

Chapter 5

LAYOUT OF THE STORAGE RING

5.1 Introduction

SESAME, a 2.5 GeV Synchrotron Radiation source with a circumference of about 125 meters and the emittance of 24 nm.rad and a nominal current of 400 mA, is dedicated to deliver photons to different experimental needs of the Middle East region [1].

In this chapter, an overall view of the SESAME storage ring will be presented. After the brief description of the machine, the materials and the manufacturing processes are discussed and followed by some descriptions about the Gate valves, bellows and the power absorbers around the ring.

5.2 Description of the SESAME Storage Ring

The design of the vacuum system of SESAME follows the chamber concept of the recently built SR sources in the world [3,4,5]. The machine consists of three main parts: Storage ring, Booster and the beam lines. The booster is a 800 MeV synchrotron which is filled by a 20 MeV Microtron [2]. The injection in the storage ring is done at 800 MeV and then the energy of the particles is ramped up to 2.5 GeV. Three Kickers are foreseen for the injection process. The RF system of the machine consists of two pairs of cavities with 250 KW klystron system [1]. Figure (5.1) shows an overview of the storage ring, booster and the RF cavities. As presented in the picture, each dipole and each straight section has a number corresponding its position on the storage ring. Short Straight Section is shown by SSS and Long Straight Sections by LSS consequently.

There exist three different types of beam lines on the SESAME machine: zero, six and twelve degree beam lines. The zero degree beam line is specified for the photons which are produced by the insertion devices like wigglers and undulators while both six and 14.5° degree beamlines are dedicated to the synchrotron radiation from the bending magnets. Each bending magnet has a curvature of 22.5°, so 14.5° beam line has been chosen as the closest possible one to the middle of the dipole where the size of the beam is minimal.

The zero degree beam lines are not foreseen on the bending magnets downstream of the injection point and RF cavities because there is no place to put the insertion devices there. Therefore, the Dipoles II-1, III-1 and IV-1 have no zero degree beam line because there is no place to put an insertion device on SSS I-2, II-2 and III-2.

The maximum possible length for the beam lines varies by their angle and their relative position in the building. Figure (5.2) shows the ring which has been placed in the building including all possible zero degree beamlines possible and Table (5.1) presents their length measured from the source point. Table (5.2) presents the length of all possible beamlines in one quarter of the ring. The source point for the zero degree beamlines is considered at the middle of the corresponding straight section and for the six and 14.5 degree beamlines from the dipole. The maximum length available for 0° beam line is 33.1 meters, for 6° beamline is about 29.3 meters and for 14.5° is about 30.6 meters which seem to be enough for almost all conventional experiment needs. Nevertheless, if longer beam lines are needed, the ring position can be optimized to provide longer ones. Figure

(5.3) shows one quadrant of the storage ring in more details. Each quadrant of the machine has an approximate length of 31.2 m.

Figure (5.4) shows the SESAME storage ring installed in the building including the shielding walls, basic beam lines, power supplies, experimental hatches and the access bridge to the inside of the ring's tunnel. Outer shielding wall has the thickness of 80 Cm all around the ring and its shape is optimized according to the outlets of the different beamlines. The inner shielding wall has a thickness of 20 Cm and continues all around the ring. There exist an additional shielding around the booster synchrotron which allows the safe access to the booster while the machine is working. The access to the inner side of the ring is possible using a bridge connecting the first floor of the building to the inner area near to the control room. The experimental hatches are foreseen for the experimentalists as an office for data recording and data evaluation.

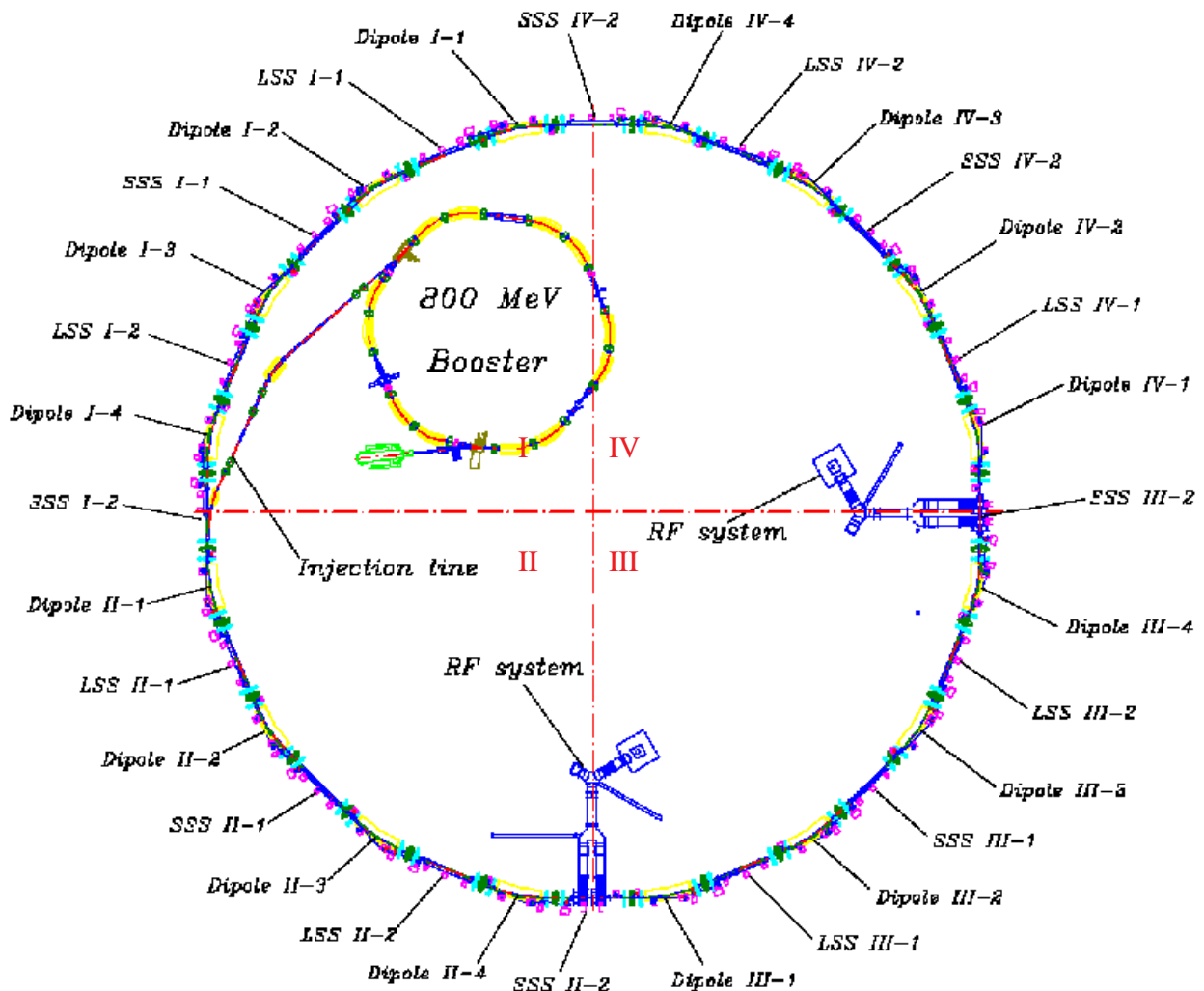


Figure 5.1: An overview of the SESAME Ring.

Each of the 8 super periods of the SESAME storage ring lattice contains 2 bending magnets, So there are 16 dipoles in the whole machine, Figure (5.5) shows the layout for one super period of the lattice. The overall circumference of the machine is 124.8 meters, so each super period is about 15.6 meters long.

The design of the dipole vacuum chamber is Chamber/Ante-chamber based, which means that the electron beam circulates in one chamber and the synchrotron radiation passes through a small gap into the ante chamber where it is absorbed by lumped absorbers or delivered to the users. Since the length of this absorbers are short compared to the circumference of the ring, the outgassing is obtained in a shorter time of conditioning. Furthermore the desorbed gases are immediately pumped by the large Ion pumps close to the absorbers. This design will be presented in more details in section 5.5 [3].

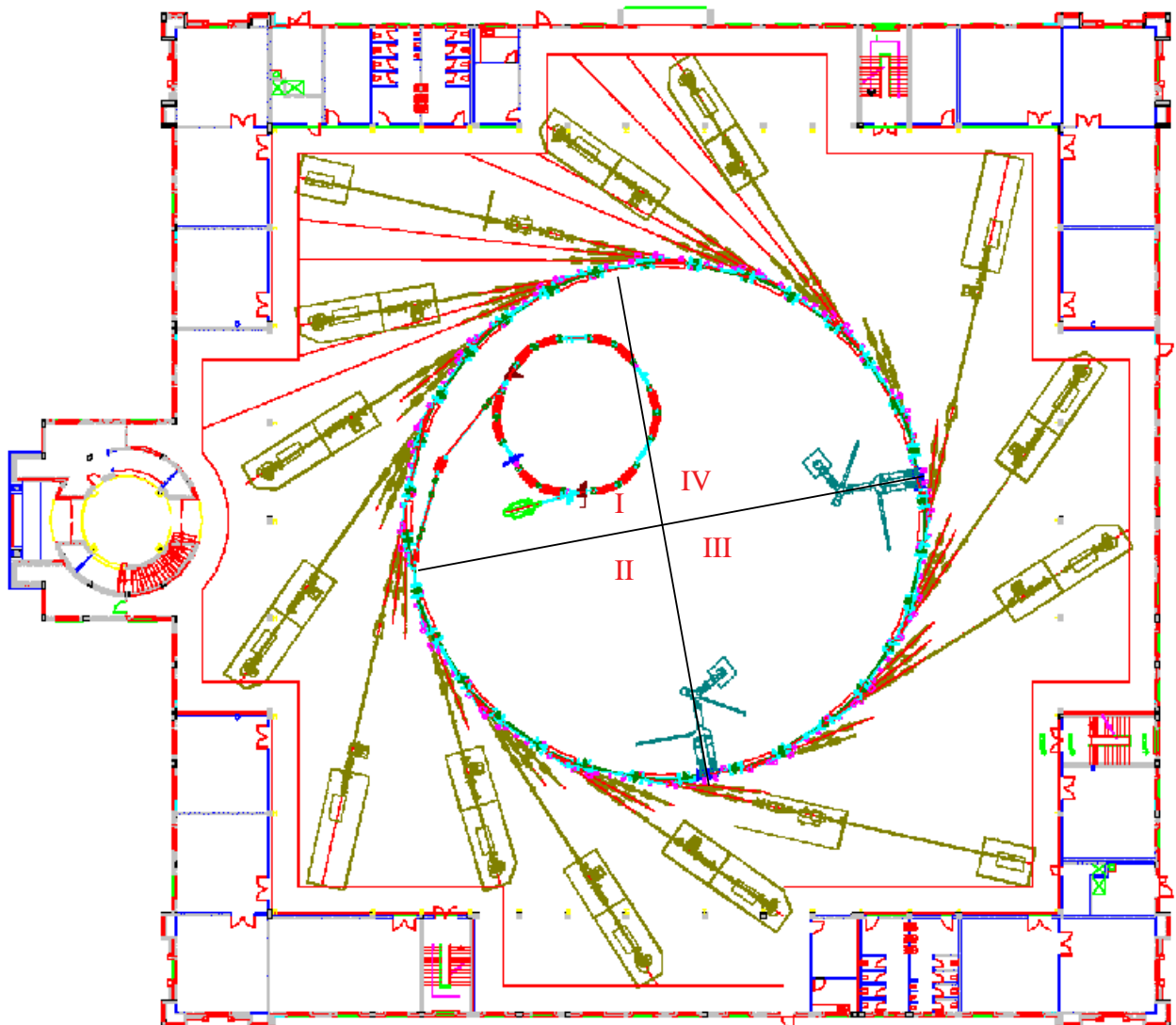


Figure 5.2: An overview of the SESAME ring placed in the building and available zero degree beamlines.

