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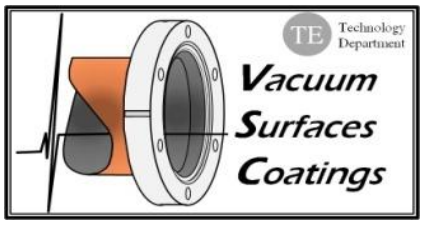

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Vacuum Report

BGI PRESSURE INCREASE

Abstract

Pressure increases were observed in the BGI during the LHC operation year 2011. Pure neon gas is injected on request into the BGI. This report identifies possible reasons for the beam induced pressure increase and shows that the pressure increases are not related to the neon injections.

This document is considered to be a working document. Further observations should be reported and possible corrections made.

Prepared by :	***Checked by :***	***Approved by :***
G. Schneider **D. Calegari**		

History of Changes

Rev. No.	*Date*	*Pages*	*Description of Changes*

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1. INTRODUCTION

The BGI are used to measure the beam dimensions and are situated around Point 4 of the LHC machine. Neon gas is periodically injected with a pressure of up to $1*10^{-8}$ mbar, measured on the Bayard-Alpert gauge. The pressure measured the Pirani/Bayert-Alpert combination gauges in the BGI right are reaching up to $1*10^{-7}$ mbar.

A beam induced pressure increase was observed during the runs in 2011.

A similar injection system is foreseen in LHCb. A pressure increase due to the neon injection must be excluded in LHCb. The main motivation for this report is the question if the pressure increase in the BGI is due to the neon injected and if there was a similar risk to LHCb.

This report gives possible reasons for the pressure increase and answers if there is a relation between the neon injection and the pressure increase.

The BGI has a magnetic field of 0.1 T and an electric field of 4 kV. The effects of the magnetic field and electric field are not studied here.

The following questions are tried to be answered:

Is there a pressure increase following an injection?

Is the pressure increase worsening or getting better with time?

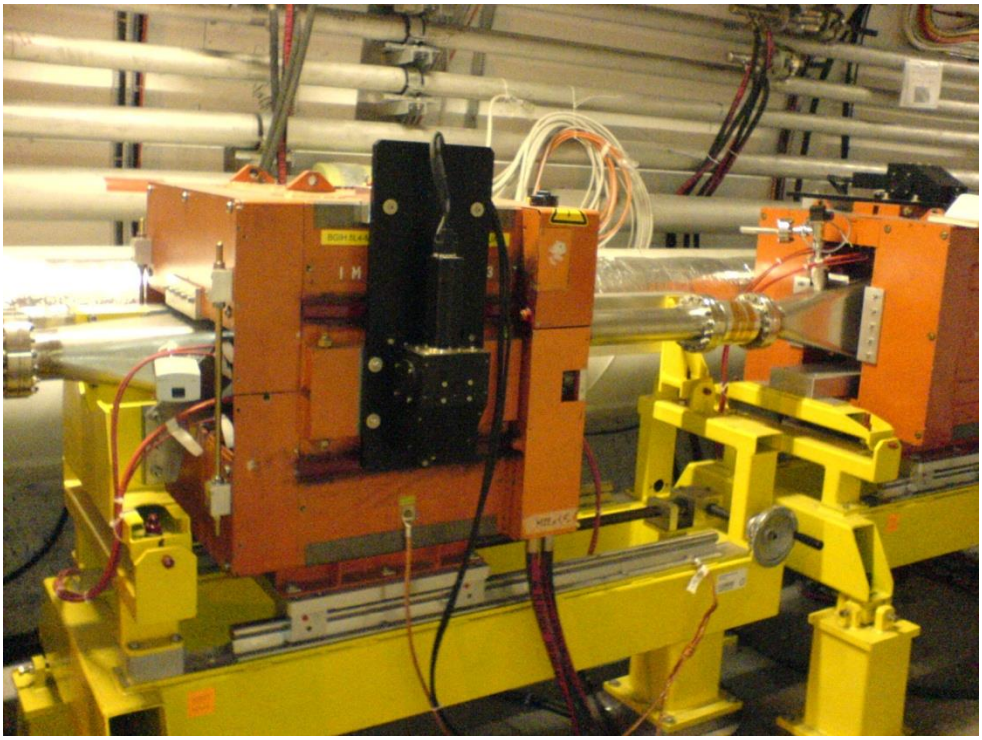
Do we have similar pressure increases in the machine, for example the TDI or the LHCb VELO?

Why do we not have a pressure increase on the opposite line?

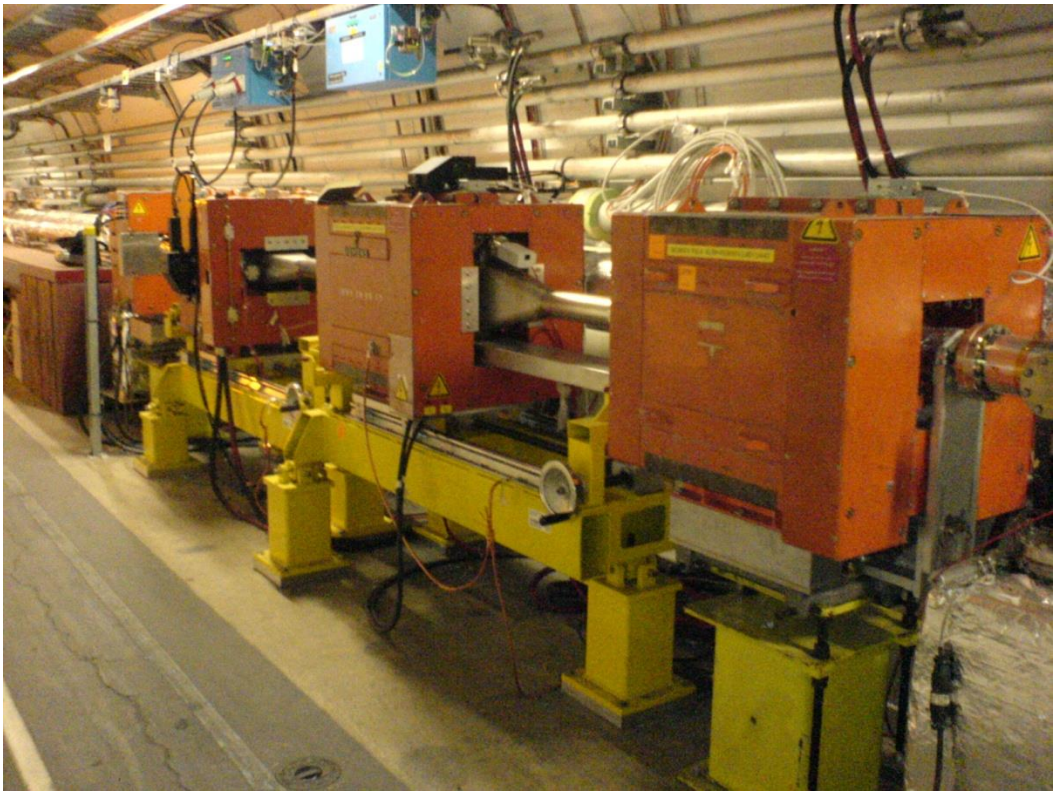
Is pressure increase driven by electron cloud, synchrotron radiation or beam impedance?

