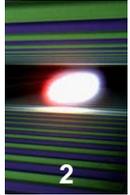


The Personnel Interlock System of the European XFEL

B. Racky

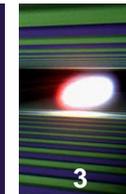
Deutsches Elektronen- Synchrotron DESY



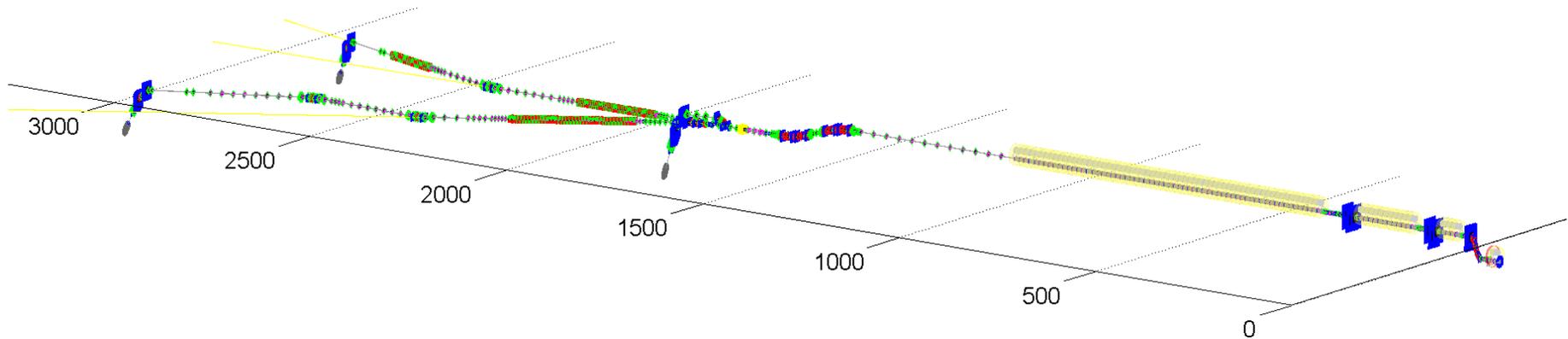
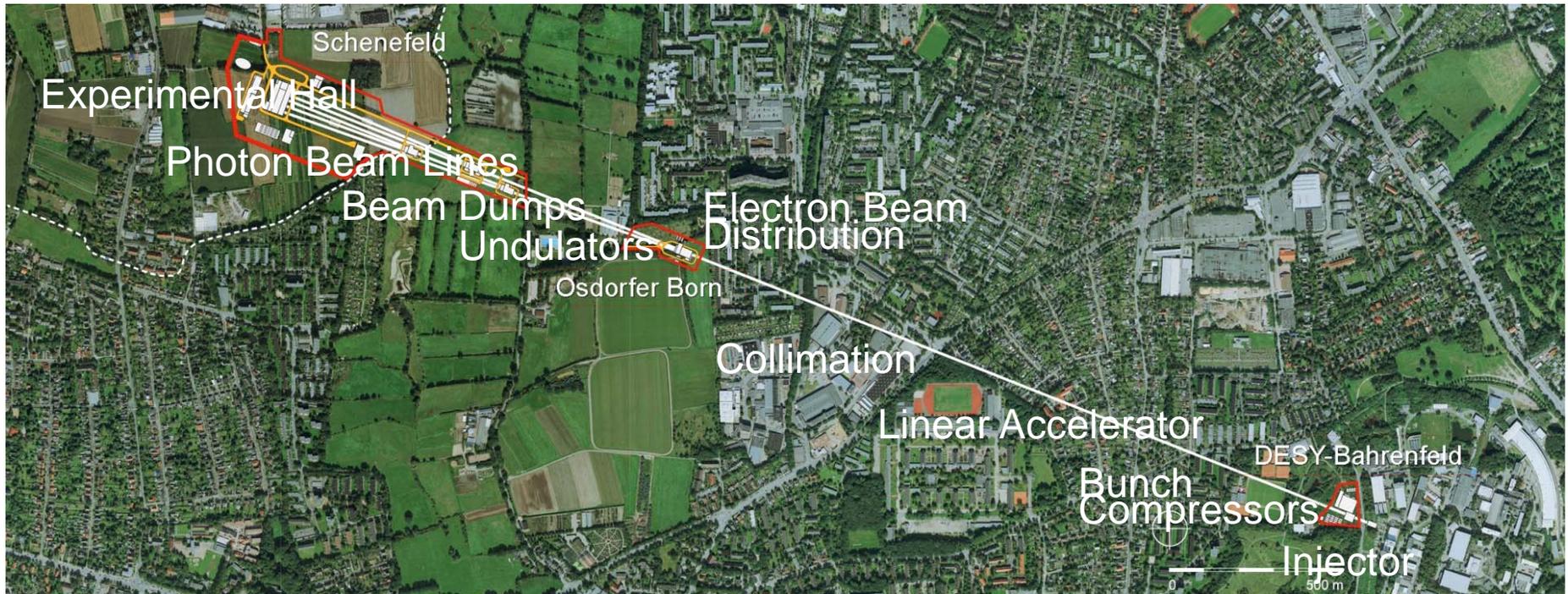
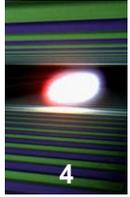


