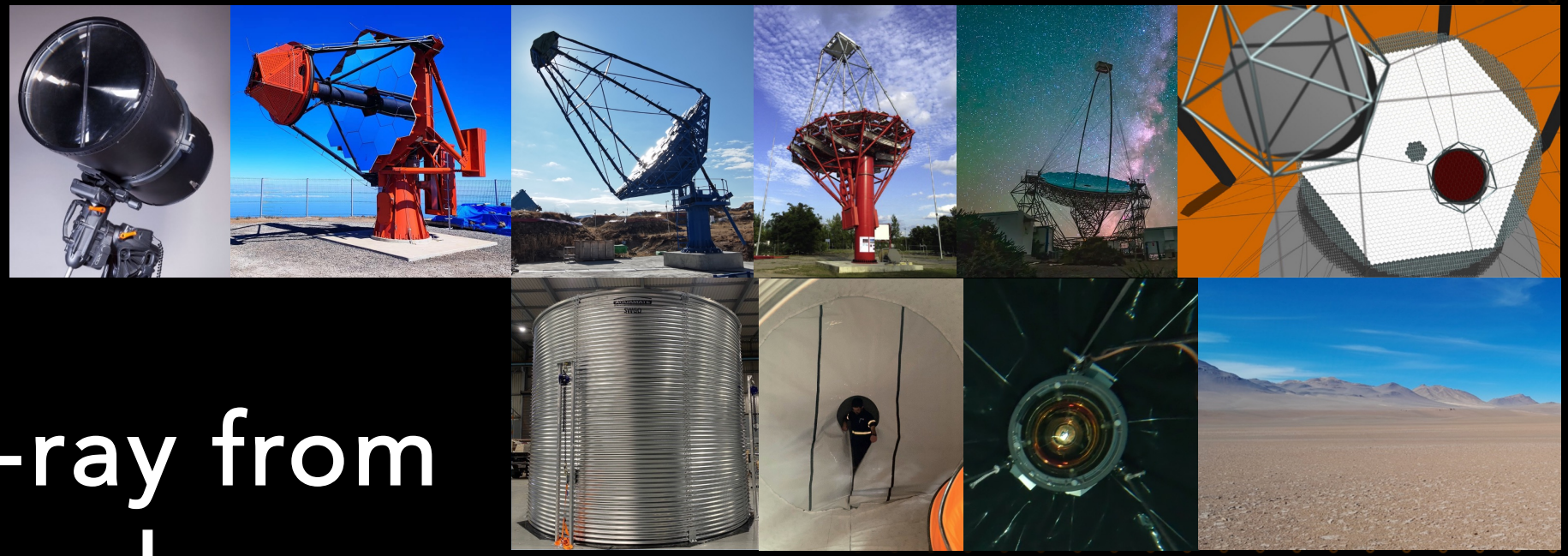
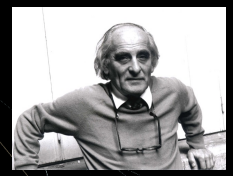


Gamma-ray from the ground – future perspectives

8th Heidelberg International Symposium on High Energy Gamma Ray Astronomy

γ 2024 MILANO

Celebrating *Beppo* Occhialini and *Nanni* Bignami



Jim Hinton

MAX-PLANCK-INSTITUT FÜR KERNPHYSIK

Gamma-ray 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

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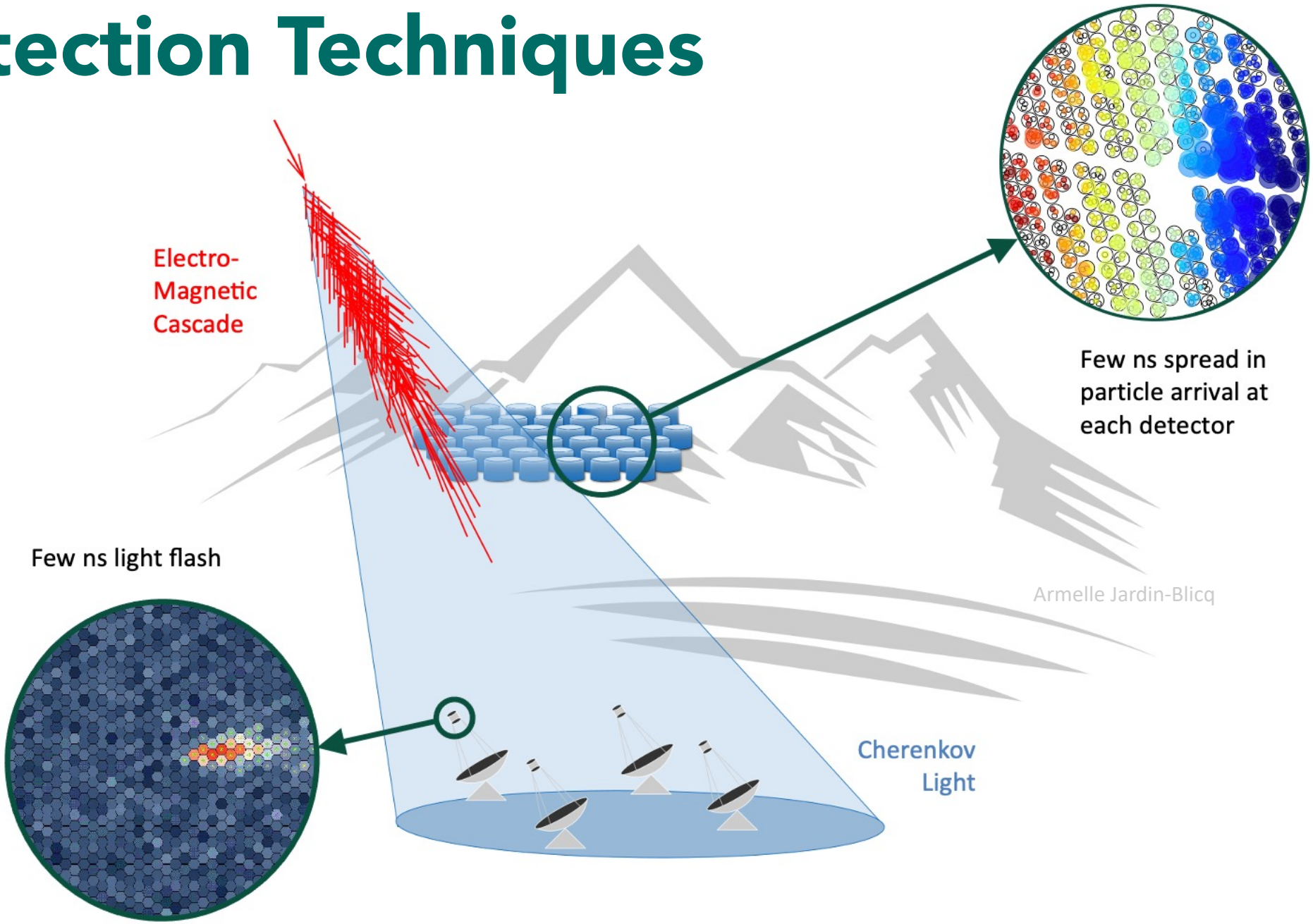
Dark Matter

