Reflection on new cabin optics to increase the field of view of the Pico Veleta 30m telescope

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14/06/2007

This document present a study done with Zemax to increase the 30m field of view in particular for bolometers observations, by changing the mirrors in the cabin, and possibly place them and the detectors at various convenient places.

Wider studies, including new subreflector (M2) and wobbler, receivers optics, aberrations, lenses, observing modes or competitions with other instruments and so on were conducted in the past years [Navarro, Greve, Peñalver, Zylka, Thum, Carter, Gélin]. From these studies it appears that as a first step, changing only the mirrors in the cabin would possibly permit at a reasonable cost, an increase for the field of view big enough to provide a potential for instrumental improvements that would not be limiting for many years. Some ideas were already expressed in these documents [Navarro]. In the present study I tried to answer the following problematic:

What are the various configurations possible in the telescope cabin using only mirrors (no lenses, thus minimizing losses and operation), and what would be their maximum field of view achievable ?

I identified 3 categories of configurations:

1) M3 reflects the beam in the elevation cabin where the bolometer instrument would stand. Santiago Navarro proposed this solution.

2) M3 is shifted along the elevation axis and M4 stays at its current position, so that more room is available for bigger M3 and M4, looking at an off-axis field of view. Bernard Lazareff proposed this solution.

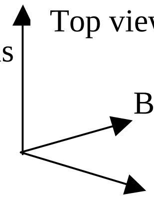
3) M3 is at the same place and reflects the beam toward a hyperboloid M4 standing somewhere between M3 and the current position of bolometers M5 and M6.

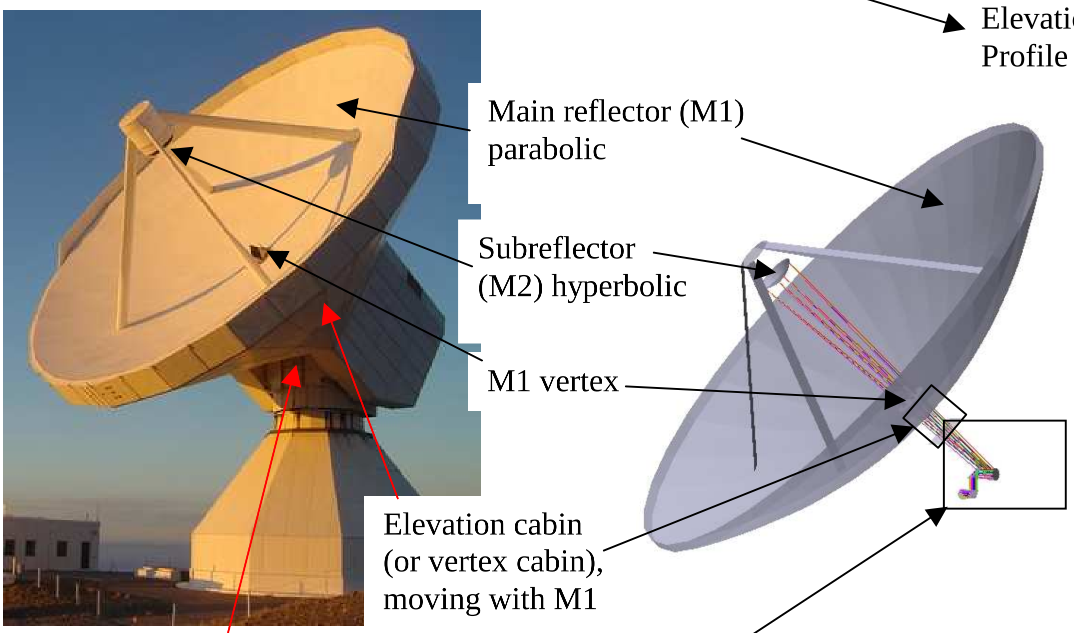
In order to be the most concise though comprehensible possible, I present these solutions in form of tables showing 2D output drawing of mirrors, beams and cabins benchmarks for 3 projection planes and for 2 extreme elevation angles: 0 and 80 degree. To avoid any confusion with the words used in the drawings, I first use some pictures of the telescope and the cabin to identify the objects listed in the tables, and as a table number 0) I present the current configurations of the mirrors at Pico Veleta.

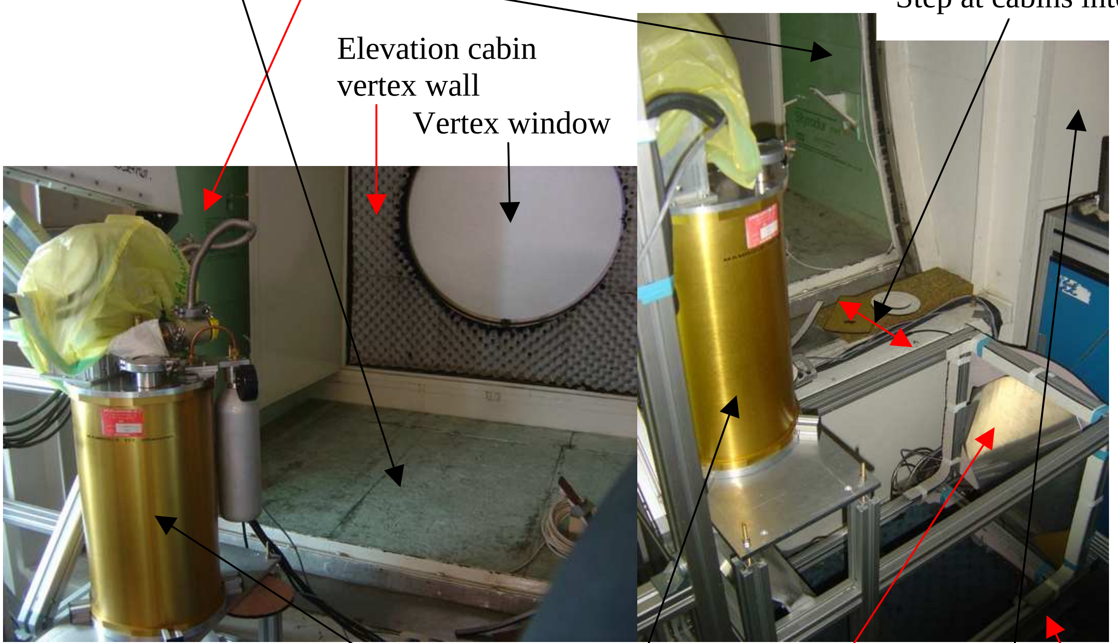
Since the drawings and the list of dimensions given for each one (in the cell "back view, 80 degree elevation") are self explanatory no further comments are given in this preliminary version. The reader can draw his own conclusion, and address me any remarks or question about this study.

A table summarizing the characteristics of all the configurations is displayed at the end of the document.

3D referential for the telescope picture and drawing:
2D projections are defined as looking from these axis
toward the origin placed at the center of M3



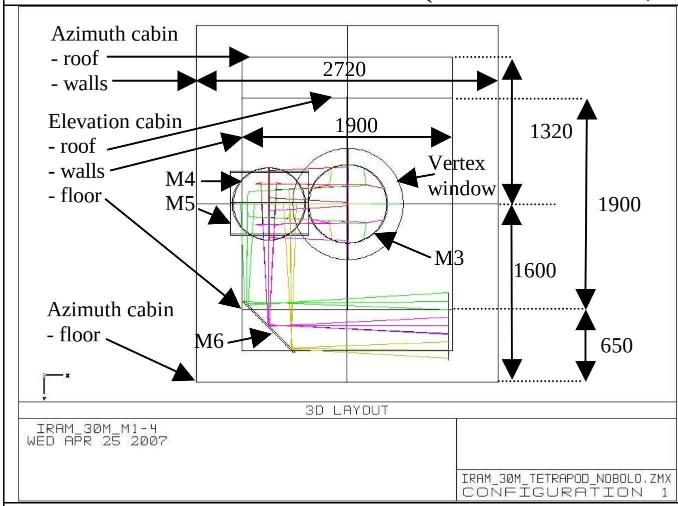


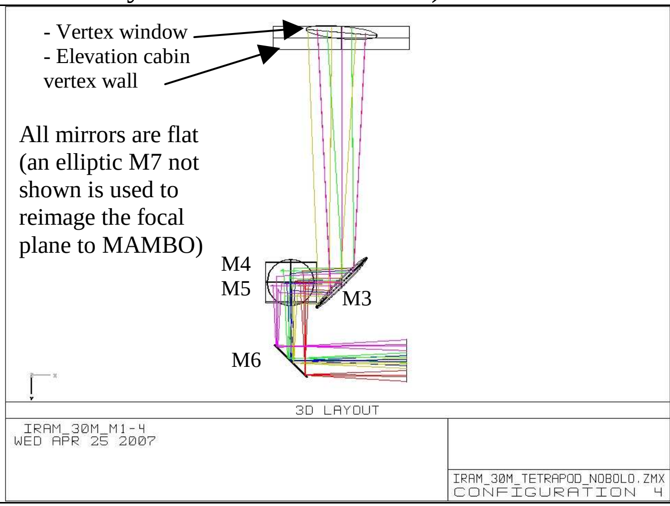


0) Current disposition of mirrors M3 and M4.

