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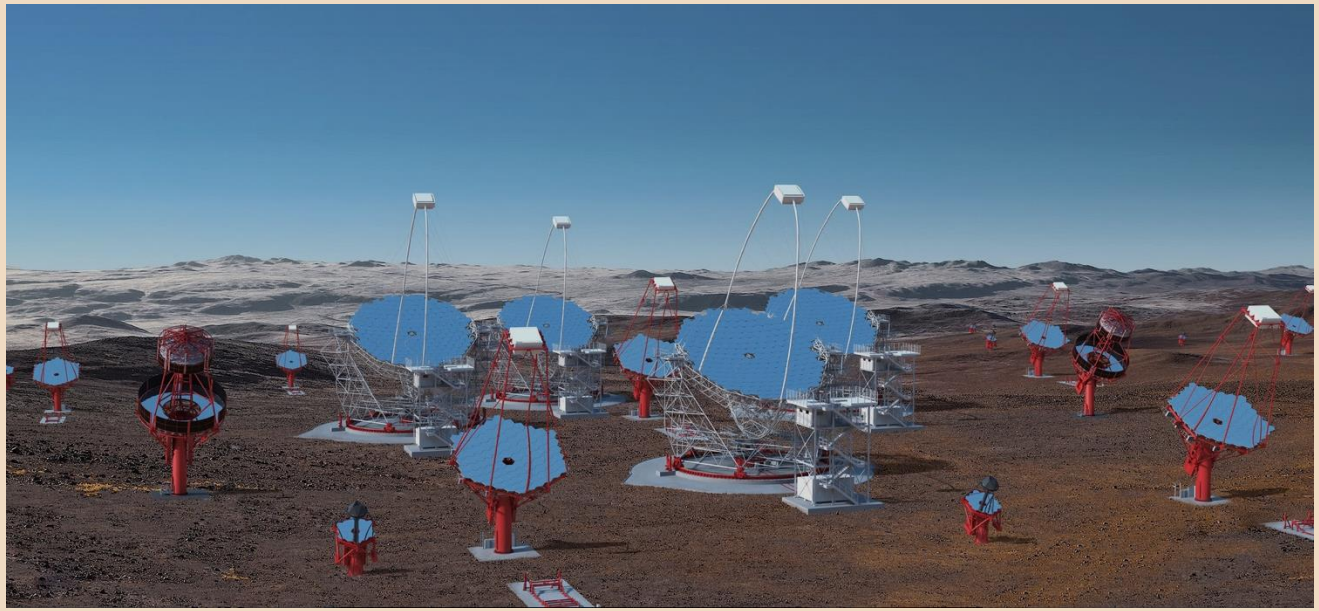
Italiadomani PIANO NAZIONALE DI RIPRESA E RESILIENZA
INFN

CTAPLUS, from the status of the project to the scientific outcome expected

C. Aramo for the CTA+ Program
INFN – Sezione di Napoli
email aramo@na.infn.it

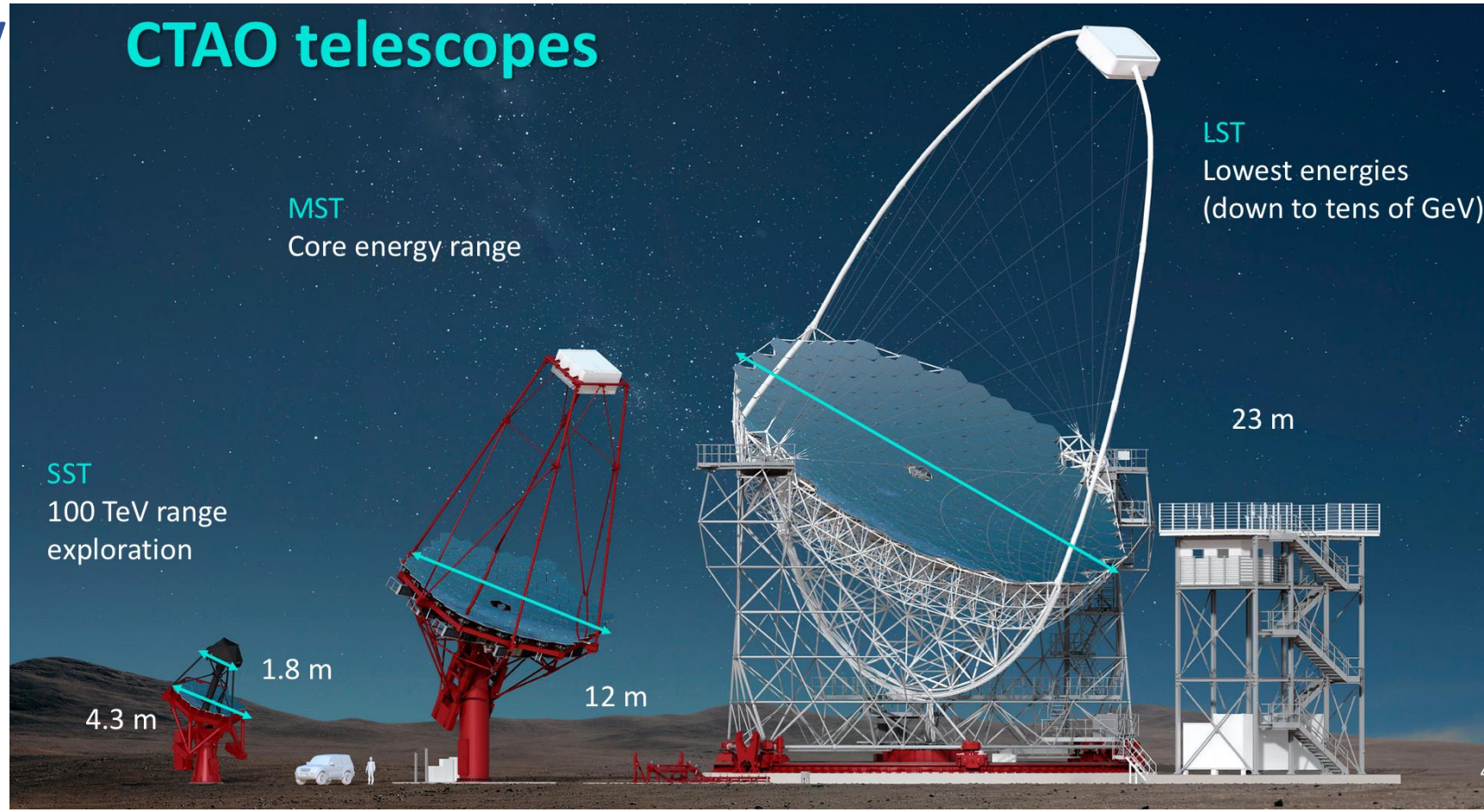
27 May 2025 2nd VHEGAM Meeting, Bari



Thanks to A. Antonelli, G. Tagliaferri, L. Orsini, M. Mattioli, F. Dazzi and R. Zanin for their help in preparing the slides.

CTAO: next-generation Cherenkov Telescope Array facility

- Originally envisioned: ~ 100 telescopes of 3 different sizes
- Alpha configuration (defined 2022): 64 telescopes
- Expected to improve sensitivity by ~ factor 10 compared to existing facilities (H.E.S.S., MAGIC, VERITAS)
- Extend energy coverage: ~ 10 GeV - >100 TeV



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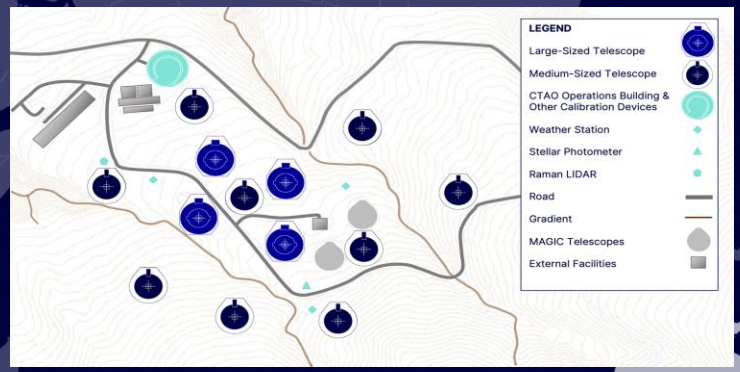
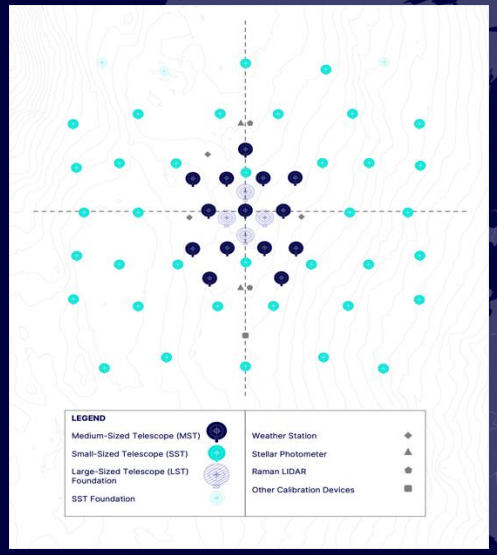
Science Data Management Centre
Zeuthen, Germany

