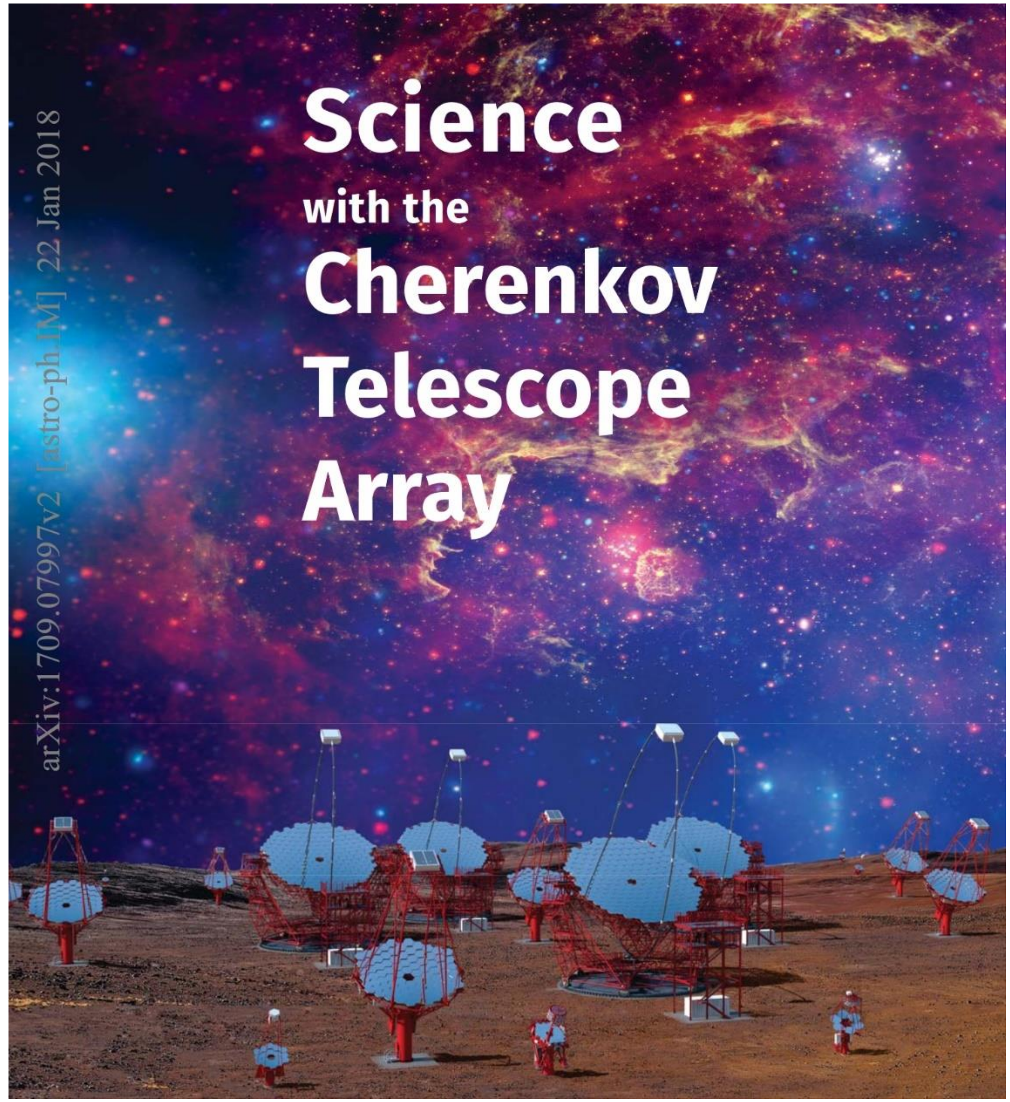
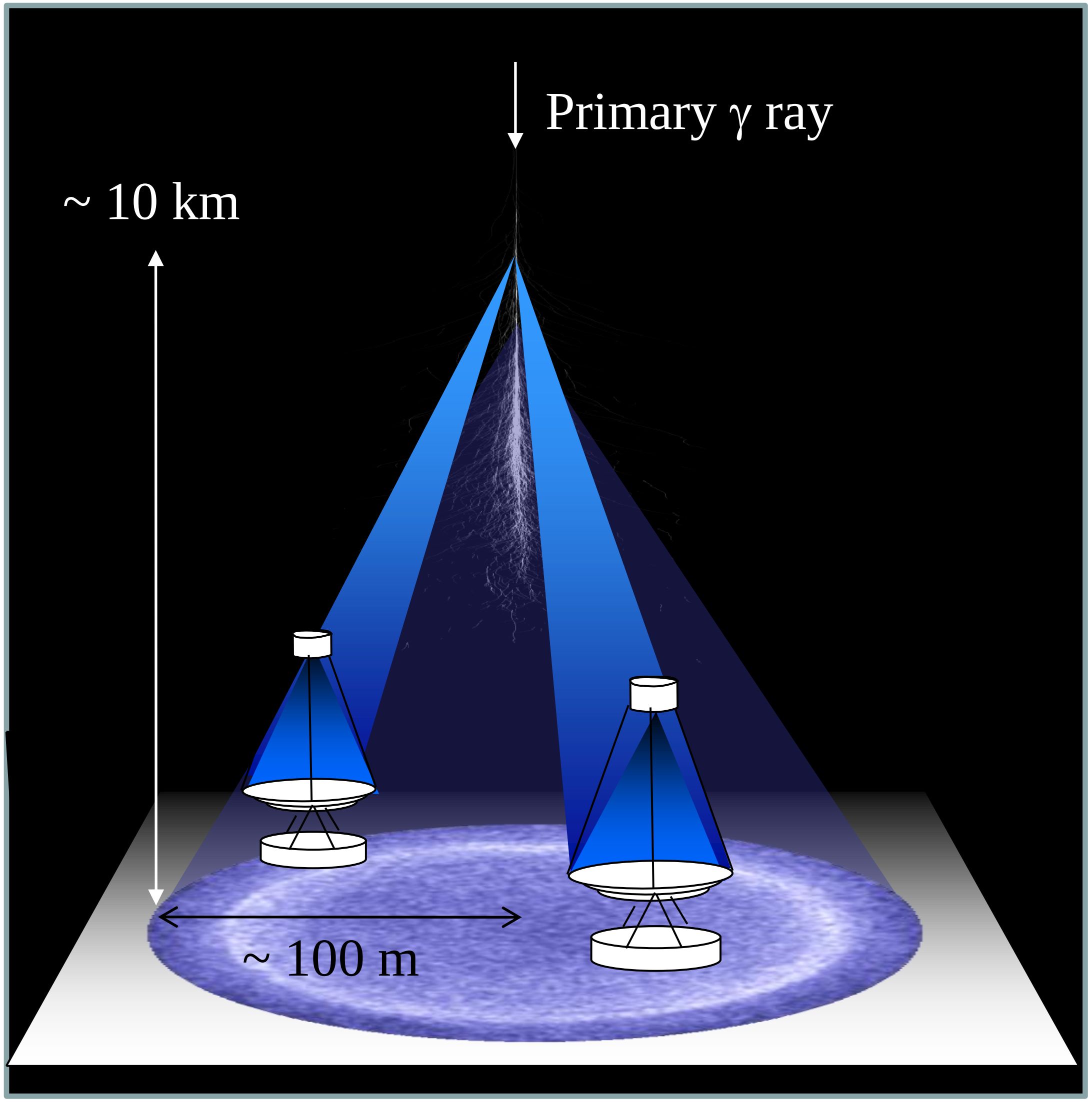
Cherenkov Telescope Array
– status May 2024

