Chapter 7

Vacuum and Vacuum Isolation

The requirements on the quality of the cavity vacuum do not come from beam gas interactions, but from the lifetime of the gun in the injector region and the performance of the superconducting cavities in the rest of the linac. The flow of gas molecules into the cold part of the linac must be kept small to avoid accumulation of gas layers on the surface of the cavities, eventually giving rise to field emission. Due to the smaller surface area the capture cavity is most critical. Without special precautions like vacuum firing of adjacent vacuum parts and differential pumping 1 monolayer of hydrogen would be accumulated in the capture cavity after 10 days [1], which seems to be the regime where field emission gets enhanced [2] [3] [4]. We therefore have vacuum parts close to the cold linac vacuum fired and install sufficient pumping speed close to the beginning of the cold section.

7.1 Requirements on Vacuum Parts

Metallic dust within the superconducting cavities must be avoided as it leads to field emission. For the cavities themselves great care is being taken to clean them and to prevent dust from entering the cavities. Comparable care has to

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[1] D. Trines, Tesla 93-20

[2] R. W. Röth et al., Universität Wuppertal, Proceedings of the 5th Workshop on RF Superconductivity, p. 559

[3] T. Tazuma et al., KEK IBID, p. 766

[4] H. Padamsee et al., *New Results of RF and DC Field Emission*, 4th Workshop of RF Superconductivity, Tsukuba, Japan 1989

be taken for the adjacent vacuum components as dust within these chambers can migrate into the cavity after successive pump downs and venting. Venting and pump down must be done such that the gas flow is directed away from the cavities. This is however not possible everywhere and is a problem for the section between capture cavity and main linac.

In addition all vacuum parts have to be treated in the clean room area to get them dustfree. During installation similar care as for the cavities has to be taken to avoid dust entering the system.

We know for example from the e-ring of HERA that ion getter pumps are a source of dust particles, which may eventually enter the beam tube. For the test facility there is no inexpensive alternative to the use of ion pumps. The production of dust particles is however dependent on the gas load that has to be pumped. It is thus appropriate to operate at low base pressure. Therefore all vacuum chambers will be vacuum fired. Pumps will only be switched on when a good base pressure is achieved by oil-free pump stations.

7.2 General Layout of the Beam Vacuum System

The linac vacuum is separated into several sections by gate valves. This permits successive setup and testing and also adherence to the philosophy of venting and pumping with the gas flow away from the cavities as much as possible (see Fig. 7.1).

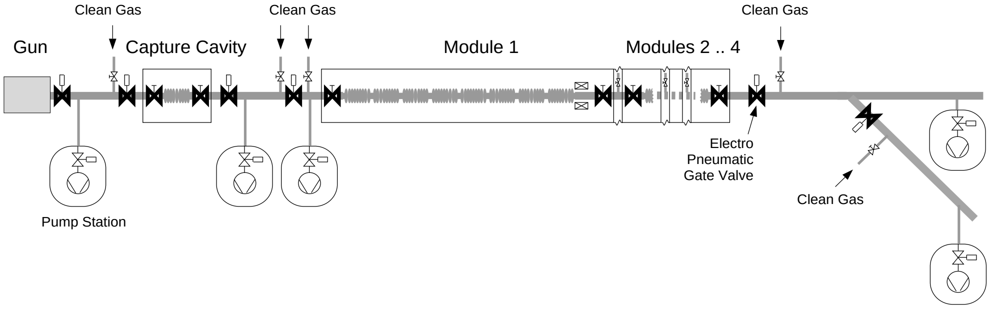

Figure 7.1: Layout for the Beam Pipe Venting

Each module of 8 cavities has manual gate valves at either end, which are mounted in the cleanroom to maintain the cleanliness of the cavities during installation (see Fig. 7.2). It is planned to use local cleanrooms at all installation work on the open vacuum system. The type of valves to be used is controversial. All-metal valves may produce metallic dust by friction, valves with organic seals may also have rub-off from the seal and they are sources of gas from or through the organic material. Valves with organic seals are mainly used in the injector, all-metal valves are used in the rest of the linac.

The cavities are connected by short bellow sections of about 10 cm length to allow for length variations of the cavity and thermal contraction during cooldown.

