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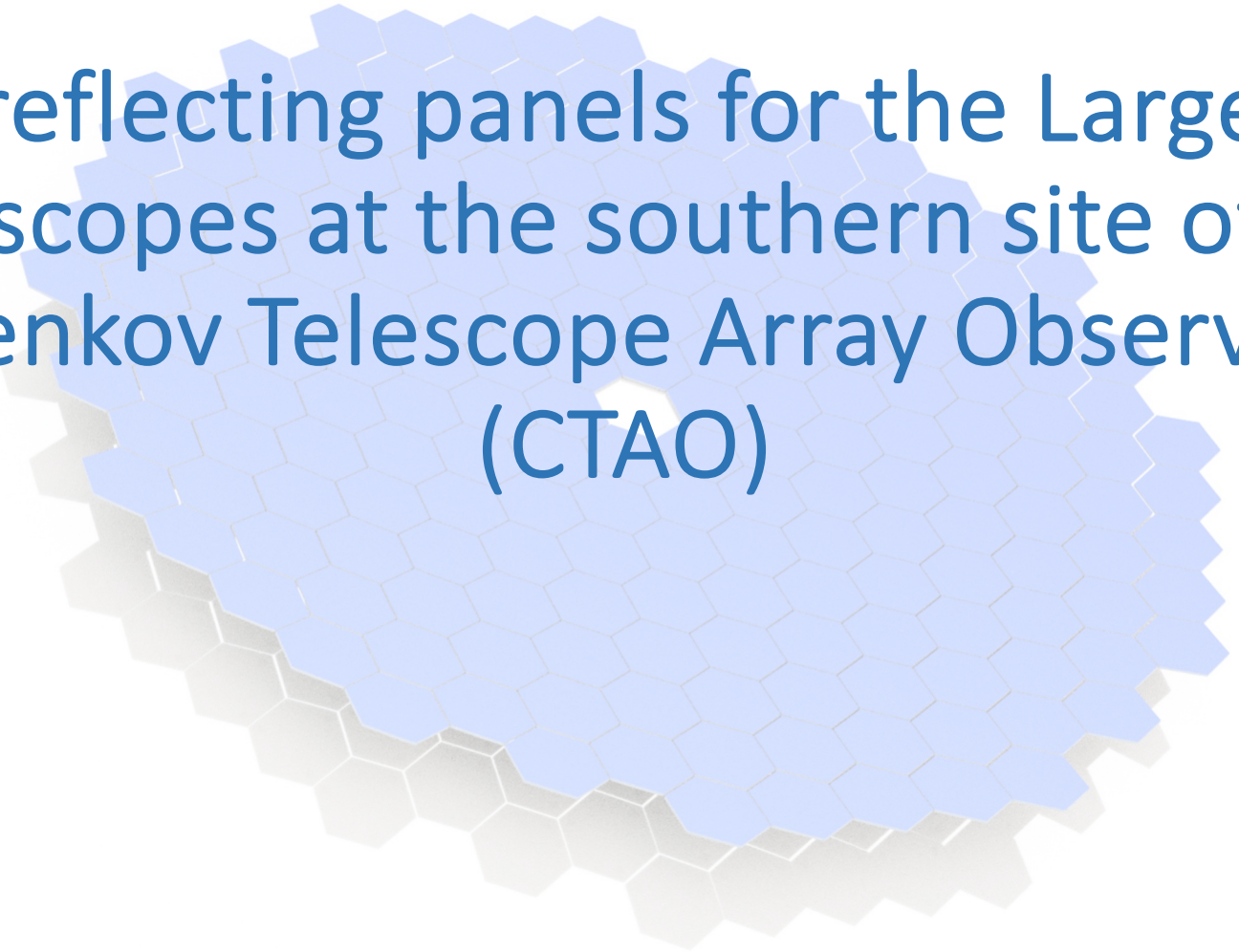
CTAO
INFN LST South

The reflecting panels for the Large Size Telescopes at the southern site of the Cherenkov Telescope Array Observatory (CTAO)



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CTAO – Cherenkov Telescope Array Observatory

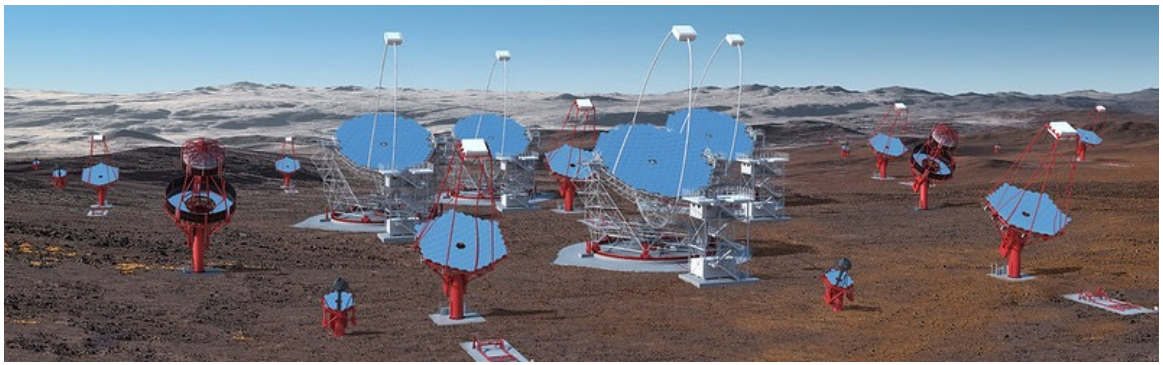
Introduction

INFN LST South

Credit: Gabriel Pérez Díaz, IAC

NORTH SITE
Observatorio del Roque de los Muchachos , La Palma
Plan for Alpha Configration:

4 LST
9 MST



Credit: Gabriel Pérez Diaz, IAC / Marc-André Besel, CTAO

SOUTH SITE
Valley between Paranal and Armazones, Chile
Plan for Alpha Configuration:

14 MST
37 SST

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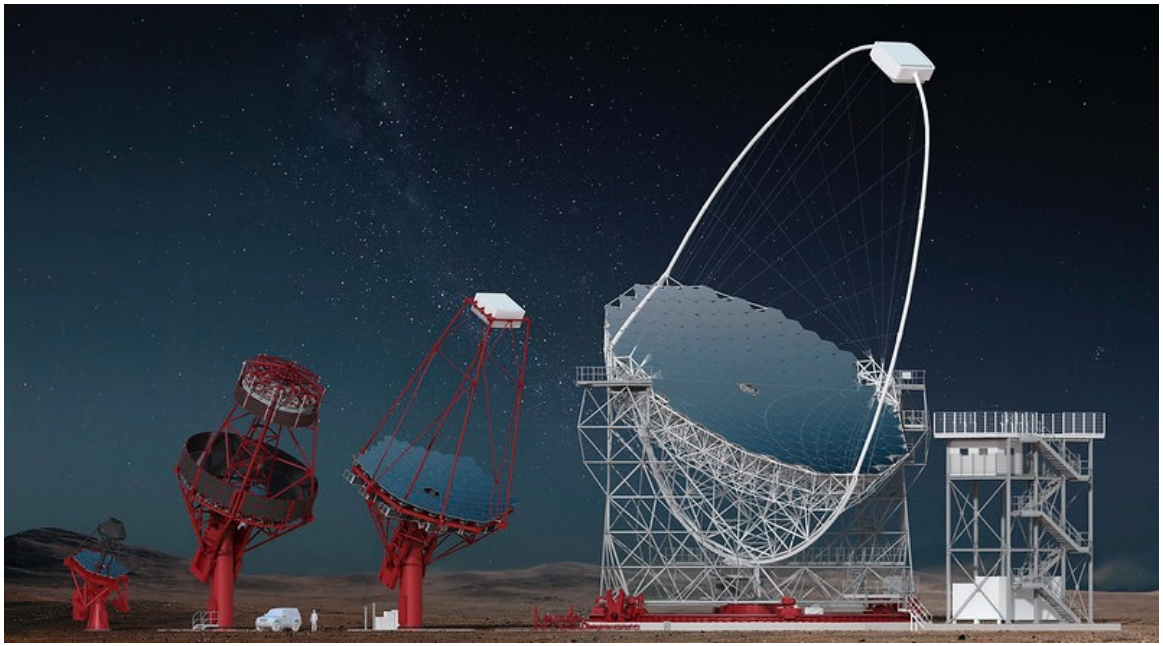
CTAO – Cherenkov Telescope Array Observatory

Introduction

INFN LST South



SST
4.3 m diam.
18 segments
850 mm

MST
12 m diam.
86 segments
1200 mm

LST
23 m diam.
198 segments
1510 mm

NORTH SITE
Observatorio del Roque de los Muchachos , La Palma
Plan for Alpha Configration:

4 LST --> 792 mirror segments
9 MST --> 774 mirror segments

SOUTH SITE
Valley between Paranal and Armazones, Chile
Plan for Alpha Configuration:

14 MST --> 1204 mirror segments
37 SST --> 666 mirror segments

~ 3500 mirror segments

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Project frame

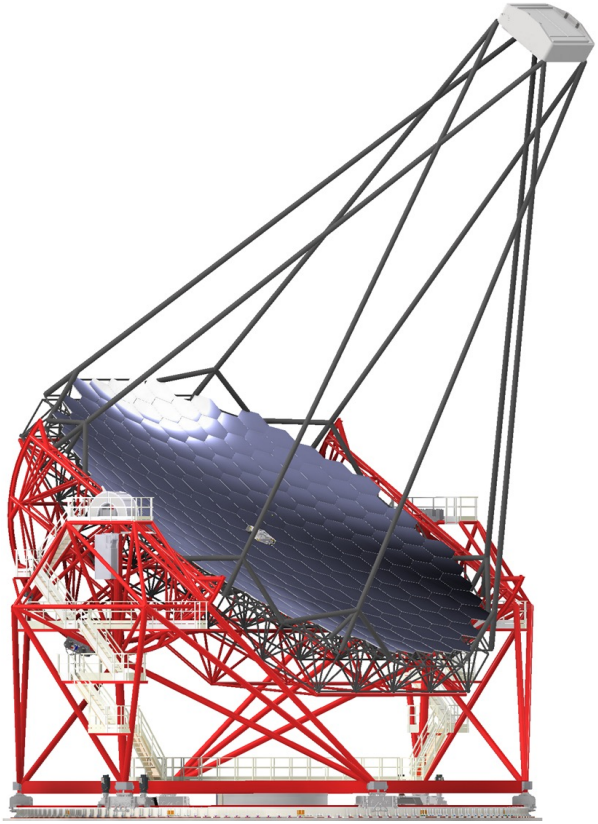
INFN LST South

CTA+, PNRR project lead by INAF and supported by INFN

2 LST-S to be added to CTAO South site alpha configuration (plus 5 more SST)

INAF-OAB responsible for the optical design and M1 mirror segments procurement (~ 500)

The challange is in the time and cost-effective mass production of several hundreds of mirror segments (~ 6000 € on average), for wide-field optical telescope with moderate resolution, to be used for Cherenkov Telescopes operating in La Palma and in Chile (environmental condition).



LST-S sketch

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LST-S Optical Design overview

INFN LST South

M1 primary mirror:

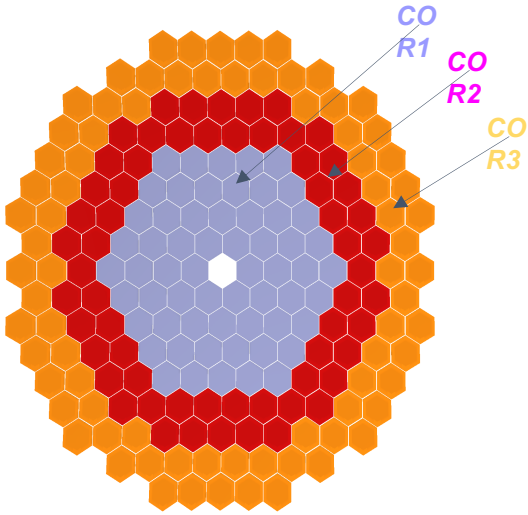
Parabolic shape

diam. 23 m

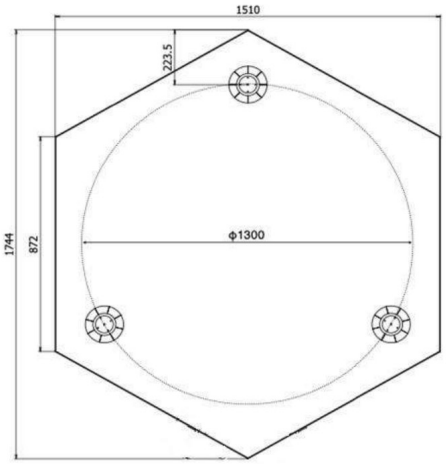
focal length 28 m

198 segments:

- hexagonal shape
- flat-to-flat 1.5 m
- Thickness < 50 mm
- 3 pads I/Fs to structure toward actuators and fix point
- spherical shape, with radius of curvature pending the position on the dish



Proposed ring distribution on the dish



Segments size and pads locations

	RoC [m]	# of segments
COR1	56.3 +/- 1.5	60
COR2	57.1 +/- 1.5	60
COR3	57.9 +/- 1.5	78

Prescription assumed for the mirror segments mass-production

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Common Environmental Requirements

INFN LST South

Observation temperature	**-15° C < T < +25° C**
Survival temperature	-20° C < T < +35° C
Temperature gradient	< 7.5° C/h
Temperature shocks	± 30° C
Survival air temperature gradients	< 0.5° C/min for 20 minutes
Observation humidity	2-90 %
Survival humidity	2-100 %
Rain in 24 hours	200 mm
Rain in 1 hour	70 mm
Rain wind speed	< 90 km/h
Rain during transition	< 2 mm/h
Survival snow load	< 20 kg/m^2
Hailstone damage	< 20 mm
Survival ice load	< 20 mm
Observation wind speed	< 36 km/h
Transition wind speed	< 50 km/h
Survival wind gust	< 170 km/h
Solar radiation	< 1200 W/m^2
Aggressive atmosphere	NO, NO_2, SO_2 < 3 ppb
Water resistance	IP67
Tape adhesion test	> 16 N
Substrate lifetime	> 15 yr
Coating lifetime	> 6 yr

