SWGO

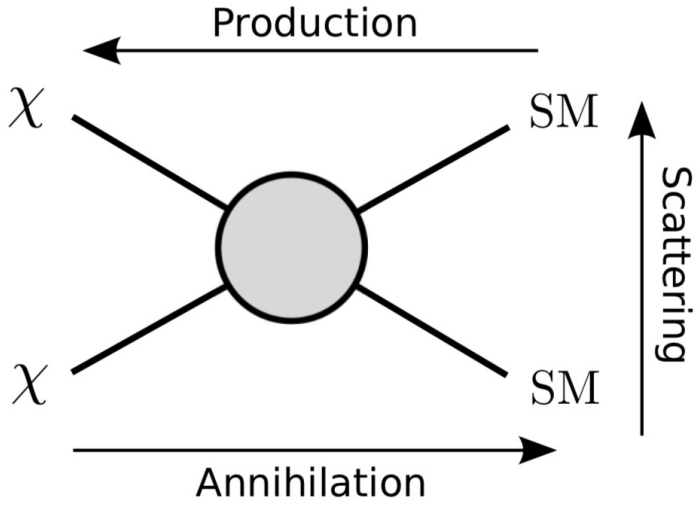
The Southern Wide-field Gamma-ray Observatory

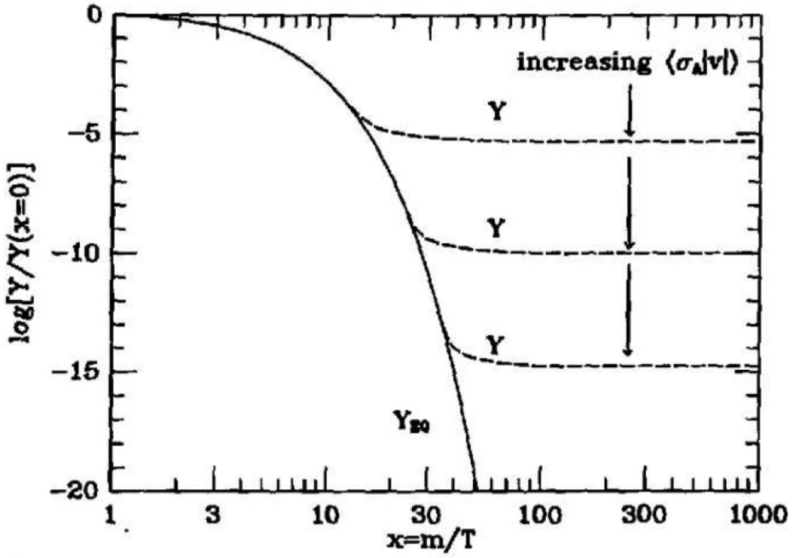
WIMP Dark Matter Prospects

Jim Hinton (MPIK, Heidelberg)

MAX-PLANCK-INSTITUT FÜR KERNPHYSIK

WIMP

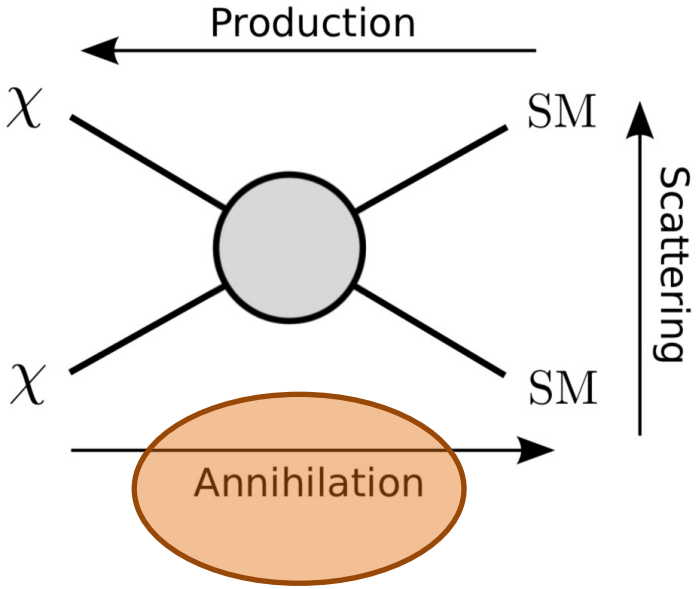


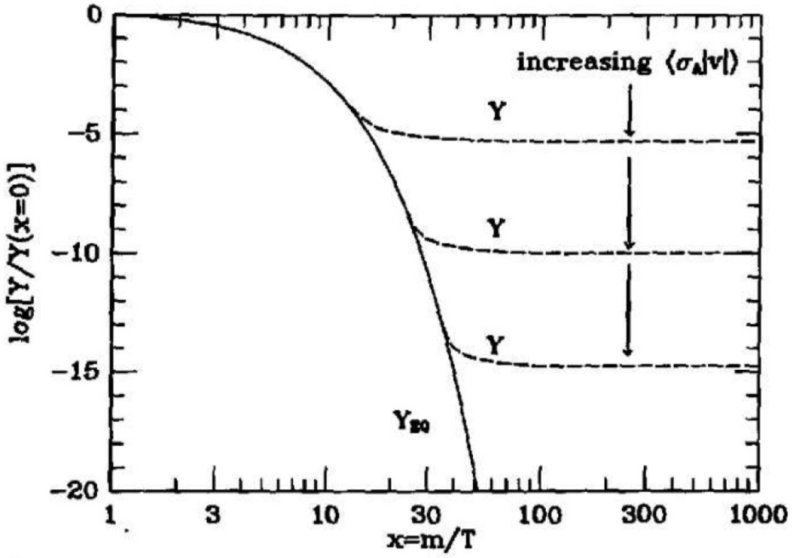


$$\frac{dn_\chi}{dt} + 3Hn_\chi = -\langle\sigma v\rangle \left(n_\chi^2 - n_\chi^{\mathrm{eq}2}\right)$$

- WIMP is thermalized with SM particles in early universe
- To get $\Omega_\chi h^2 = 0.12$, roughly $\sigma \sim 1\mathrm{pb} \sim 10^{-26}\mathrm{cm}^3/\mathrm{s} \sim 10^{-36}\mathrm{cm}^2$
- Almost independent on DM mass

WIMP





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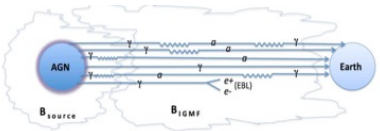
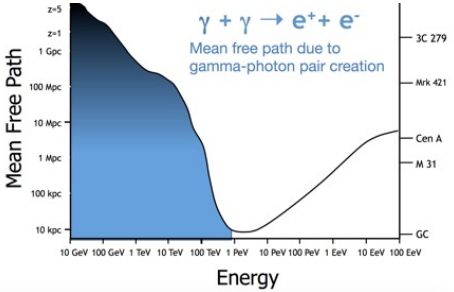
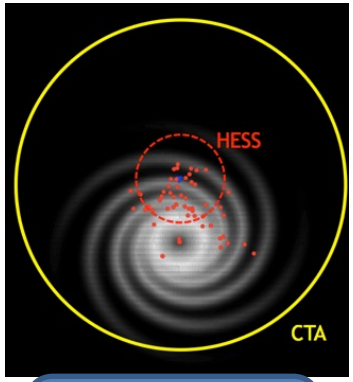
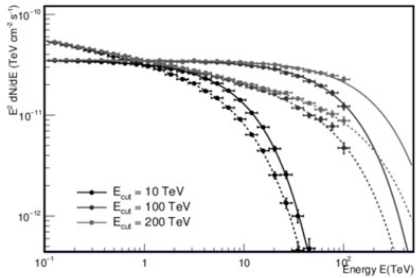
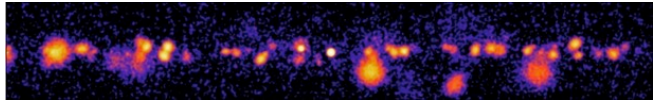
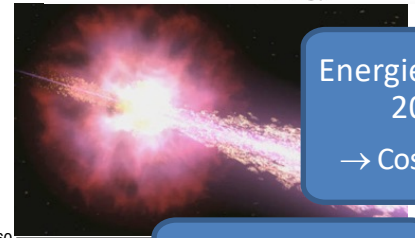


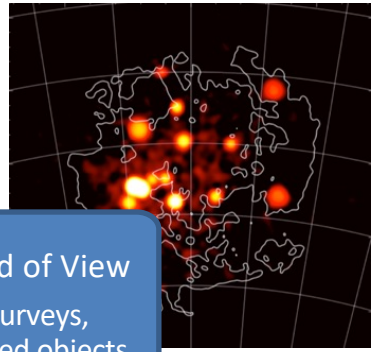








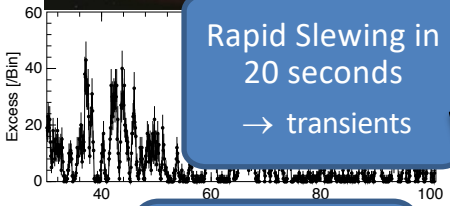




Energies down to 20 GeV
→ Cosmology++

10 x Sensitivity, Large Collection Area
→ all topics

Energies up to 300 TeV
→ Pevatrons

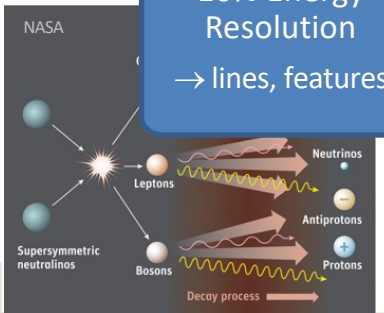


Rapid Slewing in 20 seconds
→ transients

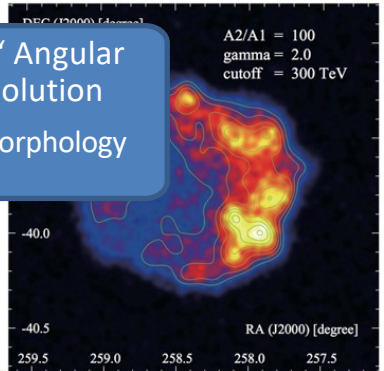
8° Field of View
→ surveys, extended objects