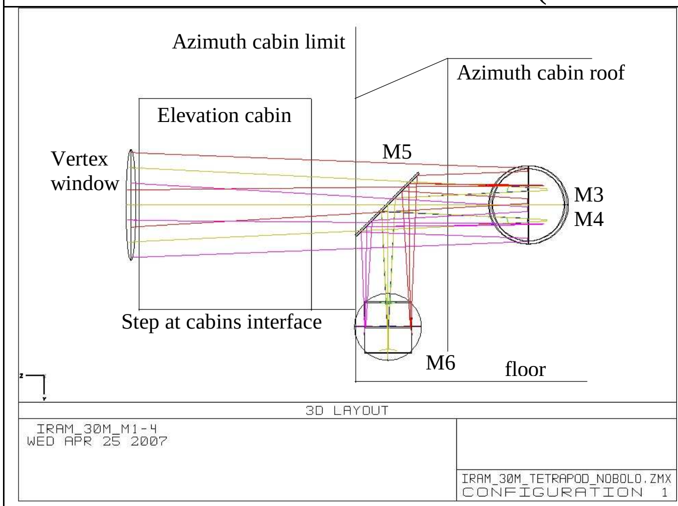
elevation = 0 degree	elevation = 80 degree

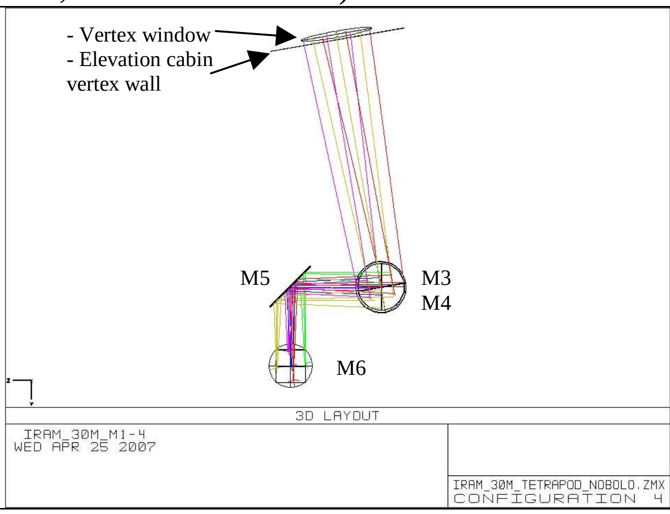
1. Back view (in azimuth cabin, from heterodyne receiver toward M3)



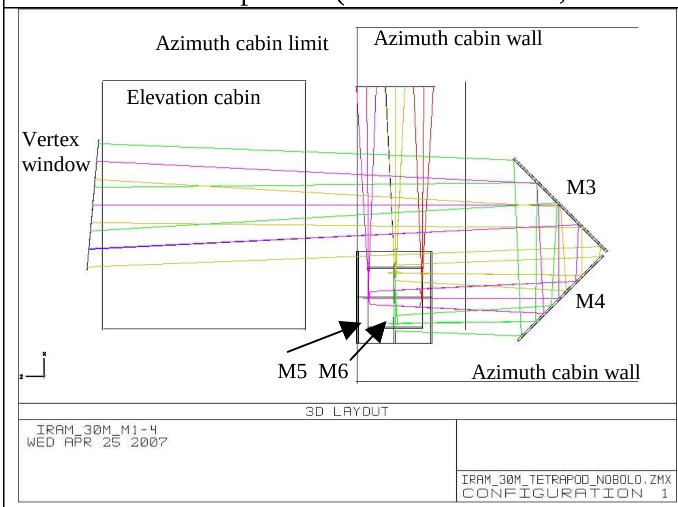


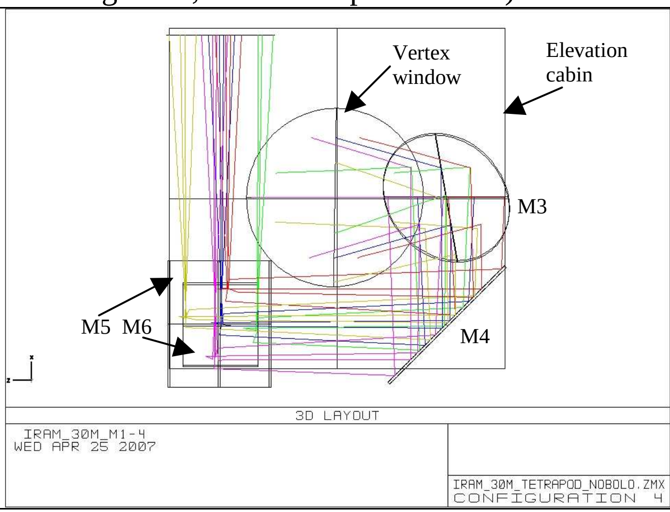
2. Profile view (in azimuth cabin, from M4 toward M3)





3. Top view (in azimuth cabin, from roof toward ground, rotation of profile view)

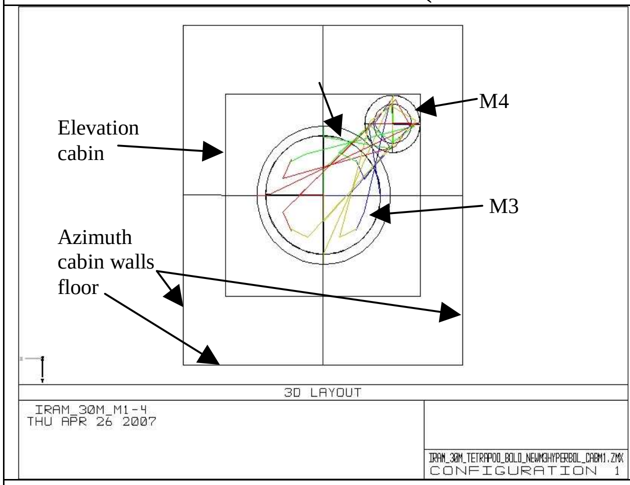




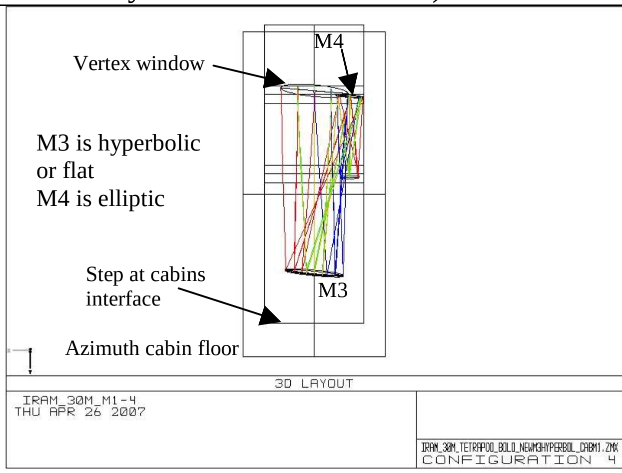
1) Bolometers and their M4 into elevation cabin.

