# 1 Infrastructure on top of the tank

The upper infrastructural complex is sitting on top of the superstructure at a height of 9700 mm. It consists of three main components:

- The clean room which houses the lock infrastructure for inserting the detectors into the cryo-tank,
- an electrical cabinet which houses the needed racks and support systems,
- a cryo and pumping corner.

A sketch of the infrastructure is shown in Fig. 1.

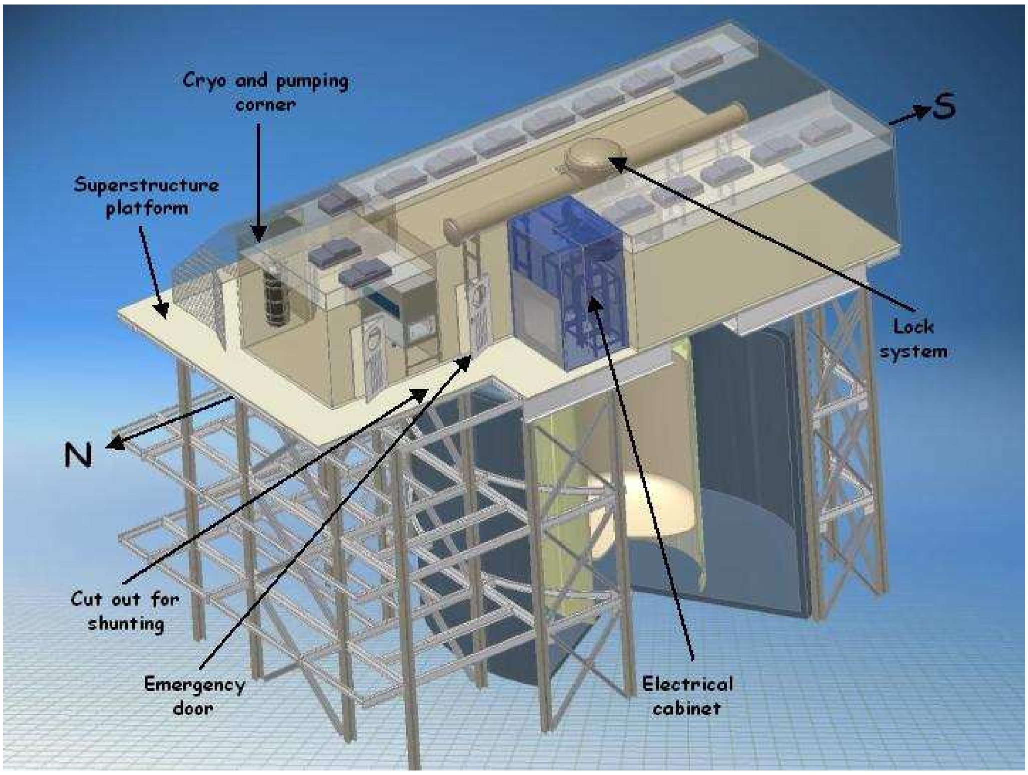


Figure 1: Sketch of the GERDA setup. The cryo-tank is enclosed within the water tank. A superstructure surrounds the water-tank. The upper infrastructural complex is placed on top of the superstructure floor above a level of 9700 mm.

## 1.1 Clean Room

The clean room is a unit by itself that is built on top of the superstructure floor. It houses the lock system and necessary infrastructure which allows the contamination-free insertion of detectors and calibration sources into the cryostat. The footprint of the clean room is determined by the superstructure platform. Due to requirements of the neighboring experiment (LVD) the clean room has a cut-out. In this area the platform forms a "landing" servicing crane operations for heavy parts and access to the penthouse. The overall clean room floor load is specified to 1 t/m$^2$. The maximum roof load is specified to 250 kg/m$^2$. This is enough to allow for the installation of a two-plate-scintillator panel on top of the clean room (scintillator plate thickness: 3 cm).

### 1.1.1 Environmental and material specifications

Radon is a major concern for the experiment. The interior of the cryostat has to be basically radon free (in total approximately 5000 $^{222}$Rn nuclei are allowed in the whole cryostat volume at one time). The inner lock is connected to the main gas volume of the cryostat. The radon concentration in the gas volume has to be lower by roughly eight orders of magnitudes compared to the tunnel air. Since the lock cannot be built completely without the use of non-metallic seals (which are subject to diffusion) it might therefore be necessary to suppress radon creeping into the lock through seals. Furthermore radon decay products might attach to aerosol particles that settle on the detector surfaces. Especially $^{210}$Pb is a dangerous source on detector surfaces. The clean room will be of class 10000. The actual handling of detectors will be done in laminar flow-boxes which provide a class 100 environment. Assuming a radon level of 1 Bq in the clean room and reasonable particle deposition rates [1] this leads to a contamination of less then 0.1 $\mu$Bq/h of $^{210}$Pb on the surface of the crystal.

The air intake of the clean room should be filtered through a radon-reduction plant. The design of the clean room has to be such as to allow for radon tightness against the tunnel atmosphere and to minimize radon emanation from the walls and the equipment. The walls of the clean room should hence be constructed out of gas-tight metal panels. The lock system as well as the work-benches and flow-boxes are constructed from steel to ensure low radon emanation.

