



From MAGIC to CTA

High Energy Astrophysics using Cherenkov radiation

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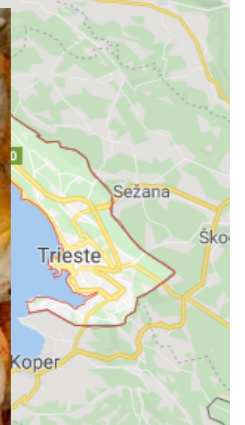
LEPCHE - CTA group
Room 120

About me - where I come from

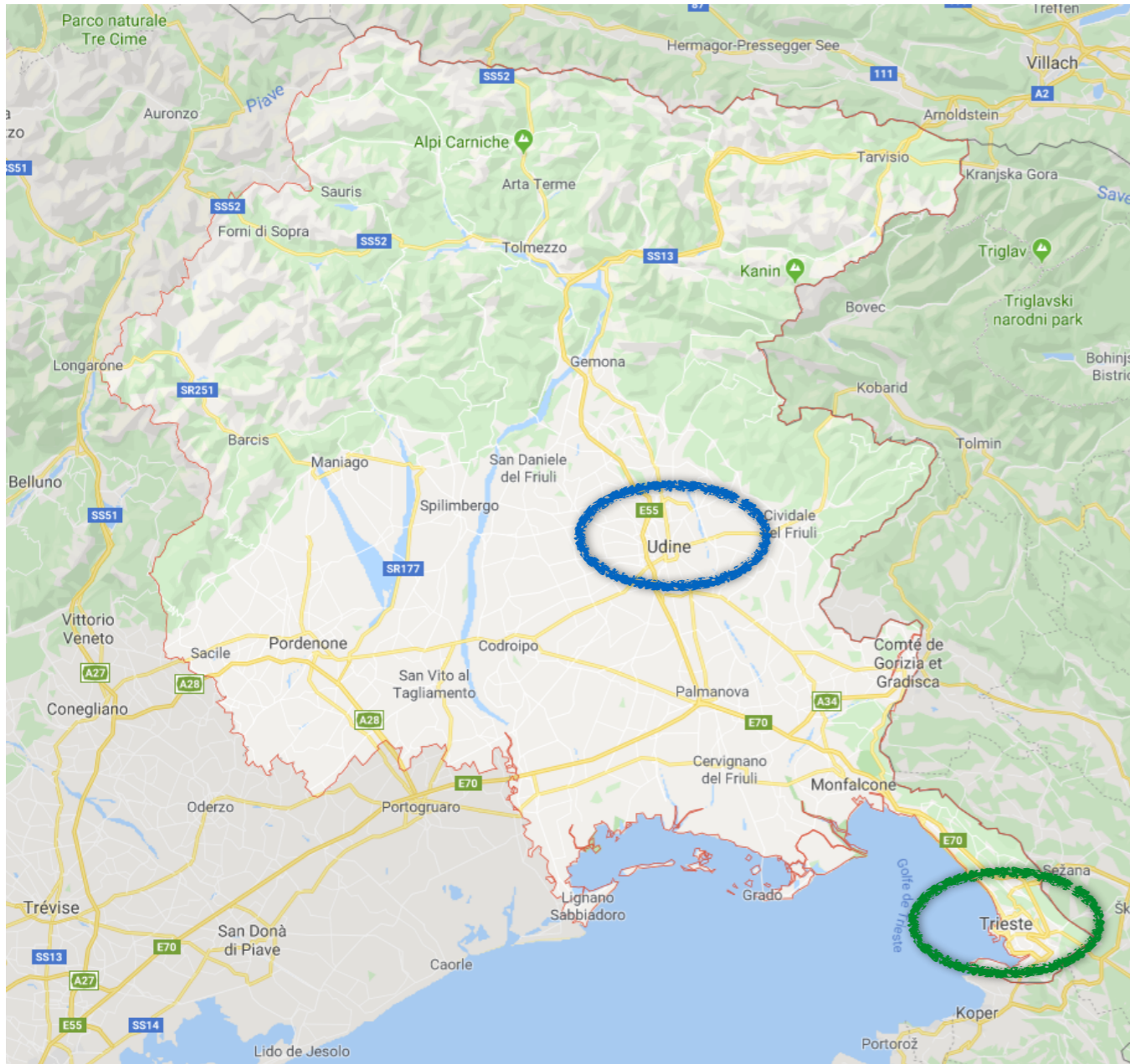
Friuli Venezia - Giulia



About me - where I come from



About me - Previous studies



Ph.D. @ University of Udine

High energy astrophysics
with the MAGIC telescopes

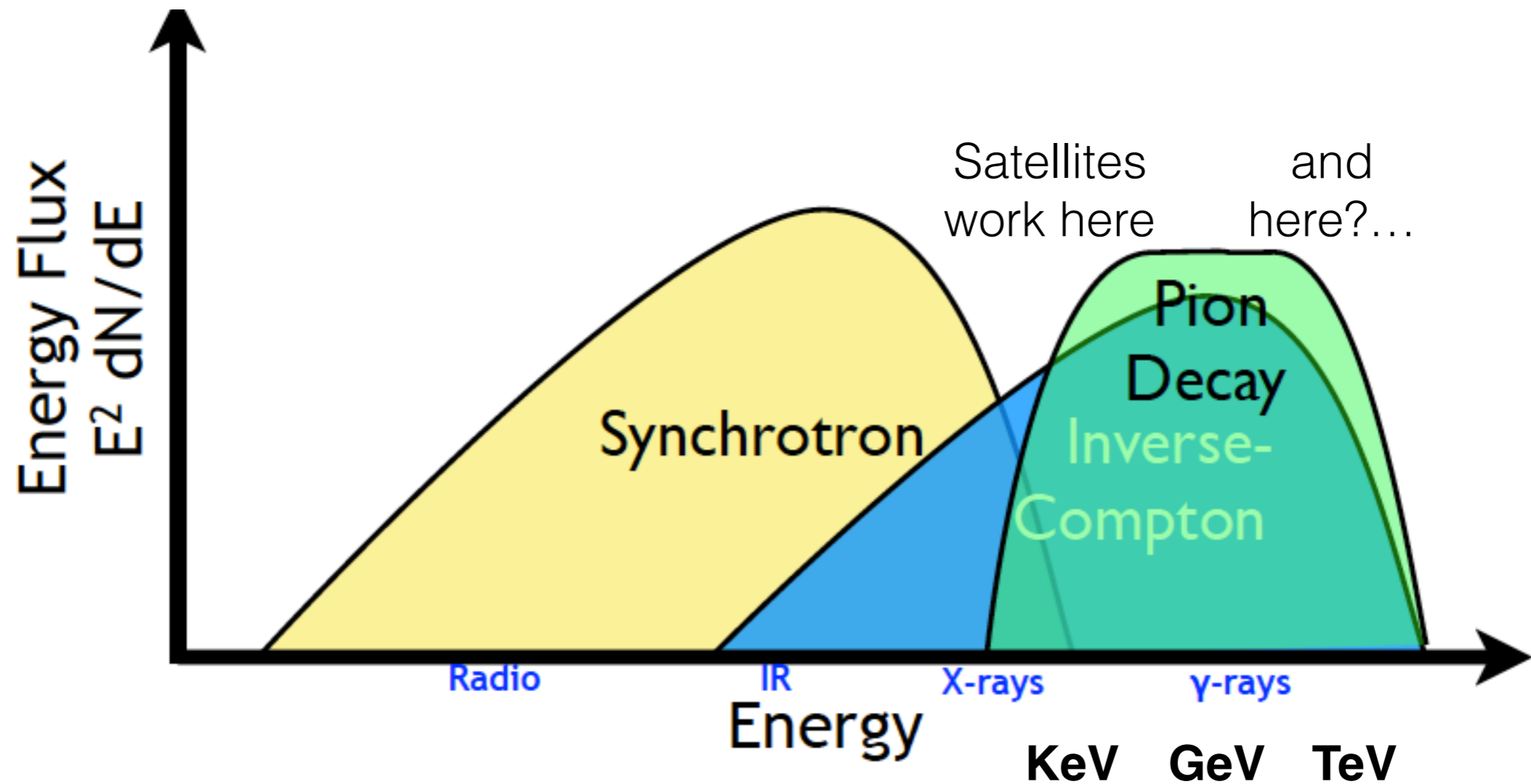
Master's degree in Trieste

from Theoretical physics
to high energy
astrophysics

Catching high energy photons

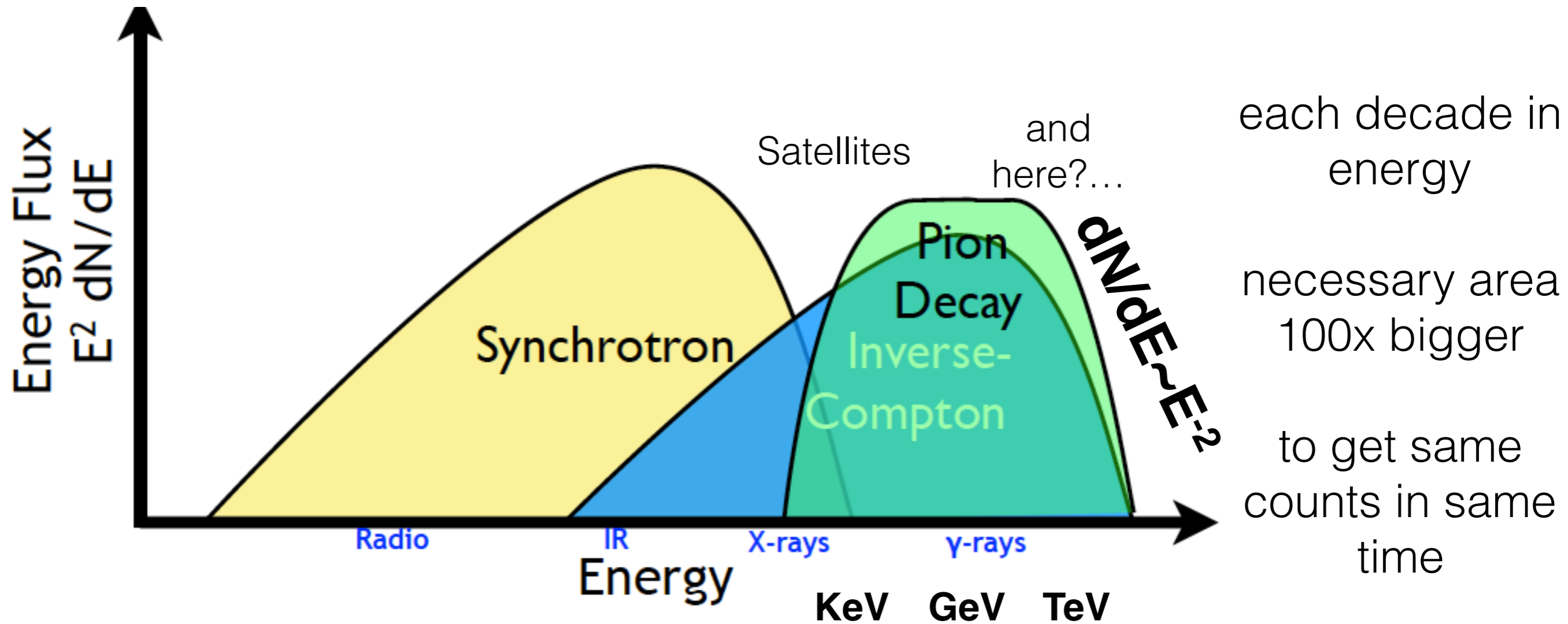
Limits of leptonic acceleration?

1 PeV cosmic ray could emit 100 TeV photons...



Catching high energy photons

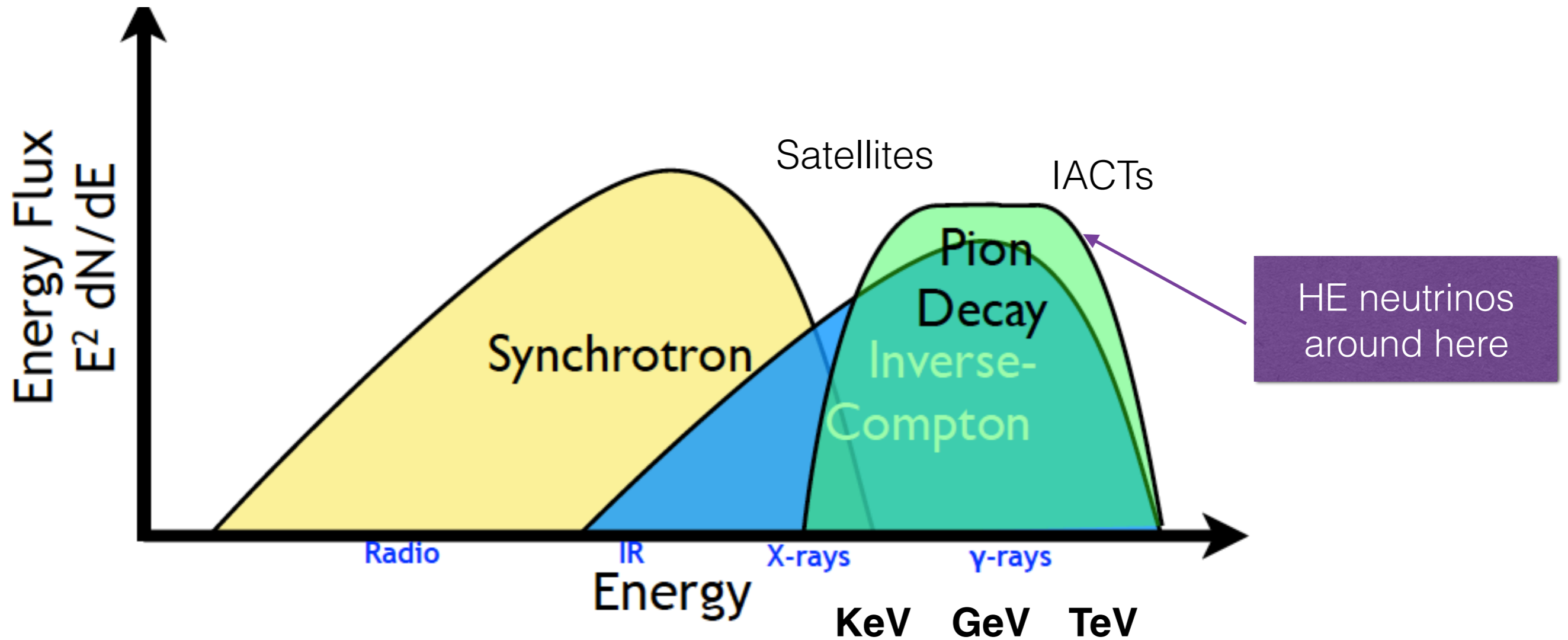
1 PeV CR could emit 100 TeV photons!



Not possible to take a football field in orbit....

