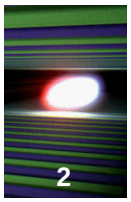
Temperature calculation

XFEL Tunnel ventilation and Air Conditioning Workshop, Desy Hamburg, October 25&26th 2010

Narcisse Ngada, MKK/WP34

Temperature Calculation



- Introduction
- XTL Tunnel design
- Mathematical approach
- Results
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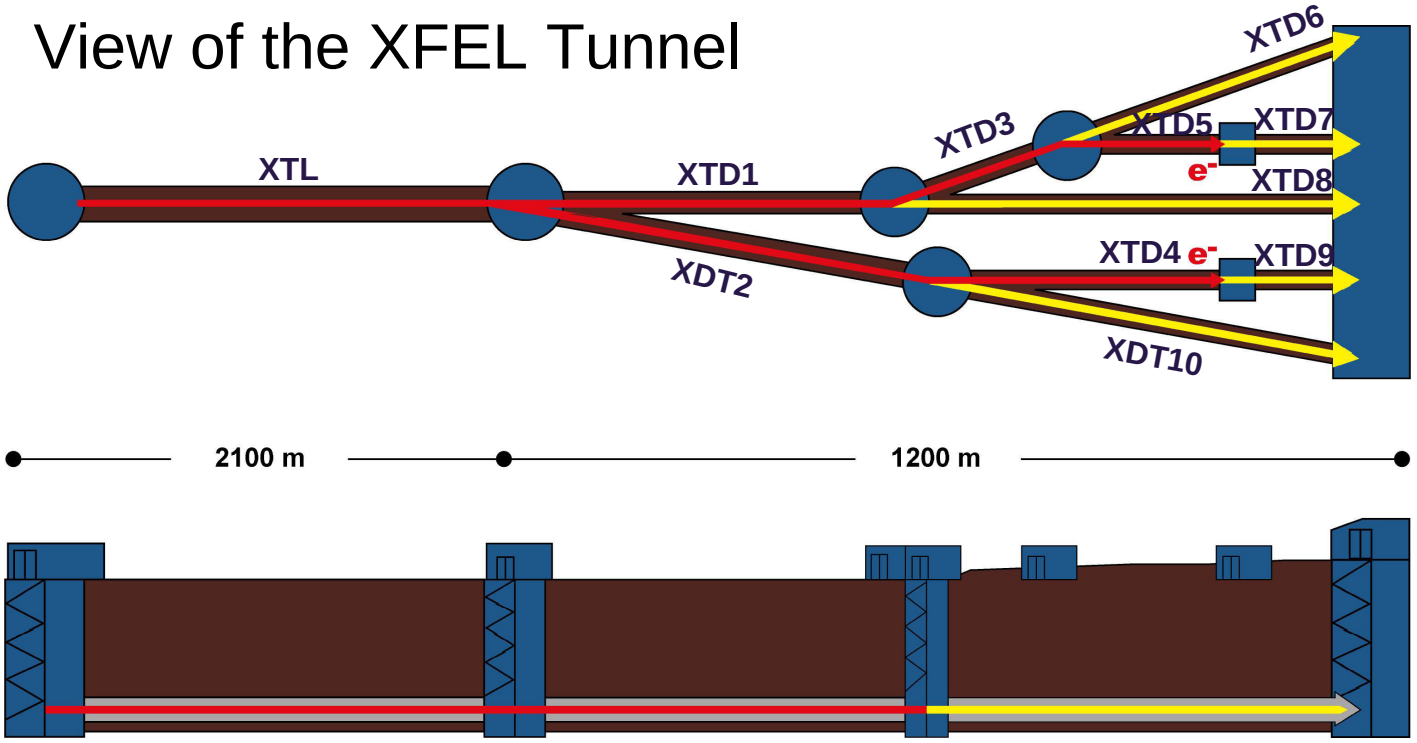
Temperature Calculation

View of the XFEL Tunnel



- Total length: about 3.4 km
- Underground tunnels
- Depth : 6 -38 m

- Diameter
  - XTL, XTD1, XTD2 → 5.2 m
  - XTD2 …XTD10 0 → 4.5 m

Temperature Calculation

Why temperature calculation?

- Air heating due to pulse cable
- Good overview of the temperature profile
- Extension of the calculations to other tunnels

What should be considered (1)

- Decking list, Book room
- Experience and measurement in HERA
- The geology of the ground
- Air volume

What should be considered (2)

- Heat sources
  - Light, Pulse cable, DC cables, HV-cables, LV-cables,
  - Waveguide, Pulse transformer and matching network,
  - Magnets (surface temperature),
  - 30°C water pipe ΔT= 20°C (in the right cable channel)

- Heat sink
  - The tunnel
  - 18°C water pipe ΔT= 10°C (in the main tunnel),
  - 2x20°C water pipes (in the left cable channel)

