Report on HERA Vacuum Status and Modifications in Preparation for the Shutdown 2003

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1 Vacuum Investigations in the IR's

Several times in 2002 dedicated measurements of the residual gas composition where carried out. The residual gas analyzer (RGA) can only be connected at a distance of 25 m to the IP, left or right, since manual valves are installed there. In all cases the pressure in the beam pipe is practically too low to be analyzed as long as the sc. magnets are cold. When they are warmed up a significant pressure increase of two or three orders of magnitude is observed. The gas composition is dominated by light hydrocarbons as Methane and Ethane. This observation might be natural since the gas is pulled over 20 m of NEG pumps on its way from the cold surfaces to the analyzer. It is known that the hydrocarbons are not pumped by NEG- and Ti-sublimation pumps but can be produced on the surface of the getter material by catalytic reaction, for example from H_2O and CO. Even without getter material hydrocarbons can be produced on the walls of the vacuum chambers when synchrotron radiation is present [1]. A typical RGA spectrum after warm up is shown in Fig. 1. The amount of gas released corresponds to about 0.15 monolayers of gas for the warm up cycle from 40 K and 0.006 monolayers for warming up from 110 K. Residual gas measurements from LEP as a function of the integrated beam current are shown in Fig. 2 for comparison. The light hydrocarbons are also detected at LEP, but they vanish relatively quick with the collected integrated current. The reason why we still observed them after 10 Ah in HERA could be the presence of the cold surfaces that store certain amounts of the gases, even at higher temperatures.

The above discussion should demonstrate that the presence of the hydrocarbons can be natural for the IR vacuum, although there is no proof that they are not an indication for contaminations by long chained hydrocarbons like oil etc. The connection of a mass spectrometer closer to the IP, eg. at 3.6 m right, can help to clarify the situation. However, this would require to vent the vacuum system with the consequence of restarting the conditioning.

Another important information of the RGA spectra is the absence of Argon that would indicate leaks if it were present.

We observe a long-term trend of gradual vacuum improvements. The improvements occurred several times suddenly and seemed to be connected with warm up, cool down cycles of the sc. magnets in connection with Ti- and NEG-pump activation. There were also periods when the vacuum situation became much worse. Although the direct connection cannot be proven, it seems that the degradation of the vacuum was connected to warm-up of the superconducting magnets to more than 100 K. This elevated temperature was kept for about 6 weeks and no improvement was seen in the detector backgrounds. A major improvement was obtained after subsequent cool-down to 40 K. As an example the pressure development at H1 is shown in Fig. 3.

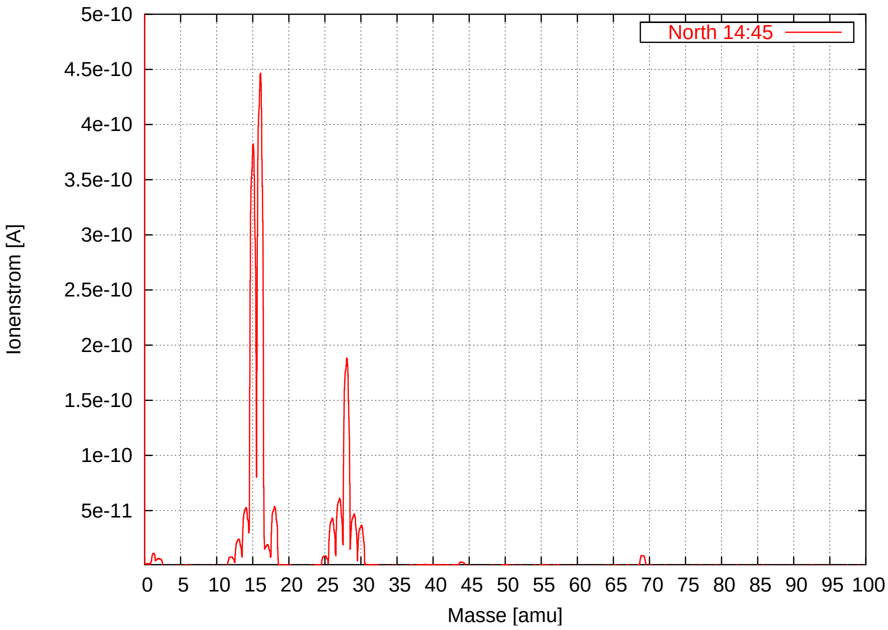

Figure 1: Residual gas spectrum, measured in November, IR north, after warming up from 110 K beam pipe temperature.

