The new TeV window into Gamma-ray Bursts

Given on behalf of the MAGIC Collaboration.
With special thanks to E. Bernardini, E. Moretti, A. Stamerra & R. Mirzoyan, D. Paneque.

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Brazilian Center for Physics Research (CBPF)

Talk outline

Gamma-ray bursts

Phenomenology at high-energies

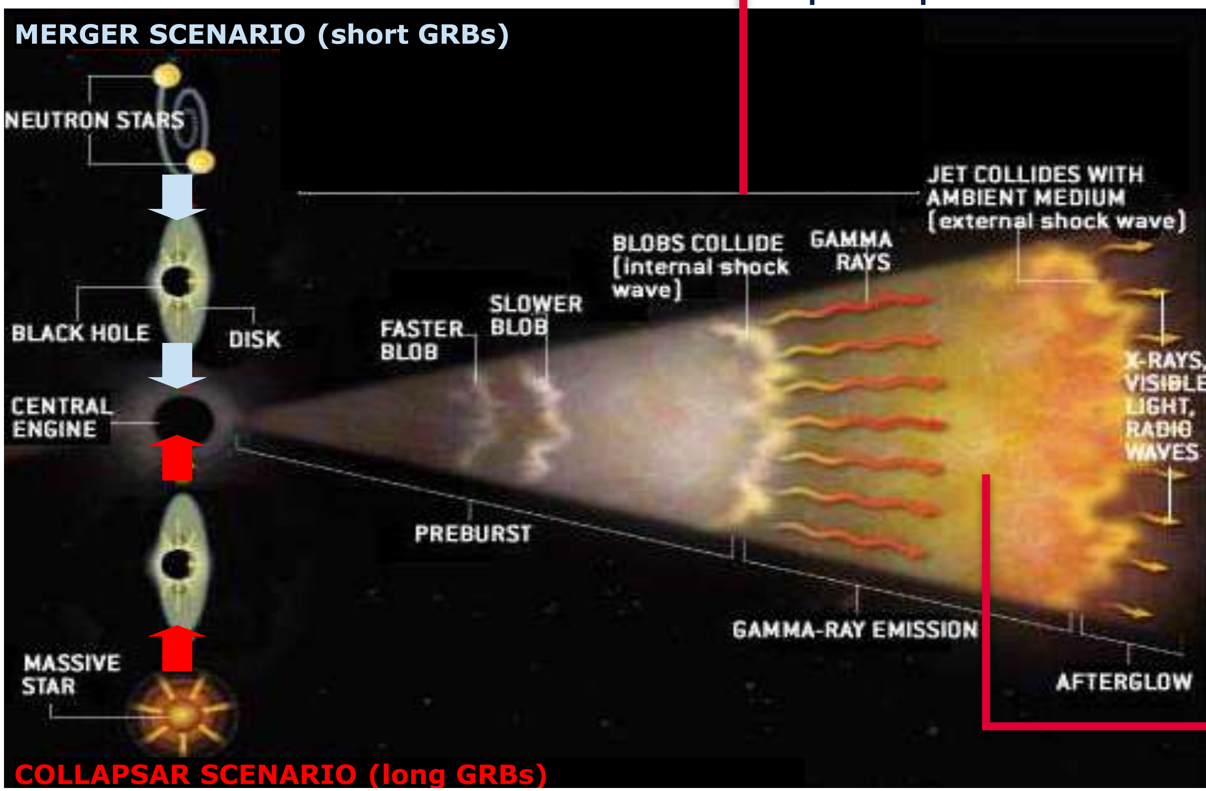
Perspectives and searches at VHEs

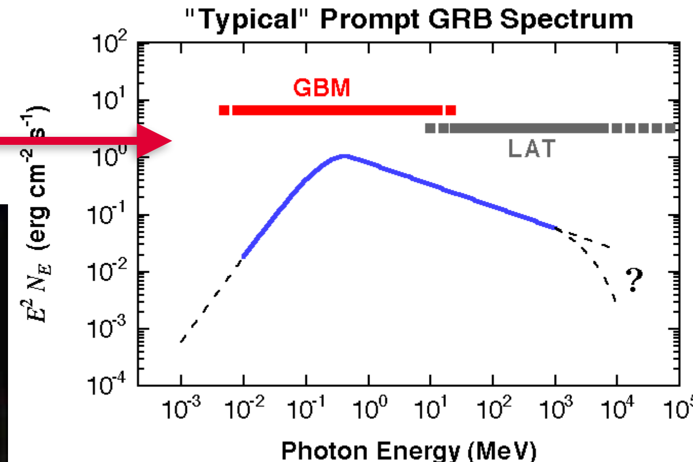
The first GRBs at sub-TeV energies

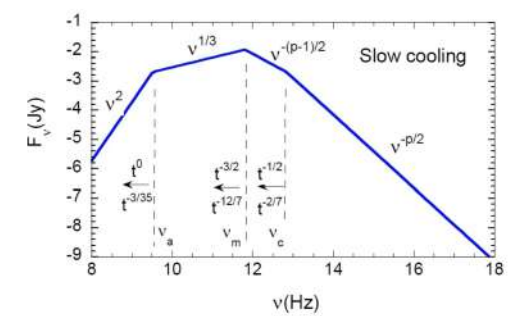
Gamma-ray bursts

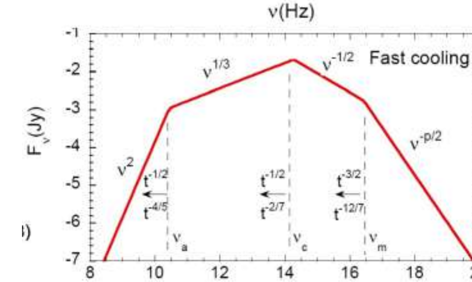
The standard fireball model of GRBs

prompt emission









afterglow
synchrotron spectrum

(but see Fermi-LAT data for GRB 130427A)

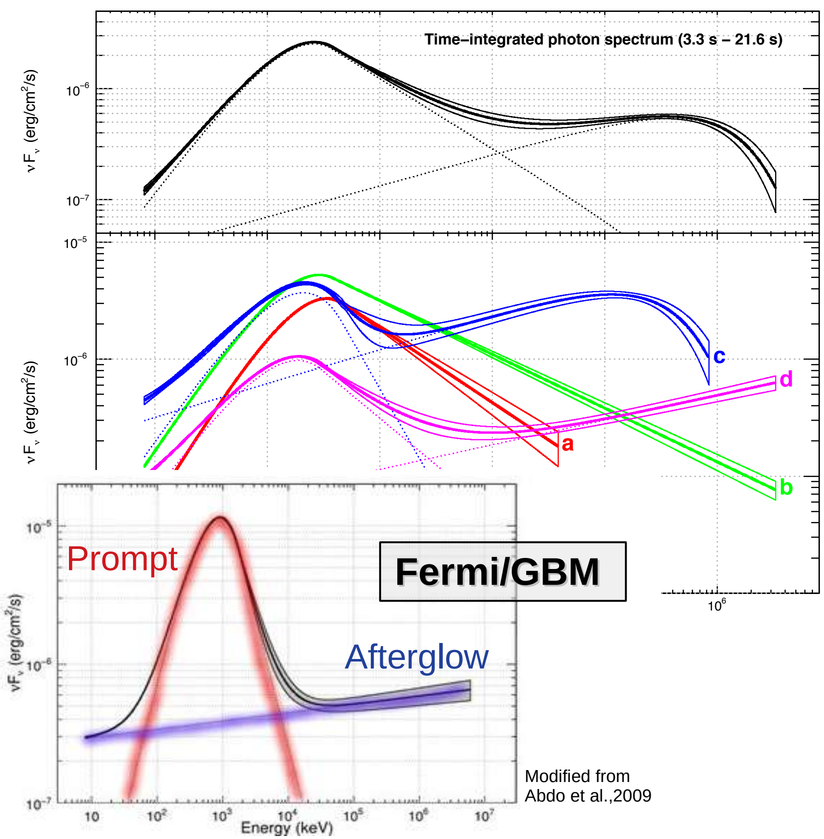
Phenomenology from Fermi-LAT

Slide adapted from A. Stamerra

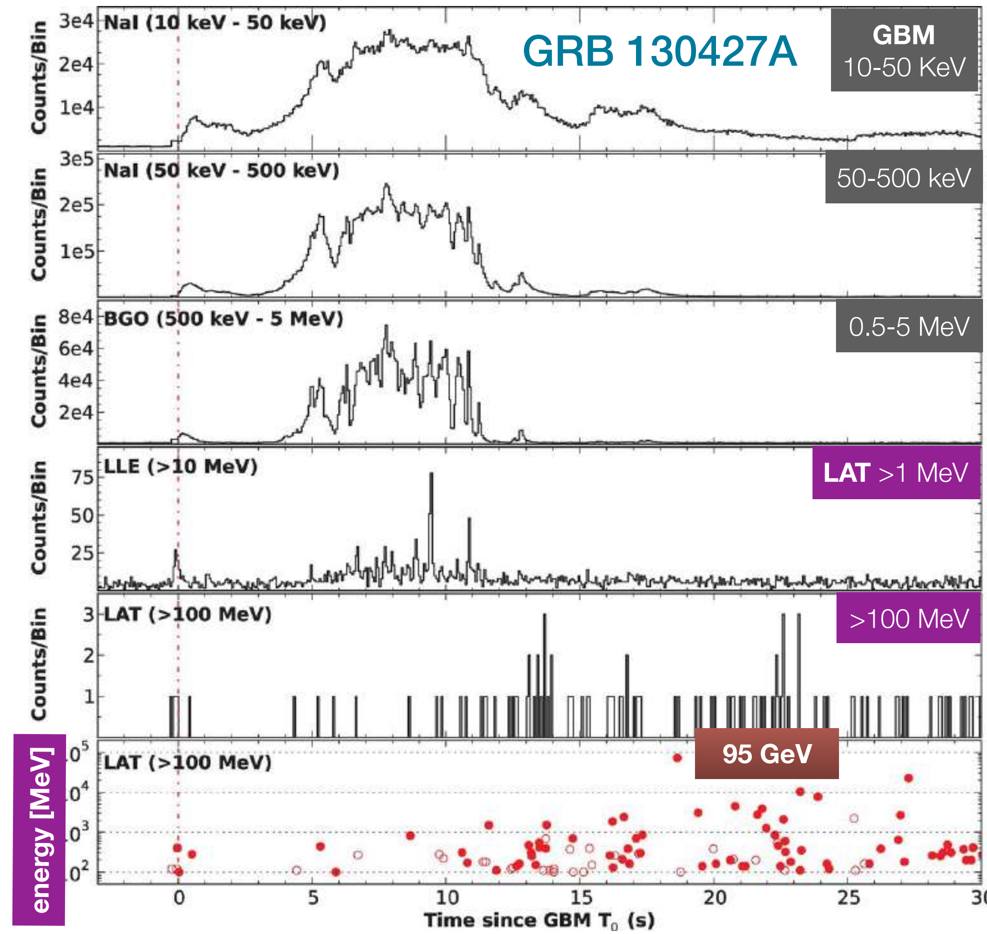
Bright LAT bursts indicate presence of late onset of a GeV component

new GeV component?