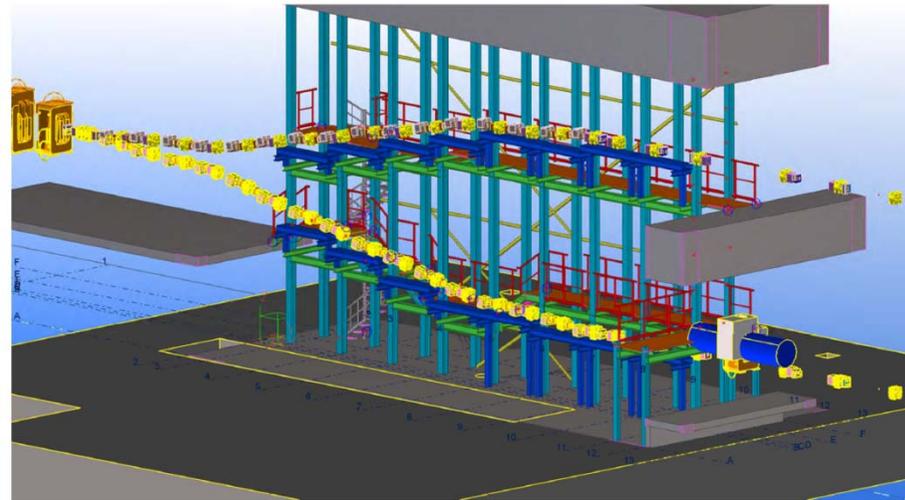
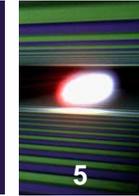
- 17.5 GeV superconducting electron linac
- 3.8 km tunnel system
- Start version: 3 undulators with variable gap/
- 6 photon experiments
- 16 institutes contributing

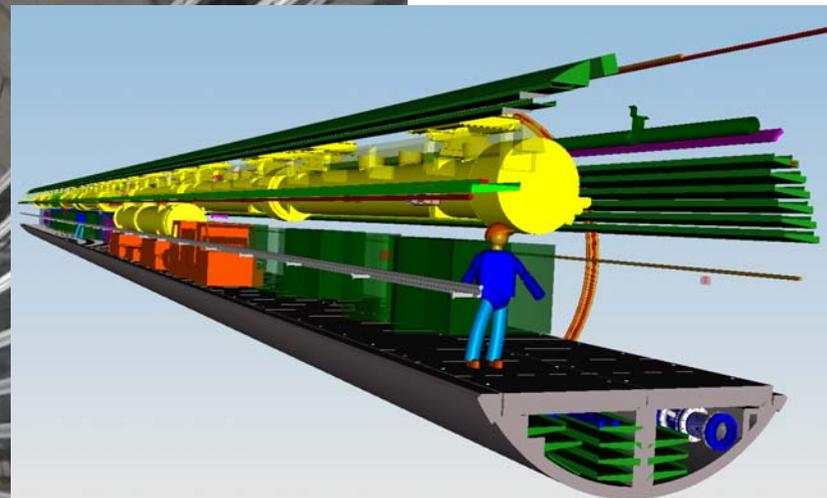
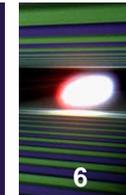


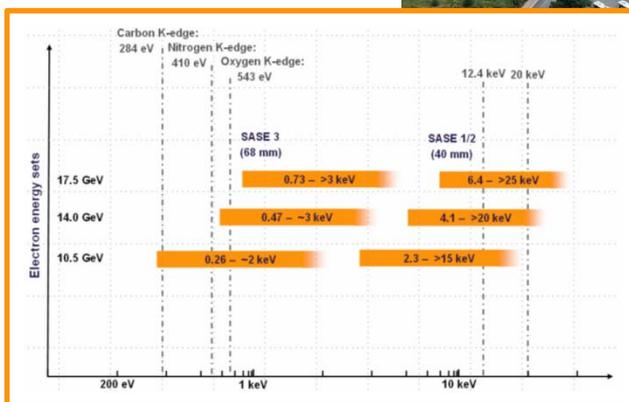
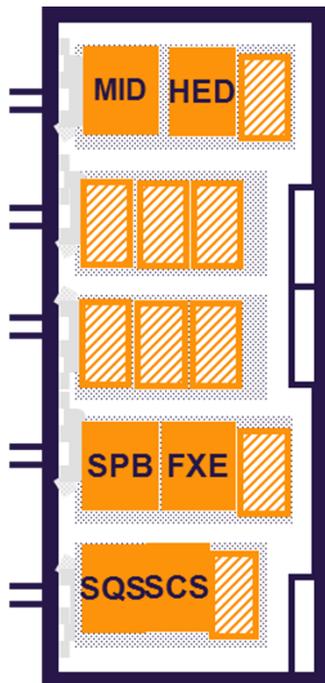
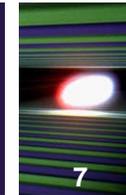


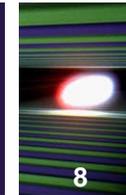
Quantity	Value
electron energy	17.5 GeV
macro pulse repetition rate	10 Hz
RF pulse length (flat top)	600 μ s
bunch repetition frequency within pulse	4.5 MHz
bunch charge	0.02 – 1 nC
electron bunch length after compression (FWHM)	2 – 180 fs
Slice emittance	0.4 - 1.0 mm mrad
beam power	500 kW
# of modules (containing eight 9-cell superconducting 1.3 GHz cavities)	101
accelerating gradient for 17.5 GeV	23.6 MV/m
# of 10 MW multi-beam klystrons	27
average klystron power (for 0.03 mA beam current at 17.5 GeV)	5.2 MW





