ASTRI Astrofisica con Specchi a Tecnologia Replicante Italiana

INAF ISTITUTO NAZIONALE DI ASTROFISICA NATIONAL INSTITUTE FOR ASTROPHYSICS

NORTH-WEST UNIVERSITY YUNIBESITI YA BOKONE-BOPHIRIMA NOORDWES-UNIVERSITEIT

cta cherenkov telescope array

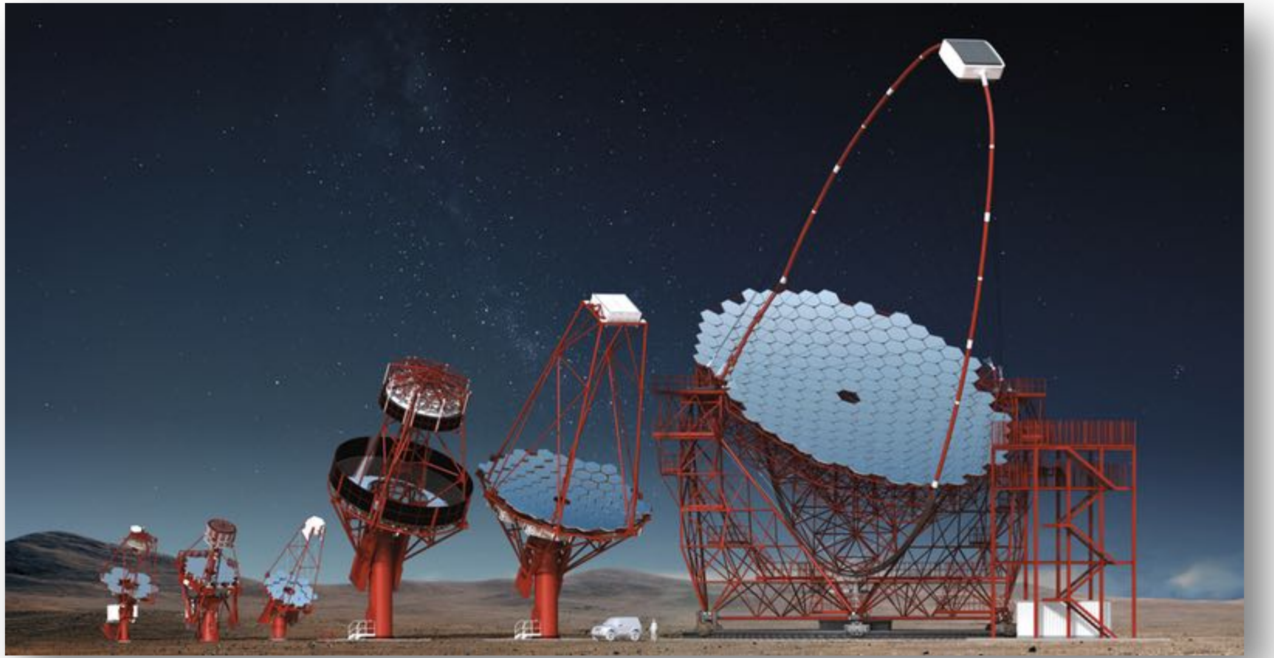
MIUR

Universidade de São Paulo

The ASTRI Program

Salvo Scuderi – INAF IASF Milano & OA Catania

for the CTA/ASTRI Project



- ASTRI Program
  - Why ASTRI
  - Organization & Funding
- ASTRI Prototype
  - The prototype in a nutshell
  - Highlights on performances of structure and optics
  - Commissioning of the camera
- ASTRI mini array
  - Production activities
  - Science
- CTA

ASTRI - Astrofisica con Specchi a Tecnologia Replicante Italiana

Astrophysics with Mirrors via Italian Replication Technology

Name given by Nanni Bignami

ASTRI: aim of the program

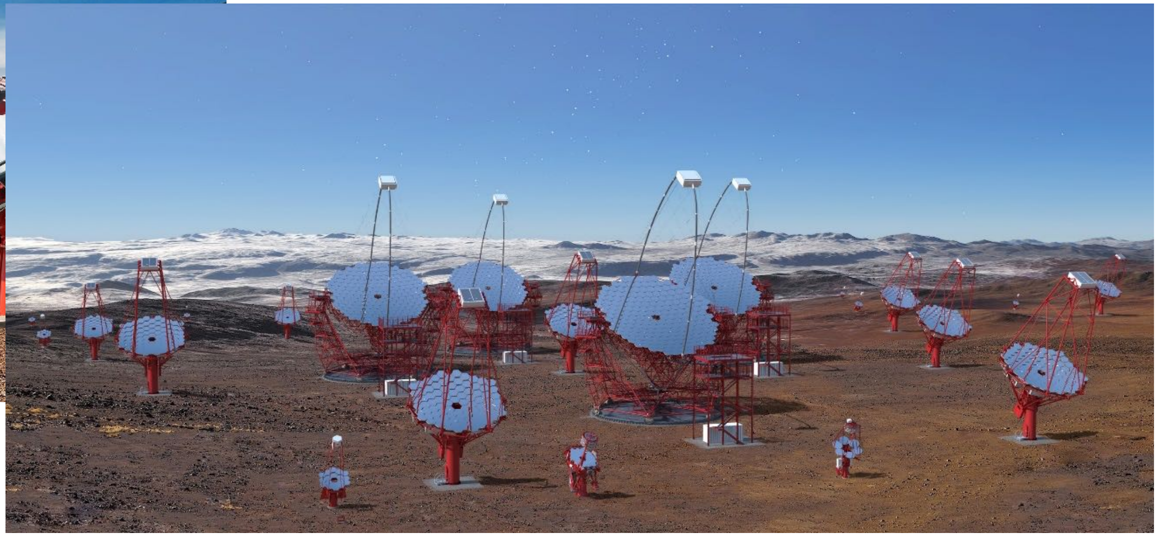
Prototype

- Demonstrator to validate the no technology
- Training facility for telescope and maintenance operations.
- Test bench for the implementation of new HW and SW.
- E2E approach validated through astrophysical Cherenkov observations

Mini-Array

- Test the stereoscopic imaging capabilities,
- Test array trigger system
- Test array control system
- E2E approach → astrophysical observations

CTAO



Contribution to the production of a number of SST telescopes for CTA south site

ASTRI: General Organization

- Principal Investigator G. Pareschi → Co-PI O. Catalano
- Project Manager S. Scuderi
  - Project Control Manager: R. Millul
  - System Engineer: E. Giro
  - Quality Manager: N. La Palombara
- System Team
  - AIV Manager: R. Canestrari
  - Telescope SSE: R. Canestrari
    - Mechanics: R. Canestrari
    - Optics: G. Sironi
  - Camera SSE: O. Catalano
    - Electronics: G. Sottile
    - Mechanics & Thermal: C. Gargano
    - SiPM detectors: G. Bonanno
    - Software: P. Sangiorgi/A. Grillo
    - DAQ/Camera Server: V. Conforti
  - Control Software: G. Tosti
    - Telescope: F.Russo/P. Bruno
    - Active Optics: F. Russo
    - Auxiliaries: P. Bruno/D. Fugazza
  - Data Management Software: A. Antonelli
    - A-SciSoft: M. Perri
      - Data Analysis Pipeline: S. Lombardi
      - MC Pipeline: C. Bigongiari
      - Sci-Tools: I. Donnaruma
      - Sci-Tech: V. Testa
    - A-SciArc: S. Gallozzi
  - Ausiliari: G. La Rosa
  - INFRA interface to CTA: F. Gianotti/C. Gargano
  - CCF interface to CTA: C. Maccarone

INAF ISTITUTO NAZIONALE DI ASTROFISICA NATIONAL INSTITUTE FOR ASTROPHYSICS

Universidade de São Paulo

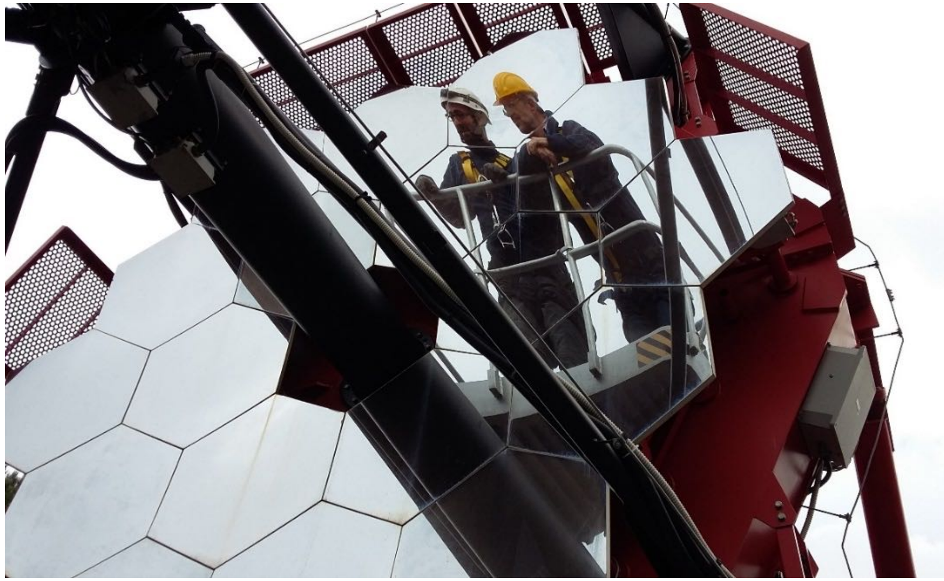
NORTH-WEST UNIVERSITY YUNIBESITI YA BOKONE-BOPHIRIMA NOORDWES-UNIVERSITEIT

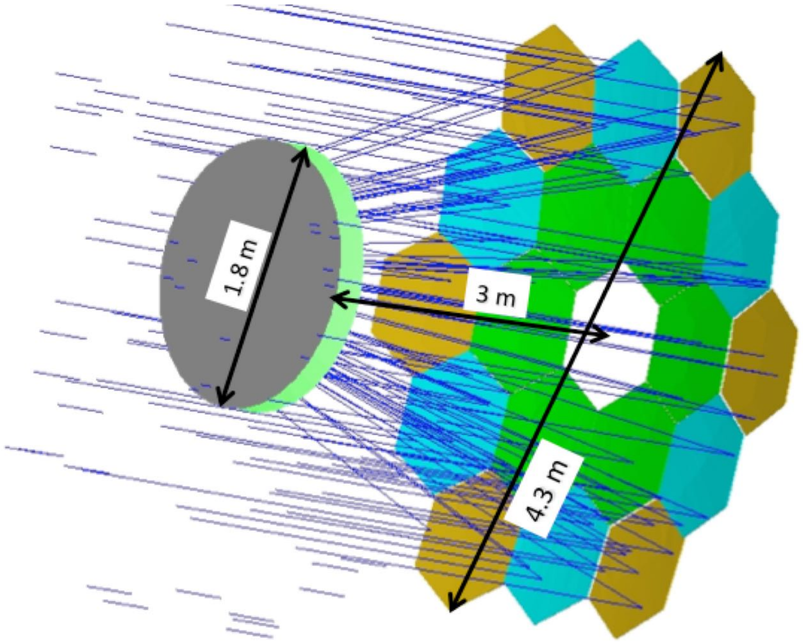
- **Prototype**: funds from MIUR through Flagship project and PRIN
- **Mini-array**: Dedicated funds from MISE – “Astronomia Industriale” (10 M€), and international partners in particular Universidade de Sao Paulo – Brazil, (1.8 M€) and North Western University – South Africa (0.3 M€)
- **CTAO**: funds from MIUR (50 M€) that undersigned an MoU with CTAO mainly, but not only, for SST implementation. Other possible contributions to Array Control, Data Handling, Calibration Facilities, LST-south…

ASTRI in a nutshell : Structure Assembly

Mechanical Structure	
Dimensions & Mass	
Height of the Telescope (pointing horizontally & vertically)	7.5 m & 8.6 m
Radius of free area for Az. Movements	5.3 m
Total Mass of the prototype	19000 kg
Tracking & Pointing	
Driver Encoder Precision	2 arcsec
Tracking Precision	<0.1°
Pointing Precision After Calibration	5 arcsec
Servo Control	
Motors & Drivers	SEW
PLC	Beckhoff
Encoders	Heidenhain

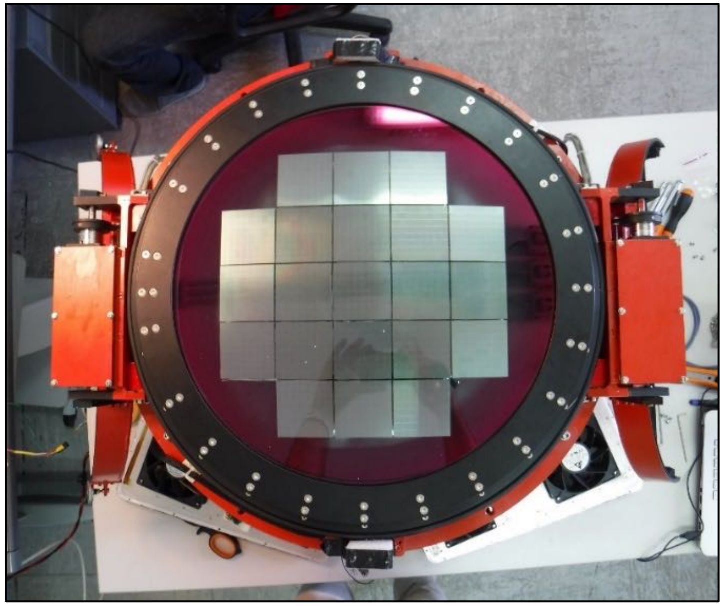
ASTRI in a nutshell : Optics





Optics	
Optical Configuration	Schwarzschild-Couder
Average effective collecting area	5 m^2
Focal Length	2.2 m
Aperture	4.3 m
f/#	0.5
FOV	10.5° (8.2° prototype)
PSF (@ 100 % of FOV diameter)	0.19°
Primary Mirror (segmented)	
Diameter	4.306 m
Number of segments	18
Size of a segment	850 mm (face-to-face)
Nominal Radius of Curvature Ring 1,2,3	8.52, 9.87, 12.54 m
Technology	Cold Slumping
Coating	Al+SiO_2
Micro-roughness (RMS, 0.1 - 200 mm spatial wavelength range)	< 2 nm
Secondary Mirror (monolithic)	
Diameter	1.8 m
Technolgy	Hot Slumping
Coating	Al+SiO_2

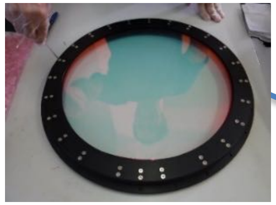
ASTRI in a nutshell: Cherenkov Camera

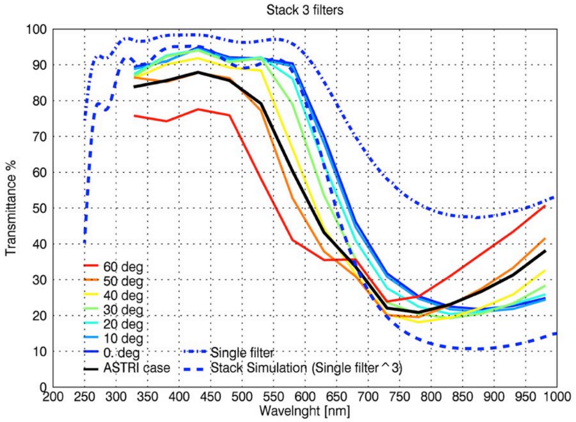


Cherenkov Camera	
Camera opening Angle	70°
Sensors	SiPM (Hamamatsu LCT5)
Number of Pixels	2368 (1344 protoype)
Pixel size	7x7 mm
Pixel rate	4kH Hz
Dynamical range	1 – 2000 (1350 prototype) pe⁻/pixel
Photon Detection Efficiency	> 35% @ 400nm
FoV	10.5° (8.2° prototype)
Weight	73 kg
Dimensions	0.52m x 0.66m x 0.56m
Power consumption	0.65 kW

