FUTURE CIRCULAR COLLIDER LOGISTICS STUDY

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Fraunhofer-Gesellschaft and Fraunhofer IML

24.500
Employees

69 Institutes
and research facilities

2,1 bn EUR
Research budget

Fraunhofer IML, Dortmund

280
Employees

250
scientific assistants and PhD students

28,4 Mio EUR
Revenue, 50% from industry (contract research)

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FCC Logistics Study covers fives areas

- Supply strategies for FCC cryo-units;
- Locations for the storage, assembly and testing facilities;
- Transport scenarios for cryo-units, including analysis of stresses and possibility of intercontinental transport;
- Design concept for a special purpose vehicles for the underground transportation and handling of cryo-units;
- Supply scenarios considering the overall FCC construction schedule.

The following assumptions about FCC have been taken into consideration

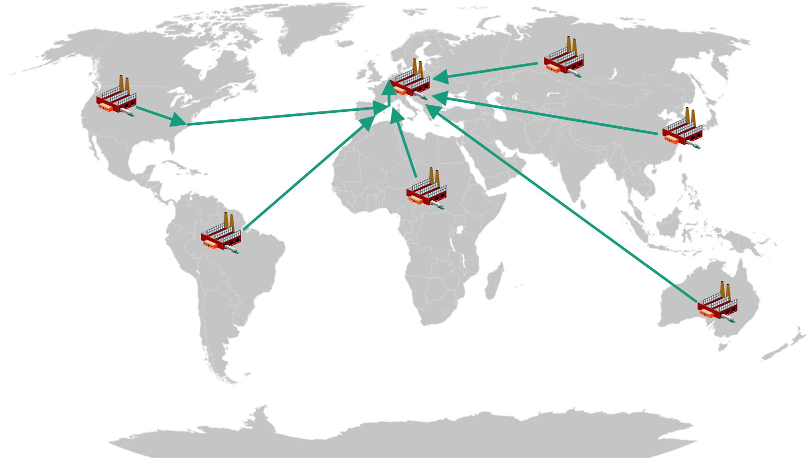
Related to installation schedule:

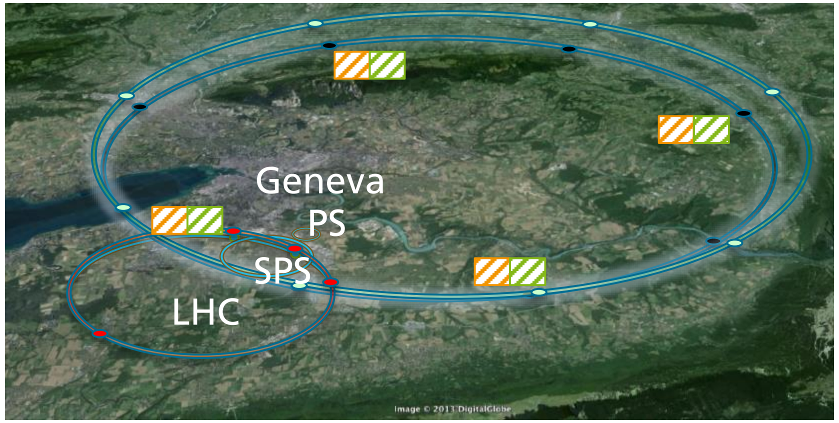
- Cryo-unit installation phase Nov. 2035 – Nov. 2039

Related to cryo-units:

- Maximum shock: 0.1 g
- Maximum tilt angle: 5%
- Weight of the cryo-unit: 60 t (Dipole Magnets)
- Dimension (L/W/H) 13,4m x 1,5m x 1,64m
- Amount of cryo-units to be transported: 5400

Supply strategies for FCC cryo-units: Questions to be answered from logistics side





- The construction of FCC entails high demands for materials that need to be installed.
- As the construction timeframe for FCC is very tight and available space for material storage on site is limited, it is very important to have effective on-site logistics and a suitable supply chain strategy.

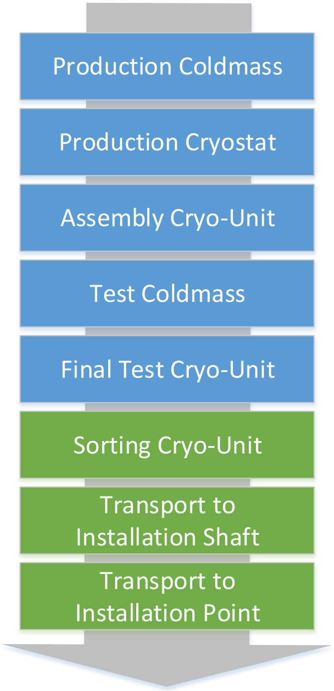
Questions to be answered from logistics side are

- Insourcing <-> Outsourcing
- Single <-> Multiple Souring
- Global <-> Local Souring
- Central <-> Decentral Facilites and Storages
- Overground <-> Undergound Transports

Supply strategies for FCC cryo-units

Completely Built Up At CERN

- Efficiency of this alternative strongly depends on the availability of proper and sufficient production **capacities** and **process know-how**.
- If both aspects are not fulfilled, high costs will arise for building up a suitable **infrastructure** and/or for modernizing or expanding the existing one as well as for **training** and **recruiting capable employees**.

