# Pros and cons of 3 solutions proposed for the rotation axes of a motorized tertiary mirror at the IRAM 30m telescope. <br> Samuel Leclercq, 02/2009. 

The definition of a global reference frame centered on M3 helps the description of the various configurations: let's call X the elevation axis of the telescope, Y the vertical axis and Z the horizontal axis perpendicular to X and Y (the line M3-M2 coincide with Z when the telescope elevation is 0 ). Axes 1 and 2 in the descriptions below refer to the axes of rotation of M3.

Solution 1: Axis $1=Y$; axis 2 = intersection of the surface of M3 with the plan XZ. Advantages: Altazimuth mount easy to understand. Mechanical stresses well distributed for the motor of axis 1 . The incoming beam can be reflected in any useful direction.
Disadvantages: The motor of axis 2 must be deported on the side of the mirror, requiring a great bracket to connect the motor 2 to motor 1 . The attachment of the axis 2 to only one side of the mirror may cause mechanical weaknesses,
 but the use of a fork reduces the field of view that can be reflected by the mirror M4 toward the heterodyne receivers.

Solution 2: Axis $1=$ in the plan $Y Z$, with an angle $\alpha$ from $Y$ toward the back of the cabin; axis 2 = perpendicular to axis 1, and at 45 degrees from the surface of M3.
Advantages: The mount is more compact than the other solutions thanks to the $45^{\circ}$ angle between axis 2 and the surface of M3. There's a position of rotation 1 where axis $2=\mathrm{X}$, offering the possibility to attach an arm similar to the current Nasmyth system in order to control M3 mechanically, hence allowing maintenance on the motorized system without impeding astronomical observations.


Disadvantages: The beams coming from M2 can't be reflected in any direction, making more complicate an efficient use of the cabin space. If $\alpha<(>) 45^{\circ}$ the rays coming from the zenith (horizon) can't be reflected higher (lower) than the plane which is $2 \alpha$ from Z. However the closest is the normal of M3 from the lines M2-M3 from horizon to zenith, the biggest is the field of view that can be reflected by M3. In practice the space between the 2 plans including X and making angles $10^{\circ}$ below Z and $80^{\circ}$ above Z , implying $\alpha=40^{\circ}$, is likely to be sufficient for any future evolution of the cabin, including exotic implementations like a receiver in the back structure of the antenna (a mirror in the vertex cabin $5^{\circ}$ below the line M2-M3 would be usable up to $85^{\circ}$ elevations). Another convenient possibility consists on choosing the plan of rotation 1 to be coincident with the plan defined by the centers of the mirrors currently proposed to increase the 30 m FOV: M4h (placed on the elevation axis like the current M4, but closer to the wall to allow a FOV up to 7') and M4b (placed roughly at the current position of the top of the M5-M6 tower hence allowing a FOV up to $10^{\prime}$ ); in this case $\alpha=14^{\circ}$. The maximum degrees of liberty would require a mechanical structure allowing to choose $\alpha$ (tray on rail with an adjustable compass).

Solution 3: Axis $1=X$; Axis $2=$ intersection of the surface of $M 3$ with the plan $Y Z$. Advantages: Like in solution 2 the reflection along the elevation axis allow to use only one motor that can be bypassed with a mechanical arm similar to the current Nasmyth system. The fork holding the mirror and the elements for the $2^{\text {nd }}$ rotation has no effect on the FOV available.
Disadvantages: The foot of the system is on
 one side of axis 1 while the mirror is on the other side; this causes two problems. First, the sheer force on the gear of the $1^{\text {st }}$ rotation may be too strong and possibly necessitate a bulky counterweight. Second, the beams can be reflected only toward the $\mathrm{X}>0$, which is compatible with the current position of M4 and the proposition for M4h and M4b, but reduces the possibilities for other future evolutions. Furthermore, the size of this system is the biggest of the 3 solutions proposed.

## Conclusion:

A qualitative approach to make a choice among the solutions proposed is to rank the best solutions for each of the main requirements asked for the motorized system:

- FOV as big as possible for current and future receivers: solutions 2 and 3, and possibly solution 1 if a study shows clearly that the use of a big bracket (no fork) can satisfy all the mechanical requirements.
- Ensemble of possible directions of the beams reflected by M3 as large as possible to allow any possible future position of a receiver: solution 1, but also solution 2 if its mount is designed carefully.
- Size of the system as small as possible: solution 2.
- Possibility to bypass the motors with an arm attached to the primary mirror: solutions 2 and 3.
- Good mechanical robustness to satisfy the specifications in terms of angular precision ( 20 "), speed ( 0 to $0.5 \%$ ), vibrations, inertia: according to Felix Hidalgo's study, the motorization he proposes can satisfy all the specifications whatever solution is chosen.
According to this list, the solution 2 is the most promising. However there are maybe other criteria not listed here that may change the ranking of the solutions. So I ask any reader of this document who would find such additional criteria to contact me at leclercq@iram.fr. Besides, although the technical characteristics of motors, gears, and coders proposed by Felix Hidalgo seems so satisfy easily the specifications, only an advanced study on the mechanical and dynamical constraints (for example with finite element method) would allow to quantify better the mechanical robustness of the various solutions.

