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ASSESSMENT OF NEW COMPONENTS TO BE INTEGRATED IN THE LHC ROOM TEMPERATURE VACUUM SYSTEM

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Abstract

Integration of new equipment in the long straight sections (LSS) of the LHC must be compatible with the TiZrV non-evaporable getter thin film that coats most of the 6-km-long room-temperature beam pipes. This paper focus on two innovative accelerator devices to be installed in the LSS during the long shutdown 1 (LS1): the beam gas vertex (BGV) and a beam bending experiment using a crystal collimator (LUA9). The BGV necessitates a dedicated pressure bump, generated by local gas injection, in order to create the required rate of inelastic beam-gas interactions. The LAU9 experiments aims at improving beam cleaning efficiency with the use of a crystal collimator. New materials like fibre optics, piezoelectric components, and glues are proposed in the original design of the two devices. The integration feasibility of these set-ups in the LSS is presented. In particular outgassing tests of special components, X-rays photoelectron spectroscopy analysis of NEG coating behaviour in presence of glues during bake-out, and pressure profile simulations will be presented.

INTRODUCTION

In the LHC room temperature vacuum system, the use of NEG coating onto the inner beam pipe walls and ion pumps ensure vacuum stability with an average pressure of 10^{-10} mbar with nominal beam [1]. After bake-out and activation, the NEG coating provides distributed pumping together with extremely low photon, electron, and ion induced desorption yields. However, not all warm vacuum components can be NEG coated due to temperature limitation and incompatible substrate materials. Consequently, the outgassing rate of such uncoated devices must be thoroughly assessed to avoid detrimental effects on the vacuum performance. This contribution focuses on two new components that could have important effects on the local pressure profile: the beam-gas vertexing and an innovative collimator based on crystal properties.

BEAM-GAS VERTEXING SYSTEM

A proposal for the installation during the long shutdown 1 (LS1) of a Beam Gas Vertexing system (BGV) was requested for non-invasive measurements of the transverse beam profile. That equipment is a demonstrator that will possibly provide essential information for further development of a full-scale BGV system, planned for the High Luminosity LHC (HL-LHC). The BGV will be installed in the Long Straight Section 4 (LSS4) of the LHC ring that is devoted to the Radio Frequency (RF) cavities.

The proposed BGV is designed to provide bunch-by-bunch beam profile measurements throughout the full LHC cycle. It necessitates a dedicated pressure bump in order to create the required rate of inelastic beam-gas interactions. A dedicated remote controlled injection system is then developed to have the proper gas density inside the BGV gas tank. Figure 1 shows a simple schematic of the BGV tank; the positions of the gas injection, the detector modules, and the position of the ion pumps are indicated. According to the BGV requirements and to ensure minimal impact on the LHC operation, the BGV vacuum system is designed to provide uniform density distribution inside the BGV gas tank (≈2 m in length), and a quick decrease of the gas density outside it.

All the products of beam-gas interaction will be measured by two tracking stations that are installed just behind a thin exit window and at about 1 m downstream. Each tracking station consists of four modules arranged around the beam pipe and it contains two mattresses of scintillating fibres providing position measurements with a resolution of about 55 μm.

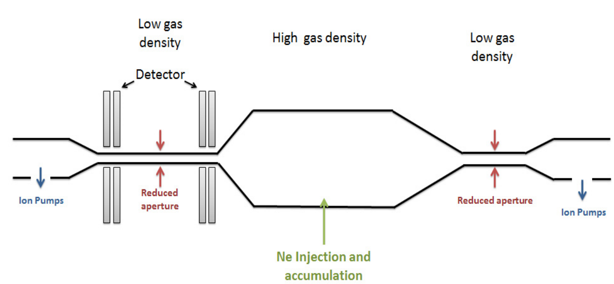

Figure 1: Schematic of the beam-gas vertexing transverse beam profile monitor.

The Implemented Injection System

Optimal gas density in the BGV tank is required in order to enhance the beam-gas interaction and have an adequate fraction of events for the measurements; the higher the cross-section of the gas, the lower the quantity of gas that can be injected in the tank. However, the use of reactive gas for a long period of time could have detrimental effects on the pressure profile [2-3] due to a progressive saturation of the NEG coating of the nearby vacuum chambers [4]. For this reason, it was chosen to inject a noble gas into the BGV. Among the possible noble gas species that can be employed, neon was chosen

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because it does not affect the sensitivity of leak detection and is already used with success in other applications in the LHC vacuum system [5]. In the cases of He and Ar, a small residual amount that may be left after the pumpdown would reduce the sensitivity of leak detections. Kr and Xe have high mass and high cross-section for beam-gas interactions that could improves the BGV sensitivity; they will be studied in a second phase.

