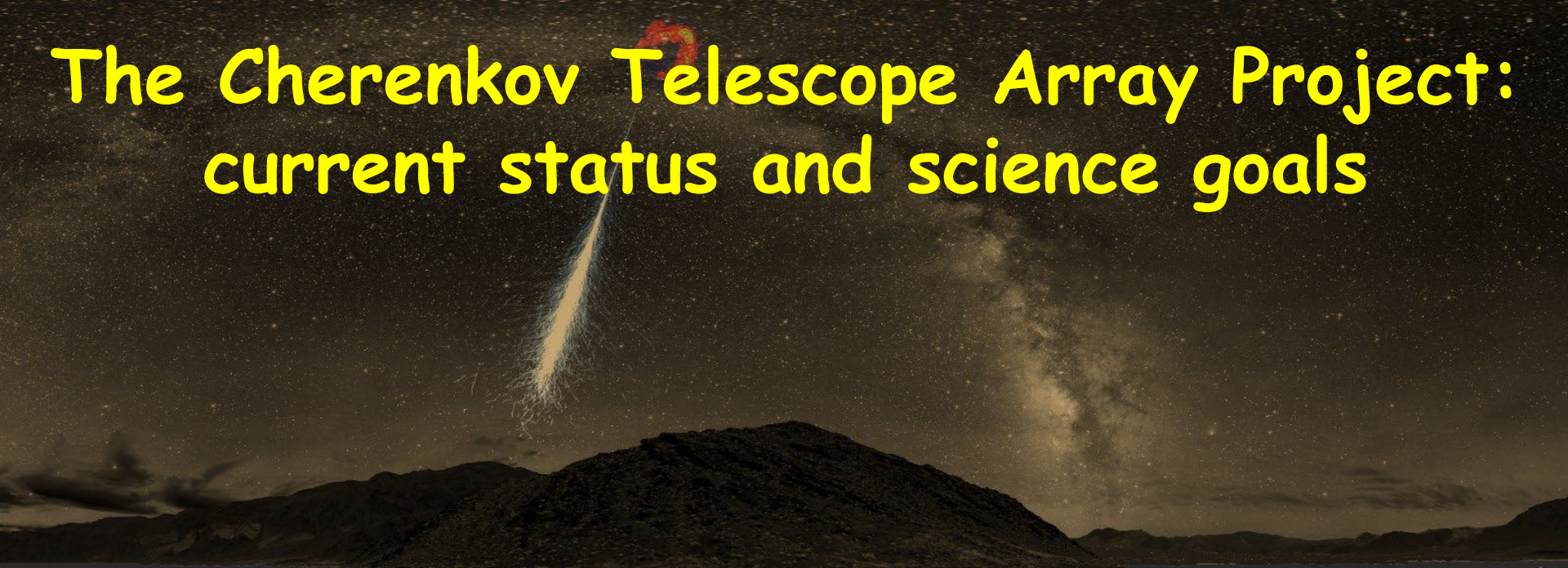
The Cherenkov Telescope Array Project: current status and science goals



the CTA Consortium

represented by Aldo Morselli

INFN Roma Tor Vergata

VULCANO Workshop 2018

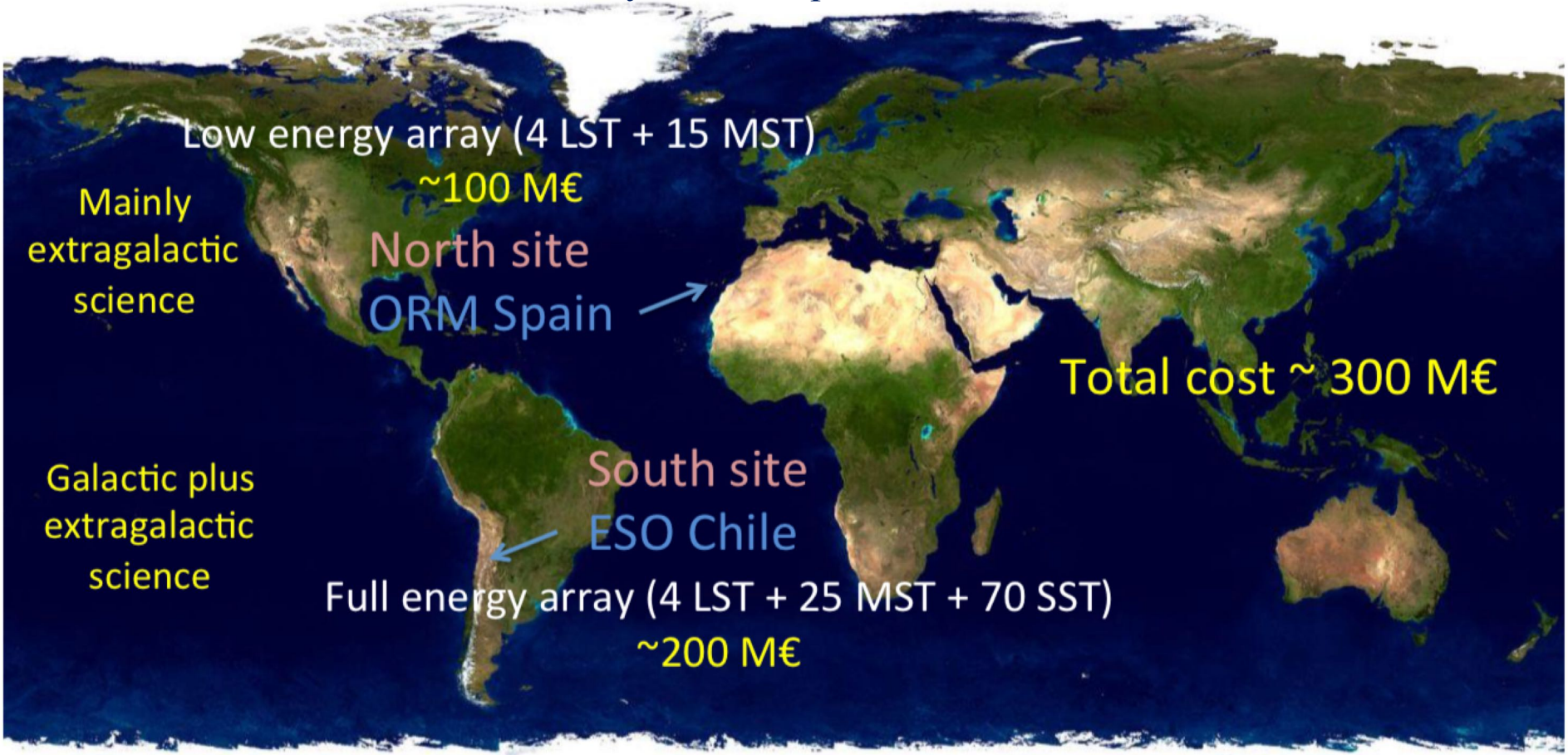
Frontier Objects in Astrophysics and Particle Physics

20th- 26th, May 2018

Vulcano Island, Sicily, Italy

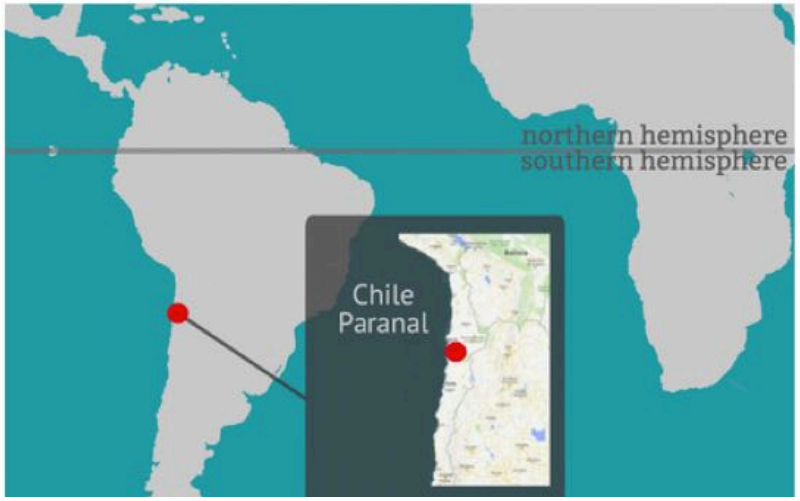
All-sky coverage: two observatories

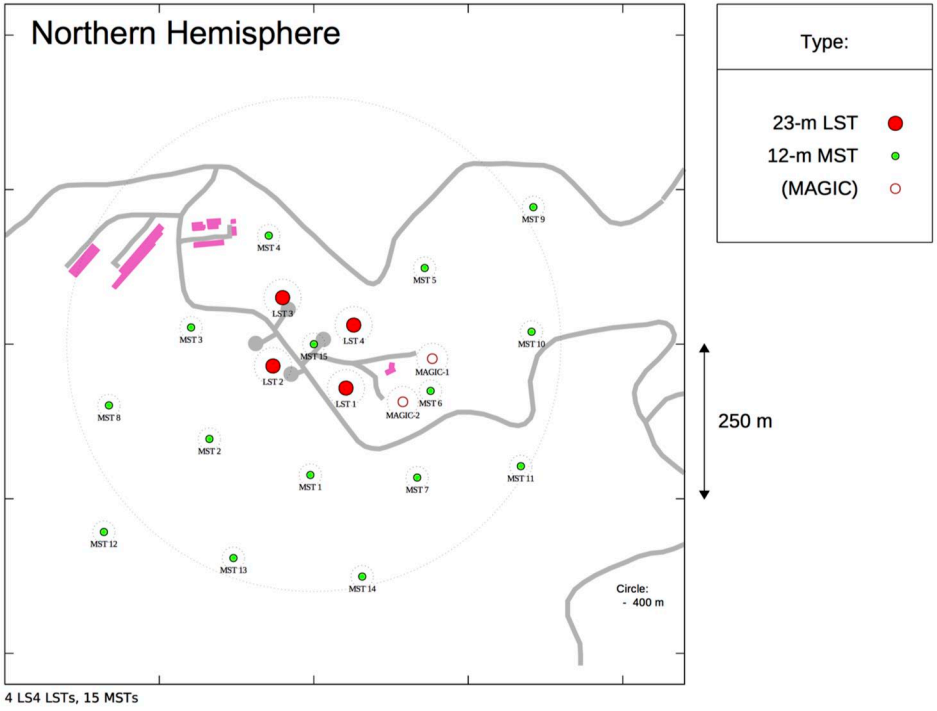
- Two sites with more than 100 telescopes
  - Southern Site: Near Paranal, Chile
  - Northern Site: La Palma, Canary Islands, Spain