1. Back view (in azimuth cabin, from heterodyne receiver toward M3)

elevation = 0 degree

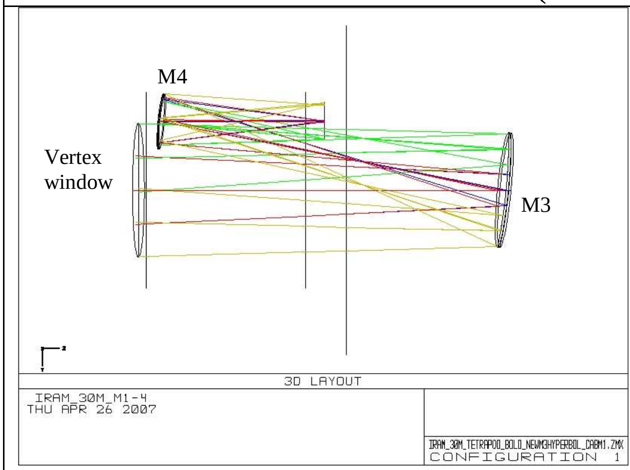


elevation = 80 degree

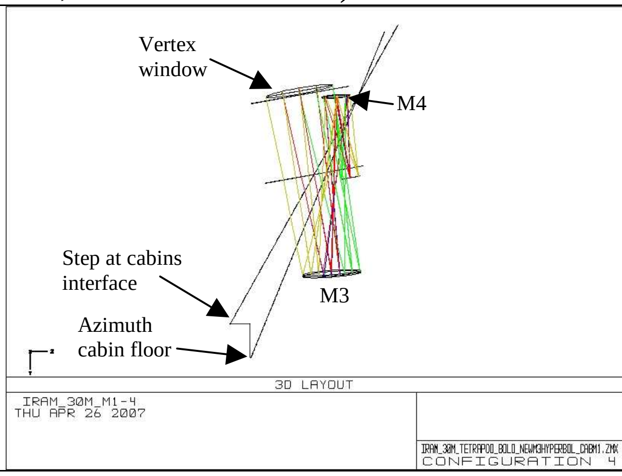


2. Profile view (in azimuth cabin, from M4 toward M3)

elevation = 0 degree

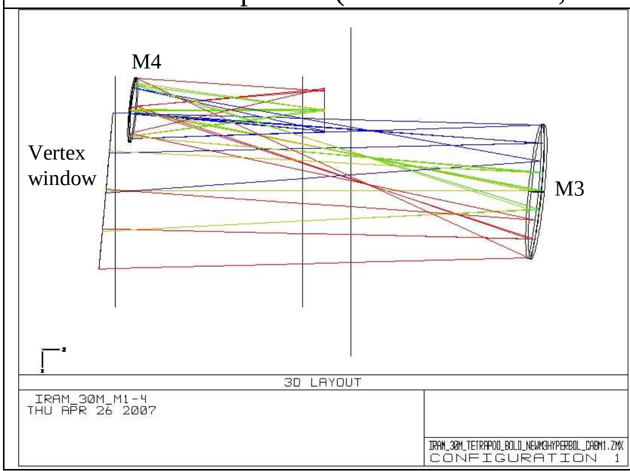


elevation = 80 degree

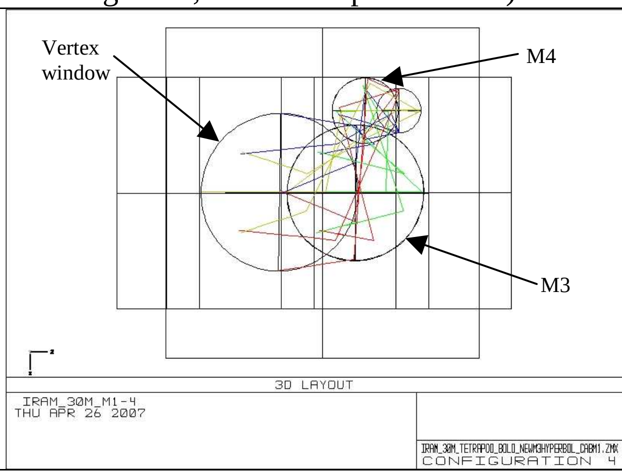


3. Top view (in azimuth cabin, from roof toward ground, rotation of profile view)

elevation = 0 degree



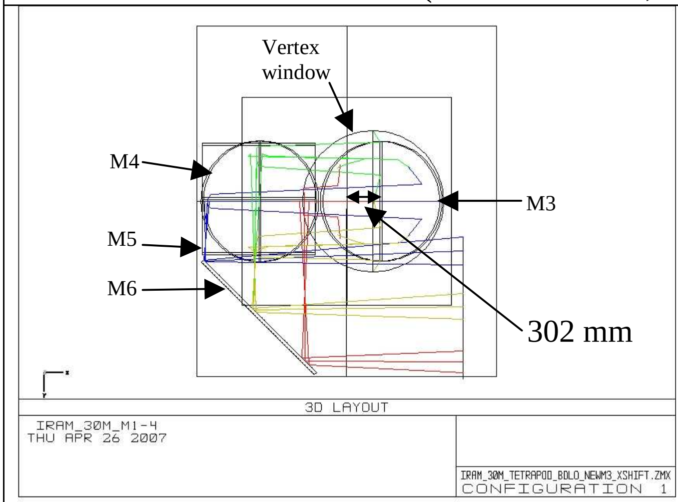
elevation = 80 degree

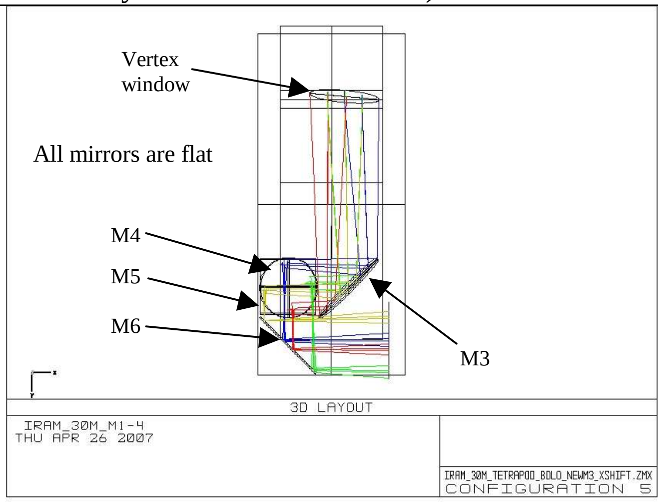


2) New M3 shifted along elevation axis.

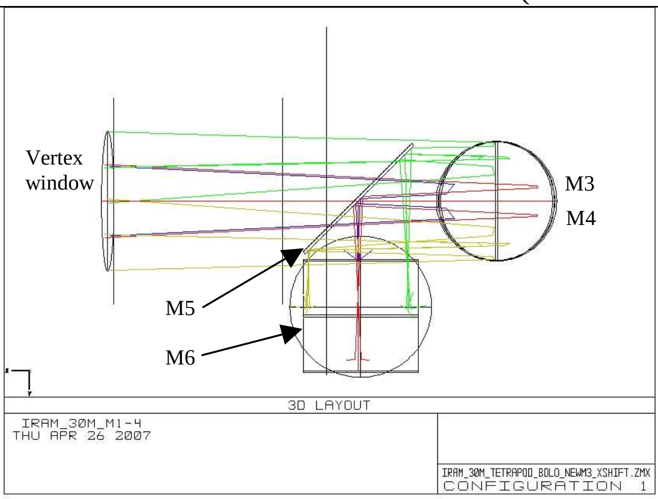
elevation = 0 degree	elevation = 80 degree

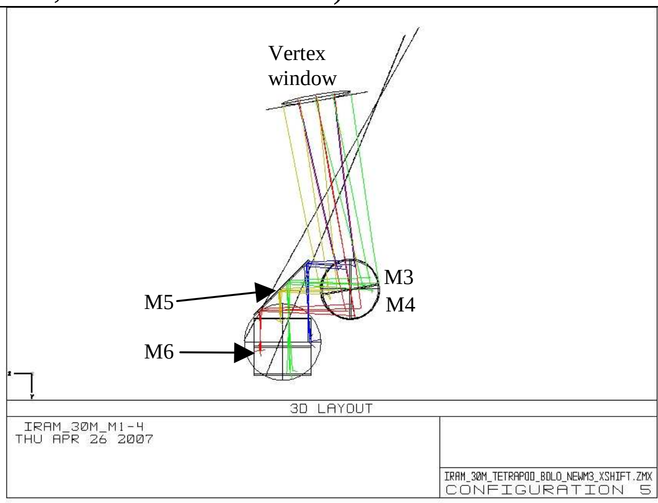
1. Back view (in azimuth cabin, from heterodyne receiver toward M3)



