UPDATE OF TRANSPORT CONCEPT FOR PERSONNEL AND MATERIAL

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- Magnet transport vehicle
  - Vehicle description and characteristics
  - Material logistics in the underground
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- People transport concept
  - Concept description and characteristics
  - People transport scenarios in the different phases
- Traffic management concept
- Next steps

Key requirements

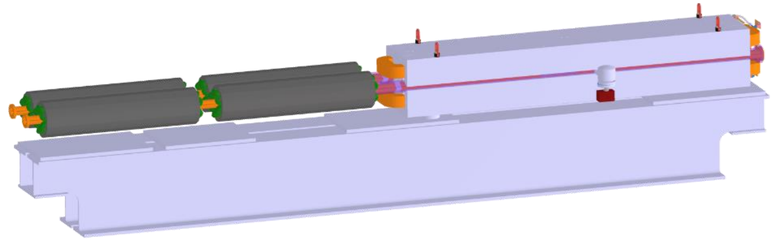
Material and magnet transport
- Heaviest load: 12 ton (Quadrupole + 2 Sextupoles + supporting girder);
- Longest item: ~12 m (Dipoles);
- The booster ring is located above the collider;
- Pick-up point: bottom of the shaft;
- Destination changes continuously.

People transport
- Capacity: 540 kg (6 people with tools);
- Maximum 200 people per sector in groups of 6 each with 10 kg luggage.

Constraints
- Vehicles shall pass through the fire doors: 2,5 m x 1,5 m (width x height);
- Concrete floor;
- Slope: 0.5%.

Requirements stated in the table are preliminary and not yet complete, in some cases assumptions were made.

All the requirements collected so far are available here: EDMS 294421



Quadrupoles and sextupoles over steel girder
Height: 1270 mm
Width: 650 mm
Length: 6500 mm

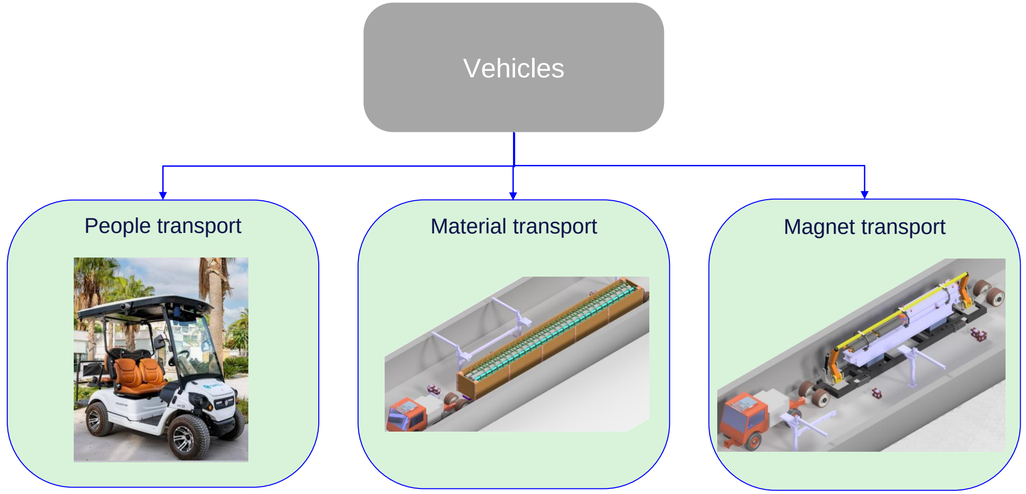
Vehicles concepts

Material and magnet transport:

- Tractor pulling trailers specifically designed for the object to be transported;
- Three types of trailers to transport and handle the three types of magnets;
- All the trailers are moved by the same tractor to have redundancy in the event of failure.

People transport:

- The concept will be based on existing vehicles and technology;
- There will still be the need to customize off-the-shelf products in order to suit the specific condition of the underground tunnel.



