The SST-1M Project of the Cherenkov Telescope Array: Status and Physics perspectives

Matthieu Heller
DPNC - Université de Genève
On behalf of the SST1M Consortium and CTA consortium

28th Texas Symposium on relativistic astrophysics, 13-18 December 2015, Geneva, Switzerland

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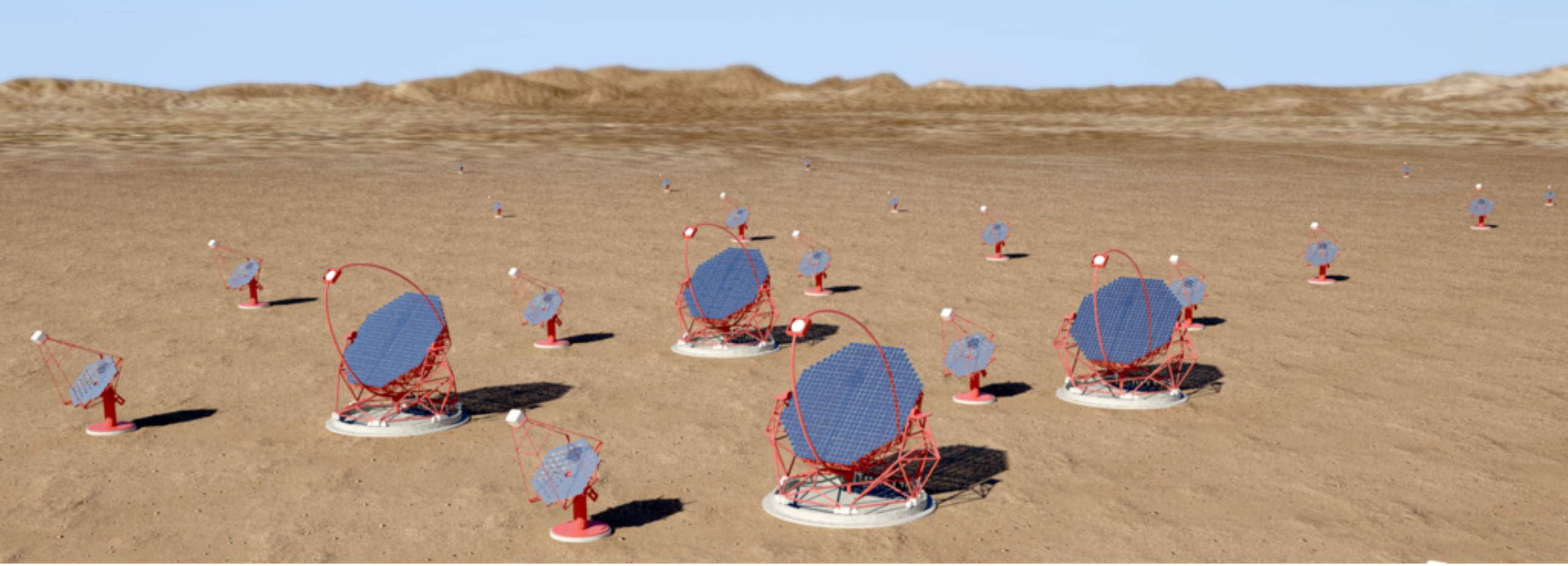
Outline

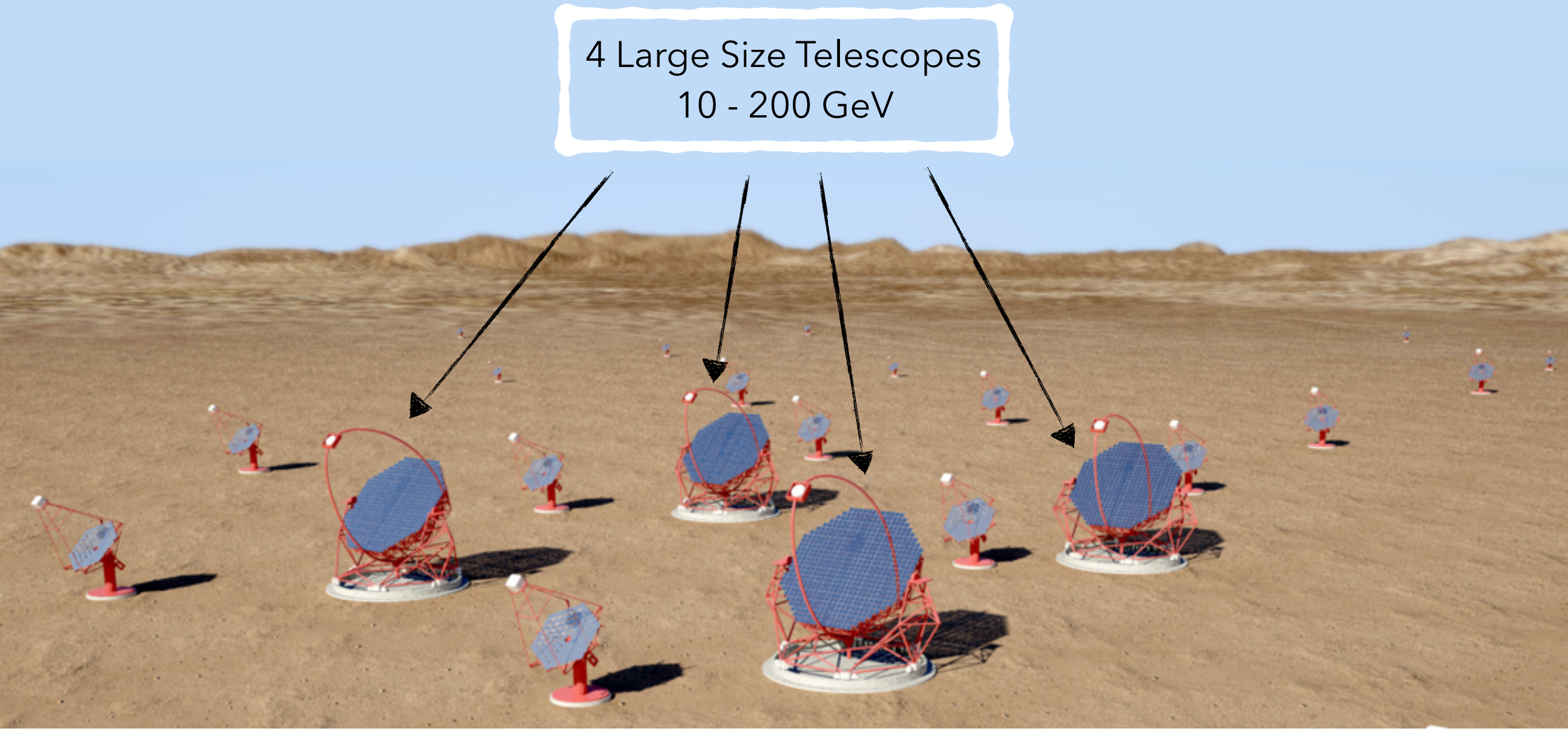
- The Cherenkov Telescope Array (CTA)
- The Single Mirror Small Size Telescope (SST-1M) project
- SST-1M performances
- Physics perspectives

The Cherenkov Telescope Array

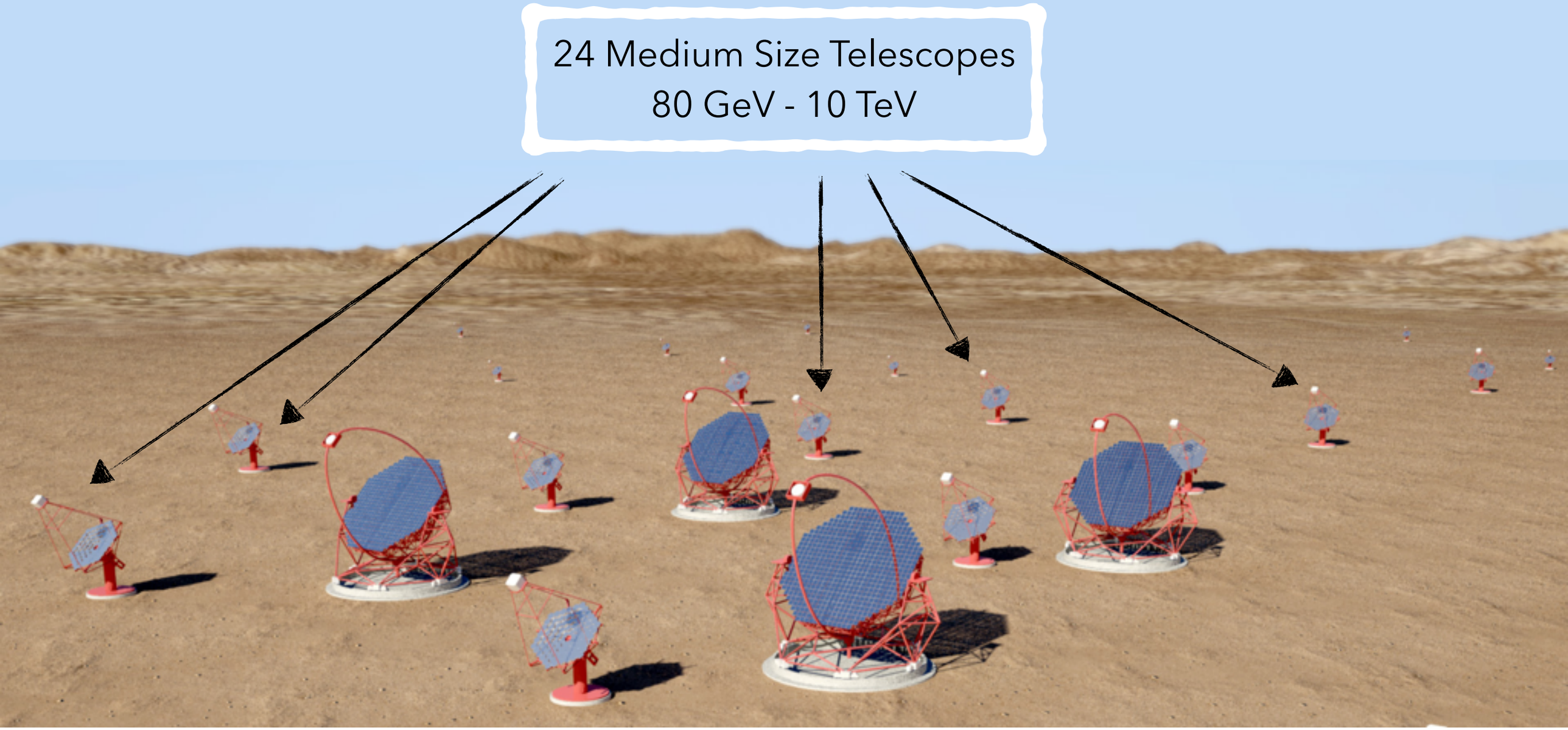
- **A user facility / proposal-driven observatory**
  - With two sites with a total of >100 telescopes
- **A 27 nation project**



