

# THE SMALL SIZE TELESCOPE PROJECTS FOR CHERENKOV TELESCOPE ARRAY

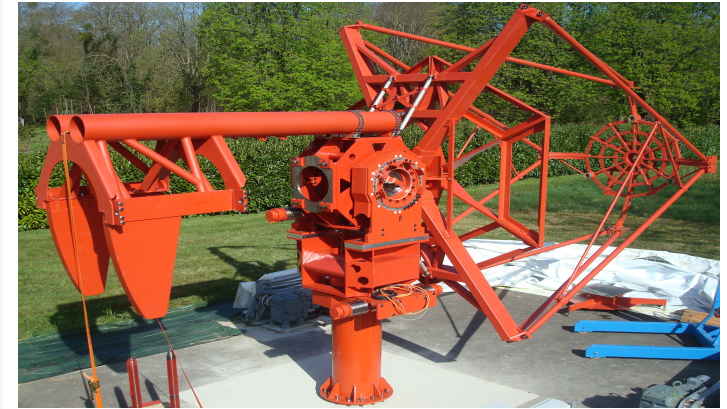


[Teresa.Montaruli@unige.ch](mailto:Teresa.Montaruli@unige.ch) for the CTA Consortium

SST-1M, Krakow since Nov. 2013

ASTRI, Serra la Nave, Mt. Etna,  
Sicily since Aug. 2014

GCT, Observatoire Paris, Meudon, since Apr.  
2015



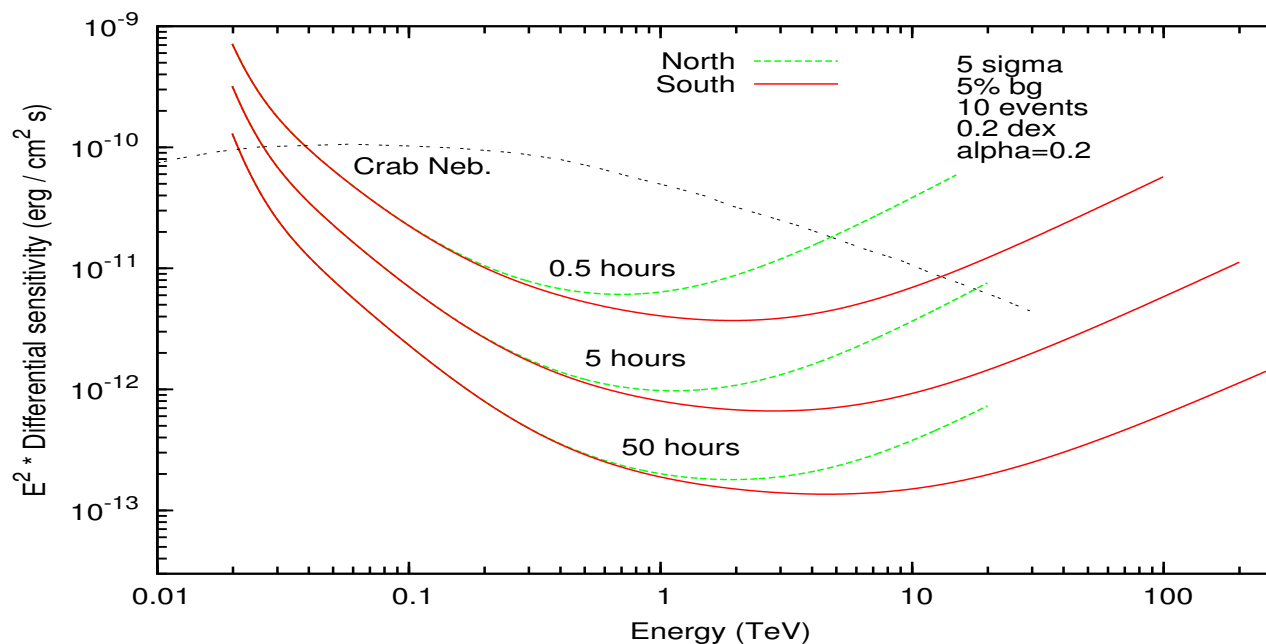
3 designs with associated prototypes proposed for the CTA array:

- A Davies-Cotton telescope with single mirror - SST-1M
- Two dual-mirror Schwarzschild-Couder telescopes: SST-2M **ASTRI** (Astrofisica con Specchi a Tecnologia Replicante Italiana) and **GCT** (Gamma-ray Cherenkov Telescope)

# REQUIRED AND GOAL SENSITIVITY

- Energy range 3-300 TeV
- SST sensitivity  $\geq 2$  (1.5) x full array required sensitivity above 10 (100) TeV
- Goal collection area of the Southern array  $> 7 \text{ km}^2$  for  $E > 100 \text{ TeV} \Rightarrow$   
telescopes at distances of the order of 220-250 m

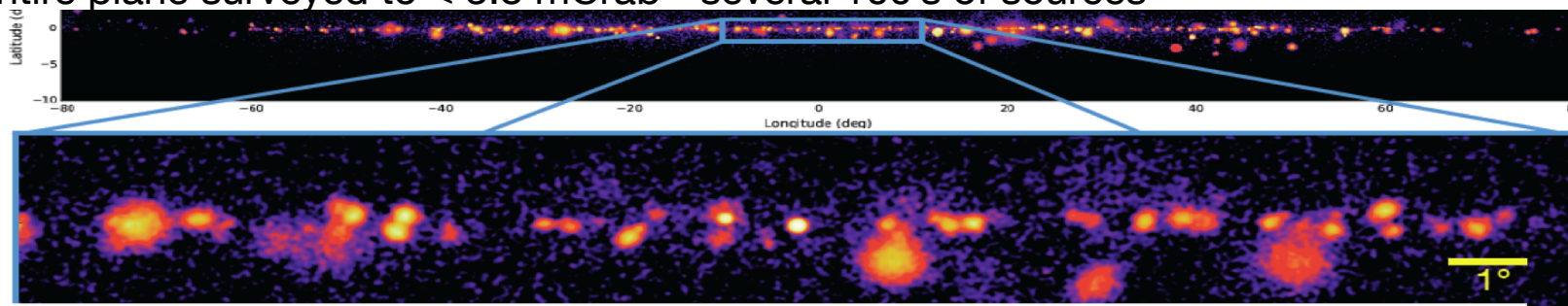
70



# CTA SST SCIENCE



Entire plane surveyed to  $< 3.8$  mCrab - several 100's of sources



## ■ Previous Surveys

1 mCrab =  $5.07 \times 10^{-13}$  photons  $\text{cm}^{-2} \text{s}^{-1}$  above 125 GeV