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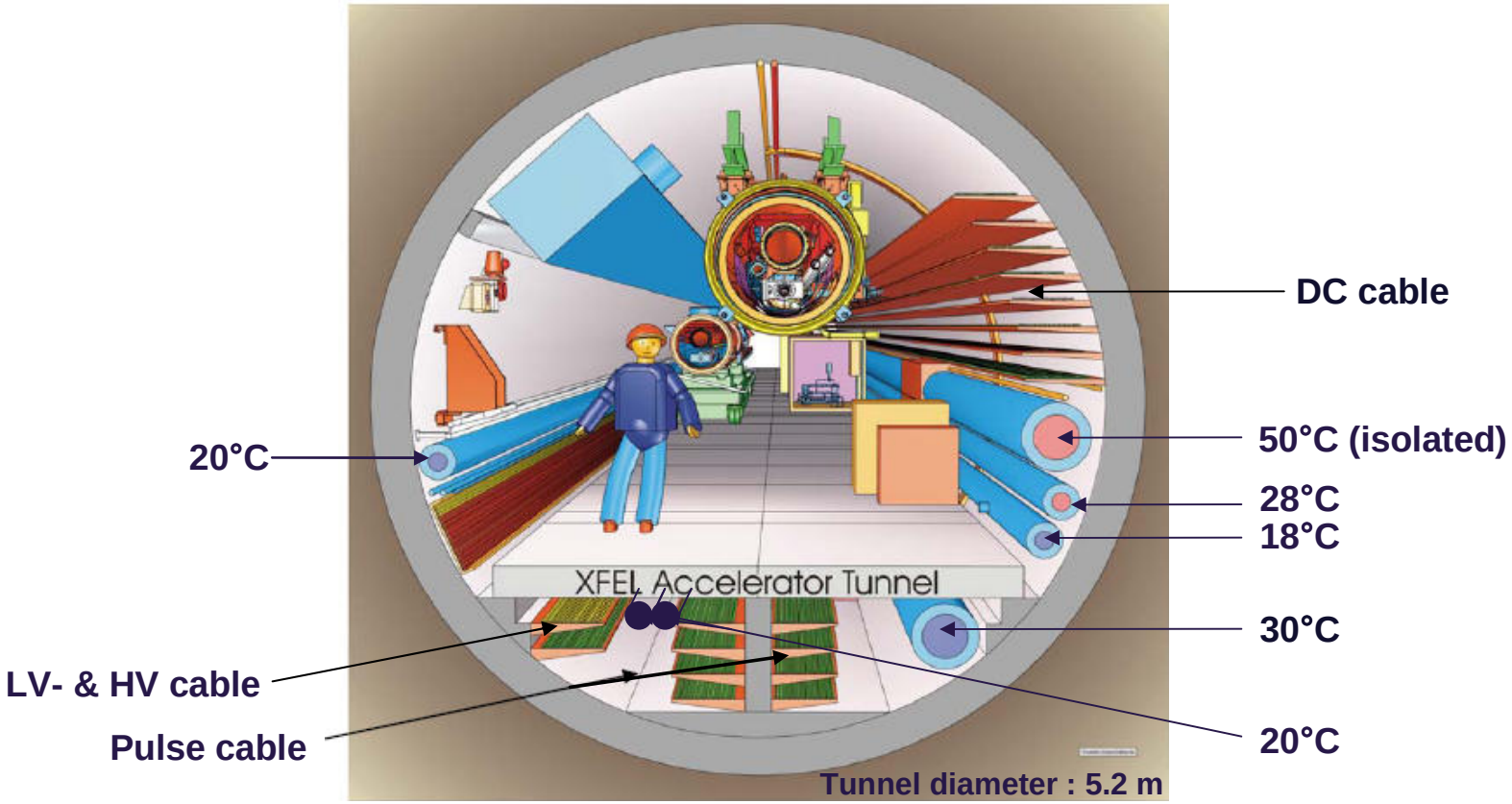
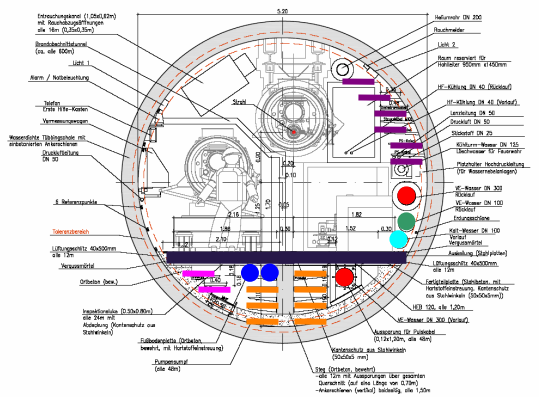
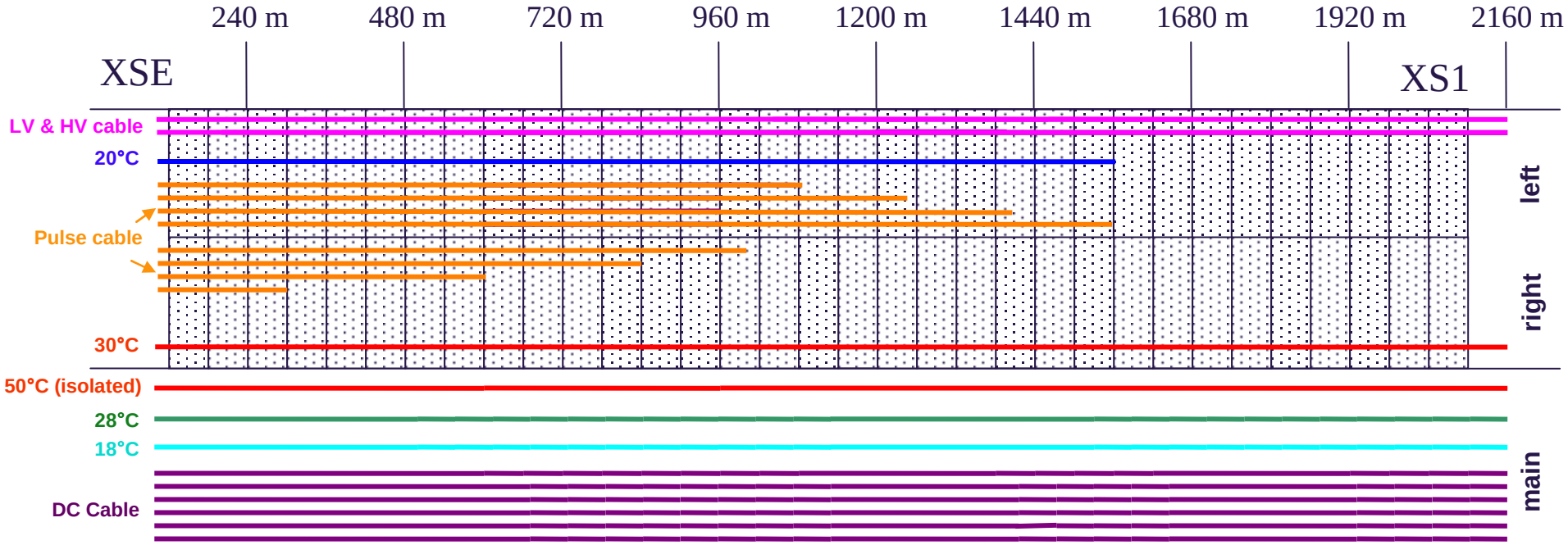
Temperature Calculation

