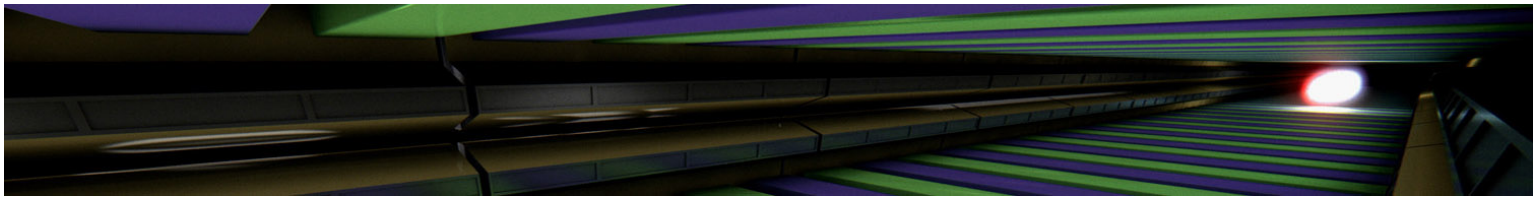
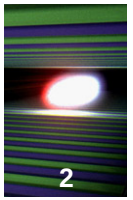


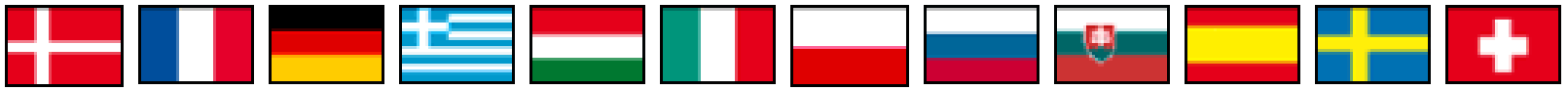
Radiation Protection in Experimental Hutches at European XFEL

Safety and Radiation Protection Group

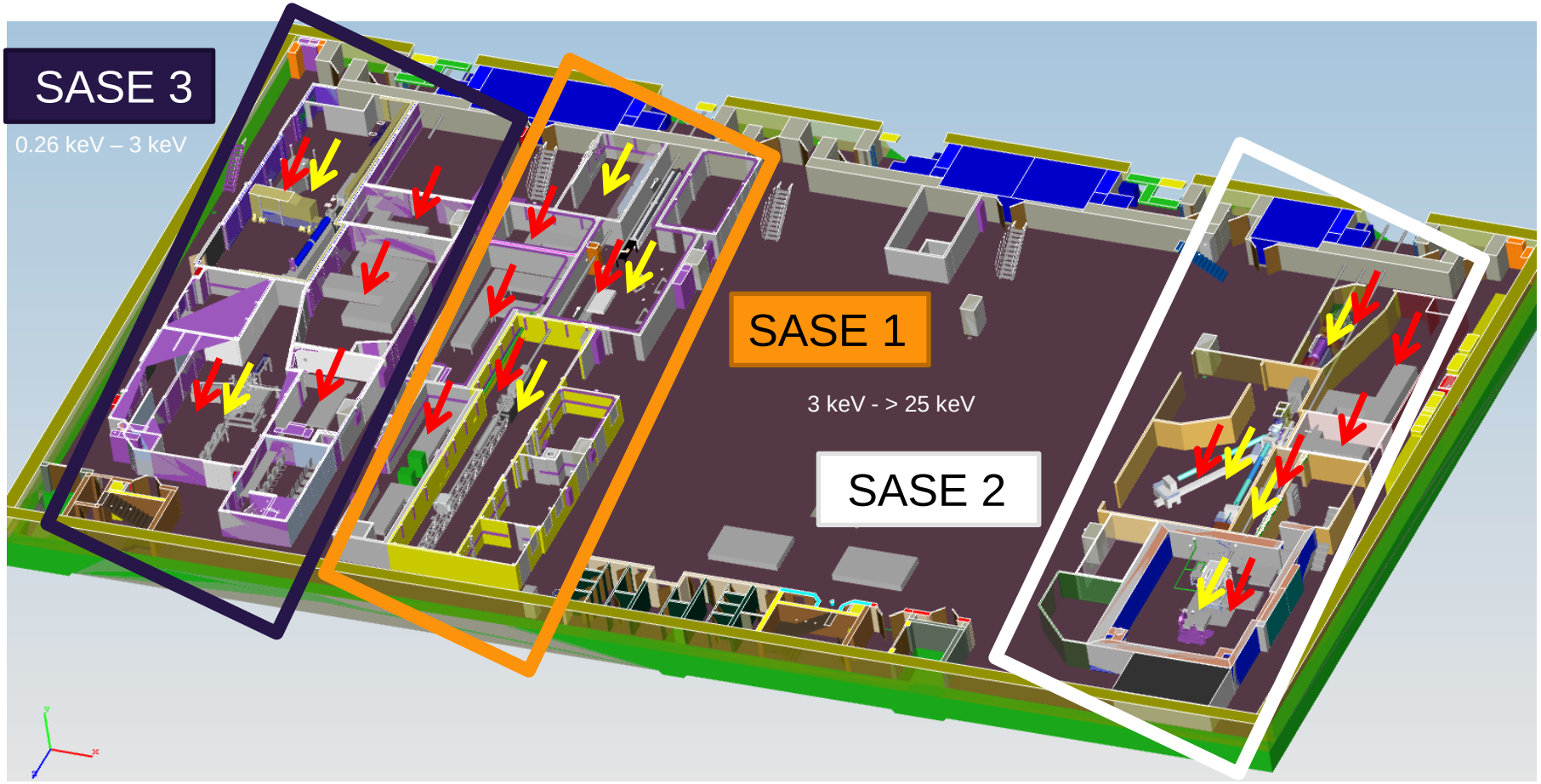
Topics



- Typical Hutch Layout at XFEL
- Shielding Calculations for Radiation Hutches
- Design of Optical Laser Transfer Arrangement
- Interlocks – interaction between radiation and laser interlocks
- Special Considerations for HED Experiment