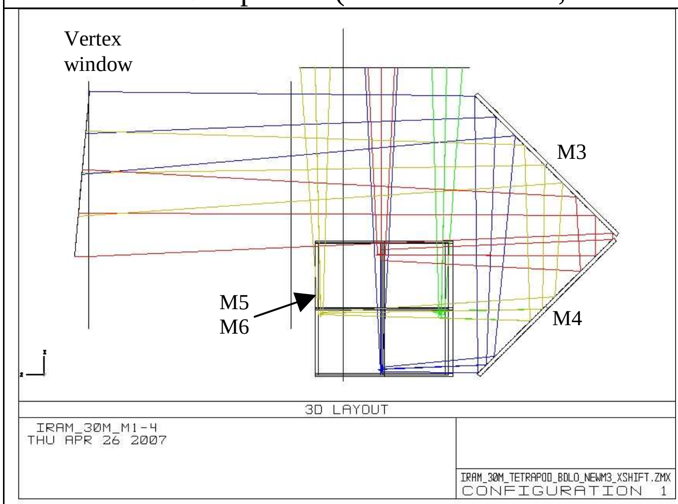


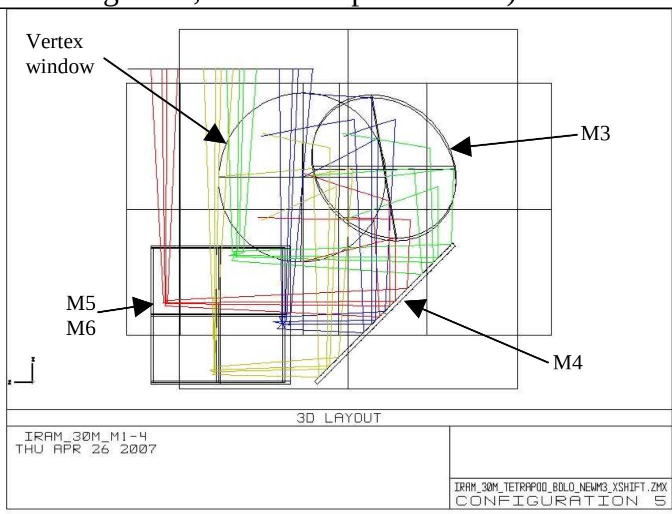
2. Profile view (in azimuth cabin, from M4 toward M3)



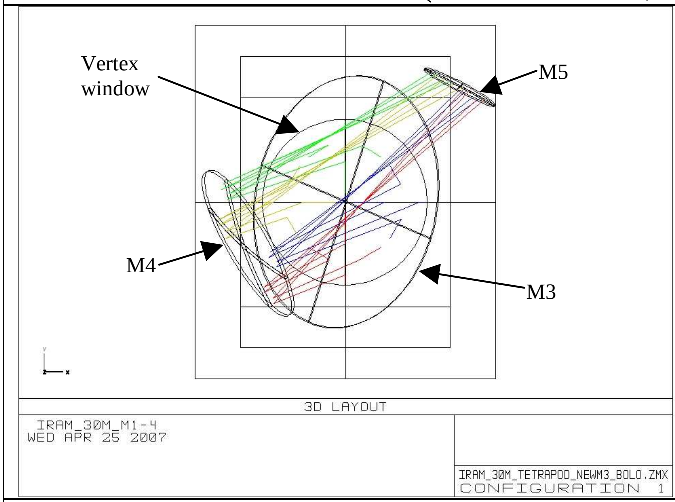


3. Top view (in azimuth cabin, from roof toward ground, rotation of profile view)





3) Biggest M3 with M4 in azimutal cabin out of elevation axis.

<table>
<tr><th>elevation = 0 degree</th><th>elevation = 80 degree</th></tr>
<tr><td colspan="2">1. Back view (in azimuth cabin, from heterodyne receiver toward M3)</td></tr>
<tr><td>


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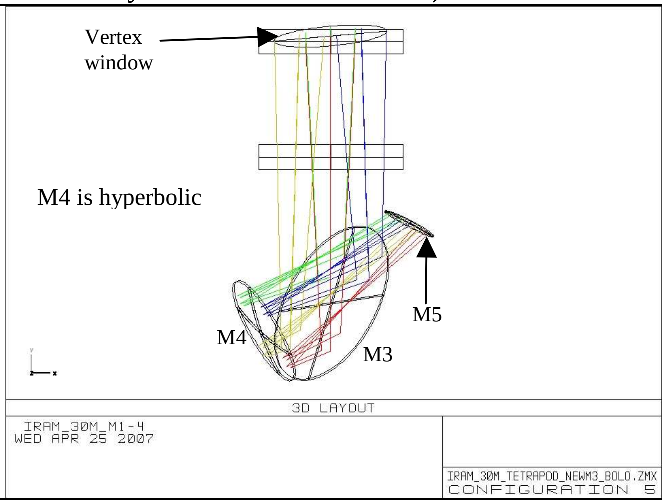
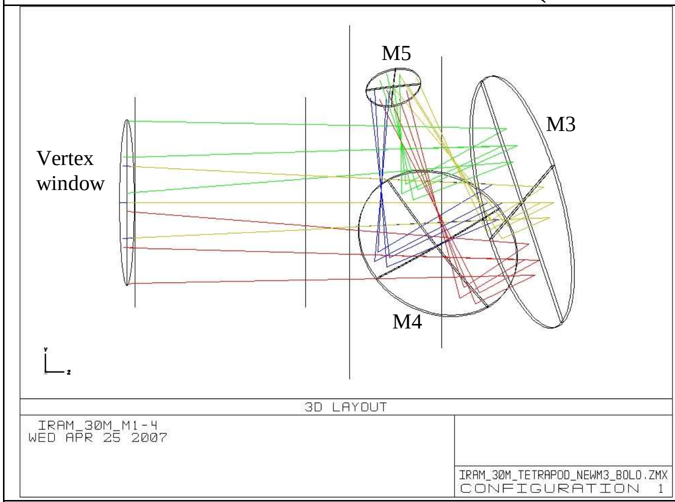


</td></tr>
<tr><td colspan="2">2. Profile view (in azimuth cabin, from M4 toward M3)</td></tr>
<tr><td>


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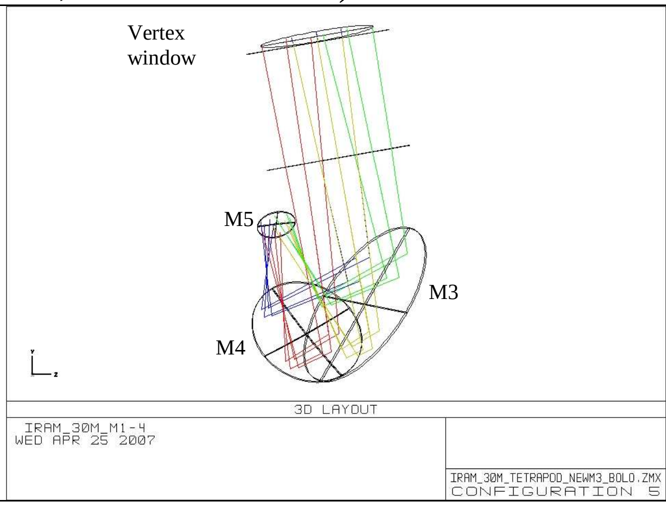

</td></tr>
<tr><td colspan="2">3. Top view (in azimuth cabin, from roof toward ground, rotation of profile view)</td></tr>
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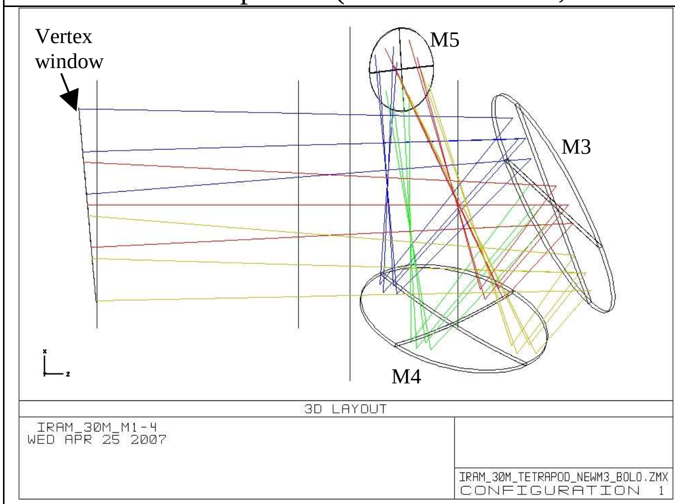

