cherenkov telescope array

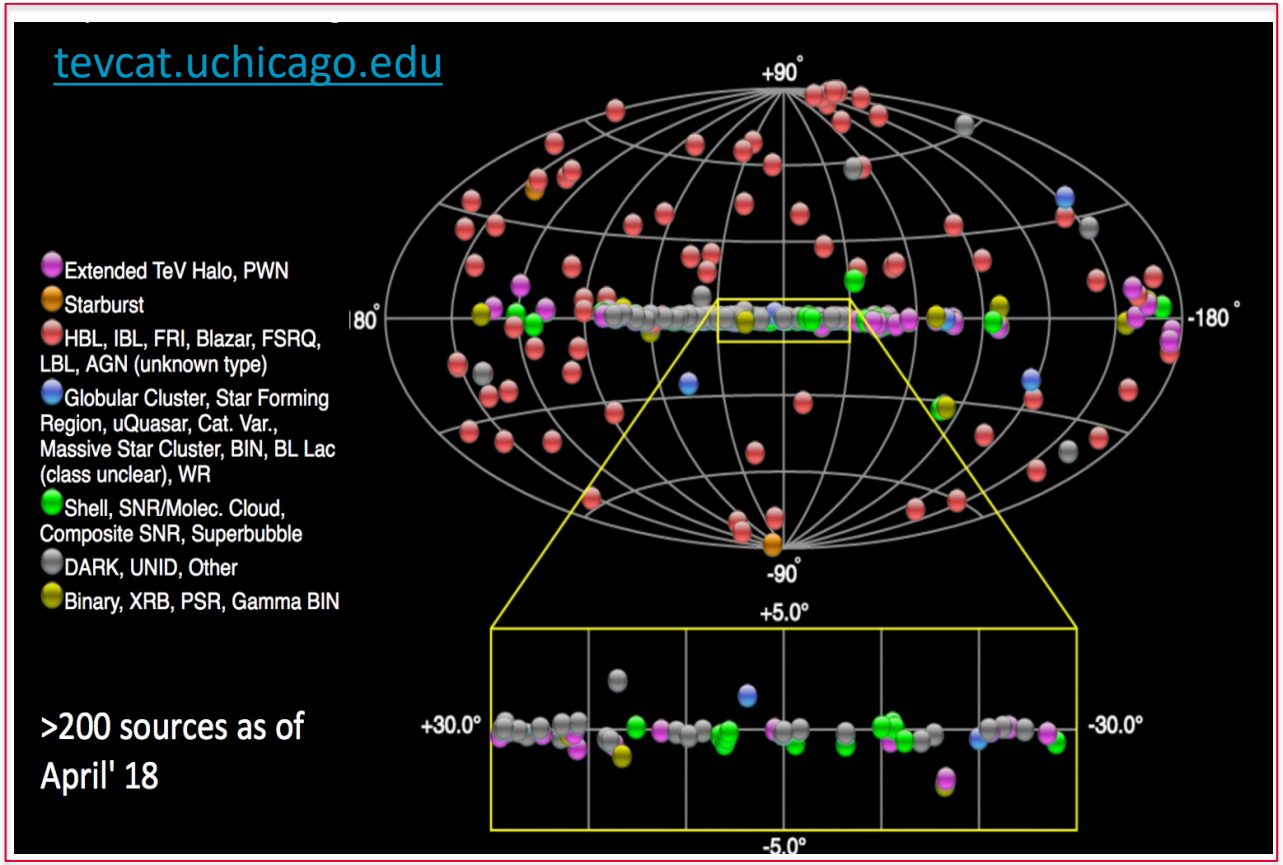
Cherenkov Telescope Array: the first VHE gamma-ray observatory

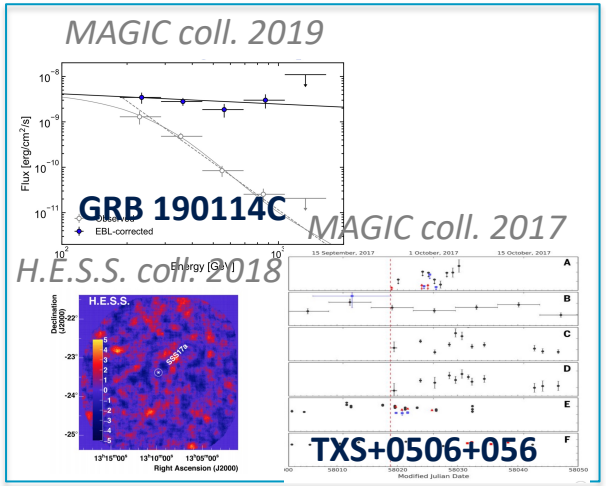
R. Zanin
Project Scientist – CTA Observatory
roberta.zanin@cta-observatory.org

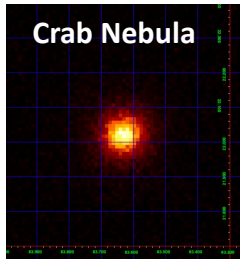
& on behalf of the CTA Consortium

CTA: First VHE gamma-ray observatory

- **Very High Energy (VHE) gamma-ray astronomy is a "recently" established field with still a large exploring power**







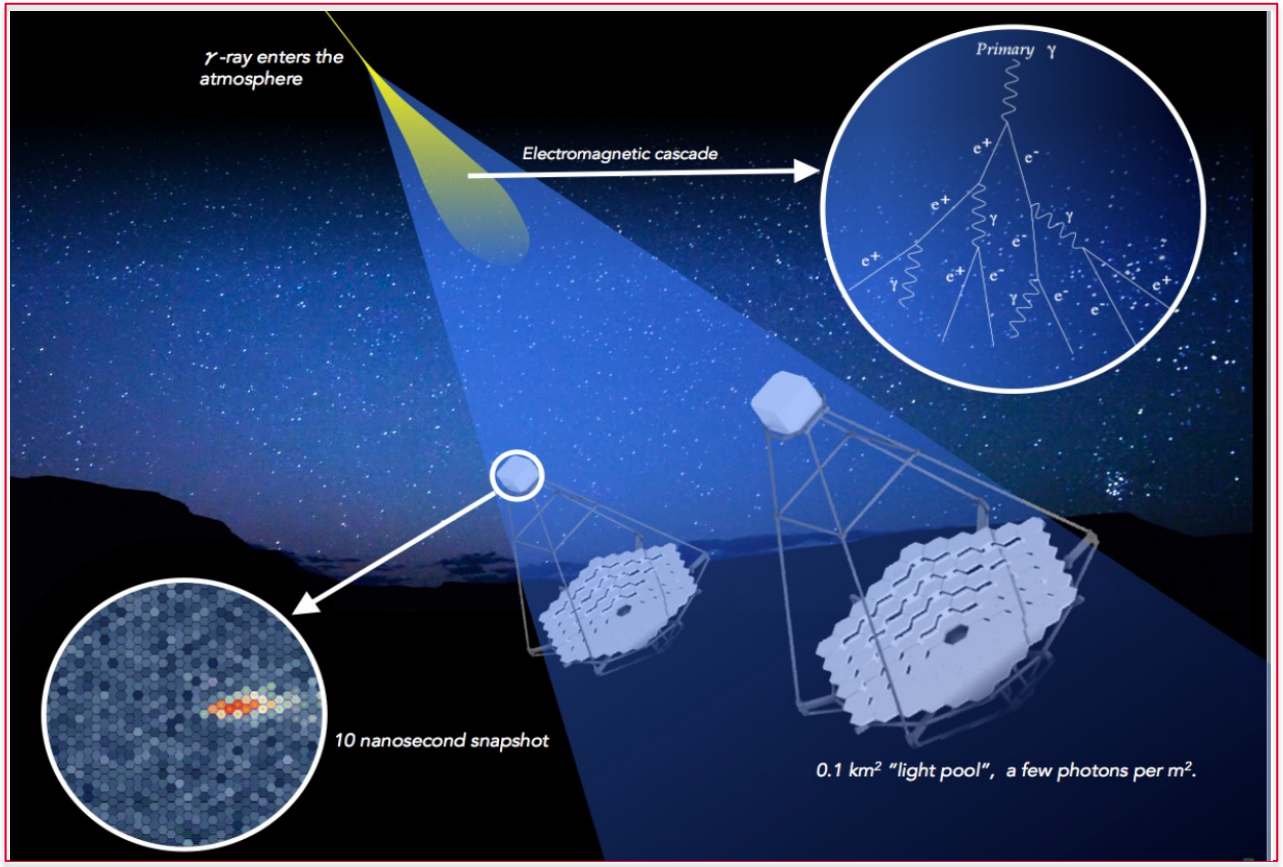
Size:
52'' 3"

