http://alto-gamma-ray-observatory.org

ALTO: A new very-high-energy gamma-ray observatory in the Southern Hemisphere

Satyendra Thoudam
Yvonne Becherini
Michael Punch
Jean-Pierre Ernenwein
Mohanraj Senniappan
Tomas Bylund

Collaborating institutes and industry:
- Linnaeus University
- APC Laboratory, Paris (France), IN2P3/CNRS
- Aix-Marseille University (France)
- TBS Yard AB (Småland)

Partikeldagarna 2017, Stockholm

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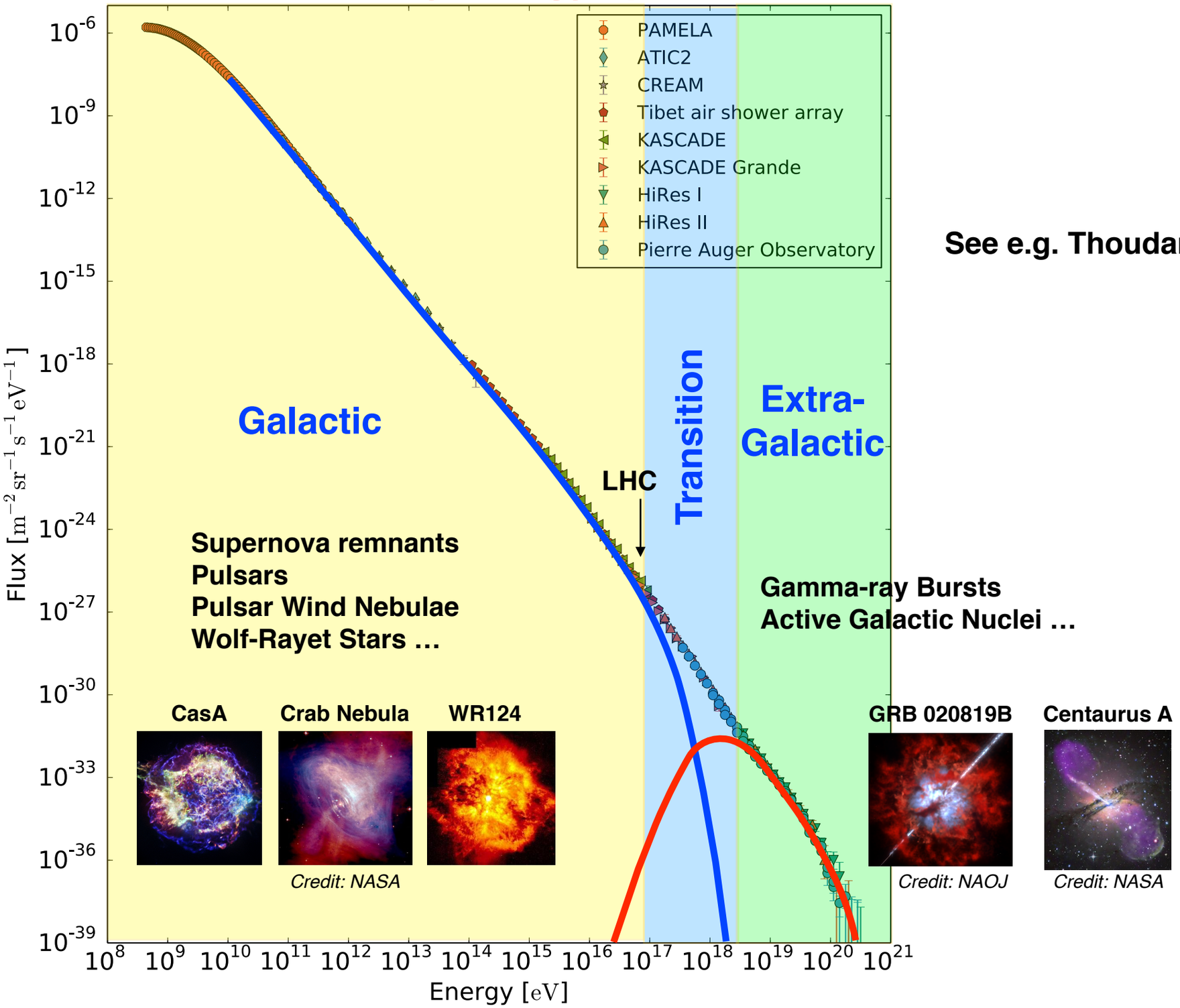
Origin of cosmic rays?

Cosmic-ray energy spectrum

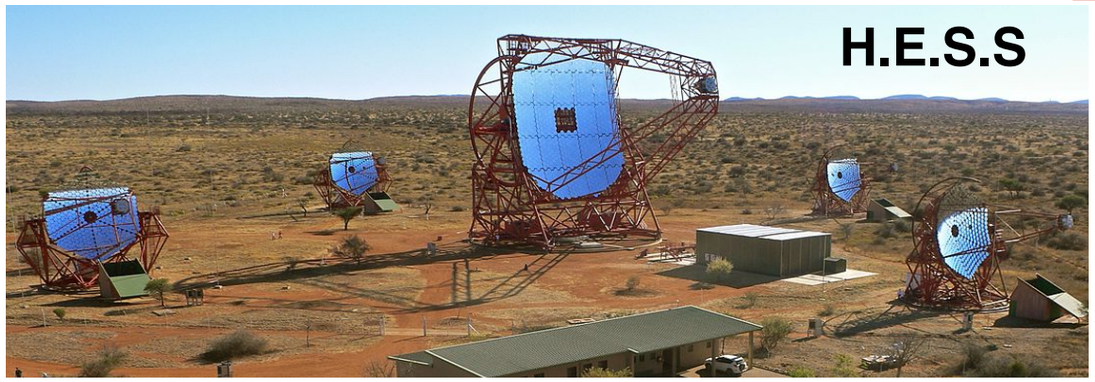


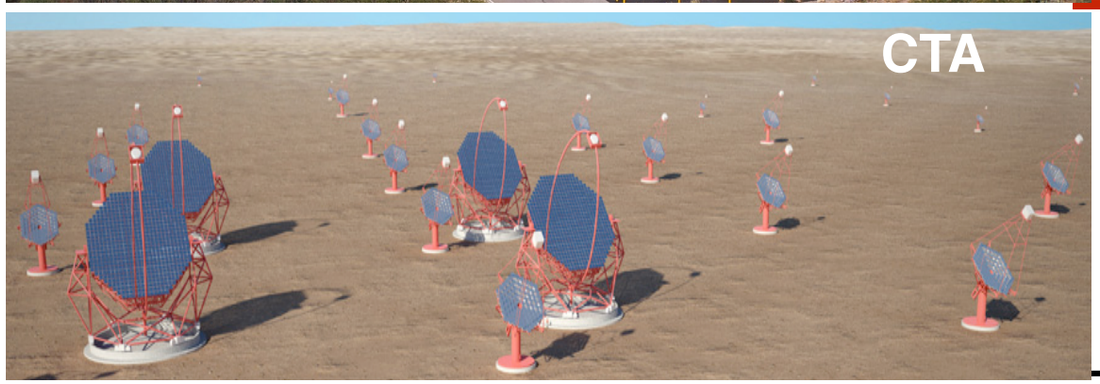
See e.g. Thoudam+ 2016

Astronomy @ 1 Trillion times the energy of optical photons

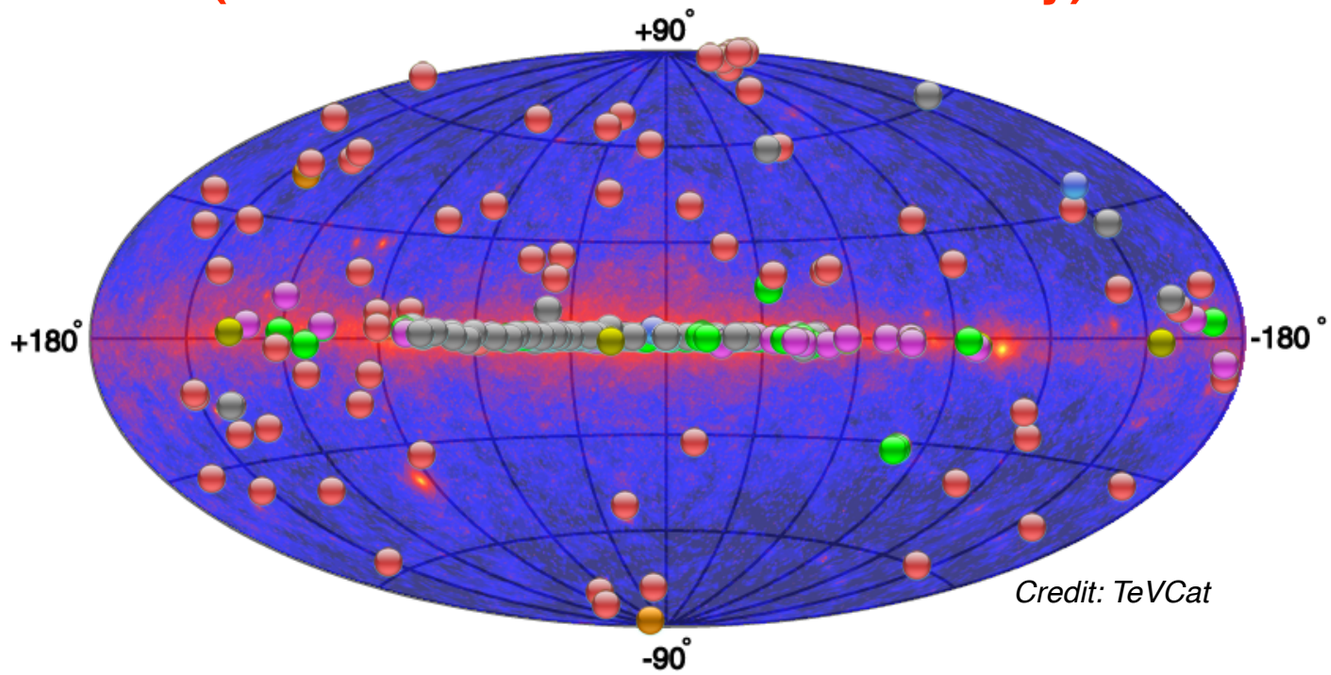
ALTO

Imaging Atmospheric Cherenkov Telescopes





TeV gamma-ray sources (overlaid over the *Fermi* GeV sky)