Figure (5.6) shows the dipole vacuum chamber which includes large pumping ports as near as possible to the crotch absorbers to pump the outgassing coming out from them due to the synchrotron radiation. Another pumping port is placed on the right hand side of dipole chamber to help keeping the pressure uniform. Using Titanium Sublimation Pumps in combination with Ion pumps is advised for dipole chamber due to their large pumping capacity for Hydrogen. Due to the forces applied on the vacuum chamber from the atmospheric pressure side, it is necessary to use some strengtheners to keep the deformation in the reasonable limits; this has been discussed in more details in section 5.5.

Table 5.1: Length of the zero degree beamlines measured from the source point.

| DIPOLE NUMBER | LENGTH OF 0° BEAM LINE [M] |
|---------------|----------------------------|
| Dipole #1 | There is none |
| Dipole #2 | 29.8 |
| Dipole #3 | 24.7 |
| Dipole #4 | 33.1 |
| Dipole #5 | There is none |
| Dipole #6 | 29.8 |
| Dipole #7 | 28.8 |
| Dipole #8 | 33.1 |
| Dipole #9 | There is none |
| Dipole #10 | 29.8 |
| Dipole #11 | 24.7 |
| Dipole #12 | 33.1 |
| Dipole #13 | 24.7 |
| Dipole #14 | 24.7 |
| Dipole #15 | 28.8 |
| Dipole #16 | 33.1 |

Table 5.2: Length of all possible beam lines in one quadrant of the ring measured from the source point.

| DIPOLE NUMBER | LENGTH OF 0° BEAM LINE [M] | LENGTH OF 6° BEAM LINE [M] | LENGTH OF 12° BEAM LINE [M] |
|---------------|----------------------------|----------------------------|-----------------------------|
| DIPOLE #10 | 29.8 | 28.6 | 30.6 |
| DIPOLE #11 | 24.7 | 21.0 | 25.4 |
| DIPOLE #12 | 33.1 | 29.3 | 28.5 |
| DIPOLE #13 | 24.7 | 22.4 | 30.6 |

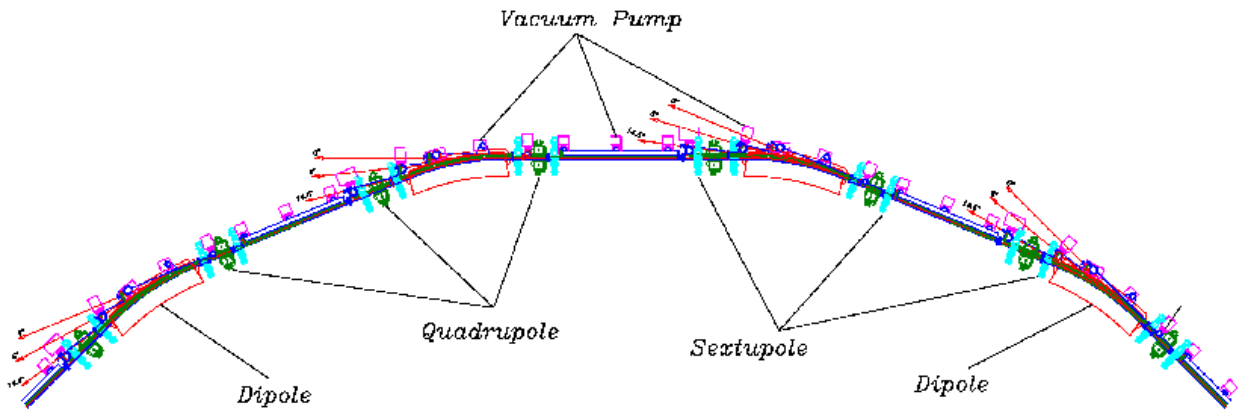


Figure 5.3: One quadrant of the SESAME ring.

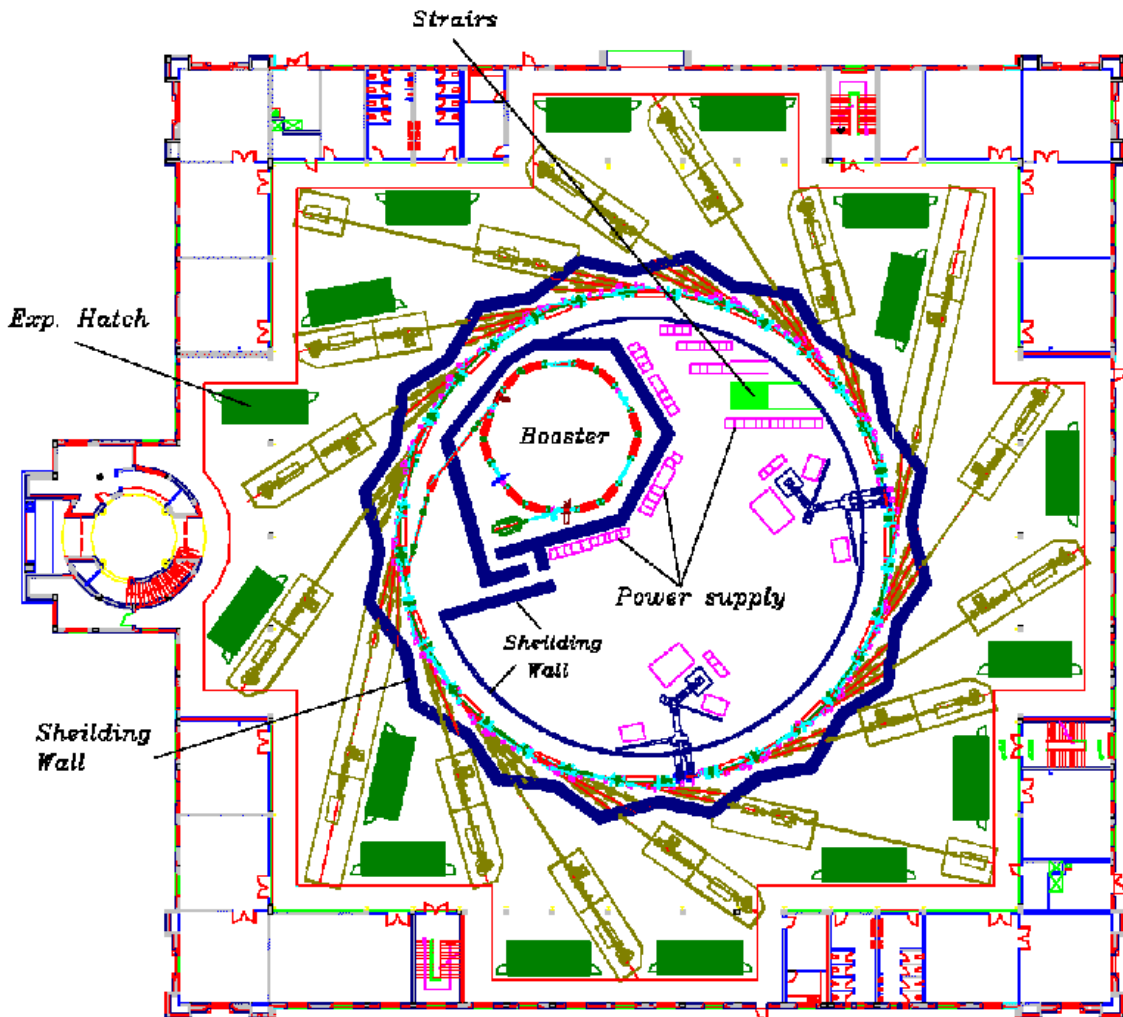


Figure 5.4: An overview of the SESAME machine.

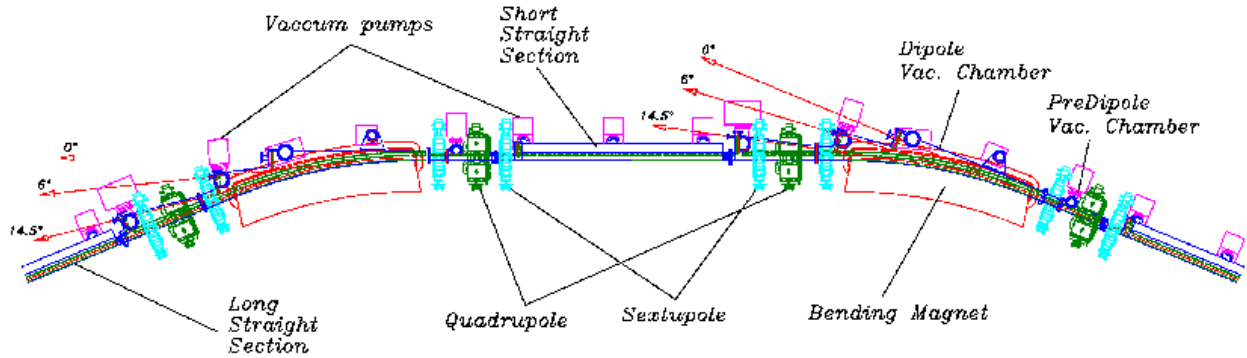


Figure 5.5: One super period of the SESAME storage ring.

