CHAPTER 6

Detector Integration

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6.1 MECHANICAL CONCEPT

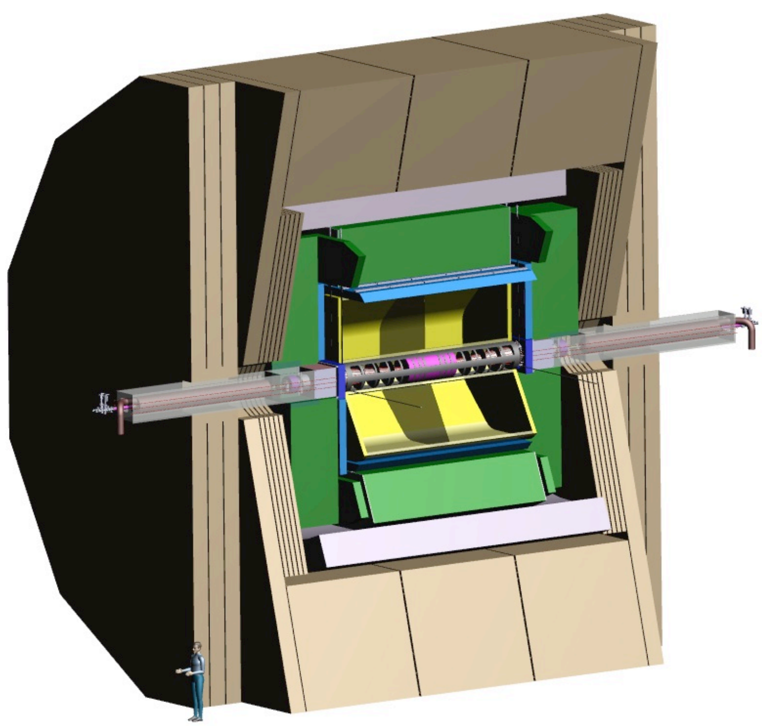

FIGURE 6.1-1. The mechanical design of the ILD detector.

The mechanical design of the ILD detector is shown in figure 6.1-1. The major parts are the five rings of the iron return yoke: three barrel rings and two endcaps. The central barrel ring carries the cryostat with the solenoid coil in which the barrel calorimeters are installed. The TPC and the outer silicon envelope detectors are also suspended from the cryostat using tie rods. The endcap calorimeters are supported by the endcap yoke sections which can be moved independently from the barrel sections to allow an opening of the detector at the beam line. The beam pipe, the vertex detector and the other inner silicon detectors are supported from a structure of carbon fibre reinforced plastic (CFRP), which hangs at the flanges of the TPC field cage. The whole structure can be aligned with respect to the beam axis using actuators and a laser alignment system. The QD0 magnets are mounted independent of the yoke endcaps in a support structure which carries the magnets and the forward calorimeters. This structure is supported from a pillar outside of the detector and is suspended from the solenoid cryostat using tie rods. The QD0 magnets are also monitored by a laser alignment system and can be moved using actuators.

6.1.1 Cabling Scheme

All cables from the barrel detectors will be routed between the cryostat of the coil and the innermost barrel tail catcher chambers to the gap between the central yoke barrel ring and the outer barrel yoke rings. The space needed for services between the cryostat and the tail catcher sums up to a thickness of 34 mm, which includes a safety margin of a factor of 2. As additional space will be needed to allow for mechanical deformations of the cryostat and the barrel yoke and clearance for the movement of the barrel ring during installation, 250 mm have been assumed in the current engineering design between the cryostat and the first iron ring of the barrel yoke.

The gaps between the barrel rings are assumed to be 50 mm wide. This allows enough space for the routing of the cables and services (34 mm) and the hard stops (10 mm) where the barrel rings are connected mechanically. An additional chimney for the helium supply of the cryostat is foreseen.

The cables of the endcap detectors will be routed through the gaps between the endcaps and the barrel. As the gaps here cannot be enlarged beyond 25 mm due to the limitation on the allowed magnetic stray fields, the cables will be routed via four channels of 100 $\times$ 825 mm which are equally distributed in ϕ.

