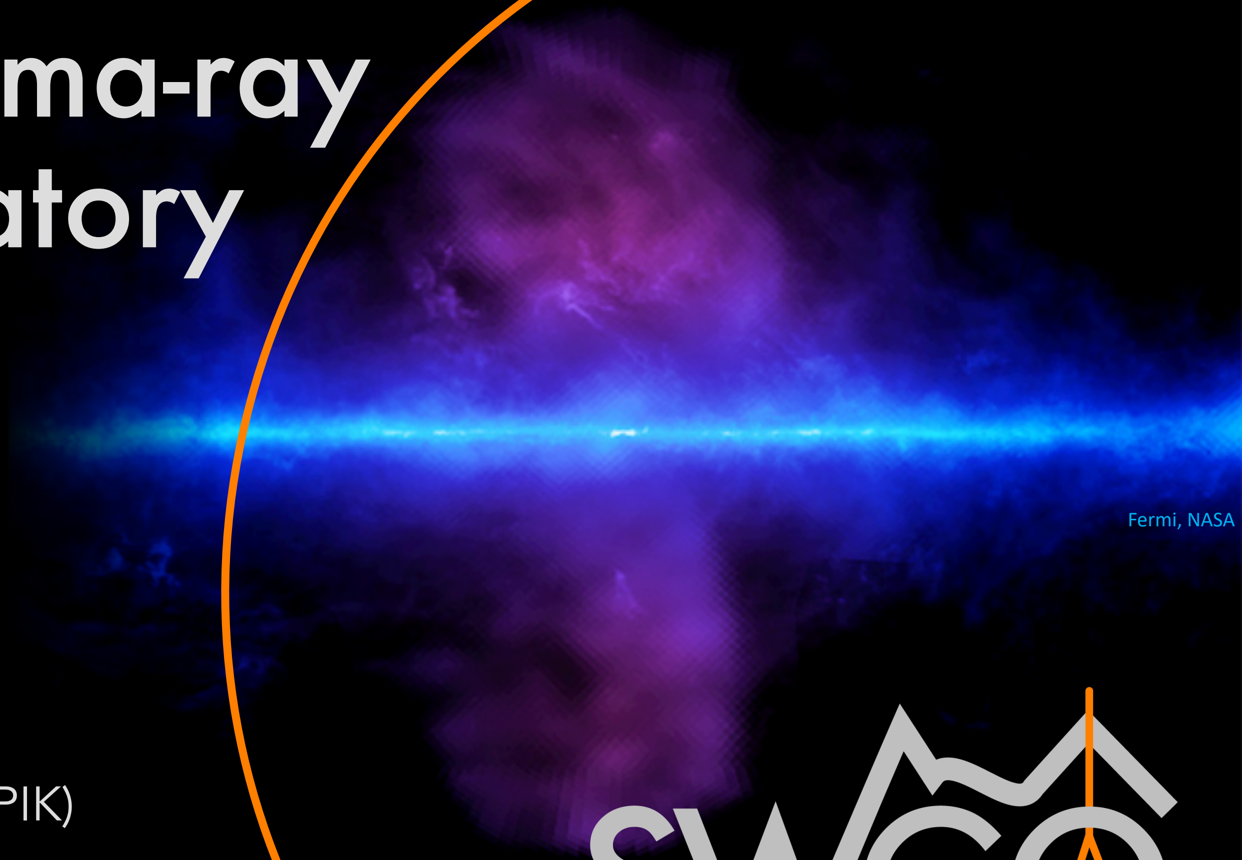
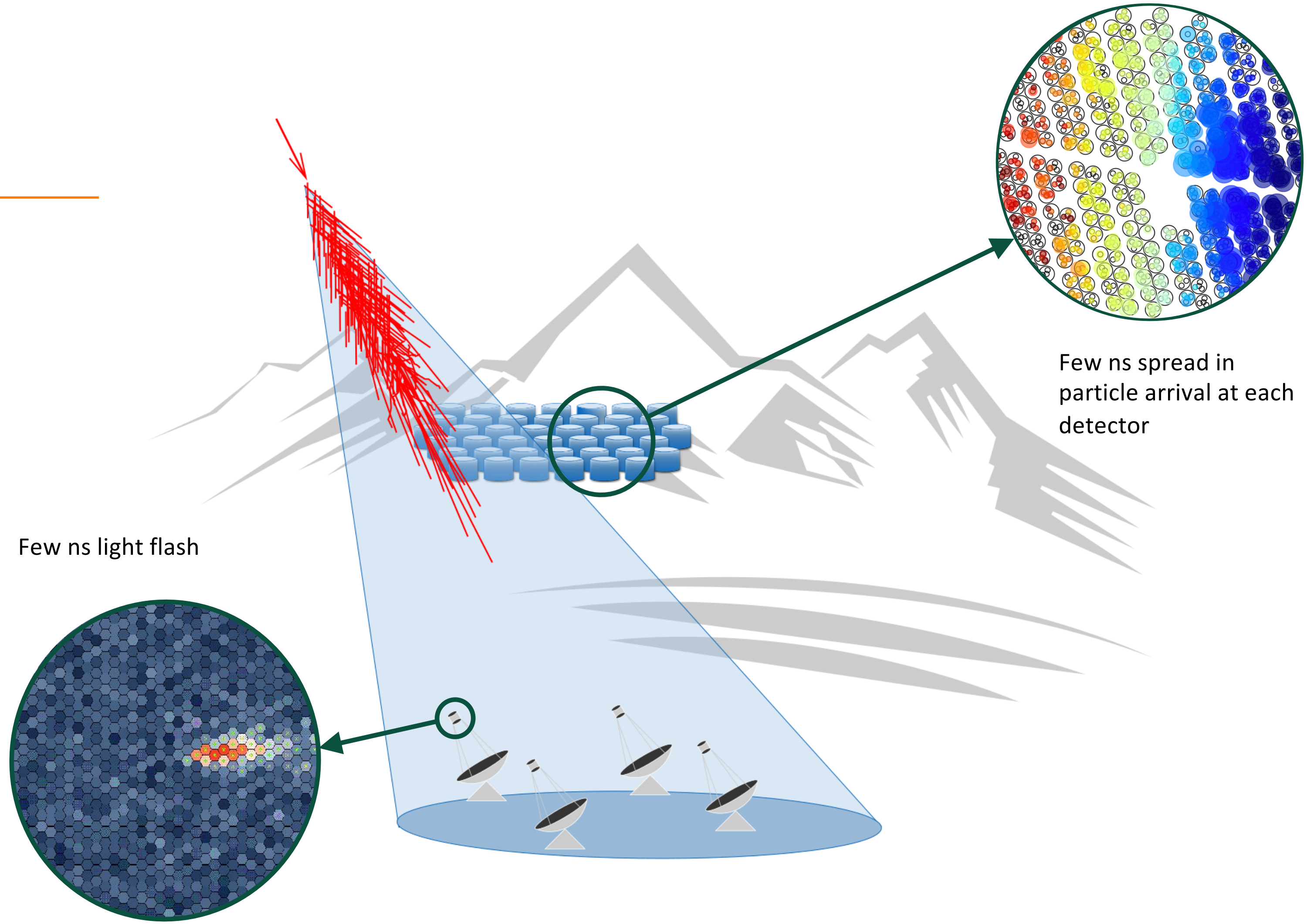
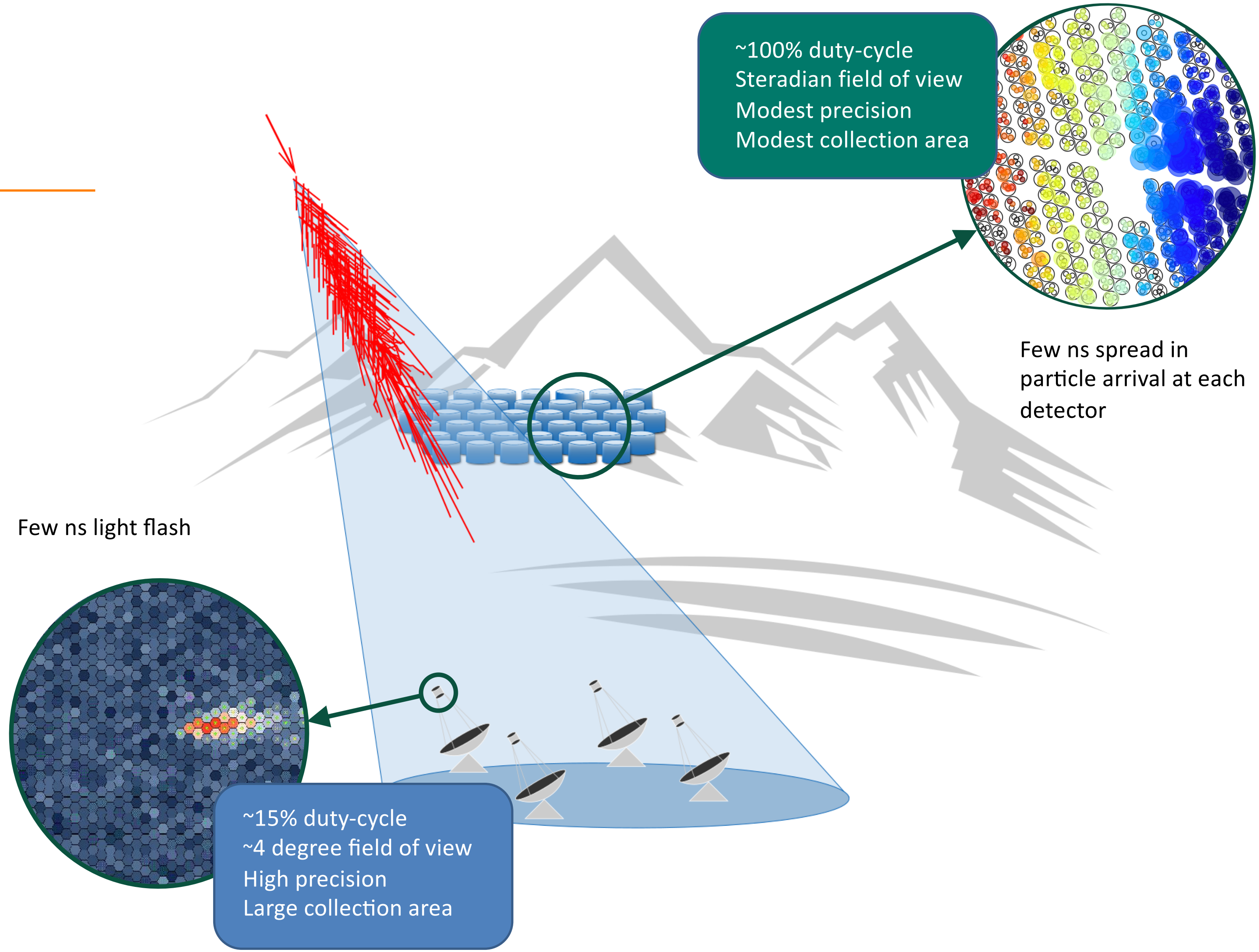
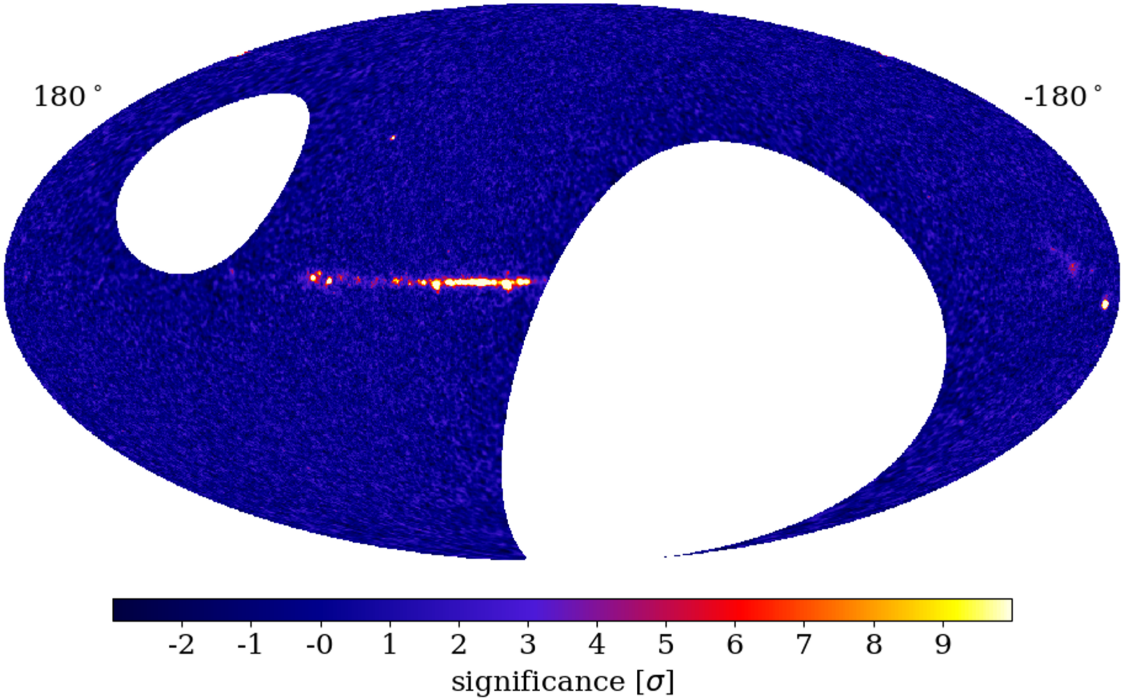
The Southern Wide-Field Gamma-ray Observatory