The clean room air is filtered approximately 40 times per hour. About 120 m$^3$/h of fresh (preferably radon-reduced) air are added continuously in the filtering process. The temperature will be regulated to 21°C, the relative humidity to about 30 %. The air conditioning and the radon reduction unit will require radon reduced water to regulate the humidity. Particle counters will be located at critical points within the clean room. Oxygen monitoring will be part of the safety system.

### 1.1.2 Clean Room functionality and components

The clean room with its integrated lock system will provide the possibility to insert and withdraw detectors in a modular way while the vessel stays at cryogenic temperatures and operating pressure. It will also be used for the final preparation of the detectors and their integration into so called "strings", the loadable assemblies of up to five detectors. The design of the clean room is such as to avoid prolonged exposure of the crystals to the (clean room) atmosphere (humidity, aerosols, $^{210}$Pb).

The main components of the clean room are labeled in Fig. 2. They are:

1. Personnel lock,
2. Air shower,
3. Material lock between personnel lock and clean room,
4. Detector preparation station,
5. Detector test stand (Gerdalinchen III),
6. Detector storage system,
7. Final assembly station,
8. Lock system.

**1,2:** Personnel enter the clean room through a personnel lock and an air shower. In the lock private storage space will be available. The air-shower is constructed to avoid external air from contaminating the clean room. During operation the air-shower is filled with clean room air. This is contaminated when the door to the personnel lock is opened. Thus the air-shower has to be flushed with clean room air not only when somebody enters, but also after somebody leaves. Exhaust is to the exterior of the clean room.

**3:** Containers with detectors or other items can enter the clean room through a material lock suitable for containers up to l=60 cm, d=50 cm, h=40 cm. On a table in the personnel-lock in front of the material-lock visible dirt can be removed with pressurized air. After the container is placed inside, the lock is evacuated to avoid contamination with air from the exterior. The

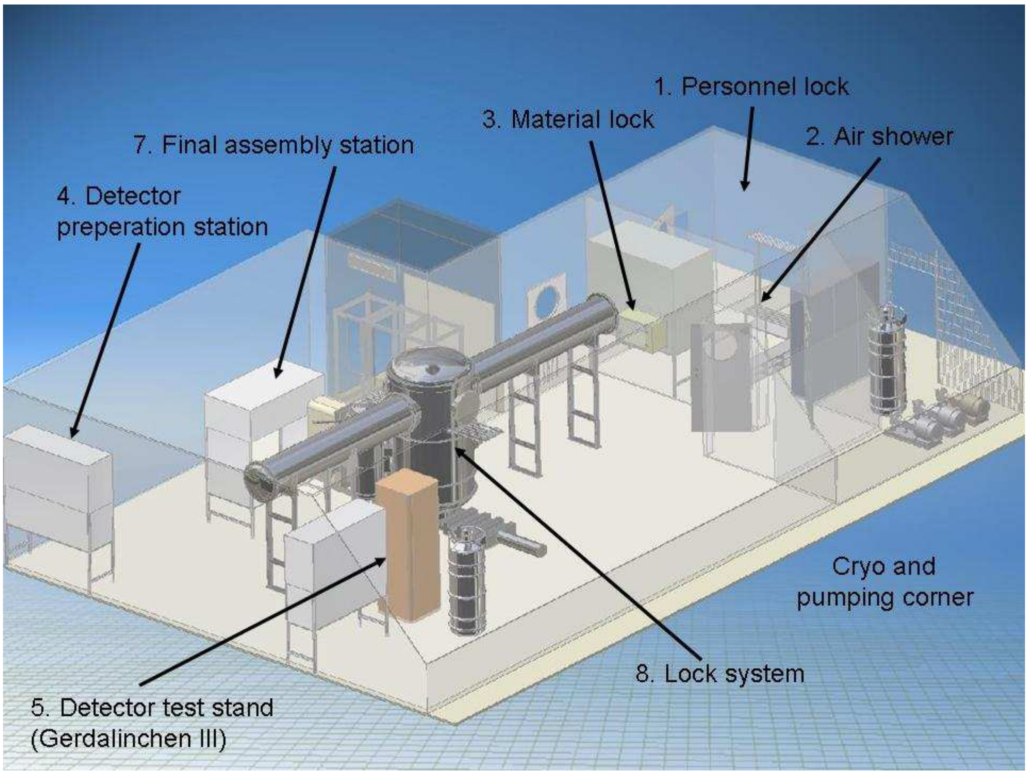


Figure 2: Sketch of the infrastructure on top of the tank.

lock is then flooded with air from the clean room or with nitrogen from bottles.

**4,7:** These stations are laminar flow-boxes. They reduce the air from class 10000 to class 100. All detector manipulations are to be performed here. When not in use the flow boxes can be switched to stand-by. All station specific tools are kept in holders within the station.

**4:** This station is used for final preparation of the detector units. Especially, the confection and positioning of read-out and HV-cables is done here. If a simple electrical testing is desired, it is to be done here.

