VACUUM INDUCED BACKGROUNDS IN THE NEW HERA INTERACTION REGIONS

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Abstract

After the rebuild of the HERA interaction regions the experimental detectors were limited by beam induced backgrounds. Four types of background mechanisms were observed and identified - proton gas scattering, lepton gas scattering, synchrotron radiation and proton beam-halo losses. With some refined beam steering methods it was possible to tune the synchrotron radiation background to acceptable limits. The remaining most important effect was the scattering of beam particles, mostly the protons, at the residual gas. In this contribution we describe our systematic attempts to investigate the complex behavior of the beam gas background and the measures taken to improve the situation. This includes dynamic pressure profile simulations and measurements, experimental determination of the background sensitivity profile along the beamline, the pressure development with current and time, and residual gas analysis. The background conditions were finally improved due to long term conditioning with beam, modifications of internal masks which were heated by higher order mode losses and moderate improvements of the pumping speed at strategic locations.

INTRODUCTION AND OVERVIEW ON THE HERA IR'S

HERA is an electron (positron) / proton collider that consists of two separate accelerator rings with a circumference of 6.3 km. Presently two experiments, ZEUS in the interaction region south and H1 in the north, analyze collisions of the two beams to investigate the internal structure of the proton. In the years 2000/01 the interaction regions of the collider were completely rebuilt to increase the achievable luminosity. In essence the upgrade involves a more compact design of the magnetic lattice for bending and focusing of the two beams close to the interaction point (IP) [1]. Superconducting magnets for the purpose of combining and separating the two beams with their very different energies are installed inside the experimental detectors. The upgrade allows for a geometric reduction of the beam cross sections by a factor 2.8, resulting in an increase of the specific luminosity by the same factor. Details on the achieved performance can be found in [2]. The beam parameters relevant in the context of this paper are summarized in table 1.

One of the critical points in the layout of the interaction region is the handling of the intense synchrotron radiation (SR) generated by the separation magnets inside the experimental detectors. The vacuum system allows to transport the radiation to 11 m distance from the IP, where a septum absorber is installed which separates the electron and proton beam vacuum systems. The septum absorber takes 4-6 kW of the radiation power, the major part is absorbed further downstream. In order to minimize the background from backscattered radiation a third beam pipe is installed behind the septum absorber that allows to transport the outer part of the radiation fan to an absorber located at 25 m right of the IP. A schematic overview of the magnet and beam-pipe arrangement is shown in Fig. 1.

	energy [GeV]	curr. (design) [mA]	rad. pow. (IP) [kW]	c. energy [keV]
e^+/e^-	27.5	35-45 (58)	15-20	100-150
p	920	90-100 (140)	-	-

Table 1: Selected parameters for the new HERA interaction regions including SR power and critical energy.

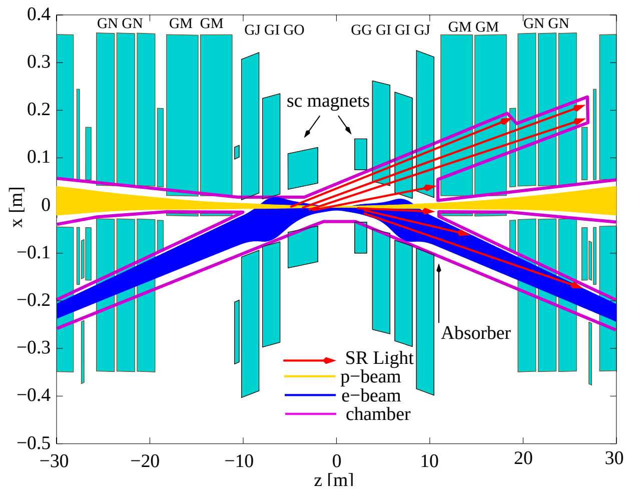

Figure 1: Schematic top view of the interaction region. Note the aspect ratio.

In principle the HERA detectors are influenced by three types of background: backscattered synchrotron radiation, positrons hitting the inner beam pipe wall due to energy loss from beam gas scattering, and protons that undergo beam gas scattering. During commissioning inadequate steering of the synchrotron radiation fan limited the operation. It was possible to cure this by precise alignment of the positron beam orbit across the IR using advanced beam based alignment techniques [3]. Later it became clear quickly that beam-gas scattered protons represented the most severe background and this limited the achievable luminosity by a substantial factor. After a year of operation the maximum current product acceptable to the detectors was only 1000 mA^2, whereas with the design values we were aiming for 8000 mA^2. As compared with the situation before the IR upgrade, the HERA experiments are