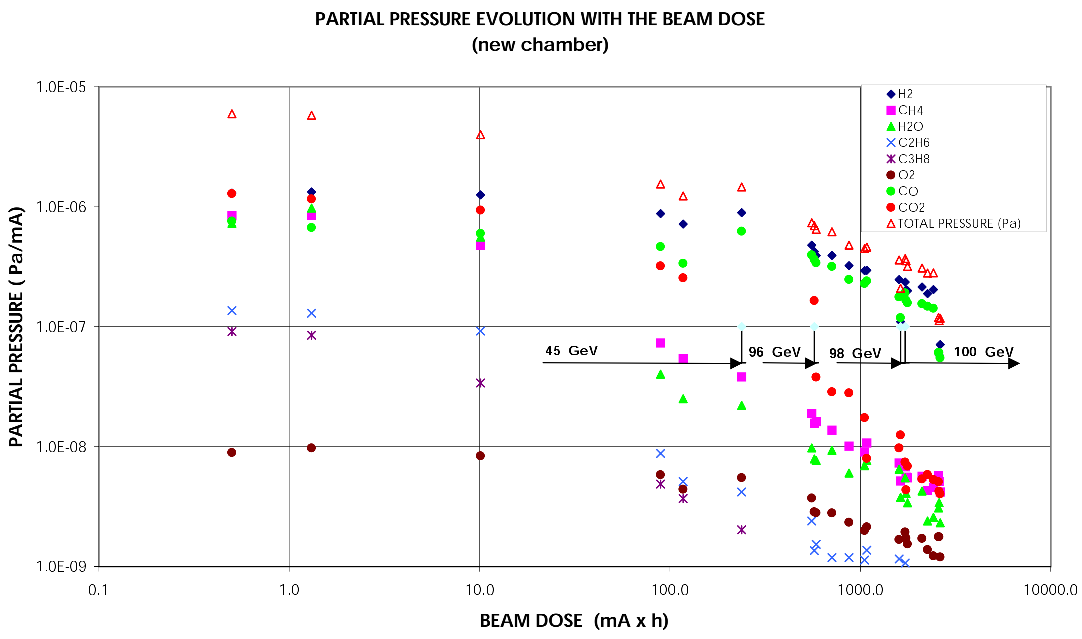

Figure 2: Residual gas development in LEP, courtesy N. Hilleret.

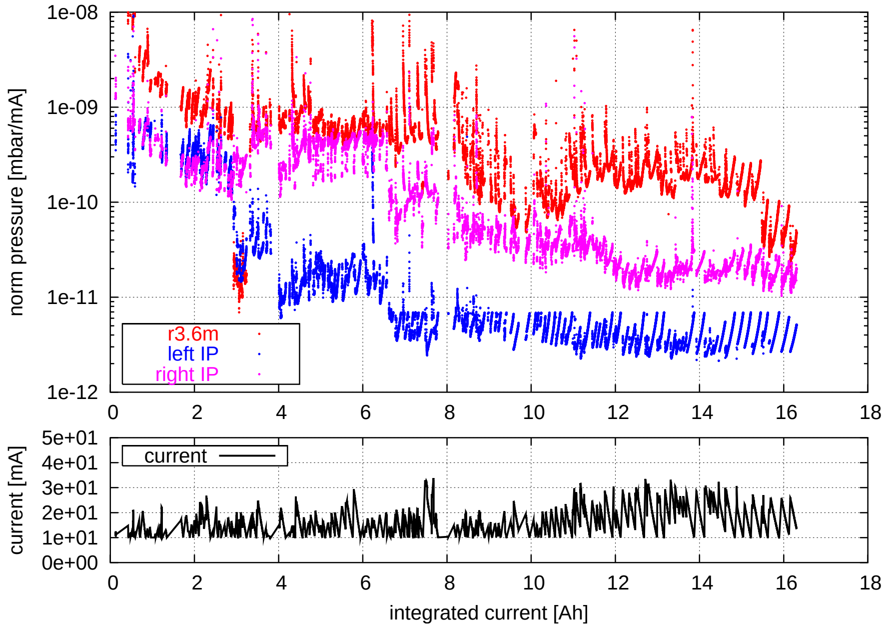

Figure 3: Pressure normalized to positron current from getter pump readings in the IR north as a function of integrated current at 27.5 GeV. Shown are 6 pumps averaged left of the IP, the pump at 3.6 m right and 6 pumps right of the IP.

Although the improvement factor measured at 3.5 m distance to the IP was more than an order of magnitude the H1 detector saw a significantly smaller reduction of the p-gas background which possibly indicates a significant contribution to the background by a pressure bump inside the detector.

