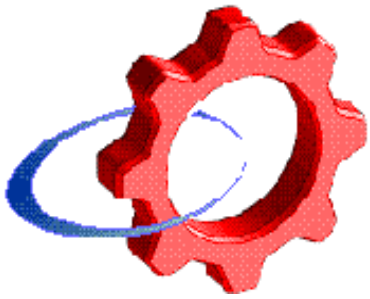

Technical Note
EST-ESI/99-08

THE COMPASS RICH-1 MIRROR WALL GEOMETRY

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CERN-EST

Abstract

The mirror wall of the Compass Rich-1 detector is made of two parts. Each part has sixty sub-mirrors put together side by side to make a continuous spherical surface This technical note presents the calculation of the sub-mirror and hexagon positions relative to their spherical centre.

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1. INTRODUCTION

Compass is a fixed target experiment at CERN SPS designed to perform third generation polarised deep inelastic scattering measurements and hadron spectroscopy studies. The apparatus consists of two consecutive spectrometers, both equipped with a RICH (**R**ing **I**maging **C**herenkov Detector) detector. RICH-1 is one of these two detectors.

The mirror wall, located inside the RICH-1 vessel, consists of spherical mirrors radius 6.6 m, segmented into 120 hexagonal pieces covering a total area larger than 20 m2 forming two spherical surfaces with different centres of curvature. The mirrors are fixed onto an aluminium grid. The mesh grid is also of hexagonal shape and each mirror is fixed to the centre of the corresponding mesh grid.

This note describes the details of the calculation made in order to compute the positions of the mirror centres and their corresponding hexagonal supports .

2. MIRROR WALL DESCRIPTION

As one can see in Fig.1 although the two spherical surfaces are identical, they are not covered in same way by the mirrors. The mirror arrangement of the lower sphere is turned by 2 degrees around the vertical axis.

The arc length between two mirror centres, measured on the equator circle (or on all great circles), corresponds to an angle of 4 degrees

The radius of both mirror spheres is 6.6 metres. The radius of the hexagon spheres was set to 6.67 metres after the mechanical design.

The vertical distance between the two sphere centres is specified as 3.2 metres.

3. COORDINATE FRAMES.

For each sphere, one coordinate frame is defined as follows:

Origin at the sphere centre, Oz axis vertical upwards, Ox belongs to the vertical symmetry plane of the spheres and Oy perpendicular to zOx plane.

For spherical coordinates, the theta angle is measured from Oz axis towards the polar vector while the phi angle is measured from Ox axis towards the projection of the polar vector onto the xOy plane.

The mirror centre coordinates will be computed in two stages:

- 1^{st} stage : the sphere equator circle is on xOy plane.
- 2^{nd} stage : rotation of the upper mirror centres by 5.15º (downwards) about the Oy axis and -5.15º (upwards) for the lower ones. These angle values were selected to optimise the mirror coverage whilst avoiding interference between the two hexagon grids

The mirror centres have been numbered as shown in Fig. 1.