cta

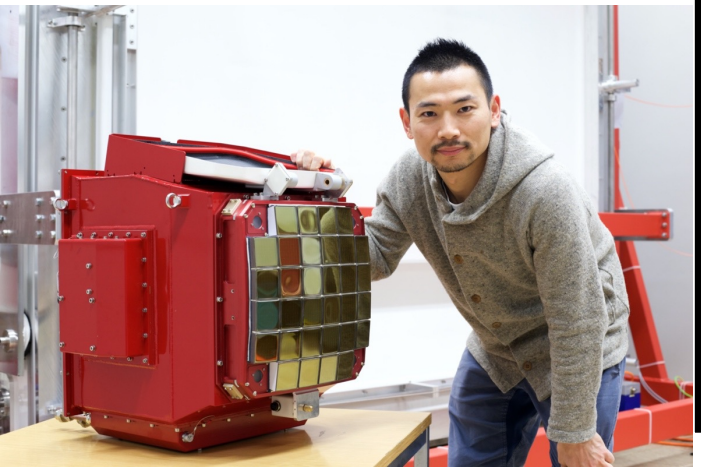
10% Energy Resolution
→ lines, features

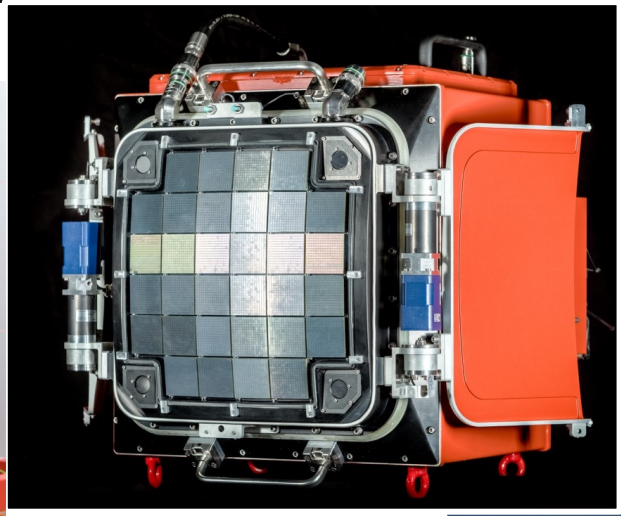


Few ' Angular Resolution
→ morphology



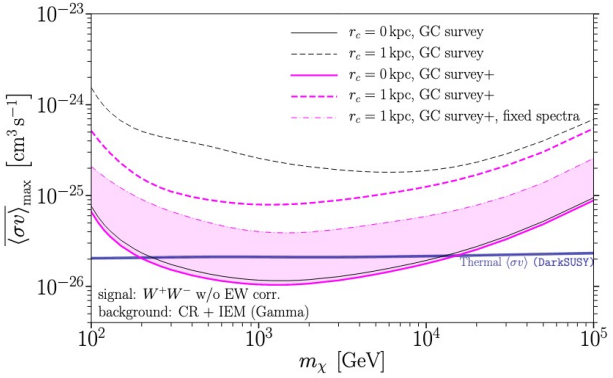
See 'Science with CTA'
https://arxiv.org/abs/1709.07997 &
https://www.cta-symposium.com/



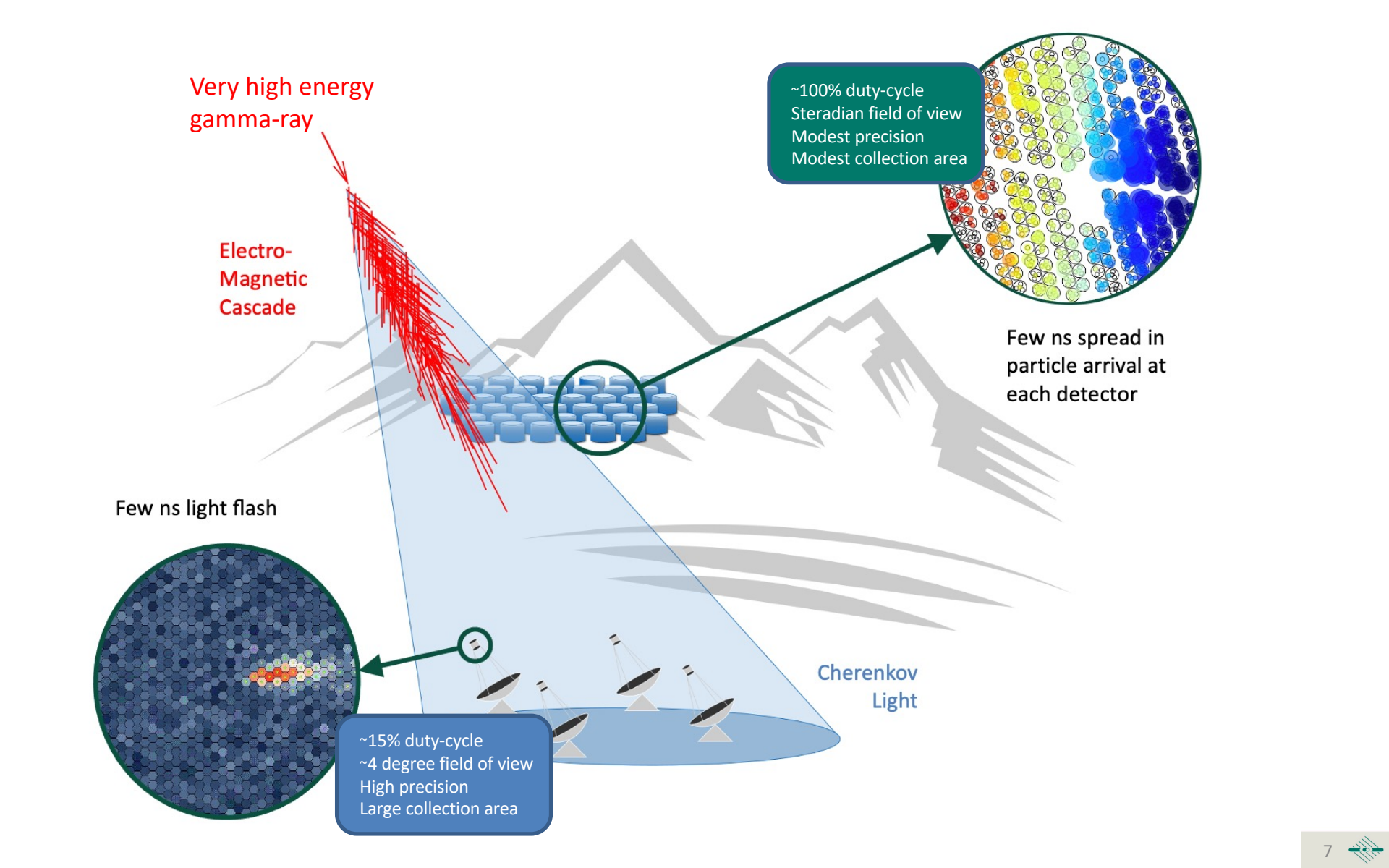


Excellent collaboration with Nagoya on SST Camera!

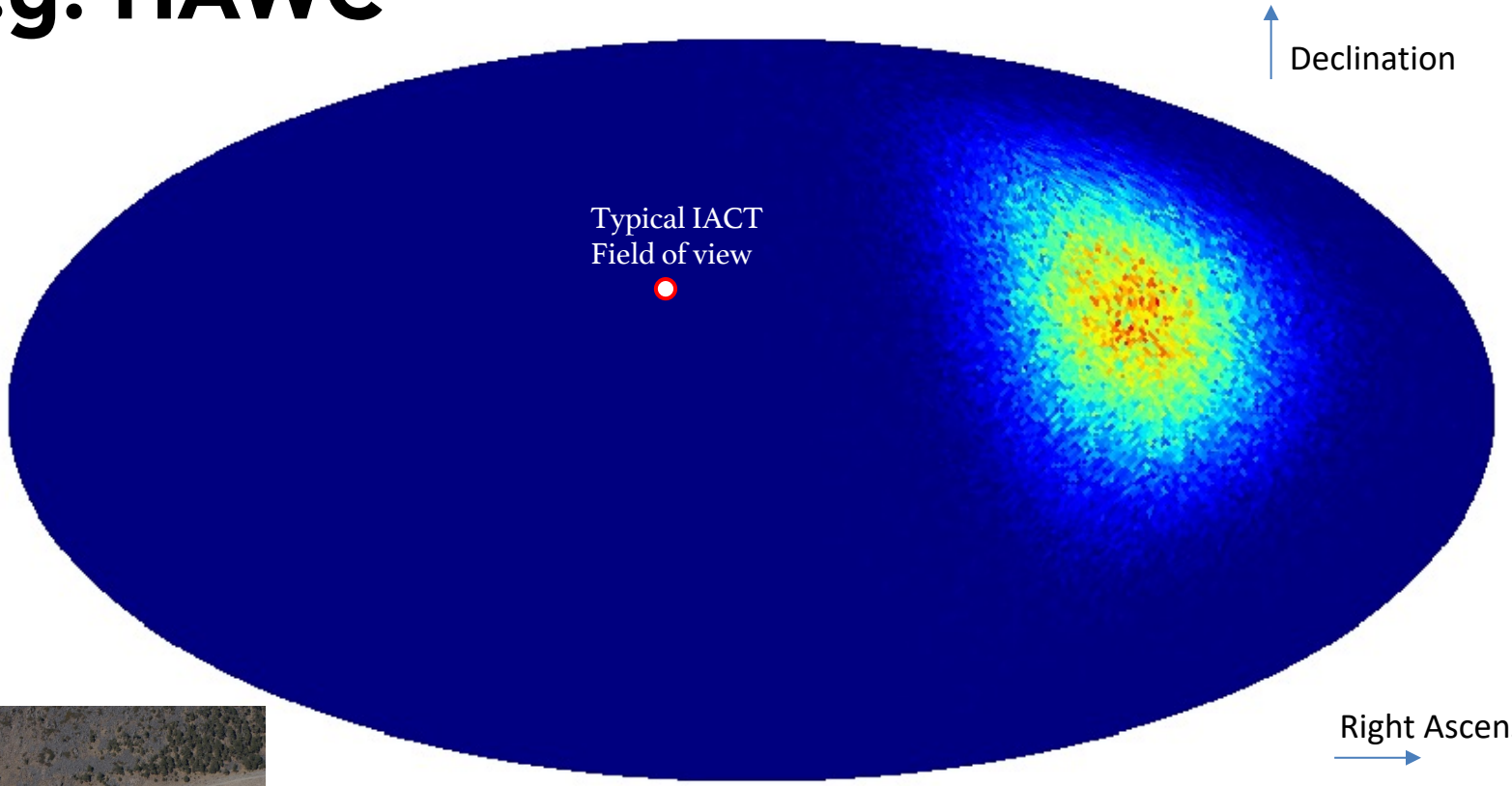
So why not *just* CTA?