Environmental test will be covered during the process qualification for LST-S optics mass-production: it is worth noting that the same process has already been qualified in the past for other IACT (good heritage: MAGIC, ASTRI, MST)

- Preliminary thermal test already performed at prototype level
- Watertight test to cover the humidity and rain requirements not yet performed at prototype level
- Survival loads deeply studied with Finite Element Method (FEM) analysis
- Coating resistance will be checked on each mirror during mass production
- Substrate and Coating lifetime already heritage with operative telescopes

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Cold Slumping Technology

INFN LST South

Technology for Mirror Production:

- sandwich panels glass-Al core-glass
- based on glass cold replication (developed by INAF initially for MAGIC2, adopted for ASTRI)

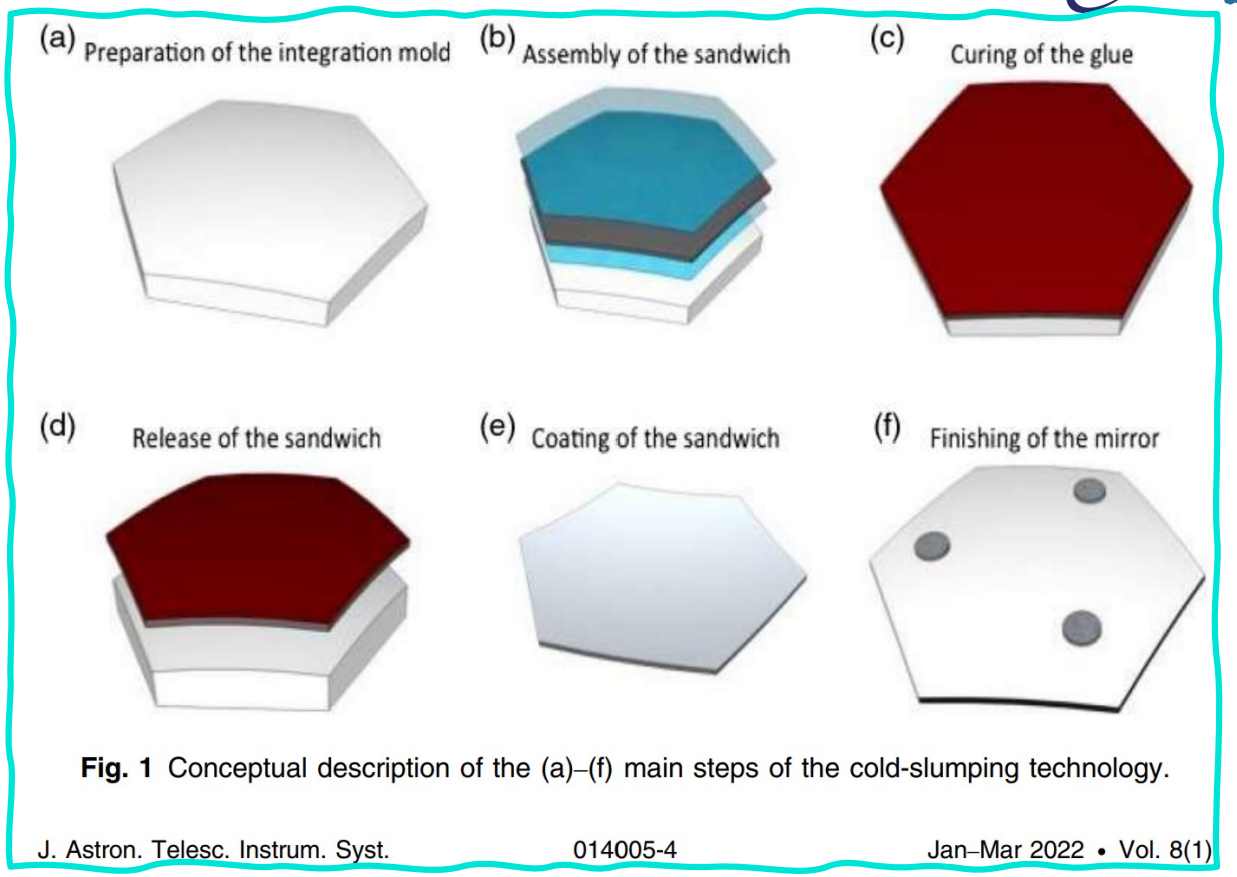
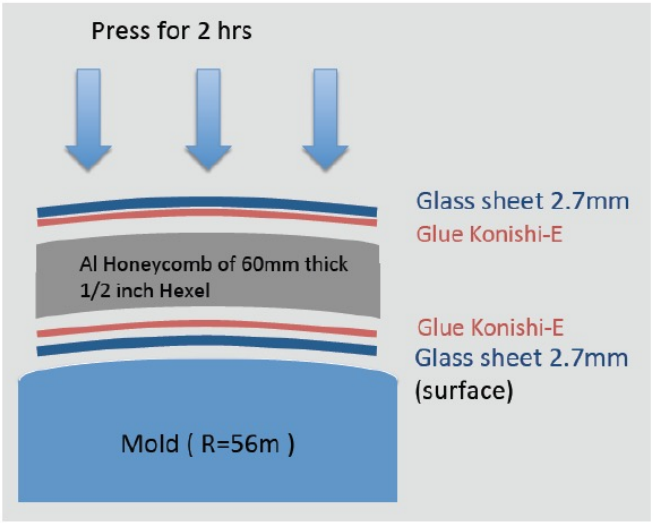


Fig. 1 Conceptual description of the (a)–(f) main steps of the cold-slumping technology.

J. Astron. Telesc. Instrum. Syst. 014005-4 Jan–Mar 2022 • Vol. 8(1)

FOR REFERENCE:
[DOI 10.1117/12.790404] → In the framework of the MAGIC2 mirrors
[DOI: 10.1117/1.JATIS.8.1.014005] → in the frame of ASTRI-MA and MST-Nord contract, for which the Substrate preparation and finishing was performed by Media Lario, and the coating was deposited by ZAOT using the INAF's technology

Production Process for LST N

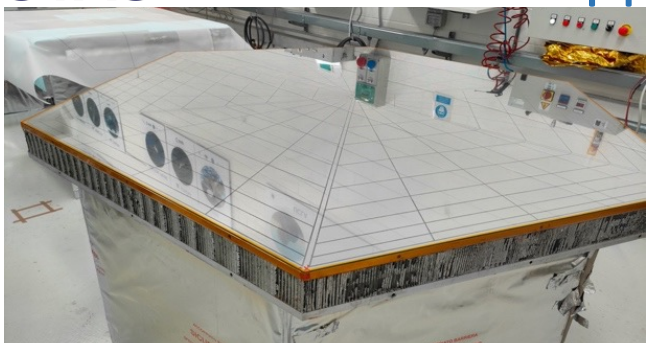


(a) Cold slump technique.

