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David Just :: Front-End Engineer :: Paul Scherrer Institute

Updated High Heat Load Front-Ends for SLS 2.0

MEDSI 2020, virtual conference presented 28.07.2021; contact: david.just@psi.ch

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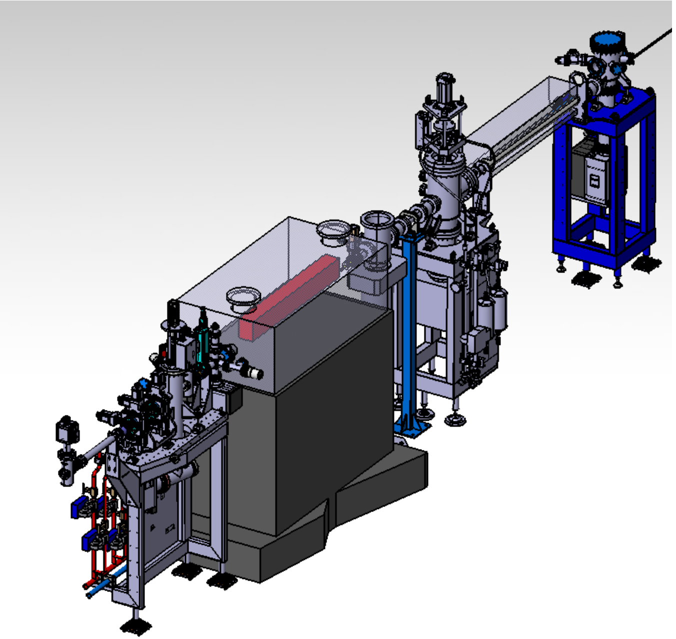
Purpose of a Front-End



- Delivers photon beam from storage ring to beam lines
- Securely blocks radiation to work in down stream area
- First beam conditioning
  - Beam size, diaphragm (aperture) and slits
  - Filters
- Provides feedback on photon beam position
- Sometimes it holds optical elements

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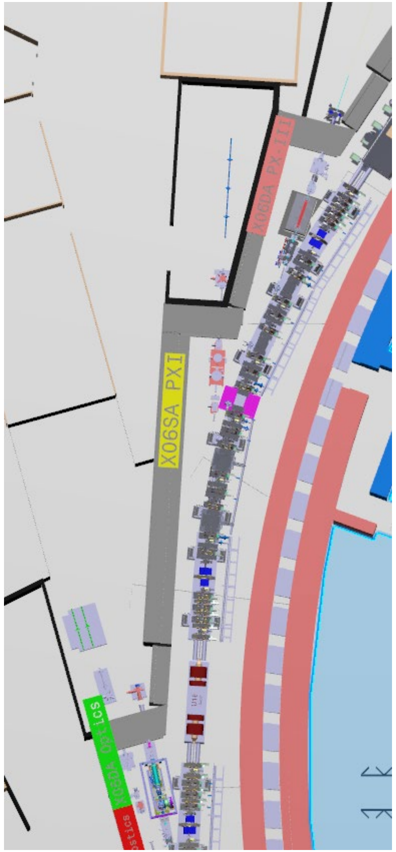
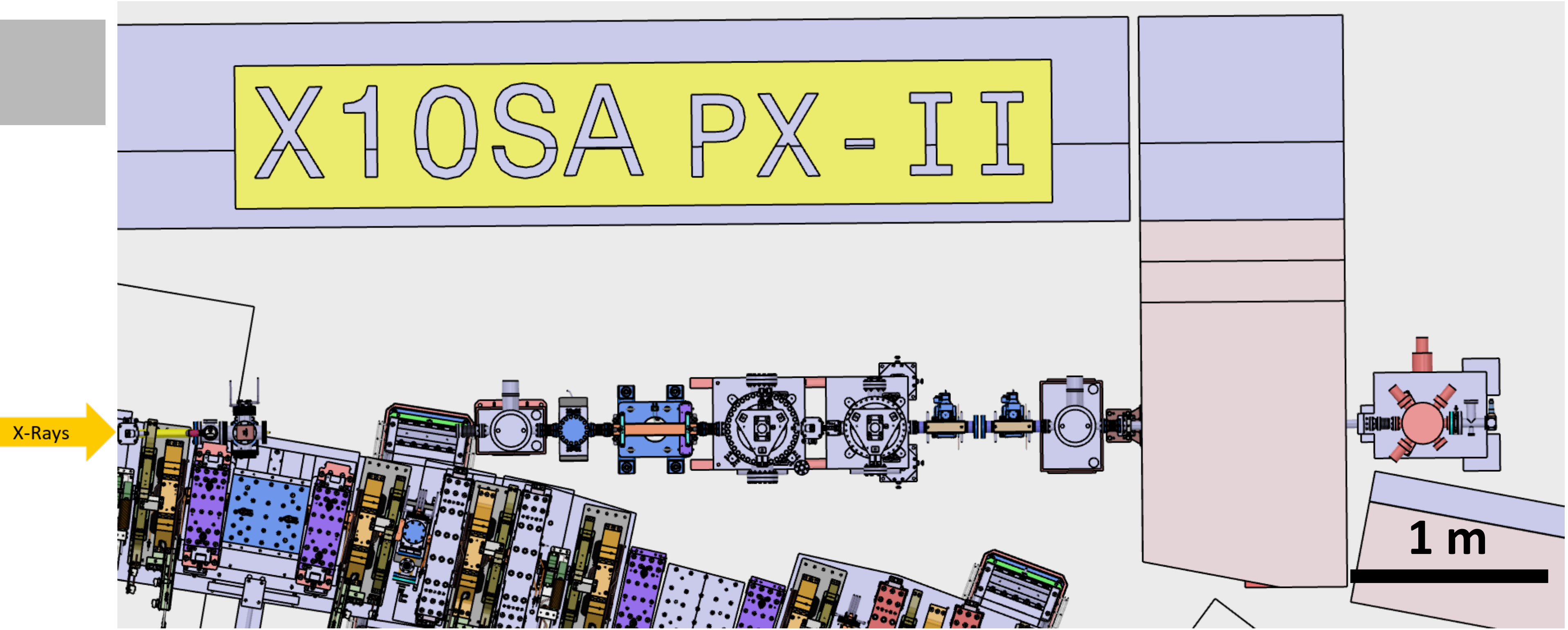
Front-Ends at SLS 2.0