6.2 DETECTOR ASSEMBLY AND OPENING

The ILD detector will be assembled in large parts in a surface building above the underground experimental hall. The pre-assembled sections will then be lowered into the underground cavern using a temporary portal crane. The largest and heaviest ($\approx$3000t) part will be the central barrel ring with the solenoid coil and the barrel calorimeters installed. The underground assembly sequence is shown in figure 6.2-2 and comprises the following steps:

1. the first pillar for the support of the QD0 magent is installed. This pillar needs to be movable in the garage position but will not move on the beam line. The service helium cryostat is also carried by the pillar.

2. the QD0 magnet is suspended from the pillar together with its support structure

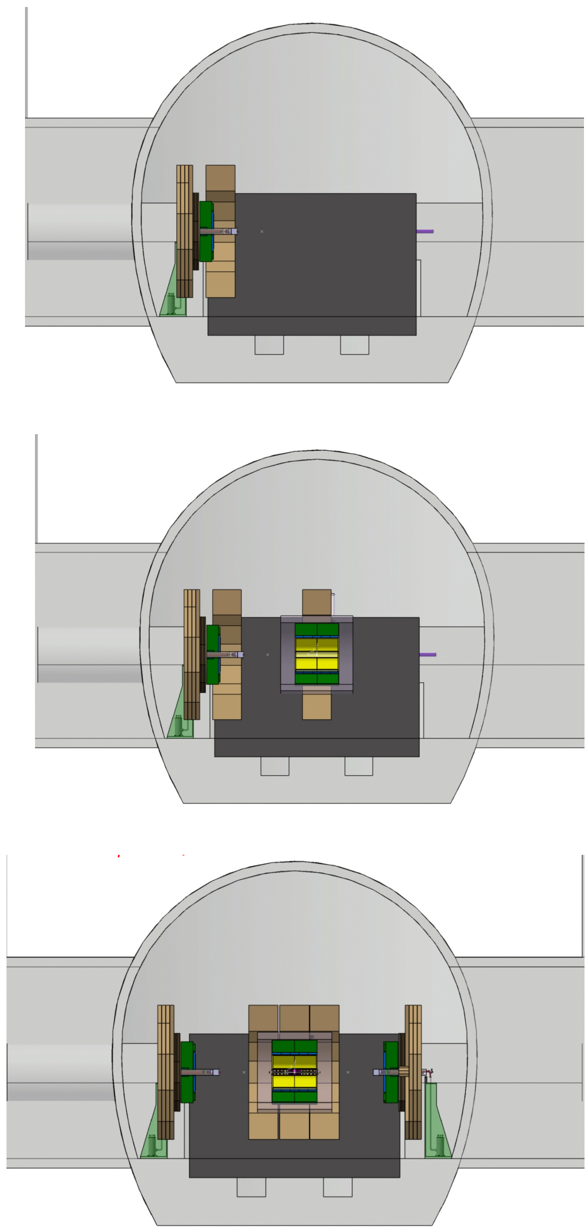

FIGURE 6.2-2. Detector assembly sequence.

3. the endcap yoke is installed

4. the endcap calorimeters are installed and the cables are routed to the outside

5. the first ring of the barrel yoke is installed

6. the central yoke part with the barrel calorimeters is installed, the cables are routed through the slits between the central yoke ring and the other rings
7. the TPC is inserted, the cables follow the routes of the barrel calorimeters
8. the inner part of the detector including the beam pipe and the inner silicon detectors is inserted into the TPC, cables are routed to the outside
9. the barrel yoke is closed
10. the second pillar, QD0 (with support) and the second yoke endcap are installed

Figure 6.2-2 shows the detectors after steps 4, 7 and 10.

The detector can be opened and maintained in the garage position using the above described procedures. The space required in the garage position is best met with a hall width of 30m.

It is planned to allow the opening of the detector endcaps also at the beam line. As space is limited there due to the machine elements, only limited access can be reached. The QF1 magnet extends to 9.5m from the IP. Additional space is needed for the QF1 cryostat and the flanges between QF1 and QD0. Preliminary studies show that access space of $\approx$1 m can be gained between the endcap and the barrel yoke. This would allow limited access to the inner detector for short maintenance actions at the beam line. Major interventions would be done in the garage position taking advantage of the push-pull system.

