The Science Case for a Southern Gamma-ray Survey observatory

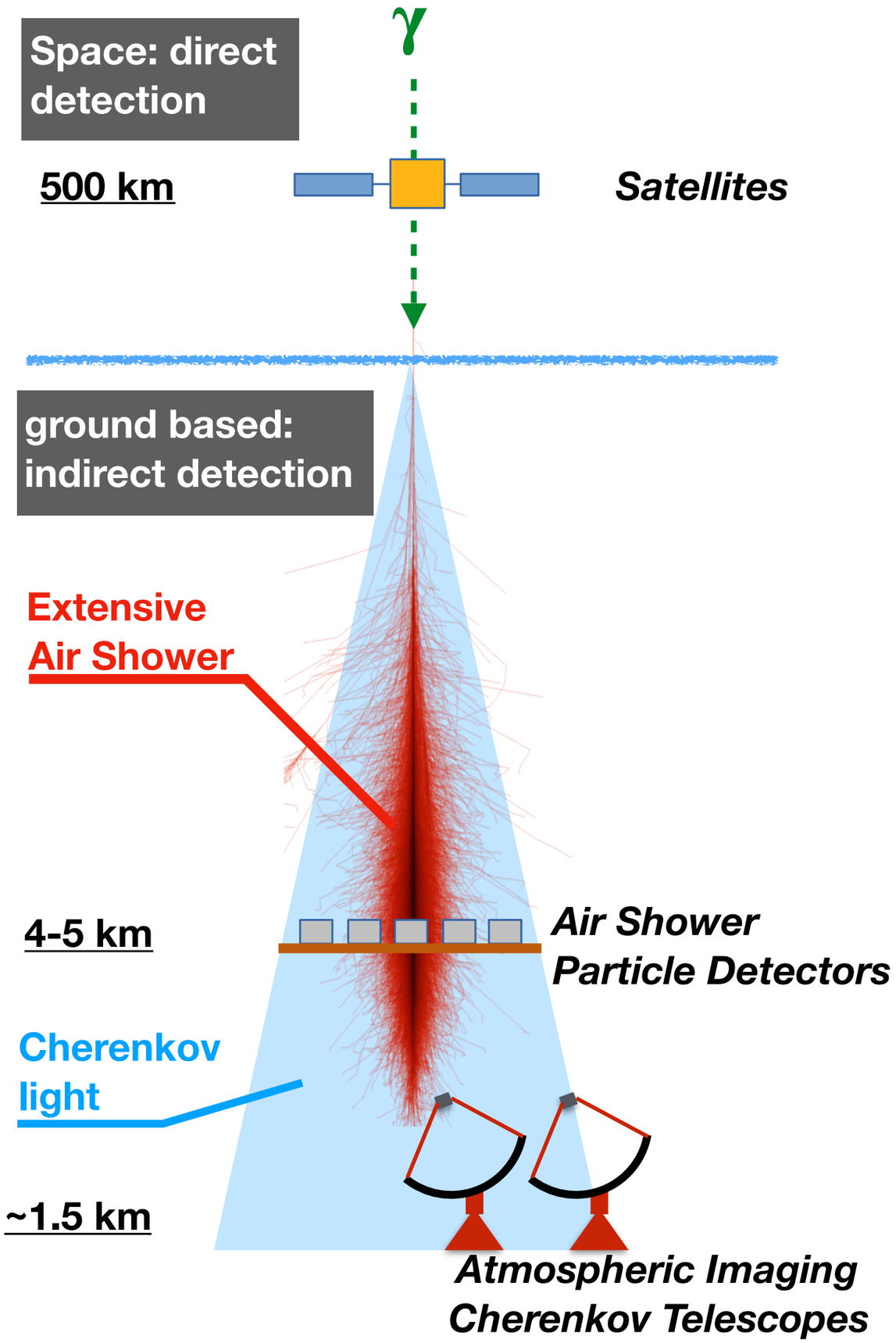
Harm Schoorlemmer,
on behalf of the SGSO-alliance

SOUTHERN GAMMA-RAY SURVEY OBSERVATORY

www.sgso-alliance.org

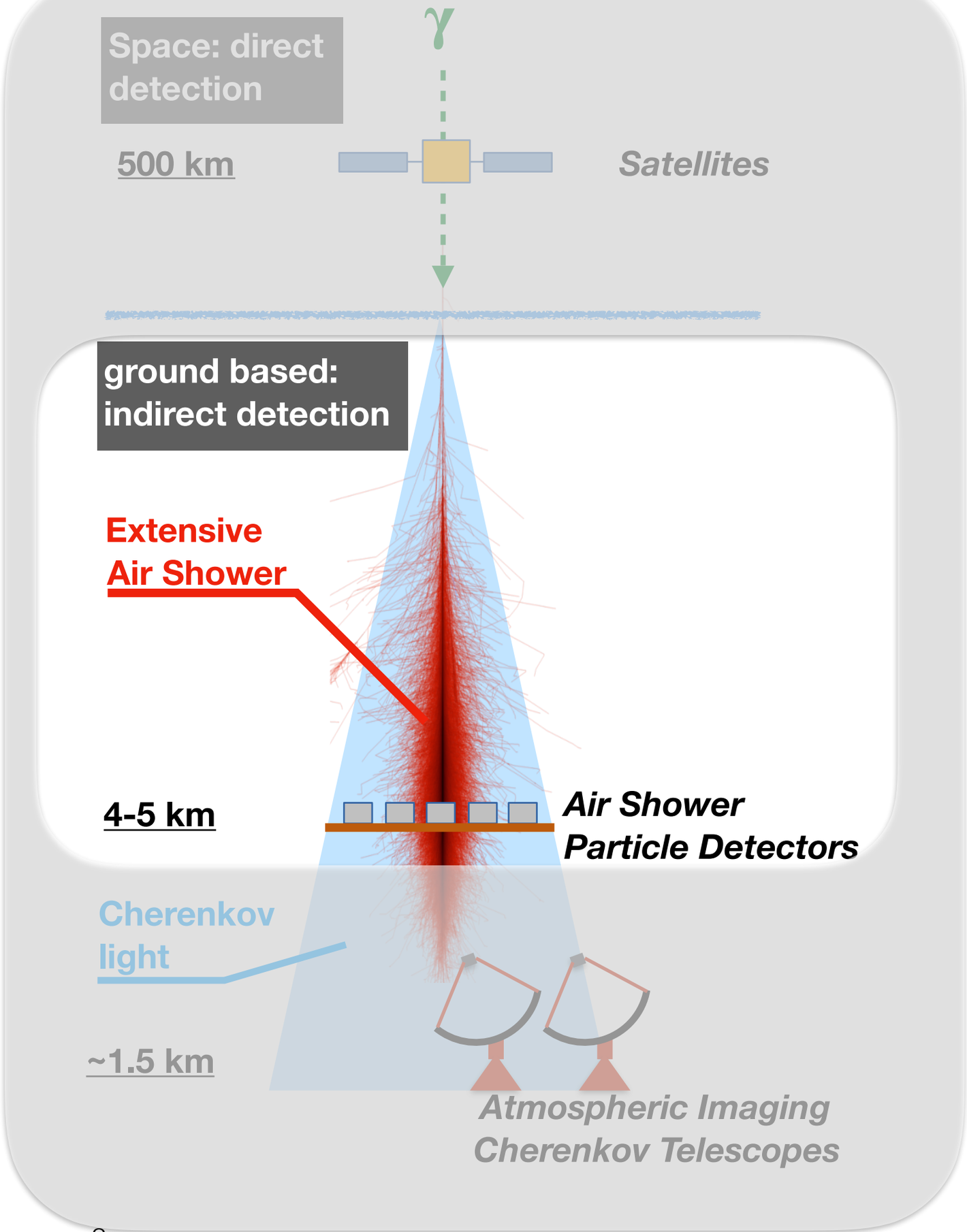
MAX-PLANCK-INSTITUT FÜR KERNPHYSIK

Detection techniques in very-high-energy gamma-ray astronomy

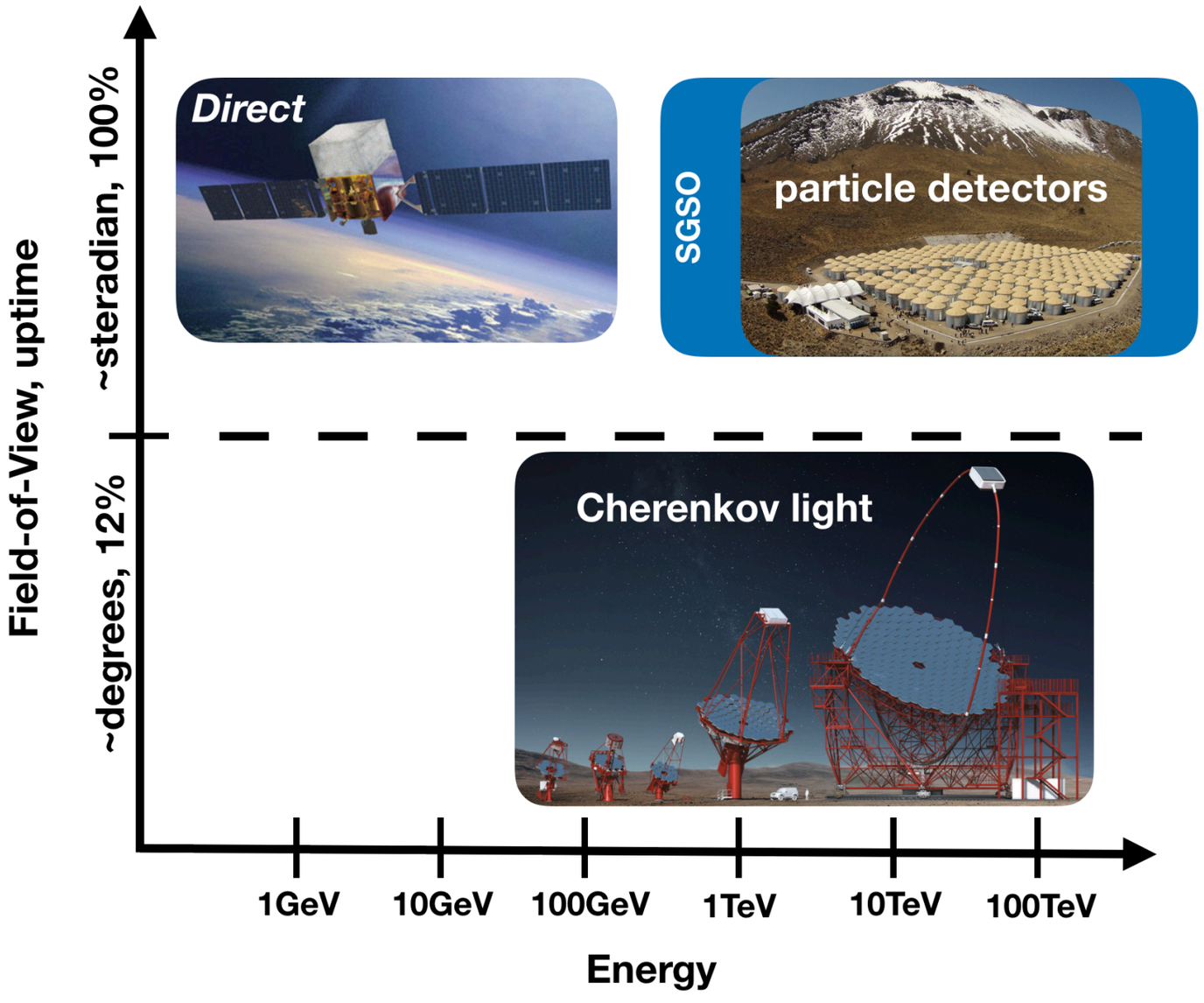


Detection techniques in very-high-energy gamma-ray astronomy

HAWC
High Altitude Water Cherenkov
Gamma-Ray Observatory



Overlap and Complementarity



Particle Detectors

Pros*	Cons*
Accurate Background estimation	Poorer energy resolution
Continuous monitoring	Poorer angular resolution
Large Aperture	Lower instantaneous sensitivity
High Energy Reach	Higher Energy threshold
Archival Data	

**with respect to IACTs*

SOUTHERN
GAMMA-RAY
SURVEY
OBSERVATORY

Who are we?…

The alliance

- Advancement of this effort in the Southern-Hemisphere
- **Organizing the writing of a white-paper on the science case**
- Documentation on site-candidates
- No decision on technical design (for now)
- Currently **84 members** from **12 countries**
- Next meeting **8-9 October Heidelberg**, Germany

