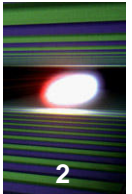


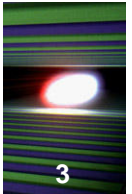


Temperature calculation

XFEL Tunnel ventilation and Air Conditioning
Workshop, Desy Hamburg, October 25&26th 2010
Narcisse Ngada, MKK/WP34

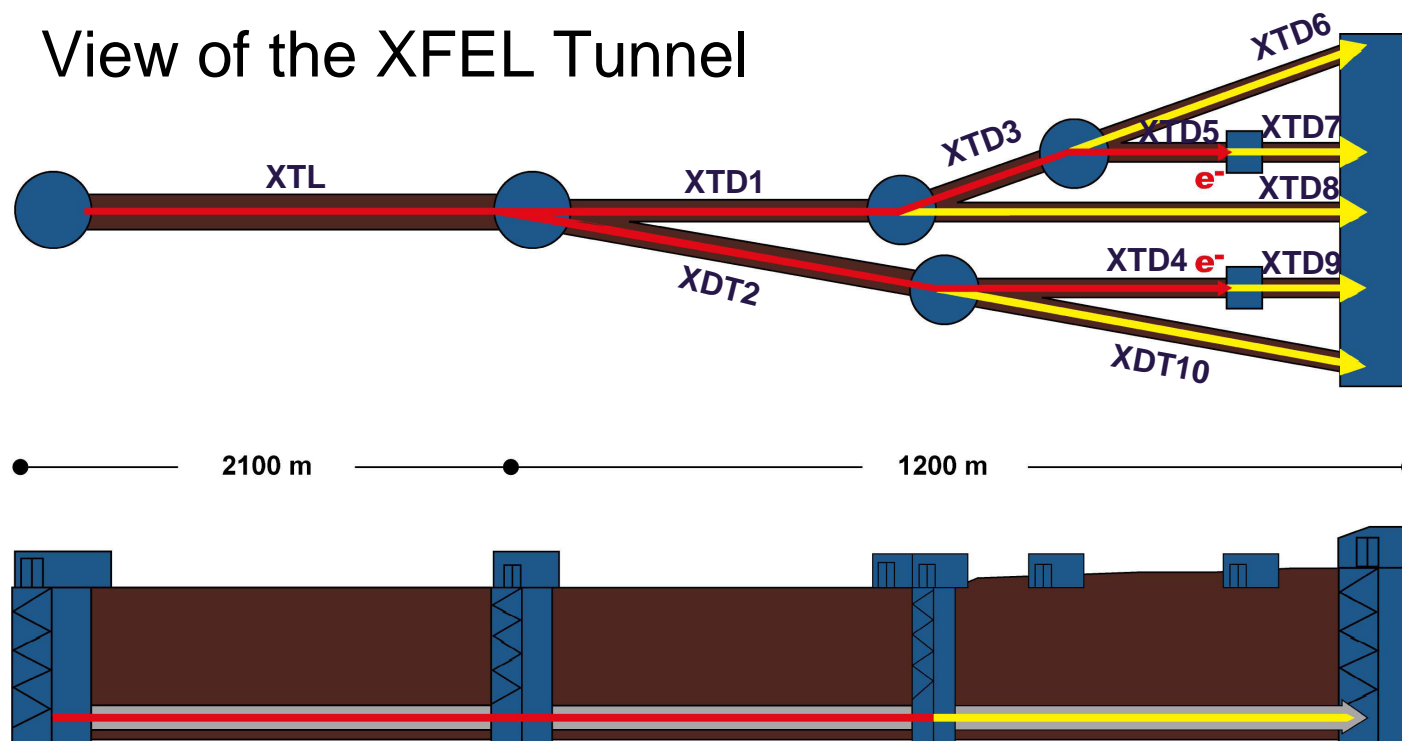


- Introduction
- XTL Tunnel design
- Mathematical approach
- Results
- Conclusion



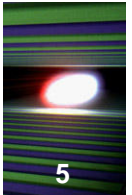
- Introduction
- XTL Tunnel design
- Mathematical approach
- Results
- Conclusion

View of the XFEL Tunnel



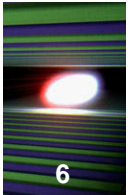
- Total length: about 3.4 km
- Underground tunnels
- Depth : 6 -38 m

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



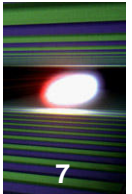
Why temperature calculation?