6.3 CIVIL FACILITIES AND SERVICES

6.3.1 Detector services

A number of services are needed for the operation of the ILD detector. The concept of push-pull puts stringent requirements as the services need to be designed for a moving detector. Therefore they must be integrated in the design of the detector and the civil facilities.

6.3.1.1 Primary services

Primary services are usually provided by plants which are located on surface due to their dimensions, possible impact on the detectors (vibrations, etc.) and related risks. Examples are water chillers which provide cooling water, high to medium voltage power transformers (e.g. 18 kV/ 400 V AC tri-phase), UPS facility (Diesel generator), Helium storage and compressor plant for the solenoid coil and gas and compressed air plants.

6.3.1.2 Secondary services

Secondary service plants need often be close to the detector and should be located in the underground areas. Typical secondary services are temperature stabilised cooling water, voltage supplies for front end electronics, AC/DC converters for the super-conducting coil and cryogenics and vacuum services. Also data connections for the transmission of the detector readout need to be included. Due to the push-pull design, these services are permanently connected and run in cable-chains towards the detector. As the flexible pipes and cables in the chains need to be kept within reasonable lengths, a service cavern for the secondary services should be located in the main underground cavern with independent ventilation and limited crane access. Electrical noise and vibrations are kept away from the vicinity of the detector.

The main benefit of the usage of cable chains is the permanent connection of the detector to all its services and readout cables. The chains can be equipped when the detector is still being assembled on the surface which speeds up the connection time in the underground cavern once the detector parts are lowered. The hall floor can be kept clean and without obstructions by the use of cable chains.

6.3.1.3 On-board services

Some secondary services need to be carried on board with the detector if the connection through cable chains is technically difficult or too expensive. As this increases the risks of the detector operation in the push-pull scenario, these on-board services should be kept at a minimum. Examples are the service cryostats for the Helium supply for the solenoid and the QD0 magnets.

6.3.1.4 Cryogenics

Figure 6.3-3 shows the block diagram of the cryogenics needed for the operation of the detector solenoid coil and the QD0 magnets. While the primary facilities like the Helium storage and compressors are on the surface, the helium liquifier (4K) an the re-heater are in the underground hall. Directly on-board of the detector are the valve box, which distributes the helium to the coil, and the liquid helium tank. Also the 2K sub-cooler and the service cryostat for the QD0 magnet are moving with the detector.

6.3.2 Surface assembly hall

The detector will be assembled in a surface hall. The RDR baseline design of the surface hall (100 × 25m, 25 m high, 400 t crane capacity) is well suited for the assembly of the ILD detector. A portal crane with a capacity of 3000 t needs to be installed temporarily at the main shafts to lower the pre-assembled detector elements into the underground cavern.

6.3.3 Underground experiment hall

The underground experiment hall needs to accomodate both push-pull detectors. The design of the hall presented in the ILD RDR **??** has not been optimised taking into account realistic assumptions for the services of the detector in the push-pull environment. Figure 6.3-4 shows a design study of the underground hall which has been optimised taking into account the following criteria:

- minimum impact on civil engineering cost with respect to the RDR baseline (reduced main cavern length)
- enhanced safety by moving the shafts from the cavern ceiling to alcoves
- small service caverns at the end of the hall for the secondary services (6.3.1)
- optimised for push-pull