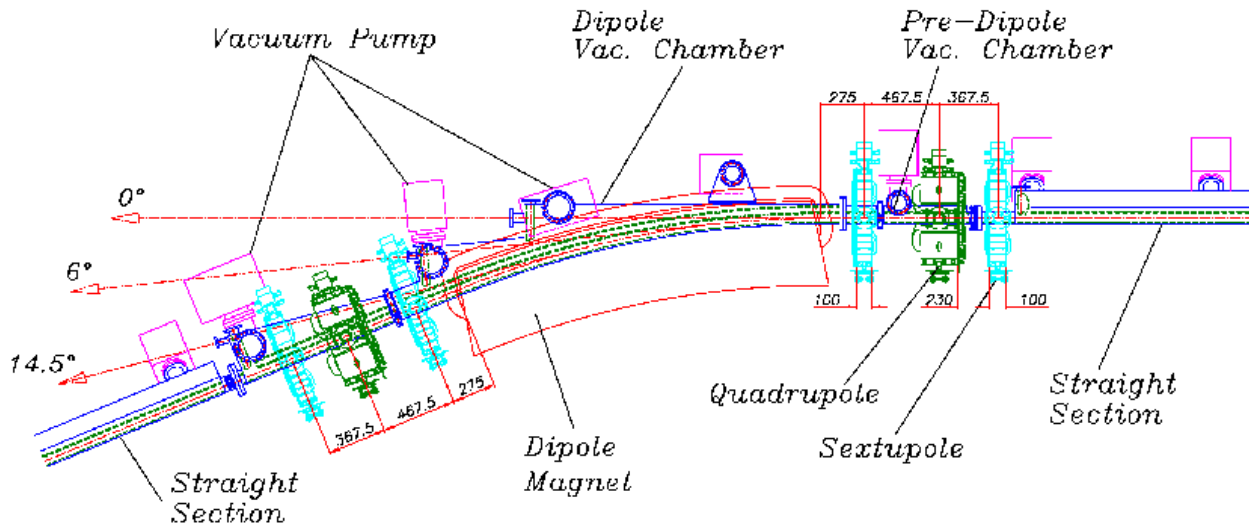


Figure 5.6: Top view of the dipole vacuum chamber.

According to the SESAME lattice, two different kinds of straight sections exist, short straight sections with the length of 3.05 m and long ones with the length of 3.23 m. These values are nominal lengths of the straight sections which means the distance between two existing focusing magnets but the usable length is a bit less because of the space needed for flanges, bellows, absorbers and gate valves. The maximum usable length of the straight sections are estimated to be 2.59 m and 2.77 m respectively. In the sections where the gate valves are installed, this length can be reduced to 2.50 and 2.69 m, Figures (5.7) and (5.8) show the long and short straight sections respectively. Three pumps, at equal distances, are installed to keep the pressure down in this long chamber and a bellows is foreseen to help correcting the mechanical errors and thermal expansions.

Some straight sections on the ring are dedicated to special purposes; one for the injection, two for the RF system and one for the beam diagnostic elements. The straight sections which are used for RF and injection, have been chosen from the short ones, So finally, there remain 8 long ones available for installation of the wigglers and 4 short ones for Undulators.

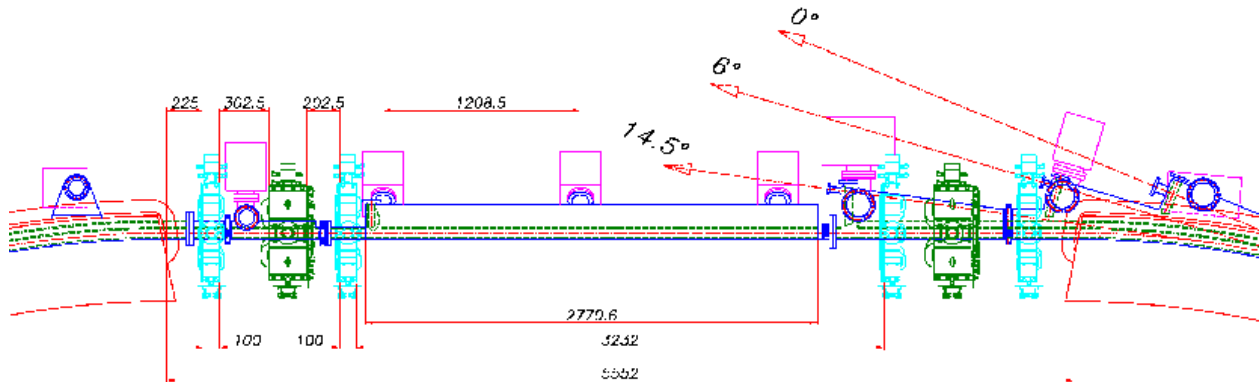


Figure 5.7: Long straight section.

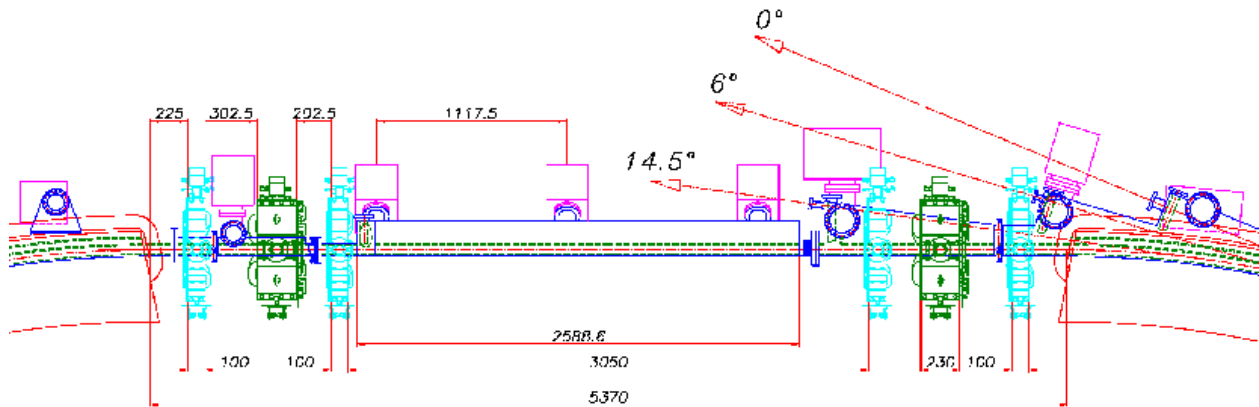


Figure 5.8: Short straight section.

5.3 Choice of Material

In ultra high vacuum systems the materials are normally chosen due to their outgassing rates, because in UHV region the main gas load comes from the surfaces. On the other hand the material should be strong enough to withstand against the forces acting from the atmospheric pressure to the under vacuum parts. The bending of the vessel walls should not exceed 0.5 mm in the worst conditions [3].

The most common material which is used in the world's accelerators is Stainless Steel. It has good mechanical properties, weld (TIG and electron beam) ability and low outgassing rate. For the SESAME storage ring, Stainless Steel 316 LN (Z2 CND) is proposed for the main chambers

including Pre-dipole, Dipole and straight sections. The relative permeability of the material should not exceed 1.005 ($\mu_r \leq 1.005$) for the raw material [3,4,6,7].

The absorbers of the synchrotron radiation on the ring should be made of a material with a high thermal conductivity. In this case, OFHC¹ copper (ASTM C 10100) is proposed for crotch absorbers. For the parts with a higher radiated power, GLIDCOP is proposed. This material has better mechanical properties compared to OFHC copper in high temperatures and is suitable for high power crotch absorbers. For more information about the materials which are used in the vacuum system and their properties please refer to the chapter 7, *The vacuum system of SESAME*.

5.4 Pre-Dipole Vacuum Chamber

Pre-dipole vacuum chamber of the SESAME storage ring consists of two symmetric parts which are electron beam welded together. The chamber body has been made of 2 mm thick stainless steel sheets which are formed by folding procedure. Figures (5.9) to (5-11) show different views of the Pre-dipole vacuum chamber. Figure (5.10) shows the cross section of the pre-dipole vacuum chamber and its corresponding ante-chamber. This special design let the radiation pass through the ante-chamber and be absorbed on the crotch absorber # 1, in the dipole magnet.

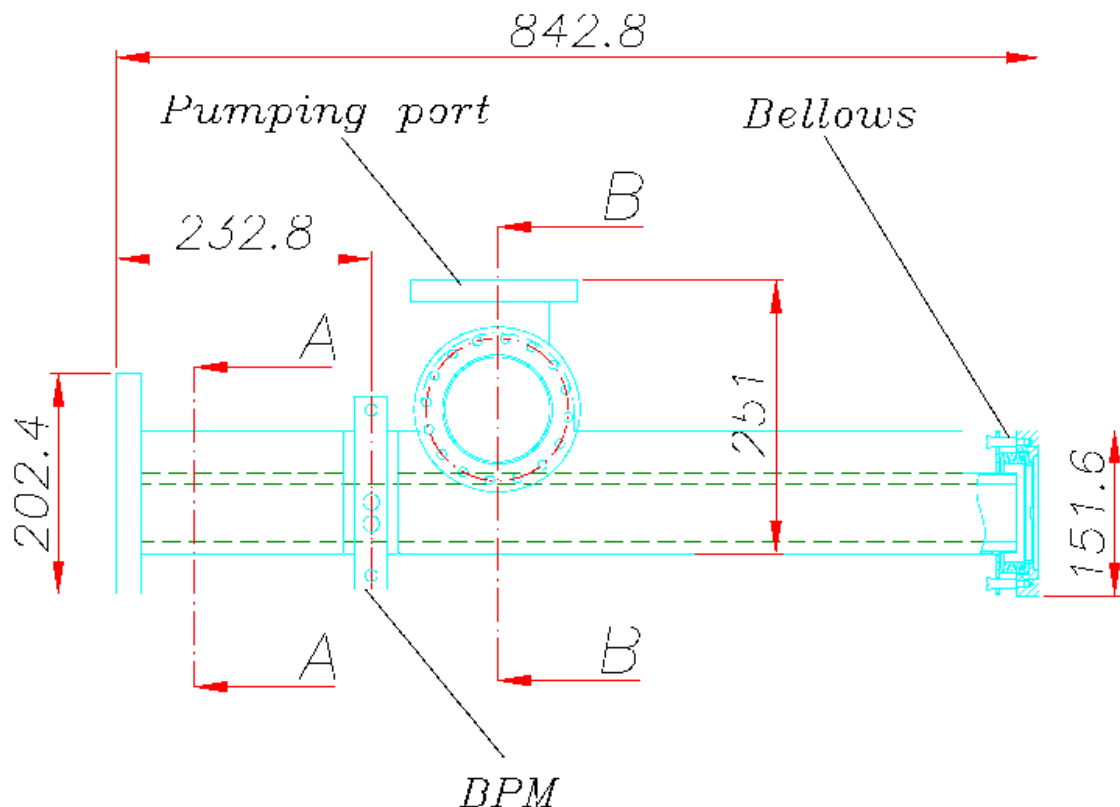


Figure 5.9: Top view of the pre-dipole vacuum chamber.

