Laboratoire d'Annecy-le-Vieux de Physique des Particules

APC, CNRS, FRANCE

LPNHE PARIS

Cherenkov astronomy

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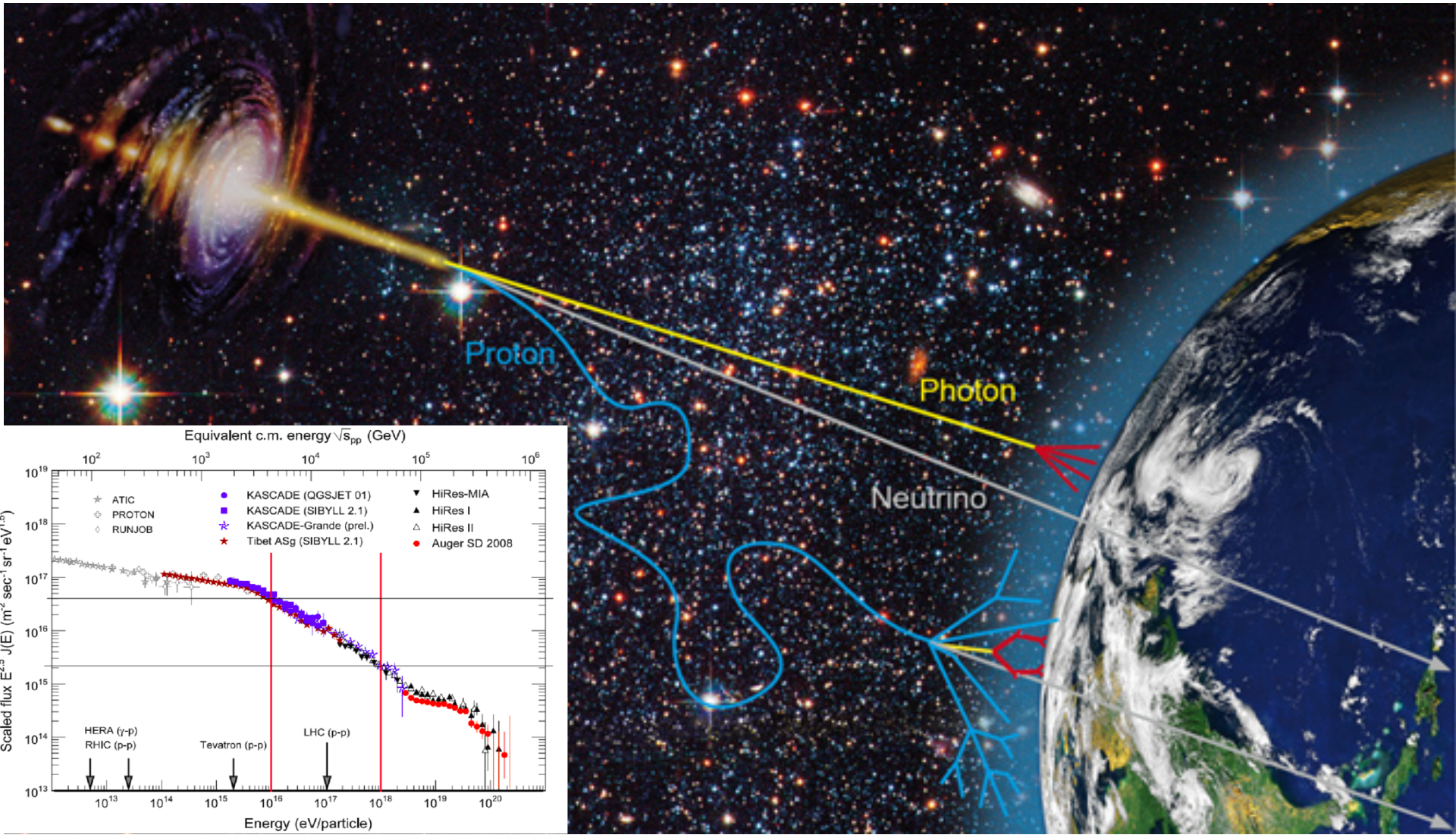
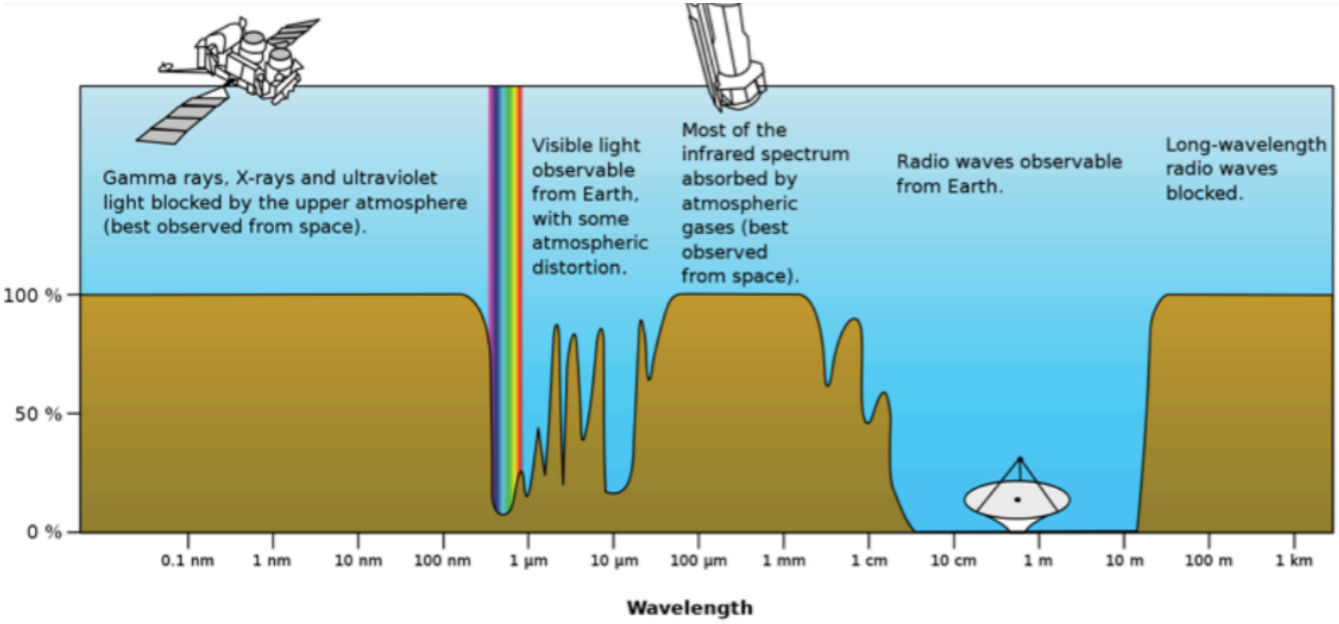
cnrs

Why using gammas ?



