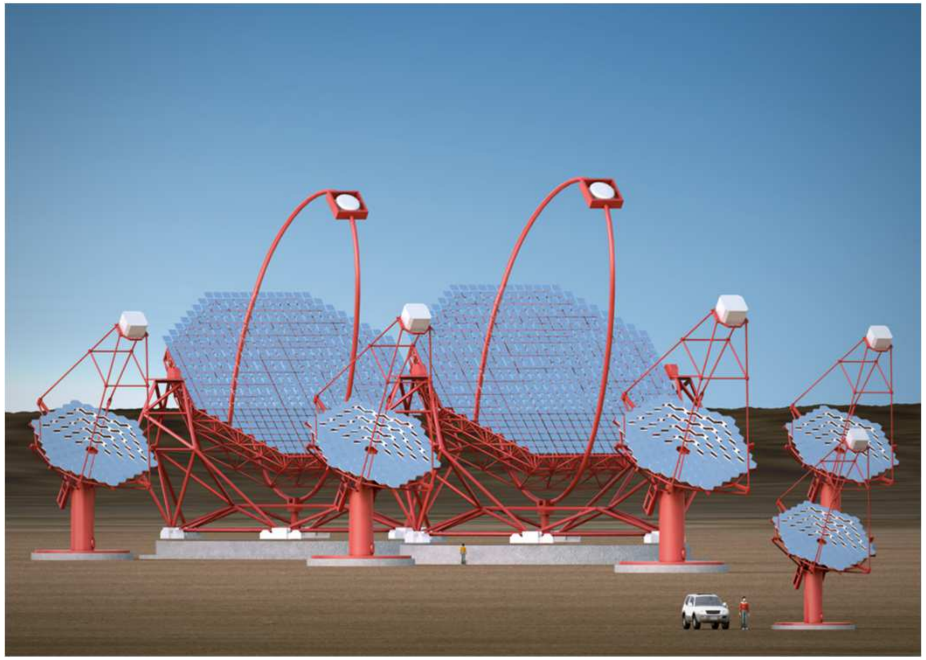
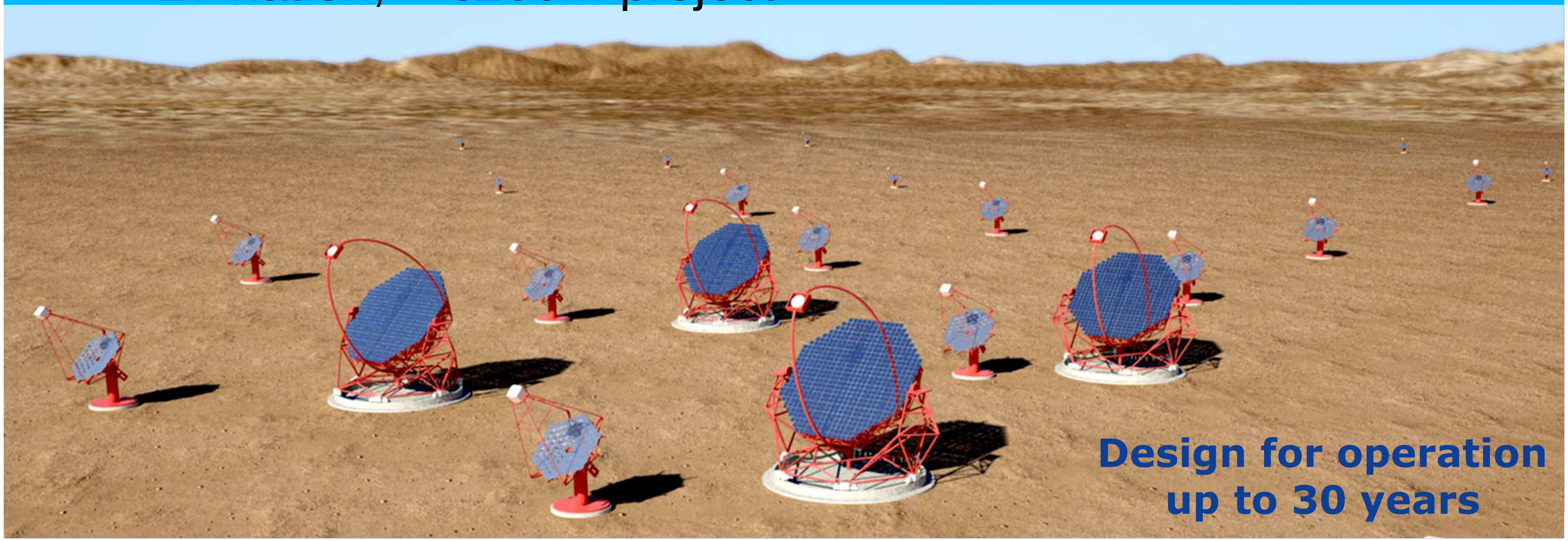
The New Gamma Ray Observatory: CTA



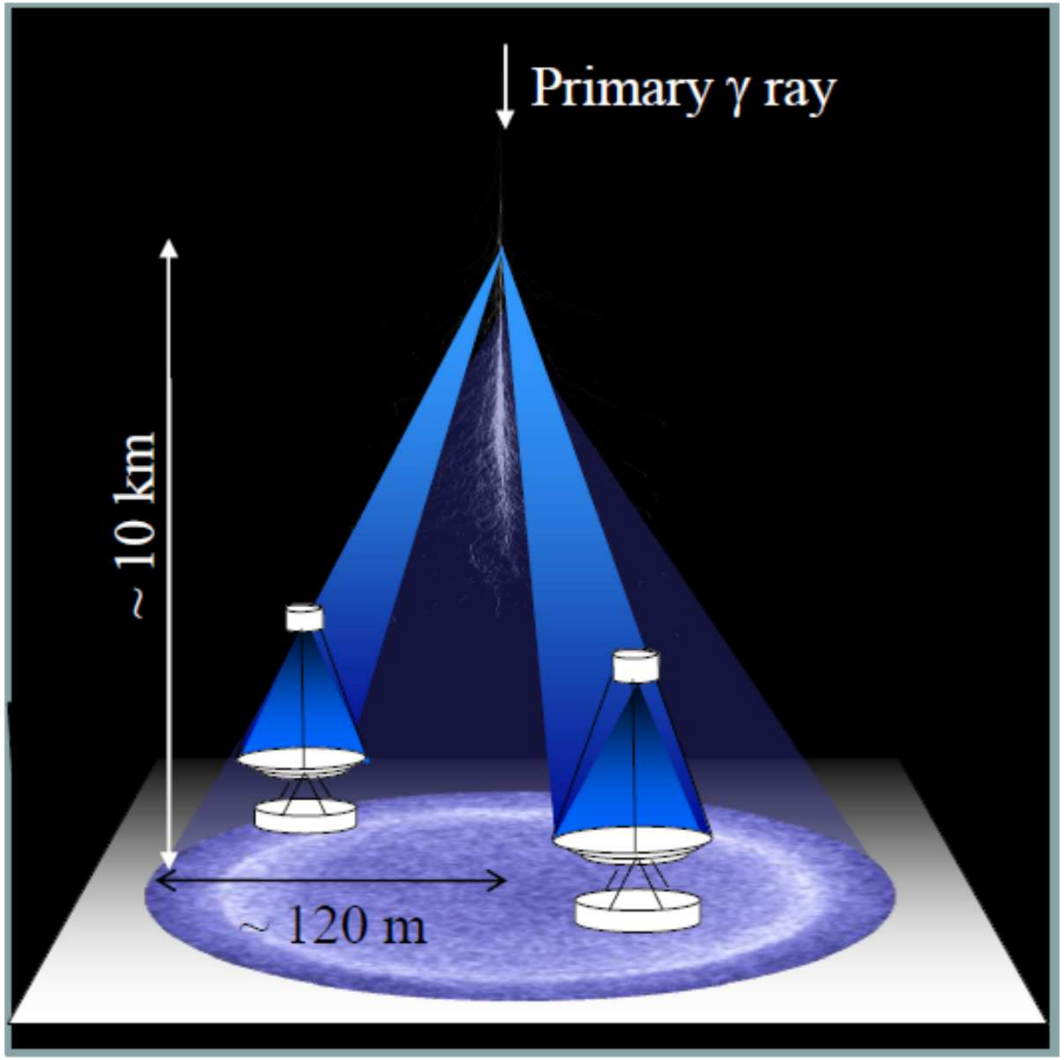
John Carr
CPPM, Marseille

CTA Project

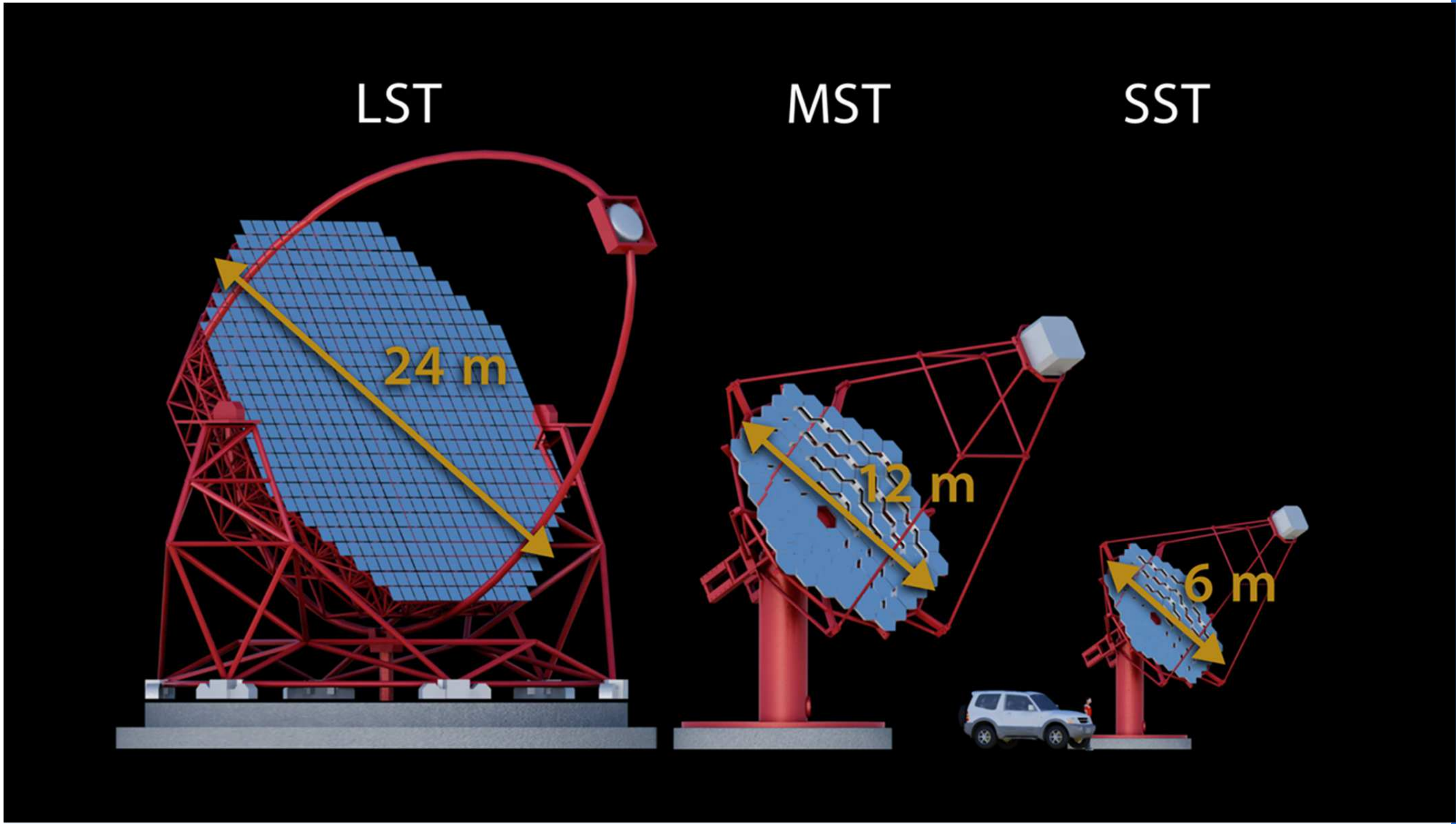
- Next generation Ground Based Gamma Ray Observatory
- Open Observatory
- Two Sites with total > 100 telescopes
- 27 nation, ~ €200M project

