PRELIMINARY T/S ASPECT BASED ON THIN GLASS SUBSTRATES

EXERCISE OF DESIGN BASED ON HYBRID SOLUTION (MONOLITHIC AND SEGMENTED SHELLS) FOR X-RAY OPTICS

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Location:
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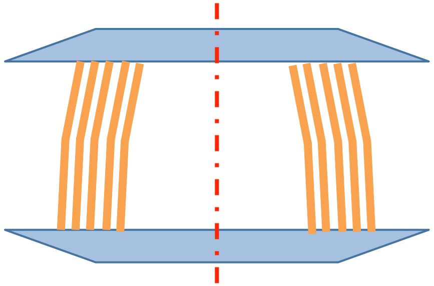
320 Sparkman Drive NW, Huntsville AL 35805

Topics

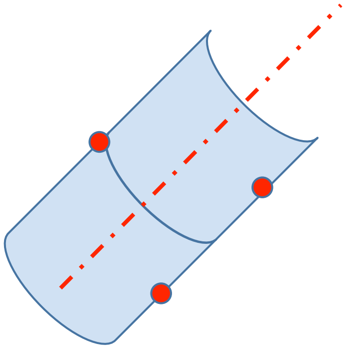
1. **monolithic shell preliminary structural consideration (BCV)**

Removing the constrain in the diameter (1m) for manufactoring, how is the behavior of monolithic shell as function of geometrical parameters, i.e. length, radius, thickness, number of points or number of spiders (1 or 2)?



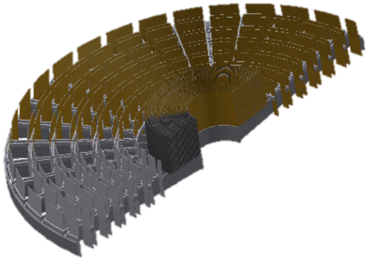
2. **A three point support for segmented shell is feasible?**

In order to achieve high angular resolution a free standing mount must be considered: the support does not introduce stress into the glass. How is the behavior of segmented shell as function of geometrical parameters, i.e. length, thickness, radius, angular width, position of three points?



3. **A preliminary concept of assembly for hybrid configuration**

monolithic shells are considered from Φ0.4m to 1m and segmented from Φ1m to 2.9m. One spider is considered because for the monolithic shell the ratio Φ/L is meanly >1



Introduction: adopted concept for optic

- **Which is the limit for monolithic shell production?**

  Current limit is Φ1m, but it's matter of money in order to build machine with a wider range for manufactoring.

- **Which is the material for shells?**

  Current propose foresees Fused Silica, but other materials are adoptable.

- **The primary and secondary reflecting surface are separated pieces?**

  No, in INAF-OAB we are developing optics with high resolution (few arcsec HEW) made in a single piece (parabola and hyperbola together)

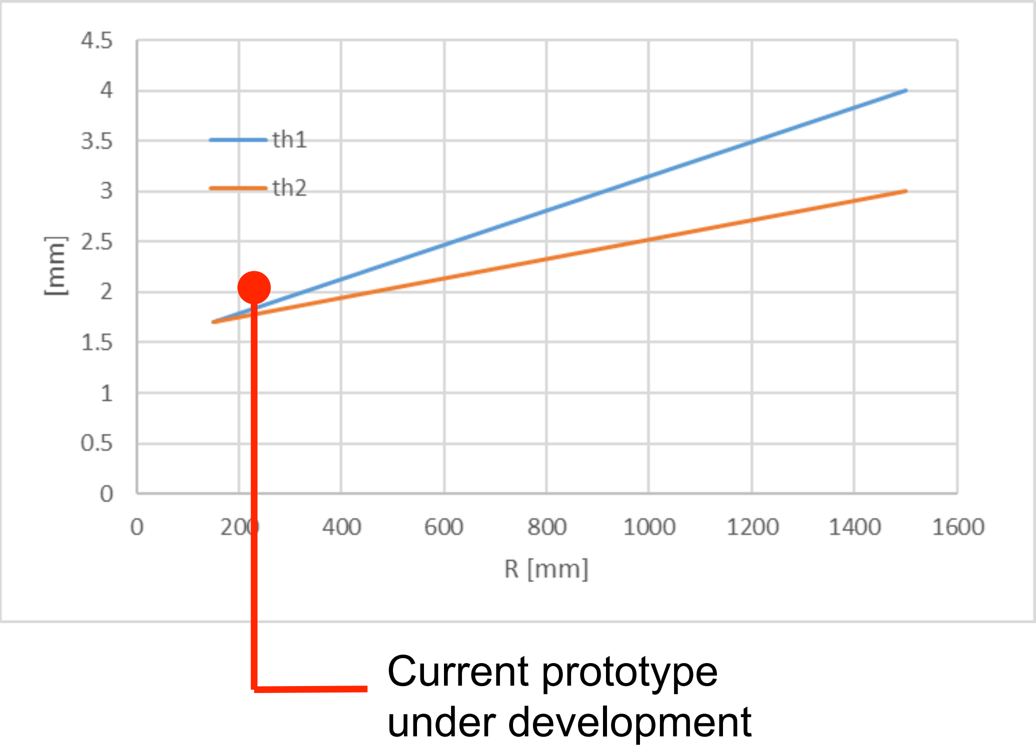
- **Which is the mass and volume limit?**

  No limit in mass and length of shells, the diameter is considered from 0.4m to 3m. 2 tons for the optics are a upper limit

Monolithic shell preliminary structural consideration

PARAMETERS RANGE:

Thickness:



Focal length:

8 – 10 – 12 m

Length (par+hyp):

600 mm – 1000 mm

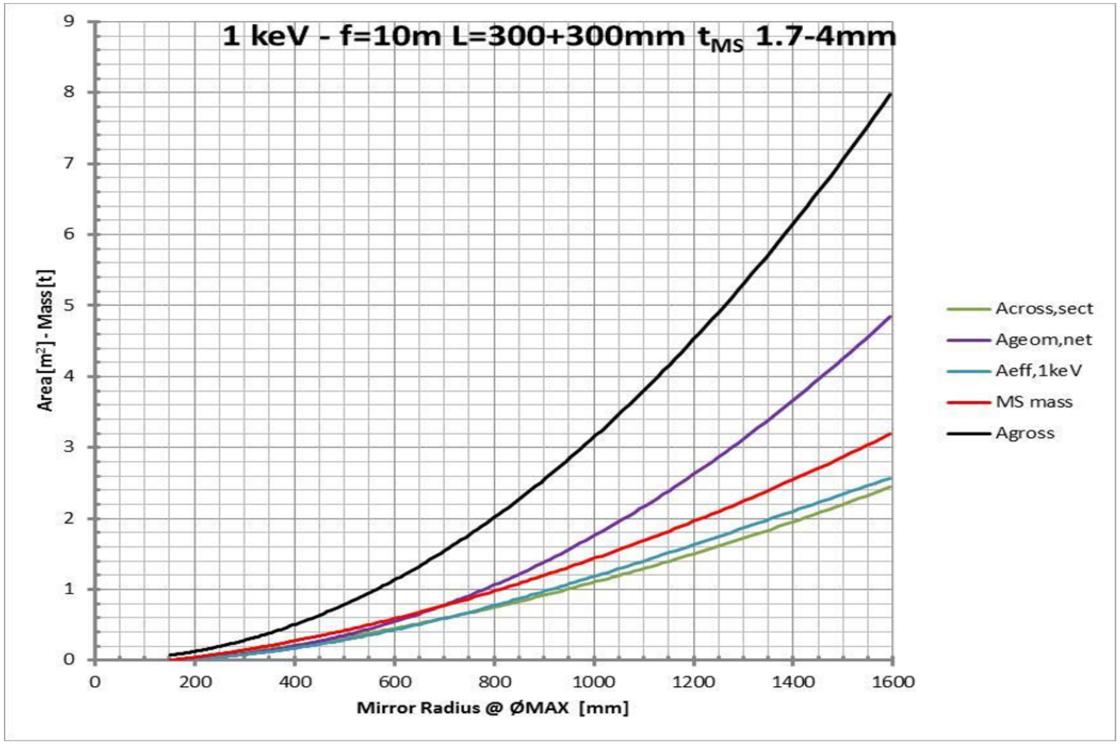
N° spiders: 1 – 2

Azimuthal distance of constrained points:

7.5° - 9° - 11.25° - 15° - 22.5°

Monolithic shell preliminary structural consideration

WHICH IS THE MAXIMUM DIAMETER IN ORDER TO ACHIEVE THE WANTED EFFECTIVE AREA?



- Agross = $\pi \times R_{MAX}^2$ being R_{MAX} the MM radius.
- $A_{CROSS,SECT}$ = The sum of the MS cross sections (area shielded by MS thickness).
- $A_{GEOM,NET}$ = Collecting area = (Agross - $A_{CROSS,SECT}$)×(1-η) being η the spider obscuration (0.12 in this report).
- Aeff,1kev = Effective area @ 1 keV.
- Mass = MS mass measured in tons.