Vehicles for magnets transport

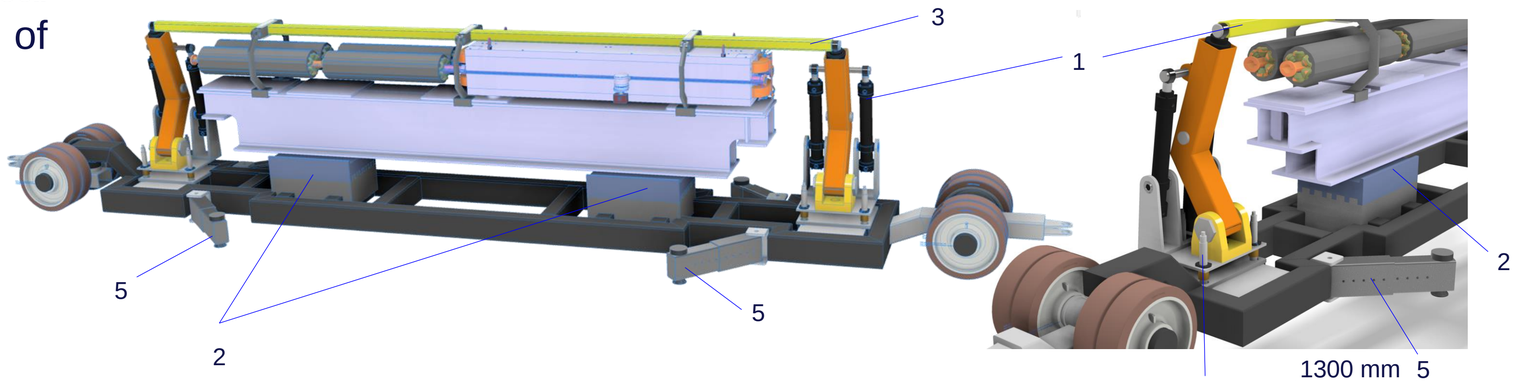
Main parts of trailer

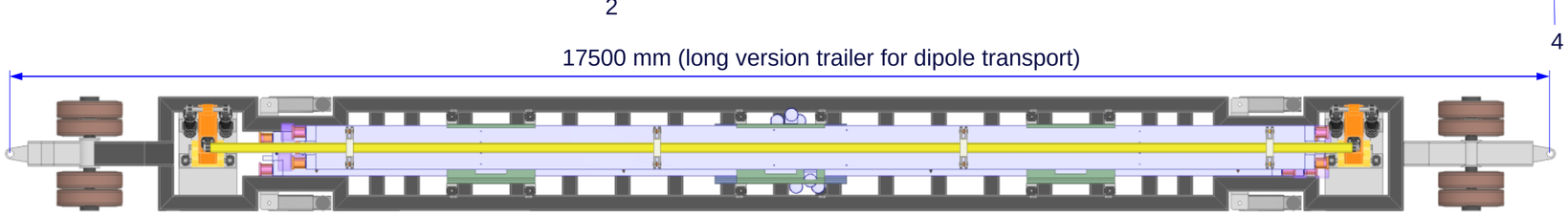
Each trailer has the same basic components:

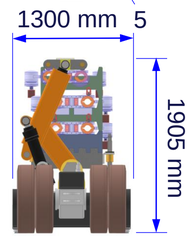
1. Robot arms driven by hydraulic cylinders.
2. Damping material for protection of magnets during transport.
3. Spreader beam including gripper for the different types of magnets.
4. Spindle gears to provide precise vertical movement (to lower down magnets on top of alignment system in tunnel).
5. Support against flipping of the trailer.

Main characteristics

Item	Value	Remarks
Robot arms capacity	12000 kg	Driven by hydraulic cylinders and spindle gears
Number of gripper systems	3	The grippers consist of a spreader beam with integrated clamps
Trailer weight	about 11000 kg	Steel frame with integration of chassis, robot arms, energy supply (battery), control system + sensors, clutches to tractors
Power supply (electrical)	380 kW	Charging stations in services caverns (used by tractors, trailers and people transport)
Speed	10 km/h with load / 20 km/h without load	