2. LOCATION AND LAYOUT

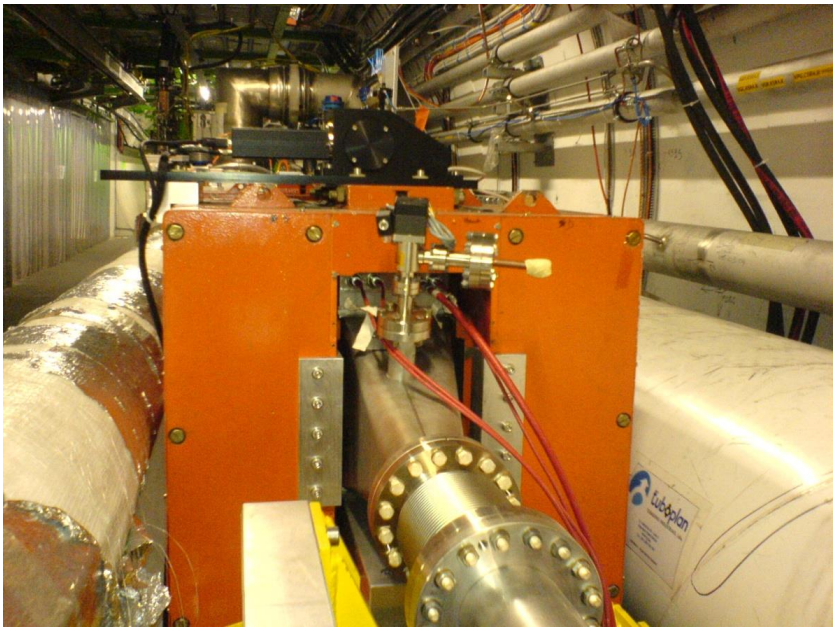
The left BGI is located in vacuum sectors D5L4.B, the right one in D5R4.R as seen in Annexes 1 and 2. The layout of the BGI can be found in Annex 3. Pictures of the BGI left and right can bee see in Picture 1, Picture 2 and Picture 3. The PVSS layout of the BGI can be found in Figure 1 and Figure 2.



Picture 1: BIG left



Picture 2: BGI left overview



Picture 3: BGI right

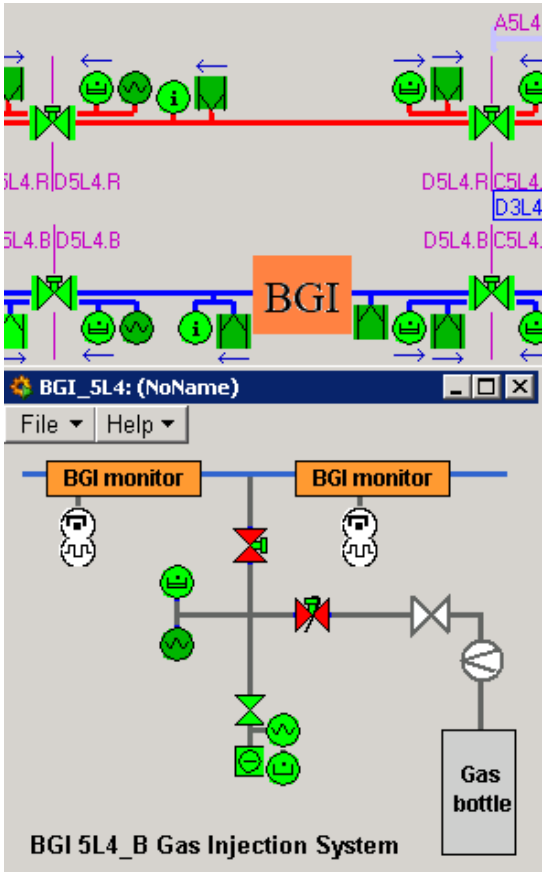


Figure 1: BGI PVSS layout left

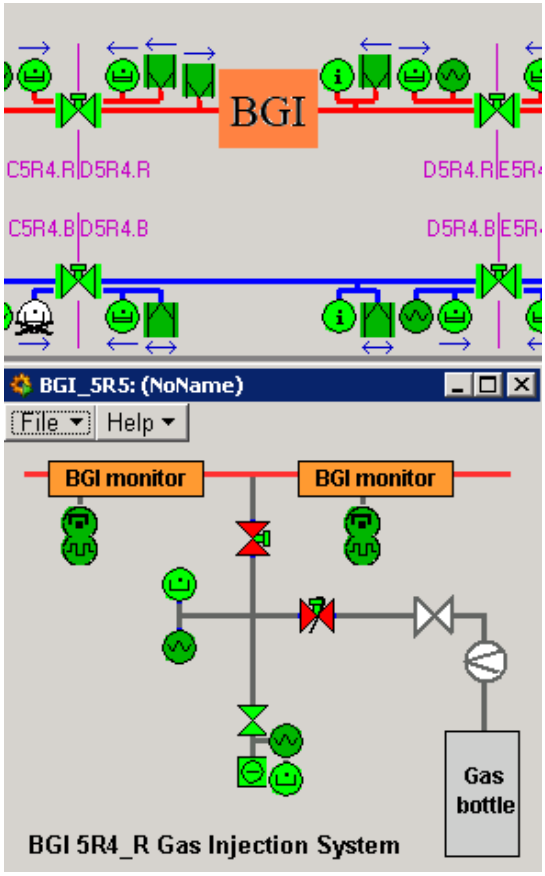


Figure 2: BGI PVSS layout right

3. INJECTION DATES

Total, 7 injections were made on the left BGI, 10 injections were made on the right side.

Table 1: Injection dates in the BGI

BGI Left	BGI Right
	26.04.2010
	28.04.2010
14.10.10	14.10.2010
05.11.2010	05.11.2010
08.11.2010	08.11.2010
09.11.2010	09.11.2010
10.11.2010	10.11.2010
06.05.2011	06.05.2011
30.06.2011	30.06.2011
	25.08.2011

4. ANALYSES OF THE PRESSURE BEHAVIOUR

4.1 PRESSURE DIFFERENCE BEFORE AND AFTER INJECTION

The pressure of the right BGI is plotted before the last injection in Figure 3 together with the beam current of 319 mA and the beam energy of 3.5 TeV. The injection was made on 25.08.2011 as seen Figure 4 during a machine development fill. As seen in Figure 5, the pressure increase is with a beam current of 321 mA is significantly less than before the fill.

	Pressure			Beam current
	VGFH.622.5R4.R	VGFH.640.5R4.R	VGI.661.5R4.R	
Last fill before neon injection	$8*10^{-8}$ mbar	$4*10^{-8}$ mbar	$7*10^{-9}$ mbar	319 mA
During neon injection	$1*10^{-7}$ mbar	$4*10^{-8}$ mbar	$1*10^{-8}$ mbar	(1 mA)
First fill after neon injection	$1*10^{-8}$ mbar	$1*10^{-8}$ mbar	$6*10^{-9}$ mbar	321 mA

The pressure after the neon injection is better than before with a similar beam current.