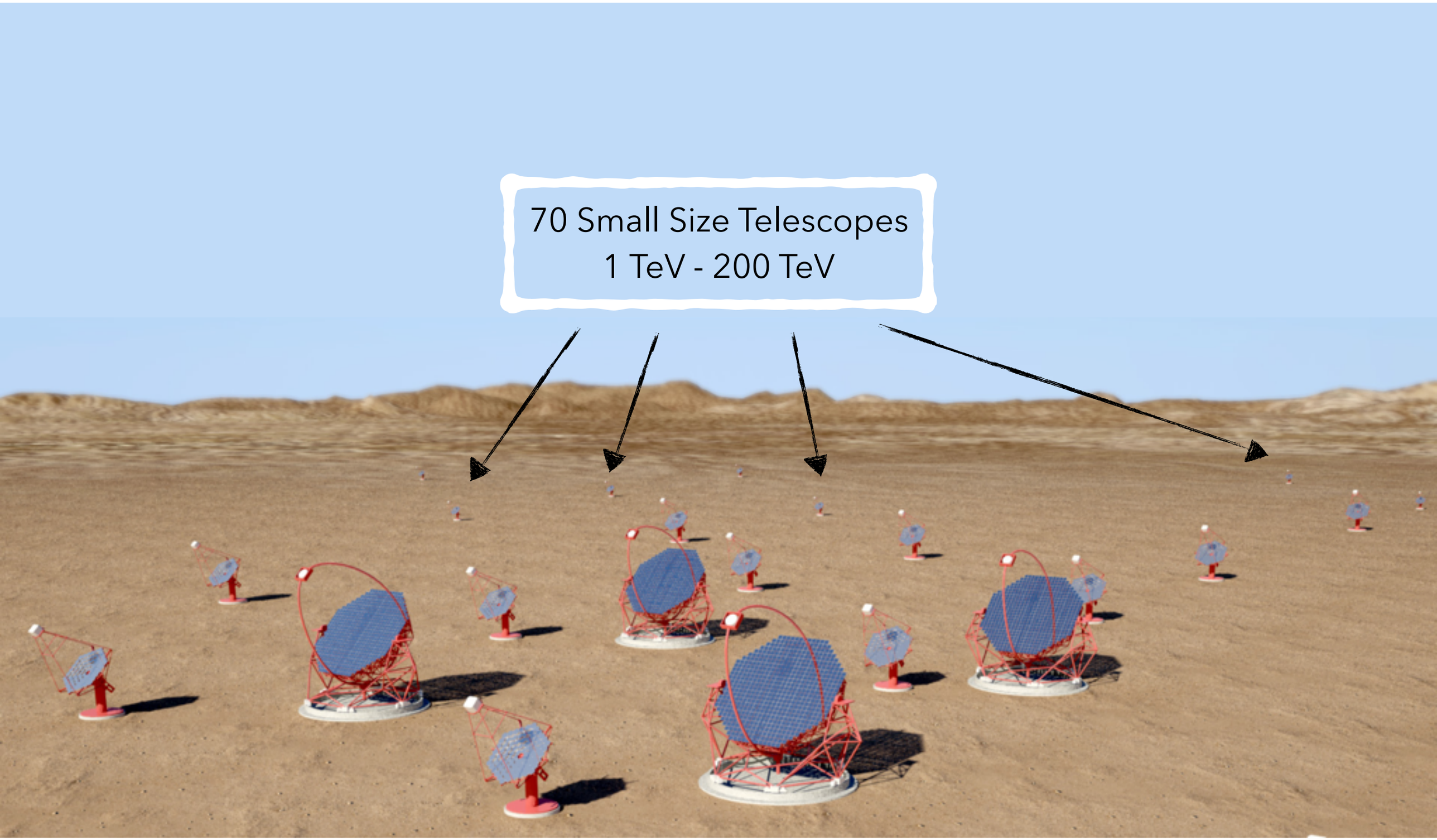
The Cherenkov Telescope Array



The Cherenkov Telescope Array



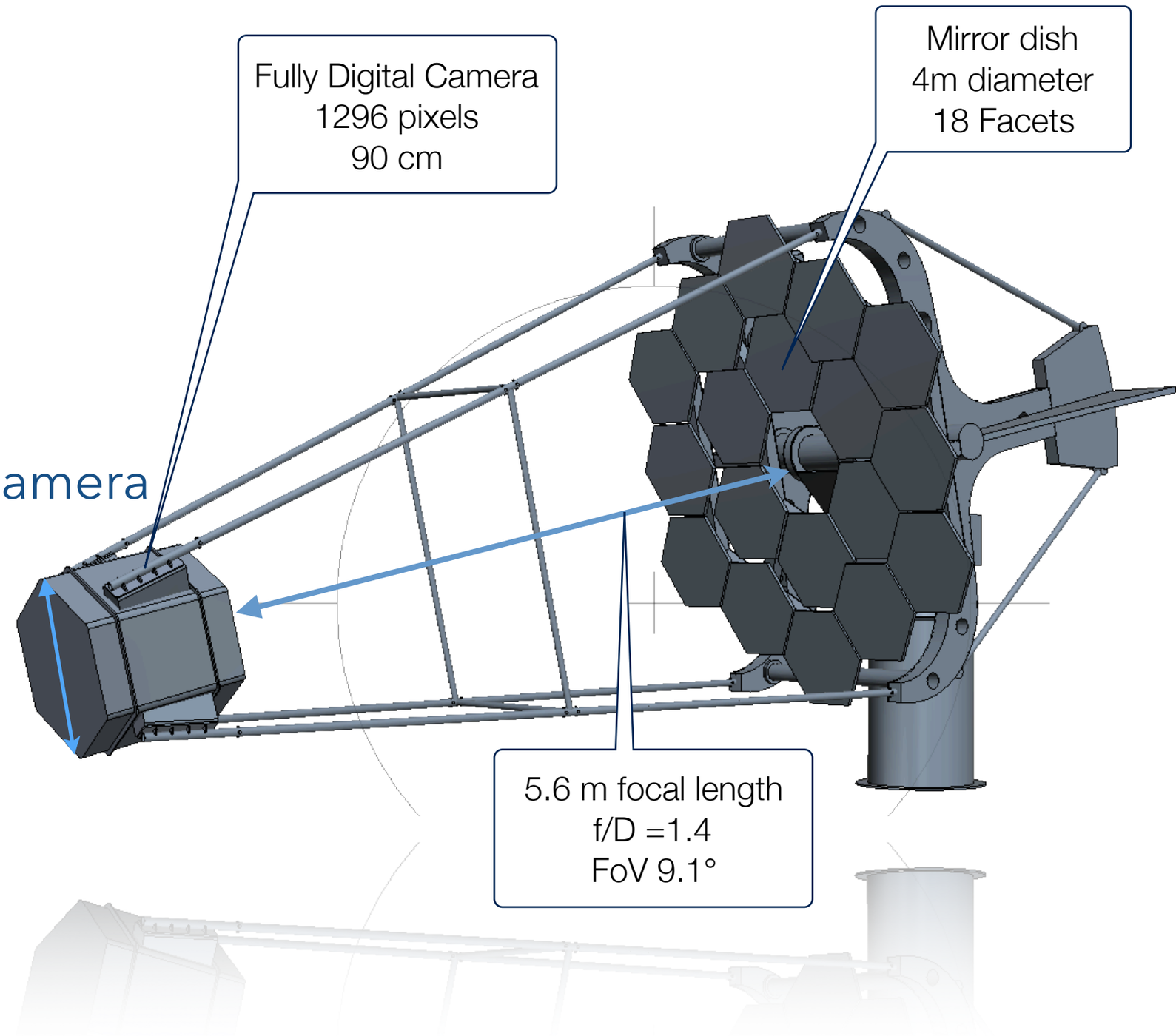
The Cherenkov Telescope Array



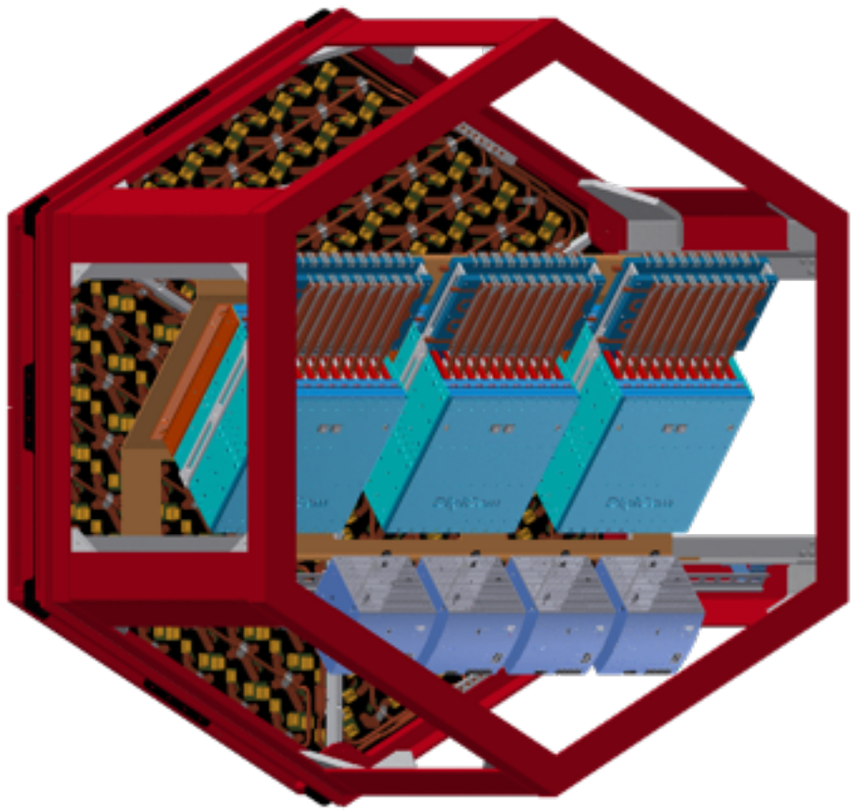
The Single Mirror Small Size Telescope project

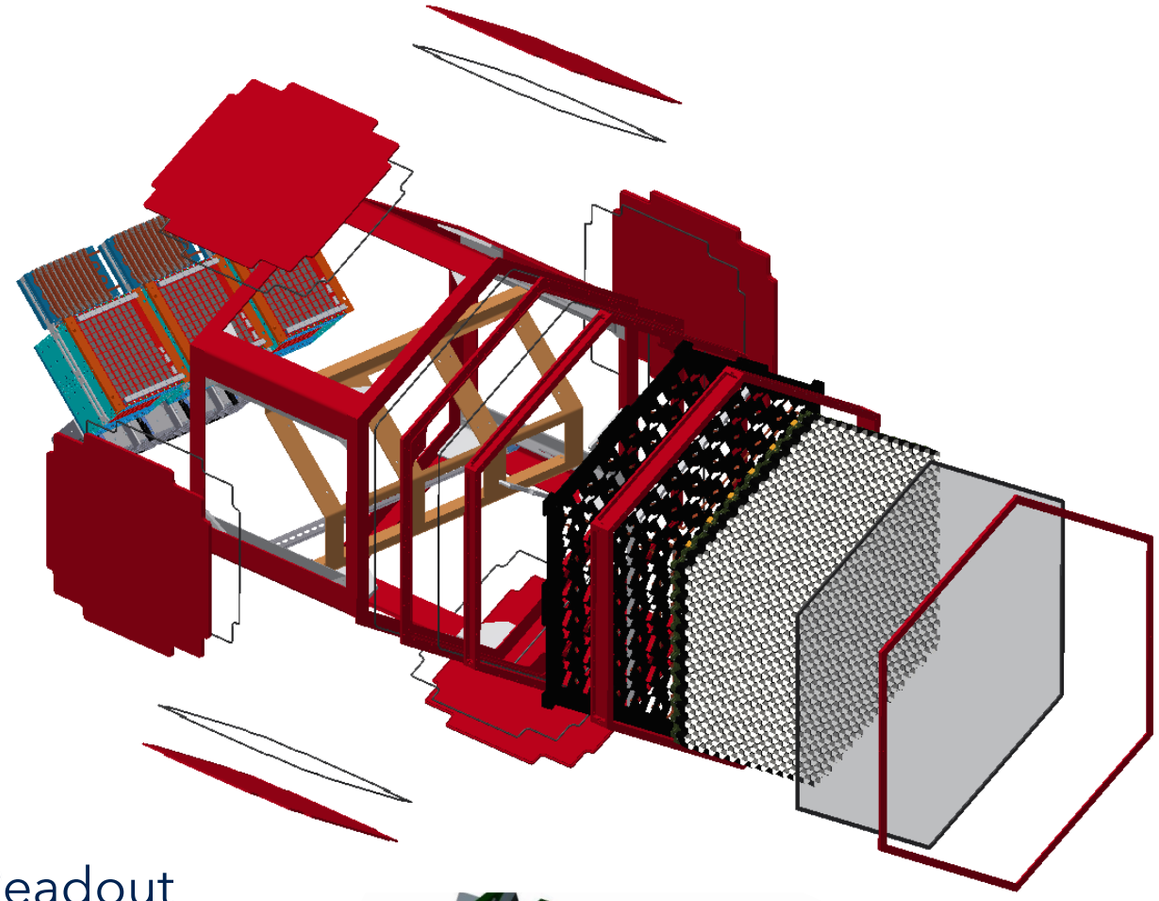
The SST-1M telescope concept

- Davies-Cotton Design
  - Low Cost
  - Easy Installation
  - Easy maintenance
  - Lightweight ~ 8.6 t
  - Innovative SiPM based camera
  - Fully digital readout

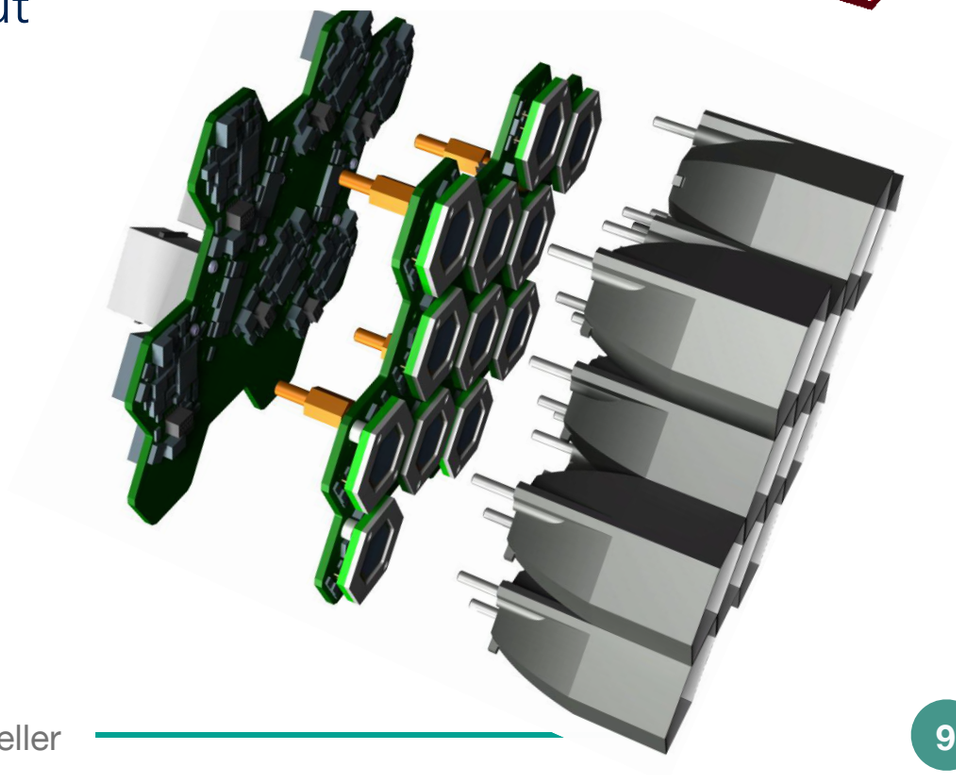


The SST-1M camera concept





- **Separation** of Photo Detector Plane and Digital Readout
  - Separate mechanics and power supplies
  - **Analogue signals**
  - DC coupling for Night Sky Background monitoring
- Window and chassis sealed
- **Water cooled** - Heat pipes on Digital board
- Compact, robust, lightweight and self-contained



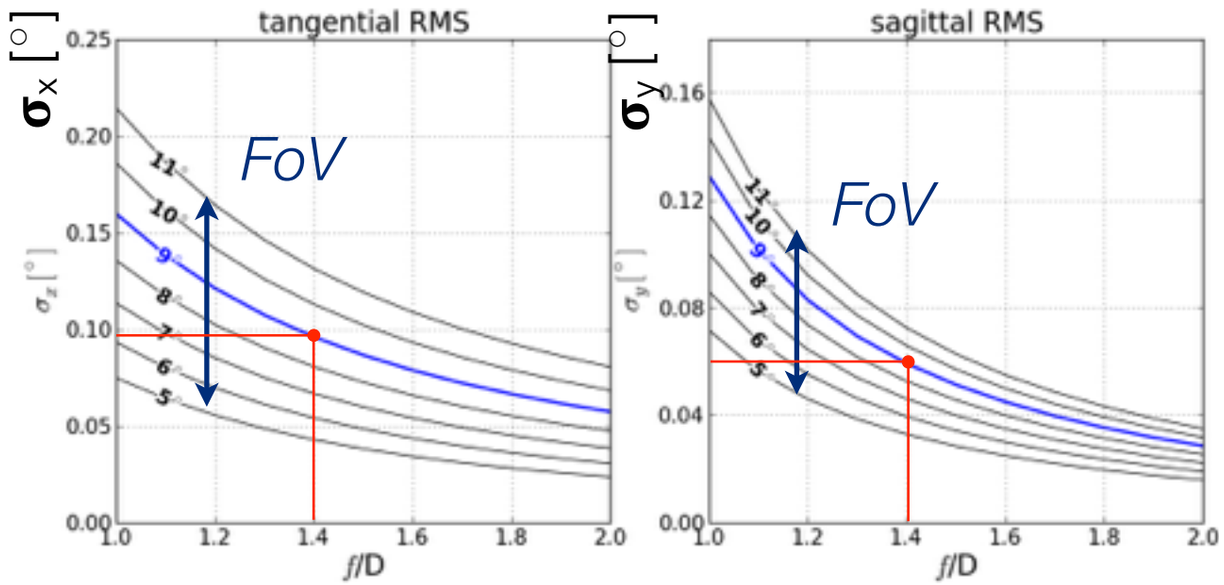
Optical design and Optical PSF

Conditions:

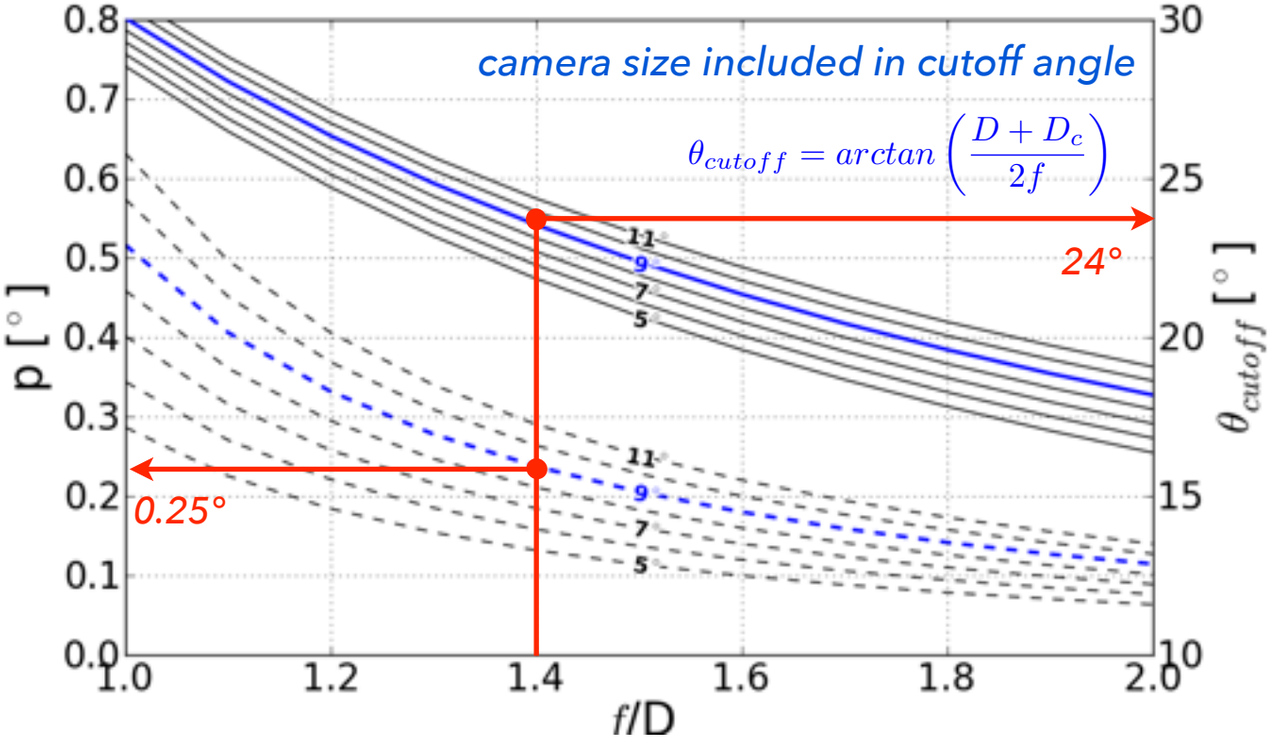
- Dish = 4 m → *energy threshold*
- FoV = 9° → *explore the galactic center*
- f/D = 1.4 → *suitable angular resolution*

- **pixel size** = 4· min(σ_x, σ_y) = 0.25°
- **pixel size (linear)** = 2.44 cm
- n_p = 1296 pixels
- **Camera size** (D_c) = 88 cm

Vassiliev et al. [arXiv:astro-ph/0612718v2]



