cherenkov telescope array

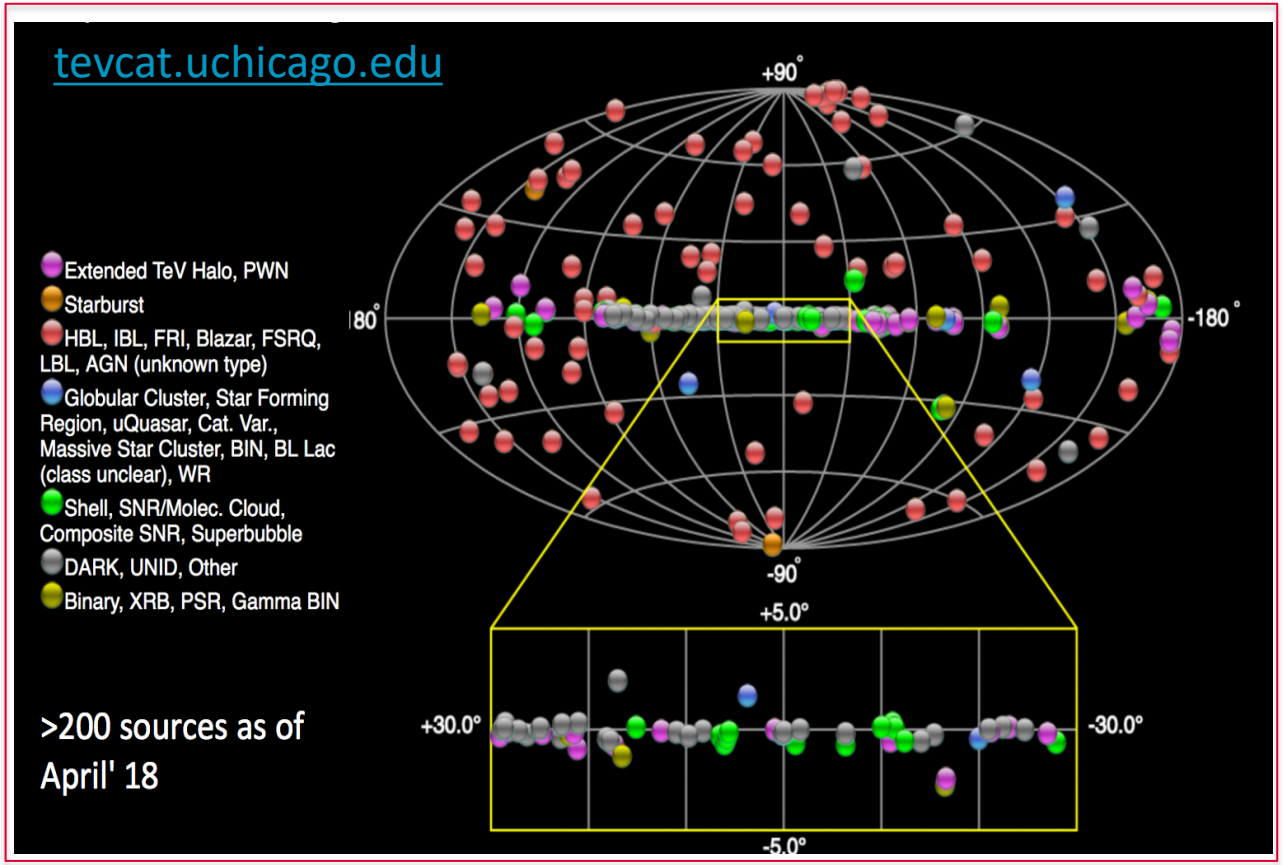
Cherenkov Telescope Array: the first VHE gamma-ray observatory

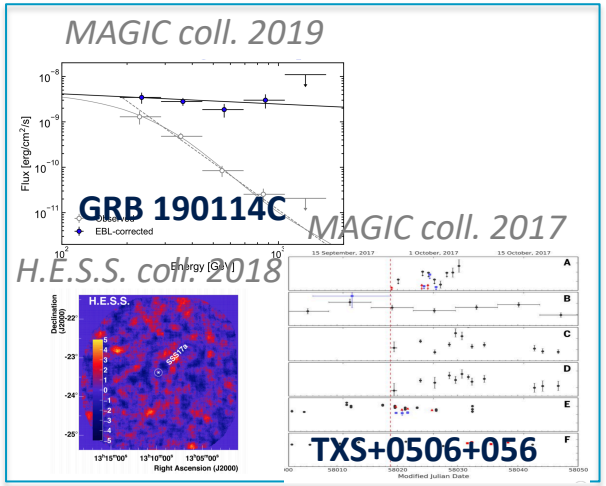
R. Zanin
Project Scientist – CTA Observatory
roberta.zanin@cta-observatory.org

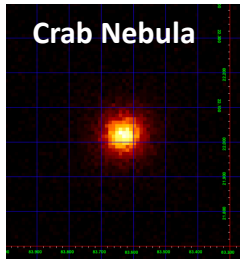
& on behalf of the CTA Consortium

CTA: First VHE gamma-ray observatory

- **VHE gamma-ray astronomy is a "recently" established field**







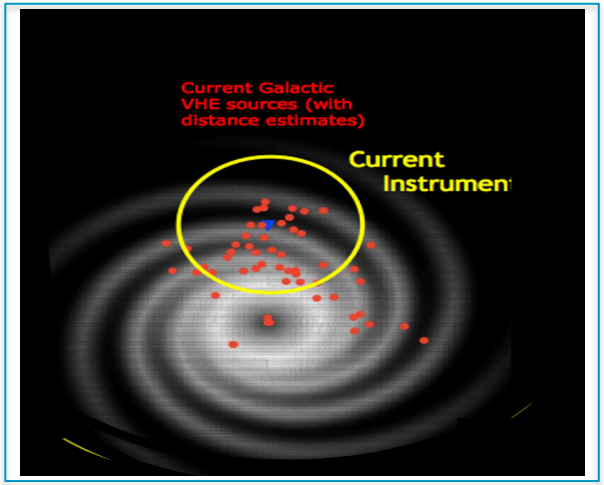
Size:
52'' 3"

H.E.S.S. Coll. 2019

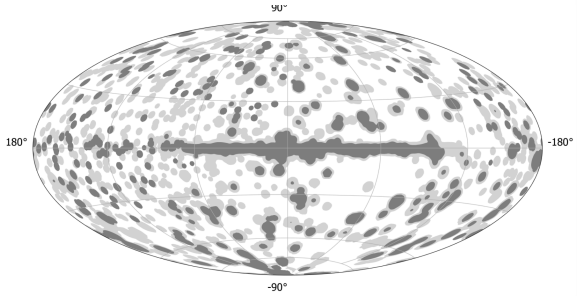
real astronomy at reach only for bright sources

CTA: First VHE gamma-ray observatory

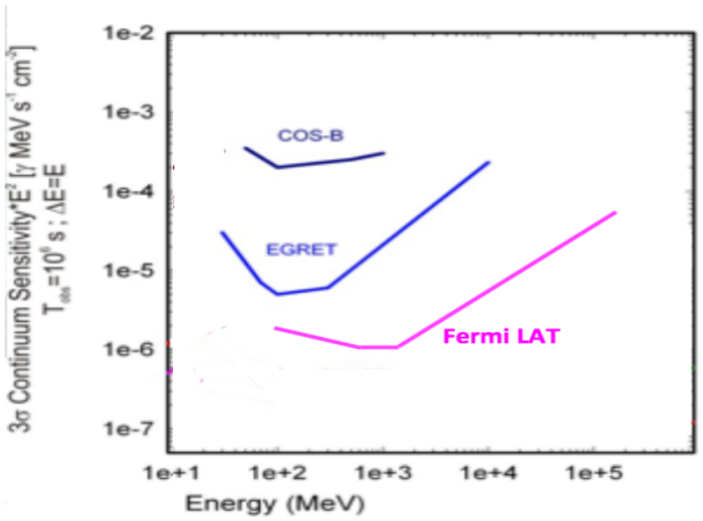
- **VHE gamma-ray astronomy is a "recently" established field with still a lot of exploring power**



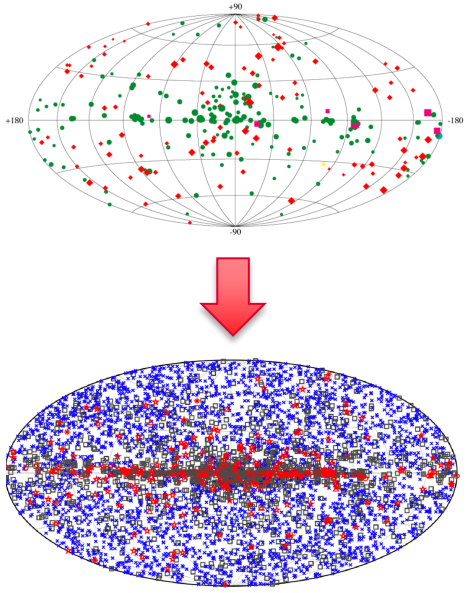
Credits to D.Parsons & E.Prandini



pointings by H.E.S.S., MAGIC & VERITAS



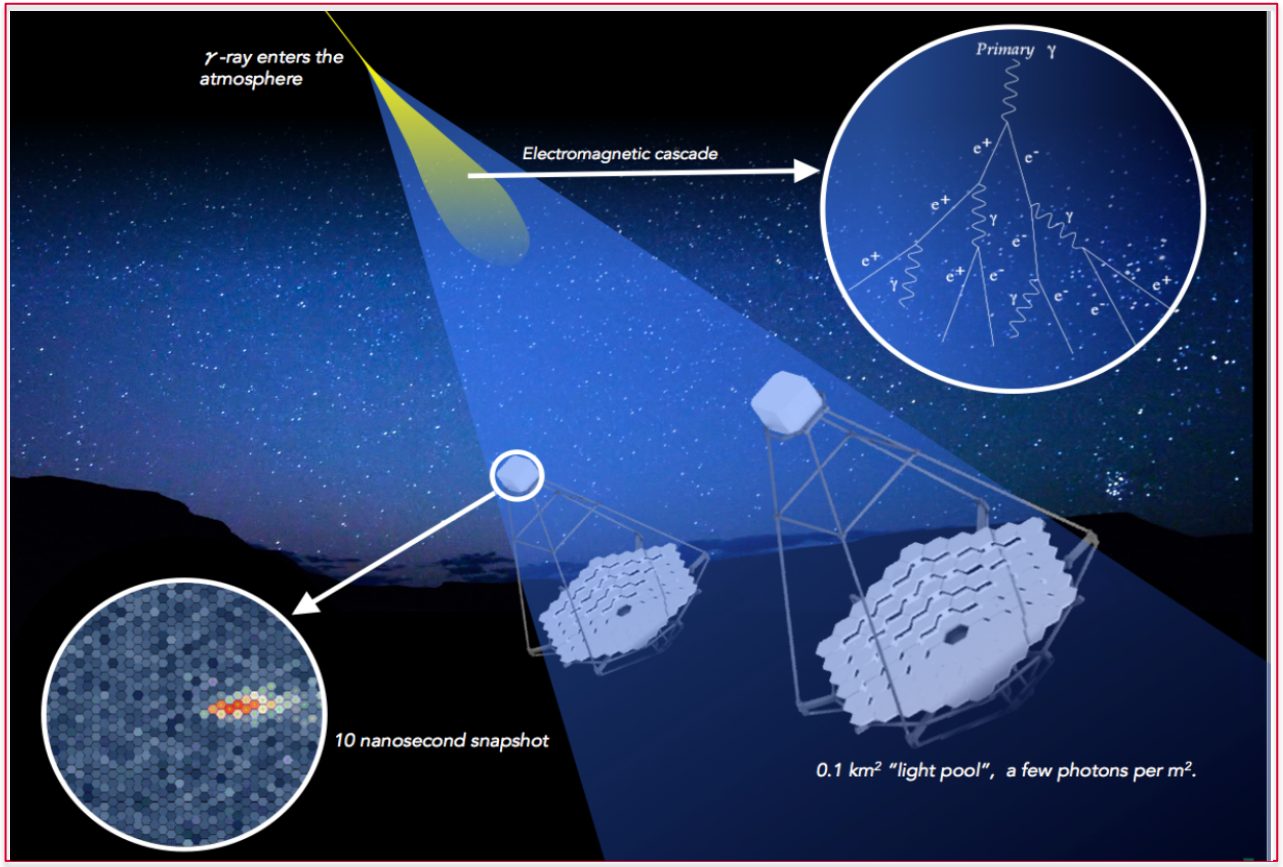
3rd EGRET cataloaue

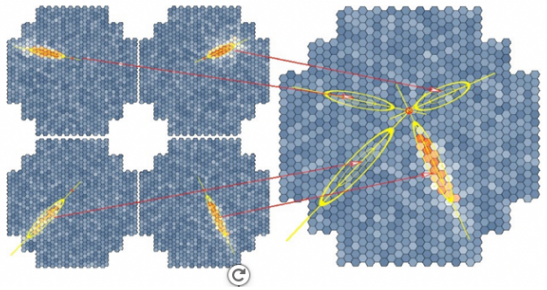


4FGL catalogue

CTA: First VHE gamma-ray observatory

- **The imaging atmospheric Cherenkov technology is a successful, mature technology**



