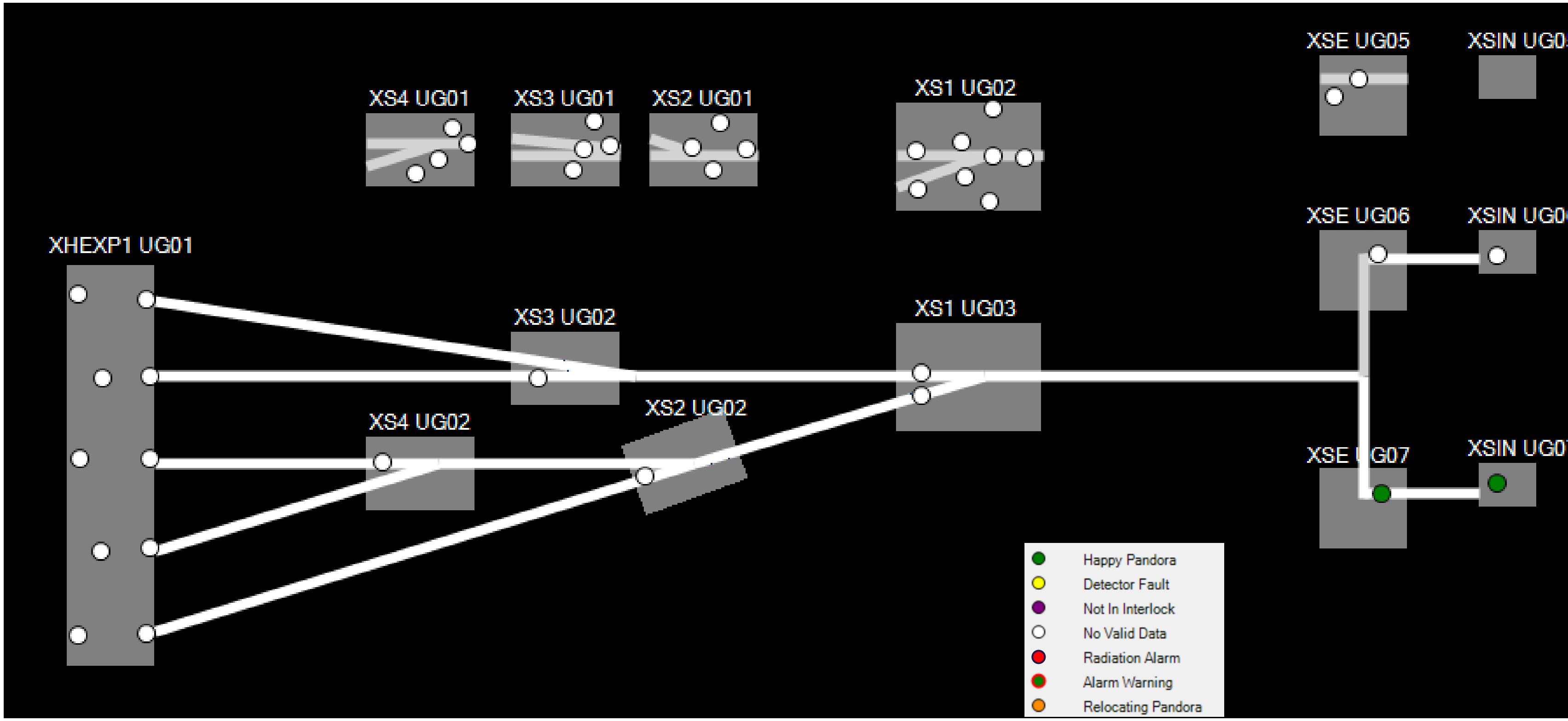


RF distribution and interlock

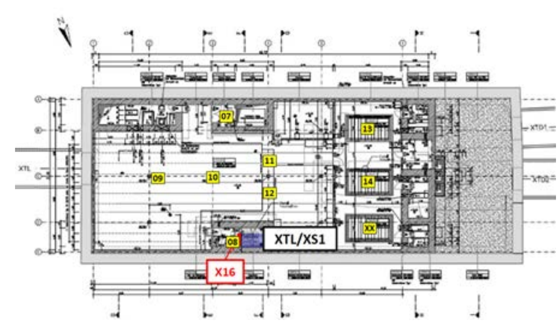
Controlled access and interlock

European XFEL

Accelerator: Measurements / PANDORAs



- **Dose rate measurements around the electron extraction at FLASH,** A. LEUSCHNER, 03.06.2015 at 15:00



Accelerator: Legal I (PFV)

- Most of the accelerator is NOT under/on DESY site
- The facility is crossing a country border (HH/SH)
- Both facts require a special legal procedure in Germany which is called “Planfeststellungsverfahren” (PFV)

