

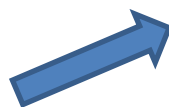


The ASTRI & CTA programmes for ground based high-energy gamma-ray astronomy up to 100 TeV



- INAF is the leader of the program with more than 100 hundred researchers involved (Milano, Catania, Palermo, Bologna, Padova and Roma)
- Several Italian universities are also involved (Perugia, Padova, Catania, Genova, and POLIMI)
- INFN participation (Roma Tor Vergata and Perugia)
- International partners:
 - **STRATEGIC PARTICIPATION of University of Sao Paulo/FAPESP (Brazil)**
 - North-West University (South Africa) and, recently **IAC (Spain)**
- Italian and foreign companies are involved in the ASTRI program with an important industrial return:

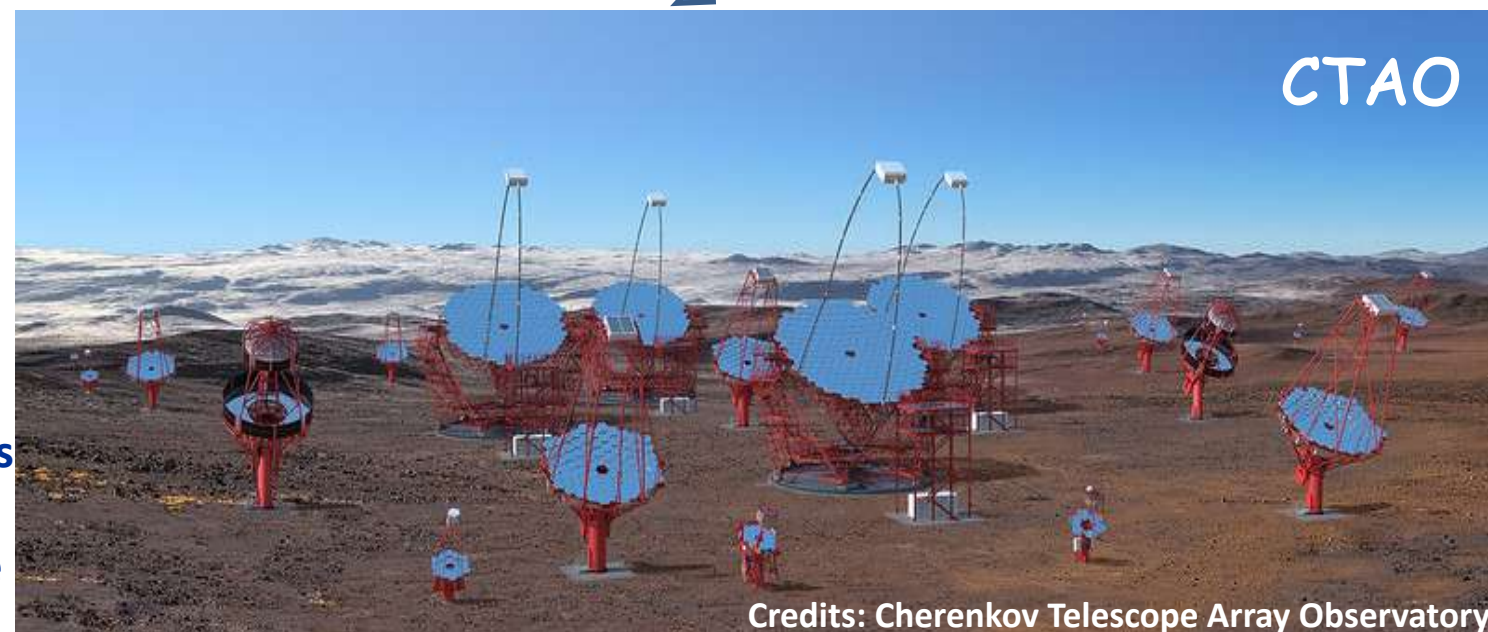
Telescope	Optics	Cherenkov Camera
<ul style="list-style-type: none">• EIE (I)• Galbiati (I)	<ul style="list-style-type: none">• Media Lario (I)• Flabeg (D)• ZAOT (I)	<ul style="list-style-type: none">• Hamamatsu (JP)• Weeroc (F)• Mindway (I)• Novasys (I)• Thermacore (UK branch)• TMA (I)

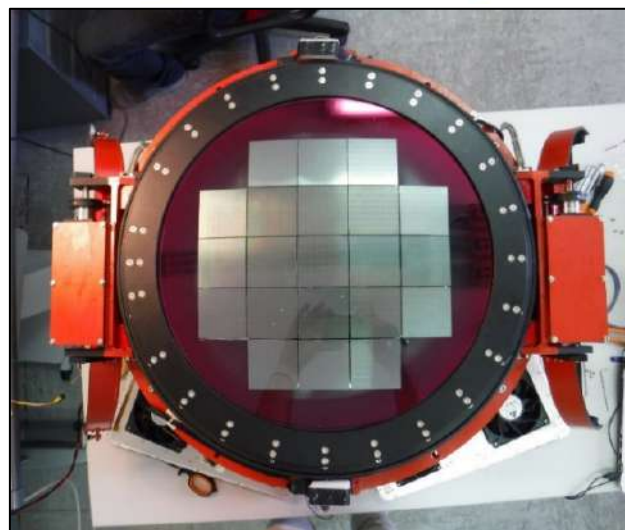
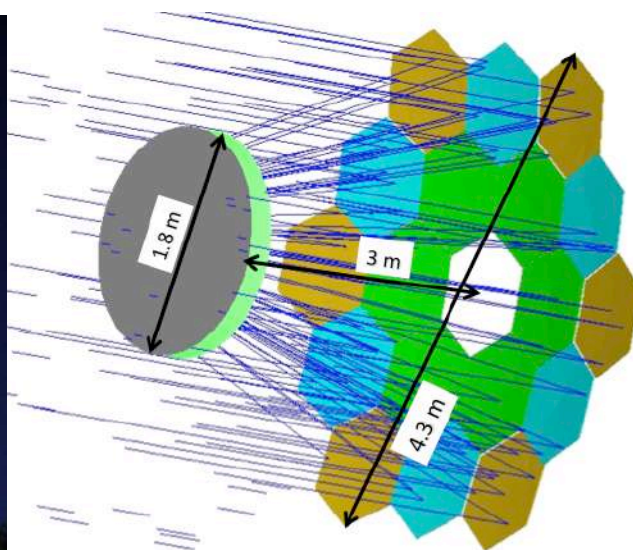


Mini-Array



1. Development of an end-to-end technological demonstrator
2. Construction and operation of the ASTRI mini-array @ Teide Observatory (Canary Islands) in collaboration with University of São Paulo/FAPESP, Instituto de Astrofísica de Canarias (IAC),, and North-West University
3. Leading the consortium that will implement the SST telescopes @ CTAO southern site





• Opto-mechanics

- Alto-azimuthal mount
- **Schwarzschild-Couder optical design**
- Primary Mirror: 4.3 m (segmented)
- Secondary Mirror: 1.8 m (monolithic)
- F/#: 0.5 m
- Average effective area: 5.0 m²
- Optical PSF ≤ 0.19 deg
- Post calibration pointing precision ≤ 7 arcsec

• Cherenkov Camera

- **Front End electronics based on CITIROC ASICs**
- **SiPM sensors: 7x7 mm**
- 1344 pixels (2368 when focal plane fully populated)
- Field of View: 8.2 deg (10.5 deg)
- Angular pixel size: 0.19 deg