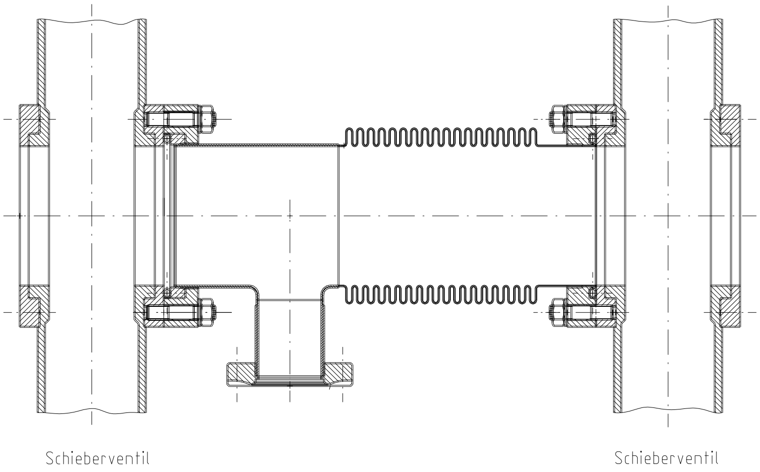

Figure 7.2: Gate valves at module interface

Consideration has been given to the installation of an RF shield to avoid higher order mode losses in the bellows which add to the cryogenic load at 1.8 K. However, all designs thought of, bared the danger of producing metallic dust by friction. Therefore it was decided not to install an RF shield. The bellows material is under discussion. It is necessary that the higher order modes propagate to the 70 K absorber to reduce resistive losses at 2 K. It is not clear at this time whether copper coated stainless bellows are adequate or if they must be superconducting.

The values of the loss factor (V/pC) as a function of the number of waves of the bellow for two values of the gap between two successive waves are shown in Fig. 7.3. This loss factor must be compared to that of a Tesla cavity =8.5V/pC.

Beyond 10 mm, the height of the bellow waves does not modify the value of the loss factor whereas the gap plays an important role: it must be kept as small as possible. So, if we take a 7 wave bellow (acceptable for a flexibility range of ±6.5 mm) with a 3 mm gap, the loss factor is 1.05V/pC. It represents an increase in the HOM losses of 1.05/8.5 = 12%, which is acceptable [5]. An example of the bellow connection is shown in Fig 7.4.

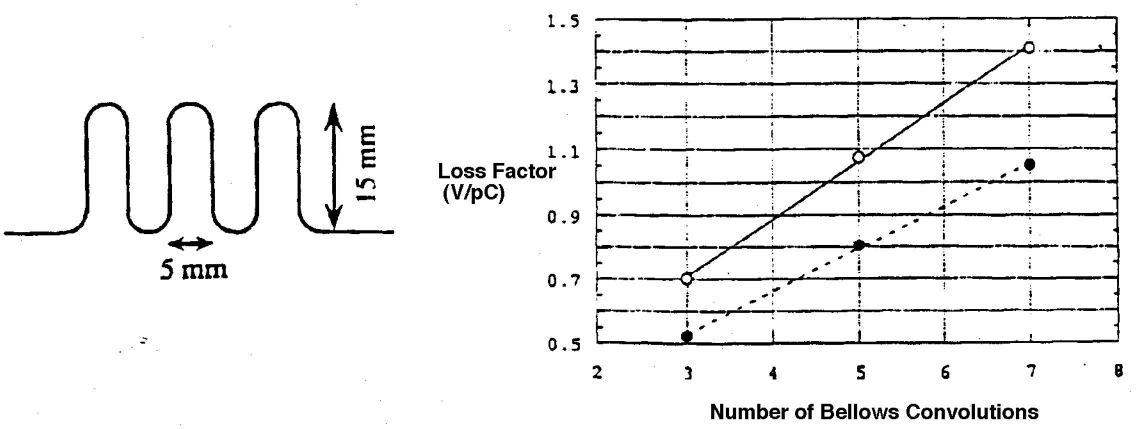

Figure 7.3: Loss factor (V/pC)

Travelling higher order modes which are not coupled out of the cavities by the HOM couplers will be absorbed in a short section of the beam pipe inside the quadrupole at the end of each module. The beam tube connecting the last cavity of one module to the first cavity of the next module will be made from stainless steel. A detailed view of the interconnection between modules is shown in Fig 7.5. Except for a section of about 60 cm it will be copper-coated from the inside. The uncoated section is in good thermal

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[5] Ph. Leconte, A. Mosnier, M. Maurier, D. Trines, A. Matheisen, *Connections between TESLA Cavities*, Tesla 93-28

contact with helium gas at 70 K, so the power of the travelling HOM is deposited at a higher temperature level.