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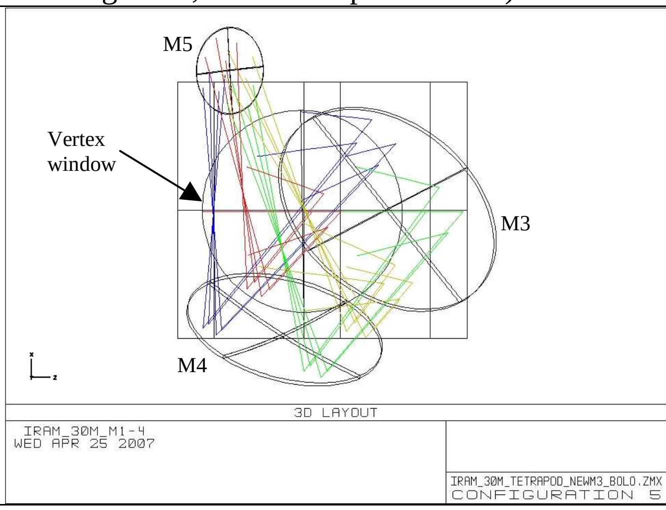
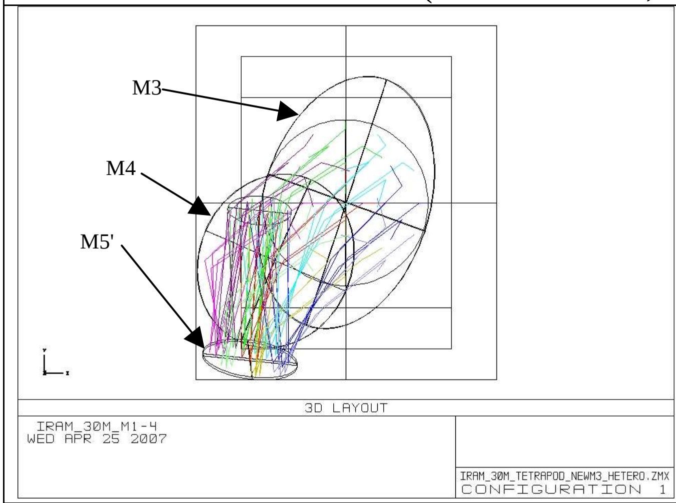
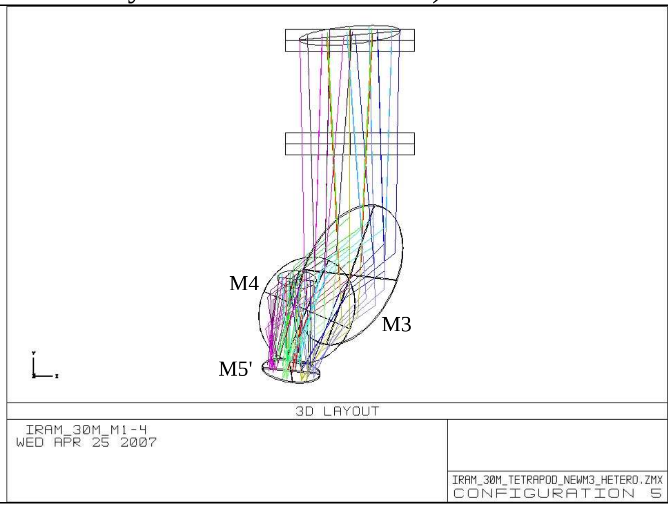


</td></tr>
</table>

1st proposition for heterodynes in configuration 3).

<table>
<tr><td>elevation = 0 degree</td><td>elevation = 80 degree</td></tr>
<tr><td colspan="2">1. Back view (in azimuth cabin, from heterodyne receiver toward M3)</td></tr>
<tr><td>
</td><td>
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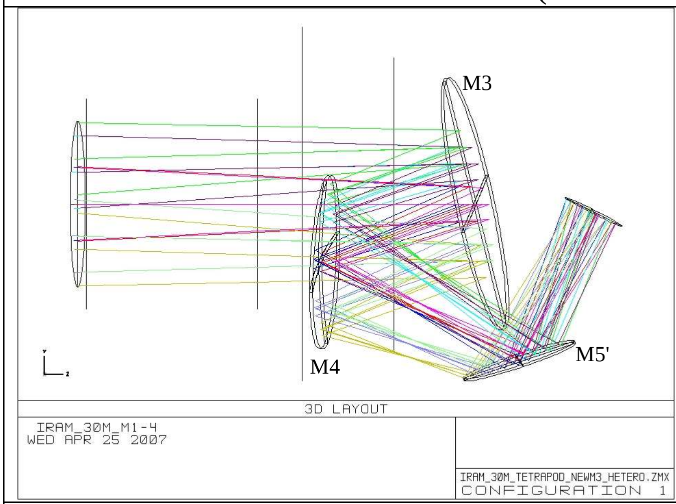
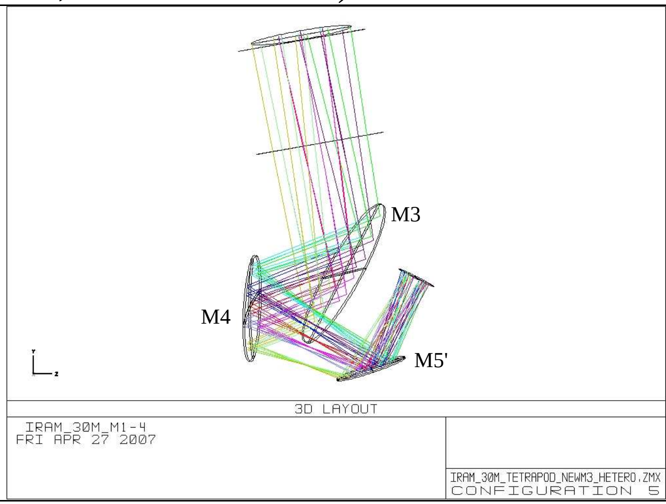
<tr><td colspan="2">2. Profile view (in azimuth cabin, from M4 toward M3)</td></tr>
<tr><td>
</td><td>
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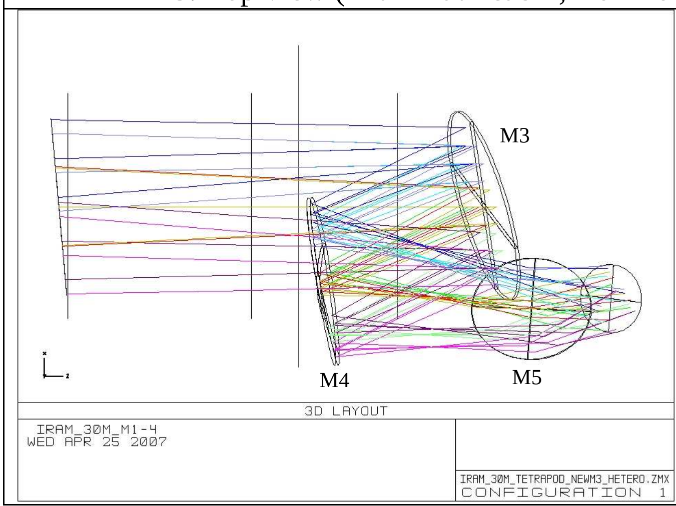
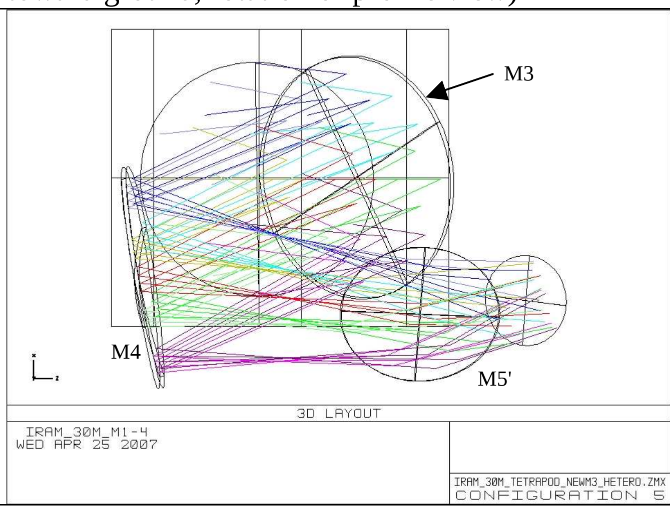
<tr><td colspan="2">3. Top view (in azimuth cabin, from roof toward ground, rotation of profile view)</td></tr>
<tr><td>
</td><td>
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2nd proposition for heterodynes in configuration 3).