¹ - Oxygen Free High Conductivity

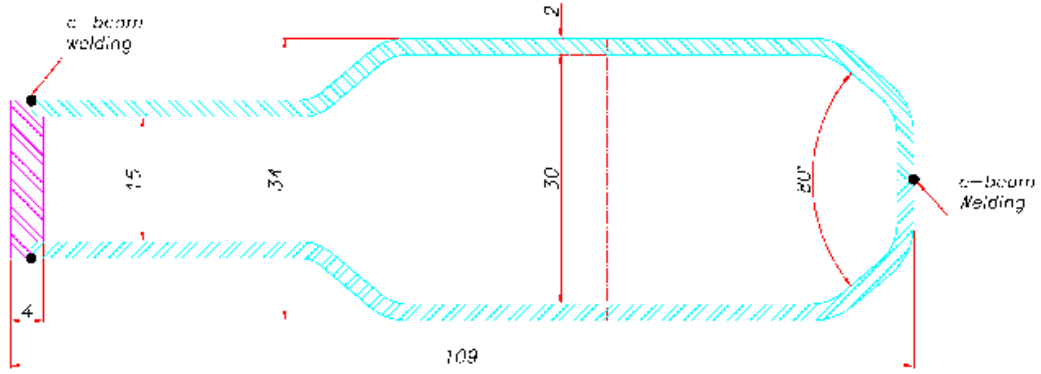


Figure 5.10: Cross section of the Pre-dipole vacuum chamber, section A-A.

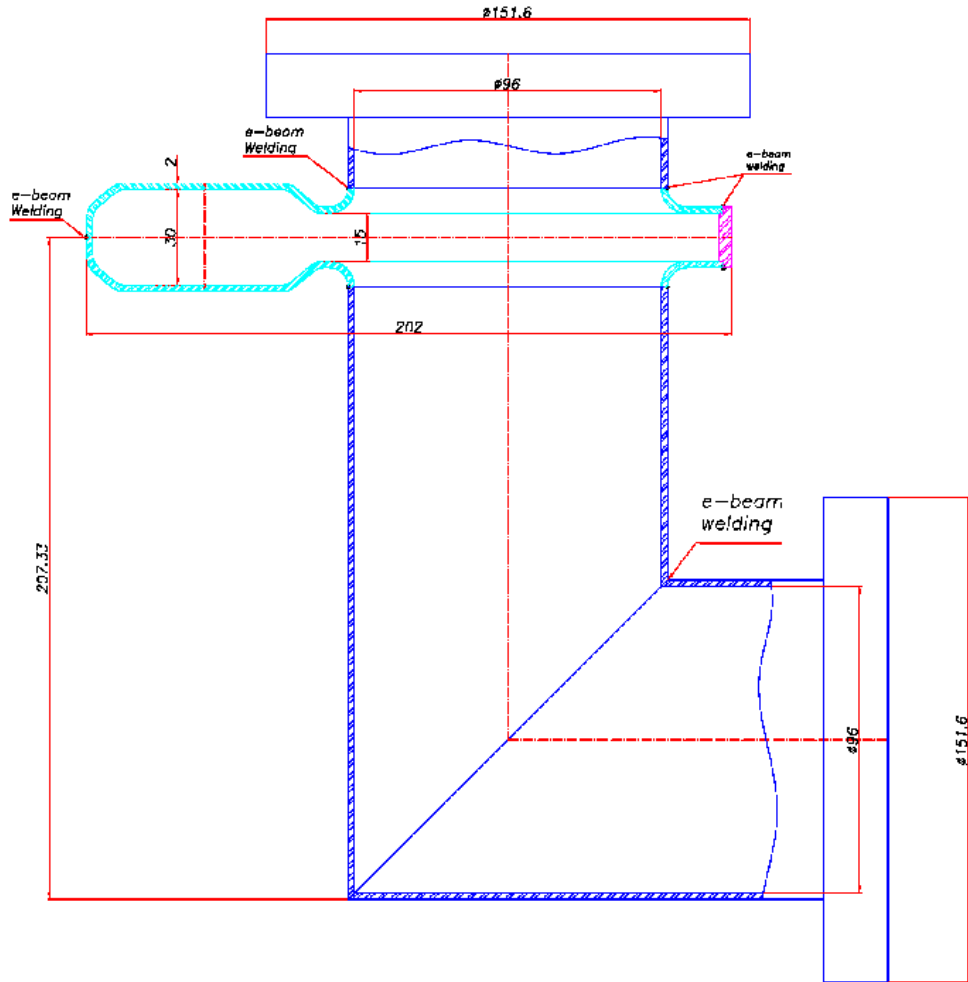


Figure 5.11: Cross section of the Pre-dipole vacuum chamber, section B-B.

5.5 Dipole Vacuum chambers

Figure (5.12) shows an overview of the dipole vacuum chamber. In this design, three crotch absorbers are foreseen in order to avoid any power excess on the absorbers. A pumping port is placed as near as possible to the absorbers to pump all the gases desorbed due to the radiation. Besides, there exist three beamlines which deliver synchrotron radiation to the users, 0° for the radiation comes from the insertion devices and two more in 6° and 14.5° for the radiation comes from the dipole. 14.5° beam line is the nearest possible angle to the middle of the dipole magnet where the size of the beam is minimum.

The design of the dipole vacuum chamber is based on the chamber/ante-chamber design which is well known and fully developed in the recent radiation sources world wide. Figures (5.13) to (5.16) show the schematic cross sections of the dipole vacuum chamber. It consists of two stainless steel plates which are preformed by deep drawing procedure and a 7 mm thick outer wall. The two plates are electron beam welded together first, then this sub-assembly is welded to the outer wall from the external side. Because of the large surface area of the this chamber, the thickness of the stainless steel sheet used in this part is 3 mm to prevent the large deformations due to the forces acting via the atmospheric pressure.

In any case, it is necessary to reinforce the chamber from outside using some blade-type strengtheners which are welded to the chamber to keep the deformation bellow 0.5mm every where. The strengthener plates should be connected to the chamber using point welding method to prevent banana effect on the chamber.

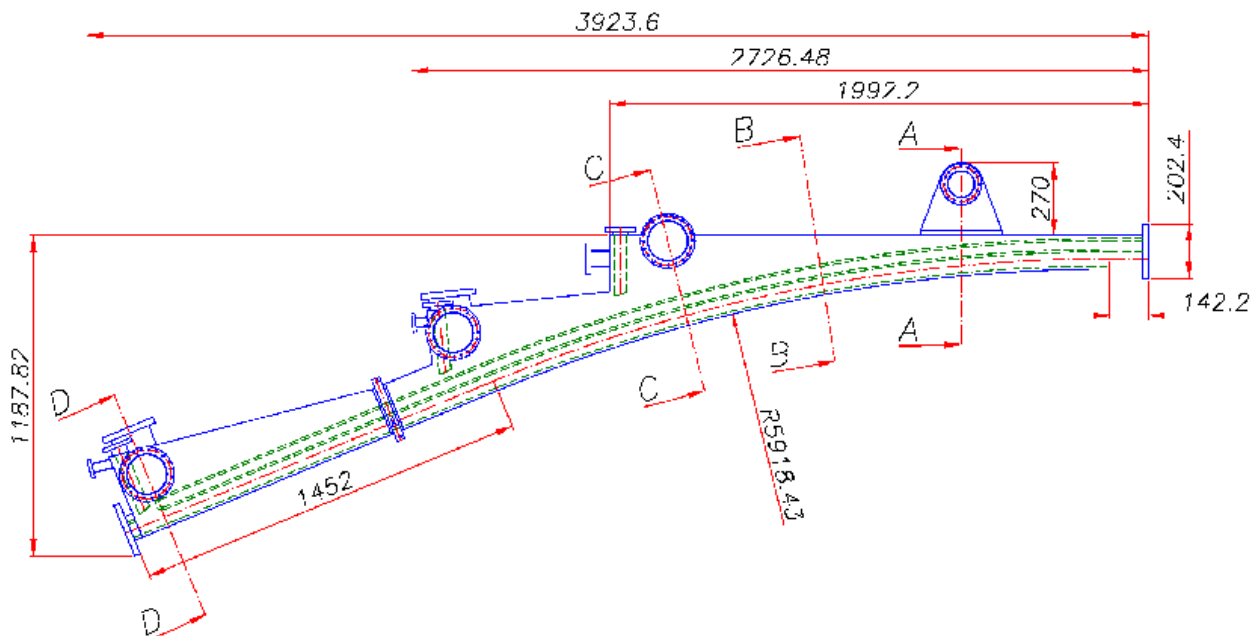


Figure 5.12: Dipole vacuum chamber.

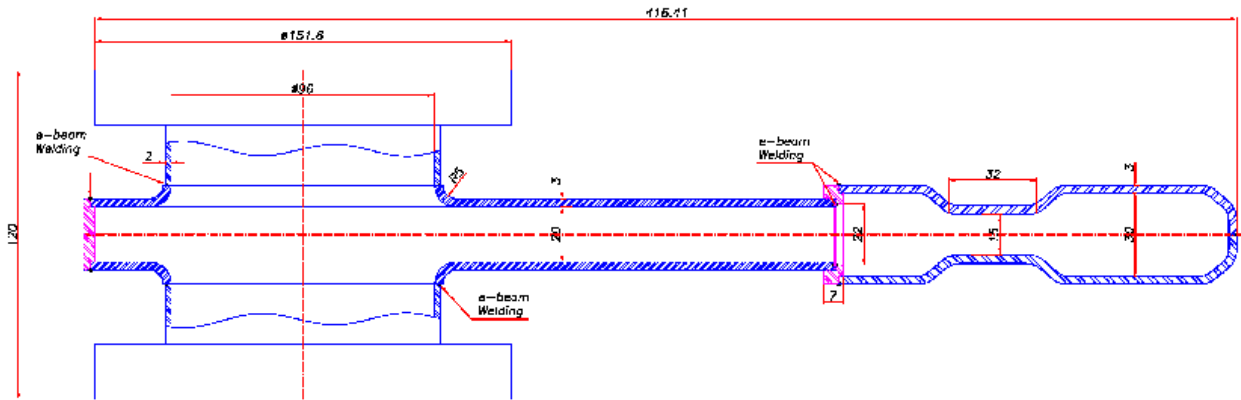


Figure 5.13: Cross section of the dipole vacuum chamber, section A-A.