GRB 090926A



Modified from Abdo et al.,2009

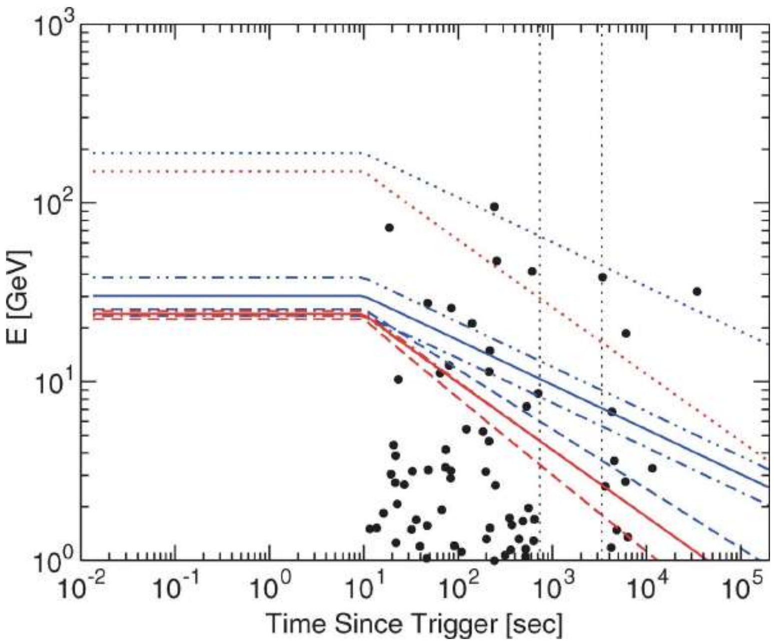


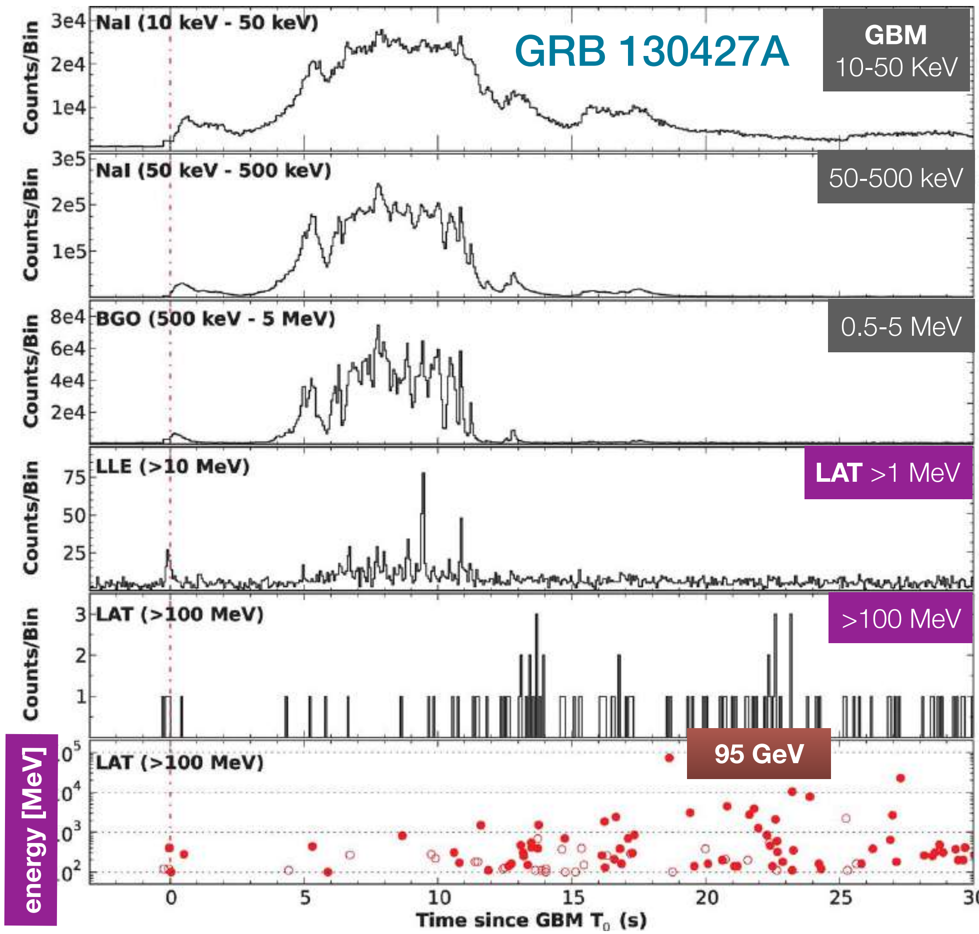
Phenomenology from Fermi-LAT

Slide adapted from A. Stamerra

Bright LAT bursts indicate presence of late onset of a GeV component

- Late HE photons challenge emission from Sy origin by shock accelerated electrons (Ackermann+ 2014)





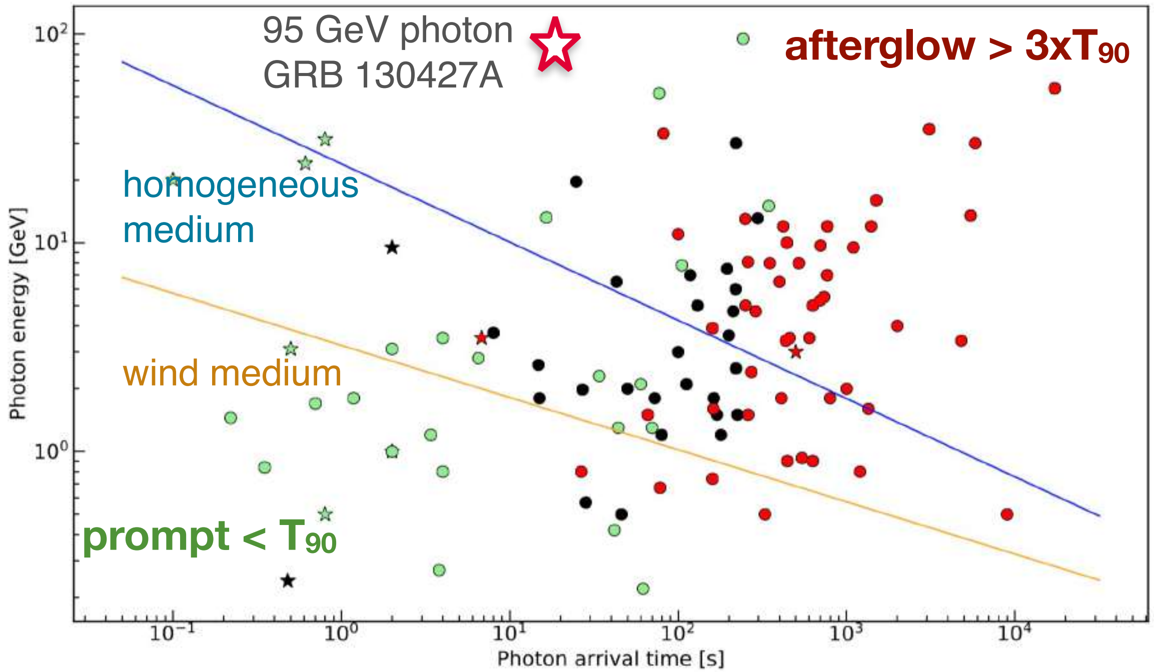
Phenomenology from Fermi-LAT

Slide adapted from A. Stamerra

Synchrotron "Burnoff" limit

- Maximum energy above which the timescale for radiative synchrotron losses becomes shorter than the acceleration timescale (see L. Nava 2018)

$$E^{\rm obs}_{\rm syn,max} \simeq 50\,{\rm MeV} \times \Gamma/(1+z)$$

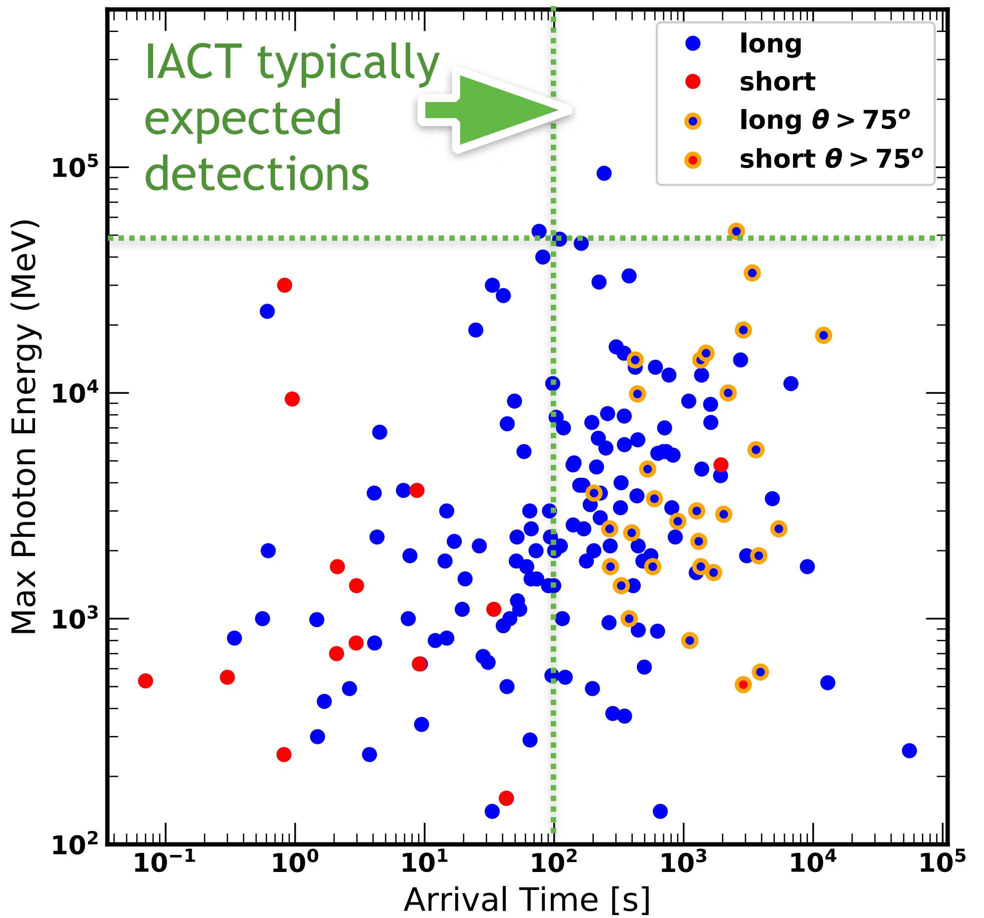


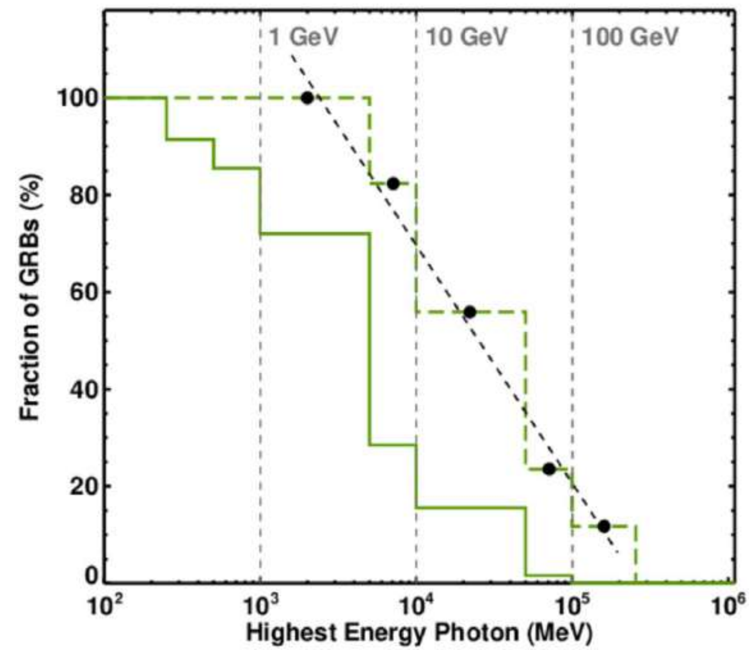
Most of photons above the limiting lines cannot be reconciled with a simple shock acceleration / synchrotron scenario unless by recourse to extreme choice of parameters and acceleration conditions.

Early perspectives for GRBs in the very-high-energies

Ten years of GRB observations with Fermi LAT

(Ajello et al. 2019)





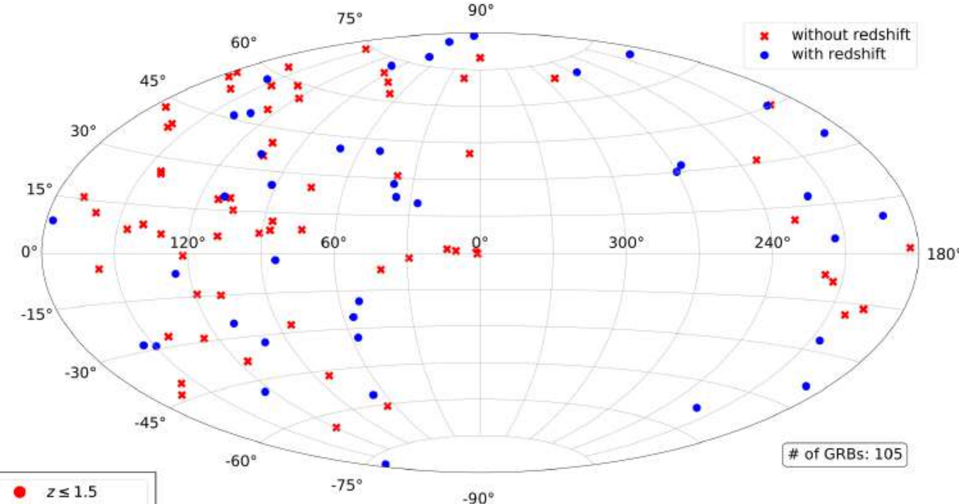
Only 20% of the circa 150 Fermi-LAT detected GRBs have highest-energy photons detected above 50 GeV, and only a handful of these with arrival times over 100 s.

The first gamma-ray bursts detected at TeV energies

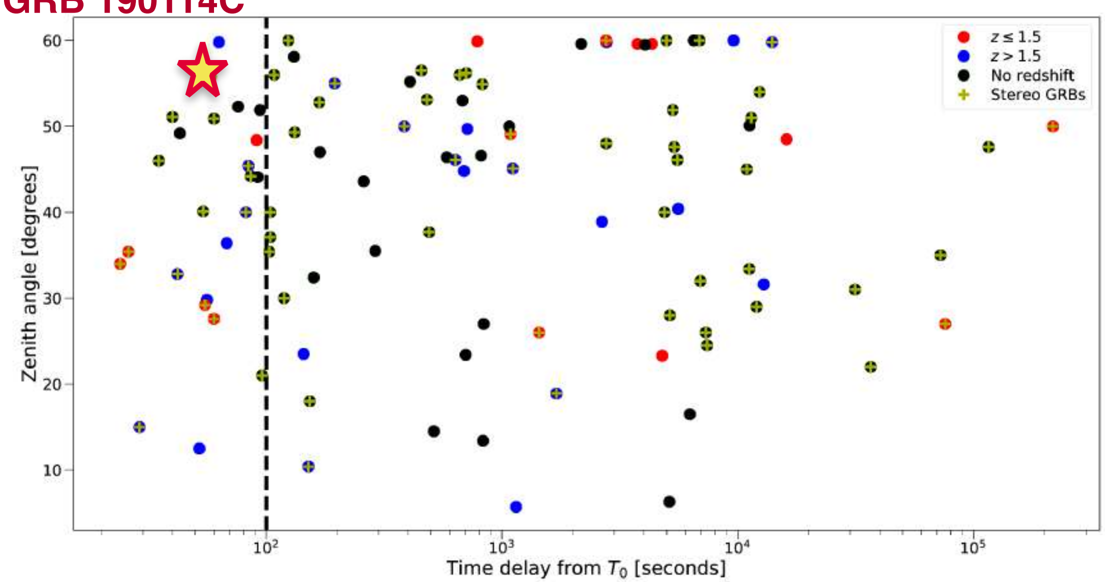
A discovery long sought-after

- 105 GRBs observed since 2005 (c. 8 GRBs/yr)
- programme profiting from light structure and fast movement capability (180º in 30s)
- a robust alert and follow-up system
- 24 GRBs within T0+100s

MAGIC observed GRBs



GRB 190114C



- first GRB caught in prompt phase was GRB 05713A at T0+40s, E > 175 GeV.