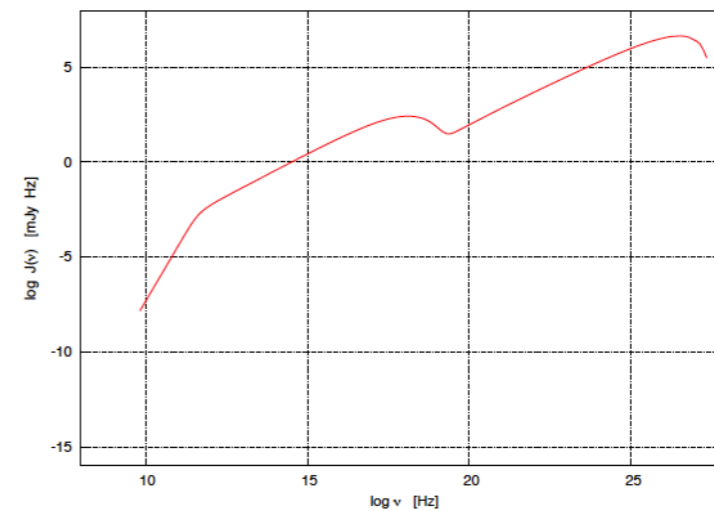
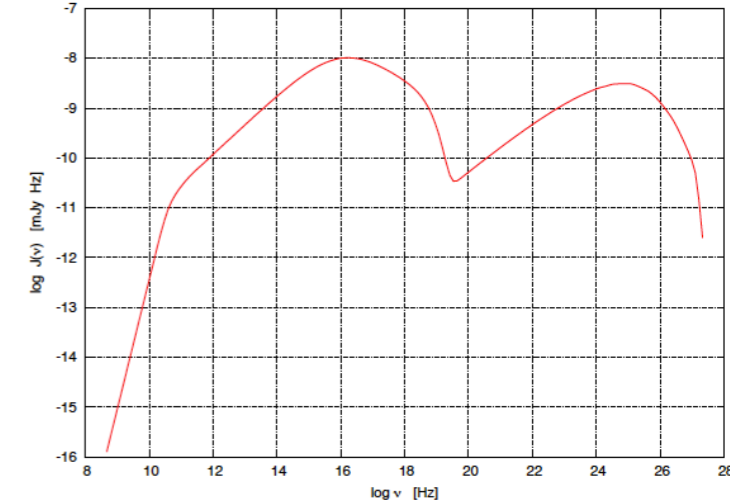
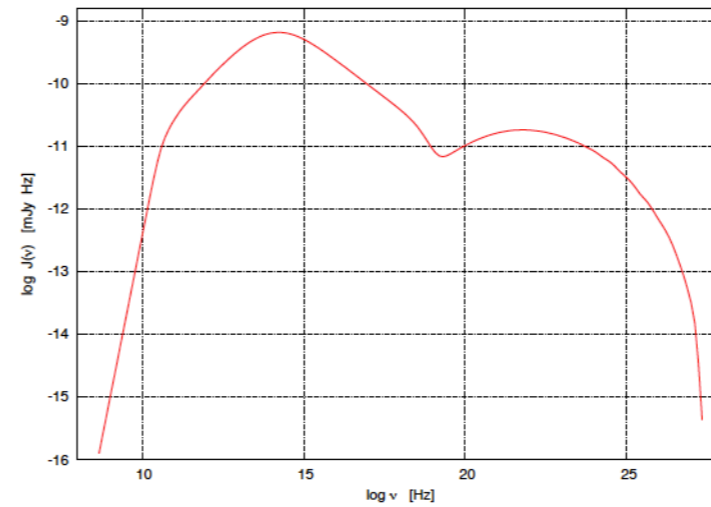
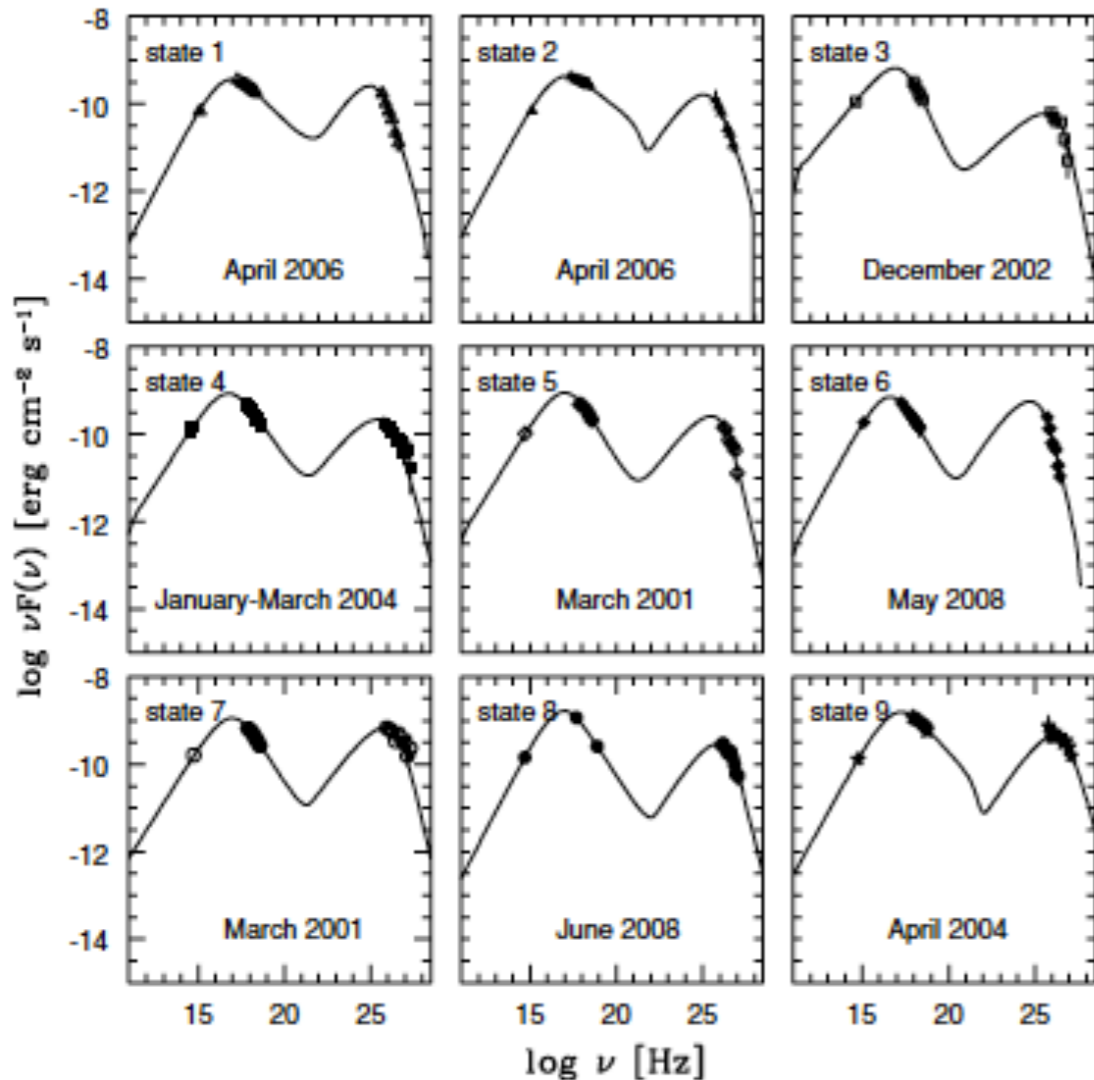
Catching high energy photons

1 PeV CR could emit 100 TeV photons!



Not possible to take a football field in orbit....

From models to TeV emission



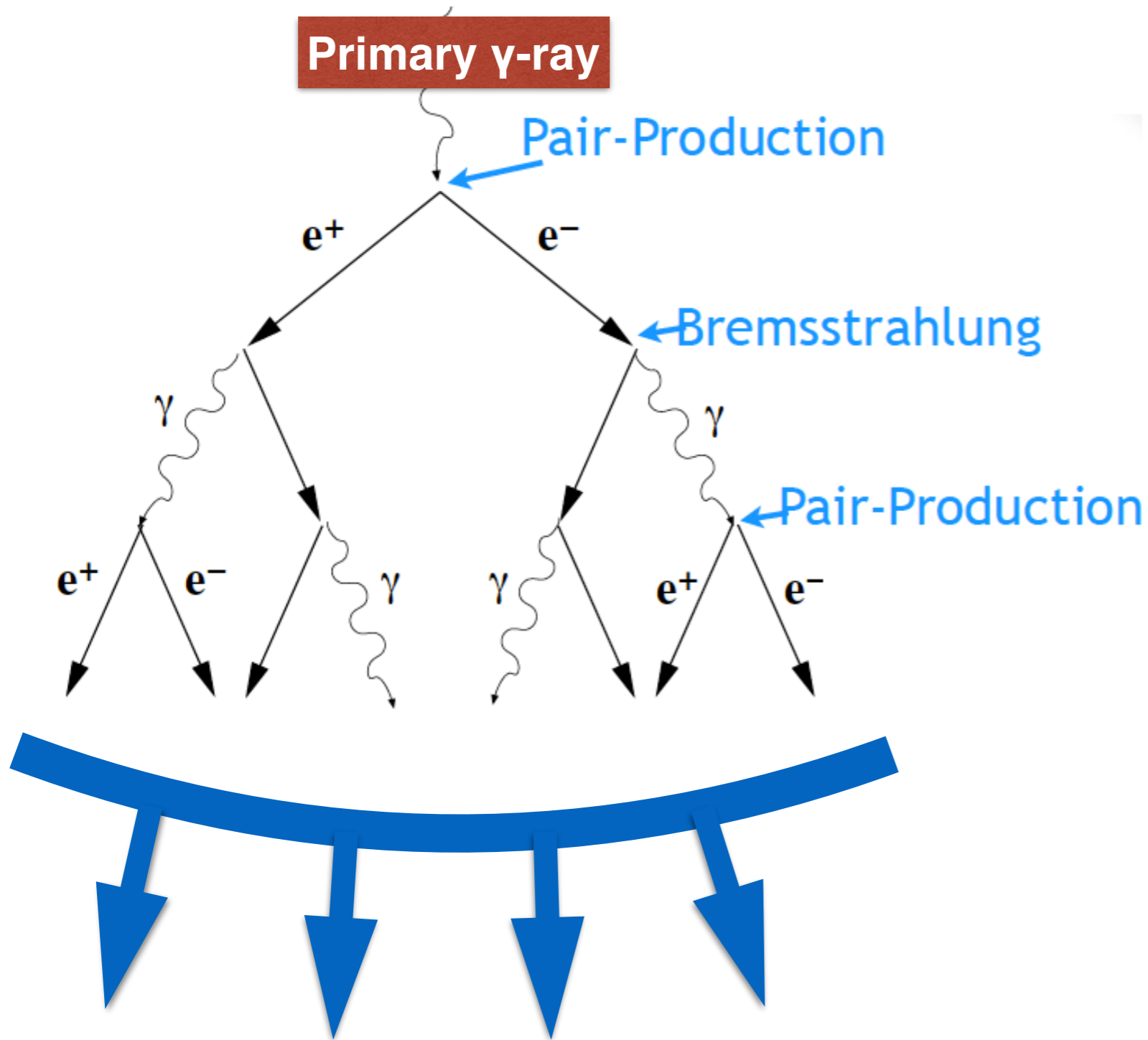
Code development for SSC emission

focus on time evolution and parameter degeneracy

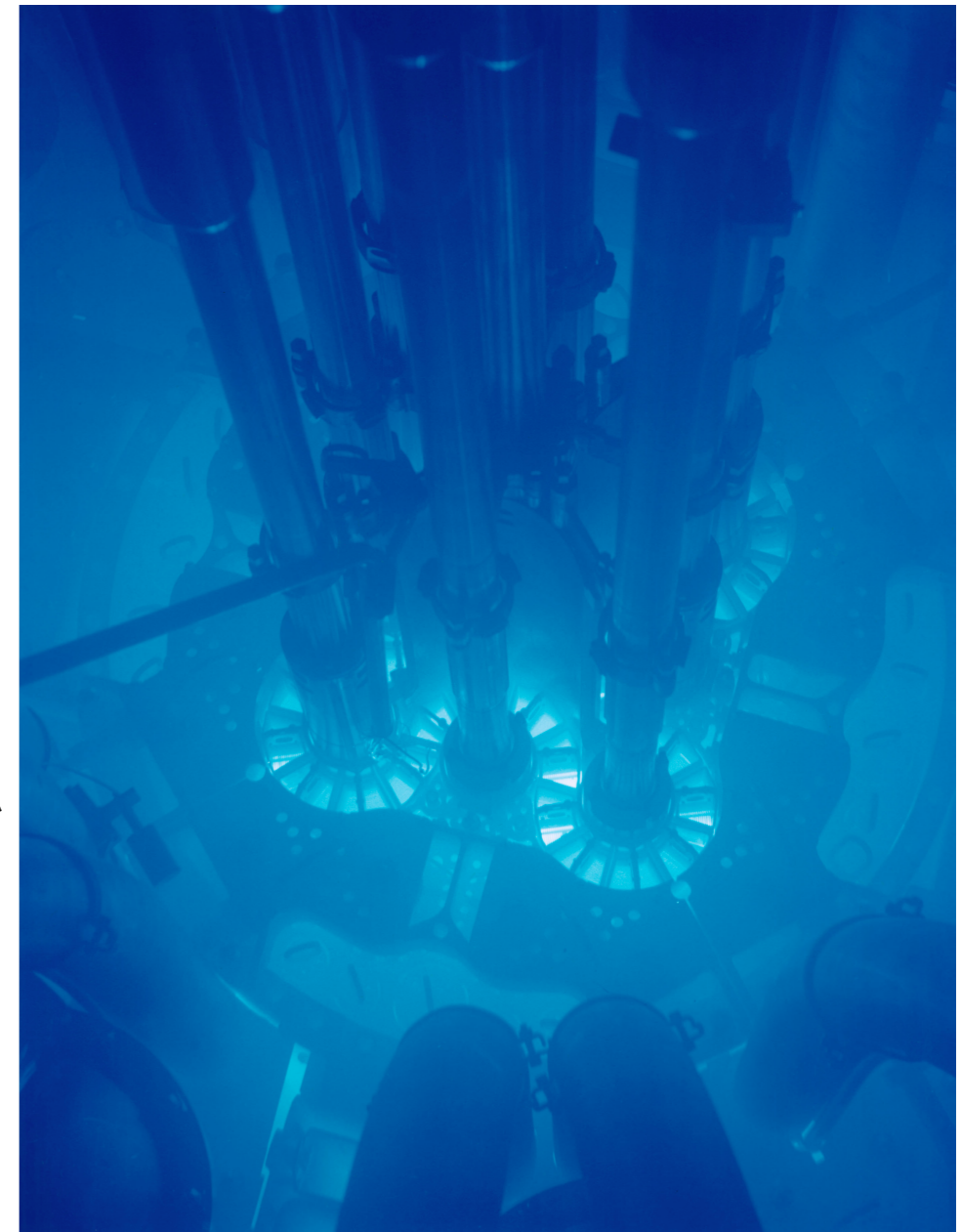
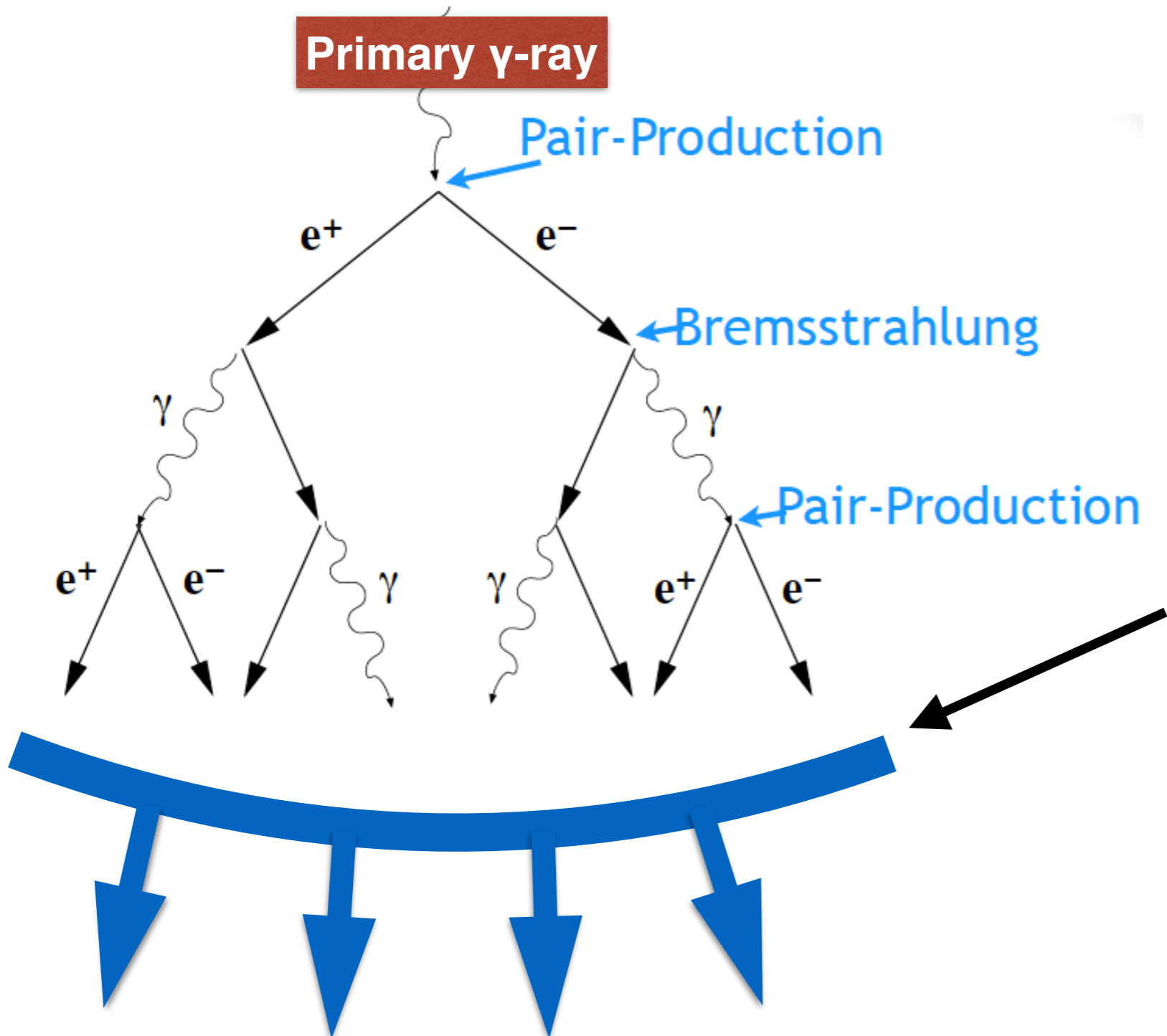
What are we looking for?

Primary γ -ray

What are we looking for?