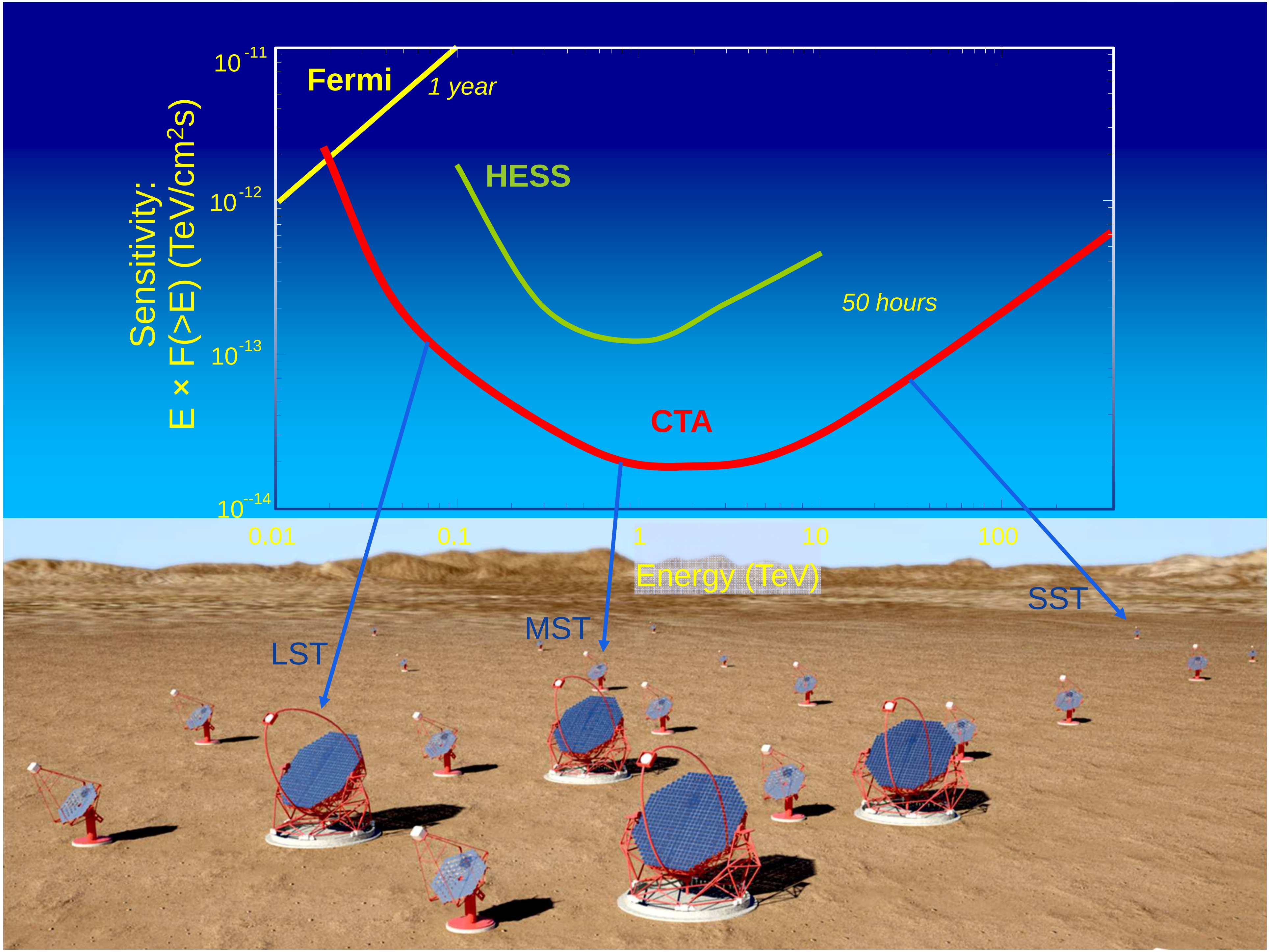


Detection Technique



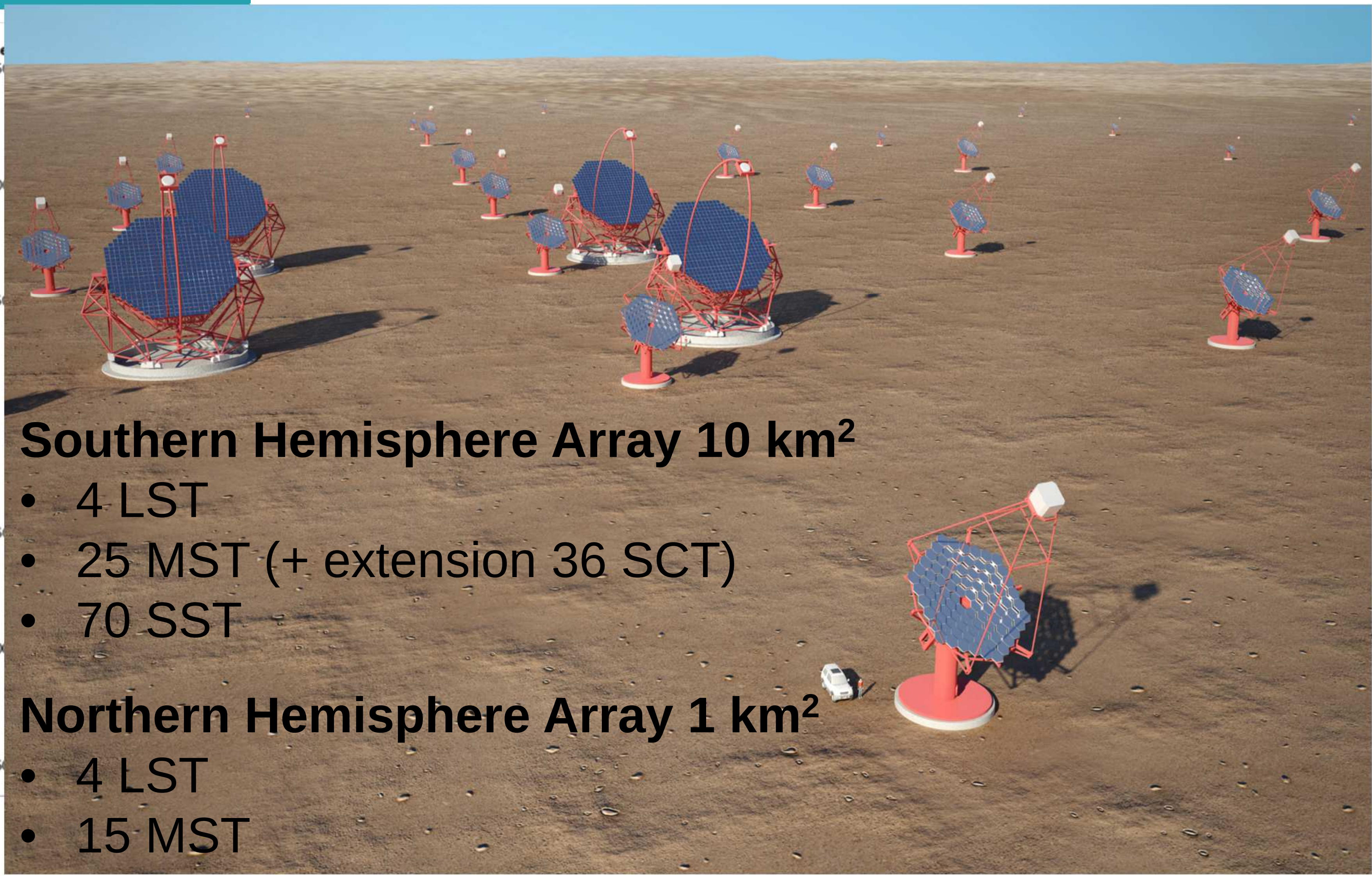
Multiple Telescope Types





Sensitivity:
E × F(>E) (TeV/cm²s)
10^-11
10^-12
10^-13
10^-14
Fermi
1 year
HESS
50 hours
CTA
0.01
0.1
1
10
100
Energy (TeV)
LST
MST
SST

Arrays in South and North Hemispheres



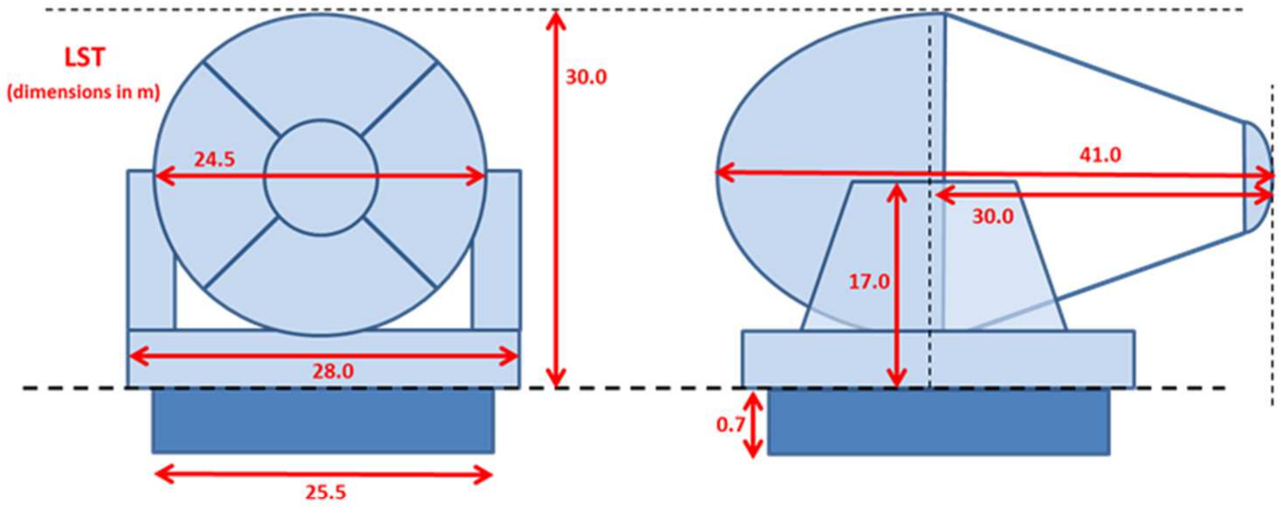
Southern Hemisphere Array 10 km^2
- 4 LST
- 25 MST (+ extension 36 SCT)
- 70 SST