- Cross section



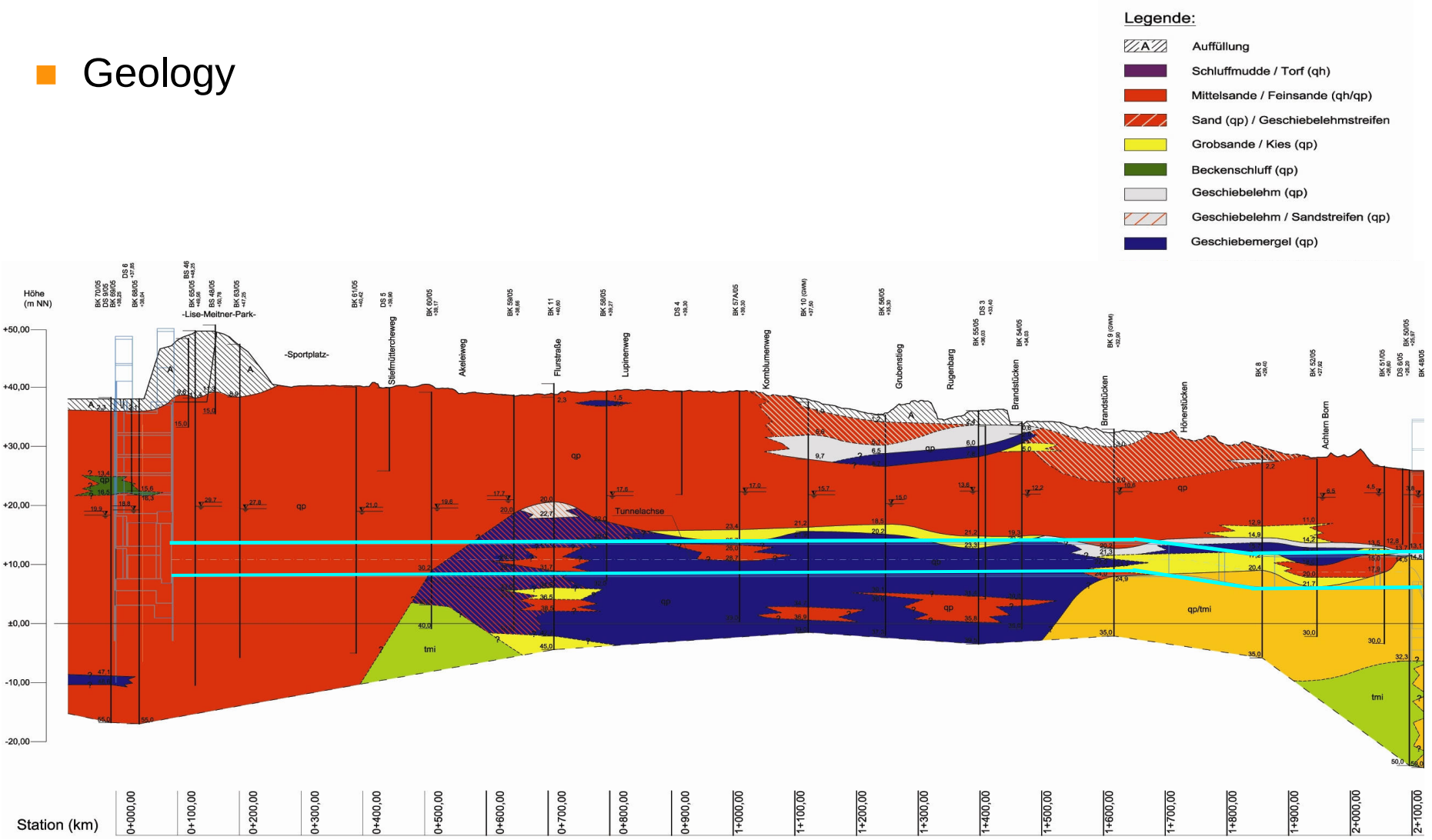
- Layout




240 m
480 m
720 m
960 m
1200 m
1440 m
1680 m
1920 m
2160 m
XSE
XS1
LV & HV cable
20°C
Pulse cable
30°C
50°C (isolated)
28°C
18°C
DC Cable
left
right
main