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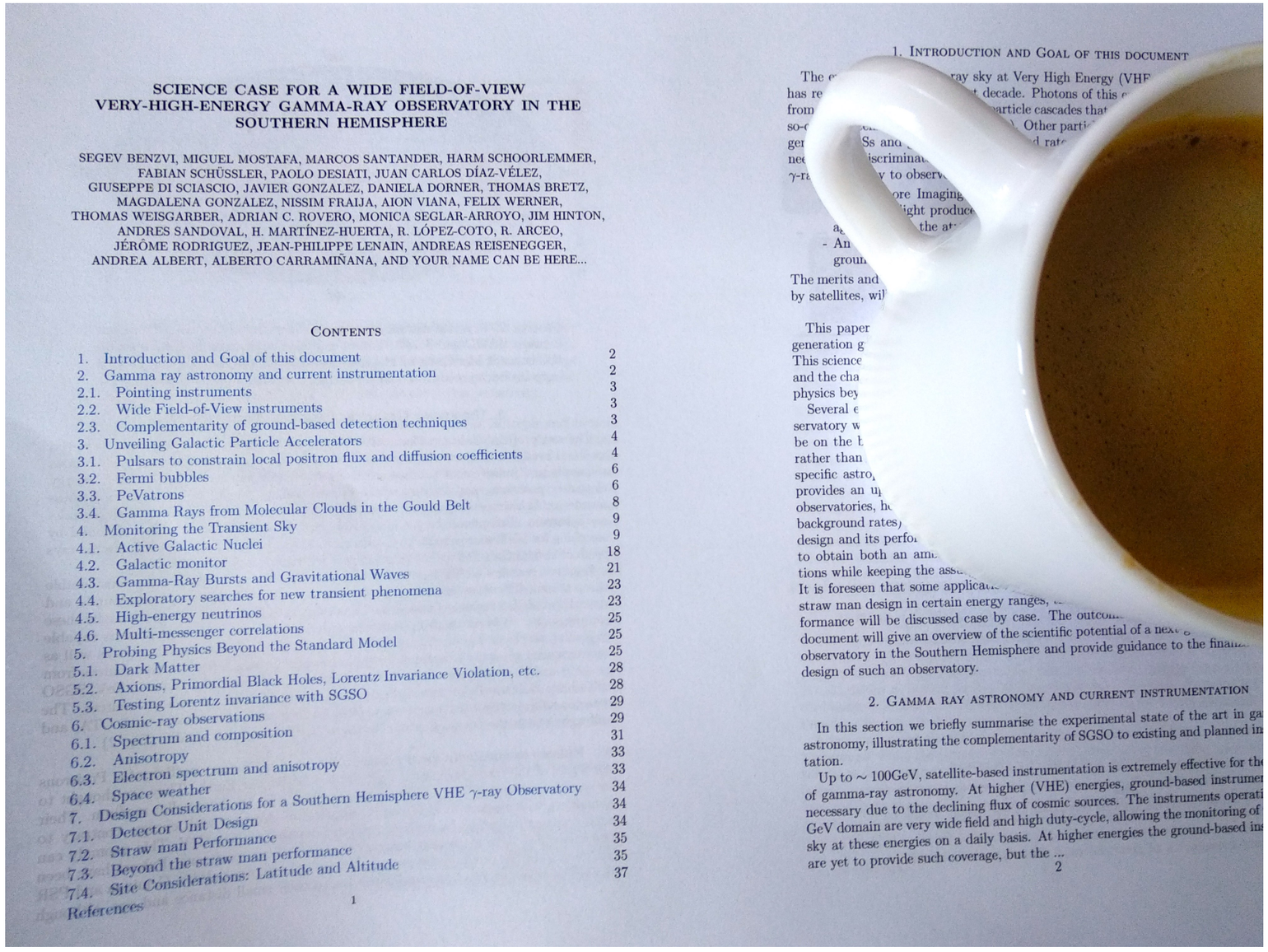
Defining the science case

White Paper:

- Community wide contributions
- Focus on how the science will drive detector requirements
- First version ready this Fall
- Public tools for writing and calculations
- Regular calls for coordination



SCIENCE CASE FOR A WIDE FIELD-OF-VIEW VERY-HIGH-ENERGY GAMMA-RAY OBSERVATORY IN THE SOUTHERN HEMISPHERE

SEGEV BENZVI, MIGUEL MOSTAFA, MARCOS SANTANDER, HARM SCHOORLEMMER, FABIAN SCHÜSSLER, PAOLO DESIATI, JUAN CARLOS DÍAZ-VÉLEZ, GIUSEPPE DI SCIASCIO, JAVIER GONZALEZ, DANIELA DORNER, THOMAS BRETZ, MAGDALENA GONZALEZ, NISSIM FRAIJA, AION VIANA, FELIX WERNER, THOMAS WEISGARBER, ADRIAN C. ROVERO, MONICA SEGLAR-ARROYO, JIM HINTON, ANDRES SANDOVAL, H. MARTÍNEZ-HUERTA, R. LÓPEZ-COTO, R. ARCEO, JÉRÔME RODRIGUEZ, JEAN-PHILIPPE LENAIN, ANDREAS REISENEGGER, ANDREA ALBERT, ALBERTO CARRAMIÑANA, AND YOUR NAME CAN BE HERE...

CONTENTS

1

1. INTRODUCTION AND GOAL OF THIS DOCUMENT

2. GAMMA RAY ASTRONOMY AND CURRENT INSTRUMENTATION

In this section we briefly summarise the experimental state of the art in ga
astronomy, illustrating the complementarity of SGSO to existing and planned in
tation.

Up to ~ 100GeV, satellite-based instrumentation is extremely effective for th
of gamma-ray astronomy. At higher (VHE) energies, ground-based instrume
necessary due to the declining flux of cosmic sources. The instruments operati
GeV domain are very wide field and high duty-cycle, allowing the monitoring of
sky at these energies on a daily basis. At higher energies the ground-based ins
are yet to provide such coverage, but the ...

2

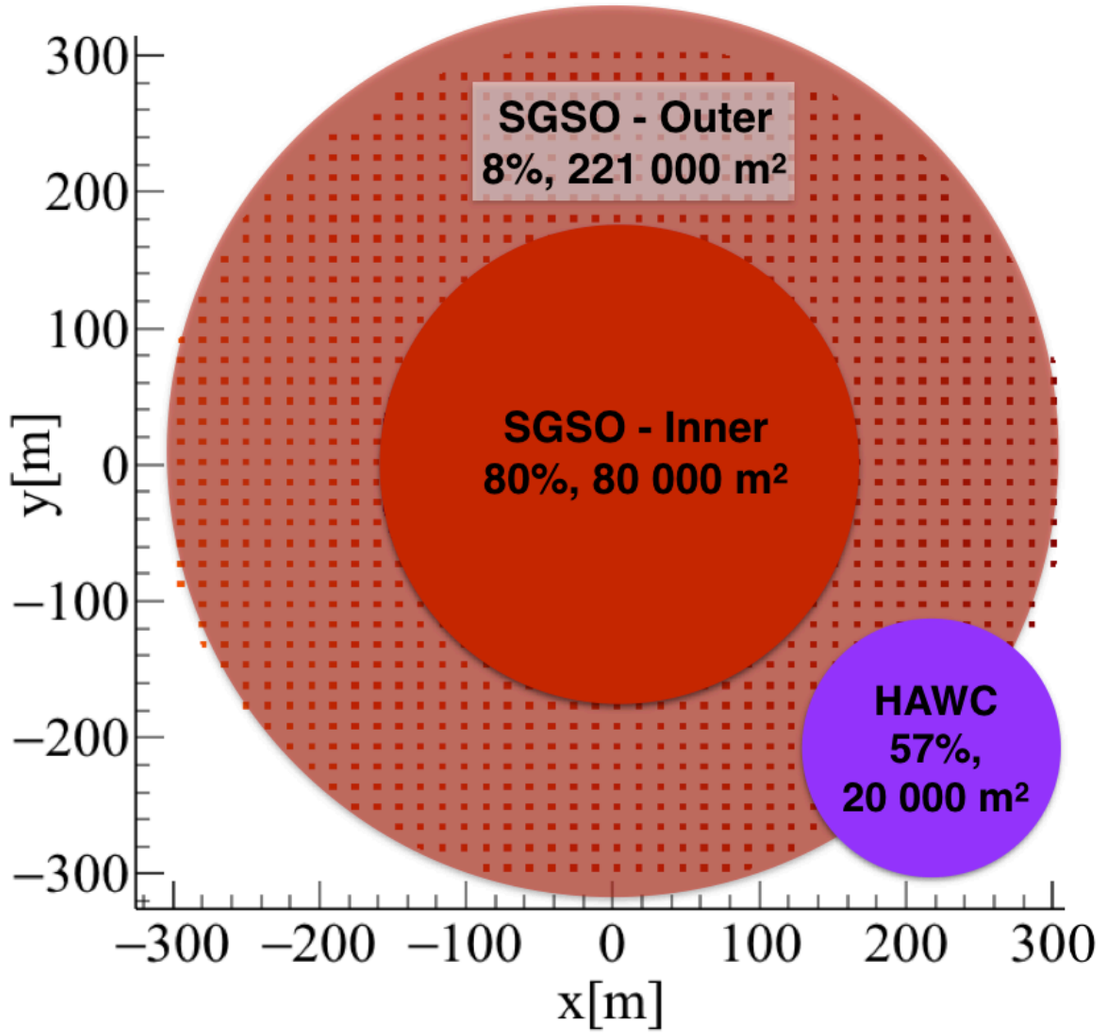
A straw mans design:
Realistic & Ambitious

HAWC performance

CORSIKA & Simple Detectors

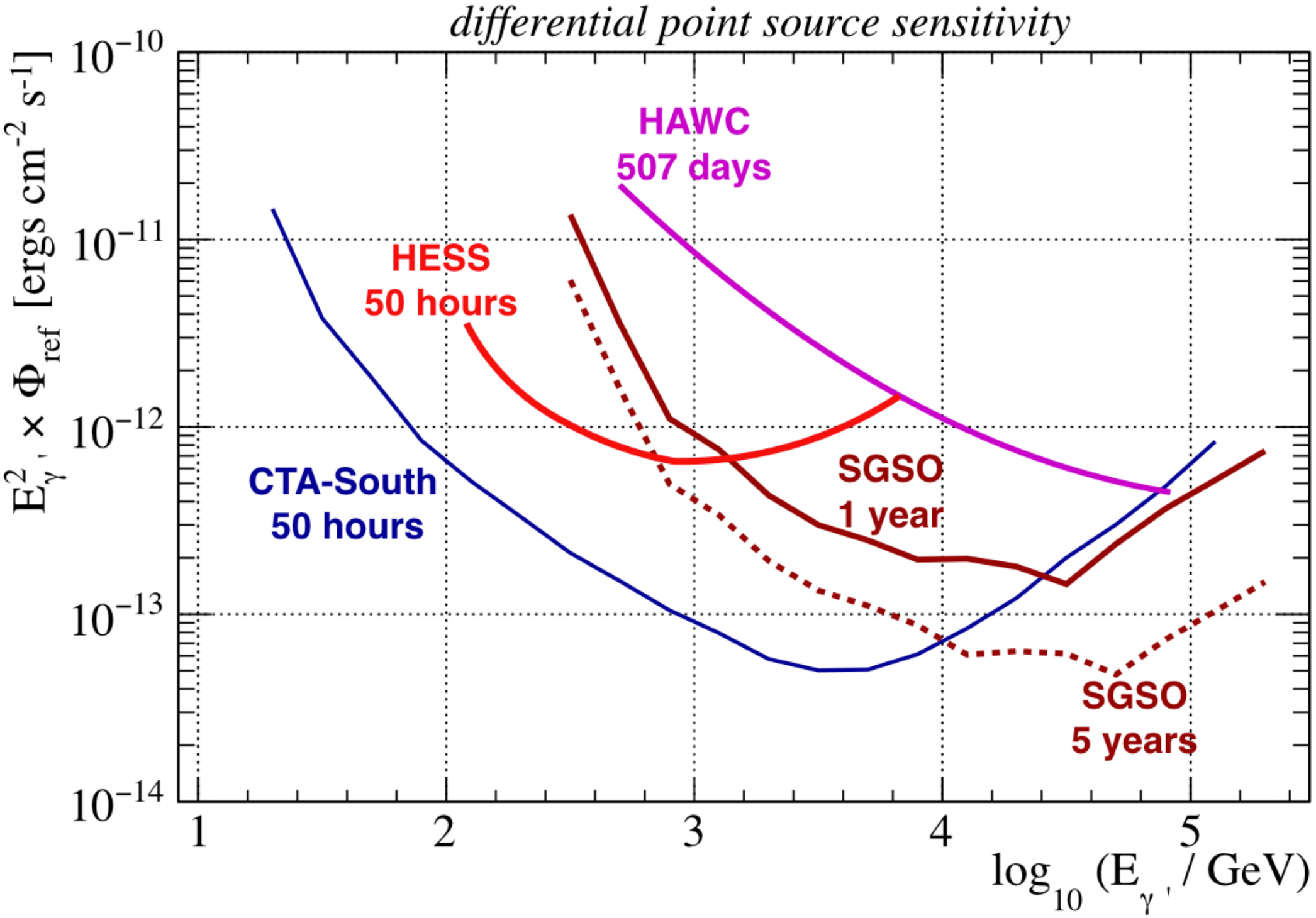
SGSO Detector Response at 5km above sea-level