- 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



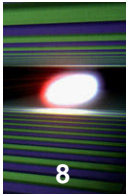
What should be considered (2)

■ Heat sources

- Light, Pulse cable, DC cables, HV-cables, LV-cables,
- Waveguide, Pulse transformer and matching network,
- Magnets (surface temperature),
- 30°C water pipe $\Delta T = 20^\circ\text{C}$ (in the right cable channel)

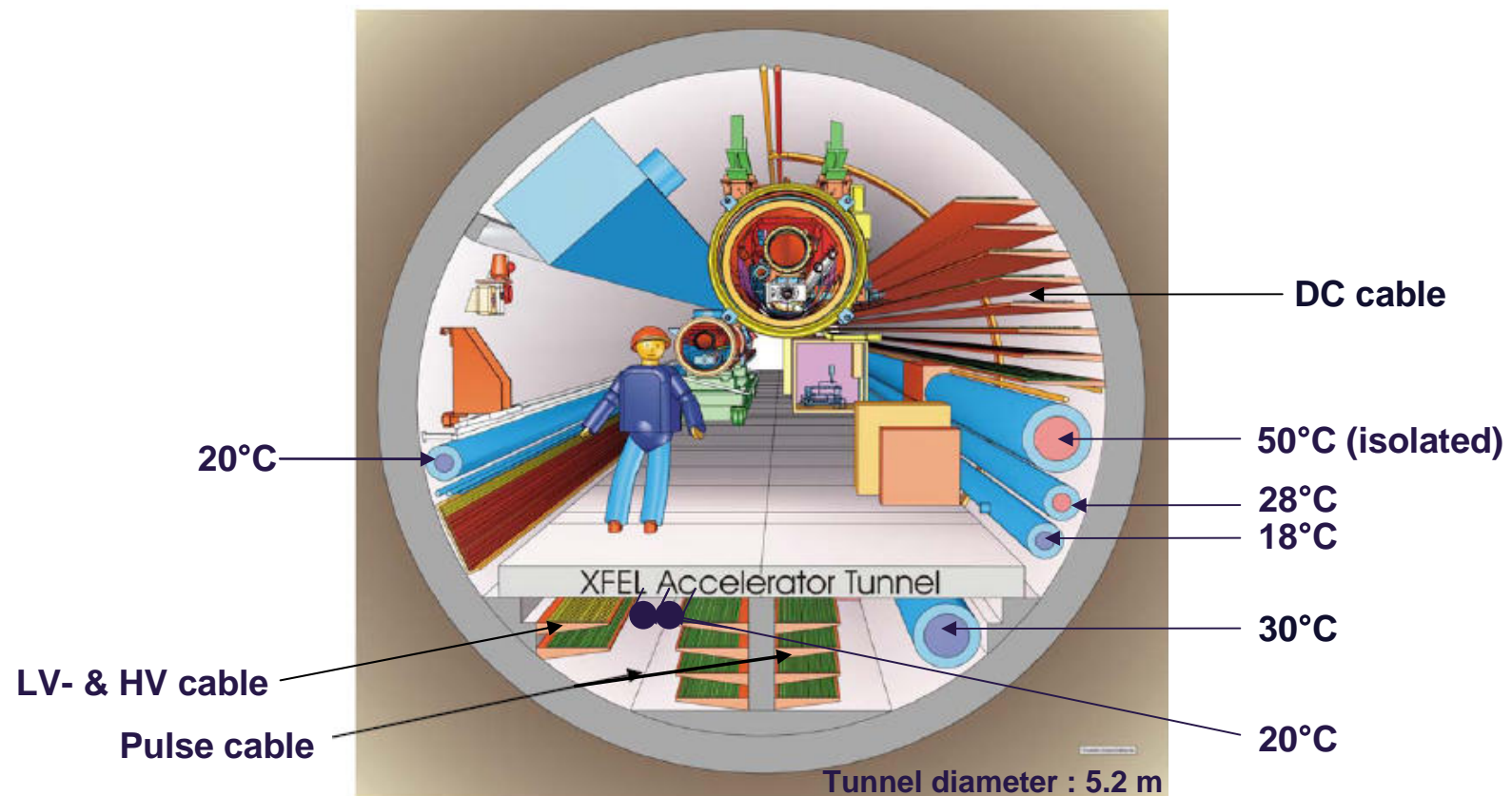
■ Heat sink

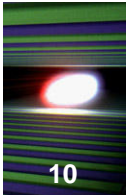
- The tunnel
- 18°C water pipe $\Delta T = 10^\circ\text{C}$ (in the main tunnel),
- 2x20°C water pipes (in the left cable channel)