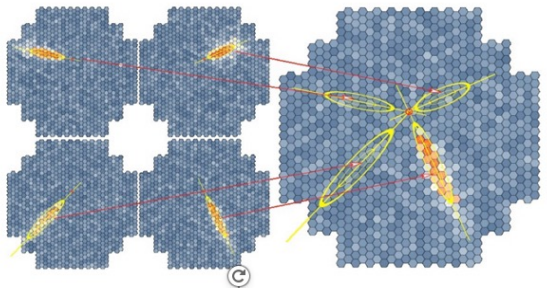
H.E.S.S. Coll. 2019

real astronomy at reach only for bright sources

CTA: First VHE gamma-ray observatory

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



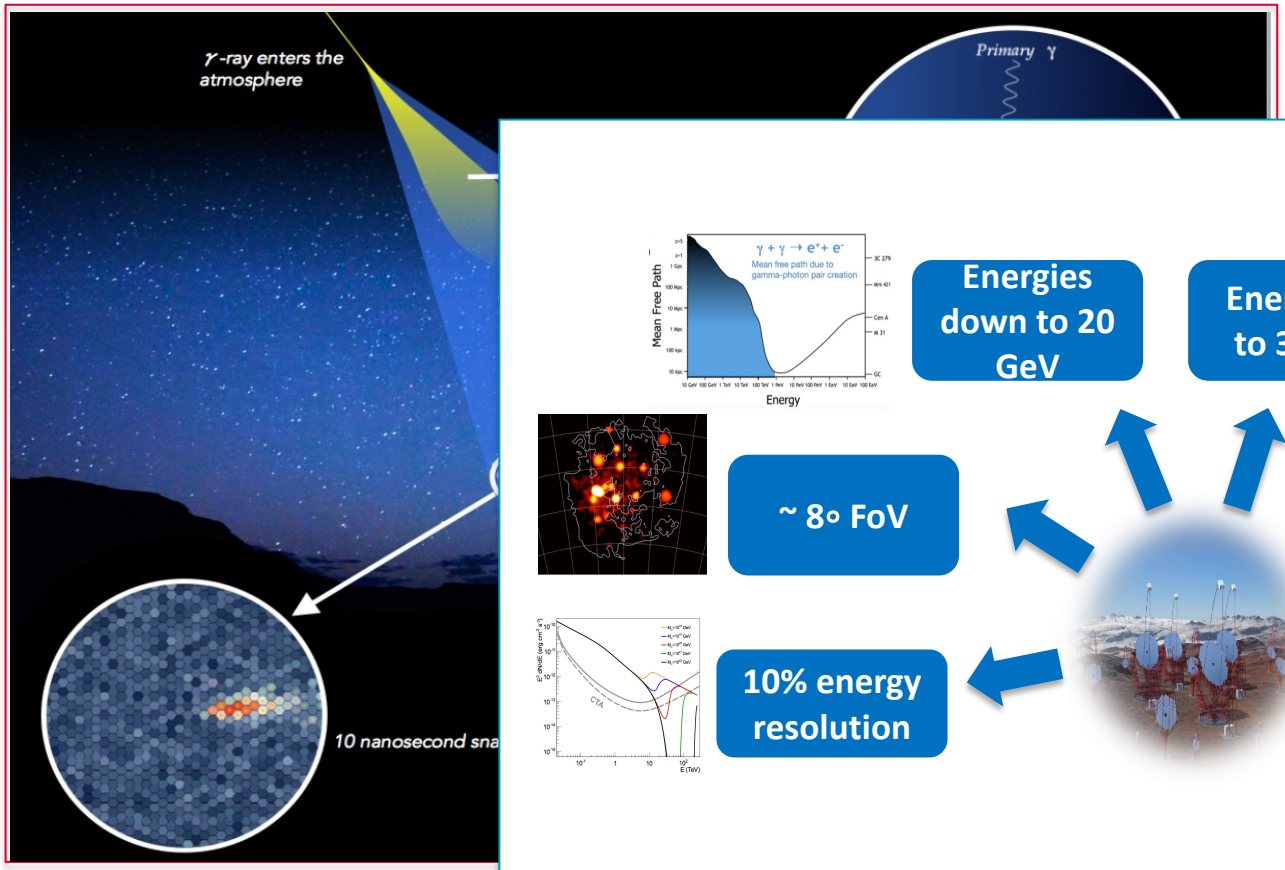


stereoscopy improves angular resolution

- 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**

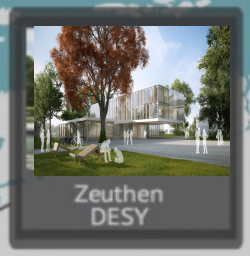


CTA Observatory

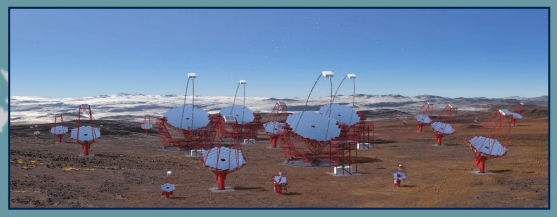
- **VHE gamma-ray observatory with Imaging Atmospheric Cherenkov Telescopes (IACTs)**
- **Open-data access observatory**
  - **data access to all scientists of participating countries**
  - **proposal driven observatory**
- **High-level data products and tools**
- **Operational lifetime of at least 30+10 yr**
  - **significant effort for maintenance and operations costs optimization**
  - **robust against advances in science & technology**

CTA Observatory

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



northern hemisphere
southern hemisphere



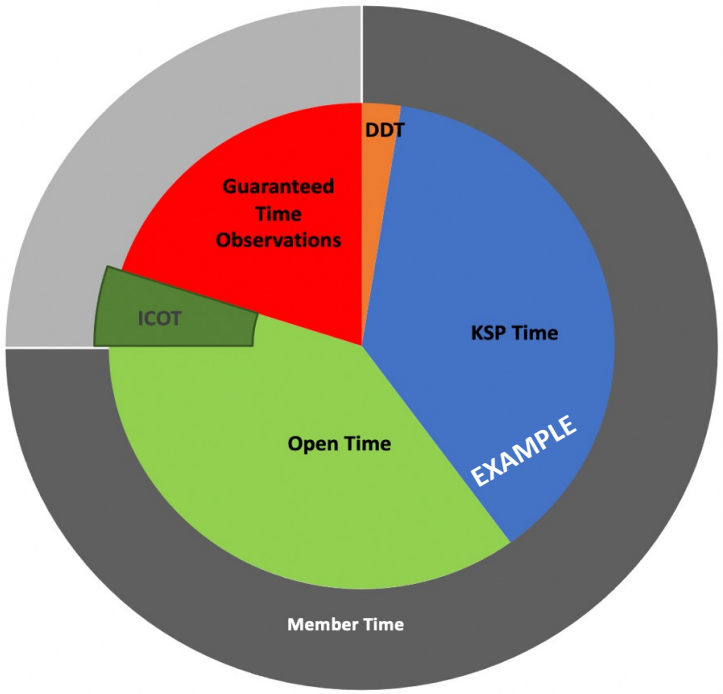
- **Geographically distributed**
  - HQs in Bologna
  - Science Data Management Centre (SDMC) in Zeuthen
  - 2 observation stations

a Palma Map: ©2015 Google, Inst. Geogr. Nacional
aranal Map: ©2015 Google

Array Sites Headquarters Science Management Centre

Requesting Observing Time

- Once excluded Guaranteed Time Observations (GTOs), most of time is devoted to scientists belonging to CTAO ERIC member states (Member Time)
- Just a small fraction open to any scientists: International Community Observing Time (ICOT)



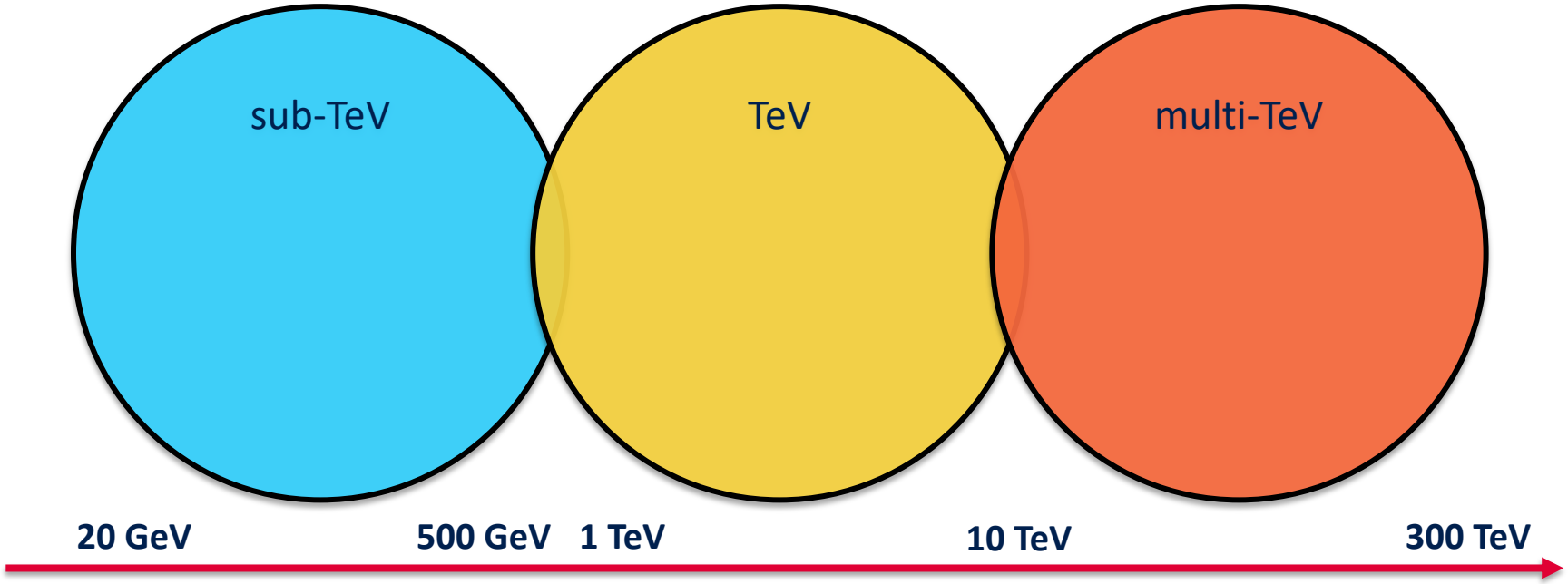
Requesting Observing Time

- **Once excluded Guaranteed Time Observations (GTOs), most of time is devoted to scientists belonging to CTAO ERIC member states (Member Time)**
- **Just a small fraction open to any scientists: International Community Observing Time (ICOT)**