Experiment	Hemisphere	Galactic Plane Coverage	Energy (GeV)	Sensitivity (mCrab)
H.E.S.S.-I	S	$-70^\circ < l < 60^\circ,  b  < 2^\circ$	$> \sim 300$	10 – 30
VERITAS	N	$67^\circ < l < 83^\circ, -1^\circ < b < 4^\circ$	$> \sim 300$	20 – 30
ARGO-YBJ	N	Northern Sky	$> 300$	240 – 1000
HEGRA	N	$-2^\circ < l < 85^\circ,  b  < 1^\circ$	$> 600$	150 – 250
Milagro	N	Northern Sky	$> 10,000$	300 – 500

## ■ Present/future Surveys

Planned surveys: Galactic plane,  
LMC, 1/4 of the sky

Observatory	Hemisphere	Energy Threshold	Angular Resolution	Pt. Source Sensitivity
CTA	N, S	125 GeV	$\sim 0.10^\circ$ at 300 GeV	2 – 4 mCrab
HAWC	N	2 TeV	$0.30^\circ$	20 mCrab

# FLUX SENSITIVITY

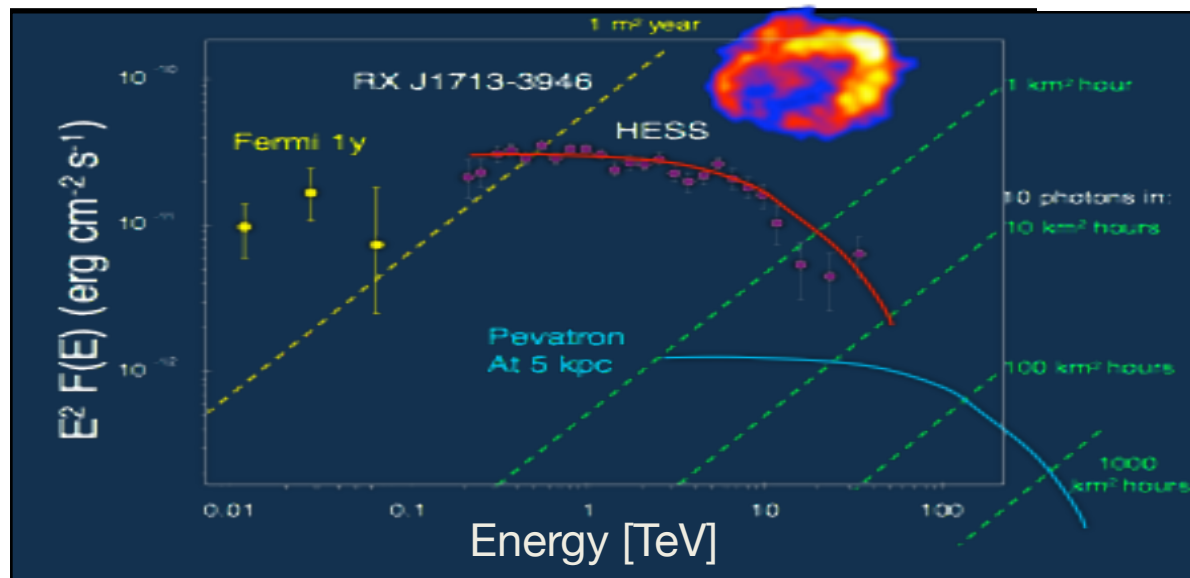
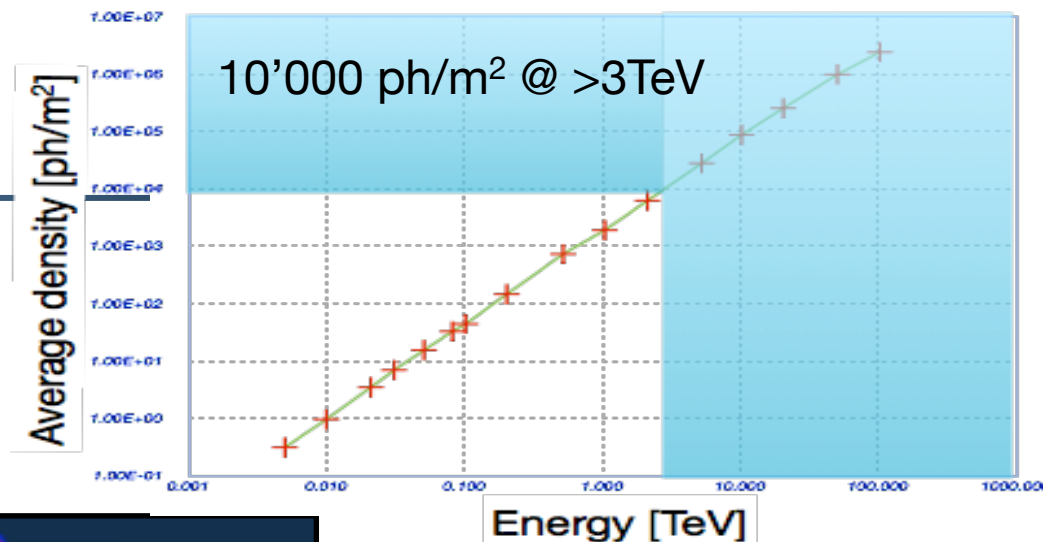
Single Telescope