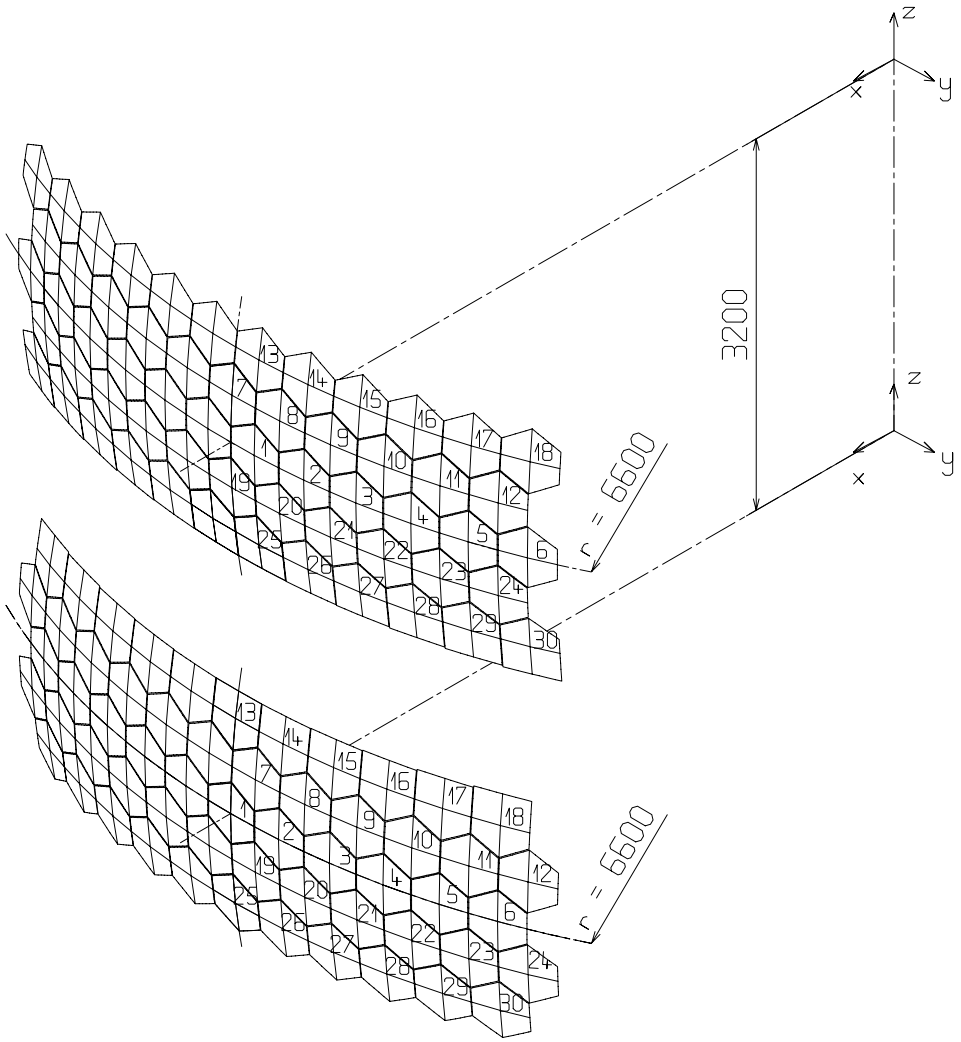

Figure 1: Mirror position : 1st stage

4. THE MIRROR SPHERE COORDINATES

4.1 Spherical coordinates:

4.1.1 φ–coordinate

The φ–coordinate of any mirror centre can easily be recovered by applying the following relation :

$$\varphi_{(n+1)} = \varphi_{(n)} + 4^{o}$$

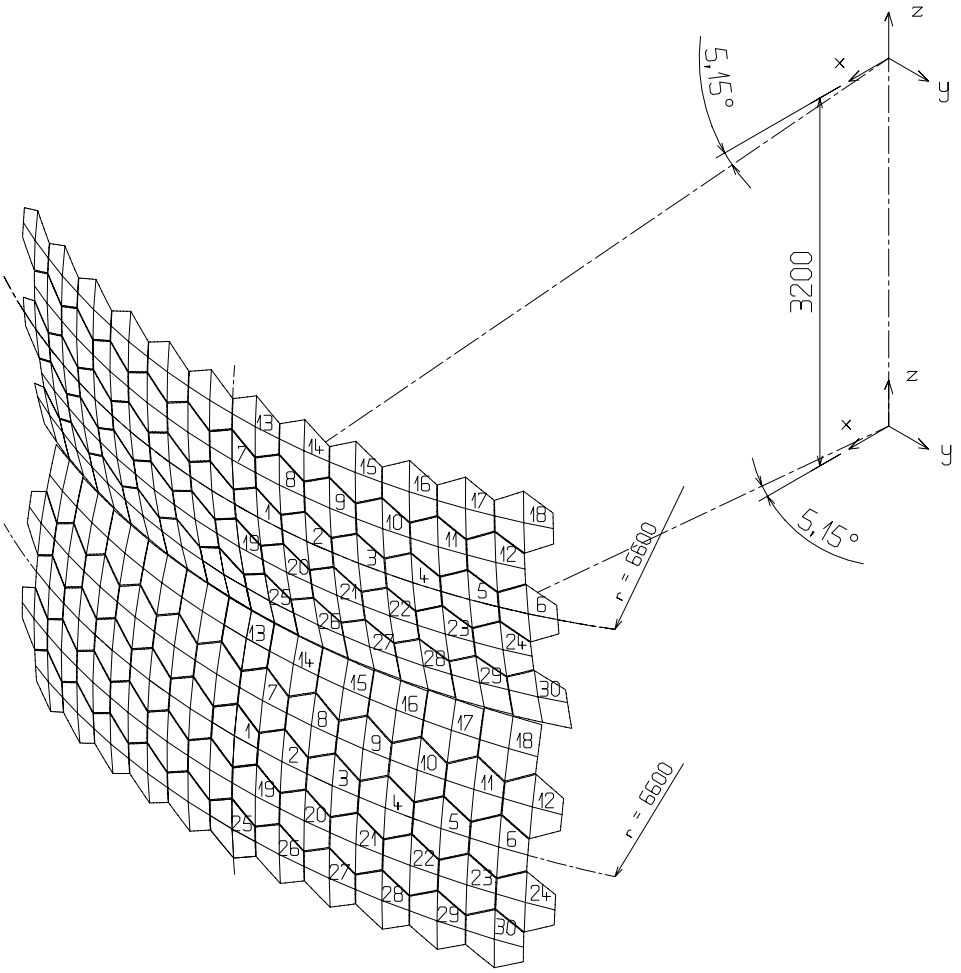

Figure 2: Mirror position : 2nd stage

Note:: this relation is only valid when the sphere equator circle is on the xOy plane .