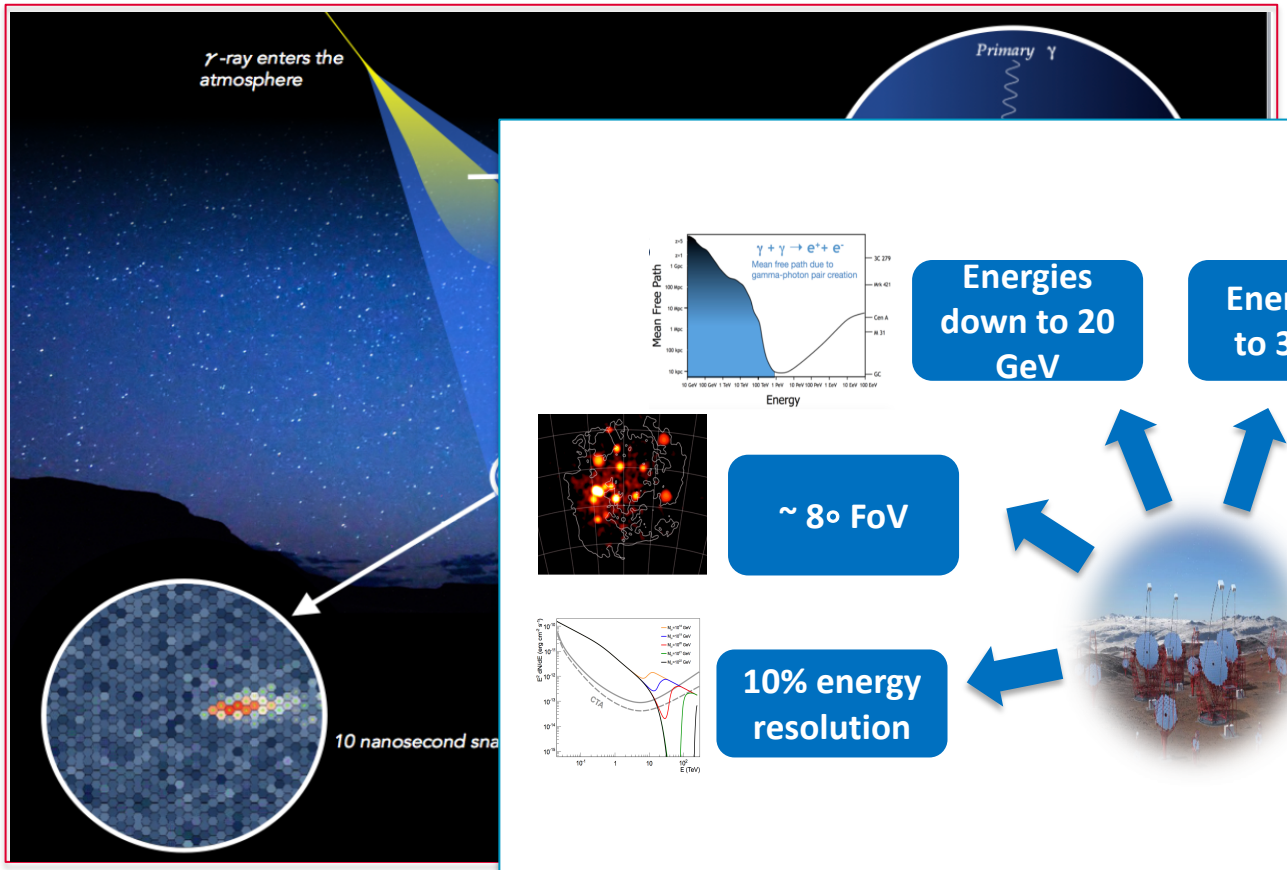


stereoscopy improves angular resolution

- Simplistically array sensitivity improves with √N
- Array sensitivity improves >> √N thanks to the good angular resolution

CTA: First VHE gamma-ray observatory

- **The imaging atmospheric Cherenkov technology is a successful, mature technology**

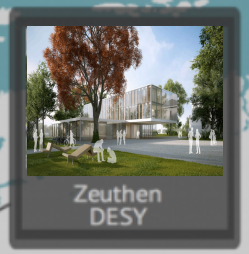


CTA Observatory

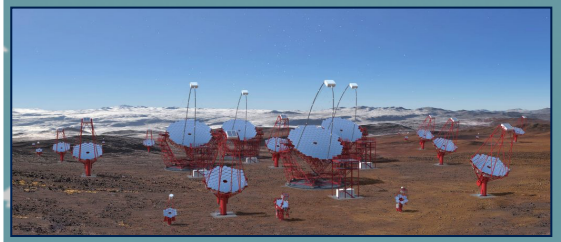
- **Open-data access observatory**
  - data access to all scientists of participating countries
  - proposal driven observatory
- **High-level data products and tools**
- **Operational lifetime of at least 30+10 yr**
  - significant effort for maintenance and operations costs optimization
  - robust against advances in science & technology
- **Integral part of the MWL/MM field**
  - wide sky coverage
  - capable of responding to external alerts as well as of generating alerts to the external community on minute timescales

CTA Observatory

- **One legal entity**
  - ad interim CTAO GmbH
  - in the process of becoming an ERIC



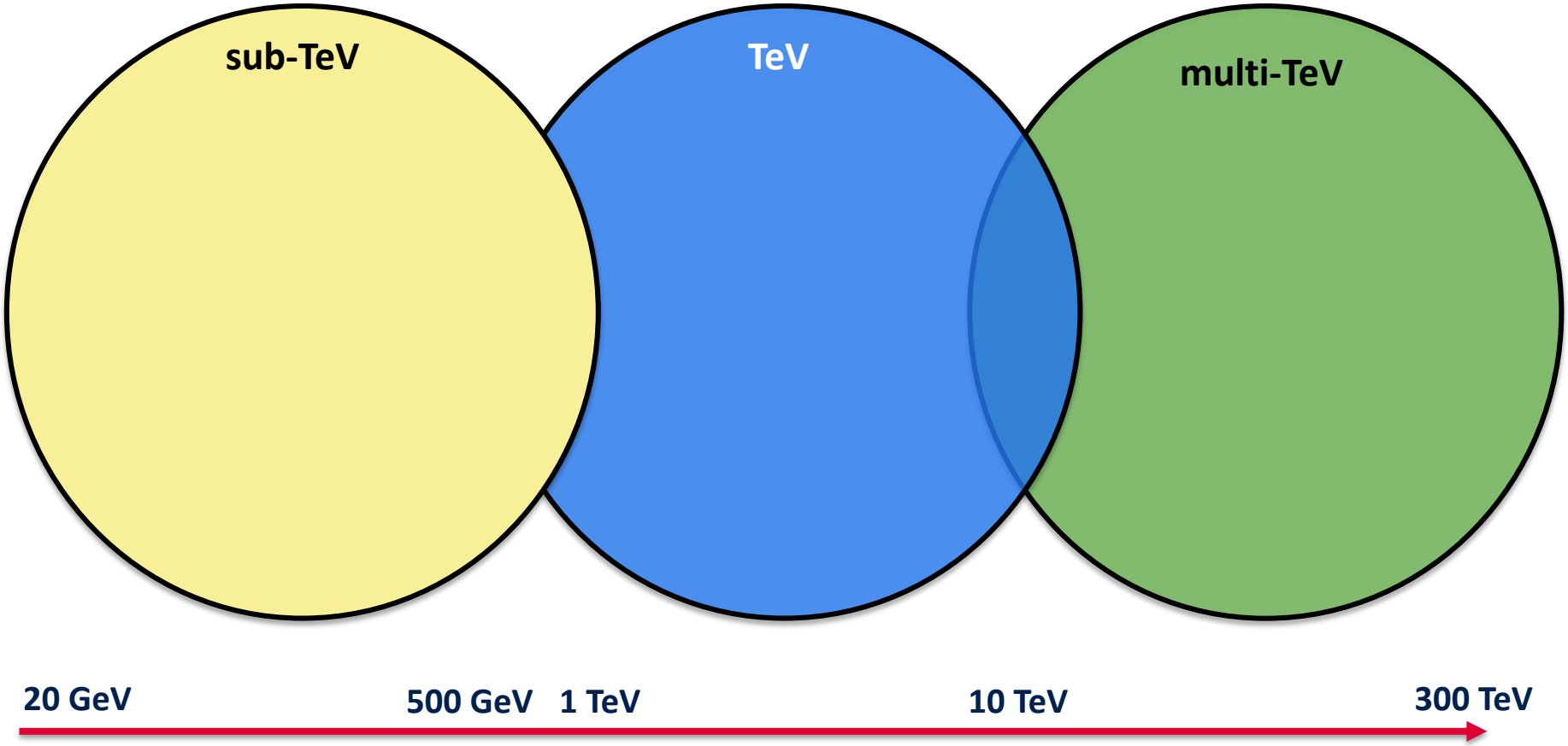
northern hemisphere
southern hemisphere



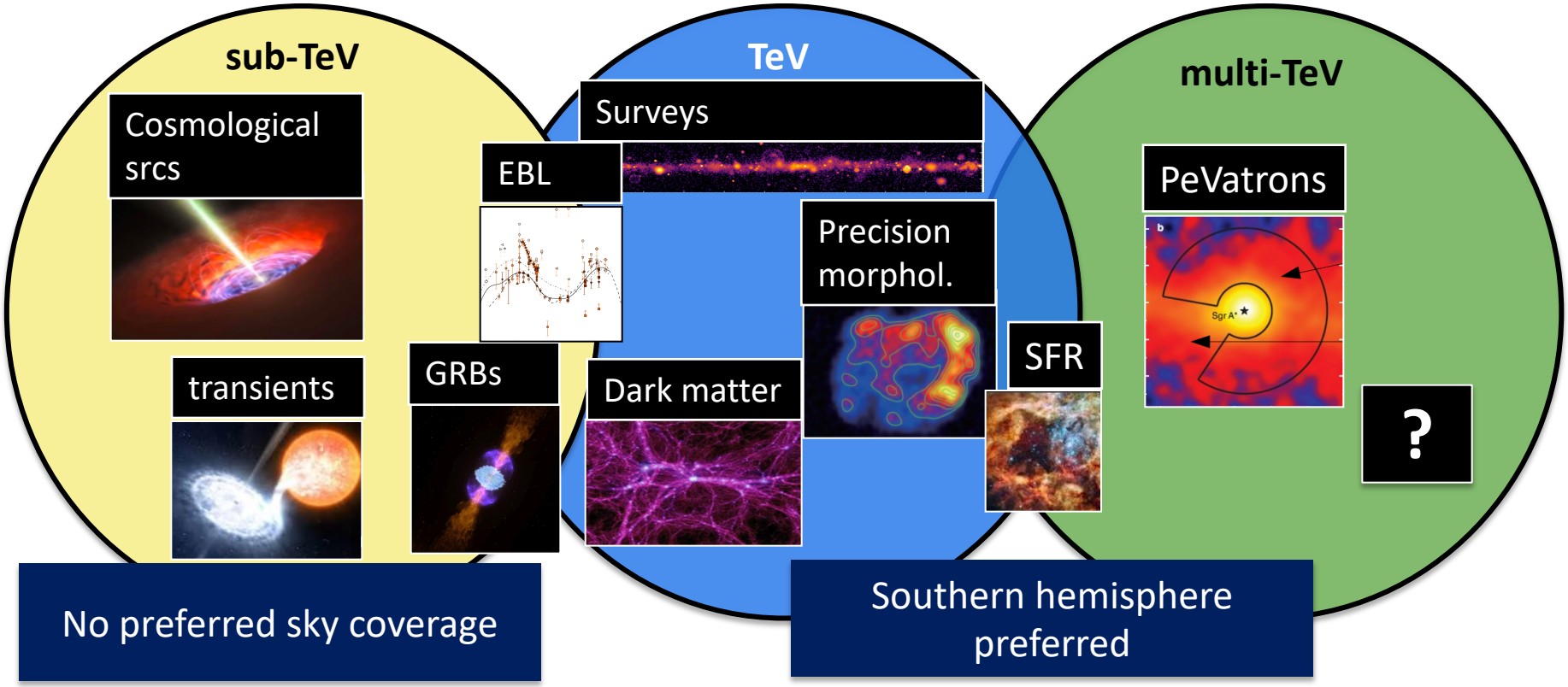
- **Geographically dislocated:**
  - headquaters in Bologna (Italy)
  - science data management center in Zeuthen (Germany)
  - two telescope sites

Array Sites Headquarters Science Management Centre

CTA science case

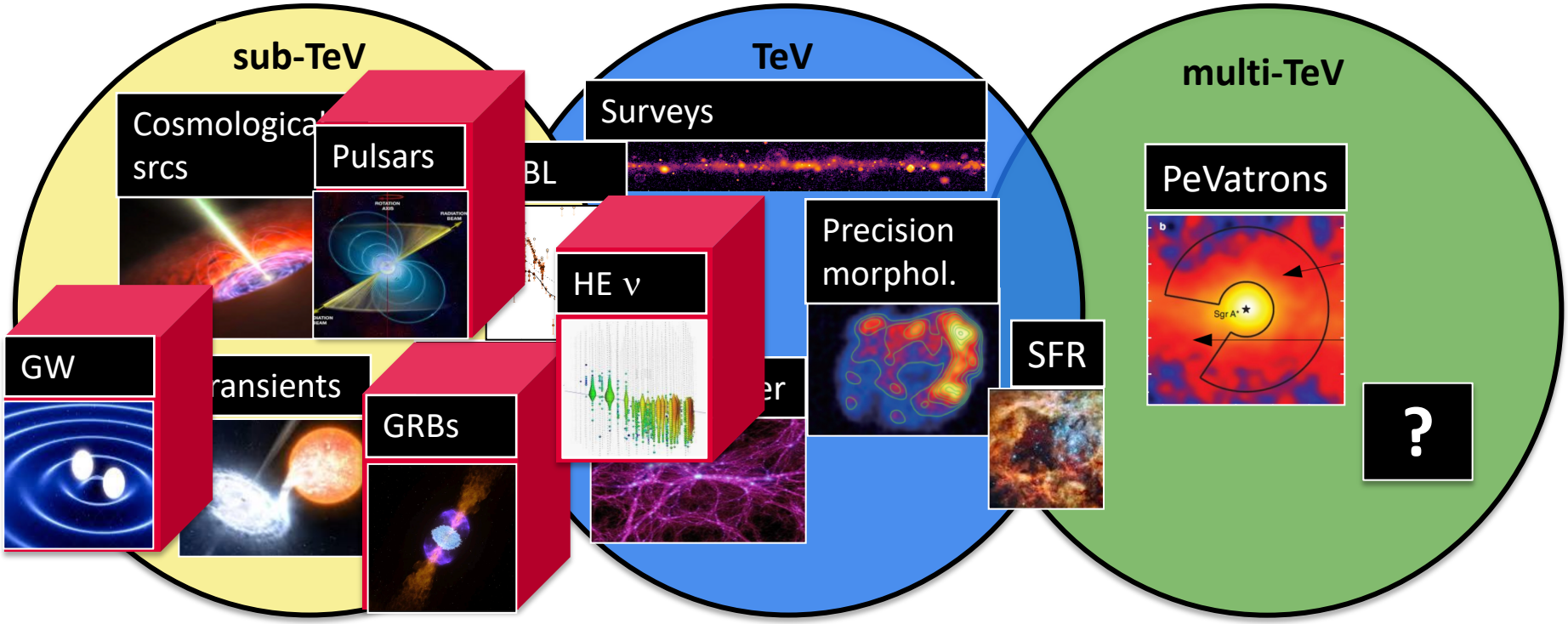


CTA science case



- **Mainly CTA consortium involved in the definition of the science cases**
  (Science with CTA, CTA Consortium 2019 - https://doi.org/10.1142/10986)