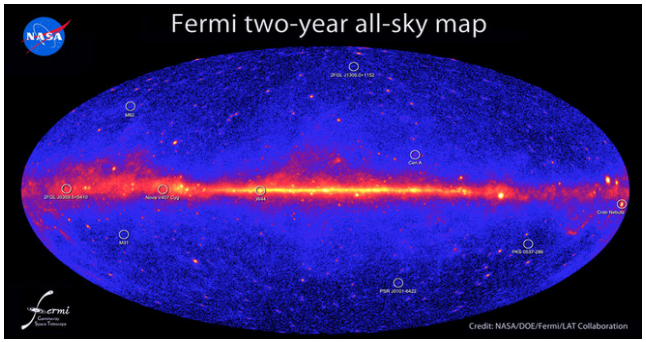
Ground-based gamma astronomy

- Atmosphere **opaque to gamma rays**



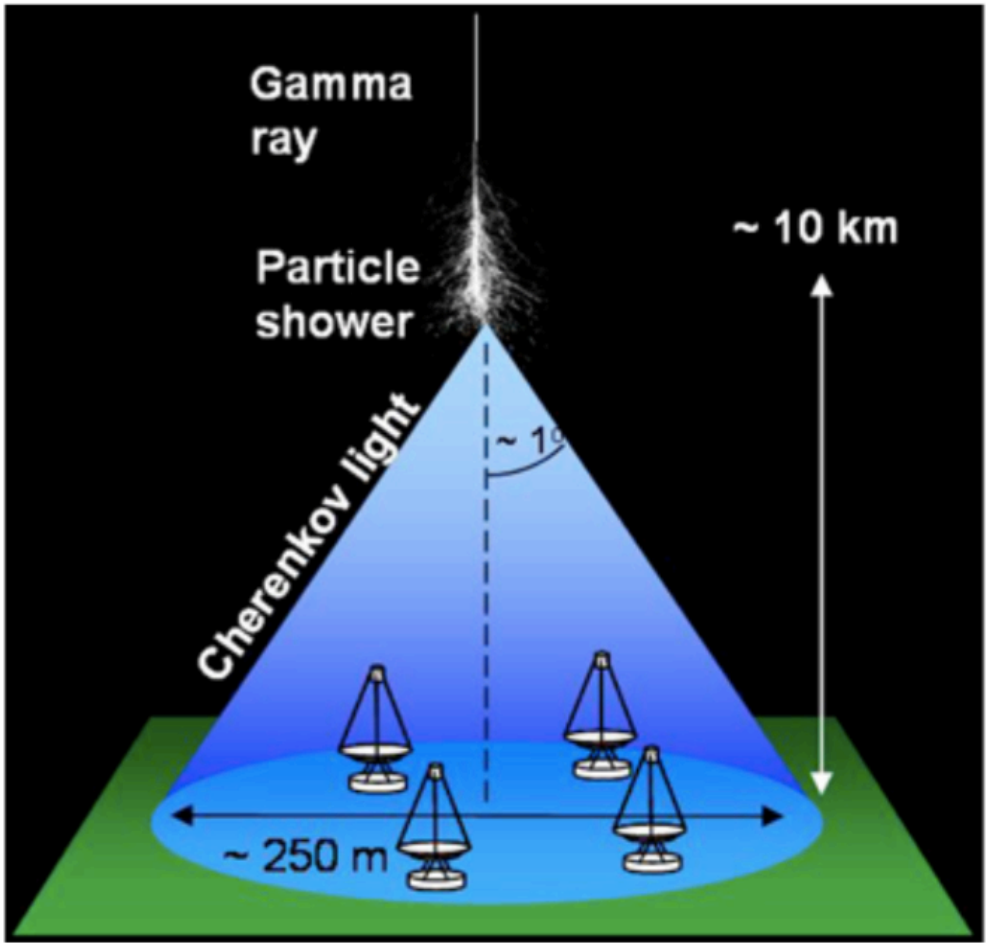
- **Gamma space telescopes** like Fermi (1 m^2)
- There is a limited size for a spatial telescope

  Problem above 100 GeV : the **flux is so low** that you have to wait thousands of years to have one photon passing through it...
- Solution: **indirect detection from the ground (10^5 m^2)**