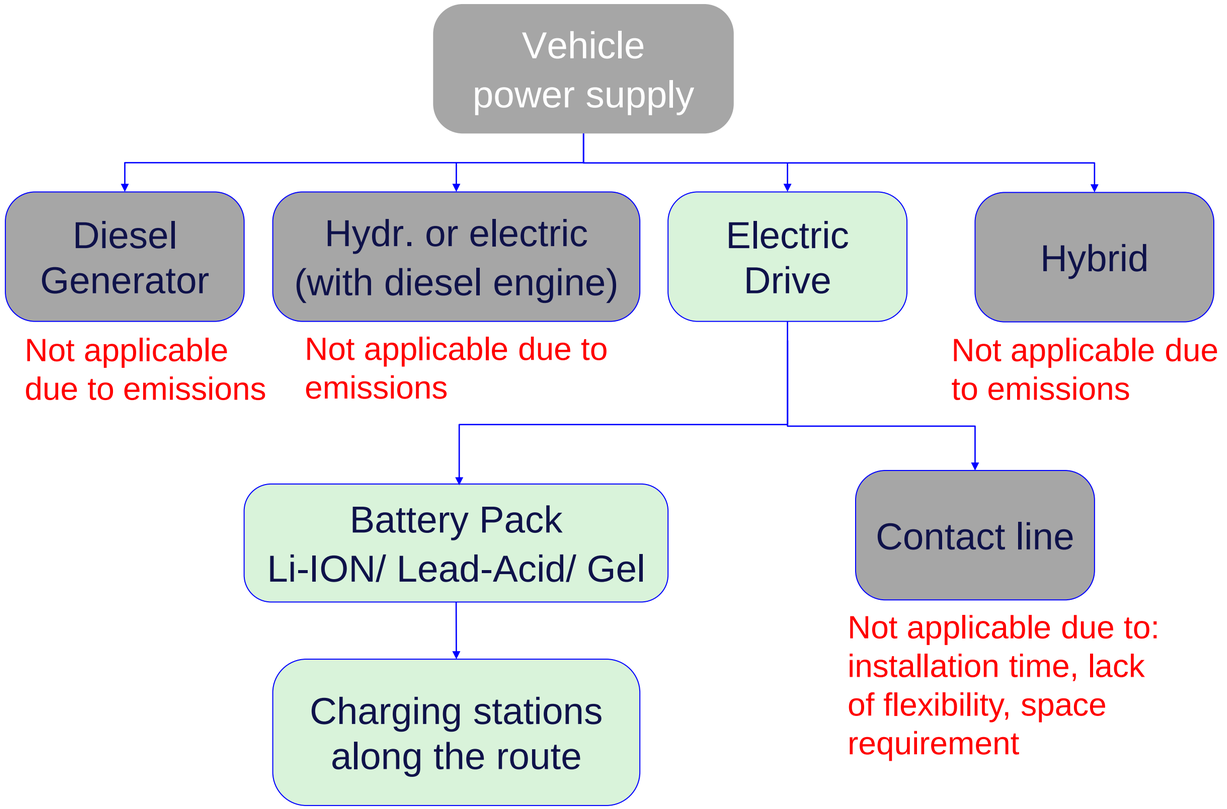




Vehicles for magnets transport

Power supply

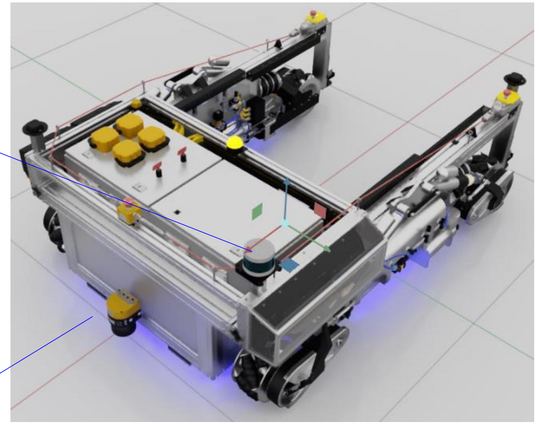
- Battery-powered vehicles to avoid exhaust gas generation and noise emissions in the tunnel;
- The batteries will be located on the pulling tractor (traction battery) and on the trailer (energy supply for robot arms, etc.);
- The batteries of the trailer can act as a backup of those on the tractor;
- Estimated autonomy: up to 500 km.



