The DAΦNE Main Ring Vacuum System

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Abstract

The DAΦNE Main Ring Vacuum System is designed for an mean operating pressure of 1 nTorr with a circulating current of about 5 A/beam. Finite elements calculations have been carried out to check the maximum possible deformation for the Bending Quadrant vacuum chamber that will be made of Al 5083-H321. Water cooled copper absorbers are employed to cope with the Synchrotron Radiation, (SR), produced in the wigglers and dipoles. The total gas load due to SR is $Q \approx 2.6 \times 10^{-5}$ Torr l/s per arc for CO, with a photodesorption rate $\eta \approx 1 \times 10^{-6}$ molec/ph, (after ≈40Ahr of commissioning), as measured at NSLS-BNL. Nine sputter ion pumps and nine titanium sublimation pumps are located in each arc to provide, respectively, the 15% and the 85% of the required pumping speed.

I. INTRODUCTION

The DAΦNE Φ-factory [1] is a twin ring 510 MeV e^+e^- collider facility under construction at INFN-LNF in Frascati. To reach the desired luminosity value of $L \approx 5 \times 10^{32}\, cm^{-2} s^{-1}$, at $\gamma = 1000$, a stored beam of $5.3A$ and a mean pressure of $1 \times 10^{-9}\, Torr$ are required in each ring. Four 10-meter-long vessels constitute the vacuum chamber of the bending sections of each ring. The selected material is Al 5083-H321. A 10÷20 mm slot divides the beam channel from an antechamber where the absorbers and the pumping stations are located. The maximum possible deformation of the vacuum chamber has been checked via a finite elements method as reported in section II. Water-cooled copper absorbers are provided to cope with the high photon flux produced in the Bending Quadrants, (BQ). The total gas load has been estimated from a photodesorption rate of $\eta \cong 1 \times 10^{-6}\, molec/ph$ for CO, after ≈40 Ahr of beam conditioning, as reported in section III. This η value is the result of an experiment on the U10B beam line at NSLS [2]. Nine Sputter Ion Pumps, (SIP), and nine Titanium Sublimation Pumps, (TSP), are located in each arc, for a total required pumping speed of $S \approx 1.3 \times 10^4\, l/s$. The TSP is designed taking into account the operating needs of DAΦNE. A full scale prototype has been built and tested. The results of the measurements and the routine performance of our vacuum system are reported in section IV.

II. MAIN RING VACUUM CHAMBER MECHANICAL ANALYSIS

The Main Ring vacuum chamber is geometrically designed in such a way that most of the Synchrotron Radiation is stopped in the antechambers by water cooled copper absorbers. The generated gas load will be pumped out by the pumping stations located close to the absorbers which are perpendicularly oriented with respect to the photon direction. Each BQ chamber will be machined, inside and outside, from two Al 5083-H321 plates and welded along the median plane.

Several cross-sections of the DAΦNE Main Ring have been analyzed by means of a finite-element code [3] in order to check the maximum deformation. Both two and three dimensional (wherever possible) computations show, under the atmospheric pressure and the bakeout temperature, a maximum vertical displacement less than 0.3 mm in most cases, and the stress field is far from critical conditions. In the quadrupole section longitudinal ribs are advisable, as first calculations show a vertical displacement of the order of 0.5 mm. The stress concentration has been investigated around the fillets of the chamber, and the adaptive-mesh algorithm methodically used. Due to several improvements and changes in the shape of the chamber, a final finite-element analysis will be carried out, via a CAD interface, as soon as the geometry will be frozen.

