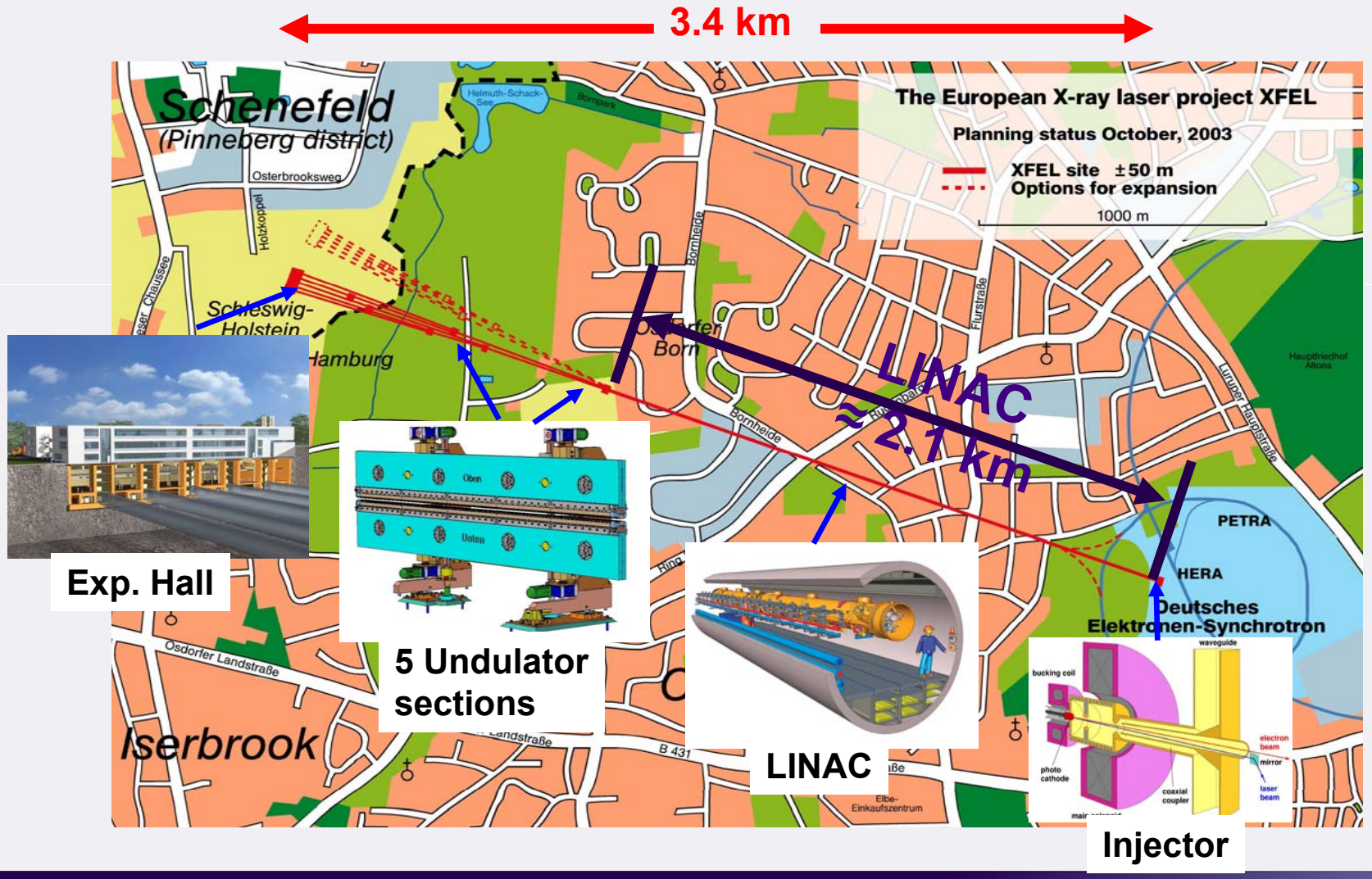
The Single Tunnel Solution(s) for the XFEL Superconducting e^--LINAC

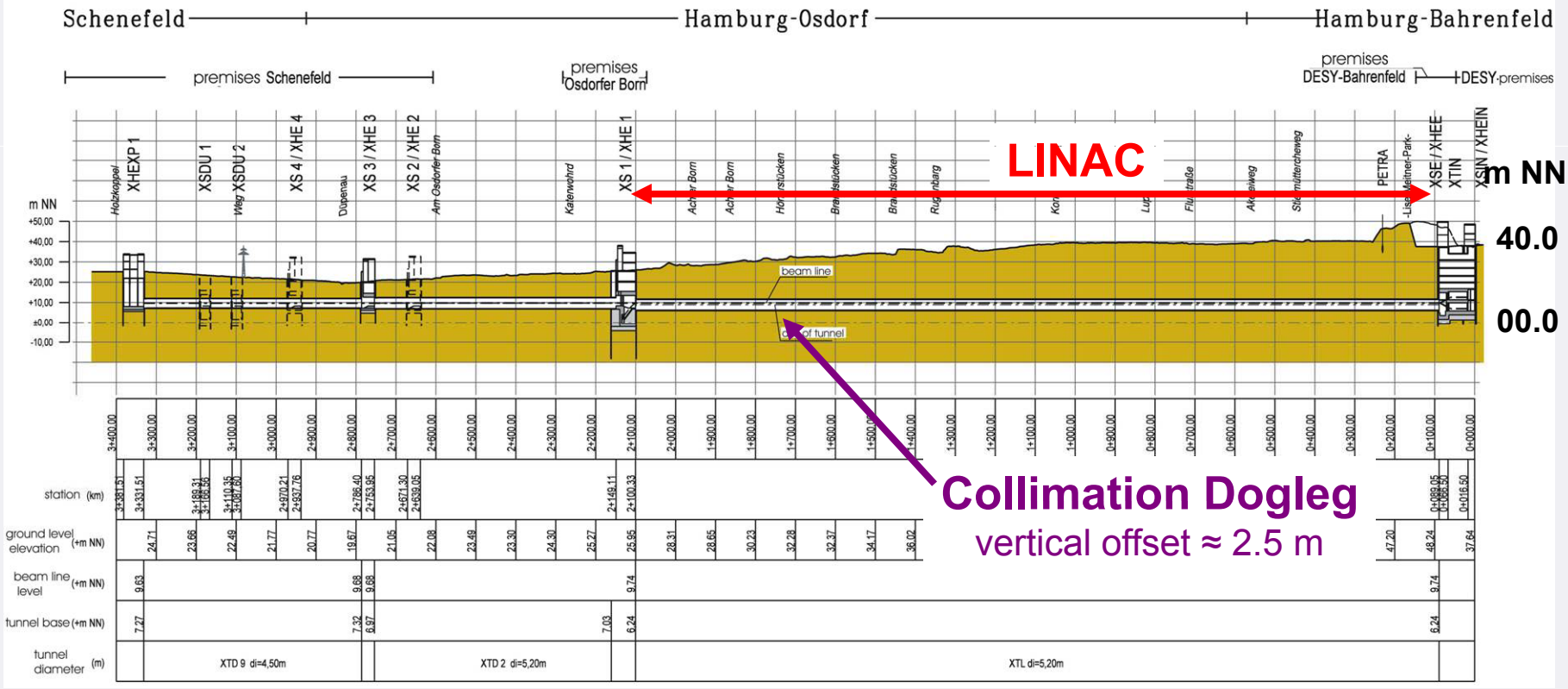
Overall layout of the European XFEL



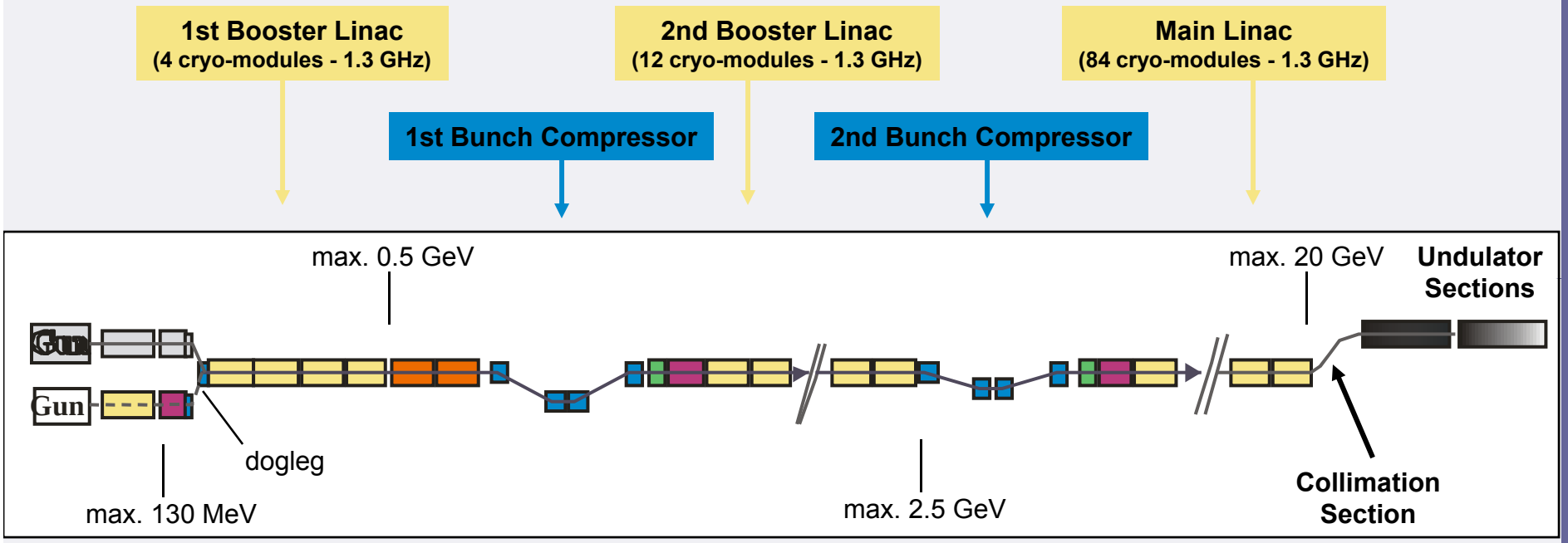
Shallow Tunnel - Soil coverage between 8 - 35 m

Schenefeld Campus **Osdorfer Born** **DESY**

Soil = basically marle
-> partly inside ground water



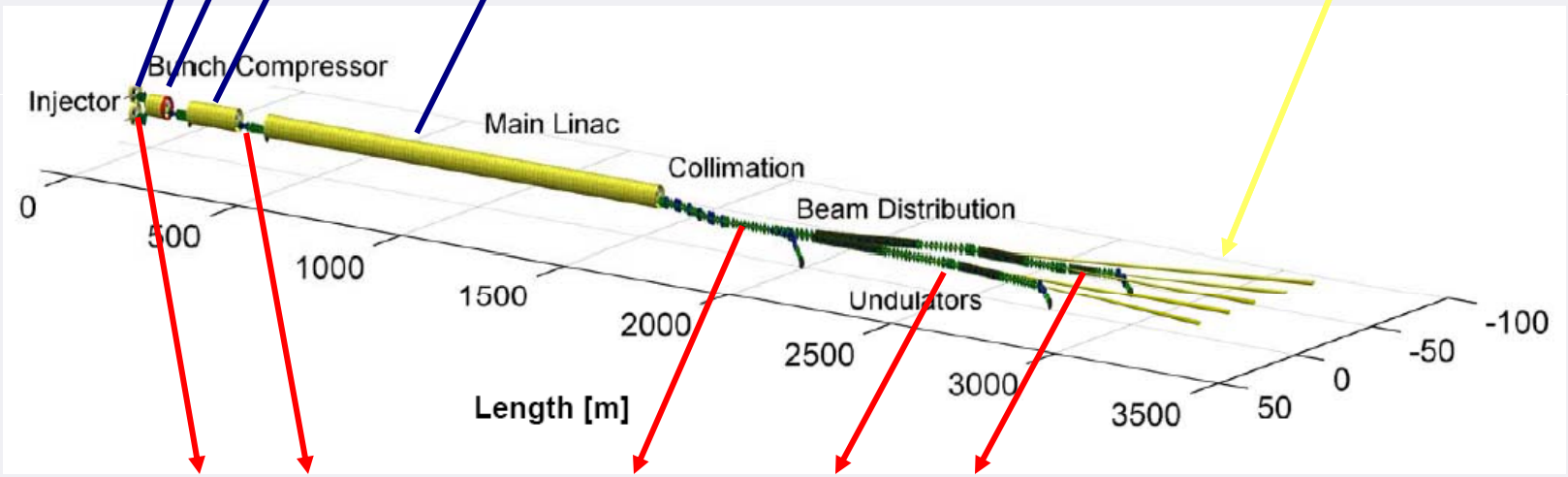
XFEL LINAC - General Layout



XFEL e⁻-Machine Layout

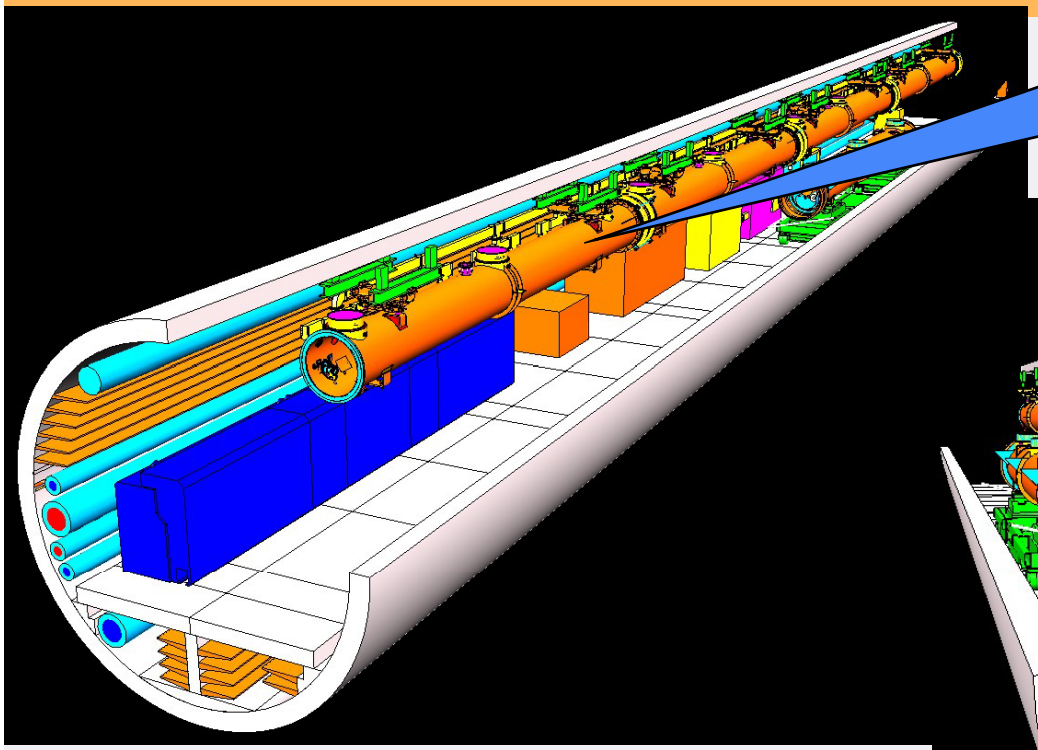
Superconducting cavities & cold vacuum systems