Headquarters
Bologna, Italy

CTAO North
La Palma, Spain



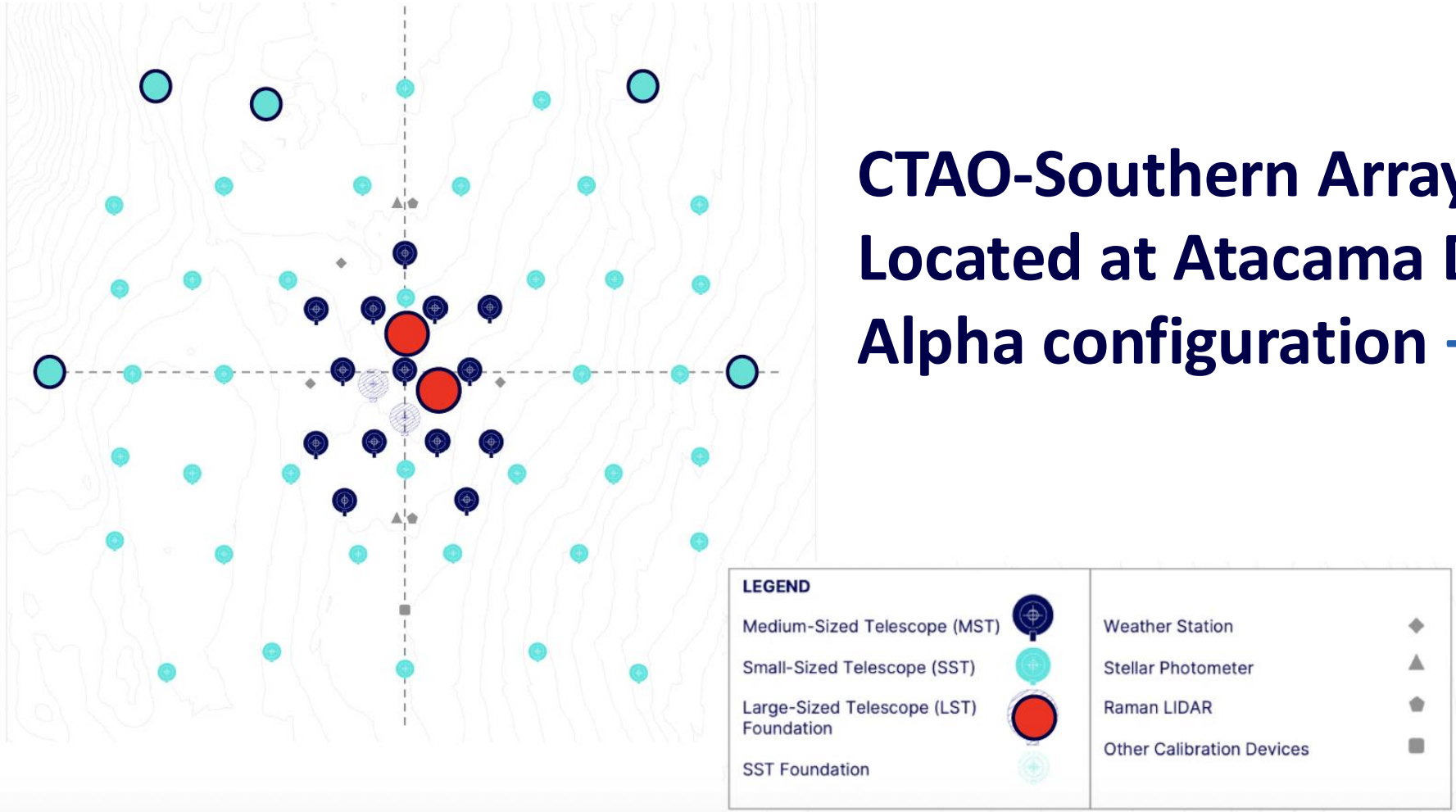


CTAO South
Paranal, Chile

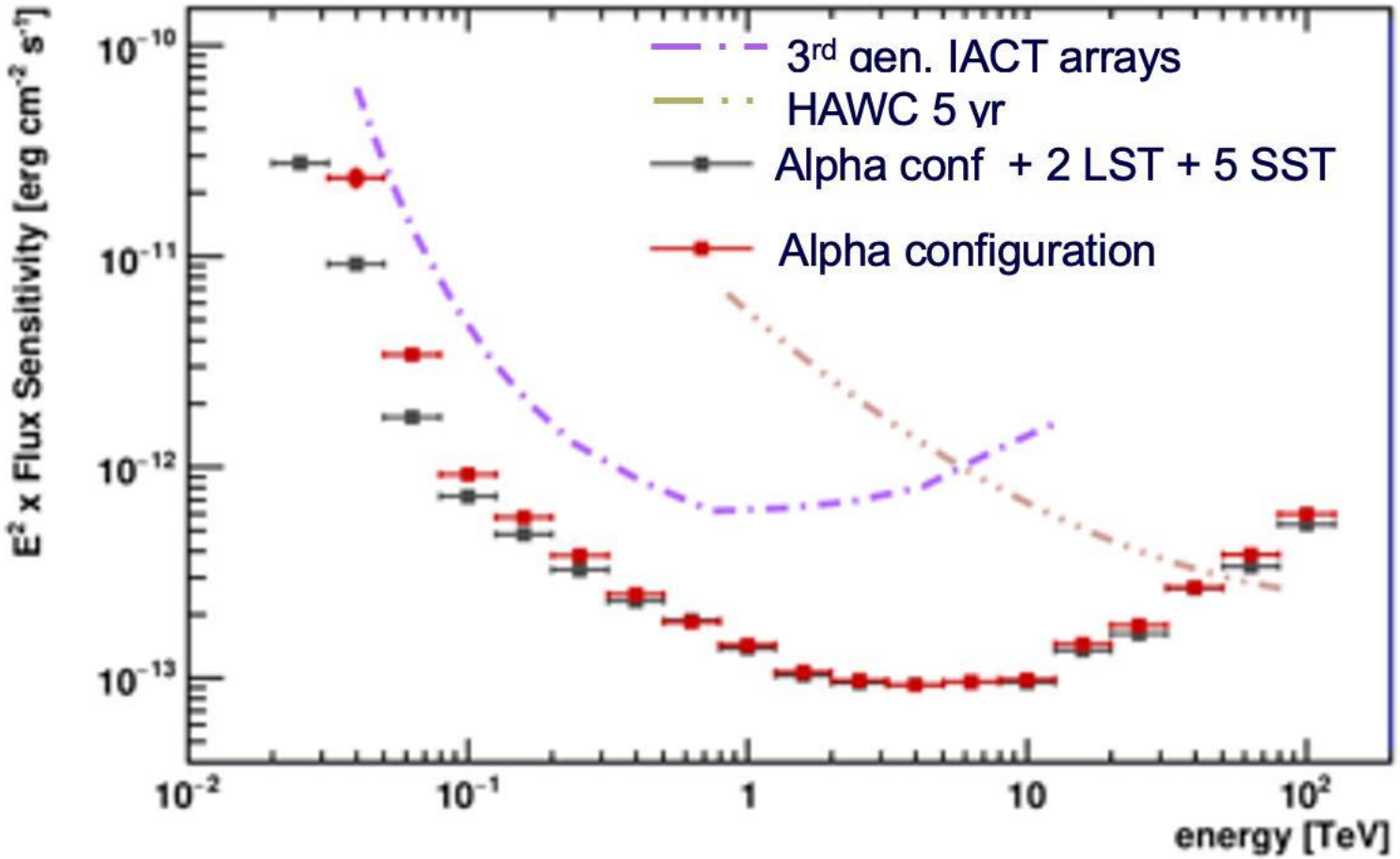
See talk by Alicia López Oramas

CTAO

CTAO-Southern Array Located at Atacama Desert, Chile Alpha configuration + CTA+



14 MSTs
37 SSTs
+
2 LSTs +
5 SSTs



CTAO

Expected Sensitivity

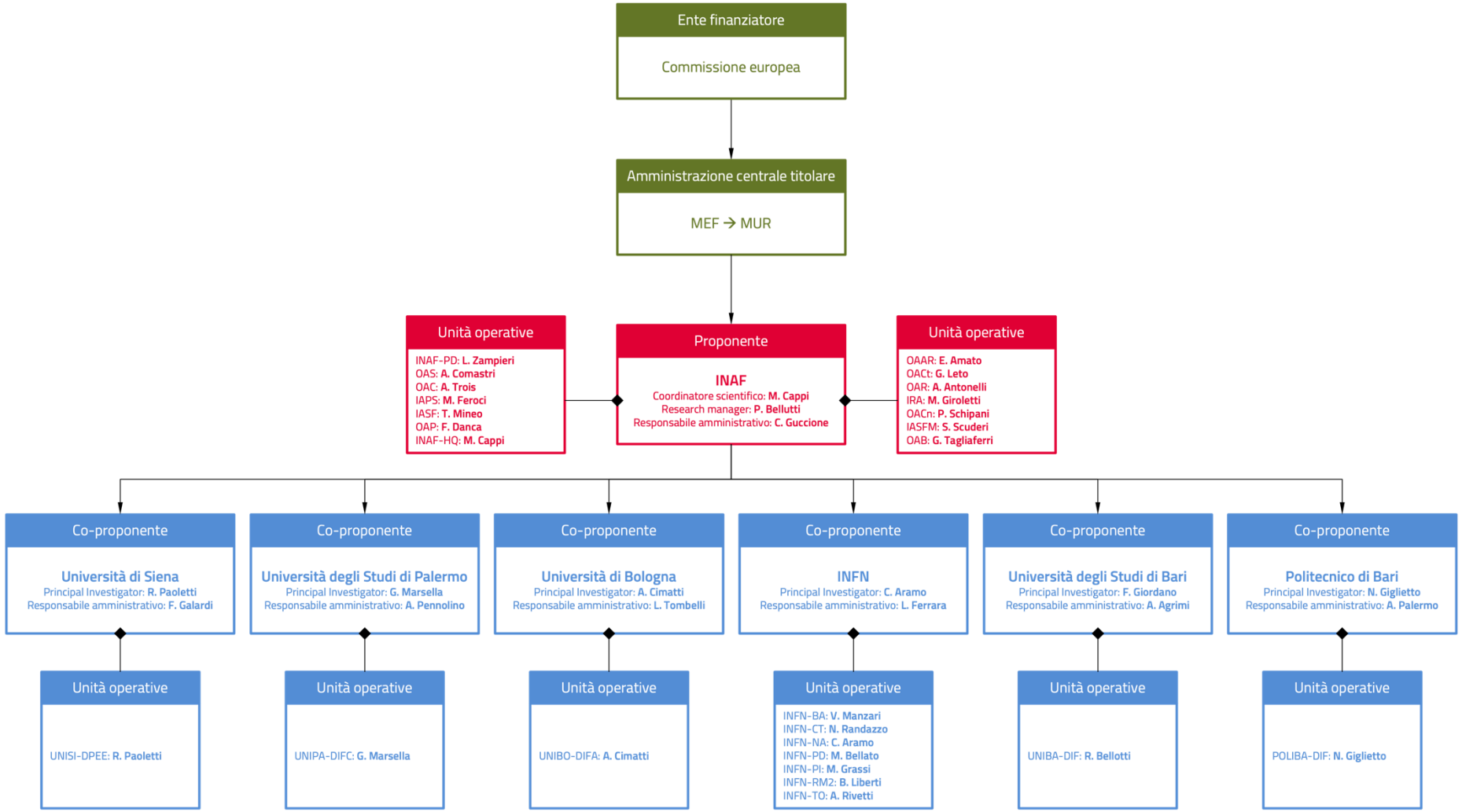
Alpha configuration + CTA+

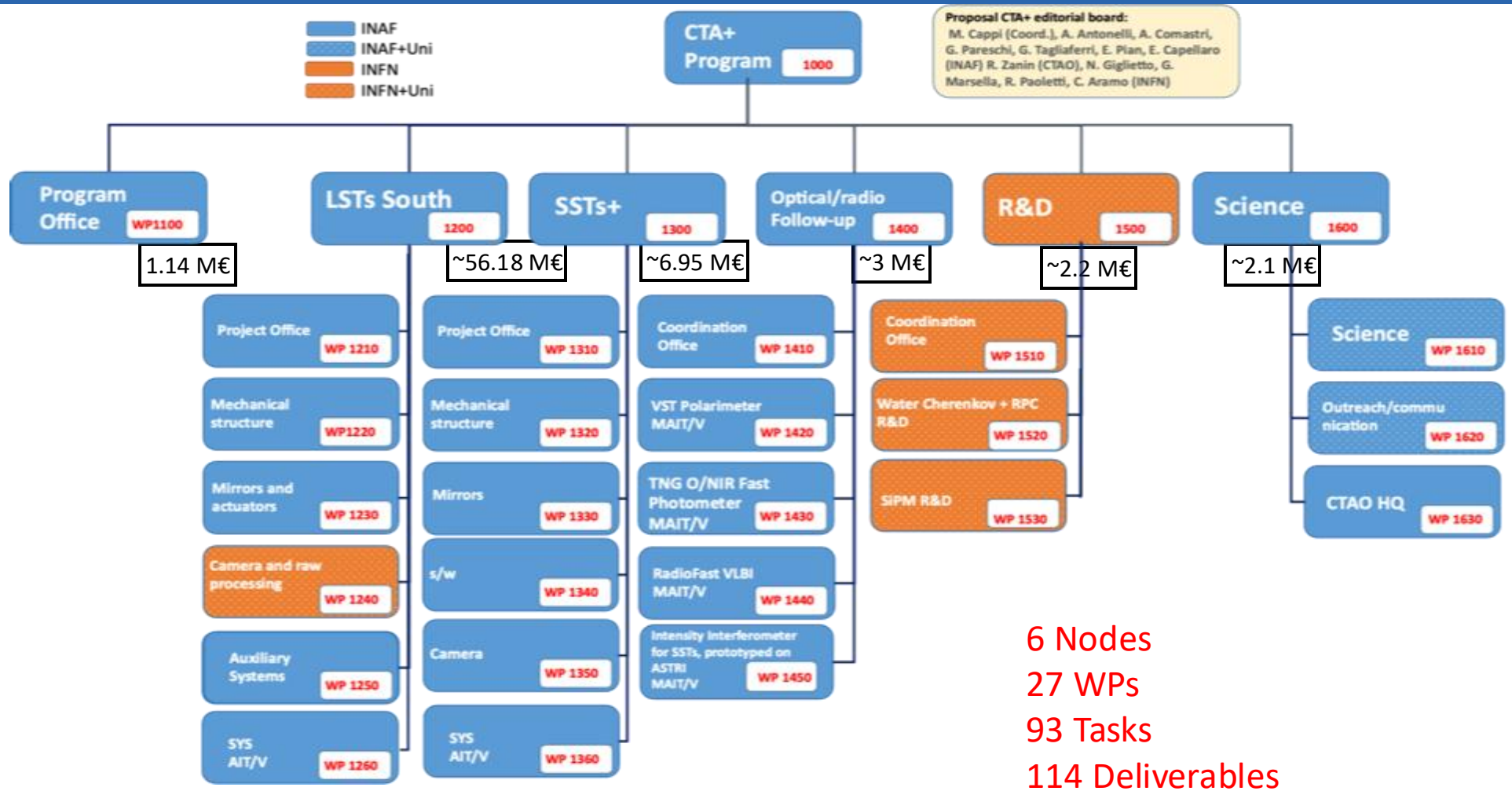
The CTA+ program

- CTA+ is an Italian program funded by PNRR to enhance the CTAO infrastructure of the CTAO southern array
- **~ 70 M€ to be spent in 36 months (KO in 01/01/2023 – end 31/12/2025)**
- INAF leadership with co-participation of INFN and several Universities
- **Main goals:**