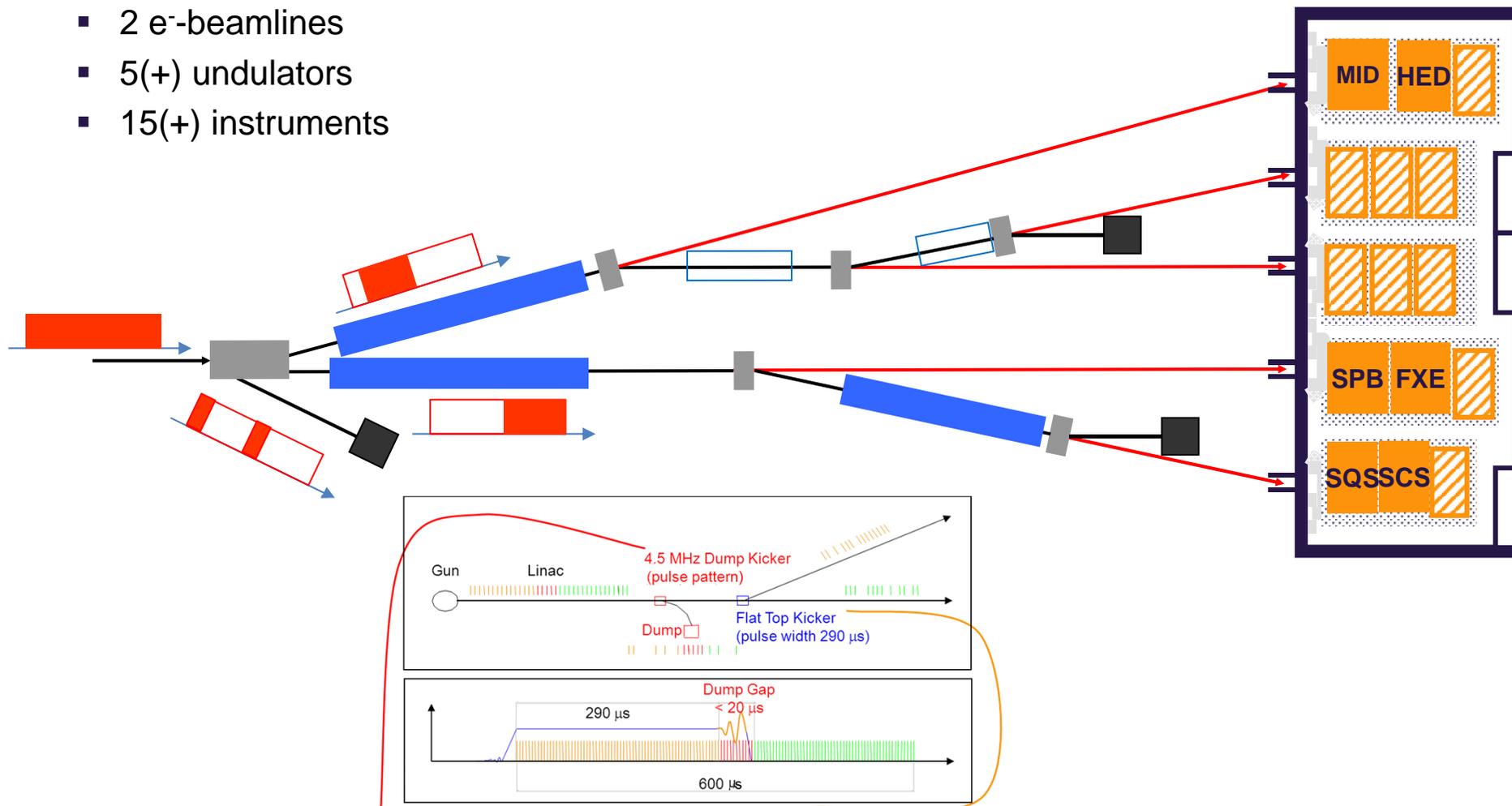


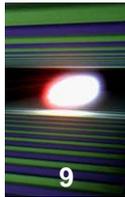




■ Within 1 RF puls

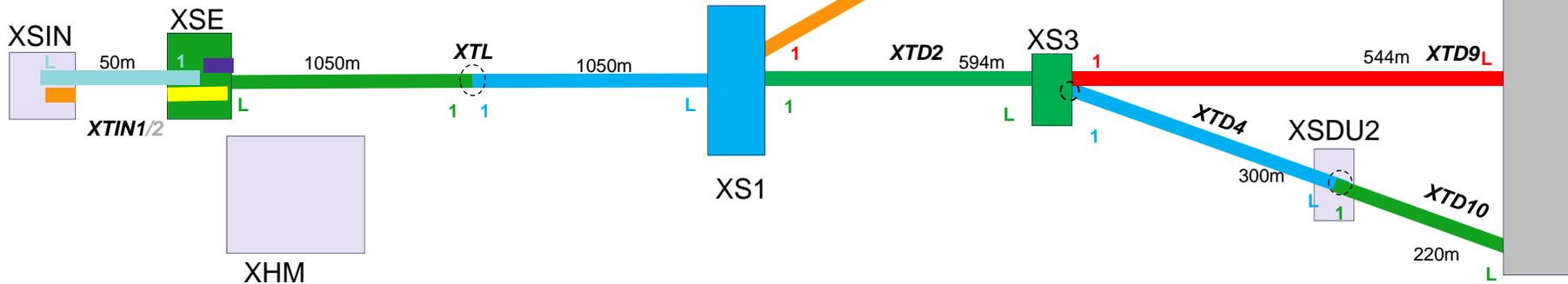
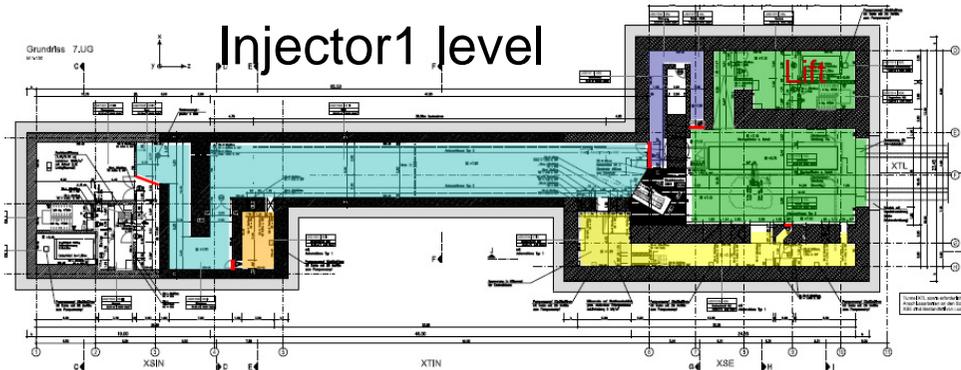
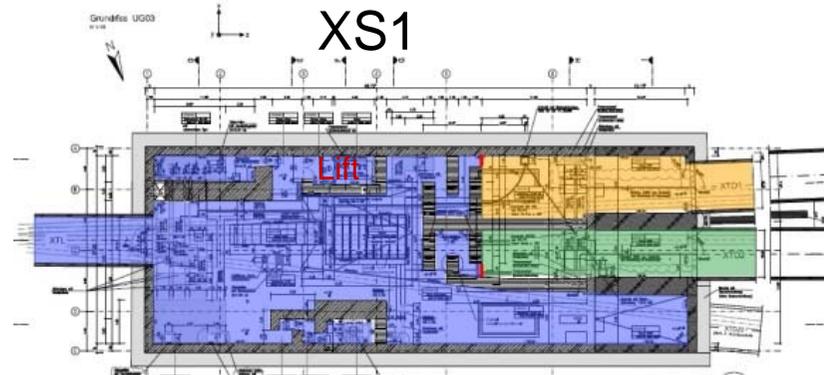
- 2 e⁻-beamlines
- 5(+) undulators
- 15(+) instruments