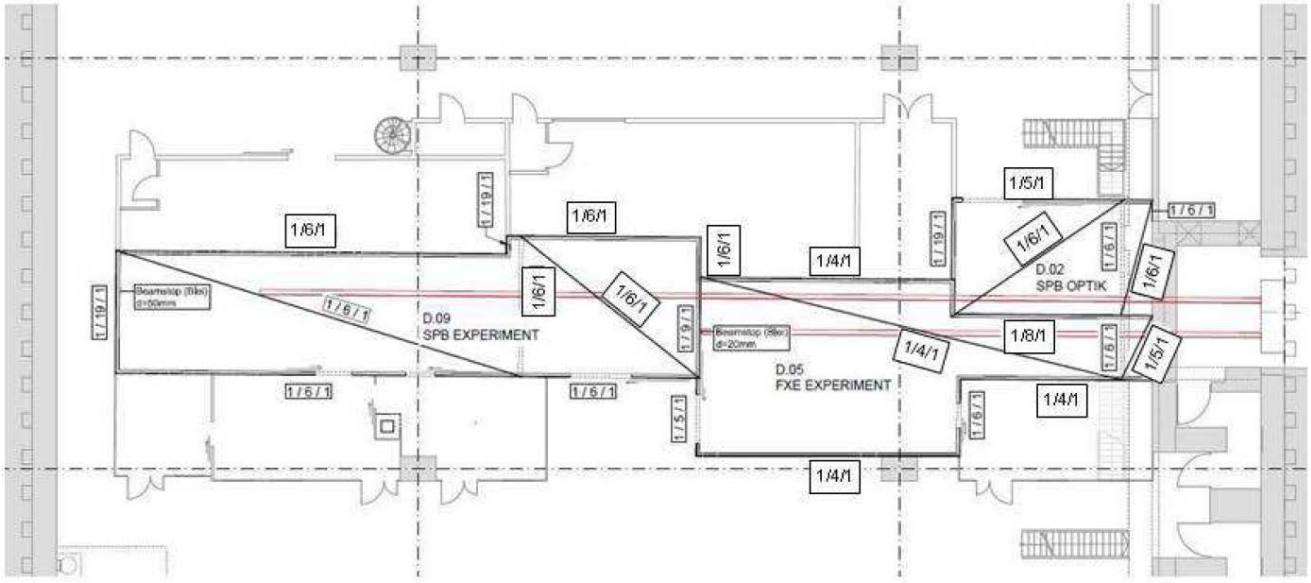


Experimental Hall



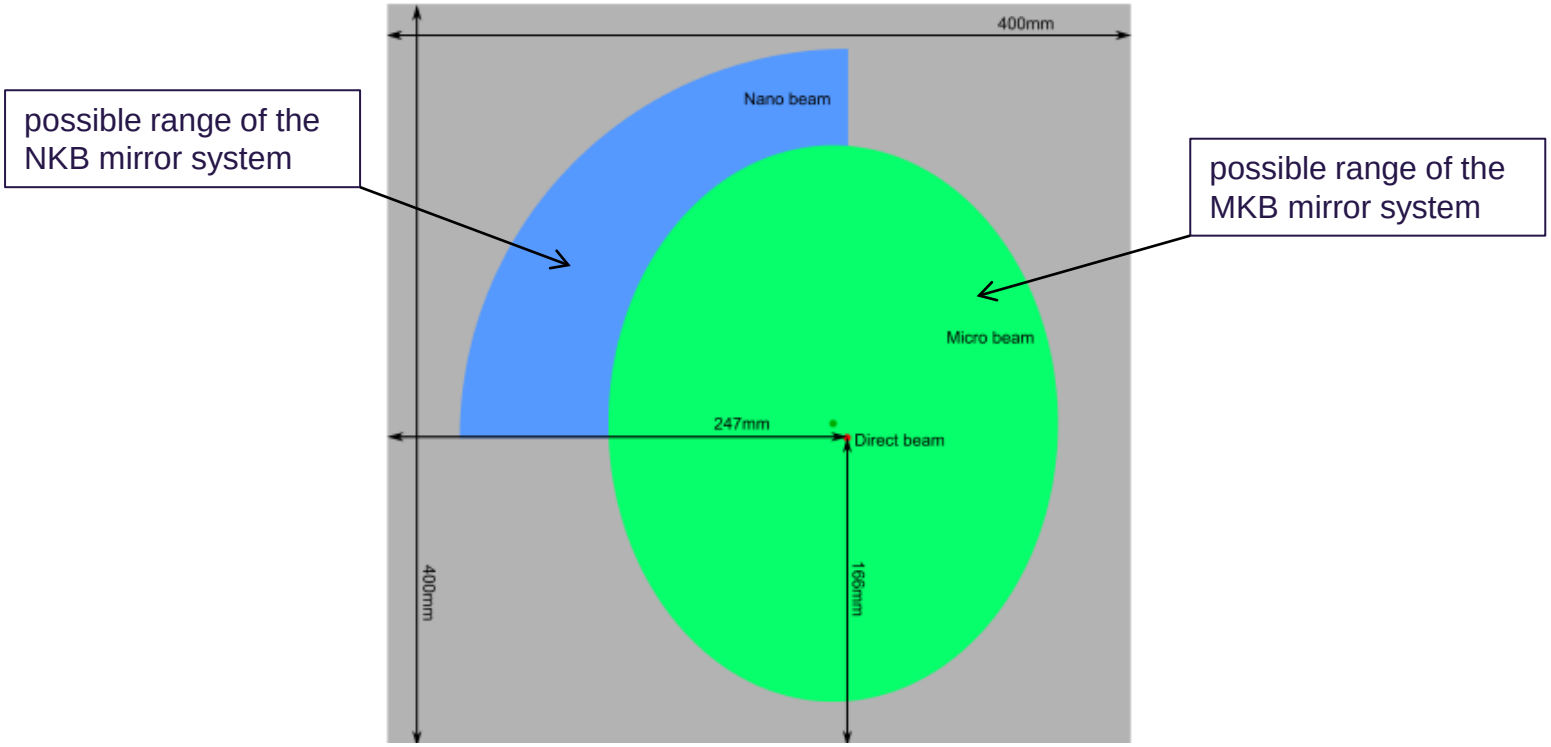
Shielding of Radiation Hutches

- Designed to limit the dose rate at the surface of the shield to significantly below the maximum dose rate of 0.5 µSv/h.
- The initial shielding-design calculations were carried out by the radiation protection expert Dr. Yoshihiro Asano from the Safety Design group at RIKEN Spring-8 Center in Japan.
- Calculated using STAC8.
- SASE 1 and SASE 2 constructed with Steel/Lead/Steel sandwiches.
- SASE 3 constructed out of steel.