Beyond Standard Model Physics

Near future instruments will have huge impact on **all**

Detection Techniques



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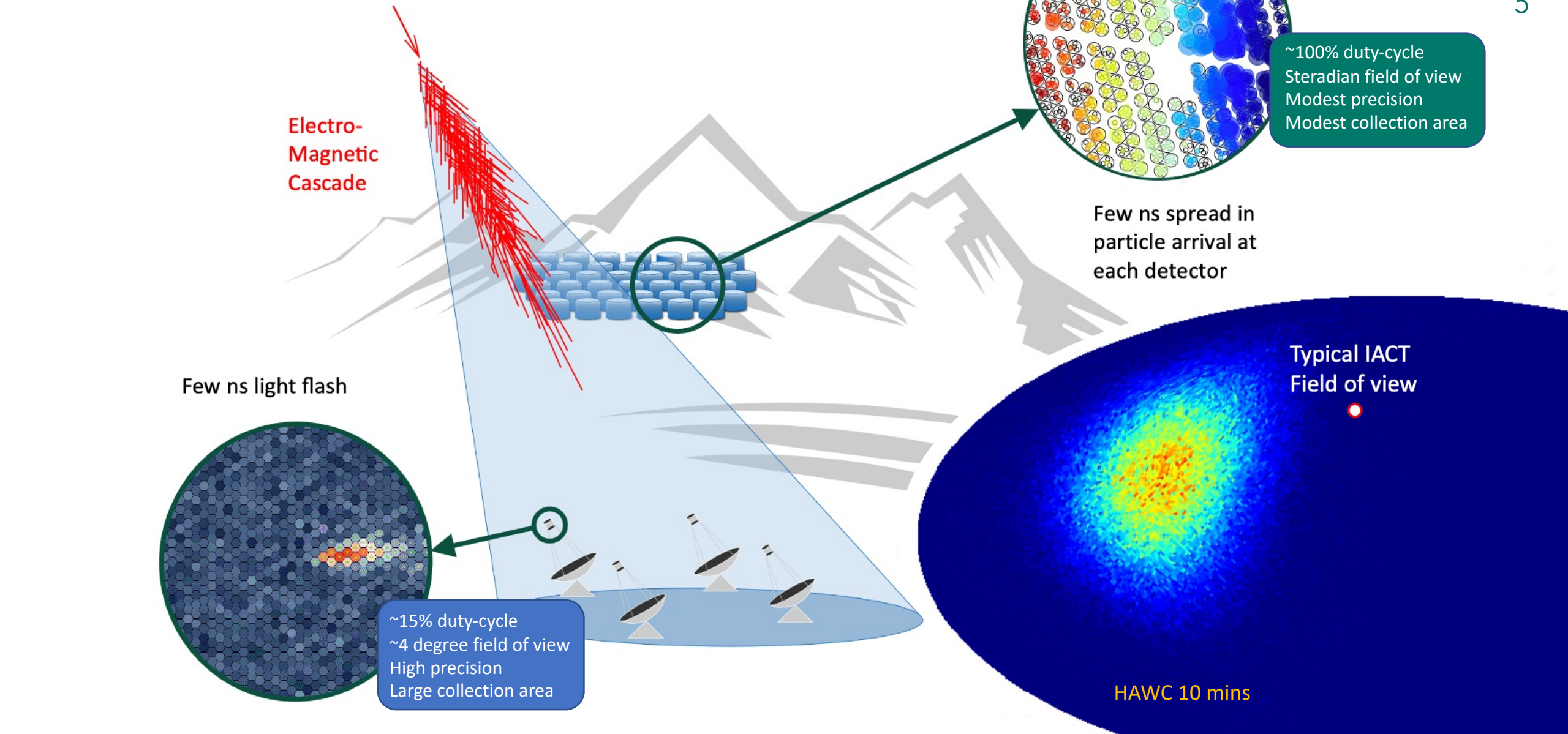
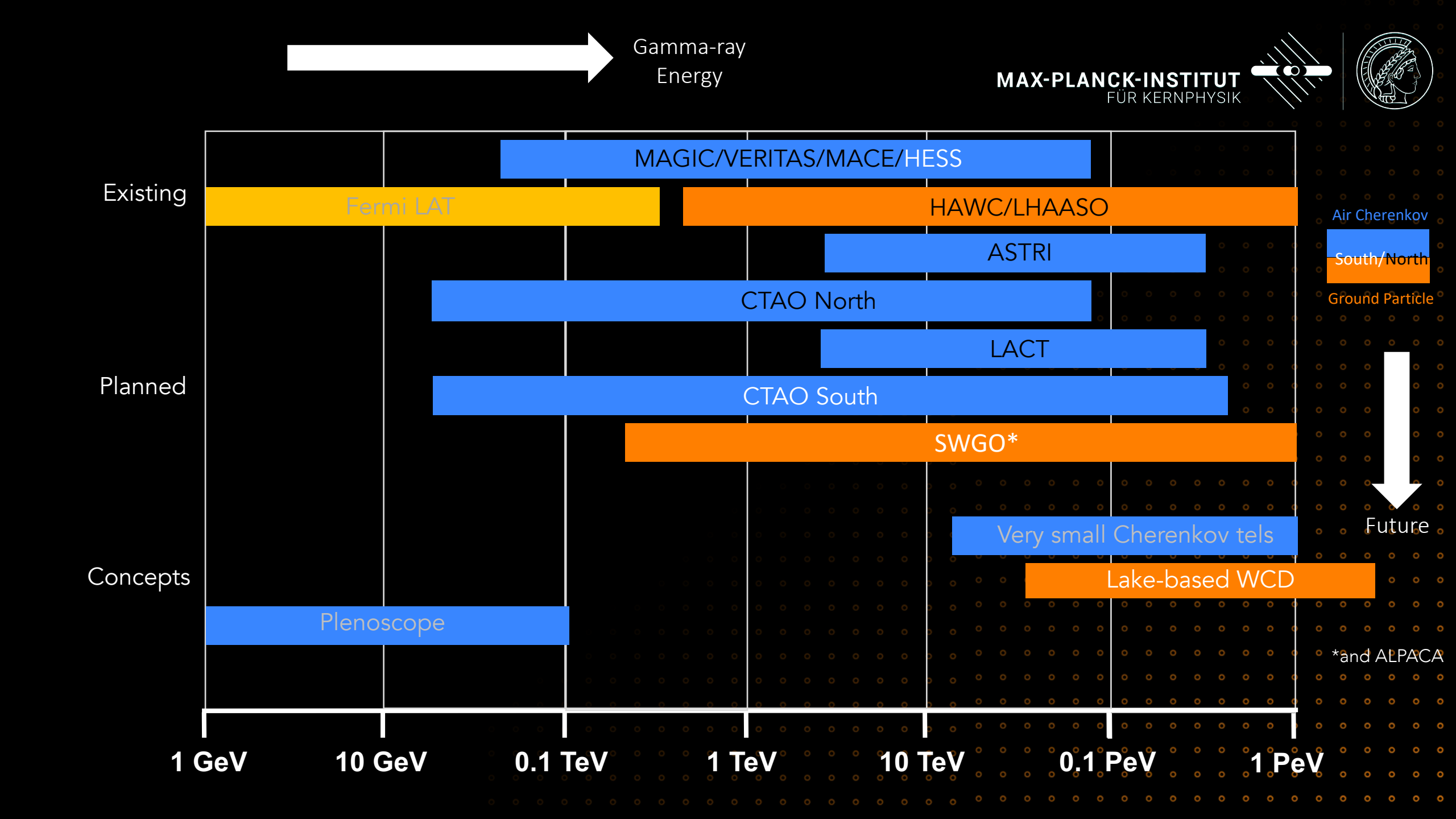
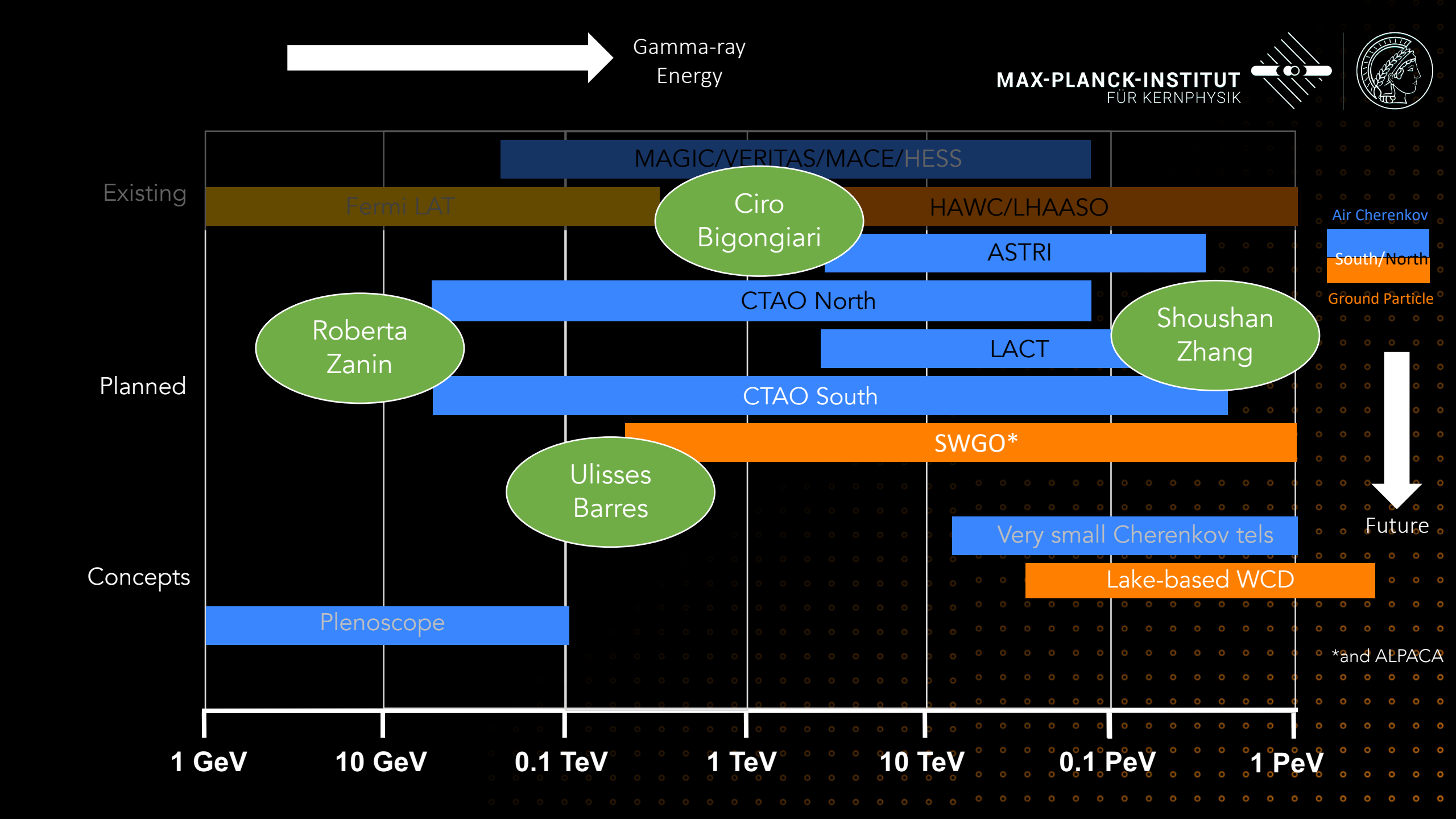



Gamma-ray Energy
MAX-PLANCK-INSTITUT FÜR KERNPHYSIK
Existing
Planned
Concepts
MAGIC/VERITAS/MACE/HESS
Fermi LAT
HAWC/LHAASO
ASTRI
CTAO North
LACT
CTAO South
SWGO*
Very small Cherenkov tels
Lake-based WCD
Plenoscope
Air Cherenkov
South/North
Ground Particle
Future
*and ALPACA
1 GeV
10 GeV
0.1 TeV
1 TeV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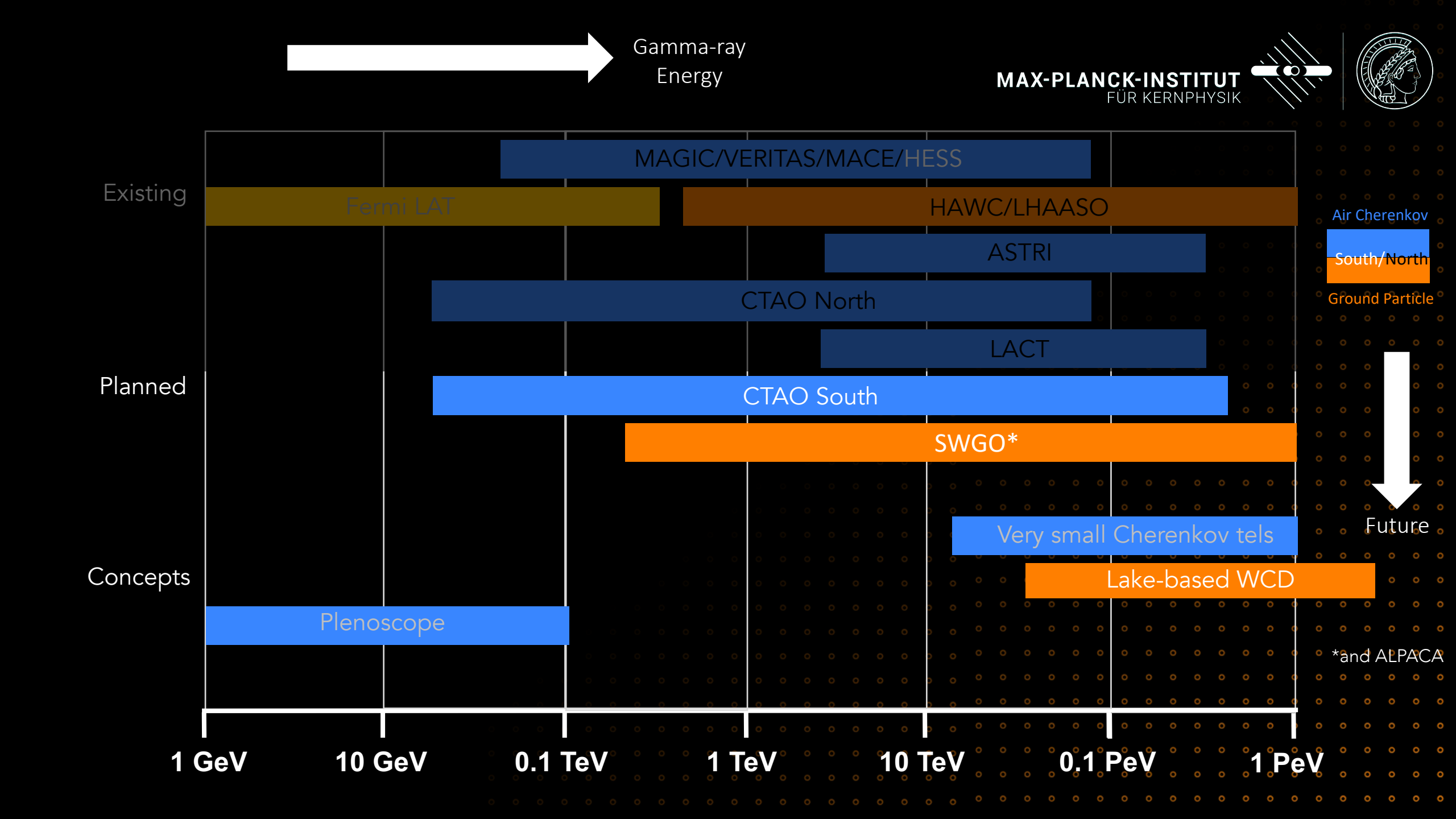
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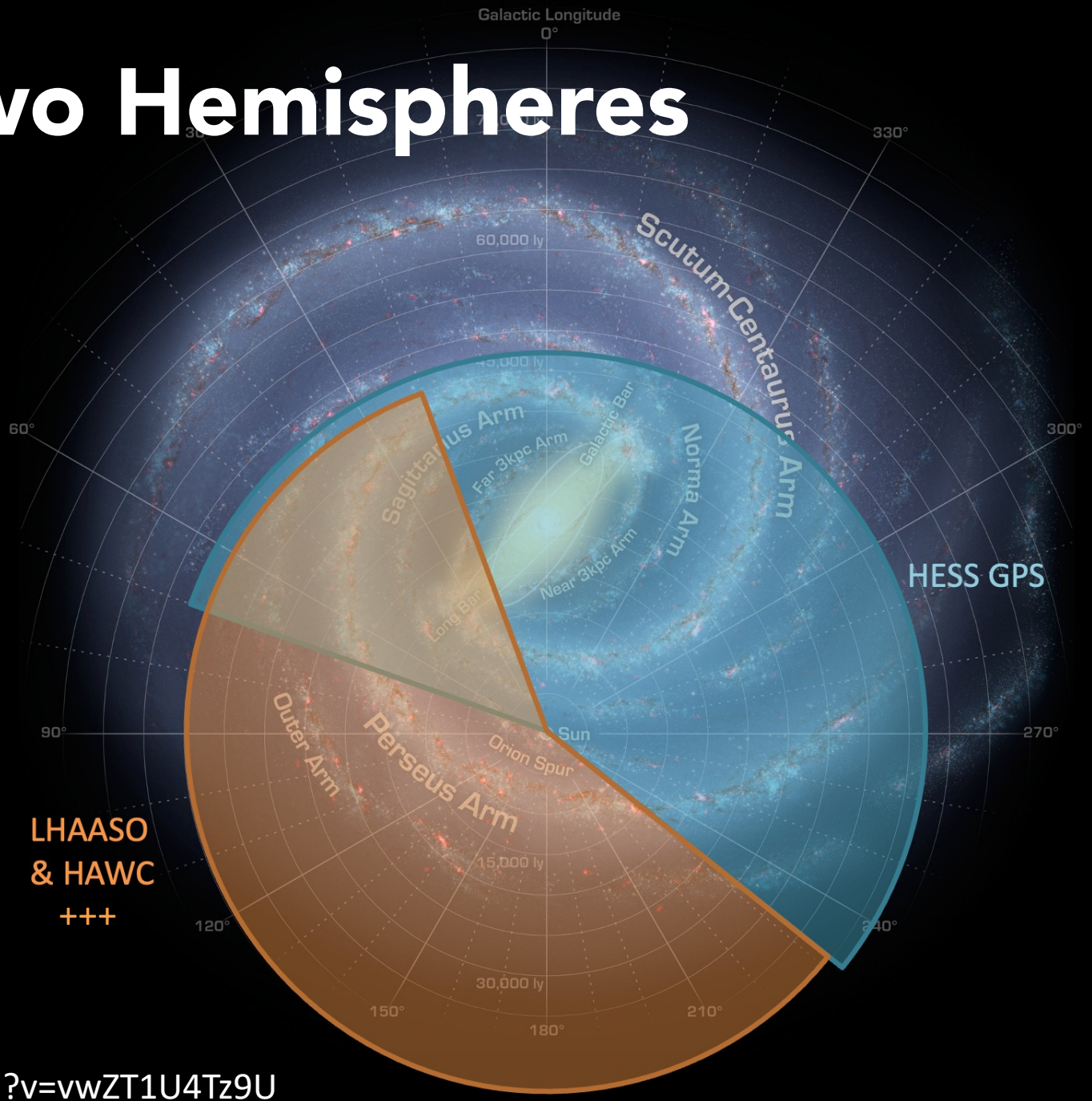
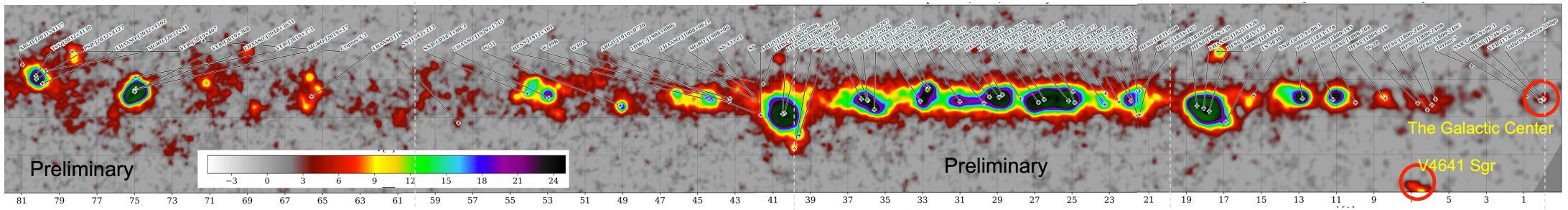
A Tale of Two Hemispheres