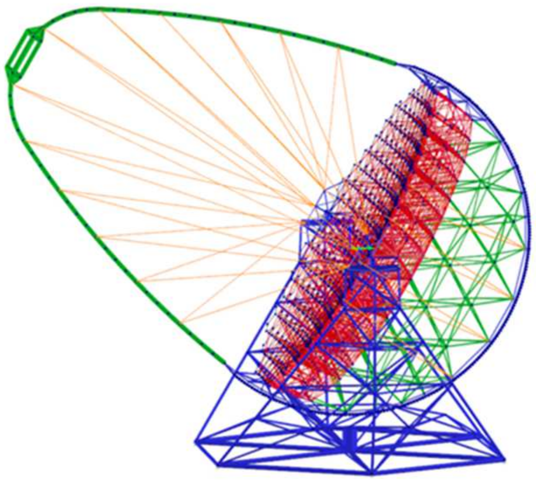
Northern Hemisphere Array 1 km^2
- 4 LST
- 15 MST

Sites: Candidates

- Many good sites
  - Extensive studies taken place
- Decisions during 2014
  - First ranking of site in Southern Hemisphere.
  - Site negotiations to start soon.
  - Decision on Northern sites later.
- Site development 2017
- First telescopes operating on site in 2017

Large Sized Telescope

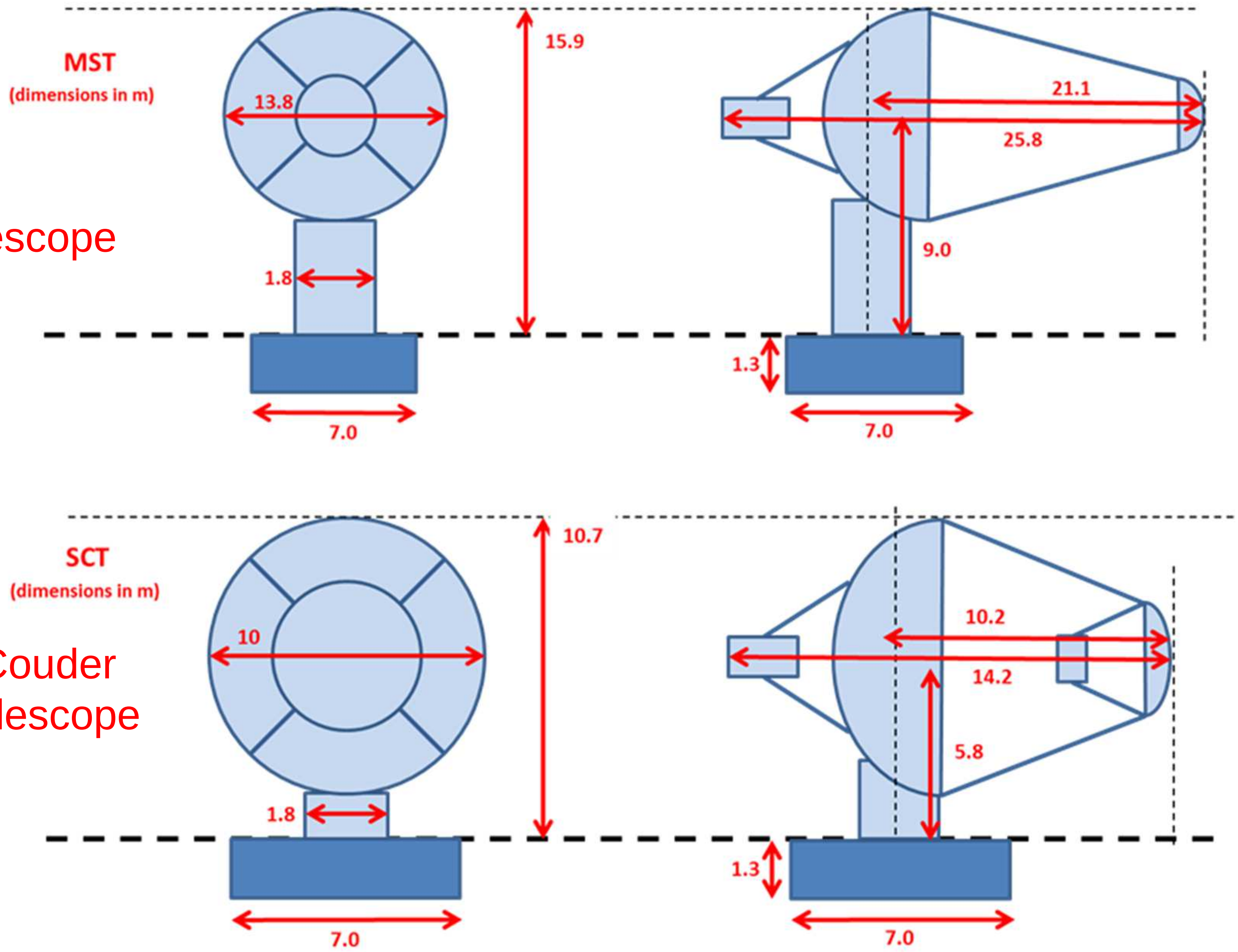




Medium Sized Telescope

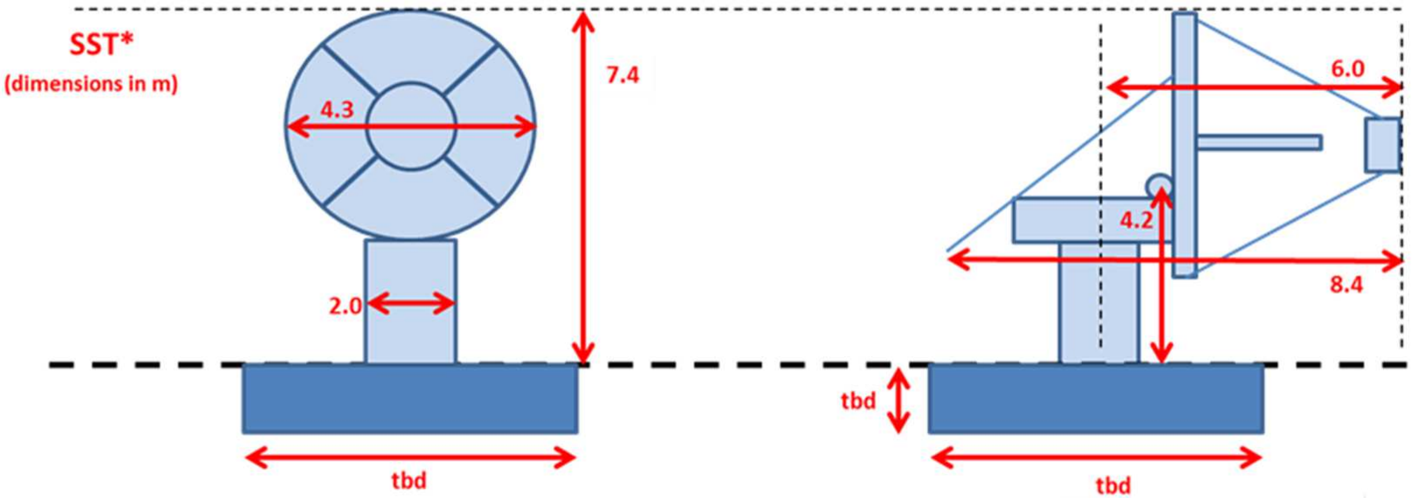
Davies-Cotton
Medium Size Telescope

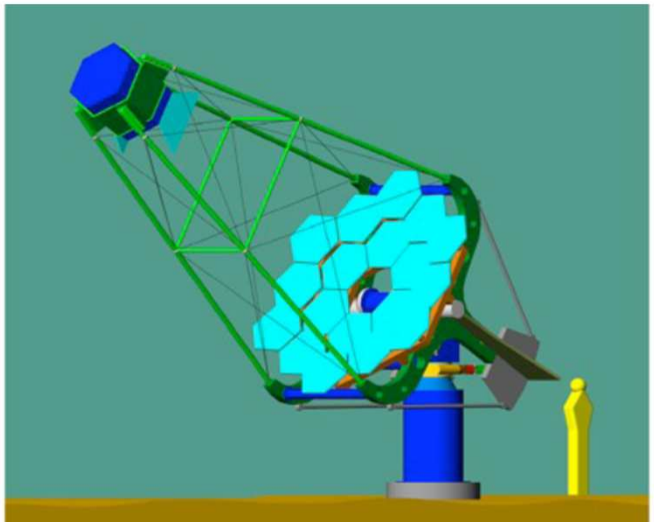
Schwarzschild-Couder
Medium Size Telescope