Fermi, NASA

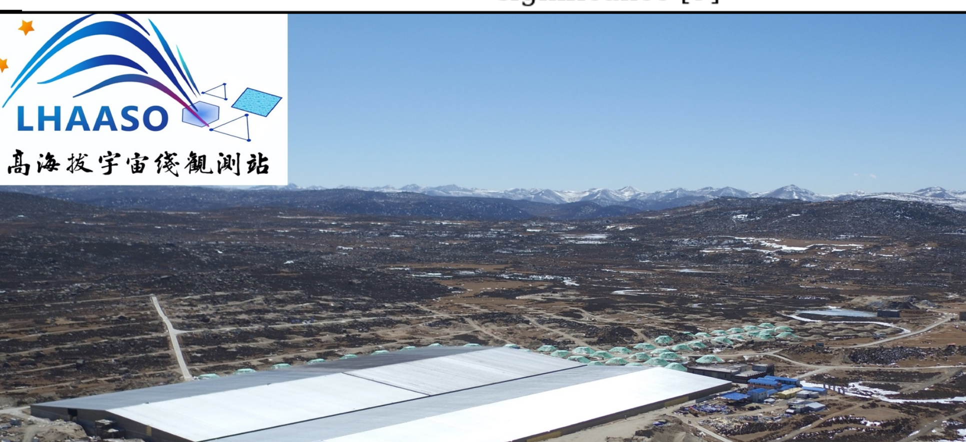
Jim Hinton (MPIK)

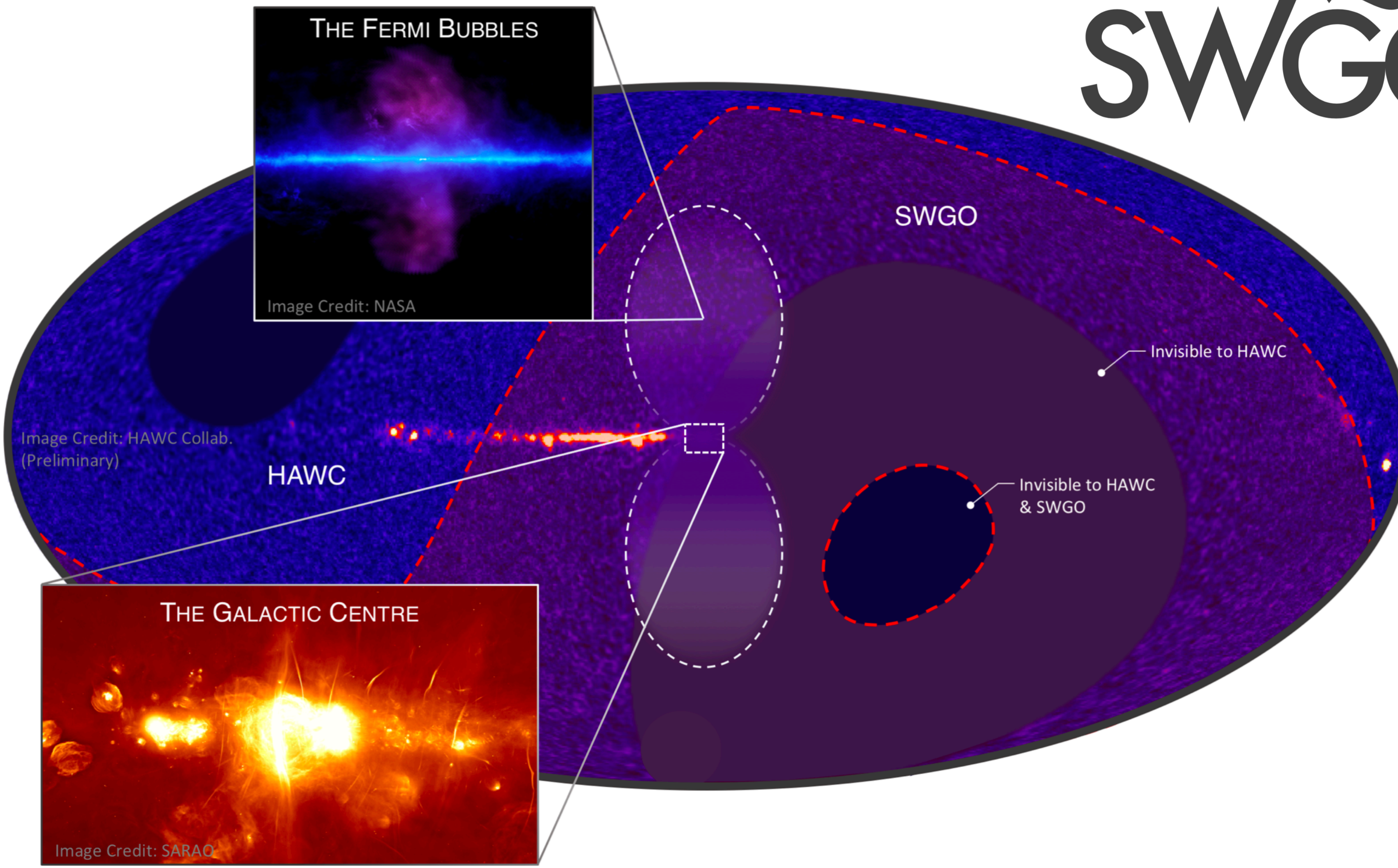

Few ns spread in
particle arrival at each
detector
Few ns light flash


~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
~15% duty-cycle
~4 degree field of view
High precision
Large collection area

