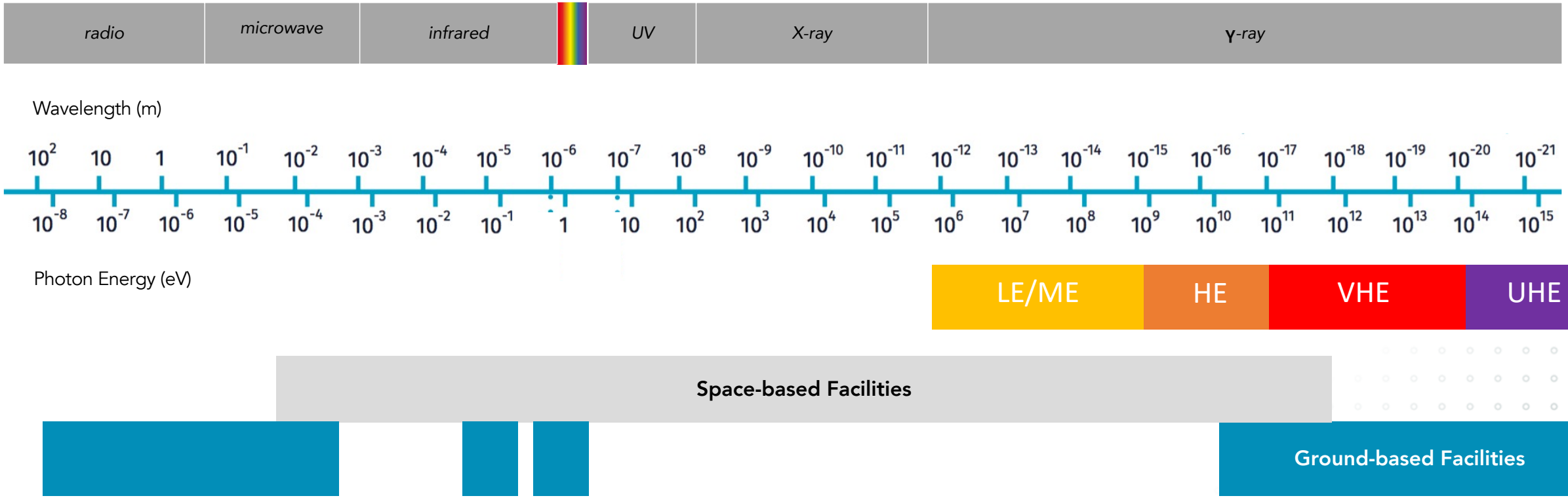
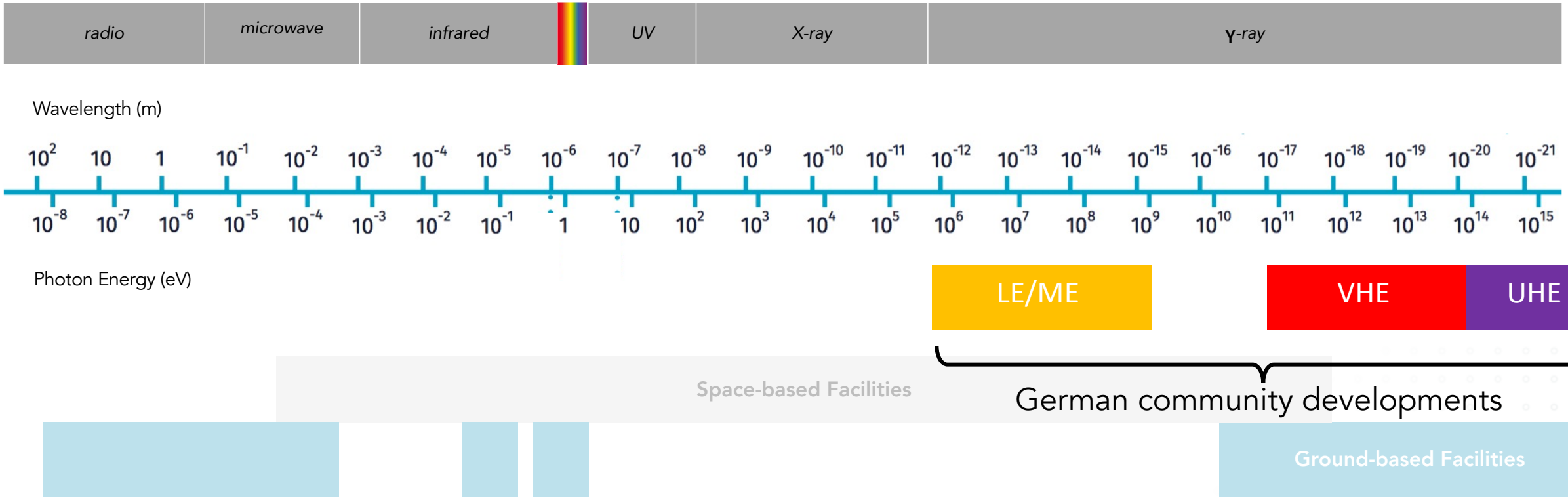
Gamma-rays

Jim Hinton, Stefan Funk, David Berge


radio
microwave
infrared
UV
X-ray
γ-ray
Wavelength (m)
10^2 10 1 10^-1 10^-2 10^-3 10^-4 10^-5 10^-6 10^-7 10^-8 10^-9 10^-10 10^-11 10^-12 10^-13 10^-14 10^-15 10^-16 10^-17 10^-18 10^-19 10^-20 10^-21
10^-8 10^-7 10^-6 10^-5 10^-4 10^-3 10^-2 10^-1 1 10 10^2 10^3 10^4 10^5 10^6 10^7 10^8 10^9 10^10 10^11 10^12 10^13 10^14 10^15
Photon Energy (eV)
LE/ME
HE
VHE
UHE
Space-based Facilities
Ground-based Facilities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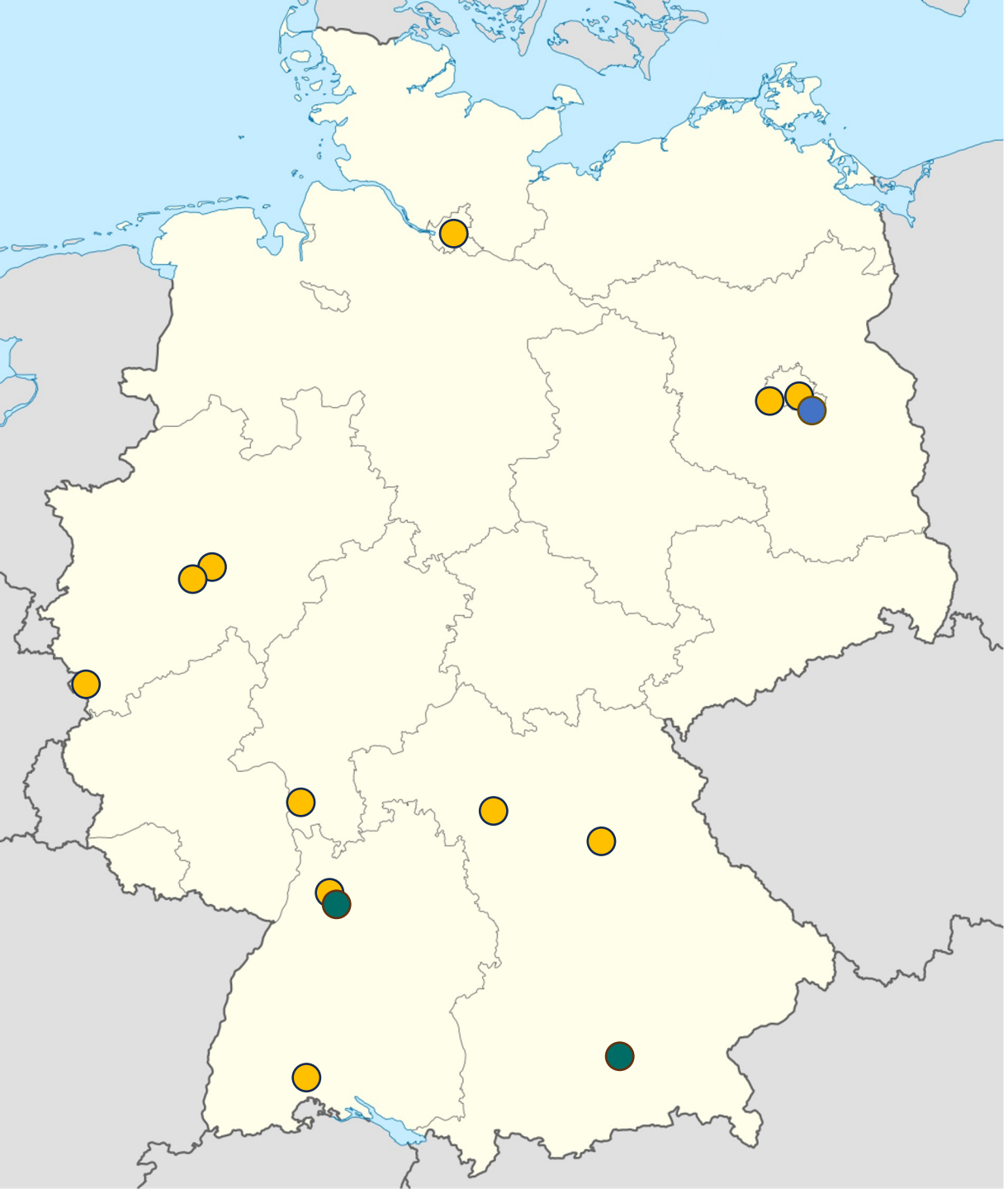
10^{2} 10 1 10^{-1} 10^{-2} 10^{-3} 10^{-4} 10^{-5} 10^{-6} 10^{-7} 10^{-8} 10^{-9} 10^{-10} 10^{-11} 10^{-12} 10^{-13} 10^{-14} 10^{-15} 10^{-16} 10^{-17} 10^{-18} 10^{-19} 10^{-20} 10^{-21}
10^{-8} 10^{-7} 10^{-6} 10^{-5} 10^{-4} 10^{-3} 10^{-2} 10^{-1} 1 10 10^{2} 10^{3} 10^{4} 10^{5} 10^{6} 10^{7} 10^{8} 10^{9} 10^{10} 10^{11} 10^{12} 10^{13} 10^{14} 10^{15}
Photon Energy (eV)
LE/ME
VHE
UHE
German community developments
Space-based Facilities
Ground-based Facilities