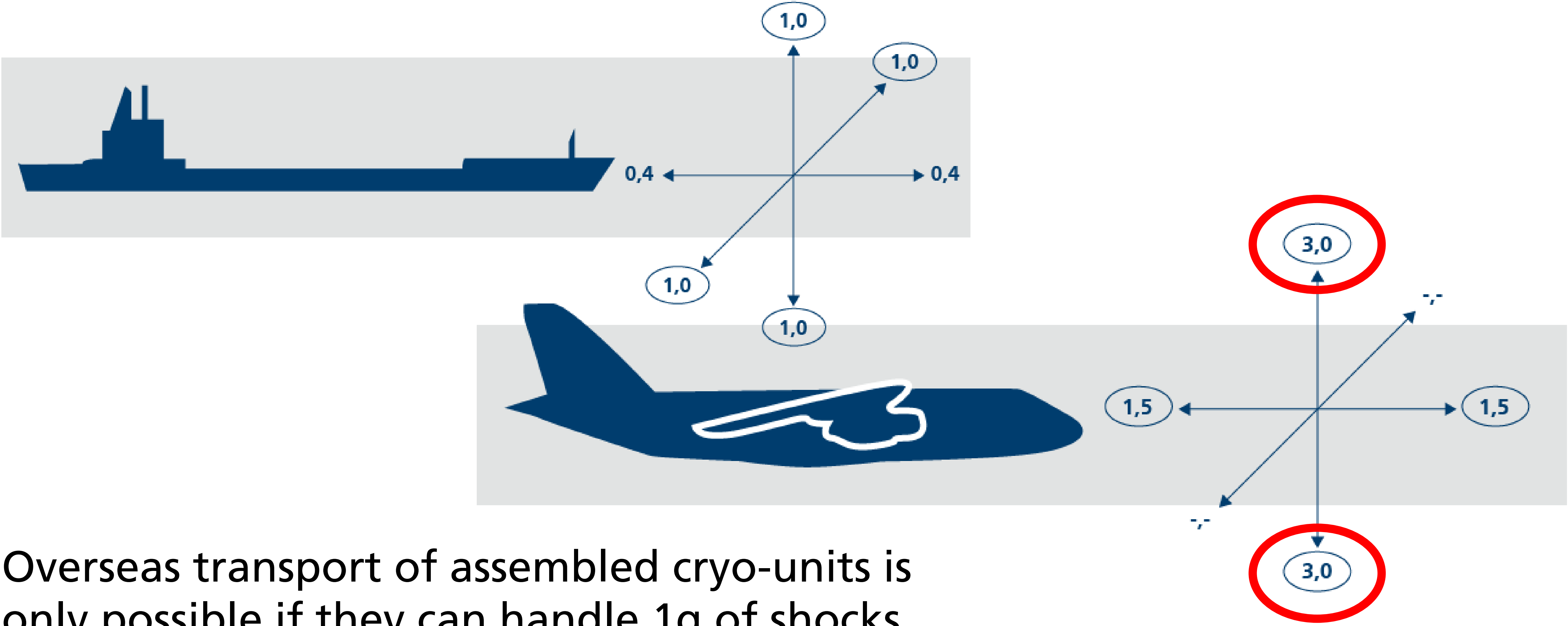


Outsourcing of Processes to Suppliers

- Outsourcing the entire value-added process or only parts of it is often proposed when suppliers offer the same services or products but at lower cost. Usually the cost reduction is a result of **economies of scale** or **lean production processes**.
- As the final product has neither been designed nor engineered yet, there are currently no suitable suppliers on the market to offer the requested product. As CERN owns process knowledge from LHC a **collaboration between CERN and the future supplier will be essential**.

Experiences gained from LHC production shows that it is possible to outsource the production of cryo-units. For test reasons a small charge of cryo-units was produced and delivered by a supplier. **The quality was satisfying.**

Transport stresses and modes of transport for international transport / overseas



Overseas transport of assembled cryo-units is only possible if they can handle 1g of shocks