  - Enahnce CTAO southern array at the lowest (< 100 GeV) and highest (> tens TeV) energies
  - Improve multi-messenger facilities for a better synergy with CTAO
  - Science and outreach program with CTAO
  - R&D activities: new detectors for Cherenkov telescopes or complementary

PNRR CTA+ Programme – Governance Breakdown Structure

F. Dazzi – Issue 1, Rev. A



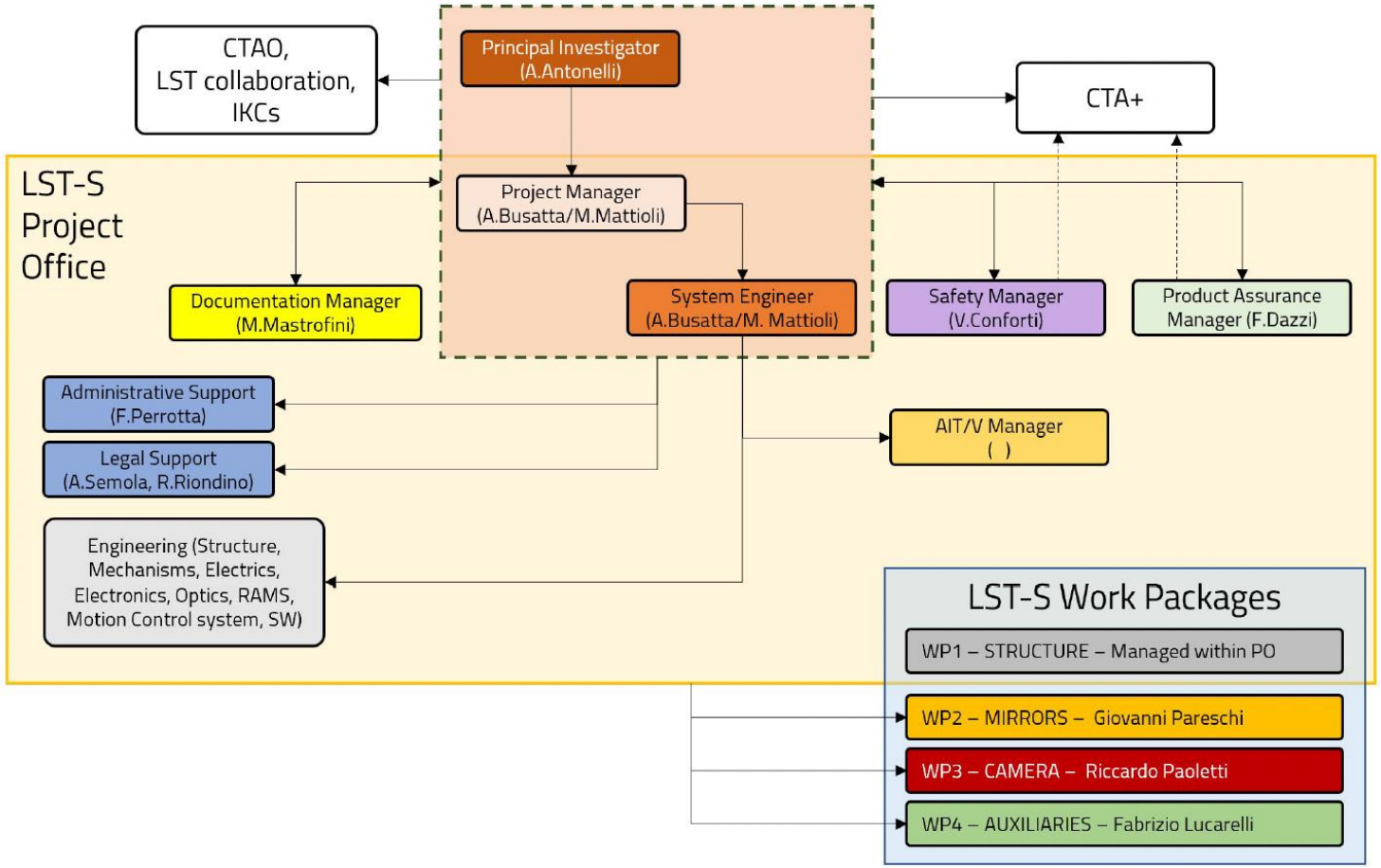


6 Nodes
27 WPs
93 Tasks
114 Deliverables

LST-South Project

CTAO | LST COLLABORATION | LST SOUTH

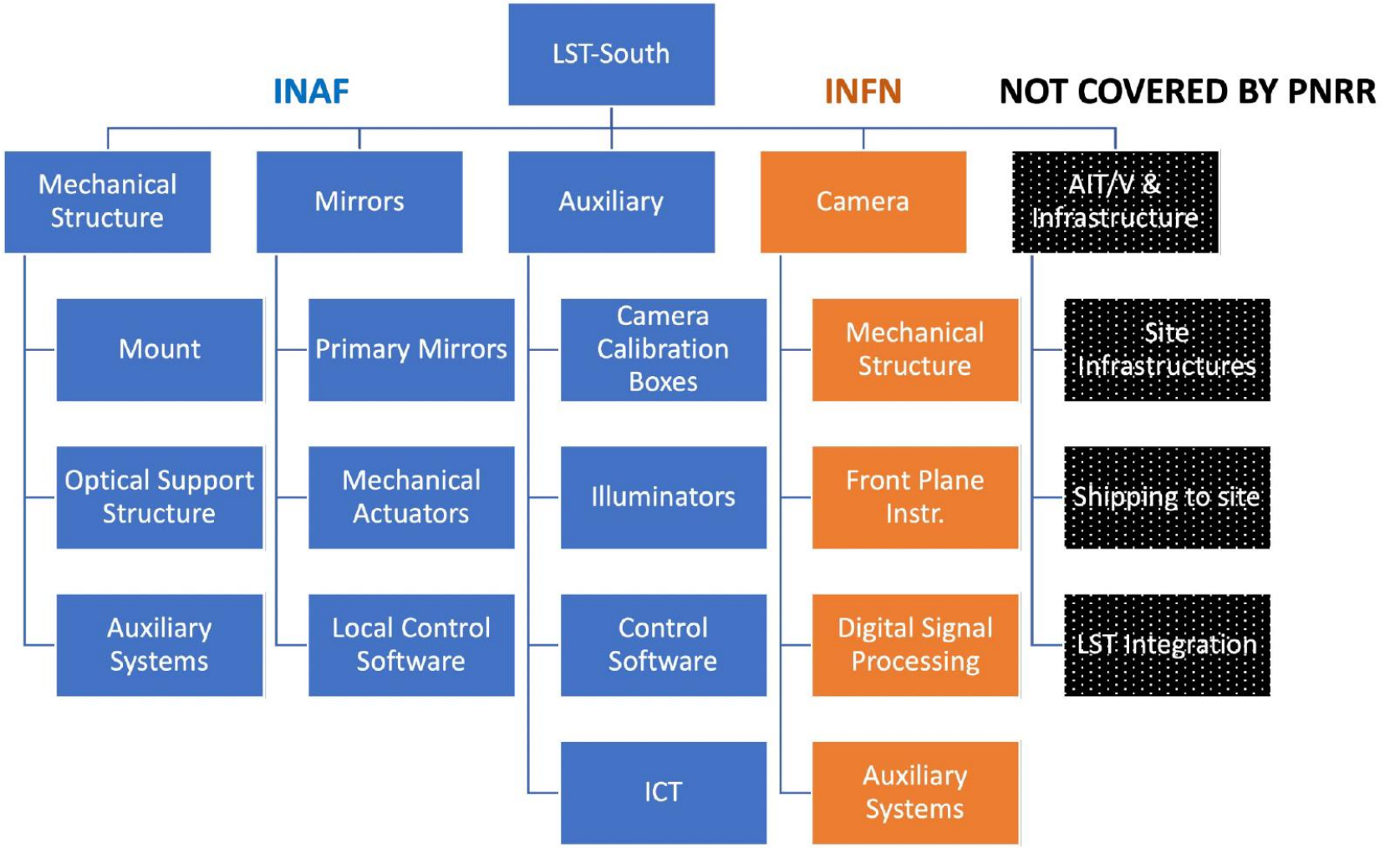
- LST South is a project of the INAF/INFN CTA+ Program and is part of the LST Consortium.
- The Project is managed by a Project Office (PO) dedicated to an end-to-end realization of LSTs.
- Telescopes will be delivered to CTAO south site.