**High Energy**  $\Rightarrow$  **High photon density**  $\Rightarrow$  **Small**

**Dish area**  $\sim 4\text{m}$

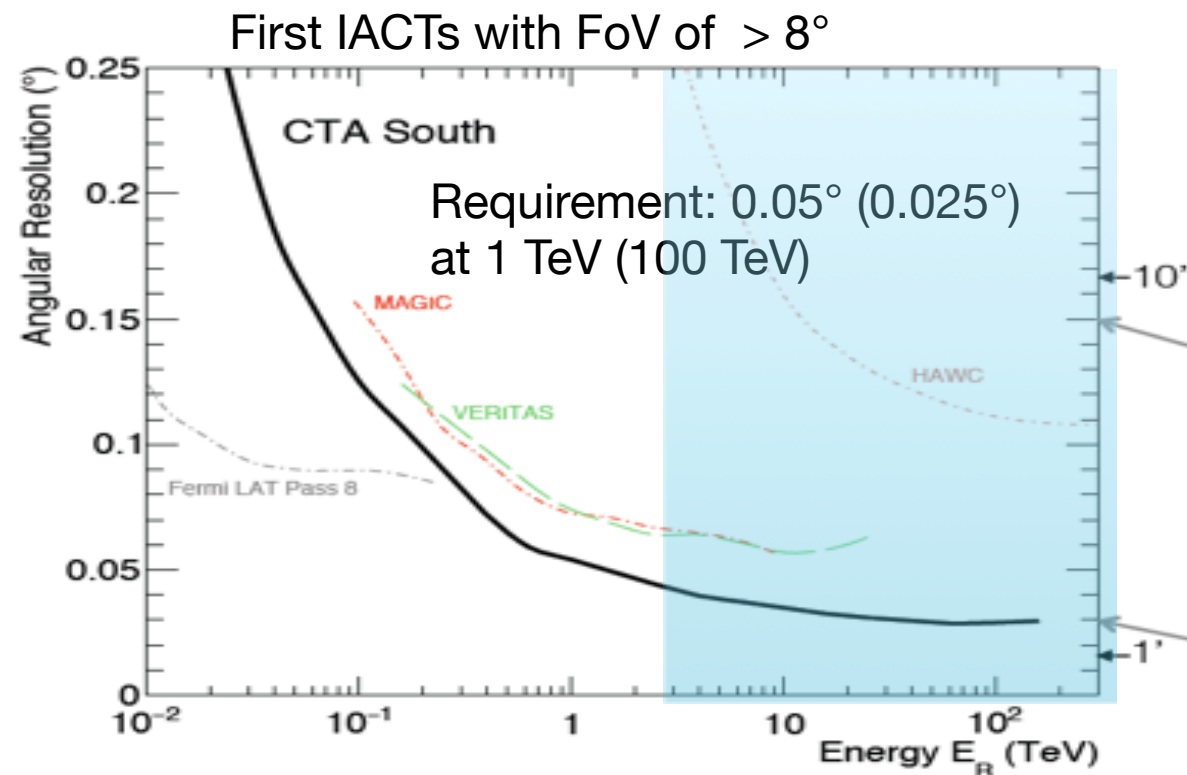
Array of Telescopes

**Shower footprint**  $\Rightarrow$  **Array collection**      **area**  $\Rightarrow$   
**number of telescopes**  $\sim 70$



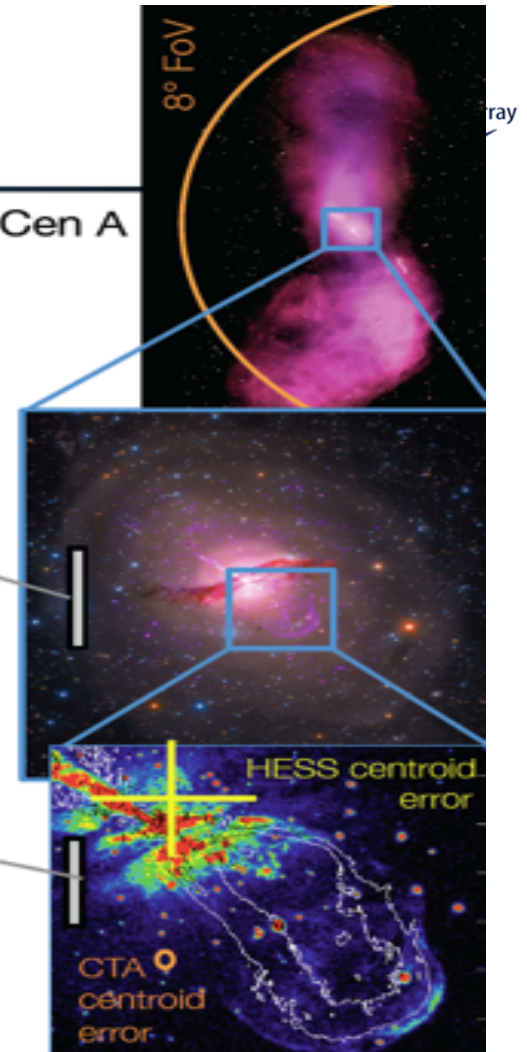
In 50 h, the spectrum above 60 TeV of a PeVatron flux ( $\sim 10^{-12}$  ph/TeV/cm<sup>2</sup>/s, spectral index -2, -2.2) will be reconstructed with an error <10%

# ANGULAR RESOLUTION AND FOV



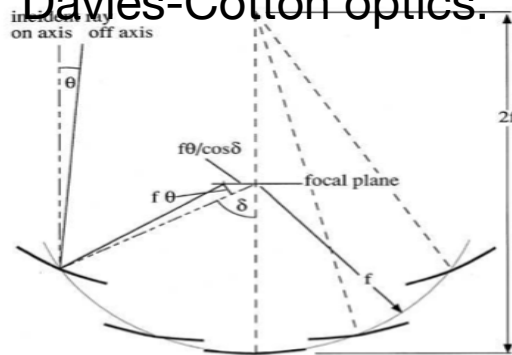
\*Event selection optimised for point-source sensitivity not resolution, significantly better resolution possible at the expense of collection area

e.g. Cen A

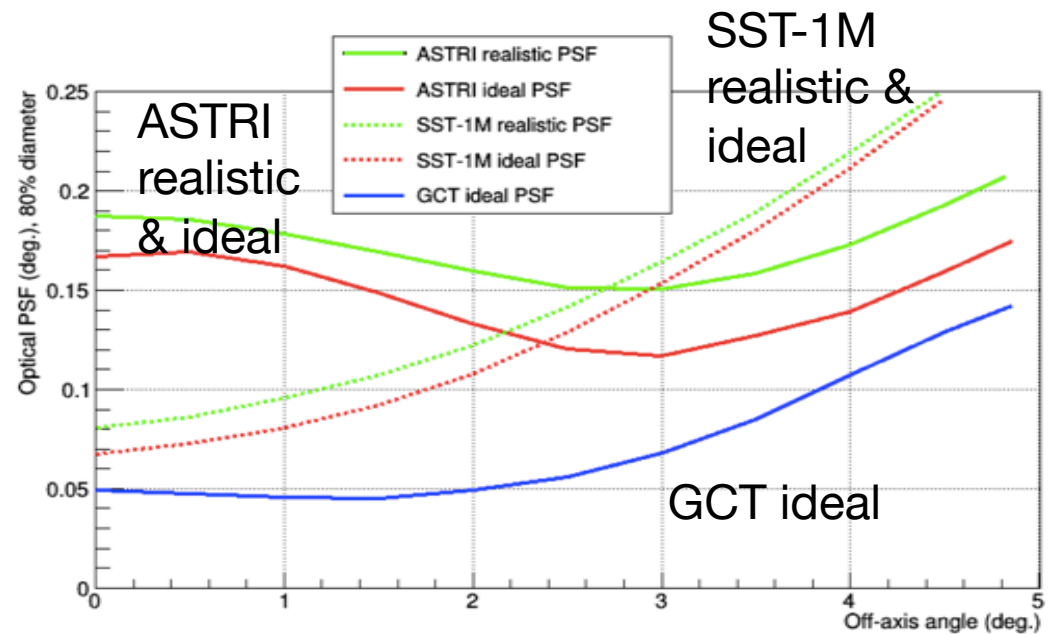
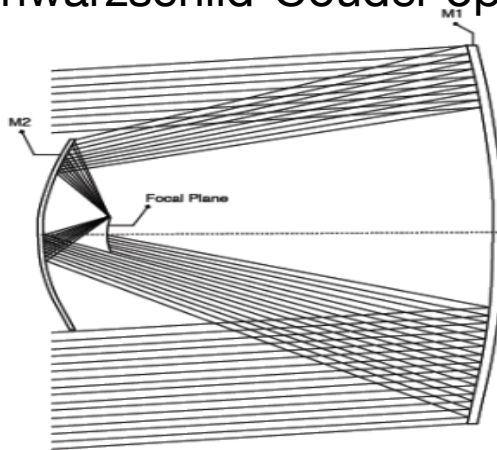