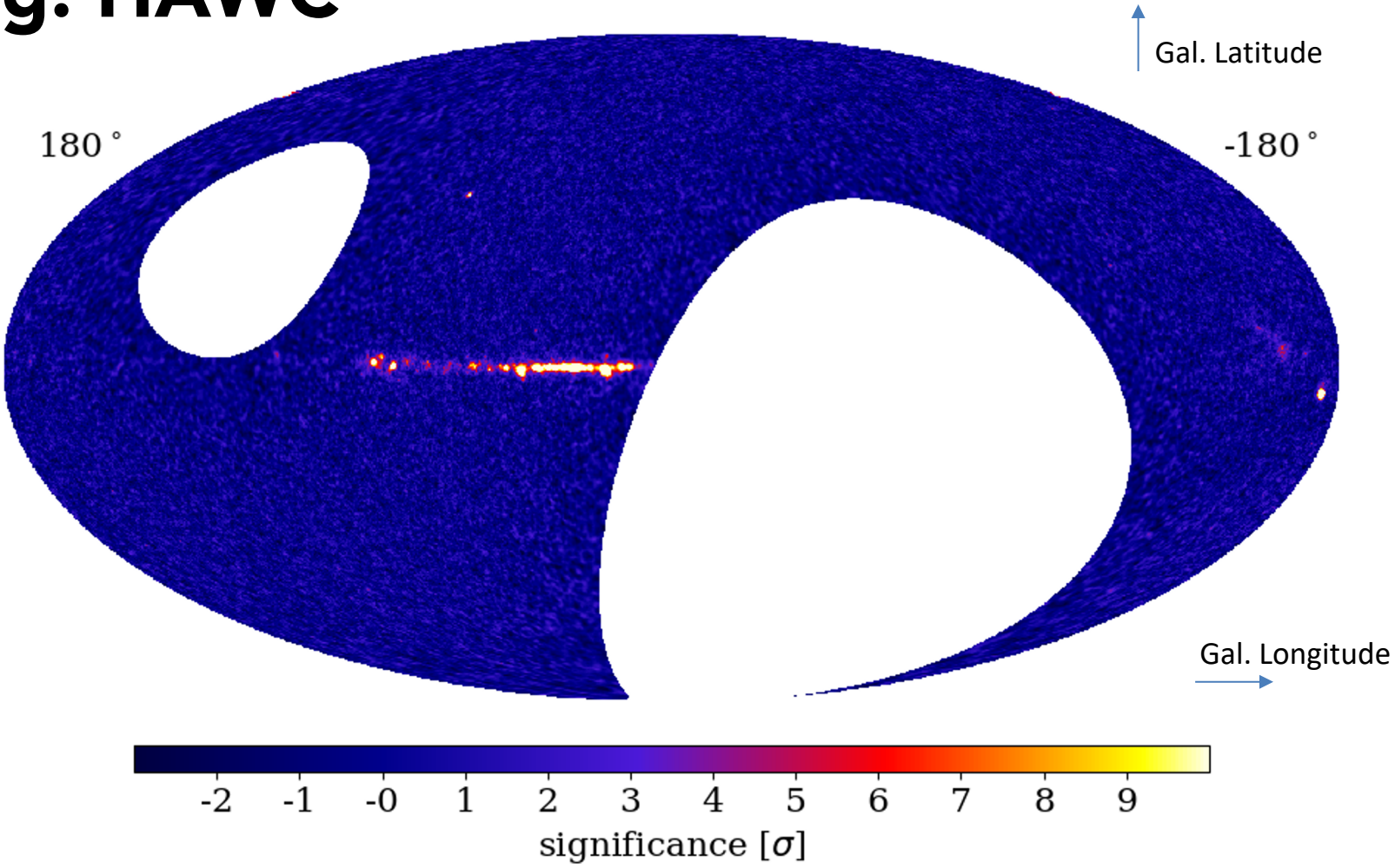
- Compelling candidates with rather **high masses** – where sensitivity of CTA is fading somewhat
  - See many talks at this meeting !! Hisano, Vollmann, Fujiwara ++
- Galactic Centre is by far the strongest source (J factor)
  - Hard for a pointed instrument to collect a long list of dwarf galaxies to stack like Fermi
  - BUT: if central density peak is not very strong/cuspy/small scale – **field of view** of CTA may become an issue (can survey but loss of depth and increased systematics)
- Confirmation by independent instrument helps a lot with acceptance (!)
- Continuation of spectrum – wider energy coverage – makes detection more convincing – and more **physics from spectral shape**


Very high energy gamma-ray
Electro-Magnetic Cascade
~100% duty-cycle
Steradian field of view
Modest precision
Modest collection area
Few ns spread in particle arrival at each detector
Few ns light flash
Cherenkov Light
~15% duty-cycle
~4 degree field of view
High precision
Large collection area

e.g. HAWC


Declination
Typical IACT
Field of view
Right Ascension
0
85

e.g. HAWC


Gal. Latitude
180 °
-180 °
Gal. Longitude
-2 -1 -0 1 2 3 4 5 6 7 8 9
significance [σ]

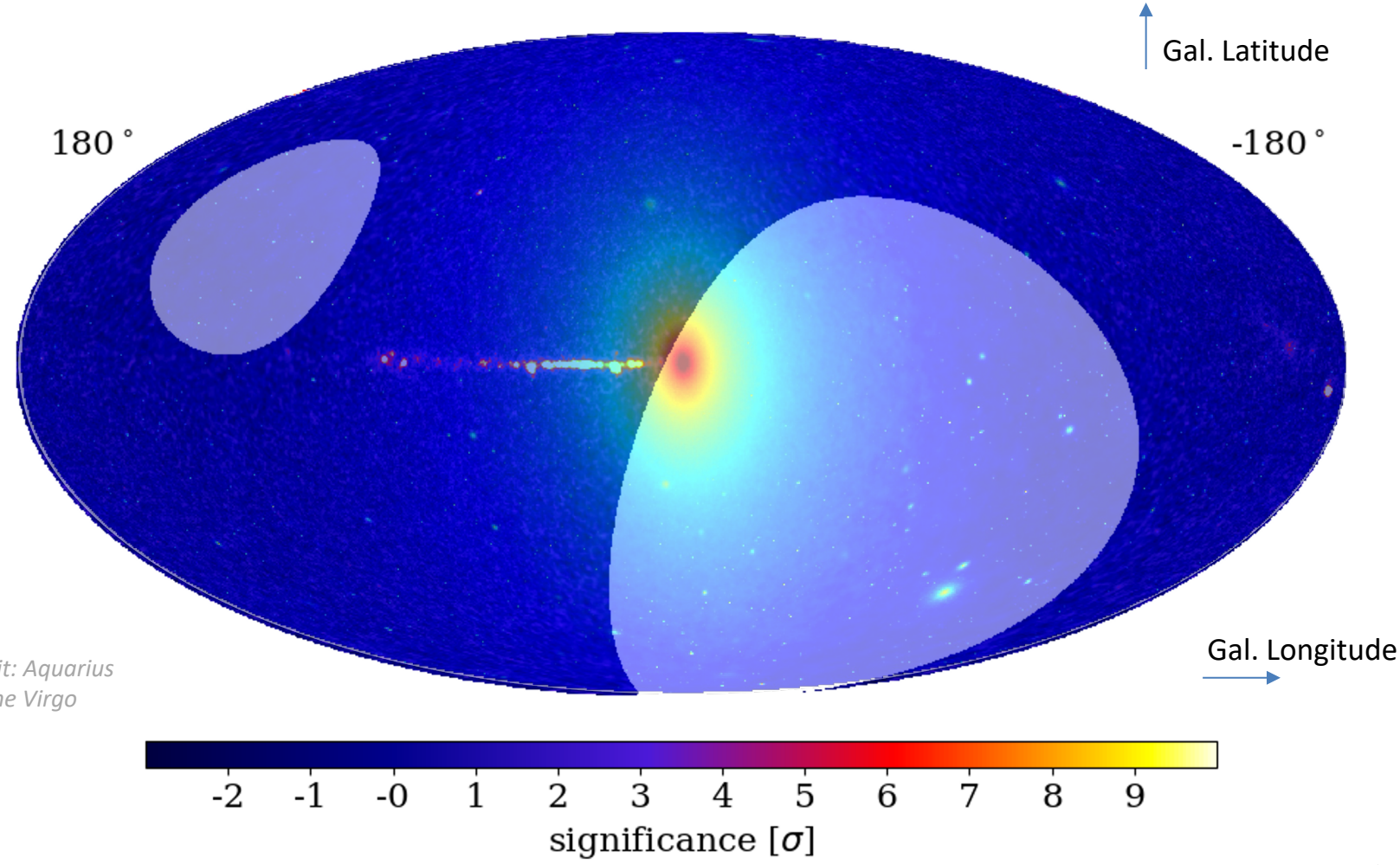
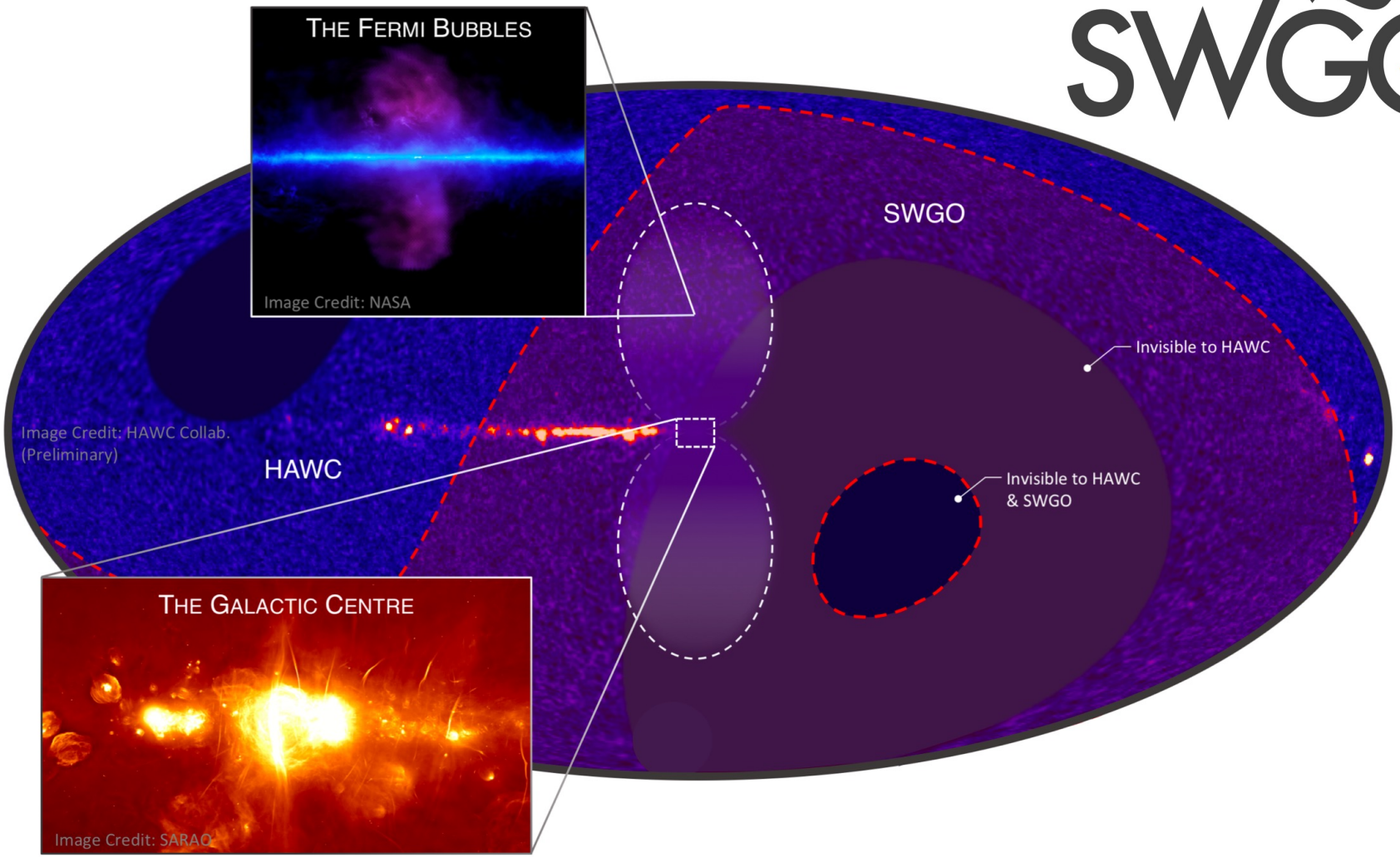