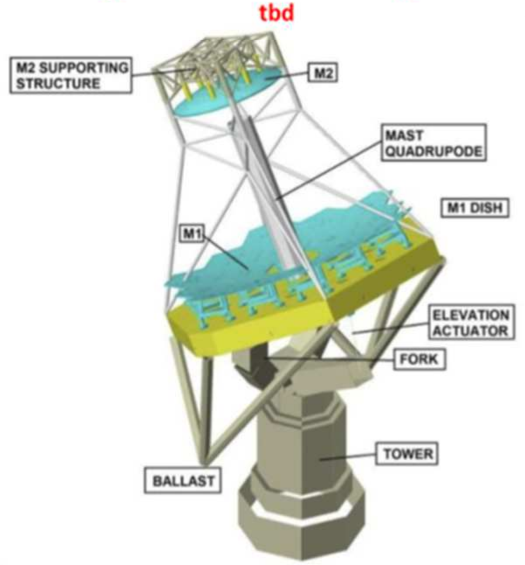


MST Prototype in Berlin

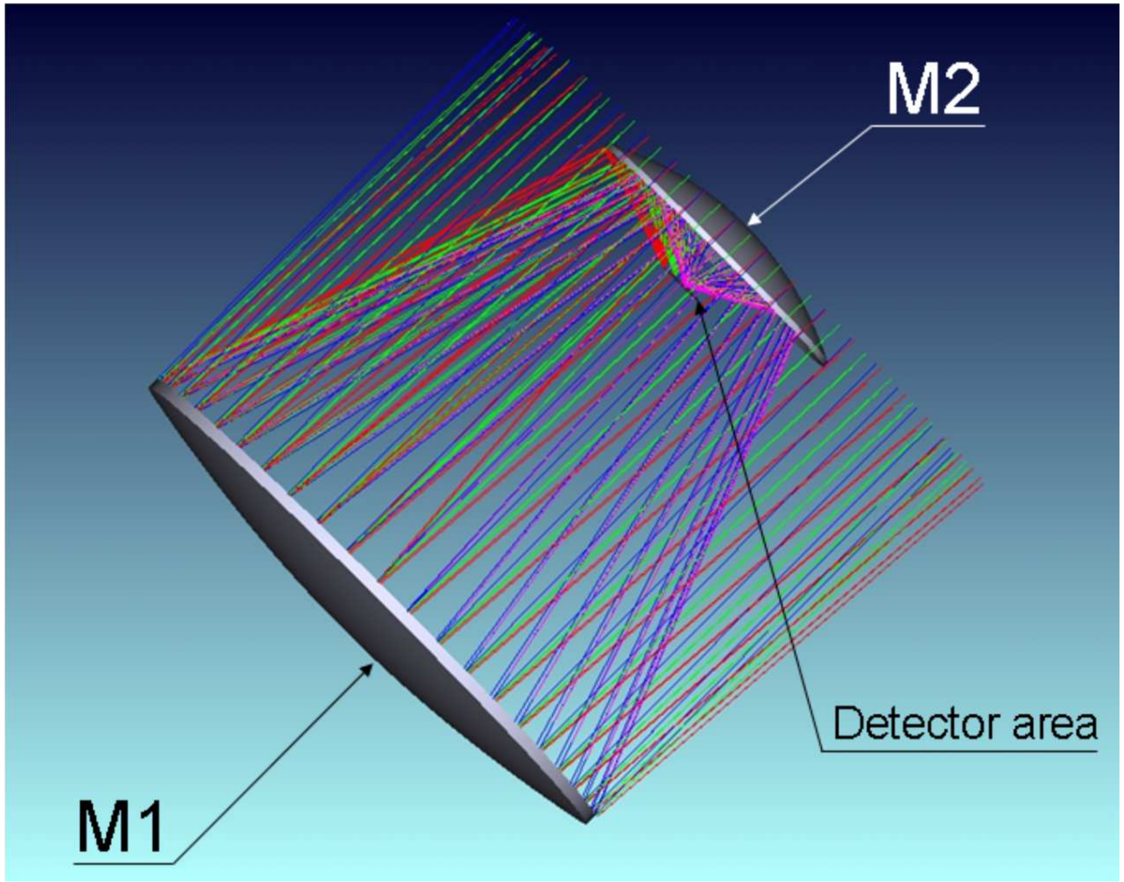
Small Sized Telescope







Dual Mirror Telescope Optics



- More compact structure
- Smaller camera

SST Prototype on Mt Etna

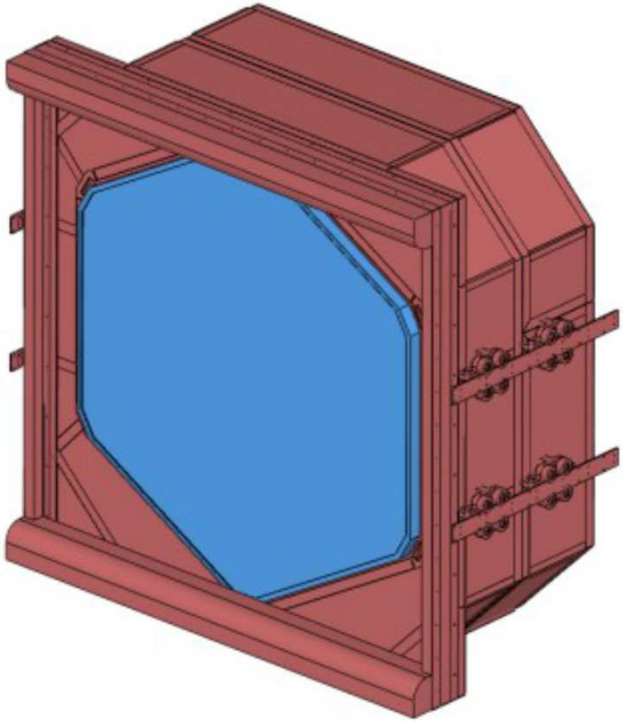
See talk of Stefano Vercellone this afternoon for details

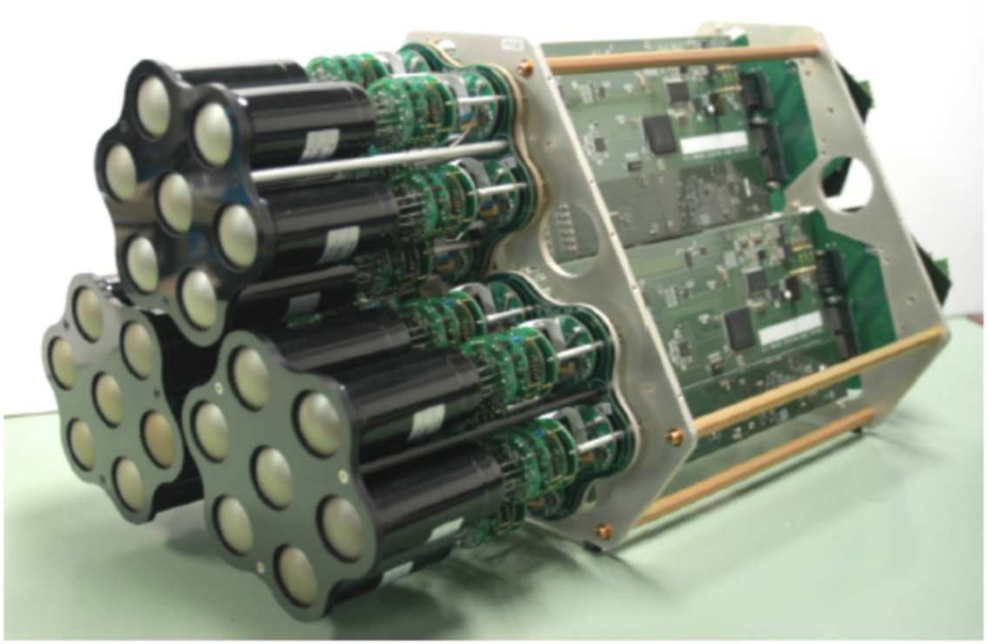
SST Prototype in Krakow

No complete camera prototypes yet…

Cameras for LST and MST-DC

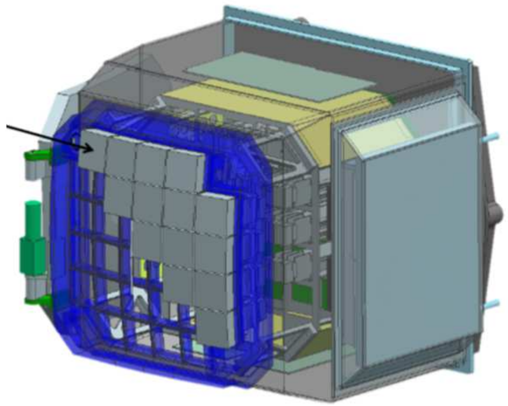
Scale ~2 metres,
Light detection with classical photomultipliers