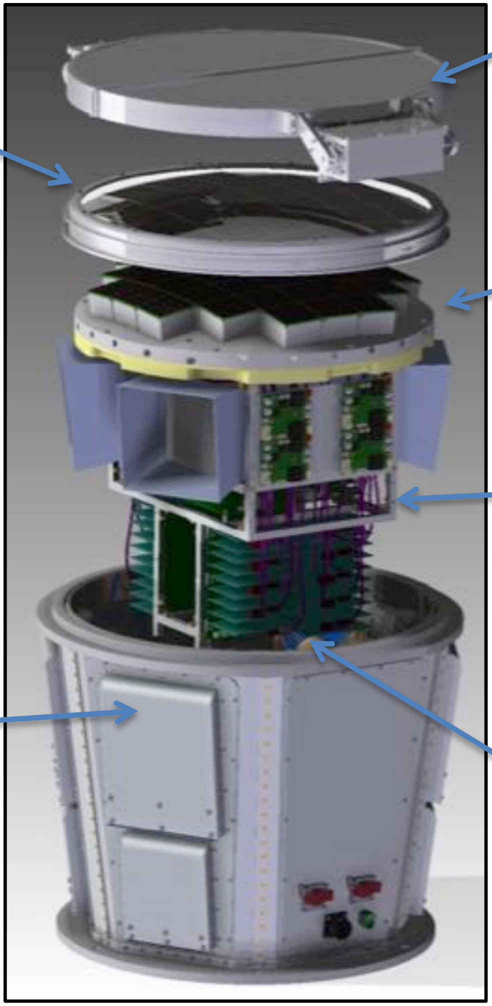
ASTRI in a nutshell: Cherenkov Camera

Front window

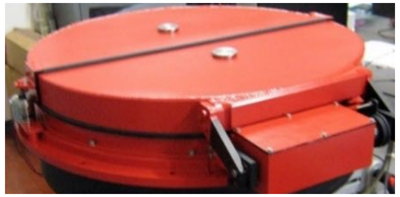




Thermal Control System



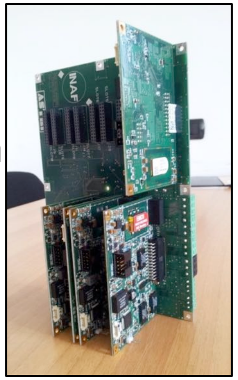
Lids



Photon Detection Module

Back-End Electronics

Voltage Distribution Board

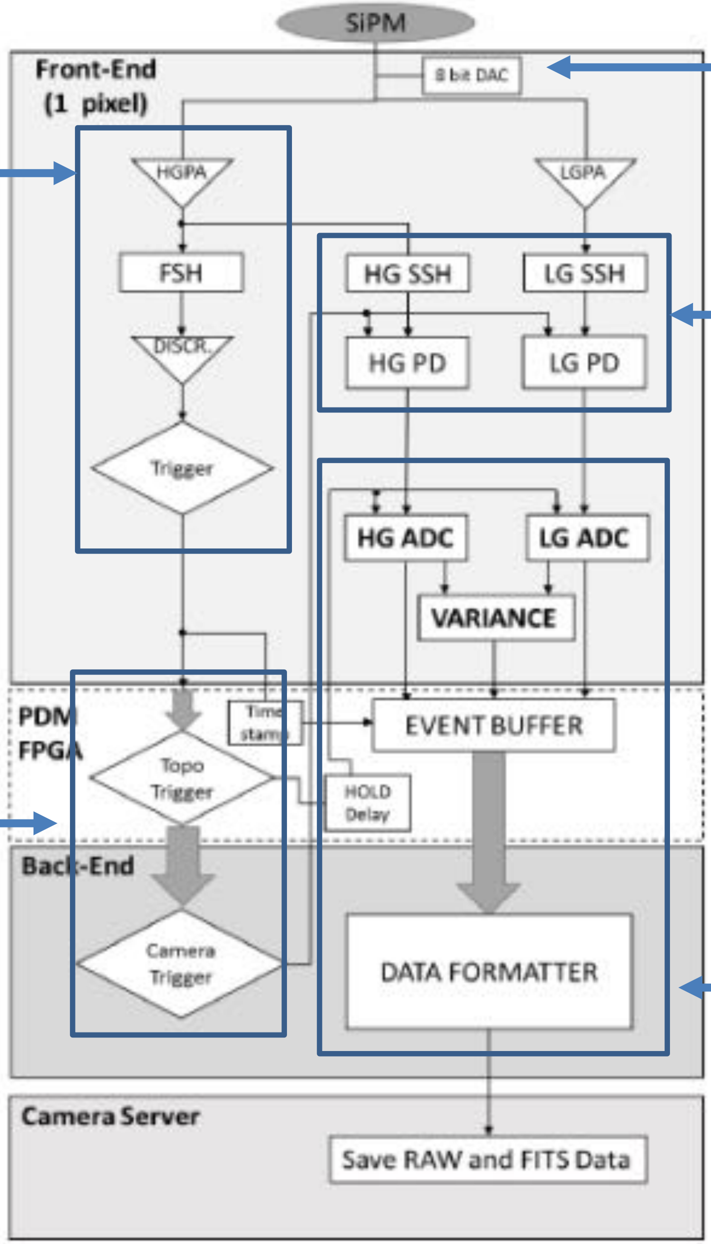


- **Front Window**
  - Multilayers Filters to reject the red part of the NSB.
- **Thermal Control System**
  - All internal → no chiller
  - TEC based, heat pipes, sink, fans → Active control
  - **Low power consumption: 450 kW**
- **Photon Detection Module**
  - SiPM → Hamamatsu LCT5 7x7mm
  - Front End Electronics
    - Based on signal shaping not sampling
    - High gain and low gain channels
    - **Low power consumption (0.3 W/chip)**
    - **Low data production (0.05 Gb/s)**
- **Back End Electronics**
  - monolithic board to manage PDMs, camera trigger & ancillary devices
- **Power Supply Distribution**
  - External power supply 24V
  - Voltage distribution board → modular system to provide independent and adjustable power supply to PDM
- **Camera DAQ & Server**

Trigger Chain

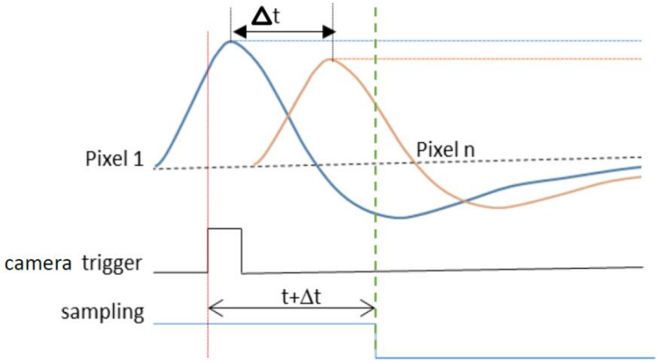
- Produce a digital output when a fast varying signal on the fast shaper (FSH) exceeds a pre-set discriminator threshold.
- Used in counting mode: Dark current and optical cross talk measurements and trigger calibration

When 4 contiguous pixels trigger (topological trigger) then camera trigger activates peak detection mode for all pixels

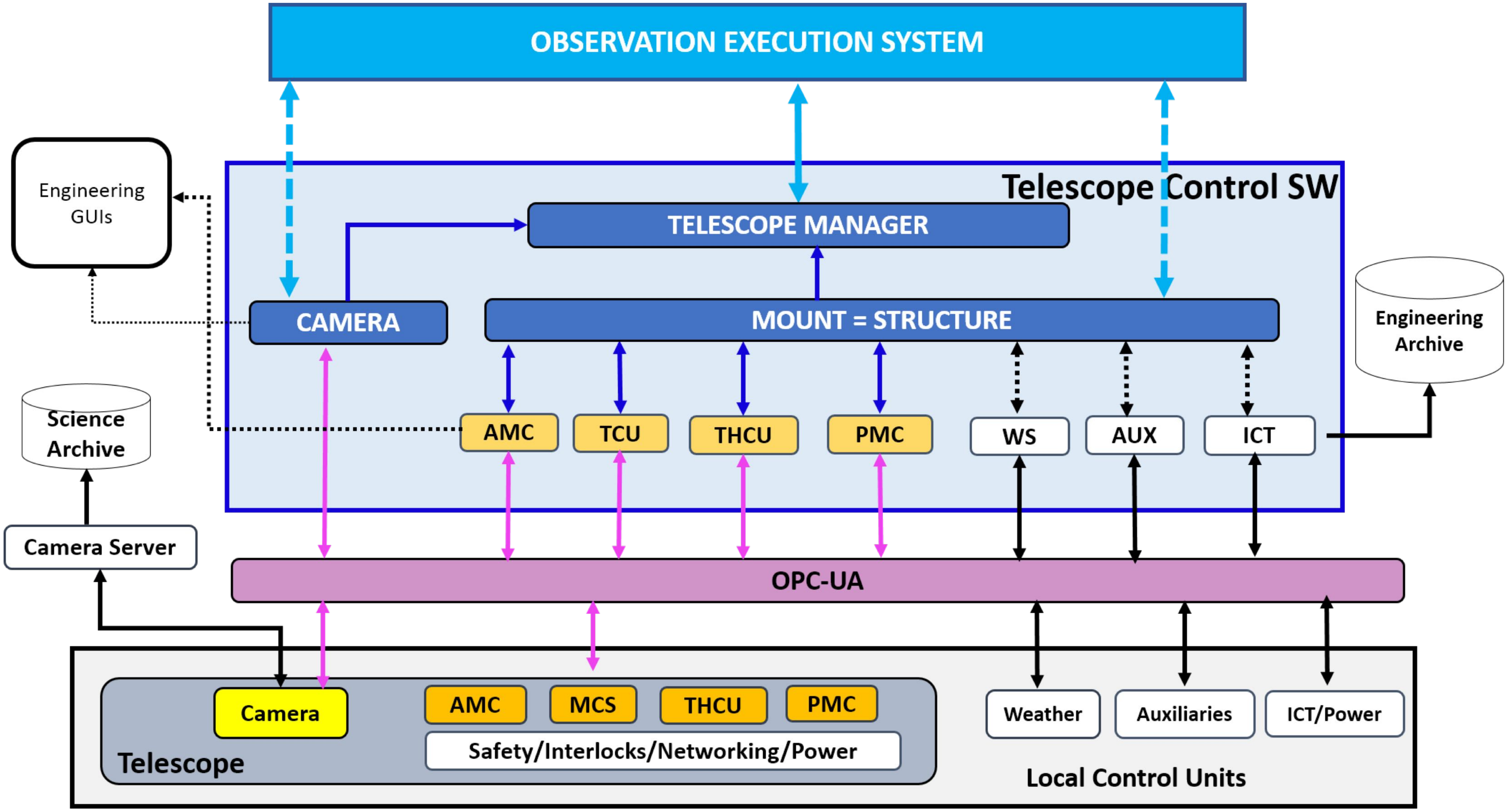


Input DAC: HV adjustment for gain equalization due to pixel-to pixel variation and temperature differences

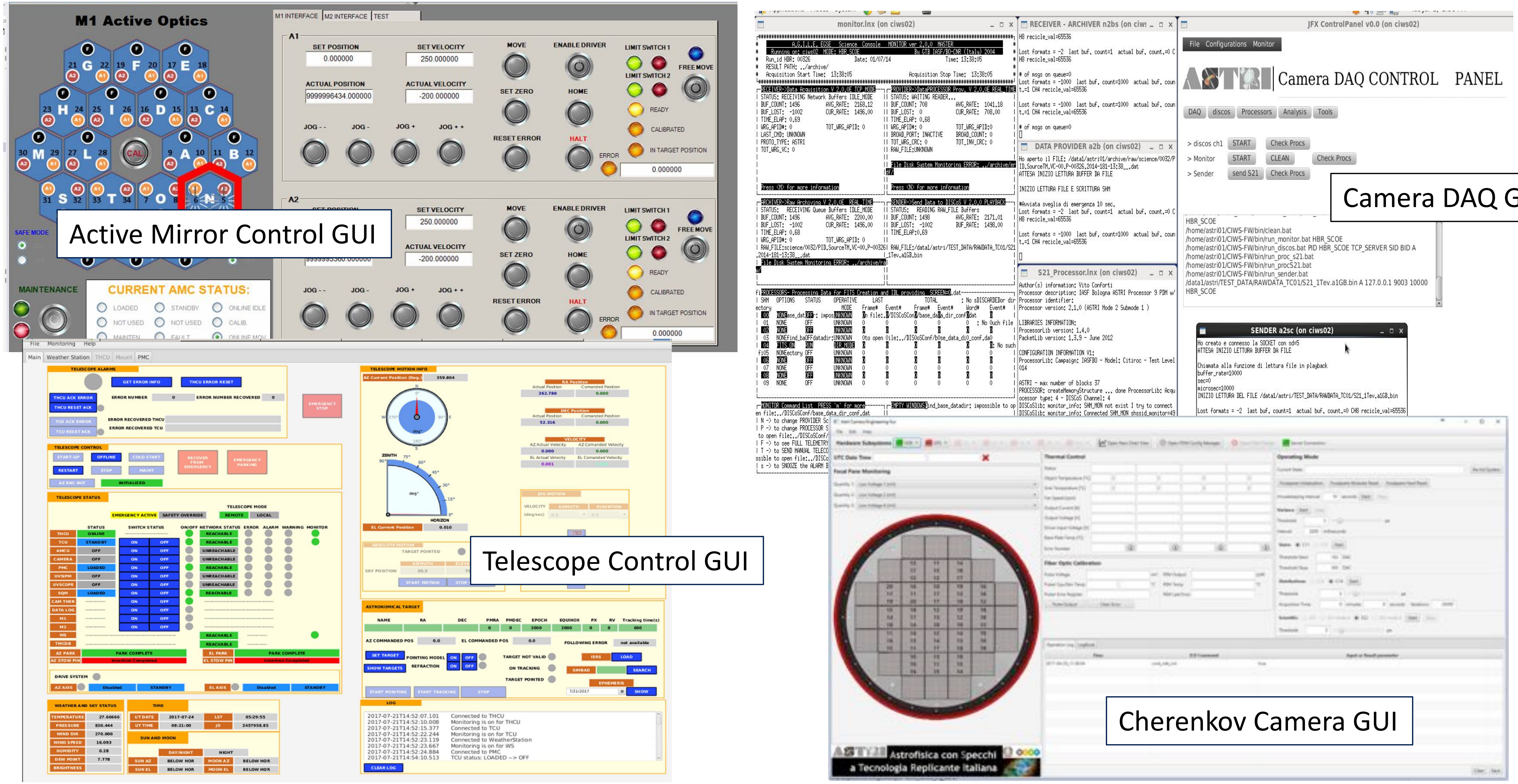
High-gain (HG) and low-gain (LG) peak detectors sample and hold the maximum amplitude of the slow shaped (SSH) signal (proportional to the injected charge in the pixel)



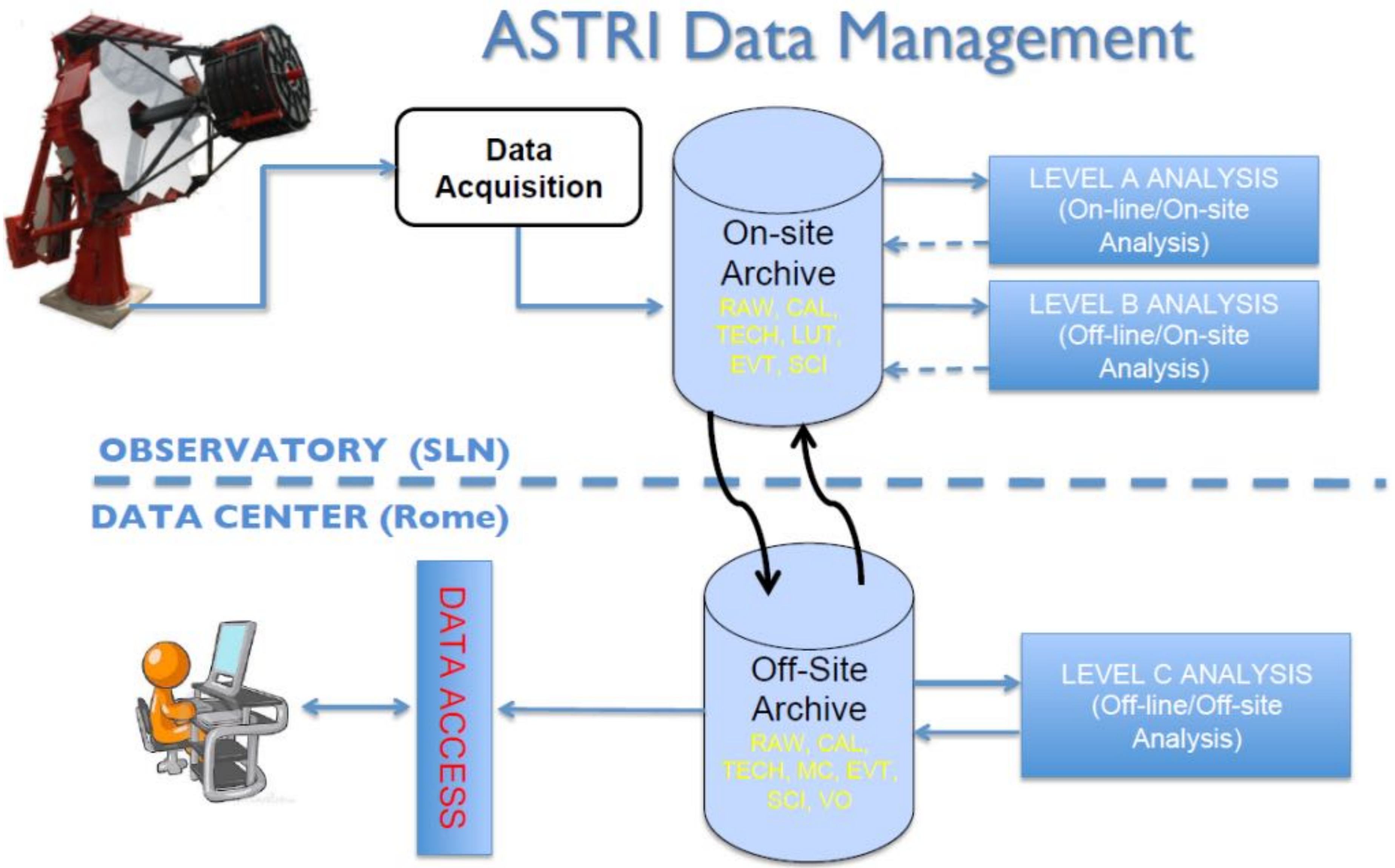
The digitized values together with pixel time stamp and SiPM temperature values are sent to BEE and then to camera server


OBSERVATION EXECUTION SYSTEM
Engineering GUIs
Telescope Control SW
TELESCOPE MANAGER
CAMERA
MOUNT = STRUCTURE
Engineering Archive
Science Archive
AMC
TCU
THCU
PMC
WS
AUX
ICT
Camera Server
OPC-UA
Camera
AMC
MCS
THCU
PMC
Safety/Interlocks/Networking/Power
Telescope
Weather
Auxiliaries
ICT/Power
Local Control Units