LST-S Project Strategy

- ***The decided strategy has been to go for an <u>end-to-end</u> approach (including AIV where possible) to have just a few tenders for HW procurement and realization.***
- We have used the CTAO requirements and specs tailored for southern site as mandatory parameters (in terms of "Applicable documents") and the open available documentation as "Reference documents."
- LST North experience and know-how have been very important for a fast realization
- Important In-Kind Contributions from other Institutes participating to LST Consortium
- Other important IKC are also expected for AIV and integration at site

LST-S WBS


LST-South
INAF
INFN
NOT COVERED BY PNRR
Mechanical Structure
Mirrors
Auxiliary
Camera
AIT/V & Infrastructure
Mount
Optical Support Structure
Auxiliary Systems
Primary Mirrors
Mechanical Actuators
Local Control Software
Camera Calibration Boxes
Illuminators
Control Software
ICT
Mechanical Structure
Front Plane Instr.
Digital Signal Processing
Auxiliary Systems
Site Infrastructures
Shipping to site
LST Integration

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LST South: Mechanical Structure & Foundations

CTAO | LST COLLABORATION | LST SOUTH

PDR was concluded after an accurate and deep analysis of the project

Foundations design is going to be used by CTAO for having a quotation by the company winning the bid for the realization of civil works at the SouthSite.

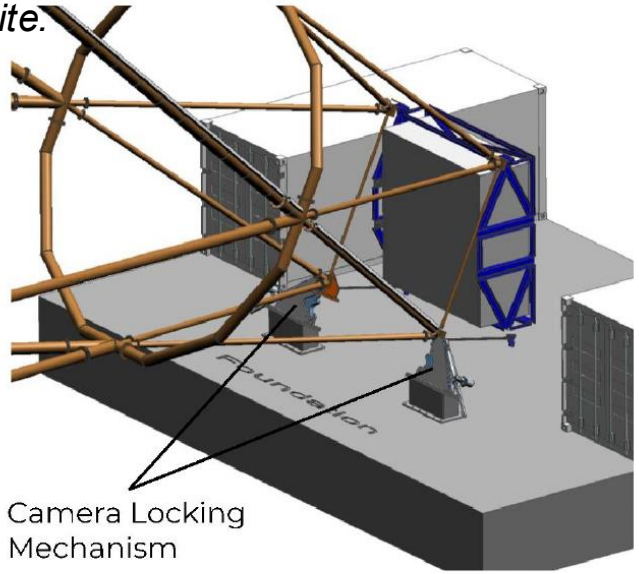
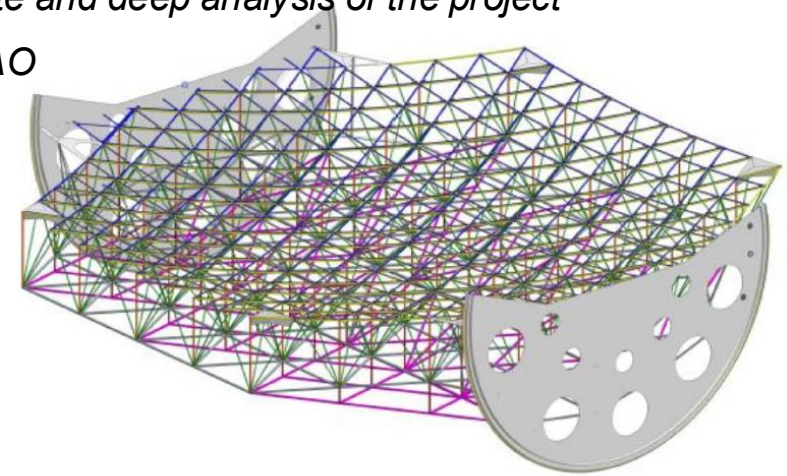
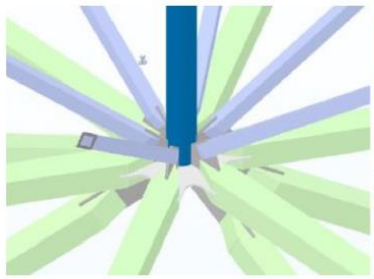
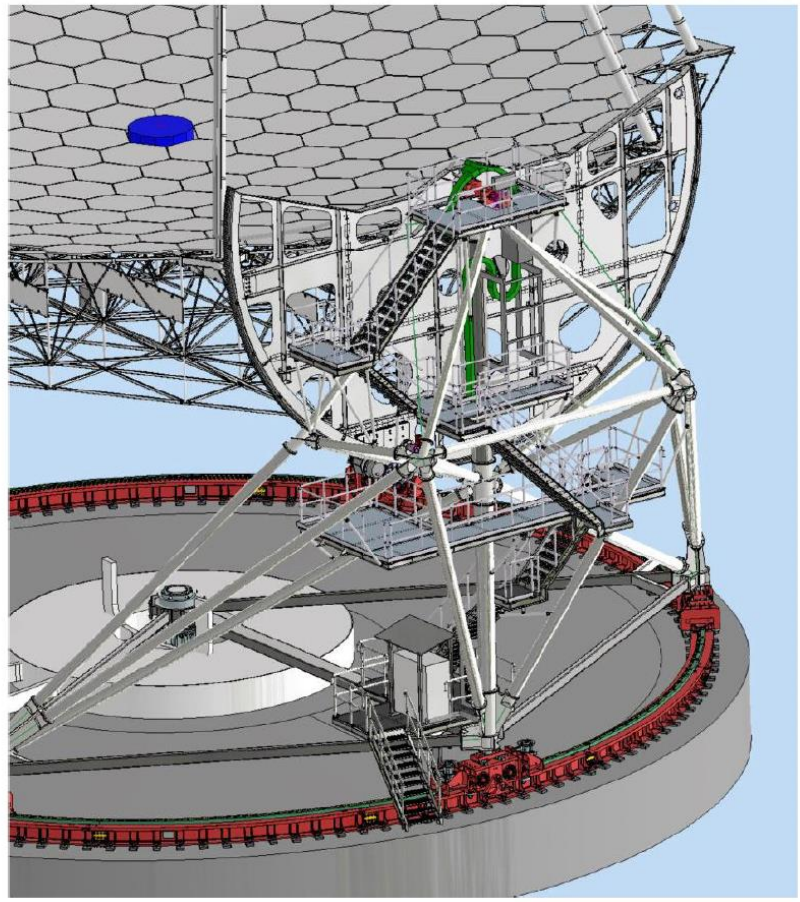


Figure 1: Camera Locking Mechanism Position- Overview







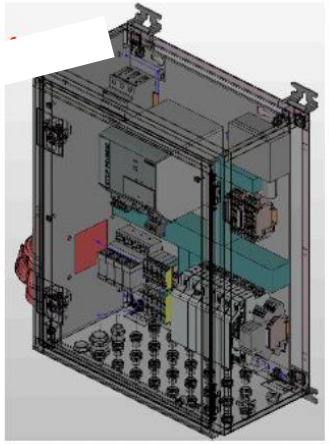
Optics development status

Mirror facets

- CDR passed on Apr. 3
- Bulk production already started

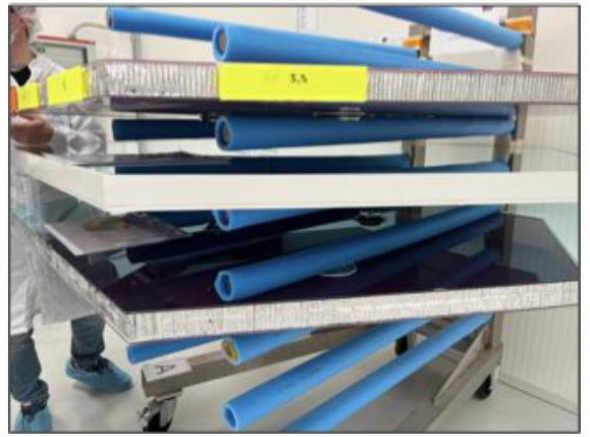
Mirror facets supports

- Fixed point fabricated and assembled (UNIGE)
- Actuators electronic boards design frozen (DESY)
- Actuators motors purchased and sent to Supplier for assembly
- Actuators massive production on going
- AMC Design frozen (UNIGE) and procurement on going



AMC Box design

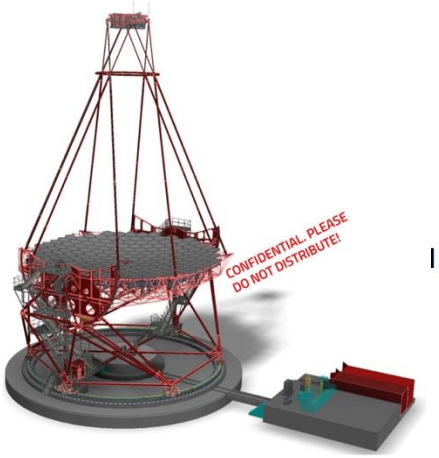
Actuator motors



CTAO

LSTS Project OBS/WBS

LST SOUTH



LSTS Project within the CTA+ Program
funded by NextGen EU and the Italian NRRP
Deadline: December 31, 2025

WP1200-S01
LST South
PI: Angelo Antonelli, INAF OAR

WP1210
LST-S Project Office
(Andrea Busatta, INAF OAPd)

WP1220
LST-S Mechanical Structure
(Angelo Antonelli, INAF OAR)
LSTS NEW DESIGN

WP1230
LST-S Optics
(Giovanni Pareschi, INAF OAB)

WP1240
LST-S Camera & Raw Processing
(Riccardo Paoletti, UNISI)

WP1250
LST-S Auxiliary
(Filippo Ambrosino, INAF OAR)

WP1260
LST-S AIT/V
(Roberto Speziali, INAF OAR)

WP1240-1
LST-CAM S/S Management
(Gaia Verna, UNISI)

WP1240-2
LST-CAM Mech Structure
(Serena Loporchio, POLIBA)

WP1240-3
LST-CAM Front Plane Instr.
(Leonardo Di Venere, INFN-BA)

WP1240-4
LST-CAM Signal Processing
(Pietro Ottanelli, INFN-PI)

