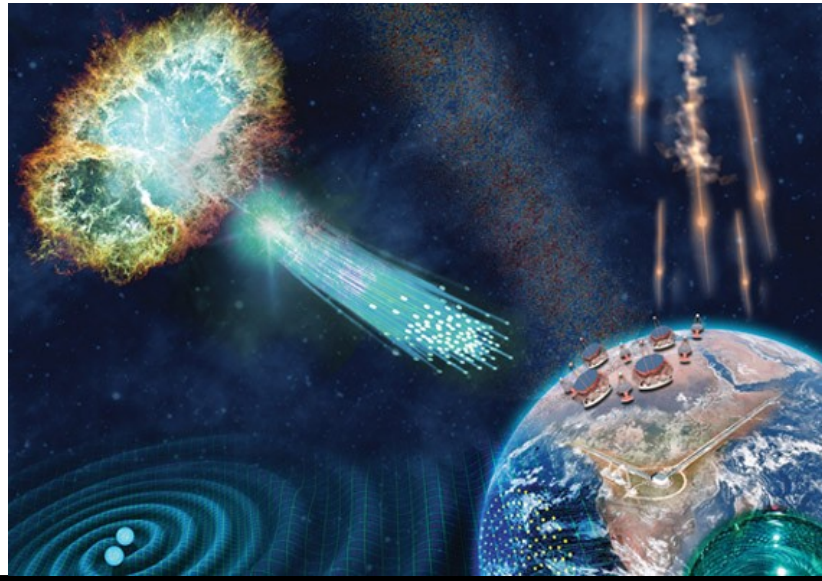
Prospectives Rayons Cosmiques

Astroparticle physics: a panorama
The extreme Universe, the dark Universe

- APPEC in European Astroparticle Physics Strategy 2017-2026:
  "Astroparticle physics is the fascinating field of research at the intersection of astronomy, particle physics and cosmology.

  It simultaneously addresses challenging questions relating to the micro-cosmos (the world of elementary particles and their fundamental interactions) and the macro-cosmos (the world of celestial objects and their evolution) and, as a result, is well-placed to advance our understanding of the Universe beyond the Standard Model of particle physics and the Big Bang Model of cosmology."



Astroparticle physics: a panorama
The extreme Universe, the dark Universe

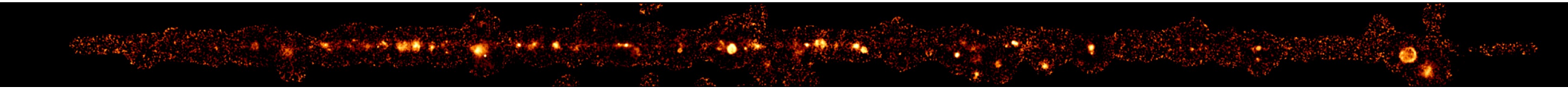
- Study of high energy processes in the Universe.
- Key questions:
  - What is the origin of the highest energy particles in the Universe ?
  - What is the nature of spacetime ?
  - What is the nature of dark matter ?
  - What is the structure of the physics beyond the Standard Model ? (link with all groups within LPNHE)

Astroparticle physics: a panorama
The extreme Universe, the dark Universe

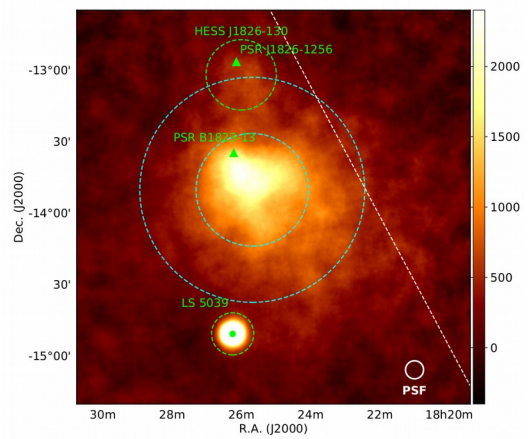
- Different messengers
  - Photons
  - Cosmic rays
  - Neutrinos
  - Gravitational waves
  - Dark matter

