The Cherenkov Telescope Array

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Outline

VHE Gamma Ray Astronomy

CTA Overview

Science Goals for CTA

Schwarzschild-Couder Telescope Extension

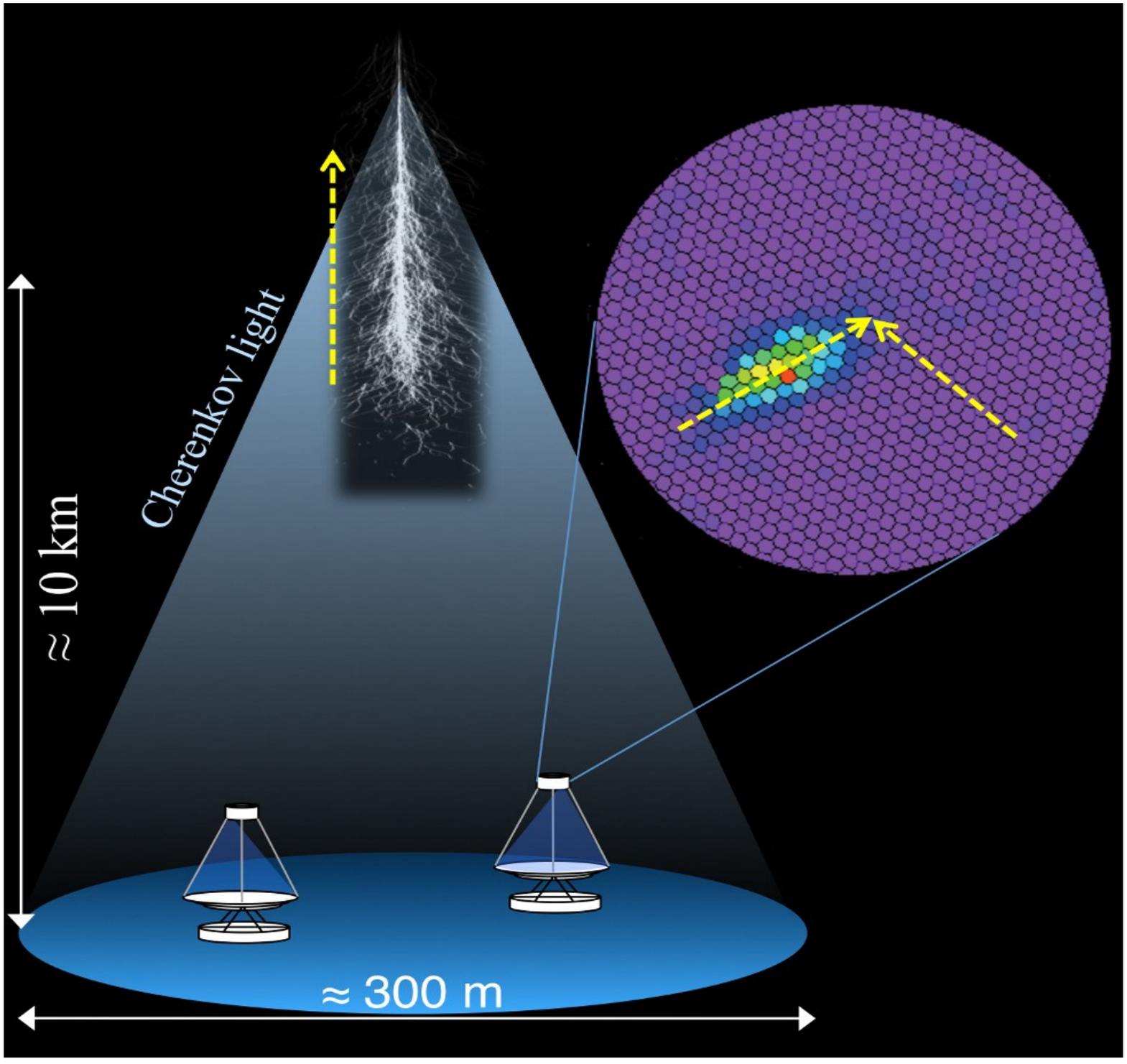
Gamma-ray Astronomy

“Gamma-rays” cover 8 orders of magnitude in energy

- Low Energy (~500 keV – ~50 MeV)
- High Energy (~50 MeV – 50 GeV)
- Very High Energy (~50 GeV+)

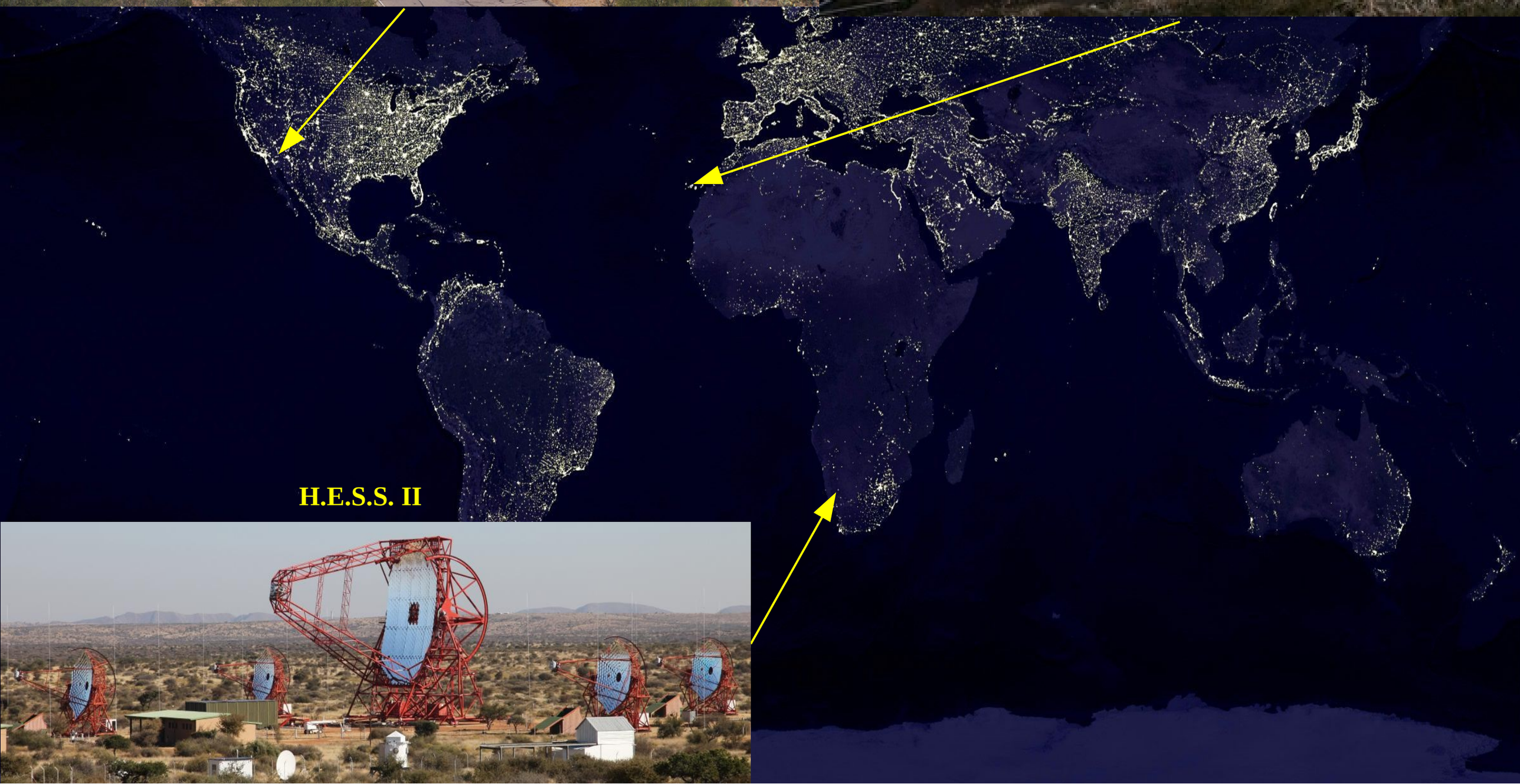
The divisions are somewhat arbitrary and based on detection techniques. There is often considerable overlap.

