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THE CAPTURE FACTOR AND PUMPING SPEED FOR SLOTS IN THE LHC BEAM SCREEN WITH BAFFLES

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The capture factor and pumping speed for slots in the LHC beam screen with baffles

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1 Abstract

This paper presents the continuation of the study of the pumping speed of the slots for the beam screens [1]. The new analytical estimation of the pumping speed of the slots is made for a possible modification where the slots have a baffle to protect the cold bore against multipacting electrons.

2 Introduction

The intensive studies of the beam induced multipacting in the LHC vacuum chamber shows [2] that during a commissioning period the power up to about 1 W/m from the electron clouds can be adsorbed on a beam screen. (This limitation comes from cryogenic installed capacity of 1.17 W/m per beam). Some electrons from the electron cloud may reach the cold bore via the pumping slots therefore their power will be adsorbed on the cold bore. This fraction reaching the cold bore can be estimated from 4.4% (the area of pumping slots in a beam screen) up to 50% (the slot coverage along a row in dipole magnetic field if the multipacting electrons are concentrated in very narrow strips [2]), in other words this could represent an unacceptable heat load to the 1.9K circuit power. Thus it may be necessary to protect the cold bore against the multipacting electrons. One proposal has been to intercept them with some kind of baffles. The aim of this study is to estimate how much the pumping speed will be reduced in the presence of such baffles.

3 Results of simulation

In the LHC arc beam screen the pumping slots lie on 8 rows along the vacuum chamber (see Figure 1). The slot length is randomly varied between 6, 7, 8, 9 or 10 mm, the average being 8 mm. The average distance between slots is 8 mm. In these simulations the pumping slots are replaced by continuos slots, having longitudinal symmetry, and this permitting a two-dimension simulation. This gives a lower value of capture factor (CF) than in the three-dimension simulation, but, given uncertainty of sticking probability of desorbed gases, these values give a reasonable estimate.

3.1 A beam screen without baffles in a cold bore at T£3K

The first estimations were made for the arc beam screen without baffles for different slot positions. The simulation scheme is shown in Figure 1. The geometrical parameters are:

- the inner cold bore diameter, *ID*;
- the height of the beam screen (outer dimension), *H*;
- the beam screen wall thickness, *c*;
- the slot width, *a*.

The baseline design parameters for the arcs are *ID* = 50 mm, *H* = 38.9 mm, *a* = 1.5 mm and *c* = 1.05 mm.

The objective of these estimations, beyond those pervious for a beam screen published in [1], was to check how the capture factor (*CF*) of the slots changes with their location. The results of the estimations of the *CF* for H_2 and CO for the different slot separation for the inner and outer rows are presented in Table 1. The baseline row separations are 10 mm and 18 mm, the alternative proposal was 15 mm and 23 mm [3]. The extreme separation of 27 mm is when the slot is placed at the edge of the flat part of a beam screen. The results are presented for three cases: (1) without SR, ions and/or electrons, (2) in presence of SR, (3) in presence of ions and/or electrons. The estimation with a wide slot (*a*=2mm) was performed to estimate the loss in pumping speed in the case if two slots rows with *a*=1.5mm compare with by one with *a*=2mm.

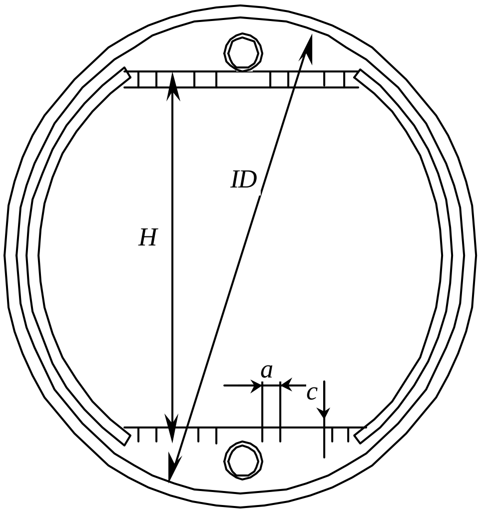

Figure 1. The actively cooled beam screen in the arcs

Table 1. The Capture Factor for the pumping slots in the arc beam screen inside a cold bore with and without synchrotron radiation (SR), ions and electrons for a sticking probability a(H2)=0.1 and a(CO)=1.