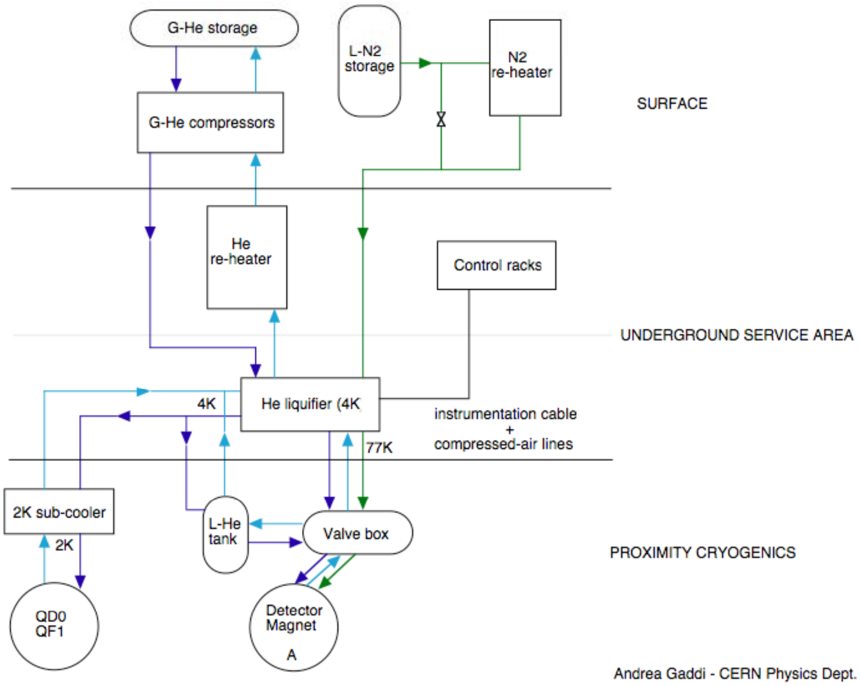

FIGURE 6.3-3. Diagram of the cryogenic services for the detector.

A hall width of 25 m is sufficient for the detector assembly and maintenance procedures as the alcoves for the vertical shafts increase the parking positions substantially. The beam height has been assumed to be 12 m from the floor of the hall. This allows for the detector on a 2.25 m high platform. As the heavy parts of the detector will be moved on air pads and on the platform, the crane capacity in the underground hall is modest. Two 40t cranes, which can be connected to form an 80t crane are sufficient.

6.4 PUSH-PULL OPERATIONS

The present ILC baseline design foresees one interaction beamline which needs to be shared by two detectors in a push-pull configuration. While one detector is taking data on the beamline, the other one is parked in its garage position in the same underground hall. Following a - still to be defined - time schedule, the detector on the beam line is moved away to its own garage position to make space for the waiting detector to collect data. This 'push-pull' scenario has never been tested at existing accelerators and poses unprecedented engineering challenges to the detector designs.

The LoI concept groups and the ILC Beam Delivery System group have agreed on a set of Minimum Functional Requirements [?] which define the boundary conditions for the push-pull operations. Most of these requirements comprise geometrical boundaries, like the size of the