- Introduction to CTA
- Progress on CTA northern and southern sites
- The Small Size Telescope and its camera
- Odds and ends
- Some CTA science
- Summary

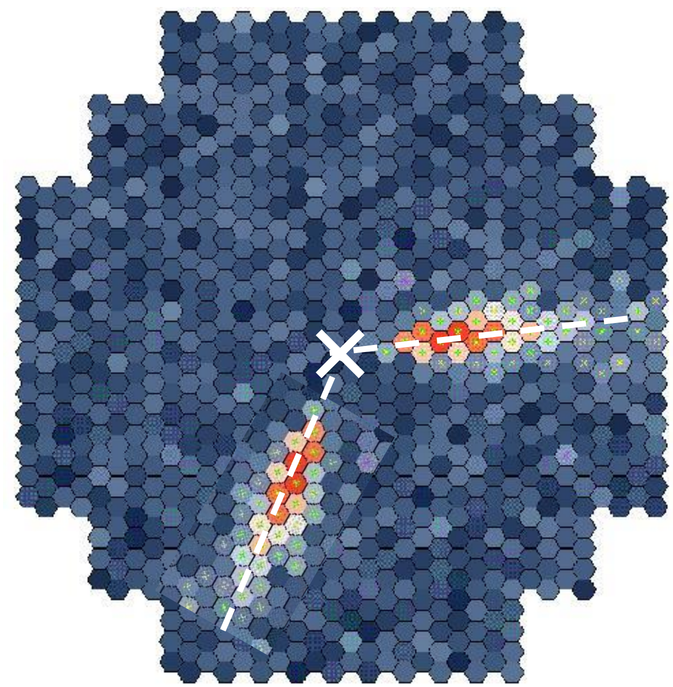
- CTA-UK:
  - Armagh Observatory
  - Durham
  - Leicester
  - Liverpool
  - Oxford



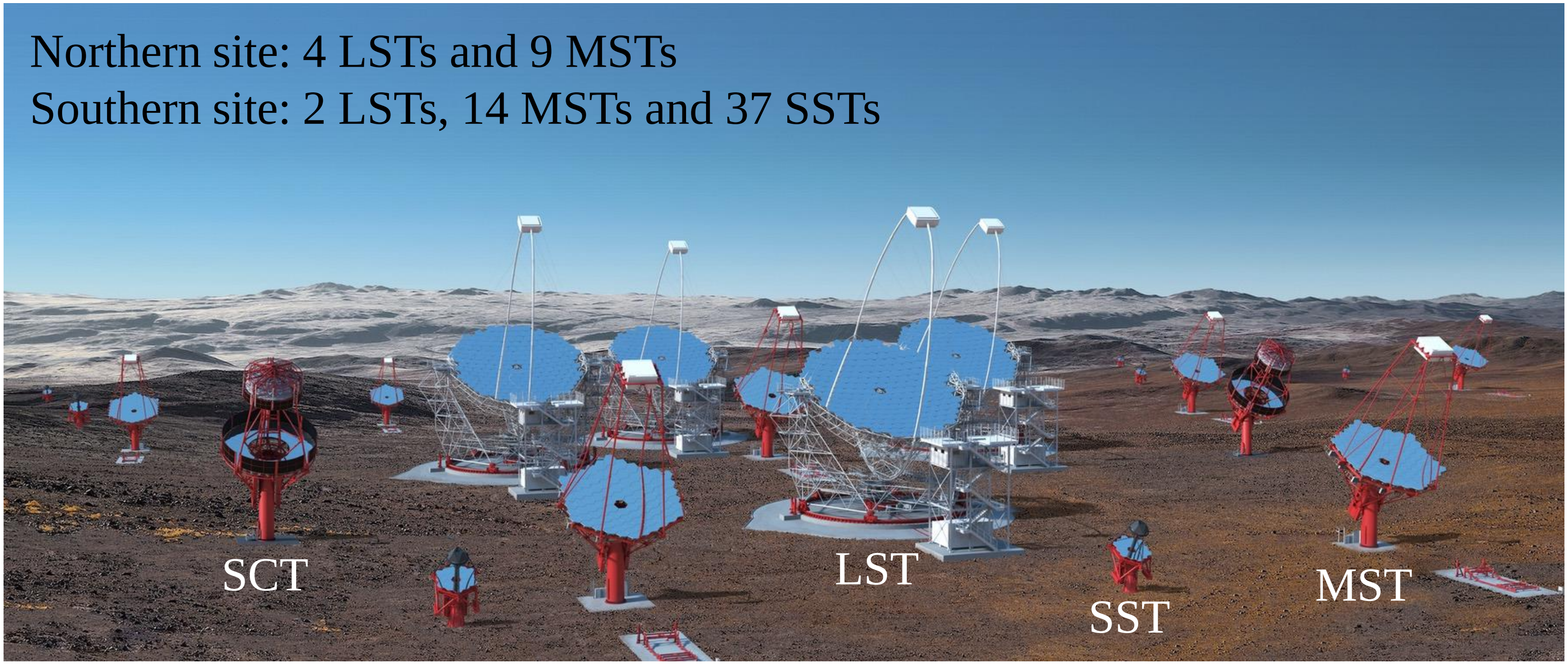
Introduction – detecting high energy γ rays



- Cherenkov light flash lasts ~ 10 ns.
- Detect with camera made of photomultipliers.
- Superimpose telescope images, find γ-ray source and intensity.