**5:** This test stand will allow for test of the electrical contacts of the detector at liquid nitrogen temperature after its transportation to LNGS.

**6:** The detector storage area is an integrated system which allows for safe storage of up to 10 detectors while-st they are not in use. In order to minimize the risk of damage, the detectors are stored individually in special containers that can be evacuated or flushed constantly with dry Argon.

**7:** The final assembly station is a special flow-box with a laminar flow volume down on the floor. In order to facilitate this it has fixed screens on the bottom and the top. On both sides sliding windows allow access to the central 100 cm. The maximal package height is 120 cm. Inside the flow-box a special holder system will facilitate the integration of detector units into strings. A string is hanging on a rail along which it can be moved. The rail of the final assembly station is connected to the lock by removable rail segments that allow to slide the assembled string into the lock system.

**8:** The lock system is used to transfer the string into the main gas volume of the cryostat. For details see the next section.

### 1.1.3 Lock functionality

The lock system is the central device of the clean room. It encompasses an outer, an inner lock and two cable arms. A preliminary drawing of the lock system can be seen in Fig. 3. The lock system is attached to the neck of the cryostat such that the two volumes are connected. A circular ISO630 shutter can separate the inner lock from the cryostat. The outer lock can be separated from the inner lock and from the clean room by two rectangular shutters with opening w=150 mm, h=1200 mm.

The outer and inner locks consist of stainless steel cylinders with a diameter of 50 cm and 140 cm, and weights of 0.5 ton and 6 ton, respectively. The cable arms consist of steel cylinders with 630 mm diameter and a length of 3500 mm with a weight of 1 ton. Between lock and cable arms, lock and circular shutter, and circular shutter and cryostat neck (bellow) Helicoflex seals are used.

The shutters are specified for an operational pressure of 0.5 bar overpressure. All standard processes, such as evacuating the inner lock while-st the cryo-tank is at its operating pressure of 0.5 bar overpressure can be tolerated by the shutters.

**String loading procedure:** This is a regular procedure. It can happen without special precautions concerning the cryostat volume.

1. Assemble string in assembly station.
2. Reduce pressure in outer lock.
3. Open outer shutter.
4. Move string into outer lock.
5. Close outer shutter.

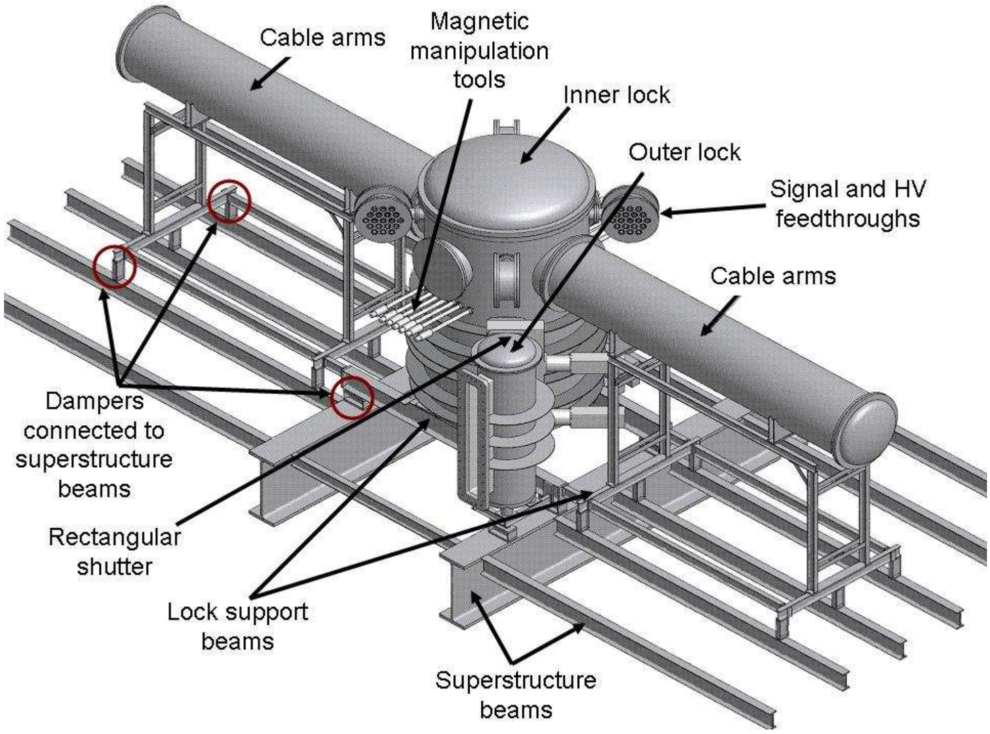


Figure 3: The lock system sitting on the cryostat neck and supported on the superstructure.

6. Evacuate outer lock.
7. Fill outer lock with gas from pure Argon buffer (if necessary repeat evacuation and flushing).
8. Adjust outer lock pressure to inner lock.
9. Open inner shutter.
10. Transfer string to inner lock.
11. Close inner shutter. Adjust pressure in outer lock.
12. Transfer string to final position.
13. Run electrical tests.
14. Lower string.