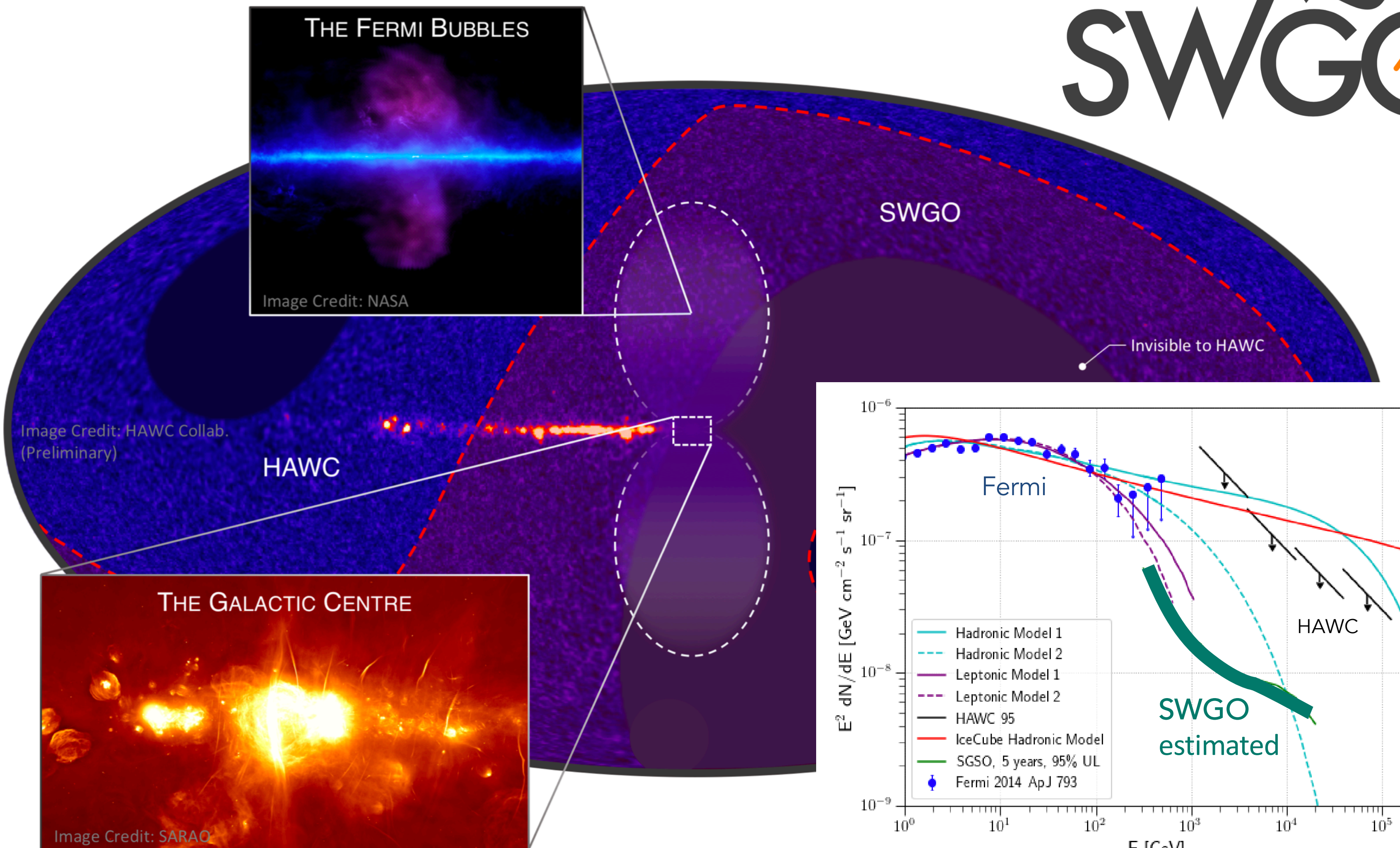


◎ Excellent coverage of northern sky





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

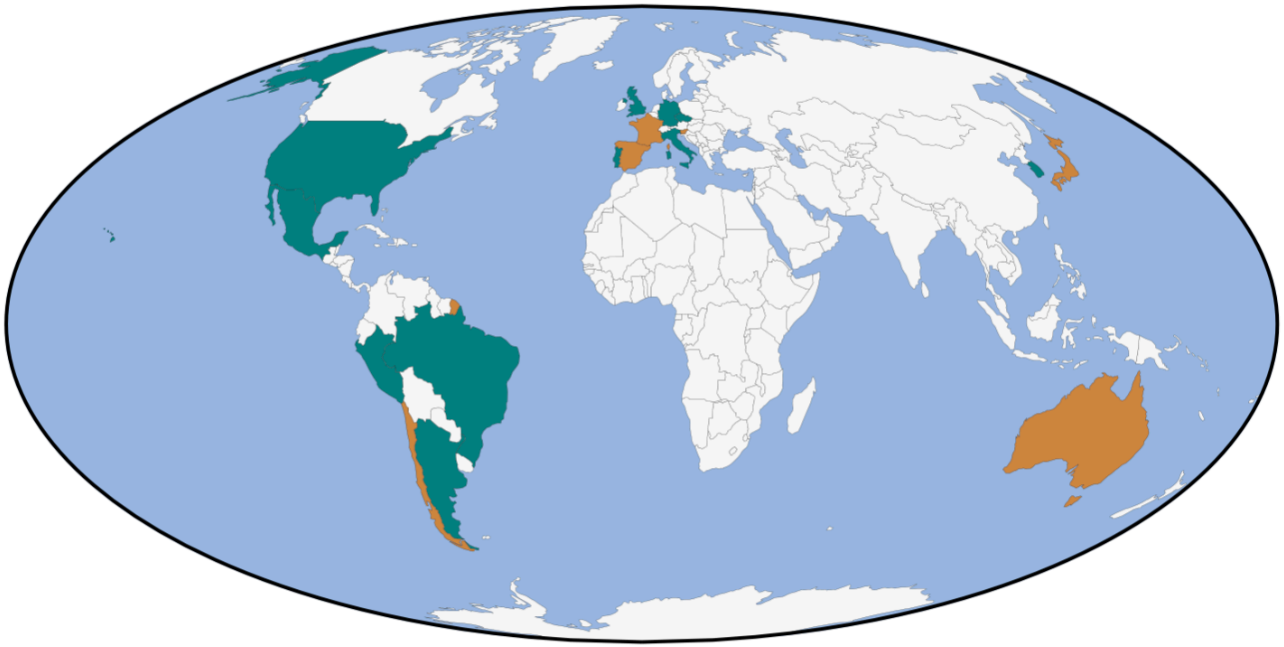


arXiv:1902.08429

Southern wide-field γ-ray Observatory

- Series of workshop culminating in Lisbon meeting in May 2019 – convergence of a large part of community
- Collaboration formed July 2019 around the core concept:
  - Ground-particle detection based high altitude (>4.4 km) gamma-ray observatory latitude -15° to -30°
  - Wide energy range 100s of GeV to 100s of TeV
  - High fill-factor core detector with area considerably larger than HAWC and significantly better sensitivity, with a low density outer array
  - Based primarily on water Cherenkov det. Units
- First collaboration meeting and kick off of 3 year design study phase – Padova Nov. 2019

The SWGO Collaboration



Countries in SWGO

Institutes

Argentina*, Brazil, Czech Republic, Germany*, Italy, Mexico, Peru, Portugal, South Korea, United Kingdom, United States*

Supporting scientists

Australia, Chile, France, Japan, Slovenia, Spain

**also supporting scientists*

- 11 countries, 44 institutes, 193 scientists
- Expertise from HAWC, ARGO, MAGIC, HESS, Auger ++

Collaboration

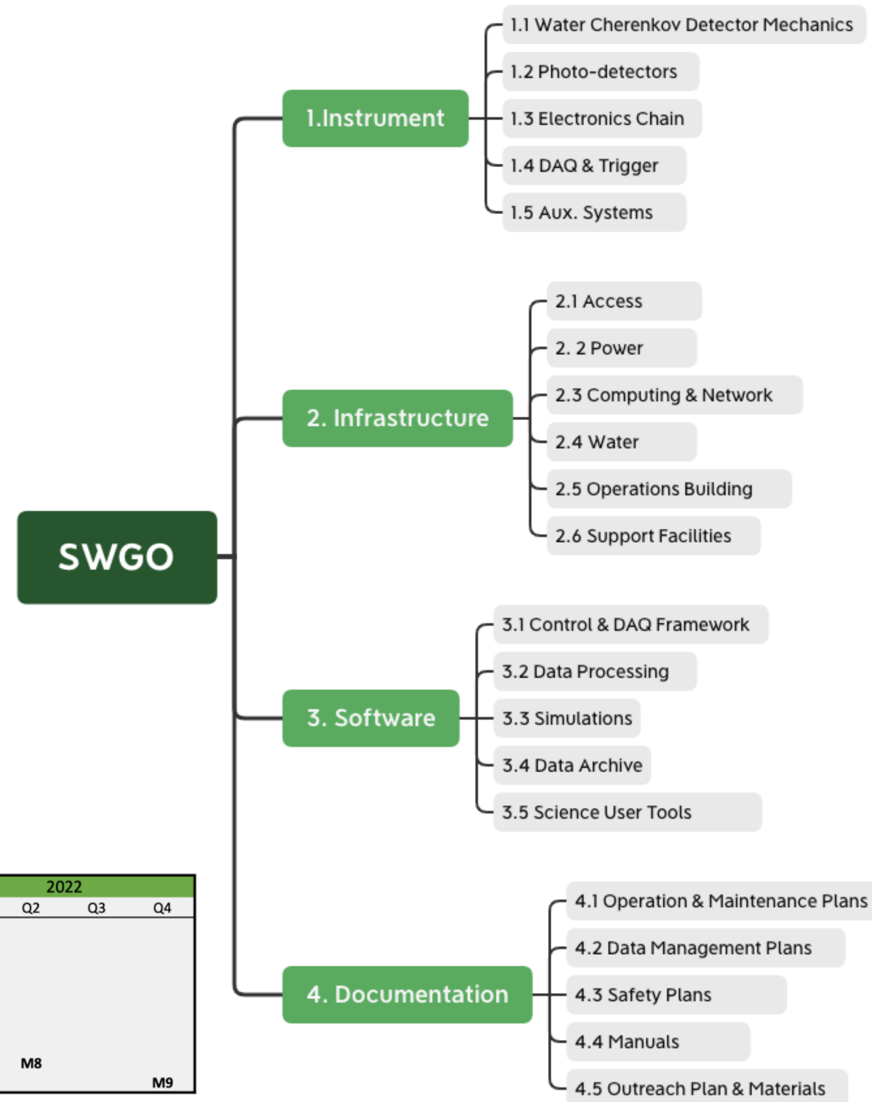
Second collaboration meeting May 2020 – not quite in Mexico City!

Planning

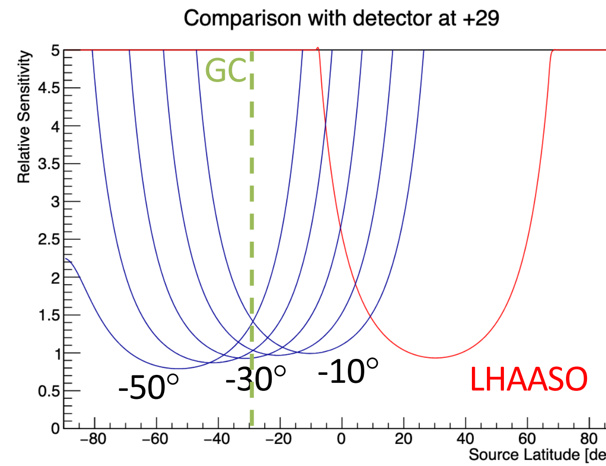
SWGO R&D Phase Milestones	
M1	R&D Phase Plan Established
M2	Science Benchmark Cases Chosen
M3	Reference Configuration & Options Defined
M4	Site Shortlist Complete
M5	Candidate Configurations Defined
M6	Performance of Candidate Configurations Evaluated
M7	Preferred Site Identified
M8	Design Finalised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

Figure 3: Table of Milestones for the R&D Project Phase.