• Expected performance

- Energy threshold ≈ 1 TeV
- Energy/Angular resolution $< \sim 25\%$ / $< \sim 0.15^\circ$
- Sensitivity ≈ 1 Crab @ 5σ in few hours



24th September 2014

Inauguration of the prototype @ INAF-Catania mountain station in Serra La Nave placed at 1725 meters on the Etna volcano

A&A 608, A86 (2017)
DOI: [10.1051/0004-6361/201731602](https://doi.org/10.1051/0004-6361/201731602)
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Astronomy
&
Astrophysics

First optical validation of a Schwarzschild Couder telescope: the ASTRI SST-2M Cherenkov telescope

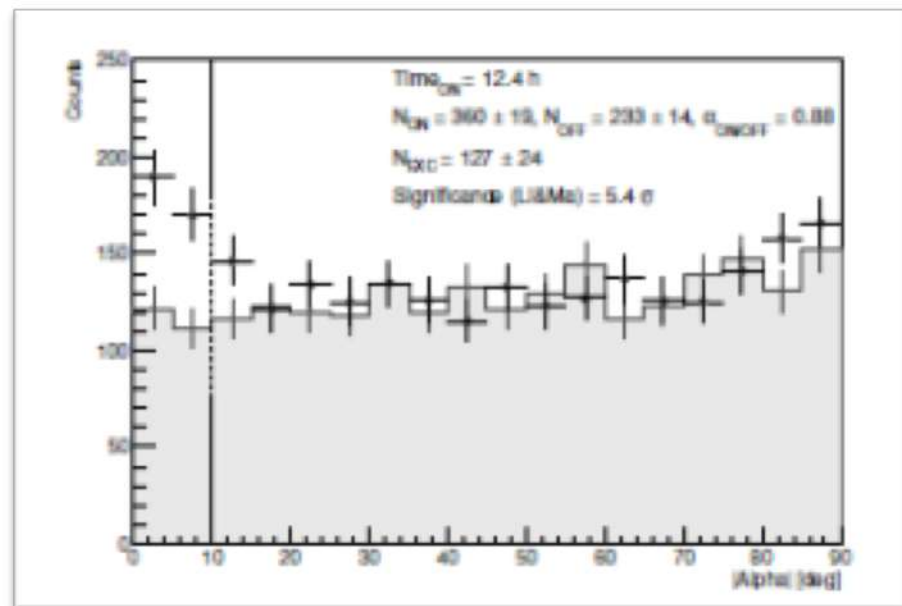
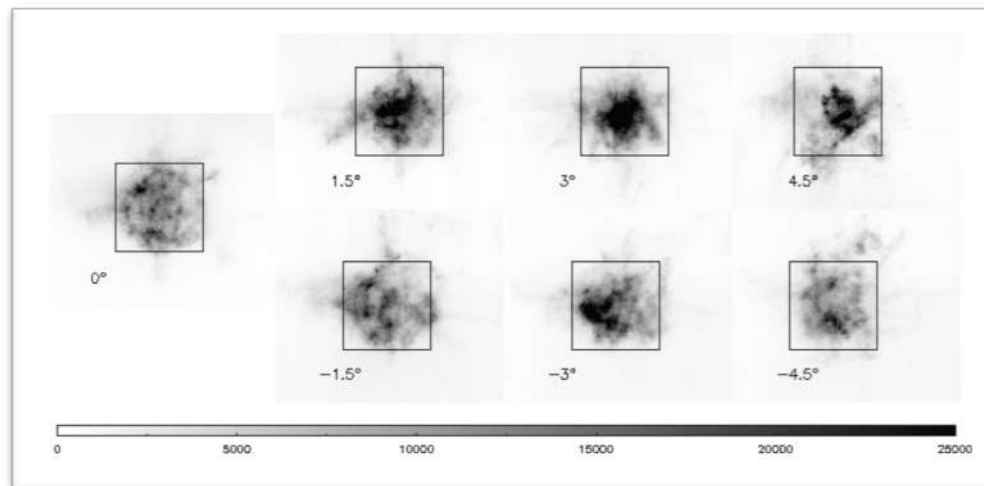
E. Giro^{1,2}, R. Canestrari², G. Sironi², E. Antolini³, P. Conconi², C. E. Fermino⁴, C. Gargano⁵, G. Rodeghiero^{1,6},
F. Russo⁷, S. Scuderi⁸, G. Tosti³, V. Vassiliev⁹, and G. Pareschi²

A&A 634, A22 (2020)
<https://doi.org/10.1051/0004-6361/201936791>
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Astronomy
&
Astrophysics

First detection of the Crab Nebula at TeV energies with a Cherenkov telescope in a dual-mirror Schwarzschild-Couder configuration: the ASTRI-Horn telescope

S. Lombardi^{1,2,*}, O. Catalano^{3,*}, S. Scuderi^{4,*}, L. A. Antonelli^{1,2}, G. Pareschi⁵, E. Antolini⁶, L. Arrabito⁷,
G. Bellasai⁸, K. Bernlöhr⁹, C. Bigongiari¹, B. Biondo³, G. Bonanno⁸, G. Bonnoli⁵, G. M. Böttcher¹⁰, J. Bregeon¹¹,
P. Bruno⁸, R. Canestrari³, M. Capalbi³, P. Caraveo⁴, P. Conconi⁵, V. Conforti¹², G. Contino³, G. Cusumano³,
E. M. de Gouveia Dal Pino¹³, A. Distefano⁴, G. Farisato¹⁴, C. Fermino¹³, M. Fiorini⁴, A. Frigo¹⁴, S. Gallozzi¹,
C. Gargano³, S. Garozzo⁸, F. Gianotti¹², S. Giarrusso³, R. Gimenes¹³, E. Giro¹⁴, A. Grillo⁸, D. Impiombato³,
S. Incorvaia⁴, N. La Palombara⁴, V. La Parola³, G. La Rosa³, G. Leto⁸, F. Lucarelli^{1,2}, M. C. Maccarone³,
D. Marano⁸, E. Martinetti⁸, A. Micciché⁸, R. Millul⁵, T. Mineo³, G. Nicotra¹⁵, G. Occhipinti⁸, I. Pagano⁸,
M. Perri^{1,2}, G. Romeo⁸, F. Russo³, F. Russo¹², B. Sacco³, P. Sangiorgi³, F. G. Saturni¹, A. Segreto³, G. Sironi⁵,
G. Sottile³, A. Stamerra¹, L. Stringhetti⁴, G. Tagliaferri⁵, M. Tavani¹⁶, V. Testa¹, M. C. Timpanaro⁸, G. Toso⁴,
G. Tosti¹⁷, M. Trifoglio¹², G. Umana⁸, S. Vercellone⁵, R. Zanmar Sanchez⁸, C. Arcaro¹⁴, A. Bulgarelli¹²,
M. Cardillo¹⁶, E. Cascone¹⁸, A. Costa⁸, A. D'Ai³, F. D'Ammando¹², M. Del Santo³, V. Fioretti¹², A. Lamastra¹,
S. Mereghetti⁴, F. Pintore⁴, G. Rodeghiero¹⁴, P. Romano⁵, I. Schwarz⁵, F. Sciaccia⁸, F. R. Vitello⁸ and A. Walter⁵