Astroparticle physics: a panorama
The extreme Universe, the dark Universe

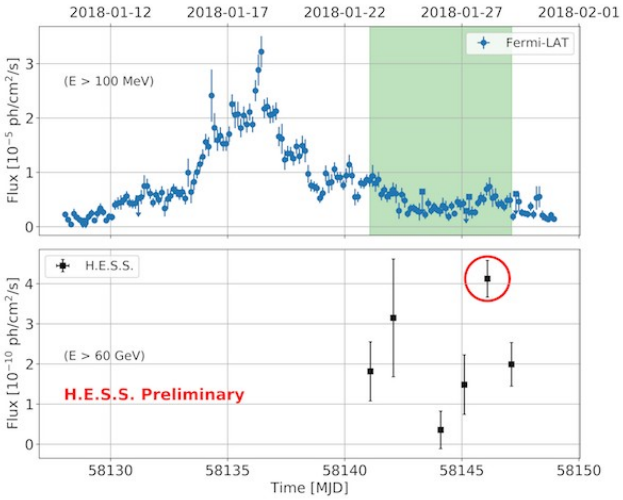
- Different messengers
  - Photons



  - Cosmic rays



  - Neutrinos



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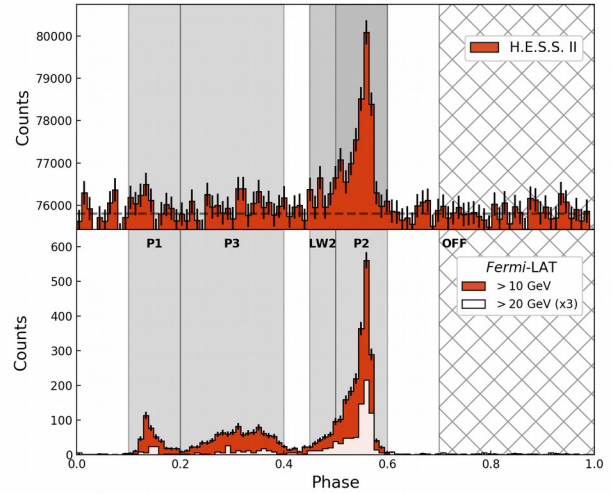

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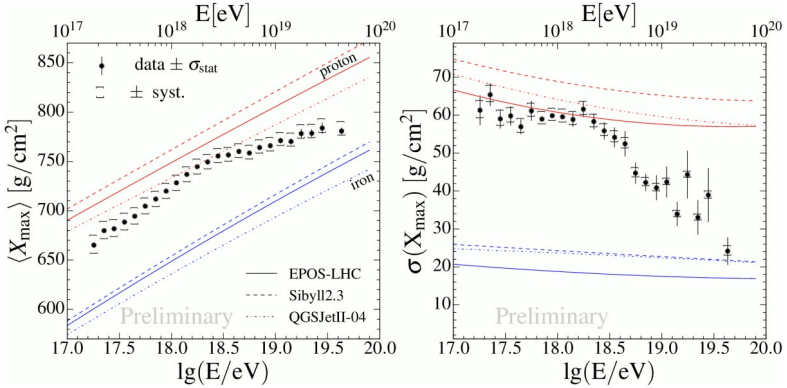
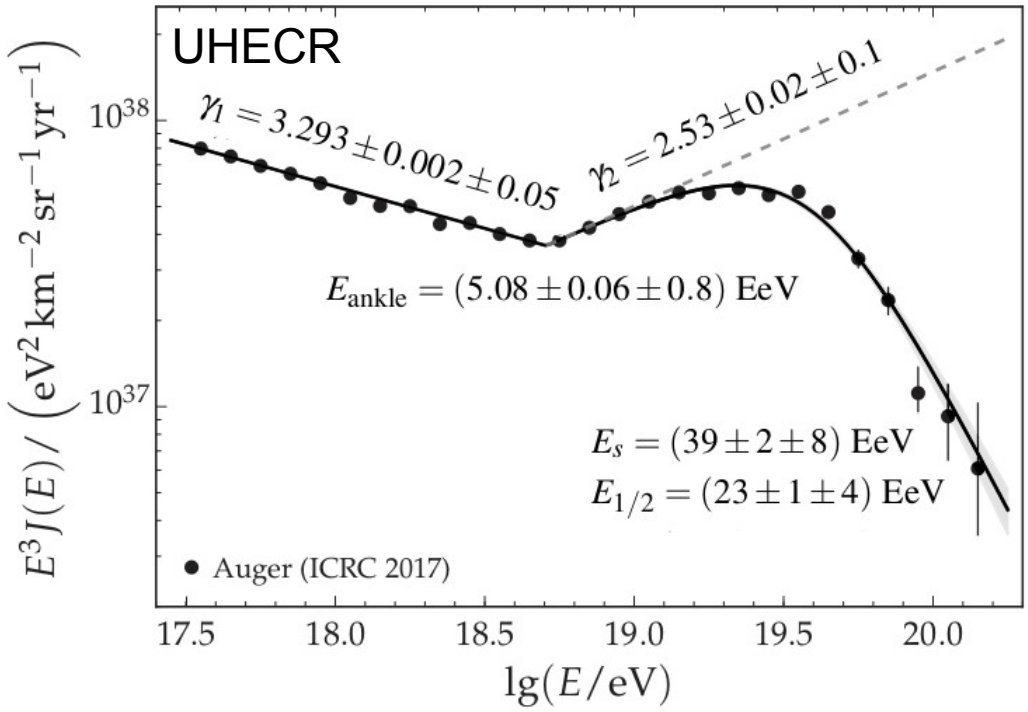
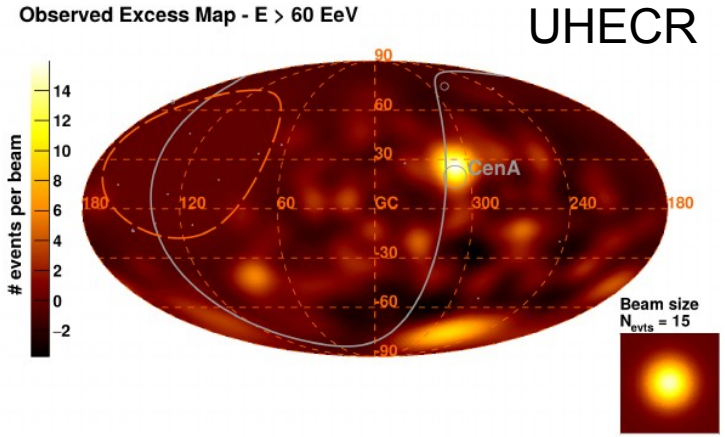
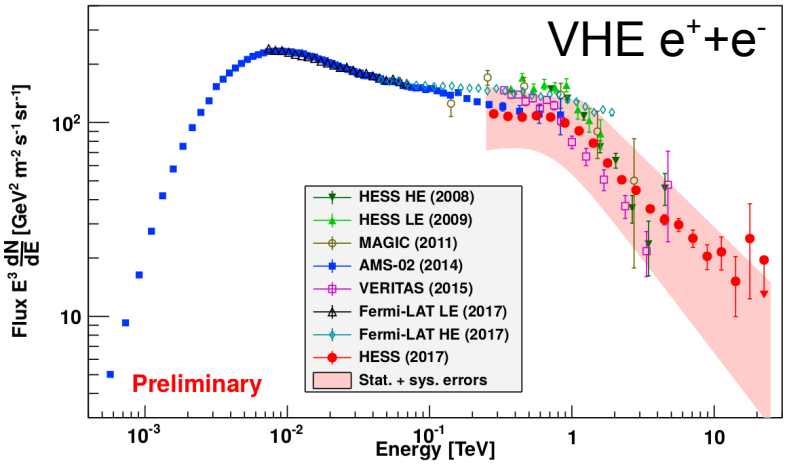