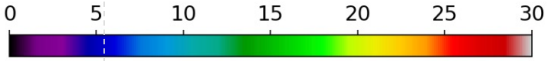


NASA/JPL-Caltech/R. Hurt

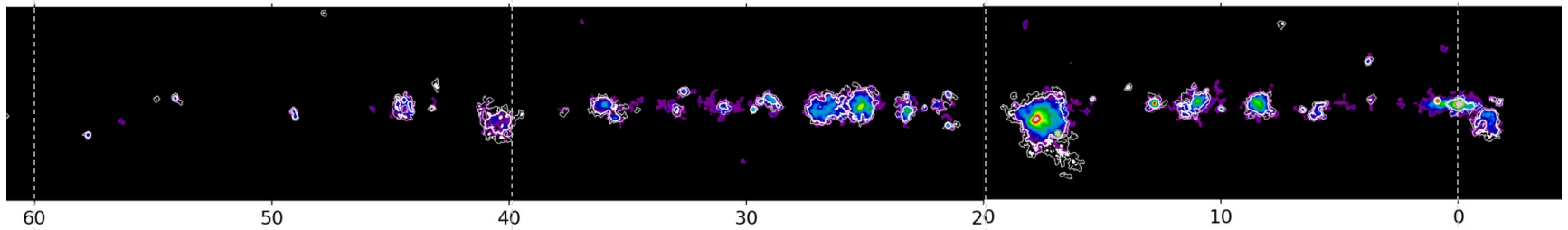
https://www.youtube.com/watch?v=vwZT1U4Tz9U

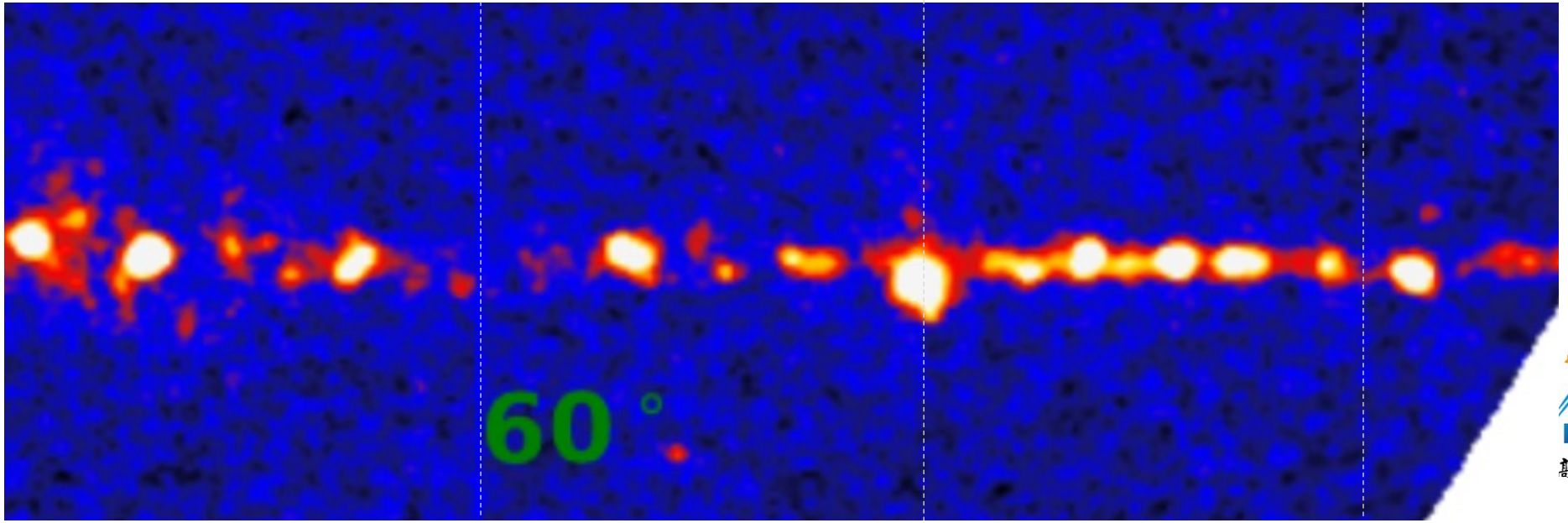
- Pass 5 prelim. Goodman Gamma2022



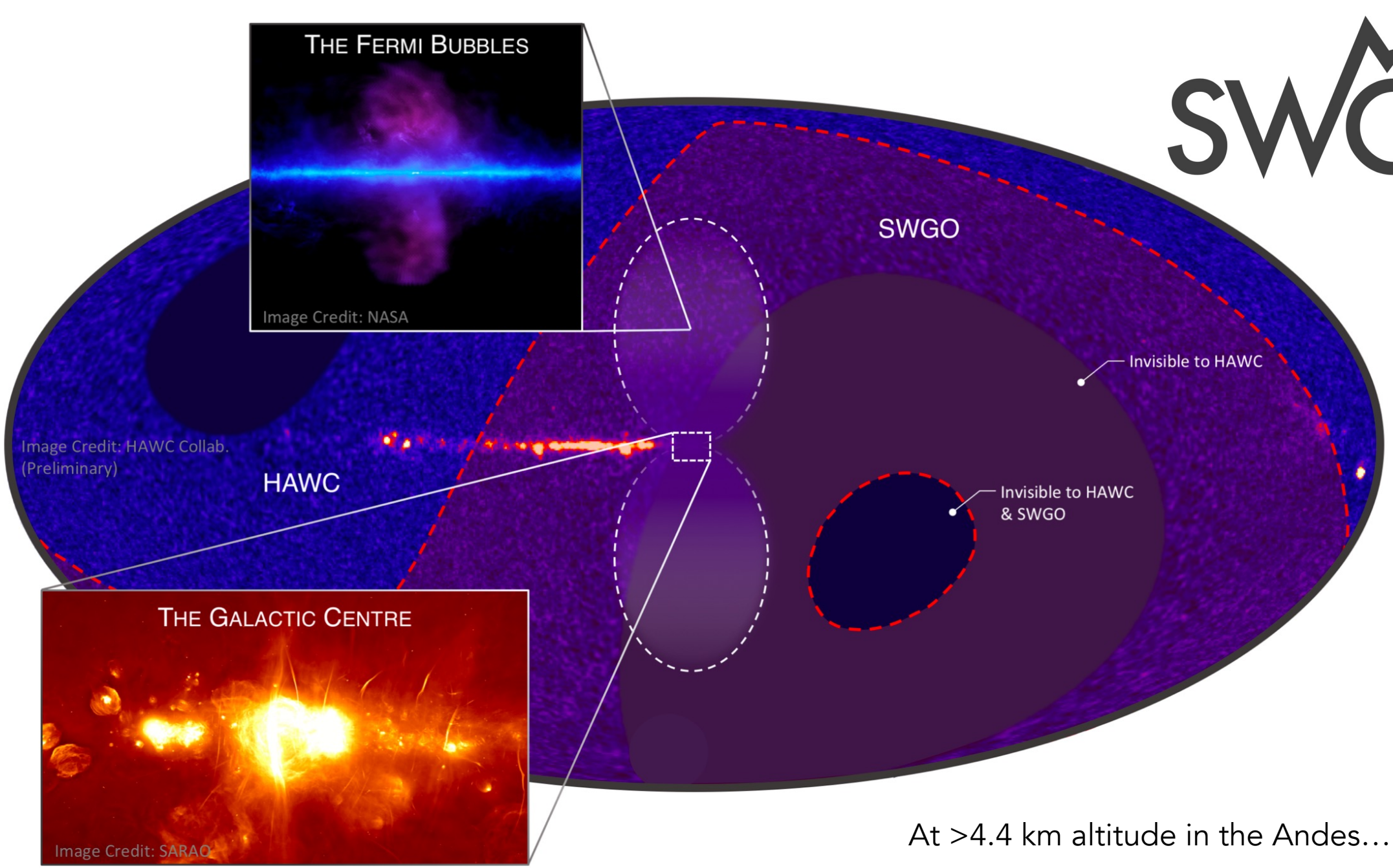


- Updated HESS GPS (Remy et al ICRC 2023)