Temperature Calculation

- Geology



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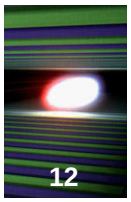

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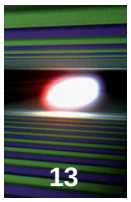


- Fundamental equation of thermodynamics

(1) $$\Delta Q = c.m.\Delta T$$

(2) $$\frac{dT}{dx} = \frac{1}{m_L.c_P}\sum_i Q_i$$

- The energy balance as a system of three **coupled** differential equations

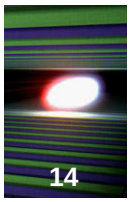
(3)

$$\frac{\partial T_1}{\partial x} = f(T_1, T_2, T_3, m_{L_1},, m_{L_2}, m_{L_3}, c_p, Q_1, Q_2, Q_3) \quad \text{Main tunnel}$$

$$\frac{\partial T_2}{\partial x} = f(T_1, T_2, T_3, m_{L_1},, m_{L_2}, m_{L_3}, c_p, Q_1, Q_2, Q_3) \quad \text{Left cable channel}$$

$$\frac{\partial T_3}{\partial x} = f(T_1, T_2, T_3, m_{L_1},, m_{L_2}, m_{L_3}, c_p, Q_1, Q_2, Q_3) \quad \text{Right cable channel}$$