- Cosmic rays







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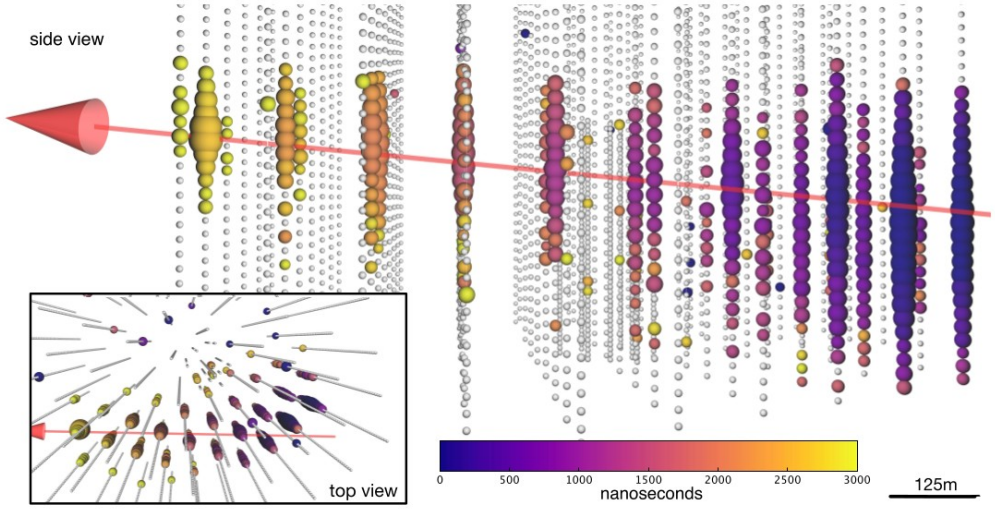
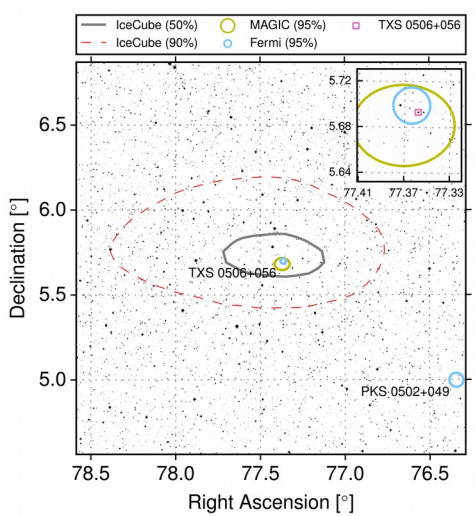
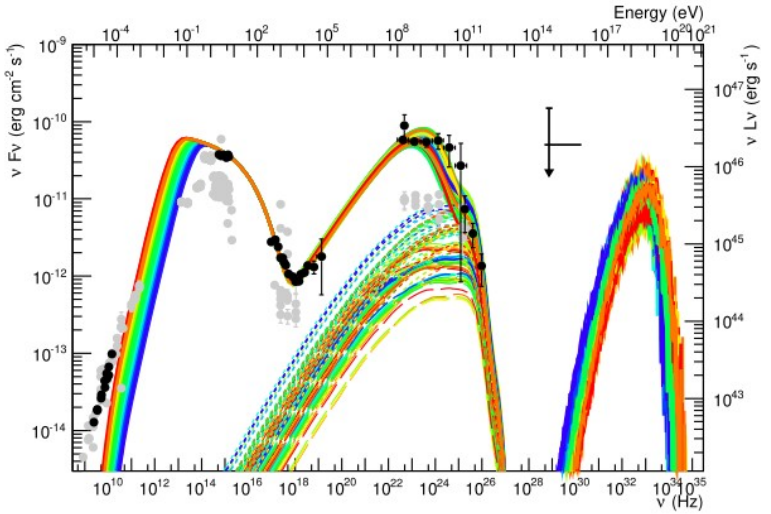