The first mirror centres considered can be located either on the vertical symmetry plane, i.e. $\varphi_{(n)}=0$,or shifted by two degrees from the symmetry plane, thus $\varphi_{(n)}=2.^{o}$

4.1.2 θ–coordinate

We consider only the first six mirror centres located on the equator circle of each sphere. They have the same θ-coordinate:

$$\theta_{(1\to 6)} = 90^{o}$$

Let us consider now the upper sphere. For the second row,(from number 7 to 12), we only know that the angle at centre of the arc length between two mirror centres located on a great circle of the sphere is equal to $2\alpha = 4°$. If we consider the spherical right angled triangle with the points (R,0,0) and mirror centres n°1 and 7 as vertices, (see Fig 1) the following relation could

be used to calculate the θ -coordinate of the mirror centre n° 7; the value obtained is also the θ-coordinate of all the mirror centres of the row.

$$\theta_{(7)} = \cos^{-1}(tg\alpha\sqrt{4\cos^2\alpha - 1})$$

This formula can also be used for the third row provided that 2α =8°.

Once these values have been calculated for the three rows of each sphere, it is only necessary to apply the evident symmetry conditions on both θ and φ coordinates to find all the remaining mirror centres spherical coordinates.

Thus the first stage is finished. These values are listed in Table 1 and 2.

Now, it remains to put the mirrors in their final place; this will be executed in the second stage which consists of rotating the upper mirror centres by 5.15° around Oy, and by -5.15° for the lower ones.

This operation will be applied to the Cartesian coordinates of the mirror centres.

4.2 Cartesian Coordinates

Once spherical coordinates (ρ,θ,φ) are known, Cartesian ones can be calculated from the following classical set of equations:

$$x_{(n)} = \rho\sin\theta_{(n)}\cos\varphi_{(n)}$$
$$y_{(n)} = \rho\sin\theta_{(n)}\sin\varphi_{(n)}$$
$$z_{(n)} = \rho\cos\theta_{(n)}$$

These values have been computed and they are also listed in Table 1 and 2. for the right half spheres, remaining values can be easily found taking the opposite of either φ or y-coordinates.

	spherical coordinates					Cartesian coordinates		
centre number	ρ[mm]	θ [deg]	θ[rad]	ϕ [deg]	ϕ[rad]	x	y	z
1	6600.000	90.00000	1.57080	2.00000	0.03491	6595.979	230.337	0.000
2	6600.000	90.00000	1.57080	6.00000	0.10472	6563.845	689.888	0.000
3	6600.000	90.00000	1.57080	10.00000	0.17453	6499.731	1146.078	0.000
4	6600.000	90.00000	1.57080	14.00000	0.24435	6403.952	1596.685	0.000
5	6600.000	90.00000	1.57080	18.00000	0.31416	6276.973	2039.512	0.000
6	6600.000	90.00000	1.57080	22.00000	0.38397	6119.413	2472.404	0.000
7	6600.000	86.53519	1.51032	0.00000	0.00000	6587.936	0.000	398.874
8	6600.000	86.53519	1.51032	4.00000	0.06981	6571.888	459.551	398.874
9	6600.000	86.53519	1.51032	8.00000	0.13963	6523.823	916.863	398.874
10	6600.000	86.53519	1.51032	12.00000	0.20944	6443.974	1369.709	398.874
11	6600.000	86.53519	1.51032	16.00000	0.27925	6332.730	1815.881	398.874
12	6600.000	86.53519	1.51032	20.00000	0.34907	6190.635	2253.207	398.874
13	6600.000	83.06615	1.44978	2.00000	0.03491	6547.738	228.652	796.773
14	6600.000	83.06615	1.44978	6.00000	0.10472	6515.838	684.842	796.773
15	6600.000	83.06615	1.44978	10.00000	0.17453	6452.193	1137.696	796.773
16	6600.000	83.06615	1.44978	14.00000	0.24435	6357.115	1585.007	796.773
17	6600.000	83.06615	1.44978	18.00000	0.31416	6231.064	2024.596	796.773
18	6600.000	83.06615	1.44978	22.00000	0.38397	6074.657	2454.321	796.773
19	6600.000	86.53519	1.51032	0.00000	0.00000	6587.936	0.000	-398.874
20	6600.000	86.53519	1.51032	4.00000	0.06981	6571.888	459.551	-398.874
21	6600.000	86.53519	1.51032	8.00000	0.13963	6523.823	916.863	-398.874
22	6600.000	86.53519	1.51032	12.00000	0.20944	6443.974	1369.709	-398.874
23	6600.000	86.53519	1.51032	16.00000	0.27925	6332.730	1815.881	-398.874
24	6600.000	86.53519	1.51032	20.00000	0.34907	6190.635	2253.207	-398.874
25	6600.000	83.06615	1.44978	2.00000	0.03491	6547.738	228.652	-796.773
26	6600.000	83.06615	1.44978	6.00000	0.10472	6515.838	684.842	-796.773
27	6600.000	83.06615	1.44978	10.00000	0.17453	6452.193	1137.696	-796.773
28	6600.000	83.06615	1.44978	14.00000	0.24435	6357.115	1585.007	-796.773
29	6600.000	83.06615	1.44978	18.00000	0.31416	6231.064	2024.596	-796.773
30	6600.000	83.06615	1.44978	22.00000	0.38397	6074.657	2454.321	-796.773

