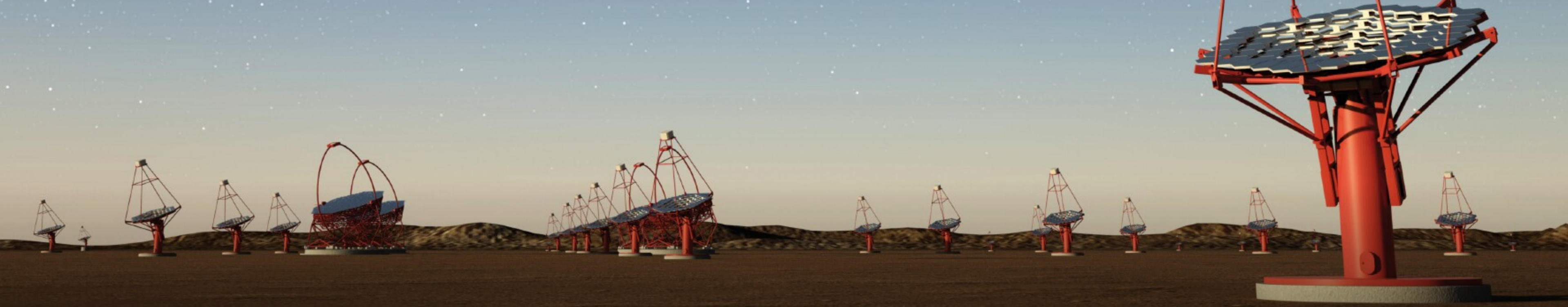
The Cherenkov Telescope Array

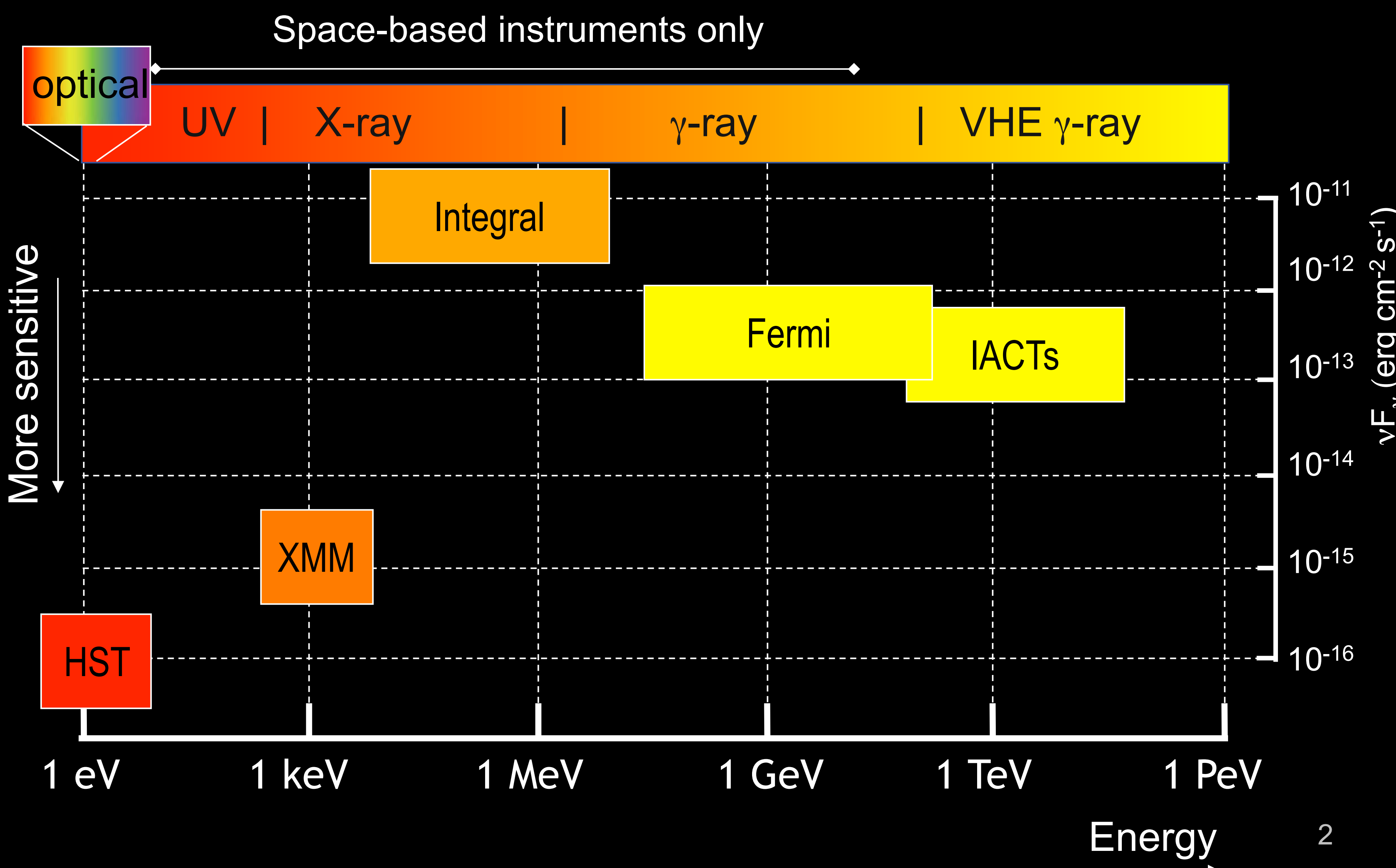
Richard White
Philip Wetton Workshop,
Oxford, June 2012



University of Leicester

cta
cherenkov telescope array

High-Energy Astronomy



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cta
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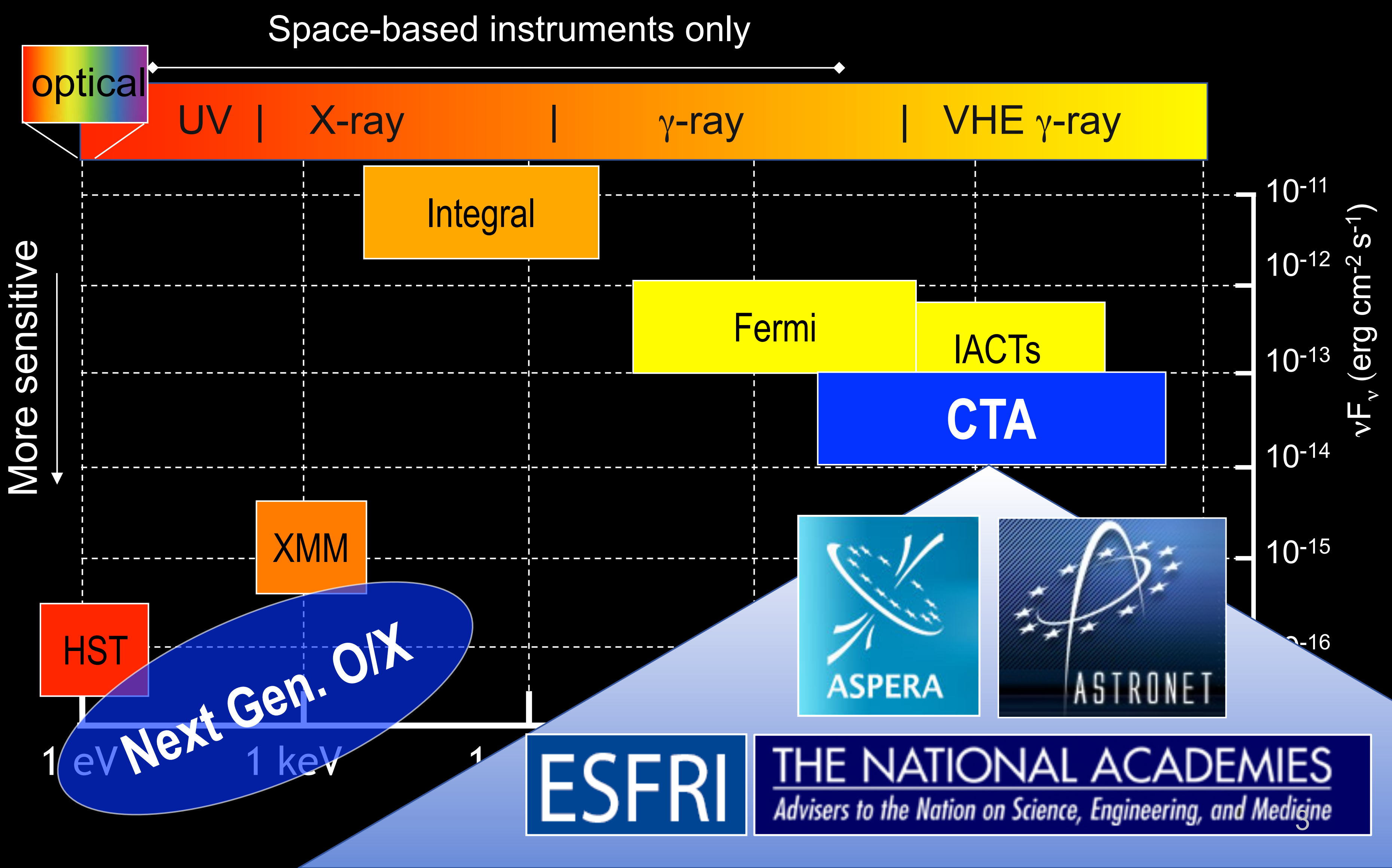
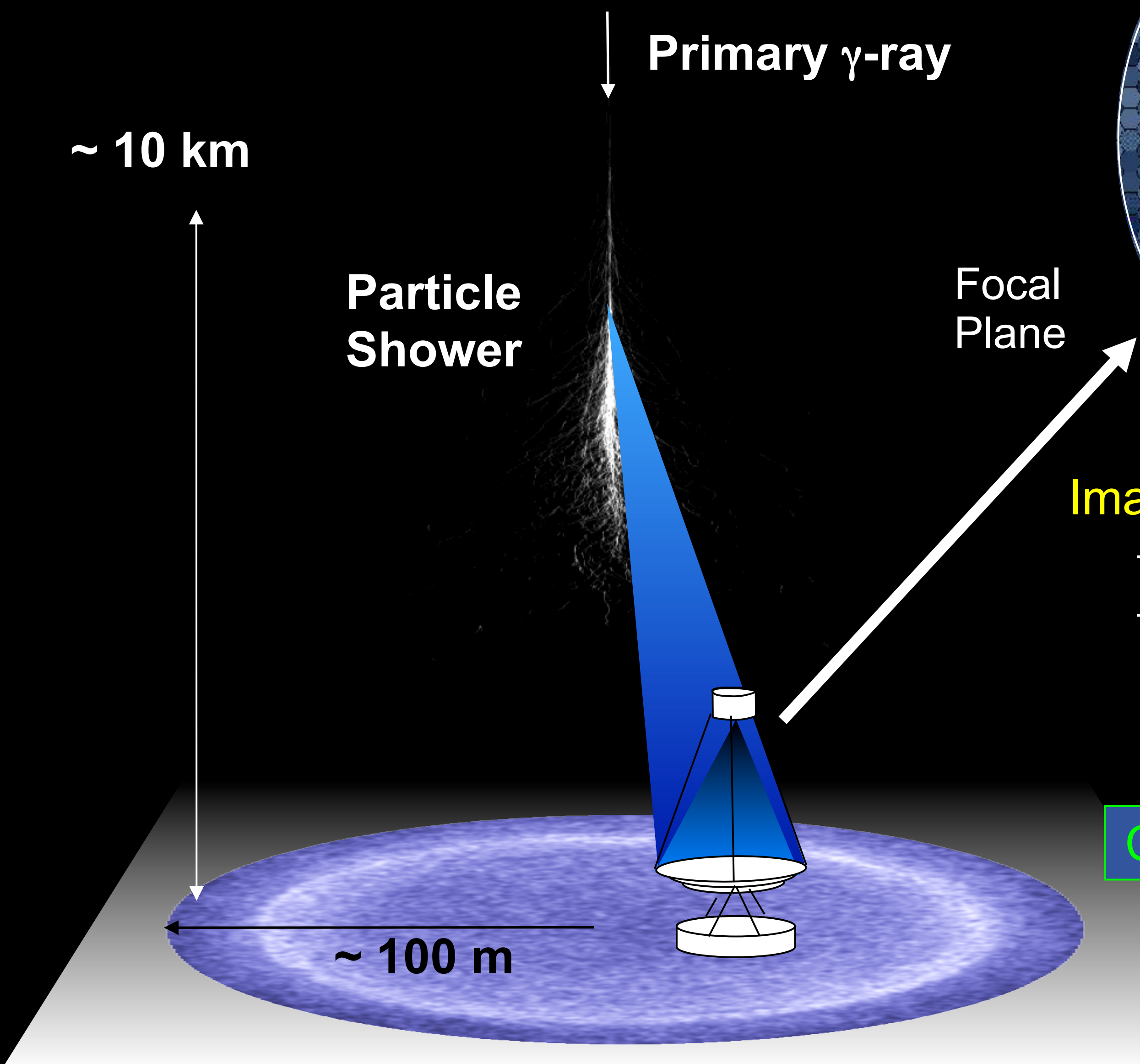


Technique

air showers



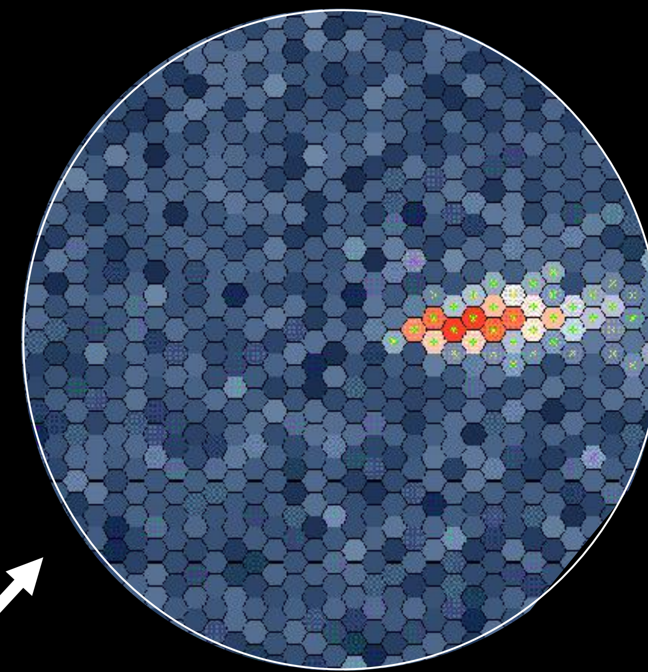


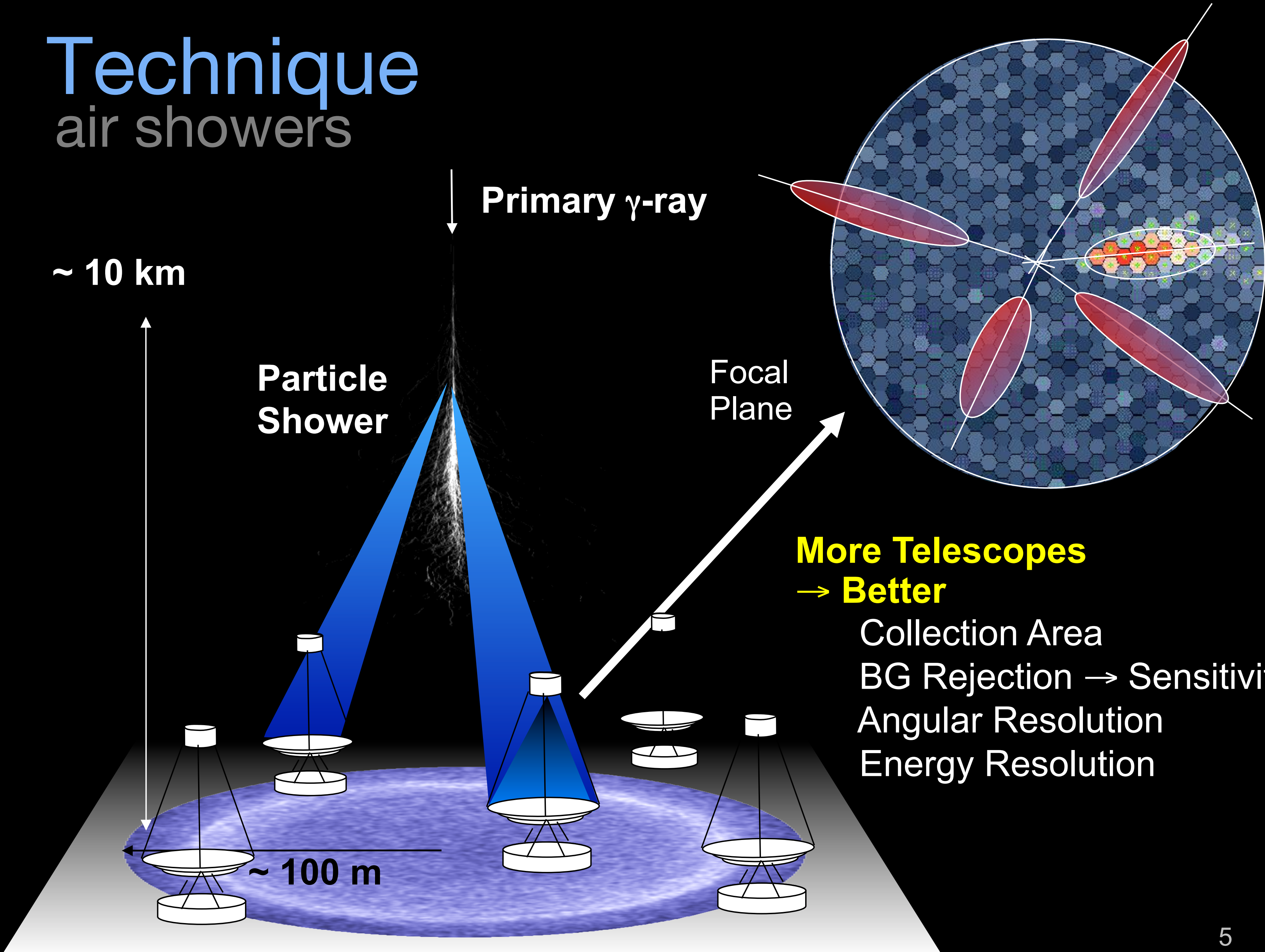
Image Analysis gives

→ Shower Energy

→ Shower Direction

Collection area ~10^5 m^2

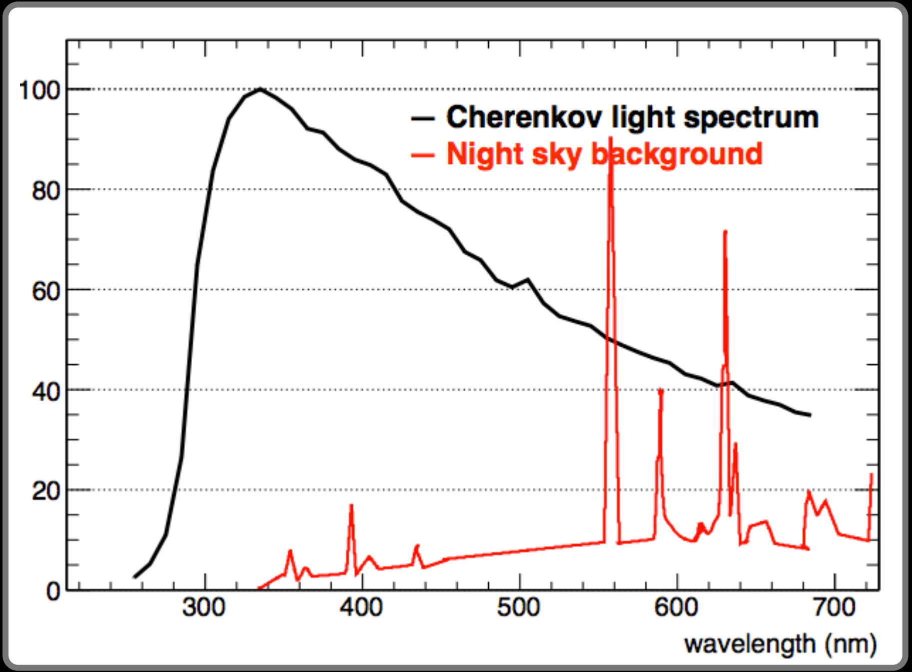
Technique
air showers



More Telescopes
→ Better
- Collection Area
- BG Rejection → Sensitivity
- Angular Resolution
- Energy Resolution

