

# THE STATUS OF THE VACUUM SYSTEMS OF THE MAX IV LABORATORY

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## Abstract

All the vacuum chambers of the 3 GeV storage ring of MAX IV laboratory are under production. NEG coating R&D has been done to validate technical solutions for the coating process. The standard vacuum chambers for the 1.5 GeV ring of MAX IV and Solaris have been purchased and they are in the final engineering design stage. We present an update of the technical design of the vacuum chambers following the interaction with the manufacturer, the implications on the production due to NEG coating and the design of the vacuum chambers of the 1.5 GeV storage ring.

## INTRODUCTION

The MAX IV Laboratory new machine will have two storage rings, with energies of 3 GeV and 1.5 GeV, with a linac as injector. The vacuum chambers of the 3 GeV ring will be made of copper with distributed absorbers and NEG coated, while the 1.5 GeV storage ring will have a more conventional design for the vacuum system; it will have stainless steel vacuum chamber with ion pumps and NEG strips.

## 3 GeV STORAGE RING VACUUM SYSTEM

### 3 GeV Storage Ring Vacuum System Status

The main design of the 3 GeV storage ring is described in [1]. The vacuum system is divided into: standard vacuum chambers, which are the main chambers of the achromat, and the non-standard vacuum chambers, which are the vacuum chambers which will be used to accommodate the injection elements, diagnostics, RF cavities and emittance measurement devices.

The standard vacuum chambers are under production, with the prototypes to be delivered early June 2013. The design of the chambers has been modified to ease the production process and to reduce the time schedule, of which the following changes to the original design have been implemented:

- Fast corrector areas: in the original design, the area of the corrector magnets (inside the magnet block) has been designed of stainless steel and to be brazed to the copper tubes. In the final design, the areas of the corrector magnets will be made of copper, and the fast correctors have been moved to specific locations where stainless steel is easy to implement (e.g. pumping port and BPM blocks) without the

need to braze to the remaining parts of the vacuum chamber.

- Cooling pipes: the original circular cooling pipes have been replaced with rectangular profile externally then brazed to stainless steel adapter allowing stainless steel tubes to be connected to the cooling connectors. At the area of the contact with the chamber body, the profile is machined to match the curvature of the tube, and assures good contact after welding, see Fig. 1.
- At the area of the corrector magnets, where the aperture is small in the vertical corrector to pass the cooling pipe in the mid-plane, a special cooling assembly has been introduced, see Fig. 1.

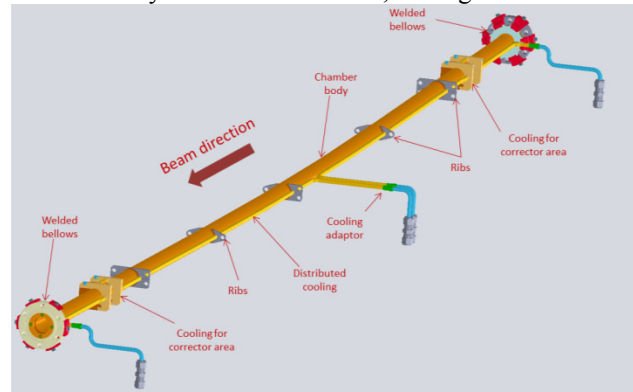


Figure 1: Model of one vacuum chamber of the 3 GeV ring of MAX IV Laboratory.

Finite element analysis (FEA) has been performed to estimate the effect of the distributed absorbers of the vacuum chambers on the mechanical stability of the BPM block. The results show that due to the symmetry of the BPM block, it will expand radially with the center of the BPM block nearly in the same position. To assist this, the clamps of the nearby bellows are made of material with low thermal conductivity to reduce the heat transfer to the BPM block; and in addition the cooling circuits are always entering from each side of the BPM allowing stable temperature around the block.

As mentioned earlier, the vacuum chambers are under production, parts of the chambers are shown in Fig. 2.

The vacuum chambers have a clearance of 0.5 mm with the magnets poles and less than 3 mm with the magnets coils. To control that no interference will occur when the chambers are installed inside the magnets, two tests will be performed: first a go-no-go test, where a gauge having an inner profile similar to that of the vacuum chamber but enlarged by 0.3 mm will pass through the outer profile of

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the vacuum chamber and all over its length, no interference between the two should occur. The second test which will be performed is based on dummy parts of the vacuum chambers which will be modeled with 3D printing or CNC machine and provided to the magnet's suppliers, this will allow them to check that no interference will occur mainly with the magnets exit leads. Figure 3 shows the two tools to be used for interferences check with the magnets.