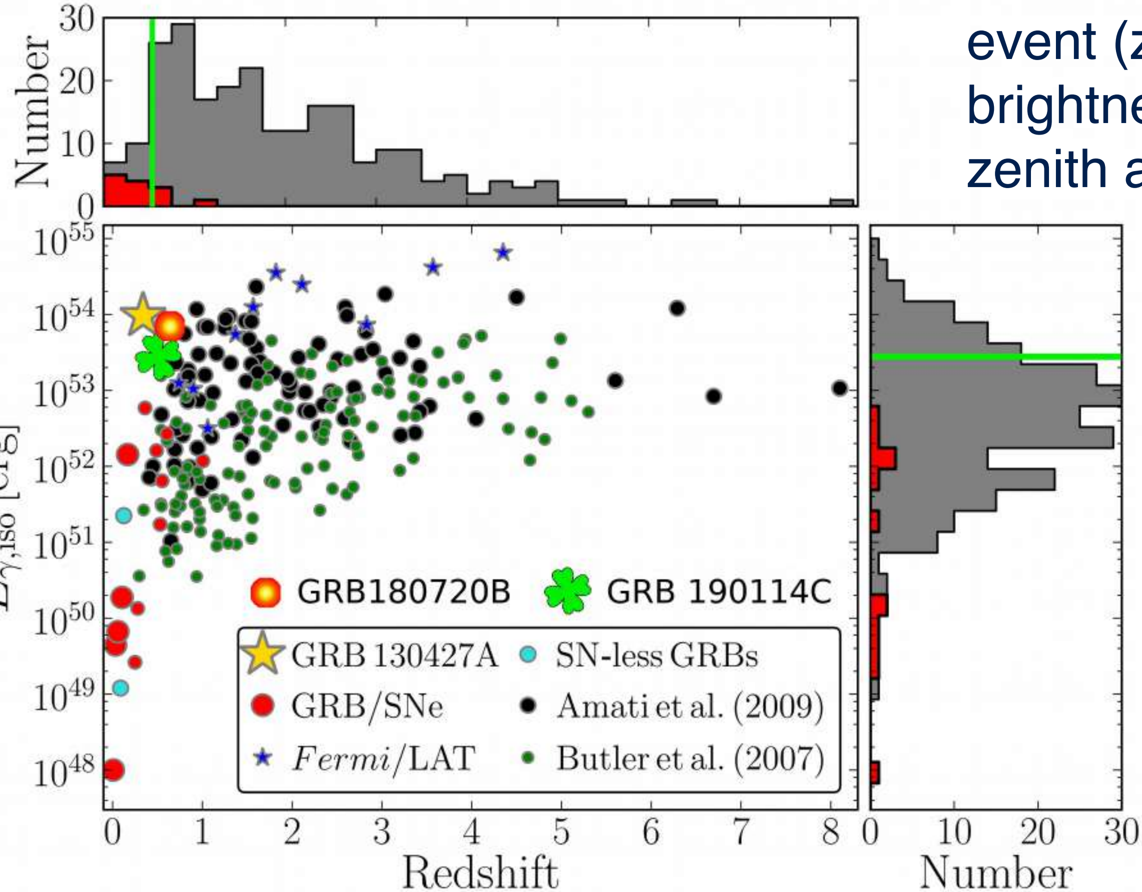
Alerts are validated

(max obs time: 4h)

Zd sun < 103.0
Zd GRB < 60.0
Moon dist. > 30.0

+ Fermi GBM dedicated filters

The extraordinary detection of an ordinary GRB

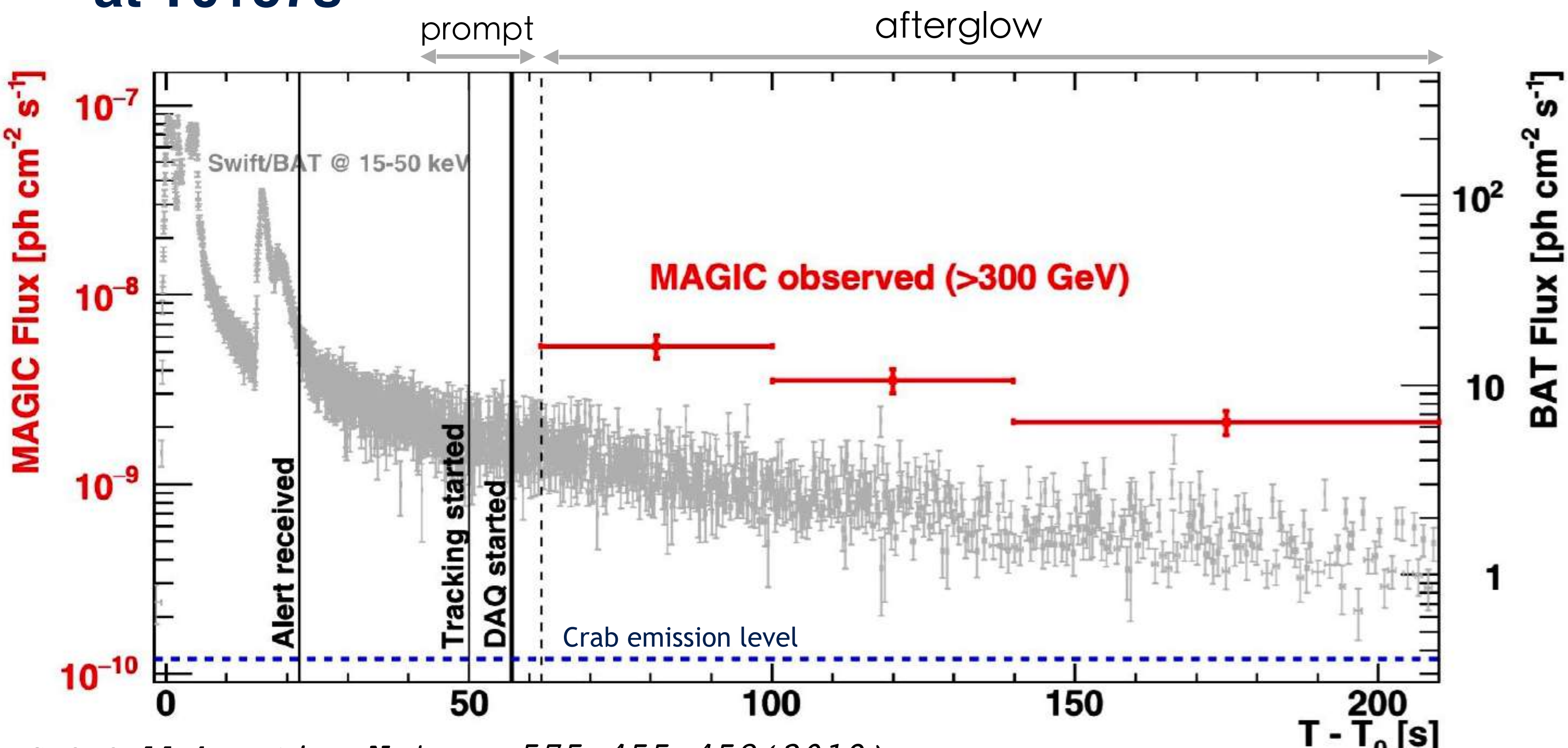


Levan et al. Space Science Reviews, V 202, I 1-4

- GRB 190114C was a low-redshift event (z=0.42), of only average brightness, detected at high zenith angle

The MAGIC observations

Data acquisition by MAGIC started 35s after the alert, at T0+57s



MAGIC Collaboration, Nature, 575, 455-458 (2019)

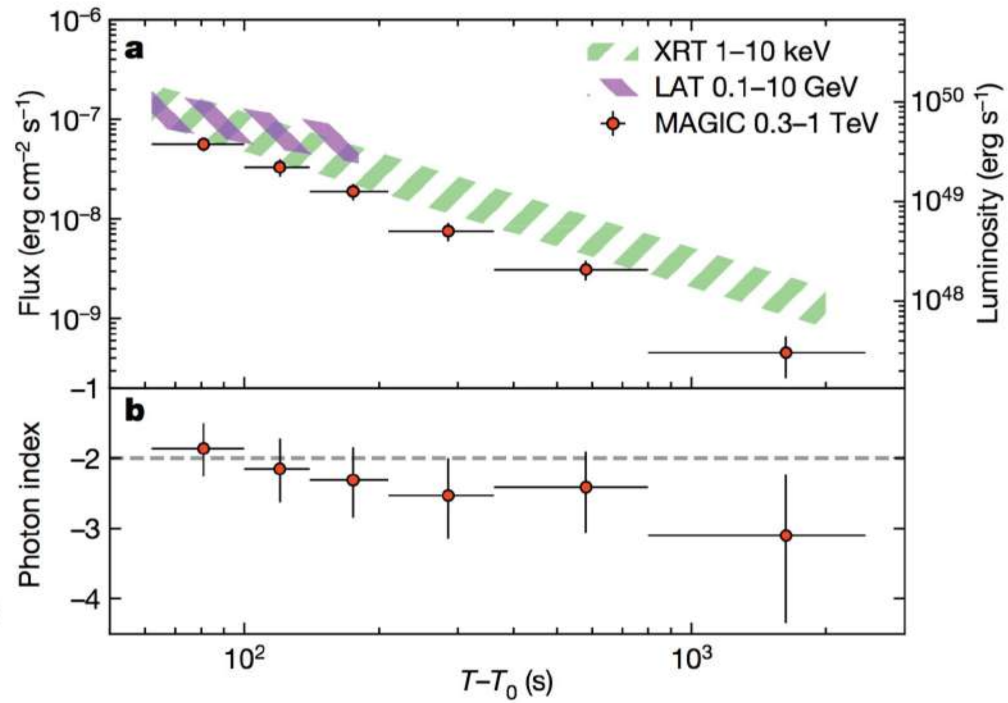
The MAGIC observations

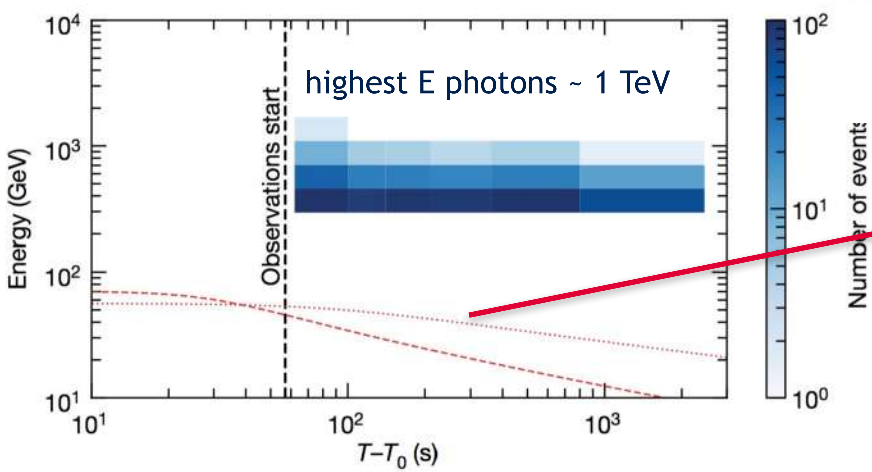
Slide adapted from E. Moretti

The measured spectrum from T0+68s to T0+2454s shows no break or cutoff in the 0.2-1TeV band

Spectral index ~ 2.2 (0.2)

Total energy flux emitted @ sub-TeV about half the flux emitted in X-rays in the same interval

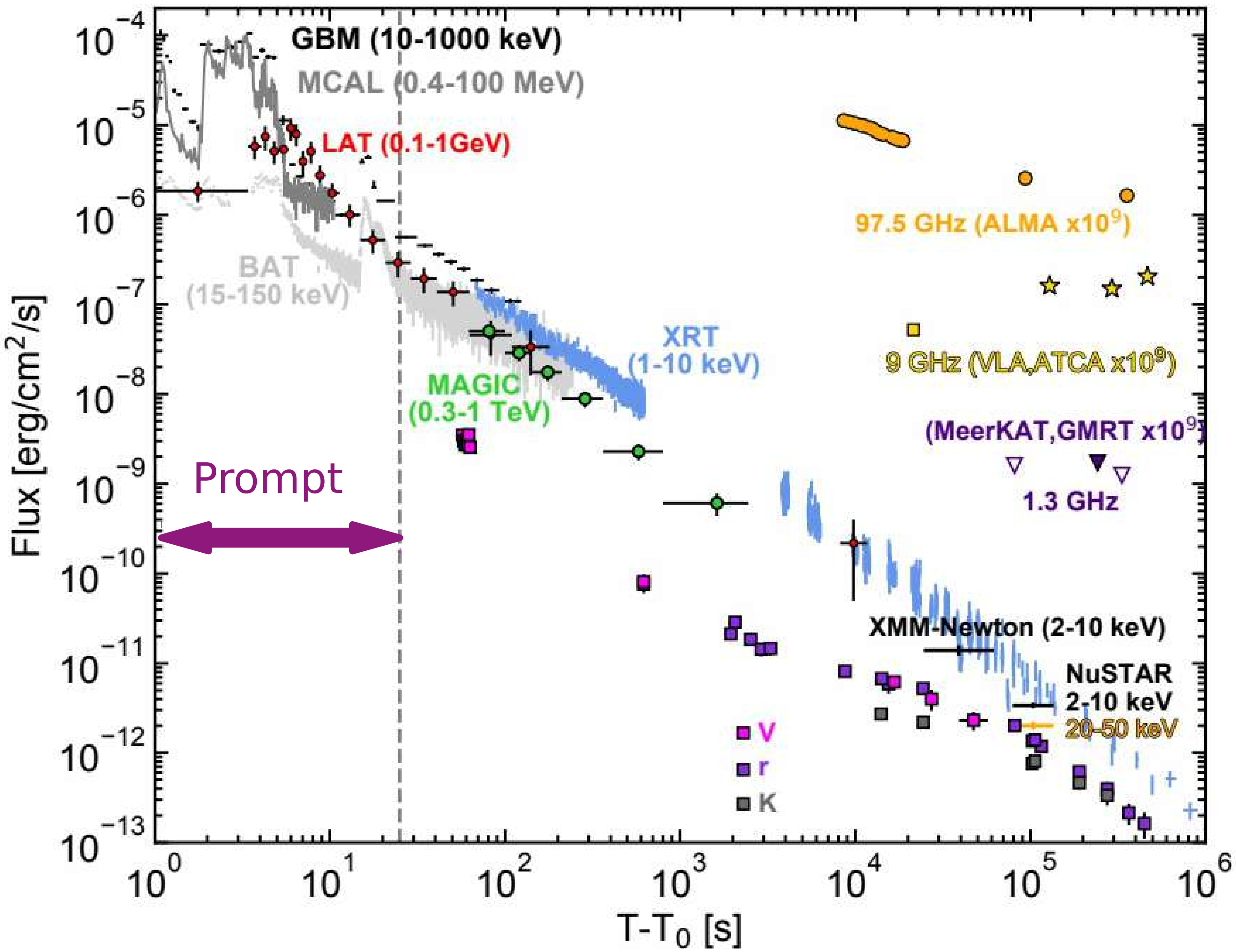




Emission cannot be reconciled with the synchrotron mechanism, much above the burnoff limit.