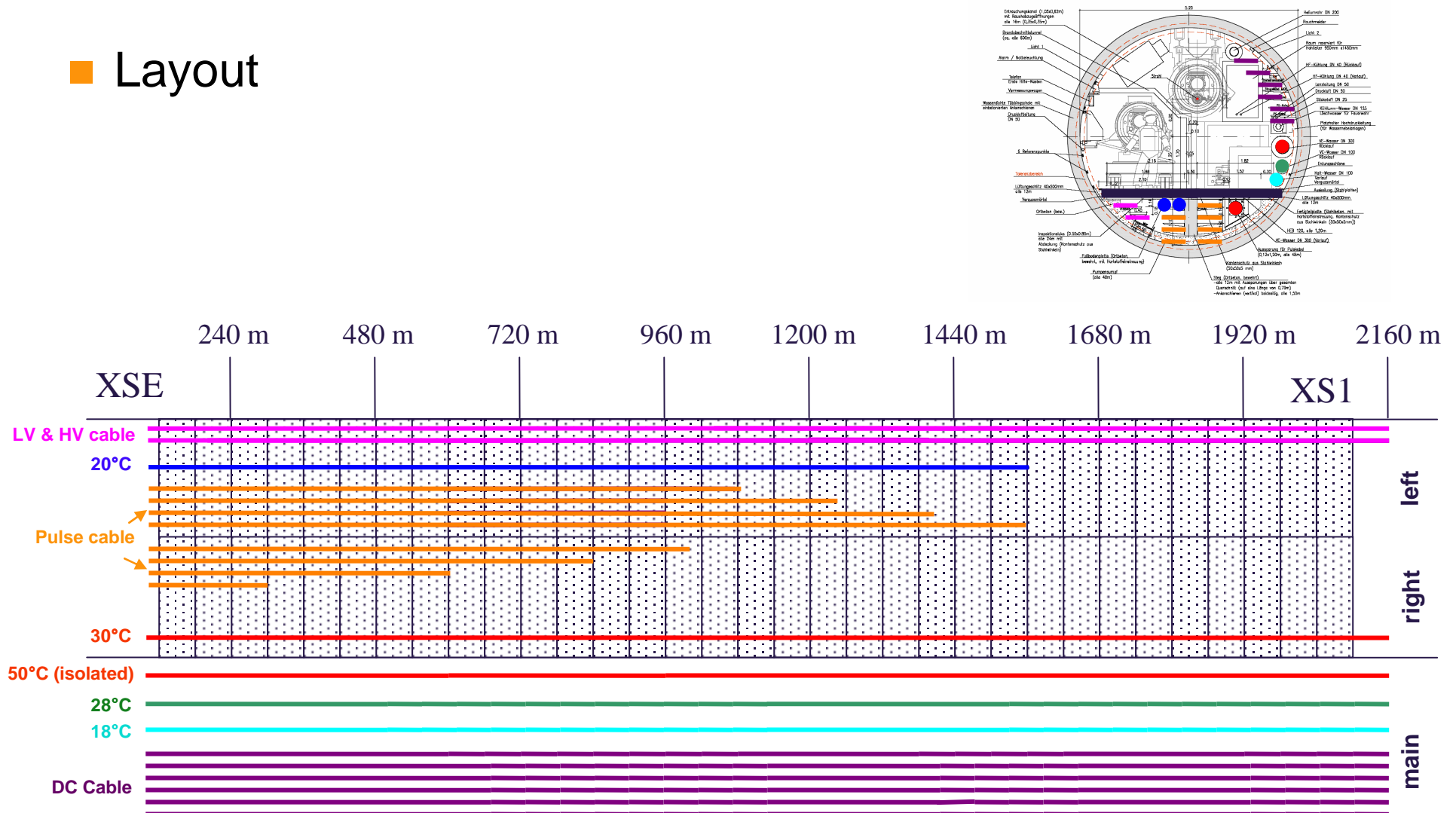
- Introduction
- **XTLTunnel design**
- Mathematical approach
- Results
- Conclusion