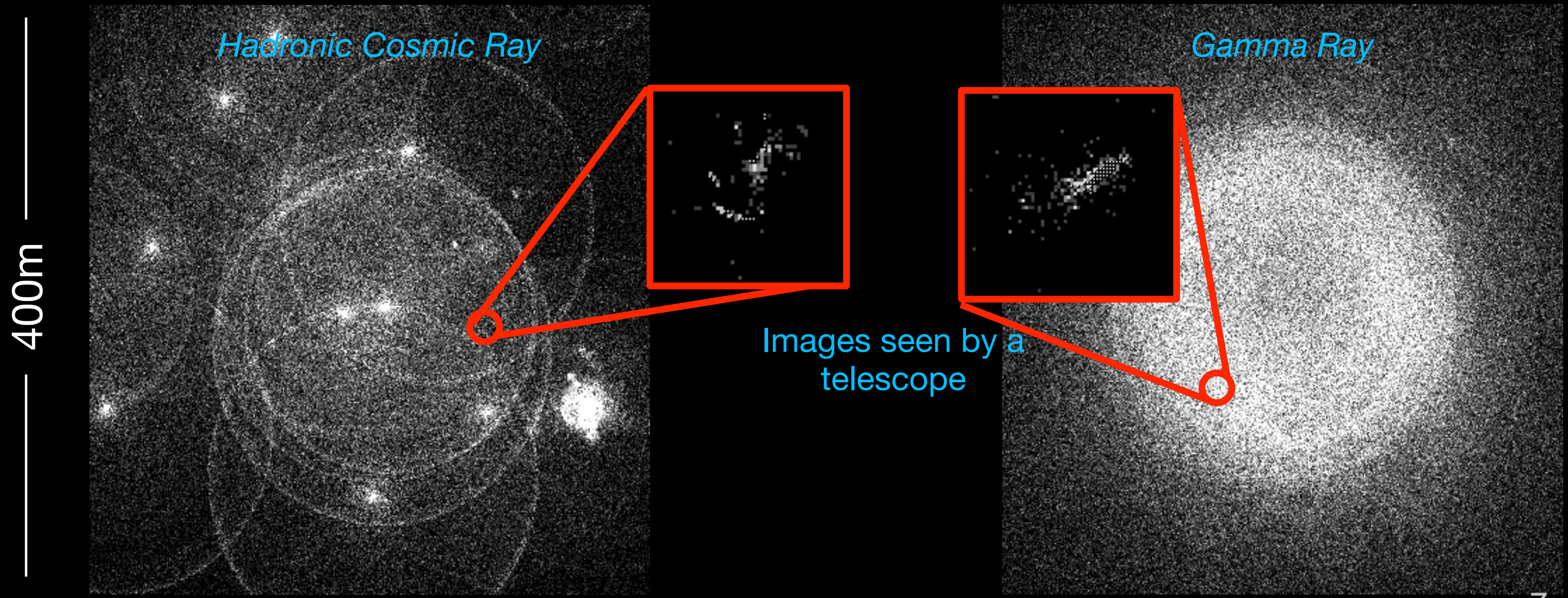
Technique
background

- Night Sky Background (NSB)
  - Stars, air-glow, Zodiacal light...
  - Extra-galactic rate ~100 MHz (100m^2, 0.15^o pix)
  - Bright regions x 3 brighter
  - Moon light x 5 brighter
  - Reduced online with a trigger.



Technique
background

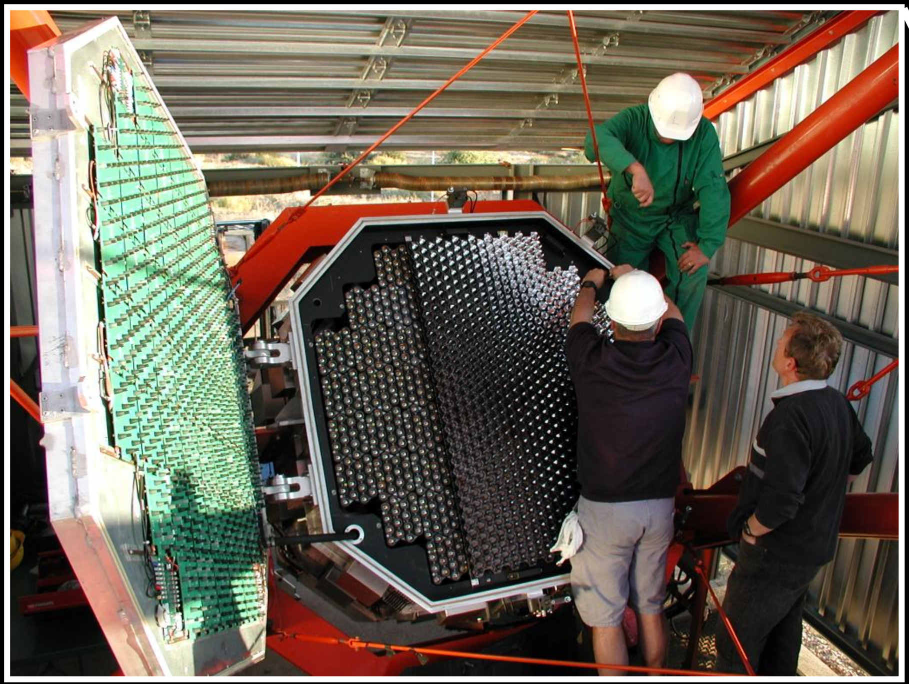
- Gamma Rays result in Cherenkov light, but so do cosmic rays.
  - Rate dominates gamma-ray rate, even after NSB is reduced.
  - Must be isolated offline using image analysis.

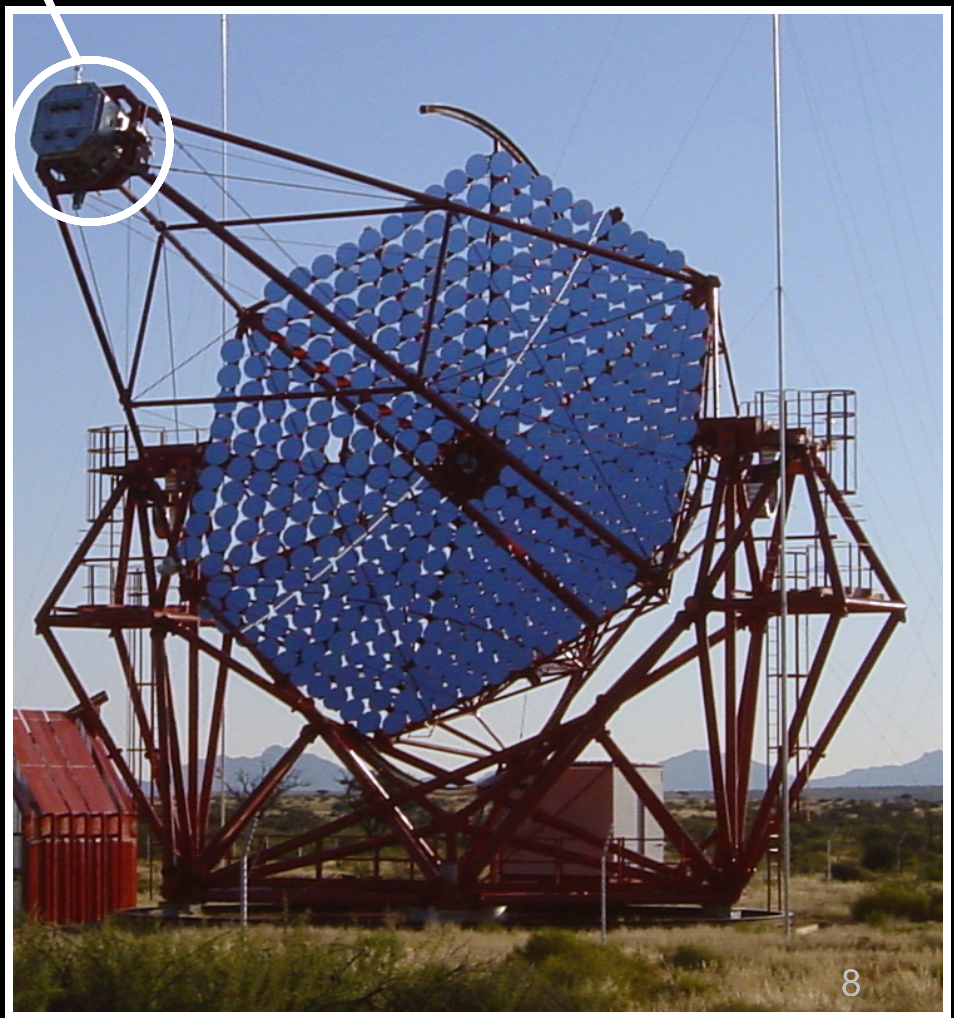


from Jamie Holder

Key Technology

the camera: an example from HESS





960 PMT pixels
Angular pixel size: 0.16°
Camera diameter:5° FoV (1.4 m)

Key Technology

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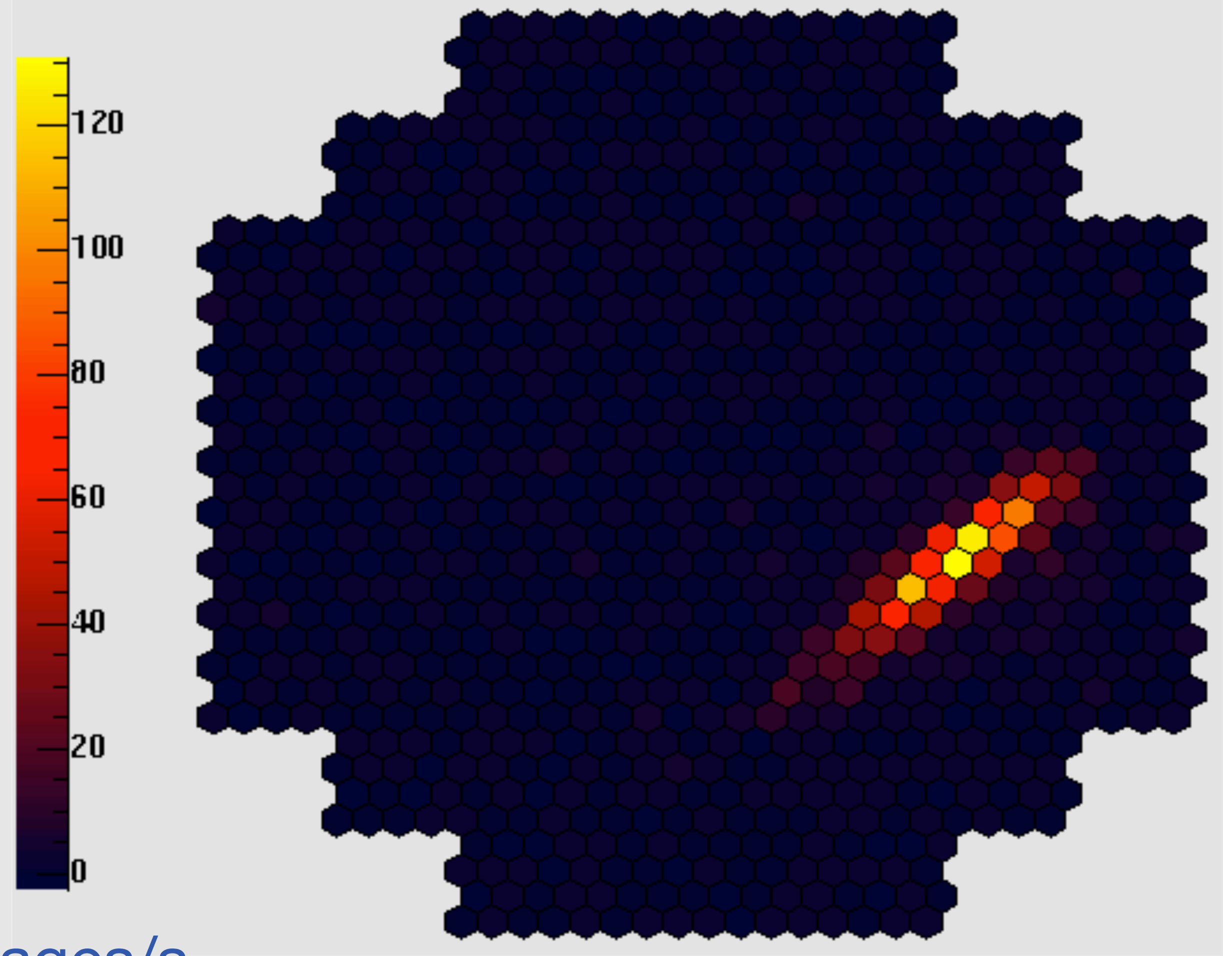
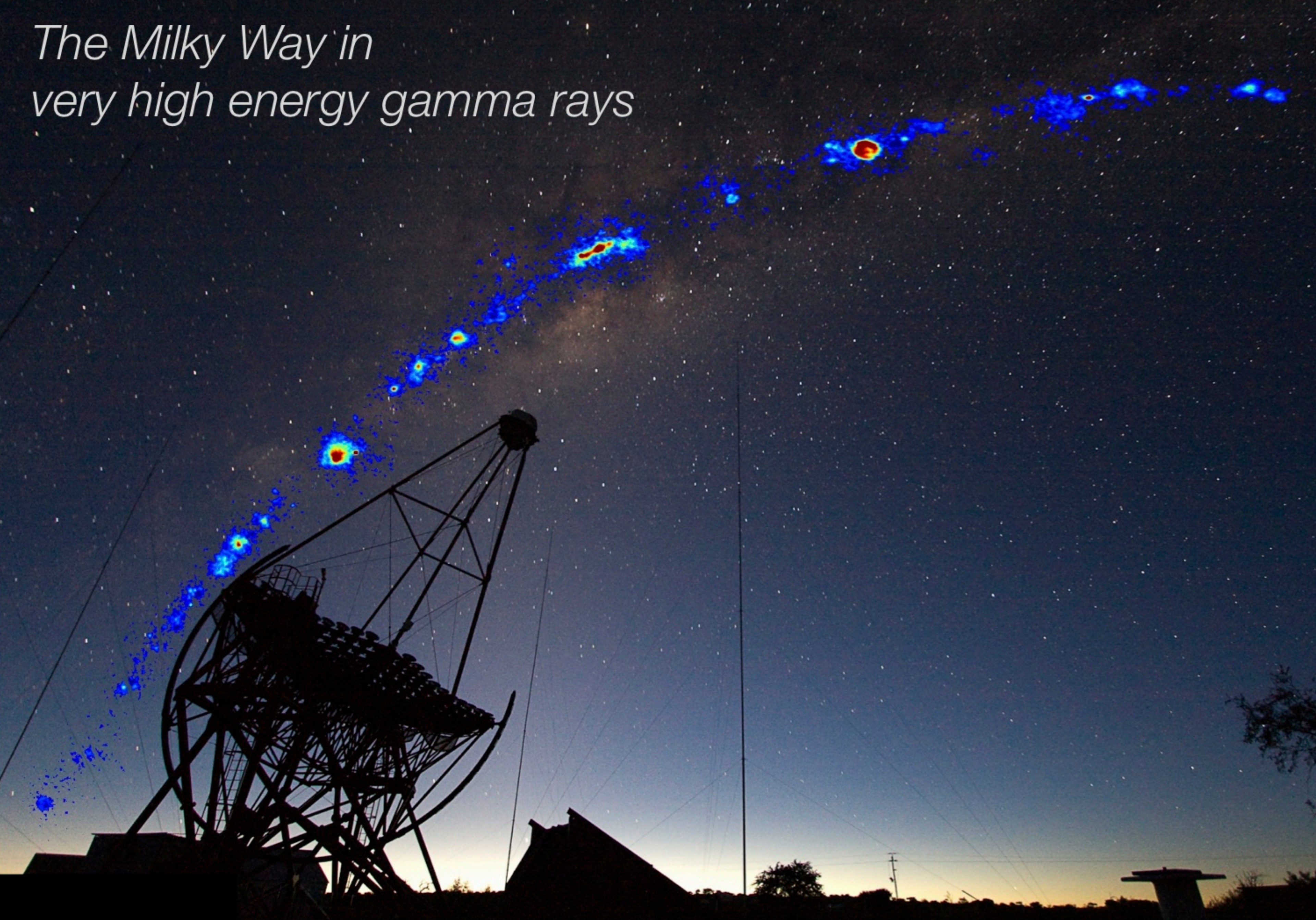