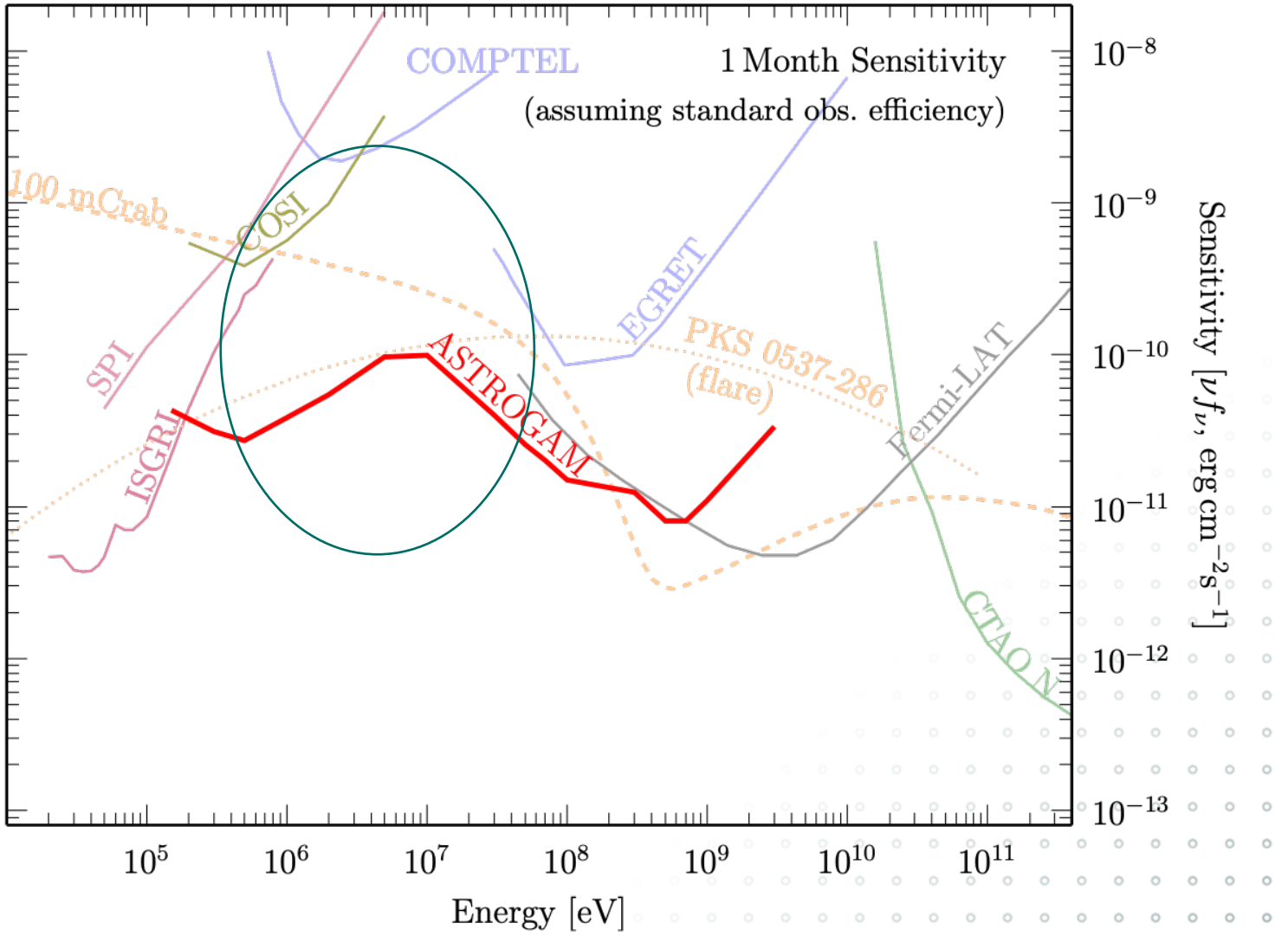


- Gamma-ray community in Germany
  - 11 University Groups
  - 2 Max Planck Institutes
    - MPIK & MPP
  - 1 Helmholtz Institute
    - DESY (Zeuthen)
- Many institutes involved MeV-PeV
  - And strong in theory as well as instrumentation/data

MeV Gammas

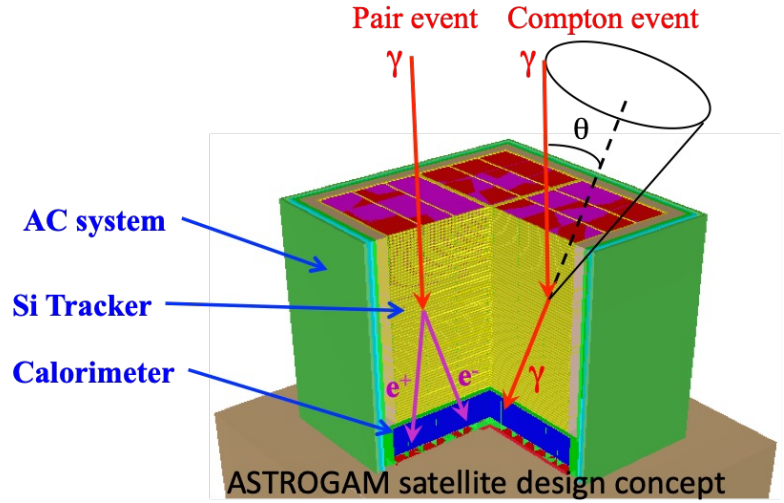
- See https://arxiv.org/abs/2102.02460

- MeV range important for very broad set of scientific topics
  - Active galaxies
  - Neutrino link
  - Nucleosynthesis*
  - Gal + EG particle accelerators
- Sensitivity gap!
  - ASTROGAM proposal failed in 2022



and Fermi will not last forever – widening the gap for time-variable objects

MeV Gammas Future?



- DLR support for COSI contributions
  - Mainz, Würzburg; launch 2027, focused Compton mission for 0.2-5 MeV with high E resolution
  - But limited mission time (2 years) and sensitive energy range
- Support needed for R&D towards general purpose MeV instrument
  - ASTROGAM bid in 2022 supported by HU Berlin, RU Bochum, Erlangen, Mainz, Potsdam, Tübingen, Würzburg plus DESY
  - Community is preparing for new bids (ESA+NASA 2025), important that Germany can continue to play a strong role