Copper beamstop

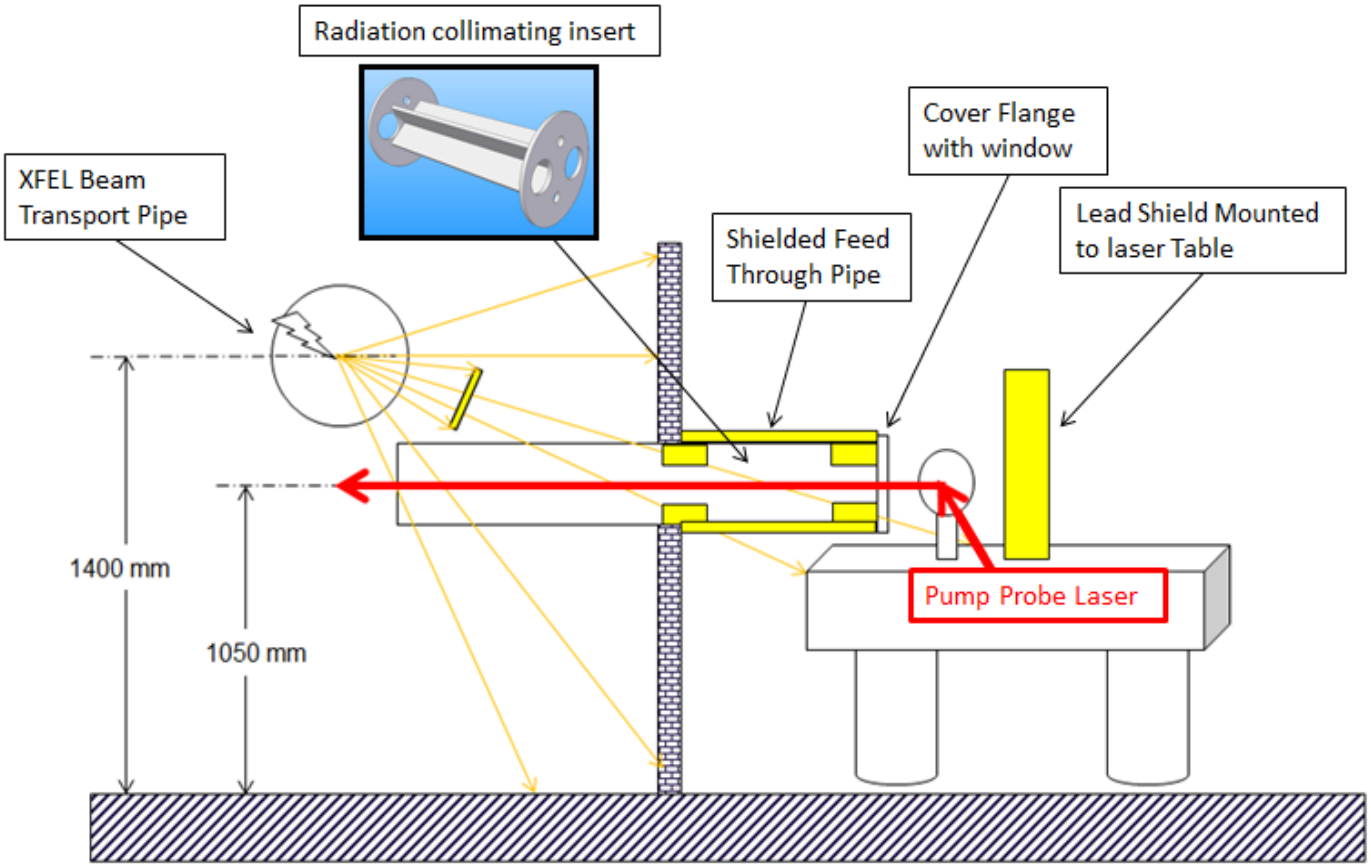
- Purpose: To protect lead hutch in case of failure of technical beam stop and UHV chamber.
- Best practical solution: 5 cm of Cu at the end of hutch.