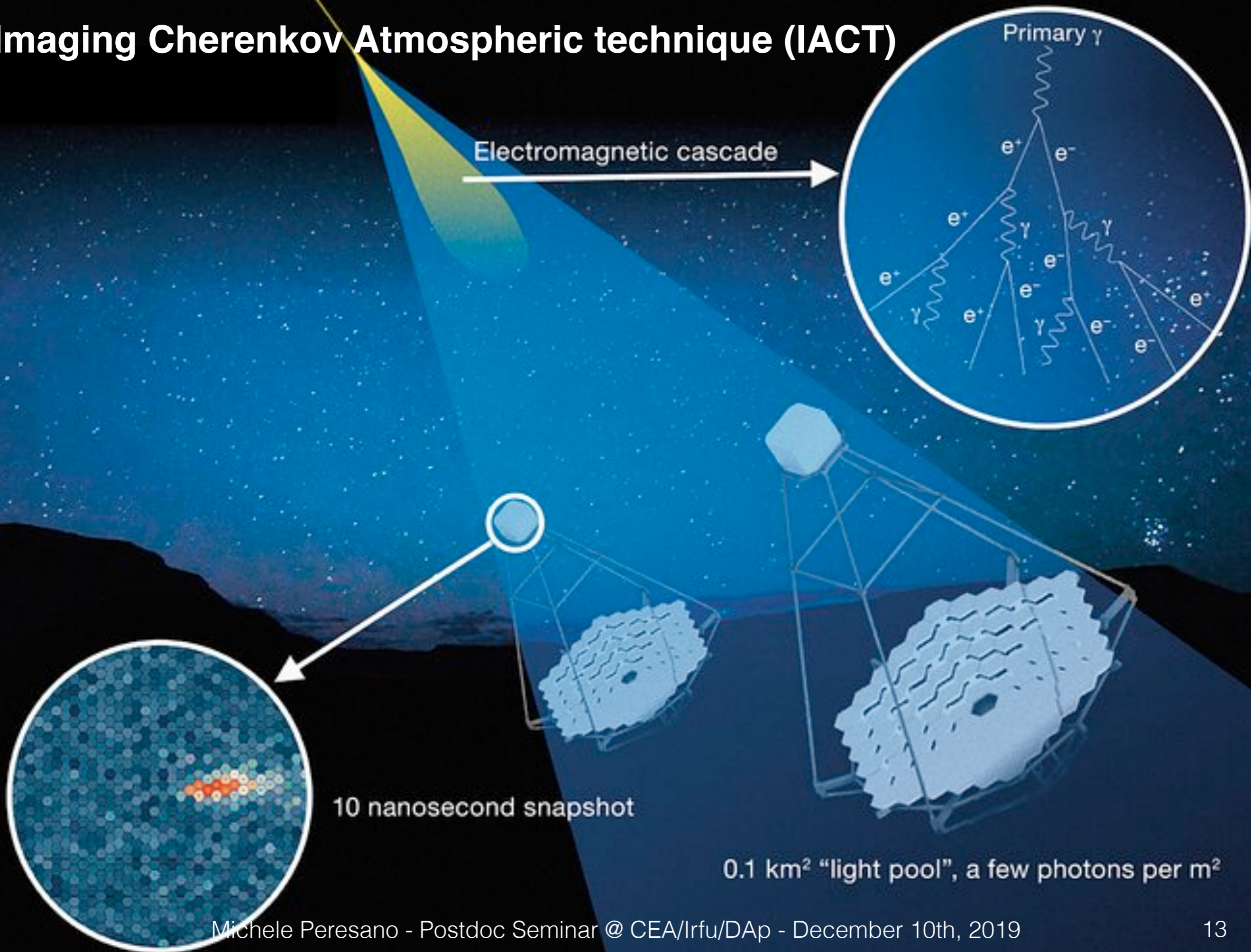
What are we looking for?



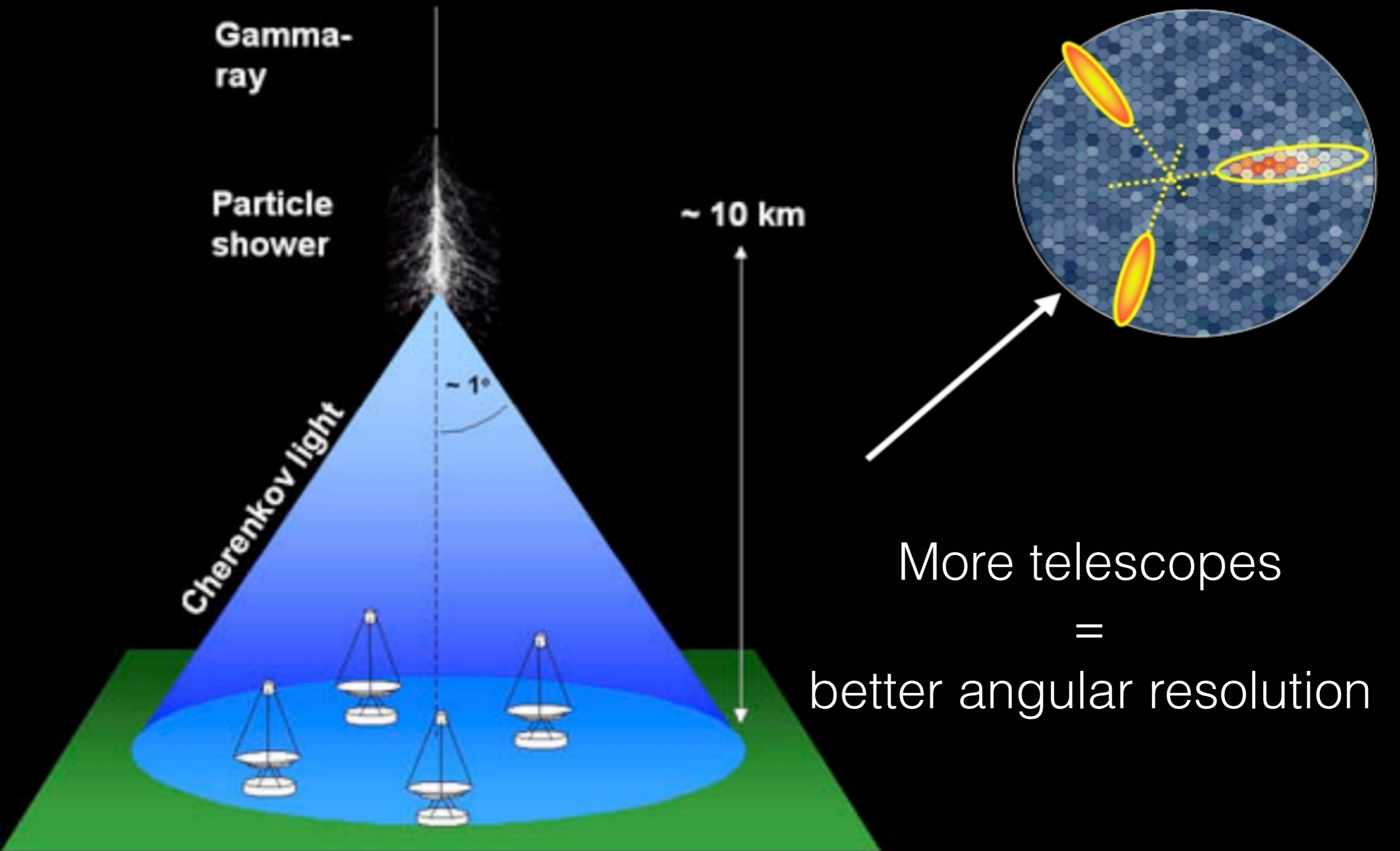
Cherenkov light

same effect but in atmosphere!

Imaging Cherenkov Atmospheric technique (IACT)



Stereoscopy with IACTs



More telescopes
=
better angular resolution

The MAGIC telescopes

- 2 x 17 m IACTs @ La Palma (Canary Islands, Spain)
- auxiliary instruments to monitor the atmosphere (LIDAR, all-sky camera, etc)
- ~50 GeV to 50 TeV,
- 64 tons
- 360° in ~26 sec

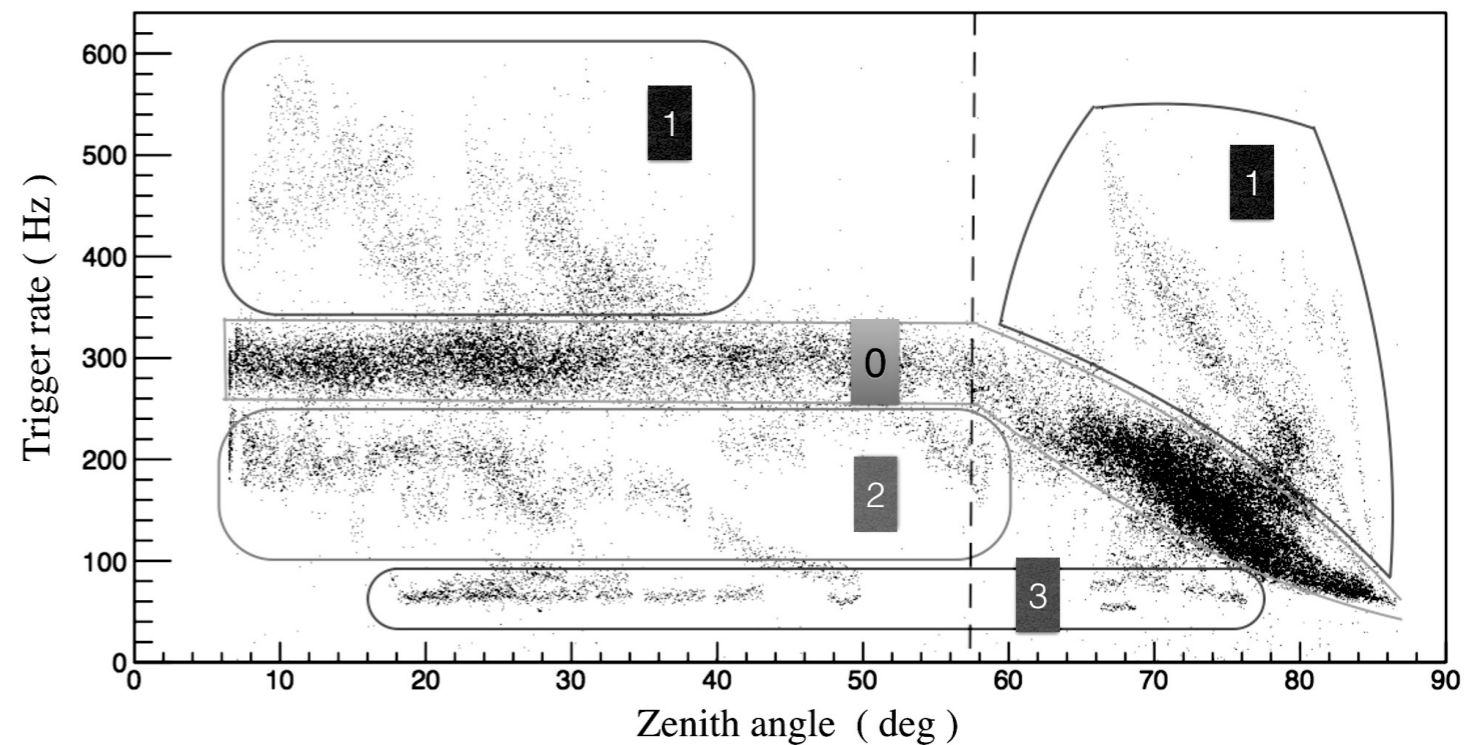
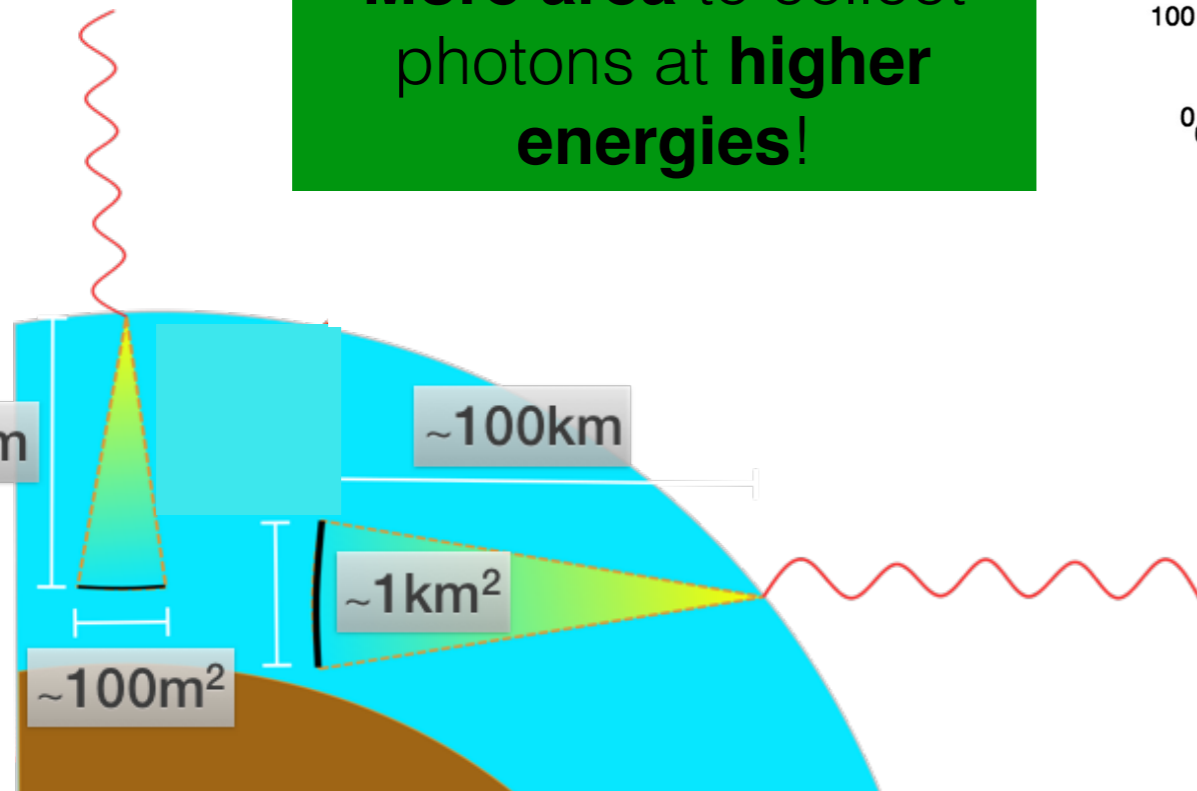


Ph.D. (1) - Very Large Zenith Angle observations

Extend energy range for e.g Pevatron studies

Longer showers
=
wider light pools

More area to collect photons at **higher energies!**



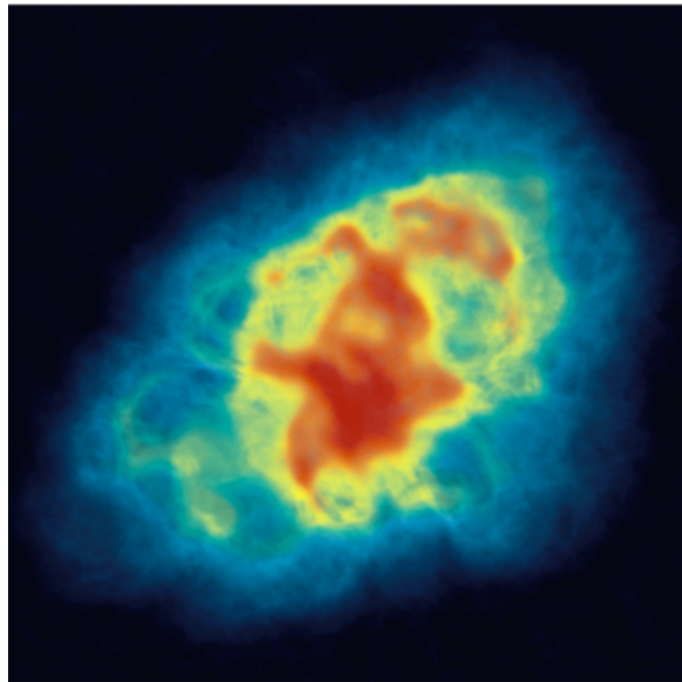
Event rate killed
by increasing
amount of
atmosphere!

