ESTIMATES OF RESIDUAL GAS DENSITY IN THE LHC

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Abstract

A short review on estimates of residual gas density in the LHC is presented. Results, presented for stable beam, are strongly dependent assumptions surface properties and beam operating configuration (beam current, energy, etc.) and represent only a 'snapshot' in time for the machine. Constant particle losses are not included at present and constitute a future study.

INTRODUCTION

Beam-gas interactions along the experimental insertion regions (i.e. between two arcs) have been indentified as one of the main sources of background noise to the experiments in the LHC [1], [2] during physics runs.

In the LHC the main gas species are expected to be hydrogen (largely dominant in the cold arcs), methane, carbon monoxide and dioxide. The presence of water should be negligible, given that room temperature sections are conditioned (baking and NEG activation), and that the water will have an extremely low vapour pressure in the cold sections.

In this paper estimates of residual gas density in the LHC are presented. Depending on the specific period of operation, the residual gas density varies with gas sources – mainly ion, electron and photon-induced gas desorption – which depend on the surface properties and on the operating configuration. On the one hand beam vacuum chamber preparation i.e. ex-situ cleaning, in-situ baking (or activation in the case of NEG surfaces), and particle bombardment, influence the gas induced desorption yields. On the other hand the beam current and energy will determine the total ionisation rate, the photon (synchrotron radiation) energy spectrum and flux to the wall, and, the electron flux and energy to the wall.

This paper details some of these dependences and present estimates made for stable proton beam (negligible beam losses) in the ATLAS interaction region, for initial beam operations and including thermal outgassing of the tertiary collimators before the Inner Triplets. The expected density in the arcs and during ion operations is also discussed.

It should be noted that if regular beam losses are expected during physics operation, their effect should be studied and added to the present calculations. Moreover, any other operating configuration should be analysed case by case, depending on the history of the machine at that moment in time.

VACUUM CALCULATIONS

The gas sources included in the simulations code (VASCO [3]) are thermal outgassing and dynamic effects, i.e. beam induced desorption phenomena: ion, electron and photon induced molecular desorption. In the case considered, the vacuum is "stable" (no pressure run away is expected due to the very high distributed pumping and low desorption), and electron cloud build up is neglected.

The results are presented in form of gas density per gas species and hydrogen equivalent gas density, i.e. weighted by the nuclear scattering cross sections as follows:

$$n_{H_2 equiv.} = n_{H_2} + \frac{\sigma_{CH_4}}{\sigma_{H_2}} n_{CH_4} + \frac{\sigma_{CO}}{\sigma_{H_2}} n_{CO} + \frac{\sigma_{CO_2}}{\sigma_{H_2}} n_{CO_2}$$

$$\frac{\sigma_{CH_4}}{\sigma_{H_2}} = 5.4;\ \frac{\sigma_{CO}}{\sigma_{H_2}} 7.8;\ \frac{\sigma_{CO_2}}{\sigma_{H_2}} = 12$$

Variation of input parameters with surface conditions and beam operations configuration

As highlighted before, the parameters determining the residual gas density strongly depends on surface conditions and beam operations. Both thermal outgassing and induced desorption yields may vary by several order of magnitudes depending on surface conditions, i.e. whether the surfaces was in situ baked/activated or if it has been bombarded by particles. Particle flux to the wall, and their incident energy, change with machine operating configuration (mainly beam intensity and energy) and history. Some examples, amongst many others, are given in the following (see talk transparencies for more data)

- NEG properties as a function of activation/venting cycle (aging), and of amount of gas pumped [4].
- Evolution of photon induced gas desorption with accumulated dose - total number of photon impinging on the surface [5].
- Evolution of electron induced gas desorption with accumulated dose - total number of electron impinging on the surface [6].
- Dependence of photon induced gas desorption with photon critical energy [7].