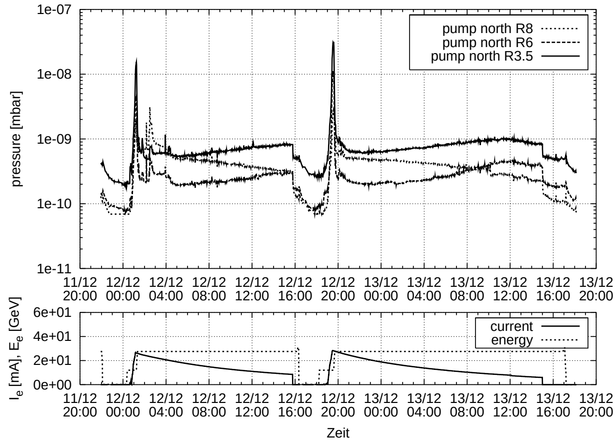

Figure 2: Typical pressure development during beam operation in the vicinity of the IR. The highest pressure rise occurs at injection energy with short bunches.

more sensitive to proton background by a factor 1.6 due to changes in the detector geometry. The remaining factor has to be attributed to the vacuum conditions in the IR. From comparison of the Bremsstrahlung rate generated by positron pilot bunches and measured in the luminosity detectors it was concluded that the pressure in the vicinity of the IP was a factor 3-5 higher than before the upgrade. Detailed studies of the background mechanism were undertaken to understand and overcome the background problem.

OBSERVATIONS

The sensitive region for proton beam-gas scattering extends from the IP to the septum absorber at 11 m in proton upstream direction (Fig. 1). This was determined with Monte Carlo studies and experimentally verified with several scintillation detectors installed along the beam pipe. A coincidence rate of hits in these individual detectors and background events in the detector was derived which confirmed that only a few percent of the disturbing events were originated beyond 11 m. Since this section has a common vacuum system for both beams the dynamic pressure rise caused by the positron beam is mainly responsible for the high p-gas rates. Indeed the backgrounds from the single, full-current proton beam are acceptable. One of the striking observations was a very high dynamic pressure rise (Fig. 2) at the positron injection energy of 12 GeV with an rms bunch length of 5 mm as compared to 10 mm at 27.5 GeV, although the SR power is much higher in the latter situation. A reasonable explanation of this behavior is higher order mode (HOM) heating of beam pipe components which was also supported by measurements of enhanced temperatures on the outside of the detector beam pipes. Several masks inside the detector were identified as candidates for these effects (see below).

Besides HOM and SR effects the vacuum behavior in the IR is also influenced by the presence of cold surfaces.

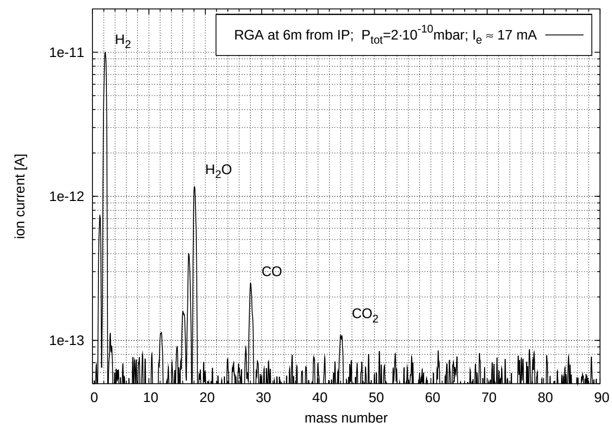

Figure 3: Residual gas composition during beam operation.

The beam pipes of the two superconducting magnets exhibit temperatures in the range 40 K to 70 K. Residual gas analysis has been performed during warm up of the magnets. A strong release of hydrocarbons (CH_4, C_2H_6, C_3H_8) and also Argon, gases that are condensed at the pipe temperature, was observed. The amount of released gas was analyzed to be in the range of 0.05 to 0.2 mono-layers of surface coverage. These observations led to several theories on possible complications arising from the neighborhood of cold and warm surfaces in the IR. For example one could imagine the cold surface being continuously collecting gas, but suddenly releasing it when beam is present. To investigate whether this is a danger a special mass spectrometer, capable of taking data in the presence of beam, was installed at 6 m distance from the IP. Fig. 3 shows a spectrum that does exhibit a gas composition which is typical for synchrotron radiation dominated vacuum systems. No hydro-carbons are present. The concentration of water is relatively high, but this peak does not change much when the spectrometer tube is separated from the beam vacuum by a valve and is probably caused by contamination of the tube itself and the connecting bellows tube. Beside these studies the beam pipes were operated for several weeks at a higher temperature around 120 K and no improvement of the background was observed. We came to the conclusion that the presence of the cold surfaces does not deteriorate the vacuum quality.