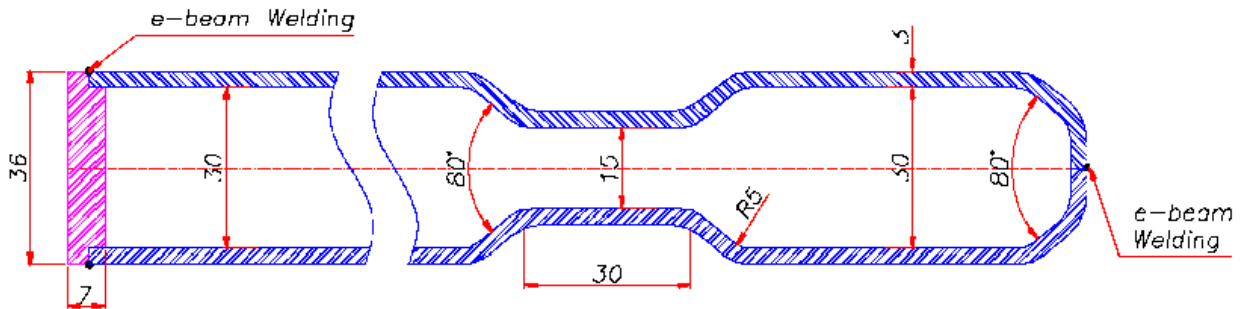


Figure 5.14: Cross section of the dipole vacuum chamber, section B-B.

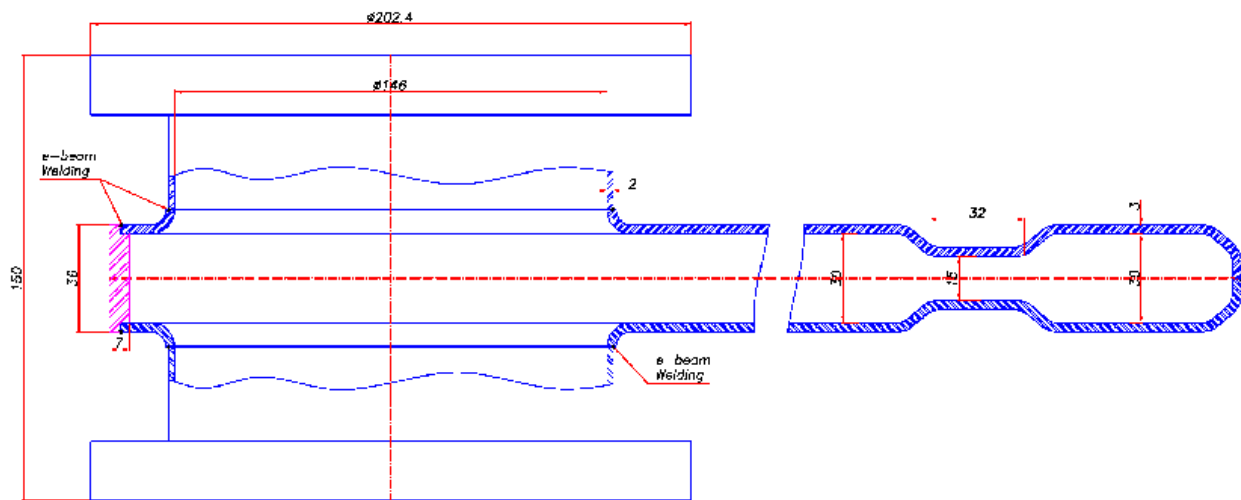


Figure 5.15: Cross section of the dipole vacuum chamber, section C-C.

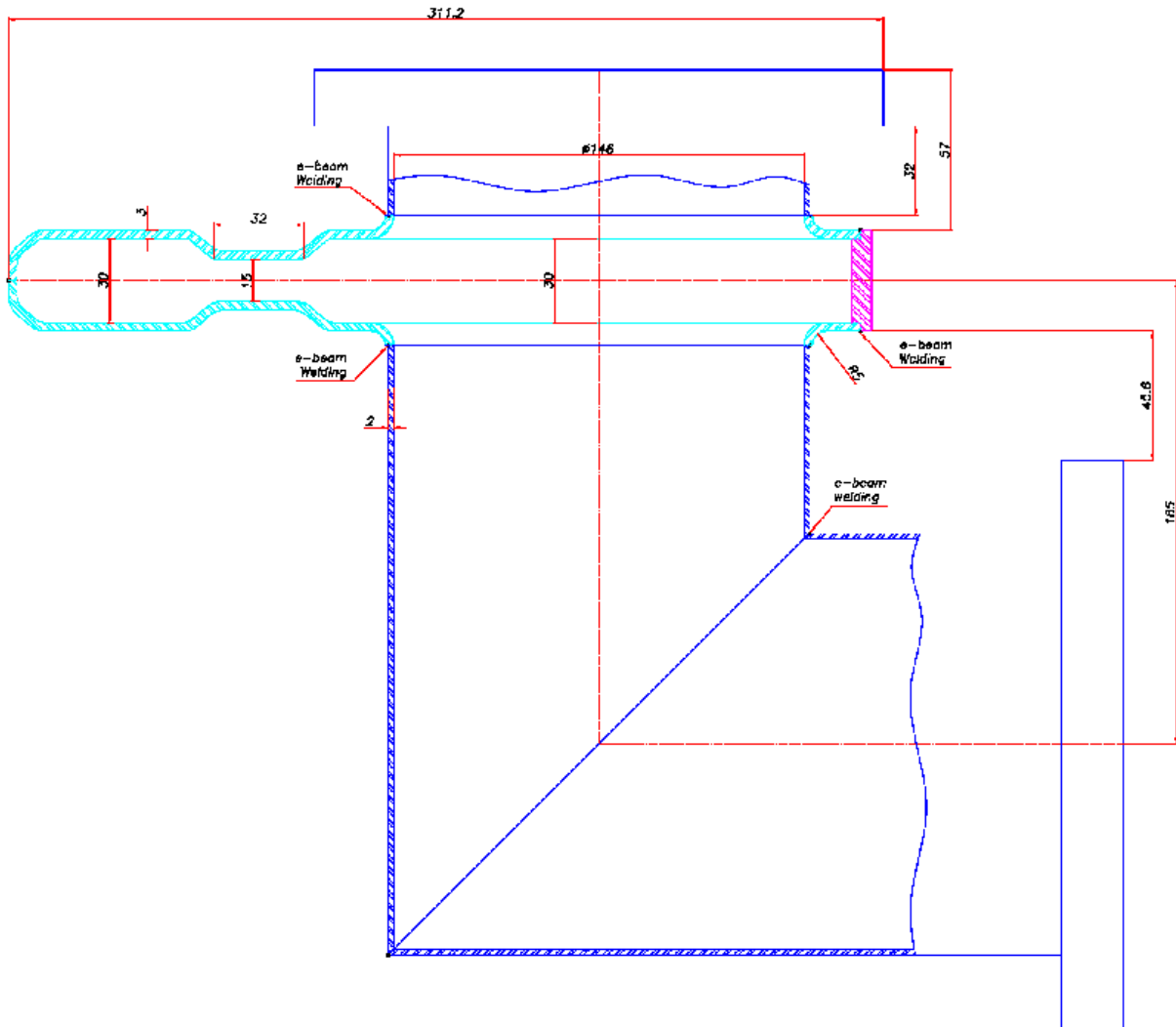


Figure 5.16: Cross section of the dipole vacuum chamber, section D-D.

5.6 Straight Sections

The vacuum chamber of straight sections is also based on the chamber/ante-chamber design. The only difference is that in this section the antechamber is simply a tube welded to the beam chamber. Definitely, it is necessary to have a crotch absorber at the end of such a straight section to absorb the radiation coming from upstream dipole. the advantage of this design can be summarized as the following:

- It is cheap as the manufacturing point of view because a standard tube is used as the antechamber.

- The conductance of the vacuum chamber is increased which helps to keep the pressure uniform and as low as possible in the straight section.
- All the radiated power is absorbed in a crotch absorber at the end of the chamber, so there will be no distributed outgassing from the outer walls due to direct photon adsorption effect.

Figure (5.17) and (5.18) are the top views of the long and short straight sections respectively. Three pumping ports are foreseen on the antechamber, which are placed with an angle of 45° in respect to the beam plane to avoid any interaction between the pumps and the possible insertion device and also the front ends. Figure (5.19) shows the cross section of this chamber. It consists of two parts which are welded together using e-beam welding method. The beam chamber is produced with folding procedure just like the pre-dipole. Three pumping ports are foreseen when one of them is placed directly on the crotch absorber with an oval port to reduce the pressure bump caused by the outgassing in this region.

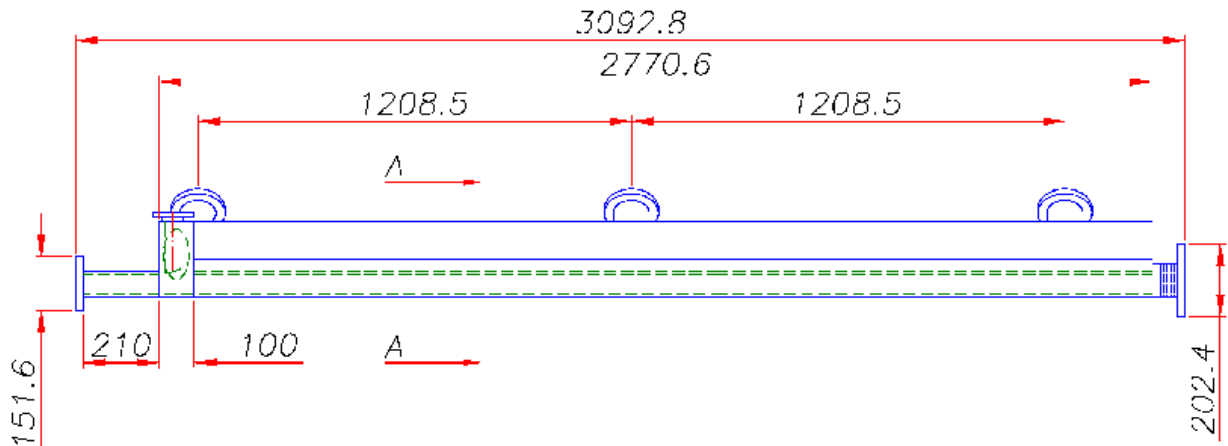


Figure 5.17: An overview of the long straight section vacuum chamber.