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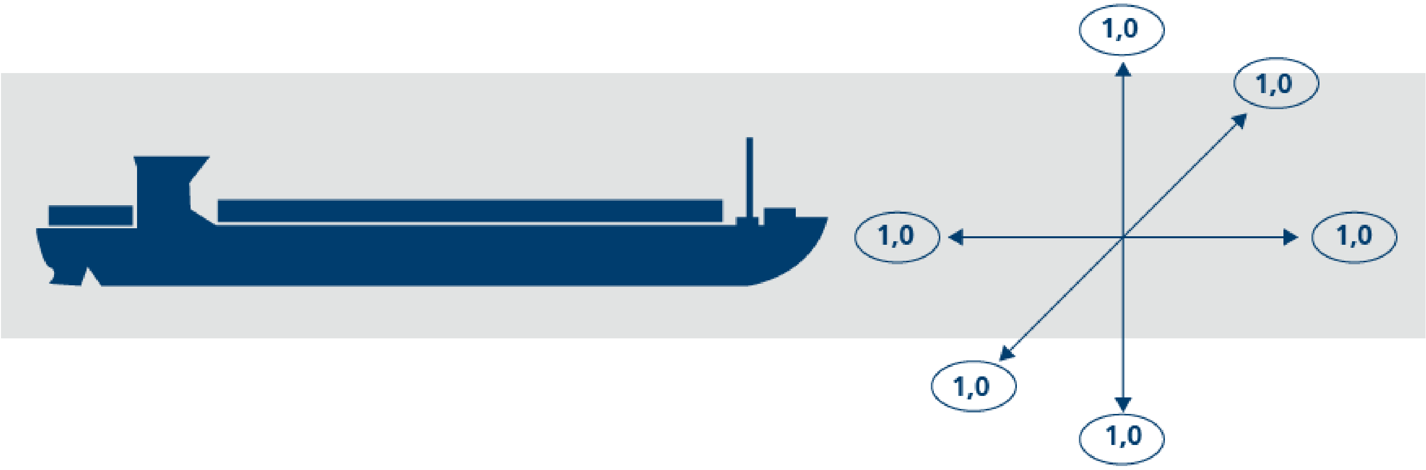
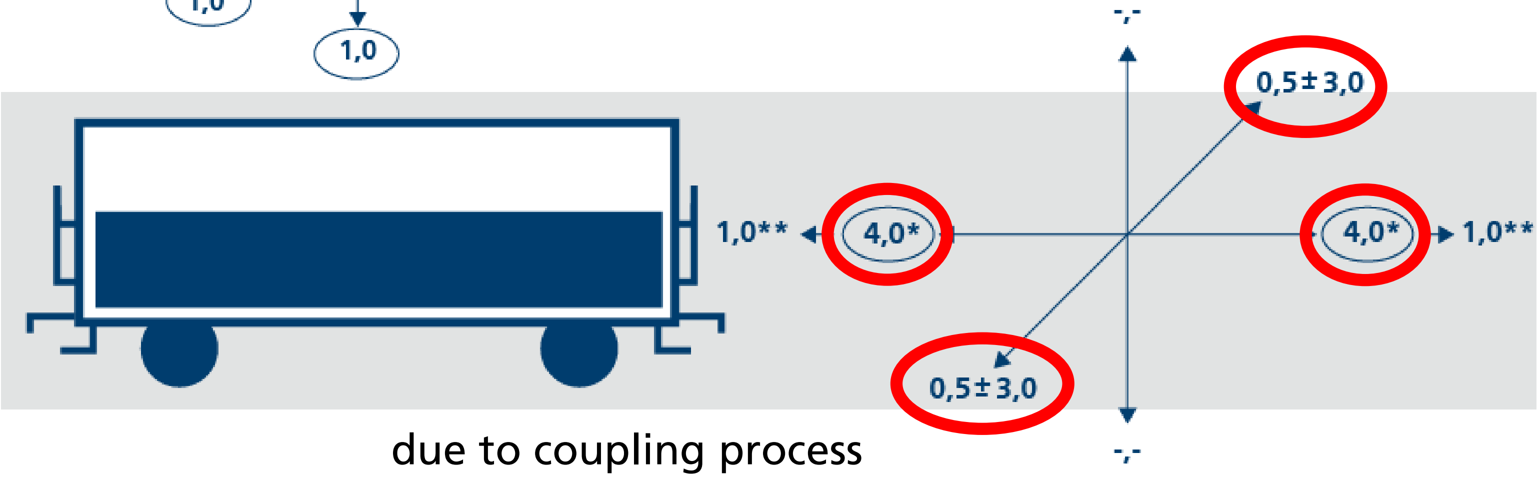
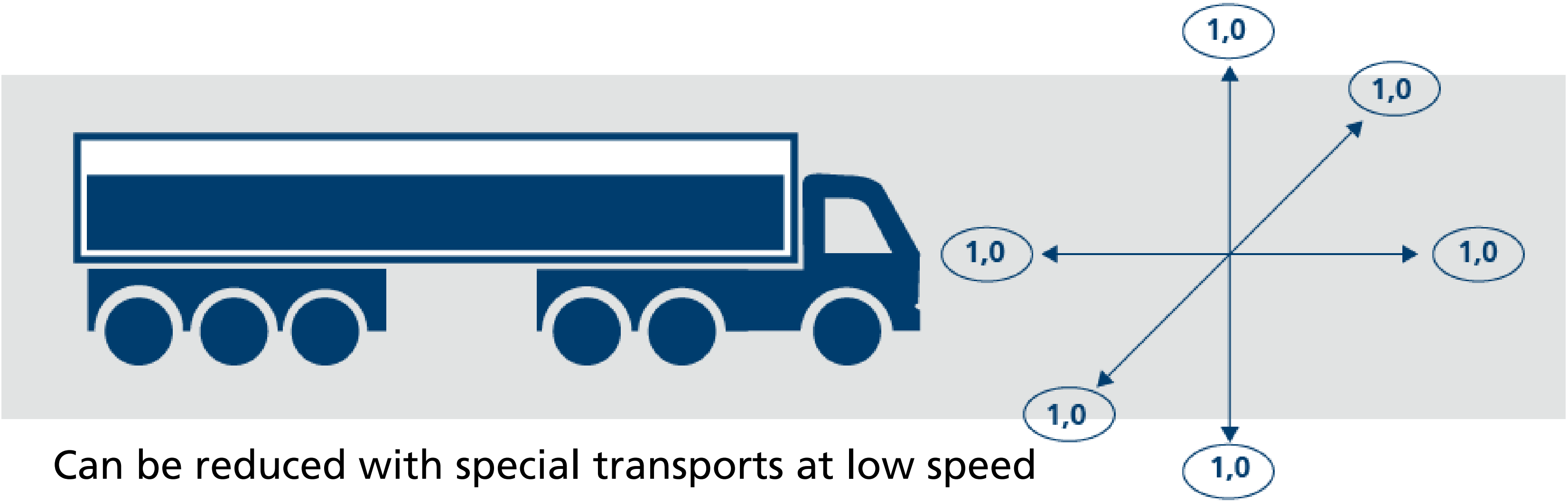
Transport stresses and modes of transport for continental transport





due to coupling process

Transport stresses and modes of transport for continental and last mile transport



