The Interaction Region Vacuum Chamber for the KLOE Experiment

A. Clozza, G. Raffone
INFN LNF
C.P. 13, 00044 Frascati (Roma)
Italy

Abstract

A vacuum and supporting system for the interaction region of the KLOE experiment, that will be installed on the DAΦNE Φ factory in Frascati (Italy), have been designed. A short description of the vacuum system and of the supporting system for the vacuum chamber will be presented on this paper.

1. INTRODUCTION

KLOE is a general purpose detector, see figure 1, that will be installed on DAΦNE the Frascati Φ factory. This detector is optimized for the study of CP violation in K^0 decays with the aim of achieving a statistical accuracy of $\sim 10^{-4}$ in one year run at the DAΦNE target luminosity of $\sim 10^{33}$ $cm^{-2}s^{-1}$.

The vacuum chamber, for the KLOE experiment interaction region, has been designed taking into account several stringent requirements needed to fulfill the operating condition of the detector itself. Some of the requirements are: mean vacuum pressure level better than $1 \cdot 10^{-9}$ torr, vacuum chamber around the interaction point as transparent as possible to the produced particles, all the components of the support, the quadrupole magnets and any other thing, that can interact with the produced particles, must stay within a maximum detector acceptance angle of 9 degrees respect to the beam axis.

2. VACUUM SYSTEM

2.1 Vacuum chamber

It is possible to divide the vacuum pipe in three main sections. The first one between the first separator magnet and the first low-β quadrupoles triplet, the second one between the first and the second low-β quadrupole triplets and the third one between the second low-β quadrupole triplet and the second separator magnet.

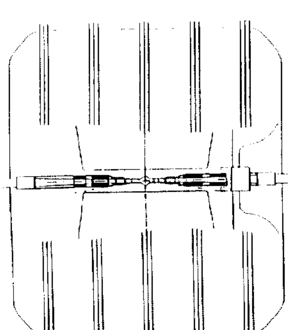

Figure 1. View of the KLOE detector

The first and the third section of the vacuum chamber are equal and are made of AISI 304 L stainless steel (2 mm thickness) with a copper coating inside in order to reduce the ohmic current losses.

2.2 Beryllium Vacuum Chamber

The second section is made of pure beryllium (0.5 mm thickness) to provide a very good transparency in terms of radiation length and scattering angle. See figure 2.

The beryllium I.R. beam pipe is about 0.7 m long and the cross section diameter grows up from 86 mm to 200 mm at the interaction point.

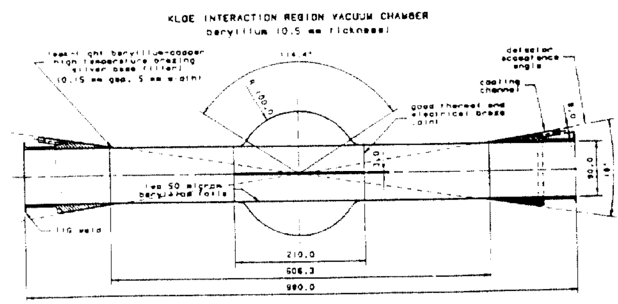

Figure 2. The KLOE beryllium vacuum chamber

The middle bulb-shaped part of the chamber makes the manufacturing difficult from several points of view: machining, brazing techniques, tight tolerances and cleaning conditions. Some brazing techniques are still under development.

The beryllium chamber is directly brazed onto the stainless steel pipe; the total length of the part of the pipe inside the detector is about 4 m and requires four simply support points.

Water pipes, brazed as close as possible to the interaction point, provide the cooling needed to compensate for the RF thermal load on the vacuum chamber.

Inside the spherical part of the chamber there is a 50 micron beryllium shield (180 mm long) to reduce RF wall losses and beam instability.

This shield is brazed at both ends in order to have a good thermal and electrical continuity. Under the thermal load the shield buckles into different shapes depending upon the initial curvatures of its surface.

When the shield is made of several circumferential strips, it is possible to shows clearly that an outward curvature of the strip often does not avoid the anti symmetric mode of buckling; furthermore the double curvature surface of the strip leads to a torsional out of plane mode of buckling.

2.3 Pumping System

The vacuum requirements for the KLOE interaction region brought us to a special design for the pumping system.

Table 1 shows the main vacuum related parameter for the interaction region. The value of the gas load has been evaluated using for the desorption coefficient η the mean value of $1 \cdot 10^{-6}$ molec/photon. Although the gas load is not very high, the geometry of the vacuum chamber and the requirements for the detector make things harder. In our case, indeed, the vacuum chamber is essentially a long narrow pipe.