Credit: TeVCat

Main limitations:-

- Limited Field-of-View ~ 4º
- Limited duty cycle: Dark moonless night

- LST: 20-200 GeV; FoV ~ 4.5º
- MST: 100 GeV - 10 TeV; FoV ~ 7º-8º
- SST: Few to 300 TeV; FoV ~ 9º

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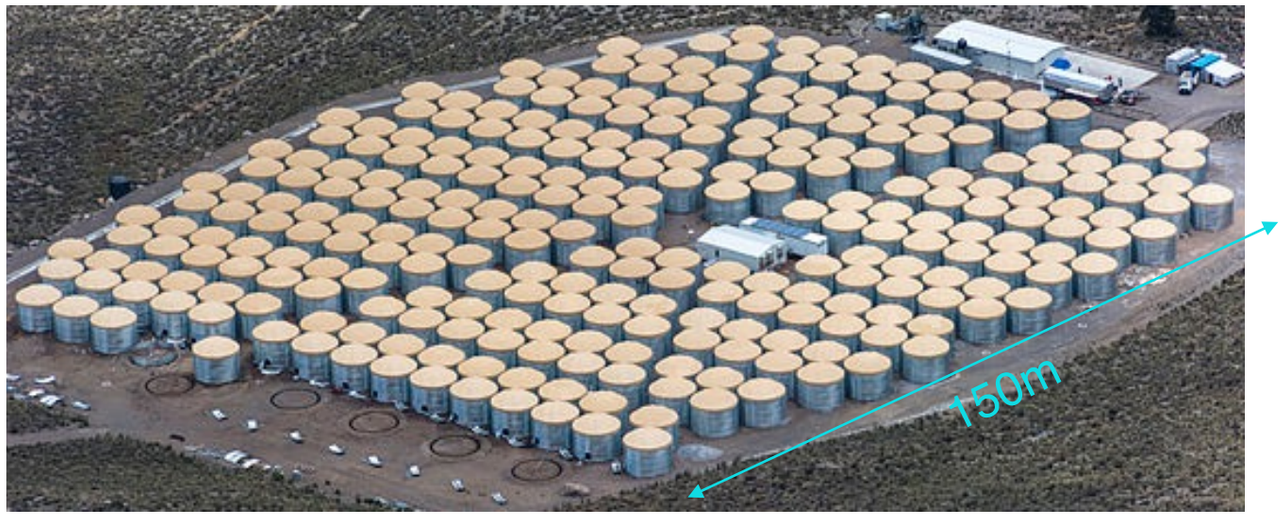
Water Cherenkov detectors (WCDs)

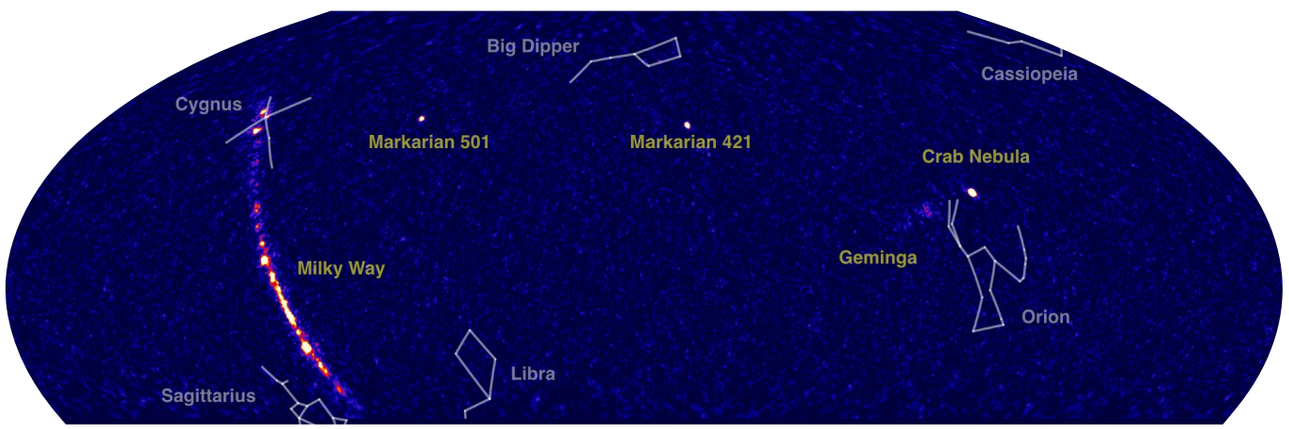
[FoV ~ 60^{o}, 100% duty cycle]

HAWC



- Northern Hemisphere (Mexico)
- Altitude 4.1 km a.s.l
- 300 WCD detectors
- Energy range ≳ 1 TeV

TeV sky from HAWC

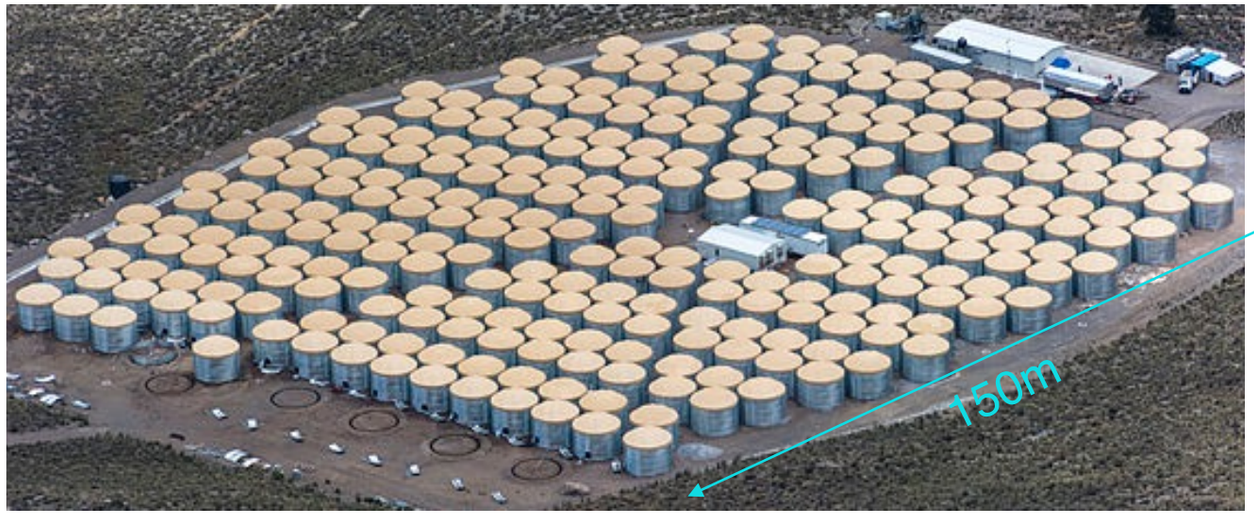


Credit: HAWC Collaboration

Water Cherenkov detectors (WCDs)

[FoV ~ 60º, 100% duty cycle]