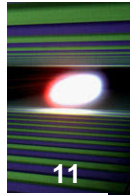
■ Cross section





Layout

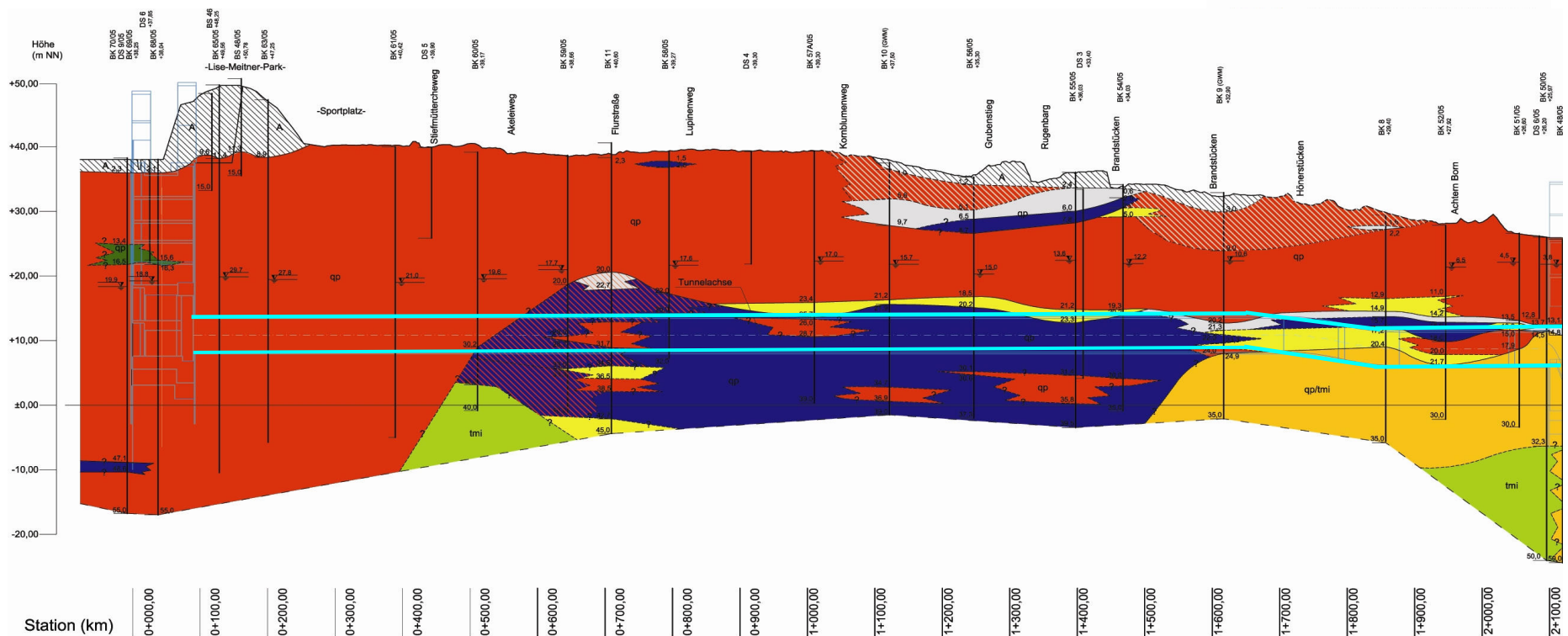


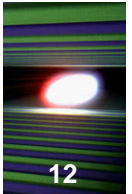


Geology

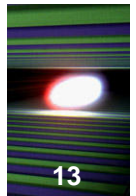
Legende:

- Auffüllung
- Schluffmudde / Torf (qh)
- Mittelsande / Feinsande (qh/qp)
- Sand (qp) / Geschiebelehmstreifen
- Grobsande / Kies (qp)
- Beckenschluff (qp)
- Geschiebelehm (qp)
- Geschiebelehm / Sandstreifen (qp)
- Geschiebemergel (qp)





- Introduction
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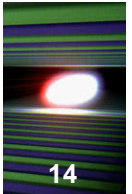
■ Fundamental equation of thermodynamics

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

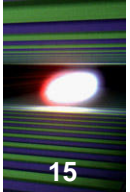
$$(2) \quad \frac{dT}{dx} = \frac{1}{m_L.c_P} \sum_i Q_i$$

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

(3) $\frac{\partial T_1}{\partial x} = f(T_1, T_2, T_3, m_{L1}, m_{L2}, m_{L3}, c_p, Q_1, Q_2, Q_3)$	Main tunnel
$\frac{\partial T_2}{\partial x} = f(T_1, T_2, T_3, m_{L1}, m_{L2}, m_{L3}, c_p, Q_1, Q_2, Q_3)$	Left cable channel
$\frac{\partial T_3}{\partial x} = f(T_1, T_2, T_3, m_{L1}, m_{L2}, m_{L3}, c_p, Q_1, Q_2, Q_3)$	Right cable channel



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



MATLAB and GUI

Variable Parameter

Wärmedurchgangskoeffizient im Mergel W/(m².K)

Wärmedurchgangskoeffizient im Grundwasser W/(m².K)