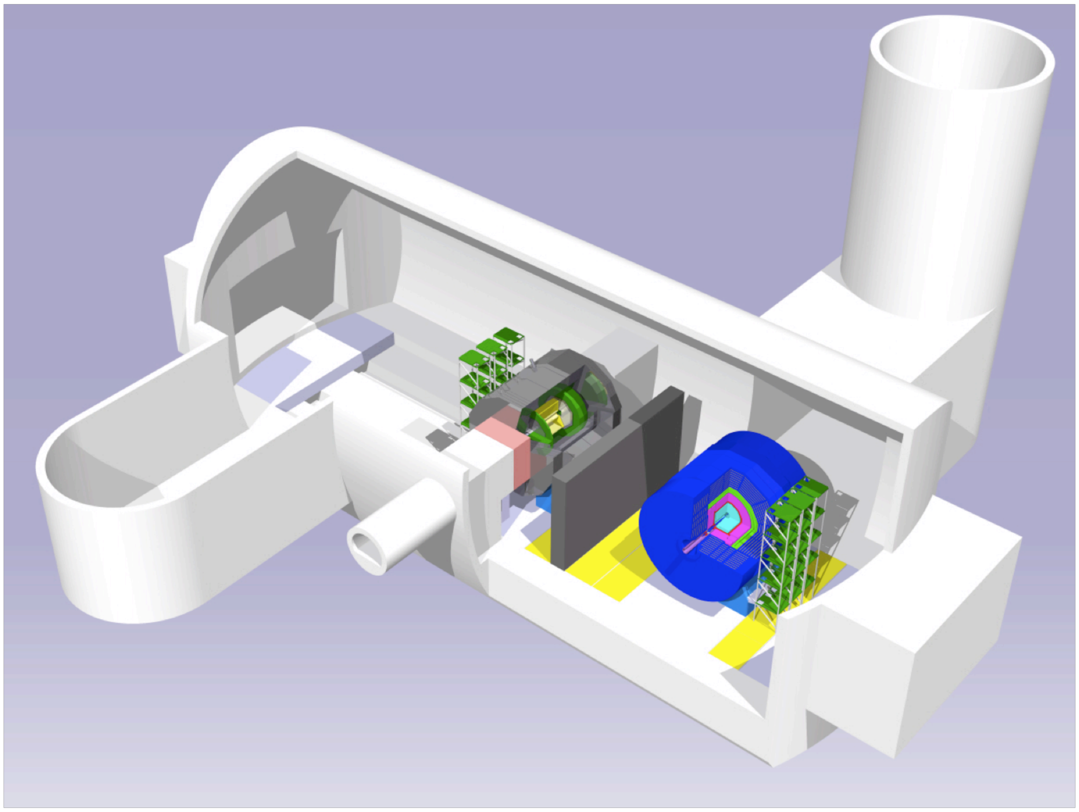

FIGURE 6.3-4. Design study of the underground experiment hall with ILD (left) and the second detector in push-pull configuration.

underground hall or the limits of the garage position of the detectors. But also physical limits for ionising radiation and magnetic fields need to be defined to allow a friendly co-existance of two detectors in one hall. In addition direct requirements come from the machine itself. As the QD0 final focus magnets will move with the detectors, requirements on alignment tolerances and vibration limits have been defined.

The timescale for the push-pull operation needs still to be defined, but it is clear that the time for the exchange of both detectors needs to be minimised to maximise the integrated luminosity. The full push-pull procedure comprises for the outgoing detector:

- powering down of the detector solenoid
- removing of the radiation shield between detector and hall
- disconnecting all local supplies (cryo, etc.)
- disconneting the beam pipe between the QD0 and the QF1 magnet
- moving the detector out toward its garage position
- connecting local supplies in the garage position

For the incoming detector the procedure is reversed, but additionally needs to include time for alignment and eventually calibration of the detector system at the beam line.

It is envisaged to complete the full push-pull operations on a timescale of maximum two days. As the full understanding of the challenges require a detailed engineering design of the hall and the procedures, a final evaluation of the push-pull operation for ILD is beyond the scope of this LoI and needs to be studied in the following Technical Design Phase. Nevertheless this section describes our conceptual understanding of the ILD operations.

6.4.1 Moving the ILD detector

The ILD detector will be placed on a concrete platform to avoid damages from vibrations during push-pull and also to ease internal alignment challenges. The concrete platform will have a size of approximately 15×20m and needs to be ≈ 2.25m thick. Figure 6.3-4 shows the ILD detector on its platform on the beam line. The platform will move on the hall floor using a system of rollers which are the most suitable solution for this one-dimensional movement.

Most supplies for the detector will be provided by using flexible supply lines which move with the platform. This includes the cryogenic lines which supply the detector solenoid with the 4K helium. As the development of flexible cryo lines for 2K helium is challenging, the QD0 magnet will be connected permanently to a service cryostat which moves together with the detector on the platform. As the detector solenoid does not need to be powered during the movement, the detector can be disconnected from the power bus bars and re-connected in the parking position. Figure6.4-5 shows a schematic drawing of the movement of the detector with the cable chains and the power bus bars.

The detector elements can be moved on the platform by using either a roller system, or by using air pads similar to the solution CMS has adopted. While the space at the beam line is limited, only the opening of the detector endcaps is foreseen to allow a limited access to the inner detectors. In the garage position more space is needed to allow major maintenance work, e.g. the removal of the TPC. More details of the opening procedures are described in section 6.2.

6.4.2 Shielding

The ILD detector will be self-shielding with respect to maximum credible accident beam loss scenarios. Detailed simulations show [**?**] that a proper design of the detector provides shielding which is sufficient to still allow access to the detector hall for professional workers. This is important to fulfil the minimum requirements which need to allow access to the other detector in its garage position during beam operations.

