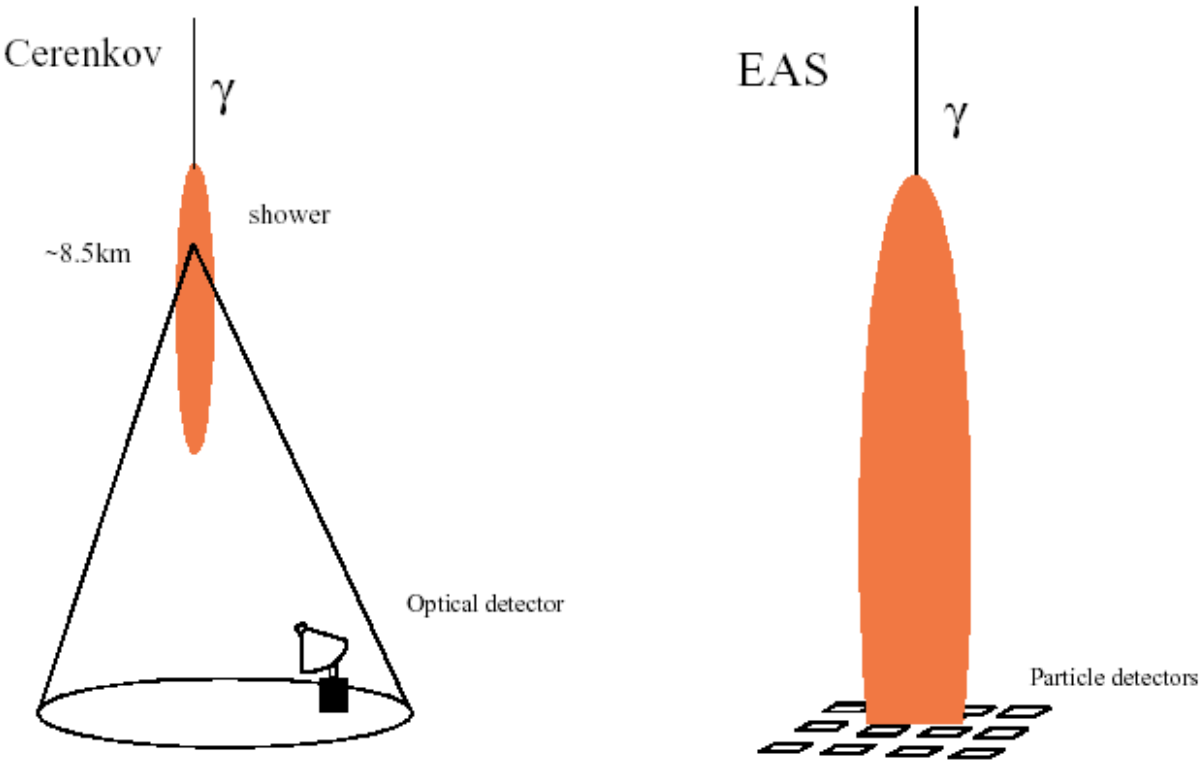
Astrofisica Nucleare e Subnucleare

TeV Astrophysics – III

TeV detectors

Cerenkov and Extensive air shower (EAS) gamma ray telescope concepts

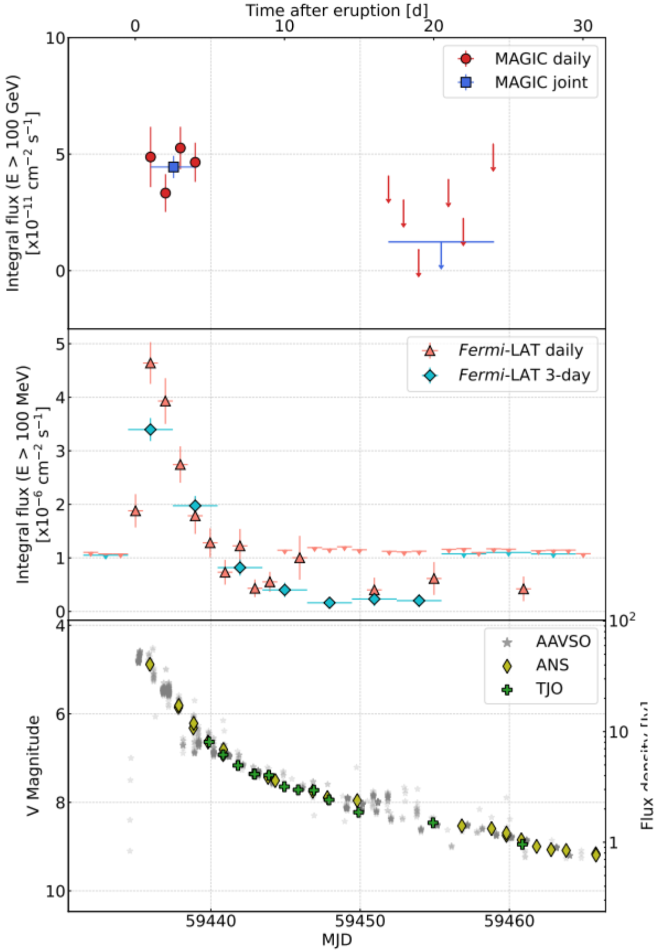


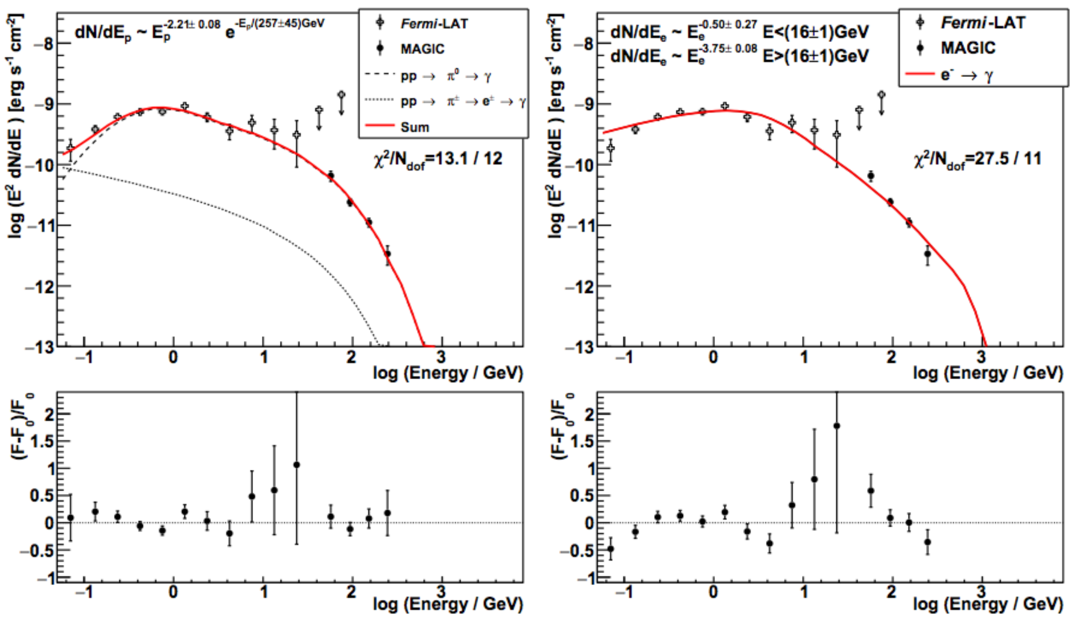
~ 40.000 m^2 , but no anticoincidence shield !

Astrofisica Nucleare e Subnucleare

VHE Galactic Sources

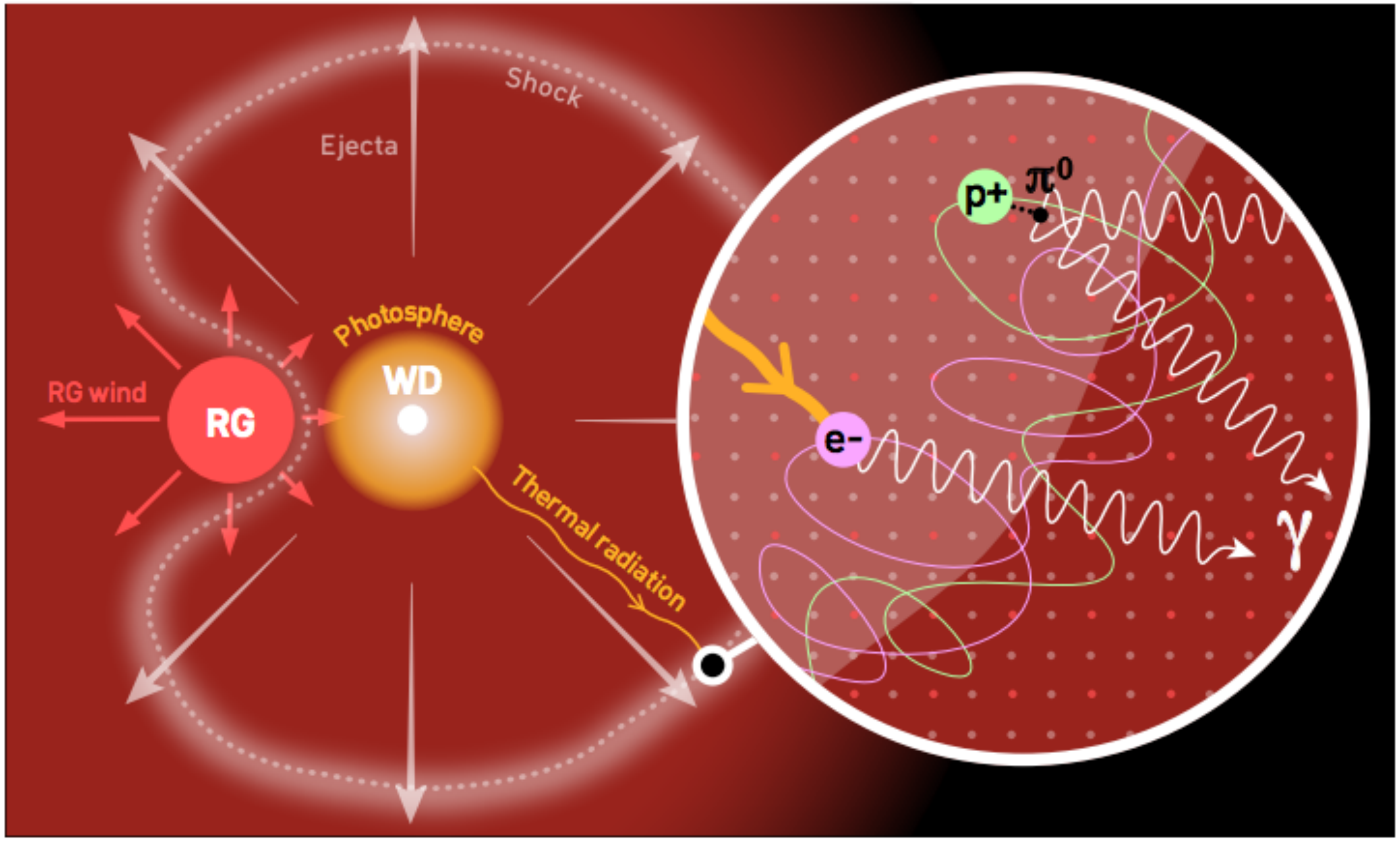
Nova in VHE gamma-rays





https://arxiv.org/pdf/2202.07681.pdf

Nova in VHE gamma-rays

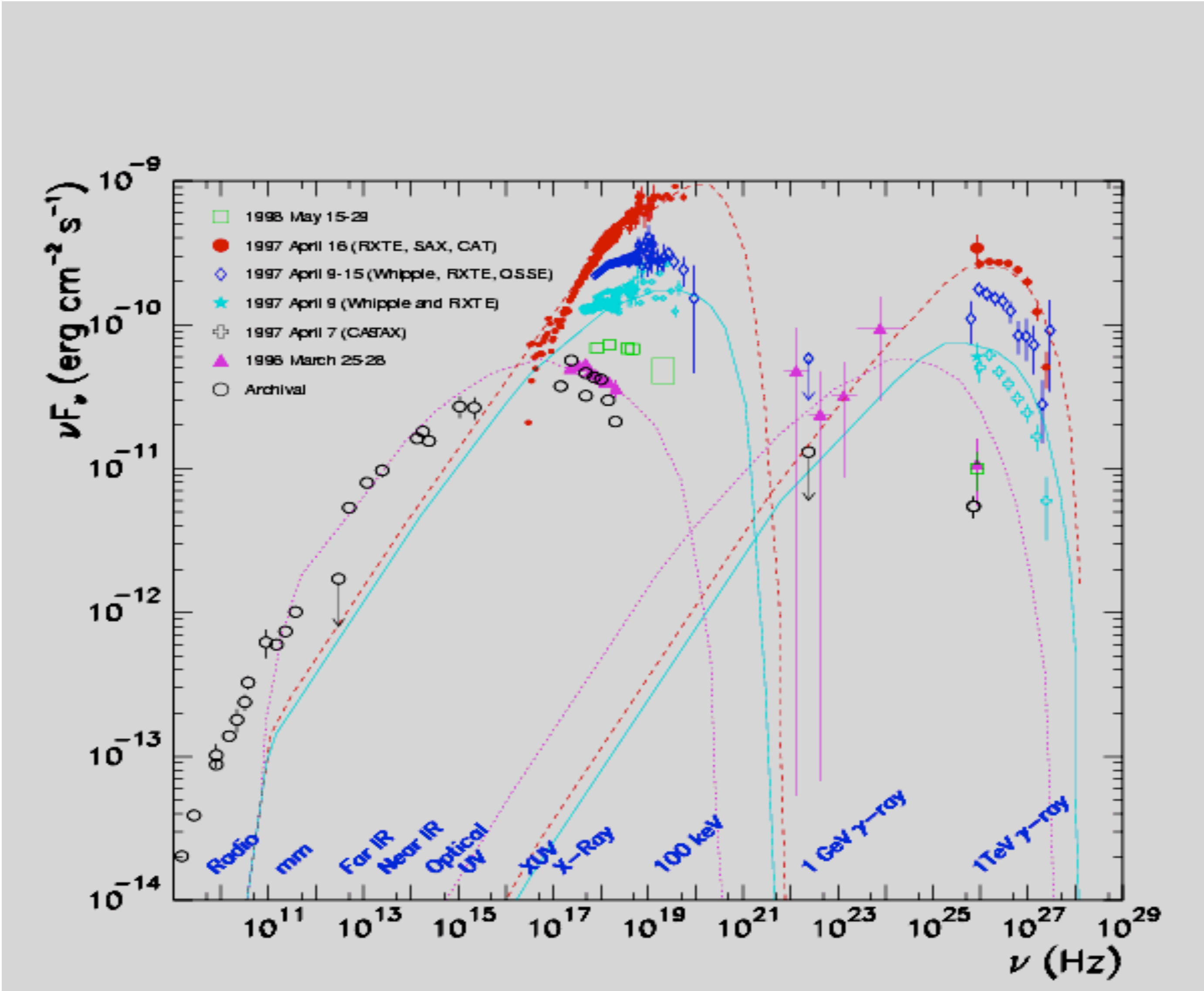


https://arxiv.org/pdf/2202.07681.pdf

Astrofisica Nucleare e Subnucleare

VHE Extra Galactic Sources

Active Galactic Nuclei

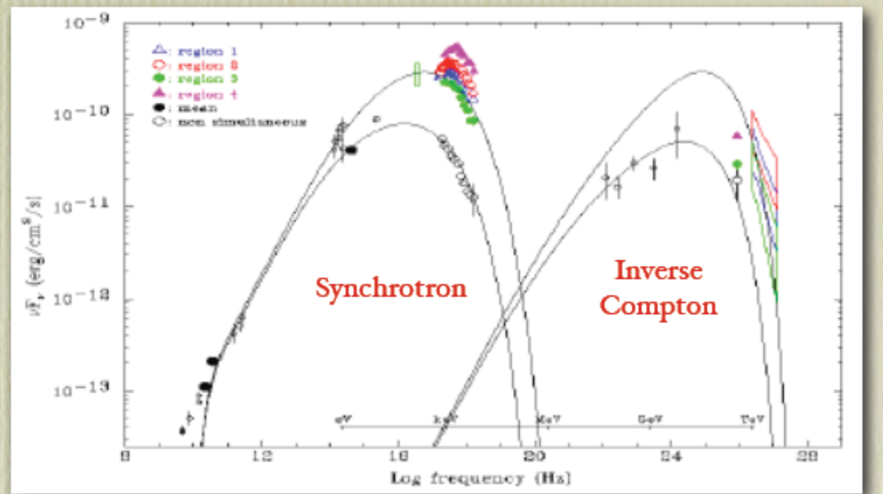


γ-ray Astronomy and Cosmic Rays

- Search for the sources of Cosmic Rays
- Investigate acceleration mechanisms
- γ-rays can be traced back to the origin

<u>Spectral Energy Distribution (SED)</u>

- characteristic two-peak structure
- competing leptonic and hadronic acceleration models.



Hadron acceleration

proton-proton interaction

p+ (TeV) + matter → π^0... → γ γ (GeV)

photo-hadron interaction

p+ (TeV) + γ (eV) → π^0... → γ γ (GeV)

Electron acceleration

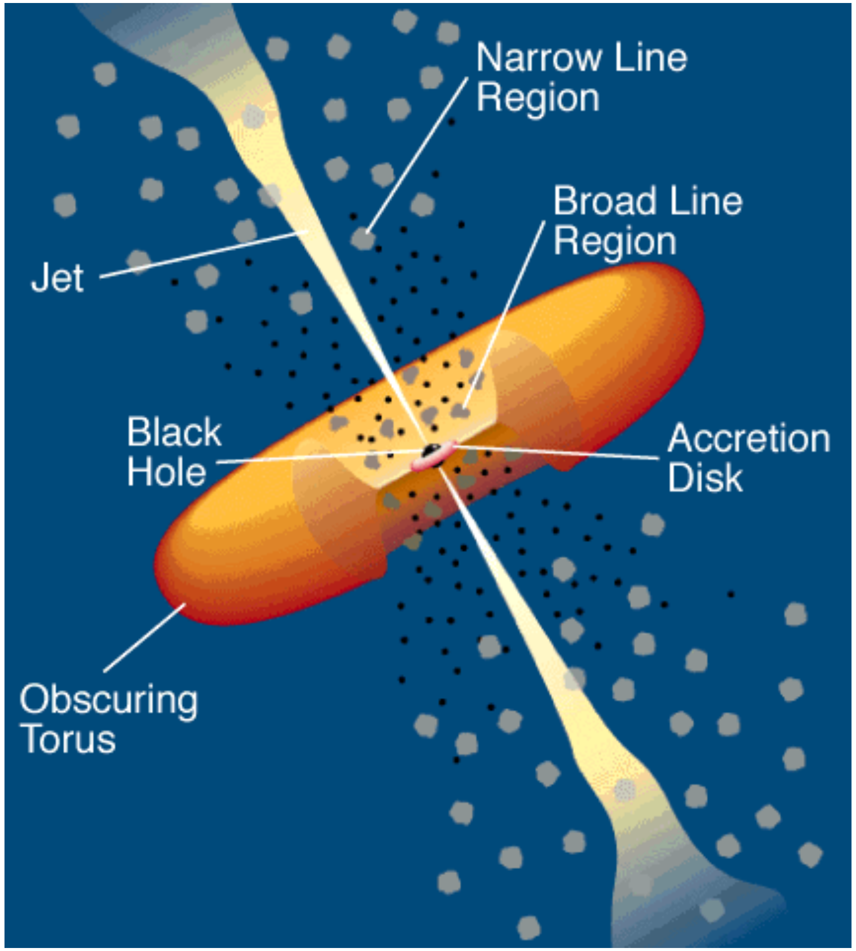
Synchrotron Radiation

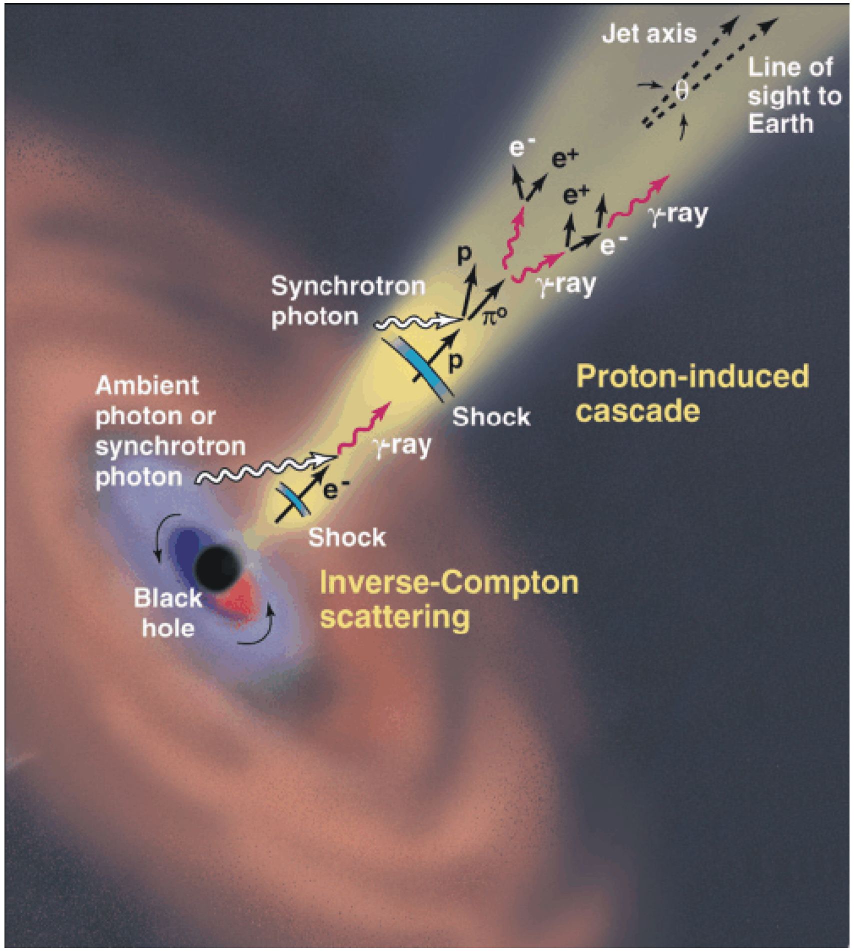
e^- + B → e^- + γ (eV-keV)

Inverse Compton Scattering

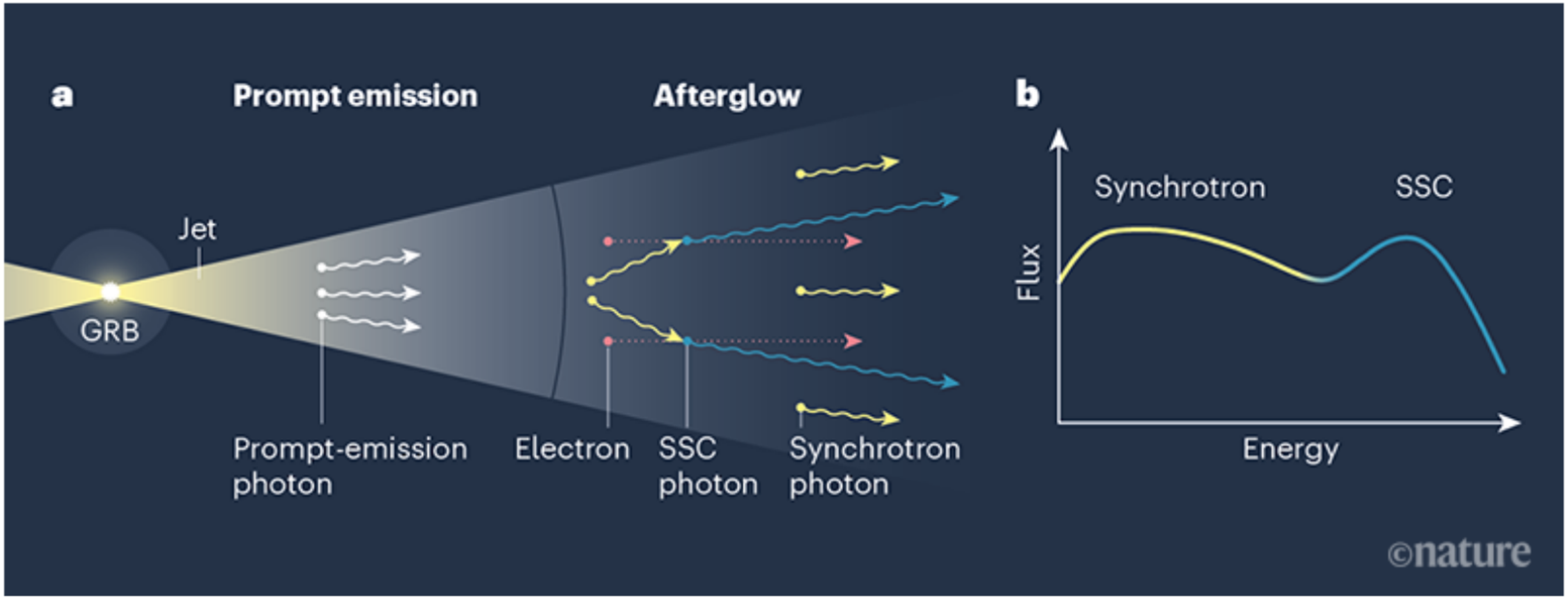
e^- (GeV) + γ (eV) → e^- + γ (GeV)

AGN model


Narrow Line Region
Broad Line Region
Jet
Black Hole
Accretion Disk
Obscuring Torus


Jet axis
Line of sight to Earth
θ
e-
e+
e+
γ-ray
e-
p
Synchrotron photon
π°
γ-ray
p
Shock
Proton-induced cascade
Ambient photon or synchrotron photon
γ-ray
e-
Shock
Black hole
Inverse-Compton scattering

MAGIC & HESS detection of GRBs

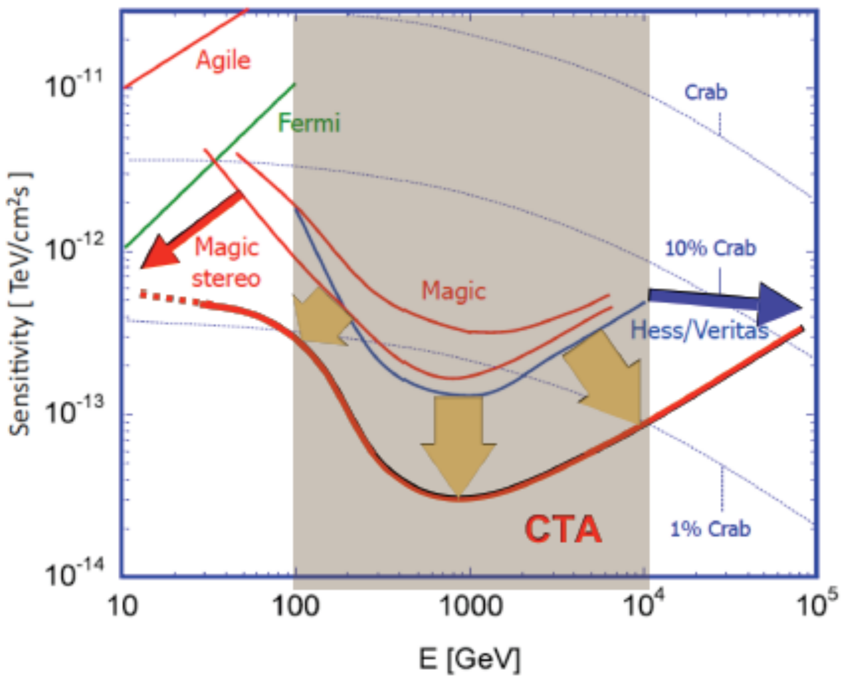


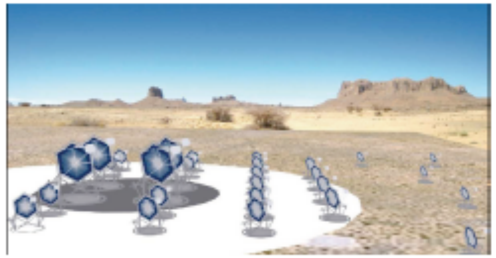
Zhang B., Nature News & Views (20/11/2019)

Astrofisica Nucleare e Subnucleare

Future detectors

CTA





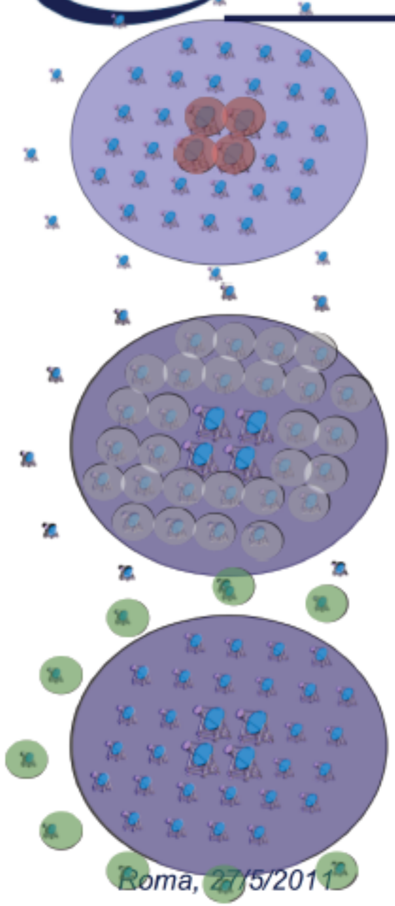
CTA will be about a factor of 10 more sensitive than any existing instrument in the 100 GeV-10 TeV energy band.

CTA will also extend the observed energy band reaching both the lower (10 GeV) and the higher (100 TeV) energies.