Can be reduced with special transports at low speed

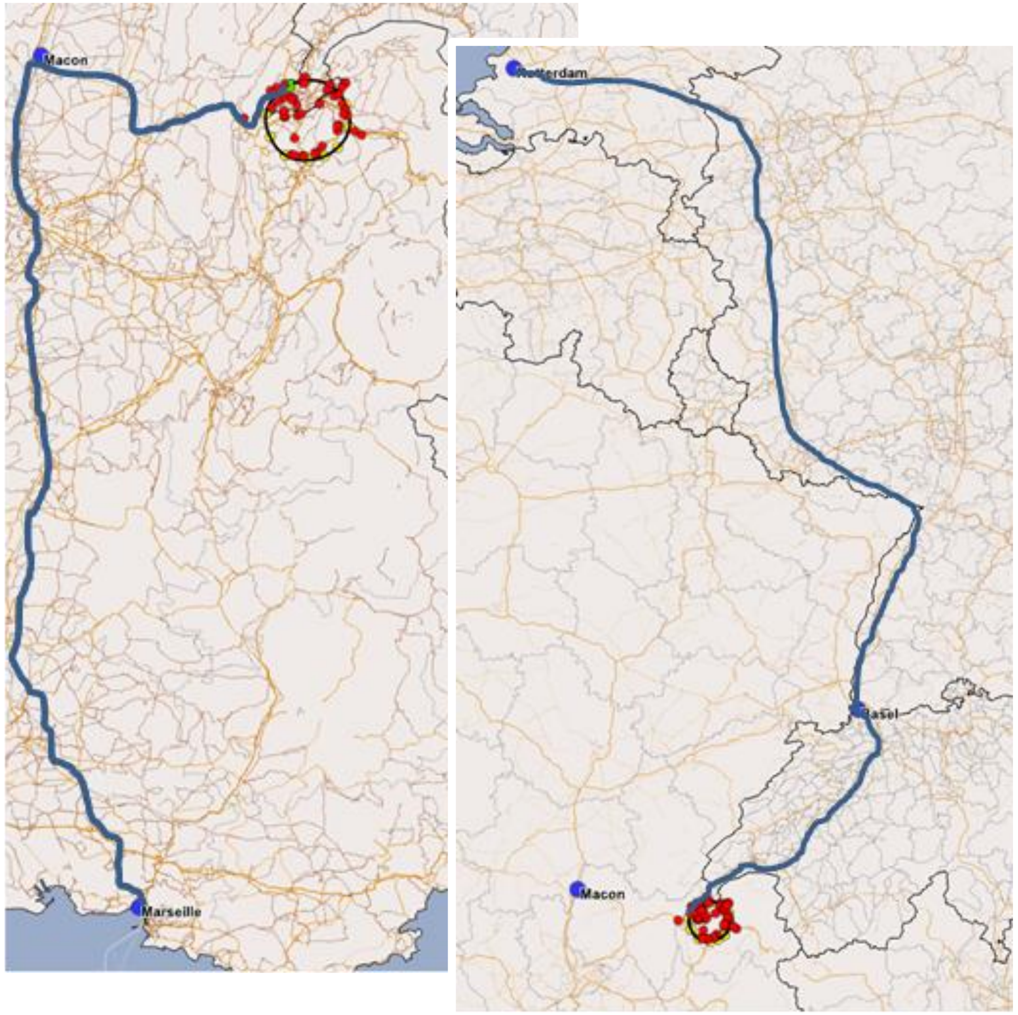
Possible routes to CERN (not complete)

Alternative A: Marseilles -> Mâcon -> CERN

- Oversea transport to Marseilles
- Barge transport to Mâcon
- Last mile via road transport to CERN
- Alternative: direct road transport from Marseilles to CERN

Alternative B: Rotterdam -> Basel -> CERN

- Oversea transport to Rotterdam
- Barge transport to Basel
- Last mile via road transport to CERN
- Alternative: direct road transport from Rotterdam to CERN



Design concept for a special purpose vehicles for the underground transportation and handling of cryo-units