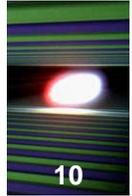




Accelerator complex

- 17 interlock areas
- 38 interlock doors
- 5 interlocked lifts





■ Special challenges due to construction geometry

- definition of reasonable interlock search segments
- fire protection doors used as interlock doors
- large media shafts
 - Injector complex: vertical interlock search of 4 levels
- Lifts for persons/material leading into the beam areas
 - Interface personnel interlock / lift controls
 - If the interlock is set the lift cannot drive into searched area
 - Interlock contacts in the lift shafts underneath the radiation protection ceiling
 - Lift breaks interlock if contacts are touched





= overriding safety functions of the door interlock

■ Safety equipment

- Each entering person takes 1 interlock access key
- All interlock keys of the corresponding operation mode must be returned for beam operation



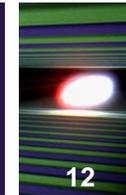
■ Safety measures

- matching locks near the interlock doors
- only 1 person may enter at each access procedure
- if any access key is missing no new beam warning is possible in the entire accelerator complex

■ Support

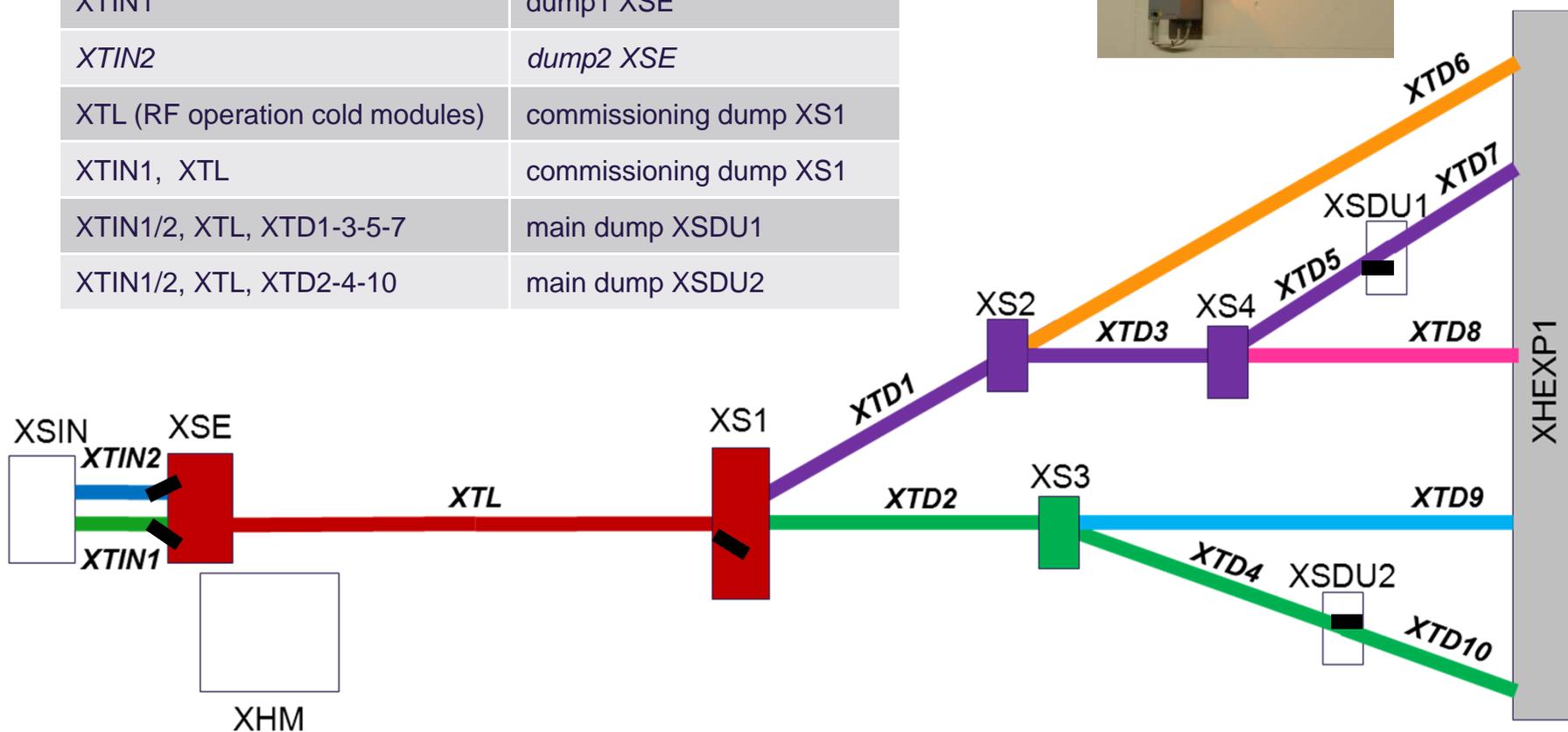
- Operators in the control room
- Camera at the door / monitor in the control room
- Intercom connection, switchable door panels





