# CHAPTER 30

# INTEGRATION AND INSTALLATION

## 30.1 INTEGRATION ISSUES

### 30.1.1 Introduction

In order to minimise civil engineering costs, the cross-section of the TI 2 and TI 8 transfer line tunnels has been kept to a minimum. Because of the very limited space available for both equipment and transport, a detailed integration study has been made for the transfer lines. This included the beamline equipment as well as the associated power and control cabling, tubing for water cooling, the transport power rail and general services such as leaky feeder cables, lights and safety elements. Furthermore, a new special purpose transport system had to be developed for installation of the accelerator components in order to meet the very stringent limitations on the space available in the transfer line tunnels. The integration of TI 2 was particularly complicated because the tunnel downstream from PMI 2 will also be used for the transport of cryomagnets to the LHC main ring. Initial installation of the LHC machine will be done without any beamline components being installed in this region. However, the integration of the final installation has taken into account the fact that the passage of cryomagnet transport convoys is still possible once the complete transfer line has been installed.

### 30.1.2 Integration of TI 8

All the integration and installation issues of TI 8 have been studied in detail. Apart from some optimisation of the cable tray positions around the MBIAV magnets, no major problems were found to incorporate all the required services. Around these MBIAV magnets, which are considerably larger than all the other beamline components, extra space for the magnet and the installation equipment had to be created. A typical TI 8 cross section is given in Fig. 30.1 and more detailed cross sections can be found on drawing LHCLSI__0006.

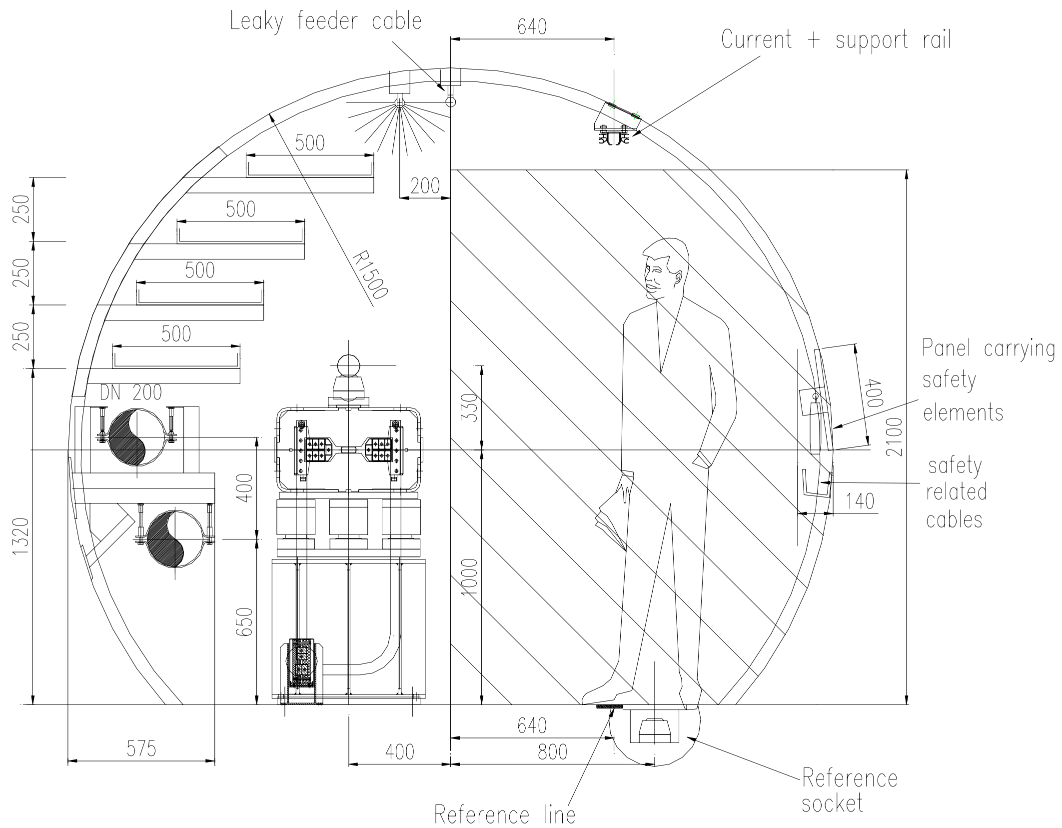


Figure 30.1: A typical TI 8 cross section, the hatched surface indicating the reserved space for transport.

