DAΦNE Vacuum System

V. Chimenti, A. Clozza, H. Hsieh, C. Vaccarezza
INFN Laboratori Nazionali di Frascati
C.P. 13 - 00044 Frascati (Roma) - Italy

Abstract

The preliminary design for an all metal ultra high vacuum (UHV) system for DAΦNE machine is described. The machine is composed by 4 main items: linac, accumulator, transfer lines, and storage ring; each item has its own vacuum system designed accordingly with the operating requirements. The linac will be bought turn on key from an external firm, with its vacuum system, the accumulator and transfer lines vacuum systems will be made using standard technologies capable to reach a working pressure in the range of 10^{-8} torr, the storage ring vacuum system will be made using special technologies in order to obtain a pressure of $1 \cdot 10^{-9}$ torr with 5 A of stored beam current.

1. INTRODUCTION

The vacuum system designed for DAΦNE machine will provide the required working condition needed to reach the luminosity goal, at $\gamma = 1000$, of $L = 2.6 \cdot 10^{32}$ cm^{-2} s^{-1} with 60 stored bunches.

The required vacuum pressure is $1 \cdot 10^{-9}$ torr with two stored beams of 5 A each, this pressure value is mainly needed to obtain a low background noise in the interaction region and to give a contribution as small as possible to the beam life time, already limited by Touschek scattering.

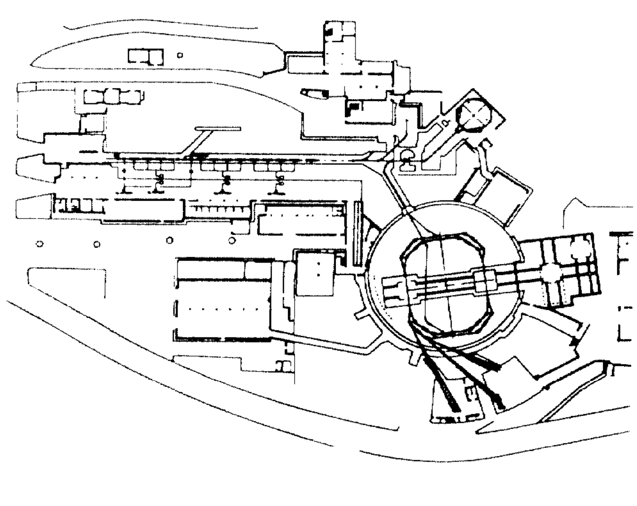

Figure 1. The DAΦNE project layout

2. LINAC VACUUM SYSTEM

The vacuum system of the linear accelerator will be supplied from the firm according to our specifications, and it must be able to reach a pressure in the range of 10^{-8} torr. All the pumps (fore vacuum and high vacuum) must be oil free.

3. ACCUMULATOR VACUUM SYSTEM

3.1. Machine vacuum related parameters

The vacuum system for an electron storage ring is closely related to certain machine parameters, in table 1 the vacuum related parameters are listed.

Table 1
Vacuum related parameters for the accumulator

Beam energy (MeV)	510
Beam current (mA)	130
Dipole bending radius (m)	1.1
Maximum working pressure (torr)	$\sim 10^{-8}$
Photon flux (phot/s)	$5.4 \cdot 10^{19}$
Synchrotron light critical energy (eV)	270

3.2. Vacuum chamber

The vacuum chamber of DAΦNE accumulator will be made of 304 L stainless steel, its shape is: in the straight sections a cylindrical pipe 291 cm long and 85 mm inside diameter, in the kicker section a 200 mm inside diameter pipe, and in the curved sections an almost rectangular pipe 86.5 cm long and 30 by 100 mm inside aperture. No in situ bake out is foreseen for the accumulator, so a very well cleaned (even with glow discharge) [1,2] and prebaked sections of the vacuum chamber must be employed. The ring, shown in fig 2, is divided into four arcs by five sector valves: two valves will isolate the RF cavity, and the other three will be placed one in each remaining long straight section.

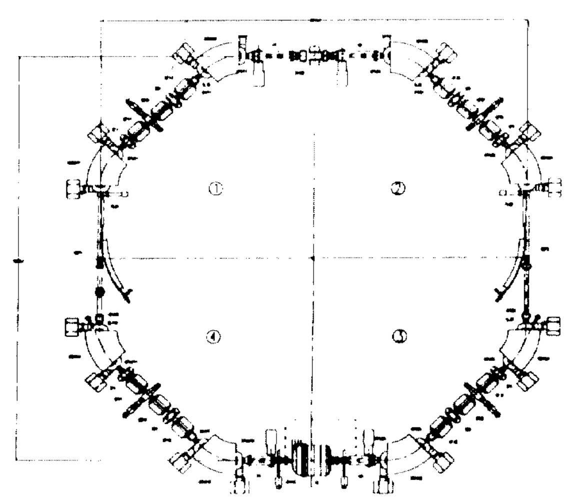

Figure 2. The accumulator ring.