Detecting Gamma-rays with Cherenkov Telescopes



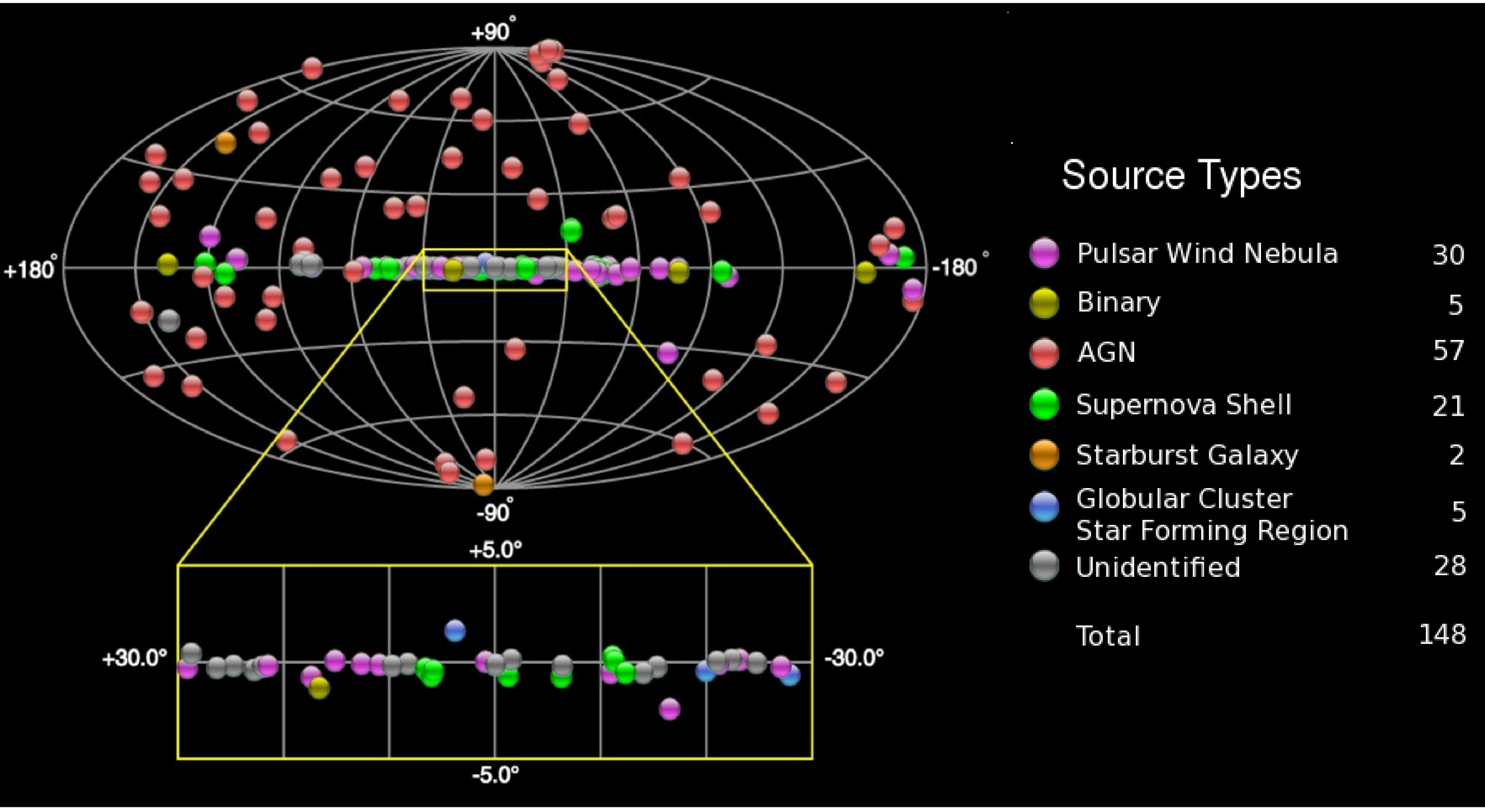
VERITAS

MAGIC-II



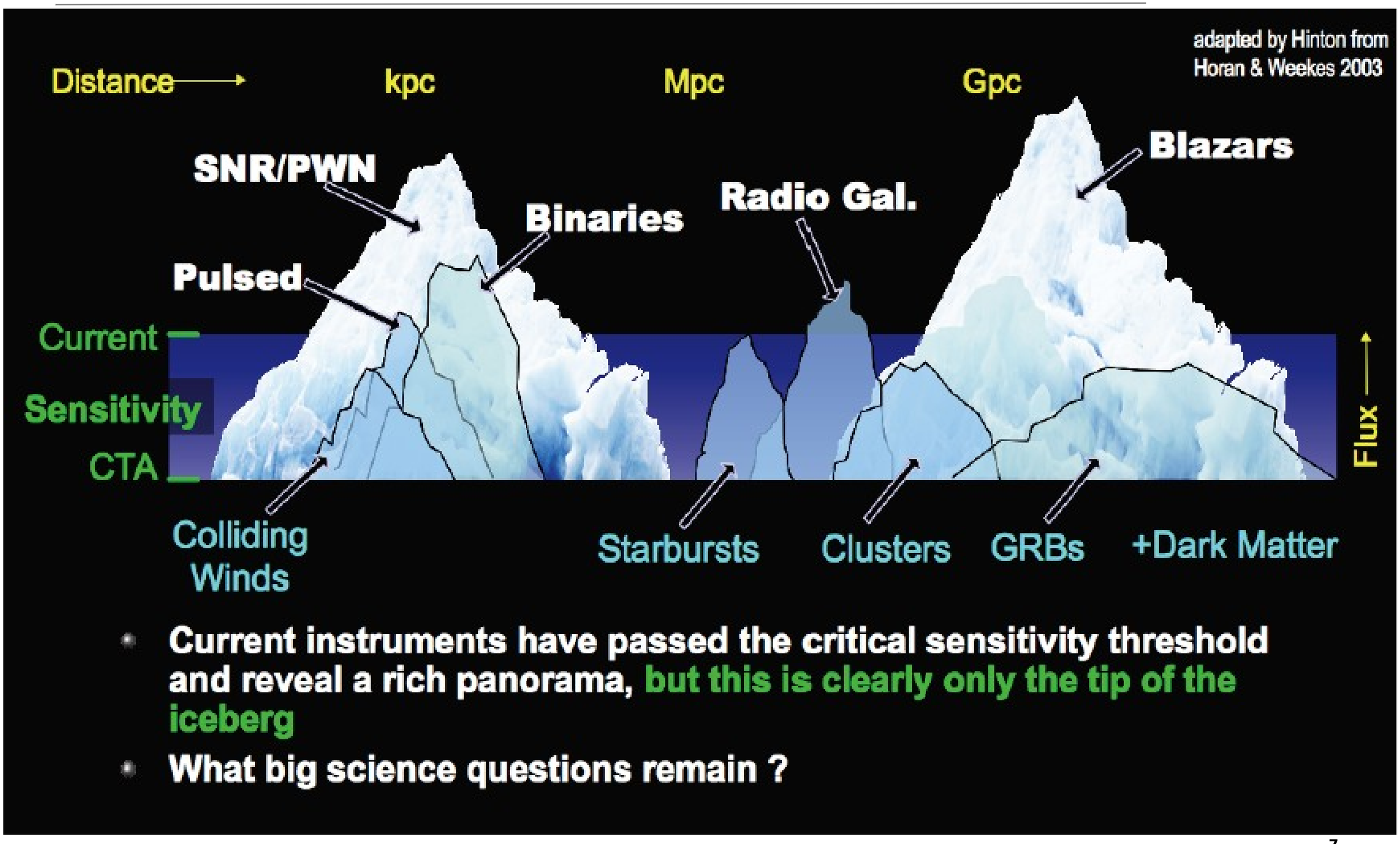
H.E.S.S. II

The VHE Gamma Ray sky



http://tevcat.uchicago.edu

CTA Discovery Space



- **Current instruments have passed the critical sensitivity threshold and reveal a rich panorama, but this is clearly only the tip of the iceberg**
- **What big science questions remain ?**

CTA Science Goals

Cosmic Ray Acceleration

- Mechanisms for particle acceleration, Galactic cosmic ray acceleration and Pevatrons, acceleration in jets and lobes of AGN, cosmic-ray transport
- What role do accelerated particles play in feedback on star formation and galaxy evolution?

Probing Extreme Environments

- Neutron stars and black holes, relativistic jets, winds and explosions, the contents of cosmic voids...

Physics Frontiers

- 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 particle exits?