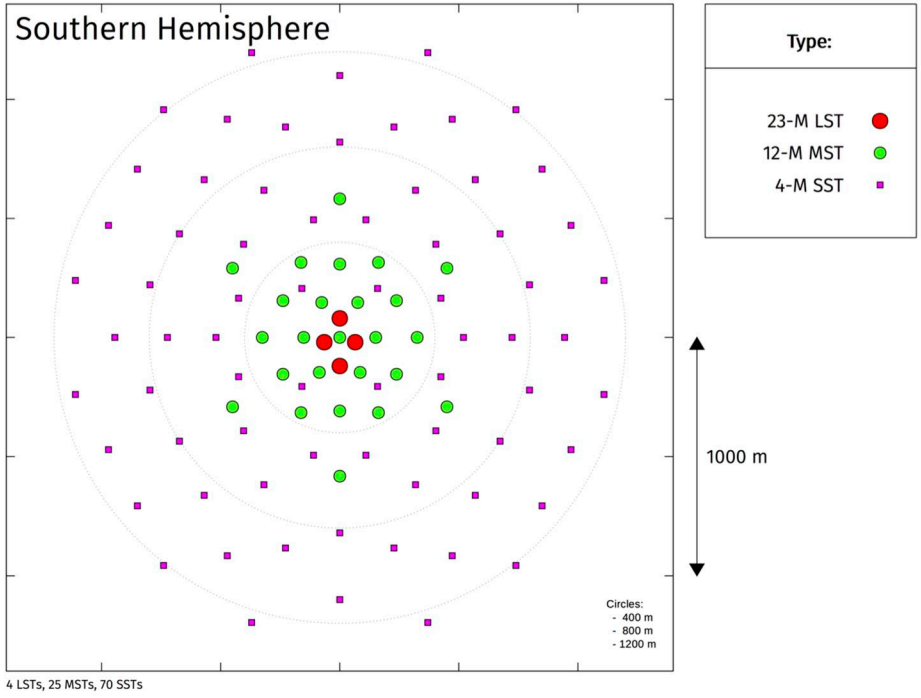


32 nations, ~300M€ project +100M€ manpower
CTA will be an Open observatory

CTA sites and proposed telescope layouts







CTA Headquarters and Science Data Centre

CTA Headquarters
for Admin and observatory operations

INAF Bologna, Italy

CTA Science Data Centre
for science operations and science products

DESY Zeuthen/Berlin, Germany

CTA PERFORMANCE

Southern Site:

4 Large-size (23m) telescopes

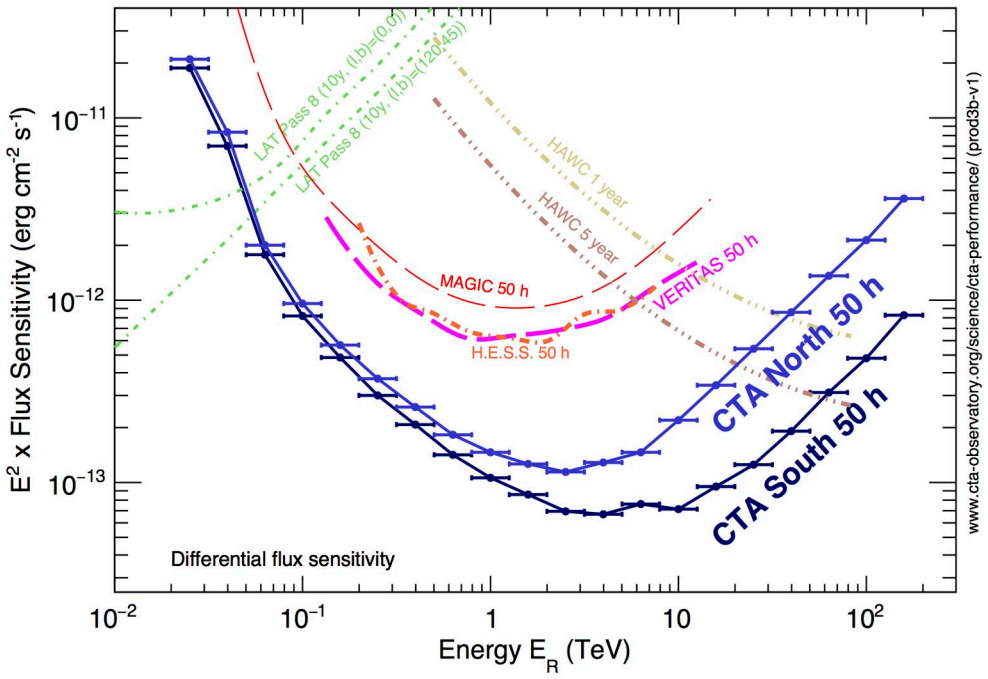
25 Medium-size (10-12m)telescopes

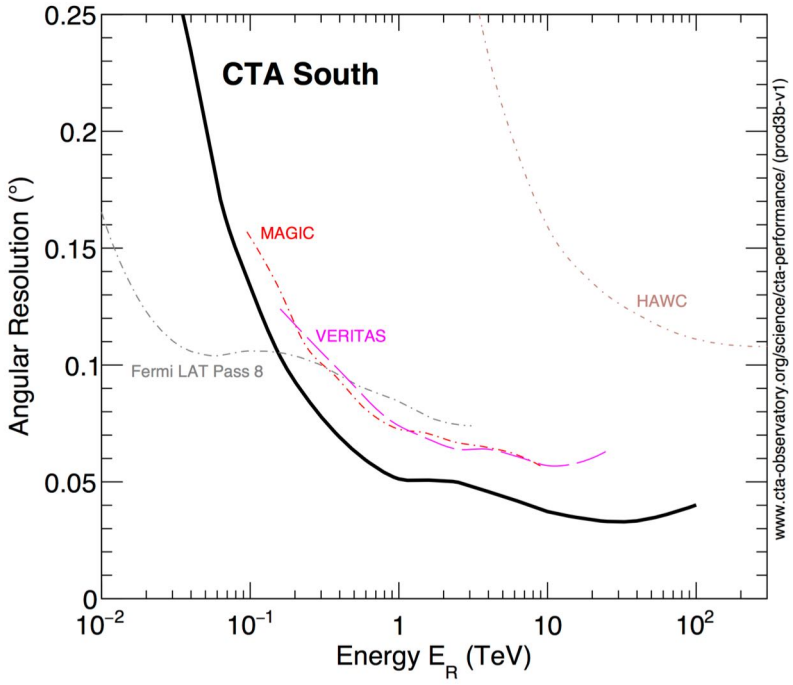
70 Small-size (~4m) telescopes

Northern Site:

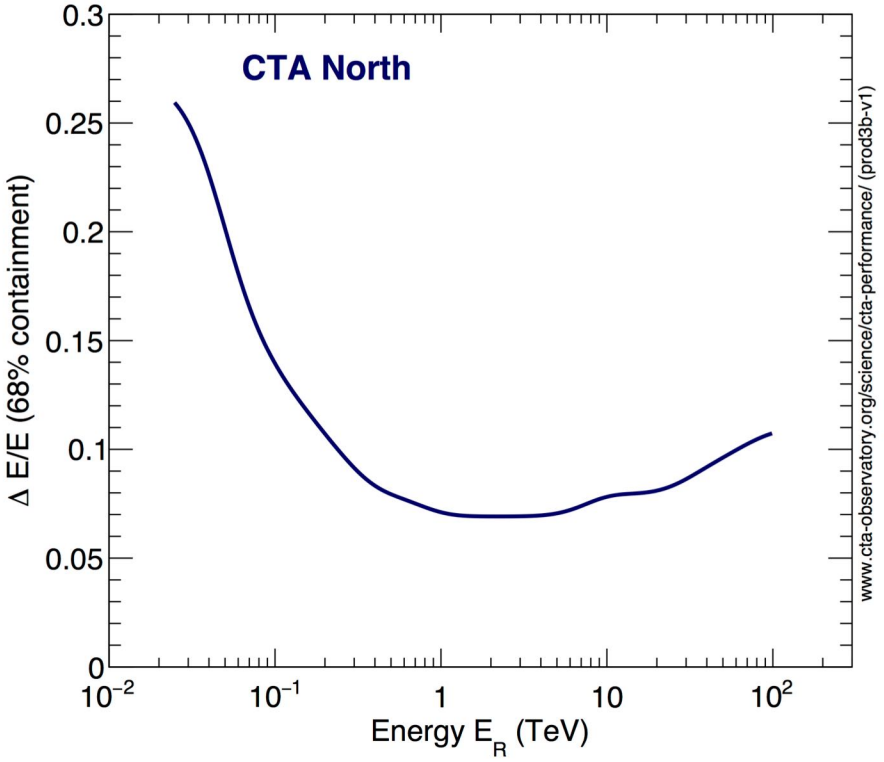
4 Large-size (23m) telescopes

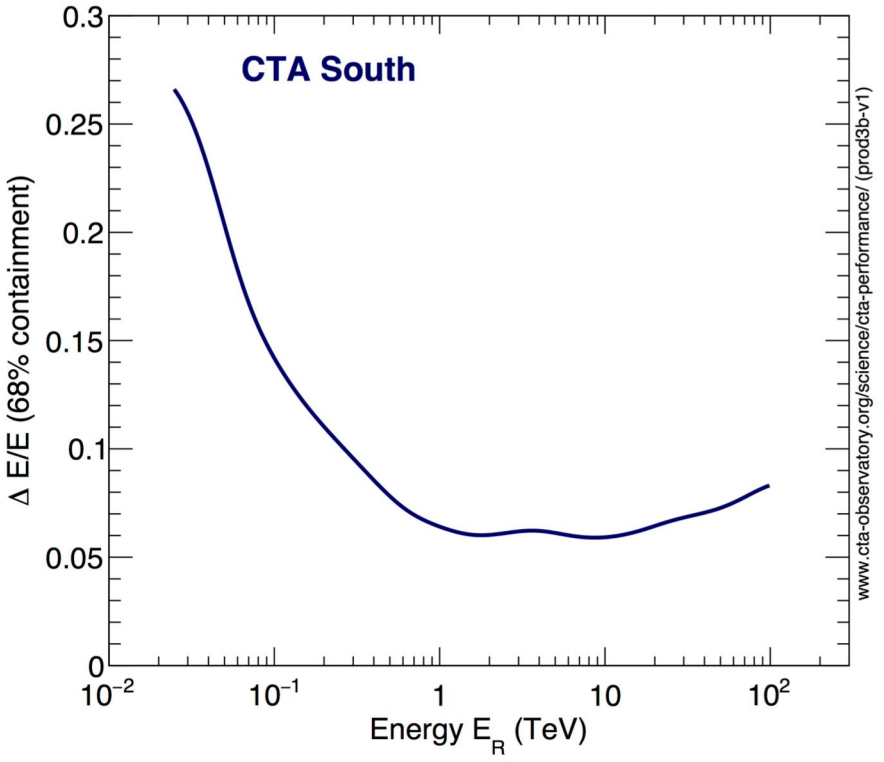
15 Medium-size (10-12m) telescopes





CTA PERFORMANCE
Energy Resolution





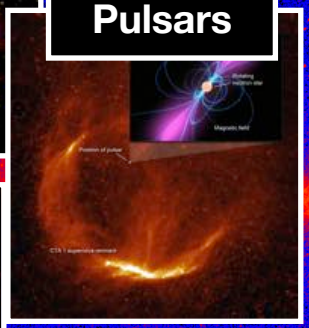
Broad Spectrum of Science

Particle Acceleration | **Dark Matter** | **Cosmology**

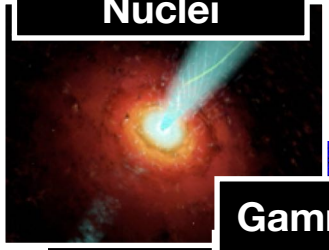
Cosmic Rays

Supernova Remnants

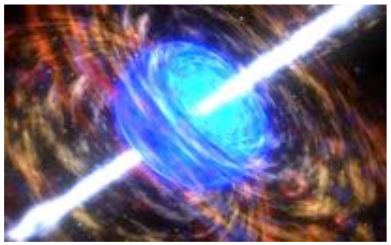
Pulsars



Active Galactic Nuclei

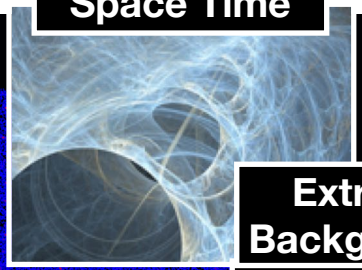


Gamma-ray Bursts



Annihilation

Space Time



Extragalactic Background Light

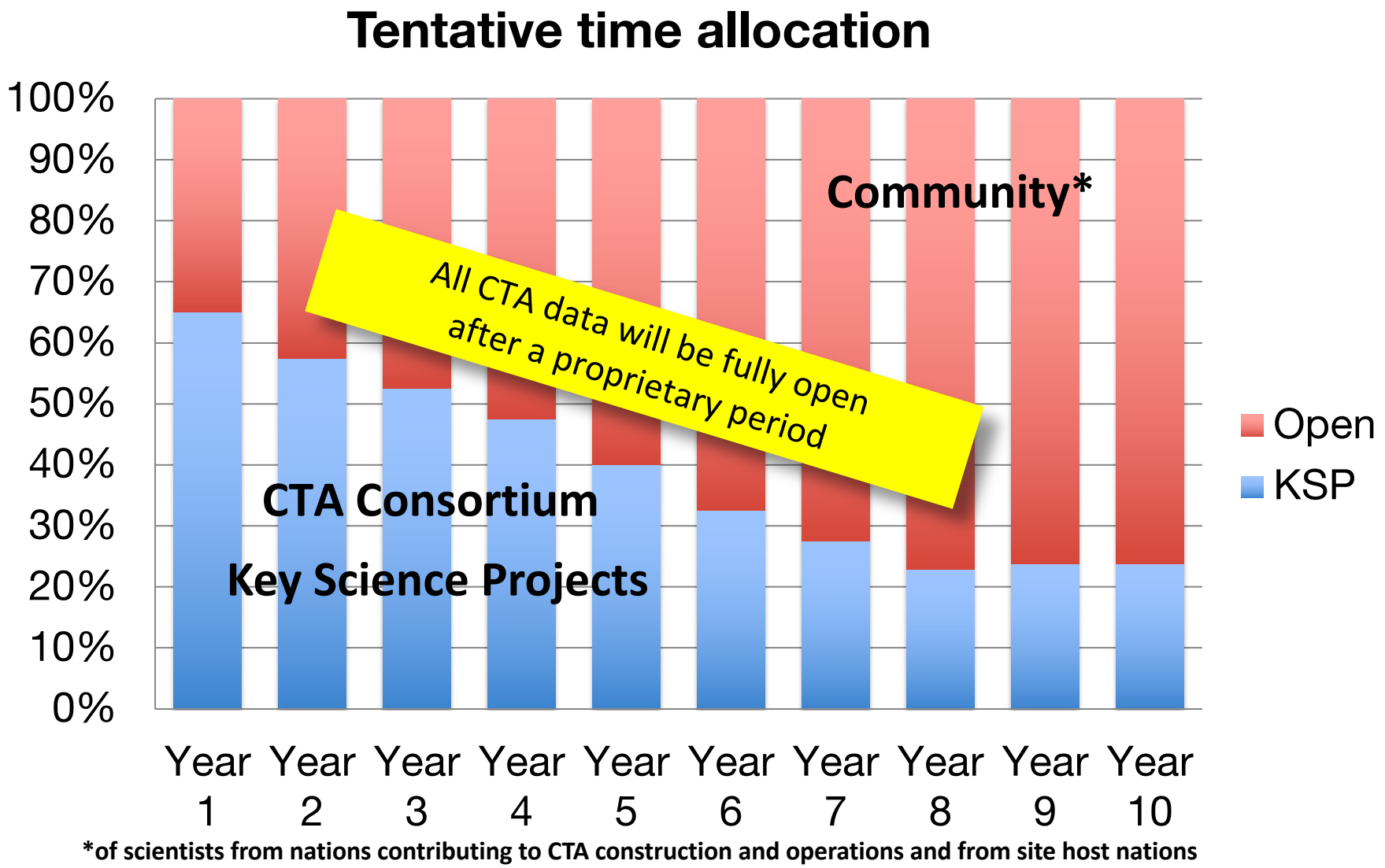
Primordial Black Holes

Axion-like Particles

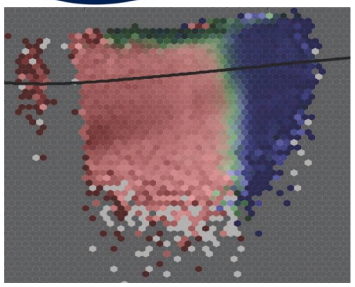
... ?

Opens discovery space by major improvements in sensitivity, FoV, energy range

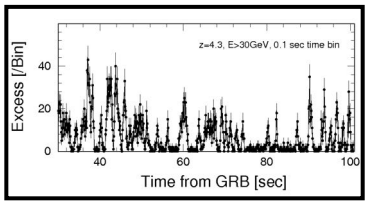
Time Allocation & Community Access



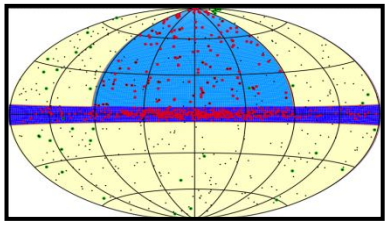
Key Science Projects (KSPs)