Vehicles for magnets transport

Sensors and navigation / autonomous driving

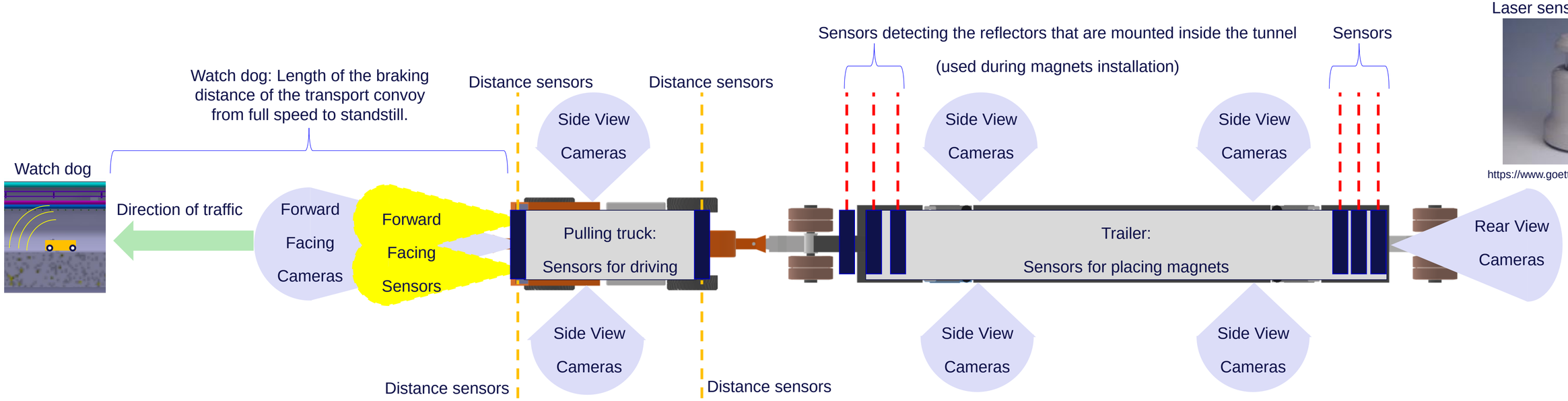
- The vehicle will be autonomous driven in the magnet transport and installation phases;
- Camera system and sensor technology already available on the market:
  - Positioning precision of the vehicle: 3 cm;
  - Minimum required side clearance: 10 cm.
- The vehicle can be guided by a human driver in case of emergency or for alignment;
- Watch-dog system: small vehicle drives ahead of the tractor to detect that the way is clear from obstacles (20-30m ahead of large vehicle).



Outdoor-Roboter »Odyn« automatisiert Palettentransport - Fraunhofer IML

Laser sensors for navigation

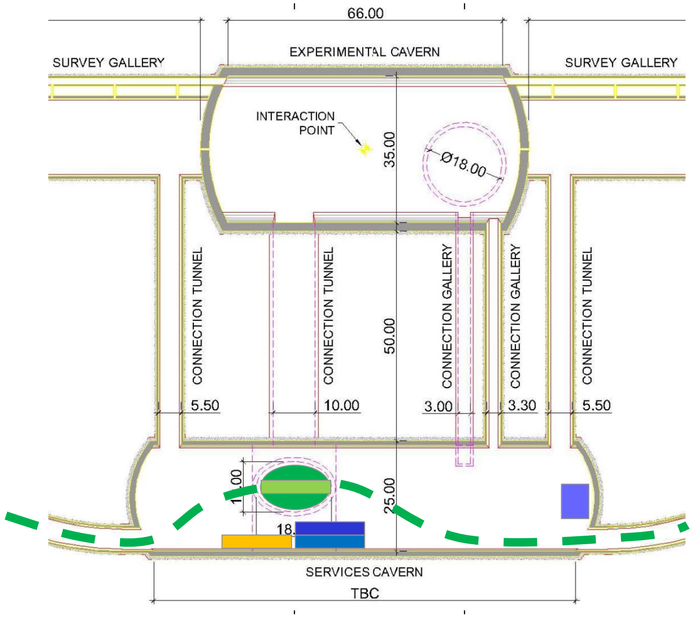
https://www.goetting.de/komponenten/43600