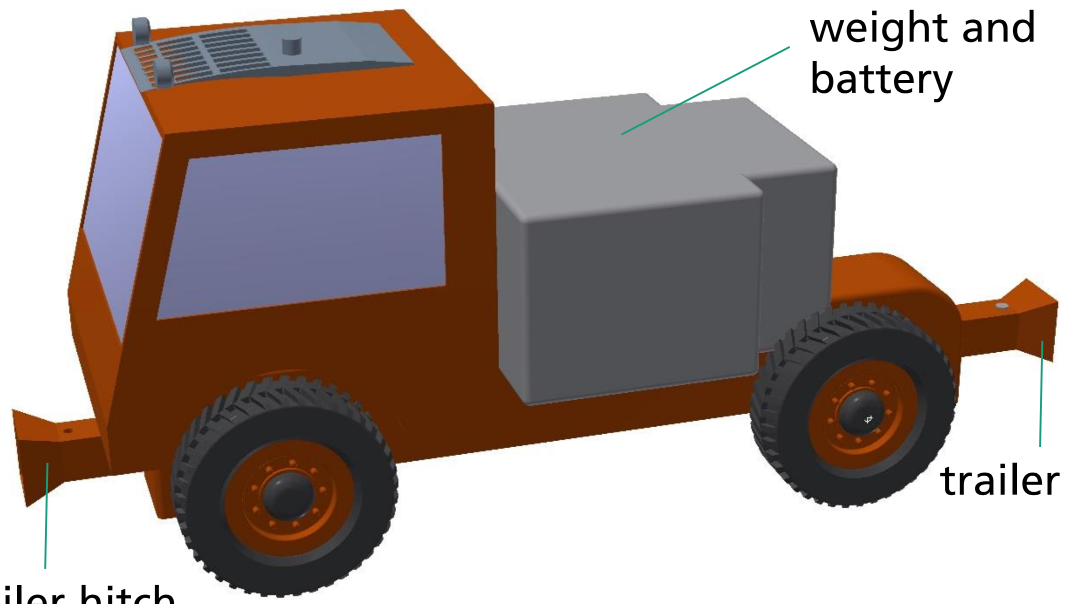
Main facts about vehicle concept:

- Maximum speed: 10km/h – loaded, 20km/h unloaded
- Maximum possible slope: ~3 Degree (ca. 5%)
- Battery technology based on lithium-ion batteries
- Autonomous driving technology based on contour navigation based on safety laser scanners and navigation scanners

Design concept for a special purpose vehicles for the underground transportation and handling of cryo-units

Pulling tractor

- The tractor is equipped with electric and emission-free drive
    - E.g. based on lithium-ion batteries
- An intelligent navigation and control system allows autonomous driving in tunnels
    - E.g. using contour navigation based on safety laser scanners and navigation scanners



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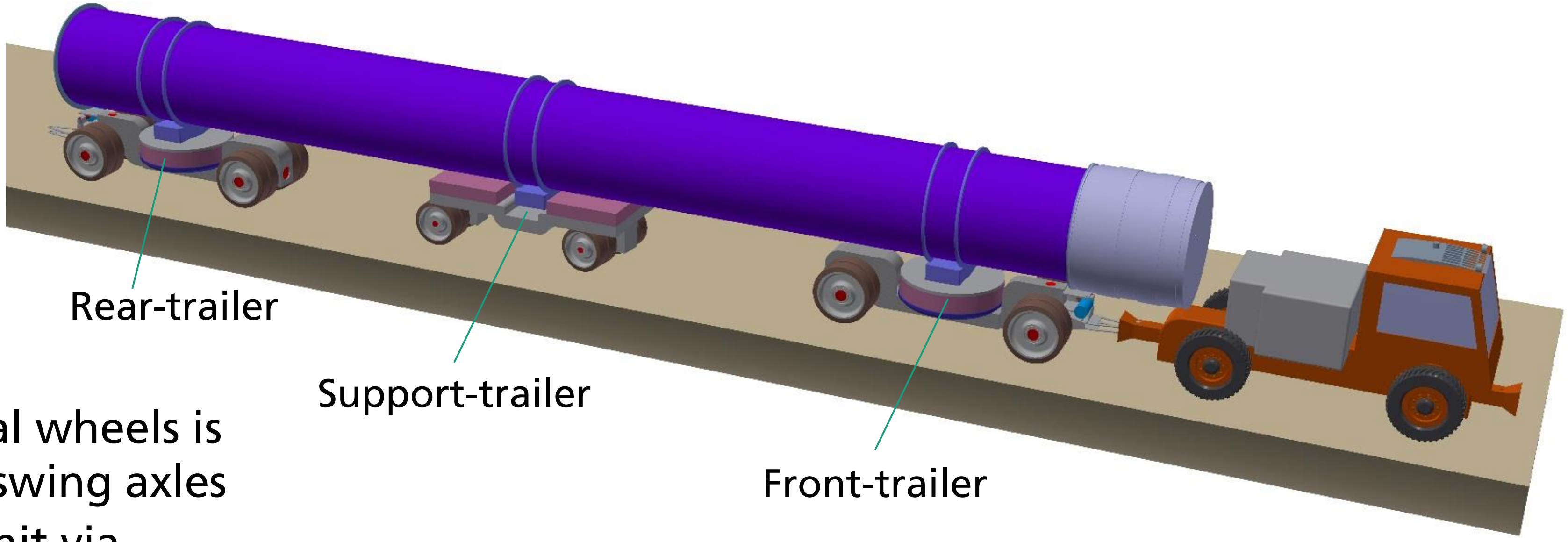
Design concept for a special purpose vehicles for the underground transportation and handling of cryo-units

- Transport trailers (rear-trailer and front-trailer) equipped with electronic steering system, drawbar and vibration-dampening support for the loading



- Ground contact of the special wheels is secured by using pendulum/swing axles
- Support for centre of cryo-unit via supporting third trailer

