Astrofisica con Specchi a Tecnologia Replicante Italiana

cherenkov telescope array

The ASTRI dual-mirror Small Size Telescope for the Cherenkov Telescope Array, CTA

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Talk outline

The ASTRI SST-2M prototype

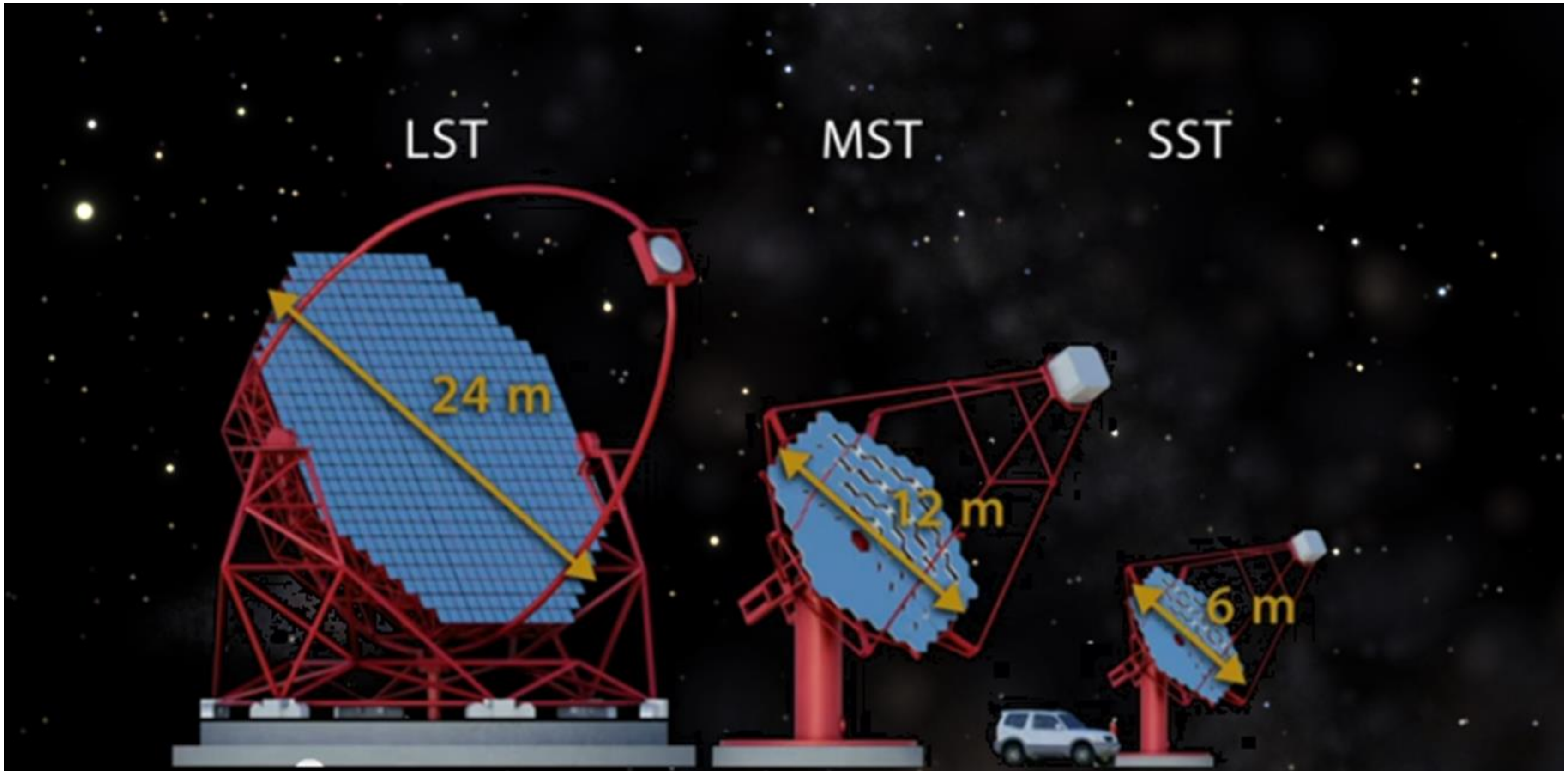
- Dual-mirror concept
- Camera innovative sensors and electronics
- End-to-end approach

The ASTRI/CTA mini-array

- First CTA seed
- Synergies with other instrumental set-ups

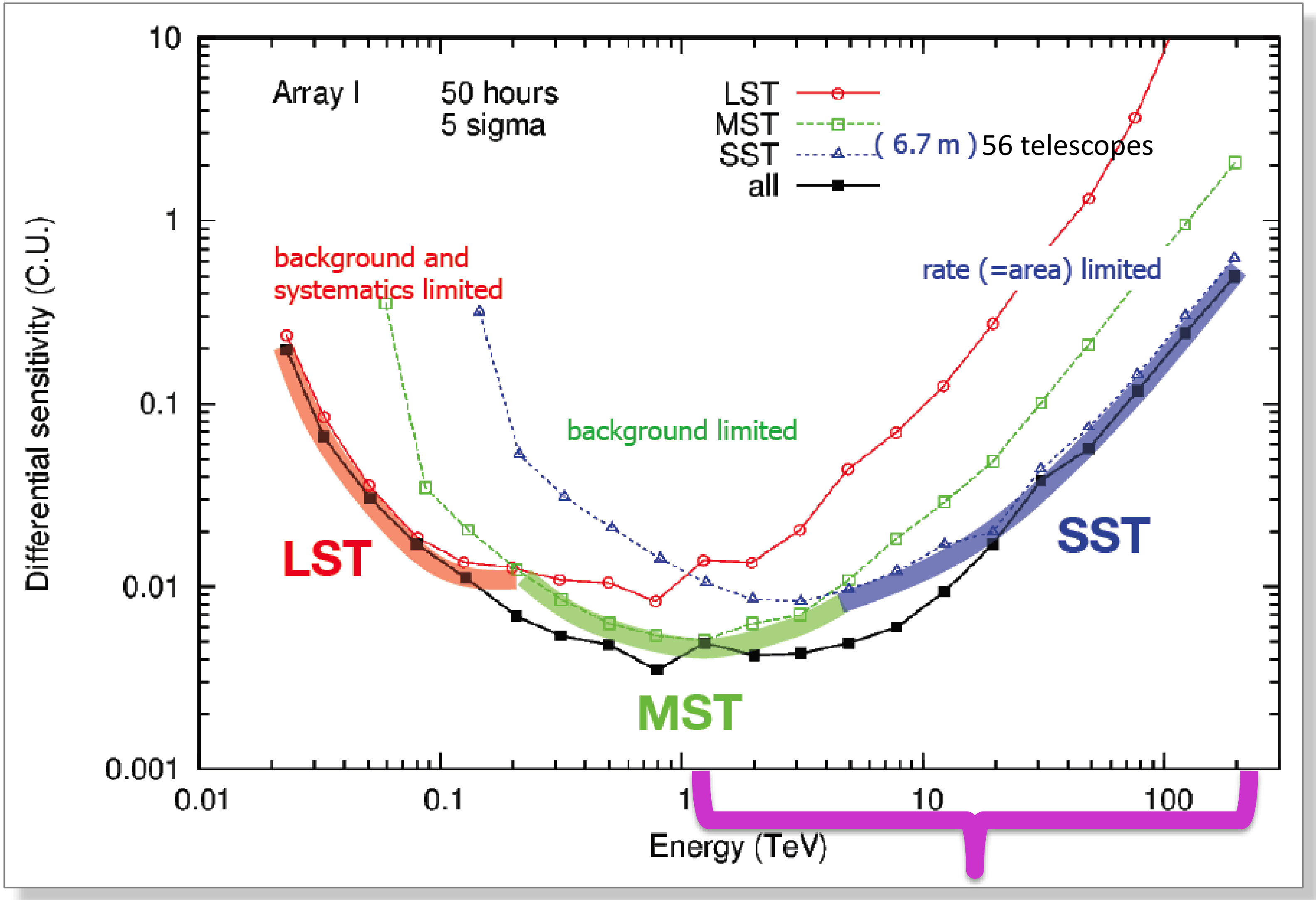
Conclusions

The CTA Project



CTA telescope class types

The CTA Project



The ASTRI project

ASTRI is an Italian "Flagship Project" funded by the Ministry of Education, University and Research (MIUR) and led by the Italian National Institute for Astrophysics (INAF).

The main goals of the project are the design, development and deployment, **within the CTA framework** of:

- **an end-to-end prototype** of the CTA small-size telescope in a dual-mirror configuration (ASTRI SST-2M) to be tested under field conditions at the INAF observing station on Mt. Etna (Sicily) at the end of **2014**;
- **a SST-2M mini-array** to be placed at the chosen CTA Southern Site starting in **2016**.

