High Energy Stereoscopic System (H.E.S.S.)
Status and recent results

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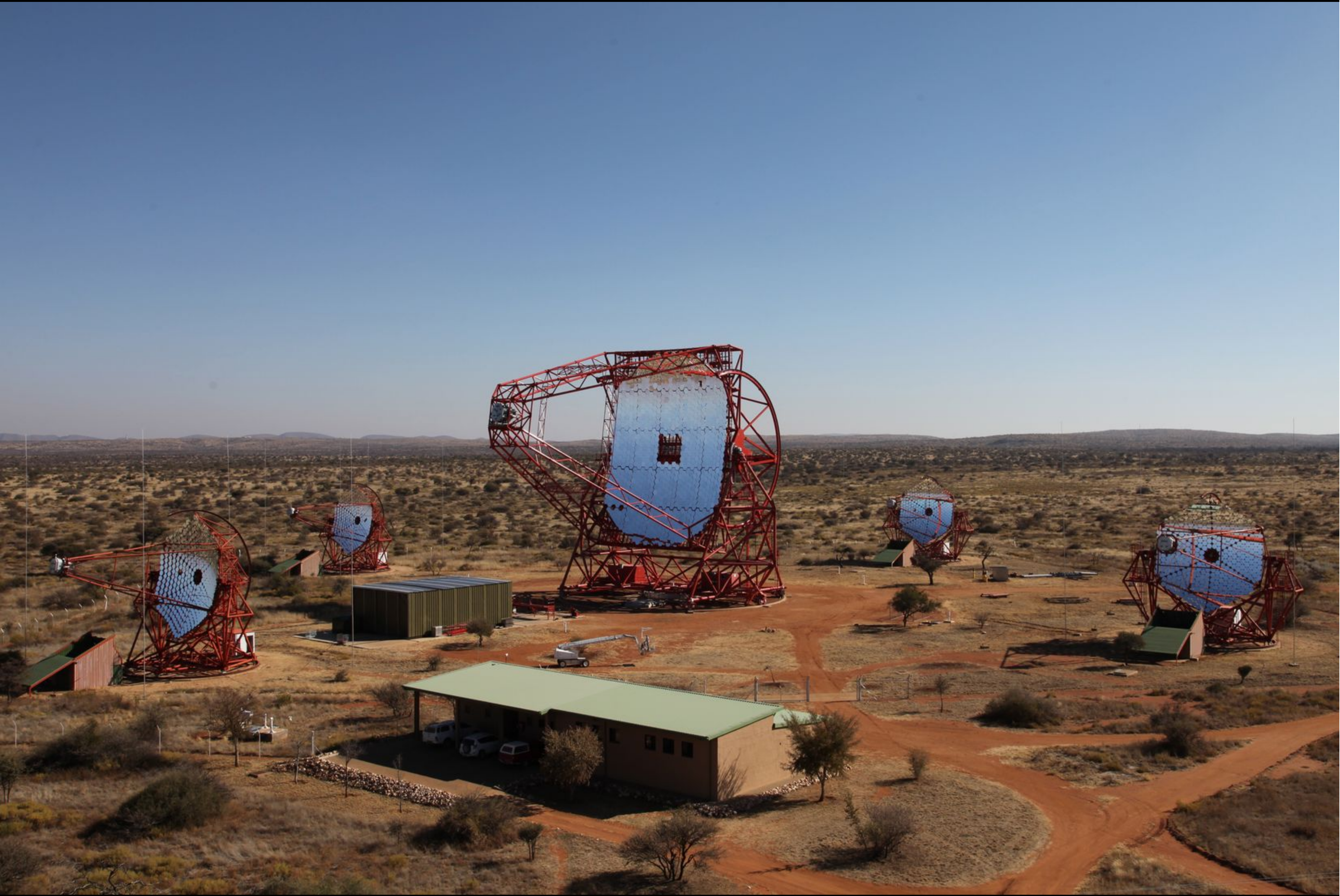
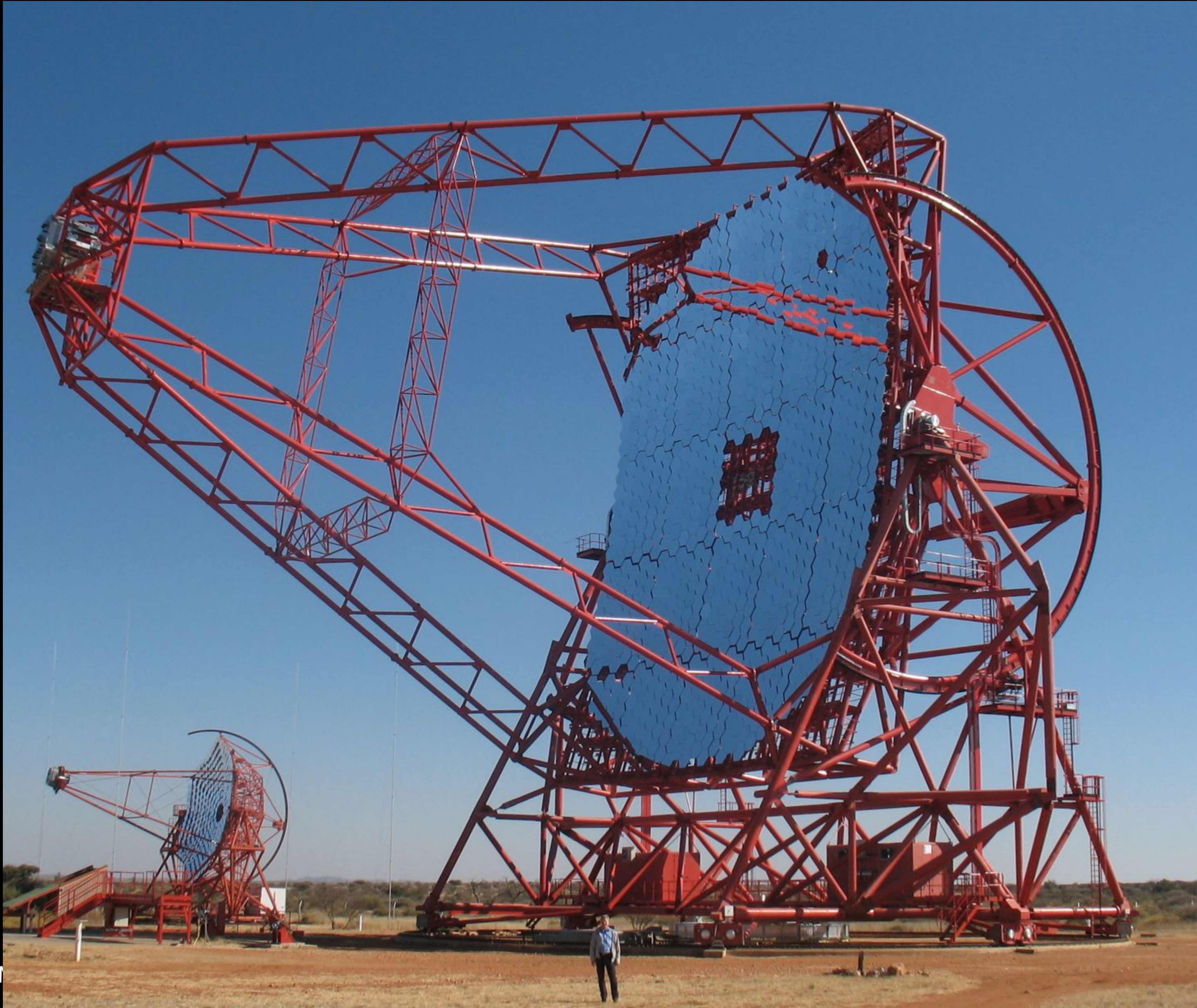
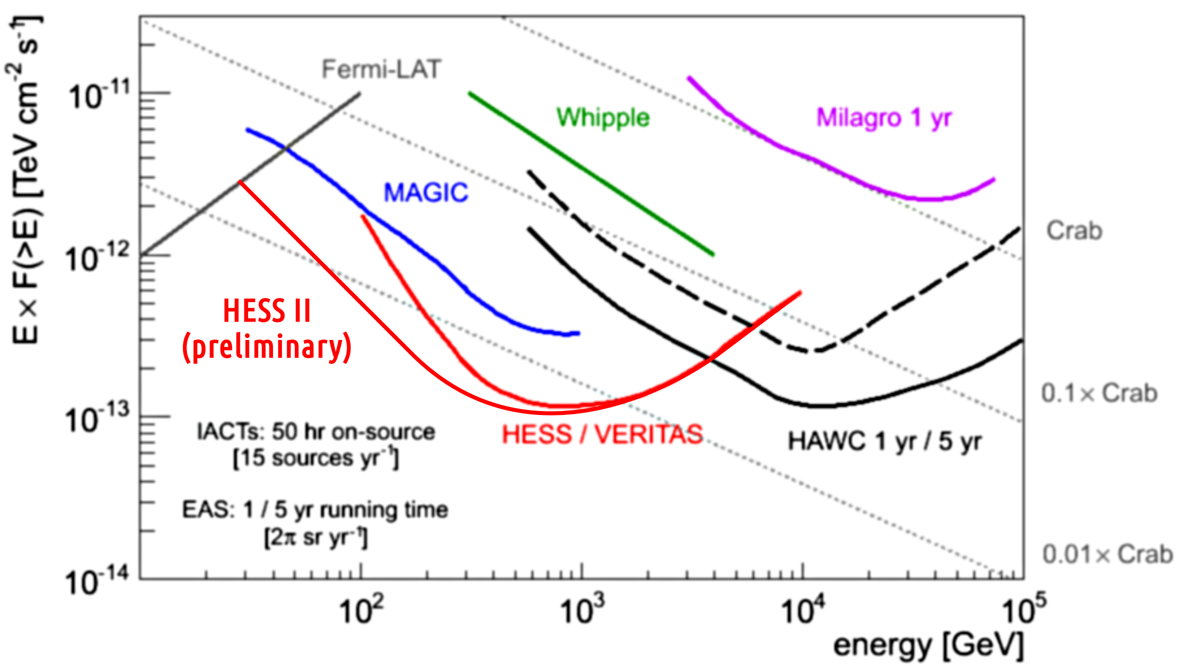