Table 1: Coordinates of upper mirror centres

	spherical coordinates					Cartesian coordinates		
centre number	ρ[mm]	θ [deg]	θ[rad]	ϕ [deg]	ϕ[rad]	x	y	z
1	6600.000	90.00000	1.57080	0.00000	0.00000	6600.000	0.000	0.000
2	6600.000	90.00000	1.57080	4.00000	0.06981	6583.923	460.393	0.000
3	6600.000	90.00000	1.57080	8.00000	0.13963	6535.769	918.542	0.000
4	6600.000	90.00000	1.57080	12.00000	0.20944	6455.774	1372.217	0.000
5	6600.000	90.00000	1.57080	16.00000	0.27925	6344.327	1819.207	0.000
6	6600.000	90.00000	1.57080	20.00000	0.34907	6201.971	2257.333	0.000
7	6600.000	86.53519	1.51032	2.00000	0.03491	6583.923	229.916	398.874
8	6600.000	86.53519	1.51032	6.00000	0.10472	6551.847	688.627	398.874
9	6600.000	86.53519	1.51032	10.00000	0.17453	6487.850	1143.983	398.874
10	6600.000	86.53519	1.51032	14.00000	0.24435	6392.246	1593.766	398.874
11	6600.000	86.53519	1.51032	18.00000	0.31416	6265.499	2035.784	398.874
12	6600.000	86.53519	1.51032	22.00000	0.38397	6108.228	2467.884	398.874
13	6600.000	83.06615	1.44978	0.00000	0.00000	6551.729	0.000	796.773
14	6600.000	83.06615	1.44978	4.00000	0.06981	6535.769	457.026	796.773
15	6600.000	83.06615	1.44978	8.00000	0.13963	6487.968	911.824	796.773
16	6600.000	83.06615	1.44978	12.00000	0.20944	6408.558	1362.181	796.773
17	6600.000	83.06615	1.44978	16.00000	0.27925	6297.926	1805.901	796.773
18	6600.000	83.06615	1.44978	20.00000	0.34907	6156.611	2240.823	796.773
19	6600.000	86.53519	1.51032	2.00000	0.03491	6583.923	229.916	-398.874
20	6600.000	86.53519	1.51032	6.00000	0.10472	6551.847	688.627	-398.874
21	6600.000	86.53519	1.51032	10.00000	0.17453	6487.850	1143.983	-398.874
22	6600.000	86.53519	1.51032	14.00000	0.24435	6392.246	1593.766	-398.874
23	6600.000	86.53519	1.51032	18.00000	0.31416	6265.499	2035.784	-398.874
24	6600.000	86.53519	1.51032	22.00000	0.38397	6108.228	2467.884	-398.874
25	6600.000	83.06615	1.44978	0.00000	0.00000	6551.729	0.000	-796.773
26	6600.000	83.06615	1.44978	4.00000	0.06981	6535.769	457.026	-796.773
27	6600.000	83.06615	1.44978	8.00000	0.13963	6487.968	911.824	-796.773
28	6600.000	83.06615	1.44978	12.00000	0.20944	6408.558	1362.181	-796.773
29	6600.000	83.06615	1.44978	16.00000	0.27925	6297.926	1805.901	-796.773
30	6600.000	83.06615	1.44978	20.00000	0.34907	6156.611	2240.823	-796.773

Table 2: Coordinates of lower mirror centres

5. TRUE COORDINATES OF THE MIRROR CENTRES IN THE RICH-1.

Once the Cartesian coordinates are available, one can apply, in a classical way, a rotation operator in order to put the mirror spheres in their final position.

Let us name X,Y,Z the new coordinates , they can be calculated from :

$$\begin{pmatrix} X \\ Y \\ Z \end{pmatrix} = \begin{bmatrix} \cos\beta & 0 & \sin\beta \\ 0 & 1 & 0 \\ -\sin\beta & 0 & \cos\beta \end{bmatrix} \begin{pmatrix} x \\ y \\ z \end{pmatrix}$$

with β=5.15° for the upper sphere and –5.15° for the lower one.

If we wish to know the corresponding spherical coordinates, the following

$$\rho = \sqrt{X^2 + Y^2 + Z^2}$$

$$\theta = \cos^{-1} \frac{Z}{\sqrt{X^2 + Y^2 + Z^2}}$$

$$\varphi = tg^{-1} \frac{Y}{X}$$

formulas shall be applied :

These relations have been used for computing the coordinates of the final location of all the mirrors and are listed in Table 3 and 4.

