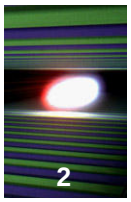
Concept of undulator air conditioning for XFEL October 2010

Carola Schulz European XFEL, WP 71

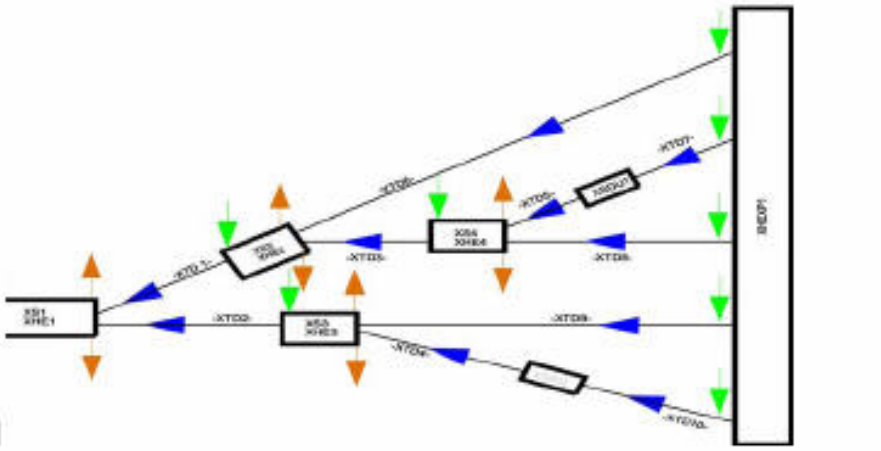
Overview



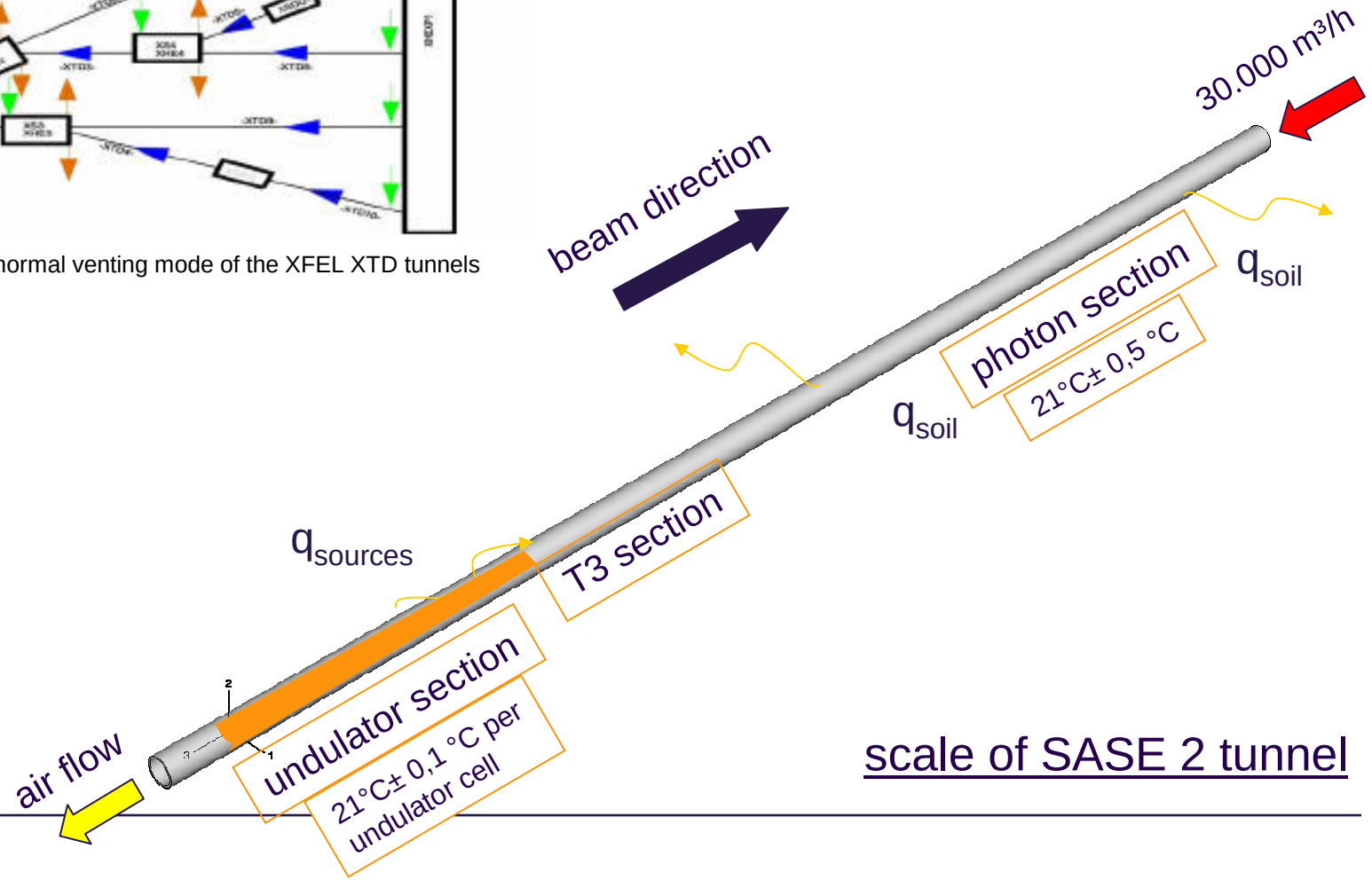
- Undulator tunnel

  - air conditioning activities
    - location overview
    - requirements
    - functional concept
    - heat sources / heat transfer
    - technical realization
    - next steps

Location overviews



Air flow directions in normal venting mode of the XFEL XTD tunnels



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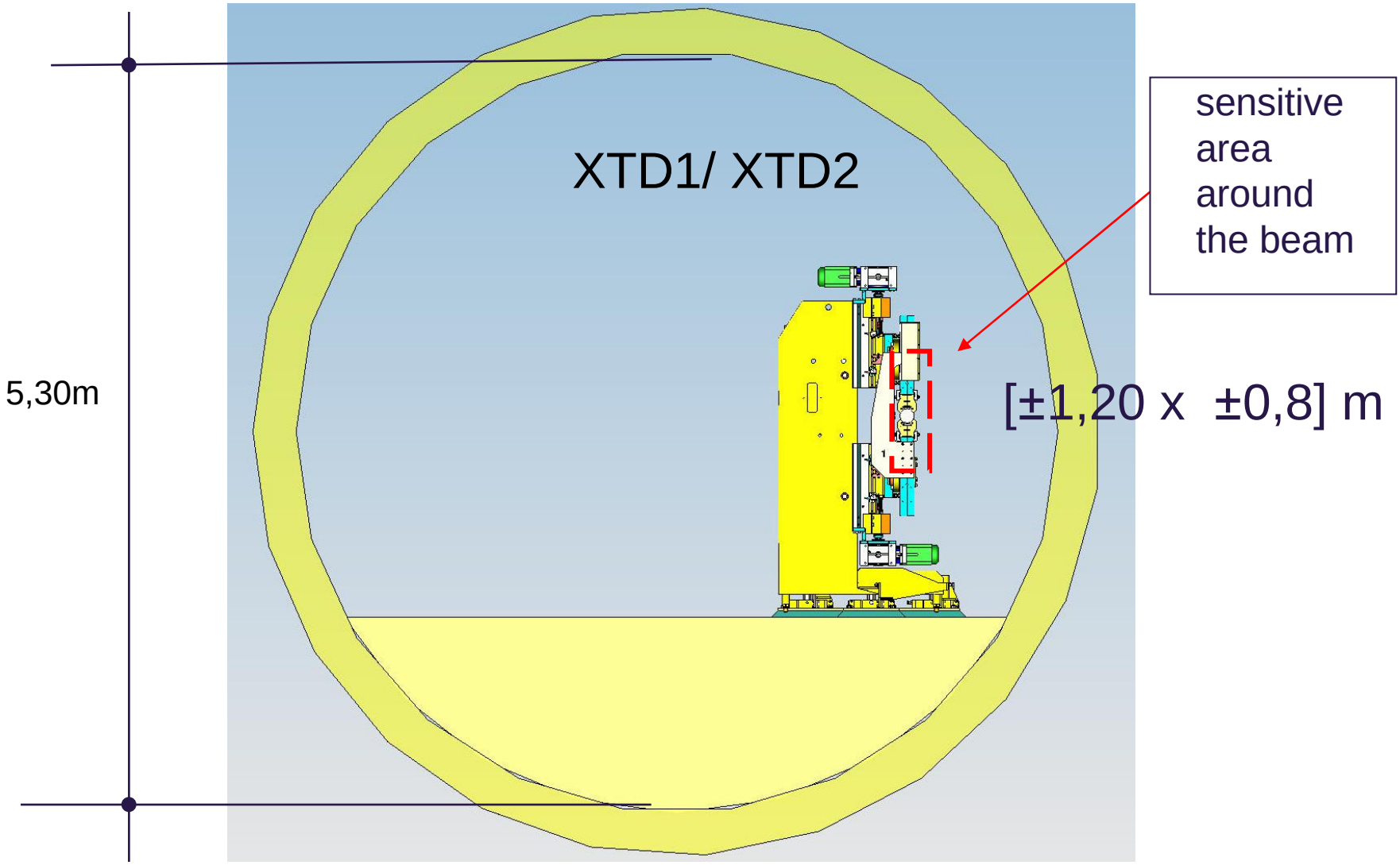
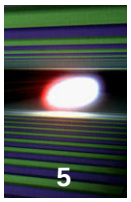
Location sensitive area