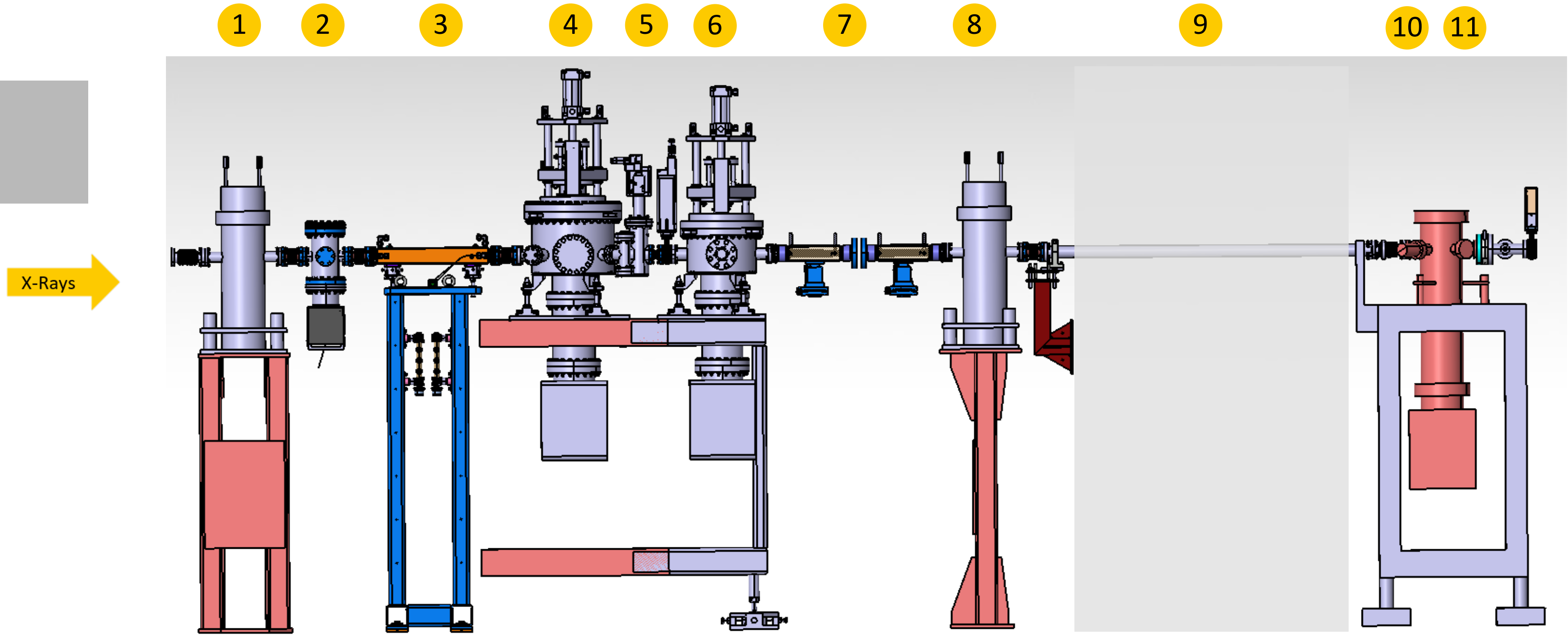


- All FEs required to be removed form tunnel during dark-time
- All source points and beam lines will move
- New spacial requirements due to new lattice
- We want to keep using the existing FE components where possible
  - Costs and reliability
  - modifications for safety
  - replacement of components subjected to wear
  - new apertures and slits to deal with increased power load and beam sizes
- Power load tripled
  - Most powerful undulator SLS1 = 3.3 kW, SLS 2.0 = 9.9 kW
  - Reason: 2.4 GeV -> 2.7 GeV and more powerful sources

Hard X-Ray Front-End



Hard X-Ray Component Layout



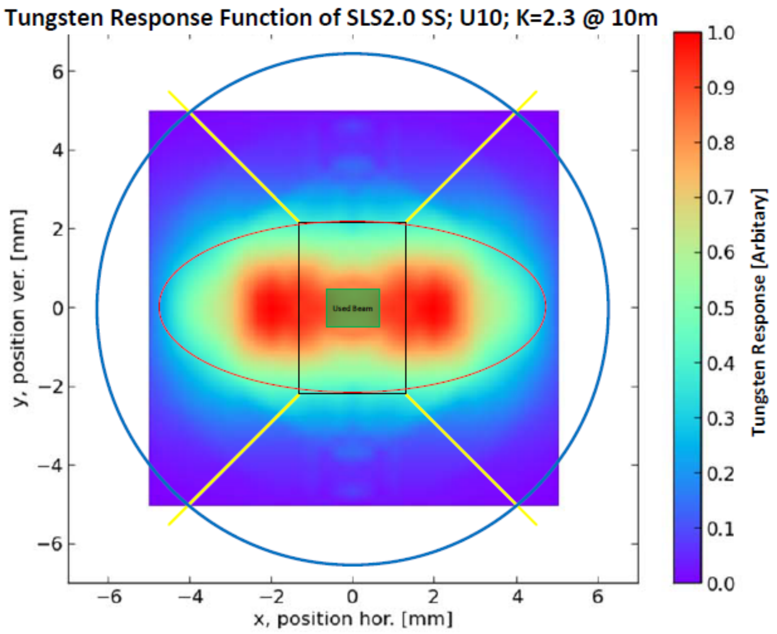
1. 1st XBPM
2. Pump stand
3. Diaphragm / aperture
4. Photon shutter
5. Fast- & gate valve
6. Beam stopper
7. Slits
8. 2nd XBPM
9. Tunnel wall
10. Pump stand
11. CVD window

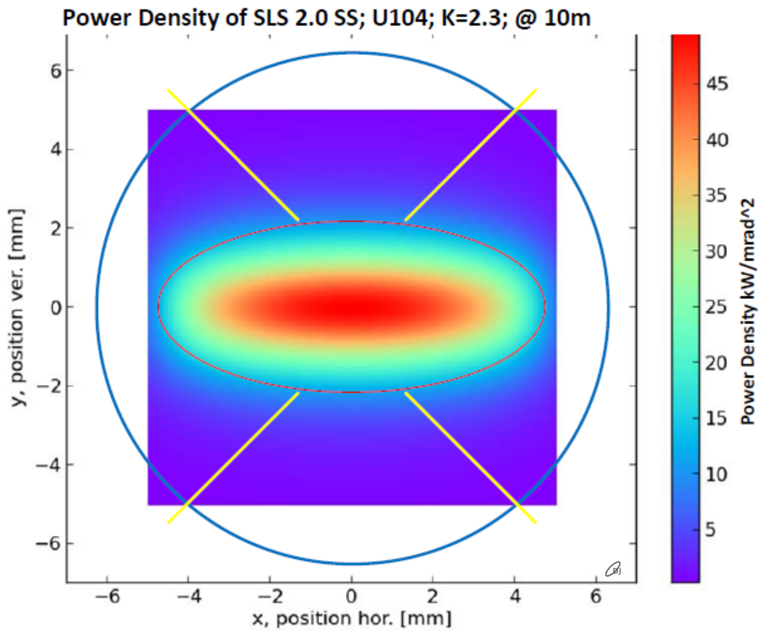
Hard X-Ray Front-End

- Six HXR beamlines, four IDs
  - CPMU14, 4.7 kW
  - SCU 10, 8.5 kW
  - U18, 8.8 kW
  - CPMU16, 9.9 kW
- Baseline Concept for 11 kW CPMU16 -> All HXR FEs use the same concept
- Acceptances: 94x80 μrad^2
- Status:
  - High heat load components are being engineered
  - 1^{st} Concept for: PX-II and cSAXS