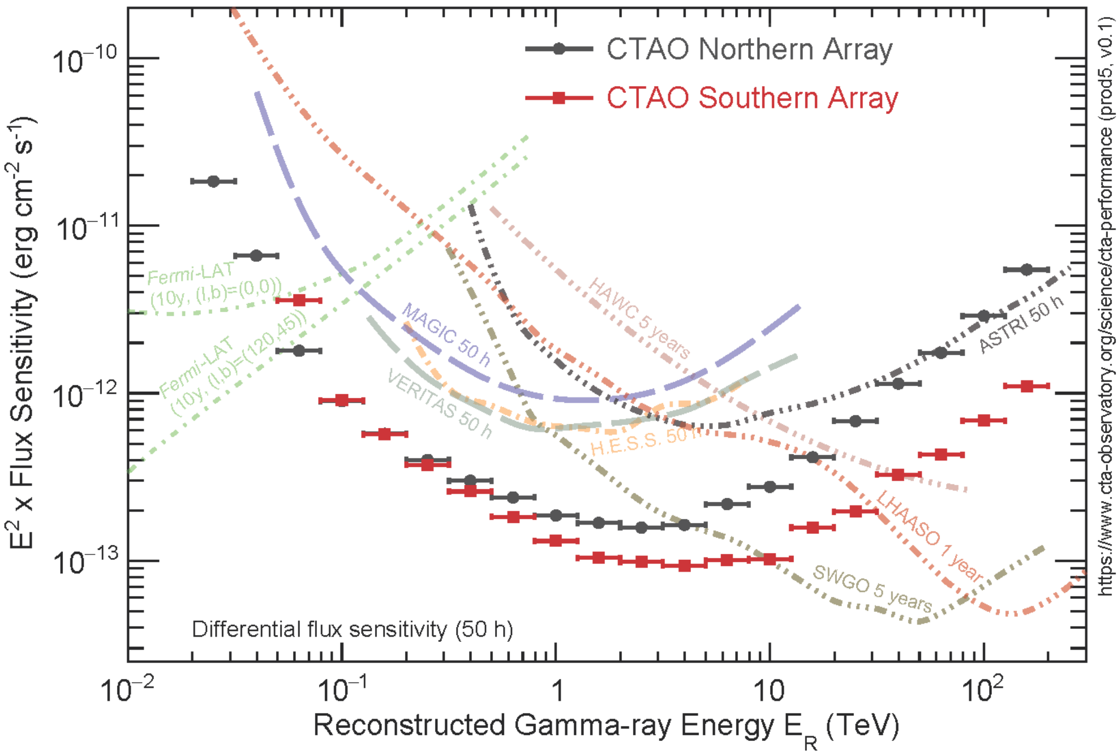
The Cherenkov Telescope Array



- CTA will use different telescope sizes on northern and southern sites to cover:
  - Low energy, 20 GeV…1 TeV, Large Size Telescopes, 23 m diameter.
  - Medium energy, 500 Gev…5 TeV, Medium Size Telescopes, 12 m diameter.
  - High energy, 1 Tev…300 TeV, Small Size Telescopes, 4.3 m diameter.

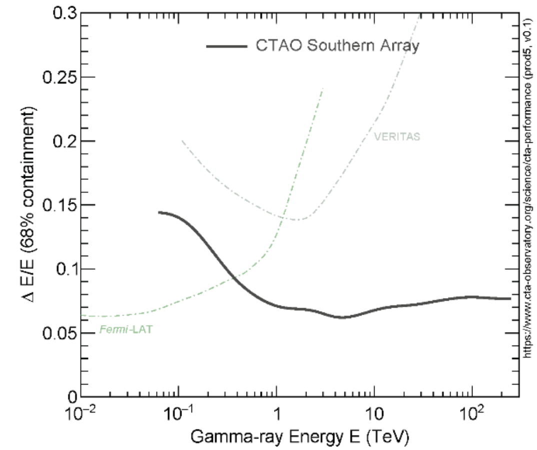
CTA performance

- CTA sensitivity:

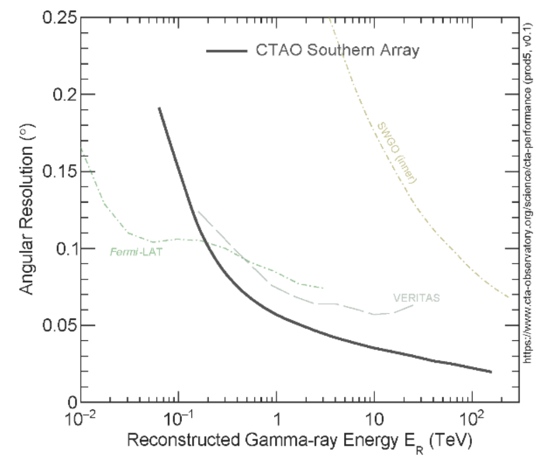


- Performance dominated by SSTs at energies above 5 TeV.

- $\Delta E/E < 10\%$ for $E_\gamma > 1$ TeV.