MWL Campaign

Slide adapted from E. Moretti

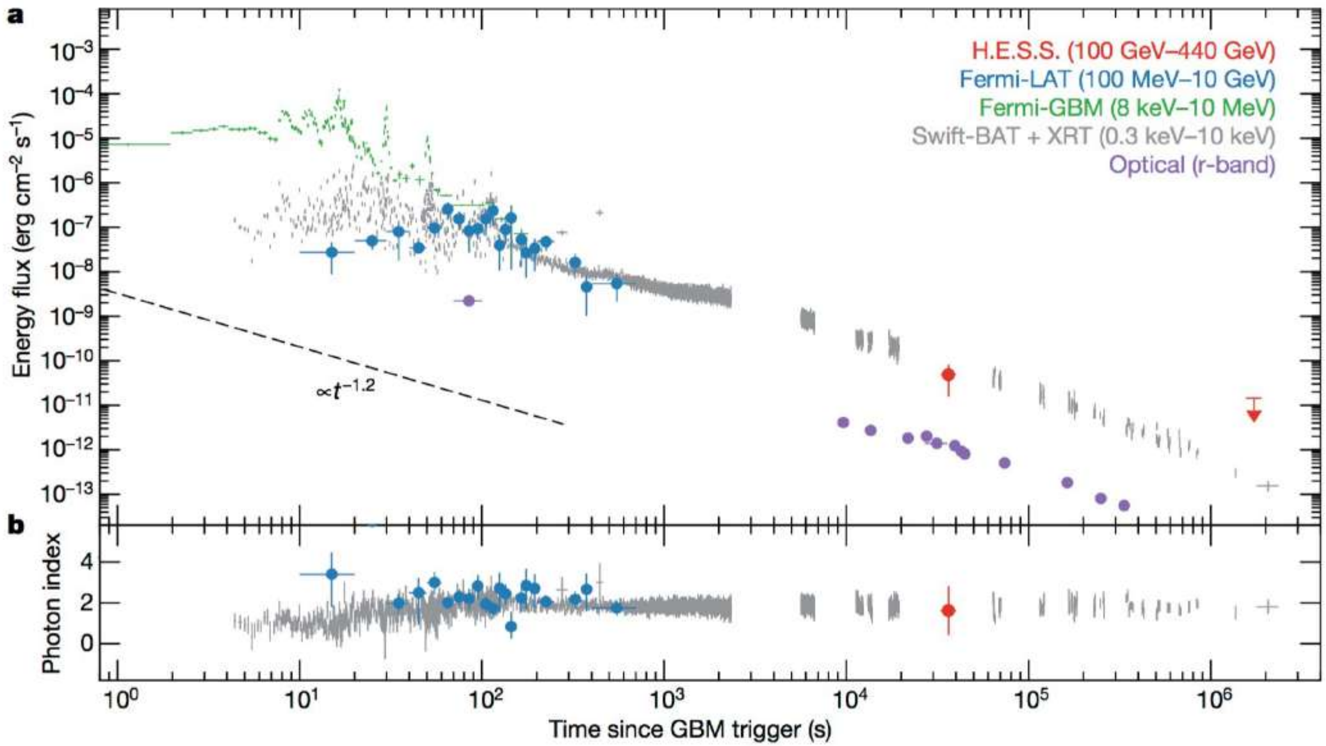


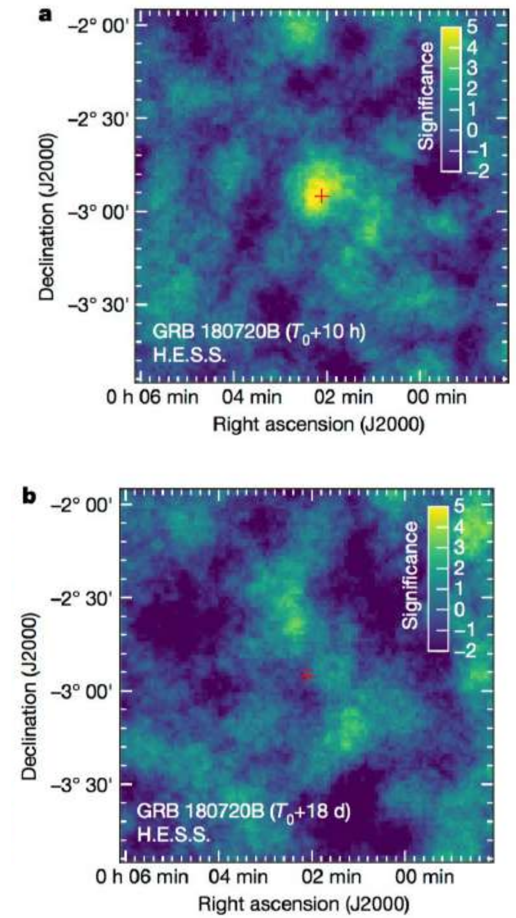
- Prompt phase lasted for 12 s
- MAGIC observations started in the early-afterglow phase
- The temporal profile suggests that the sub-TeV emission originates in similar conditions to the X-rays and GeVs, in the forward external shock.

Not the single GRB in 2019…

- H.E.S.S. announced in May the (marginally significant) detection of GRB 180720 (z=0.653)
  - Detection happened in the late afterglow 10h after T0!
    with much implication for future detection perspectives.

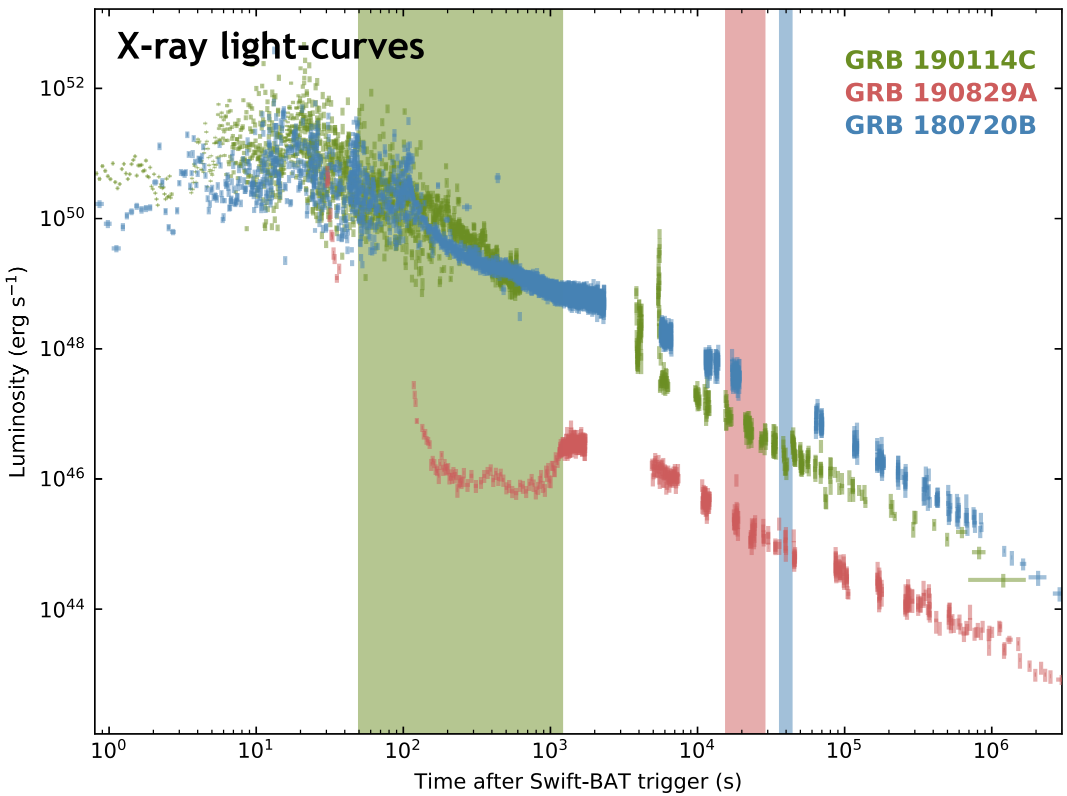
H.E.S.S. Collaboration, Nature, 2019





Not the single GRB in 2019…

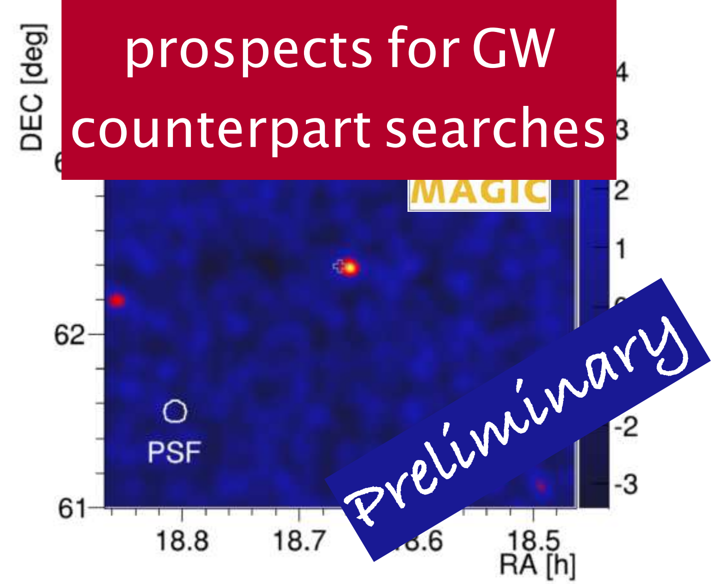
- A second detection by H.E.S.S., of GRB 190829A, also in late afterglow!



Hinton & Ruiz-Velasco 2019.

- Recall a 4σ hint signal from the **short GRB 160821B** (Berti et al. 2019), at z=0.16, and recently associated to a kilonova (Lamb et al. 2019, Troja et al. 2019)

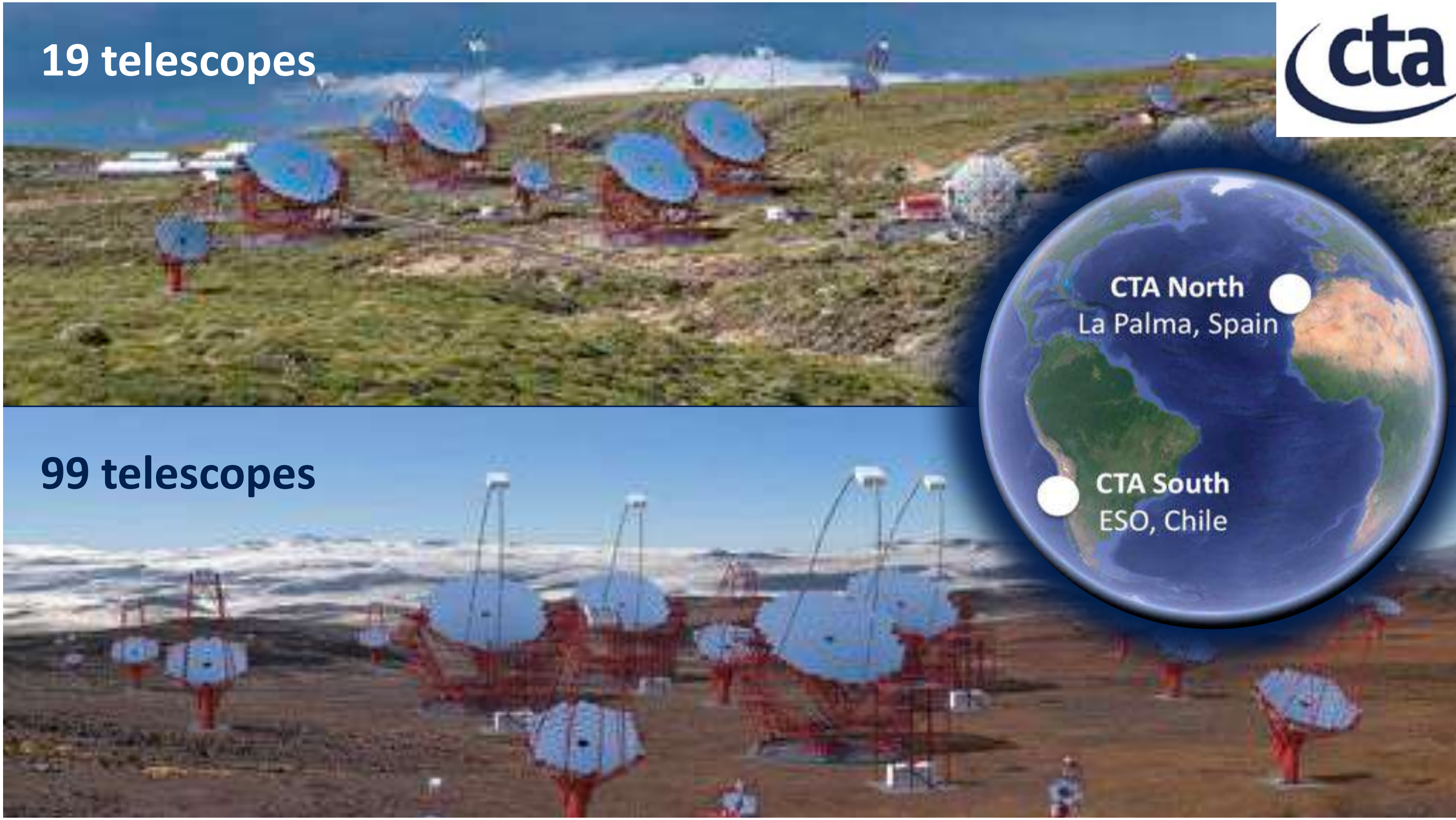
Strenghens the prospects for GW counterpart searches