ASTRI SST-2M

Energy threshold

- 1 TeV

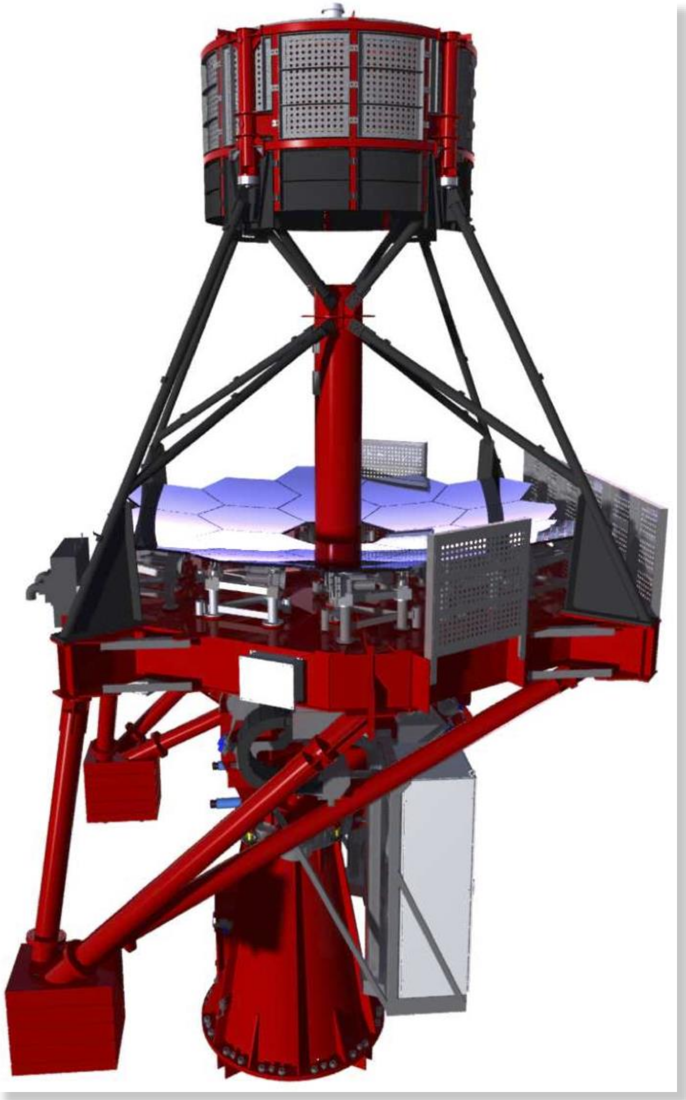
End-to-end SST-2M Prototype

Telescope properties

- Optical design = Schwarzchild-Couder
- Primary mirror = 4.3m
- M1 type = Segmented (18, 3 concentric rings)
- Secondary mirror = 1.8m (2.2m RoC)
- M2 type = Monolithic
- M1-M2 distance = 3m
- Effective area = $6.5m^2$
- $F/D_1 = 0.5$, F = 2.15m

Camera properties

- Number of logical pixels = 1984
- Pixel size = 0.17° (plate scale = 37.5mm/°)
- Total Field of View = 9.6°
- Sensors type = SiPMs



Dual-mirror concept

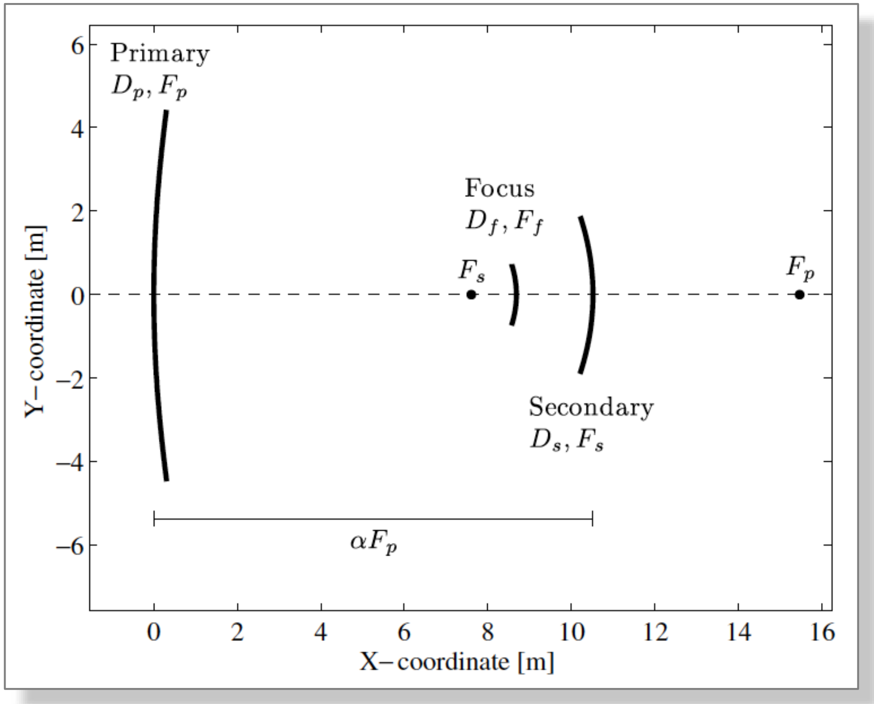
ASTRI SST-2M telescope design complies with small pixel size, large field of view, and controlled cost requirements.

New dual-mirror, Schwarzchild-Couder (SC) based on aplanatic design has been proposed and developed [Vassiliev, Fegan & Brousseau, 2007, A.Ph., 28, 10]

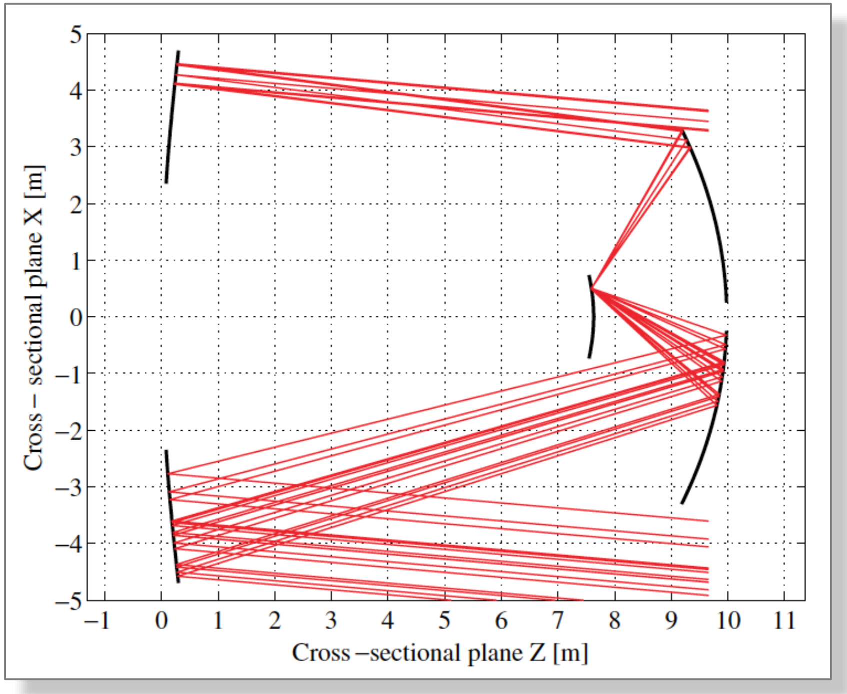
The dual-mirror layout allows us:

- to obtain a more compact and stiffer mechanical structure
- to reduce the dimension, the weight, and the cost of the camera at the focal plane of the telescope
- to adopt Silicon-based photo-multipliers as light detectors, thanks to the reduced plate-scale. SiPMs allow us to perform observations during Moon-light, increasing the observatory duty-cycle
- to have an optimal imaging resolution across a wide field of view

Dual-mirror concept



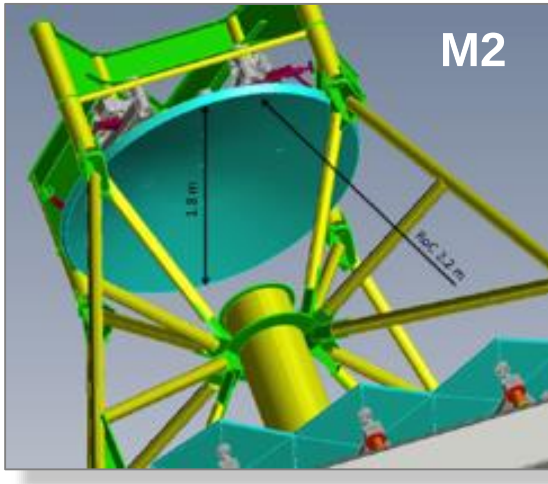
"Wide field aplanatic two-mirror telescopes for ground-based γ-ray astronomy"
Vassiliev, Fegan & Brousseau, 2007, A.Ph., 28, 10