A movable concrete shield needs to fill the gap between the detector and the walls of the underground hall. As this shielding needs to fit both detectors, no engineering effort has been pursued so far to find a detailed design. This has been referred to the Technical Design Phase where it will be studied in collaboration with the second detector concept group. Nevertheless, these kind of shieldings have been used in other accelerator experiments (e.g. at HERA) and pose no conceptual design challenge.

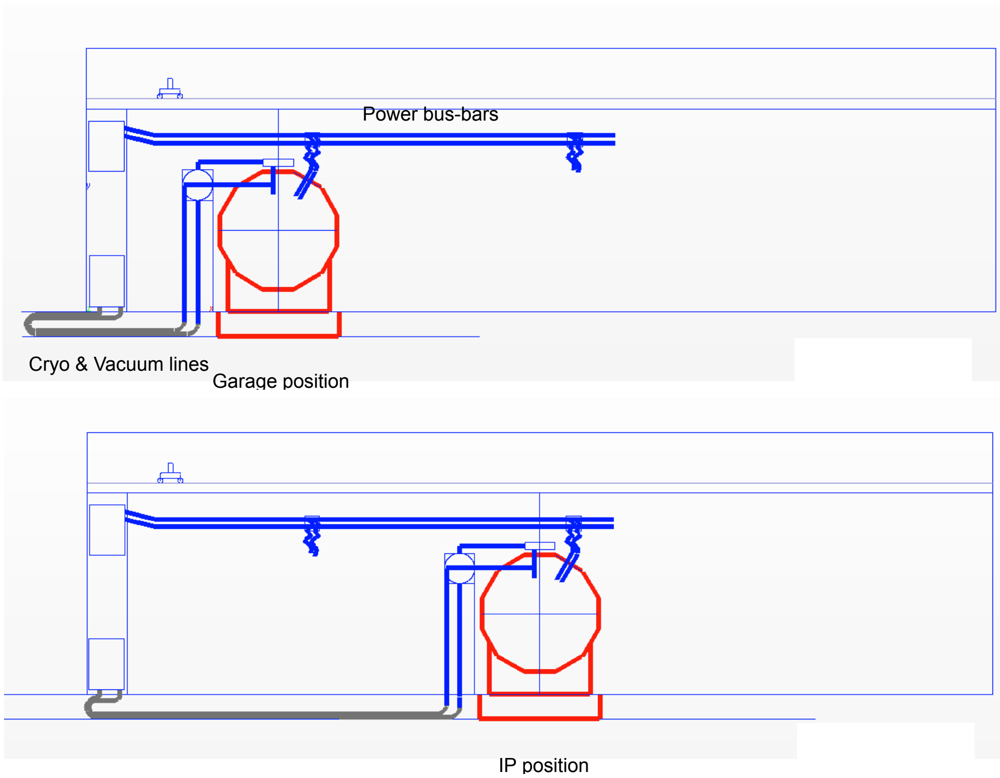

FIGURE 6.4-5. ILD detector in the garage position and on the beam line.

6.4.3 Alignment and Calibration

Though the ILD detector will be moved on a platform, the alignment of the detector after being brought to the beam position is not trivial. The functional requirements ask for an alignment accuracy of the detector axis $\pm$1mm and 100μrad after push-pull. The requirements for the QD0 magnet are even tighter: $\pm$ 200 μm and 5 μrad. ILD will be equipped with a laser-interferometric alignment system like MONALISA [**?**]. This system allows for a alignment of both QD0 magnets which are carried by the detector to the ILC beam lines on each side of the hall. In addition the detector itself can be positioned within the required tolerances using this system. The QD0 magnets will be placed on actuators which allow for an independent alignment of the magnets with respect to the detector.

After the alignment of the detector and the commissioning of the beam, some calibration data needs to be taken at the energy of the Z resonance. The internal alignment of the detector can then be done most precise in offline analysis. The experience from LEP shows that about 1 pb^{-1} of calibration data on the Z peak will be needed after the push-pull procedure.