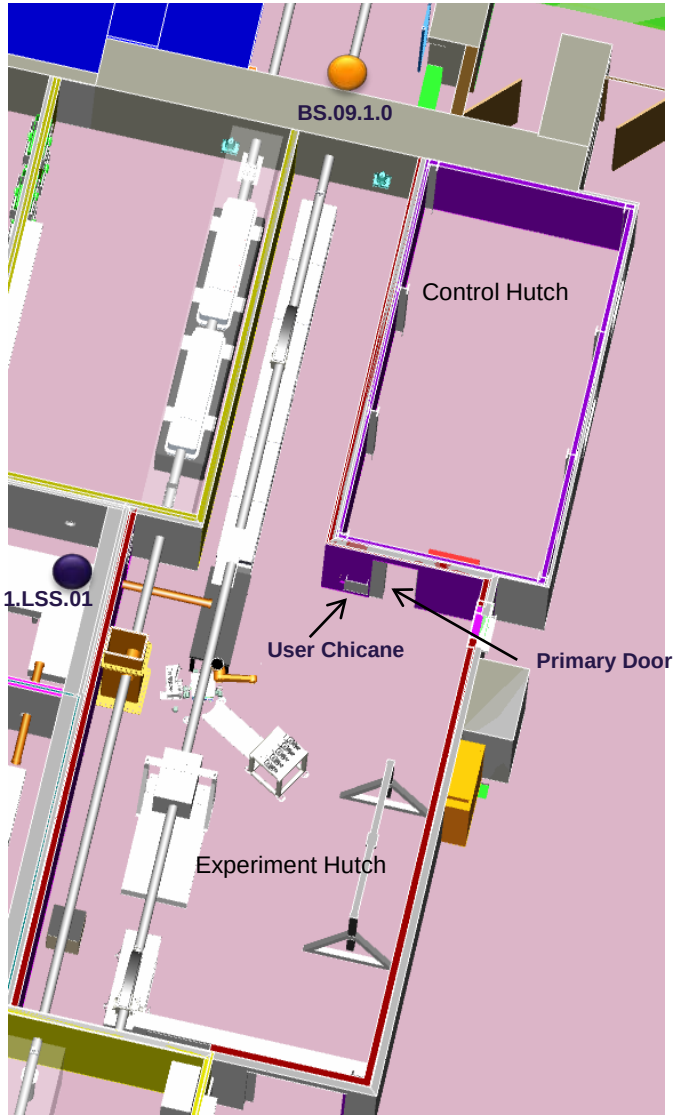
European XFEL

SASE 1 Radiation/Laser Interaction

Laser Transfer Arrangement

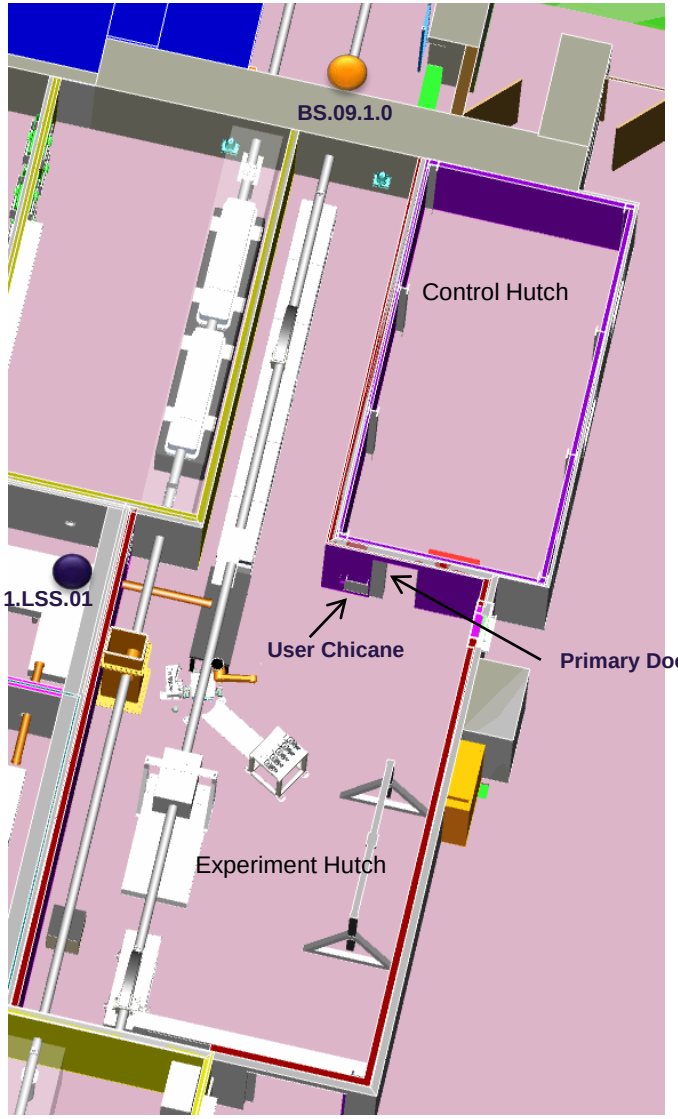


FXE Interlocks

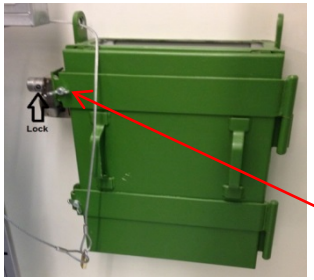


- Laser safety shutter 1.LSS.01 prevents class IV lasers from entering the FXE experiment hutch
  - Normally operated from laser control panel in FXE experiment hutch
  - After a hutch search it can be operated from computer in the control hutch (Therefore laser interlocks must have signal from the hutch search)
- Photon beam shutter BS.09.1.0 prevents FEL operation inside this hutch
  - Can be operated from control panel next to primary door in the control hutch or from computers also in the control hutch.

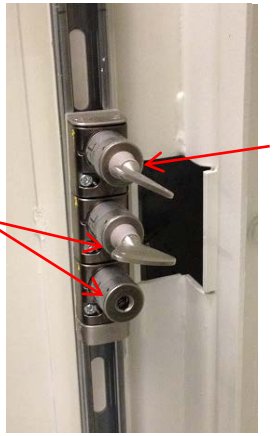
FXE Interlocks



- User Chicanes – required to be interlocked with a key (all user chicanes must be interlocked to operate FEL and Lasers inside the hutch)