Size & Fill factor



A straw mans design: Point source sensitivity

(not so important…)



The four main themes…

Galactic Particle Acceleration & Propagation

Monitoring the transient & variable sky

Physics beyond the Standard Model

Local cosmic rays (Air showers)

In the back of our minds…

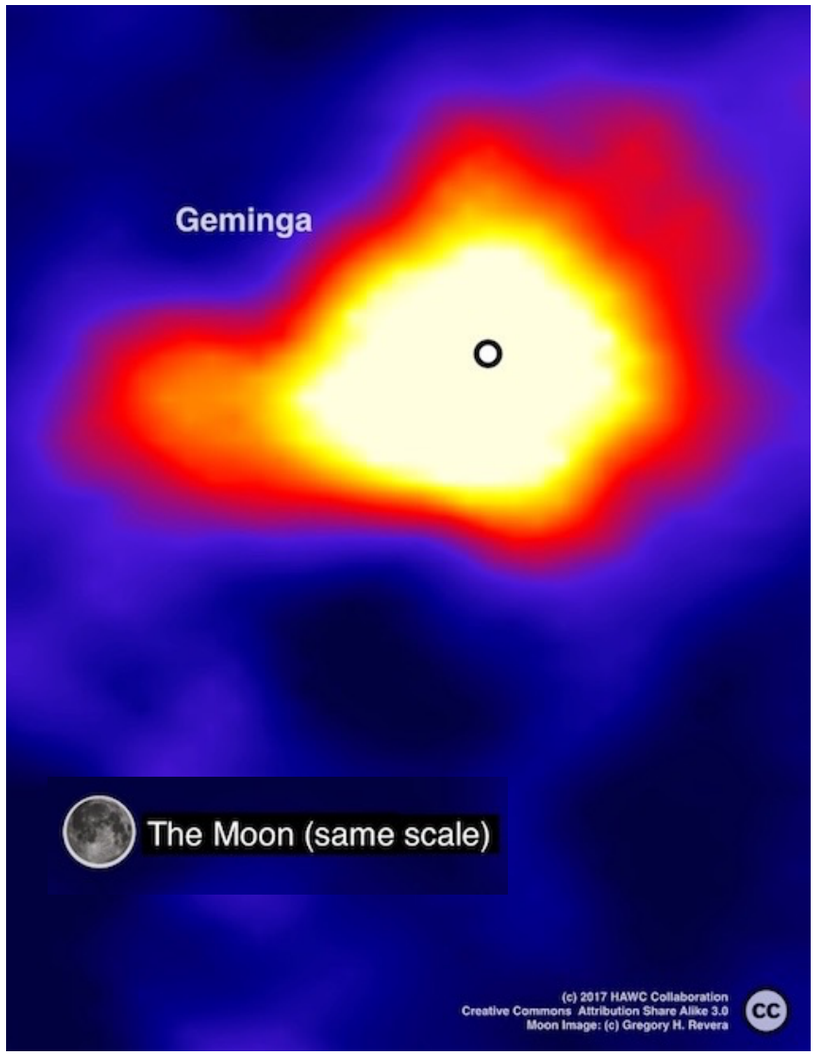
What brings SGSO to table while we have CTA?

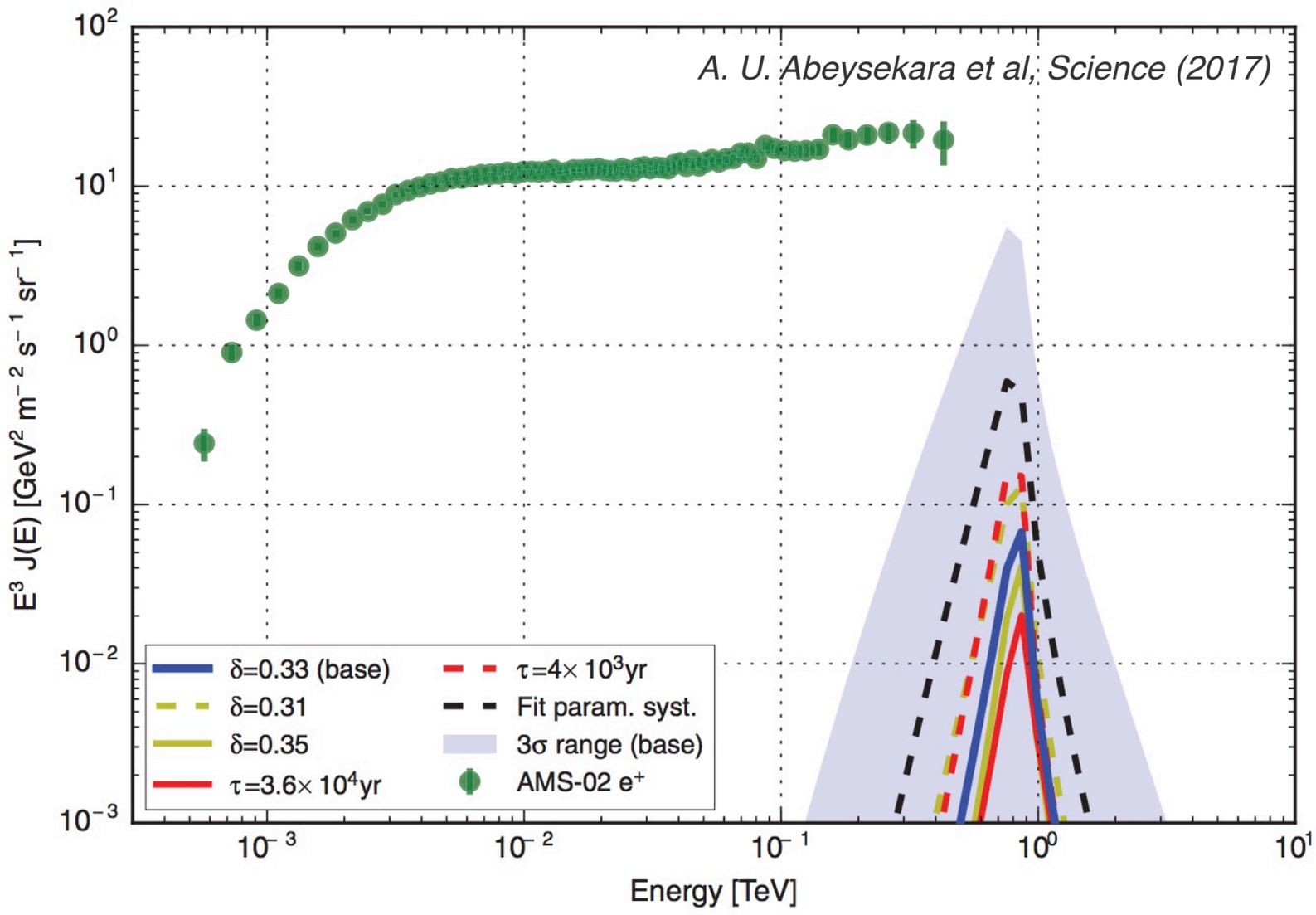
What are the design drivers?

Galactic Particle Acceleration & Propagation

Pulsars to constrain local positron flux & diffusion coefficients

Ideal source
(background rejection)





Pulsars to constrain local positron flux & diffusion coefficients

Ideal source

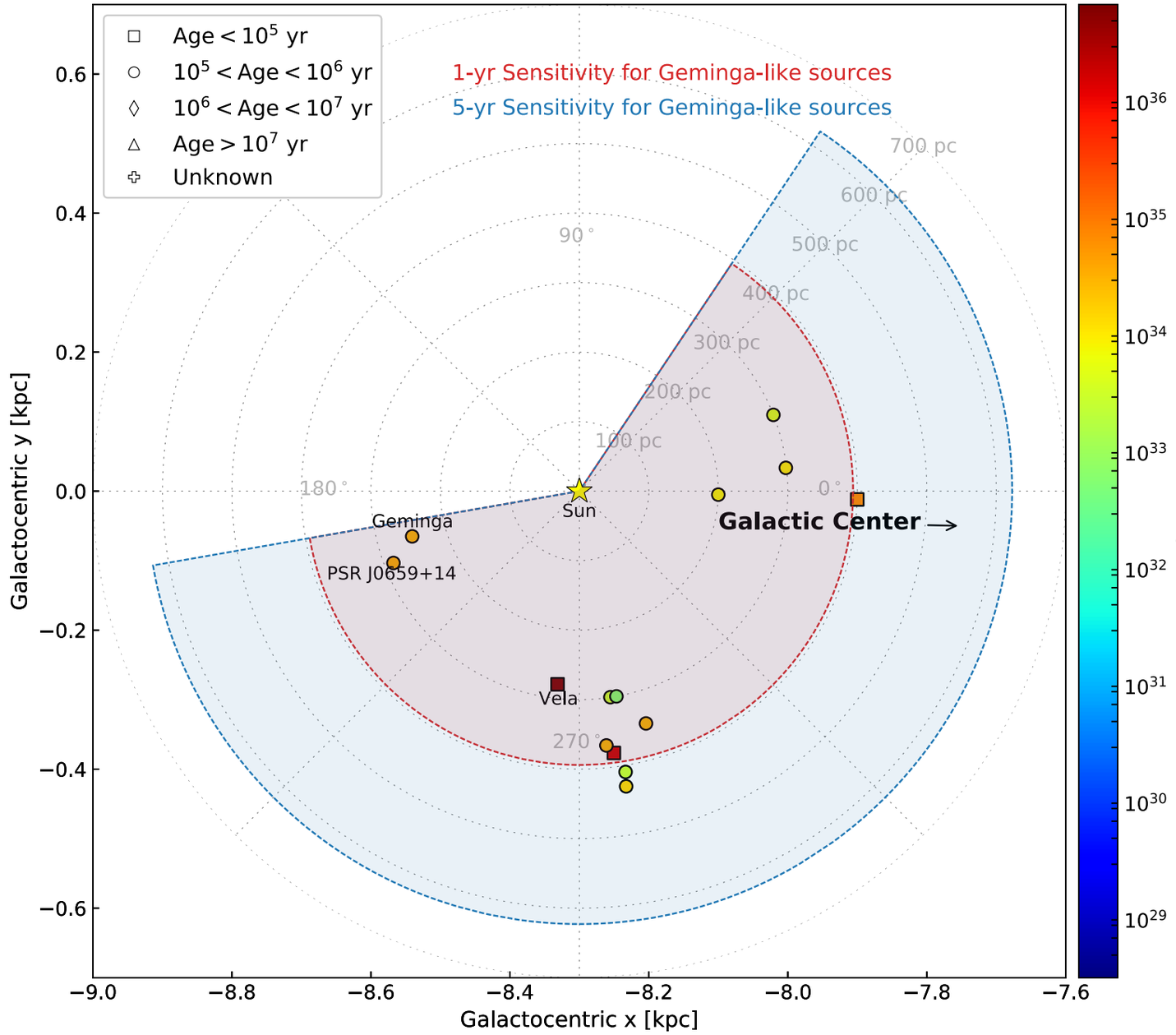
Find nearby pulsars

- Together with HAWC & LHAASO in the north almost full sky coverage
- Local sources might be away from the galactic plane