- This PFV cumulates all needed approvals and permissions in one global process
- The public is involved in this procedure in form of the possibility to ask questions and object against planned actions and they can change and even stop the whole process
- The final public hearing (“Erörterungstermin”) had been in October 2005 and the final approval of plan (“Planfeststellung”) had been in July 2006
- After finding all the money we started the construction beginning of 2009

Accelerator: Legal II (RP Organization)

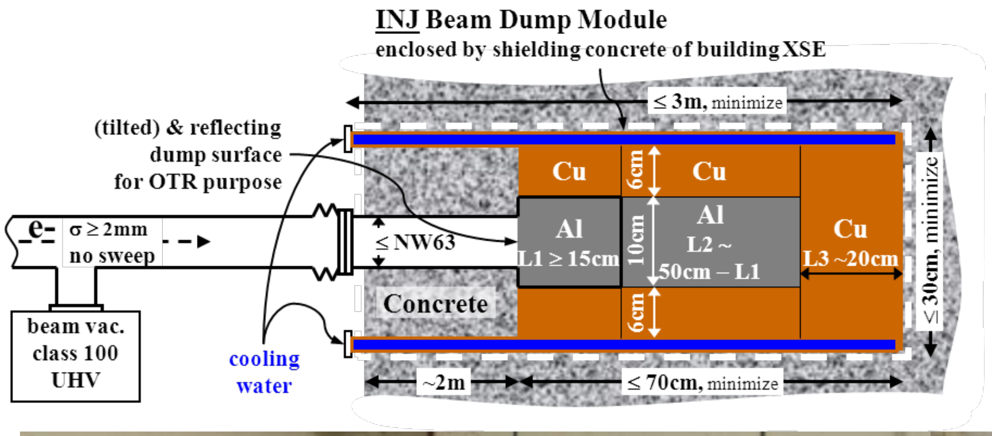
Construction and commissioning phase (until 2016)

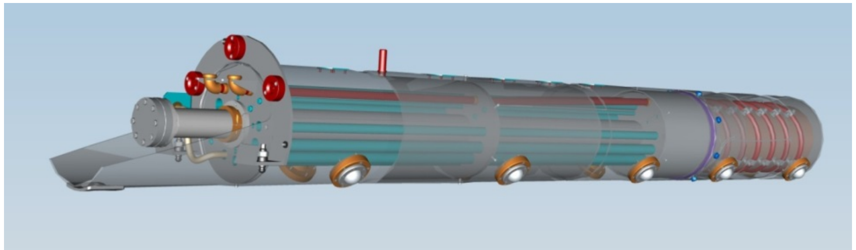
- DESY is the legal operator ("Betreiber") of the facility
- Therefore DESY has the responsibility for radiation protection
- DESY operates (technically) the machine and performs all radiation protection issues

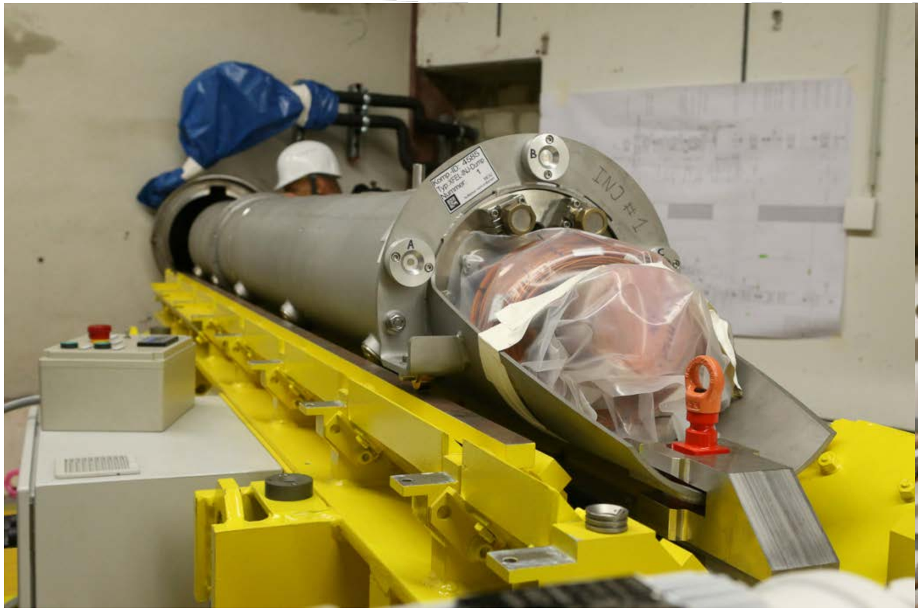
User operation phase (from 2017 on)