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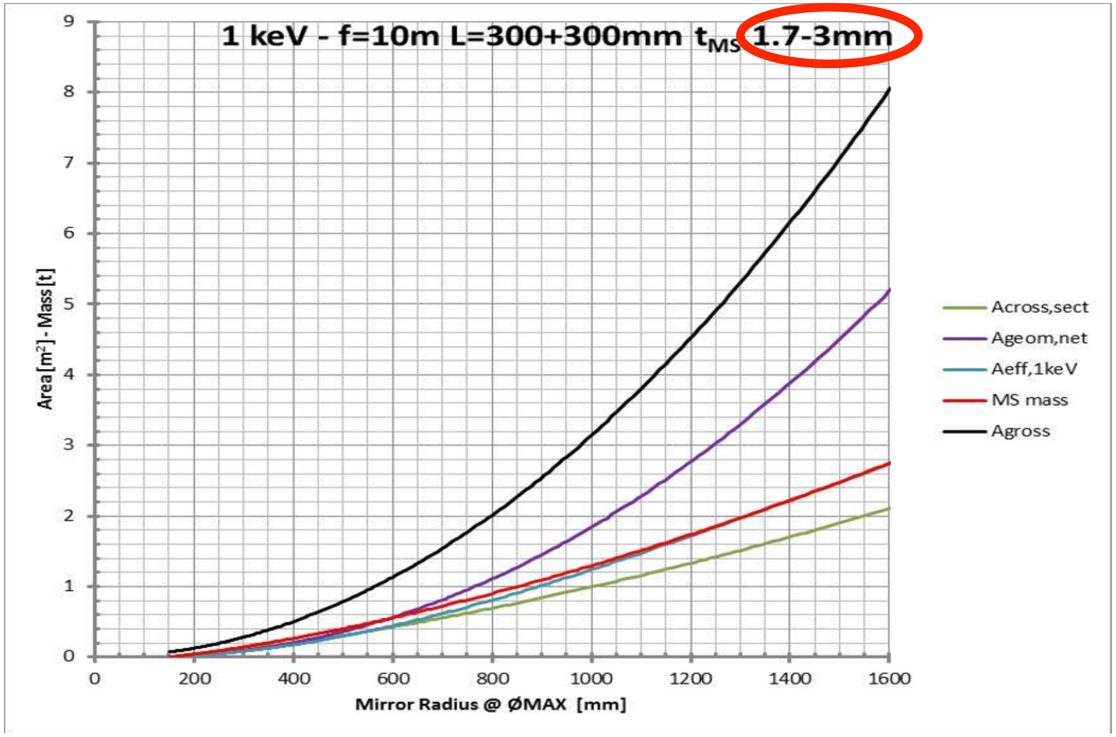

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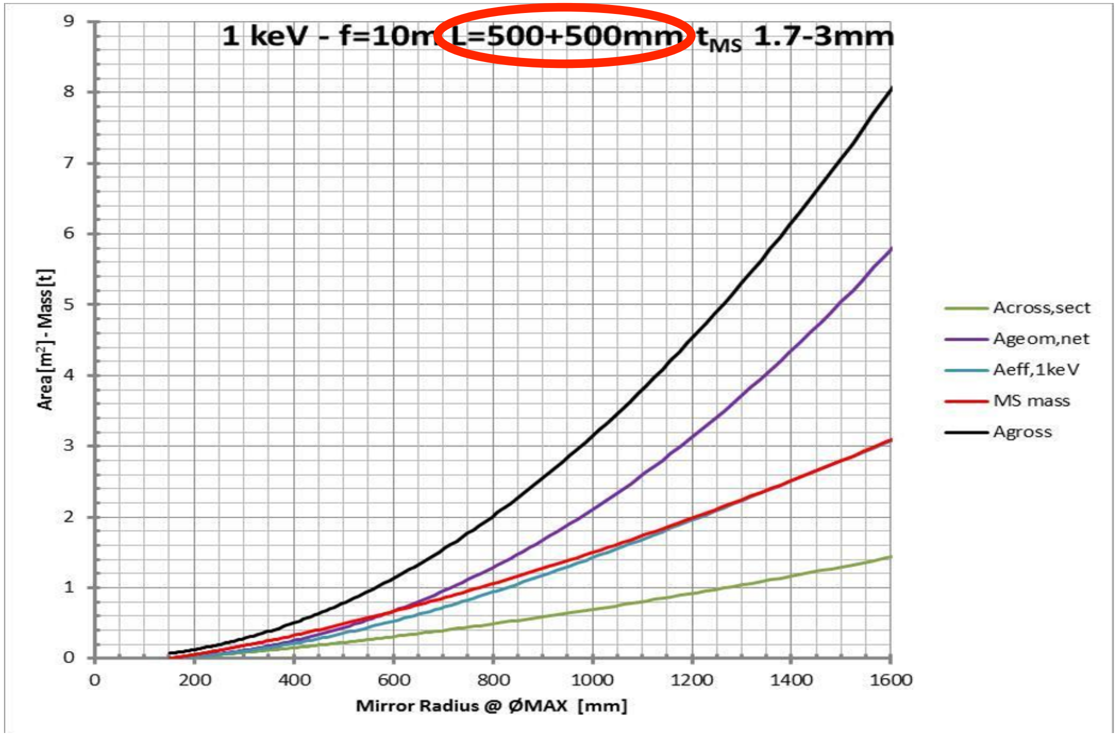

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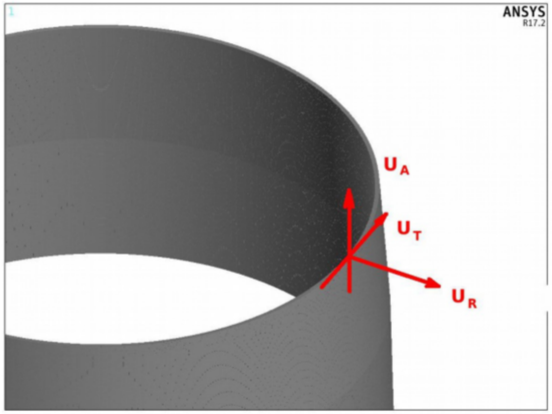
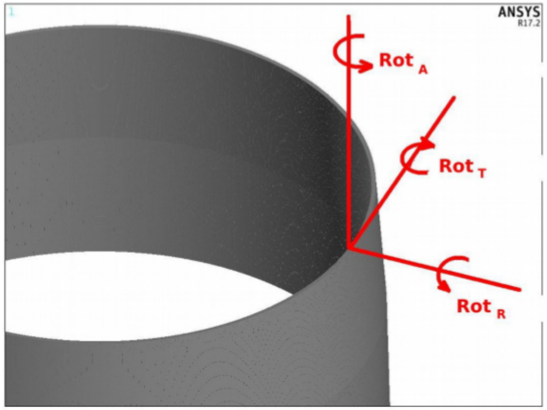
Monolithic shell preliminary structural consideration

WHICH IS THE STIFFNESS AND THE FIRST EIGENFREQUENCY FOR THE INTEGRATED SHELLS?

4 type of constrains:

Constrain	UR	UT	UA	ROTR	ROTT	ROTA
SH	fixed	fixed	fixed	free	free	free
AF	fixed	fixed	fixed	fixed	fixed	fixed
H_UR	free	fixed	fixed	free	free	free
F_UR_ϕT	free	fixed	fixed	fixed	free	fixed





Spoke number (equally spaced in azimuthal direction).

Mirror shell degrees of freedom constrained to the “infinitely stiff” spoke

Spoke wheel number: one or both end sections.

Monolithic shell preliminary structural consideration

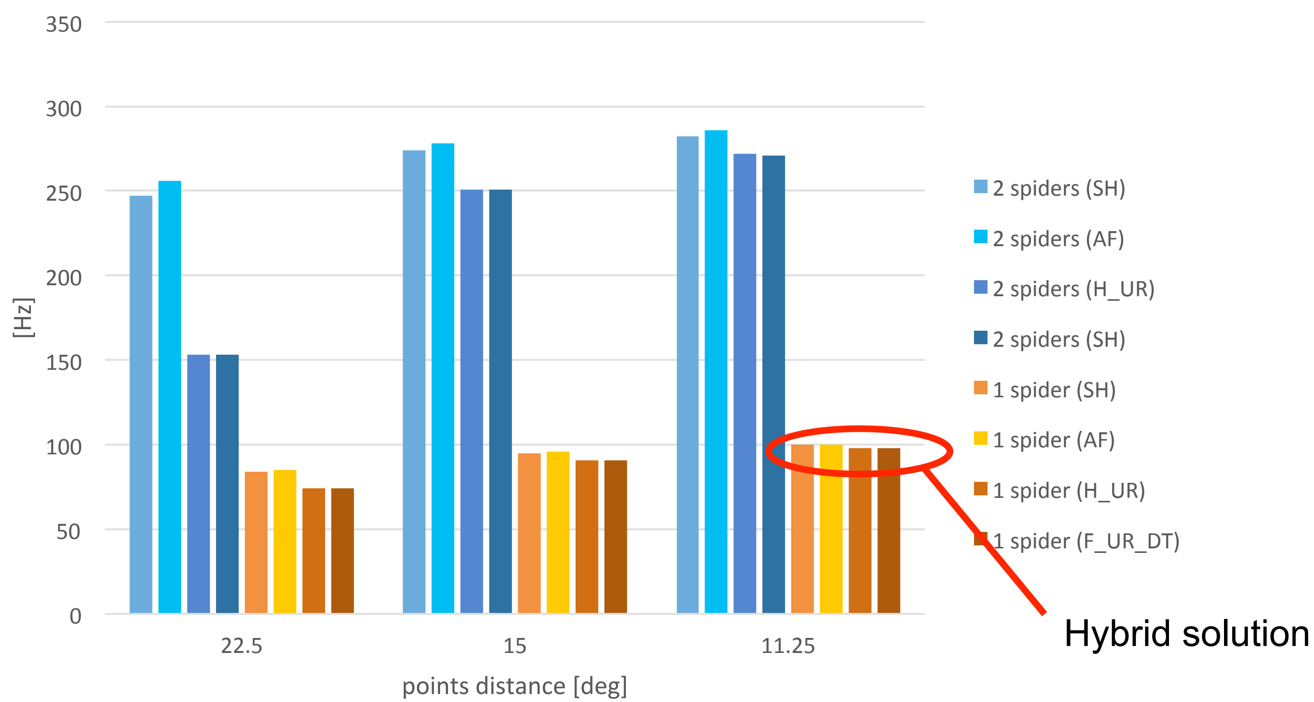
WHICH IS THE STIFFNESS AND THE FIRST EIGENFREQUENCY FOR THE INTEGRATED SHELLS?