In order to have an optimal beam-gas scattering, the required pressure inside the tank is fixed at 6×10^{-8} mbar of Ne. To guarantee a sharp and fast decrease of pressure outside the BGV tank, four 500 l/s ion pumps are installed at the extremities granting an averaged pressure in the 10^{-9} mbar range in the vacuum sector. At both extremities of the BGV tank, reduced-aperture vacuum chambers will help to confine the injected Ne in the tank. Additionally, the Ne injected in the BGV tank will be purified with a commercial NEG filter so as to reduce the concentration of contaminants from ppm to ppb level [6].

Figure 2 shows the simulated pressure profile for the BGV vacuum sector during the Neon injection. The position of the four ion pumps is highlighted.

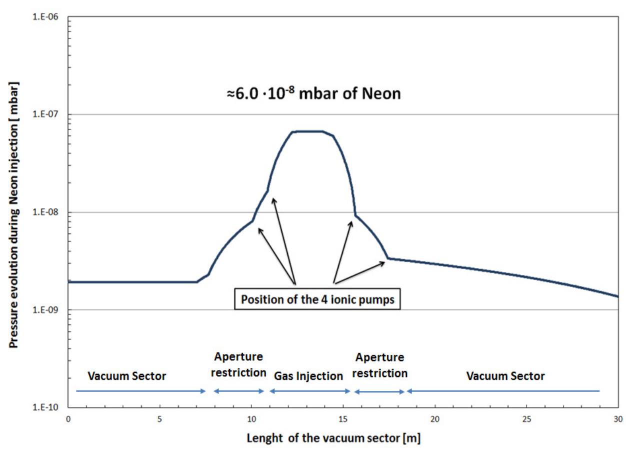

Figure 2: Calculated pressure profile in the vacuum sector where the BGV will be installed.

LUA9 EXPERIMENT

The LHC collimation system is based on multiple sets of jaws that are used to remove the beam halo. The primary set of jaws defines the aperture of the machine. Particles with low impact parameters on these jaws have a finite probability of scattering out of the collimator and form a secondary halo [7]. For this reason a secondary set of jaws is used to remove the produced halo and increase the collimator efficiency.

It was demonstrated by the UA9 experiment [8] at CERN in the SPS accelerator that by using bent crystal channelling it is possible to give a well-defined angular kick to the particles that enter the crystal. A secondary collimator can then be used to remove these particles. This process should reduce the amount of secondary halo that is generated and improve collimation efficiency.

The LUA9 project (extension of the UA9 to the LHC) is an experiment aiming at having a direct comparison of the obtained collimation cleaning efficiency with and without the use of bent crystals in the LHC [9,10]. A goniometer and Cherenkov detector are being designed to operate crystals and to monitor the system in each of the transversal planes, respectively. In the first experimental stage, two goniometers will be installed in the LHC vacuum system. The goniometer will support a crystal that will act as primary collimator. In order to achieve the correct particle deflection, the crystal will be aligned with ~2 μrad precision with respect to the direction of incoming particles. For this reason, the crystal is mounted on a high precision piezoelectric goniometer. The goniometer itself is installed on a linear translator, in order to define its transversal position in accordance with the centre of the beam and to retract it in "parking position" when not in operation. All this equipment is embedded in a single tank.

The UA9 experiment was installed in the SPS vacuum system which is less demanding than that of the LHC in terms of outgassing-rate acceptance thresholds. For such a reason, not "standard" UHV materials used for the LUA9 experiment like optical lenses, optical fibres and glues were thoroughly tested. Acceptance criteria were defined so as to preserve the vacuum performances of the adjacent sectors, on a short and long term operation. Moreover, the extensive use of NEG coatings does not allow introducing any fluorine and chlorine contamination in the LHC vacuum system. For such a purpose, each "special" component for the LUA9 experiment was tested individually in a dedicated vacuum vessel. Residual gas analysis and degassing properties were probed after bake-out by the throughput method [11]. In addition, in order to detect surface contaminants, each component was baked-out together with a NEG-coated coupon sample for X-ray photoelectron spectroscopy (XPS) measurements.