Several experiments and simulations were carried out to gain a better understanding of the vacuum behavior in the IR's and its contribution to the detector backgrounds. That includes the simulation of the vacuum profile under different boundary conditions, the production of artificial pressure bumps by pump heating and their simulation, laboratory experiments with NEG pumps, Ti pumps and purposely provoked contaminations of vacuum recipients. For the sake of compactness this will not be discussed here.

2 Modifications in Preparation

It is planned to install the modifications discussed here in the HERA shutdown 2003, for which we assume completion approximately in June/July.

2.1 Coating of the Septum Absorber

The septum absorber, also called absorber 4, represents the closest surface counted from the IP that is hit by synchrotron radiation. In order to reduce the amount of backscattered radiation it is planned to coat the surface of the absorber by 100 μm silver and 20 μm copper on top.

The absorber receives at maximum 8 kW of synchrotron radiation in a narrow fan of about 1 mm height. In order to spread the heat the surface is tilted by 40 mrad vertically. The induced thermal stresses present the major problem for the stability and integrity of the coating. To provide sufficient cooling the thermal contact has to be excellent.

We follow up three slightly different concepts for the production of the coating:

- brazing of individual silver and copper foils on copper bulk material with nickel foils in-between as diffusion barrier
- galvanic production of the coating sandwich on copper bulk material, ie. nickel strike on copper, then silver, again nickel strike, copper
- use a 100 μm silver foil and produce galvanic layers of nickel and finally copper on both sides; finally braze the foil onto bulk copper

Since it was realized that modifications of the existing absorbers are too risky and difficult two new absorber blocks are in production. Because of the large dimensions and the complicated production technique this takes a considerable amount of time. Necessary modifications of the drawings for the absorber have been finished. Blocks of OFHC copper with the necessary dimensions have been ordered. Presently three bids from different workshops that are able to perform the wire EDM (electro discharge manufacturing) of the absorber halves are requested. We expect to have the bodies by end of march. Then several brazing steps have to be carried out, including brazing in four 5 mm thick copper plates with the desired coating. If no problems occur the absorbers will be ready for installation in June 2003.

2.2 Movable Collimator in Absorber 1

Absorber 1 is located in electron-downstream direction at 3.5 m distance to the IP. The collimator, made of two 5 mm thick tungsten jaws above and below the beam, is supposed to reduce the amount of photons backscattered from the 11 m septum absorber. The design is practically finished. An ion getter and a Ti sublimation pump are connected to the top and bottom side of the absorber. A 10 cm long additional piece of vacuum pipe will be inserted between absorber and each vacuum pump. This pipe contains a lever arm mechanics that allows to move the collimators by about 20 mm. A stepper motor is installed aside those pipes. This design helps to keep the reduction of the pumping speed at a minimum. However, this layout has two serious drawbacks. The relatively complicated mechanics contains threads and screws, is difficult to clean and a nightmare from the vacuum point of view. Secondly the jaws will heat up dramatically if only a moderate amount of HOM power is deposited on their surface. It is mechanically impossible to install a water cooling system, and consequently the main cooling mechanism is radiation cooling which is effective only at high temperatures. High temperatures will result in huge out-gassing rates at this location which is very critical for the p-gas background. The HOM losses are presently simulated by S. Wipf and once we have the result this problem needs more discussion.

The mechanical design is finished and parts can be ordered now. During the shutdown the absorber has to be taken out and slits for the jaws have to be machined perpendicular to the pumping slits. RF contacts will be mounted. These modifications should take maximally one week.

2.3 Movable Absorber at 65 m Left

There is a fixed SR absorber installed at this location. Its function is to keep the radiation generated by the BI magnet away from the central IR. During machine operation over the last year it became clear that a movable absorber at this location would be desirable. At 27 GeV it can be adjusted close to the beam, and be retracted at injection where the beam needs more space.

For a completely new design of such an absorber with internal water cooling we don't have enough time nor capacity of experienced designers. The idea is therefore to modify the design of existing SR absorbers in the IR and adopt it to the situation at 65 m. One problem is that the BI power is significantly higher than the one for the model absorbers. We try to complete the absorber until June. In the worst case it has to be exchanged later during the run.

2.4 Additional Pumps for the Electron Beam Line Inside the GA Magnet

This is a concern for the e-gas rate, produced by bremsstrahlung events of the positrons at gas molecules. The positrons loose energy and are deflected stronger than the nominal beam in the field of the sc. bending magnet GO, and hit finally the detector beam pipe. Those bremsstrahlung electrons are collected over the straight section left of the IP. The electron beam pipe inside the GA magnet, one of the focusing quadrupoles for the proton beam, is not pumped over a length of 6 m. It was not possible to install NEG pumps in this magnet because of limited transverse space. Consequently we expect a significant pressure bump in this region.