Image Credit: Aquarius Project of the Virgo Consortium

www.swgo.org

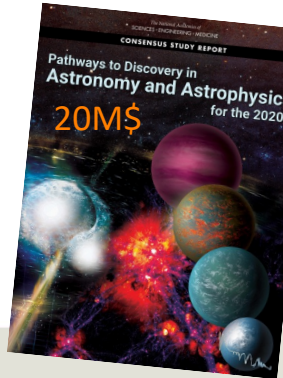

THE FERMI BUBBLES
Image Credit: NASA
SWGO
Invisible to HAWC
Image Credit: HAWC Collab.
(Preliminary)
HAWC
Invisible to HAWC
& SWGO
THE GALACTIC CENTRE
Image Credit: SARAO

Status & Plan

		SWGO R&D Phase Milestones
✓	M1	R&D Phase Plan Established
✓	M2	Science Benchmarks Defined
✓	M3	Reference Configuration & Options Defined
	M4	Site Shortlist Complete
✓	M5	Candidate Configurations Defined
	M6	Performance of Candidate Configurations Evaluated
	M7	Preferred Site Identified
	M8	Design Finalised
	M9	Construction & Operation Proposal Complete

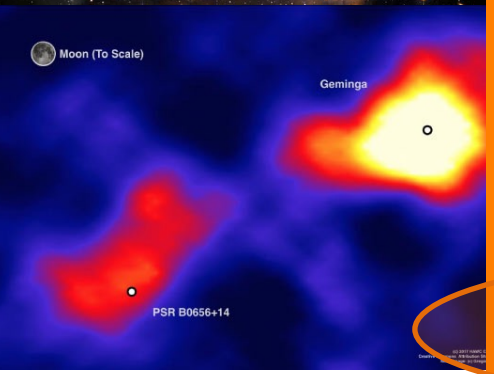
- SWGO partners
  - 48 institutes in 13 countries
  - + supporting scientists

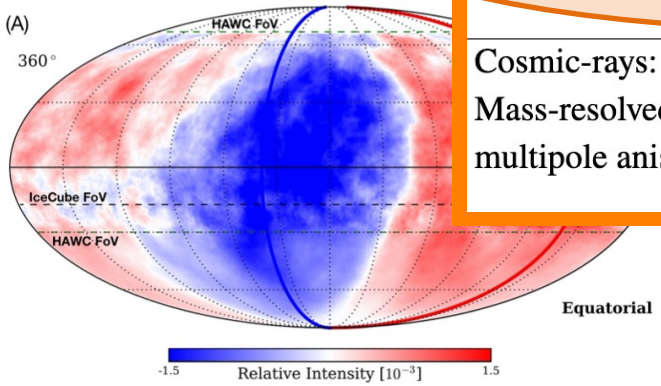
- R&D Phase
  - Kick off meeting Nov 2019
  - Expected completion early 2024
    - Site and main design choices made 2023
  - Then:
- Preparatory Phase
  - Detailed construction planning
  - **Engineering Array 2024+**
    - **At final site – already scientifically interesting, modest financial requirements**
- (Full) Construction Phase
  - 2026+



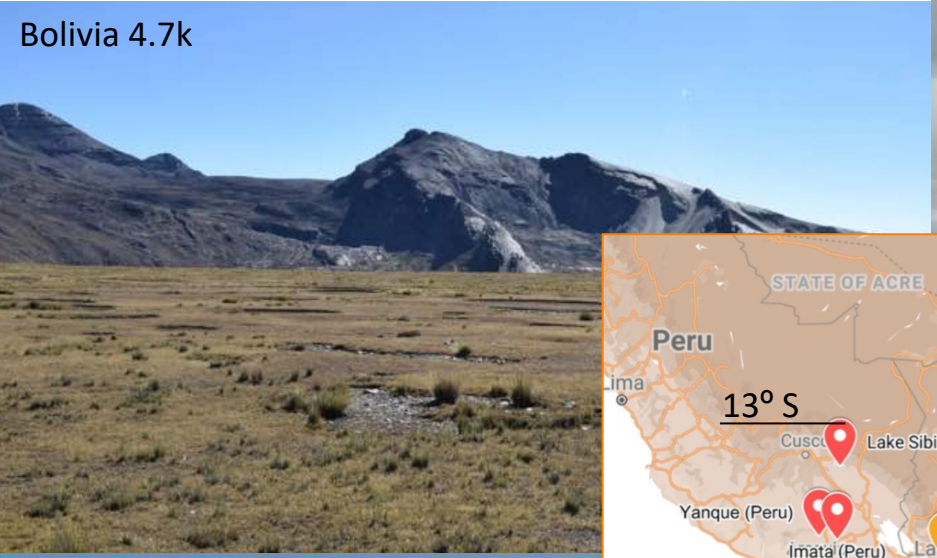
Very open to new partners / interested scientists!

Science Case	Design Drivers
Transient Sources: Gamma-ray Bursts	Low-energy sensitivity & Site altitude[a]
Galactic Accelerators: PeVatron Sources	High-energy sensitivity & Energy resolution[b]
Galactic Accelerators: PWNe and TeV Halos	Extended source sensitivity & Angular resolution[c]
Diffuse Emission: Fermi Bubbles	Background rejection
Fundamental Physics: Dark Matter from GC Halo	Mid-range energy sensitivity Site latitude[d]
Cosmic-rays: Mass-resolved dipole / multipole anisotropy	Muon counting capability[e]

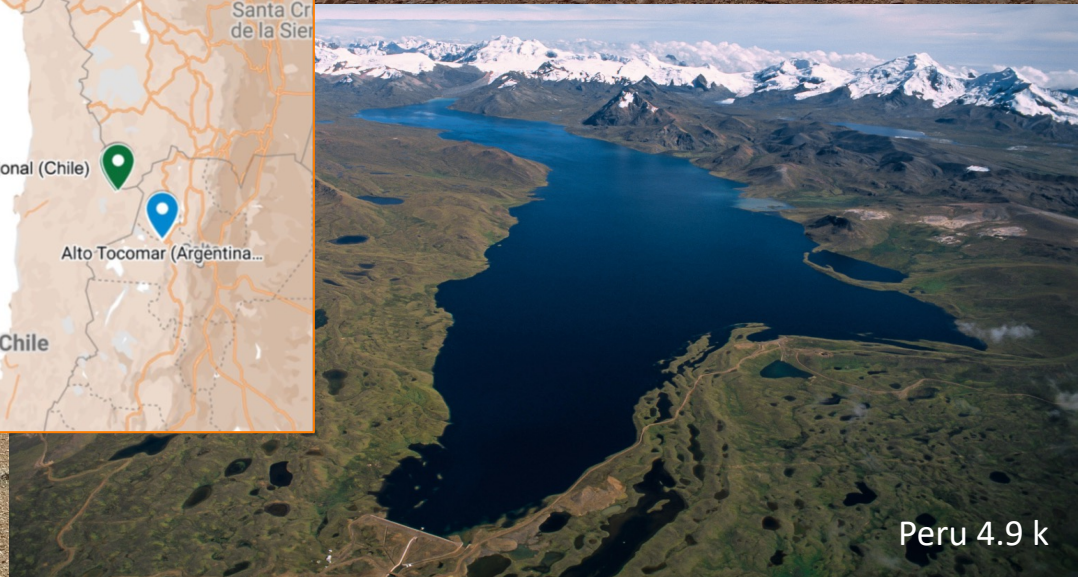





Bolivia 4.7k
Chile 4.8 k
STATE OF ACRE
Peru
Lima
13° S
Lake Sibinacocha (Peru)
Yanque (Peru)
Imata (Peru)
Chacaltaya (Bolivia)
Bolivia
Cochabamba
AAP Pajonal (Chile)
24° S
Alto Tocomar (Argentina...
Chile
Argentina 4.8 k
Peru 4.9 k

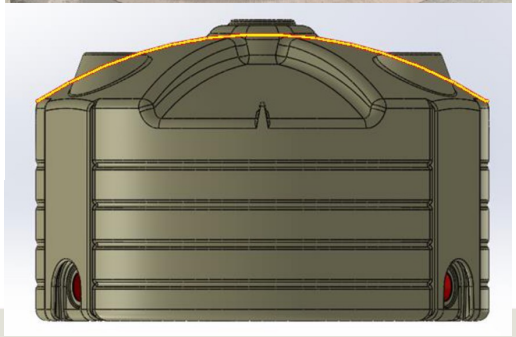


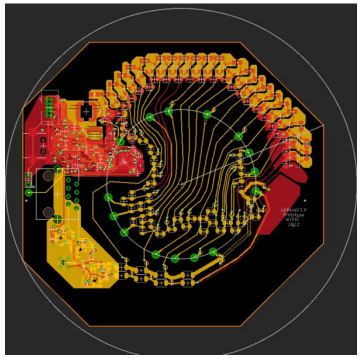
Site shortlisting: September 2022
Site team visits: October 2022
Preferred Site identified: Autumn 2023
On-site prototyping activities: from 2022



WCD Unit

- Lake
  - Natural Lake
  - Artificial Lake/Pond
- Tank
  - Steel Tank
  - Rotomolded Plastic