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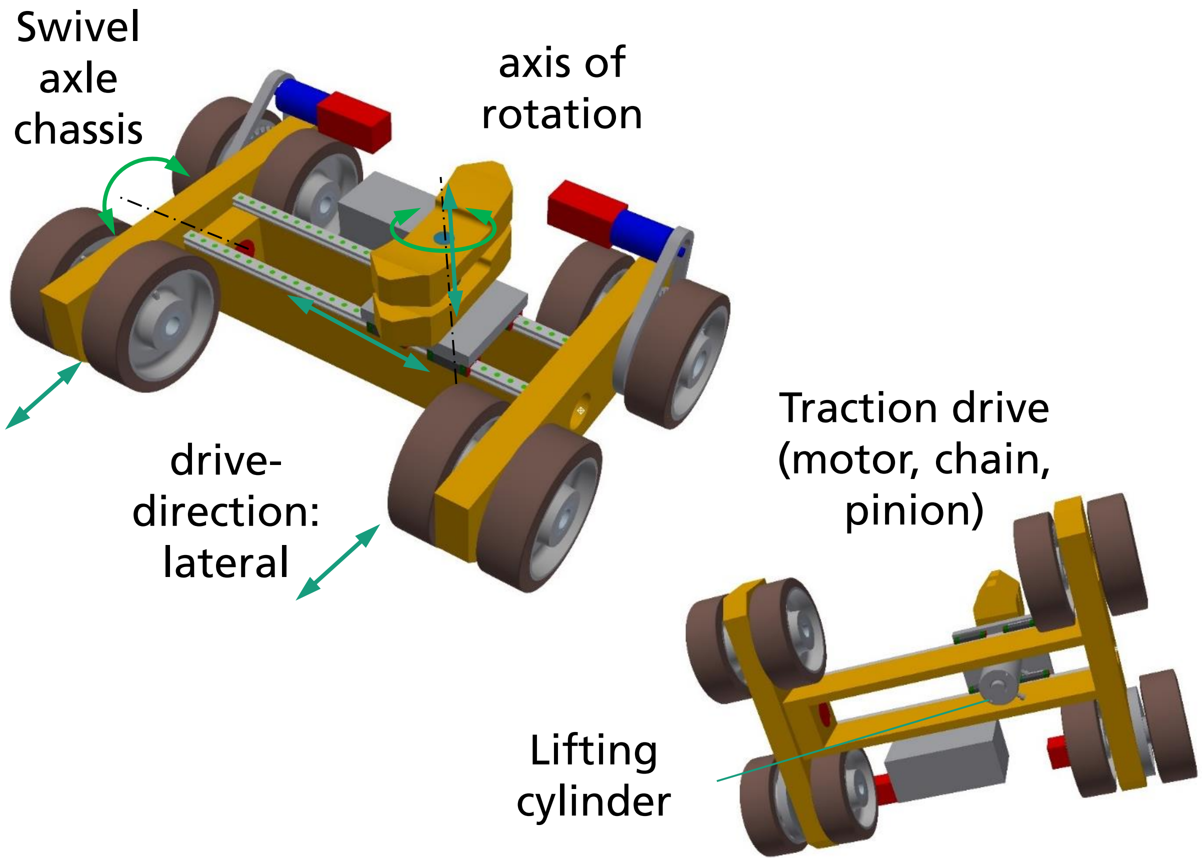
Design concept for a special purpose vehicles for the underground transportation and handling of cryo-units

- Two transfer tables equipped with hoists are used for unloading the cryo-units of the transport vehicle
- When the tractor with cryo-unit arrives at its designated position (mounting position) in the tunnel, the two transfer tables drive below the cryo-unit
- The two transfer tables lift the cryo-unit and move it laterally into the assembling position of the cryo-unit



