The NGS WFS of MAORY

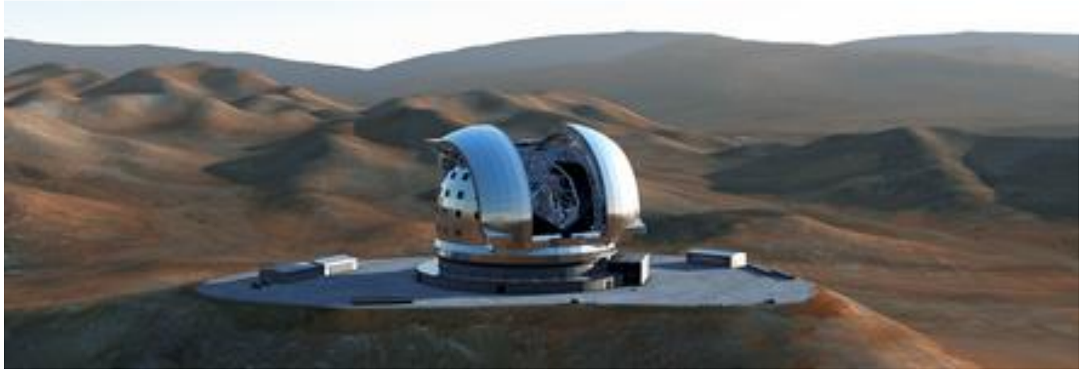
Presented by Marco Bonaglia

Adoni workshop
Padova, 10th-12th April 2017

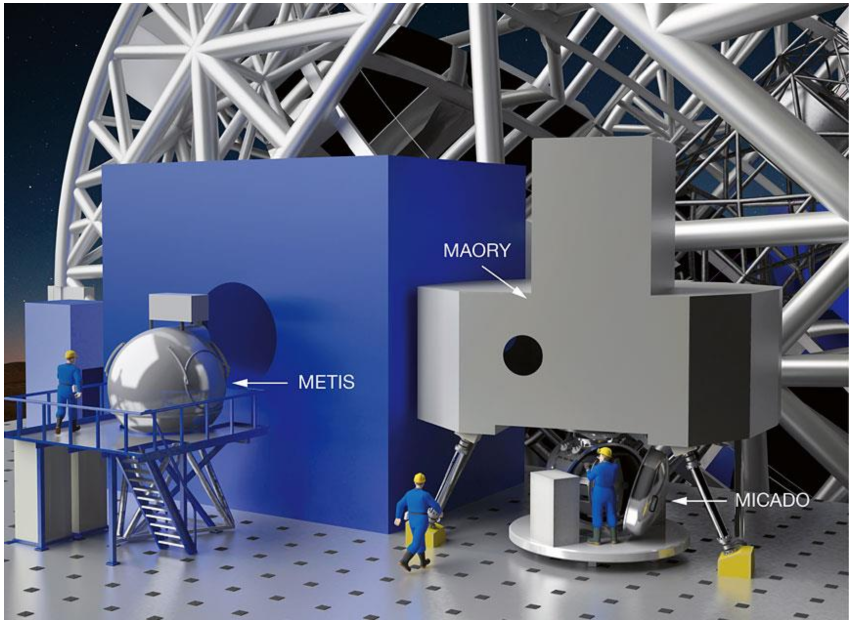
Summary

- Introduction of MAORY NGS WFS
- Error budget breakdown
- Support structure (Green doughnut)
- Design solutions for the NGS WFS
- Future activities