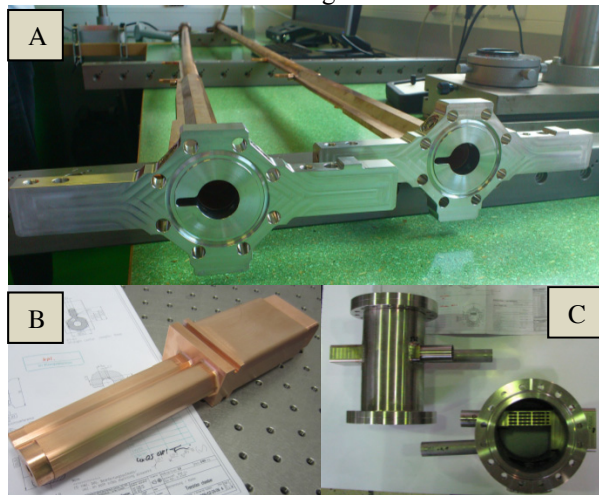


Figure 2: Parts of the vacuum chambers of MAX IV: A, B: photon extraction vacuum chambers, C: stainless steel pumping port with photon beam pipe.

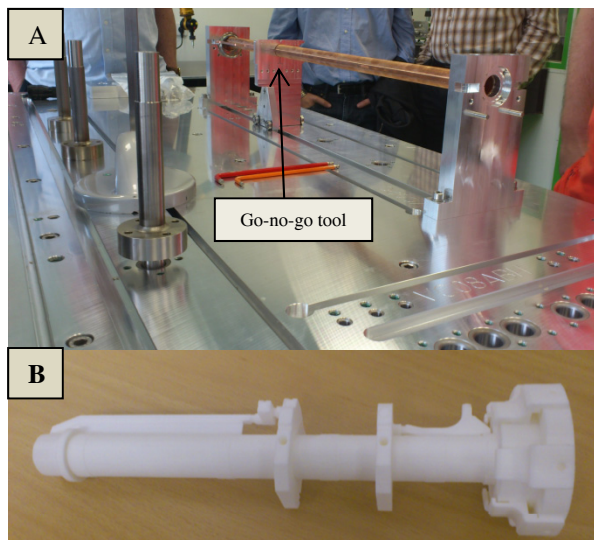


Figure 3: A measuring table with Go-no-go tool, B: 3D printing of the vacuum chamber.

The non-standard vacuum chambers are under final engineering design, the design includes introduction of the injection elements and RF cavities and diagnostics, like stripline, scrapers, YAG screens...etc into the vacuum system. The integration of these items presented a challenge into the design; mainly to keep the effect on the machine impedance to a minimum and to be able to perform NEG coating to those vacuum chambers. Figure 4 shows the model and cross section of the horizontal and vertical scraper vacuum chambers.

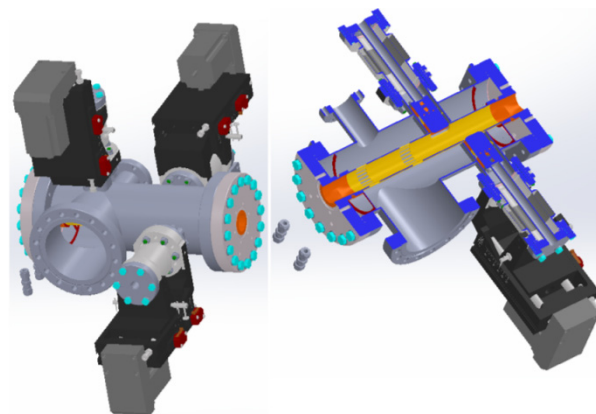


Figure 4: The scraper vacuum chamber.

### NEG Coating for the 3 GeV Vacuum Chambers

During 2011, collaboration between CERN and MAX IV laboratory has been established, covering a range of activities, aiming at developing and testing procedures for NEG coating of the MAX IV vacuum chambers. Details of these activities are presented in [2].

In addition, an order has been placed with industry to perform the NEG coating of the majority of the vacuum chambers and collaborations with CERN and the ESRF have been established to coat the more challenging chambers.

### 1.5 GeV STORAGE RING VACUUM SYSTEM LAYOUT

The 1.5 GeV vacuum chambers have been purchased and are undergoing the final engineering design and the preparation of the manufacturing drawings.

The 1.5 GeV storage ring vacuum chambers will be made of 2 mm thick 316LN stainless steel sheets, bended or deep drawn to give the shape of the profile required. Crotch absorbers made of OFHC copper have been introduced to extract the photon beam to the front ends and also just downstream of the second dipole and at the end of the straight sections where there are no magnets. However, due to the difficulties of introducing crotch absorbers inside the magnet blocks, distributed copper absorbers brazed to the stainless steel chamber body have been used. Ion pumps and TSPs are located near the crotch absorbers, while NEG strips are located close to the distributed absorbers.

FEA has been performed to validate the design, mainly stress and strain analysis for the crotch and distributed absorbers and the mechanical stability of the vacuum chambers due to the atmospheric pressure forces, as a result, the thickness of the vacuum chambers has increased from 1.5 mm in the original design into 2 mm in the current design. In addition, the effect of the high temperature during the activation of the NEG strips on the temperature of the magnet block has been studied, with the results show safe temperature of the magnet block during activation.