Ground-based Gammas

Scientific Themes

Cosmic Particle Acceleration
Cosmic Ray Impact

Non-Thermal Astrophysics

Multi-Messenger Astronomy

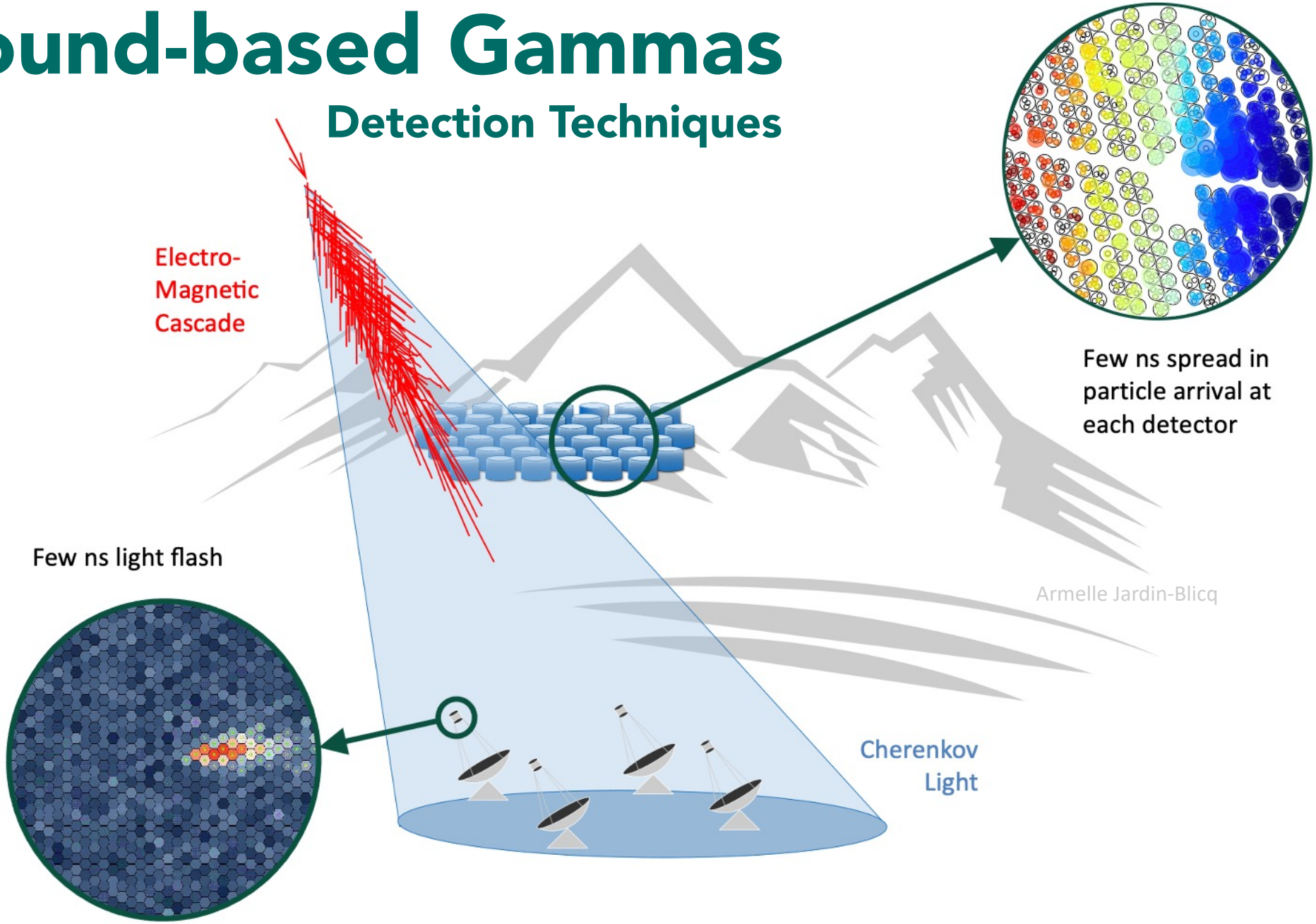
Gravitational Wave Transients
The Cosmic Neutrino Sky
UHE Cosmic Ray Origin