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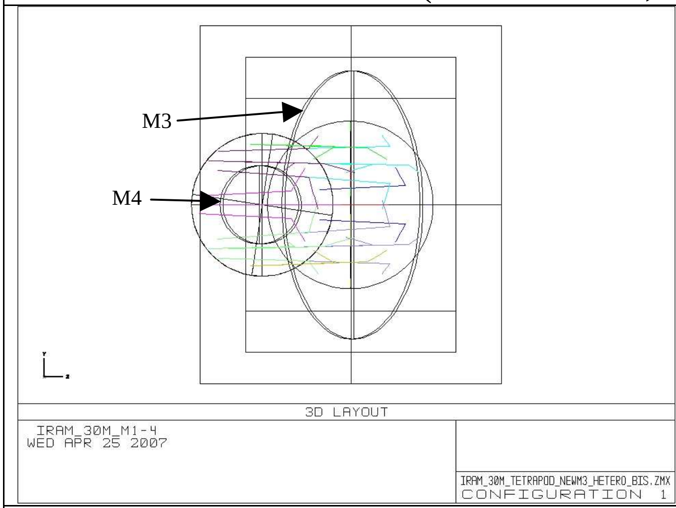
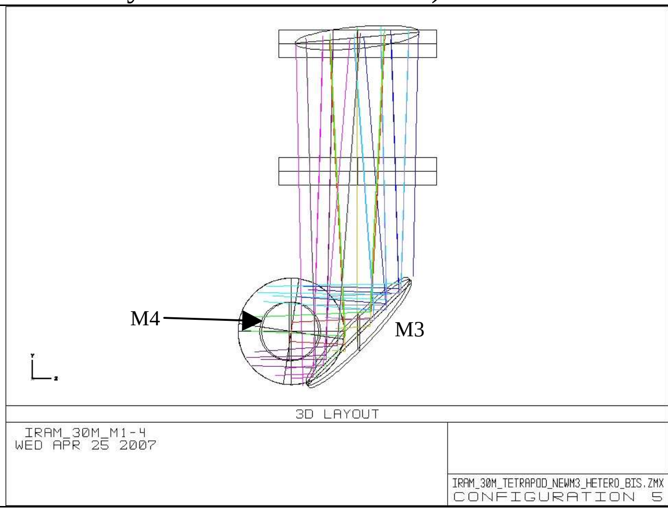
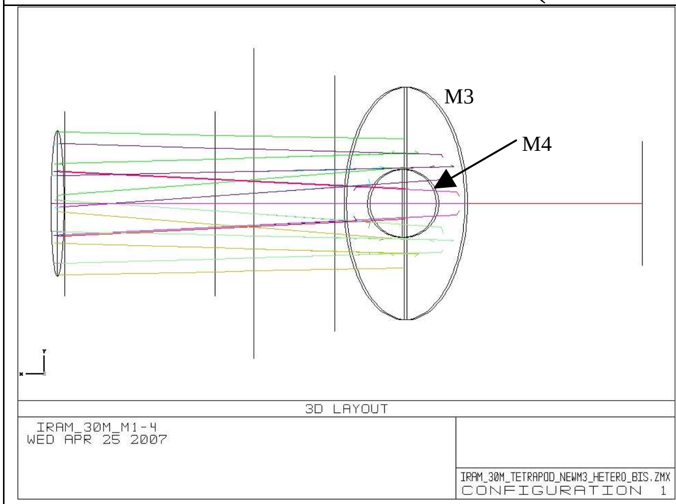
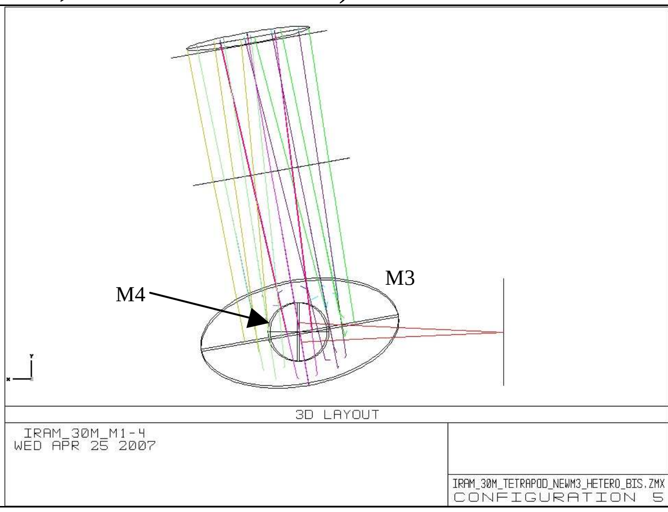
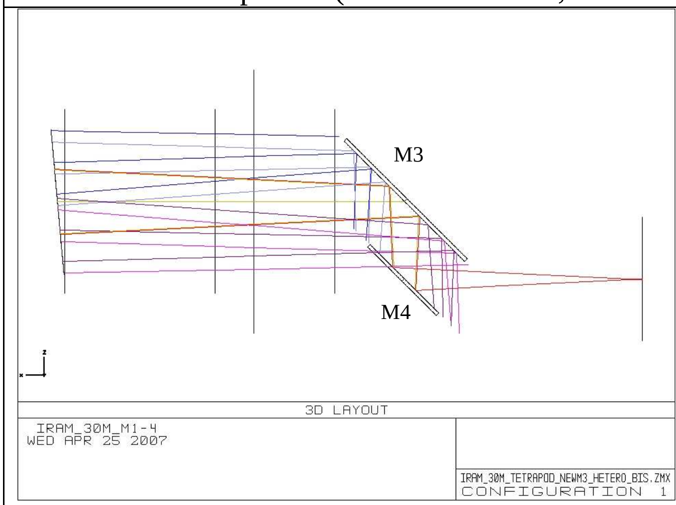
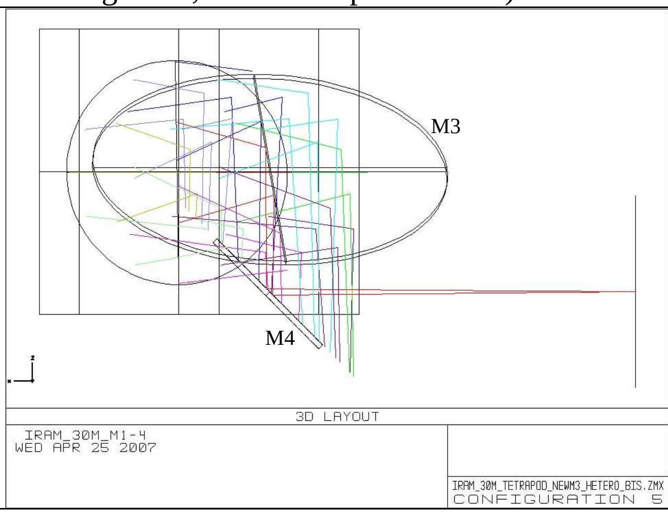
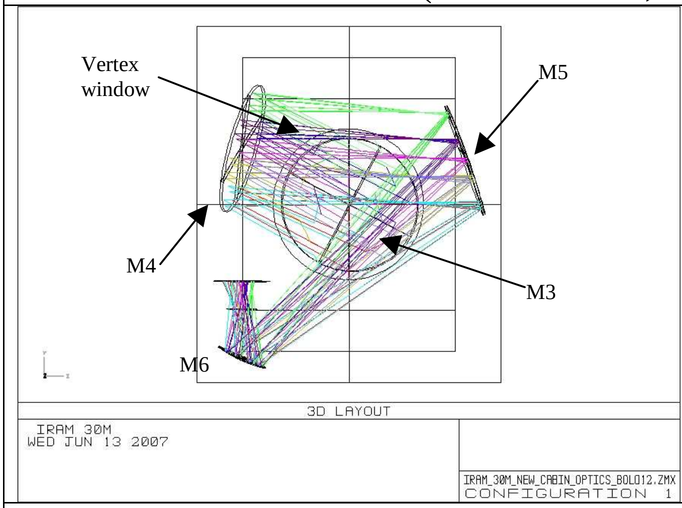
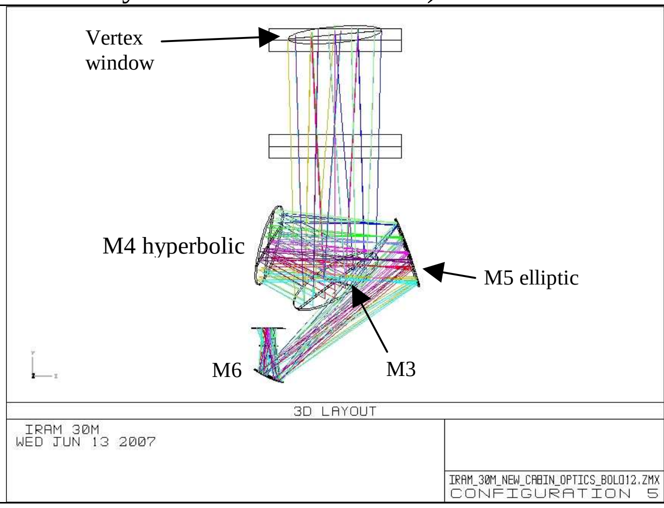
<tr><td>
</td><td>
</td></tr>
<tr><td colspan="2">2. Profile view (in azimuth cabin, from M4 toward M3)</td></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td colspan="2">3. Top view (in azimuth cabin, from roof toward ground, rotation of profile view)</td></tr>
<tr><td>
</td><td>
</td></tr>
</table>