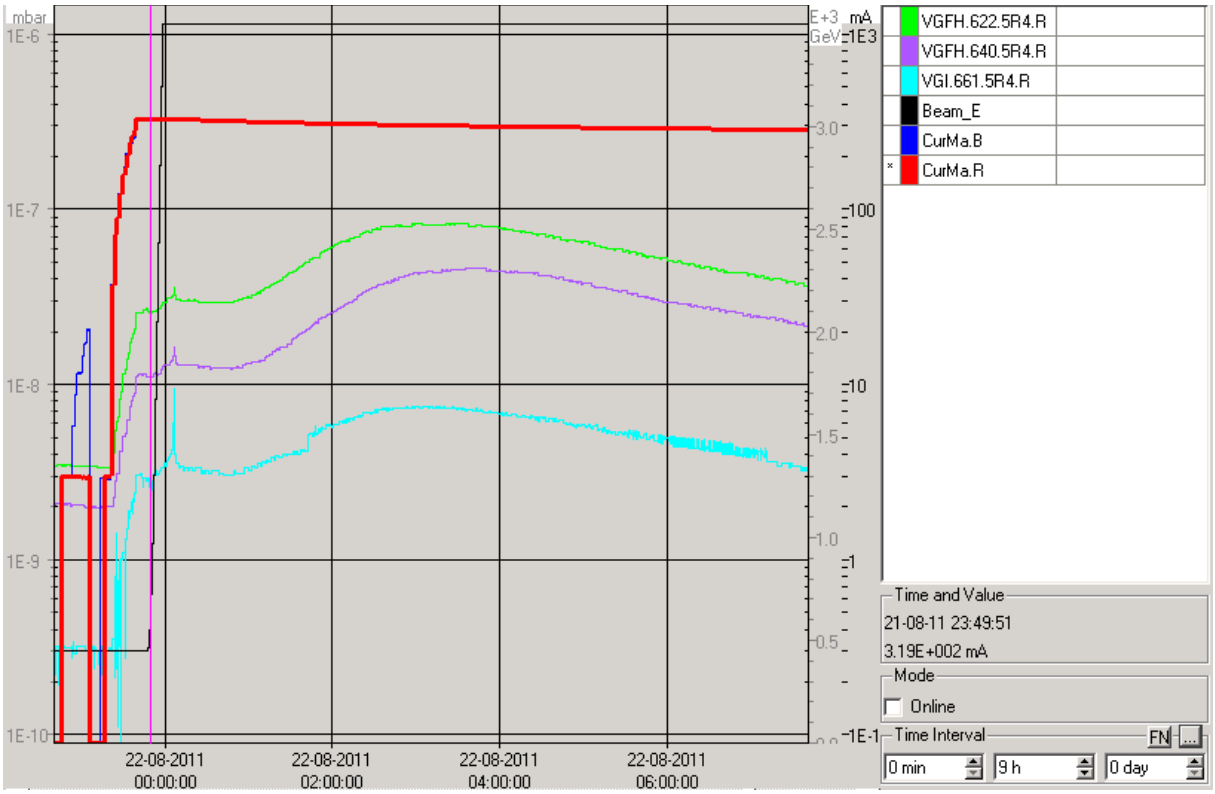


Figure 3: Pressure, beam current and beam energy before last injection in BGI right

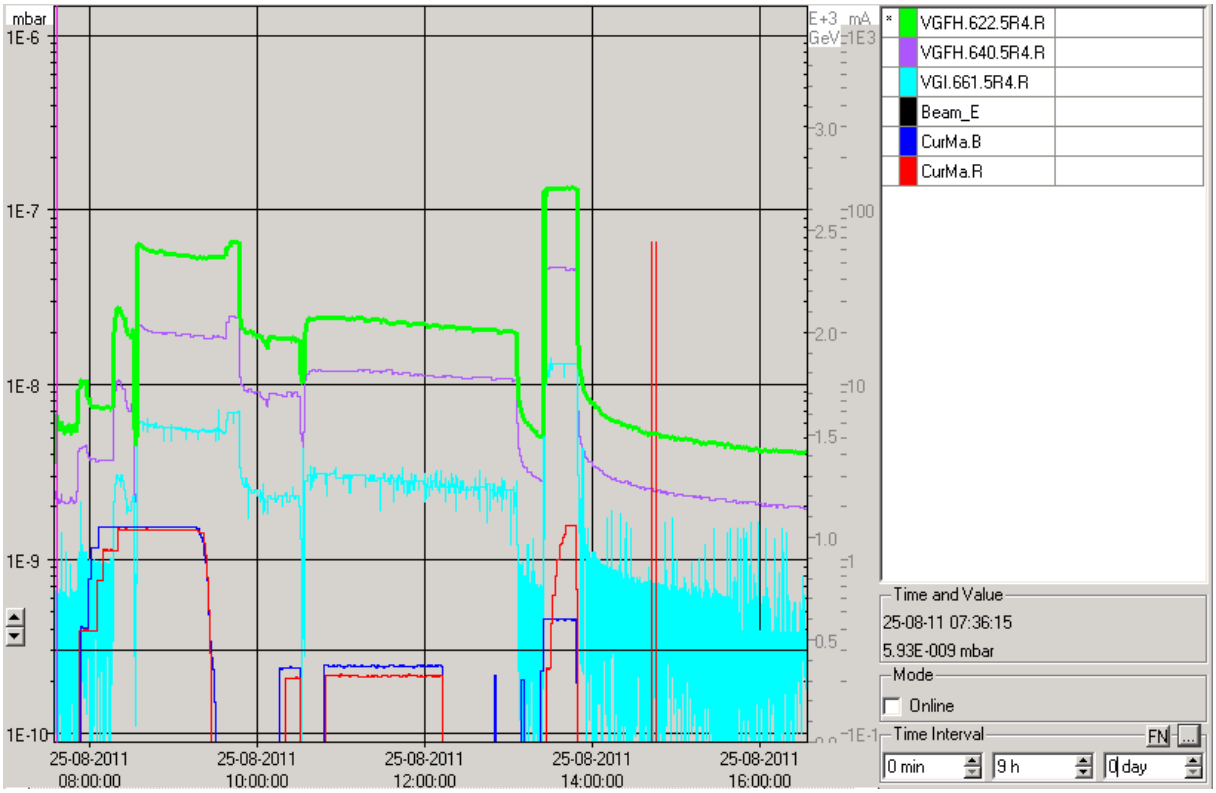


Figure 4: Neon injection in the BGI right.

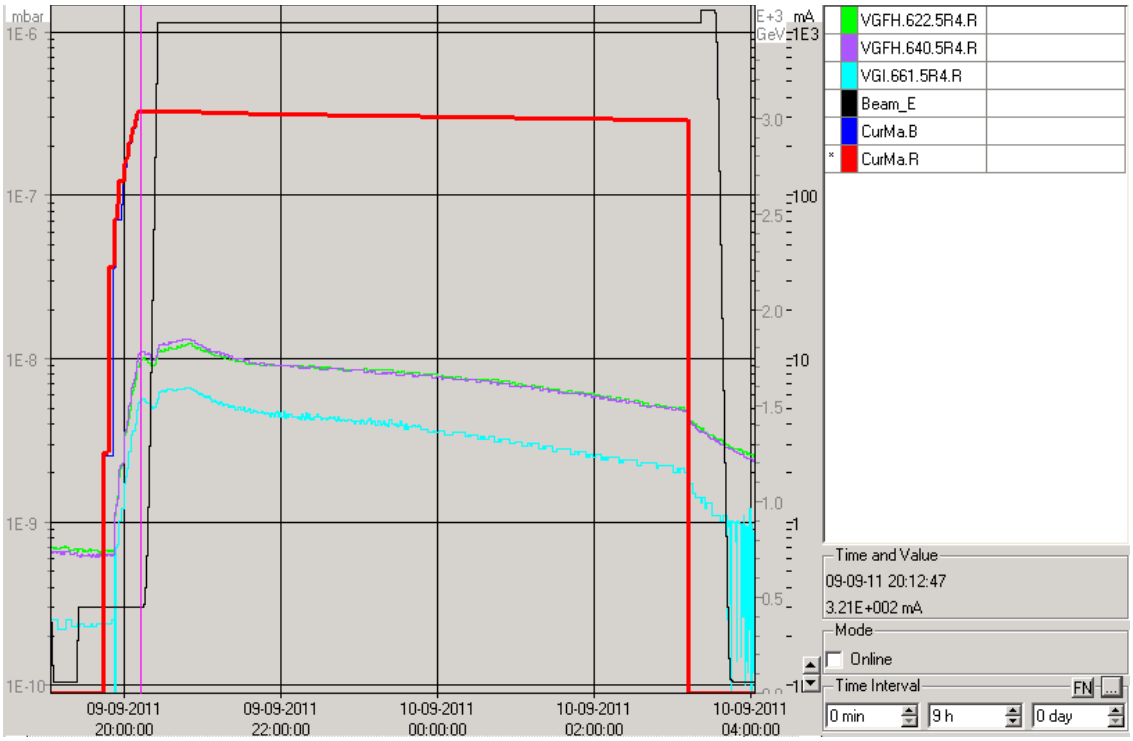


Figure 5: Beam induced pressure increase with the first long fill after the neon injection in the BGI right

4.2 PRESSURE EVOLUTION WITH TIME AND BEAM CURRENT

The pressure in the BGI right was stable over the last 3 month, with maximum pressures typically in the high 10^{-8} mbar range for the VGFH.622.5R4.R and VGFH.640.5R4.R and in the low 10^{-8} mbar range for the VGI.661.5R4.R, see Figure 6.