Slots position (mm)	Slots separation (mm)	Slots width (mm)	Capture Factor for H_2			Capture Factor for CO		
			no SR or ions	with SR	with ions or electrons	no SR or ions	with SR	with ions or electrons
The beam screen in the arcs								
Baseline	**10, 18**	***a*=1.5**	**0.61**	**0.53**	**0.61**	**0.76**	**0.66**	**0.74**
Wide	15	*a*=1.5	0.61	0.53	0.61	0.76	0.66	0.74
	23			0.51	0.58		0.63	0.73
	23	*a*=2.0	0.6	0.47	0.56	0.80	0.61	0.76
Extreme	27	*a*=1.5	0.52	0.45	0.52	0.76	0.56	0.73
	27	*a*=2.0	0.50	0.42	0.49	0.80	0.53	0.75

For all cases the *CF* and the pumping speed for H_2 is always less than for CO due to the lower sticking probability. The slots pumping speed is proportional to the capture factor and the slot width: $S \propto CF \cdot a$. For all studied slots the minimum pumping speed is in presence of reflected photons (column 'with SR'), the reduction of pumping speed is up to 20% comparing to the column 'no SR or ions'. The reduction of pumping speed by electrons or ions is much less (the columns and 'with ions or electrons').

One can see there are no significant difference in a pumping speed between the baseline slots separation (10 and 18 mm), the wider separation one (15 and 23 mm). The pumping speed of one 2-mm wide slot with a slot separation of 23 mm will have 59% of baseline design pumping speed and this figure is 53% for a slot separation of 27 mm.

3.2 A beam screen with baffles with a cold bore at T£3K

3.2.1 V-type baffles

One proposal is to have a simple screen to protect the cold bore against the electrons. Such a baffle could be made from a thin metal strip with V-shaped profile and welded between two rows of pumping slots. Since in a dipole magnetic field the electrons can move only along magnetic field lines the baffles should overlap the pumping slot. An overlap of 0.5 mm from each side was chosen for the estimations.

The simulation scheme is shown in Figure 2. The results of the estimations of the CF for H_2 and CO for the different angles of V's from horizontal position and slot separations are presented in Table 2.