HAWC



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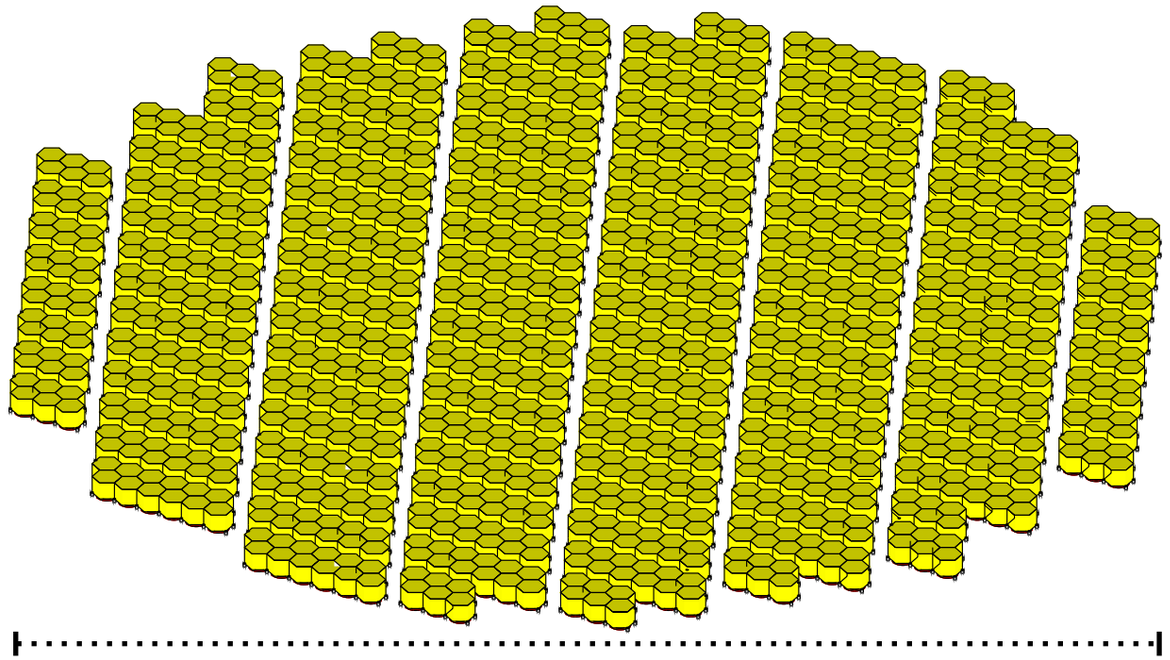
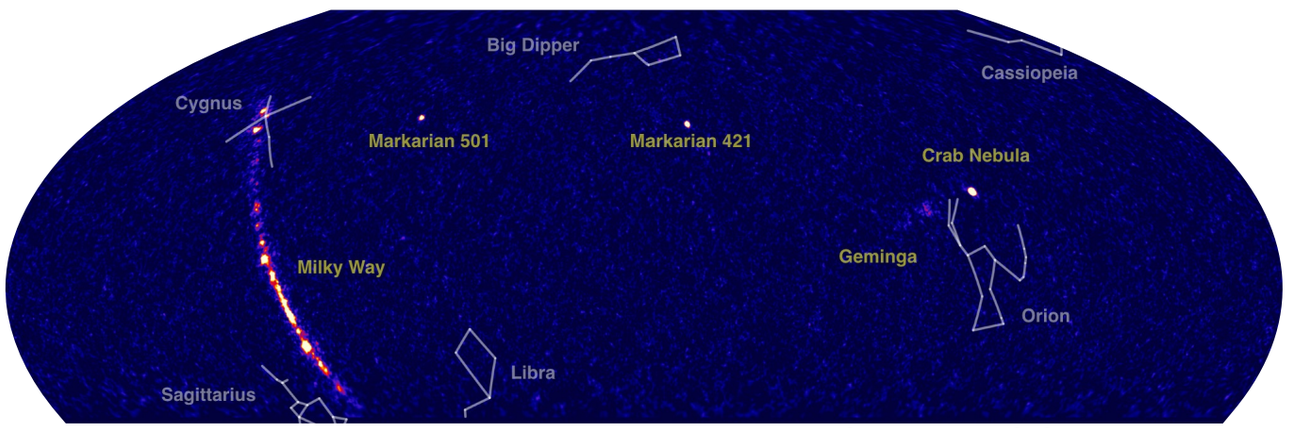
ALTO



- Southern Hemisphere (Chile/Argentina)
- Altitude 5.1 km a.s.l -> Lower threshold
- **Energy range ≳ 200 GeV**
- Sub-ns timing -> Better angular resolution
- 1242 small-sized WCDs } Better sensitivity
- **Scintillator detectors** }

TeV sky from HAWC

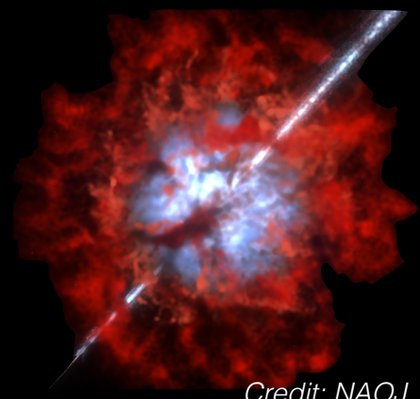


Credit: HAWC Collaboration

Science with ALTO

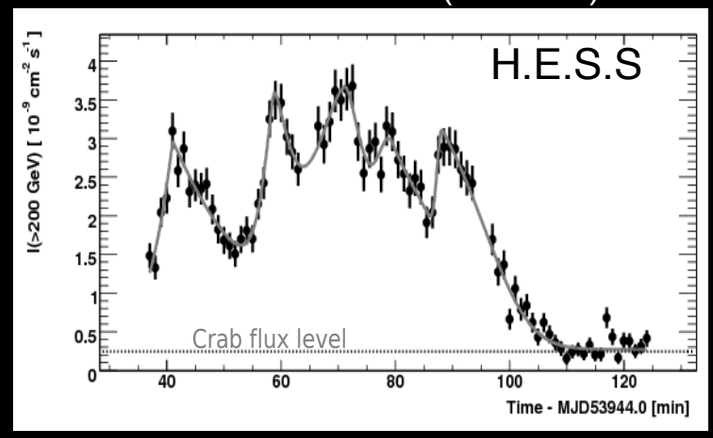
- **Transients & highly variable sources:**
  - Gamma-ray bursts
  - Fast radio bursts
  - Blazars
- **Extended sources:**
  - Active Galactic nuclei
  - Fermi bubbles
  - Galactic diffuse emission
- **High-energy end of spectrum**
- **PeVatrons (Galactic sources->10^{15} eV)**
- **Monitoring/Survey:**
  - Known gamma-ray sources
  - Galactic center region
- **Cosmic-ray measurement:**
  - Spectrum
  - Composition
  - Anisotropy
- **Complementary observations & alerts to other observatories like CTA**

GRB 020819B



Credit: NAOJ

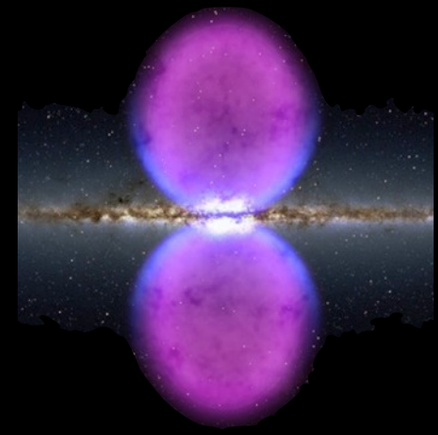
PKS 2155-304 (blazar)



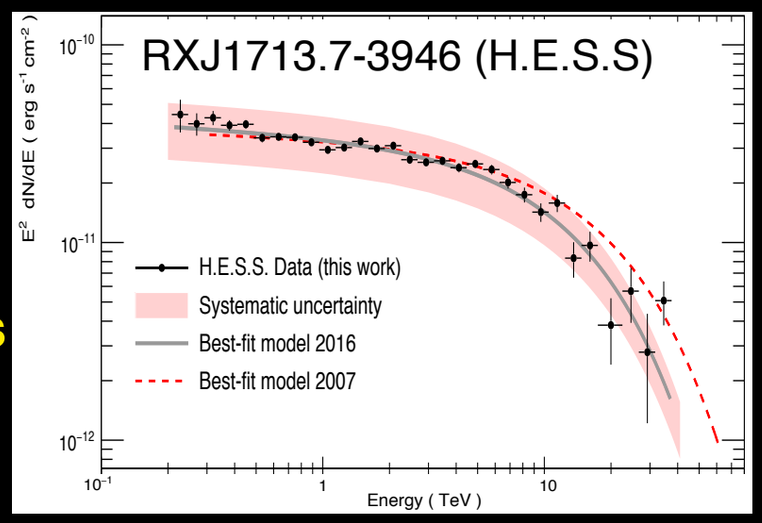
Centaurus A

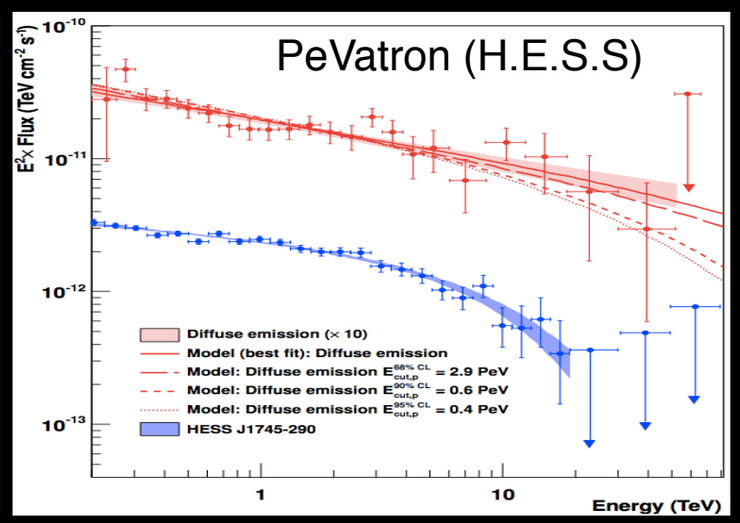
Credit: NASA/CXC/CfA

Fermi Bubbles



Credit: NASA GSFC





Astrophysical source

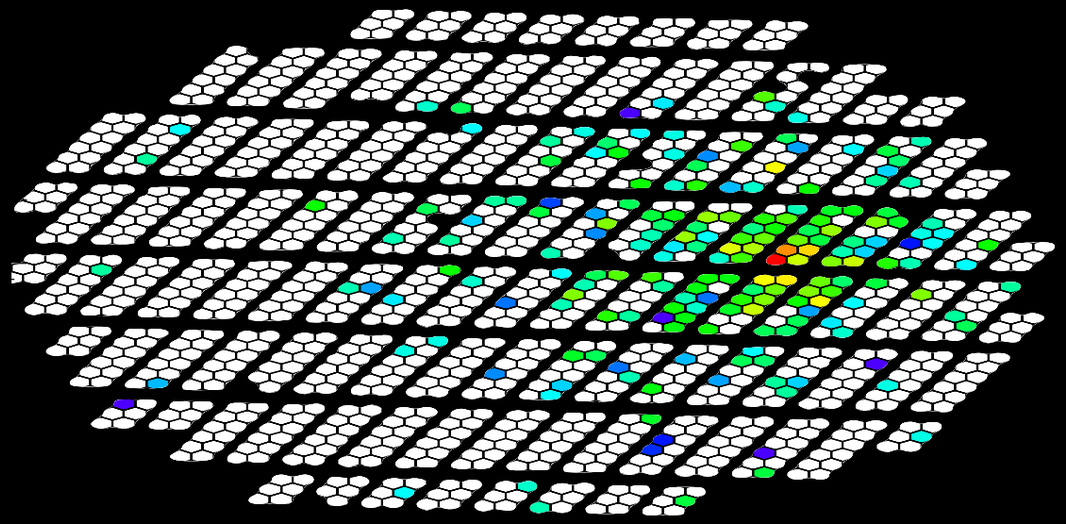
Cosmic ray (protons)