The TED beam stoppers, which are movable for operational reasons, are other large objects in the transfer line tunnels. The stroke of the movement has been increased such that the complete object can be moved further towards the tunnel wall during installation in order to avoid interference with the transport equipment.

As a result of the complexity of the interference between the transfer line and the LHC tunnel, the complete integration studies of the downstream part of the tunnel, between TED87765 and MKIMA5R8 were done by using 3-D techniques. The study included the UJ88, RH87 and RA87 parts of the LHC tunnel and all equipment and services were successfully integrated. The only outstanding integration issue concerns the TCDI collimators, where the mechanical design still has to be finalised. Nevertheless, preliminary studies have shown that sufficient space is available for these objects, although the design of the TCDI for the protection of the MSI will need to take into account the close proximity of the beam pipe of the second ring of the LHC.

### 30.1.3 Integration of TI 2

The integration and installation issues of the TI 2 transfer line upstream of PMI 2 are comparable to those of TI 8. On the other hand the part downstream from PMI 2 was more complicated, since this section of the tunnel will be used for the transport of cryomagnets to the LHC main ring. Although the initial installation campaign will be done before any injection line magnets are installed, the integration studies needed to take into account the required space in case a cryodipole needs to be replaced once all equipment is installed. For the standard cross section, a solution has been found and a TI 2 cross section downstream of PMI 2 is given in Fig. 30.2, showing the most critical situation around a MBIAV magnet. More detailed cross sections can be found on drawing LHCLSI__0007.