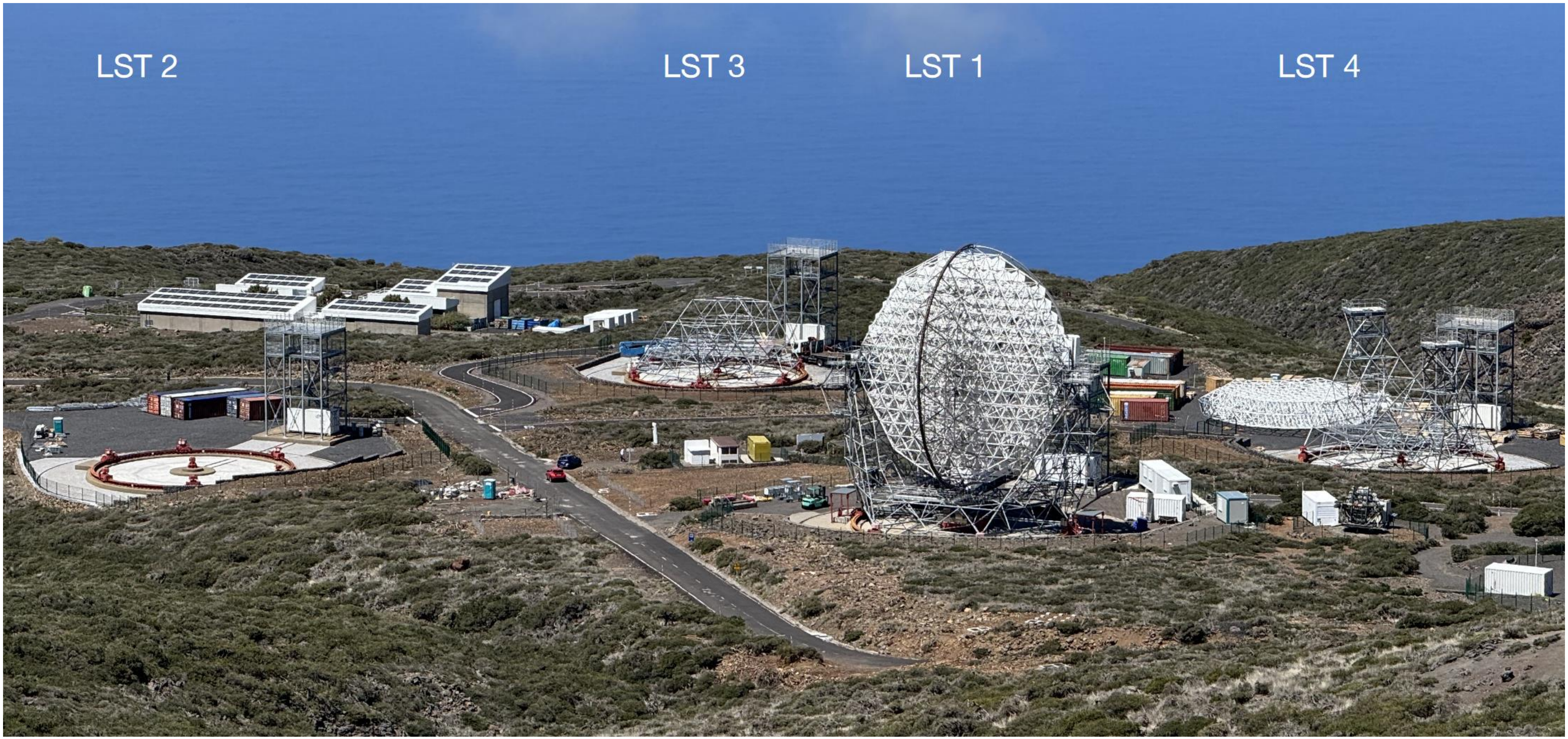


- Ang. Res. $< 0.05°$ for $E_\gamma > 1$ TeV.



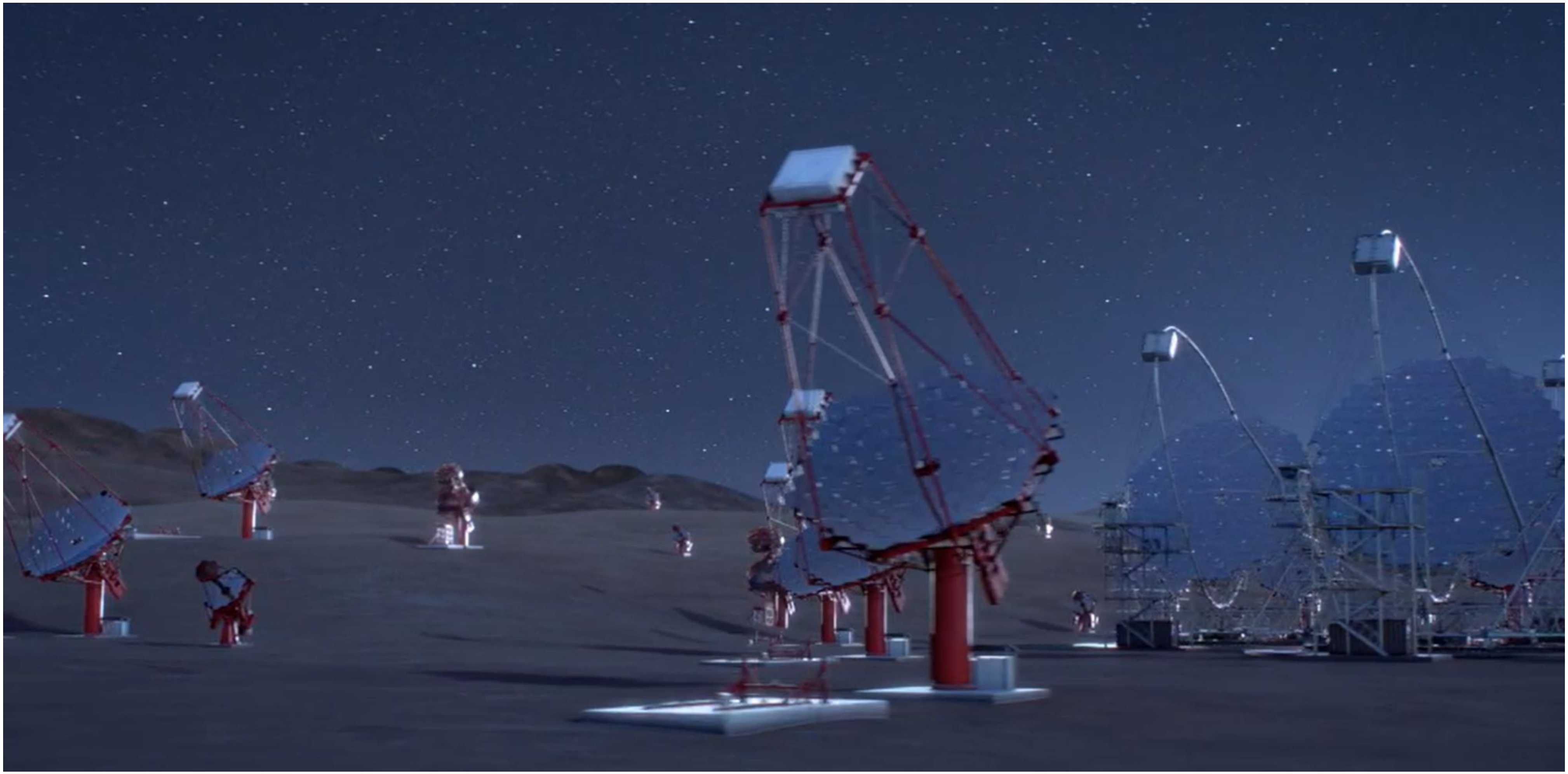
Status northern site

- Roque de los Muchachos Observatory, La Palma, April 2024:



Status southern site

- Paranal, Atacama Desert, Chile:



Southern site

- Paranal, June 2023:

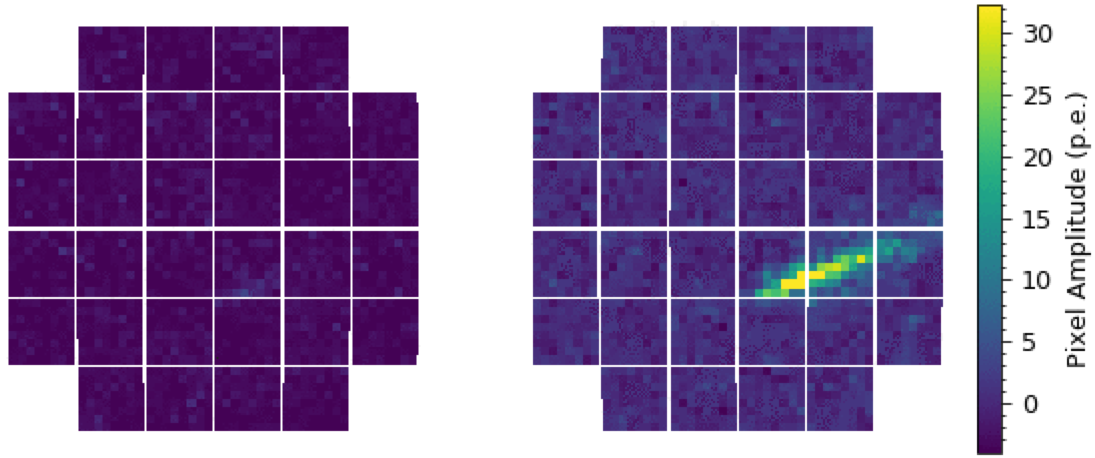
Small Size Telescope

- UK proposed use of Schwarzschild-Couder (dual mirror) optics for SSTs.
- Original optical design by Liverpool and Durham, later by Brera Observatory, Italy.
- Current design has:
  - Primary diameter 4.3 m.
  - Secondary diameter 1.8 m.
  - Focal length 2.15 m.
  - F = 0.5.
  - Focal plane diameter 0.4 m.
  - Field of view 9°.
- UK camera selected for SST after international review.

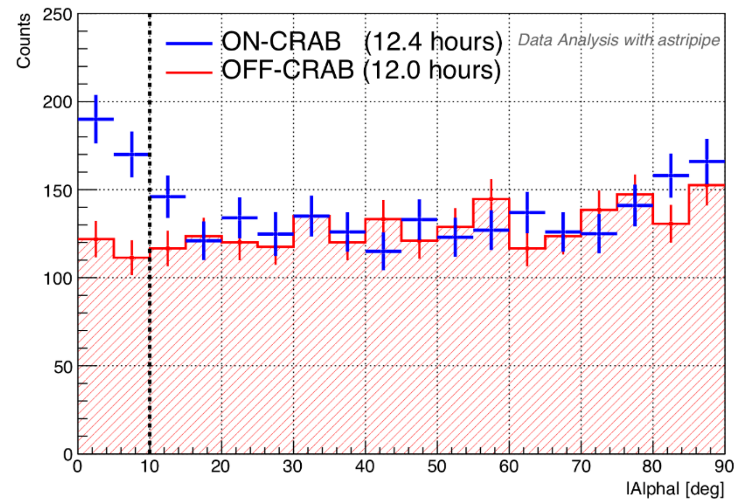
SST camera based on CHEC-S

- ASTRI telescope and CHEC-S camera at the Serra La Nave observatory in Etna, Sicily.

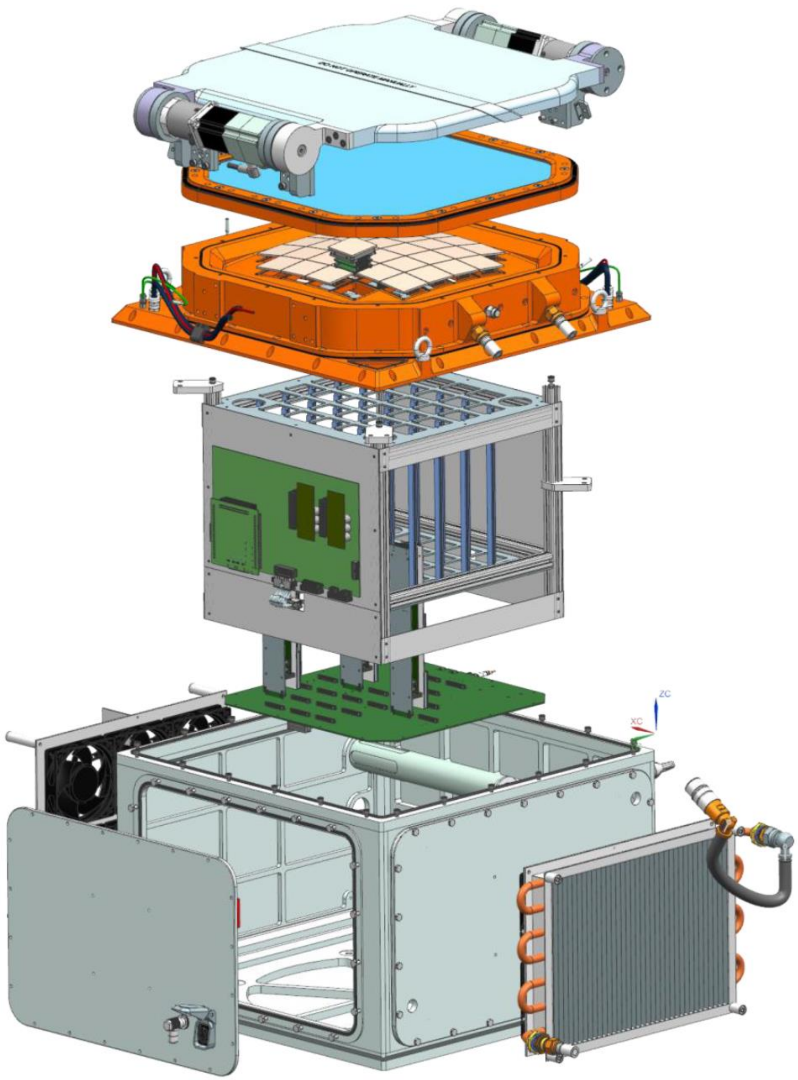
- Examples images, 1 ns time slices:



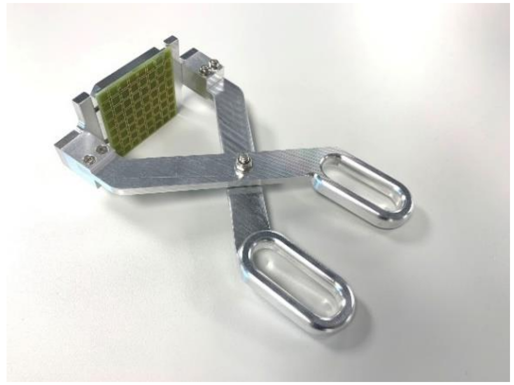
- First dual-mirror VHE detection of Crab nebula:



SST camera Sensors

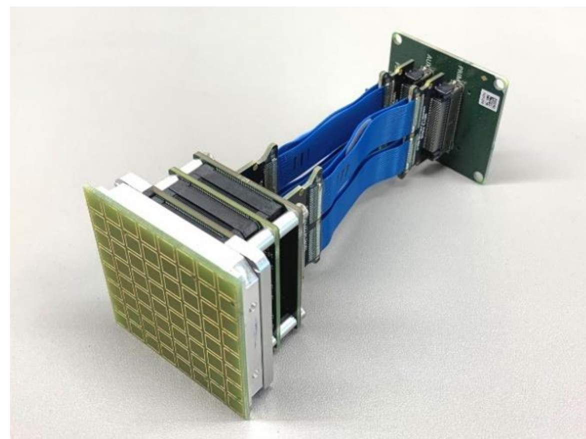


- Thirty-two tiles of 8×8 Hamamatsu SiPMs.
- Pixel size 5×5 mm^2.