Gamma ray

e- e+ e- γ e+ γ e- γ e- e+ e+ γ

π+ π- π0 μ+ μ- γ γ μ+ e- e+ e-

Air shower

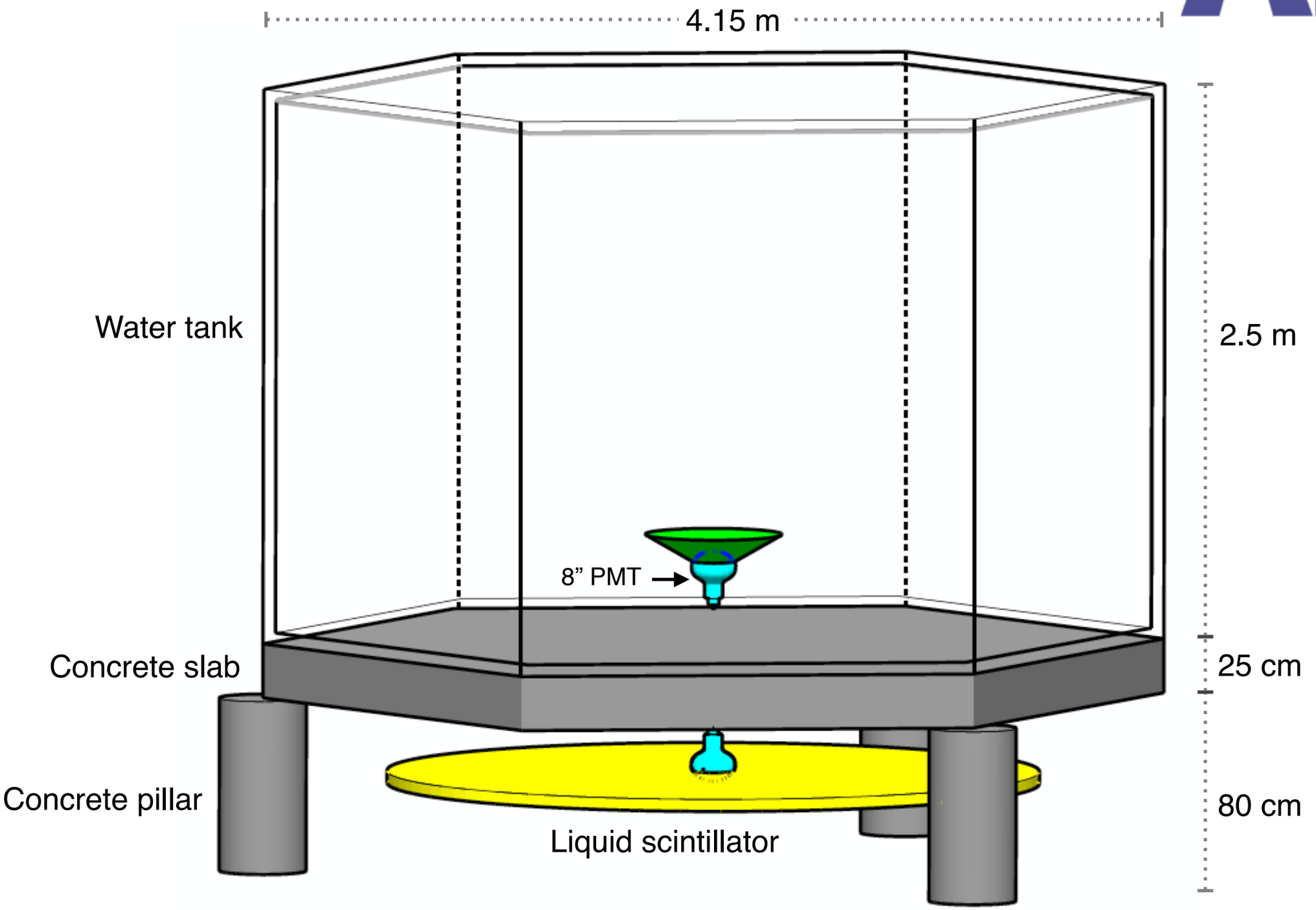


Detector array

Major challenge

- No. of gamma rays < 1% the cosmic-ray background
- Requires background rejection @ 99.9%

An ALTO detector unit



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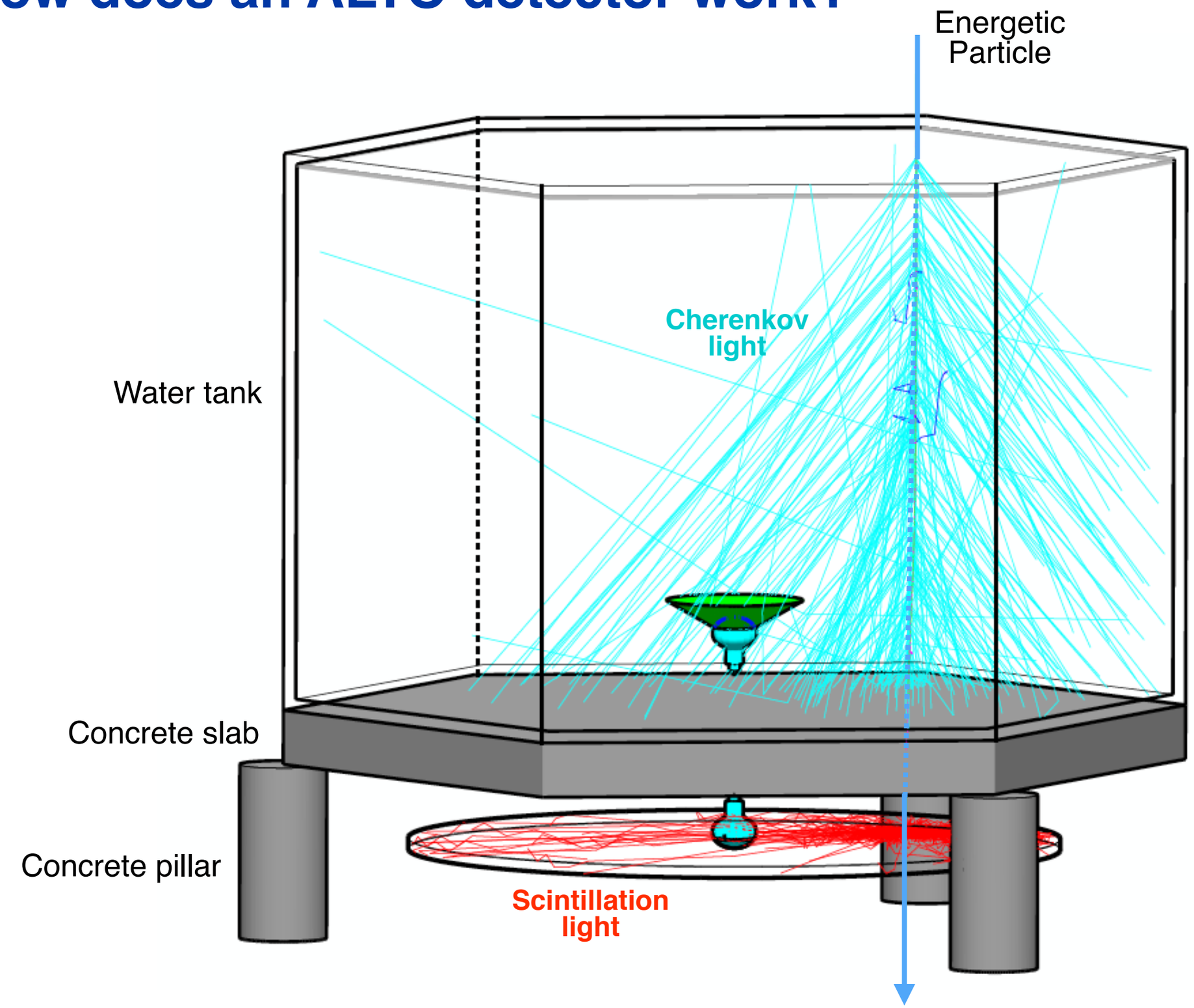
How does an ALTO detector work?