- Neutrinos
- Gravitational waves
- Dark matter



(a) Proton synchrotron modeling of TXS 0506+056

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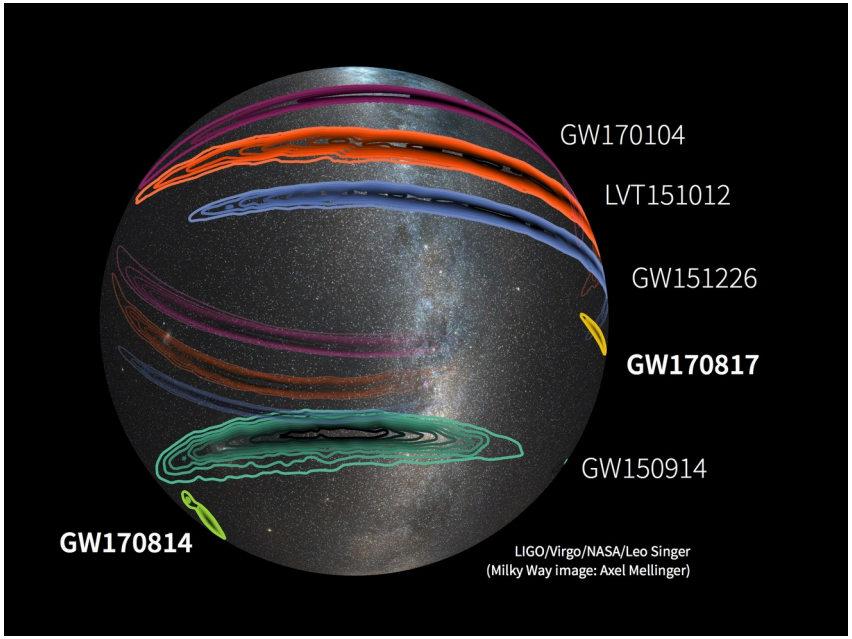
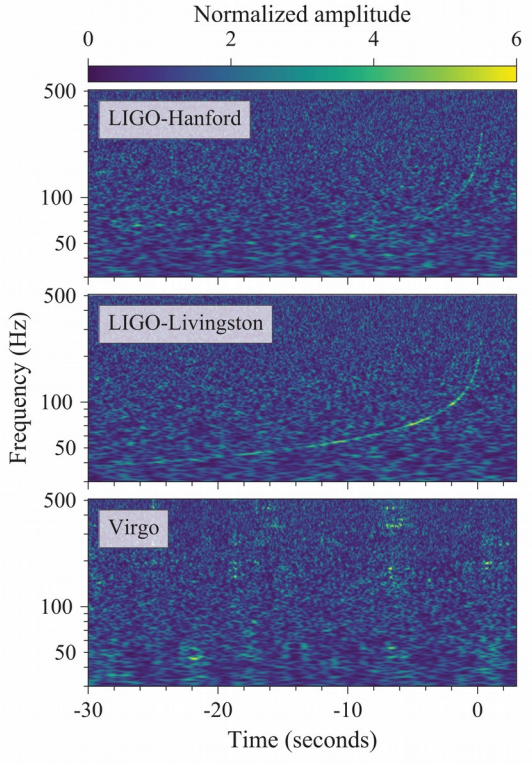
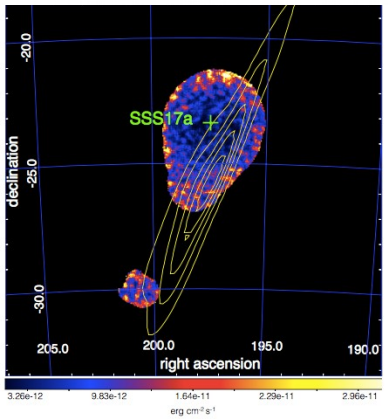
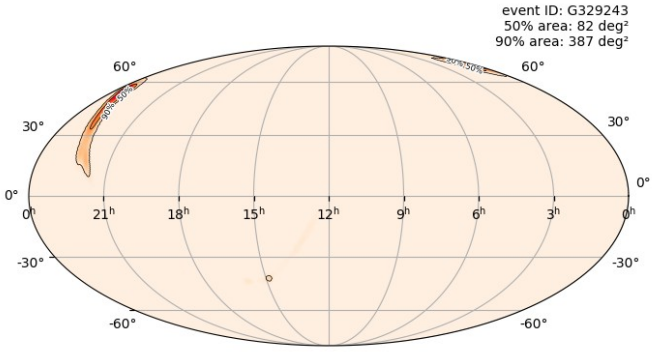