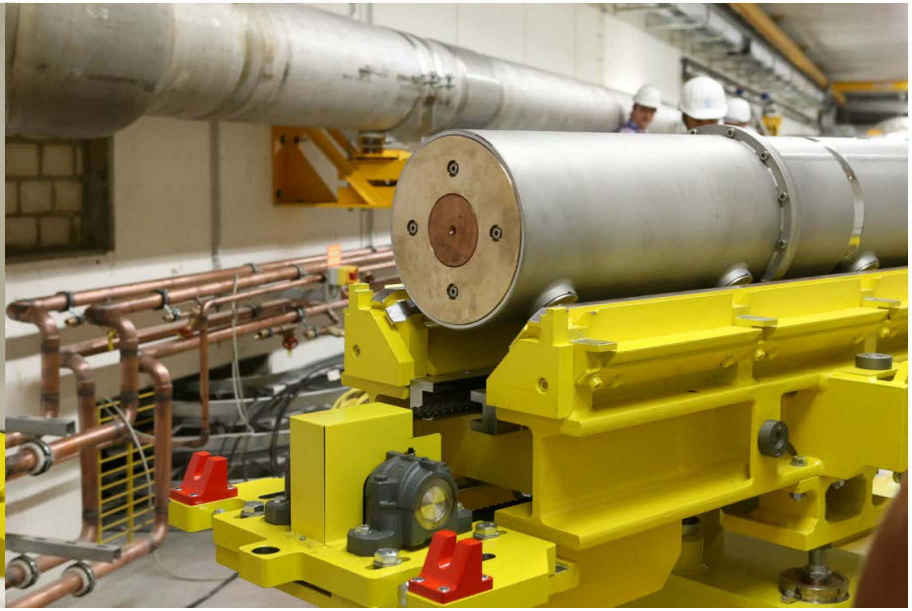
- XFEL GmbH should become the legal operator ("Betreiber") of the facility, this is a very strong political requirement from the government
- Therefore XFEL GmbH will have responsibility for radiation protection
- But DESY should still operate (technically) the machine and should still perform (nearly) all radiation protection issues
- In the moment we are trying to solve this difficult situation which has a lot of unwanted side effects
- One of these is the fact that all DESY people would enter an external facility after this change of legal operator with all consequences (extra dosimetry, radiation worker pass)