ASTRI Prototype: GUIs



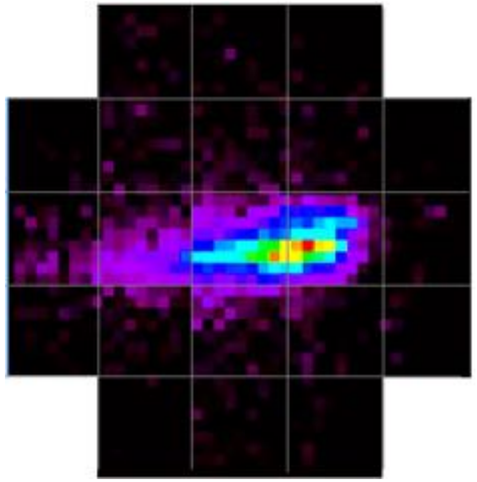
ASTRI in a nutshell: Data Handling Software

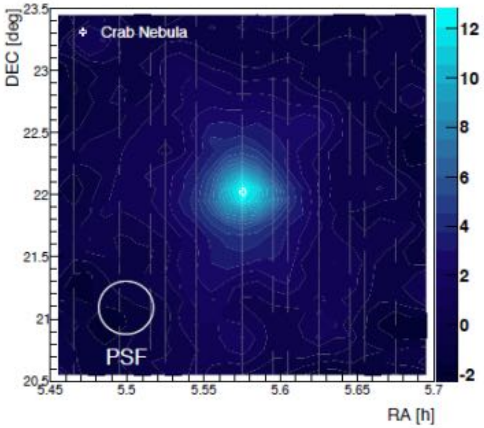


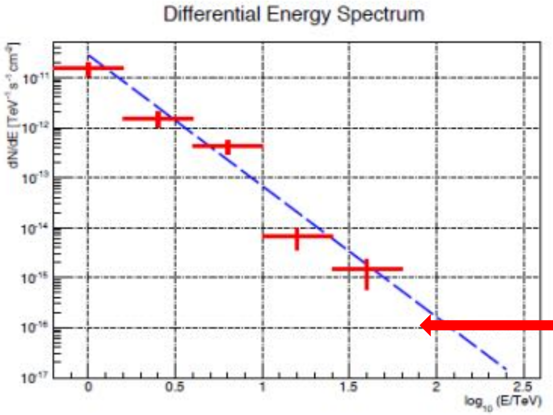
ASTRI: Data Handling Software

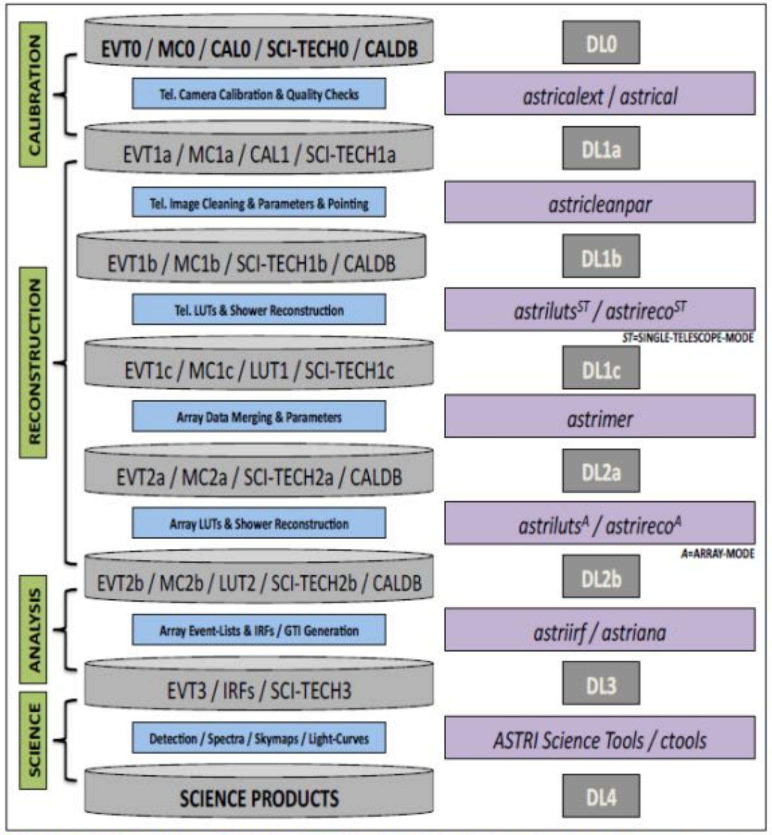
A-SciSoft is a dedicated software package for data reconstruction and scientific analysis The software perform data reduction (from DL0 up to DL4) for ***real-like ASTRI SST-2M prototype data***

Raw Data









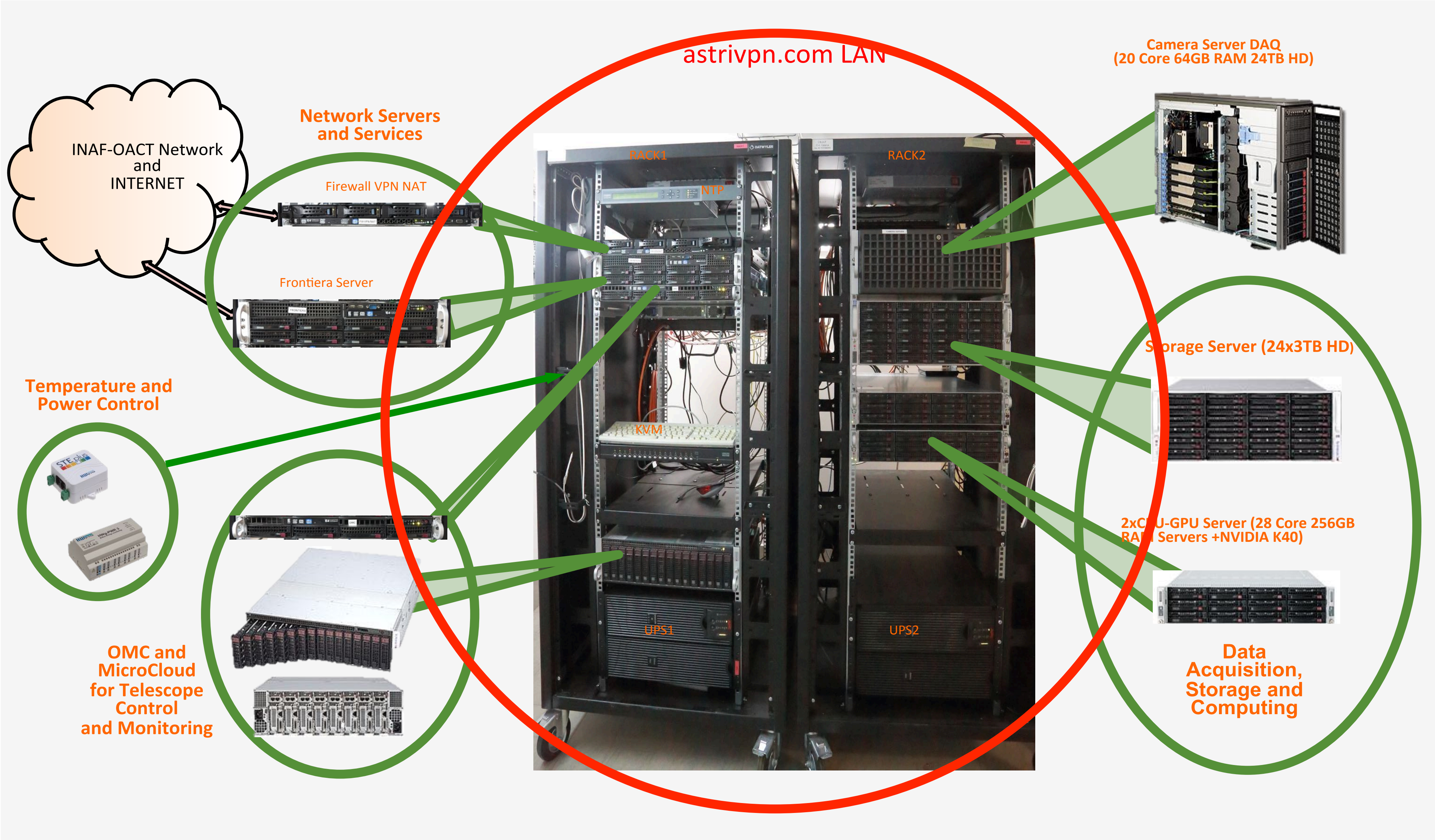
Breakdown stages; Basic components; Executable modules; I/O Data level.

Science Products

ASTRI Scientific Software

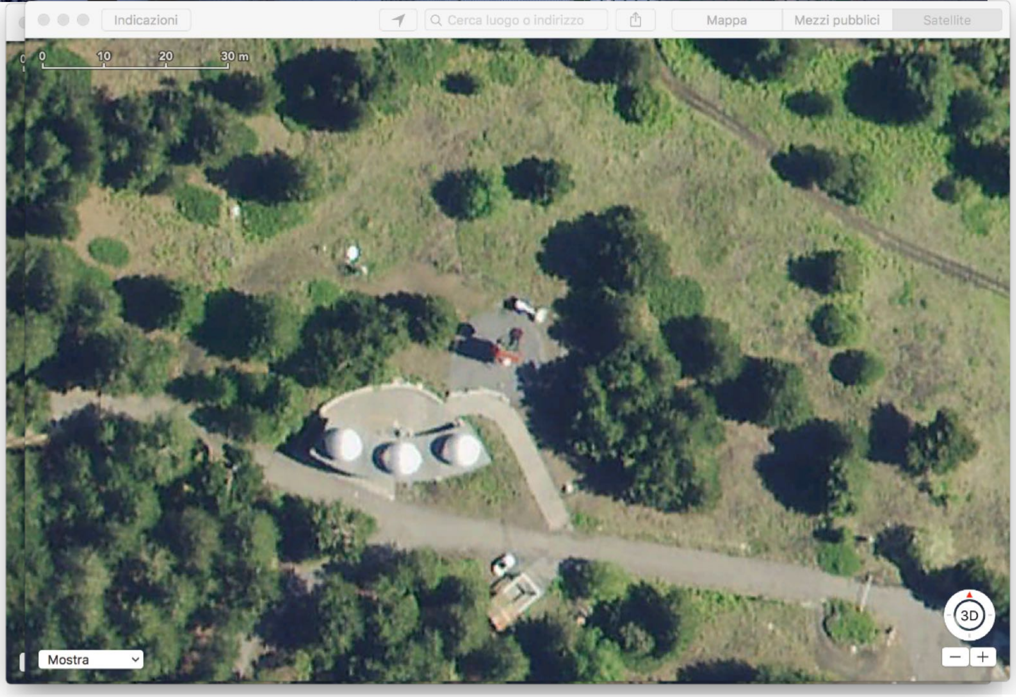
- can handle real and MC data for both prototype and mini-array
- follows the general CTA design and data model scheme defined in CTA Data Management
- is developed for on-line/on-site/off-site data reduction pipelines
- manages FITS data from DL0 to DL4 (`cfitsio/CCfits` libraries) (for mini-array, DL0 in RAW format)
- can run on x86 / ARM CPUs & NVIDIA GPUs
- is developed in independent software modules linked by pipelines written in Python
- uses CTA Science Tools

ASTRI-SST-2M ICT overall schema



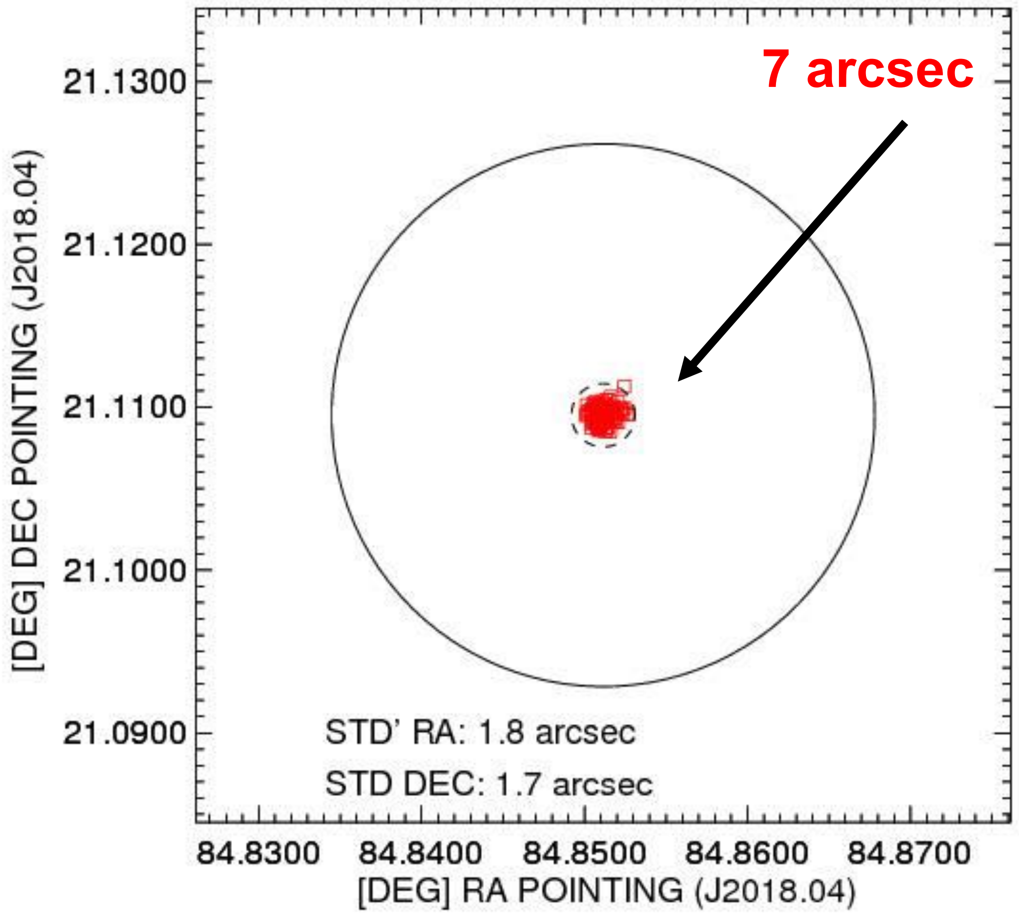
ASTRI Prototype: The telescope @ Serra La Nave

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

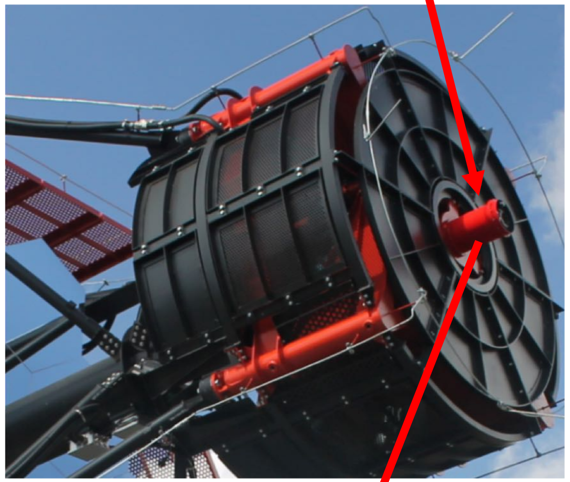


ASTRI Prototype: Telescope Pointing Performances

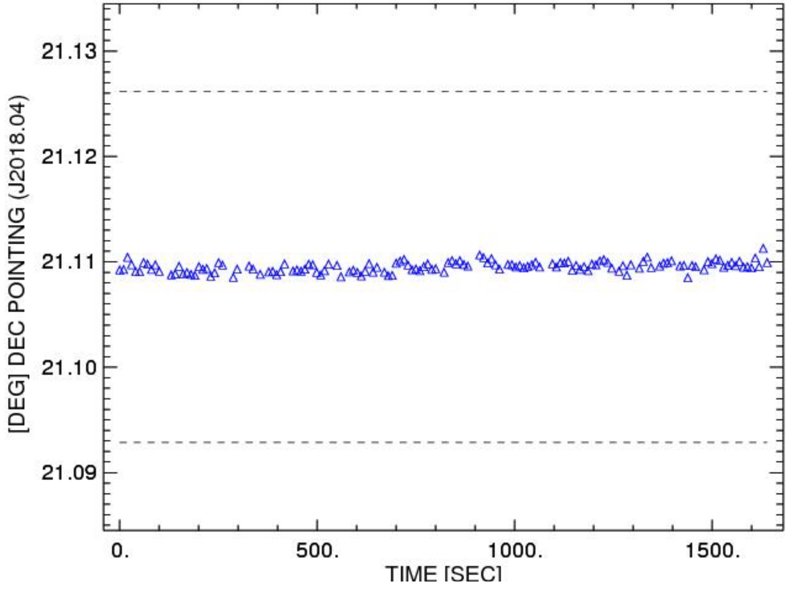
Pointing accuracy

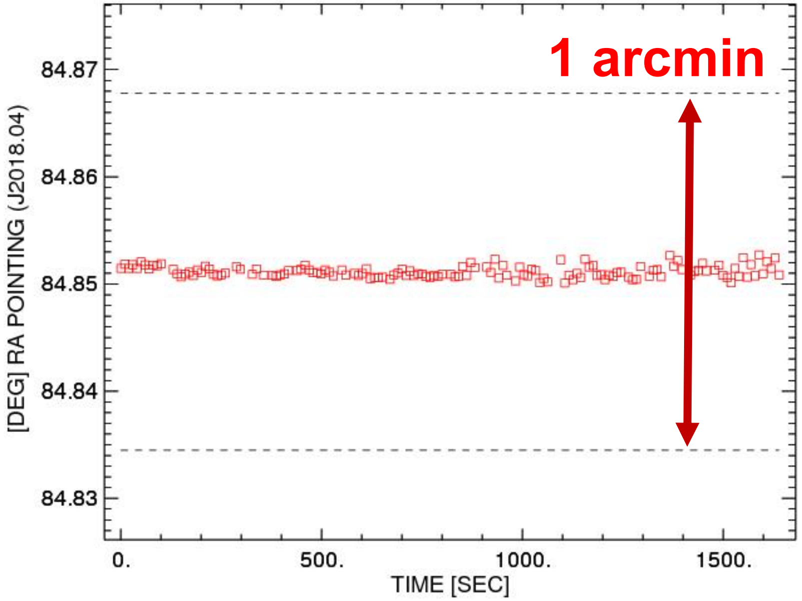


Pointing & tracking performance was measured using a small CCD camera mounted on the M2 support structure.