CTA

cta
cherenkov telescope array

CTA concept

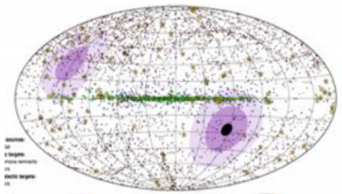


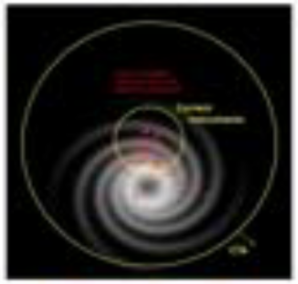
- Few Large Size Telescopes should catch the sub-100 GeV photons
  - Large reflective area
  - Parabolic profiles to maintain time-stamp
  - Contained FOV

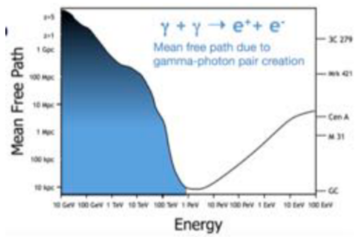
- Several Medium Size Telescopes perform 100 GeV-50 TeV observation
- well-proven techniques (HESS, MAGIC)
- goal is to reduce costs and maintenance
- core of the array
- act as VETO for LSTs

- Several Small Size Telescopes perform ultra-50 TeV observation
- challenging design
- Large field-of-view (8°)
- New camera technology

Design drivers

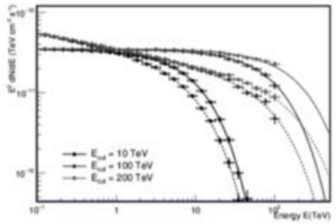






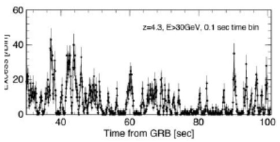
Full sky coverage

10 x sensitivity



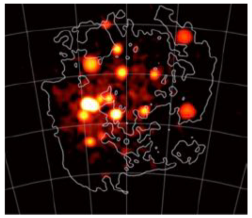
Energies down to 20 GeV

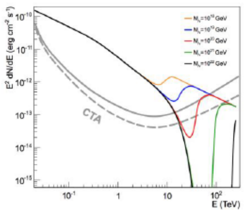
Energies up to 300 TeV



Rapid slewing 20 sec

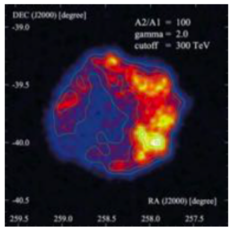
~ 10° FoV



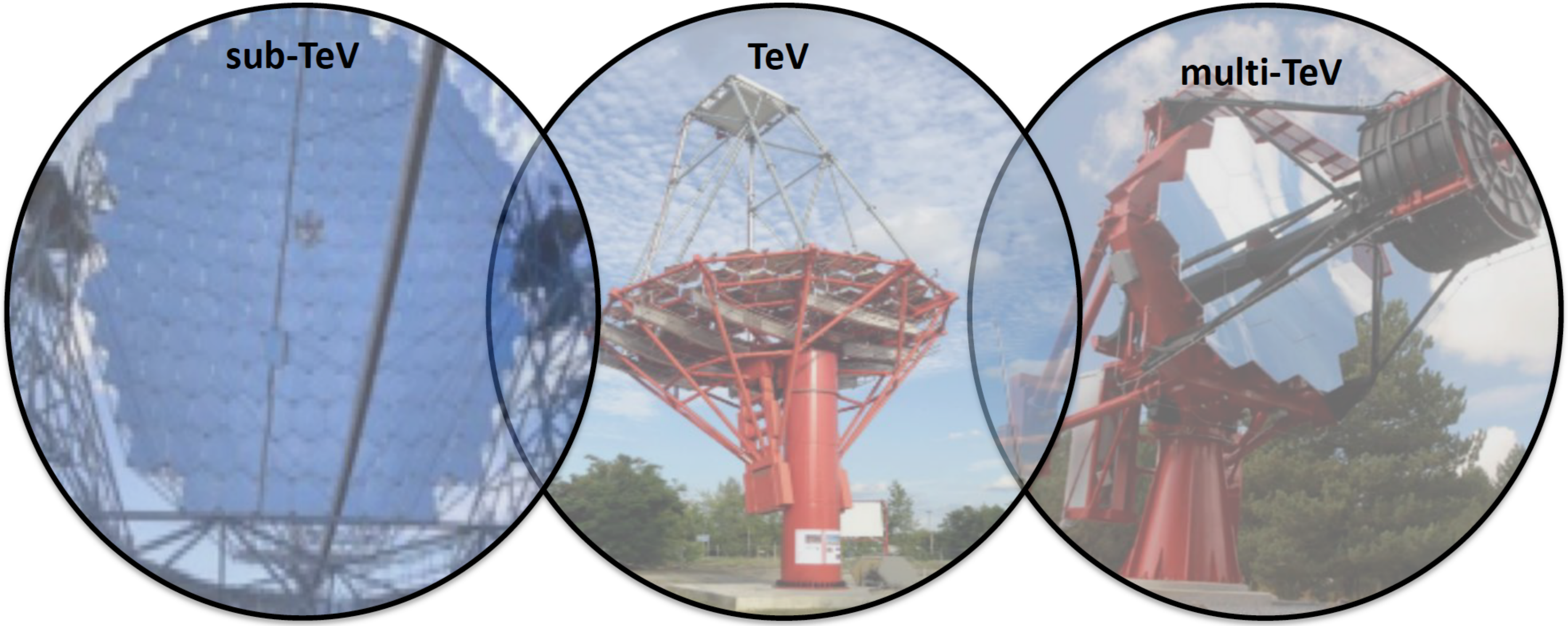


10% energy resolution

arcmin angular resolution



Science cases and design

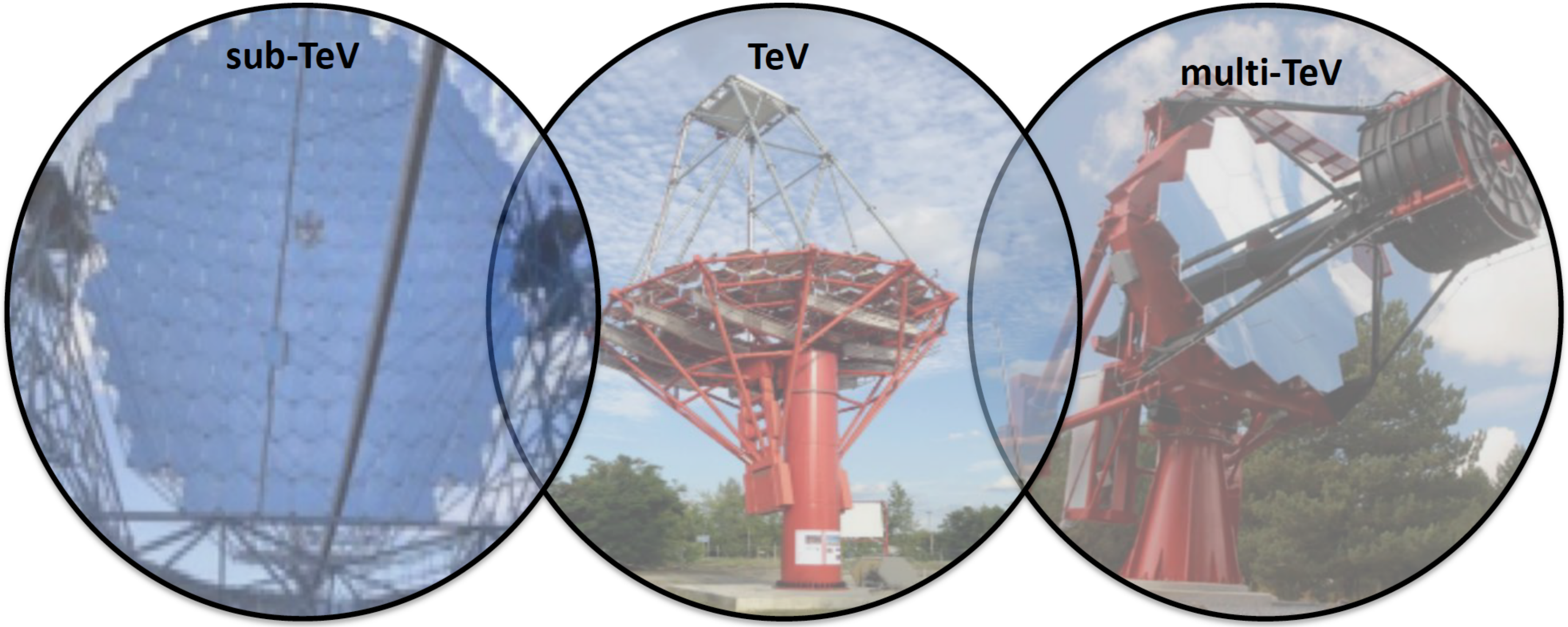


- Parabolic optical design
- 23 m mirror diameter
- PMT camera

- Davies-Cotton optical design
- 12 m mirror diameter
- PMT camera

- Schwarzschild-Couder optical design
- 4 m dual mirror
- SiPM T camera

Science cases and design



- Lowest energies (tens of GeV)
  → **cosmological sources**
- Deepest sensitivity for short timescale phenomena
  → **Time domain unexplored**

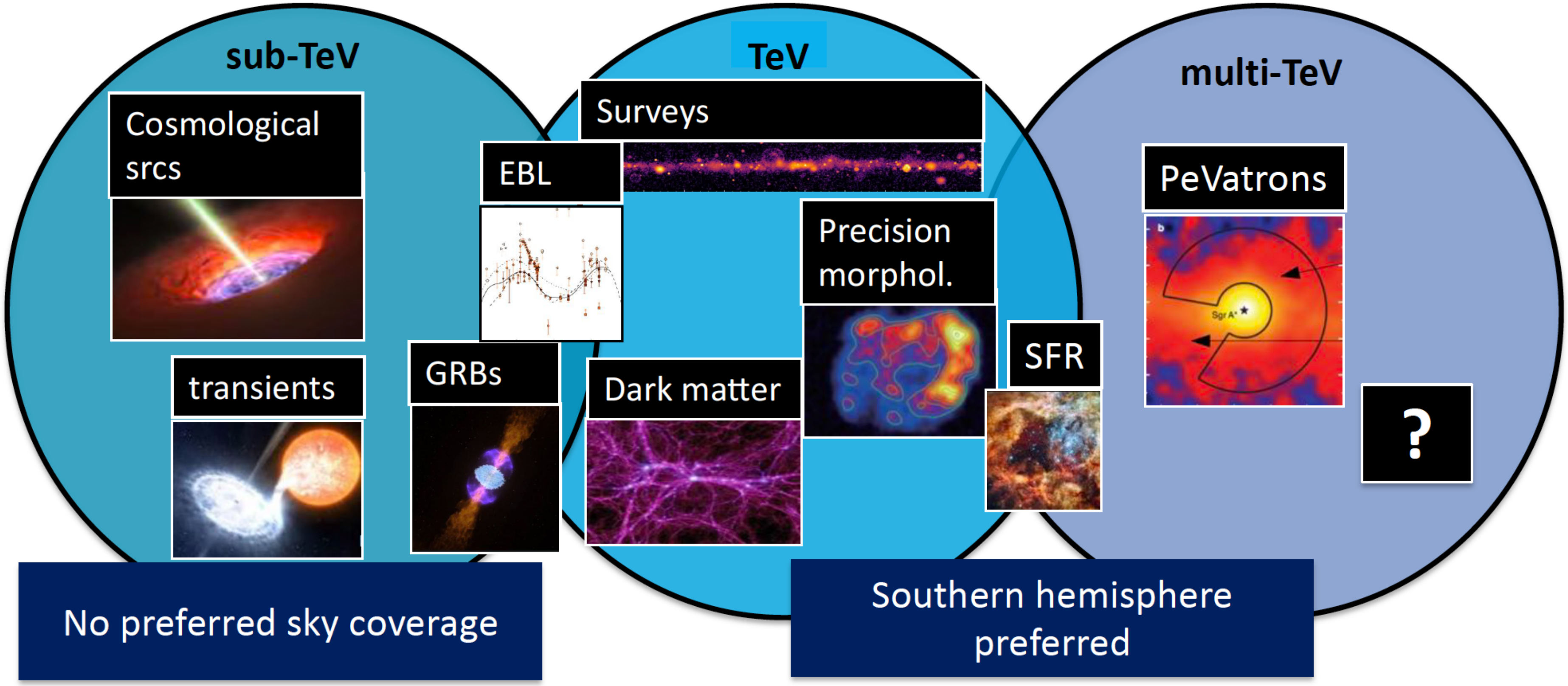
- deepest sensitivity ever
- arcmin angular resolution
- large FoV

- Surveys & precision studies

- Precision measurements in a still little explored energy range

- **100 TeV range unexplored**
- **precision studies**

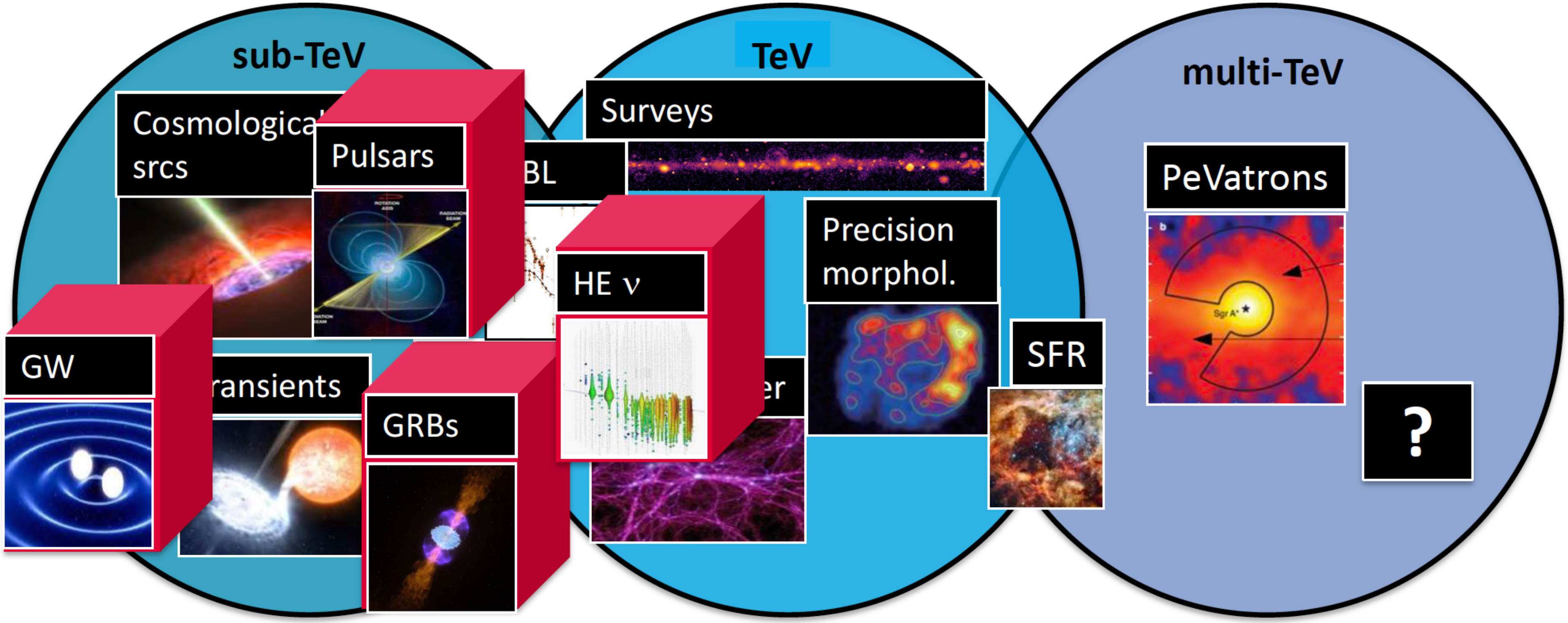
Science cases



- **Mainly CTA consortium involved in the definition of the science cases**

(Science with CTA, CTA Consortium 2019 - https://doi.org/10.1142/10986)

Science cases



- **Mainly CTA consortium involved in the definition of the science cases**

(Science with CTA, CTA Consortium 2019 - https://doi.org/10.1142/10986)

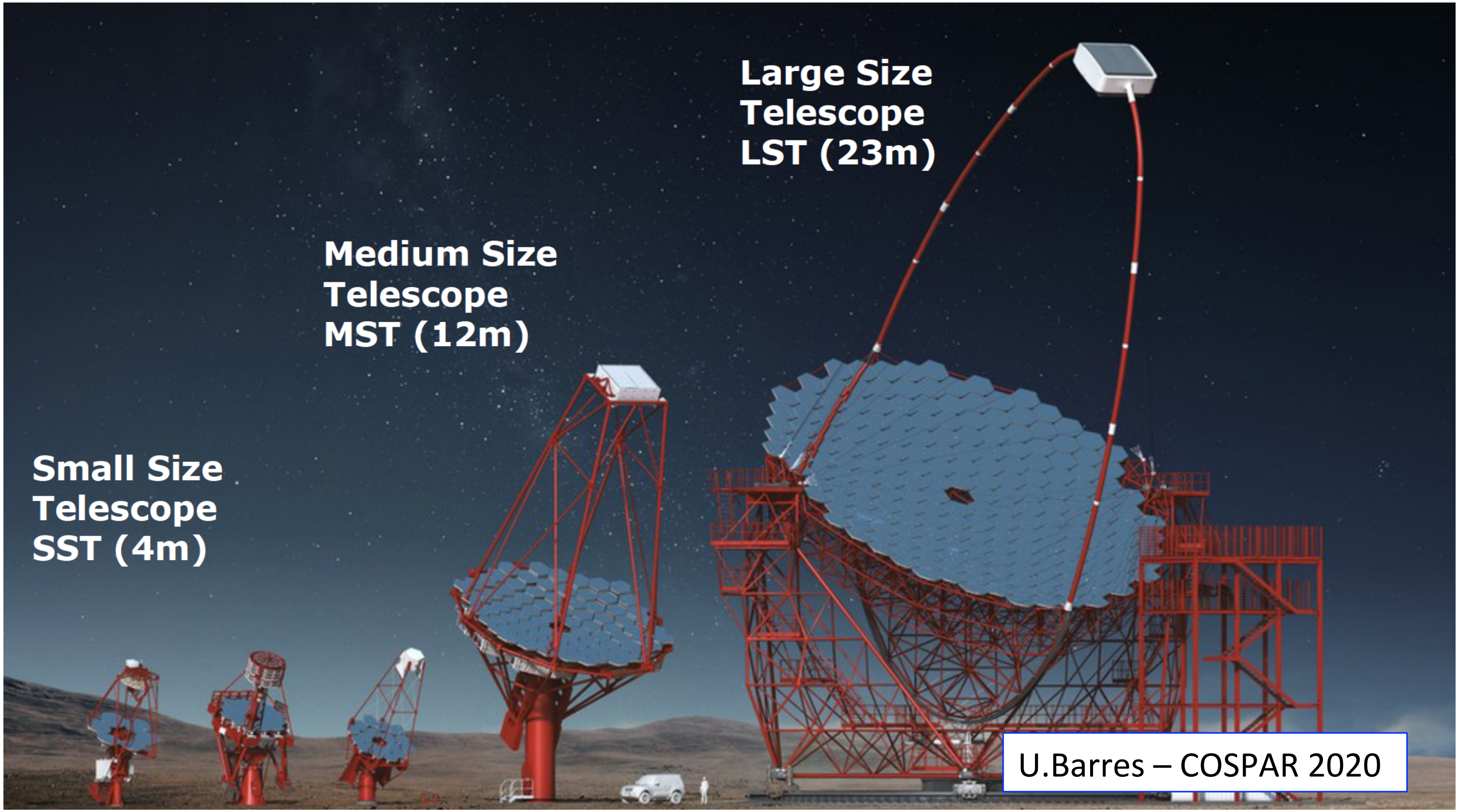
The CTA Sites

A Global Observatory…

U.Barres – COSPAR 2020

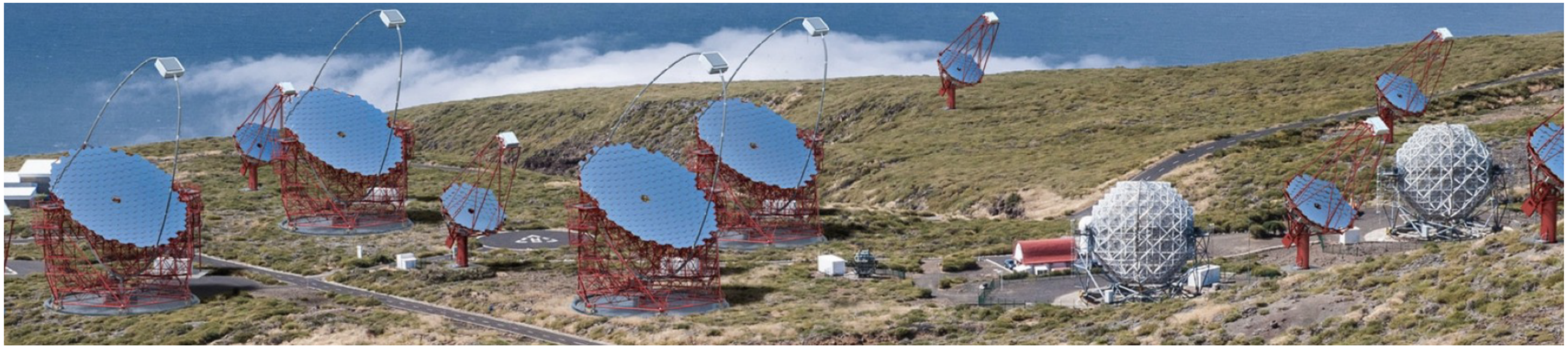
The CTA Telescopes

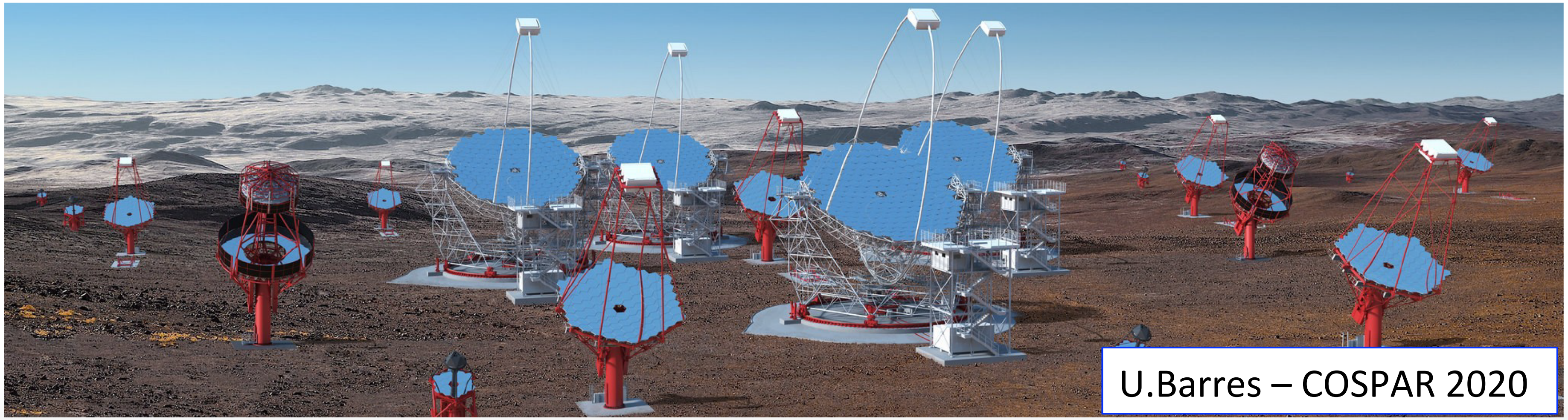
A Hybrid Observatory…



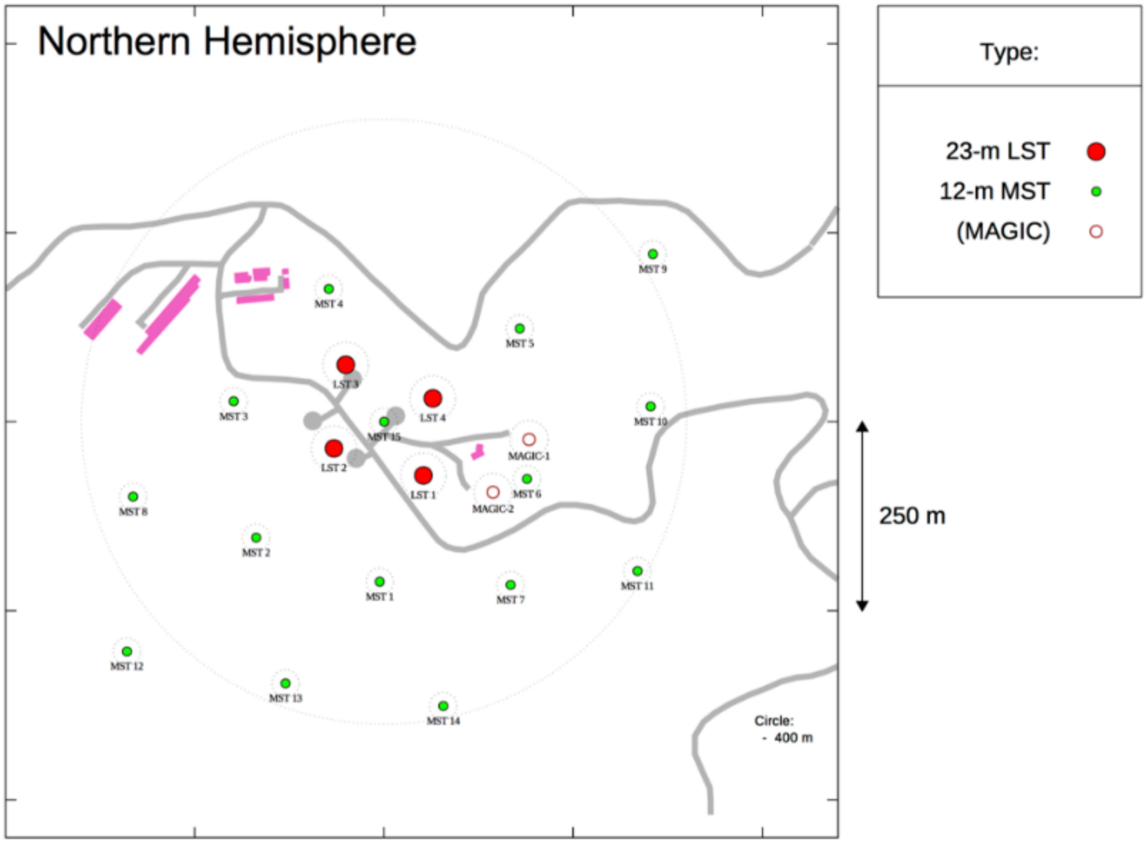
CTA North & CTA South

Phase 1		CTA Construction
Northern Array	Number of LSTs	4
	Number of MSTs	5
Southern Array	Number of LSTs	0
	Number of MSTs	15
	Number of SSTs	50
Total		74





CTA - North

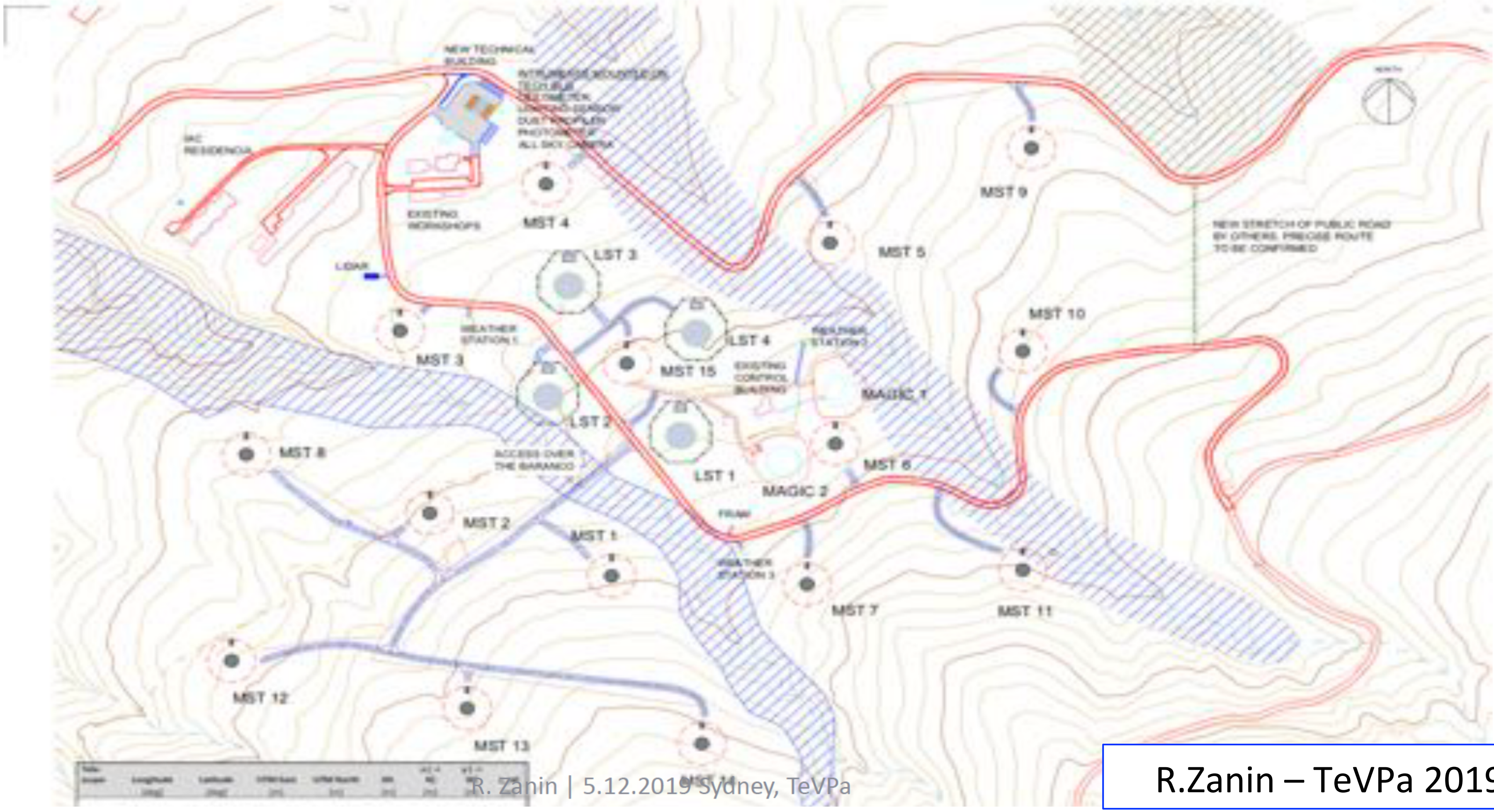


4 LS4 LSTs, 15 MSTs

https://www.cta-observatory.org/science/cta-performance/

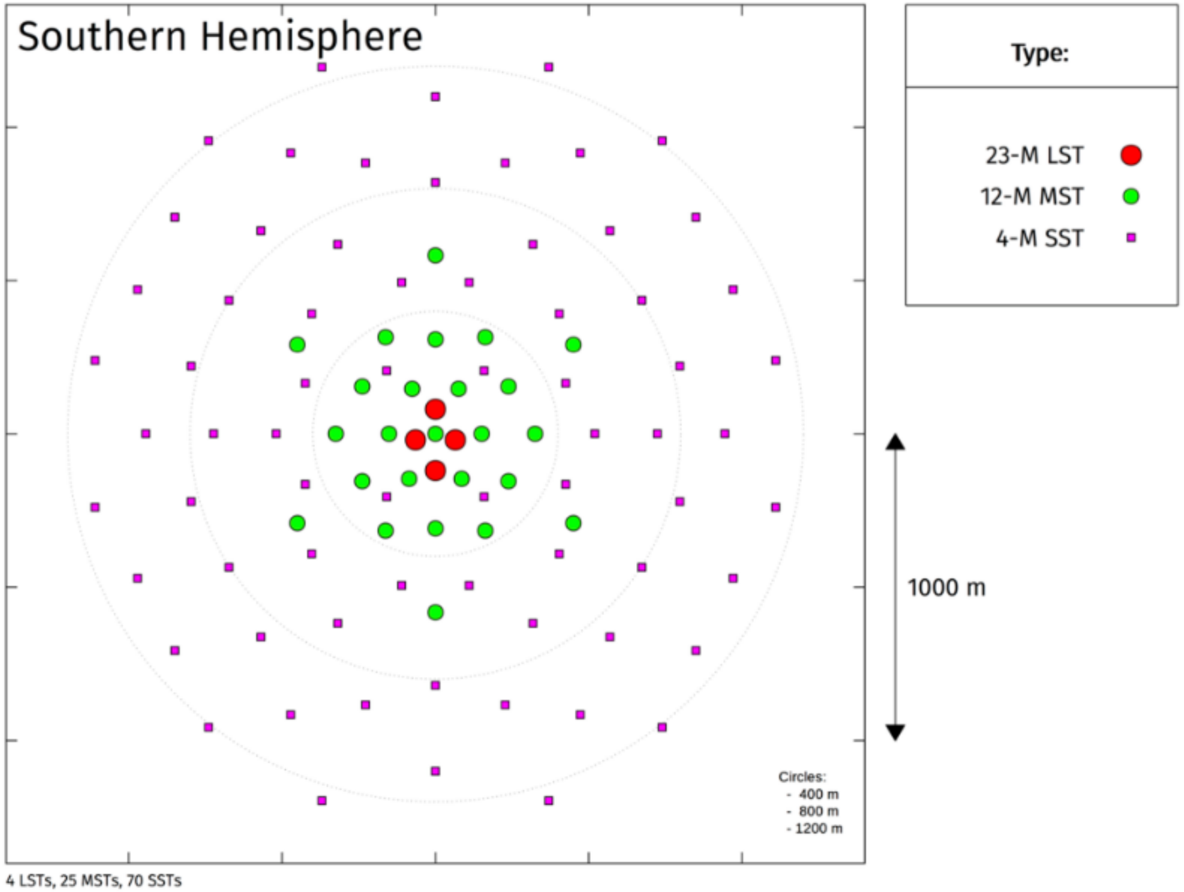
CTA-North site

- **4 LSTs + 15 MSTs (baseline configuration)**
  - **Focus on sub-TeV and TeV energy range**



