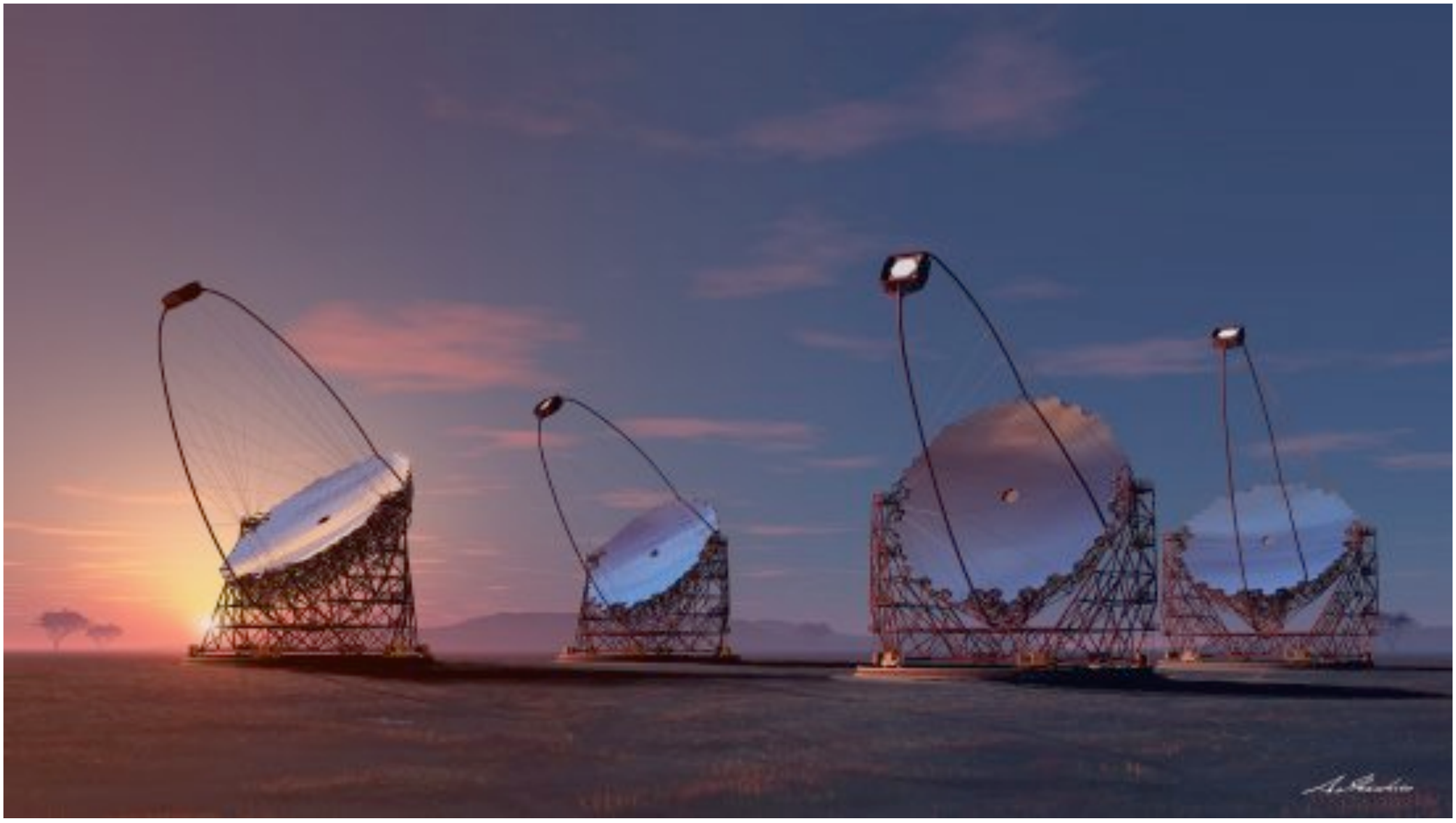
Dark Matter searches with Cherenkov Telescope Array

Heidi Sandaker *on behalf of the CTA collaboration*

ICNFP2016, Kolymbari, Greece,

6-14. July 2016.

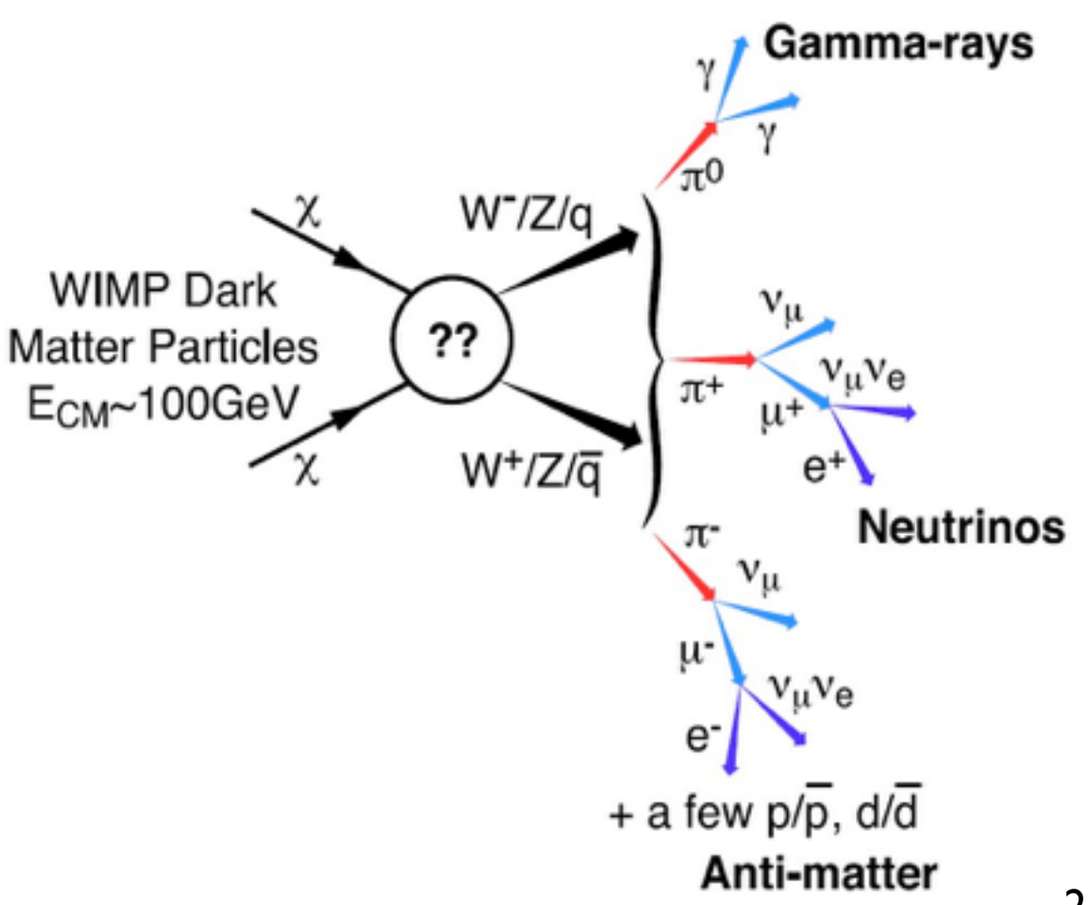


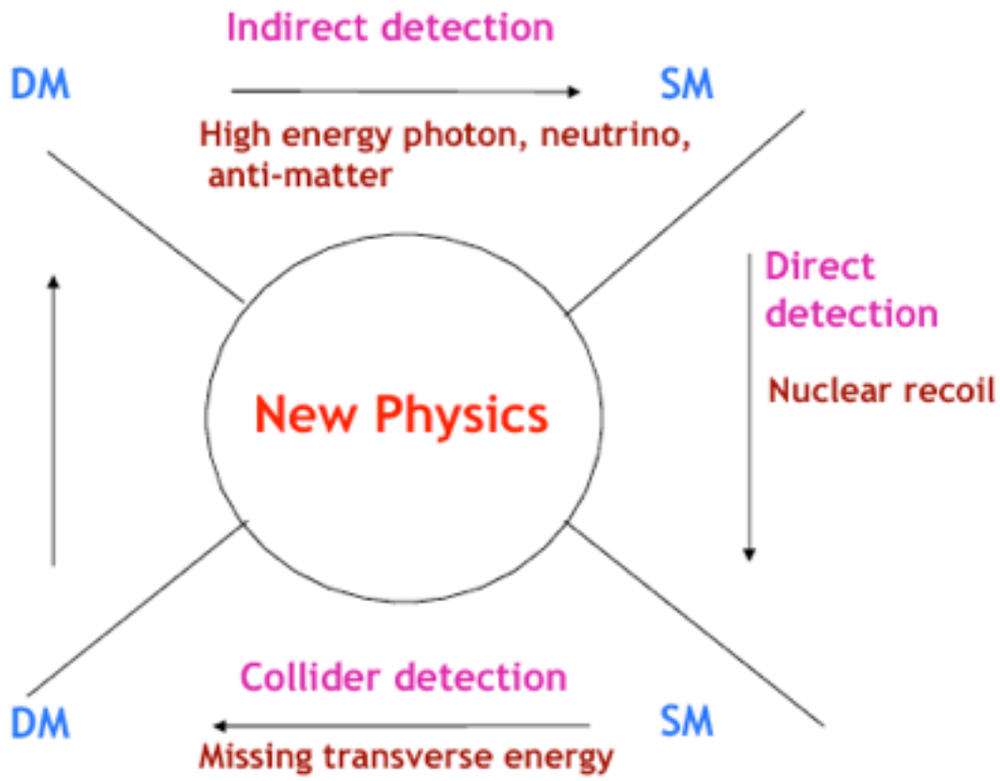
Indirect searches for Dark Matter

Indirect detection of Dark Matter

- Observation in the universe indicate the existence of Dark Matter in the form of a new particle
  - ➡ ***Dark matter 26.8% of the universe***
- Dark Matter is expected to annihilate in pairs into SM particles with $\langle\sigma v\rangle = 3 \times 10^{-26}$ cm^3/s
- Imaging Atmospheric Cherenkov Telescopes are already an important probe for Dark Matter