Dark Matter Programme

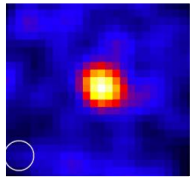


Transients



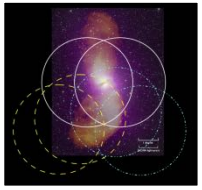
ExGal Survey

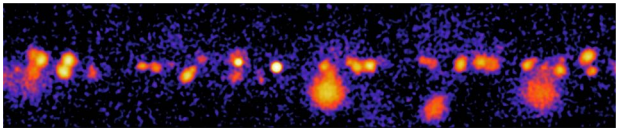
Galaxy Clusters



Star Forming Systems

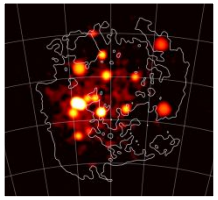
AGN



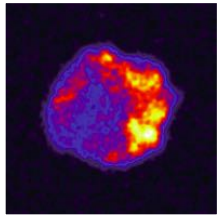


Galactic Plane Survey

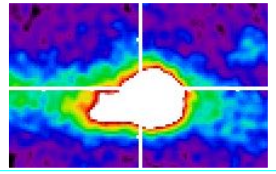
LMC Survey



PeVatrons



Galactic Centre

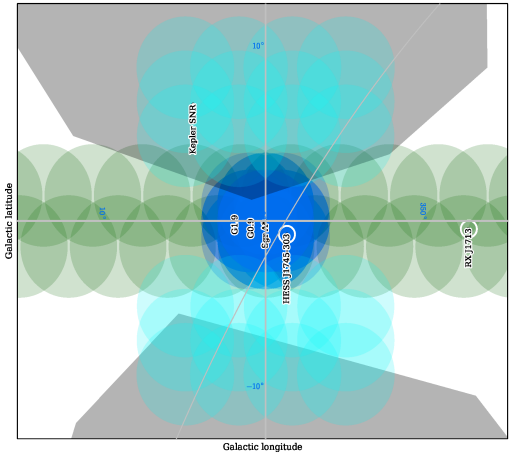


Extragalactic

Galactic

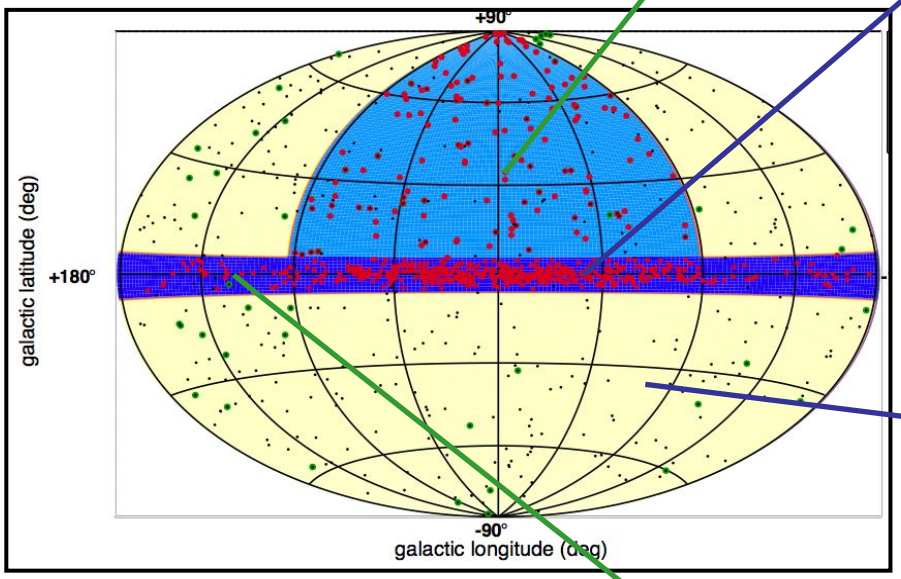
Science with the Cherenkov Telescope Array
Int. J. of Modern Physics D subm.
[arXiv:1709.07997] ~210 pp.

The Survey Key Science Projects



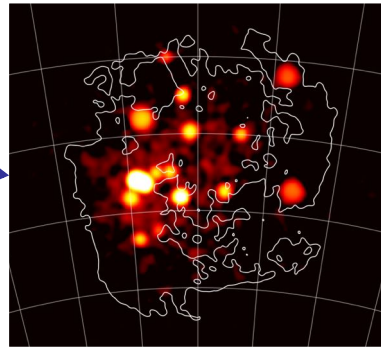
Extragalactic Survey:

Unbiased survey of ¼ sky to ~6 mCrab
VHE population study, duty cycle
New, unknown sources; 1000 h



Galactic Centre Survey:

ID of the central source
Spectrum, morphology of diffuse emission
Deep DM search
Central exposure: 525 h, 10^ox10^o : 300 h



Science with the Cherenkov Telescope Array
Int. J. of Modern Physics D subm.
[arXiv:1709.07997] ~210 pp.

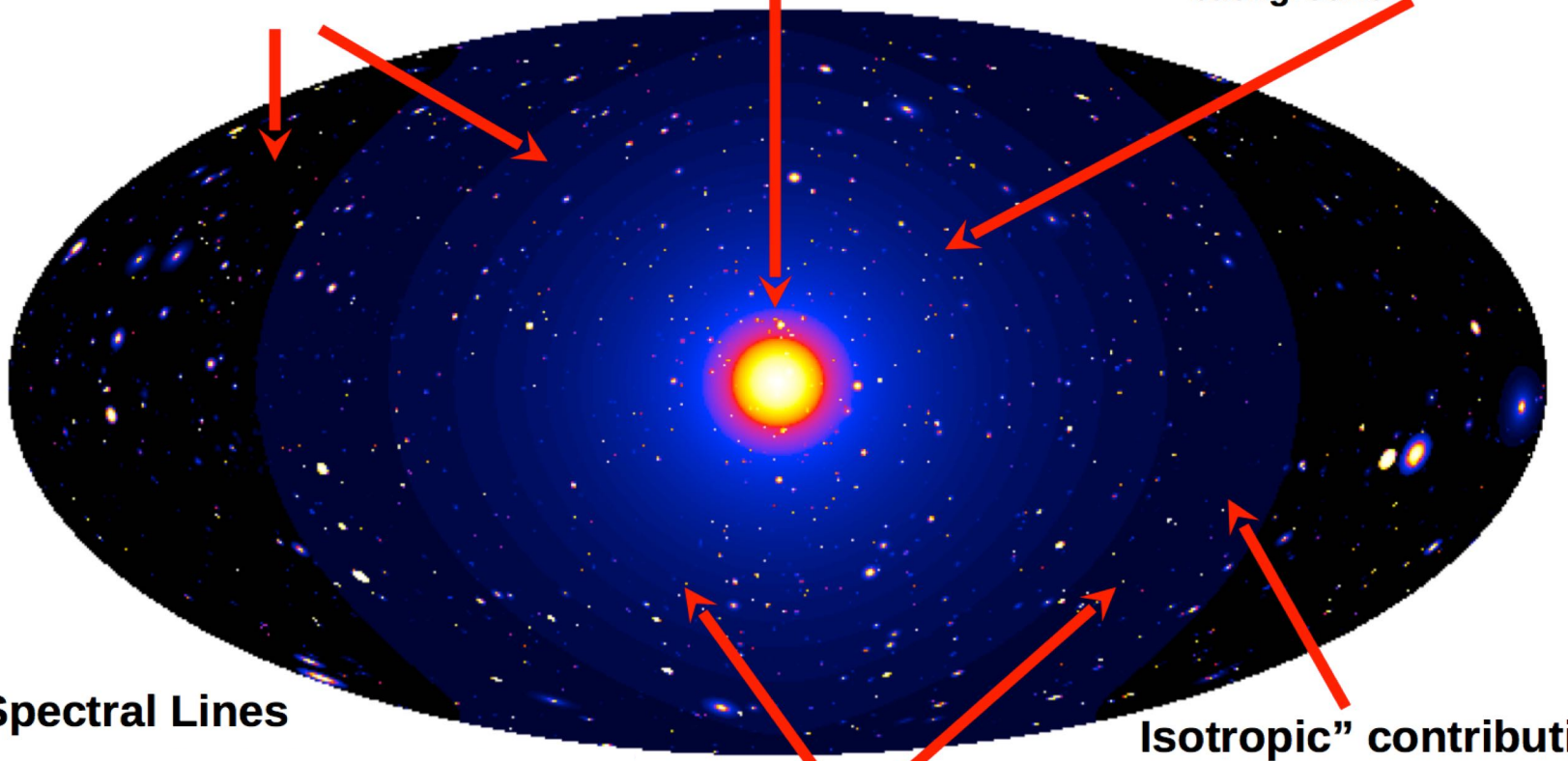
Galactic Plane Survey:

Survey of entire plane to ~2 mCrab
Galactic source population: SNRs, PWNe, etc.
PeVatron candidates, early view of GC, 1620 h

Large Magellanic Cloud Survey:

Face-on satellite galaxy with high SFR
Extreme Gal. sources, diffuse emission (CRs)
DM search; 340 h in six pointings

Dark Matter Search: Targets and Strategies



Satellites

Low background and good source id, but low statistics

Galactic Center

Good Statistics, but source confusion/diffuse background

Milky Way Halo

Large statistics, but diffuse background

Spectral Lines

Little or no astrophysical uncertainties, but low sensitivity because of expected small branching ratio

Galaxy Clusters

Low background, but low statistics

Isotropic" contributions

Large statistics, but astrophysics, galactic diffuse background

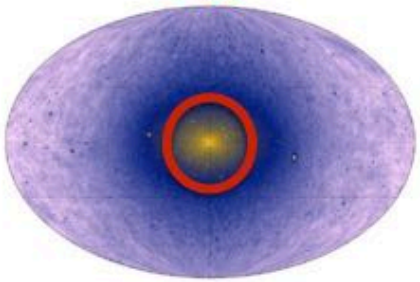
Dark Matter simulation: Pieri+(2009) arXiv:0908.0195

Dark Matter Search: Targets and Strategies

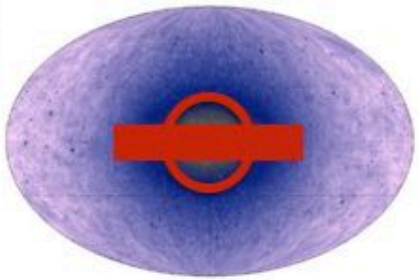
(Another way to see it)