CBPF

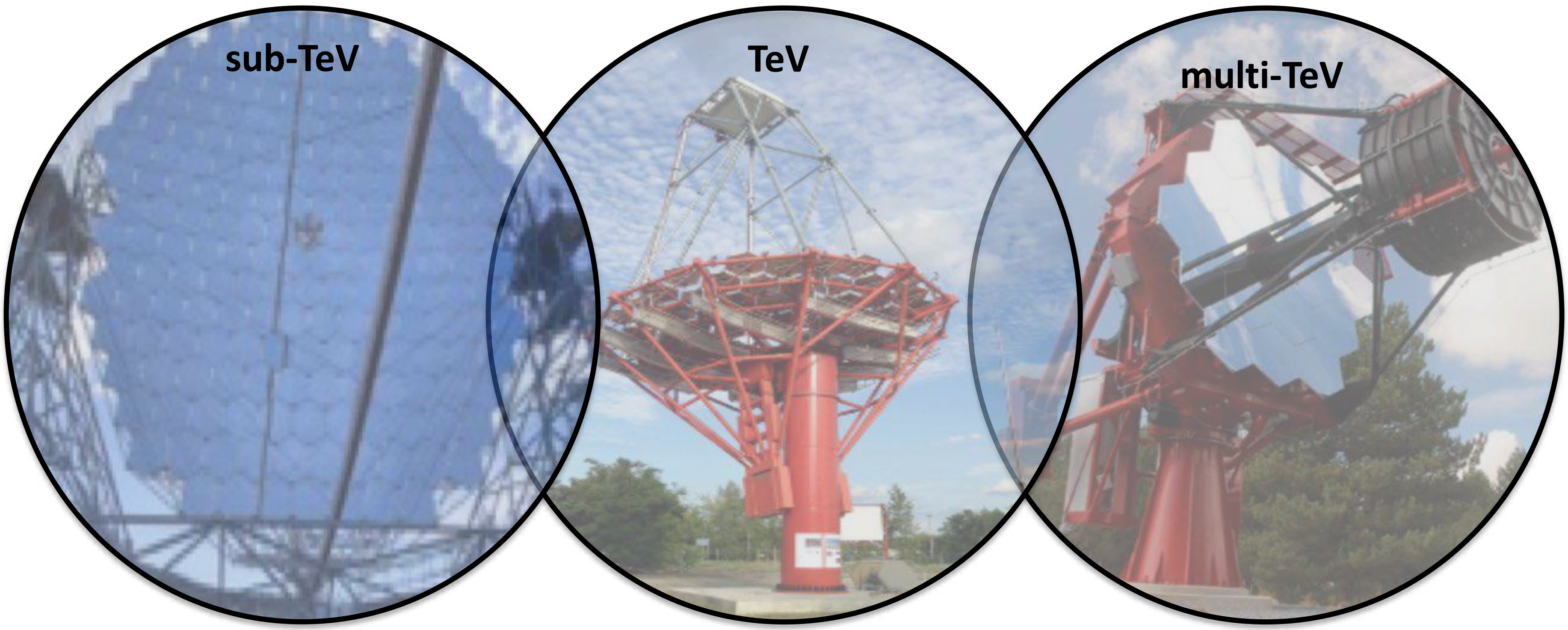
serrapilheira

The next generation: The Cherenkov Telescope Array



Slide adapted from R. Zanin

Hybrid instrumental design and multiple R&D partners

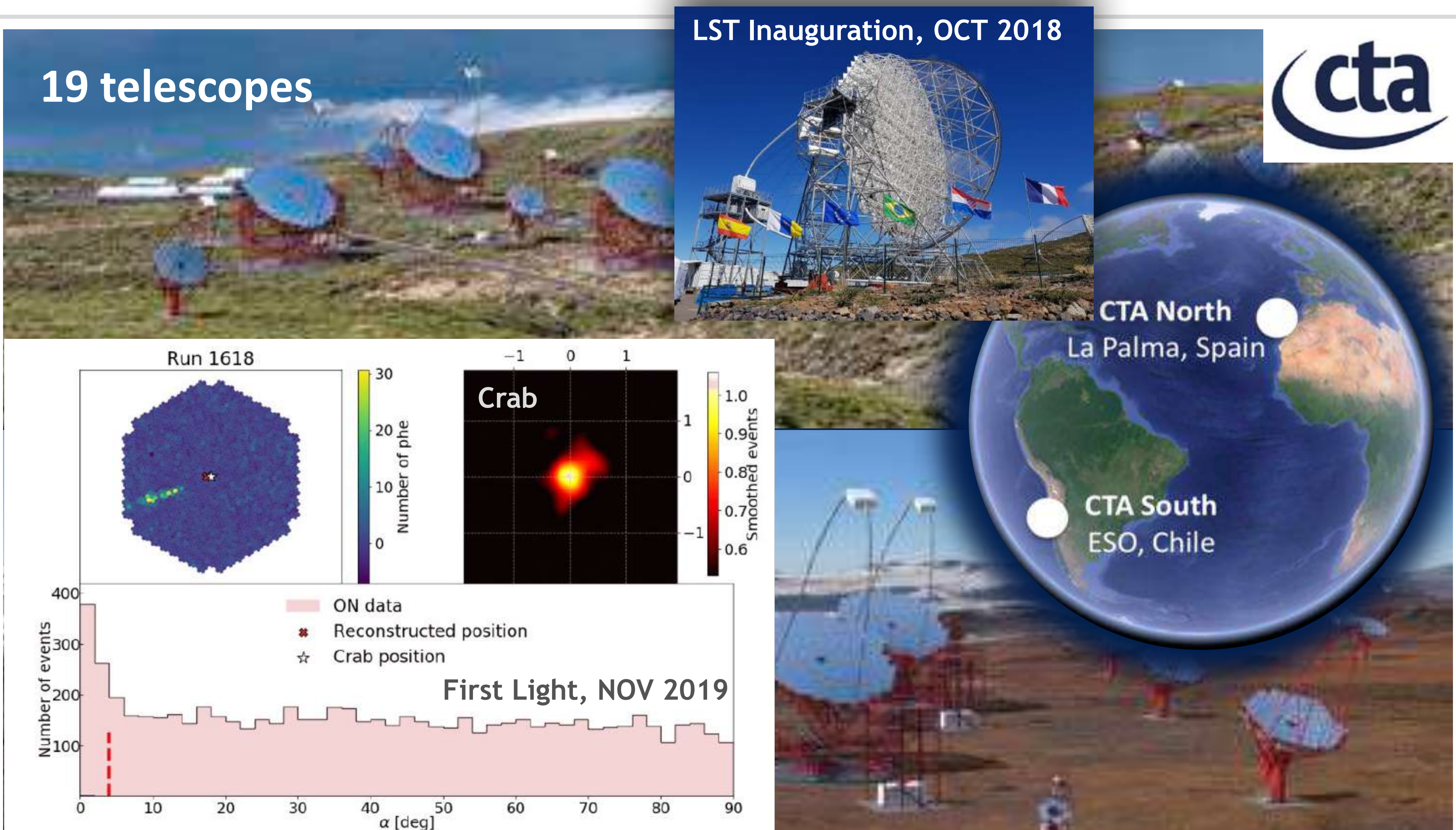


- Parabolic optical design
- 23 m mirror diameter
- PMT camera

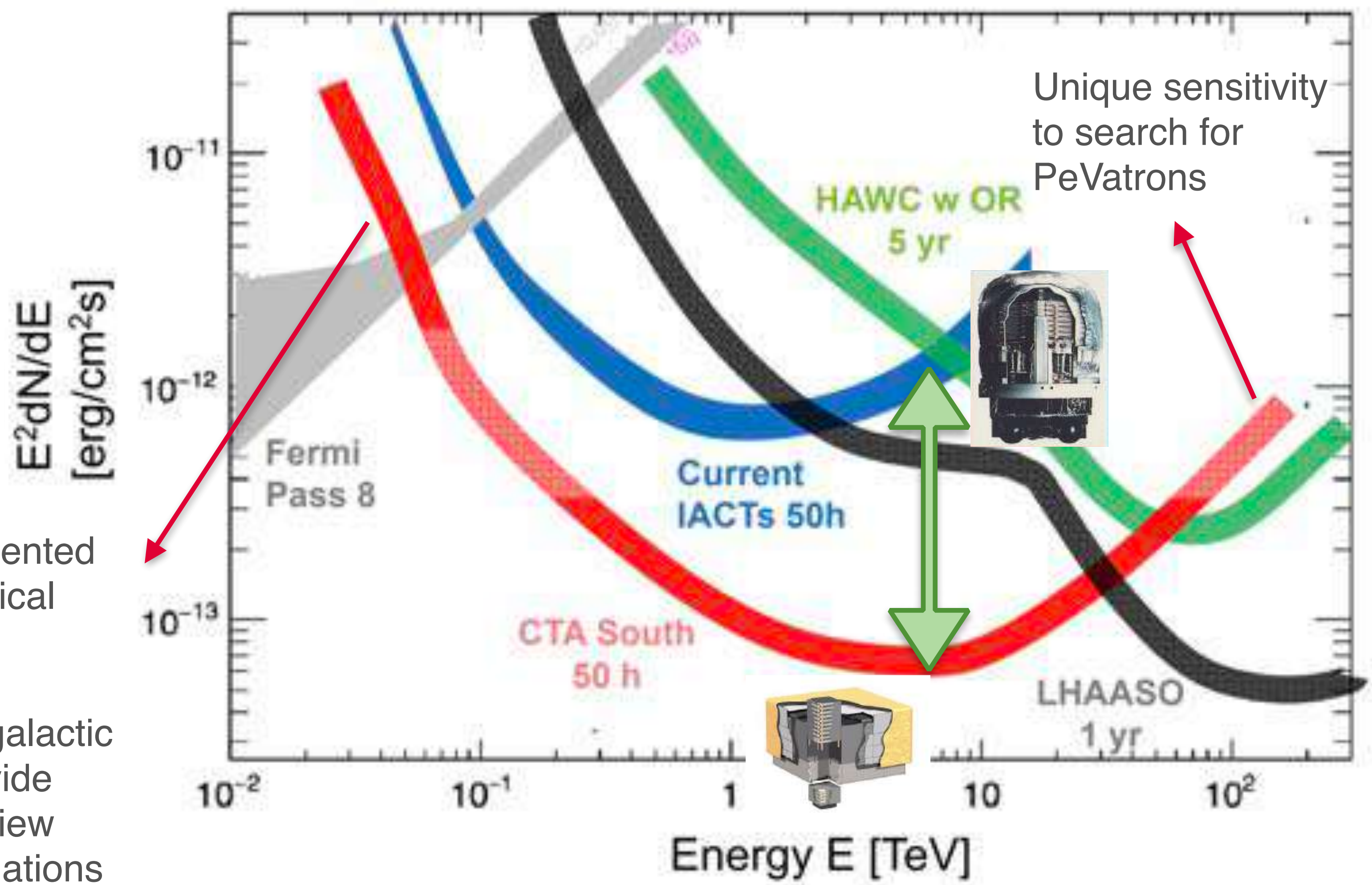
- Davies-Cotton optical design
- 12 m mirror diameter
- PMT camera