Nasa

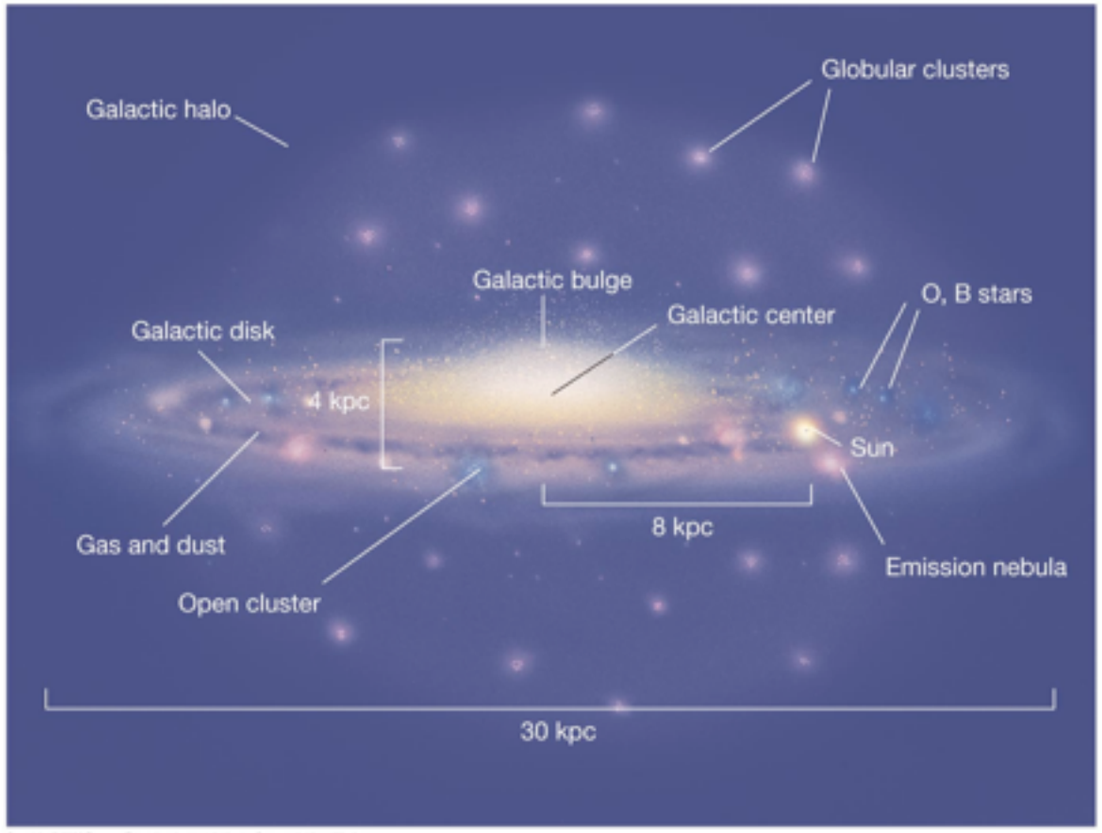


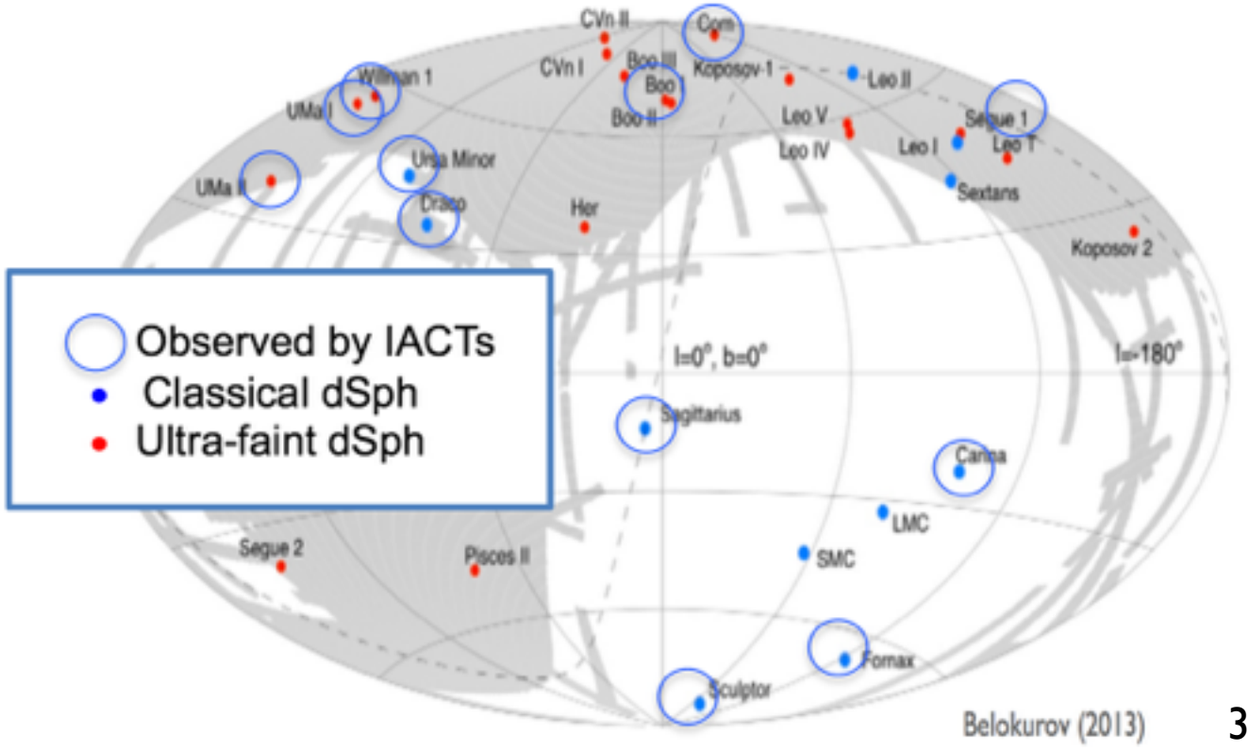


Indirect searches for Dark Matter

Where to look

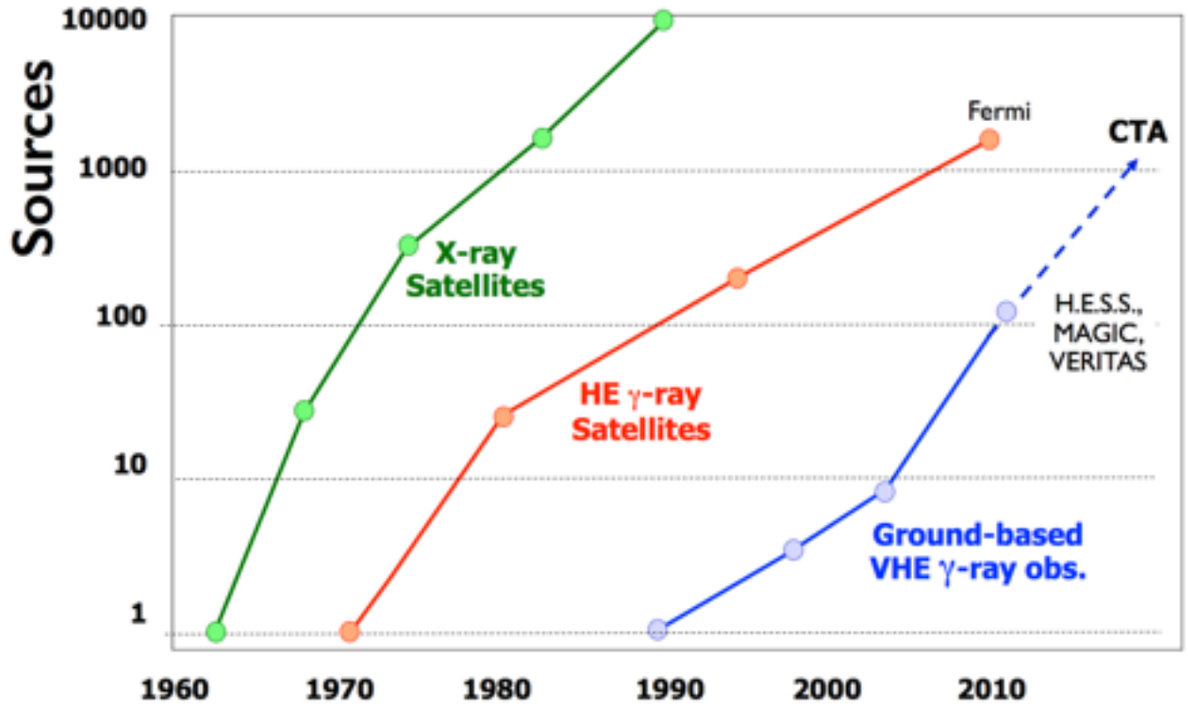
- ***Galactic centre and galactic halo***
  - *Many good VHE sources*
  - *Promising source of Dark Matter*
  - *High background from the halo*
- ***Dwarf Spheroidal Galaxies*** *(~ 20 known)*
  - *Appear as near point sources*
  - *Ratio of DM O(10^3) more than regular galaxies*
  - *Low astrophysical background*



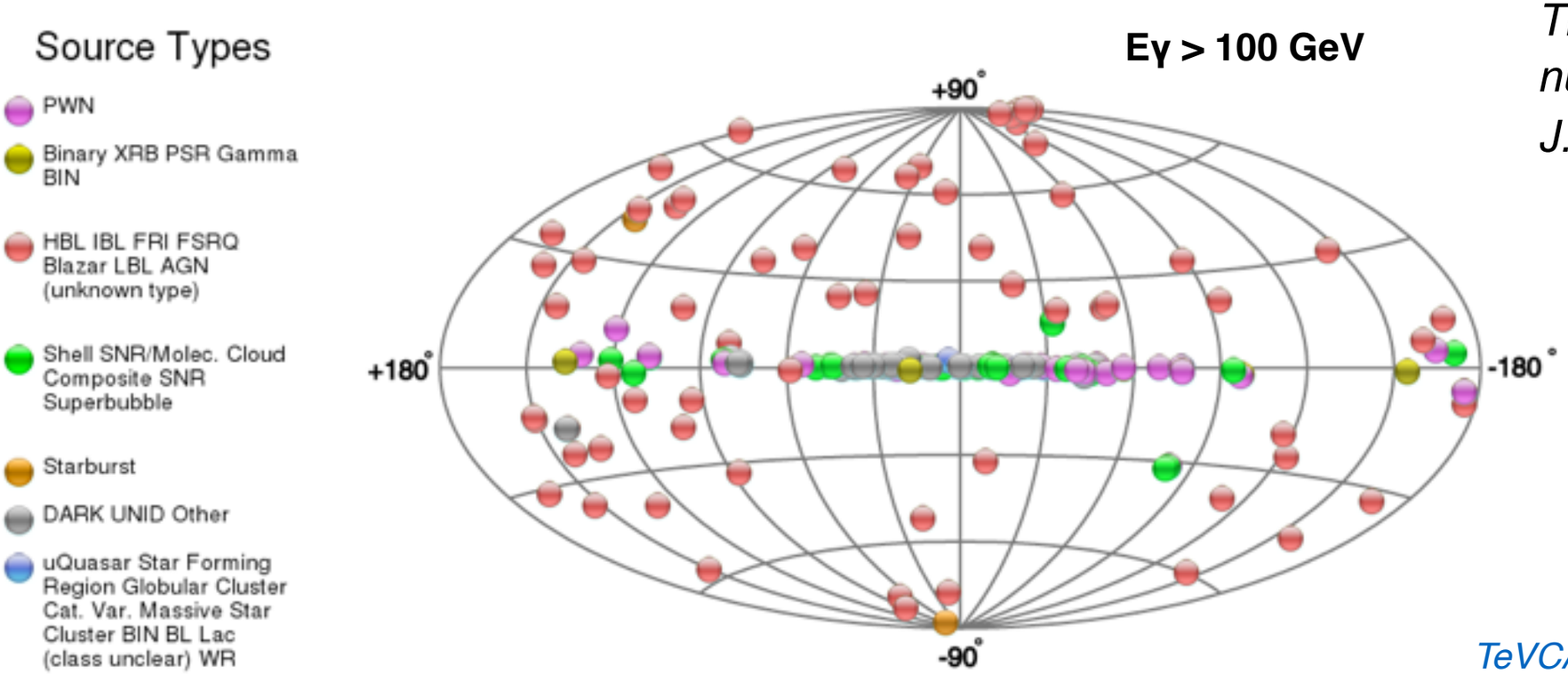


Cherenkov Telescope Array - motivation

- **The universe is rich in objects producing Very High Energy (VHE) radiation**
  - ➡ 176 sources today with E > 100 GeV
- **Various types of sources:**
  - e.g Dwarf Spheroidal Galaxies (dSph), pulsar wind nebula (PWN), active galactic nucleus (AGN), Supernova remnant (SNR) , …
- **And more to be discovered …**



The accumulation of the number of discovered sources J. Knapp, CRIS 2016



Distribution and types of gamma-ray sources

TeVCAT: http://tevcat.uchicago.edu

Cherenkov Telescope Array - motivation

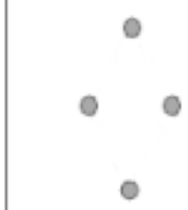
- **The potential to discover more objects and study them is high**
  - Increased sensitivity together with larger Field of View allows for a full VHE sky survey
- **The Imaging Atmospheric Cherenkov Telescope has a large potential for improvements**
  - Extensive telescope arrays at the start of being explored
  - Novel camera technologies promises improved telescopes

➡ *Possibly 1000 new gamma-ray sources*

CTA could become an important probe for Dark Matter for a large range of masses

Finding and studying dark matter in the universe.