Tracking accuracy





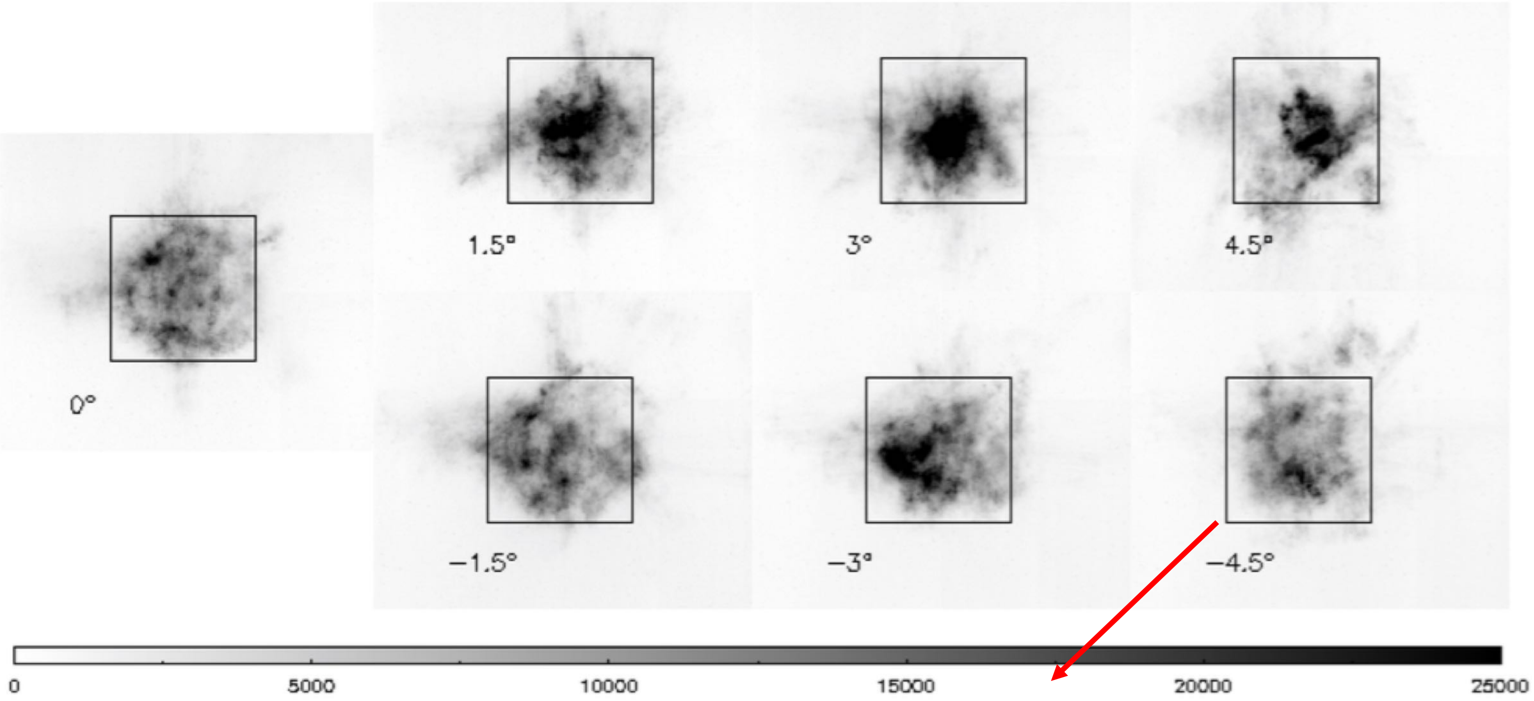
- CTA post calibration astrometric accuracy: 7 arcsec
- CTA online astrometric accuracy: 1 arcmin

ASTRI Prototype: PSF across the field of view

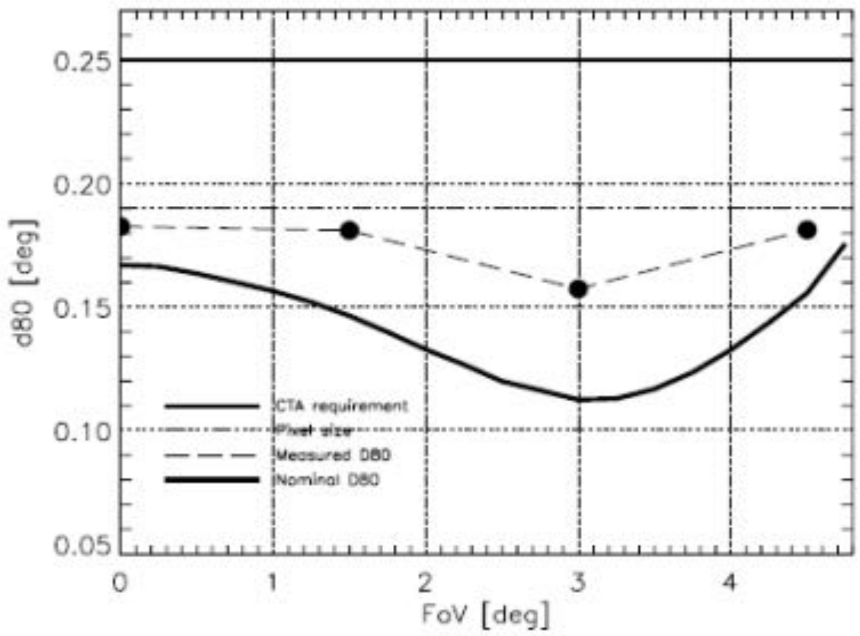
Astronomy & Astrophysics manuscript no. a˙a˙paper˙optical˙quality˙ver3˙arXiv © ESO 2017
September 28, 2017

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

E. Giro[1,2], R. Canestrari[2], G. Sironi[2], E. Antolini[3], P. Conconi[2], C.E. Fermino[4], C. Gargano[5], G. Rodeghiero[1,6], F. Russo[7], S. Scuderi[8], G. Tosti[3], V. Vassiliev[9], and G. Pareschi[2]



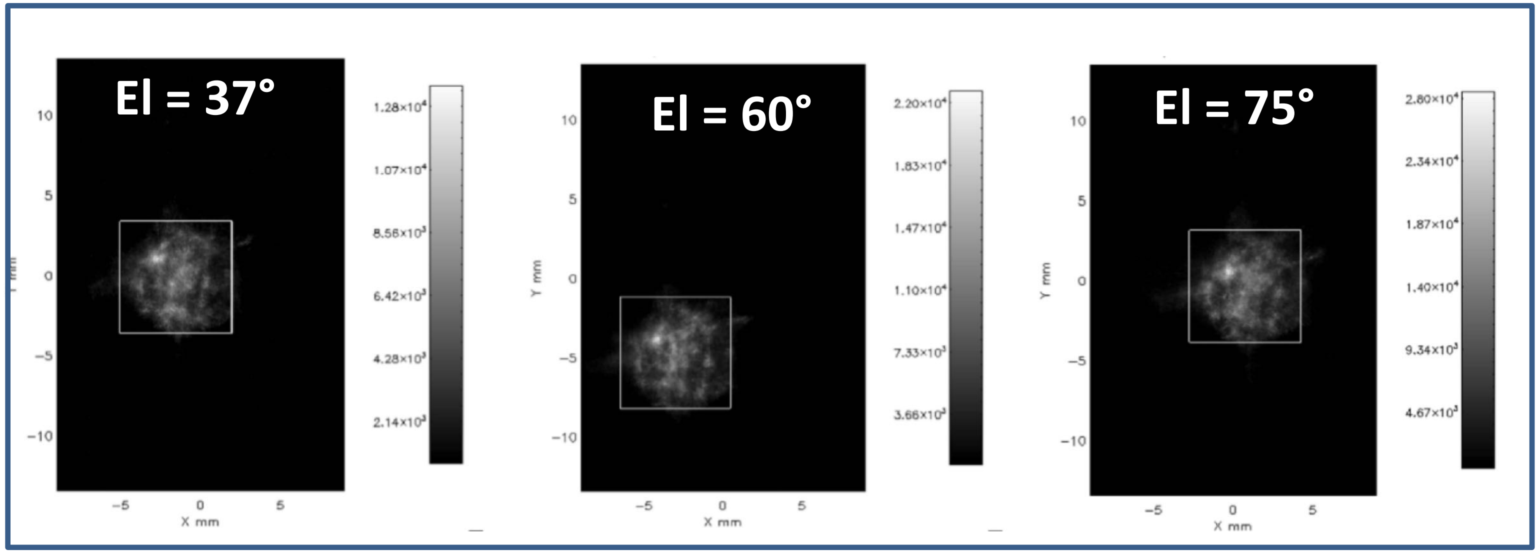
SiPM pixel linear dimension: 7 mm → 11.2 arcmin



FoV position (deg)	D80 (mm)
4.5	6.72
3.0	6.32
1.5	7.28
0.0	6.86
-1.5	6.32
-3.0	5.50
-4.5	6.90

ASTRI Prototype: PSF spatial and temporal stability

Spatial Stability

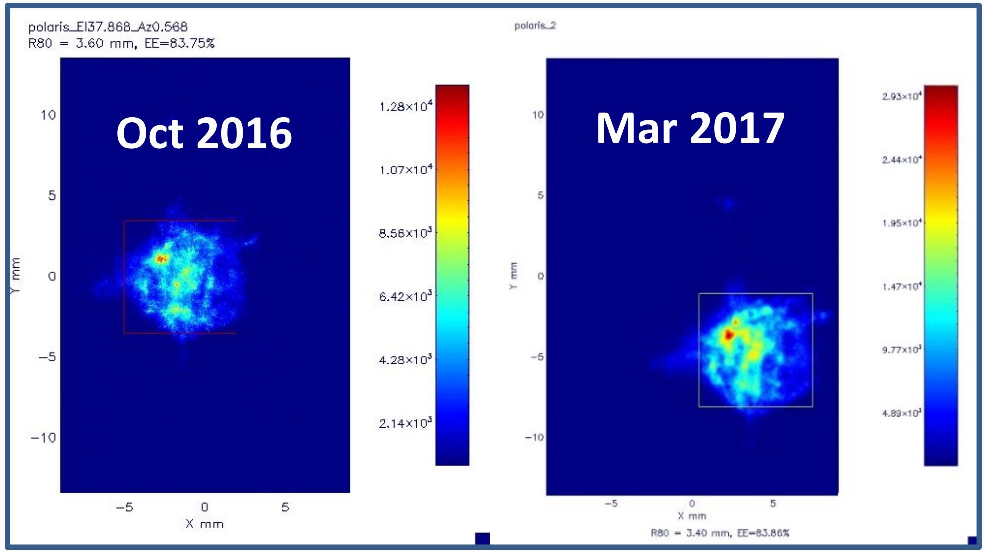


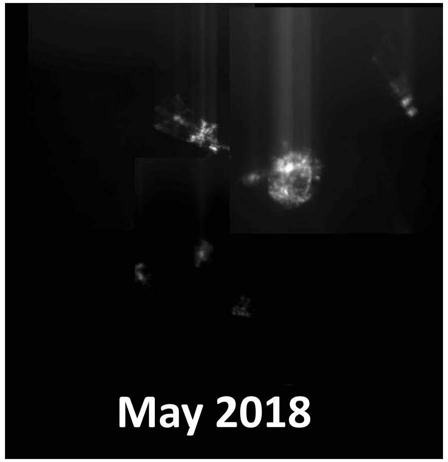
- Acquisition of PSF for different elevations have been obtained.
- Acquisition of PSF were obtained 6 months apart.

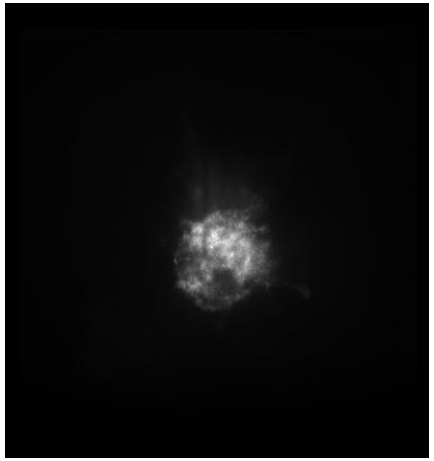
The PSF shows excellent stability both in morphology and d80 values.

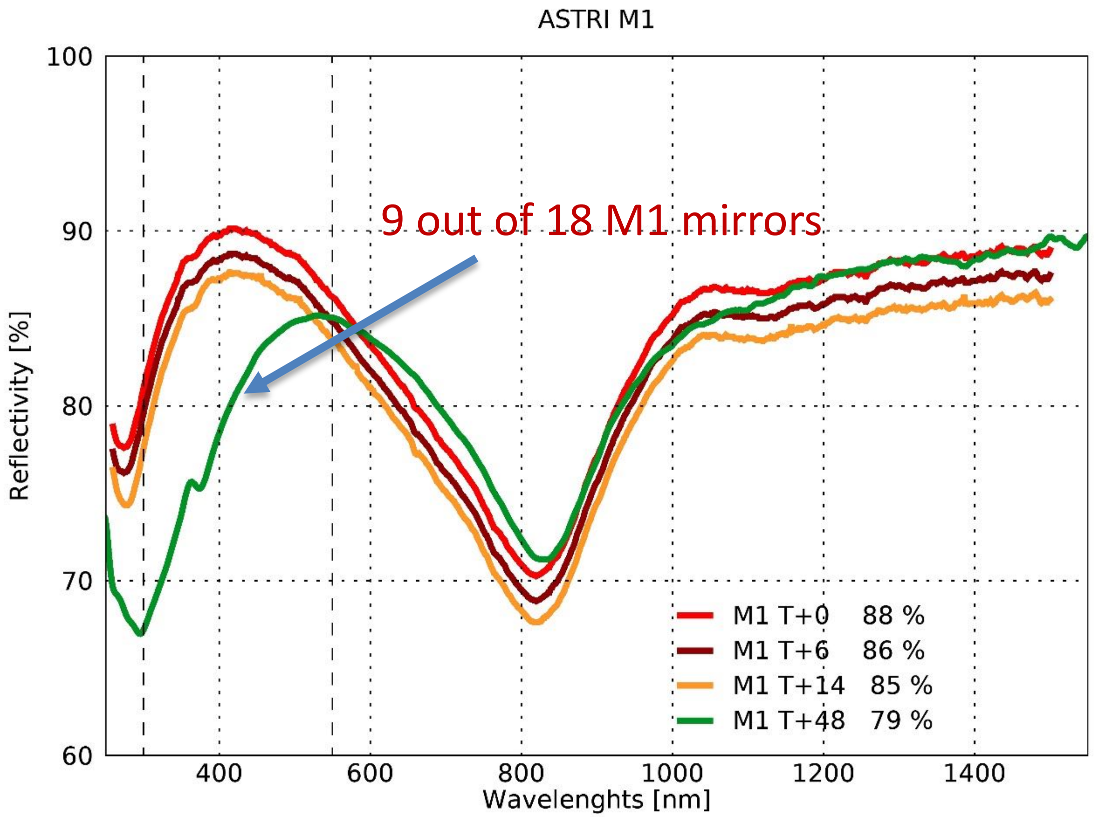
No active mirror control is necessary for normal operations → Tool for Assembly, Integration, Validation (AIV) and maintenance activities