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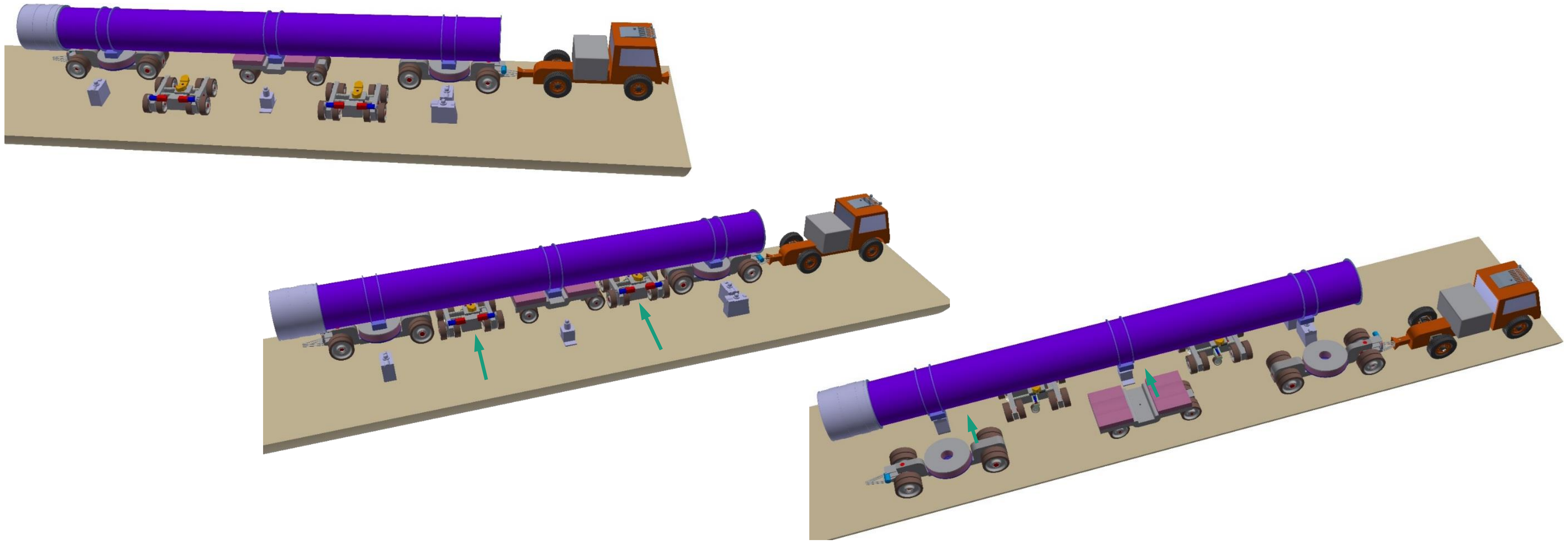
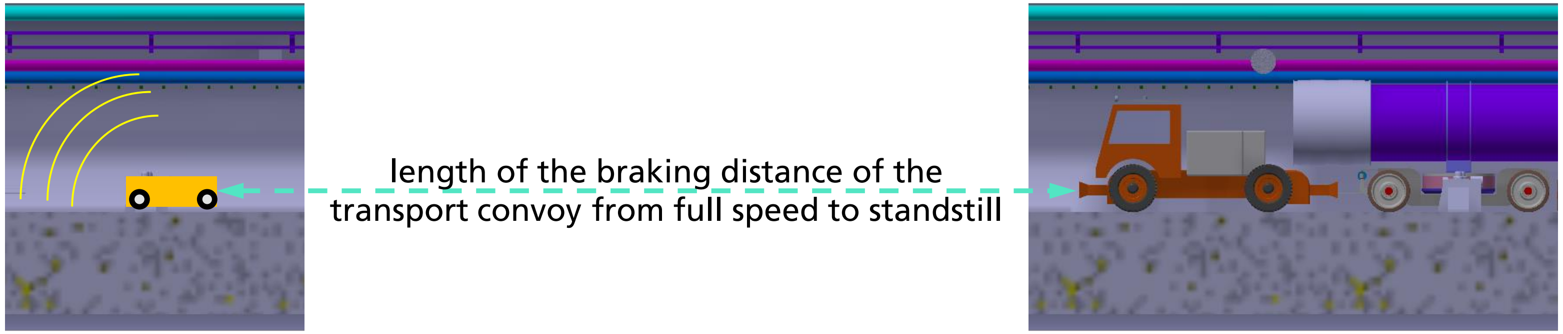
Design concept for a special purpose vehicles for the underground transportation and handling of cryo-units

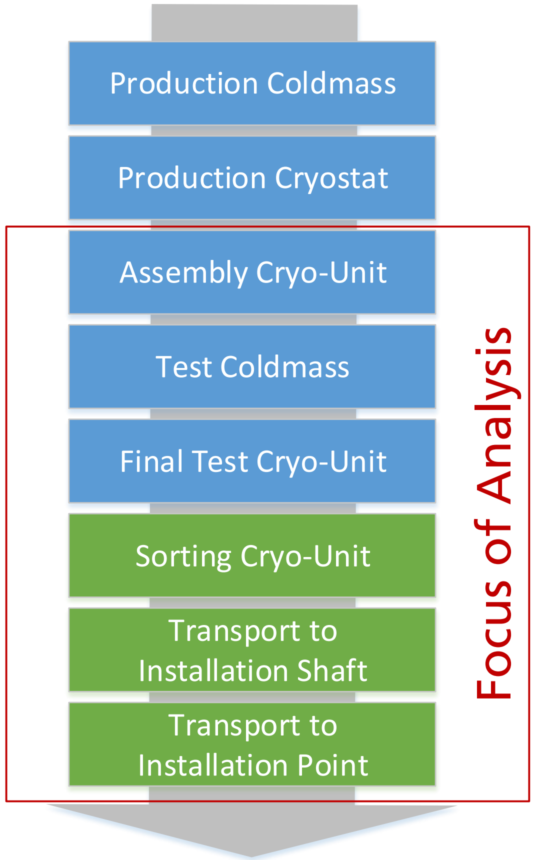


Design concept for a special purpose vehicles for the underground transportation and handling of cryo-units

- Speed of vehicles is limited by their capability to do emergency breaks fully loaded within the range of safety sensors
- Higher velocities could be realised by the development of a "**watchdog**" principle, where an additional vehicle or even drone is moving in front of the transport convoy in the tunnel
- This watchdog is scanning the environment to identify possible blockings (e.g. assembly tools, cleaning tools, building materials, etc. remaining in the tunnel) and humans on the track
- If something is detected the watchdog will trigger an emergency break at the convoy to prevent a collision -> The distance from the watchdog to the transport convoy needs to be at least the distance between the braking distance (length of the braking distance of the transport convoy from full speed to standstill).