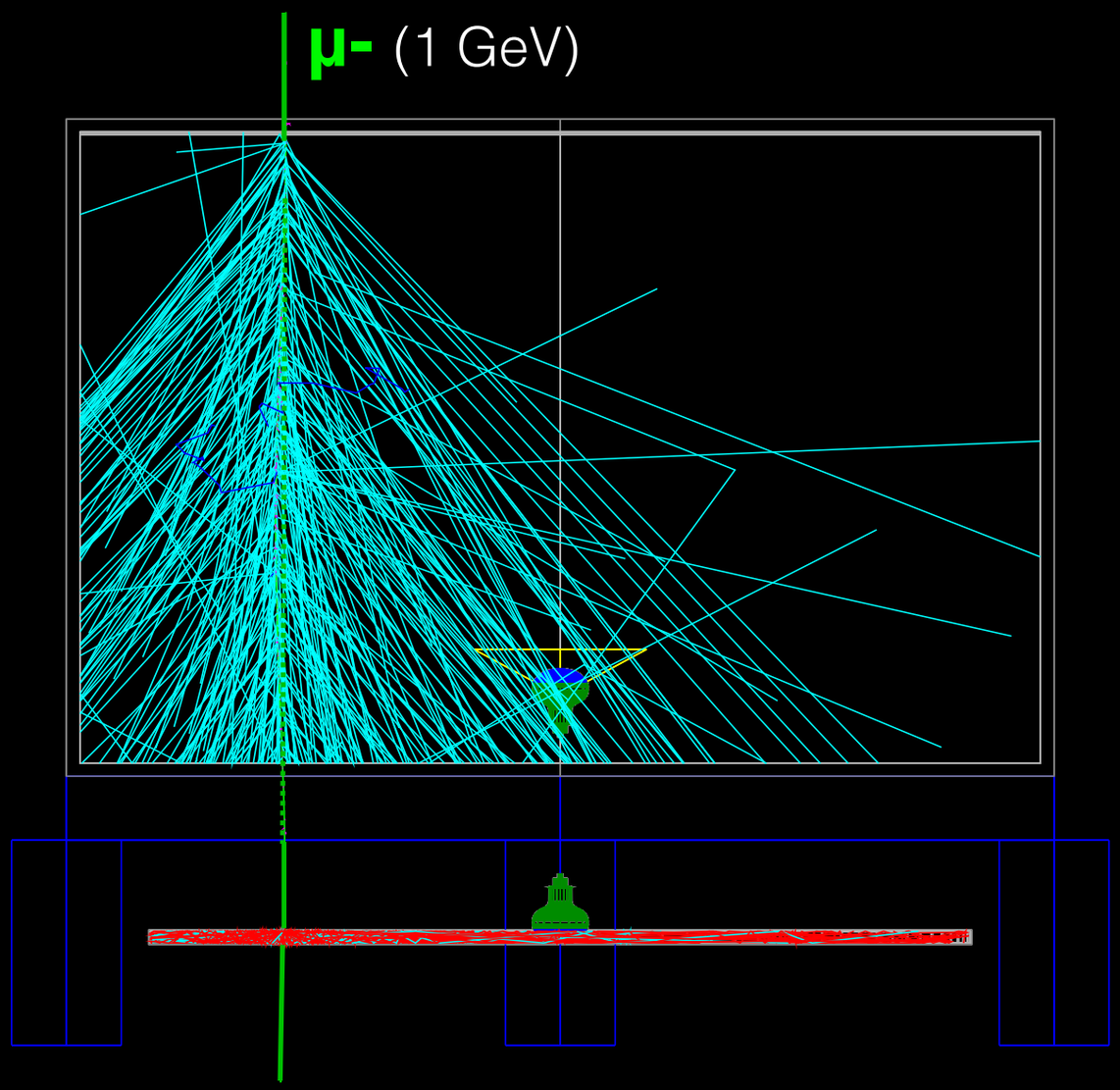
Air shower simulation: CORSIKA (version 7.4000)

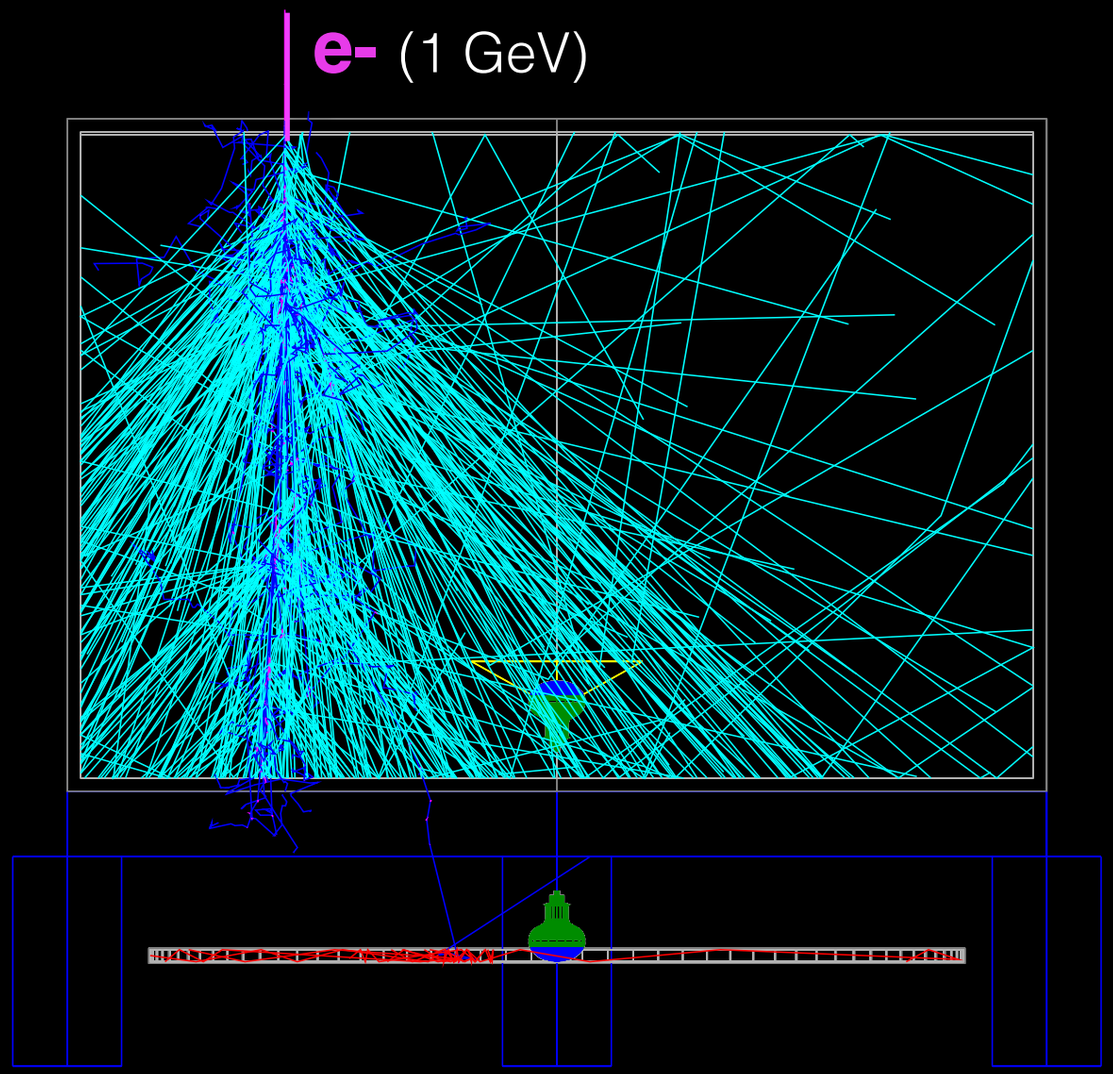
- Realistic model of Earth's atmosphere, magnetic field, refractive index, ….
- Electromagnetic and hadronic interactions based on particle physics models

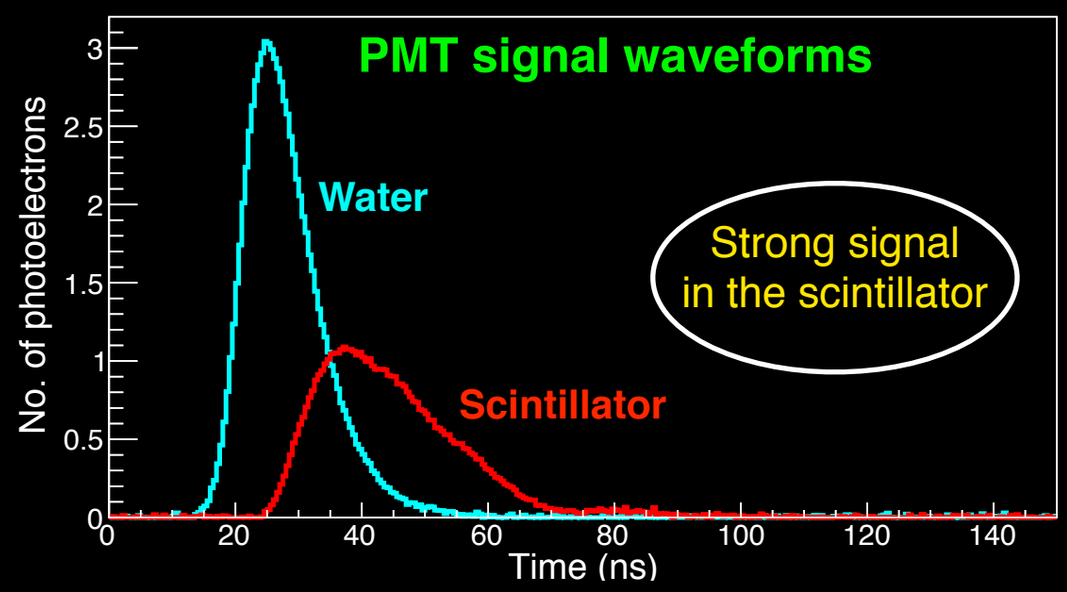
Detector simulation: GEANT4 (version 10.2)