Temporal Stability

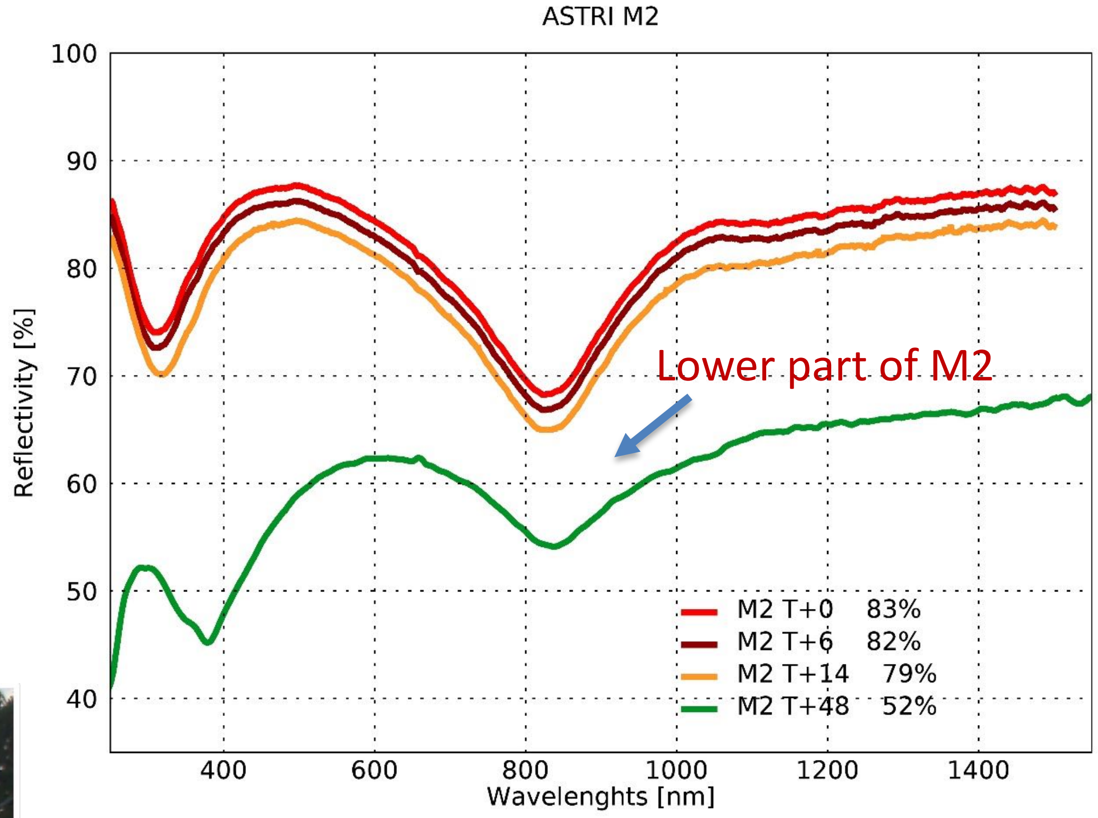








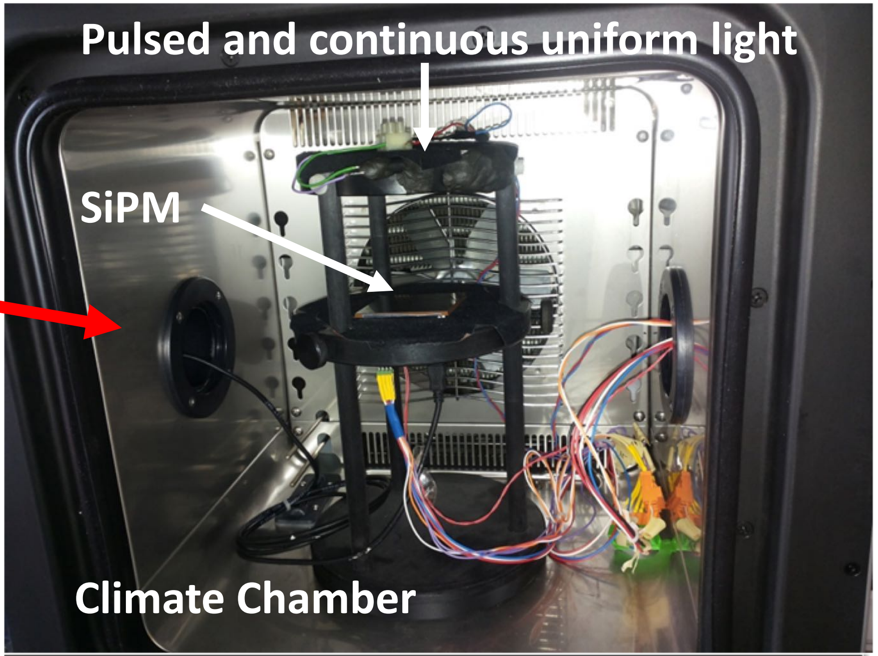
Last run of measurements February 2018

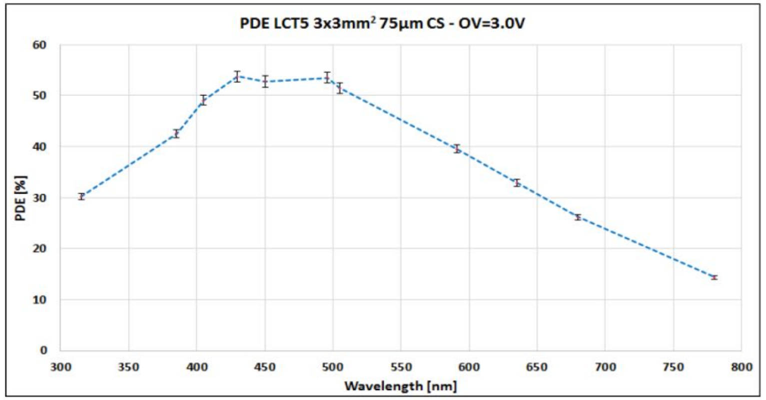


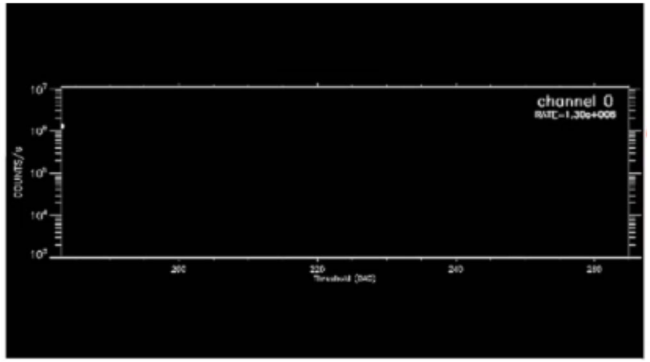
Ageing faster than expected likely due to aggressive atmosphere (mount Etna is an active volcano)

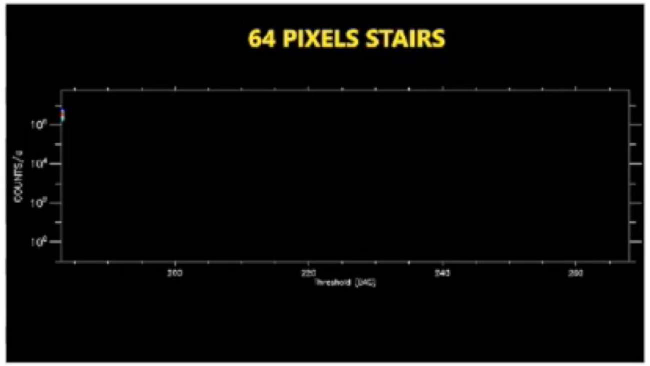
- Trigger alignment within ± 1/20 pe equivalent
- Relative gain calibration
- Photoelectron equivalent
- Dynamical range up to 1350 pe
- Photo Detection Efficiency & Optical Cross Talk

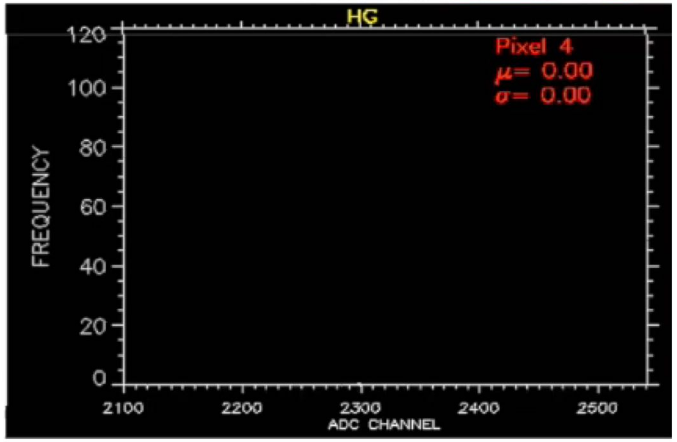
Lab Setup

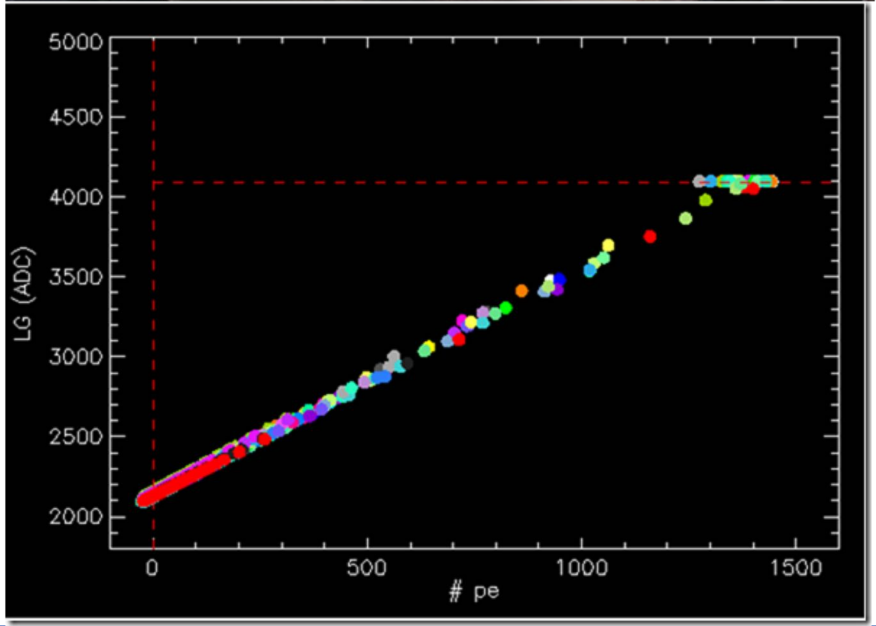


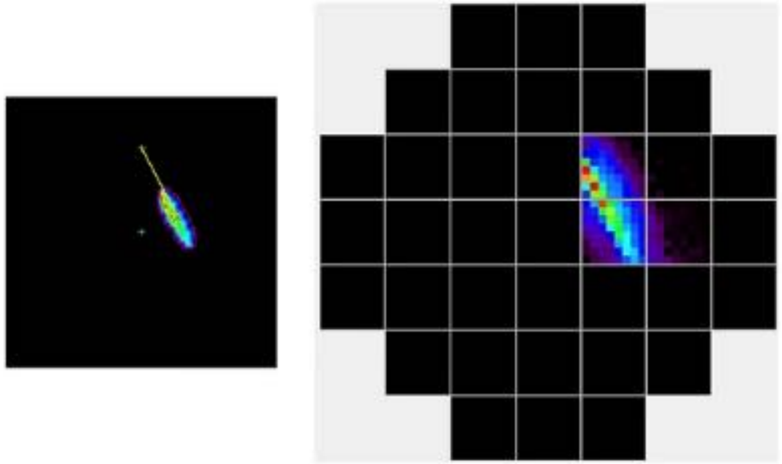






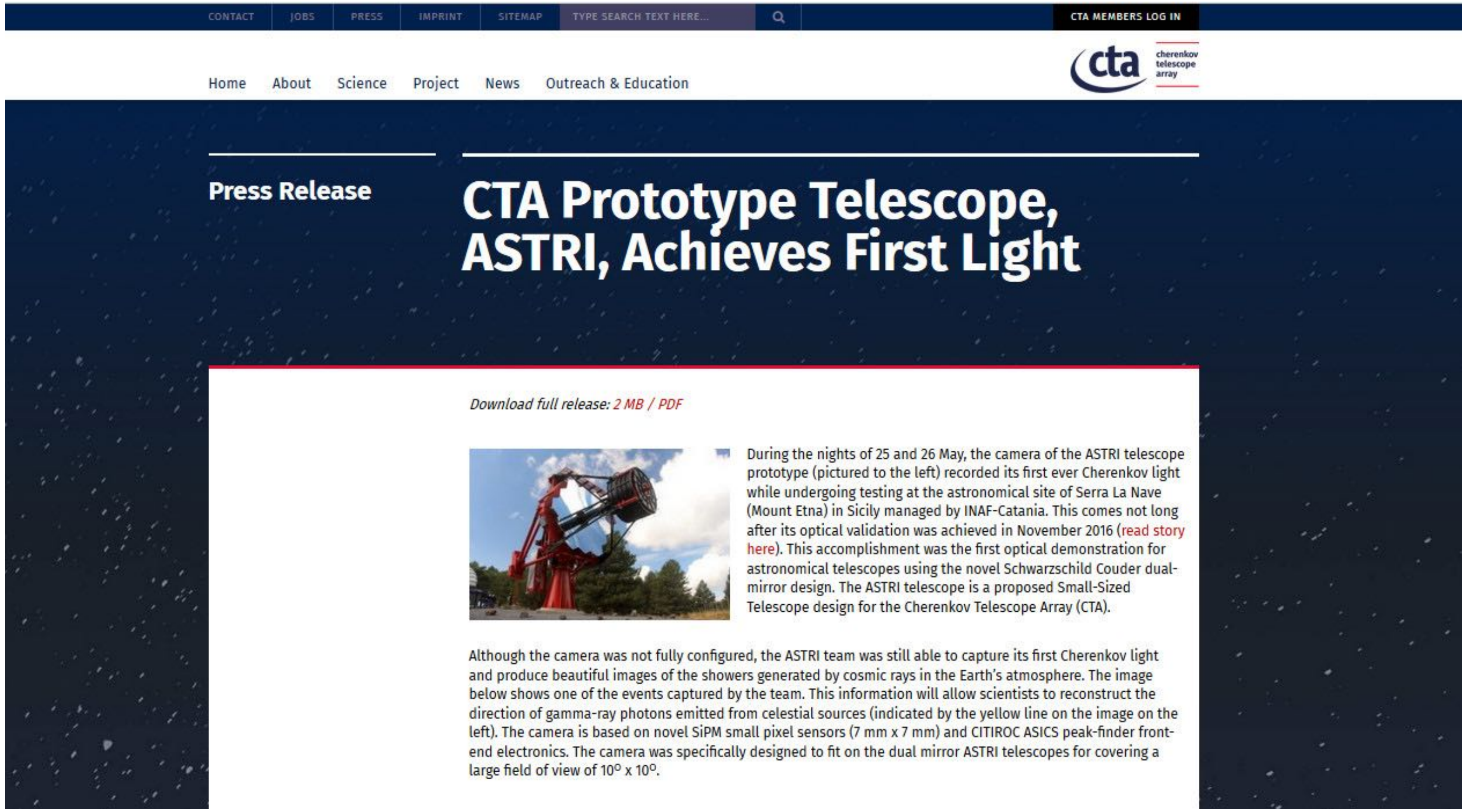






25th of May 2017

First Cherenkov light with the ASTRI camera



CONTACT | JOBS | PRESS | IMPRINT | SITEMAP | TYPE SEARCH TEXT HERE... | CTA MEMBERS LOG IN

Home About Science Project News Outreach & Education

cta cherenkov telescope array

Press Release

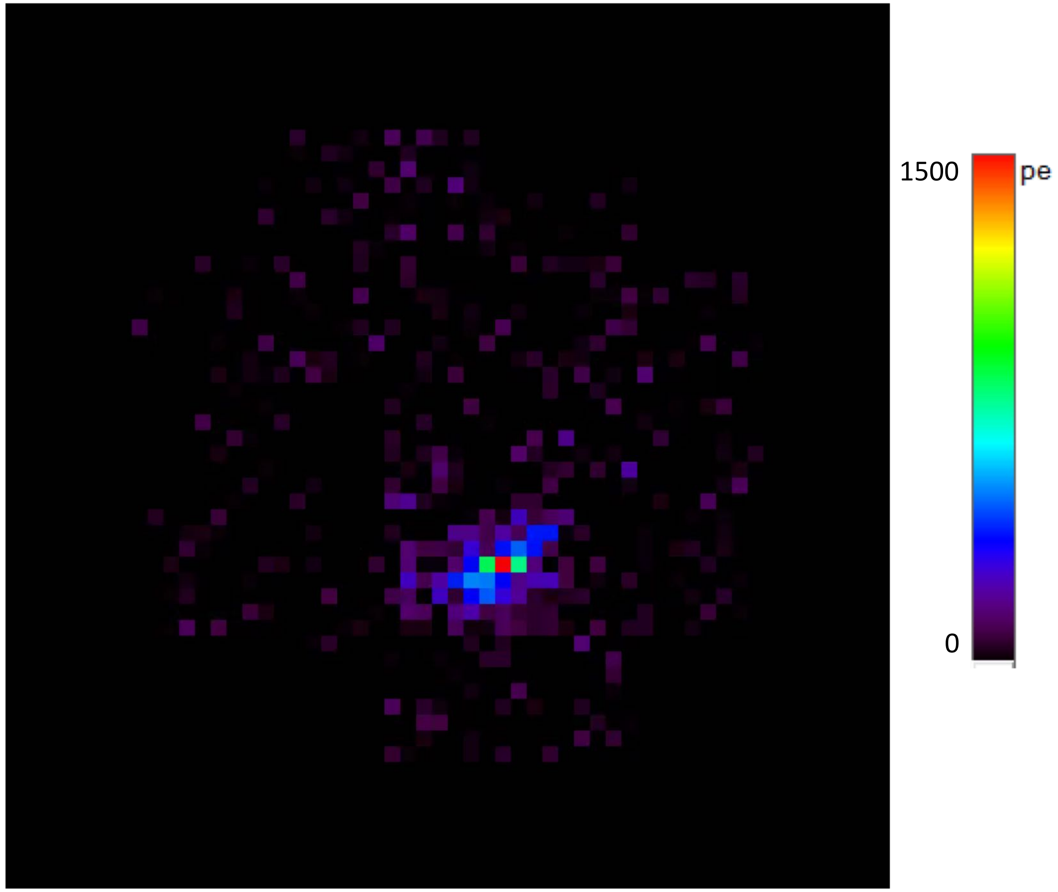
CTA Prototype Telescope, ASTRI, Achieves First Light