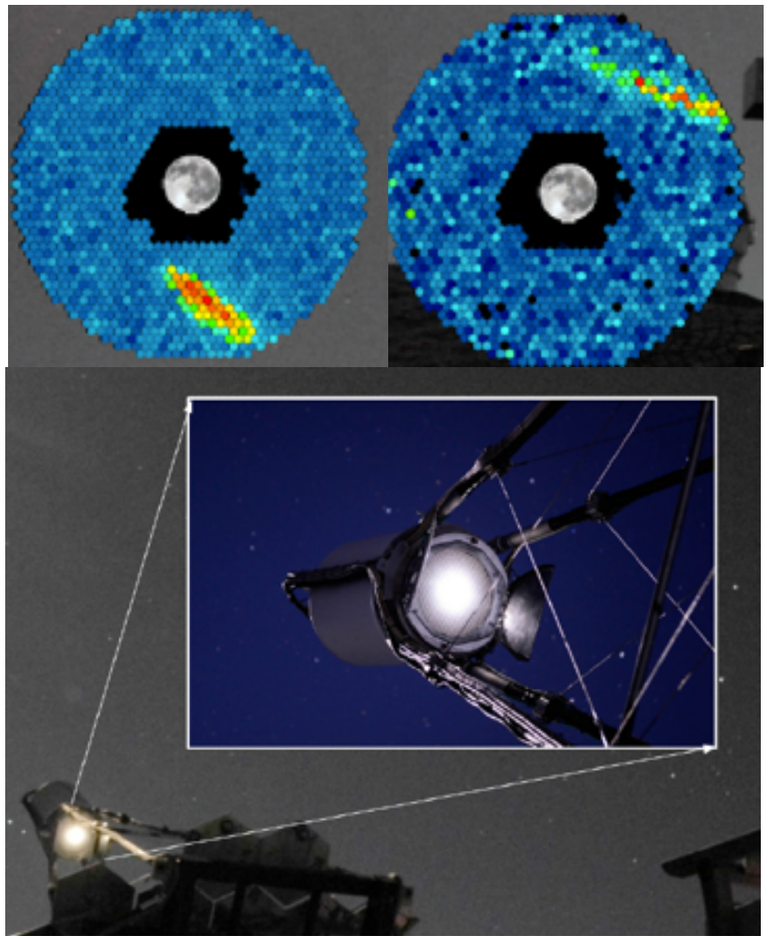
Point Spread Function



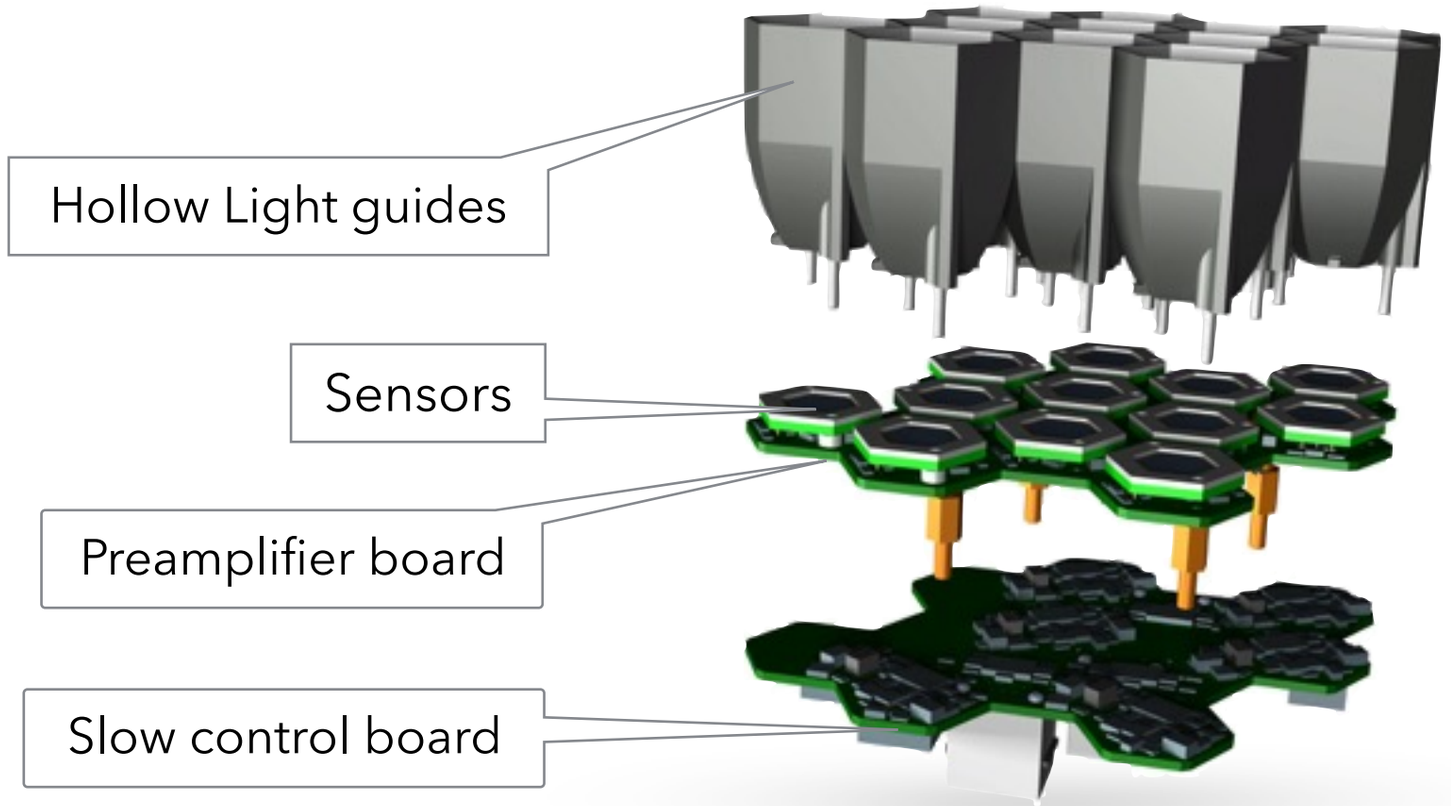
Pixel size and cut off angle

Photo Detection Plane

- 1296 pixels: **hollow light guide**, Silicon Photomultipliers (**SiPM**), front-end electronics
- As demonstrated by FACT, SiPM can operate with high level of background light



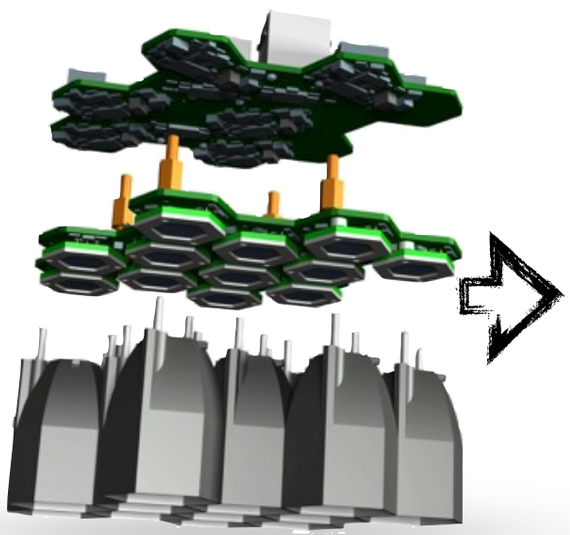
FACT result

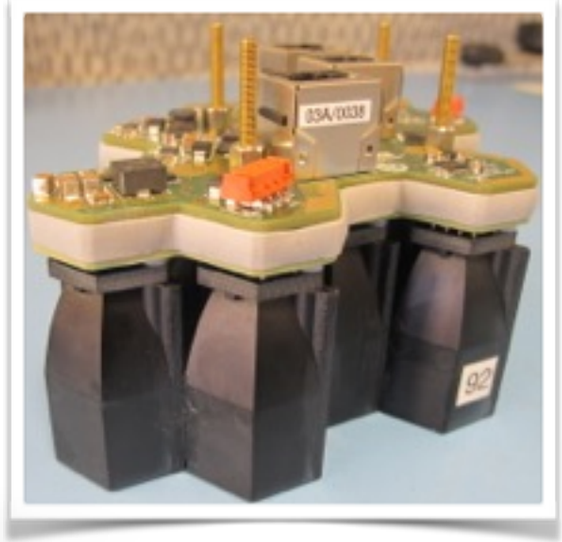


Project status

- Telescope structure *inaugurated in November 2013*, has been operated > 3 times/week for 15 min to 3 hrs/day
- All modules are *assembled*
- Cooling system *designed* and under qualification
- Digital electronics *produced and under systematic tests* (prototype performance already assesed)

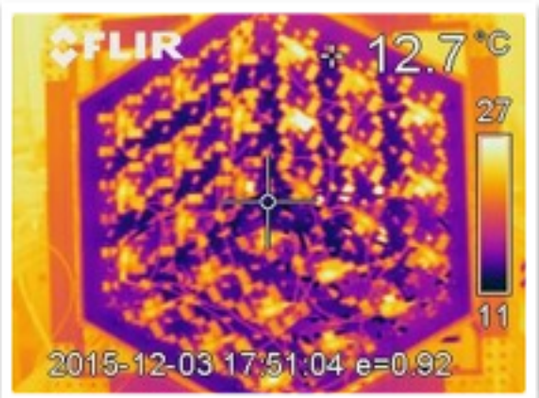
Telescope in movement





Module assembly

Cooling system



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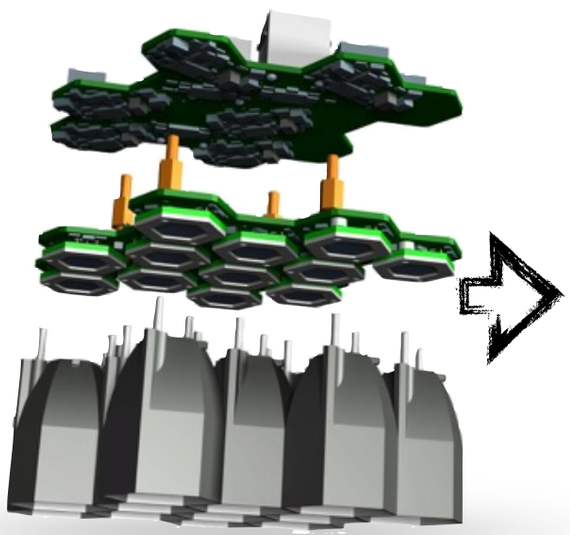
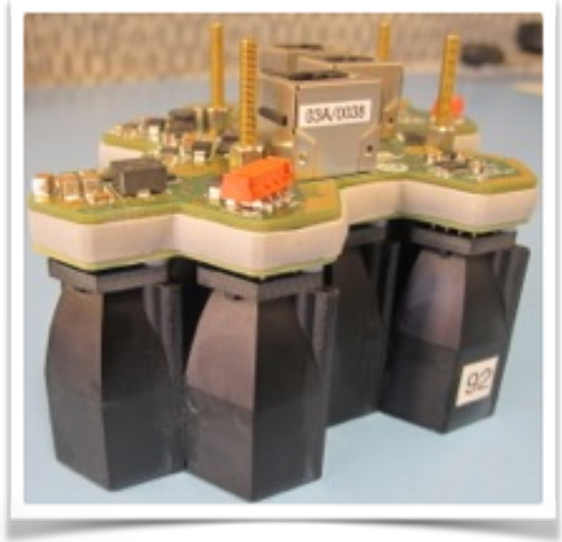
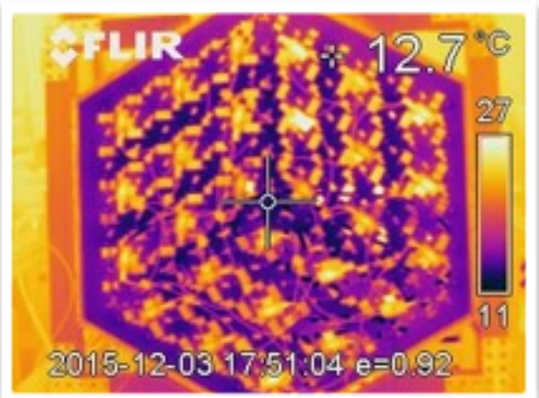




Module assembly

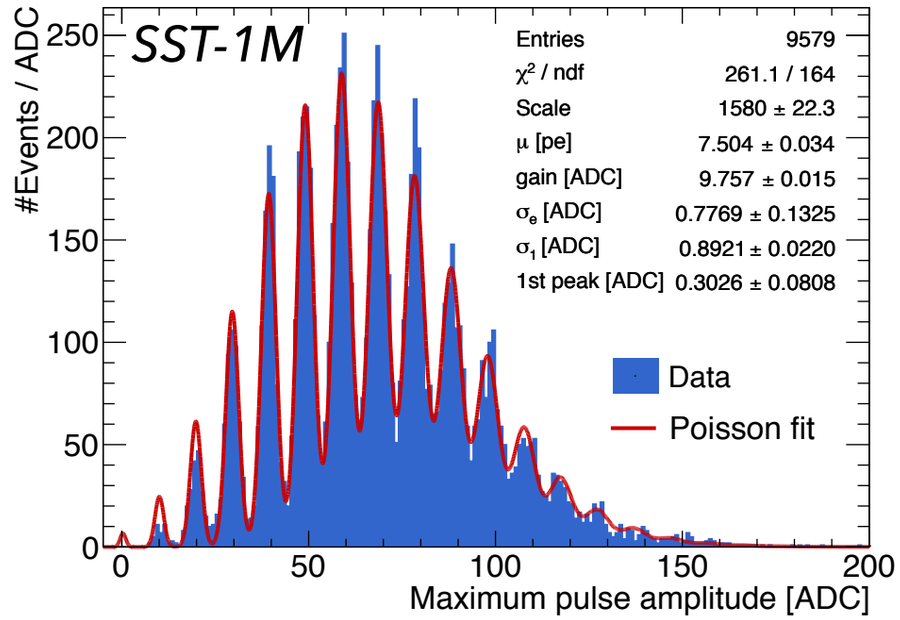
Cooling system

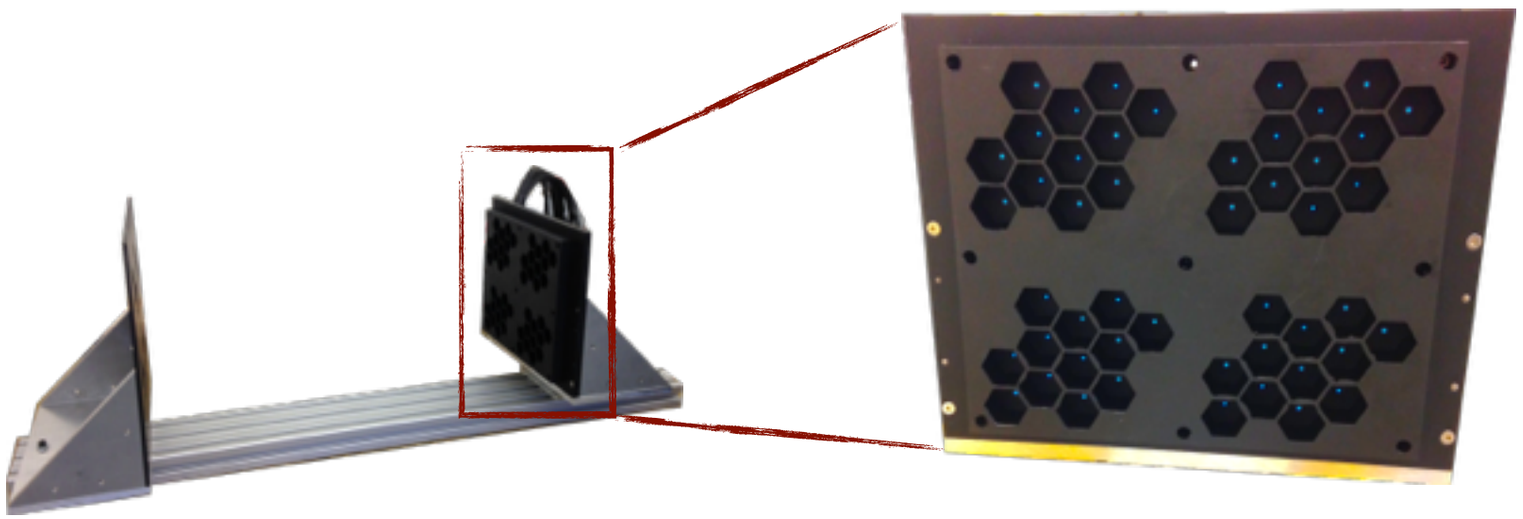


Camera calibration and performance

- Each of the 1296 pixel of the camera undergoes a *complete calibration*
- The gain, the cross talk (optical, electronics), the pulse shape, … are calculated and stored in data base for aging studies
- Most of the CTA physics requirements lead to a single detector performance requirement: ***the charge resolution.*** The measurements performed with the full electronics chain give results below the CTA goal