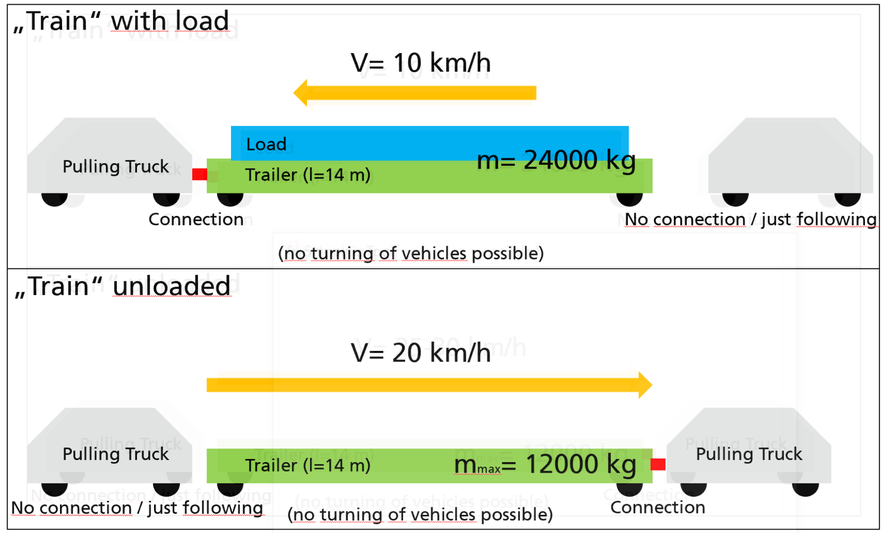


Vehicles for magnets transport

Underground transport and installation

- Magnets will be lowered with cranes from the surface to the trailers at the bottom of the shaft in the service cavern.
- The vehicles will leave the cavern and reach the accelerator tunnel via the bypass tunnels in autonomous mode at slow speed.
- Elapsed time between the moment that the crane hook reaches the bottom of the shaft and the vehicles enters the accelerator tunnel: 56 minutes.
- Estimated time to handle the magnet over the alignment block: 23 minutes.
- In the routing through the tunnel system, "enlargements" are provided into which the vehicles can overtake.
- Trailers will always have a tractor ahead and a tractor behind; only one tractor connected at a time.

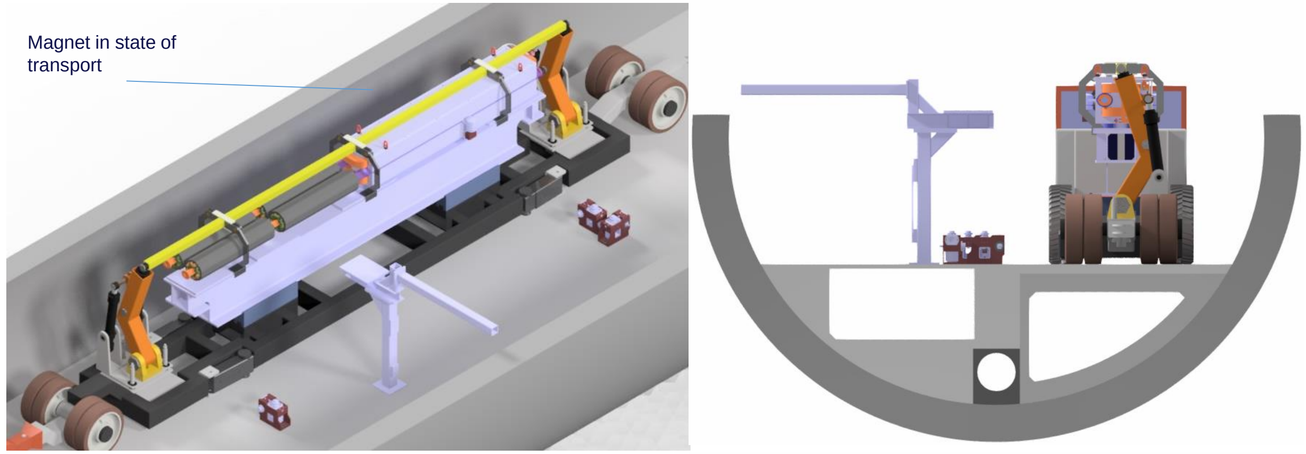


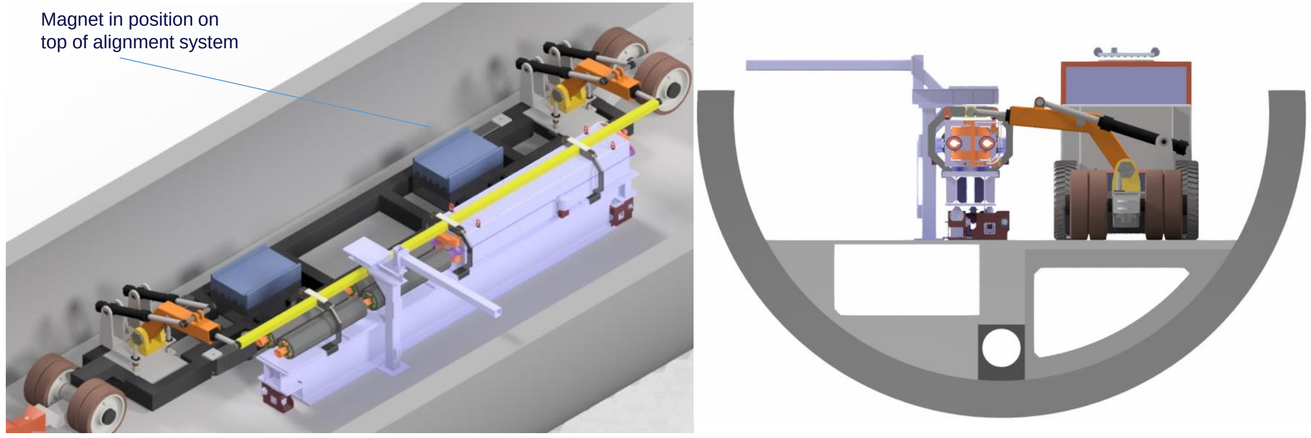


Vehicles for magnets transport

Transport of steel girder with quadrupole and sextupoles

- The hydraulic cylinders carry out the main handling operation.
- The spindle type lifting gear performs the secondary movement (adjustment) while placing the steel girder on top of the alignment blocks.