	spherical coordinates					Cartesian coordinates		
centre number	ρ[mm]	θ [deg]	θ[rad]	ϕ [deg]	ϕ[rad]	X	Y	Z
1	6600.000	95.14685	1.66063	2.00810	0.03505	6569.352	230.337	-592.078
2	6600.000	95.12171	1.66019	6.02414	0.10514	6537.347	689.888	-589.193
3	6600.000	95.07155	1.65931	10.03971	0.17523	6473.492	1146.078	-583.438
4	6600.000	94.99663	1.65800	14.05450	0.24530	6378.100	1596.685	-574.841
5	6600.000	94.89731	1.65627	18.06823	0.31535	6251.634	2039.512	-563.443
6	6600.000	94.77409	1.65412	22.08062	0.38538	6094.710	2472.404	-549.300
7	6600.000	91.68519	1.60021	0.00000	0.00000	6597.145	0.000	-194.092
8	6600.000	91.67268	1.59999	3.99438	0.06972	6581.162	459.551	-192.652
9	6600.000	91.63521	1.59934	7.98856	0.13943	6533.291	916.863	-188.337
10	6600.000	91.57297	1.59825	11.98232	0.20913	6453.764	1369.709	-181.170
11	6600.000	91.48625	1.59674	15.97549	0.27882	6342.970	1815.881	-171.184
12	6600.000	91.37549	1.59480	19.96788	0.34851	6201.448	2253.207	-158.429
13	6600.000	88.21304	1.53961	1.98633	0.03467	6592.826	228.652	205.809
14	6600.000	88.18817	1.53917	5.95895	0.10400	6561.055	684.842	208.673
15	6600.000	88.13855	1.53831	9.93141	0.17334	6497.668	1137.696	214.386
16	6600.000	88.06442	1.53701	13.90364	0.24266	6402.973	1585.007	222.920
17	6600.000	87.96614	1.53530	17.87554	0.31199	6277.432	2024.596	234.235
18	6600.000	87.84417	1.53317	21.84705	0.38130	6121.656	2454.321	248.275
19	6600.000	98.61481	1.72115	0.00000	0.00000	6525.537	0.000	-988.620
20	6600.000	98.60216	1.72093	4.03818	0.07048	6509.554	459.551	-987.179
21	6600.000	98.56428	1.72027	8.07592	0.14095	6461.682	916.863	-982.864
22	6600.000	98.50136	1.71917	12.11282	0.21141	6382.156	1369.709	-975.697
23	6600.000	98.41372	1.71764	16.14844	0.28184	6271.362	1815.881	-965.711
24	6600.000	98.30180	1.71569	20.18242	0.35225	6129.840	2253.207	-952.956
25	6600.000	102.08066	1.78164	2.03035	0.03544	6449.784	228.652	-1381.305
26	6600.000	102.05524	1.78120	6.09077	0.10630	6418.013	684.842	-1378.441
27	6600.000	102.00454	1.78032	10.15037	0.17716	6354.626	1137.696	-1372.728
28	6600.000	101.92880	1.77899	14.20861	0.24799	6259.930	1585.007	-1364.194
29	6600.000	101.82843	1.77724	18.26497	0.31878	6134.389	2024.596	-1352.879
30	6600.000	101.70393	1.77507	22.31897	0.38954	5978.613	2454.321	-1338.839

Table 3: Final coordinates of upper mirror centres

	spherical coordinates					Cartesian coordinates		
centre number	ρ[mm]	θ [deg]	θ[rad]	ϕ [deg]	ϕ[rad]	X	Y	Z
1	6600.000	84.85000	1.48091	0.00000	0.00000	6573.357	0.000	592.439
2	6600.000	84.86258	1.48113	4.01616	0.07010	6557.344	460.393	590.996
3	6600.000	84.90025	1.48179	8.03200	0.14018	6509.385	918.542	586.673
4	6600.000	84.96283	1.48288	12.04722	0.21026	6429.713	1372.217	579.493
5	6600.000	85.05001	1.48440	16.06151	0.28033	6318.716	1819.207	569.489
6	6600.000	85.16135	1.48635	20.07460	0.35037	6176.935	2257.333	556.710
7	6600.000	81.38836	1.42049	2.01912	0.03524	6521.540	229.916	988.259
8	6600.000	81.41364	1.42094	6.05713	0.10572	6489.593	688.627	985.380
9	6600.000	81.46407	1.42182	10.09450	0.17618	6425.855	1143.983	979.636
10	6600.000	81.53940	1.42313	14.13081	0.24663	6330.637	1593.766	971.054
11	6600.000	81.63924	1.42487	18.16566	0.31705	6204.402	2035.784	959.677
12	6600.000	81.76309	1.42704	22.19868	0.38744	6047.765	2467.884	945.559
13	6600.000	77.91615	1.35989	0.00000	0.00000	6453.759	0.000	1381.663
14	6600.000	77.92887	1.36012	4.06063	0.07087	6437.864	457.026	1380.230
15	6600.000	77.96696	1.36078	8.12071	0.14173	6390.256	911.824	1375.940
16	6600.000	78.03022	1.36188	12.17969	0.21258	6311.166	1362.181	1368.811
17	6600.000	78.11834	1.36342	16.23706	0.28339	6200.981	1805.901	1358.881
18	6600.000	78.23084	1.36539	20.29230	0.35417	6060.237	2240.823	1346.196
19	6600.000	88.31793	1.54144	1.99720	0.03486	6593.148	229.916	193.732
20	6600.000	88.34294	1.54188	5.99151	0.10457	6561.202	688.627	190.853
21	6600.000	88.39283	1.54275	9.98550	0.17428	6497.464	1143.983	185.108
22	6600.000	88.46736	1.54405	13.97899	0.24398	6402.246	1593.766	176.527
23	6600.000	88.56616	1.54577	17.97179	0.31367	6276.011	2035.784	165.149
24	6600.000	88.68875	1.54791	21.96374	0.38334	6119.374	2467.884	151.032
25	6600.000	91.78385	1.60193	0.00000	0.00000	6596.801	0.000	-205.451
26	6600.000	91.79629	1.60215	3.97265	0.06934	6580.906	457.026	-206.884
27	6600.000	91.83356	1.60280	7.94520	0.13867	6533.298	911.824	-211.174
28	6600.000	91.89547	1.60388	11.91756	0.20800	6454.208	1362.181	-218.303
29	6600.000	91.98173	1.60538	15.88963	0.27733	6344.023	1805.901	-228.233
30	6600.000	92.09192	1.60731	19.86134	0.34665	6203.279	2240.823	-240.918