Dark Matter Searches

Dark matter annihilation is expected to produce a gamma-ray Flux

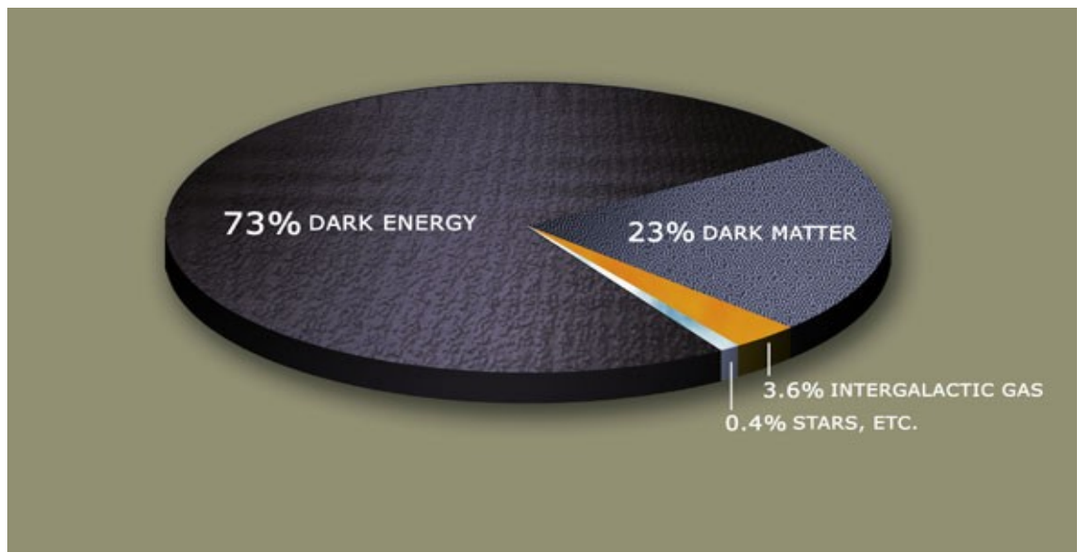
$$\frac{\mathrm{d}\Phi_\gamma}{\mathrm{dE}_\gamma} = \frac{1}{4\pi} \underbrace{\frac{<\sigma_{\mathrm{ann}} v>}{2\mathrm{m}^2_{\mathrm{WIMP}}} \sum_f \frac{\mathrm{dN}^f_\gamma}{\mathrm{dE}_\gamma} \mathrm{B}_f}_{\text{'Particle Physics'}} \times \underbrace{\int_{\Delta\Omega} \mathrm{d}\Omega' \int_{\mathrm{los}} \rho^2 \mathrm{d}l(r,\theta')}_{\text{'Astrophysics' or } J(E)}$$

Both particle physics and astrophysics terms have unknowns

- Assumptions must be made on one to put constraints on the other

Astrophysical uncertainties

- Density profile of dark matter
- Astrophysical interference



Targets for indirect DM searches

Dwarf Spheroidal Galaxies

- Minimal astrophysical backgrounds (little/no star formation)

Galaxy Clusters

- Distant
- DM dominated but likely contain AGN and cosmic ray emission

Galactic Center

- Brightest potential source by far
- Many astrophysical sources in the region

Line Searches

- Monoenergetic gamma-rays hard to produce astrophysically

Lorentz Invariance Violation

A measurement of energy dependent speed of light would be strong evidence for Lorentz invariance violation

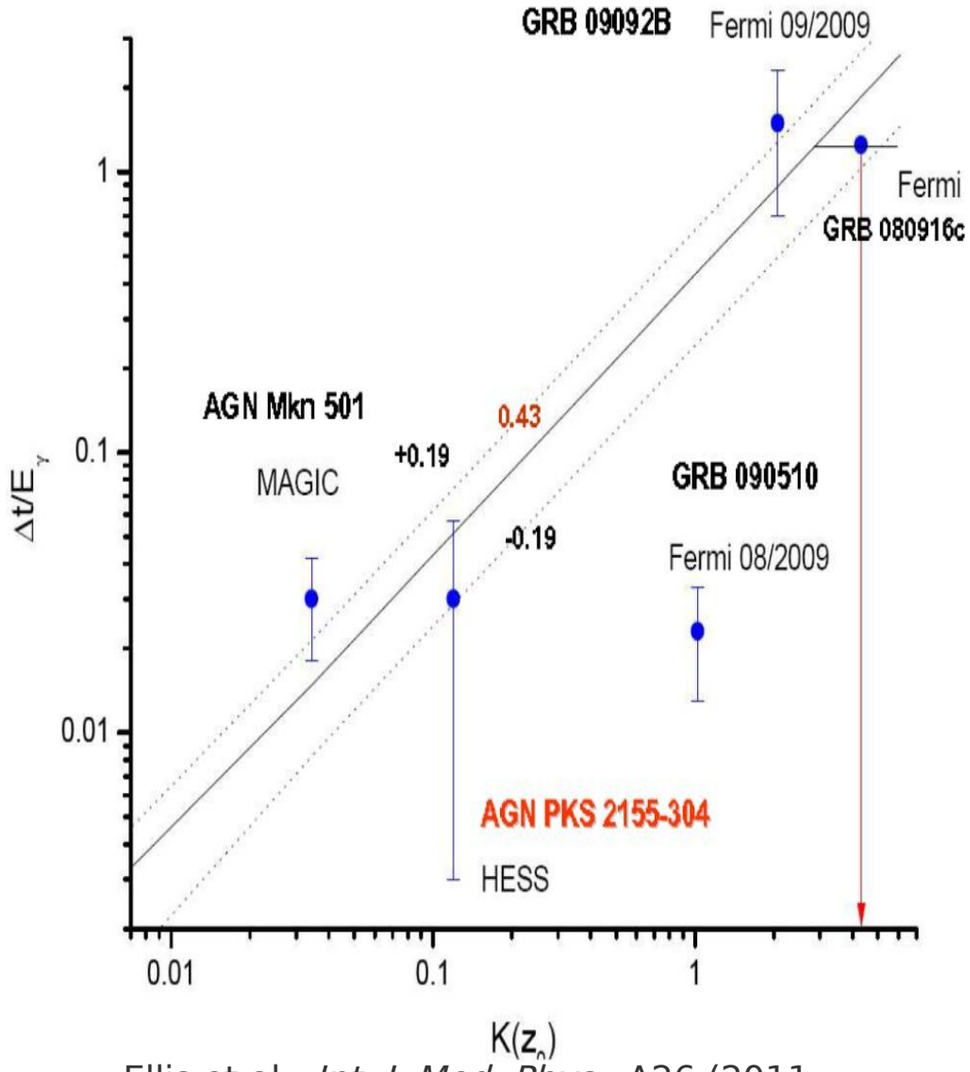
The more precise the arrival time and the further away the object the better the limit

Best limit is from a GRB detected by Fermi

~31 GeV photon from a z=0.9 GRB

Pulsars also give useful LIV tests

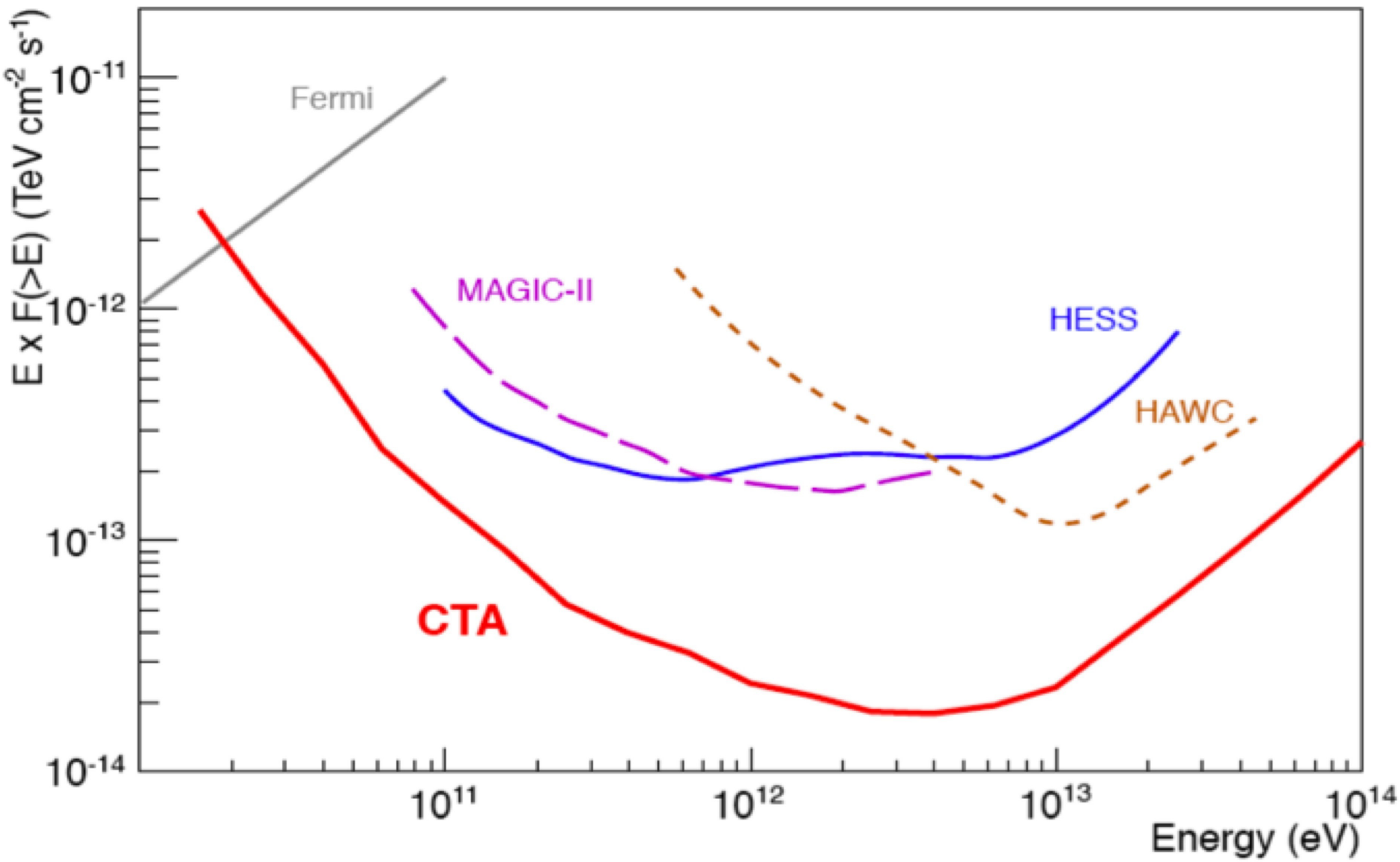
Precision of timing pulse makes up for shorter distances to pulsars