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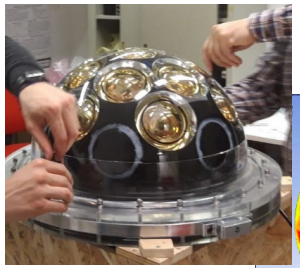
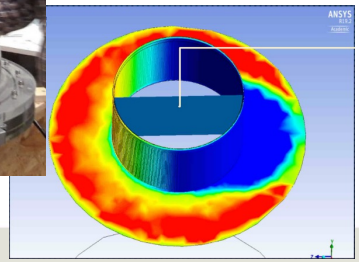
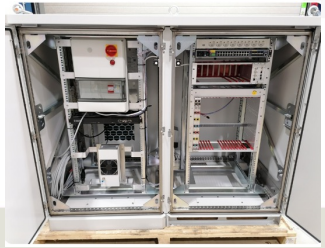
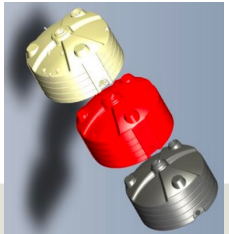
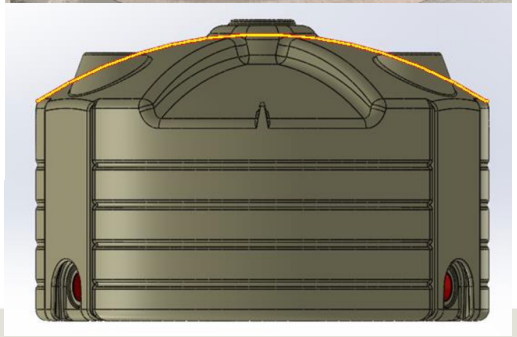






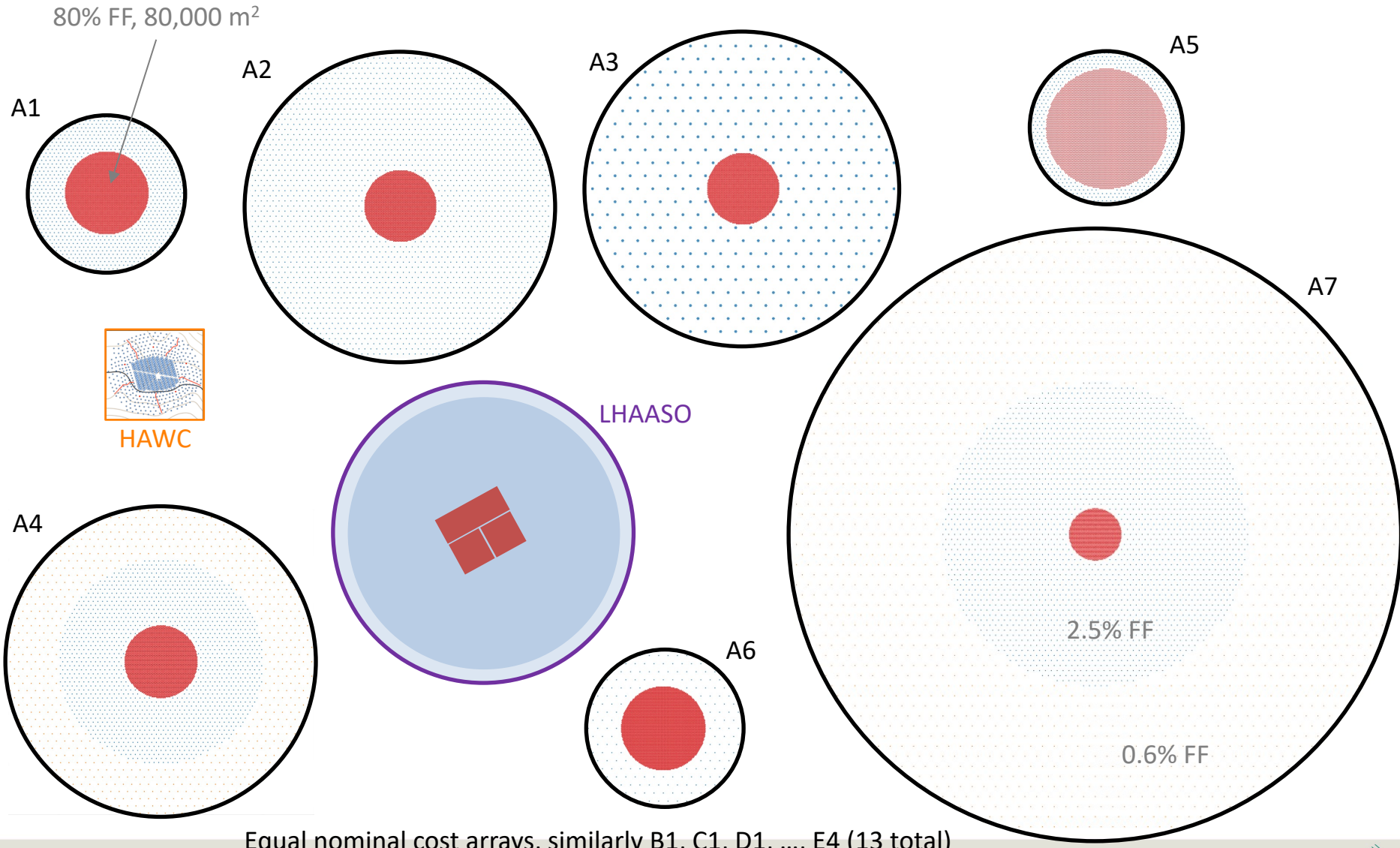




*cooperation with KM3NeT

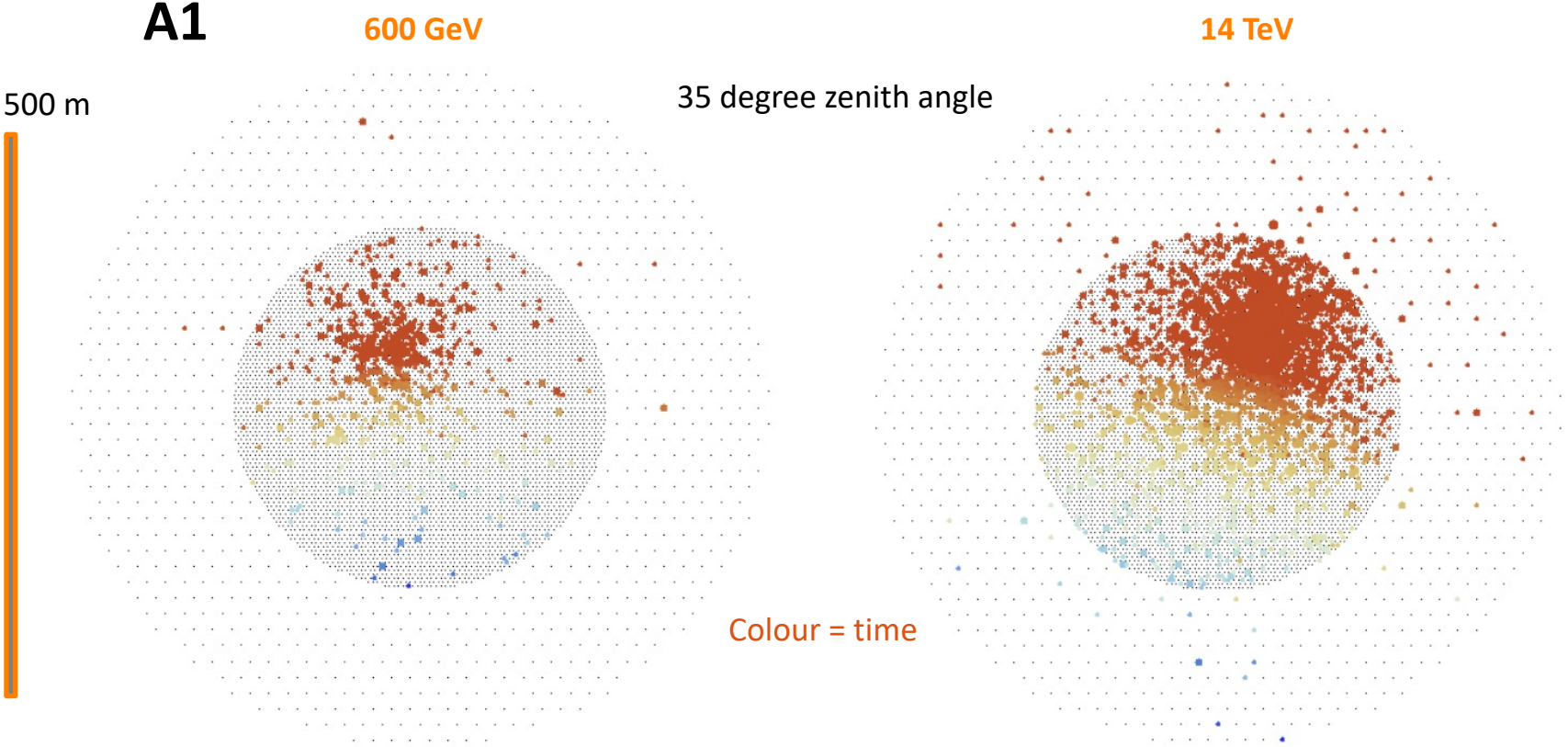
Mod in prep.

Gewässersimulationstank!