mixing of all
observing
conditions

=

Very dirty data

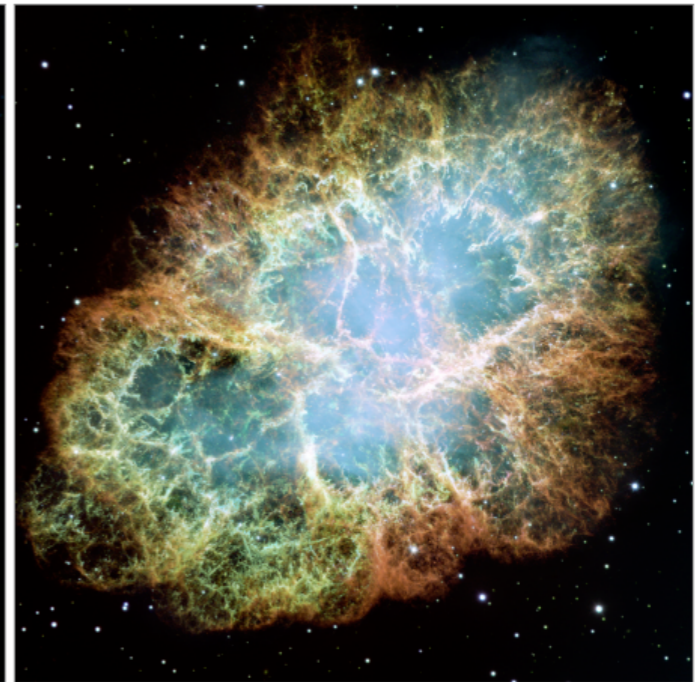
Crab Nebula as a reference source



RADIO



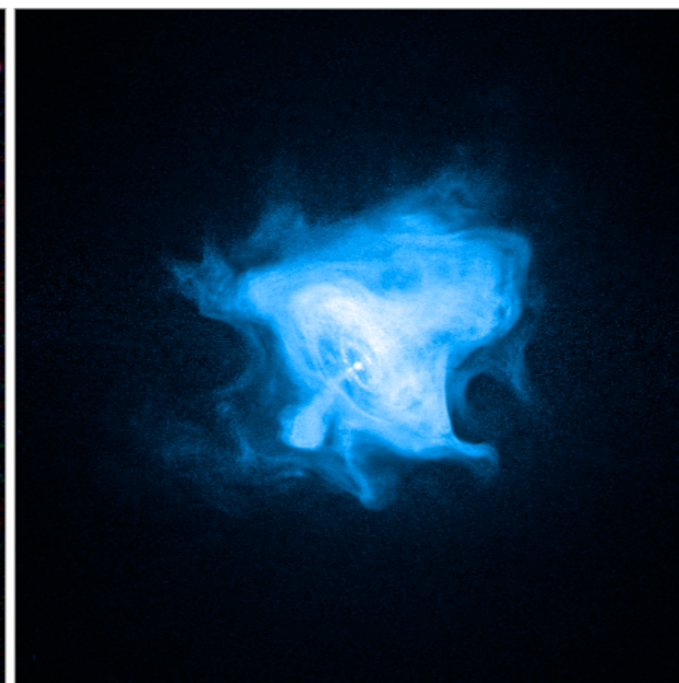
INFRARED



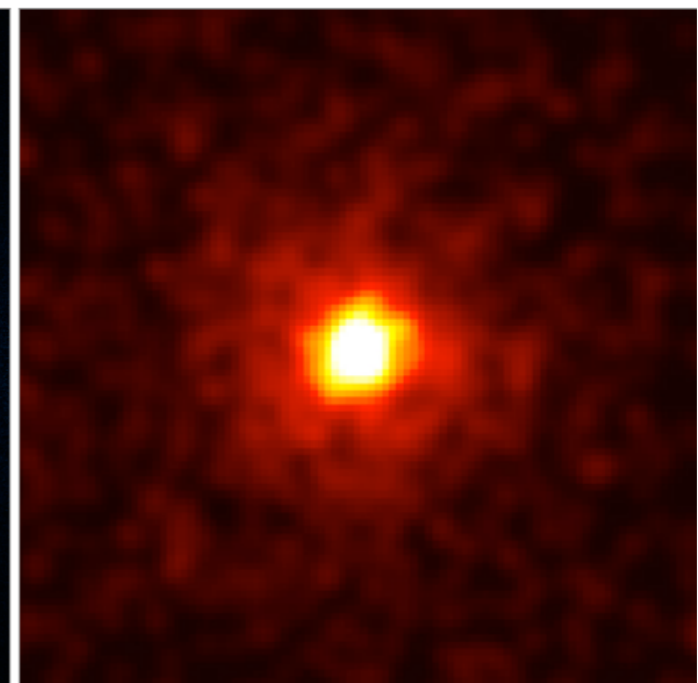
VISIBLE LIGHT



ULTRAVIOLET

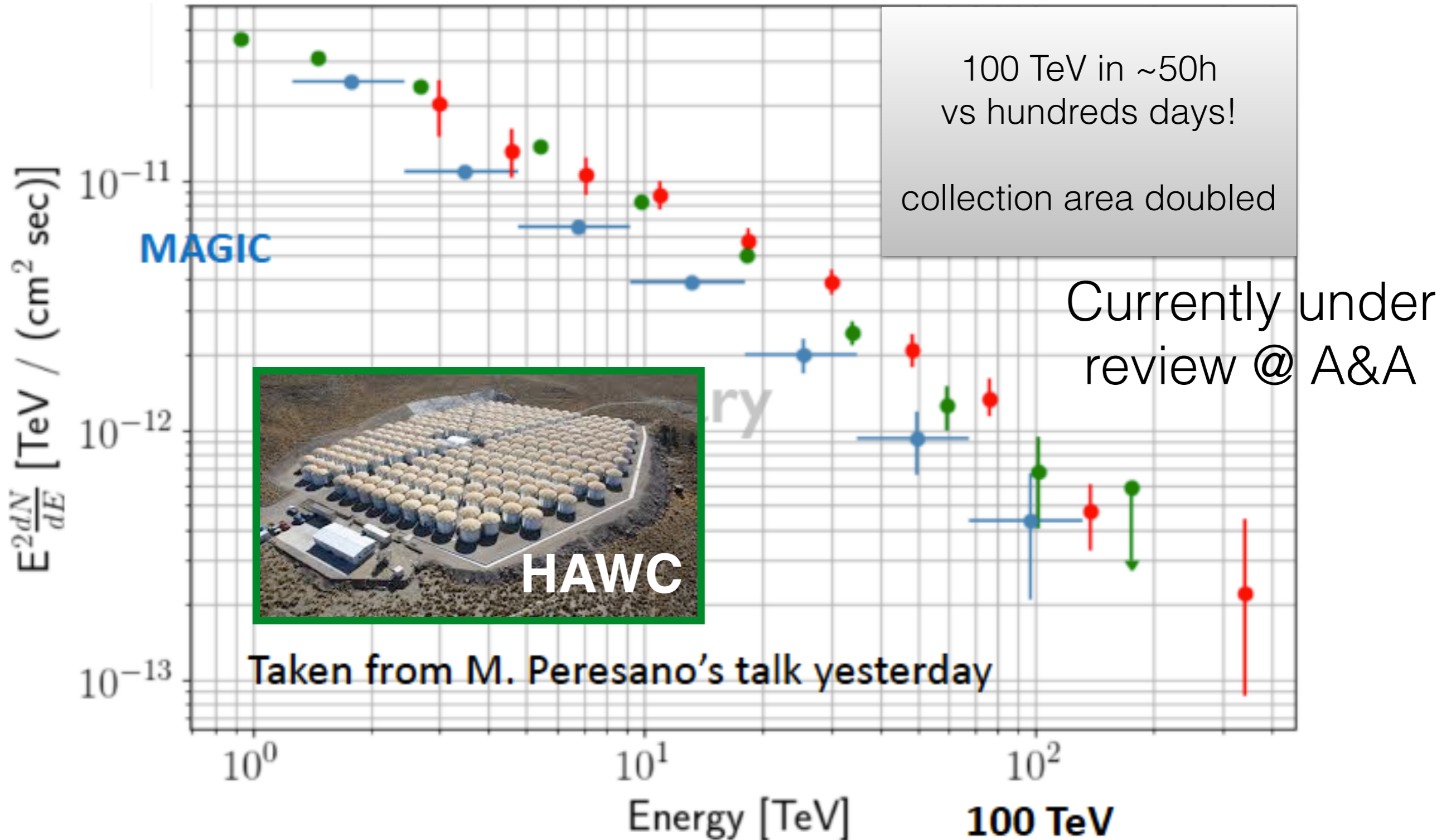


X-RAYS



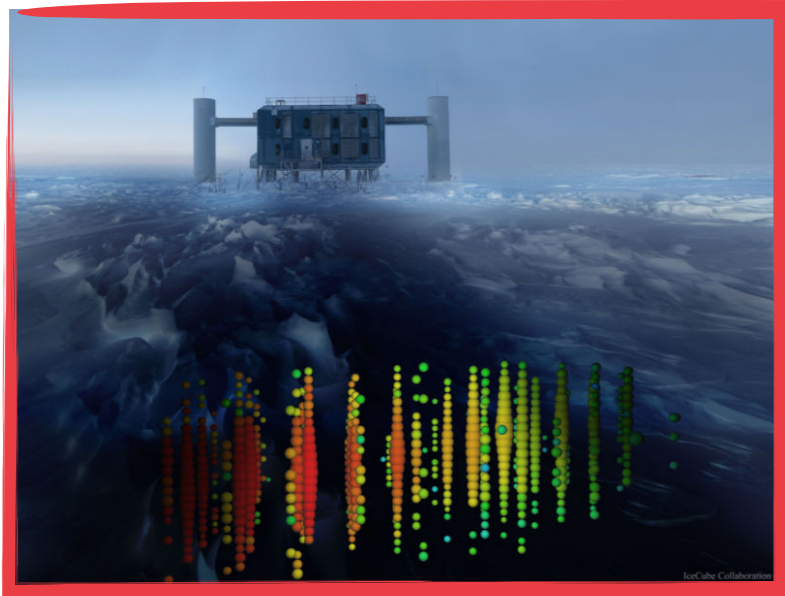
GAMMA RAYS

Ph.D. (1) - Very Large Zenith Angle observations



from ICRC2019 this summer: we got cited by our competitors

Ph.D. (2) - 1st likely source of high-energy neutrinos and CRs



I - September 22nd 2017: *MAGIC* receives neutrino-alert from **IceCube observatory** (neutrino later measured to be $\sim 300\text{TeV}$)

+ many other facilities



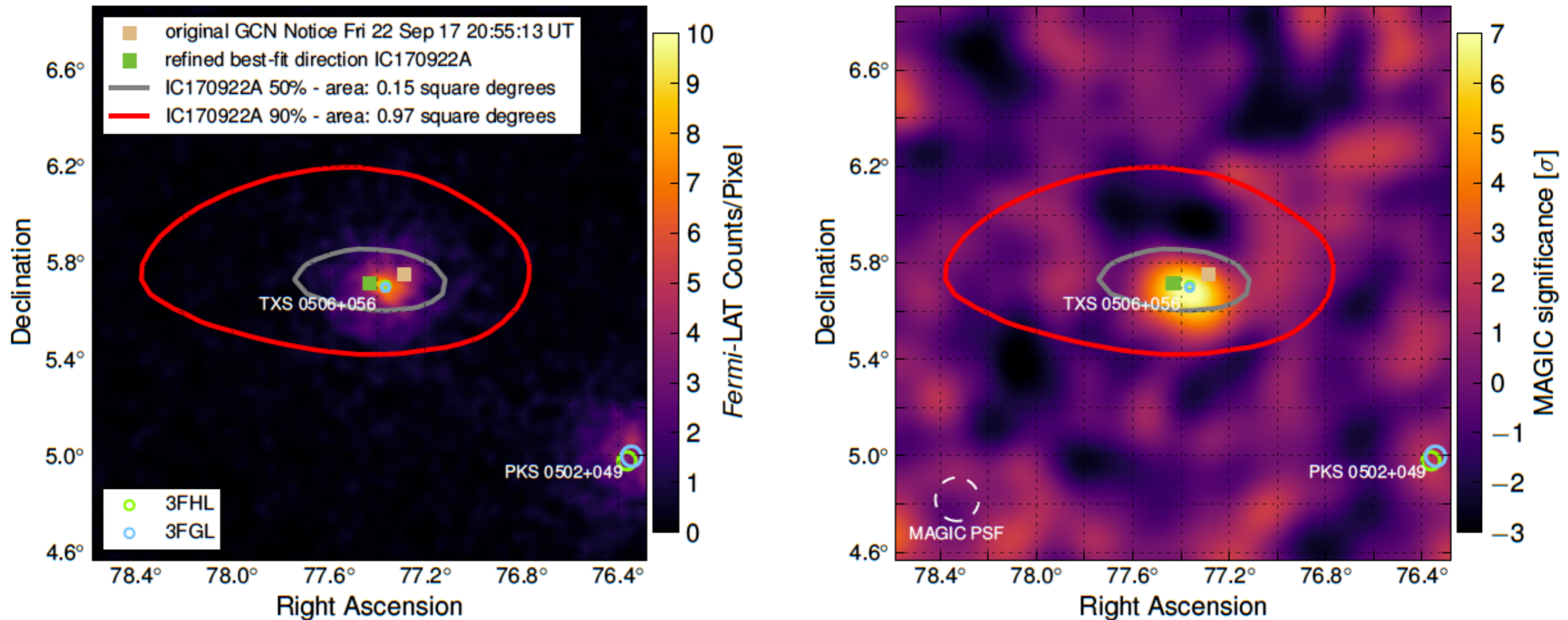
II - **MAGIC telescopes** follow-up



III - September 26th 2017 **Fermi γ -ray Space Telescope** blazar TXS0506+056 flaring GeV energies within IceCube error region.

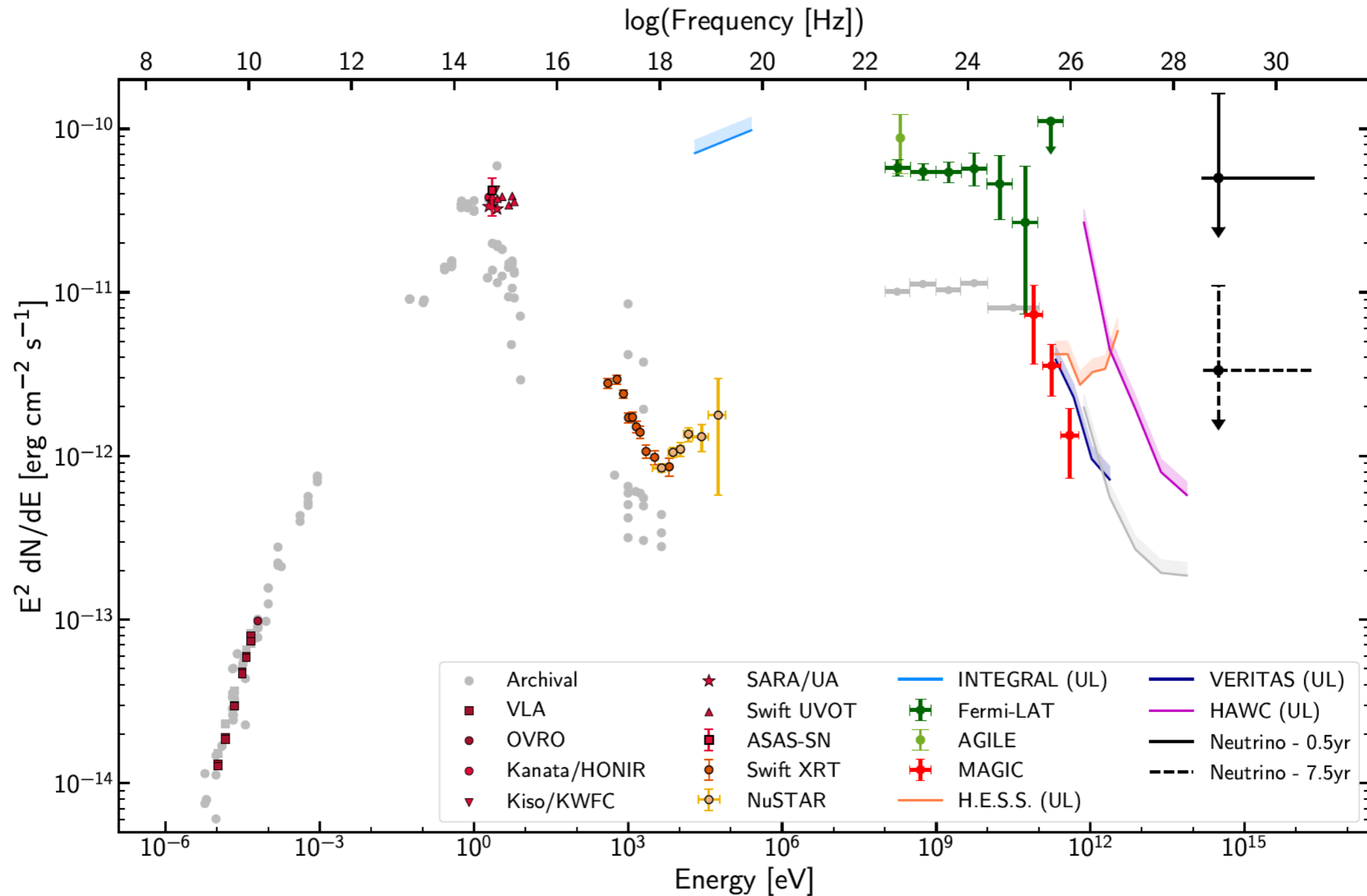
400 GeV γ -rays +
neutrino emission
=
CR acceleration
site!

Ph.D. (2) - 1st likely source of high-energy neutrinos and CRs



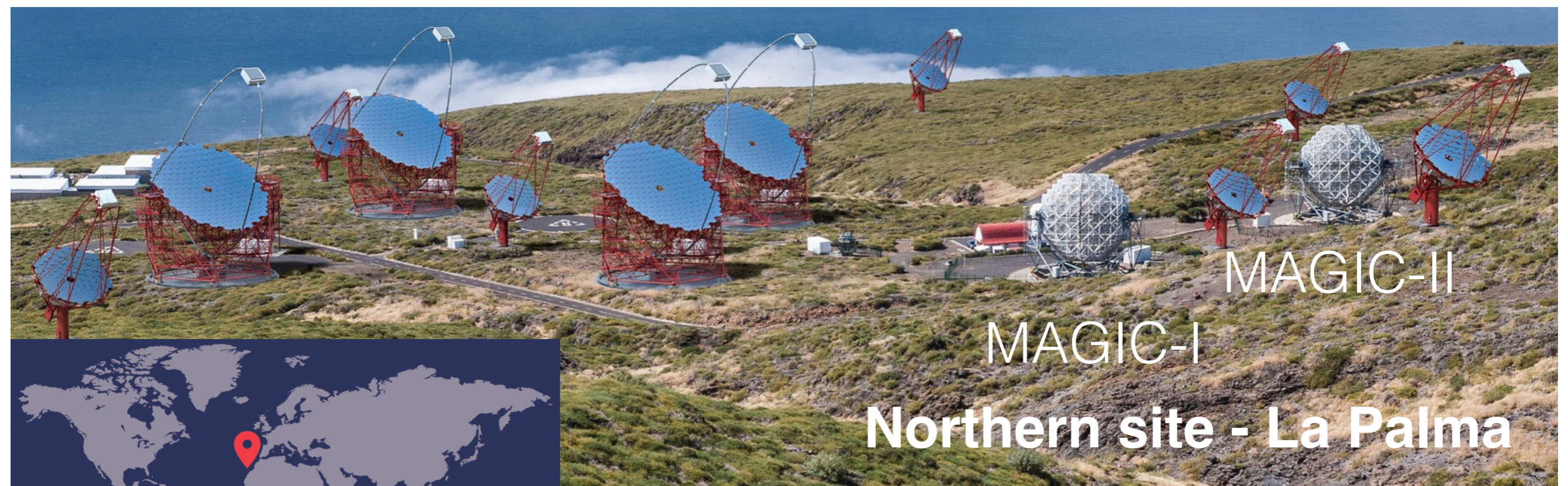
Skymaps using data of IceCube and Fermi-LAT (left) and with MAGIC (right) from *Science* 361, eaat1378 (2018)

Ph.D. (2) - Identification of the first likely source of high-energy neutrinos and cosmic rays



Spectral energy distribution of quiescent (grey) and active (colored by instrument) states (S. Ansoldi et al 2018 ApJL 863 L10)