MAORY introduction

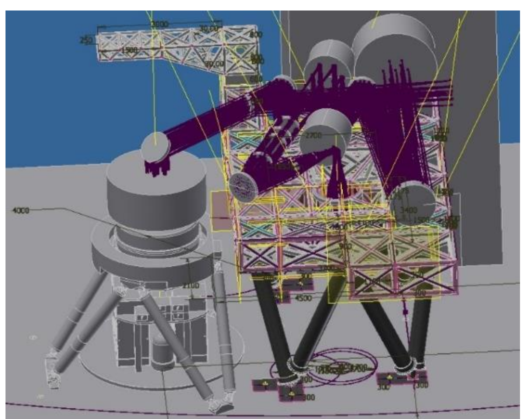


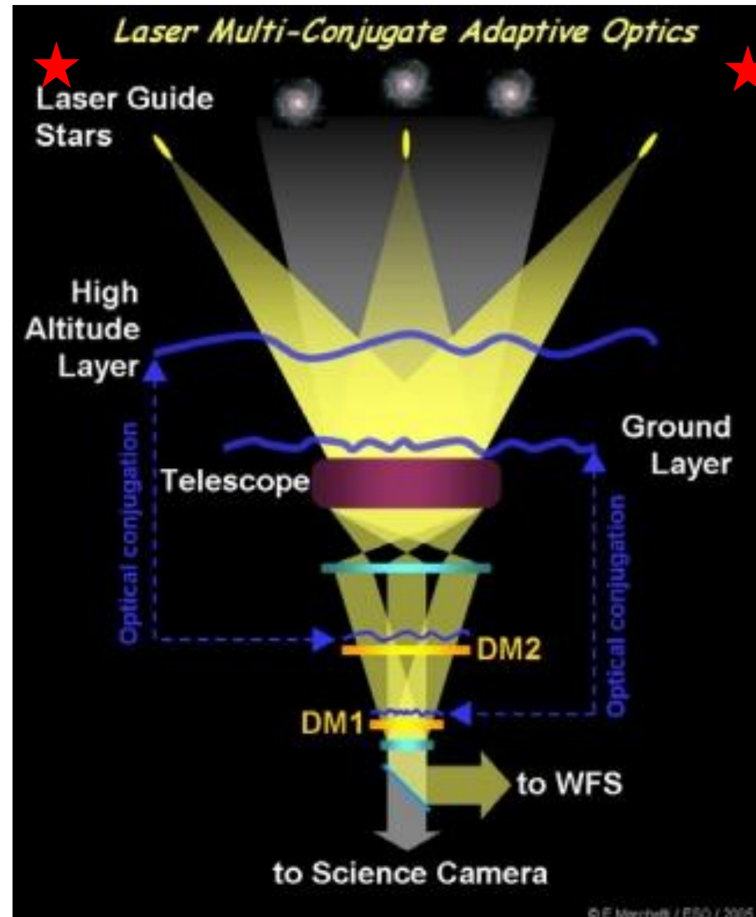
- **Post-focal AO facility of the E-ELT installed on Nasmyth platform since first light**
- **Will serve MICADO IR imager and spectrograph (+ a 2° gen. instrument)**



MAORY MCAO

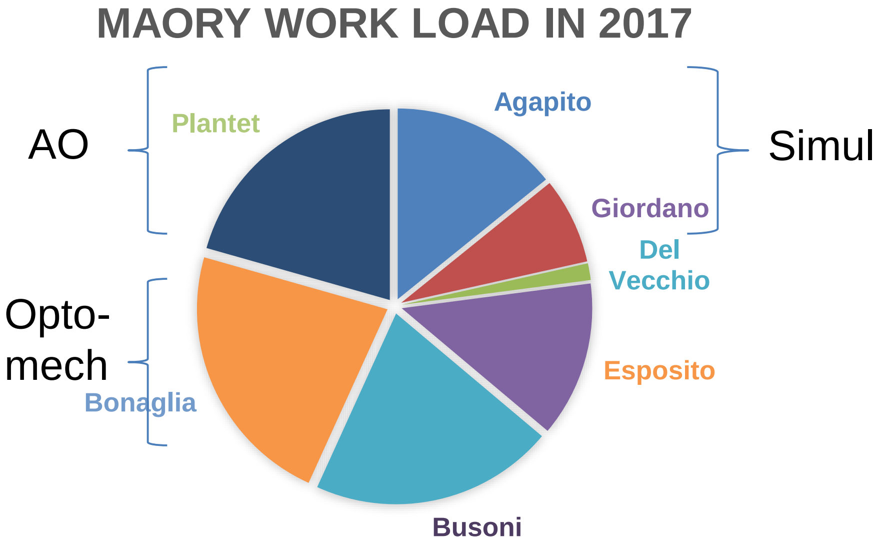
- MAORY will perform a tomographic measurement of the atmosphere through 6x LGS WFS.
- 3x NGS WFS used to sense low orders (TT, focus, astigmatism).
- MCAO correction implemented by M4 & post focal DM.





MAORY @ Arcetri

- **Arcetri contributes in the development of the NGS WFS**
- **6 people are involved (w/ > 25% of work hours):**
  - S. Esposito: local coordinator
  - L. Busoni: system engineer
  - C. Plantet: AO engineer
  - G. Agapito: control engineer
  - C. Giordano: control engineer
  - M. Bonaglia: opto-mechanical engineer, AWG MAORY-MICADO
  - ○ G. Di Rico: electronic engineer (Teramo obs.)