R.Zanin – TeVPa 2019

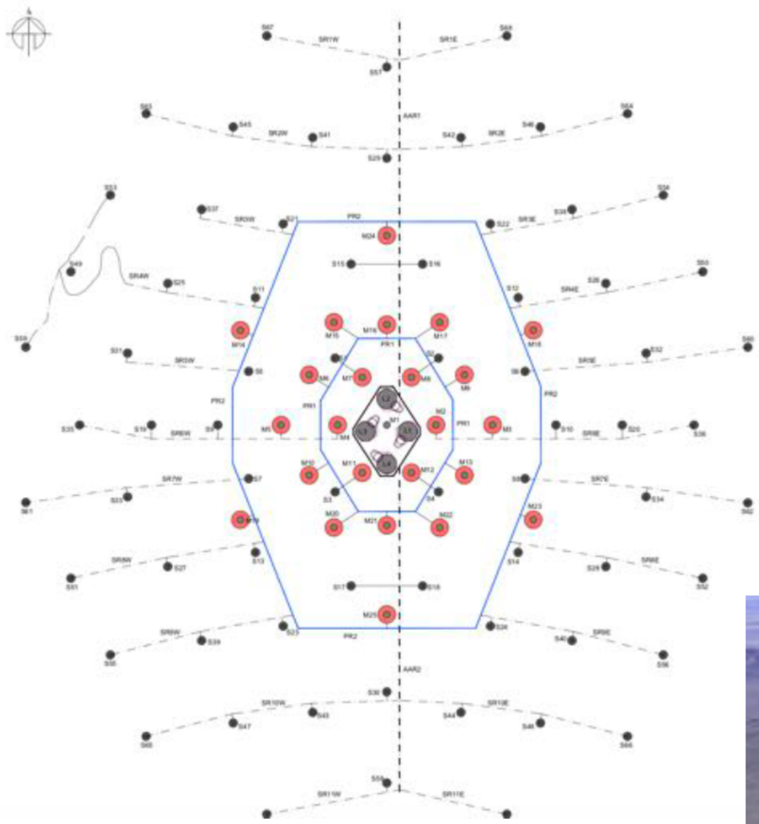
CTA – South



https://www.cta-observatory.org/science/cta-performance/

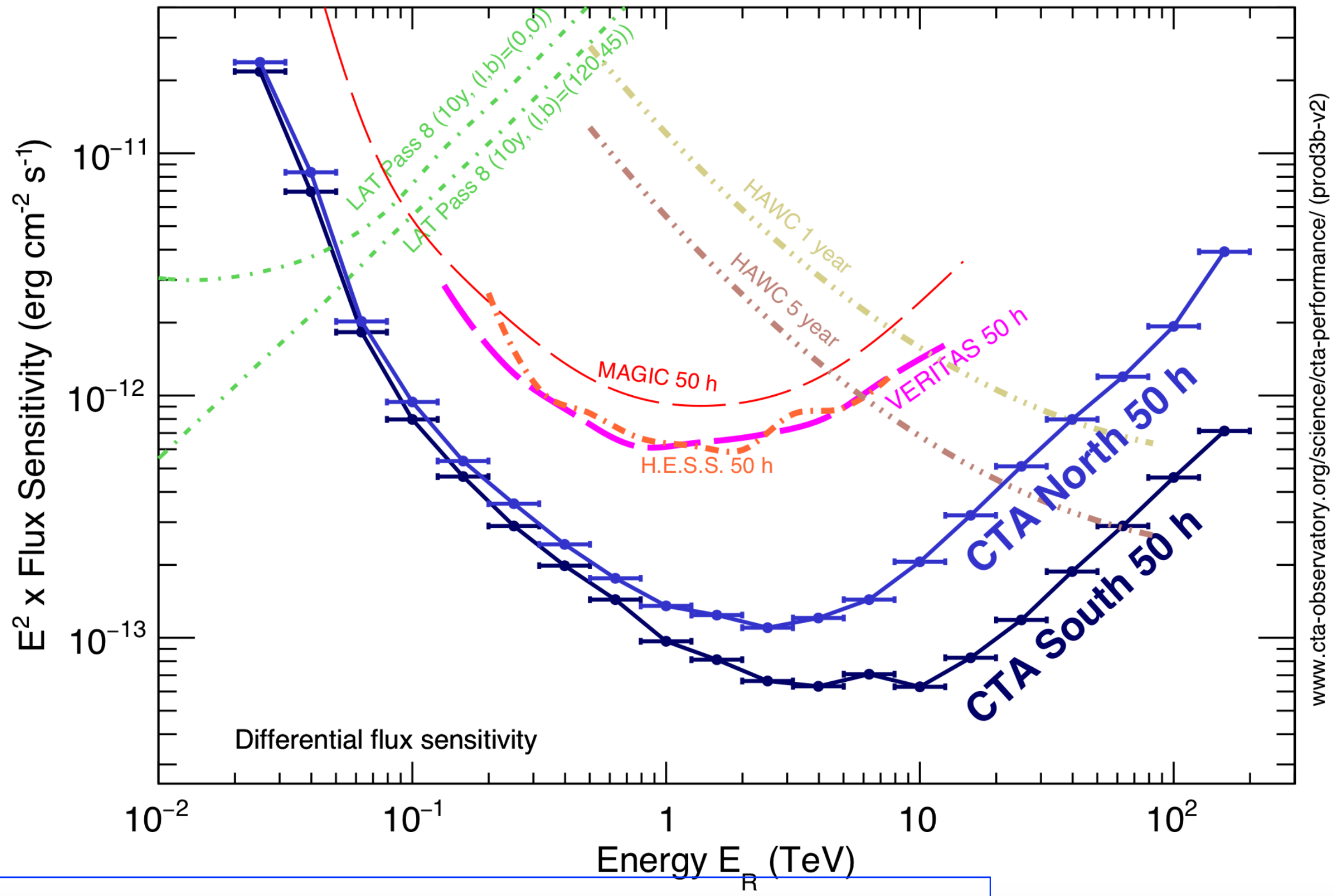
CTA-South site

- **4 LSTs + 25 MSTs + 70 SSTs (baseline-configuration)**



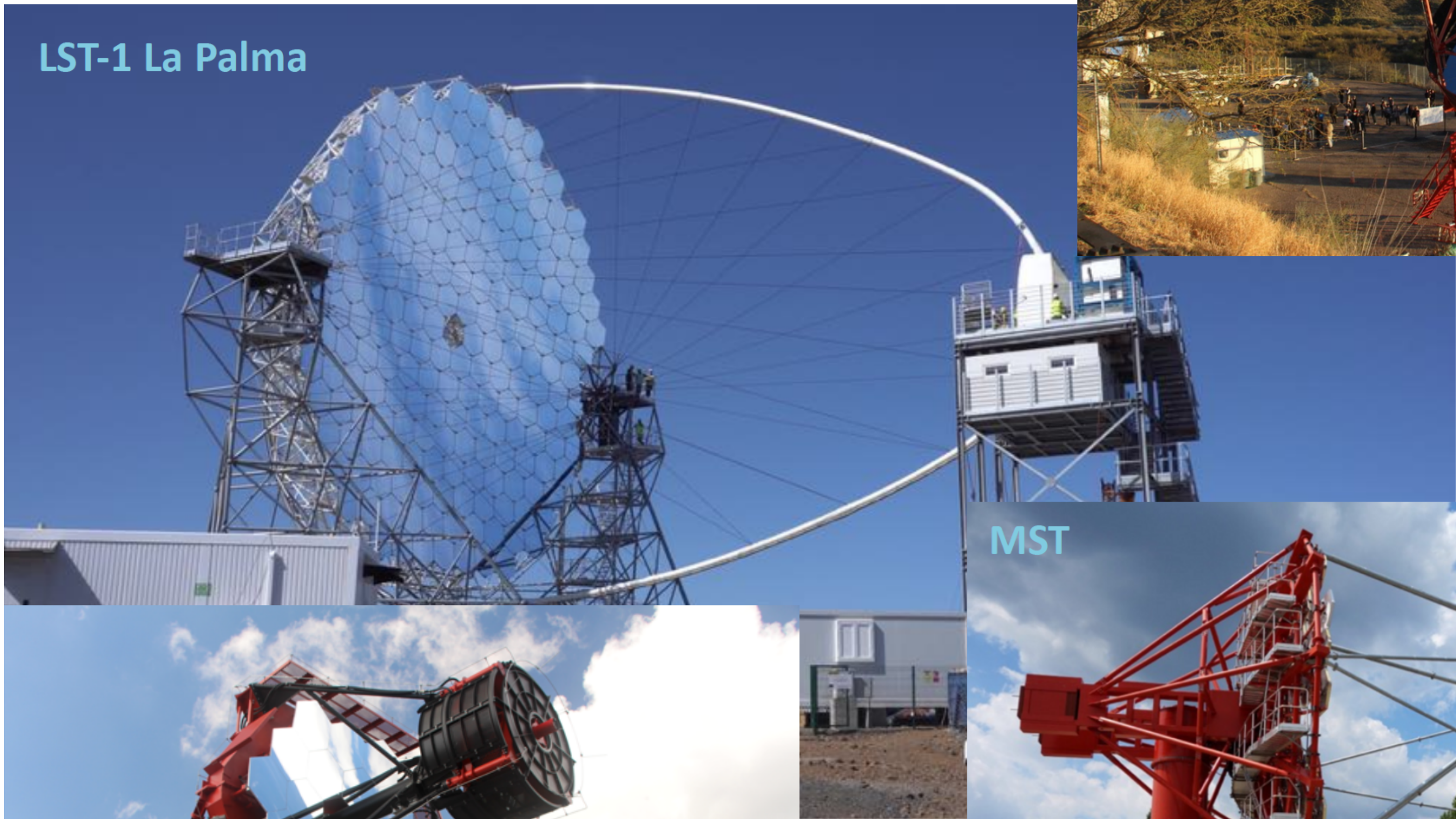
- **Site agreement signed in Dec 2018**
- **Aim to start with site infrastructure construction soon**

CTA performance



https://www.cta-observatory.org/science/cta-performance/

The CTA Telescopes



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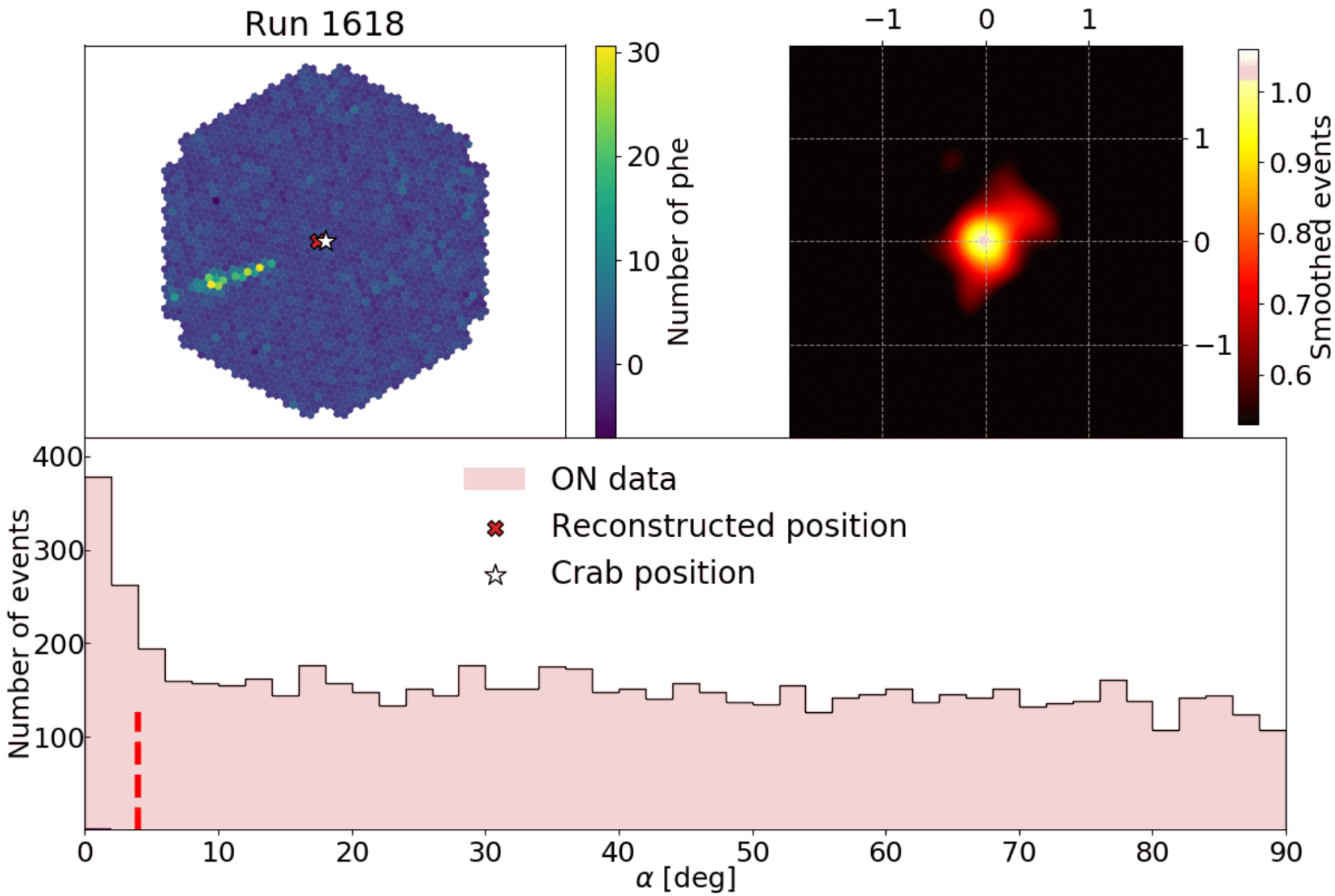
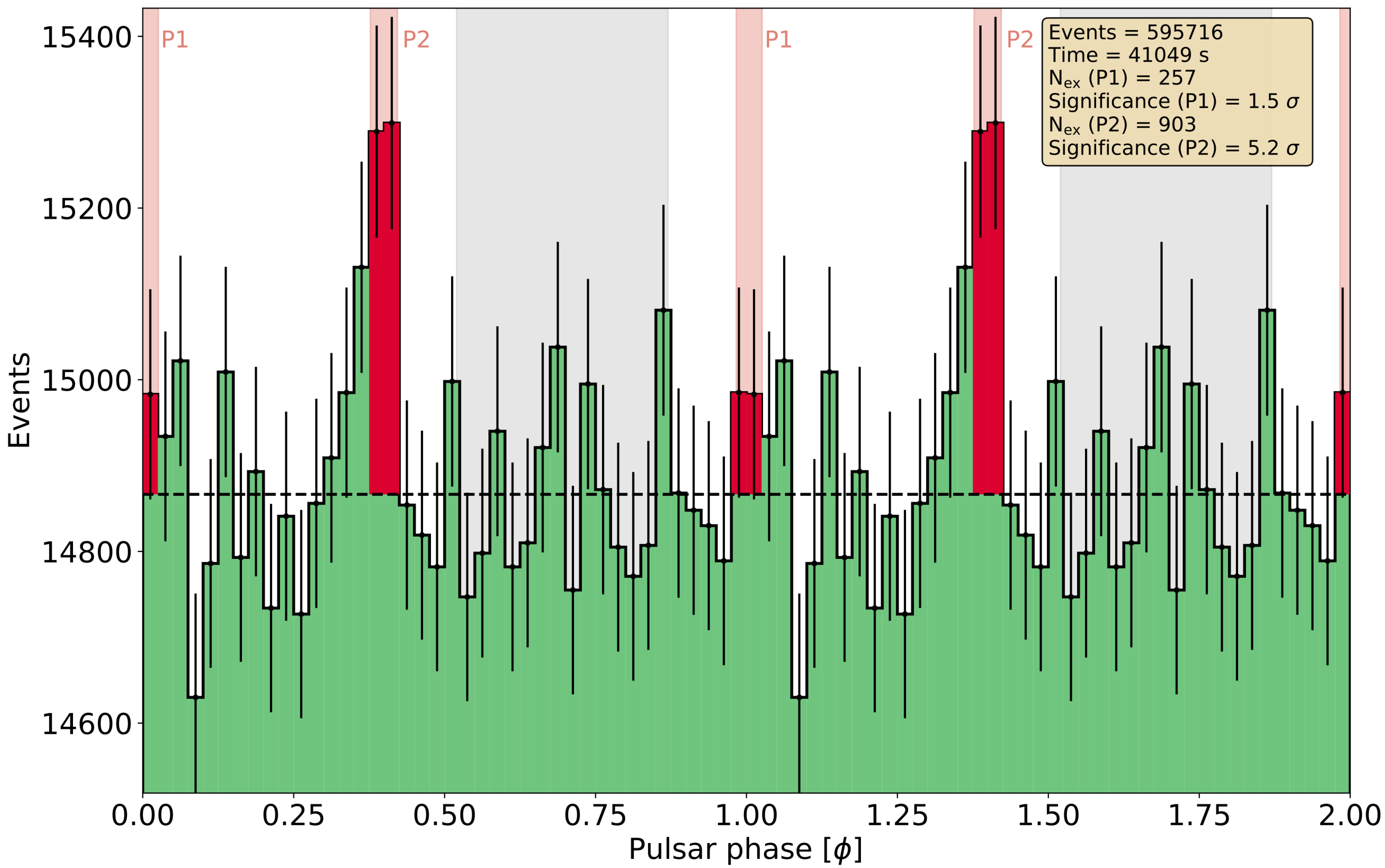
CTA telescopes – first results



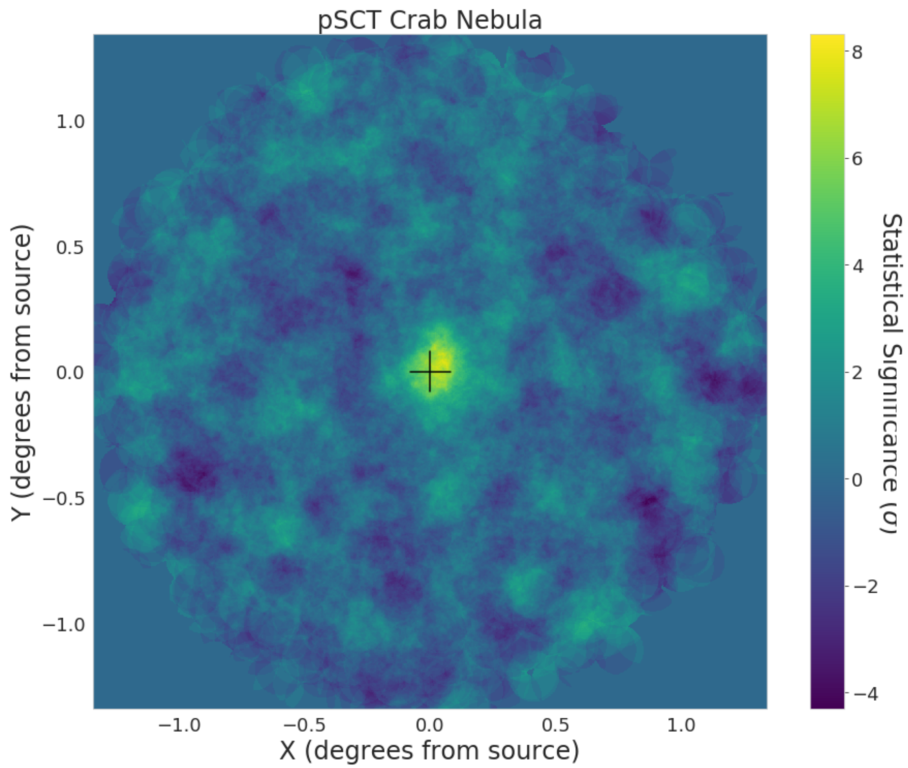
https://www.cta-observatory.org/lst1-detects-first-gamma-ray-signal/

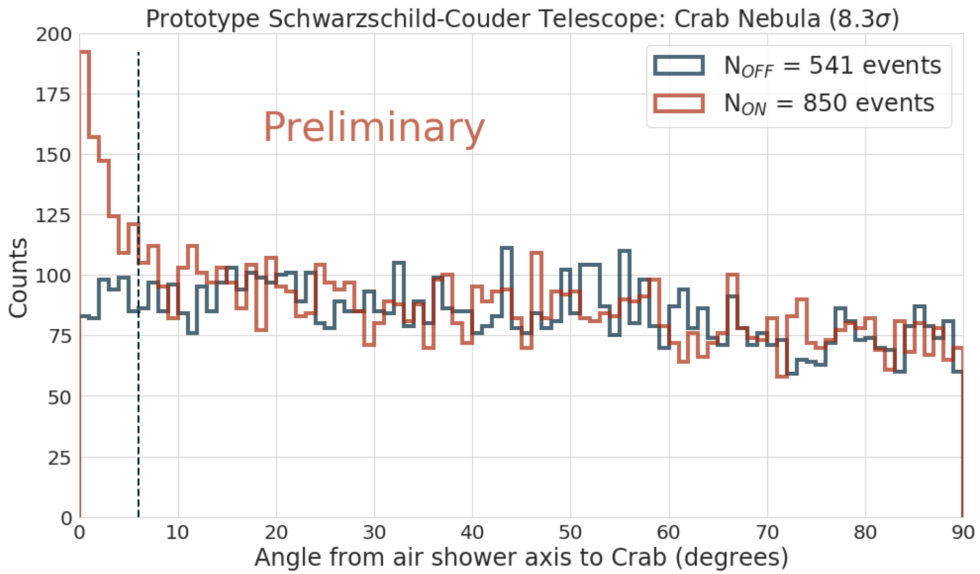
CTA telescopes – first results



https://www.cta-observatory.org/lst1-detects-vhe-emission-from-crab-pulsar/

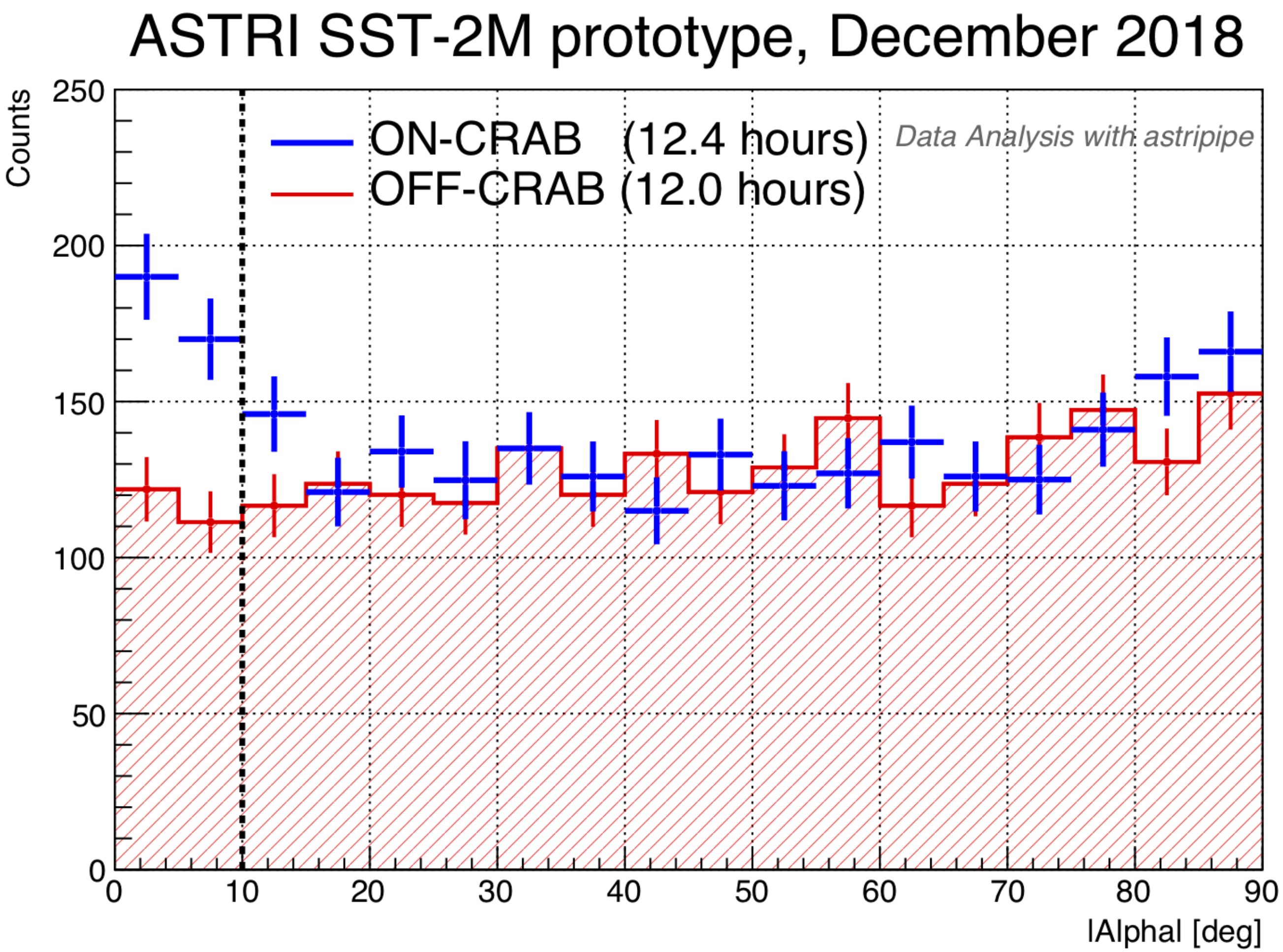
CTA telescopes – first results





https://www.cta-observatory.org/sct-detects-

CTA telescopes – first results



https://www.cta-observatory.org/astri-detects-crab-at-

CTA telescopes – first LST ATEL

https://astronomerstelegram.org/?read=14783

Detection of very-high-energy gamma-ray emission from BL Lac with the LST-1

ATel #14783; ***Juan Cortina for the CTA LST collaboration***

*on **13 Jul 2021; 21:03 UT***

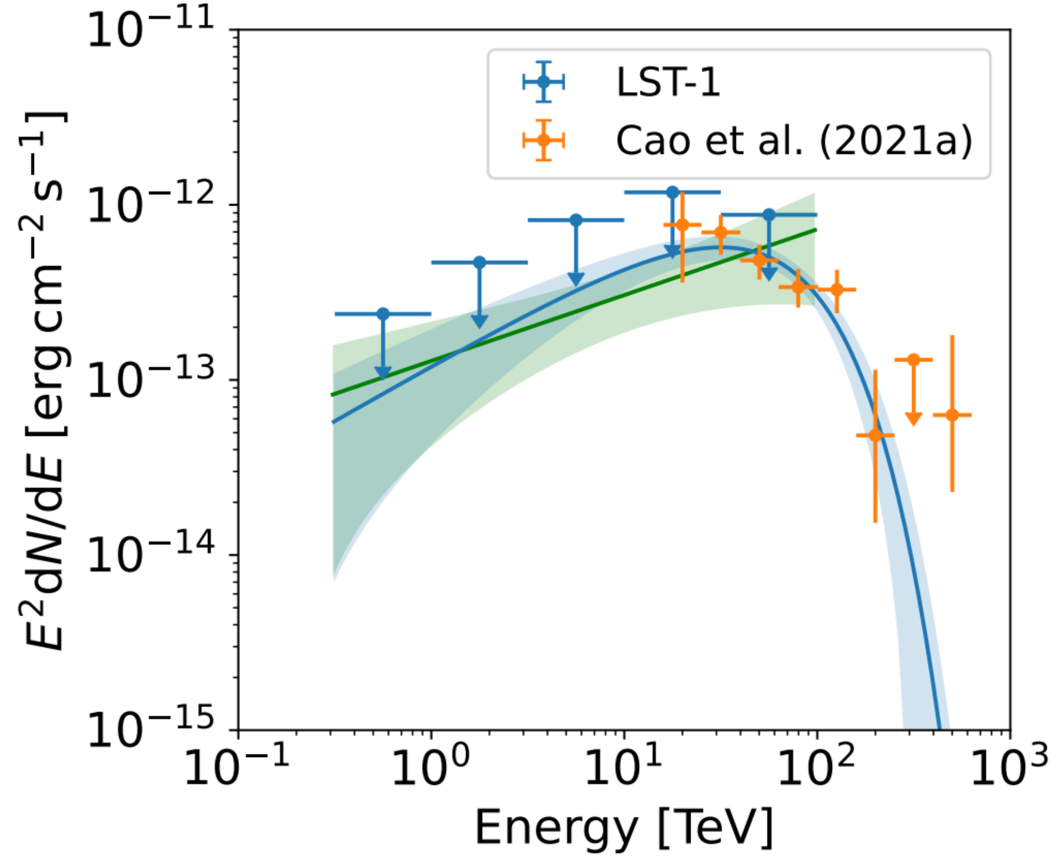
Credential Certification: Juan Cortina (Juan.Cortina@ciemat.es)

Subjects: TeV, VHE, Request for Observations, AGN, Blazar, Transient

Referred to by ATel #: 14820, 14826, 14839

The LST-1 telescope has observed an increase in the very-high-energy (VHE; >100 GeV) gamma-ray flux from BL Lacertae (RA=22:02:43.3, DEC=+42:16:40, J2000.0). The preliminary offline analysis of the LST-1 data taken on 2021/07/11 (MJD 59406), triggered by an increase of the optical flux (see ATEL #14773 and references therein), has been detected with a significance of 8 sigma with a differential flux of 1.3 +/- 0.2 10^-9 cm-2 s-1 TeV-1 (25% of the Crab Nebula) at 100 GeV. Note though that this is the result of a quick-look analysis and the data were taken under non-optimal weather conditions (atmospheric transmission at 9km of ~50-60%), hence this flux measurement is a lower bound on the true flux. The LST-1 observations were performed during commissioning which began in 2018. LST-1 is a prototype of the Large-Sized Telescope for the Cherenkov Telescope Array, and is located on the Canary island of La Palma, Spain. The LST-1 is designed to perform gamma-ray astronomy in the energy range from 20 GeV to 3 TeV. LST-1 observations on BL Lacertae will continue during the next few nights, multi-wavelength observations are encouraged. The preliminary offline analysis has been performed by Daniel Morcuende (dmorcuen@ucm.es) and Ruben Lopez-Coto (ruben.lopezcoto@pd.infn.it). The LST-1 contact persons for these observations are Masahiro Teshima (mteshima@mpp.mpg.de) and Juan Cortina (juan.cortina@ciemat.es).

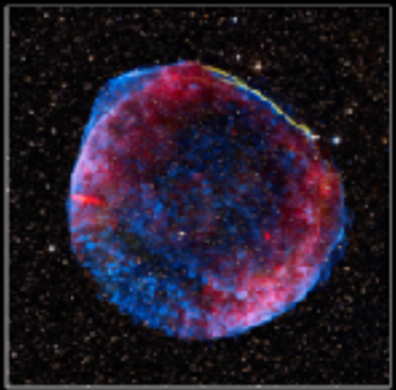
CTA telescopes – first LST paper

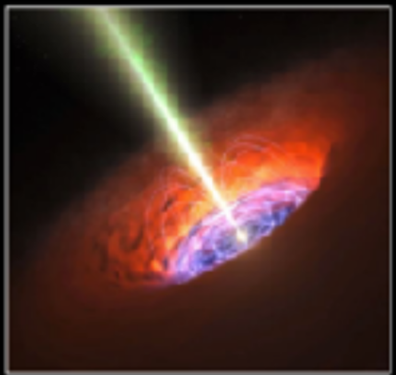


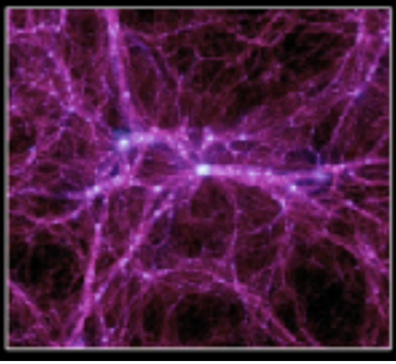
https://arxiv.org/pdf/2210.00775.pdf

https://www.cta-observatory.org/lst-collaboration-publishes-first-scientific-paper/

Astrophysics with IACTs







- **COSMIC PARTICLE ACCELERATION**

What are the sites and mechanisms of particle acceleration in the cosmos?