CTA science case



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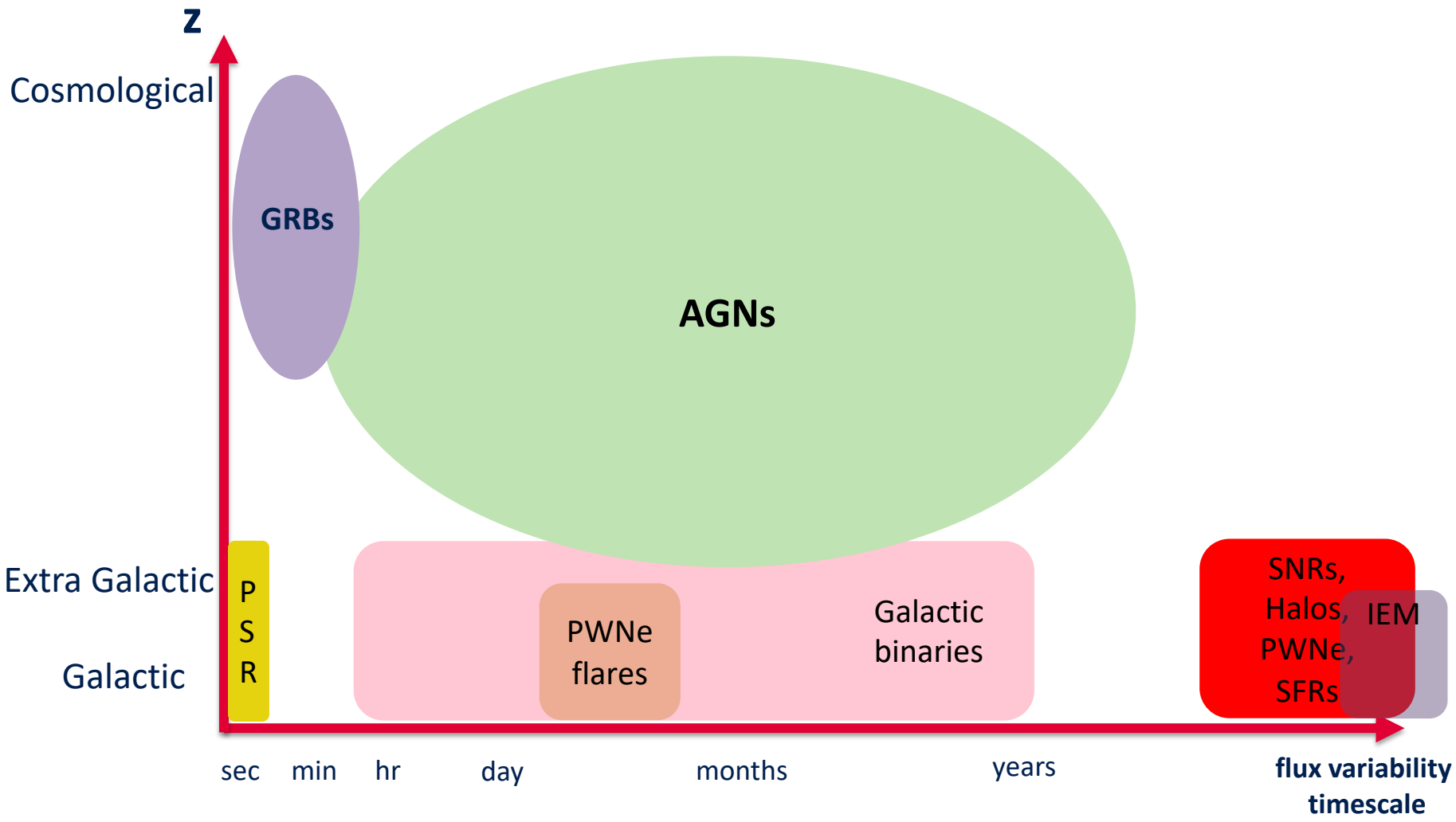
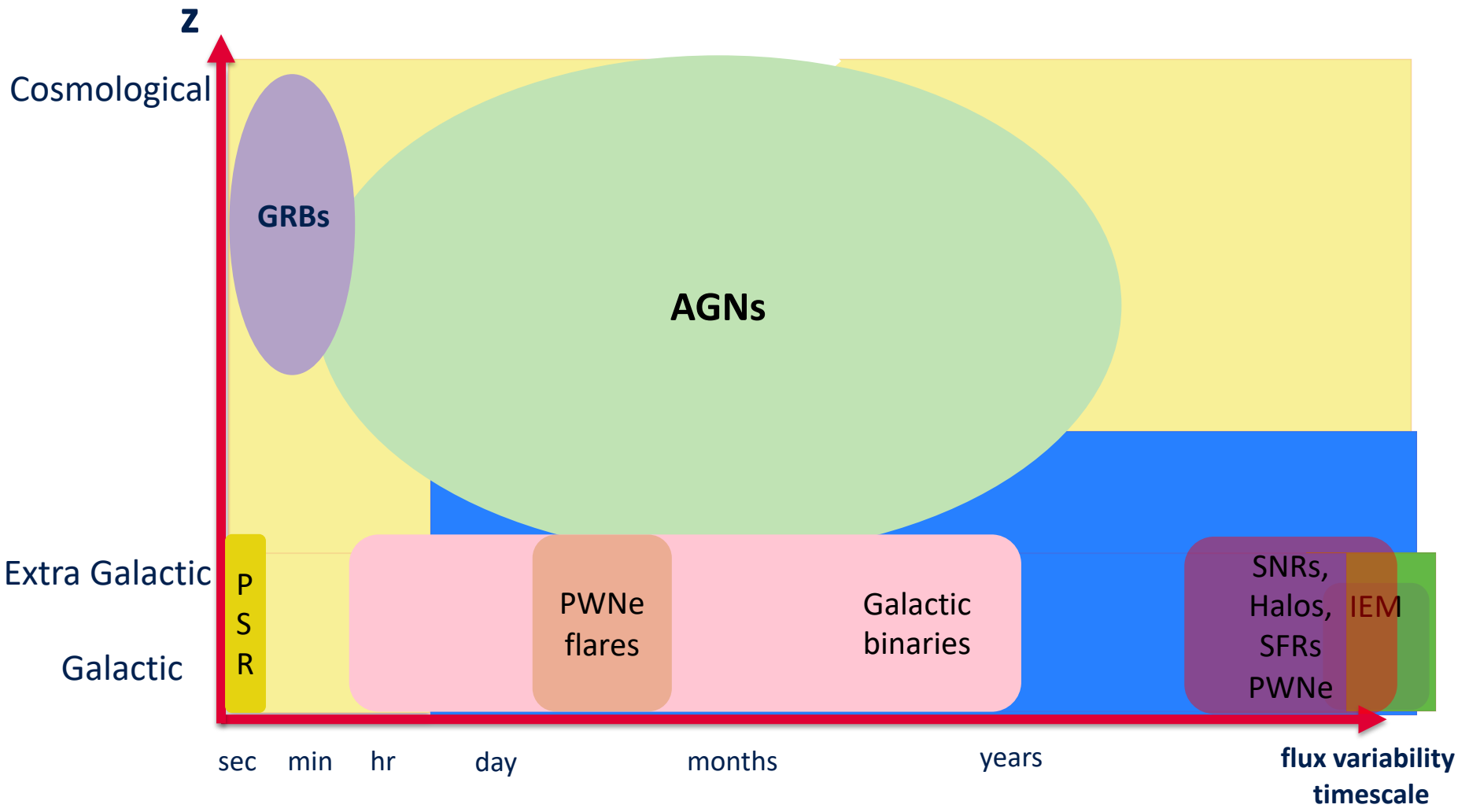
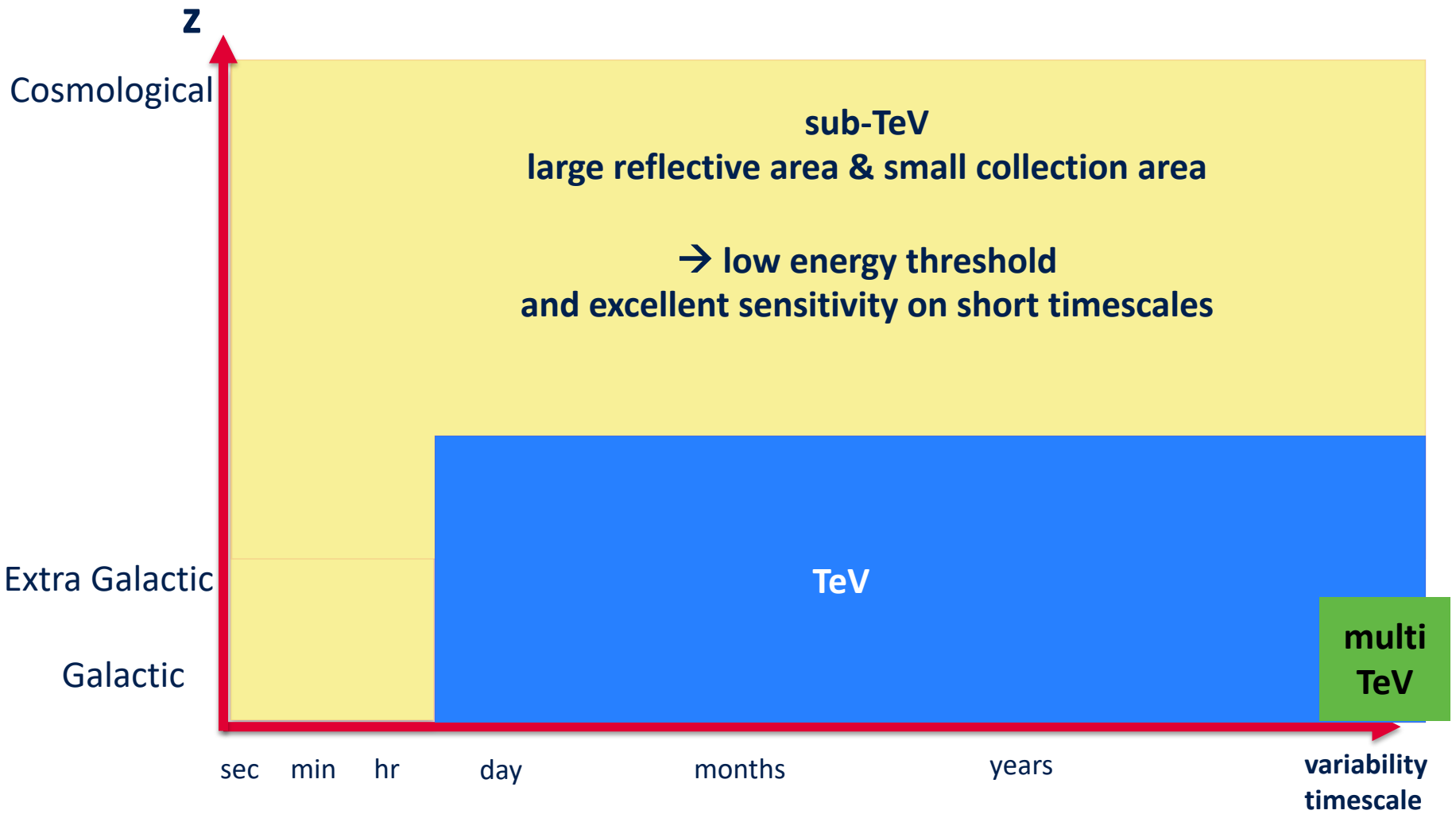
CTA science case