**The detector array in the inner lock:** The lock system is designed to house up to 13 Phase II and 3 Phase I strings as well as three service strings (calibration source or camera). The array is shown in Fig. 4. As visible from Fig. 4 the orientation of the detectors on the strings is essential, especially for the Phase I strings and has to be of a precision of ±5°. For Phase II crystals with diameter of 75 mm there is a minimum distance of 10 mm between two neighboring detectors. The string lowering procedure has to be well controlled and the liquid Argon level has to be known with a precision of better than 5 mm.

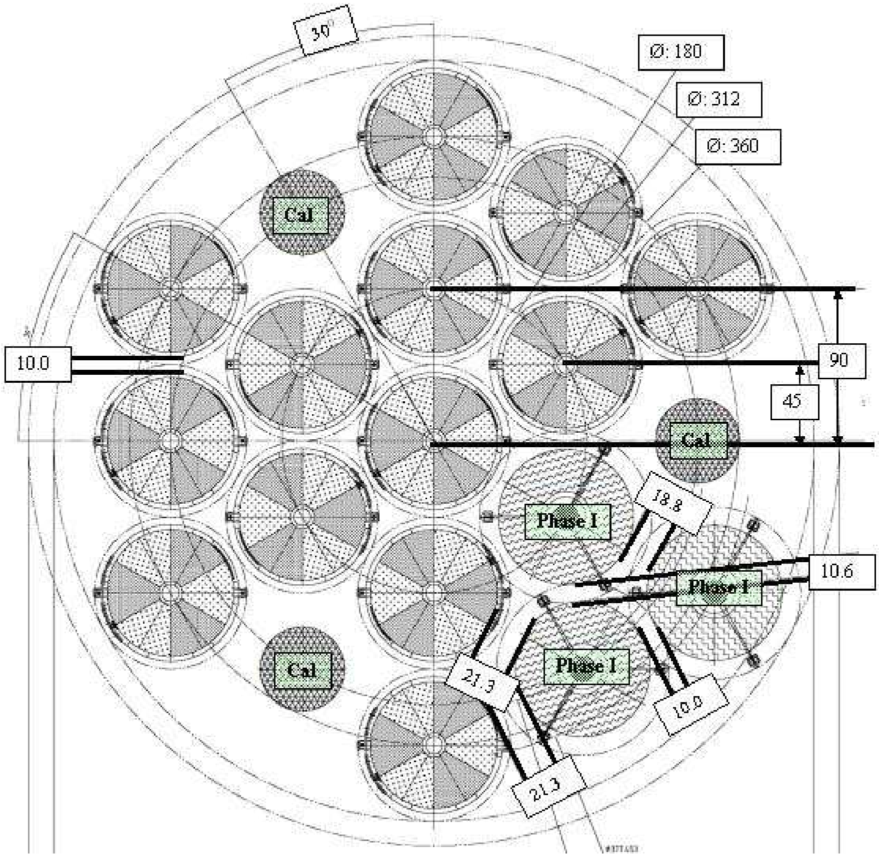


Figure 4: Array configuration of the detector and service strings.

**The lock internal rail system:** An assembled string (which can either be a detector assembly or a calibration source or a camera) is transferred to the array within the inner lock by a rail system. Each string is attached to a sled, which can slide along the rails.

The procedure to move the string from the final assembly station to its final array position within the inner lock can be separated into four movements (see Fig. 5):

- From the final assembly station to the outer lock.
- From the outer lock to the inner lock circular rail.
- Along the circular rail to the central rail.
- From the circular rail along the central rail on the base plate to the final array rail segment.