Example: Placing W-Blades

New XBPM Layout for High Power Beamlines using U10





Legend

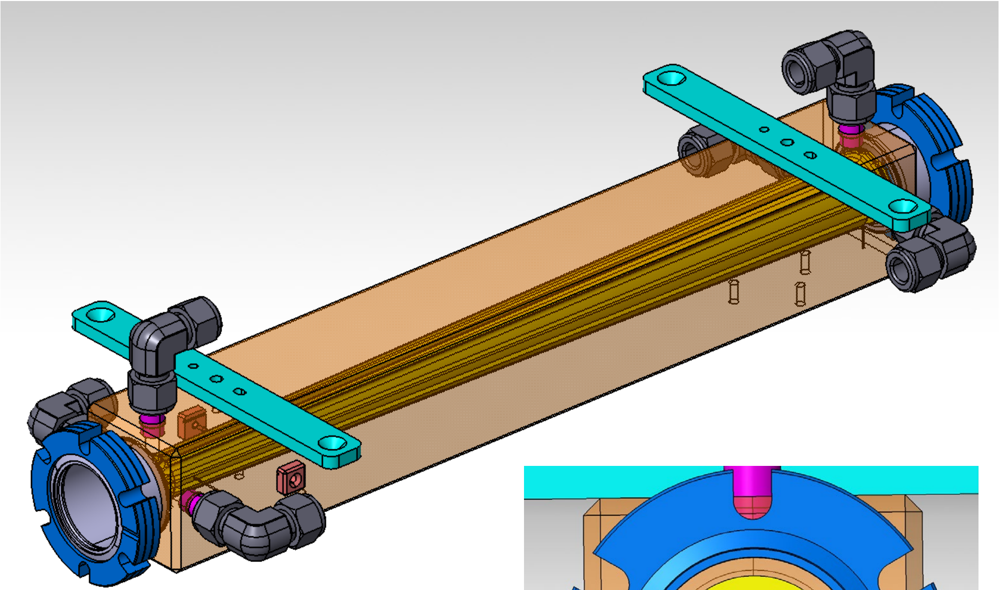
- Used Beam
- Opening of Blades (0.26x0.42 mrad^2)
- Blades
- Heat Shield
- High Power Region

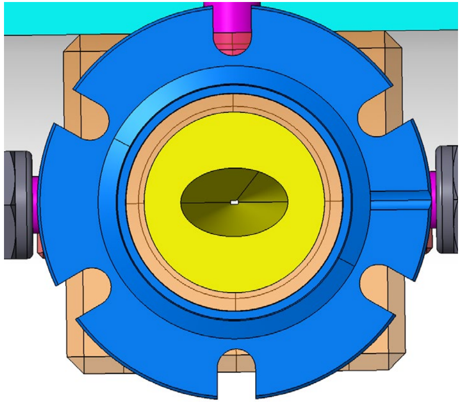
Blade Thickness: 0.258 mm
Incident Angle of Blade: 26 °

$$Y = \int_{30\ eV}^{30\ keV} F'(E) \cdot BW \cdot \sigma_{ph}(E)\, dE$$

with: Y being the tungsten response, $F'(E)$ the flux density per Energy [ph/s/mrad^2/0.1BW], BW the band width and $\sigma_{ph}(\mathrm{E})$ the photoelectric cross section.

New High Power Diaphragm: Model





- Defines beam-size and protects photon shutter
- Fixed positioned
- 3 in and outlet channels (Ø 10 mm)
- 12 cooling channels (12 mm^2 cross section each)
- Water flux 18 l/min
- 2 thermo couples
- Outside dimensions (HxWxL): 60x60x468 mm^3
- Tapering 0.8°
- made from OFHC

Des. Eng.: R. Oeschger

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New HP Diaphragm: Thermal Specs

- Distance form source: **10.6 m**
- Max power load (absorbed): 14 kW
  - U16*: 10 kW
- Max power density at distance: 693 W/mm^2 (effective taperd: 11.6 W/mm^2)
  - U16* on axis: 539 W/mm^2
- Inlet opening: 1.2x0.7mrad^2
- Outlet opening: 0.094x 0.085 mrad^2

*U16, 3.4 m, K=2.1, n= 189

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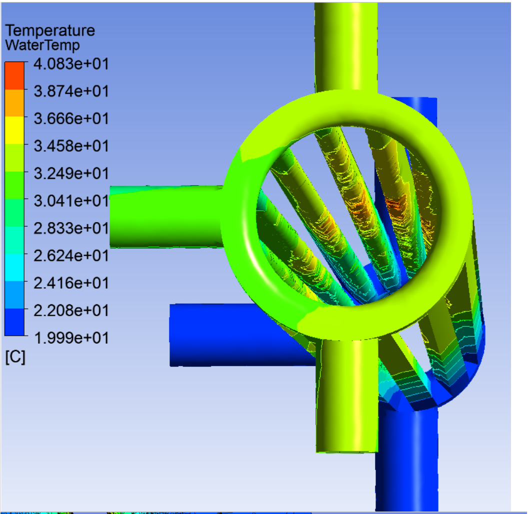
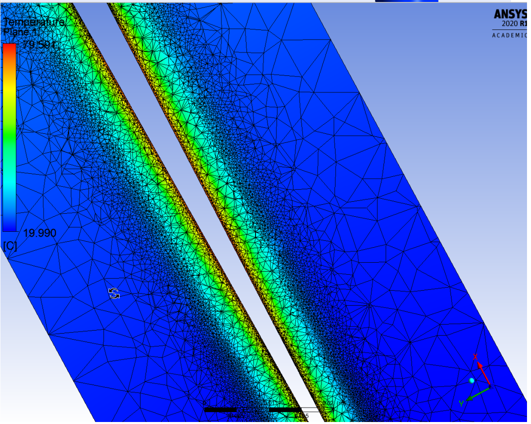
New HP Diaphragm FEA:

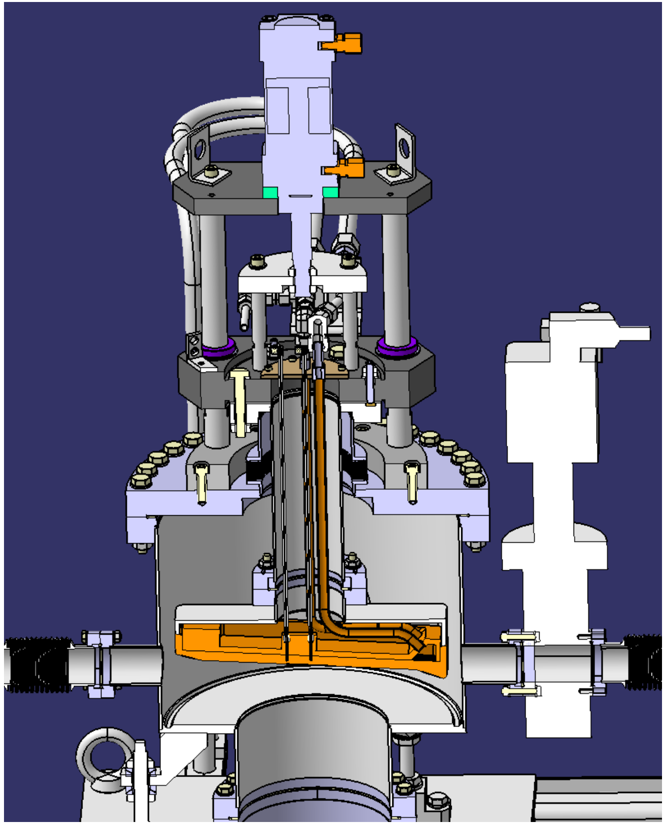




	SF = 1.1 P_{tot} = 12 kW	SF = 1.4 P_{tot} = 15 kW	Reference Value Cu OFHC	Reference Value Glidcop
Tot. power abs. [kW]	11.2	13.9		
Max. power density [W/mm^2]	9.3	11.6	20 [1] > 45 [2]	70 [1] >150 [2]
Max. body temperature [°C]	65	80	**400** [6] 541 [3]	**300** [5]
Max. water temperature [°C]	29	41	**150** [4]	**150** [4]
Displacement [µm]	20	19		
Max. stress [MPa]	150	190	250..300 [6] 75 [1]	**400** [5] **450** [5]
Max. strain [%]	0.07	0.09	0.1 .. 0.5 [6] **0.2**	0.2 % [7]

(1) *F. Thomas et al. (ESRF): X-Ray Absorber Design and Calculations for the EBS Storage Ring, MEDSI 2016*
(2) *L. Zhang et al. (ESRF): ESRF Thermal Absorbers: Temperature, Stress and Material Criteria, MEDSI 2002, For Absorber (low temperature cycling)*
(3) *APS design criteria from: F. Thomas et al.: X-Ray Absorber Design and Calculations for the ESB Storage ring, Proc. of MEDSI 2016)*
(4) *Boiling temperature of water at 5 bar; SLS cooling water pressure = 10 bar, SLS 2.0 in discussion*
(5) *APS design criteria, private communication Yifei Jaski, 450 MPa for corner stresses.*
(6) *Diamond design criteria, private communication Xia Liu, using elasto-plastic strain.*
(7) *Alba design criteria from: F. Thomas et al.: X-Ray Absorber Design and Calculations for the ESB Storage ring, Proc. of MEDSI 2016)*

Updated Hard X-Ray Photon Shutter



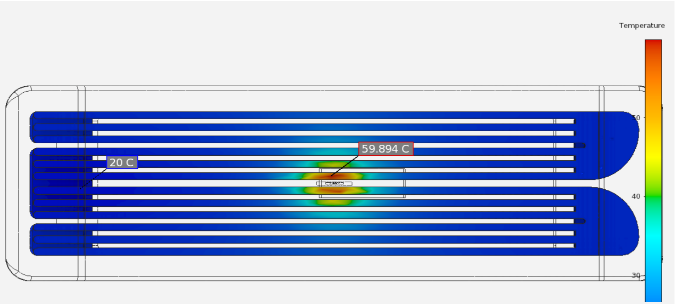
- Existing photon shutter can be reused
- Additional adaptions to be made (new end switches, fall through protection)
- Safety certification required (PL-R = d [potentially also e])
- New support required

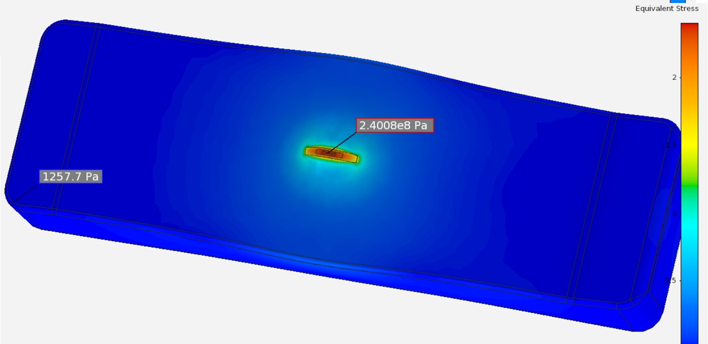
Thermal

- Distance form source: 10.9 m
- Max power load (absorbed): 770 W
  - U16*: 530 W
- Max power density at distance: 723 W/mm^2 (effective at 3°: 40 W/mm^2)
  - U16* on axis: 539 W/mm^2

*U16, 3.4 m, K=2.1, n= 189

Updated Hard X-Ray Photon Shutter FEA





	SF = 1.1 P_{tot} = 11 kW	SF = 1.4 P_{tot} = 15 kW	Reference Value Cu OFHC	Reference Value Glidcop
Tot. power abs. [W]	541	771		
Max. power density [W/mm^2]	27	40	20 (1) > 45 (2)	70 (1) >150 (2)
Max. body temperature [°C]	138	191	**400 (6)** 541 (3)	**300 (5)**
Max. water temperature [°C]	48	60	**150 (4)**	**150 (4)**
Displacement [µm]	13	18		
Max. stress [MPa]	166	240	250..300 (6) 75 (1)	**400 (5)** **450 (5)**
Max. strain [%]	0.13	0.2	0.1 .. 0.5 (6) **0.2**	0.2 % (7)