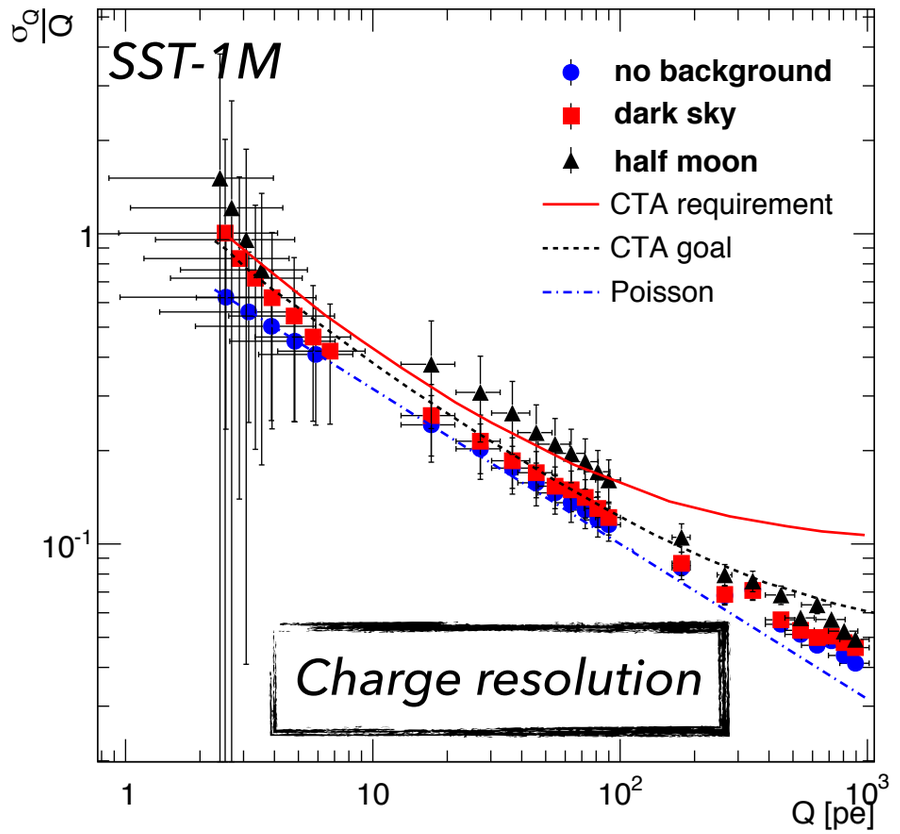
Single Photon Spectrum

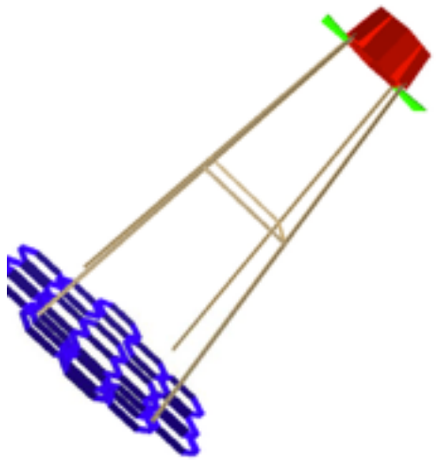


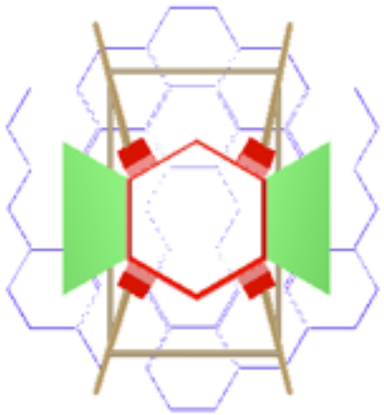


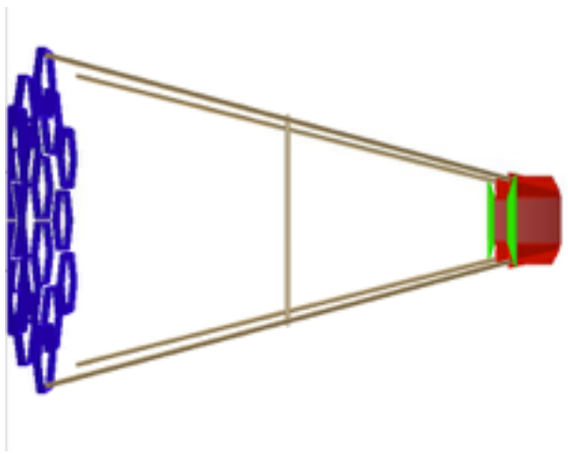
Optical test setup

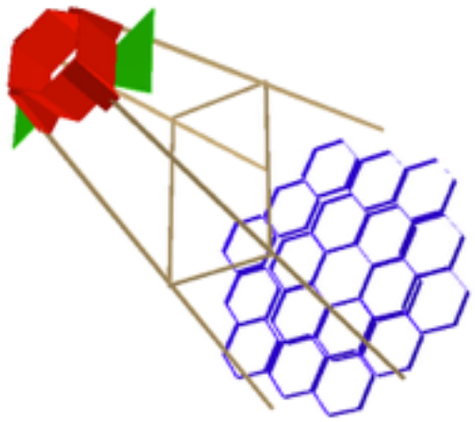
Testing 4 modules at a time



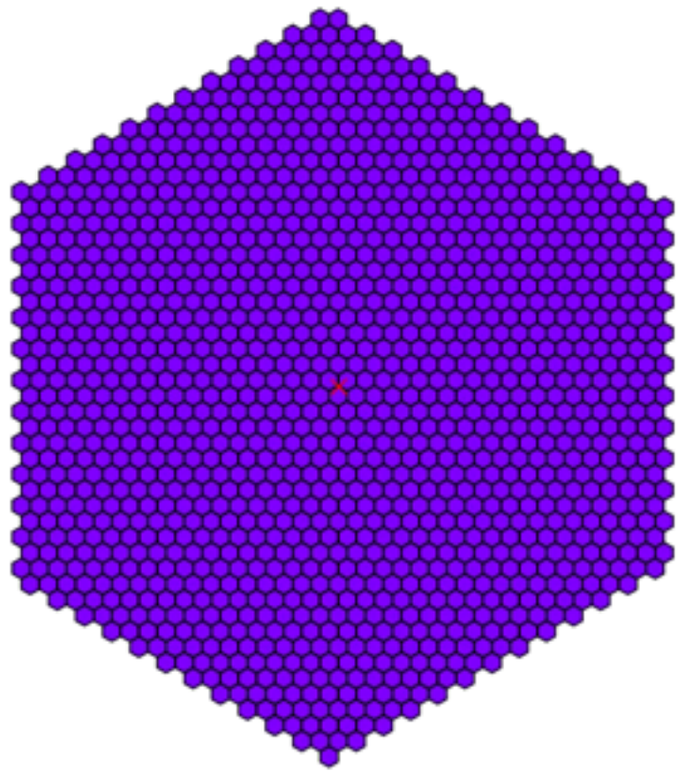




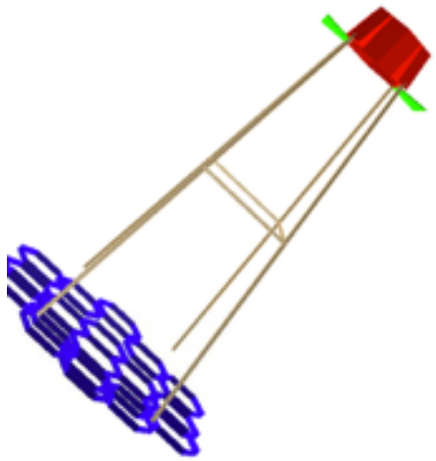


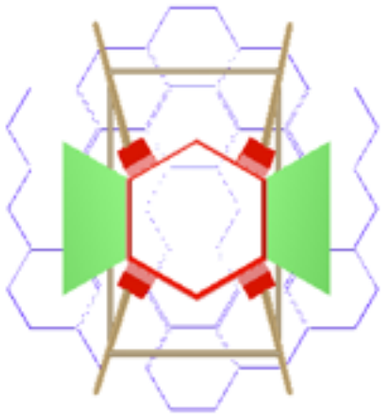


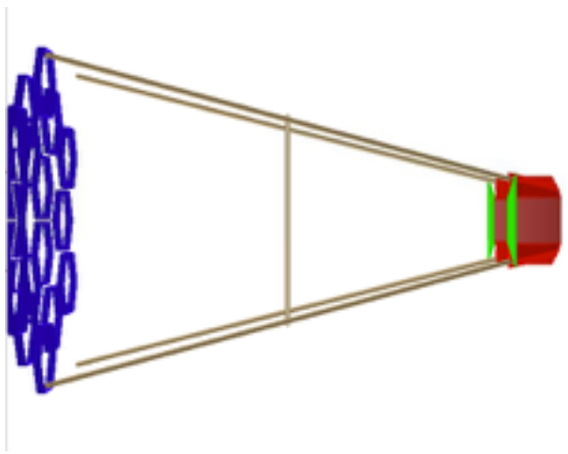
SST-1M performances

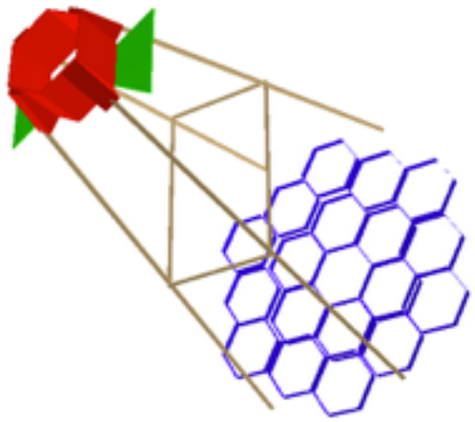


76.94 TeV gamma ray on SST-1M

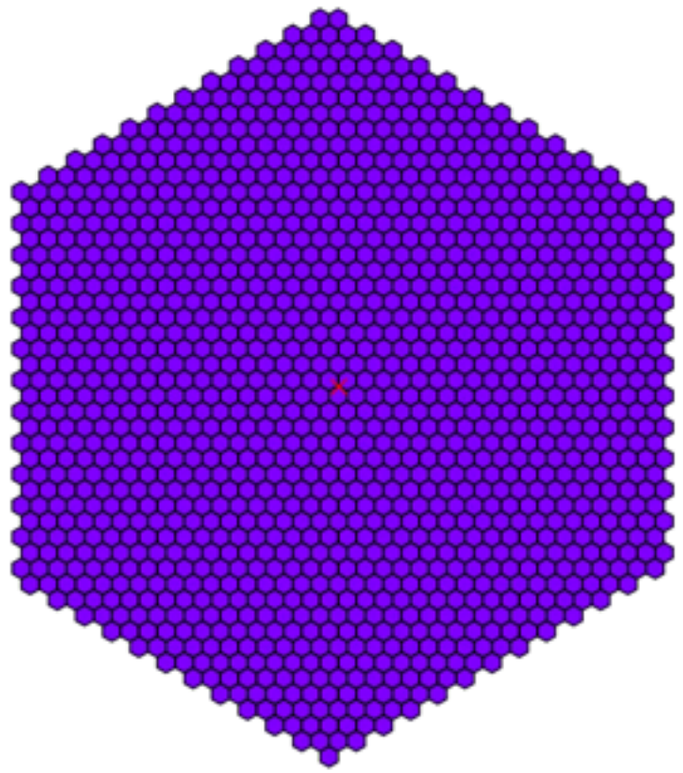






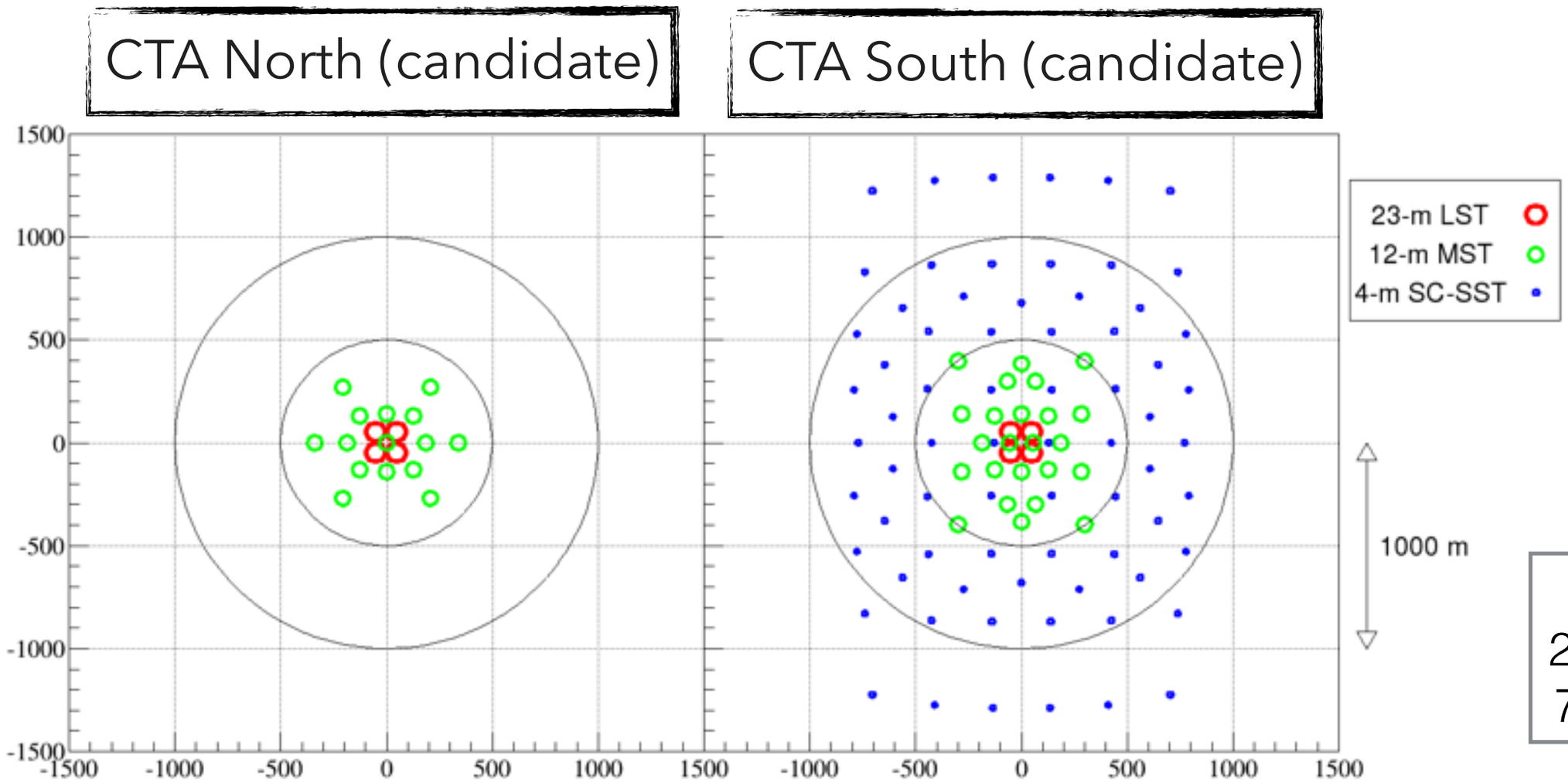


SST-1M performances



76.94 TeV gamma ray on SST-1M

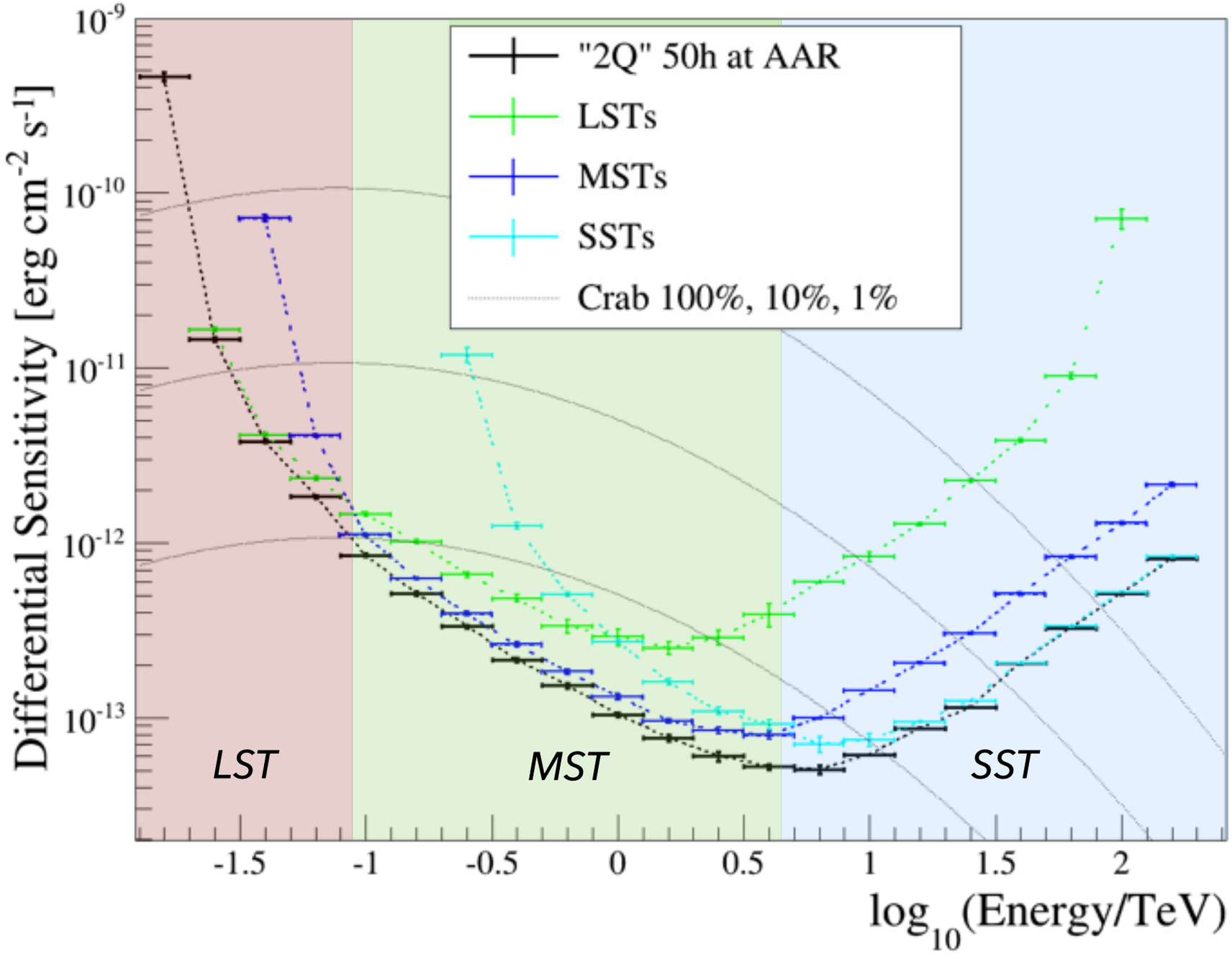
Cherenkov Telescope Array simulated layout