Requirements: Temperature



- **Reduced Tolerances on Air Conditioning**
  Y. Li, B. Faatz, J. Pflueger, Phys. Rev. ST-AB 1,100701 (2008)
  - Requirement of ± 0.1°C Variation over whole Systems is relaxed to ± 0.1-0.2°C over ONE undulator Cell
  - Temperature Deviation is compensated with Gap Adjustment
- **Temporal Temperature Stability of ± 0.1°C/ day**
- **Temperature gradient over one undulator section ≤ 4K**
- ***Temperature stability is most important only in the sensitive area around the beam, the temperature can relaxed outside of beam position.***

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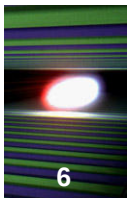
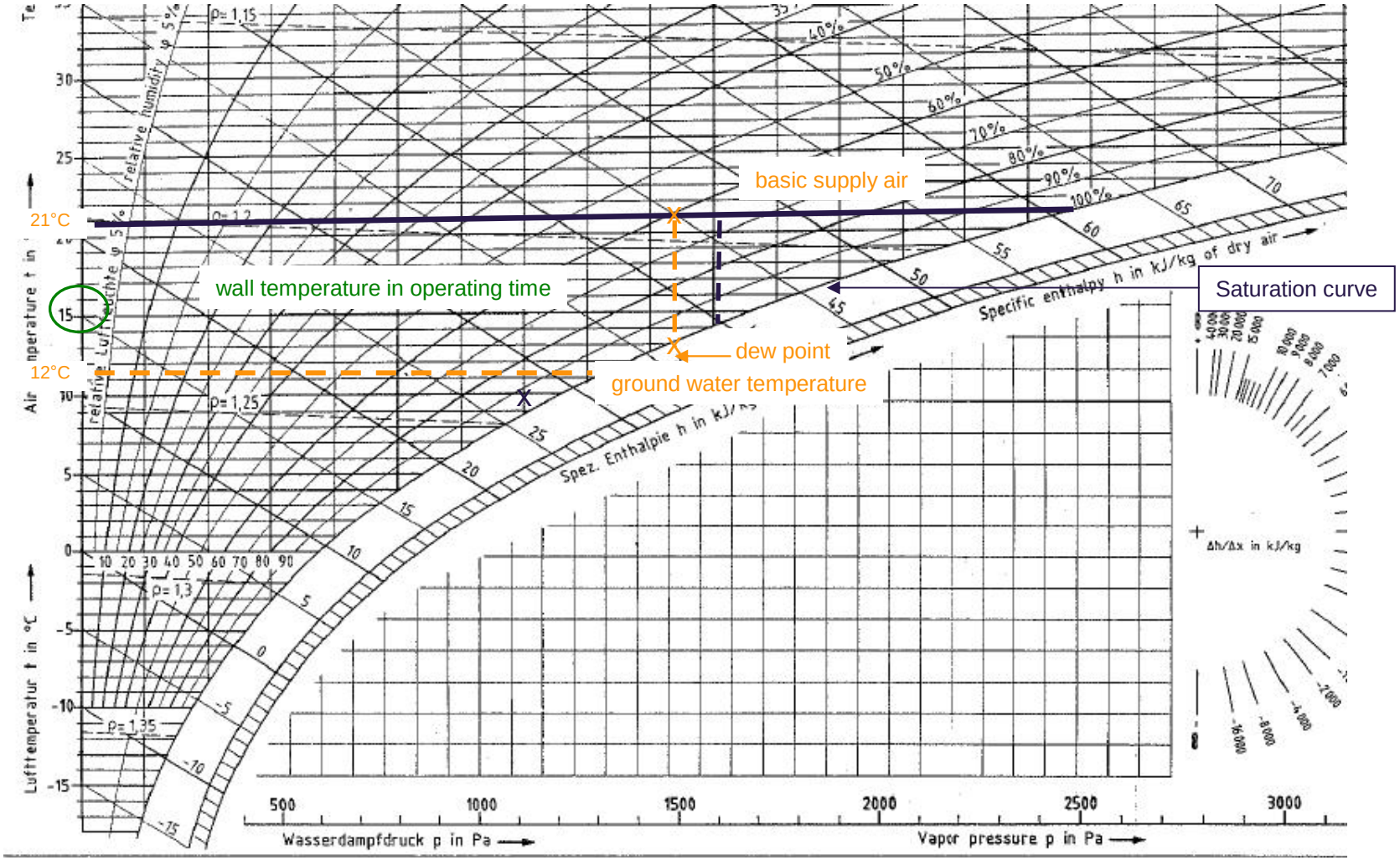
Requirements: air conditioning



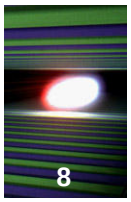
- **Set- point temperature 21°C at the beginning of undulator section**
- **Undulator-sections are the last part of XTD1, XTD2 and XTD4-XTD10 in the air flow direction**
- **Use longitudinal Air Flow with displacement concept**
- **The basic air volume is 30.000 m³/h in the operating time**
- **Different surrounding sections - with sand+ groundwater and sections with glacial till.**

Requirements: supply air keep humidity ≤ 60% r.H



Psychometric chart by Mollier

Longitudinal Air flow with displacement concept



knowledge and control of the thermal transient

1.heat sources ↔ 2.heat transfer

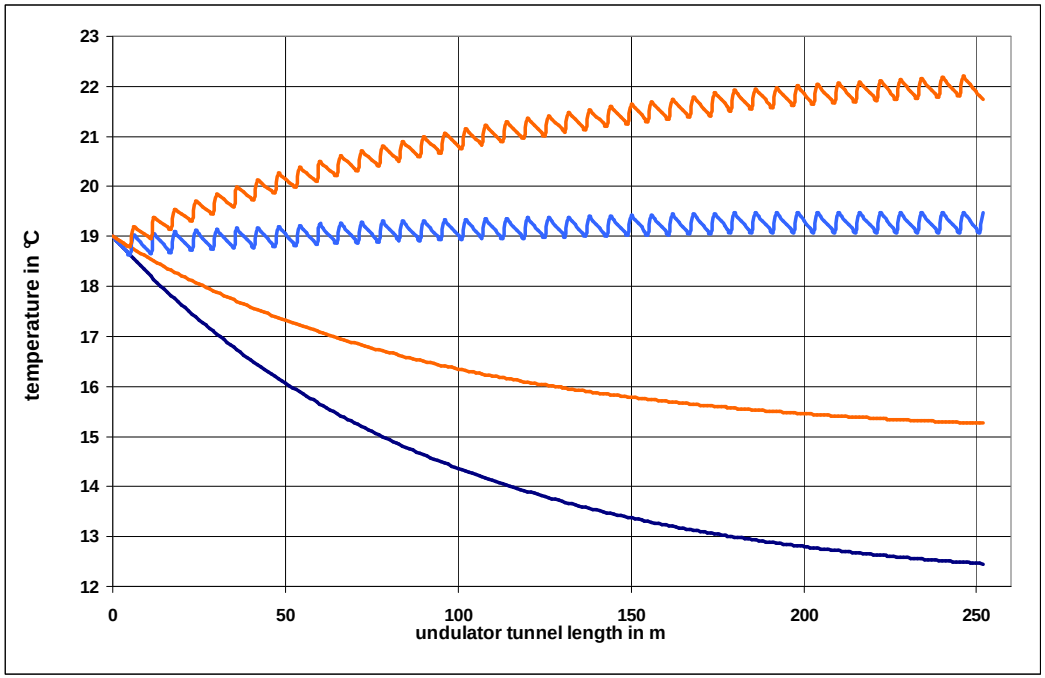
quantify the heat sources

- Access
  - People, equipment brought in, leakage of air
- Undulator System
  - See following slides
- Utilities
  - Lighting, exit signs, power lines, chilled and hot water lines, phone/data
- Other systems
  - ?/ photon systems/ t-systems/dump
- Many different time scales: quasi-static to random

quantify the heat loss depending on the soil layers

- Tunnel walls and floor
  - Sand in groundwater
  - Glacial till

Longitudinal air flow with displacement concept



- heat sources and heat loss do influence the temperature
- thermal lift from heat sources influences the air flow
- the longitudinal air flow transports humidity and heat