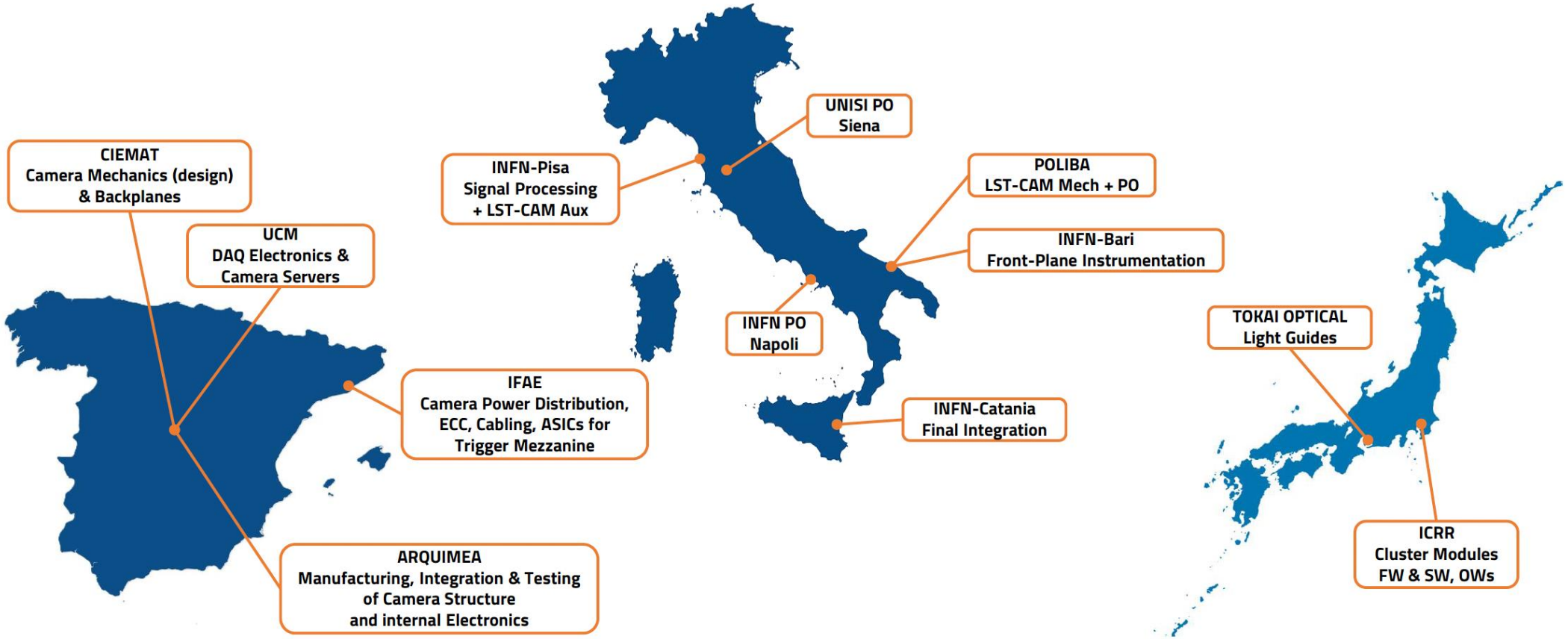
WP1240-5
LST-CAM Auxiliary Systems
(Leonardo Orsini, INFN-PI)

WP1240-6
LST-CAM Integration
(Giovanni Marsella, INFN-CT)

CTAO

LSTS-CAM Contributions

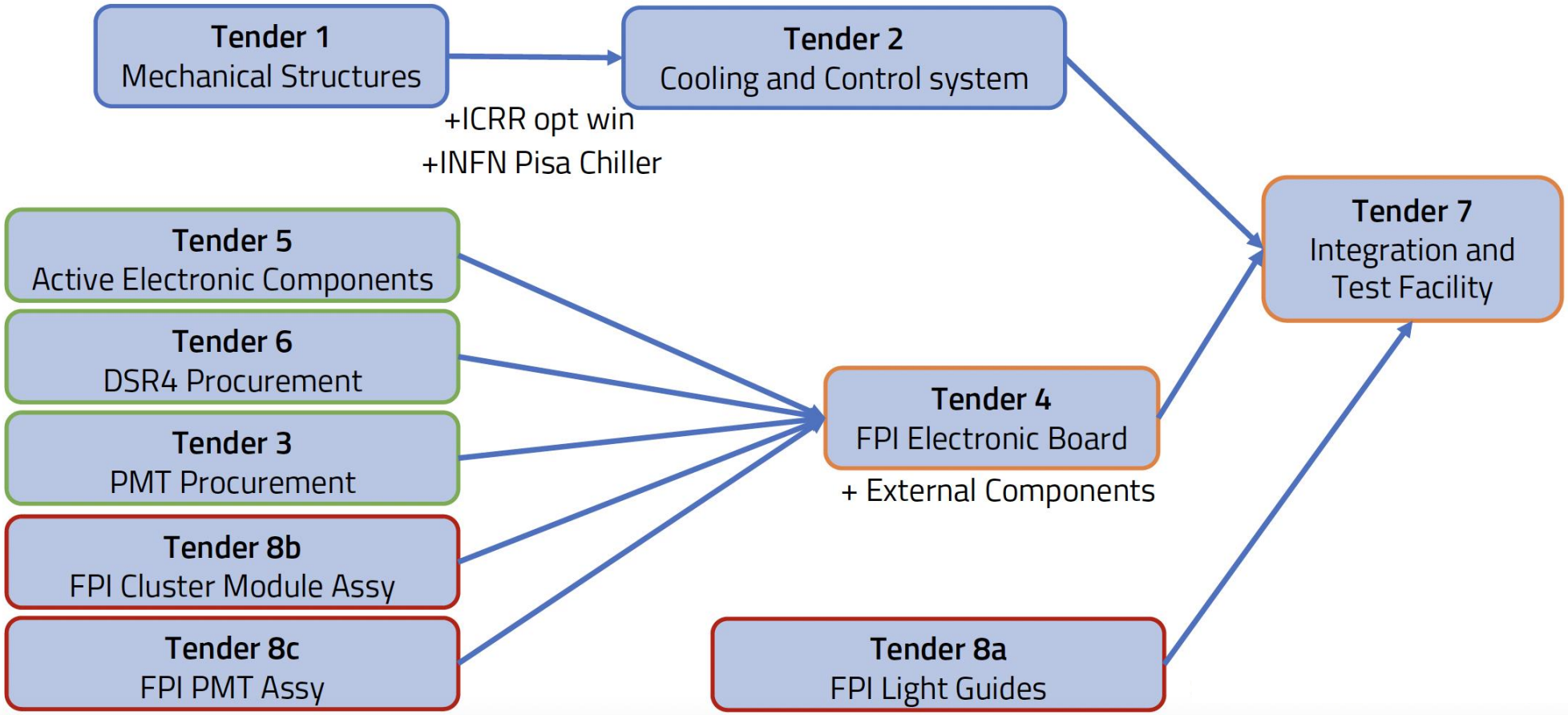
LST SOUTH



CTAO

Camera

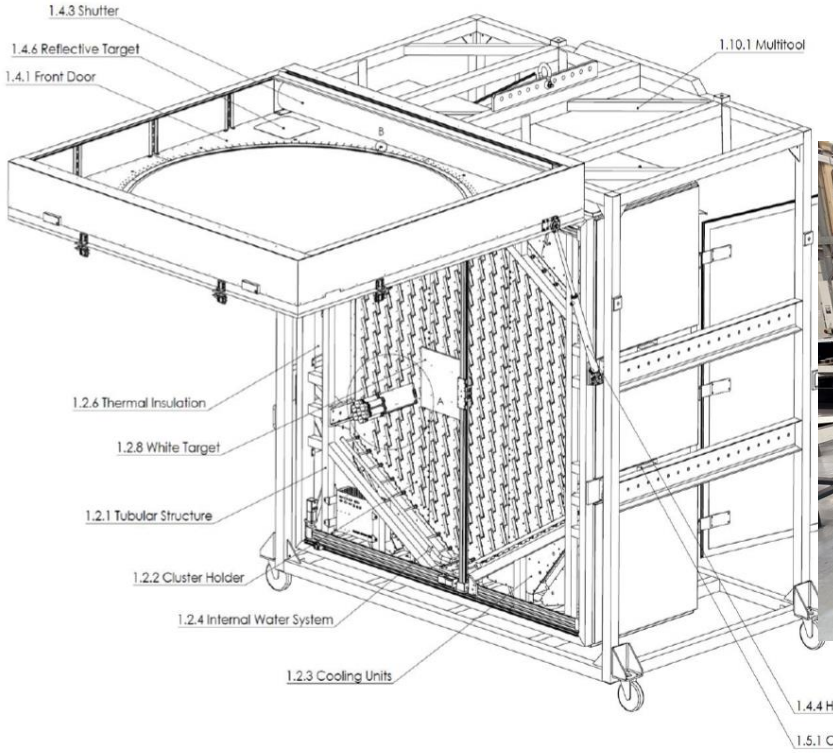
LST SOUTH

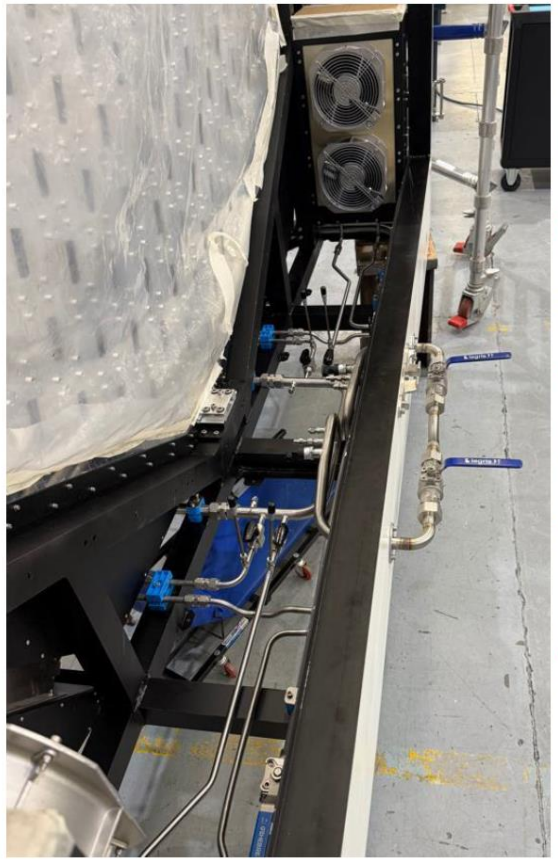


CTAO

Tender 1 – Camera Mechanics

LST SOUTH



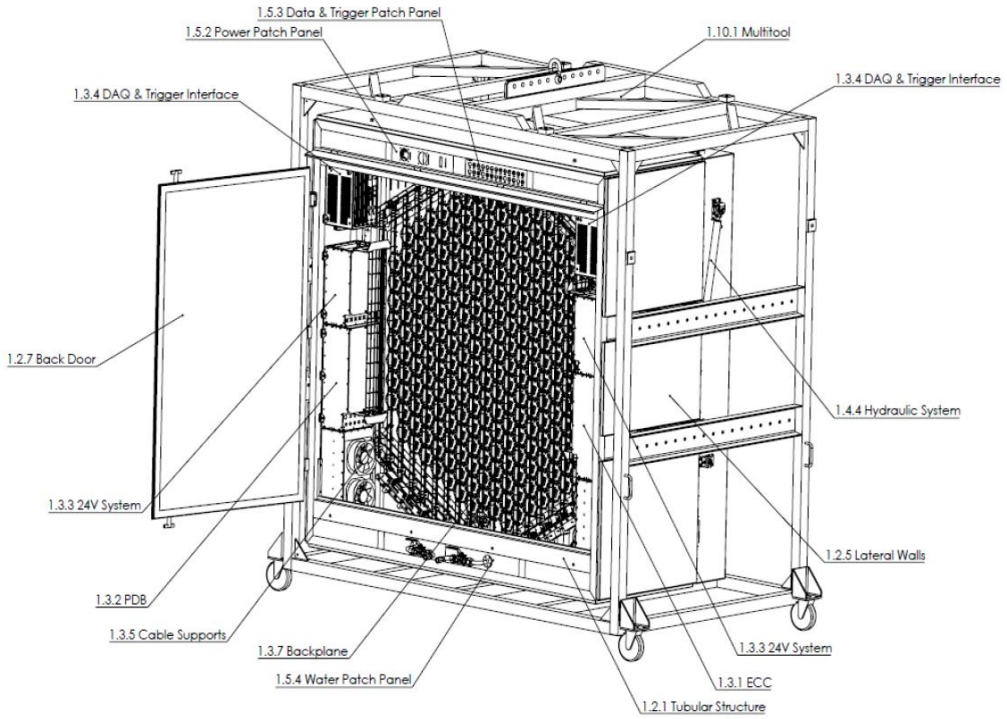


Handover to Tender 2 foreseen within the first half of July 2025.