Data of first trimester 2017

Work load is evenly distributed btw simulation, system & opto-mech design

The NGS WFS requirements

Critical points addressed in the NGS WFS design:

Goal	Task
1. Ensure the astrometric performance: in the MAORY error budget the component allocated to the NGS WFS amounts to 12 µas.	Analysis of error sources and breakdown of the astrometric error budget into the NGS WFS
2. Ensure sky coverage: 50% when NGS WFS operates at 100-1k Hz and $M_H > 7$ and < 19 mag	Tradeoff study btw FoV diameter, overlapping, NGS pickoff architecture.
3. Ensure MAORY performances: 30% SR in K-band under median seeing conditions	Numerical simulations taking into account pre-correction from MCAO relay.

Astrometric error budget

- **MAORY simulations shown that astronomical images post-processing (3rd order transformation, …) translate the 12 µas astrometric budget for the NGS WFS into a differential pointing error of 1.8 mas stdev btw the 3 NGS WFS.**

⇒ **The plate scale on F17.7 translates the NGS WFS differential pointing error to < 6 um SD.**

~1/5 of PSF @ H band

- **Further complexity added to ensure that the astrometric performance are reached:**
  1. Timescale of 1 min (single exposure) => over 1.35° of rotator angle
  2. Dithering w/in 10'' radius => over 66 mm of displacement

Pointing error sources

The possible contributors to the NGS WFS pointing error have been identified.

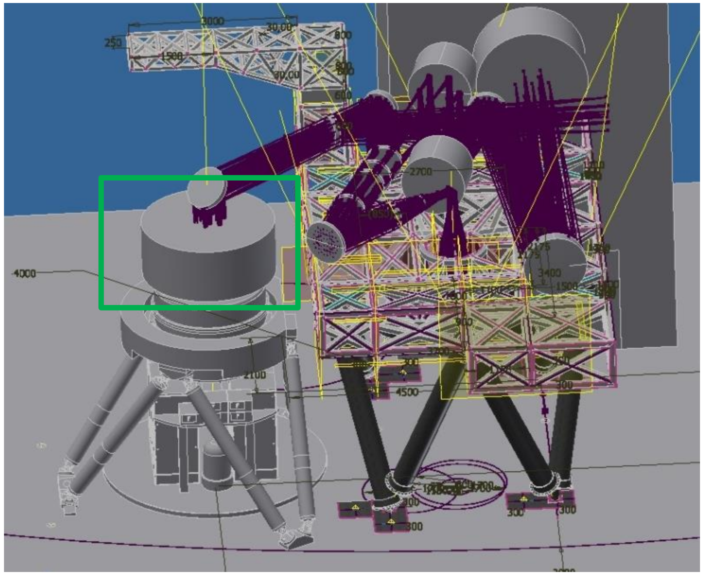
Contributor	Expected value	Single exp. / dithering	Control
Field distortion from MCAO relay	6 mas / deg @ 90“	8 mas	Calibrati on (LUT)
Atmospheric Field Differential Refraction	60” tg(Z)	1 mas	LUT
Support structure flexures	TBD	TBD	Design (LUT)
Atmospheric chromatic dispersion	0.8 mas / °Z	1 mas	ADC
Chief Ray tilt (non telecentric beam)	28 mas / ” off-axis	280 mas	Active device