Milestone	2019	2020				2021				2022			
	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
R&D Phase Plan Established		M1											
Science Benchmark Cases Chosen			M2										
Reference Configuration & Options Defined				M3									
Site Shortlist Complete					M4								
Candidate Configurations Defined							M5						
Perf. of Candidate Configurations Evaluated								M6					
Preferred Site Identified									M7				
Design Finalised											M8		
Construction & Operation Proposal Complete													M9



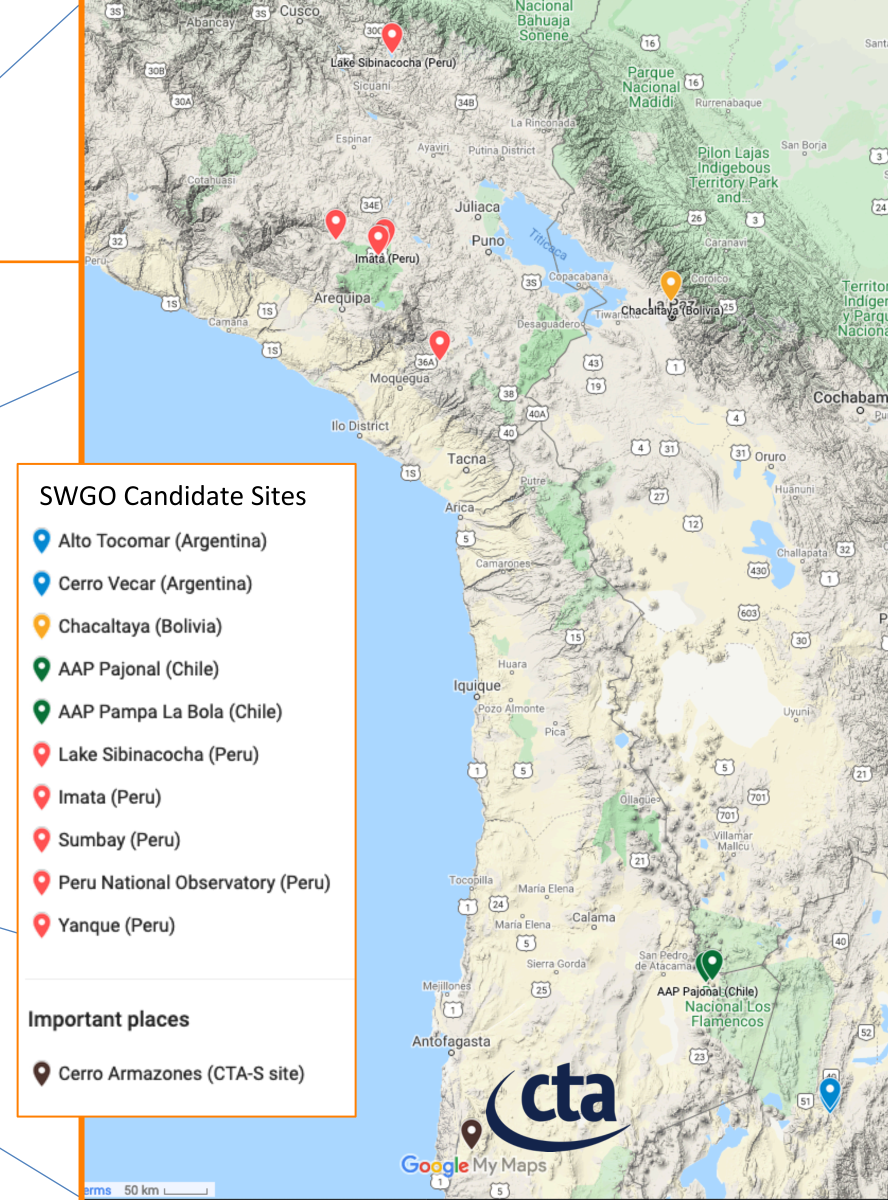
Site?



>4.4 km above sea level
Good access to Galactic Centre
Good overlap with LHAASO
Latitude ~ -25 to -15 degrees

Site?


Caribbean Sea
North Atlantic Ocean
South Pacific Ocean
South Atlantic Ocean
COLOMBIA
VENEZUELA
ECUADOR
PERU
BRAZIL
BOLIVIA
PARAGUAY
CHILE
ARGENTINA
URUGUAY
AMAZON BASIN
BRAZILIAN HIGHLANDS
Scale 1:35,000,000
Azimuthal Equal-Area Projection


SWGO Candidate Sites
Alto Tocomar (Argentina)
Cerro Vecar (Argentina)
Chacaltaya (Bolivia)
AAP Pajonal (Chile)
AAP Pampa La Bola (Chile)
Lake Sibinacocha (Peru)
Imata (Peru)
Sumbay (Peru)
Peru National Observatory (Peru)
Yanque (Peru)
Important places
Cerro Armazones (CTA-S site)
Lake Sibinacocha (Peru)
Imata (Peru)
Chacaltaya (Bolivia)
AAP Pajonal (Chile)
Cusco
Arequipa
Juliaca
Puno
Moquegua
Tacna
Arica
Iquique
Calama
Antofagasta
cta
Google My Maps
50 km

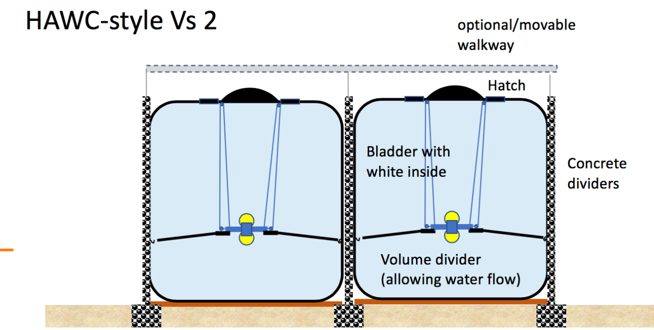
Site?

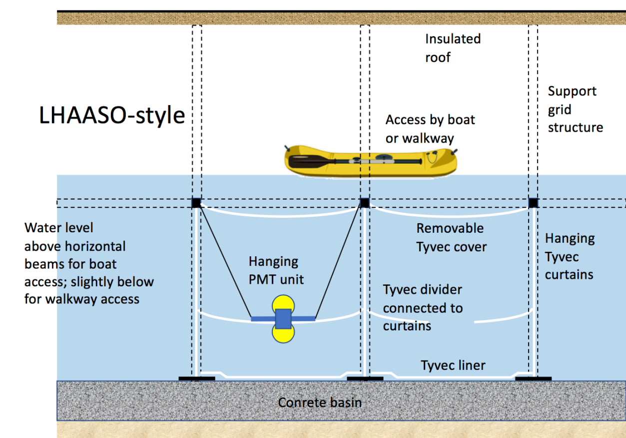
e.g.

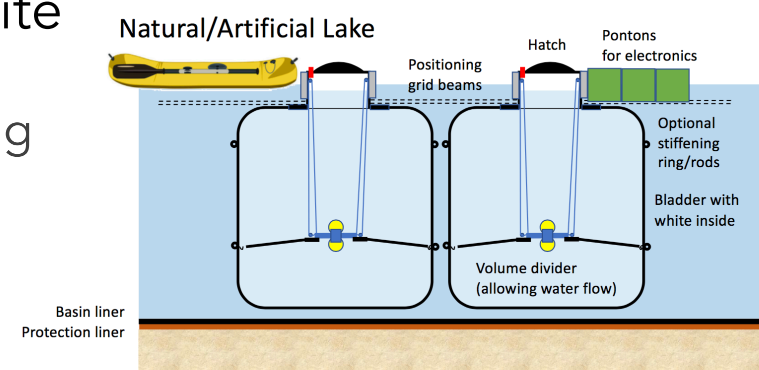
- Detailed characterisation work started
  - → Shortlist by end 2020

Detector Options

- Water Cherenkov detector units is core technology -three options under evaluation
  - Tanks, Ponds and Lake-based
- All aspects being optimised
  - Unit dimensions, wall reflectivities, photosensor nature/locations, …
- Final design will depend on choice of site
  - e.g. cost of water transportation in comparison to other costs, civil engineering costs, feasibility for lake-based solution



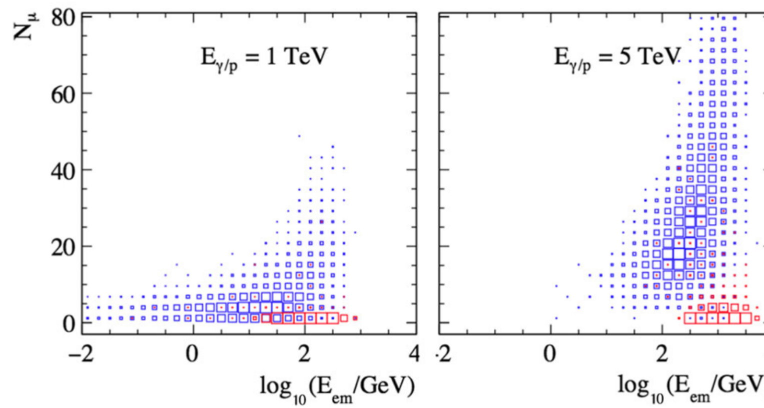


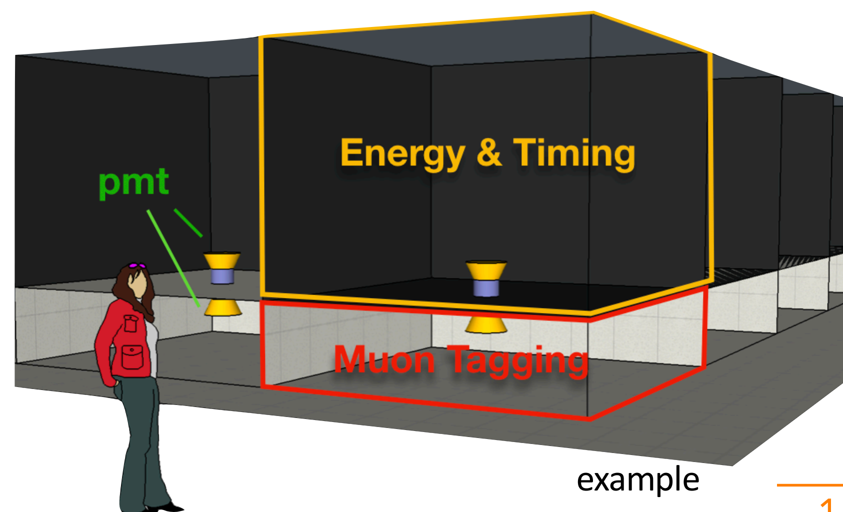


Muon Identification

- Muon tagging has huge potential for gamma/hadron sep. (above about 1 TeV)
  - c.f. LHAASO
- Aim to incorporate muon identification in to (all of) the water Cherenkov detector units
  - Double layer, or
  - Multi-sensor – time and intensity measurements to tag single through-going particles