Particle propagation

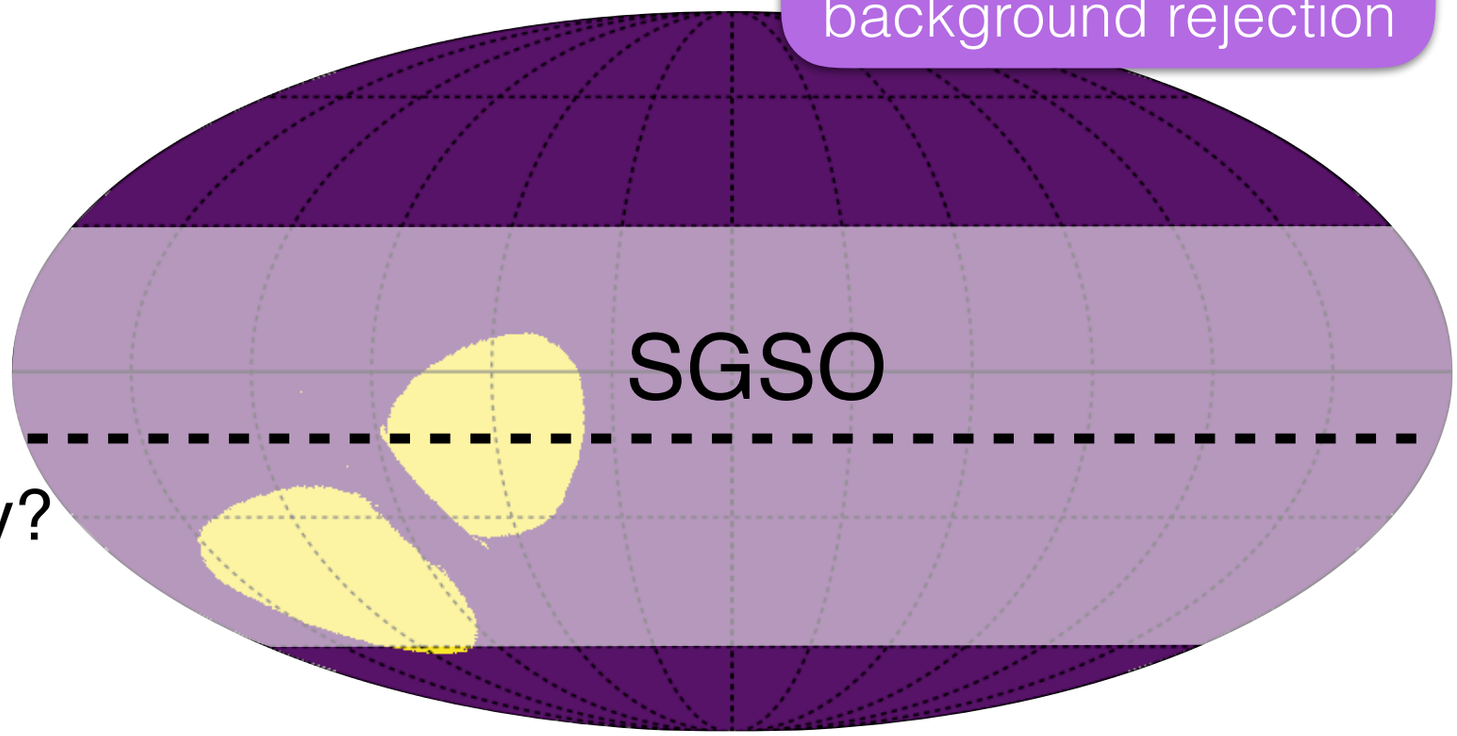
- Measure diffusion coefficients
- Constrain positron flux at the Earth
- ~10 Sources

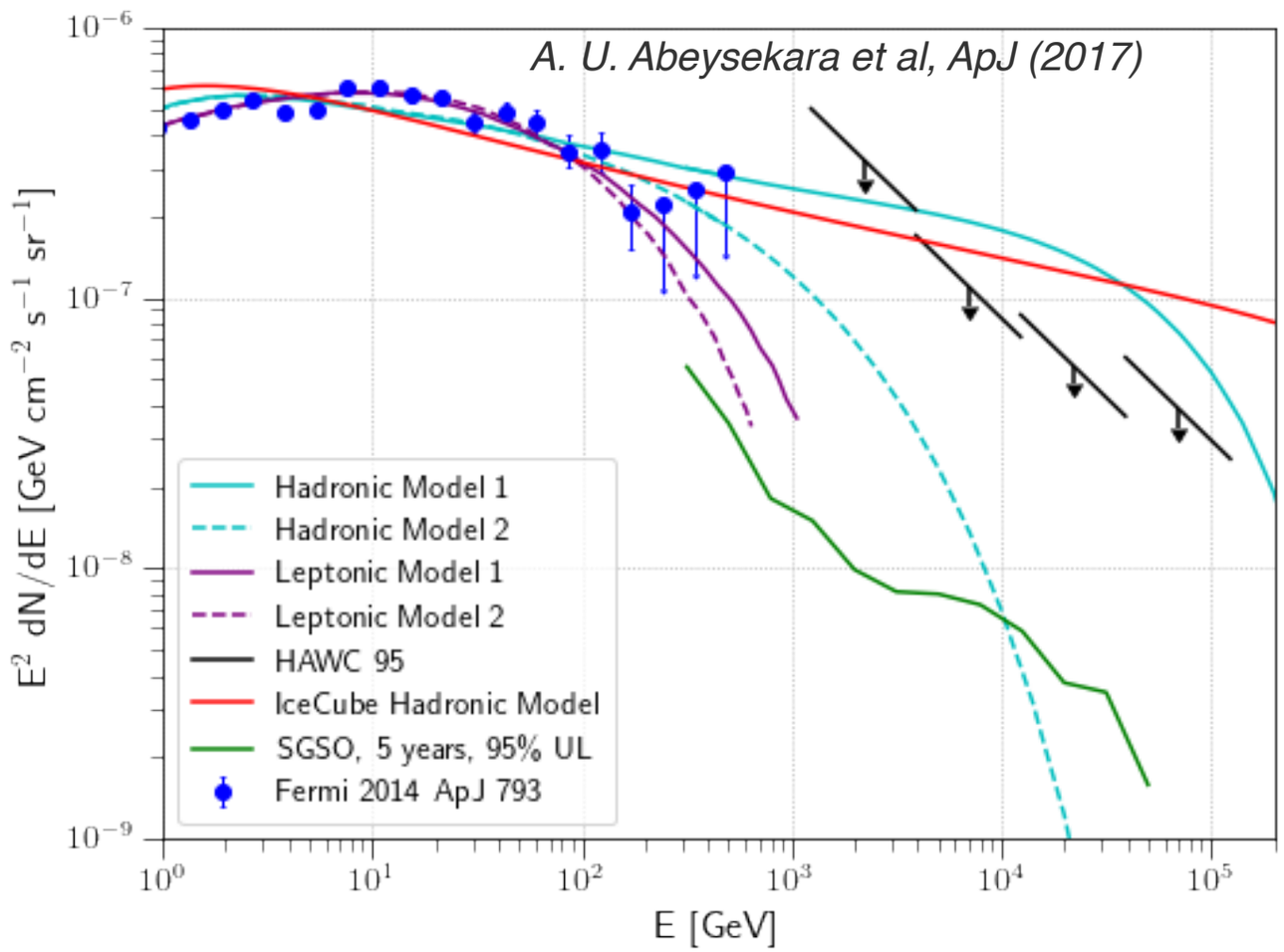
Local pulsars younger than 10^6 yr

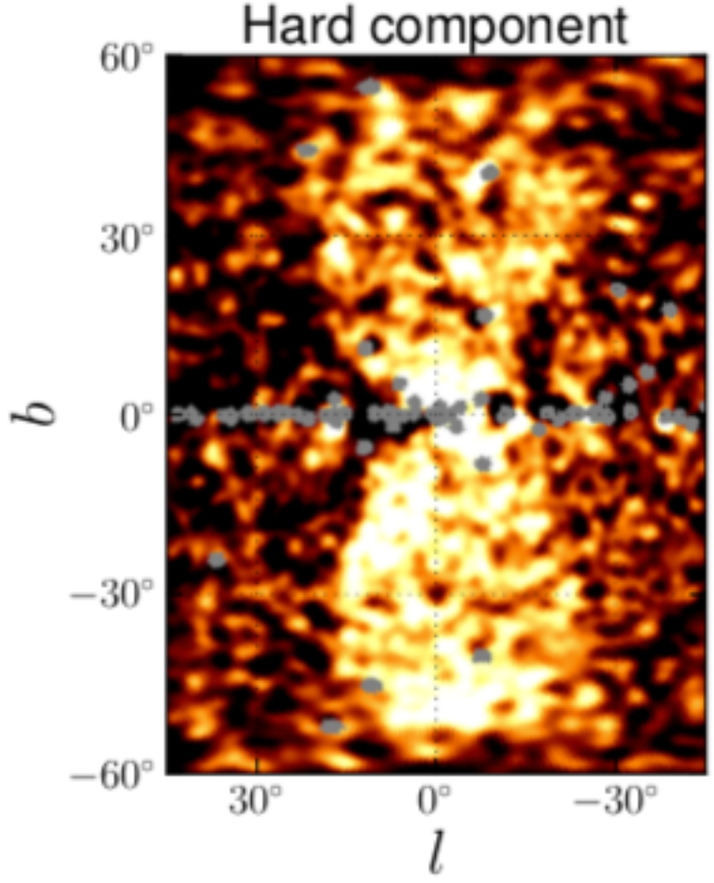


Fermi Bubbles

- Extremely extended
- Measure spectral cut-off, constrain the emission mechanism
- Energy dependent morphology?
- Define edge more accurate, helpful for CTA







M. Ackermann, ApJ (2017)

PeVatrons

Deeper and more detailed observations with CTA on individual sources

However, SGSO can provide the deepest unbiased survey at the highest energies

- Find new faint hard spectra sources
- Measure cut-offs for the majority of sources
- Verify observations of CTA with different systematics

High energy reach

Galactic Variable sources

Deeper and more detailed observations with CTA on individual sources

However, SGSO will measure every day

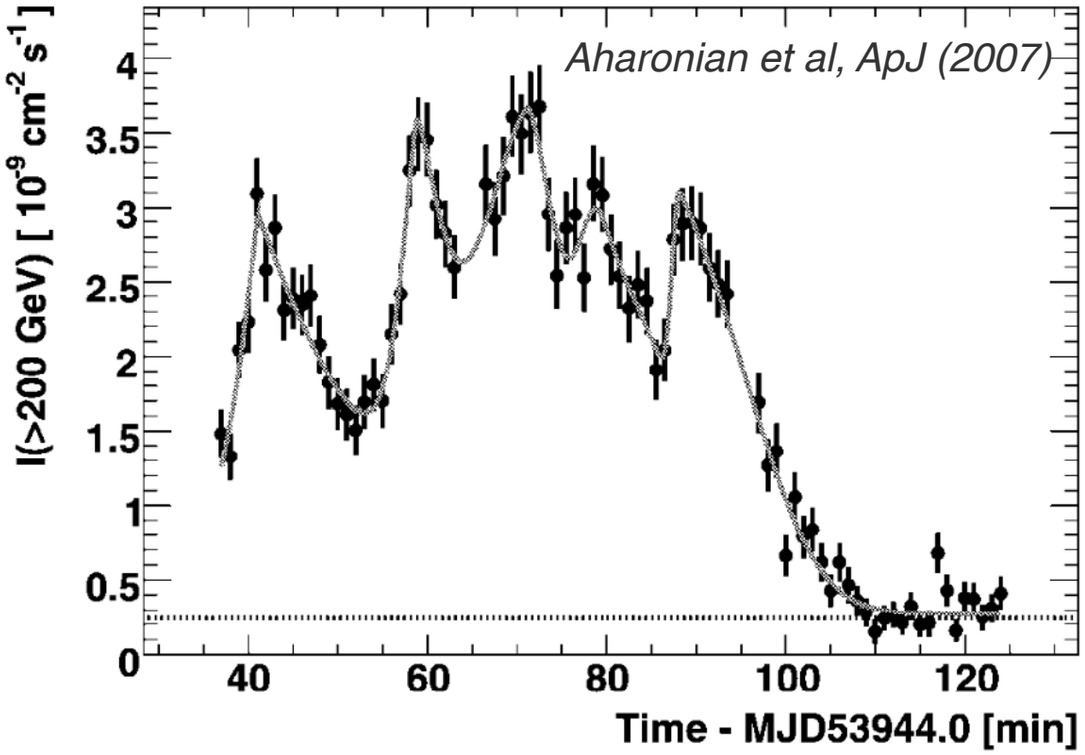
- Out of season sources for CTA
- Unexpected sources