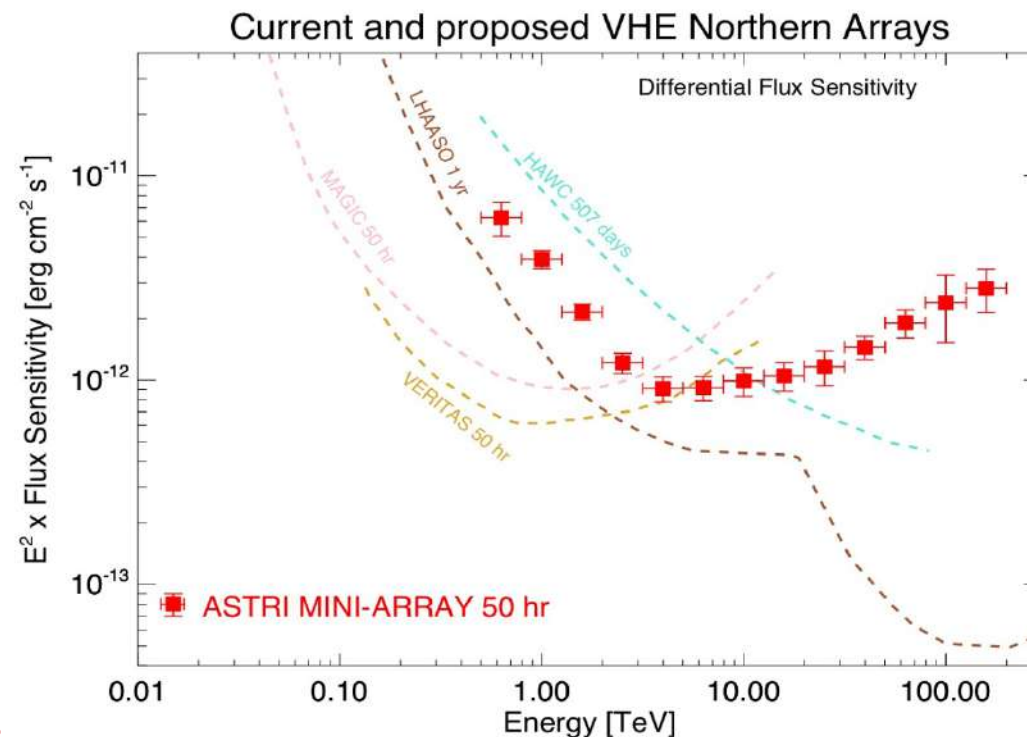




The ASTRI mini-array will be a new pathfinder of the arrays of Cherenkov telescopes

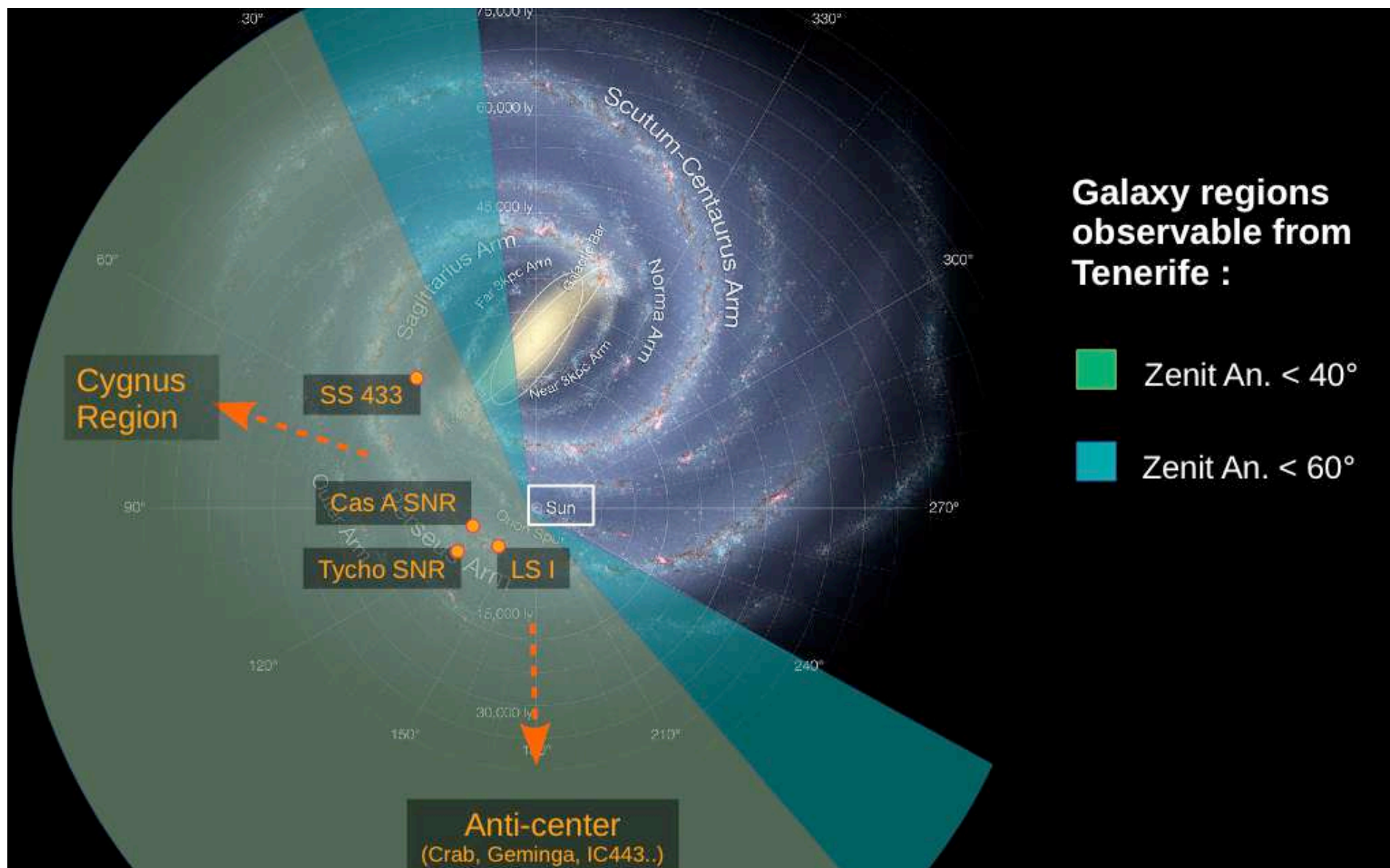
- INAF commitment with the Italian government and international partners (**University of Sao Paulo/FPESP - Brazil**, North-West University - South Africa)
- Dedicated funding
- It will be composed by 9 ASTRI telescopes, **evolution** of the ASTRI-Horn prototype successfully implemented and tested
- It will be deployed at the Teide Observatory (Canary Islands) in collaboration **with IAC**

Science at very high gamma ray energy in the northern hemisphere!