Table 1
Vacuum related parameters

Total photon flux	$3 \cdot 10^{19}$ phot./s
Total gas load	$9 \cdot 10^{-7}$ torr l/s
Total power load	180 W
Max. mean pressure	$5 \cdot 10^{-10}$ torr

The main problem to solve, designing a pumping system for a long pipe with a distributed gas load, shown in figure 3, is to have a pressure distribution, along the pipe, as uniform as possible. The simplest solution is a pumping system which pumps are placed at regular distance along the pipe.

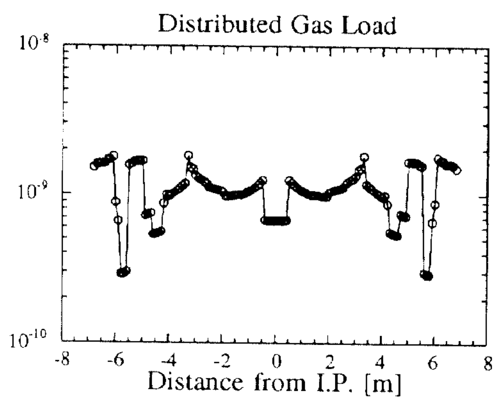

Figure 3. Gas load distribution along the vacuum chamber.

The solution we adopted is a compromise between the uniform distribution of the pumping elements and the mechanical constrains of the detector and of the vacuum pipe itself. Figure 4 shows the pumps arrangement we have chosen for the interaction region. This pumping system is a combination of lumped sputter ion pumps, distributed sputter ion pumps and non evaporable getter pumps. In figure 4 it is possible to see the location of the various pumps: a pair of 230 l/s lumped sputter ion pumps is placed after each splitter magnet, a 200 l/s distributed sputter ion pump is placed inside each splitter magnet, a 500 l/s distributed sputter ion pump is placed inside each compensator magnet, and a 800 l/s non evaporable getter pump is placed between each compensator magnet and the KLOE solenoid. There are no pumps inside the detector near the interaction point.

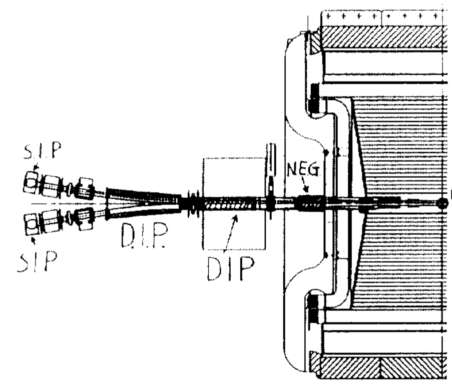

Figure 4. Pumping system arrangement

Lumped sputter ion pumps are simply available on the market. On the contrary, for distributed sputter ion pumps and non evaporable getter pumps we did an R&D work whose results are described below.

For the distributed ion pump placed inside the splitter magnet, where the magnetic field strength is about 1.7 kG, like in a commercial pump, we will use a pumping element with the same cell dimensions of a standard diode ion pump. In the compensator magnets, where the magnetic field strength is about 1.5 T, we will use a special pumping element, which cell dimensions are shown in table 2.

Table 2
Pumping element dimensions

Cell diameter	10 mm
Cell length	20 mm
Anode-cathode gap	5 mm

With a prototype of this pump (anode composed by 100 cells) we have measured a pumping speed of 50 l/s at $1 \cdot 10^{-9}$ torr, this means that the pumping speed for the single cell is 0.5 l/s. In the compensator magnets there is sufficient room to obtain about 500 l/s of pumping speed with this kind of pump.

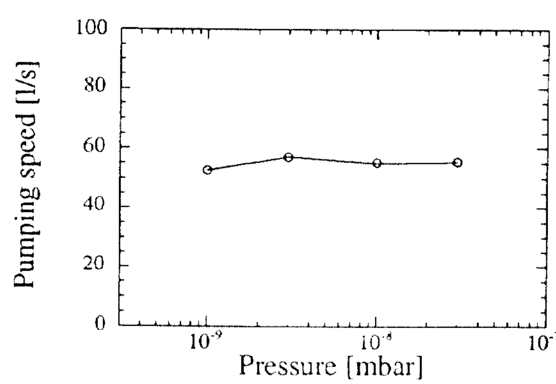

Figure 5. Pumping speed of the prototype of the distributed sputter ion pump working at 1 T.

The decision to use a Non Evaporable Getter pump arises from the development of a new kind of getter from SAES Getters.