Analysis Tunnel Transport and Delivery Scenario



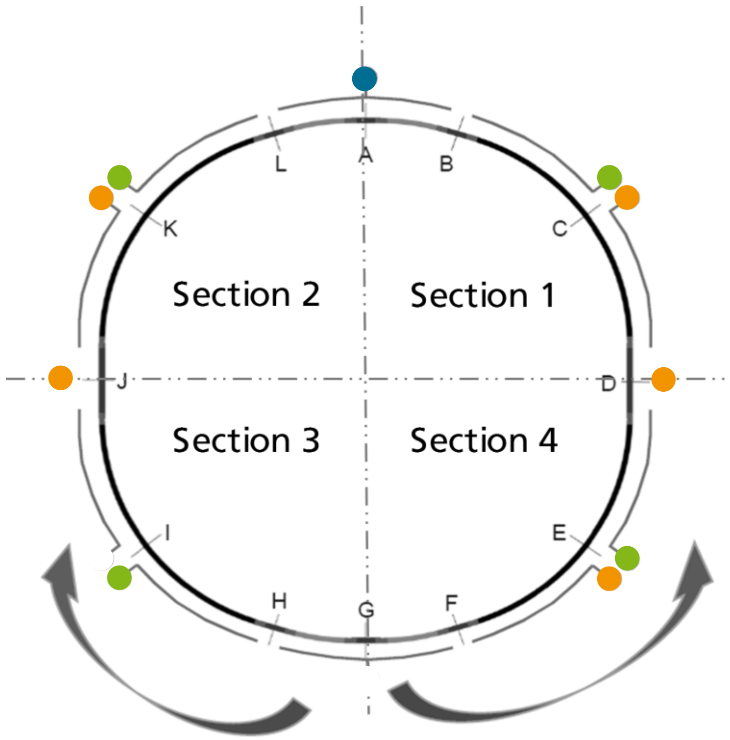
- The focused processes can be executed by a supplier or by CERN, either organized central or decentral.
- The aim of the following investigation is to analyse different scenarios for a central or decentral organized logistics by CERN. Therefore, a two-step approach was executed:
  - Identification of a valid tunnel transport scenario
  - Identification of a proper delivery strategy

Three different alternatives are investigated

Central Supply Via Shaft A

Decentral Supply Via Two Shafts
Short Overground Transport from CERN: C – K
Opposite Location: E – K
Equal underground Transport Distances: J – D
Combination CERN and additional shaft: A – E

Current Planning
Decentral Supply Via Four Shafts
C – K – E – I



Analysis Tunnel Transport and Delivery Scenario

Assumptions

Parameter	Value
Underground transport (speed loaded)	10 km/h
Underground transport (speed unloaded)	20 km/h
Transport time interval	10 PM – 6 AM (Duration: 8 hours)
Loading time (crane transport included)	1h
Unloading time	1h
Duration assembly (LHC x1 / x2 / x3) in days	5,33 / 10,66 / 15,99
Duration coldmass test (LHC x1 / x2 / x3) in days	5 / 10 / 15
Duration final test (LHC x1 / x2 / x3) in days	0,5 / 1 / 1,5

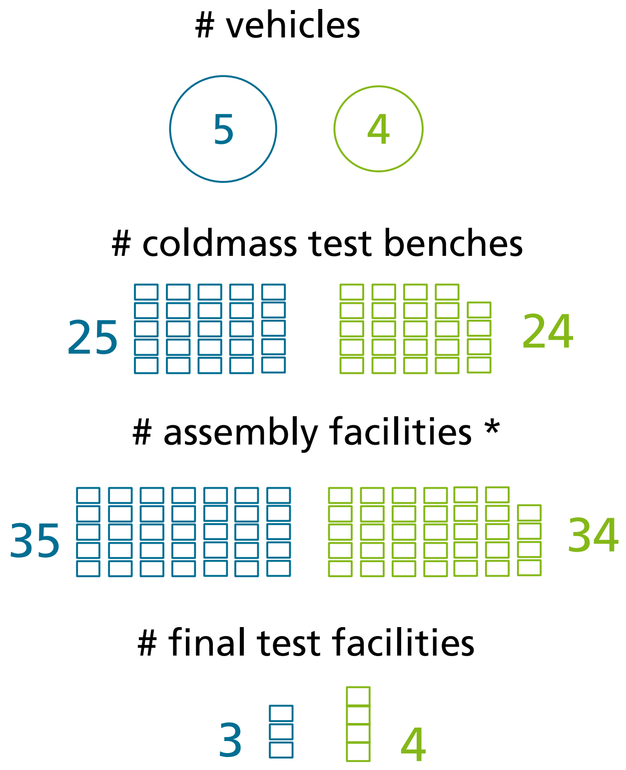
Supply scenarios considering the overall FCC construction schedule

Central supply via shaft A

+ existing capacities at CERN can be used (cryo-plant, storage capacities,..)
– disturbances in the tunnel or at the shaft like delay in installing, crane failures will have a major impact on compliance of construction schedule

Decentral supply via two shafts A and E

+ existing capacities at CERN can be used (cryo-plant, storage capacities,..)
+ alternative far more robust
– Costs for construction higher than central supply alternative,
– additional area outside CERN needed for facilities at second shaft
– long transport ways for tested magnets on public roads if test/assembly facilities remain at CERN area



* Reduction if assembly and coldmass test shift times are adapted (coldmass test - 7 d/w, Assembly - 5 d/w)

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Follow-up and Discussions

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