COLLIMATOR FOR ESRF-EBS

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Abstract

The function of the Collimator is to localize the majority of the electron losses in the ESRF-EBS storage ring (SR). In addition, the Collimator of the ESRF-EBS should absorb about 1200 W of synchrotron radiation. For ESRF-EBS, the electron losses due to intra bunch scattering (Touschek scattering) will be higher than in the current ESRF SR. To limit the level of radiation outside the storage ring, and the activation level of the vacuum chambers, it is more efficient to localize the electron losses and block the radiations at one place rather than reinforce all of the SR tunnel shielding. Once the collimator is put on line with the electron beam at nominal intensity, it will no longer be possible to intervene on it (due to the activation of the materials). As a consequence, a high level of reliability is required.

The design takes into account all the diverse requirements from a safety, accelerator physics, thermal and mechanical point of view.

INTRODUCTION

The ESRF-EBS storage ring is very different with the previous one. Electron losses from intra bunch beam scattering is higher. This is the raison to introduce a Collimator to localize the majority of electron losses in two places, surrounded by a heavy concrete block.

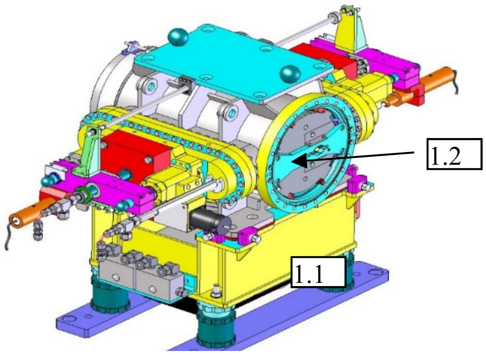

Figure 1: Collimator General assembly.

DESCRIPTION

As shown in Figures 1 to 3, the ESRF-EBS Collimator is composed of: the vacuum chamber and its support (1.1), the inner fixed shielding (1.2), fixed blades (2.1) and movable blades (2.2), its motorization (3.1) and the guiding system (3.2). In addition, concrete fixed shielding (Fig. 10) is placed around the collimator to absorb radiations outside the collimator vacuum chamber. This paper will only describe the Collimator itself (Fig. 1). The ESRF-EBS Collimator is designed to have a 300 mm active length with a 15 mm fixed aperture in the vertical and 12 mm (+/-2 mm) adjustable aperture in the horizontal plane. The maximal horizontal opening is 32 mm.

At the entrance and at the exit of the Collimator there are “RF fingers” (Fig. 4.1). Their specific shape makes the transition between the omega internal shapes of the ESRF-EBS high profile chamber and the square shape of the Collimator inner section (Fig. 2).

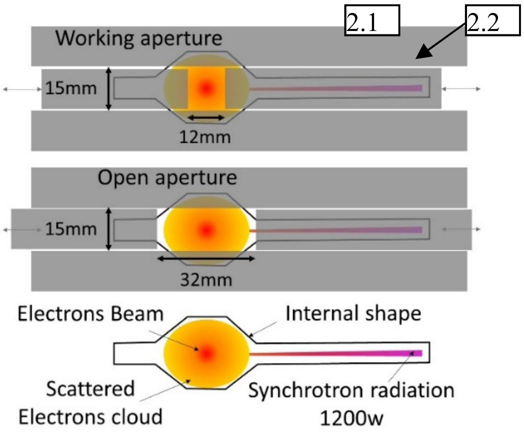

Figure 2: section of the collimator blades in two positions: the working position and fully open.

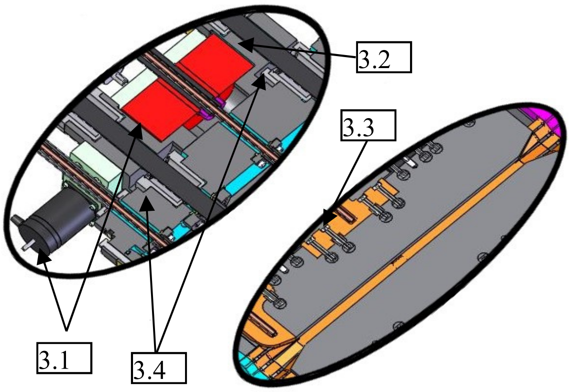

Figure 3: Details of internal view in horizontal cut.

Inside the collimator there is an absorber (Fig. 4.2) to stop the synchrotron radiation from the upstream dipoles. This absorber is made in “Glidcop Al 15©” with cooling in a concentric shape.

In order to adapt the shape of the horizontal blades as smoothly as possible, there is a 30mm taper at each end of the horizontal blades.

In addition to the blades (fixed and movable), there is a fixed shielding (Fig. 8) in the vacuum chamber to block the radiation from the scattering of the electrons absorbed by the Inermet IT180 blades.