H.E.S.S. - basic data

– **High Energy Stereoscopic System**;
– **five telescopes** 120 m x 120 m area;
– **4x13 m diameter** spherical main mirror f=13 m, 362 circular mirror facets 60 cm diameter, 4 x 107m^2 collecting area, camera: 960 vacuum tube photo-multipliers, field of view ~5°; 1ns sampling;
– **1x28 m diameter** parabolic mirror f=36 m, 614 m^2 area, 875 hexagonal mirror facets 90 cm (flat-to-flat), camera: 2048 photo-multipliers, 1 ns sampling, field of view ~3.2°, 2.8 t
– duty cycle ~1000h/yr (moonless nights required);
– **energy range: ~20GeV – 10TeV**
– **resolution: angular – 0.1°, energetic – 15% @ 1TeV**
– **sensitivity: 1% Crab (5σ, 25h)**



HESS Collaboration

>12 countries, >30 scientific institutions, >100 scientists

Max-Planck-Institut für Kernphysik, Heidelberg, Germany
Humboldt Universität Berlin, Germany, Institut für Physik
Ruhr-Universität Bochum, Germany, Fakultät für Physik und Astronomie
Universität Erlangen-Nürnberg, Germany, Physikalisches Institut
Universität Hamburg, Germany, II. Institut für Experimentalphysik
Landessternwarte Heidelberg, Germany
Universität Tübingen, Germany, Institut für Astronomie und Astrophysik (IAAT)
Laboratoire Leprince-Ringuet (LLR), Ecole Polytechnique, Palaiseau, France
LPNHE, Universités Paris VI - VII, France,
APC, Paris, France
CEA Saclay, France
Observatoire de Paris-Meudon, DAEC, France
LAPP Annecy, France
Université de Grenoble, France
LPTA, Université Montpellier II, France
CERS, Toulouse, France
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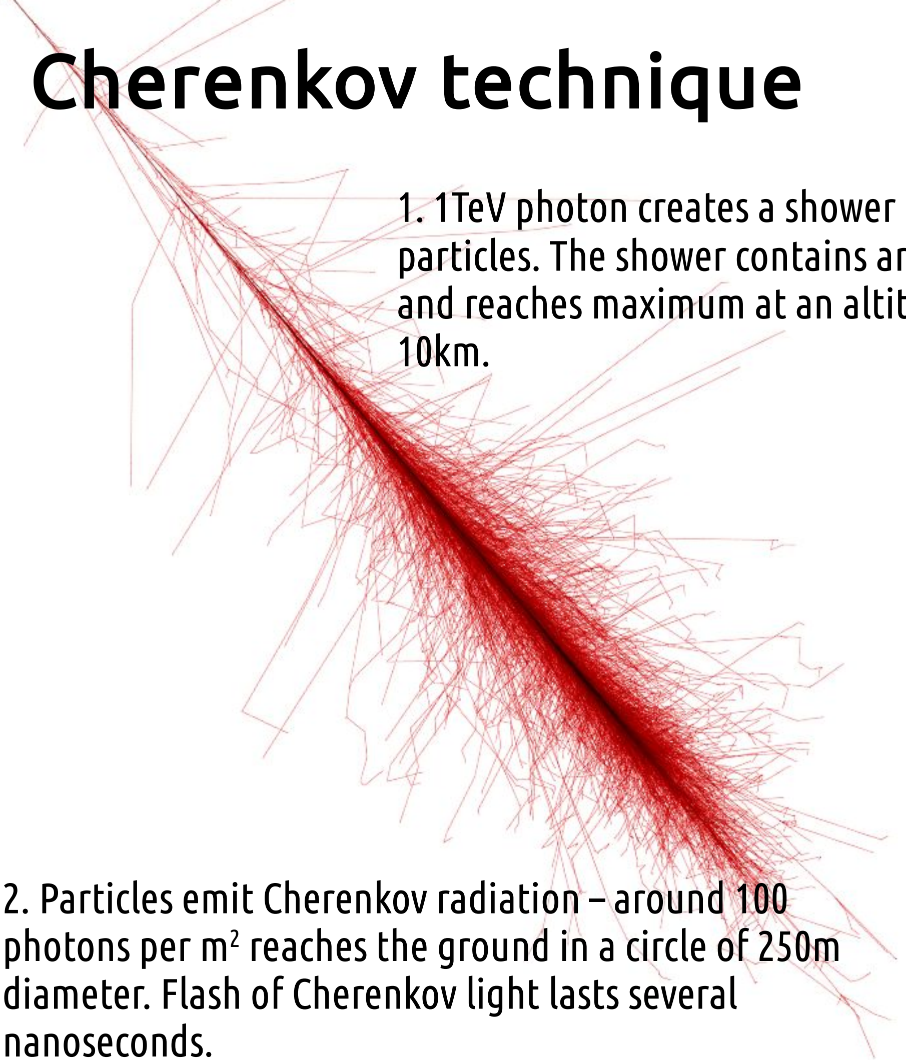
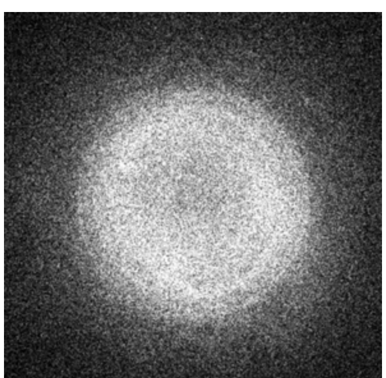
Charles University, Prag, Czech Republic, Nuclear Center
Yerevan Physics Institute, Yerevan, Armenia
University of Adelaide, Australia, School of Chemistry and Physics
University of Namibia, Windhoek, Namibia
North West University, Republic of South Africa