- **EXTREME ASTROPHYSICAL ENVIRONMENTS**

The physics of neutron stars, black holes and their energetic environments, such as relativistic jets, winds and stellar explosions.

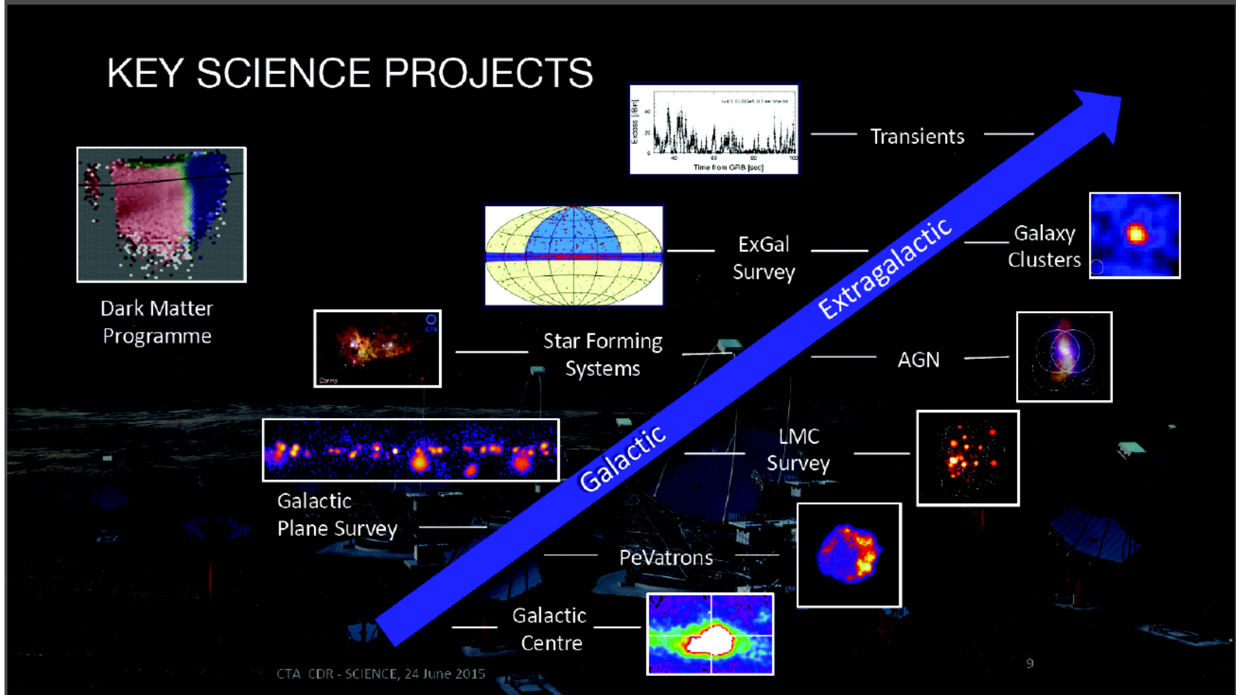
- **FUNDAMENTAL PHYSICS FRONTIERS**

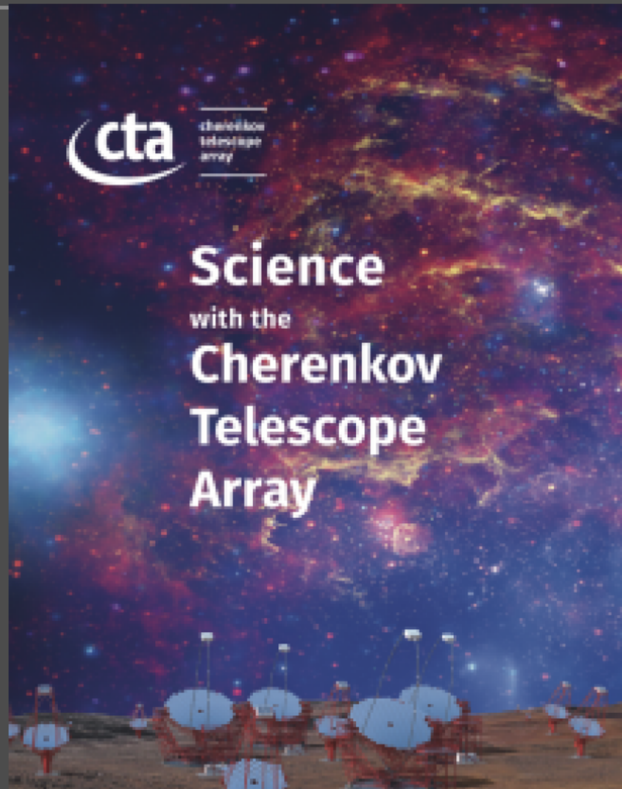
Probing the nature of Dark Matter, the existence of axion-like particles, and Lorentz invariance violation

CTA's Science

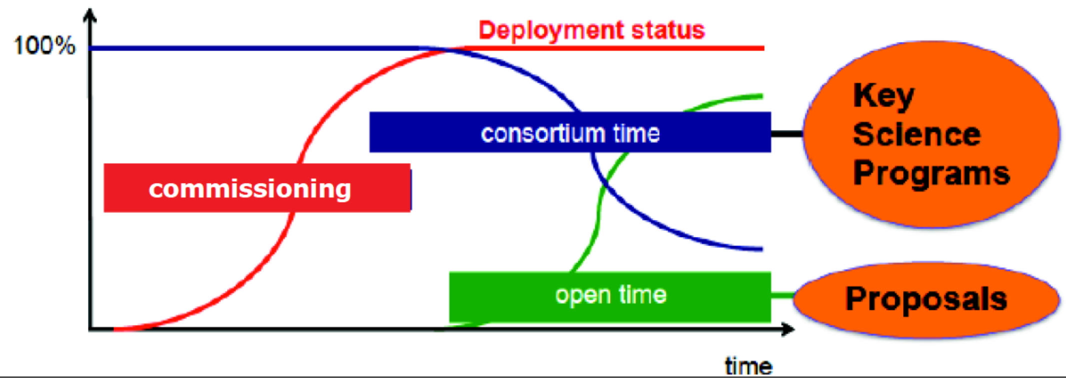
Key Science Projects: ~40% of observing time in first 10 yrs devoted to major projects.

https://www.worldscientific.com/worldscibooks/10.1142/10986





G. Rowell – COSPAR 2020



Signficant multi-wavelength support needed.

e.g optical/radio coverage > 500 hr/yr

The Science of CTA

CTA will target major science questions in high-energy astrophysics, through a large observational programme.

Sky Surveys

- Galactic and X-Gal Scan
- Dark Matter Programme
- Magellanic Clouds

Deep Targeted Observations

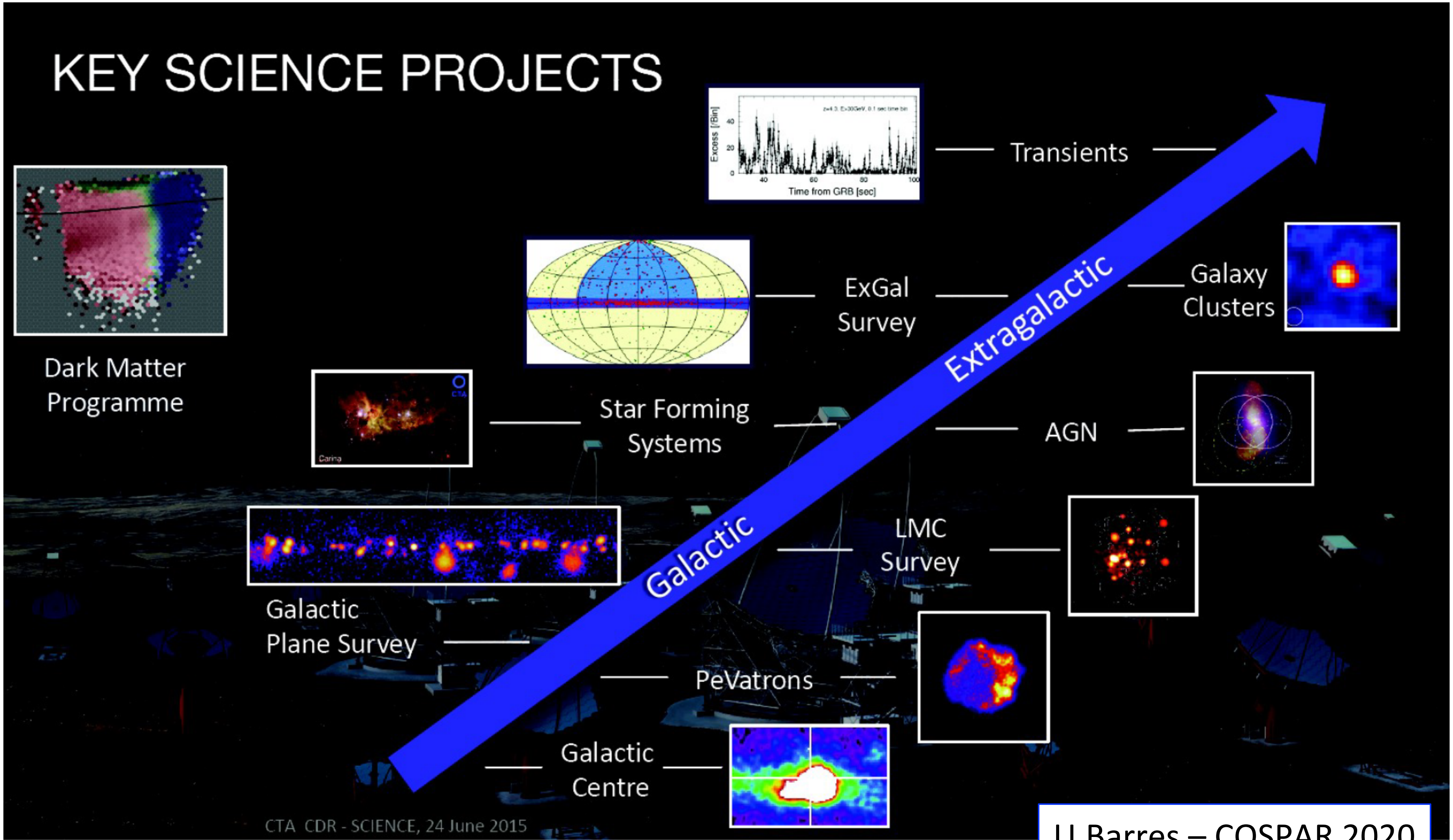
- PeVatrons
- Star-forming Systems
- Radio Galaxies & Clusters

Follow-ups of Transient and Multi-messenger events

Monitoring of Variability notably of AGN

U.Barres – COSPAR 2020

A Census of particle accelerators across all cosmic scales



U.Barres – COSPAR 2020

Science with CTA

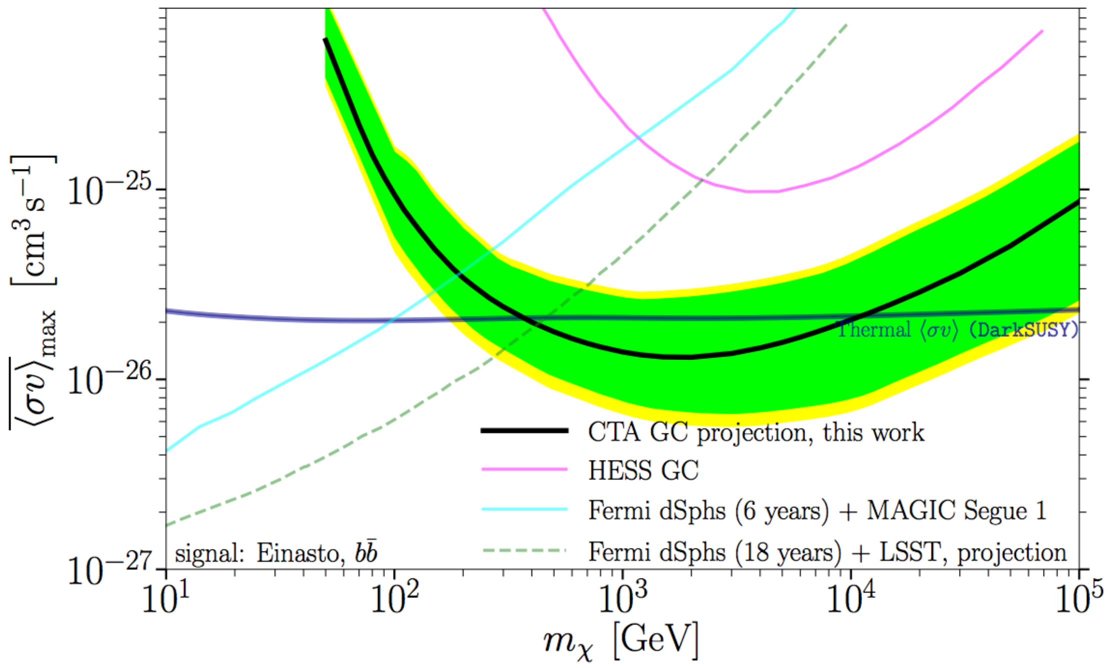
CTA will have important synergies with many of the new generation of major astronomical and astroparticle observatories. Multi-wavelength and multi-messenger approaches combining CTA data with those from other instruments will lead to a deeper understanding of the broad-band non-thermal properties of target sources, elucidating the nature, environment, and distance of gamma-ray emitters. Details of synergies in each waveband are presented.

https://arxiv.org/abs/1709.07997

The Dark Matter Programme

Comparison with other experiments

- The GC and Halo provide the most promising sites for CTA Dark Matter searches
- Over 500 h planned observation time at the GC
- CTA will complement data from direct DM detection and other indirect experiments in the energy range of 10s of TeV



U.Barres – COSPAR 2020

arXiv:2007.16129

Dark Matter with CTA

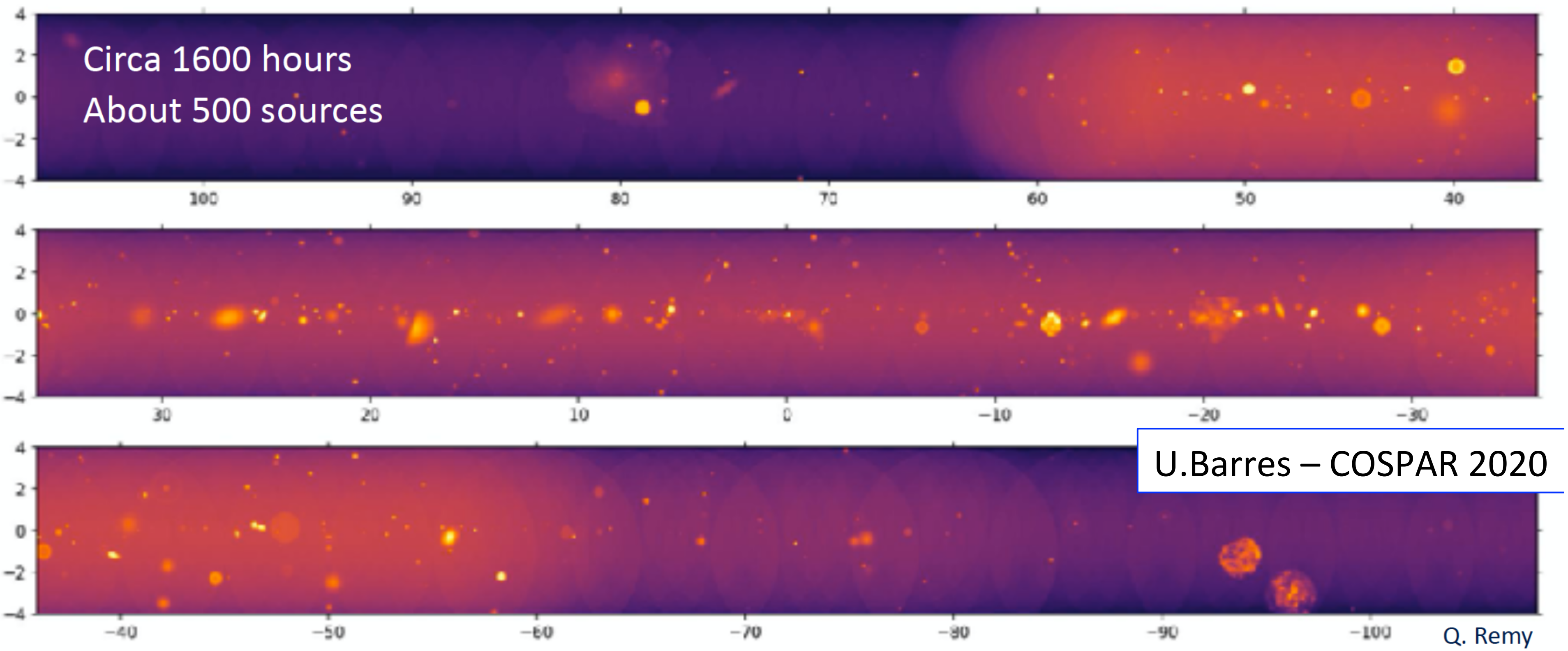
Sensitivity of the Cherenkov Telescope Array to a dark matter signal from the Galactic centre

Abstract. We provide an updated assessment of the power of the Cherenkov Telescope Array (CTA) to search for thermally produced dark matter at the TeV scale, via the associated gamma-ray signal from pair-annihilating dark matter particles in the region around the Galactic centre. We find that CTA will open a new window of discovery potential, significantly extending the range of robustly testable models given a standard cuspy profile of the dark matter density distribution. Importantly, even for a cored profile, the projected sensitivity of CTA will be sufficient to probe various well-motivated models of thermally produced dark matter at the TeV scale. This is due to CTA's unprecedented sensitivity, angular and energy resolutions, and the planned observational strategy. The survey of the inner Galaxy will cover a much larger region than corresponding previous observational campaigns with imaging atmospheric Cherenkov telescopes. CTA will map with unprecedented precision the large-scale diffuse emission in high-energy gamma rays, constituting a background for dark matter searches for which we adopt state-of-the-art models based on current data. Throughout our analysis, we use up-to-date event reconstruction Monte Carlo tools developed by the CTA consortium, and pay special attention to quantifying the level of instrumental systematic uncertainties, as well as background template systematic errors, required to probe thermally produced dark matter at these energies.

https://arxiv.org/abs/2007.16129

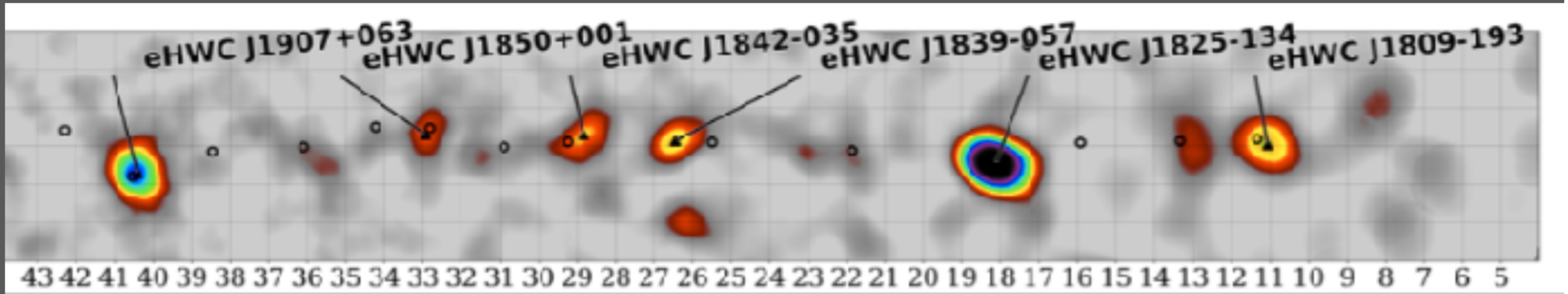
CTA Galactic Science

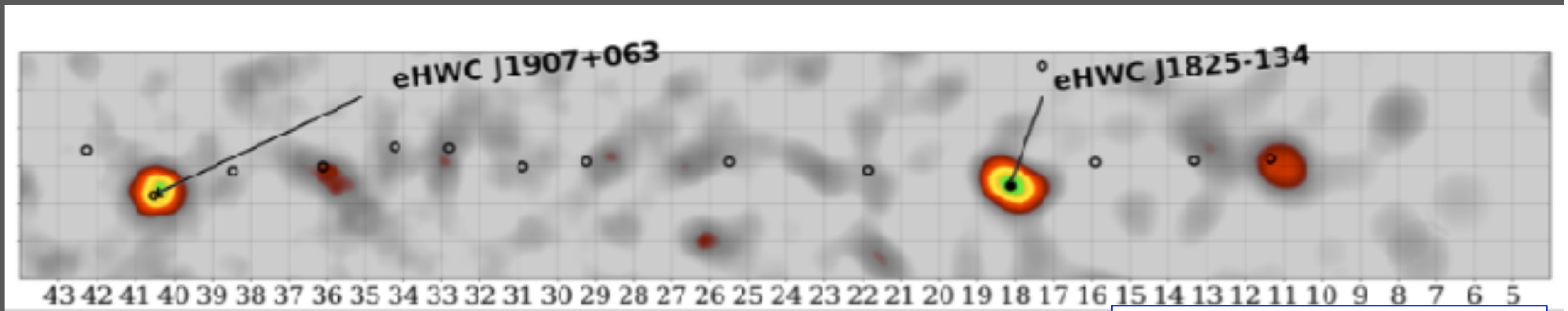
- Survey speed about 300x greater than H.E.S.S.
- Much deeper reach, to scan the entire galaxy for PWNe and SNRs, as opposed to the few-kpc reach of current instruments.



PeVatrons: the extreme energy frontier

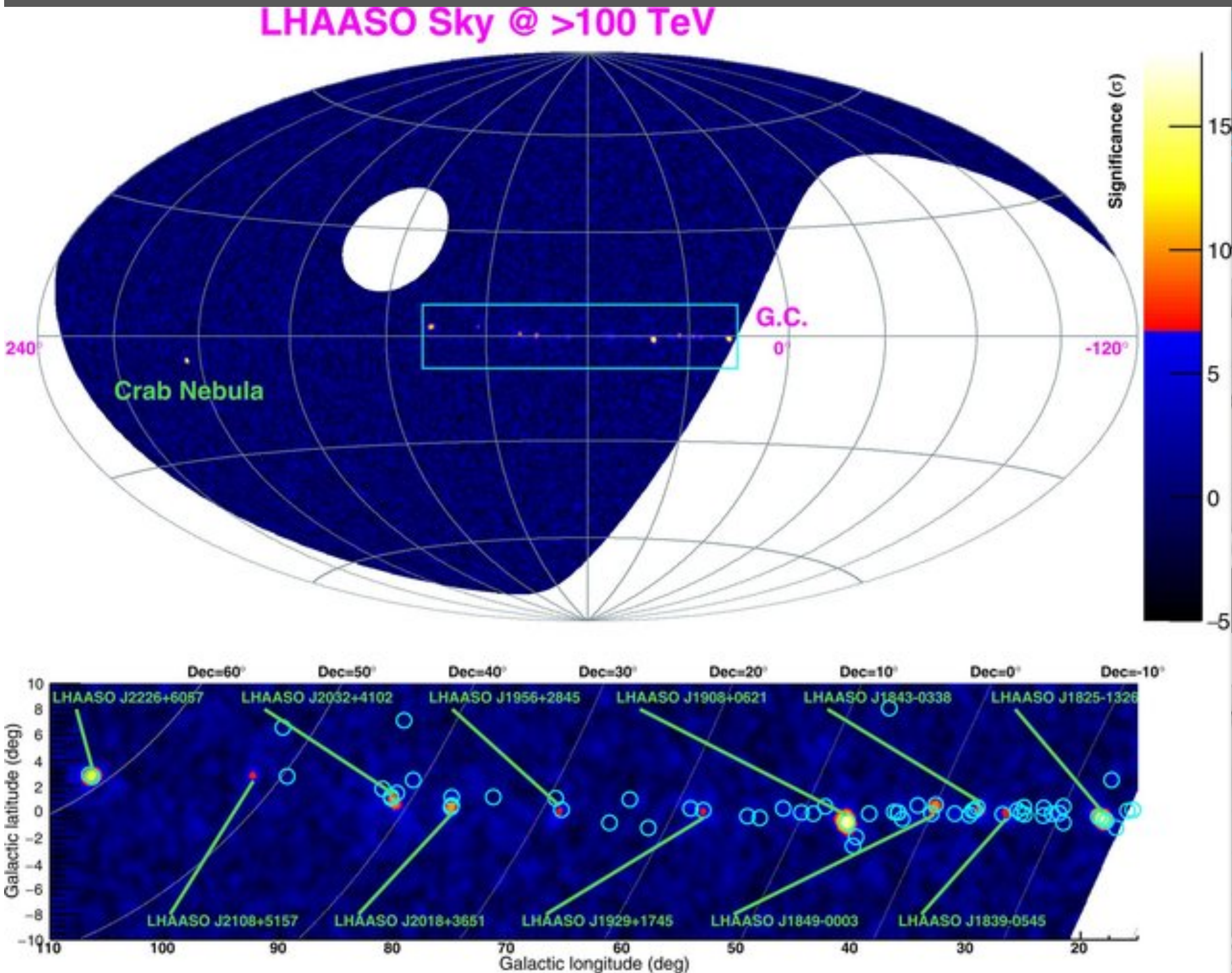
HAWC (arXiv:1909.08609) has opened a window into the PeVatron frontier that can be extensively probed and expanded by CTA





U.Barres – COSPAR 2020

PeVatrons: the extreme energy frontier



Ultrahigh-energy photons up to 1.4 petaelectronvolts from 12 γ-ray Galactic sources

LHAASO (Nature 2021)

CTA telescopes – first LST ATEL

https://astronomerstelegram.org/?read=147

Detection of very-high-energy gamma-ray emission from BL Lac with the LST-1

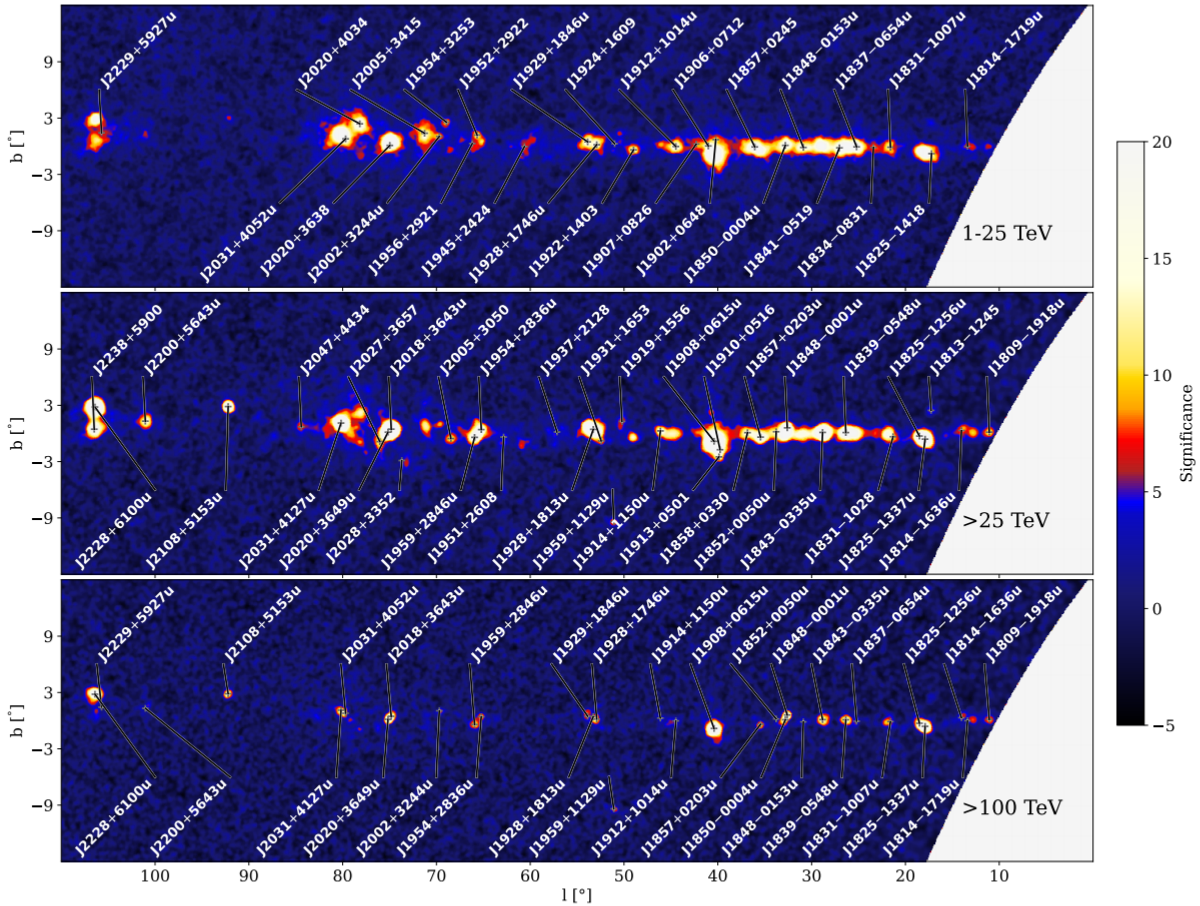
ATel #14783; ***Juan Cortina for the CTA LST collaboration***
on ***13 Jul 2021; 21:03 UT***
Credential Certification: Juan Cortina (Juan.Cortina@ciemat.es)

Subjects: TeV, VHE, Request for Observations, AGN, Blazar, Transient

Referred to by ATel #: 14820, 14826, 14839

The LST-1 telescope has observed an increase in the very-high-energy (VHE; >100 GeV) gamma-ray flux from BL Lacertae (RA=22:02:43.3, DEC=+42:16:40, J2000.0). The preliminary offline analysis of the LST-1 data taken on 2021/07/11 (MJD 59406), triggered by an increase of the optical flux (see ATEL #14773 and references therein), has been detected with a significance of 8 sigma with a differential flux of 1.3 +/- 0.2 10^-9 cm-2 s-1 TeV-1 (25% of the Crab Nebula) at 100 GeV. Note though that this is the result of a quick-look analysis and the data were taken under non-optimal weather conditions (atmospheric transmission at 9km of ~50-60%), hence this flux measurement is a lower bound on the true flux. The LST-1 observations were performed during commissioning which began in 2018. LST-1 is a prototype of the Large-Sized Telescope for the Cherenkov Telescope Array, and is located on the Canary island of La Palma, Spain. The LST-1 is designed to perform gamma-ray astronomy in the energy range from 20 GeV to 3 TeV. LST-1 observations on BL Lacertae will continue during the next few nights, multi-wavelength observations are encouraged. The preliminary offline analysis has been performed by Daniel Morcuende (dmorcuen@ucm.es) and Ruben Lopez-Coto (ruben.lopezcoto@pd.infn.it). The LST-1 contact persons for these observations are Masahiro Teshima (mteshima@mpp.mpg.de) and Juan Cortina (juan.cortina@ciemat.es).