4 LSTs
24 MSTs
72 SSTs

SST: for the moment considered only in the Southern site (4 km^2)

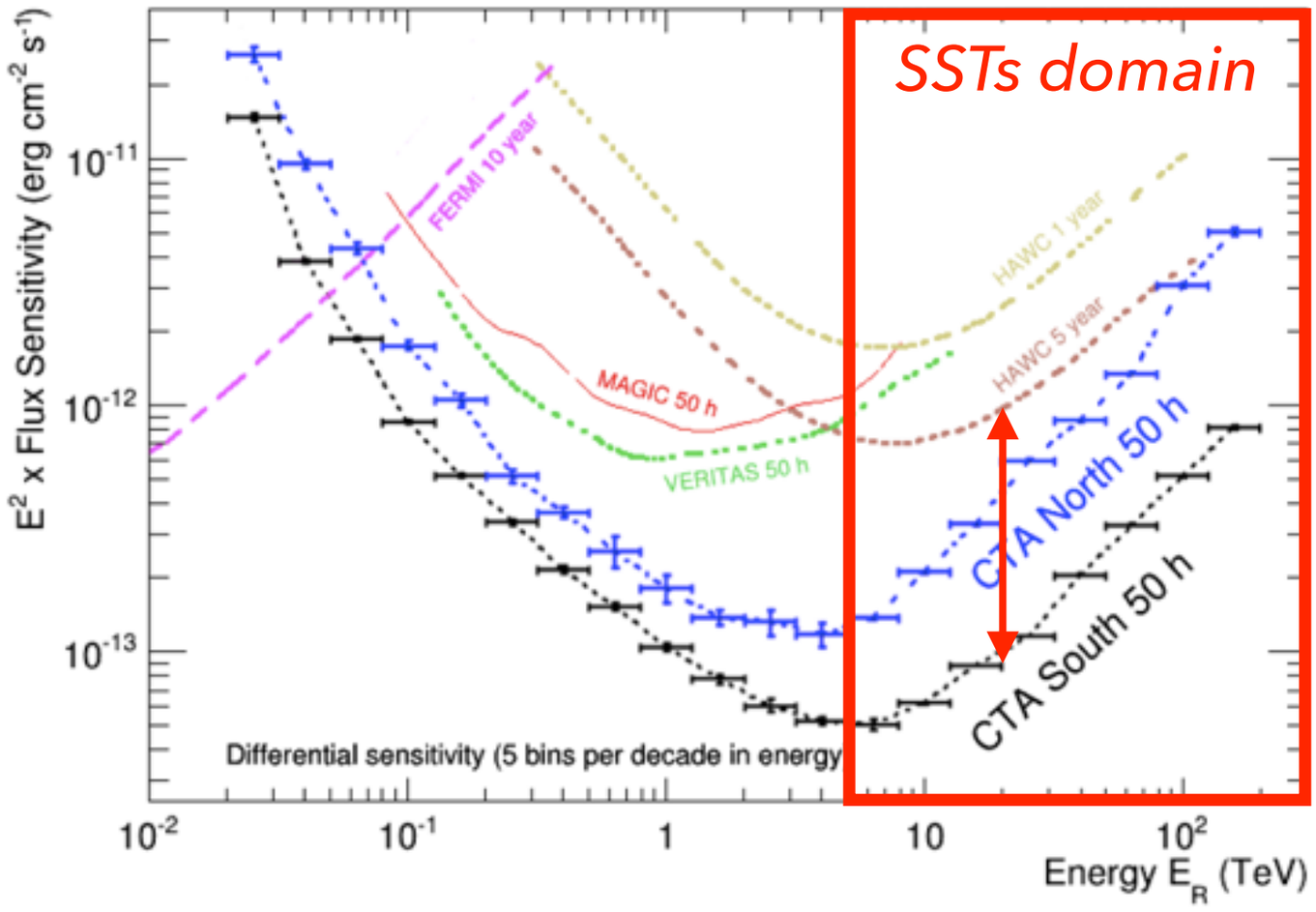
CTA sensitivity: the contribution of different telescope types



T. Hassan et al.
ICRC 2015
(ArXiv:1508.06075v1)

SSTs dominate the sensitivity curve at the highest energies (above 5 TeV)

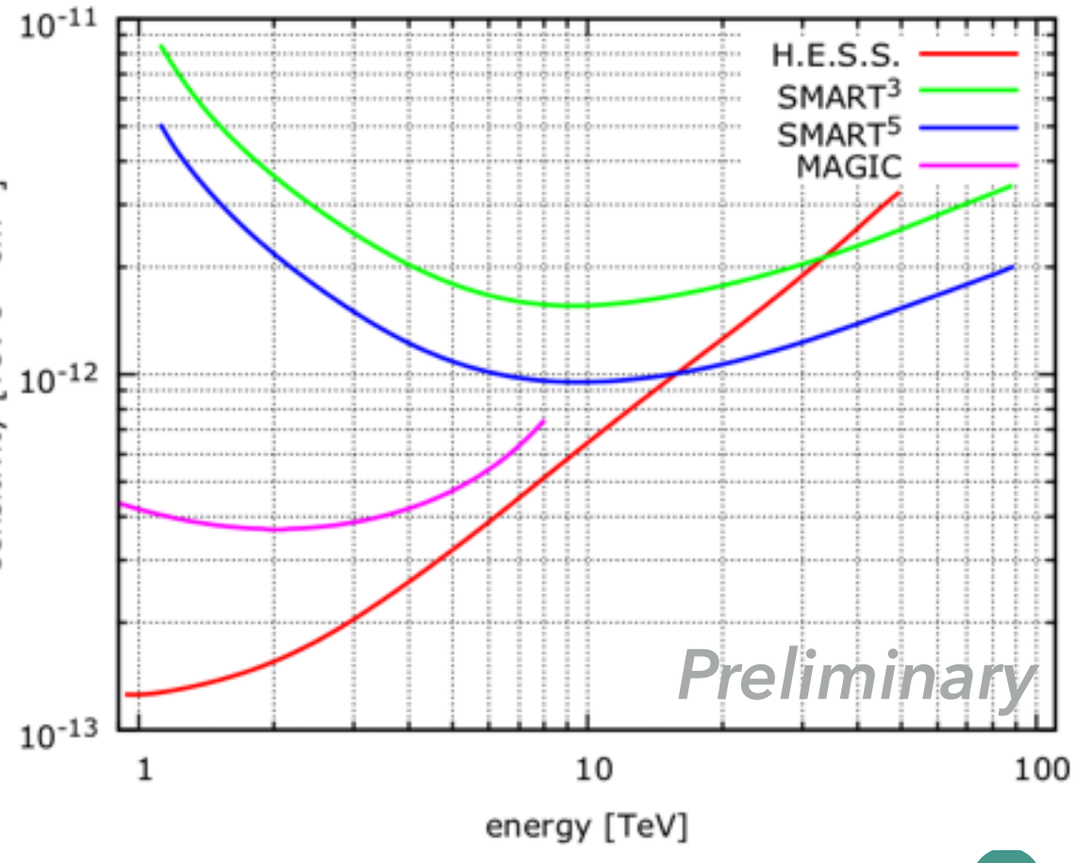
A jump in the sensitivity in the >TeV regime



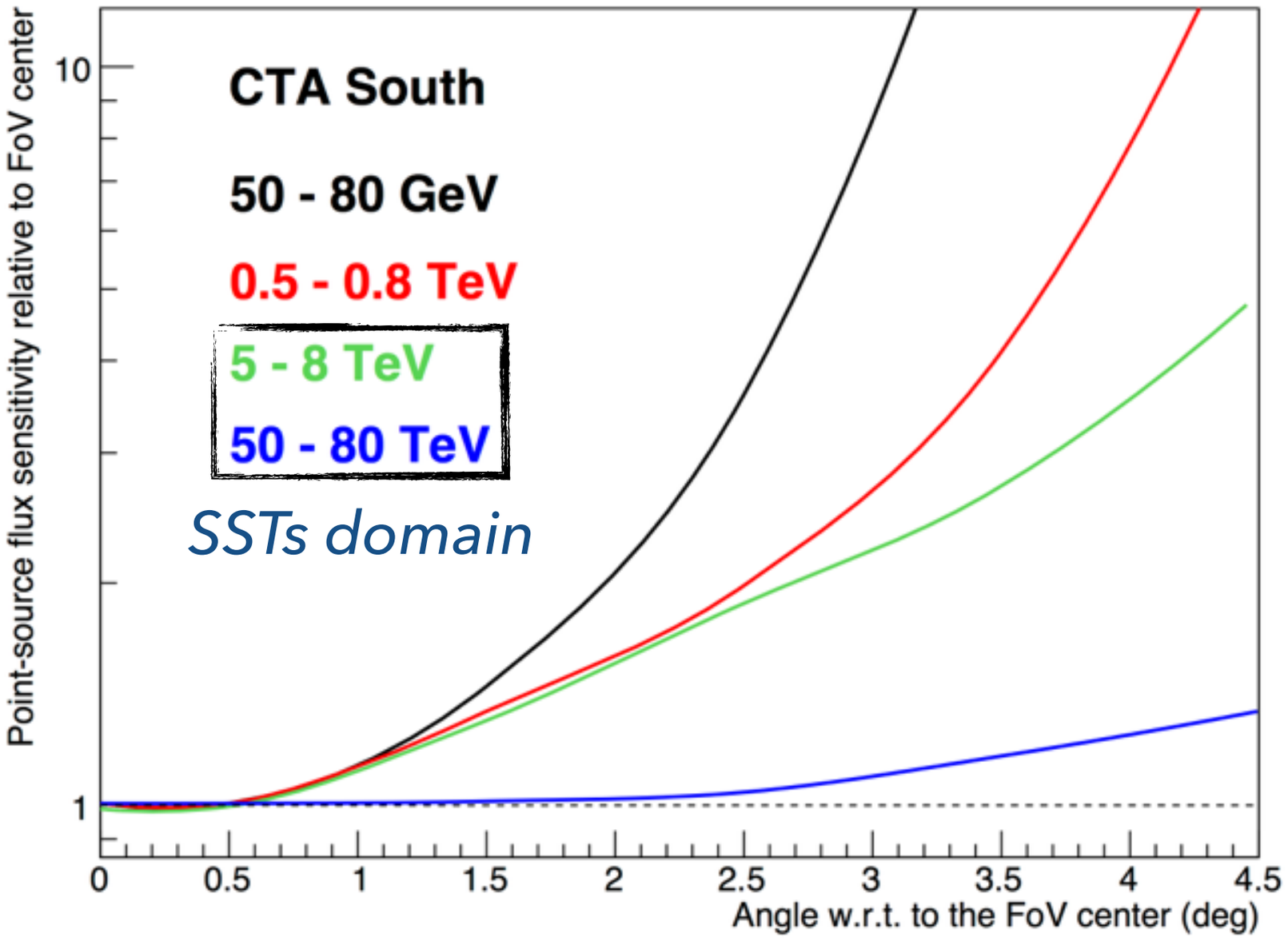
50h observation of a single object with CTA corresponds to **1 year operation** of the array

1 order of magnitude in sensitivity better than HAWC after 5 years of operation

- Smart 3 (5): Mini array of SST-1Ms composed of 3 (5) telescopes
- Better sensitivity than H.E.S.S from 30 (20) TeV