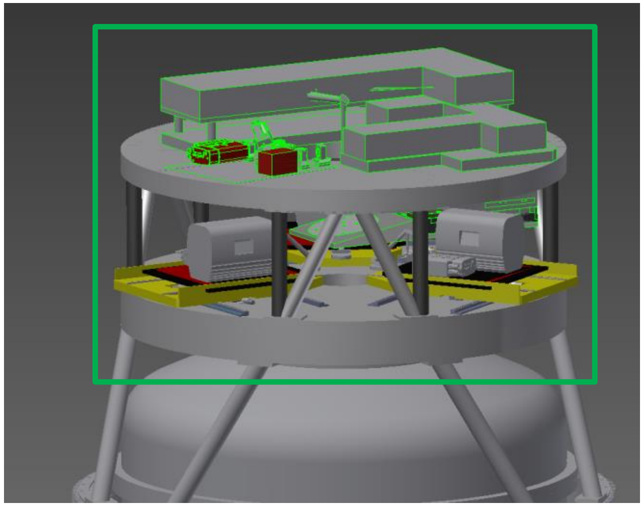
External to NGS WFS design

NGS WFS design must limit these contributions

Support structure overview

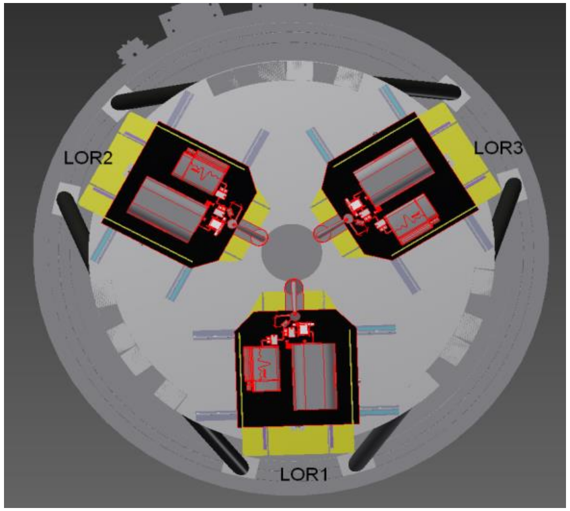
- The NGS WFS are hosted in a volume btw the MAORY bench and the MICADO cryostat where also the SCAO system must be implemented (Green doughnut).
- In March ‘17 an agreement was reached w/ MICADO consortium to split the volume in two: SCAO system will occupy the top part, NGS WFS the bottom one.





Feasibility study

- **Arcetri outsourced a feasibility study of the NGS WFS support structure to Tomelleri S.r.l.**
- **The goal was to limit the differential flexures of the 3 NGS WFS by the optimization of the support plate design already at PDR level.**



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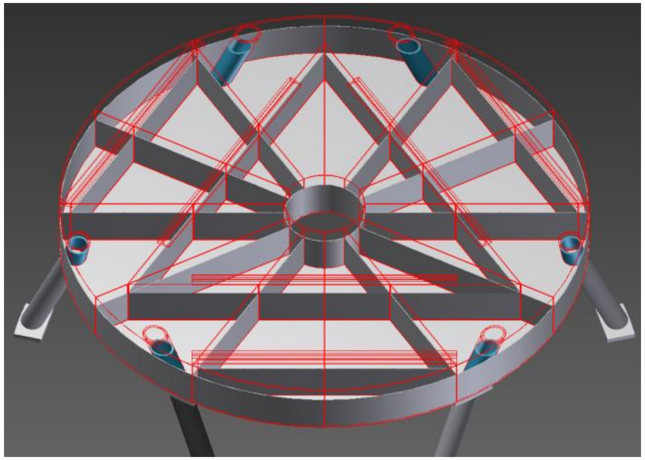
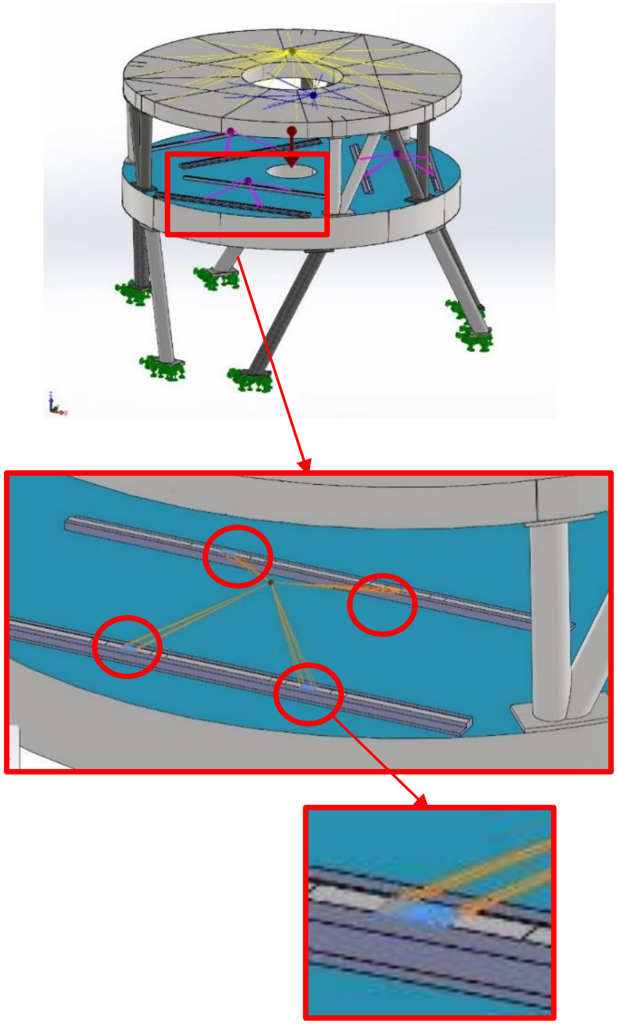
- The goal was to limit the differential flexures of the 3 NGS WFS by the optimization of the support plate design already at PDR level.
- Steel hollow structure to reduce mass.
- Rails welded directly on the stiffening elements.