Interaction between a high-energy photon and the atmosphere

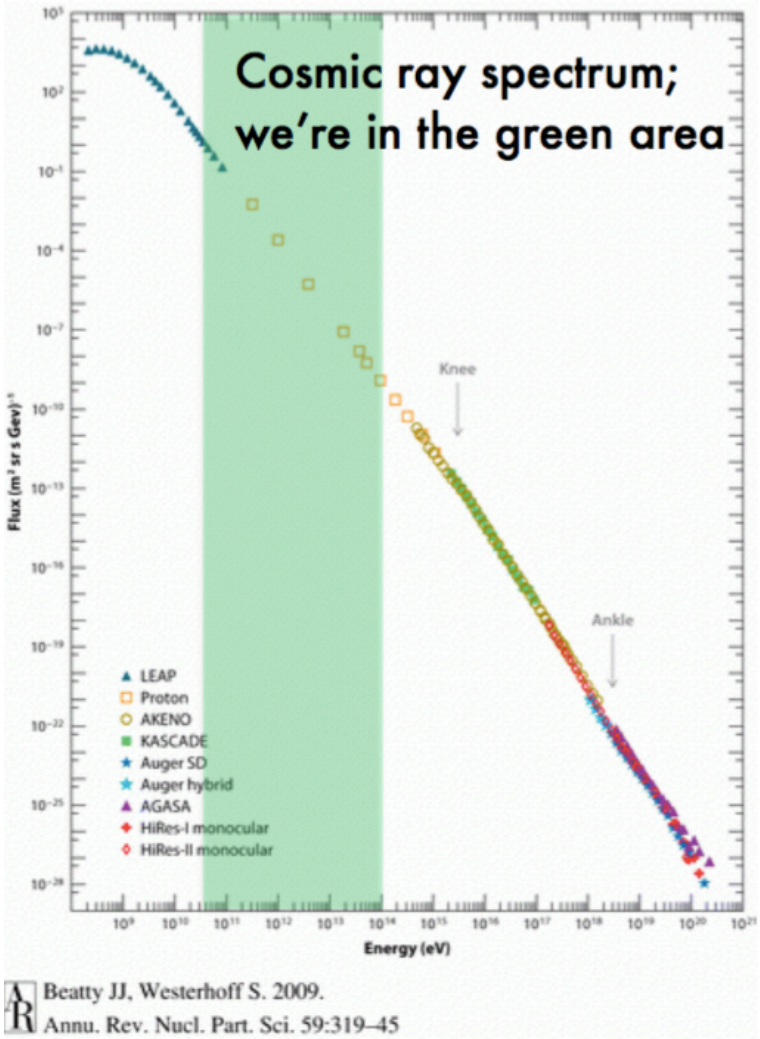
- When the gamma photon reaches the high atmosphere, it interacts with it and creates an **e+/e- pair**
- The pair continues in the same direction, towards the Earth, and emits **Bremsstrahlung radiation**
- An **electromagnetic cascade** takes place and lasts for about 100 m around 10 km of altitude
- The electrons and positrons go faster than light and emit a **Cherenkov radiation**



What else could emit a Cherenkov light ?

Earth is bombarded by cosmic rays

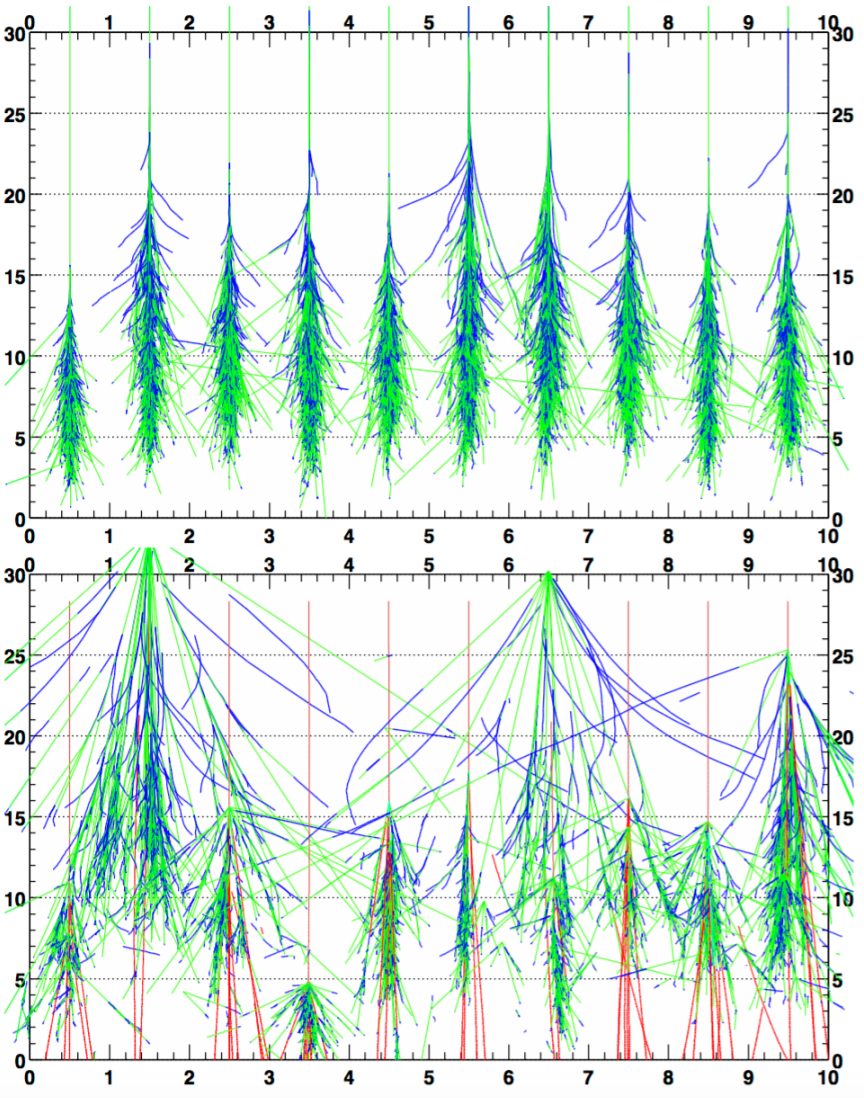
- **About $10^5/10^6$ protons for one gamma photon**
- They each develop a hadronic shower that also emits Cherenkov light : a **very loud background** !
- Need to discriminate between the photons (signal) and the hadrons (background)