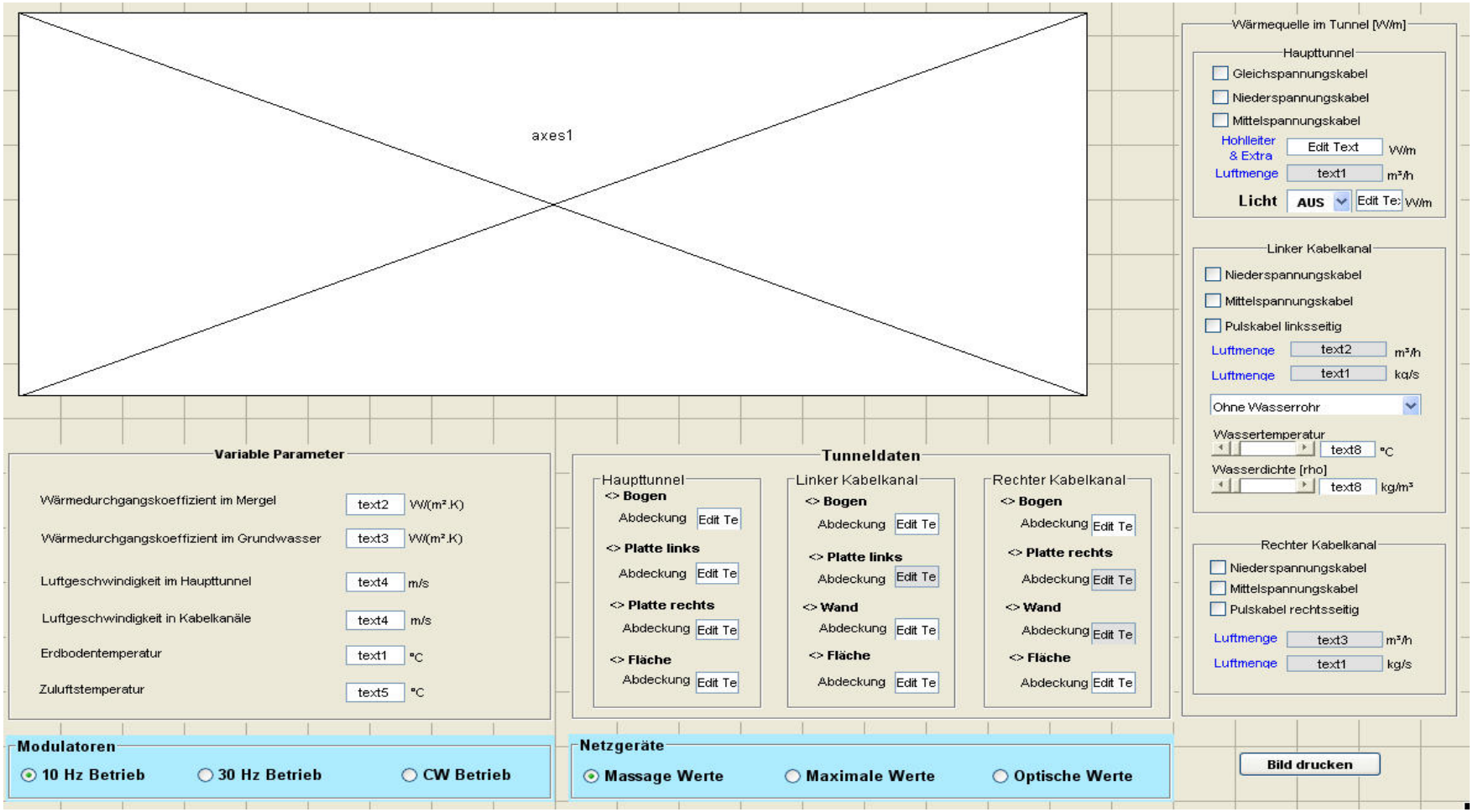
Temperature Calculation



- Overall heat transfer coefficient
  - Sand in ground water: h = 1.2 W/(m^{2}K)
  - Glacial till : h = 1.2 W/(m^{2}K)
- Only heat transfer by free convection
- Static calculation in the longitudinal direction
- Initial temperatures as starting values

Temperature Calculation

- **MATLAB** and **GUI**



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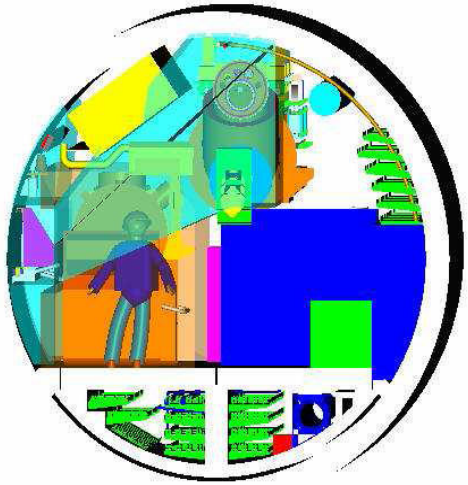
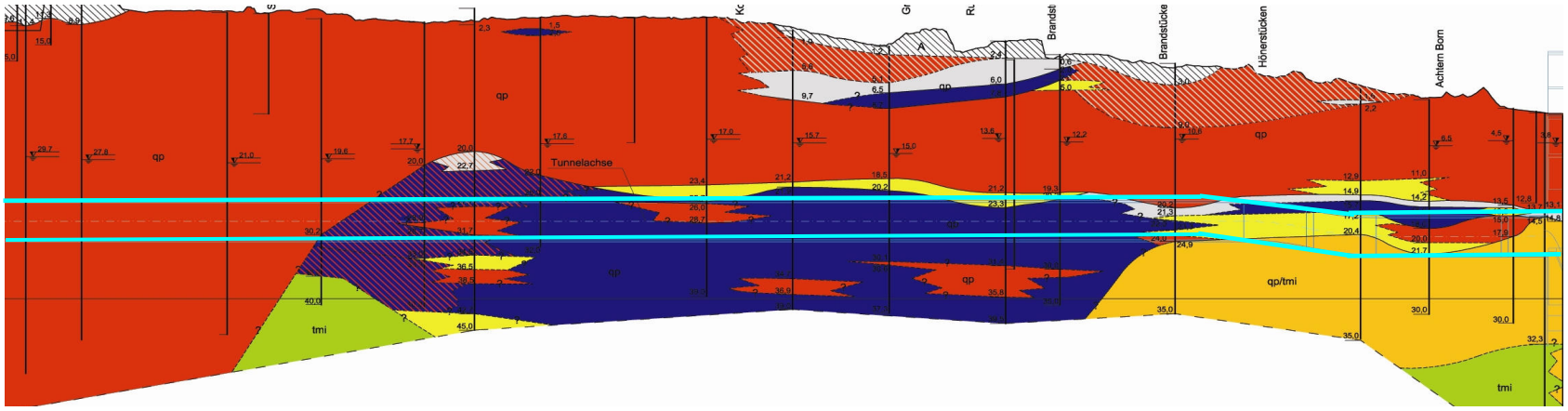
Temperature Calculation

Different operating conditions

- Tunnel in the winter: θZL = 19 ° C
  - Start of commissioning: h = 1.2 W/(m²K)
  - After few years h = 0.36 ~ 1.2 W/(m²K)
- Tunnel in the summer: θZL = 32 ° C
  - Start of commissioning: h = 1.2 W/(m²K)
  - After few years h = 0.36 ~ 1.2 W/(m²K)