No direct relation can be established between the beam current and the pressure increase, see Figure 7.

The trend seems to be, however, whenever the current is increased to a new higher level, the pressure increases significantly, as seen in Figure 8 and Figure 9.

Beam cleaning is observed.

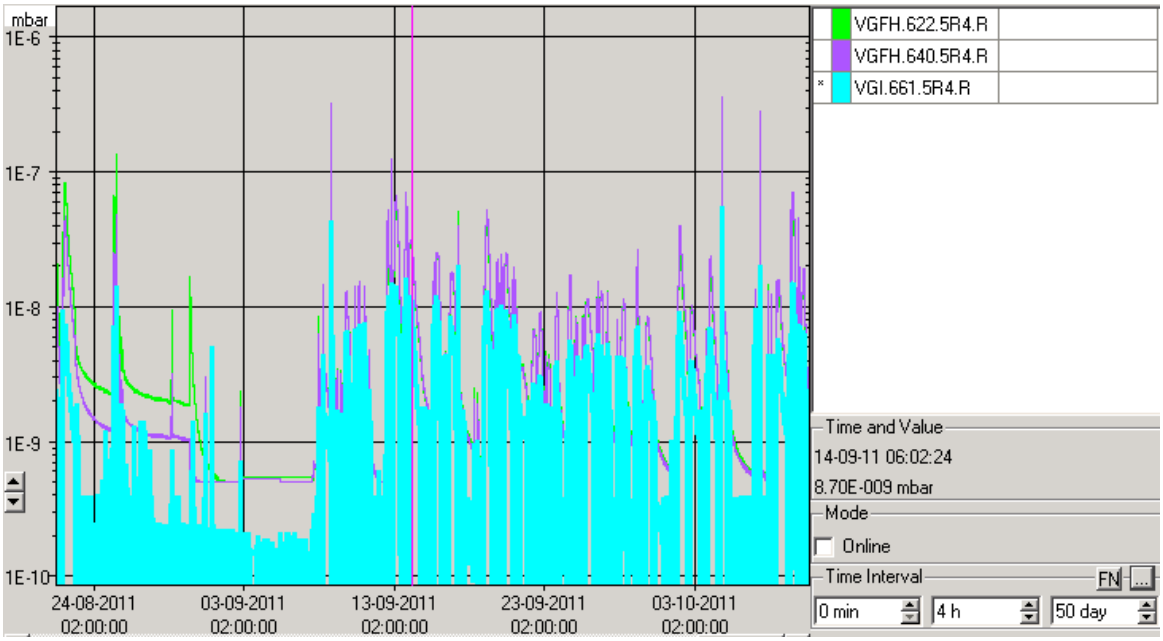


Figure 6: Pressure in the BGI right over the last 3 month.

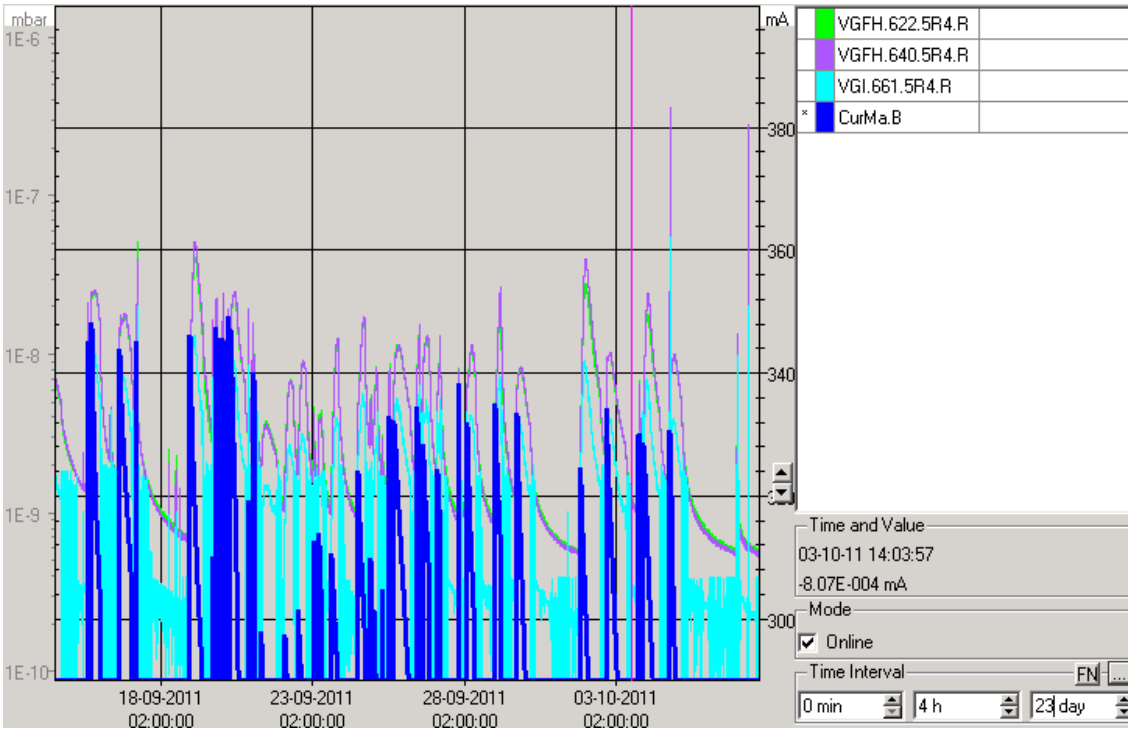


Figure 7: Pressure and beam current in the BGI right.