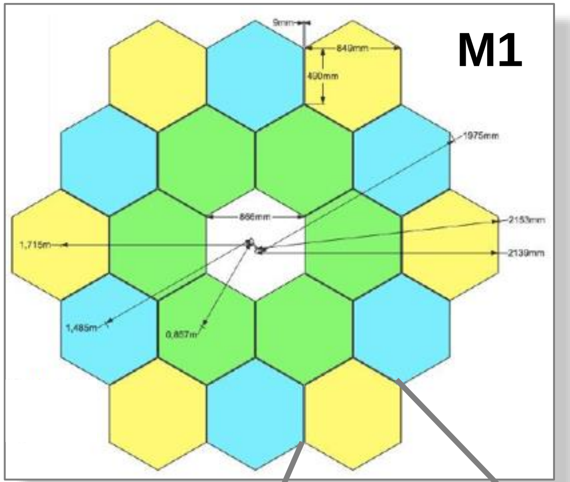


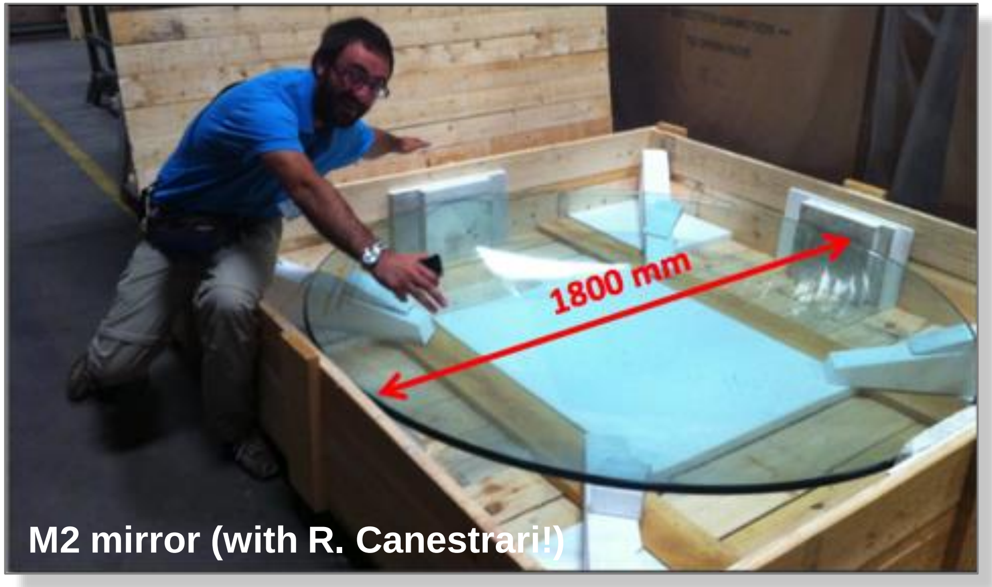
In the SC telescope, the focal plane is located in-between two aspherical mirrors, close to the secondary mirror.

No Cherenkov telescope adopted this optical system up to now

ASTRI mirrors



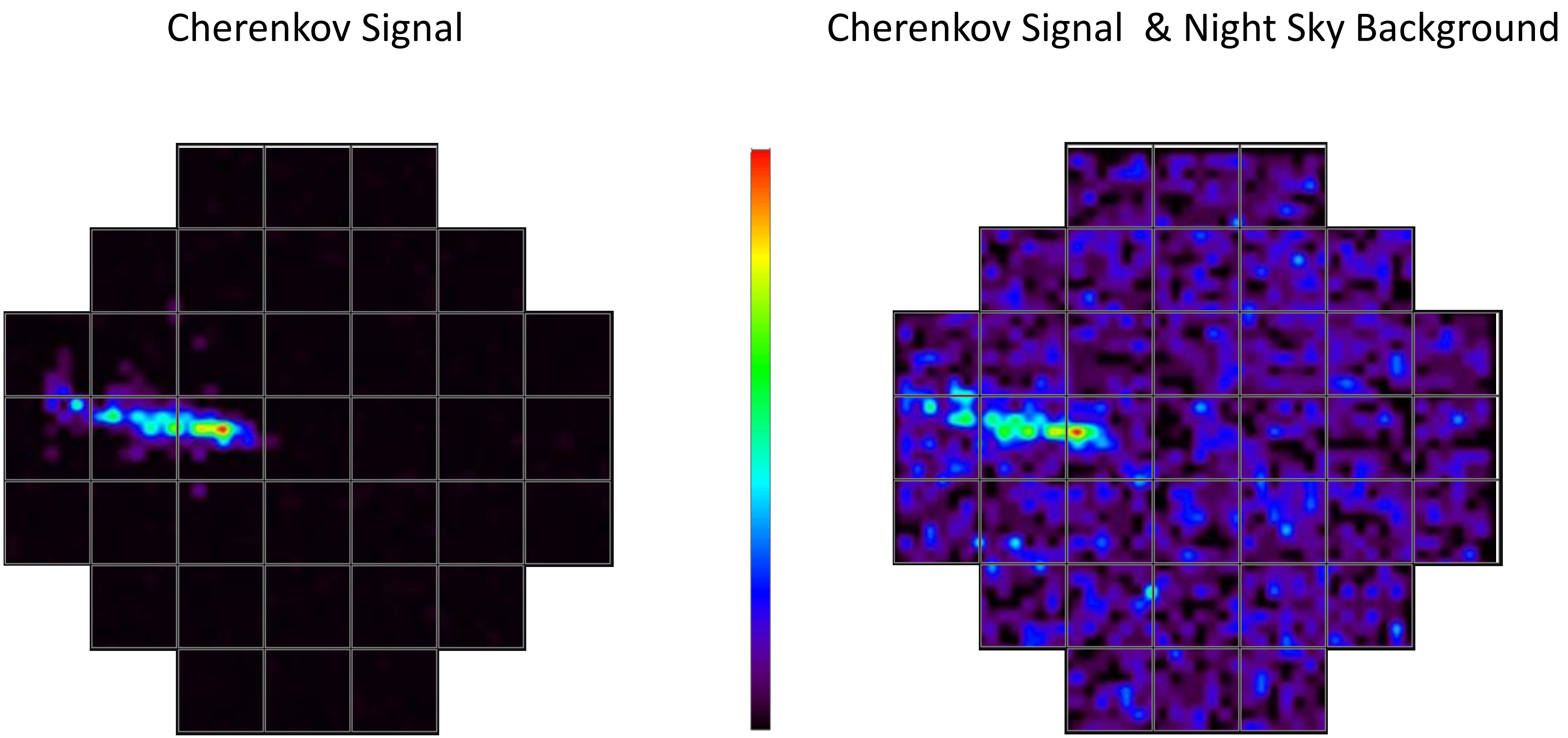




M2 mirror (with R. Canestrari!)

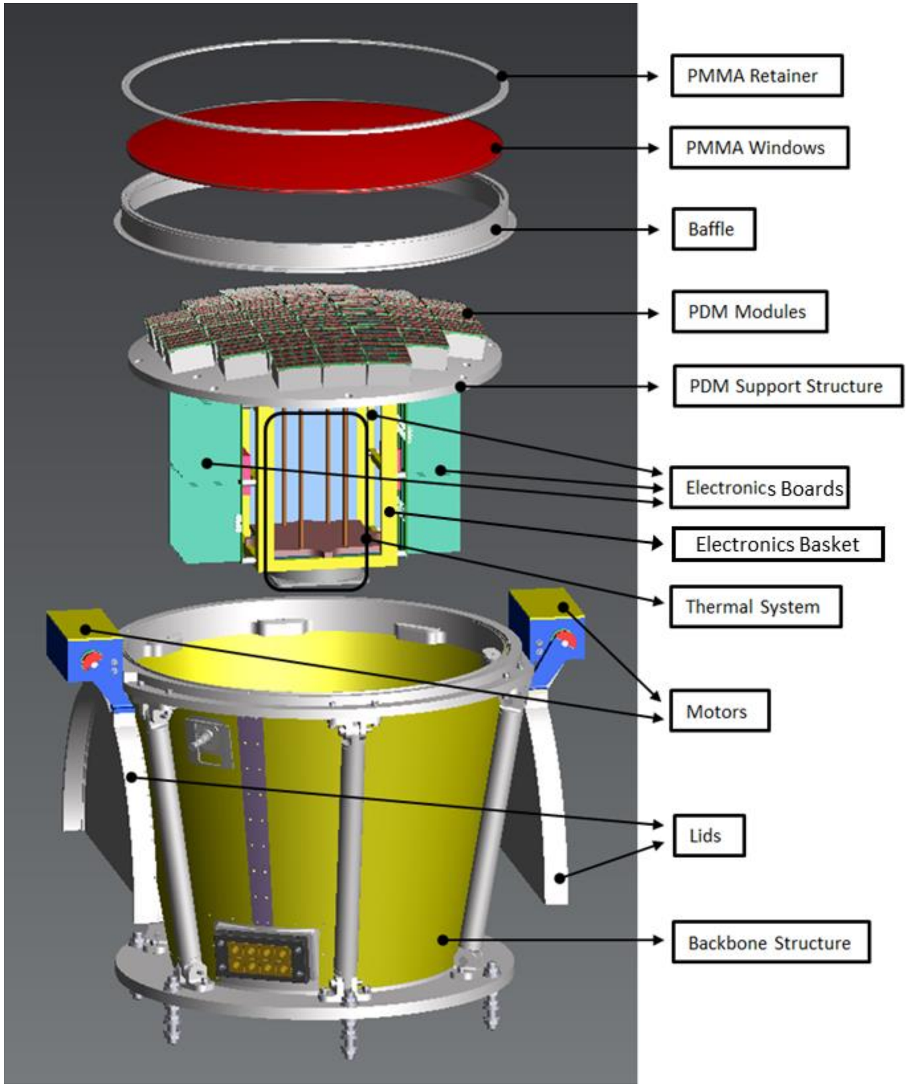
M1 external segment

ASTRI camera



Cherenkov Signal produced by Air Shower lasts few ns
Focal plane high pixelizzation required (~ 2000 pixels)