PRESSURE PROFILE SIMULATIONS

Pressure profile simulations were performed to develop a model of the residual gas distribution in the IR and to adopt this model to the pressure values measured at discrete pumps. The interaction region contains three types of pumps: distributed NEG pumps with an effective pumping speed of 50-100 l/s m (including pump slit conductance), discrete titanium sublimation pumps and discrete ion getter pumps which are mostly installed in combination. The ion-getter pumps are also used to monitor the pressure. With realistic outgassing rates and pumping speeds one obtains

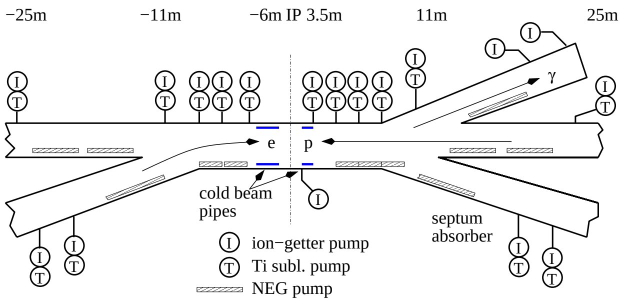

Figure 4: Schematic layout of the IR vacuum system. The common region for both beams extends from -11 m to 11 m.

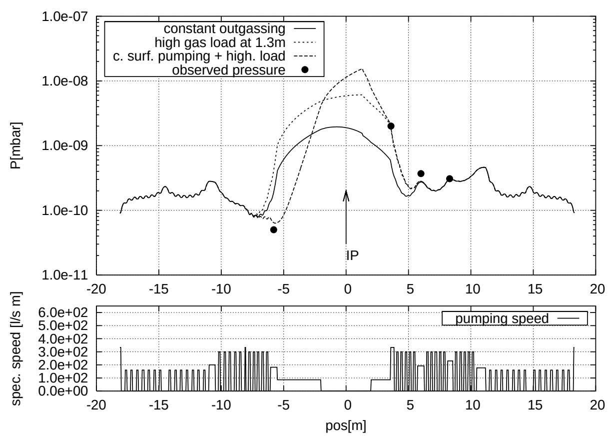

Figure 5: Pressure profile simulations for the inner interaction region at H1, for different outgassing and pumping scenarios in comparison with observed pressure readings.

a pressure profile as shown in Fig. 5. The measured profile with enhanced pressure at 3.6 m right can only be reproduced by assuming a strong gas source inside the detector, for example at the position of a mask around 1.3 m right. Furthermore the cold surface has to be given some pumping speed to obtain the low pressure measured on the left side. Together with the observation of HOM induced pressure rise at 12 GeV these simulations indicated a possible problem with the internal masks.

IMPROVEMENT BY MODIFICATIONS AND BEAM CONDITIONING

In the shutdown 2003 several measures were undertaken to improve the situation. Both detectors had insufficiently cooled masks for suppressing backscattered photons in the beam vacuum. An example of H1 is shown in Fig. 6. These masks were replaced by new ones, improved with respect to tapering and cooling. Indeed a strong reduction of the HOM induced pressure rise was observed after the shutdown. As another measure the pumping speed at 3.6 m and 6 m was enhanced by installing larger pumps and increasing the geometric conductance. Nevertheless the situation was not immediately improved after the shutdown. A one

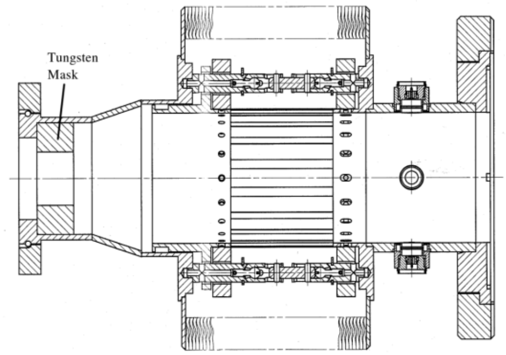

Figure 6: Tungsten mask inside H1 which was suspected to be heated by HOM's and cause enhanced outgassing.

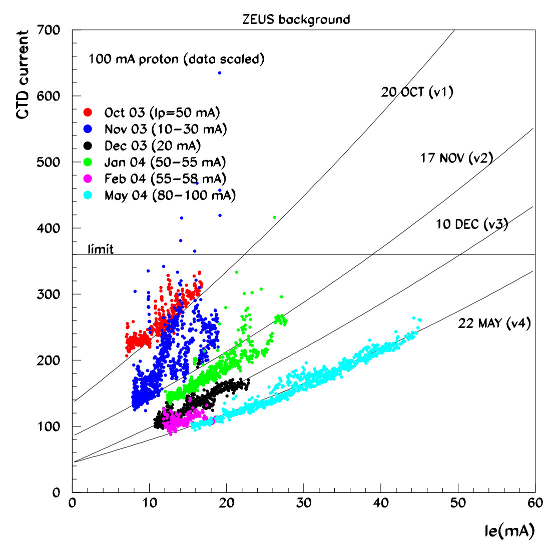

Figure 7: ZEUS drift chamber leakage current rescaled to a proton current of 100 mA vs. positron current in 2003/04. The operational limit of the drift chamber is indicated.

week program of baking at 12 GeV was performed and then the positron current at 27.5 GeV was kept close to the acceptable maximum. With time a strong improvement, obviously due to beam conditioning, was observed (Fig. 7). By March 2004 both detectors had backgrounds that would be still acceptable at extrapolated design currents for both particle species. At presence, in June 2004 we were successfully operating with 100 mA proton current and 45 mA positron current.

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