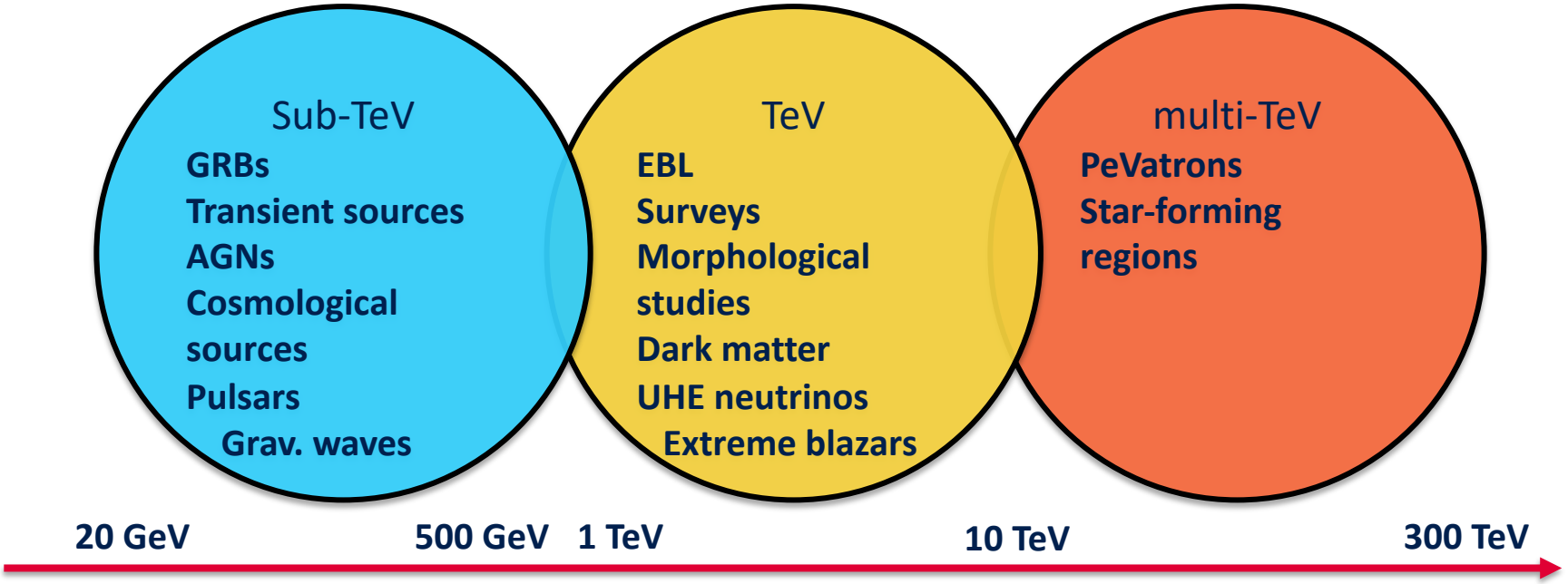
- **Observing Time can be requested through:**
  - **Key Science Projects**
  - large observation programs ensuring that the key science issues for CTAO are addressed in a coherent fashion, and providing legacy Science Data Products.
  - Proposals developed by the CTA Consortium: https://www.worldscientific.com/worldscibooks/10.1142/10986

  - **Standard Proposals**
  - In response to an Announcement of Opportunity Call (once per year)