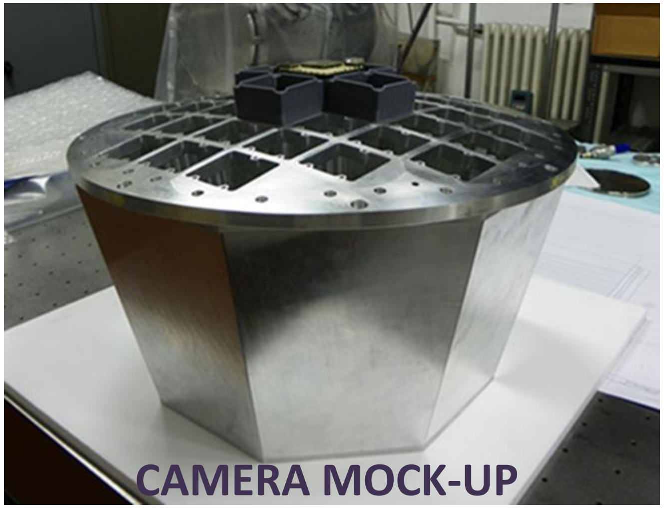
ASTRI camera



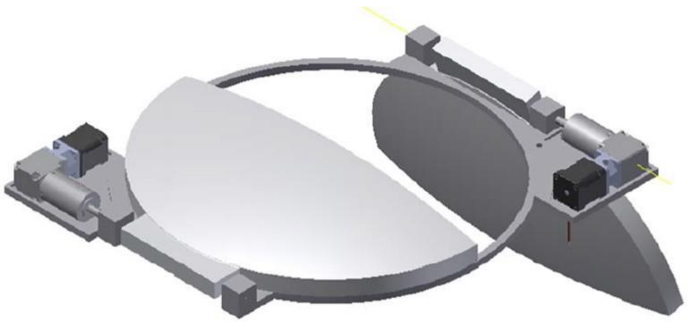
Take away numbers

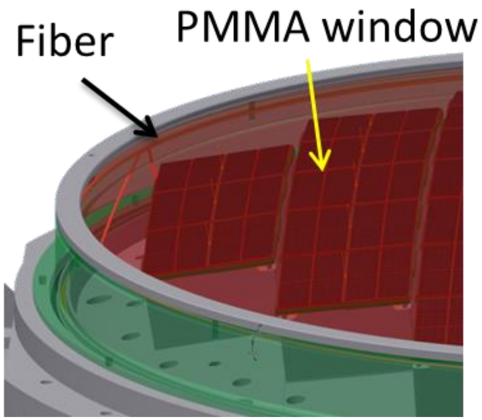
- All parts fully integrated in the camera body (dimensions= 500 mm x 490 mm x560 mm)
- Logical pixel size = 6.2mm x 6.2mm
- Number of pixels = 1984
- Field of view = 9.6° (RoC = 1m)
- Weight ~ 50kg
- FFE ASIC = CITIROC [signal shaper]
- Photo-sensors = SiPMs S11828-3344M

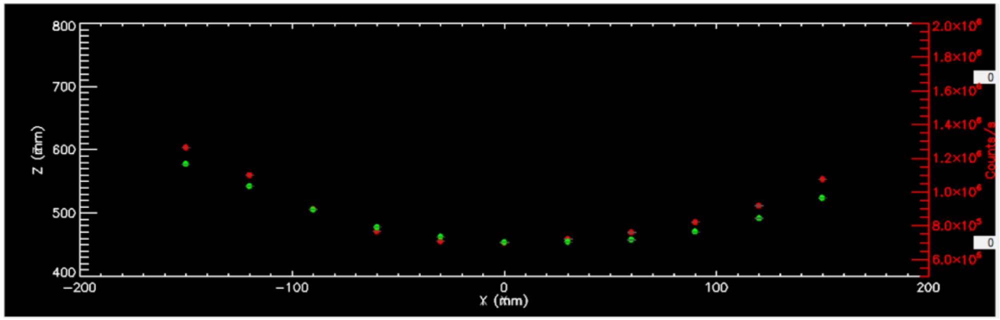
(new sensors under test for the mini-array)



ASTRI camera





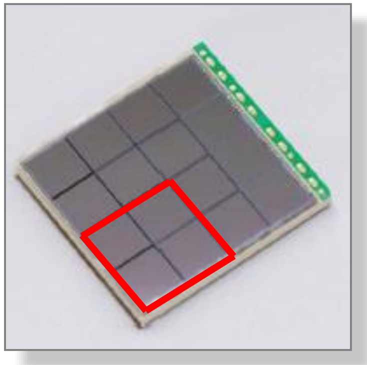


Sampled points along two orthogonal directions

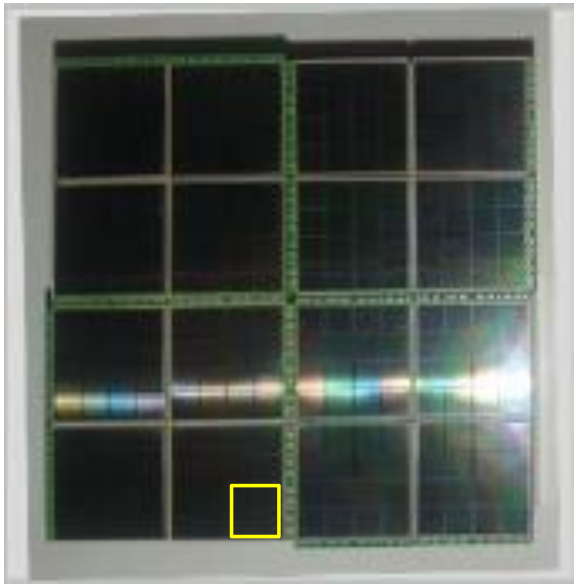
Lids and Poly-Methyl MethAcrylate (PMMA) protective window

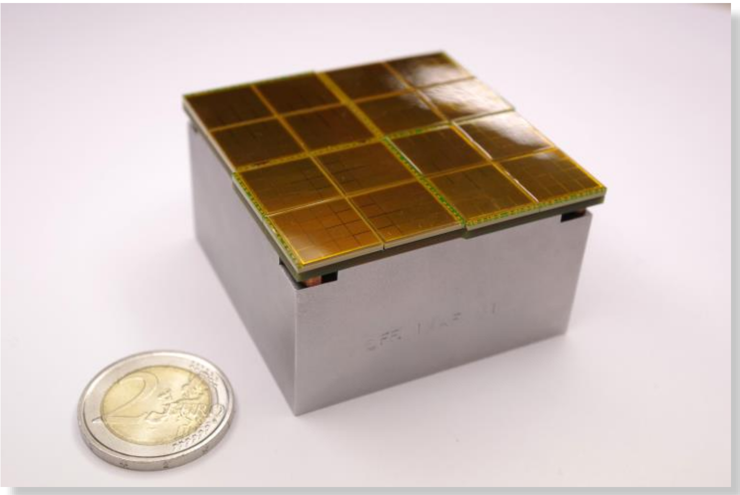
- Light-tight lids prevent accidental incidence of sunlight on the focal plane detectors
- optical fiber slot machined out in the backbone plate flange allows the photons generated by continuous or pulsed LED light to illuminate almost uniformly the PMMA window (fiber in optical contact with PMMA)