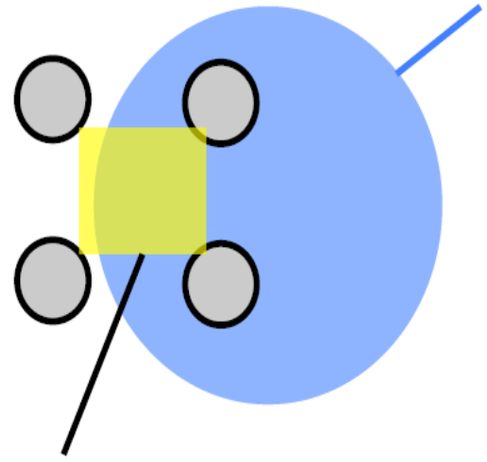
Ellis et al., *Int. J. Mod. Phys.,* A26 (2011

CTA Sensitivity

CTA seeks an order of magnitude improvementb in sensitivity over current generation instruments

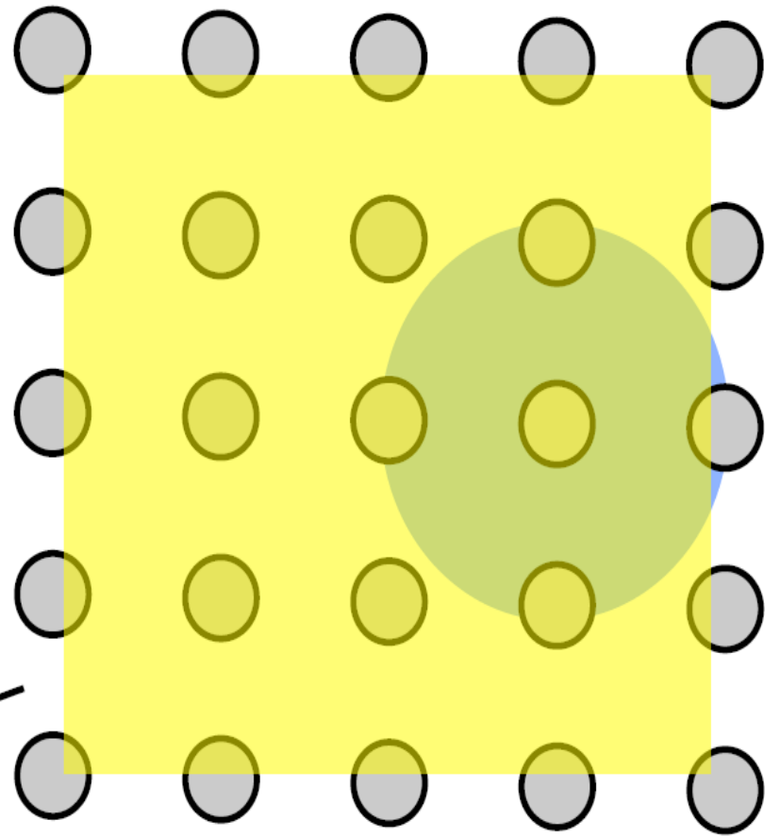


Advantage of a large Array



light pool radius
R ≈100-150 m
≈ typical telescope spacing

Sweet spot for
best triggering
and reconstruction:
most showers miss it!



large detection area
more images per shower
lower trigger threshold

The CTA project

LSTs (4)

Low-energy section

energy threshold

of ~ 20–30 GeV

23 m telescopes

MSTs (~25)

Medium energies

mcrab sensitivity

~100 GeV–10 TeV

9-12 m telescopes

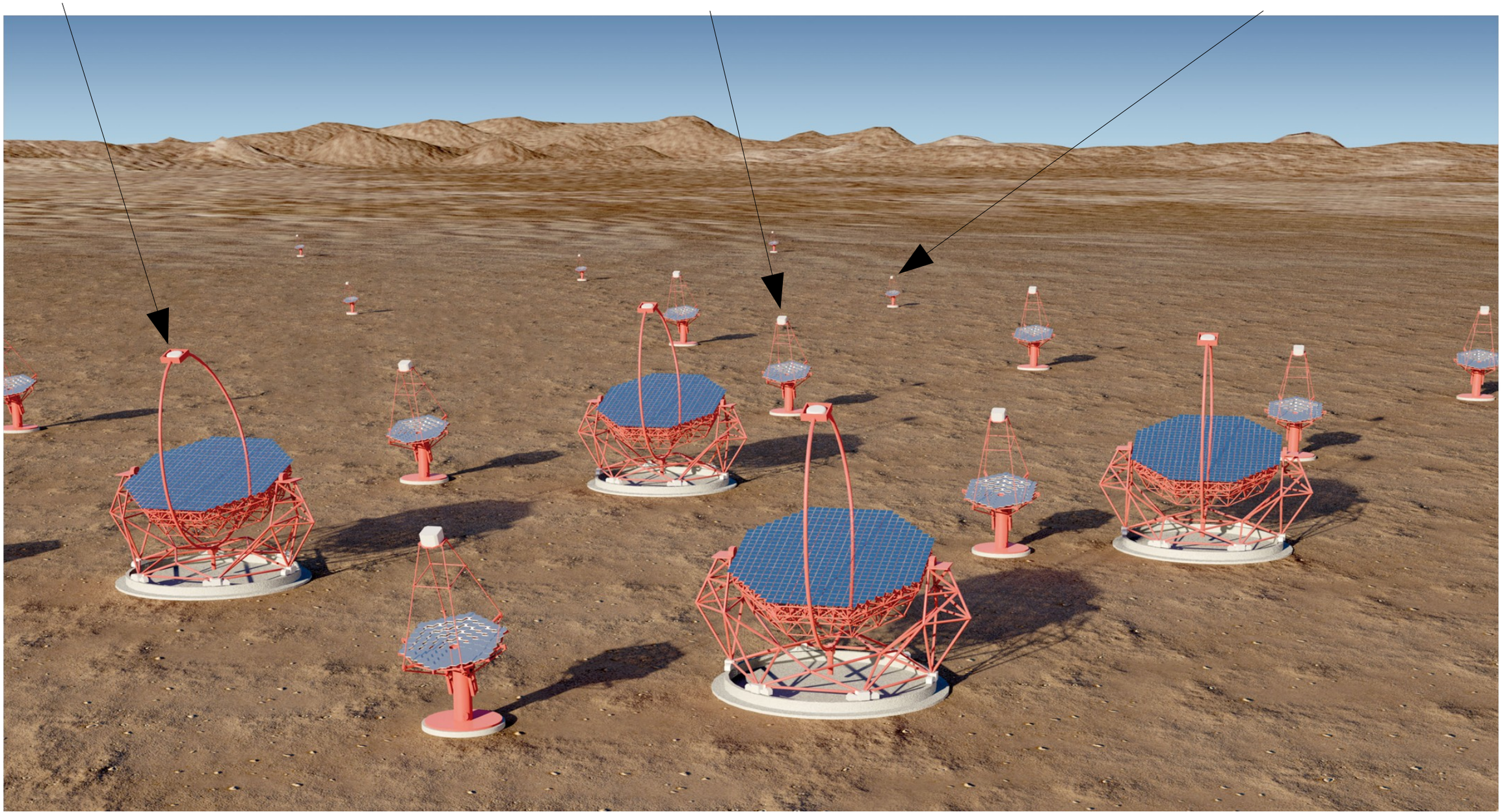
SSTs (~70)