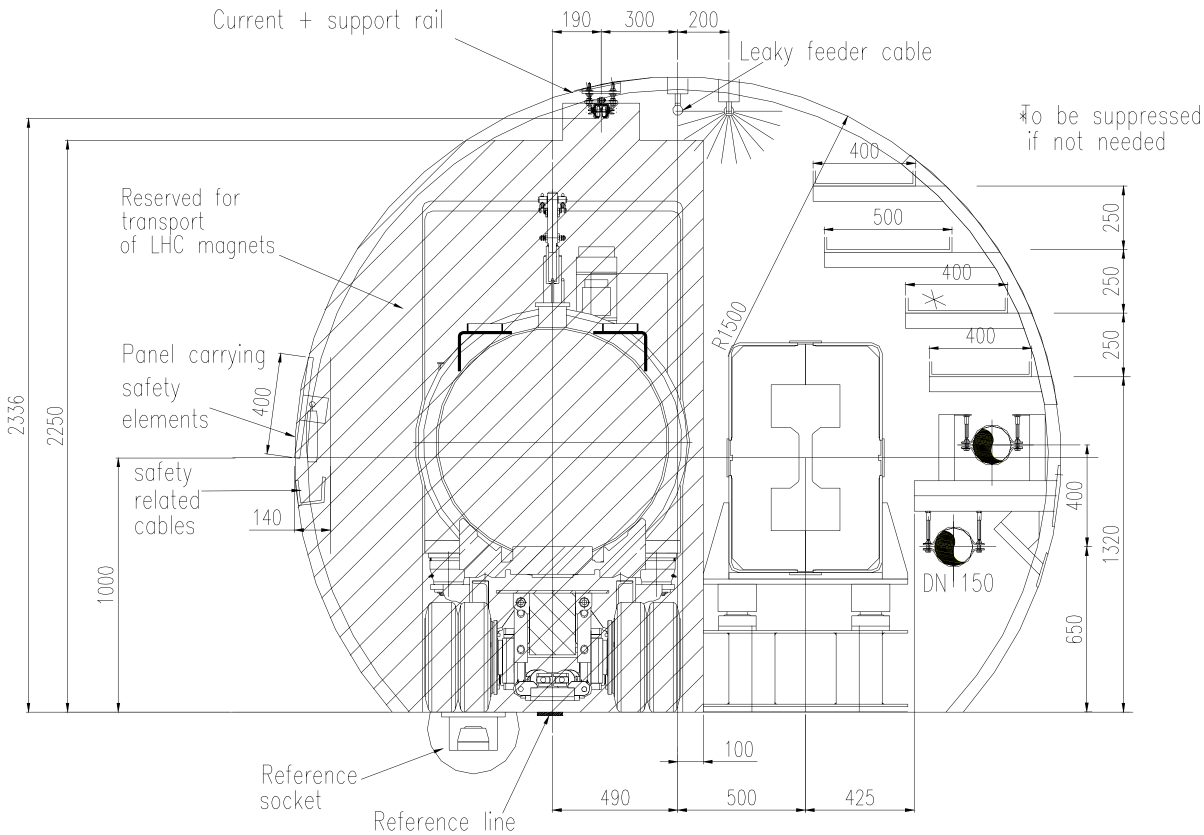


Figure 30.2: A typical TI 2 cross-section between PMI 2 and UJ22, in this case around an MBIAV.

As for TI 8, the complete integration studies of the downstream part of the tunnel, between TED29133 and MKID5L2B1 were done by using 3-D techniques. The study included the UJ22, RH23 and RA23 parts of the LHC tunnel with the area were the TI 2 tunnel joins UJ22 being particularly complicated since the cryomagnet transport follows the axis of the transfer line beam pipe which moves very close to the TI 2 tunnel wall at the exit. The integration studies showed that insufficient space was available for all services and in particular the cable trays in this region. For this reason the power cabling now enters the TI 2 tunnel by means of 2 special purpose Ø250 mm holes which have been drilled between the LHC and TI 2 tunnels about 4 meters upstream of TED29133. The same remarks concerning the integration of the TCDI collimators into TI 2 apply as for TI 8. Furthermore, the optimum position of the 90° horizontal TCDI is 6 m downstream of TED29133, this being the same space limited area were the TI 2 tunnel joins UJ22 as mentioned above, which may strongly influence the design and maximum size of the TCDI vacuum vessel.

## 30.2 TRANSPORT AND INSTALLATION SYSTEM

### 30.2.1 Passage of cryomagnets in TI 2

A downstream part of the TI 2 tunnel will be used for the transport of the approximately 1700 cryomagnets that are to be installed in the LHC main ring. This region includes the PMI 2 shaft and the downstream tunnel right to UJ22, where the TI 2 tunnel joins the LHC main ring. In addition, the first 200m of tunnel upstream of PMI 2 will be used for parking vehicles waiting for cryomagnets to be lowered down the PMI 2 shaft.

Because of the limited TI 2 cross section, the beamline components in the downstream part of TI 2 will not be installed until the cryomagnet installation transport activities have been completed. A typical TI 2 cross section downstream of PMI 2 before installation of accelerator components is given in Fig. 30.3. Also the distance between the beam line and the centre of the tunnel downstream of PMI 2 has been increased to 500 mm, as compared to 400 mm in the rest of TI 2 and TI 8 (see Fig. 30.1). This action was taken in order to allow more room for the cryomagnet vehicle passage once the injection line magnets have been installed. After beamline installation, the passage of cryomagnet transport convoys will still be possible, but with small clearances and the recovery of a vehicle in the event of breakdown will therefore be more difficult and time consuming.