Table 4: Final coordinnates of lower mirror centres

6. CLEARANCE BETWEEN MIRROR SIDES

The clearance between mirrors can be calculated with the following relation by setting $2\alpha=4°$:

$$d = 2\alpha R \sin\theta - w$$

As the mirror width has been set to w=452 mm, hence :

- At the equator level d=8.76 mm
- At the 1st row level d=7.92 mm
- At the 2nd row level d=5.39 mm

7. THE HEXAGON GRID MESH COORDINATES

The two following tables list the mesh grid centre coordinates. They have been calculated in the same way as for mirrors except that the sphere radius has been set to 6.67 m. These values shall be used for the design of the jig needed for hexagon mesh assembly.

	spherical coordinates					Cartesian coordinates		
centre number	ρ[mm]	θ [deg]	θ[rad]	ϕ [deg]	ϕ[rad]	x	y	z
1	6670.000	90.00000	1.57080	2.00000	0.03491	6665.937	232.780	0.000
2	6670.000	90.00000	1.57080	6.00000	0.10472	6633.461	697.205	0.000
3	6670.000	90.00000	1.57080	10.00000	0.17453	6568.668	1158.233	0.000
4	6670.000	90.00000	1.57080	14.00000	0.24435	6471.872	1613.619	0.000
5	6670.000	90.00000	1.57080	18.00000	0.31416	6343.547	2061.143	0.000
6	6670.000	90.00000	1.57080	22.00000	0.38397	6184.316	2498.626	0.000
7	6670.000	86.53519	1.51032	0.00000	0.00000	6657.808	0.000	403.104
8	6670.000	86.53519	1.51032	4.00000	0.06981	6641.590	464.425	403.104
9	6670.000	86.53519	1.51032	8.00000	0.13963	6593.015	926.588	403.104
10	6670.000	86.53519	1.51032	12.00000	0.20944	6512.319	1384.236	403.104
11	6670.000	86.53519	1.51032	16.00000	0.27925	6399.896	1835.141	403.104
12	6670.000	86.53519	1.51032	20.00000	0.34907	6256.293	2277.104	403.104
13	6670.000	83.06615	1.44978	2.00000	0.03491	6617.184	231.077	805.224
14	6670.000	83.06615	1.44978	6.00000	0.10472	6584.945	692.106	805.224
15	6670.000	83.06615	1.44978	10.00000	0.17453	6520.626	1149.762	805.224
16	6670.000	83.06615	1.44978	14.00000	0.24435	6424.539	1601.817	805.224
17	6670.000	83.06615	1.44978	18.00000	0.31416	6297.152	2046.069	805.224
18	6670.000	83.06615	1.44978	22.00000	0.38397	6139.085	2480.352	805.224
19	6670.000	86.53519	1.51032	0.00000	0.00000	6657.808	0.000	-403.104
20	6670.000	86.53519	1.51032	4.00000	0.06981	6641.590	464.425	-403.104
21	6670.000	86.53519	1.51032	8.00000	0.13963	6593.015	926.588	-403.104
22	6670.000	86.53519	1.51032	12.00000	0.20944	6512.319	1384.236	-403.104
23	6670.000	86.53519	1.51032	16.00000	0.27925	6399.896	1835.141	-403.104
24	6670.000	86.53519	1.51032	20.00000	0.34907	6256.293	2277.104	-403.104
25	6670.000	83.06615	1.44978	2.00000	0.03491	6617.184	231.077	-805.224
26	6670.000	83.06615	1.44978	6.00000	0.10472	6584.945	692.106	-805.224
27	6670.000	83.06615	1.44978	10.00000	0.17453	6520.626	1149.762	-805.224
28	6670.000	83.06615	1.44978	14.00000	0.24435	6424.539	1601.817	-805.224
29	6670.000	83.06615	1.44978	18.00000	0.31416	6297.152	2046.069	-805.224
30	6670.000	83.06615	1.44978	22.00000	0.38397	6139.085	2480.352	-805.224