- Schwarzschild-Couder optical design
- 4 m dual mirror
- SiPM T camera

The next generation: The Cherenkov Telescope Array



CTA: major evolutions from current status

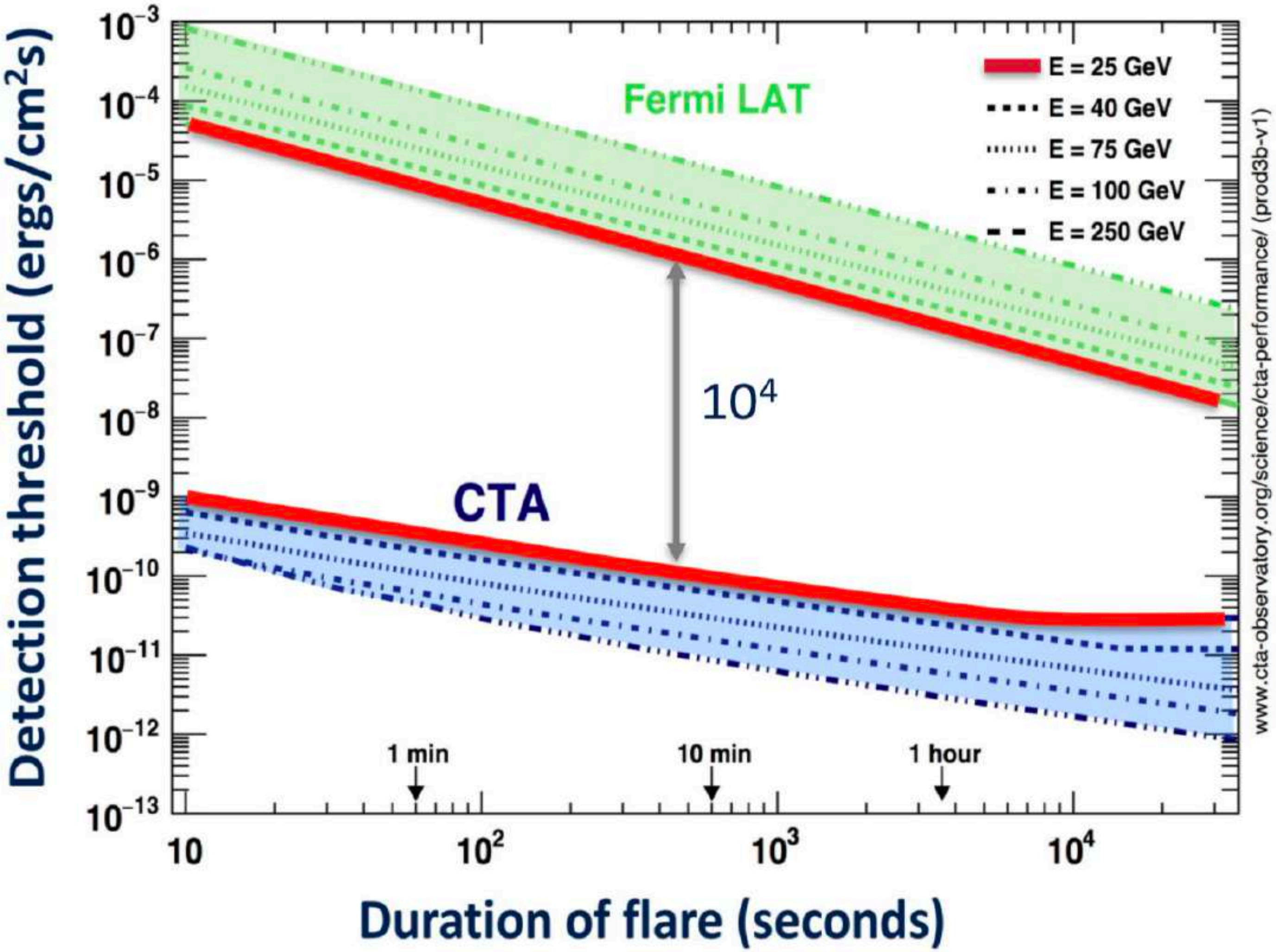


Unique sensitivity to search for PeVatrons

Unprecedented cosmological reach.

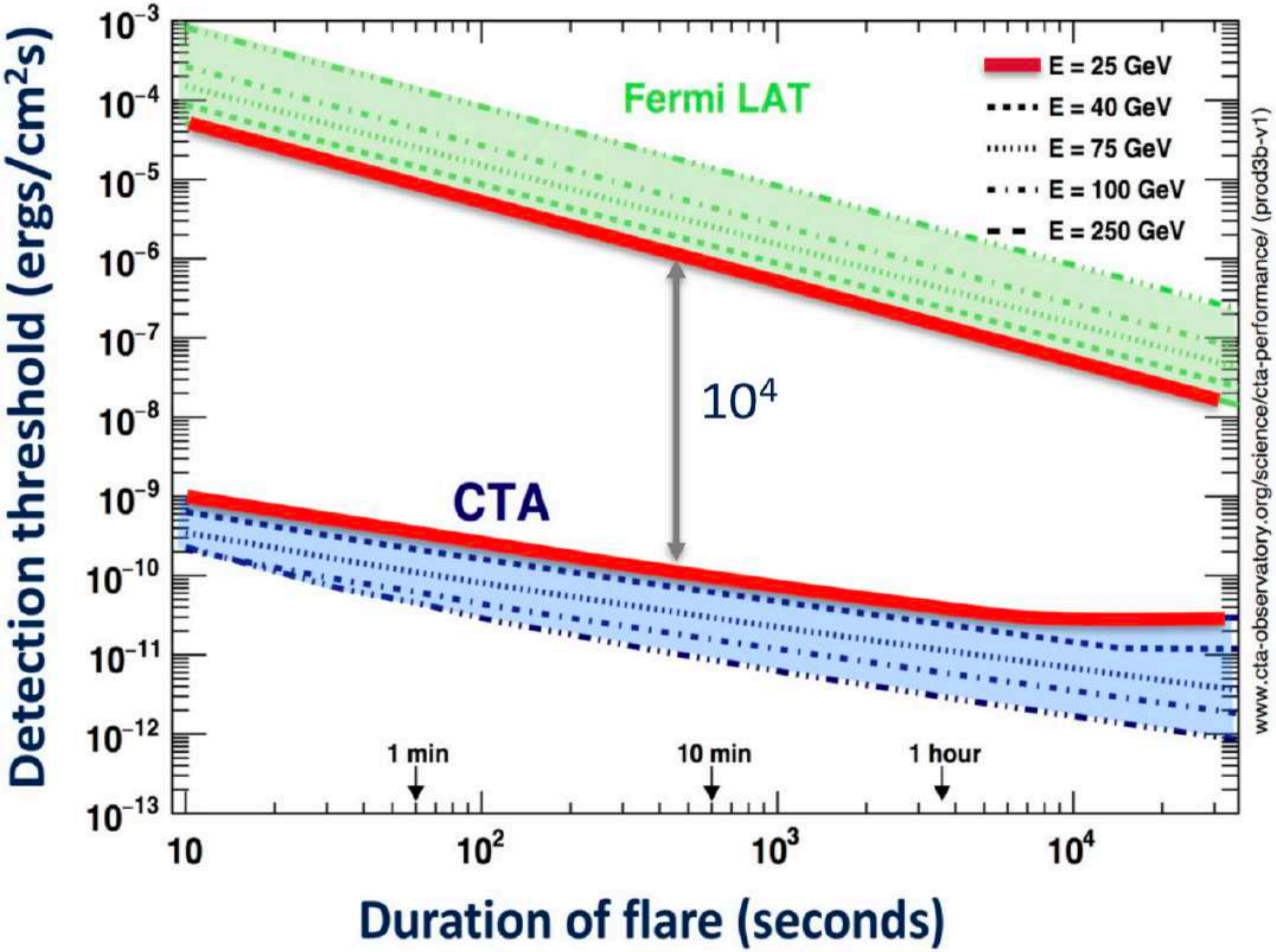
The CTA extragalactic survey will provide first unbiased view of source populations in the VHEs

CTA: major evolutions from current status



CTA will be a unique transient observatory at the highest energies.

GRB perspectives with CTA



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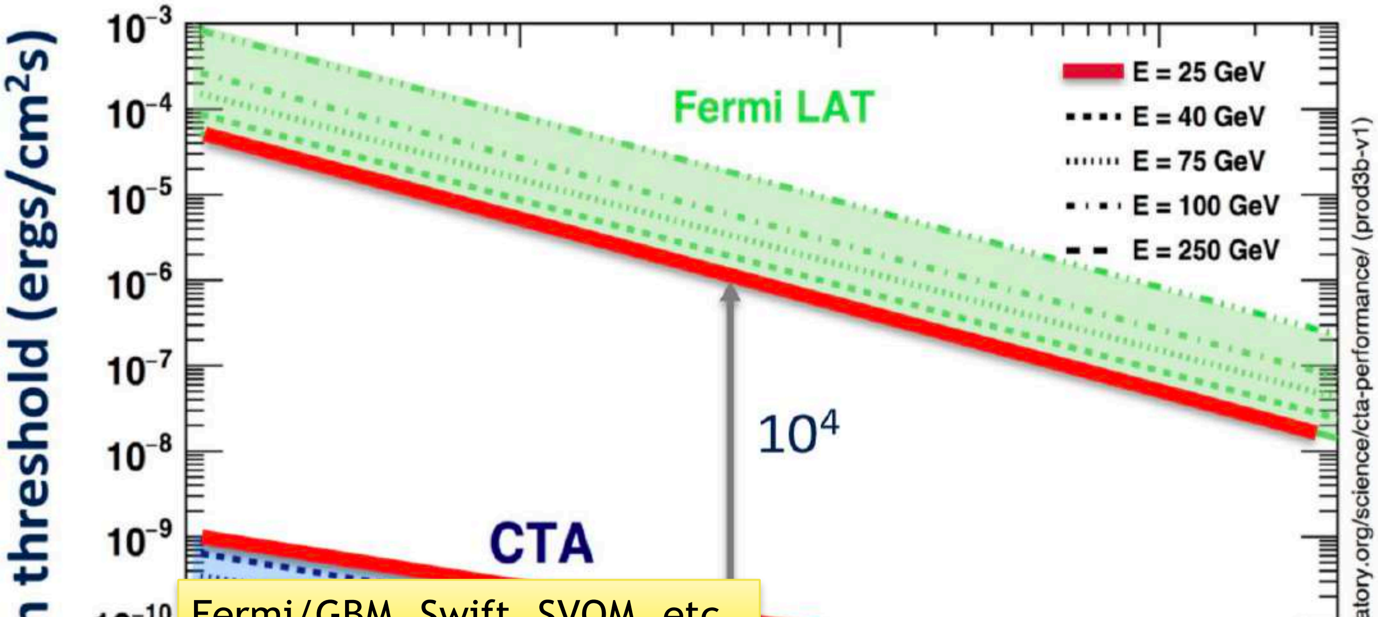
CTA observations of GRBs:

> 100 photons from average GRB E > 30 GeV

+ unprecedented spectral and temporal resolution

GRB perspectives with CTA



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Strategy	Expected event rate (yr^{-1})	Exposure per follow-up (h)	Exposure per year ($h\ yr^{-1}$)
Prompt follow-up of accessible alerts	~12	2	25
Extended follow-up for detections	0.5–1.5	10–15	10–15
Late-time follow-up of HE GRBs not accessible promptly	~1	10	10