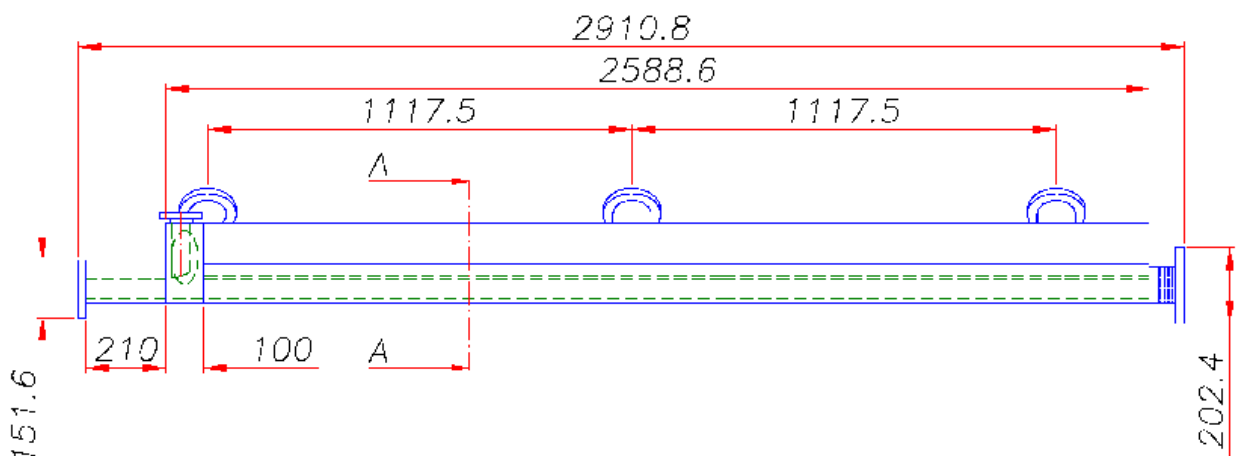


Figure 5.18: An overview of the short straight section vacuum chamber.

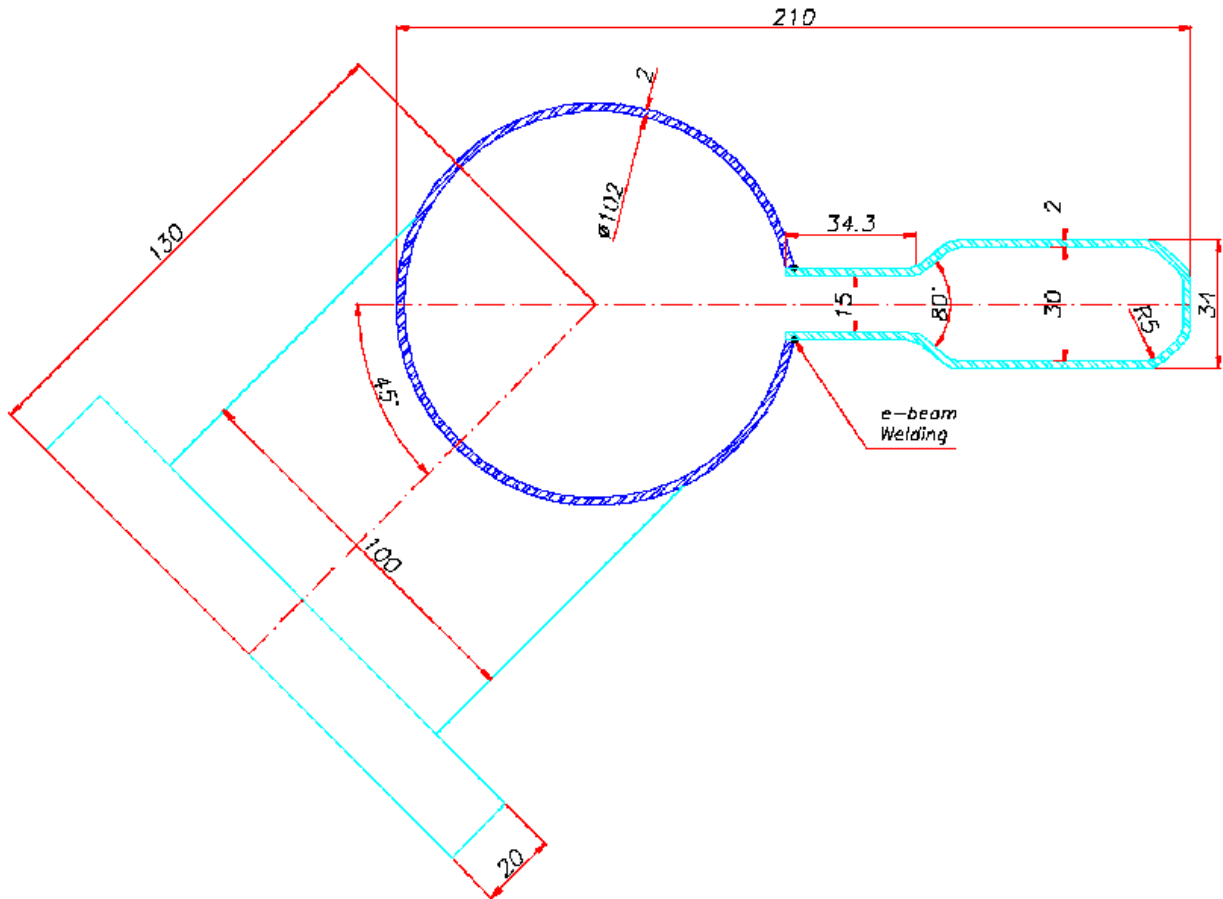


Figure 5.19: Section A-A of the straight section vacuum chamber.

5.7 Bellows and Gate Valves

The main reasons to have the bellows in the vacuum system are to make mounting procedure easier and to absorb the mechanical stresses due to the thermal expansions of the chamber. They are also useful in modifying manufacturing errors of different parts. It is recommended to use RF shielded bellows to prevent sudden changes of the cross section along the beam chamber. Two RF shielded bellows per straight section (32 in the whole machine) are foreseen in SESAME storage ring, one on the straight section vacuum chamber and the other on the pre-dipole. Figure (5.20) presents a sketch of such a bellows [4] and figure (5.21) shows the position of the bellows in the straight section. For more information please refer to the chapter 7, *The vacuum system of SESAME*.

Gate valves are mainly used to divide the machine into smaller sectors. It is so important to prevent the air to affect the entire ring in case of a leak. SESAME storage ring will be divided into four sectors by the gate valves, each part is defined by as a separate vacuum section, which will allow a separate pumping down, and will make it possible to be isolated from the rest of the

machine in case of venting for upgrading purposes or due to vacuum failures. The valves must be fast closing with the same aperture of the vacuum chamber and RF shielded by using a screen with RF fingers so the beam will see a smooth surface change. The best design for the Gate valves with an RF shield is commercially available from the market.

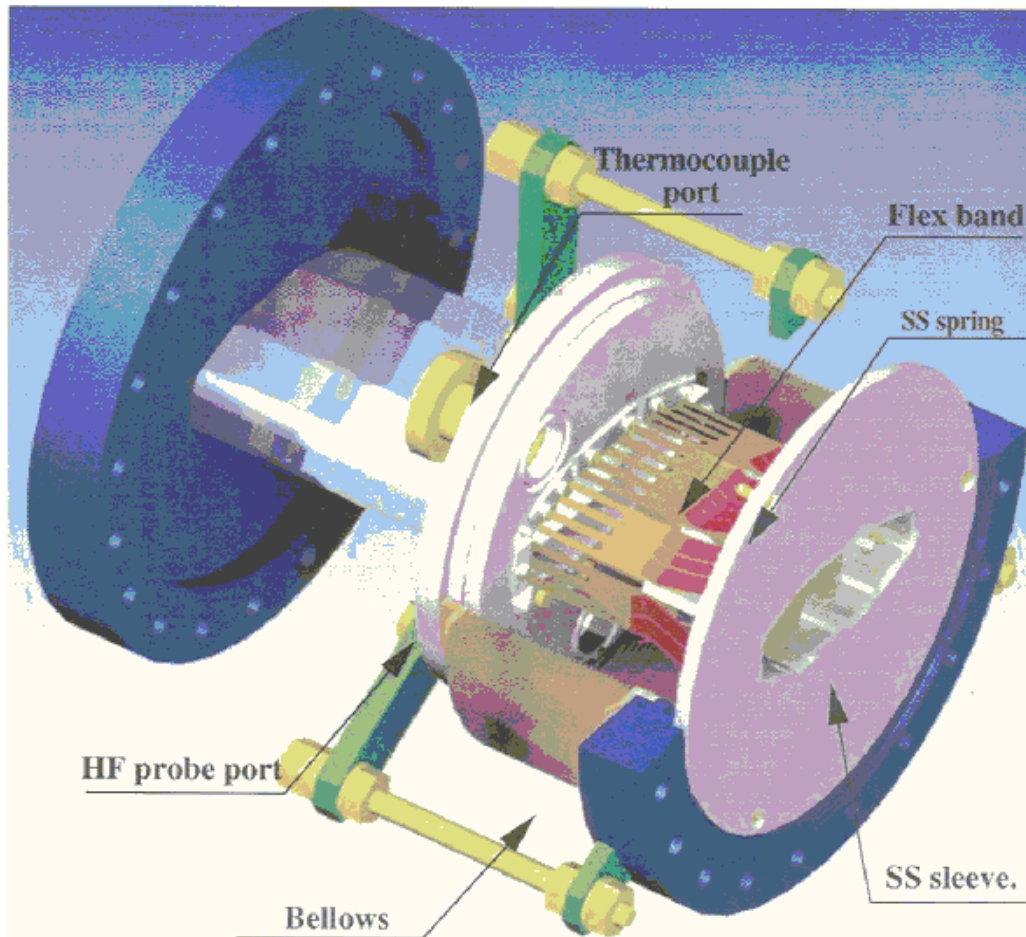


Figure 5.20: Schematic of an RF shielded bellows, SLS/SOLEIL cooperation [4].

Six Gate valves are foreseen for SESAME storage ring, one in the injection section (SSS I-2) two pairs at both ends of the RF cavities (SSS II-2 & SSS III-2), and another one in the SSS IV-2 in order to divide the whole ring into four equal vacuum sectors. Each sector contains 4 Dipoles so in the case of any possible leak or any necessary maintenance operation $\frac{1}{4}$ of the machine should be vented. As you can find, all the gate valves are placed in the short straight sections in order not to use the valuable space in the long ones. In addition, one gate valve will be located after the Microtron, and one between the booster synchrotron and the booster-storage ring transfer line.