1000 images/s

16 ns exposures

The Milky Way in very high energy gamma rays



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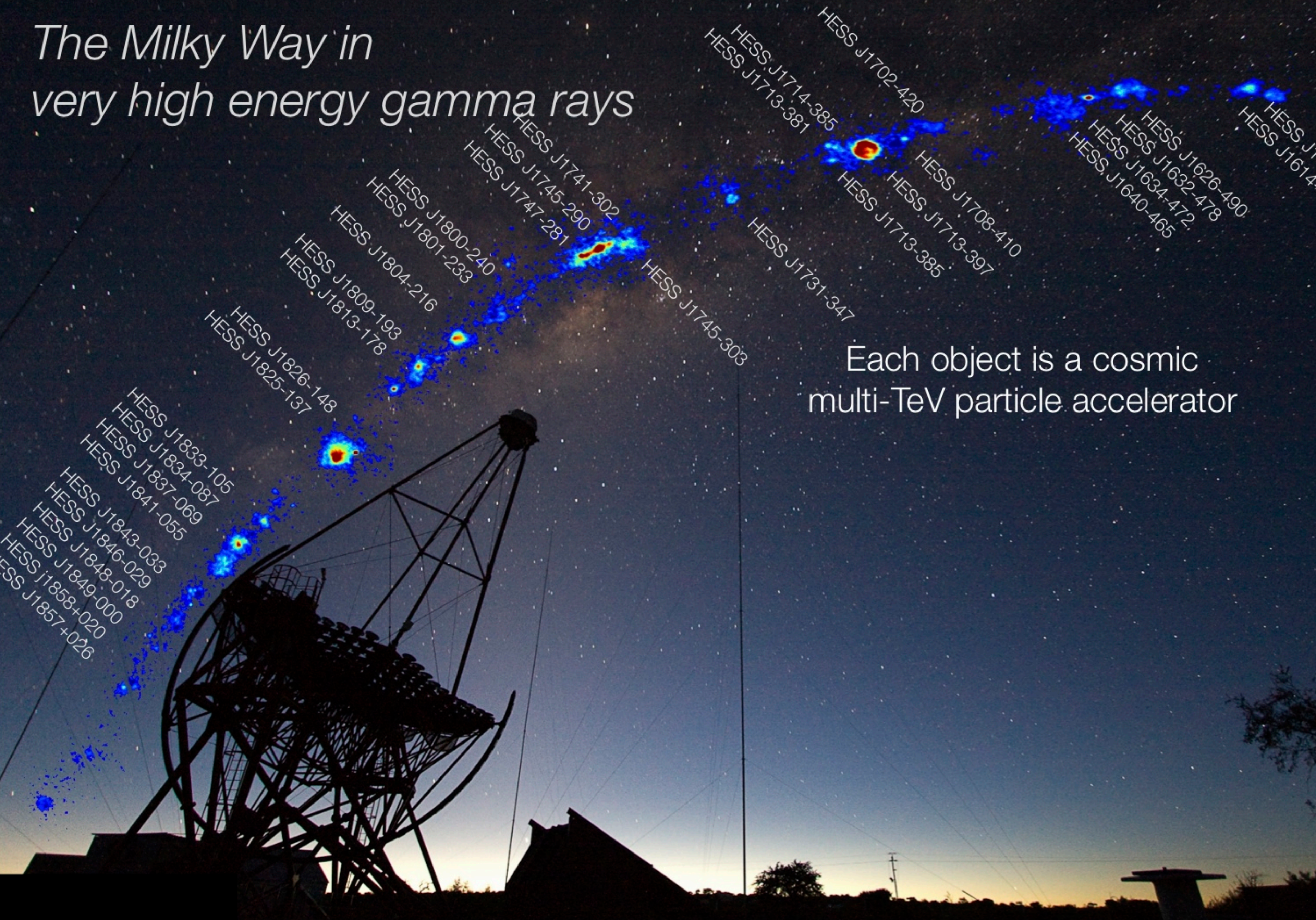


How can we do better?

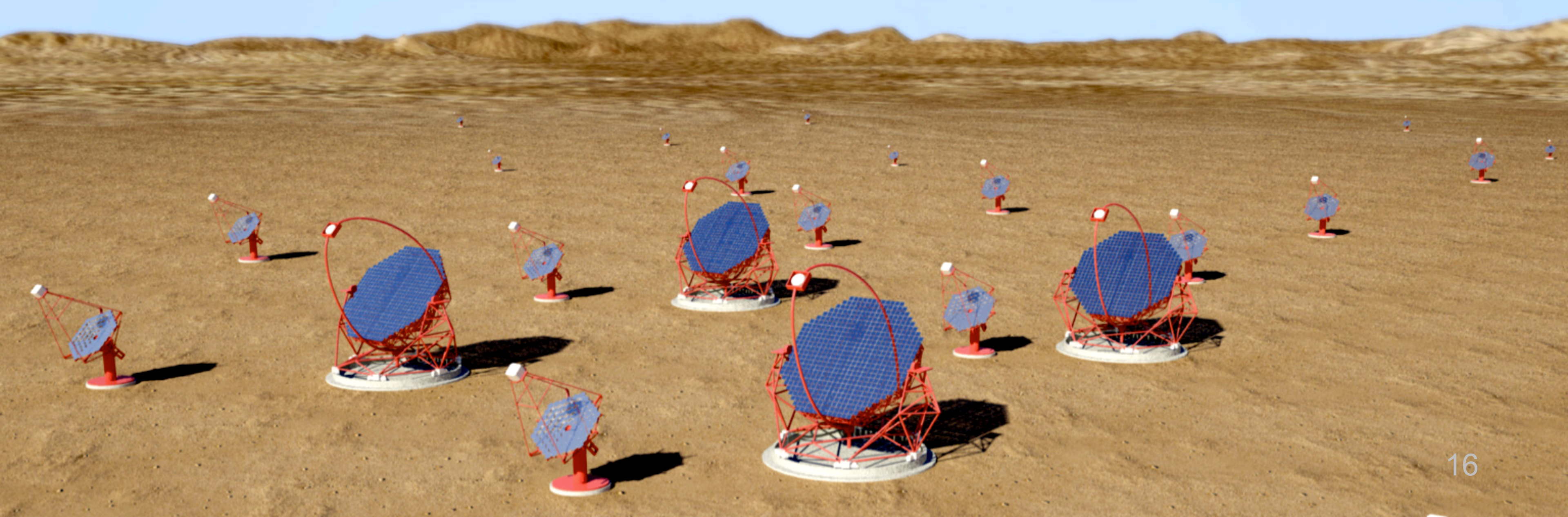
Bigger Telescopes?

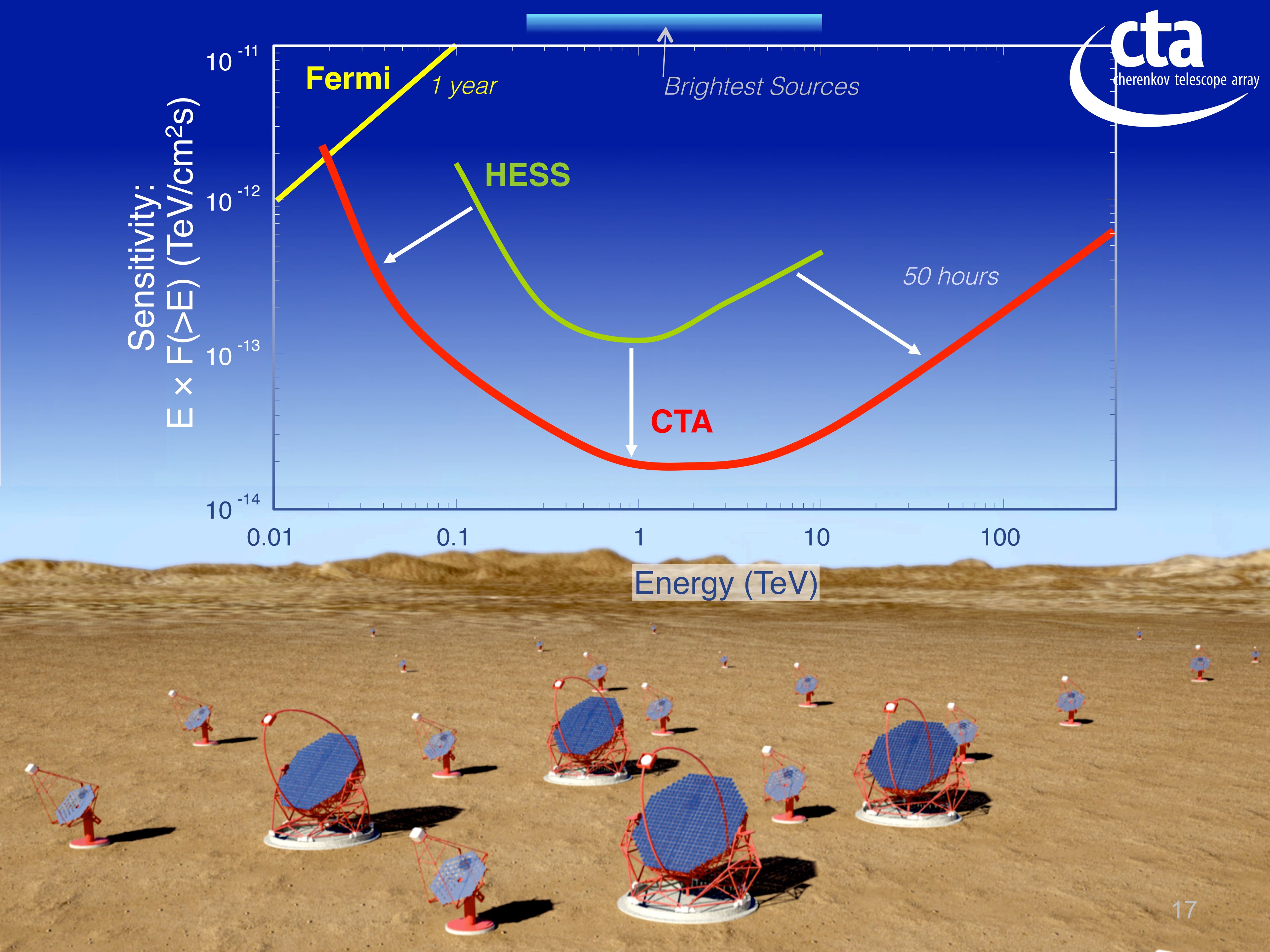
cta
cherenkov telescope array

More Telescopes?

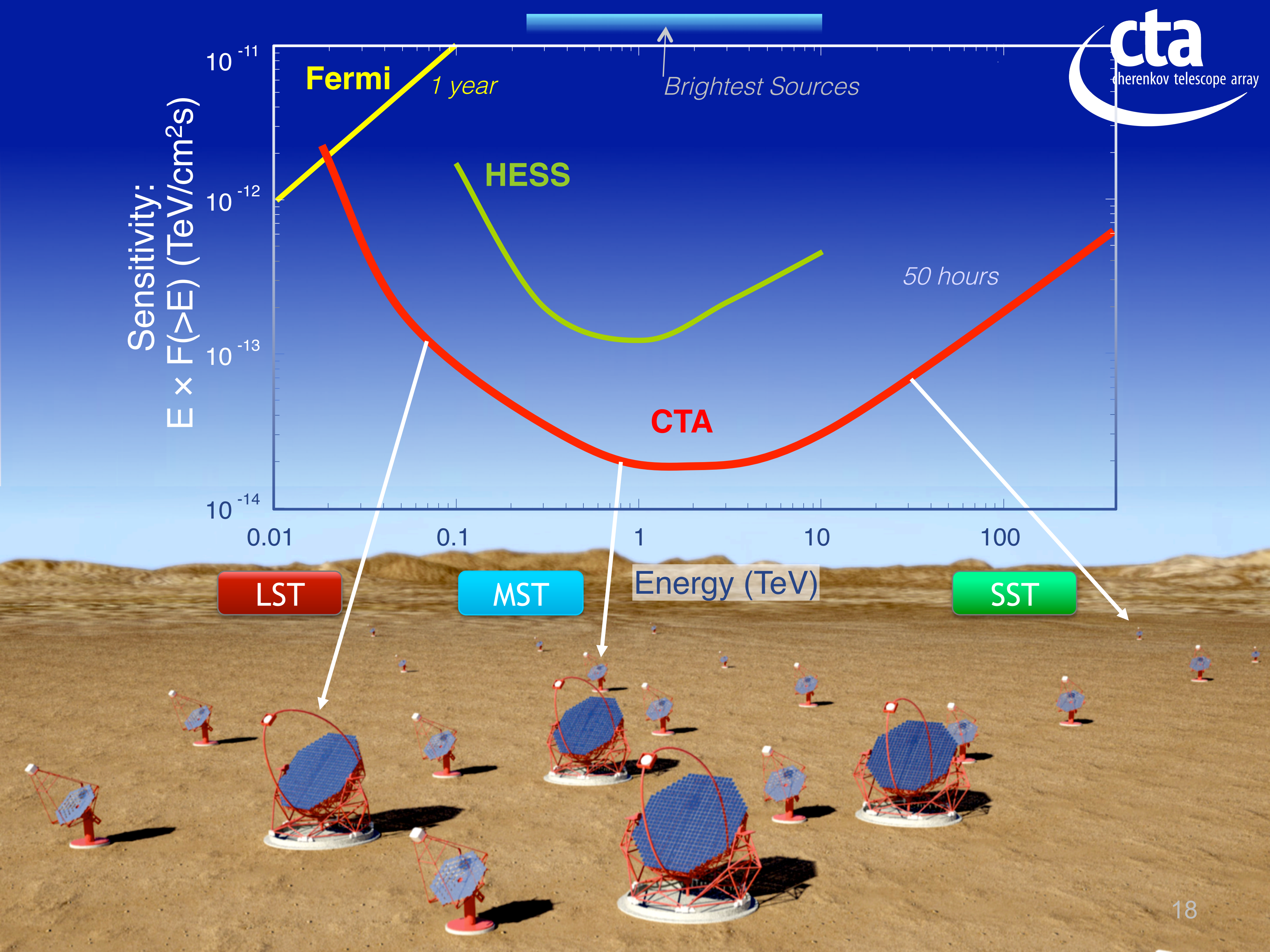
The Cherenkov Telescope Array

- A factor 10 more sensitive than current instruments
  - Plus - much wider energy coverage, substantially better angular and energy resolution & wider field of view
- A ~ 200M€ International Project
  - Builds on expertise from HESS, MAGIC and VERITAS
  - >125 institutes in 27 countries
  - Two sites, ~80 Cherenkov telescopes





cta
cherenkov telescope array
Brightest Sources
Fermi
1 year
HESS
50 hours
CTA
Sensitivity:
E × F(>E) (TeV/cm²s)
10^-11
10^-12
10^-13
10^-14
0.01
0.1
1
10
100
Energy (TeV)



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10
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Energy (TeV)
LST
MST
SST

The Telescopes

cherenkov telescope array

LST

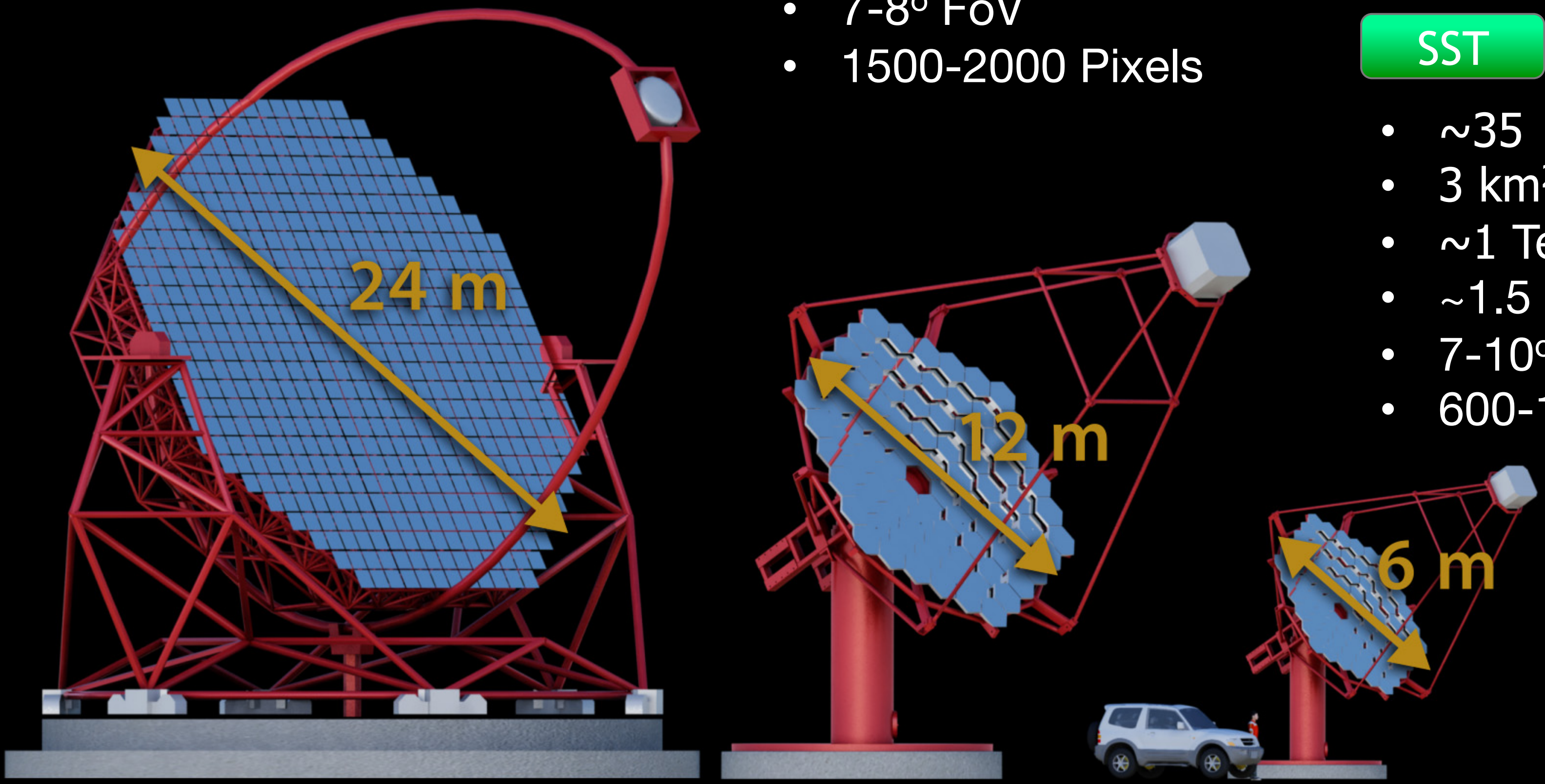
- ~4
- threshold ~30 GeV
- ~2.2 m Camera
- 4.5° FoV
- 1700 Pixels