Photon beam lines

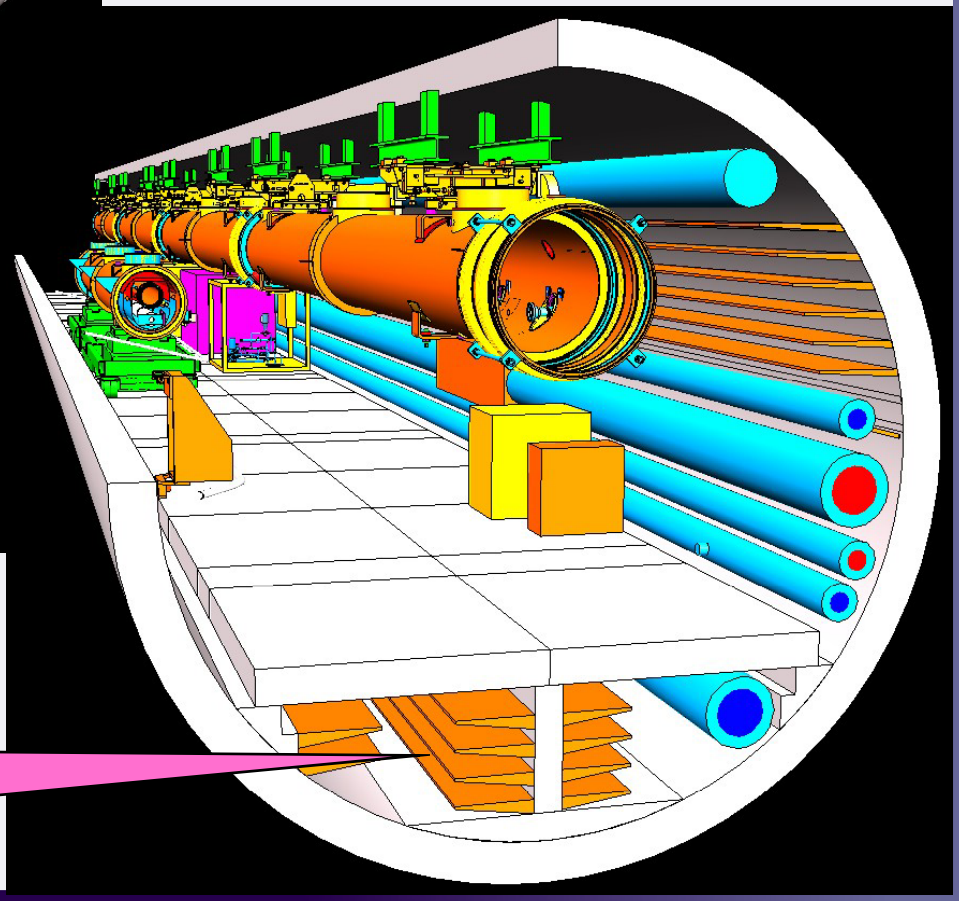


Warm beam line sections = Room temperature vacuum systems

Tunnel - Basic Layout Ideas

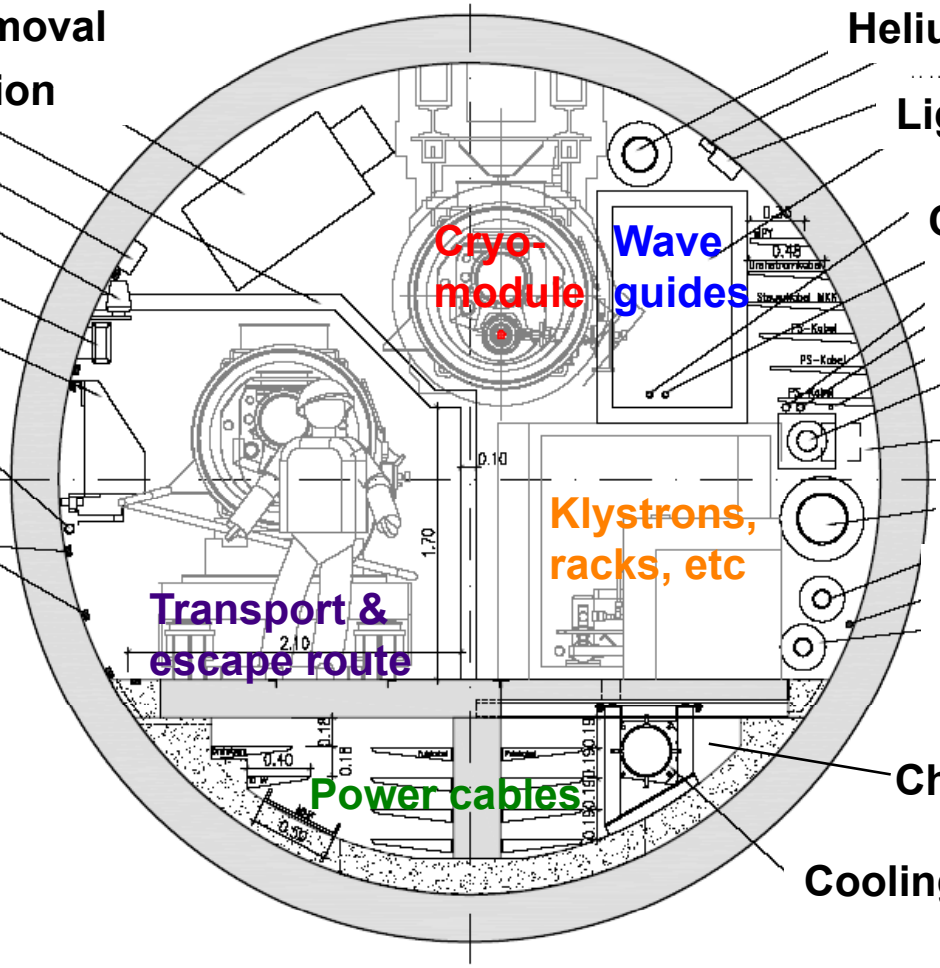


Accelerator modules are suspended from the ceiling to provide maximum space underneath for equipment and to grant 'access' to the floor slabs



Underfloor space will be used for infrastructure installations -> Pulse cables, 10kV Lines, cooling water

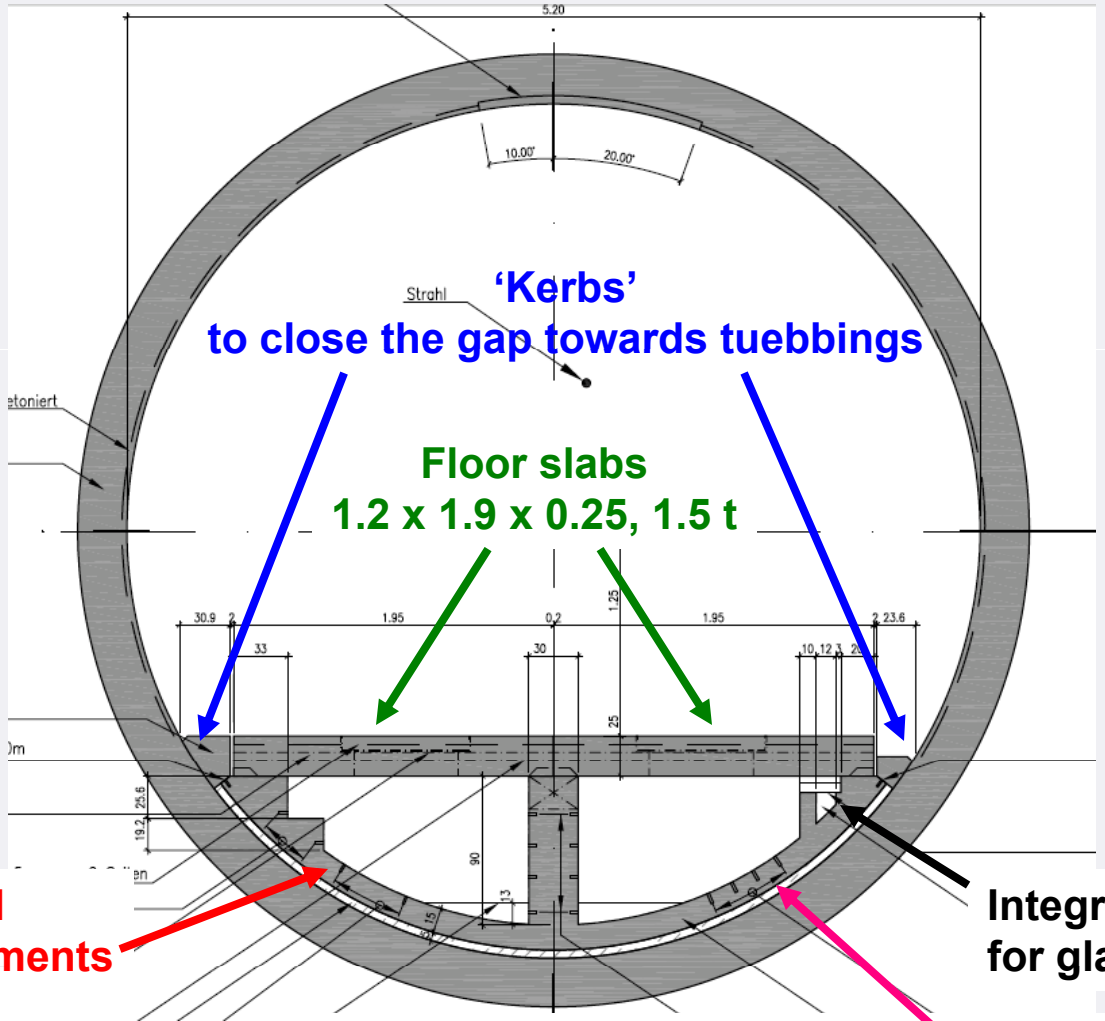
Tunnel cross-section @ modules - Technical layout



Duct for smoke removal
Fire safe separation
Lights
Alarm svstems
Phone
Survey trolley
Compressed air
Survey marks

Helium exhaust line
Lights
Cable trays
Water for cooling towers & 'normal' fire fighting
High pressure water for fire fighting
Cooling water 30° (ret.)
Cooling water 18° (ret.)
Cooling water 18° (in)
Channel for glass fibres
Cooling water 30° (in)

Complicated floor / underfloor construction



Floating pre-casted high precision segments 1.20 m in Z

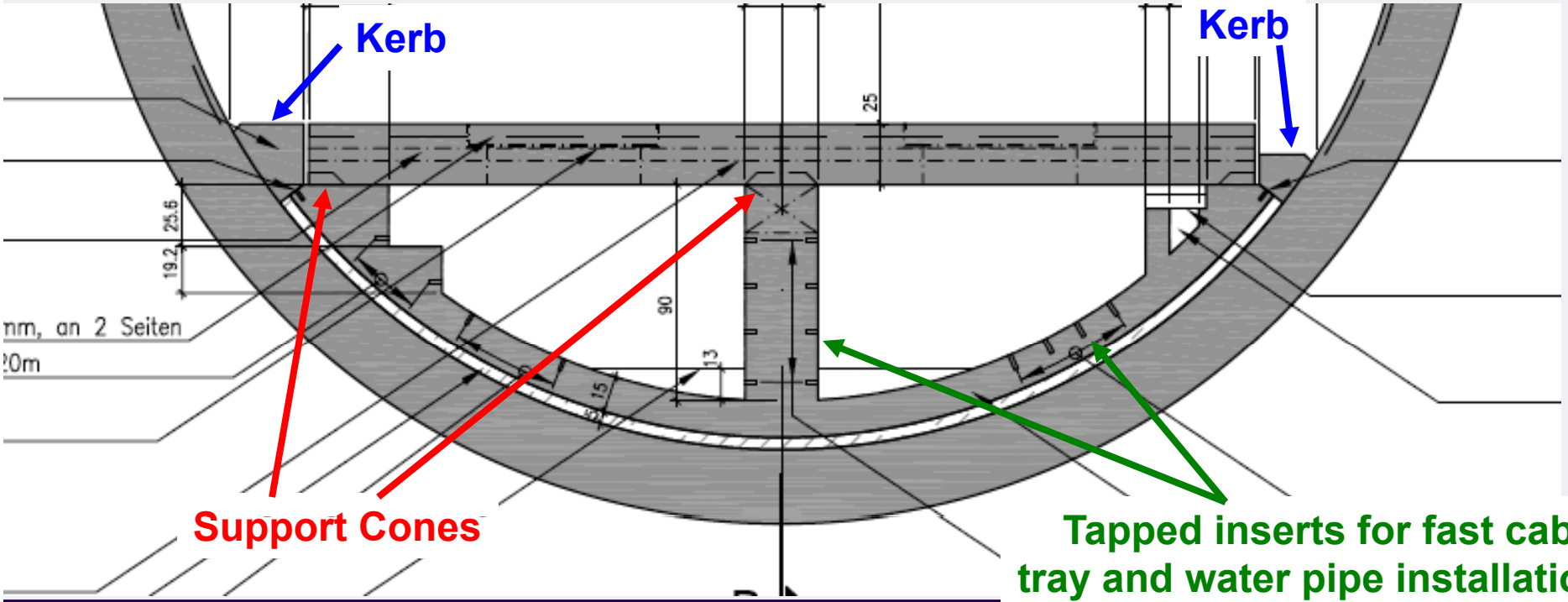
Integrated channel for glass fibres

In-situ mortar layer for gap filling towards tuebbing shell

Complicated floor / underfloor construction

Each floor slab rests on 4 cones -- one at each corner -- to ensure perfect fit and its remain in position, even when heavy transports pass.
→ Gaps and vertical offset between adjacent slabs ≤ 2 mm !!!