Expected performance:

- **Sensitivity: better than current IACTs ($E > 10$ TeV):**
 - Possibility to extend the spectra of already detected sources and/or measure cut-offs
 - Possibility to characterize the morphology of extended sources at the highest VHE
- **Energy/Angular resolution: $< \sim 10\%$ / $< \sim 0.1^\circ$ ($E > \sim 10$ TeV)**
- **Wide FoV ($\geq 10^\circ$), with homogeneous off-axis acceptance**
 - Optimal for multi-target fields, surveys, and extended sources
 - Enhanced chance for serendipity discoveries

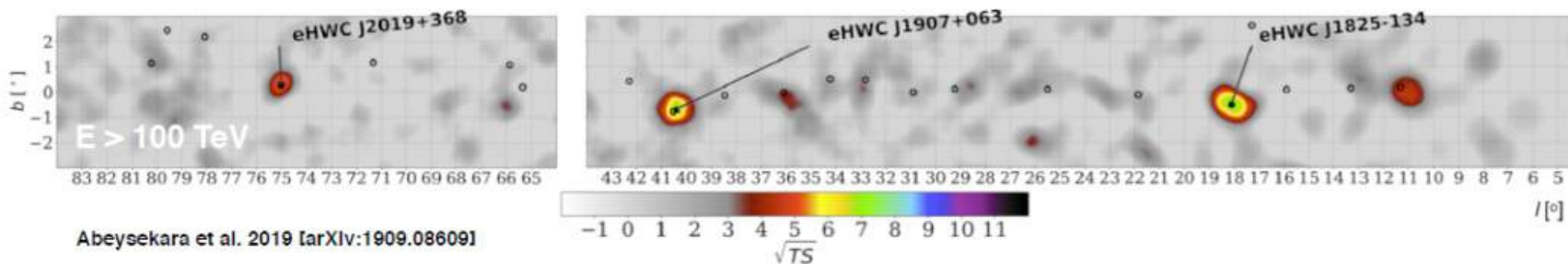
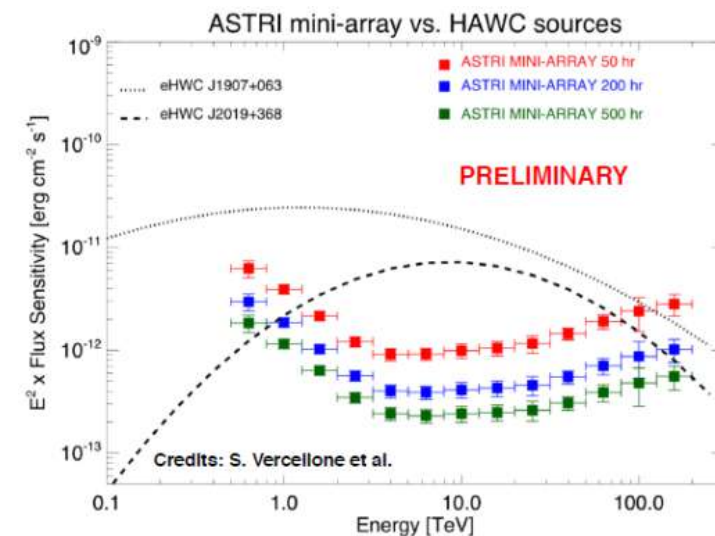
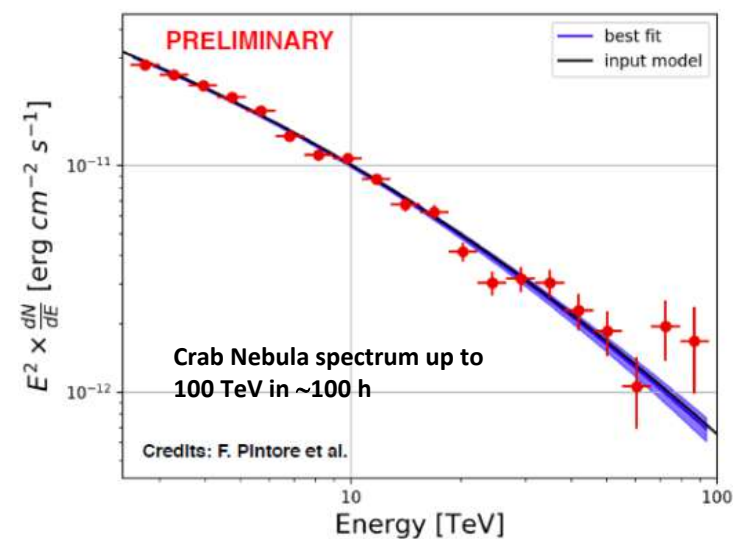


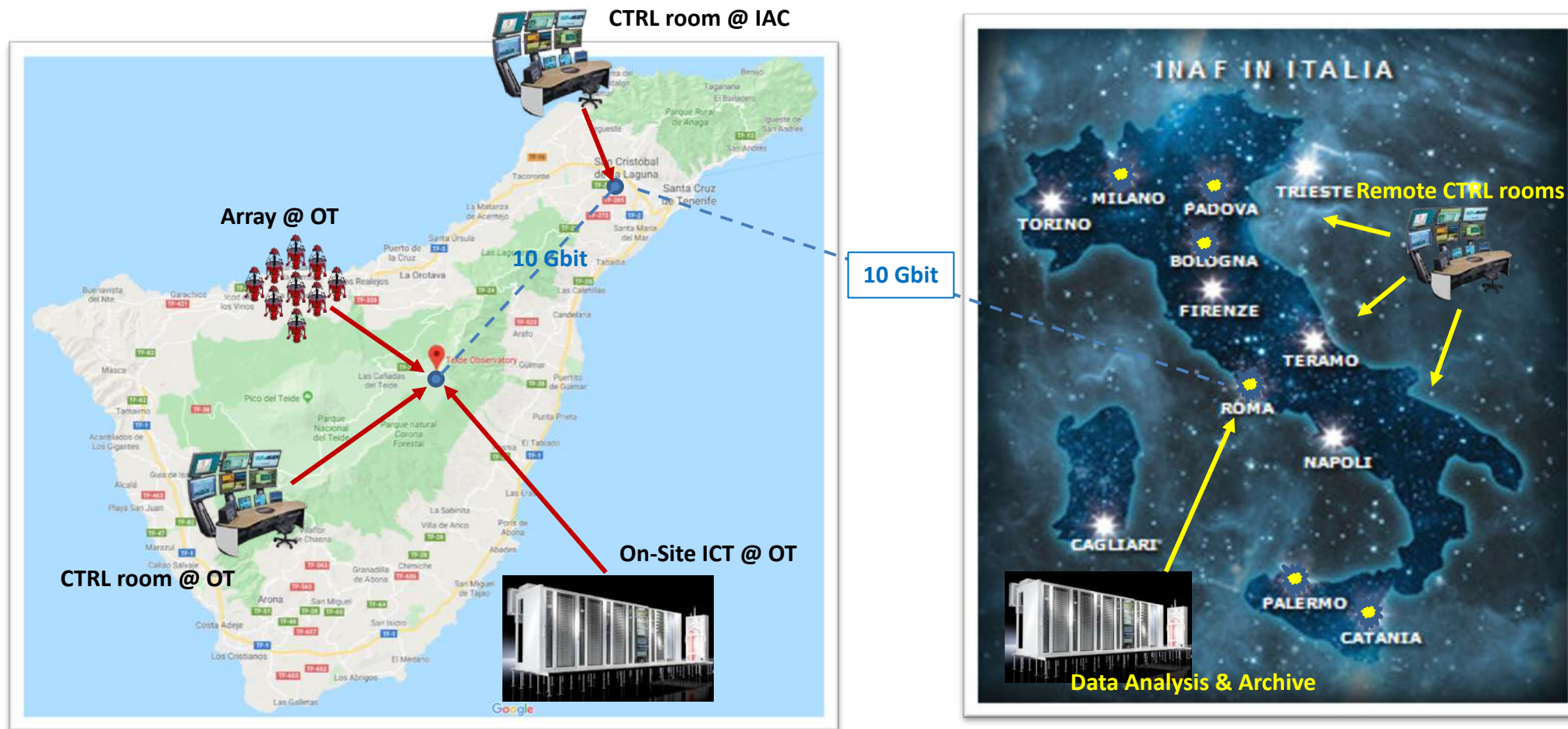
Core science program in the first ~2/3 years (detailed strategy under definition):