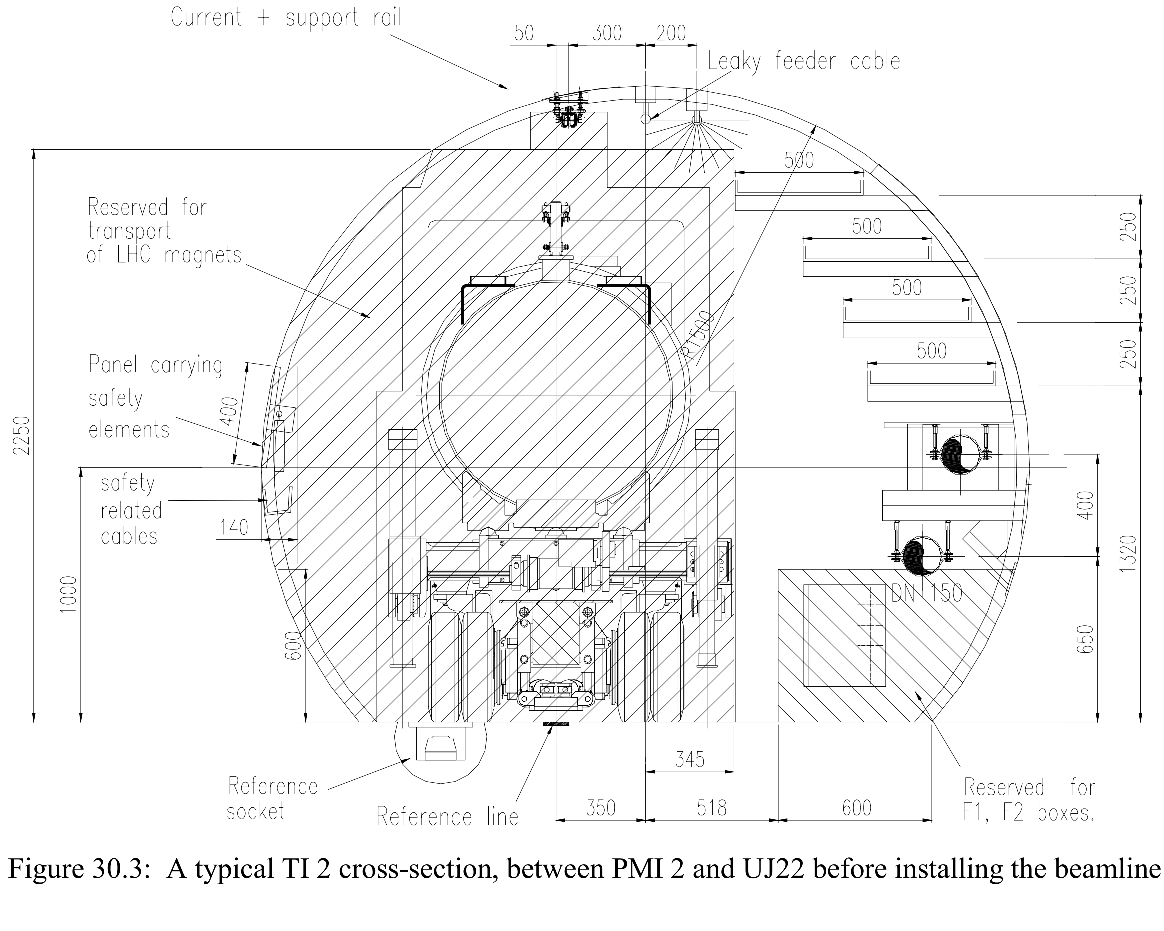


Figure 30.3: A typical TI 2 cross-section, between PMI 2 and UJ22 before installing the beamline

The electrical power needed for the cryomagnet transport vehicle will be provided by a sliding conductor rail mounted along the upper surface of the tunnel. The same type of power rail will be fitted throughout the length of the TI 2 and TI 8 tunnels to also provide power for the special vehicles used for the transport of transfer line components. The power supply trolleys running on the power rails are suitable for both cryomagnet and injection line transport vehicles. An automatic guidance system has been implemented, which is also identical for both types of vehicle, in order to allow reasonably fast passage in the restricted space available. The path to be followed by this system is defined by a highly reflective line on a black background painted on the floor along the transport passage in TI 2 and TI 8.

During installation, space will be necessary at the base of the PMI 2 shaft for the facilities and equipment to be used by the transport operators. After completion of the installation, the base of the PMI 2 shaft will be closed with concrete shielding blocks, forming a wall and roof over the injection line. If a cryomagnet needs to be replaced this shielding will be removed using the crane of the SMI 2 building.

The LHC design report, Vol. II, Chap. 12 gives a more detailed description of the cryomagnet transport vehicles and their operation [1].

### 30.2.2 Transport System for Transfer Line Components

A new transport system for the installation of the beamline components has been conceived to meet the very stringent space requirements in the LHC transfer line tunnels. A modular system of very compact electrical tractors, so-called buggies, was chosen. These motorised carrier vehicles can turn 90° on the spot in order to displace and position a load laterally and are equipped with a set of air cushions for lifting and lowering of the weight. In this way magnets or other accelerator components can be placed directly onto their supports in the beamline.