H.E.S.S.

- **Topics covered at LPNHE :** Extragalactic sources, testing Lorentz invariance, diffuse emissions and indirect search for dark matter.
- **Group :** 2 PhD, 1 Postdoc, 1 MdC, 1 CR, 1 Pr.
- **2019 :** end of French cameras (decision by CB : 20??).
  - CT1-4 upgraded in 2017.
  - New camera for CT5 (09/2019) : High QE.
    Observations with moonlight (+20% time).
- **2020–2022 :** Experiment extended (3 years renewable 2 x).
  - Mainly in “alert” mode (ToO)
  - Multi-messenger campaigns
  - Population studies
  - Preparation for CTA



Event S190408an

H.E.S.S.

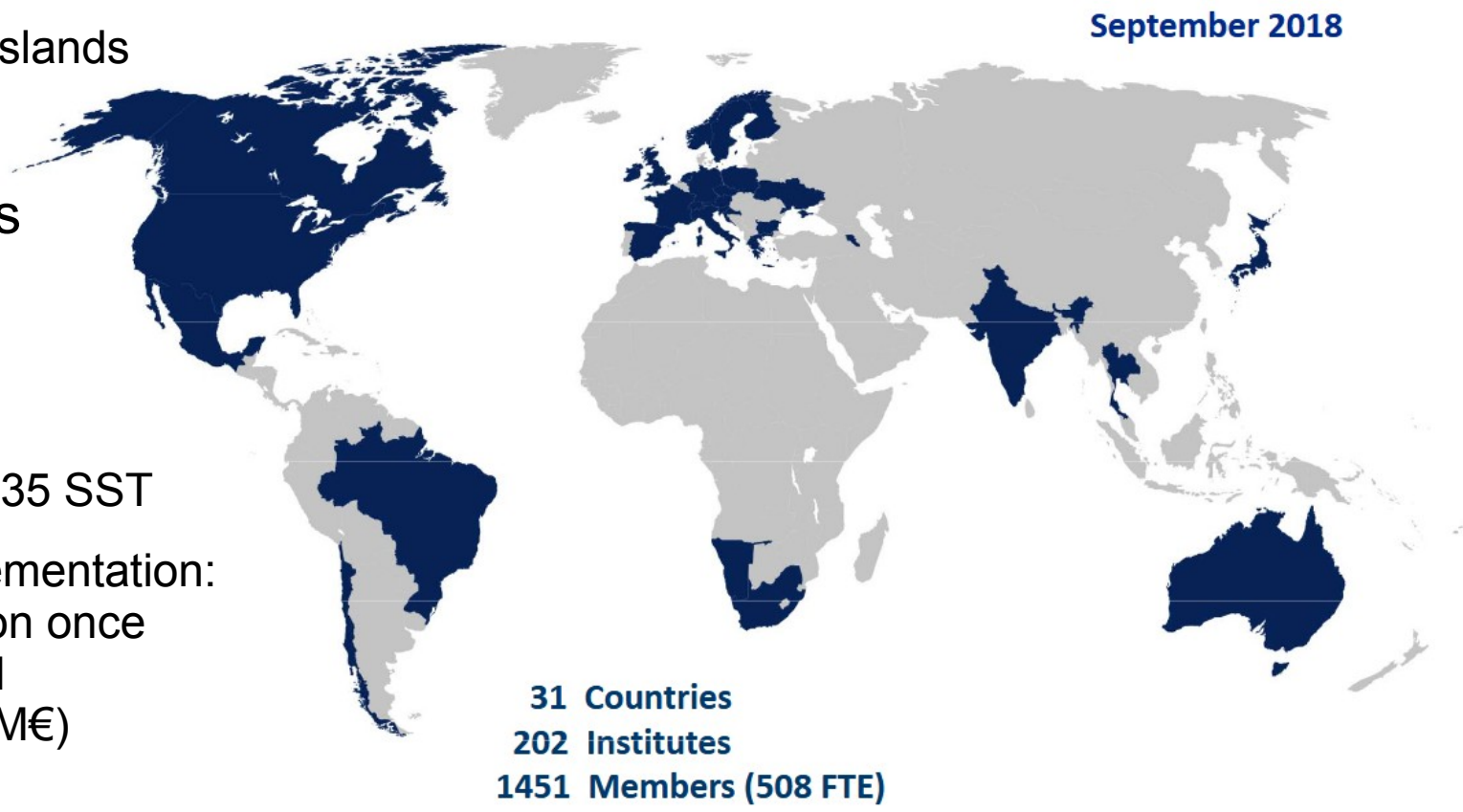
- CTA not expected to supersede H.E.S.S. until 2023.
  Even after, CT5 will remain largest single Cherenkov telescope.