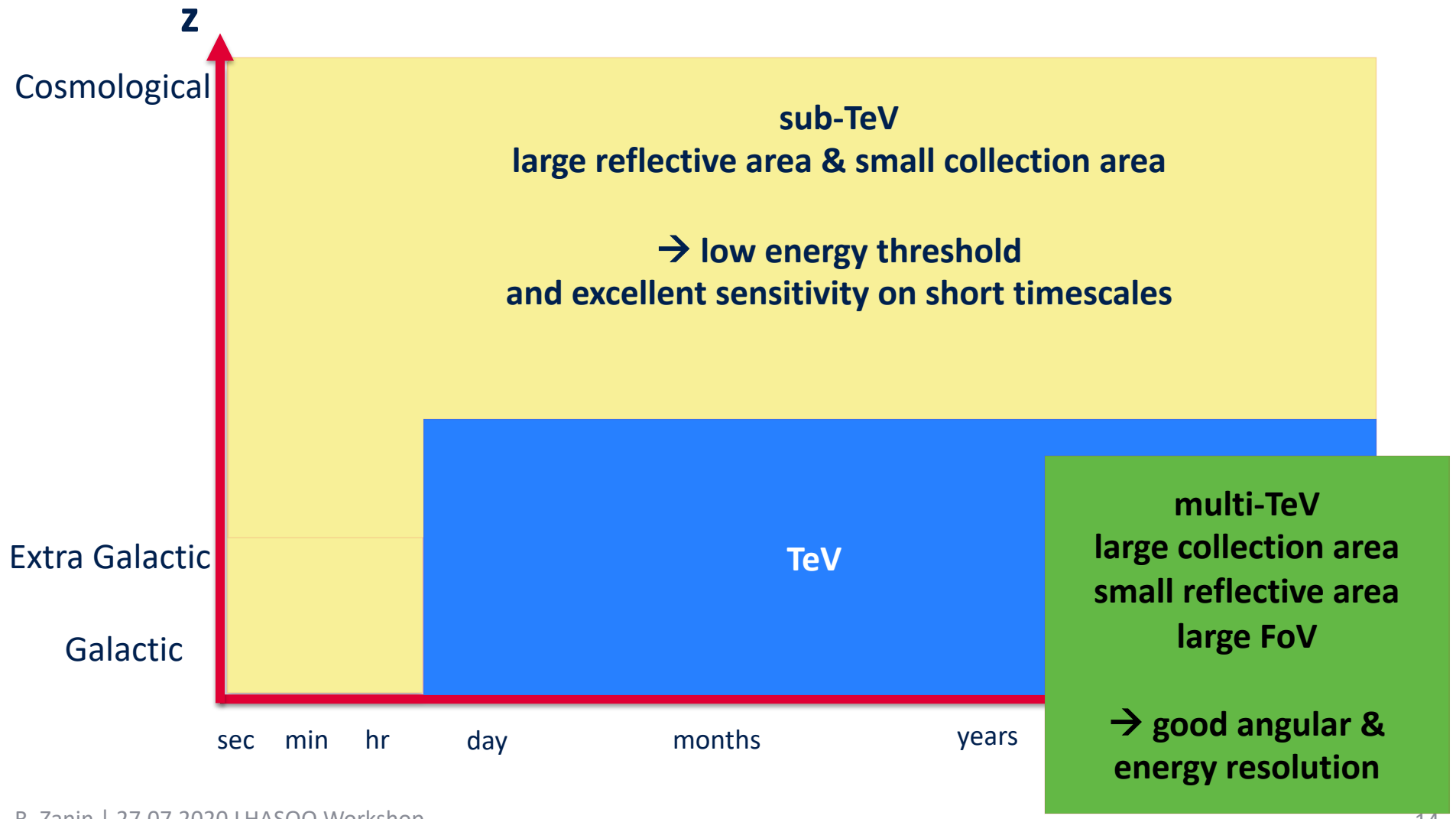
CTA science case



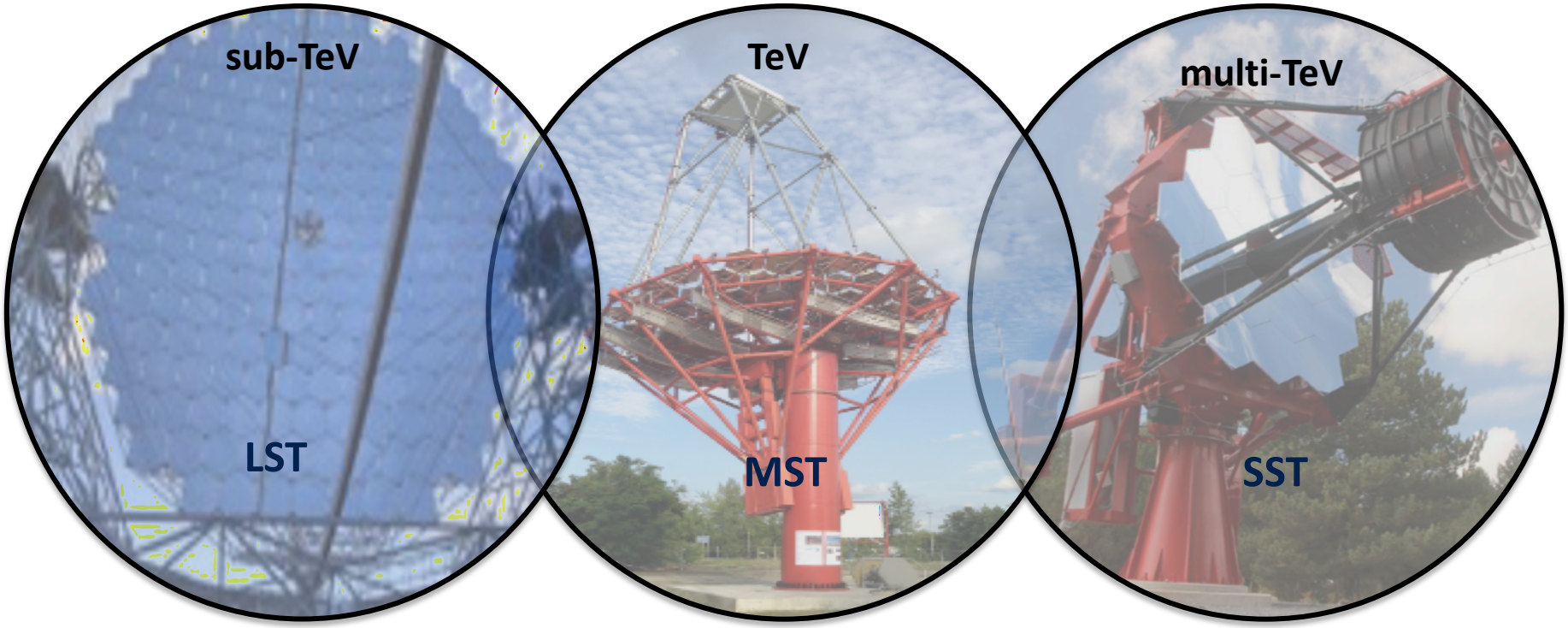
CTA science case & instrument design



CTA science case & instrument design



Telescope design



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

- 4 LSTs at the array center

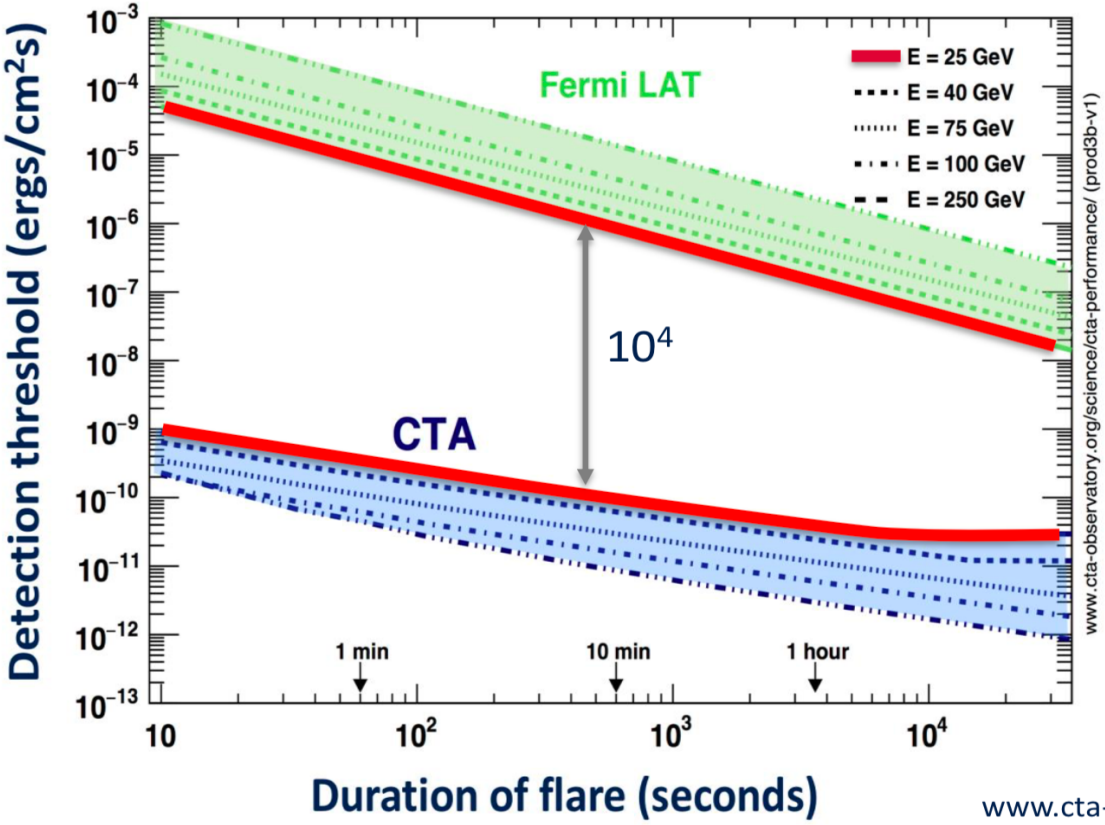
- Davies-Cotton optical design
- 12 m mirror diameter
- PMT camera

- MSTs are workhorse
- ~1km^2 area covered

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

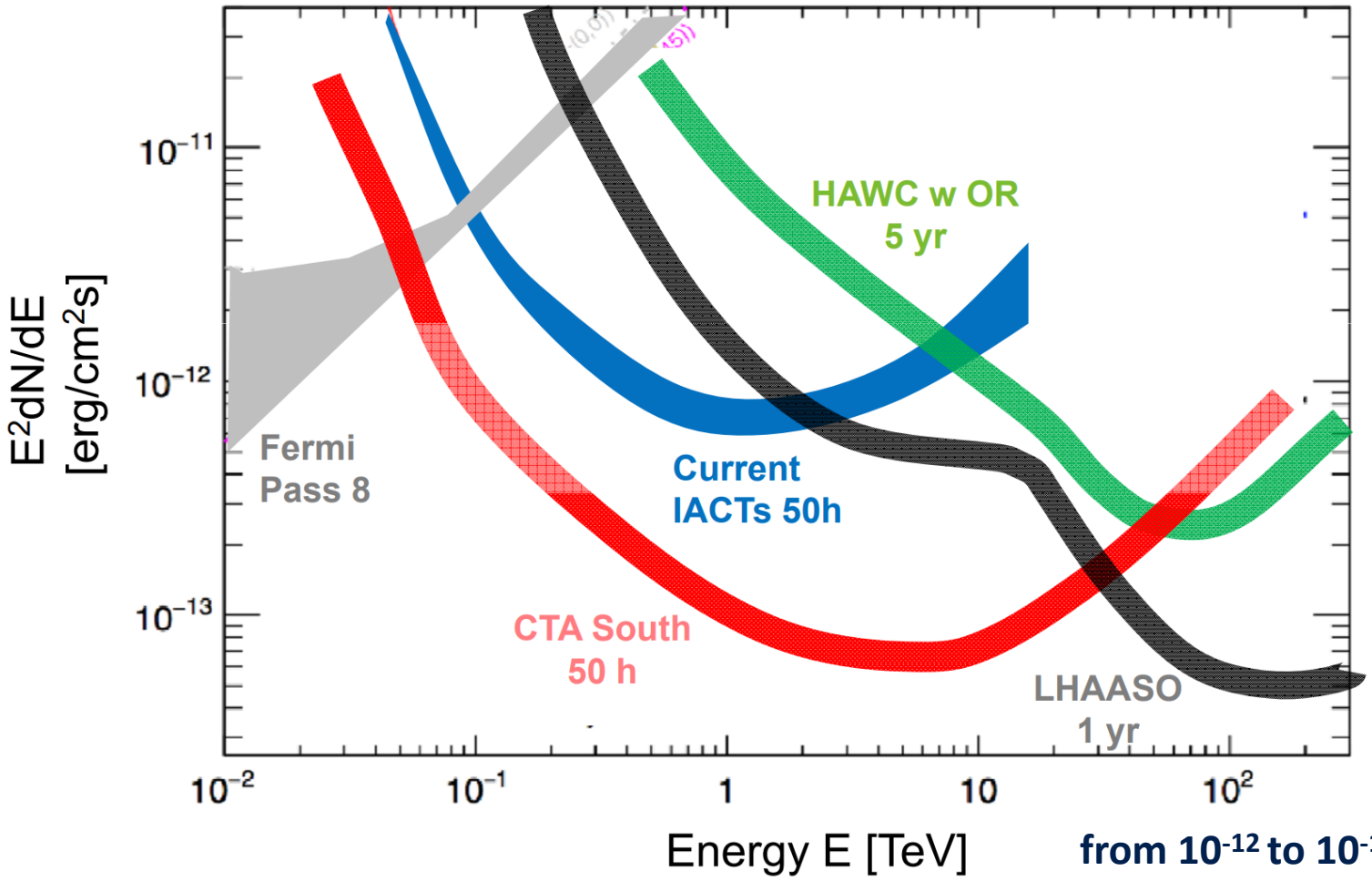
- >50 SSTs
  ~4m^2 area coverage

CTA performance



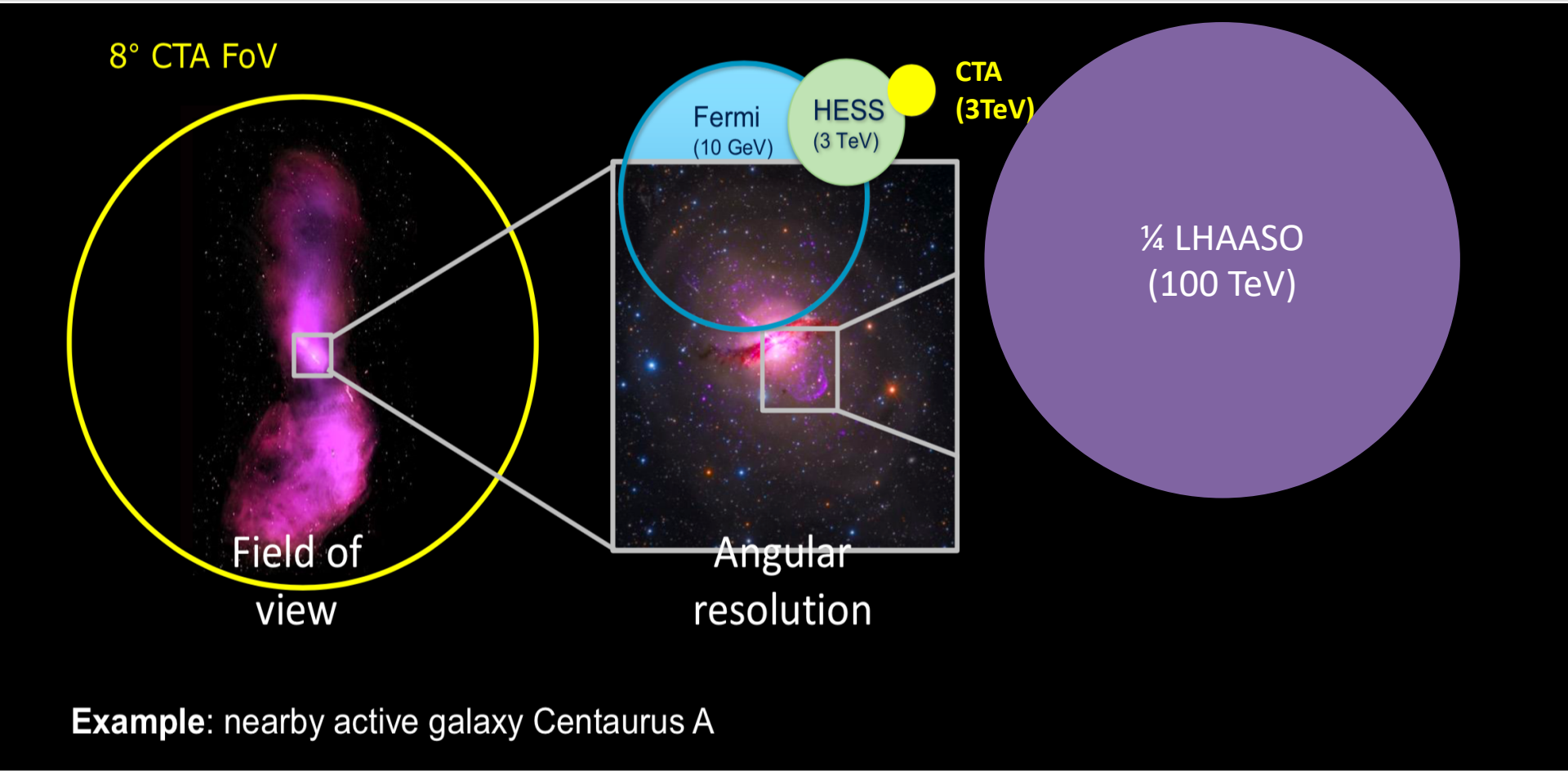
If CTA can get there, it the most sensitive instrument at these energies
but given the limited FoV requires external triggers:
→ LHAASO can play this role providing a selection of the highest energy events