Download full release: 2 MB / PDF

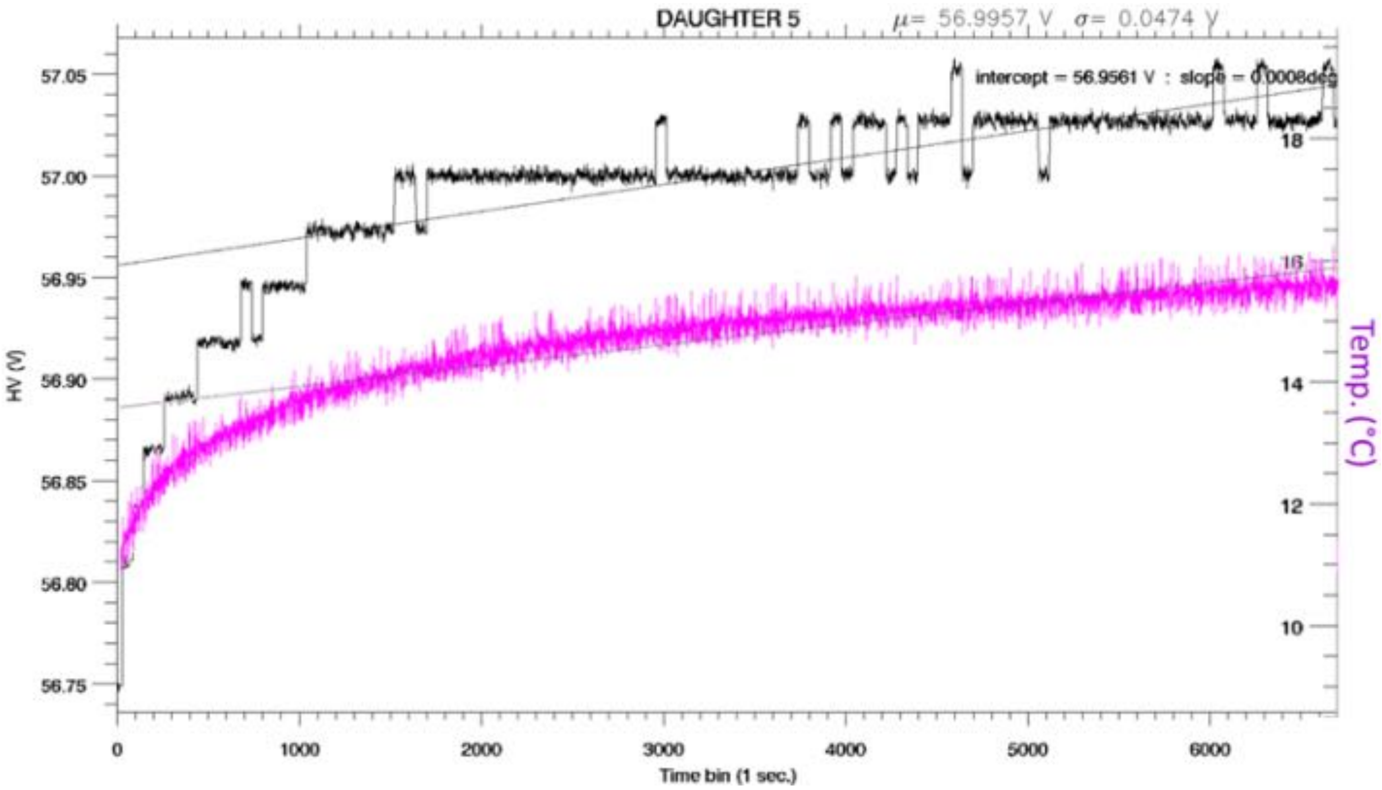
During the nights of 25 and 26 May, the camera of the ASTRI telescope prototype (pictured to the left) recorded its first ever Cherenkov light while undergoing testing at the astronomical site of Serra La Nave (Mount Etna) in Sicily managed by INAF-Catania. This comes not long after its optical validation was achieved in November 2016 (read story here). This accomplishment was the first optical demonstration for astronomical telescopes using the novel Schwarzschild Couder dual-mirror design. The ASTRI telescope is a proposed Small-Sized Telescope design for the Cherenkov Telescope Array (CTA).

Although the camera was not fully configured, the ASTRI team was still able to capture its first Cherenkov light and produce beautiful images of the showers generated by cosmic rays in the Earth's atmosphere. The image below shows one of the events captured by the team. This information will allow scientists to reconstruct the direction of gamma-ray photons emitted from celestial sources (indicated by the yellow line on the image on the left). The camera is based on novel SiPM small pixel sensors (7 mm x 7 mm) and CITIROC ASICS peak-finder front-end electronics. The camera was specifically designed to fit on the dual mirror ASTRI telescopes for covering a large field of view of 10° x 10°.

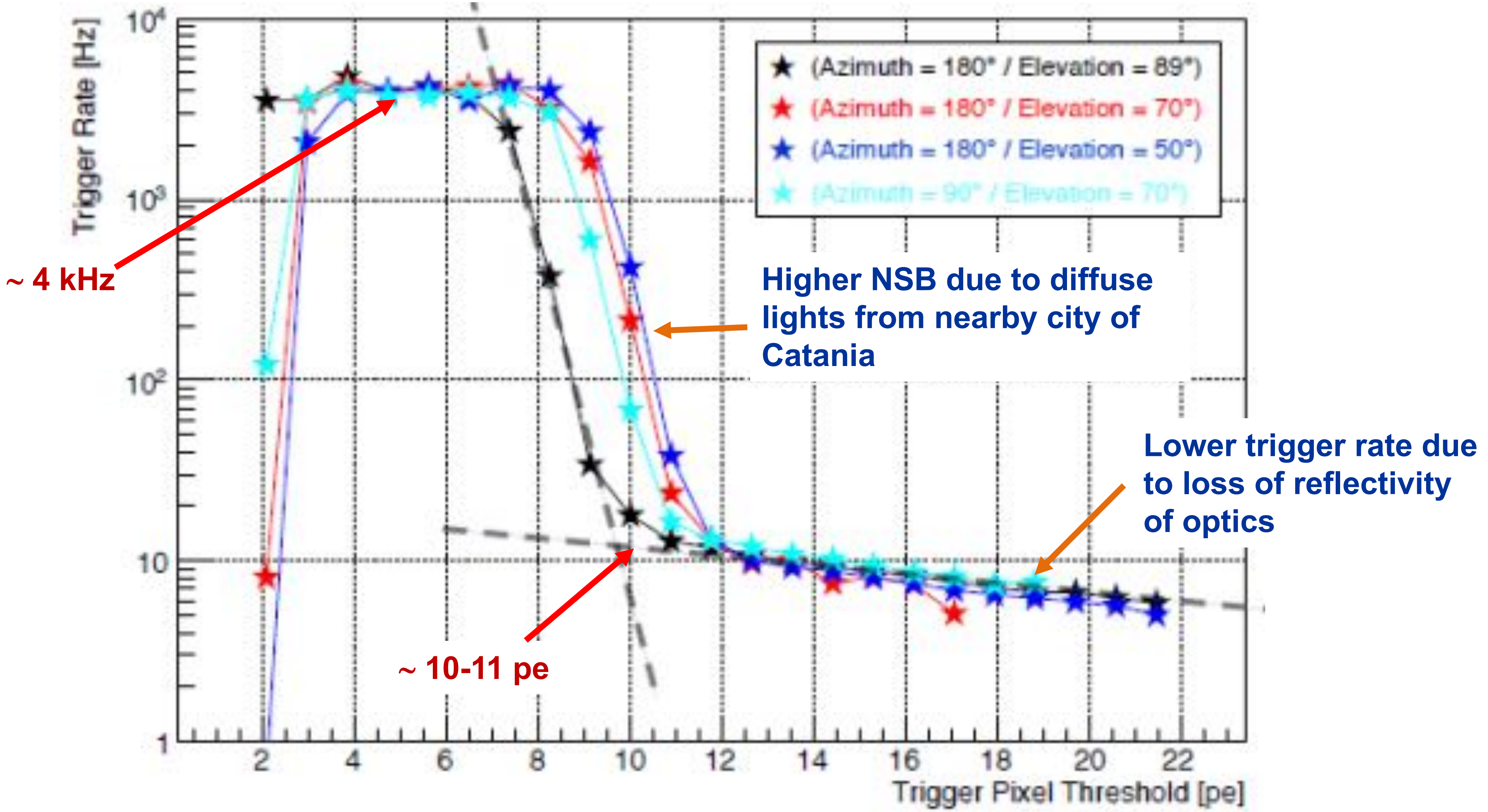
ASTRI Prototype: Camera on sky tests



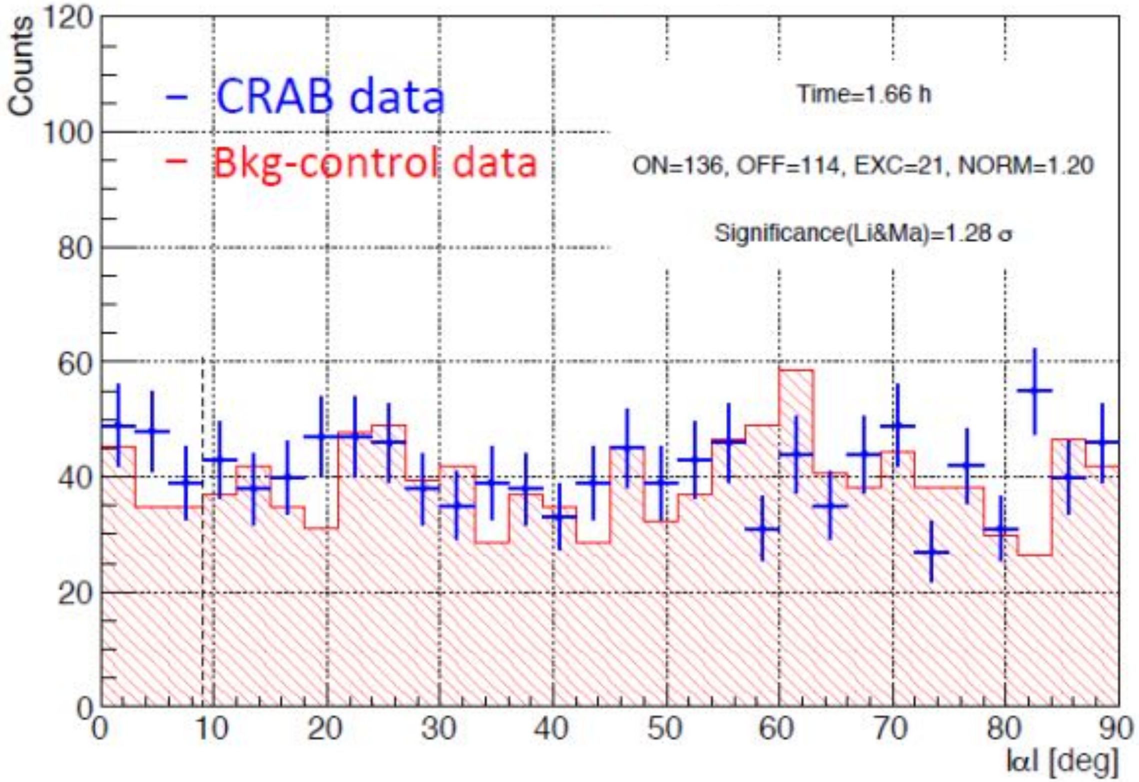
- Runs in December, January, February & March bad weather, May, June
- Technical calibrations (lots) and scientific observations (very few up to now) on going



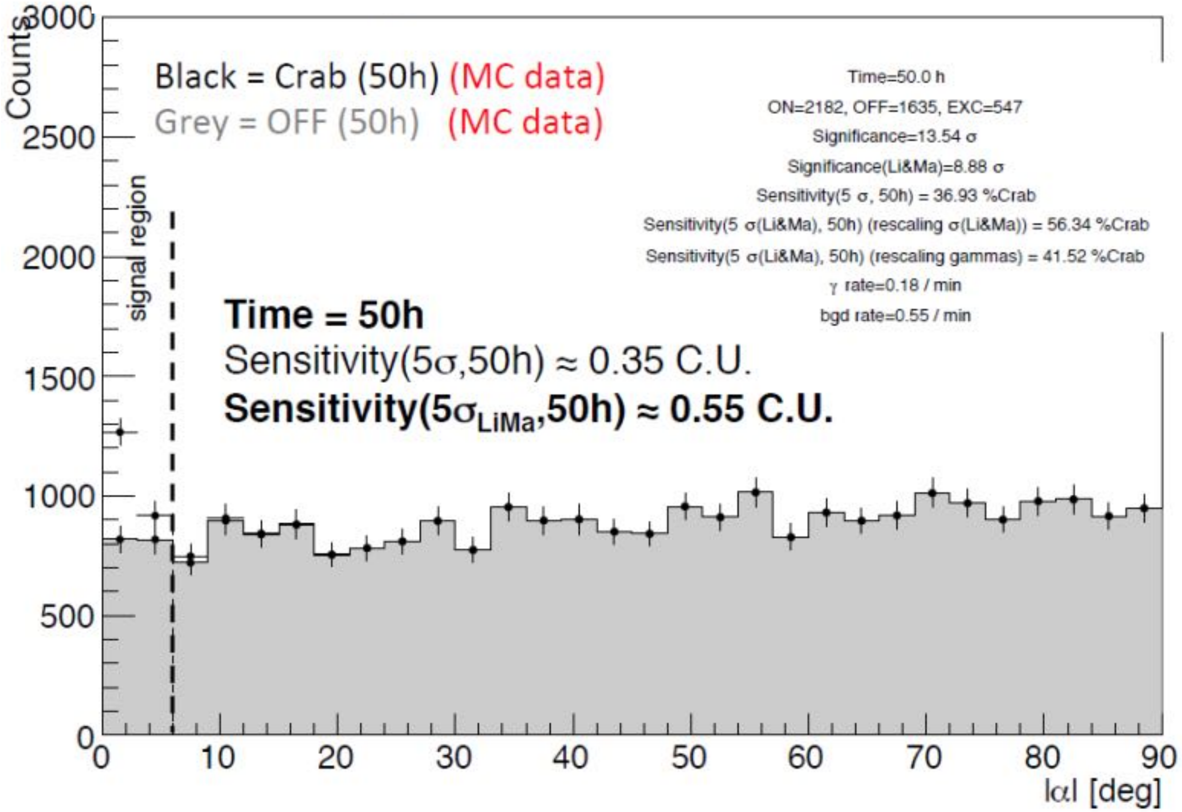
Trigger rate vs Trigger threshold



Real Data

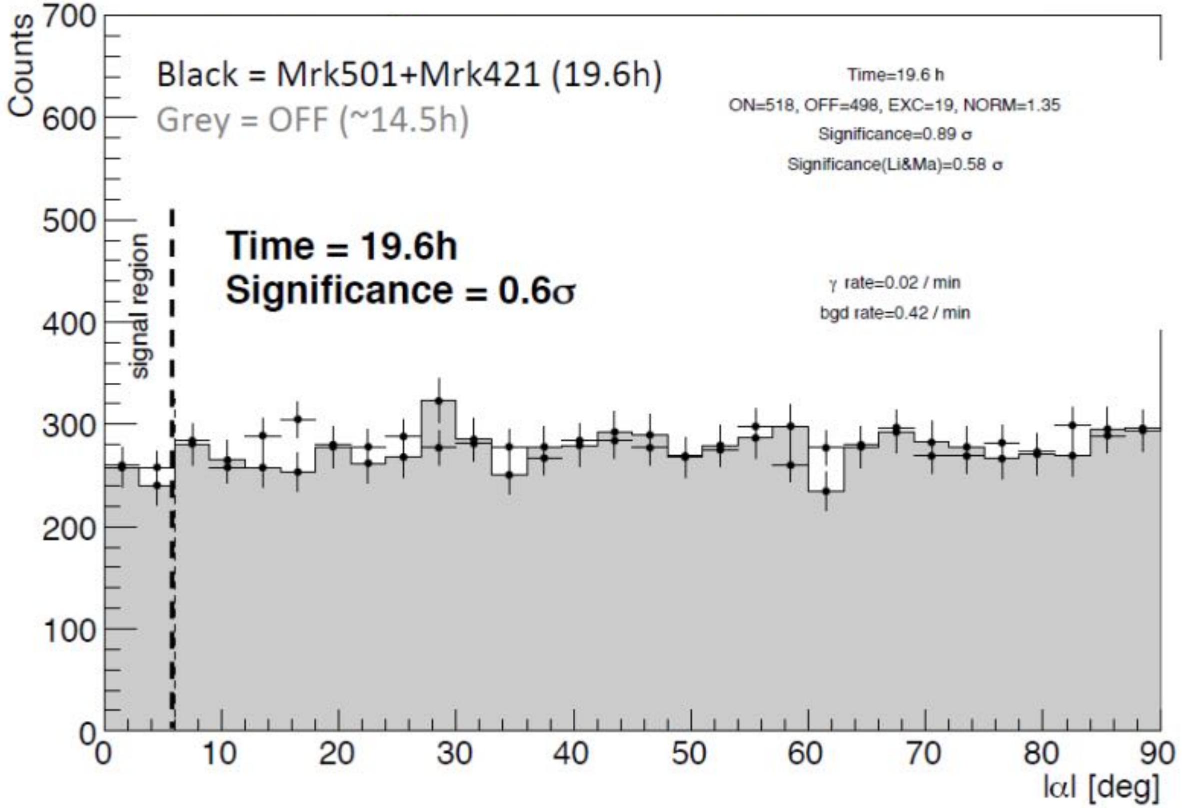


MC simulations

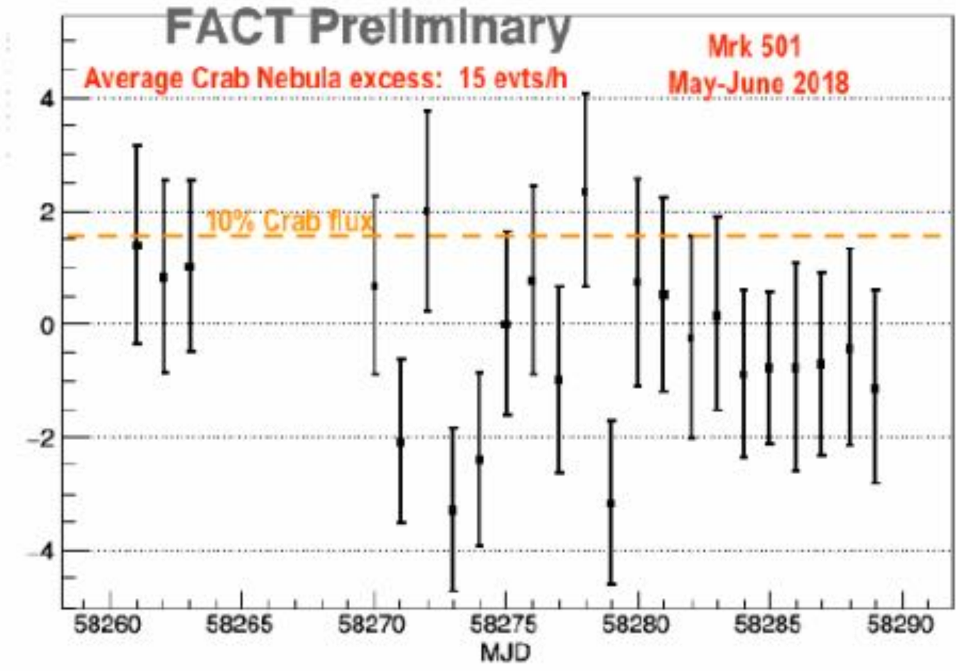


- **Crab not detected after 1.66 hours of observations**
- **Due to low efficiency of optics 5 sigma detection of Crab in 15 h**
- **Not yet validated MC simulations available**