R: **500** mm

Th.: **2** mm

L: 300+300 mm

Constrain	UR	UT	UA	ROTR	ROTT	ROTA
SH	fixed	fixed	fixed	free	free	free
AF	fixed	fixed	fixed	fixed	fixed	fixed
H_UR	free	fixed	fixed	free	free	free
F_UR_ϕT	free	fixed	fixed	fixed	free	fixed



Monolithic shell preliminary structural consideration

WHICH IS THE STIFFNESS AND THE FIRST EIGENFREQUENCY FOR THE INTEGRATED SHELLS?

R: **1500** mm

Th.: **3** mm

L: 300+300 mm

Constrain	UR	UT	UA	ROTR	ROTT	ROTA
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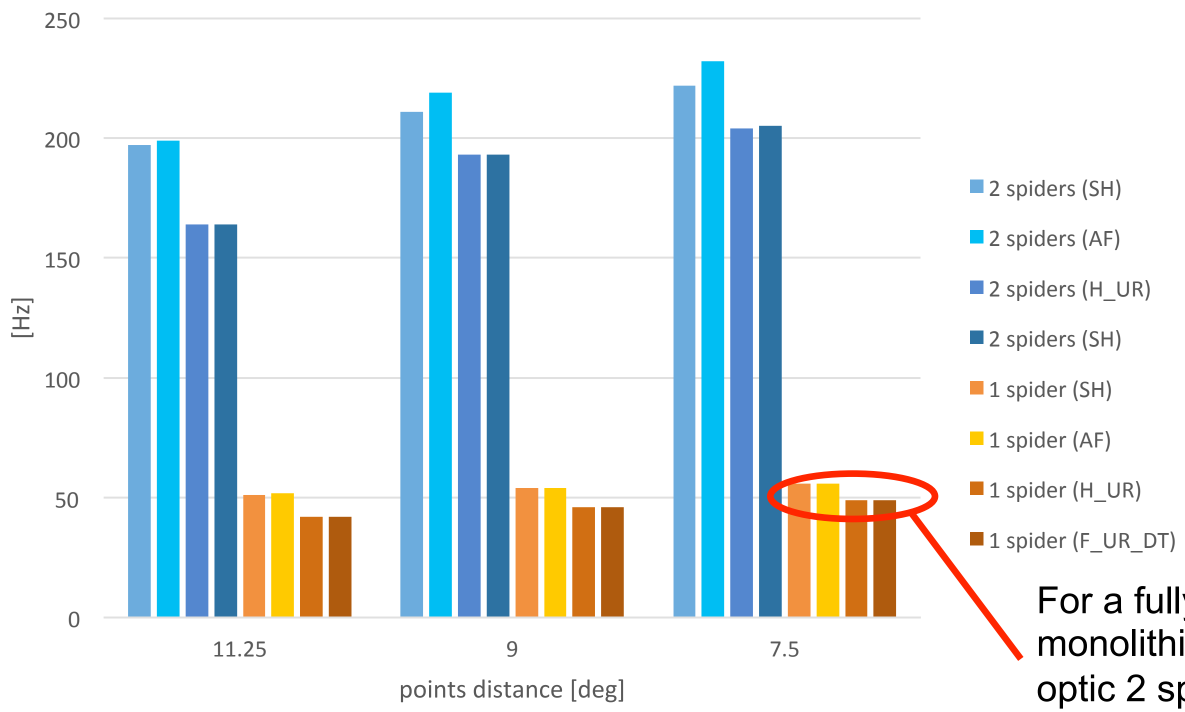
AF	fixed	fixed	fixed	fixed	fixed	fixed
H_UR	free	fixed	fixed	free	free	free
F_UR_ϕT	free	fixed	fixed	fixed	free	fixed



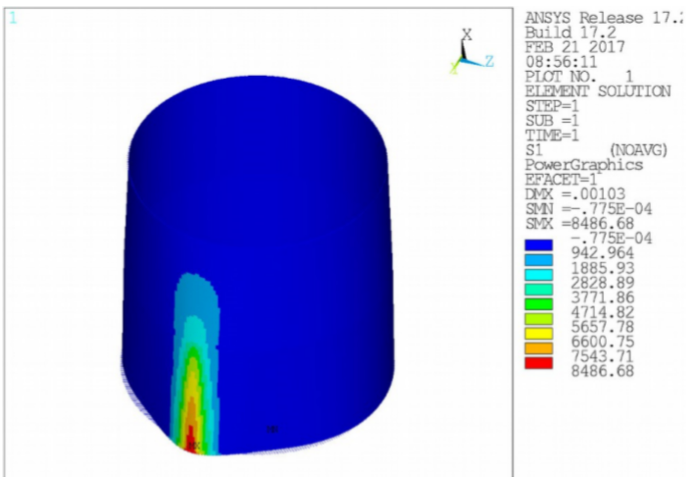
For a fully monolithic optic 2 spiders are suggested

Monolithic shell preliminary structural consideration

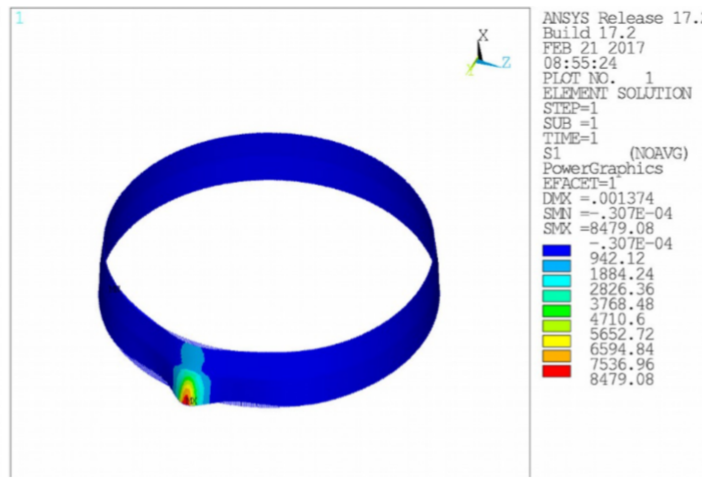
FEM FOR FEASIBILITY OF POLISHING (supported with SSS)

See Civitani presentation

R: 500 mm	R: 1500 mm
Th.: 2 mm	Th.: 3 mm
L: 500+500 mm	L: 300+300 mm



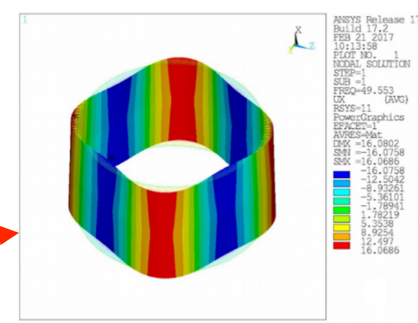
1° principal stress: 8.5 MPa



1° principal stress: 8.5 MPa

For all the case with a pad width of 50-100 mm and a length equal to half the shell length (pressure of 0.3 N/cm^2):

- the first principal stress is in the range of 6-10 Mpa
- The natural frequencies are in the range: 20-73 Hz



$Ø_{MS}$=1m L_{MS}=0.6m th_{MS}=2.037mm

Monolithic shell preliminary structural consideration

WHICH IS THE GRAVITY EFFECT FOR THE INTEGRATED SHELLS?