	wit heat surces 0,4 K, wall temperature 15 °C
	wit heat surces 0,4 K, wall temperature 12 °C
	without heat surces, wall temperature 15 °C
	without heat surces, wall temperature 12 °C

heat loss over the tunnel wall into surrounding earth is important

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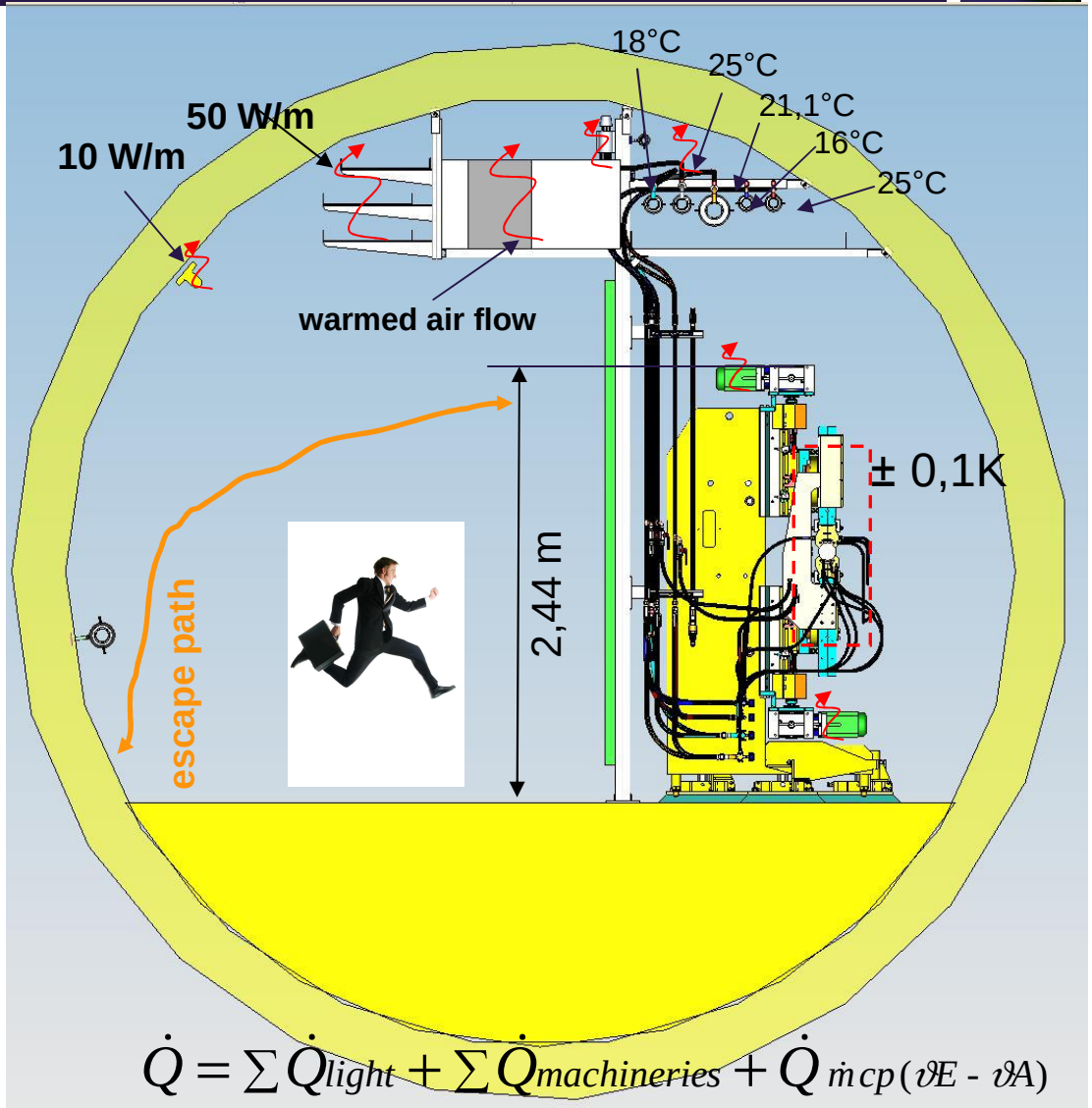
1. heat sources

- **reduce the heat loss, (cooling water 30/55 °C was removed)**
- **arrange the maximum heat sources on the tunnel ceiling**

- **Cable traces are outside from the escape path (cable traces are fire loads)**



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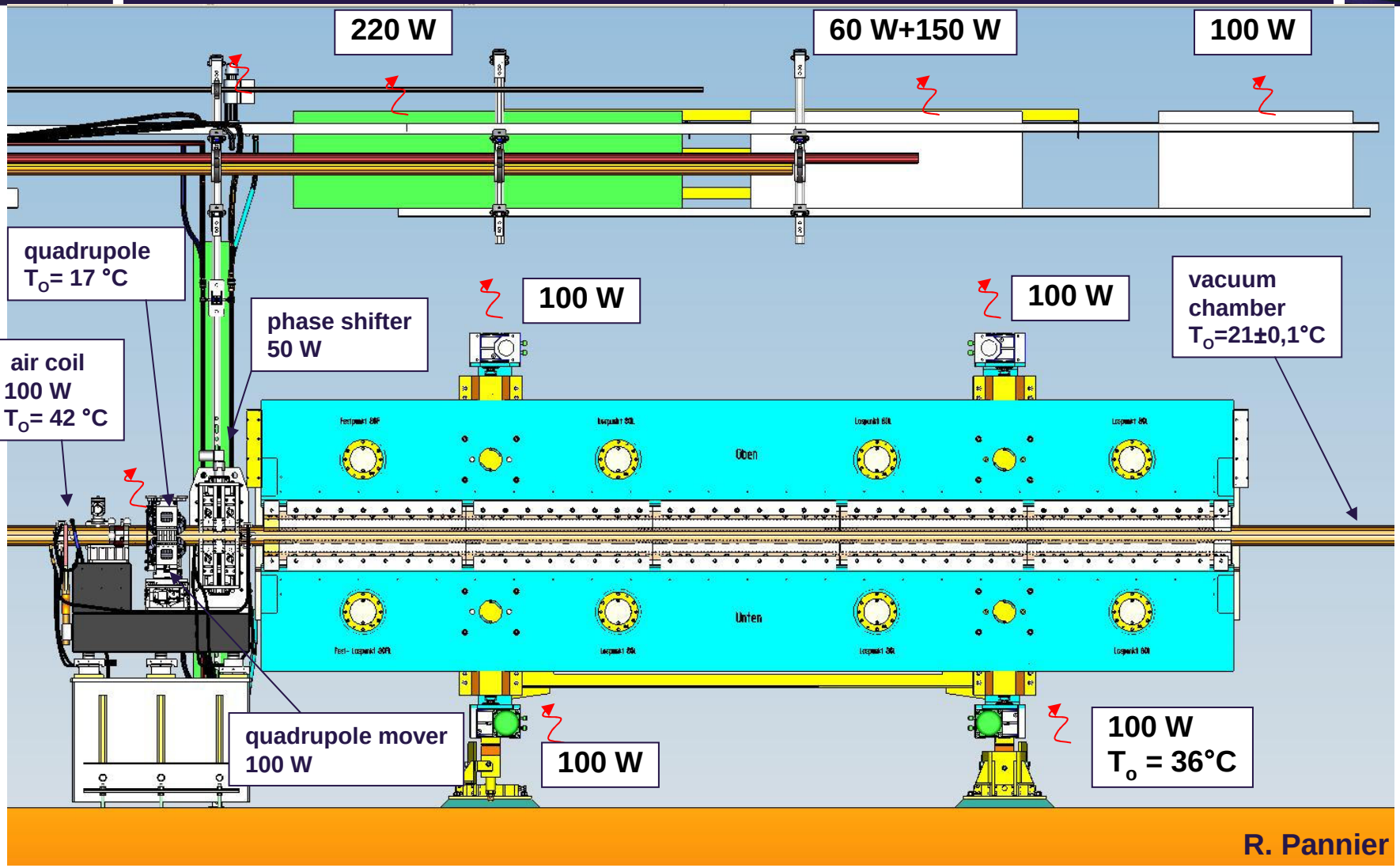
1. heat sources



wall side

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1. heat sources - process cooling

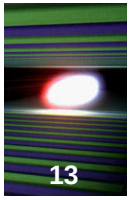
developed together with DESY, WP34 , F.-R. Ullrich

<u>two cooling circuits with thermal insulations in the undulator tunnel</u>

1. Vacuum Chamber; Aluminium
   precision regulated via 3-way valve to 21±0.1°C
   with 18°C/25°C and 21°C process cooling water