- Restricted number of targets/deep exposures ($> \sim 200$ h) \rightarrow strong scientific cases
- Galactic sources: wide FoV \rightarrow multi-target fields
- Extragalactic sources: survey of a few promising targets at $> \sim 10$ TeV scale
- Fundamental physics: studies on LIV, EBL, Axion-Like Particles, ...
- Science beyond VHE astronomy also envisaged \rightarrow Stellar Intensity Interferometry

Synergies with current VHE Northern Arrays:

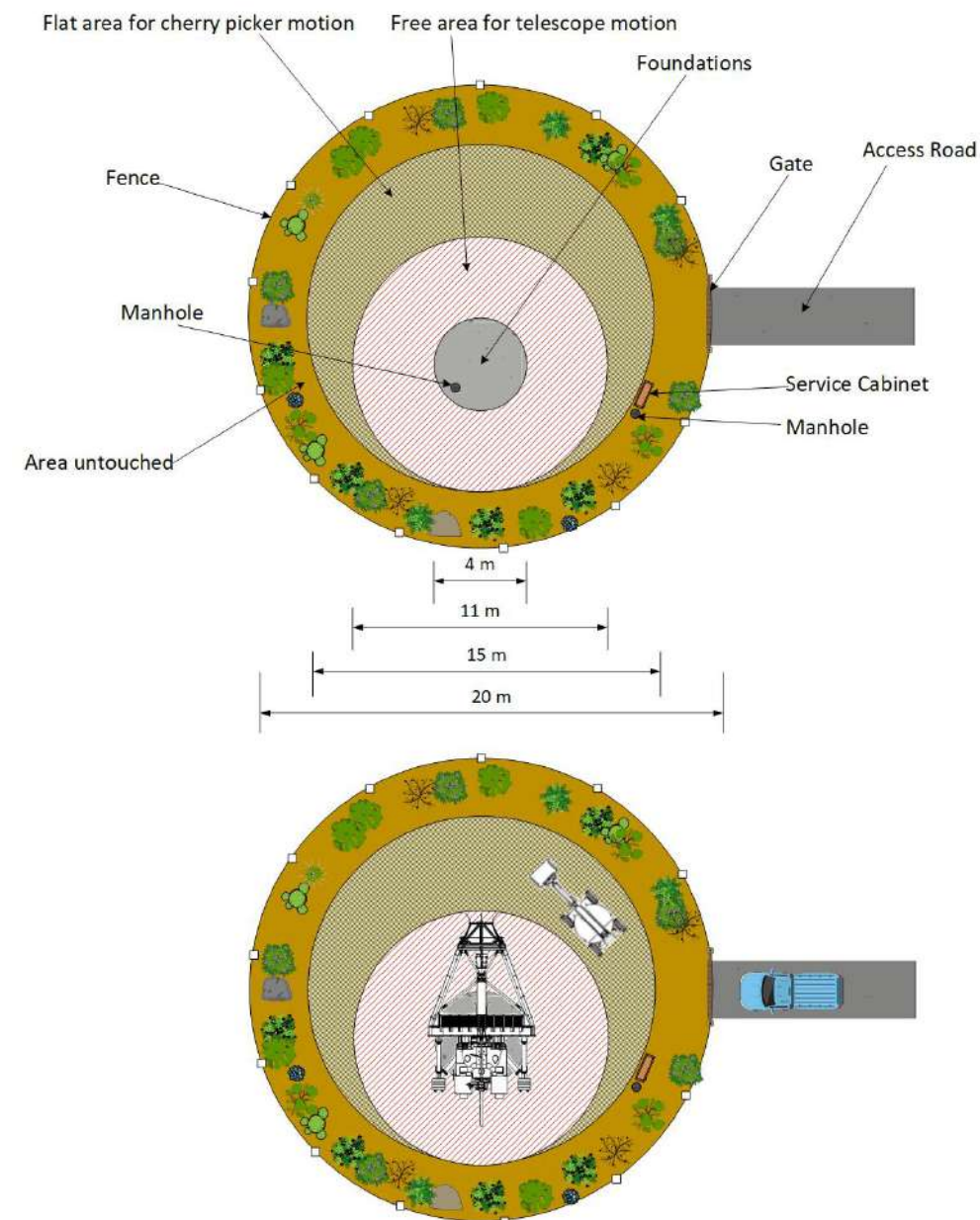
- Observations of HAWC sources with much higher angular/energy resolution
- Simultaneous observations with MAGIC and LSTs will be possible





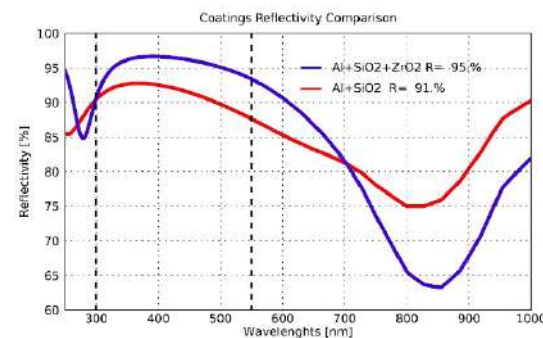
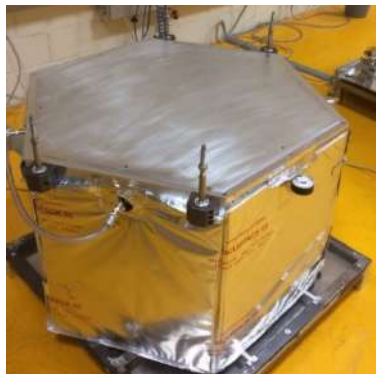
- It will be developed in order to be operated, after the commissioning phase, remotely.
- Data analysis will be performed off-site

Site ready to host the first telescope in one year



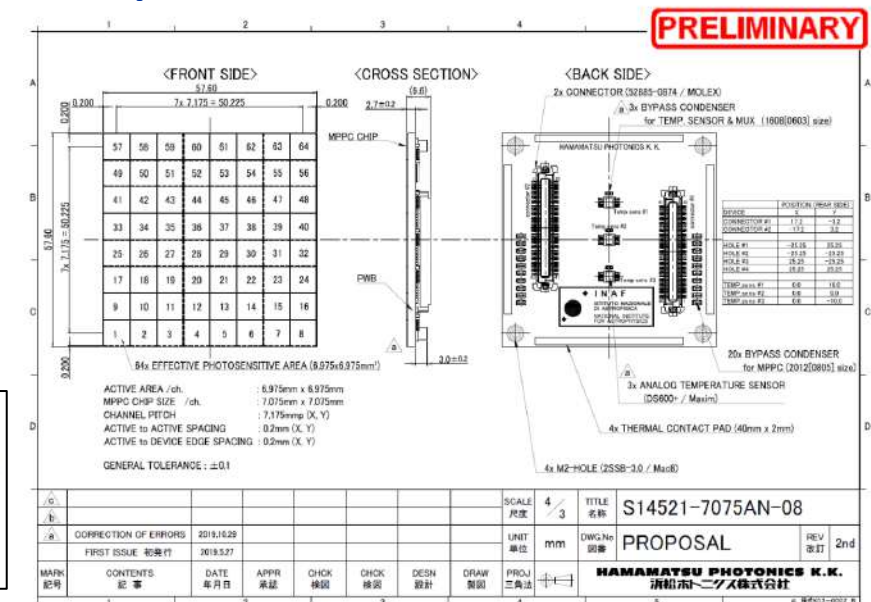
Mirrors & Camera

M1 and M2 production completed and mirrors packed and ready for shipping



Credits: Media Lario, Flabeg, ZAOT

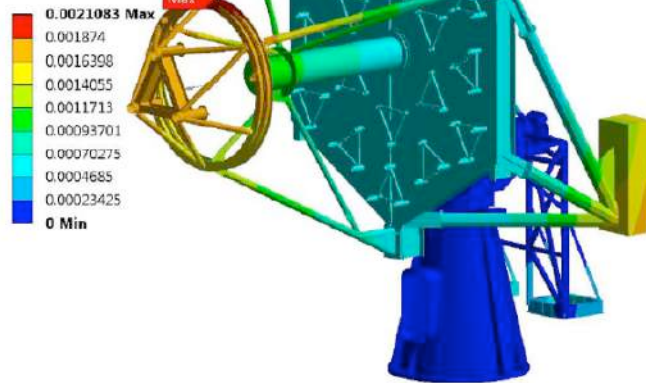
- Procurement of CITIROC-1A completed
- Procurement of SiPM detectors ongoing
→ Hamamtsu LV3, 7x7 mm, uncoated
- Procurement of Cherenkov Camera
→ tender process started