Eur. Phys. J. C (2019) 79:427



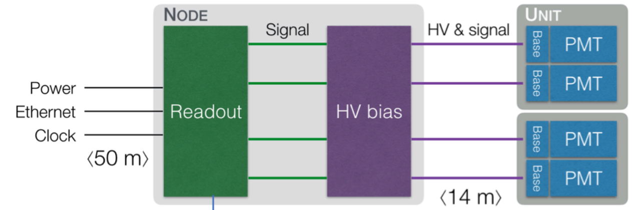


example

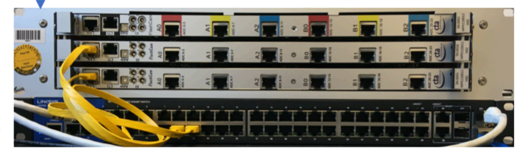
Tab. 1 Compatibility of the proposed combinations and options—green: compatible, yellow: disfavoured, red: incompatible.

PBS Item		Option	Multi-pixel DOMs	Active Cells	Passive Cells
WCD Mechanics	Water Container	Bladder in tank			
		Bladder in matrix			
		Bladder in lake			
		Segmented pool & roof			
	Optical Separator	None			
		Divider			
Photodetectors	Detector & Base	Single PMTs			
		Single SiPM array(s)			
		Multi-pixel module			
		Matrix of PMTs/SiPMs			
	Magnetic Shield	None			
		Mu-metal cylinder			
	Light Guide	None			
		Winston cone			
		Baffle			
		WLS fibres			
Electronics Chain	Photodetector Supply	Multi-channel HV			
		Active base			
	Signal pick-off and Shaper	Active			
		Passive			
	Digitiser	Sampling			
		TDC/ToT			
	Cabling and Connectors	Coaxial			
		Differential			
		Optical			
	Timing Distribution	WR-like			
		RapCal-like			

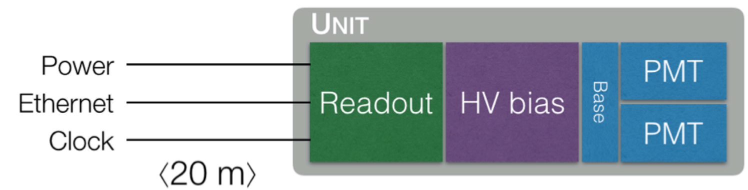
Nodes (like HAWC outriggers)

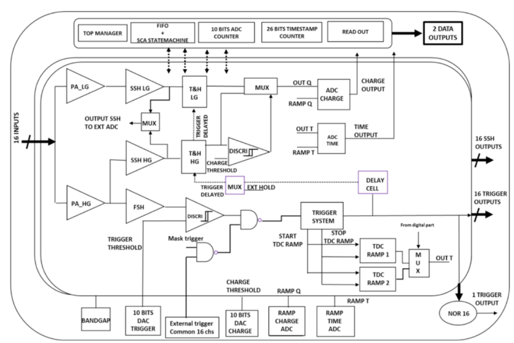


e.g. rack-based 250 MS/s ADCs with GbE readout + HV/pick-off boxes



Smart units (like IceCube)

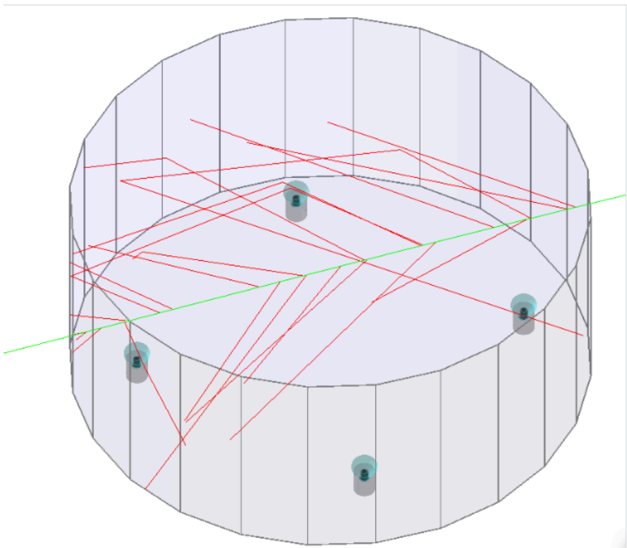


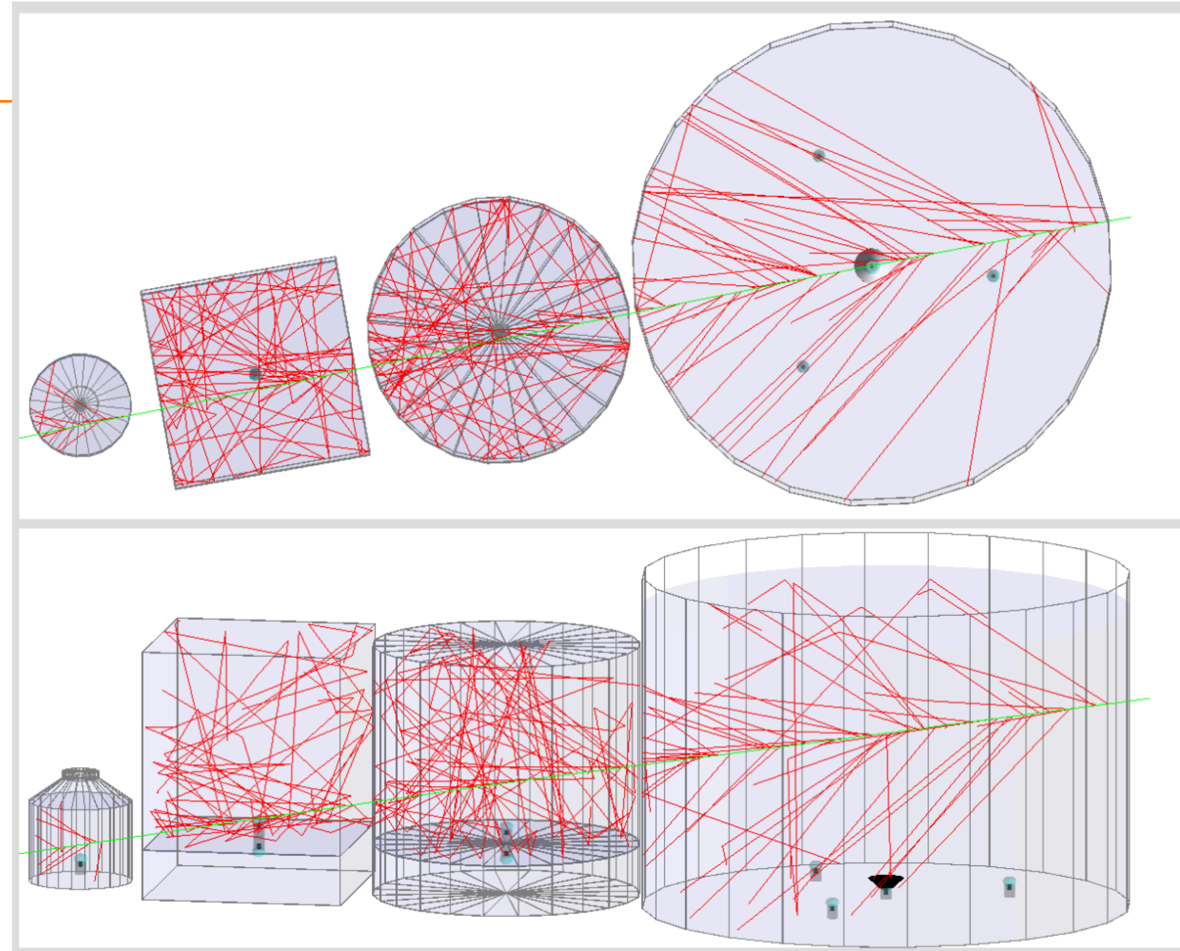


Adapted IceCube Upgrade mDOMS?

Multi-sensor, CATIROC?

Simulations



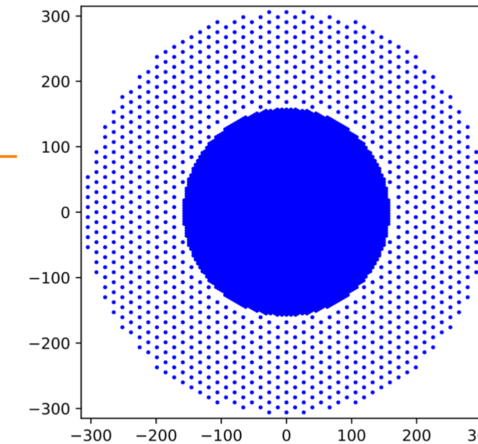


CORSIKA + GEANT4
Building on HAWC simulation & analysis framework

Reference Configuration

- Defining right now a ‘Reference Configuration’
  - Plausible and costable, not yet optimised
  - Start point for simulations and analysis development
- Simulate a ‘super-configuration’
  - Subset is Reference Configuration
  - Simultaneously test:
    - ✓ Single layer, multi-sensor v double layer
    - ✓ White v. black walls
    - ✓ Larger/smaller arrays
    - ✓ Higher QE PMTs, etc, etc