Cherenkov Telescope - next generation

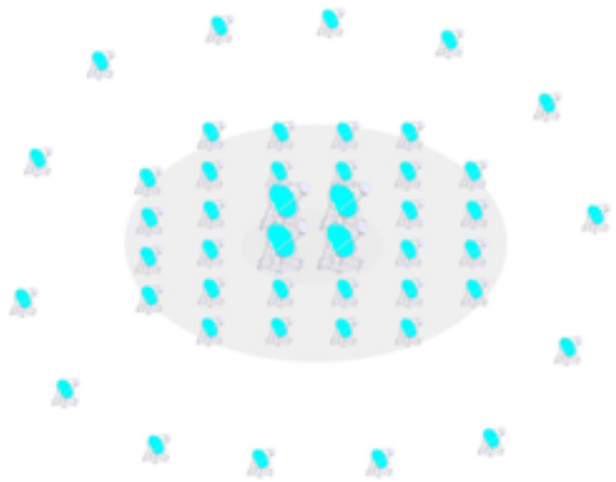
CANGAROO-III *Woomera, South Australia*		
HAGAR *Ladakh, India*		
H.E.S.S. *Namibia*		
MAGIC *La Palma, Spain*		

PACT *Madhya Pradesh, India*		
TACTIC *Rajastan, India*		
VERITAS *Arizona, USA*		

Telescope arrays are not to scale

New : Cherenkov Telescope Array

Two sites: Southern (10 km2) and Northern hemisphere

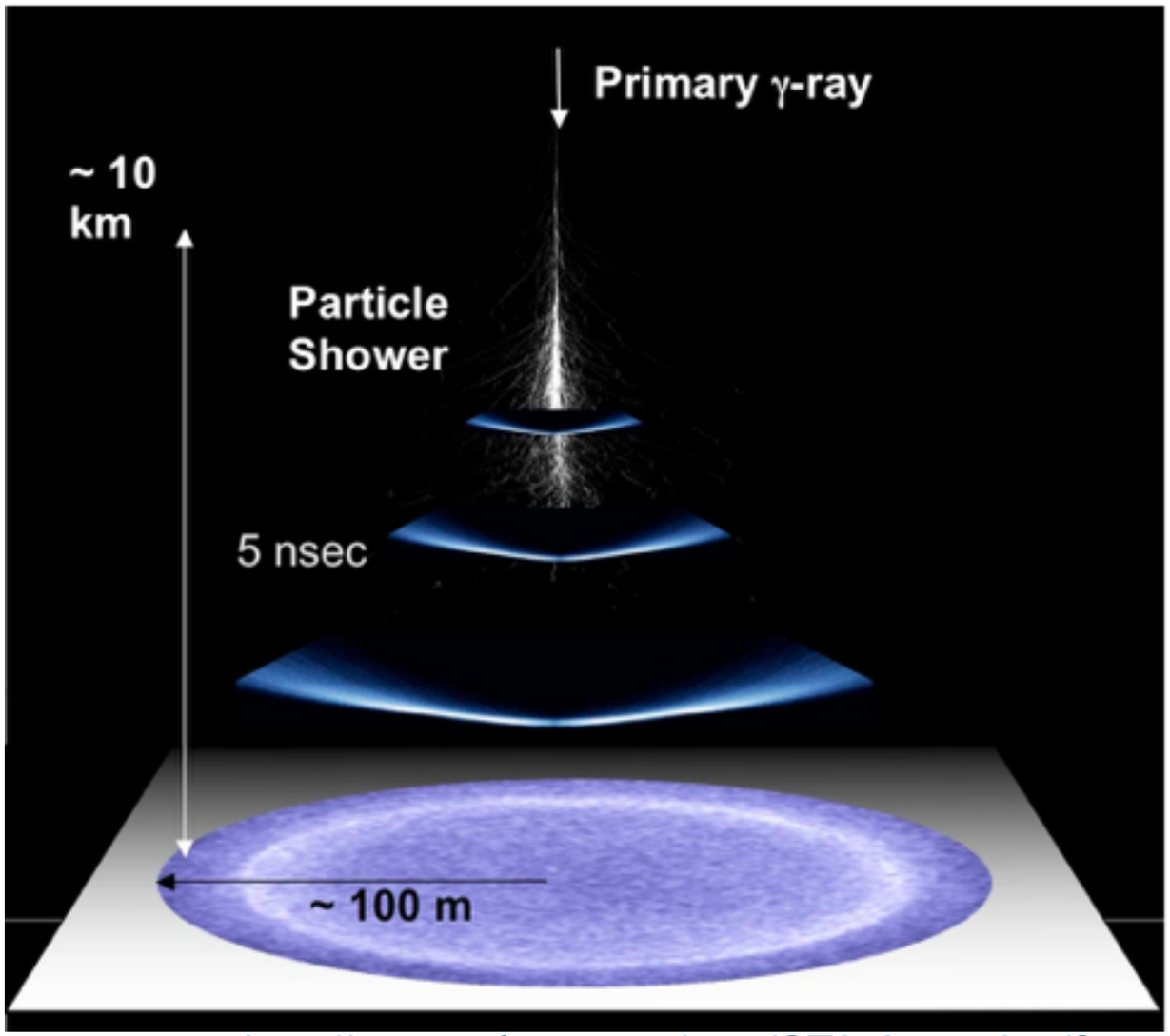


http://inspirehep.net/record/871405/

Cherenkov Telescope Array - proposal

Large scale telescope array at two sites with many different sized telescopes (~100) spread over a large area (~ few km)

- **Improved energy coverage**
  - 20 GeV to 300 TeV
- **Good energy resolution**
  - <10% (goal), <15% (requirement)
- **Excellent field of view**
  - LST >4.5^{o}, MST >7^{o}
- **Angular resolution**
  - < 0.1^{o} for most of the EeV range
- **Improved sensitivity and collection area**
  - x 10
- **Rapid Slew to catch flares**
  - 20 s



http://astrum.frm.utn.edu.ar/CTA-Argentina/?p=1001

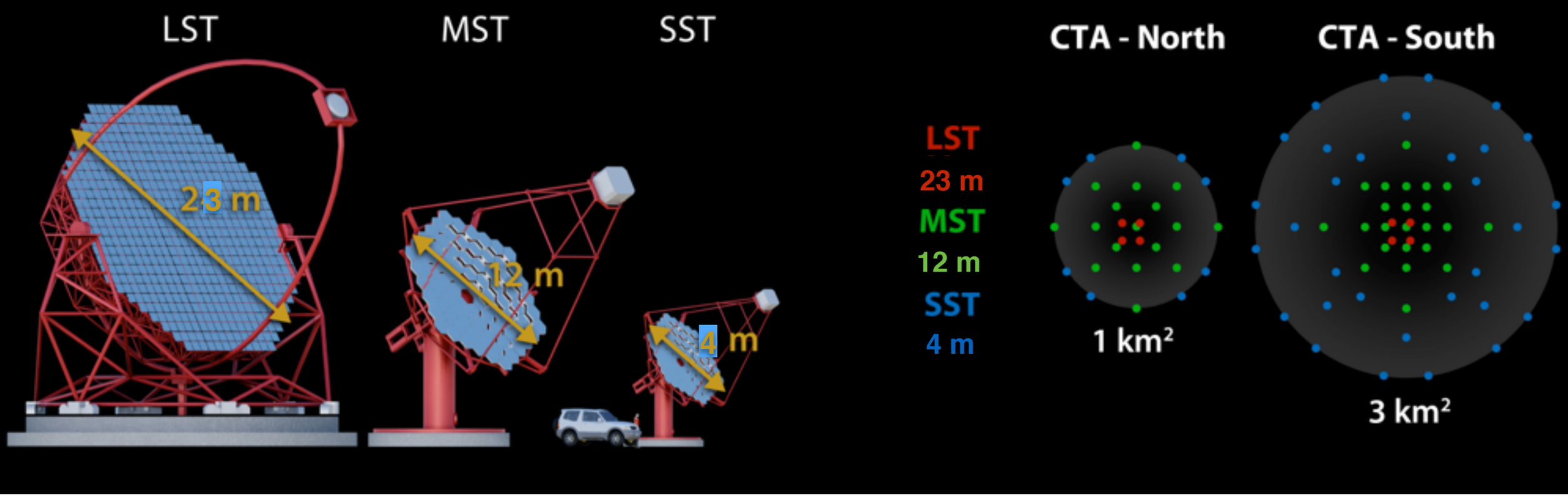
➡ ***full-sky*** *coverage,* ***10x*** *more sensitive than current instruments, much* ***wider energy coverage*** *and* ***field of view****, substantially* ***better angular*** *and* ***energy resolution.***

Cherenkov Telescope - Layout and camera types

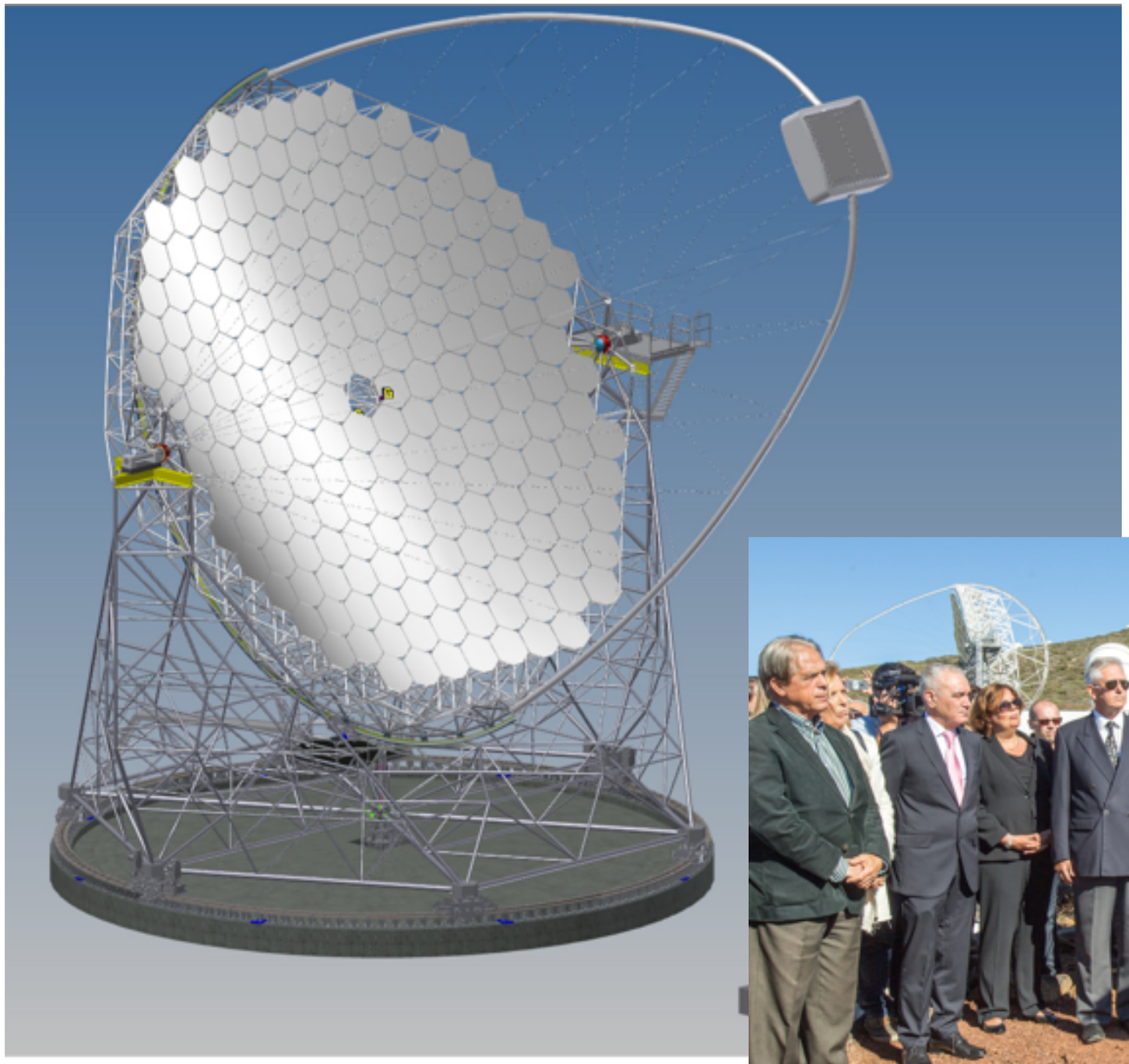
- **Southern site**
  - 4 large, 25 medium and 70 small-sized telescopes, area of telescopes ~ 4 km^2
  - Covering the full energy range
- **Northern site**
  - 4 large large and 15 medium sized telescopes, area of telescopes ~ 0.4 km^2
  - Significant sensitivity up to 50 TeV

