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Strategy for allocating the MSI magnets and vacuum chambers

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Abstract

The known aperture limits in the MSI septa, together with the magnet and vacuum chamber geometry measurement, allows an optimisation of the installation regarding magnet and chamber allocation. The improvements are small but significant, of the order of 0.4 mm from allocation of the magnets and 0.7 mm from sorting and orienting the chambers; however, these gains are essentially for free, and should be implemented, since the apertures in these magnets are tight.

1. Overall alignment constraints

- Each MSI magnet is aligned [1] in the vertical plane to follow the injected beam trajectory, Figure 1.
- Each MSI magnet is aligned in the horizontal plane to follow the circulating beam trajectory.
- The vacuum chambers for the injected beam are aligned to follow the horizontal beam trajectory, Figure 2.

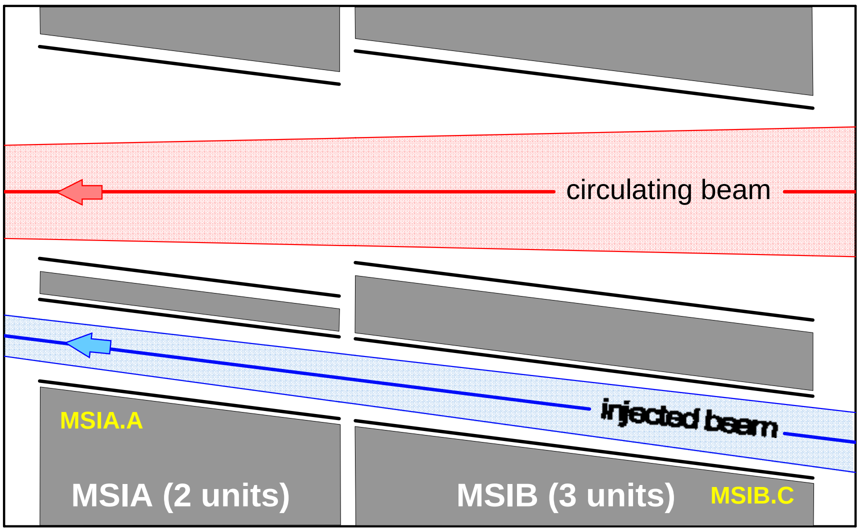

Figure 1. Vertical alignment of MSI septa

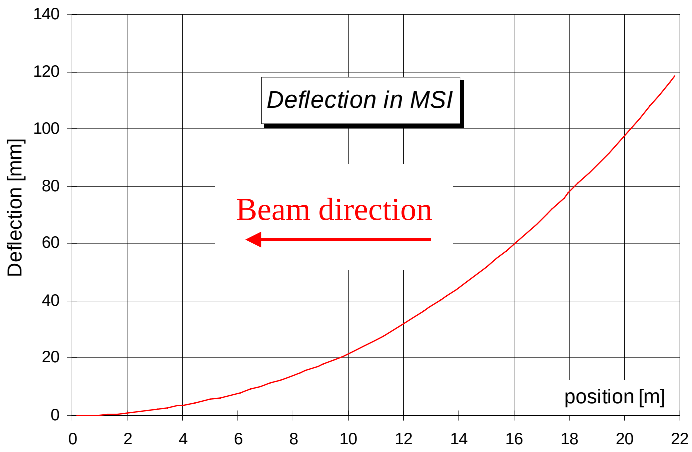

Figure 2. Horizontal trajectory in MSI septa

2. Aperture at limiting locations

2.1 Injected beam

The vertical aperture is the most critical, with this limiting location at the entrance to the first MSIB (in the injected beam direction), Figure 3.