signal strength

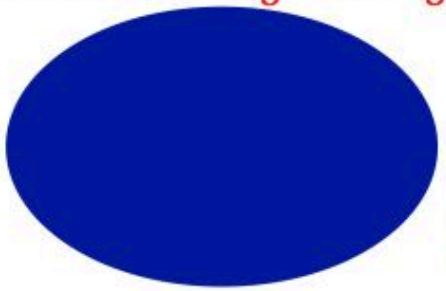
GC



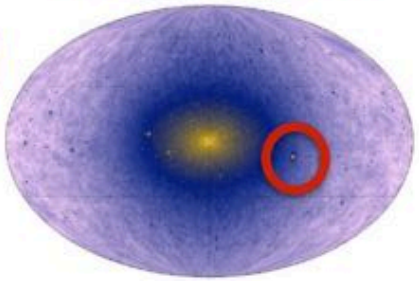
GC halo

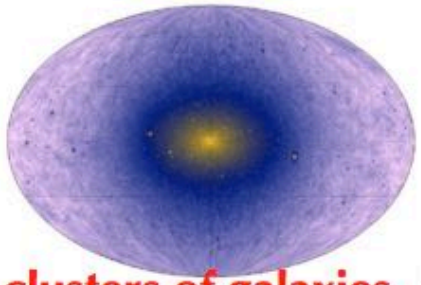


cumulative extragalactic signal



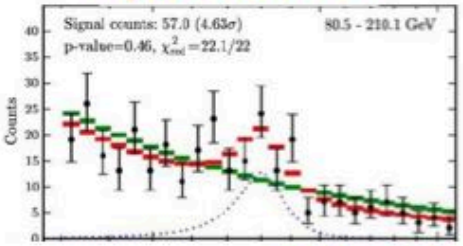
dwarf satellites





clusters of galaxies

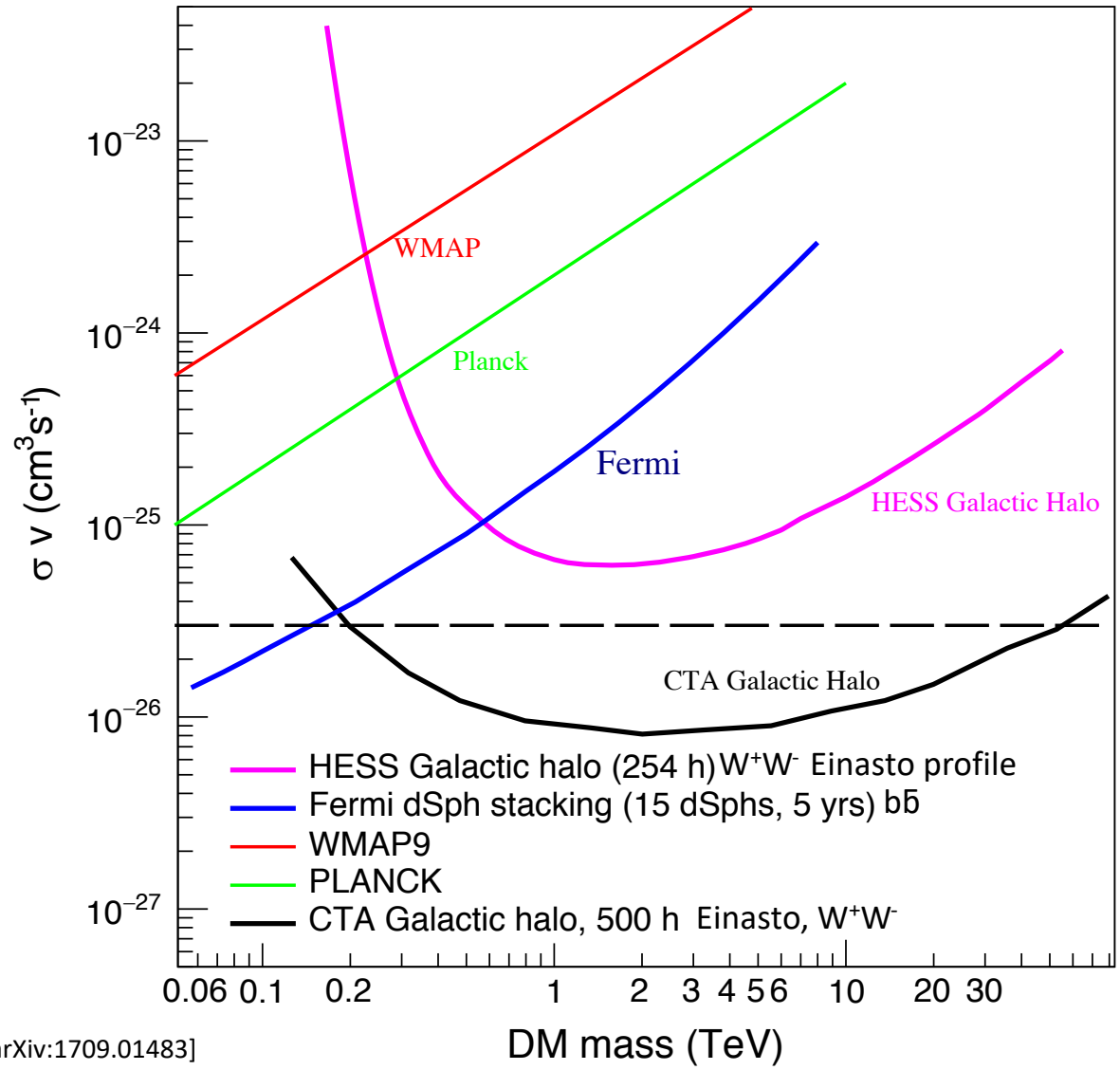
spectral line



robustness

CTA, HESS, FERMI, PLANK DM upper-limits

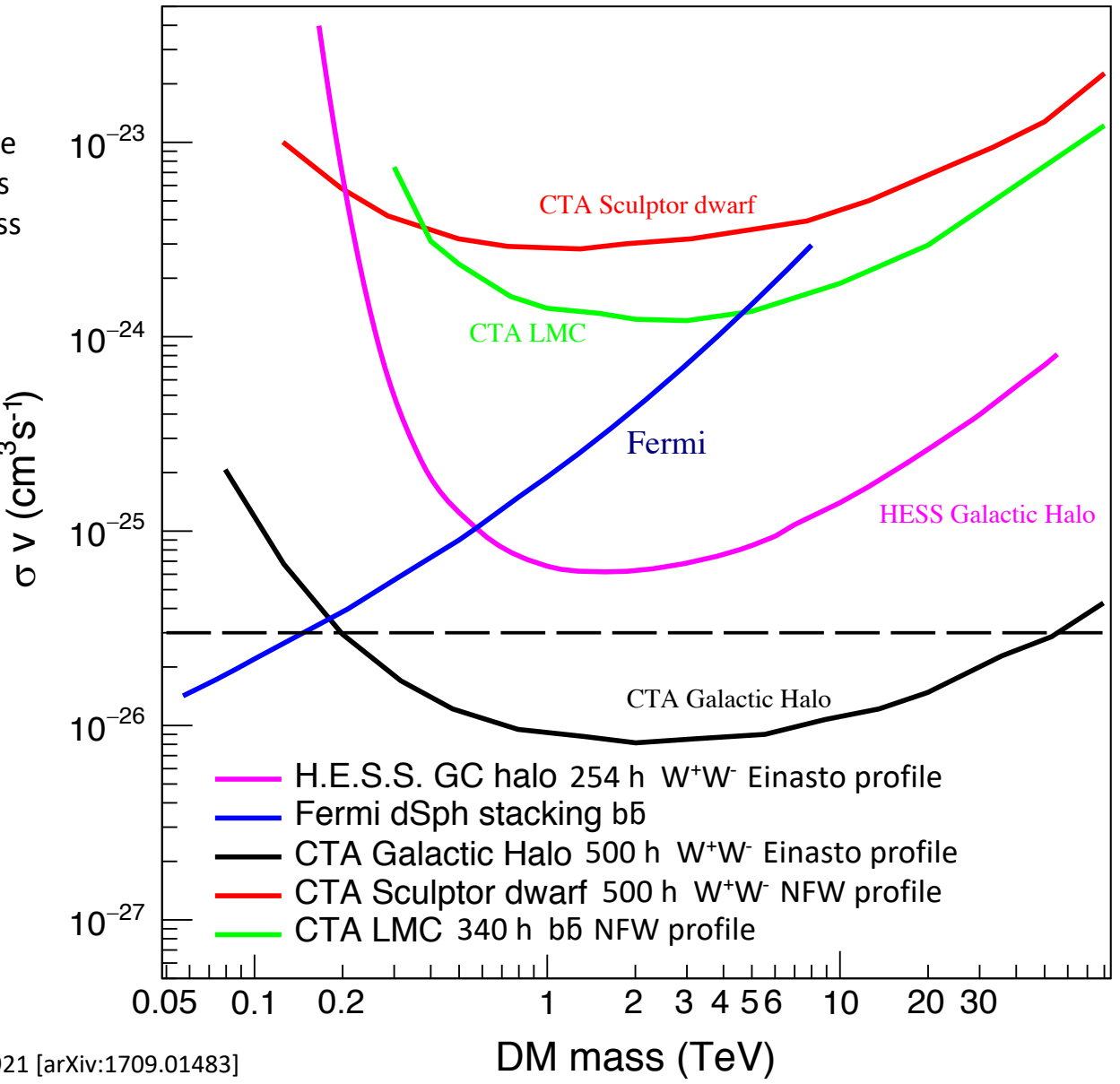
- Together Fermi and CTA will probe most of the space of WIMP models with thermal relic annihilation cross section.
- The expectation for CTA for the Galactic Halo is for the Einasto profile and is optimistic as includes only statistical errors.
- The effect of the Galactic diffuse emission can affect the results by ~ 50%



A.Morselli,CTA Cons, PoS(ICRC2017)921 [arXiv:1709.01483]