Control Box

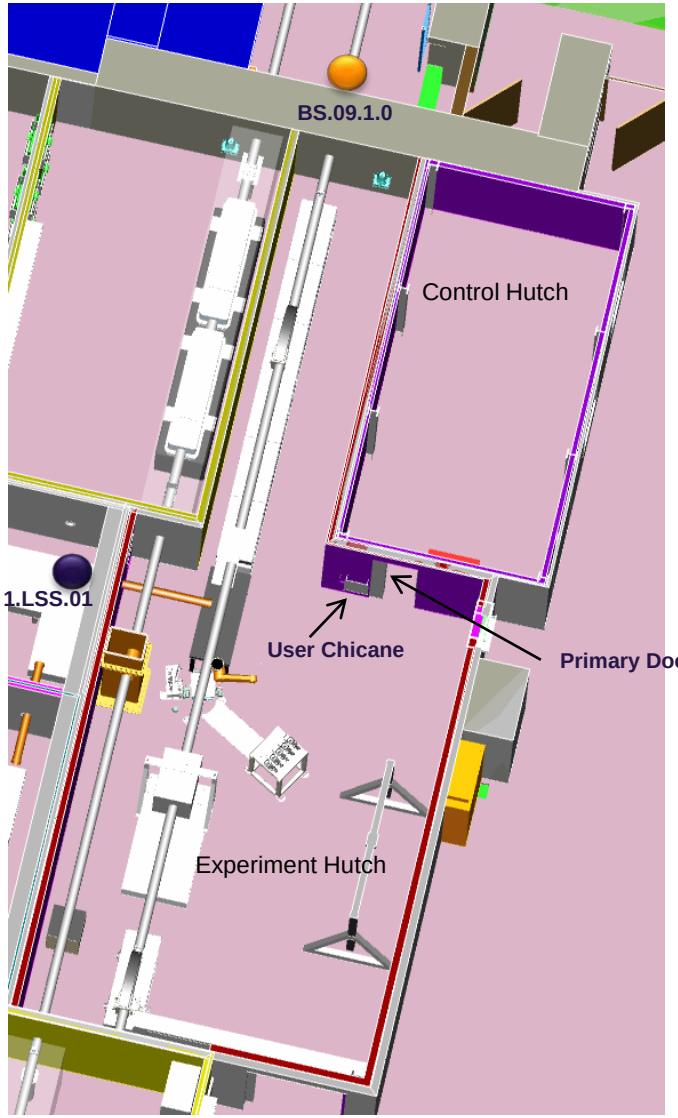


Master Key

Chicane keys

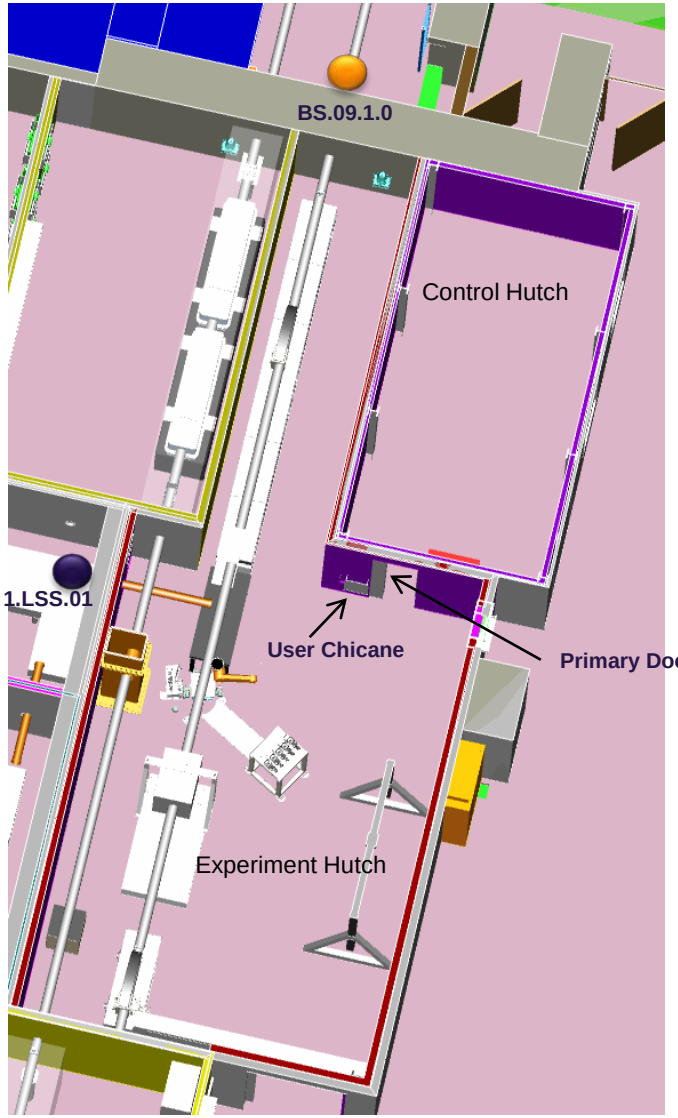
- When both chicane keys are in the holder the master key can be removed and place in the control box

FXE Interlocks



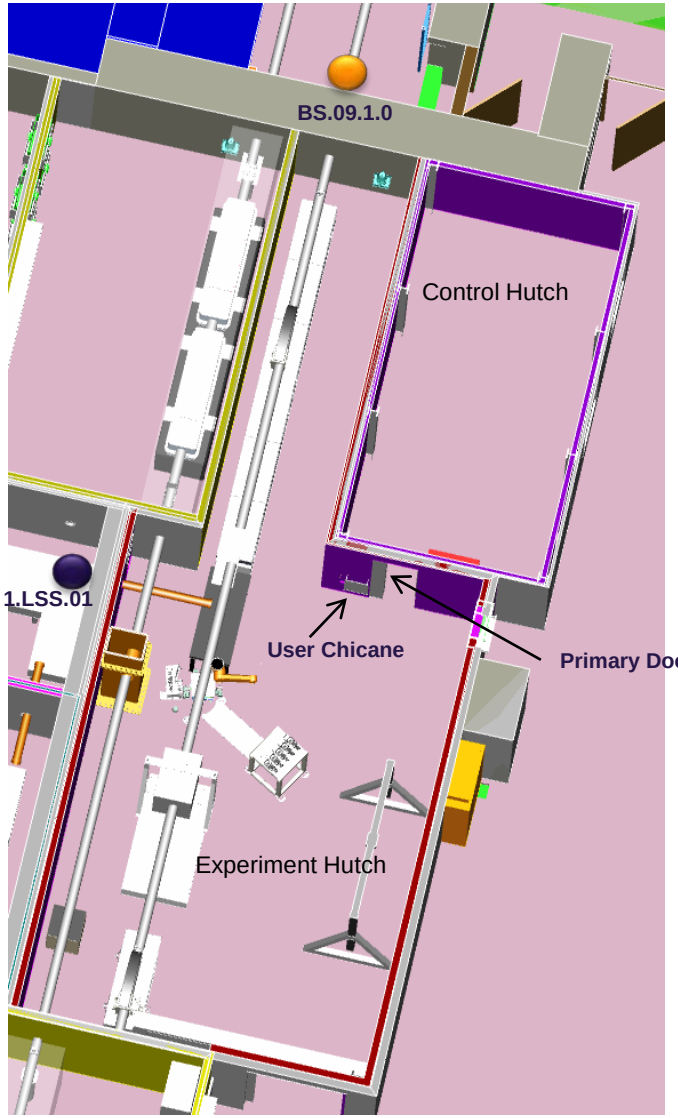
- Emergency Off – Buttons will be located throughout the experiment and laser hutches.
  - Close BS.09.10
  - Close 1.LSS.01
  - Remove FEL Beam Operation Permission Signal
  - Remove all electrical power from the hutch
  - Open motorized sliding doors