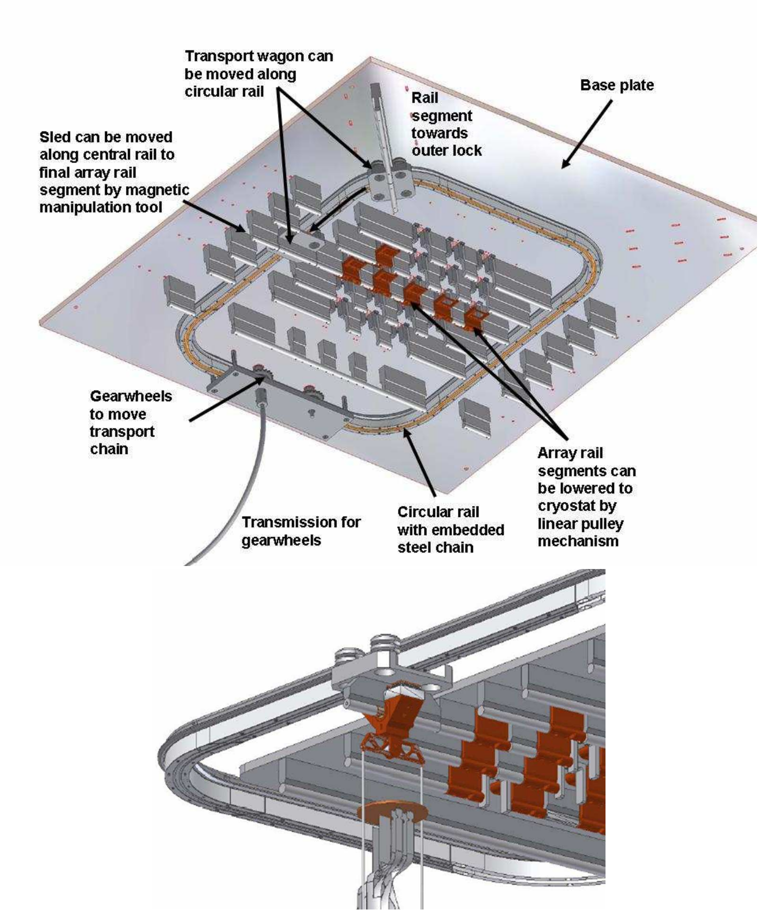


Figure 5: The lock internal rail system. Upper picture: The rail system on the base plate inside the lock as seen from below. Lower panel: Sled attached to the transport wagon on the circular rail.

**1:** In the final assembly station a string is hanging on a rail segment. Once the shutter between outer lock and clean room is opened, a rail segment is placed to connect the rail within the outer lock to the rail of the string assembly station. The assembled string is consecutively carefully pushed into the outer lock. The connecting rail segment is removed before the shutter can be closed again.

**2:** After the shutter between outer and inner lock has been opened, a connecting rail segment is positioned between the rails in the outer and the inner lock. A magnetic transfer arm connected to the outer lock above the outer rectangular shutter is used to push the string to the inner lock.

**3:** The string is hanging on a rail segment that is attached to a wagon. A steel chain embedded into the circular rail is attached to the wagon. The steel chain and thus the wagon can be moved along the circular rail around the base plate by a crank lever. The wagon is positioned such that the wagon rail segment is connecting to the base plate rail which serves the destination array position.

**4:** Using a transfer arm the string is pushed from the wagon rail segment along the central rail to its final array rail segment. This rail segment can be lowered to the cryostat by means of the linear pulley system described below.

**The linear pulley** The array rail segments are attached to two 0.8 mm stainless steel string-support wires. The signal- and HV-cables from the base plate to the lock feedthroughs are led between these two string support wires. The area between the wires available for the signal- and HV-cables is 20 mm x 10 mm. The bending radius of the cables has to be less then 20 mm in compound.

The string-support wires and cables are installed quasi-permanently. In lifted up position they are housed in the two horizontal cable arms connected to the inner lock. The two string support wires per string and the detector cables run from a strain relief at the inner lock to a movable cable pulley at the outer end of the cable arm. The wires and the cables are led around the cable pulley backwards to the center of the inner lock. Here they go around a stationary cable pulley and are led downwards towards the cryostat. They are attached to the array rail segment that is fixed inside a bore of the base plate. The movable cable pulley inside the cable arm can be sled from the outer end of the cable arm towards the center by 3.5 m with a crank lever. By sliding it from the outer to the inner end of the cable arm the array rail segment can thus be lowered from the base plate by 7 m to the cryostat volume. A schematic view of the system can be seen in Fig. 6.

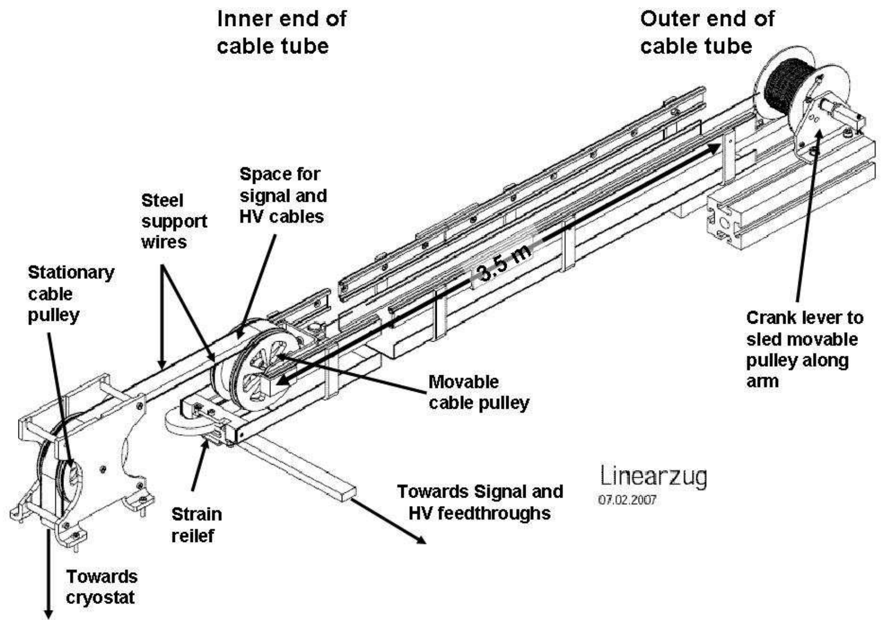


Figure 6: Sketch of the linear pulley system. The array rail segment is in its lowered position in this figure.