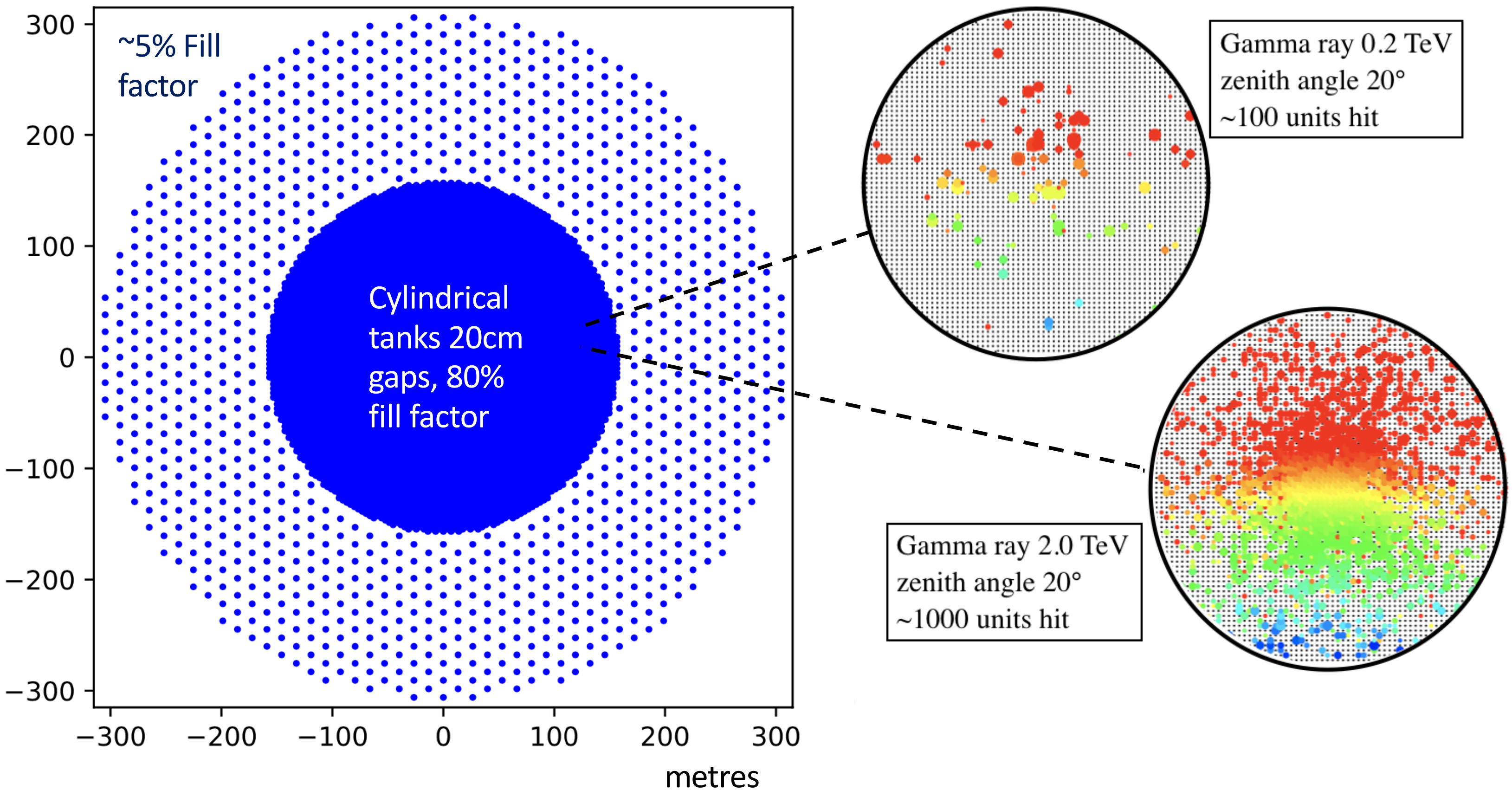
80% Fill factor inner region 160m radius



Reference PMT HPK R5912 (8’)

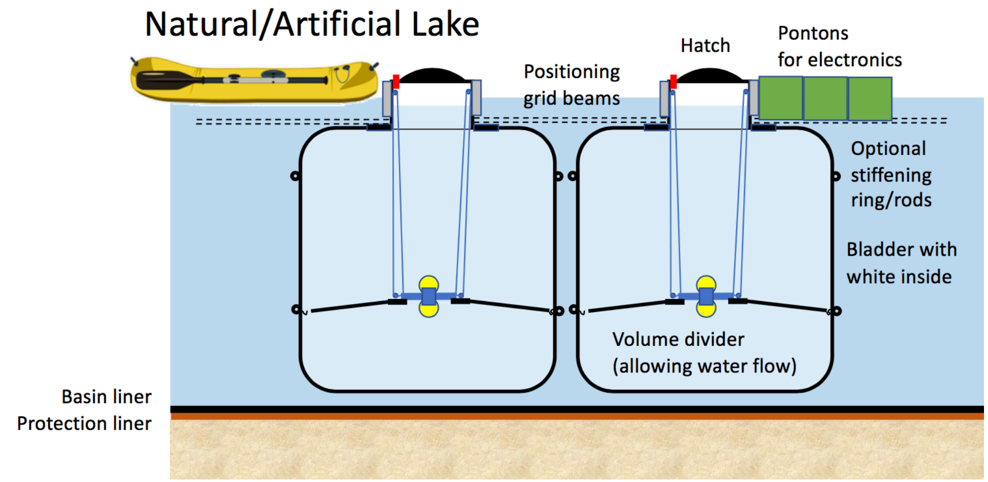
Reference tank size – 3.9m diam., 2.5m deep

Events



~5% Fill factor
Cylindrical tanks 20cm gaps, 80% fill factor
300
200
100
0
−100
−200
−300
−300
−200
−100
0
100
200
300
metres
Gamma ray 0.2 TeV
zenith angle 20°
~100 units hit
Gamma ray 2.0 TeV
zenith angle 20°
~1000 units hit

Lake Concept



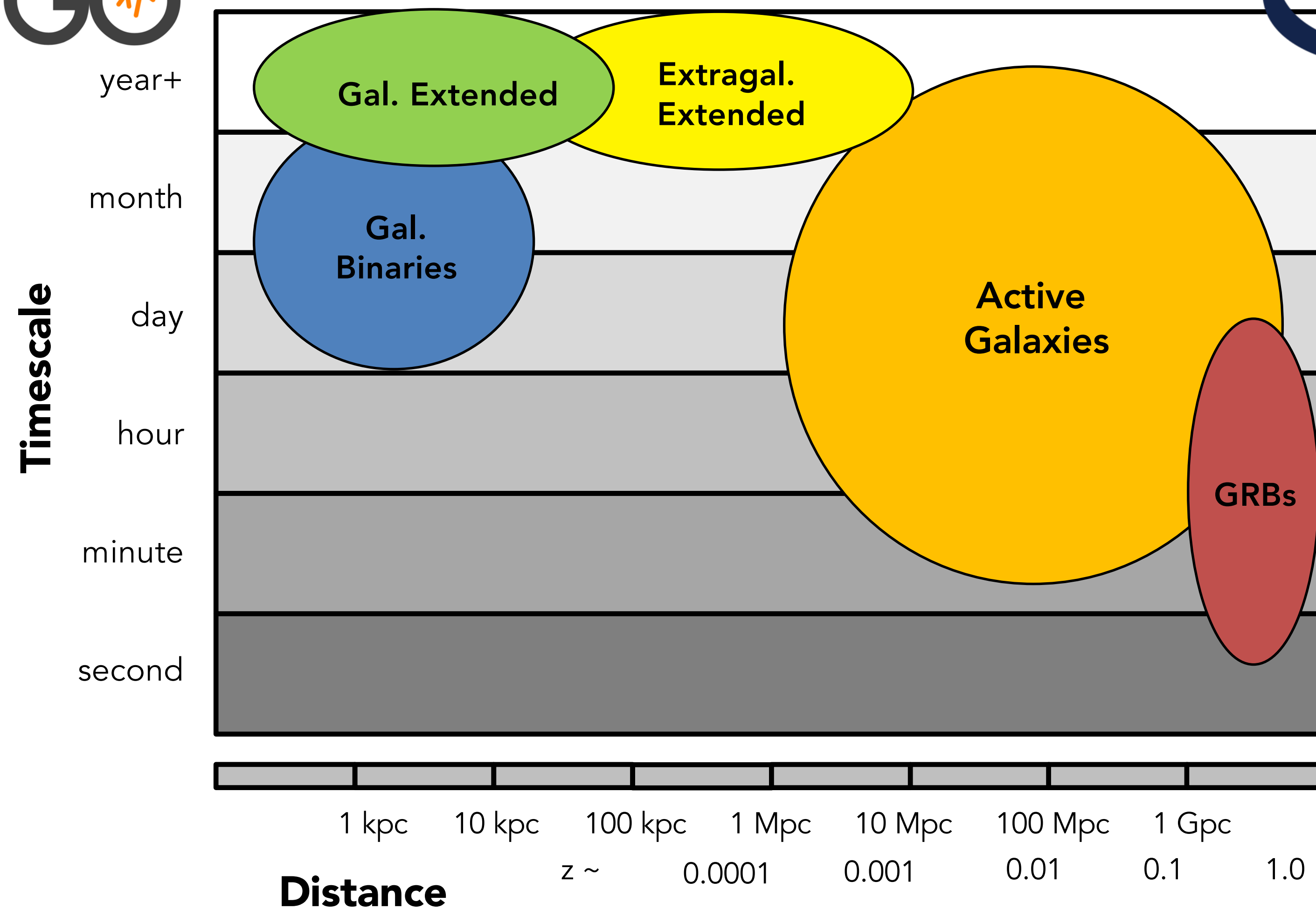
- Test facility just being finished at MPIK