Loosely inserted kerbs provide drain channels -- to ensure that any water from above the slabs is guided quickly in the underfloor chambers towards pump sumps



Special Floor Slab Lifter

Laying floor slabs will be far from trivial:

Weight = 1.5 t, Size = 1.2 x 1.9 x 0.25 m

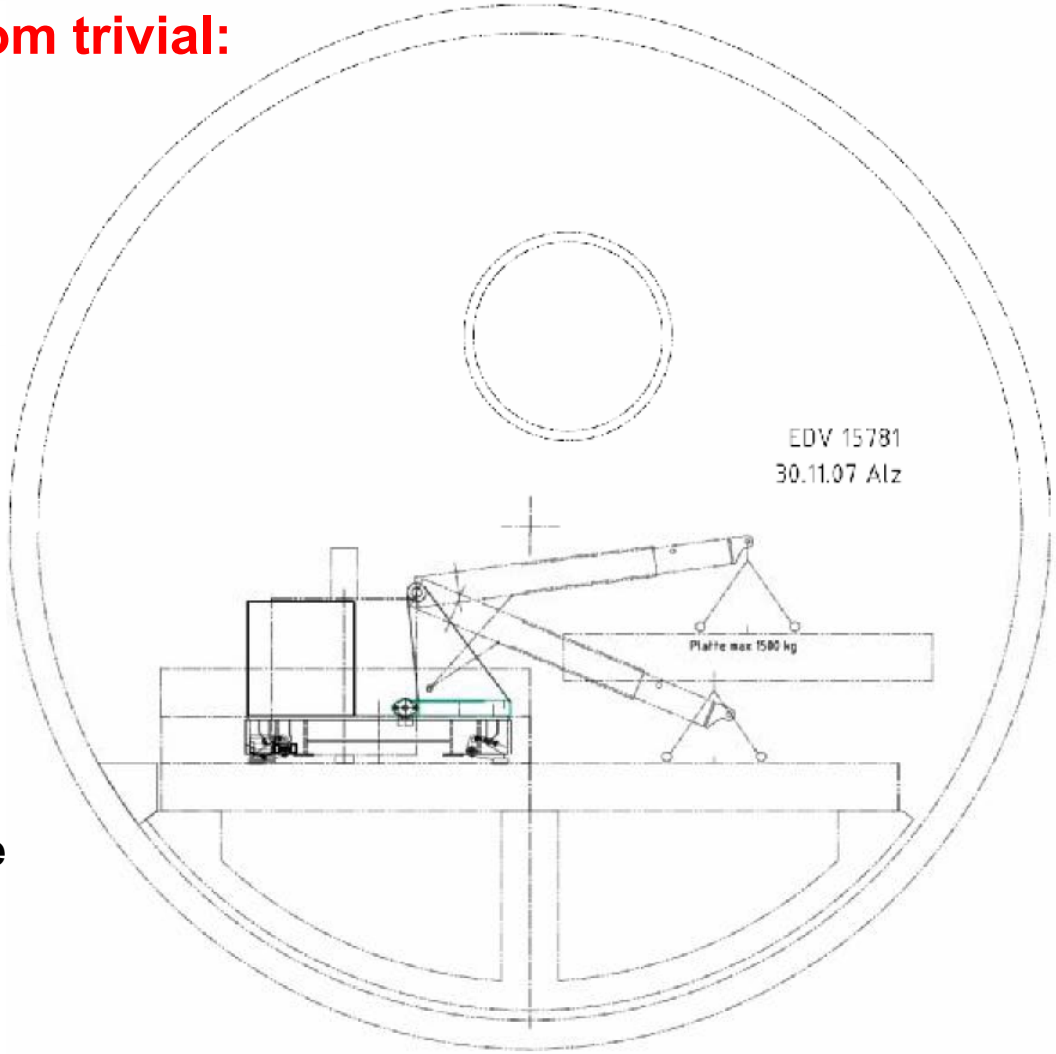
Placing precision < 1 cm

At first only one side must be laid to provide a transport lane while granting access to the other side's cable chamber

Later on slabs must be swapped several times during primary infrastructure installation

Finally all slabs have to be laid -> in front and aside, while slab supply comes from behind

It might be necessary/must be possible to take some slabs, while equipment is already installed in the proximity -> without damaging anything

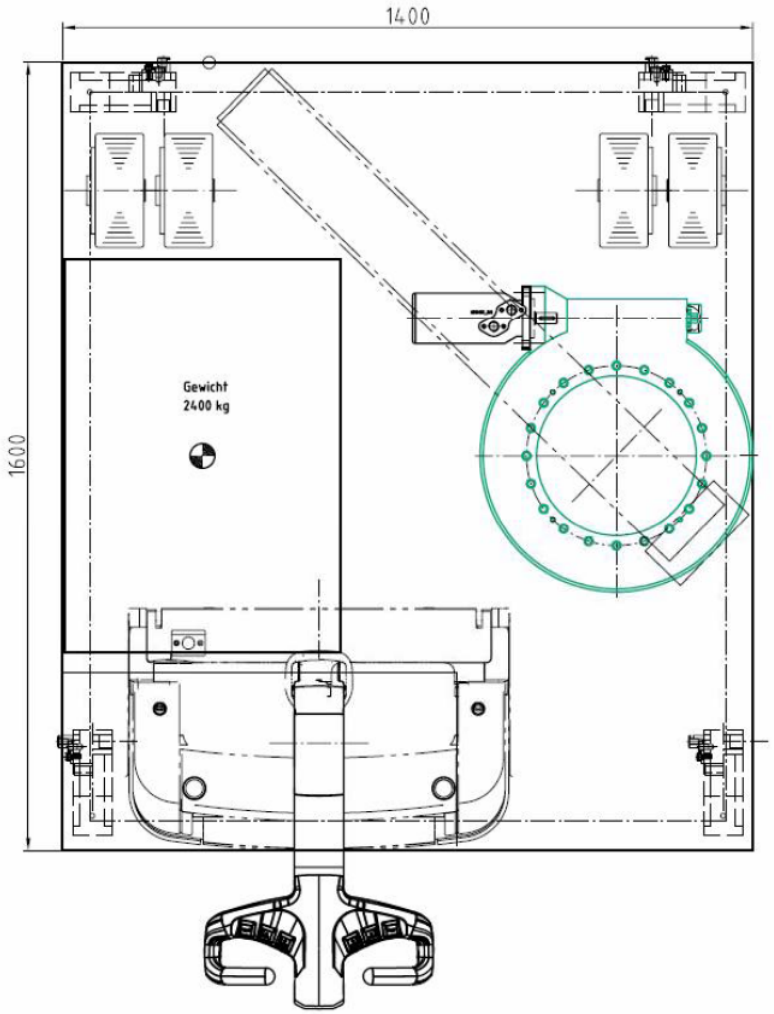


Special Floor Slab Lifter

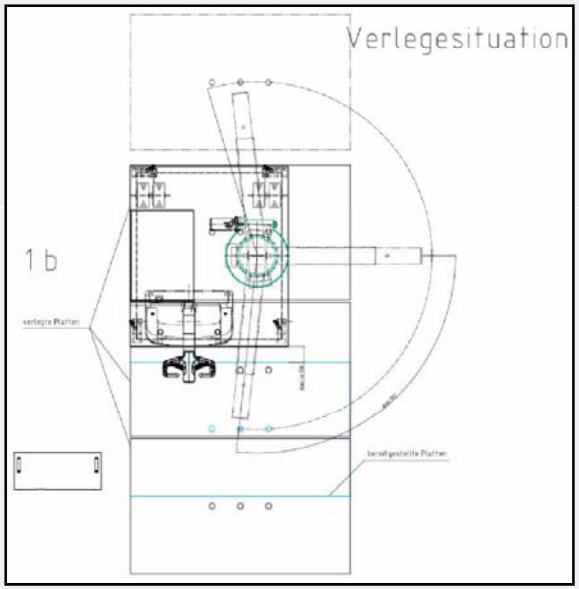
- Drive taken from a "off the shelf" pallet truck
- Custom made modified

(It's not the right one.)

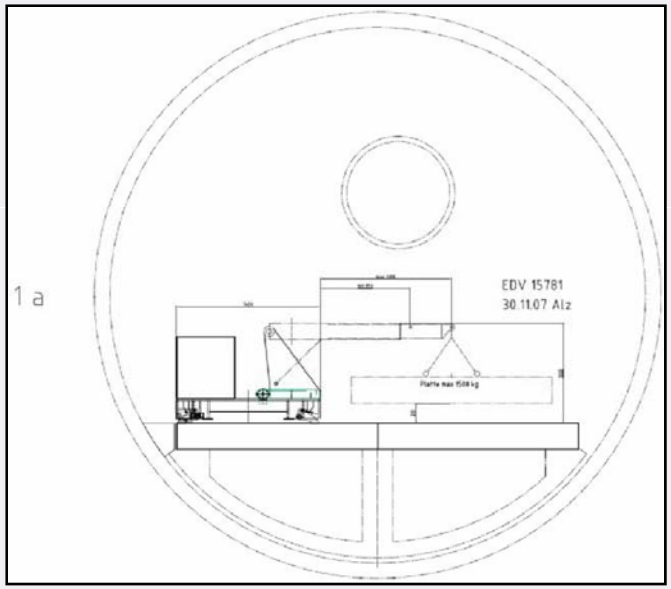
- Steered by a tiller
- Cable based remote control for the crane
- Rests on jacks during crane operation
- 2.4 t counterweight



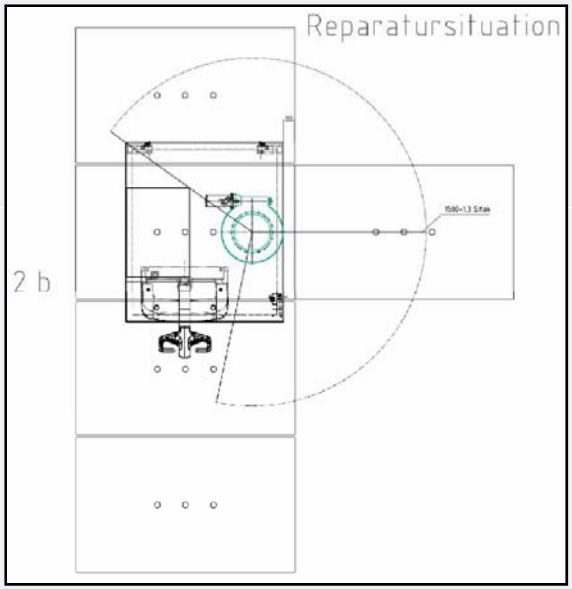
Special Floor Slab Lifter



Forward laying
- top view -



- side view -

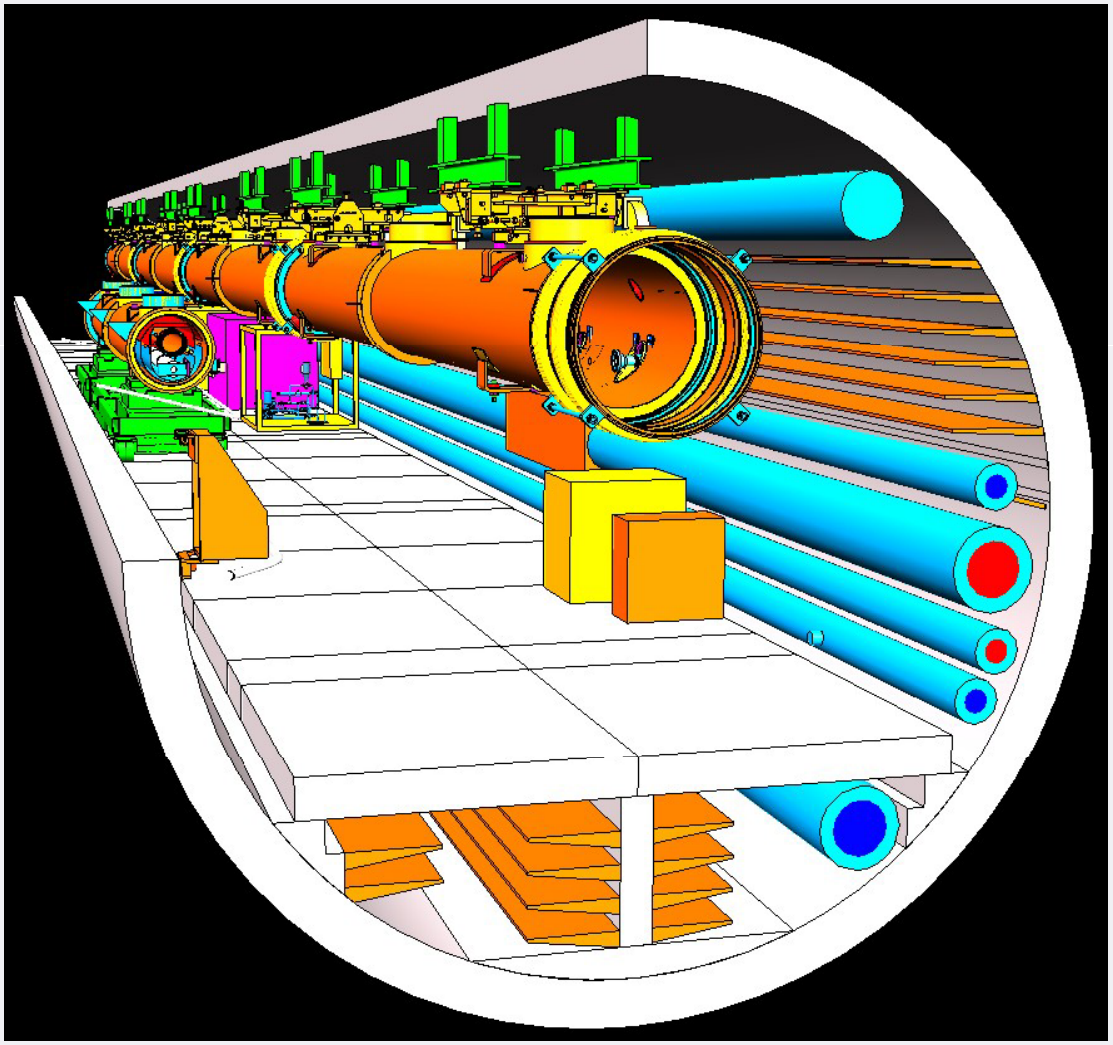


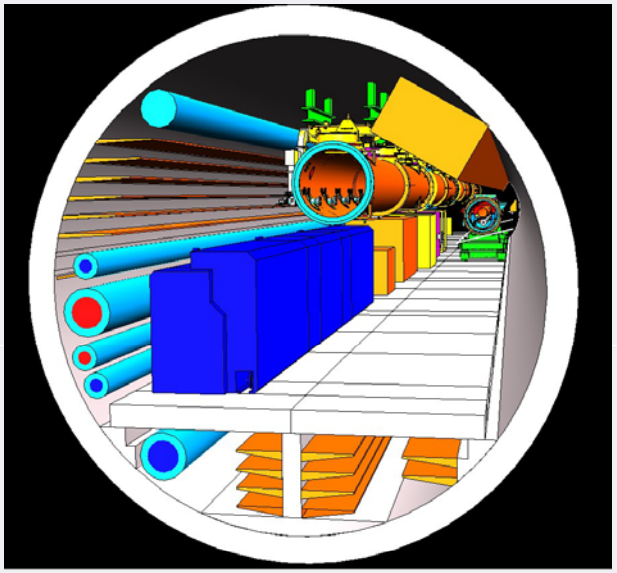
Aside laying
- top view -

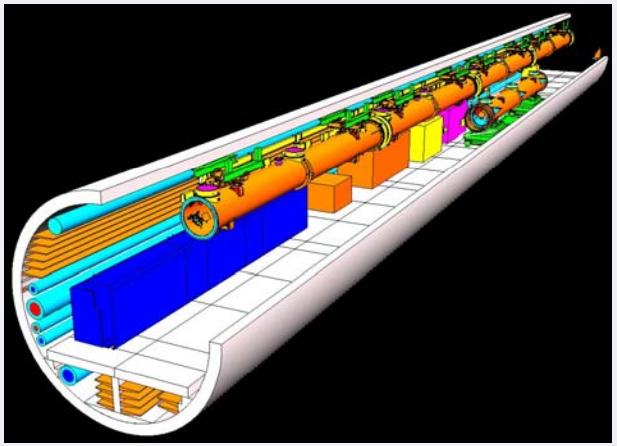
Conclusions about underfloor construction