Monitoring the transient & variable sky

Flaring and 5σ detection time scales

AGNs

- **Daily** Monitoring of **All** AGNs in the field of view
- Long term light curves
- Alert the community
- ~Minute timescale light curves for the brightest flares



Low energy background rejection and angular resolution

spectral index
2.0
2.5
3.0
3.5
4.0

PKS 2155-304, flare

Crab

$\phi(100\ \mathrm{GeV})\ [\mathrm{m^2\ s^{-1}\ TeV^{-1}}]$

duration [s]

Monitoring the transient & variable sky

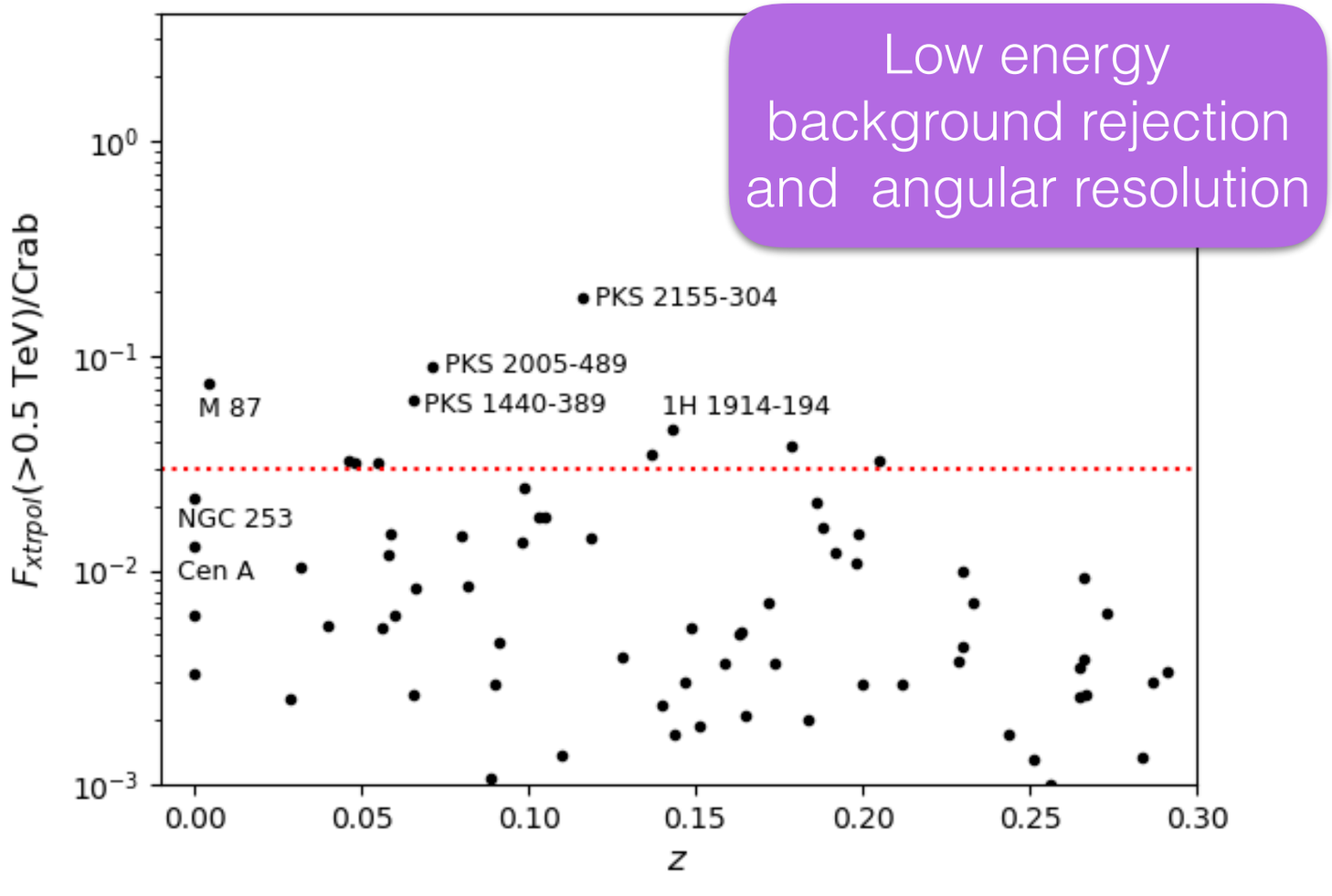
Population of Interesting AGN's previously seen with TeV instruments

3FHL source	Counterpart	Redshift	TeVCat flux and threshold
3FHL J0627.13528	PKS 0625–35	0.055	0.04 Crab @ 580 GeV
3FHL J0303.4–2407	PKS 0301–243	0.266	0.014 Crab @ 200 GeV
3FHL J2009.4–4849	PKS 2005–489	0.071	0.03 Crab @ 400 GeV
3FHL J0238.4–3117	1RXS J023832.6–311658	0.030	Not specified
3FHL J0449.4–4350	PKS 0447–439	0.233	0.03 Crab @ 250 GeV
3FHL J0648.7+1517	RX J0648.7+1516	0.179	0.033 Crab @ 200 GeV
3FHL J1010.2–3119	1RXS J101015.9–311909	0.143	0.008 Crab @ 200 GeV
3FHL J1443.9–3908	PKS 1440–389	0.065	0.03 Crab @ 220 GeV
3FHL J1548.7–2250	PMN J 1548–2251	0.192	TeV candidate
3FHL J2158.8–3013	PKS 2155–304	0.116	0.15 Crab @ 300 GeV
3FHL J1325.5–4300	Cen A	3.8 Mpc	0.08 Crab @ 250 GeV
3FHL J1230.8+1223	M87	16 Mpc	0.033 Crab @ 730 GeV
3FHL J0047.6–2517	NGC 253	3.5 Mpc	0.002 Crab @ 220 GeV
3FHL J1517.6–2422	Ap Librae	0.049	0.02 Crab @ 300 GeV

TABLE 6. TeV observations of 3FHL Southern AGNs. The bottom four are particular nearby objects of interest.

Extrapolating from 3FHL taking into account EBL absorption

Longterm study possible for ~10 sources



Monitoring the transient & variable sky

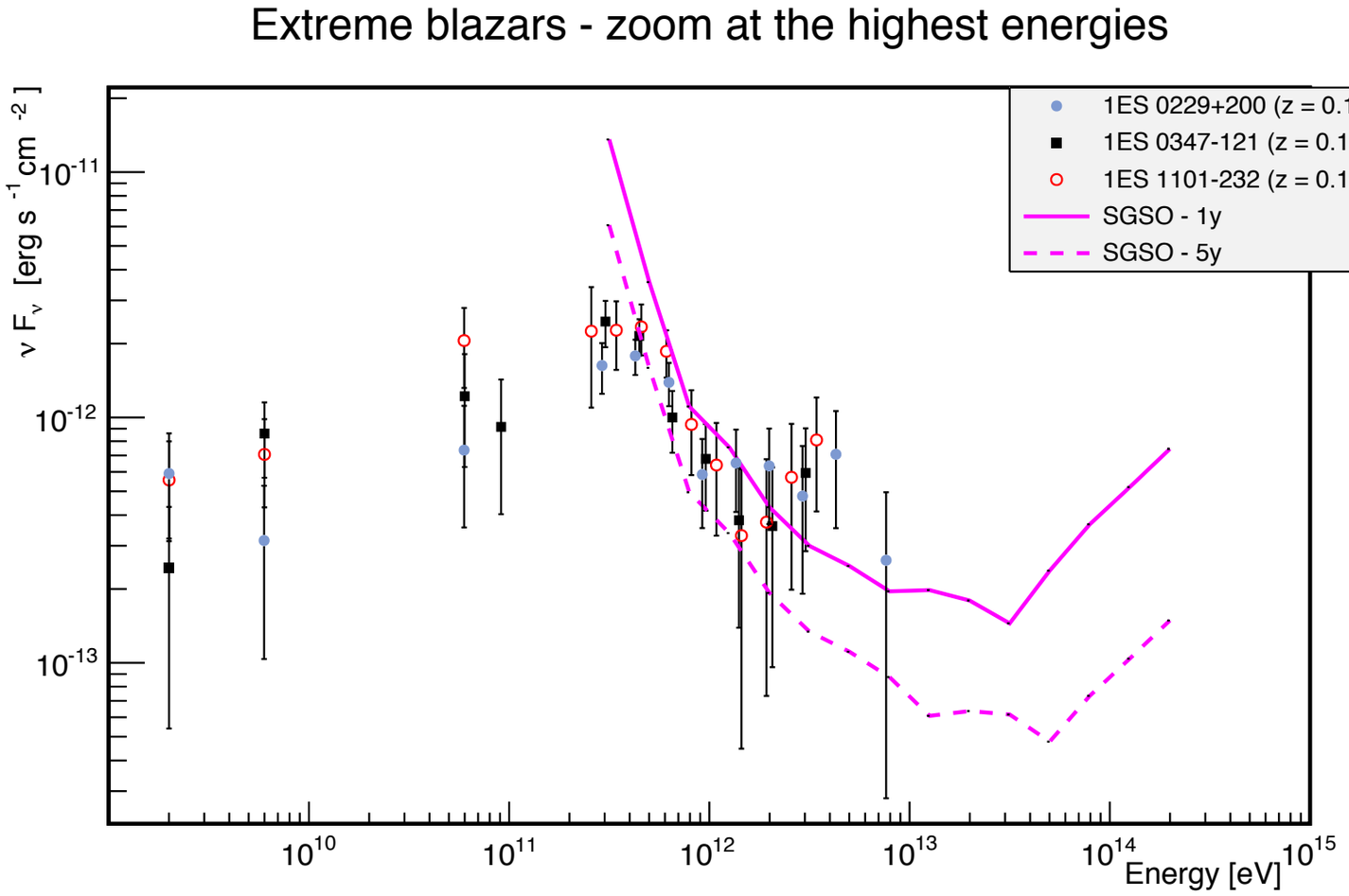
Extreme blazars

(EHBL = Exteme High-Synchrotron Peaked BL Lac objects)

- Faint objects
- Not many known in the South
- Variability?
- Unbiased sample of the closest (z < ~0.3) EHBL's
- High energy sensitivity might be able to measure the IC peak position