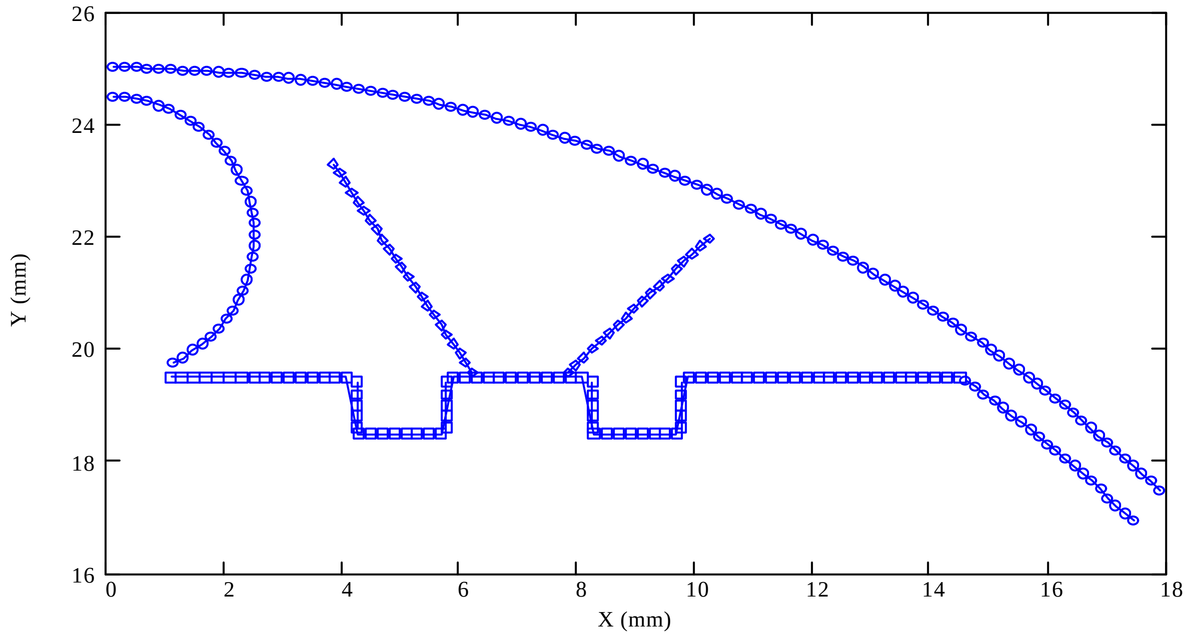

Figure 2. The actively cooled beam screen with V-type baffle

3.2.2 ▯-type baffles

Another proposal was also studied: to replace two rows of the pumping slots with one row with wider pumping slots, for example with a=2 mm, this simplifying the baffle shape.

The simulation scheme is shown in Figure 3. The results of the estimations of the capture factor for H_2 and CO for the different angles of V's and slots separation are presented in Table 2.

The same as without baffles there are no significant difference in a pumping speed between the baseline slots separation (10 and 18 mm) and the wider separation one (15 and 23 mm). The pumping speed of one 2-mm wide slot with a slot separation of 23 mm and /-type baffle will have 68% of pumping speed for the baseline design slot separations with V-type baffle.

By comparing results in Table 1 and Table 2 it can be concluded that, in presence of baffles, there is a reduction of pumping speed about 40%.