Luftgeschwindigkeit im Haupttunnel m/s

Luftgeschwindigkeit in Kabelkanäle m/s

Erbodientemperatur °C

Zuluftstemperatur °C

Modulatoren

☒ 10 Hz Betrieb ☐ 30 Hz Betrieb ☐ CW Betrieb

Tunneldaten

Haupttunnel

<> **Bogen** Abdeckung

<> **Platte links** Abdeckung

<> **Platte rechts** Abdeckung

<> **Fläche** Abdeckung

Linker Kabelkanal

<> **Bogen** Abdeckung

<> **Platte links** Abdeckung

<> **Wand** Abdeckung

<> **Fläche** Abdeckung

Rechter Kabelkanal

<> **Bogen** Abdeckung

<> **Platte rechts** Abdeckung

<> **Wand** Abdeckung

<> **Fläche** Abdeckung

Wärmequelle im Tunnel [W/m]

Haupttunnel

☐ Gleichspannungskabel

☐ Niederspannungskabel

☐ Mittelspannungskabel

Hohlleiter W/m

Luftmenge m³/h

Licht **AUS** W/m

Linker Kabelkanal

☐ Niederspannungskabel

☐ Mittelspannungskabel

☐ Puls kabel linksseitig

Luftmenge m³/h

Luftmenge kg/s

Ohne Wasserrohr

Wassertemperatur °C

Wasserdichte [rho] kg/m³

Rechter Kabelkanal

☐ Niederspannungskabel

☐ Mittelspannungskabel

☐ Puls kabel rechtsseitig

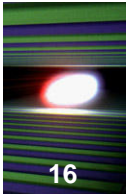
Luftmenge m³/h

Luftmenge kg/s

Netzgeräte

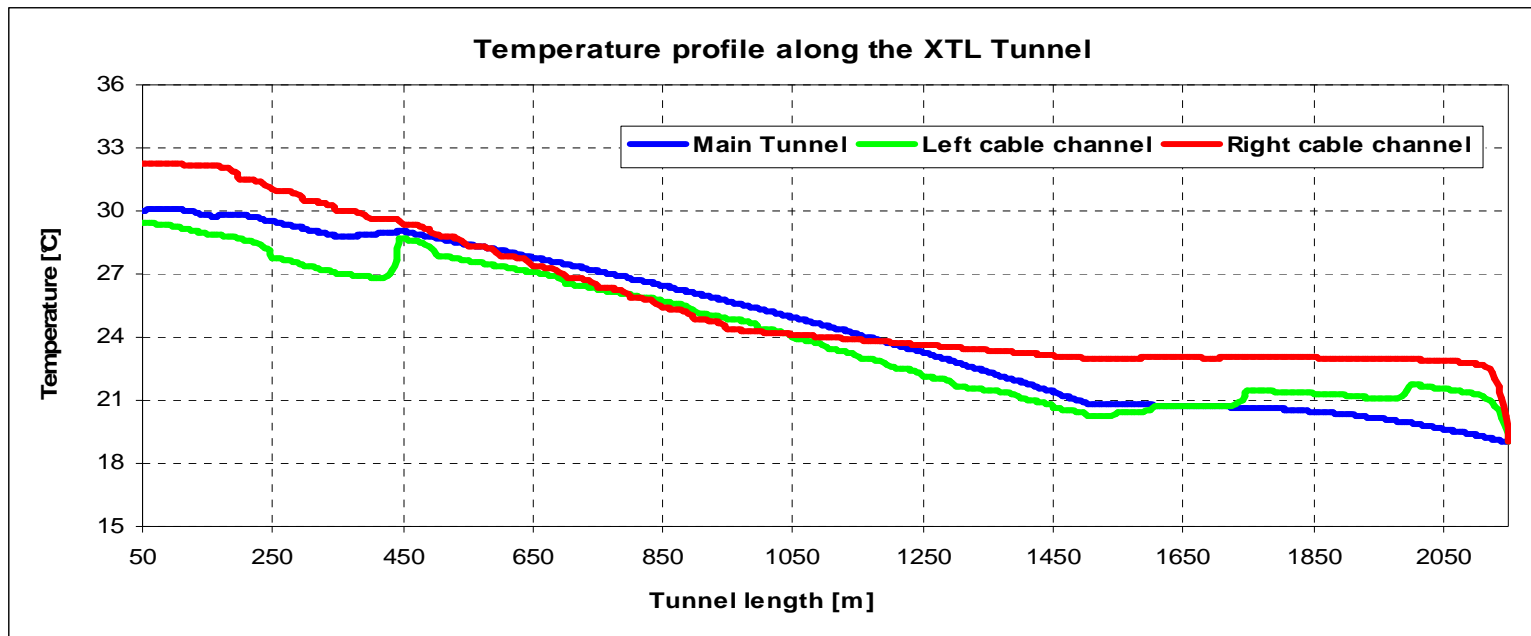
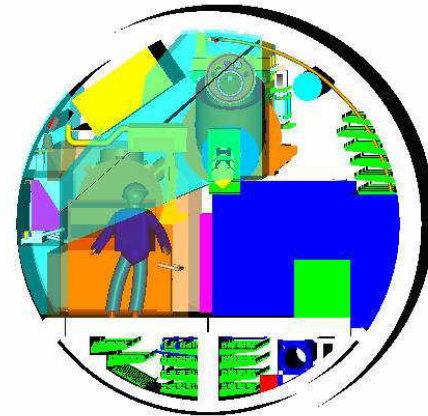
☒ Messwerte ☐ Maximale Werte ☐ Optische Werte