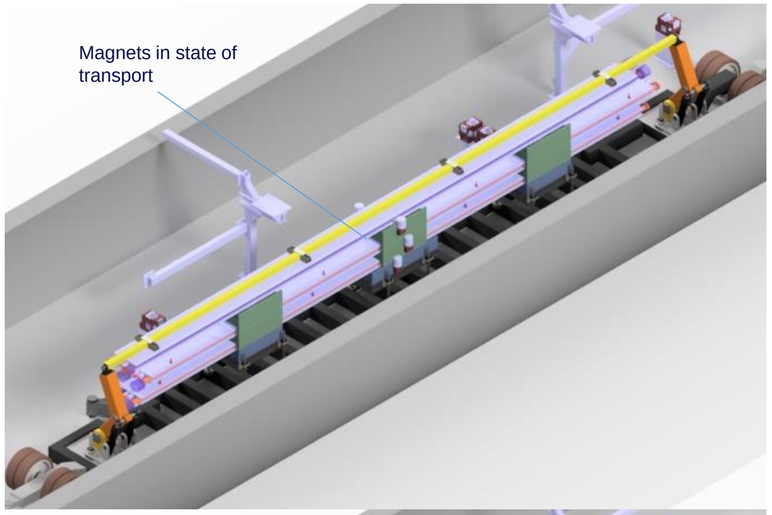


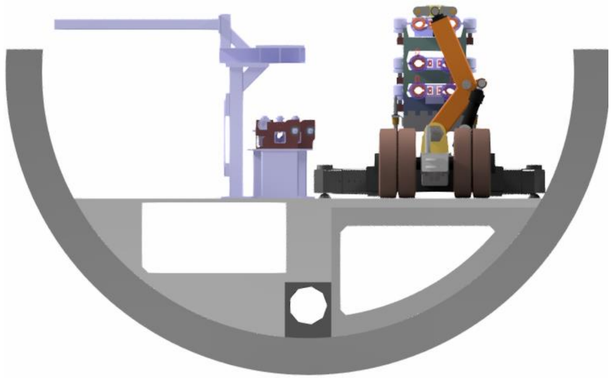


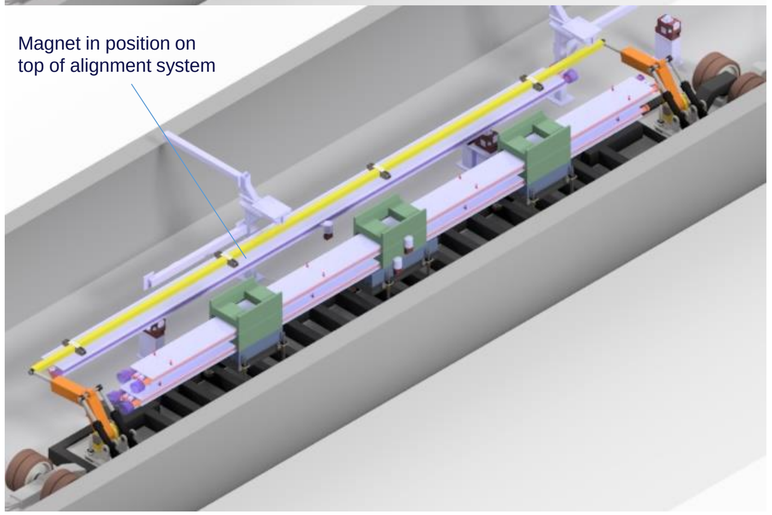
Vehicles for magnets transport

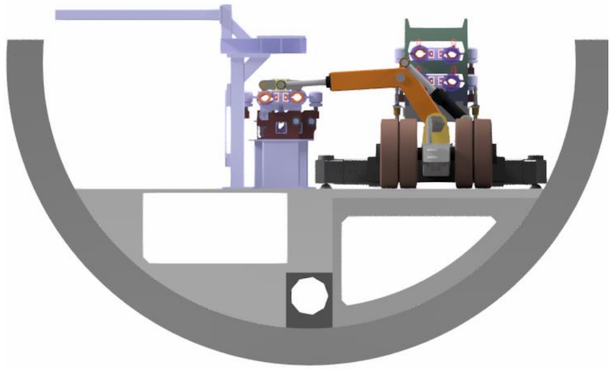
Transport of dipoles

- To increase the transport efficiency, the trailer has the capability to carry three dipoles at the same time.
- The dipoles are stored in a special rack. The rack can be raised and lowered down by spindle type lifting gear in order to position each dipole at the correct height.