2. Quadrupole; Cupper
   by process cooling water at 16°C/25°C
   then we have +21°C average surface temperature

1.heat sources - up date June 2010



	SASE 1 total length 595 m	SASE 2 total length 479 m	SASE 3 total length 546 m
undulator cell $\dot{Q}_1 = \sum \dot{Q}_{light} + \sum \dot{Q}_{cable} + \sum \dot{Q}_{machinerys}$	1,6 KW	1,6 KW	1,6 KW
undulator section $\dot{Q}_2 = n \bullet \dot{Q}_1$	**52,8 KW** (length 201 m)	**59,2 KW** (length 225 m)	**33,6 KW** (length 134 m)
	~ 260 W/m	~ 260 W/m	~ 260 W/m
T_N XSDU2	**38 KW**	**3 KW**	**13 KW** **13 KW?**
photon section	**20 KW?**	**8 kW?**	**20 KW?**
	~ 170 W/m	~ 50 W/m	~ 110 W/m
total load $\dot{Q} = \sum \dot{Q}$	**110,8 KW**	**70,2 KW**	**83,6 KW**

Conclusion: Undulator system is the main heat source

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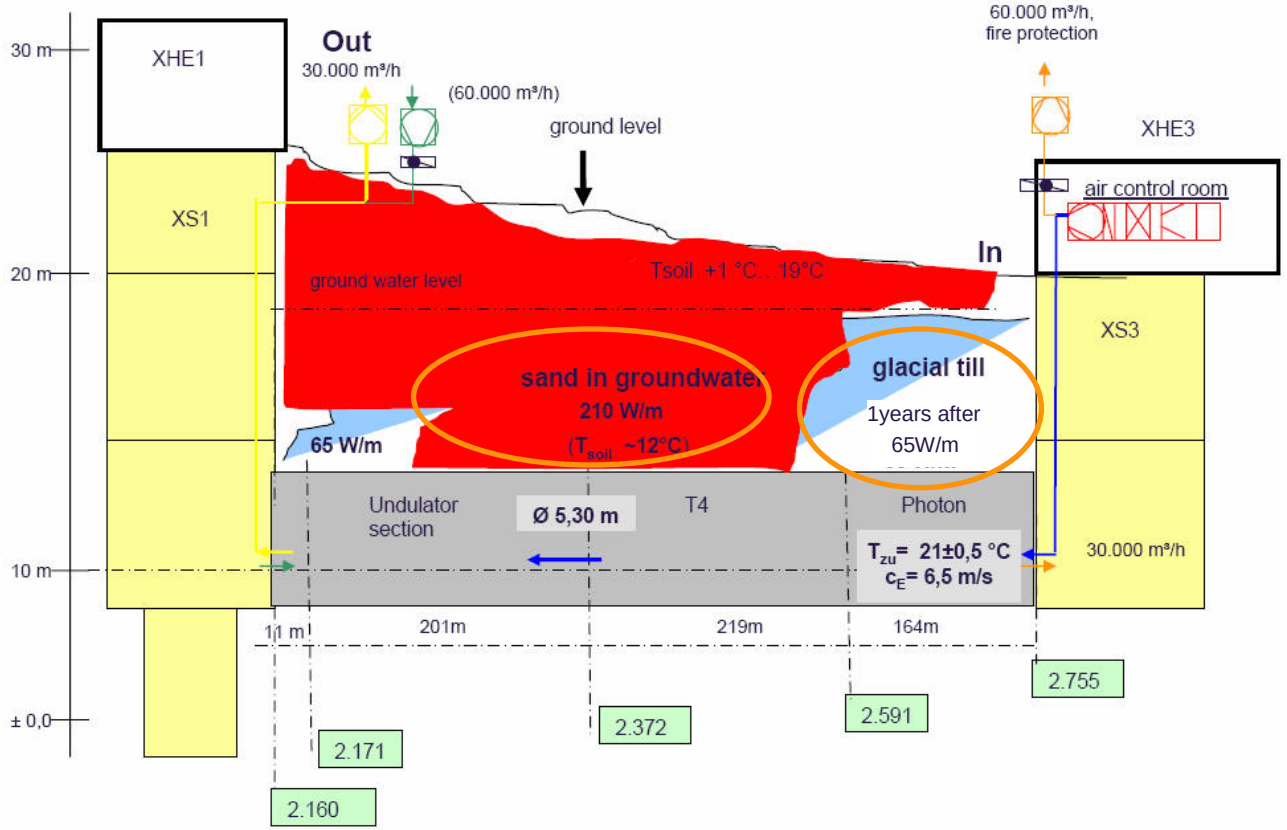
2. heat transfer

classification of soil layers	thermal conductivity λ [W/mK]	density ρ [kg/m³]	heat capacity c_p [kJ/kgK]	specific weight γ/γ' [kN/m³]
glacial till	1,7	2100	1,09	21/11
sand in groundwater	2,4	1900	1,34	18/10

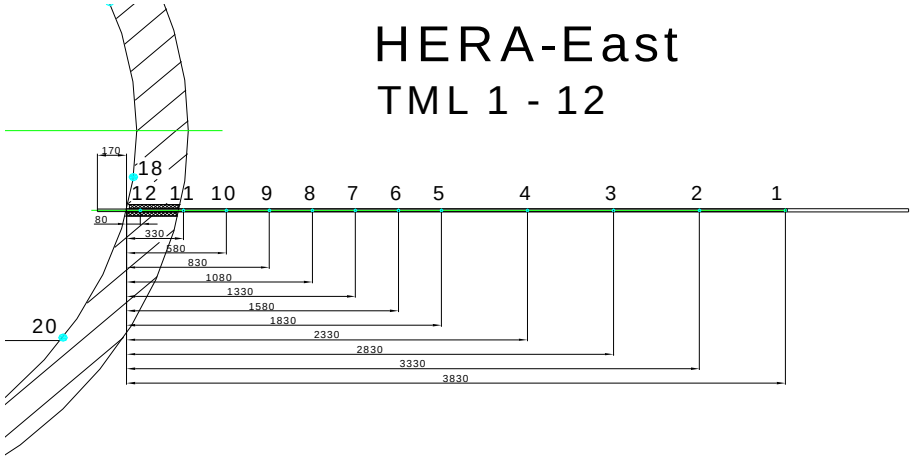


SASE 1/ SASE 2

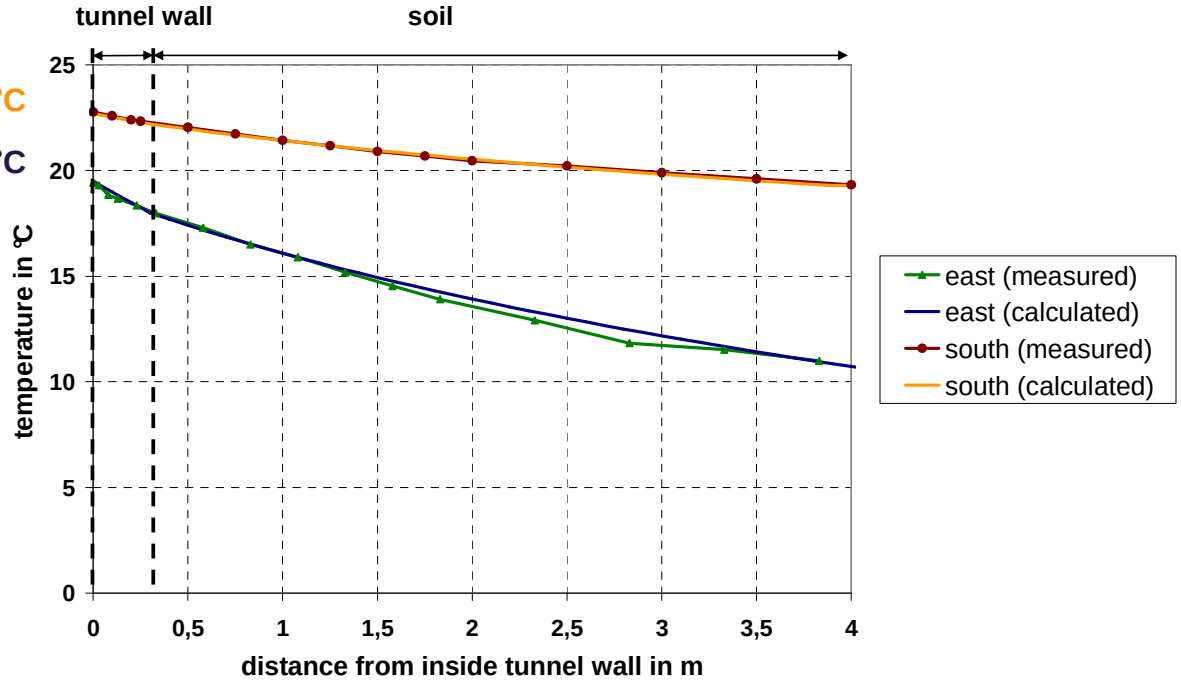
2. heat transfer- HERA measurements

two measurement positions :

- sand in groundwater
- marl



2. heat transfer- HERA results measurement 2009



During the operating time

	east-right	south-right
soil properties	sand in ground water	glacial till
heat transfer $\dot{Q}\ [W/m]$	**210**	**65**