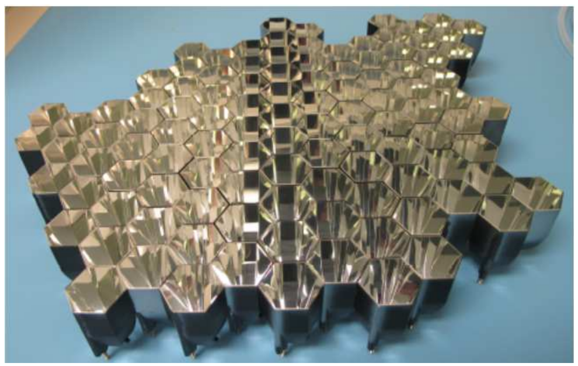


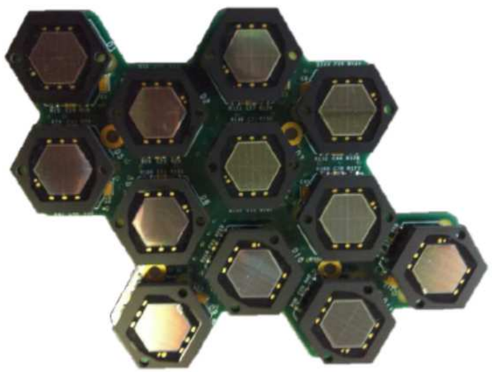


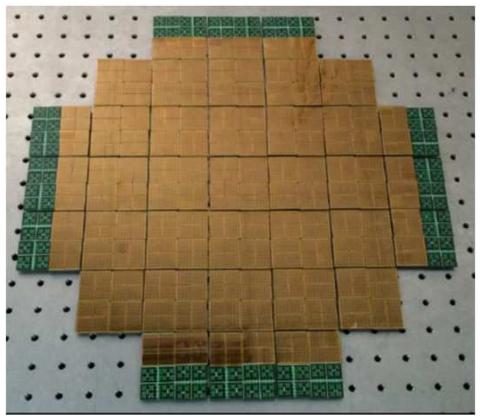
Cameras for SST and MST-SC

Scale <1 metres,
Light detection with silicon photomultipliers

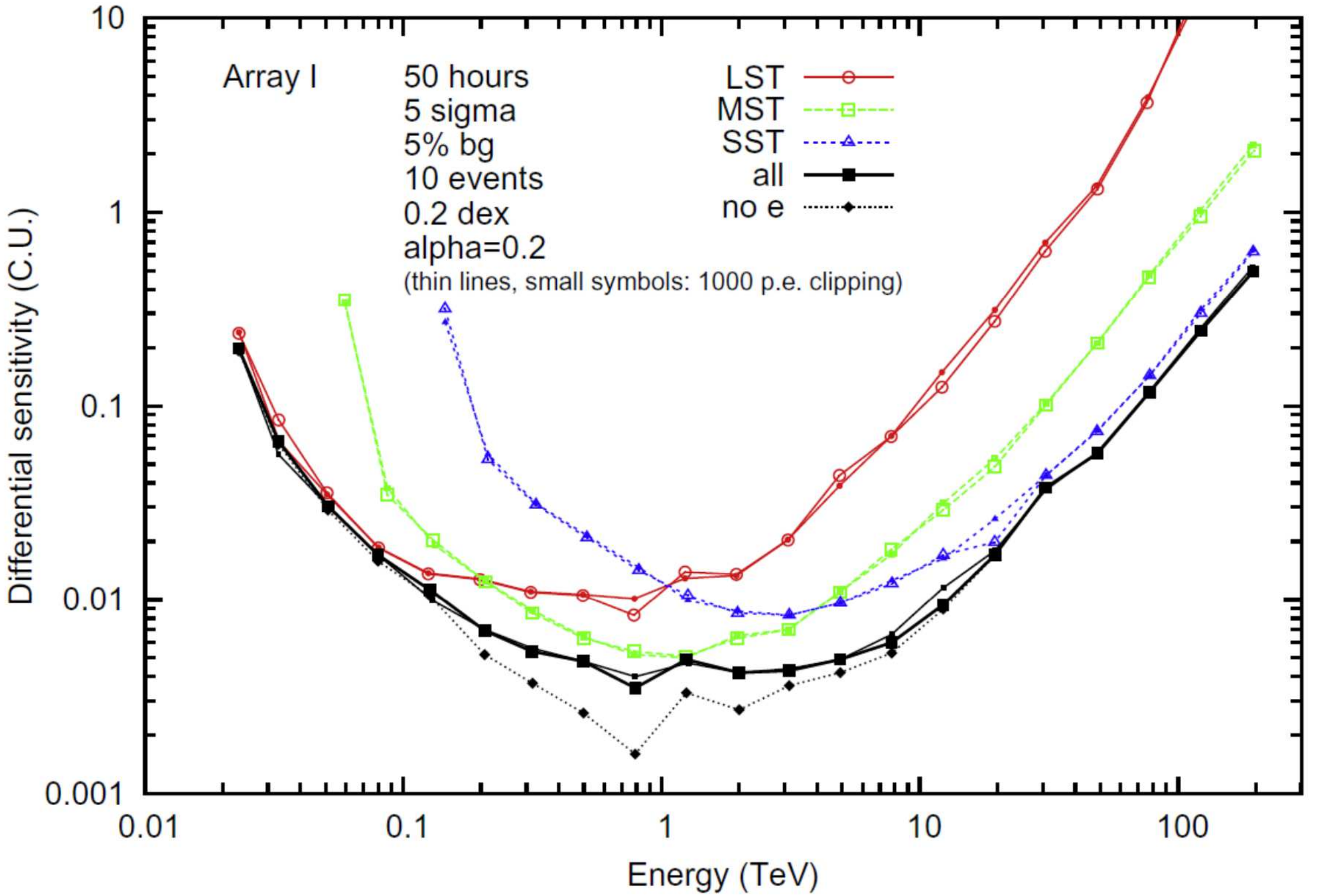






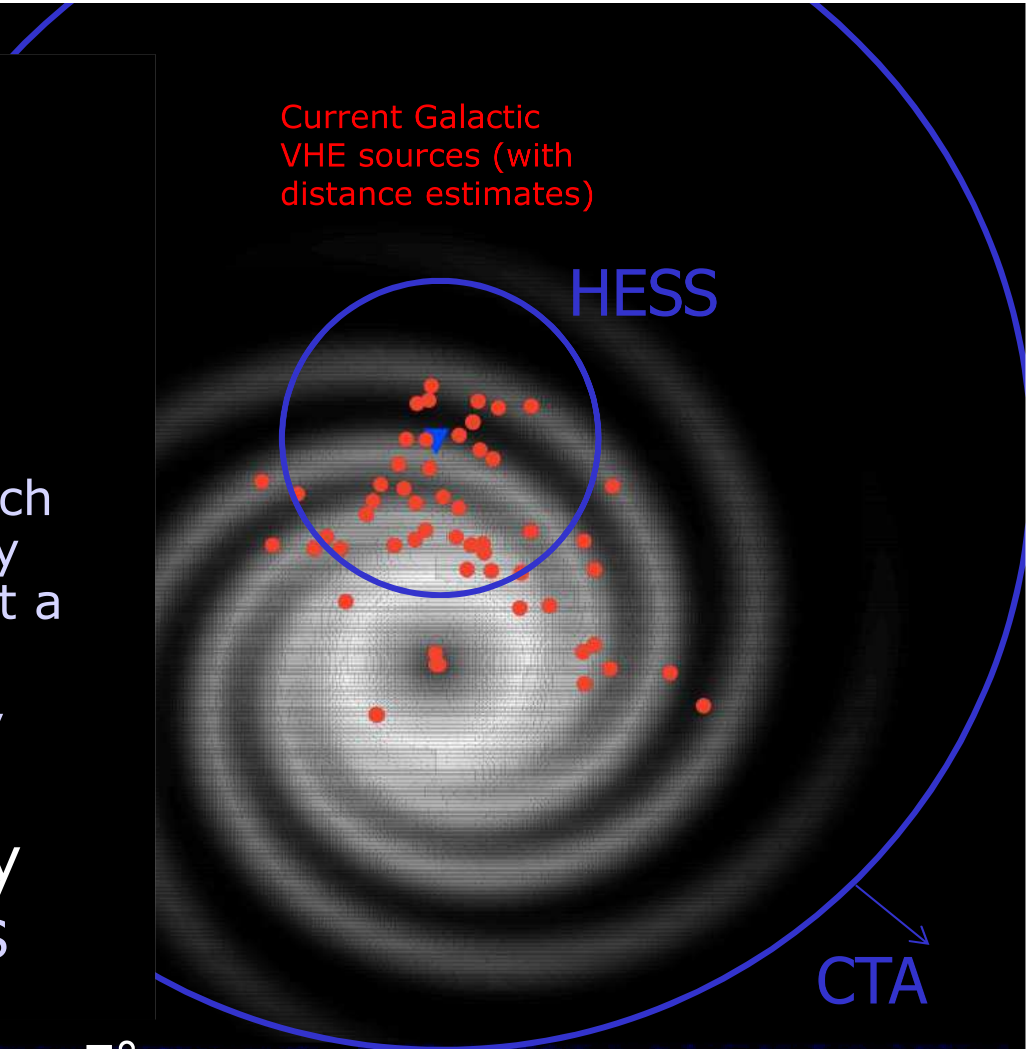


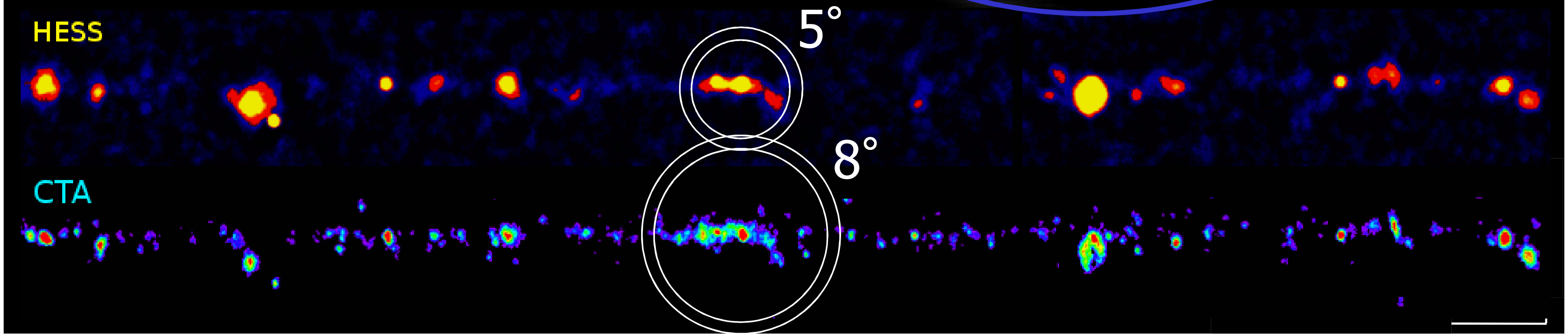
Energy Range of Different Telescopes



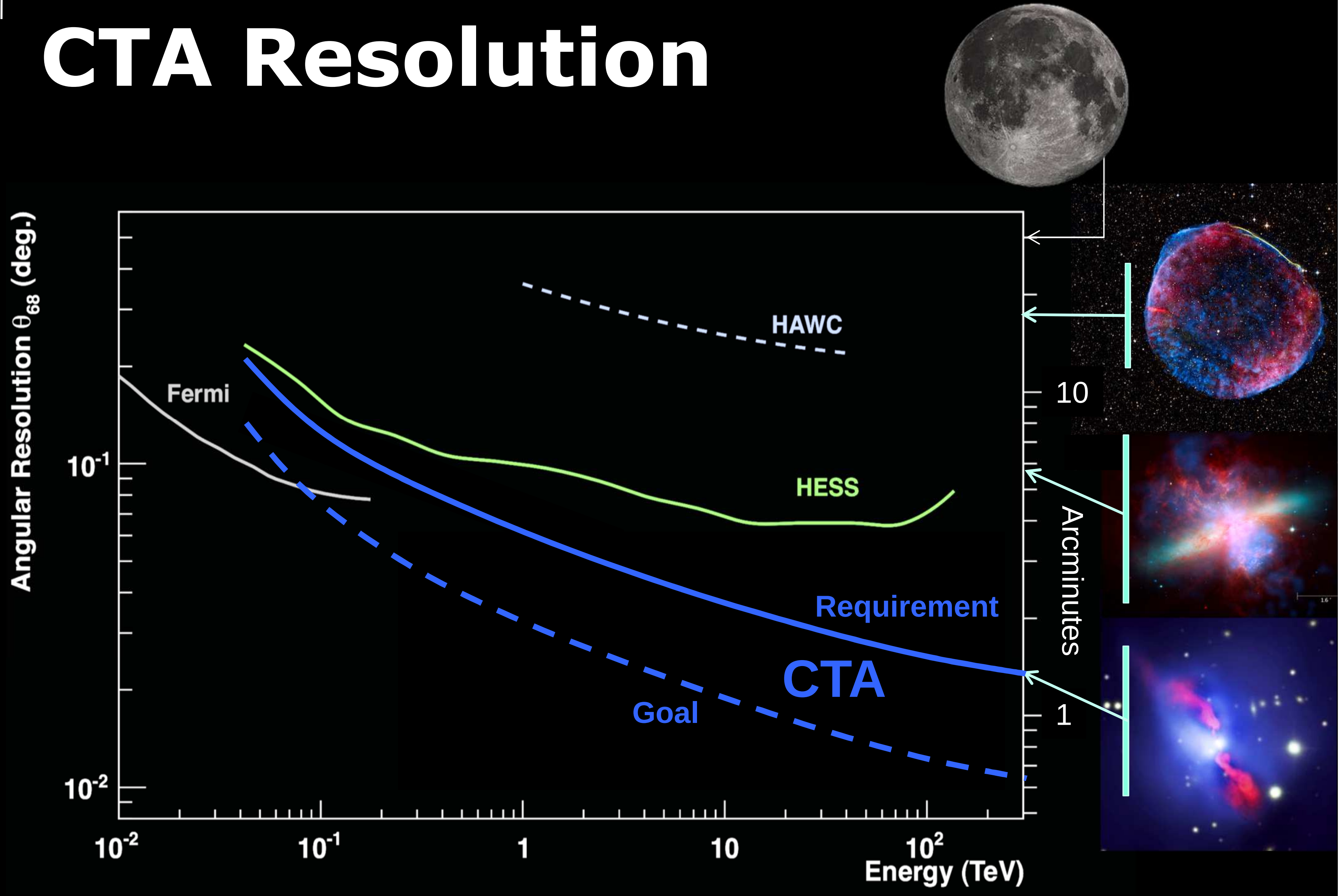
CTA Reach

- Galactic objects
  - Newly-born pulsars and supernova remnants
    - have typical brightness such that HESS etc can see only relatively local (typically at a few kpc) objects
  - CTA will see **whole** Galaxy
- Field of view + sensitivity
  - Survey speed ~300 × HESS