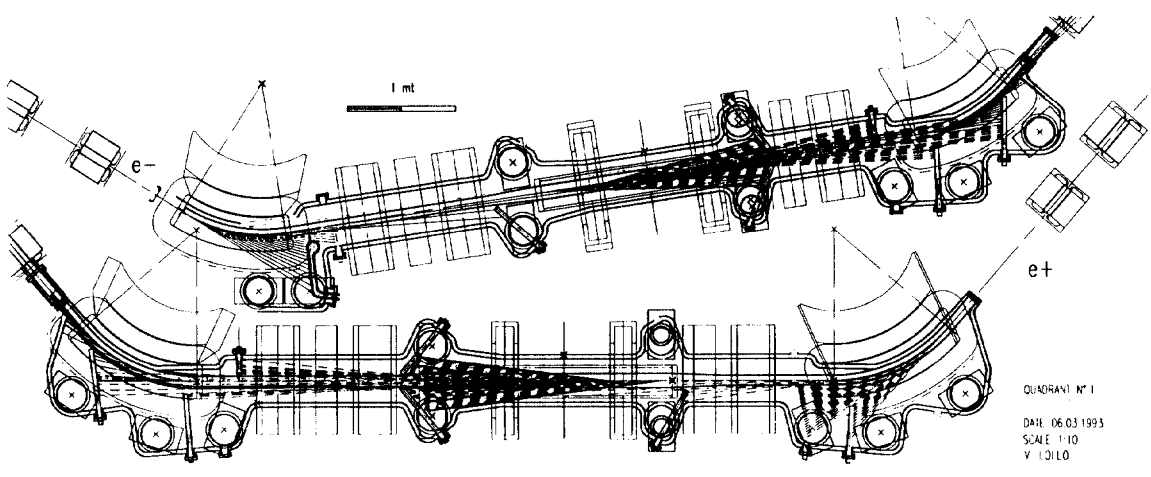

Figure 1 The DAΦNE Bending Quadrant layout.

III. SYNCHROTRON RADIATION INDUCED DESORPTION

Four wigglers and eight bending magnets constitute the bending sections of the Main Ring. The total number of ph/s emitted from the bending magnets is:

$$\frac{dN}{dt} = 8.08\times10^{20}\cdot E(GeV)\cdot I(A) = 2.2\times10^{21}\ ph/s.$$

From the wigglers about $1.3\times10^{21}\ ph/s$ are emitted, and the total photon flux per arc is:

$$N_{tot} = 8.8\times10^{20}\ ph/s.$$

The total gas load is related to the photon flux by:

$$Q = \frac{N_{tot}\cdot\eta}{3.4\times10^{19}} = 2.6\times10^{-5}\ Torr\cdot l\cdot s^{-1},$$

where η *(molec/ph)* is the photodesorption rate of the vacuum chamber. In order to estimate the right value of η we set up an experiment on the U10B beamline at the VUV ring in Brookhaven [2], having critical energy ε_c =490eV. Since the DAΦNE beam chamber and antechamber are made of aluminum and most of the Synchrotron Radiation is incident on a copper absorber, an aluminum tube containing a copper bar was exposed to a white photon beam and desorption coefficients were measured. In Table 1 the results obtained for the photodesorption rate of H_2, CH_4, CO, CO_2, after N_2 glow discharge cleaning, are reported. Due to the differences between DAΦNE and U10B parameters, listed in Table 2, the values obtained at the U10B beamline have to be multiplied by a factor of 0.52, (see ref. [1]), in order to get the appropriate $\eta\approx1.\mathrm{x}10^{-6}$ molec/ph for the DAΦNE vacuum system.

Table 1
Photodesorption coefficient η for H_2, CH_4, CO, CO_2, after N2 glow discharge, for different values of accumulated photon dose [2].

	η $(molecules/photon)$		
photon dose	1×10^{23} ph/m	5.5×10^{23} ph/m	$*1\times10^{24}$ ph/m
H_2	1×10^{-5}	7×10^{-6}	6×10^{-6}
CH_4	$<1\times10^{-7}$	$\approx1\times10^{-8}$	1×10^{-8}
CO	6×10^{-6}	2.5×10^{-6}	$<2\times10^{-6}$
CO_2	1.5×10^{-6}	6×10^{-7}	4×10^{-7}
*extrapolated	After N_2 glow $1\times10^{18}\ atom/cm^2$		

Table 2
Comparison of U10B and DAΦNE parameters

	VUV	DAΦNE	WIG-GLERS	
E_c Crit. Energy	490	208	330	eV
Flux correction	1	0.84	0.92	
Low energy cut-off	5	0	0	eV
Angle of inc. on absorber	5.7	80-90		degrees
correction*	1	0.59		
Total correction on η		0.52		

*from electrical measurements.