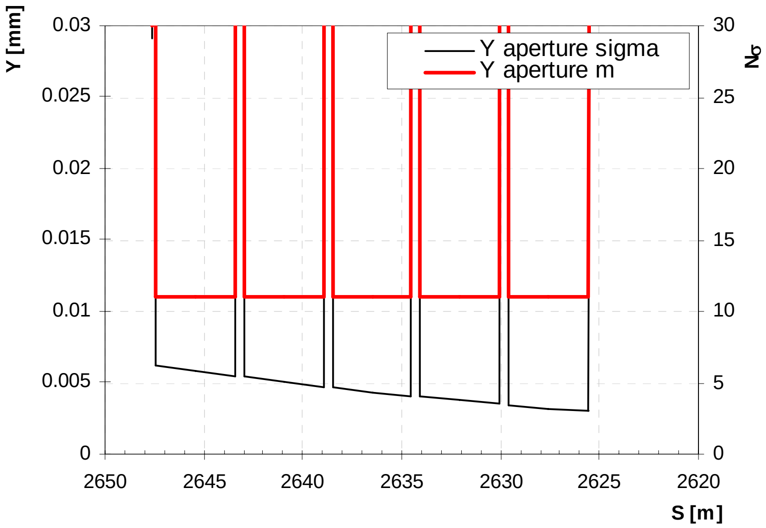

Figure 3. Aperture for injected beam in MSI (IR8 shown).

2.2 Circulating beam

For the circulating beam aperture, the calculated n_1 values [2] are given in Table 1 at the MSIA.A exit, the MSIB.A exit and the MSIB.C entrance (with entrance and exit always defined here in the sense of the injected beam), Figure 4.

Table 1. n_1 values for the circulating beam in the different locations and apertures

	MSIA.A	MSIA.B	MSIB.A	MSIB.B	MSIB.C
IR2. injected beam	9.1	>10	8.5	>10	8.7
IR2. non-injected beam	**7.3**	>10	8.8	>10	>10
IR8. non injected beam	**8.1**	>10	9.7	>10	>10
IR8. injected beam	8.5	>10	8.3	>10	9.0