- Future of *Fermi*:
  danger that funding won't be extended beyond ~2025
  → imperative to maximize synergy *Fermi*-LAT/existing Cherenkov tels.

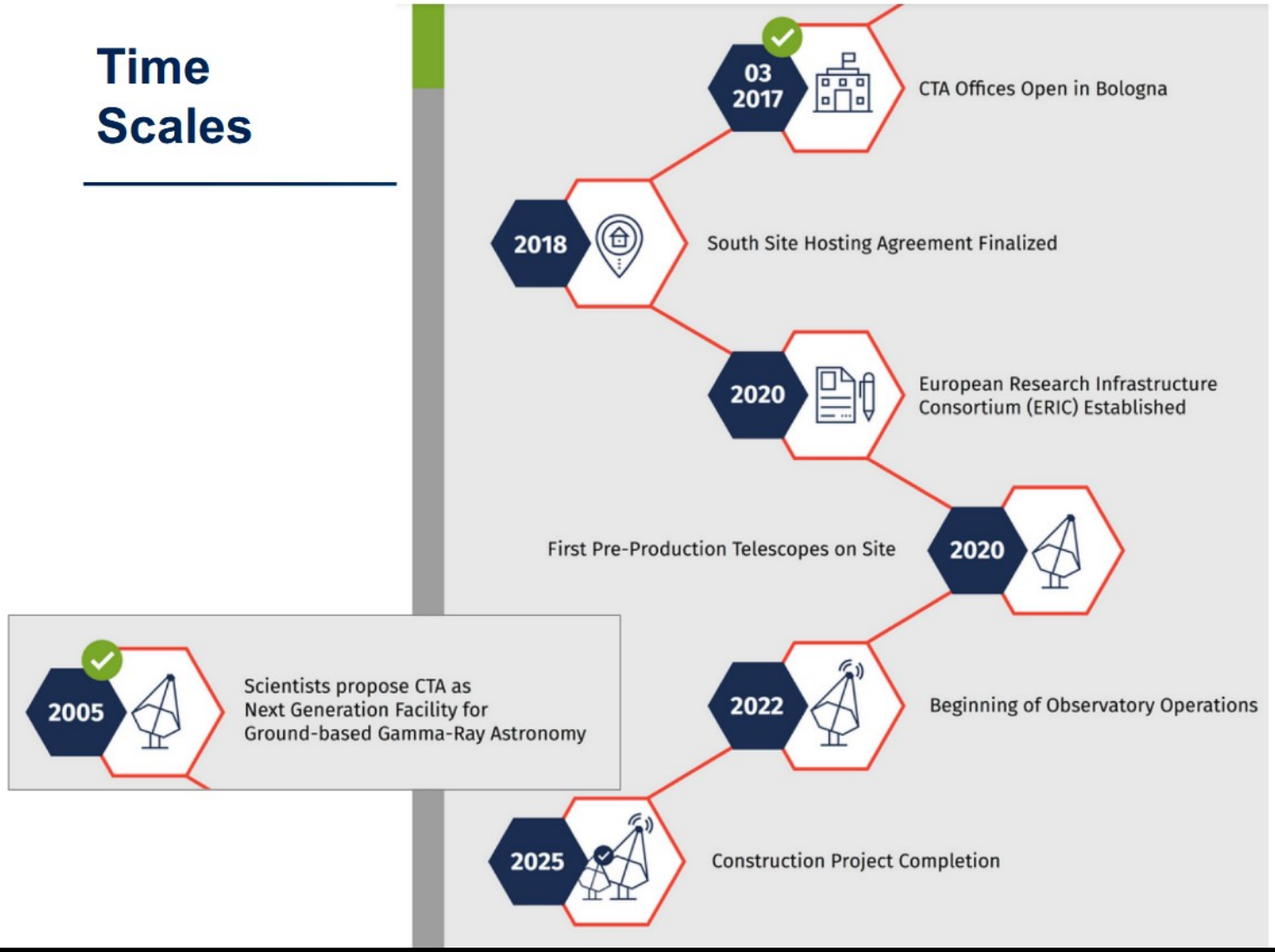
CTA

Consortium Membership

- 2 sites
  - North: Canaria islands
  - South: Chile
- 3 telescope sizes
  - North
    4 LST, 15 MST
  - South
    4 LST, 24 MST, 35 SST
  - Threshold implementation:
    Start construction once
    250 M€ secured
    (total cost: 400 M€)
- Group:
  2 PhD, 1 Postdoc,
  1 MdC, 1 CR (all in H.E.S.S.)