Axion-like Particles
Lorenz Invariance Violation
Dark Matter

Beyond Standard Model Physics

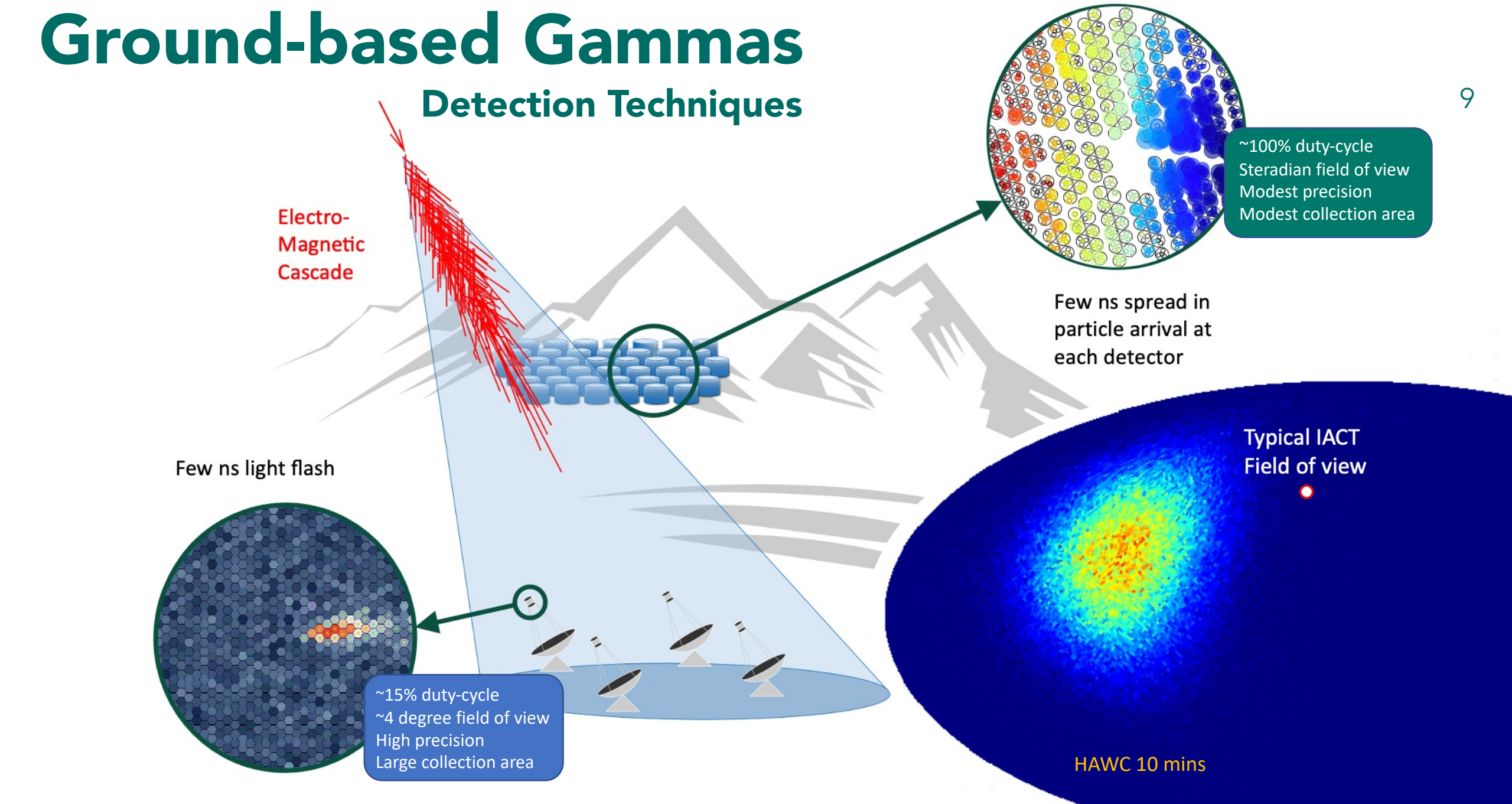
Ground-based Gammas

Detection Techniques



Ground-based Gammas

Detection Techniques

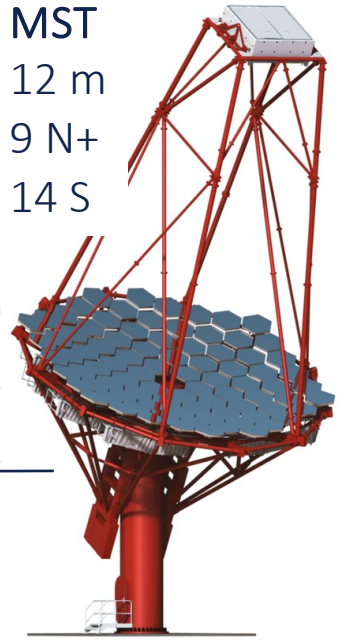


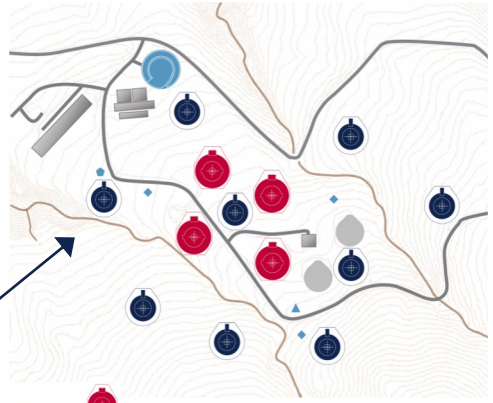

VERITAS
HAWC
MAGIC
LHAASO
CTAO
SWGO
HESS

Paranal

1 km

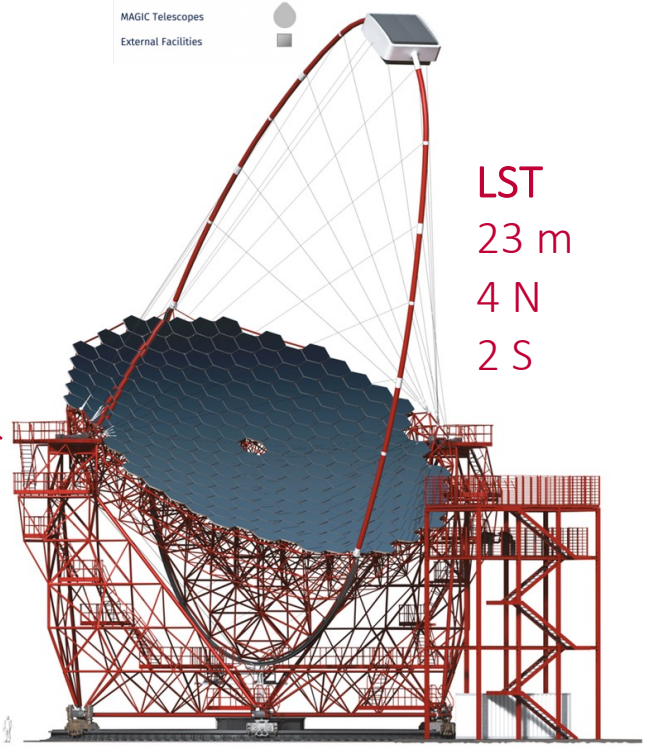
MST
12 m
9 N+
14 S





La Palma

LST
23 m
4 N
2 S



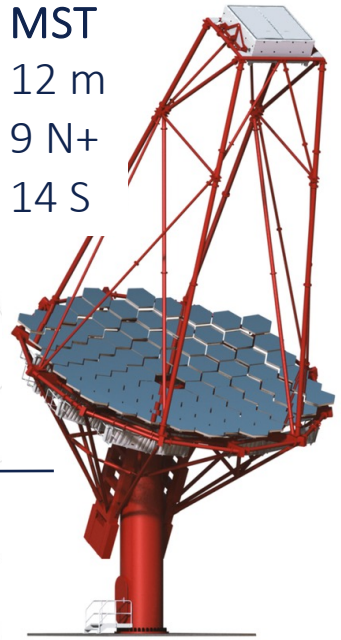
SST
4 m
42 S

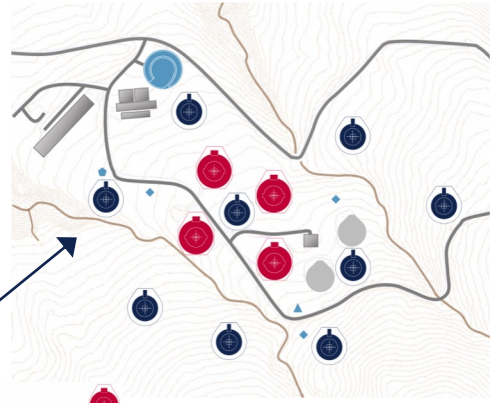
CTAO
Initial Phase Plan

Paranal

1 km

MST
12 m
9 N+
14 S

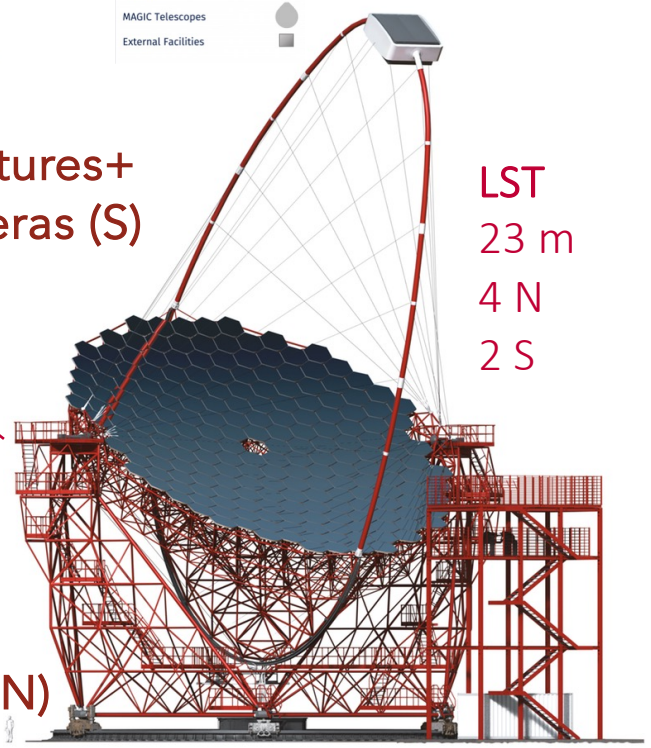




La Palma

DE:
Structures+
Cameras (S)

LST
23 m
4 N
2 S



SST
4 m
42 S

DE:
Cameras

CTAO
Initial Phase Plan

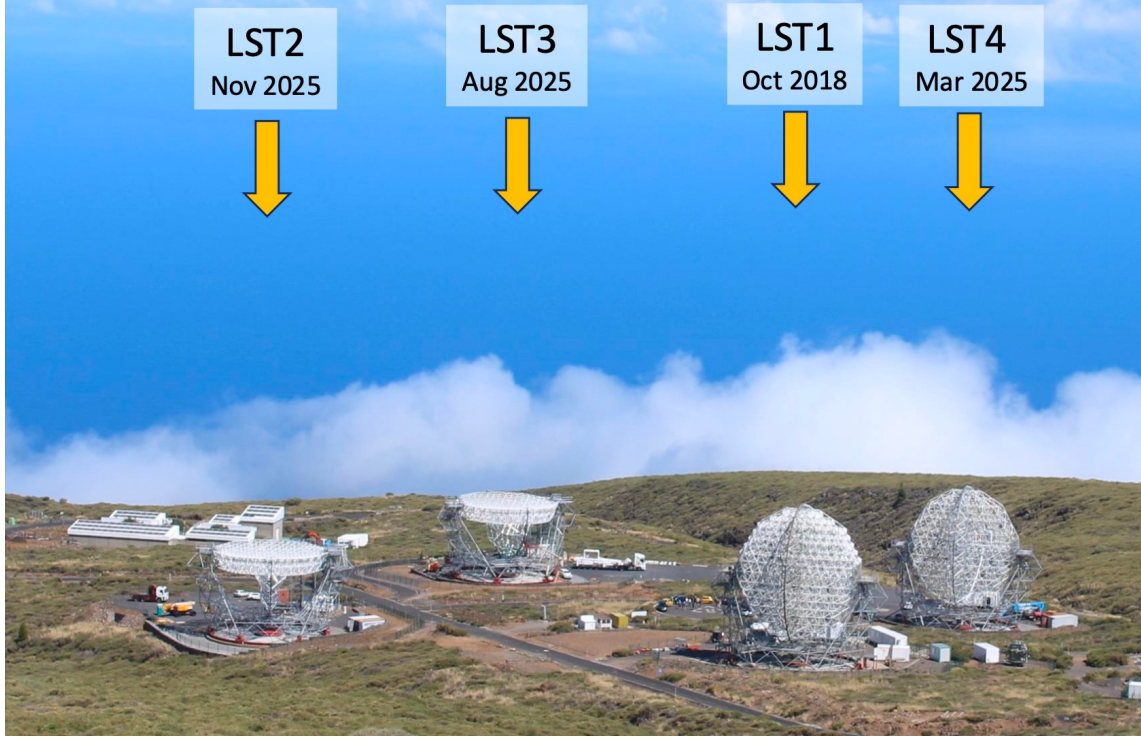
DE:
Structures+ (N)

CTAO Status?

- Rapid progress on all fronts

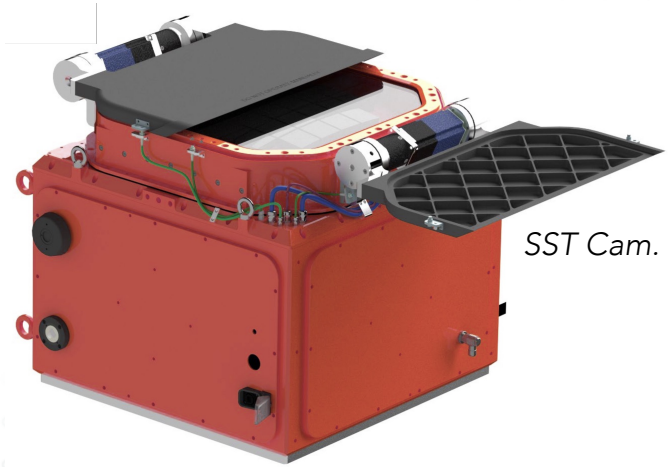
Everything prototyped and tested

Preparations for first CTA South 'Pathfinders'