The 1st LHAASO catalog



https://arxiv.org/pdf/2305.17030.pdf

CTA Pevatrons KSP

Sensitivity of the Cherenkov Telescope Array to spectral signatures of hadronic PeVatrons with application to Galactic Supernova Remnants

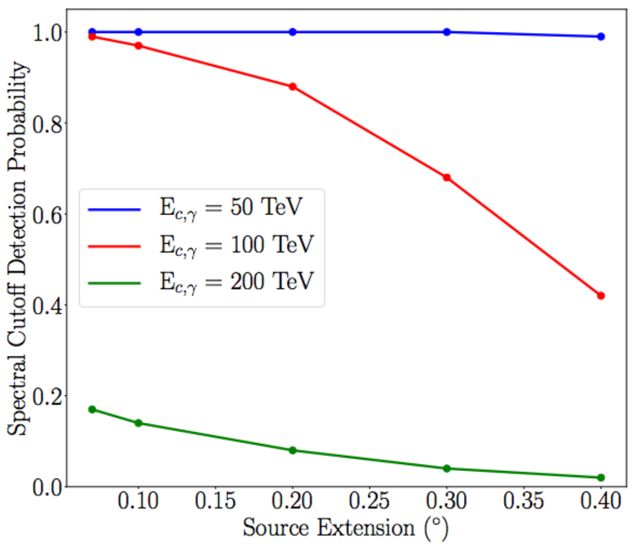
Abstract

The local Cosmic Ray (CR) energy spectrum exhibits a spectral softening at energies around 3 PeV. Sources which are capable of accelerating hadrons to such energies are called hadronic PeVatrons. However, hadronic PeVatrons have not yet been firmly identified within the Galaxy. Several source classes, including Galactic Supernova Remnants (SNRs), have been proposed as PeVatron candidates. The potential to search for hadronic PeVatrons with the Cherenkov Telescope Array (CTA) is assessed. The focus is on the usage of very high energy γ-ray spectral signatures for the identification of PeVatrons. Assuming that SNRs can accelerate CRs up to knee energies, the number of Galactic SNRs which can be identified as PeVatrons with CTA is estimated within a model for the evolution of SNRs. Additionally, the potential of a follow-up observation strategy under moonlight conditions for PeVatron searches is investigated. Statistical methods for the identification of PeVatrons are introduced, and realistic Monte–Carlo simulations of the response of the CTA observatory to the emission spectra from hadronic PeVatrons are performed. Based on simulations of a simplified model for the evolution for SNRs, the detection of a γ-ray signal from in average 9 Galactic PeVatron SNRs is expected to result from the scan of the Galactic plane with CTA after 10 hours of exposure. CTA is also shown to have excellent potential to confirm these sources as PeVatrons in deep observations with $\mathcal{O}(100)$ hours of exposure per source.

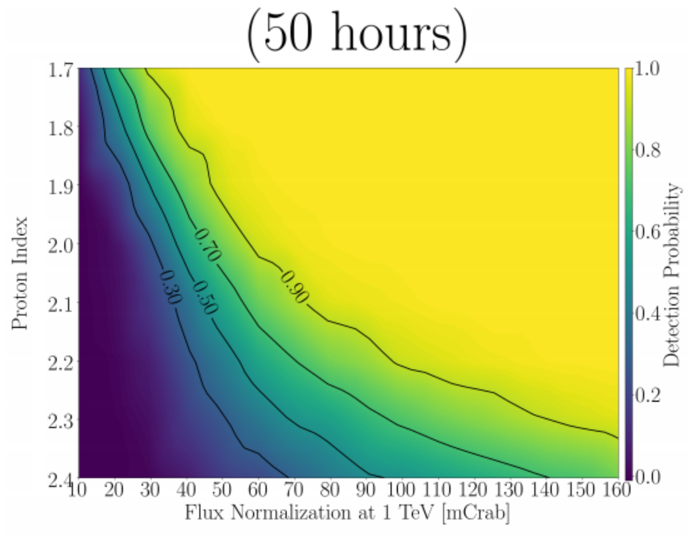
Keywords: Gamma rays: general, Cosmic rays, Galactic PeVatrons, (Stars:) supernovae: general, Methods: data analysis, Methods: statistical

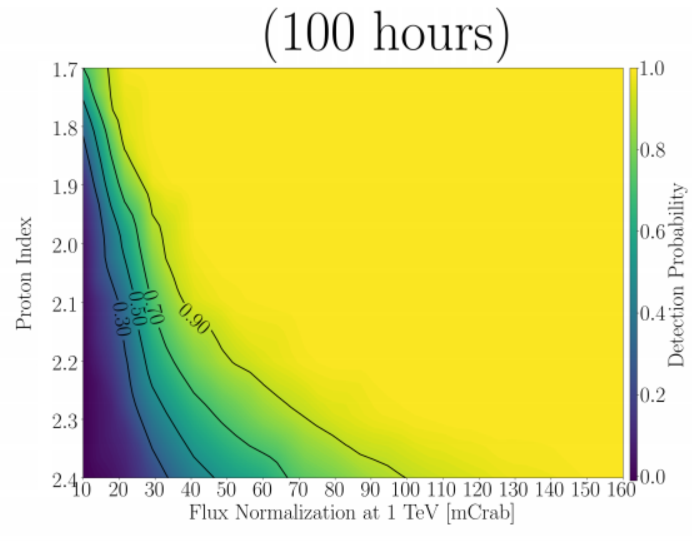
https://arxiv.org/pdf/2303.15007.pdf

CTA Pevatrons KSP



https://arxiv.org/pdf/2303.15007.pdf





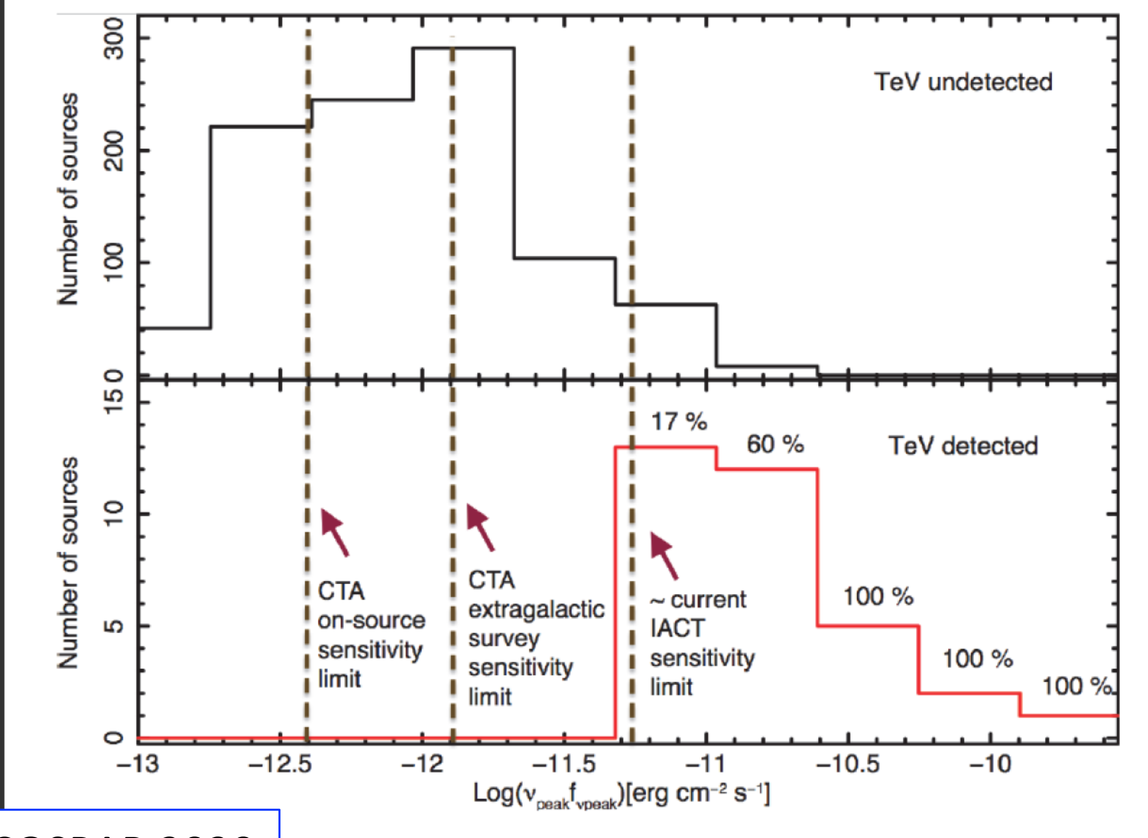
CTA's Prospects for AGN

CTA will detect many 100s of AGN to z~2

FoV up to 10 degrees → several AGN in FoV at same time.

Light curve details down to sub-minutes.

Spectral resolution to reveal sub-components:
- Hadronic (synchrotron from protons, muons, + secondaries)
- Leptonic (SSC)



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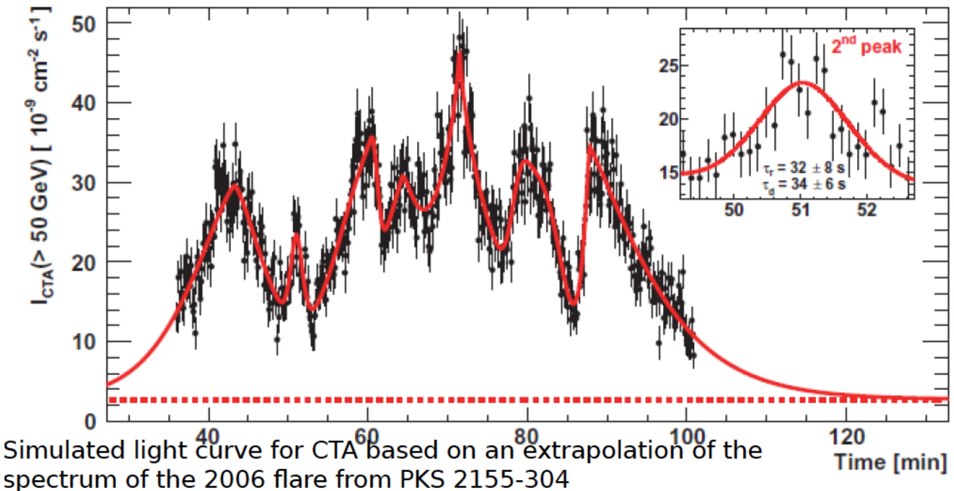
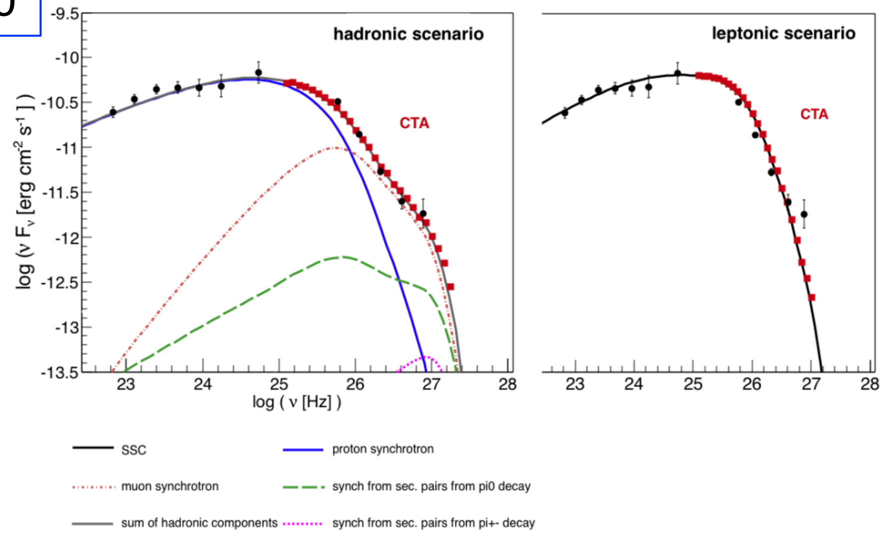


Simulated light curve for CTA based on an extrapolation of the spectrum of the 2006 flare from PKS 2155-304



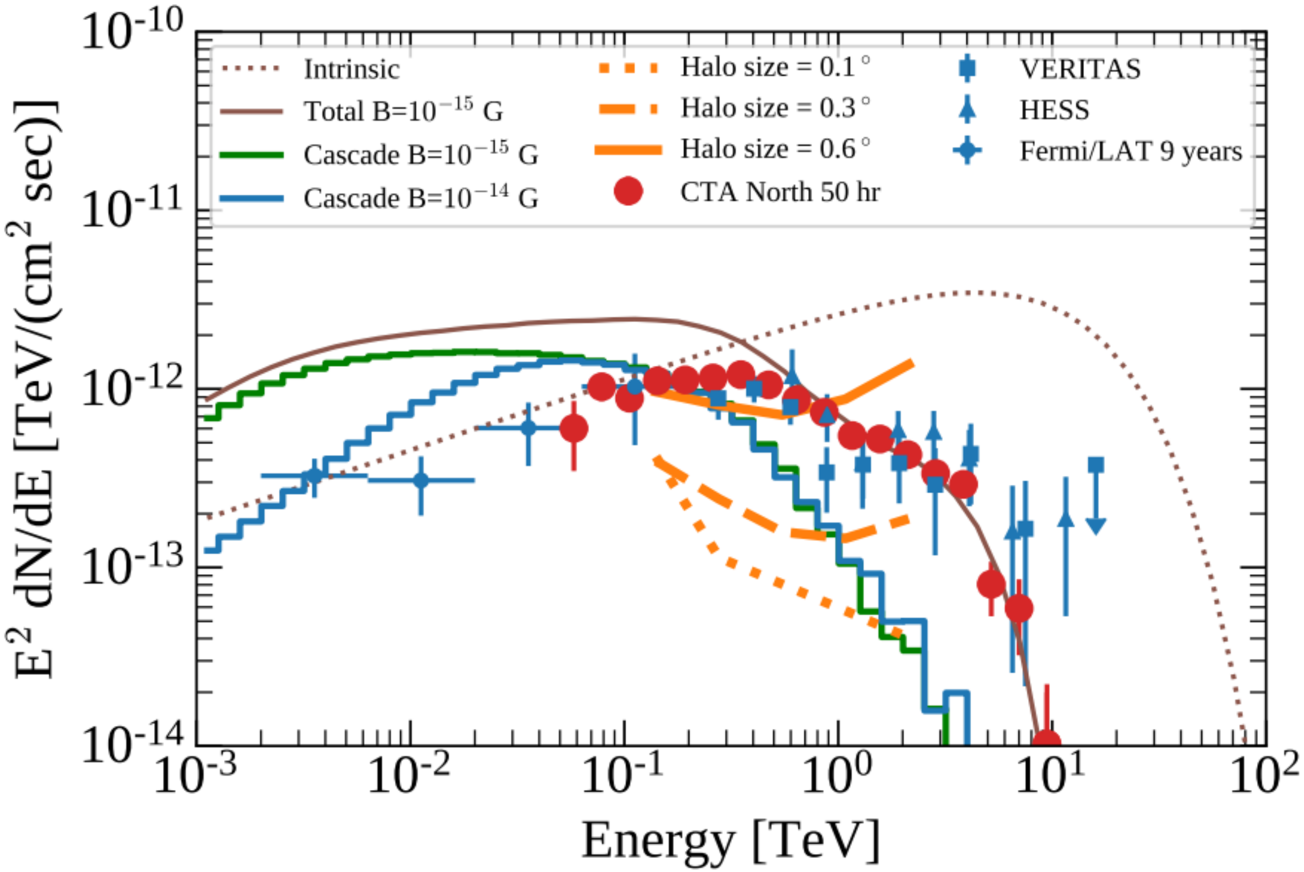
Cosmology and Fundamental Physics

Sensitivity of the Cherenkov Telescope Array for probing cosmology and fundamental physics with gamma-ray propagation

Abstract. The Cherenkov Telescope Array (CTA), the new-generation ground-based observatory for γ-ray astronomy, provides unique capabilities to address significant open questions in astrophysics, cosmology, and fundamental physics. We study some of the salient areas of γ-ray cosmology that can be explored as part of the Key Science Projects of CTA, through simulated observations of active galactic nuclei (AGN) and of their relativistic jets. Observations of AGN with CTA will enable a measurement of γ-ray absorption on the extragalactic background light with a statistical uncertainty below 15% up to a redshift $z = 2$ and to constrain or detect γ-ray halos up to intergalactic-magnetic-field strengths of at least 0.3 pG. Extragalactic observations with CTA also show promising potential to probe physics beyond the Standard Model. The best limits on Lorentz invariance violation from γ-ray astronomy will be improved by a factor of at least two to three. CTA will also probe the parameter space in which axion-like particles could constitute a significant fraction, if not all, of dark matter. We conclude on the synergies between CTA and other upcoming facilities that will foster the growth of γ-ray cosmology.

https://arxiv.org/abs/2010.01349

Cosmology and Fundamental Physics



https://arxiv.org/abs/2010.01349

The new window of VHE Gamma-ray Bursts

First time detection of a GRB at sub-TeV energies; MAGIC detects the GRB 190114C

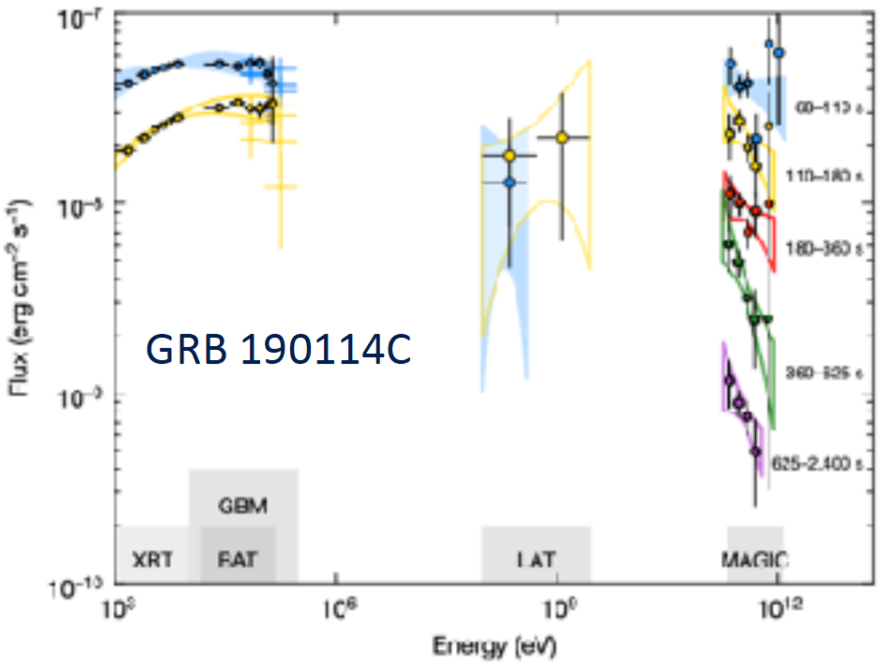
ATel #12390; ***Razmik Mirzoyan on behalf of the MAGIC Collaboration***
*on **15 Jan 2019; 01:03 UT***
Credential Certification: Razmik Mirzoyan (Razmik.Mirzoyan@mpp.mpg.de)

Subjects: Gamma Ray, >GeV, TeV, VHE, Request for Observations, Gamma-Ray Burst

Referred to by ATel #: 12395, 12475

Tweet

The MAGIC telescopes performed a rapid follow-up observation of GRB 190114C (Gropp et al., GCN 23688; Tyurina et al., GCN 23690, de Ugarte Postigo et al., GCN 23692, Lipunov et al. GCN 23693, Selsing et al. GCN 23695). This observation was triggered by the Swift-BAT alert; we started



Three long GRBs detections announced in the past two years:

- GRB 180720B (z=0.65)
- GRB 190114C (z=0.42)
  - Afterglow detected > 300 GeV
  - Huge statistics (1000s gammas)
  - Sub-minute timescale spectra
- GRB 190829A (z=0.08)

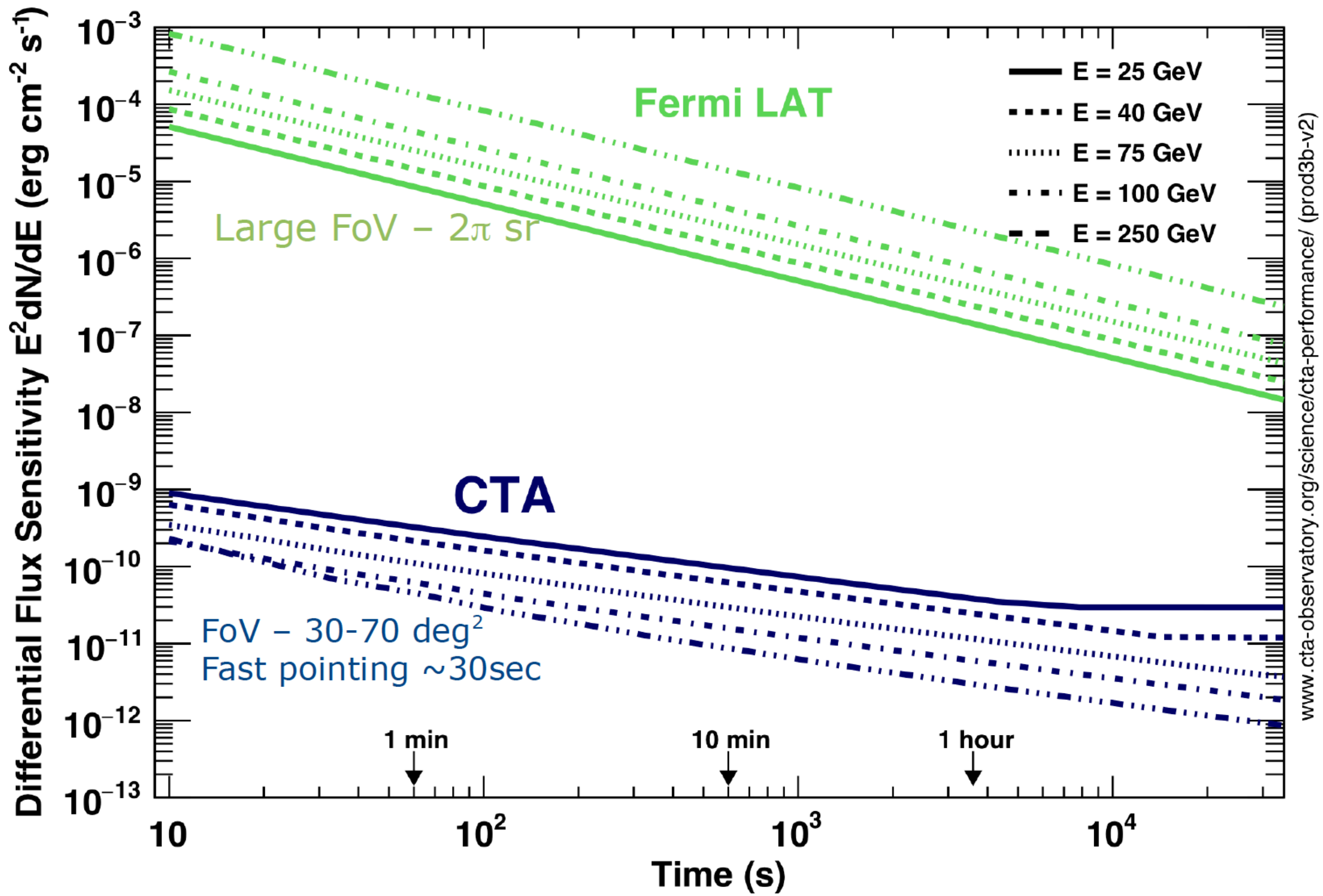
+ GRB 201216C (z = 1.1)

Strong MWL and MM synergies for spectral and variability studies

U.Barres – COSPAR 2020

Transients & Variable Sources: CTA Sensitivity vs. Time

(CTA Collab 2019)



CTA >10,000 times more sensitive than Fermi-LAT in multi-GeV range

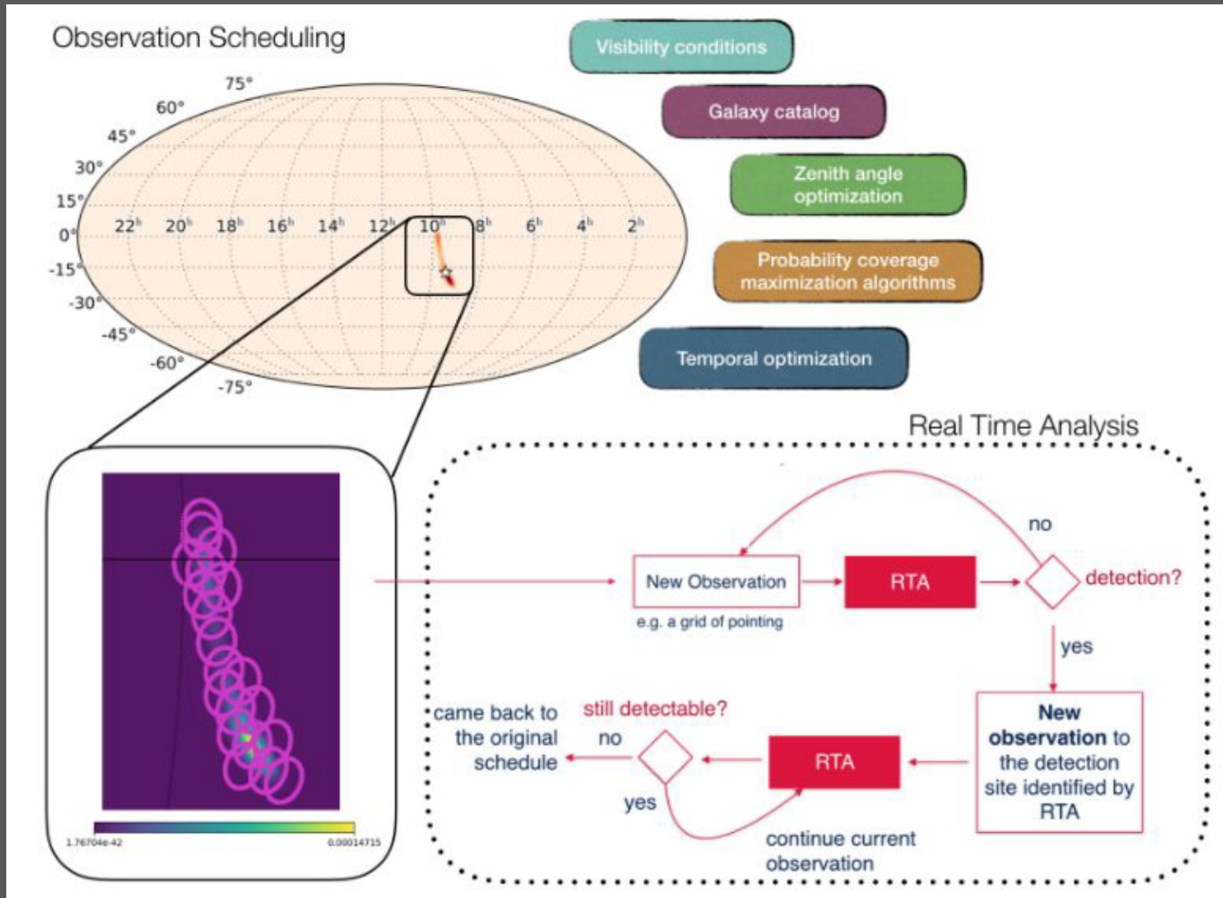
→ GRBs, AGN, giant pulses, FRBs, GW, SGR bursts...

G. Rowell – COSPAR 2020

Gravitational wave follow-ups

CTA will represent an important improvement on the follow-up of gravitational wave events

- Larger field of view of 5º - 7º means quicker scan of GW error regions
- An optimised pointing strategy will be used to efficiently cover the sky area of the GW signal



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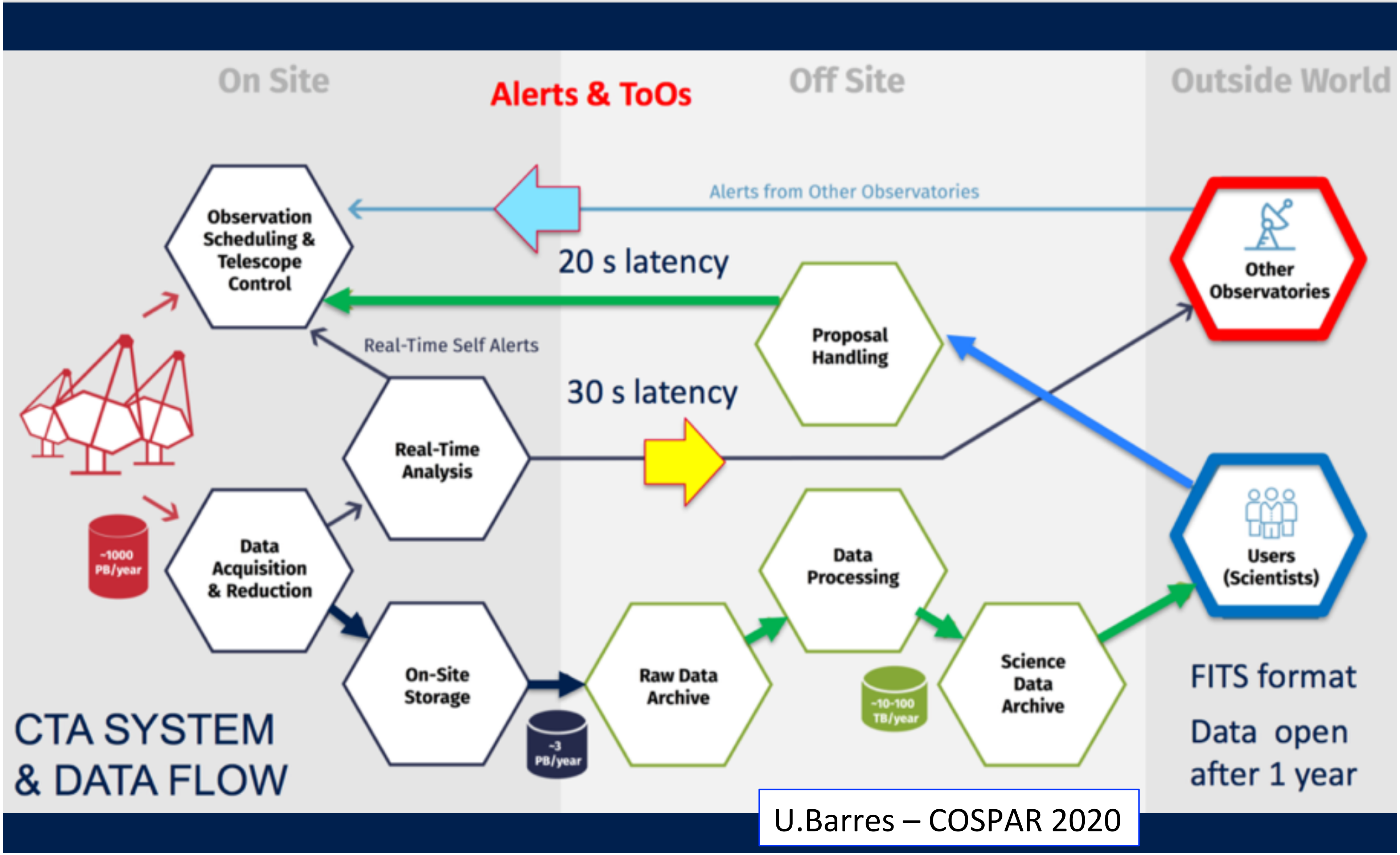
CTA Transients Science