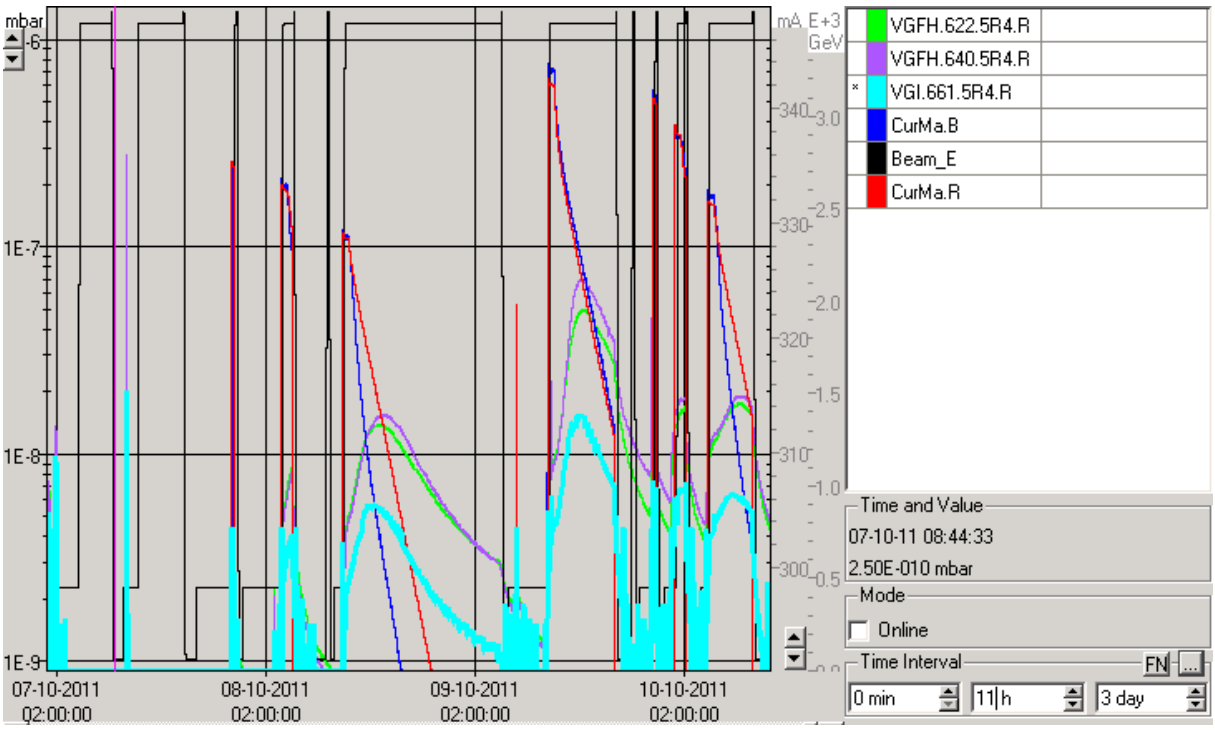


Figure 8: Pressure and beam current in the BGI right detail.

4.3 COMPARISON OF THE BGI, TDI AND LHCB VELO

Pressure increases are observed in various parts of the LHC machine. To compare the beam effects, the BGI, TDI and the LHCb VELO were taken.

Total, 9 neon injections to atmosphere were made in the LHCb and re-pumped without NEG activation. There is no neon injection in the TDIs.

As seen in Figure 9 for a maximum beam current of 345 mA, all 3 sectors have a qualitatively similar start of the pressure rise with the increase of the beam current. This is assumed to be electron cloud. Only the BGI seems to have a small effect when the beam energy is increased from 450 GeV to 3.5 TeV.

The slow pressure rise seen on the TDI and the BGI is assumed to be due to a beam impedance effect, warming up part of the beam vacuum system.

No such effect is seen on the LHCb VELO. The VELO detector system itself is actively cooled.

The BGI peak is reached typically after 4 hours, the one of the TDI only after about 6 to 8 hours.

No link can be established between the systems where neon was injected or not.

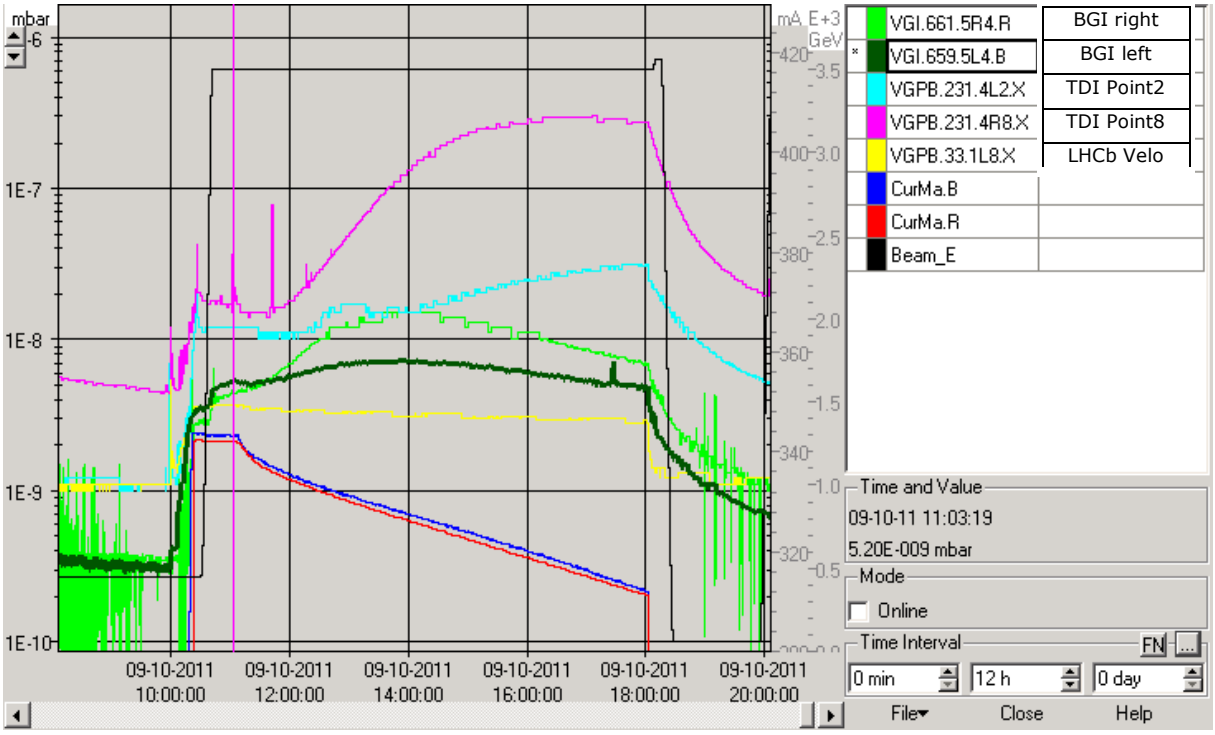


Figure 9: Comparison of the BGI, TDI and the LHCb VELO

4.4 INFLUENCE OF THE SYNCROTRON RADIATION AND BEAM DIRECTION

In order to see if synchrotron radiation plays a role in the BGI pressure increase, the entry and the exit of the arc next to IP4 are compared with the BGIs.

The red beam runs counter clockwise, exits the Arc 4-5 at VGPB.864.7R4.R, runs through the BGI right at VGI.661.5R4.R and enters the Arc 3-4 at VGPB.875.7L4.R.

The blue beam runs clockwise, exits the Arc 3-4 at VGPB.875.7L4.B, runs through the BGI left at VGI.659.5L4.B and enters the Arc 4-5 at VGPB.864.7R4.B.

It should be expected that the exits of the arcs have a maximum of synchrotron radiation and the same behavior during beam injection and acceleration. The entries of the arc should have little synchrotron radiation. The highest pressure increase seen over the last 3 month is shown Figure 10 and Figure 11 and summarized in Table 2.

Comparing the curves, it is surprising that the profile of the pressure increase at the end of the arc is rather depending of the beam direction then the position left or right of IP4. The BGI pressure increase has a similar profile as the clockwise turning beam during the beam injection and acceleration.

It is assumed that the pressure increase at the end of the beam acceleration are driven by synchrotron radiation. Other beam effects, however, cannot be excluded.