- The singe tunnel design forces to use the space underneath the floor slabs for placing the pulse cables for the klystrons, 10 kV lines and cooling water forerun (DN 300)
- The most appropriate way in terms of civil construction efficiency, future access, high (floor) point loads (≤ 5t) seemed for us to be high-precision pre-casted segments, which are covered by 2 high-precision pre-casted floor slabs each
- This will be quite expensive compared to a compact in-situ concreted floor
- This might, but not necessarily, require some extra time for the civil construction
- This design requires a special slab lifter
- It requires about 60 weeks of primary infrastructure installation before first machine components can be installed (might not necessarily be a disadvantage)
- It allows to get everything installed in 1 tunnel and safes the costs for a second one

Hanging Accelerator Modules





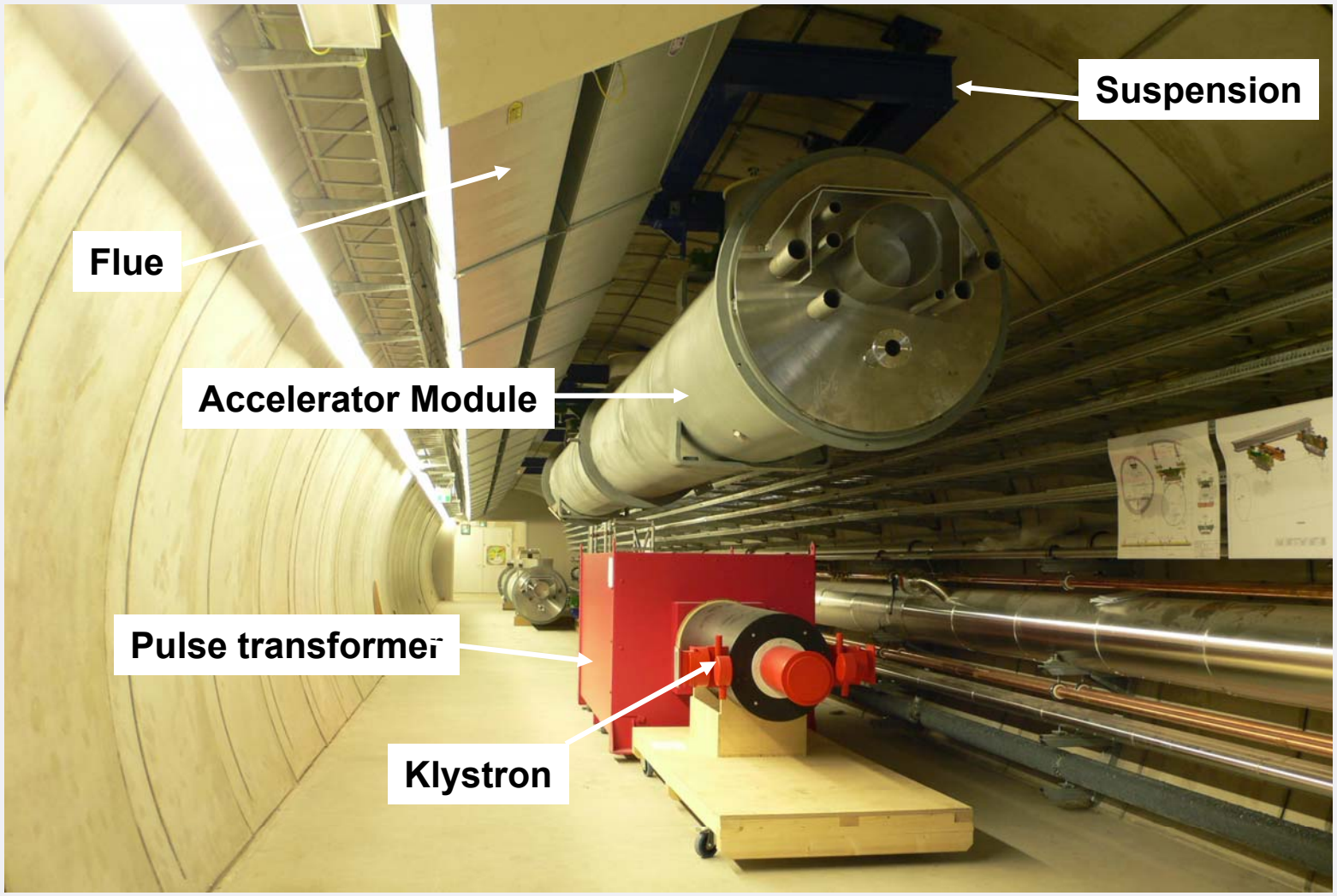


Module Suspension

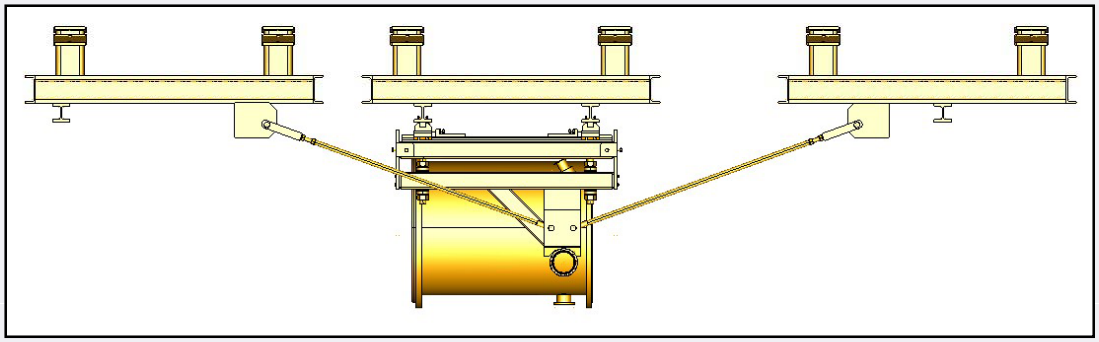
Welded ceiling interfaces
- 2 per cryomodule -

Alignment & suspension mechanics:
- **1 side fixed, other side longitudinally sliding**
- **3 Point suspension**
- **Alignment via turnbuckle tie rods**

Hanging Accelerator Modules -> XFEL Mock-Up



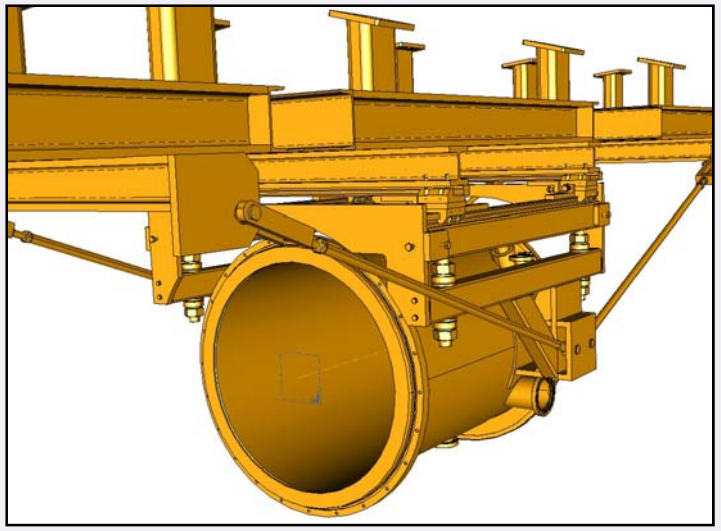
Suspension of Cryoboxes



Cryoboxes are required at each beginning and end of a cold section, as well as each 12 modules, for controlling the He flow and providing vacuum barriers.

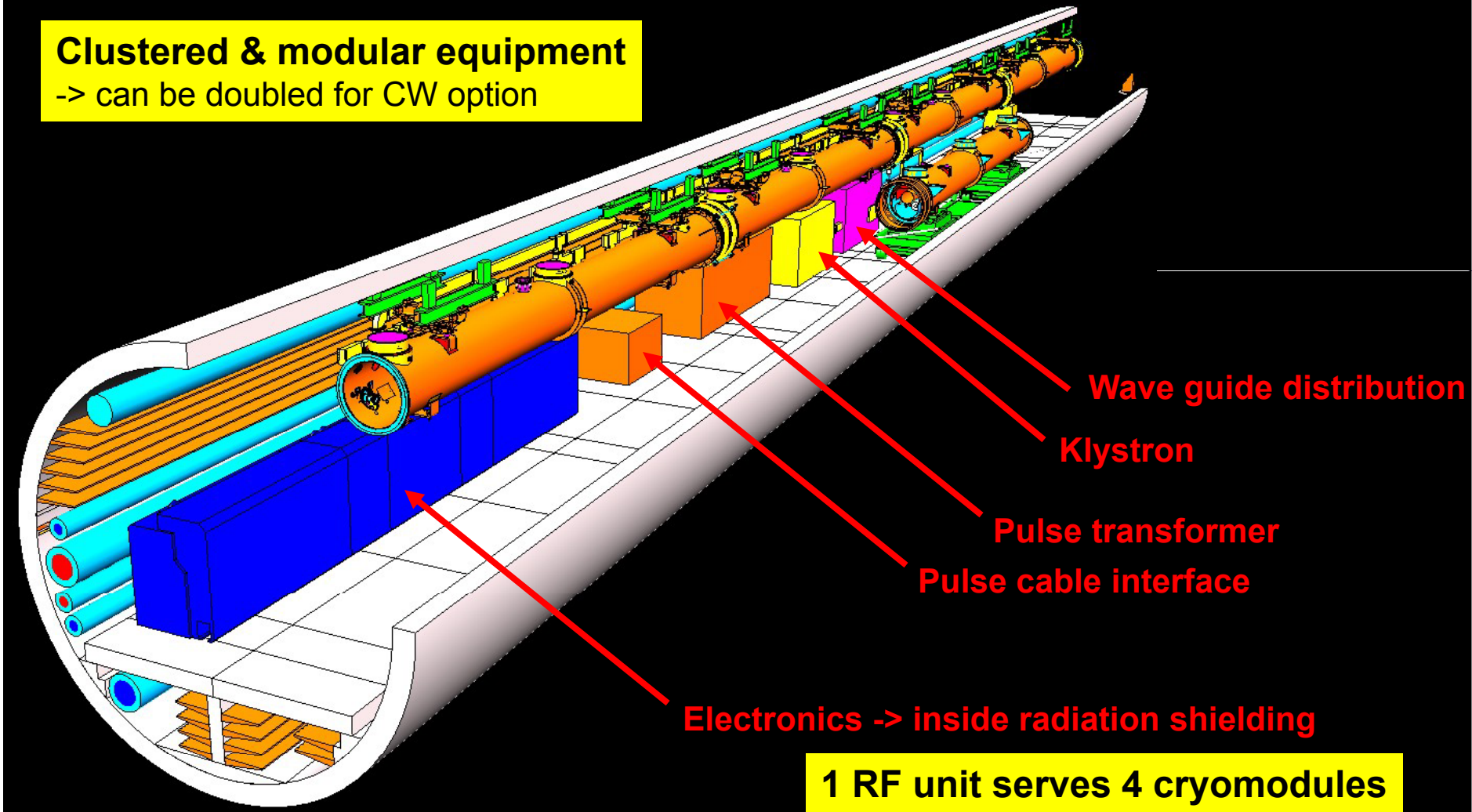
Cryobox suspensions must allow precise alignment while being also capable of taking longitudinal forces of up to 13 t in either direction.

A 3-point suspension for the own weight support and turnbuckle tie rods for the alignment is therefore combined with diagonal tension rods, which will transfer longitudinal vacuum forces into the tunnel shell (always working in tension and never in compression).



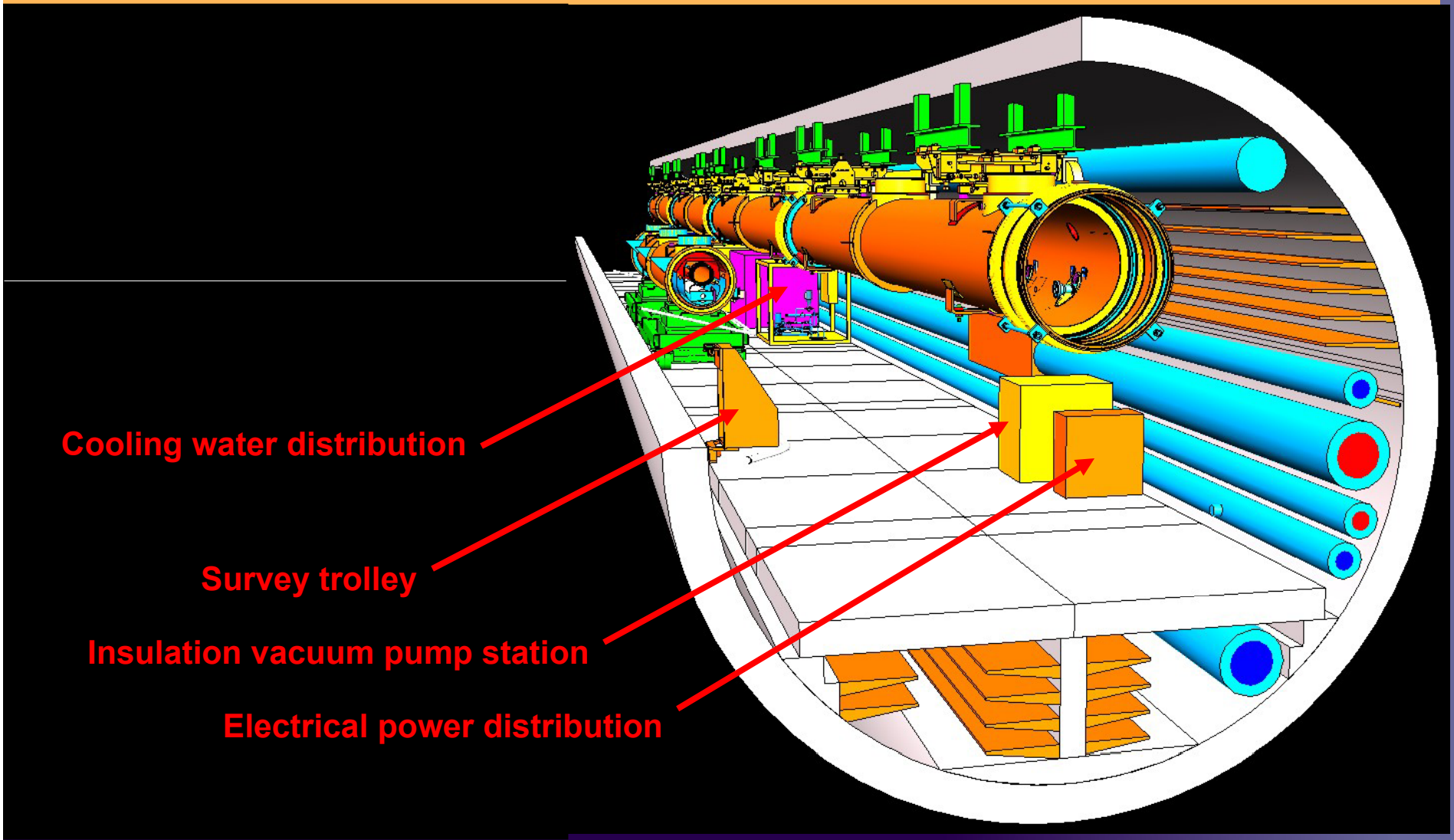
Equipment Underneath Accelerator Modules - 1 RF Unit