IV. TITANIUM SUBLIMATION PUMP DESIGN AND TESTS

To reach the required average pressure of 1 $nTorr$, the pressure in the BQ has to be about 2 $nTorr$, since the straight sections must operate at pressures in the low 10^{-10} $Torr$ range. For the pumping speed this constraint yields :

$$S_{BQ} = \frac{2.6\times10^{-5}}{2\times10^{-9}} = 1.3\times10^{4}\ l/s.$$

This pumping speed can be achieved by employing TSP's, which are well suited to pump a large quantity of Hydrogen at low pressures [4], [5] and [6], together with sputter ion pumps. In Figure 1 the BQ layout is shown where nine 200 l/s SIP's and nine TSP's are provided. In this way the required pumping speed for each TSP is:

$$S_{TSP} \cong 1.2\times10^{3}\ l/s.$$

To test the capacity of a TSP to pump such a high gas load for a reasonable time, i.e. to guarantee the desired mean pressure for a duration of two weeks without being switched on, a first TSP prototype, simulating the operating conditions in the BQ antechamber, has been built and tested at Frascati.

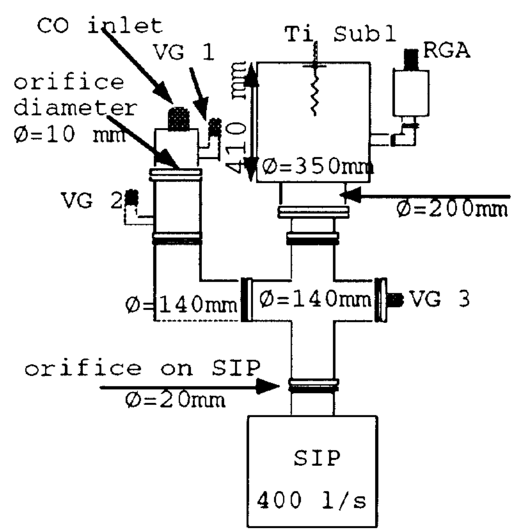

Figure 2 Experimental set-up.

In Figure 2 the experimental apparatus is shown. A *Varian* Titanium Filaments Cartridge was employed as Ti source. Three filaments are available in the standard cartridge for 3 grams of total evaporable Ti. Three Varian B.A. vacuum gauges were used, two for the CO throughput determination with the orifice method, VG1 and VG2, and the third, VG3, to record the pressure in the experimental chamber. A *Vacuum Generator* SX-200 Residual Gas Analyzer was used to determine the partial pressures of the gas species. The pumping speed S_G of a getter film of area A is [6]:

$$S_G/A = 3.64 f(T/M)^{1/2}\, l \cdot s^{-1} \cdot cm^{-2}$$

The data available in literature [4] for the sorption characteristics of flashed Ti films give $f \approx 0.38$ as the sticking coefficient of freshly deposited Ti, and 23×10^{15} *atom/cm²* of CO as the total amount pumped by $\approx 1900 \times 10^{15}$ *atom/cm²* of Ti. In Figure 3 the curve of our TSP's pumping speed vs. the total amount of CO pumped is reported, for 500 nominal monolayers of deposited Ti, (T=293 K). In this prototype the area actually covered by Ti is about 2400 cm^2, leading to an initial sticking coefficient for CO of about $f \approx 0.6$. This value is higher than the sticking coefficient quoted in literature, but this can be attributed to a greater area actually covered by Ti, due to a deep sand-blasting of the surface. Furthermore, in this preliminary prototype, the presence of a short pipe, with different cross sections, between the TSP and the location of the vacuum gauge affects the accuracy of the measurements. However this uncertainty is easily avoided directly connecting the TSP to the experimental chamber, without limiting conductance between the two, as planned for a second prototype. As far as the sorption capacity is concerned, $1 Torr \cdot l$ of CO corresponds to about 14 monolayers of gas, in relative agreement with Harra's results considering that the thickness of our Ti film is only ≈500 monolayers. A second full scale prototype of TSP has been built and is now under testing, see Figure 4. In the new set-up the TSP pump is directly connected with a full scale prototype of a dipole vacuum chamber, in order to avoid any conductance between the TSP and the antechamber. Furthermore, an internal sawtooth shaped structure has been added to the TSP to increase the surface covered by the getter film. Accurate measurements are now in progress at Frascati to test this method of increasing the sorption capacity of the pump, in order to operate in an experimental set-up reproducing the actual operating conditions of DAΦNE.