Table 2: Comparison of pressure increase at the arc exists next to point 4 compared with the BGI

		Without Beam [mbar]	With 450 GeV [mbar]	With 3.5 TeV [mbar]	Maximum Pressure [mbar]
Beam Exit of Arc	VGPB.864.7R4.R	$7*10^{-11}$	$1*10^{-10}$	$8*10^{-10}$	$8*10^{-10}$
	VGPB.875.7L4.B	$7*10^{-11}$	$2*10^{-9}$	$1*10^{-9}$	$1*10^{-9}$
Beam Entry of Arc	VGPB.875.7L4.R	$8*10^{-11}$	$3*10^{-10}$	$4*10^{-10}$	$5*10^{-10}$
	VGPB.864.7R4.B	$4*10^{-10}$	$2*10^{-9}$	$2*10^{-9}$	$2*10^{-9}$
BGI	VGI.661.5R4.R	$3*10^{-10}$	$3*10^{-9}$	$4*10^{-9}$	$1*10^{-8}$
	VGI.659.5L4.B	$3*10^{-10}$	$4*10^{-9}$	$5*10^{-9}$	$7*10^{-9}$

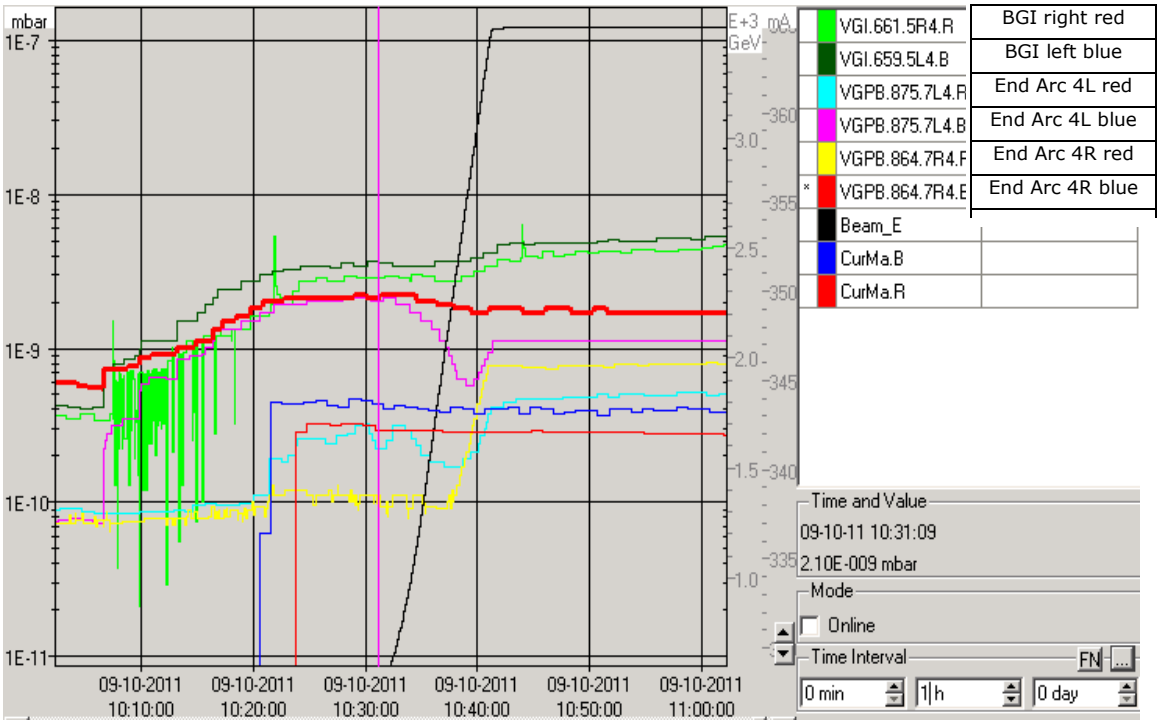


Figure 10: End of beam injection followed by the acceleration or arc ends in IP4 compared with the BGI.

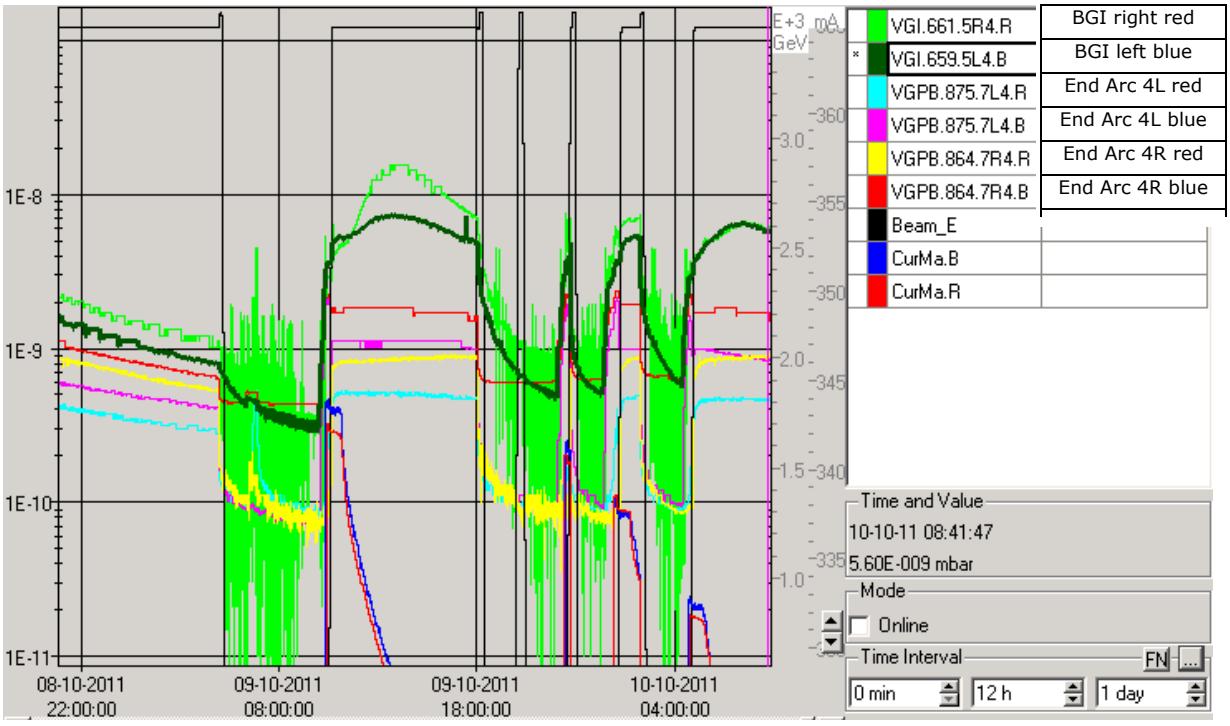


Figure 11: Pressure increases at the end of the arc in IP4 compared to BGI

5. CONCLUSIONS

No pressure increase following a neon injection was found in the BGI.

The pressure increases are seen in the BGI and TDI have a similar profile.

The profile of the pressure increase in the LHCb VELO is different from the one of the BGI.

The maximum pressure increases in the BGI typically up to $3*10^{-8}$ mbar during beam injection measured by the Bayard-Alpert gauges. The immediate effect of the increase of beam energy up to 3.5 TeV is minor, typically 1*10-8 mbar higher then before the ramp. It cannot be said be said with certainty if this is due to a change of the beam structure of syncrontron radiation.

The highest pressure is usually reached after about 4 hours after the injection. The most probalbe reason seems to be thermal degassing resuting from a beam induced heating of part of the BGI vacuum chamber or inserts.