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External Needs Matrix

cherenkov telescope array

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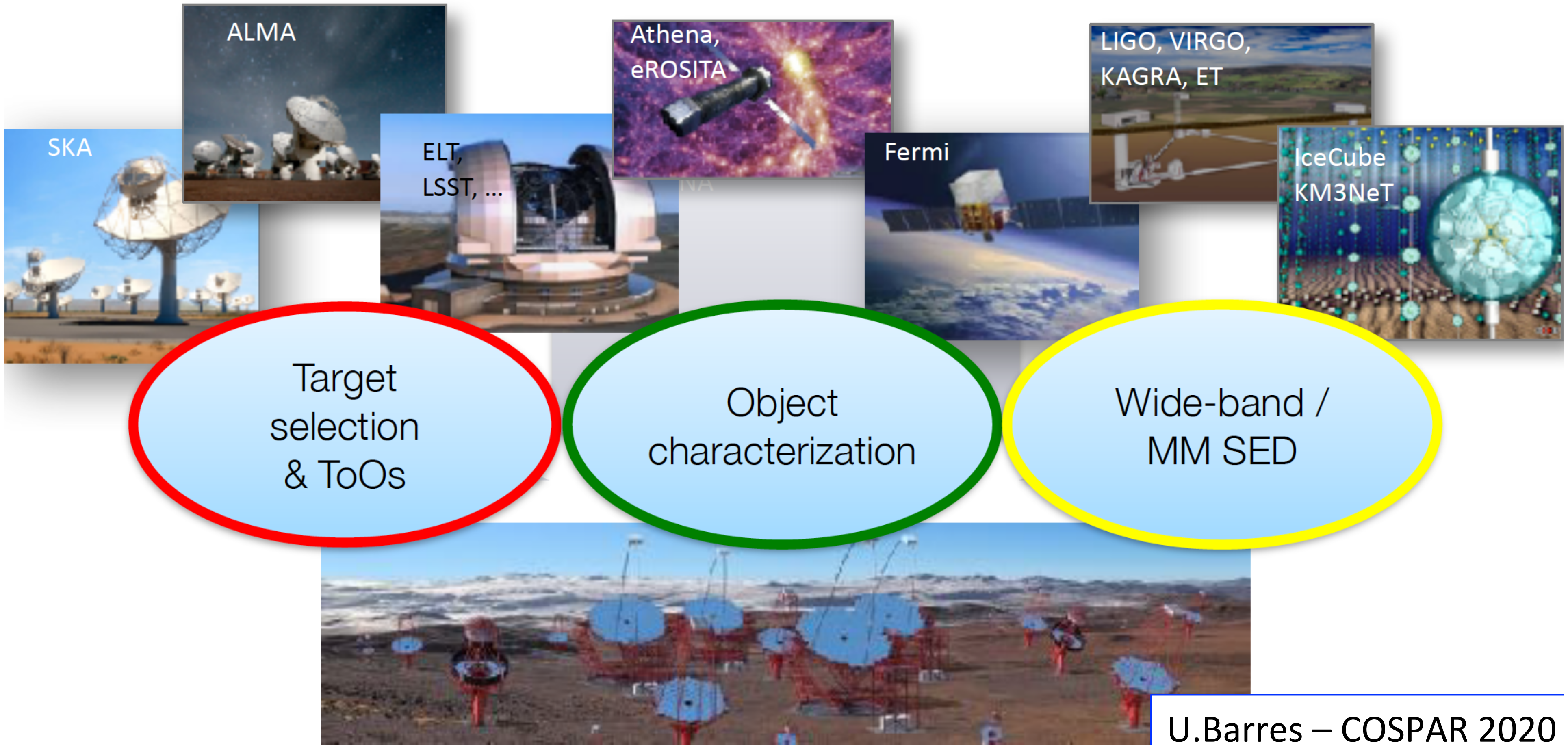
✓ = important ✔ = critical

Band or Messenger	Astrophysical Probes	Galactic Plane Survey	LMC & SFRs	CRs & Diffuse Emission	Galactic Transients	Starburst & Galaxy Clusters	GRBs	AGNs	Radio Galaxies	Redshifts	GWs & Neutrinos
Radio	Particle and magnetic-field density probe. Transients. Pulsar timing.	✔	✓	✔	✓	✓	✓	✔	✓		✓
(Sub)Millimetre	Interstellar gas mapping. Matter ionisation levels. High-res interferometry.	✔	✔	✔		✓		✓	✔		
IR/Optical	Thermal emission. Variable non-thermal emission. Polarisation.	✓	✔	✓	✔	✔		✔	✓	✔	
Transient Factories	Wide-field monitoring & transients detection. Multi-messenger follow-ups.						✓	✔			✓
X-rays	Accretion and outflows. Particle acceleration. Plasma properties.	✔	✔	✓	✔	✔	✔	✔	✔		✓
MeV-GeV Gamma-rays	High-energy transients. Pion-decay signature. Inverse-Compton process	✓	✓	✔	✓	✔	✔	✔			✔
Other VHE	Particle detectors for 100% duty cycle monitoring of TeV sky.	✓	✓	✓		✓		✓			
Neutrinos	Probe of cosmic-ray acceleration sites. Probe of PeV energy processes.			✓			✓	✔			✔
Gravitational Waves	Mergers of compact objects (Neutron Stars). Gamma-ray Bursts.						✔				✔

MWL and Multi-Messenger Perspectives

Synergies with astrophysical facilities…



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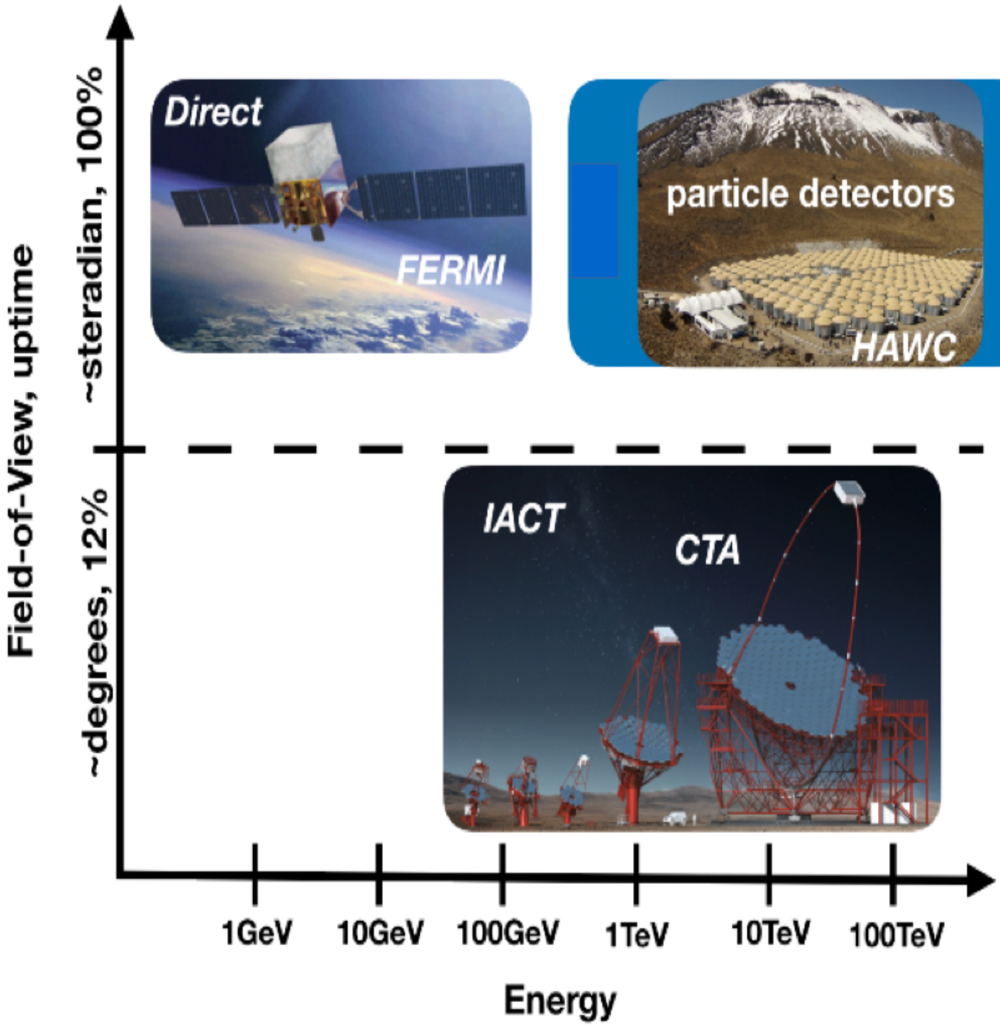
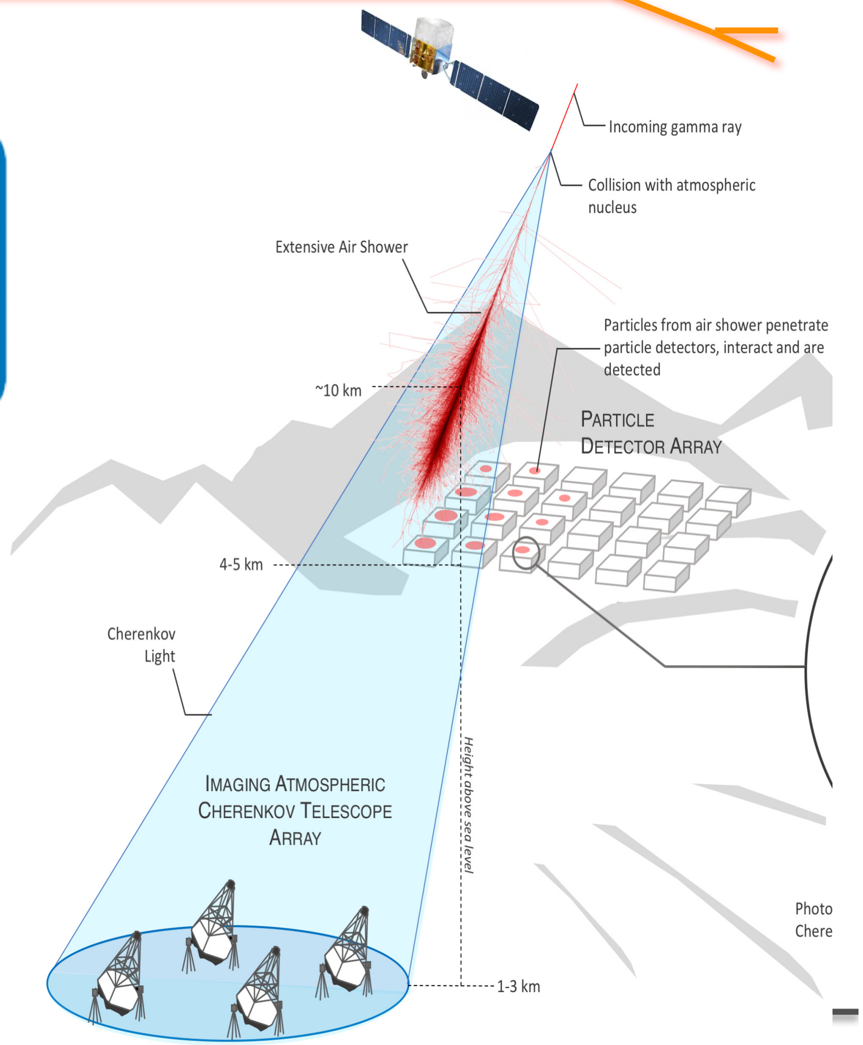
Gamma-ray Astronomy



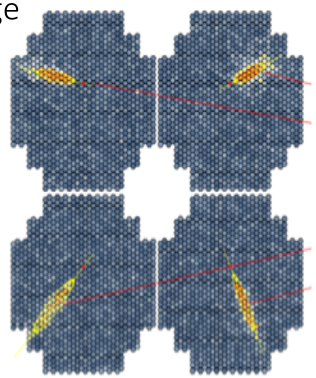


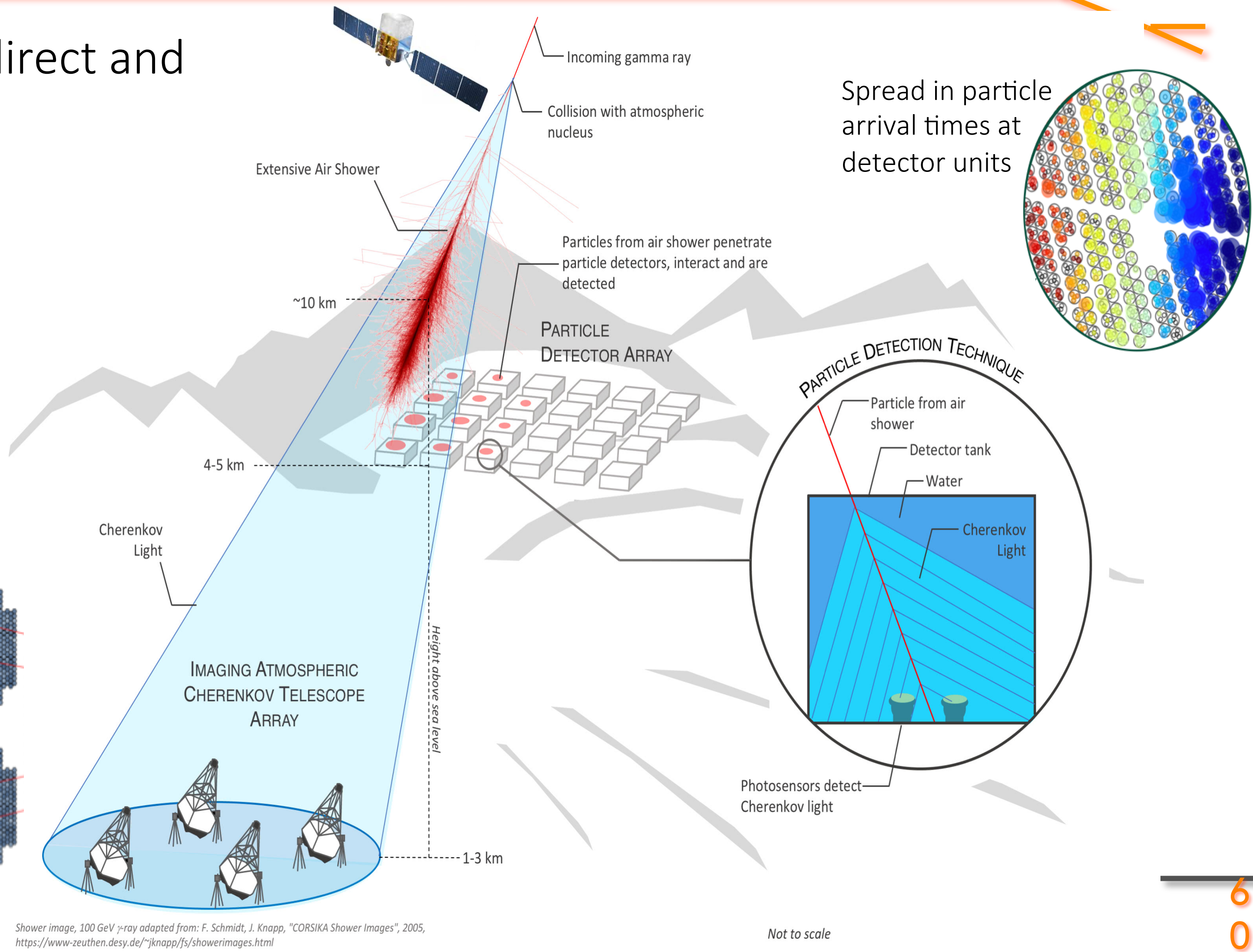
Shower image, 100 GeV γ-ray adapted from: F. Schmidt, J. Knapp, "CORSIKA Shower Images", 2005, https://www-zeuthen.desy.de/~jknapp/fs/showerimages.html

Gamma-ray Astronomy

Complementary direct and indirect detection techniques

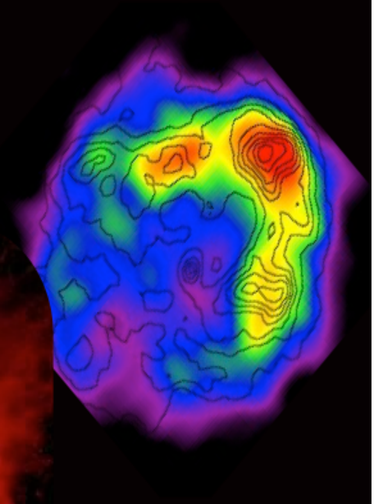
Atmospheric Cherenkov light image

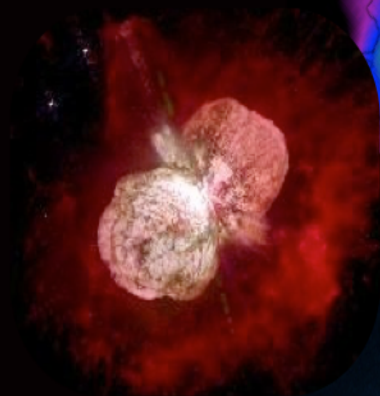


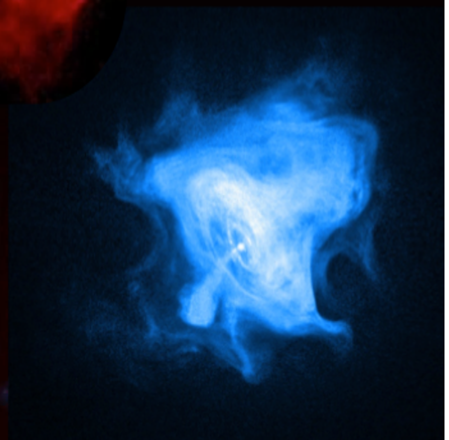


Spread in particle arrival times at detector units

- Astonishing variety of TeV* emitters
  - Within the Milky Way
    - Supernova remnants
    - Bombarded molecular clouds
    - Stellar binaries - colliding wind & X-ray
    - Massive stellar clusters
    - Pulsars and pulsar wind nebulae
    - Supermassive black hole Sgr A*
  - Extragalactic
    - Starburst galaxies
    - MW satellites
    - Radio galaxies
    - Flat-spectrum radio quasars
    - ‘BL Lac’ objects
    - Gamma-ray bursts
- Acceleration to TeV energies is common, gamma-rays are an effective probe
  - Strongly complementary to sync. measurements



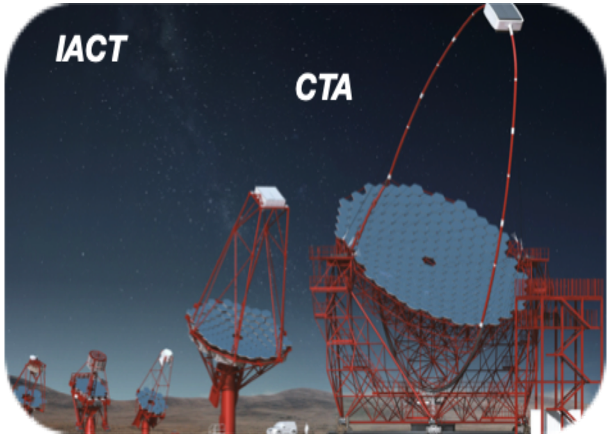


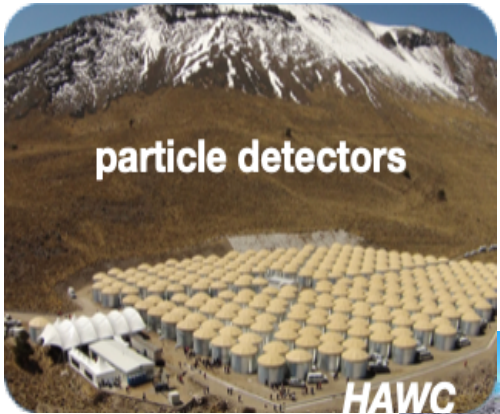


*0.05-50 TeV

Observational Panorama

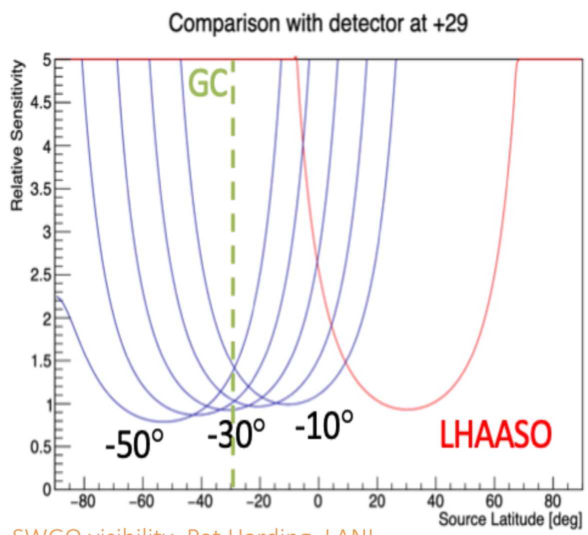
- Cherenkov Atmospheric Telescopes
  - 20% duty-cycle
  - Pointing (few degrees FoV)
  - Energy threshold down to 10s GeV
  - Good energy and angular resolution





- Particle Detector Arrays
  - → 100% duty-cycle
  - → Wide-field of View (~ steradian)
  - → Energy range 100s GeV up to 100s TeV
  - → Continual view and accurate background determination

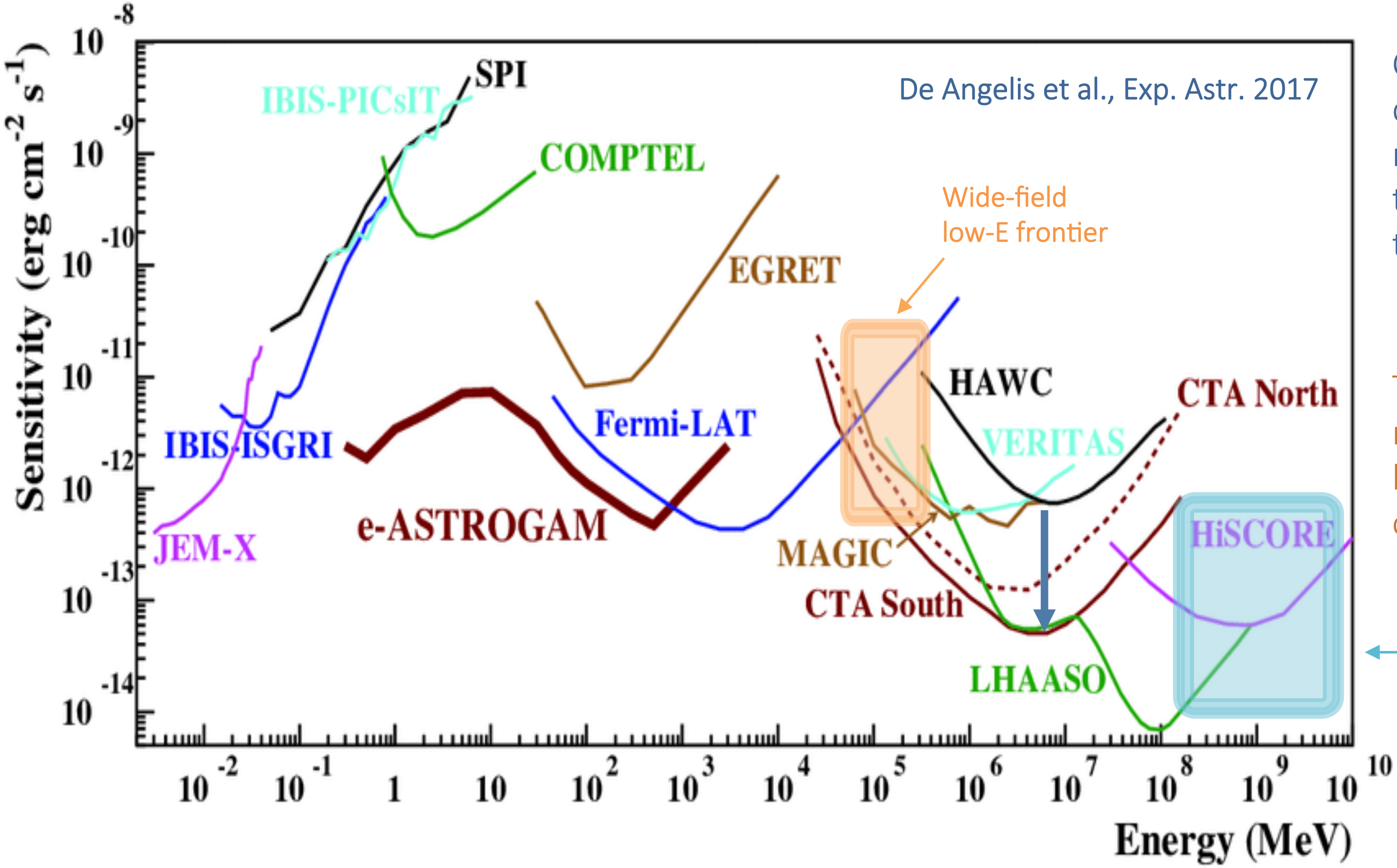
Geographic distribut



SWGO visibility, Pat Harding, LANL

Broadband panorama of high-energy Astrophysics

- Point source sensitivity for X- and gamma-ray instruments



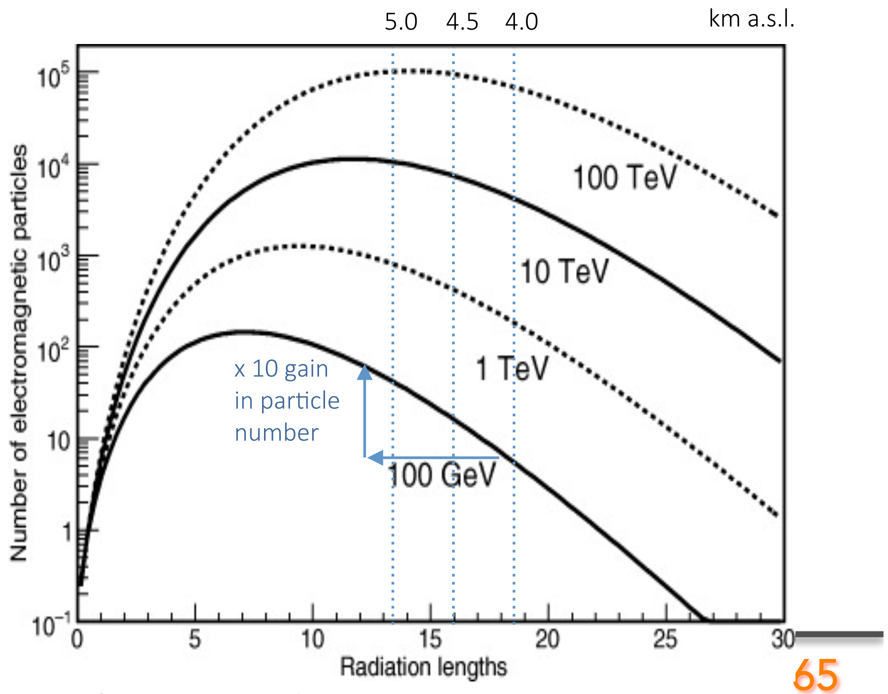
CTA and LHAASO will drive an order of magnitude increase in the TeV - PeV region in the next decade.

The 100 GeV frontier remains to be explored by wide-field gamma observatories.

High-sensitivity TeV-PeV frontier

The high-altitude frontier

The Andes provides a number of high-altitude plateaus and high-altitude lakes that constitute suitable sites for a particle array aiming to extend the low-energy frontier for Wide-Field Observatories.



Adapted from G. Sinnis, NJPh, 2009

The Southern Wide-field Gamma-ray Observatory

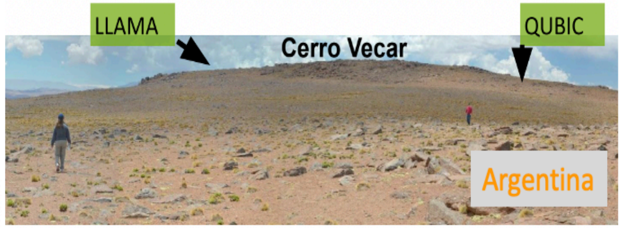
Candidate Sites

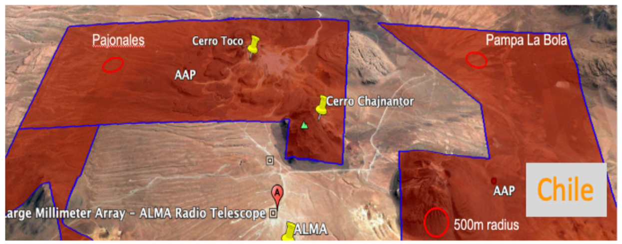
lat. 15 S

lat. 23 S

- Alto Tocomar (Argentina)
- Cerro Vecar (Argentina)
- Chacaltaya (Bolivia)
- AAP Pajonal (Chile)
- AAP Pampa La Bola (Chile)
- Lake Sibinacocha (Peru)
- Imata (Peru)
- Sumbay (Peru)
- Peru National Observatory
- Yanque (Peru)

The complete list of potential sites is still under investigation, aiming at an evaluation for site choice by 2021.