### 1.1.4 The internal gas system

A sketch of the internal gas system is shown in Fig. 7.

**Normal operation:** During normal operation (measurement) the inner lock is connected to the cryostat volume. The operational pressure is 0.5 bar overpressure. To maintain a permanent gas flow exhaust gas is taken from the lid of the inner lock and from the cable arms at a controlled rate of roughly 10 $m^3$/day using flow-controllers. Exhaust gas can be transfered to the radon monitor unit. As the evaporation of the liquid in the cryostat might not be sufficient to allow for a flux of 10 $m^3$/day (corresponding to roughly 12 l of LAr) through the inner lock the possibility for additional gas flow from the pure Argon buffer is foreseen. It is injected at the bottom of the lock.

The outer lock is separated from the inner lock and from the final assembly area by rectangular stainless steel vacuum shutters. Both rectangular shutters are closed and the volume is regulated by a feedback system to be half the pressure of the inner lock volume, i.e. around 0.25 bar overpressure during normal operation. A stream of gas from the inner into the outer lock is maintained by the bypass from the outer lock and regulated by a flow controller.

The inner lock has a safety valve that is specified to open at 0.8 bar overpressure. Additionally, a burst-disc can be installed. If operational, it is connected to the main exhaust pipe. The diameter should be the same as for the burst-disc at the cryostat. The gas system, especially the safety aspects, has to be integrated into the main cryo system.

**Construction and maintenance:** During construction or to facilitate special maintenance of the neck or the inner lock it is possible to separate the volume of the inner lock from the cryostat by a ISO 630 vacuum shutter immediately above the neck of the cryostat. All strings have to be withdrawn for such an operation.

Both inner and outer lock can be evacuated with an attached dry roots pump system down to a pressure of $10^{-2}$mbar within 30 minutes. Vacuum gauges can monitor the pressure inside the lock components.

The outer lock can be filled with gas from the pure Argon buffer.

**The pure Argon buffer:** A 160 l storage cryostat is foreseen for pure Argon gas or liquid supply in the clean room.

The maximum consumption of liquid Argon for the detector test stand Gerdalinchen III is 160 l per day. Refilling of the buffer will happen through a 1/2" pipe from the deradonized Argon supply of the cryo-system.

A vaporiser supplies the following components with Ar-gas:

- Gas for flushing the volumes after evacuation,
- additional Argon flux through lock system,
- differential shutter seals,
- storage system,
- gas for detector test stand.

An amount of 30 $m^3$ of clean Argon gas at operating pressure should be available per day.