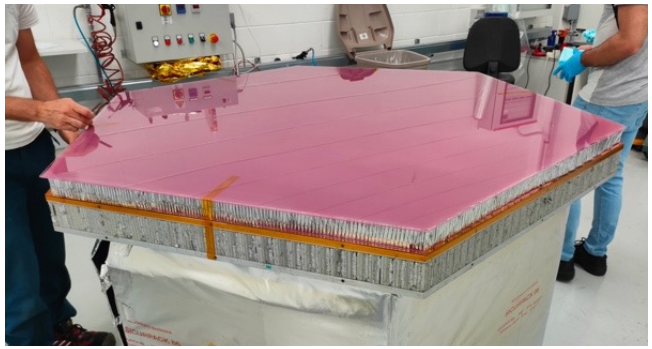
(b) Mirror facet.

Figure 2.32 – *(a):* The cold slump technique (replica method) used for the production of the mirror facets, which have a sandwich structure. *(b):* A 1.5 m flat to flat hexagonal mirror produced at company *Sanko* in Japan.

Prototype production results



mock-up mould prepared for process



Sandwich structure on the mould

Glue curing

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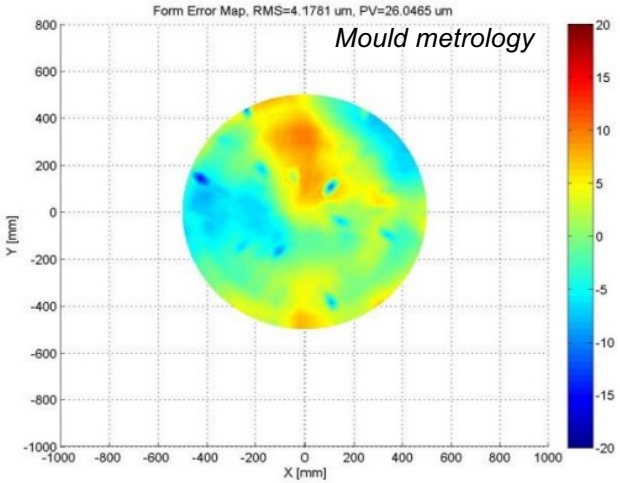
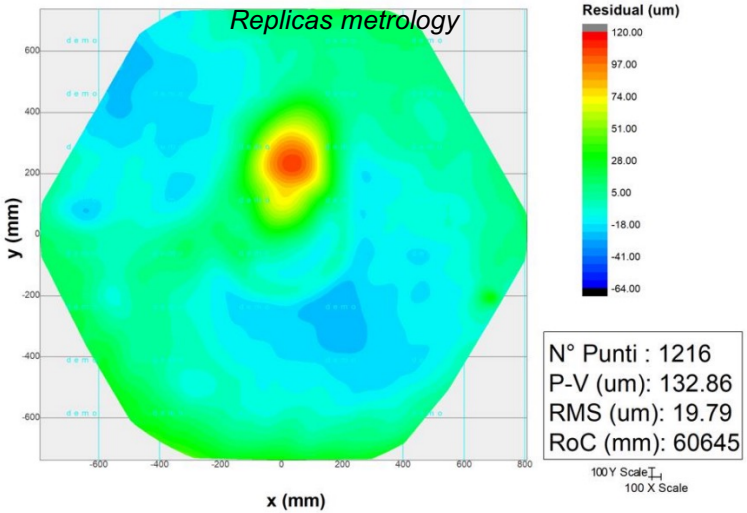
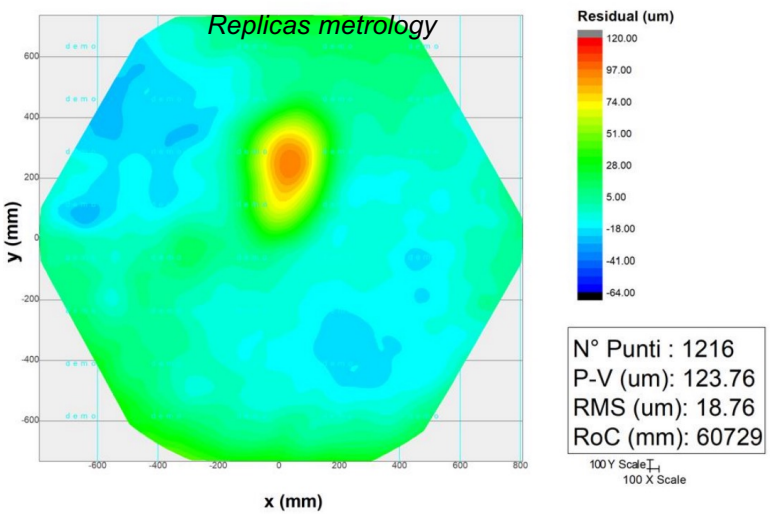
Prototype production results

INFN LST South







INFN mould with clear variation from the ideal shape
Residuals of the order of micrometers

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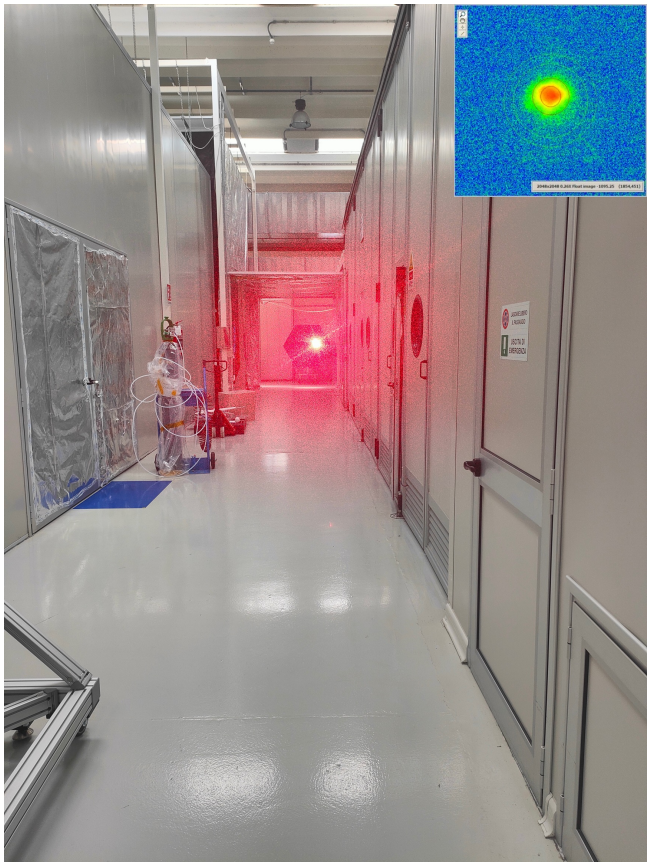
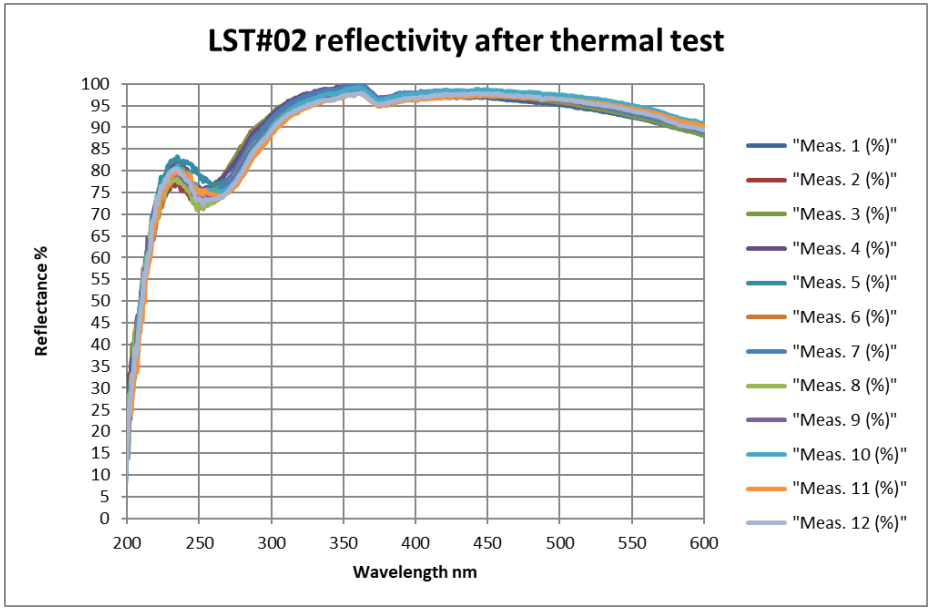
Coating checks