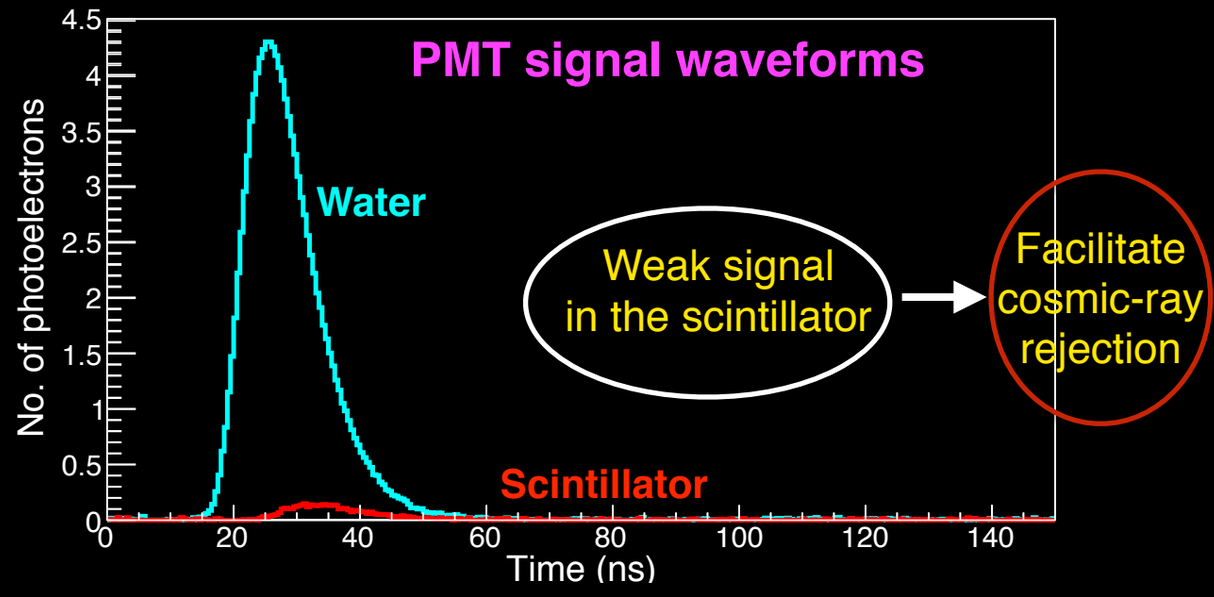
- All material properties are included
  - Density, refractive index as function of wavelength
  - Photon reflectivity, absorption and scattering coefficients as function of wavelength
- All important physical processes are included
  - Electro-magnetic processes:
    - γ's: Photoelectric effect, Compton scattering, Pair production, Rayleigh scattering
    - $e^{\pm}$, $\mu^{\pm}$, $\pi^{\pm}$, nuclei: Multiple scattering, ionisation, bremsstrahlung, annihilation (positrons)
    - Unstable particles: Decay
  - Optical processes:
    - Cherenkov and Scintillation photons production
    - Their emission spectrum, absorption, scattering …..
- Particle tracking
  - All particles are completely tracked by GEANT4 except for optical photons inside water tank
  - Optical photons (Cherenkov/Scintillation) are produced ~100,000 in each tank
  - For optical photons inside water tank:
    - Only those that would hit the PMT are allowed to track by GEANT4
  - For optical photons inside scintillator:
    - They are all tracked by GEANT4