Only the configuration with 2 spiders is considered

Constrain:

Constrain	UR	UT	UA	ROTR	ROTT	ROTA
SH	fixed	fixed	fixed	free	free	free
H_UR	free	fixed	fixed	free	free	free

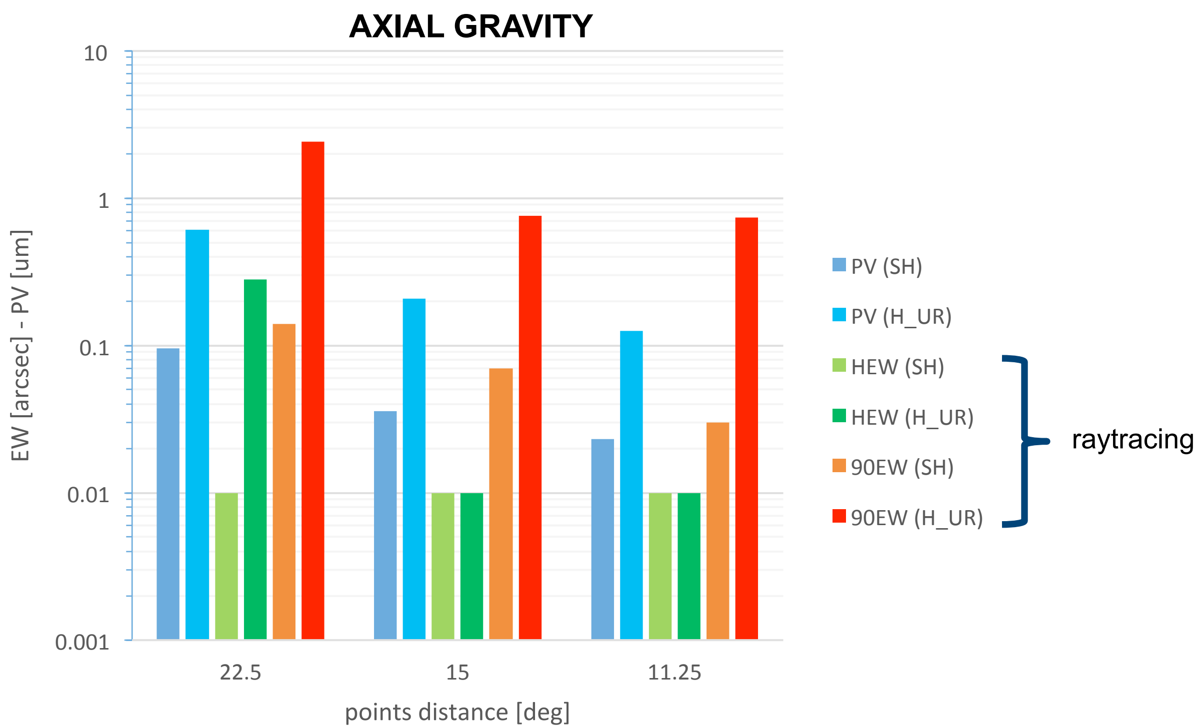
Load:

- 1g lateral
- 1g axial

R: **500** mm

Th.: **2** mm

L: 300+300 mm



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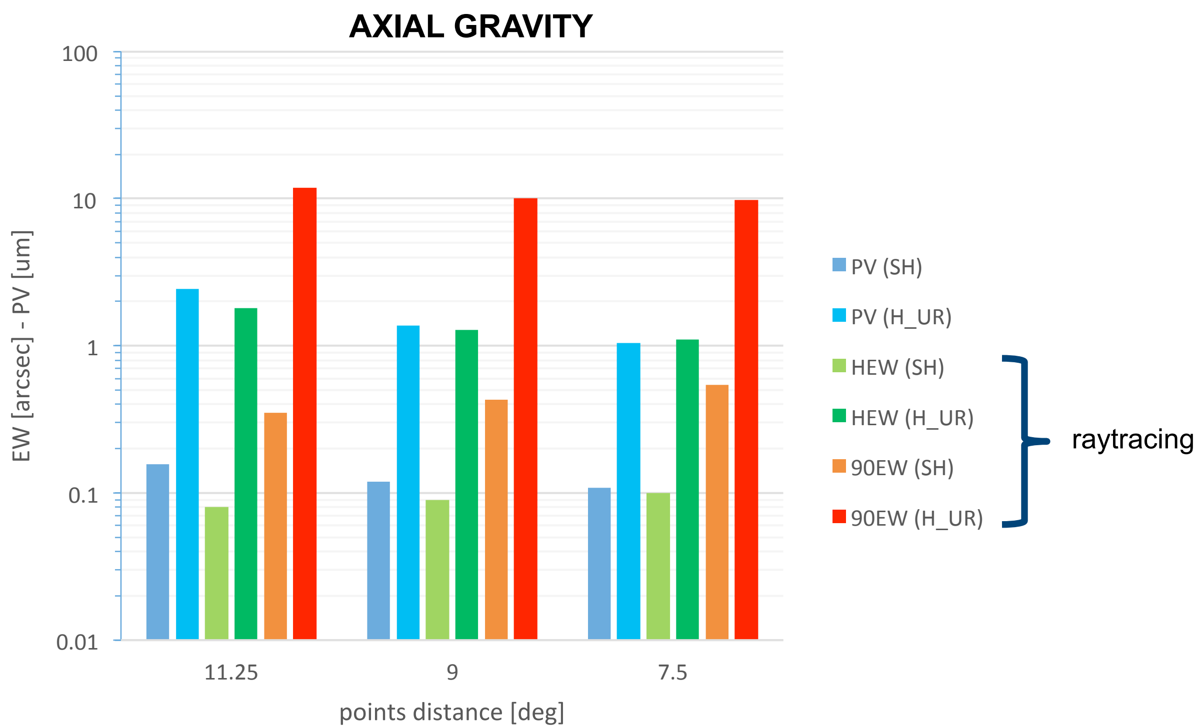

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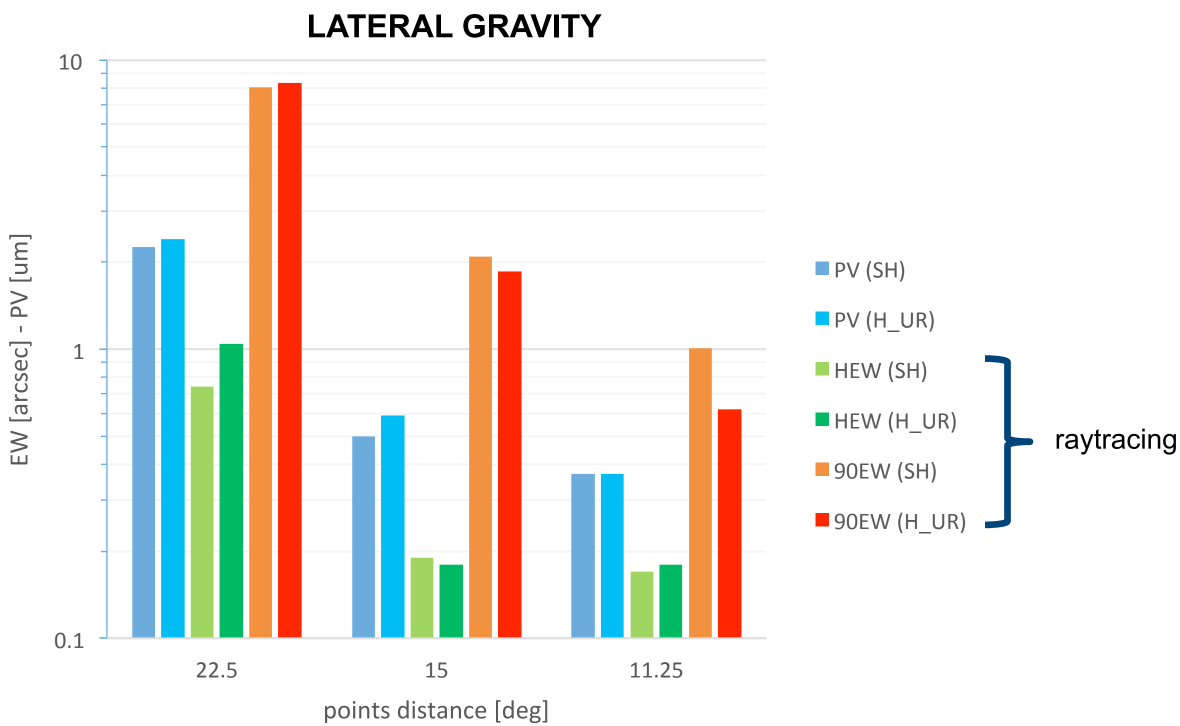

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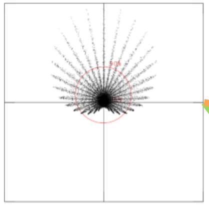
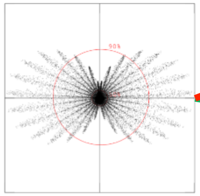
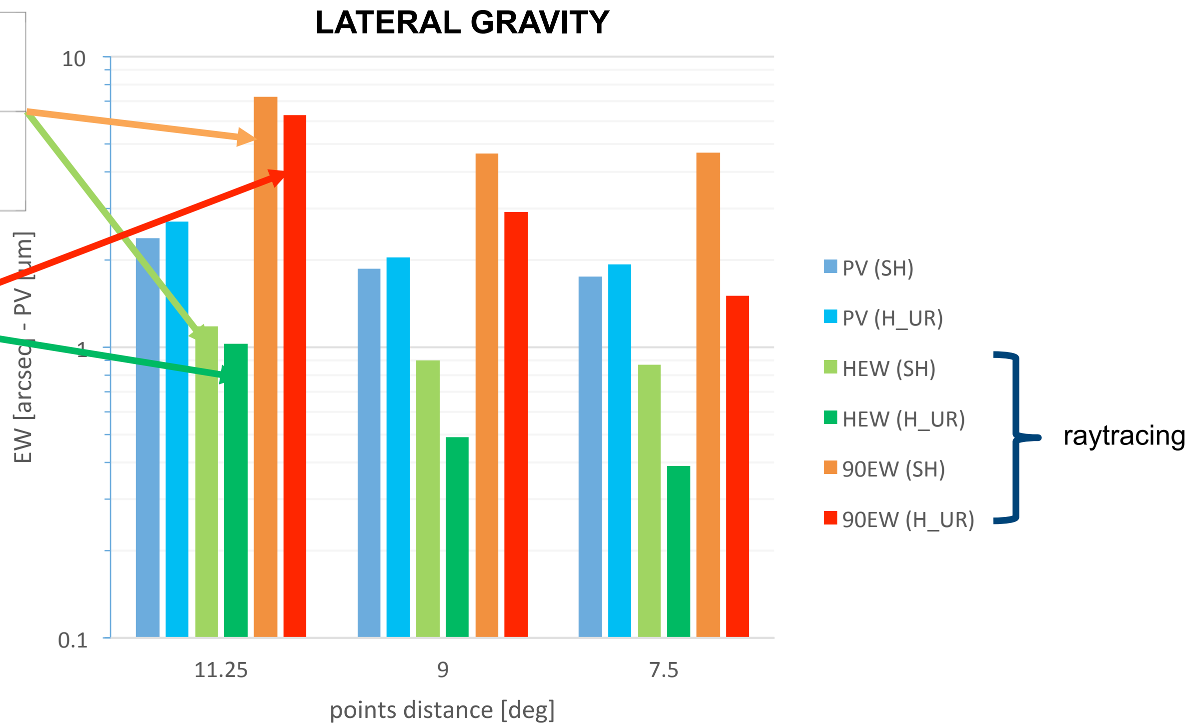