Beam Dumps: Injector Dumps

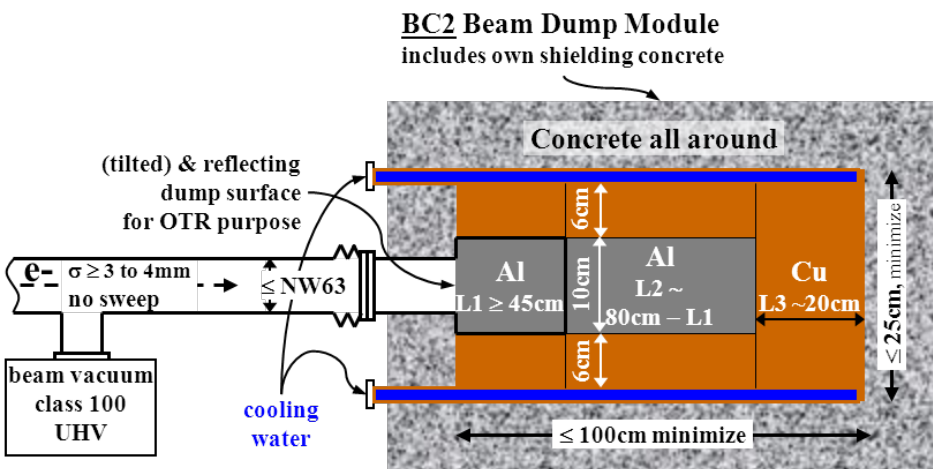


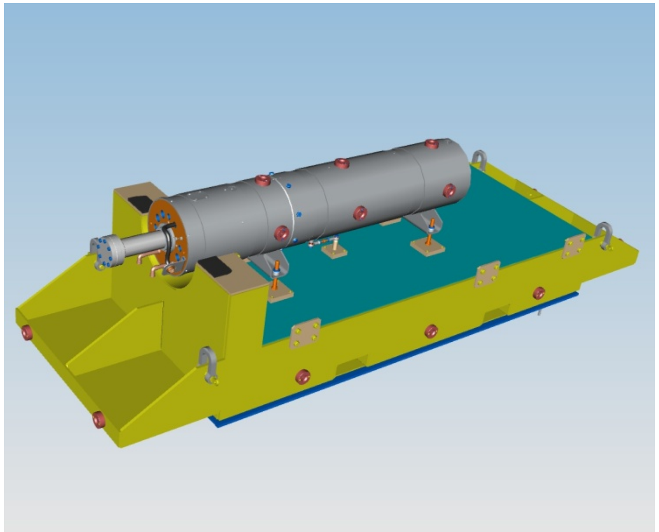


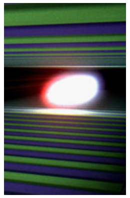




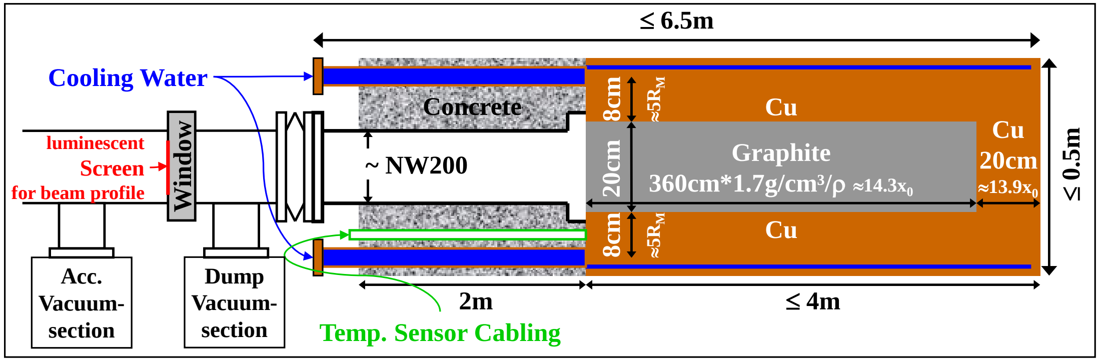
Beam Dumps: Bunch Compressor Dumps

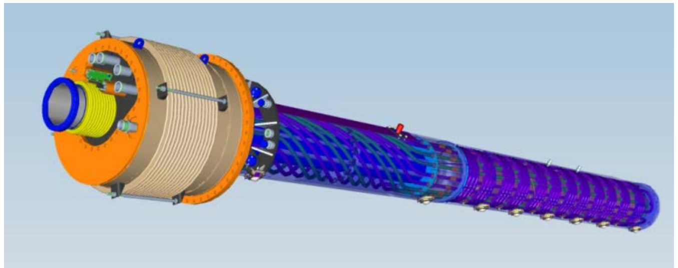




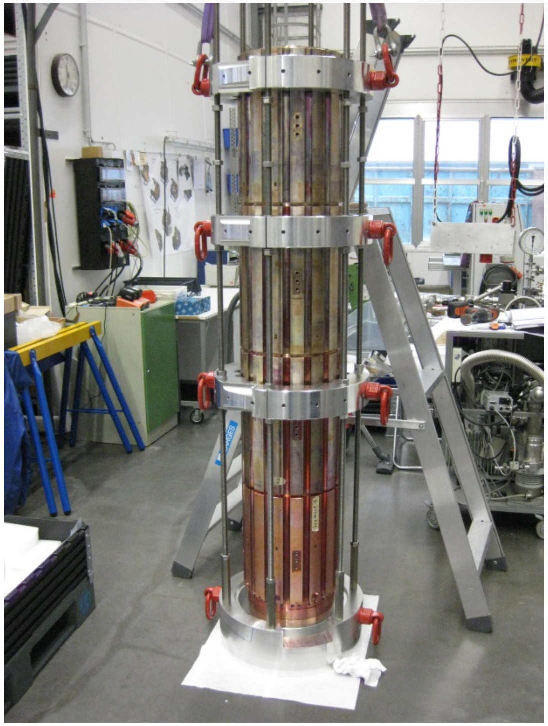


Beam Dumps: Main Dumps



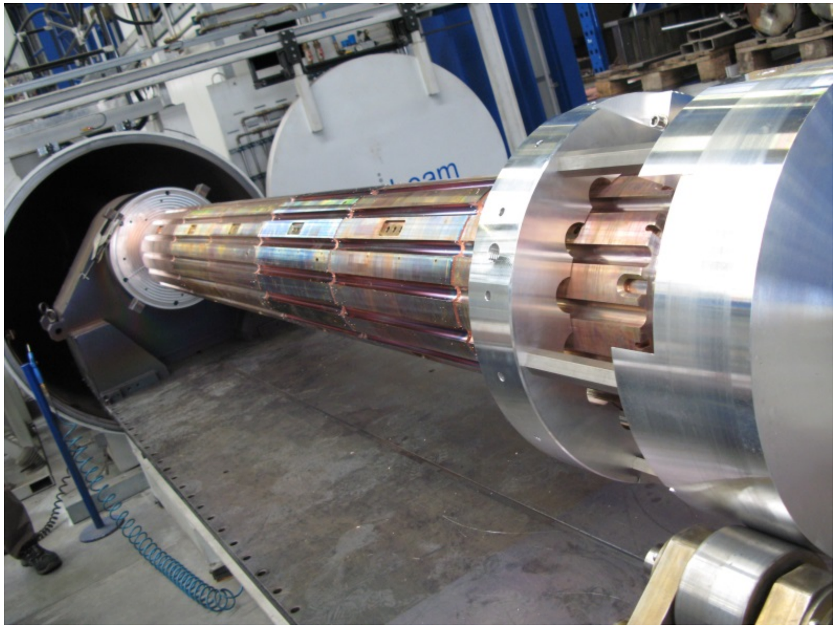


Main dump with muff for Argon system



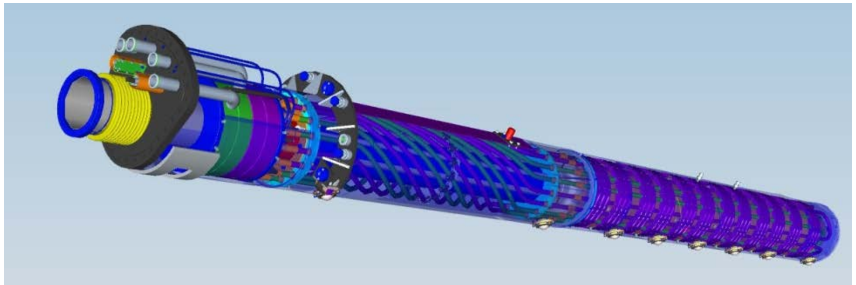
Main dump segments before EB welding

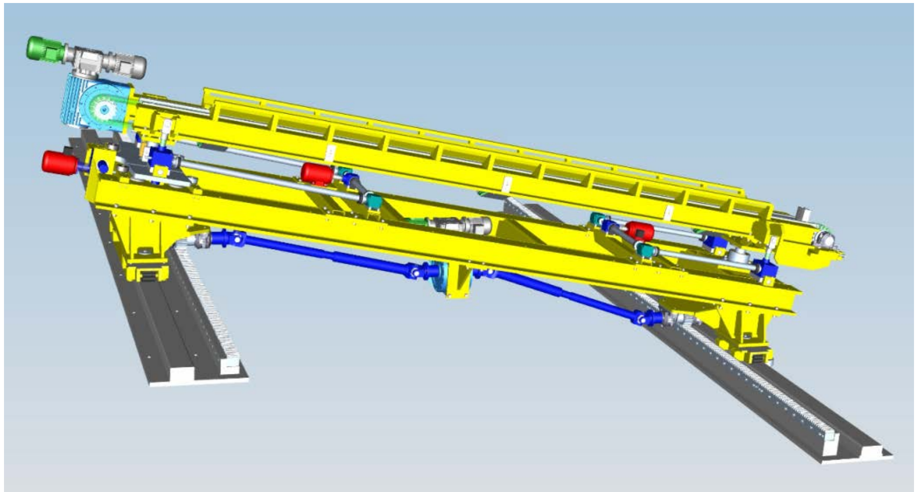
Main dump segments after EB welding



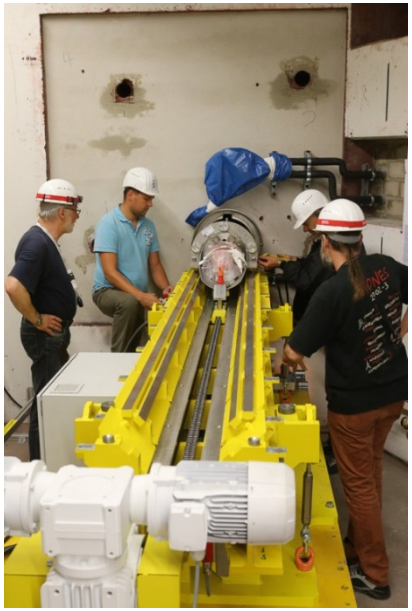
Beam Dumps: Concept of Construction

- Construction of all dumps parts has been done such that the probability of exchange in the operation time of 20 years will be as low as possible (careful selection of materials and joining technologies, extensive testing program after each production step, high level of monitoring, possibility of running with reduced performance in case of failure)
- Construction of all tools for beam dump exchange has been done such that the systems are reliable as possible (careful selection of materials and joining technologies, extensive testing of the procedure before start up, regular testing during operation period, redundant systems of the most important components)