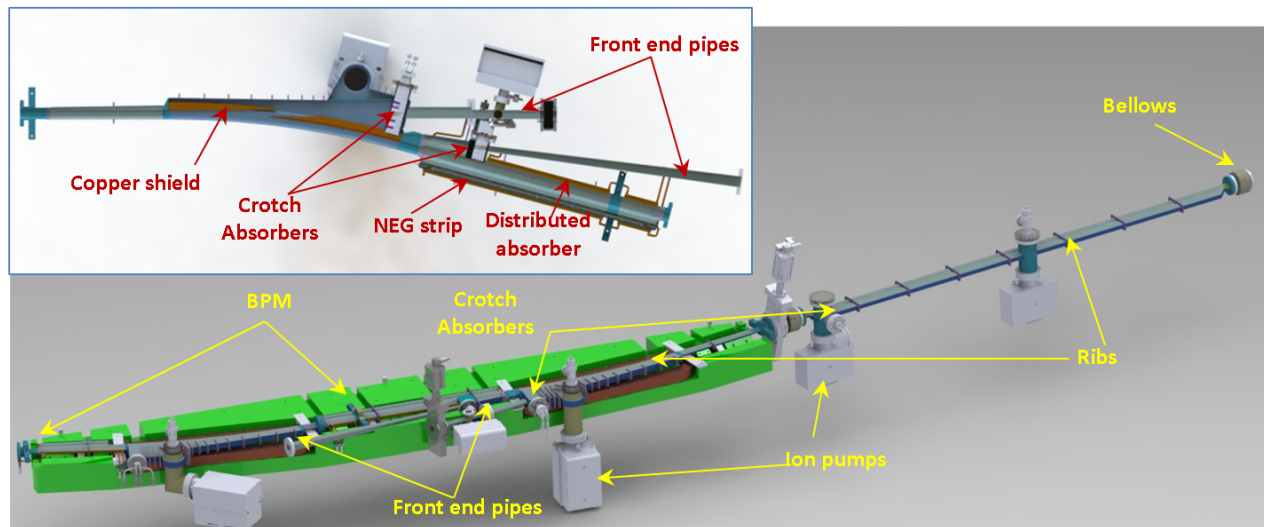


Figure 5: The vacuum layout of one achromat of the 1.5 GeV, in the frame: cross section of the vacuum chamber of the first dipole of the achromat.

The design of the non-standard vacuum chambers for injection, RF, emittance measurement and diagnostics is under work.

Figure 5 shows the layout of the vacuum system of one achromat of the 1.5 GeV together with the cross section of the vacuum chamber where beam extraction section. Figure 6 shows the cross section of the vacuum chamber inside the dipole and the sextupole.

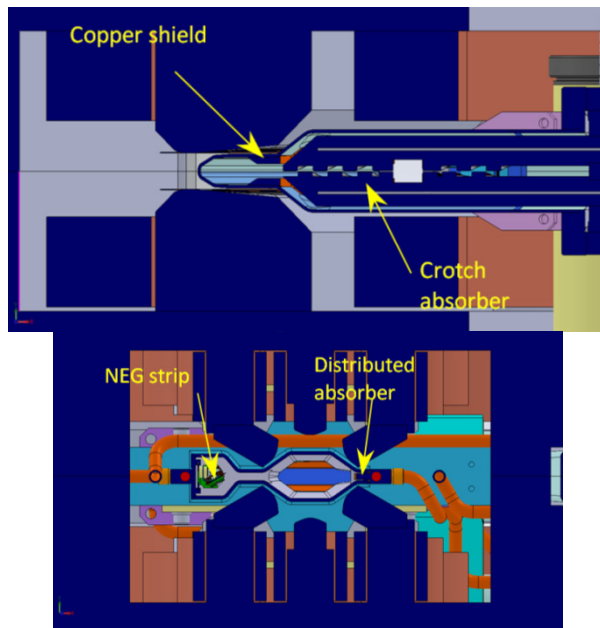


Figure 6: Cross section of the vacuum chambers inside the dipole and the sextupoles, respectively.

## CONCLUSION

The status of the vacuum systems for the MAX IV laboratory has been reviewed, highlighting the main activities with the design and the manufacturing of the two rings.

FEA has been used to validate the design, and several tools will be used by the supplier of the vacuum chambers and the magnets to guarantee no interferences between the two systems.

NEG coating introduced a challenge for the design and manufacturing, and the NEG coating itself is a challenge which has been deeply studied with the help of CERN.

## ACKNOWLEDGMENT

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## REFERENCES

- [1] E. Al-Dmour et. al., "Vacuum System Design for the MAX IV Vacuum System 3 GeV Ring", IPAC'11, San Sebastian, September 2011, P. 1554 (2011), <http://www.JACoW.org>
- [2] M. Grabski et. al., "NEG Thin Film Coating Development for the MAX IV Vacuum System", THPFI044, these proceedings.