Modes of operation

- **deep observations** (all telescopes pointed onto one object)
- **normal observations and monitoring** (a few telescopes oriented towards a few potentially interesting sources)
- **sky scans** (all telescopes scan a large area of sky in the long-term observations)



Cherenkov Telescope - Large Sized Telescopes

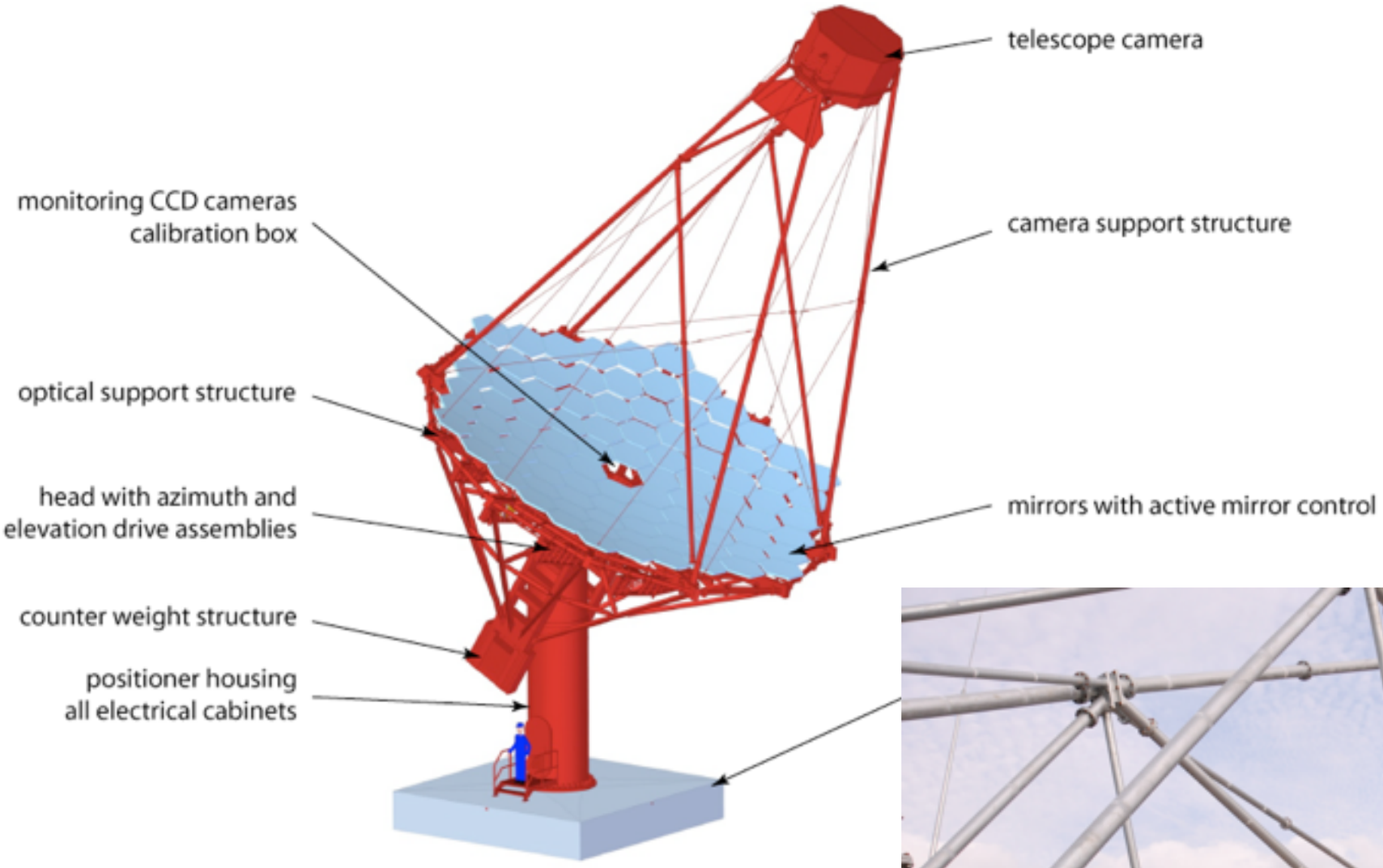


Large Sized Telescopes

- 23 m diameter
- 20-200 GeV
- Moderate field of view (~4.5º)
- PMT based cameras

Laying the first stone of the prototype LST, La Palma

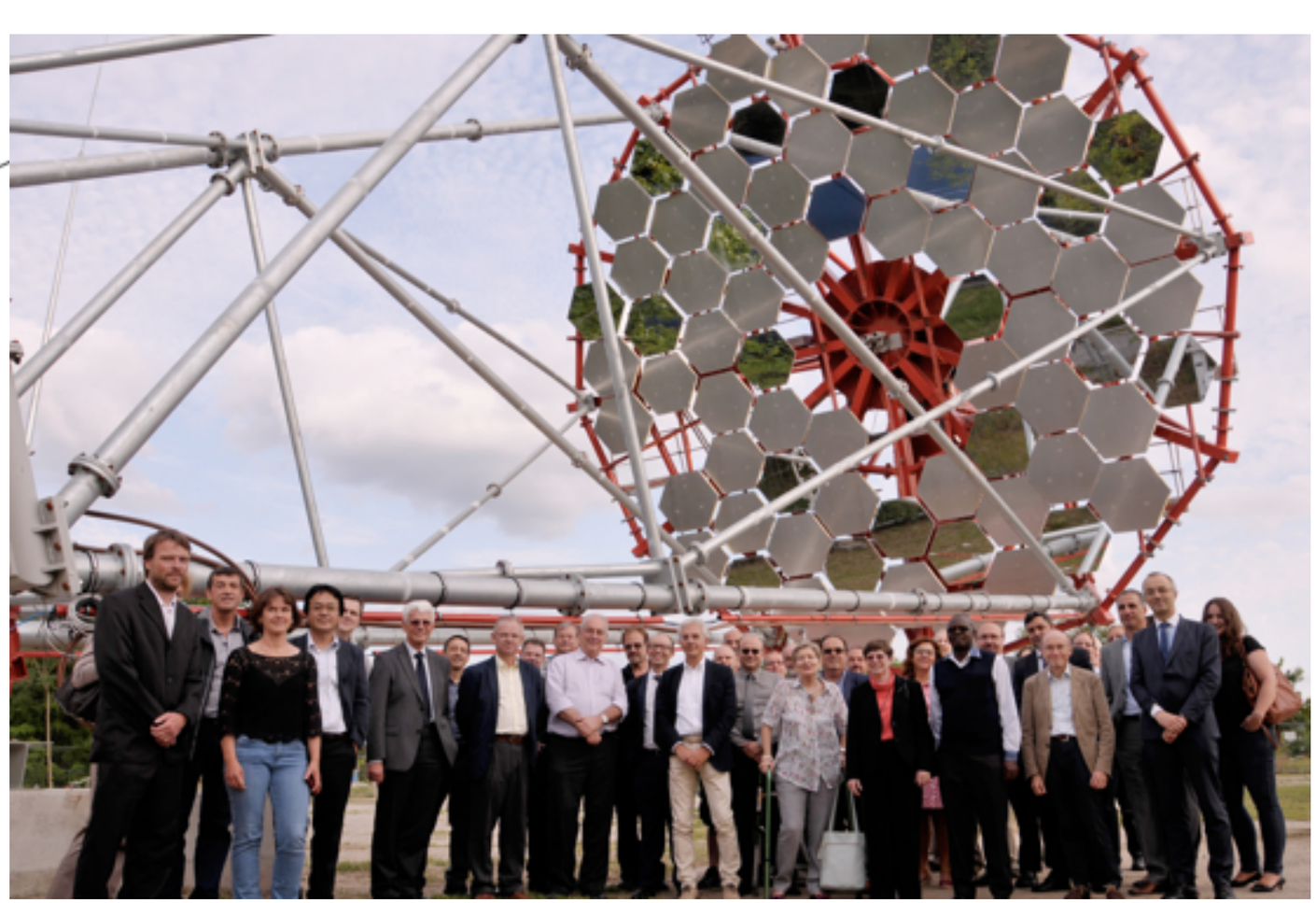
Cherenkov Telescope - Medium Sized Telescopes



Medium Sized Telescopes

- 12 m diameter
- 100 GeV - 10 TeV
- FoV of 7^{o} (> 8^{o} SCT)

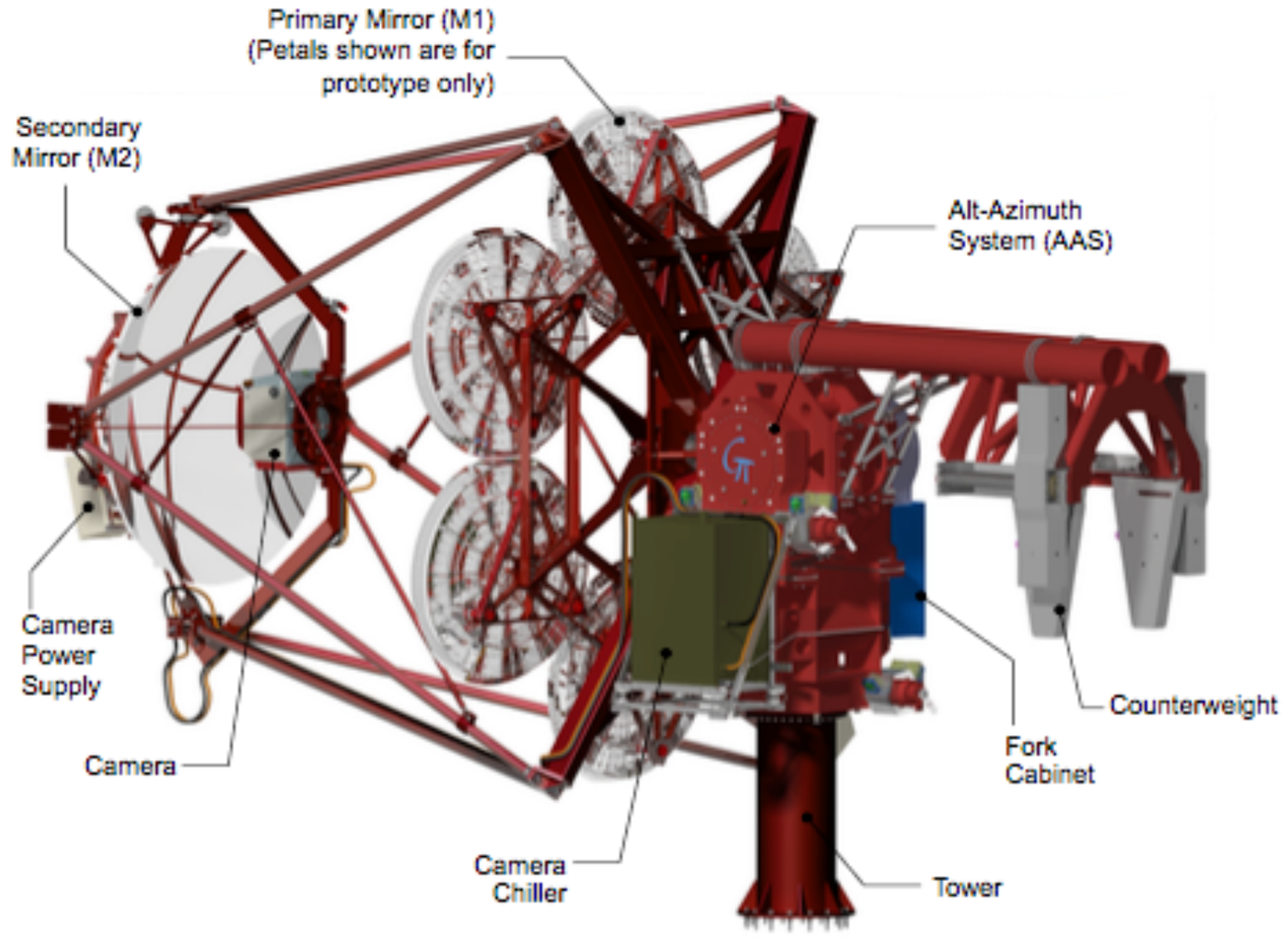
- Davis-Cotton reflector and PMT camera and/or Schwarzschild-Couder dual-mirror optical layout and SiPM camera