Bild drucken



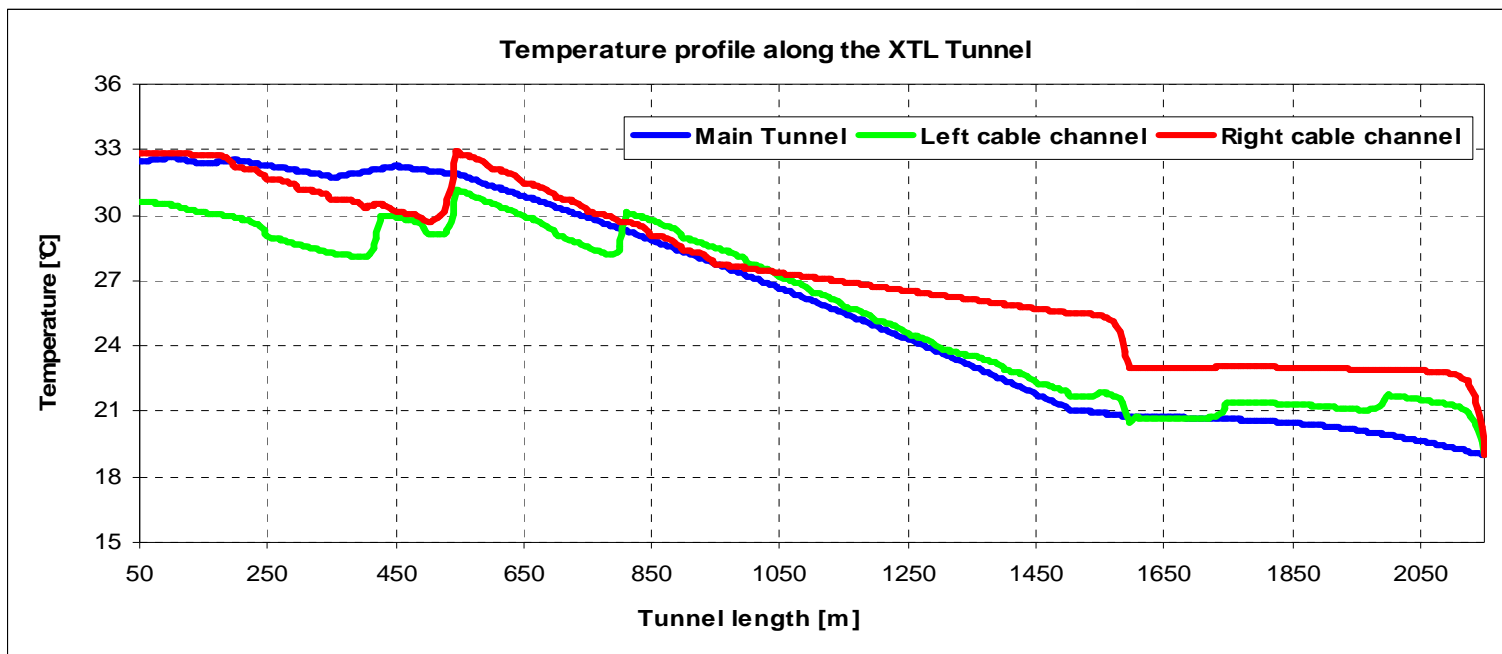
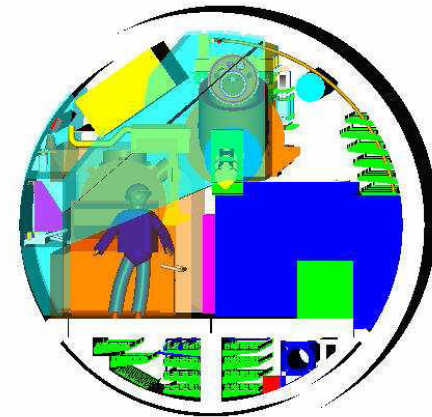
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- Tunnel in the winter: $\theta_{ZL} = 19^\circ \text{C}$
- Start of commissioning: $h = 1.2 \text{ W}/(\text{m}^2\text{K})$