Stationary temperature profile in the tunnel wall (tübbing segment) and ground

Q : *Heat Flux*

R: *thermal conductivity*

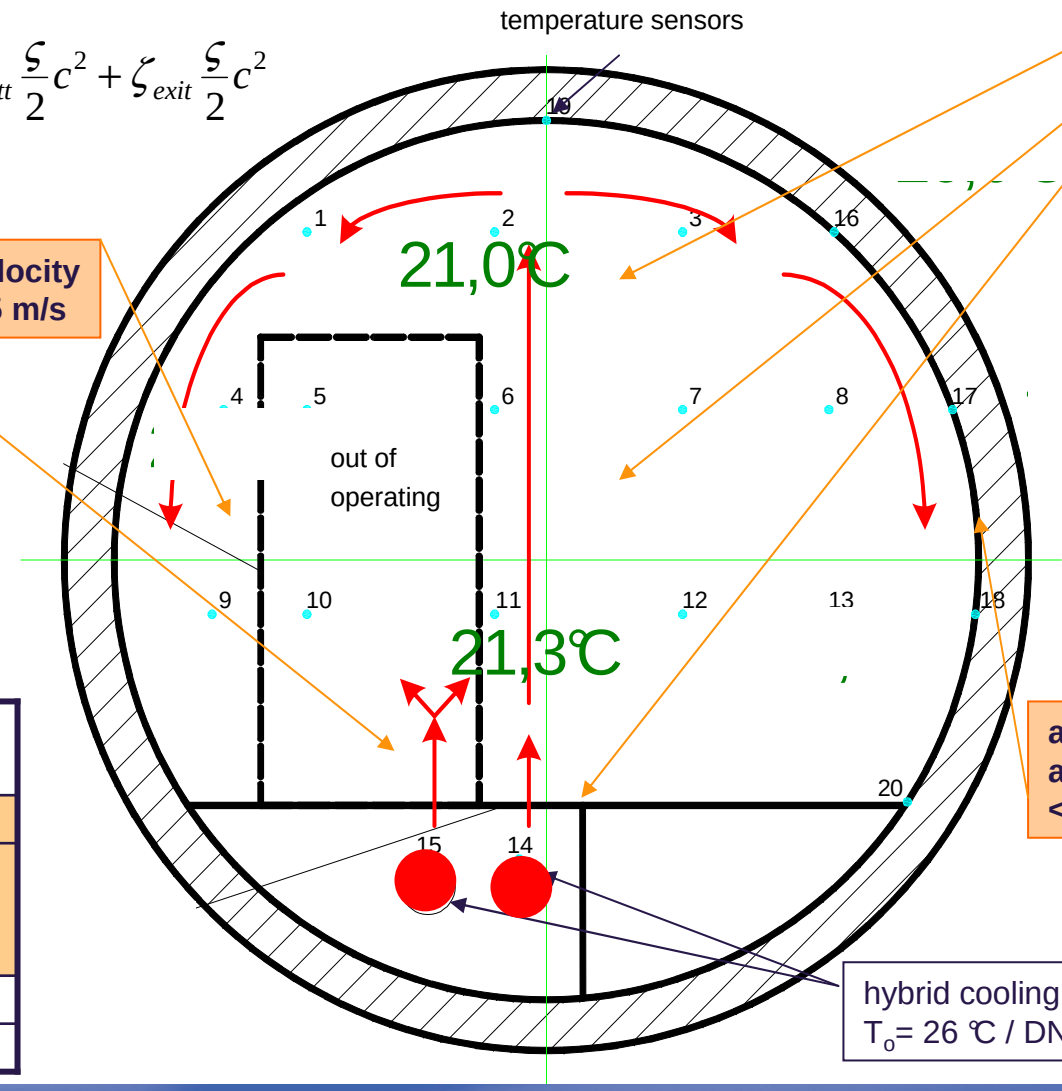
d: *Thickness of Concrete 0.3m*

ΔT : *Temperature Difference*

$$\dot{Q}_{ges} = \frac{\left(T_{L,i} - T_{Erdr}\right)}{R_{ges}} \quad (5)$$

boundary condition : *the influence of the thermal lift on the temperature distribution /difference in air velocity*

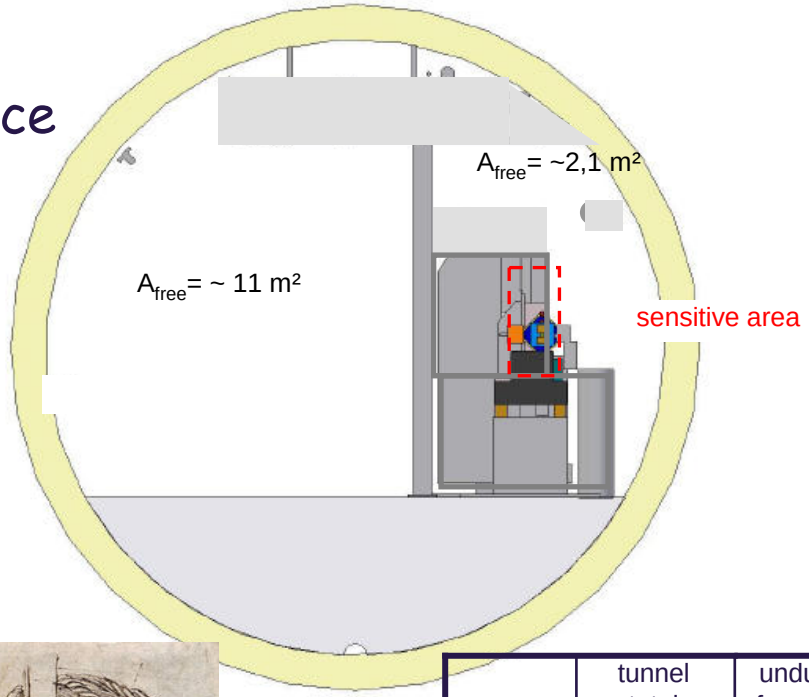
(4) $$\Delta p_{tunnel} = \lambda \frac{l}{d} \bullet \frac{\varsigma}{2} c^2 + \zeta_{inlett} \frac{\varsigma}{2} c^2 + \zeta_{exit} \frac{\varsigma}{2} c^2$$



measurement point	after 330 m/e.r.
air flow	18.800m³/h
quantity air velocity in the tunnel	0,25m/s
heat sources	hybrid cooling
Tunnel diameter	5,20m

boundary condition: pressure loss

air flow takes the way
with of minimal resistance



	tunnel total length [m]	undulator free cross section [m²]	air velocity undulator section [m/s]	total way time [min]
SASE 1	595	~13	0.65	~13
SASE 2	479	~13	0.65	~11
SASE 3	546	~8,5	0.97	~9

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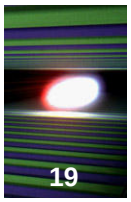
conclusion



Our investigations show that we have a chance to fulfil the temperature requirements for the undulator section,

but some open issues remain:

- *The heat power of internal heat sources is not exactly defined.*
- *The influence of the thermal lift on the temperature distribution in the tunnel is not clear, temperature layer is possible.*
- *Are the internal heat sources stable in the whole tunnel over the operating time?*