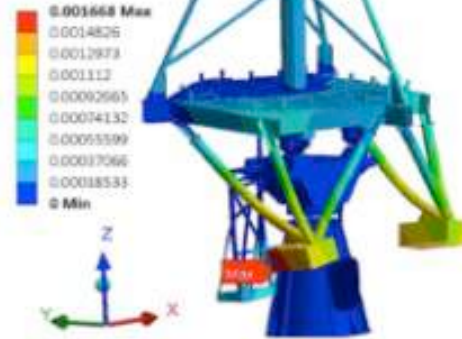
Credits: Hamamatsu Photonics, Weeroc

Electro-Mechanical Structure

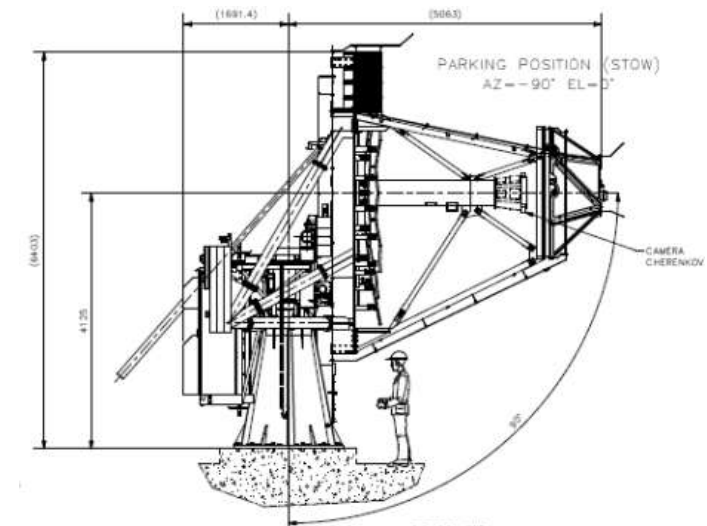
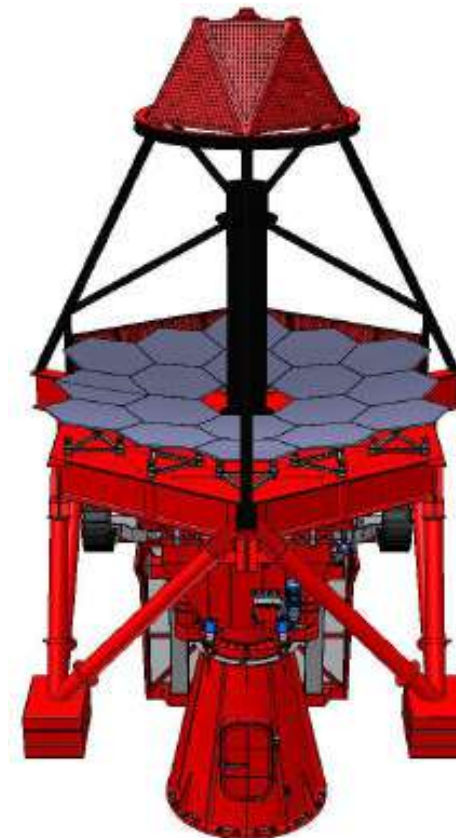
H: Static Structural 0°
Total Deformation
Type: Total Deformation
Unit: m
Time: 1



B: Static Structural 90°
Total Deformation
Type: Total Deformation
Unit: m
Time: 1
07/08/2017 15:43



- Production of first three structures started
- Tender for remaining six to be issued

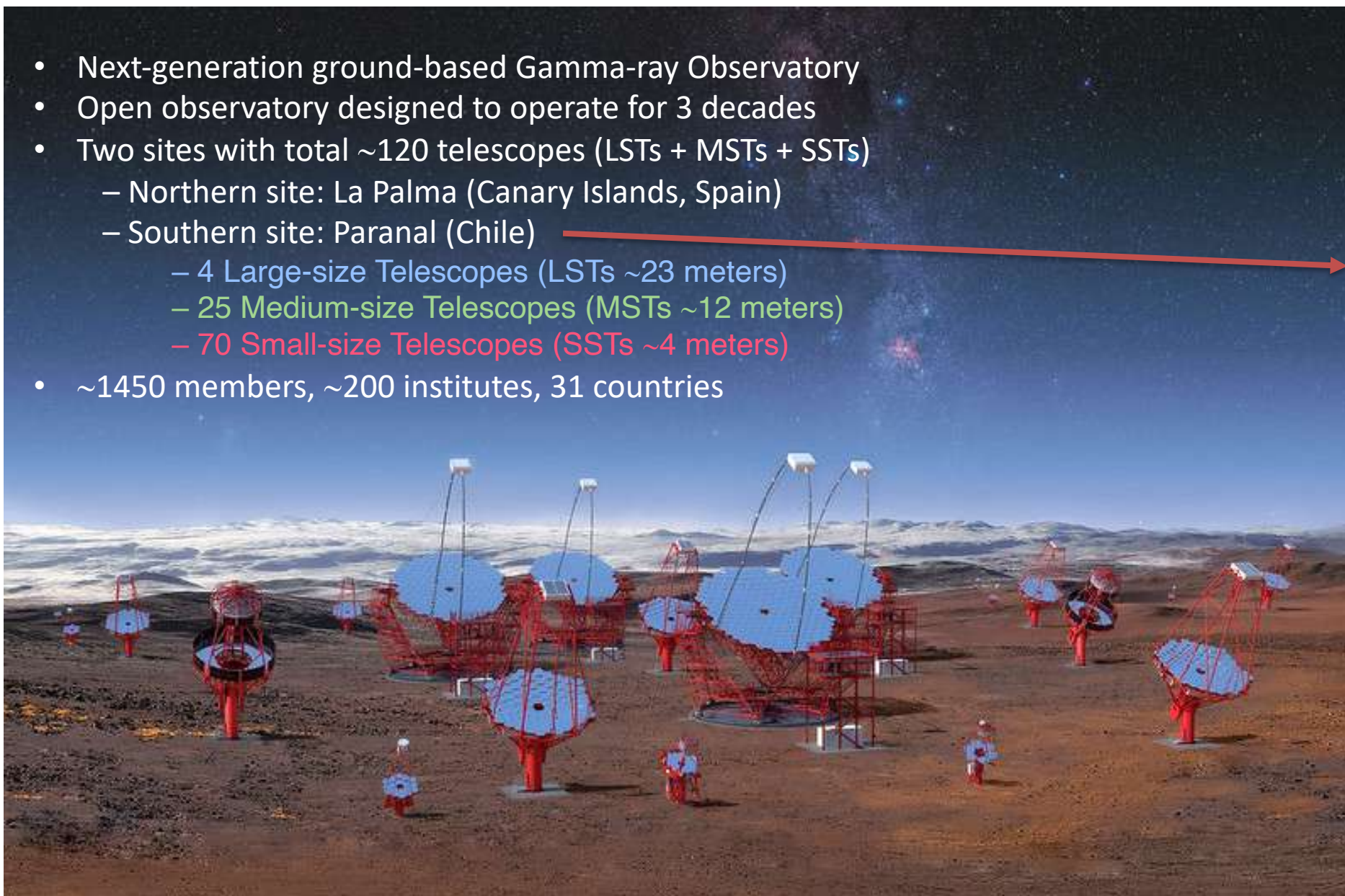
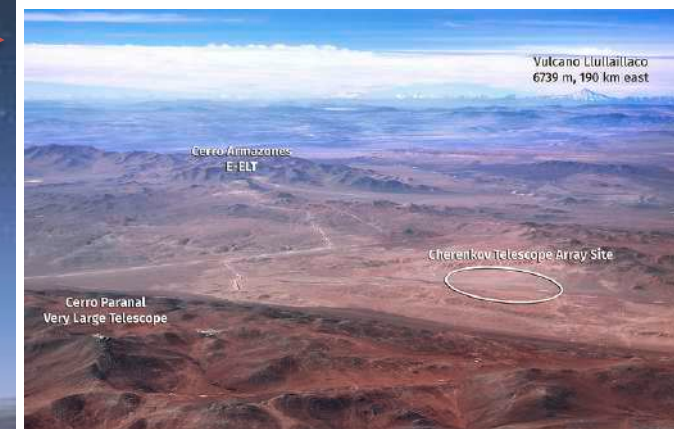