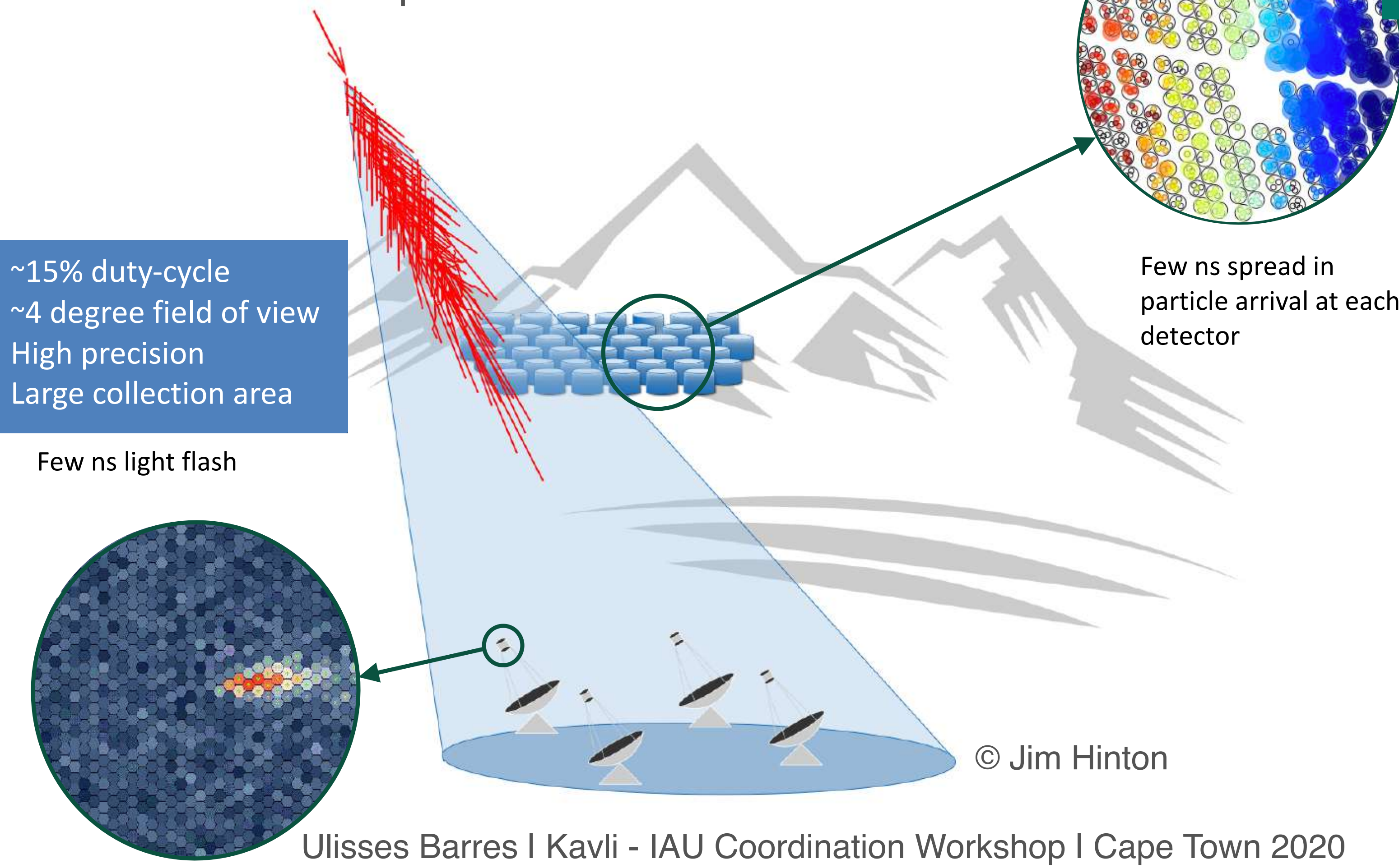
→ Real Time Analysis <30s

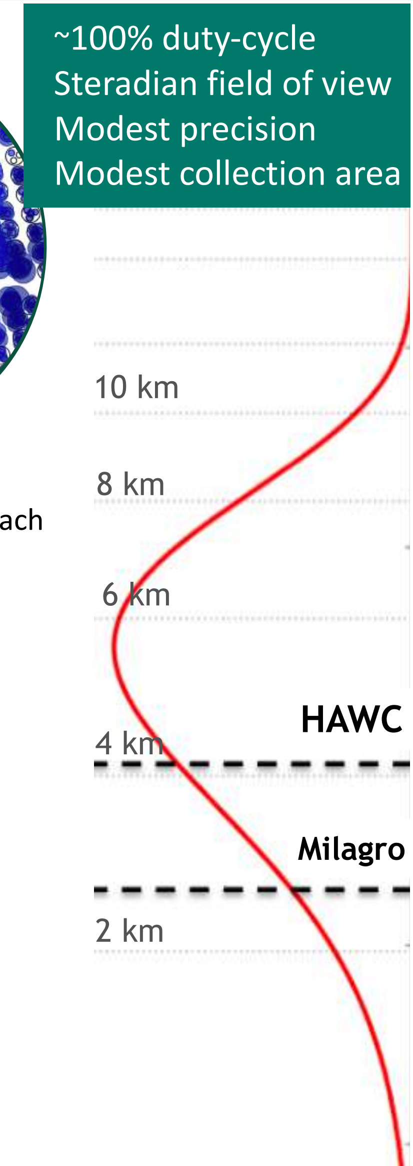
Summary of GRB follow-up strategy per one site

(see Table 9.2 from “Science with CTA” Consortium paper, World Scientific, 10.1142/10986, arxiv:1709.07997)

Coming of age of the wide-field facilities

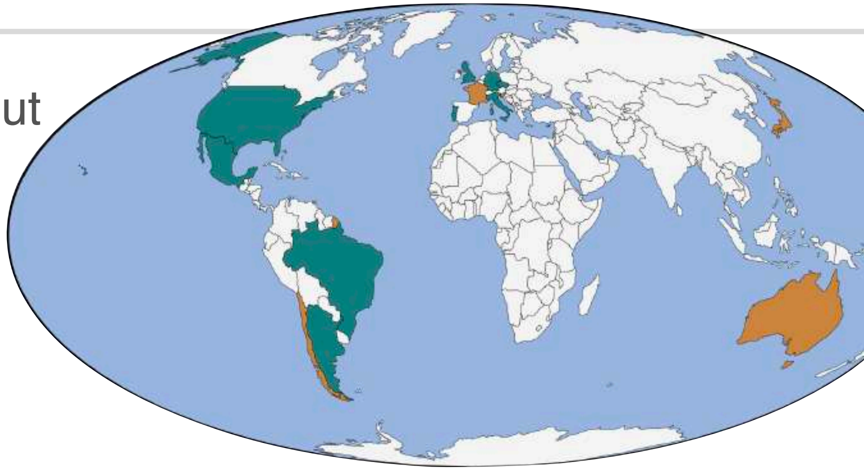
Wide-field instruments, based on the direct detection of the air shower particles, are the natural complement to Cherenkov telescopes at VHEs.

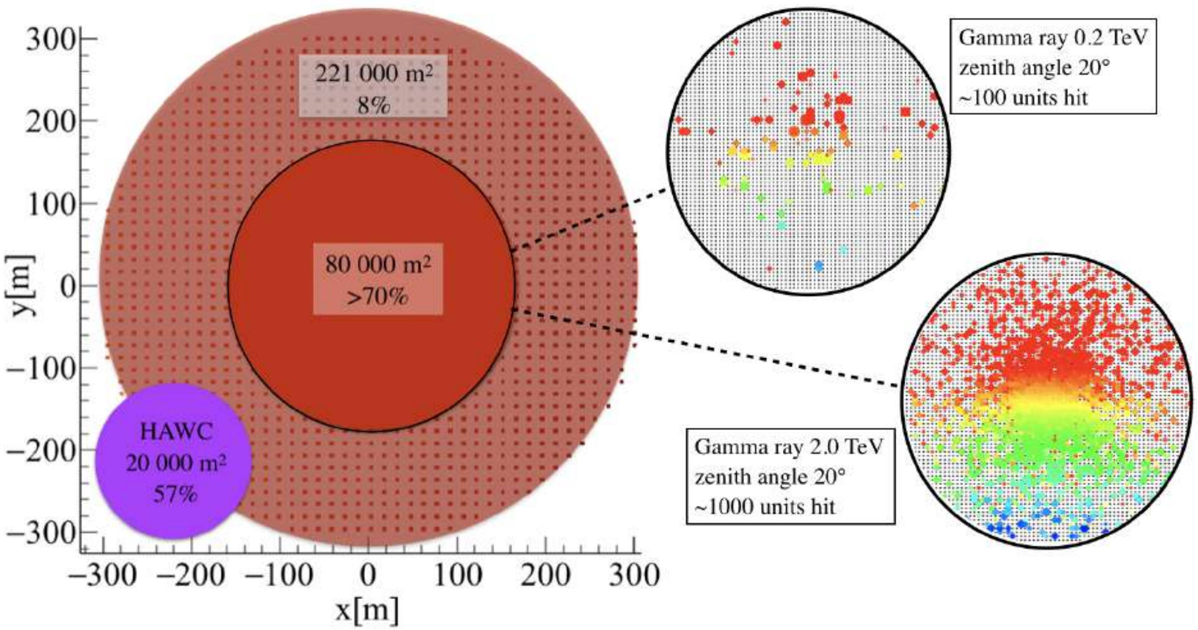




SWGO: a long-awaited WFO in the South

- Most of the Galaxy, and specially the GC are out of the reach to both HAWC and LHAASO.
- A high-duty cycle, wide-field, lower-energy threshold detector is invaluable for transients research in the multi-messenger & CTA era.





Activities Started in 2019
for a 3-year design plan

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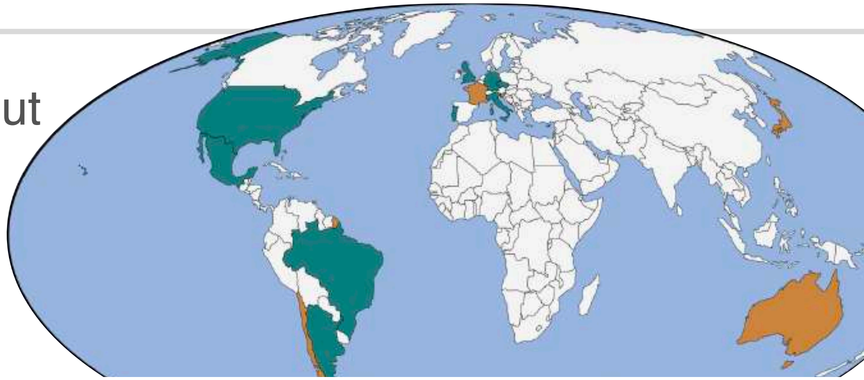
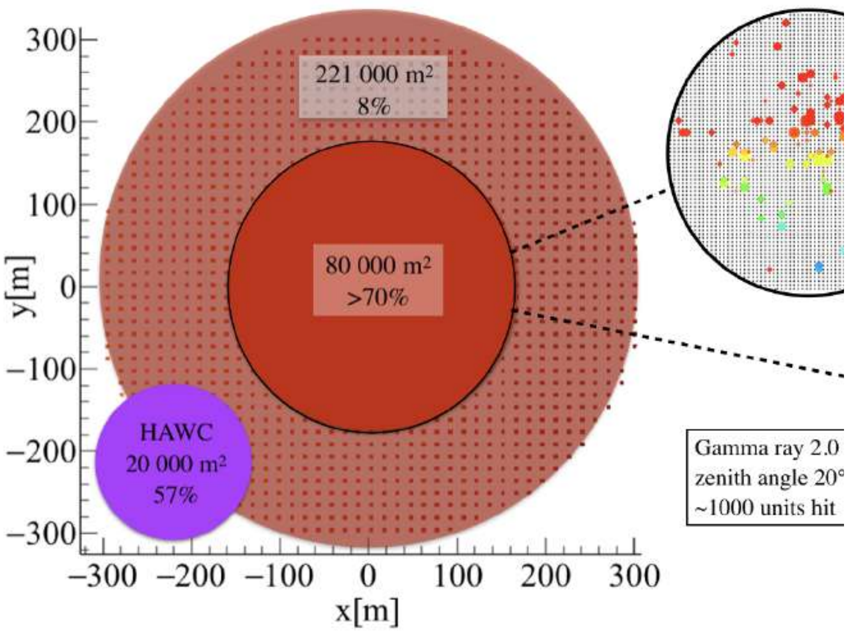
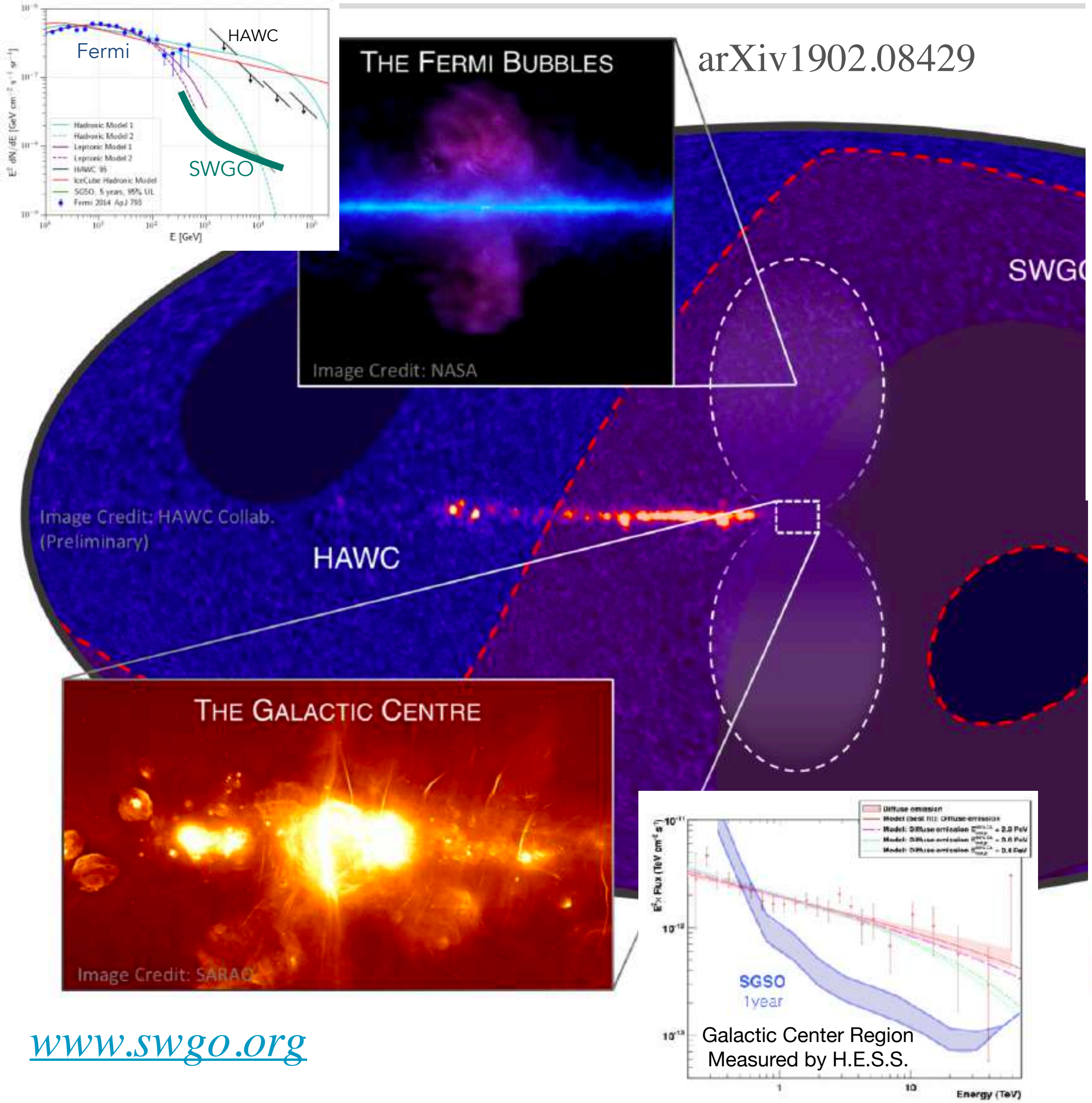