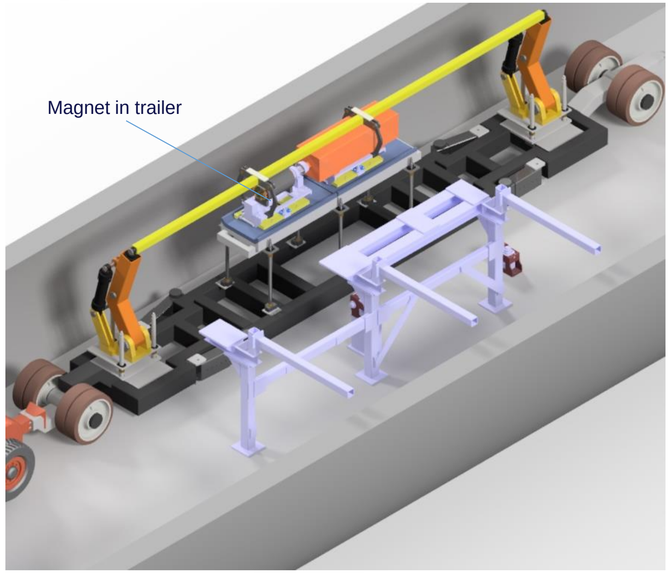
Vehicles for magnets transport

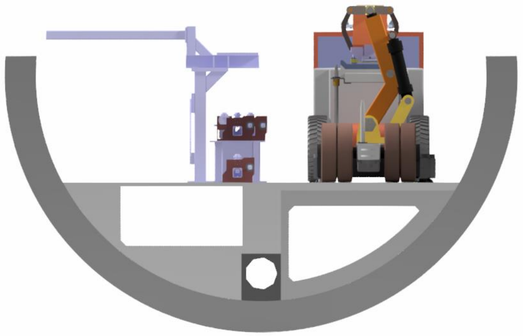
Transport of components of booster ring

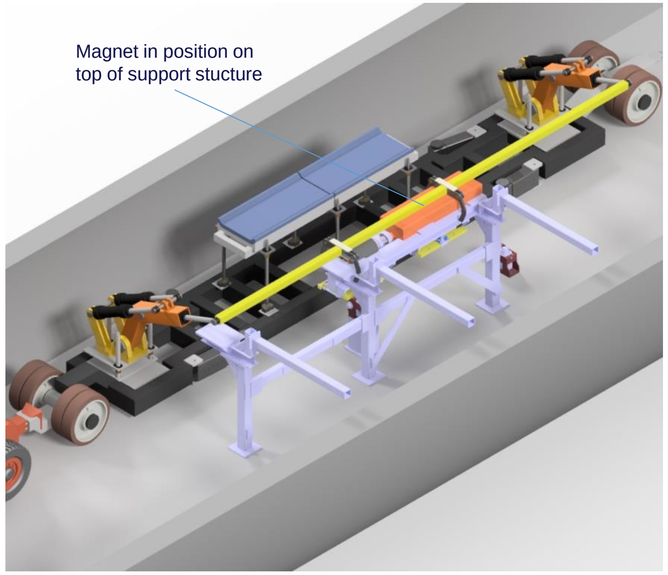
The handling technique for the booster components consists of a two-stroke movement:

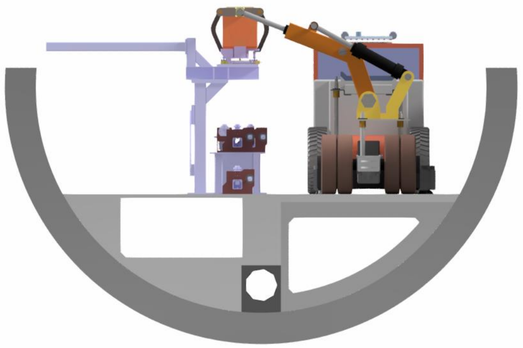
1. The components of the booster ring are lifted from the trailer vertically by the spindle gear.