Different detector response to different type of particle



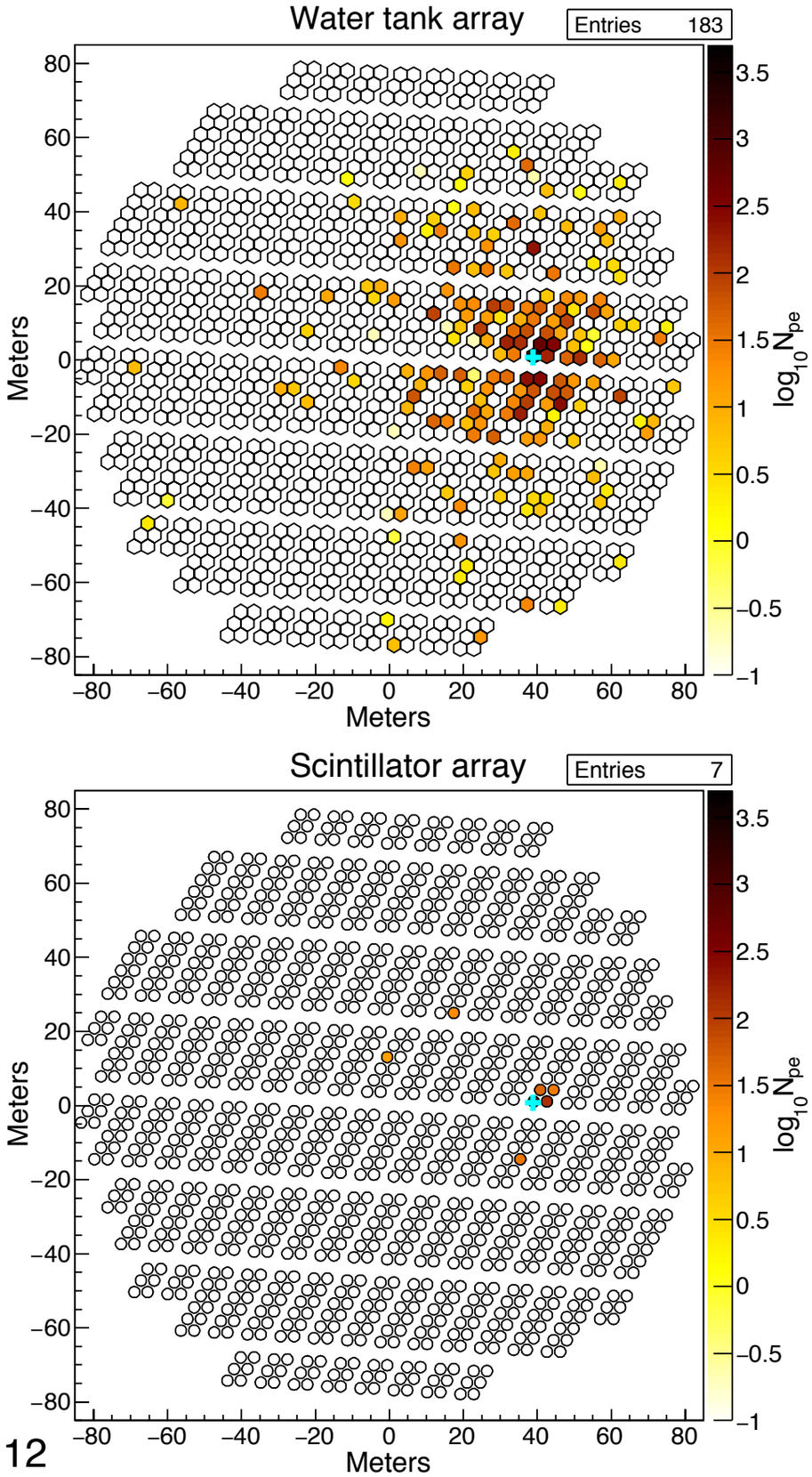




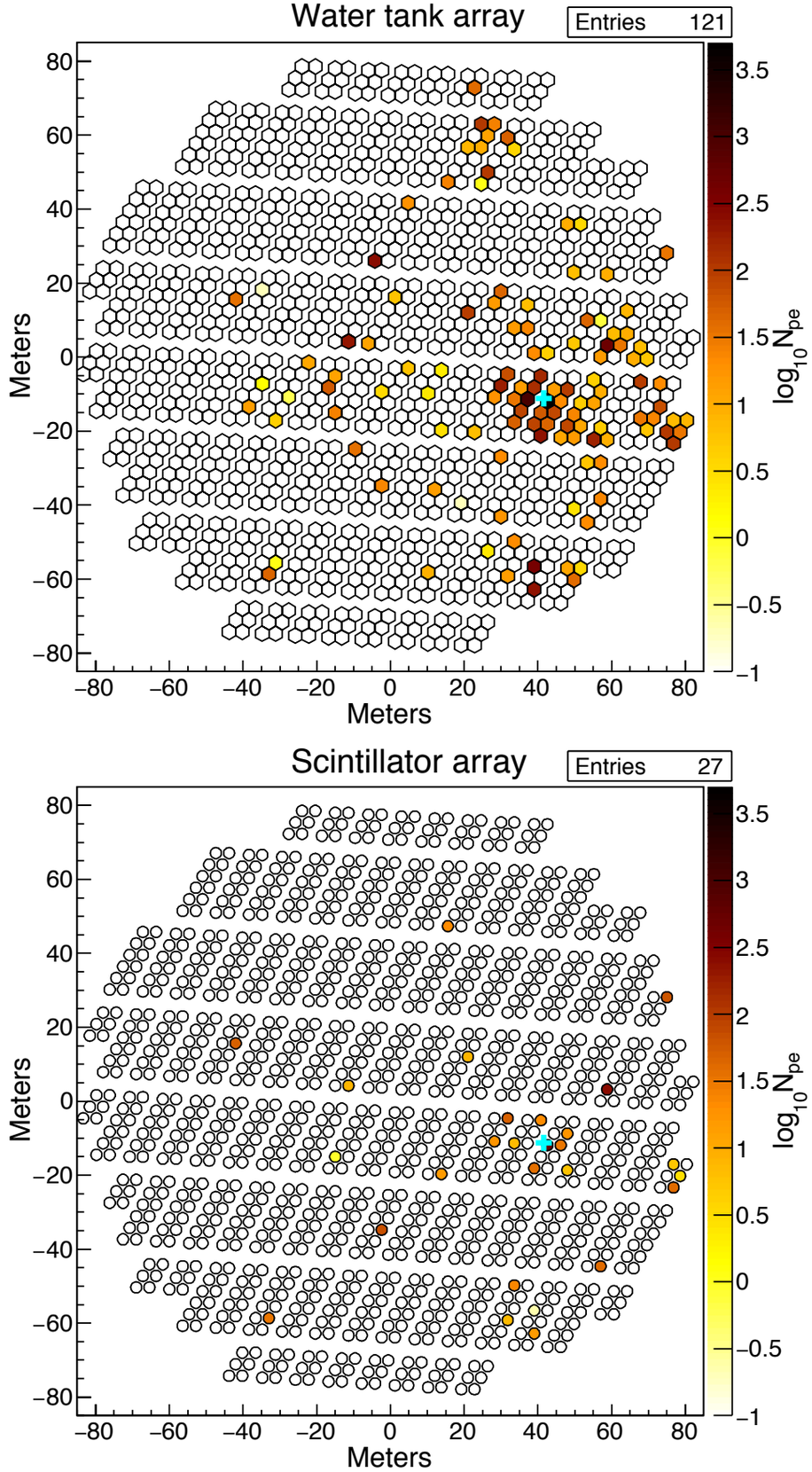


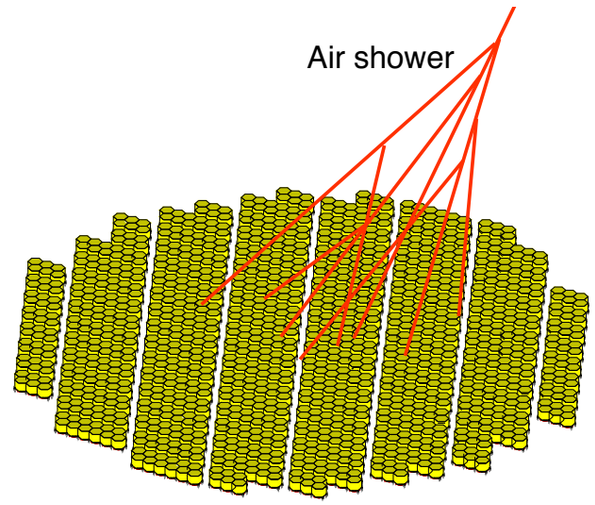
Simulated Air shower events of 1 TeV observed with ALTO

Gamma ray



Cosmic-ray proton





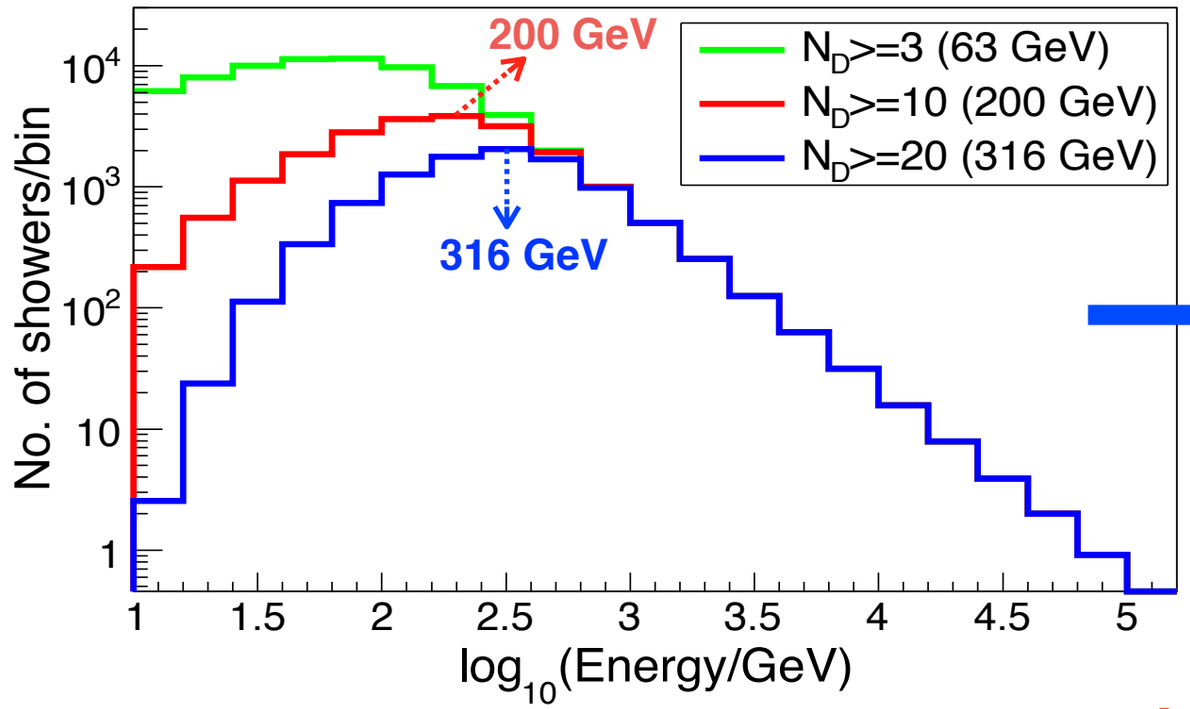
Gamma ray
-More compact
-Regular pattern

Cosmic ray
-Clumpy
-Hot spots in the scintillators at large distance from the core