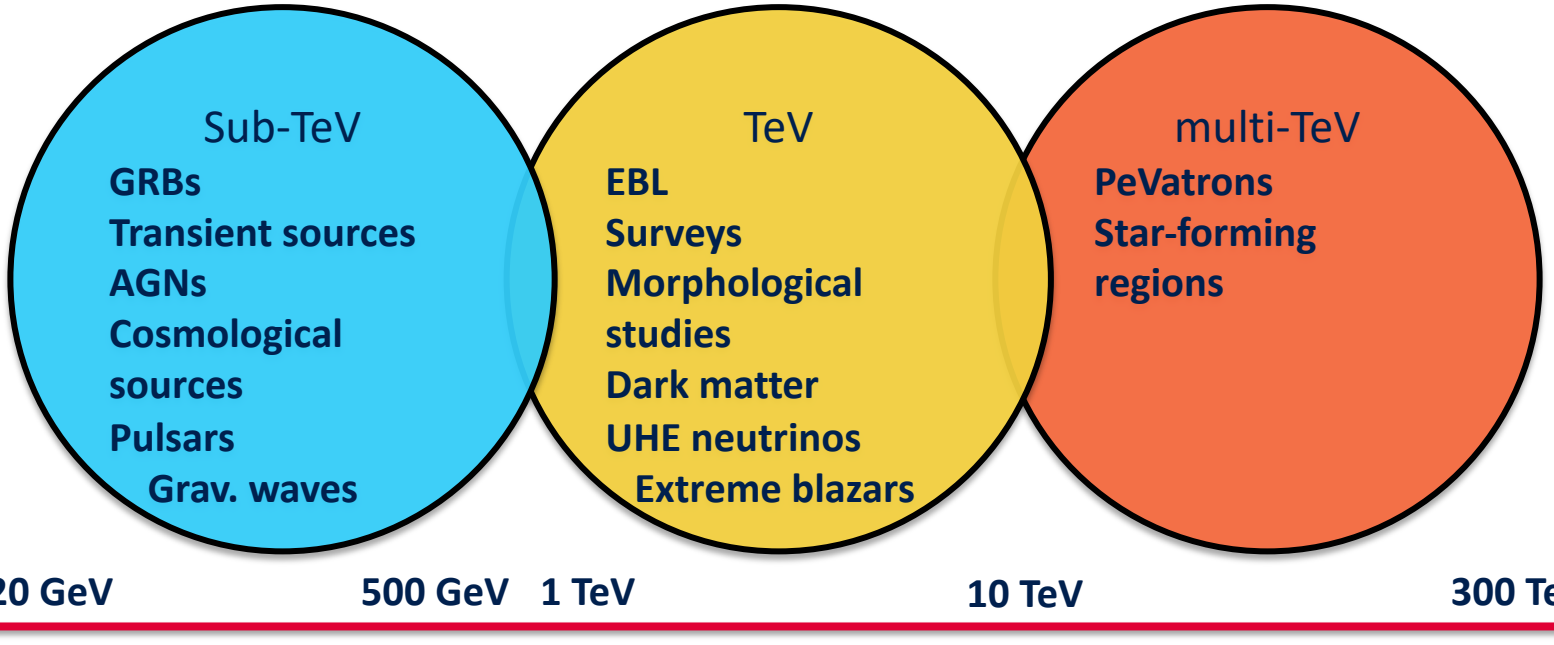
CTA science case

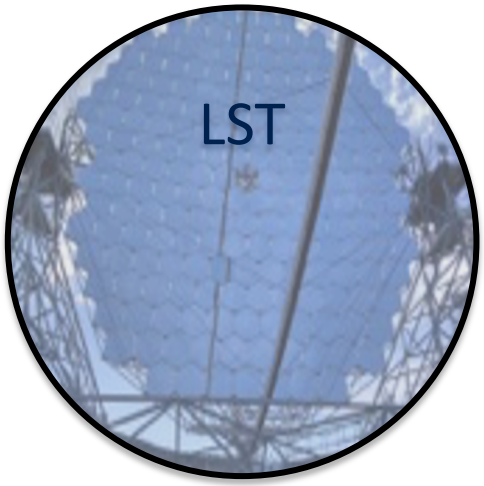


CTA science case

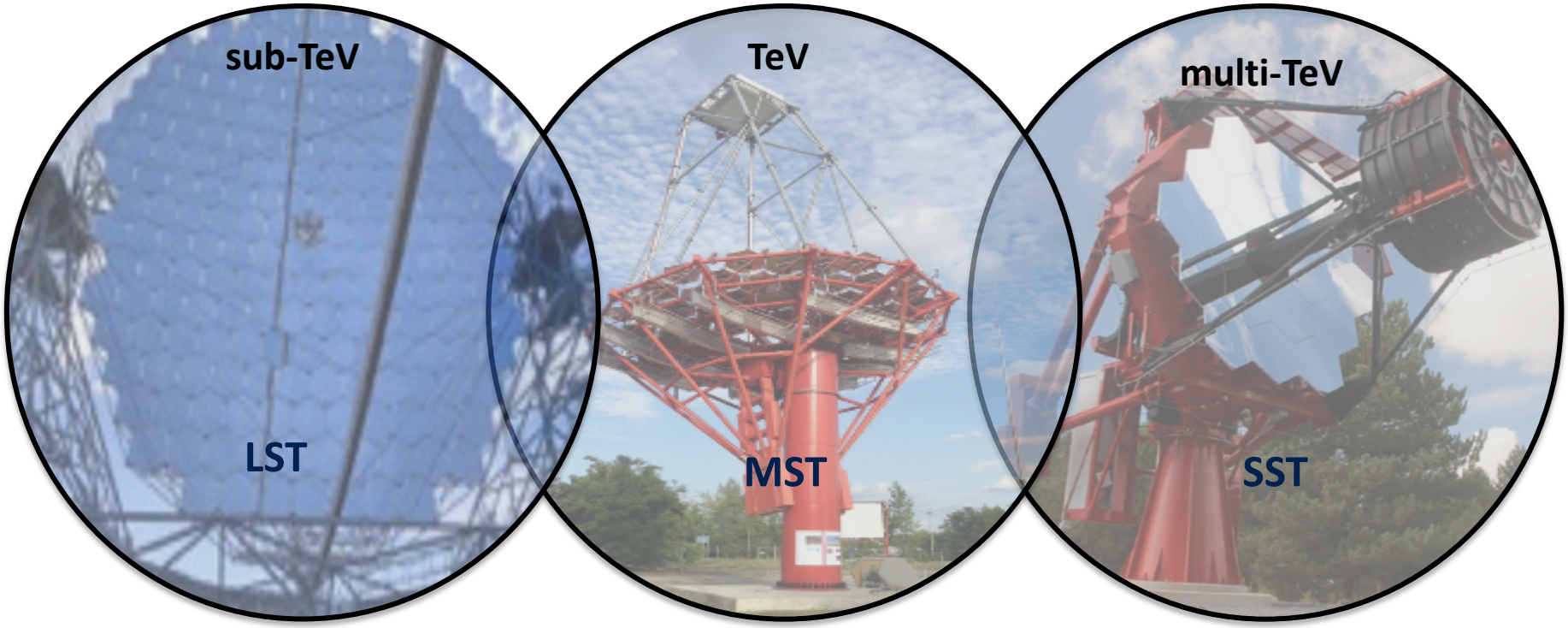


From the science case to the design





Telescope design

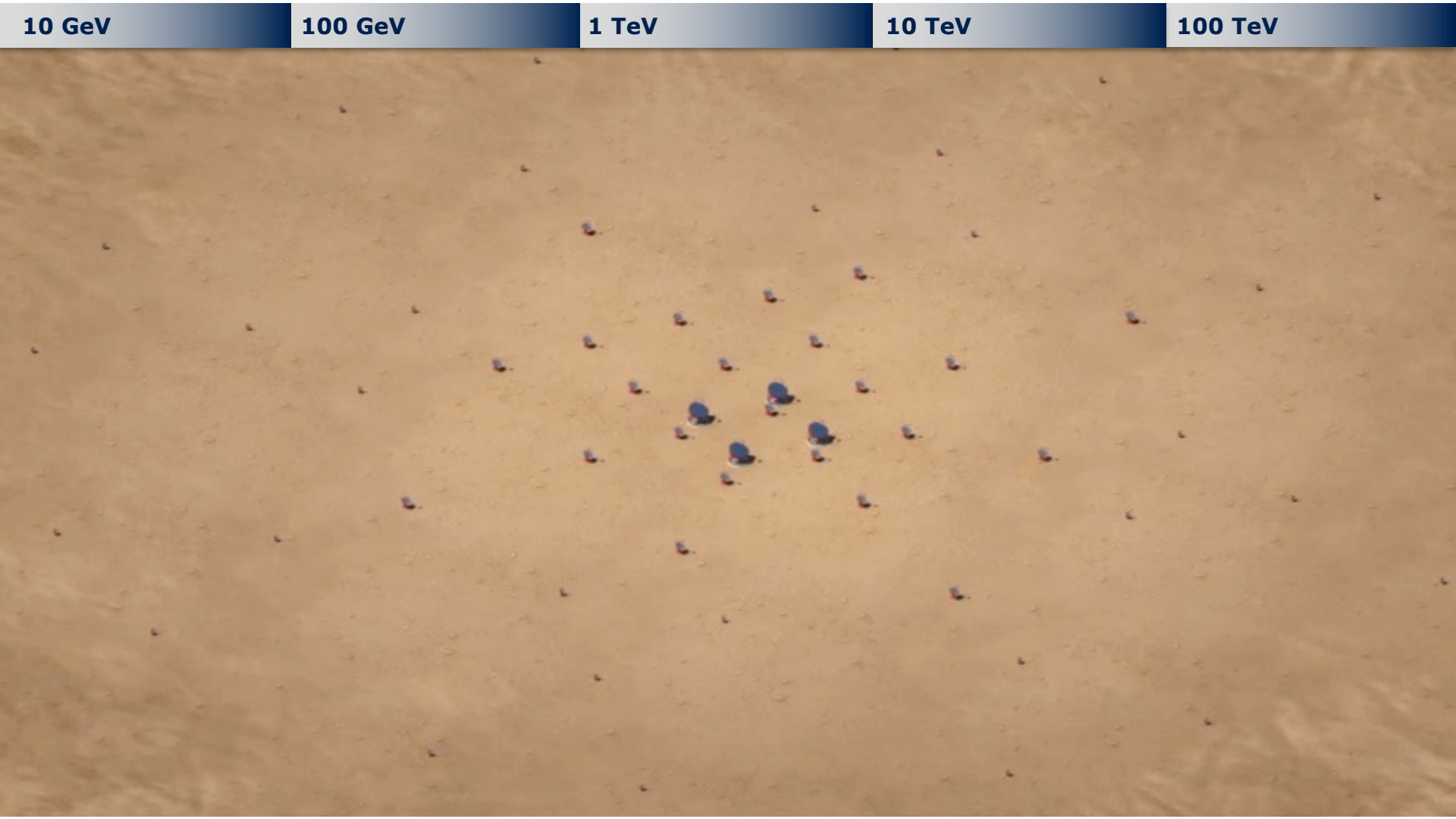


- Parabolic optical design
- 23 m mirror diameter
- PMT camera
- ~4 deg FoV
- 4 LSTs at the array center

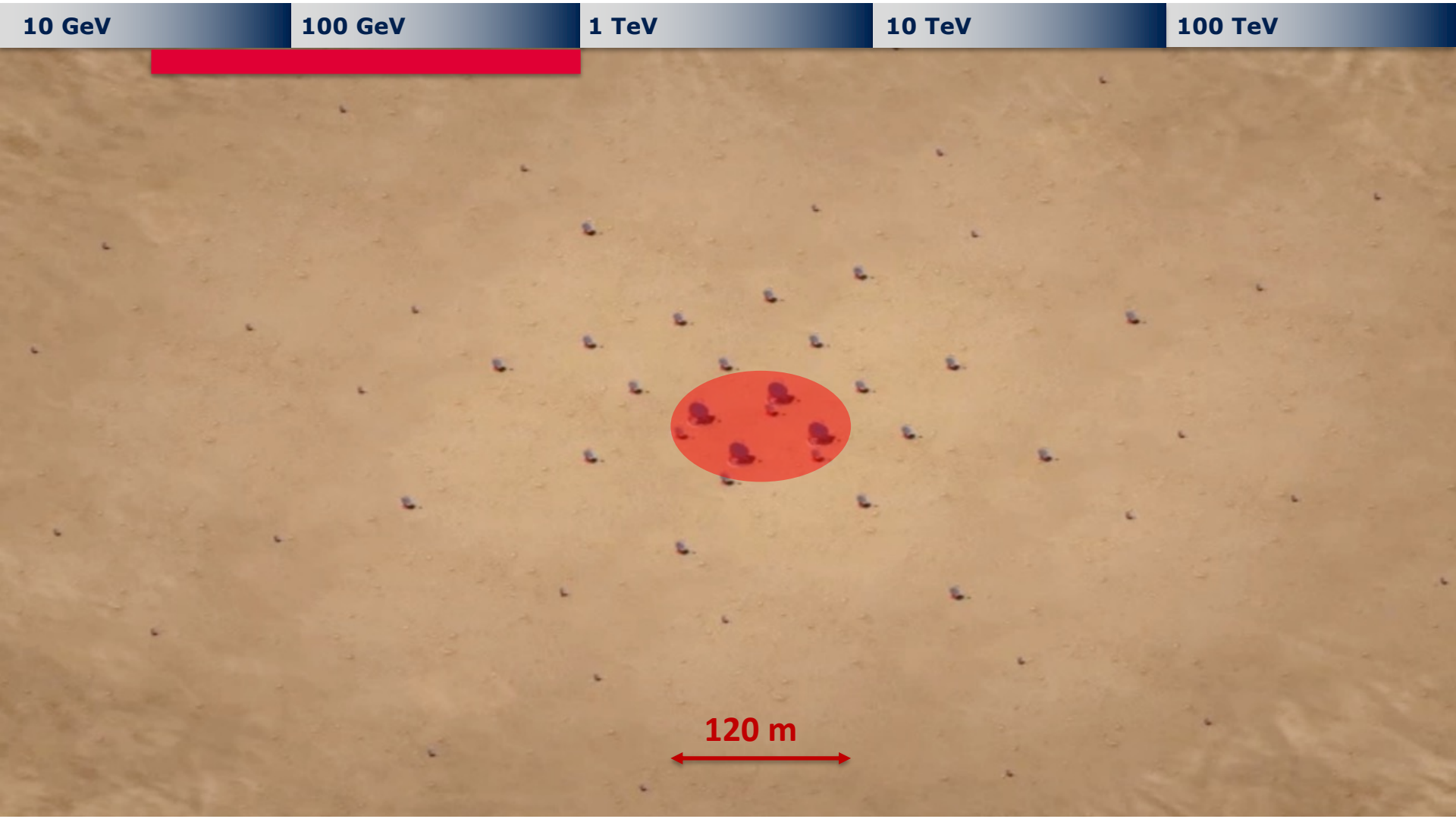
- Davies-Cotton optical design
- 12 m mirror diameter
- PMT camera
- ~7 deg FoV
- MSTs are workhorse
- ~0,5 km^2 area covered