Reflectivity measurement carried out on 12 points distributed along three diagonals on prototype

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Thermal test on prototype

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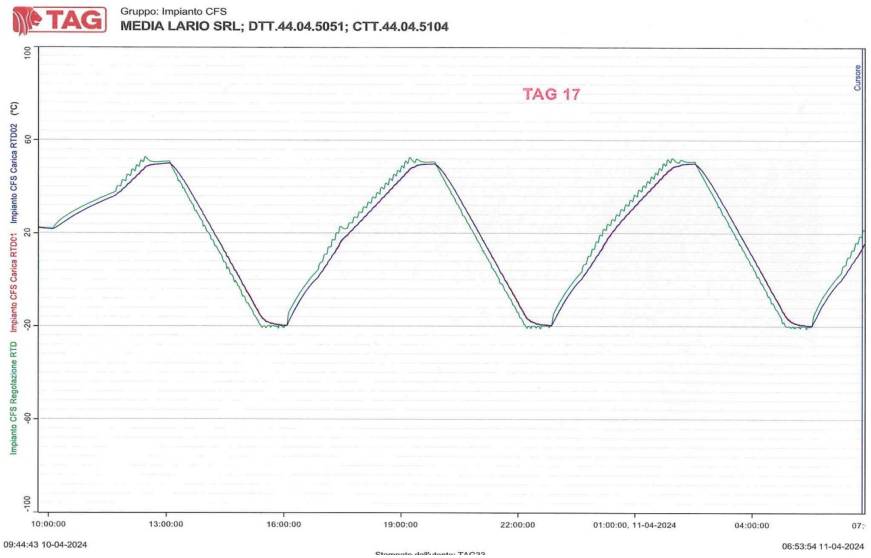
- Thermal test for stability check
  - Range: -20/+50 °C
  - Rate: 30 °C/h (0.5°C/min)
  - Dwell time: 30 min
  - Number of cycle: 3
- Survival @ thermal environmental condition confirmed
- No degradation (change) in shape accuracy – variation inside meas. repeatability
- No degradation in reflectivity values
- VI successfully passed



Confirmation of production method applicability for this size of mirrors, and check of handling procedures and test jigs. Fine-tuning of all process parameters to be carried out during the qualification phase of optics contract with industry.

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What's coming next → LST-S mass-production

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DDVP MODEL PHILOSOPHY

TESTS PLAN

Pre-production

- 2 COR1 segments
- 2 COR2 segments
- 2 COR3 segments

PROCESS QUALIFICATION

Dim. and weight
Shape 3D probe
Optically tested
Coating adhesion
Coating reflectivity
I/Fs (pads position)
Environmental Tests

Production Start

- 10 COR1 segments
- 10 COR2 segments
- 10 COR3 segments

PRODUCTION LINE QUALIFICATION & STABILITY

Dim. and weight
Shape 3D probe
Optically tested
Coating adhesion
Coating reflectivity
I/Fs (pads position)

Mass Production

- > 120 COR1 segments
- > 120 COR2 segments
- > 156 COR3 segments

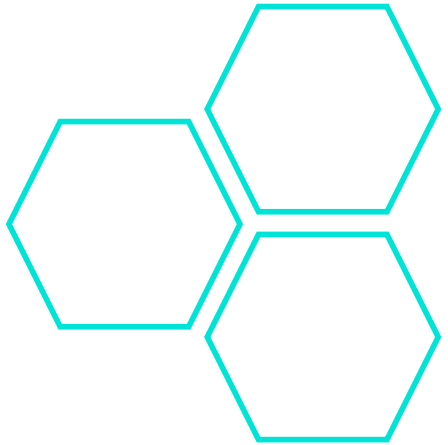
COMPLETE PROCUREMENT for 2 LST-S

Dim. and weight
Shape 3D probe (every 10 segments)
Optically tested (TBC)
Coating adhesion
Coating reflectivity (every 5 segments)
I/Fs (pads position)

Concluding Remarks

- ***PROTOTYPING ACTIVITY CARRIED OUT***
  - Applicability of technology for such large segments proved (both by analyses and experimentally)
  - Good obtained results with mock-up mould
  - Tool, setup and procedures assessed and already put in place or designed

- ***MASS-PRODUCTION TO START SOON***
  - Process qualification for process parameters fine tuning
  - Mass production