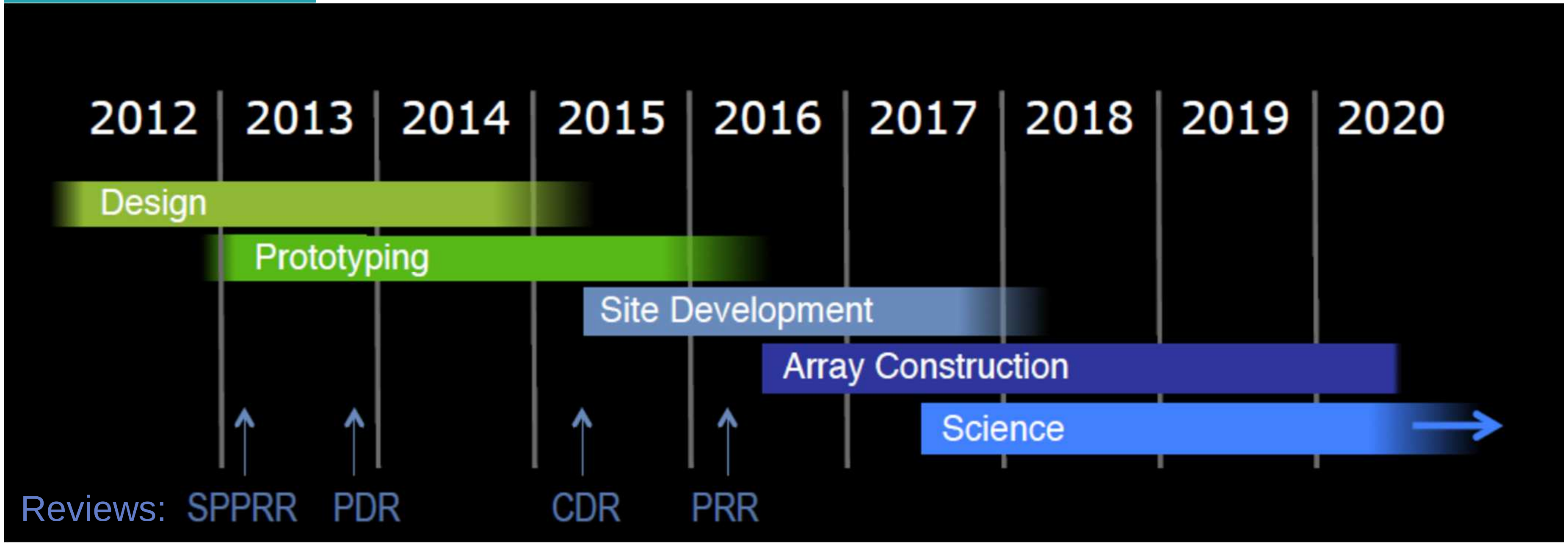




CTA Resolution



CTA Schedule



Aiming for project approval mid-2015

CTA Science

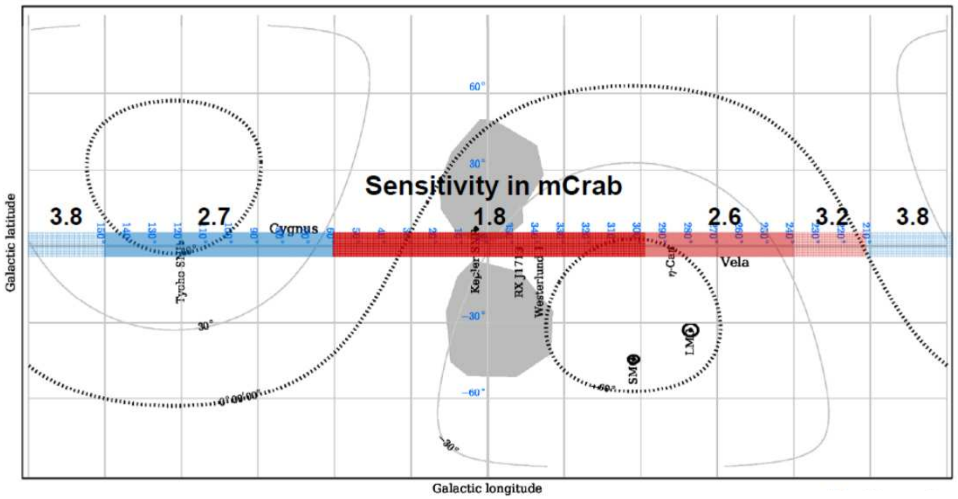
- **Cosmic Particle Acceleration, Propagation and Impact**
  - Mechanisms for particle acceleration, galactic CR acceleration and Pevatrons, acceleration in jets and lobes of AGN, cosmic ray transport, …
  - What role do accelerated particles play in feedback on star formation and galaxy evolution?
- **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 particles exist?

CTA Observatory

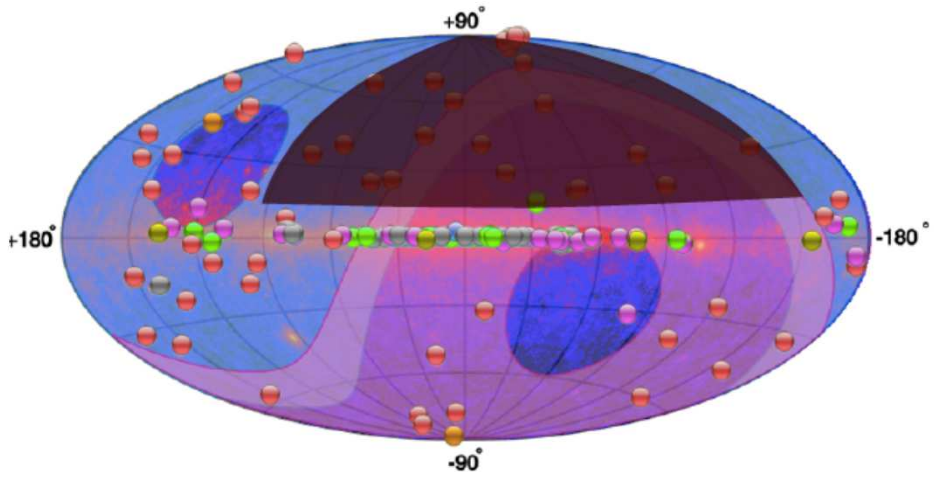
- CTA will be an Open Observatory
- CTA Consortium, which builds the telescopes, will get guaranteed time (~50%) with rest open to external proposals.
- CTA Consortium in the process of defining a “Key Science Program” to use the consortium time allocation

Systematic Surveys

Galactic Plane Survey
±4° latitude

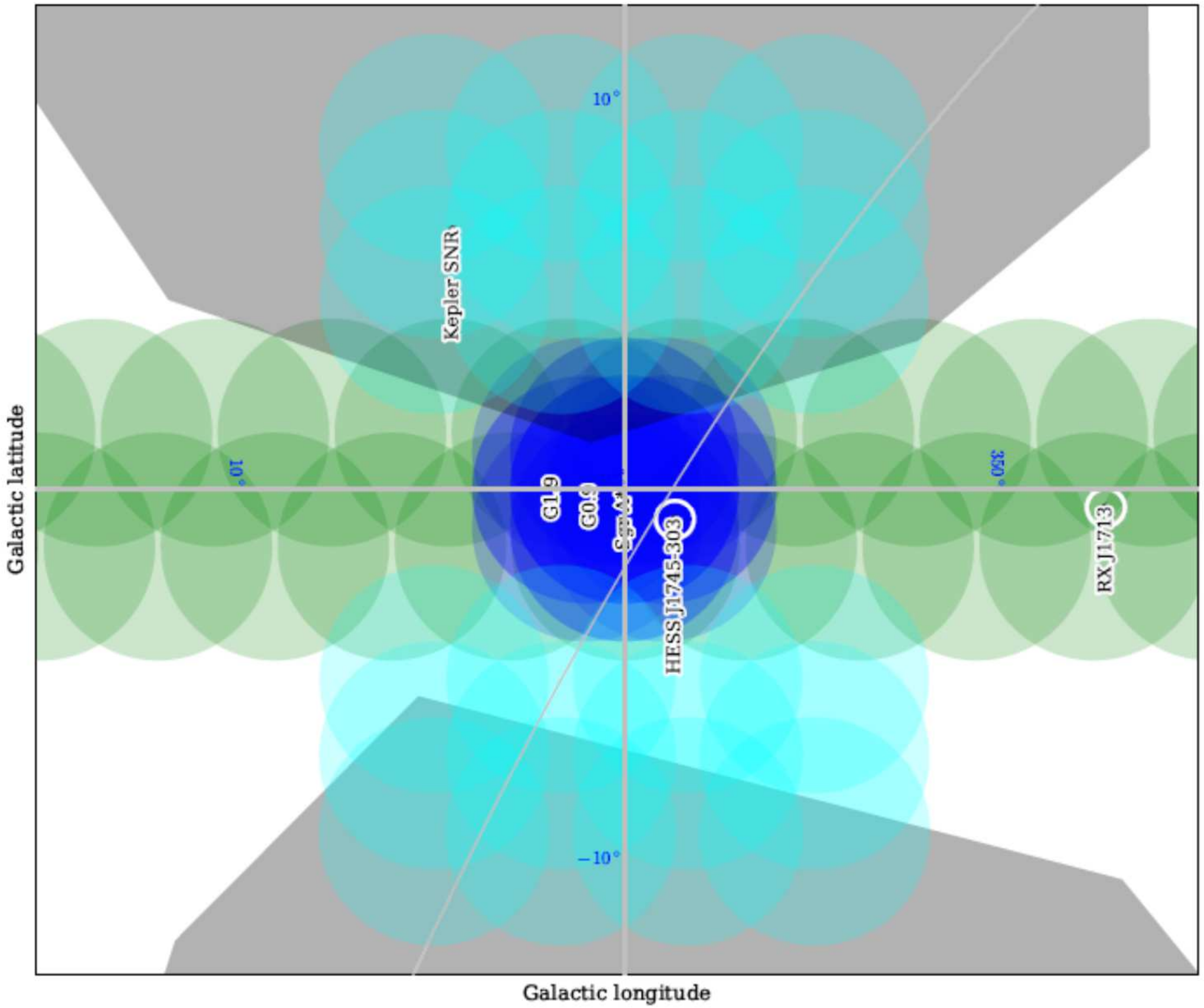


Extra Galactic Survey
25% of whole sky



Deep Galactic Centre Survey

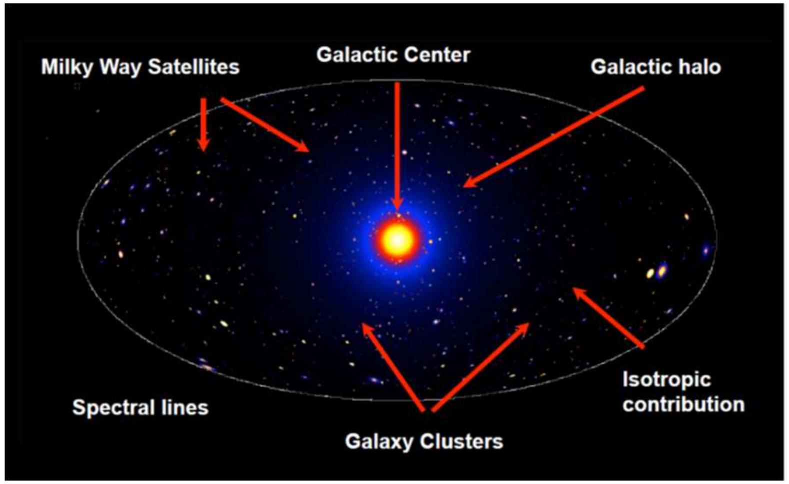
500 hours
in ±4° around
Galactic Centre



Indirect Search for Dark Matter

- For the first time in gamma-ray indirect dark matter searches, CTA has the sensitivity to probe the expected parameter region for popular models