- Schwarzschild-Couder optical design
- 4 m dual mirror
- SiPM camera
- ~8 deg FoV
- >50 SSTs
- ~4km^2 area coverage

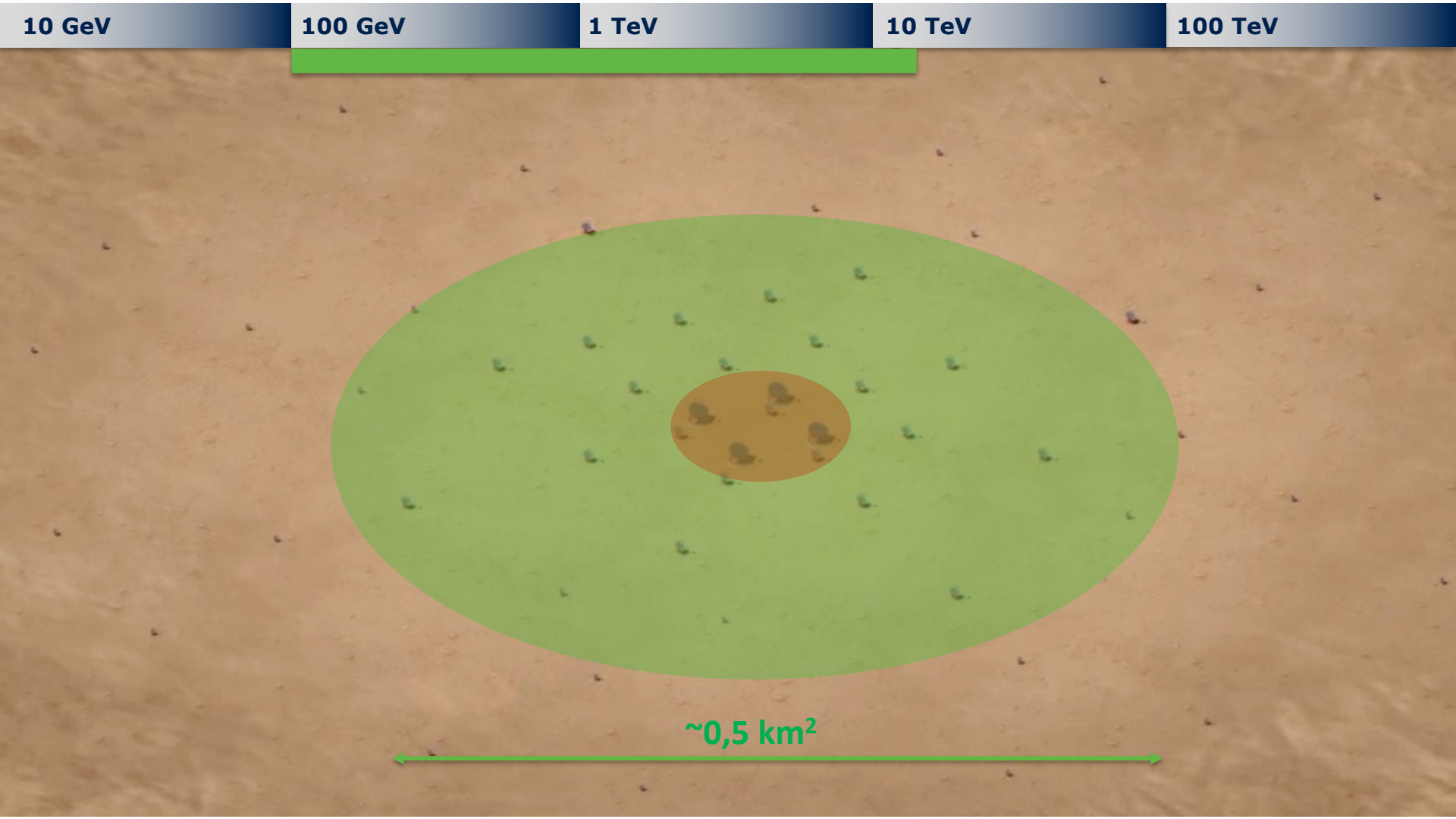
Array design



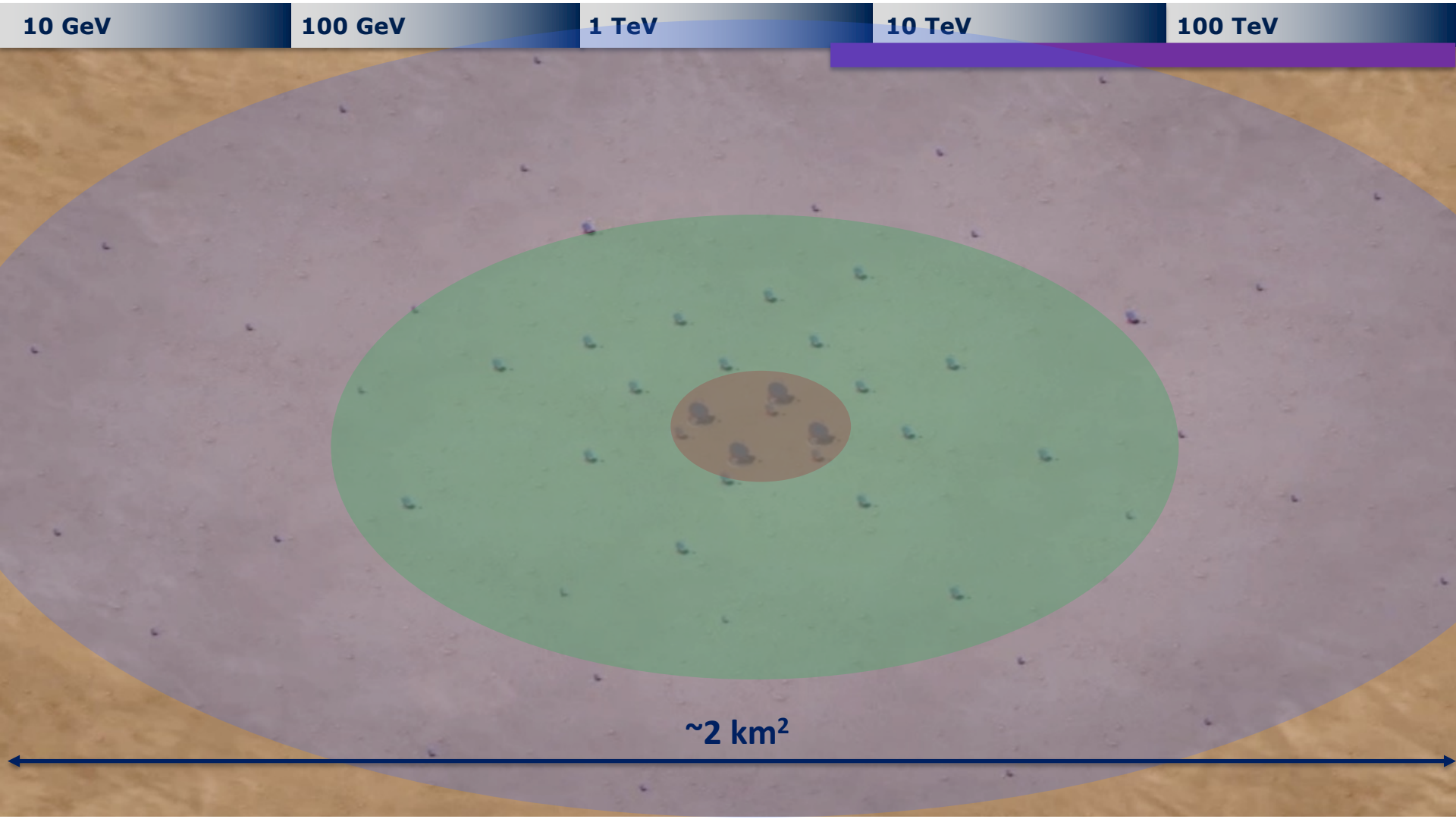
Array design



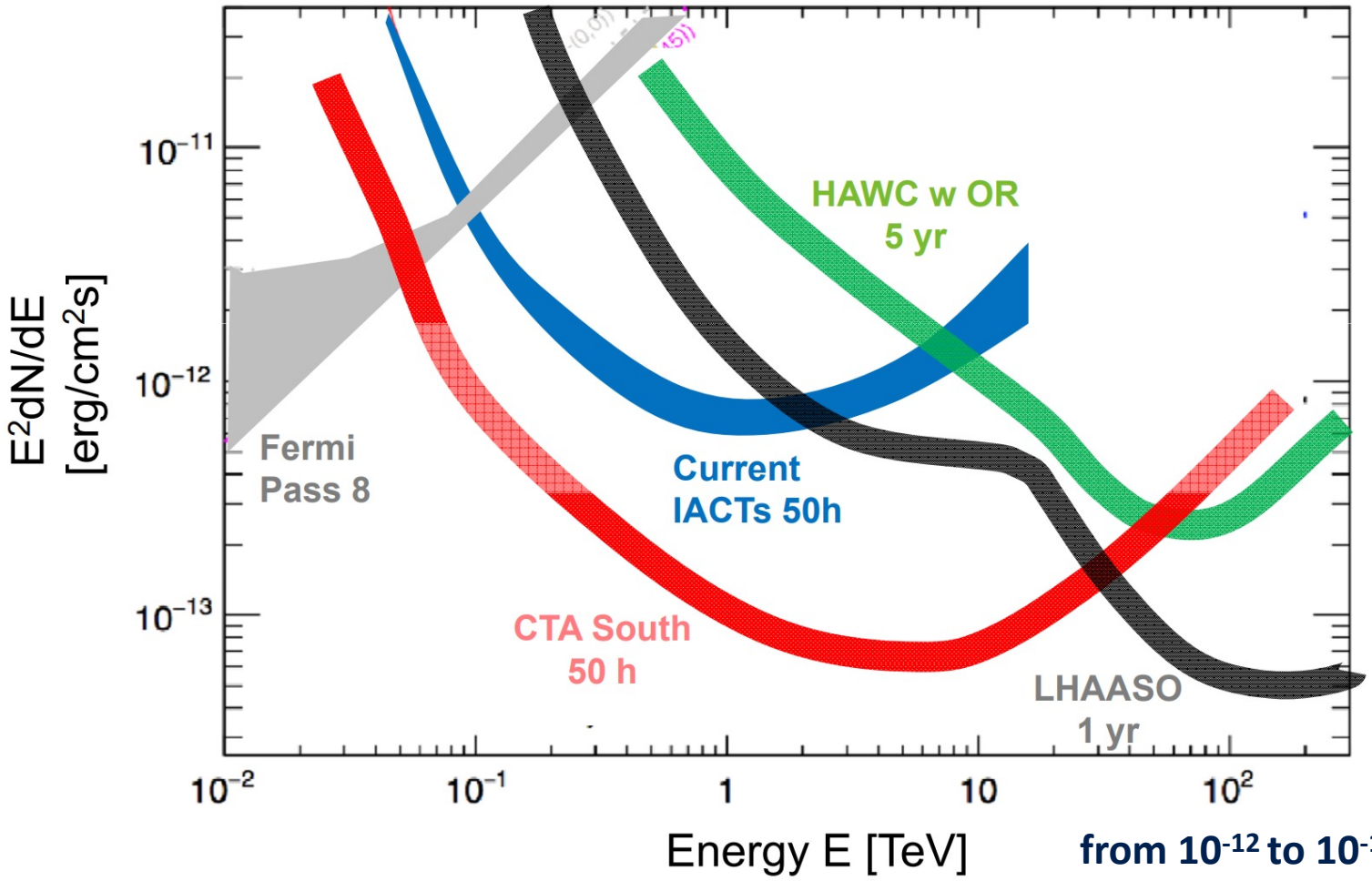
Array design



Array design



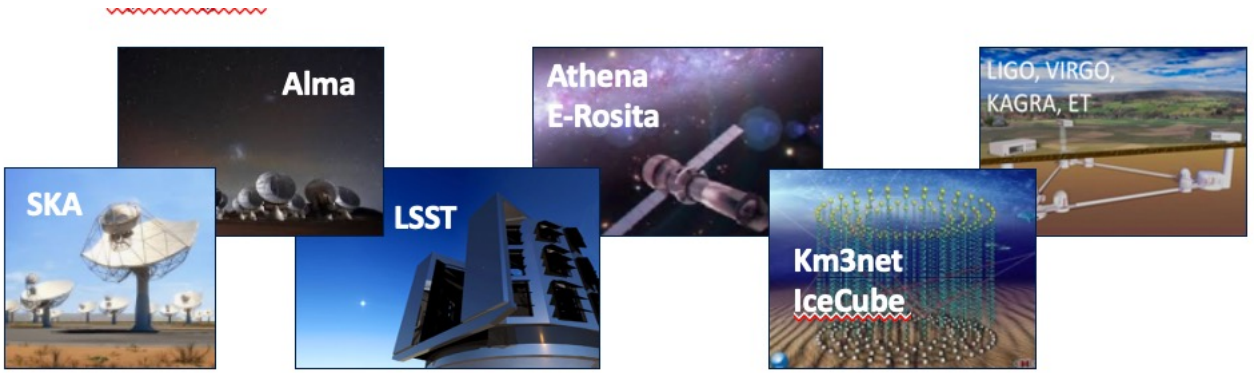
CTA performance



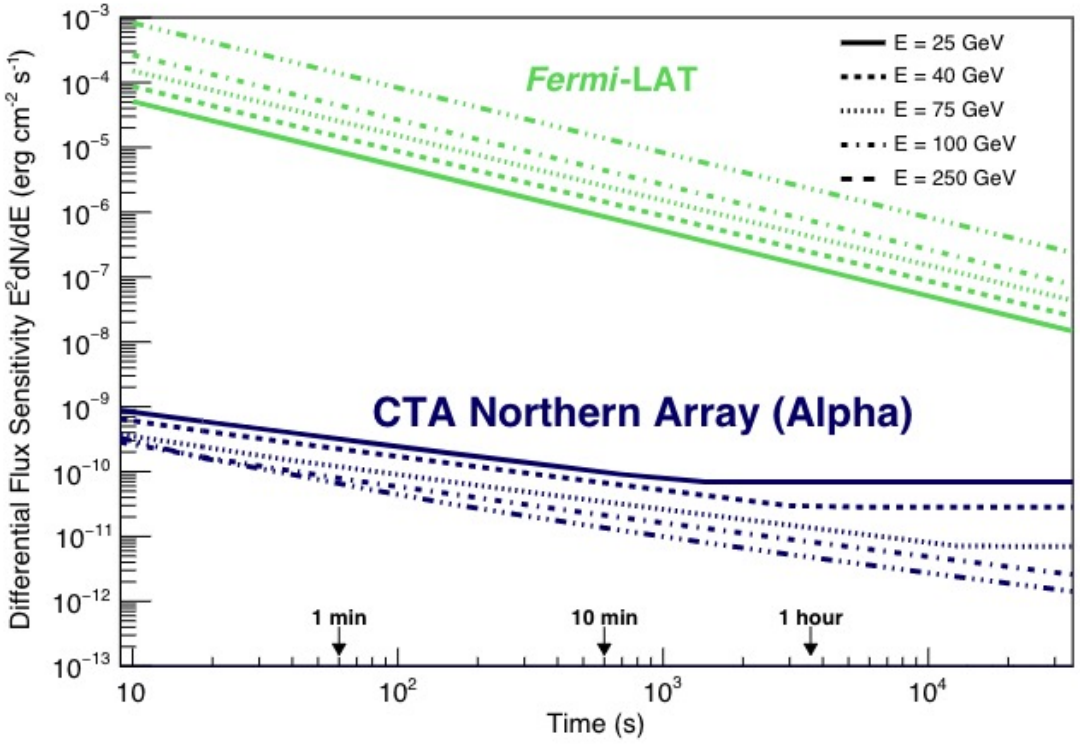
from 10^{-12} to 10^{-13} erg/cm^{2}s

CTA Observatory: a key player in the MM era

- **Integral part of the MWL/MM field**
  - wide sky coverage
  - Several degrees of gamma-ray FoV
  - Capability of issuing science alerts to external observatories within 30 seconds from the internal detection
  - Repointing within 1 minute from the alert notification
  - Source localization down to 5-10 arcsec
  - Unprecedented Short-term Sensitivity