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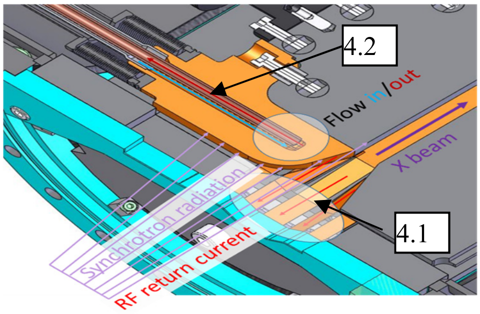

Figure 4: Detail of the entrance of the Collimator.

DESIGN

The design of the movable blade, exposed to synchrotron radiation, was critical. At the initial stage of the study, tungsten was envisaged as a material able to absorb the radiation. Nevertheless, the integration of a cooling circuit in the tungsten blade is by no means trivial and the results were not conclusive (Figs. 5 and 6). In addition, water connection was not possible. The most suitable solution was to split the function of radiation and electron absorber. The last thermal calculation shows that maximum temperature will be 186°C for Glidcop (Fig. 7) instead of 360 °C or 300 °C for Inermet.

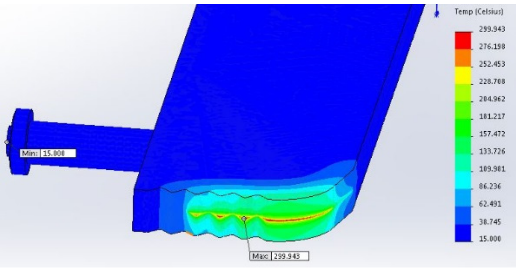

Figure 5: Example of FEA calculation W absorber.

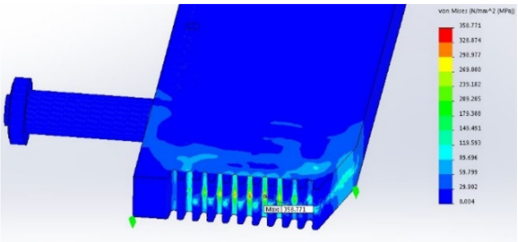

Figure 6: Example of FEA calculation W absorber.

In the final version, the temperature calculated for the surface in contact with water is still relativly high (88 °C, Fig. 7), but it is the lowest result obtained from a series of scenarios.

The final shape of the absorber is flat (Fig. 7). Initially, a shape with teeth was envisaged to enlarge the projected surface in contact with the radiation but this impled moving the cooling channel in the absorber further away from the exposed surface. An additional cooling circuit was added in the middle of the blade (Fig. 3.3) to cool the longitudinal surface as well in order to achieve a better average temperature of blade.

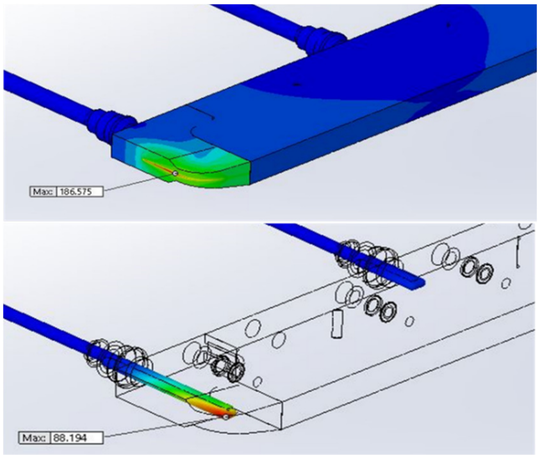

Figure 7: Final FEA calculation.

The material chosen for the collimator blades, and for the fixed shielding, is Inermet© IT180 manufactured by Plansee (Fig. 8); a solution inspired by the CERN-LHC Collimator [1]. This material has very good mecanical and thermal properties, with thermal conductivity rather close to pure tungsten (110 W/m.°C as compared to 160 W/m.°C), it is non magnetic and density is very high (18 kg/dm3- 19.3 for pure W) which has major avantages for absorbing electrons and scattering radiations from absorbed electrons. The calulation made by the ESRF Safety Engineer shows that only high energy (gamma range) radiations can pass through the collimator.

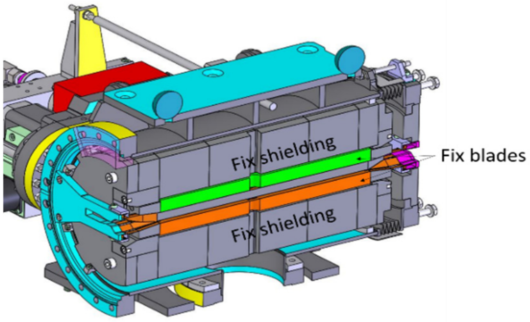

Figure 8: Vertical cut through the colimator: fixed shielding (grey) and fixed vertical blades (green, orange).

To guarantee high level movement of the adjusted blade, out-of-vacuum recirculating ball bearings guided the bars holding each blade (Fig. 3.4). The blade movement system is motorised by stepper motors and a non-reversible gear box (Fig. 3.1). Guides and motorization are fixed to the reference flange to enable consistent metrology phases to be set prior to assembly. There is also an anti-collision system to prevent contact between the two movable blades. An LVDT sensor controls the position of each blade.