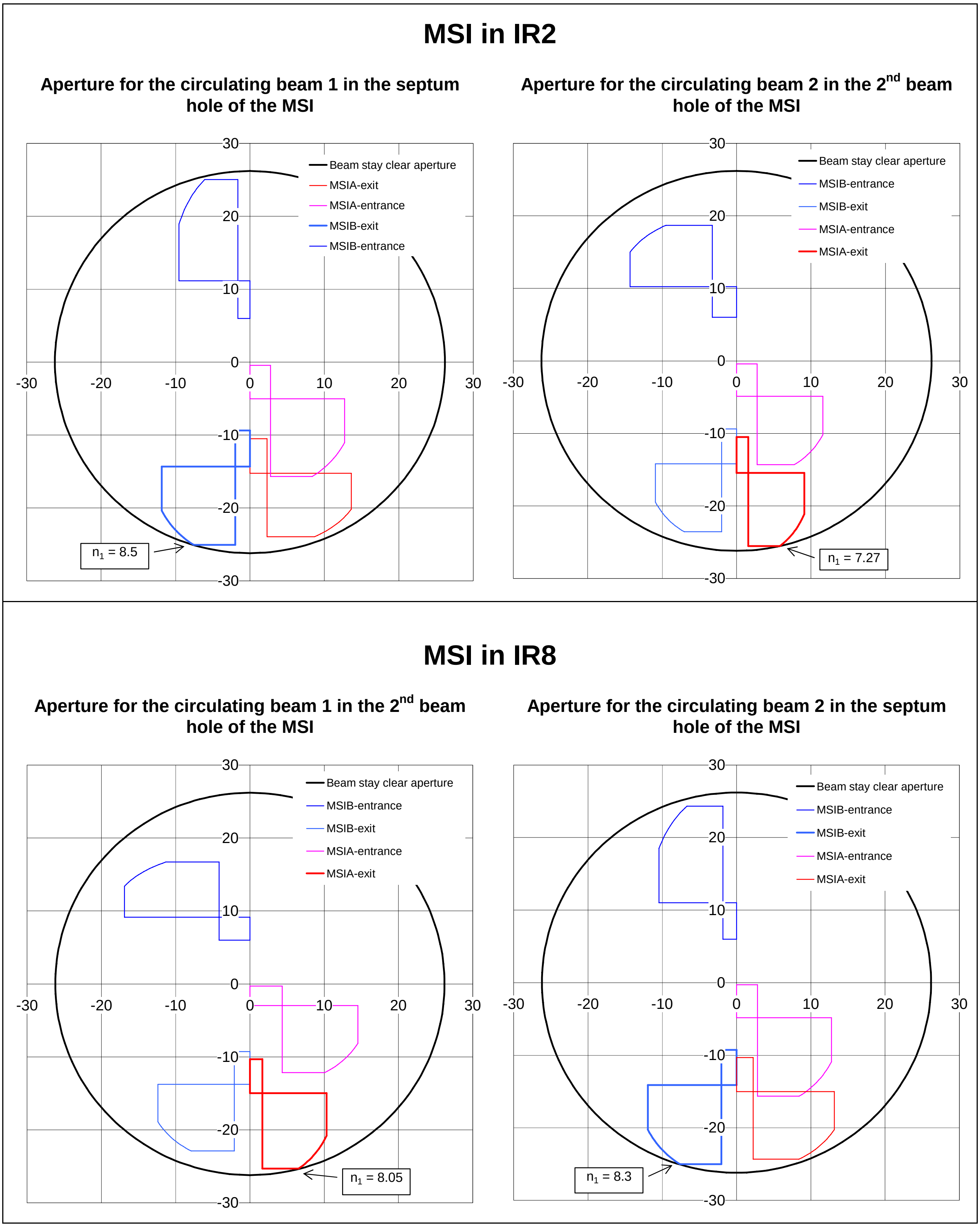

Figure 4. n_1 for the apertures at the MSIA.A exit and MSIA.B entrance, and at the MSIB.A exit and MSIB.C entrance, for beam 1 and beam 2 in IR2 and IR8 [2].

3. Circulating beam chamber measured geometry

3.1 Outer diameter and ovalisation

The measured chamber diameters [3] are extremely regular, with the distribution of minimum and maximum OD (measured at the two extremities) having mean values of 59.41 and 60.13 mm, with standard deviations of only 0.04 and 0.05 mm respectively, Figure 5. The spread in the actual values will be even smaller, since this figure includes the measurement error. Orientation of the chambers in the magnet with the larger axis in the preferred direction will therefore gain up to 0.68 mm in the available aperture.

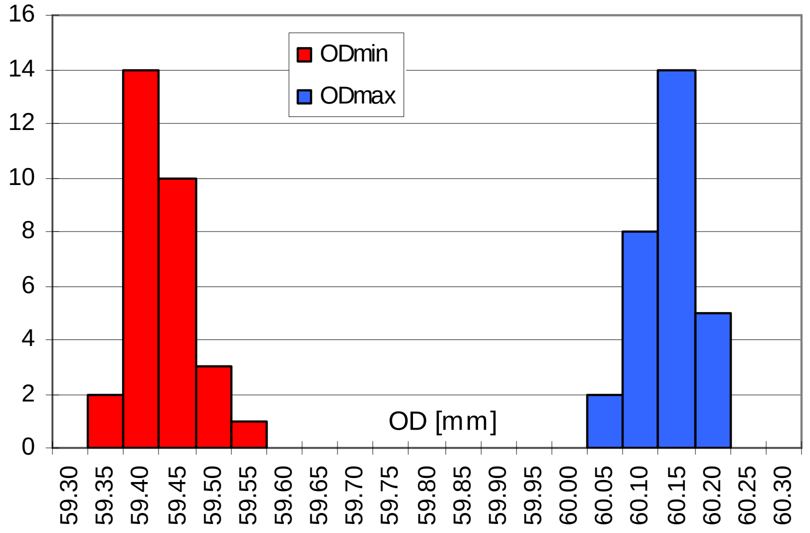

Figure 5. Distribution of chamber min OD and max OD.

3.2 Rectitude

The chambers show a large variation in the rectitude, with most chambers having a value of 0.5 or 1.0 mm over the total length. However, there are 4 'bad' chambers, with values of up to 4.0 mm, Figure 6. The mean is 1.3 mm and the standard deviation of 1.1 mm.