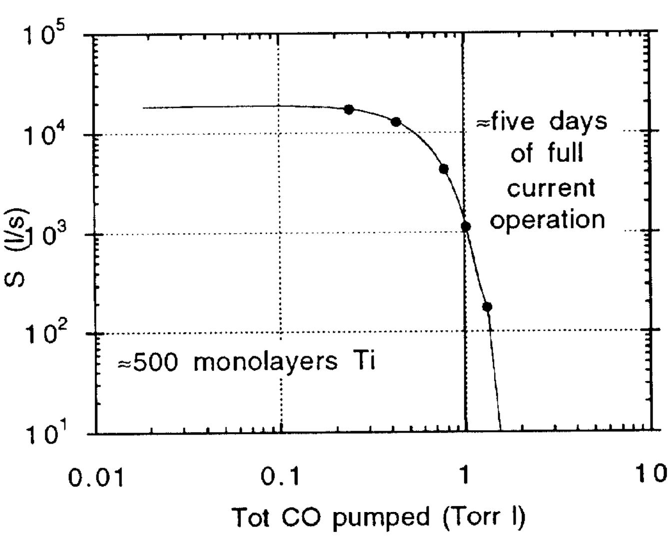

Figure 3. TSP's pumping speed vs. the total amount of CO pumped for 500 nominal monolayers of deposited Ti.

V. SUMMARY

A vacuum system has been designed for the DAΦNE Main Ring. Due to the high Synchrotron Radiation load in the bending quadrants, a slot divides the beam channel from the copper absorbers and pumping stations locations. Based on the photodesorption yield of the Al vacuum chamber, after the commissioning, nine SIP's and nine TSP's will be provided in each BQ in order to guarantee an average pressure of 1 *nTorr* for about two weeks of full current operation.

VI. REFERENCES

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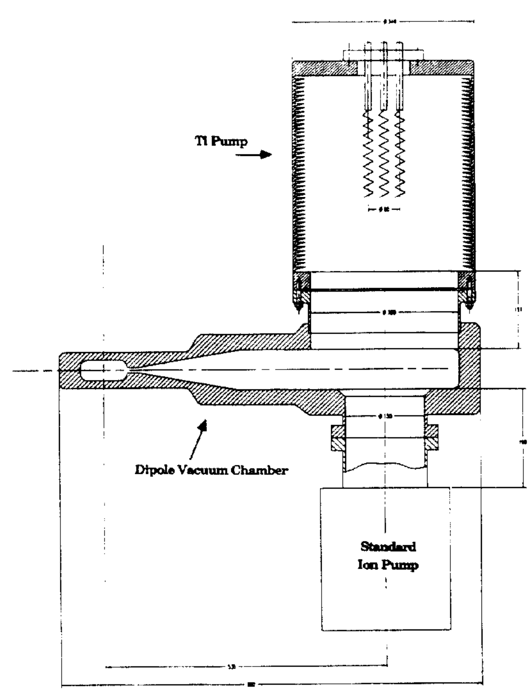

Figure 4. Final full scale prototype of DAΦNE TSP and Dipole Vacuum Chamber.