- Many possible targets and methods

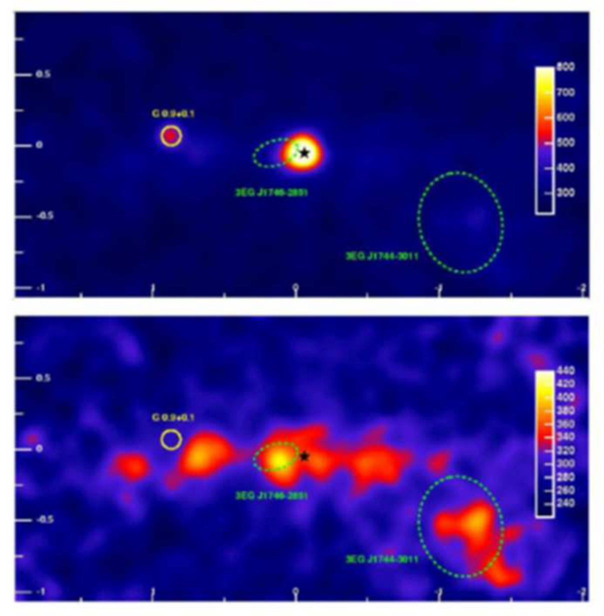


- Galactic halo brightest, close source has highest potential sensitivity

- Dwarf galaxies have advantages with systematics but lower sensitivity

Targets for IDM Searches

Milky Way



Large Magellanic Cloud

"Dark Targets":
Dwarf Galaxies
Clumps

Studies in progress to decide best way to use observation time

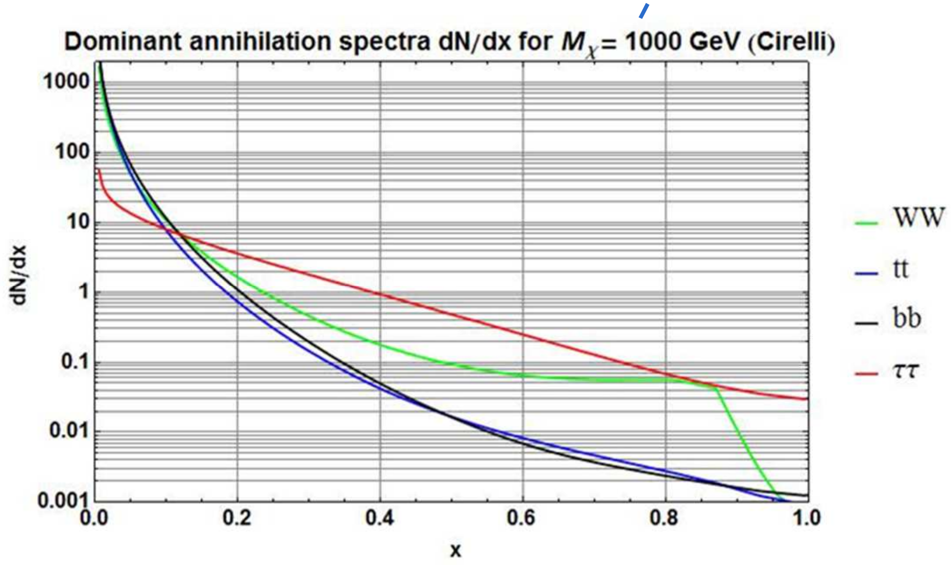
Rates for DM Annihilation

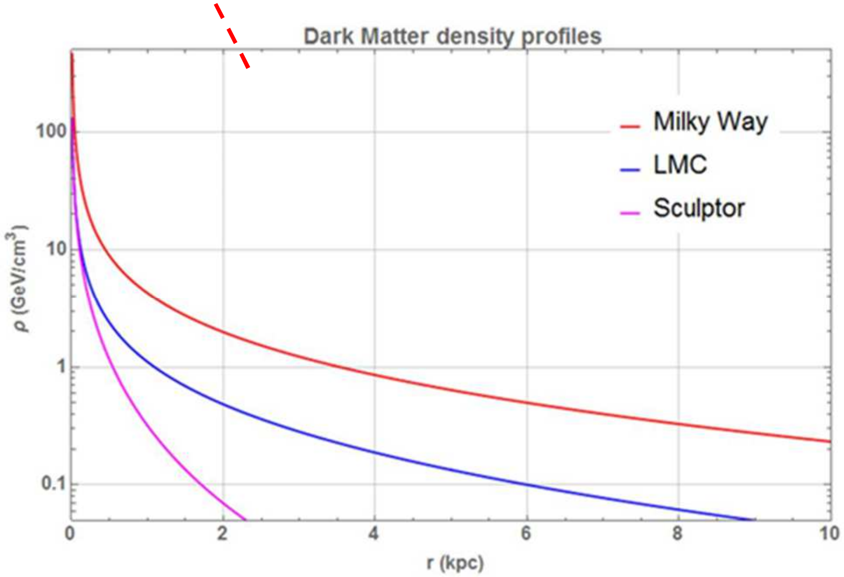
$$\frac{d\Phi}{dE} = \frac{1}{4\pi}\frac{\langle\sigma v\rangle}{\nu m_\chi^2}\frac{dN_\gamma}{dE} \iint \rho^2 \, ds \, d\Omega$$