The gate valve will be interlocked by a signal from two ion pumps located inside the vacuum section, so if two pumps indicate an increase in the pressure (above the set point) from the reading of their potential, then the beam is dumped and the valves will be closed.

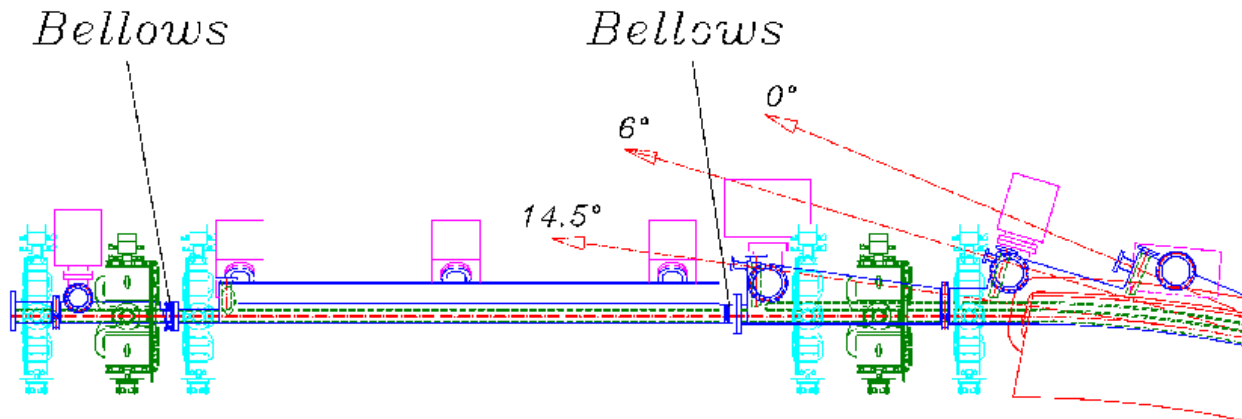


Figure 5.21: the reserved positions for the bellows in the straight section.

5.8 Synchrotron Radiation and Absorbers

Each electron/positron storage ring has a power loss due to the synchrotron radiation. This power hits the walls of the vacuum chamber and causes temperature rise. Lumped and distributed absorbers are necessary to remove the produced heat from the system. Total radiated power over the machine circumference can be calculated using the Equation (5.1).

$$P_T = 88.5 \frac{E^4 I}{\rho} \quad (5.1)$$

P_T : Total radiated power over machine circumference [Watts].

E : Energy of the particles [Gev].

I : The beam current [mA].

ρ : Bending Radius [m].

So for SESAME storage ring with $E=2.5$ GeV and $I=400$ mA and $\rho= 5.956$ m, total radiated power in all circumference is 232.2 [KW] which means 36.95 [W/mrad] or 644.92 [W/deg]. This power is absorbed by the lumped absorbers in dipoles and straight sections and also distributed ones in pre-dipole.

Suppose d corresponds the distance between the source point and a target normal to the photon beam and L the length of the target (e.g.: Crotch absorber), the linear power density [W/mm] is calculated by formula (5.2), Figure (5.22) shows the different parameters which have been used in this formula.

$$P = \frac{Pr}{2 \cdot \pi \cdot d} = \frac{Pr \times \theta}{360 \times L} \quad , \quad \theta : \text{in degrees} \quad (5.2)$$

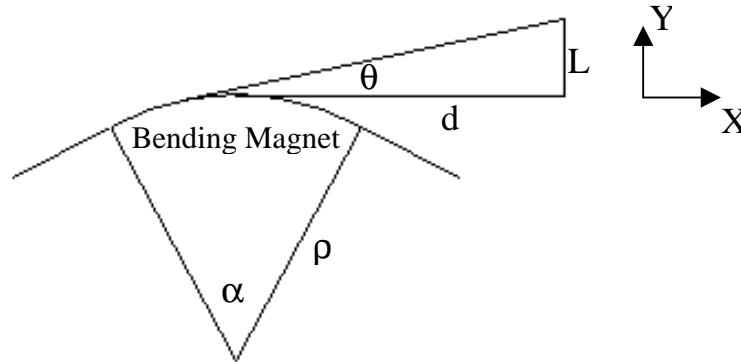


Figure 5.22 : Different parameters of the Equation (5.2)

The power absorbers on half an achromat of the SESAME ring are shown in Figure (5.23) in more details. The nomination of the Crotch absorbers starts from bending magnet, there are four crotches per dipole magnet which means 64 on the whole ring. The power density on the crotch absorbers has been shown in the Figures (5.24) to (5.27). In these charts, “length” of the crotch absorbers has been shown in the Figures (5.24) to (5.27). In these charts, “length” of the absorber which is hit by the synchrotron radiation and measured from top to bottom.

According to these charts, the maximum linear power density on the crotches is around 27 W/mm. In this case SLS/ANKA type crotch could be a perfect selection and be used without any problem because they can withstand up to 50 W/mm. Figure (5.28) and (5.29) show sketches of ANKA/SLS type crotch absorbers [5].

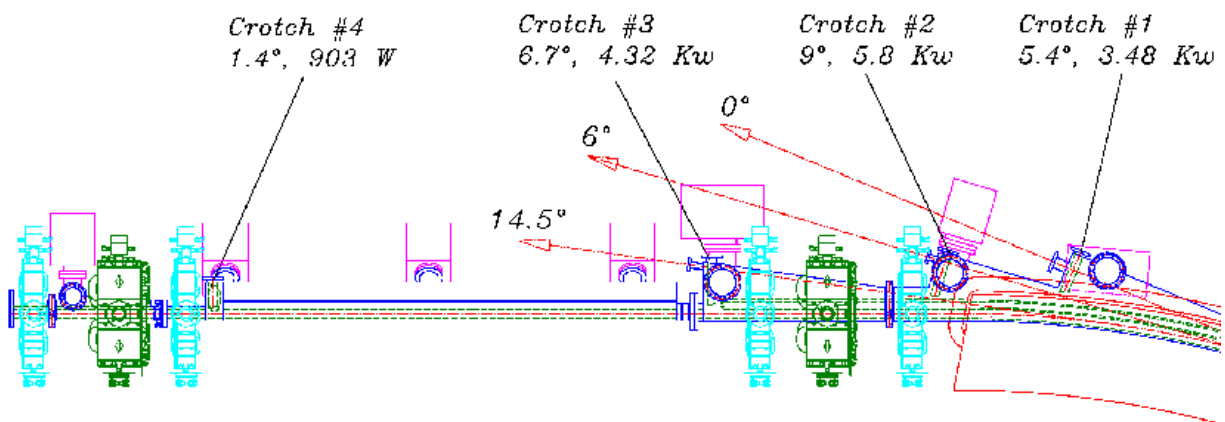


Figure 5.23: Nomination of the power absorbers on half an achromat.

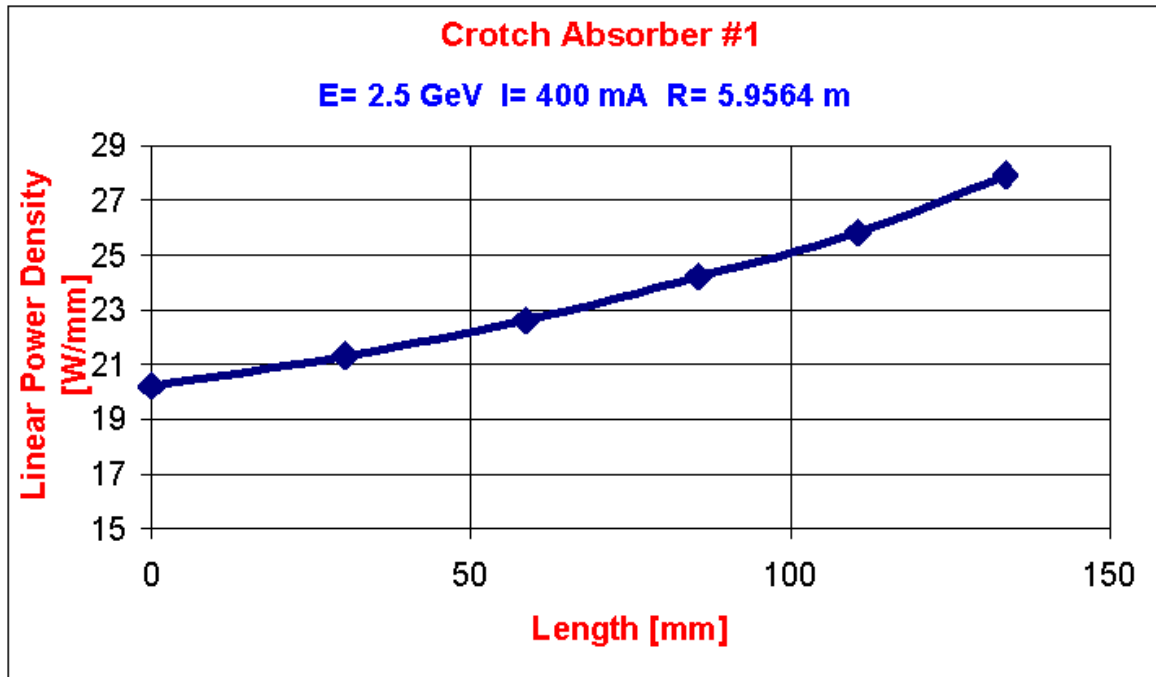


Figure 5.24: Power absorbed by the crotch absorber #1, the overall power is 3.48 KW.