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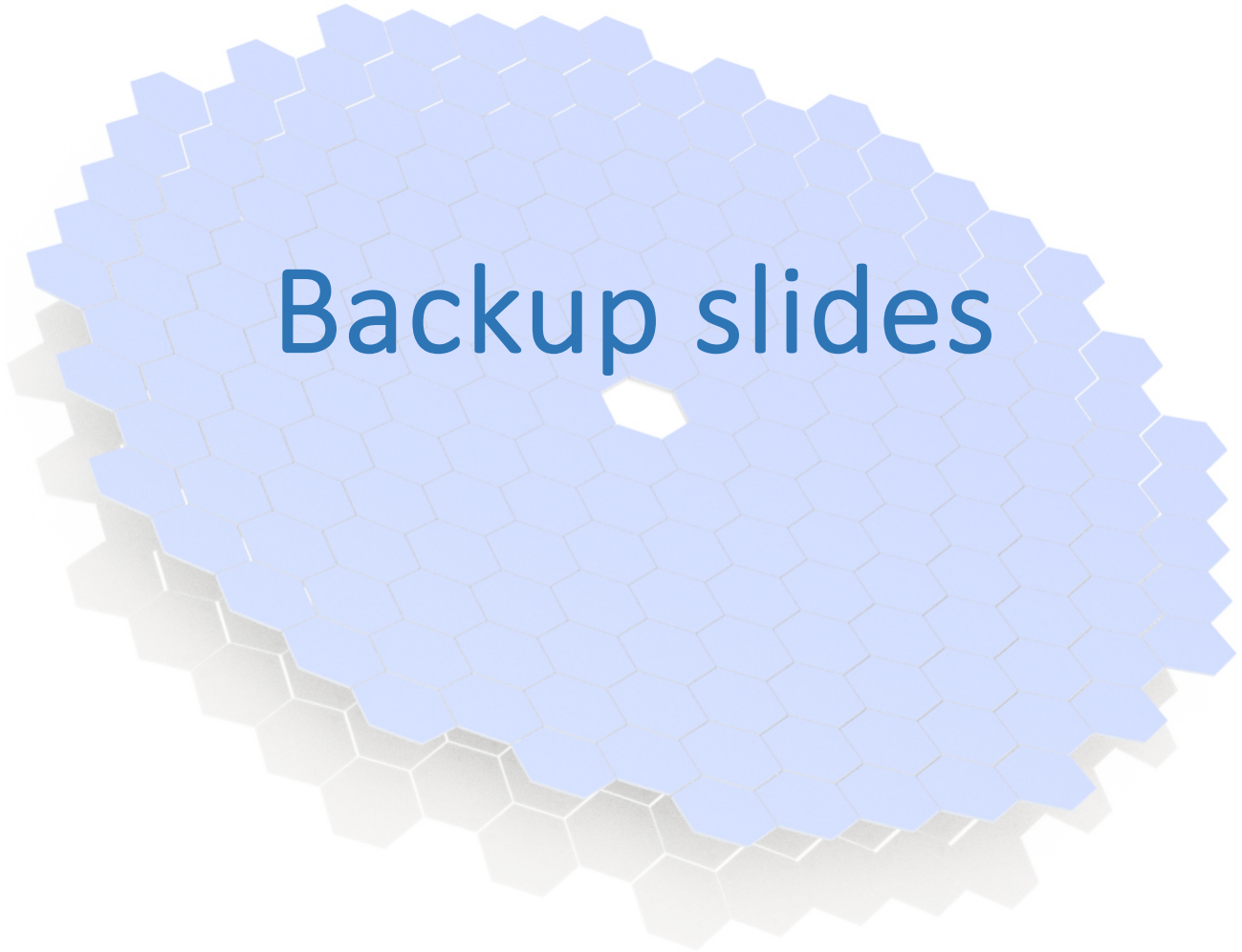
Thank you!

October/2024

LST-S Optics team



Backup slides

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Introduction

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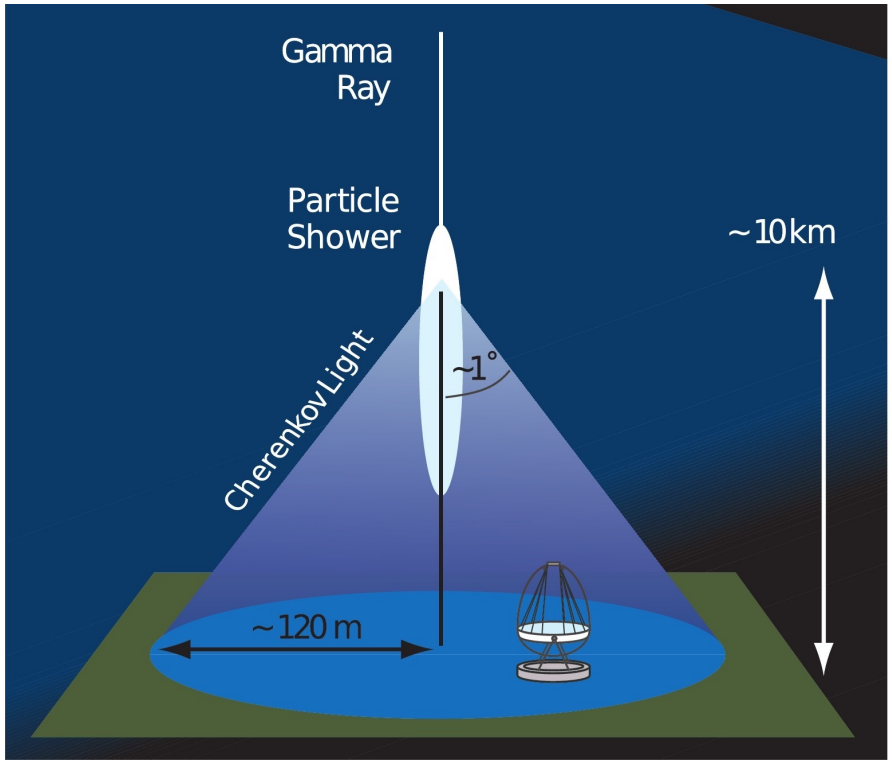
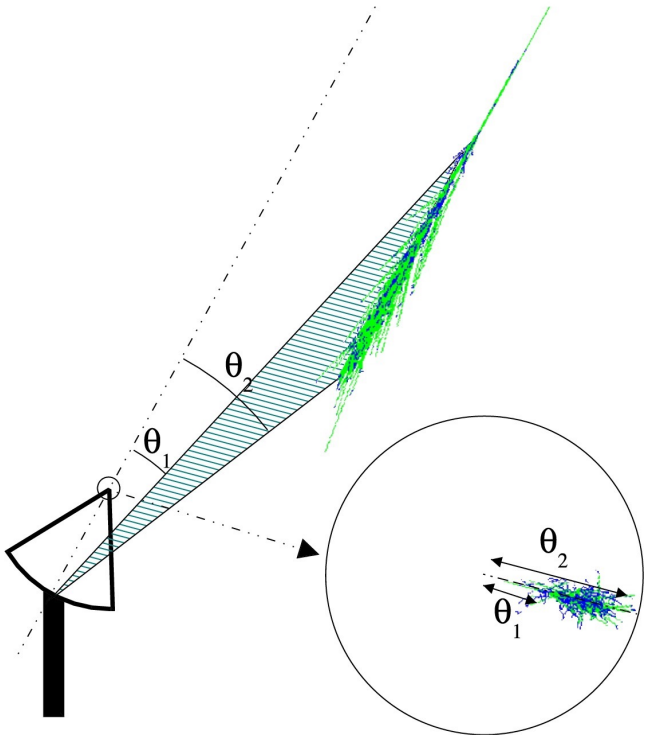
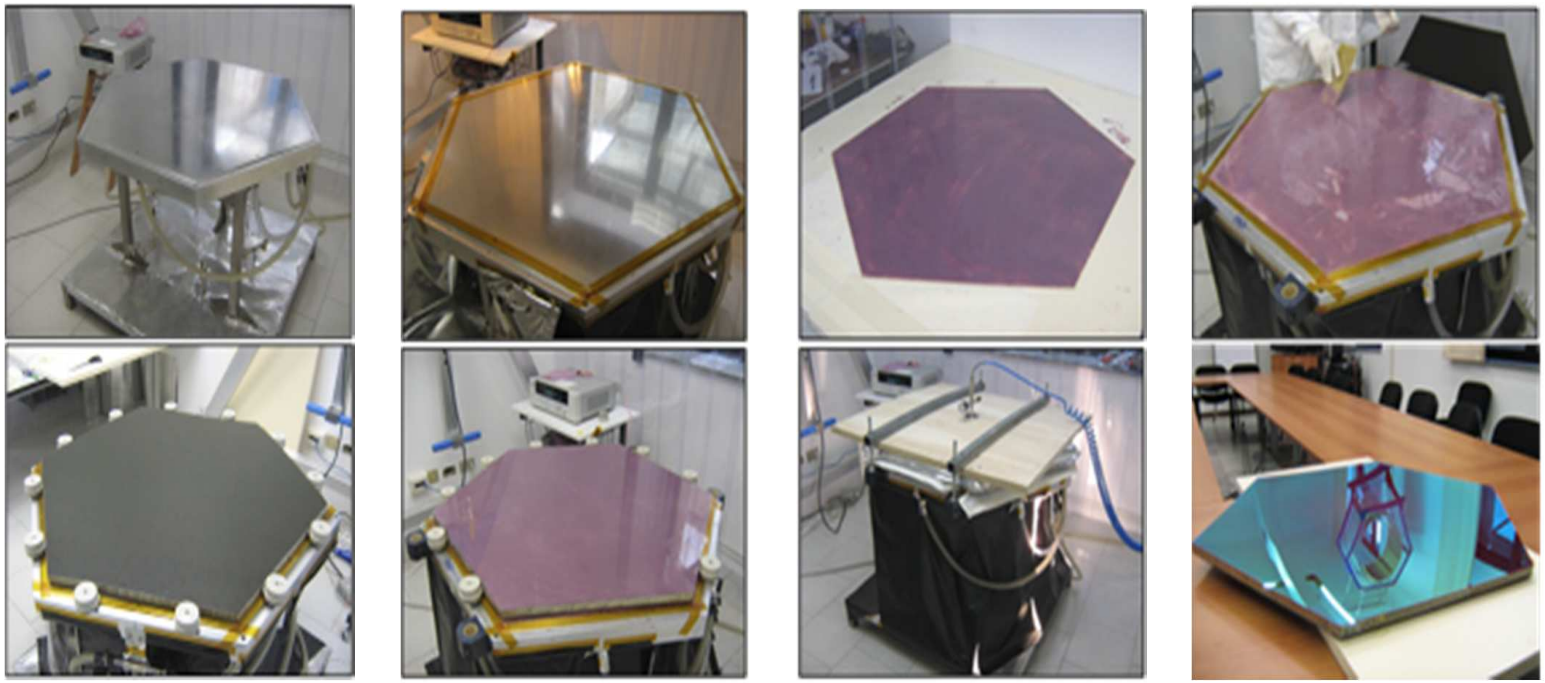
IACT – Imaging Atmospheric Cherenkov Telescope