MST

- ~25
- 200 GeV– 5 TeV
- ~2 m Camera
- 7-8° FoV
- 1500-2000 Pixels

SST

- ~35
- 3 km^2 area
- ~1 TeV - 300 TeV
- ~1.5 m Camera
- 7-10° FoV
- 600-1300 Pixels



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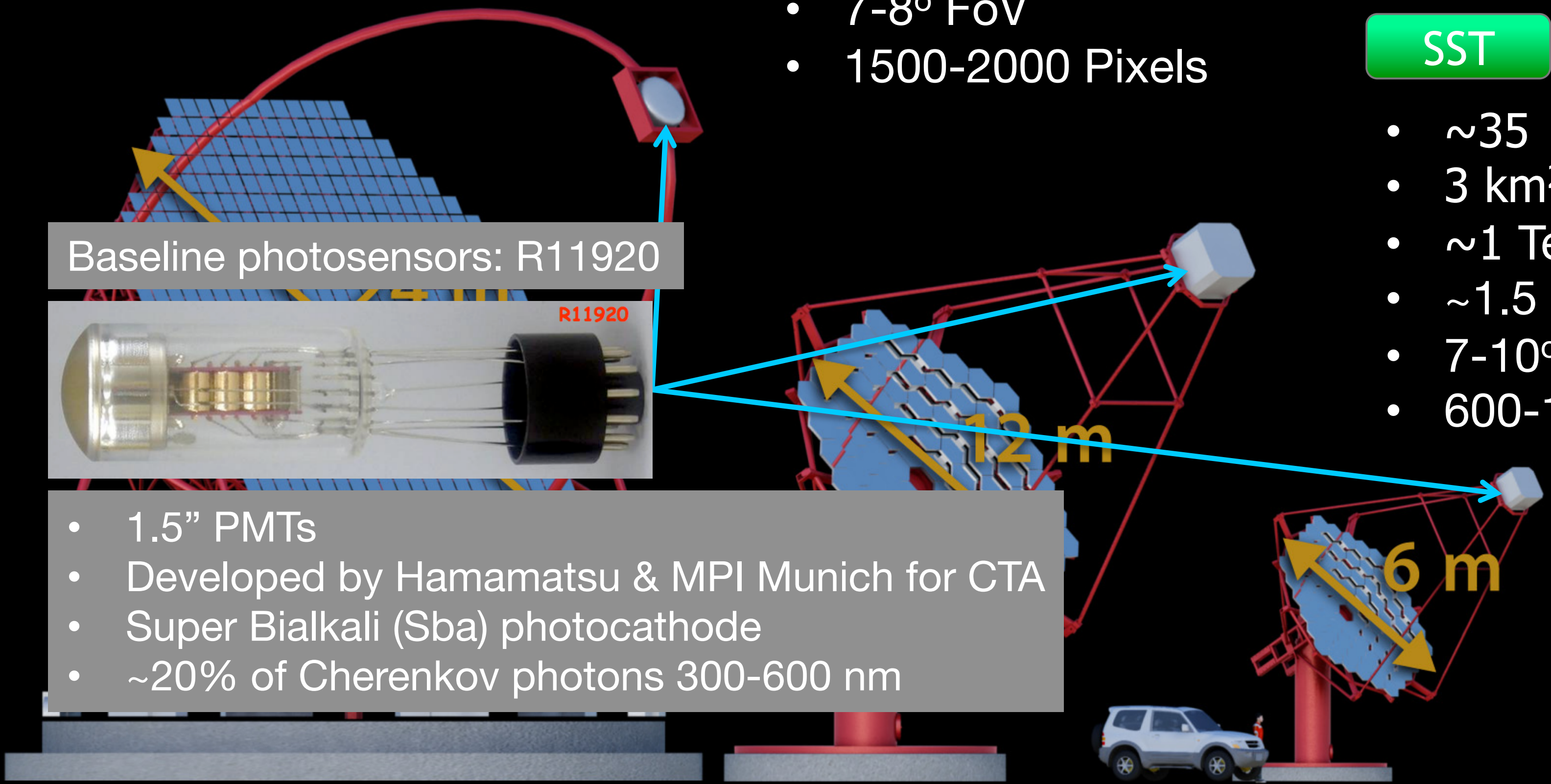

Baseline photosensors: R11920

- 1.5” PMTs
- Developed by Hamamatsu & MPI Munich for CTA
- Super Bialkali (Sba) photocathode
- ~20% of Cherenkov photons 300-600 nm

The Telescopes

LST

- ~4

Majority of the cost is in the structure (carbon fibre).

- 1700 Pixels

MST

- ~25

Camera and structure cost approximately the same.

- 1500-2000 Pixels

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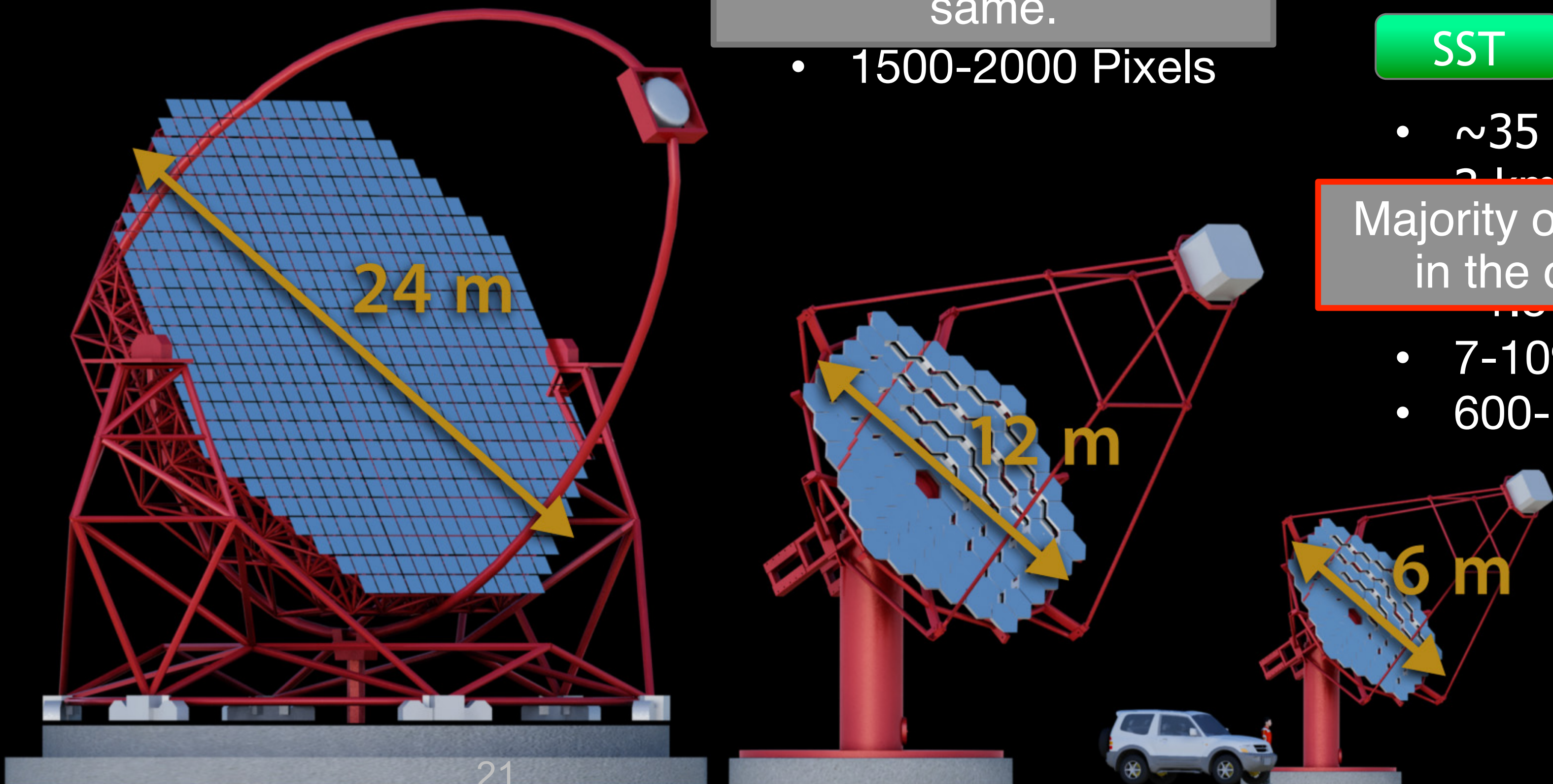

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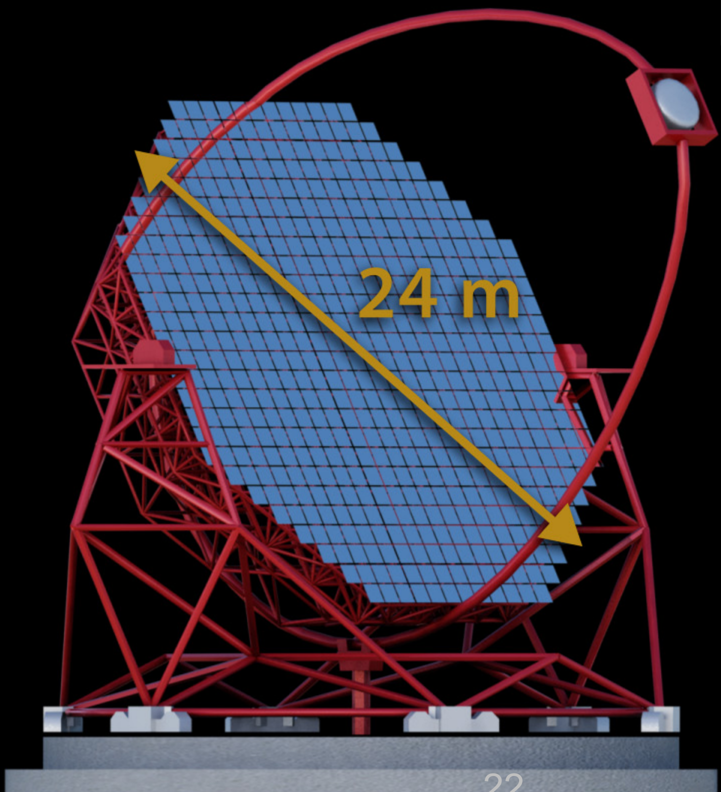

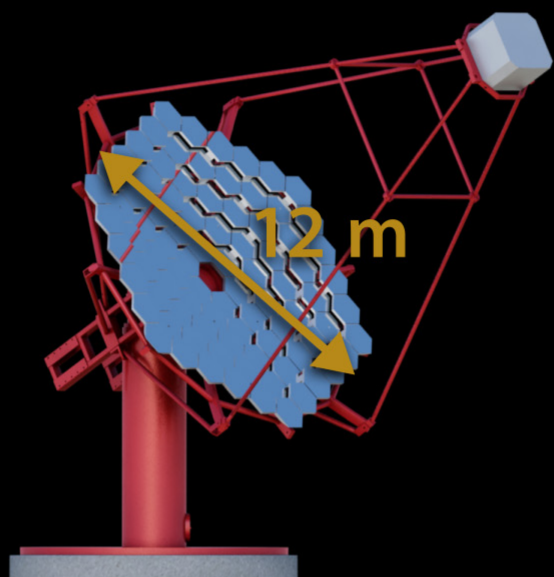

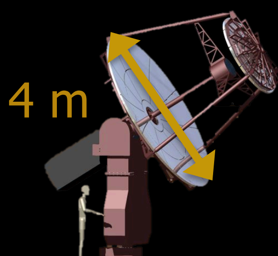

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The Telescopes

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MST

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- ~2 m Camera
- 7-8^{o} FoV
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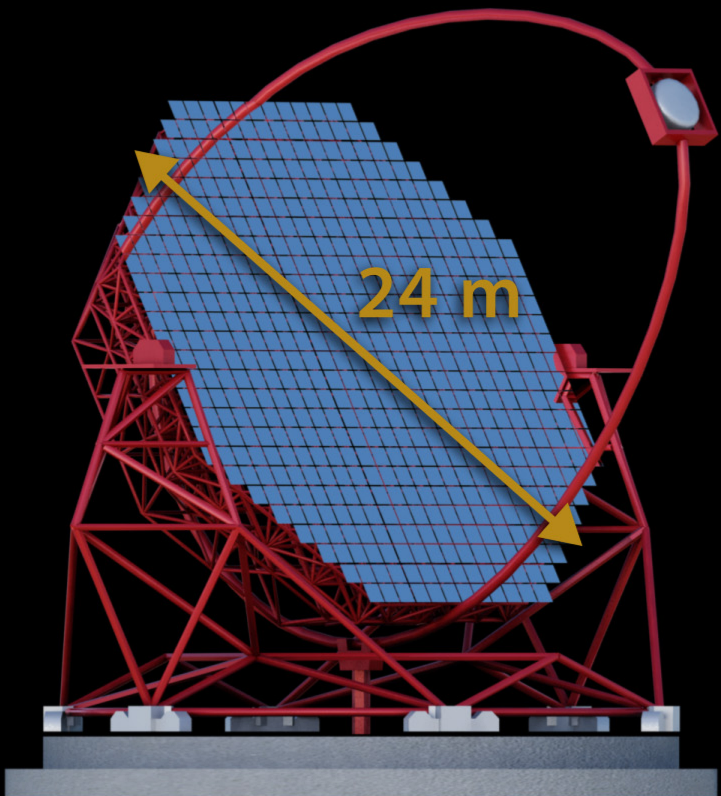
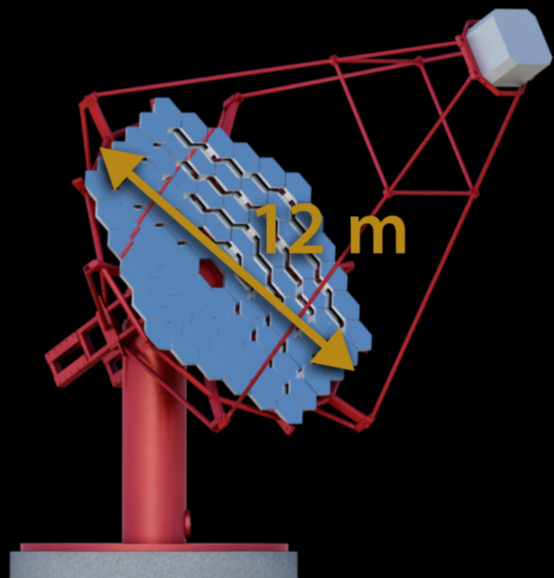
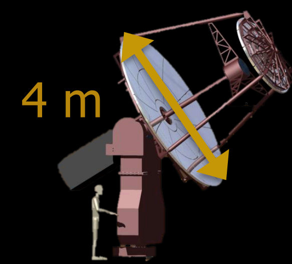
Dual-Mirror SST

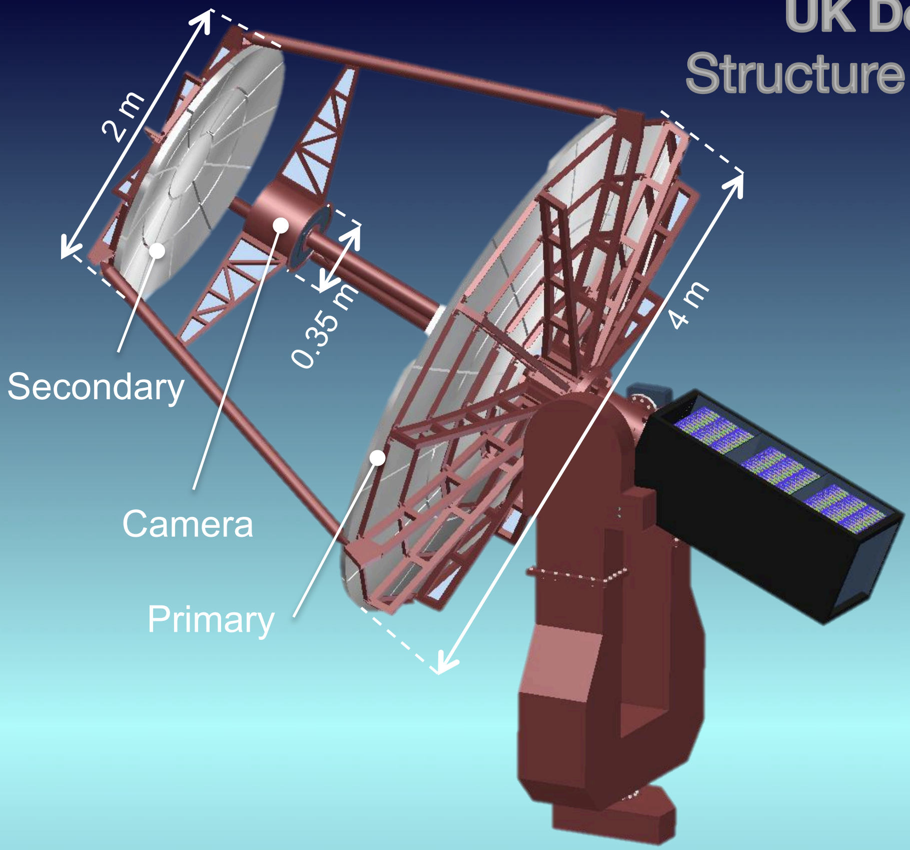
- 70
- 7 km^2 area
- ~1 TeV - 300 TeV
- ~0.4 m Camera
- 9^{o} FoV
- 2000 Pixels