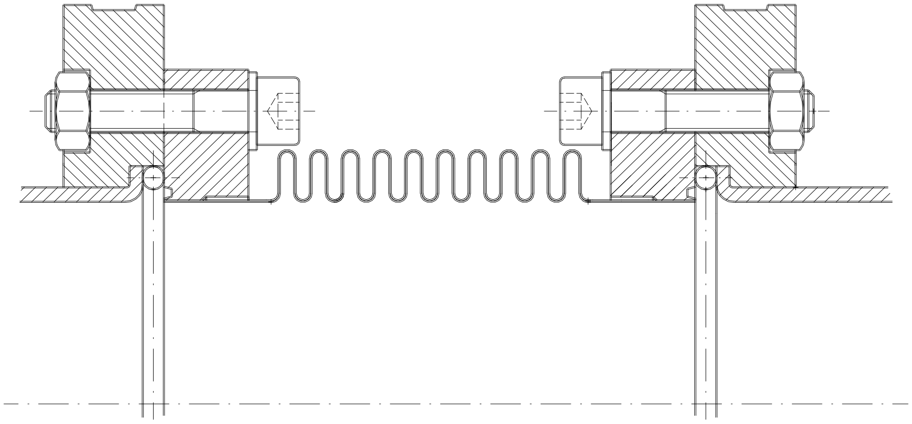

Figure 7.4: Layout of the bellow section between cavities

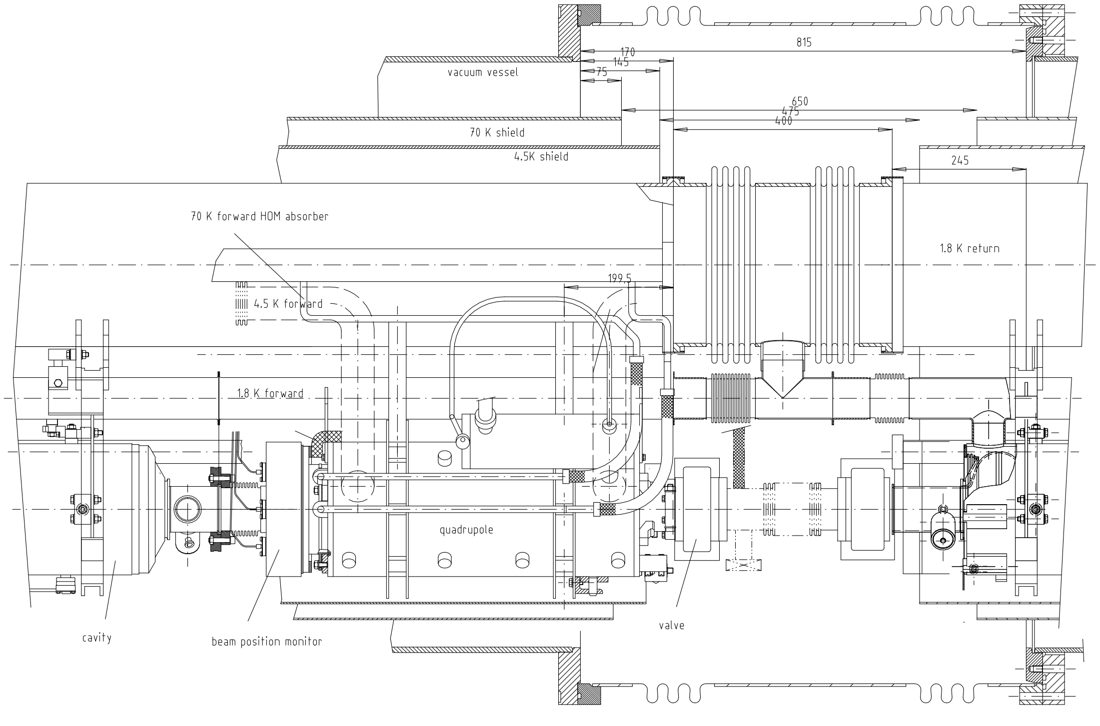

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Figure 7.5: Interconnect of modules

Between modules and between the valves at the ends of the cavity string a beam pipe section of about 20 cm length will be inserted. It contains a copper-coated bellow and a pumping port with an additional manual valve to pump and purge. The manual valves to the pumped cavity strings will only be opened when the intermediate piece is clean and pumped to UHV.