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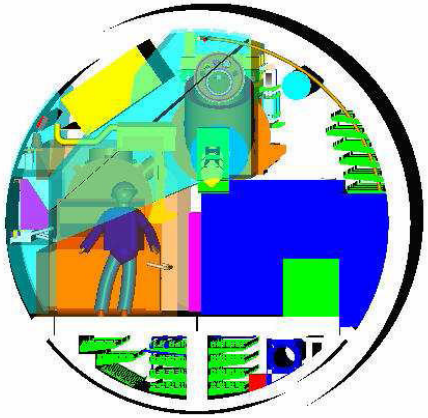
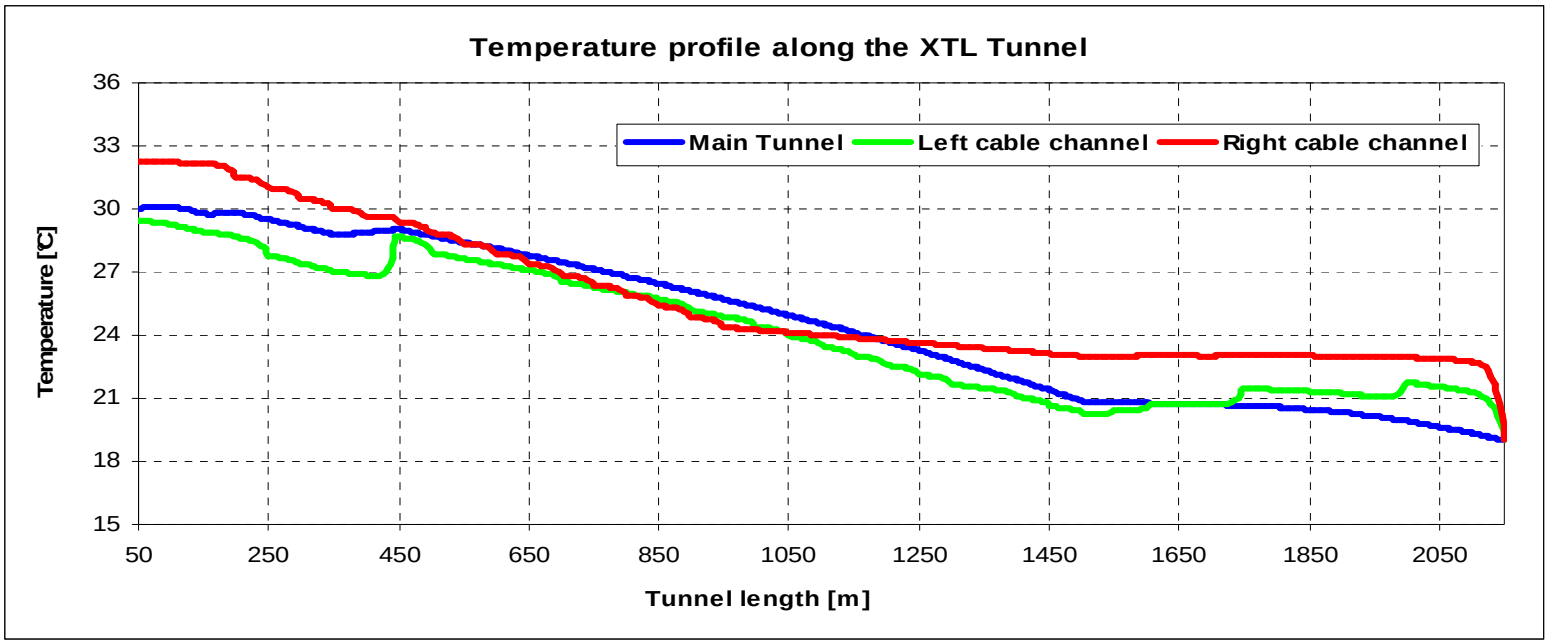
- Tunnel in the winter: θZL = 19 ° C
- Start of commissioning: h = 1.2 W/(m²K)