4) Compromise: FOV>10’ ; M3-M4-M5<1.50m ; room for operator ; pixel size ≈ λ + 10% .

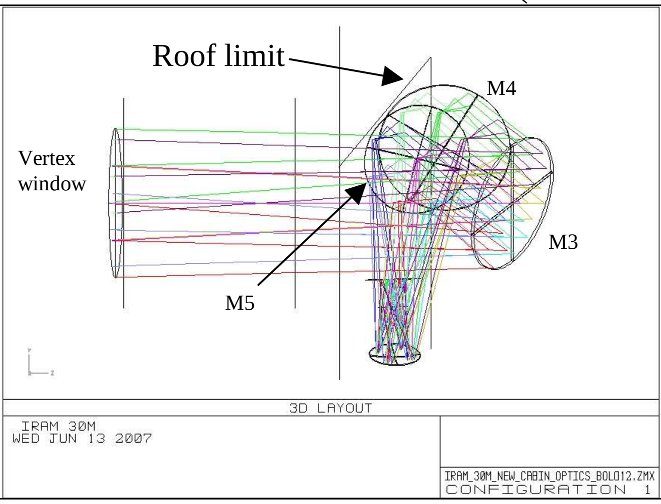
elevation = 0 degree	elevation = 80 degree

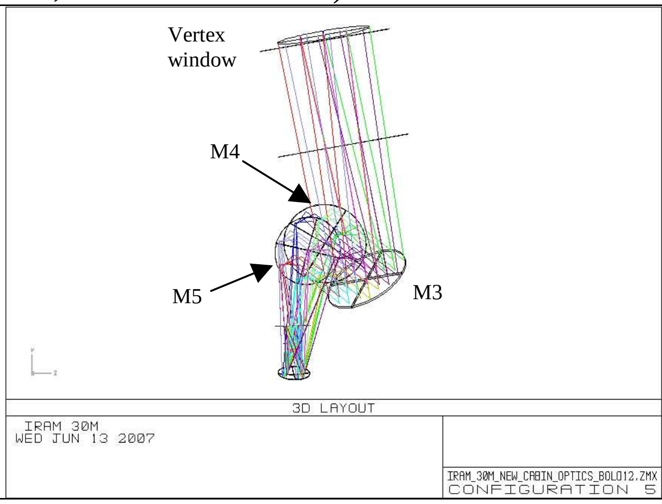
1. Back view (in azimuth cabin, from heterodyne receiver toward M3)



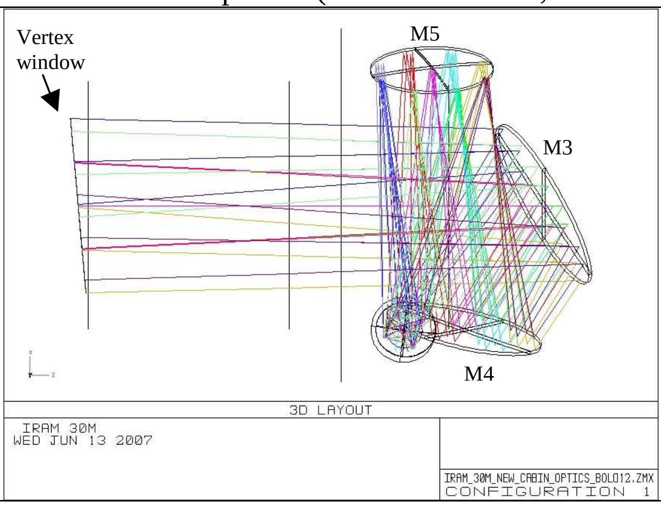


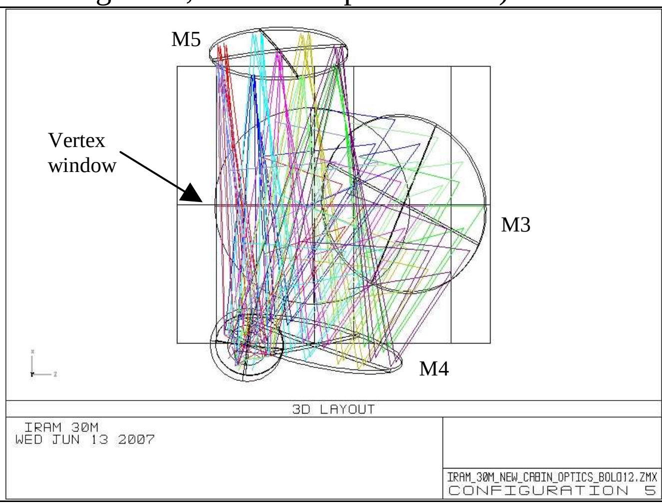
2. Profile view (in azimuth cabin, from M4 toward M3)



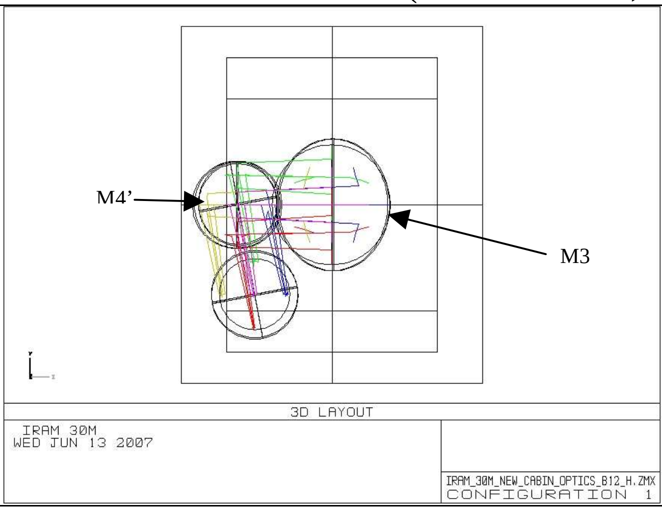
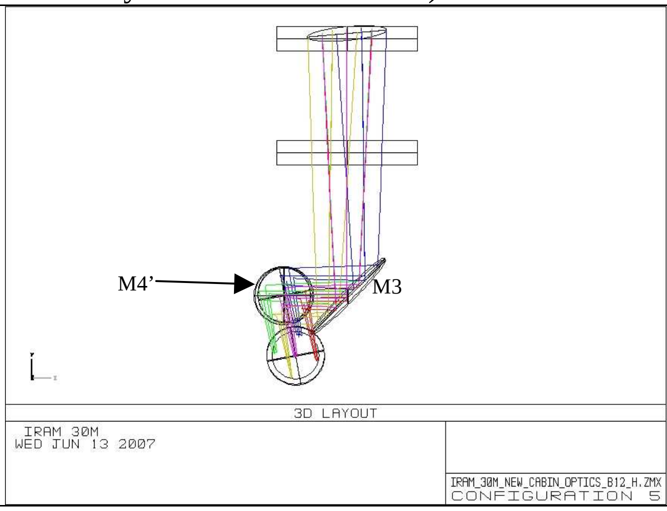


3. Top view (in azimuth cabin, from roof toward ground, rotation of profile view)





Proposition for heterodynes in configuration 4).