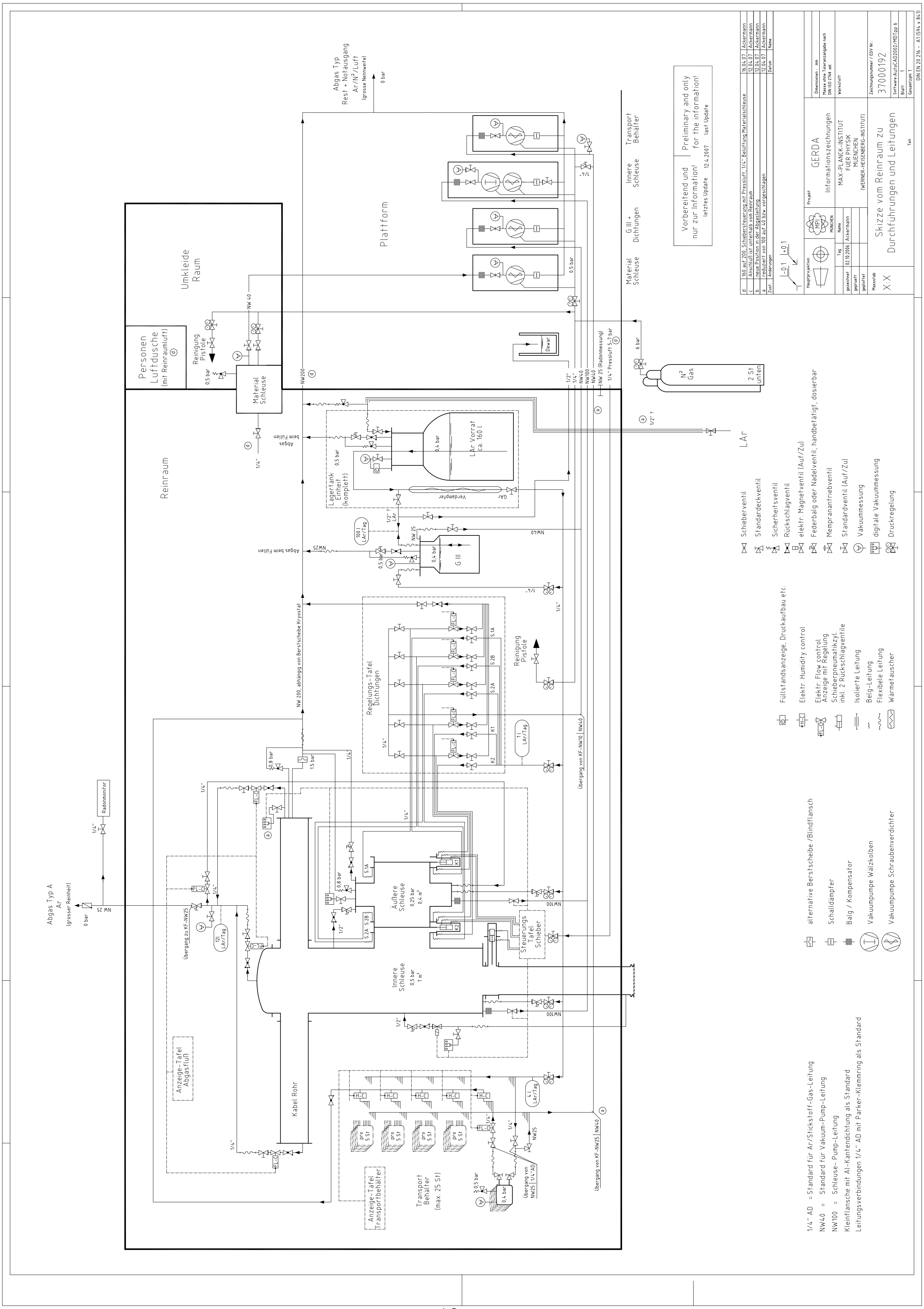




Figure 7: Gas System

**Dry gas supply:** Clean dry gas (nitrogen) for flushing of the material lock and the pressurized gas gun is provided by two gas bottles that are located in a lockable cabinet on the ground floor of the experiment. The gas is brought to the top level by 1/4" inch floor and enters the clean room and the personnel lock through feedthroughs.

### 1.1.5 Climatization of the clean room

The clean room will have a controlled atmosphere with a temperature of 21°C±1°C and 30% humidity. In case a radon reduction unit is implemented it can be used to control temperature and humidity: The output air of the radon reduction unit is completely dry and can have a temperature between 0°C and 21°C. A humidifier using deradonized water is thus needed to get up to an air humidity of 30%. In case no radon reduction unit is installed, an air-conditioning unit and a chiller unit for dehumidification will be needed. The air conditioning unit should be in the proximity to the clean room, i.e. not further away than one floor below the top level. The chiller unit could be placed on the ground level.

### 1.1.6 The clean room floor

The clean room floor is built onto the superstructure floor at a level of 9700 mm. Around the cryostat neck there will be a cut out, where the clean room floor needs to be lowered in order to house the shutter body. On an area of 1.8 m x 4.12 m the clean room floor will be built above a level of 9660 mm at the height of the upper edge of the IPE120 and HEB700 superstructure beams.

The clean room needs to be sealed against the tunnel air around the neck of the cryostat. Clean room floor and lock need to be decoupled. The seal will thus be done by two Neoprem bellows that connects a collar around the shutter flange with the lowered clean room floor. The space between the two bellows can be flushed with dry nitrogen.

A sketch of the system is shown in Fig. 8.

### 1.1.7 Mechanical coupling and damping

The lock will be supported by two beams that are attached to the superstructure main beams (see Fig. 3). The xy neck center position with respect to the superstructure has to be known with a precision of ±20 mm or better.

Mechanical damping of the lock system from the superstructure is not necessary for earthquake safety according to [2]. However, the lock system

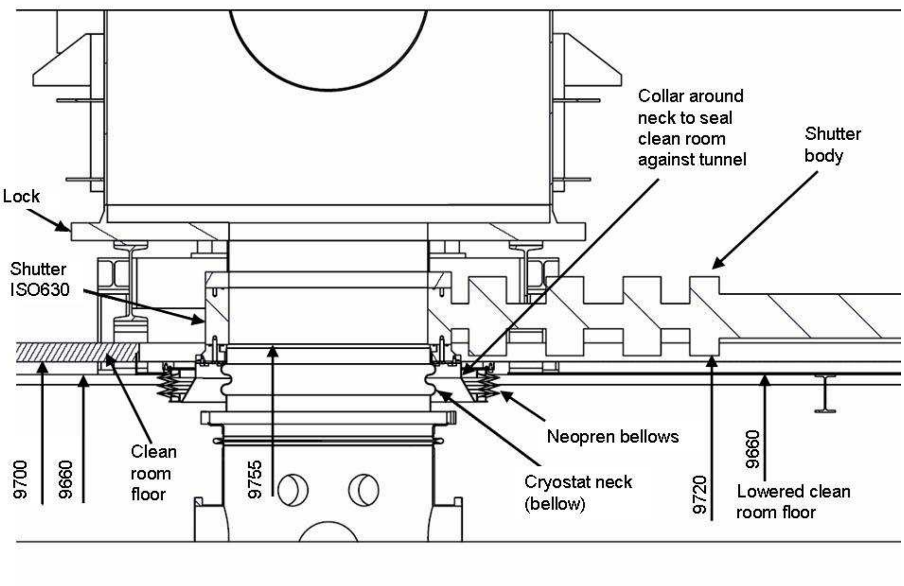


Figure 8: Sketch of the neck part of the clean room floor.

should be decoupled from the superstructure, as otherwise any vibration that might occur on the superstructure will be transmitted to the lock body.