A preliminary design, done in collaboration with SAES Getters, foresees a pump composed by 480 blades, which initial pumping speed is of the order of 2000 l/s, for CO, and decreases to about 800 l/s after having pumped about 50 torr liters of gas, this means about 2 years of full current 24 hours a day machine operation.

2.4 Pressure Profile

The vacuum system designed for the interaction region is able to reach a mean pressure of about $3.2\cdot10^{-9}$ torr after 100 Ah of stored beam, the mean pressure falls down to $9\cdot10^{-10}$ torr after 1000 Ah and to $4\cdot10^{-10}$ torr after 5000 Ah.

The maximum value of the pressure with the proposed configuration of pumps is $8\cdot10^{-9}$ torr after 100 Ah of stored beam, and is determined by the conductance of the vacuum pipe between the NEG pumps and the Interaction Point.

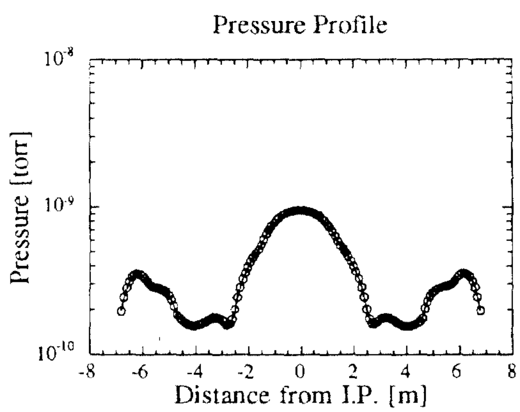

Figure 6. Pressure profile at full conditioning

3. SUPPORTING SYSTEM

The supporting system consists mainly into two independent structures: the vertex detector support and the triplet assembly support.

The basic idea is to have two independent supports to allow relative motions between them during the mechanical alignment of the permanent magnet quadrupoles.

The vertex support is made of carbon fiber composite material; it is a simple cylindrical structure (light and rigid) about 4 m long and supported at the end cones of the tracker chamber. There is a small gap between the vertex support and the tracker inner wall (500 mm diameter) to house a proper tooling device during the installation.

As before pointed out, the vacuum pipe needs four simply support points to avoid both high bending stresses and the Brazier's effect.

These support points are more or less equally spaced along the vertex support; two of them are collars rigidly joined to the end plates of the vertex detector; the other two are located at the end of the vertex support (i.e. close to the end cones of the tracker). Then a compact structure involving both the vertex detector and the beam pipe is obtained.

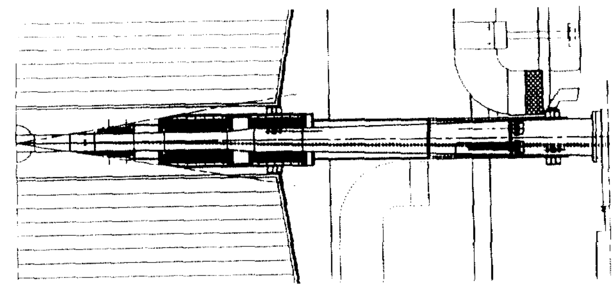

Figure 7. Supporting system layout

The triplet support allows a remote control of five of its degrees of freedom (vertical and horizontal positions, roll, pitch and yaw angles) by means of a five cams system; this support will be able also to carry an additional calorimeter besides the low-β permanent magnets.

The main part of this support will be made of a carbon fiber in order both to minimize the amount of material inside the detector and to obtain an acceptable bending at its end.

It will be simply supported in two sections: the latter inside the detector, right on the end of the tracker cone, and the former outside close to the compensator solenoid.

This support must be splitted longitudinally to allow the beam pipe and the permanent magnets installation.

4. CONCLUSIONS

The vacuum and supporting system for the interaction region of the KLOE experiment has been designed to meet the requirements needed to fulfill the operating condition of the detector itself.

The vacuum chamber has a structure, 2 mm thick stainless steel and 0.5 mm beryllium, enough rigid, that could be self supporting, and at the same time it provides a very good transparency, 0.5 mm beryllium, in therms of radiation length and scattering angle.

The pumping system is able to reach a mean pressure of about $5\cdot10^{-10}$ torr at full current, 5 A of stored current for each beam, after a reasonable conditioning of the order of 2 or 3 months.

The supporting system, made of carbon fiber composite material, consists mainly into two independent structures to allow relative motions between the vertex detector and the triplet assembly during the mechanical alignment of the permanent magnets. The vertex detector supporting structure will hold also the vacuum chamber.