Table 5: Upper hexagon centre coordinates

	spherical coordinates					Cartesian coordinates		
centre number	ρ[mm]	θ [deg]	θ[rad]	ϕ [deg]	ϕ[rad]	x	y	z
1	6670.000	90.00000	1.57080	0.00000	0.00000	6670.000	0.000	0.000
2	6670.000	90.00000	1.57080	4.00000	0.06981	6653.752	465.276	0.000
3	6670.000	90.00000	1.57080	8.00000	0.13963	6605.088	928.285	0.000
4	6670.000	90.00000	1.57080	12.00000	0.20944	6524.244	1386.771	0.000
5	6670.000	90.00000	1.57080	16.00000	0.27925	6411.616	1838.501	0.000
6	6670.000	90.00000	1.57080	20.00000	0.34907	6267.750	2281.274	0.000
7	6670.000	86.53519	1.51032	2.00000	0.03491	6653.752	232.354	403.104
8	6670.000	86.53519	1.51032	6.00000	0.10472	6621.336	695.930	403.104
9	6670.000	86.53519	1.51032	10.00000	0.17453	6556.661	1156.116	403.104
10	6670.000	86.53519	1.51032	14.00000	0.24435	6460.043	1610.670	403.104
11	6670.000	86.53519	1.51032	18.00000	0.31416	6331.952	2057.376	403.104
12	6670.000	86.53519	1.51032	22.00000	0.38397	6173.012	2494.059	403.104
13	6670.000	83.06615	1.44978	0.00000	0.00000	6621.217	0.000	805.224
14	6670.000	83.06615	1.44978	4.00000	0.06981	6605.088	461.873	805.224
15	6670.000	83.06615	1.44978	8.00000	0.13963	6556.780	921.495	805.224
16	6670.000	83.06615	1.44978	12.00000	0.20944	6476.527	1376.628	805.224
17	6670.000	83.06615	1.44978	16.00000	0.27925	6364.722	1825.055	805.224
18	6670.000	83.06615	1.44978	20.00000	0.34907	6221.909	2264.590	805.224
19	6670.000	86.53519	1.51032	2.00000	0.03491	6653.752	232.354	-403.104
20	6670.000	86.53519	1.51032	6.00000	0.10472	6621.336	695.930	-403.104
21	6670.000	86.53519	1.51032	10.00000	0.17453	6556.661	1156.116	-403.104
22	6670.000	86.53519	1.51032	14.00000	0.24435	6460.043	1610.670	-403.104
23	6670.000	86.53519	1.51032	18.00000	0.31416	6331.952	2057.376	-403.104
24	6670.000	86.53519	1.51032	22.00000	0.38397	6173.012	2494.059	-403.104
25	6670.000	83.06615	1.44978	0.00000	0.00000	6621.217	0.000	-805.224
26	6670.000	83.06615	1.44978	4.00000	0.06981	6605.088	461.873	-805.224
27	6670.000	83.06615	1.44978	8.00000	0.13963	6556.780	921.495	-805.224
28	6670.000	83.06615	1.44978	12.00000	0.20944	6476.527	1376.628	-805.224
29	6670.000	83.06615	1.44978	16.00000	0.27925	6364.722	1825.055	-805.224
30	6670.000	83.06615	1.44978	20.00000	0.34907	6221.909	2264.590	-805.224

Table 6: Lower hexagon centre coordinates

8. COORDINATES OF HEXAGON CENTRES IN THE RICH-1

The two following tables give the coordinates of the hexagon centres in the RICH-1 vessel. They will be useful to check their real position after mounting and before fixing the mirrors.

	spherical coordinates					Cartesian coordinates		
centre number	ρ[mm]	θ [deg]	θ[rad]	ϕ [deg]	ϕ[rad]	X	Y	Z
1	6670.000	95.14685	1.66063	2.00810	0.03505	6639.027	232.780	-598.358
2	6670.000	95.12171	1.66019	6.02414	0.10514	6606.682	697.205	-595.442
3	6670.000	95.07155	1.65931	10.03971	0.17523	6542.151	1158.233	-589.626
4	6670.000	94.99663	1.65800	14.05450	0.24530	6445.746	1613.619	-580.938
5	6670.000	94.89731	1.65627	18.06823	0.31535	6317.939	2061.143	-569.419
6	6670.000	94.77409	1.65412	22.08062	0.38538	6159.351	2498.626	-555.126
7	6670.000	91.68519	1.60021	0.00000	0.00000	6667.115	0.000	-196.151
8	6670.000	91.67268	1.59999	3.99438	0.06972	6650.963	464.425	-194.695
9	6670.000	91.63521	1.59934	7.98856	0.13943	6602.583	926.588	-190.335
10	6670.000	91.57297	1.59825	11.98232	0.20913	6522.213	1384.236	-183.091
11	6670.000	91.48625	1.59674	15.97549	0.27882	6410.244	1835.141	-173.000
12	6670.000	91.37549	1.59480	19.96788	0.34851	6267.221	2277.104	-160.110
13	6670.000	88.21304	1.53961	1.98633	0.03467	6662.750	231.077	207.992
14	6670.000	88.18817	1.53917	5.95895	0.10400	6630.642	692.106	210.886
15	6670.000	88.13855	1.53831	9.93141	0.17334	6566.582	1149.762	216.659
16	6670.000	88.06442	1.53701	13.90364	0.24266	6470.883	1601.817	225.285
17	6670.000	87.96614	1.53530	17.87554	0.31199	6344.010	2046.069	236.719
18	6670.000	87.84417	1.53317	21.84705	0.38130	6186.582	2480.352	250.908
19	6670.000	98.61481	1.72115	0.00000	0.00000	6594.747	0.000	-999.105
20	6670.000	98.60216	1.72093	4.03818	0.07048	6578.594	464.425	-997.649
21	6670.000	98.56428	1.72027	8.07592	0.14095	6530.215	926.588	-993.289
22	6670.000	98.50136	1.71917	12.11282	0.21141	6449.845	1384.236	-986.045
23	6670.000	98.41372	1.71764	16.14844	0.28184	6337.876	1835.141	-975.954
24	6670.000	98.30180	1.71569	20.18242	0.35225	6194.853	2277.104	-963.064
25	6670.000	102.08066	1.78164	2.03035	0.03544	6518.191	231.077	-1395.955
26	6670.000	102.05524	1.78120	6.09077	0.10630	6486.083	692.106	-1393.061
27	6670.000	102.00454	1.78032	10.15037	0.17716	6422.023	1149.762	-1387.288
28	6670.000	101.92880	1.77899	14.20861	0.24799	6326.324	1601.817	-1378.662
29	6670.000	101.82843	1.77724	18.26497	0.31878	6199.451	2046.069	-1367.228
30	6670.000	101.70393	1.77507	22.31897	0.38954	6042.023	2480.352	-1353.039