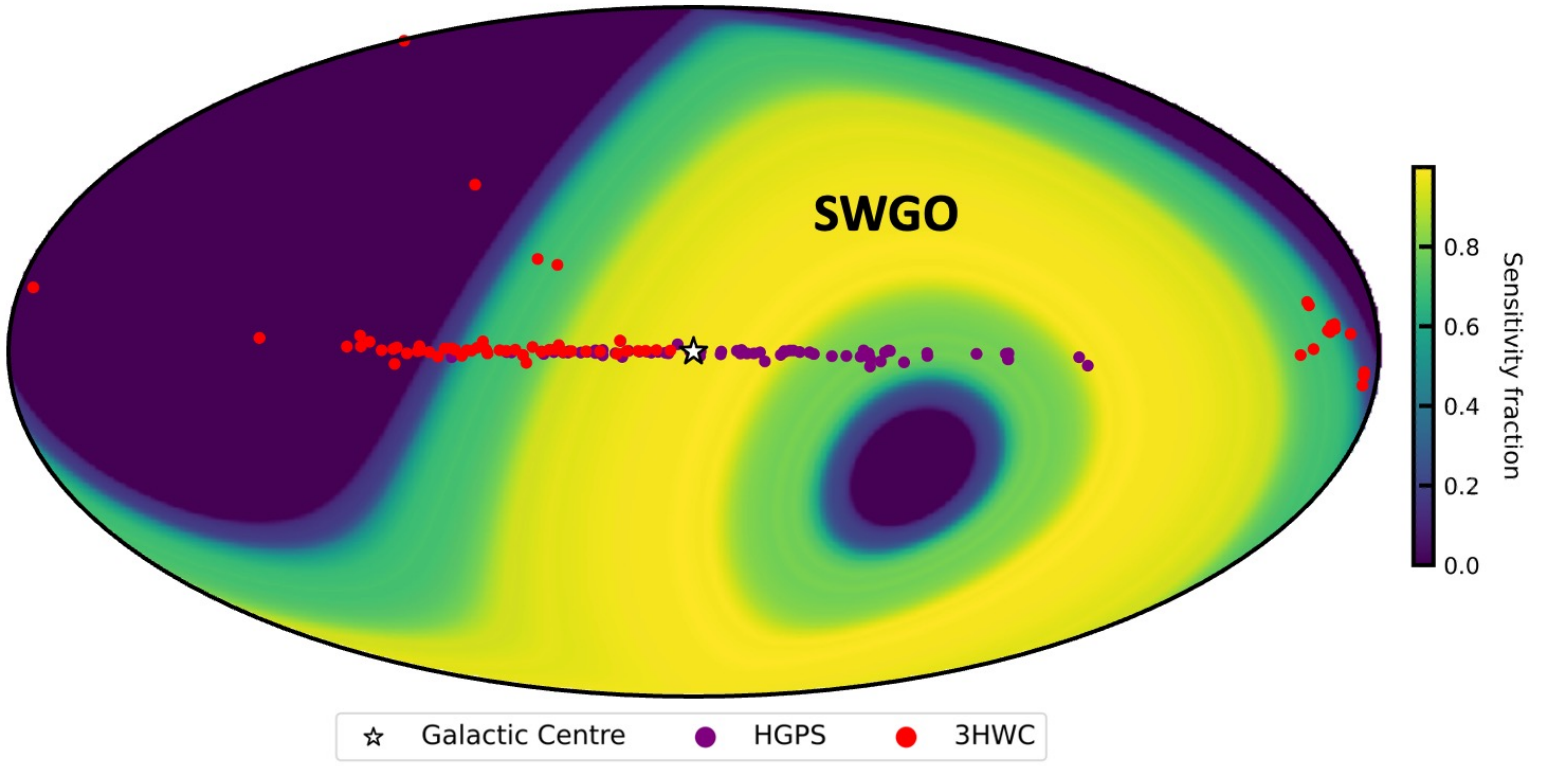
- 1st LHAASO Catalogue : KM2A



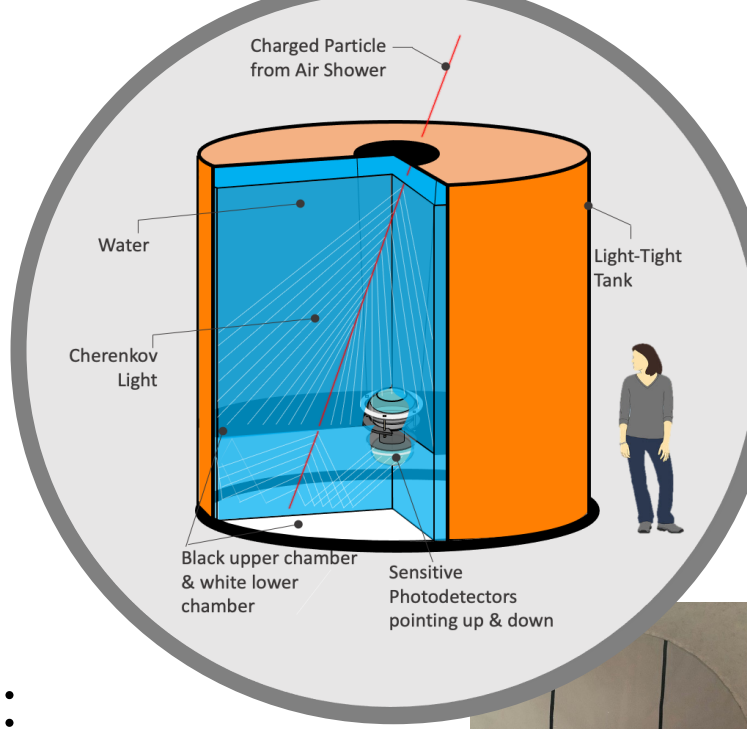
At >4.4 km altitude in the Andes…

SWGO Primary Site, Pampa La Bola, 4760 m

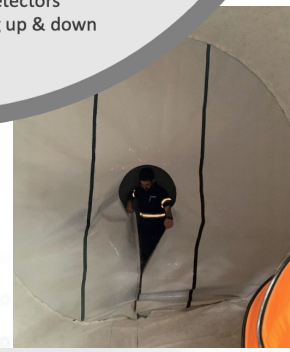
SWGO

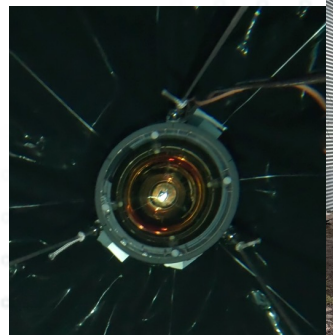


SWGO Status



- Rapidly reaching end of R&D phase
  - Aim for small # of WCDs on site during 2025
  - Major funding applications in prep.
- Narrowing down the phase space towards baseline:
  - Zoned array: inner FF > 50%, outer to ~1 km^2 scale (“A4”)
  - Inner array - dual layer WCD 4-5.2 m diameter, 3-4 m deep “A”-”D”
  - Outer array – WCD design still open
- Excellent γ/h separation from dual layer approach



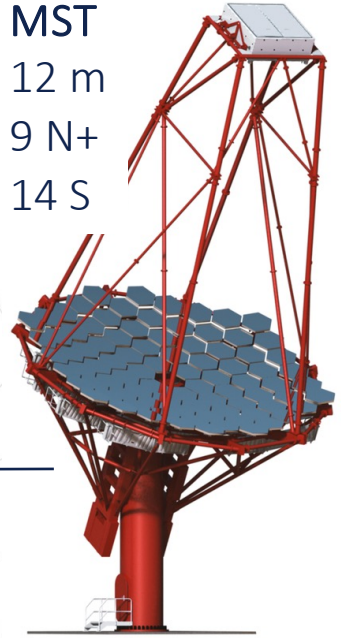


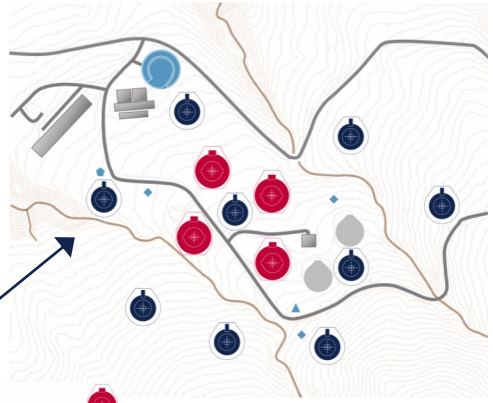
See Ulisses’s talk!

Paranal

1 km

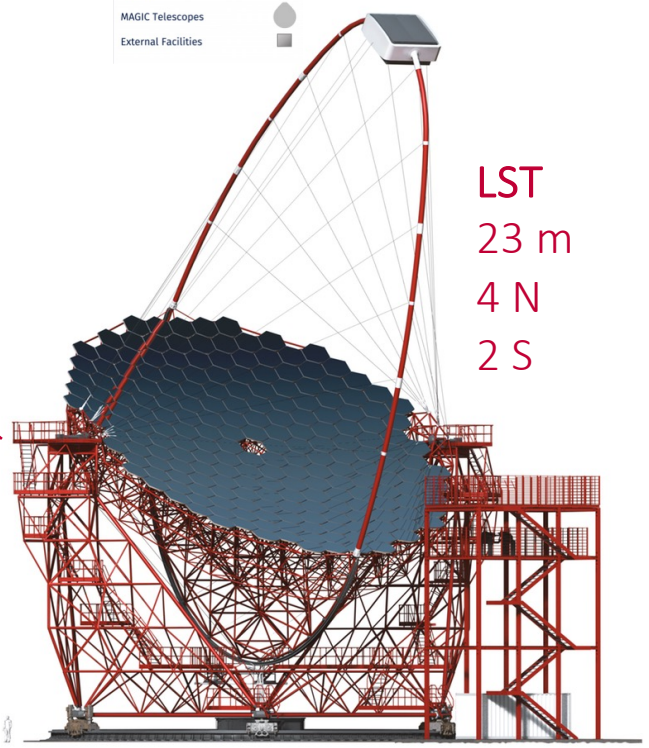
MST
12 m
9 N+
14 S





La Palma

LST
23 m
4 N
2 S



SST
4 m
42 S

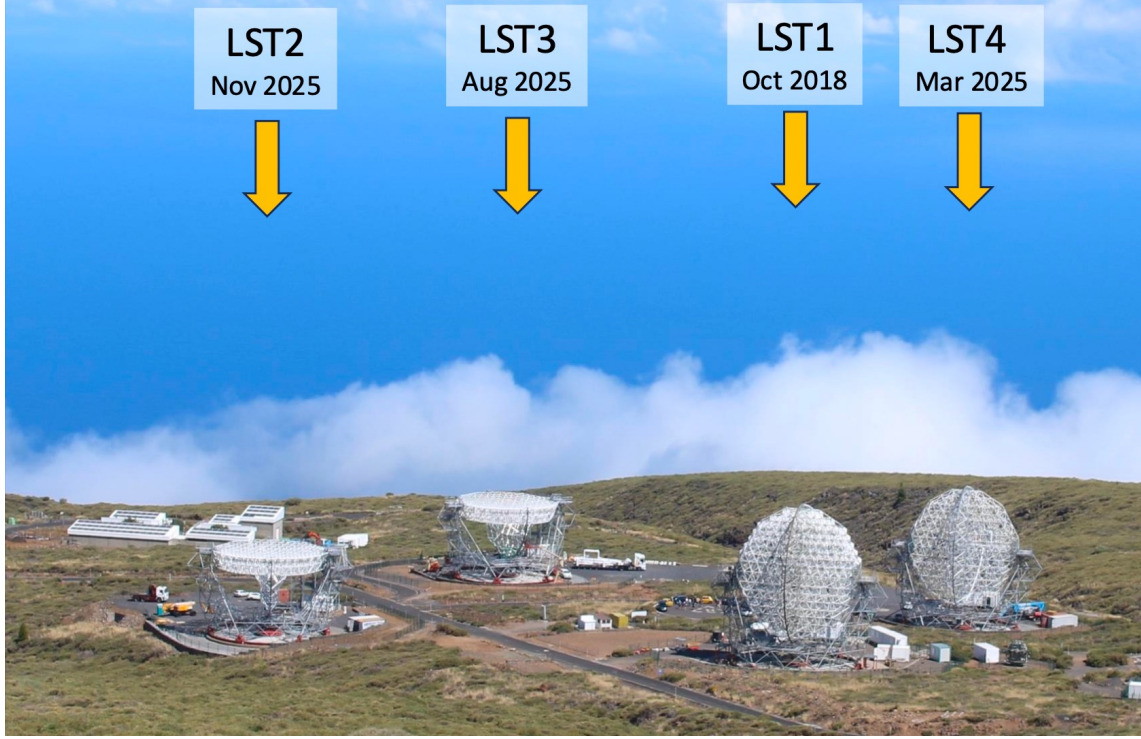
CTAO
Initial Phase Plan

CTAO Status?