Measuring the Inter Galactic Magnetic Field

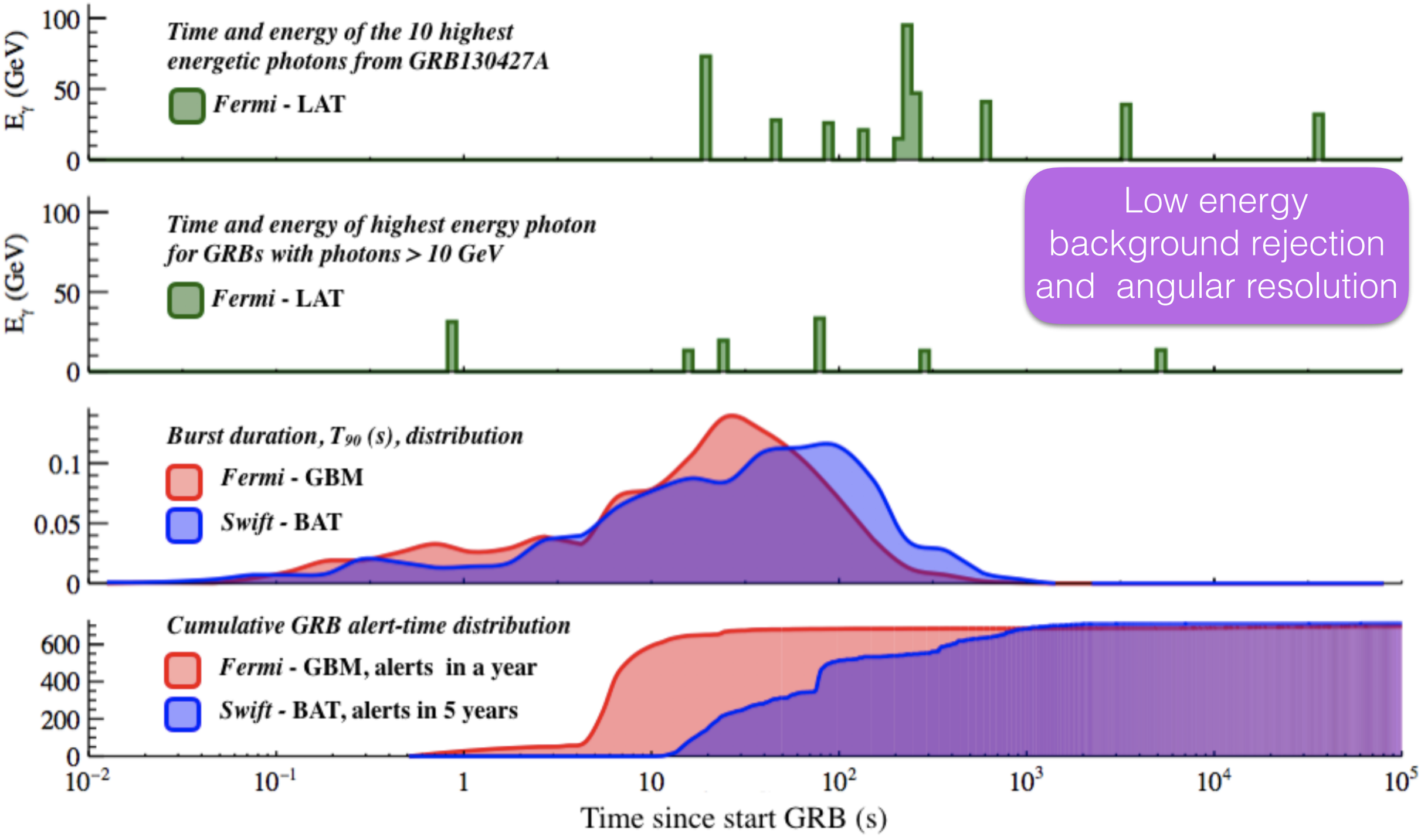
- Measuring flux over the typical timescale of cascade development (~ yr)
- Together with CTA's angular resolution will provide more robust measurement



Low energy background rejection and angular resolution

Gamma Ray Burst & Gravitational Waves

No special observation mode needed!

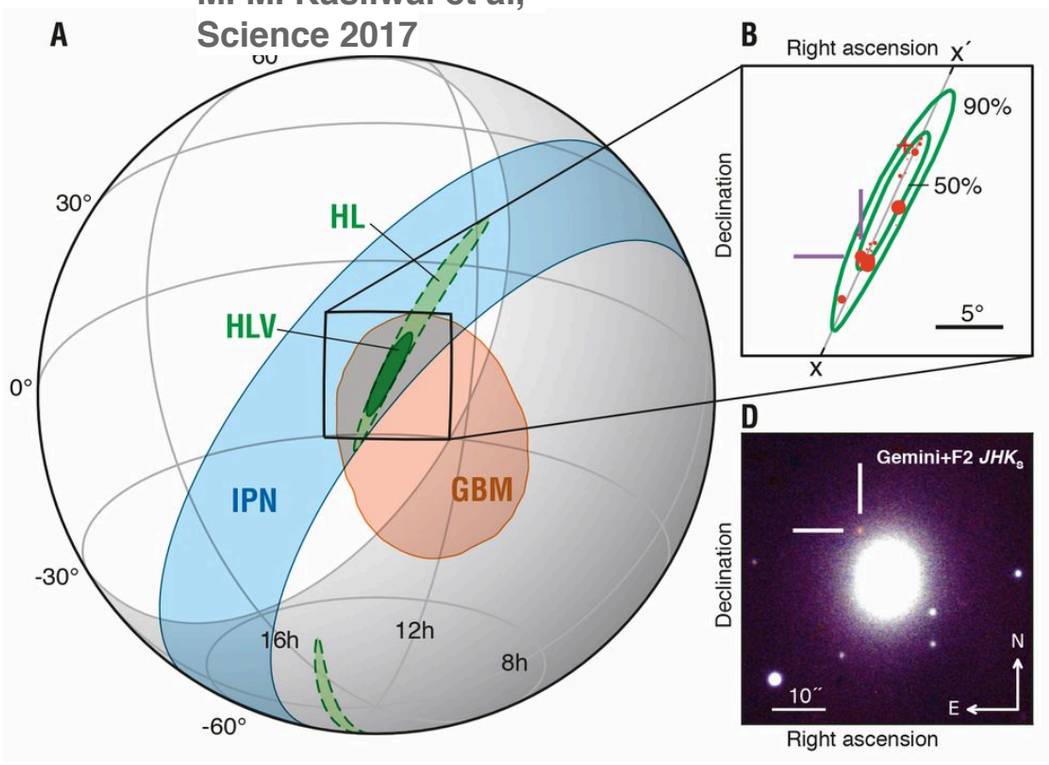


Low energy background rejection and angular resolution

Gamma Ray Burst & Gravitational Waves

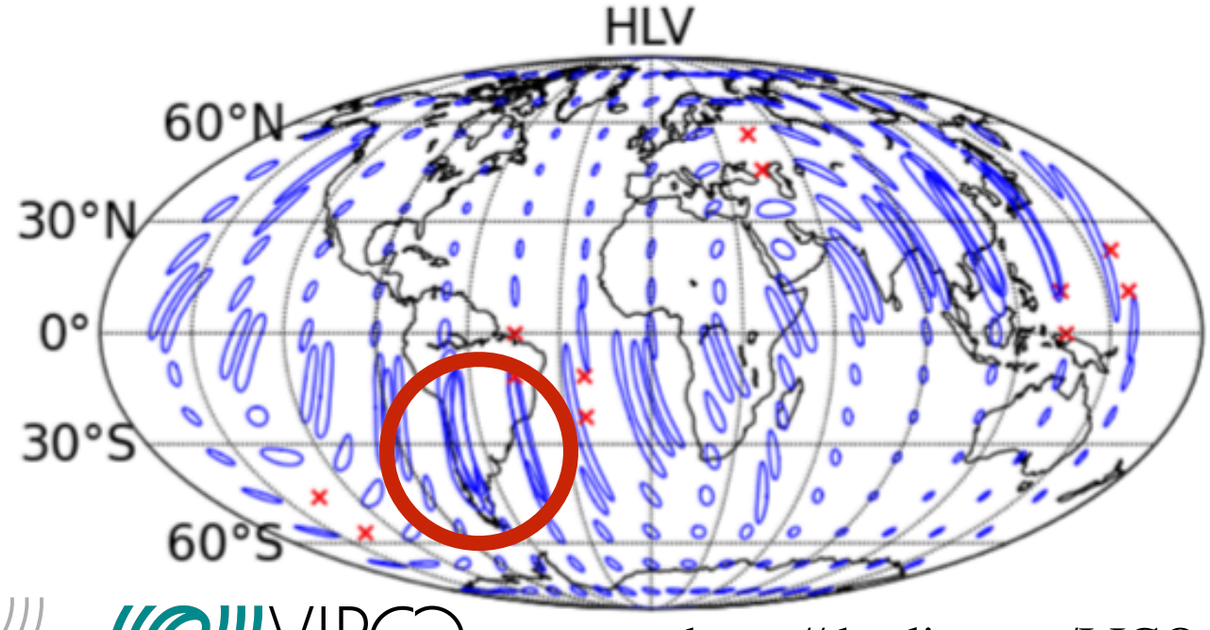
Low energy background rejection and angular resolution

Localization uncertainties…

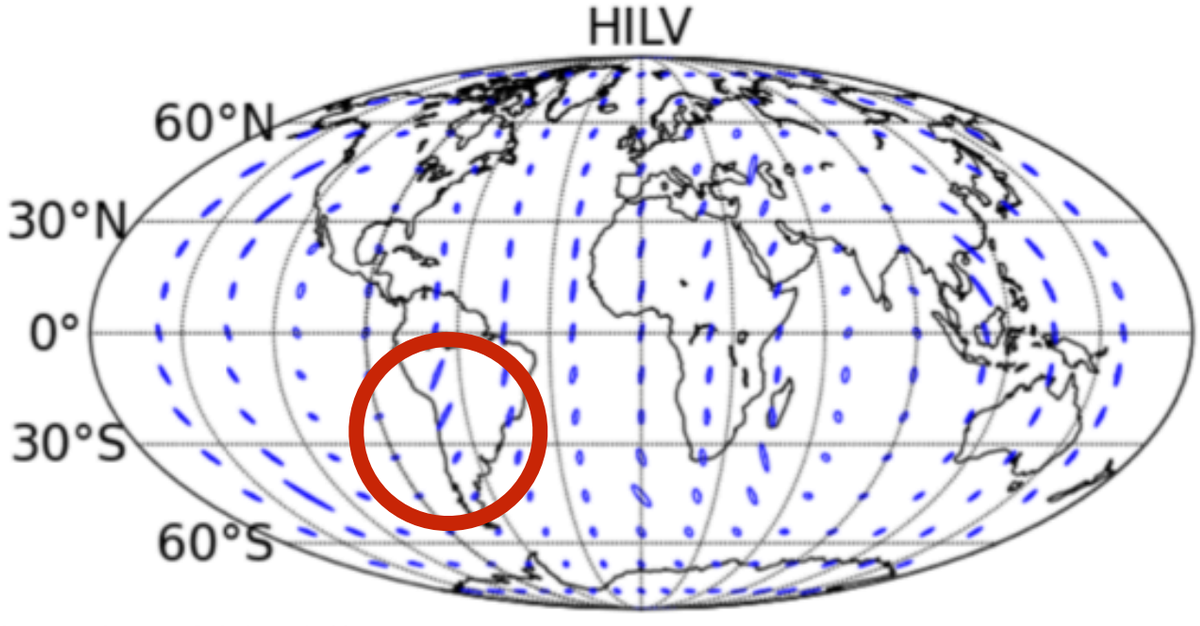


90 % confidence localization

2019+



2022+



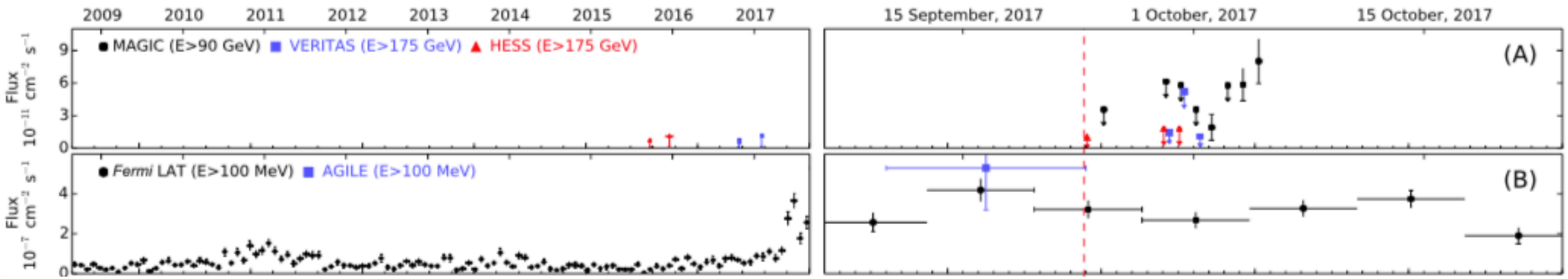
LIGO VIRGO

https://dcc.ligo.org/LIGO-P1200087-v32/public

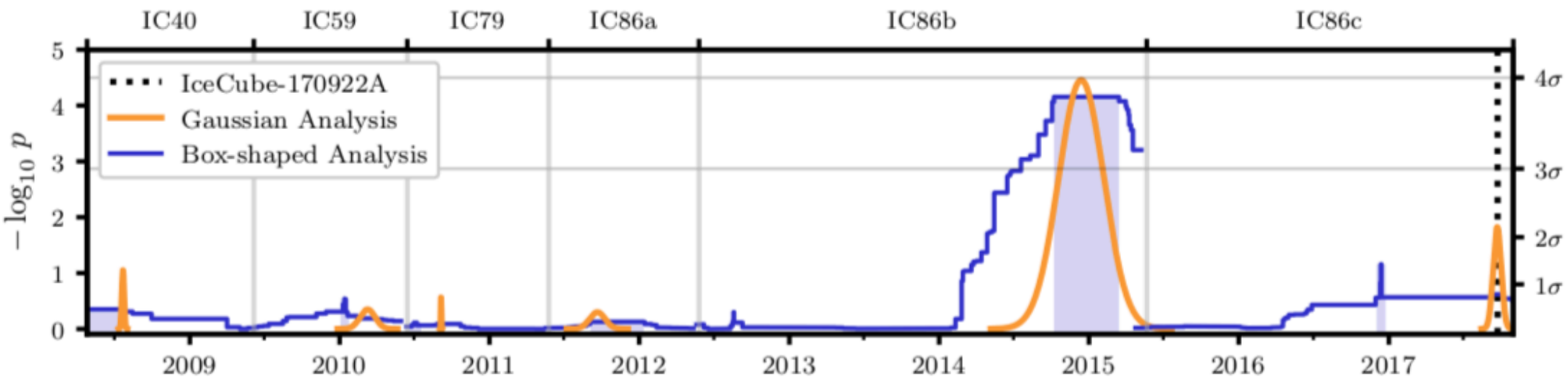
Neutrinos follow-up

Low energy background rejection and angular resolution

11days



Everyone et al, Science (2018)