10m diam, 6m high

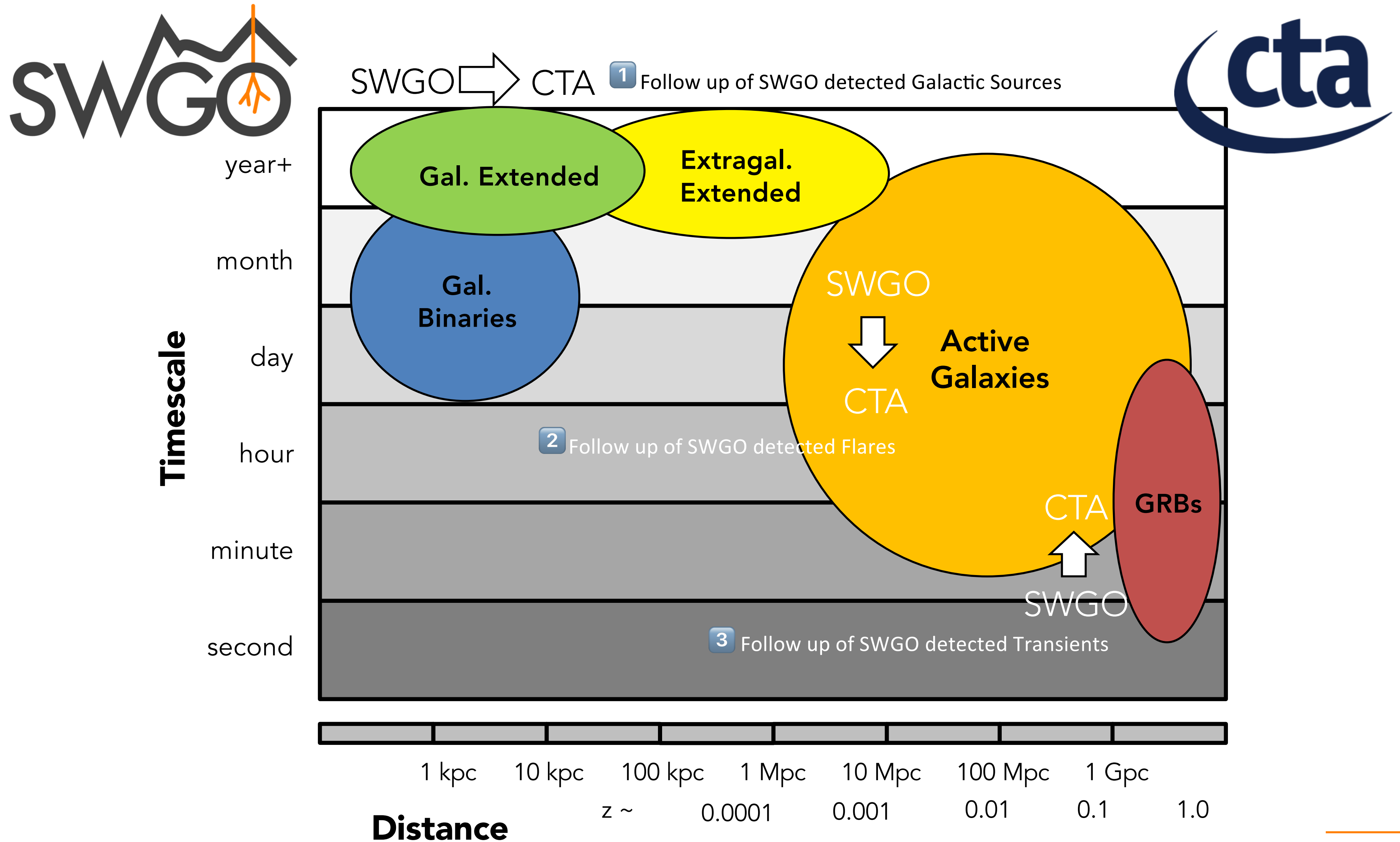
Science Performance Benchmarks

SCIENCE CASE	BENCHMARK	Instantiations	Crucial design parameter	Crucial design parameter	Added Value	Latitude
Short-timescale phenomena	Minimum transient timescale at 5-sigma detection level for given observed spectra/flux	(i) Number of GRB triggers per year (ii) Number of AGN flare alerts per year	Detection low-energy threshold	Real-time analysis /trigger capability	Unique VHE South trigger instrument	N/A
PeVatrons & UHECRs	Max energy of exponential cut off in PWL spectra detected at 95% C.L. for given ref flux level.	(i) Number of PeVatrons detected?	Flux Sensitivity at 100+ TeV	Energy resolution better than at 100 TeV	Unique for PeV census & CenA	Lat S > 15 deg
PWNe and Haloes	Minimum distinguishable spectral index between two PWL spectra for a given angular size (TBD ref. flux level and energy scale)	(i) Number of (spectrally resolved) PWNe detected (ii) Number of (resolved) haloes detected	Flux sensitivity at 10s TeV	Angular resolution at few 10s TeV	Unique Galactic Plane access	Lat S < 25 deg
Diffuse emission	Level of residual charged cosmic-ray background for diffuse gamma detection at 30 TeV	gamma/hadron separation level at 1E-5 at 30 TeV	Flux sensitivity at 20+ TeV	Gamma/hadron separation power at 20+ TeV	Detectability of diffuse emission below 100 TeV	Lat S > 15 deg
Dark Matter	Sigma-v limit attainable as a function of energy for GC.	(i) Limits for GC and Halo (ii) Limits from Dwarfs	Flux sensitivity at 100 TeV	Energy resolution better than 15% at 100 TeV	Unique probing capability wrt to any instrument	Lat S > 15 deg
Cosmic-ray anisotropy	Minimum detectable amplitude to a dipole anisotropy at given PeV scale; **AND** Maximum multipole order detectable at 5-sigma level @ 10 TeV	**Long term:** minimum detectable amplitude for 10 deg scale @ 100 TeV?	Extended FoV	Energy resolution at 10 TeV	Unique LHAASO complement to full sky coverage	Lat S range : [-40, -10] deg
Cosmic-ray composition	δA/A < 0.8 at PeV scale	May be expanded to include mass-resolved anisotropy sensitivity for e.g. p+ and Fe.	Mass resolution = good muon tagging		Unique among any instrument	N/A
Survey	Survey depth for point sources after 1 year and 5 years integration time for Z < 30°	Number of expected source detections for selected object classes?	Point source sensitivity		Unique sky coverage	N/A

- Science Benchmarks under development → optimisation of the detector design for best science performance

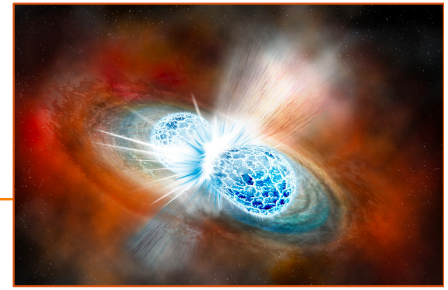


Timescale
year+
month
day
hour
minute
second
Gal. Extended
Extragal.
Extended
Gal.
Binaries
Active
Galaxies
GRBs
1 kpc
10 kpc
100 kpc
1 Mpc
10 Mpc
100 Mpc
1 Gpc
z ~
0.0001
0.001
0.01
0.1
1.0
Distance

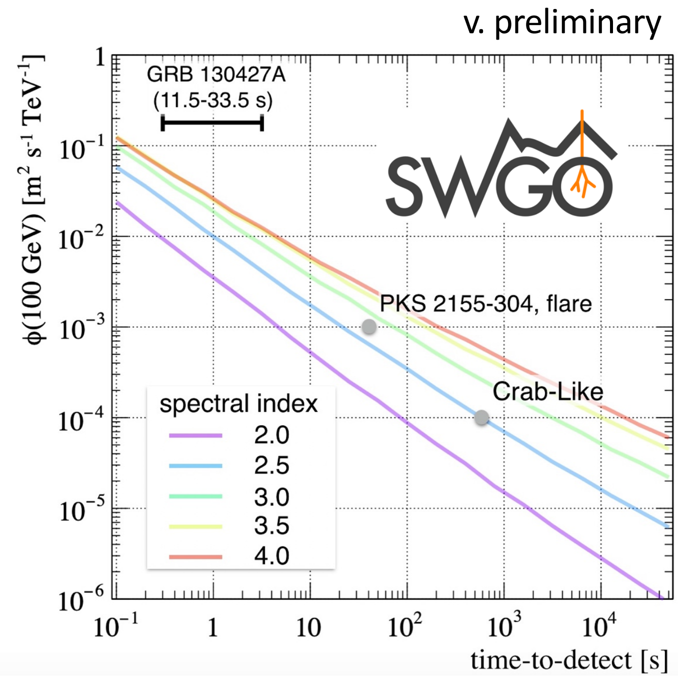


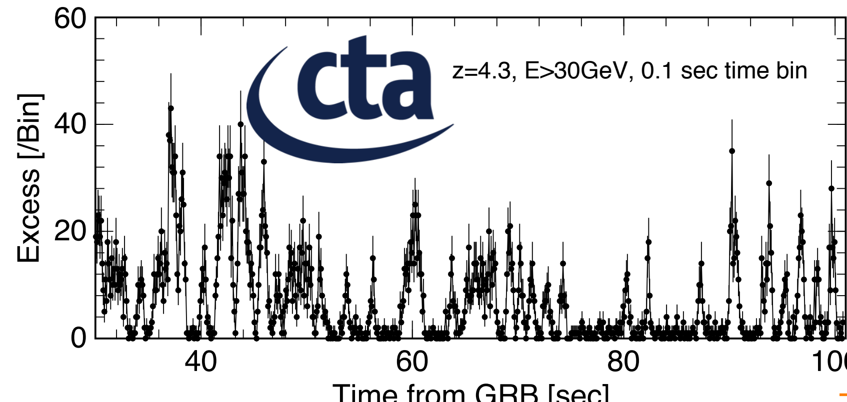
SWGO
cta
SWGO → CTA
1 Follow up of SWGO detected Galactic Sources
year+
month
day
hour
minute
second
Timescale
Gal. Extended
Extragal. Extended
Gal. Binaries
SWGO
CTA
Active Galaxies
2 Follow up of SWGO detected Flares
CTA
GRBs
SWGO
3 Follow up of SWGO detected Transients
1 kpc
10 kpc
100 kpc
1 Mpc
10 Mpc
100 Mpc
1 Gpc
z ~
0.0001
0.001
0.01
0.1
1.0
Distance

GRBs



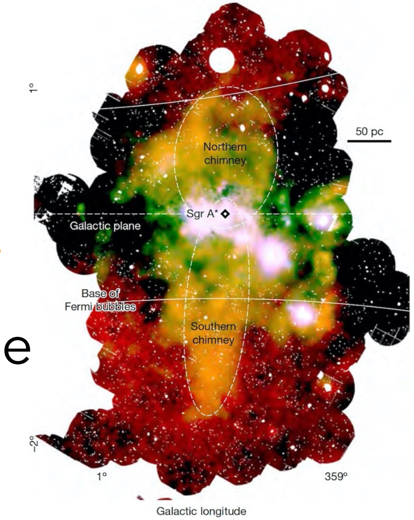
- The big news of 2019
  - → 3 GRB detections - HESS+MAGIC
  - → Emission up to ~TeV established
  - → Emission deep in to afterglow
  - → All Swift-BAT triggers
- Most GRBs are not well localised
  - → BAT FoV is 1.4 sr
  - → SWGO as a finder for VHE bursts →triggers to CTA
- Also GW error boxes…