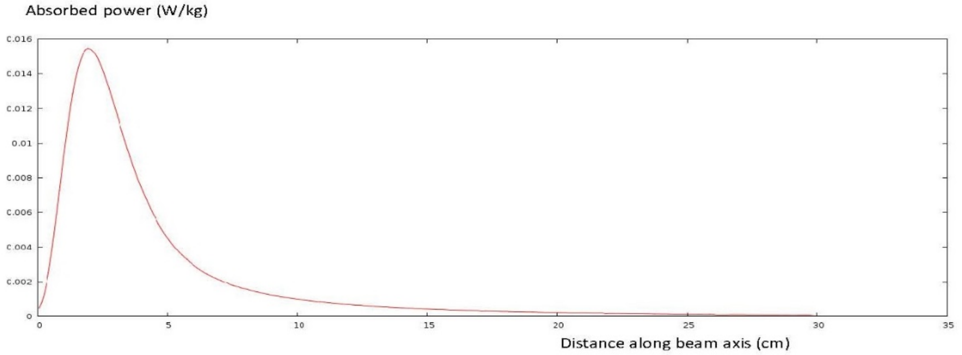

Figure 9: Absorbed dose distribution as a function of the longitudinal distance from the entrance face of the collimator.

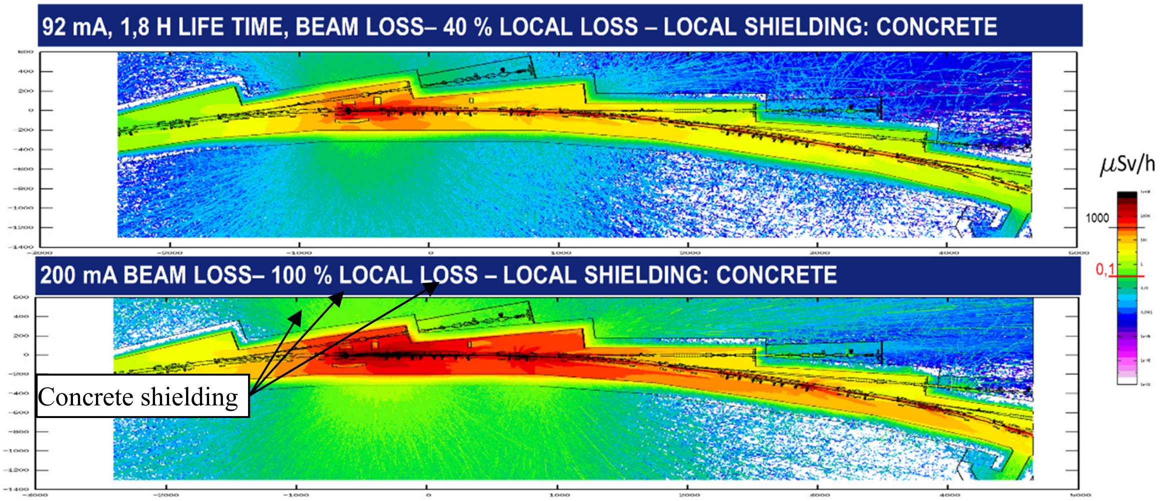

Figure 10: Radiation emission of the Collimator.

SAFETY

The Collimator is a safety apparatus designed to reduce the level of radiation outside the storage ring tunnel as much as possible. The collimator also makes perturbations on the electron beam. The Collimator inner aperture should be adjusted to perturb the electron beam as little as possible but to absorb as many scattered electrons as possible. Figure 9 shows how electrons are absorbed by 300 mm of Inermet IT180. Figure 10 shows how the radiation is absorbed in the storage ring tunnel in two cases: normal operation at 90mA and beam lost on Collimator at 200 mA. In both cases, the simulation shows that maximum radiation level is less than 0.1mSv/h outside of the storage ring tunnel, thus respecting the safety criteria.

CONCLUSION

Two units of the Collimator will concentrate about 80% of the total electron losses of the ESRF-EBS storage ring in two dedicated and shielded areas of the storage ring. This reduces activation in the rest of the storage ring, which is obviously important from a radiation safety point of view. But also, other storage ring equipment will benefit from this protection. The collimator is a complicated device due to the different requirements concerning the stopping of 6 GeV electrons, absorption of synchrotron radiation, reliability, and very limited available space. The ESRF design accommodates all of these requirements but will still have to prove its expected performance during the ESRF-EBS commissioning in 2020.

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[1] M. Cauchi *et al.*, “Thermomechanical response of Large Hadron Collider collimators to proton and ion beam impacts”, *Phys. Rev. ST Accel. Beams,* vol. 18, iss. 4, April 2015, doi:10.1103/PhysRevSTAB.18.041002.