<table>
<tr><td>elevation = 0 degree</td><td>elevation = 80 degree</td></tr>
<tr><td colspan="2">1. Back view (in azimuth cabin, from heterodyne receiver toward M3)</td></tr>
<tr><td>
</td><td>
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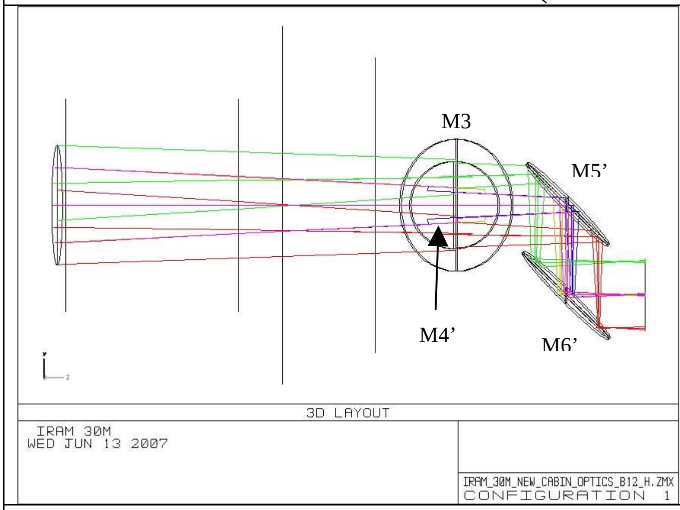
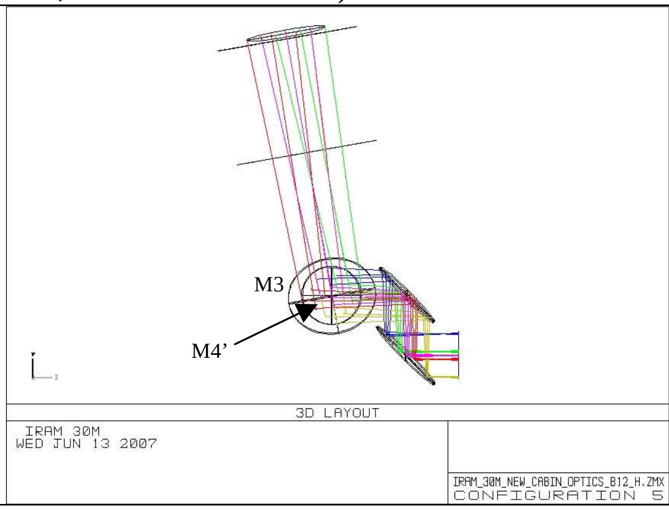
<tr><td colspan="2">2. Profile view (in azimuth cabin, from M4 toward M3)</td></tr>
<tr><td>
</td><td>
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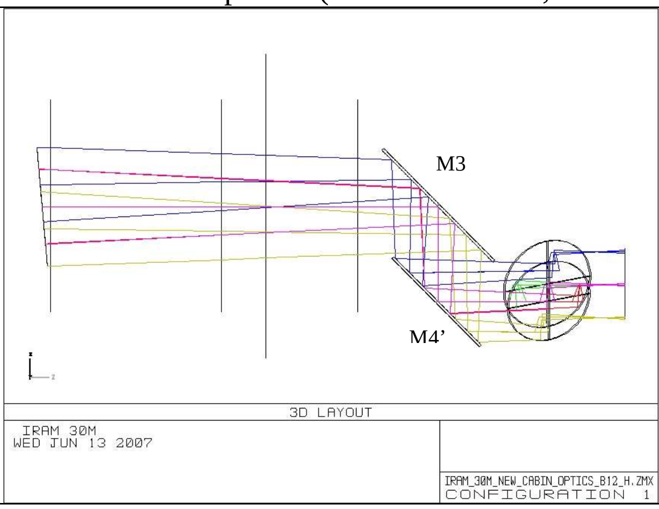
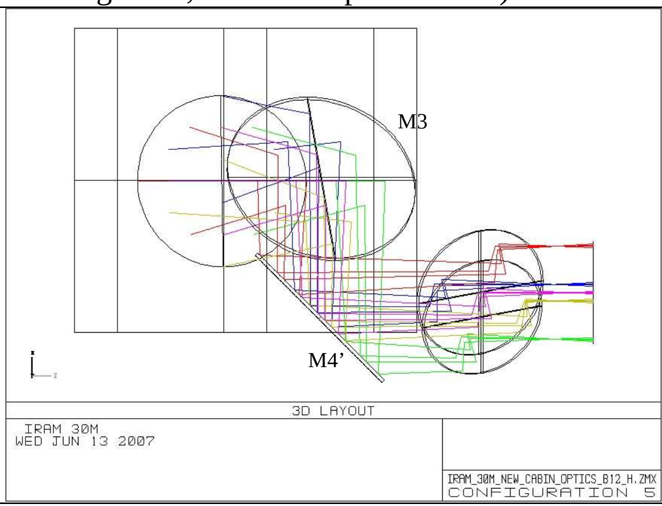
<tr><td colspan="2">3. Top view (in azimuth cabin, from roof toward ground, rotation of profile view)</td></tr>
<tr><td>
</td><td>
</td></tr>
</table>

Summary of all the configurations:

The contour of the mirrors is always an ellipse which dimension in the table is expressed from border to border, that is to say:
(2 x semimajoraxis) x (2 x semiminoraxis) !

Configuration → Element ↓	Current (0)	In elevation cabin (1)	M3 shifted 302 mm on elevation axis (2)	Max FOV, Max instrument room (3)	Best compromise: FOV, room, mirror and pixels size (4)
Vertex window diameter [mm]	1000	1300	1284	1490	1352
M3 ellipse [mm]	1040 x 740	1120 x 1120	1530 x 1090	1760 x 2400	1420 x 1180
M4 ellipse [mm]	920 x 650	540 x 540	1468 x 1040	1460 x 1520	1240 x 1140
M5 ellipse [mm]				(heterodyne conf (a) 1060 x 860)	940 x 1040
M6 ellipse [mm]					460 x 460
M3 curvature	flat	hyperbolic / flat	flat		flat
M4 curvature	flat	parabolic	flat		hyperbolic
M5 curvature					elliptic
M6 curvature					hyperbolic
M3-M4 [mm]	700	3500	1080	1250	1230
M4-M5 [mm]	1260		1260	5450	2020
M5-M6 [mm]	1100		1050		2700
FOV [arc min]	**4.6**	**11.0 / 6.5**	**10.7**	**14.4**	**12**
M4 hetero [mm]	same as bolo		same as bolo	same as bolo (a) / current shifted (b)	new M4 (flat) 1120 x 780
M3-M4	same as bolo		same as bolo	1600 / 740	850
FOV	4.6		10.7	~10 / ~5	**7**

As you can guess, my absolute preferred configuration is the last one since it passes with margin all the constraints I could imagine; that is to say:

1. FOV ≥ 10 arcmin for bolometers and FOV ≥ 7 arcmin for heterodynes.
2. Pixel size ≈ λ + 10 %. Smaller would create additional diffraction from the pixel itself, bigger is less favorable for microfabrication (less pixels per wafer).
3. Less optical elements than before: thanks to M6, the image has the correct dimension and no lens is needed (currently for MAMBO II we have M5,M6,M7 and a thick lens !).
4. All the mirrors are less than 1.6m in their largest dimension, which the maximum size acceptable to polish the mirror surface at 15μm rms accuracy (guesstimate from J-L Pollet).
5. Enough room so that operators and cryogen bottles can be moved between the elevation cabin and M3.
6. Enough room for the instrument (if necessary it is still possible to adjust a better compromise between instrument room and operator room…).
7. None of the mirrors are touching the walls, roof or ground of the cabin, and none of them are cutting the beam path.

In this last configuration (4), M3 needs to be moved along 2 axis of rotation so that the beam is always directed toward M4 for every elevations. This implies to remove the current arms holding the current M3 and to use 2 motors instead.