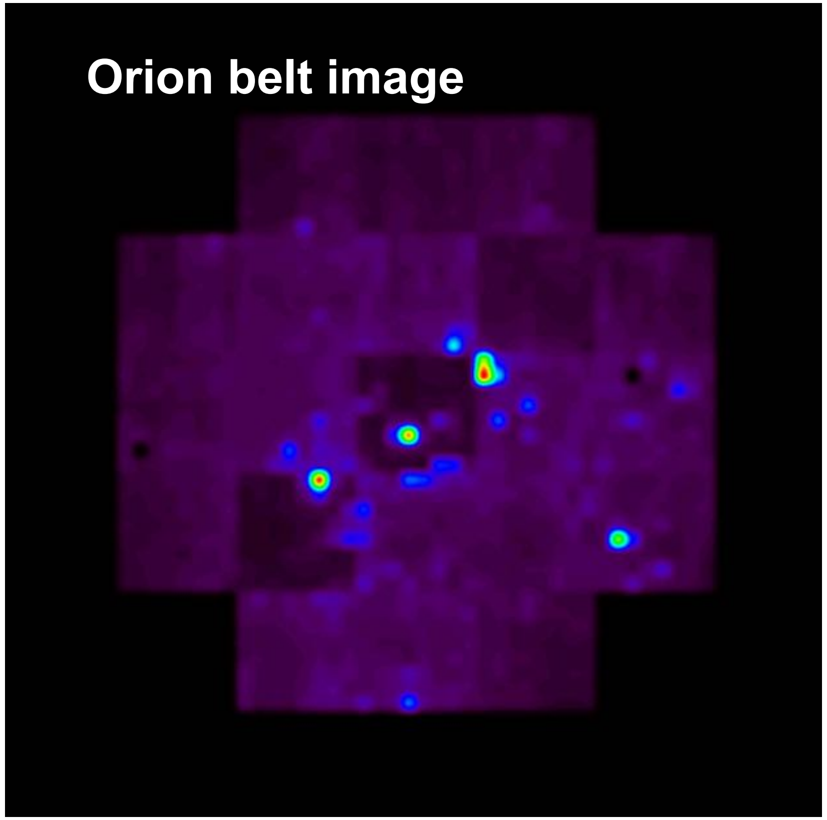
Detection alpha plot



Mrk501



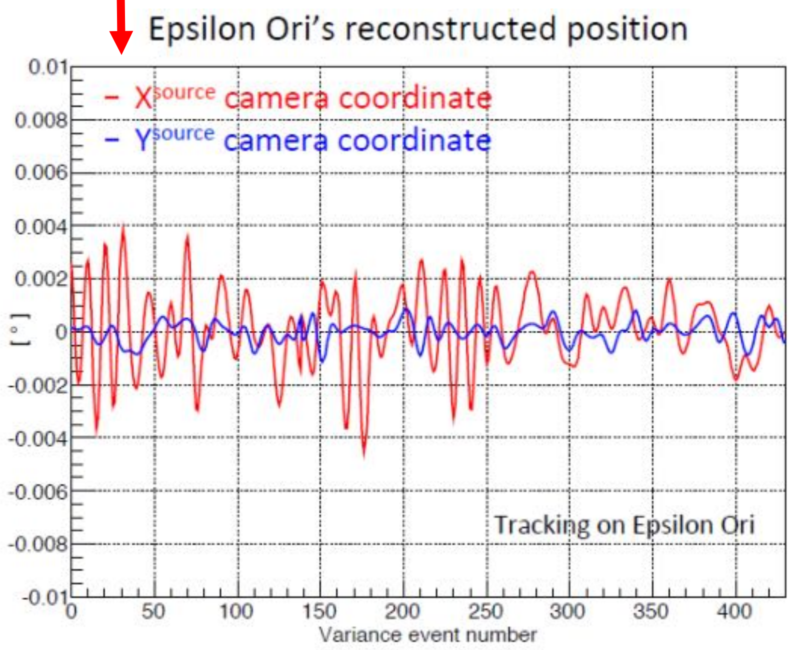
Flux too low (≤ 0.1 Crab) to be detected

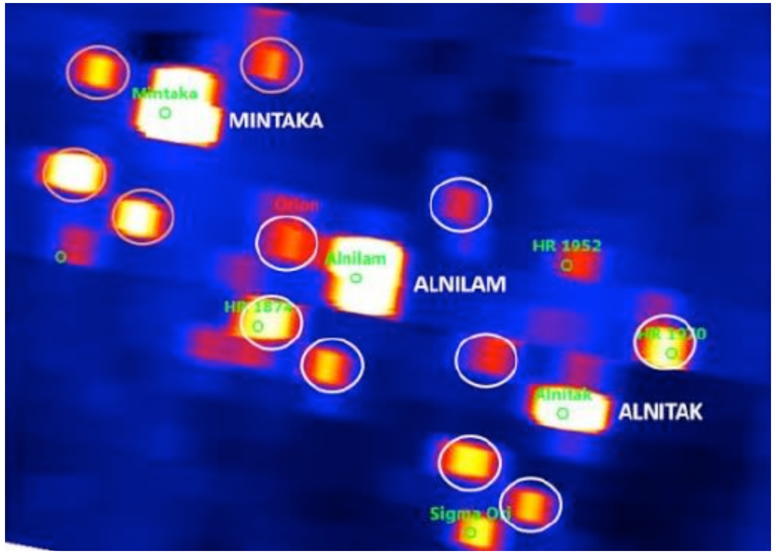


The electric signal generated by each pixel not triggered is continuously sampled and the variance of the sequence of ADC values is proportional to the photon flux.

The acquisition of the variance data is done in parallel with the normal Cherenkov data acquisition

- Measurement of Night Sky Background (NSB)
- Monitoring of the mirrors optical alignment
- Monitoring of telescope pointing accuracy





ASTRI mini-array: The next step of the program

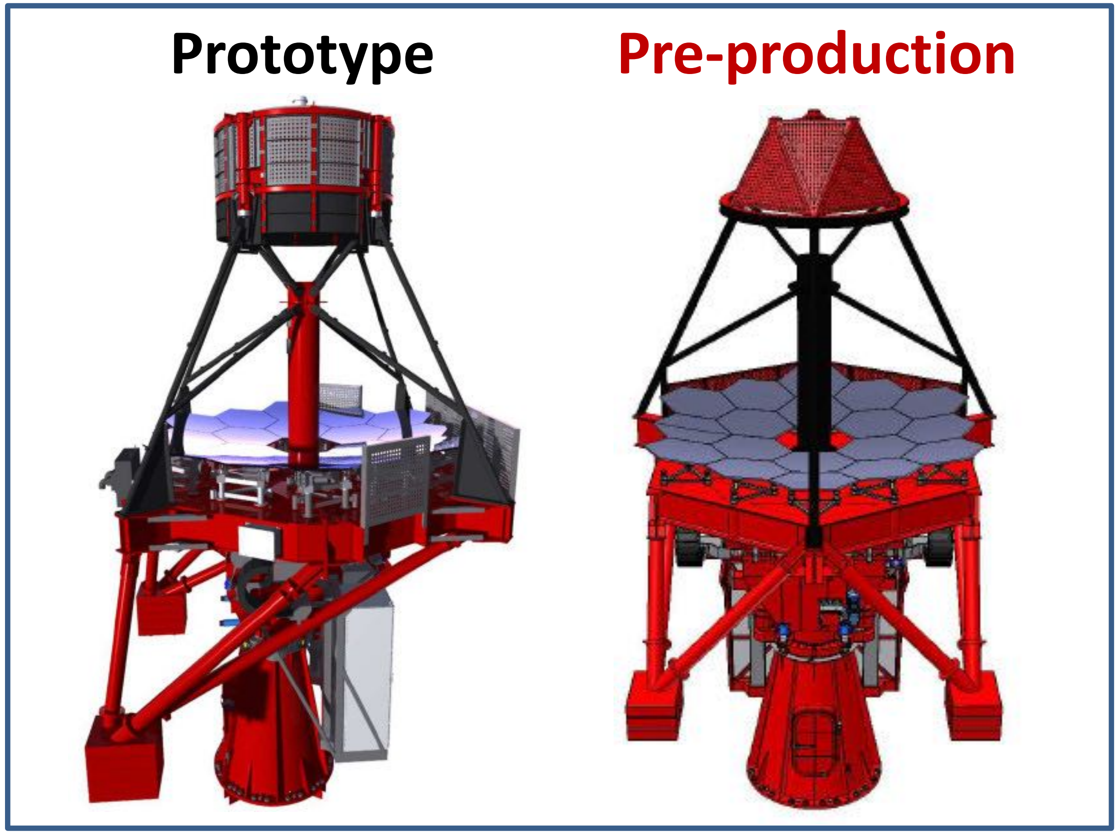
Implementation of a mini-array of 9 ASTRI SST-2M

- 9 ASTRI telescope & cameras + 1 spare camera (procurement via industrial contracts started)
- End to end: validation and commissioning of the array (including trigger and SW) through Cherenkov astronomical observations
- Commitment with the Italian government and international partners to build it
- Funds: dedicated funding outside the 50 M€ of the Italian contribution to CTA
- Site: hopefully CTA-south but in case other locations possible
- Timeline: 3 years to have the first complete telescope at the site

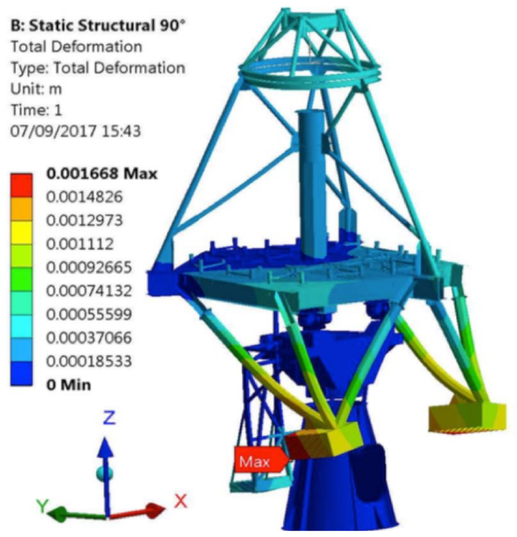
Procurement through industrial contracts

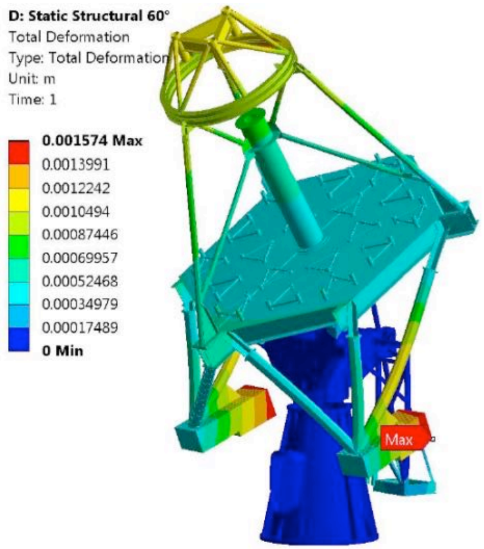
- Specs starting from CTA requirements
- Qualification phase of products
- Quality control and acceptance procedures → Industrial standards
- Manufacture started from low risk (design consolidated) components → Mirrors & ASICs

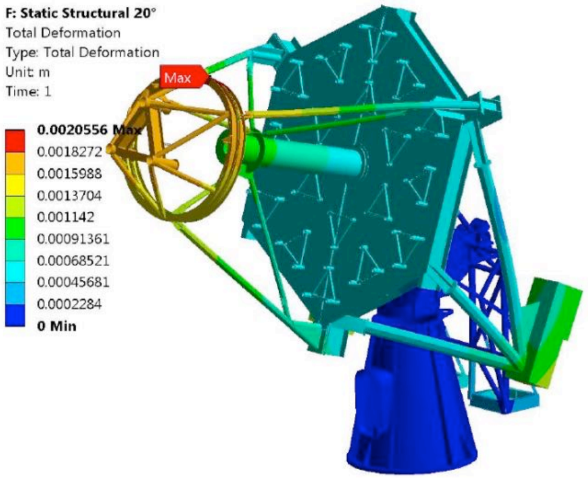
  - Structures
    - Tender for 3 structures assigned and consolidation phase almost completed
    - Construction will start in autumn
    - Tender for further structures to be issued
  - Optics
    - Production of M1 (10 ASTRI & 2 MST) started in September 2017 → 1/3 ready
    - Production of 10 M2 substrates completed in December 2017, coating started
  - Camera Assembly
    - Production of ASICs (CITIROC1A) started in March 2018 → ½ ready
    - Tender for SiPM to be issued
    - Tender Camera (mechanics, electronics, thermal) to be issued

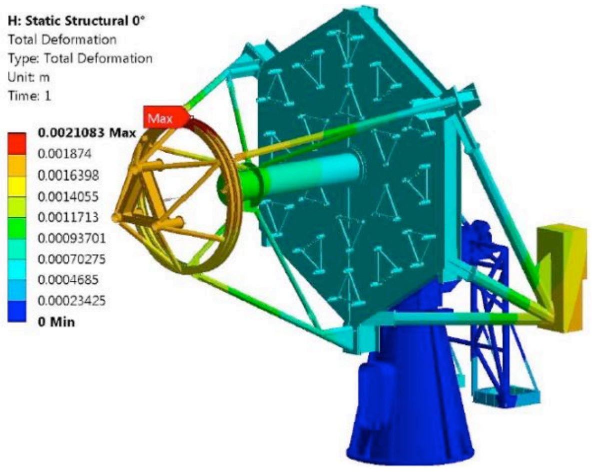


- **Mass reduction (25%)**
  - Design consolidation of the dish and secondary support to maintain the same stiffness lowering telescope weight
  - M2 support structure modified
  - Mast structure with only three legs
  - Dish rotated for an easier integration and realized with commercial parts
- **Active Mirror Control (AMC) simplification**
  - No need for AMC during scientific acquisition
  - No need refocusing telescope during operations
  - AMC radially mounted for an easier mirrors integration
  - AMC mounted only during AIV phase and for maintenance purposes









FEA model

- Modal Analysis → OK
- Static Analyses → OK
- Wind & Seismic Analyses → CTA requirement consolidation

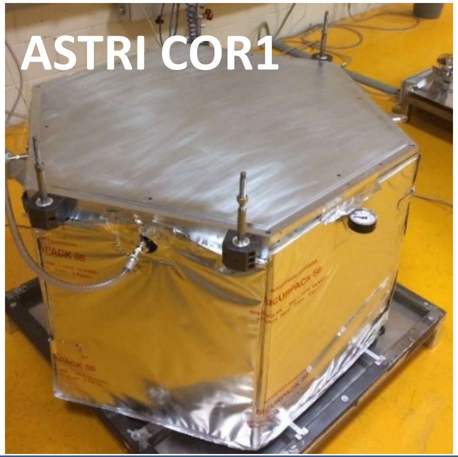
Seismic analyses were carried out to evaluate the structural stress with respect to the scenario described by the "Collapse prevention" specifications.

The structure is able to support these loads, without suffering any damage (structural or permanent) that will prevent motion.