8 beam warning sections defined

Interlocked tunnels	Beam dump
XTIN1	dump1 XSE
XTIN2	dump2 XSE
XTL (RF operation cold modules)	commissioning dump XS1
XTIN1, XTL	commissioning dump XS1
XTIN1/2, XTL, XTD1-3-5-7	main dump XSDU1
XTIN1/2, XTL, XTD2-4-10	main dump XSDU2





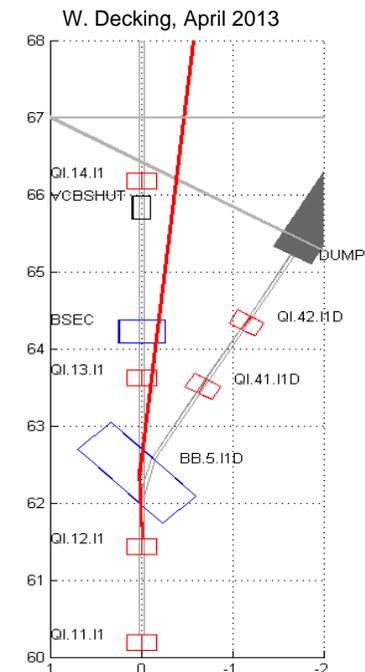
■ Challenges

- Safety against direct electrons in experimental hall
- access to tunnels during beam operation in other branches

- **Problem:** Fast distribution system (septa, flat top kickers) cannot be controlled by personnel interlock

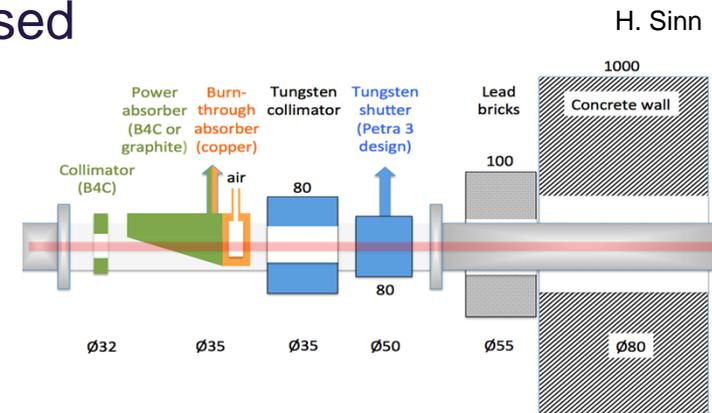
■ Safety measures

- Survey of dipole magnets
 - ➔ Status off / grounded
 - ➔ Status on / $I > \text{threshold}$ (no fail safe concept)
- Insertion of permanent dipole magnets
 - ➔ Moved into electron beam lines for access
 - ➔ Fix installation in photon beam lines (not interlocked)
- Beam shutters

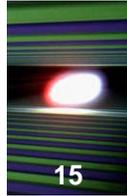




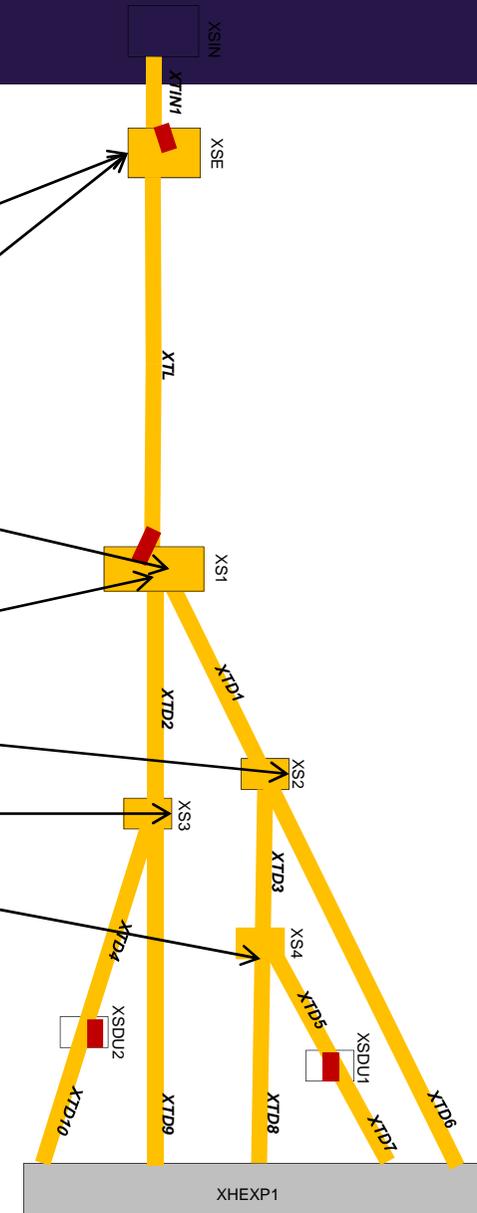
- clearance signal of the personnel interlock to steer open
- BS serve as shielding for bremsstrahlung
- BS can be damaged if hit by electron or photon beam
- BS protection measures are surveyed by the personnel interlock
 - Photon beam lines (design WP-73)
 - ➔ BS open **or** protecting Absorber closed



- Electron beam lines (design WP-19)
 - ➔ BS open **or** deflecting magnets ok
- In case of failure: abort of beam operation (RF off)