FXE Interlocks



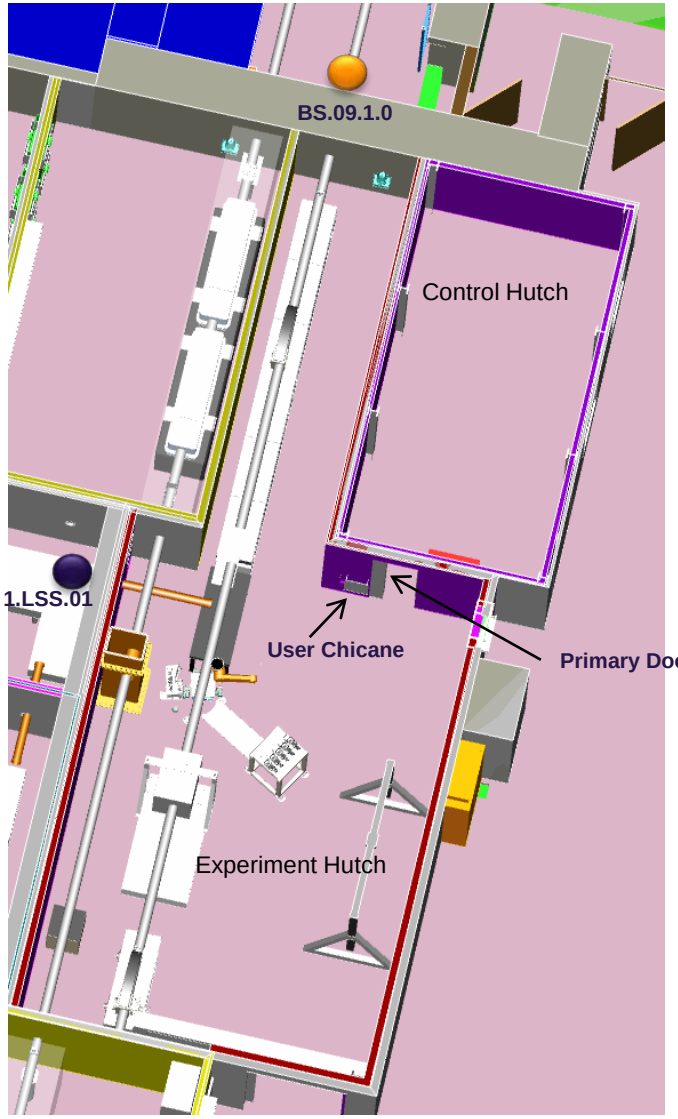
- Emergency Access – Buttons will be located near every exit on the inside and outside of laser and experiment hutches.
  - Close BS.09.10 (signal comes from doors unlocking)
  - Close 1.LSS.01 (signal comes from doors unlocking)
  - Unlock associated doors
  - If door contacts open before the beam shutter is closed the FEL beam operation permission signal will be removed

FXE Interlocks



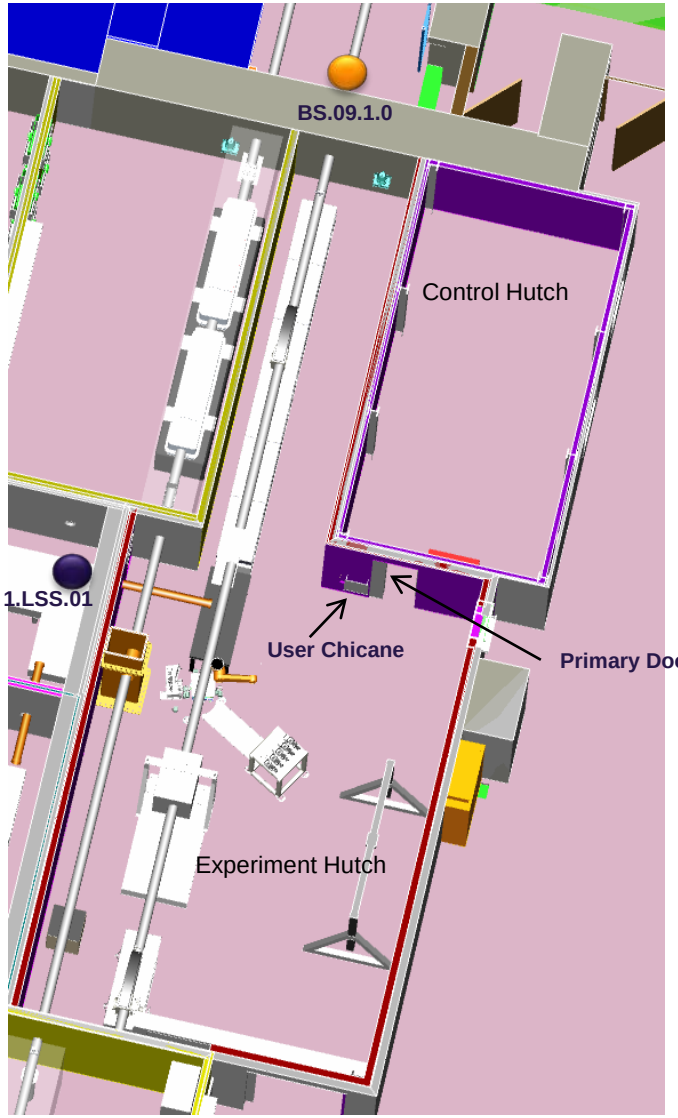
- Door contacts - Each door in the Experimental Hutches will have three magnetic contacts
  - 2 contacts for radiation protection
  - 1 contact for laser safety
    - Signals will act independently from one another.
  - Breaking of a contact
    - During FEL operation results in the shutting of all upstream beam stops and removing the beam permission operation signal
    - During Laser operation results in the shutting of 1.LSS.01, unless the laser curtain is closed