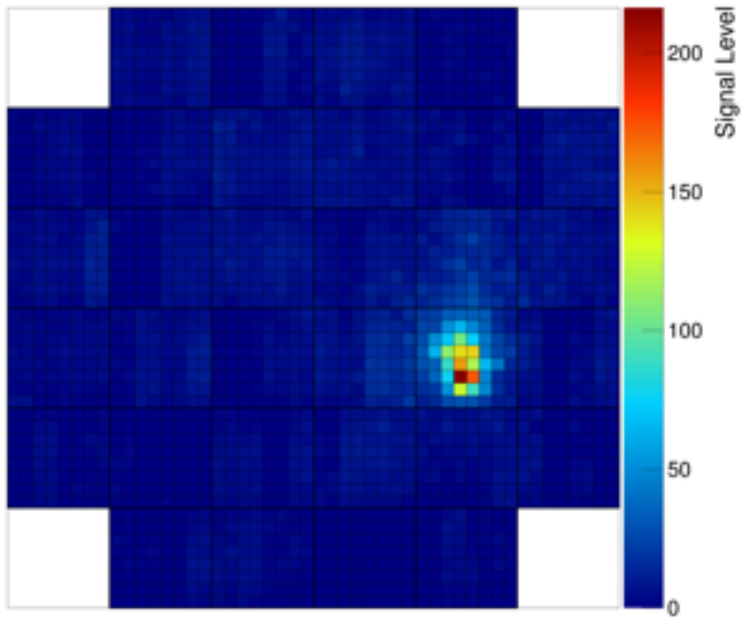


Cherenkov Telescope - Small Sized Telescopes

Small Sized Telescopes

- 4 m diameter
- 5-300 TeV
- FoV of 9^{o}
- Three different projects, one is based on Davies-Cotton optical design and two on the Schwarzschild-Couder





First Cherenkov light - November 2015

- One of the proposed telescopes (GCT) recorded first ever Cherenkov light during tests in Paris
- The ASTRI telescope captured the first optical image in May 2015 with its diagnostics camera

https://arxiv.org/pdf/1606.08190v1.pdf

Cherenkov Telescope - improved reach

Angular resolution

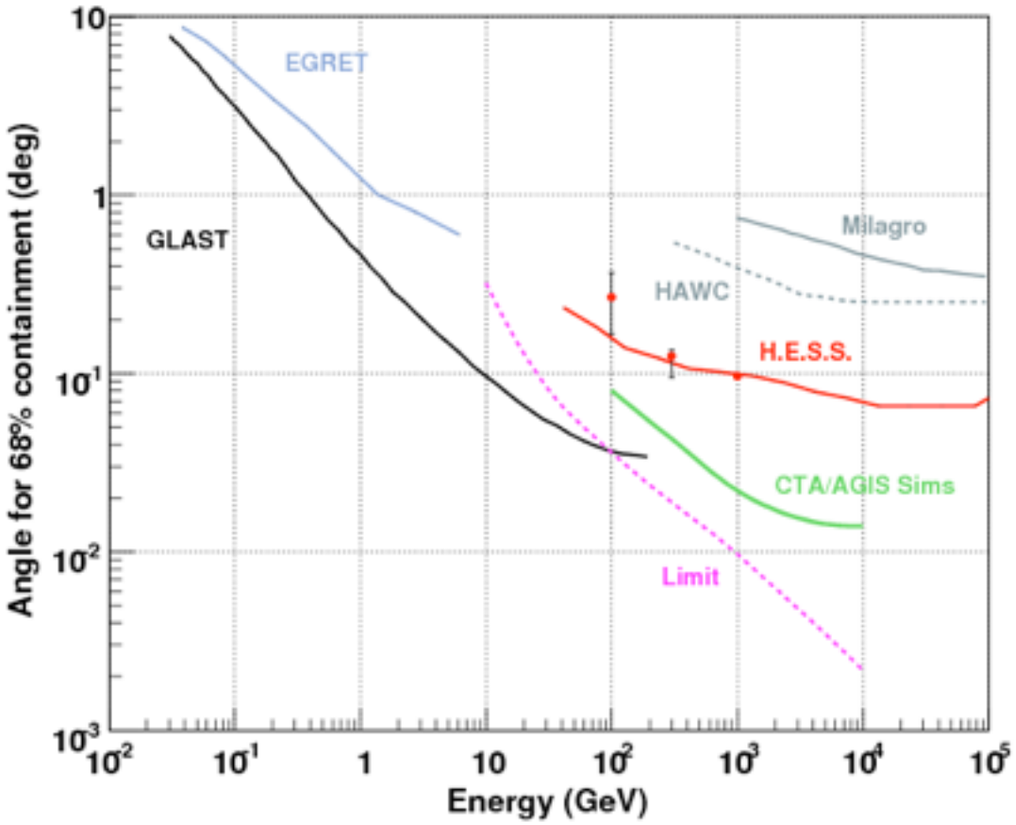
- CTA (green) is using a example layout of 49 telescopes

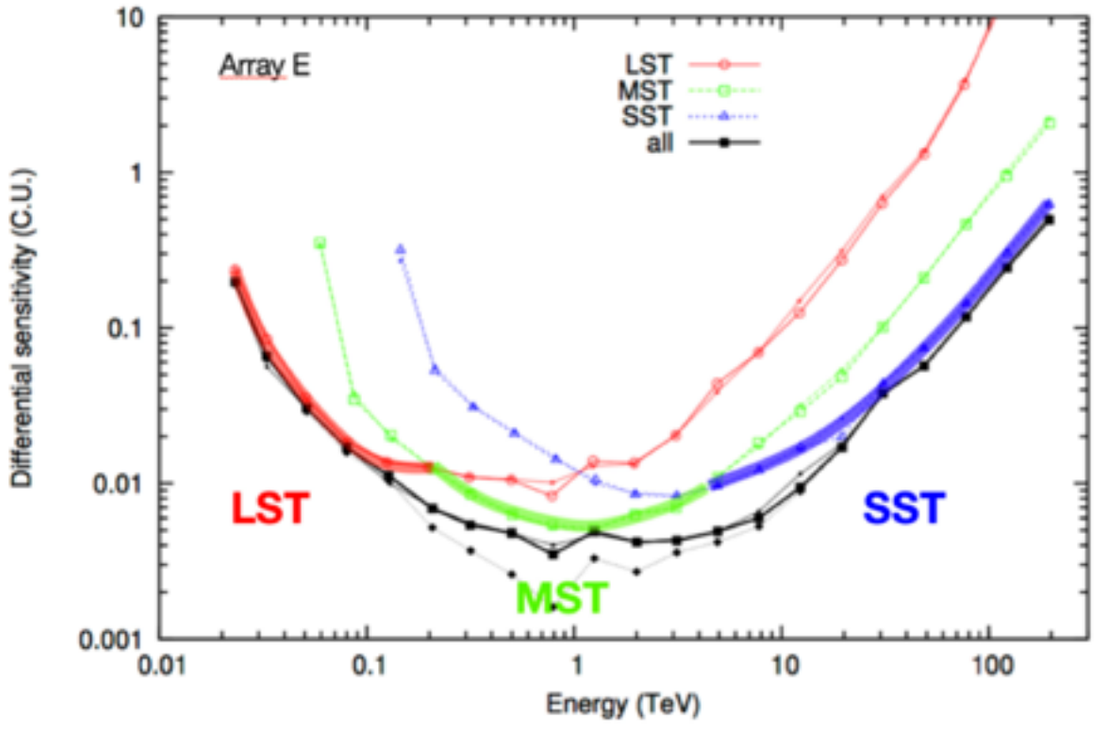
Differential sensitivity

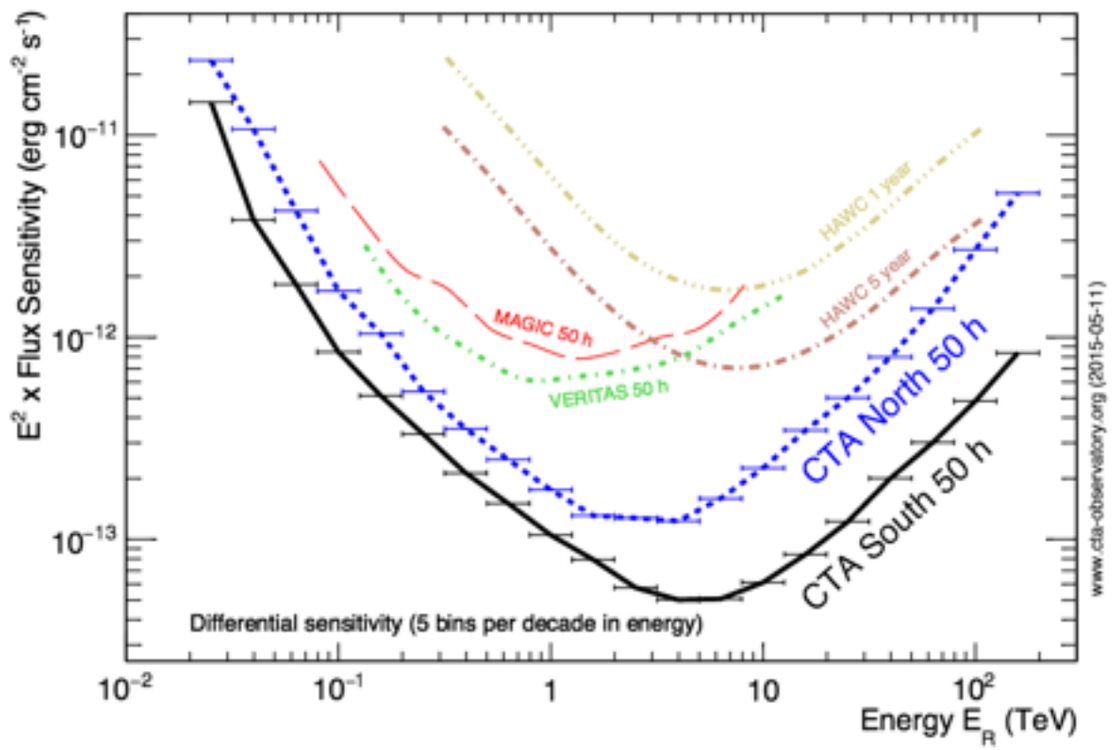
- Southern and Northern array (50 h) compared to MAGIC-II ,VERITAS ad HAWC sensitivity

Point source sensitivity

- Example layout (black layout) compared to its components: 3 LSTs, 18 MSTs and 56 SSTs