The relative compactness of the load carrying buggies was achieved by displacing the cubicles for powering and controlling the motors onto a common auxiliary vehicle, which is linked via cables to the buggies. The vehicles can be powered from the power rails via buffer batteries, which provide autonomy of about 3 km, as well as absorb electrical power produced during downhill transport. Cabins at front and rear of the auxiliary vehicle seat two transport staff and house the touch screens for programming and monitoring the automatic guidance system of the convoy. The cabins are also equipped with a steering wheel and brake pedals for direct control by the driver and manual driving and positioning of the vehicles can also be done via a handheld, wireless control unit.

*The Buggy-modules*

The original and quite unusual concept of the buggies, specified in detail in [2] and [3], consists of a combination of three wheels turning individually under a load carrying chassis with a longitudinally nodding saddle structure. A three dimensional view of the buggies is given in Fig. 30.4.

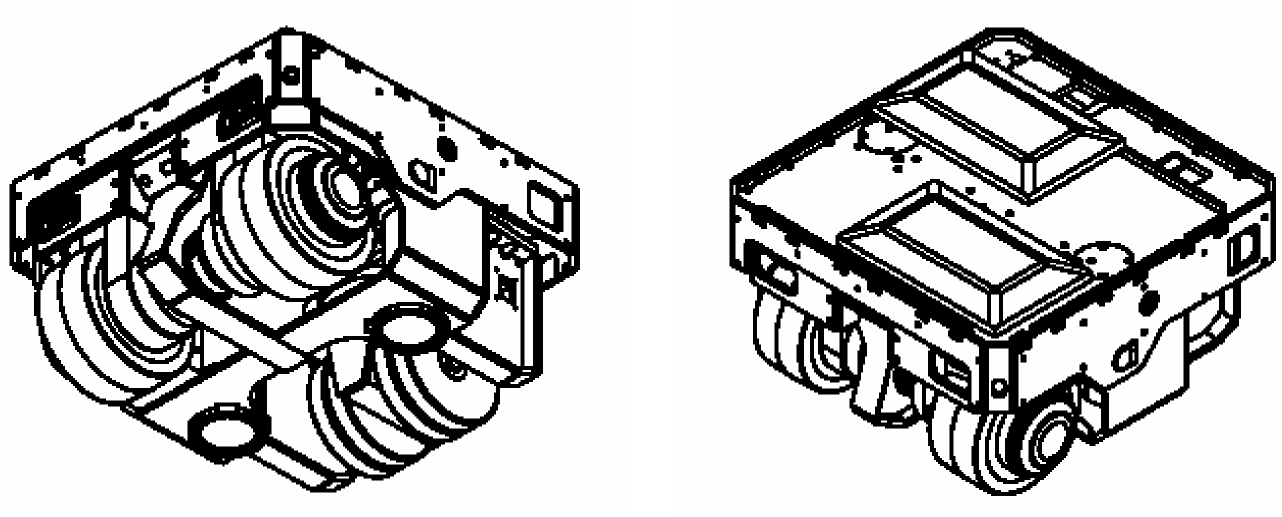

Figure 30.4: Three dimensional, bottom and top view of the buggies.

The positions of the motorised wheels are individually calculated and controlled by a central computer and each module has a load carrying capacity of 9 tonnes. This robust design has the possibility to combine up to 8 of these load carrying modules into one convoy. The mobility of the buggies is based on one castor wheel, built up from four slices, together with two motorised wheels, each equipped with a 3.4 kW in-wheel motor. Each of the wheels can be turned 130° by individually controlled steering motors. The motorised wheels are equipped with disc brakes and a 25.9:1 planetary reduction gear, which allows the vehicle to climb slopes up to 8 %.

A maximum load of 9 tonnes can be placed on the saddle-like structure, distributing the weight equally onto the wheels and allowing the chassis underneath to follow changes in slope. Each Buggy-module is 960 mm long, 940 mm wide and 540 mm high. Two rectangular air cushions placed on top of the saddle structure allow the load to be lifted by about 60 mm.