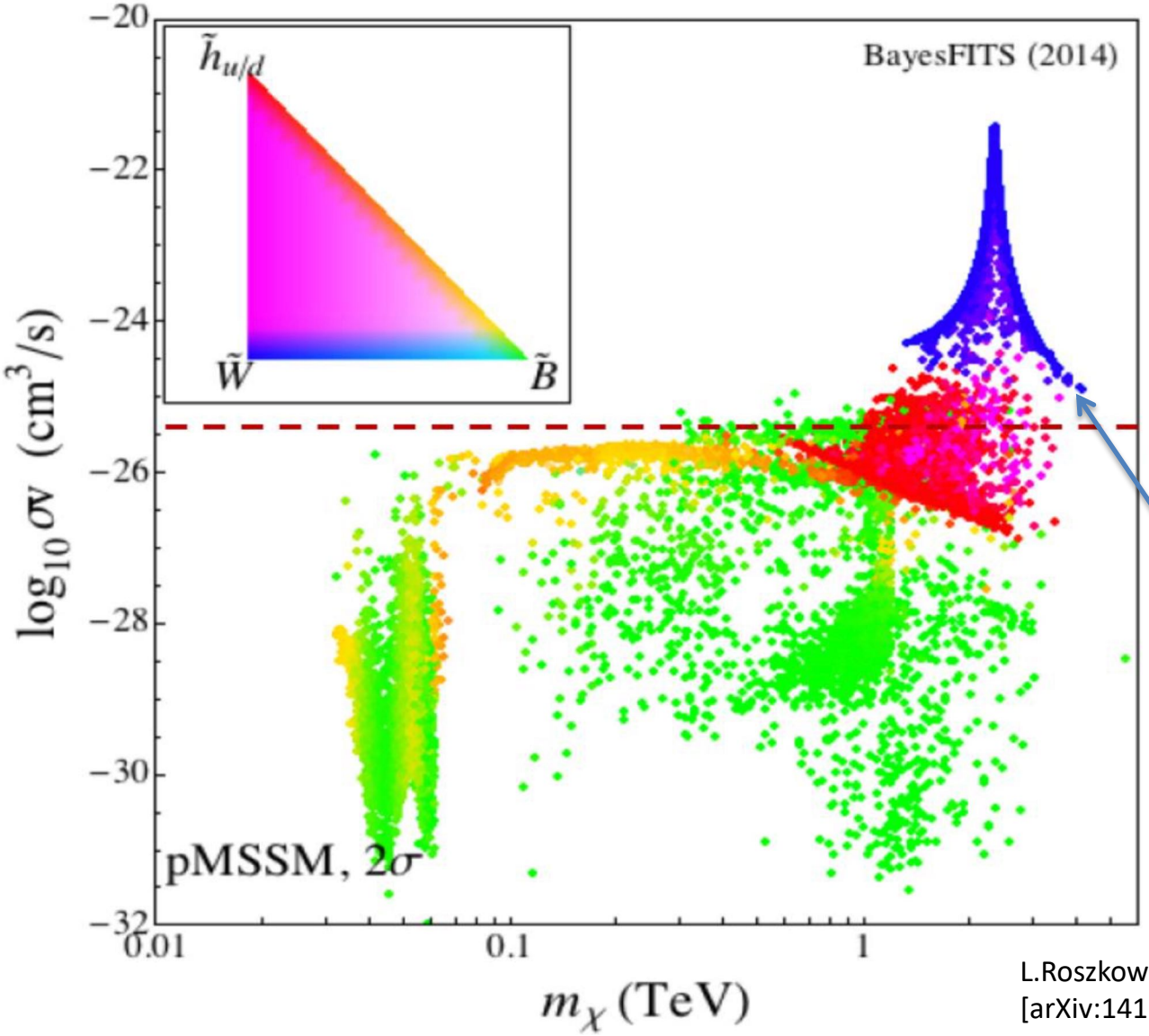
CTA, Fermi,HESS DM upper-limits

- Together Fermi and CTA will probe most of the space of WIMP models with thermal relic annihilation cross section.
- The expectation for CTA for the Galactic Halo is for the Einasto profile and is optimistic as includes only statistical errors.
- The effect of the Galactic diffuse emission can affect the results by ~ 50%.
- The limits from dwarfs are much less dependent on the systematic uncertanties.



A.Morselli, CTA Cons, PoS(ICRC2017)921 [arXiv:1709.01483]

note:the "thermal" cross section is only a reference value. The real cross section can be higher or lower



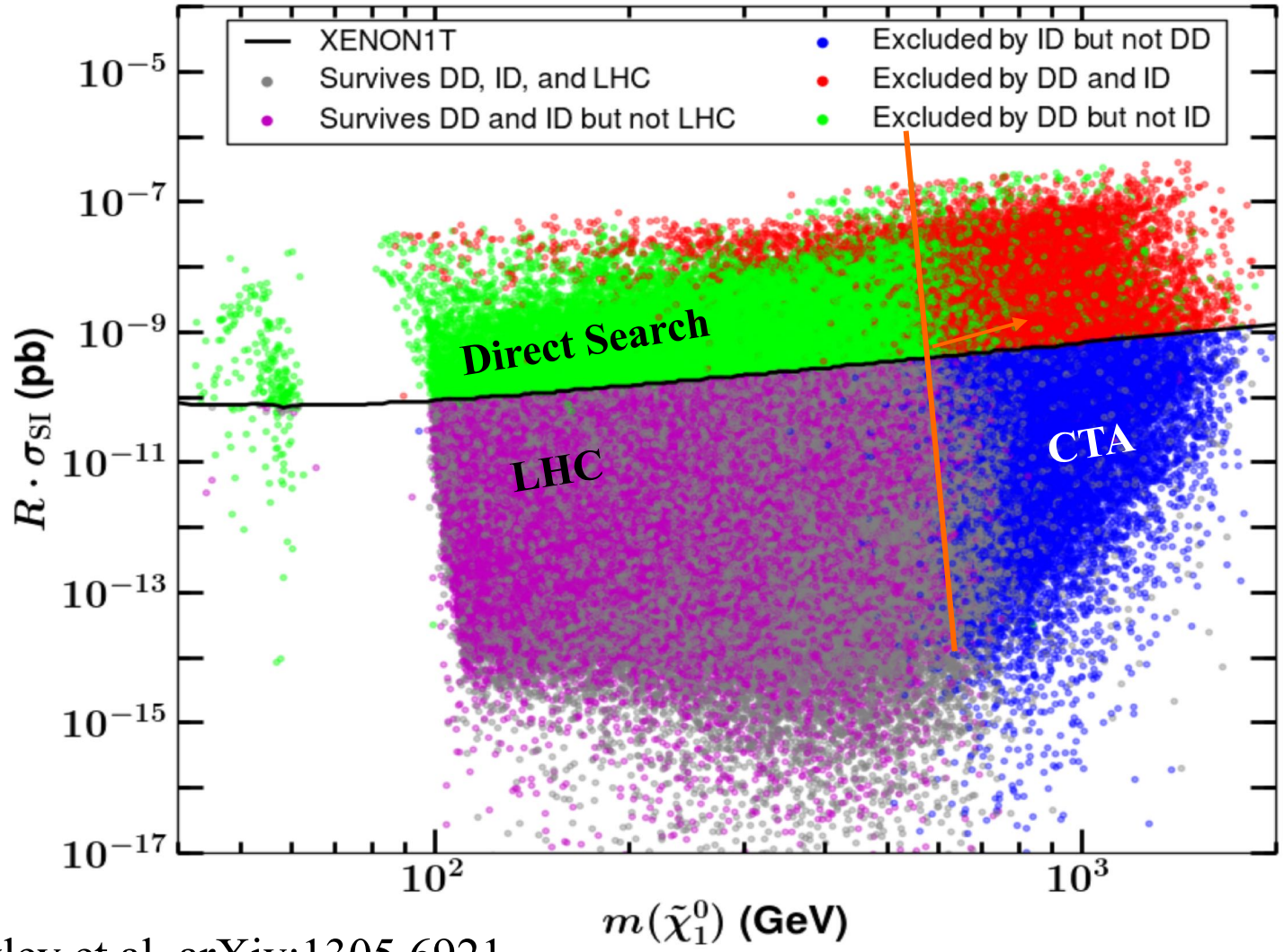
Example: Annihilation cross-section points from a 19 dimensional pMSSM fit

"thermal" cross-section
3×10^{-26} cm^3 s^{-1}

Note that a strong enhancement of the annihilation cross section occurs for winos around 2-3 TeV due to Sommerfeld enhancement.

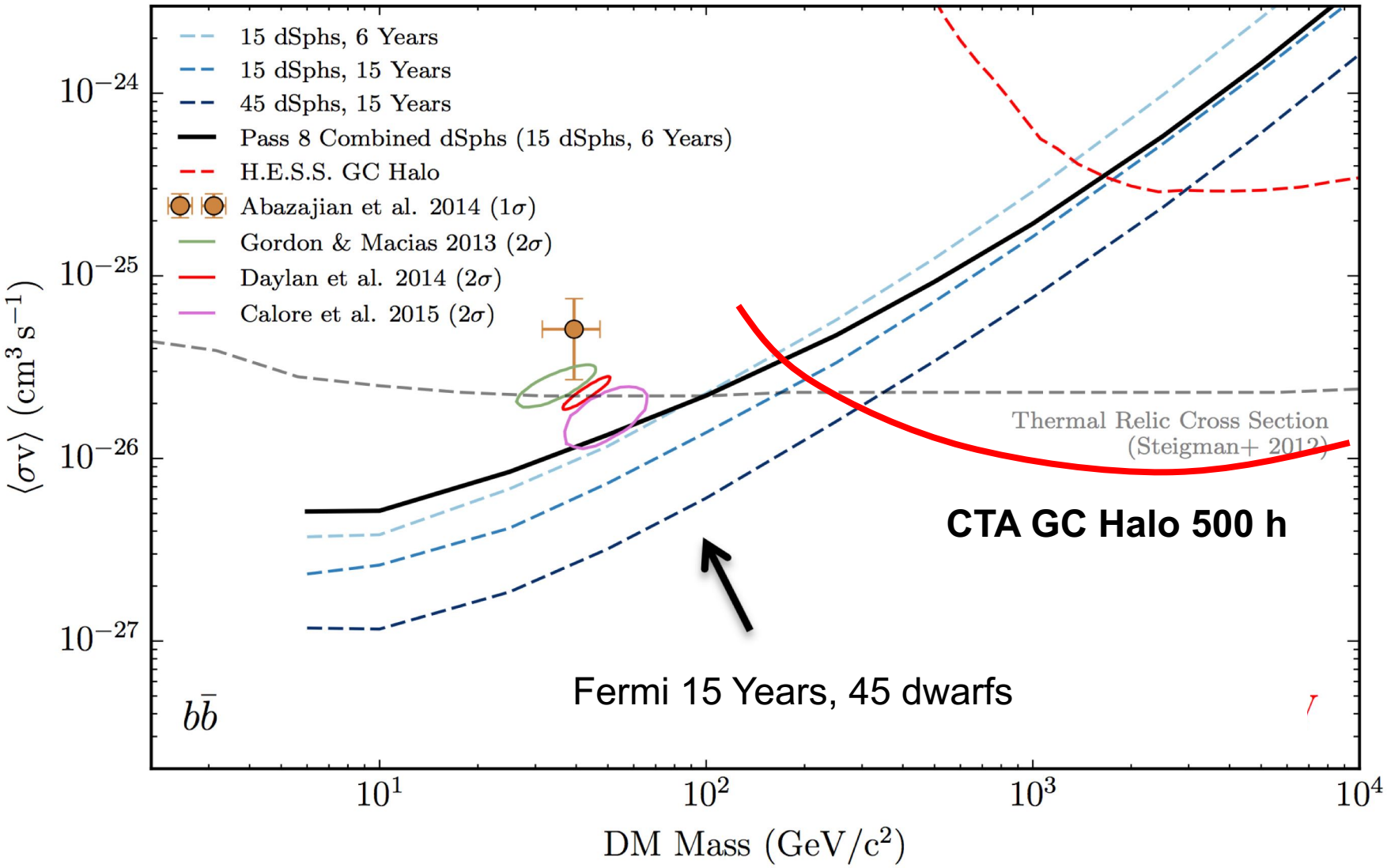
L.Roszkowski et al., JHEP 1502 (2015) 014 [arXiv:1411.5214]

Complementarity and Searches for Dark Matter in the pMSSM



Cahill-Rowley et al. arXiv:1305.6921

DM limit improvement estimate in 15 years (2008- 2023)



Together Fermi and CTA will probe most of the space of WIMP models with thermal relic annihilation cross section

CTA DM Detection Strategy

Year	1	2	3	4	5	6	7	8	9	10
Galactic halo	175 h	175 h	175 h							
Best dSph	100 h	100 h	100 h							
				in case of detection at GC, large σv						
Best dSph				150 h	150 h	150 h	150 h	150 h	150 h	150 h
Galactic halo				100 h	100 h	100 h	100 h	100 h	100 h	100 h
				in case of detection at GC, small σv						
Galactic halo				100 h	100 h	100 h	100 h	100 h	100 h	100 h
				in case of no detection at GC						
Best Target				100 h	100 h	100 h	100 h	100 h	100 h	100 h

First 3 years

- The principal target is the Galactic Center Halo (most intense diffuse emission regions removed)
- Best dSph as "cleaner" environment for cross-checks and verification (if hint of strong signal)

Next 7 years

- If there is detection in GC halo data set (525h)
  - Strong signal: continue with GC halo in parallel with best dSph to provide robust detection
  - Weak signal: focus on GC to increase data set until systematic errors can be kept under control
- If no detection in GC halo data set
  - Focus observation on the best target at that time to produce legacy limits.