CTA performance



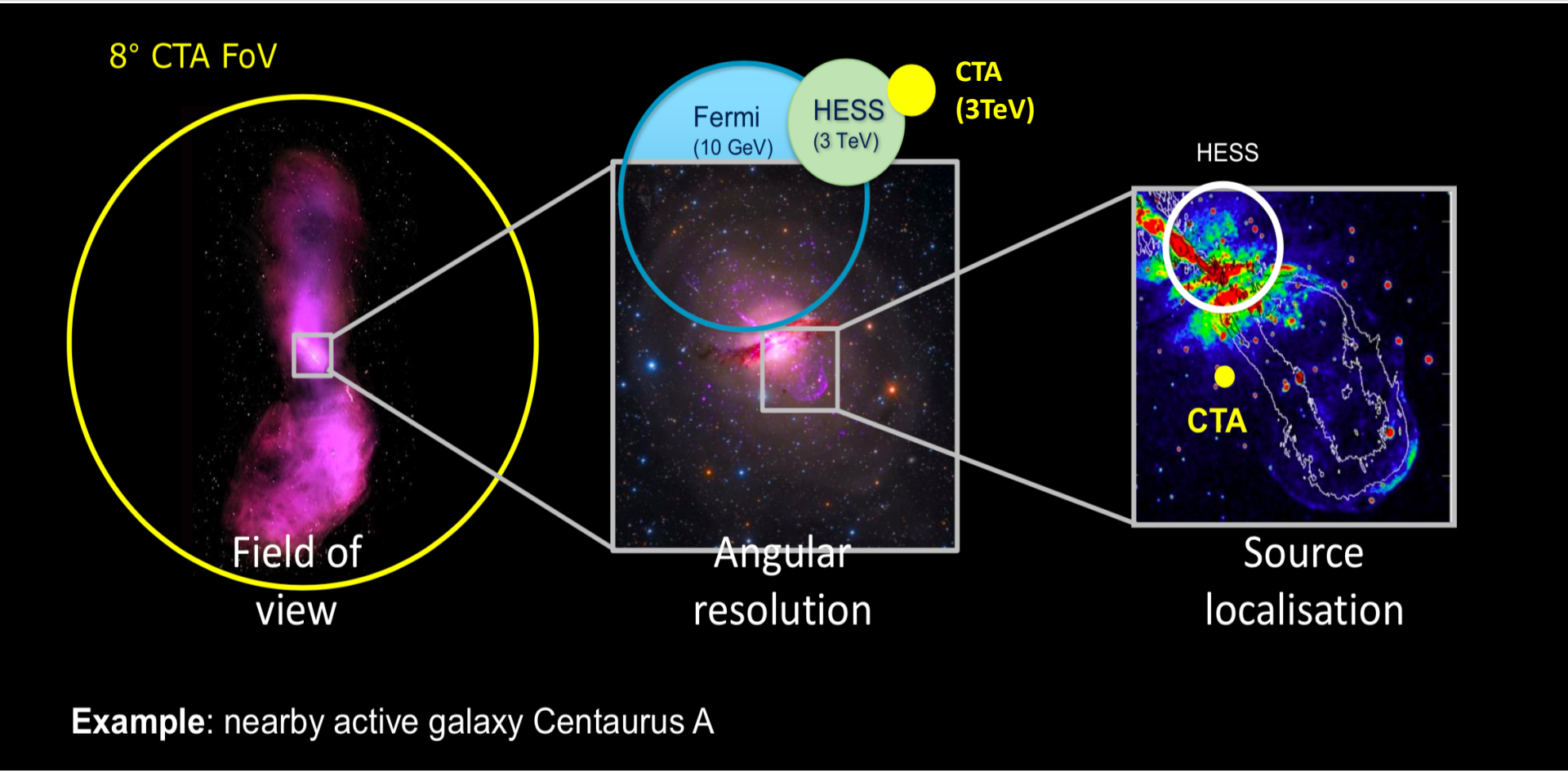
from 10^{-12} to 10^{-13} erg/cm^{2}s

CTA performance



CTA can follow up and resolve the steady sources at 100 TeV detected by LHAASO
arcminute resolution and 10% energy resolution are crucial to study the physical mechanisms

CTA performance

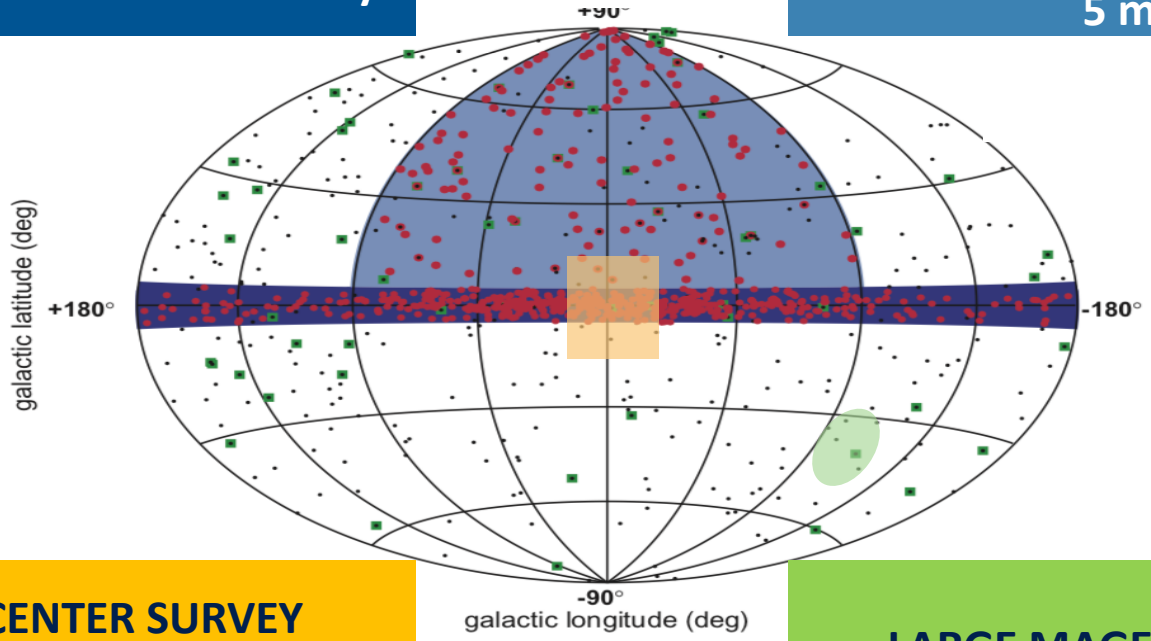


CTA can follow up and resolve the steady sources at 100 TeV detected by LHAASO
arcminute resolution and >10% energy resolution are crucial to study the physical mechanisms

CTA surveys

GALACTIC PLANE SURVEY
not uniform sensitivity across the plane 2-4 mCrab
pilot survey: first results after 1-2 yr

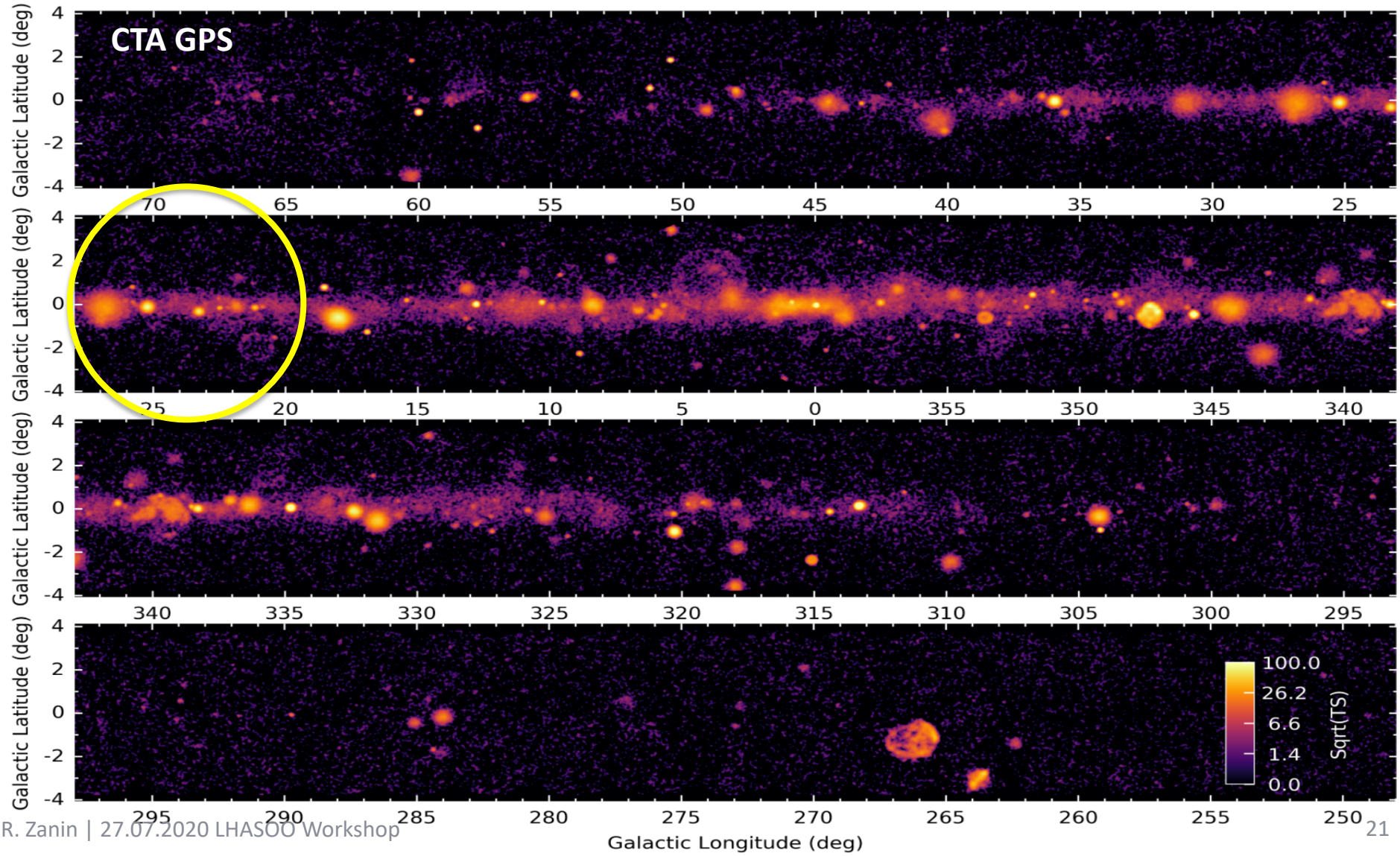
EXTRAGALACTIC SURVEY
first unbiased survey of VHE sky → huge discovery space
25% of the sky
5 mCrab



GALACTIC CENTER SURVEY
deeper obs around the GC,
10∘ x 10∘
2 mCrab

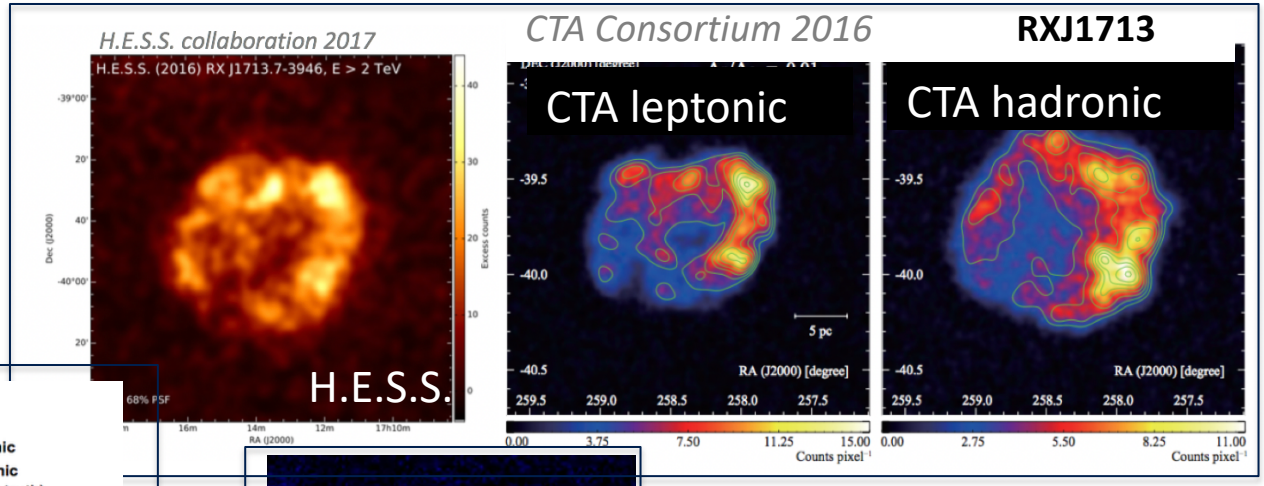
LARGE MAGELLANIC CLOUD SURVEY
All region in 10 pointings