# OPTICAL DESIGN AND OPTICAL PSF

Davies-Cotton optics.



Schwarzschild-Couder optics.

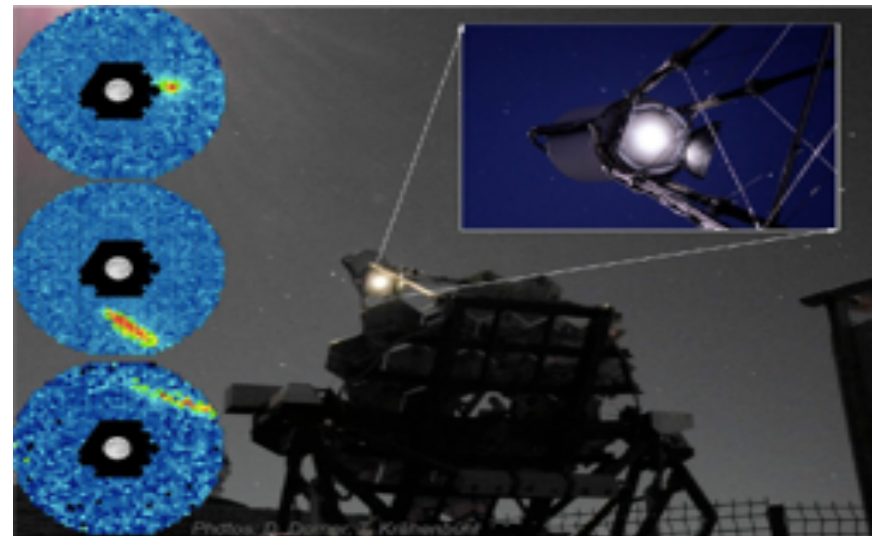


Optical PSF from ray-tracing

# SILICON-BASED CAMERAS



- New technology in Imaging Cherenkov Astronomy, envisaged by E. Lorenz and applied by FACT;
- robust and stable;
- self calibrating;
- cost-effective;
- high photo-detection efficiency, low x-talk sensors, dark noise few 10 kHz;
- 30% additional exposure thanks to operation with high Moon;
- photosensor sizes available are suitable for SST cameras of diameter of 40-90 cm with 1300-2200 channels;
- uniform and mass producible.

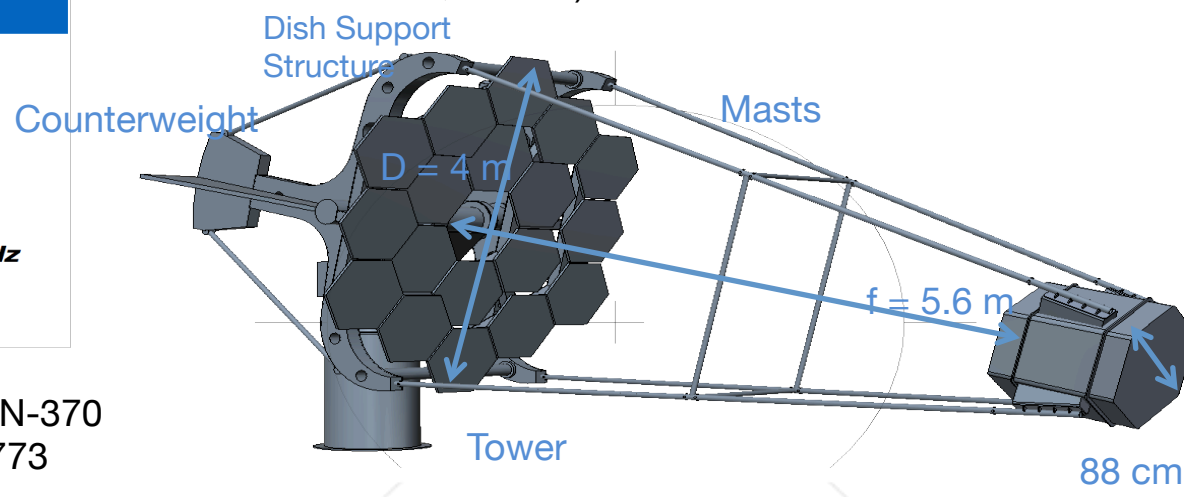


FACT can operate at full Moon  
with 5 GHz/pixel Night Sky  
Background (NSB);