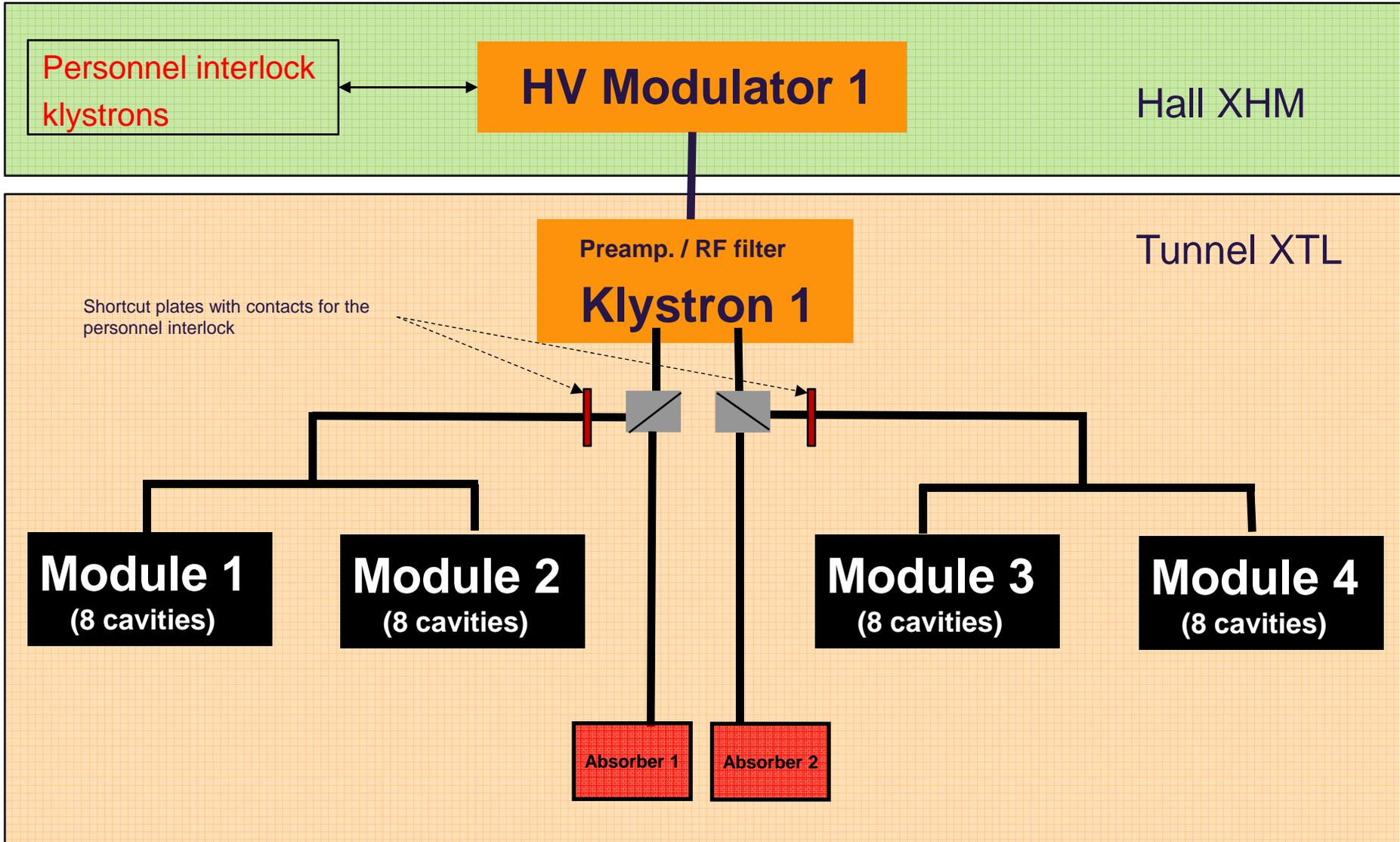
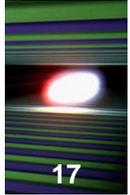
Access to	Beam in	Interlocked safety components
XTL	XTIN1	Dipole magnet dump I1 on Permanent magnet I1 moved in Beam shutter Inj.1 closed
XTIN1	XTL	Beam shutter Inj.1 closed
XTD1	XTL (+ XTD2)	Dipole magnet BD.2.T1 on Magnets T1 off Beam shutter T1 closed
XTD2	XTL (+ XTD1)	Dipole magnet BD.10.T2 on Permanent magnet T2 moved in Beam shutter T2 closed
XTD6	XTD1 (-3-7)	Beam shutter & absorber T6 closed
XTD9	XTD2 (-4-10)	Beam shutter & absorber T9 closed
XTD8	XTD1 (-3-7)	Beam shutter & absorber T8 closed
XHEXP1	XTD1 (-3-7)	Magnets T3, T5, T5D on
XHEXP1	XTD2 (-4-10)	Magnets T4, T4D on





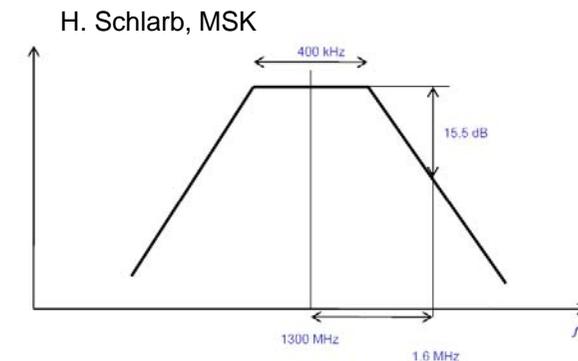
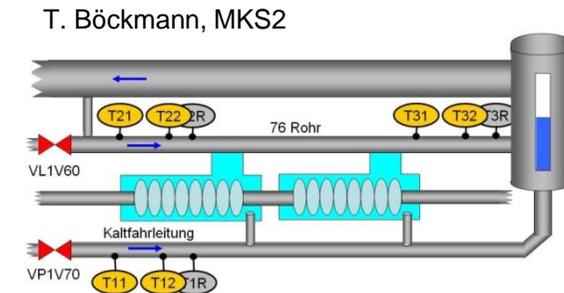
- Personnel Interlock
 - Magnet power supplies (electrical safety)
 - All klystron modulators
 - Beam shutters and absorbers