High-energy section

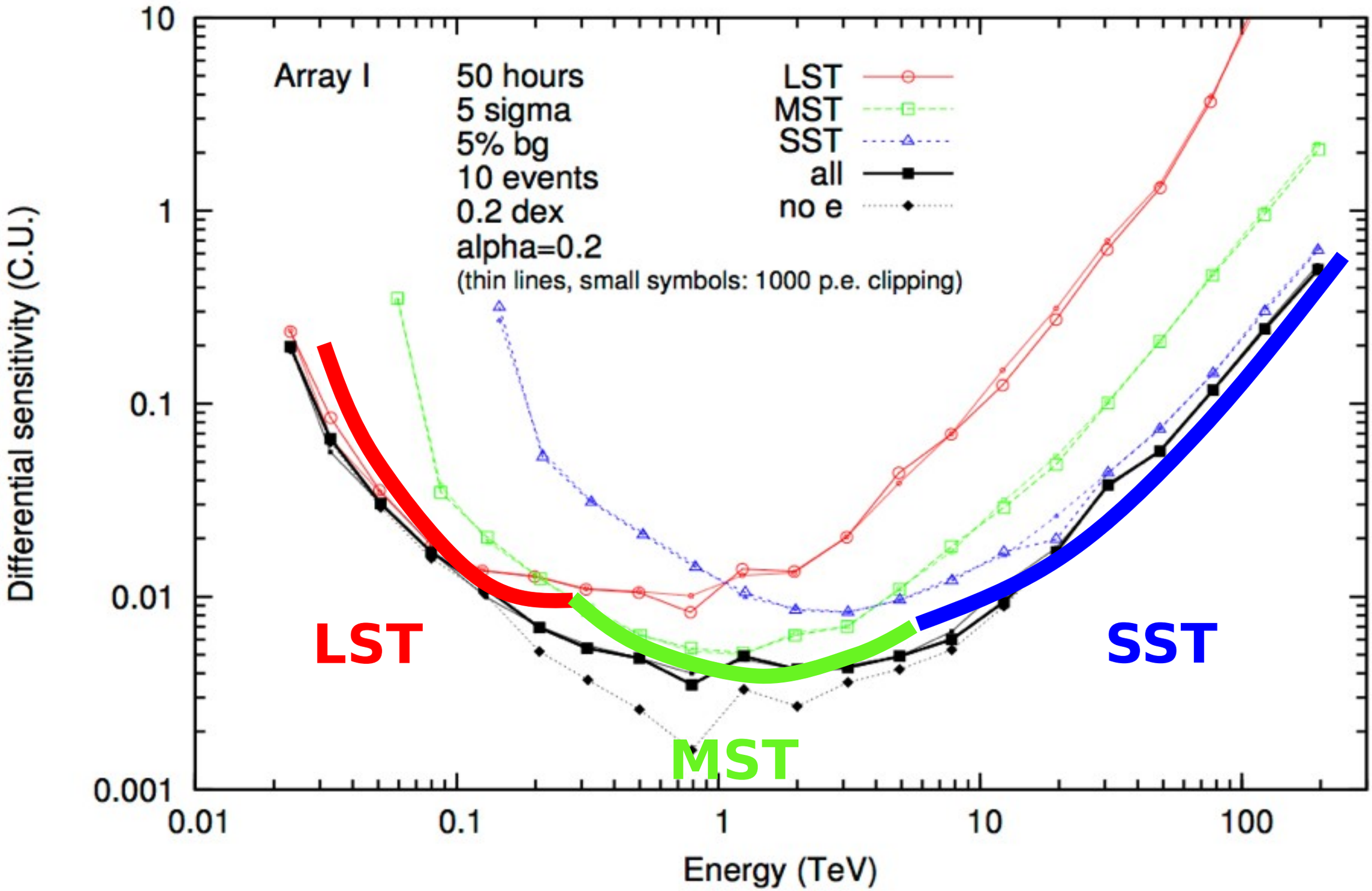
~10 km^2 area at

multi-TeV energies

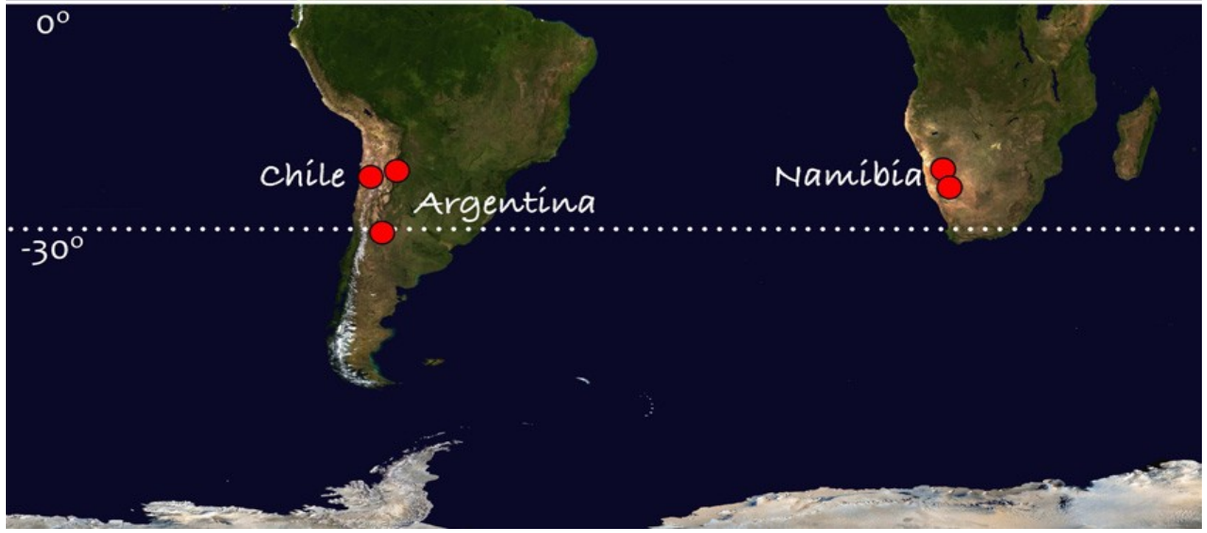
4 m telescopes



Sensitivity



CTA site Selection



CTA Consortium has identified the two most promising southern sites and has begun negotiation with the host countries

- Aar, Namibia
- Cerro Armazones, Chile

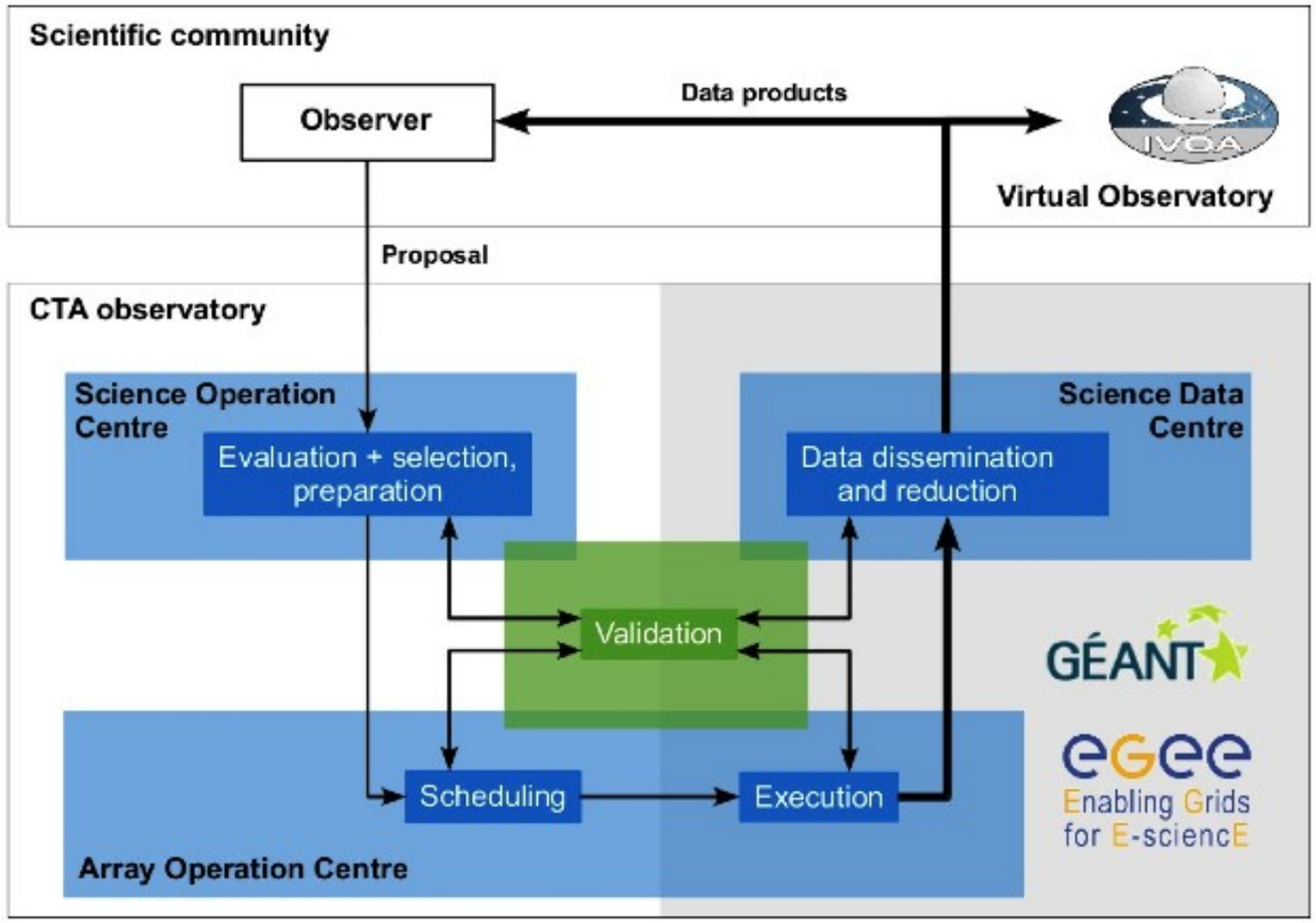
Northern sites under investigation:

- Meteor Crater, Arizona,USA
- San Pedro Martir, Mexico
- Tenerife, Canary Islands, Spain

Scientific Evaluation

- Annual observing time (clear skies)
- Best instrument sensitivity (dark, steady, high-transmission skies)
- Elevation

CTA as an Observatory



Operated as an ‘‘open’’ Observatory

- Peer-reviewed process on submitted proposal
- Observations performed by full-time telescope operators
- Foreseen ‘‘legacy’’ data (Galactic Plane, full-sky survey)

Schwarzschild-Couder Extension

The goal

- Boost CTA performance for the widest spectrum of science topics by improving angular resolution performance and collection area in the central (around 1 TeV) energy domain by a factor of 2.