CTA timeline



CTA: Broad science goals

- Theme 1: Understanding the Origin and Role of Relativistic Cosmic Particles
  - What are the sites of high-energy particle acceleration in the universe?
  - What are the mechanisms for cosmic particle acceleration?
  - What role do accelerated particles play in feedback on star formation and galaxy evolution?
- Theme 2: Probing Extreme Environments
  - What physical processes are at work close to neutron stars and black holes?
  - What are the characteristics of relativistic jets, winds and explosions?
  - How intense are radiation fields and magnetic fields in cosmic voids, and how do these evolveover cosmic time?
- Theme 3: Exploring Frontiers in Physics
  - What is the nature of dark matter? How is it distributed?
  - Are there quantum gravitational effects on photon propagation?
  - Do axion-like particles exist?

arXiv:1709.07997

Science with CTA

arXiv:1709.07997

Theme		Question	Dark Matter Programme	Galactic Centre Survey	Galactic Plane Survey	LMC Survey	Extra-galactic Survey	Transients	Cosmic Ray PeVatrons	Star-forming Systems	Active Galactic Nuclei	Galaxy Clusters
Understanding the Origin and Role of Relativistic Cosmic Particles	1.1	What are the sites of high-energy particle acceleration in the universe?		✔	✔✔	✔✔	✔✔	✔✔	✔	✔	✔	✔✔
	1.2	What are the mechanisms for cosmic particle acceleration?		✔	✔	✔		✔✔	✔✔	✔	✔✔	✔
	1.3	What role do accelerated particles play in feedback on star formation and galaxy evolution?		✔		✔				✔✔	✔	✔
Probing Extreme Environments	2.1	What physical processes are at work close to neutron stars and black holes?		✔	✔	✔			✔✔		✔✔	
	2.2	What are the characteristics of relativistic jets, winds and explosions?		✔	✔	✔	✔	✔✔	✔✔		✔✔	
	2.3	How intense are radiation fields and magnetic fields in cosmic voids, and how do these evolve over cosmic time?					✔	✔			✔✔	
	3.1	What is the nature of Dark Matter? How is it distributed?	✔✔	✔✔		✔						✔
Exploring Frontiers in Physics	3.2	Are there quantum gravitational effects on photon propagation?						✔✔	✔		✔✔	
	3.3	Do Axion-like particles exist?					✔	✔			✔✔	

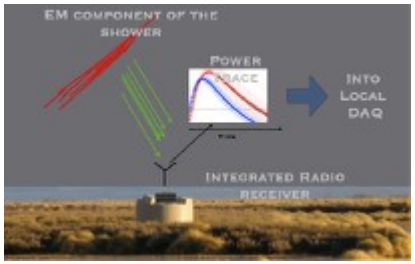
CTA @ LPNHE

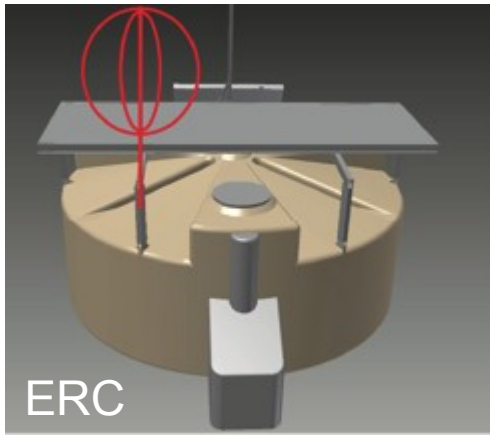
- NectarCAM: take over by CTAO: need to pass critical design review (CDR, by end 2019 ?).
  - Camera n°2-15: subcontracted production
    - Official French engagement towards CTAO needed (TGIR currently covers camera n°1 only)
- Science Tools: development on gammapy

- Longer-term prospective
  - Idea: GPU-based online gamma/hadron discrimination

Auger: 2020–2025

UPMC Emergence





- Auger-Prime

  Panneaux de scintillateurs sur chaque cuve Cherenkov d'Auger pour mesurer la composante EM des cascades des gerbes verticales (zenith<60°).

  Permet de reconstruire la masse du RC initialen l'absence de profile FD

  → Etudes d'anisotropie avec contraintes de composition pour remonter aux sources.