LST Construction in La Palma

ASTRI array as proving ground for CTA SST technologies



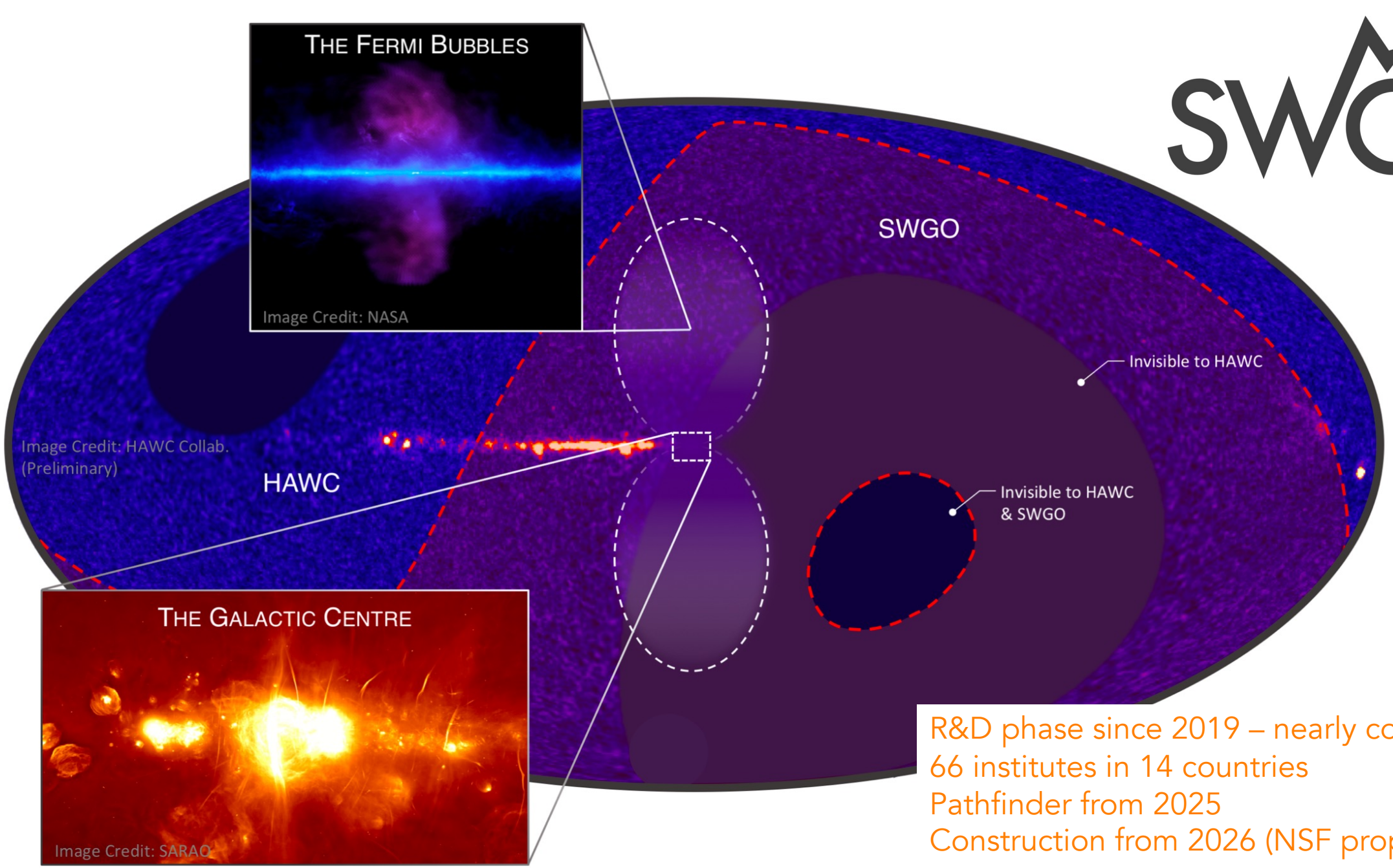
Preparations for 'mass production' for Cherenkov Cameras

CTAO Status?

- Not just technical progress
  - Expect final legal entity (CTAO ERIC) to be established very early in 2025
  - Procurement process in motion for roads and foundations in Chile
    - first foundations in place by end of 2025
  - Science Data Management Centre in Zeuthen
    - New building - inauguration this week

Copyright: DESY /Marco Urban

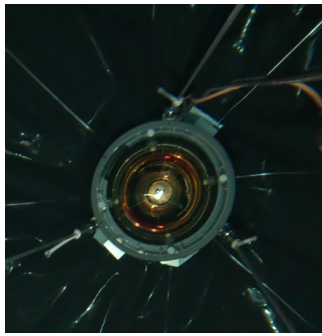
- ***Strategy?***
  - *While the focus of the German groups for the next decade will be on the construction, commissioning and science operation of CTA data, plans are being developed to upgrade parts of the hardware of the system, that will be operated for several decades*



R&D phase since 2019 – nearly complete
66 institutes in 14 countries
Pathfinder from 2025
Construction from 2026 (NSF prop.)

SWGO Status?