R: **1500** mm

Th.: **3** mm

L: 300+300 mm

CONCLUSION TOPIC 1

- **The mass expressed in tons is approximatively equal to the effective area expressed in m^2.**
- **The first frequency is more than 100 Hz for short shell (300+300mm) only for a diameter less than 1m, if they are fixed with one spider. If the diameter is more than 1m 2 spiders are suggested.**
- **The polishing is possible also for large shell even if the SSS should be re-design to meet complexity of manufacturing of large shell and keeping into attention to the coupling between the tool spin and natural frequency of the shell.**
- **The gravity effect is acceptable (even if it is worse for for shell with large diameter).**

3 points support for segmented shell

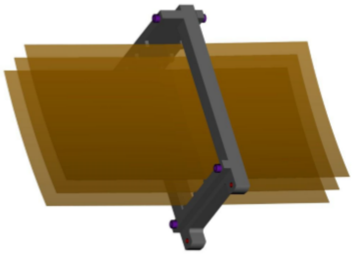
PARAMETERS RANGE:

Thickness: from 0.4 mm to 3.6 mm

Length (par+hyp): from 200 mm to 600 mm

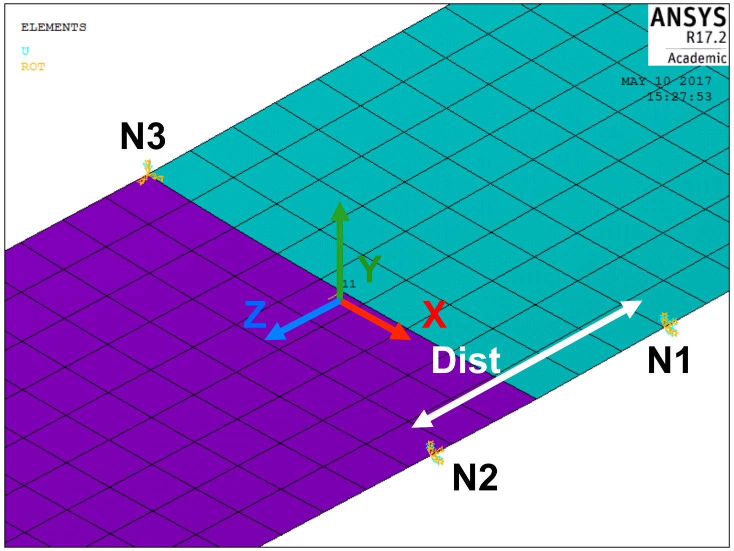
Angular width: 5°; 10°; 15°

Focal length: 10 m



Courtesy: Max-Planck-Institute for extraterrestrial Physics

Constrains

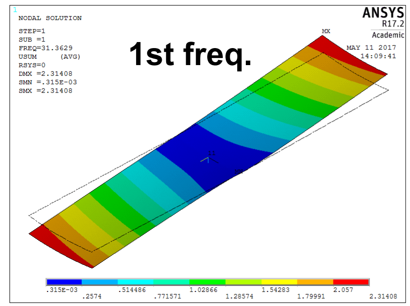


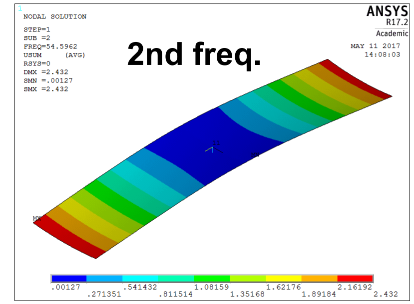
code	Dist [mm]	Type	Constr.
Vinc1	26	isostatic	N1: UX,UY,UZ,ALLROT = 0 N2: UX,UY,ALLROT = 0 N3: UY = 0
Vinc2	L	isostatic	N1: UX,UY,UZ,ALLROT = 0 N2: UX,UY,ALLROT = 0 N3: UY = 0
Vinc3	26	Hard-mount	N1: UX,UY,UZ,ALLROT = 0 N2: UX,UY,UZ,ALLROT = 0 N3: UX,UY,UZ,ALLROT = 0
Vinc4	L	Hard-mount	N1: UX,UY,UZ,ALLROT = 0 N2: UX,UY,UZ,ALLROT = 0 N3: UX,UY,UZ,ALLROT = 0
Vinc5	26		

3 points support for segmented shell

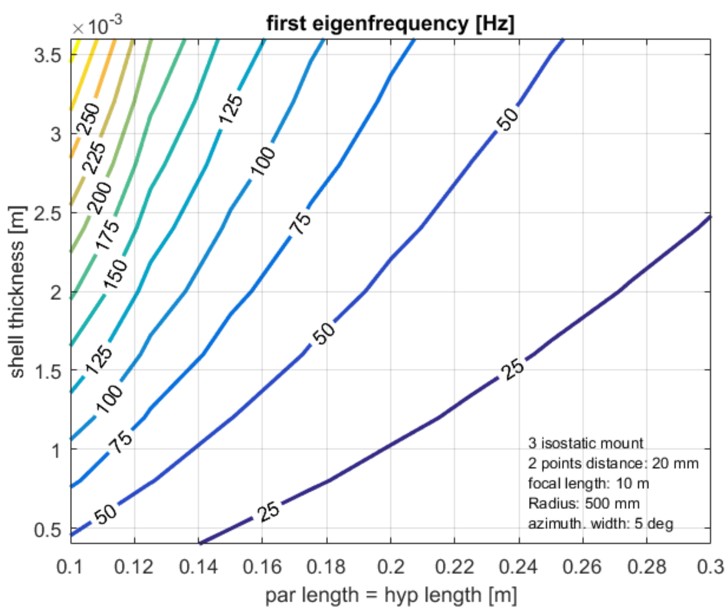
WHICH IS THE STIFFNESS AND THE FIRST EIGENFREQUENCY FOR THE INTEGRATED SHELLS?

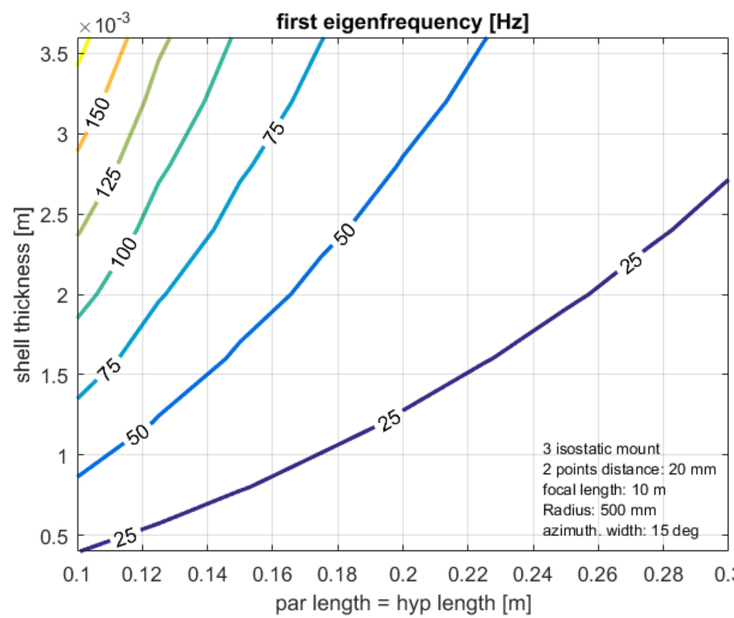
Code	Dist [mm]	Type	Constr.
Vinc1	26	isostatic	N1: UX,UY,UZ,ALLROT = 0 N2: UX,UY,ALLROT = 0 N3: UY = 0





R: 500 mm
Angular width: 5° (left) and 15° (right)





3 points support for segmented shell

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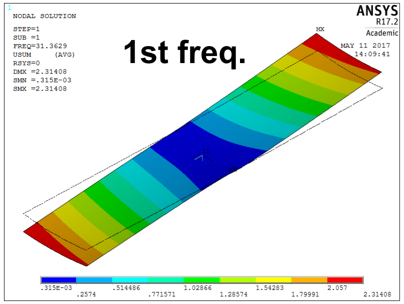