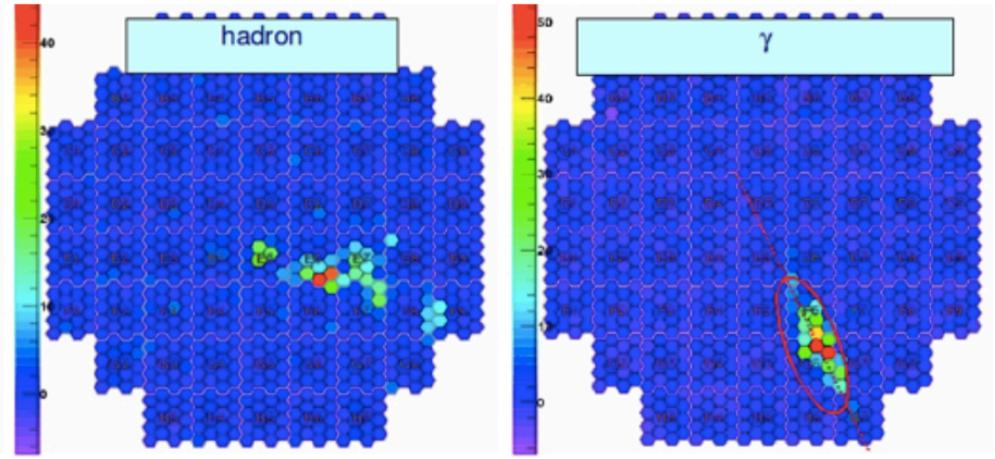


Beatty JJ, Westerhoff S. 2009.
Annu. Rev. Nucl. Part. Sci. 59:319–45

How do we find a needle in a haystack ?

- Electromagnetic and hadronic showers are **different**
- On top 10 electromagnetic showers induced by a 300 GeV photon, on the bottom 10 hadronic showers induced by a 300 GeV proton



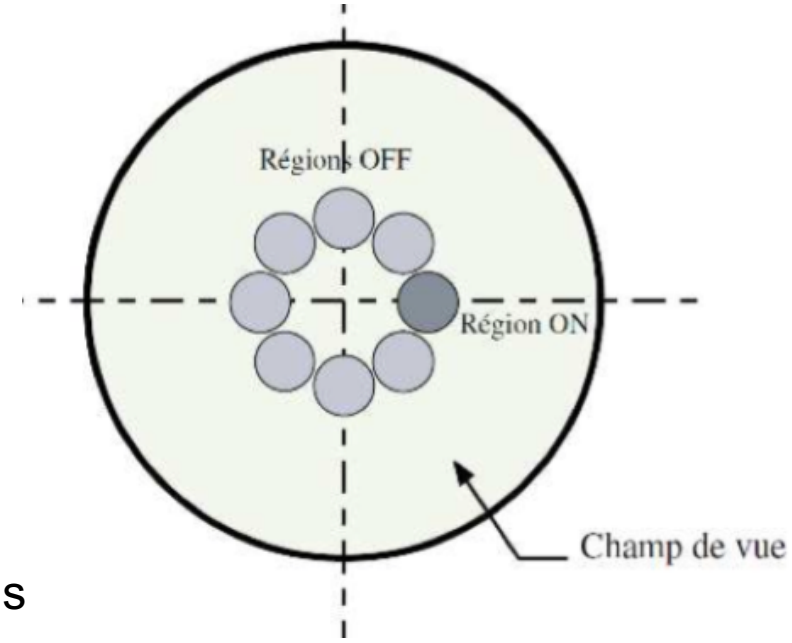


How do we find a needle in a haystack ?

Different analysis levels

- First, hadron/photon discrimination
- After, defining ON and OFF regions
- Assuming a uniform background we can substract the background

$$N_{excess} = N_{on} - \alpha N_{off}$$



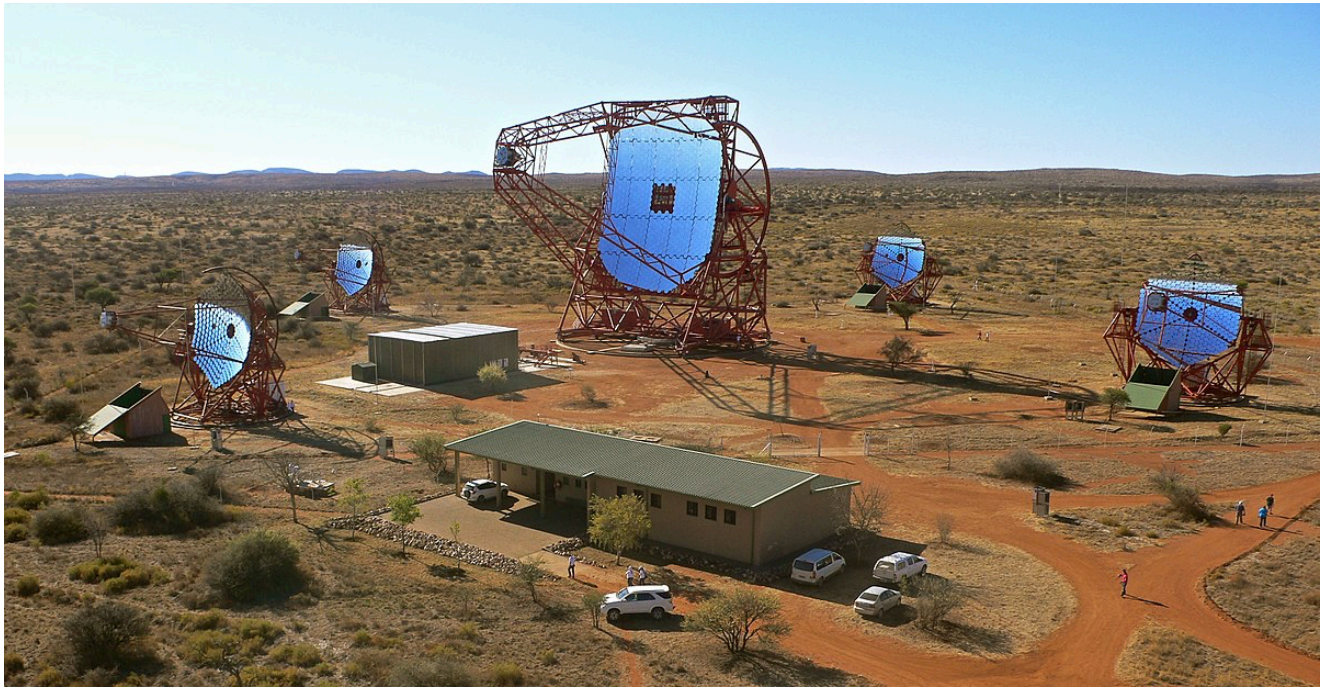
With α: ration of OFF regions and ON regions