The Cherenkov Telescope Array (CTA): sites

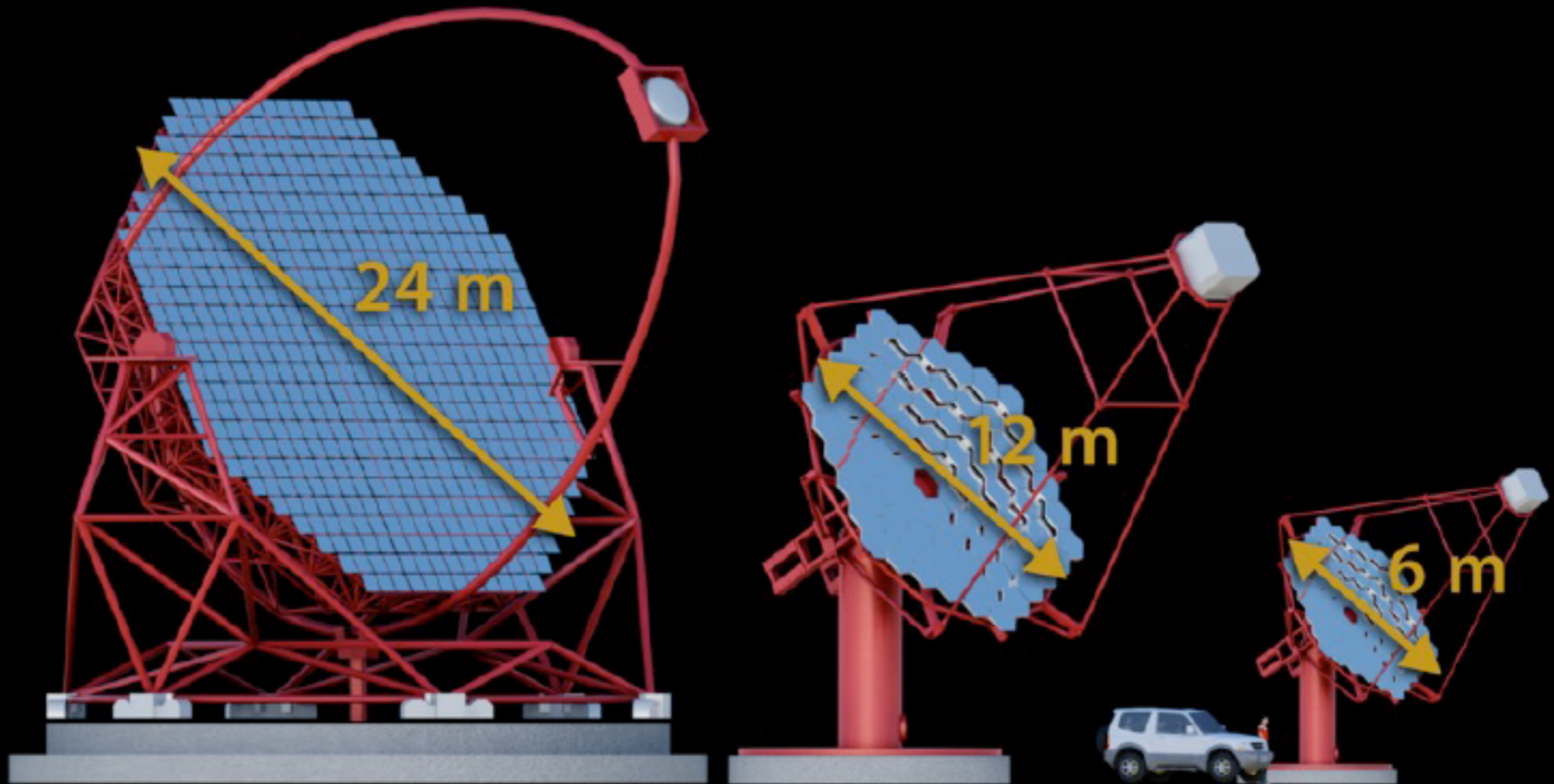


The Cherenkov Telescope Array (CTA): sizes

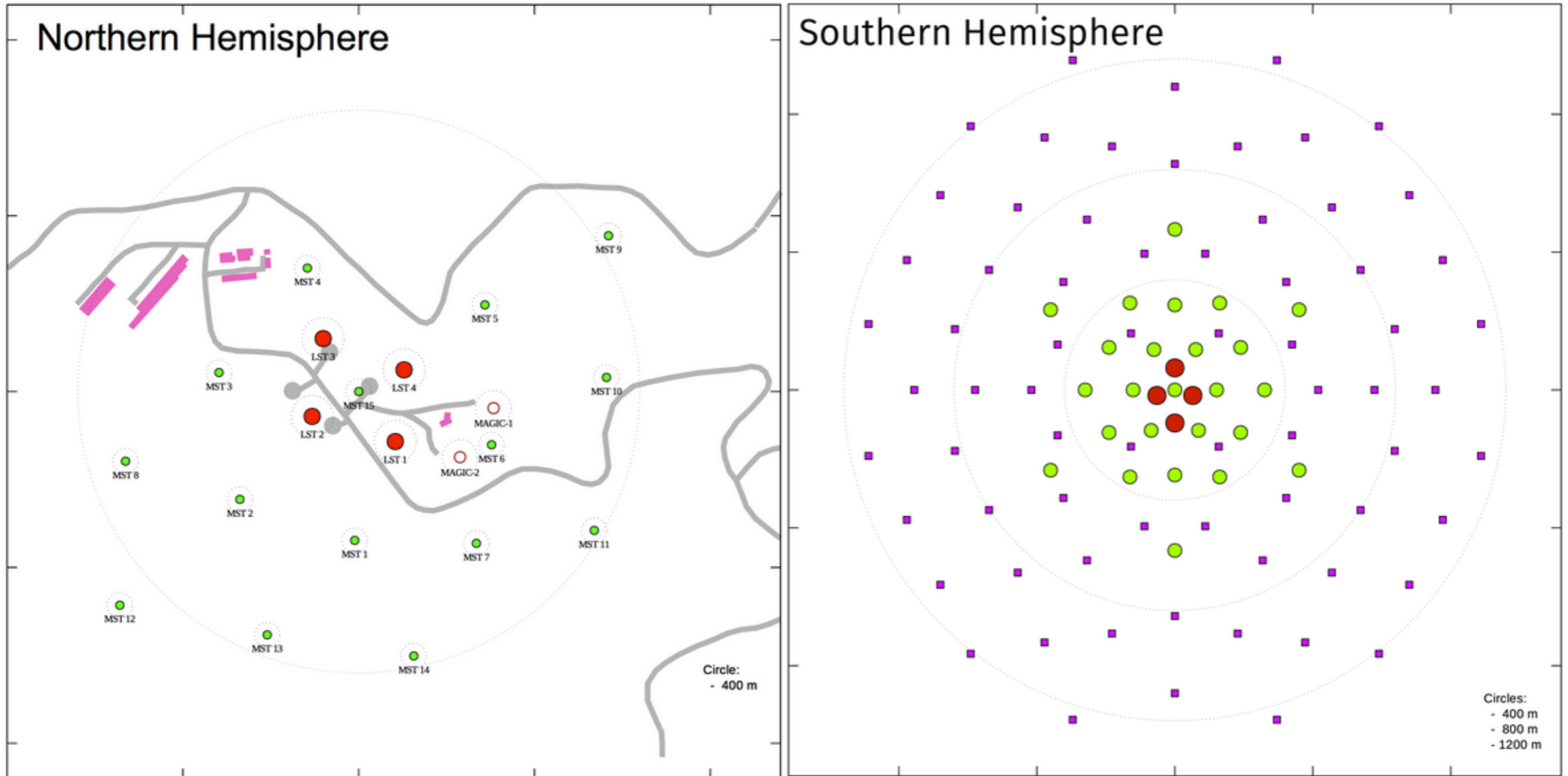
LST

MST

SST



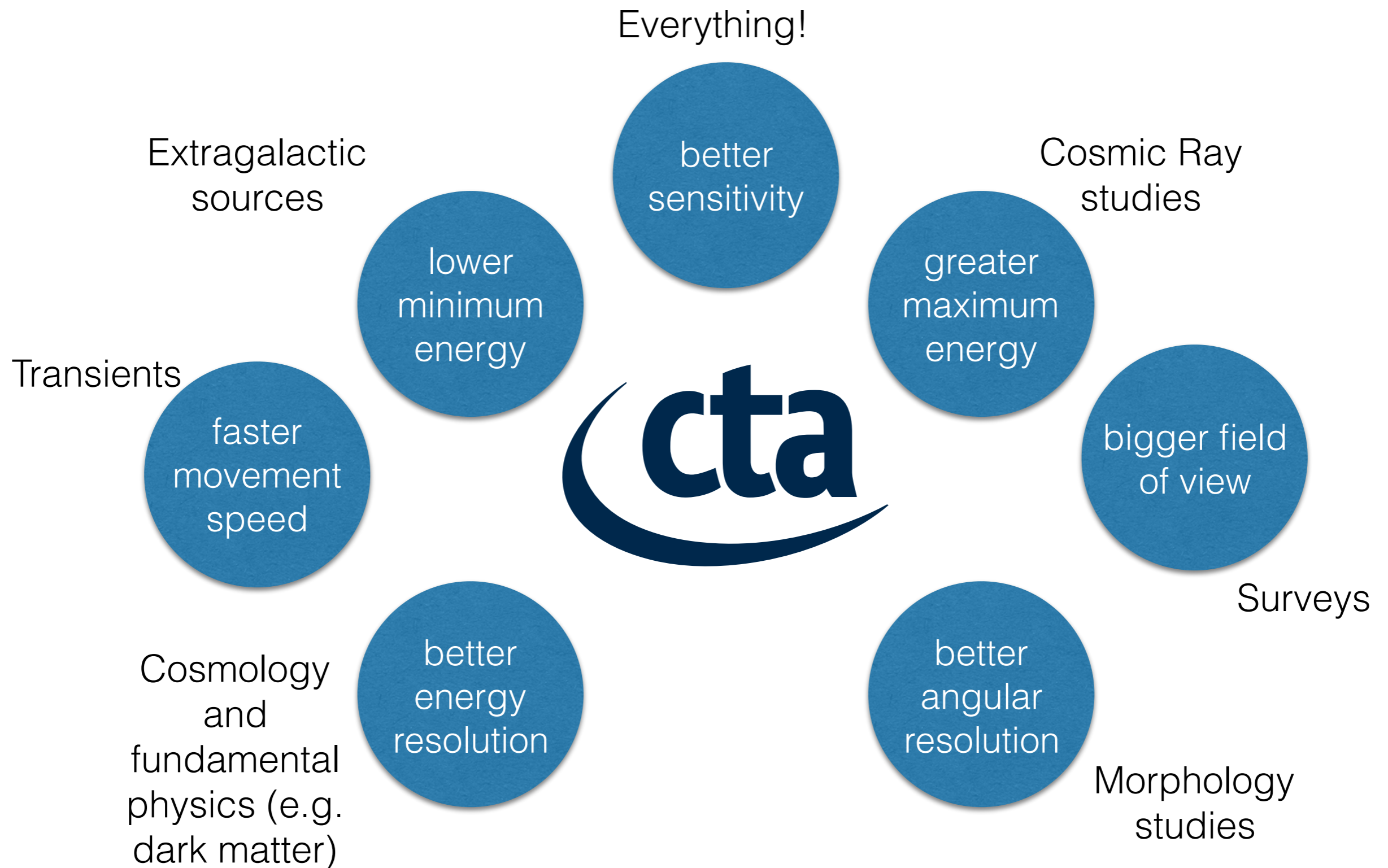
The Cherenkov Telescope Array (CTA) : arrays



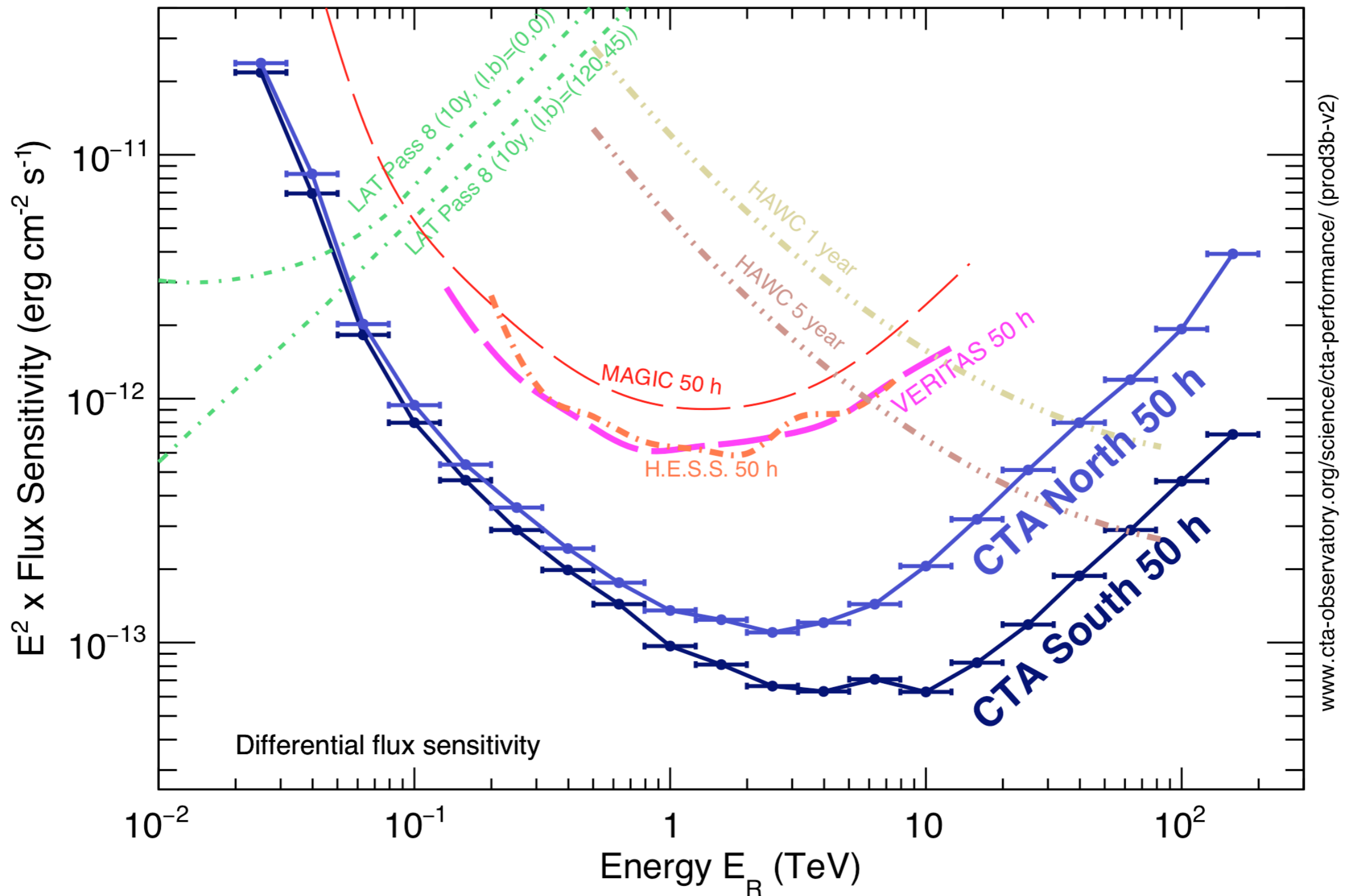
4 LSTs + 19 MSTs

4 LSTs + 25 MSTs + 70 SSTs

CTA: why a new facility?