M.G. Aartsen et al. Science (2018)

KM3NeT

IceCube South Pole Neutrino Observatory

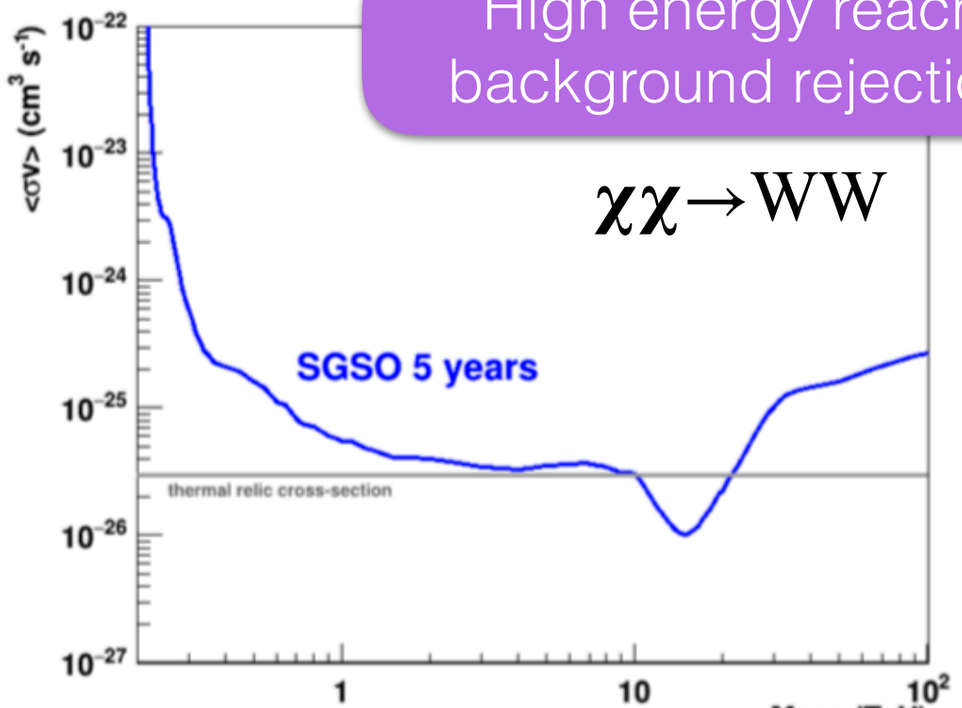
Physics beyond the Standard Model

Physics beyond the Standard Model: Dark matter

Galactic center

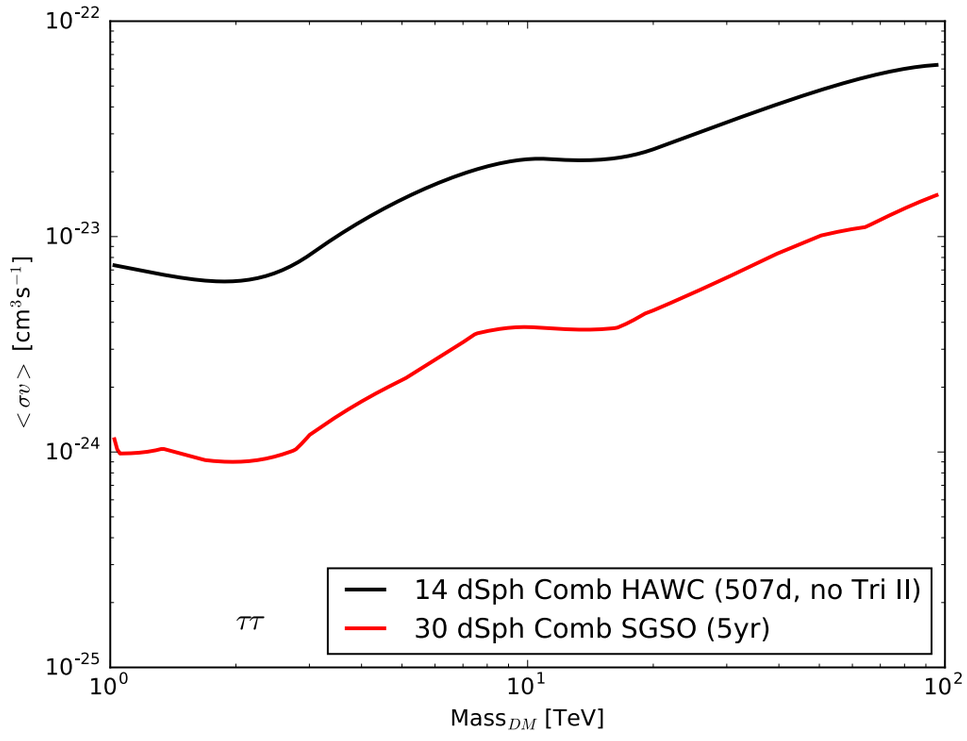
- Galactic Center in field of view
- Test Morphology (especially for more extended profiles)
- Comparable Sensitivity as CTA above > 30 TeV
- If signal seen in GC by CTA, SGSO might be able to confirm it

High energy reach background rejection



Dwarf Spheroidal galaxies

- Stacking
- Archival data
- Comparable to CTA on individual sources
- Many to be discovered ….

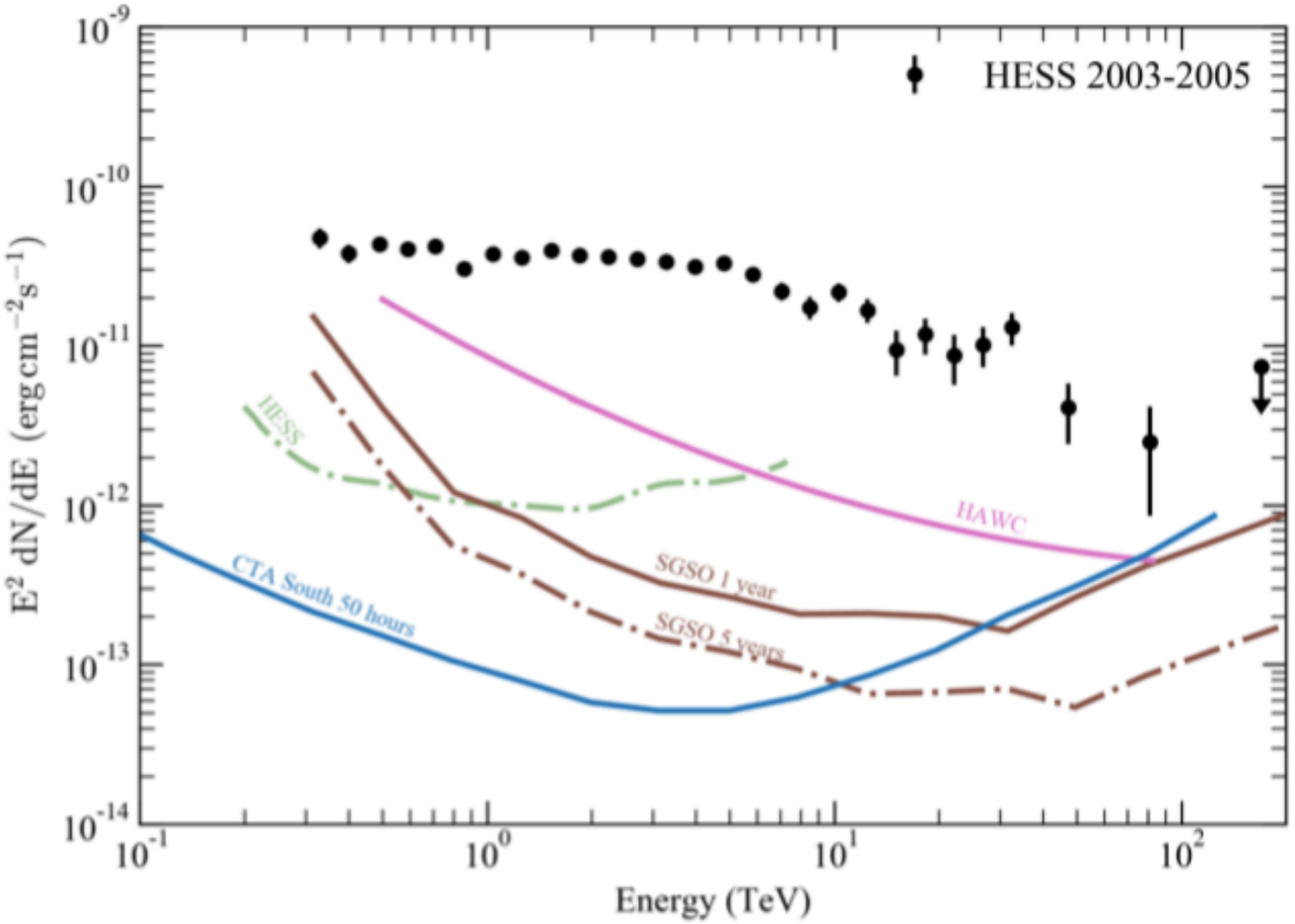


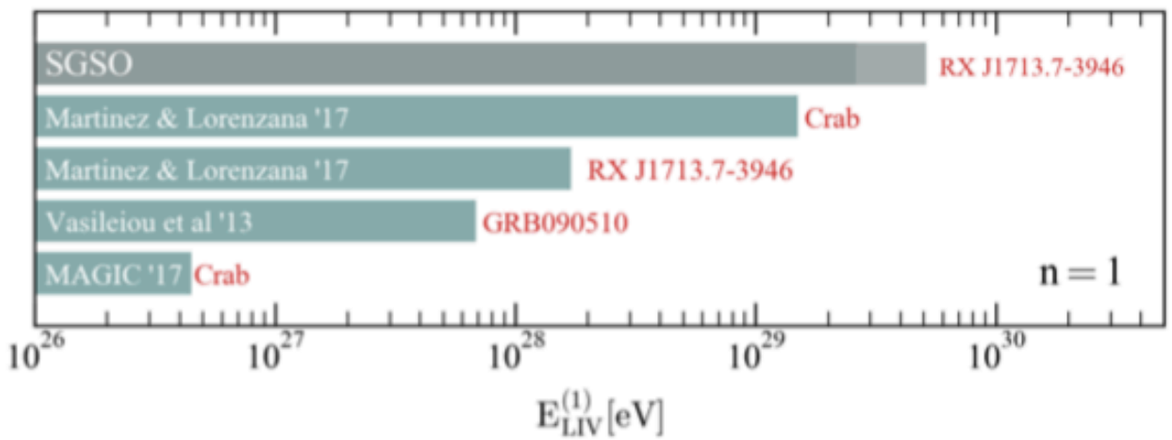
Physics beyond the Standard Model: *Lorentz invariance*