Cherenkov Telescope - the science program

Galactic γ-Ray sources

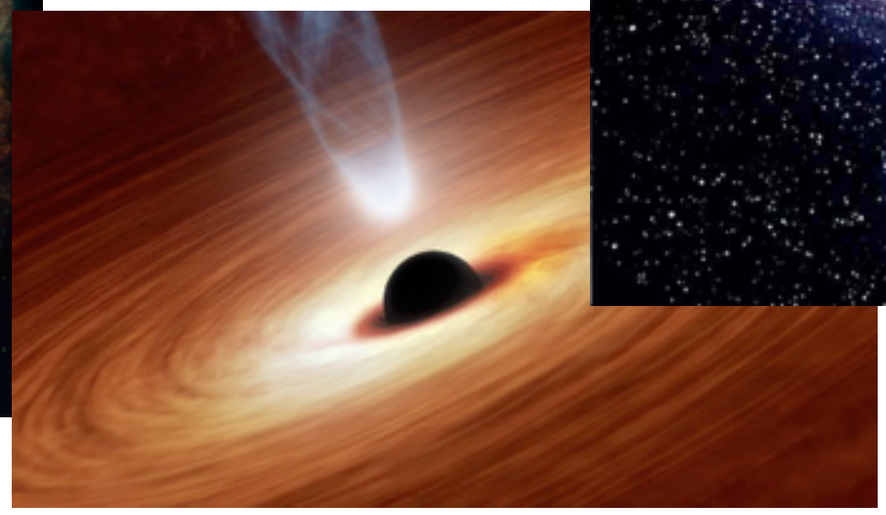
- *Supernova remnants*
- *Pulsars*
- *Star formation regions*
- *Galactic centre*
- *X-ray binaries & microquasars*
- *Sky survey*

Supernovas

Cosmic ray particles in the Galaxy and beyond

Extragalactic γ-Ray sources

- *Active Galactic Nuclei*
- *Extragalactic background light*
- *Gamma-ray Bursts*
- *Galaxy clusters*



Black holes and its role as particle accelerator

Fundamental physics

- ***Dark Matter***
- *Quantum gravity*
- *Charged cosmic rays*

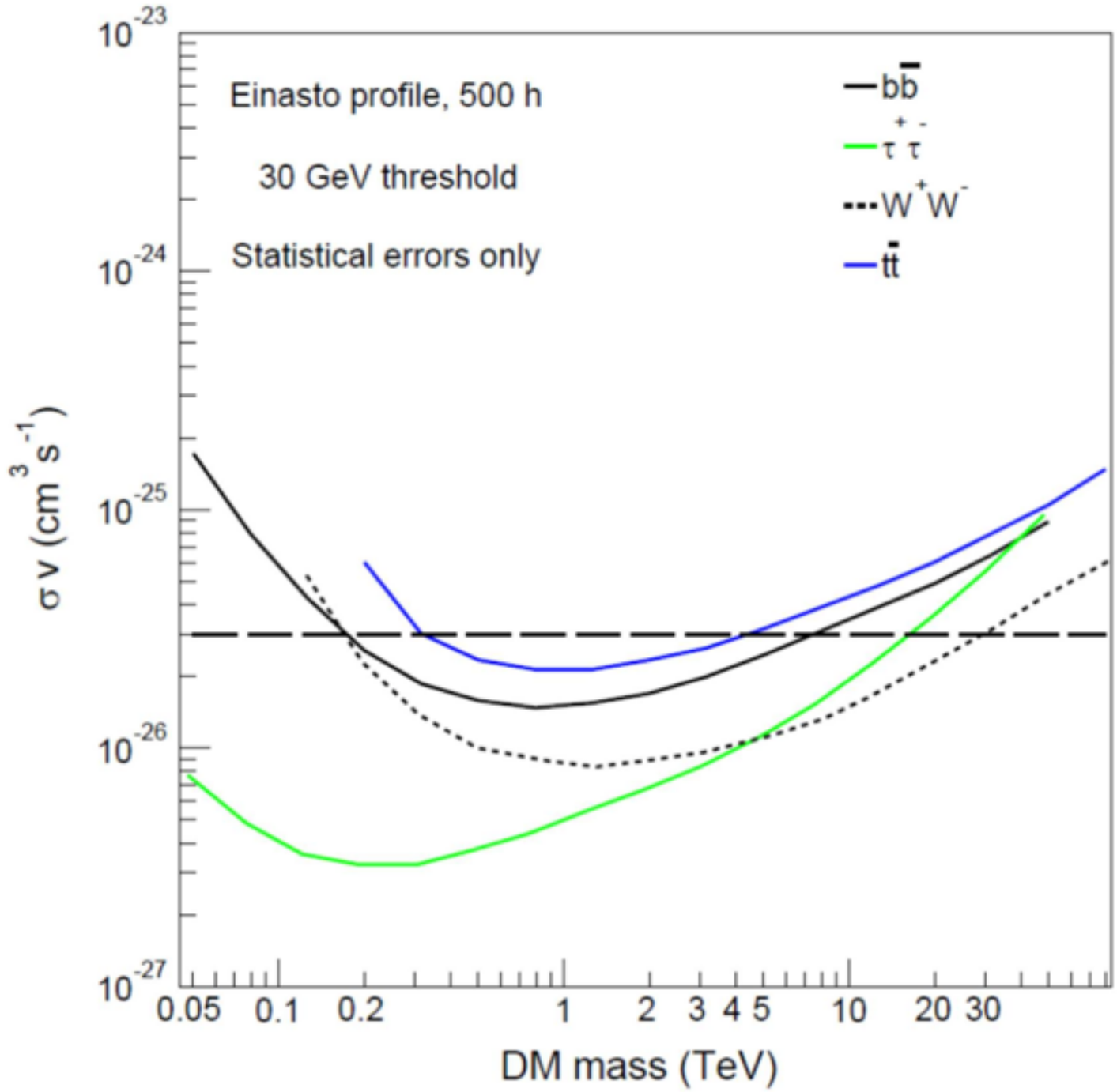
What happens at the galactic centre

Nature of Dark matter

Cherenkov Telescope - dark matter

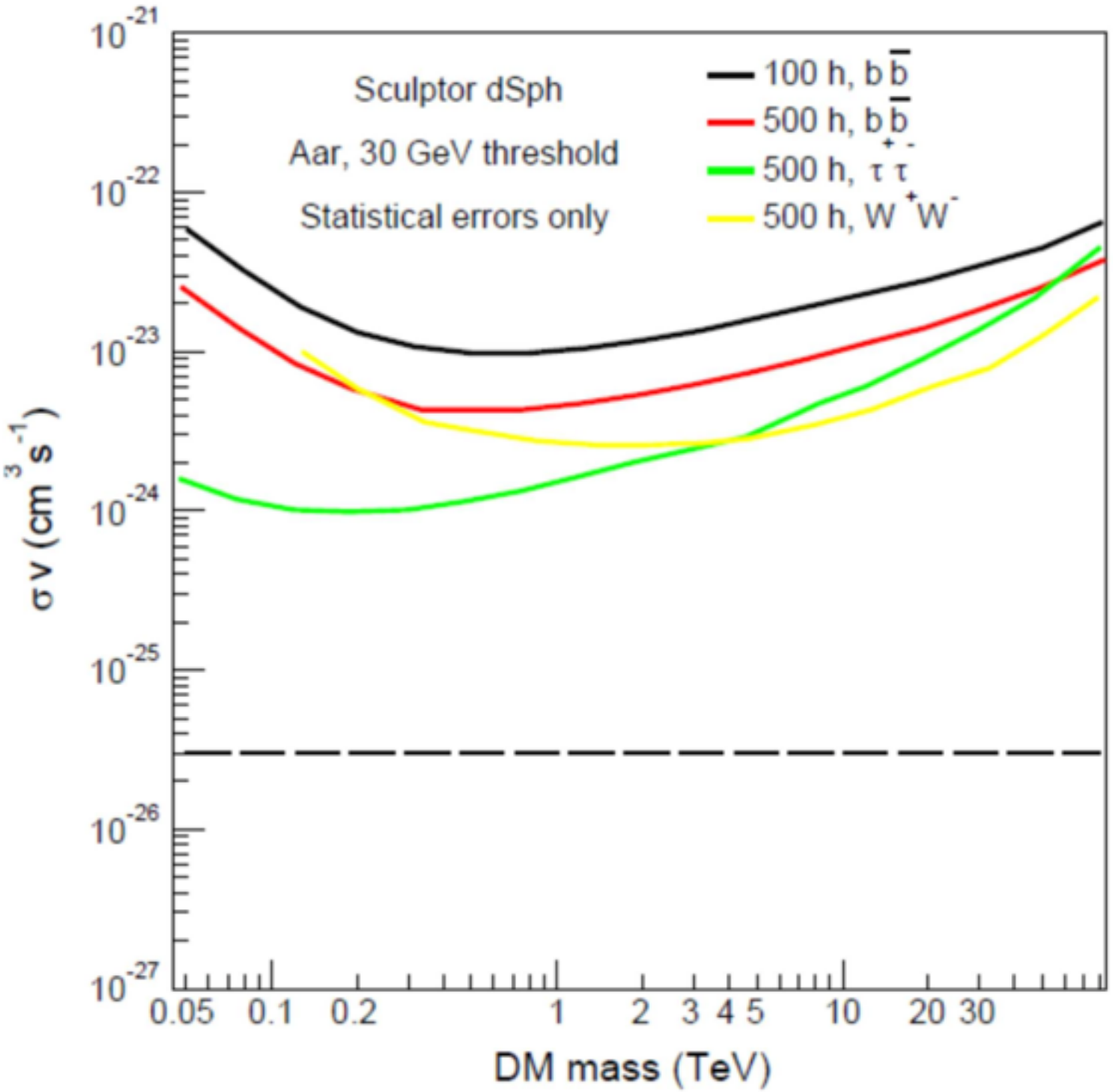
Galactic Halo

- Sensitivity for σv to a Dark Matter observation on the Galactic Halo
- 500 hours observation time
- 30 GeV threshold
- Different annihilation modes: bbar, tau+tau-, W+W-, ttbar
- Einasto dark matter profile



http://arxiv.org/pdf/1508.06128v1.pdf

Cherenkov Telescope - dark matter



Dwarf Sferoidal Galaxies

- Sensitivity to Sensitivity for σv a Dark Matter observation on the classical dwarf galaxy Sculptor
- 100 and 500 hours observation time
- Different annihilation modes: bbar, tau+tau-, W+W-