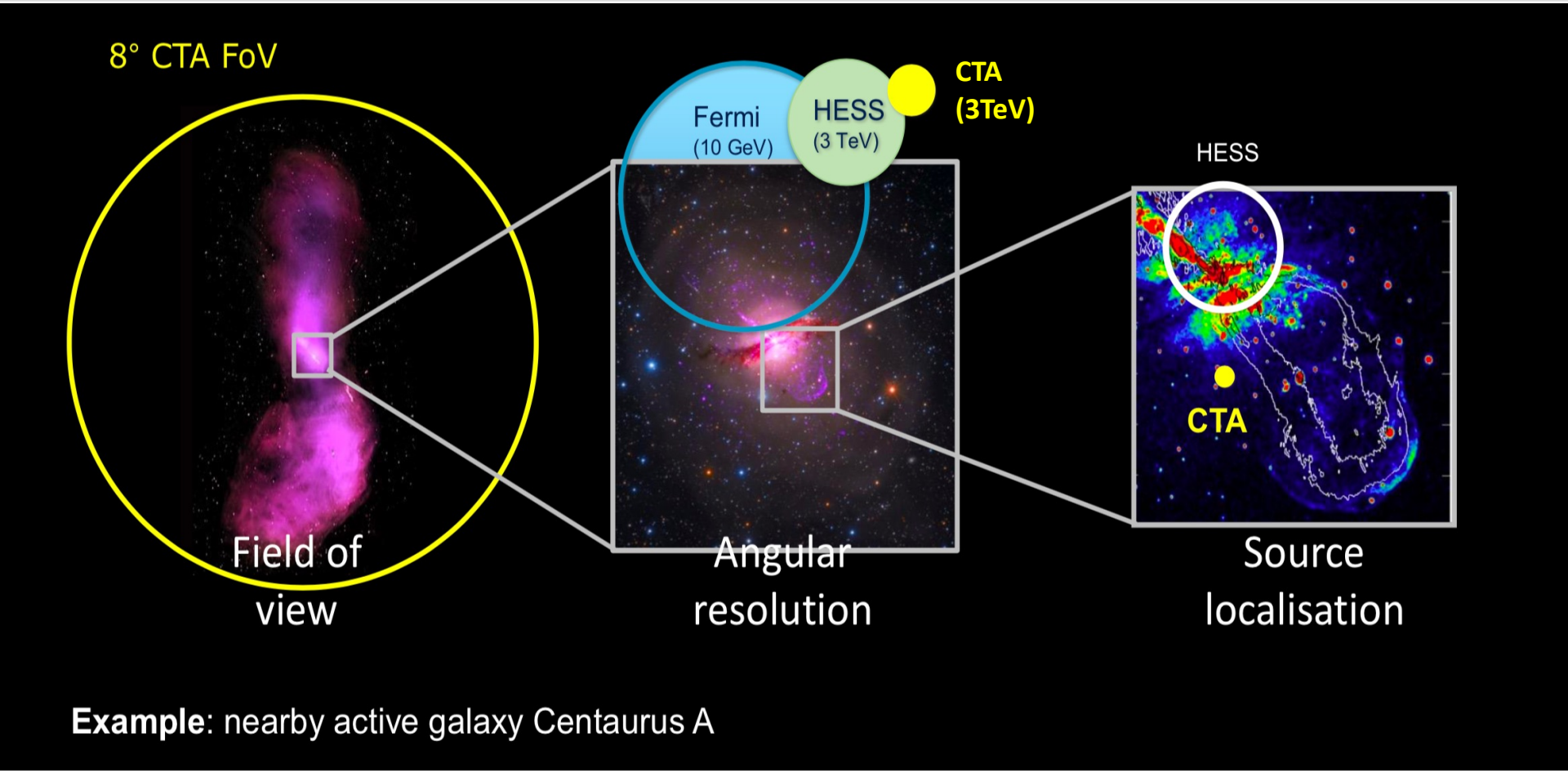


Short-term Sensitivity



If CTA can point at the transient phenomena, it is the most sensitive instrument but given the limited FoV & limited duty cycle it requires external triggers:

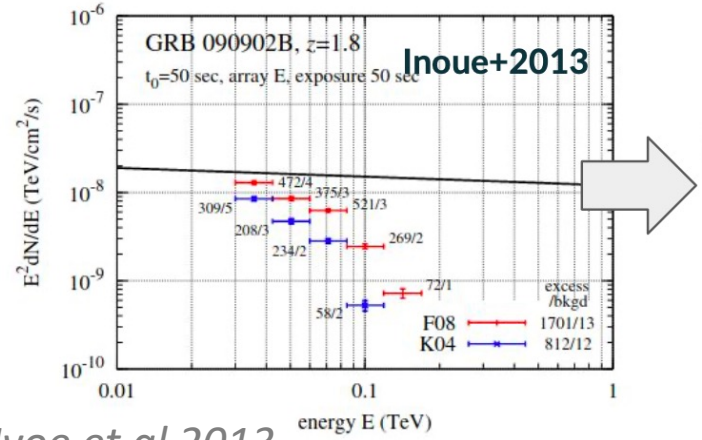
CTA performance



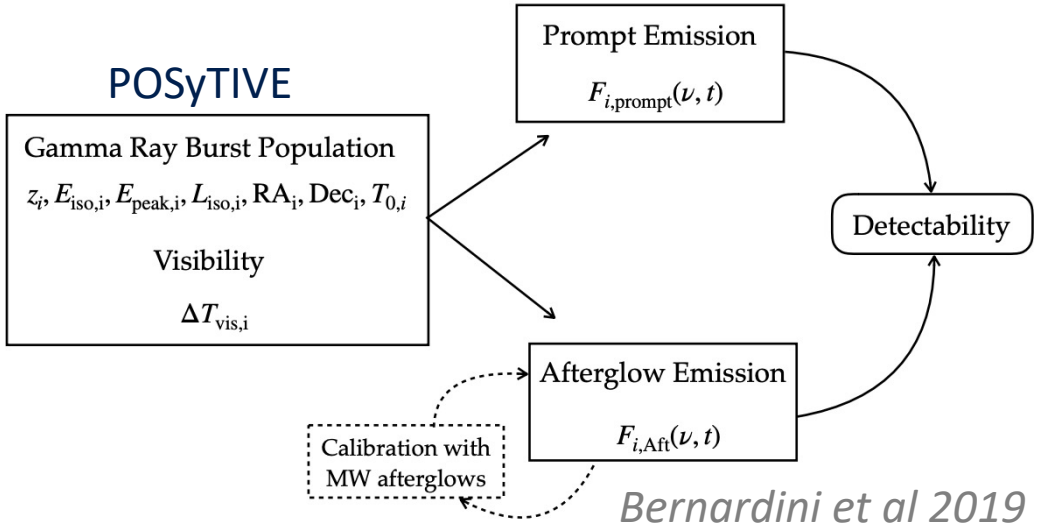
Example: nearby active galaxy Centaurus A

Gamma Ray Bursts

From an empirical to a theorectical approach



Ivoe et al 2013



Bernardini et al 2019

From an empirical to a theorectical approach

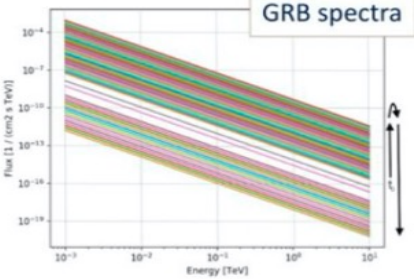
- Allows to estimate the GRB detection rate and study the space phase of parameters that can be explored

Gravitational Waves

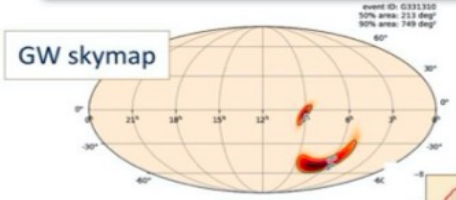
Simulation of BNS mergers and GW signal in local universe

Synthetic GW-GRBs Phenomenological model of VHE emission, from short-GRB

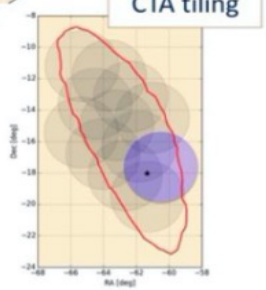
GRB spectra



GW skymap



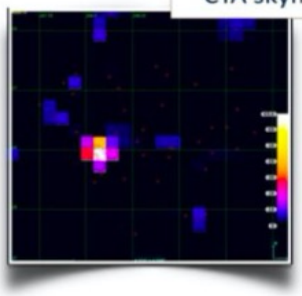
CTA tiling



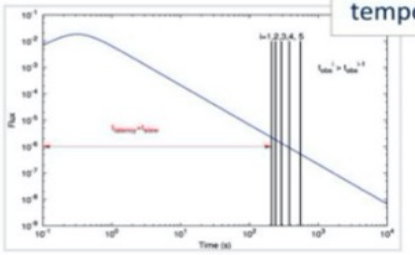
Observation optimisation and scheduler CTA observing strategy