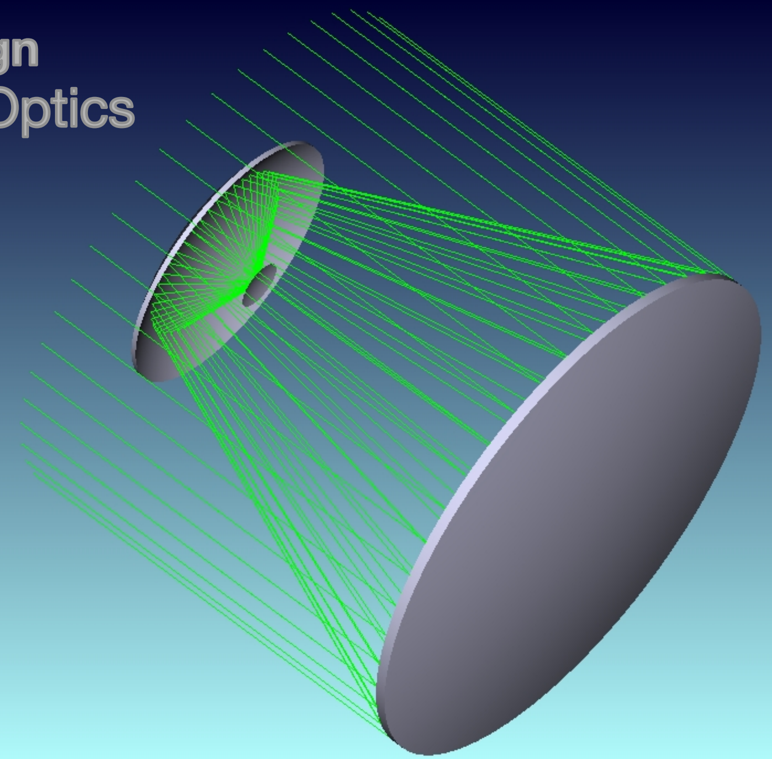




SST: Dual Mirror Design



UK Design
Structure + Optics



- Secondary optics facilitates a reduced plate scale.
- The camera becomes 0.35 m - 0.5 m across

The UK Contribution

- Focus on High Energies:
  - Best angular/energy resolution
  - Biggest potential improvement
  - Good match to UK science interests

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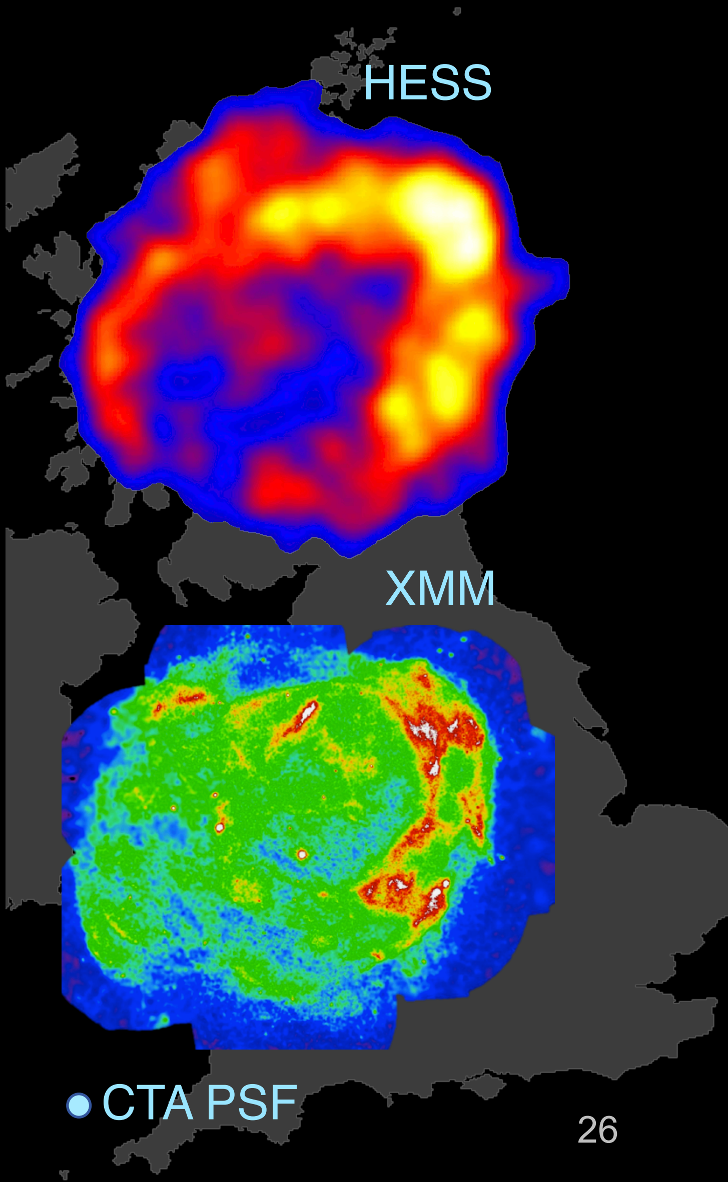
Science Example: SNR

- No directional information about PeV particle acceleration in our galaxy
  CTA SSTs will revolutionise this!!

- With resolved sub-structure can test models for acceleration
  eg Bell et al (Oxford/RAL).

- Sensitivity to detect ALL young SNR in our galaxy.



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- Groups:
  - Core: Leicester, Liverpool, Durham, Leeds, Oxford
  - Wide interest in CTA science
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Hinton
UK PI,
MC Coordinator

White
SST Camera
Coordinator

Greenshaw
SST
Coordinator

Chadwick
Outreach
Coordinator

Knapp
Consortium Board
Chair

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Synchrotron and inverse-Compton emission from blazar jets I: a uniform conical jet model.

William J. Potter* and Garret Cotter

Oxford Astrophysics. Denys Wilkinson Building, Keble Road, Oxford, OX1 3RH, United Kingdom

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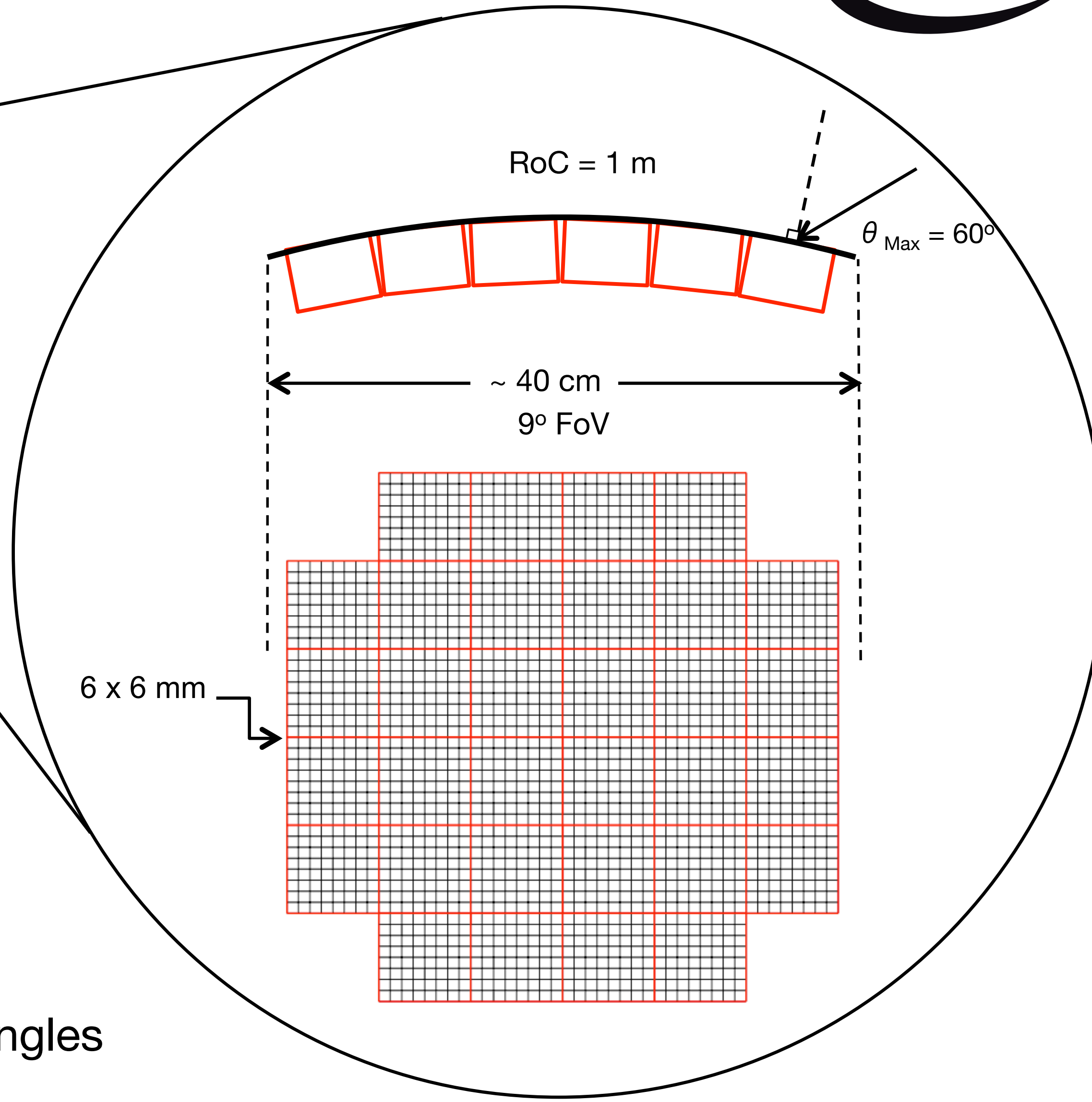
- STFC funding received:
  - Optimise the SST subsystem
  - Design and build a prototype camera for the Dual Mirror SST: Compact High Energy Camera (CHEC).
- Long-term Goal:
  - Position the UK for early CTA science

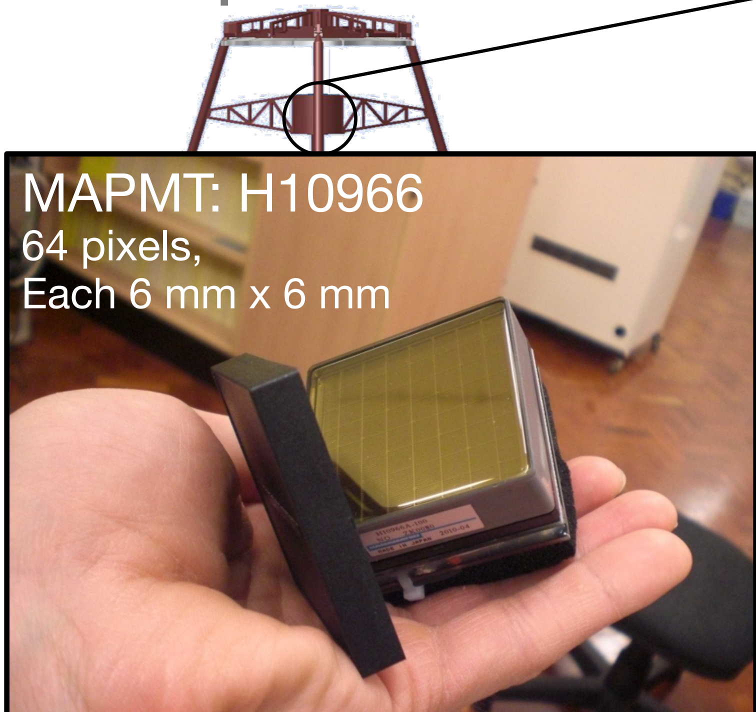
CHEC

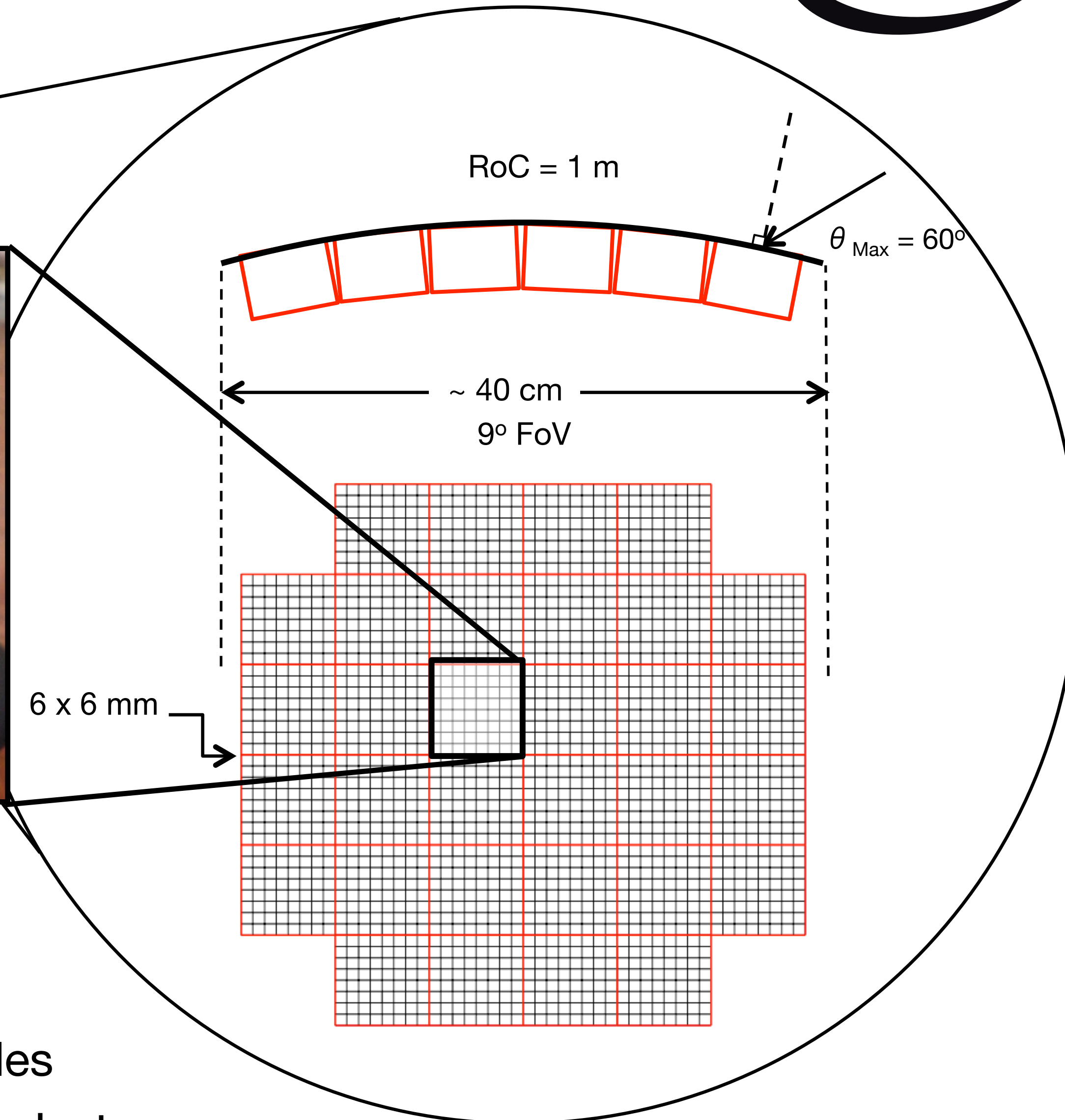
focal plane



- Not without challenges:
  - Curved focal plane
  - Incident light from large angles

CHEC
focal plane

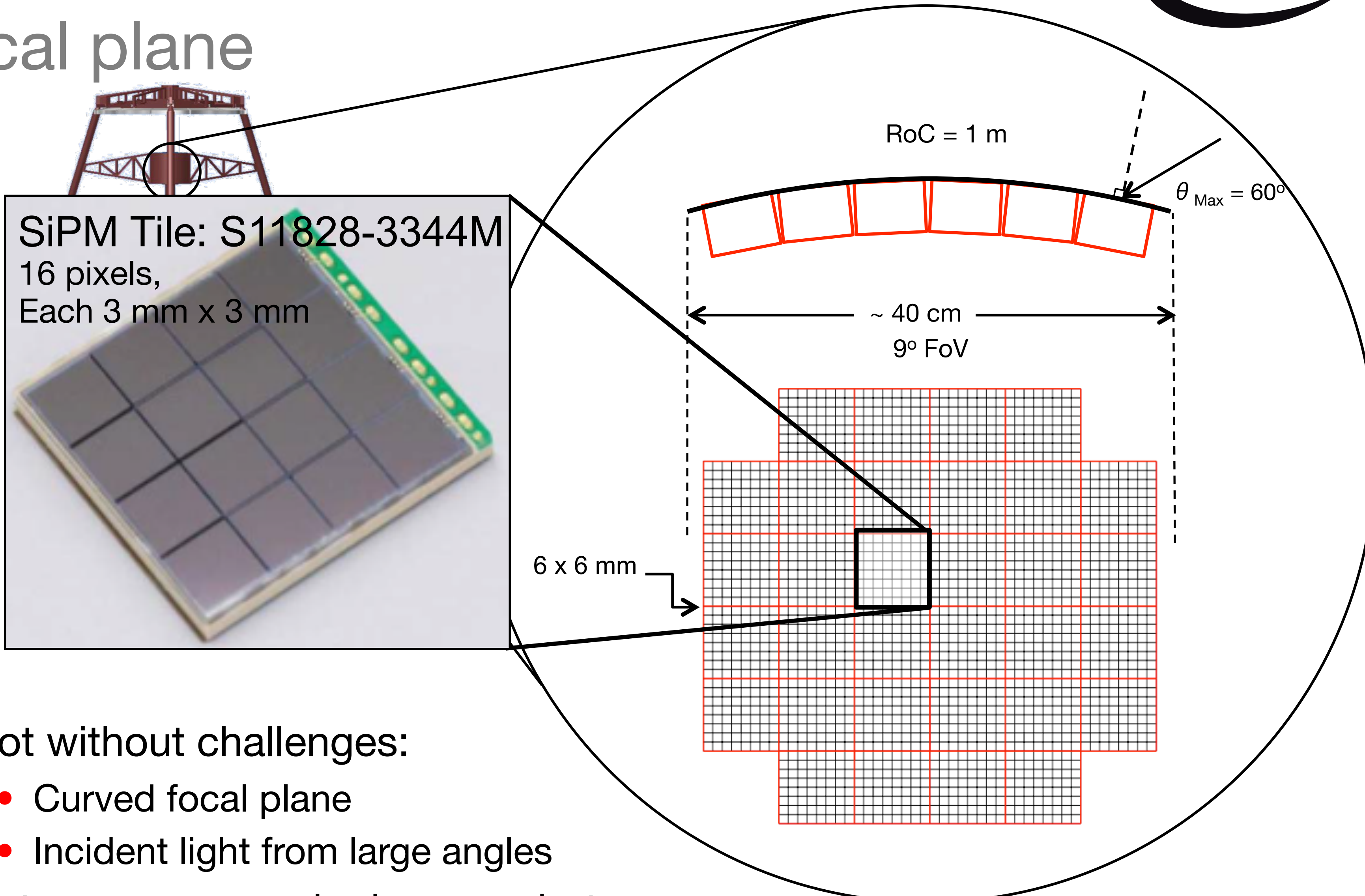




- Not without challenges:
  - Curved focal plane
  - Incident light from large angles
- But - can use much cheaper photosensors
  - 1 tonne, £1M -> ~60 kg, ~£100k