http://arxiv.org/pdf/1508.06128v1.pdf

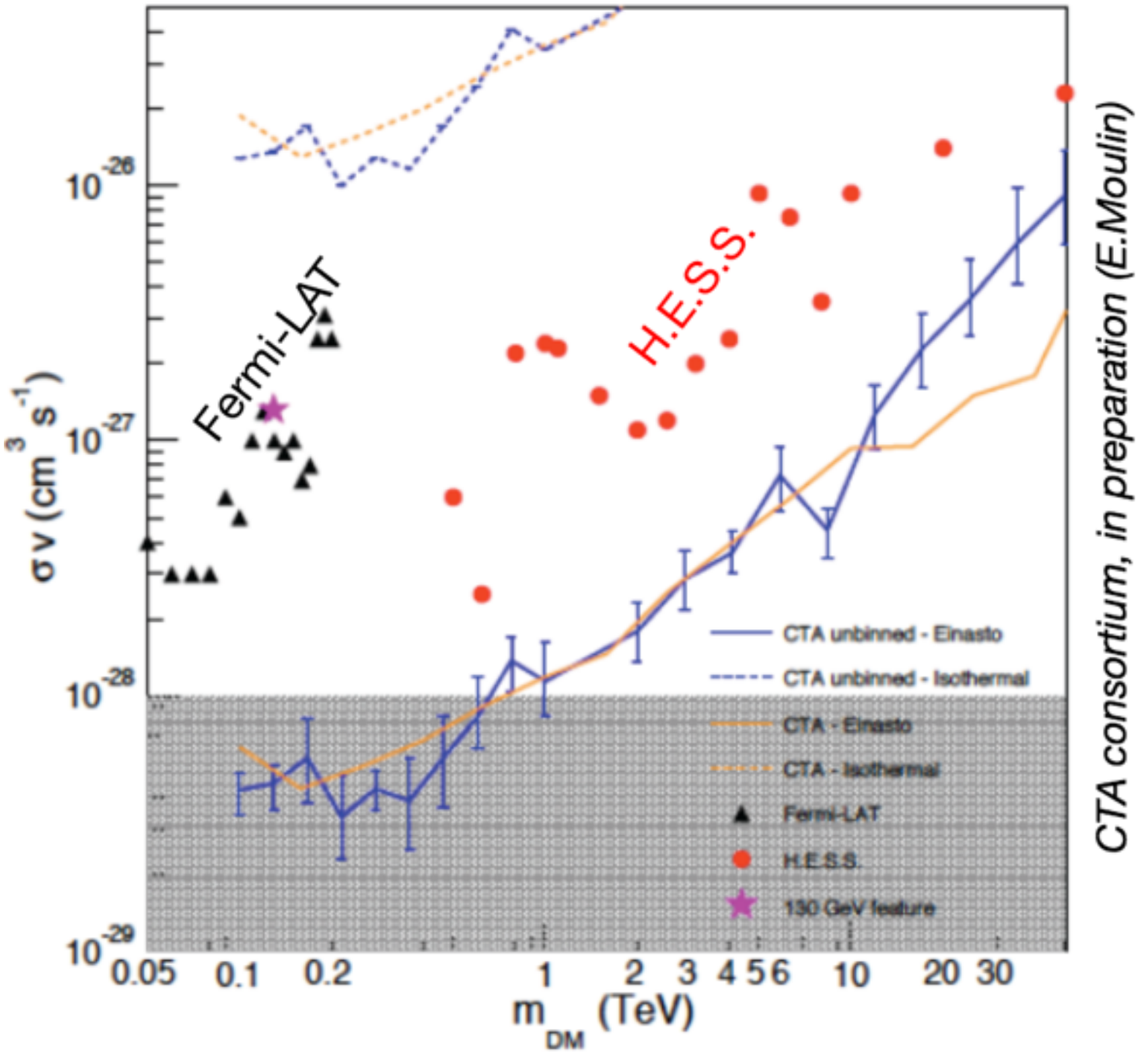
Cherenkov Telescope - dark matter

Gamma-Ray lines

- *Gamma rays may annihilate into photons creating a line*
- *Comparison with the current reach of FERMI-LAT and H.E.S.S.*

Virtual Internal Bremsstrahlung

- *Radiative correction to processes with charged final states is also studied*

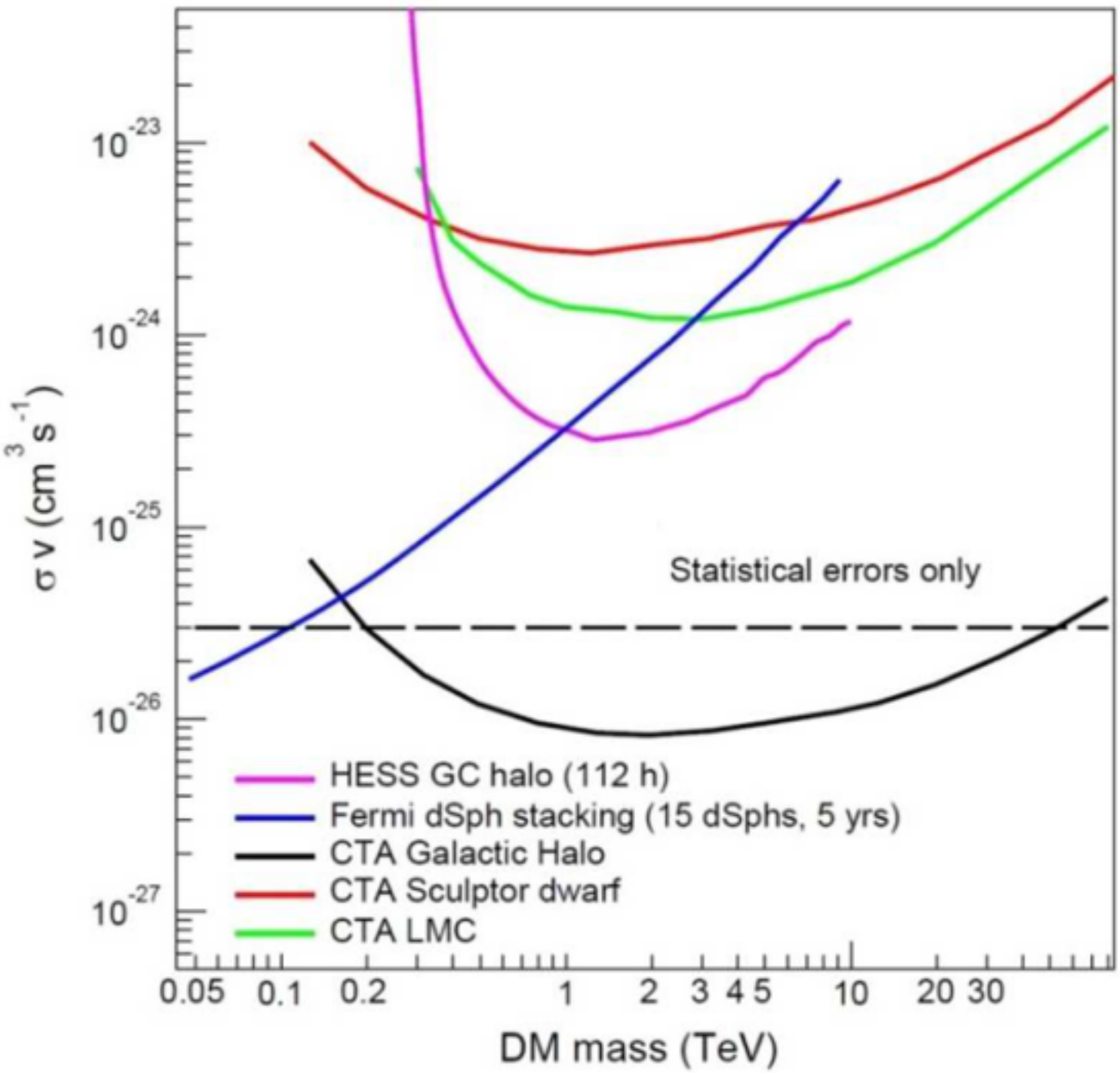


https://conferences.pa.ucla.edu/dm16/talks/vassiliev.pdf

Sensitivity and comparison

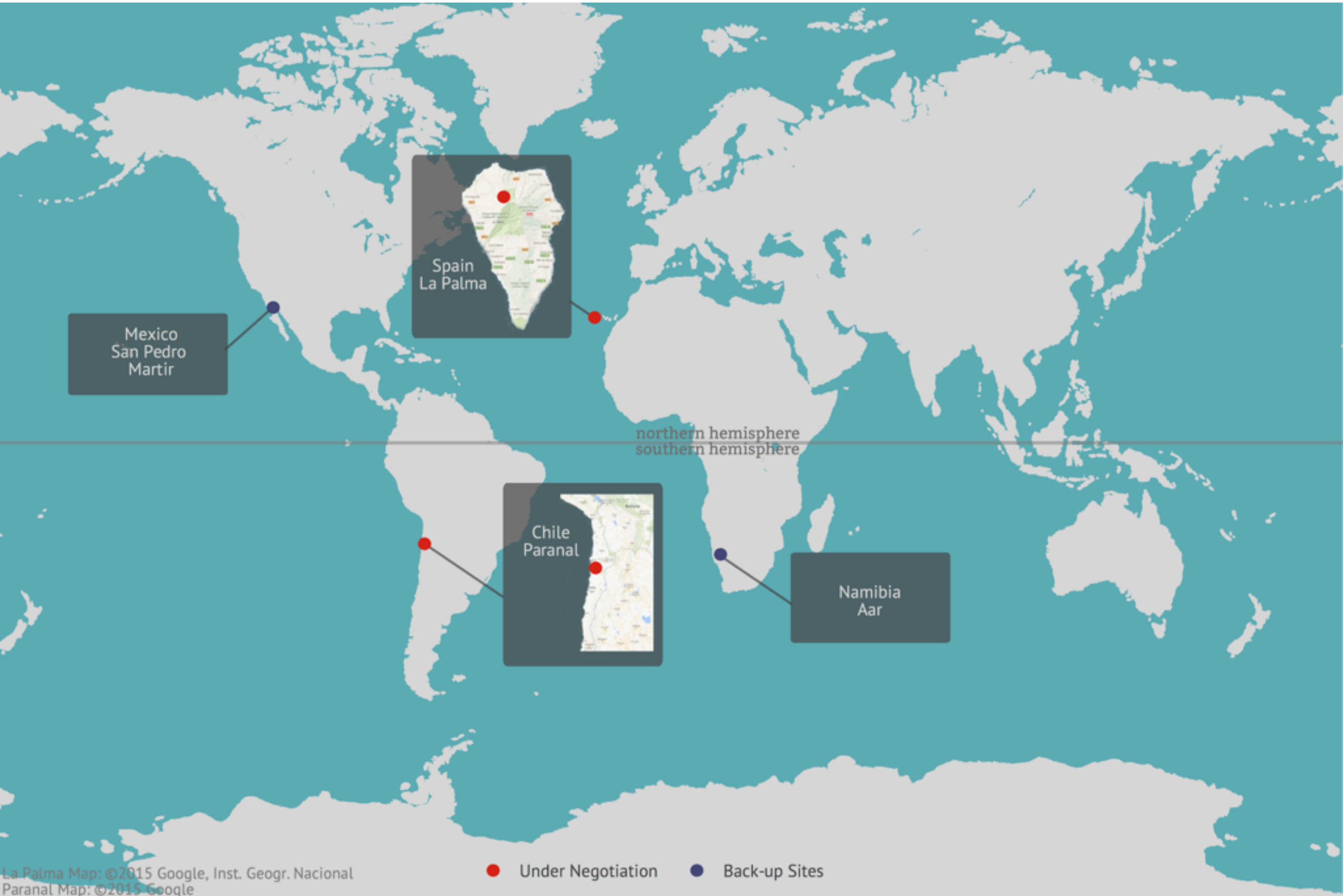
- Above 200 GeV, CTA may probe for the first time WIMP models with thermal relic cross-section
- Between 200 GeV and TeV, CTA will be able to provide a complementary measurement to other experiments
- Above TeV, for heavy WIMPs, CTA will be a unique probe to parameter space not reachable by any other experiments planned today.
- Complementary to searches with e.g. LHC

http://arxiv.org/pdf/1508.06128v1.pdf



The sensitivity predictions for the Galactic Halo, the dwarf galaxy Sculptor and the Large Magellanic Cloud

Cherenkov Telescope - the proposed sites



Cherenkov Telescope - the sites

- **Southern hemisphere** : the European Southern Observatory (ESO) Paranal grounds in Chile, 10 km southeast of the existing site in the Atacama desert, one of the driest and most isolated regions on earth.
- **Northern hemisphere** : the Instituto de Astrofisica de Canarias (IAC), Roque de los Muchachos Observatory in La Palma, Spain

First candidate for the Northern Site

Open observatory

- **Open access** to the community through calls for submission of proposal competing for observation time
- **Serving a wide astrophysics community**

First candidate for the Southern Site

Cherenkov Telescope - status of construction (June 2016)

- Selection of CTA headquarters - overall administration of Observatory observations
  - ~ 24 persons, technical coordination and support, administrative services
  - Istituto Nazionale di Astrofisica (INAF) at the Bologna University Department of Physics and Astronomy.
- The Science Data Management Centre
  - ~ 20 persons, science coordination including software maintenance and data processing
  - 100 petabytes of data by the year 2030
  - Will be located at the Deutsches Elektronen-Synchrotron (DESY)