Clustered & modular equipment
-> can be doubled for CW option

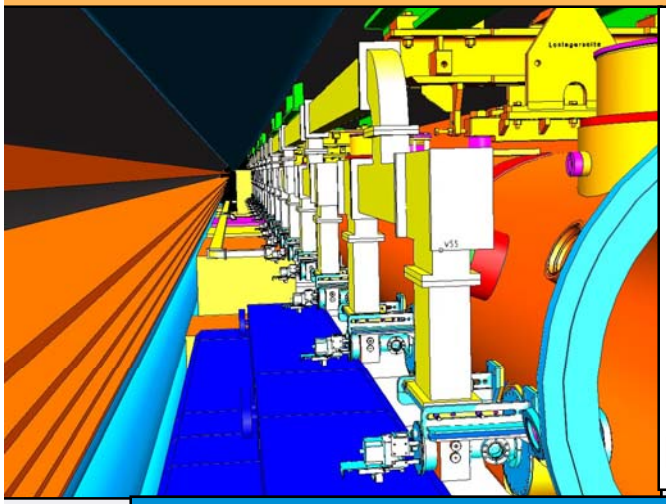


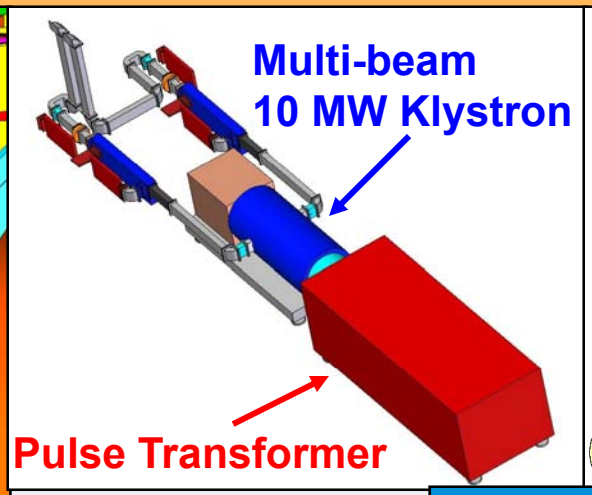
1 RF unit serves 4 cryomodules

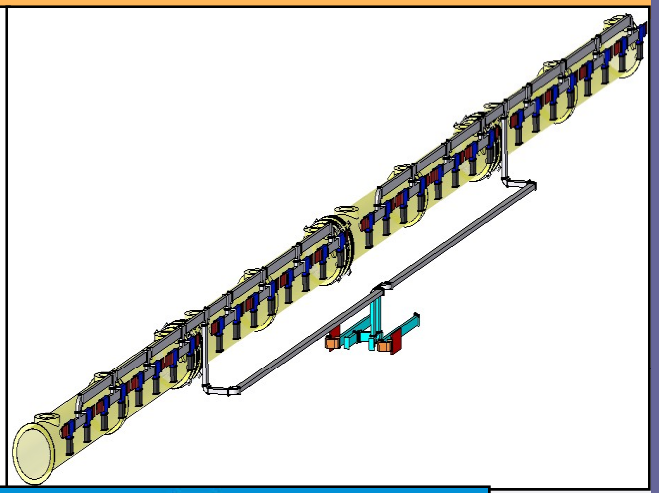
Equipment Underneath Accelerator Modules - 1 RF Unit

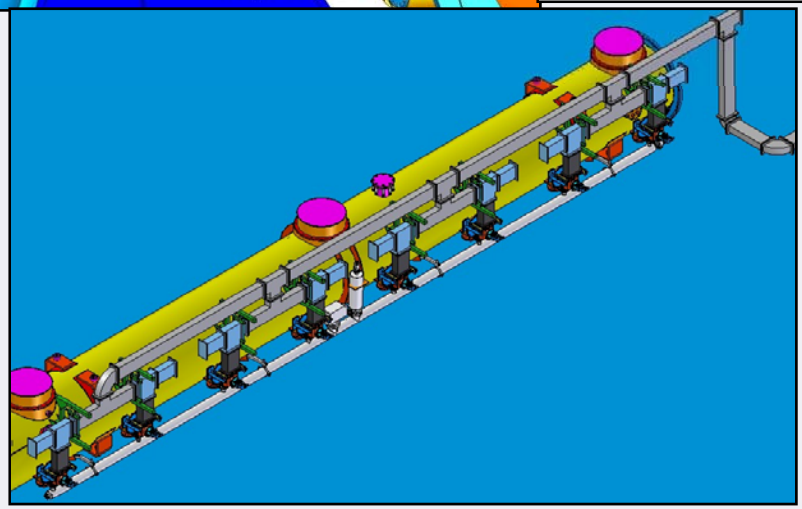


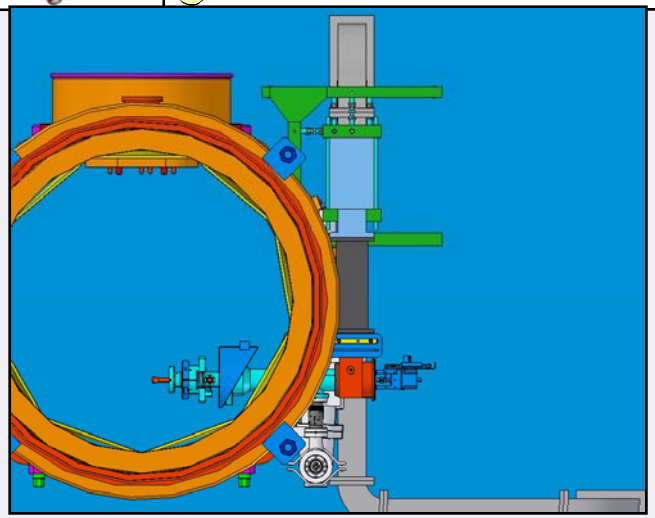
Wave Guides - A very compact (almost 2D) design











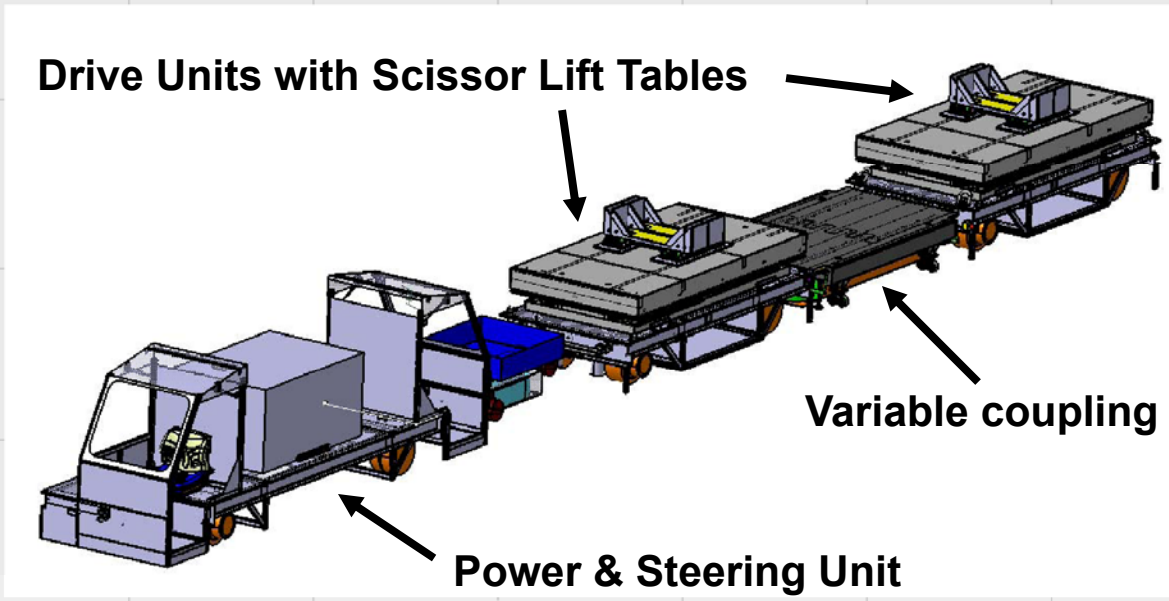
Modules will be transported & installed with WGs attached

Transport & Installation Vehicle

TEC

Tunnelfahrzeug

- Tunnelfahrzeug mit eingefahrener Verbindungsplattform



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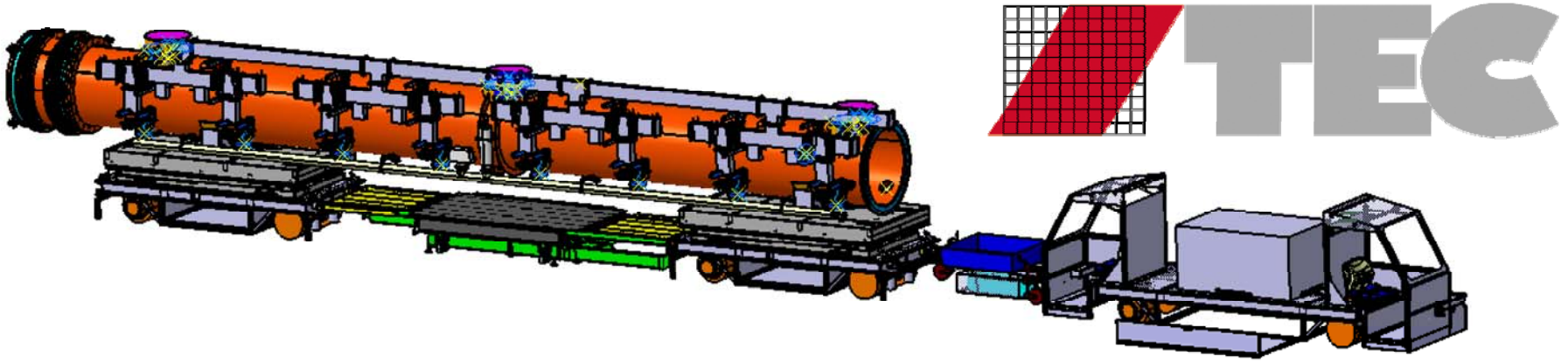
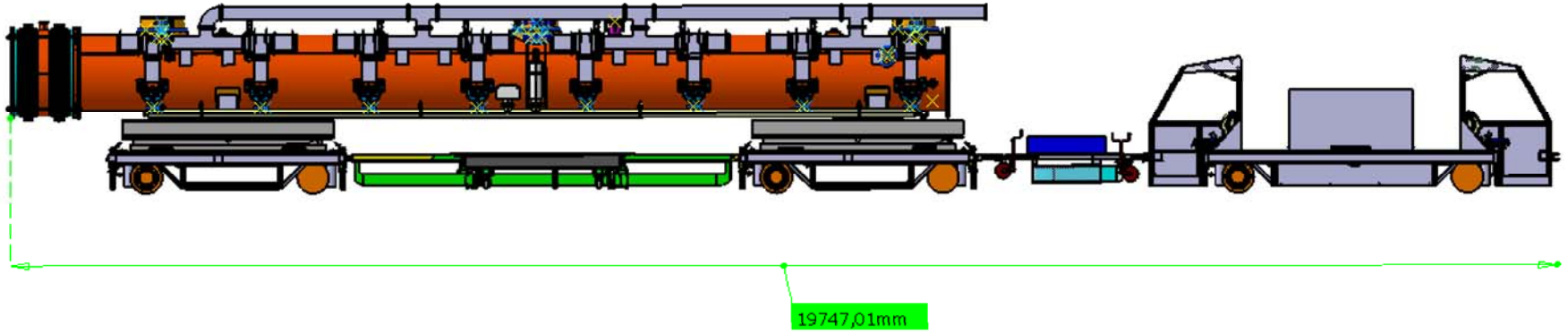
Module Transport



Total Height = 2245mm (without Wave Guide Distribution)
(Transport Clearance = 2350mm; Wave Guides +180mm)

Total Length ~ 19000mm; Vehicle Width = 1400mm



Scissor Lift & Module Interface

TEC

Plattformwagen

Stand:

-Außenverkleidung

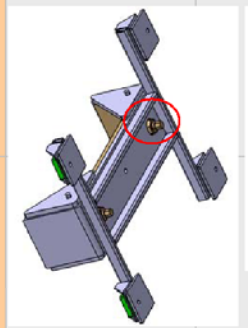
-Aufnahme Beschleunigungsmodul

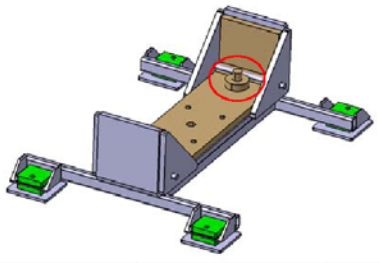
-Position für Hydraulikanschlüsse

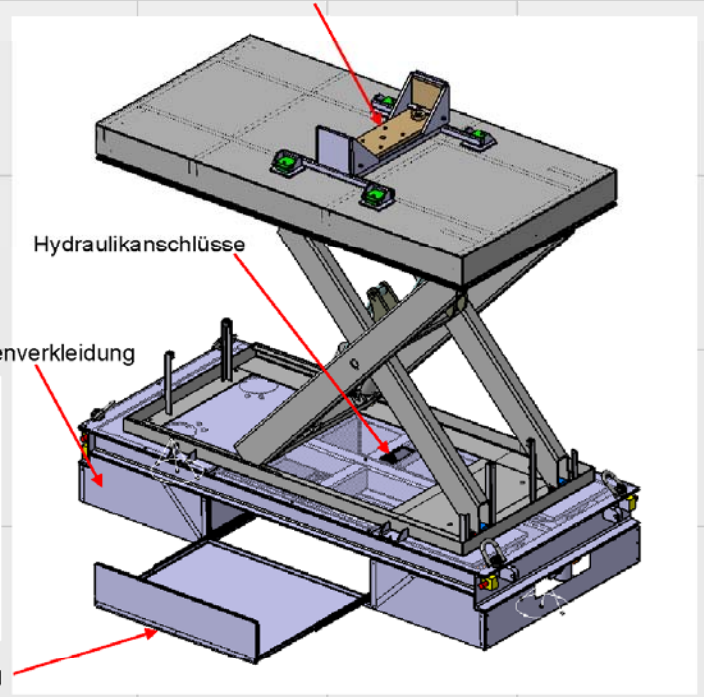
-Einseitiger Auszug der Steuerung

-**Offen:**

-Kann die Gewindestange für die Modulaufnahme genutzt werden







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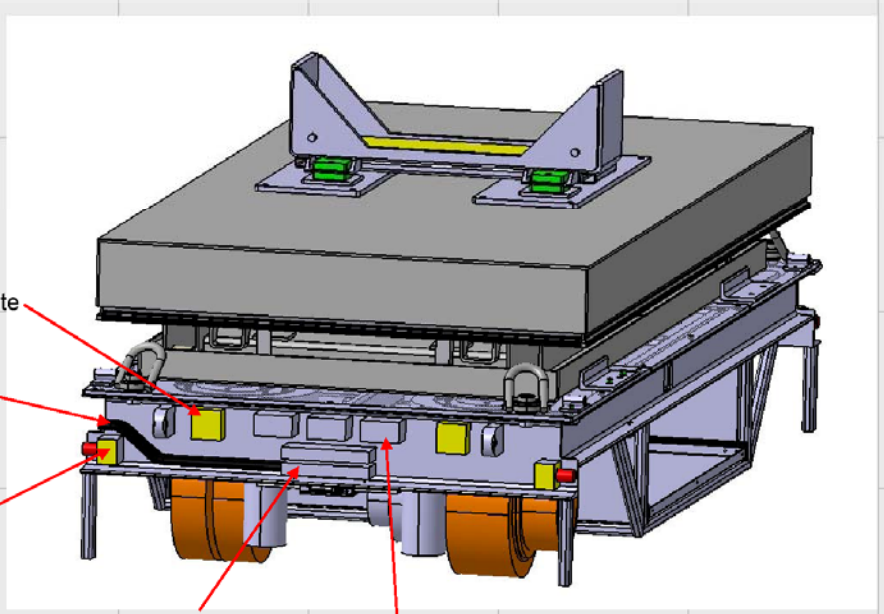
Complete Drive Unit

TEC

Tunnelfahrzeug

- **Plattformwagen**



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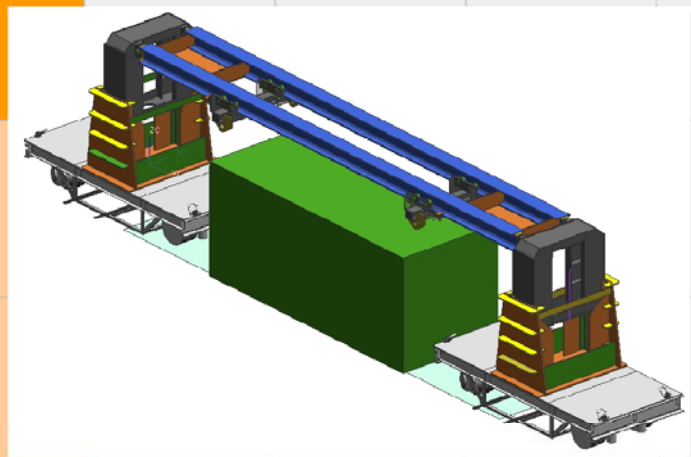
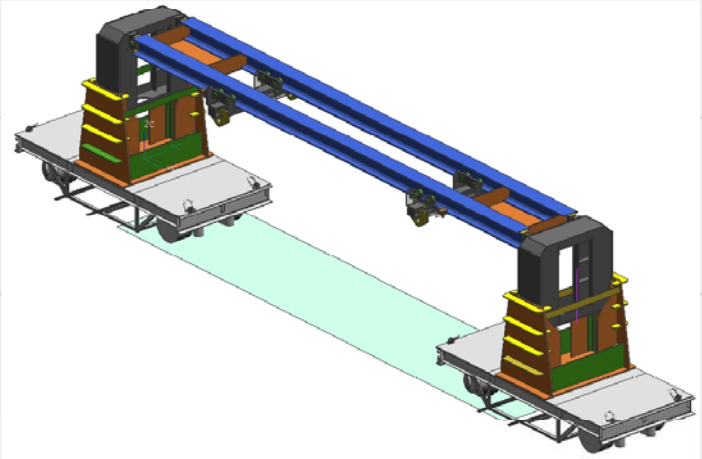
Gantry Crane for Pulse Transformer Transport

TEC

Lastbrücke

Stand:		Offen:
Entwurf siehe Bilder		-Anschlagpunkte der Lasten?
Höhe:	1600mm / 2300mm	-nicht breiter als 1250mm
Hub:	700mm	**Info:**
	- die höchste Last kann ca.200mm angehoben werden	-ca. 100mm für Anschlagmittel zur Verfügung (z.B. Kette)
Breite:	max.1400mm (Abstand zwischen den Lastaufnahmemittel max. 1250mm)	





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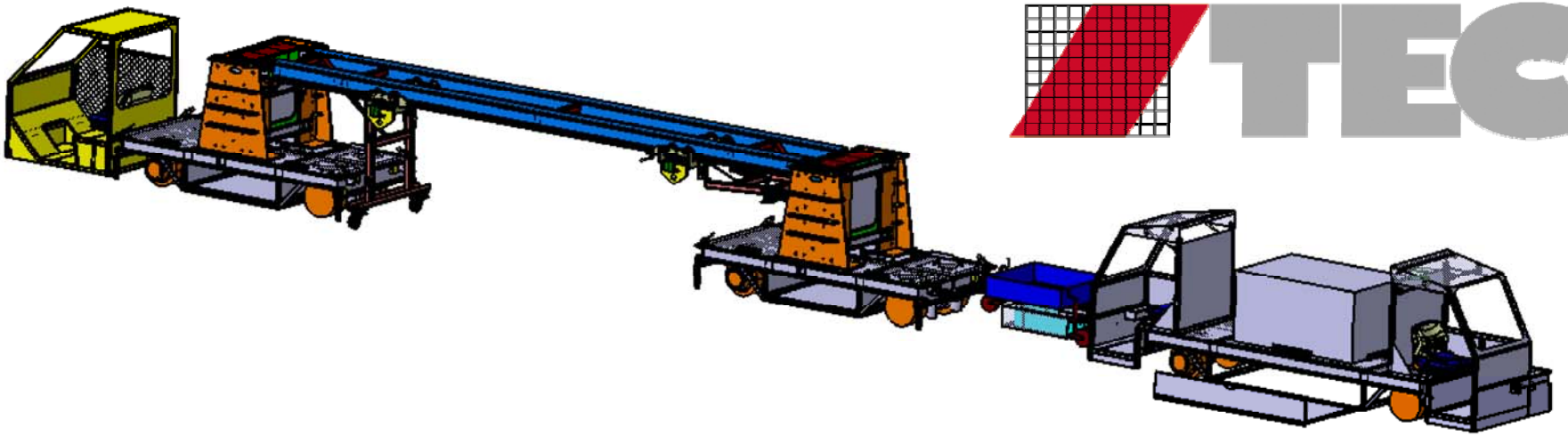
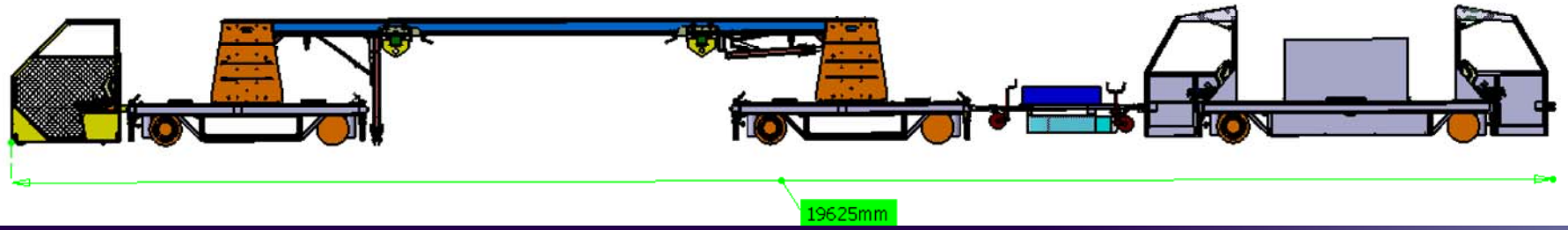
Gantry Crane for Pulse Transformer Transport



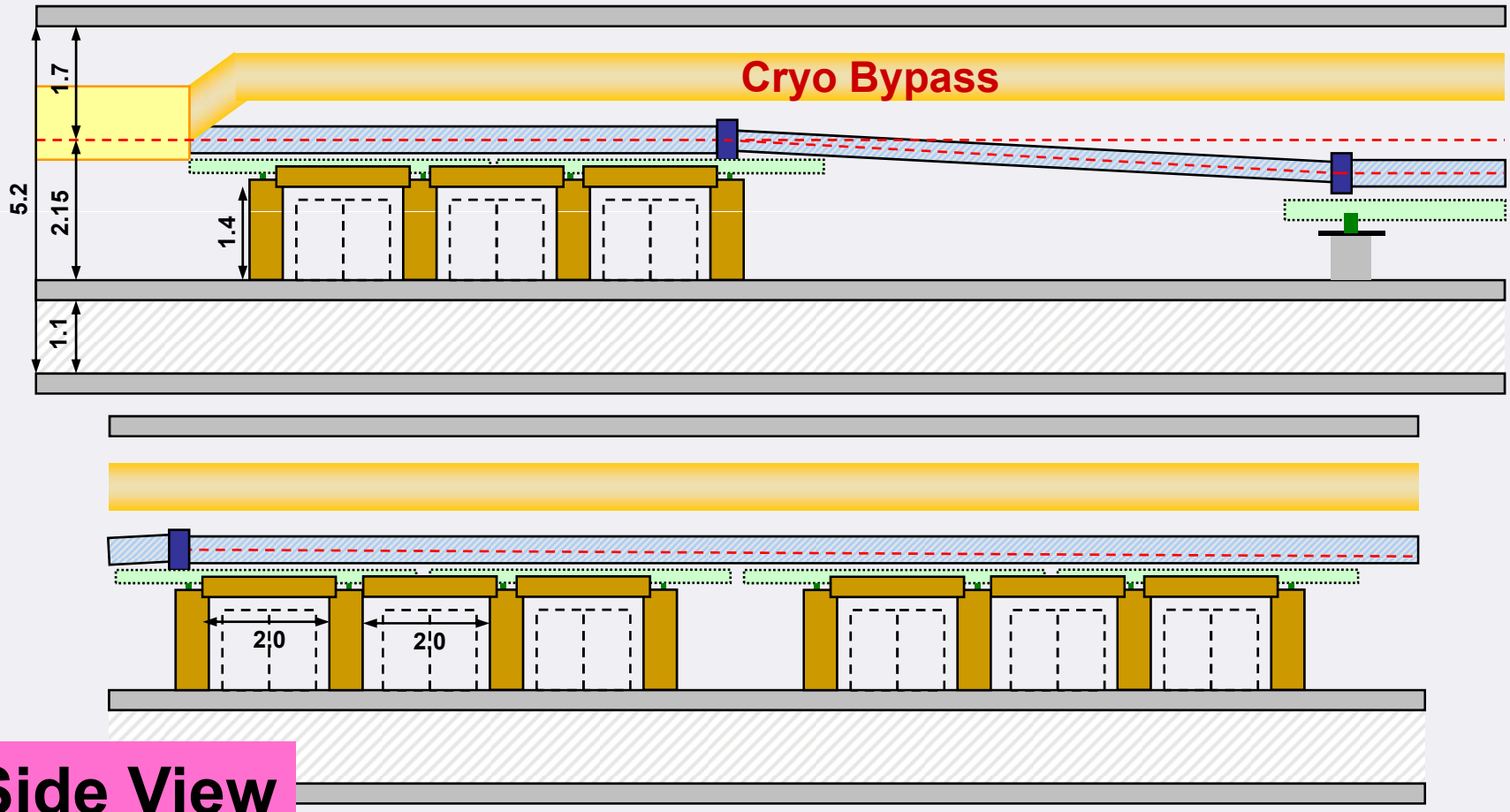
Max. Load = 8t
Vehicle Width = 1400mm
Total Length = 19625mm

Height Load Unit = 1592mm
Lifting Height = 700mm ➔ 2292mm
Height Operator Unit = 1735mm
(can be reduced to = 1600mm)



Baseline layout for BCs, resp. all warm sections

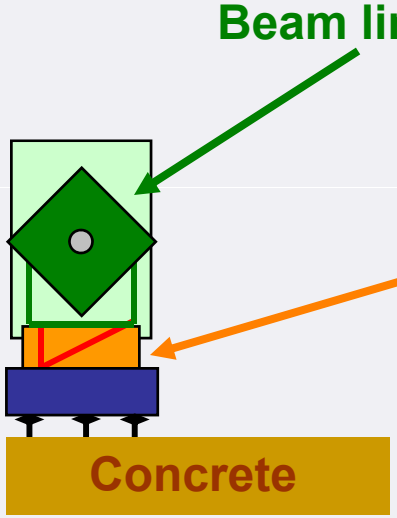
'Standing' warm machine, beam line assembled on girders, supported by 'integrated' shielding concrete for the electronics