FXE Interlocks



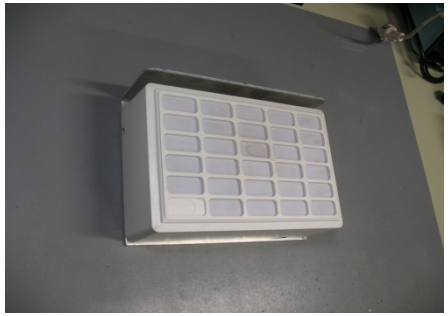
- DESY Access Handling Control System (DACHS)
  Used for hutch searches and to controlled access.
- Online terminals used for hutch searches
- Offline terminals used for access control
  - Only trained Class IV laser operators are allowed access to the hutch when laser operations are present.
  - DACHS card must be scanned prior to entry
  - Unauthorized access results in a protective trip

FXE Interlocks

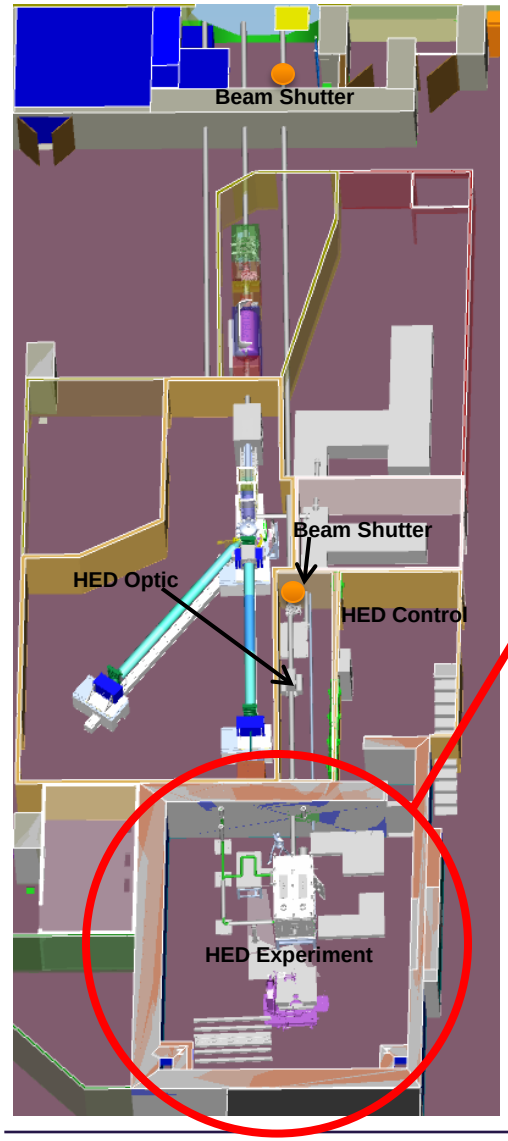


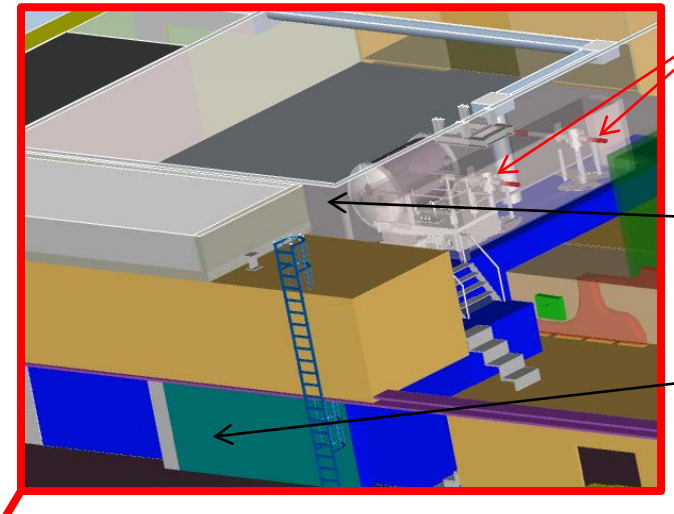
Hutch search

- A one person search is conducted prior to FEL operations to ensure that no people are located inside the hutch when the FEL enters the hutch
- Once the search is complete if any doors are opened the search is voided and a new search must be performed from the beginning in order to allow the FEL in the hutch.
- Once the search is complete the 1.LSS.01 can be opened from the control hutch.



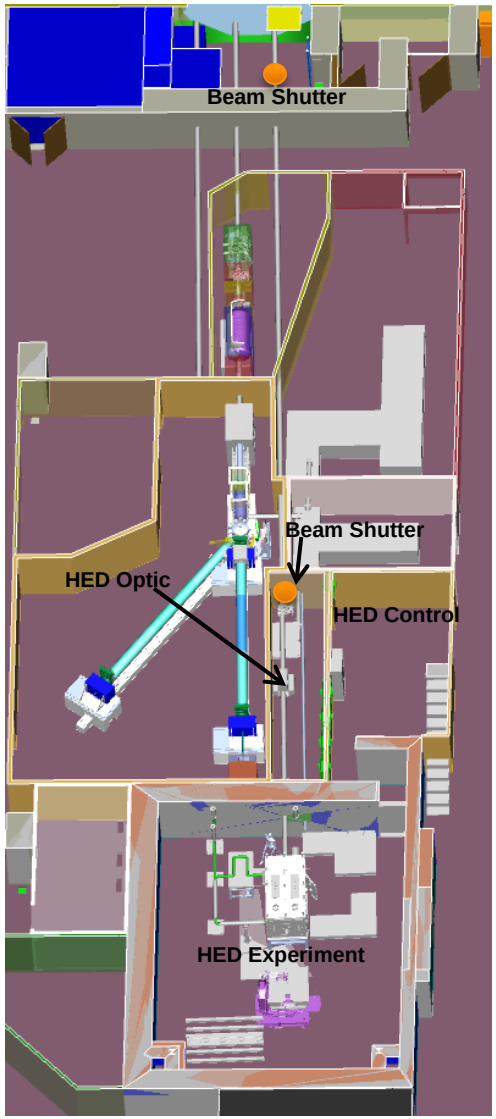
HED Experiment





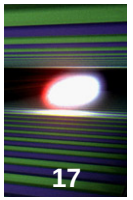
- **Ultrahigh-intensity optical laser (UHI-OL)**
  - a 100 TW–class short-pulse laser
- **High-energy optical laser (HE-OL)**
  - a 100 J–class diode-pumped solid-state laser