The H.E.S.S. telescopes

Located in Namibia :

- Desert to avoid light pollution
- Southern hemisphere interesting because of the Galactic center
- 1800 meters of altitude : good distance to the cascade

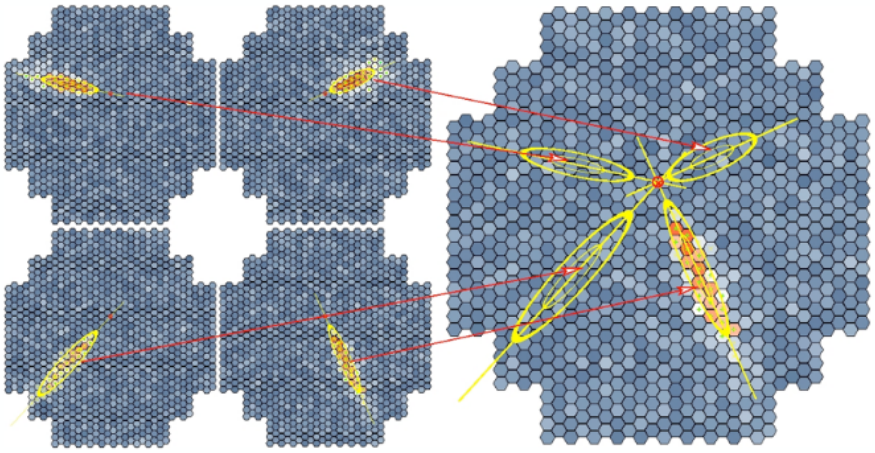
Mostly European collaboration consisting of ~200 members



HESS I and HESS II

Four small (12m mirrors) telescopes installed between 2002 and 2004: HESS I

Multiple telescopes allow for the use of stereoscopic reconstruction
→ better shower reconstruction and discrimination
Energy threshold :0.16 TeV at zenith, 0.22 TeV at 30 degres,...

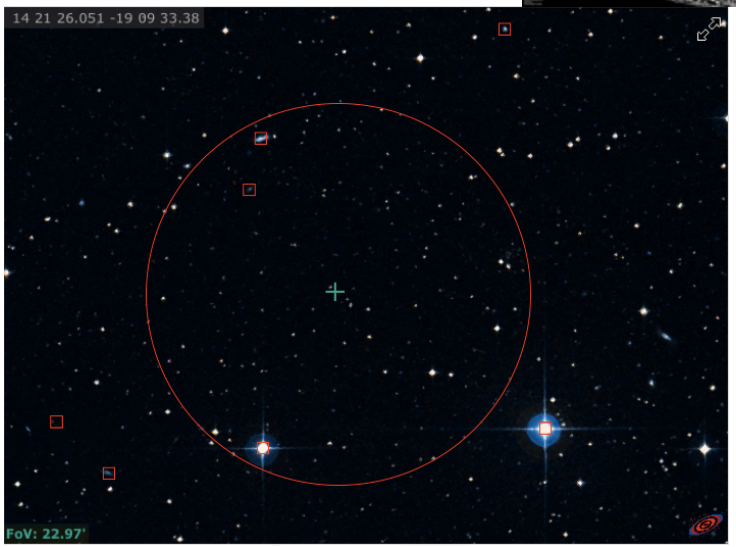


A big (28m mirror) telescope installed in 2012: HESS II

- More telescopes: larger detection surface: more sensitive
- Larger telescope: sensitive to fainter Cherenkov light: more sensitive to lower energies → energy threshold = 0.08 TeV

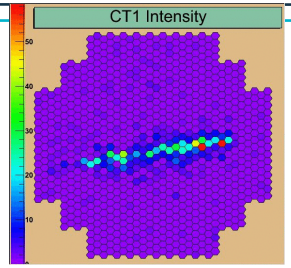
H.E.S.S. with some numbers

- Duty cycle 10% → 1000h/year
- Energy resolution : 15-20%
- Pointing speed : ~50s
- Field of view : 3° diameter
- Angular resolution : 0.1°



H.E.S.S. resolution

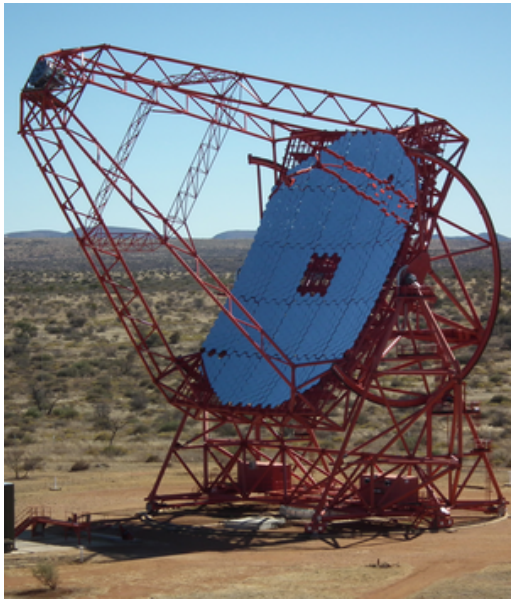
H.E.S.S. analysis chain



Source

gamma

H.E.S.S. site

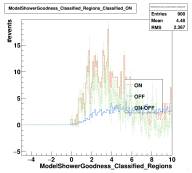


Raw data

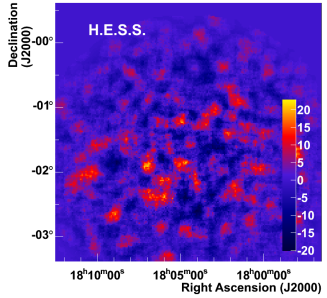
Calibration

Target	Run Duration (mn)	Status	Date	Calib
BZB J0316-2607	28	DONE	2017-07-14 04:58:10	paris-0-8-34
BZB J0316-2607	28	DONE	2017-07-14 09:17:16	paris-0-8-34
BZB J0316-2607	25	DONE	2017-07-14 05:42:18	paris-0-8-34
ACO 400	26	DONE	2017-08-05 03:30:52	paris-0-8-34
SMC pos 4	28	DONE	2017-08-02 21:29:34	paris-0-8-34
SMC pos 1	28	DONE	2017-07-14 02:51:16	paris-0-8-34
SMC pos 1	28	DONE	2017-07-14 02:27:01	paris-0-8-34
SMC pos 1	20	DONE	2017-07-14 04:46:53	paris-0-8-34
SMC pos 1	19	DONE	2017-07-14 02:35:50	paris-0-8-34