Design Consolidation

- **Mass reduction (25% → 17 Tons)**
 - Design consolidation of the dish and secondary support to maintain same stiffness lowering telescope weight
 - **Finite Element Analysis → The structure is able to support seismic loads without suffering damages that will prevent motion.**
- **Active Mirror Control (AMC) simplification**
 - No need for AMC during operations
 - AMC radially mounted for easier mirrors integration
 - AMC mounted only in integration phase and for maintenance

Credits: EIE, Galbiati

- Next-generation ground-based Gamma-ray Observatory
- Open observatory designed to operate for 3 decades
- Two sites with total ~120 telescopes (LSTs + MSTs + SSTs)
 - Northern site: La Palma (Canary Islands, Spain)
 - Southern site: Paranal (Chile)
 - 4 Large-size Telescopes (LSTs ~23 meters)
 - 25 Medium-size Telescopes (MSTs ~12 meters)
 - 70 Small-size Telescopes (SSTs ~4 meters)
- ~1450 members, ~200 institutes, 31 countries



Status of the SST-Project

- May 2018 → CTAO Council decision to *“to evolve towards a single design for the SST structure and camera”*
- Fall 2018 → Start of the *“harmonization”* process through a Request for Information.
 - Three *“proposals”* submitted (ASTRI/CHEC, GCT/Obs. de Paris, Consortium 1M)
- June 2019 → Council resolution on the SST configuration

SST Programme Proposal

A high-level implementation plan for the provision of the SSTs

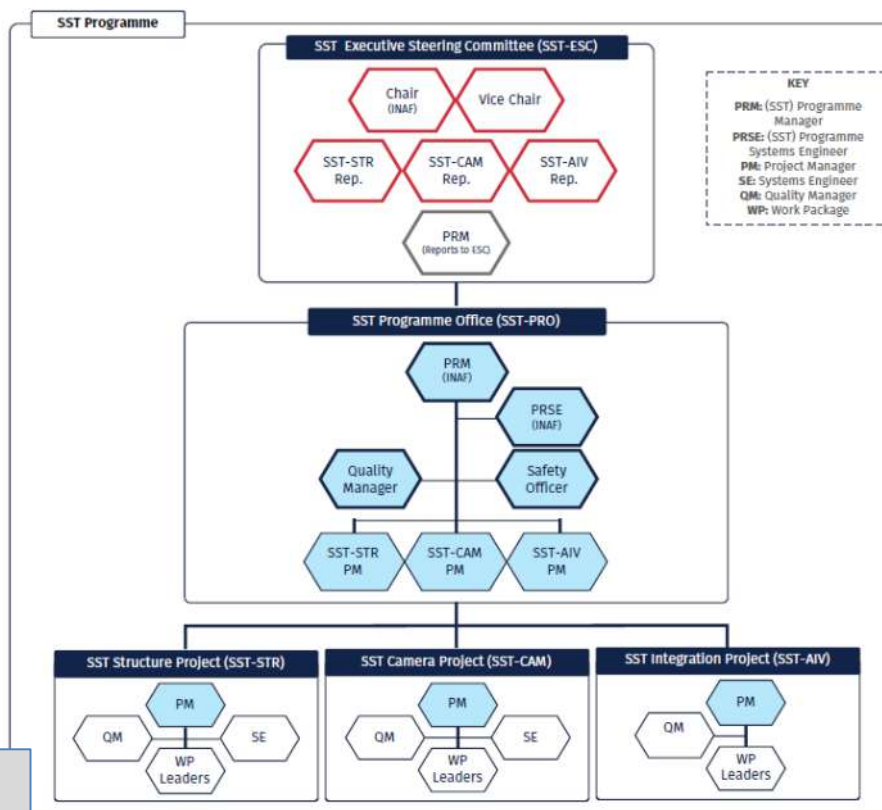
Version
V2.0 (08-01-2020)

Editorial Board

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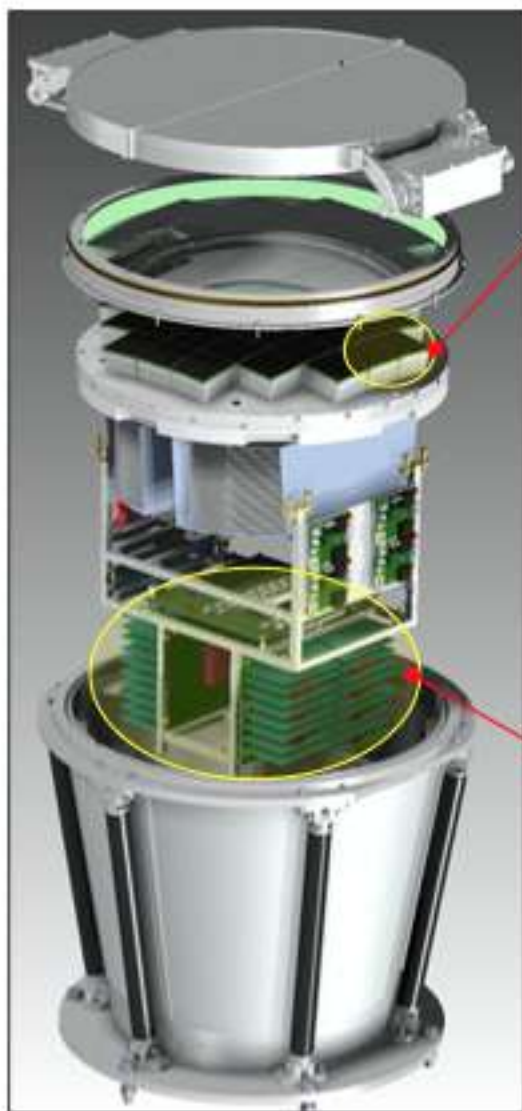
OVERALL COST about 50 MEURO