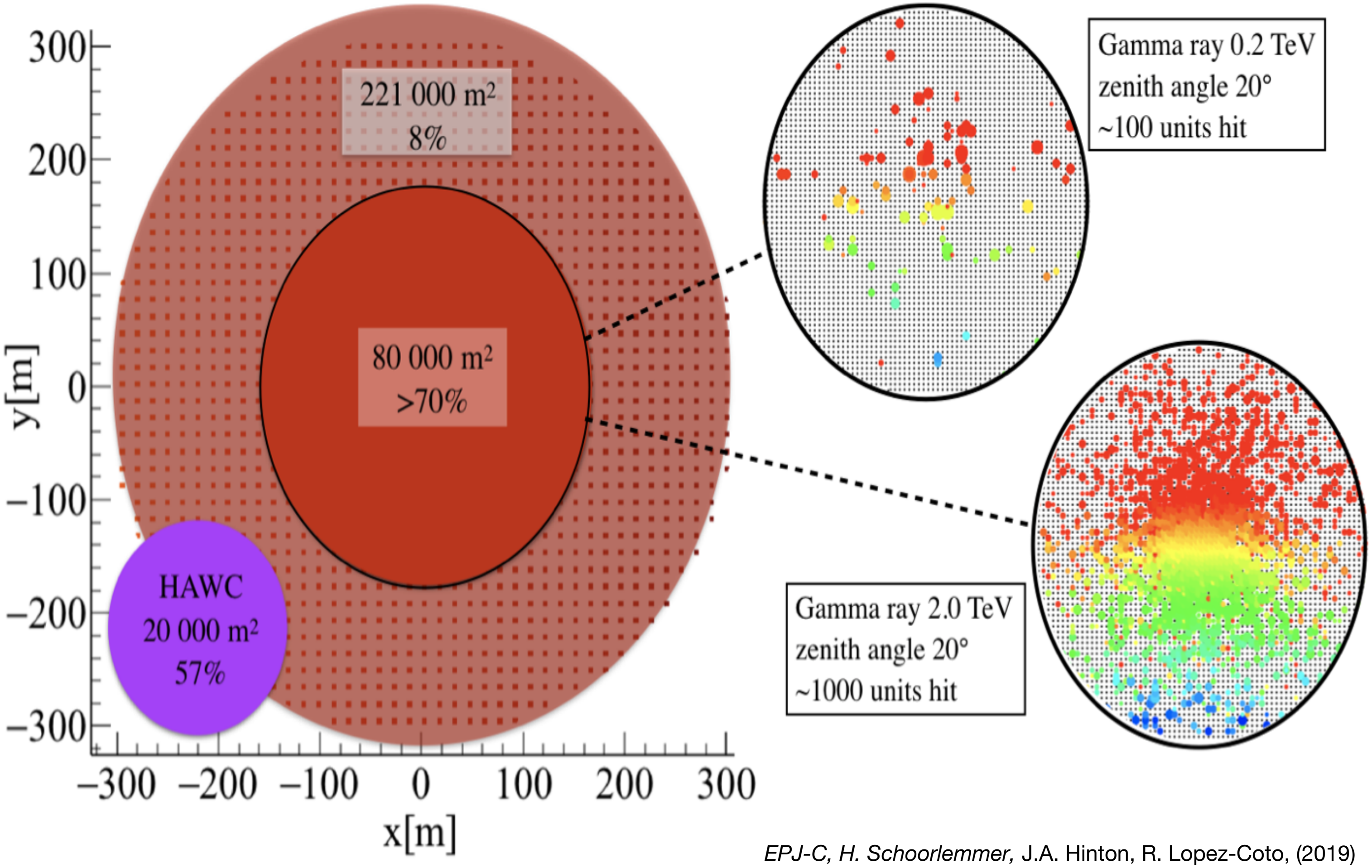


The Southern Wide-field Gamma-ray Observatory

The SWGO Concept

Detector array

Large array for low-energy events
Compact core with large instrumented area



EPJ-C, H. Schoorlemmer, J.A. Hinton, R. Lopez-Coto, (2019)

- ‘Strawman’ - reference detector layout

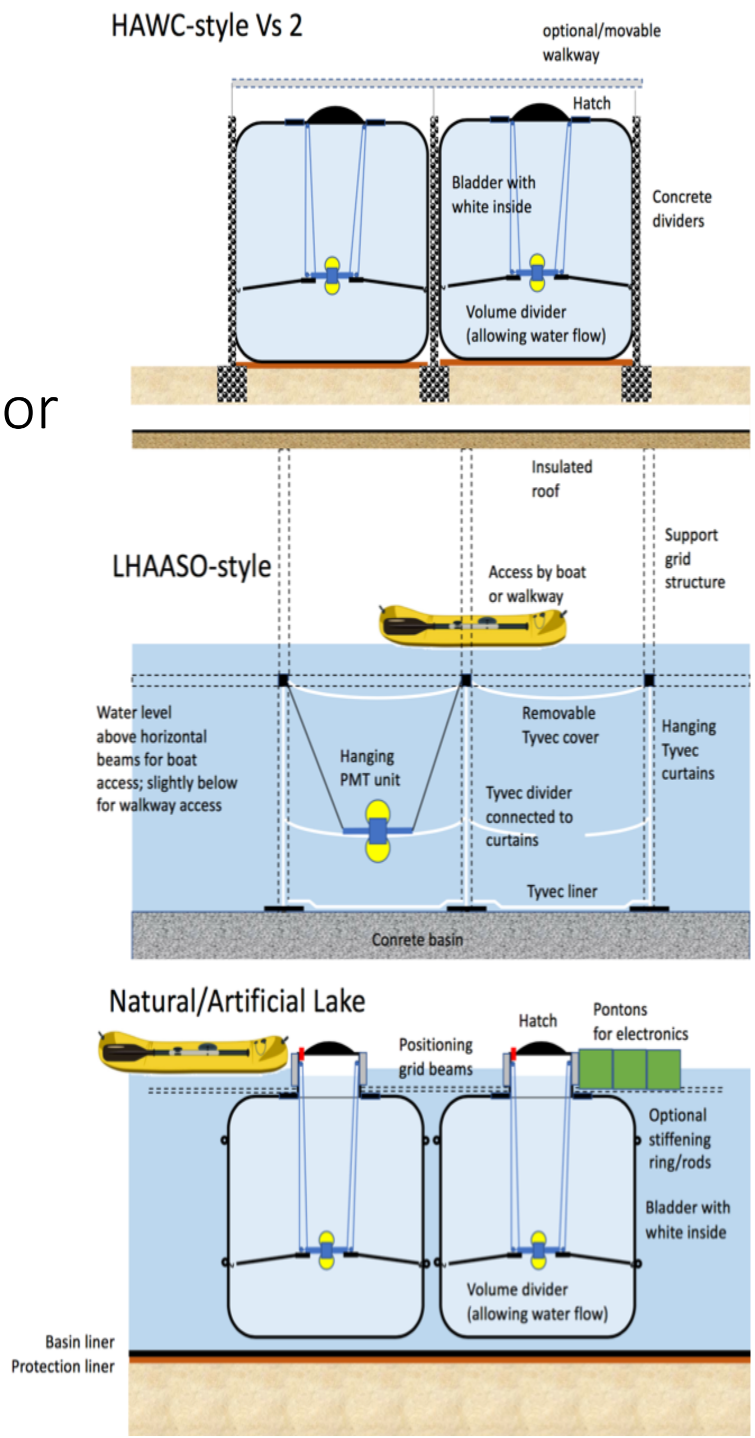
The SWGO Concept

The Southern Wide-field Gamma-ray Observatory

Detector units

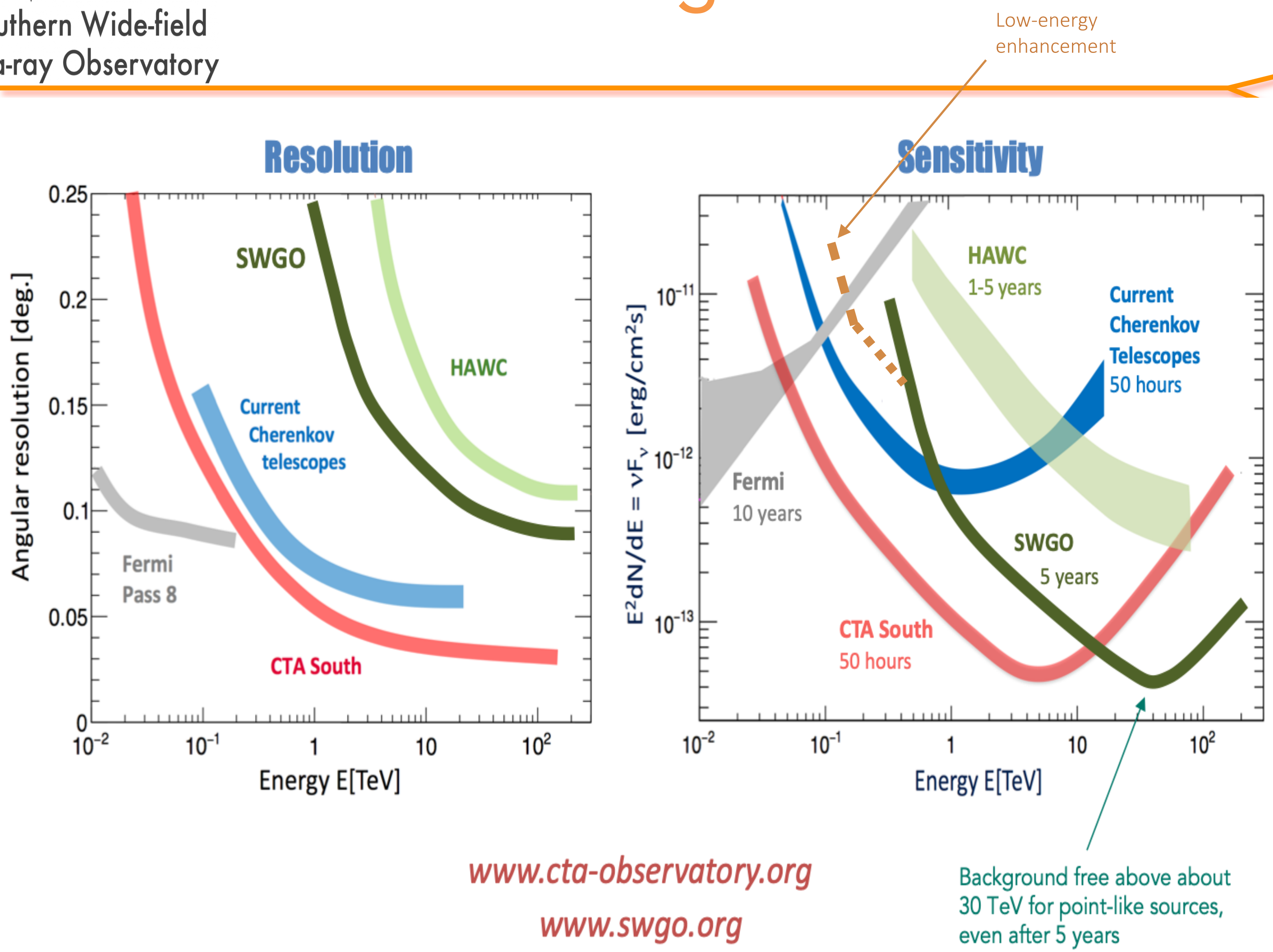
Multiple detector options to be investigated

- Core unit is a water-Cherenkov Detector
  - Options being investigated based on tanks (HAWC-like), ponds (Milagro-like) and lake-base (test pool under construction at MPIK-Heidelberg)
- Simulations currently ongoing to constrain all aspects of the detectors
- Design strongly dependent on site choice
  - Water access, construction costs, infrastructure feasibility, compatibility with scientific driven main design goals…



The Southern Wide-field Gamma-ray Observatory

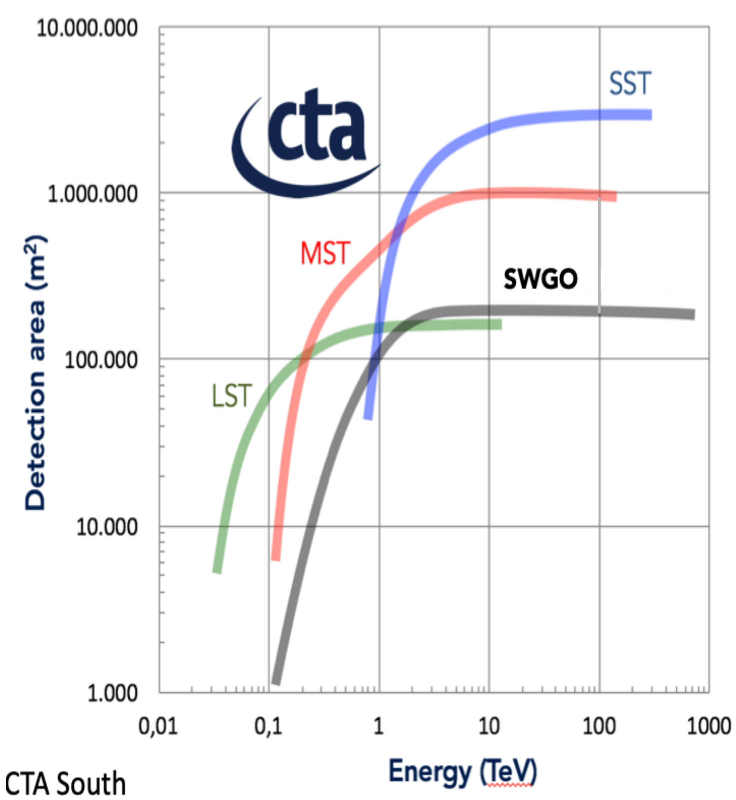
Performance goals



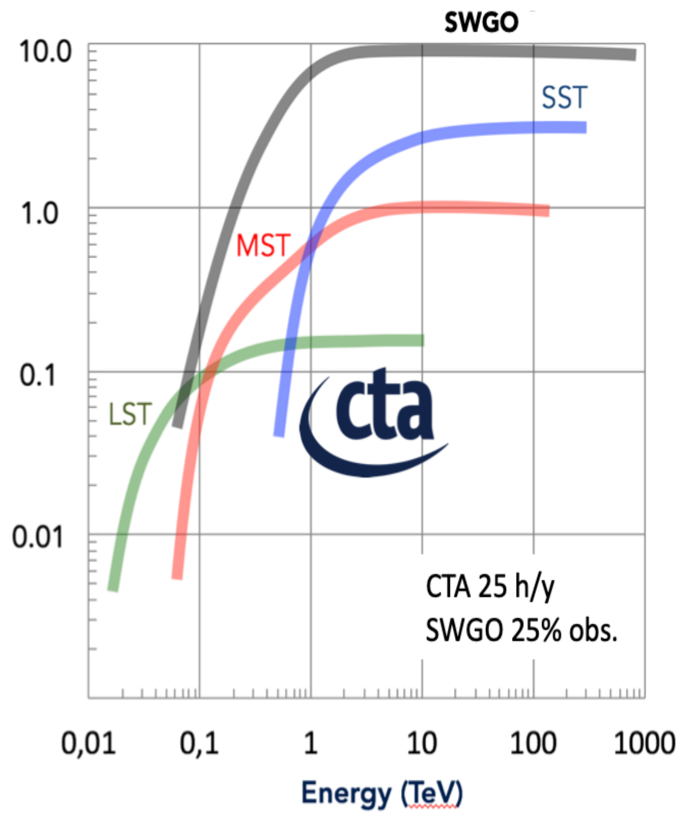
www.cta-observatory.org

www.swgo.org

Performance goals



Detection Area



Annual Exposure

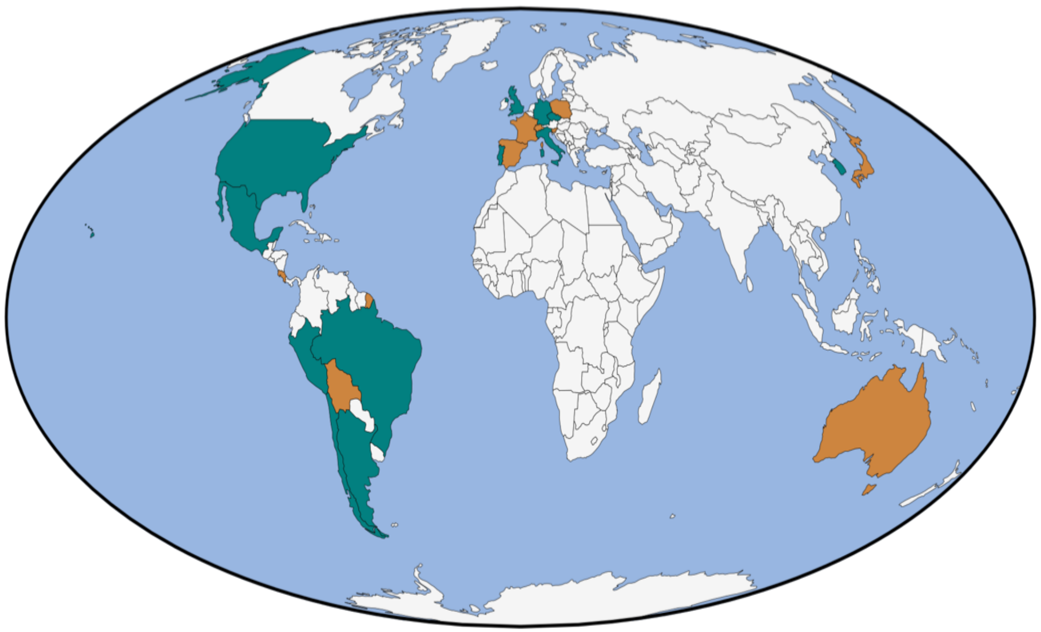
Potentially more sensitive than CTA over several years integration time provided good background suppression is achieved.

The Collaboration

- Southern Wide-Field Gamma-ray Observatory
  - + higher altitude (4400+ m asl) and larger area
  - + more efficient detector units + muon tagging capability
  - → improved sensitivity and lower E threshold

Established in July 2019
3 year R&D Programme

www.swgo.org



Institutes

Argentina*, Brazil, Chile, Czech Republic, Germany*, Italy, Mexico, Peru, Portugal, South Korea, United Kingdom, United States*

Member institutes signed the SoI.

Supporting scientists

Australia, Bolivia, Costa Rica, France, Japan, Poland, Slovenia, Spain, Switzerland

**also supporting scientists*

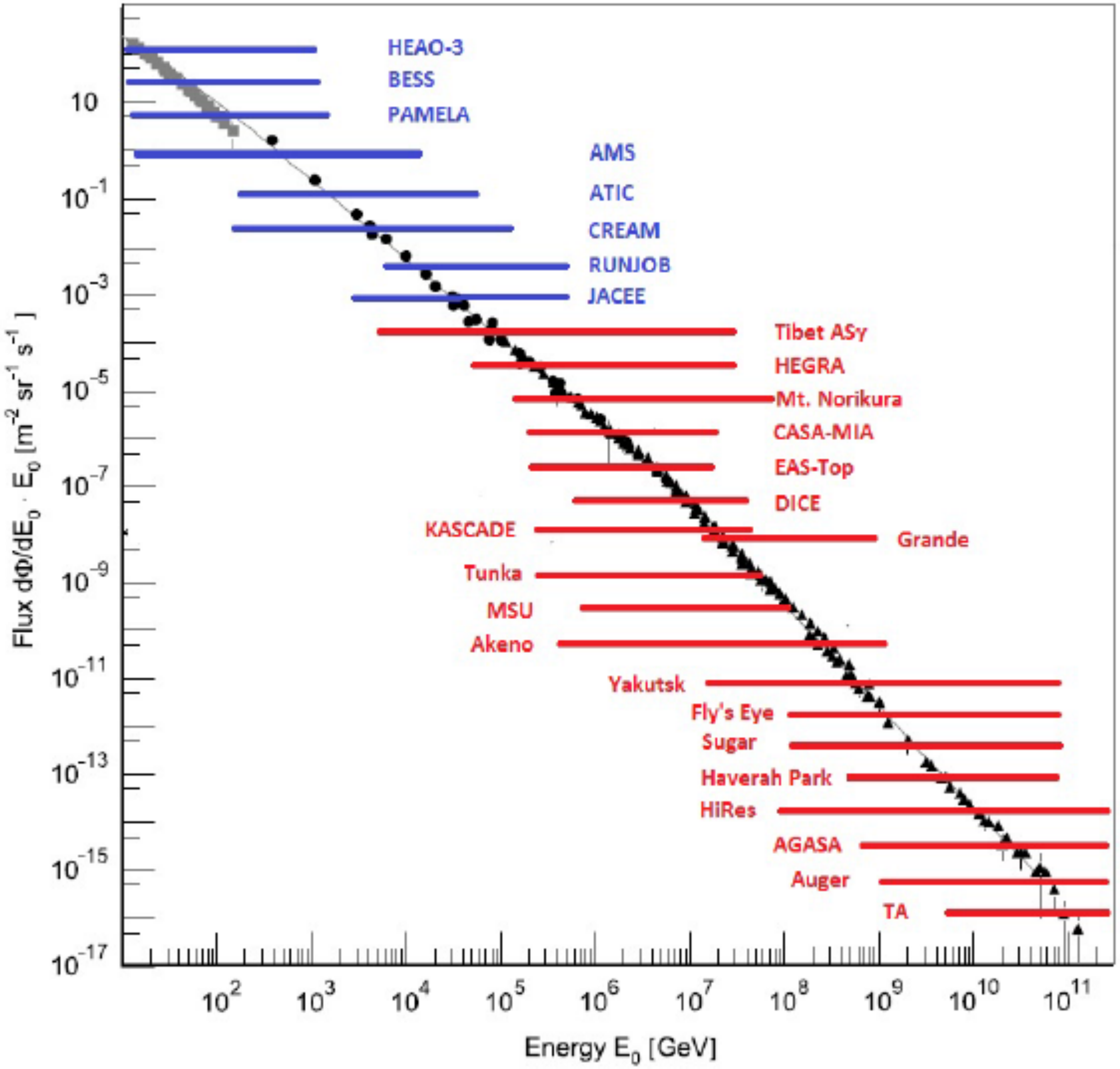
Any interested individual can become supporting scientist.

Astrofisica Nucleare e Subnucleare

UHECR

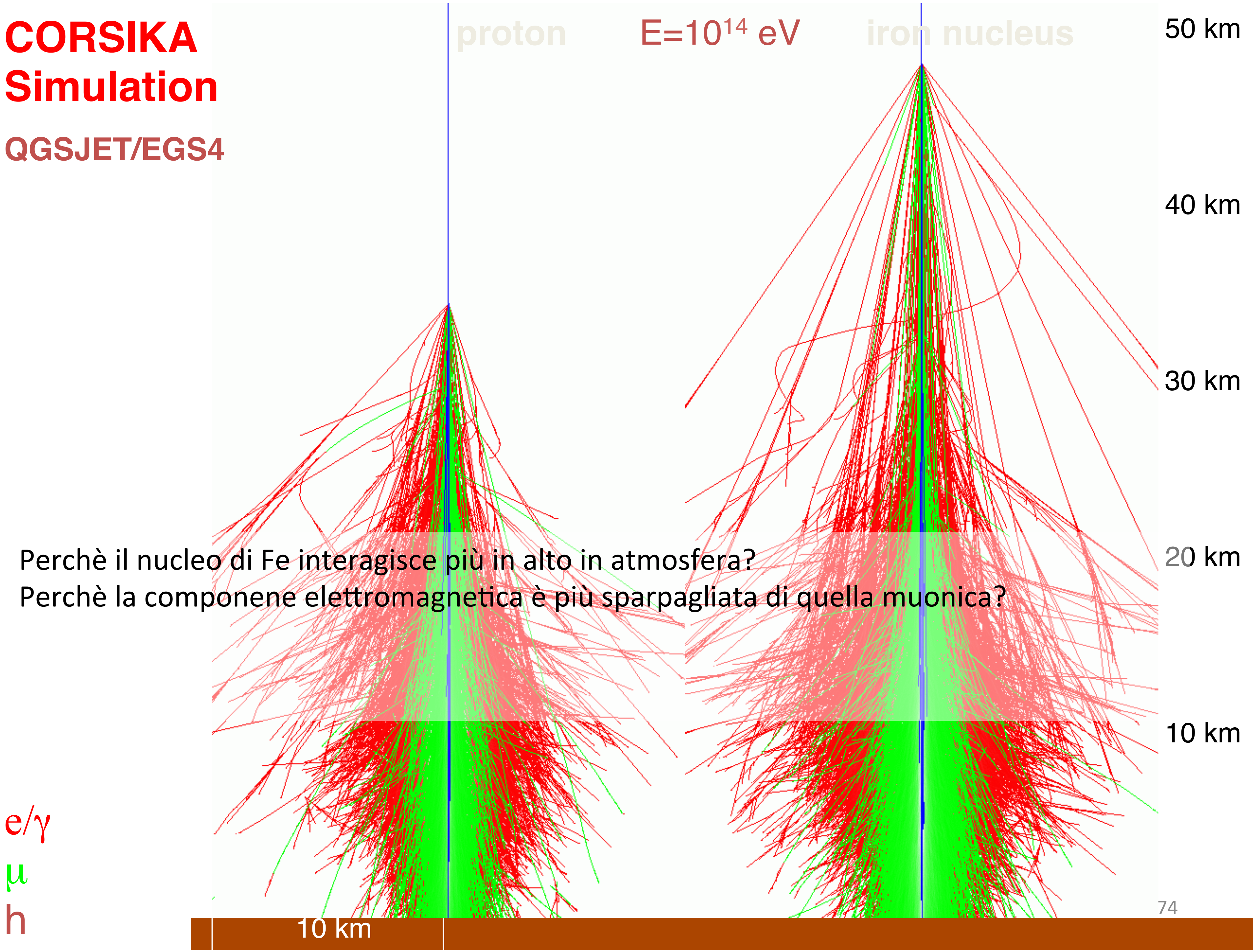
Metodi di misura dei raggi cosmici

Misure dirette
E<10^{14} eV
Misure indirette,
E>10^{14} eV



CORSIKA Simulation

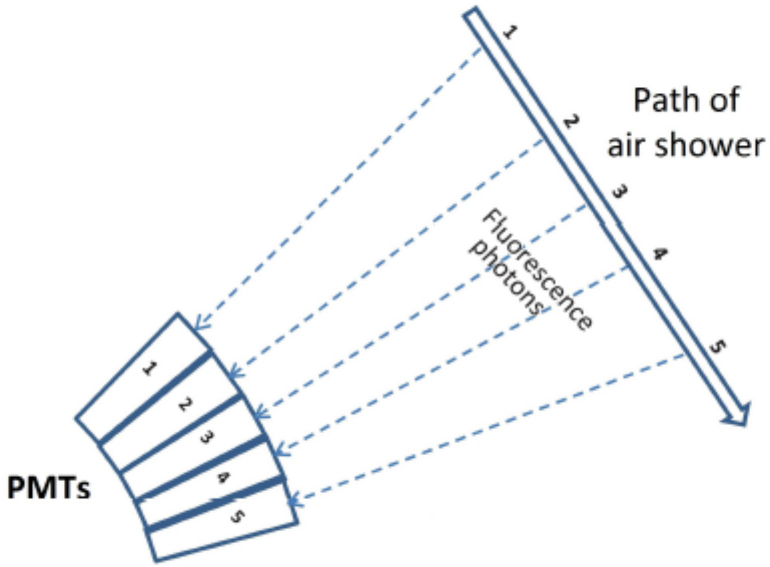
QGSJET/EGS4

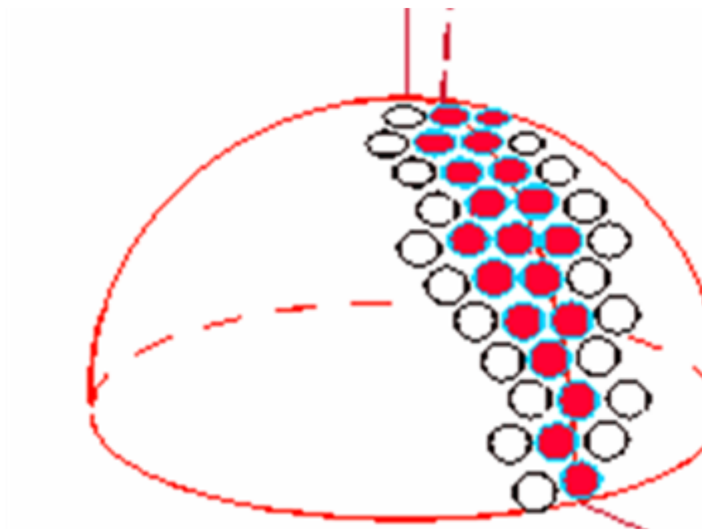


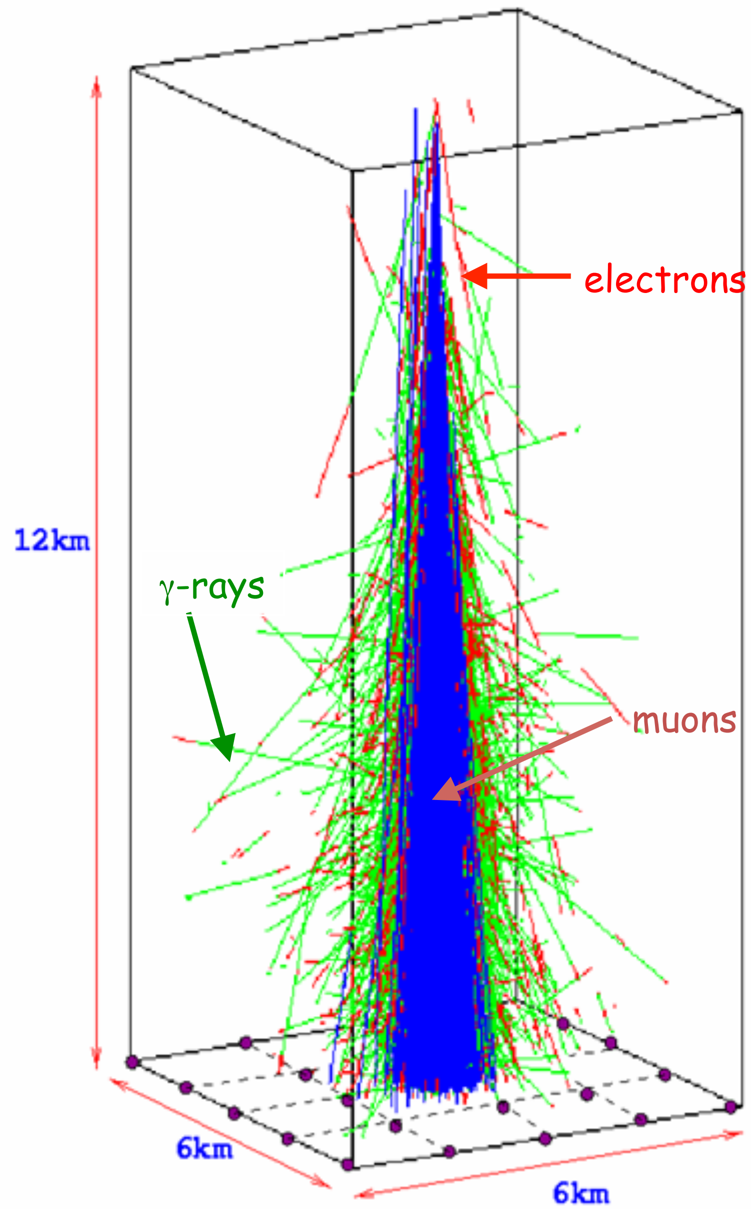
Perchè il nucleo di Fe interagisce più in alto in atmosfera?

Perchè la componene elettromagnetica è più sparpagliata di quella muonica?

Rivelatori di sciami di alta energia







AUGER: Un rivelatore ibrido

Rivelatore di sciami: 1600 taniche cilindriche (ciascuna di 10 m^2 ed alte 1.5 m) riempite di acqua, per rivelare gli sciami al suolo tramite la luce Cerenkov emessa dagli elettroni nell'acqua

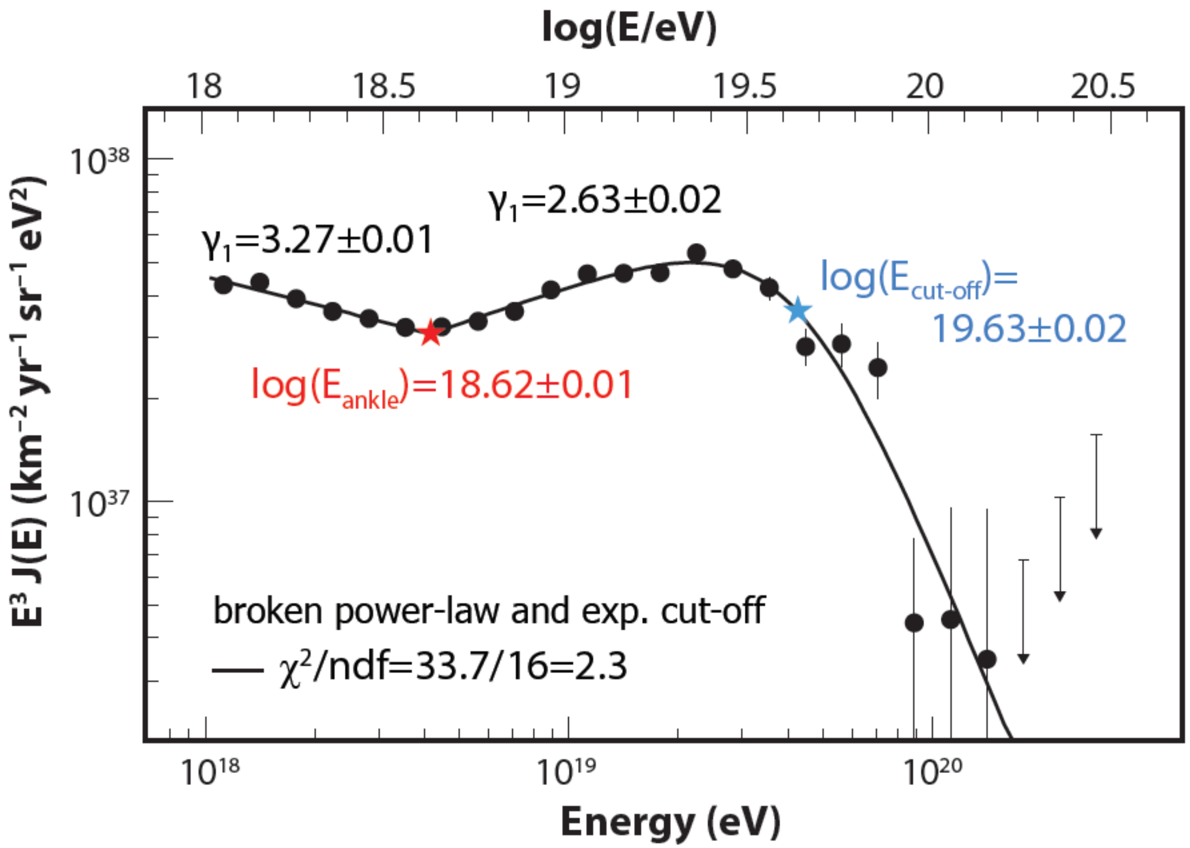
- Il rivelatore di sciami misura la distribuzione laterale e temporale dello sciame
- Distanza tra taniche: 1.5 km
- Area di forma esagonale, di 60×60 km^2
- Rivelatori di fluorescenza: 6 telescopi con ciascuno 4 "occhi" per determinare il profilo longitudinale dello sciame e l'altezza del suo massimo.