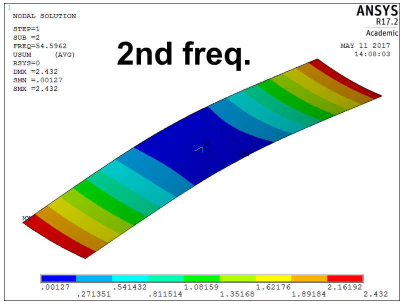

R: 1500 mm
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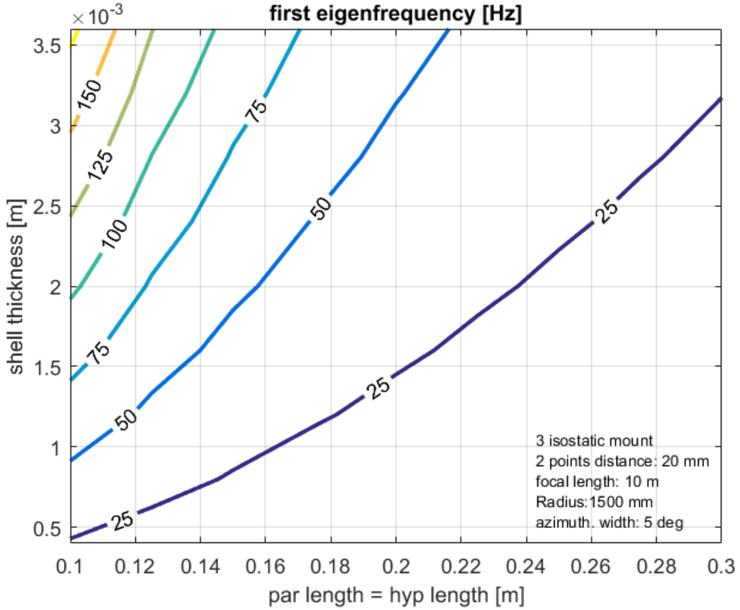

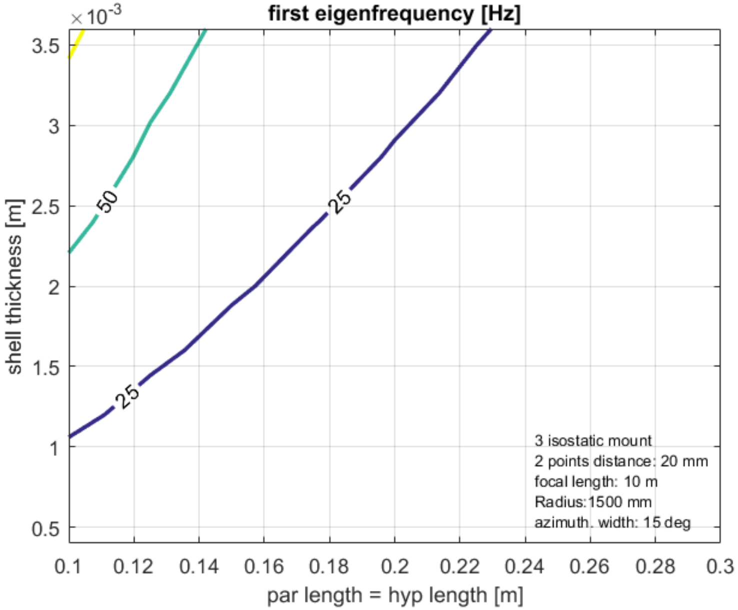

3 points support for segmented shell

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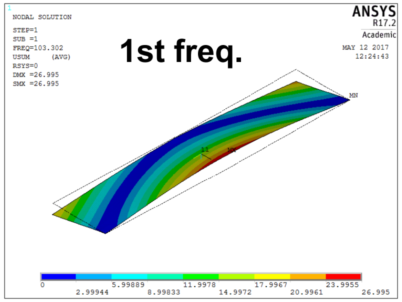
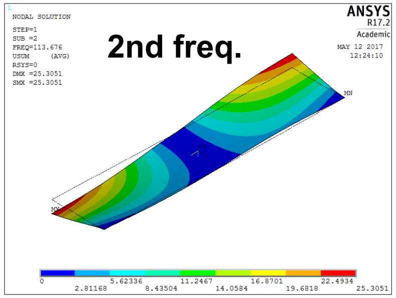
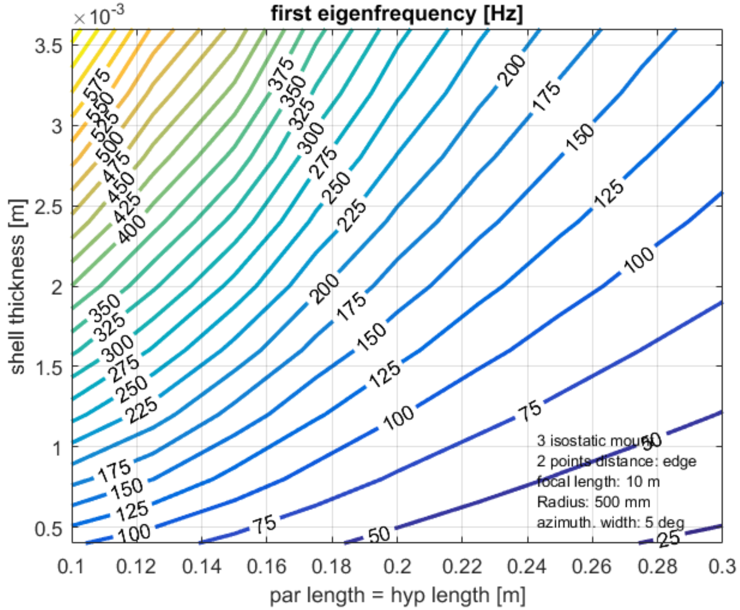
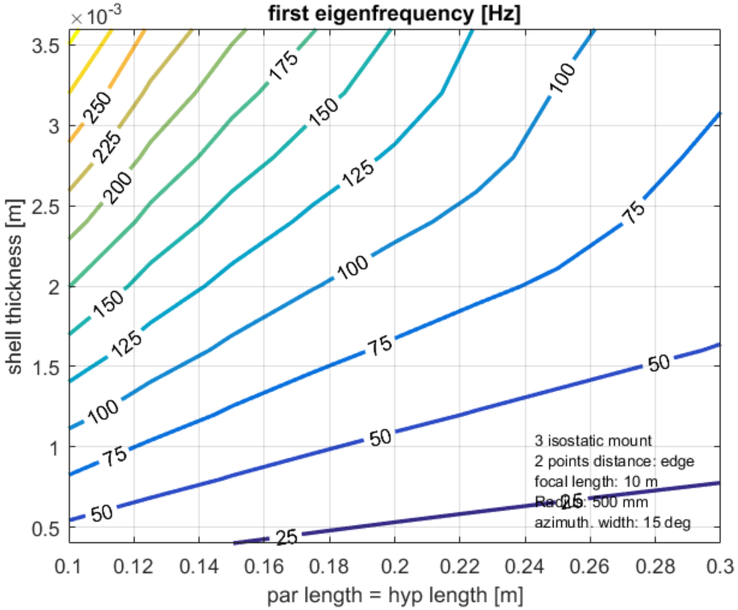
Code	Dist [mm]	Type	Constr.
Vinc2	L	isostatic	N1: UX,UY,UZ,ALLROT = 0 N2: UX,UY,ALLROT = 0 N3: UY = 0





R: 500 mm
Angular width: 5° (left) and 15° (right)





3 points support for segmented shell

WHICH IS THE GRAVITY EFFECT FOR THE INTEGRATED SHELLS?

Code	Dist [mm]	Type	Constr.
Vinc2	L	isostatic	N1: UX,UY,UZ,ALLROT = 0 N2: UX,UY,ALLROT = 0 N3: UY = 0

Loads: 1g in lateral direction (X)
1g in radial direction (Y)
1g in axial direction (Z)

R: 500 mm

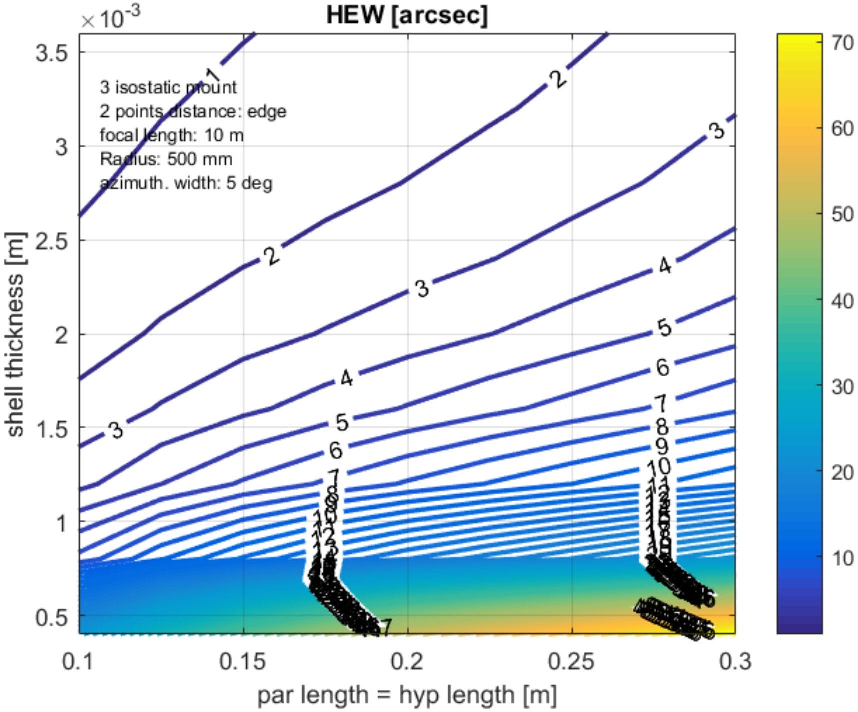
Angular width: 5°

Note: HEW is computed as

HEW = $NROT_{50\%}$*4*206264,

$NROT_{50\%}$ is the median of nodal rotation expressed in rad.
(206264 is the coefficient to convert radians into arcsec)

Rapresentative of X-ray measurement



3 points support for segmented shell

WHICH IS THE GRAVITY EFFECT FOR THE INTEGRATED SHELLS?