- Machine protection system
 - beam loss monitors
 - proper steering of the beam to avoid losses
 - Control of dump load

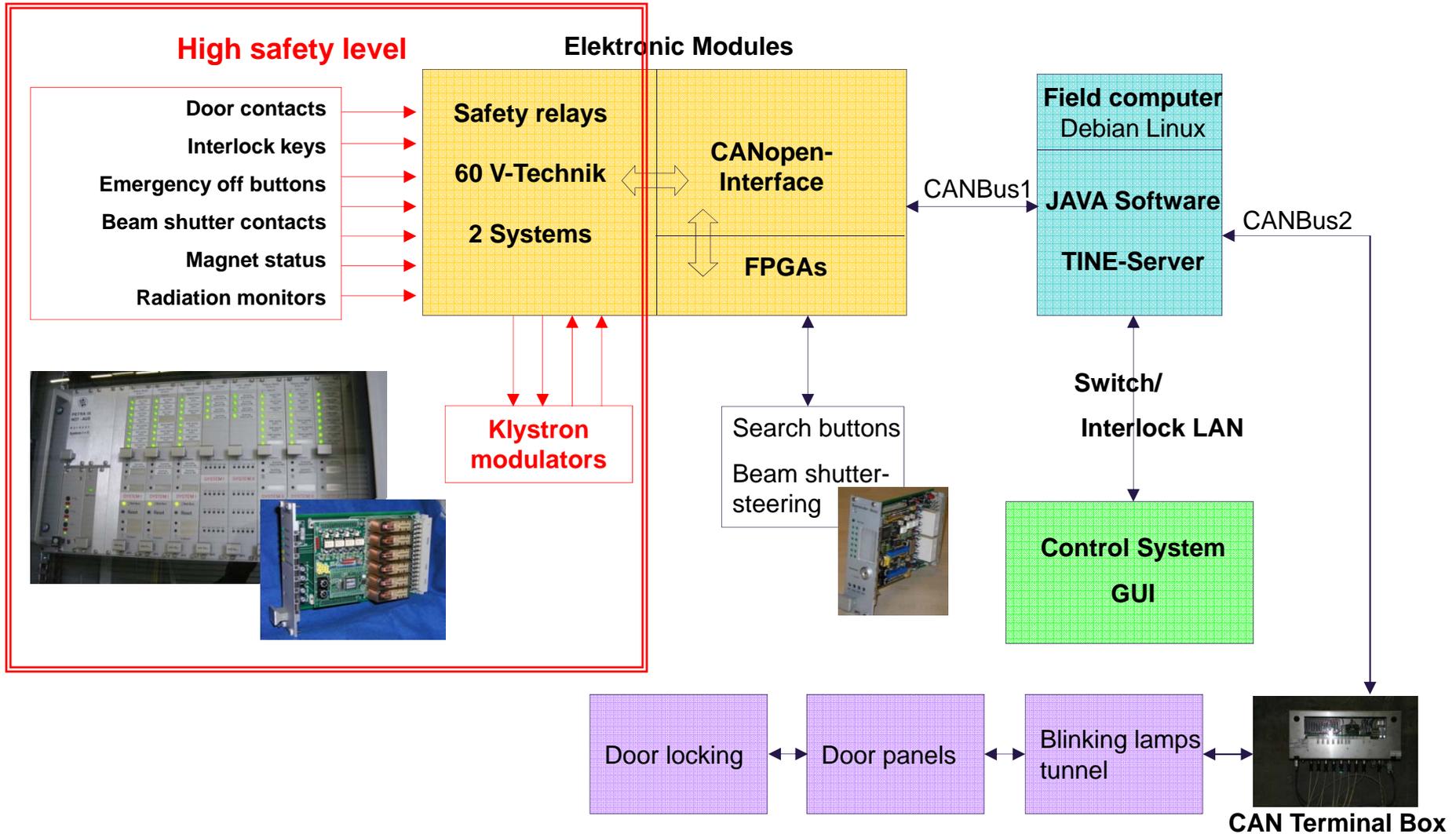
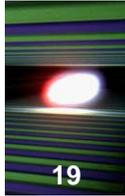