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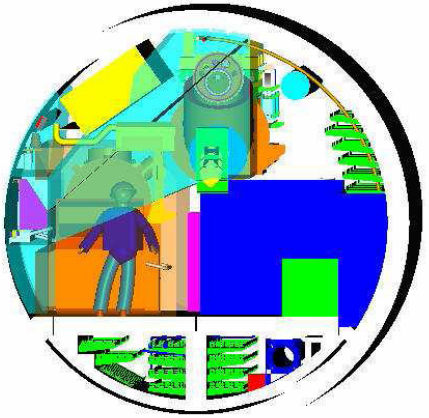
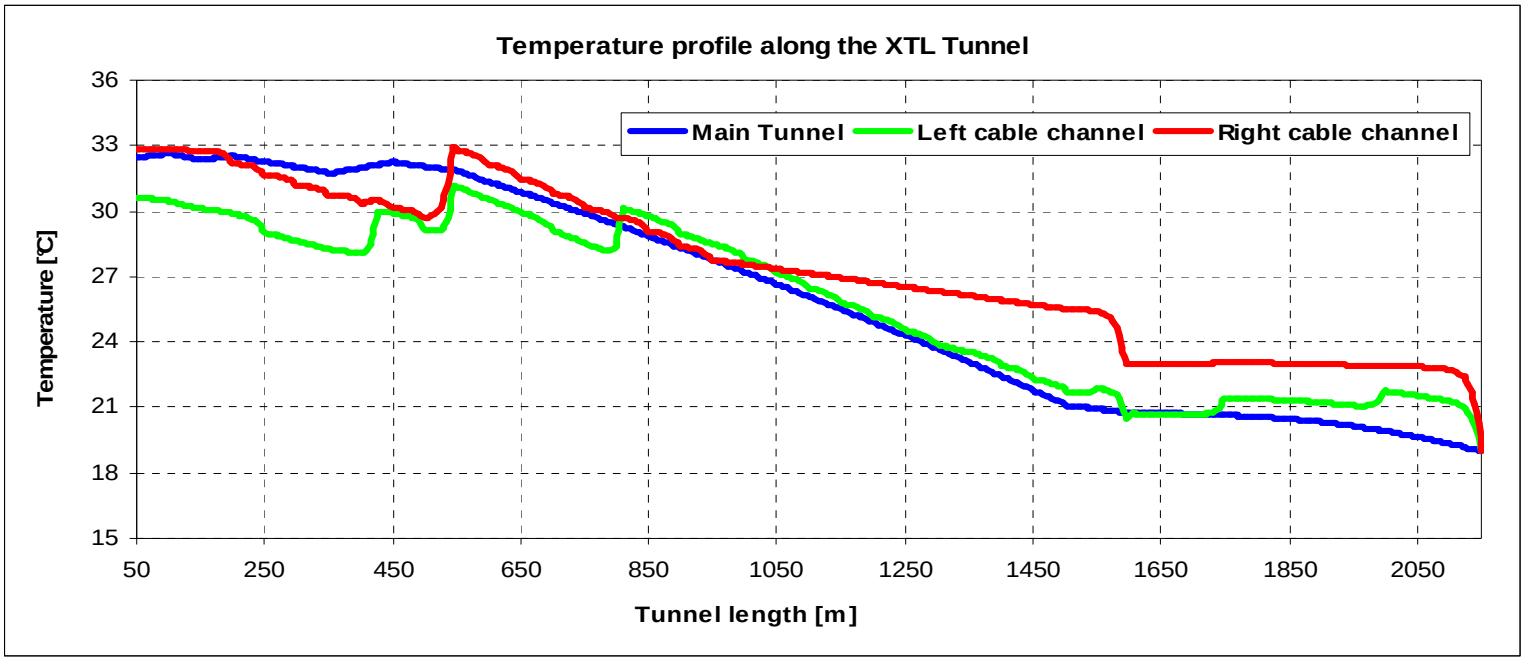
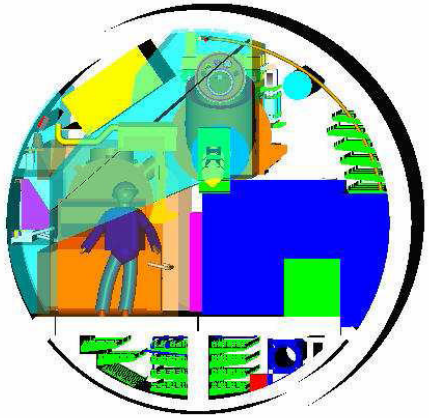
- Tunnel in the winter θZL = 19 ° C
- After few years

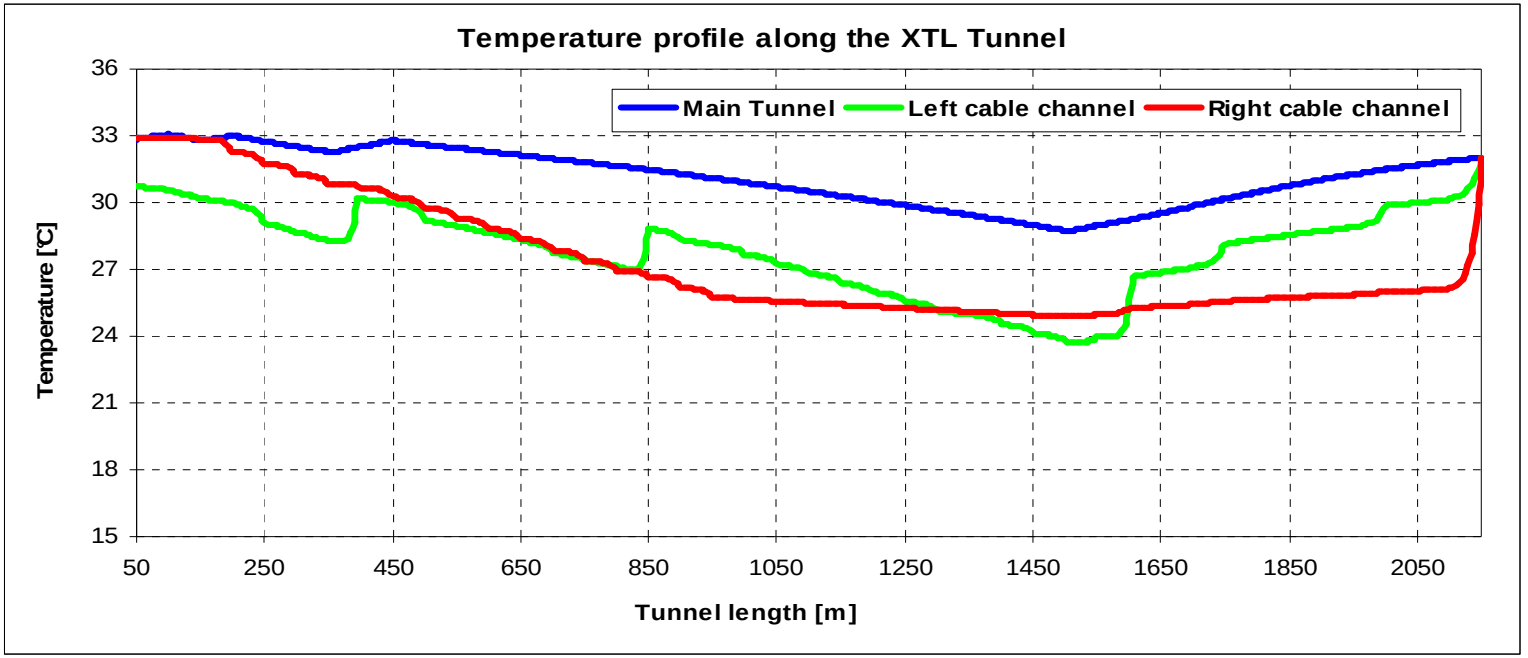




Temperature Calculation

- Tunnel in the summer θZL = 32 ° C
- Start of commissioning: h = 1.2 W/(m²K)