Code	Dist [mm]	Type	Constr.
Vinc3	26	Hard-mount	N1: UX,UY,UZ,ALLROT = 0 N2: UX,UY,UZ,ALLROT = 0 N3: UX,UY,UZ,ALLROT = 0

Loads: **1g in lateral direction (X)**
1g in radial direction (Y)
1g in axial direction (Z)

R: 500 mm

Angular width: 5°

Note: HEW is computed as

HEW = $NROT_{50\%}$*4*206264,

$NROT_{50\%}$ is the median of nodal rotation expressed in rad. (206264 is the coefficient to convert radians into arcsec)

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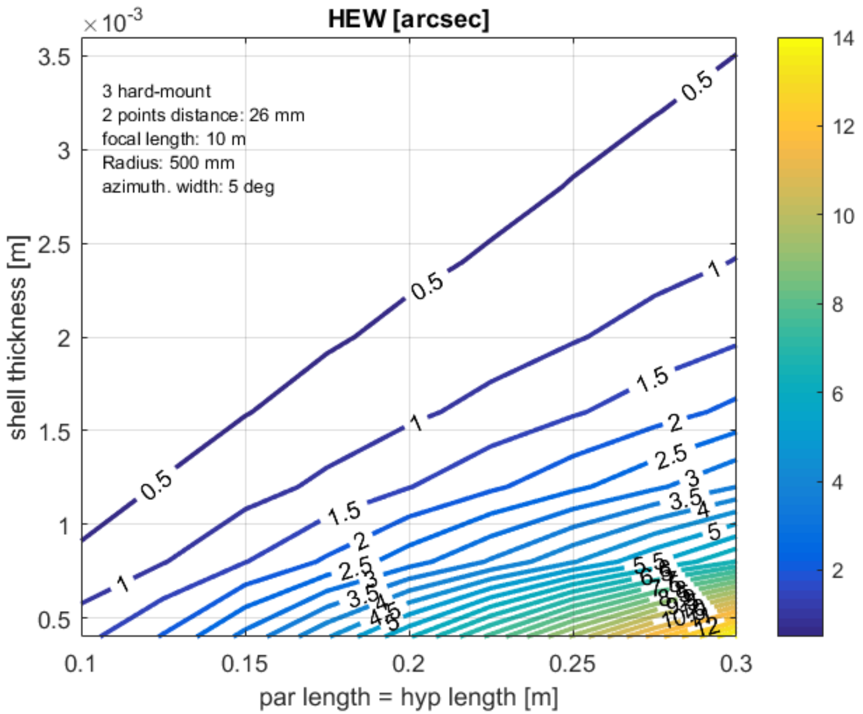


3 points support for segmented shell

HOW THE 3 POINT SUPPORT AFFECT THE SHELL DUE TO DISTORTION?

Representative for thermal loads or glue shrinkage

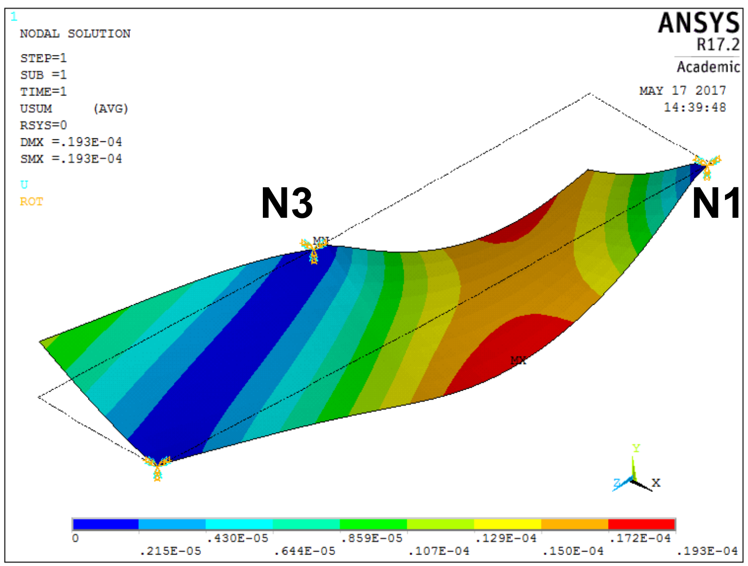
R: 500 mm

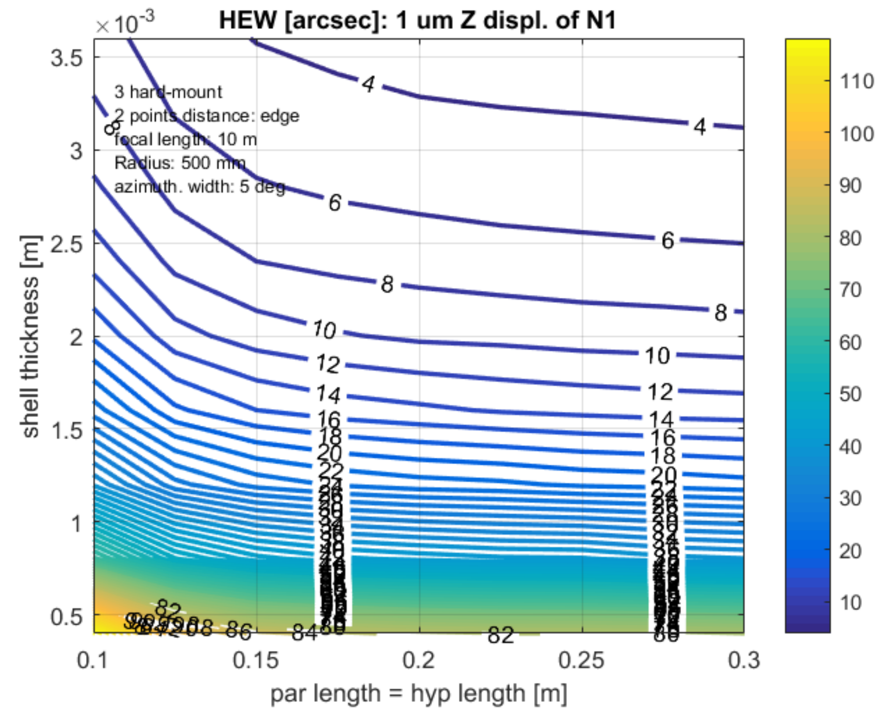
Angular width: 5°

cases:

- N1: UX = 1 μm
- N1: UY = 1 μm
- **N1: UZ = 1 μm**
- N3: UX = 1 μm
- N3: UY = 1 μm
- N3: UZ = 1 μm

Code	Dist [mm]	Type
Vinc4	L	Hard-mount

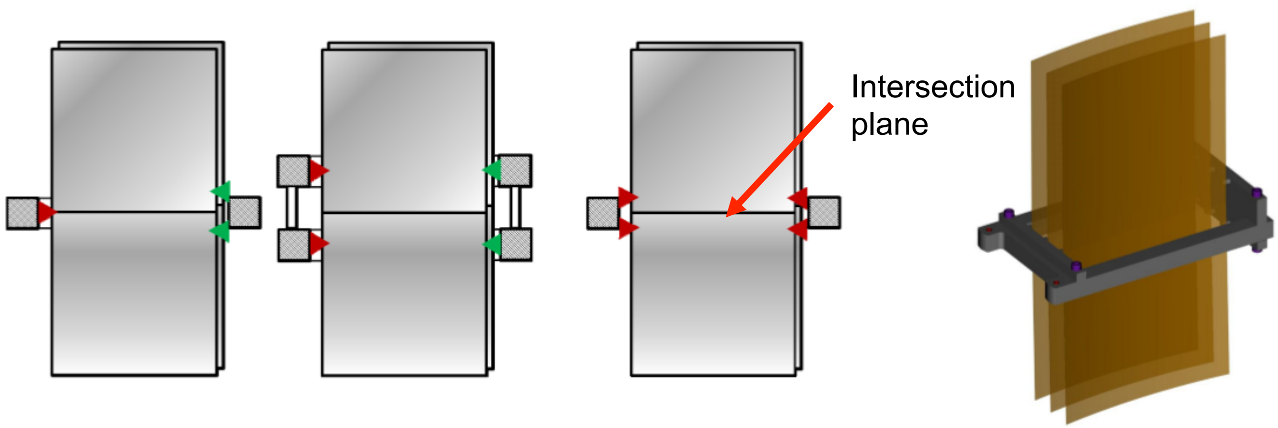




3 points support for segmented shell

CONCLUSION

- **Three points support is feasible for shell with a thickness in the range 1.5-3.6**
- **The distance of the points is a trade off between freq. Requirements and optical performance: if the distance is greater the freq. are higher while the optical performance should be better if the 3 point becomes a 2 points support in corrispondence of the intersection plane**