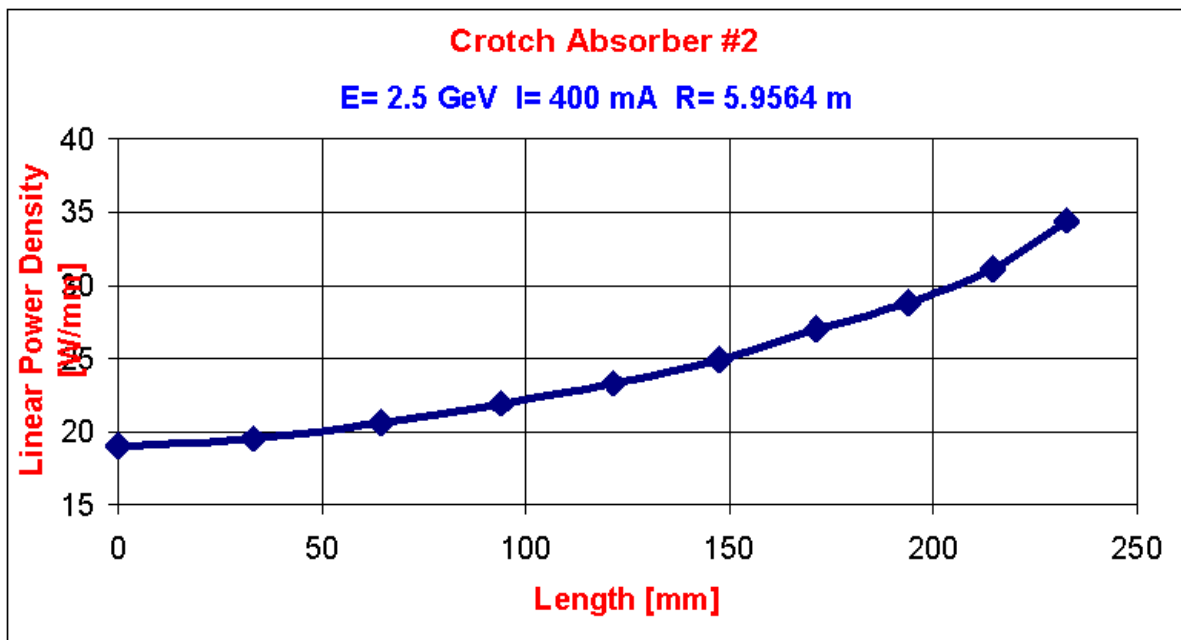


Figure 5.25: Power absorbed by the crotch absorber #2, the overall power is 5.8 KW.

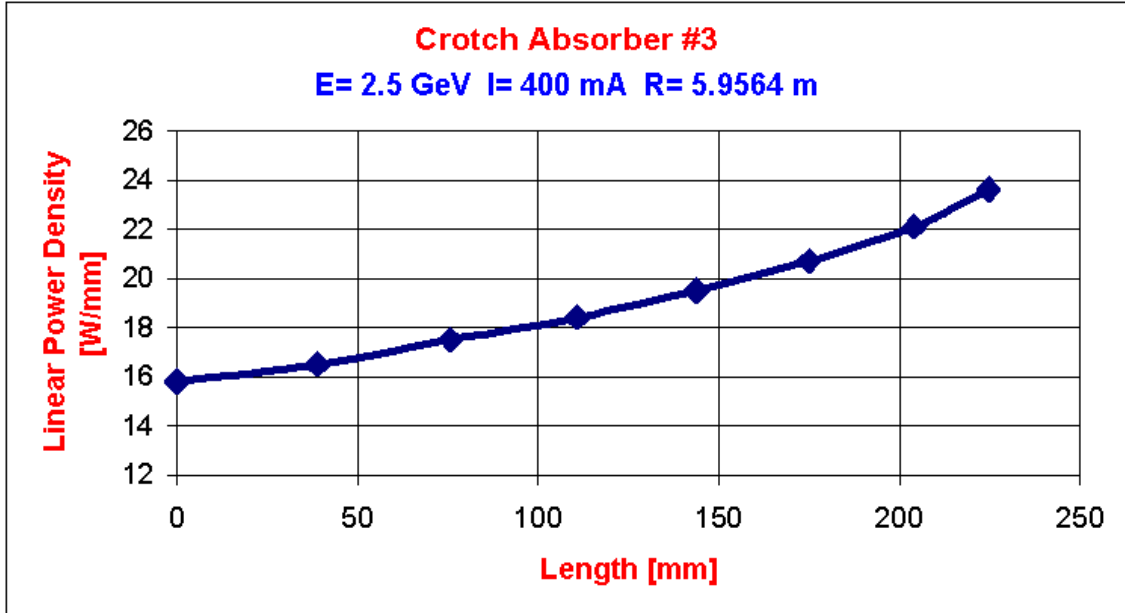


Figure 5.26: Power absorbed by the crotch absorber #3, the overall power is 4.32 KW.

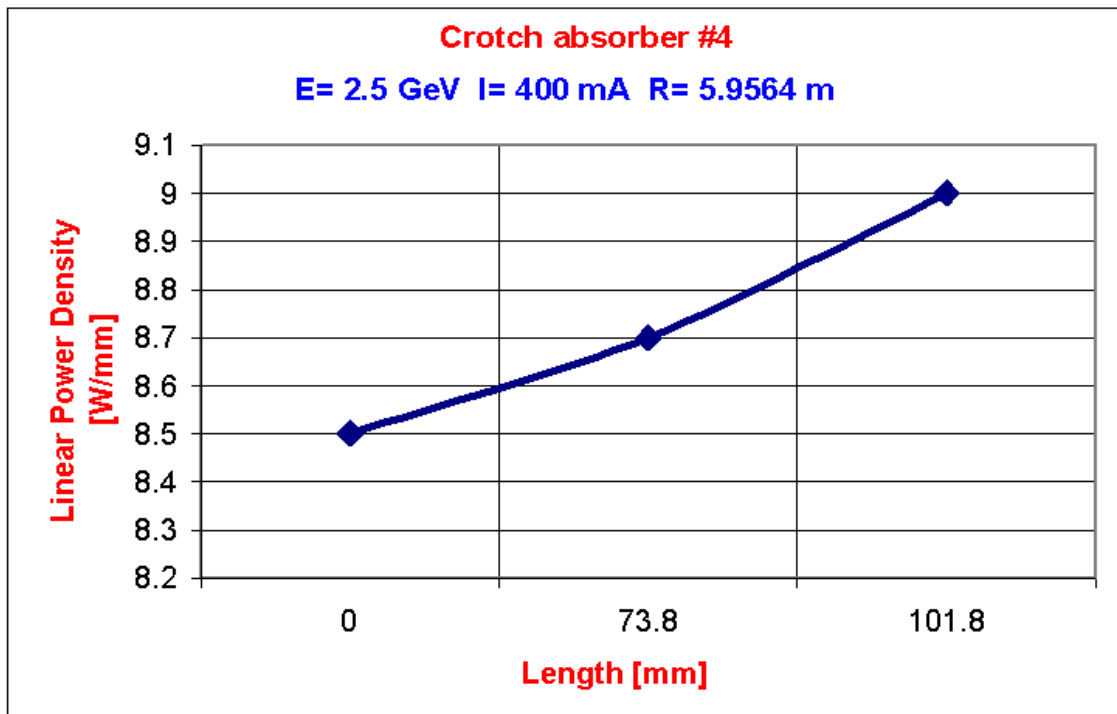


Figure 5.27: Power absorbed by the crotch absorber #4, the overall power is 903 W.

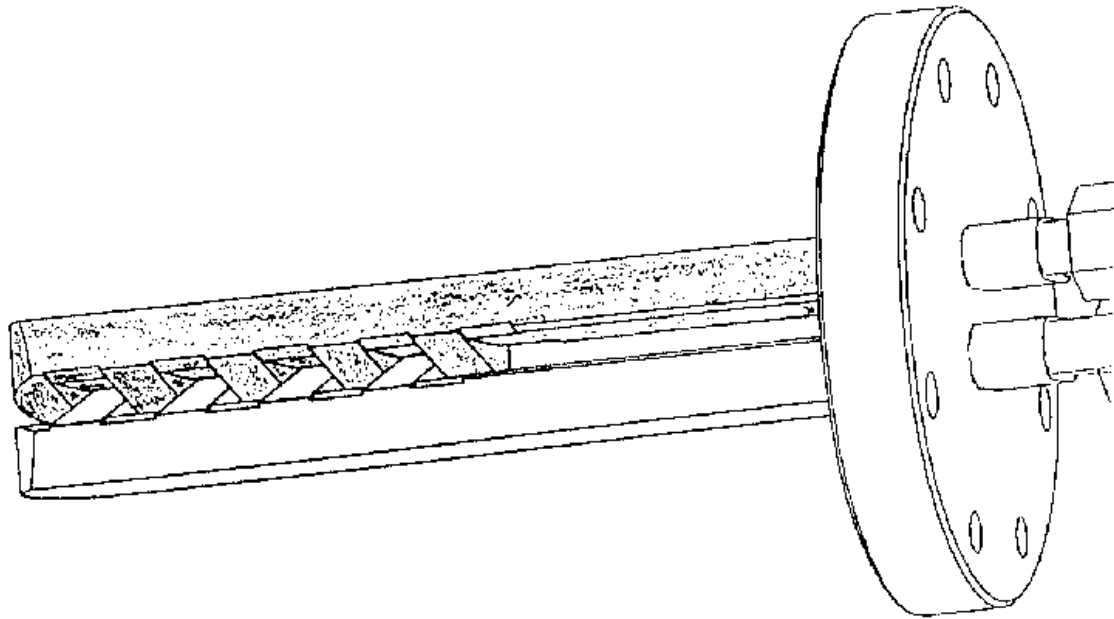


Figure 5.28: An overall view of the SLS type crotch absorber.

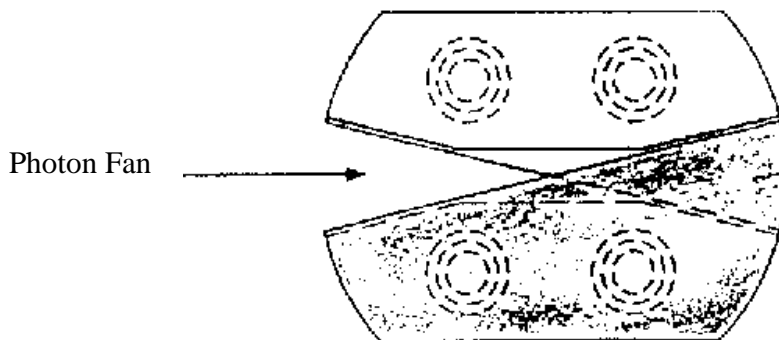


Figure 5.29: Cross section of the crotch absorber.

References

- [1] D. Einfeld, SESAME, First Draft of Conceptual Design, version 8, March 2002.
- [2] SESAME A Proposal for a Synchrotron Radiation Source in the Middle East, Oct. 1999.
- [3] E.Huttel, D. Einfeld, "The vacuum system for the synchrotron radiation Source ANKA".
- [4] SOLEIL, "Rapport d'Avant Projet Détaillé", Jun 1999.
- [5] Vacuum system of SLS.
- [6] Vacuum system of CLS.
- [7] Vacuum system of spear III.