Table 7: Real upper hexagon centre coordinates

	spherical coordinates					Cartesian coordinates		
centre number	ρ[mm]	θ [deg]	θ[rad]	ϕ [deg]	ϕ[rad]	X	Y	Z
1	6670.000	84.85000	1.48091	0.00000	0.00000	6643.074	0.000	598.722
2	6670.000	84.86258	1.48113	4.01616	0.07010	6626.892	465.276	597.264
3	6670.000	84.90025	1.48179	8.03200	0.14018	6578.424	928.285	592.896
4	6670.000	84.96283	1.48288	12.04722	0.21026	6497.907	1386.771	585.639
5	6670.000	85.05001	1.48440	16.06151	0.28033	6385.733	1838.501	575.529
6	6670.000	85.16135	1.48635	20.07460	0.35037	6242.448	2281.274	562.615
7	6670.000	81.38836	1.42049	2.01912	0.03524	6590.708	232.354	998.741
8	6670.000	81.41364	1.42094	6.05713	0.10572	6558.422	695.930	995.831
9	6670.000	81.46407	1.42182	10.09450	0.17618	6494.008	1156.116	990.026
10	6670.000	81.53940	1.42313	14.13081	0.24663	6397.780	1610.670	981.353
11	6670.000	81.63924	1.42487	18.16566	0.31705	6270.206	2057.376	969.855
12	6670.000	81.76309	1.42704	22.19868	0.38744	6111.908	2494.059	955.588
13	6670.000	77.91615	1.35989	0.00000	0.00000	6522.208	0.000	1396.317
14	6670.000	77.92887	1.36012	4.06063	0.07087	6506.144	461.873	1394.869
15	6670.000	77.96696	1.36078	8.12071	0.14173	6458.031	921.495	1390.533
16	6670.000	78.03022	1.36188	12.17969	0.21258	6378.103	1376.628	1383.329
17	6670.000	78.11834	1.36342	16.23706	0.28339	6266.749	1825.055	1373.293
18	6670.000	78.23084	1.36539	20.29230	0.35417	6124.512	2264.590	1360.474
19	6670.000	88.31793	1.54144	1.99720	0.03486	6663.076	232.354	195.787
20	6670.000	88.34294	1.54188	5.99151	0.10457	6630.790	695.930	192.877
21	6670.000	88.39283	1.54275	9.98550	0.17428	6566.376	1156.116	187.072
22	6670.000	88.46736	1.54405	13.97899	0.24398	6470.148	1610.670	178.399
23	6670.000	88.56616	1.54577	17.97179	0.31367	6342.574	2057.376	166.901
24	6670.000	88.68875	1.54791	21.96374	0.38334	6184.276	2494.059	152.634
25	6670.000	91.78385	1.60193	0.00000	0.00000	6666.768	0.000	-207.630
26	6670.000	91.79629	1.60215	3.97265	0.06934	6650.704	461.873	-209.078
27	6670.000	91.83356	1.60280	7.94520	0.13867	6602.590	921.495	-213.414
28	6670.000	91.89547	1.60388	11.91756	0.20800	6522.662	1376.628	-220.618
29	6670.000	91.98173	1.60538	15.88963	0.27733	6411.308	1825.055	-230.654
30	6670.000	92.09192	1.60731	19.86134	0.34665	6269.071	2264.590	-243.473

Table 8: Lower hexagon centre coordinates

9. CONCLUSION

Mirror and hexagon centre positions have been listed for two different configurations.

Values from Tables 1, 2, 5 and 6 could be used for the design and manufacturing of the hexagon jig, as for the pre-assembling of the mirror wall.

Values from Tables 3, 4, 7 and 8 will help for dimensional checks in the vessel once the assembly is completed.