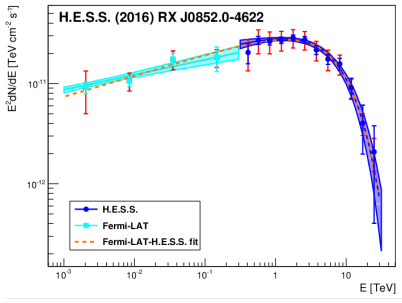
High level data



Results



Map/spectra

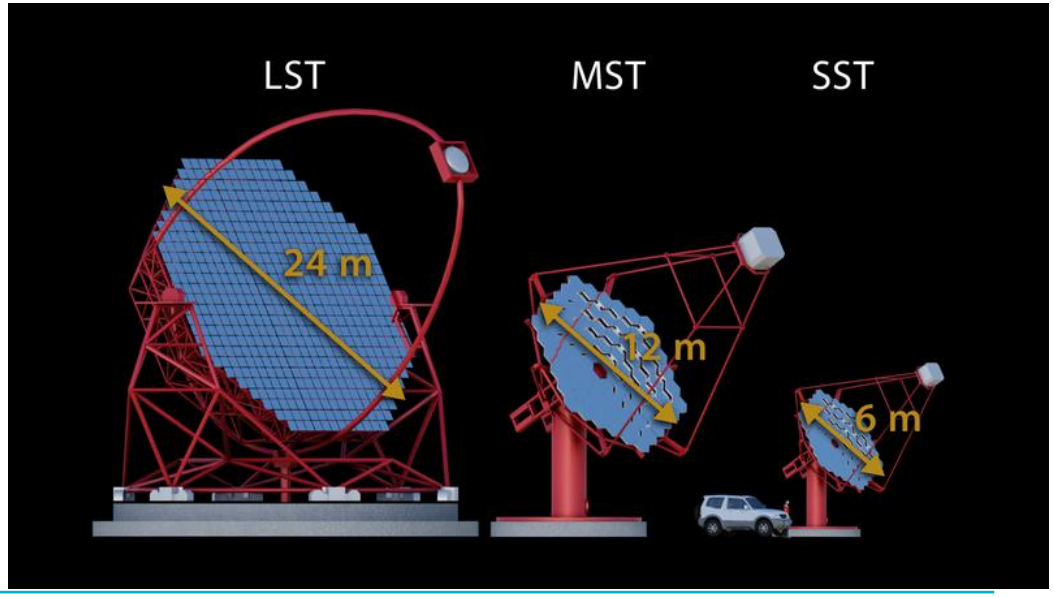


2 sites:

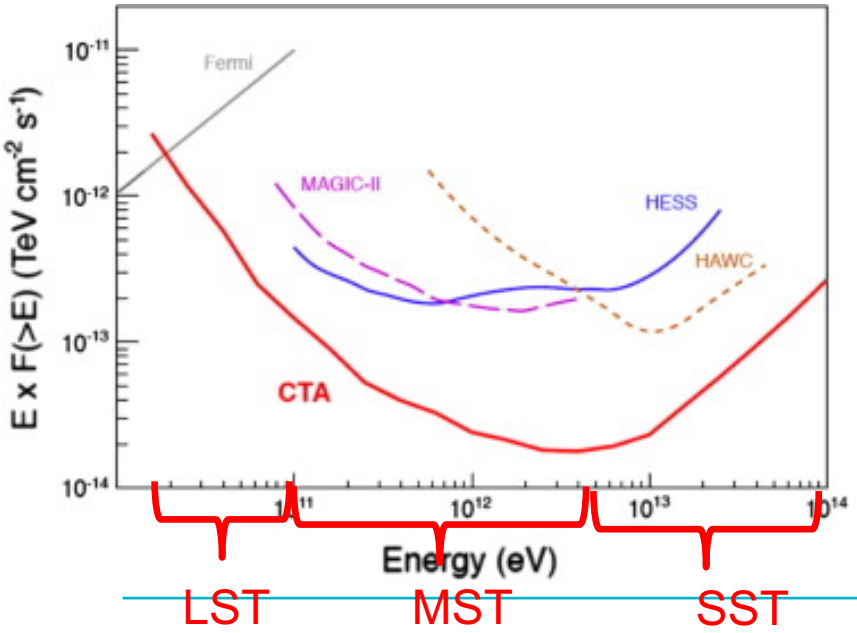
- Northern site: La Palma, Canary islands
- Southern site: ATACAMA desert, Chile