- Rapid progress on all fronts

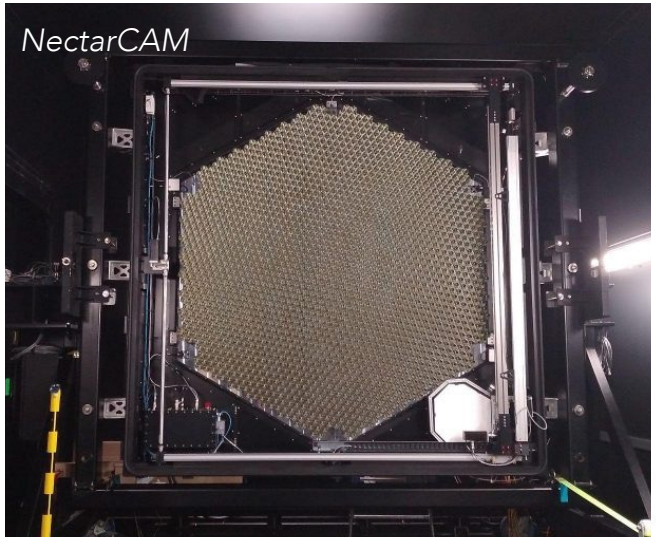
Everything prototyped and tested

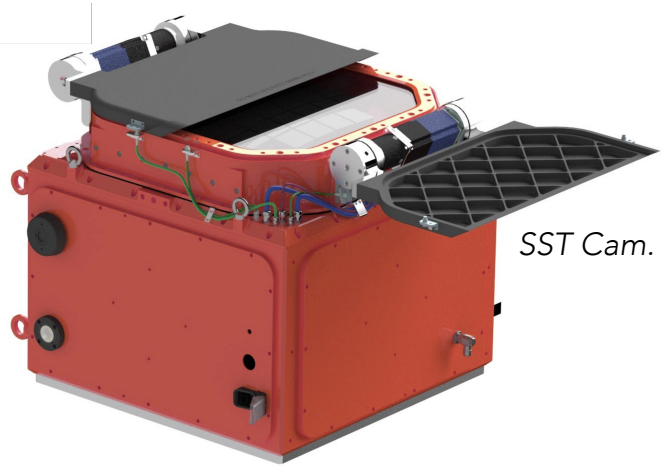
Preparations for first CTA South 'Pathfinders'



LST Construction – M. Teshima yesterday

ASTRI array as proving ground for CTA SST technologies





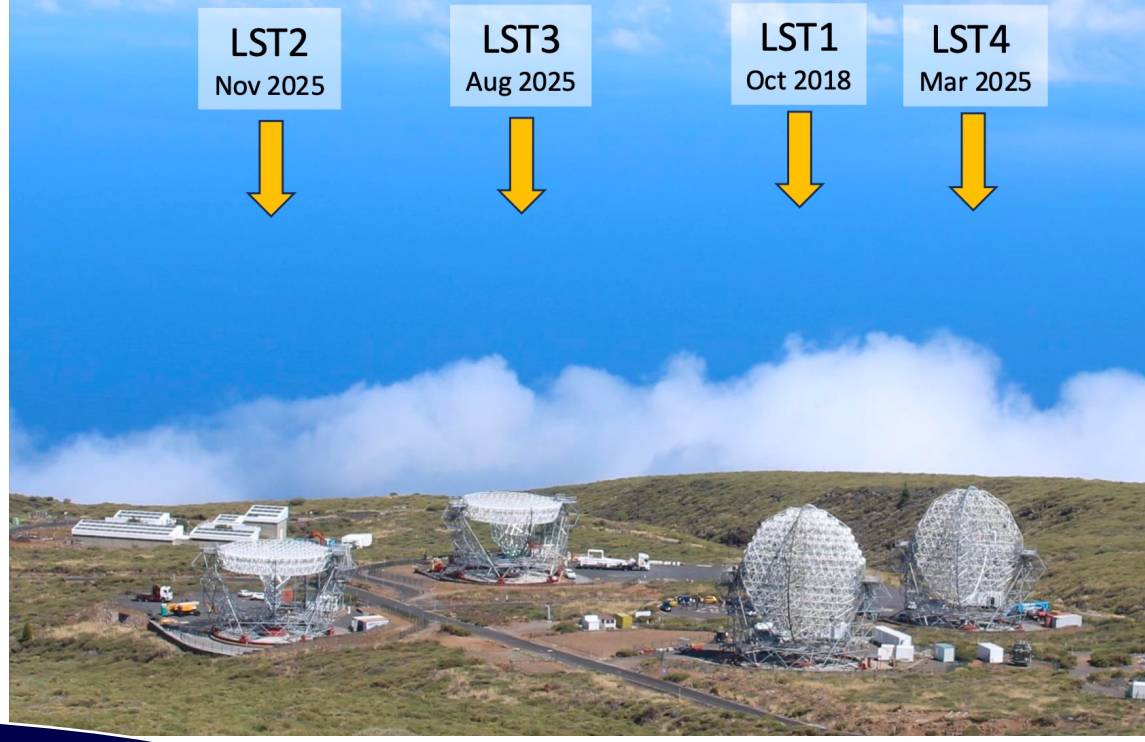
Preparations for 'mass production' for Cherenkov Cameras

CTAO Status?

- Rapid progress on all fronts

Everything prototyped and tested

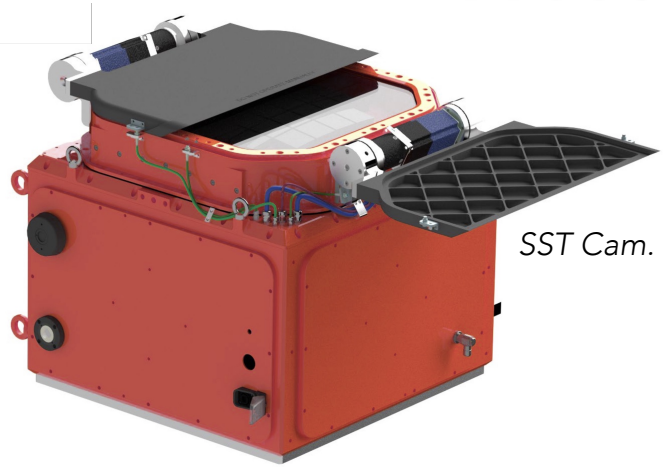
Preparations for first CTA South 'Pathfinders'



LST Construction – M. Teshima yesterday

See Roberta's talk!

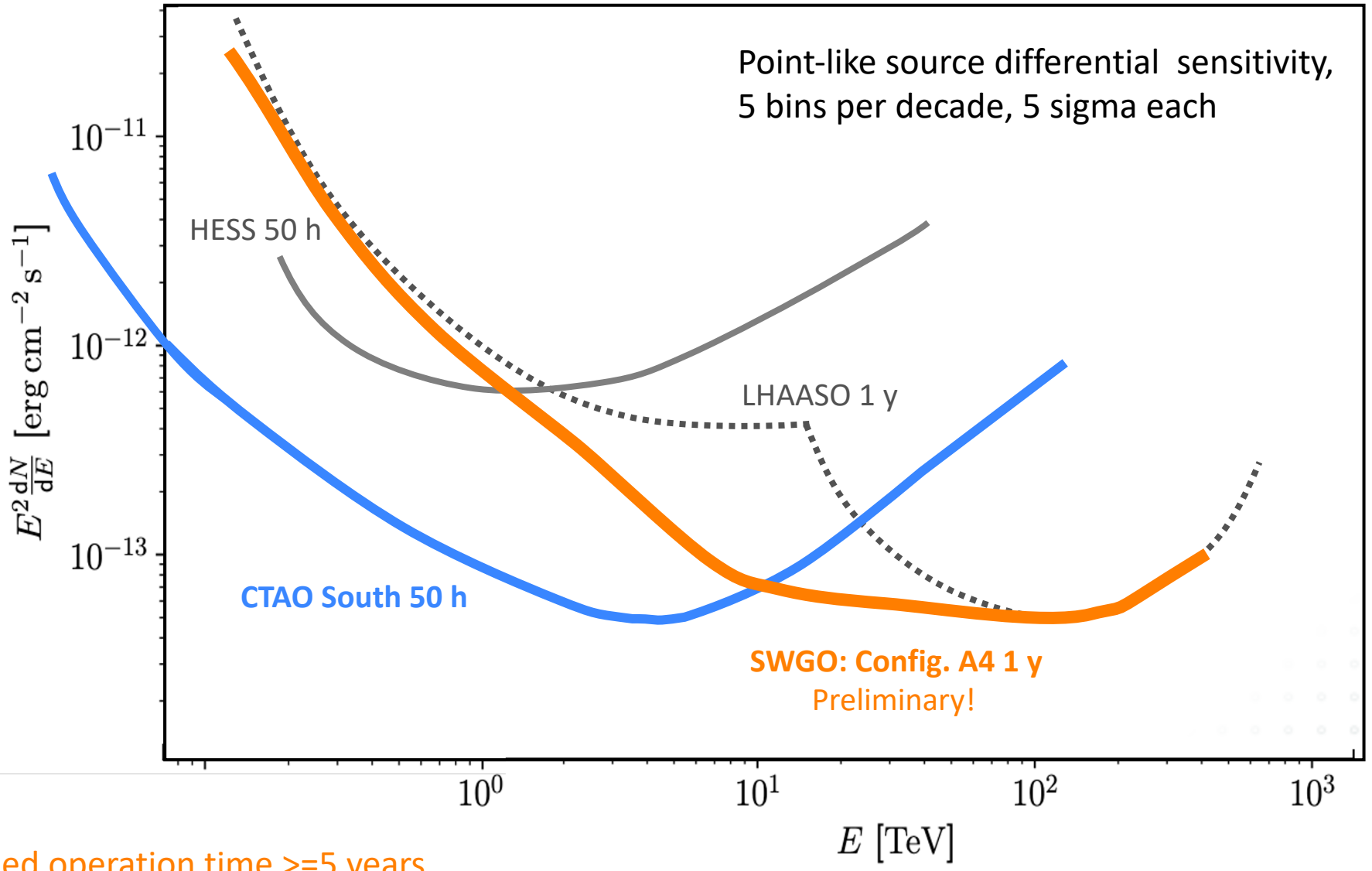
ASTRI array as proving ground for CTA SST technologies



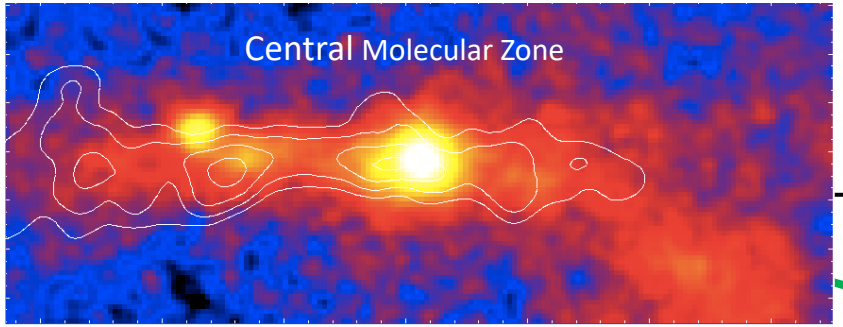
SST Cam.