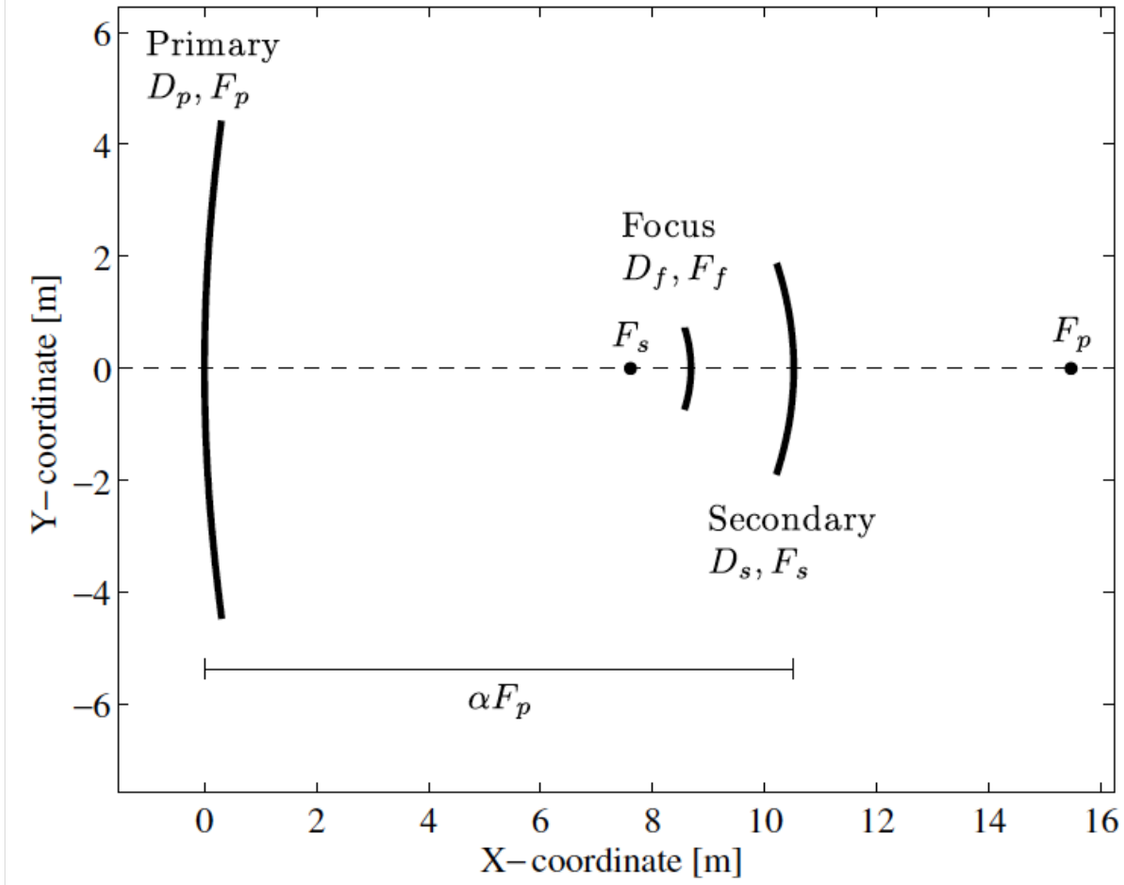
The solution (science-wise)

- Increasing the number of medium-sized telescopes, improving the angular resolution (with a reduced pixel-size), and widening the field of view.

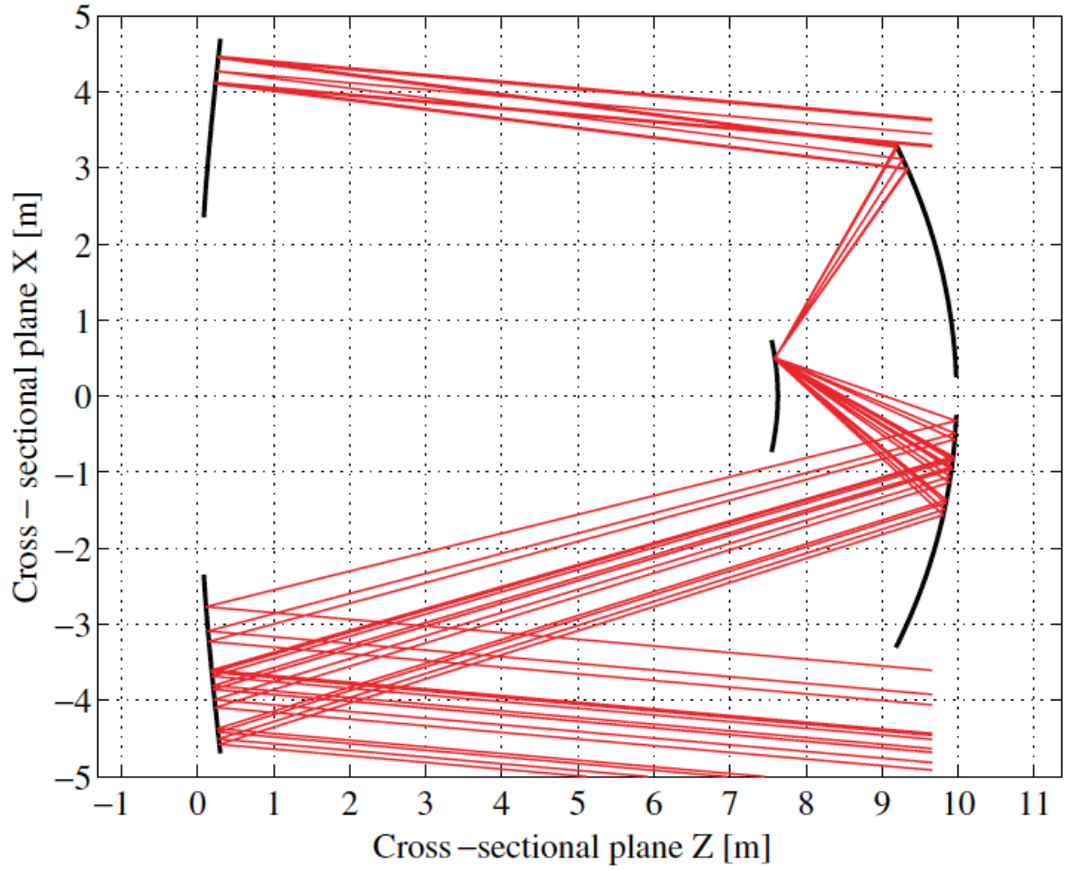
The solution (technical-wise)

- ~24 Schwarzschild-Couder (medium-sized, 9.5m) telescopes with a 0.067° pixel and a 8° FoV. Extremely challenging with traditional Davies-Cotton telescopes.