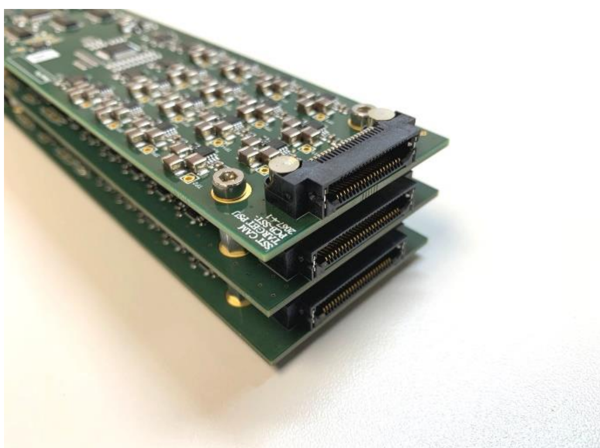
- Cross talk due to photons scattering in SiPM resin coating observed in CHEC-S, use uncoated Si.
- Care needed in assembly!

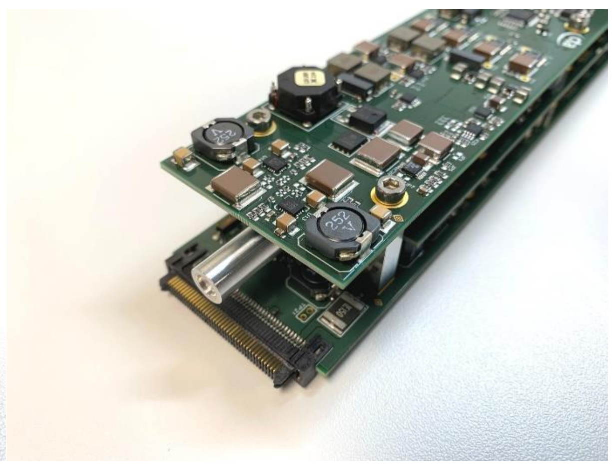
- Delivery and test of production versions has started (MPIK providing funds to Leicester).



Camera trigger and readout

- Trigger and readout (1 Gsample/s) using custom TARGET ASICS.
- First modules manufactured and tested.

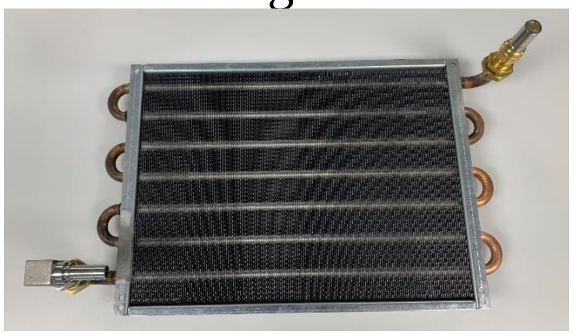




- Initial tests successful: no layout errors found.
- Individual pixel HV control needed for gain matching.
- Provision of TARGET modules foreseen as UK contribution to CTA.

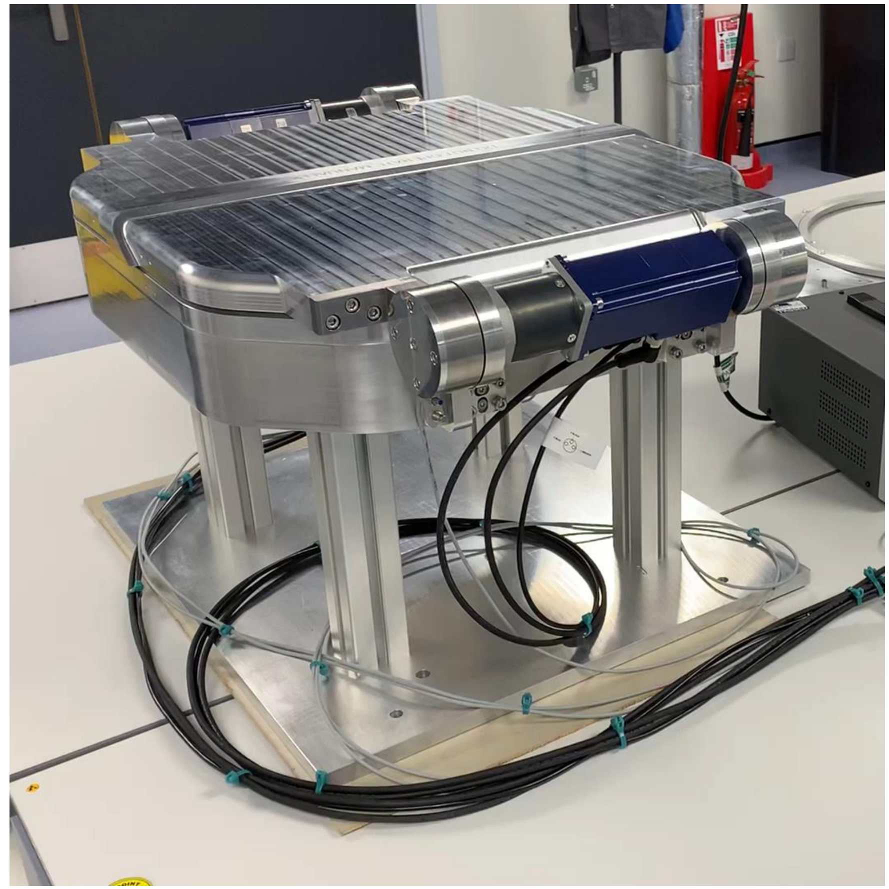
Camera mechanics

- First production enclosure under test.
- UK contributions to mechanics include overall design plus:
  - Heat exchangers