Double 8-10 “ PMT module



FlashCam readout

Inner array baseline

5.2 m diameter dual-layer WCD

Prototype @ HAWC

SWGO in Germany

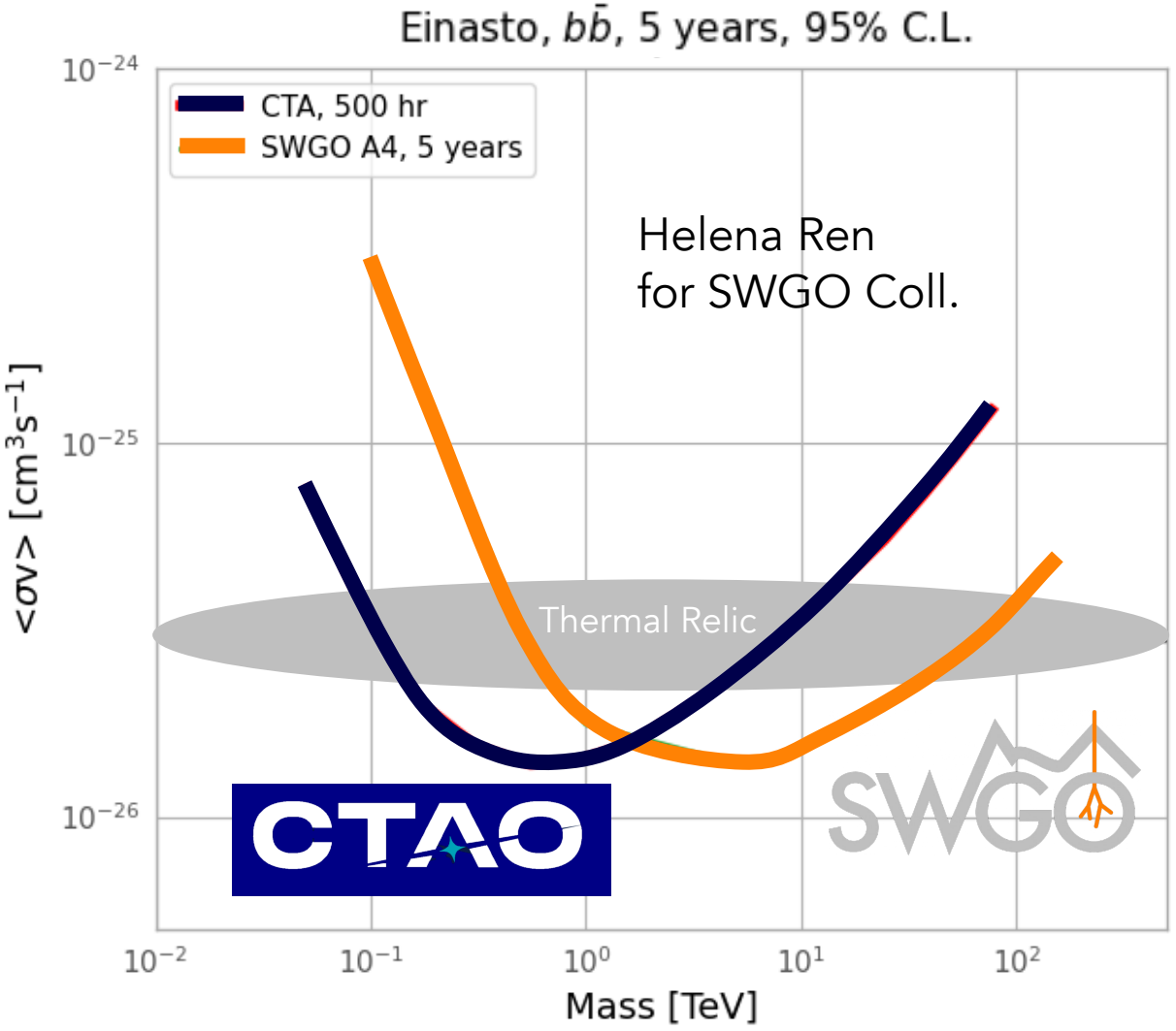
SWGO-A: 2026-2029

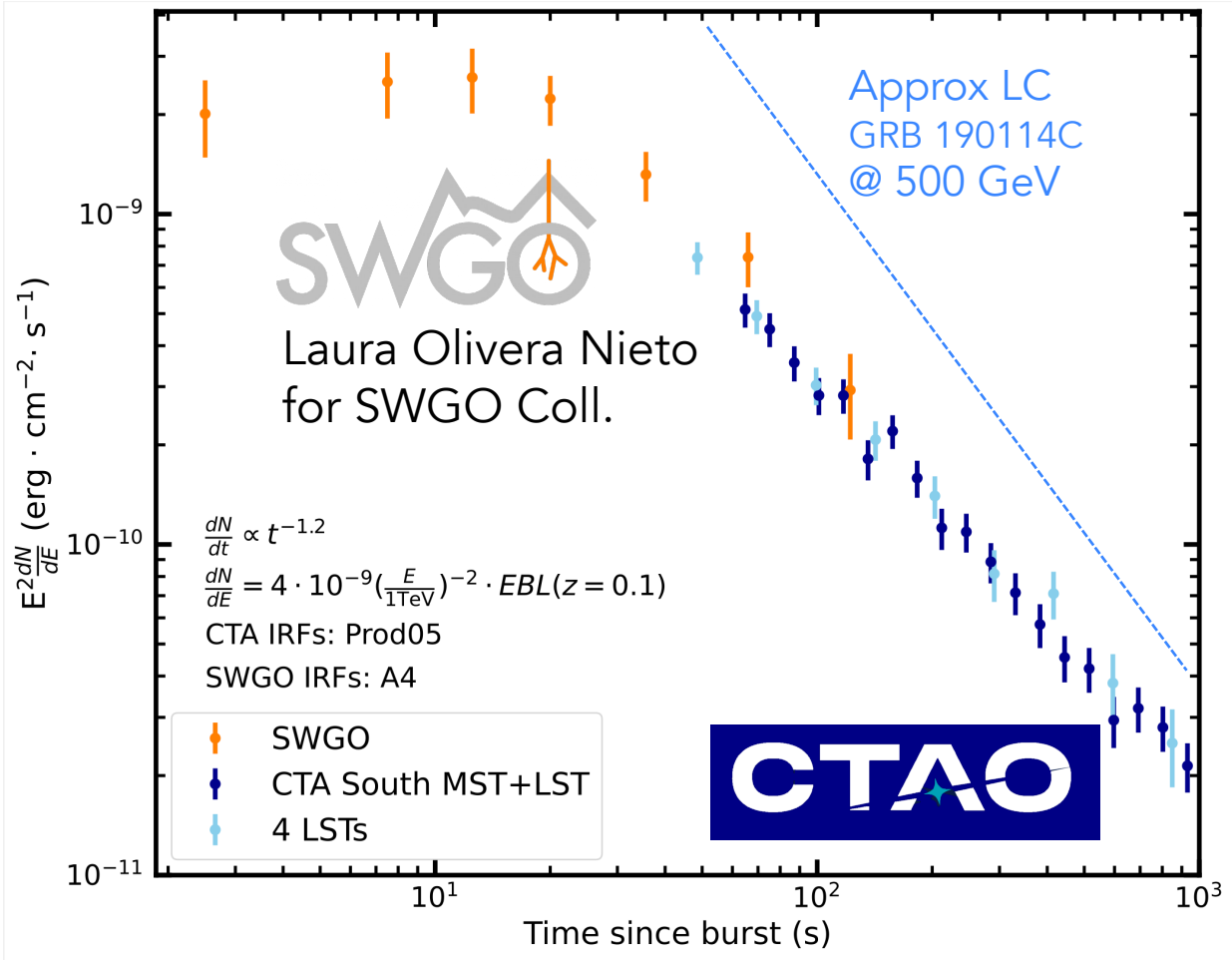
Application to NSF in prep. - deadline Nov 22. $18M + 'in-kind' contributions from other partners. Sensitivity > HAWC in new hemisphere

Outer array proposals expected in 2025

- Institutes
  - MPIK, Erlangen, Dortmund, Aachen (so far!)
- Activities
  - Photosensors, electronics, simulations & analysis, science synergies CTA
  - (Exploration of lake-based option → now a possible future extension)
  - Leadership roles?
    - JAH is Spokesperson, Working Group Coordinators: R. White (MPIK, Detector), J. Glombitza (ECAP, Analysis & Simulations), ++
- Next steps
  - Significant role in SWGO-A (NSF-led), ANTARES PMTs, FlashCam electronics, +++
  - Support needed for University groups

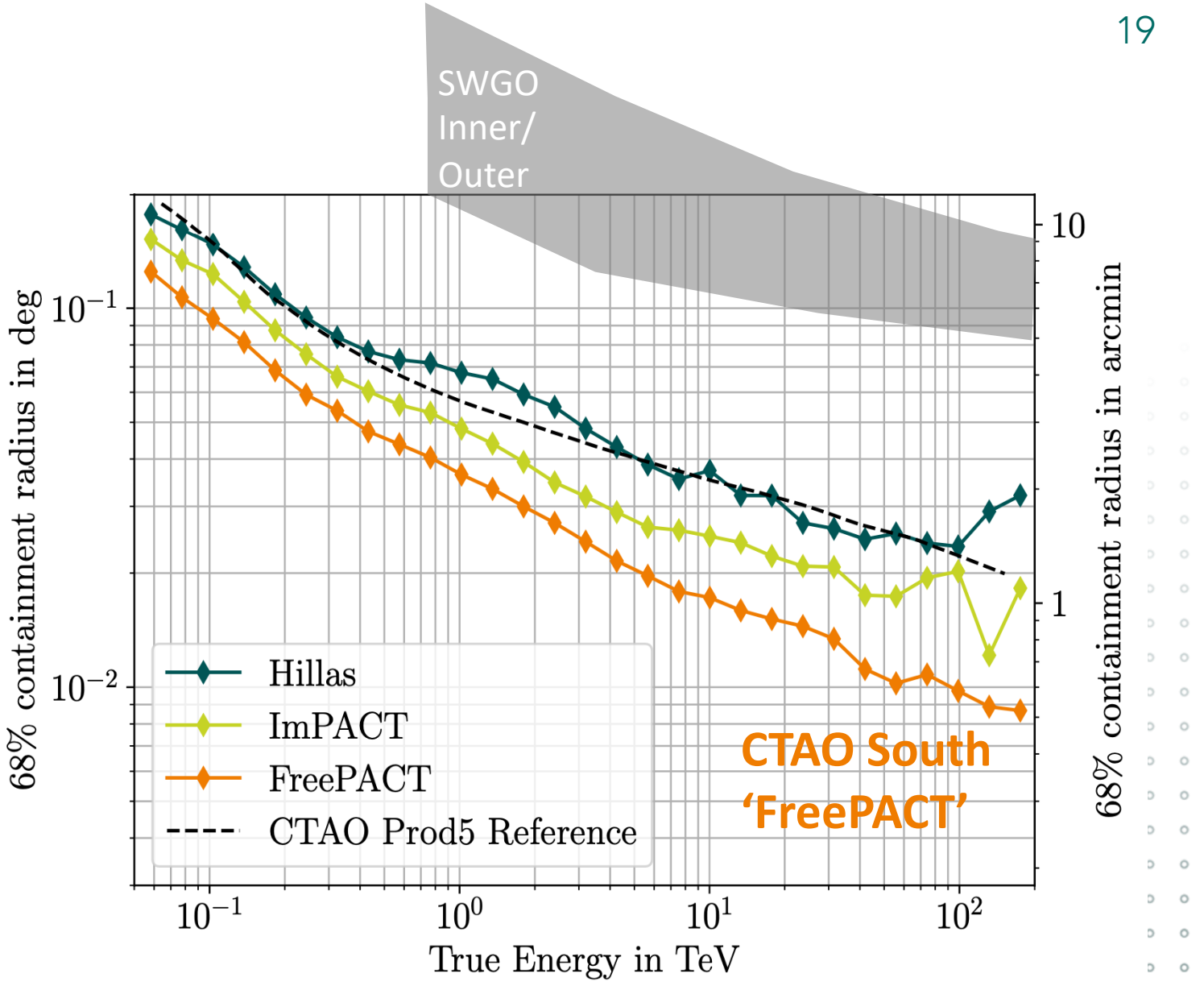
SWGO+CTA


Einasto, $b\bar{b}$, 5 years, 95% C.L.
CTA, 500 hr
SWGO A4, 5 years
Helena Ren
for SWGO Coll.
Thermal Relic
CTAO
SWGO
$<\sigma v>$ [cm^{3}s^{-1}]
Mass [TeV]


Approx LC
GRB 190114C
@ 500 GeV
SWGO
Laura Olivera Nieto
for SWGO Coll.
$\frac{dN}{dt} \propto t^{-1.2}$
$\frac{dN}{dE} = 4 \cdot 10^{-9} (\frac{E}{1\text{TeV}})^{-2} \cdot EBL(z = 0.1)$
CTA IRFs: Prod05
SWGO IRFs: A4
SWGO
CTA South MST+LST
4 LSTs
CTAO
$E^2 \frac{dN}{dE}$ (erg · cm^{-2}. s^{-1})
Time since burst (s)

Angular Resolution

- Ground-particle arrays cannot compete with CTAO
- Huge opportunity for precision astronomy at energies > ~10 TeV (SSTs)
  - e.g. new hybrid machine learning/likelihood fitting
    - Schwefer, Parsons, Hinton 2024 (APh 163, 103008)
  - 30 arcsecond resolution possible with CTA at 100 TeV!