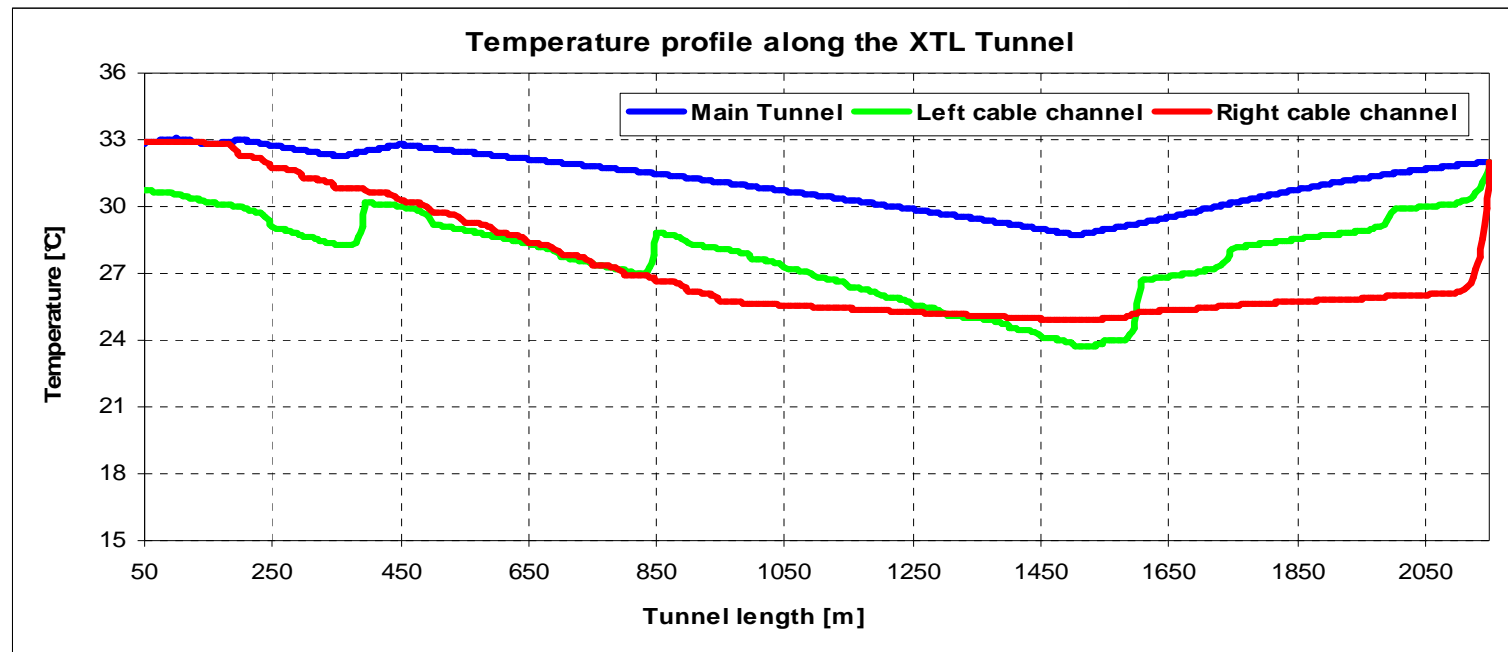
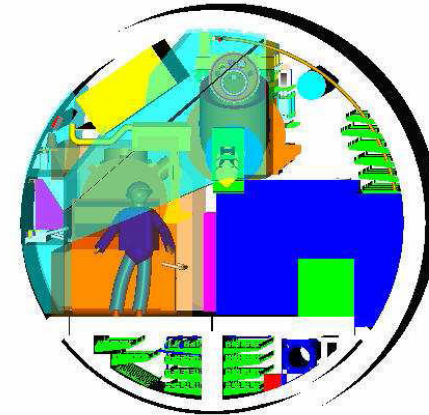