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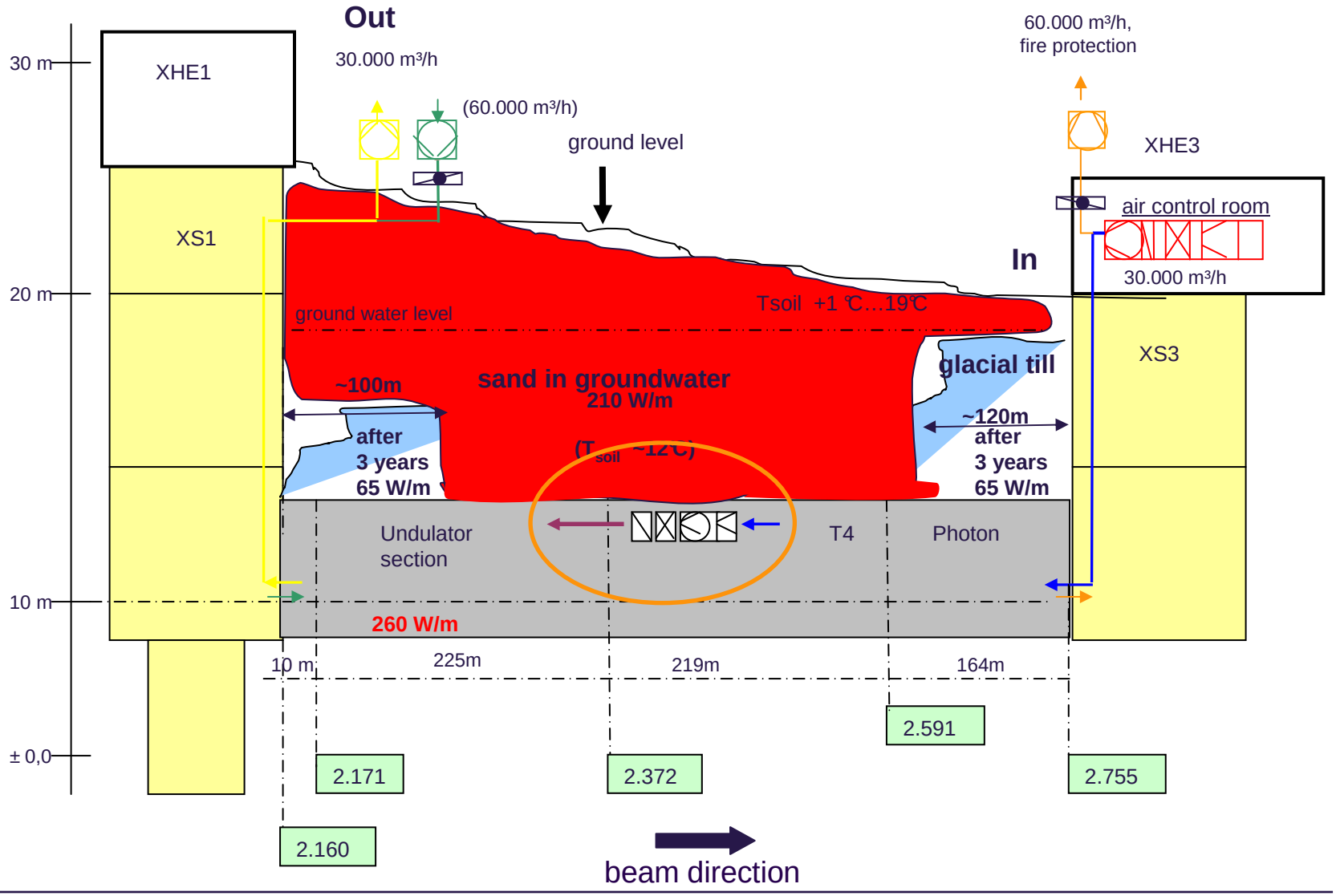
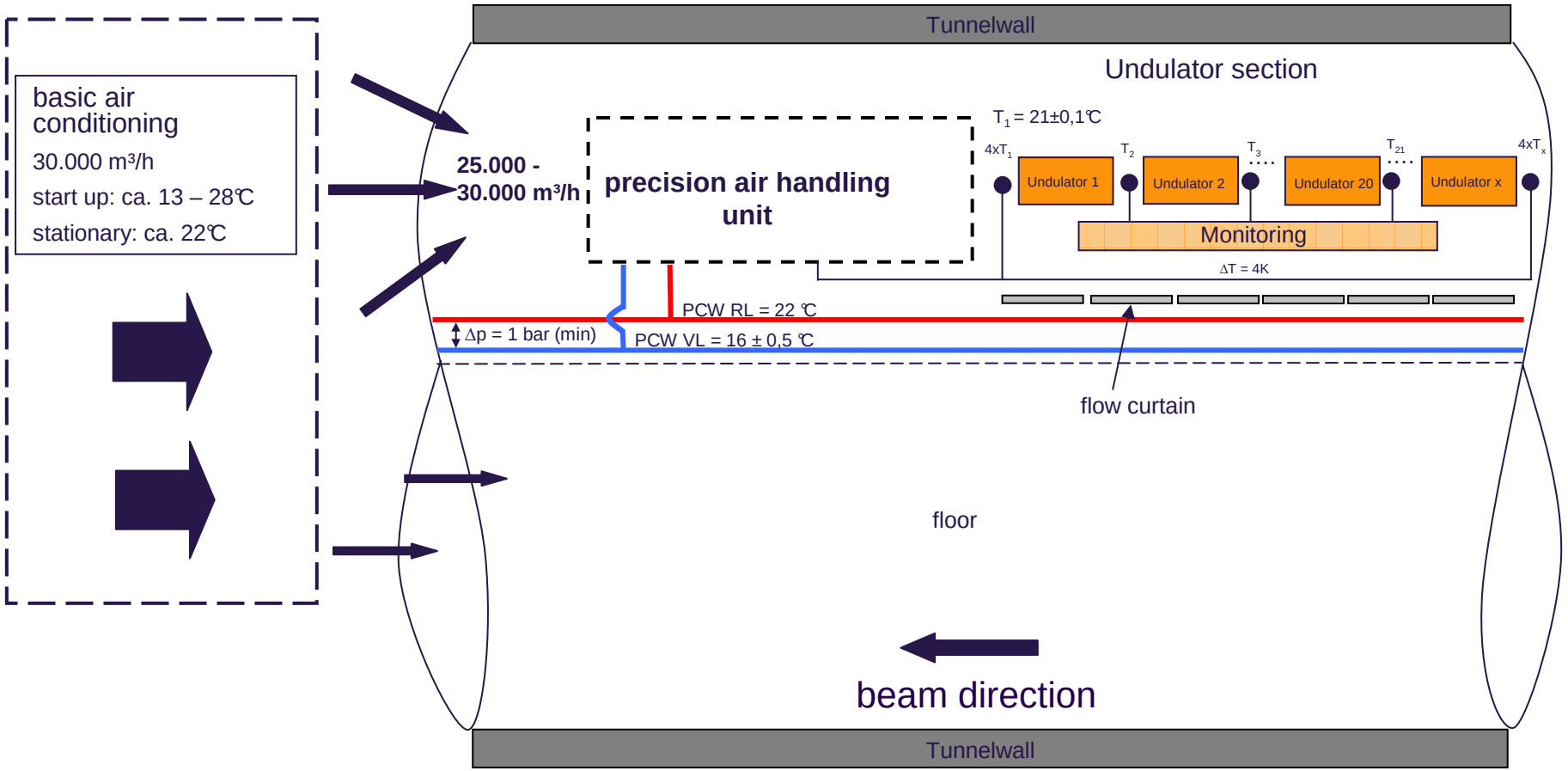
thermal uncouple undulation cells