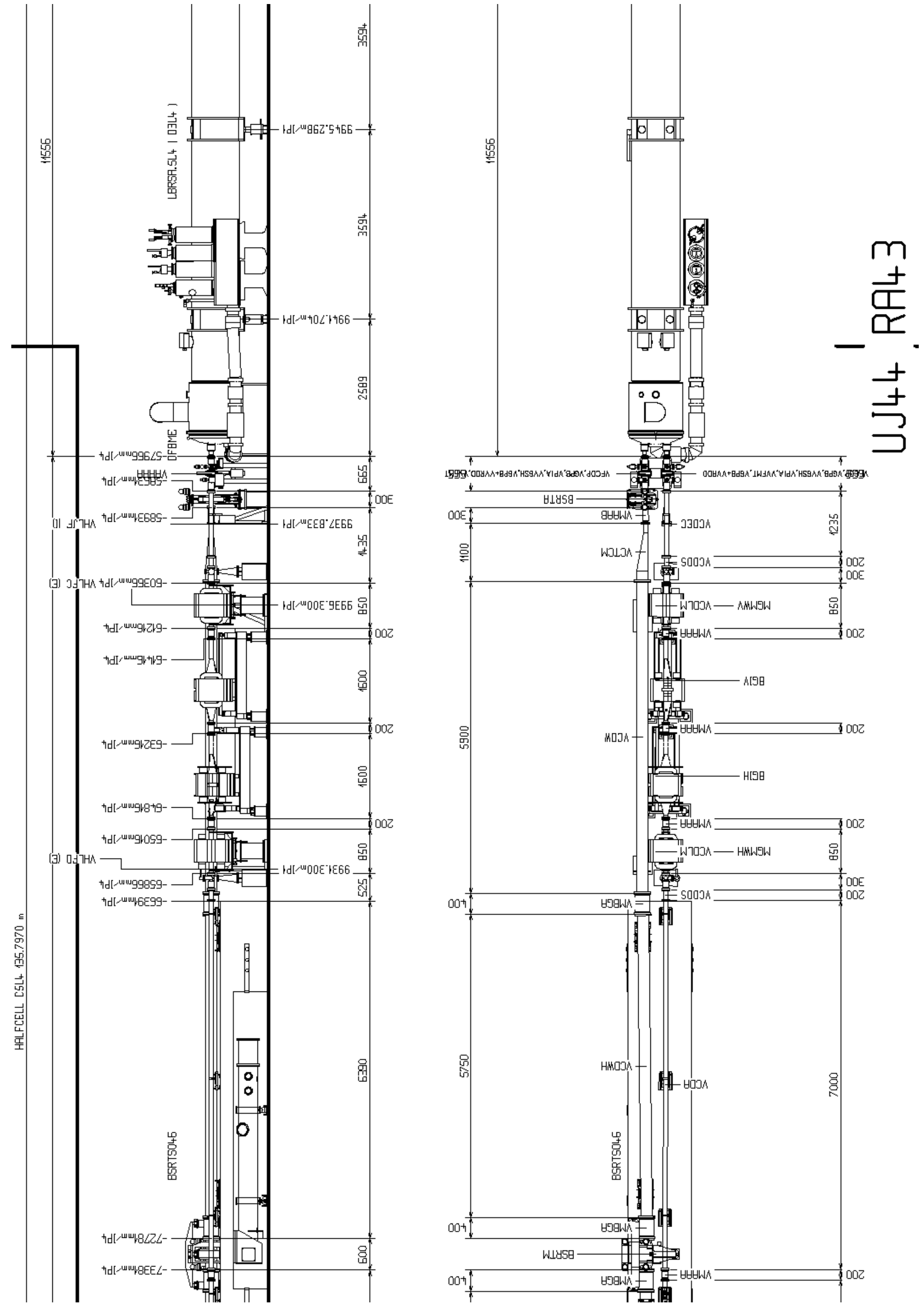
No pressure increase is seen on the opposite line of the BGI. This beam line is in diameter 200 mm as see in Annex 4, so electron cloud effects should be little.

The effects of the magntic field and the electic fields of the BGI remain to be studied in detail.

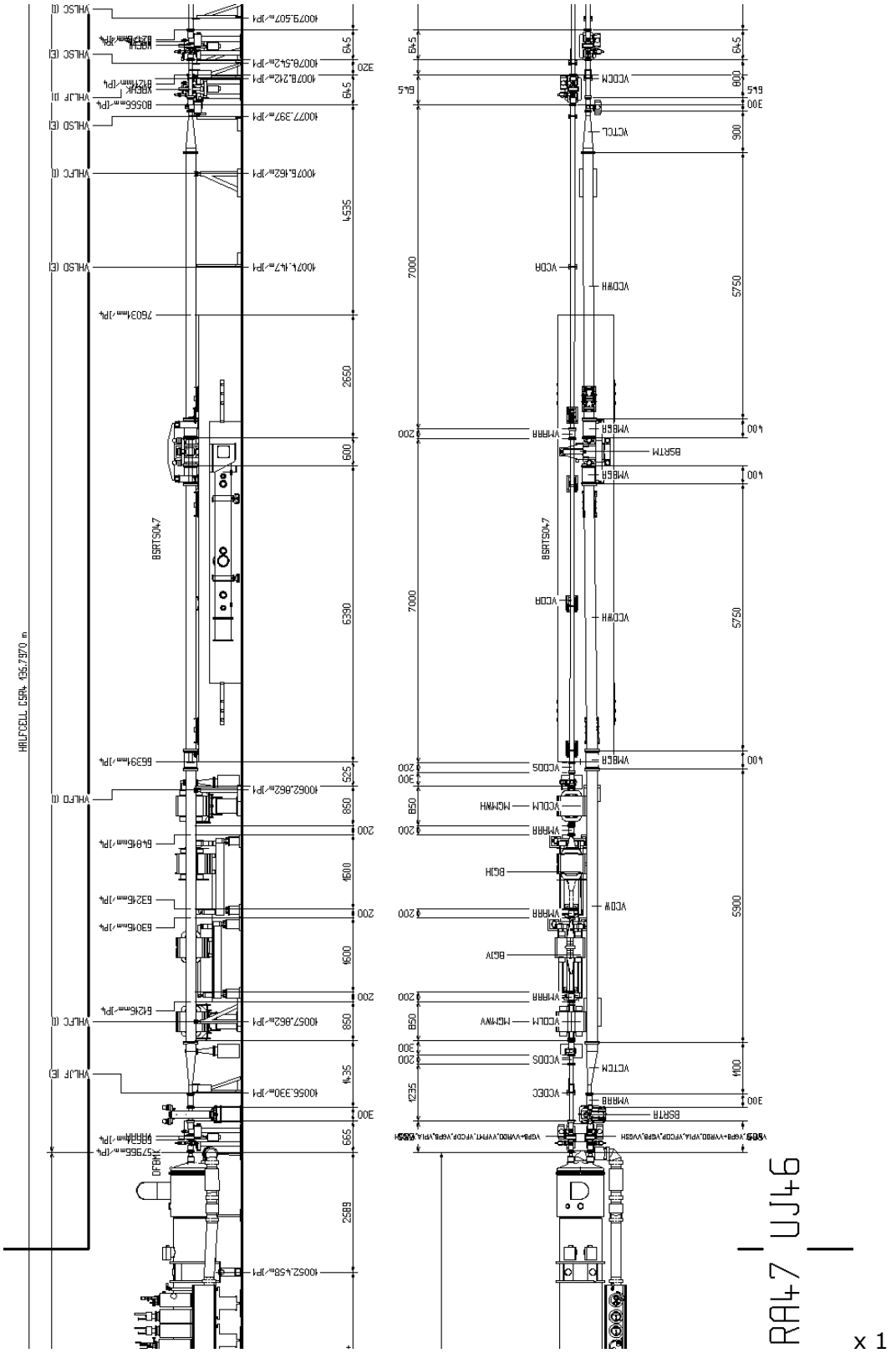
6. OUTLOOK

A reduction of the pressure is expected over time, assuming similar beam parameters. As soon as the beam current is increased above 360 mA per beam, significant pressure increases are expected.