(1) *F. Thomas et al. (ESRF): X-Ray Absorber Design and Calculations for the EBS Storage Ring, MEDSI 2016*
(2) *L. Zhang et al. (ESRF): ESRF Thermal Absorbers: Temperature, Stress and Material Criteria, MEDSI 2002, For Absorber (low temperature cycling)*
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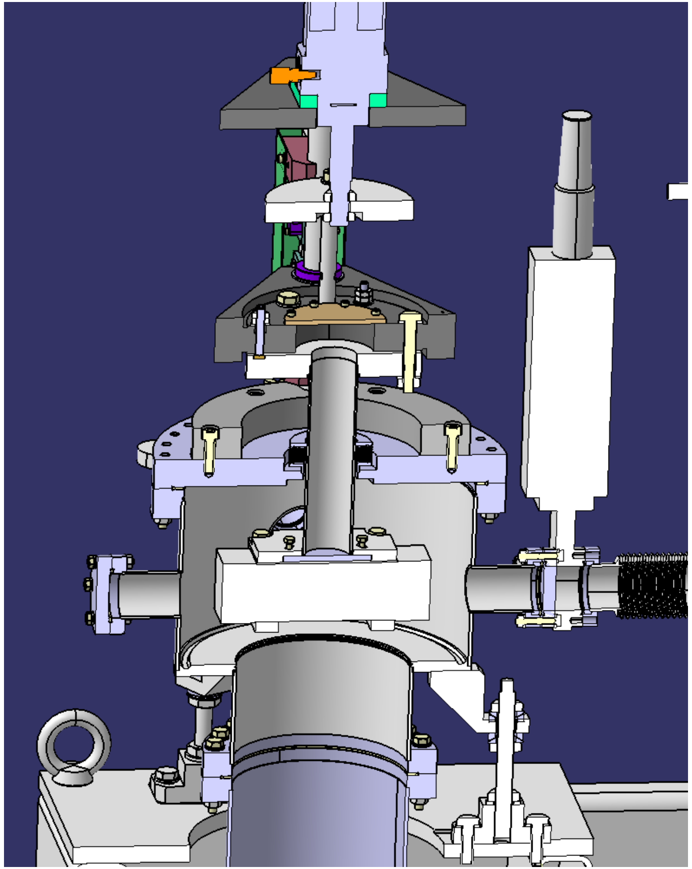
(6) *Diamond design criteria, private communication,*
(7) *Alba design criteria from: F. Thomas et al.: X-Ray Absorber Design and Calculations for the ESB Storage ring, Proc. of MEDSI 2016)*

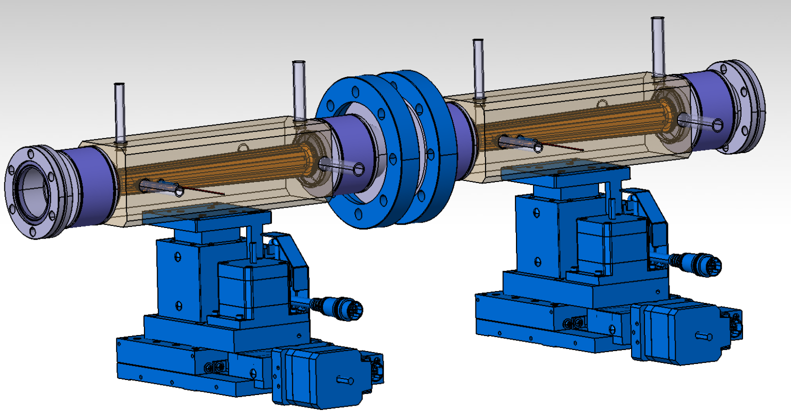
Updated Beam Stopper



Beam Stopper, 30040.26.005

- In principal existing beam stopper can be reused
- Additional safety features
  - New fall through protection
  - New certified end-switches
- Bremsstrahlung coverage needs to be re-evaluated
  - Existing (180 mm) tungsten length @ 2.7 GeV

New Insertion Device Slits

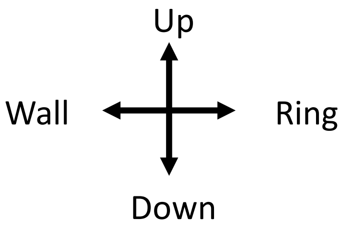


New ID Slits, 30050.20.526
Des. Eng.: S. Guntli

- To be used for HXR and SXR
- Capable to fully shut the beam
- Overall length 652 mm
- Made from OFHC
- Max power: 780 W
  - U16*: 533 W
- Max power density at distance: 730 W/mm^2 (effective tapered: 8.9 W/mm^2)
  - U16* on axis: 439 W/mm^2
- Middle flanges supported to prevent parasitical motion
- Absolut encoders
- Positioning accuracy: ~1 µm

*U16, 3.4 m, K=2.1, n= 189


Beam


Up
Wall
Ring
Down

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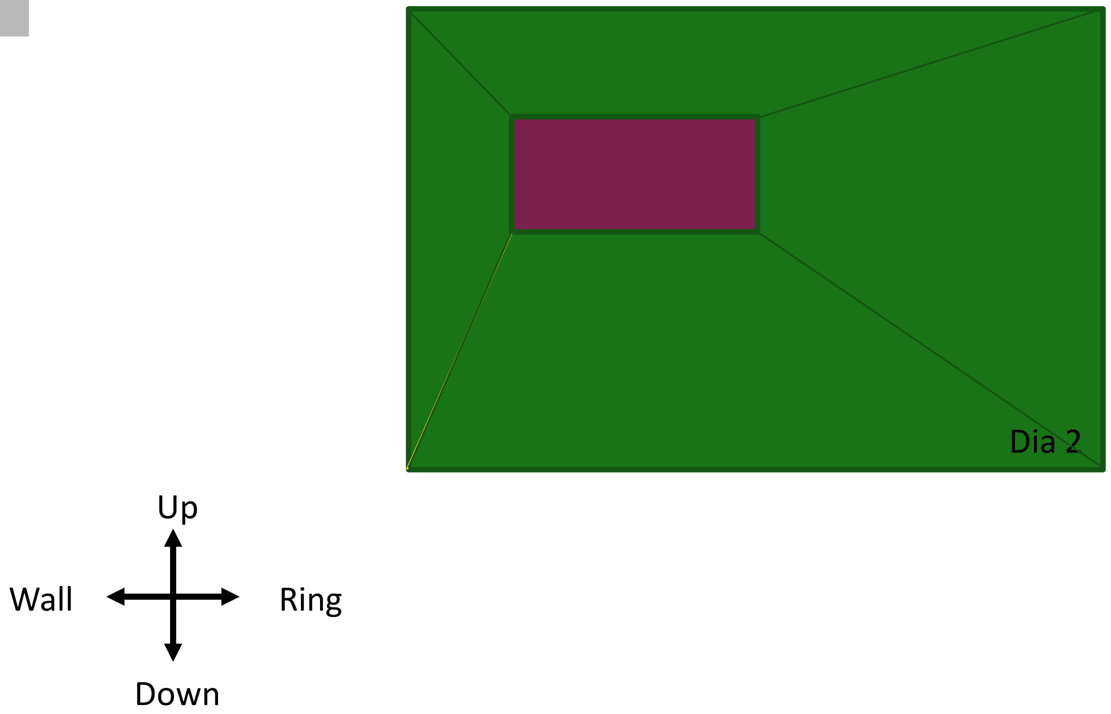