Preparations for 'mass production' for Cherenkov Cameras

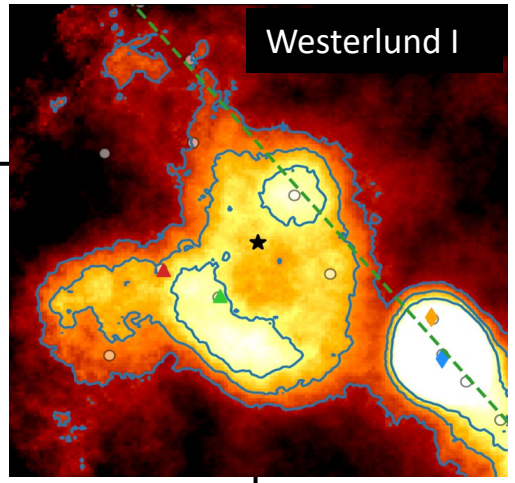
Sensitivity?

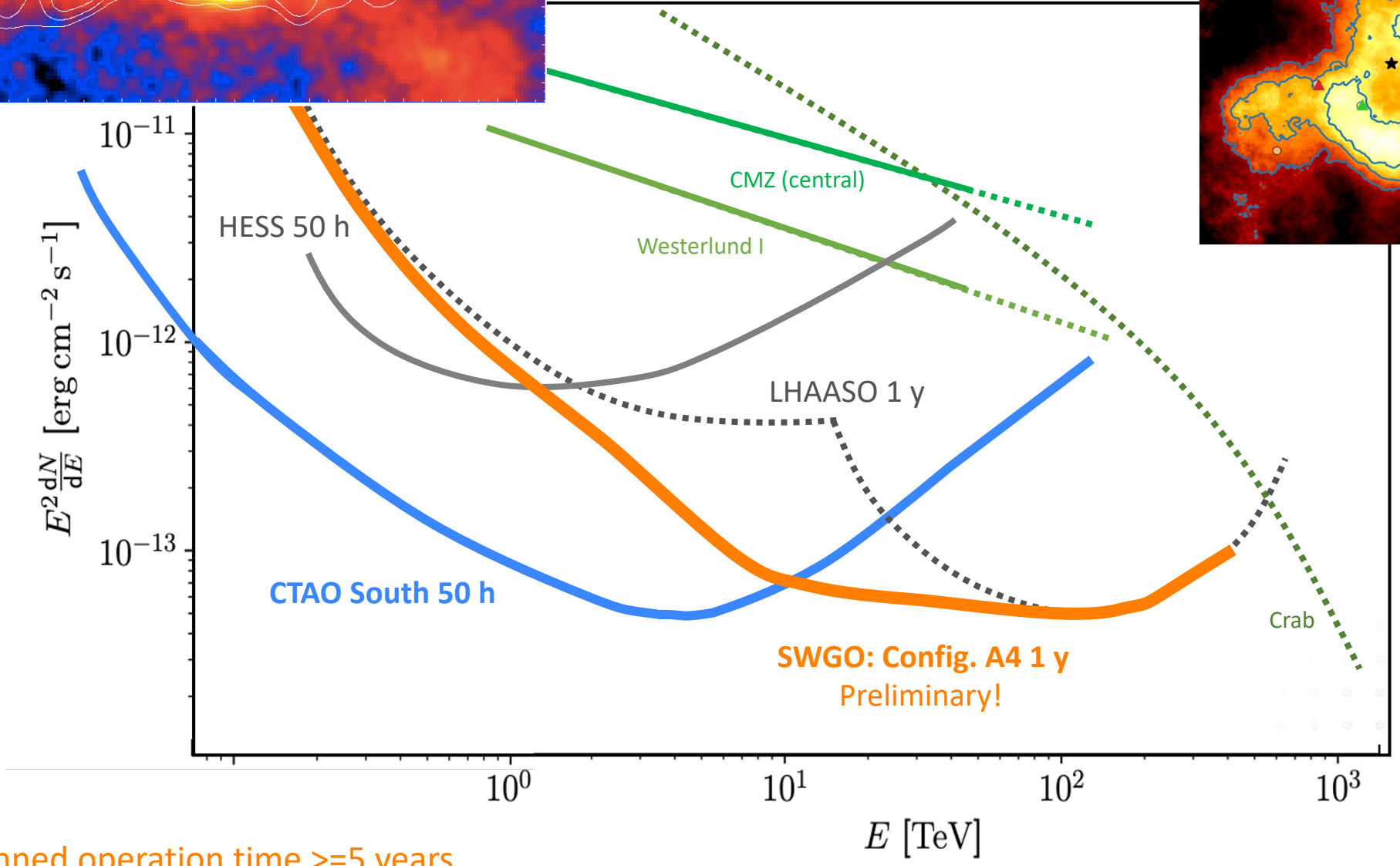


*planned operation time >=5 years



Southern Hemisphere
UHE sources





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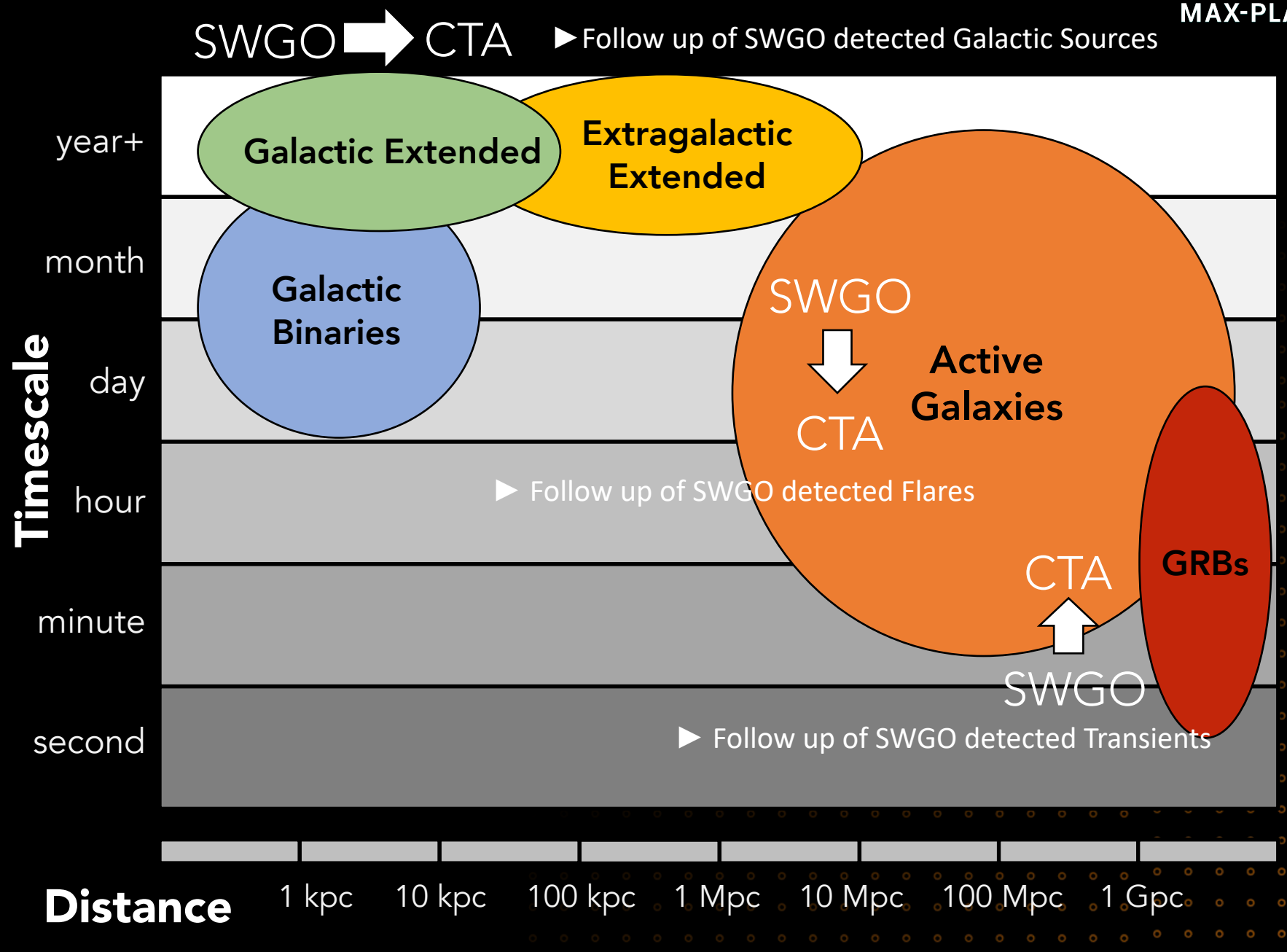
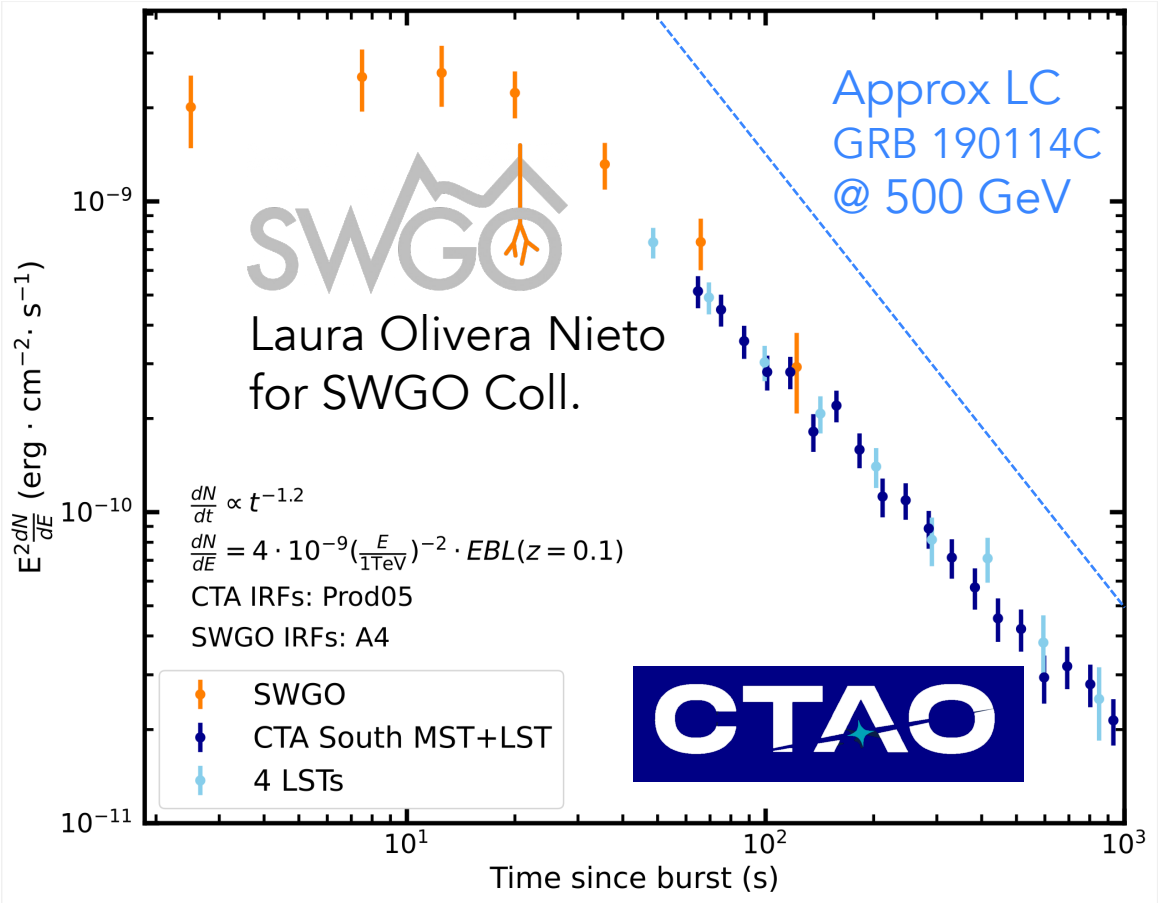
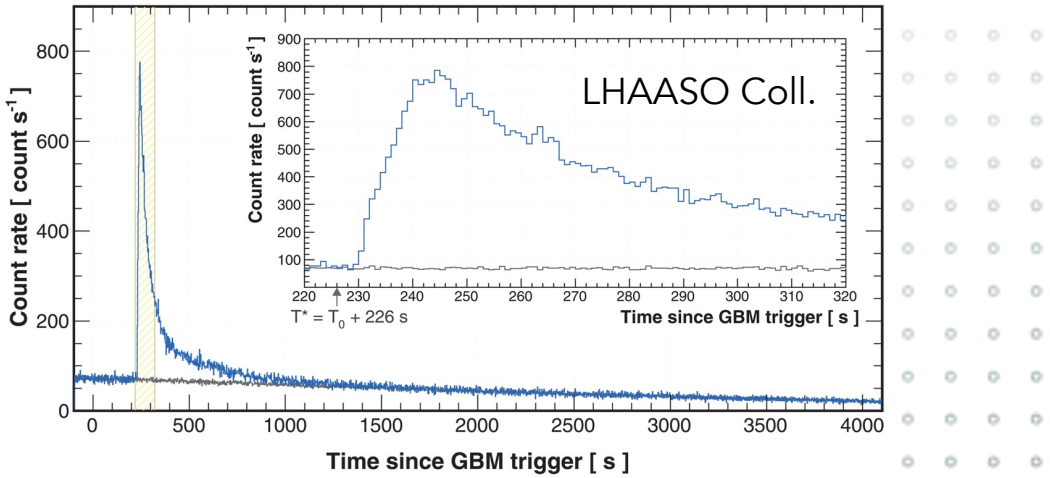