Optical guidance is done via a camera, equipped with 16 laser diodes, which is mounted onto the front of the chassis and is centred between the steered wheels. A convoy travelling at its maximum speed of about 4 km/h can be guided within a precision of +/-10 mm. Figs. 30.1, 30.2 and 30.3 show the position of the overhead current and support rail which is used for powering the vehicles and the reference line on the floor for the automatic guidance system.

*Typical applications, girders and adapters*

The Buggy modules will work in sets of two, linked mechanically on one side by a girder in order to have a well defined steering geometry. The girders are situated on the passage side of the tunnel to allow the convoy to enter under the beamline without interfering with the magnet supports, as shown in Fig. 30.5. This is also the optimum arrangement to channel cables and supply hoses between the auxiliary vehicle and the Buggies. In addition, this configuration gives a maximum freedom for tilt between the modules, to compensate for imperfections in the tunnel floor.

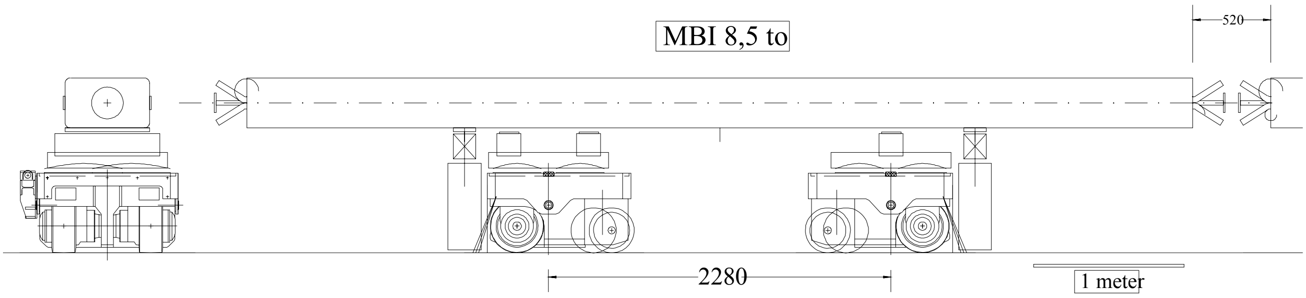


Figure 30.5: Typical application of the transport system in the transfer lines, showing an MBI installation.

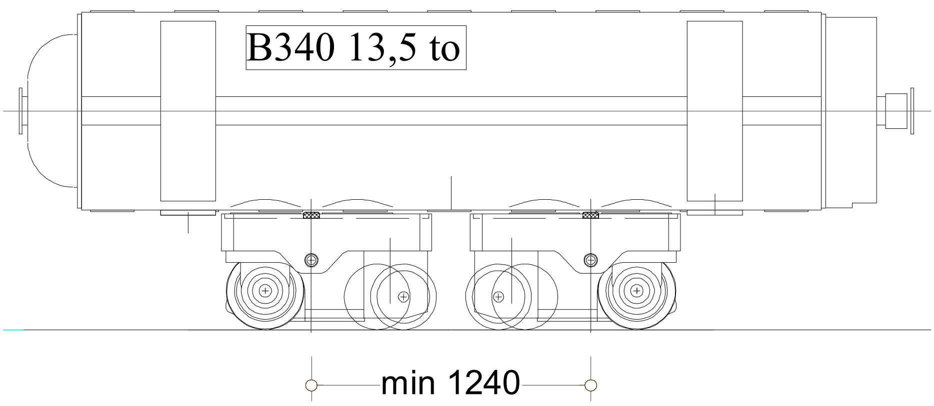


Figure 30.6: MBIAV transport in the transfer lines

The girder structures, which typically add 120 mm to the width of a convoy, are based on reinforced I-profiles and allow the distance between two Buggies to be changed in steps of 40mm within the range of 1240 mm to 3160 mm. Typical applications of the transport system for the transfer line components are shown in Figs. 30.5, 30.6 and 30.7.