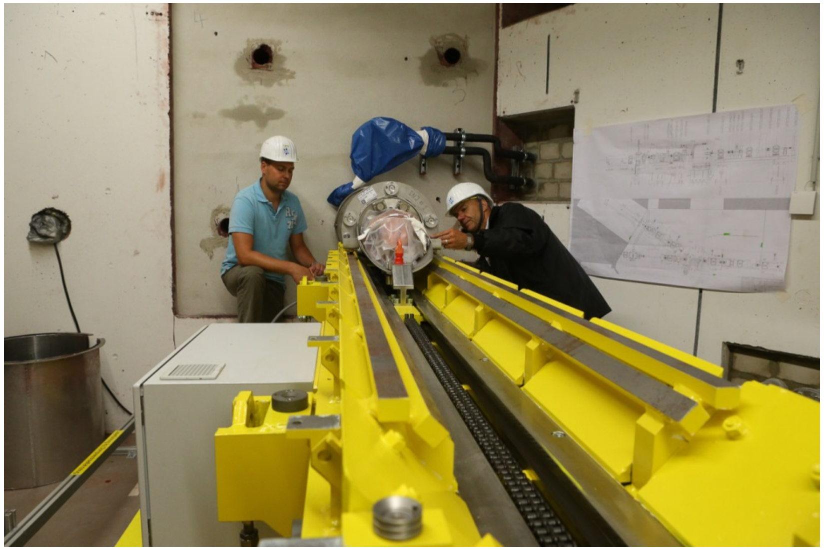




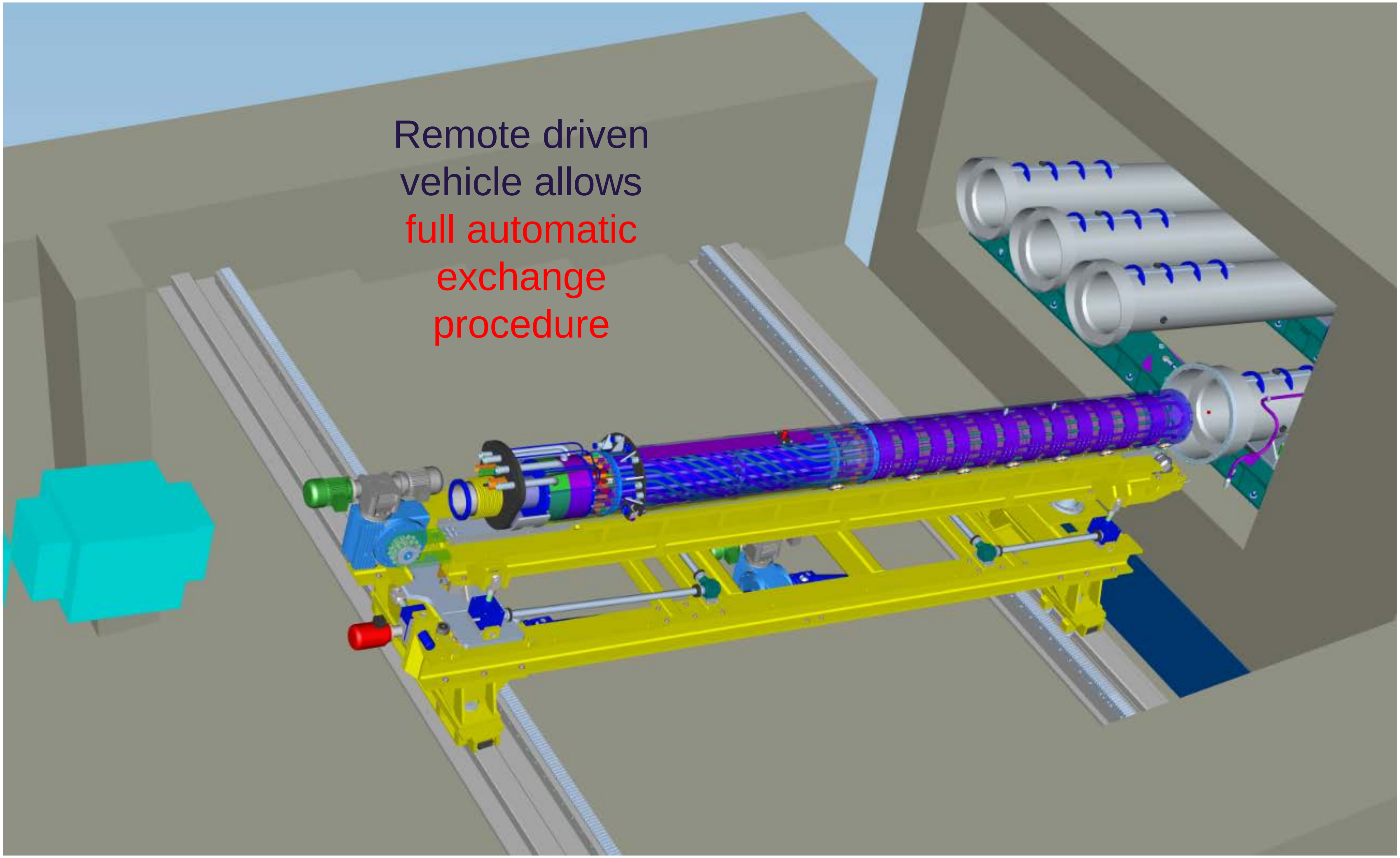
Beam Dumps: Concept of Exchange (Injector)