2. The robotic arm with gripping system transfers the components of the booster ring on top of the support structure.









Vehicles for people transport

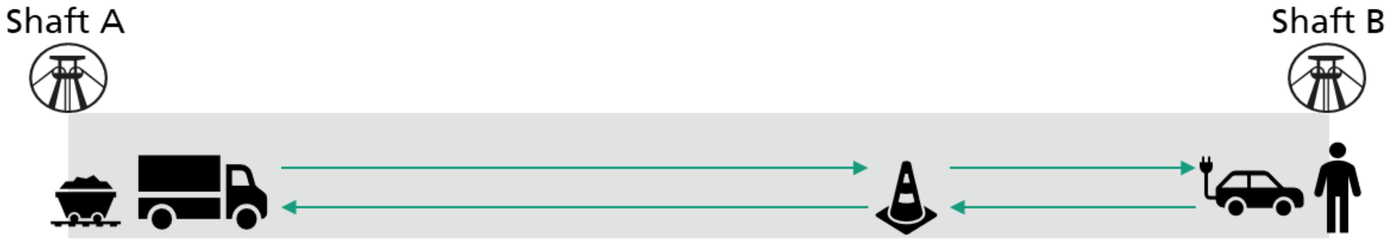
Underground people transport

Concept:
- Autonomous battery powered vehicle that can also be steered manually
- Small vehicles for up to 6 persons and small luggage/cargo/tools
- Existing solutions as basis for adaptions preferred

Existing solutions:
- Golf Carts (already attempts to drive autonomous)
- Climatized Golf Carts with doors

Description:
- Velocity up to 30 km/h
- Range 35 - 50 km (depending on mode of operation)
- Different sizes (2 to 6 people per vehicle)
- Mix of laser sensors and 3D Camera for contour navigation

Vehicles for people transport



Underground people transport

Operation mode during installation phase

- Magnets or big items is transported from Shaft A, people are transported from shaft B to minimize crossings
- People are transported to their work place at the beginning of the shift and back at end of the shift
- Two scenarios:
  - Vehicle stays with people (to have it in case of emergency)
  - Vehicle drives back to pick up another group (in this case another emergency strategy is necessary)

Operation mode during technical and unplanned stops

- All shafts are used for people transport (as long as no magnets are transported)
- People are transported to their work place at beginning of work and back at end of shift
- Two scenarios:
  - Vehicle stays with people (to have it in case of emergency)
  - Vehicle drives back to pick up another group (in this case another emergency strategy is necessary)

Vehicles for people transport

Underground people transport

Emergency operation mode

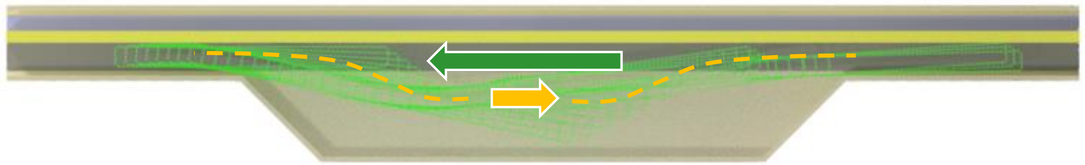
- Either people transport vehicles stay close to workers or other option is necessary
- Other option could be
  - Provision of E-Scooter or E-Bikes in a sufficient number in every alcove/enlargement
  - E-Scooter could be mounted to wall like fire extinguisher (battery needs to remain charged)

Traffic management

A traffic management system will be needed to coordinate the single maneuvers both in normal and emergency conditions of the people and the magnet transport vehicles.

The system shall:

- Be informed of all the vehicles running in the tunnel.
- Record in real-time any maneuver taking place in the tunnel (possible use of RFID technology).
- Manage the vehicles crossing in correspondence of the small laybys according to a predefined priority hierarchy. Example:
  - Normal conditions: magnet transport has priority with respect to people transport;
  - Emergency conditions: people transport has priority with respect to magnet transport.



sensors for safety

sensors for navigation

sensors for safety

sensors for navigation

Sick S30b-2011da Agv Sensor

https://www.goetting.de/komponenten/43600

Vehicles

Personnel transport and material transport

General Traffic Management

Next steps

- Further development of magnet vehicle design (not exhaustive):
  - Possible review of robot arms design according to new collider position;
  - Detailed design of the robot arms: cylinders, bearings, structure, mounting platform, electrical installation;
  - Engineer the spreader bar with gripper (interface to be agreed with CERN EN-MME group);
  - Detailed design of the chassis;
  - Identify components suppliers.
- People vehicle:
  - Finalize the emergency strategy.
- For magnet and people vehicles: take contact with possible industrial partners.

We thank you for your attention