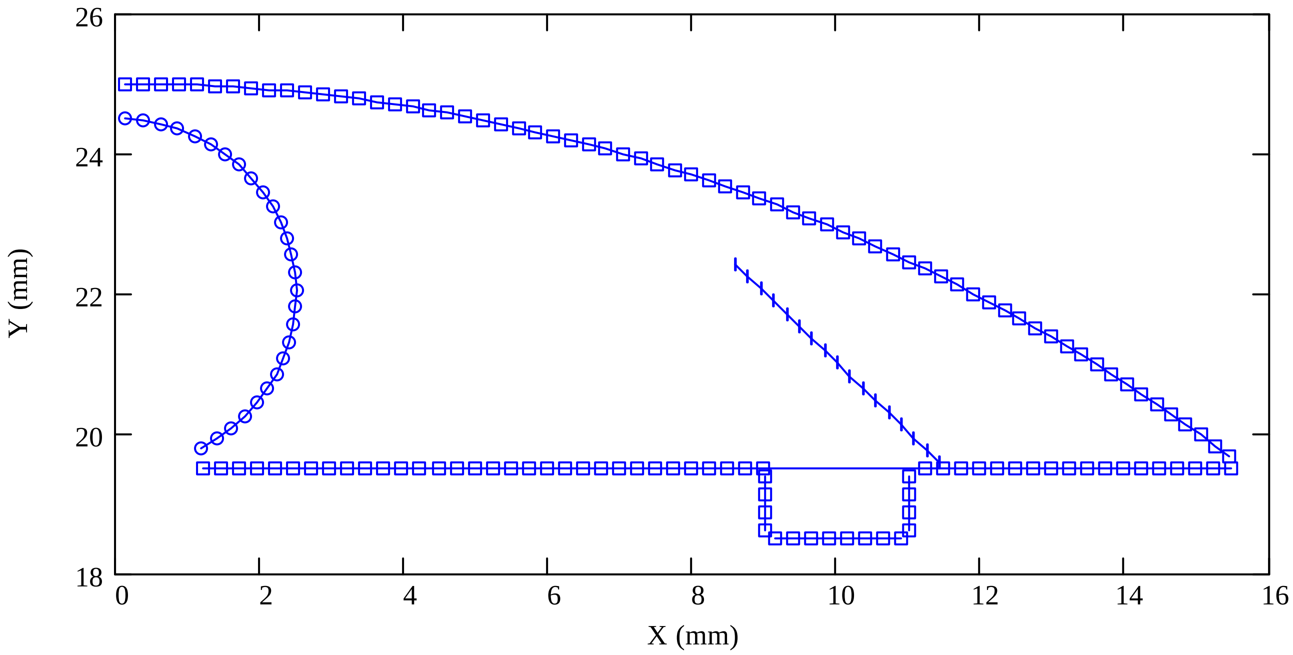

Figure 3. The actively cooled beam screen with a /-type baffle

Table 2. The Capture Factor for the pumping slots with baffles in the arc beam screen inside a cold bore with synchrotron radiation, ions and electrons for a sticking probability a(H2)=0.1 and a(CO)=1.

Baffle	Angles of baffles	Slots separation (mm)	Slots width *a*(mm)	Capture Factor for H_2	Capture Factor for CO
V-type	**45° and 45°**	**10 and 18**	**1.5**	**0.31**	**0.44**
	58° and 45°	**10 and 18**	**1.5**	**0.30**	**0.47**
	45° and 30°	15 and 23	1.5	0.28	0.43
	58° and 30°	15 and 23	1.5	0.28	0.47
/-type	50°	18	2.0	0.29	0.45
	50°	18	2.5	0.26	0.51
	40°	**23**	**2.0**	**0.32**	**0.50**
	40°	23	2.5	0.26	0.49

3.3 A beam screen with V-type baffles in a cold bore at T>3K.

In the Long Straight Sections there are cryogenic elements with a cold bore at T>3 K. The cold bore of these elements do not pump H_2 and a cryosorber is required. It looks very natural to place the cryosorber inside the 'V' of the baffle where the cryosorber is shielded against photons, electrons and ions. Another advantage of this is that the gases like CO, CO_2 and CH_4 will be mainly adsorbed on the outer walls of the beam screen or on the cold bore and so the cryosorber will have a higher capacity for pumping of H_2. Since the sticking probability of H_2 depends on cryosorbing material the estimations are made for two different sticking probability 0.1 and 1. The results of the estimations of the capture factor for H_2 and CO for the different angles of V's and slots separation are presented in Table 3. The best results for H_2 are for baseline design slot separation with 45° angles of baffles. Meanwhile it is only 43–55% of pumping speed without baffles.

Table 3. The CF for the pumping slots with V-type baffles and a cryosorber in a beam screen inside a cold bore with synchrotron radiation, ions and electrons for a sticking probability α(H2)=0.1, α(H2)=1 and α(CO)=1.

Angles of baffles	Slots separation (mm)	Capture Factor for H_2		Capture Factor for CO
		α=0.1	α=1	
30° and 30°	10 and 18	0.22	0.28	0.44
45° and 45°	**10 and 18**	**0.23**	**0.29**	**0.55**
58° and 45°	10 and 18	0.22	0.28	0.58
45° and 30°	15 and 23	0.19	0.26	0.49
58° and 30°	15 and 23	0.17	0.22	0.52

4 Conclusions

1. The estimation of capture factor for different slot row separations is presented.
2. The estimation of capture factor for slots with baffles shows the reduction of about 40% in the slot pumping speed.
3. In a vacuum chamber with a cold bore at T>3K the baffles loaded with a cryosorber will provide 43–55% of pumping speed estimated for a vacuum chamber with a cold bore at T≤3K without baffles.

References

1. O.B. Malyshev. The capture factor and pumping speed for slots in the LHC beam screen. Vacuum Technical Note 00-17, August 2000, CERN. - 20 p.
2. F. Zimmerman. Electron cloud simulations for SPS and LHC. Proc Chamonix 10, CERN-SL-2000-007-DI.
3 N. Kos. Private communication.