CHEC

focal plane



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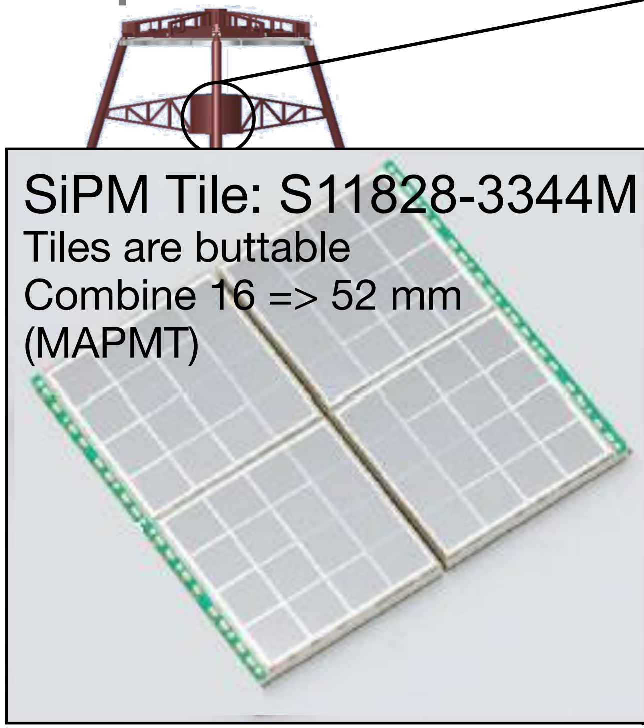

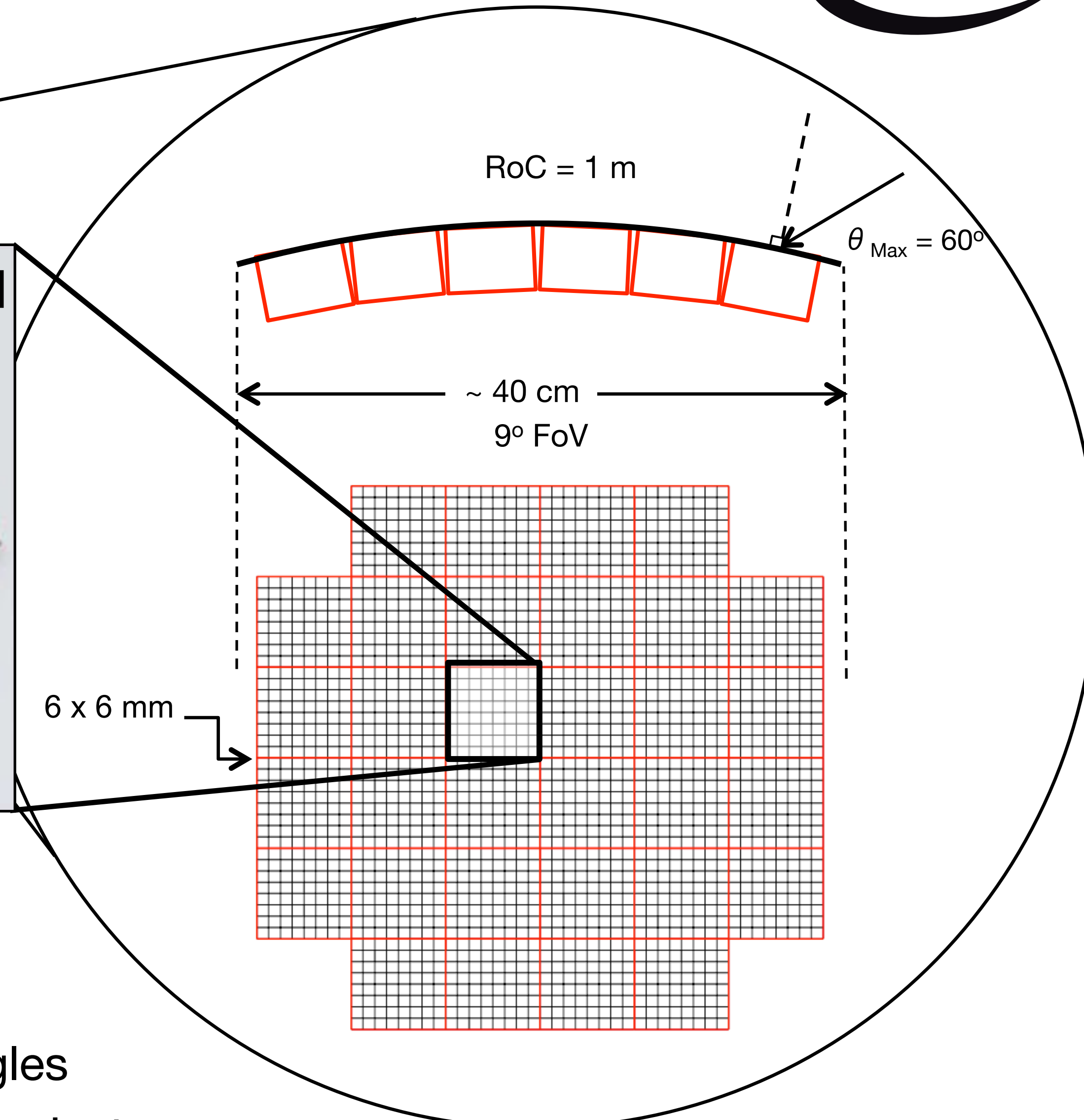

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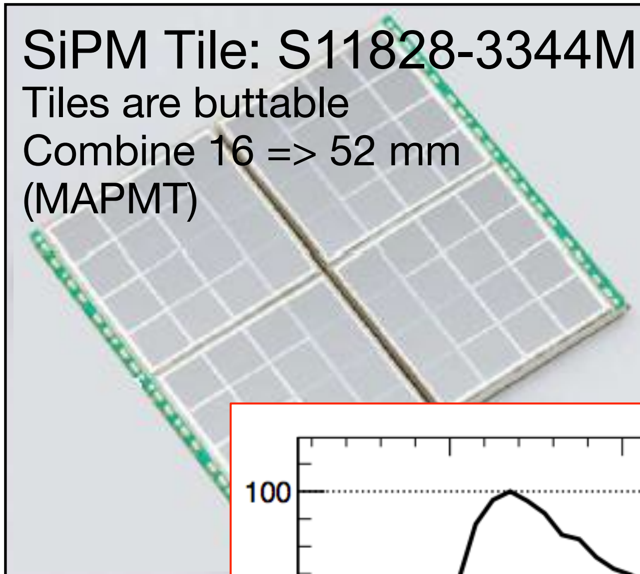
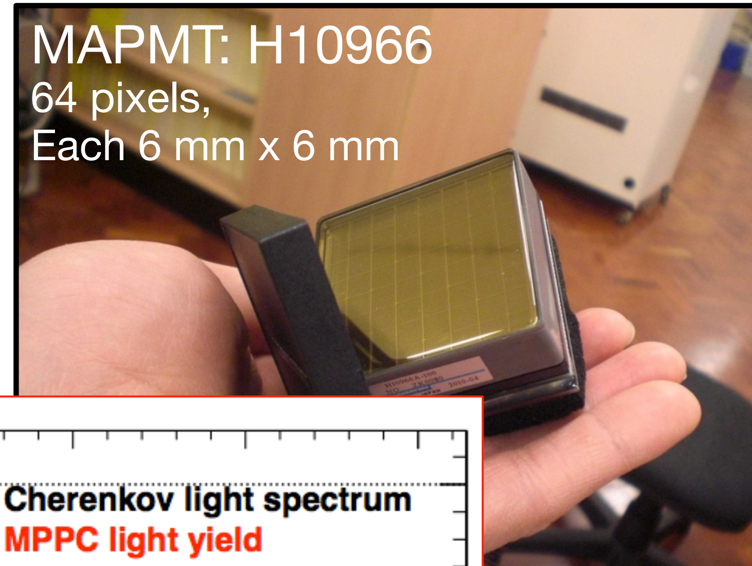
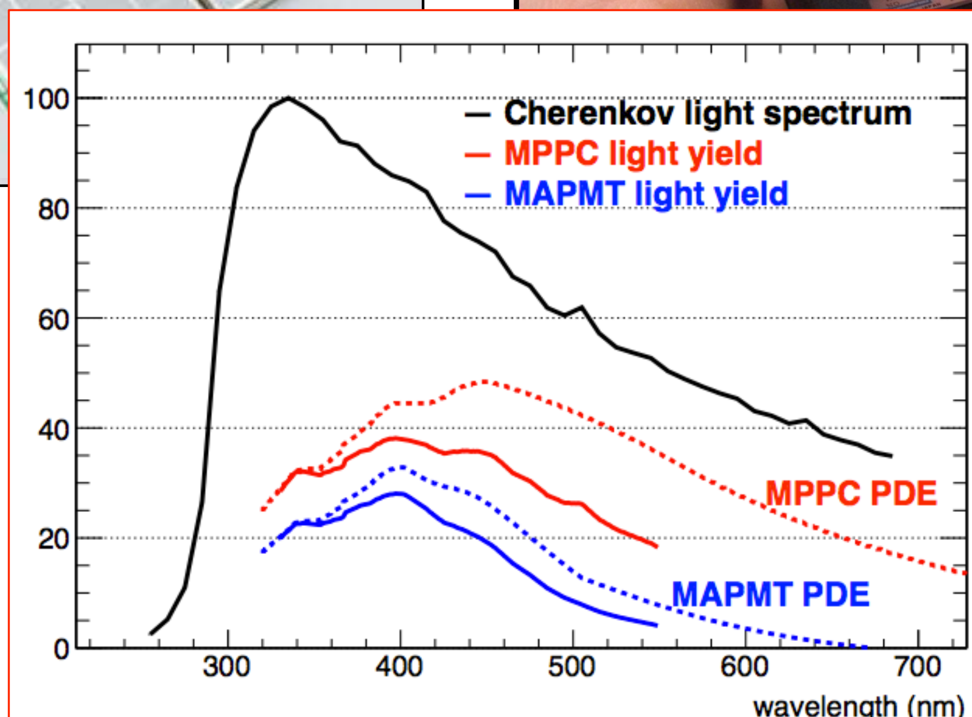
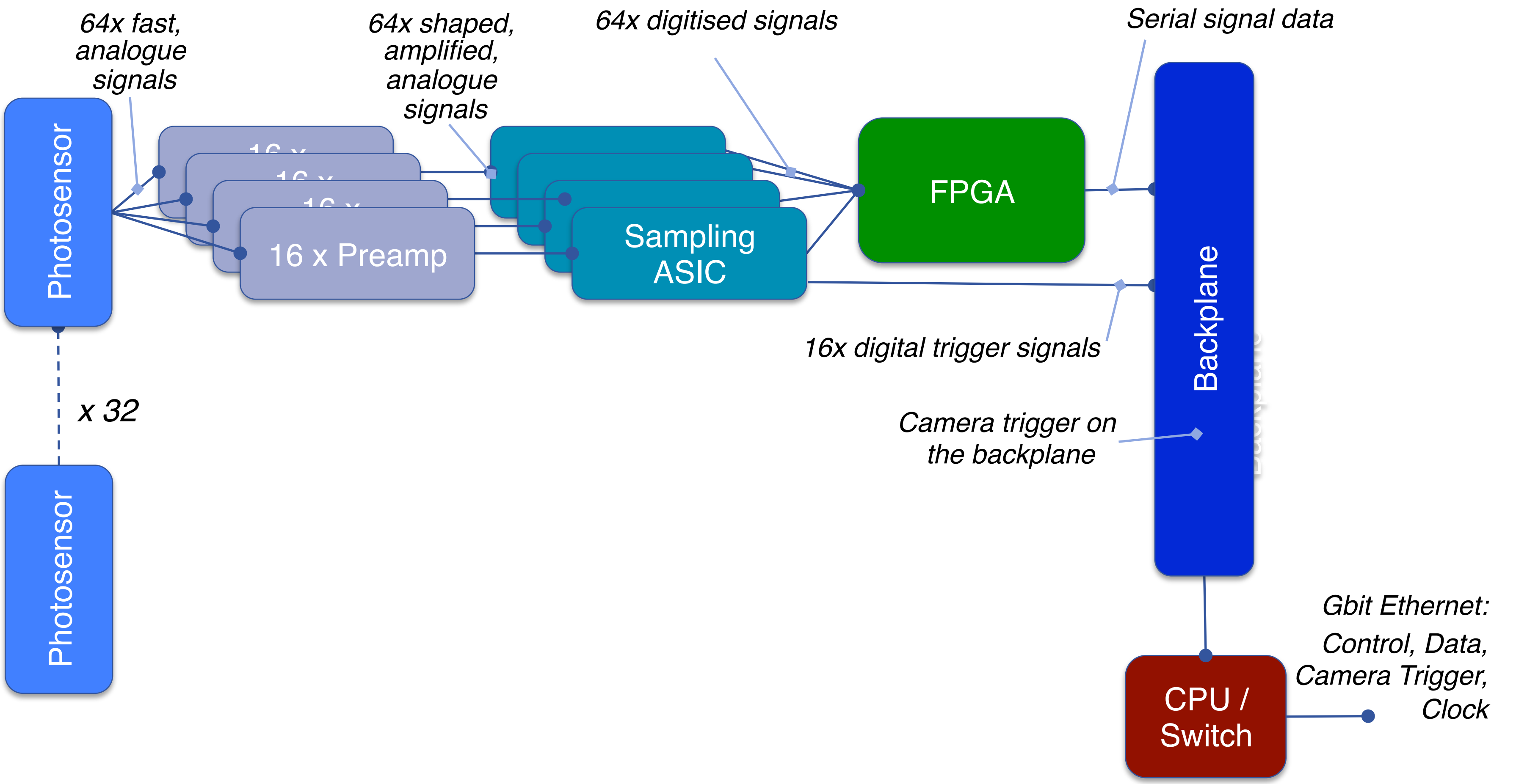






CHEC
electronics & readout



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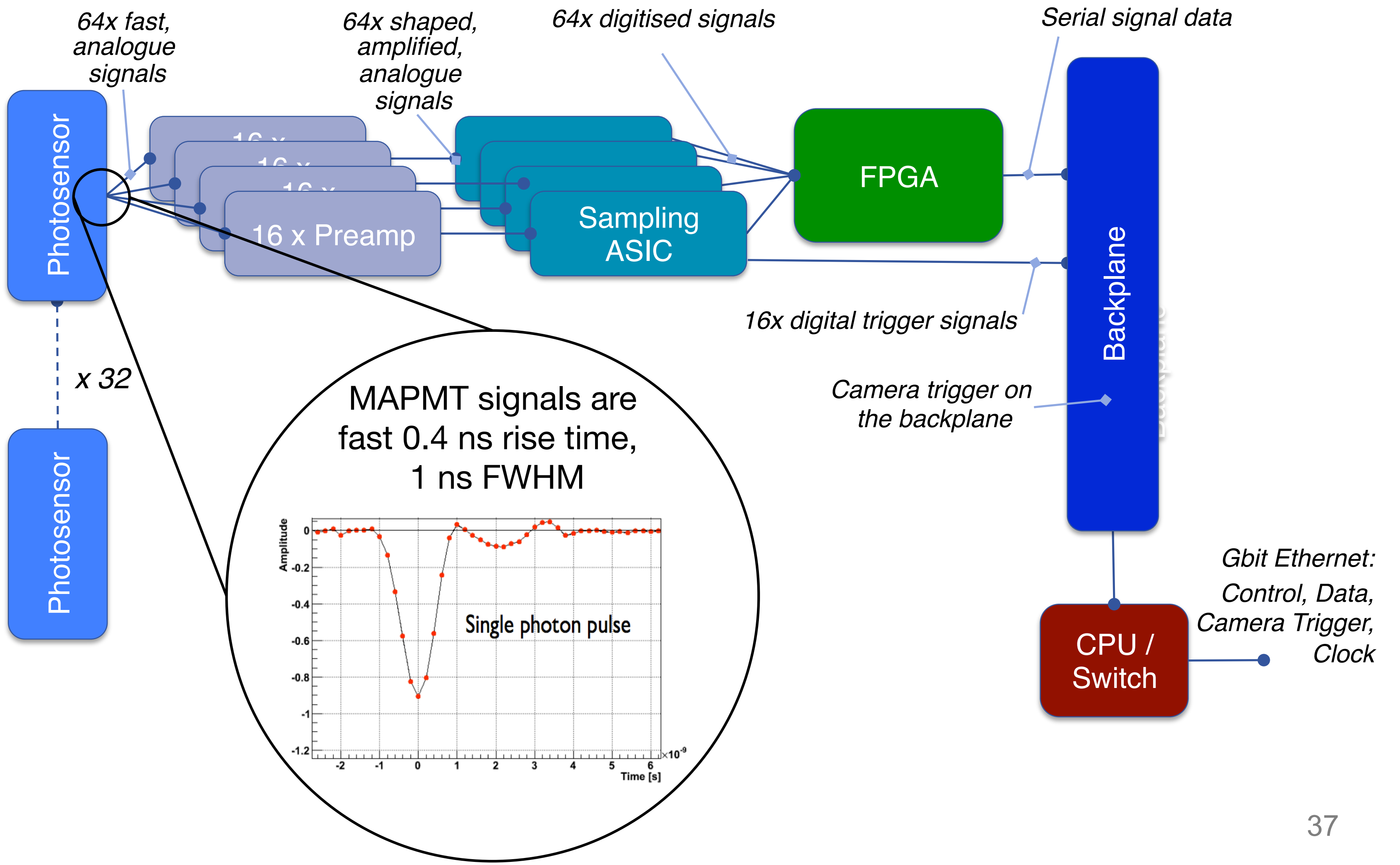