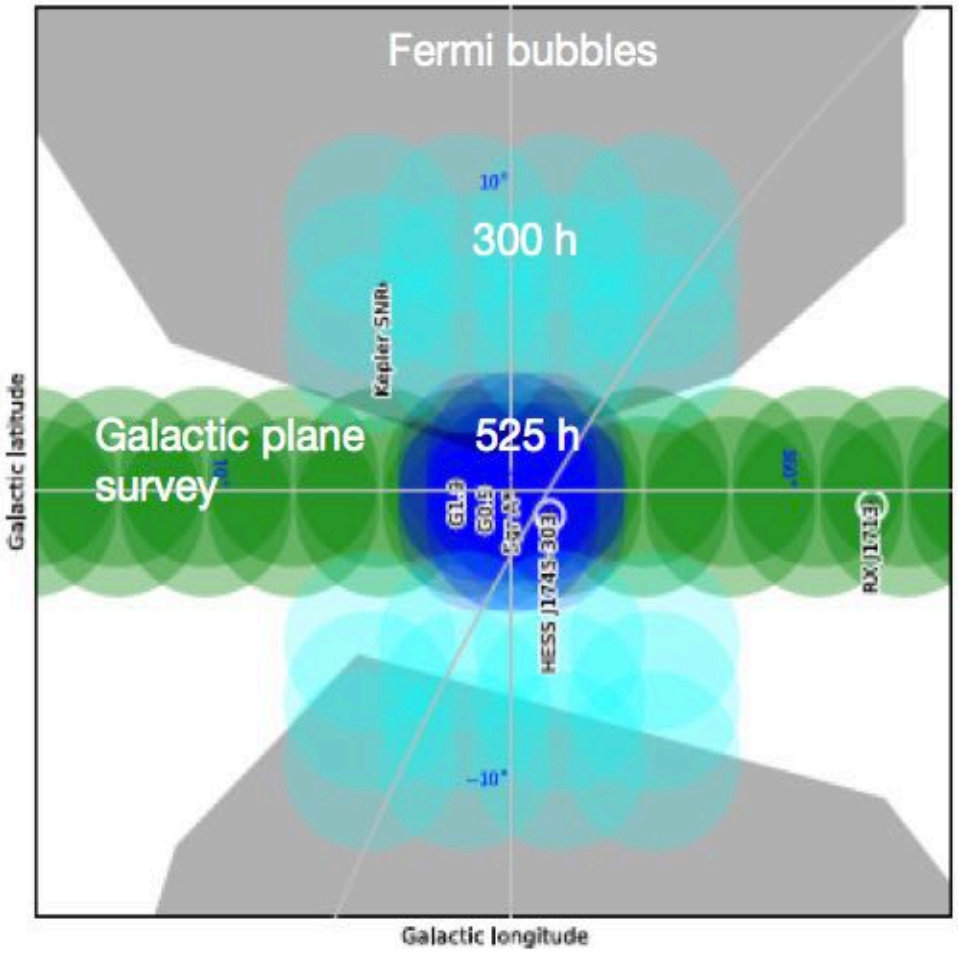
DEEP OBSERVATIONS OF GC REGION

Deep 525 h exposure in the inner 5° around Sgr A*;

Extended 300 h survey of 10°x10° region;

Produce CTA legacy data set for large range of scientific topics, which include

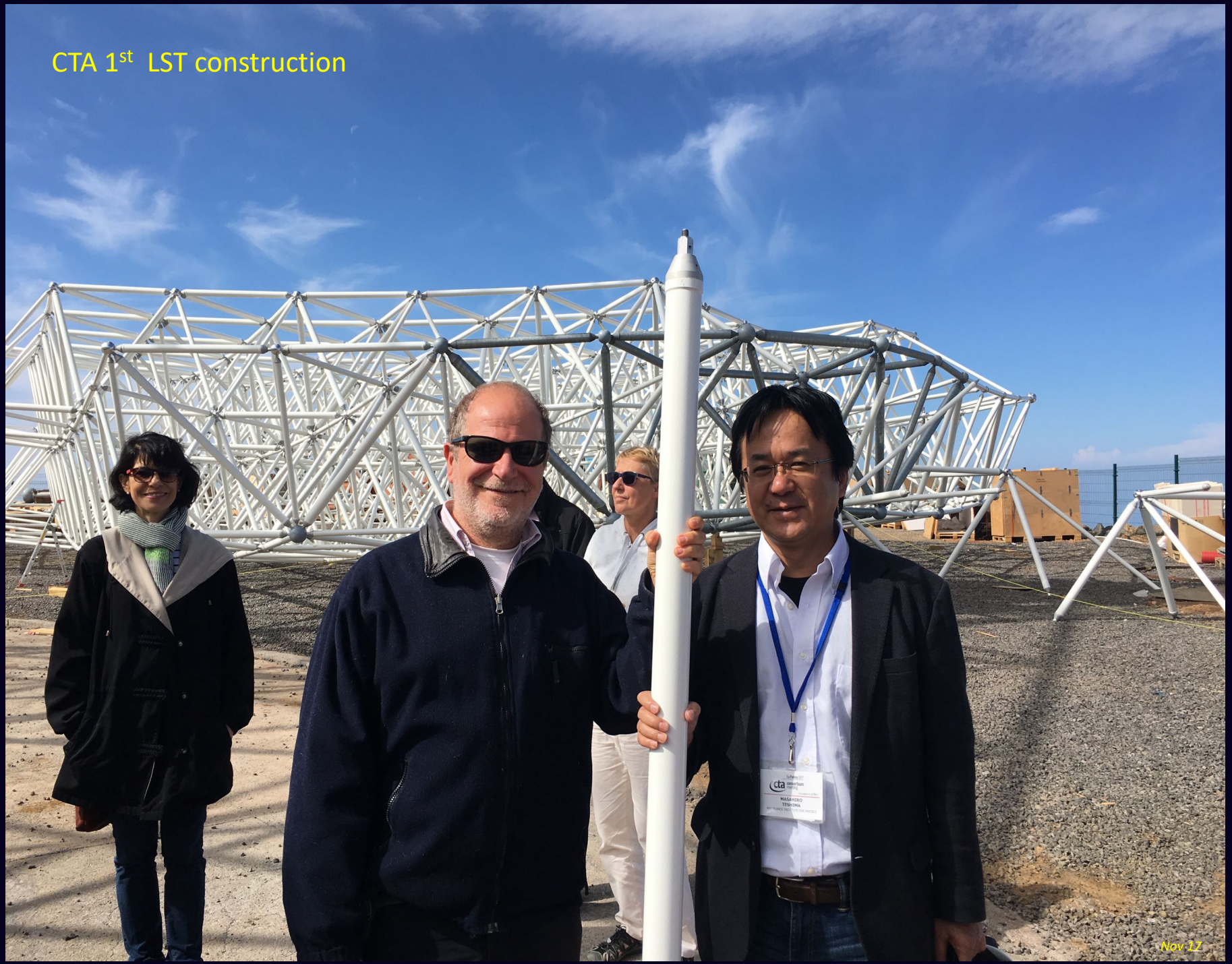
- GC and GC DM halo
- Understand "backgrounds" pin down VHE sources and map diffuse emission
- Astrophysics of SNRs (multiple sources, e.g. G1.9, …)
- Astrophysics of PWNe and Pulsars
- Extended objects such as Central Radio lobes (central ±1°) and arc features.



CTA legacy data set

CTA Consortium Meeting, La Palma Nov.2017

CTA 1st LST construction



Nov-17

CTA 1st LST construction

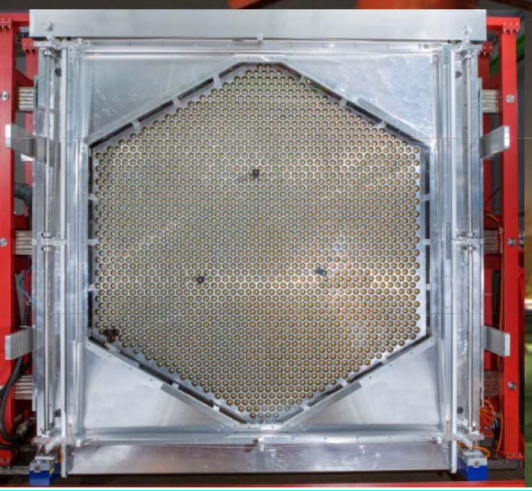
Feb 18
Photo Credit: Chiara Righi (MAGIC, INAF, Brera)


CTA 1st LST construction
Inauguration 10 October 2018
17-02-2018
photo Credit: Thomas Schweizer, MPP, Munich

Medium Telescope (MST)

cta cherenkov telescope array

Prototype MST near DESY (Berlin)



Prototype FlashCAM camera

100m² mirror dish area
16 m focal length
1.2 m mirror facets

8° field of view
~2000 x 0.18° PMT pixels

25 MSTs on South site
15 MSTs on North site

Medium 2-mirror Telescope

cherenkov telescope array

Prototype SCT at Whipple Obs, Arizona

Schwarzschild-Couder Telescope (SCT)