The Cherenkov Telescope Array (CTA): estimated sensitivity



CTA in CEA

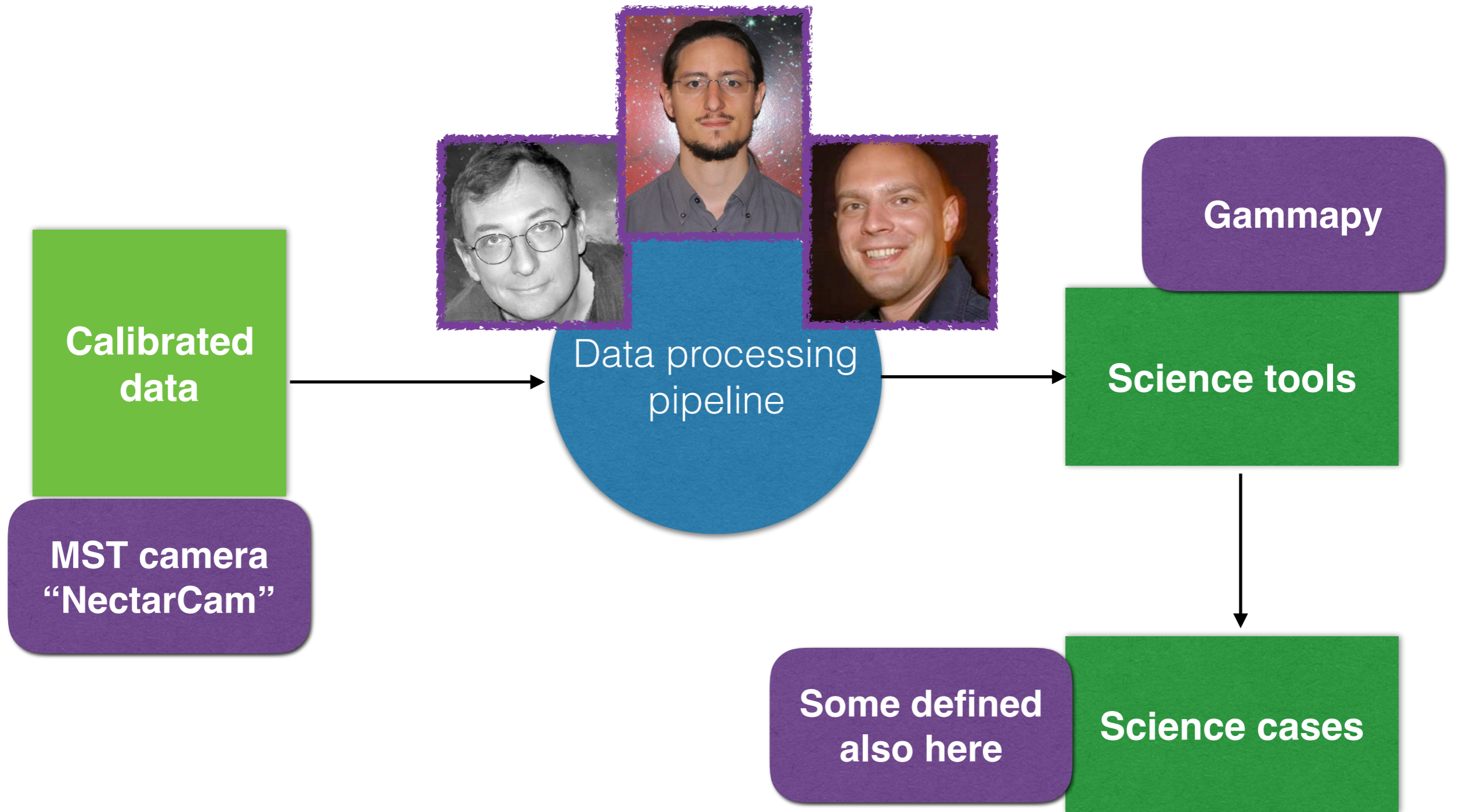
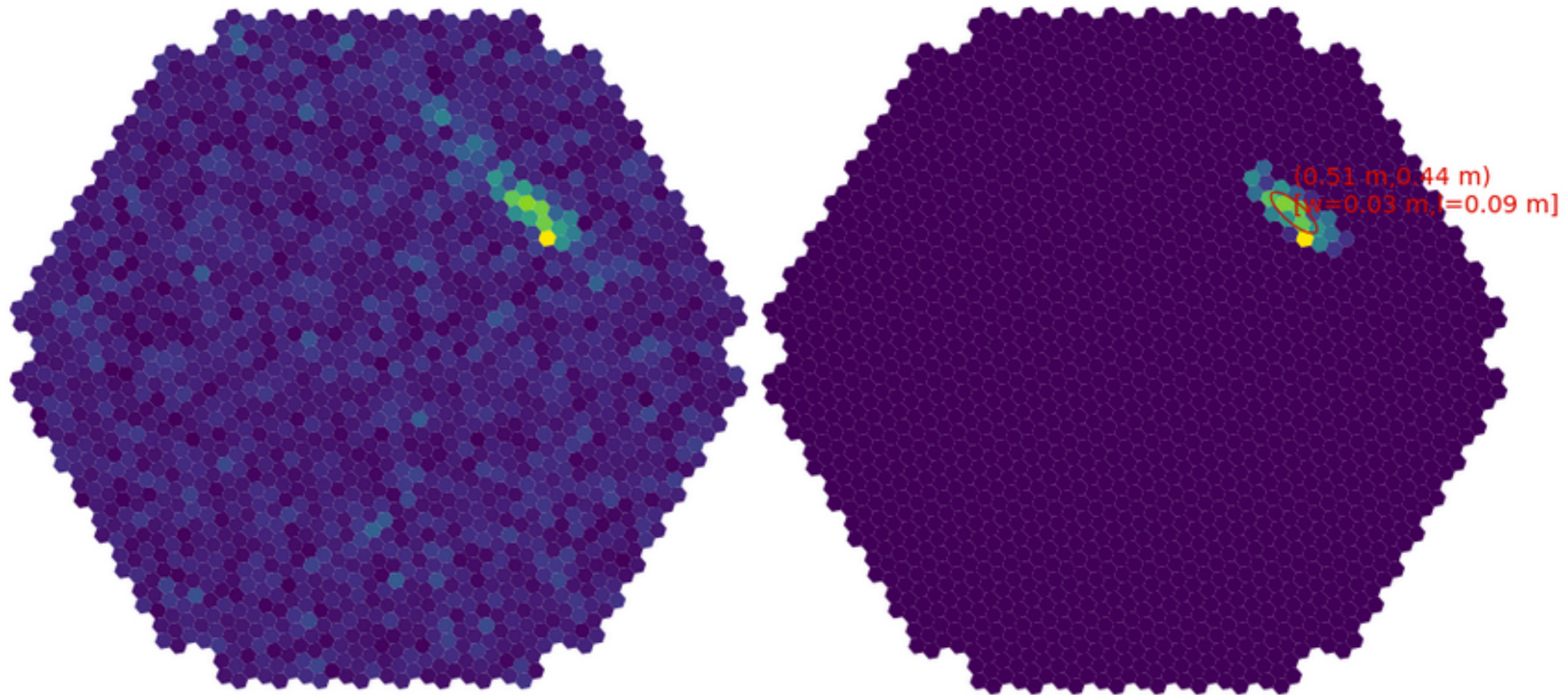


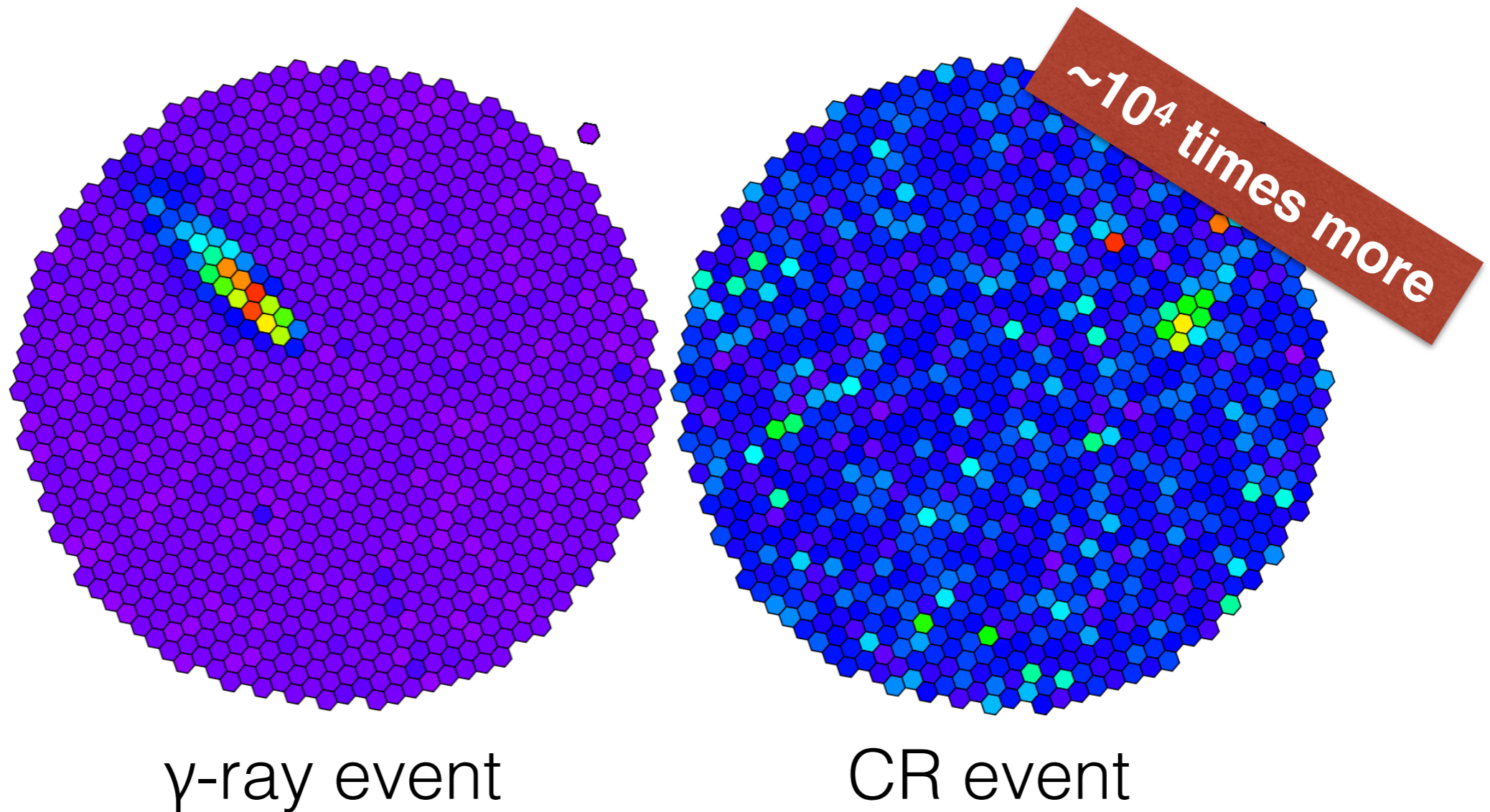
Image cleaning



Each image need to be cleaned and parametrized

Parameters quantify shower's physical properties

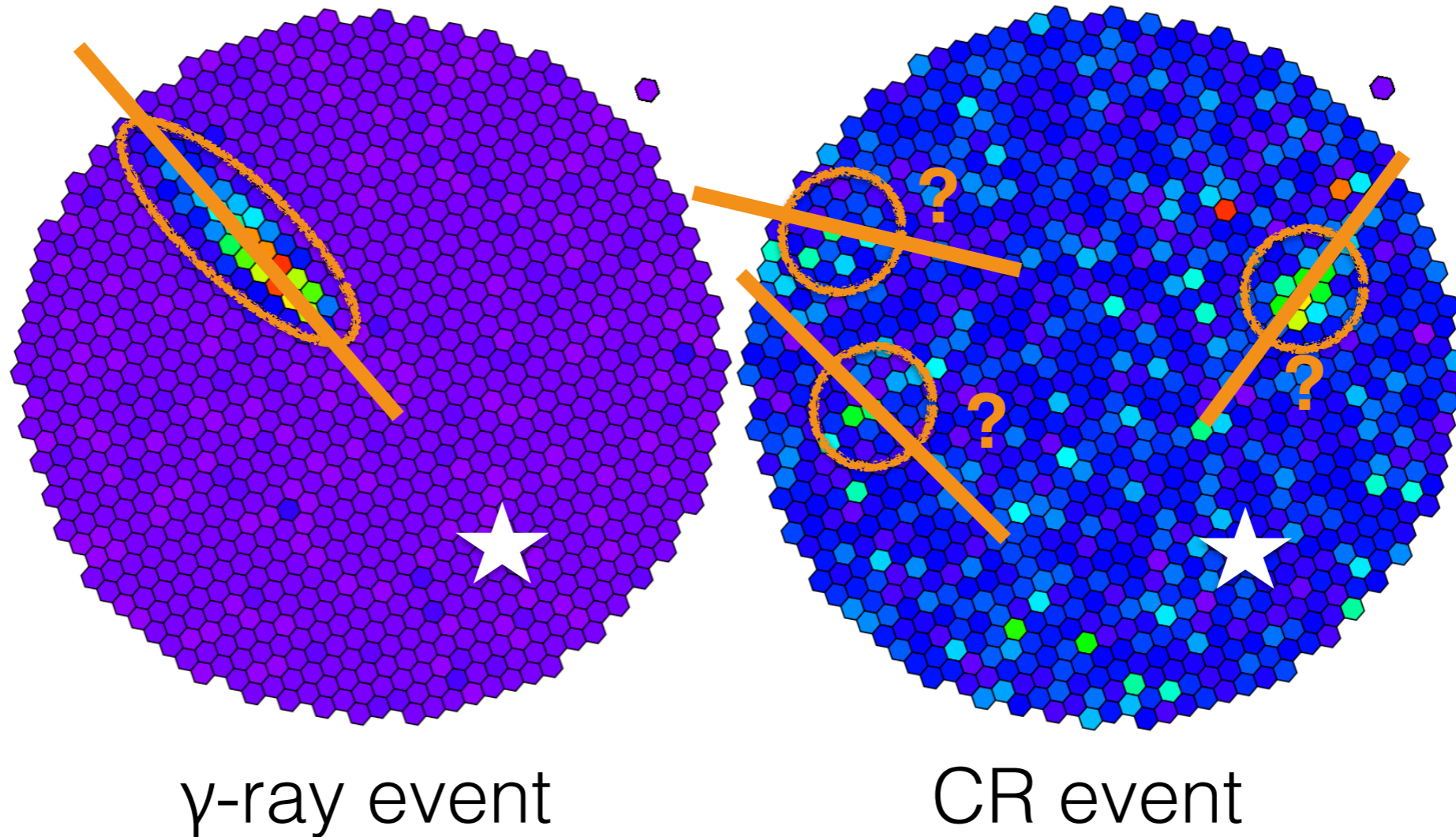
Particle classification



Machine learning used to train/test images

Random Forest
Deep learning

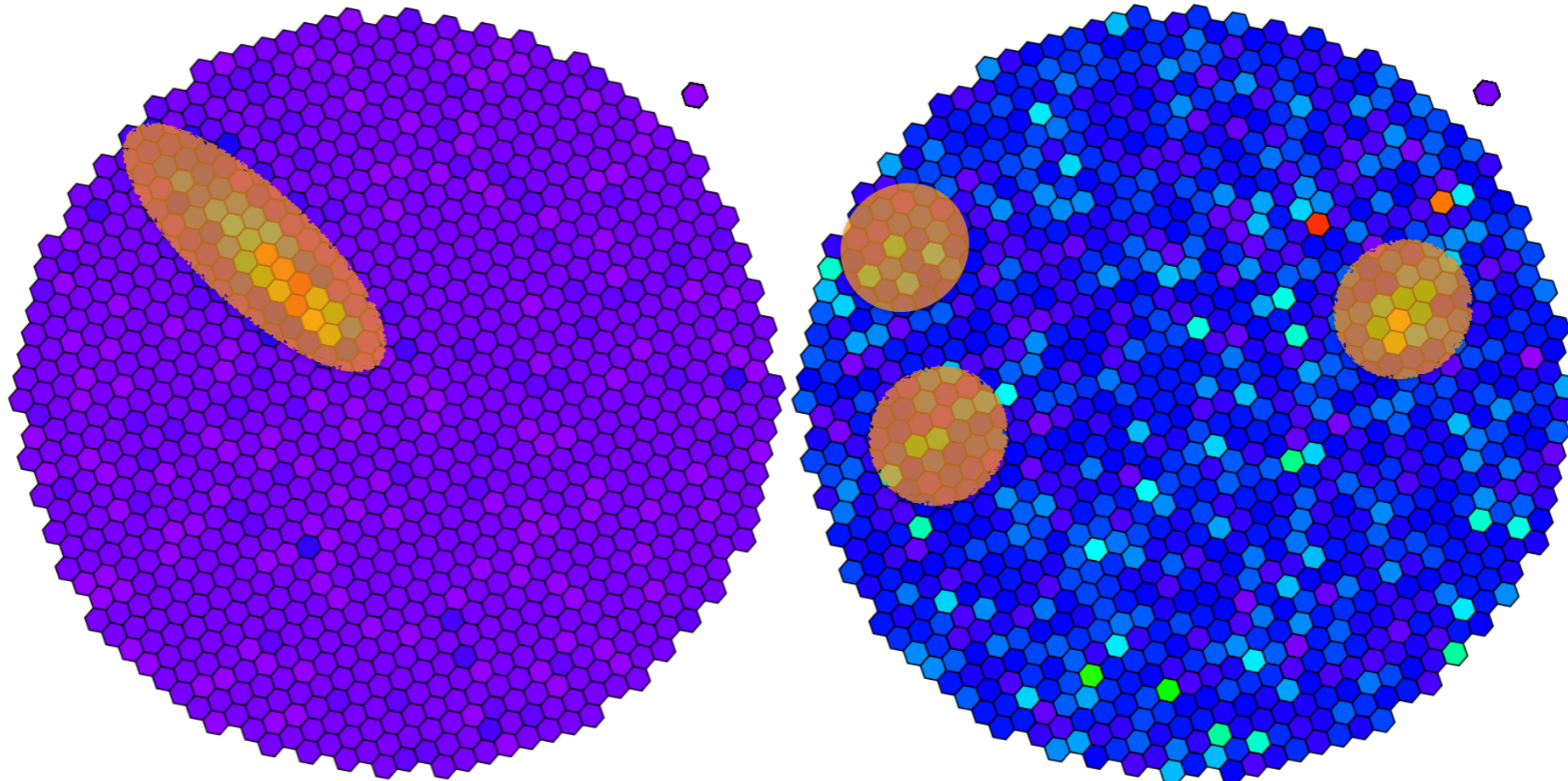
Direction reconstruction



Cleaning and classification are critical

A mistake could lead to completely wrong sky positions!