Courtesy: Max-Planck-Institute for extraterrestrial Physics

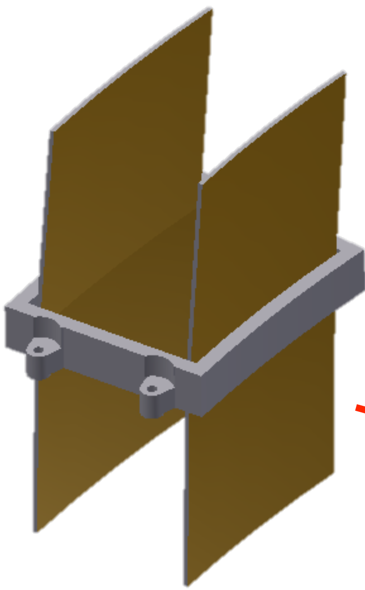
Supporting system with 2 different type of glue: hard (red) and soft (green)

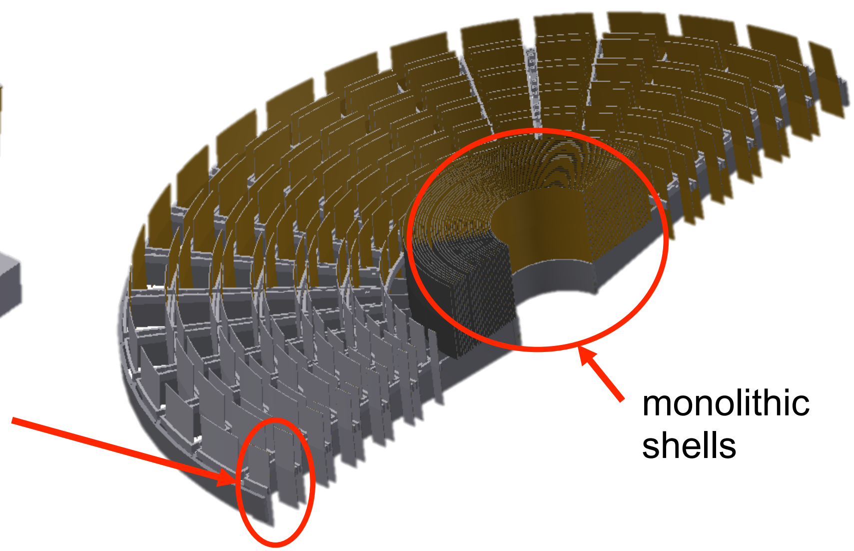
A preliminary concept of assembly for hybrid configuration

CONSIDERATIONS

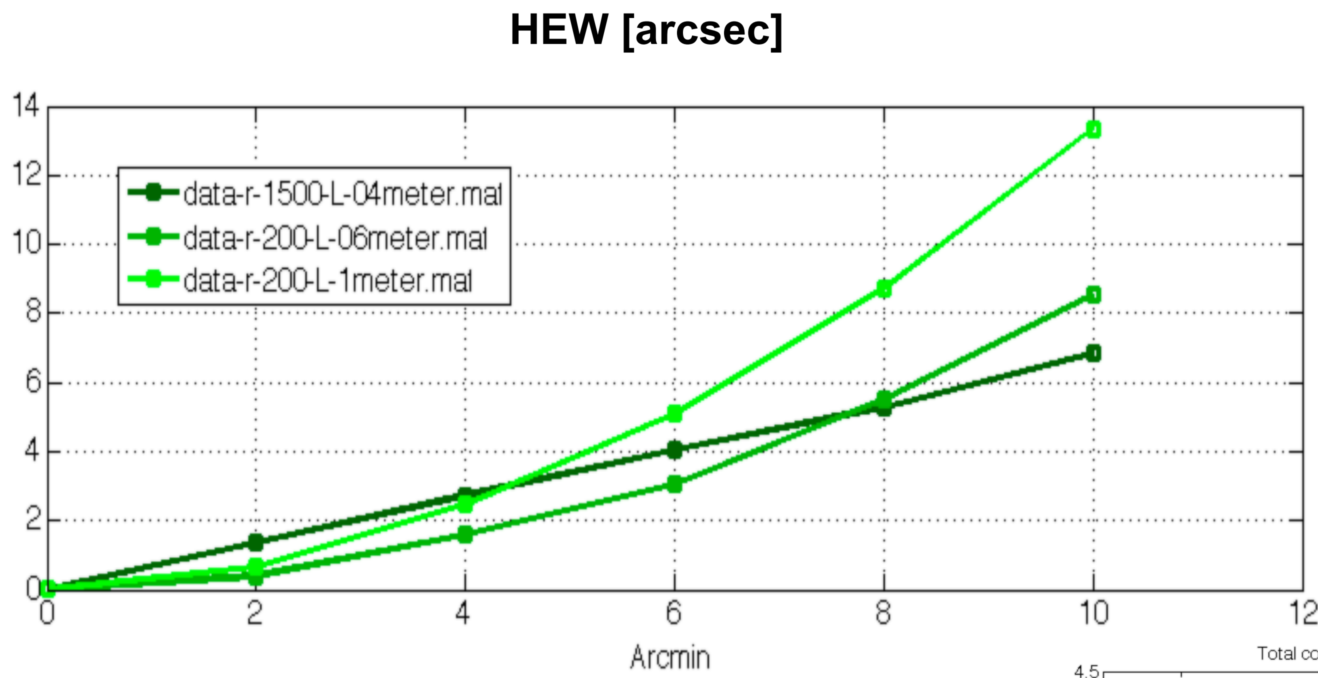
- **The shell length affects the PSF off-axis → mirror shells as short as possible… but the number of shell increases!**
- **The 1 spider (Dmax side or Dmin side) is preferable for monolithic shell because the D/L is >1. 1 spider is also ideal for segmented shell, fixed in proximity of Intersection plane**

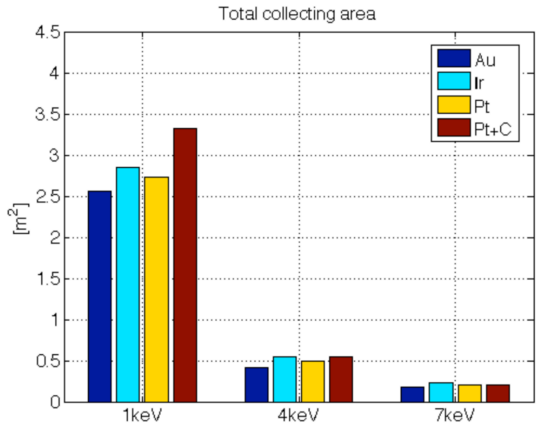
With 1 spider the intersection plane of segmented is not the same of monolithic shell:
Spacers could be needed depending on the off-axis resolution requirement





A preliminary concept of assembly for hybrid configuration



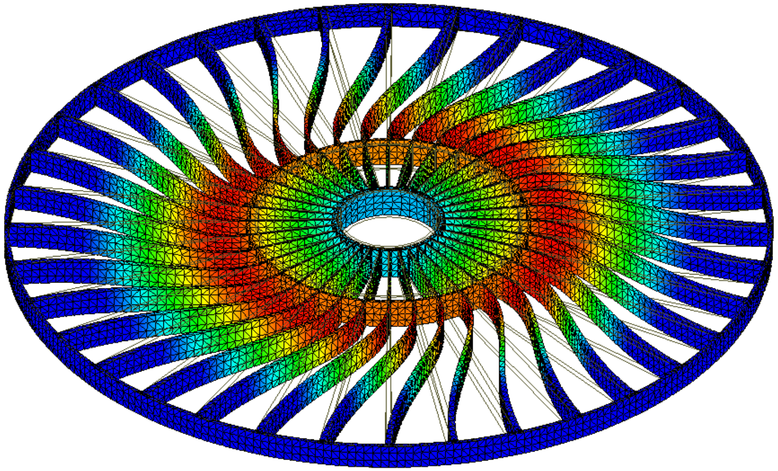


A preliminary concept of assembly for hybrid configuration

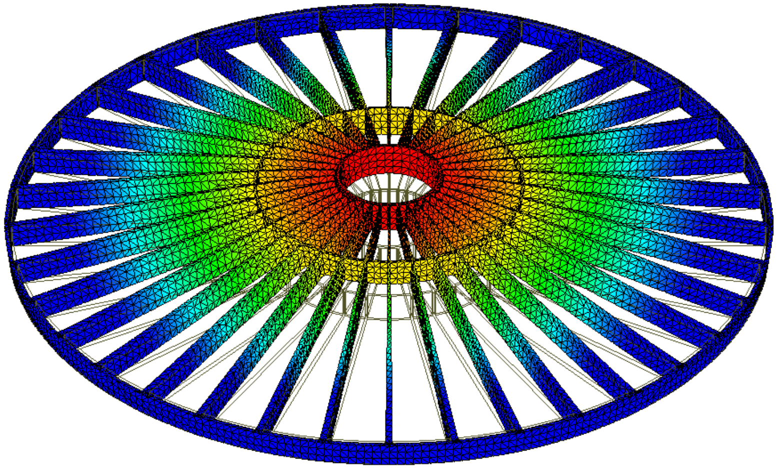
FEM analysis are ongoing

Example: modal analysis of spider (420 kg) without shells

freq1: 30Hz



freq2: 51 Hz



CONCLUSION

- **A preliminary study is ongoing in order to understand that the technology developing in OAB are applicable to a mission concept like Lynx.**
- **A fully monolithic shell solution is possible (with 2 spiders)**
- **A hybrid solution seems to be possible (with 1 spider)**
- **The main difficulty is achieving the angular resolution thinking to a process based on direct polishing and ion-beam process of thin glass substrate… but we are working to reach it**