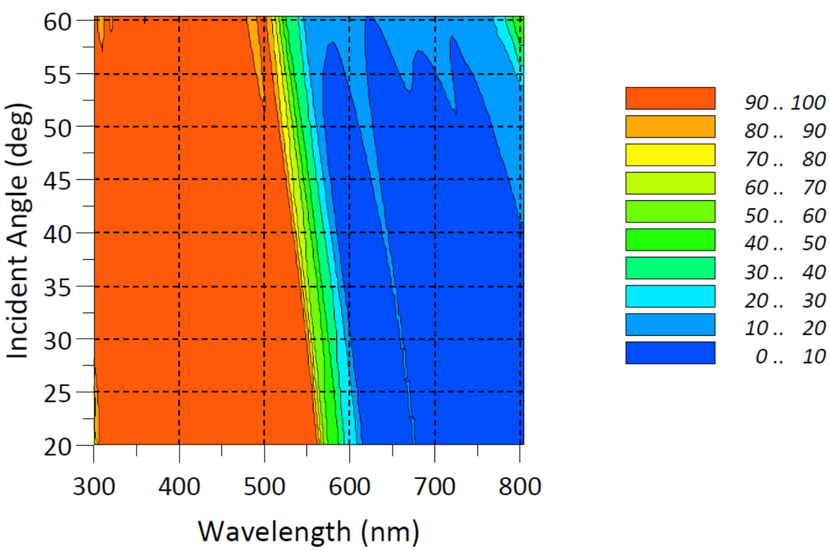
  - Fan banks…

- …and doors.

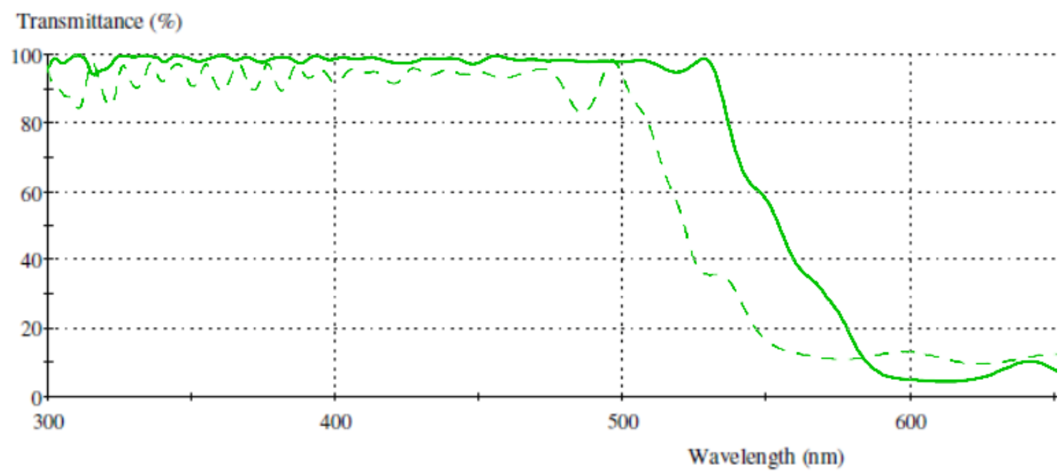


Camera calibration and windows

- UK planned to provide flashers for camera calibration.
- And quartz windows with coating that transmit UV/blue light and block IR (night sky background).
- Coating developed by Thin Metal Films, Basingstoke.



- "Needle" design consists of 81 layers (hafnia, silica…).
- Transmittance (mean polarisation): solid line at 20° incidence angle; dashed line at 60° incidence.



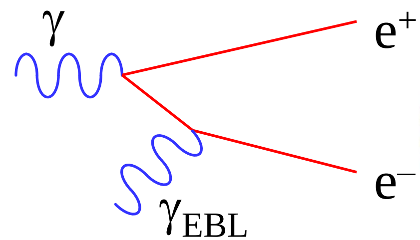
- Rear coating prevents reflection of IR photons produced in SiPMs back onto sensors.
- UK has funded camera windows.

Odds and Ends

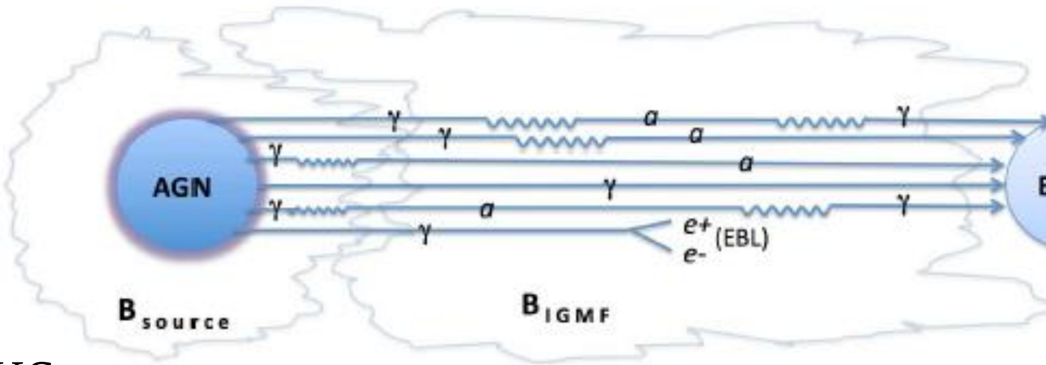
1. Project's name and descriptive title
CTA: An advanced facility for ground-based high-energy gamma ray astronomy
2. Short description of project and main characteristics
Imaging atmospheric Cherenkov telescopes have proven an extremely successful approach to gamma ray astron... in the energy range above a few tens of GeV. The proposed facility will consist of a large ...scopes, aiming to (a) increase sensitivity by another order of magnitude for deep obs... significantly boost the detection area and hence the detection rates, particularly imp... ...nt phenomena and at the highest energies, (c) to increase the angular resolution and hen... ...solve the morphology of extended sources, (d) to provide wide and uniform energy ... ...ound 10 GeV to beyond 100 TeV, and (e) to boost the survey and monitoring capability by sp... ...into multiple subarrays. These features will allow to explore non-thermal processes in the U... ...lose cooperation with and complementing observatories in other wavelength ranges of electro... ...agnetic radiations, and for other messenger types.