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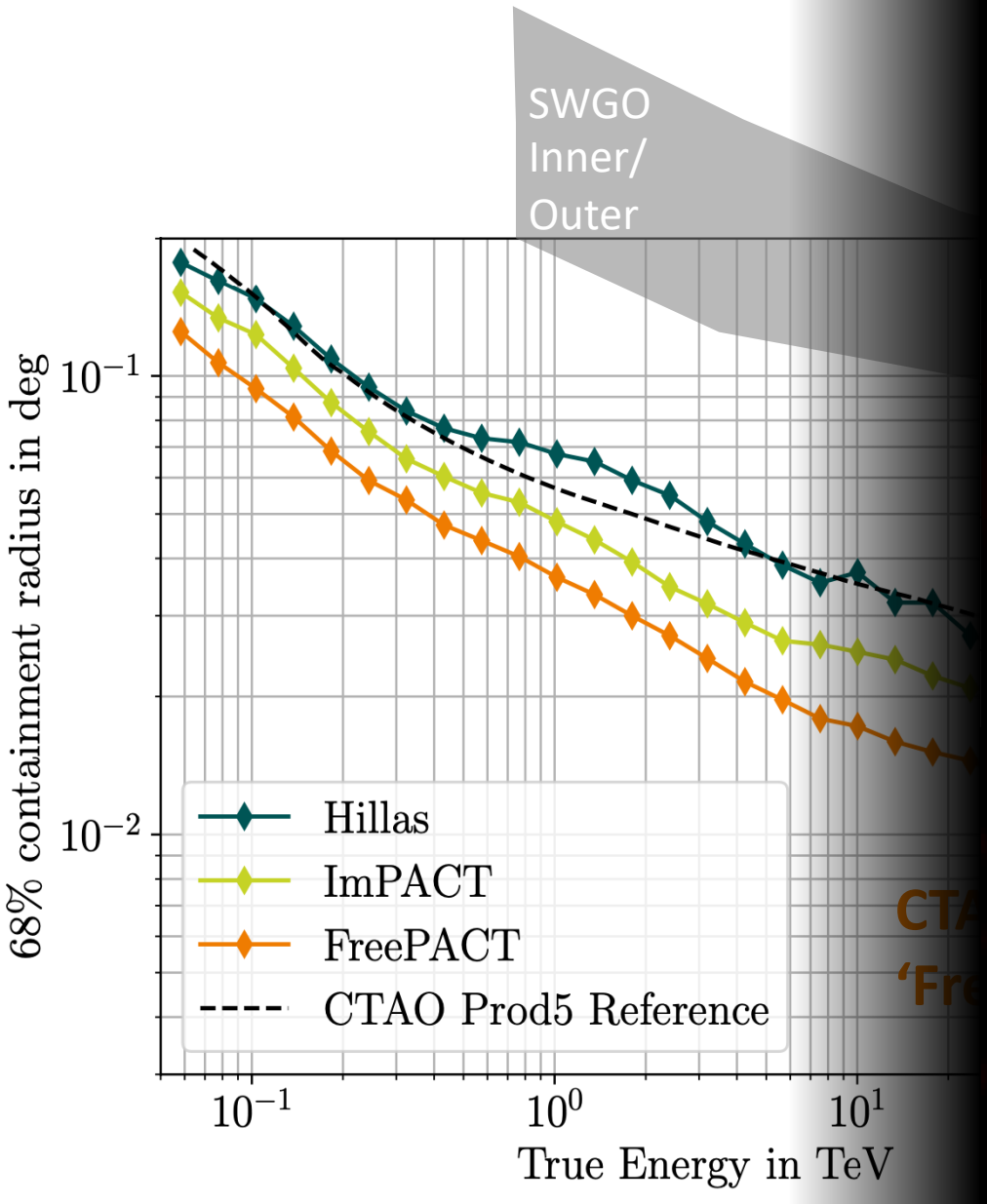
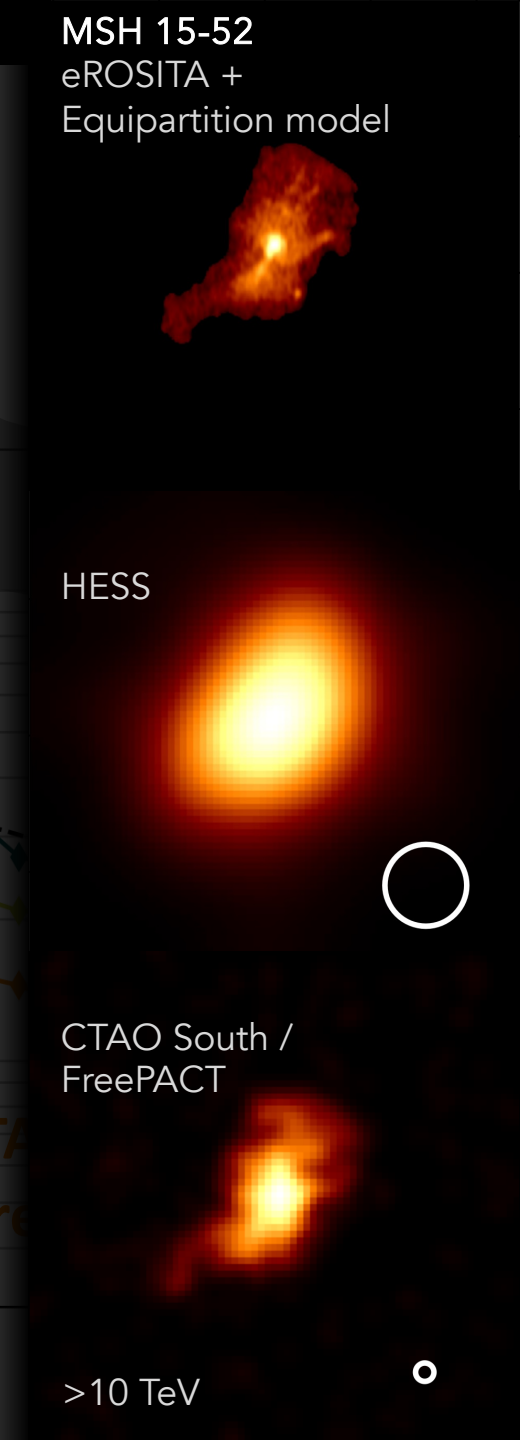
Schwefer et al (in prep.)