concept / functions schema

M+W GROUP

schema undulator tunnel



concept / installation situation Tunnel Ø 4,6m

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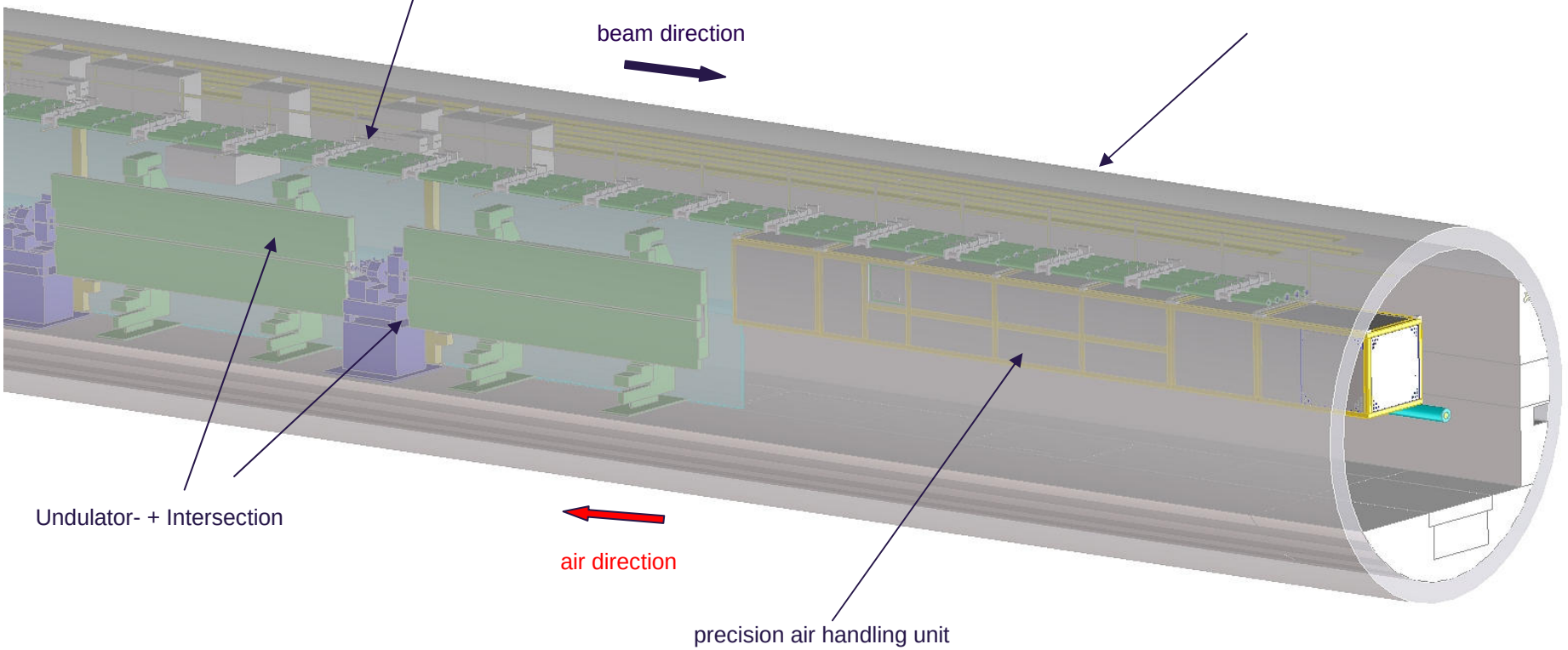
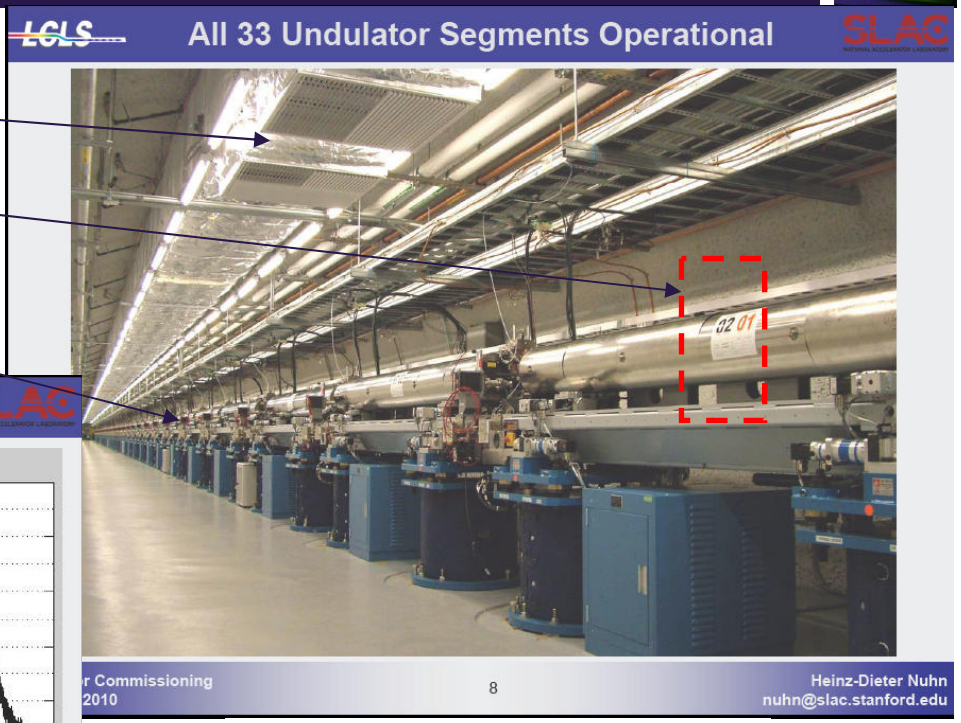
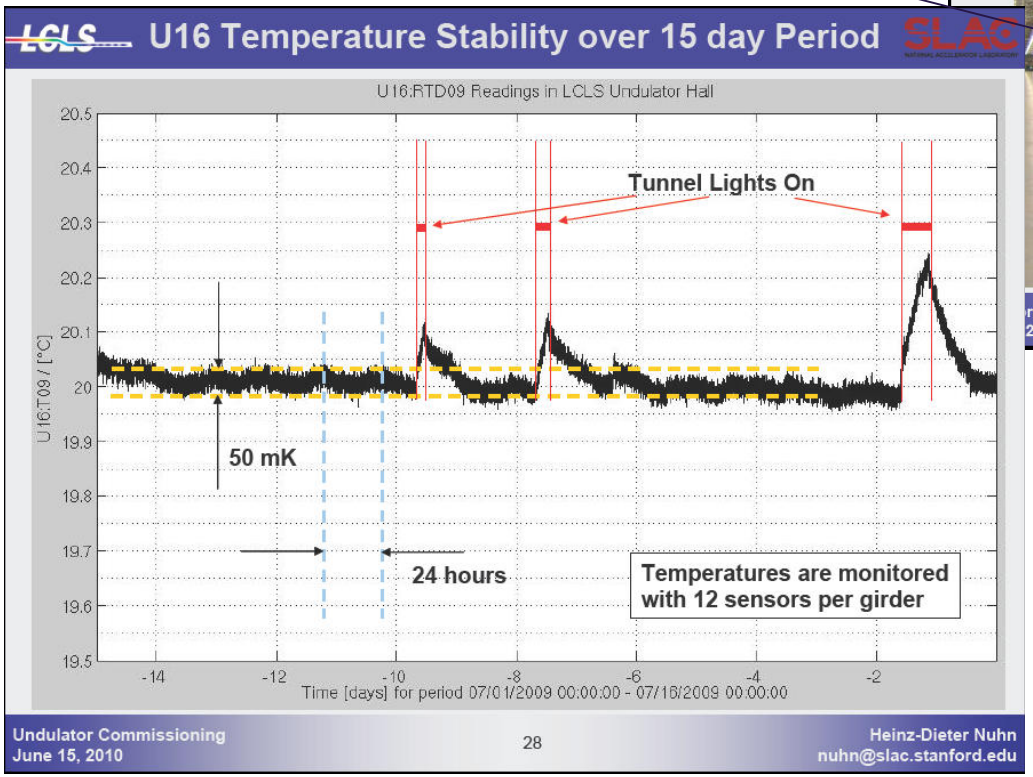


air outlet

sensitive area

local heat sources 50 W/m





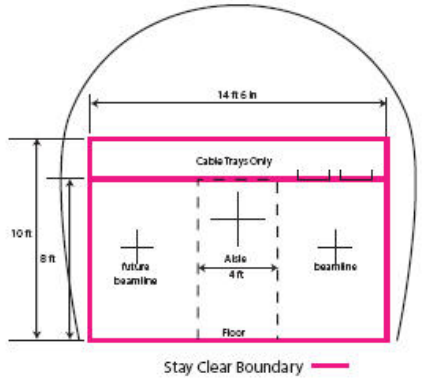


Figure 2: Minimum cross sectional size of the Undulator Hall.

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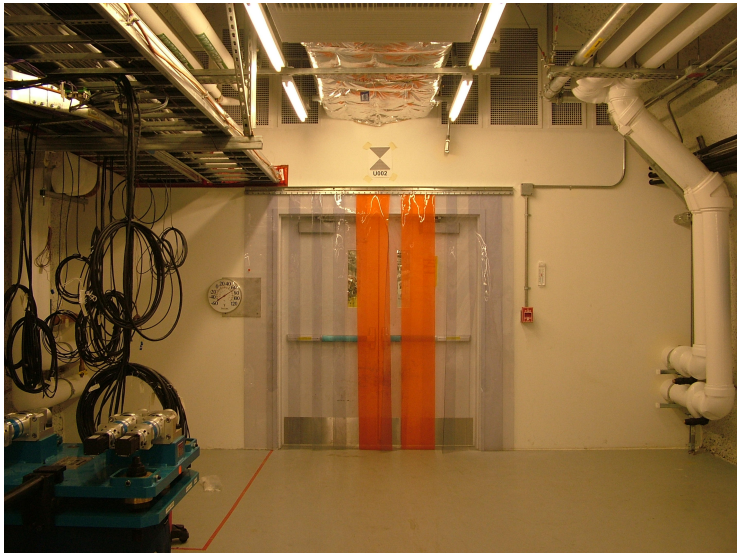
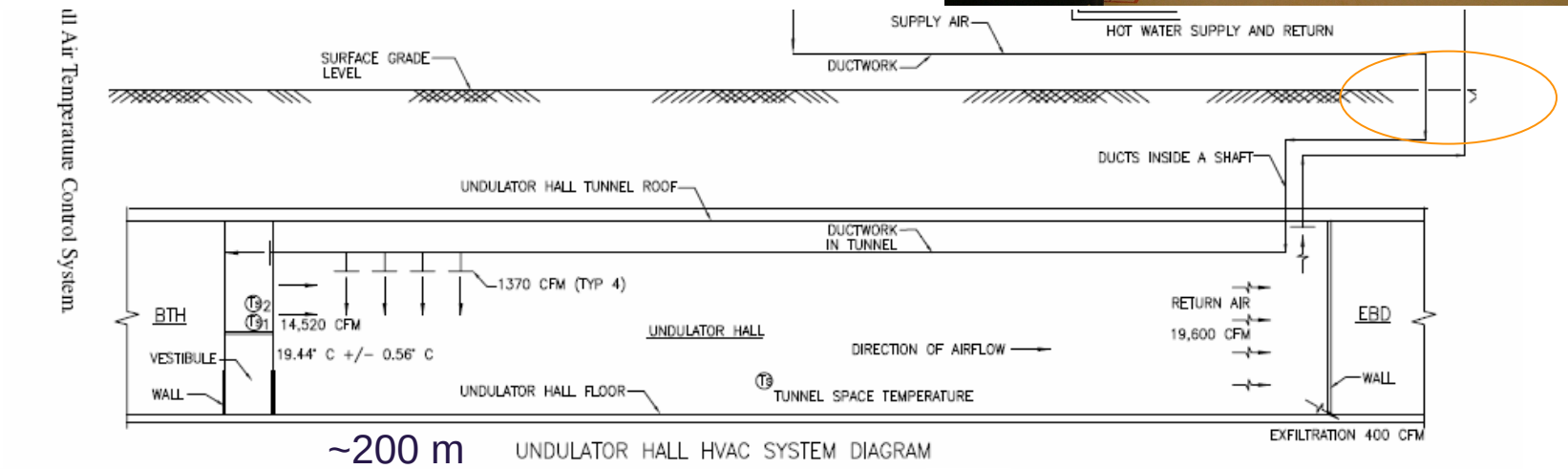
LCLS