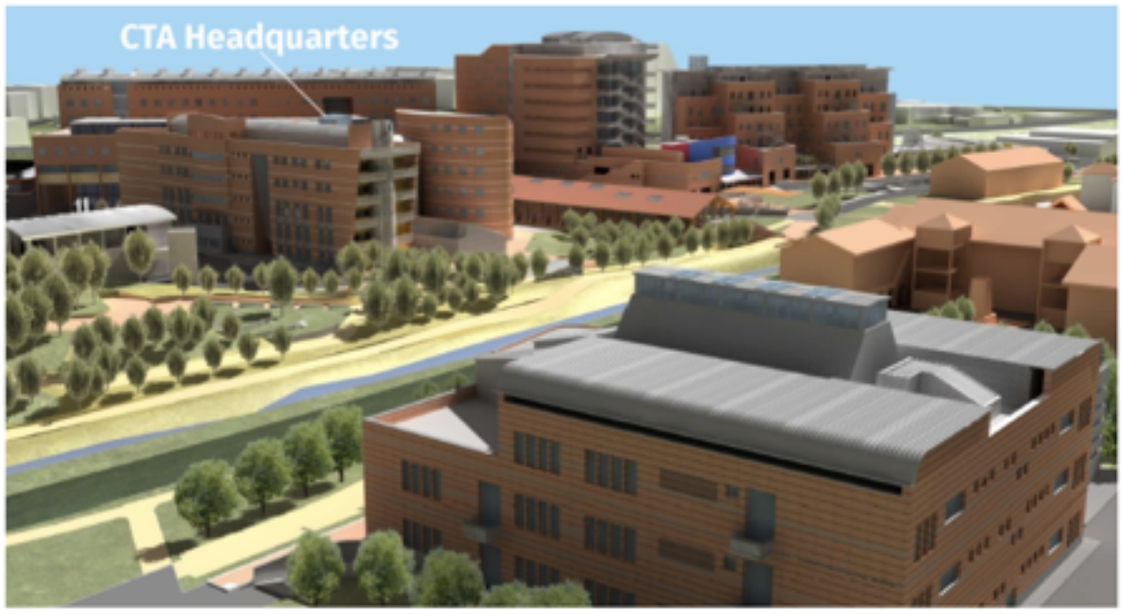
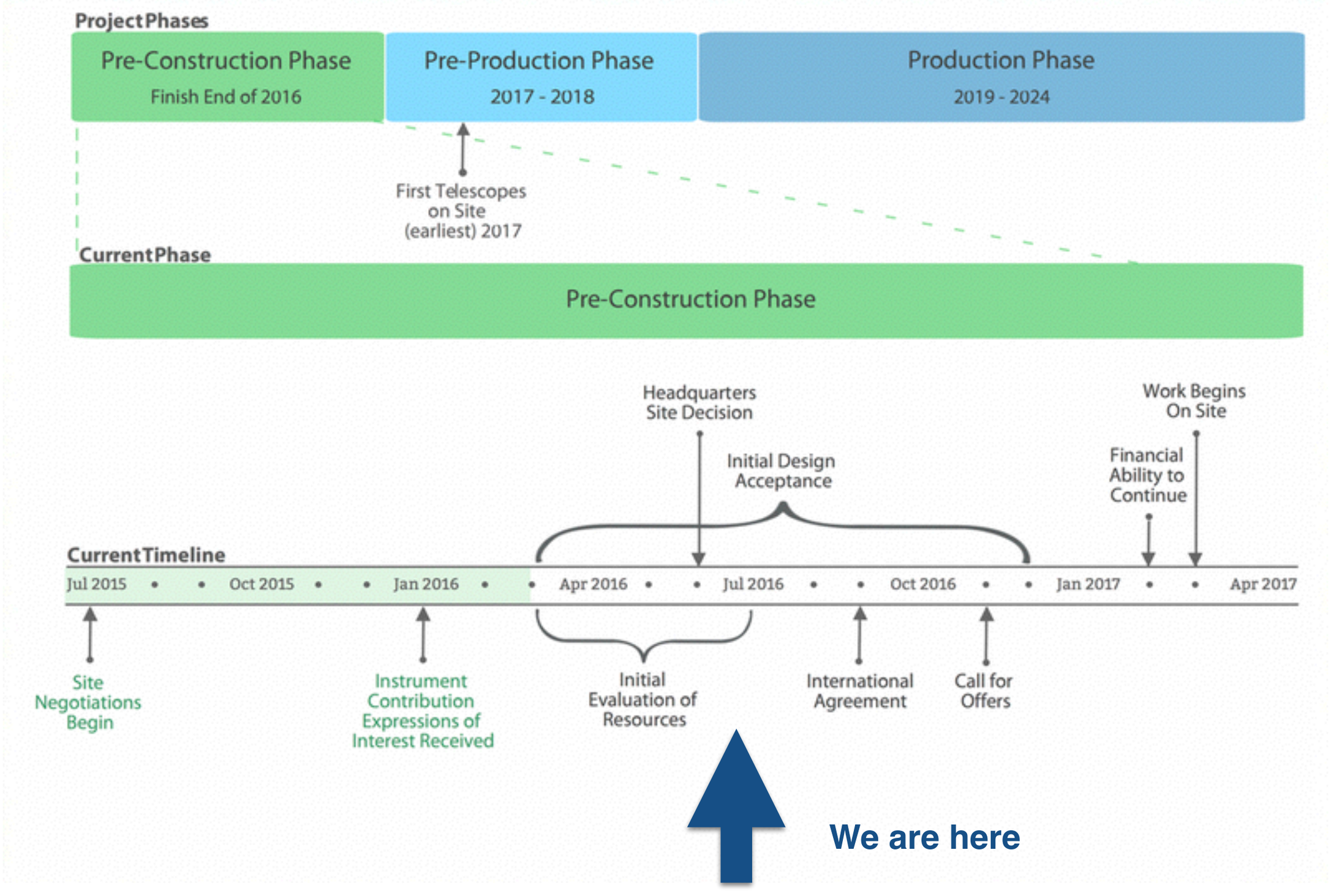


Figure 1: Computer rendering of CTA Headquarters Building, Bologna (Credit: Bologna University Project Office)

Figure 2: Architectural rendering of CTA Science Data Management Centre Building, Zeuthen (Credit: Dahm Architekten & Ingenieure, Berlin)

Cherenkov Telescope - timeline



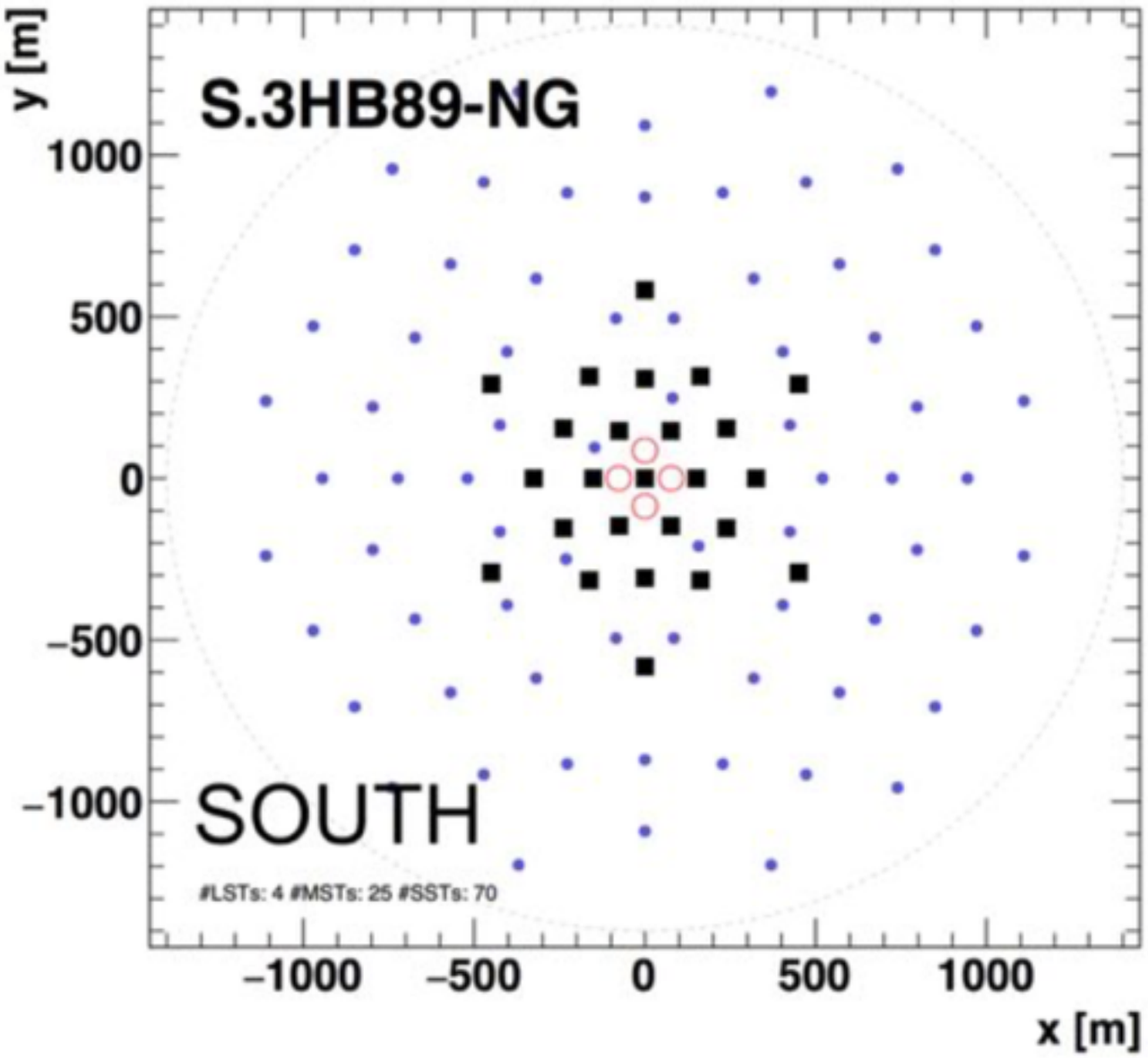
Cherenkov Telescope - Summary and outlook

- *CTA has passed several important milestones on its way towards construction*
- *First telescopes have been constructed and first Cherenkov light detected*
- *The improved sensitivity and energy range (among others) will make CTA a unique probe for studying new physics*
- *The reach for dark matter is significant and we hope to discover its nature*

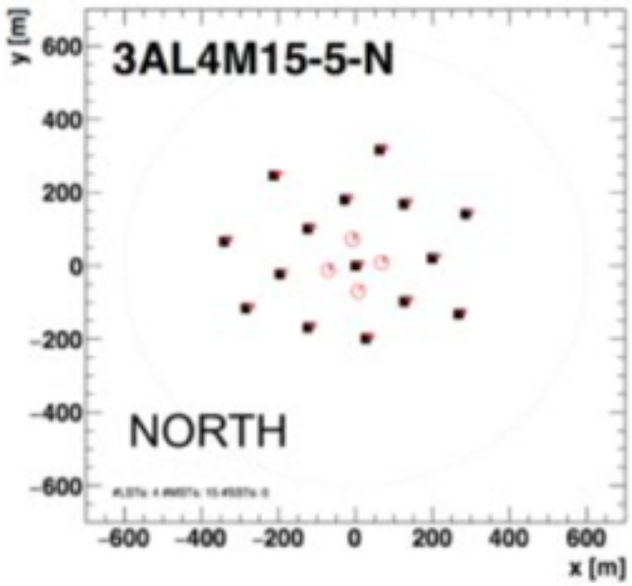
First telescopes on site expected 2017 (earliest)

First data soon after, full operation ~ 2022

Thank you !



full energy range



to scale

mainly low energies

J. Knapp, CRIS 2016