# THE SST-1M PROJECT



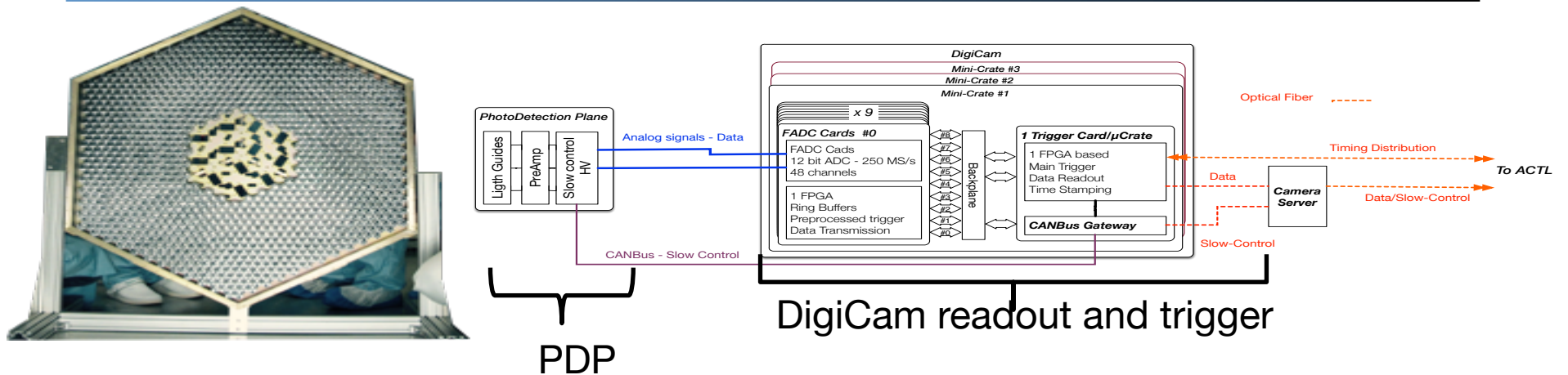
OPTICAL PROPERTIES	
Focal Length	5.6 m
Dish Diameter	4 m
Mirror Effective area (after shadowing & mirror TX)	6.47 m <sup>2</sup>
Mirror Facet Size (flat-to-flat)	780 mm
RMS of optical time spread	<0.24 ns
MECHANICAL PROPERTIES	
Elevation range	-16-97°
Azimuth range	±280°
Drive speed (min,max)	1-4000 rpm
Oscillation Modes	2.8/3.4/3.8 Hz
Total Weight	8.6 tons



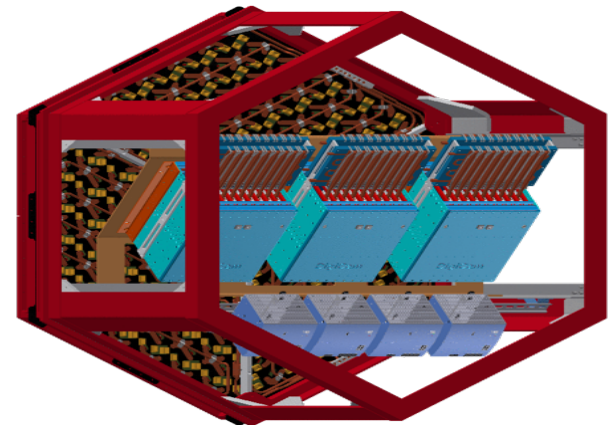
J. Niemiec et al, telescope structure, GA-IN-370

K. Seweryn et al., optical system, GA-IN-773

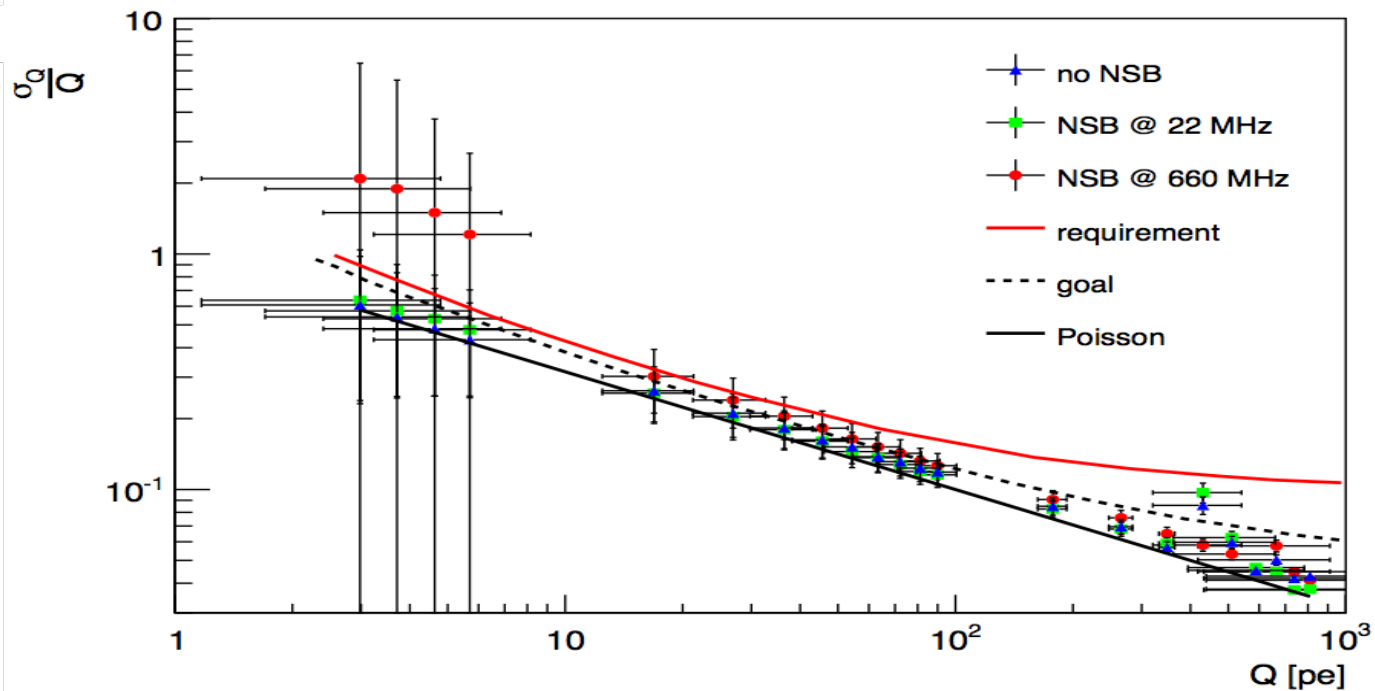
# CAMERA



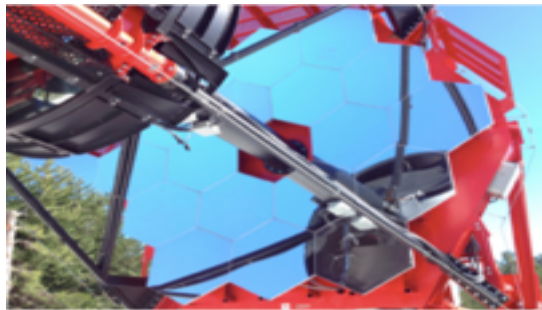
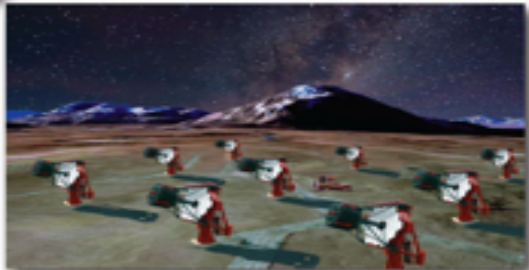
E. Schioppa et al, PDP, GA-IN-65  
P. Rajda et al., DAQ and Trigger (DigiCam), GA-IN-78