7.3 Vacuum System for the Input Coupler

The part of the input coupler between the cold ceramic window at 70 k and the room temperature ceramic window is pumped separately. At each input coupler there is a small all metal valve (NW16) which allows the connection of the couplers to a pipe of 100 mm diameter which runs along the module (see Fig. 7.6). The pipe is pumped by one ion getter pump with 100 ℓ/sec pumping speed. The header can be pumped down via an additional manual valve by a turbomolecular pump station.

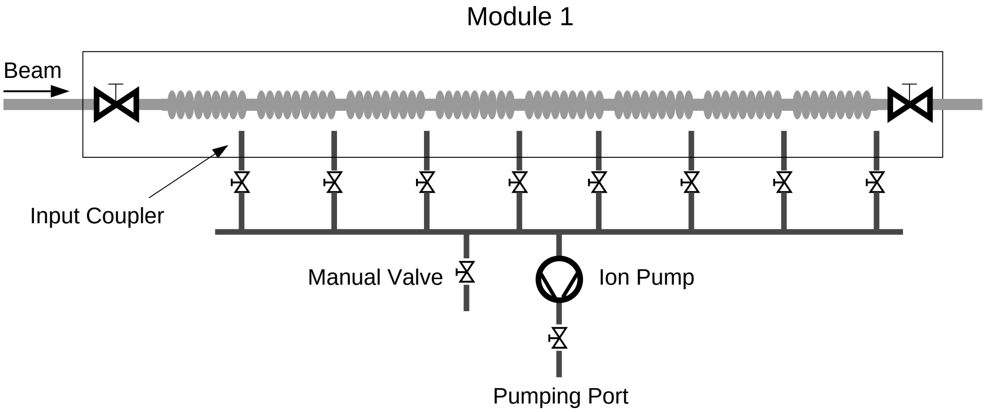

Figure 7.6: Input Coupler Vacuum System for the TTF Modules

7.4 Oil-Free Turbomolecular Pump Stations

To avoid pollution of the cavity surfaces by hydrocarbons we built pump stations containing turbomolecular pumps without oil lubrication and oil-free roughing pumps (see Fig. 7.7).