HED Experiment



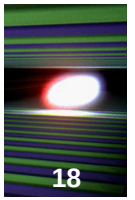
- Special considerations for HED Experiment
  - HED high powered laser can produce ionizing radiation
  - Only HED Experiment Hutch will be a radiation area when these lasers are operating in Experiment mode
  - Prior to operating these lasers the experiment hutch must be searched. This will be the same search that is performed prior to FEL operation
  - Laser shutters must be open prior to lasers operating in experiment mode to prevent radiation in the HED laser room

Summary



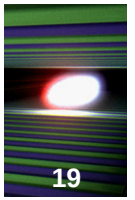
- 8 of 9 radiation interlocked hutches will also contain class IV lasers that will also require laser interlocks
  - User chicanes
  - Hutch search feature
  - Door contacts
  - Emergency off/access
  - Access control
- HED Experiment requires addition radiation protection measures for use of its high powered optical lasers

Acknowledgements



- XFEL Laser Group
  - Max Lederer
  - Guido Palmer
  - Gerd Priebe
- XFEL CIE
  - Wolfgang Tscheu
- SPRING8
  - Yoshihiro Asano
- DESY MPS
  - Brunhilde Racy
  - Michael Dressel
  - Andreas Rathjen
- DESY MEA
  - Klaus Witt

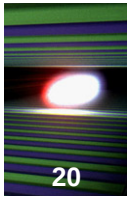
Thank you for your attention.



The End

Questions?

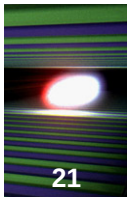
PP Laser



- Optical Probing
- Sample excitation
- Timing reference with respect to the X-Ray beam

Laser type	Basic properties on sample	Pulse duration	Beam diameter before focus	Spot size on sample
PP–OL I	λ ~ 0.8 µm / ~ 3 mJ / 0.2–4.5 MHz intraburst	15–100 fs	3–5 cm	3–300 µm Airy pattern
PP–OL II	λ ~ 1 µm / ~ 100 mJ / 200 kHz intraburst	0.8 ps / 500 ps	3–5 cm	3–300 µm Airy pattern

Shielding Calculation Assumptions

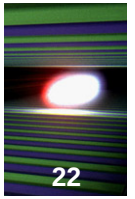


Beamline shielding calculations for Euro-XFEL

1. Calculation conditions and assumptions
   (1) Bremsstrahlung due to beam loss of accelerated electrons and gas bremsstrahlung never propagate into experimental hutch.
   (A.L : distance (off-set) between primary beam axis and secondary light beam axis is set to 2.5 cm for SASE1 &2 and 3.5 for SASE3, and it is enough length from the electron beam to experimental hutches to remove high energy radiation due to bremsstrahlung)
   (2) Only spontaneous emission photons (SR) and free electron laser photons can be introduced into experimental hutch
   (3) The boundary of radiation controlled area is set to the walls of experimental hutches so that the doses outside of the experimental hutch must be less than 0.5 μSv/h
   (4) The doses at the surface of the beam transport pipes which will be installed into experimental hutches are also less than (0.5μSv/h)
   (5) Mirror reflection is considered without roughness for radiation safety.
   (6) Total power of the 3rd and 5th XFELs are 1% and 0.03% power of fundamentals, respectively.
   (7) Parameters for the calculations are as follows,

European XFEL

Beam Parameters



Beamlines at SASE 1		
Electron energy	20 GeV	
Pulse repetition rate	27000 pulses/s	
Charge/pulse	1 nC	
Undulator length	175 m	
Number segments	35	
Period length	40 mm	
Total number of period	4375	
Max. magnetic field	1.1 Tesla	
Deflection parameter K	4.11	
1st harmonics	10 KeV	24 keV
1st XFEL power	1.9mJ/pulse ($1.2x10^{12}$/pulse)	1.0mJ/pulse ($2.60x10^{11}$/pulse)
3rd XFEL	19μJ/pulse ($4x10^{9}$/pulse)	10μJ/pulse ($8.68x10^{8}$/pulse)
5th XFEL	0.57μJ/pulse ($7.2x10^{7}$/pulse)	0.3μJ/pulse ($1.56x10^{7}$/pulse
Offset Mirror	double (SPB) triple (FXE)	
Glancing angle	1.1-3.6 mradian	
Coating material	Pt	

Beamlines at SASE 3		
Electron energy	20 GeV	
Pulse repetition rate	27000 pulses/s	
Charge/pulse	1 nC	
Undulator length	175 m	
Number segments	21	
Period length	68 mm	
Total number of period	1533	
Max. magnetic field	1.75 Tesla	
Deflection parameter K	11.1	
1st harmonics	0.89 KeV	4 keV
1st XFEL power	10mJ/pulse ($7.02x10^{13}$/pulse)	5.0mJ/pulse ($6.25x10^{12}$/pulse)
3rd XFEL	100μJ/pulse ($2.34x10^{11}$/pulse)	50μJ/pulse $2.60x10^{10}$/pulse)
5th XFEL	3μJ/pulse ($4.21x10^{9}$/pulse)	1.5μJ/pulse ($4.69x10^{8}$/pulse)
Offset Mirror	double	
Glancing angle	6.01-20 mradian	
Coating material	Ni	