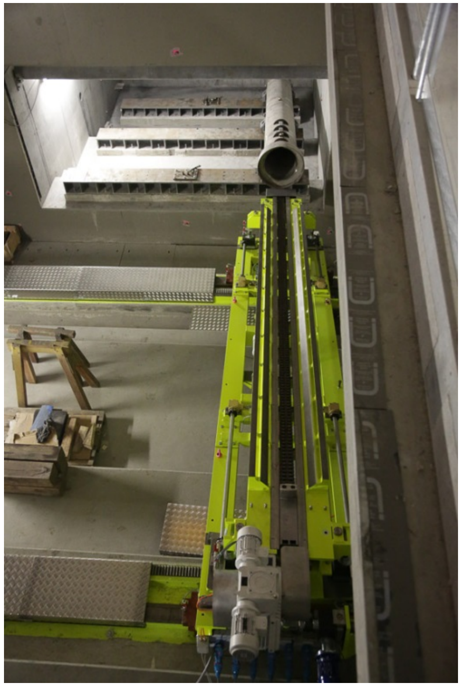
Laser driven vehicle allows semi automatic exchange procedure

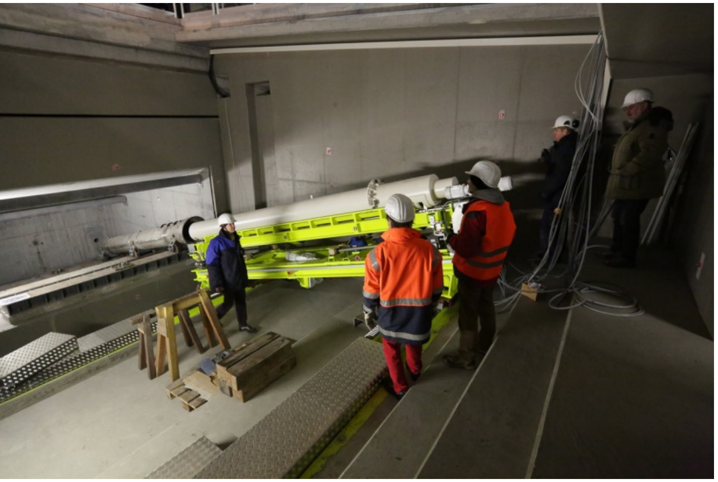


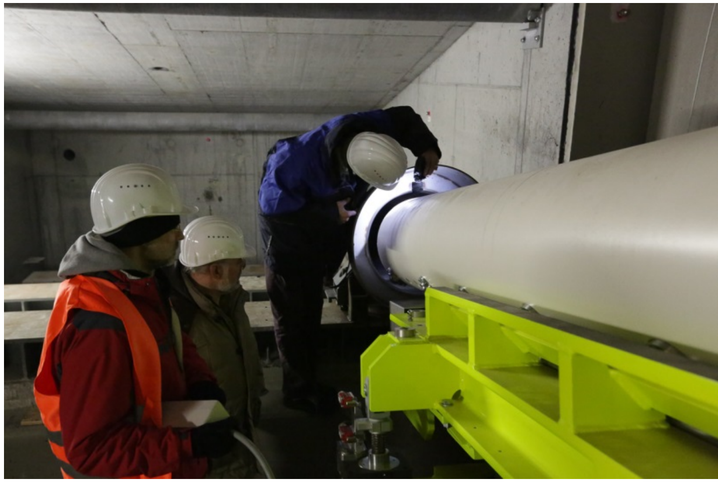
Beam Dumps: Concept of Exchange (Main)