9.7 m primary
5.4 m secondary
5.6 m focal length, f/0.58
50 m^2 mirror dish area
PSF better than 4.5′
across 8° FOV

8° field of view
11328 x 0.07° Si-PM pixels

➜ Improved γ-ray angular resolution

Small Sized Telescopes (SSTs)

cherenkov telescope array

- 3 different prototype designs
- 2 designs use two-mirror approaches (Schwarzschild-Couder design)
- All use Si-PM photosensors
- 8-10 m^2 mirror area, FOV > 9^o

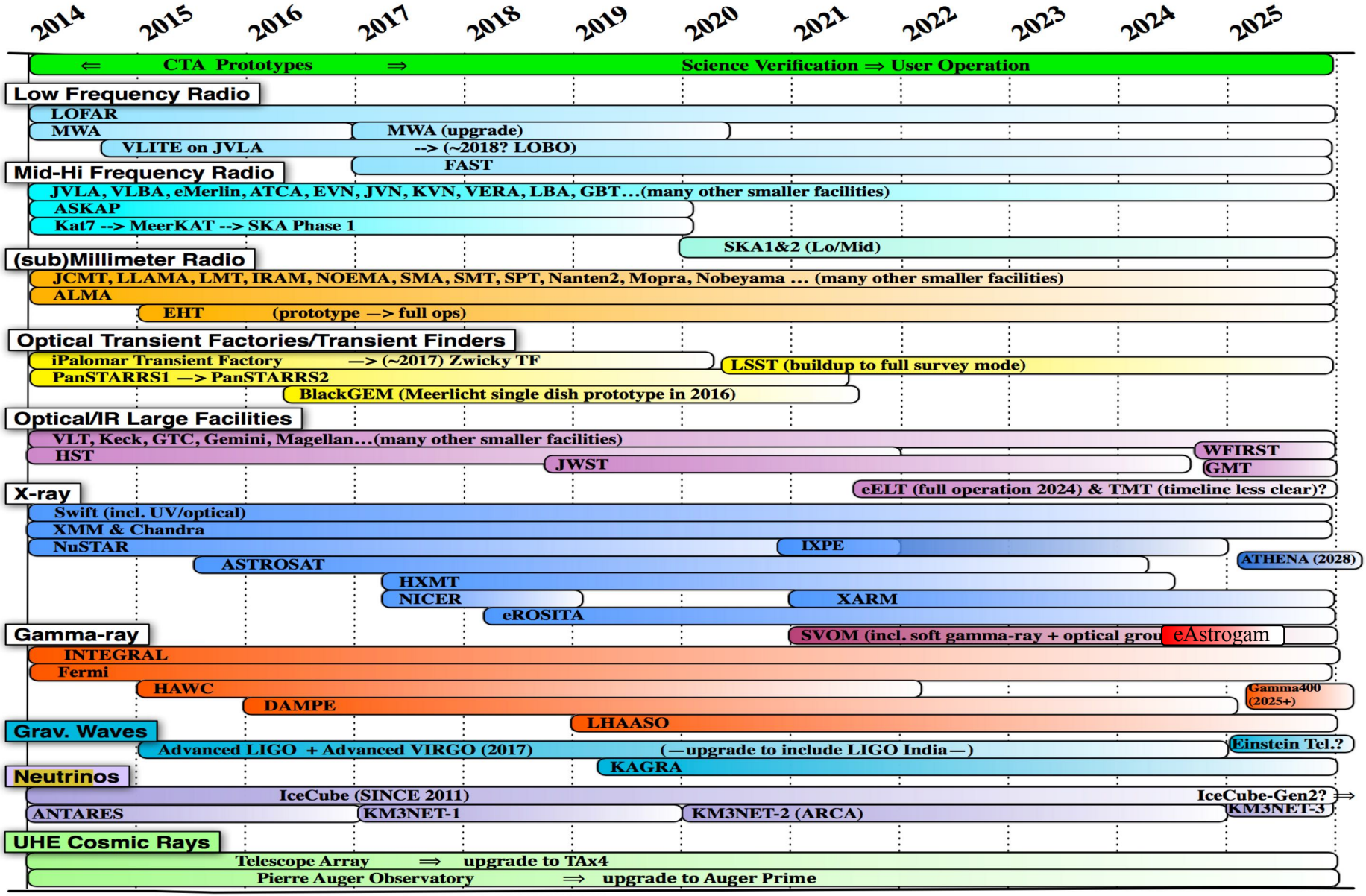
SST-1M
Krakow, Poland

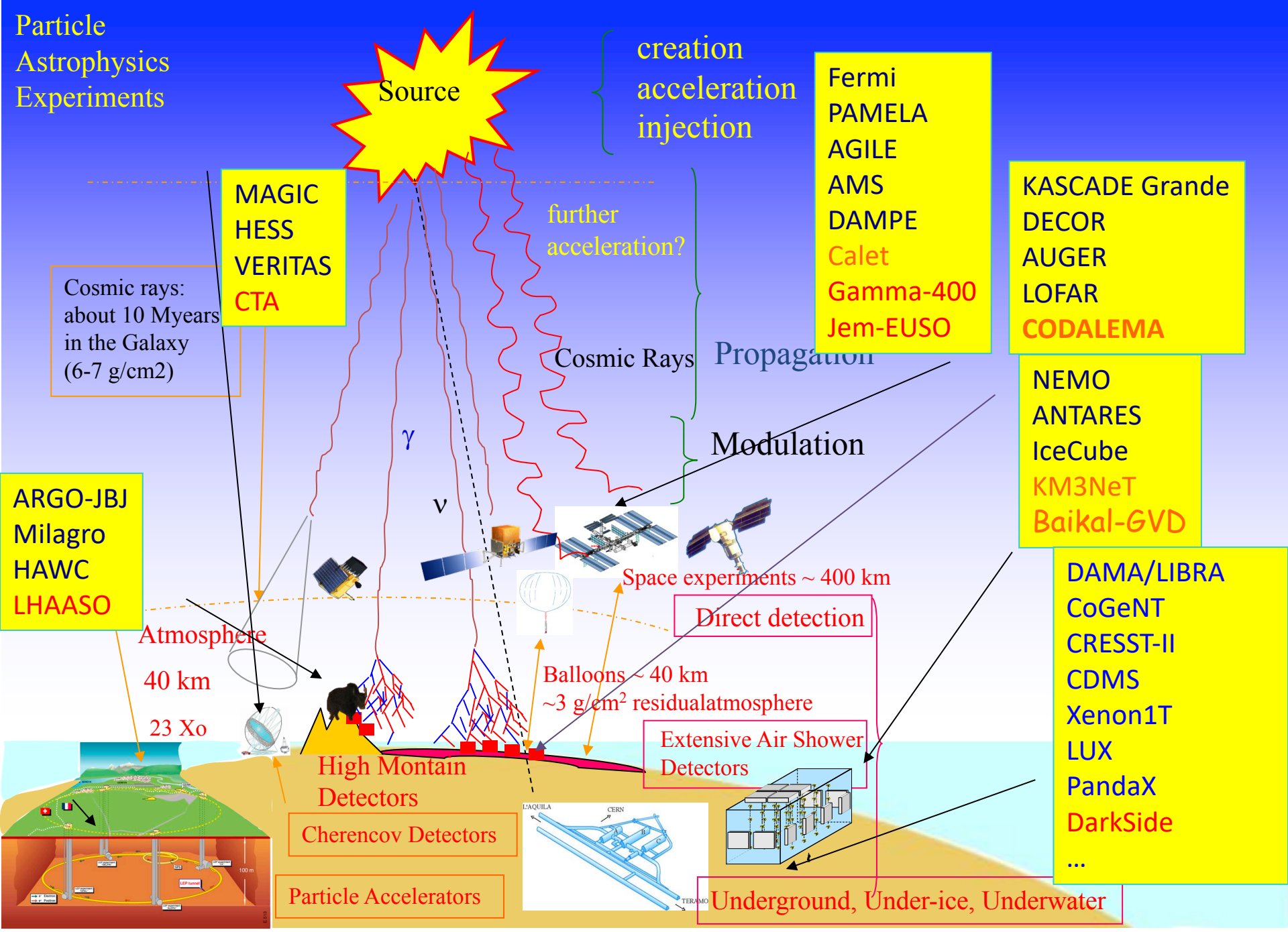
SST-2M ASTRI
Mt. Etna, Italy

first light May 17

SST-2M GCT
Meudon, France

multi-wavelength/multi-messenger facilities over the next decade




Particle Astrophysics Experiments
Source
creation
acceleration
injection
Fermi
PAMELA
AGILE
AMS
DAMPE
Calet
Gamma-400
Jem-EUSO
KASCADE Grande
DECOR
AUGER
LOFAR
CODALEMA
MAGIC
HESS
VERITAS
CTA
Cosmic rays:
about 10 Myears
in the Galaxy
(6-7 g/cm2)
further
acceleration?
Cosmic Rays
Propagation
Modulation
γ
ν
NEMO
ANTARES
IceCube
KM3NeT
Baikal-GVD
ARGO-JBJ
Milagro
HAWC
LHAASO
Space experiments ~ 400 km
Direct detection
Atmosphere
40 km
23 Xo
Balloons ~ 40 km
~3 g/cm2 residualatmosphere
DAMA/LIBRA
CoGeNT
CRESST-II
CDMS
Xenon1T
LUX
PandaX
DarkSide
...
Extensive Air Shower
Detectors
High Montain
Detectors
Cherencov Detectors
Particle Accelerators
Underground, Under-ice, Underwater

CTA: The Future of VHE Gamma-Ray Astrophysics

- Covers a unique energy band (20 GeV – 300 TeV) complementary to space missions
- ~10-fold improved sensitivity for TeV studies of the cosmos
  - ✓ Analogous to the advance from EGRET to Fermi-LAT
- Angular resolution substantially better
- Detailed studies of Galactic cosmic-ray acceleration
- New sensitivity to the high-energy processes in blazar jets
- Astrophysics foundation and sensitivity for recognizing new fundamental physics
- Sensitive searches for dark matter in its cosmic home
- Broad access to CTA by scientists in participating countries