# CAMERA PERFORMANCE



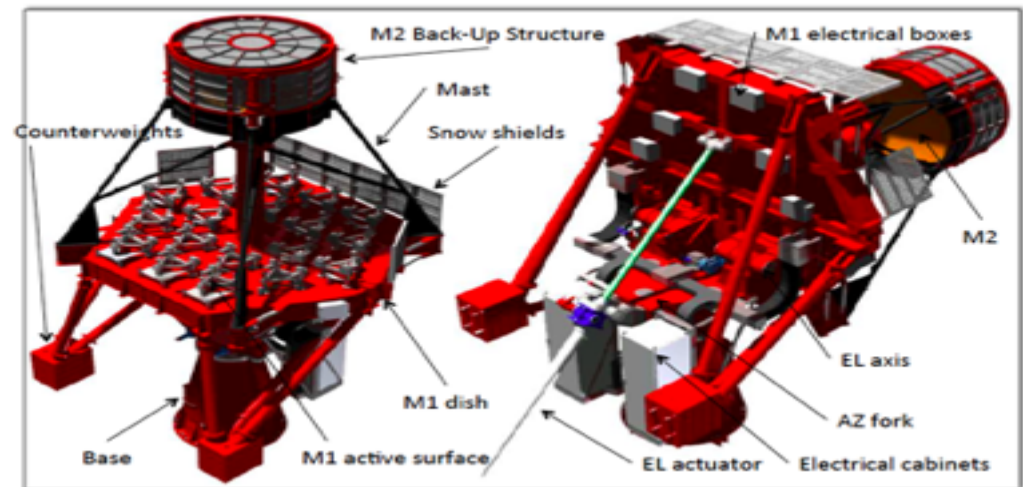
Charge resolution with different NSB  
660 MHz =  $\frac{1}{2}$  moon at  $5^\circ$  from camera.  
22 MHz: dark night



**ASTRI** Astrofisica con Specchi  
a Tecnologia Replicante Italiana



Initial operations with prototype are ongoing

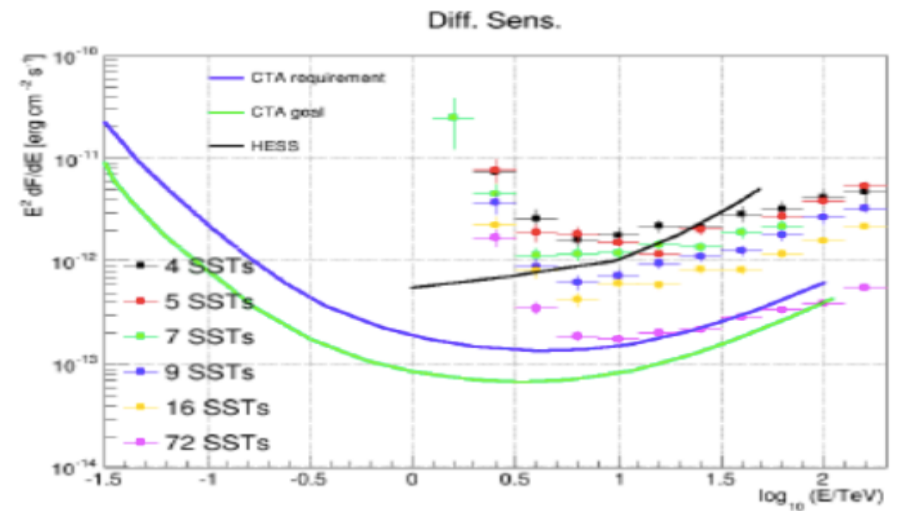
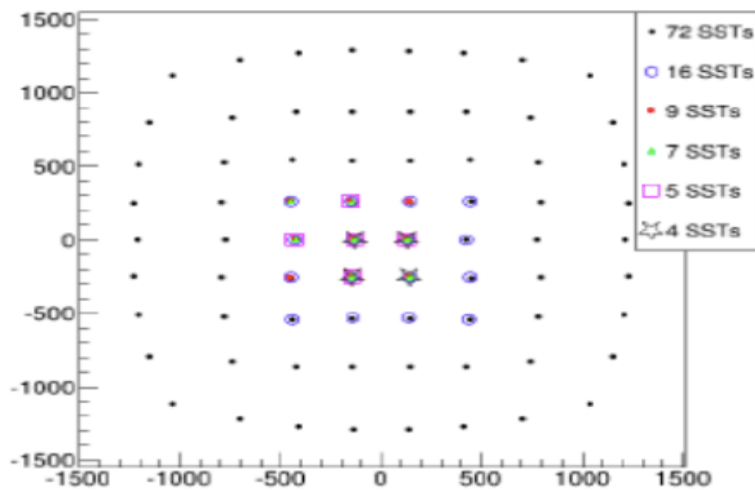


Next step is the deployment of a mini-array of 9 SST-2M and the production will contribute 21 more telescopes