Simulation of CTA response (set of IRFs) *gammapy, ctools*

CTA skymap



temporal scan



Expected Results and CTA prospects

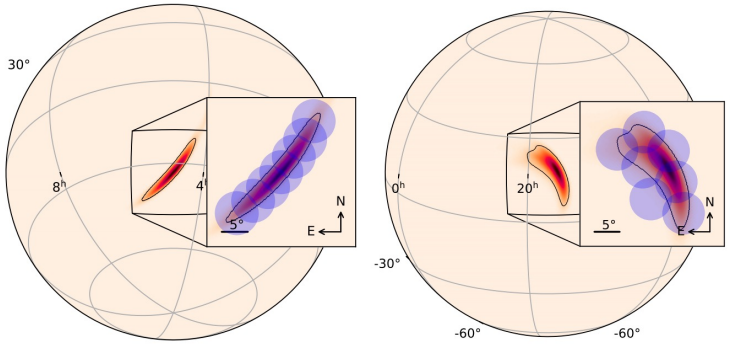
- ✓ Joint GW-CTA detection rates and coverage
- ✓ Optimal observation strategies

Credits to A. Stamerra, B. Patricelli

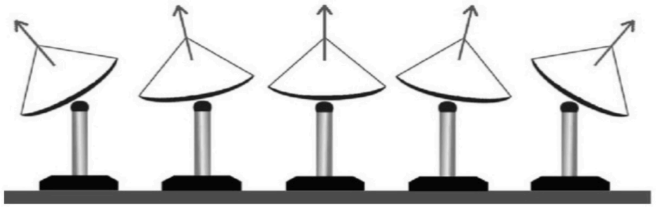
Gravitational Waves: observation strategy

- The observation strategy is a critical point for instruments with limited FoV:

1. Tiling pattern *Patricelli et al 2018, Bartos + 2019, Seglar-Arroyo et al 2019*
   - Coverage maximization versus exposure time per tail
   - Exposure time depends on the latency time
   - Galaxy density can be taken into account although may work properly only for “closeby” GW



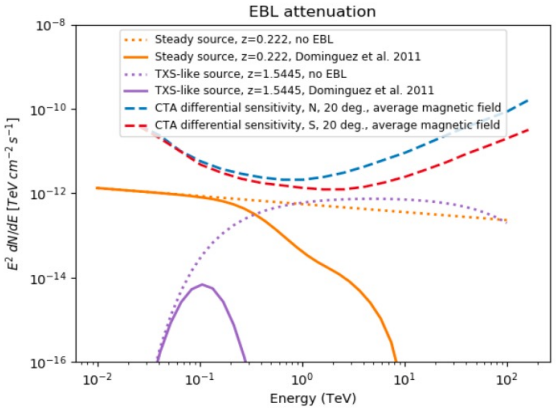
2. Increasing the FoV of the instrument by implementing a divergent array pointing mode

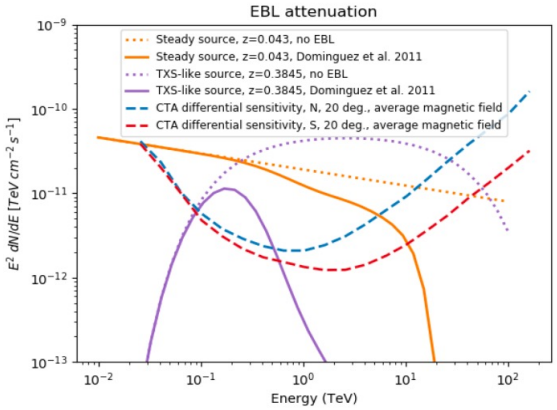


3. Coordination among the 2 array sites to be considered

UHE neutrinos

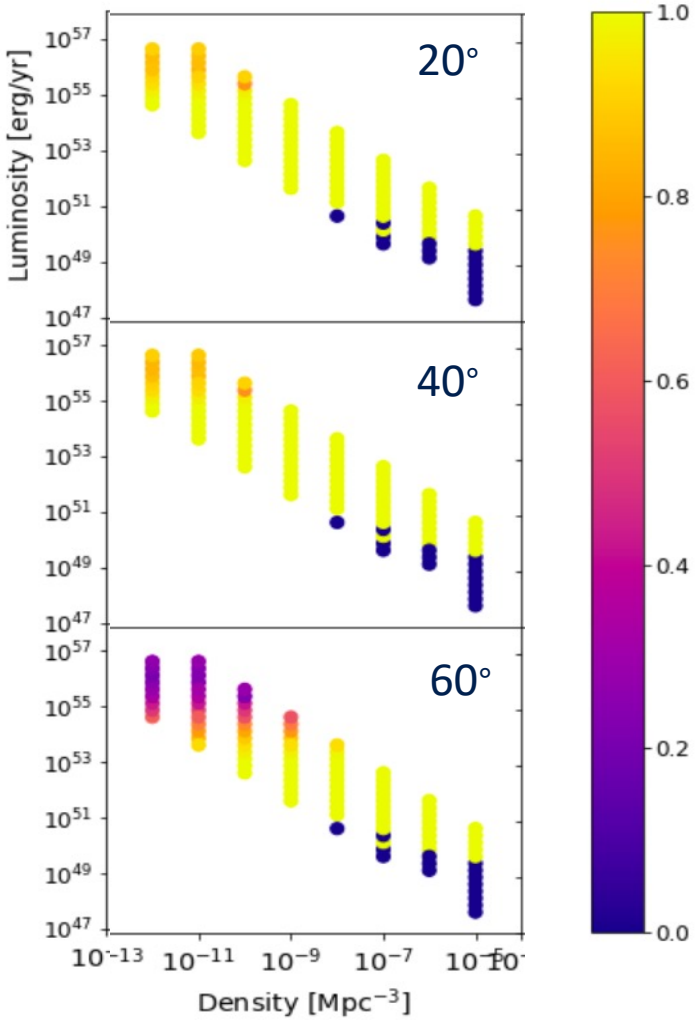
Develop an observation strategy for follow-up of UHE neutrino events to maximize the chances of VHE counterpart detection





- **2 neutrinos source populations simulated by FIRESONG** () to resemble the diffuse astrophysical neutrino flux
  - **TXS-like source population** (after the 2014 TXS 0506 flare)
  - **Steady sources following star formation evolution**
- corresponding **gamma ray emission** (pγ interactions) computed and simulated it taking into account CTA IRFs & EBL absorption

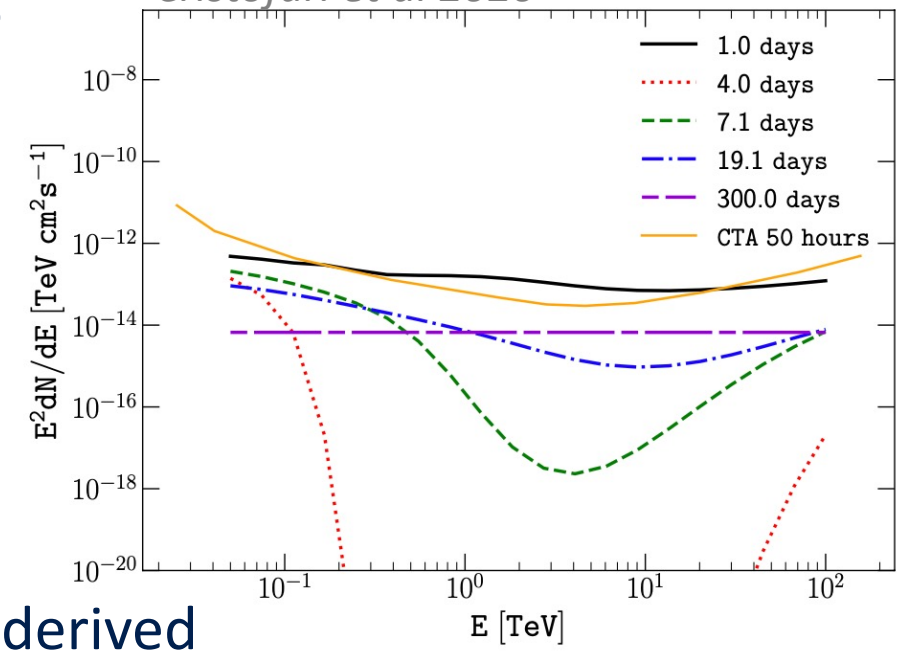
UHE neutrinos



Supernovae

- using SN 1993J as template to model VHE emission at different times
  - non-isotropic attenuation leads to a more optimistic scenario
- Prospects for such a type of observation during the first days/months/years are being derived

Cristofari et al 2020



- SNe for which the shock radius would rapidly becomes larger than the photospheric radius might be promising targets for CTA

Conclusions

- CTA will usher in a new era in VHE Astrophysics
  - rich science program answering many open questions
  - large new discovery space
  - The full exploitation 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