Side View

Girder Concept

Front View

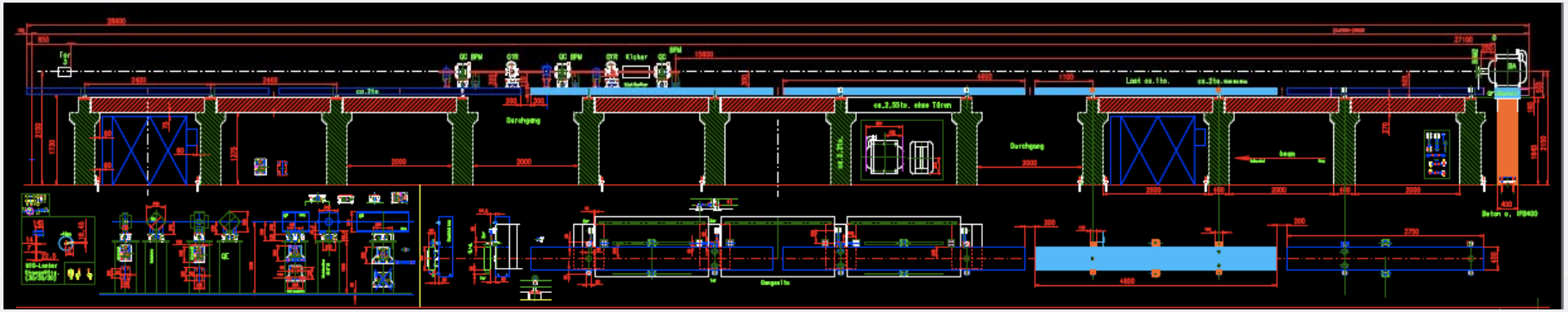


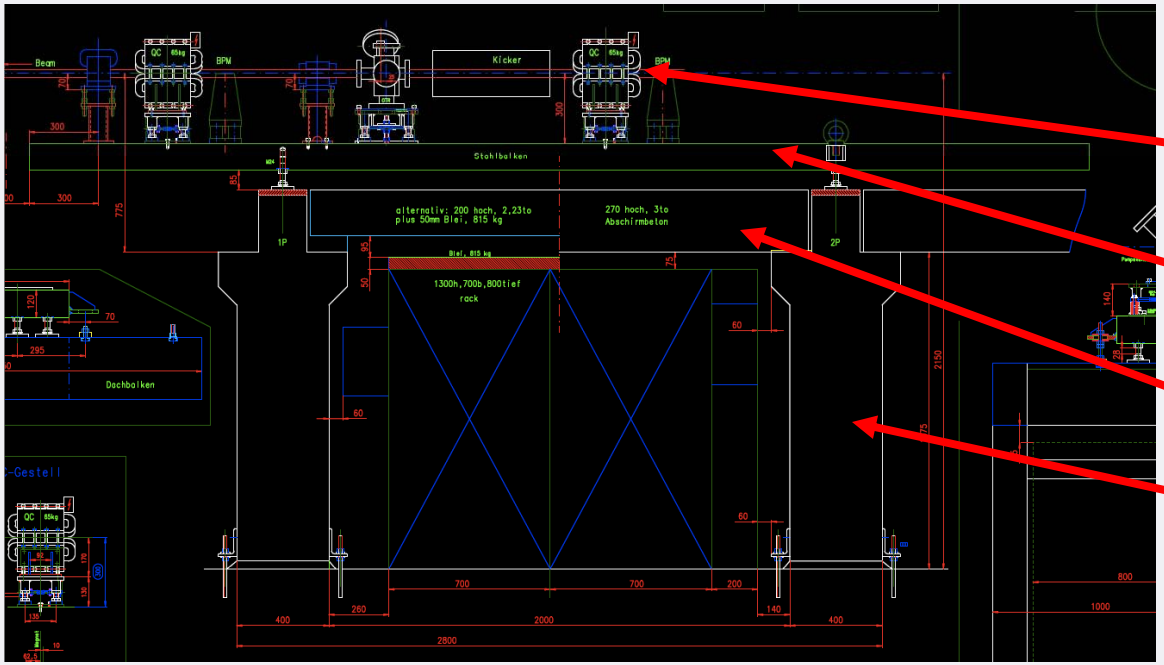
- 3 points support
- Flat (massive) material
- Thickness = 120 mm

- **Girders will be supported on 3 points**
- **Longitudinal & Transverse alignment via turnbuckle tie rods**

Girder Concept - Detailed Layout

- supported by electronics shielding -





Beam line components

Steel girder

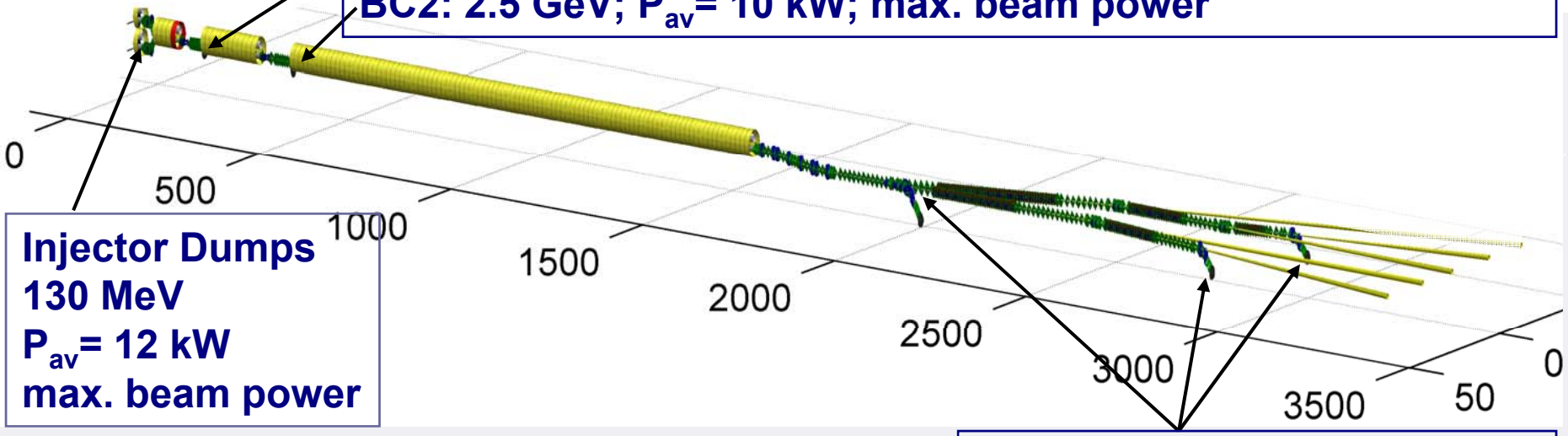
Cover slab

Concrete pillar

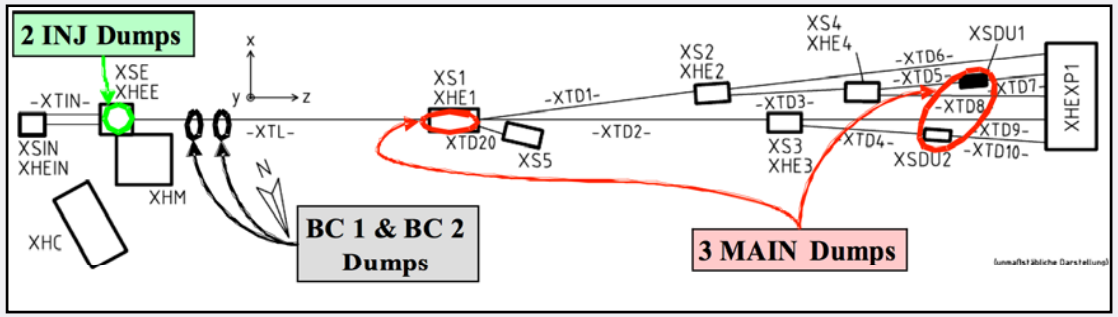
Side View

Dump Systems in the XFEL facility

Bunch Compressor Dumps
BC1: 0.5 GeV; P_{av}= 200 W; small fraction of max. beam power
BC2: 2.5 GeV; P_{av}= 10 kW; max. beam power



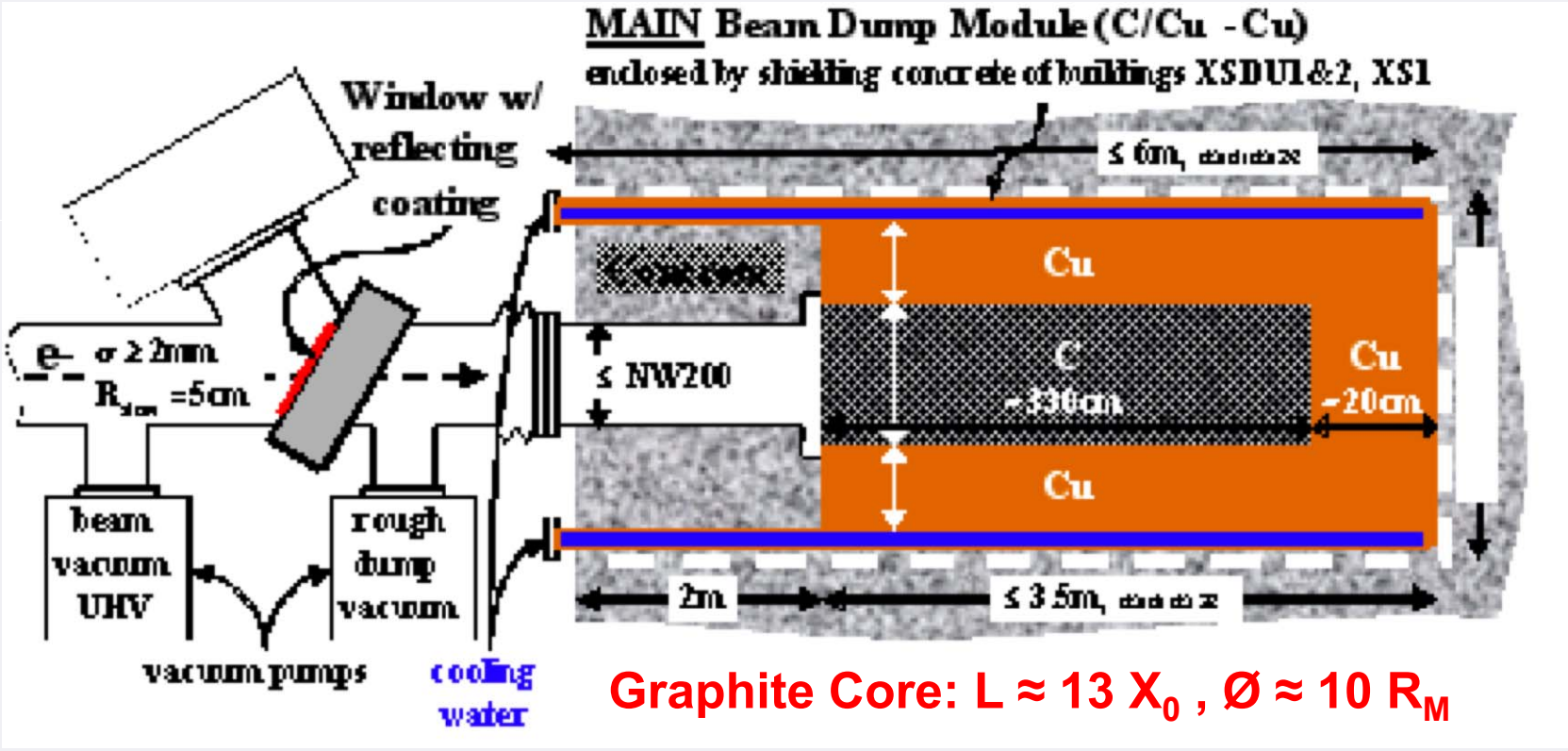
Injector Dumps
130 MeV
P_{av}= 12 kW
max. beam power



Main Dumps
up to 20 GeV
P_{av}= 300 kW
1/2 max beam power
beam magnified
slow sweep to distribute heat

Main Dumps - General layout

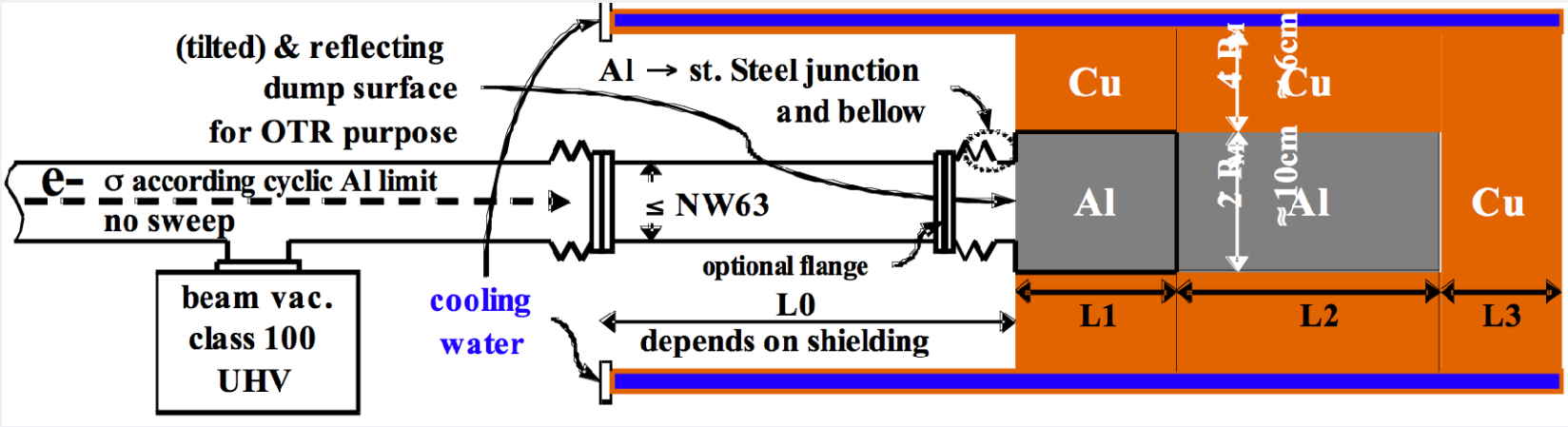
Graphite-Core, Cu-Shell, Beam Vacuum separated by a special 'Window' from Graphite-Core



General layout of the MAIN-Dump, installed in the dead end hole of the shielding concrete and coupled to the spent-beam line via the beam exit window

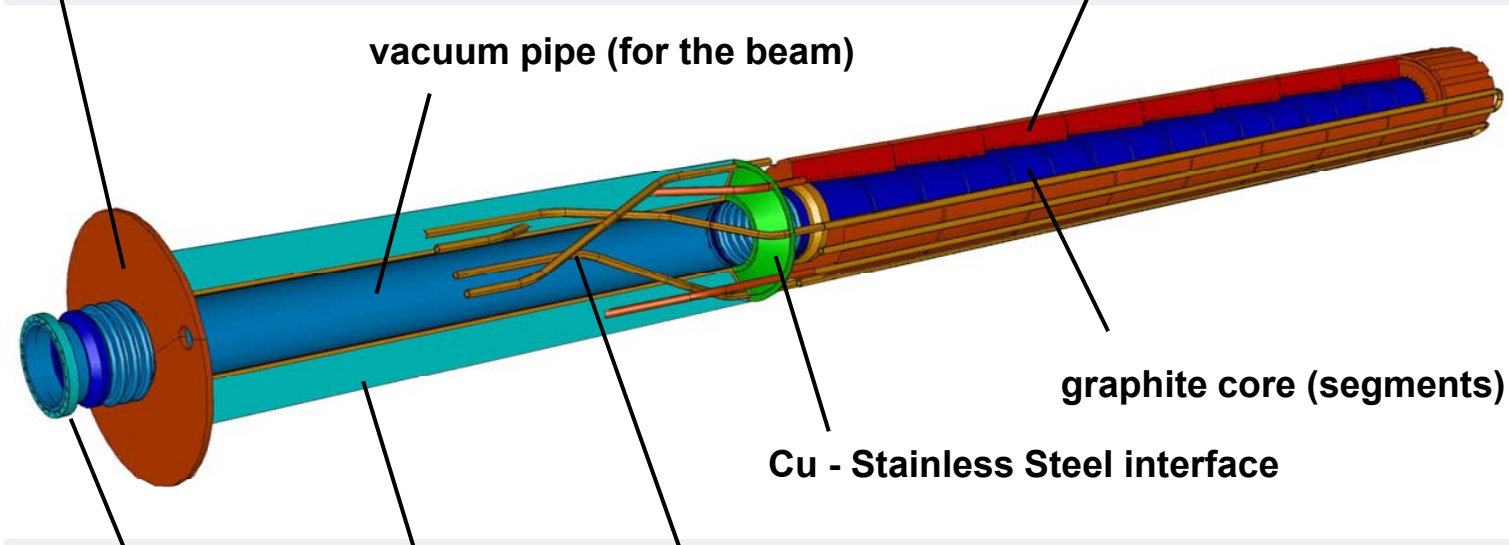
Injector, BC1, BC2 Dumps - General layout

Al-Core, Cu-Shell, Beam Pipe directly connected to first Al-Segment -> Special Al-SS Joint



Common general layout concept of absorbing part and front extension for all low energy dumps (INJ, BC2 and BC1).