A large Field of View (FoV) at the highest energies

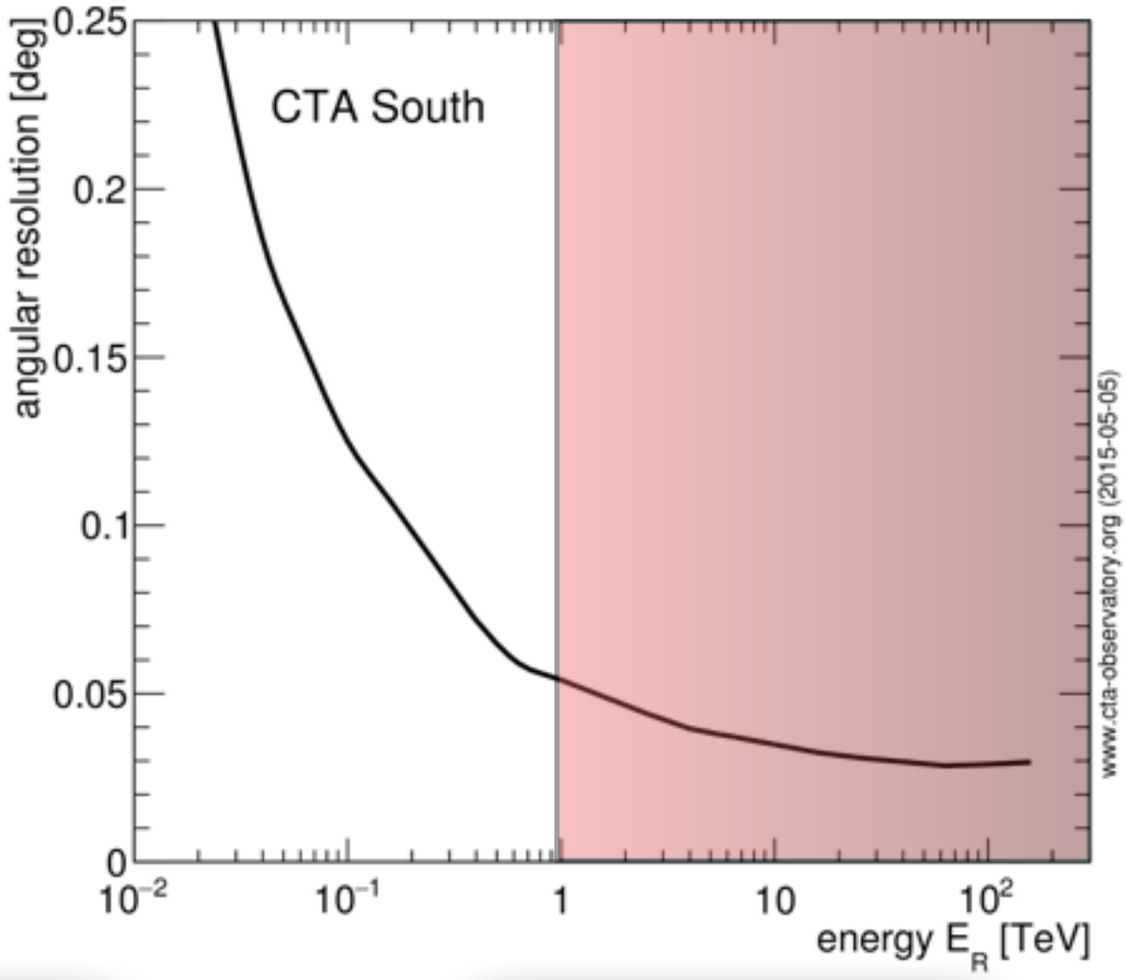


~ 9 deg FoV

Wide surveys for the first time accessible with IACT telescopes

Angular resolution

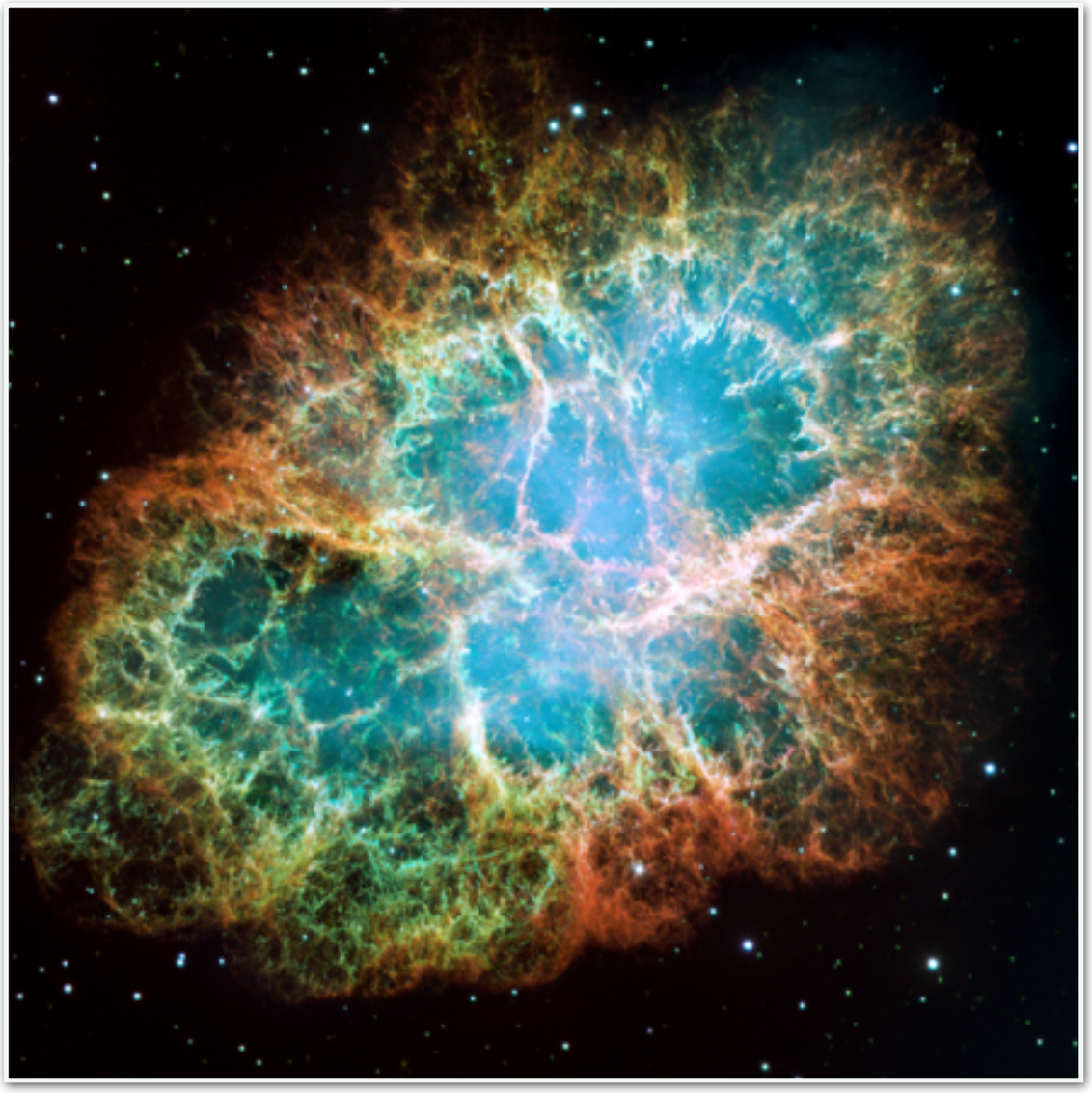
Extended sources in the TeV domain



0.004°
XMM 10 keV

0.1°
Simulation with current IACT

0.02°
CTA @ few TeV

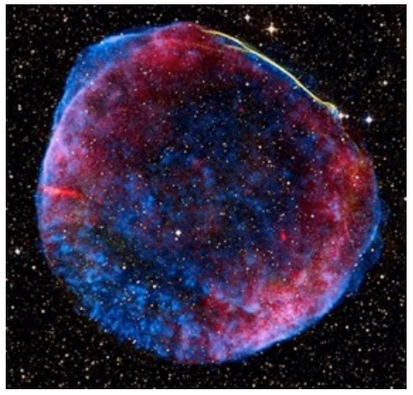


SST-1M physics perspectives

CTA Key Science

Cosmic particle Acceleration

- How and where are particles accelerated ?
- How do they propagate ?
- What is their impact on the environment ?



Probing Extreme Environments

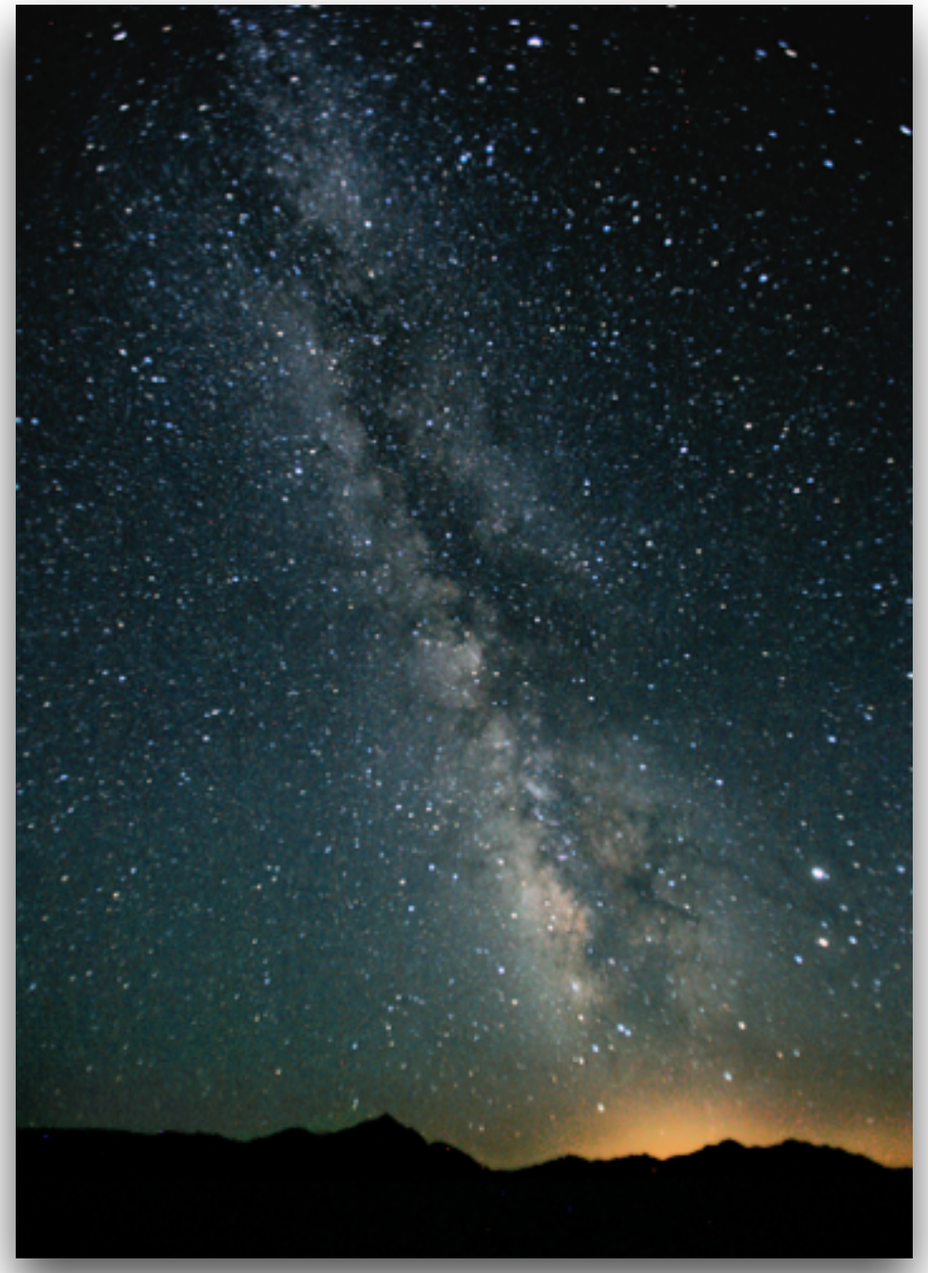
- Processes close to neutron stars and black holes ?
- Processes in relativistic jets, winds and explosions ?
- Exploring cosmic voids

Physics frontiers - beyond the Standard Model

- What is the nature of Dark Matter ? How is it distributed ?
- Is the speed of light a constant for high-energy photons ?
- Do axion-like particles exist ?

SST-1M Physics goal

- Blind surveys
- Nearby Extragalactic objects
- Galactic objects
  - Fermi Bubbles
  - Galactic Pevatrons
  - SNRs
- Dark Matter search



Surveys

Galactic

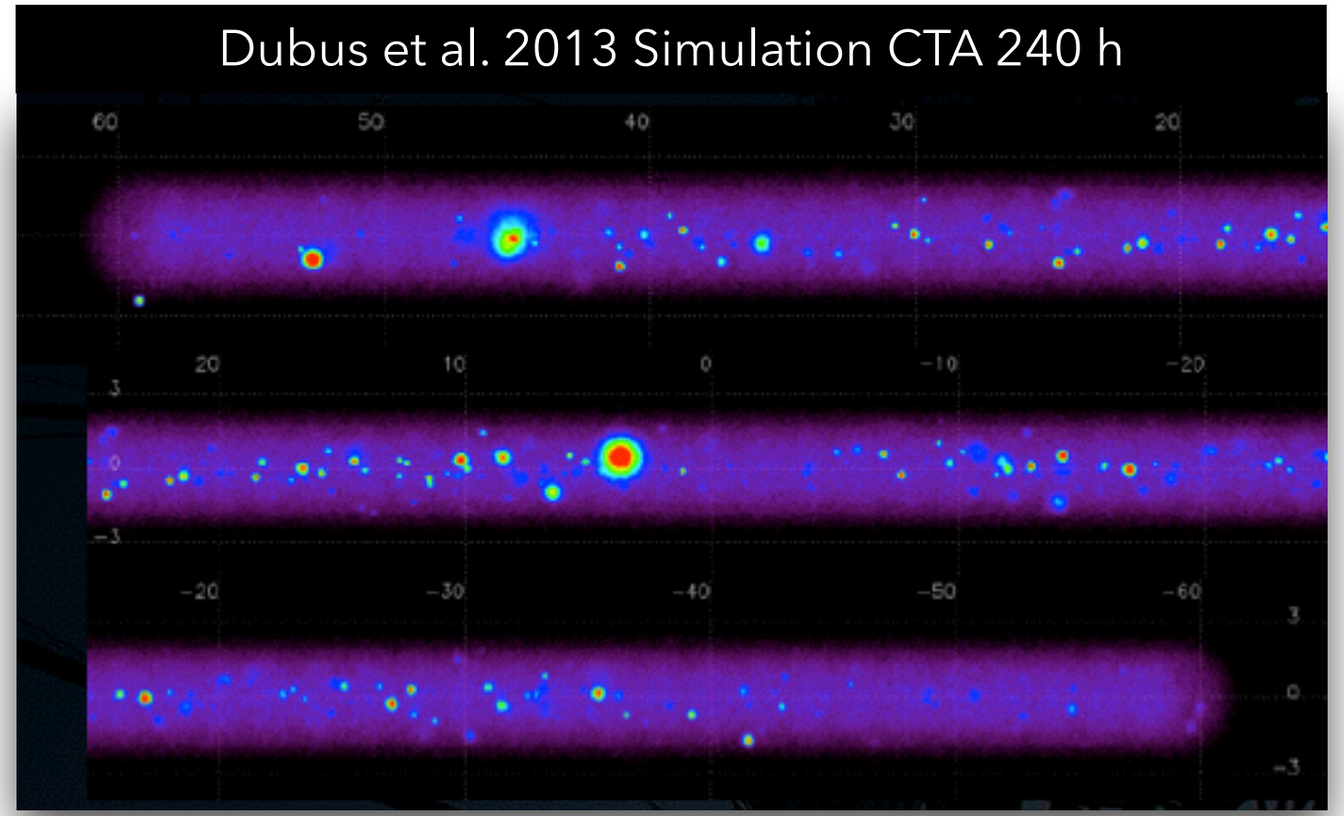
➡ We expect to detect >1000 sources

➡ The majority: PWNe and SNRs

Extragalactic

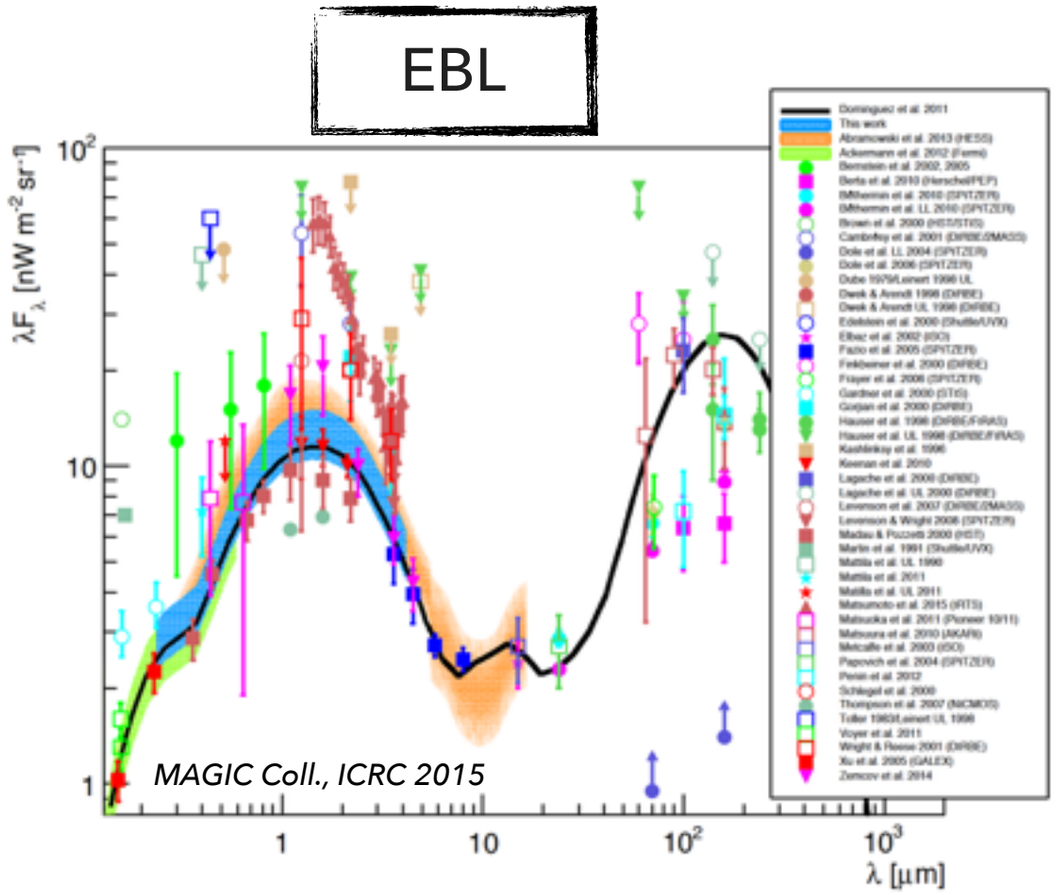
➡ blind survey of 1/4 sky

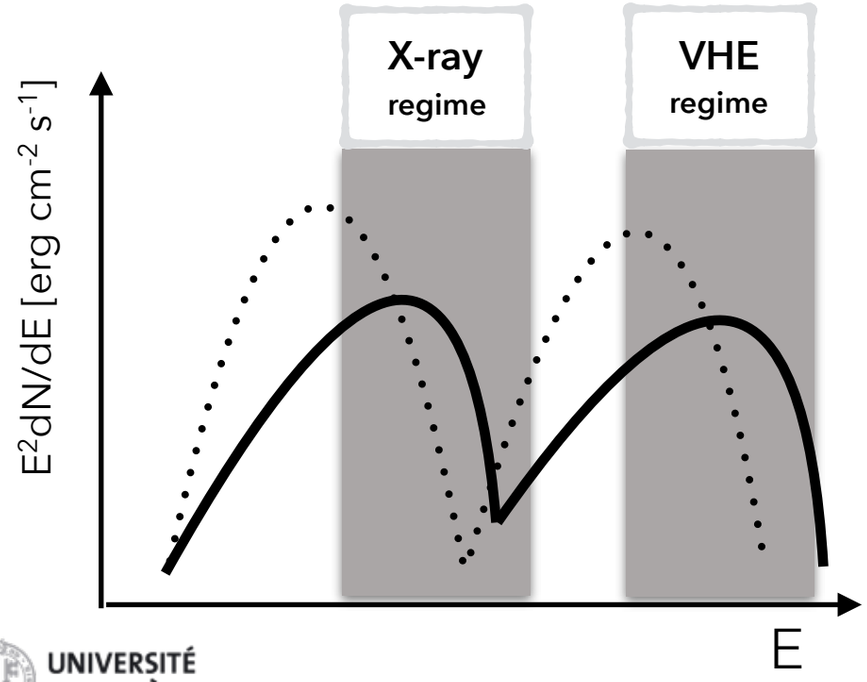
➡ new VHE sources / source classes



Population studies!