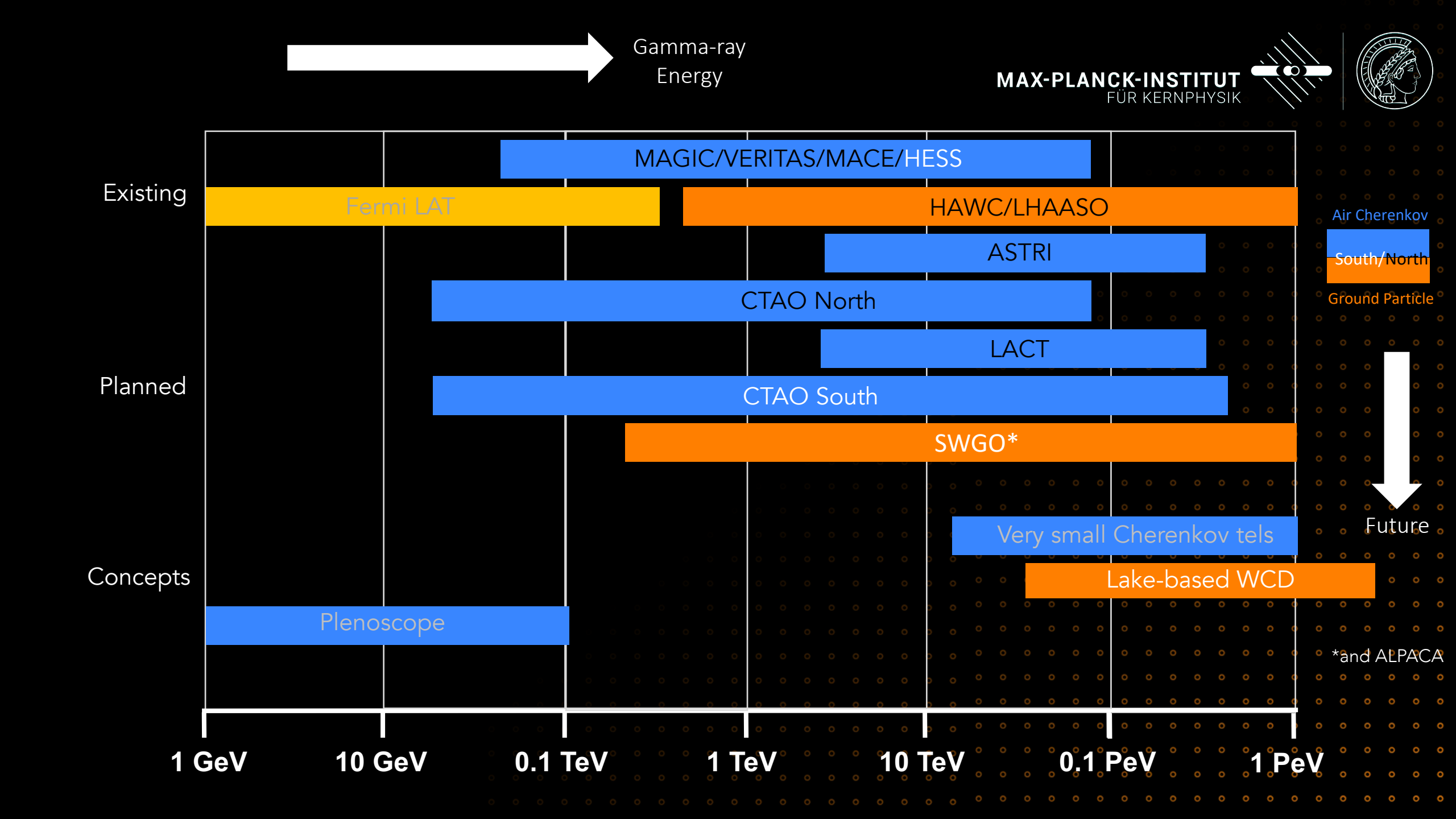


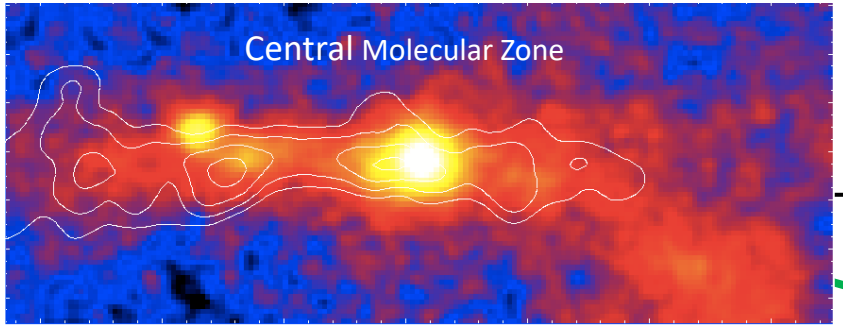


Conclusions

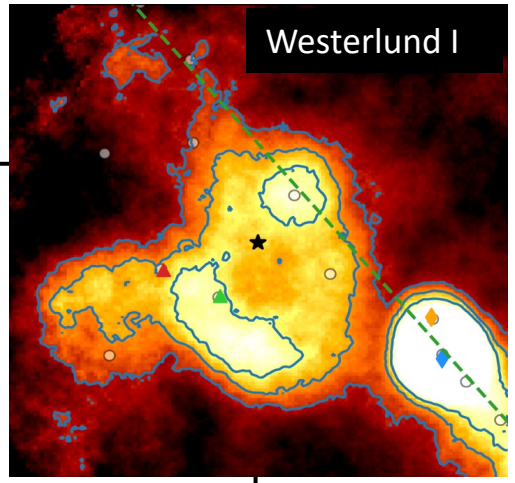
- CTA Observatory is clear priority of the community and entering a critical (exciting!) phase
  - Support needed for construction, commissioning, early science – but also to start preparing upgrade options for the 2030s
- SWGO is a strongly complementary array with major German role
  - German community is well-placed to exploit the synergies with CTAO
  - Support needed to ensure that German unis can properly participate
- Closing the ‘MeV gap’ a major priority of the global community
  - Germany is well-placed to play a major role, close connections neutrino astronomy as well as VHE gammas +++
  - Support need for detector R&D

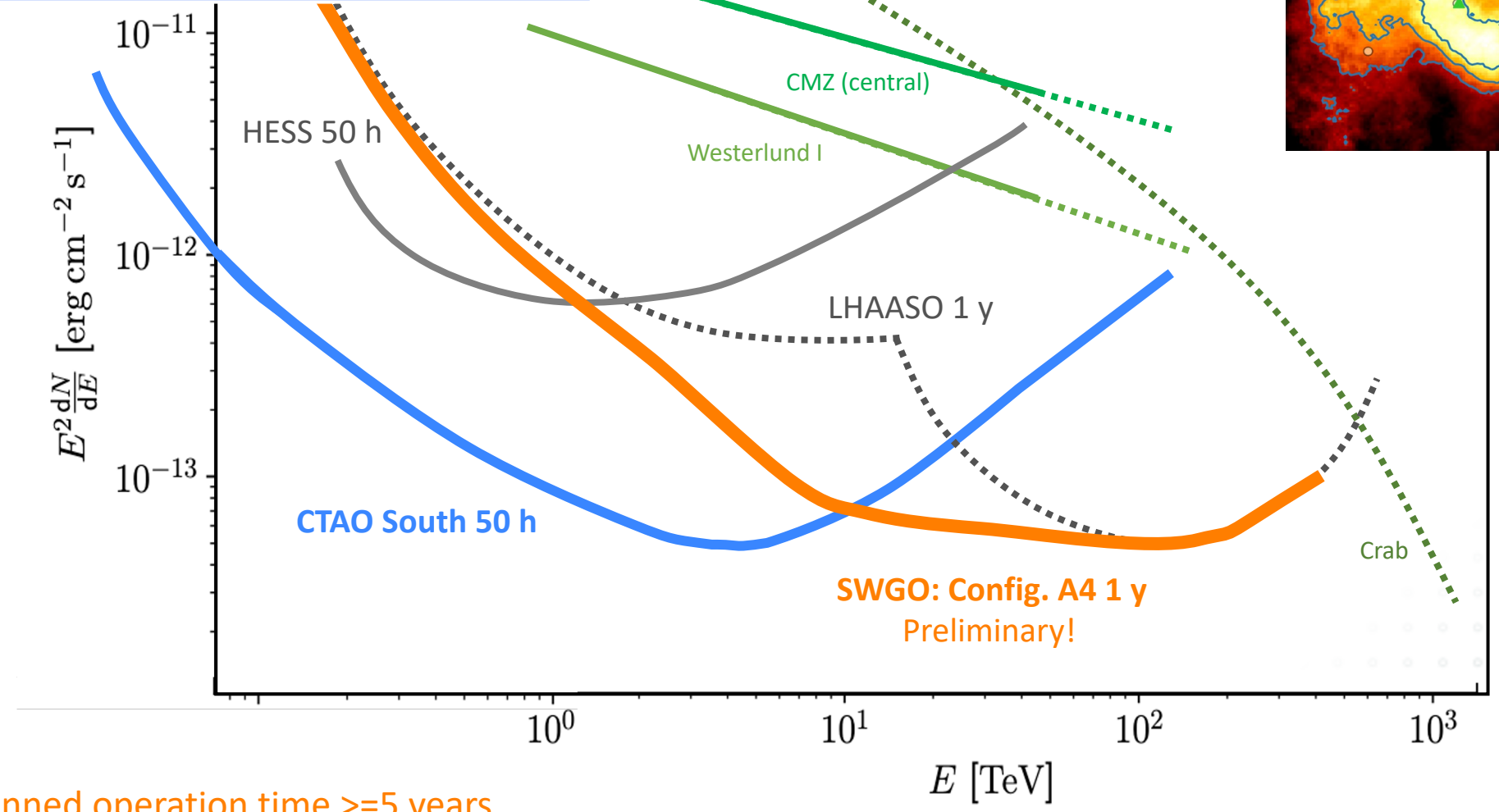
Discussion


Gamma-ray Energy
MAX-PLANCK-INSTITUT FÜR KERNPHYSIK
Existing
Planned
Concepts
MAGIC/VERITAS/MACE/HESS
Fermi LAT
HAWC/LHAASO
ASTRI
CTAO North
LACT
CTAO South
SWGO*
Very small Cherenkov tels
Lake-based WCD
Plenoscope
Air Cherenkov
South/North
Ground Particle
Future
*and ALPACA
1 GeV
10 GeV
0.1 TeV
1 TeV
10 TeV
0.1 PeV
1 PeV



Southern Hemisphere
UHE sources





*planned operation time >=5 years

UHE Lake

- R&D effort over last few years within context of SWGO
  - New lake facility at LHAASO site
  - Deep under water bladders as cost-effective alternative to buried muon detectors of LHAASO
  - Surface WCD development at MPIK+++
- Possible UHE extension to SWGO
  - Under evaluation