Telescope configurations

Northern site	Southern site
4 LSTs	4 LSTs
15 MSTs	25 MSTs
	70 SSTs

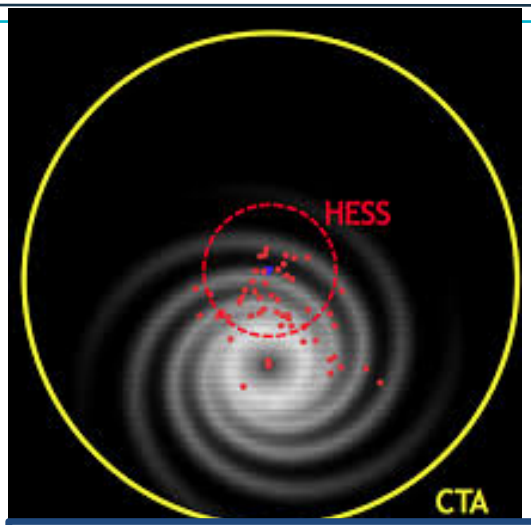


CTA characteristics

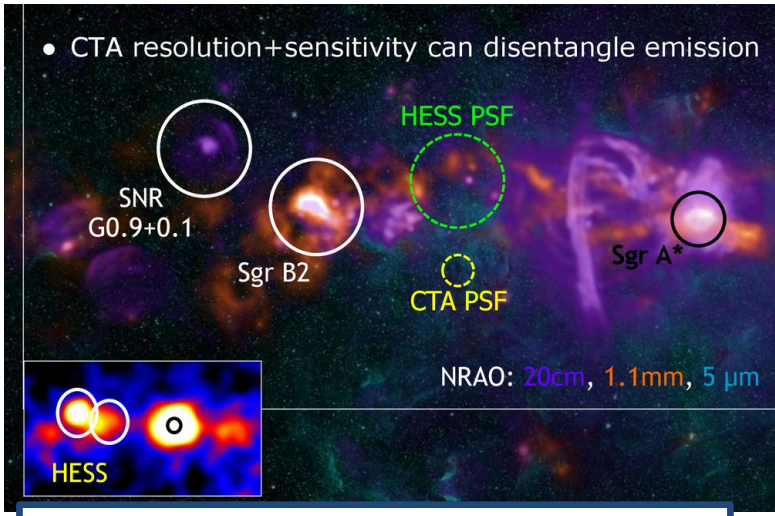


- X10 sensitivity in the whole energy range
- Energy range: 15GeV – 100TeV
- Fast slewing capabilities for the large telescopes

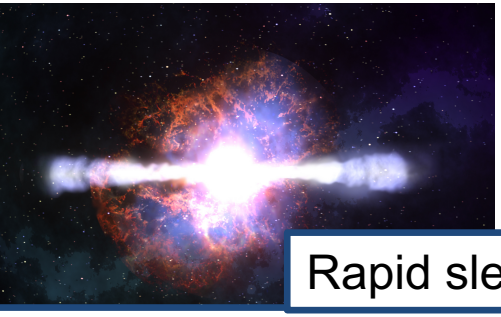
Science with CTA



10 x Sensitivity, Large Collection Area
→ all topics

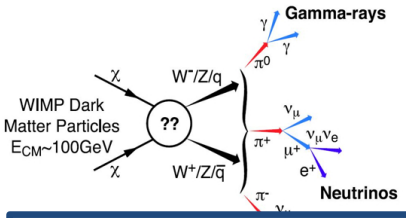


8° Field of View
→ surveys, extended objects



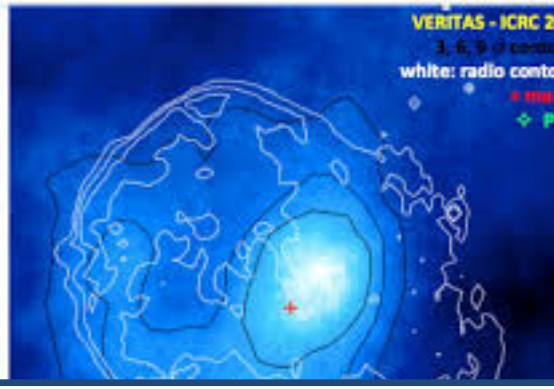
Rapid slewing in 20s

Energies down to 20 GeV



10% Energy Resolution
→ emission lines

cta
cherenkov telescope array



Improved angular resolution
→ morphology

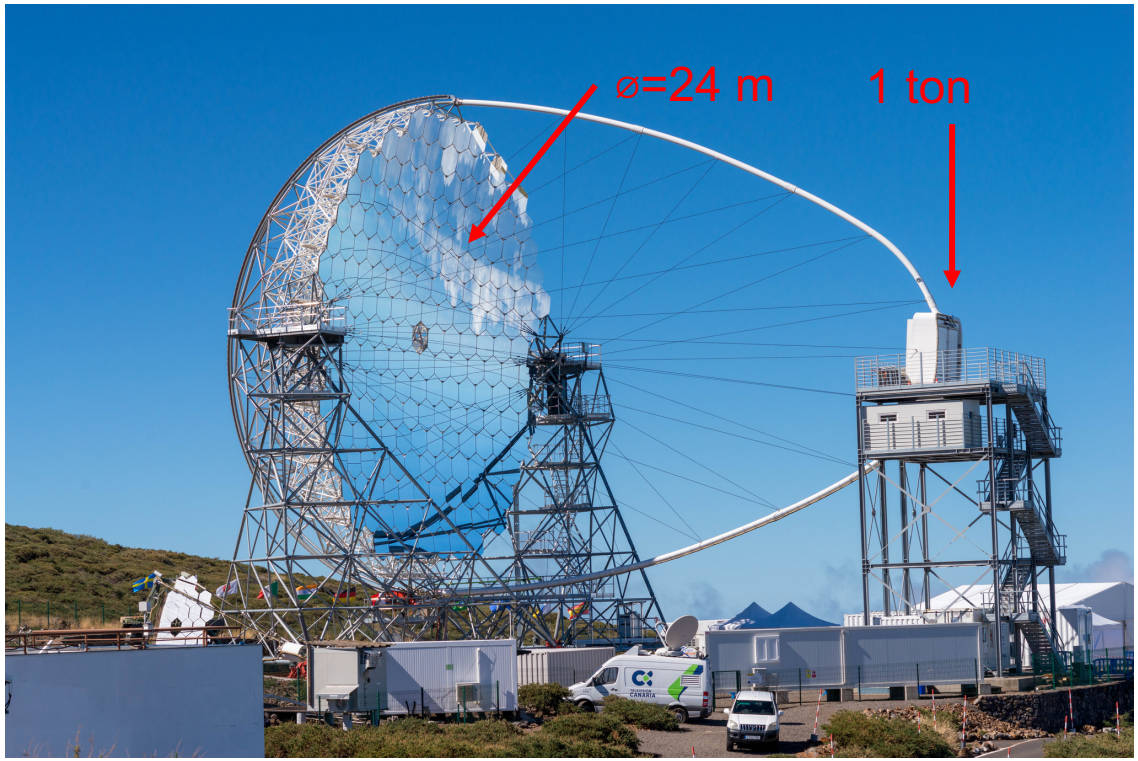
The Large Size Telescope (LST)