Particle physics factor

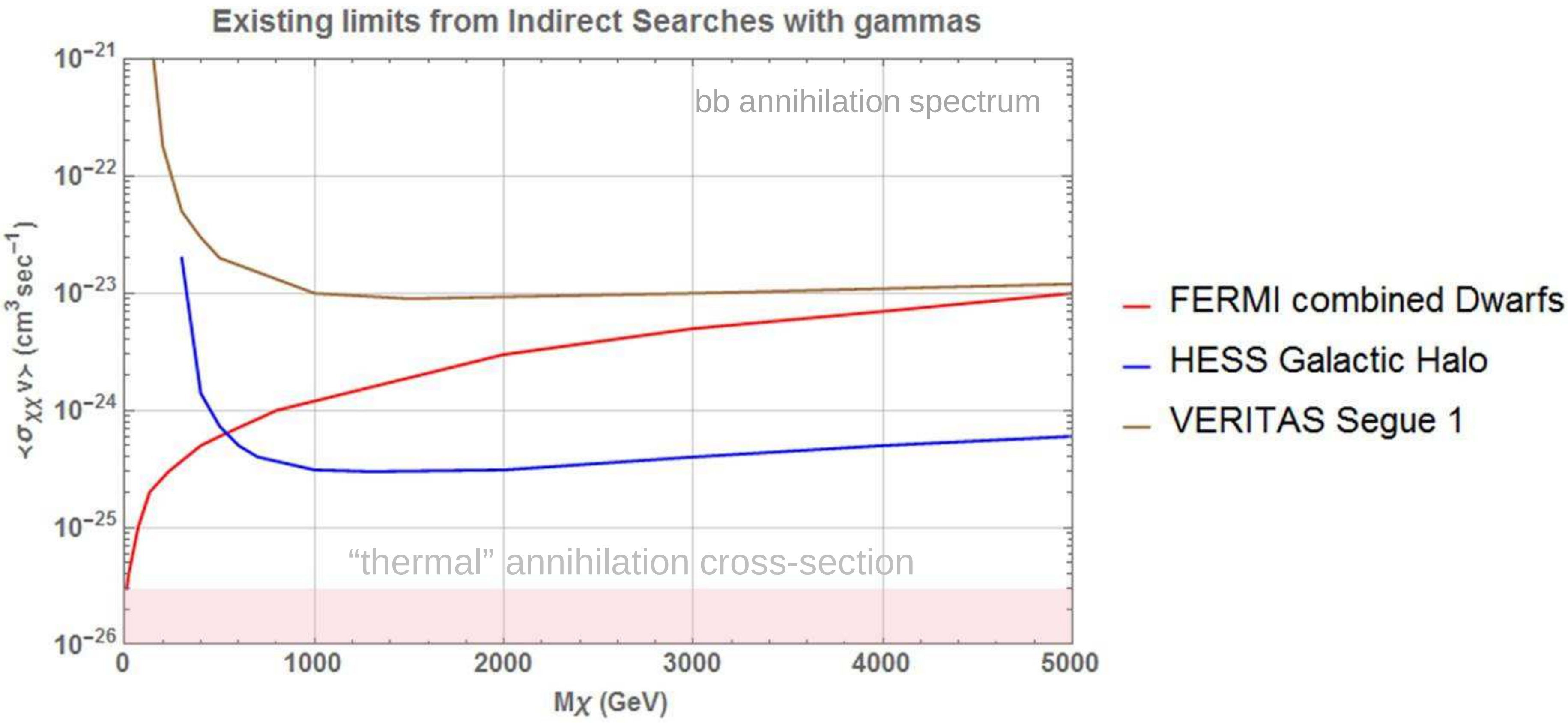
Astrophysical factor

J



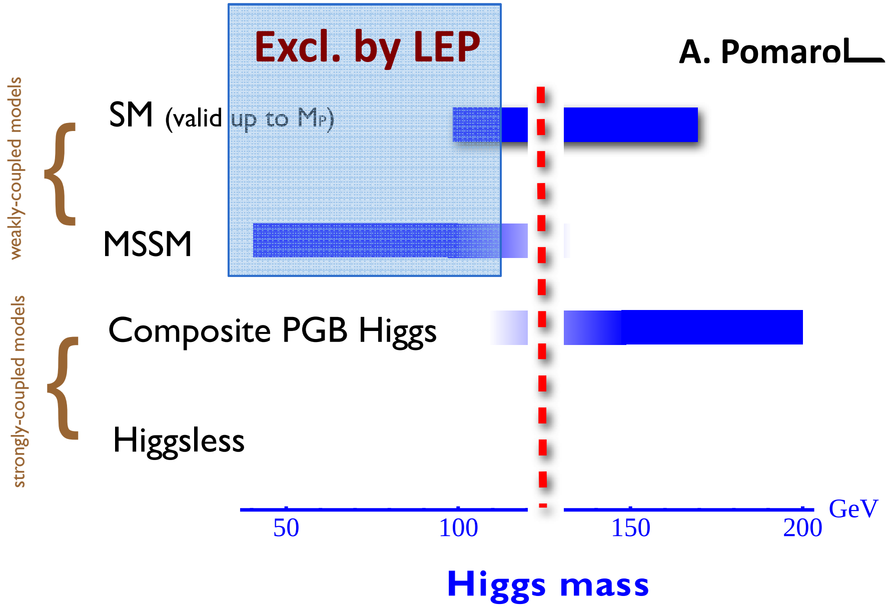


Existing Limits from Indirect Gamma

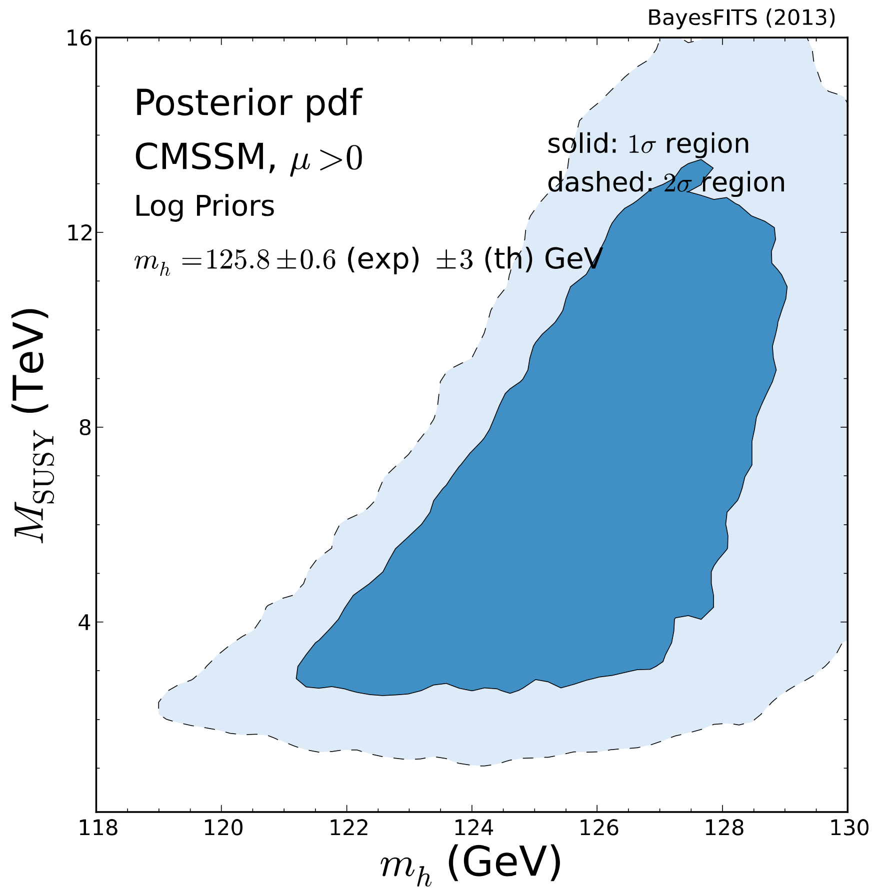


Fermi has best limits up to ~500 GeV mass

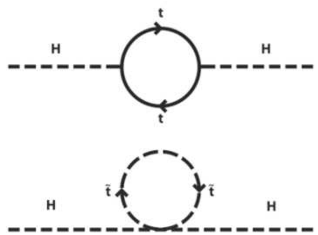
126 GeV Higgs is Strong Constraint on SUSY DM



SUSY parameter space allowed by LHC



1 loop correction to Higgs mass



$$X_t = A_t - \mu \cot \beta$$

$$M_{\rm SUSY} \equiv \sqrt{m_{\tilde{t}_1} m_{\tilde{t}_2}}$$

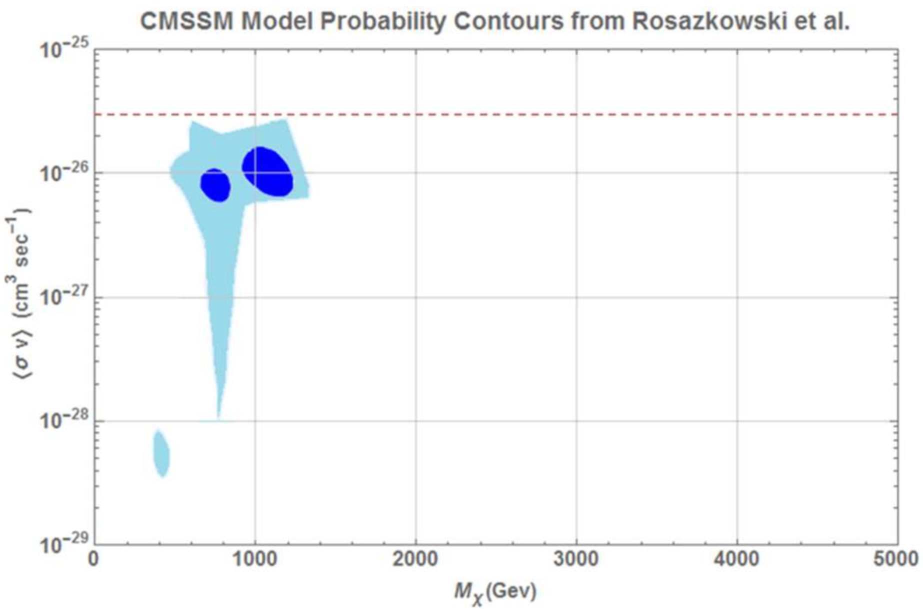
$$\Delta m_h^2 = \frac{3 m_t^4}{4\pi^2 v^2}\left[\ln\left(\frac{M_{\rm SUSY}^2}{m_t^2}\right) + \frac{X_t^2}{M_{\rm SUSY}^2}\left(1 - \frac{X_t^2}{12 M_{\rm SUSY}^2}\right)\right]$$

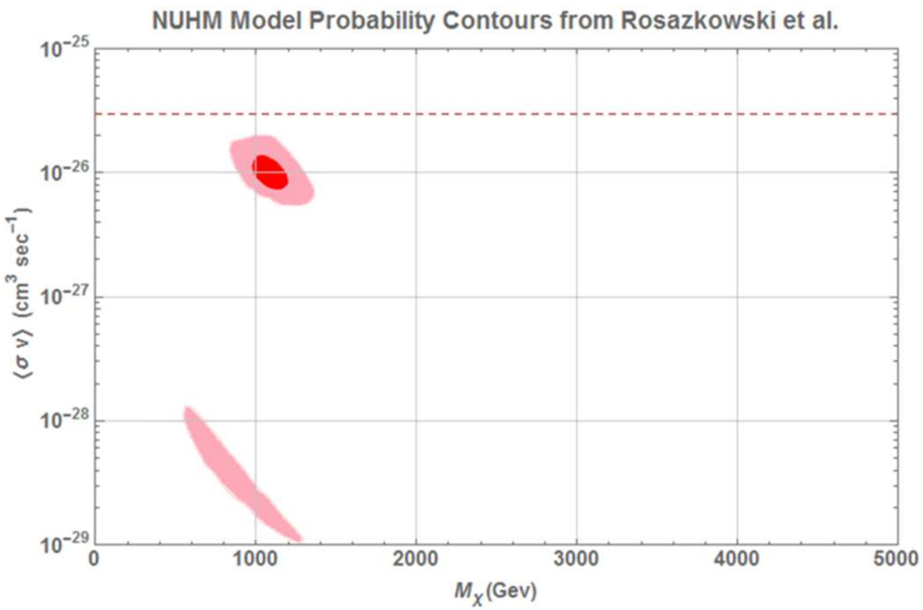
Expectations for WIMP Dark Matter

In thermal picture of early Universe,
relic density and annihilation cross-section are inversely related: $\Omega_{DM}h^2 \propto \frac{1}{<\sigma_{\chi\chi}\, v>}$

For $\Omega_{DM}h^2 = 0.1$: $<\sigma_{\chi\chi}v> = 3 \times 10^{-26}$ cm^3 sec^{-1} "thermal" cross-section

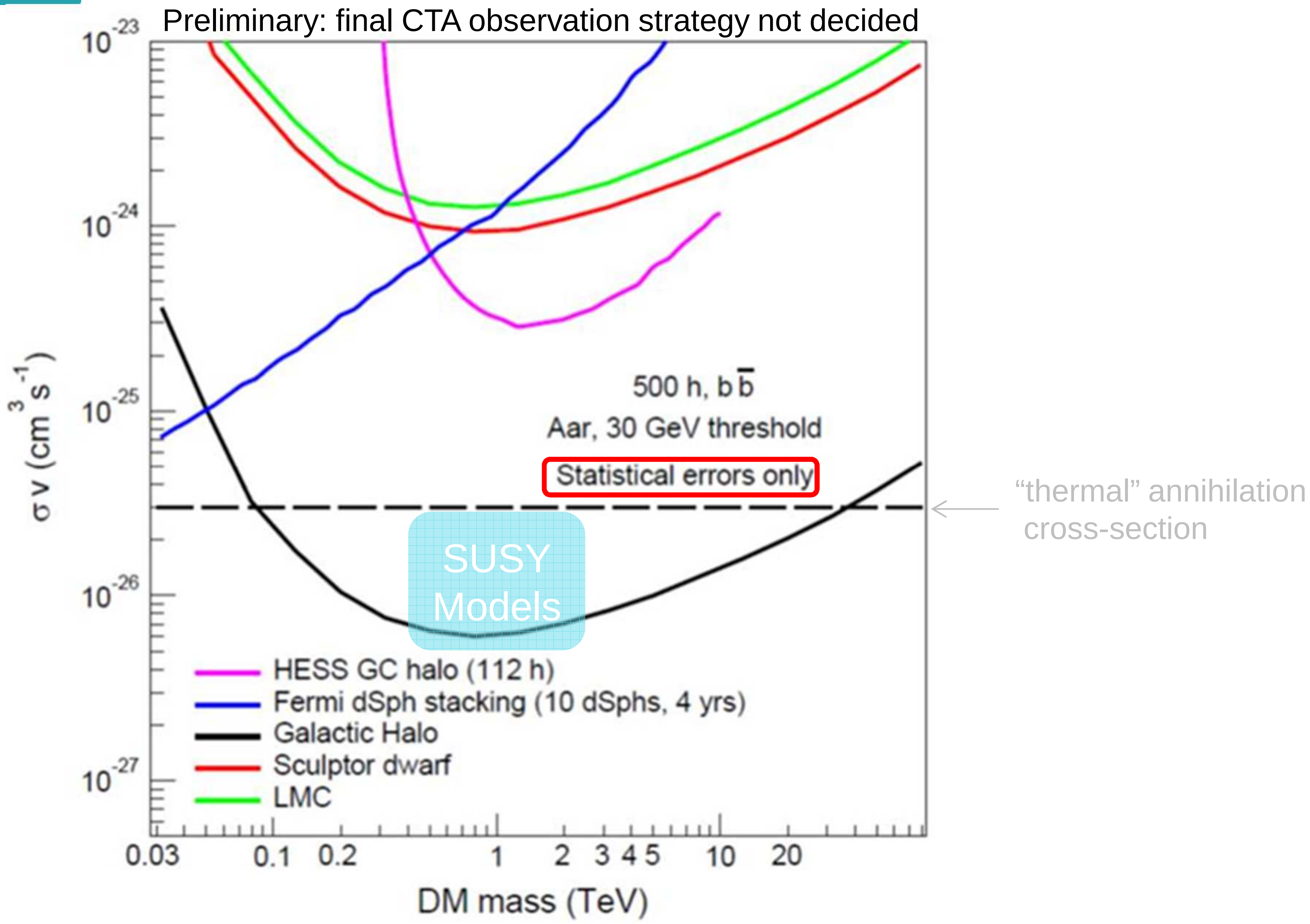
Roszkowski et al., arXiv:1405.4289, expectations for common SUSY models





Many SUSY models give M_{χ}: 0.5 to 2.5 TeV with $<\sigma\, v>$ 5×10^{-27} to 3×10^{-26} cm^3 sec^{-1}

Dark Matter Sensitivity Predictions



Summary

- CTA expected to start science in 2017
- Factor 10 improvements on existing facilities
- Great possibility to discovery dark matter
- And very many other science opportunities