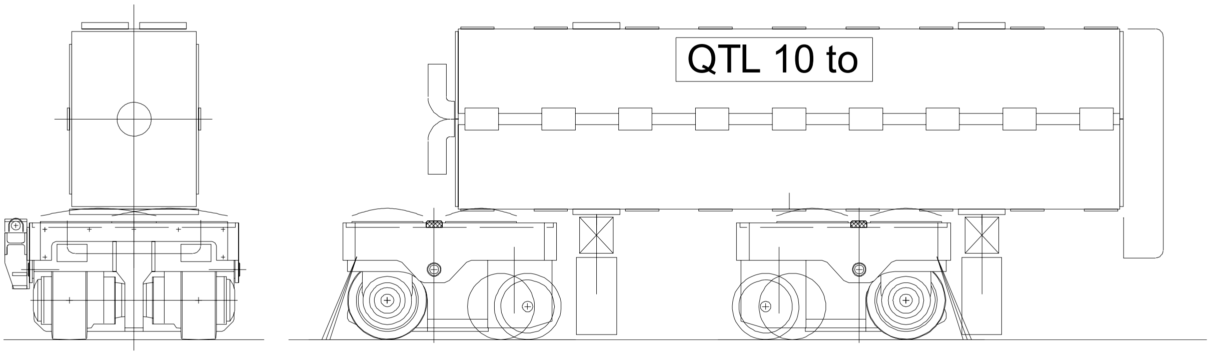


Figure 30.7: Transport and installation of a QTL magnet.

Special modifications are planned to install a series of tilted main bending magnets in TI 8 and in the TT41 beam line of the CNGS project. The adapter allows the magnets to be transported in the safe horizontal position and then tilting them up to 20 degrees before placing them onto their supports in the beamline. Fig. 30.8 shows this modification of the transport system during the installation of an MBIT magnet.

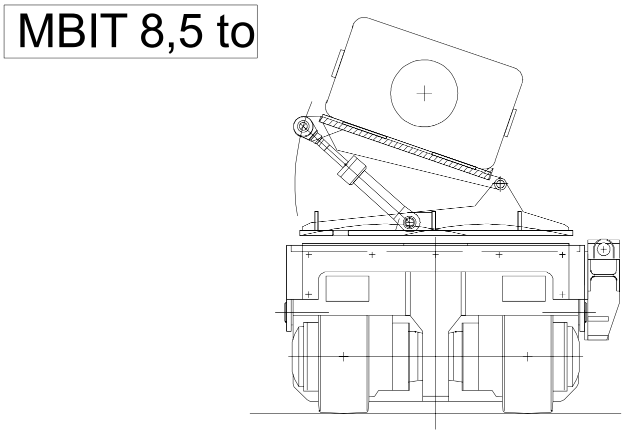


Figure 30.8: Modification of the transport system in the transfer lines for MBIT installation.

A special purpose crane girder has been developed for the installation of the 1.1 tonne MQI quadrupoles. A second more bulky version has also been built which can handle charges of up to 3.2 tonne-meter. Fig. 30.9 shows the installation of an MQI quadrupole using the standard crane girder.

The transport of the TED beam dump was done with a configuration of three modules, as shown in Fig. 30.10, ensuring a reasonable load distribution for transport in regions with a changing slope. The girder for this combination therefore allows the central module to move freely up and down and have a tilt independently of the position of the other two buggies. Correct load sharing can be achieved by adding or releasing air from the cushions of the central buggy in such a way that the pre-selected overall pressure on all modules stays constant.

A special purpose lifting device has been fitted into the roof of the tunnel at the TED position in TT40, TI 2 and TI 8 to transfer the heavy TED from the buggy convoy onto its beamline supports, as shown in Fig. 30.10.

*Convoy configurations and potential of the system*

The versatility of the Buggy concept has opened the possibility to use the application in other areas than the initially planned transfer lines and adapters for special cases are presently under study. Examples are the installation of magnets to which the system is currently not matched, such as the warm insertion- and CNGS-magnets.