- Telescope mainly dedicated to low energy alert follow-ups :
  - GRB (see my talk)
  - AGN flare (see Gabriel's talk)

- Repoint any position in the sky in less than 20s

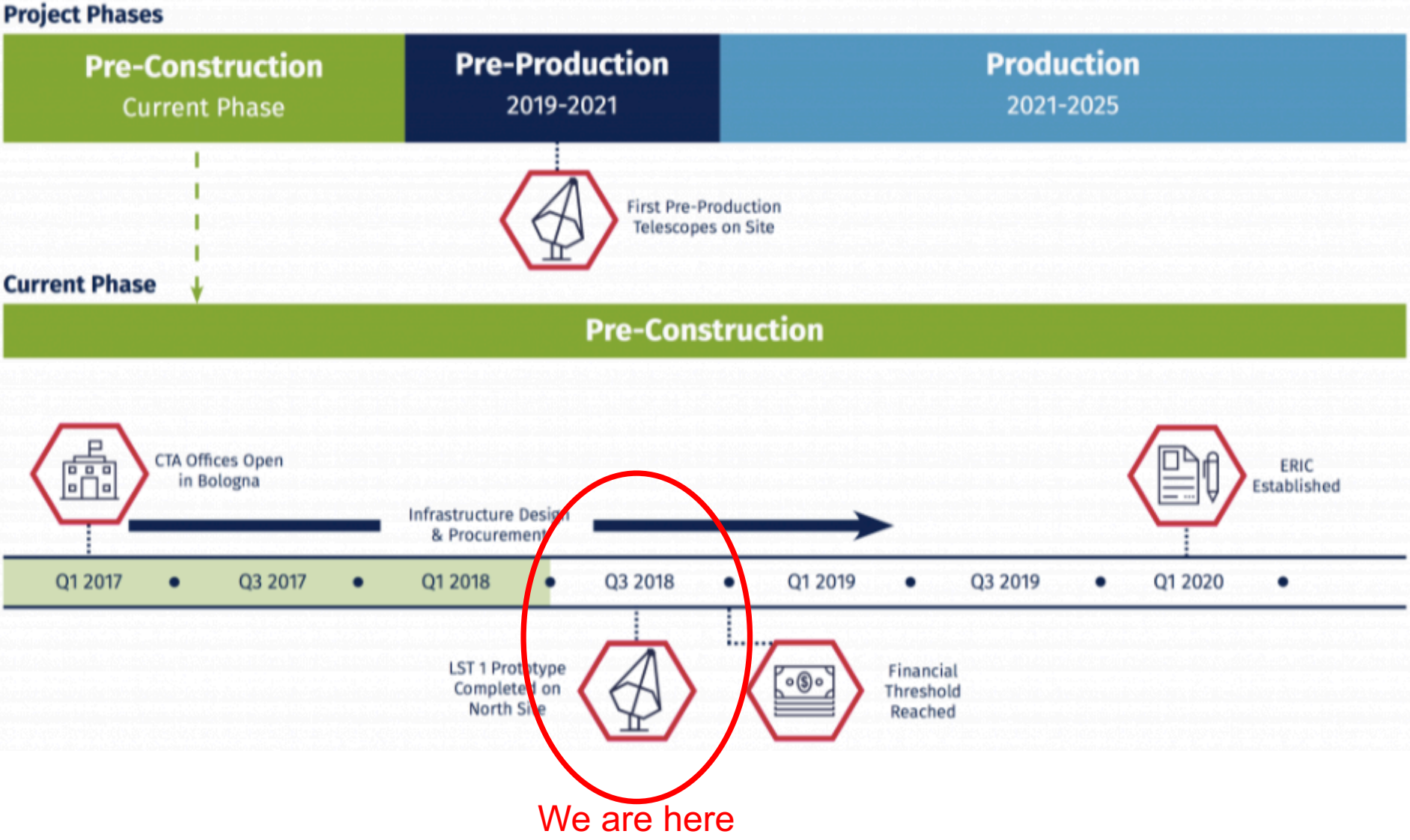
For a 180° movement
4.71m/s=17 km/h

- Tracking precision 30 arcsec ($8.3\ 10^{-3}$°)



- First LST prototype under construction on La Palma, Canary islands

Planning of CTA



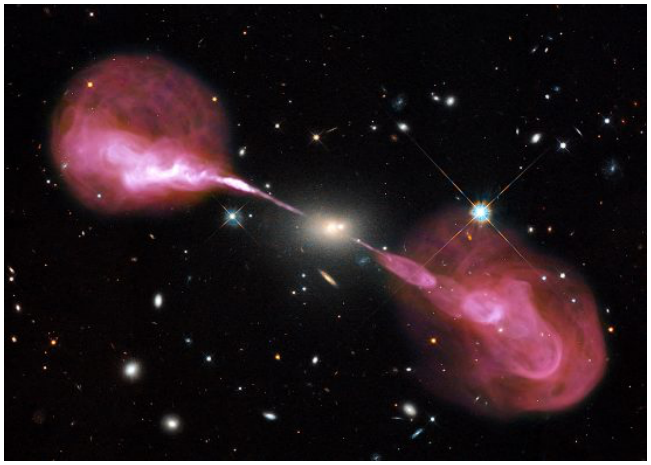
More than 100 sources have been discovered with ground based gamma astronomy…

…but this domain in energy is still full of mysteries…

…discover some of them in the following talks about :

Pulsars
(Marion)

Active Galactic Nuclei
(Gabriel)



Gamma-Ray Burst
(Quentin)