Nearby AGNs at the highest energies





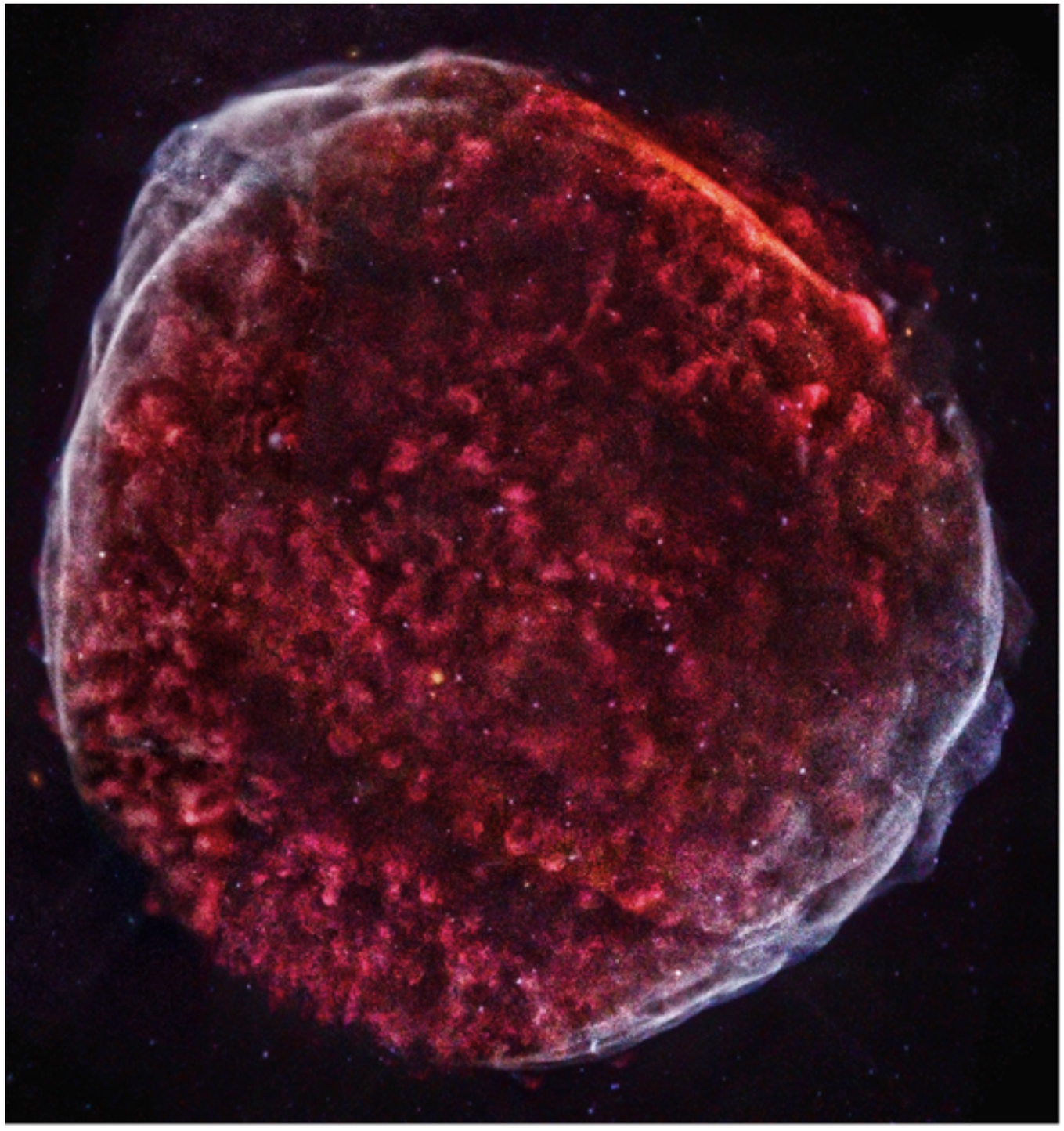
- Above 5 TeV, only nearby blazars are visible at VHE
  - Extragalactic Background Light (EBL)
- Main target: "**Extreme Blazars**", i.e. blazars with SEDs peaks located at extreme energies

SSTs can:

1 - monitor of bright known sources

2 - discover new sources

SNRs



SN1006, Chandra, 2003 NASA/CXC/Rutgers/J.Hughes et al.

- Sub-structure of SNR shock fronts will become visible at TeV energies
- Source morphologies

0.004°
XMM 10 keV

0.1°
Simulation with current IACT

0.02°
CTA @ few TeV

Galactic Pevatrons and the enigma of galactic cosmic rays

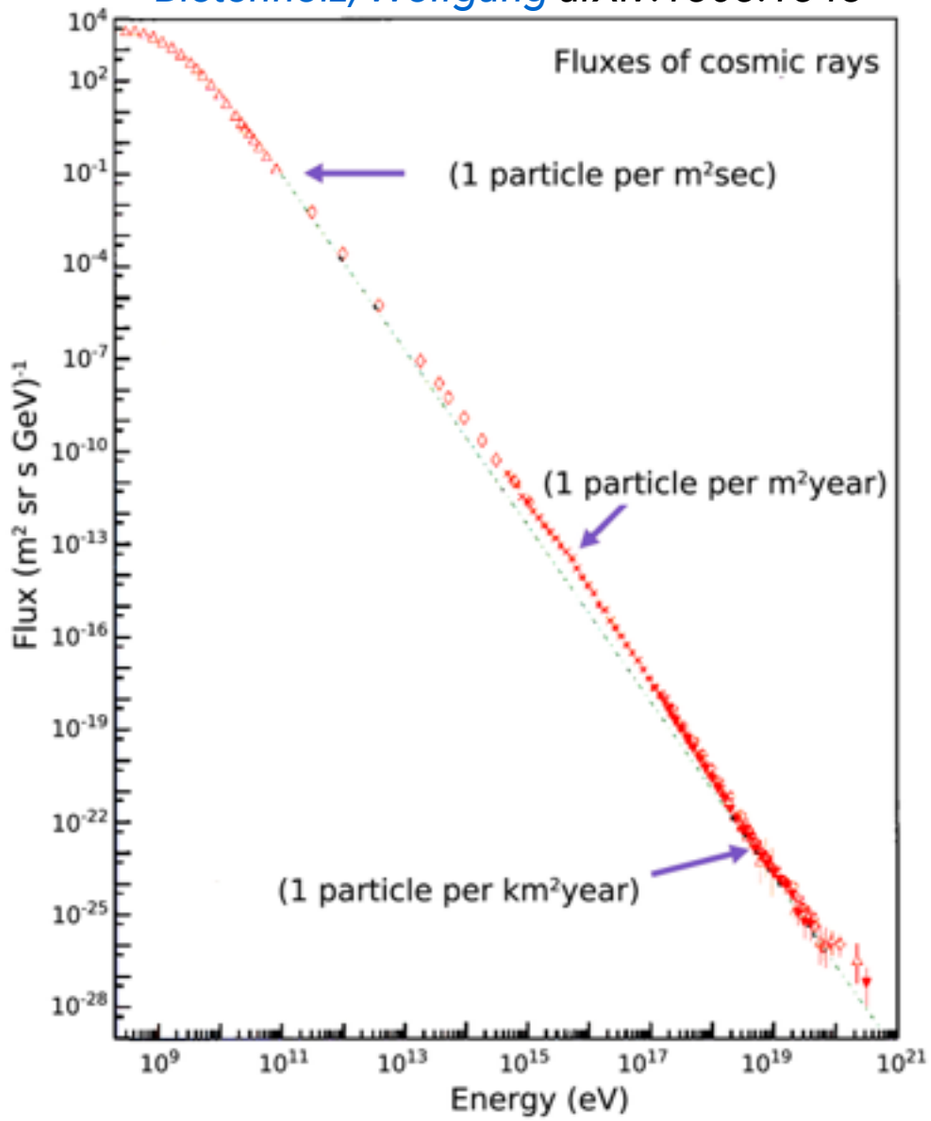
Origin of cosmic rays (CRs) is a century old problem

- SNRs can satisfy CR energy budget; but no evidence at E ~20 TeV and above

- CTA Key Science Project aims to identify PeVatrons – sources that accelerate CRs to PeV energies

- Hypothesize that young SNRs may accelerate CRs to PeV energies

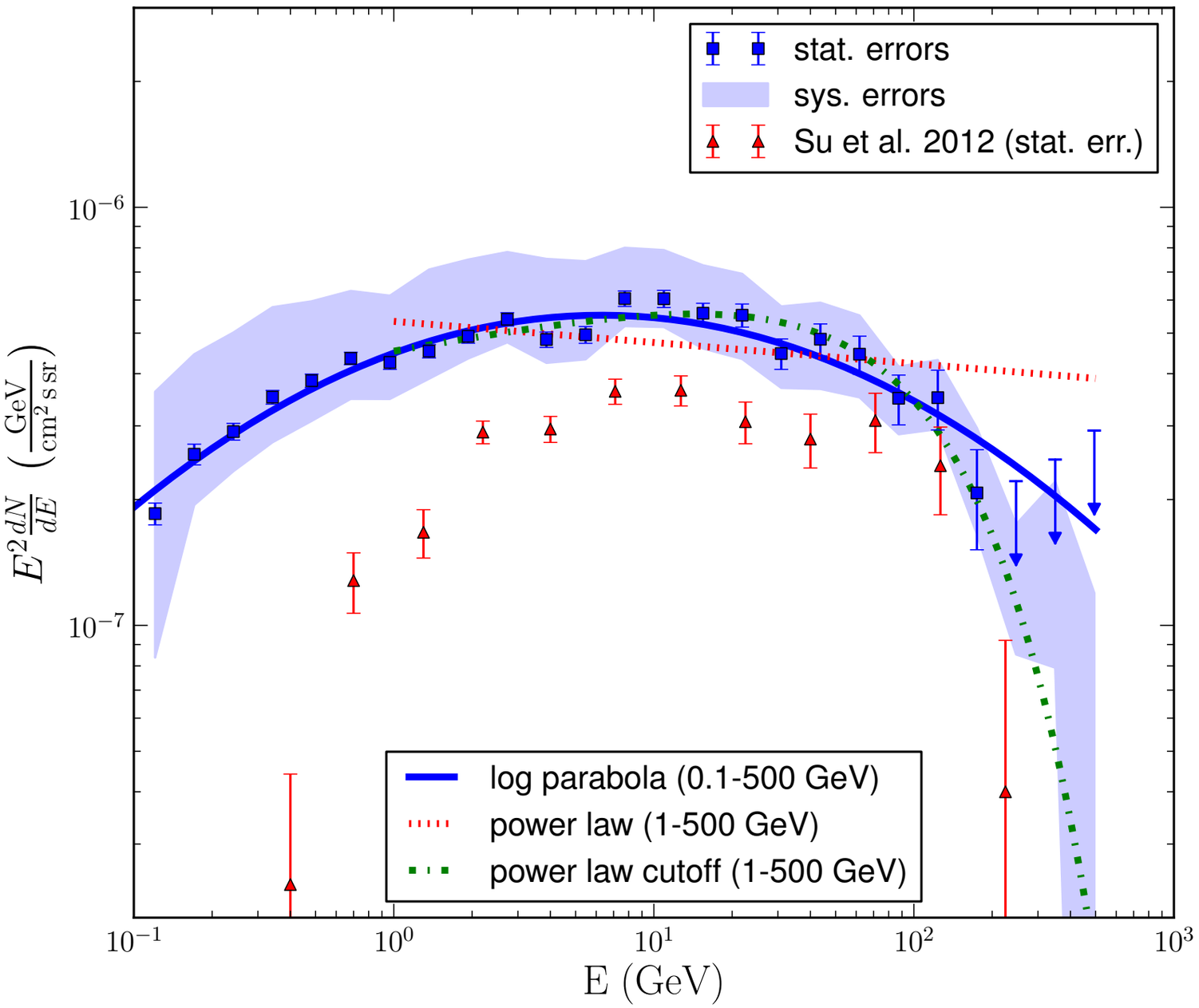
Bietenholz, Wolfgang *arXiv:1305.1346*



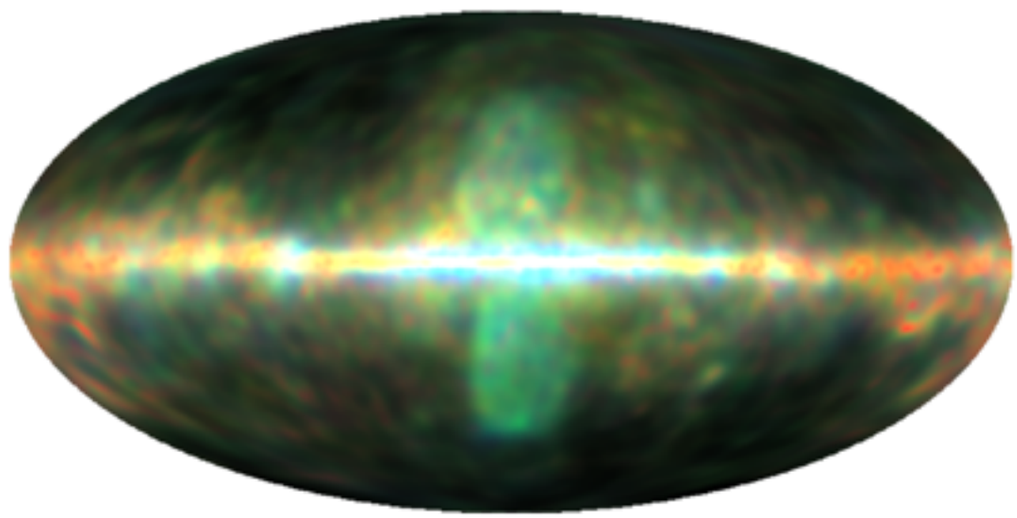
SSTs will probe this hypothesis!

Extended TeV sources: Fermi Bubbles

Ackermann et al. ApJ 793 2014



γ-ray emission leptonic or hadronic?
SST can contribute adding statistics above few TeVs and scanning different latitude regions



A light on Dark Matter?