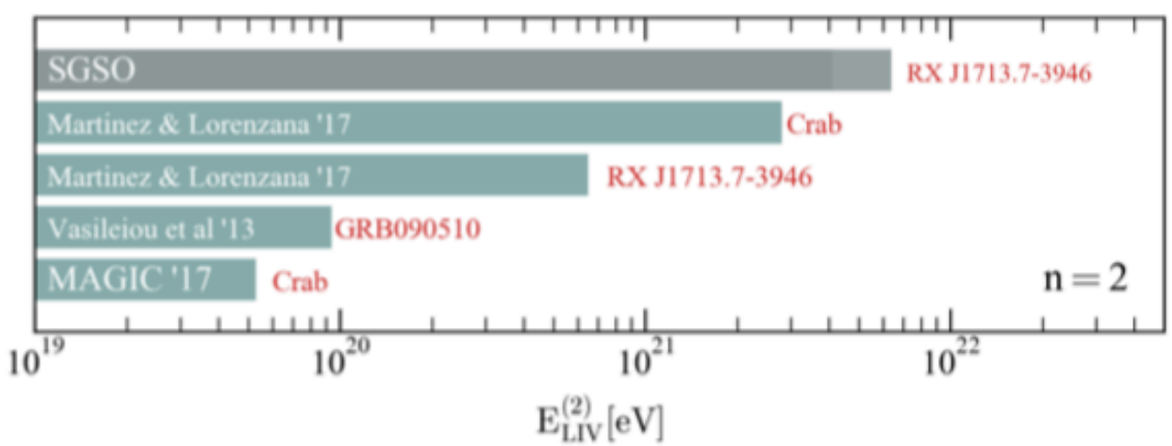
High energy reach

At very high energy photons might become unstable and decay, measuring the highest energies photons will constrain the energy scale.

$$E_\gamma^2 - p_\gamma^2 = \pm \frac{E_\gamma^{n+2}}{(E_{LIV}^{(n)})^n}$$







Local cosmic rays
from air showers observations

Local cosmic rays

Measurement the CR - anisotropy:

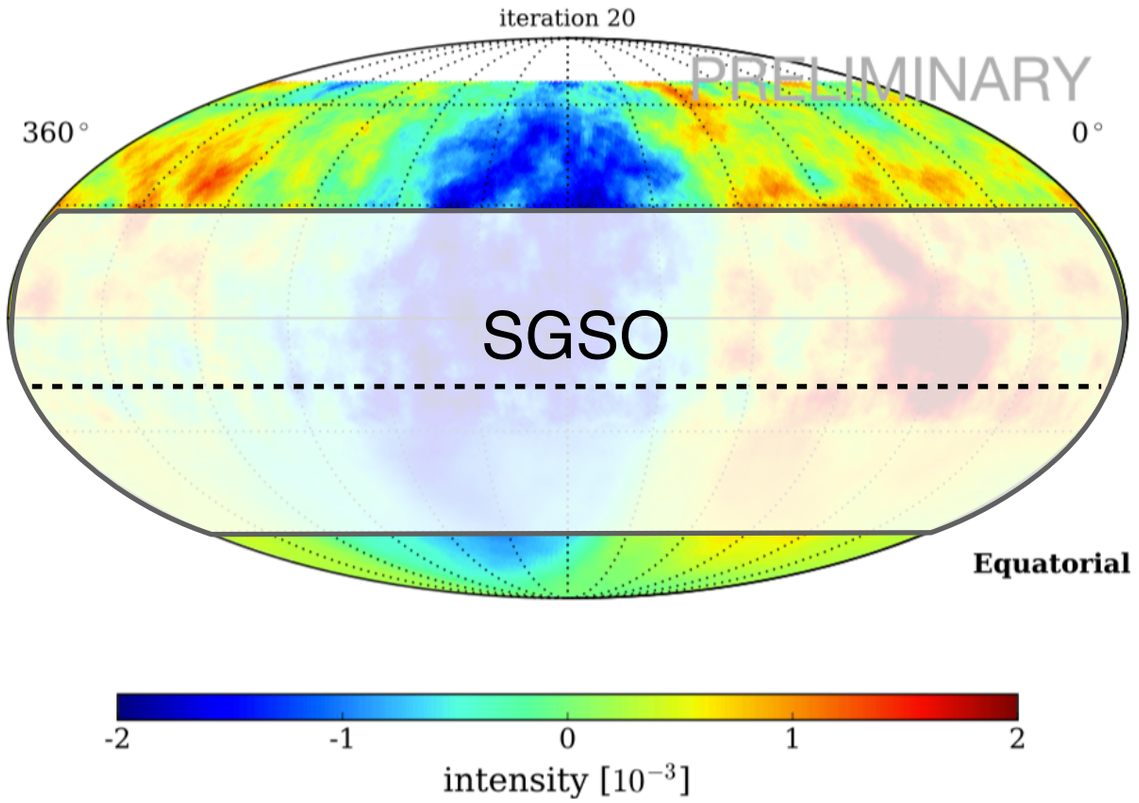
- Additional measurement in the Southern-Hemisphere
- Composition Dependency
- Electron Anisotropy

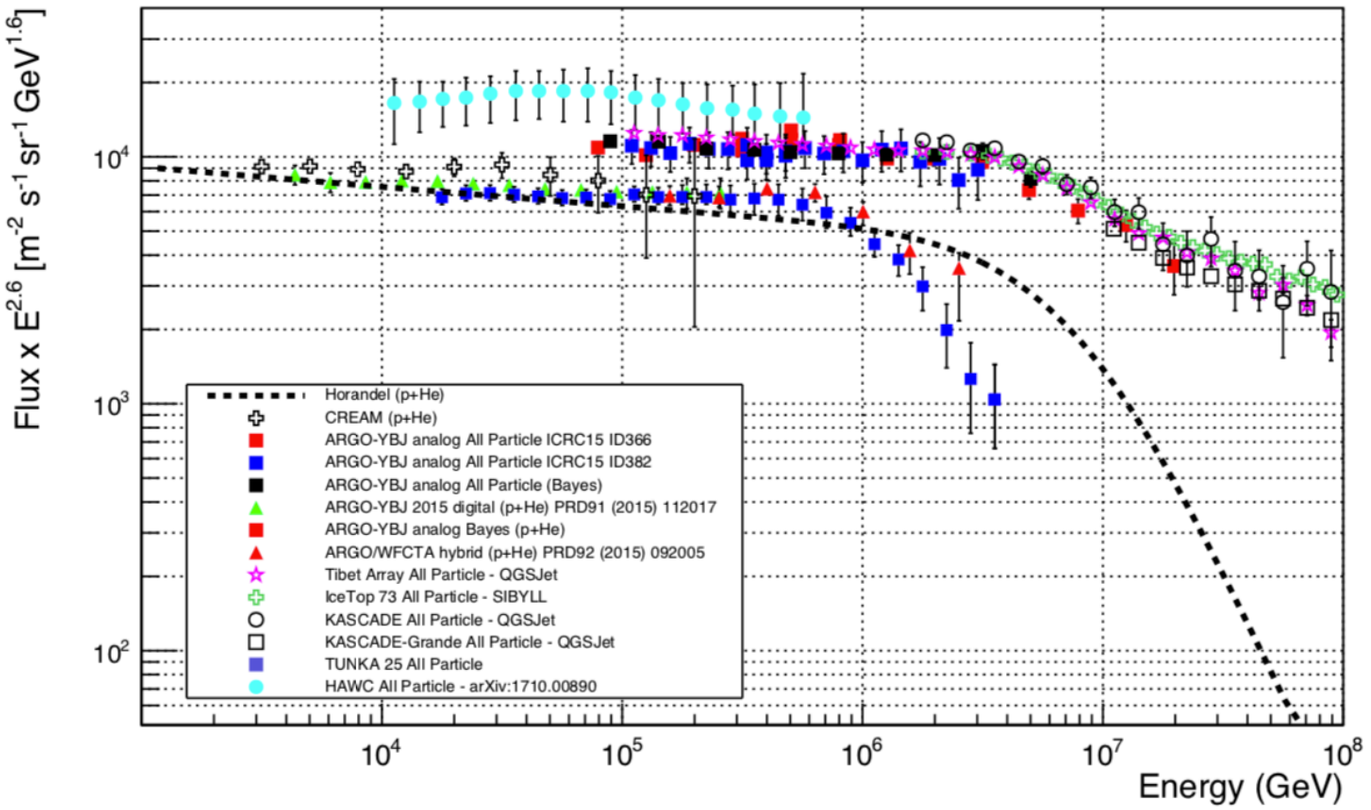
Spectrum & Composition:

- High - Altitude measurement
- Energy calibration with moon shadow
- Test of Hadronic interaction models

Muon tagging

High energy reach





Conclusion

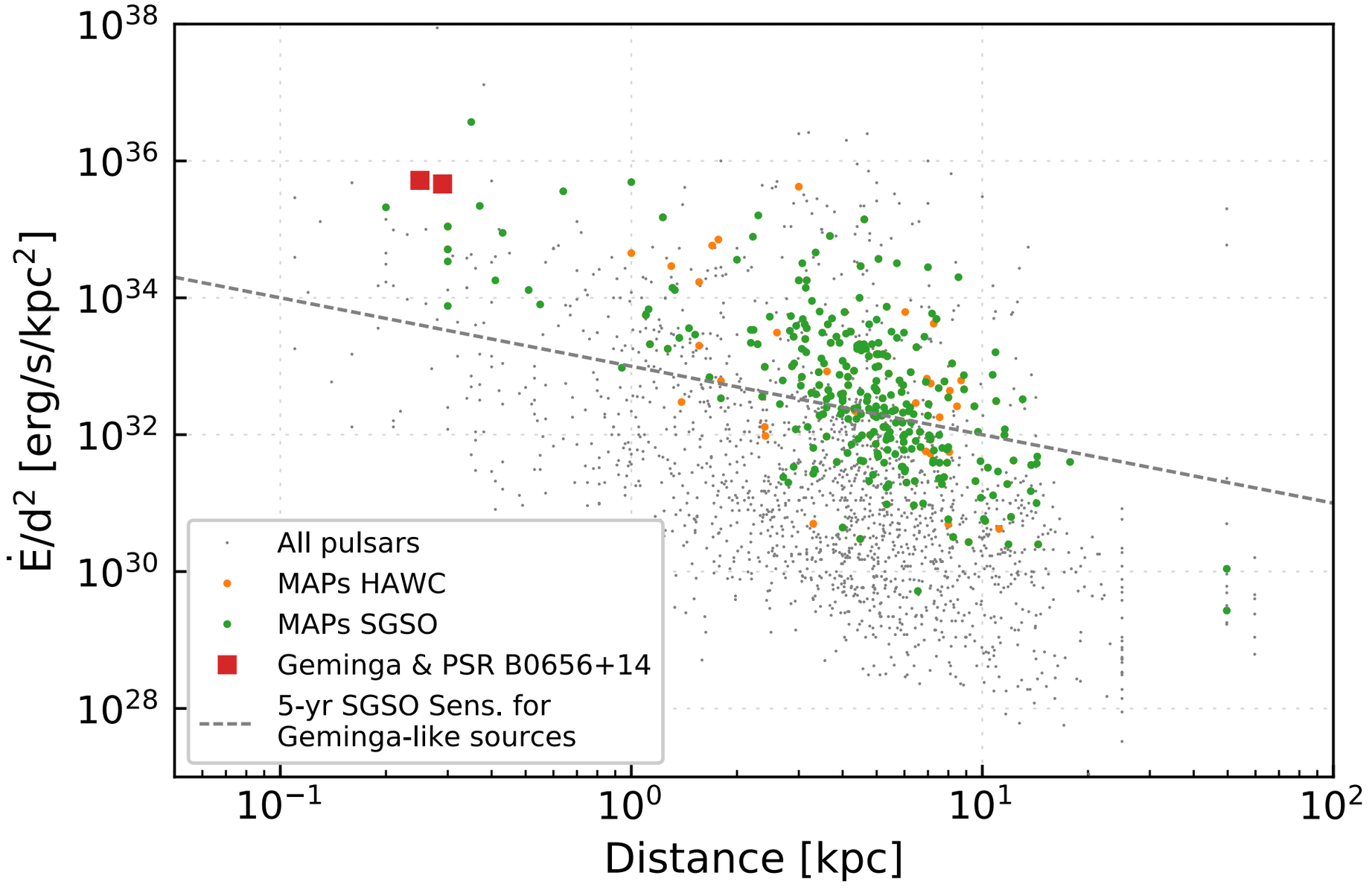
There is a broad range of topics where a southern gamma-ray survey observatory can contribute

Community wide effort in exploring the science case, contributions are welcome!

If you are interested to join: www.sgso-alliance.org

Cảm ơn bạn

Pulsars to constrain local positron flux & diffusion coefficients



Low energy background rejection and angular resolution

Muon tagging

Low energy background rejection

Ideal source

High energy reach