Credit: deNaurois+ 2015 C.R. Phys. 16 610

Glass Mirrors cold-replica approach (set-up by INAF and Media Lario with BCV support since 2006)



Credits: R. Canestrari

MAGIC II Telescope, La Palma, Canary Islands 17 m diameter

The cold glass slumping technology was introduced for MAGIC II

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CTA/ MST glass sandwiched mirrors – Media Lario + INAF

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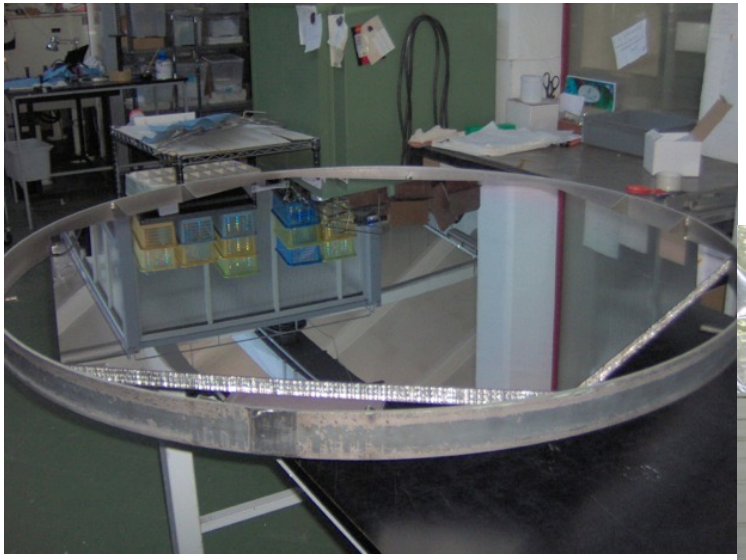
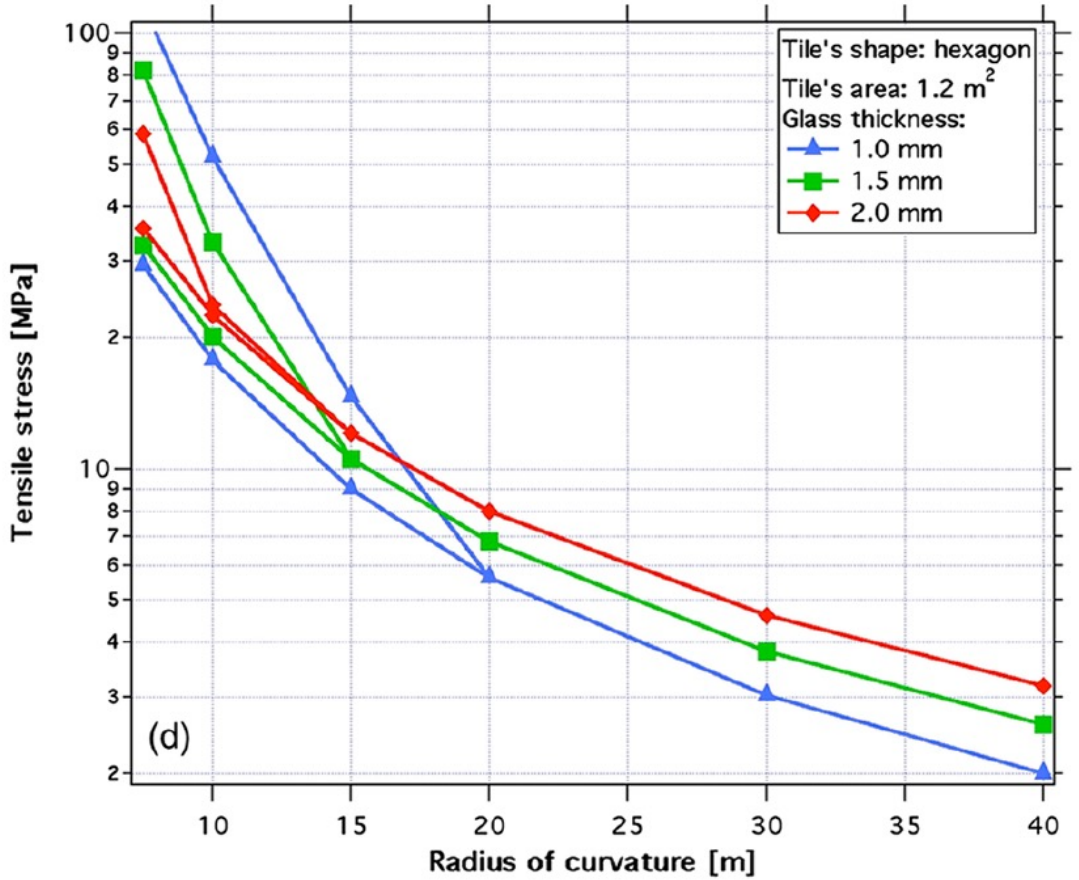