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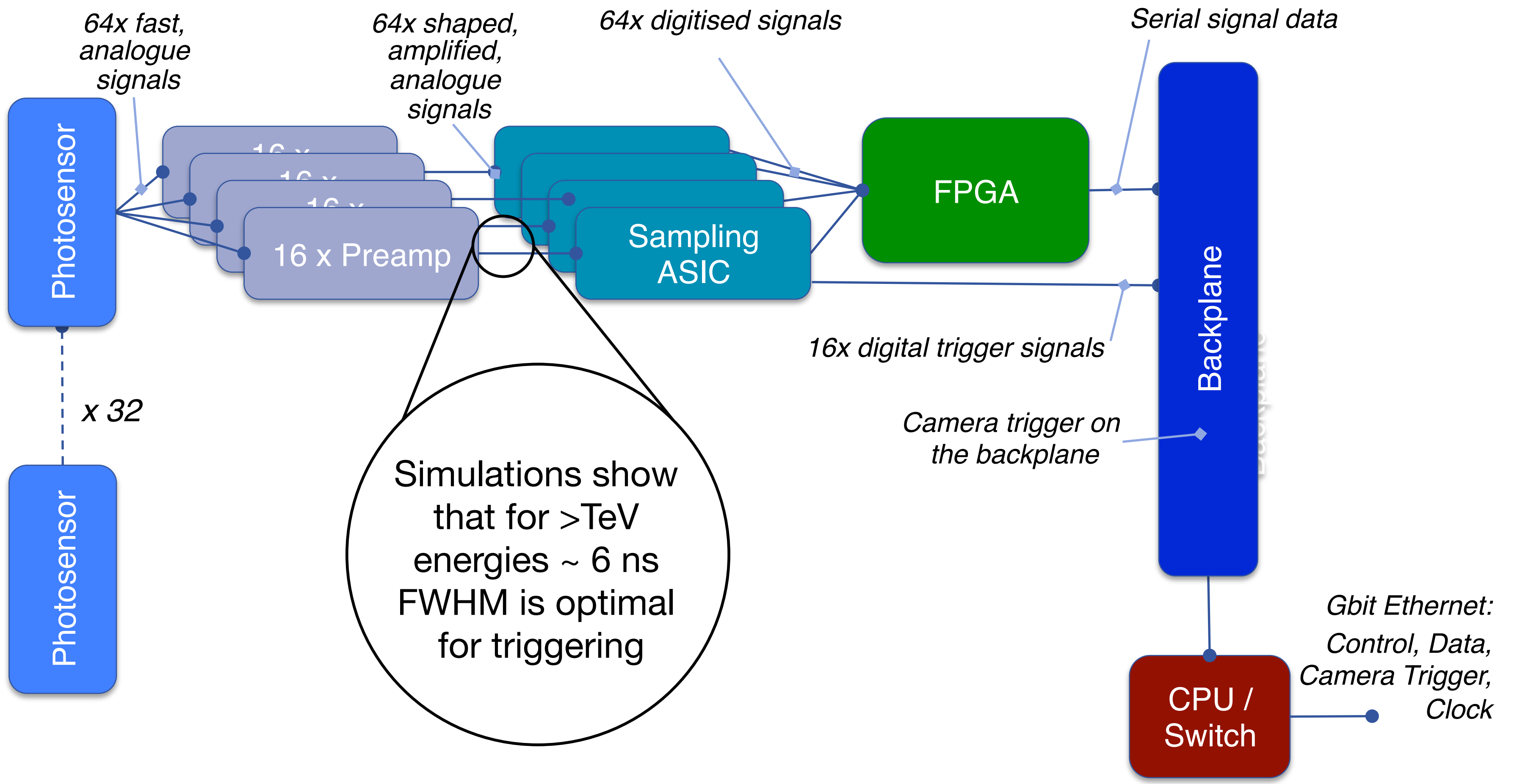

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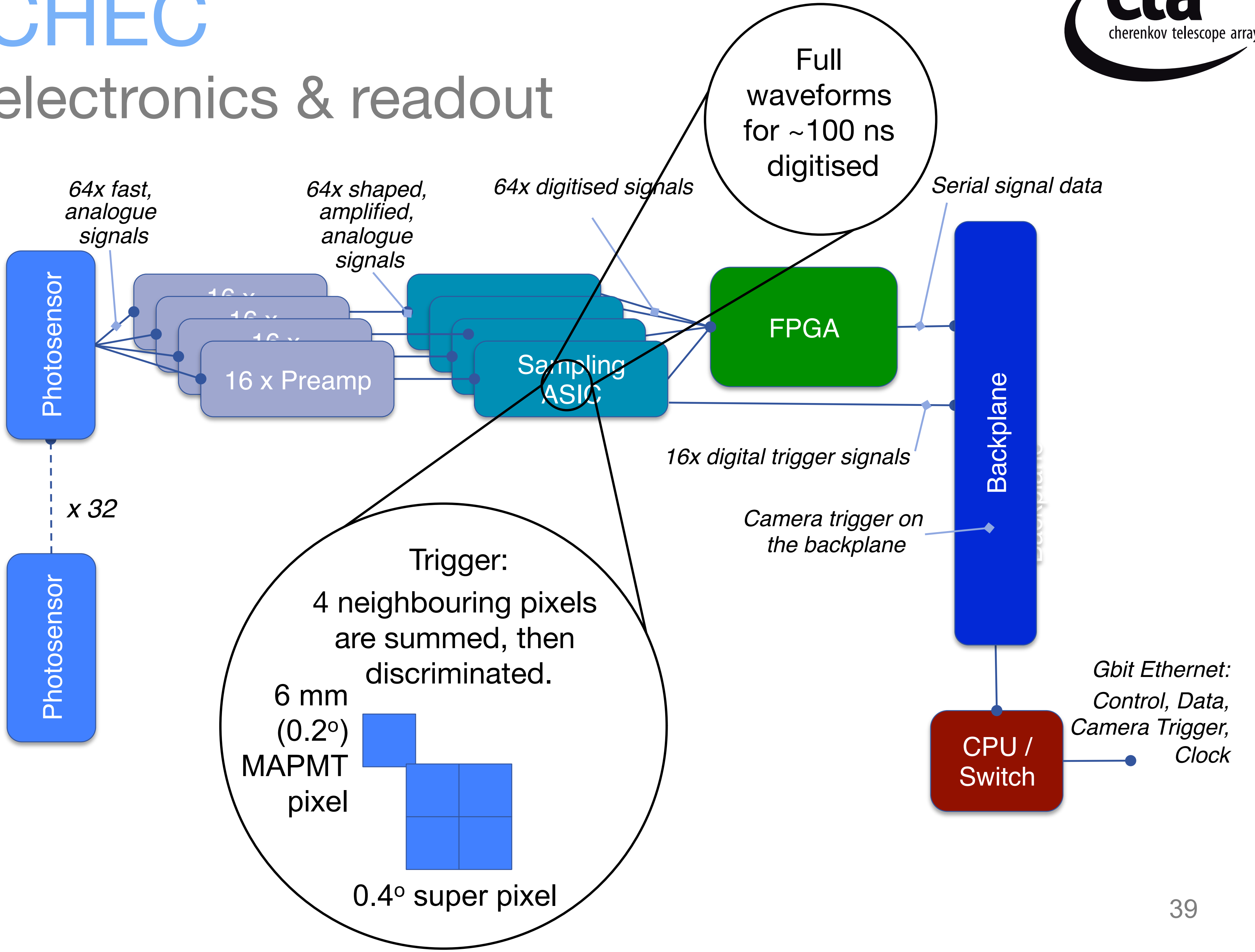

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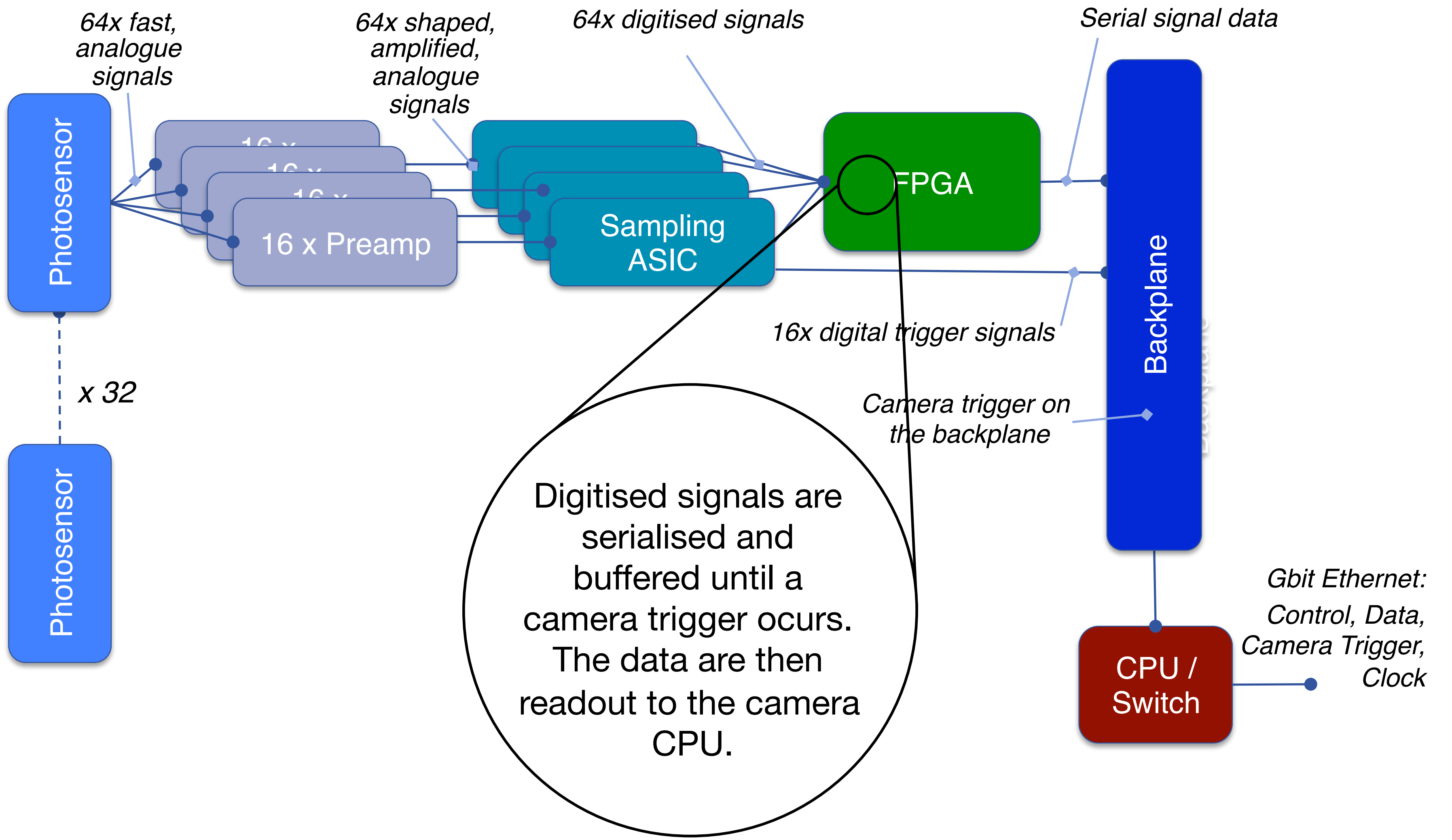

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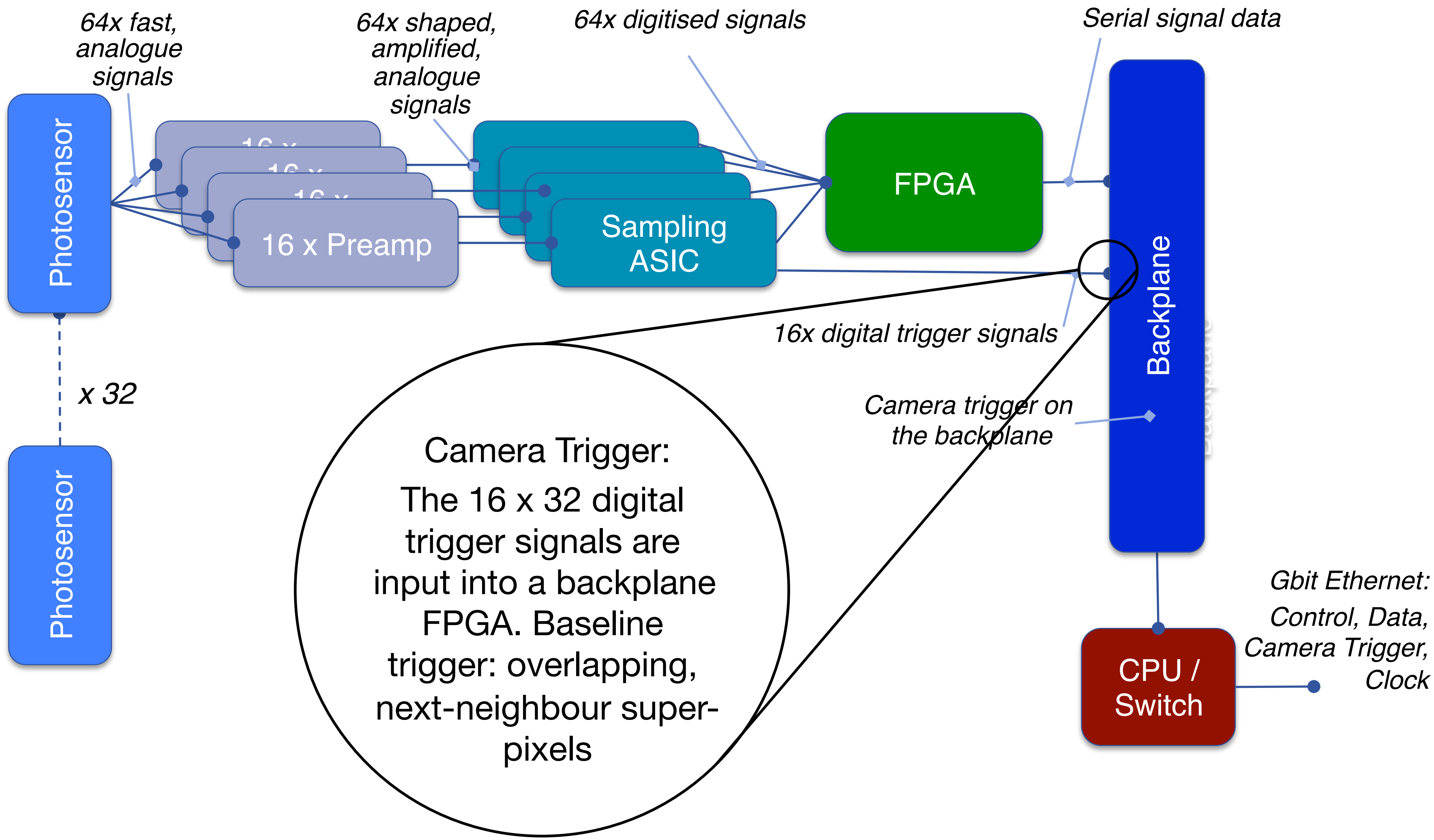