SCT Optics



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



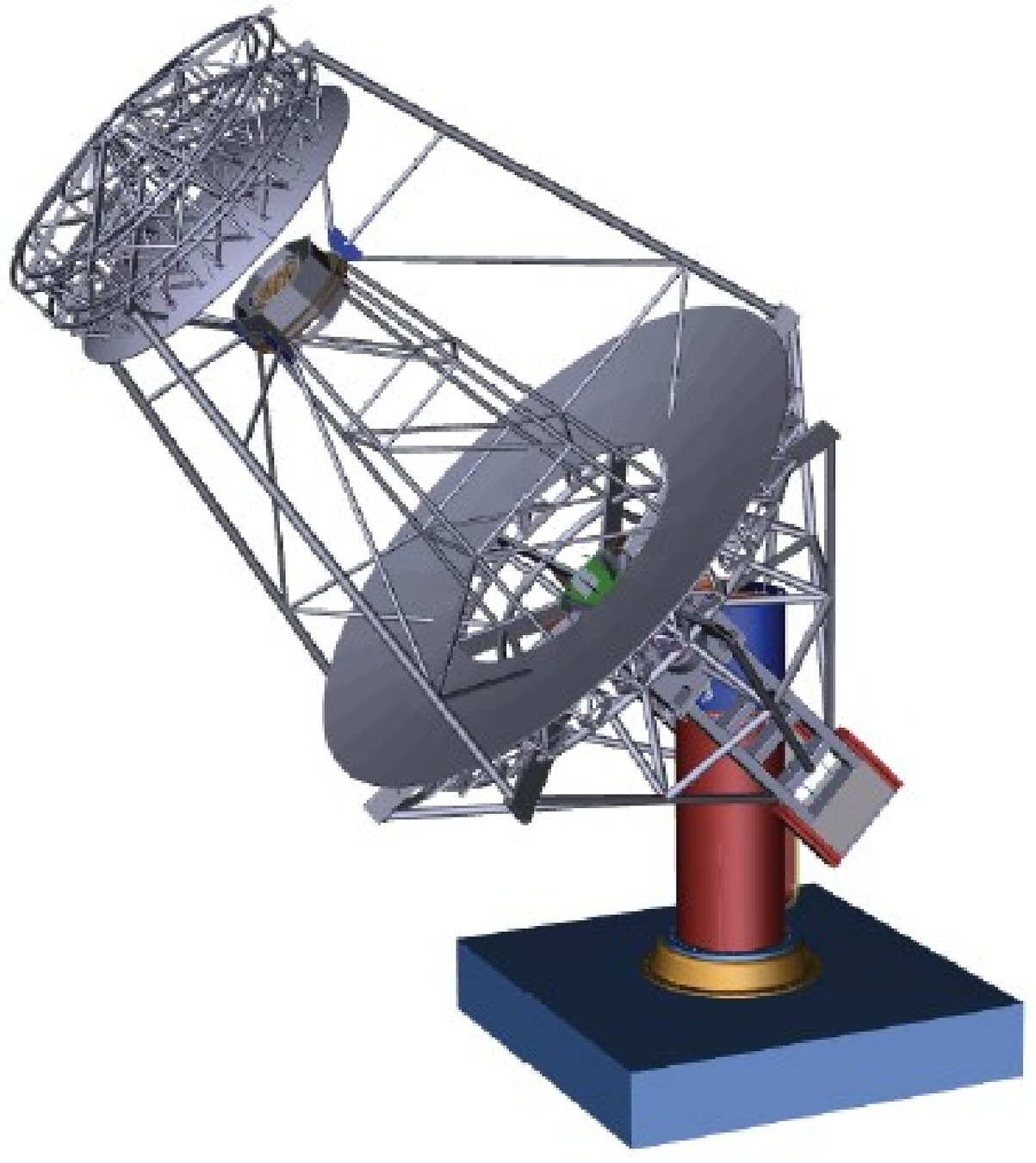
In the SC telescope, the focal plane is located in-between two aspherical mirrors, close to the secondary mirror.

No Cherenkov telescope adopted this optical system up to now

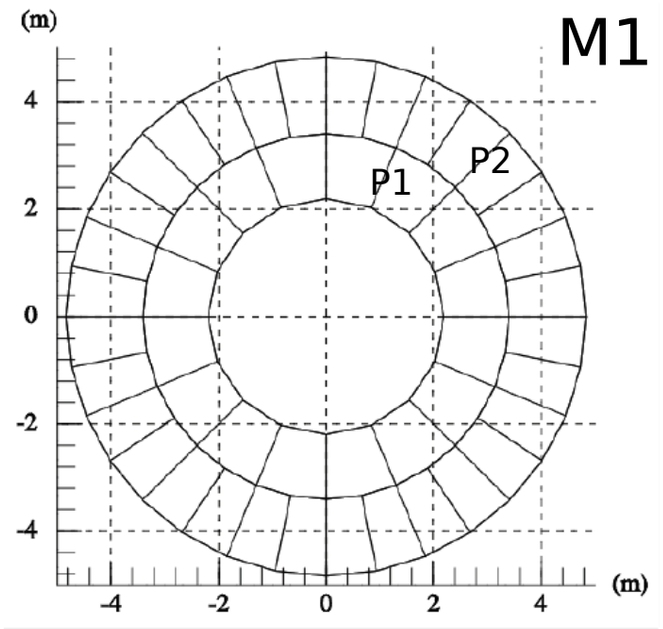
SCT

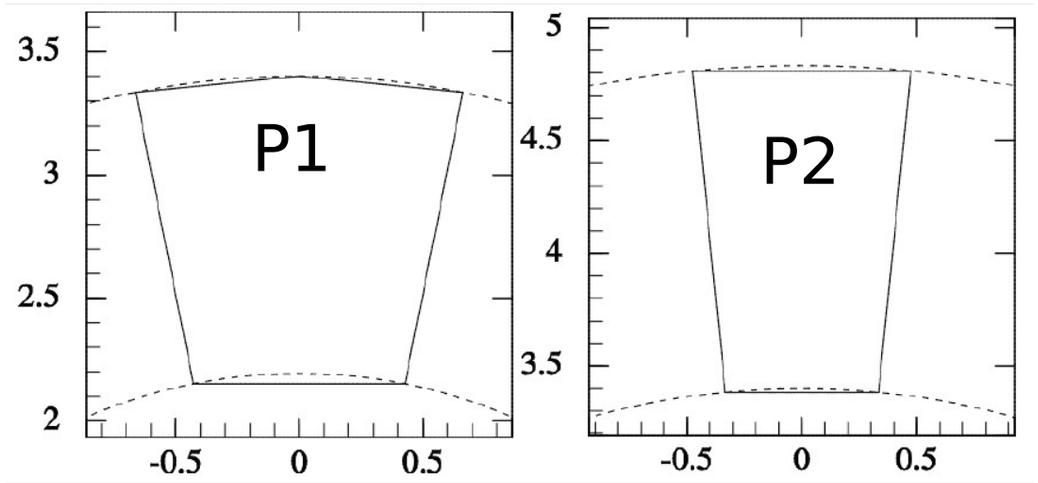
Telescope properties
- Primary mirror = 9.66m
- Secondary Mirror size = 1.2m

Camera properties
- Number of pixels = 11328
- Pixel size = 0.067°
- Sensors type = SiPMs
- Field of view = 8°

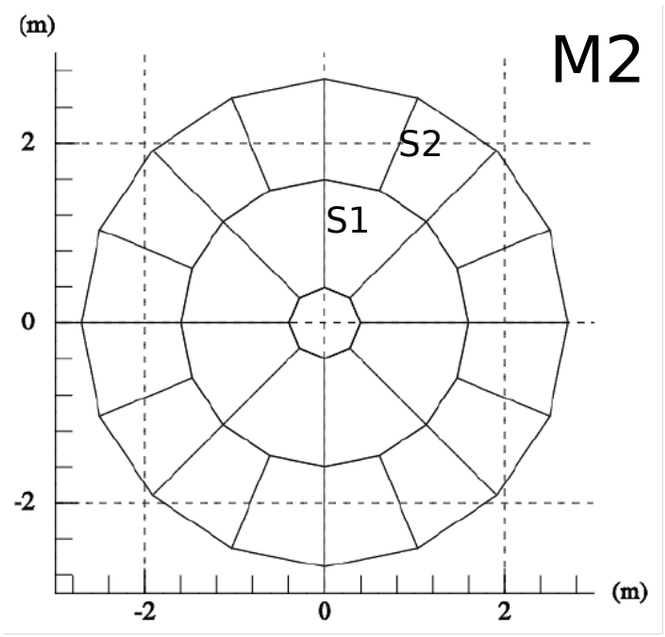


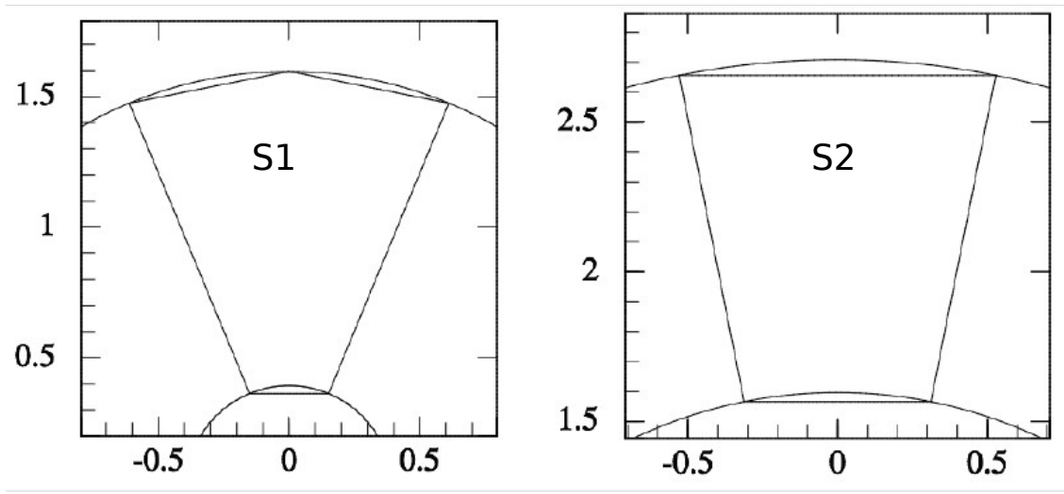
SCT Mirrors


M1
(m)
P1
P2
4
2
0
-2
-4
-4
-2
0
2
4
(m)