- Auger-Horizon (ERC)

  Antennes radio (30–80 MHz) sur chaque cuve Cherenkov d'Auger pour mesurer la composante EM des cascades des gerbes horizontales (zenith>60°).

  Complète le programme du SSD à tous les angles zénithaux et augmente les capacités de détection des neutrinos

  → Etudes d'anisotropie avec contraintes de composition pour remonter aux sources.

Par ses contributions passées, le LPNHE peut intégrer à tout moment ces développements et les analyses de physique qu'autoriseront ces nouvelles données.

GRAND

Financé/En cours

Prospectif
Tributaire des résultats précédents

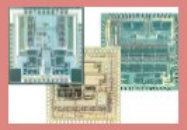
GRANDProto300

GRANDProto35

GRAND10k

GRAND200k

2018 | 2020 | 2025 | 203X

	2018	2020	2025	203X
Goals	standalone radio array: test efficiency & background rejection	standalone radio array of very inclined showers (θ_z>70°) from cosmic rays (>$10^{16.5}$ eV) + ground array to do UHECR astro/hadronic physics	first GRAND subarray, sensitivity comparable to ARA/ARIANNA on similar time scale, allowing discovery of EeV neutrinos for optimistic fluxes	first neutrino detection at 10^{18} eV and/or neutrino astronomy!
Setup	35 radio antennas 21 scintillators 	• 300 HorizonAntennas over 300 km² • Fast DAQ (AERA+ GRANDproto35 analog stage) • Solar panels (day use) + WiFi data transfer • Ground array (à la HAWC/Auger)	DAQ with discrete elements, but mature design for trigger, data transfer, consumption	200,000 antennas over 200,000 km², ~ 20 hotspots of 10k antennas, possibly in different continents Industrial scale allows to cut down costs: 500€/unit ➔ 200M€ in total
Budget & stage	160k€, fully funded by NAOC+IHEP, deployment ongoing @ Ulastai	1.3 M€ to be deployed in 2020	1500€ / detection unit 	 ASIC Cost ~10M€ ➔ few 10€/board Consomption < 1W Reliability

Proposition de projet GRAND @ LPNHE

- GRANDProto300:
  - Validation du principe de détection de GRAND: détection, identification et reconstruction efficace des rayons cosmiques avec trajectoires inclinées dans la gamme $10^{16.5}$-10^{18}eV et données radio seules.

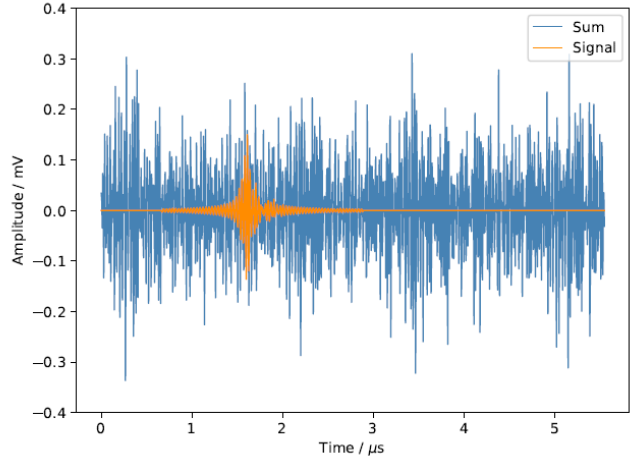
➔ @LPNHE: optimisation des techniques de calibration, identification et reconstruction des signaux radio dans le cas des gerbes inclinées.

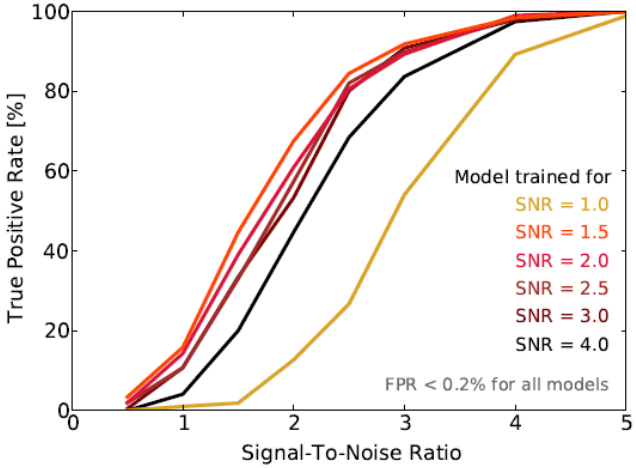
  - Banc de test pour les étapes suivantes du projet (GRAND10k)

➔ @ LPNHE: R&D sur méthodes de trigger innovantes (cf pres @ réunion du Vendredi 12/04)

- GRAND10k et GRAND200k :
  - Quel potentiel de physique pour quel design?

➔ @LPNHE: simulations multi-messager de phénomènes transitoires extragalactiques & optimisation du réseau





Erdmann et al, astro-ph/1901.04079