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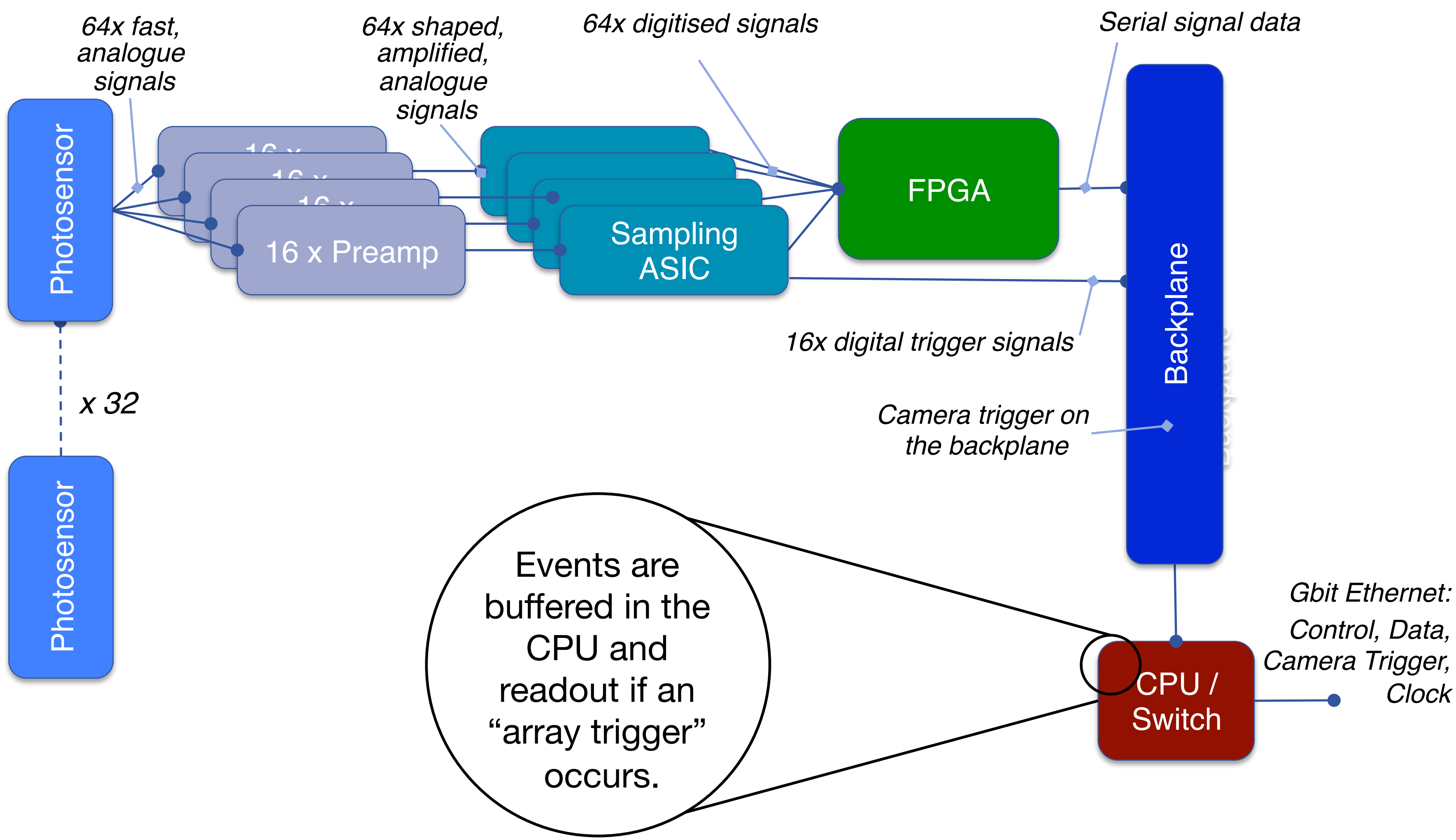
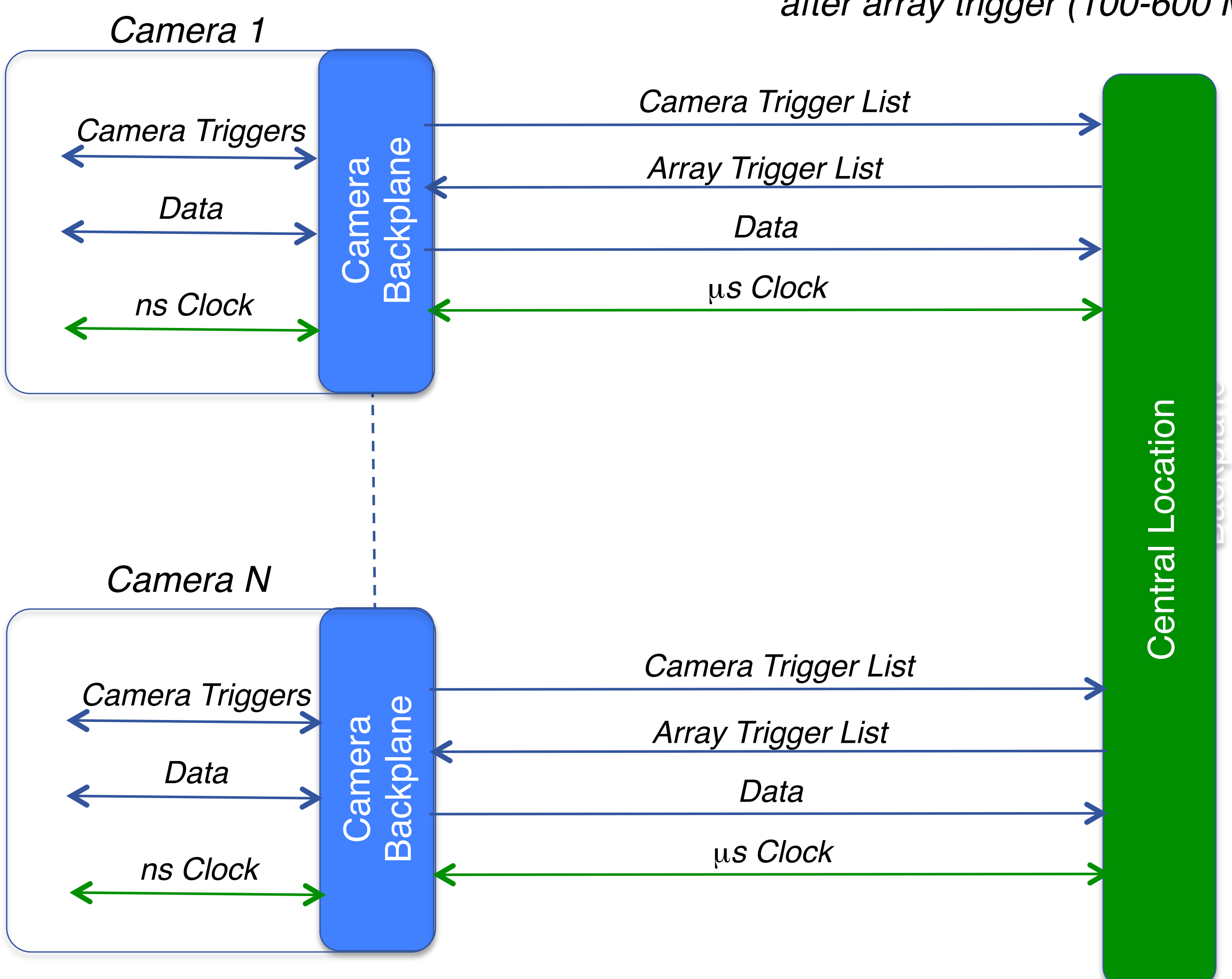


CHEC

electronics & readout

Data sent over ethernet, 10-60 MByte/s per camera after array trigger (100-600 Mbyte/s before).



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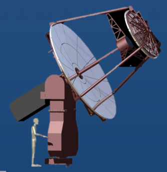
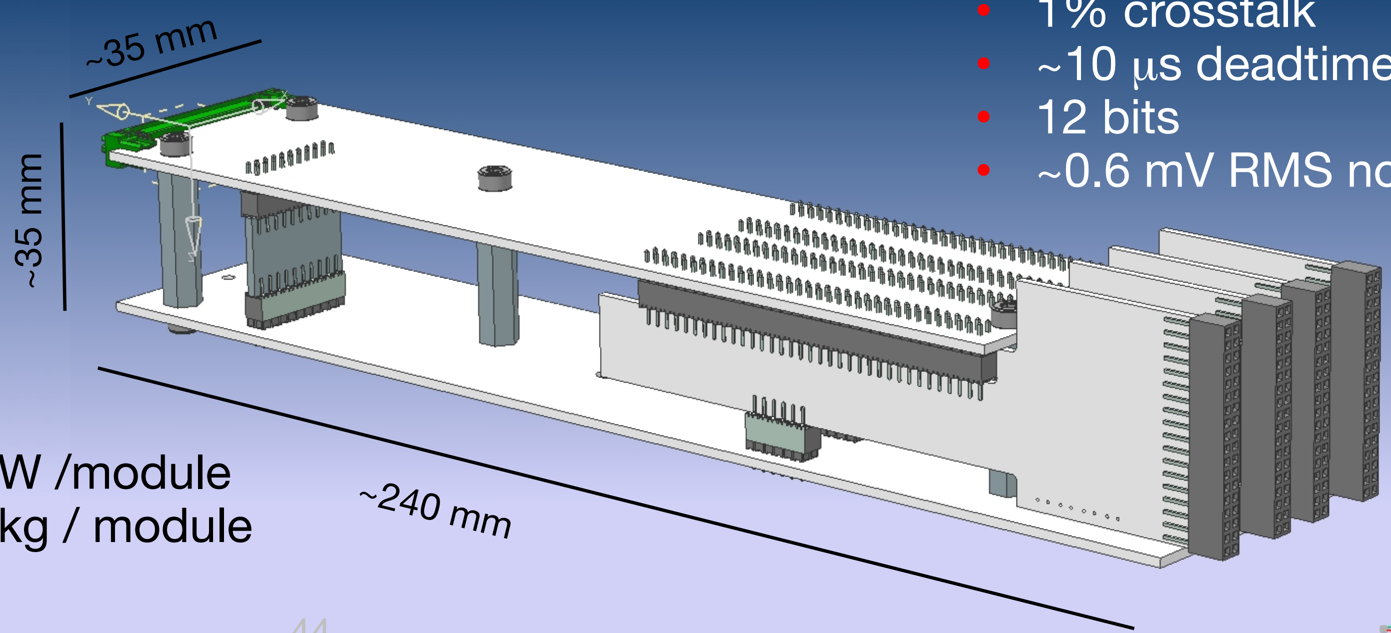


TARGET modules

- Dual Mirror SST design allows a small camera, but requires compact electronics.
- Modules based on the TARGET ASIC developed at SLAC.

- 64 ch
- 0.2 - 1.2 GSPS
- 300 MHz analogue bandwidth
- 1% crosstalk
- ~10 μs deadtime (48 samples)
- 12 bits
- ~0.6 mV RMS noise



- 4.5 W /module
- 0.2 kg / module

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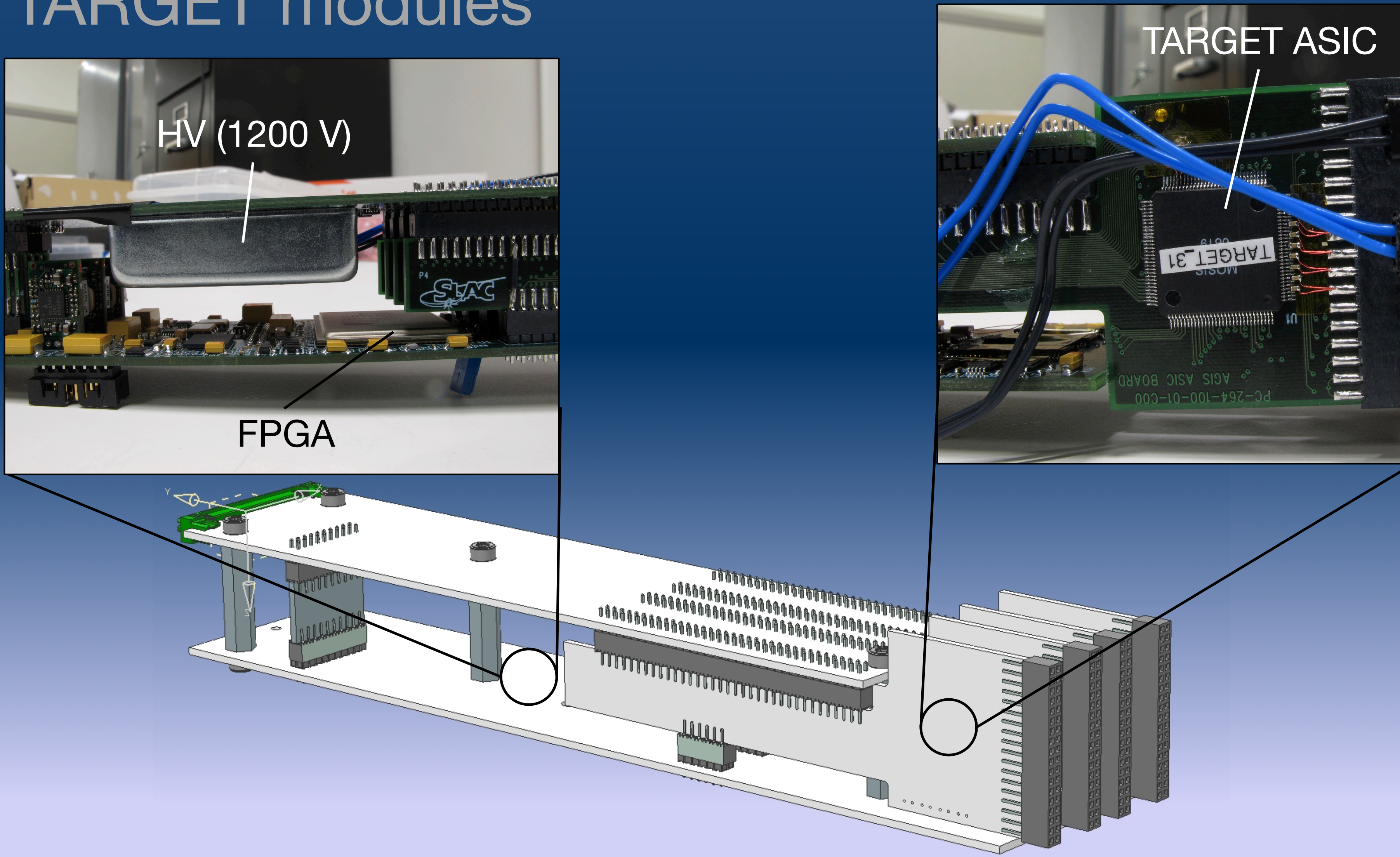
CHEC

TARGET modules



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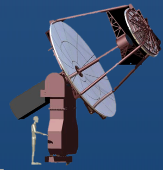
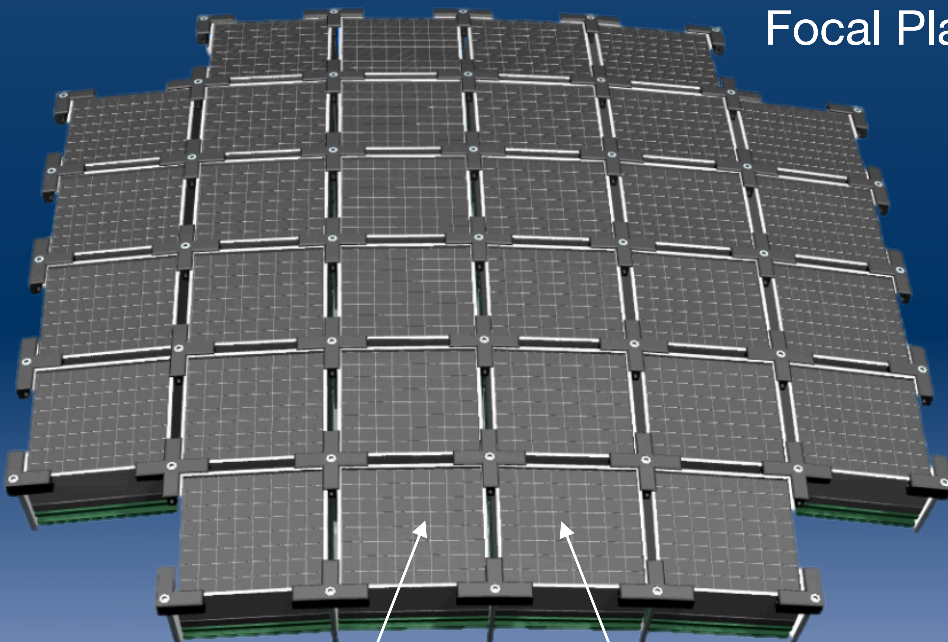
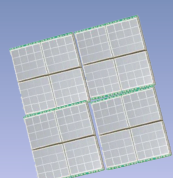
CHEC mechanics

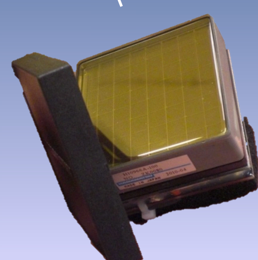


Preliminary Design Only

Focal Plane





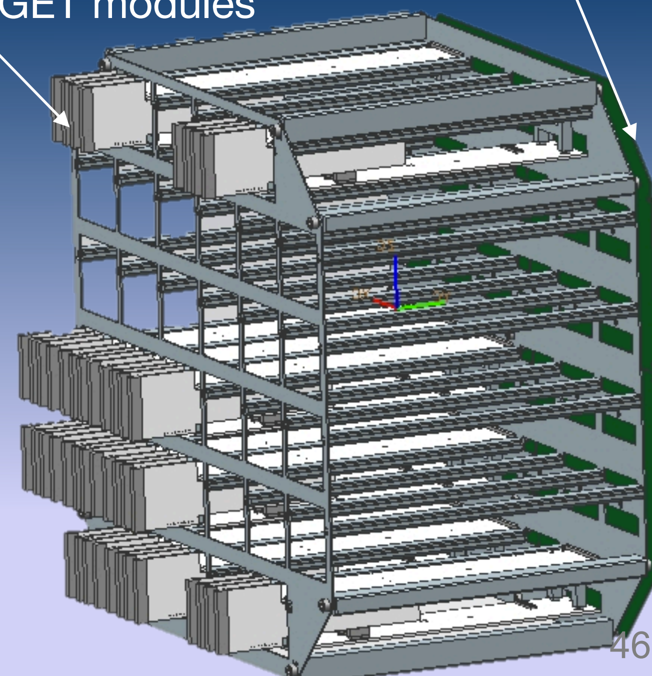


1 x MAPMT (H10966A)
or
16 x SiPM Tile (S11828-3344M)

Electronics

Backplane with single Virtex 7 FPGA

32 TARGET modules



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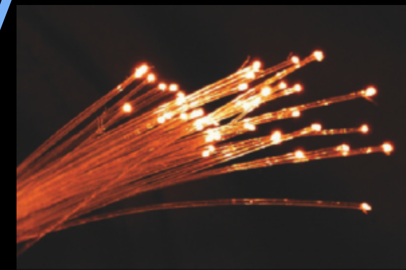
Technology Synergy



- Data rates
- Clock synchronisation
- FPGAs & ASICs
- Telescope structure sizes
- Reliability - expected to operate 20-30 years.
- Cost:
  - 50 € per pixel for the Dual Mirror SST camera
  - 100 M€ camera instrumentation cost

Conclusions

- CTA is the future of gamma-ray astronomy, from energies overlapping with Fermi to 300 TeV.
- Nanosecond cameras and array signal distribution are key technology.
  - Photosensors and ASICs have been developed for CTA and may be useful elsewhere.
- The potential of CTA >1 TeV maximised with a dual mirror SST design.
  - Offers the opportunity to use the next generation of photosensors and compact electronics.
  - The UK is funded to design, build and test a dual mirror SST camera.

cherenkov telescope array

Where to read more?

Exp Astron (2011) 32:193–316
DOI 10.1007/s10686-011-9247-0

ORIGINAL ARTICLE

Design concepts for the Cherenkov Telescope Array CTA: an advanced facility for ground-based high-energy gamma-ray astronomy