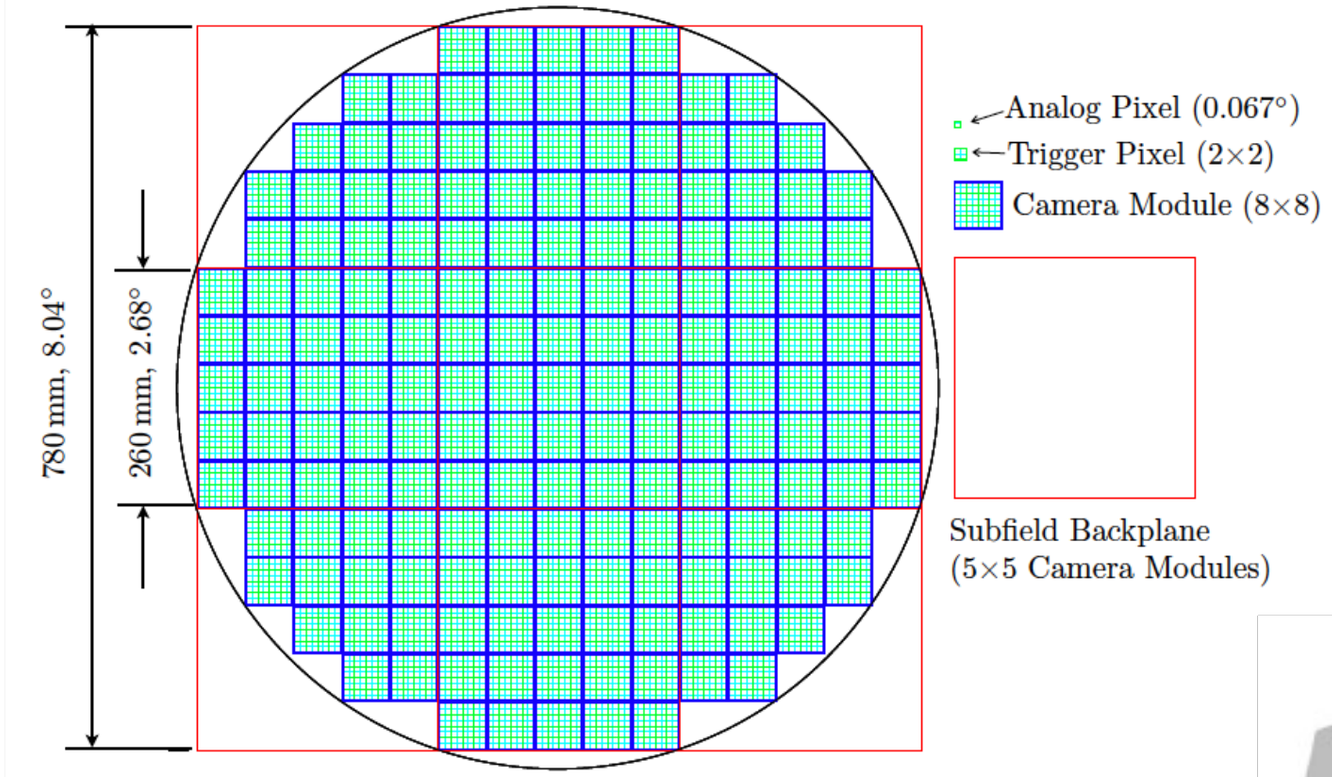

P1
P2
3.5
3
2.5
2
-0.5
0
0.5
5
4.5
4
3.5
-0.5
0
0.5

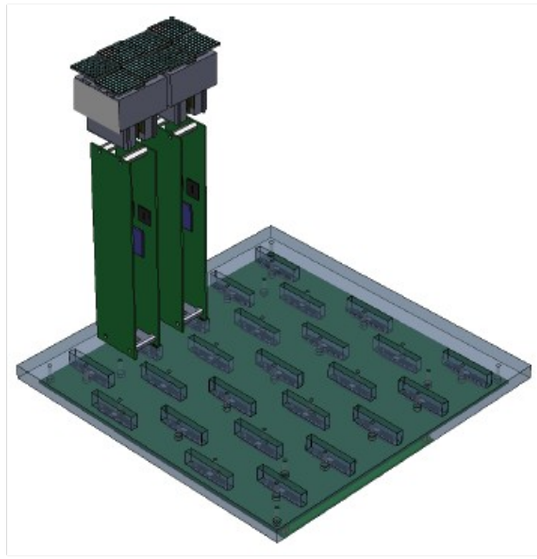
M1-P1 panel

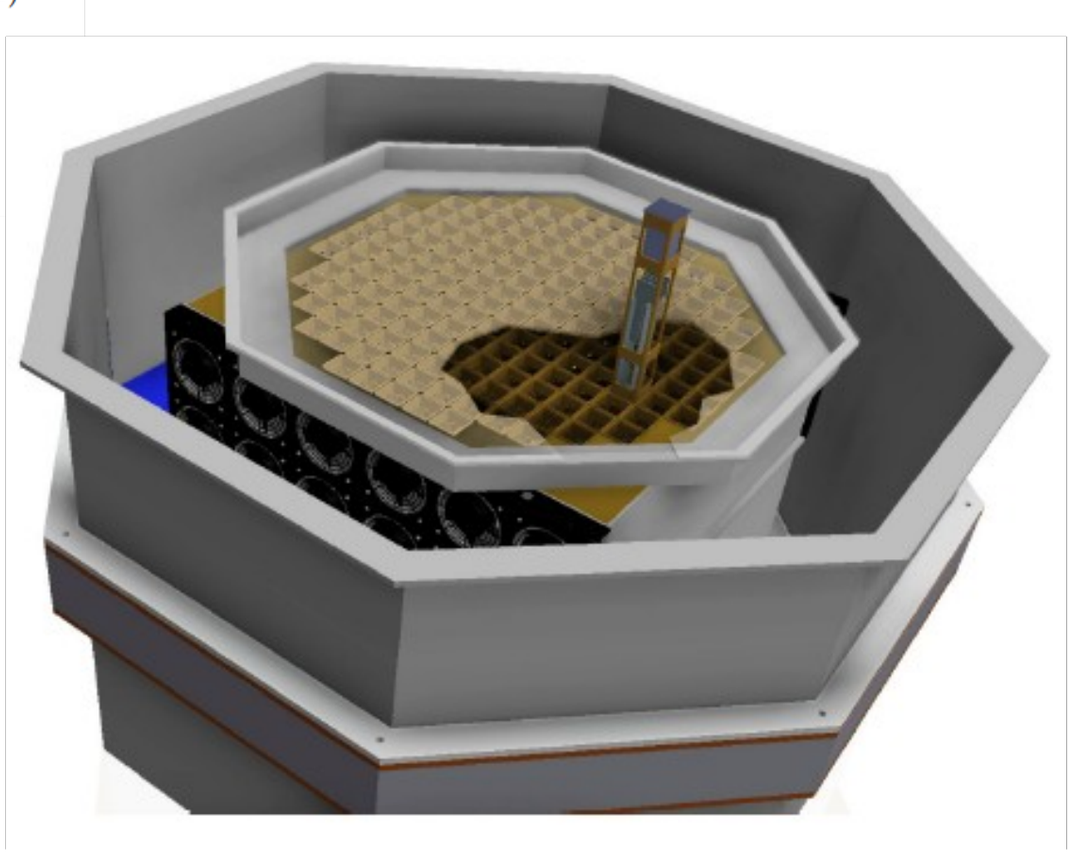

M2
(m)
S2
S1
2
0
-2
-2
0
2
(m)


S1
S2
1.5
1
0.5
2.5
2
1.5
-0.5
0
0.5
-0.5
0
0.5

SCT Camera







- Highly integrated design: All signals digitized in camera
- SiliconPM photosensors
- Removable modules
- Temperature stabilization of focal plane

Summary and Conclusions

- CTA will offer a 10-fold improved sensitivity for VHE studies of the cosmos
- Guaranteed science studying known high-energy sources
- Huge discovery potential for the physics of Galactic and extra-Galactic sources, and for fundamental physics studies
- CTA will serve the entire astrophysics community
- Site selection for Southern site by the end of the year
- Operations expected to begin within 5 years
- Proposed US extension significantly increases CTA's sensitivity with a two-mirror, SiliconPM based telescope