3.3. *Pumping system*

The high vacuum pumping system for the accumulator must provide a sufficient pumping speed to reach a pressure P in the range of low 10^{-8} torr with a maximum of 130 mA of stored beam, such a current produce a photodesorbed gas load Q of about $2 \cdot 10^{-5}$ torr l/s, so the required pumping speed S is:

$$S = \frac{Q}{P} = 2000 \text{ l/s} \qquad (1)$$

a value easily obtained with traditional lumped sputter ion pumps. A total of 16 pumps are placed along the accumulator vacuum chamber, one of 200 l/s on the RF cavity, one of 400 l/s in the middle of the kicker straight section and the remaining 14 pumps, 200 l/s each, are placed at each end of bending magnets, connected as close as possible to the vacuum chamber via a short pipe, in this way is possible to obtain an effective total pumping speed, taking into account the conductances of the connecting pipes with the vacuum chamber, of about 2000 l/s.

The fore vacuum system consists of a portable magnetic bearing turbo molecular pump backed by an oil free mechanical pump, this system is able to reach a pressure of 10^{-5} torr.

4. TRANSFER LINES VACUUM SYSTEM

A system of vacuum transfer lines, about 130 m long, is used to connect the linac, the accumulator and the main ring, the working pressure of this system is about 10^{-8} torr. 304 L stainless steel has been selected for the beam pipe, no in situ bake out is foreseen except for about 10 m at the entrance to the main ring. The vacuum pipe will be prebaked and cleaned with glow discharge before installation.

The pumping system for the transfer lines is based on sputter ion pumps. Because the conductance of the pipe is about 20 l/s for meter, and the gas load is $2 \cdot 10^{-8}$ torr l/s per meter of vacuum pipe, a 100 l/s pump every 10 meters is sufficient to reach a pressure of about 10^{-8} torr.

The fore vacuum system is the same as for the accumulator.

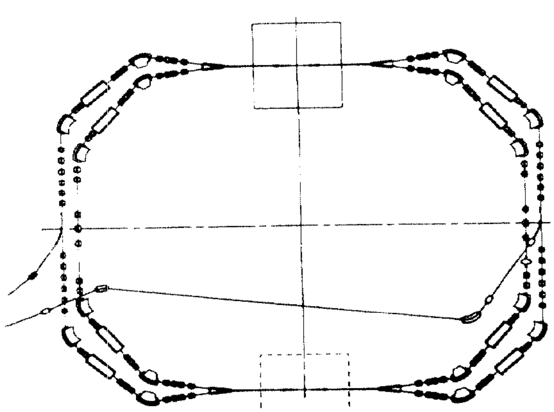

Figure 3. DAΦNE storage rings layout.

5. STORAGE RING VACUUM SYSTEM

5.1. *General*

The DAΦNE machine is made by two intersecting storage rings, see figure 3, one for electrons and the other one for positrons.

The vacuum system goal is to reach a mean pressure P = $1 \cdot 10^{-9}$ torr with a stored beam of 510 MeV and 5.5 A of full current.

Table 2
Vacuum related parameters for the storage rings

Beam energy (MeV)	510
Beam current (A)	5.5
Dipole bending radius (m)	1.4
Maximum working pressure (torr)	$1 \cdot 10^{-9}$
Dipole photon flux (phot/s)	$2.9 \cdot 10^{20}$
Wiggler photon flux (phot/s)	$3.3 \cdot 10^{20}$
Dipole synchrotron light critical energy (eV)	220
Wiggler synchrotron light critical energy (eV)	330
Total synchrotron radiation power/beam (kW)	50

5.2. *Synchrotron radiation photon flux and thermal load*

The very high value of the stored current generates high gas desorption so special and unusual solution are needed in order to obtain the desired mean pressure in the vacuum chamber. In our case the total number of photons emitted per second from the bending magnets is:

$$\frac{dN}{dt} = 8.08 \cdot 10^{20} \cdot E \cdot I = 2.3 \cdot 10^{21} \frac{\text{phot.}}{\text{s}} \qquad (2)$$

with E in GeV and I in A. For the wigglers a detailed calculations give a value of $3.3 \cdot 10^{20}$ phot./s. The emitted power form the bending magnets is:

$$P = \frac{88.5 \cdot E^4 \cdot I}{\rho} = 24 \text{ kW} \qquad (3)$$

with E in GeV, I in A and ρ in m. The emitted power from a wigglers is about 6.5 kW.