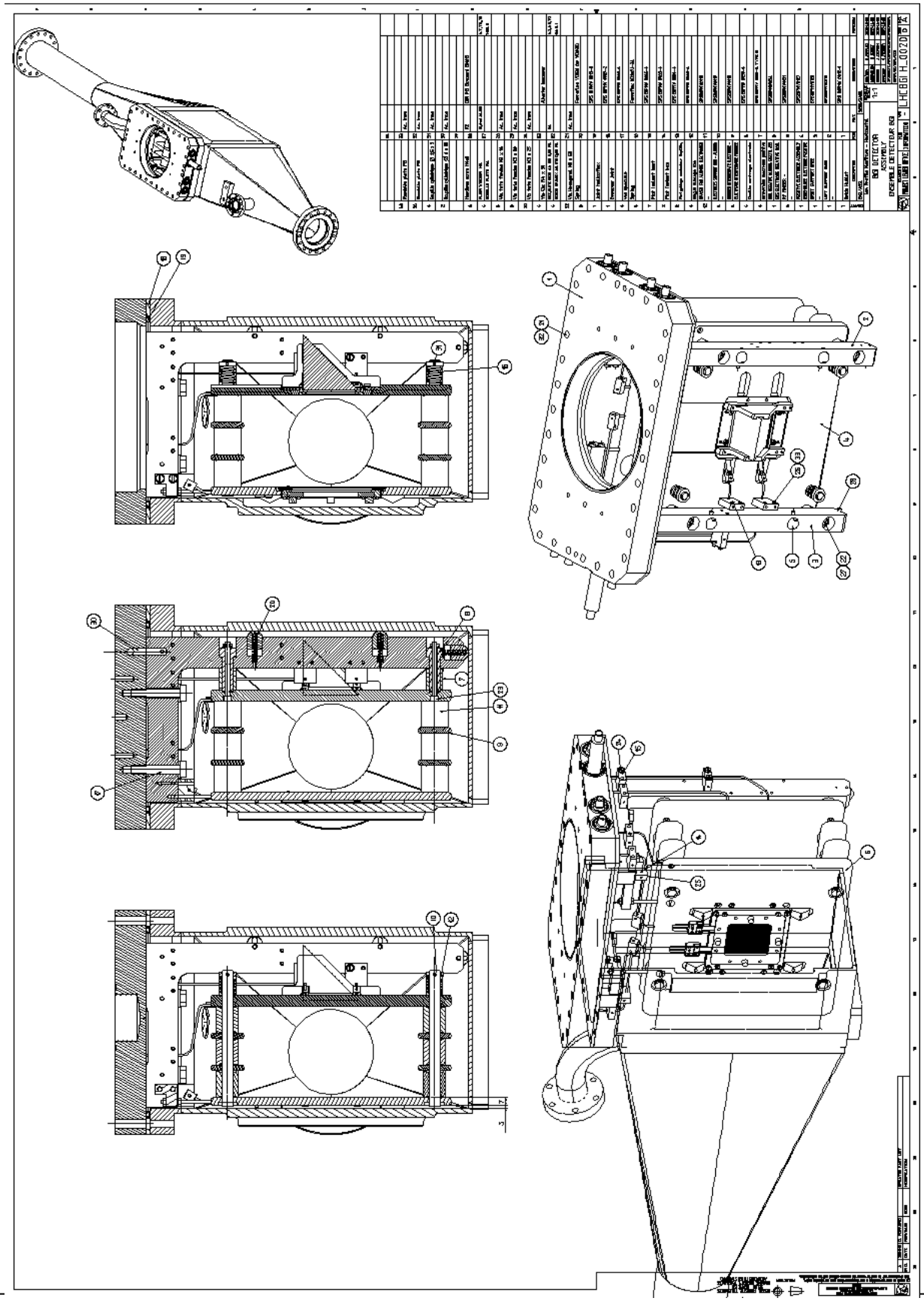
ANNEX 1



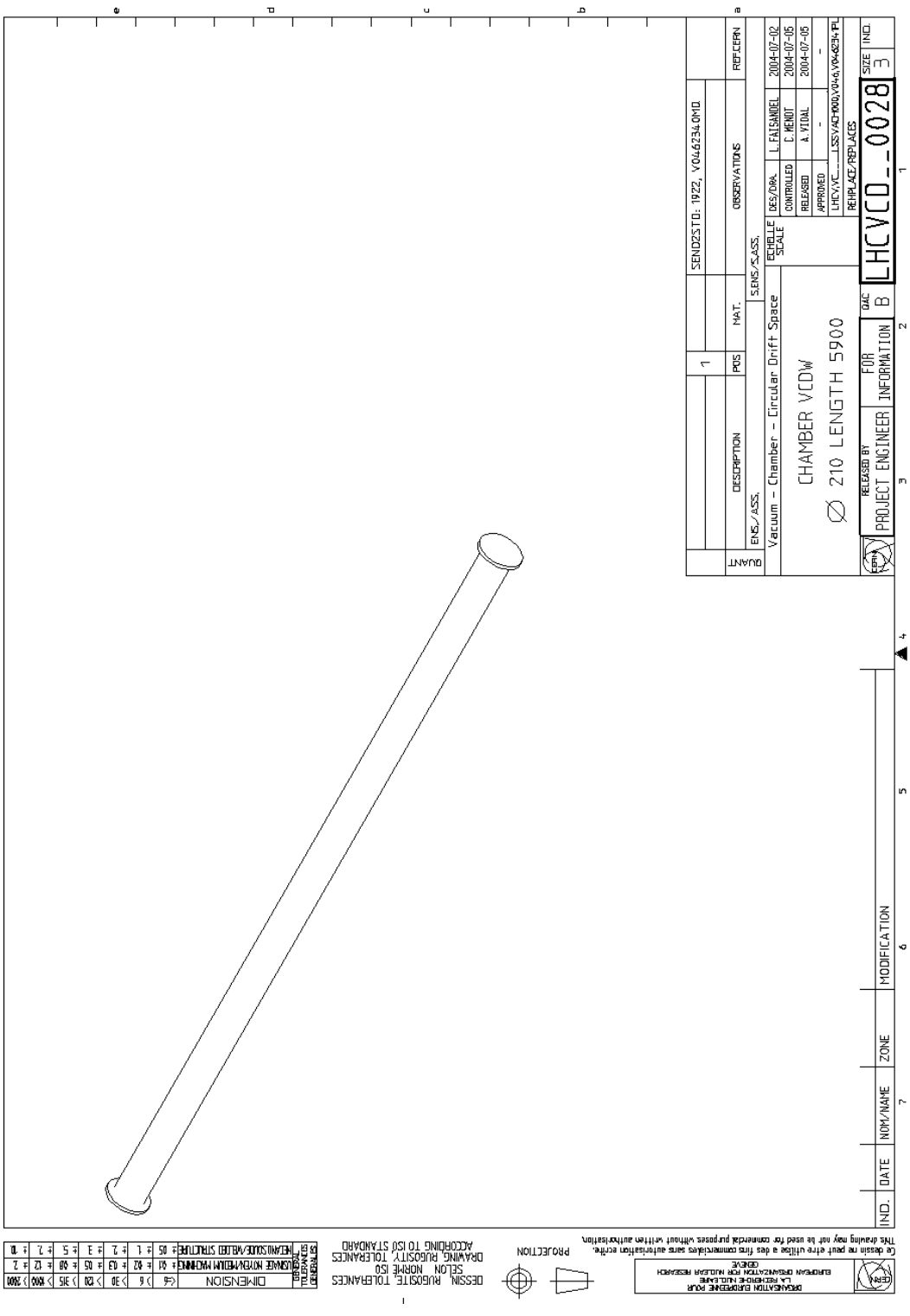
ANNEX 2



ANNEX 3



ANNEX 4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