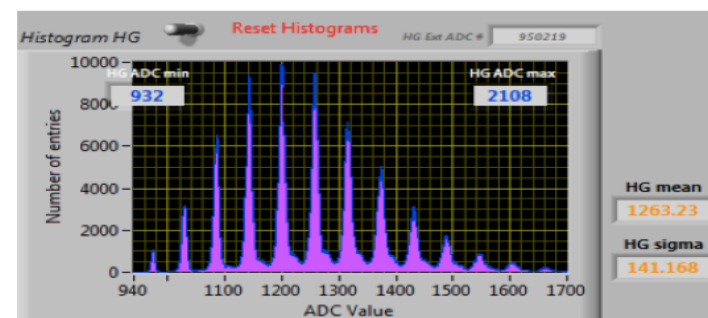
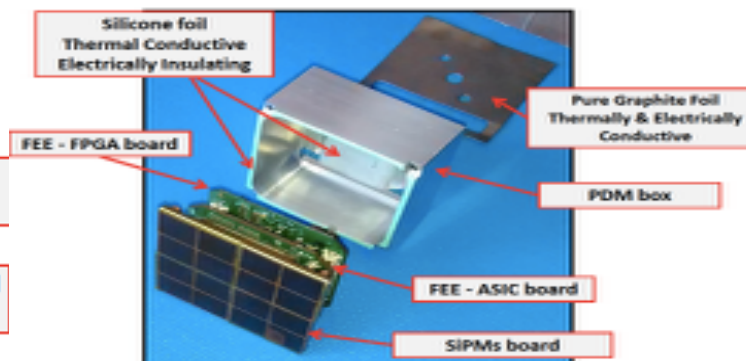
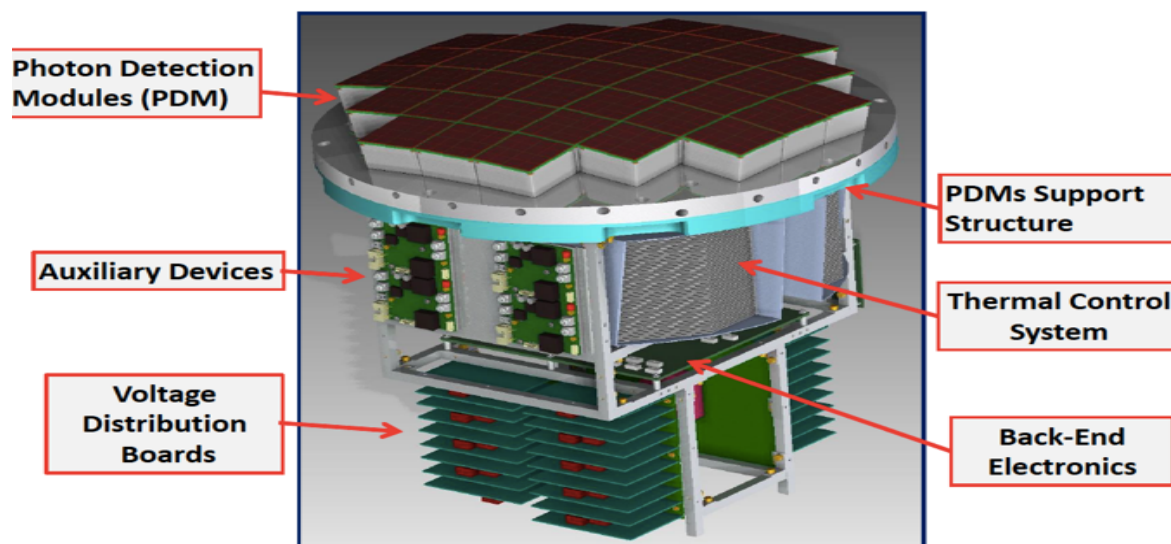
# MINI-ARRAY PERFORMANCE



Simulations indicate that the mini array sensitivity will be already better than H.E.S.S. above 1 TeV

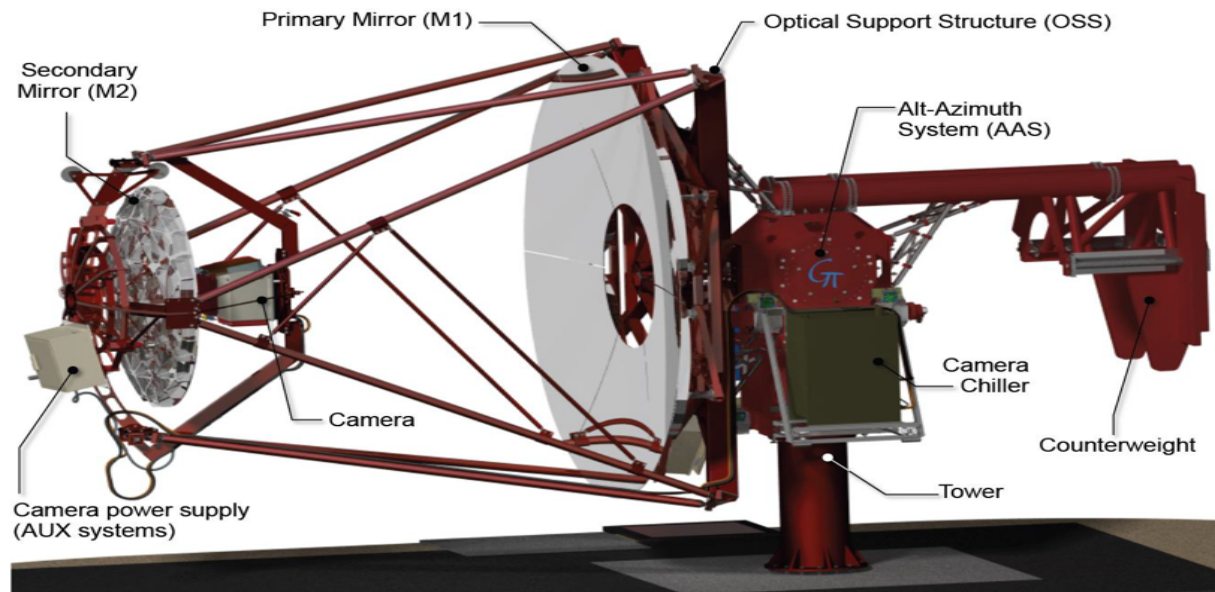


# ASTRI CAMERA

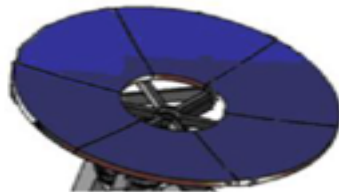
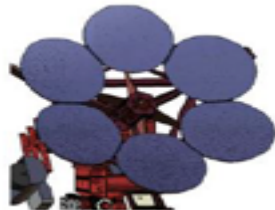


**Hamamatsu: Low-Crosstalk LCT1-B**

# THE GAMMA-RAY CHERENKOV TELESCOPE (GCT)

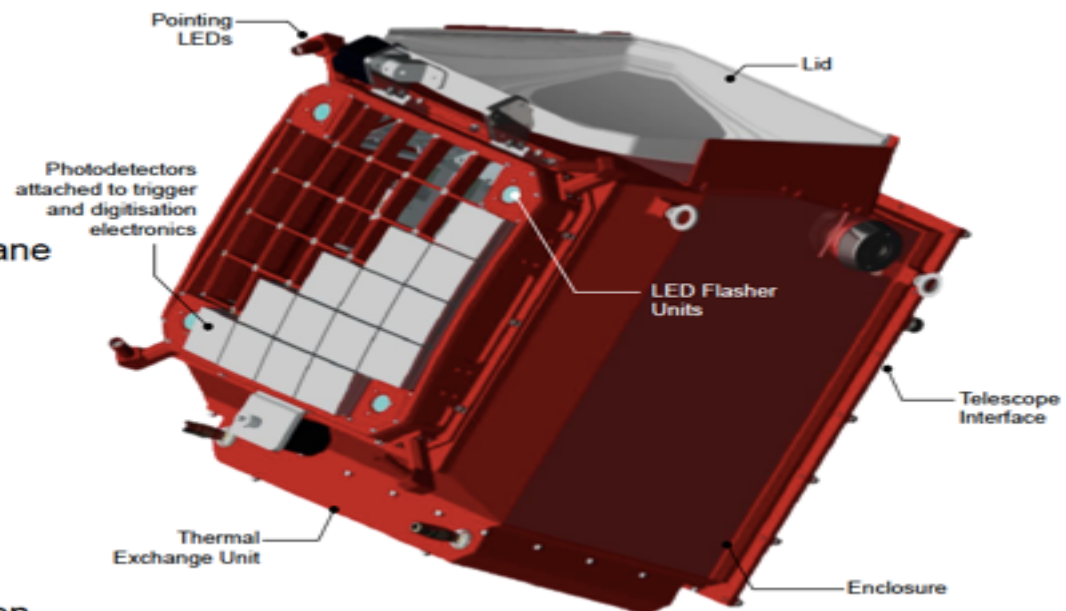


- Schwarzschild-Couder optics.
- Alt-Az mount.
- Designed for ease of manufacture, assembly and maintenance.
- Compact camera with full waveform readout and low cost.
- Overall width  $\times$  height 5.4 m  $\times$  8 m.
- Total mass 7.8 tons.