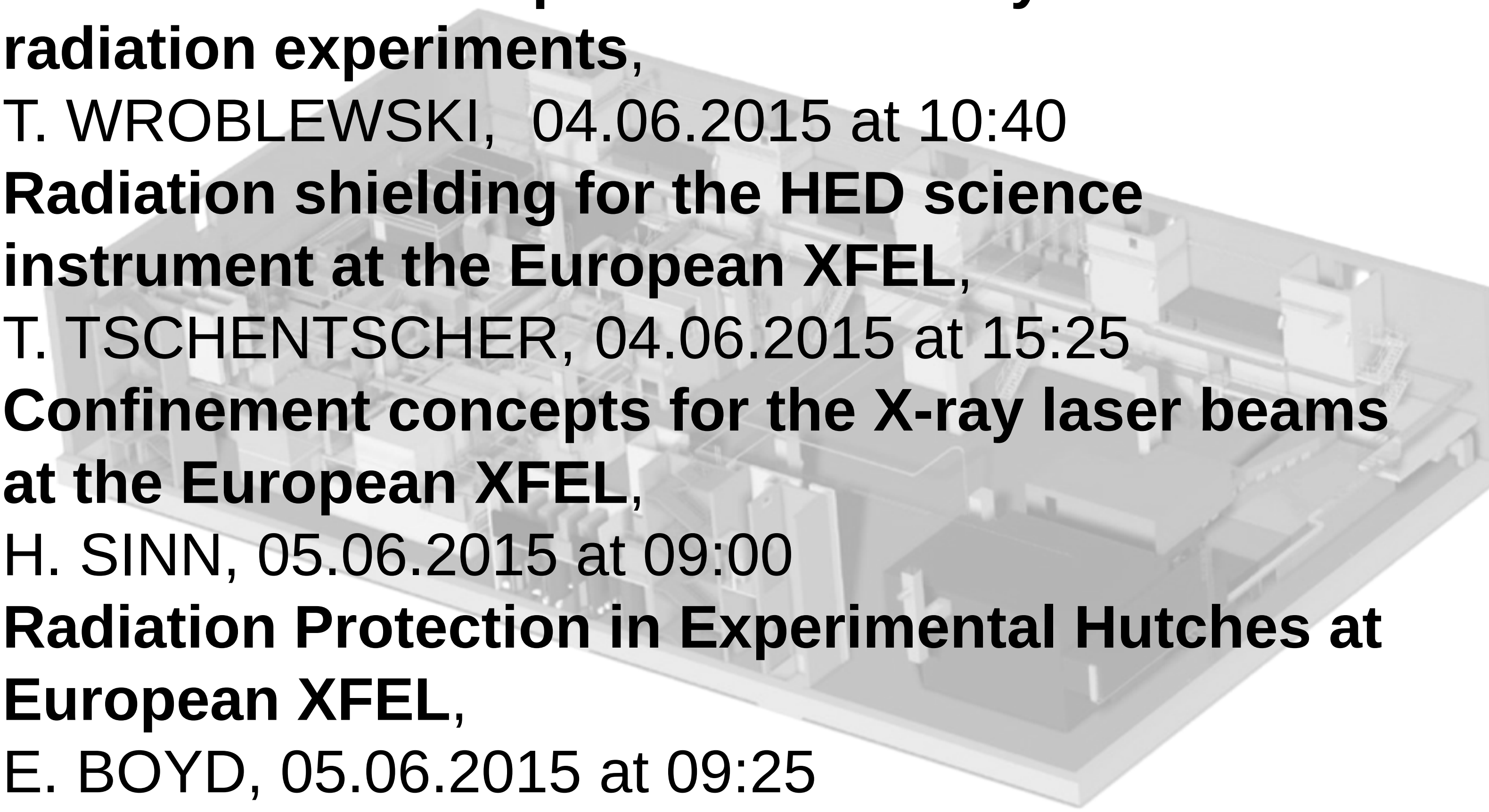
Beam Dumps: Concept of Exchange (Main)







Experiments: Other Talks



- **Lead thickness required to shield synchrotron radiation experiments**,
  T. WROBLEWSKI, 04.06.2015 at 10:40
- **Radiation shielding for the HED science instrument at the European XFEL**,
  T. TSCHENTSCHER, 04.06.2015 at 15:25
- **Confinement concepts for the X-ray laser beams at the European XFEL**,
  H. SINN, 05.06.2015 at 09:00
- **Radiation Protection in Experimental Hutches at European XFEL**,
  E. BOYD, 05.06.2015 at 09:25

Summary

- Construction of the XFEL is a big challenge for all involved parties and it will be not trivial to follow the given time table
- Concepts of radiation protection for the accelerator are under control
  - Electron enclosure with current monitoring and permanent magnets
  - Shielding construction followed the simulation results
  - Ventilation concept with long stay of activated air inside the tunnel
  - Warm conditioning with temperature and filter control
  - Interlock concepts
  - Radiation measurements (PANDORAs and air monitoring)
  - Radiation protection organization might be a little bit complicated
- Concepts for the beam dumps are under control
  - Construction had been a big challenge and is nearly finished
  - Exchange procedures are already tested and are working well
- Radiation protection of experiments will be presented later