ASTRI camera



S11828-3344M



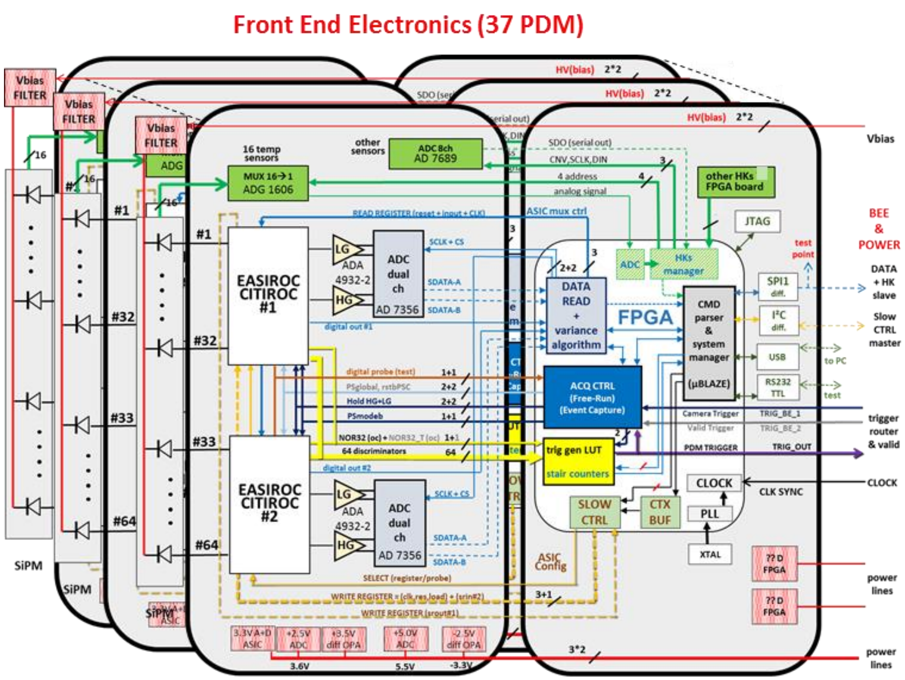


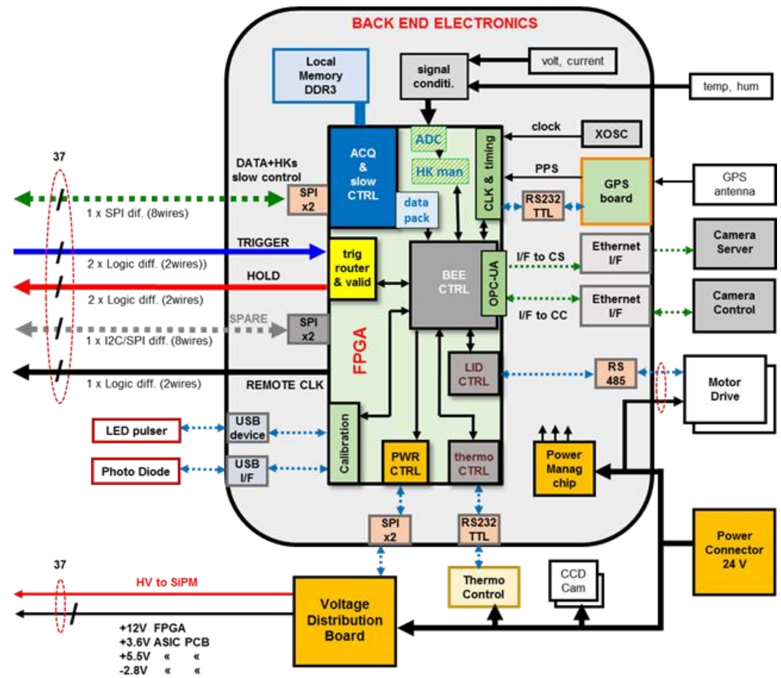
SiPM on top of an assembled PDM

Photon-Detection Module (PDM) sensors

- Focal plane camera consists of 37 PDMs
- A PDM consists of 16 monolithic SiPM
- Number of pixels per PDM = 64
- Photo-sensors = SiPMs Hamamatsu S11828-3344M

ASTRI camera

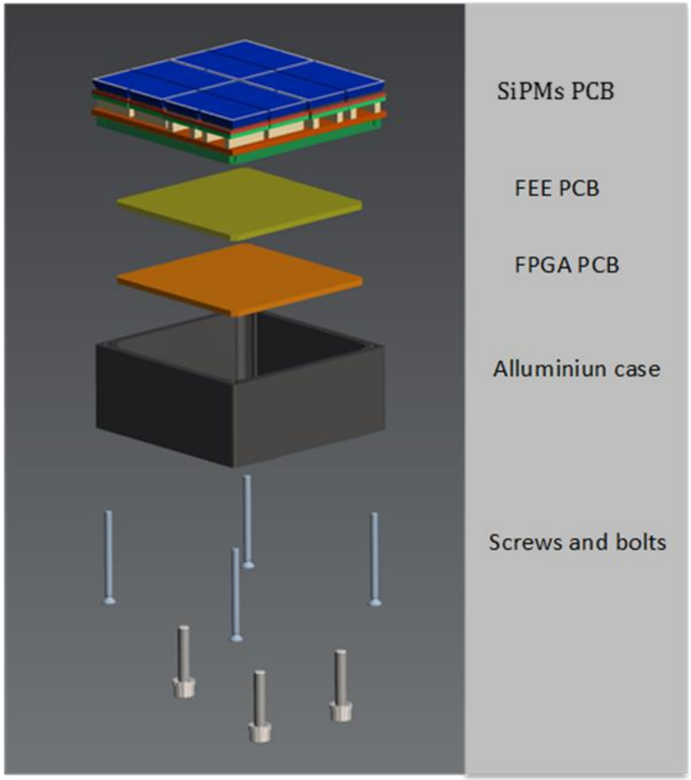




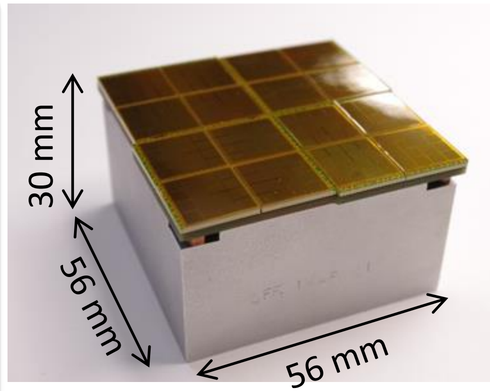
Camera electronics architecture

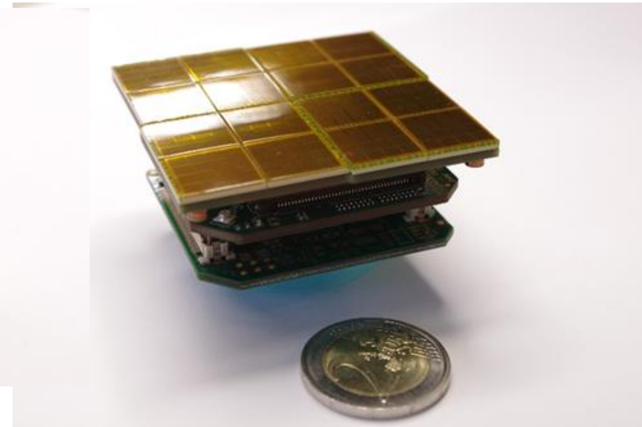
- 37 PDM electronics each consisting of : 1 SiPM , 1 Front-End, 1 FPGA PCBs
- A Back-End PCB
- A Voltage Distribution PCB
- Ancillary devices: GPS, Thermo Control, LED pulser, Energy meter, Lids motor controller, CCD cameras

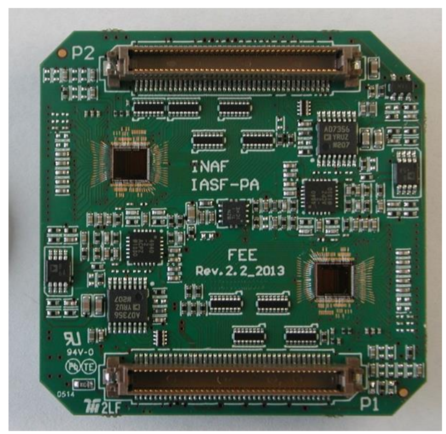
ASTRI camera

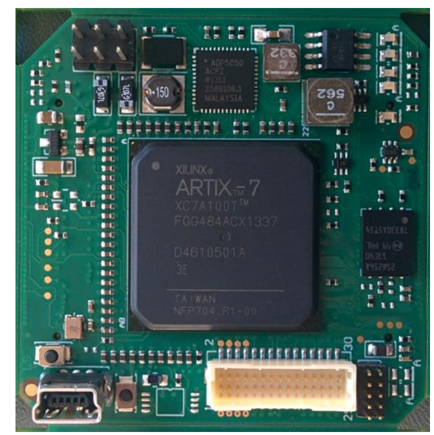


PDM exploded view





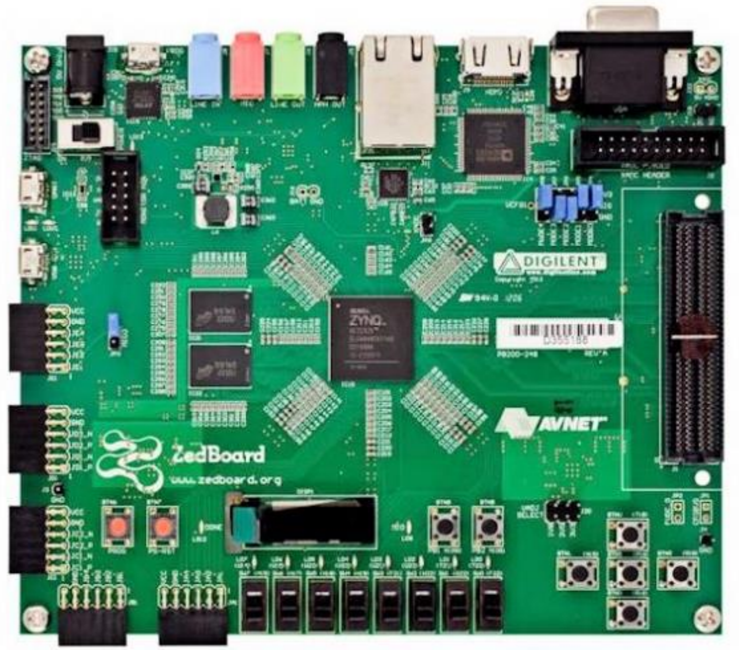




PDM Front-End Electronics (FEE) and Read-Out

- FEE PCB consists of 2 CITIROC ASICs (fast signal shaper) and two fast ADC devices
- PCB read-out, triggering and slow control is based on ARTIX 7 XILINX FPGA