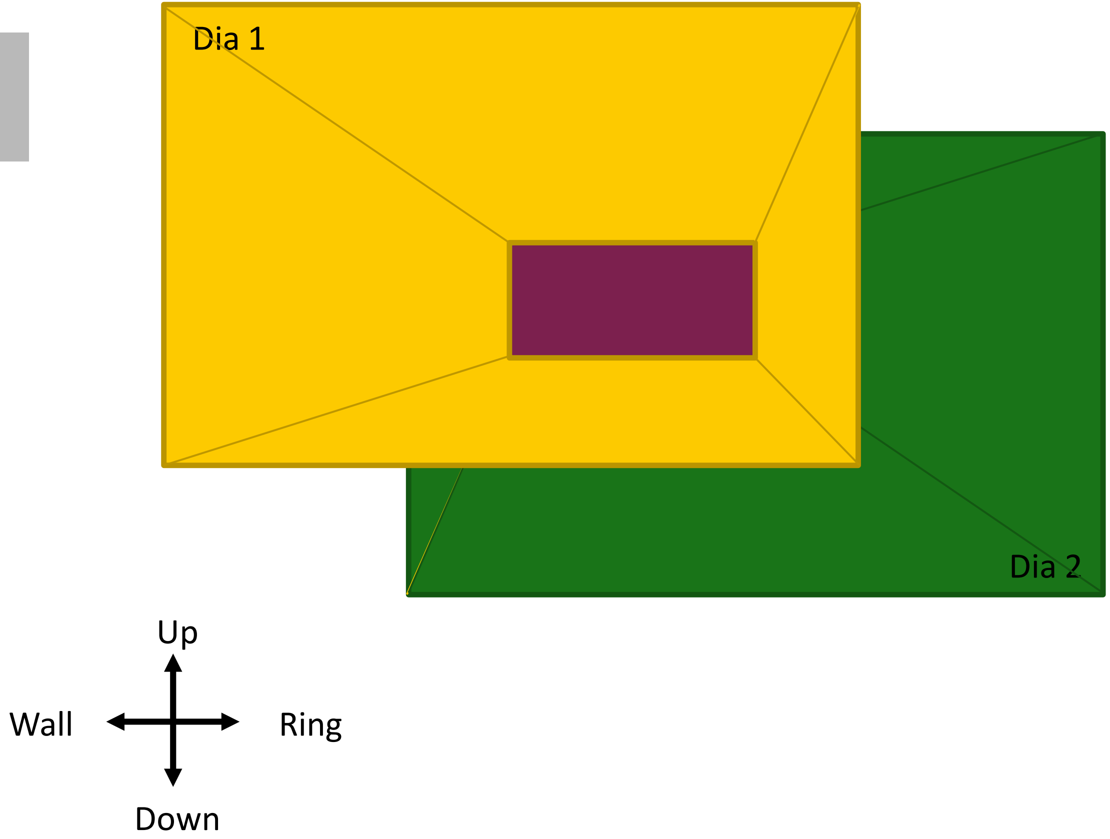
Dia 1
Dia 2
Up
Wall
Ring
Down

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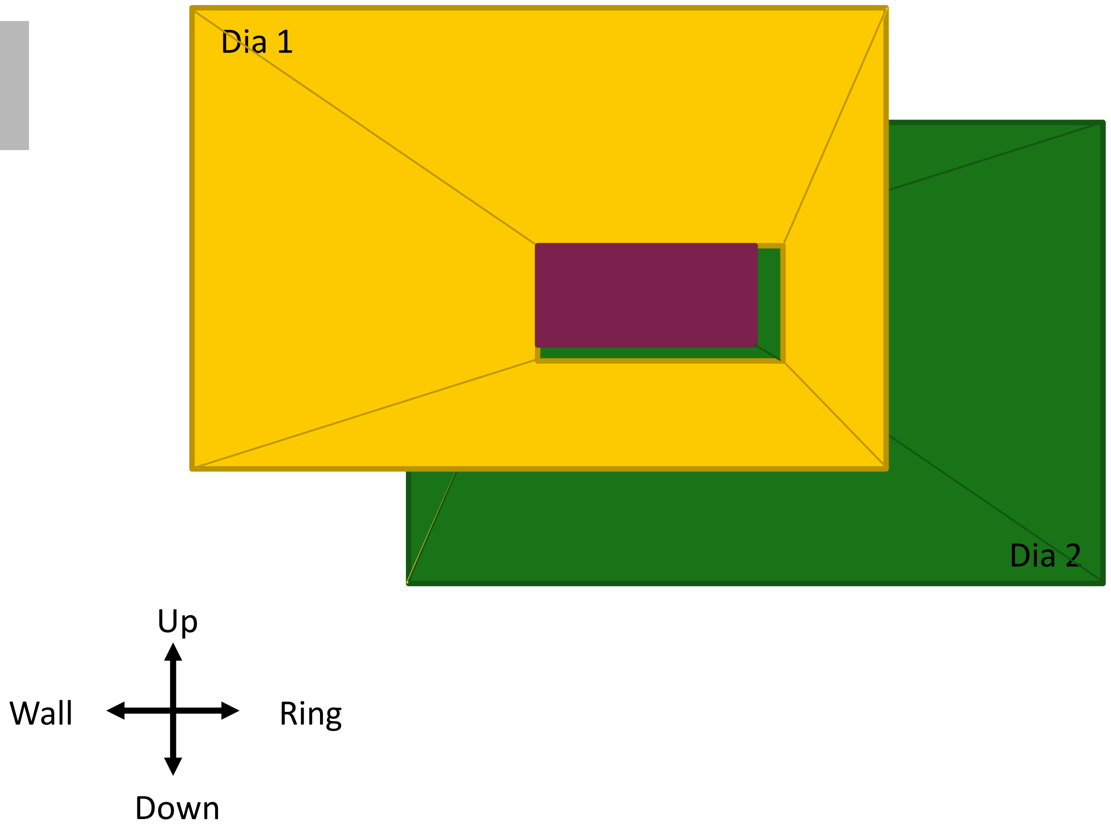
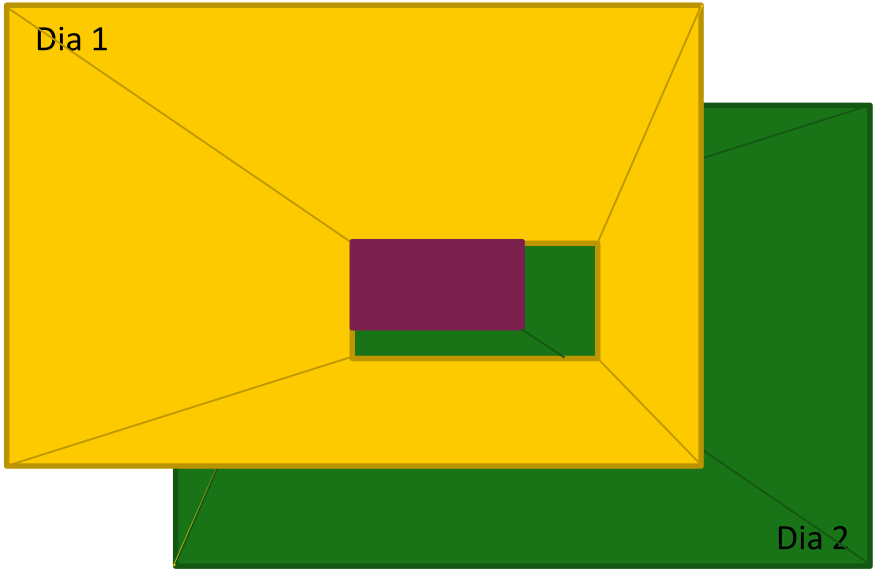
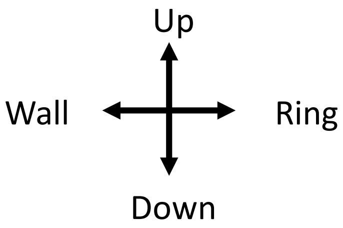