In this machine the synchrotron light is generated locally in that sectors, called arcs, including a wiggler magnet and the two neighboring bending magnets. In each arc we have a total photon flux of $9 \cdot 10^{20}$ phot./s and an emitted power of about 13 kW. Assuming for the desorption efficiency η the value $1 \cdot 10^{-6}$ mol/phot, after conditioning [3], the gas load Q for each arc is $3 \cdot 10^{-5}$ torrl/s, that in order to obtain a pressure P = $1 \cdot 10^{-9}$ torr a total pumping speed S, given by equation (1), of 30000 l/s is needed. To cope with such high gas loads some special criteria must be followed for the design of the vacuum system: no photons must hit the vacuum chamber walls, all the synchrotron radiation must be intercepted, possibly at normal incidence [4], by water cooled photon absorbers, the vacuum pumps must be located as close as possible to the photon absorbers, the thermal load of the synchrotron radiation must be dissipated.

5.3. Vacuum chamber

Three materials are mainly used in vacuum technology: stainless steel, aluminum and copper. The arc vacuum chamber, see figure 3, will be made using 6061-T4 aluminum alloy, because of its low outgassing rate, even after a 150° C

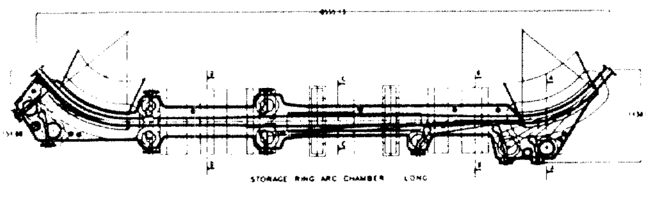

Figure 3. Arc vacuum chamber

bake out, its high thermal conductivity, and it is easily machinable and also the chemical cleaning treatments are easy. In figure 4 it is shown the cross section of the arc vacuum chamber in correspondence of a quadrupole.

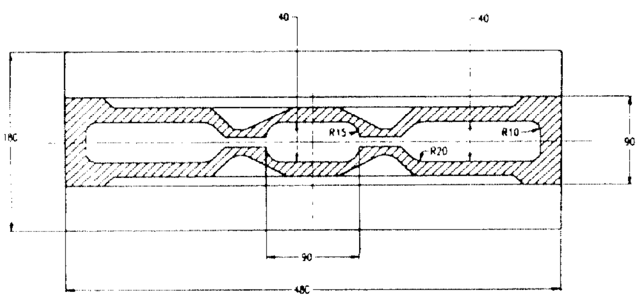

Figure 4. Arc vacuum chamber cross section (quadrupole)

The synchrotron radiation absorbers will be made using a rod of OFHC copper with a water cooling channel in order to take away the synchrotron radiation thermal load.

The straight sections vacuum chamber does not present any particular requirement, its cross section is almost rectangular and a not so high photon flux hits the vacuum chamber, in this case it is possible to use 316-L stainless steel for the vacuum pipe.

5.4. Pumping system

The very high and concentrated gas load and the relatively little room to put pumps bring us to discard the following pumping system solutions: non evaporable getters, distributed sputter ion pumps, lumped sputter ion pumps and other similar devices.

The only solution that seems to give some positive results is to use very big pumps concentrated placed over the gas sources, the absorbers, in order to increase as much as possible the conductance from the pump to the source. The devices that can give the needed pumping speed are: titanium sublimators, cryopumps and turbo molecular pumps. Excluding the solutions with cryopumps and turbomolecular pumps because they are very expensive and they need maintenance, our choice falls on the titanium sublimation pumps. This kind of pumps are cheap, they need very low maintenance and they can give a very high pumping speed, about 8 l/s for each square centimeter of active surface, so a pump with a inner surface of 4000 cm^2 will have about 3200 l/s of pumping speed for CO, in this case we need a total of 10 titanium sublimation pumps for each arc. Using sublimators we must take into account that they do not pump noble gases and methane, that is produced by the interaction of the synchrotron radiation with the residual gas and with the inner walls of the vacuum chamber; a possible solution to this problem is to add a few sputter ion pumps capable to pump well noble gases and methane, triode ion pumps are an example. As the desorption efficiency for methane is more than 10 times lower than that for CO, it possible to estimate the required pumping speed in the range of about 1000 l/s at $1 \cdot 10^{-9}$ torr.

The fore vacuum pumping system consists of a portable station composed by a magnetic bearing turbomolecular pump baked by an oil free mechanical pump, this system must be able to reach a pressure in the range of 10^{-7} torr, a pressure at which the ion pumps can easily start.

6. Conclusions

A fully oil free vacuum system for DAΦNE machine has been designed using both standard and special solutions. The linear accelerator, the transfer lines and the accumulator use a relatively simple vacuum system based on standard technologies, while the storage ring vacuum system requires special solution for the vacuum chamber, made of aluminum machined in a particular shape, and for the pumping system, mainly based on titanium sublimators. The total pumping speed installed on the storage ring is about 250000 l/s over 200 meters of vacuum chamber. With this pumping system is possible to reach the pressure of $1 \cdot 10^{-9}$ torr with stored beam of a maximum current of 5.5 A.

7. References

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