ASTRI camera



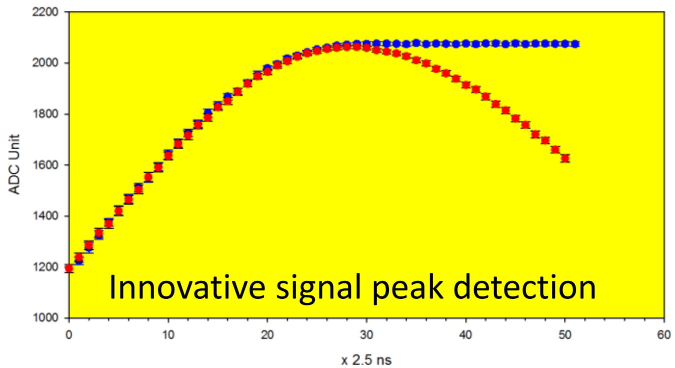
ZYNQ evaluation board

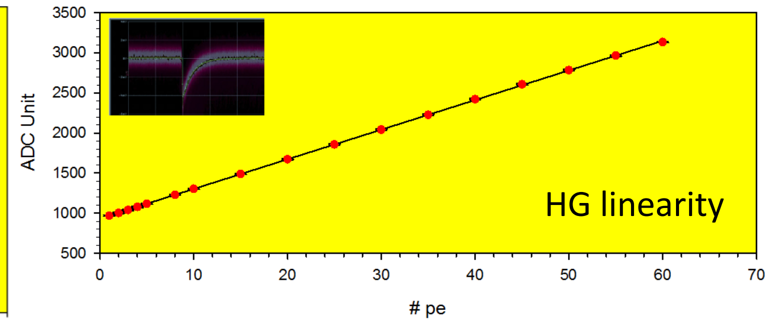
ASTRI ZYNQ PCB coming soon

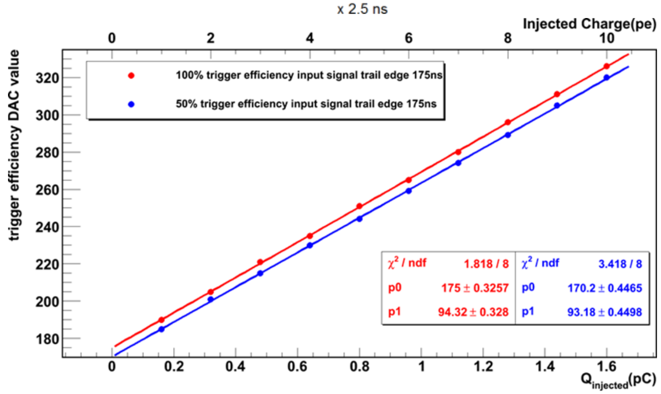
Back-End Electronics (BEE)

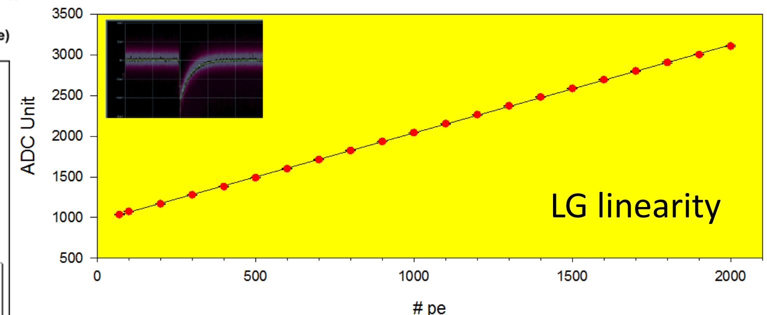
- BEE PCB is based on the powerful XILINX FPGA, ZYNQ-7000 (Dual ARM® Cortex™-A9 MPCore™ embedded)
- BEE manages the communication to/from the FEE and the external world

ASTRI camera





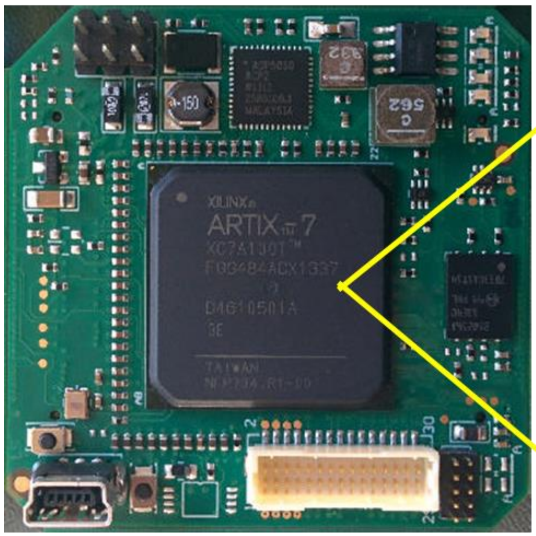




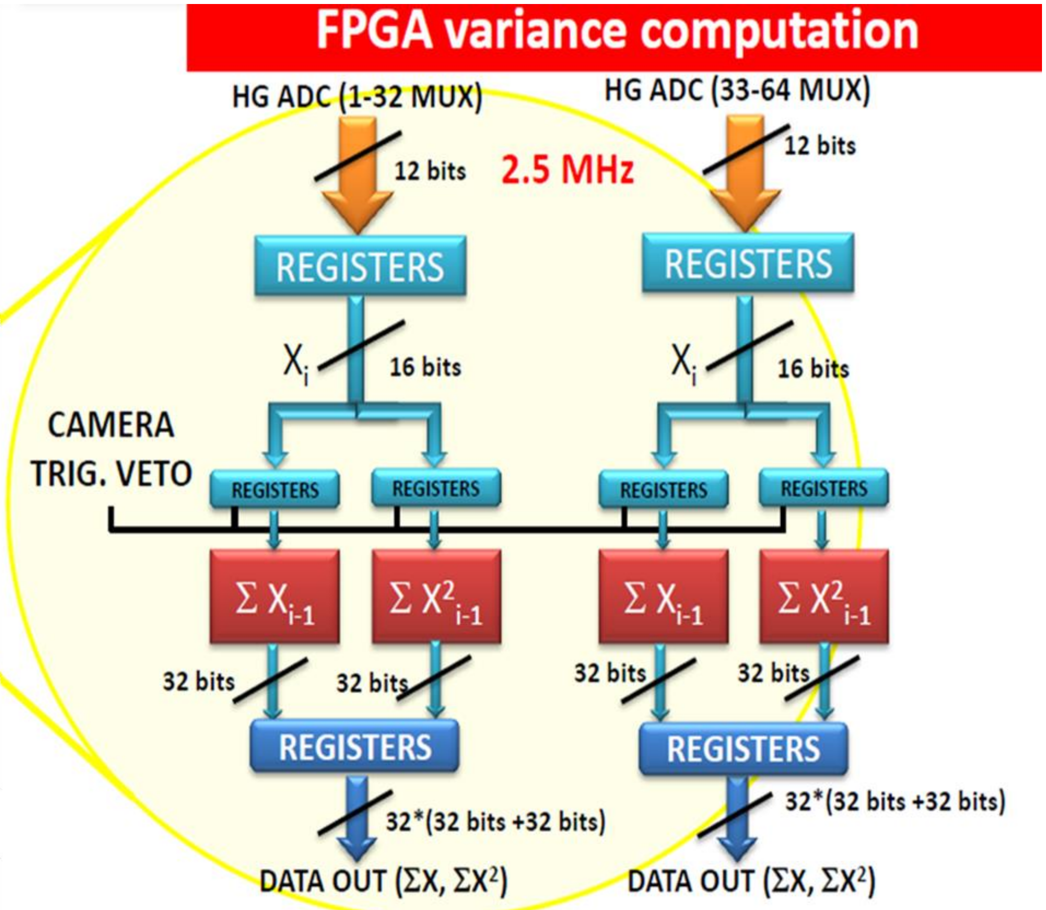
A bit of Performance

- Innovative signal peak detection implemented in CITIROC resolves Cherenkov image time gradient
- Dynamic range from 1 to 2000 pe
- Superb trigger linearity