CTAO

Tender 2 – Camera Control Systems

LST SOUTH



- **INFN PI - AAS KO meeting on Jul 16, 2024**

- Most of the electronic boxes have been assembled, standalone tests are ongoing
- Procurement of Camera Servers and ECCs ongoing but purchase orders have been released with some delays due to unexpected increase of cost
- Mitigation:
  - Camera Server specifications have been revised by UCM to reduce costs;
  - Purchase of ECC spare unit in standby.

- **Initial delay of 6-9 months** introduced by INFN administrative issues
  - 3 months may be recovered but **handover from Tender 1 is driving the schedule**.

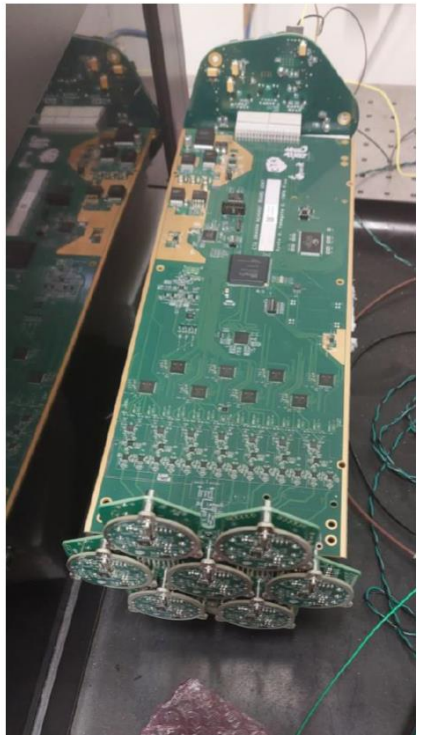
Shipment to Catania is foreseen on September 17, 2025

Tender 3, 5, and 6 – PMTs and FPI active components

- **Procurement of PMT R12992-100-20 completed**
  - 6000 units received, characterized by Hamamatsu and sample tested at INFN Bari (10%)
  - First test on Jun 18, 2025
  - Last test on May 5, 2025
  - Tests show compliance with specifications

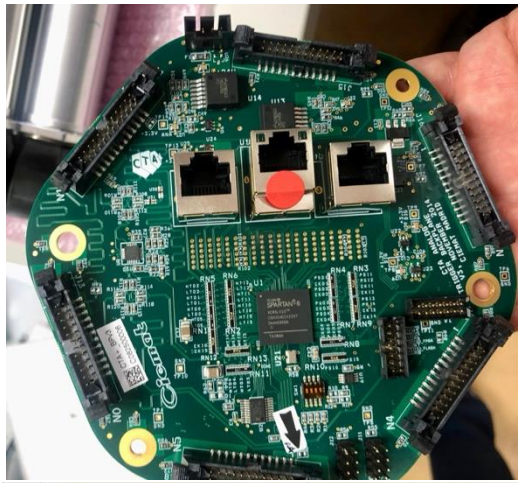
- **All active electronic components** (DRS4, FPGAs, etc…) **have been purchased and delivered** to Tender 4 on January 29, 2025
  - must be installed on the PCBs for the Cluster Modules
  - PACTA, L0 and L1 ASICs procured within Tender 4 as contributions from CIEMAT and IFAE.

Tender 4 – Cluster Modules Electronics



Backplane:

- **First batch of 10 backplanes produced** by Cupersafety
- Installation of QC setup in Cupersafety performed in December 2024 with CIEMAT support
  - QC tests performed on the first 10 backplanes resulted in a slightly higher noise compared to LST2-4 production, but still within specifications
  - After deep investigation by CIEMAT team, the cause was found in the QC setup itself, not in the boards, so Backplane **full production started**.
- Full production will be enough to assemble 1000 modules.



Other PCBs:

- Completed production and assembly of 10 clusters
- QC tests started @INFN-Bari, setup to be replicated in Cupersafety

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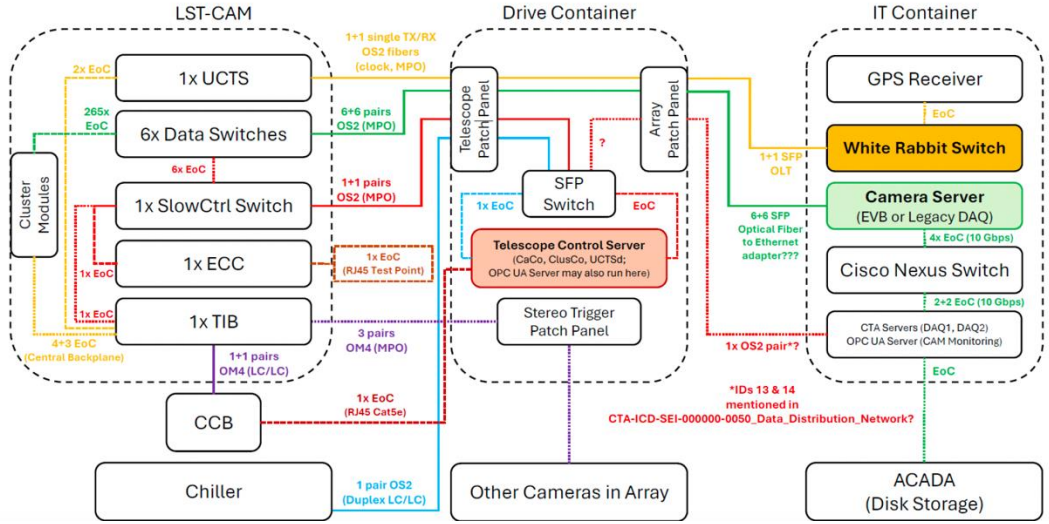
CTAO

Tender 7 – Integration Facility

LST SOUTH

Status on May 14, 2025

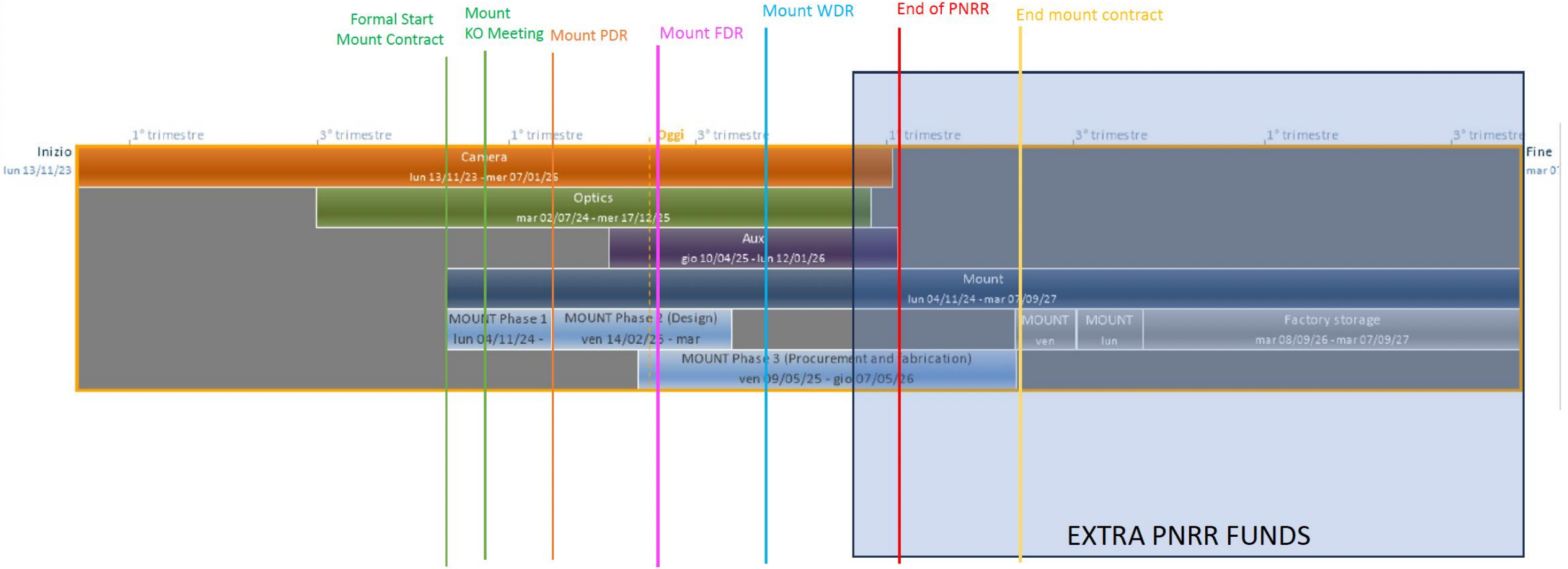
Network scheme adapted from LST1, to be (partially) implemented in Catania for testing activities