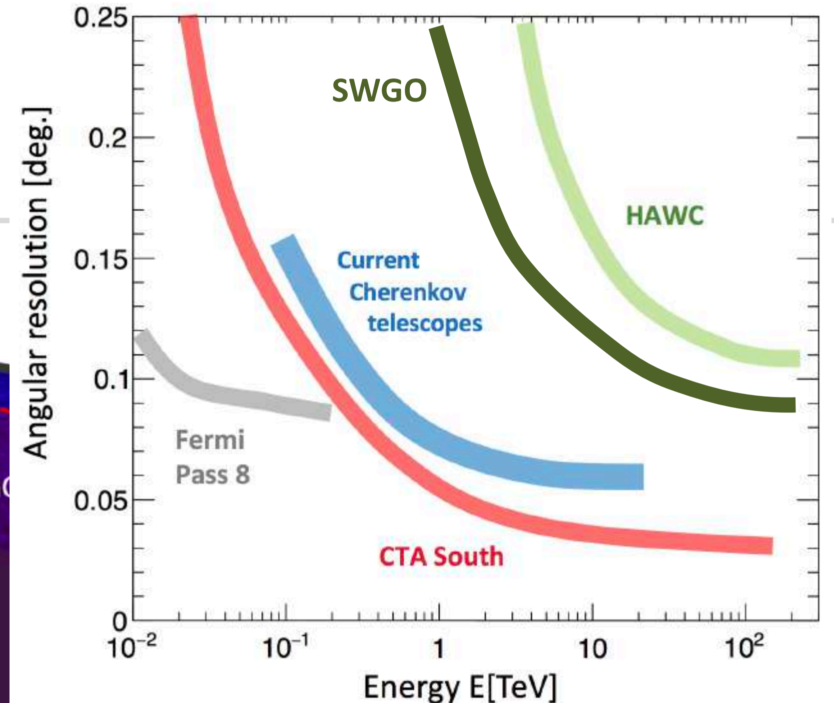


SWGO

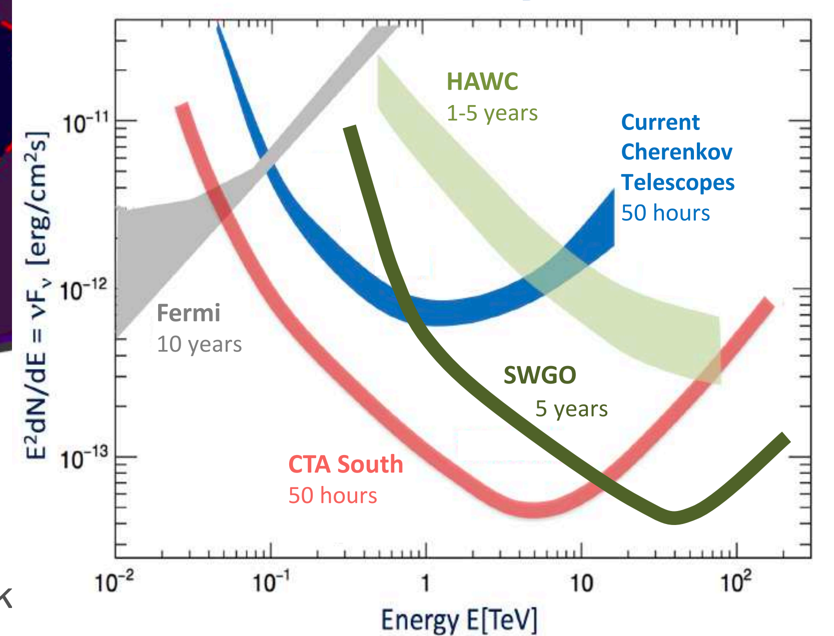
arXiv1902.08429



Resolution

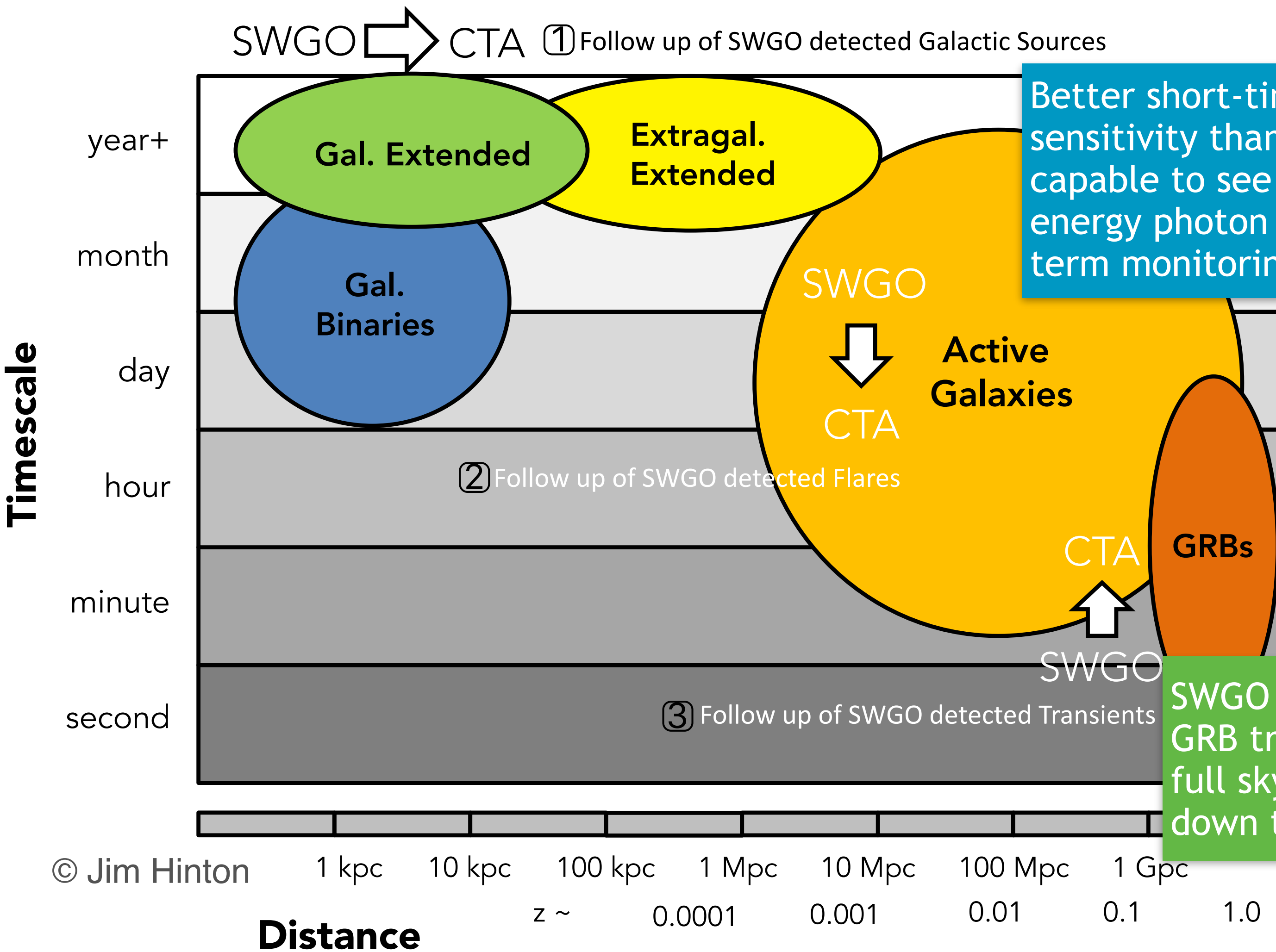


Sensitivity



www.swgo.org

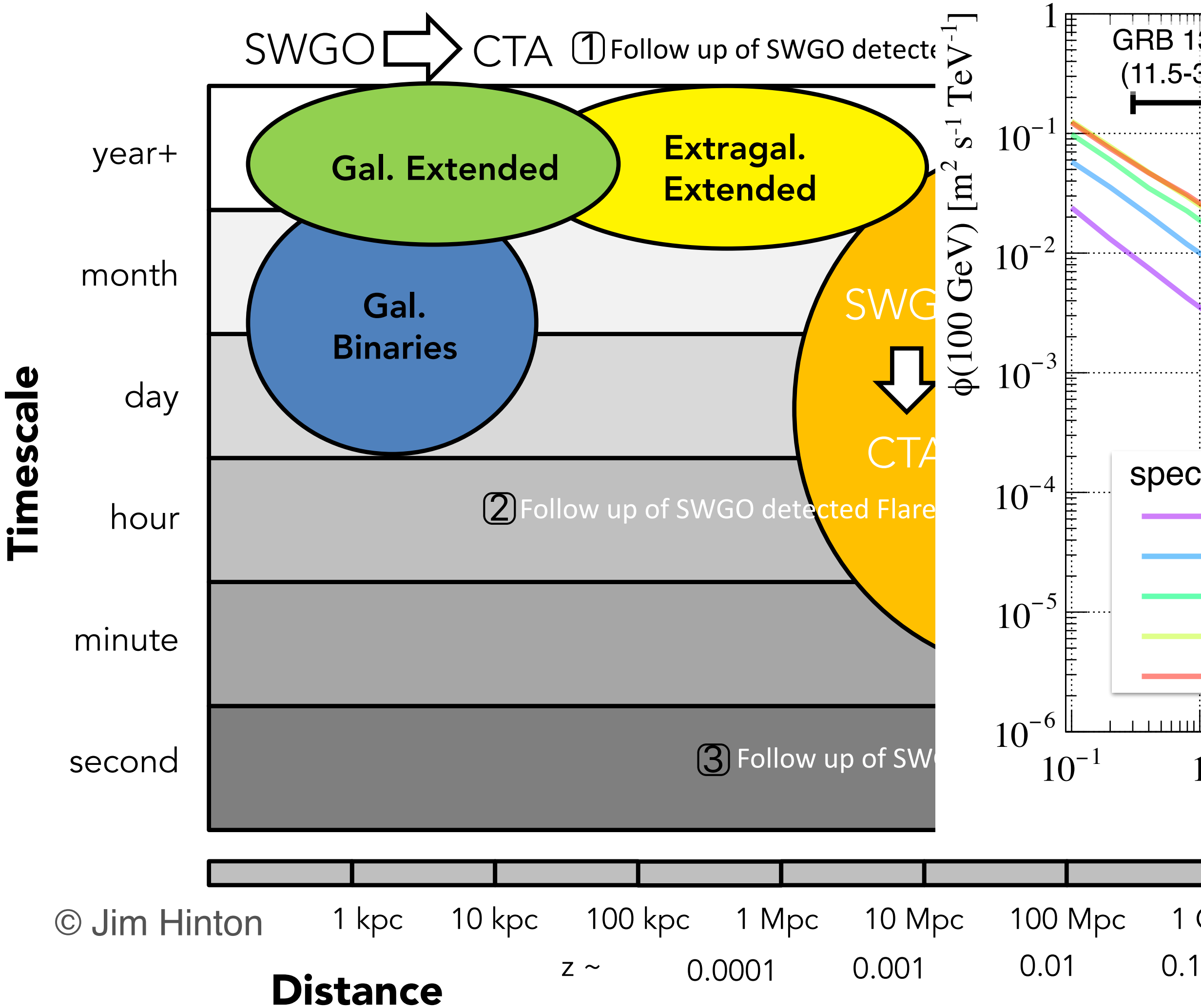
SWGO: pivotal role on transients

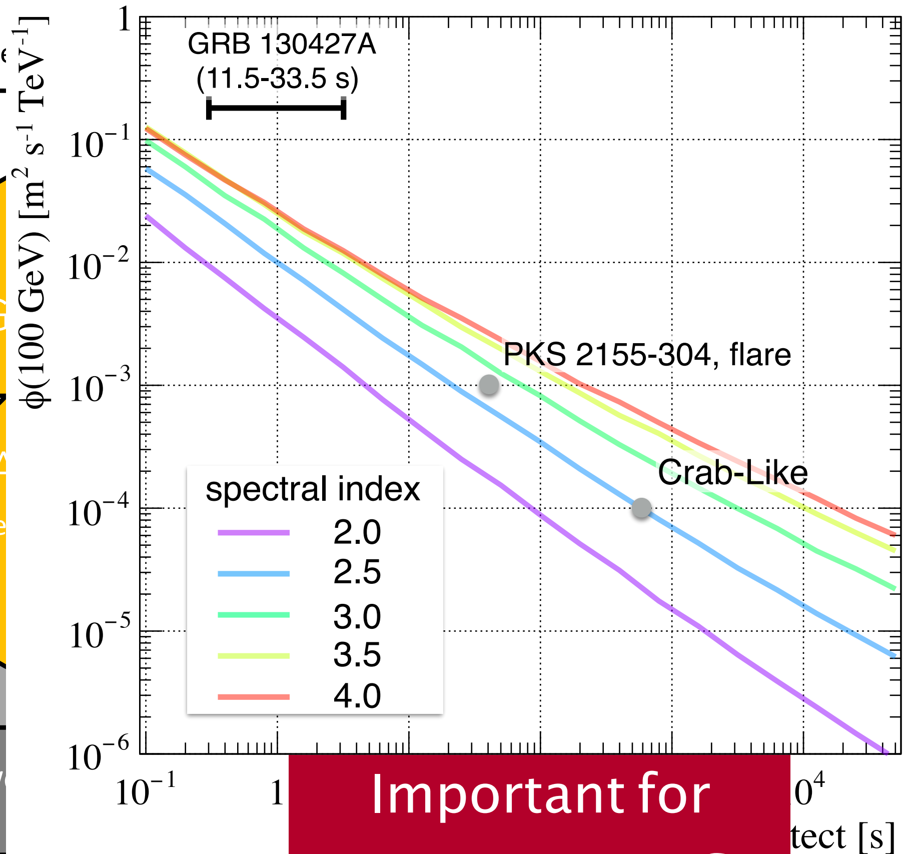


Better short-timescale sensitivity than Fermi, capable to see high-energy photon + long-term monitoring.

SWGO will be ideal GRB trigger, with full sky coverage down to 100 GeV.

SWGO: pivotal role on transients





Important for perspectives in GW and neutrino MM correlations