Energy estimation



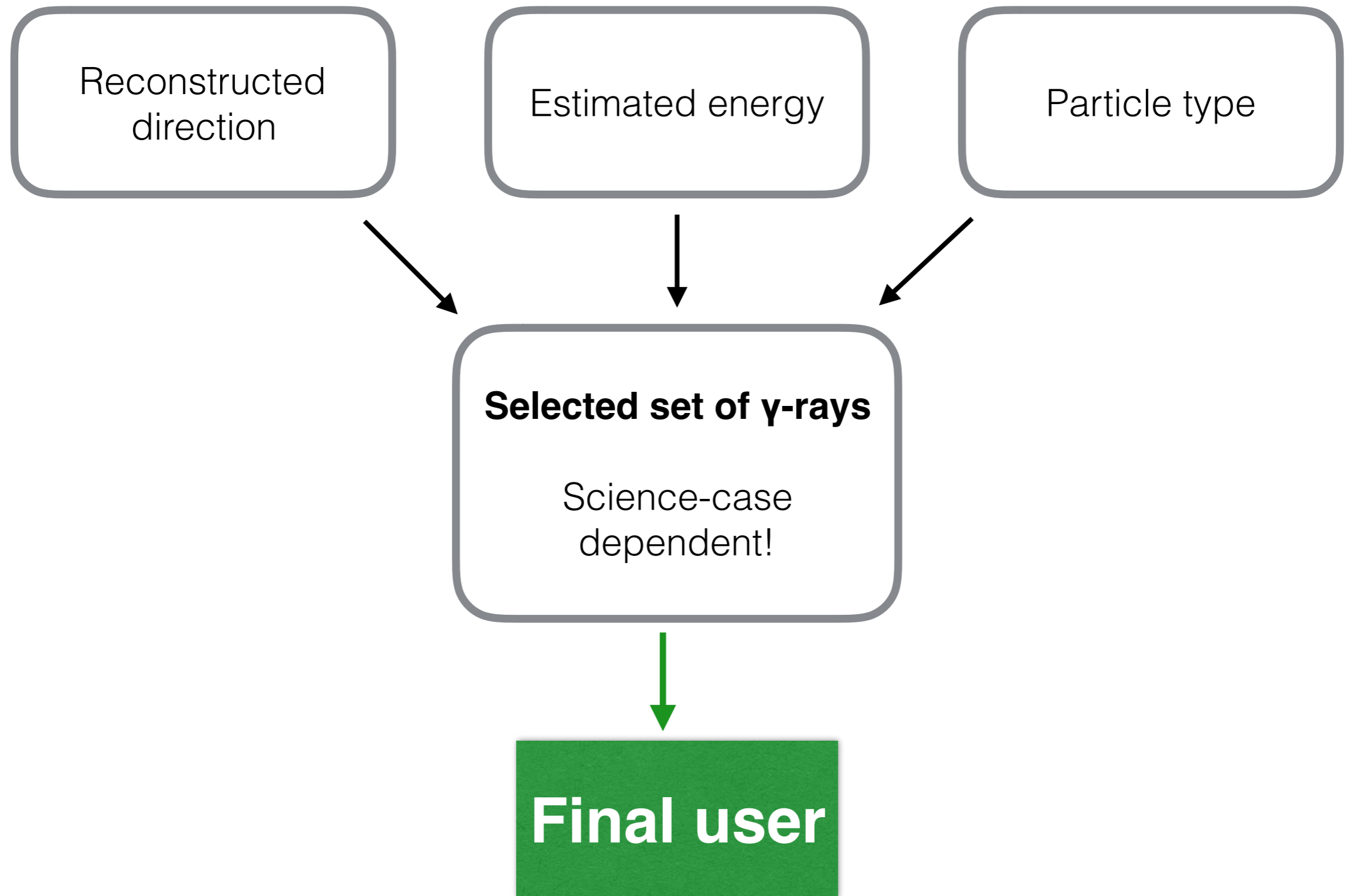
γ -ray event

CR event

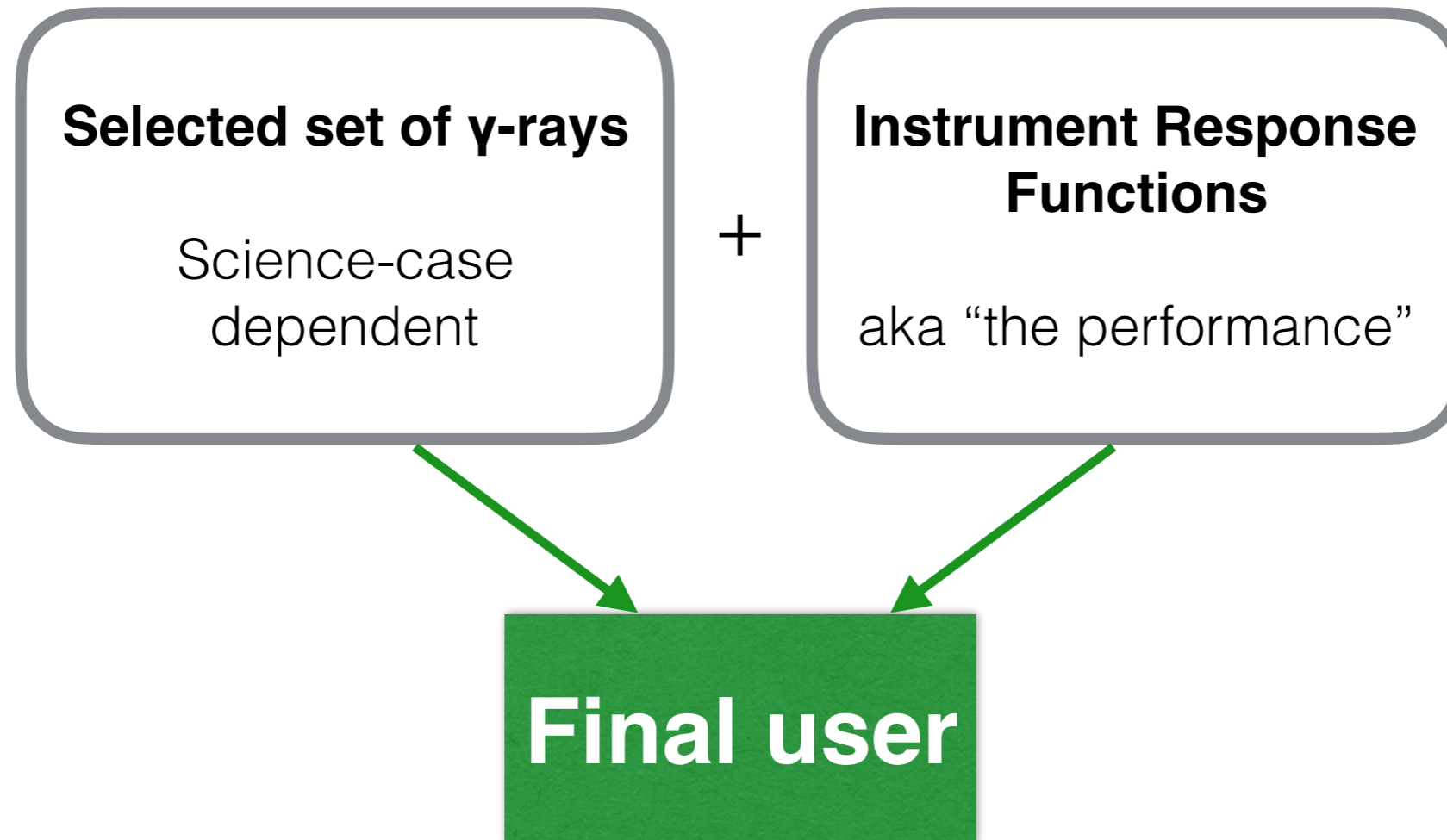
Different methods

Look-up tables from Montecarlo simulations
Machine learning (Adaptive Boost Regression)

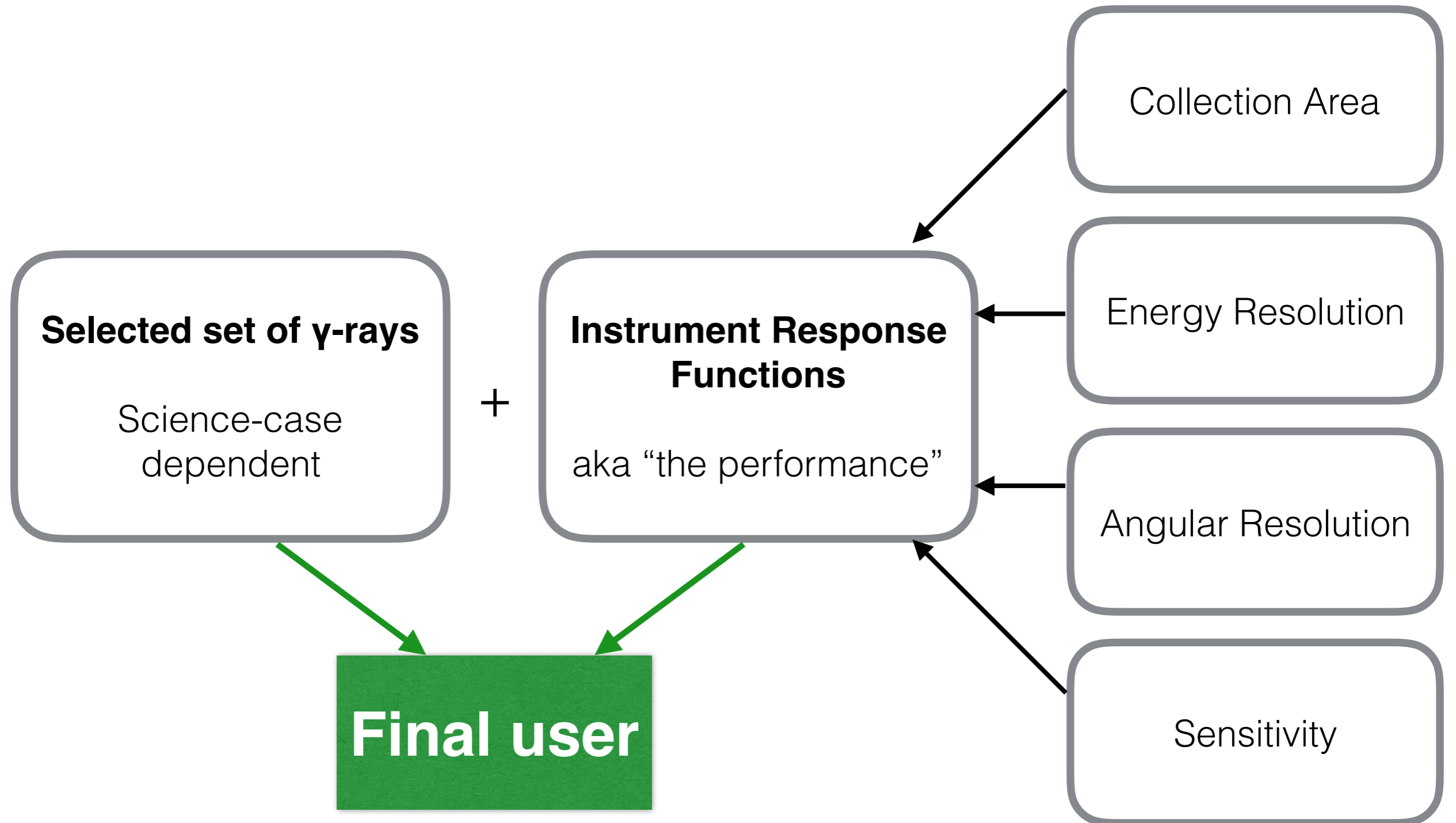
What we want to provide



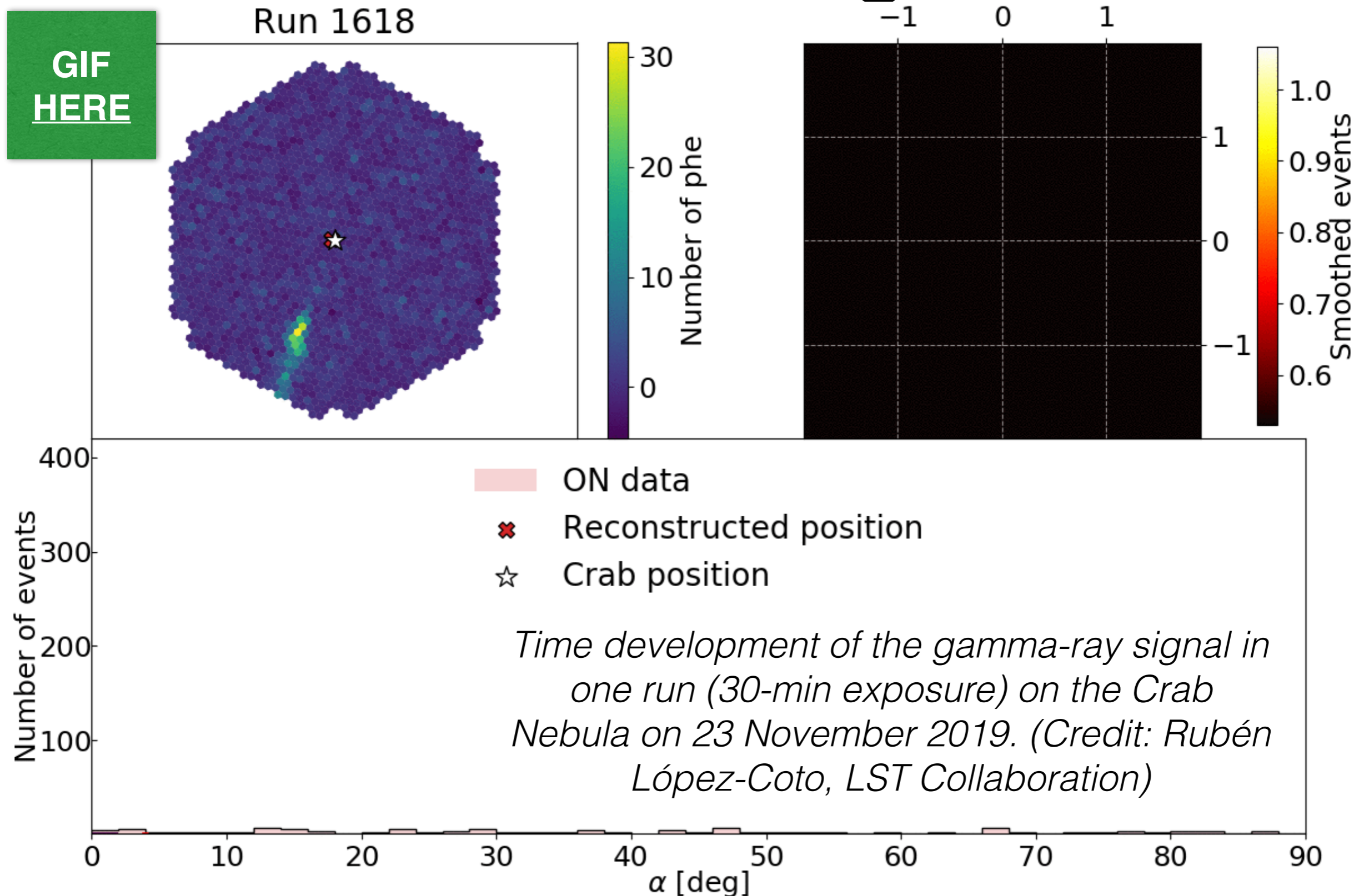
What we want to provide



What we want to provide



Latest news: first light from LST

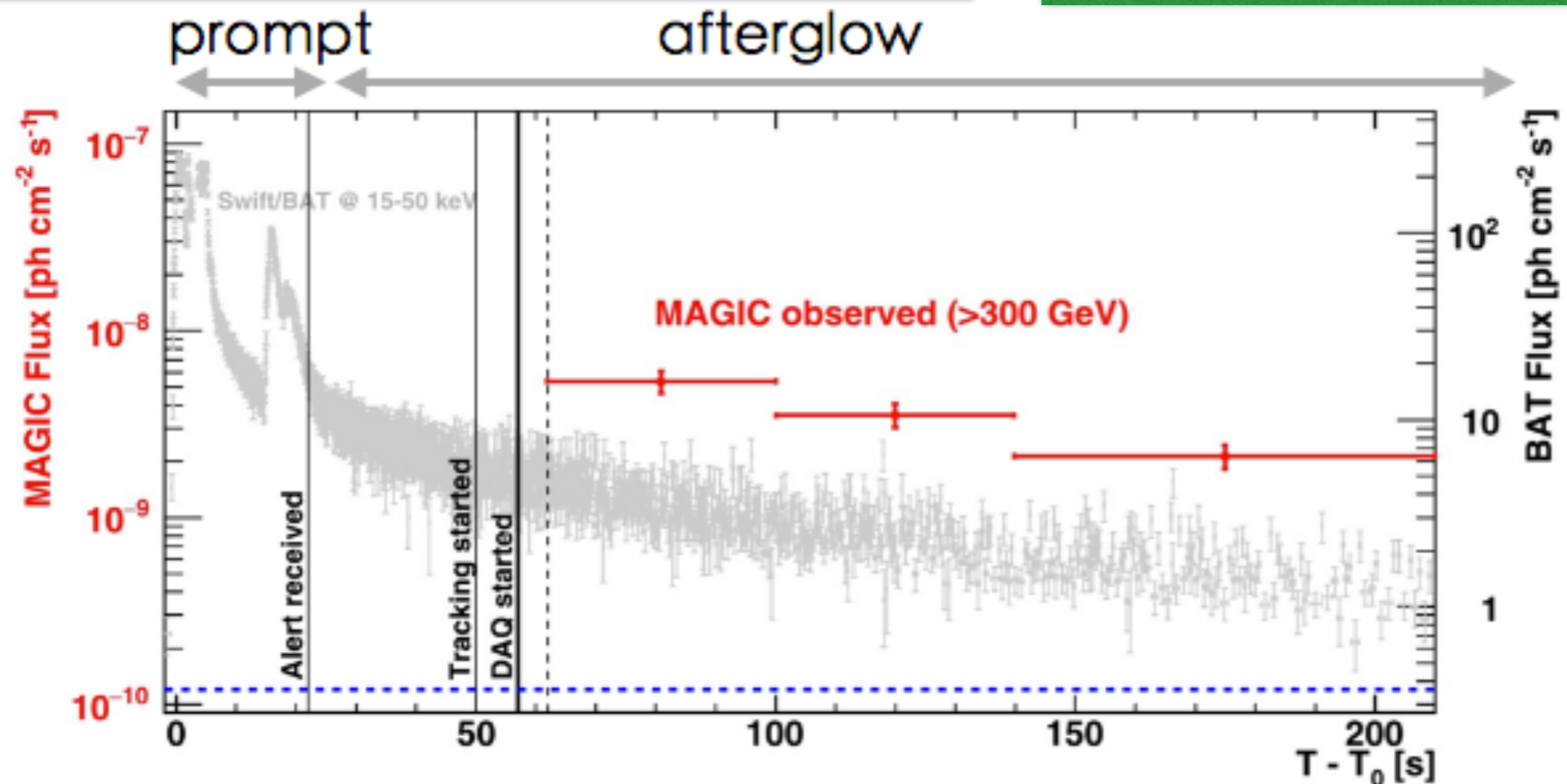


GRB 190114A

GRB @ $z = 0.4$ detected in afterglow phase \Rightarrow **new spectral component at VHE**

Observed also at
Very Large Zenith Angles!