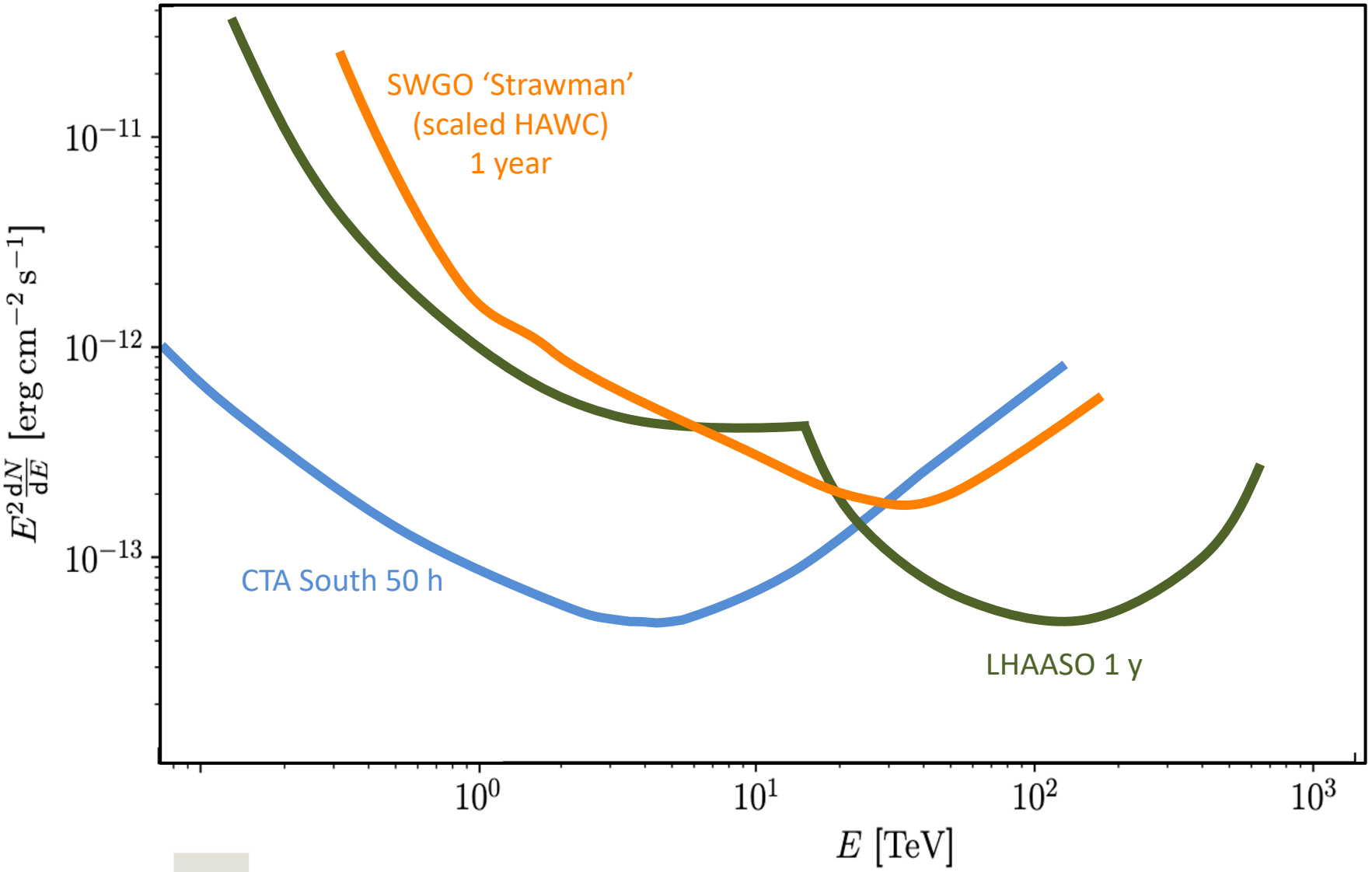


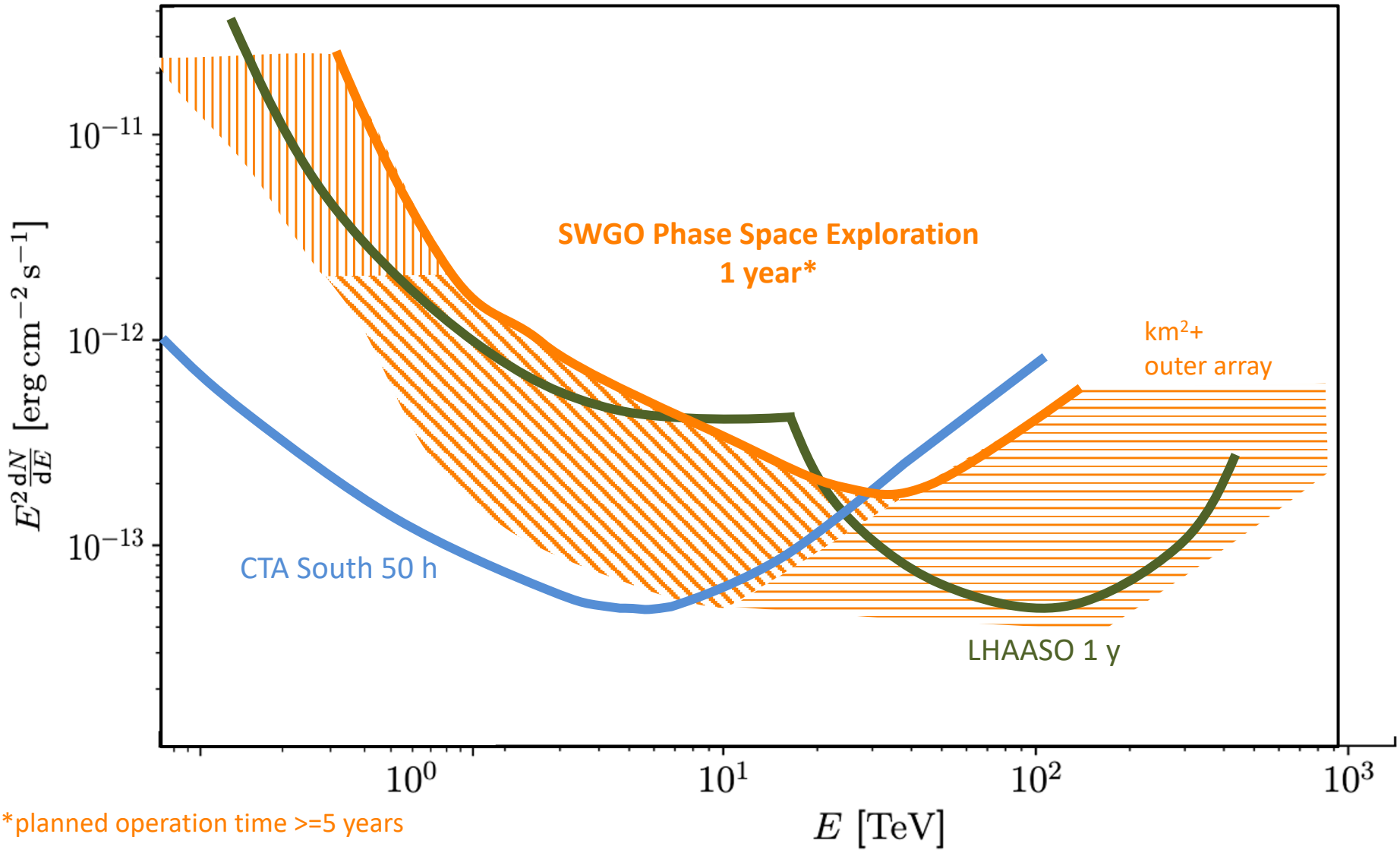
Equal nominal cost arrays, similarly B1, C1, D1, …, E4 (13 total)

A1



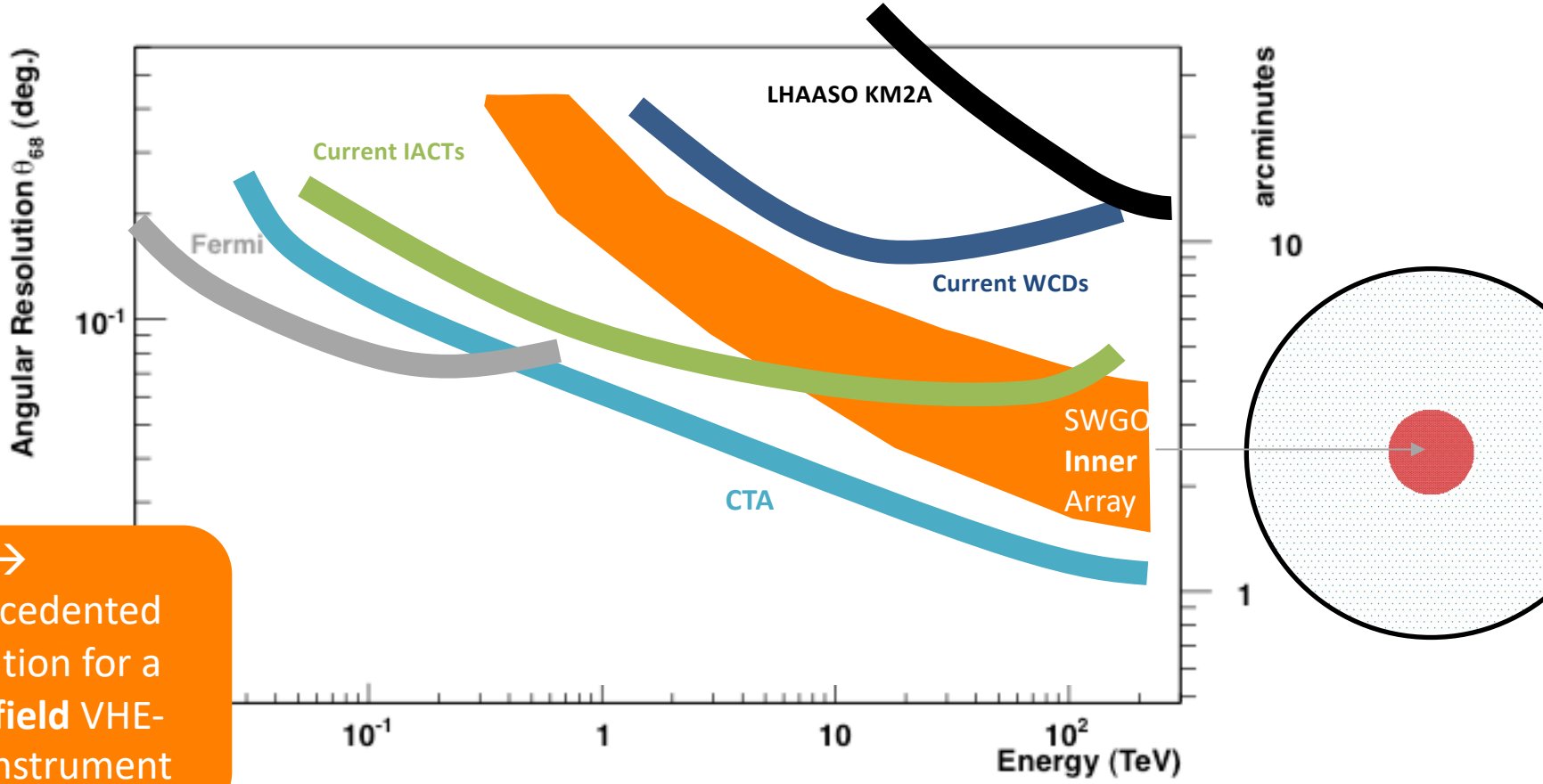
- Larger detector array and increased altitude w.r.t. HAWC
  - → Very precise measurements possible even below 1 TeV
- Layout decision made based on performance on science benchmarks


SWGO ‘Strawman’
(scaled HAWC)
1 year
CTA South 50 h
LHAASO 1 y
10^{-11}
10^{-12}
10^{-13}
$E^2 \frac{dN}{dE}$ [erg cm^{-2} s^{-1}]
10^0
10^1
10^2
10^3
E [TeV]