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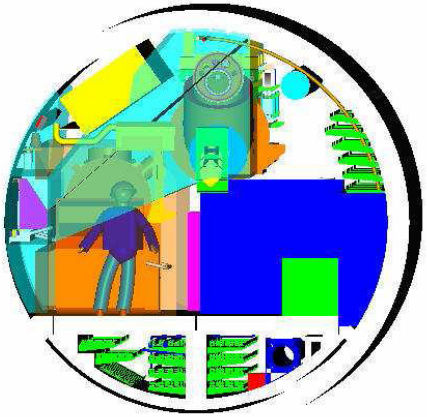
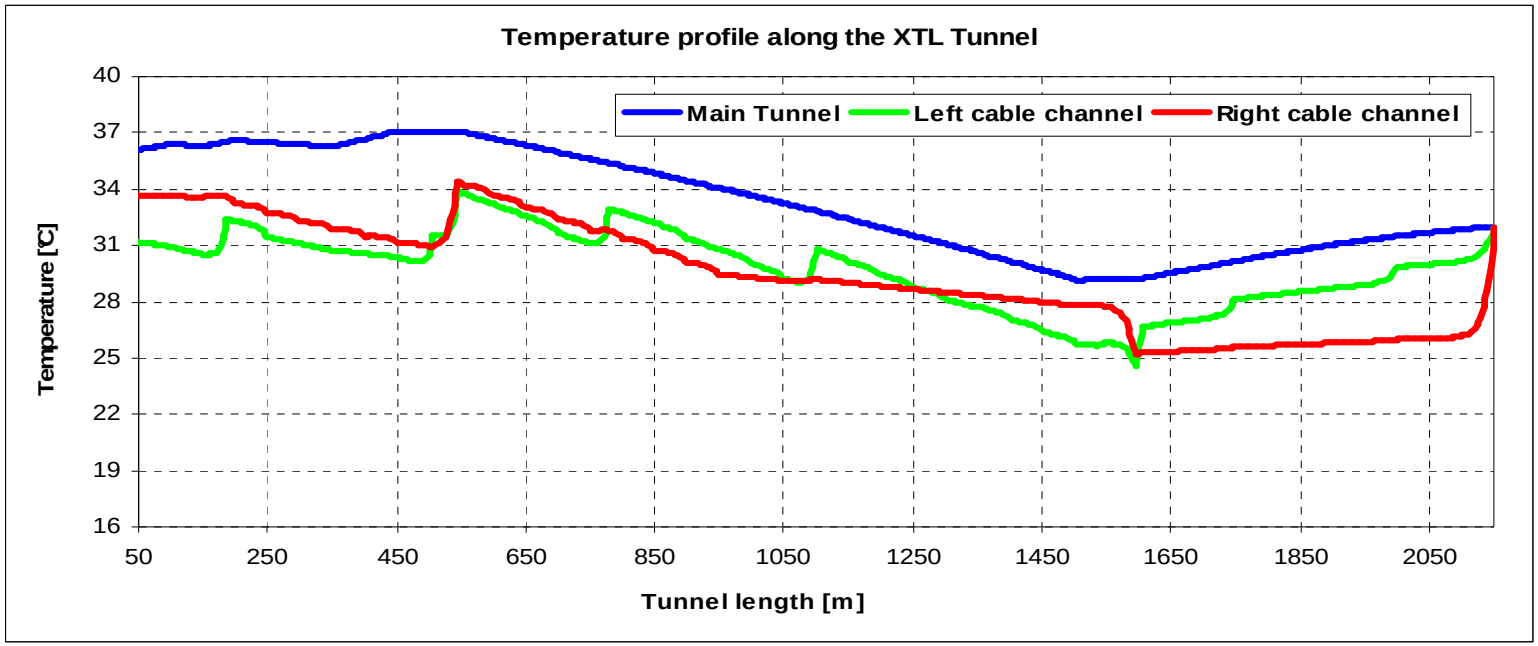
- After few years





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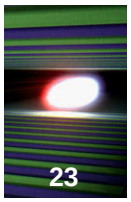

- Air volume : 60 000 m^3 / h
- Max. temperature about 29-37 ° C
- Temperature profile strongly depends on
  - the Inlet temperature
  - the geology of the ground
- Dynamic behaviour needed

Acknowledgement

- To many people from Work Packages of the XFEL
  - Jörg Eckoldt, Frank-Reinhard Ullrich, Slyke Feuker, Jens-Peter Jensen, Michael Koepke, Jan Havlicek,
  - and many other from MKK group

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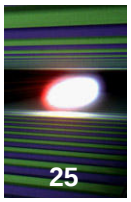

Thank you !