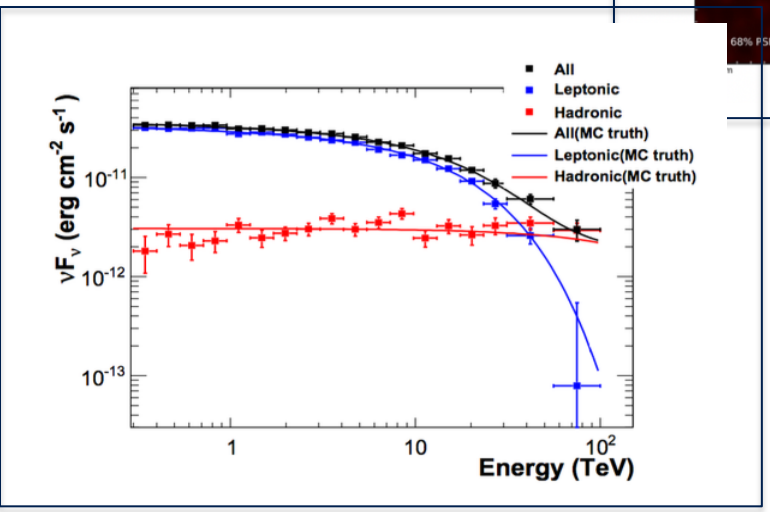
Galactic plane survey

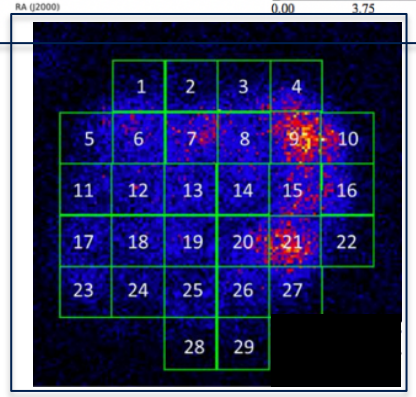


Galactic plane survey

- VHE census will increase by a factor about 5
- study of the properties of the interstellar emission from large scale CR sea at TeV
- rich variety of high-resolution data





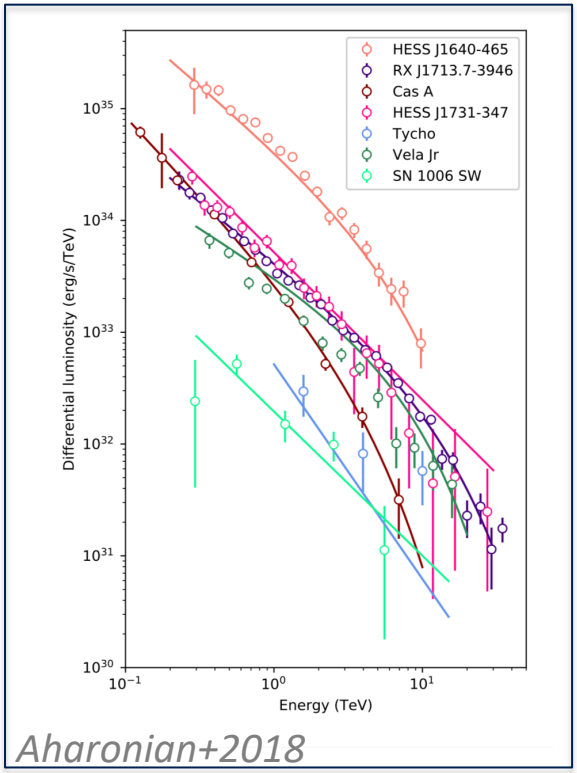


- sub-arcminute resolution
- spatial resolved spectroscopy
- <10% energy resolution

Multi-TeV science cases: PeVatrons

- **Galactic CRs up to the knee**
  - standard picture: **shock-acceleration in SNRs**
  - BUT: only a few SNRs provide evidence for hadronic accel & only up to 10-20 TeV

- **What are the PeVatrons?**
  - **SNR during a limited period (100 yr) in the earliest stages**
    - **SN1987A optimal test case**
  - **molecular clouds illuminated by escaping CRs** *(Aharonian1981, Casanova2010)*
  - **Other sources?**
    - **Galactic Center?** *(H.E.S.S. coll. 2018)*
    - **??? → Unbiased scan** *(Anguner+2019)*
    - **Star forming regions?** *(Aharonian+2018)*

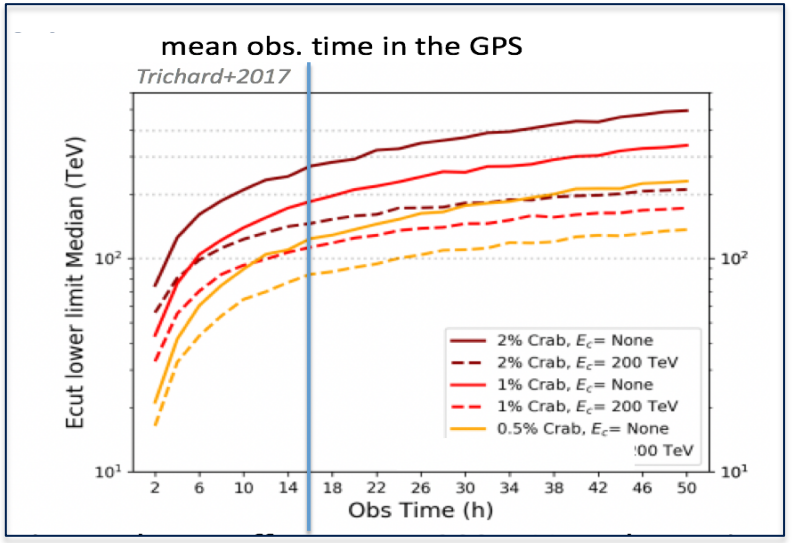


Aharonian+2018

Multi-TeV science cases: PeVatrons

- **The unbiased scan approach is based**

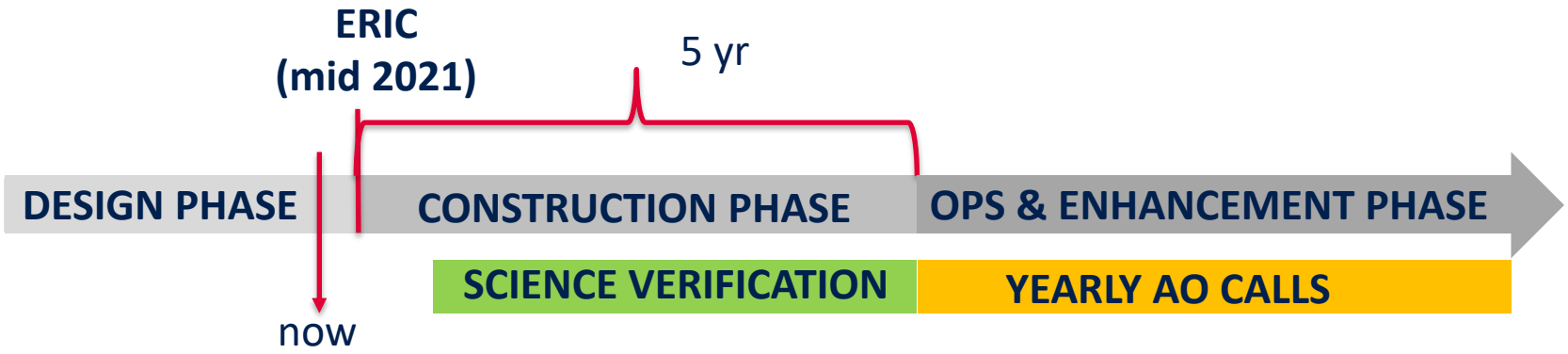
1. **follow up of potential PeVatrons candidates emerging from the CTA GPS**



2. **follow up of potential PeVatrons candidates emerging from the HAWC or the LHAASO GPS**
   - selection of sky regions with detected emission up to 100 TeV
   - key ingredient for the sources in the Northern hemisphere where the limited size of the array can hamper the unbiased search for PeVatrons candidates

once identified the target, CTA will provide a key contribution by characterizing the energy cut-off on spatial resolved regions

Project Status

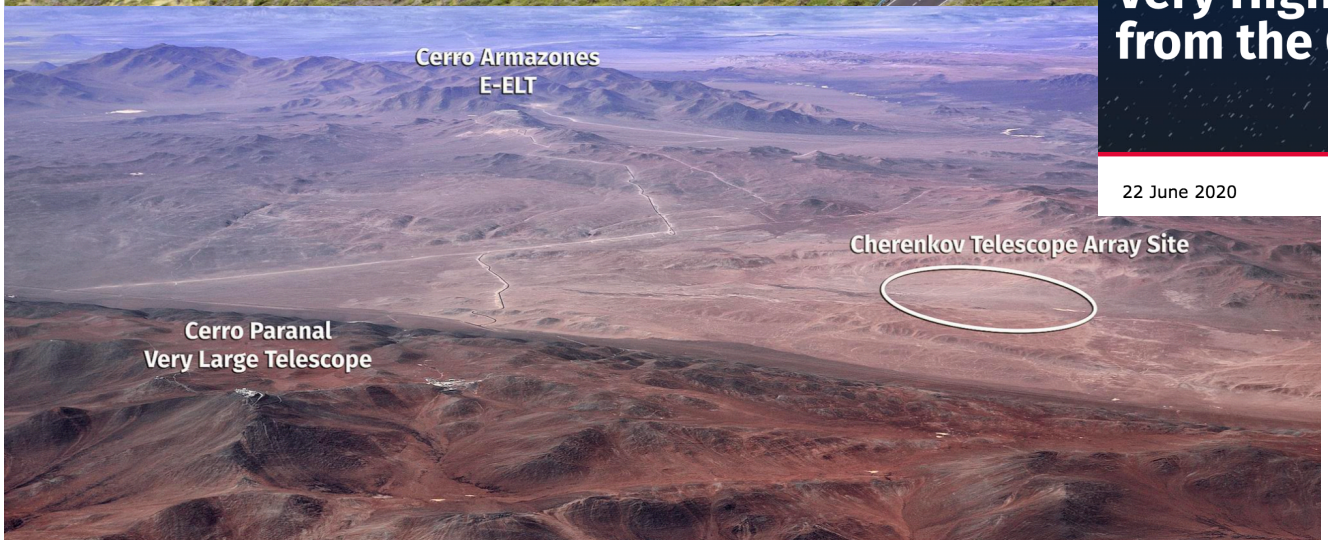


- **Construction phase: construction of a threshold configuration**
  - **a significant performance improvement wrt the currently running facilities**
    - guarantees high-impact science covering most of the science cases
    - guarantees a significant increase of the discovery space
- **Operations & Enhancement phase: operations of the construction configuration + construction towards the full-scope configuration**

Project Status

CTA Prototype LST-1 Detects Very High-Energy Emission from the Crab Pulsar

22 June 2020



Conclusions

- **CTA will usher in a new era in VHE Astrophysics**
  - **rich science program answering many open questions**
  - **large new discovery space**
  - **complementarity with air shower array will be a key element for the advance of our understanding of the Universe**
- **The full exploitaiton of CTA science cases requires MWL/MM synergies**

- **CTA will be the first gamma-ray ground-based observatory, openly delivering data to the community**

Thank you

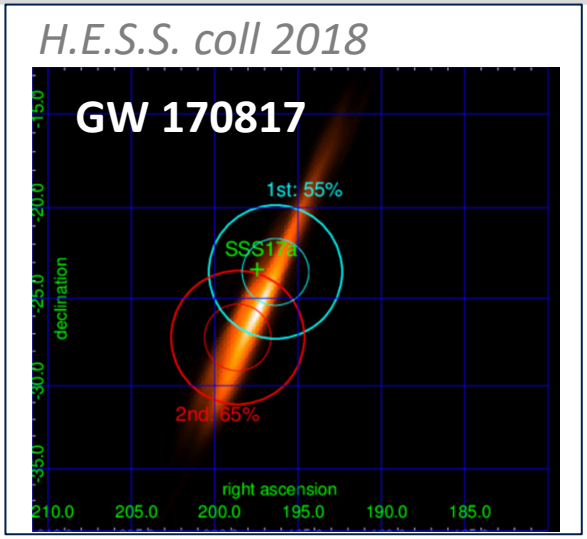
Transients in the MM era

Gravitational wave follow-up

Schussler+2019,

- **Violent events with electromagnetic counterpart established.**
  TeV emission? Sheding light on the physical parameters of the mergers

H.E.S.S. coll 2018



High-energy ν follow-up

Sataleka+2019

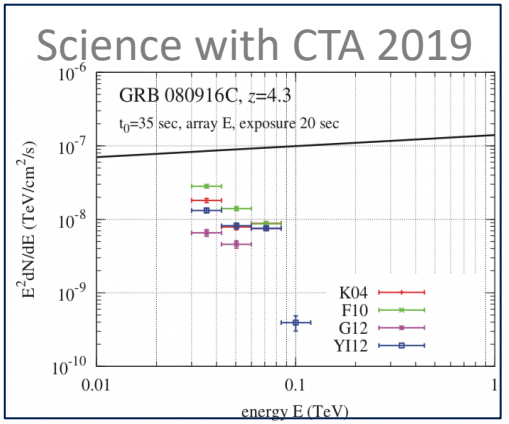
- **What's the origin of the TeV-PeV cosmic ν?**