A possible way to improve the situation is to modify the magnet by opening the iron yoke piecewise along the electron beam pipe. Three or four openings with dimensions of approximately $120 \times 40\,\mathrm{mm}^2$ are sufficient to connect ion getter pumps. An efficient way to modify the chamber is to take it out, machine openings in the side walls and connect adapter pieces for the pumps by inductive brazing. This procedure is presently prepared and tested. The bigger uncertainty lies in the field quality of the magnet with the additional openings.

2.5 Absorbers in RF Shielded Bellows

This task is not directly connected to the detector background problems. When synchrotron radiation passes such a bellows under steep angle it can shine on the RF fingers. It occurred in the south IR that the RF springs made from a Cu-Be alloy melted and tilted downwards, thereby limiting the aperture for the particle beam. Identification of the aperture limitation, repair and conditioning of the vacuum afterwards took a long time. The situation with the SR fan was kind of unusual because the fan was tilted upwards purposely in order to keep the radiation away from the ZEUS detector. For illustration a photograph of the molten fingers is shown in Fig. 4.

The problem can be solved by integrating a copper absorber with a few mm tighter aperture than the RF springs. A number of such modified bellows pieces have been manufactured and they can be exchanged during the shutdown.

3 General Comments and Open Questions

According to our present knowledge on the background problems a significant part of the p-gas events is generated inside the detector region, ie. within 3.5 m distance to the IP. Higher order mode (HOM) power originated by the positron beam heats up SR masks and possibly bellows. The out-gassing rate scales exponentially with the temperature and we observe a steep increase of the pressure with the beam current especially at injection energy. There are several obvious measures to improve the situation:

- reduce the power losses and thereby the resulting heating of components by tapering

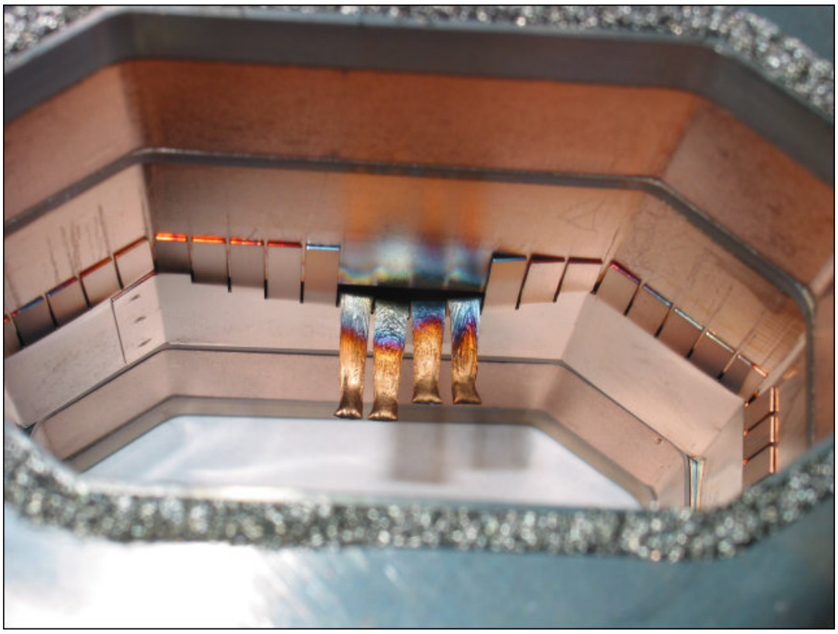

Figure 4: Molten RF springs in a vacuum bellow.

the shape of SR masks or narrowing slits in RF shieldings; quantitative estimates of the expected improvement can be predicted by S. Wipf

- careful baking of critical components like masks with galvanic coating and bellows
- improve the cooling of such components in some way; for example the SR masks in H1 have only loose thermal contact to the beam pipe
- apply additional pumping speed in the inner region; H1 has no internal pump over a length of about 9 m; unfortunately there are doubts on the proper functioning of the ZEUS pump since it interacts in a not understood way with the beam and it shows no significant effect on the detector background when switched off - consequently the ZEUS pump in its present layout might not be a good model for an additional H1 internal pump; the problems with the pump have to be understood and the design should be improved also for ZEUS

References

[1] O. Gröbner, A.G. Mathewson, P.C. Marin, CERN AT/93-12, Gas Desorption from an OFHC Copper Vacuum Chamber by Synchrotron Radiation Photons

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