SWGO → CTA
► Follow up of SWGO detected Galactic Sources
Timescale
year+
month
day
hour
minute
second
Galactic Extended
Extragalactic Extended
Galactic Binaries
SWGO
CTA
Active Galaxies
► Follow up of SWGO detected Flares
CTA
GRBs
SWGO
► Follow up of SWGO detected Transients
Distance
1 kpc
10 kpc
100 kpc
1 Mpc
10 Mpc
100 Mpc
1 Gpc

Gamma-ray Bursts

- Key science target
  - Relativistic shock acceleration ‘as you watch’ !
  - LIGO-Virgo-KAGRA gravitational wave events /short GRBs (z<0.1)
- IACTs
  - **Sensitivity**: day-timescale afterglow measurements (HESS, GRB 190829A)
  - **Low energy access**: high redshift early times (MAGIC, GRB 190114C)
- Ground particle
  - **No trigger needed, high duty cycle:** early stages (LHAASO: BOAT)
- CTAO+SWGO is fantastic combination

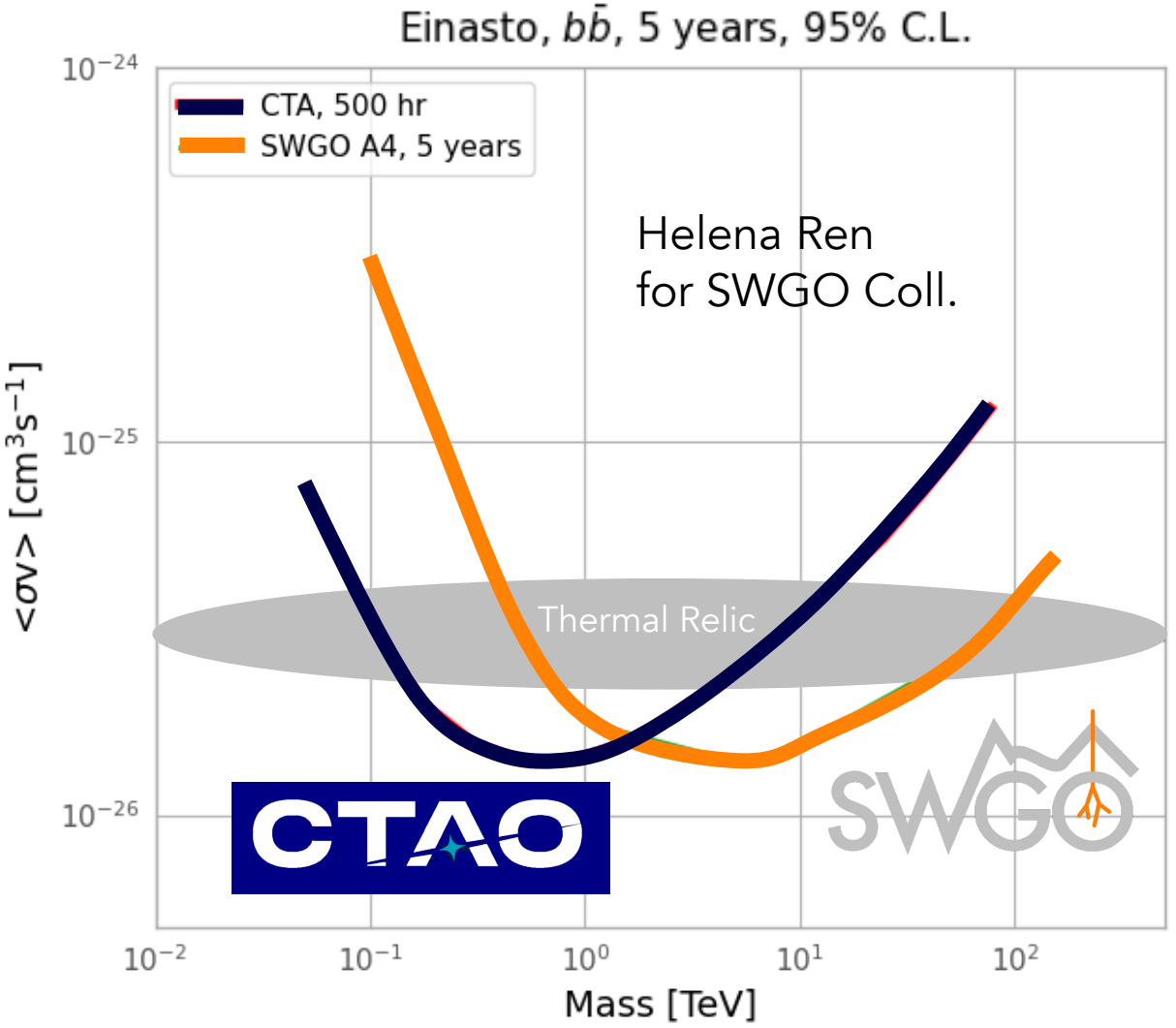




Dark Matter

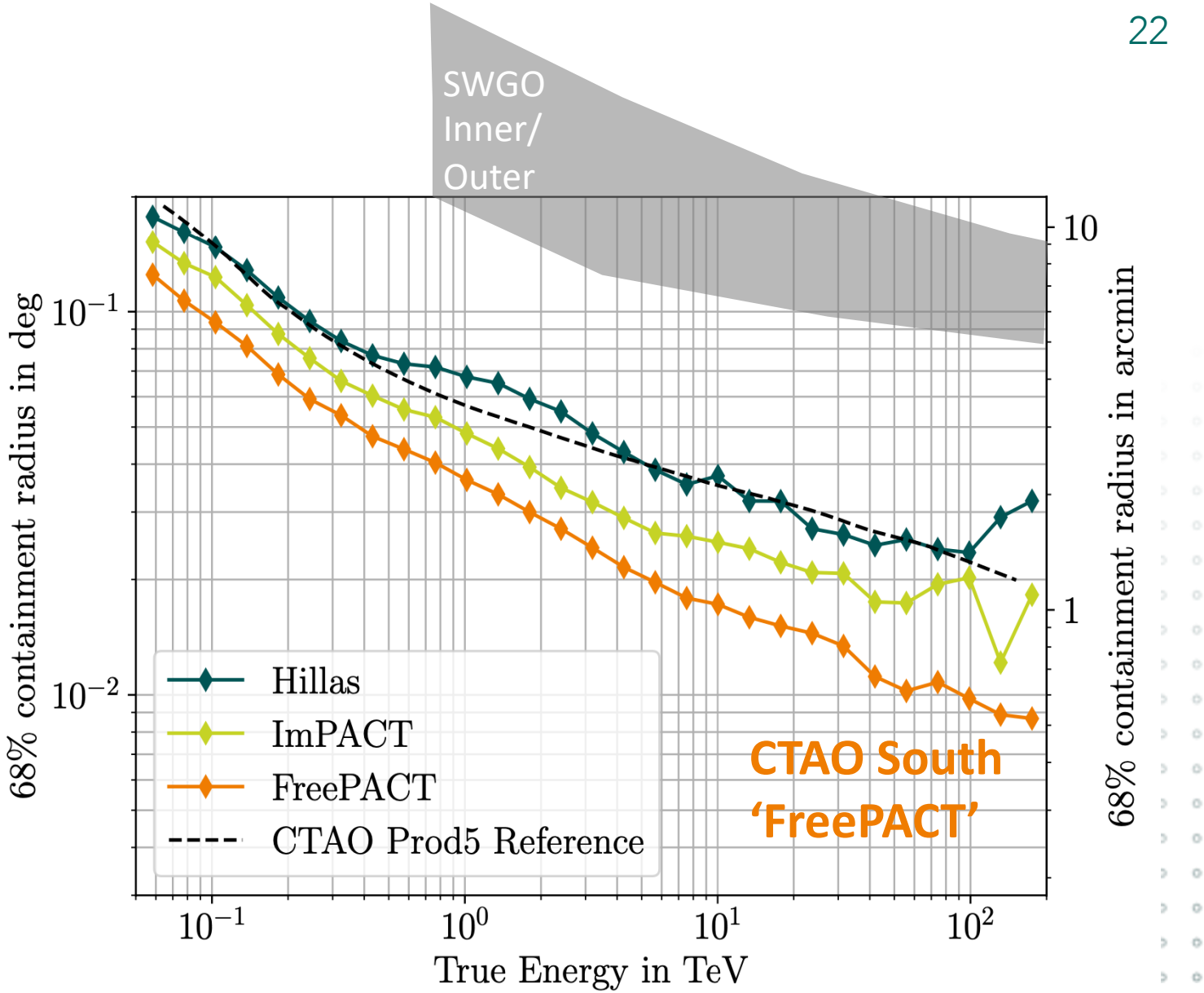
A **Python** package for **gamma-ray** astronomy

- A thermal relic WIMP still a strongly motivated dark matter candidate
- Indirect detection from Galactic Centre annihilation signal is a very effective method
- Thermal relic cross-section can be reached by CTAO and SWGO for a wide range of WIMP masses