ASTRI camera



algorithm implemented in the
Front-End FPGA

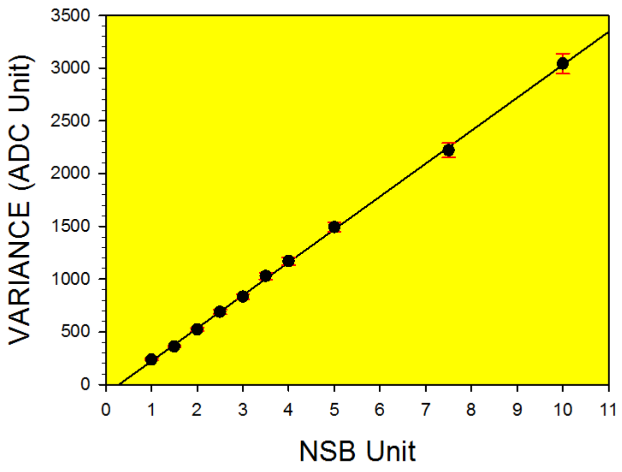


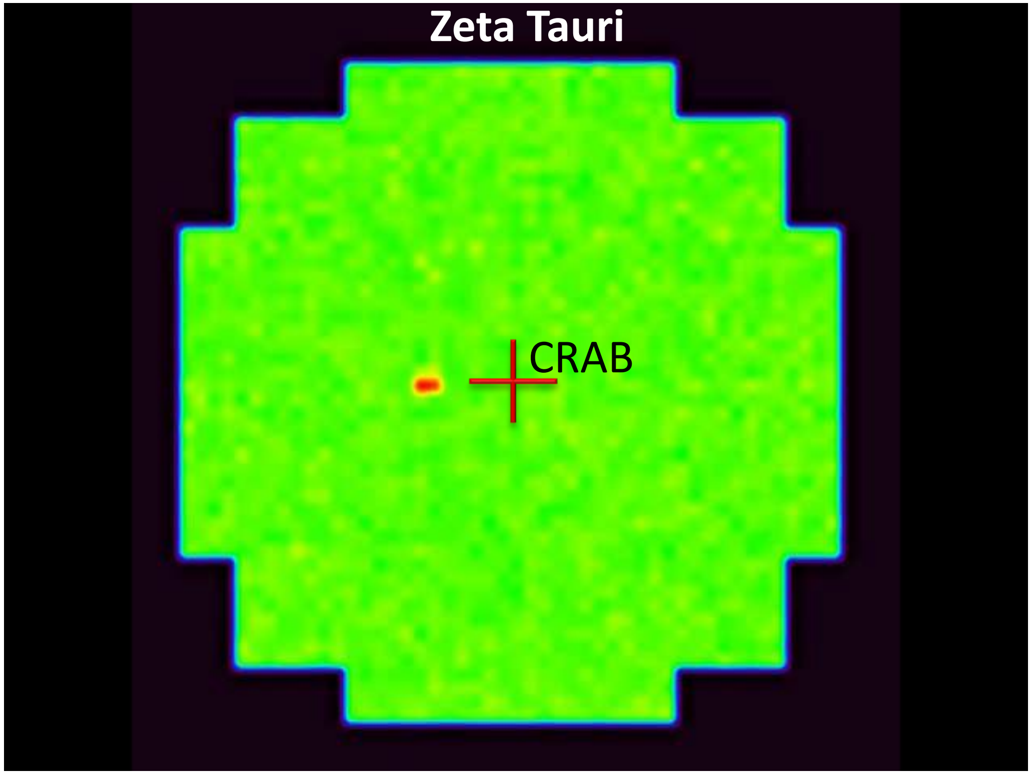
A bit of Performance

- AC coupling of Front-End prevents a direct measurement of the slow varying NSB flux. This can be computed from the baseline variance thus providing in real time the NSB flux, pixel by pixel, for the whole camera.

ASTRI camera

NSB unit = 22 MHz





A bit of Performance

- Variance simulated response

ASTRI site

The ASTRI SST-2M prototype will be installed at the INAF Facility on Mt. Etna (Sicily) at 1735m a.s.l.. The location altitude and the end-to-end approach will allow us to perform observations of the Crab, MKN 501 and MKN 421.

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- Dual-mirror concept
- Innovative sensors and electronics
- End-to-end approach

The ASTRI/CTA mini-array

- First CTA seed
- Synergies with other instrumental set-ups

Conclusions

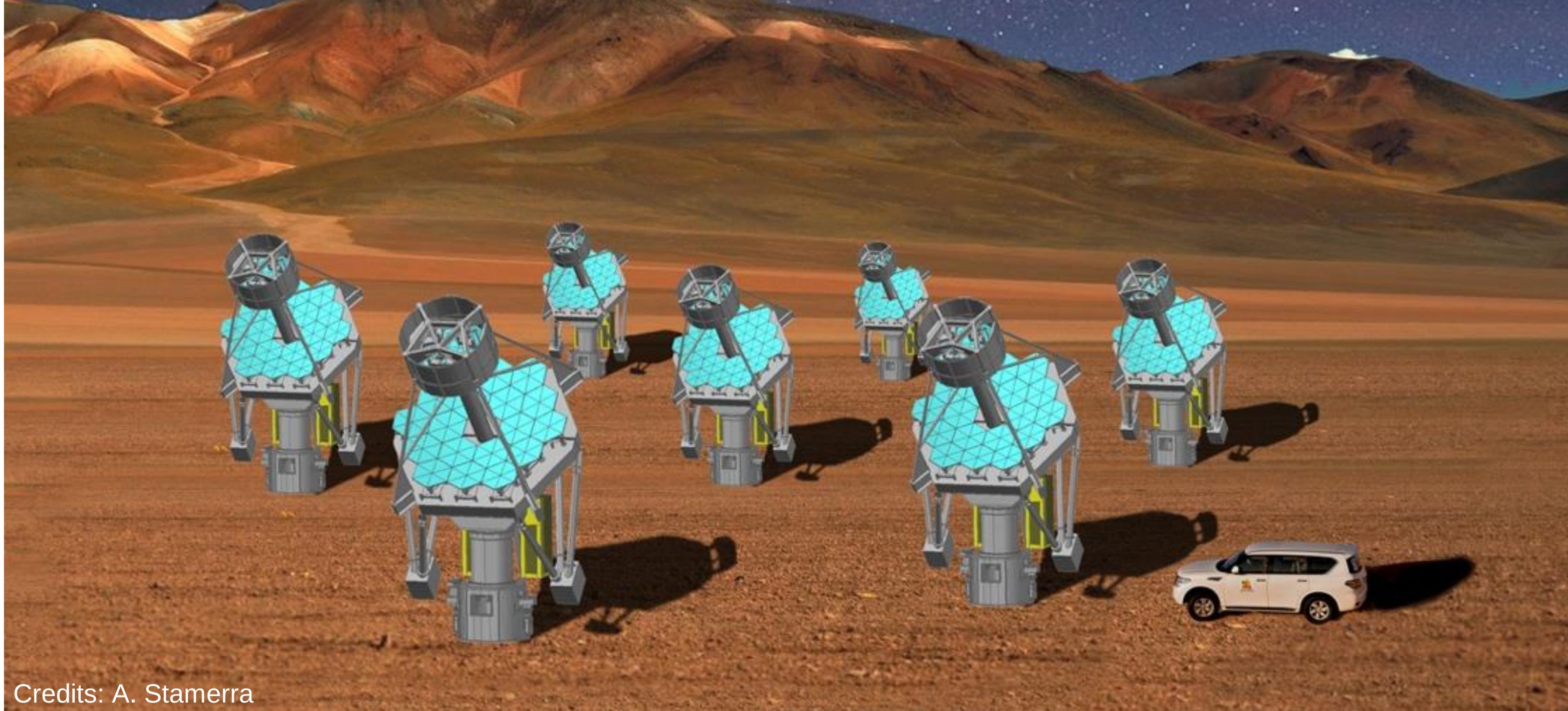
ASTRI/CTA mini-array

Led by the Italian National Institute for Astrophysics

Additional financial contributions from

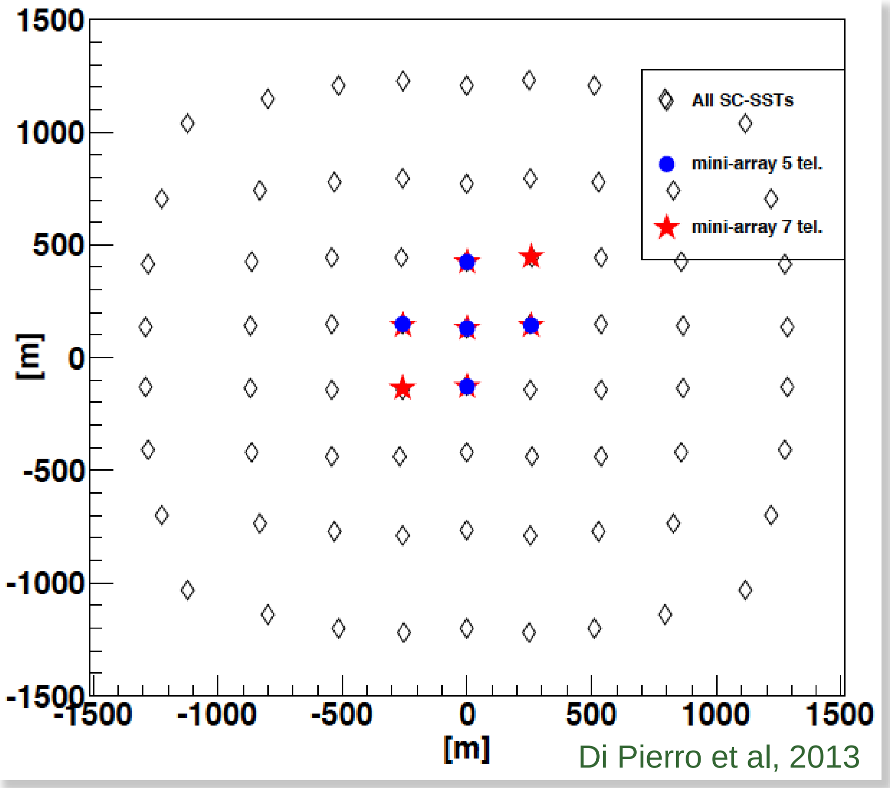
North-West University, Potchefstroom, South Africa