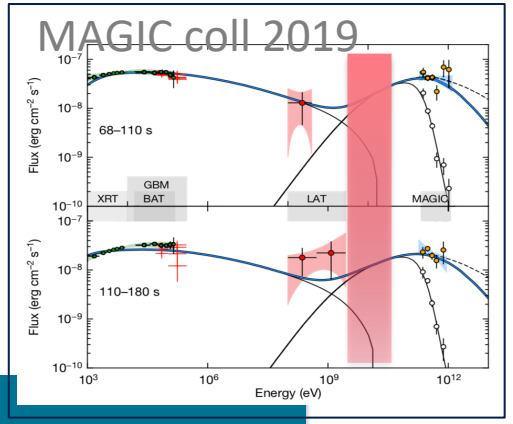
  - **CTA can play a fundamental role in the event localization (arcmin)** given the coarse measurements from HE satellites/ν detector
    - Real-time issuing alerts within 2 min

Transients

GRBs *Di Girolamo+2017, Bernardini+2019*

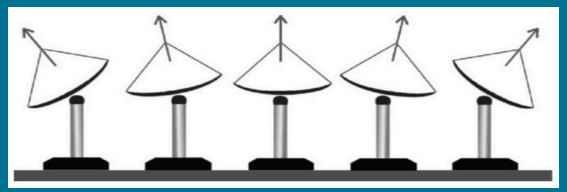
- **How does the prompt dynamic work?**
- **How does the afterglow dynamic work?**
  - **CTA has short-GRB at reach**
  - **CTA can detect GRB up to days after t_0**
  - **CTA will probe the early universe**
- **What's the mechanism behind the VHE production?**
  - **Access to tens of GeV range is crucial**





Observational strategy

- Fast response to external alerts
- Joint MWL/MM campaigns to identify short bursts within FoV
  → divergent pointing



Transients

Galactic transients:

- Novae, microquasars, tidal disruption events

Serendipitous transients discovered by CTA *Schussler+2019*

- Extreme, high impact events
  - Real-time analysis issuing alerts (VO complaint) within 2’

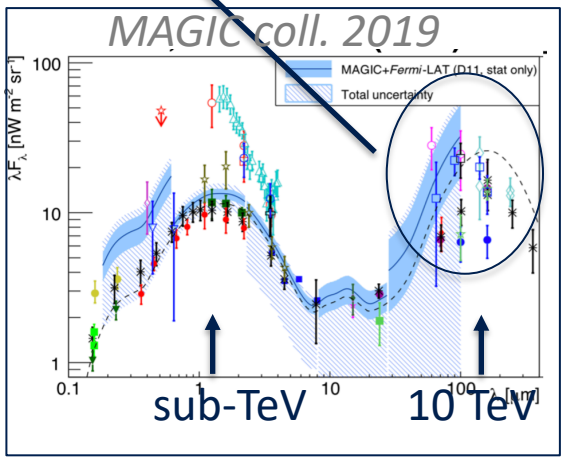
AGNs *Zech+2019, Martinez-Huerta+2019*

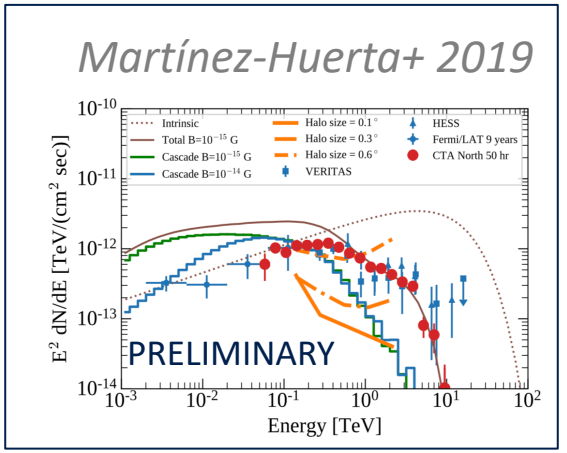
- Does the blazar sequence hold?
- Are there other classes of AGNs, other than blazars & radio galaxies ?
- Is there a strong population of extreme blazars?
  - monitoring program + deep observations of key sources + hunt for new sources

γ-ray cosmology

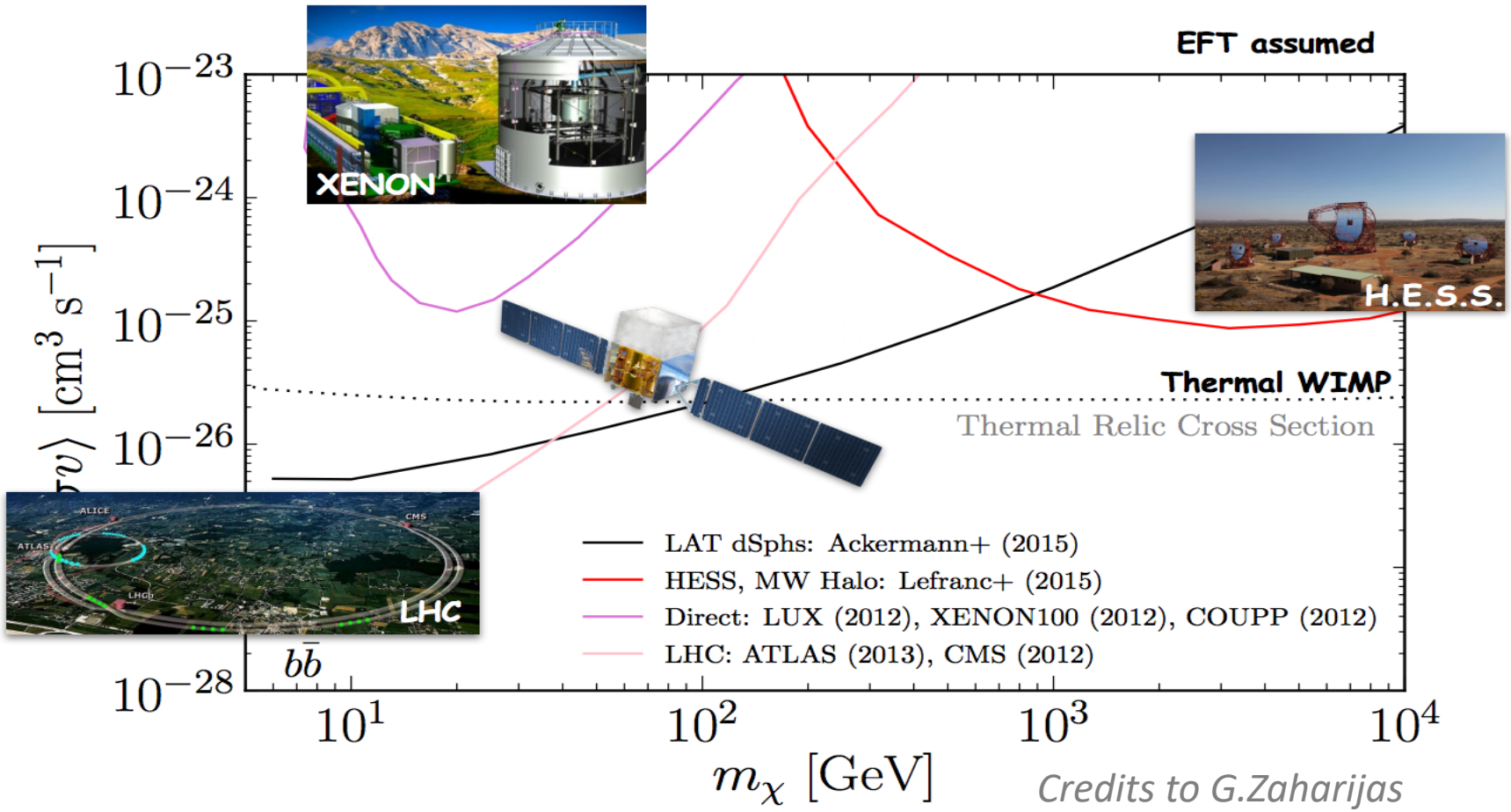
- **What is the spectrum of the EBL at z=0?**
  - CTA can improve precision & explore the IR range
    - CTA large energy coverage has the unique capability **to measure unabsorbed intrisic (GeV) and attenuated (TeV)** part of the spectra
    - **Large sample of srcs at different z**
      - GRB are excellent candidates
- **How the EBL evolves with z?**
- **What's the strenght of the IGMF?**