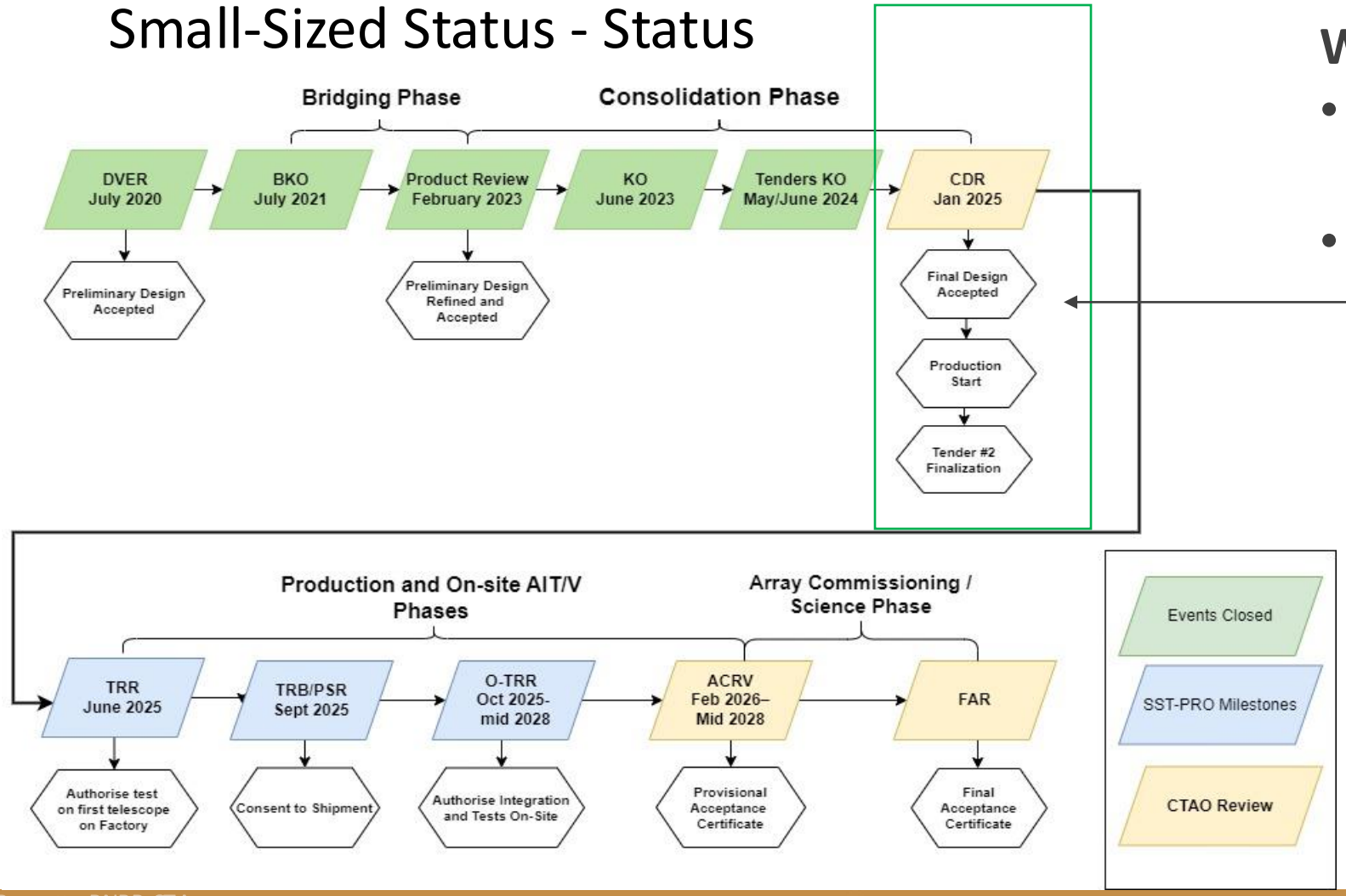
Work is ongoing and will be completed in July, in the meantime:

- standard lab equipment to be purchased
- integration and Test workflow to be defined
- minimum set of acceptance tests to be defined

Overall schedule



Small-Sized Status - Status



We are in Production Phase:

- **1st Telescope commissioned by 2026**
- **firsts 5 by 2027**

Small-Sized Telescopes: SST-MEC

CTAO | SST COLLABORATION

SST-MEC (Electro-mechanical Structure) Tender:

- The Contract wil Dal Ben spa started early June 2024

- Aftert the CDMR, the Production phase started:
  10 SST-MEC produced, tested and ready for shipment by 2025

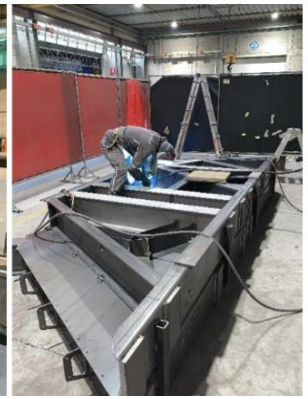


Figura 2: Puntatura masse contrappesi sinistre (SST1-22-000-01

Small-Sized Telescopes: Mirrors

CTAO | SST COLLABORATION

M1: 46 M1 already produced (180 by end of 2025)

- All mirrors have their own Identity Card

M2: 4 M2 substrates already slumped (probably 30 slumped by end of 2025)

- metrology is very good: rms is < 100 micron along all the mirrors

2 M2 mirrors already coated

- Reflectivity measurement on-going

Small-Sized Telescopes: Cherenkov Camera

CTAO | SST COLLABORATION

SST-CAM (Cherenkov Camera):

- It needs a Delta-CDR due to a couple of issues:
  - electrical cross-talk => requires a redesign of Focal Plane Electronic (partially complete)
  - backplane malfunctioning => new design completed now in construction

- QCAM (Engineering model with 1 quarter of the SiPM) built and under test in MPIK
- JULY 2025: After laboratory tests, the QCAM will be shipped in Tenerife to be integrated on ASTRI to perform «On Sky Tests»
- September 2025: QCAM will be shipped to the SST-MEC Contractor to be integrated in the first telescope on factory

CTA+ outreach program

- The CTA+ program also includes many outreach and science communication activities, with events for the general public, but above all with activities for students and training for teachers to bring them closer to the fascinating world of gamma rays and astroparticle physics.

- Among all these activities, I will briefly describe two courses dedicated to Italian high school teachers, also using the Cosmic Ray Cube telescopes, founded by CTA+ program

Discovering cosmic rays" for in-service high school physics teachers

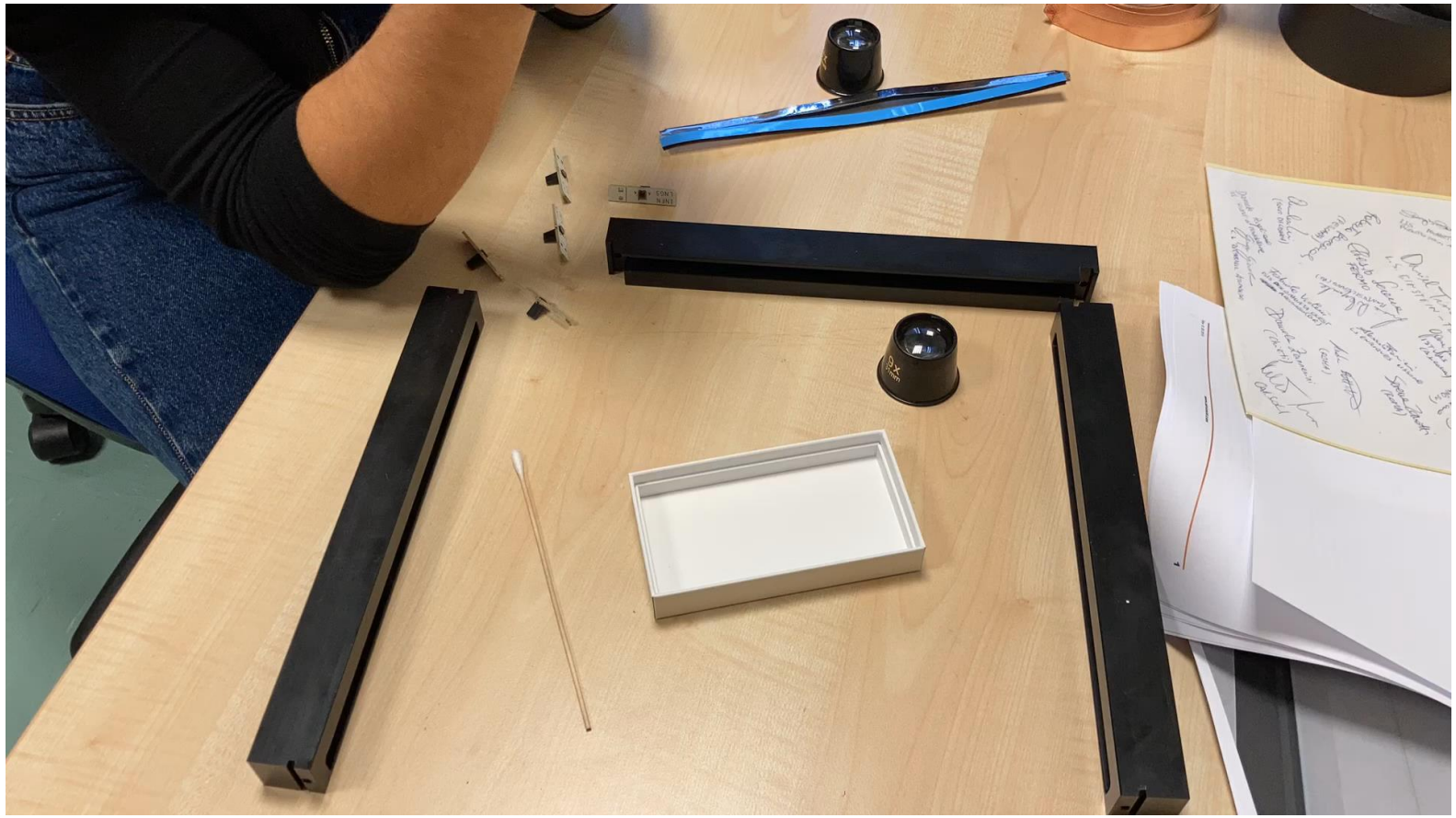
From 10 to 13 December 2023, 17 secondary school teachers from all over Italy attended the "Discovering Cosmic Rays" a course at the Gran Sasso National Laboratories.

The 2.5-day residential course was an opportunity to learn more about the fascinating topic of cosmic rays and gamma rays, the experiments that observe them and the messages they can bring us from space.

During the practical sessions, **participants were actively involved in building a muon telescope**, performing a muon flux measurement and analysing the data. A lot of space was given to the development of learning pathways in order to have a concrete and usable output.

The aim of the course was to provide an overview of the subject matter, enabling participants to familiarise themselves with the activities, experience them first hand and build on their prior knowledge and skills, **thus facilitating immediate implementation of the activities in the classroom.**

Teachers building the CRC during the course at LNGS



Second Teachers' Course: 8-11 September 2024 - Department of Physics and Astronomy, University of Padua.

- The 2.5-day residential course was attended by 30 high school teachers and aimed to introduce them to the topic of gamma rays, the experiments that observe them and the astronomical sources that produce them.
- During the practical sessions, the participants used an online astronomical portal "firmamento" to obtain data from the latest astronomical observatories.
- Some data analysis activities were then proposed and carried out in small groups.