Analysis results

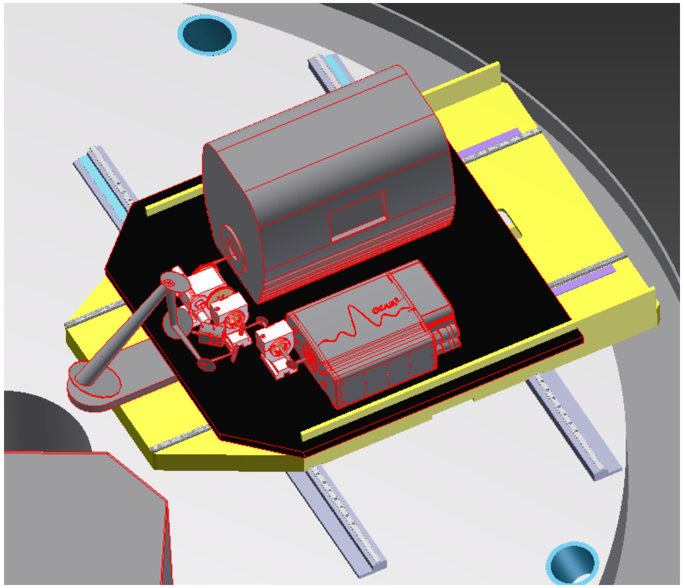
- Performance were evaluated in the most “realistic” conditions (i.e. load distribution in the flexure evaluation, fine meshes in the FEA, …)
- The plate flexures have been measured moving independently the 3 NGS WFS w/in 60 mm (to simulate for dithering operation)
- Differential pointing error < 0.5 um (8% spec)

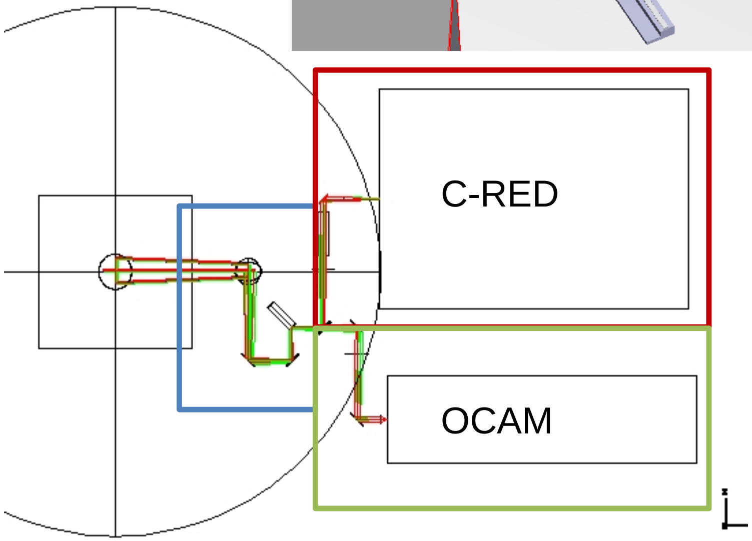


NGS WFS overview

Each NGS WFS will implement:

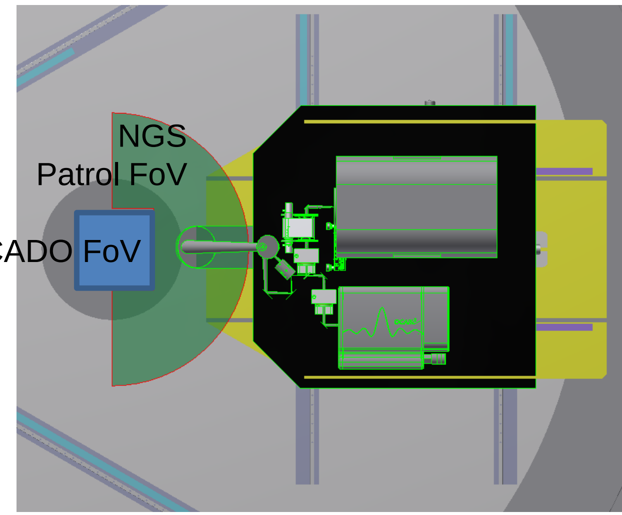
- **XY stages for NGS acquisition**
- **Pre-optics for focus and CR tilt compensation**
- **LO WFS: 3x3 IR SHS to measure fast tip-tilt, focus astigmatism**
- **Ref. WFS: 10x10 Vis SHS to de-trend LGS measurements**





NGS acquisition stages

- **The NGS WFS XY stages allow to acquire the NGS in a 300 x 600 mm area around MICADO FoV.**
- **Relying on VLT-ERIS experience the design and realization of the XY stages will be outsourced to companies (Steinmeyer).**
- **Design requirements have been identified and positive feedback received.**



R020	Overall accuracy linear per axis	5um over the full range
R021	Bidirectional repeatability	0.5um
R022	Positioning repeatability linear per axis	0.5um
R023	Positioning repeatability pitch and yaw	1 arcsec
R024	Accuracy for offsets per axis	0.5um for offsets <30mm
R025	Pitch and yaw for offsets	<1 arcsec for offsets <30mm

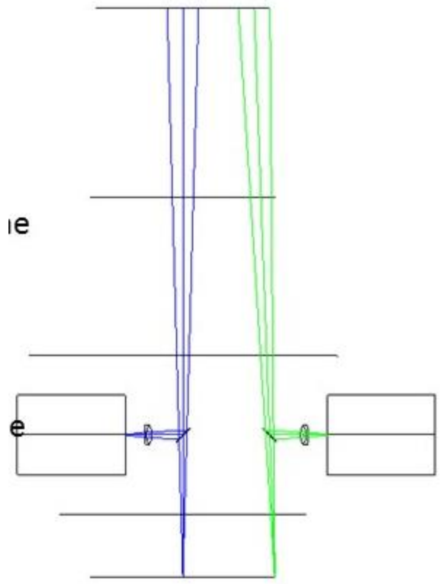
Design ensures 0.5 um repeatability = 0.15 mas (8% of spec)

CR tilt compensation

- **MAORY exit pupil @ ~ 8 m from FP**

⇒ **Expected a CR tilt up to 2.5° @ 90" off-axis**

⇒ **An active device to compensate for the CR tilt is needed**



CR tilt compensation

- MAORY exit pupil @ ~ 8 m from FP

⇒ Expected a CR tilt up to 2.5° @ 90'' off-axis

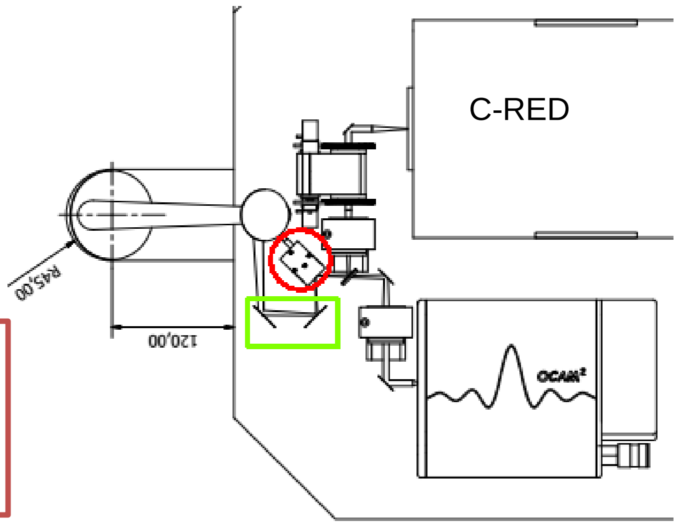
⇒ An active device to compensate for the CR tilt is needed

- A piezo driven TT mirror is the first candidate (i.e. PI S334.1SL)
- PROs: position feedback and 5 urad repeatability