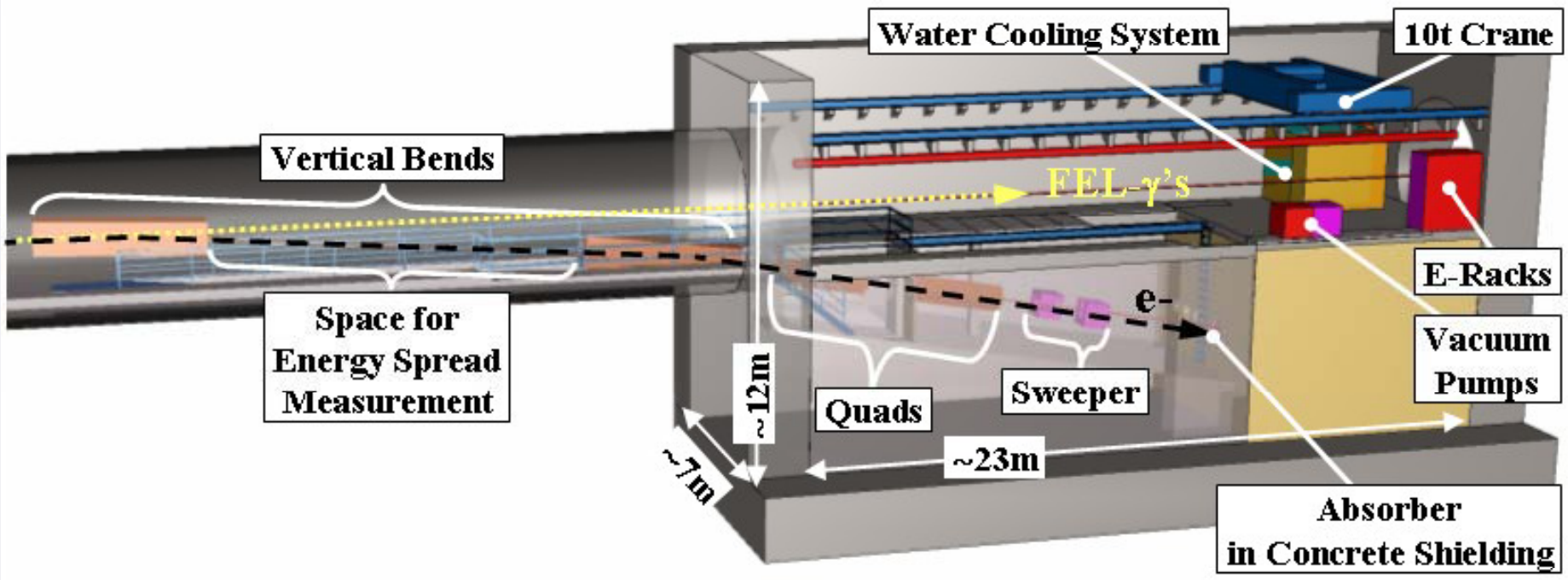
Main Dump proper



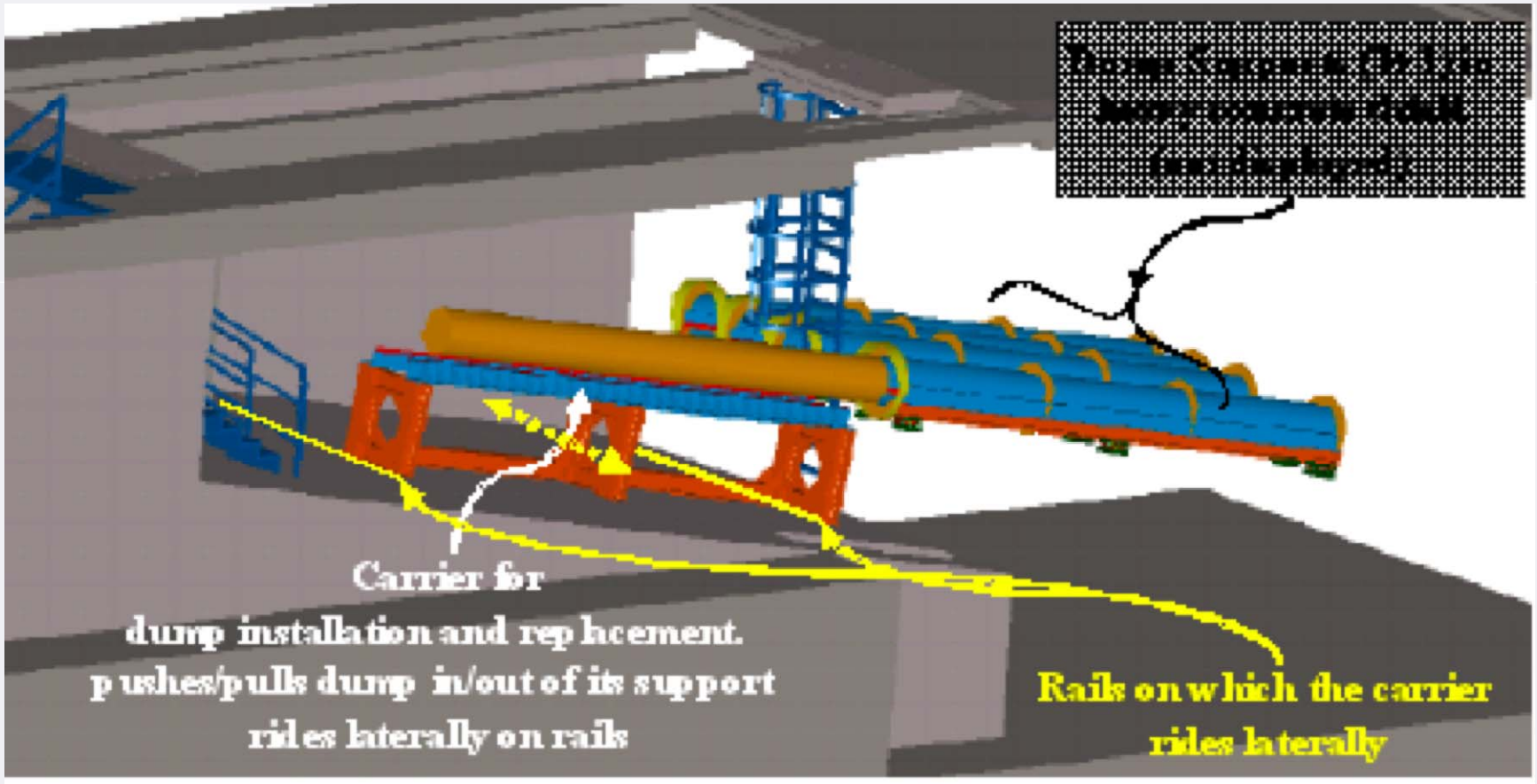
Grooves for vacuum pumping, machined into the inner surface of a Cu-segment in order to protect the graphite of oxidation

Graphite core segments are shaped conical in order to achieve best possible mechanical and thus thermal contact with the Cu-shell

Main Dumps - Integrated in buildings

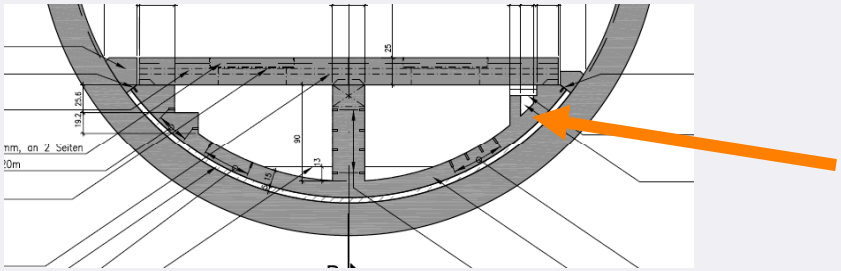


Main Dumps - Exchange and storage



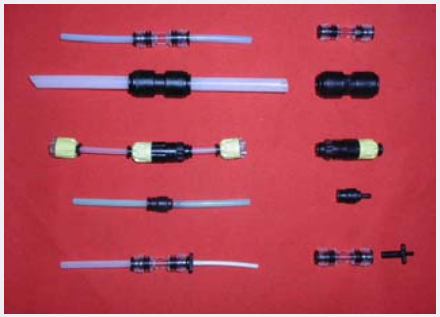
Baseline concept of the MAIN-dump exchange concept

Glass fibres for signal transfer -> Air-injection technology

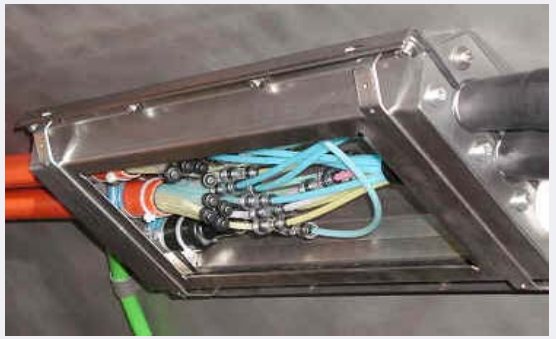


Master tube with capillaries

Air-injection (blow-in) technology
Different capillaries:
$Ø_{o/i}$ = 3/2mm -> Single Fibre - Coating
$Ø_{o/i}$ = 5/3.2mm -> 12 Fibres - Coating -> up to 1.5 km
$Ø_{/i}$ = 10/8mm -> 72 Fibres - Sheth -> up to 3 km

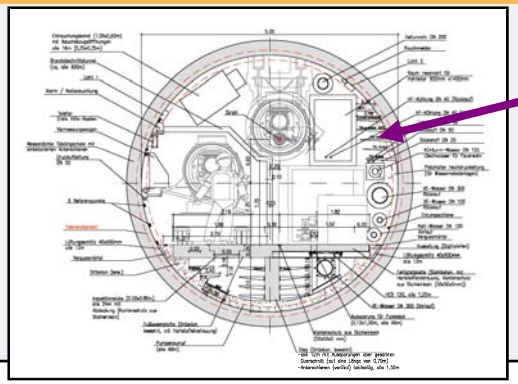


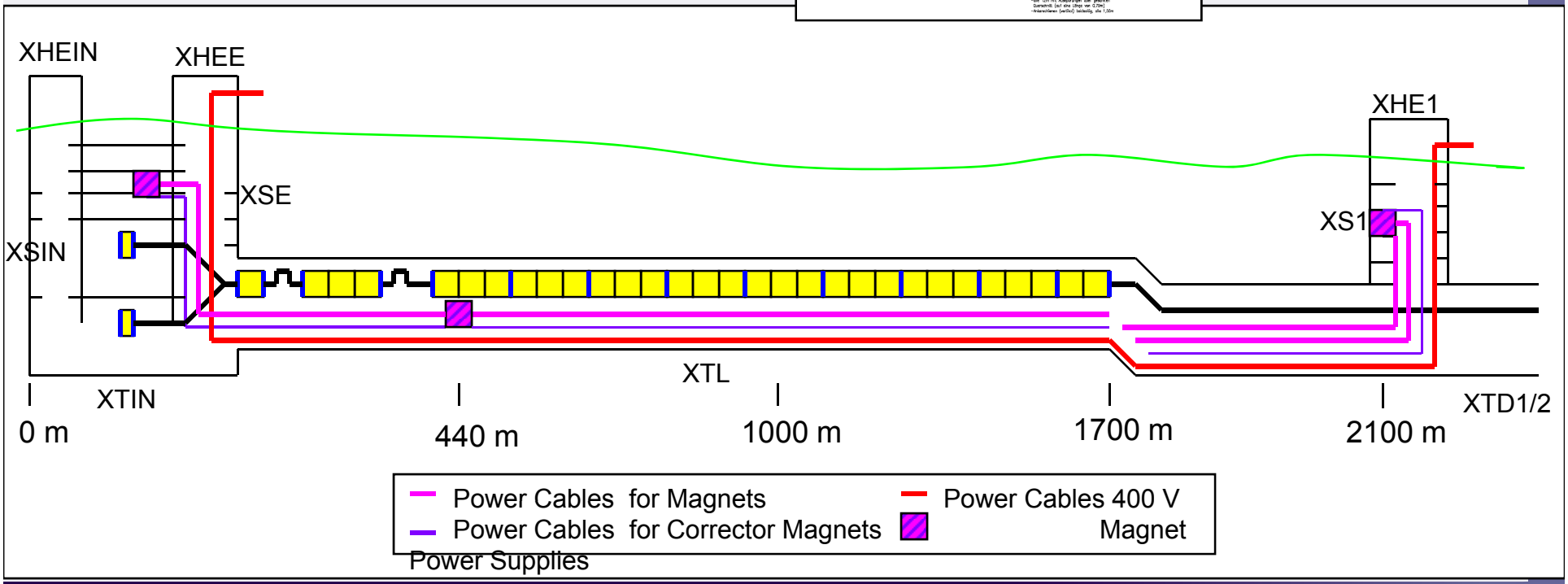
Distribution fittings



Distribution box

Cabling -> Magnet Power from 2 sides





Summary

- **The XFEL singe tunnel requires a diameter of 5.2 m at least, which can be only realised with a tuebbing construction, for the soil conditions given at DESY - merle and inside ground water (the cheaper pipe drive technology seems to be excluded -> would work for 4.5 m diameter)**
- **It requires to use the space underneath the floor**
- **It requires a sophisticated and costly floor & underfloor structure**
- **It requires a considerable extra time for the underfloor installations, which might not necessarily be a disadvantage**
- **It requires special tooling and time to remove & place floor slabs**
- **It suggest to not-install the modulators inside, rather build a dedicated surface hall to house them (for the reason of easy access during beam operation)**
- **It allows to get everything installed in 1 tunnel and safe the costs for a second one**
- **Many technical solutions have been developed for XFEL !!!**