*planned operation time >=5 years

Angular Resolution

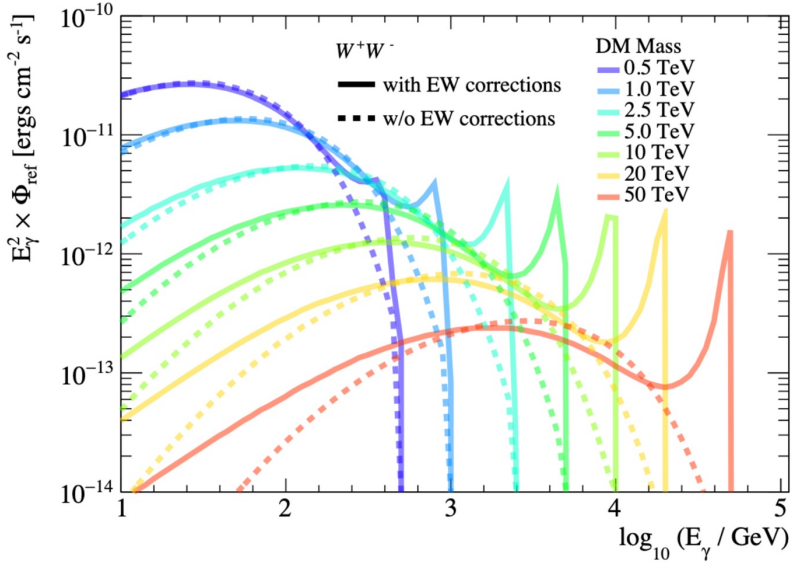


Goal → unprecedented resolution for a **wide field** VHE-UHE instrument

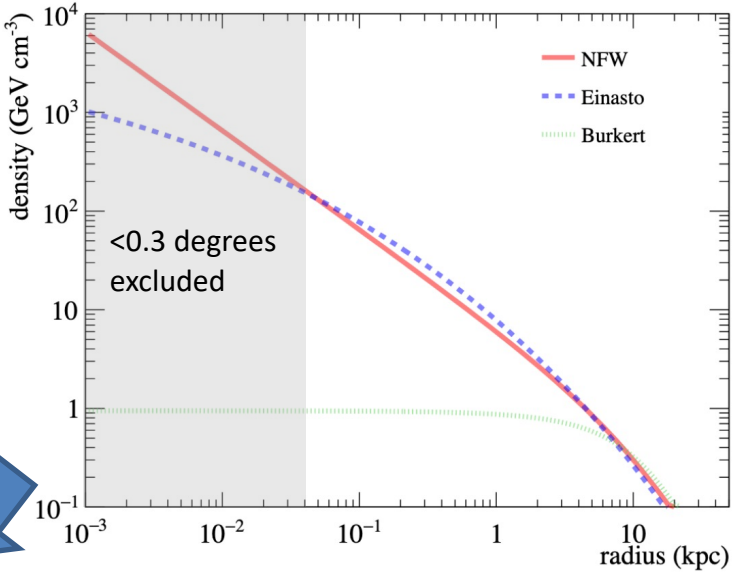
Why the GC?

- Strongest emission !
  - Largest J factors by a very long way
  - By the time we see annihilation from individual dSph the GC will be shouting in our faces ☺
- But what about the bad Fermi Experience (see slides ~~Horiuchi!~~) ?
  - Fermi problem - population of sources with roughly symmetric large scale distribution around GC + DM-like (strongly peaked SED) spectrum
    - There might be TeV sources associated to old stellar populations of the bulge… (but again as Fermi – bulge morphology)
    - BUT would be very unlikely to repeat story of spectral similarity to DM
      - Pulsar magnetospheric physics leads to sharp suppression ~10 GeV
      - No sign of universality of spectral cut-offs in known TeV populations

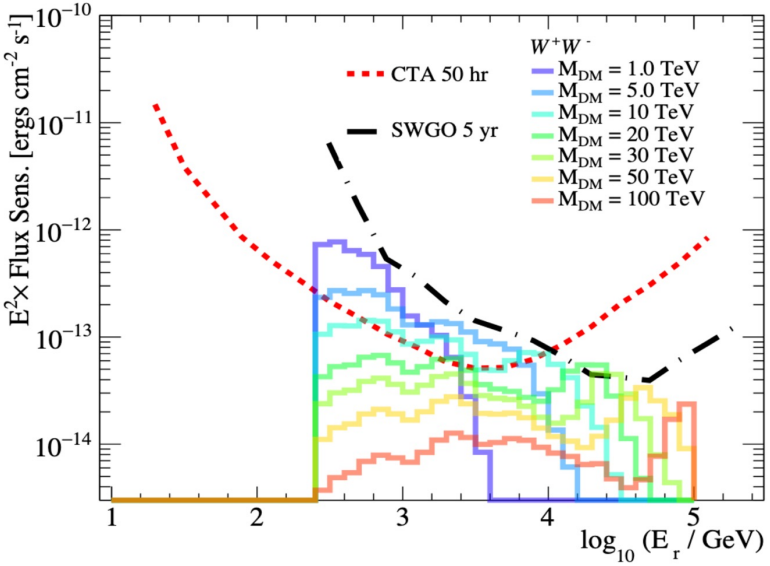
all Dwarf Galaxies of southern hemisphere anyway ‘for free’ with SWGO

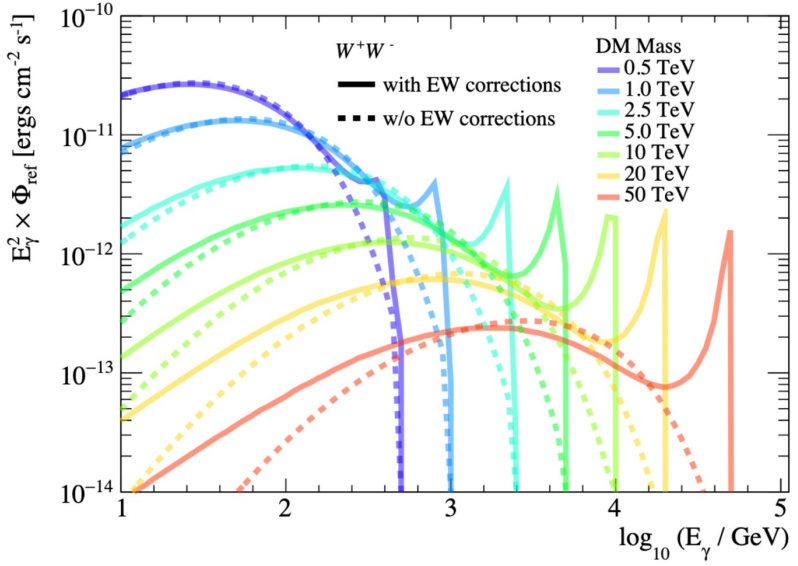


Poor Particle Physicist Cookbook



Poor Astrophysicist Guesswork





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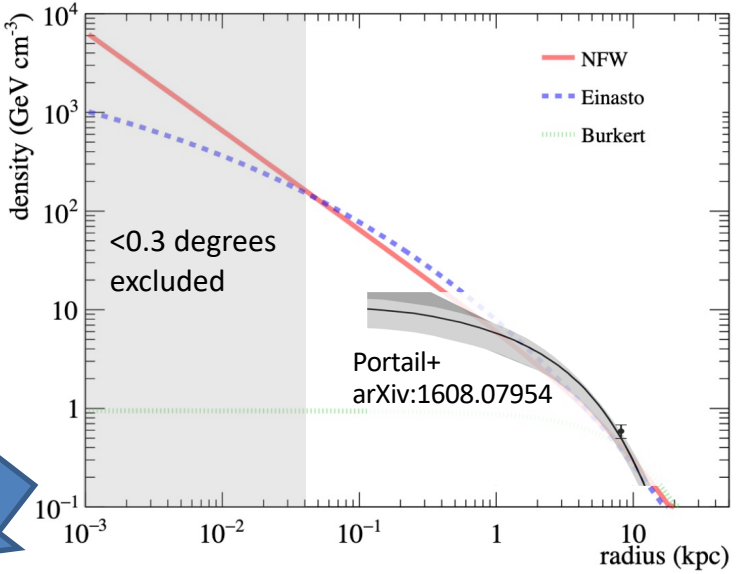
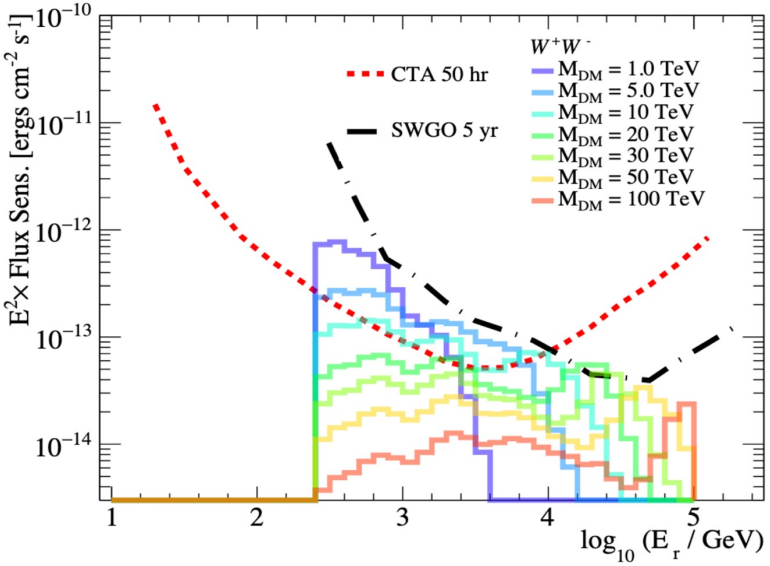
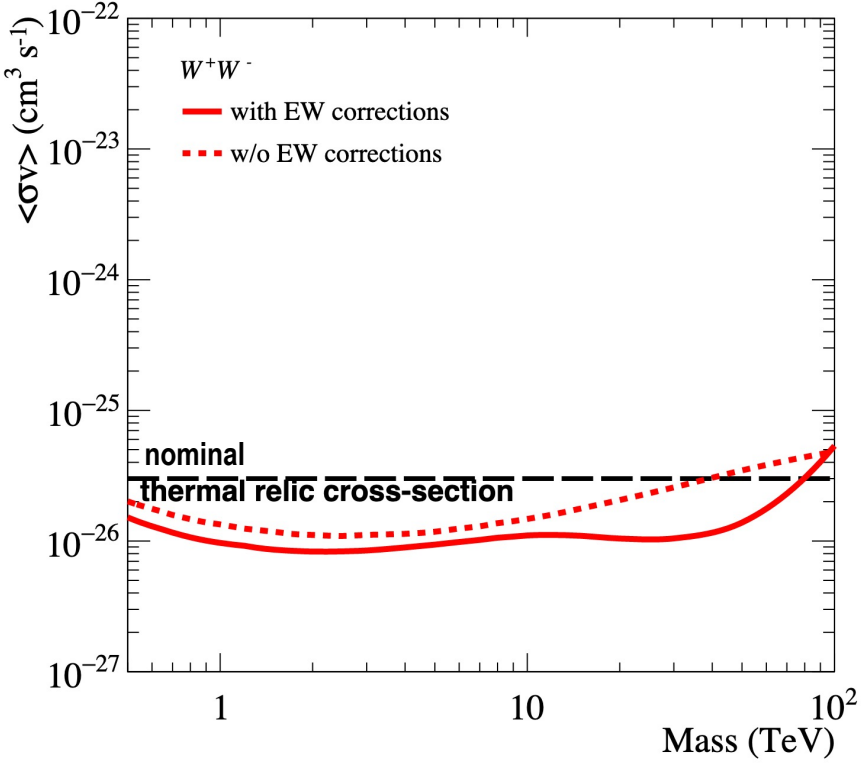
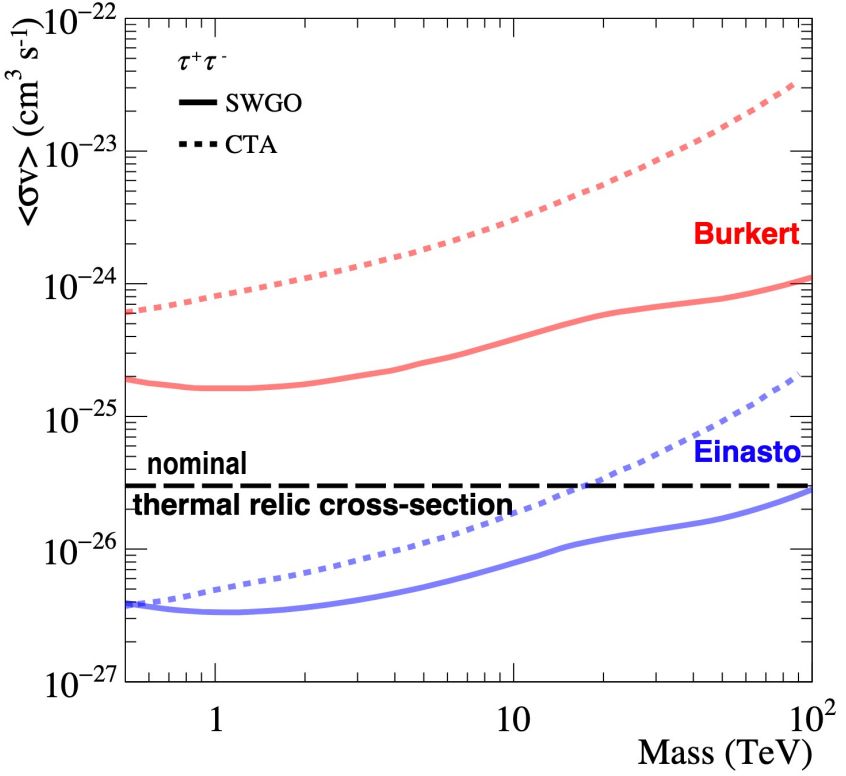