⇒ To limit the impact on the NGS WFS pointing error the TT mirror must be placed close to the FP

Beeing able to place the mirror w/in ±10 mm from FP the 5 urad repeatability translates to a 15 uas pointing error (0.8% of spec)

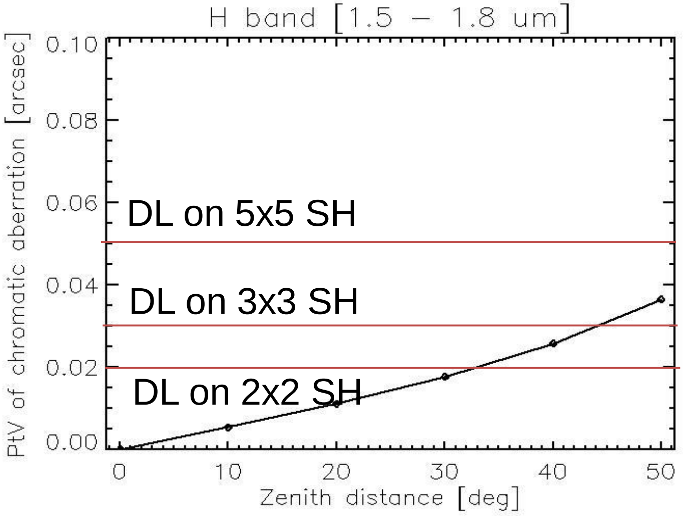
Closed-loop tilt angle	50	mrad
Open-loop resolution	0.5	µrad
Closed-loop resolution	5	µrad
Linearity	0.05	%
Repeatability	5	µrad



ADC for the LO WFS

- **Atmospheric chromatic dispersion will degrade the PSF quality delivered by the MAORY MCAO correction (expecially it case of low # of Subaps)**

⇒ **An H band ADC will be needed in the LO WFS**



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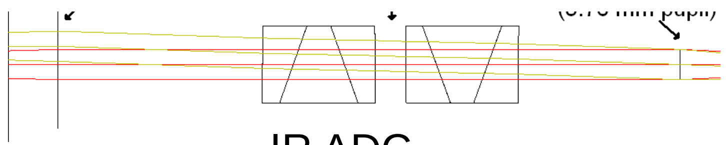
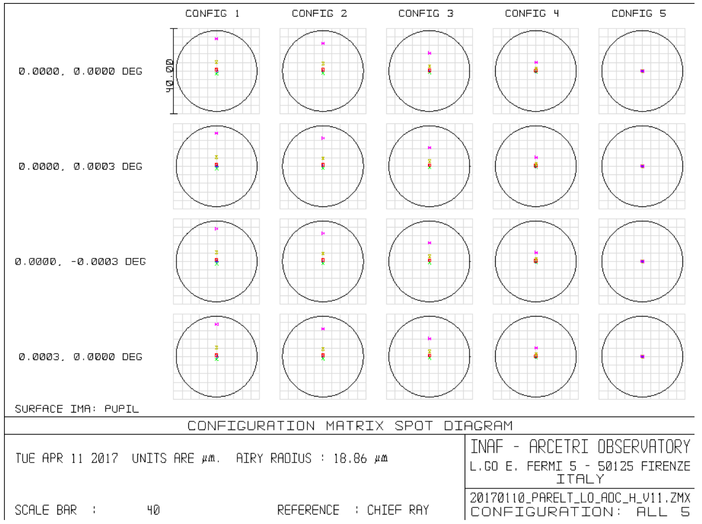
- **The ADC design is optimized to minimize CR shift or tilt**

Collimator
F= 105 mm

Lenlet array
Øpup= 5.76mm



IR ADC
ABA – ABA
(S-TIM2, S-FPM2)



- **Max pointing error at Z= 60° is 0.66 um = 0.2 mas (10% of spec)**
- **Pupil color < 2% (~1/20 subap)**

Conclusions

- MAORY astrometric accuracy requirement put tight constraints in the design of the NGS WFS, error budget has been breakdown into the WFS components.
- Design of the NGS WFS support structure is ongoing: volume splitting will ease the collaboration w/ MICADO.
- All NGS WFS functionalities have been identified and proper design solutions have been found.

Next steps:

- Open external contract for the design of the acquisition stages.
- Identify suitable control systems for NGS WFS DoF.
- Sketch AIT and alignment plans.
- Delivery of PDR documentation w/in 8 months.