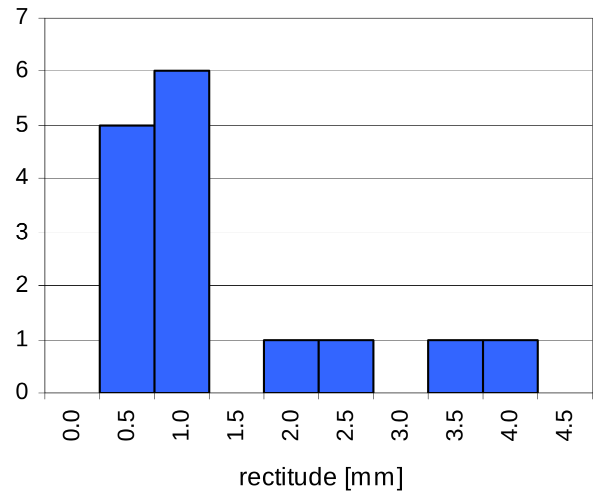

Figure 6. Distribution of measured chamber rectitude.

4. Magnet geometry

The magnets are measured horizontally and vertically, and the sagitta S_c determined as the full width of the envelope of measured positions with respect to the average centre line. Since the holes for the circulating beam are not in the centre of the magnet, Figure 7, but offset and amount Δ_b (85 mm and 279 mm), the maximum possible twist α_t of the magnet yoke and these offsets must also be taken into account when the maximum sagitta S_b is calculated for the beam apertures.

$$S_b = S_c + \alpha_t \times \Delta_b$$

The same argument holds for the injected beam – in this case the offset changes from -35 to +85 mm, since the injected beam deflection is 120 mm. For ease of calculation the offset is assumed to be 85 mm in all cases, for estimating the sagitta for the injected beam.