See talk by Antonio Iuliano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PORTALE INFN

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NEWS SCUOLA

NEWS SCUOLA 09 SETTEMBRE 2024

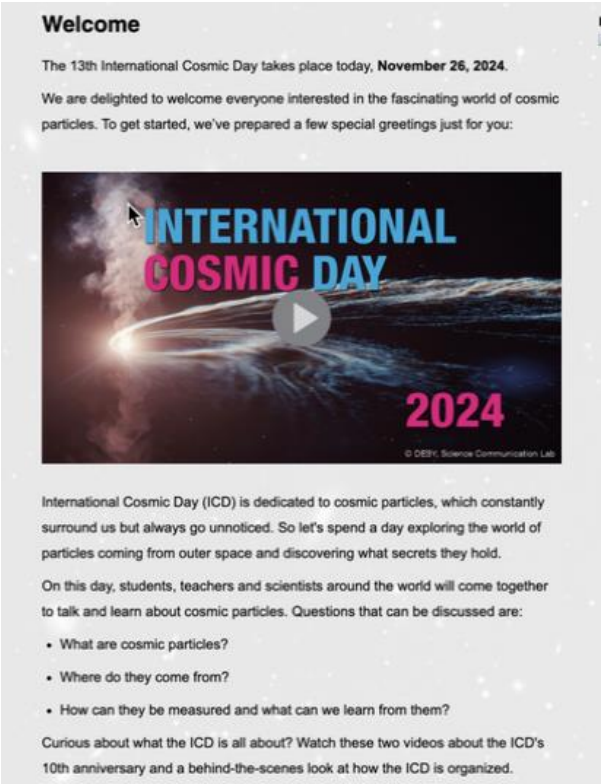
INSEGNANTI ALLA SCOPERTA DELL'UNIVERSO DELLE ALTE ENERGIE

Al via oggi, 9 settembre, fino all'11 settembre, il corso promosso dall'INFN "Alla scoperta dell'universo delle alte energie" dedicato a docenti delle scuole superiori di tutta Italia. Tre giorni di seminari, analisi di dati astrofisici e studio delle sorgenti di raggi cosmici di altissima energia, il tutto nella cornice del Dipartimento di Fisica e Astronomia dell'Università degli Studi di Padova e della Sezione di Padova dell'INFN.

Dopo il successo della prima edizione, lo scorso anno, questa volta sono stati selezionati, tra 180 docenti candidati, 30 docenti da 15 regioni italiane, con l'obiettivo di far loro conoscere più da vicino l'affascinante tema dei raggi cosmici per conoscere gli esperimenti che li osservano e le sorgenti astrofisiche che li producono. Le docenti e i docenti stanno partecipando in prima persona all'analisi di dati di osservatori astronomici attraverso l'uso di portali dedicati. Il corso ha, infatti, anche l'obiettivo di consentire ai docenti di prendere dimestichezza con le attività sperimentali, provarle in prima persona e accrescere conoscenze e competenze pregresse, per facilitare la loro condivisione in classe. Un momento significativo sarà la visita ai Laboratori Nazionali di Legnaro dell'INFN, dove i docenti potranno osservare da vicino le attività sperimentali in corso.

International cosmic day 2024

1200 students in person and 1300 online for 24 INFN Divisions



PCTO started at ICD 2024 in Naples (120 students)

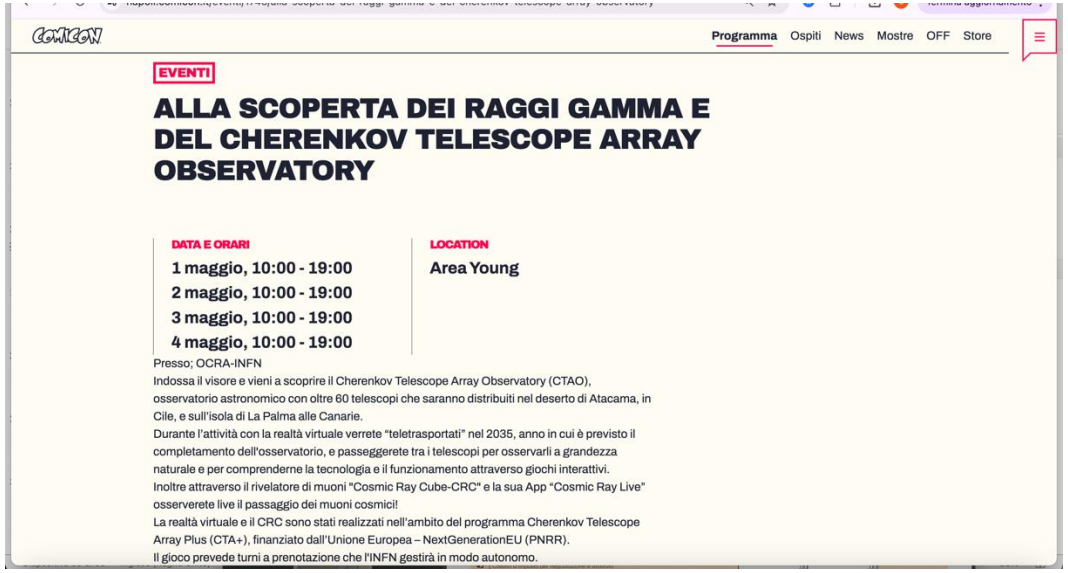
Firmamento and CRC analysis by high school classrooms

Gamma… hunting

During the 4 days of Futuro Remoto we organised a treasure hunt involving more than 200 students and dozens of visitors.
By retrieving 4 clues and composing a password, participants could access an escape room where they could, through virtual reality and immersive videos, solve questions to discover the gamma sky and how to observe it.
The participating teams had to identify 4 different locations, scattered around the Futuro Remoto site, run by researchers and each characterised by a particular activity: Cosmic Ray Cube, CTAO and CTA+, LST and ASTRI.

Comicon - May 1-4, 2025 - Napoli

At Comicon 2025, visitors were able to experience the virtual reality developed with CTA+ and use the visors to discover the Cherenkov Telescope Array Observatory.
During the activity, visitors were 'teleported' to 2035, the year in which the observatory is scheduled for completion. They were able to walk among the telescopes, observe them life-size, and learn about their technology and operation through interactive games.
In addition, through the 'Cosmic Ray Cube-CRC' muon detector and its 'Cosmic Ray Live' app, they were able to observe the passage of cosmic muons live.


COMICON Programma Ospiti News Mostre OFF Store

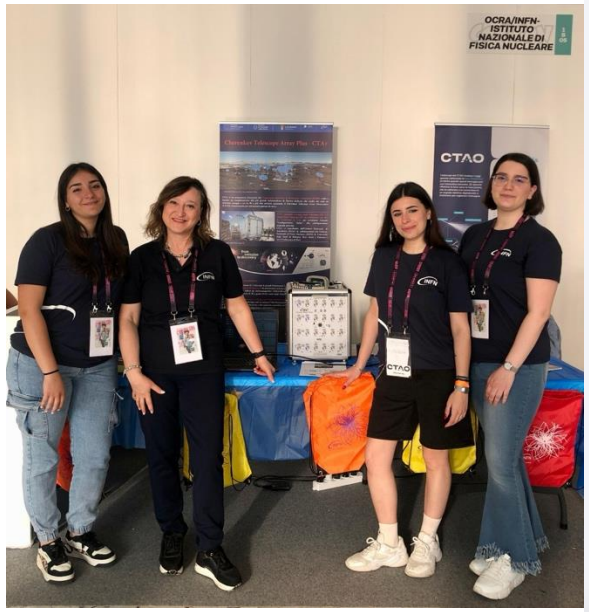
EVENTI

ALLA SCOPERTA DEI RAGGI GAMMA E DEL CHERENKOV TELESCOPE ARRAY OBSERVATORY

DATA E ORARI
1 maggio, 10:00 - 19:00
2 maggio, 10:00 - 19:00
3 maggio, 10:00 - 19:00
4 maggio, 10:00 - 19:00

LOCATION
Area Young

Presso; OCRA-INFN
Indossa il visore e vieni a scoprire il Cherenkov Telescope Array Observatory (CTAO), osservatorio astronomico con oltre 60 telescopi che saranno distribuiti nel deserto di Atacama, in Cile, e sull'isola di La Palma alle Canarie.
Durante l'attività con la realtà virtuale verrete "teletrasportati" nel 2035, anno in cui è previsto il completamento dell'osservatorio, e passeggerete tra i telescopi per osservarli a grandezza naturale e per comprenderne la tecnologia e il funzionamento attraverso giochi interattivi.
Inoltre attraverso il rivelatore di muoni "Cosmic Ray Cube-CRC" e la sua App "Cosmic Ray Live" osserverete live il passaggio dei muoni cosmici!
La realtà virtuale e il CRC sono stati realizzati nell'ambito del programma Cherenkov Telescope Array Plus (CTA+), finanziato dall'Unione Europea – NextGenerationEU (PNRR).
Il gioco prevede turni a prenotazione che l'INFN gestirà in modo autonomo.



INFN - Istituto Nazionale di Fisica Nucleare
3 maggio alle ore 09:00 ·

🎉 Fino a domenica, alla Mostra d'Oltremare di Napoli, puoi giocare con la scienza!

In occasione della venticinquesima edizione di COMICON, il festival dedicato al fumetto e al mondo dell'intrattenimento, il progetto dell'INFN #OCRA Outreach Cosmic Ray Activities ha organizzato l'attività "Alla scoperta dei raggi gamma e del Cherenkov Telescope Array Observatory".

🚀 Ti basterà raggiungere lo stand 1S05 del padiglione 1, nel distretto GameLab, indossare il nostro visore VR, e prepararti a essere "teletrasportato" nel 2035! Tra dieci anni il CTAO Cherenkov Telescope Array Observatory, il più grande osservatorio al mondo per lo studio dei #RaggiGamma, raggiungerà la sua configurazione finale, e tu potrai ammirarla in anteprima passeggiando virtualmente tra i suoi 60 telescopi nel deserto di Atacama, in Cile, e sull'isola di La Palma alle Canarie.

Scopri tutti i dettagli: https://collisioni.infn.it/.../linfn-al-comicon-napoli-2025/

Conclusions

- CTA+ will improve the performance and the scientific outcome of the CTAO-South array
- The larger and most ambitious goal of the CTA+ Program is to realize two LSTs and 5 SSTs in the CTA south site in about three years by following an end-to-end approach.
- The two telescopes will be realized following the same baseline design of the northern LSTs, apart fromthose changes needed to fulfill the environmental specifications of the southern site and further reduce the construction risks and costs.
- The production of the auxiliaries, cameras, mirrors, and mechanical structures is realized through large industrial contracts supervised by the CTA+ management with the support of the LST Collaboration and CTAO.
- Some international partner countries in the LST Collaboration also provide in-kind contributions to the realization of part of the telescopes.
- R&D program for future CTAO detectors and ancillary instrumentations
- The science and outreach programme is well-improved.

Acknowledgement

This work has been realized with the EU funding program "Next Generation EU" in the context of the PNRR-IR "CTA+". The acknoledgements for CTA Consortium are listed here: https://www.cta-observatory.org/consortium_acknowledgments/ . We gratefully acknowledge financial support from the following agencies and organisations listed here: https://www.lst1.iac.es/acknowledgements.

Questions?