Universidade de São Paulo, Brazil



Credits: A. Stamerra

ASTRI/CTA mini-array



Di Pierro et al, 2013

Limiting flux

- comparable or slightly better than H.E.S.S. above a few TeV for an array composed by 7 telescopes

Angular resolution

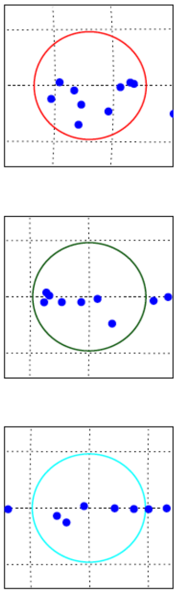
- a few (4-5) arcmin

Energy resolution

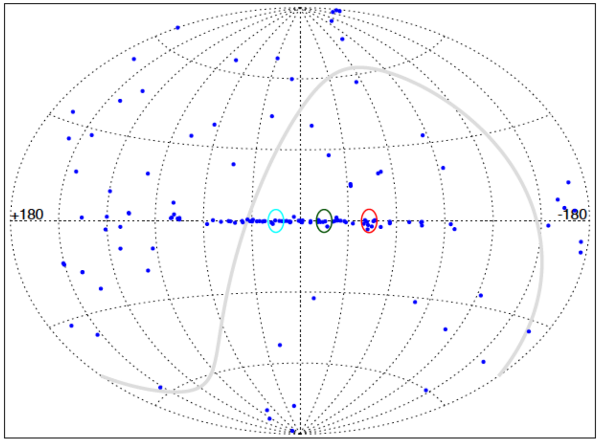
- of the order of 10-15 %

Wide field of view

Credits : Stefano Vercellone



TevCat Sources



Vercellone et al., 2013

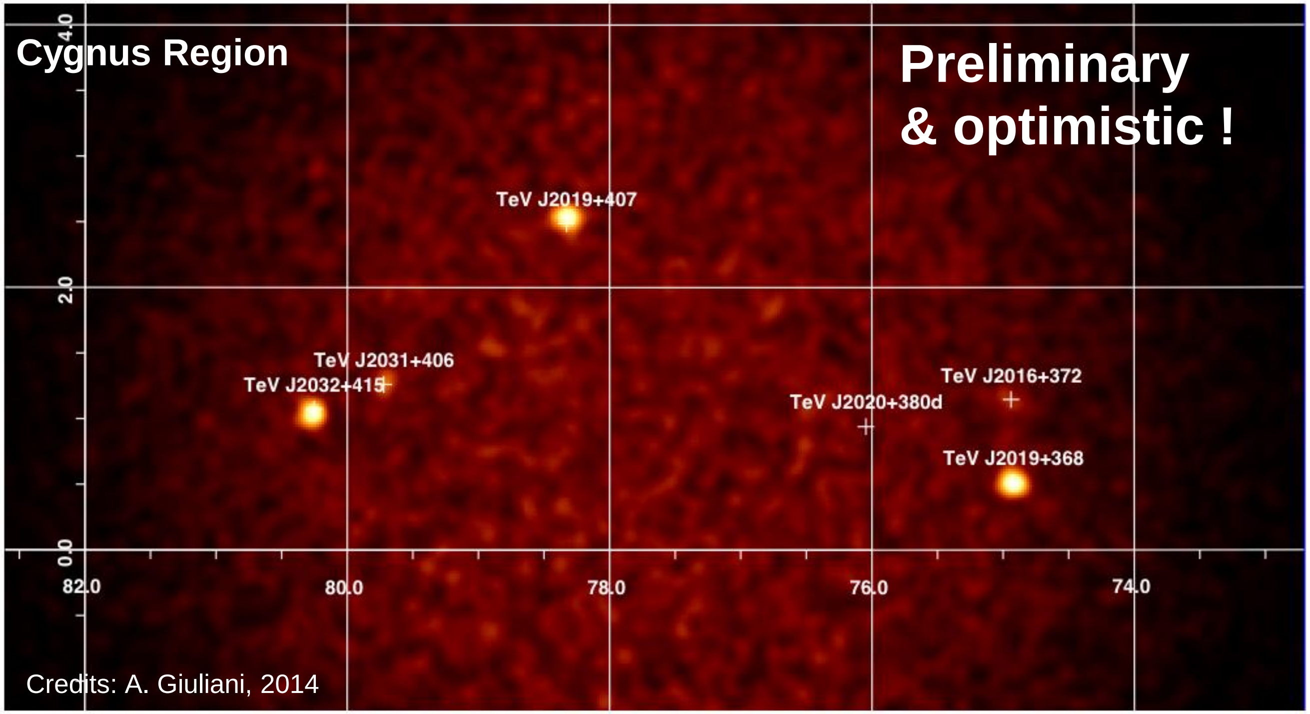
The ASTRI/CTA mini-array will have a larger field of view w.r.t. the current IACT ones.

Although the actual sensitivity will substantially drop for off-axis sources, a few targets can be monitored simultaneously.

- Close (angular distance < 3^o) and bright (about 10^{-12} erg cm^{-2} s^{-1} above a few TeV) sources can be observed pointing in a “smart” direction:
    - HESS J1825-137 & LS 5039
    - Vela-X & Vela Junior
    - RX J1713.7-3946 & HESS J1718-385.
- Detections of serendipitous strong flares (a few Crab units) from hard spectrum sources will be possible as well.
- Several GeV *Fermi*/LAT sources lie within the central region of each pointing.

Field of view simulations

Credits : Stefano Vercellone



- Preliminary ASTRI/CTA mini-array simulation of the Cygnus region.
- The simulation is centered on Galactic coordinates of (l,b) = (77.7, 1.0)
- Net observing time of 150 hours
- Energy greater than 3 TeV
- Source parameters (position, flux, spectral index) from ASDC

ASTRI/CTA mini-array

The ASTRI/CTA SST-2M mini-array can verify some array properties:

- **check of the trigger algorithms**
  - Preliminary MC simulations shows that a typical event will trigger a number O(5-7) of the whole CTA-SSTs sub-array.
- **check of the wide field of view performance**
  - by detecting VHE showers with the core at a distance up to 500m
- **compare the mini-array performance with the Monte Carlo expectations**
  - by means of deep observations of a few selected targets
- **do the first CTA science**
  - by means of a few solid detections during the first year

Synergies

Credits : Stefano Vercellone

- ***"Given the similar <u>sensitivities</u>, how to compare with H.E.S.S. ?"***
- CTA requires that at about 3º off-axis the sensitivity should be not less than half of the on-axis one. Therefore, we will have a better sensitivity at the edge of very extended sources (e.g. RX J 1713.7-3946). Moreover, we can check both technological aspects (e.g., PSF, off-axis sensitivity, etc...) and scientific ones (VHE emission at the very edges, spectral properties in different region of the source, etc...).
- We are free to choose just a few (2-3) targets and devote to them very long exposures, e.g. T>200-300 hr each target.
- Long exposures will help also for E-HBLs (e.g., KUV 00311-1938) in order to improve the determination of the possible hadronic origin of its VHE emission by means of detections at E > 10TeV.
- We extend our sensitivity above 10 TeV and beyond, a never-explored energy range by IACTs.

Synergies

Credits : Stefano Vercellone

- ***"Given the similar <u>energy range</u>, how to compare with HACD ?"***
- The lower imaging energy threshold of current and future HACD (~100 GeV) and the wider energy range of the ASTRI/CTA mini-array (beyond 10 TeV) will allow a direct comparison of scientific data (spectra, light-curves, integral fluxes) of those sources which could be monitored simultaneously (e.g., Crab Nebula, MKN 421 [at high ZA], MGRO J1908+06).
- The region near the Galactic Center will be accessible by both the ASTRI/CTA mini-array and future EAS. Thanks to the wide field of view of the ASTRI/CTA mini-array (9.6^o in diameter) a large portion of the sky will investigated simultaneously.
- The high-energy boundary of both EAS and the ASTRI/CTA mini-array will allow to study the VHE (E>10 TeV) emission from extended source such as SNRs and PWN, and to investigate the presence of spectral cut-offs.

Conclusions

- **CTA will be a 10-fold improvement** in sensitivity for VHE studies, an analogous to the advance from EGRET to Fermi/LAT.

- **The ASTRI SST-2M prototype**, will be inaugurated on September 2014 during the CTA Consortium Meeting in Sicily, and will perform the first Crab observations with a Schwarzchild-Couder telescope equipped with SiPMs in 2015.

- **The ASTRI/CTA mini-array** will constitute a seed for the whole CTA array, allowing us to investigate innovative technological solutions.

- **CTA early science** performed by means of ASTRI/CTA mini-array observations of a few selected targets will allow us to obtain a few solid detections during the first year.

- **Excellent synergies** with ground- (e.g., HAWC, LHAASO, …) and space-based (*Fermi*, *Swift*) observatories from 2016 and beyond.

Thank you !