Generally, for each validation test, a set of 3 NEG-coated coupon samples is tested by XPS: as coated, after activation at 230°C for 24 h in the test bench without and with the component to be analysed. The XPS tests were carried out by checking the surface composition of the as received samples. In addition, the evolution of the oxygen and carbon content onto the NEG surface were monitored after *in situ* heating at 160, 200, and 250°C for 1 h.

The data of Fig. 3 show a decrease of the oxygen concentration when increasing the heating temperature; this indicates that the NEG films activated normally. Such a result has confirmed the compatibility of the optical fibre with NEG coating for the specific heating temperature of this experiment. No indication of F and Cl contamination were detected.

Figure 4 shows the surface concentration analysis for three different NEG coated samples baked-out together with three different types of glues. The XPS analysis was used in order to check possible contaminants of the NEG surface.

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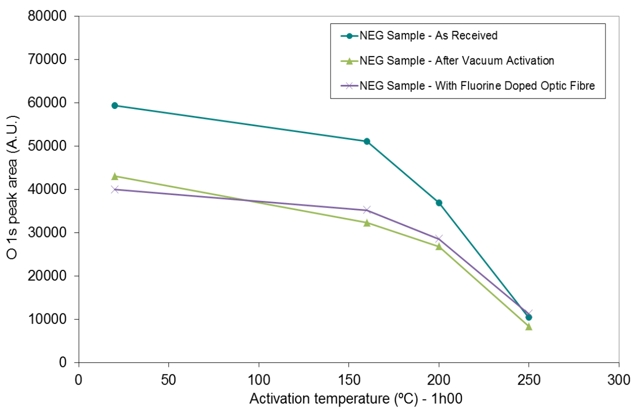

Figure 3: Oxygen content evolution on NEG coated copper samples recorded by XPS measurement.

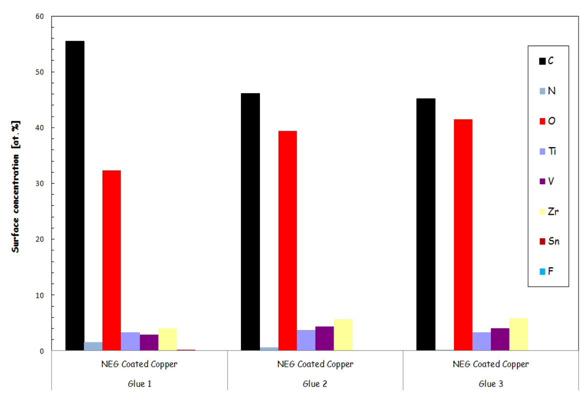

Figure 4: Surface concentration of three NEG coated copper samples after heating in a vacuum system together with 3 different glues for possible UHV application.

After the compatibility tests of the non-standard components, two goniometers were assembled and a complete vacuum acceptance test was performed. Figure 5 shows the residual gas analysis, at room temperature after 4 days of bake-out at 110°C, normalized to the main H_2 peak. The acceptance limits applied at CERN for baked components are also indicated. In addition to the RGA acceptance test, the total outgassing rate was measured; a value of about $5 \cdot 10^{-8}$ [mbar·l/s] was recorded. The details of the acceptance test can be found in ref. [11]. Both goniometer were fully validated and will be installed in the LSS7 of the LHC during the LS1 period.

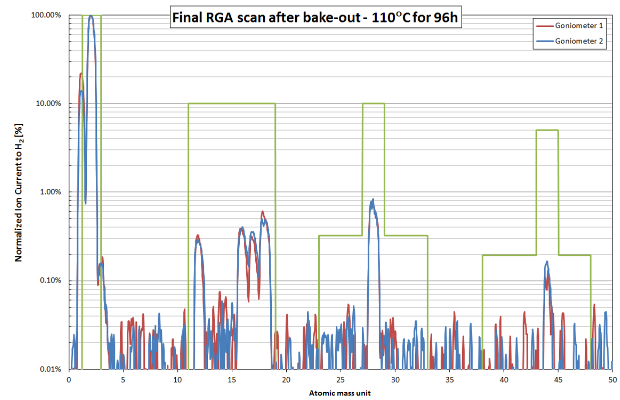

Figure 5: Normalized RGA scan for the two goniometers of the LUA9 experiment; the acceptance thresholds are shown in green.

SUMMARY

The integration of new equipment in the beam vacuum system of the LHC are always carefully studied and assessed by surface analysis and vacuum methods. Acceptance criteria are imposed before any new installation in the LHC vacuum system. The absence of fluorine and chlorine contamination and a low outgassing rate after bake-out are the most important criteria to be taken in account.

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