Poor Astrophysicist Guesswork



Sensitivity: cross-sections and profiles



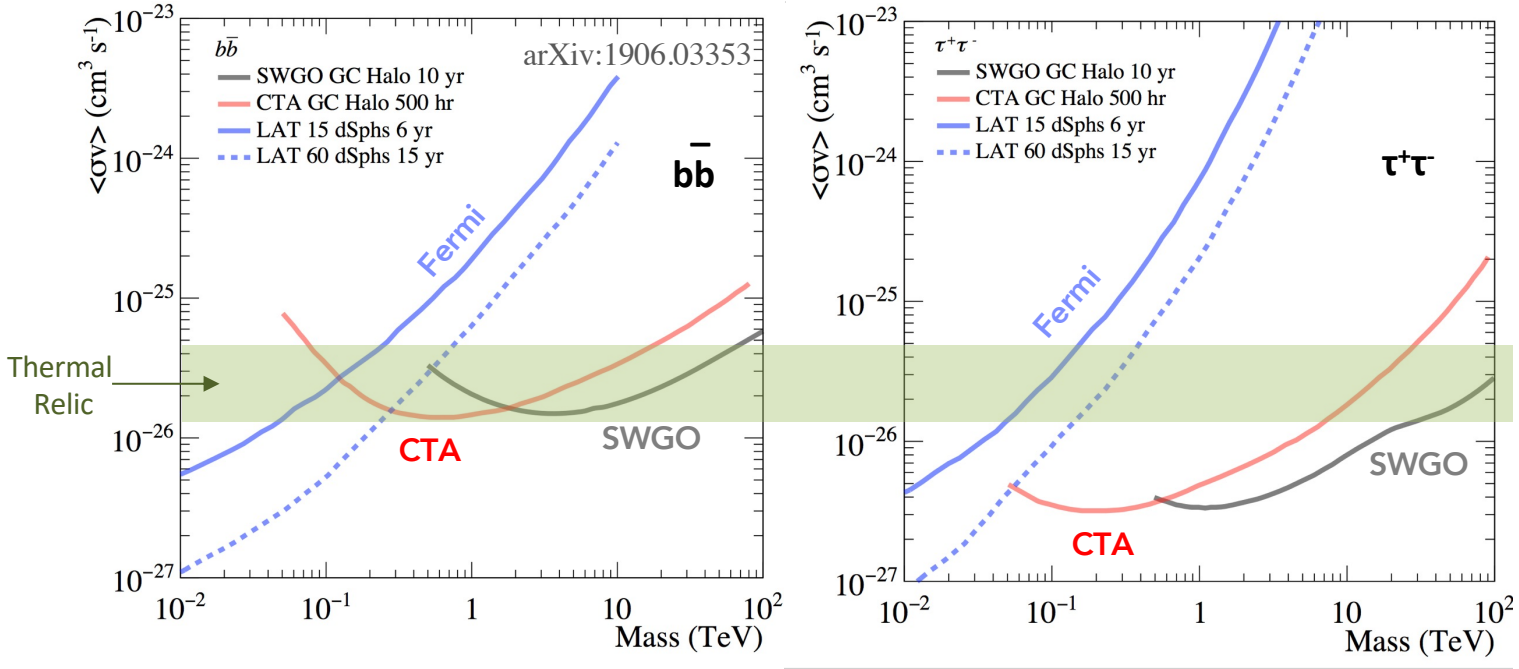


Viana et al, JCAP 2019, arXiv:1906.03353

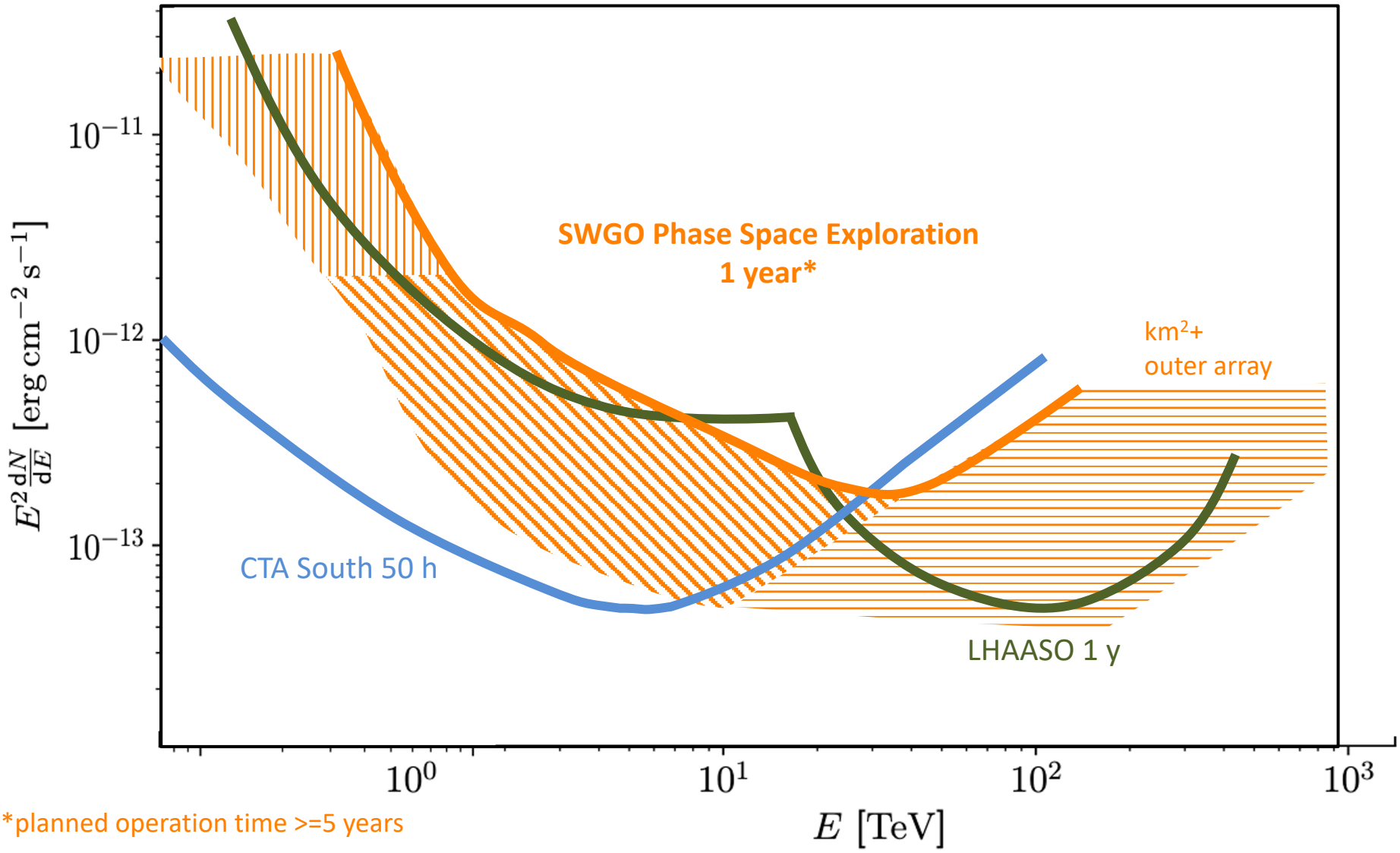
⊙Fermi+CTA+SWGO will reach the critical sensitivity

⊙ Thermal relic WIMP accessible over a very wide mass range (Galactic Centre/Halo observations @ VHE)*

NB – CTA sens. updated in the meantime



*As long as the universe is not too unkind w.r.t. halo shape + Sommerfeld etc etc



*planned operation time >=5 years

A 50yrs-old story of wimps

Coming to an end with Cherenkov telescopes?

- Freeze-out mechanism / **WIMP** miracle
  - Electroweak sector ⇔ dark matter

Supersymmetry

  - Pure “wino”/ “higgsino” ➠ **minimal BSM content**
- **Cherenkov Telescopes** can search for TeV-scale spectral lines
  - **Sommerfeld** effect: enhancements by several orders of magnitude
  - Besides the Sommerfeld effect, large EW effects at the endpoint (**Sudakov double logarithms**) have to be understood and resummed
- **Crucial** to have a **reliable computation** of the **full** continuum+line **spectrum**

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Ground-based gamma-ray astronomy

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