AUGER Energy spectrum

SD+Hybrid Combined Spectrum

#893: Salamida

#724: Dembinsky

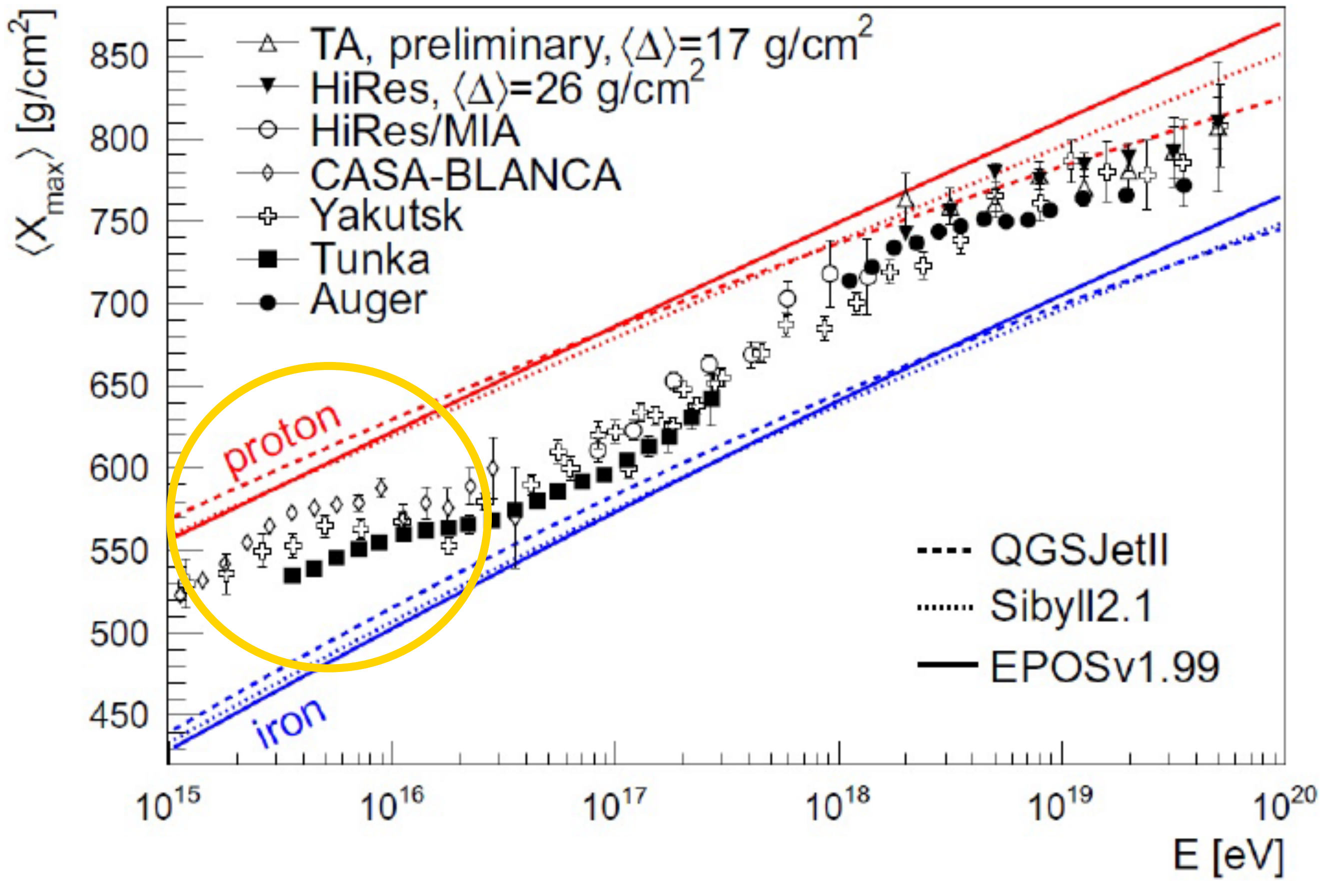


Exposure = 20905 km² sr yr (60% increase over PLB 685 (2010) 239)

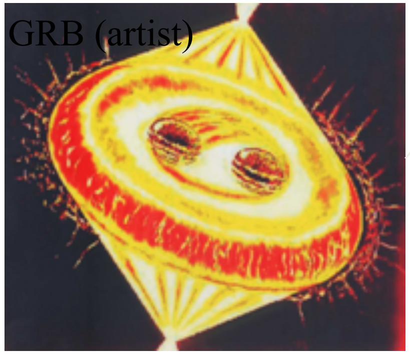
Inclined showers add another 5300 km² sr yr (→ #724)

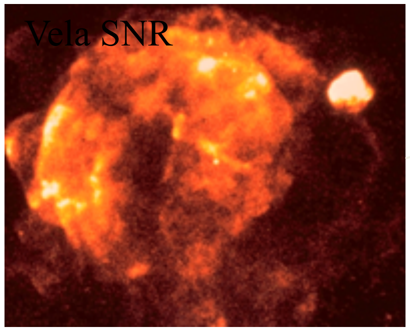
Composizione chimica dei RC nella regione degli EAS

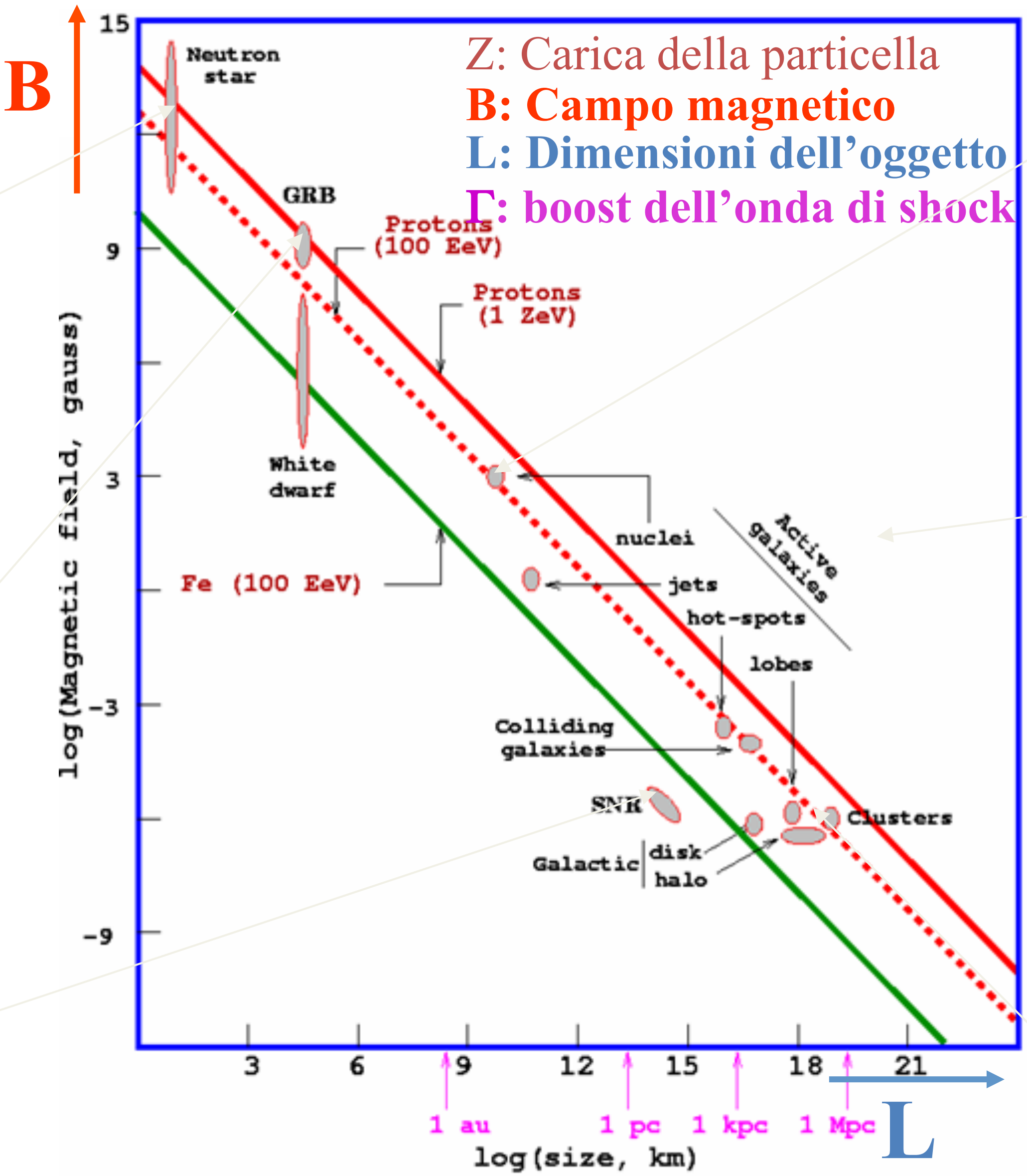
- Il modello del *leaky box* prevede un arricchimento di elementi pesanti nei RC sino al ginocchio.
- Gli EAS possono misurare <A> con difficoltà.
- Le misure possono essere poi confrontate con *modelli estremi* (solo p o Fe) via MC

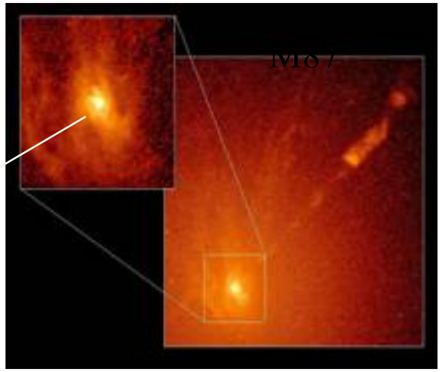


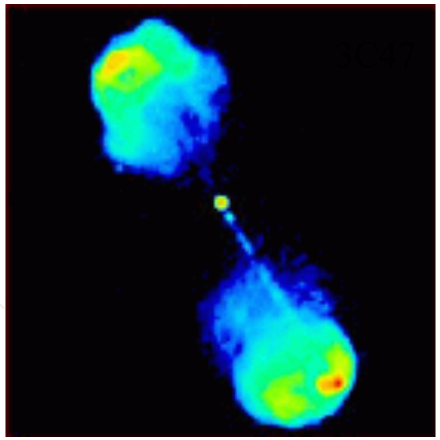
Possibili macchine acceleratrici







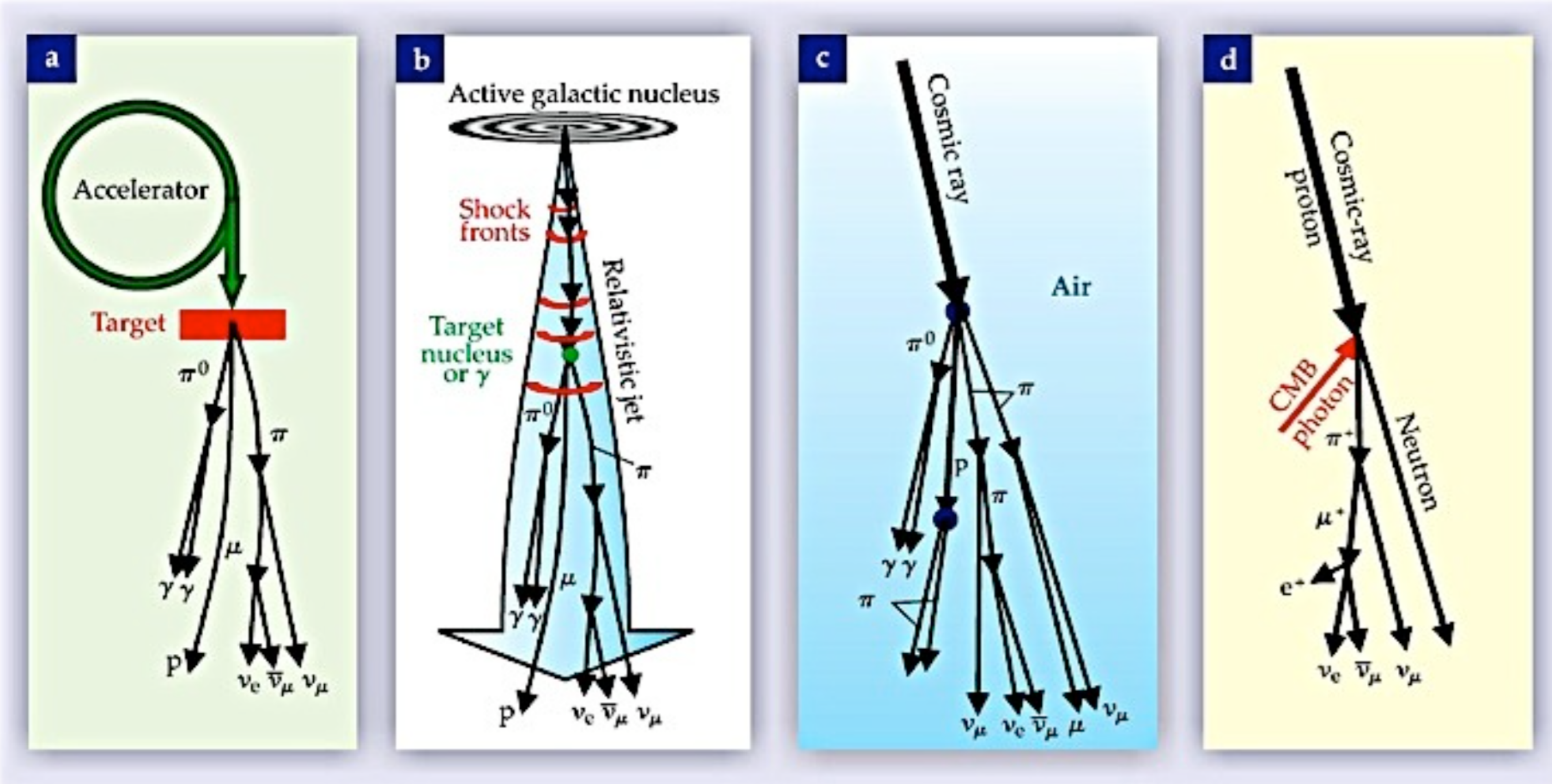




Astrofisica Nucleare e Subnucleare

Astrophysical Neutrinos

Summary of neutrino production modes



From Physics Today

THE ICECUBE NEUTRINO OBSERVATORY

Deployed in the deep glacial ice at the South Pole

5160 PMTs

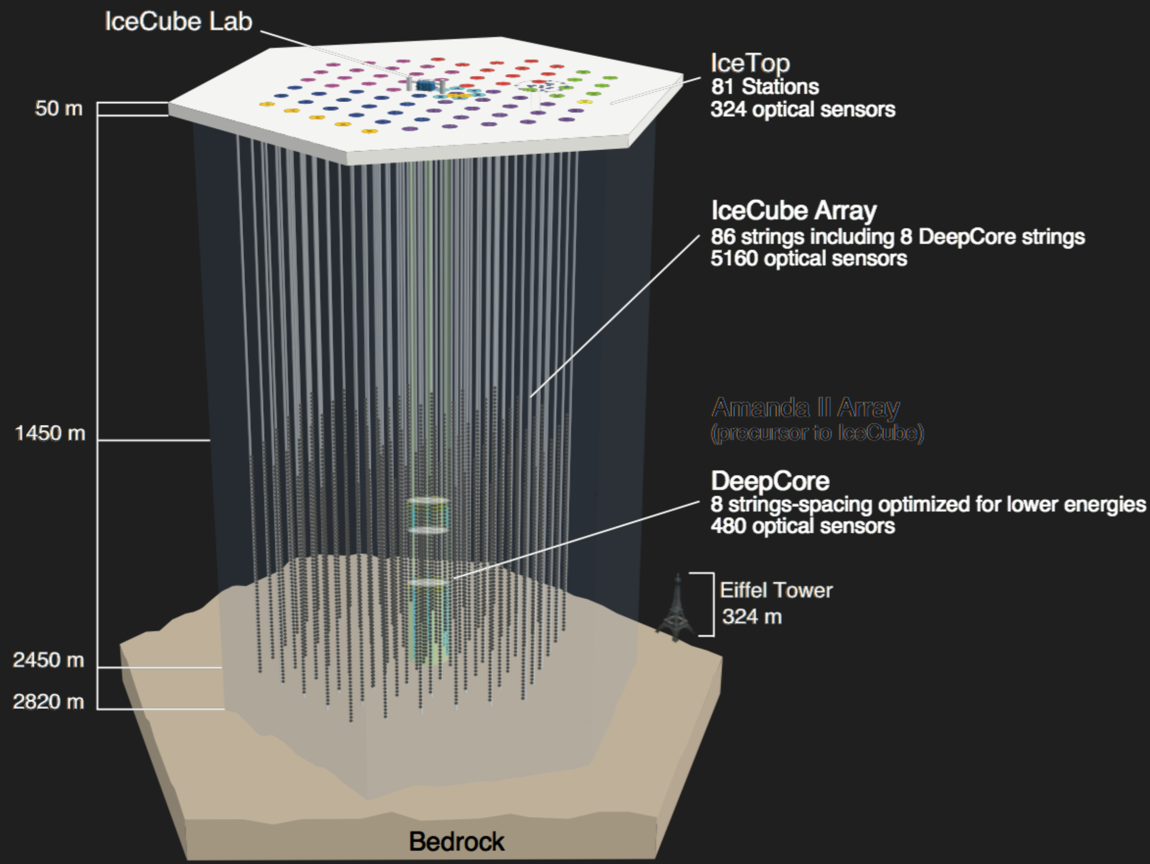
1 km^3 volume

86 strings

17 m vertical spacing

125 m string spacing

Completed **2010**

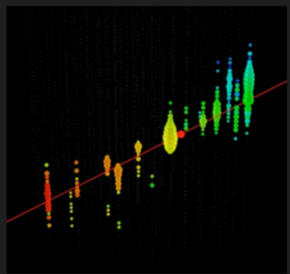


NEUTRINO EVENT SIGNATURES

Signatures of signal events

time

CC Muon Neutrino

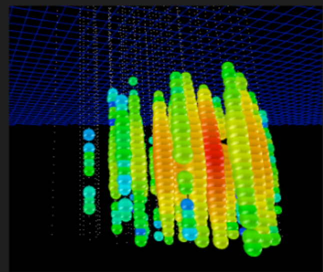


$$\nu_\mu + N \to \mu + X$$

track (data)

factor of ≈ 2 energy resolution
< 1° angular resolution at high energies

Neutral Current / Electron Neutrino



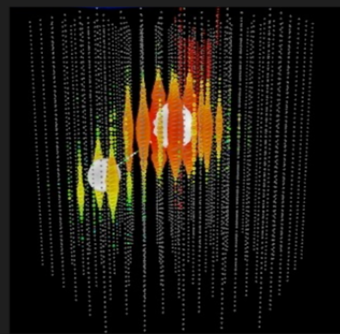
$$\nu_e + N \to e + X$$

$$\nu_x + N \to \nu_x + X$$

cascade (data)

≈ ±15% deposited energy resolution
≈ 10° angular resolution (in IceCube)
(at energies ≳ 100 TeV)

CC Tau Neutrino

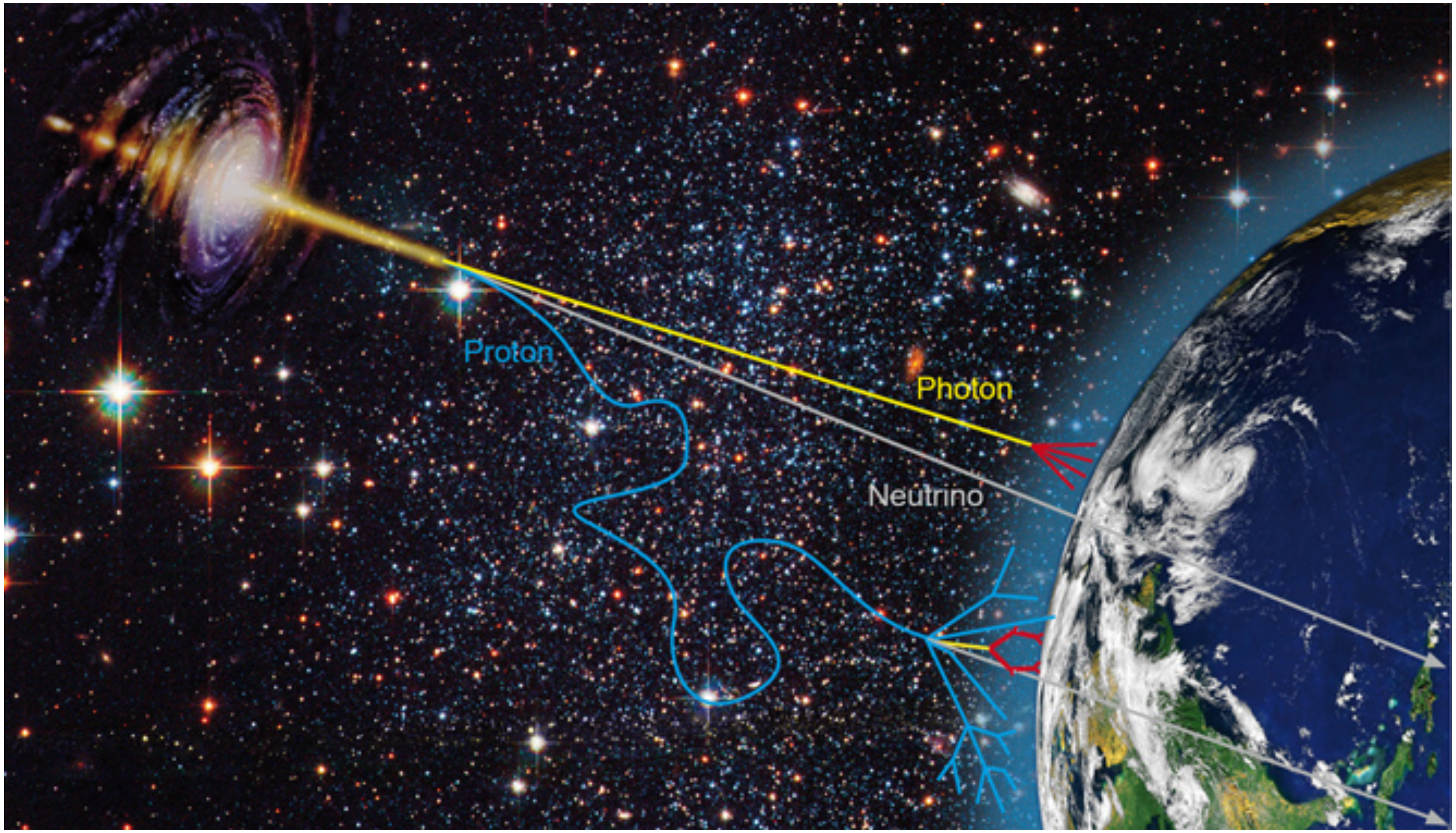


$$\nu_\tau + N \to \tau + X$$

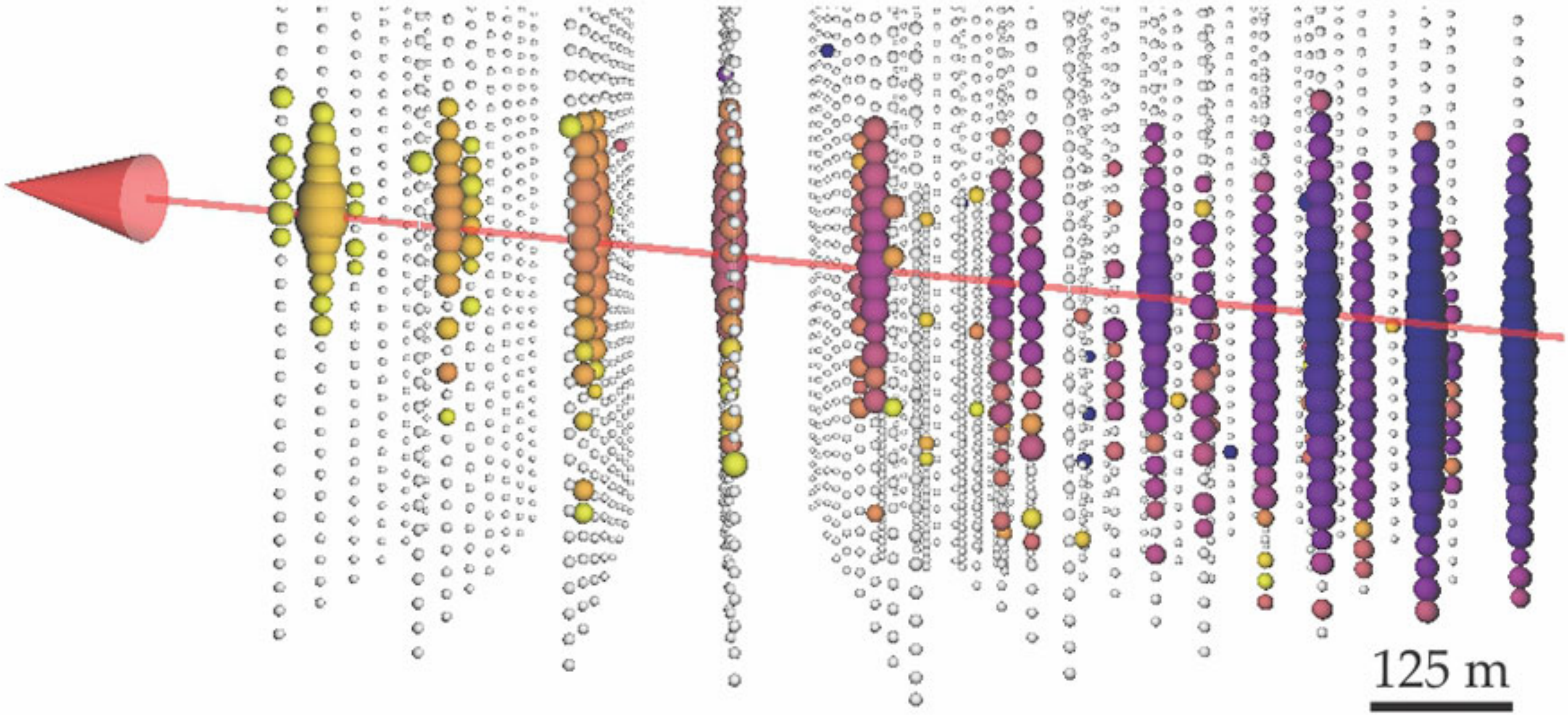
"double-bang" (≳10PeV) and other signatures (simulation)

(not observed yet: τ decay length is 50 m/PeV)

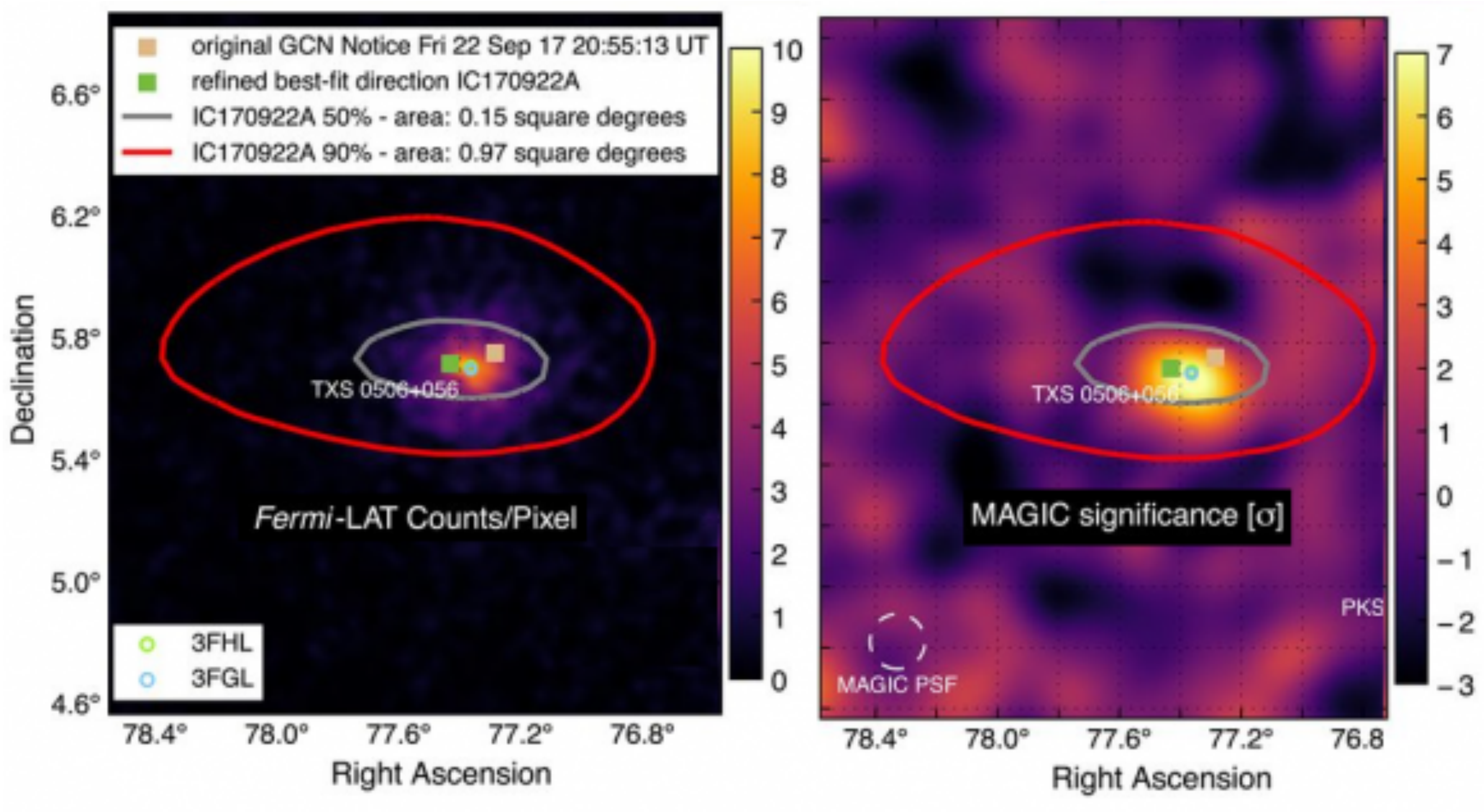
Astrophysical Neutrinos



“The” neutrino …

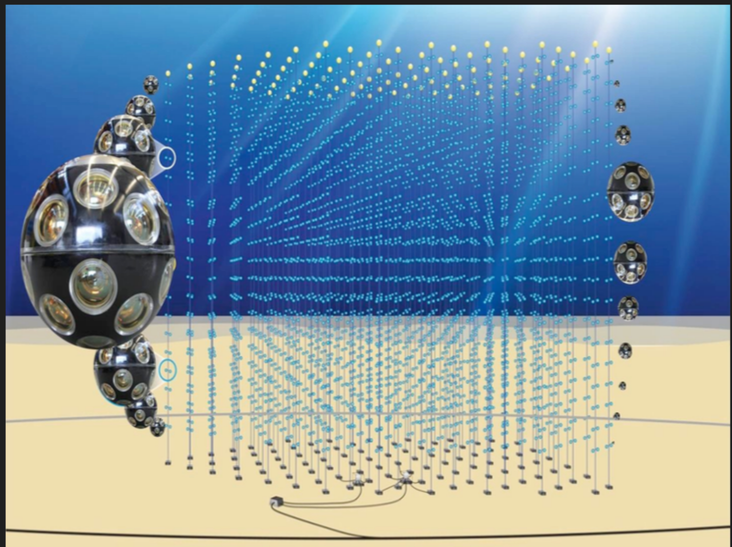


TXS 0506+056

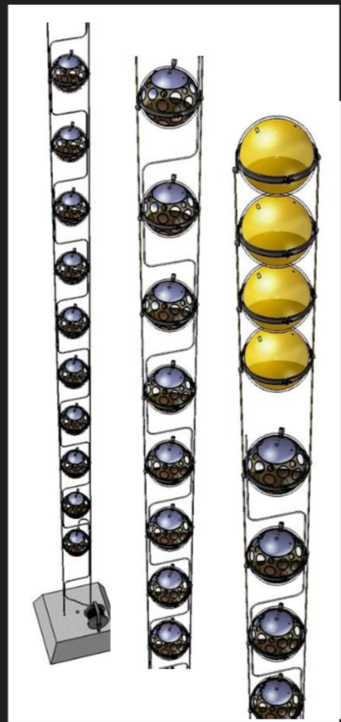

original GCN Notice Fri 22 Sep 17 20:55:13 UT
refined best-fit direction IC170922A
IC170922A 50% - area: 0.15 square degrees
IC170922A 90% - area: 0.97 square degrees
TXS 0506+056
Fermi-LAT Counts/Pixel
3FHL
3FGL
Declination
Right Ascension
6.6°
6.2°
5.8°
5.4°
5.0°
4.6°
78.4°
78.0°
77.6°
77.2°
76.8°
10
9
8
7
6
5
4
3
2
1
0
TXS 0506+056
MAGIC significance [σ]
MAGIC PSF
PKS
Right Ascension
78.4°
78.0°
77.6°
77.2°
76.8
7
6
5
4
3
2
1
0
−1
−2
−3

THE KM3NET NEUTRINO TELESCOPE

Multi-site installation in the Mediterranean Sea (France, Italy), instrumented in "building blocks", started construction



KM3NeT "building block"



string with OMs

Multi-PMT digital optical module ("DOM")