It is foreseen to install a two-stage decoupling of the strings from the superstructure. The lock itself will be attached to the supporting beam through dampers. This might be springs that are surrounded by elastic rubber material. The main decoupling from superstructure vibrations happens inside the lock. The base plate on which the strings are hanging and the linear pulley system will sit on a spring system.

#### 1.1.8 Feedthroughs

For the infrastructure on top of the tank to be fully functional several feedthroughs are unavoidable. According to our suggestion for the gas system the following feedthroughs are foreseen:

**Cryostat to clean room (in clean room floor):**

- 1/2" shutter bypass tube for Argon-gas

**Material lock to clean room:**

- 1/2” bypass for flushing material lock with clean room air.

**Material lock to personnel lock:**

- NW40 for evacuating material lock,
- 1/2” for gas supply from bottles.

**Personnel lock to cryo-pumping corner:**

- NW40 for evacuating material lock,
- 1/2” for gas supply from bottles.

**Cryo-pumping corner to clean room:** These will be integrated into one panel in the wall.

- 1/2” LAr feedthrough for removing LAr from test stand,
- 1/2” (?) deradonized clean LAr supply for storage dewar inside clean room,
- 1/4” for pressurized air supply (5-7 bar for shutters),
- 1/4” for clean gas supply from (6 bar) bottles,
- NW 40 for storage pots vacuum system,
- NW 40 for gas- vacuum system shutter seals,
- NW 100 for lock vacuum pump.

**Clean room to tunnel:**

- NW 25 for clean Argon exhaust from lock,
- NW 200 (depending on cryostat system) for emergency exhaust.

**Clean room to Air shower:**

- NW 40 for clean room air supply to air shower.

**Air shower to tunnel:**

- NW 40 for exhaust from air shower.

Note that feedthroughs needed for the radon reduction device or the air conditioning are not listed here.

## 1.2 Electrical cabinet

The electrical cabinet has a depth of 1900 mm and consist of two segments of 950 mm each. The outer segment needs to be demountable as to allow for LVD module shunting. Access to the cabinet will be through a roll-up door. The electric cabinet will be climatized by a separate mini-chiller. Electric needs and feedthroughs to the cabinet are specified by task group 9.

## 1.3 Plastic muon veto

On top of the roof there will be space on an area of 5 m x 5 m for two scintillation plates of 3 cm thickness each.

## 1.4 Cryogenic and Pumping corner

At the northeastern corner of the platform there is another cutout of the clean room reserved for cryogenic infrastructure and vacuum pumps. The dimensions of this corner will allow for storage of a 200 l dewar and four vacuum pumping systems in a lockable chamber.

## 1.5 Infrastructural requests

The following infrastructure will be needed:

**Cryo-liquids:** In peak times 160 liter deradonized high purity LAr per day should be available. The 160 liter dewar inside the clean room should be refillable within 30 minutes.

**Electrical supply:** The following is required from the normal electricity supply:

- Pumping stations next to the air shower cabinet WKP + Revo + rest : 10 kW One three phase plug 7 kW at peak times, 5 power plugs up to 1 kW each at peak times

- Clean Room: Air conditioning 3 phases: 5 kW - 50 kW constantly (depending on availabilitiy of radon reduction unit and cold water)
- Clean Room: Lights, Particle counters: 3 kW constantly
- Clean Room: Electrical connectors, 5 per flow-box
- 3 Flow boxes with 220 V power plug, ca. 2 kW/flow-box
- 1t/500kg crane. Three phases, 2 kW at peak times
- Gerdalinchen III: 10 powerplugs 1kW constantly
- Power plugs in personnel lock

For the following parts electricity has to be available on the UPS system:

- Emergency lamps, each with 220 power plug, 50W each while charging,
- Oxygen sensors and alarm system,
- 5 power plugs for flowmeter, humidity gauge, etc. (0.5 kW),
- Control system power (incl. shutters) SPS, three phase plug, 1 kW constantly.

**Water:** Cooling water is needed for the possible air conditioning system. The cooling water should be reliably at a temperature of 10°C.

## 1.6 Safety considerations

The oxygen content of the clean room atmosphere will be constantly monitored. Oxygen masks will be provided for the case of accidents.

As the direct view into the hall is obscured, video monitoring of the hall will be available in order to allow fast assessment of external dangers. The inner and outer lock is video controlled to assess possible internal mechanical failures.

An internal alarm system informs about all safety relevant failures.

Escape routes follow the main staircase. An emergency exit connects the clean room with the landing in front of the staircase. As the staircase directly faces the LVD setup, a second emergency escape route has to be considered away from the LVD experiment. This could be implemented by emergency slides as used in airplanes towards the TIR tunnel.

# References

[1] USGS *Geochronology of terrestrial Sediments in South Florida* http:sofia.usgs.gov/metadata/sflwww/metholms.html

[2] G. Pace, Analisi sismica del sistema strutturale, report for Max-Planck-Institut für Physik, 2007.