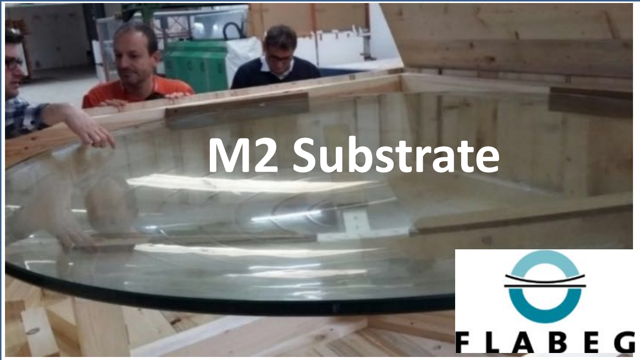
ASTRI Pre-production: Optics procurement

Production Status

Mirror type	Bonded	Coated	Sealed	Finished	Packed	Delivered	Total
pSCT S1						10	10
pSCT S2						20	20
MST	23		2	5	38		68
ASTRI-COR1	3						3
ASTRI-COR2	16						16
ASTRI-COR3	17	1	7		10		35
Total	59	1	9	5	48	30	152



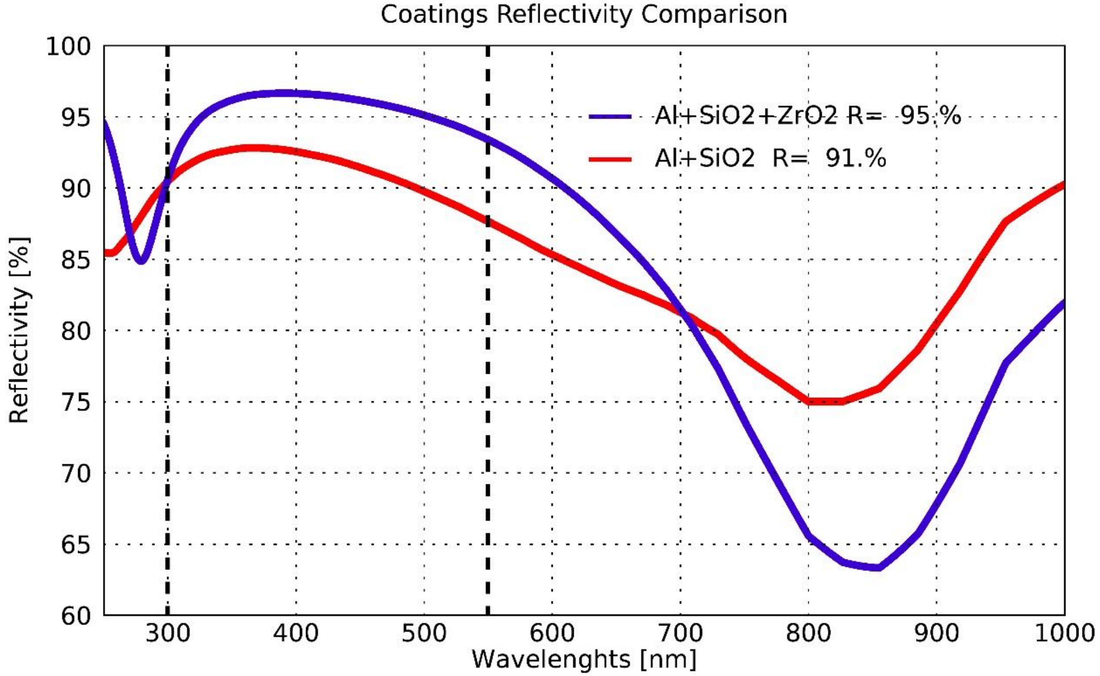
M1



M2

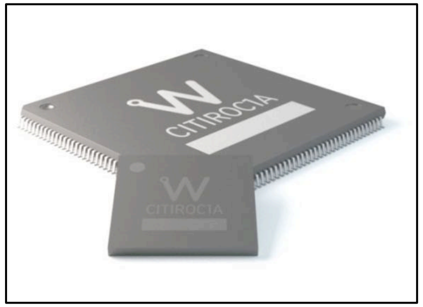
- M2 substrate production completed (9 + 1 spare)
- Coating
- Pads integration

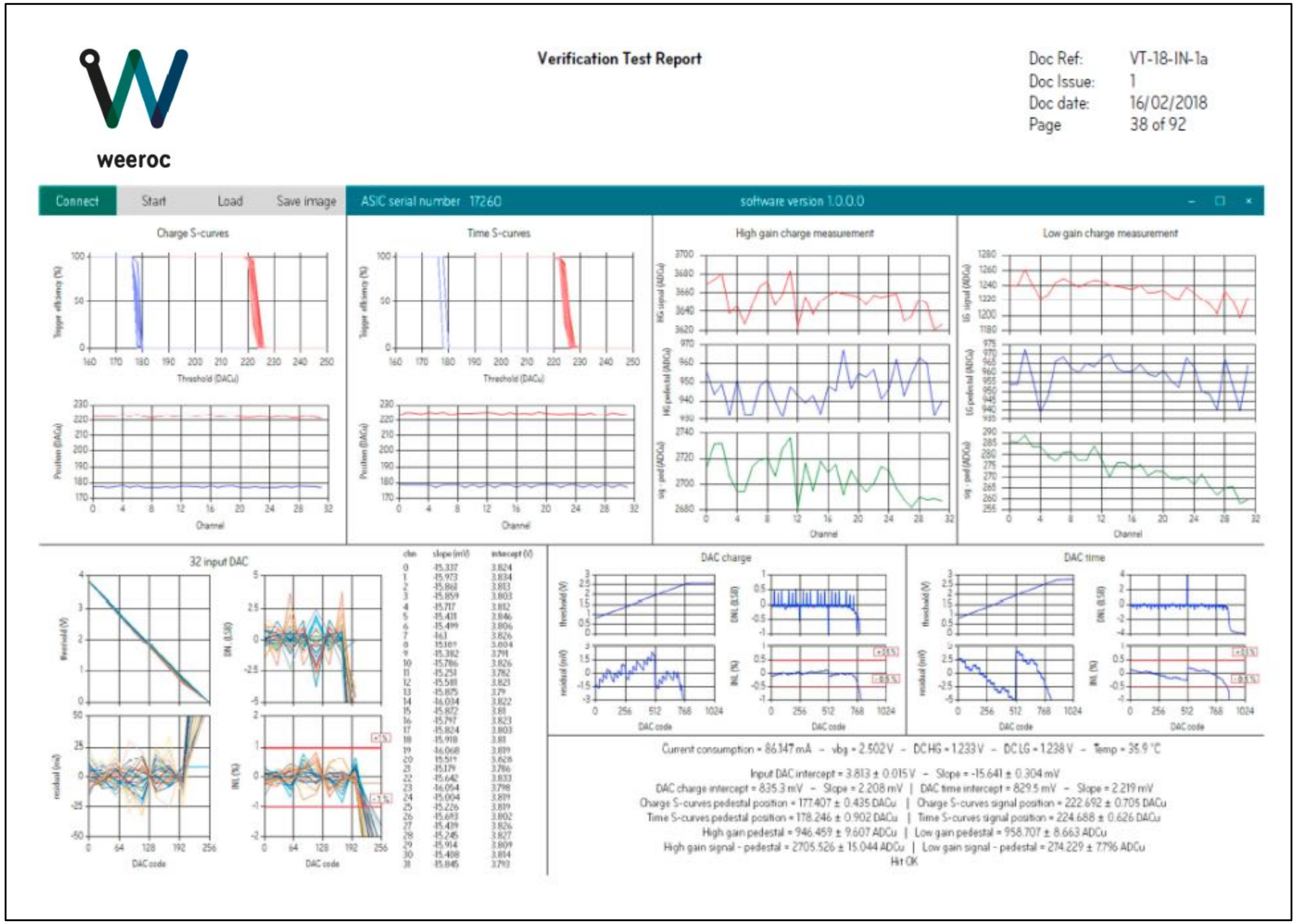
Coating



- **Test for reflectivity stability**
  - Dry Heat
  - Damp Heat
  - Solar radiation
  - Abrasion
  - Salt Mist
  - Aggressive atmosphere
  - Sand blast (waiting for requirement & test definition)

- **ASICS → procurement of 1010 CITIROC1A**
  - **Contract assigned to Weeroc**
  - **KOM: 19th of June**
  - **Production Plan Review: 1st of August**
  - **Qualification phase: completed March 2018**
  - **Production started**





ASTRI Pre-production activities: White Rabbit Boards

Inventory:

- 1 White Rabbit switch
- 5 White Rabbit boards
- 2 CTA TiCkS & 1 CTA ZEN card
- GPS GNS 1005/D Timing Reference GNSS
- Clock generator CG635
- NIM 2 LVDS signal converter
- 4 PCs to interface with WR network

Lab test:

- Test CTA TiCkS & Zen WR cards performance.
- Check maximum trigger rate using UDP & TCP protocols.
- Test camera server software
- Test SWAT software
- Test GPS stability

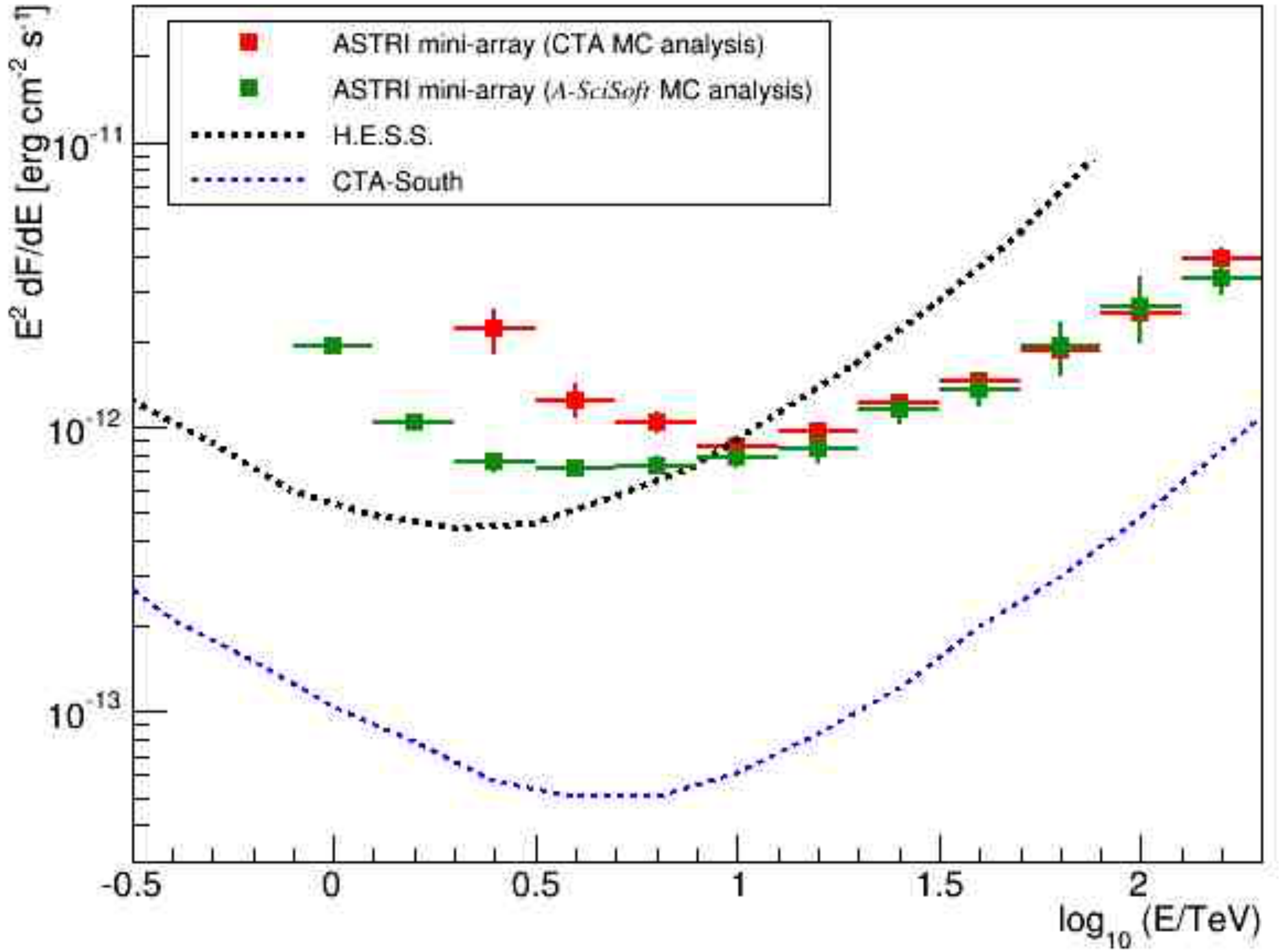
INFN Sezione di Roma Tor Vergata

Test Facility at INFN

Gonzalo Rodriguez Fernandez, Aldo Morselli

Work for ASTRI :

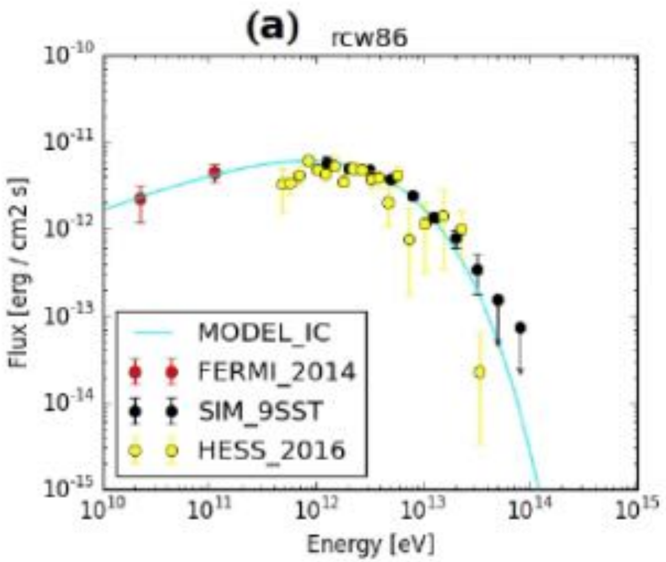
- Test of the software that concerns the timing
- Choose the best Timing card for ASTRI and help the integration with the Camera electronics

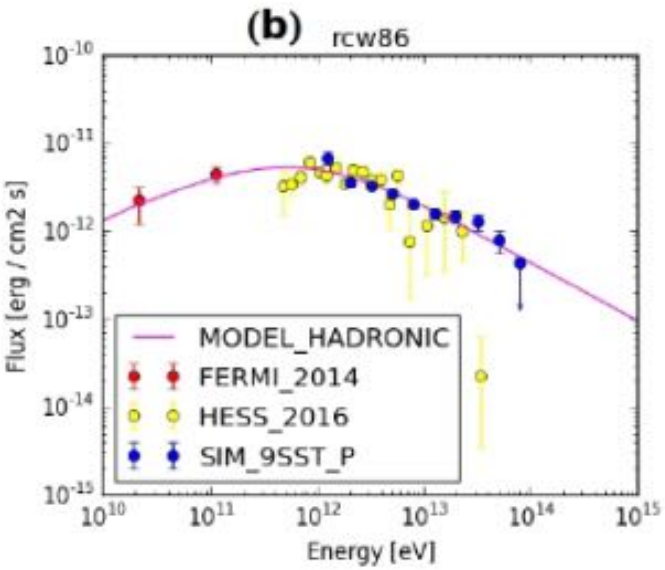


- **Differential sensitivity curves (5σ, 50 hours) for 9 telescopes, relative distance ~250 m, square layout**
- **Better the H.E.S.S. above several TeV**

The ASTRI mini-array will exploit its better sensitivity and extended spectral range to investigate:

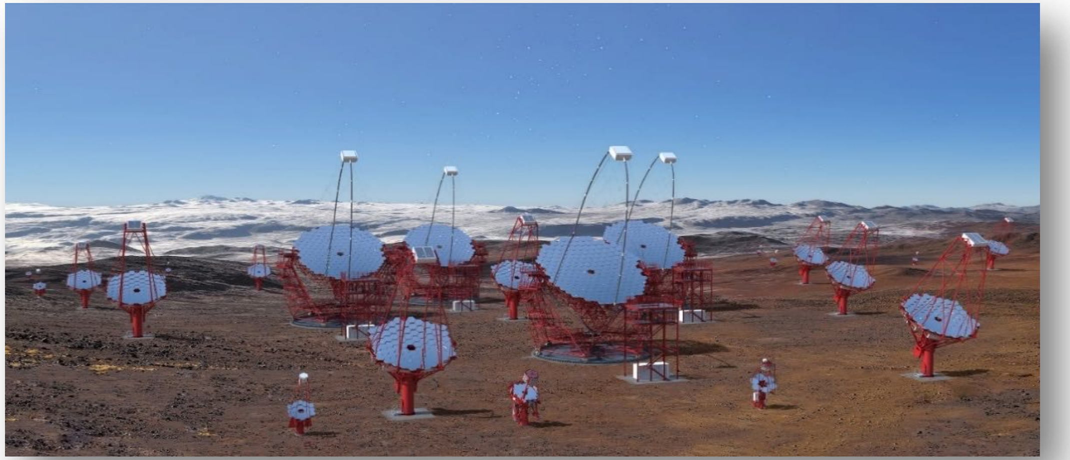
- Extreme blazars (KUV 00311–1938)
- Nearby BL Lac objects (Mrk 501)
- Radio galaxies (M 87)
- Galactic pulsar wind nebulae (Crab Nebula, Vela-X)
- Supernovae remnants (Vela-junior, RX J1713.7–3946)
- Galactic Centre.
- Search for cosmic ray (CR) PeVatrons.



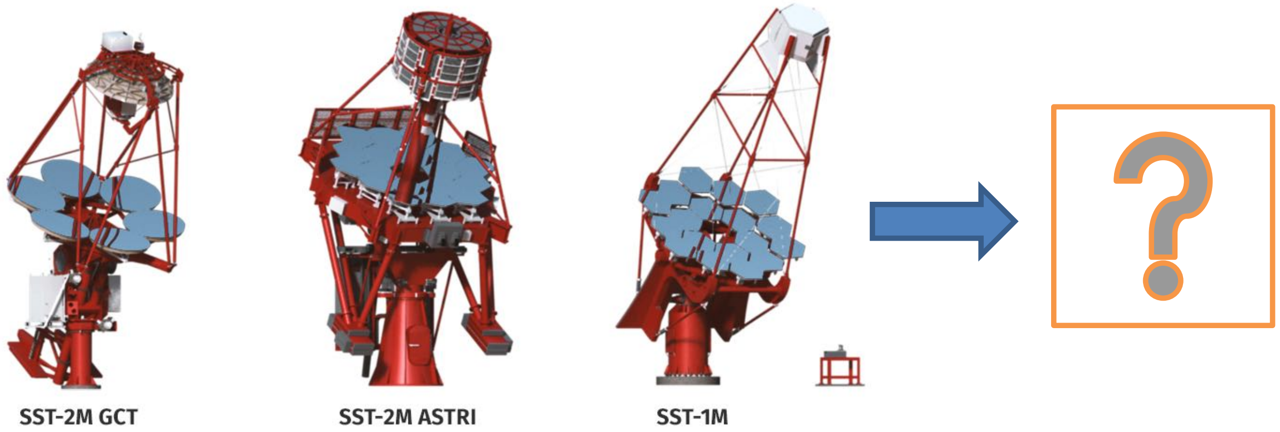


Simulated spectra of the SNR RCW 86 observed with the ASTRI mini-array (200 h) assuming leptonic or hadronic origin for the gamma-rays

Burtovoi et al. 2017



Resolution of SST Shareholders at a CTA council meeting (09 May 2018) to implement only one SST design at the observatory



- The harmonization process started in May
- We (SSTs) should evolve existing designs into a single one preserving previous work
- CTAO management decided to review and evaluate current designs through an external panel
- Deadline to submit proposal/information end of October