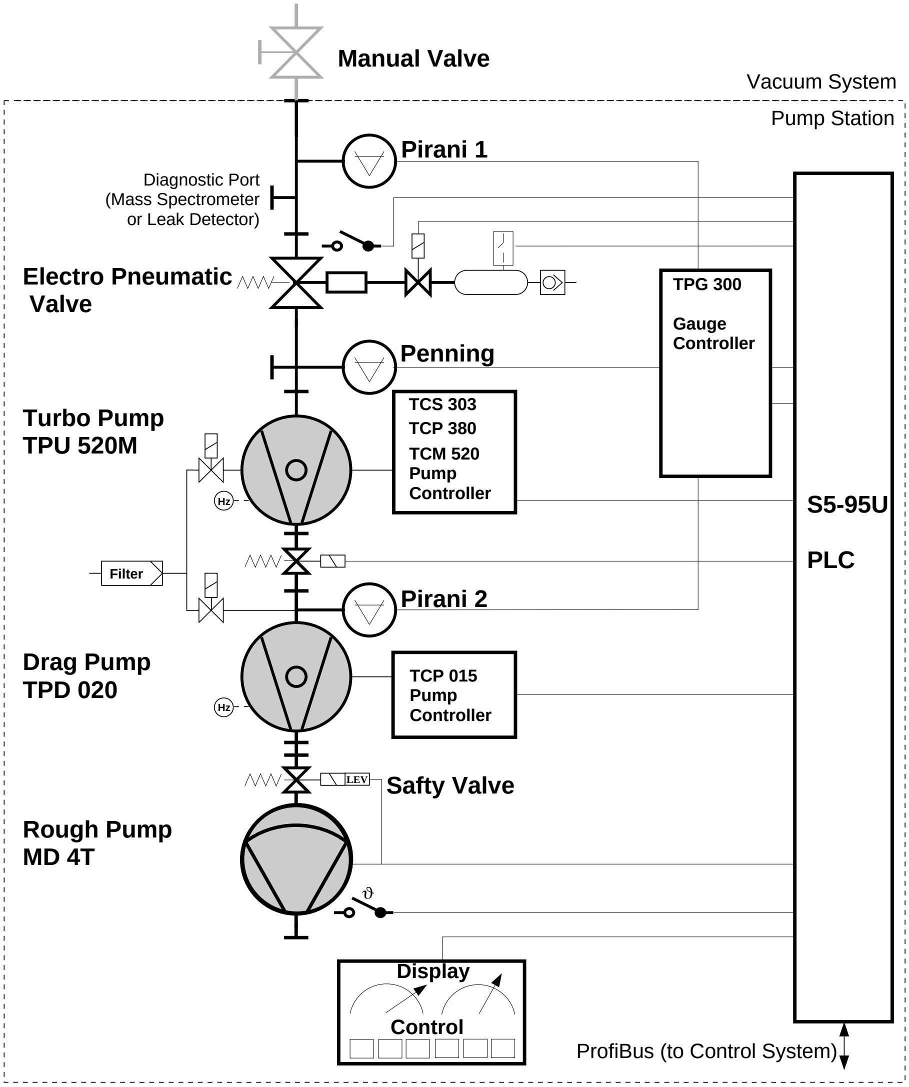

Figure 7.7: Oil-Free Pump Station.

We ordered different types from different companies to find out which type will fit our requirements best at adequate cost. The logic of all pump stations is similar. There is a electropneumatic valve at the pumping port of each pump station. It can only be opened if certain conditions are fulfilled.

Before the valve can be opened, the pump station must have demonstrated that it is fully operational: all pumps must be running properly and a pressure below 10^{-5} mbar at the valve must be achieved.

In front of the valve there is a pirani gauge to measure the pressure in front of the valve. If the pressure is below 10^{-2} mbar and the turbomolecular pump is operated at full rotational speed the pneumatic valve can be opened.

If the valve is requested to open at pressures larger than 10^{-2} mbar, the turbomolecular pump will be switched off and the valve will open when the rotational speed of the pump with magnetic ball bearing is below a critical limit. When the pressure has been reduced by the roughing pump below 10^{-2} mbar the turbomolecular pump will be switched on automatically. If the pressure at the turbopump will exceed 10^{-1} mbar due to a sudden gas load for example, the pump will switch off automatically and only switch back on again if a pressure below 10^{-2} mbar is reached.

7.5 The Insulating Vacuum

The insulating vacuum of the four cryostat modules will be maintained by one turbomolecular pump station of the type used at the superconducting magnets of HERA. The pumping speed of $150\ell/\mathrm{sec}$ is sufficient to maintain a pressure below 10^{-4} mbar with the module string at room temperature. The total gas load due to desorbing surfaces and permeation through O-rings is comparable to the HERA magnet system. If there are no larger leaks from the helium circuits into the insulating vacuum the pumps can in principle be turned off once the string is cooled down to operating temperatures.

This may be possible for the short string of four modules in the TTF. However for the large system in the 500 GeV collider one has to be able to cope with a certain number of helium leaks, as we have learned form HERA. Thus one has to assume that some turbomolecular pumps have to run all the time. This may cause problems with vibrations transferred from the pump station to the cavities. This problem and ways to get rid of it can be studied at the TTF.

The insulating vacuum of the feedbox and the transferline will be separated from the module vacuum by vacuum barrieres. Also the capture cavity is separated from the modules.

There will be bypass tubes with valves, however, which allow to couple the various systems, thus minimizing the number of pump stations needed during operation.

For pump-down and commissioning all systems can be pumped separately. On the module string there is a pumping port at each interconnect between modules. In case of a leak they can be used to help localize the leak within the string.

All seals at the insulating vacuum systems will be O-rings. The sealing of the vacuum vessel at the interconnects between modules is done in a similar way to the sliding sleeve layout used at the superconducting magnets in HERA.

The ends of the string are a concern due to the large forces (order 10^4 kg) acting on the endplates. The bellows in the sliding sleeves needed to make up for tolerances can be bridged by rigid bars before pump-down. However, to avoid motion of the endplates in case the rods have not been installed properly and to provide anchor points for internal piping the preferred solution appears to be to fix the end plates to the floor by rigid supports.