Telescope	Shape + F2F distance (m)	Radius of Curvature (m)	Thickness of glass and Hexacell (mm)	Number of produced mirrors
Magic I/II	Squared 0.98	34 (average)	1.7 / 20	> 100 Magic II > 100 Magic I
MST	Hexagonal 1.1	32.1	2.1 / 30	200 (+ 30 prototypes) (800 to be produced to complete MS N)
SST/ASTRI	Hexagonal 0.8	8.5 m	1.6 / 20	200 ASTRI MA + 36 ASTRI Horn (800 to be produced for the SST array)
LST - S	Hexagonal 1.5	56 - 58.4	< 2.7 - < 60	500

Principle tensile stress versus bending radius



Prototype characteristics and tests

Parameter	Value
Size	Hexagonal shape of 1500 mm flat to flat
Shape	Spherical with around 60 m RoC (3D CMM TCX meas. and 2f set-up)
Thickness	46 mm in total (3mm glass foils + 40 mm Aluminum honeycomb core)
Coating	Al + SiO_2 protective layer Reflectivity checks for value and uniformity, adhesion test
PADs	3 glued on the back at 120° on a circle of 1300mm from center
Optical specifications	Shape: measure with 3D CMM TCX, Optical spot: PSF meas. with 2f set-up
Thermal test	Range: -20/+50 °C Rate: 30 °C/h (0.5°C/min) Dwell time: 30 min Number of cycles: 3

Characteristics selected for:

- Replication mould already existent to “mock-up” (not optimal shape) provided by INFN Padua for development purpose
- Extensive support from FEM analyses for sandwich panels parameters
  - 3 mm glass
  - 40 mm Aluminum honeycomb
  - Internal stresses ~ 3 Mpa

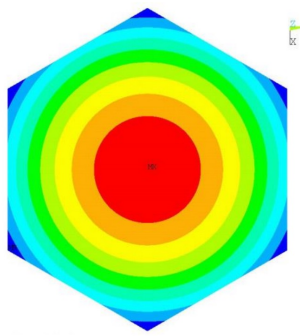


FIGURE 8-1
Face-sheet deformed shape at the end of CS
Axial displacement contours are quoted in m

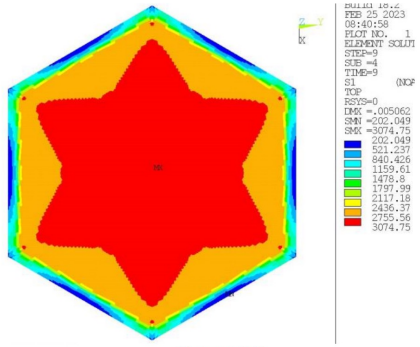


FIGURE 8-2
Glass principal stress pattern at the end of CS
Contours quoted in kPa

Ref. BCV Progetti, P2938 report 1 - Issue 2, Milano, May 2023, 26th, CTA-SOUTH PROJECT MIRROR SEGMENTS FOR LST – M1 STRUCTURAL ANALYSIS OF THE SANDWICH SEGMENTS

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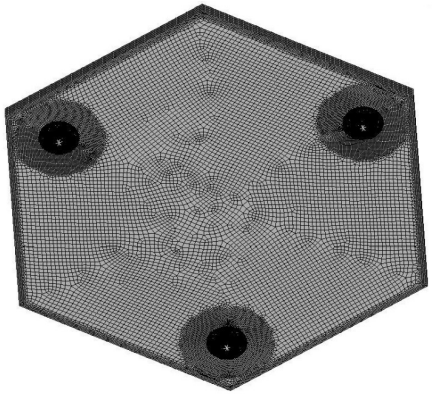
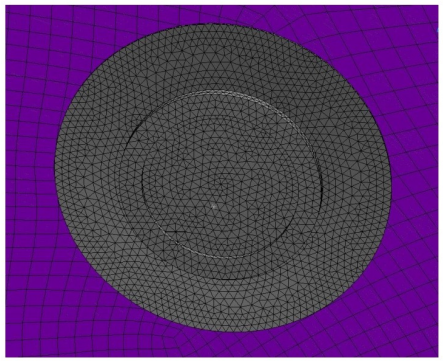
FEM analyses

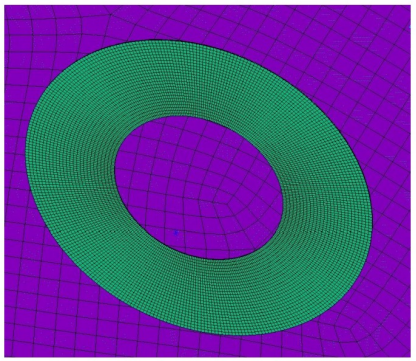
The prototype activities have been supported by extensive FEM analyses campaign in order to individuate the optimized mirror segment design.

Load cases includes:

- Gravity loads
- Ice loads
- Operative wind
- Survival wind
- Bulk Temperatures
- Temperature gradients (along surface and thickness)
- **Cold shaping**
- 26 different combinations of the above single loads have been analyzed







Code: Ansys Mechanical
Size: > $2{,}5\times10^{6}$ dof

FEM analyses

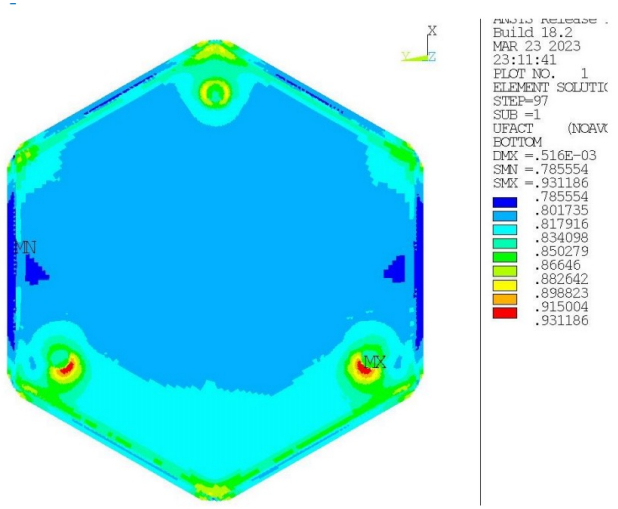
According to Standard (EN 16612) the design glass strength assumed:
fatigue delamination growth = 7.25 MPa in loading combinations with just permanent loads (cold slumping and gravity CS and G).
fatigue delamination growth = 18.5 MPa in loading combinations with wind (W).
fatigue delamination growth = 11.25 MPa in loading combinations without wind (just permanent loads, ice and/or temperature loads I / T).

Upper Glass Faceplate

Load combination	Maximum Tensile Stress	Utilization Factor
G	4.58	0.63
I / T	10.1	0.90
W	12.9	0.70

Lower Glass Faceplate

Load combination	Maximum Tensile Stress	Utilization Factor
G	4.81	0.66
I / T	10.5	0.93
W	16.2	0.87



Utilization Factor distribution for I / T load combinations