- Tunnel in the winter $\theta_{ZL} = 19^\circ \text{C}$
- After few years

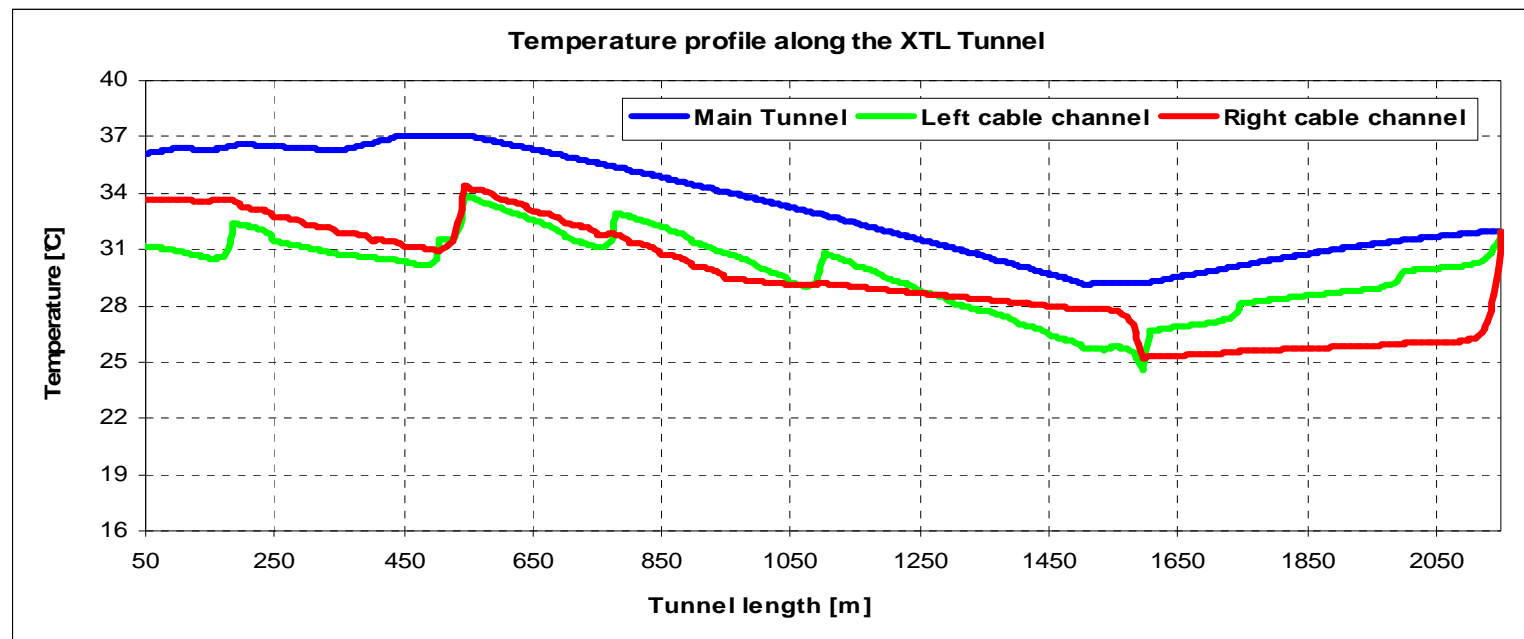
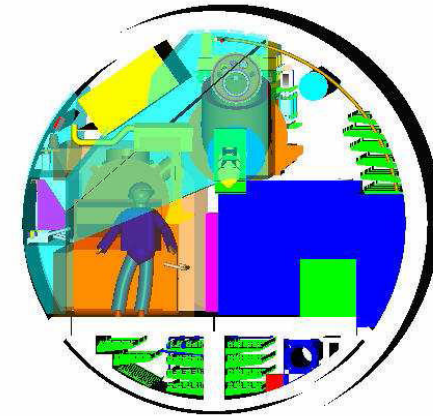


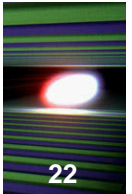
- Tunnel in the summer $\theta_{ZL} = 32^\circ \text{C}$
- Start of commissioning: $h = 1.2 \text{ W}/(\text{m}^2\text{K})$



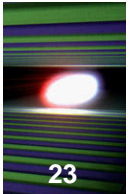


- Tunnel in the summer $\theta_{ZL} = 32\text{ }^{\circ}\text{C}$
- After few years





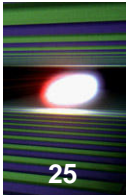
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- Air volume : 60 000 m³ / h
- Max. temperature about 29-37 ° C
- Temperature profile strongly depends on
 - the Inlet temperature
 - the geology of the ground
- Dynamic behaviour needed

Acknowledgement

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



Thank you !