Indirect search for dark matter

- **gamma ray** emission from dark matter annihilation/decay

Promising targets:

- Galactic Center
- Galactic Halo
- Dwarf Galaxies
- Galaxy clusters

A target for dark matter searches: the Sculptor dwarf spheroidal galaxy. (Image: David Malin, Anglo-Australian Observatory)

The SSTs observations will test the hypothesis of WIMPs as dark matter candidates in the energy (mass) range above few TeV

Conclusions

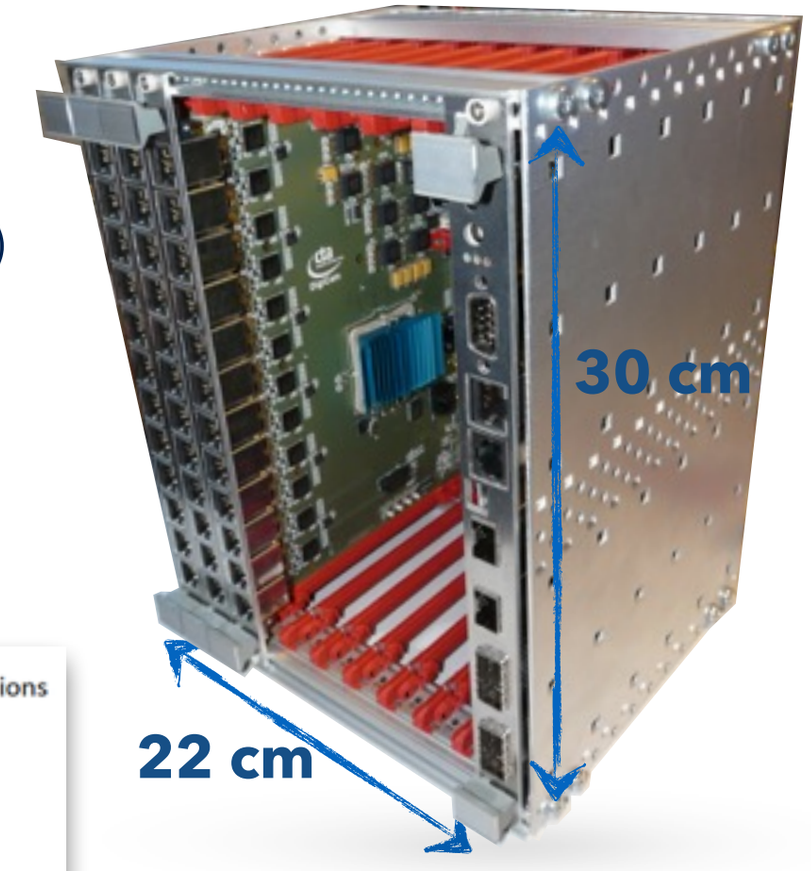
- *The SST-1M prototype*
  - Telescope structure ready and working daily since November 2013
  - Installation of remaining mirrors and connection of actuators (alignment) in December
  - Camera assembly and calibration in January
  - Triggering system mid-2016
  - Camera integration and first data June 2016

- *Physique perspectives*
  - The improvement compared to previous IACTs open new physics domain:
    - Improved sensitivity in TeV range:
      - Pevatrons
      - Fermi bubbles
      - Extreme blazars
    - Improved angular resolution:
      - Source morphology
    - Large field of view:
      - Survey

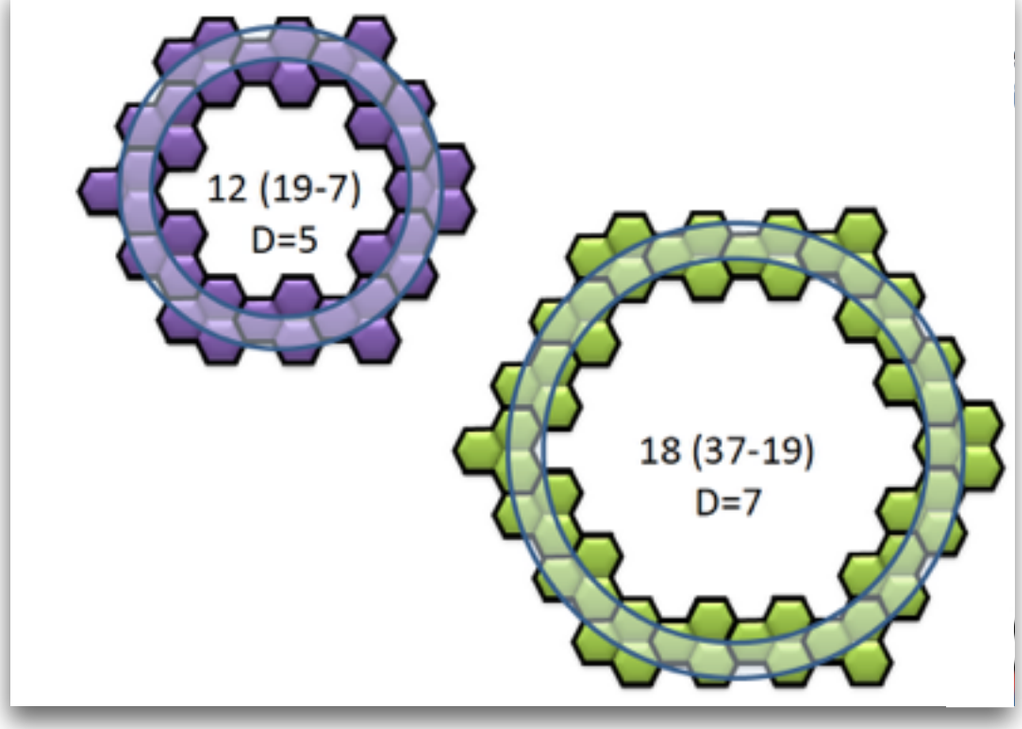
Backup slide

DigiCam Design - Trigger & Readout

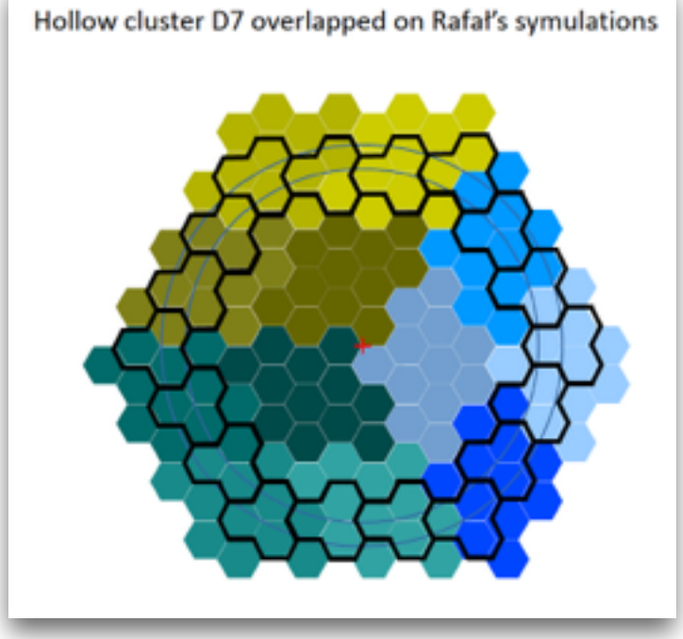
- Readout rate: 32 kHz @ 80 ns readout window, no dead-time
- Sampling rate 250 MHz
- Fully digital trigger and readout (High-speed/High-throughput)
- Serial architecture based on multi-Gigabit links (trigger and ADC readout)
- Trigger path with reconfigurable algorithms and signal preprocessing



μ-Crate 10 Slots



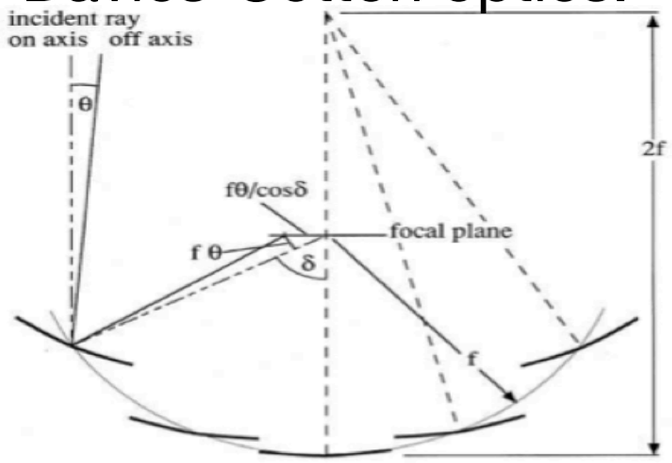
Dedicated trigger patterns



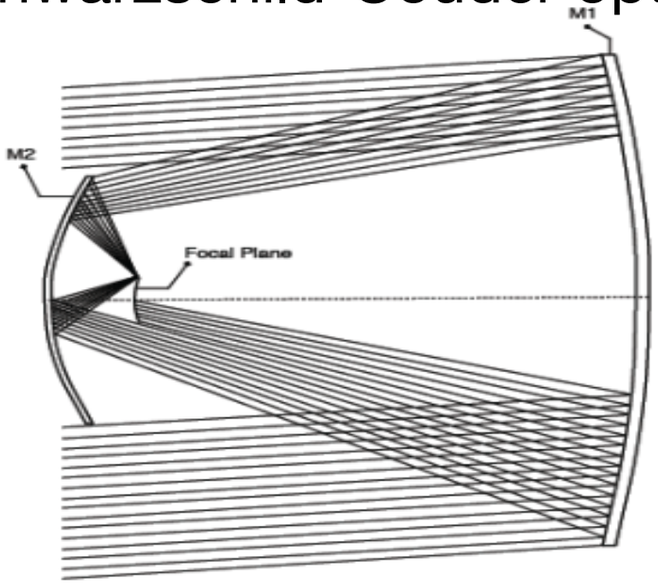
"Hollow" muon trigger cluster for muon energies > 10 GeV size of rings 1.1-1.25 deg - perfect match!

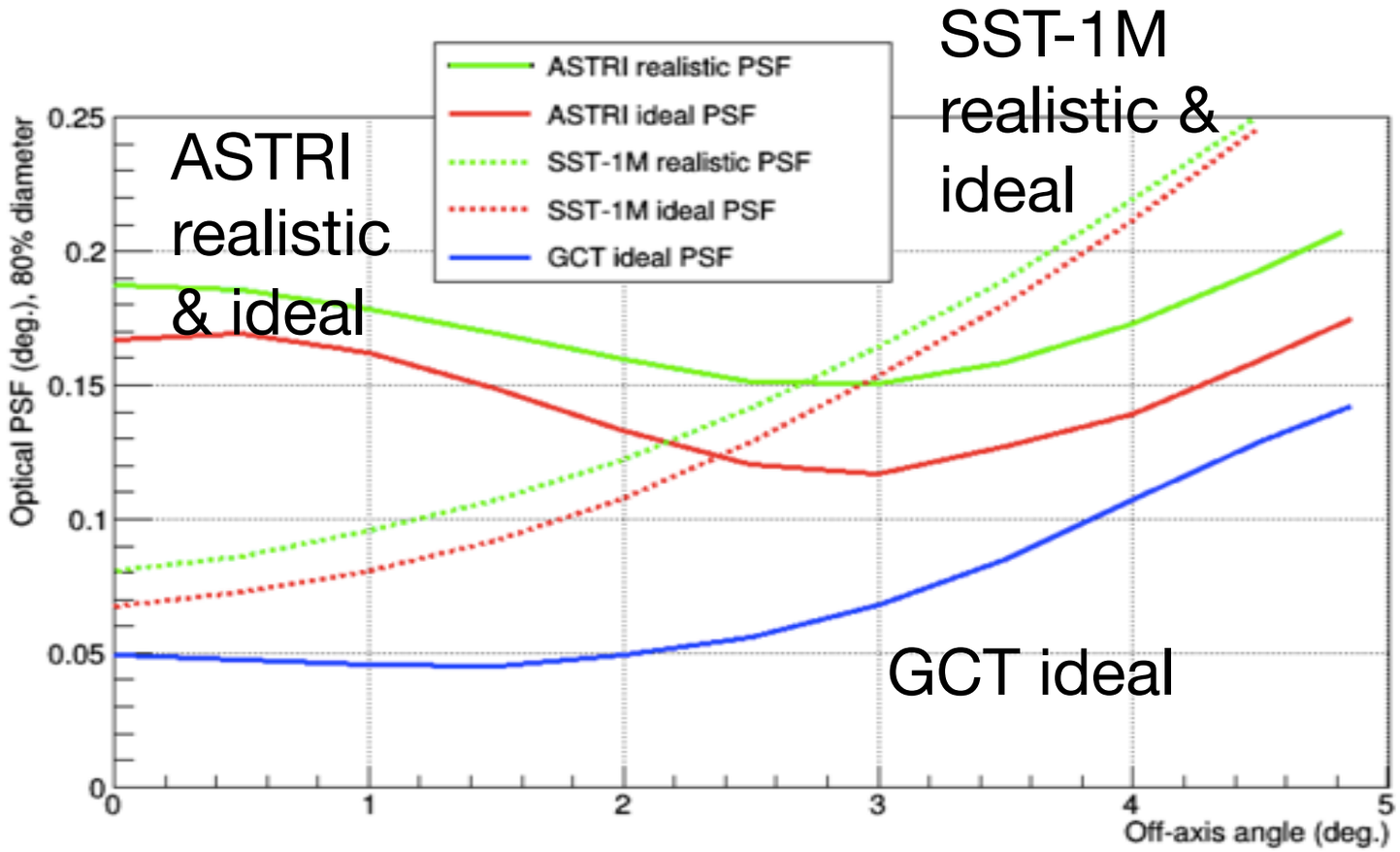
Optical design and optical PSF

Davies-Cotton optics.



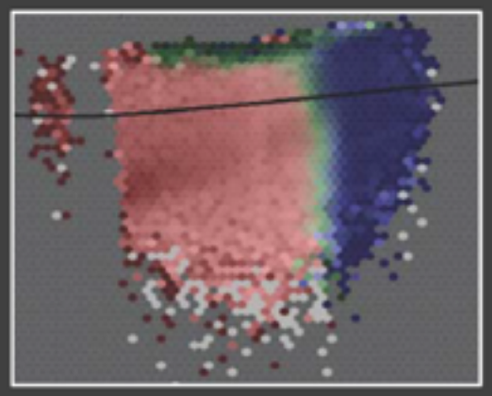
Schwarzschild-Couder optics.



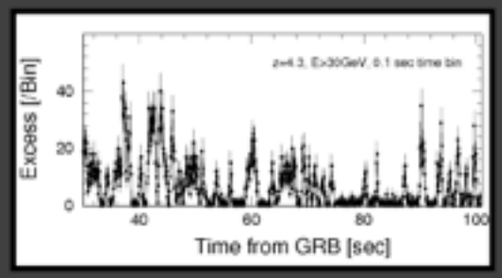


Optical PSF from ray-tracing

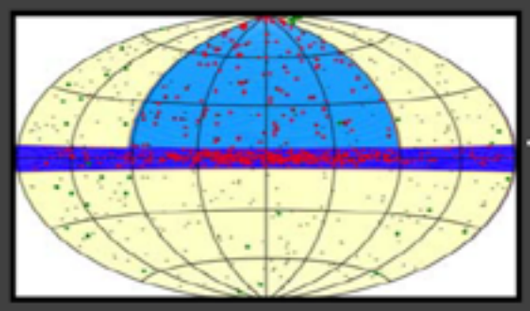
CTA KEY SCIENCE



Dark Matter Programme

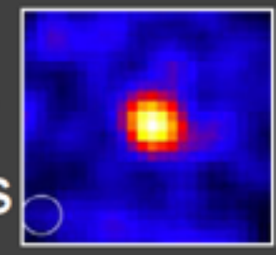


Transients

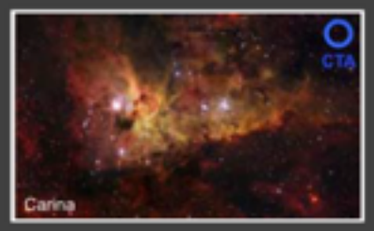


ExGal Survey

Galaxy Clusters

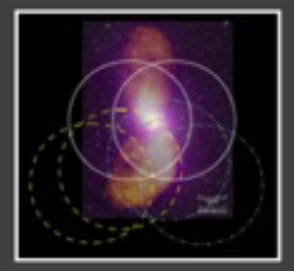


Extragalactic

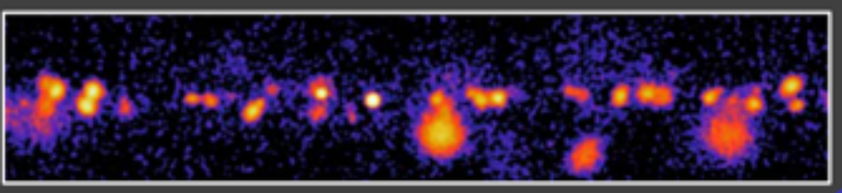


Star Forming Systems

AGN

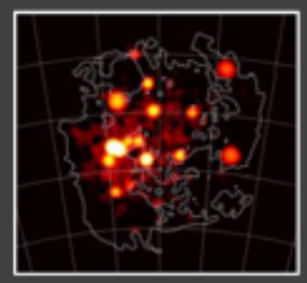


Galactic

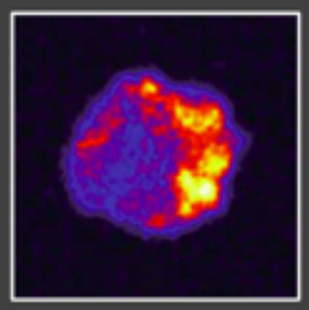


Galactic Plane Survey

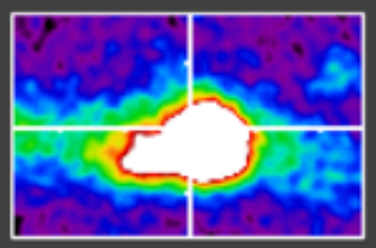
LMC Survey



PeVatrons



Galactic Centre



cta
cherenkov telescope array