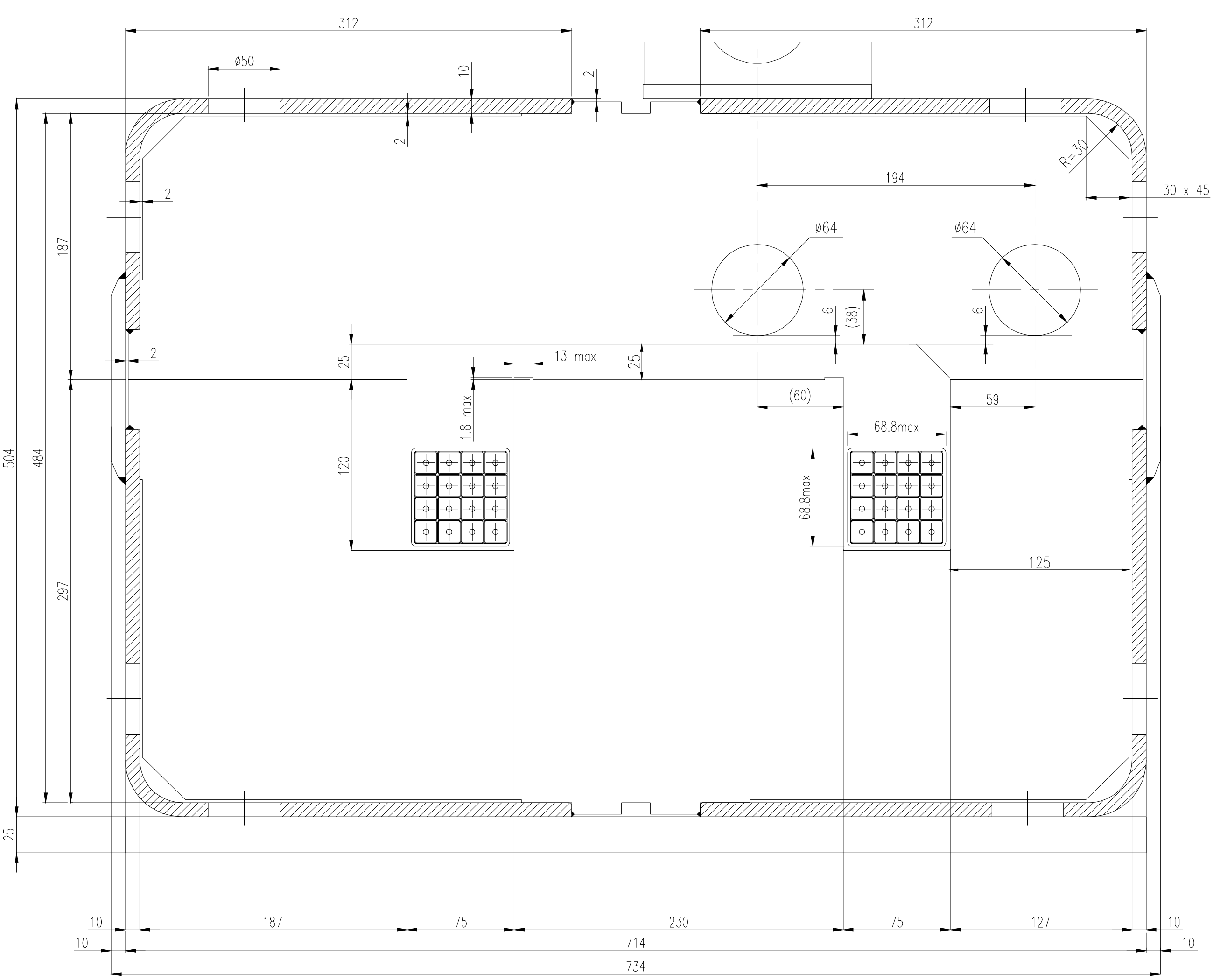

Figure 7. MSIA cross-section.

The measured sagitta and twists are given in Table 2, together with the vertical sagitta S_{bi} and S_{bni} calculated for the injected and non-injected circulating beam apertures, Figure 8. The vertical sagitta for the injected beam aperture is assumed to be equal to S_{bi}. Magnet MSIB06 is clearly anomalous regarding the twist.

Table 2. Measured sagitta and twist, with calculated max. sagitta at the beam aperture.

	twist [mrad]	Sc V. [mm]	Sc H. [mm]	Sbi V [mm]	Sbni V [mm]
MSIA03	0.36	0.26	0.05	0.29	0.36
MSIA02	0.36	0.29	0.05	0.32	0.39
MSIA01	0.83	0.22	0.16	0.29	0.45
MSIA05	0.48	0.34	0.05	0.38	0.47
MSIA04	0.99	0.37	0.15	0.46	0.65
MSIB02	0.30	0.26	0.15	0.28	0.34
MSIB05	0.36	0.34	0.07	0.37	0.44
MSIB04	0.71	0.32	0.12	0.38	0.52
MSIB01	0.48	0.36	0.04	0.40	0.49
MSIB03	0.66	0.40	0.10	0.46	0.58
MSIB07	0.27	0.69	0.10	0.71	0.76
MSIB06	**1.93**	0.48	0.13	0.65	**1.02**

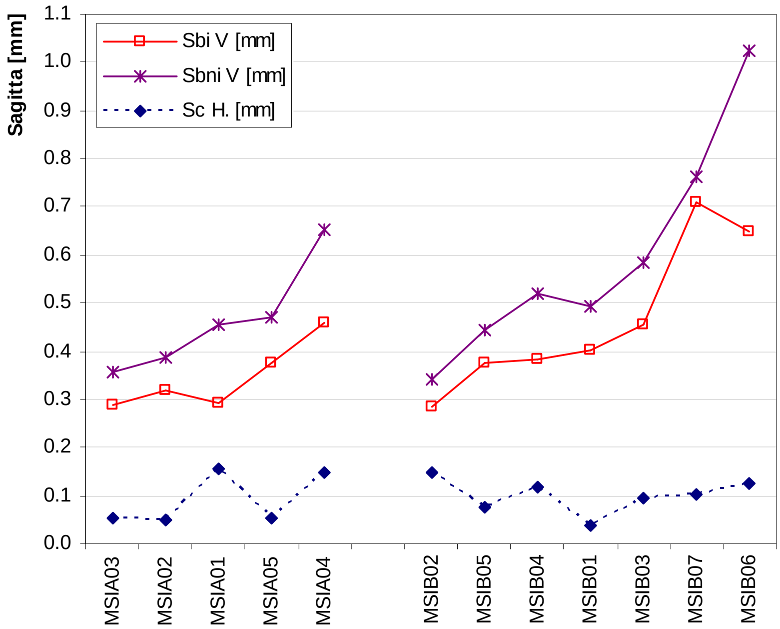

Figure 8. Calculated $S_{c\ H}$, $S_{bi\ V}$ and $S_{bni\ V}$ for the MSI magnets.