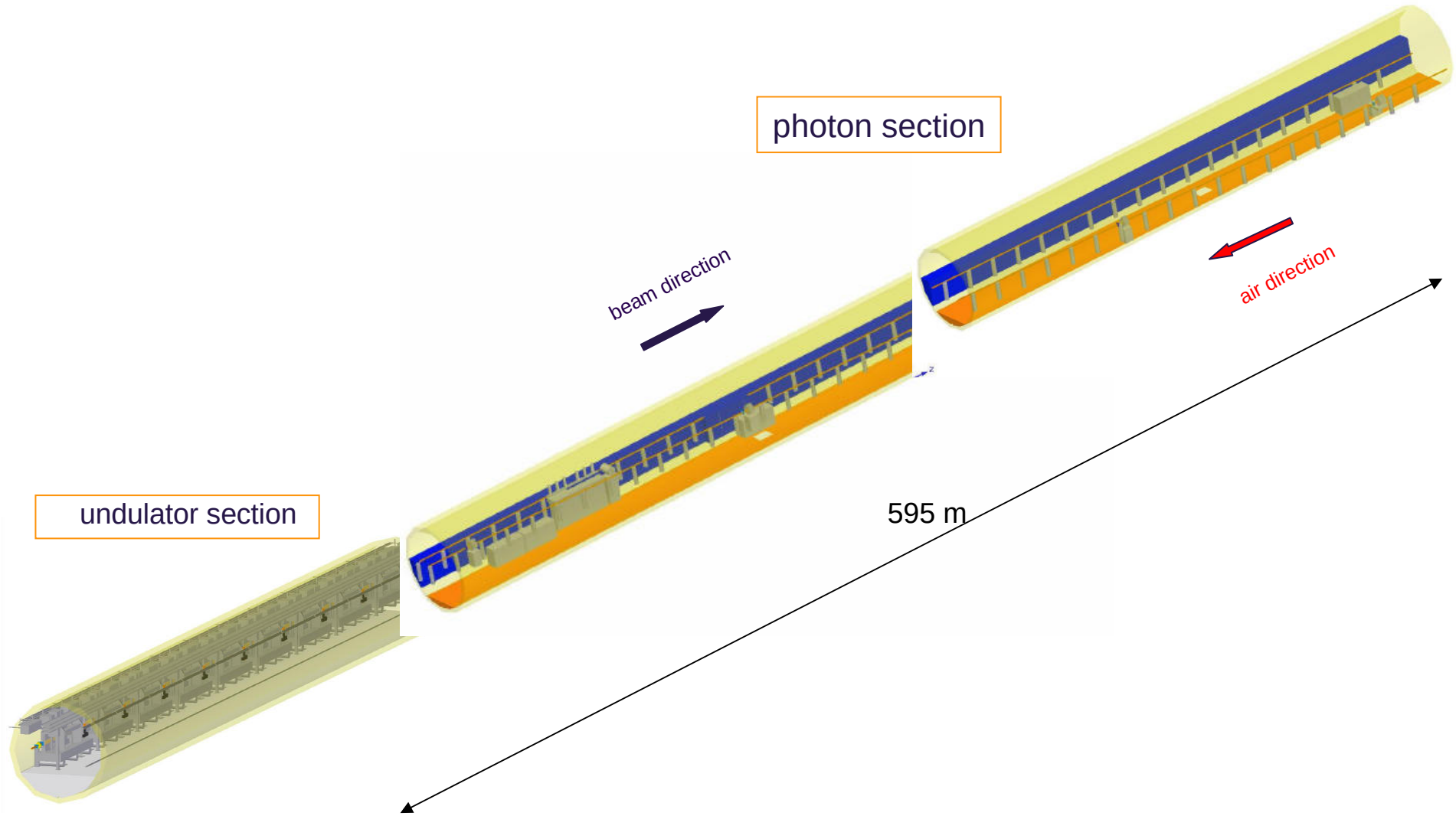
LCLS	European XFEL
21 ± 0,2 °C for ~ 200 m undulator tunnel	21 ± 0,1 °C for per undulator section 6,1m
50 W/m heat sources	260 W/m heat sources
separate supply air	exhaust air from the preceding tunnel section
constructional decoupled separate tunnel	a last part of the SASE in air flow direction



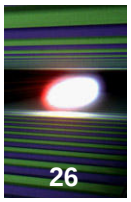


~200 m UNDULATOR HALL HVAC SYSTEM DIAGRAM

next step – Fluent Simulation for the whole tunnel

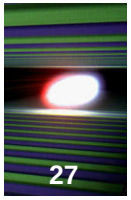


next step – Fluent Simulation



We hope to found answer the following questions through CFD-simulation :

- How will the unit operate in case that the incoming air temperature is not 21± 0,1°C? (what is the best mass flow rate and outlet temperature?)
- What is the optimal position for the precision air handling unit?
- How big is the impact of heat sources on the air distribution, especially in the sensitive area?
- Do we need to use a curtain to separate undulator and floor?
- Can we increase the air velocity in the small cross section of the sensitive area?



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F.-R. Ullrich, S. Feuker (DESY)

R. Pannier (Eur. XFEL)

Thank you for your attentions

Influence of the surface temperature

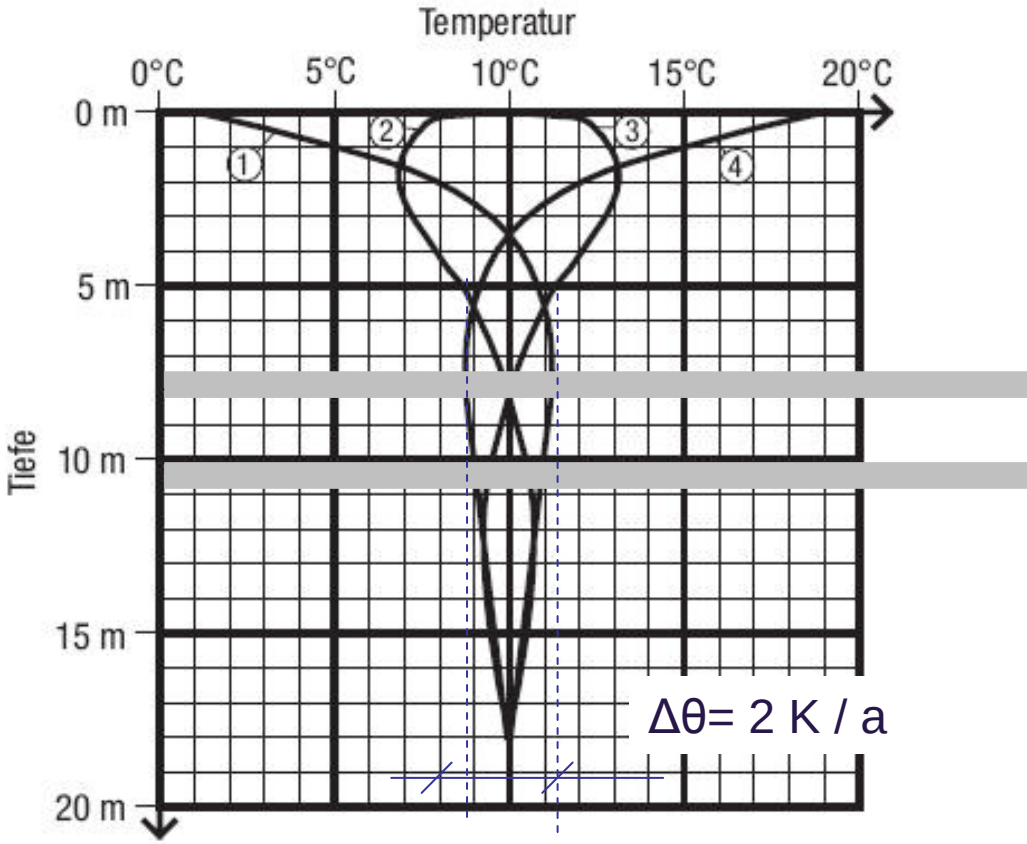

Abb.39 Jahrestemperaturniveau in verschiedenen Bodentiefen

Dissertation K. Dahlem, Universität Kaiserlautern, 2000

HERA -Temperature curve during the operating time, *May 2006*