Dia 1
Dia 2


Up
Wall
Ring
Down

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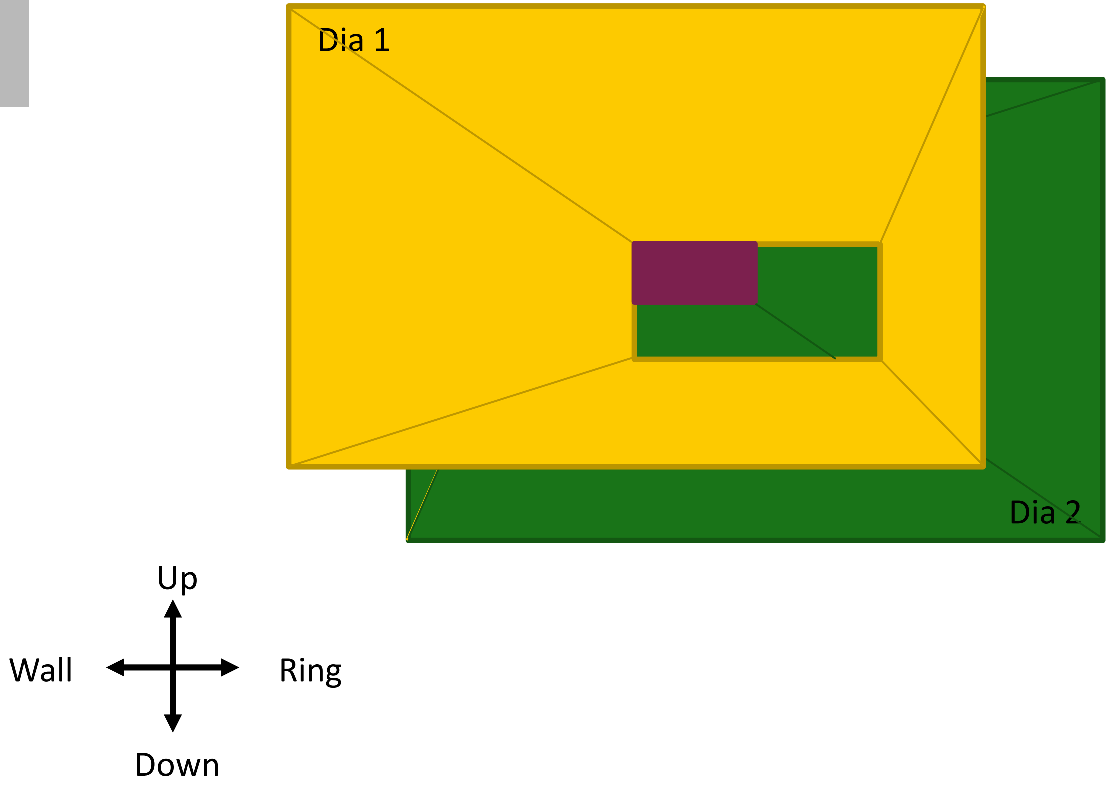