5. Magnet and chamber allocation

To allocate the magnets and chambers using the above data, the following method has been applied. The resulting allocations are in Table 3, for magnets and chambers.

- The two MSIB with smallest Sbi are allocated to slots C.IR2 and C.IR8.
- The two MSIA with smallest Sbni are allocated to slot A.IR2 and A.IR8.
- The two remaining MSIB with smallest sum (Sbi + Sbni) are allocated to slots A.IR2 and A.IR8.
- The MSIA and MSIB with the worst calculated Sbi are kept as spares.
- The circulating beam chambers are sorted with regard to the rectitude, with the best installed in the most critical locations. They are not sorted with respect to the measured ID, since the spread in this is very small.
- The circulating beam chambers are installed with the orientation of the ovalisation such that the vertical aperture is maximised.

Table 3. MSI allocation and vacuum chamber choice for circulating beam apertures.

Location	nσ inj	n1 inj	n1 non inj	# cham inj	# cham non inj	Magnet #	Sbi [mm]	Sbni [mm]
IR2.MSIA.A	5.5	9.1	7.3	# 9	# 6	MSIA03	0.29	0.36
IR2.MSIA.B	4.7	>10	>10	any	any	MSIA01	0.29	0.45
IR8.MSIA.A	6.1	8.5	8.1	# 2	# 8	MSIA02	0.32	0.39
IR8.MSIA.B	5.0	>10	>10	any	any	MSIA05	0.38	0.47
MSIA spare				any	any	MSIA04	0.46	0.65
IR2.MSIB.A	4.1	8.5	8.8	# 18	# 70	MSIB04	0.38	0.52
IR2.MSIB.B	3.5	>10	>10	any	any	MSIB03	0.46	0.58
IR2.MSIB.C	3.0	8.7	>10	# 7	any	MSIB02	0.28	0.34
IR8.MSIB.A	4.2	8.3	9.7	# 5	# 63	MSIB01	0.40	0.49
IR8.MSIB.B	3.5	>10	>10	any	any	MSIB07	0.71	0.76
IR8.MSIB.C	2.9	9.0	>10	# 13	any	MSIB05	0.37	0.44
MSIB spare				any	any	MSIB06	0.65	1.02

6. Injected beam chambers

The injected beam chambers should be measured, with particular attention paid to the vertical aperture; the chambers can be sorted on this basis to match the nσ for the injected beam given in Table 3.

7. Spare policy

The spare magnets have the worst geometry and so will reduce the aperture if they need to be installed in the limiting locations – however, 1 additional MSIA and 2 more MSIB are being built, and should have geometries which are better than these extreme cases.

8. Chamber metrology

Metrology on the remaining chambers should be carried out, to make sure that the chambers are all within specification and can be used in the non-critical locations, and to determine the ovalisation plane. Presently only 15 of 71 chambers have been measured.

9. Summary

The simple measures described in this document allow approximately 1 mm to be gained on the aperture available for the circulating beam in the MSI septa.

10. References

[1] M. Gyr, "Alignment of injection (MSI) and extraction septa (MSD)", LHC-MS-ES-0001 rev 1.1, EDMS 488061, 2004.

[2] M. Gyr, minutes of the Injection Working Group meeting on 28 July 2004, http://cern.ch/lhc-injwg/Minutes/20040728/InjWG04_05.htm.

[3] J. Scalet, "Contrôle dimensionnel statistique de chambres en Mumétal, origine Spécitubes-Vallourec", Certificat de Contrôle, EDMS 494516, 2004