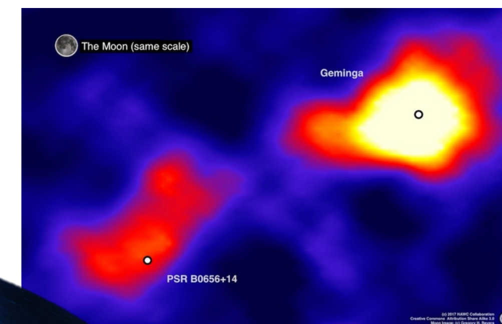


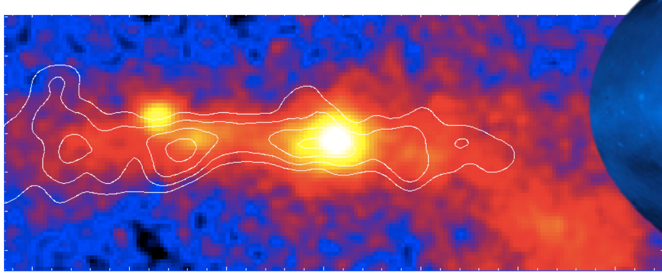
CTA simulation based on GRB 080916C

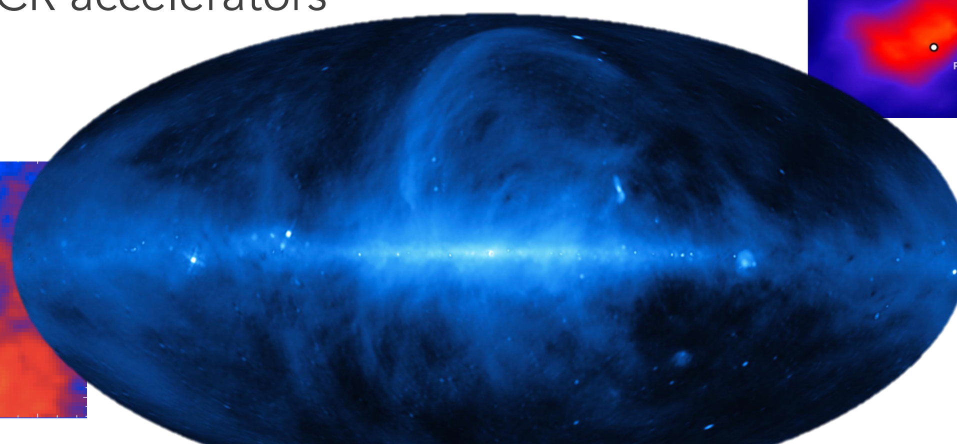
Large-scale emission



- CTA will give the detailed view of the Galactic Plane
- SWGO?
  - Local (off-plane, large angular size) sources
  - Diffuse Galactic Emission (e.g. atomic gas and IC emission up to large scale heights)
  - CMZ → Chimneys → Fermi Bubbles
  - 'Halos' around CR accelerators
  - WIMP search







Large-scale emission

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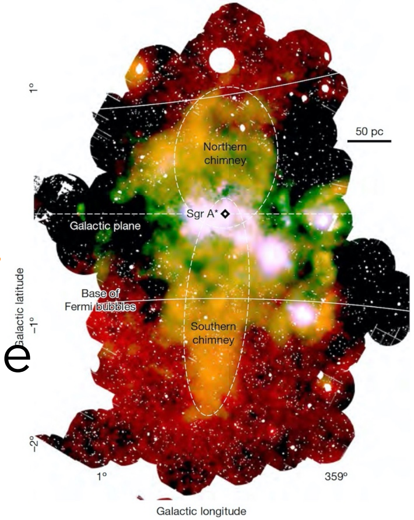
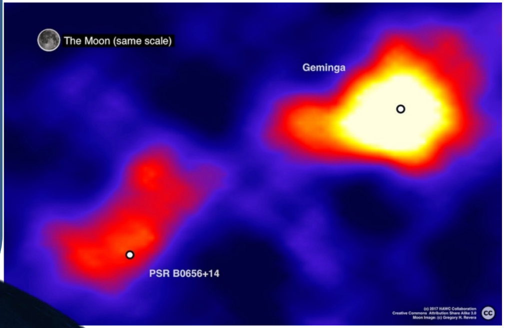
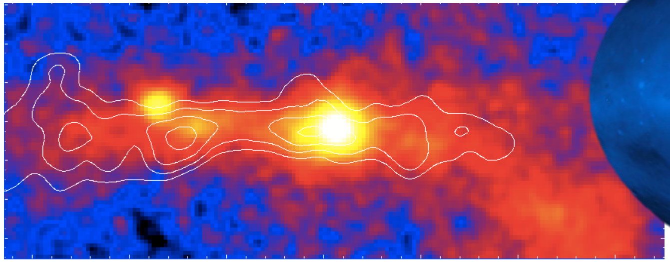
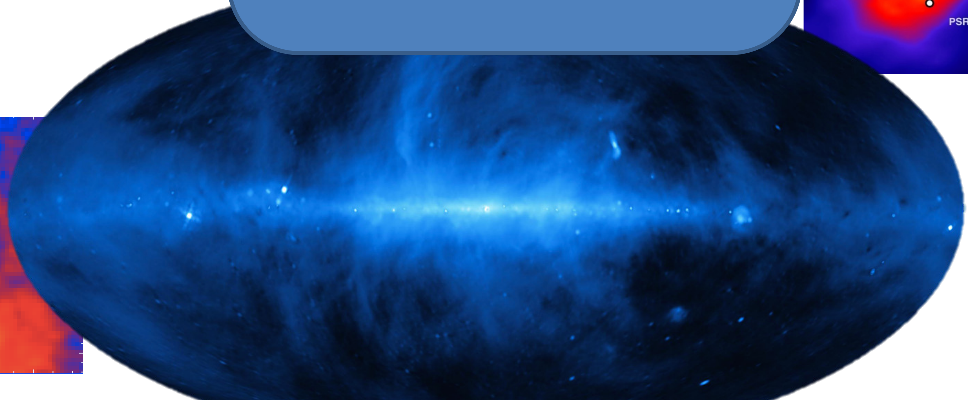
    emission up to large scale
  - CMZ → Chimneys → Ferm
  - 'Halos' around CR accelera
  - WIMP search

SWGO+LHAASO: Very powerful in combination with the neutrino sky from IceCube-Gen2. & KM3Net: ARCA



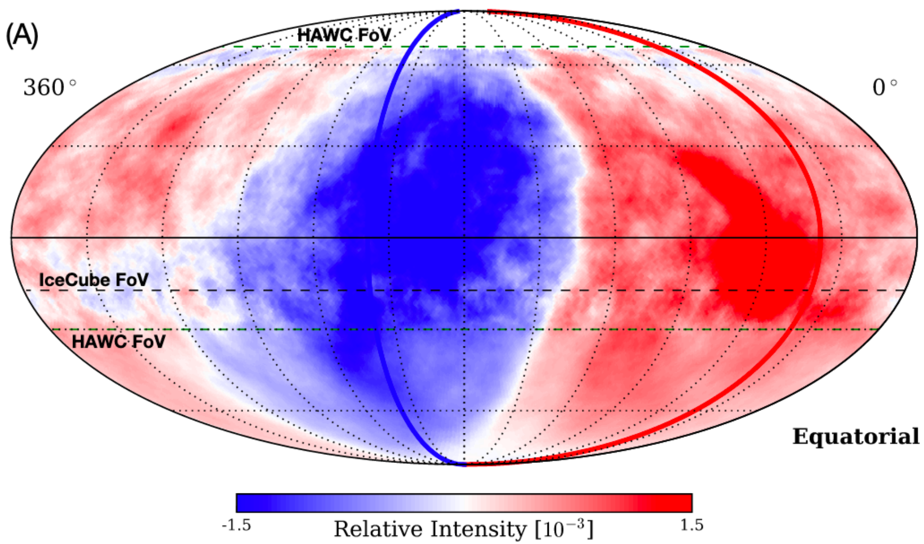






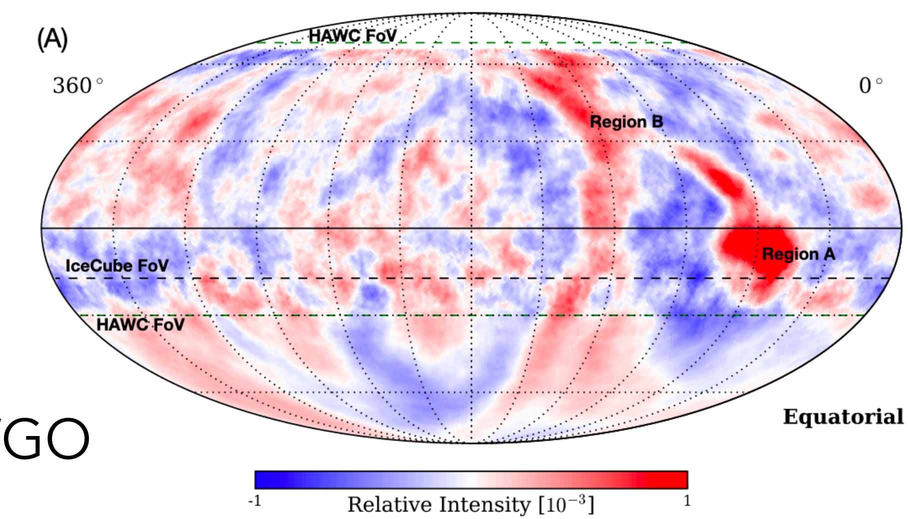
Cosmic ray measurements

- In particular – **anisotropy**



→ *Understanding interstellar turbulence and local CR sources*

arXiv:1812.05682



- HAWC+IceCube → LHAASO+SWGO

Conclusions

- Strong motivation for a southern hemisphere wide field of view high duty cycle detector!
  - SWGO – 3 year design/preparation period → project launch!
- Strong complementarity between SWGO & CTA
  - Detecting hard spectrum sources → CTA follow-up
  - Triggering CTA: flares and transients
  - Large scale emission complementing CTAs detailed view
- **SWGO & LHAASO**
  - **Huge potential for scientific and technical synergies!**
  - **SWGO collaboration very enthusiastic about collaboration**

Fermi, NASA