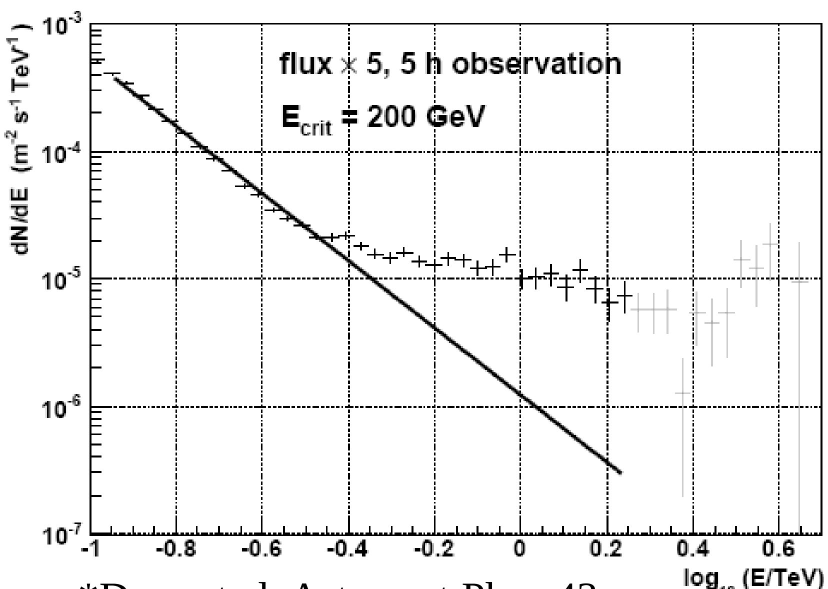
SUBMITTED TO ESFRI IN DEC. 2005

CTA science – searches for axions



- HE γ rays interact with EBL (for E_γ > 1 TeV) and CMB for E_γ > 100 TeV).
- Opacity of universe changes if there are axion-like particles.
- E.g. simulation of 5 h flare of PKS 1222+21, see change in spectrum*.

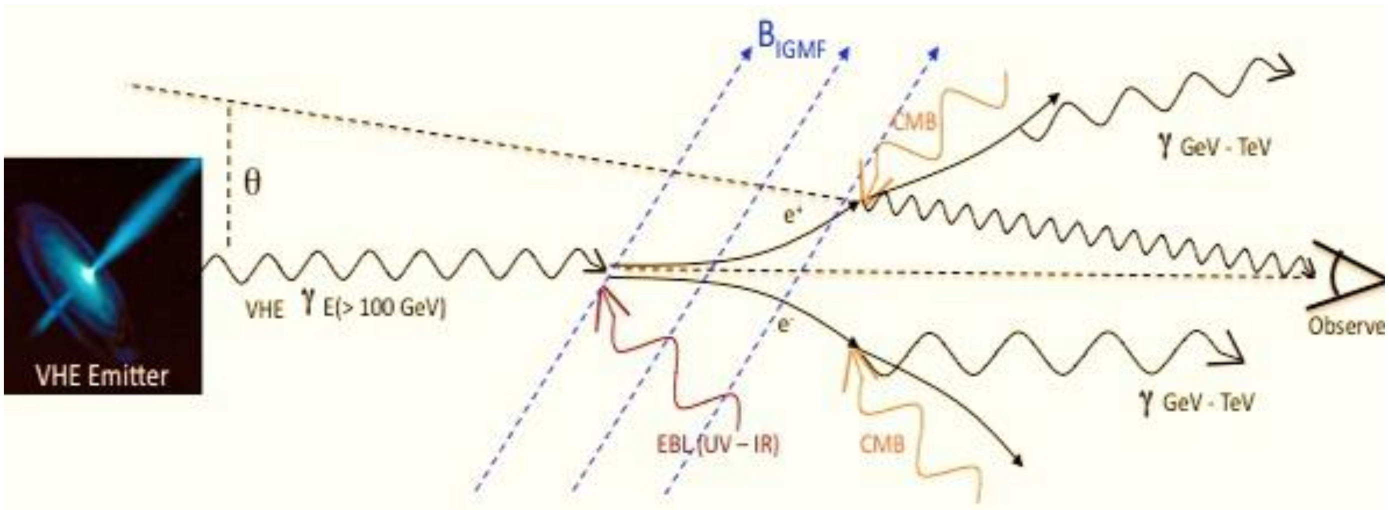


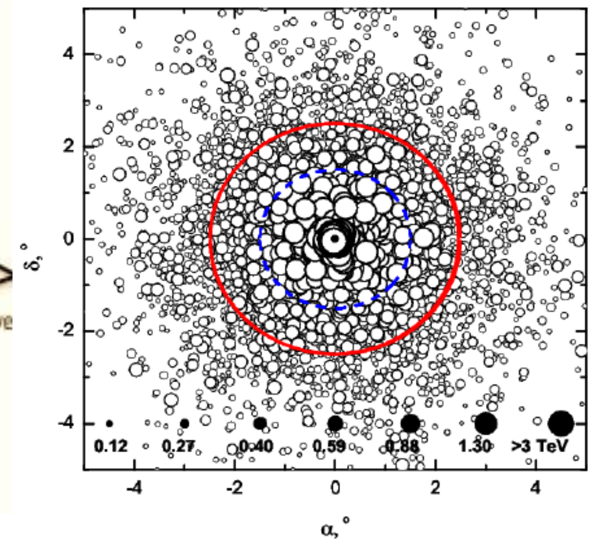


*Doro et al, Astropart Phys 43

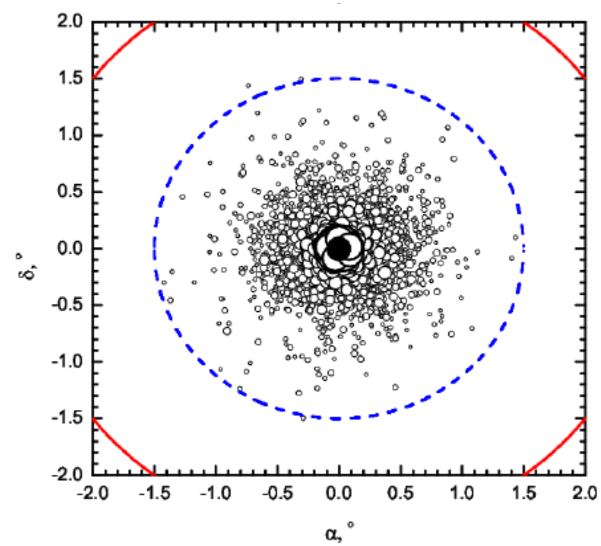
- Allows searches for ALPs in mass and coupling regions not otherwise accessible.
- Also provides a measurement of the EBL density.
- Allows inferences about first "population III" stars and the stellar formation rate, primordial black holes, and decays of exotic particles to photons in the early universe.

CTA science – Probing intergalactic magnetic fields with CTA





- Explore origin of magnetic fields in galaxies.
- Look for extended γ-ray emission and pair haloes associated with primary γ-ray source at 120 Mpc.
- Top Fig. IGMF 10^{-14} G, bottom IGMF 10^{-15} G.
- For lower fields, look for "pair echoes".



Summary

- CTA allows study of fundamental physics (WIMPs, axions, Lorentz invariance viol…) astrophysics (acceleration of cosmic rays, extra-galactic BG light, intergalactic B fields…).
- ASTRONET Science Vision and Infrastructure Roadmap 2022-2035 has CTA as top priority new ground-based project.
- Funding in place, commissioning in South 2027…28.
- Hope that money can be found so UK scientists can profit from CTA in general and Liverpool's contribution to the SST-Cam in particular.