Expected performance of ALTO:
Based on simulation results for gamma-ray showers

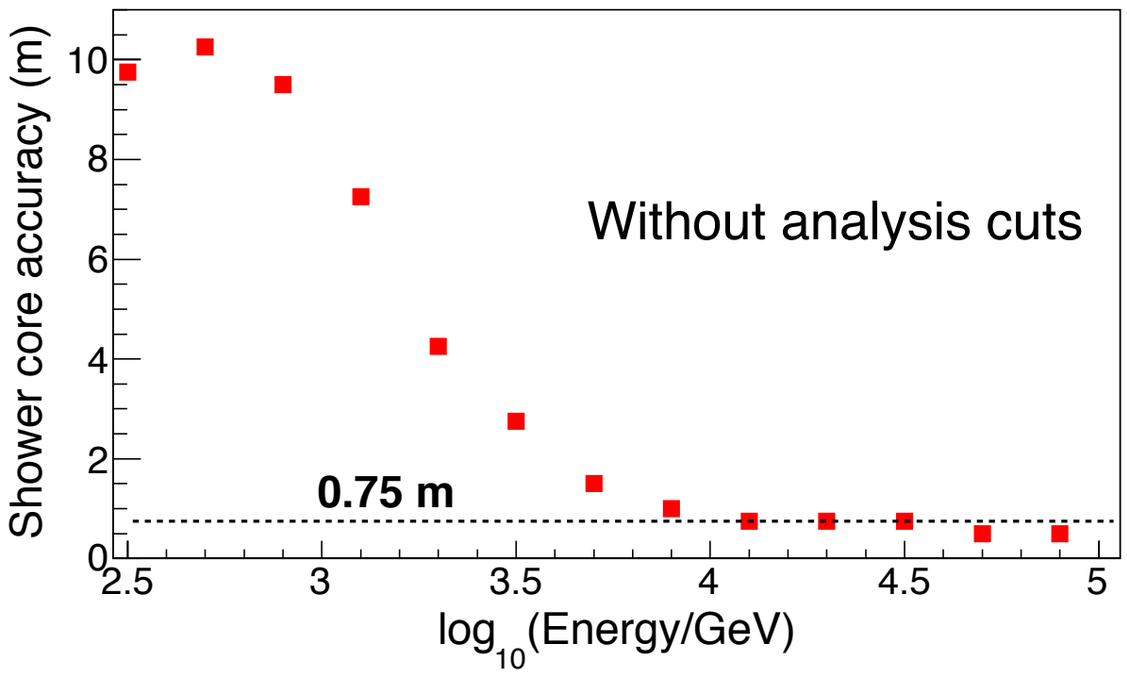
Slope=-2.5
Zenith=18°
True core<60 m

Energy distribution

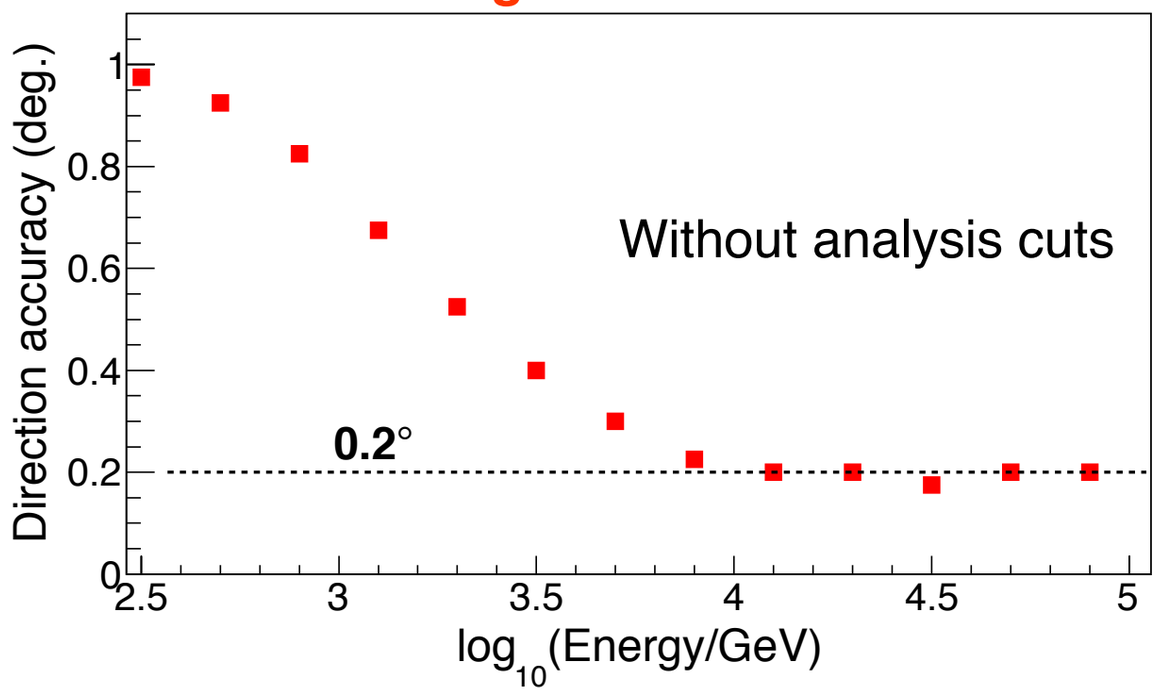


Energy threshold ~200 GeV

Shower core resolution



Angular resolution



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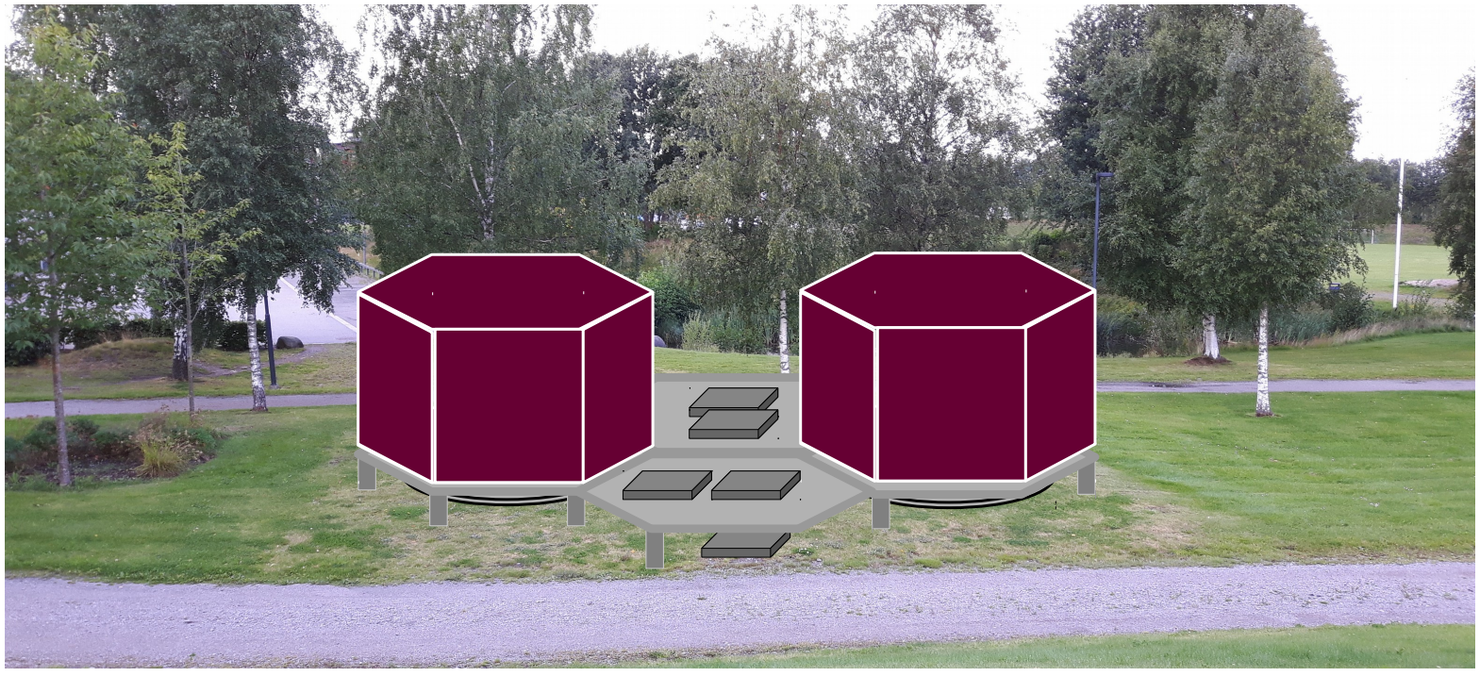
Current status

- Detector design: Finalised
- Measurement of optical properties of the tanks: Ongoing
- Measurement of PMT light response: Ongoing
- Signal/background discrimination study: Ongoing
- Prototype construction in LnU campus
    - Preparations almost ready



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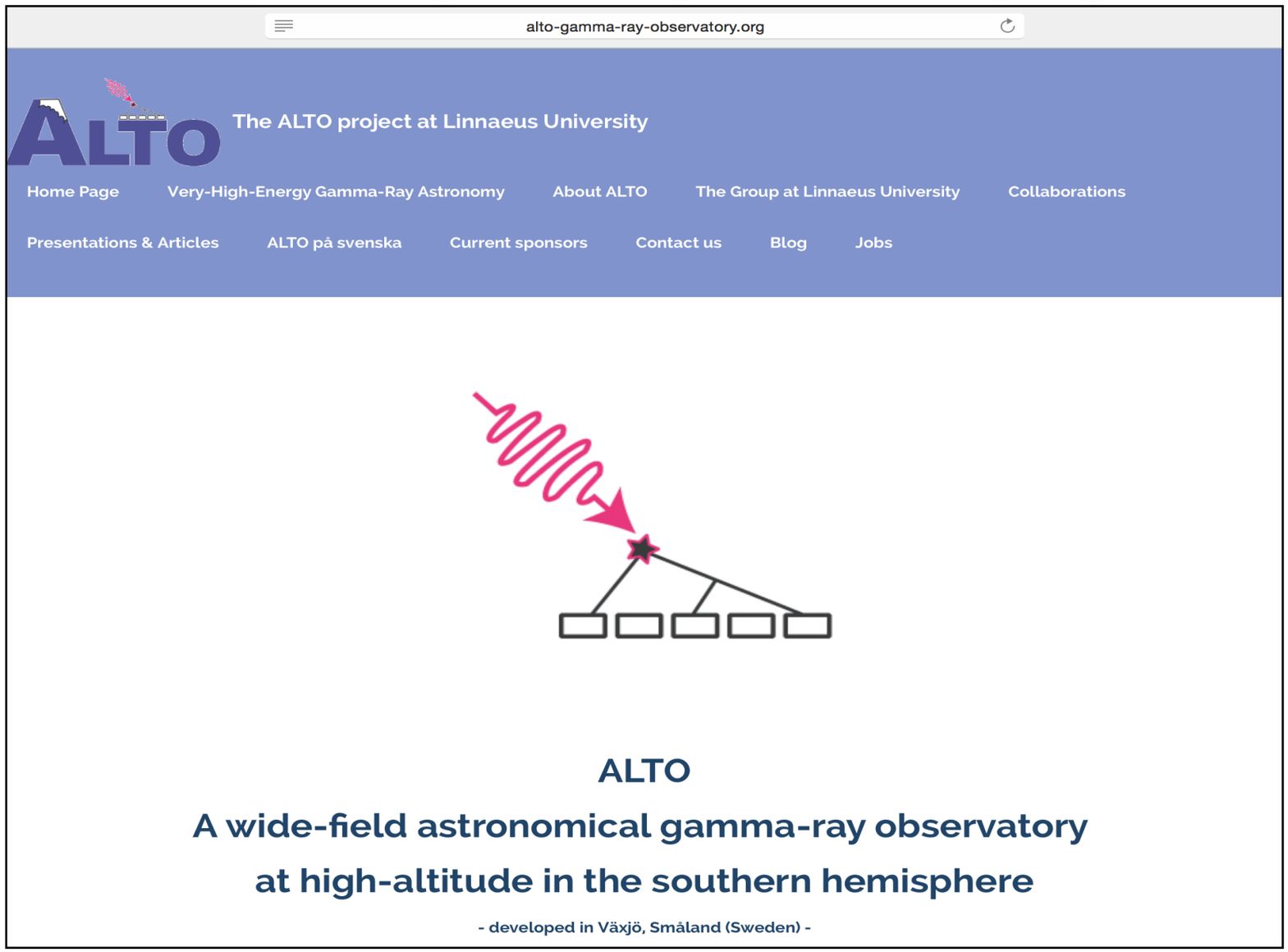

Thank you for your attention !