- **Idea:** Conditioning of RF power couplers in warm accelerator modules

- 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**



- First implementation at XFEL module test facilities

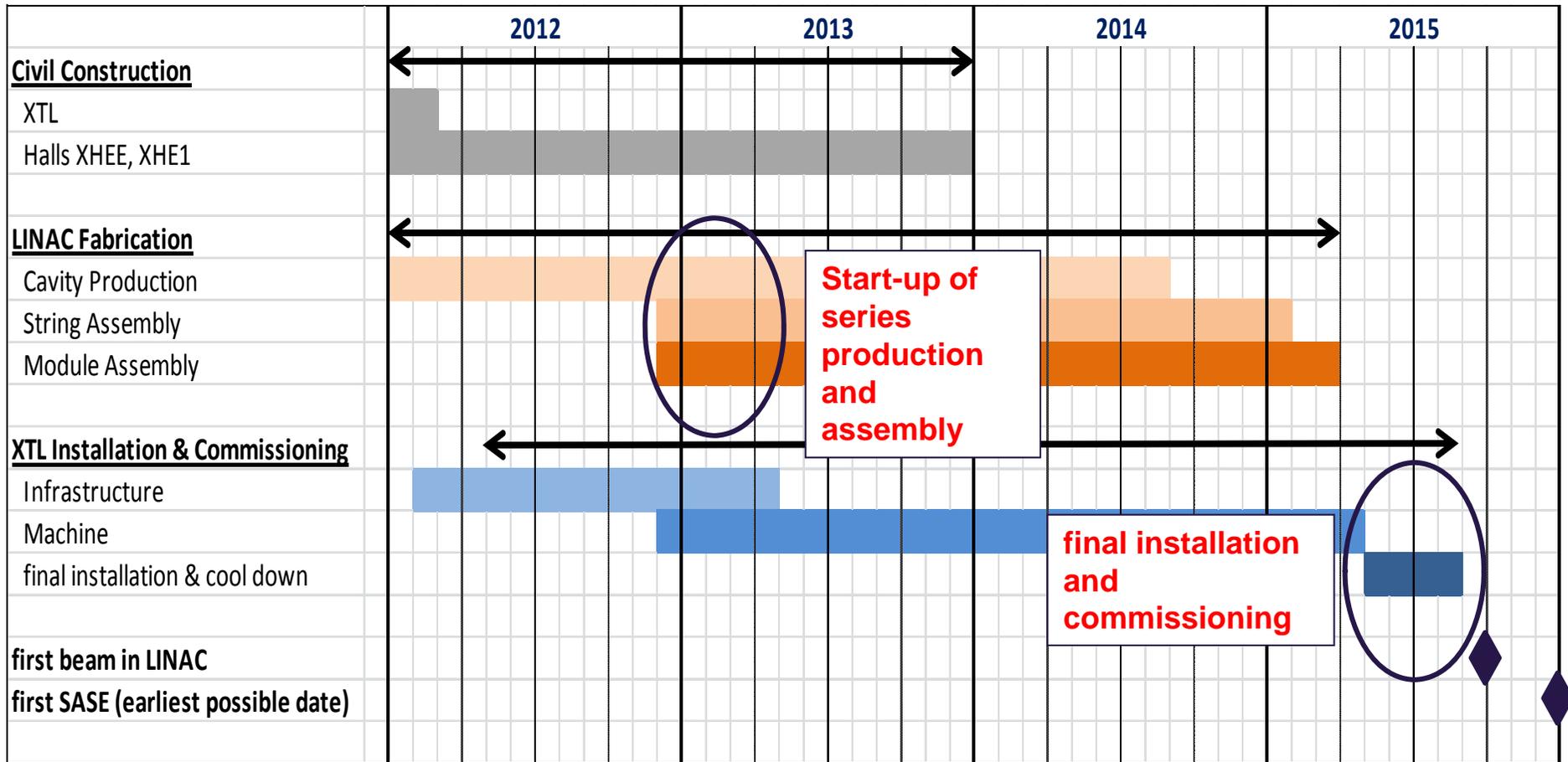
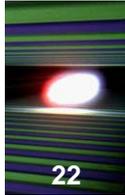


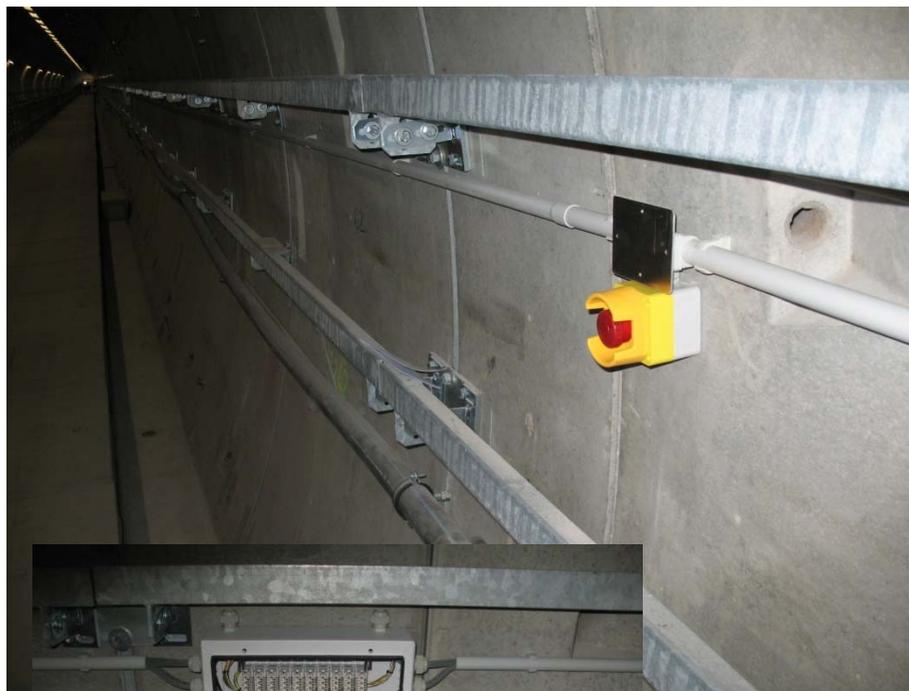
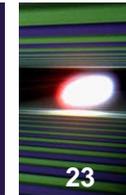


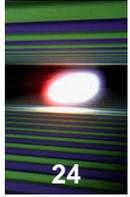
- New type of door interlock modules
 - Processing of controlled access
 - Safety PLC for special applications
 - Ethersound for warning announcements
 - Intercom and video system, HD cameras
 - LED warning lamps (yellow blinking)
-
- First implementation at FLASH2 (2013)



- CE certifications required for in house developments
 - no problem for interlock electronics
- Standard for safety systems: EN 61508
 - EN ISO 13849 not applicable for our system architecture
 - Alternative standard EN 62061 must be applied
 - Review of the functional safety of approved systems
 - Calculation of safety performance levels
 - High QM requirements: review /upgrade of documents and procedures
 - Qualification of staff
 - Consultation by TÜV Rheinland
 - Germany's leading experts in functional safety







- DESY interlock group MPS



- Conceptual design XFEL interlock
 - M. Dressel, A. Rathjen, B. Racky
 - W. Decking, M. Bieler
 - N. Tesch, A. Leuschner, W. Clement

Thank you for your attention