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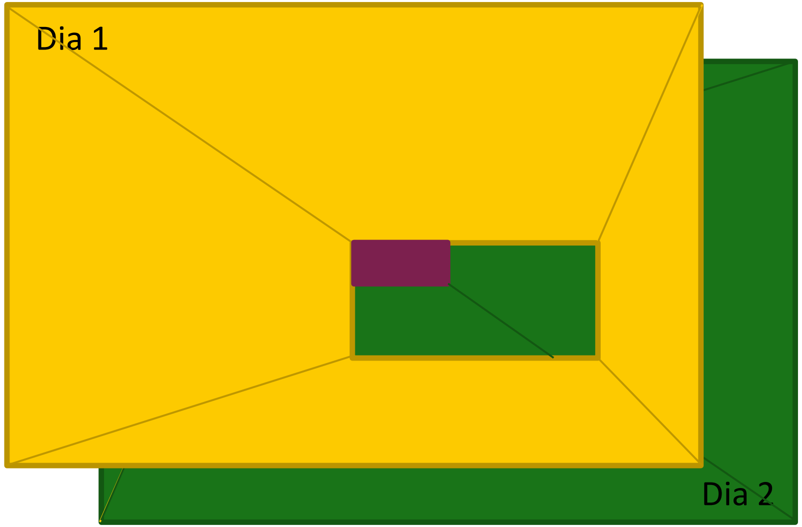
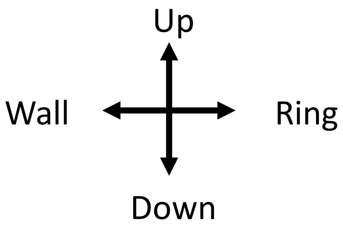
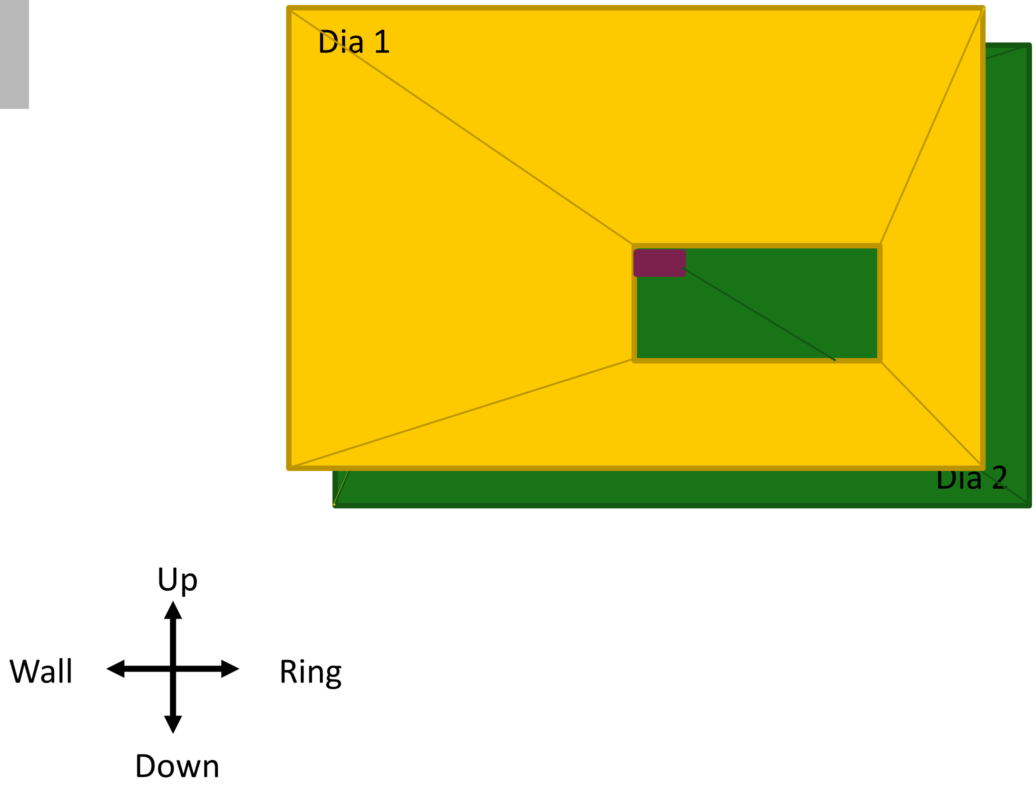
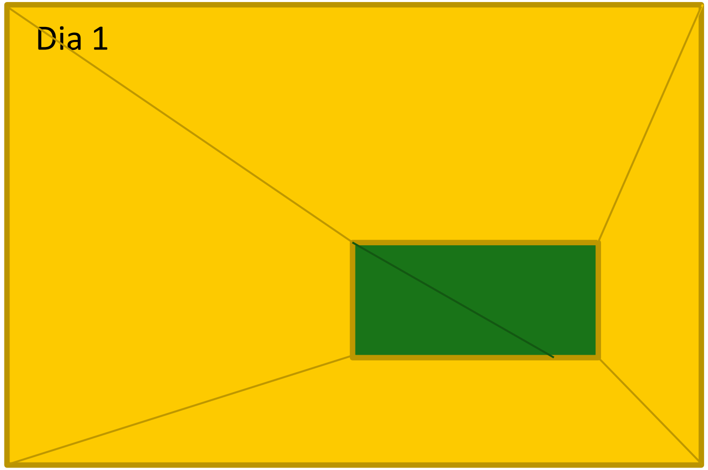
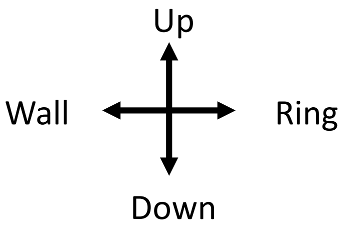


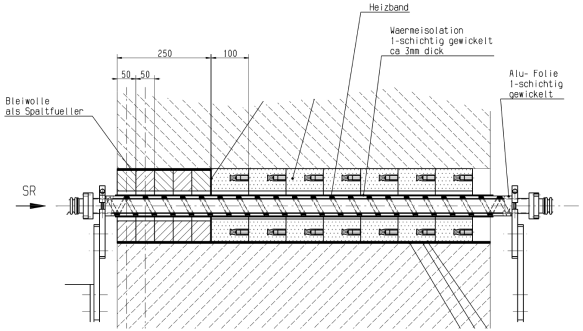



Dia 1
Dia 2
Up
Wall
Ring
Down

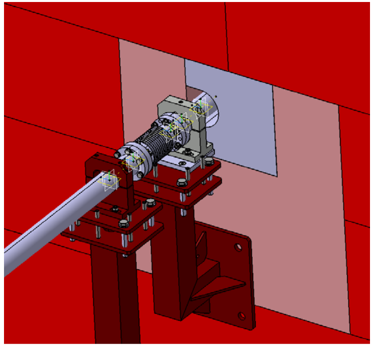

Dia 1


Up
Wall
Ring
Down

Tunnel Wall Break Through

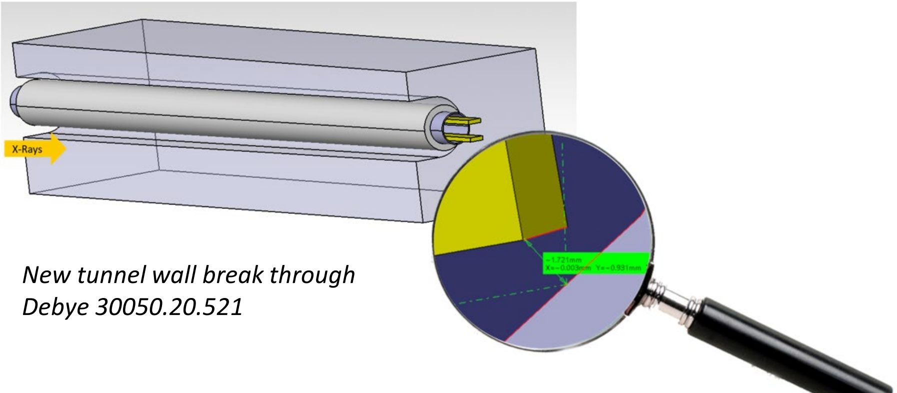


Existing tunnel wall break through 30040.36.409



New tunnel wall break through SIM 30050.20.575

- The existing tunnel wall break through can be reused in some cases
- New concept with casted mono block heavy concrete
  - Simulations for radiological safety planed by designated group



New tunnel wall break through Debye 30050.20.521

My thanks go to

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