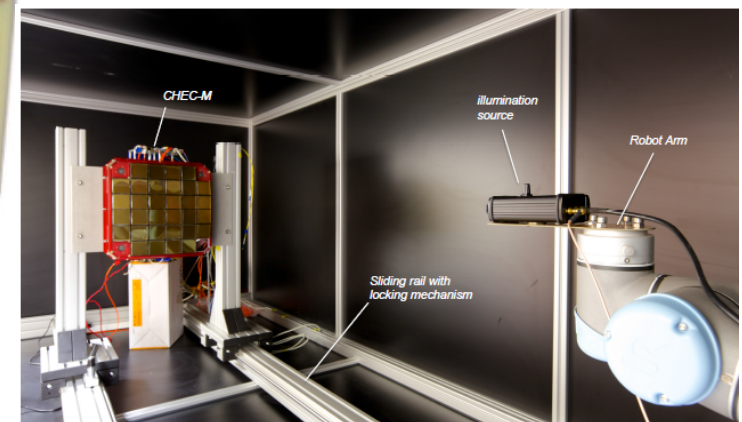
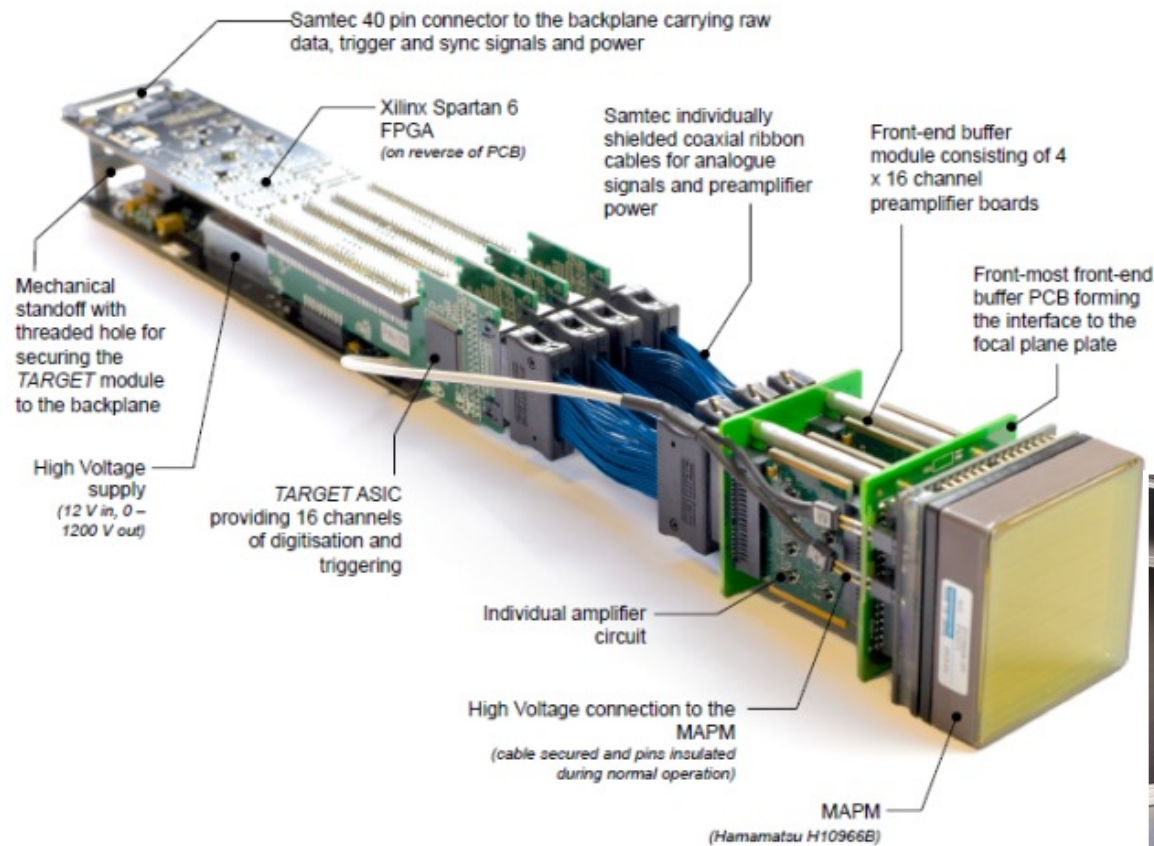


# GCT CAMERA

- 2048 pixels of size  $6 \times 6 \text{ mm}^2 \dots 7 \times 7 \text{ mm}^2$  ( $0.15^\circ \dots 0.2^\circ$ ).
- Readout/front end trigger TARGET ASIC (1 Gs/s, 12 bits), 32 modules.
- Camera trigger via Backplane PCB/FPGA.
- Dimensions  $0.35 \times 0.35 \times 0.5 \text{ m}^3$ .
- Mass 45 kg.
- Power 450 W.
- MAPM/SiPM versions (CHEC-M/CHEC-S) under test/construction.
- Incorporates LED calibration flasher units.



# TARGET MODULE



# CONCLUSIONS: SST ARRAY STRATEGY



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The SST array will operate in the discovery region above 50 GeV with unprecedented sensitivity. It is extremely powerful for VHE surveys.

Multiple SST designs increase prototyping effort which is a very instructive process and essential for first implementations of new technologies (dual mirror and SiPM).

Projects will provide  $> 20$  telescopes each to CTA.

Develop as many common systems as possible.

- Similar foundations for all SSTs

- Common HW and SW Drives

- Cameras can be interchanged between ASTRI and GCT SST-2M

- Working towards common telescope control hardware and software.

Strategy will minimize SST infrastructure and operation cost.



31 Countries  
194 Institutes  
>1200 Members