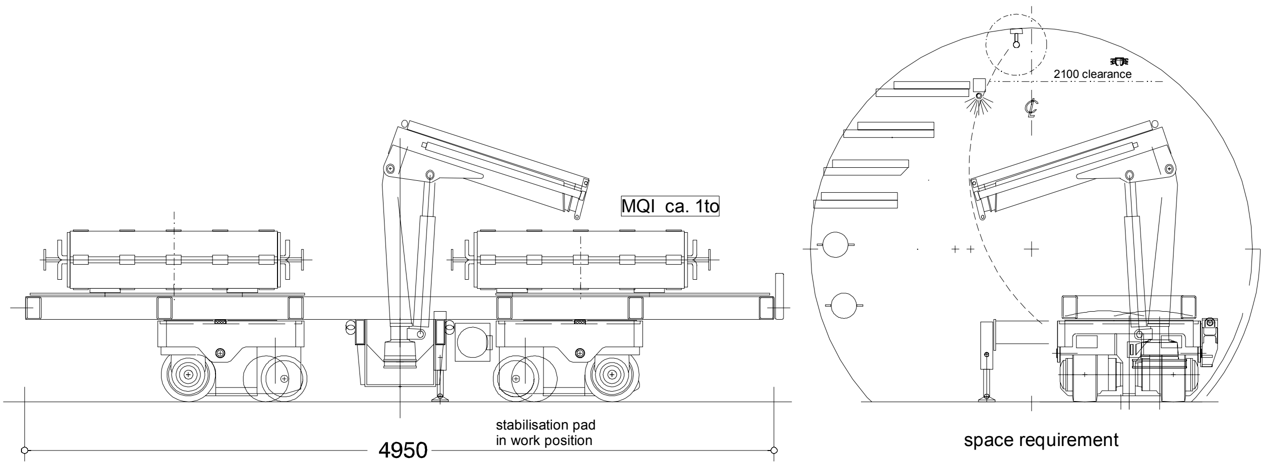


Figure 30.9: Installation of an MQI quadrupole using the special purpose crane girder.

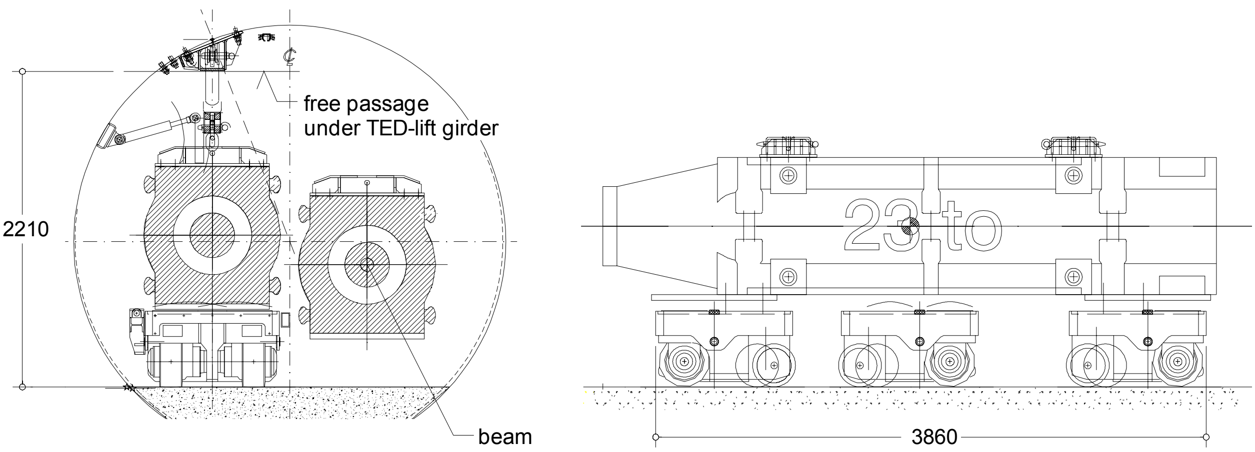


Figure 30.10: TED lifting device and transport configuration.

## REFERENCES

[1] R. Saban, "*Logistics and Installation*", LHC Design Report, volume II - LHC Infrastructure and General Services, Chap. 12.

[2] G. Kouba, "*Supply of Induction Guided Bogies for Magnet Installation in TI2 and TI8*", CERN SL, IT-2949-SL-LHC, 2001-02-22, EDMS 306286.

[3] G. Kouba, "*Supply of optically guided Buggies*", Revision of IT-2949-SL-LHC.