poorly constrained





Dark matter search

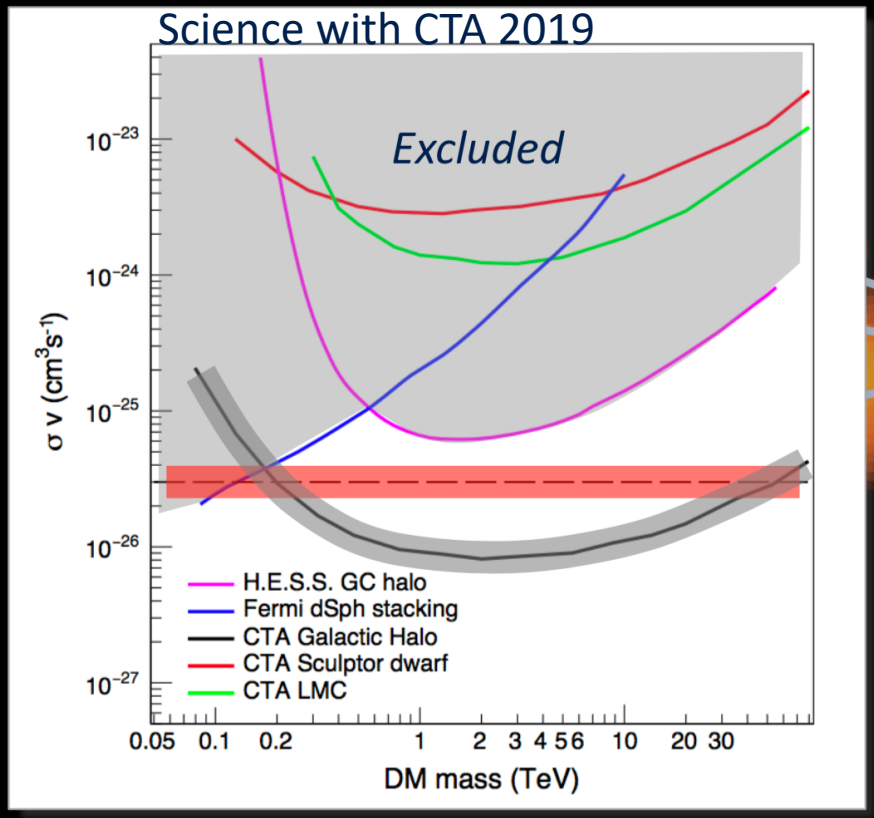


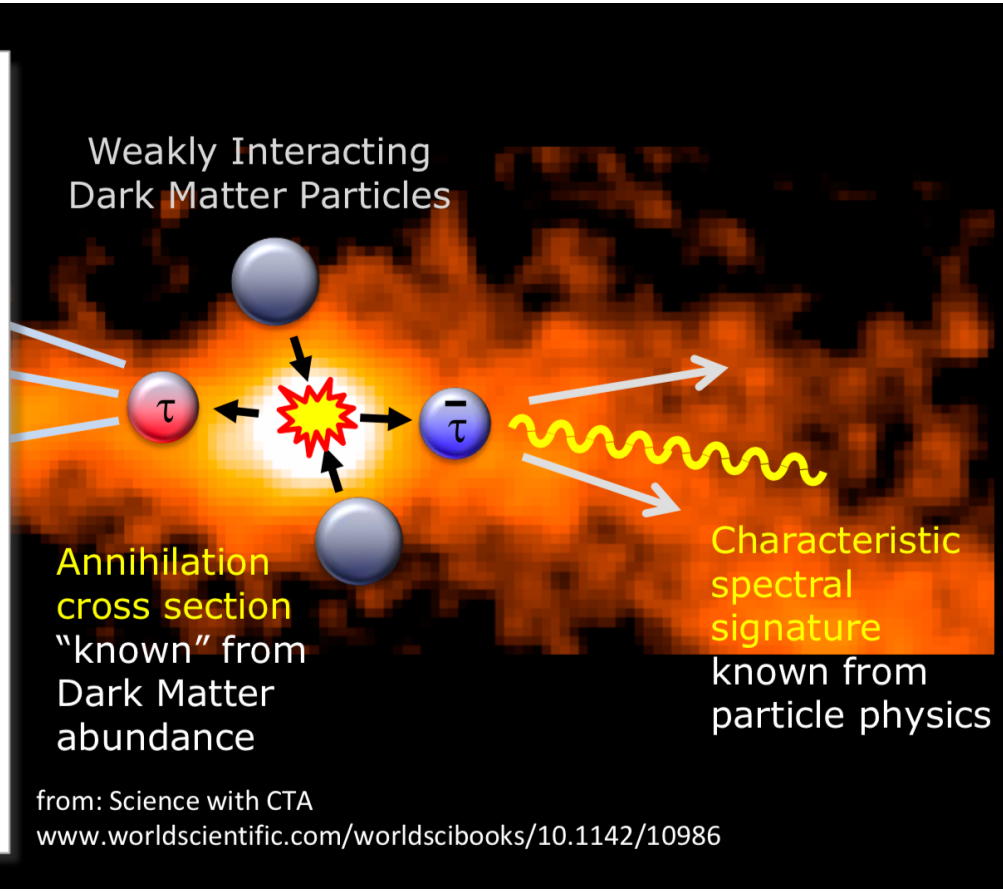
Credits to G.Zaharijas

- WIMP is not ruled out *(Leane+ 2018)*
- The TeV mass domain is unexplored

Dark matter search

- CTA will constrain the WIMP paradigma in case of non-detection





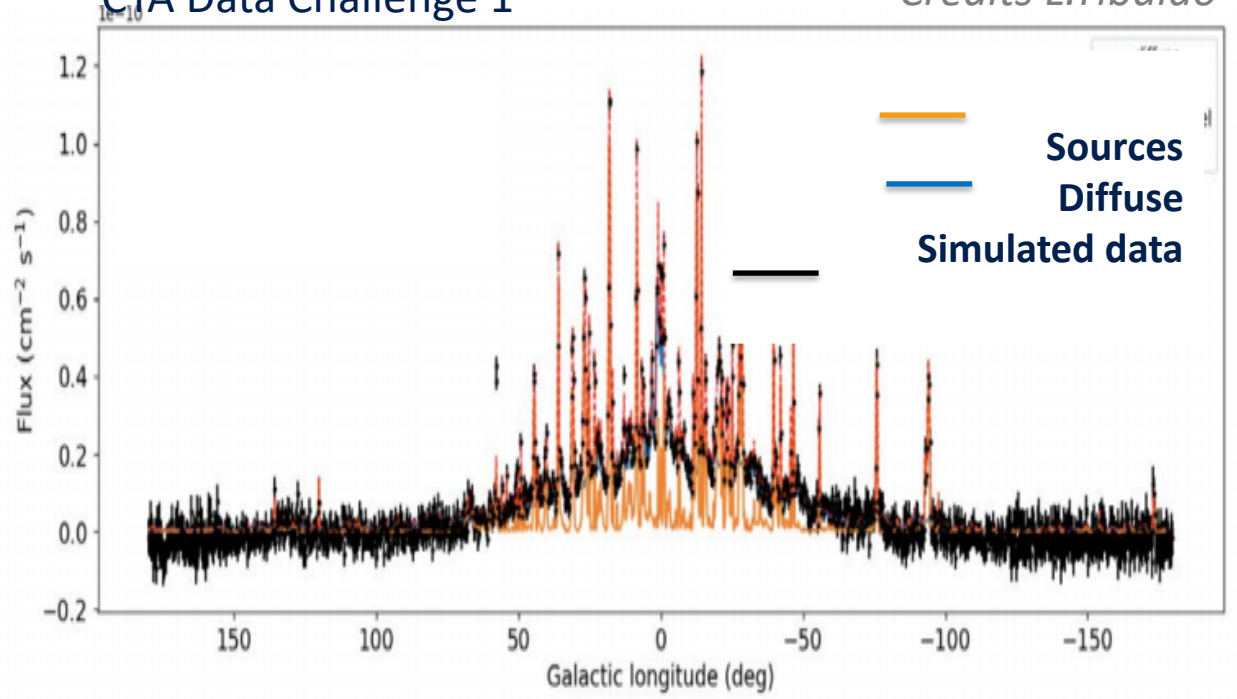
from: Science with CTA
www.worldscientific.com/worldscibooks/10.1142/10986

Diffuse emission

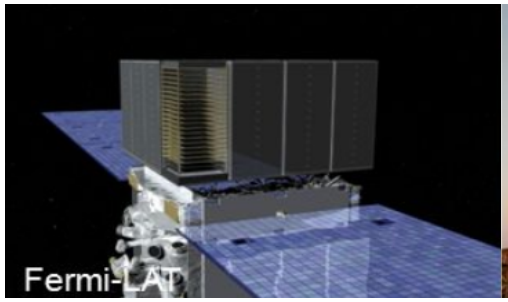
- **CTA will provide the study of the diffusion emission across the Galactic plane**
  - **Interstellar fraction expected to be 70-90%**

CTA Data Challenge 1

Credits L.Tibaldo



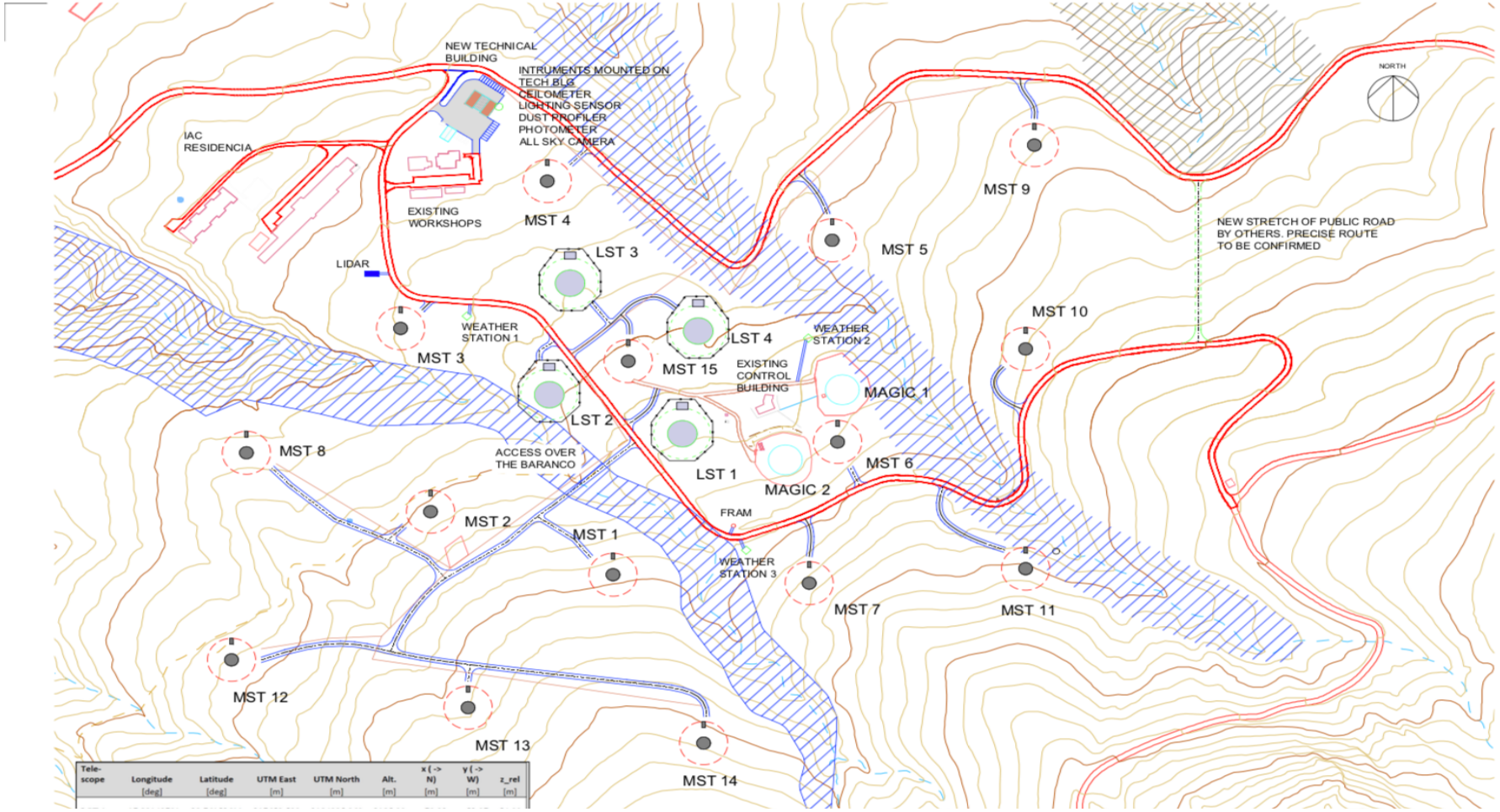
Three different approaches



	Fermi LAT	IACTs	EAS arrays
Energy range	100 MeV – 1 TeV	50 GeV – 50 TeV	1 TeV – 200 TeV
FoV	20% of the sky	5 degree	15% of the sky
Effective area	1 m^2	10^5 m^2	10^5 m^2
Duty cycle	Full year	1400 hr	Full year

CTA-North site

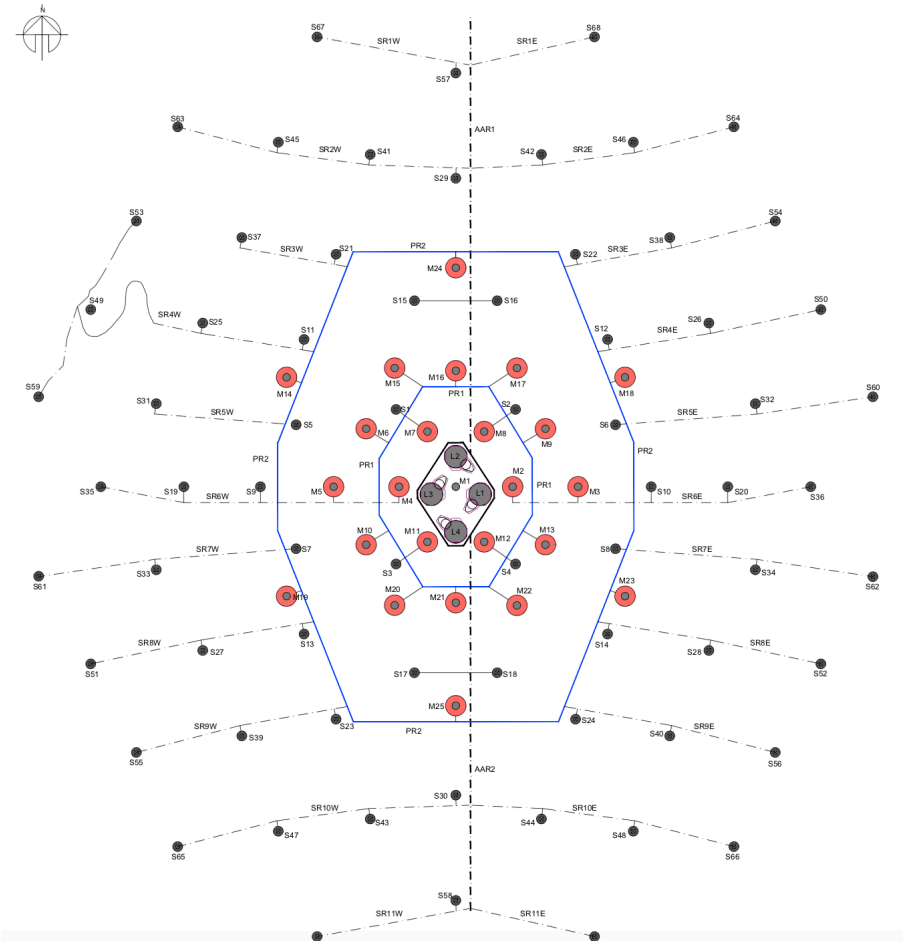
- **4 LSTs + 15 MSTs (full-scope configuration)**
  - **Focus on sub-TeV and TeV energy range**



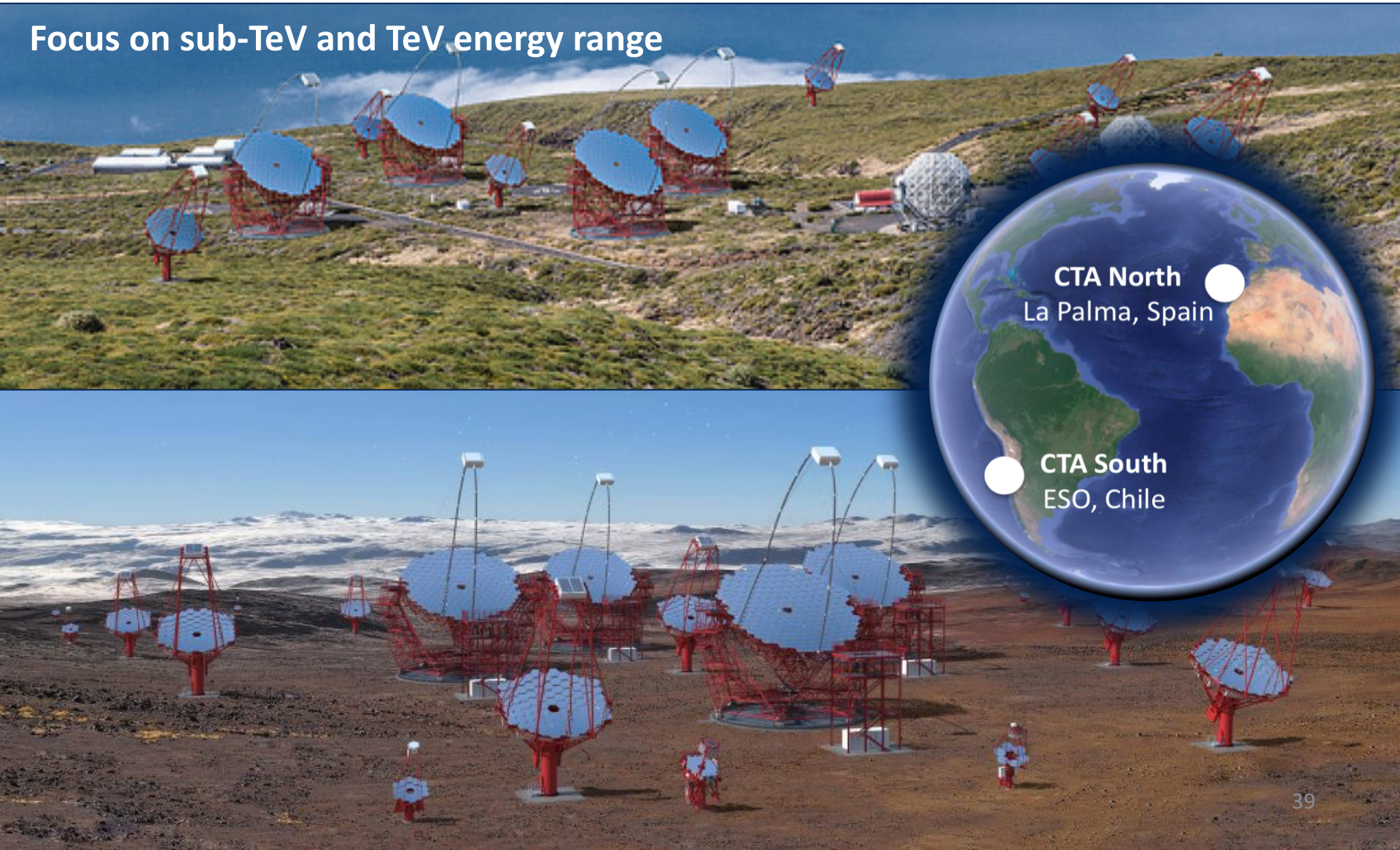
Tele-scope	Longitude [deg]	Latitude [deg]	UTM East [m]	UTM North [m]	Alt. [m]	x (-> N) [m]	y (-> W) [m]	z_rel [m]

CTA-South site

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



1 Observatory - 2 array sites



Off-axis sensitivity