OUR PARTICIPATION *so far*

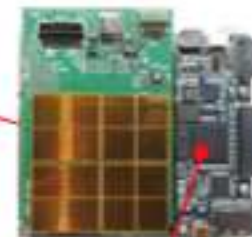
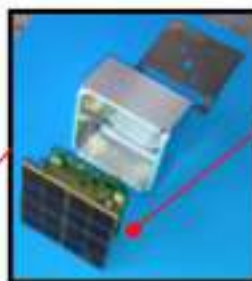


- **2016 ASTRI MOU** involving USP, FAPESP and INAF: roles and responsibilities of the parties
transfer of technology, intellectual property use, governance and maintenance of the MINI-ARRAY
- **1.6 MEuro** issued to INAF for 3 ASTRI Structures (2017)
- **Several scholarships** (in our Project: 6 postdocs, 2 JPs, 6 PhDs, 1 M)
- **Training of Human Resources:** SPSAS-HighAstro CTA - Sao Paulo Advanced Science School on High Energy and Plasma Astrophysics at the CTA Era (2017)
- **Development of the Science Working Packages** of CTA & ASTRI Mini-Array
- **Editorial board** of ASTRI papers (ASPO)
- **Engineers** Renato Gimenes and Carlos Fermino: technical tasks in Italy

BRAZILIAN ENGINEERS @ IASF Palermo



ASTRI Camera



PDMs – Photodetector Modules

- *Hardware Improvements and EMI Countermeasures*
- *Calibrations, Test Set-Ups and PC Applications*



VDB – Voltage Distribution Box

- *Hardware and Firmware Corrections and Improvements*
- *Test Set-Ups, Test Jigs and PC Control Software*
- *Calibration Routines and Climate Tests*
- *DC/DC Converter Design for New SiPMs Biasing*

BRAZILIAN ENGINEERS @ ASTRI: structure/cam/software development



Active optics tests (Torino)

- With Daniele Gardiol & Federico Russo

Performed task:

- Segment motion
- Data collection and calibration
- Repeatability verification

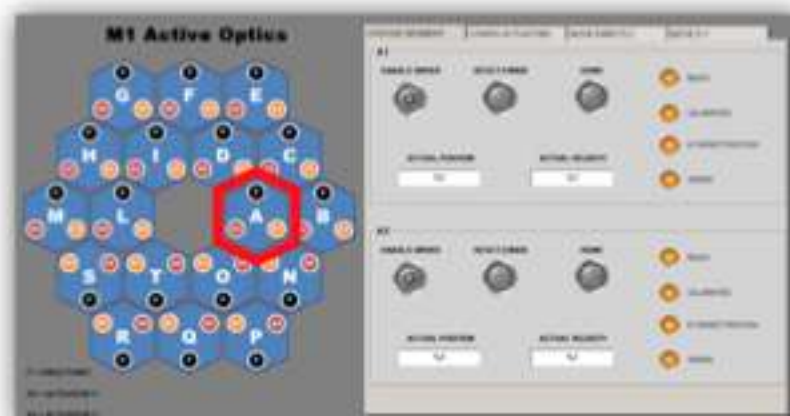


M1 Interface elaboration (Catania)

- W/ Matteo Munari, Salvo Scuderi, Enrico Giro, Luca Stringhetti, Elisa Antolini

Performed task:

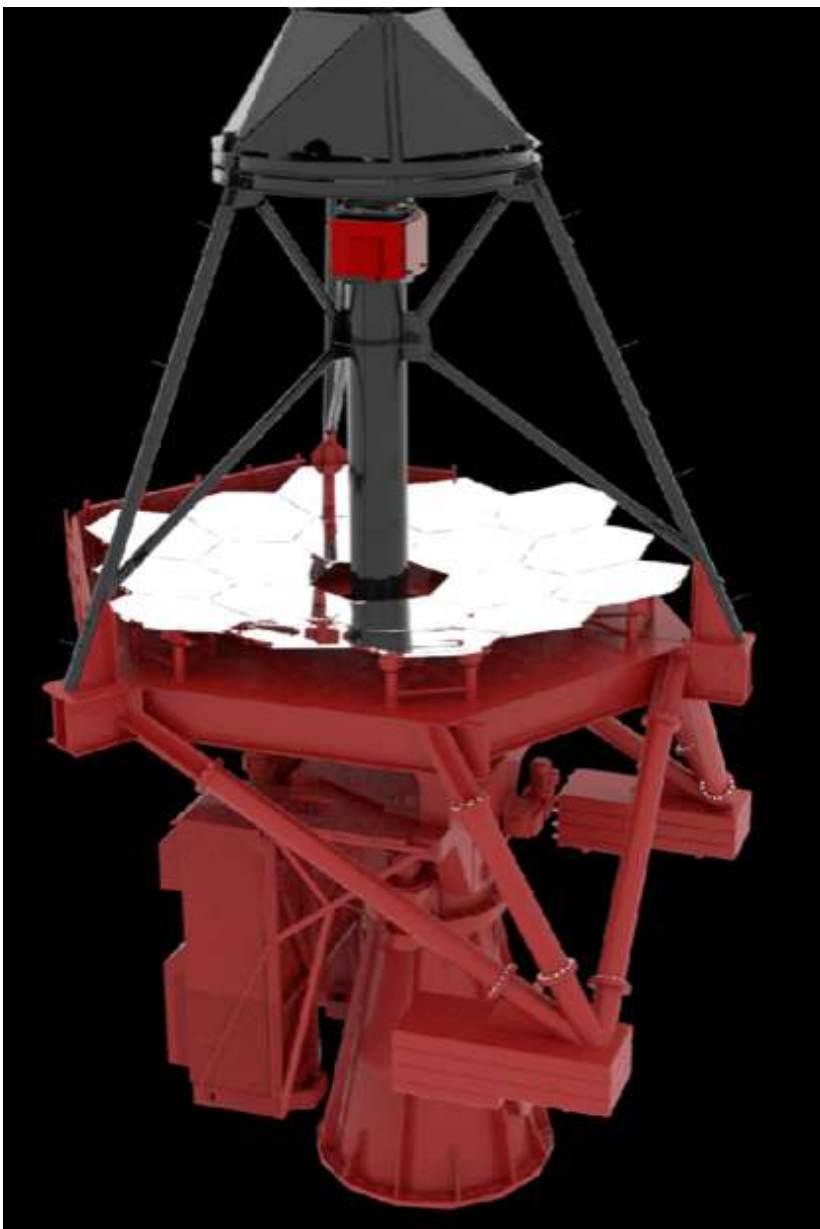
- Actuator configuration as in CANopen
- Screens preparation for driving motors
- interface implementation with users, scheduling tests, etc.
- Teaching on operation of logics for future change and implementation
- Teaching hardware & software Beckhoff



NEXT STEP PARTICIPATION in SSTs for



- Brazil in the SST Program: ASTRI+CHEC (editorial board document)
- Currently: ~60 members in CTA-Br (~29 in this Project)
- Plans for manufacturing in Brazil at least 11 of the 50 ASTRI SSTs structures of CTA-South array



- Design Review of the ASTRI/CHEC design organized by CTAO with external members (also able to consider different solutions for subsystems)
- Optimization of the design for both Structure and Camera and finalization of the design leading to a Critical Design Review and then to production
- Preparation of the Implementation and Managements plans → ad interim (waiting for ERIC and IKC) Program Office and Steering Committee will be appointed
- Verification of the resources and trade off (in close collaboration with CTAO)

Thank you



Credits: E. Marcuzzi, EIE