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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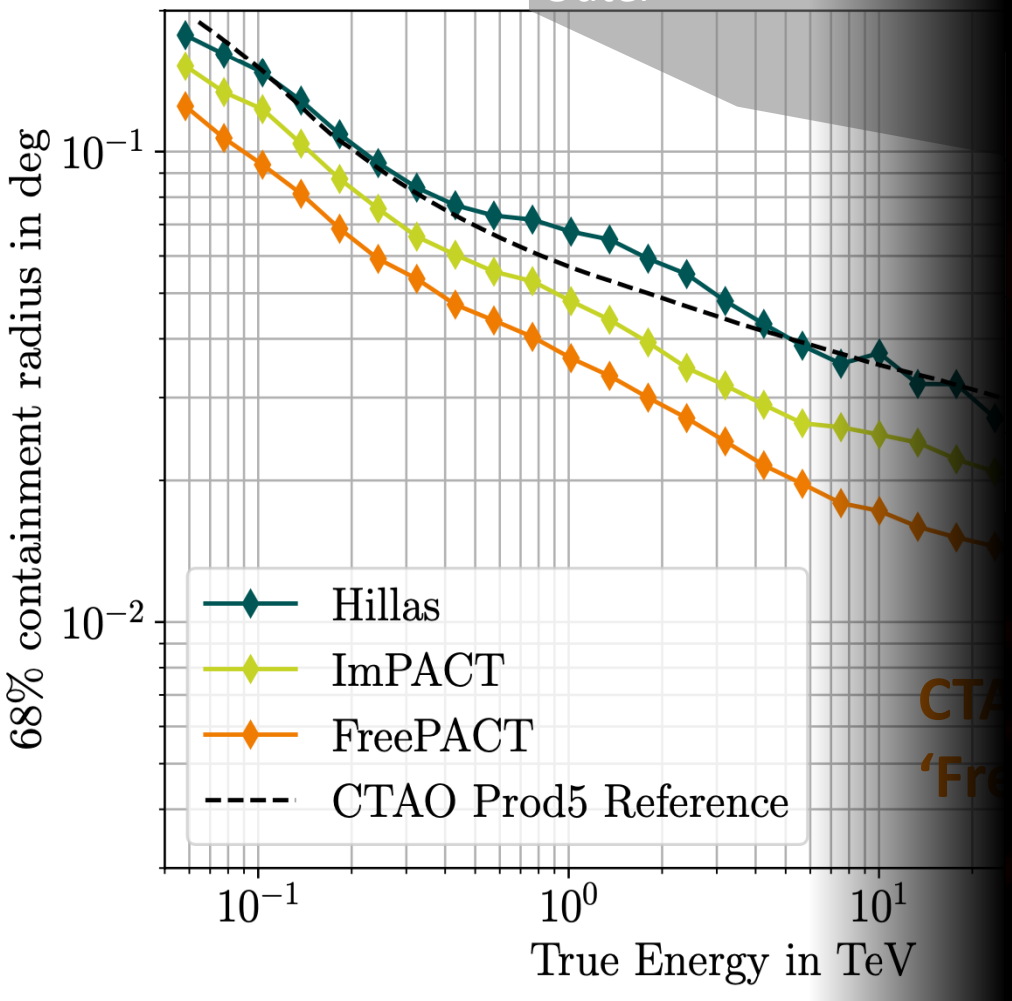
Schwefer et al (in prep.)

MAX-PLANCK-INS
FÜR KER

SWGO
Inner/
Outer



MSH 15-52
eROSITA +
Equipartition model

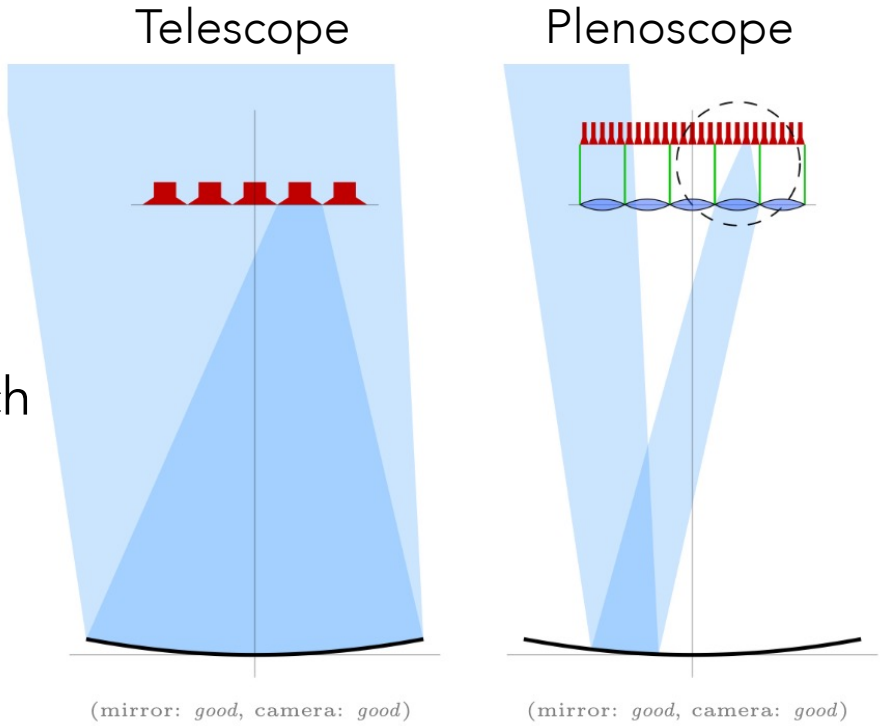
HESS

CTAO South /
FreePACT

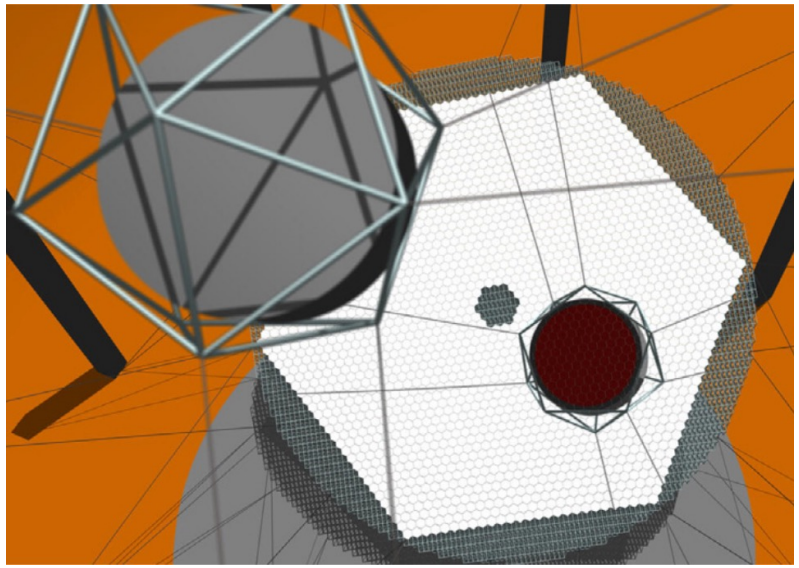
>10 TeV

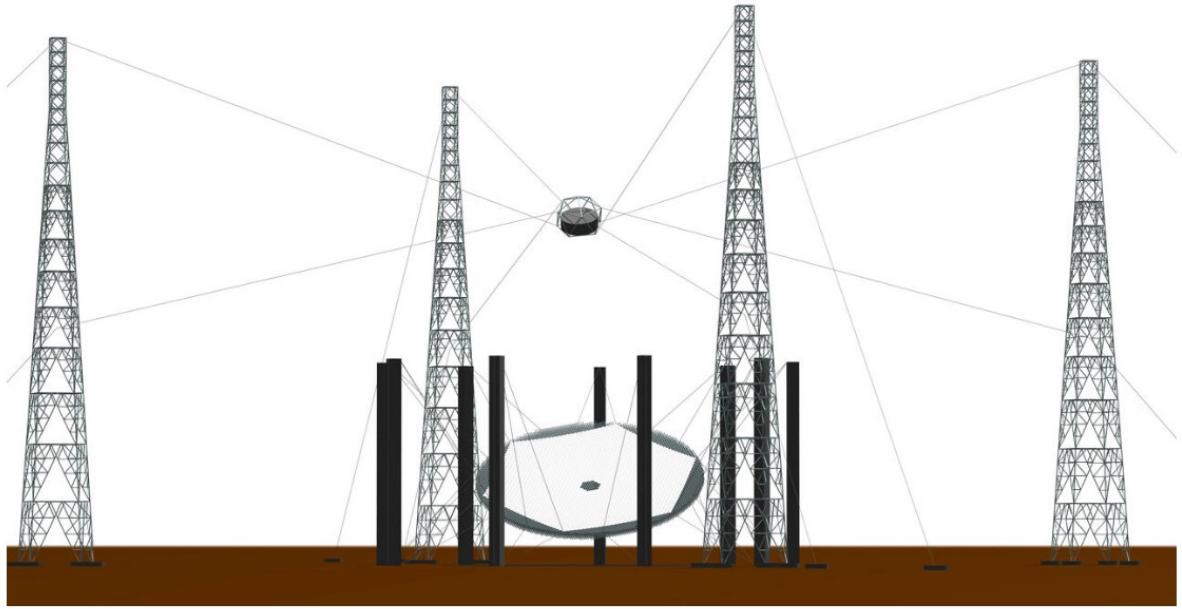
Plenoscope

- PORTAL - single 70 m dish
  - Overcoming depth of field issues with ‘plenoscope’ approach
- Müller et al. APh 158, 102933 (2024)
- ~1 GeV threshold seems possible
  - Challenges for resolution and BG rejection
  - An explorer for short-timescale variability



12 m, 6.5° camera
8443 ‘eyes’
515k photosensors



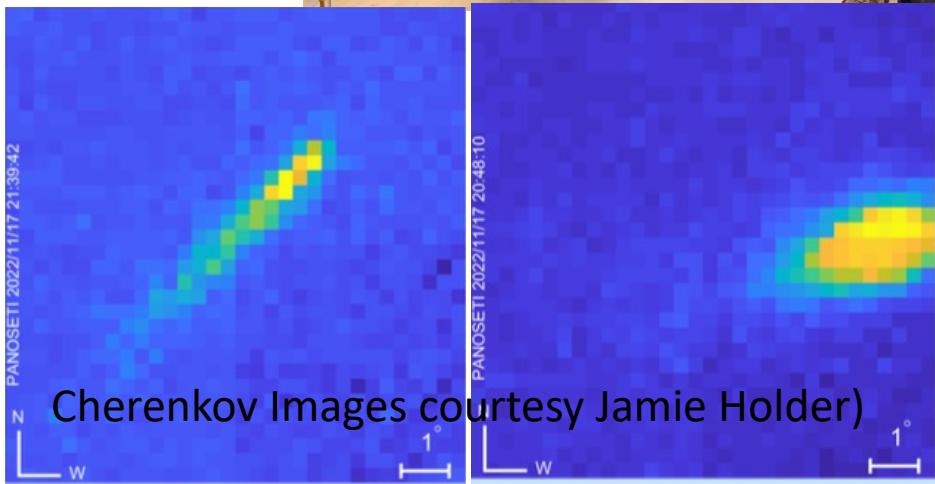


UHE Lake

- 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

Very small Cherenkov tels

- Observations possible with modest tel. size for UHE showers, even at large core distance
- e.g. PANOSETI
  - Developed for optical SETI, now running as air shower arrays (VERITAS tests ++)
  - 46 cm diameter Fresnel lens, 3x3 mm SiPM + CITIROC 1024 pixel cameras
  - Very low unit costs – large arrays possible…
- Big question is rejection of CR background
  - Hybrid systems?

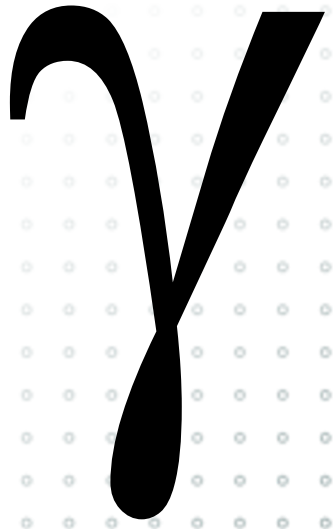


Cherenkov Images courtesy Jamie Holder)

Conclusions

MAX-PLANCK-INSTITUT FÜR KERNPHYSIK

- Huge global push right now in ground-based gamma-ray astronomy – built on the success of existing instruments
- Very soon in the **North**
  - ASTRI, CTAO LSTs, LHAASO+LACT: amazing opportunity if we can bring the data from these instruments together effectively
- Not too long to wait for the **South** / inner galaxy
  - CTA South pathfinders in preparation
  - SWGO Site selected and first on-site activities about to begin
- Many interesting ideas for the father future
  - Expanding the energy range and improving performance



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FÜR KERNPHYSIK

QUESTIONS?

Neutrino Links?

MAX-PLANCK-INSTITUT FÜR KERNPHYSIK

- Dominant IceCube source class inaccessible to TeV gamma?
  - High optical depth AGN… BUT: Diffuse Galactic Signal ++
- KM3Net is coming: crazy event (many 10s of PeV) ++
- LHAASO+SWGO will map the TeV-PeV galactic emission over the whole sky – perfect compliment to IceCube+KM3Net
- CTAO as main probe of lower-optical depth extragalactic neutrino sources (responding to flares++)