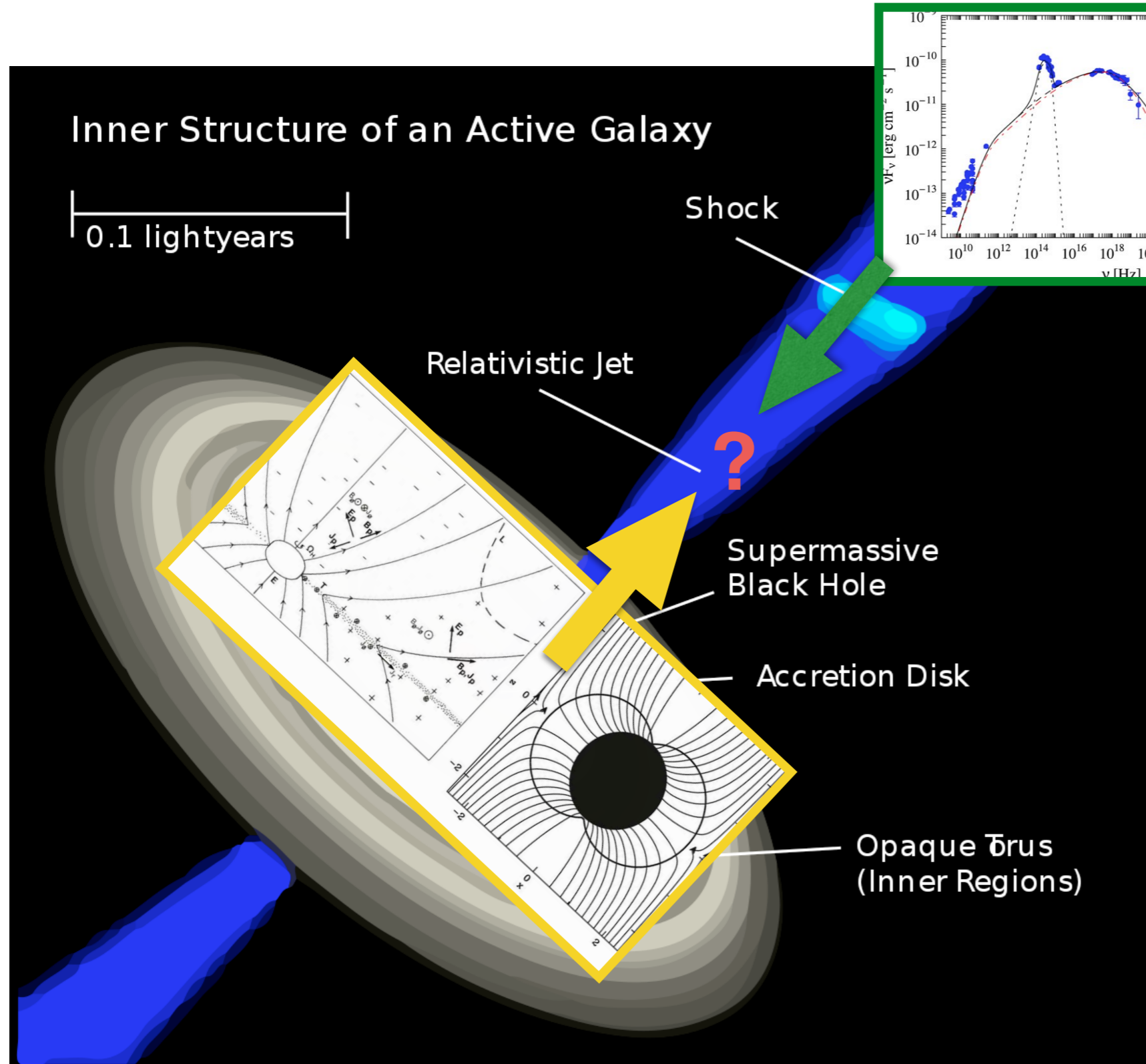
In the 1st 30 seconds 100x
brighter than Crab Nebula!



Nature, 575, 455-458 (2019) <https://www.nature.com/articles/s41586-019-1750-x>

Backup

From models to TeV emission

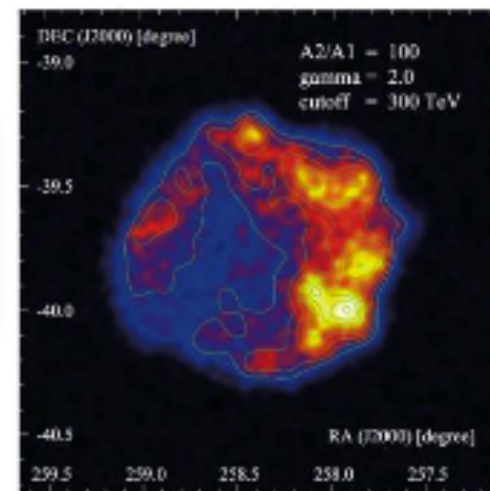
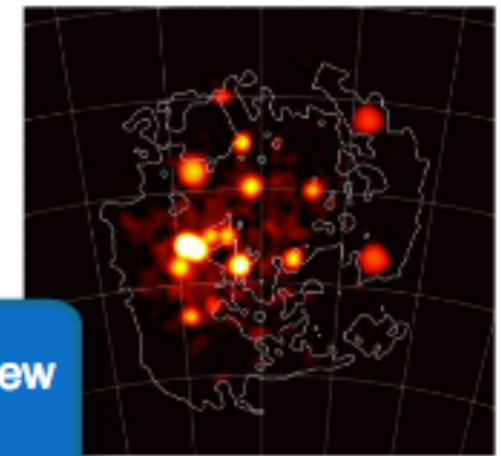
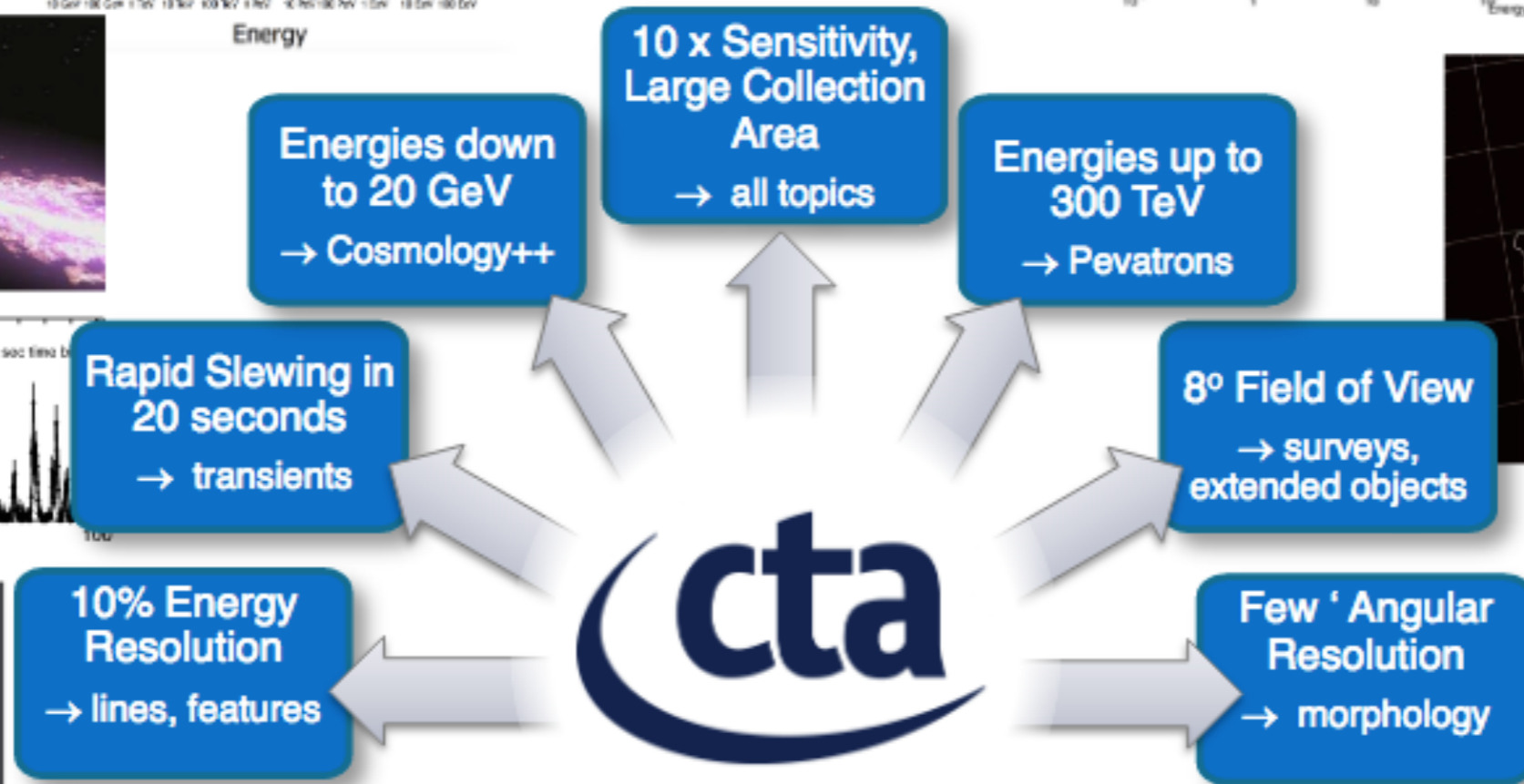
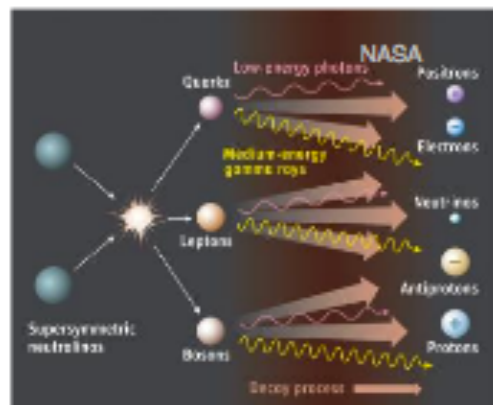
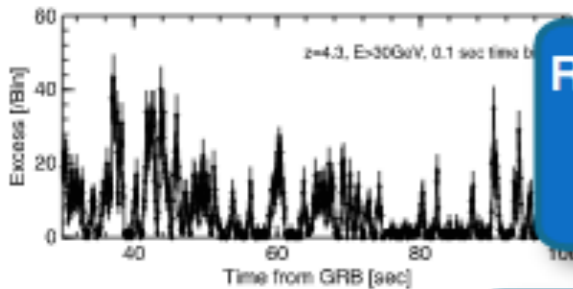
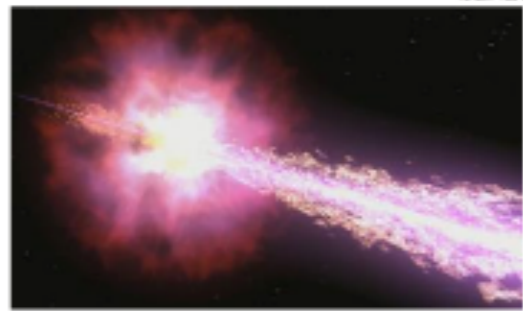
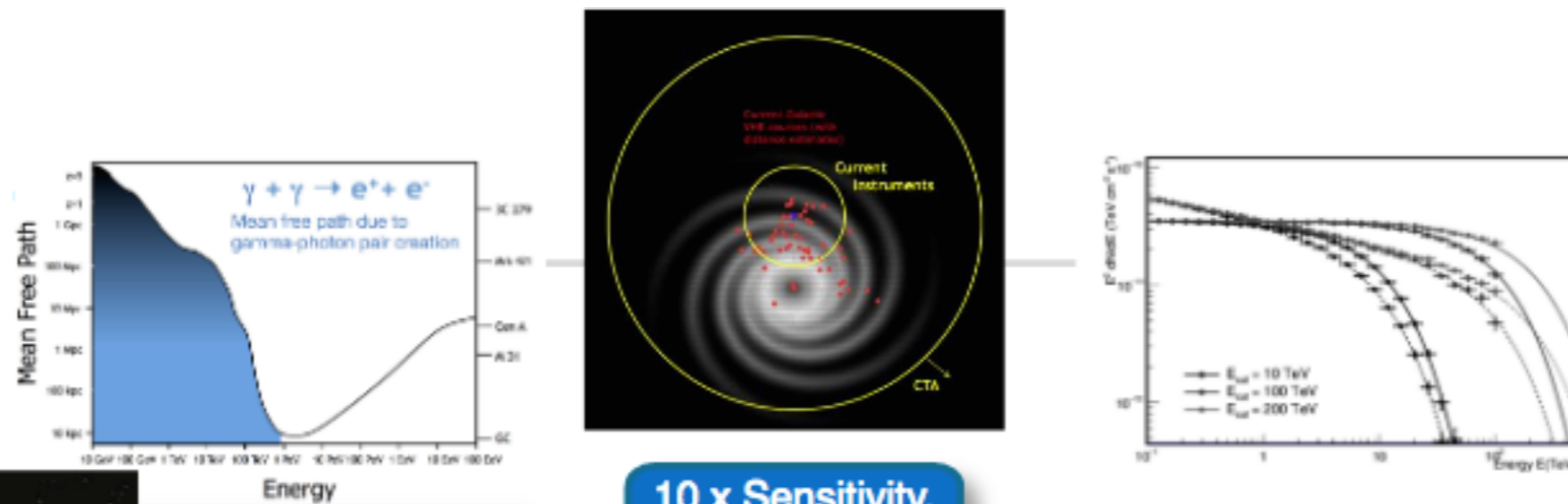


**Inside out
approach very
complicated**

**From outside
direct link to data**

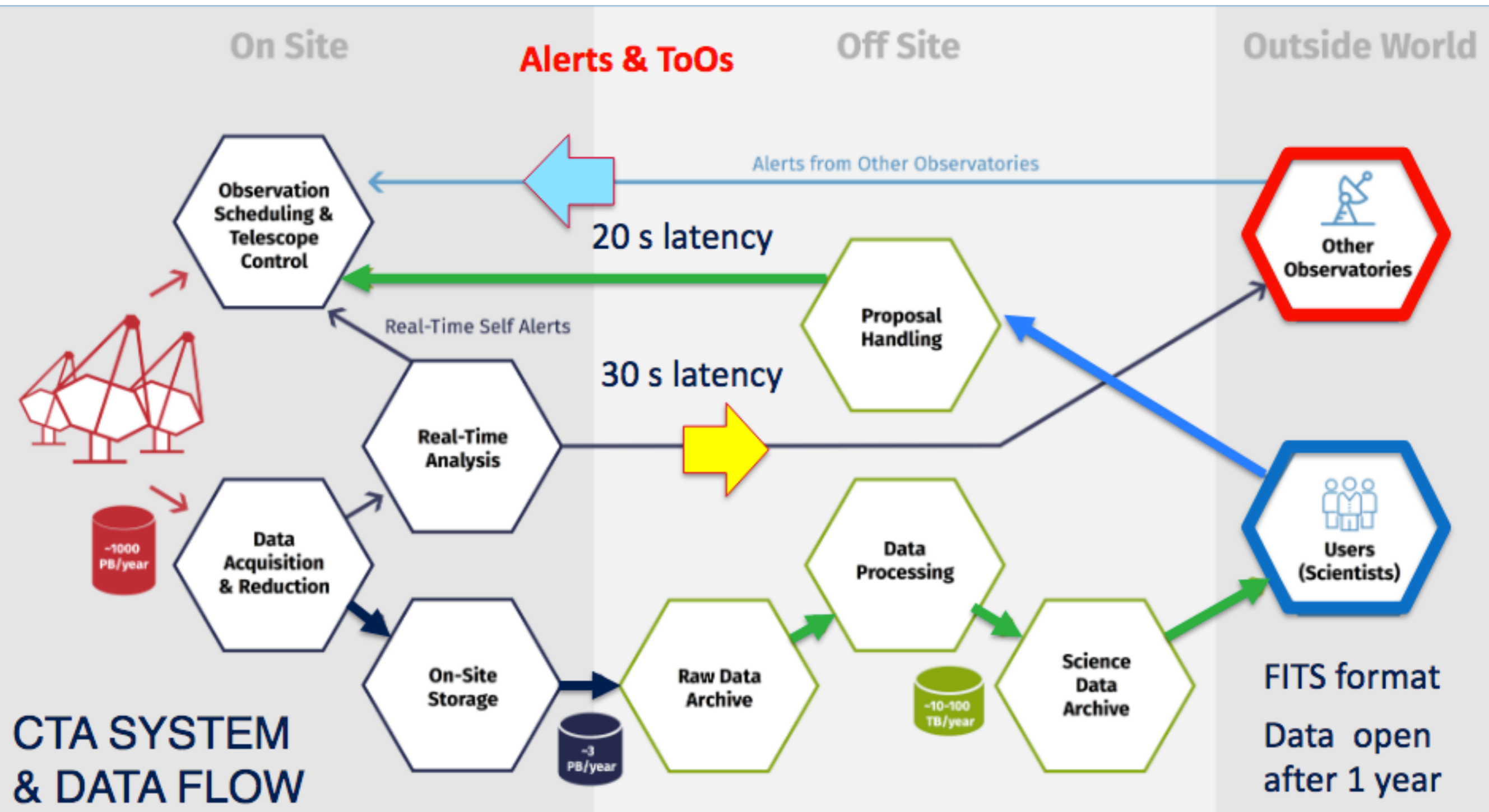
**TeV radiation
emitted far away
from center...**

CTA: why a new facility?



Adapted from W. Hoffmann - 1st CTA Science Symposium

CTA will be an observatory



Adapted from W. Hoffmann - 1st CTA Science Symposium