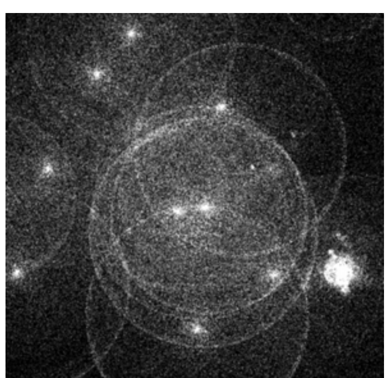
Cherenkov technique

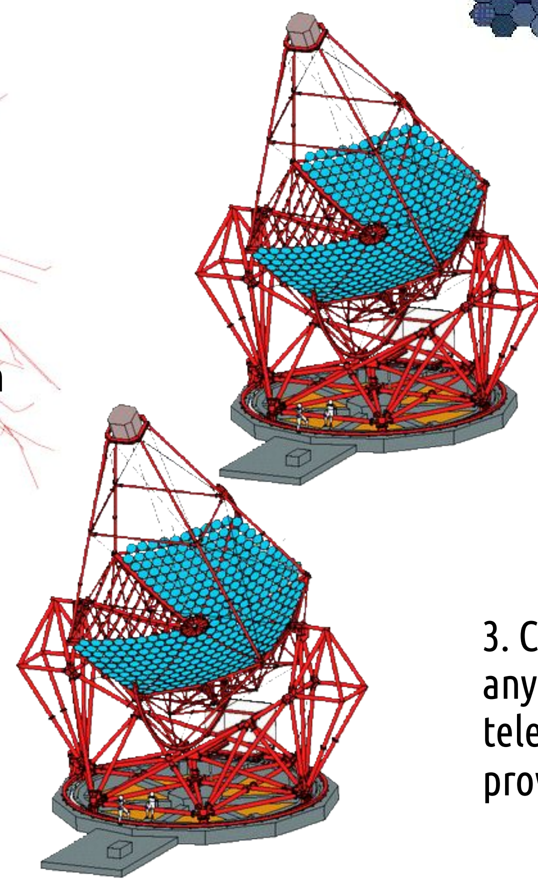


1. 1TeV photon creates a shower of secondary particles. The shower contains around 10^5 e^+e^- pairs and reaches maximum at an altitude of around 10km.

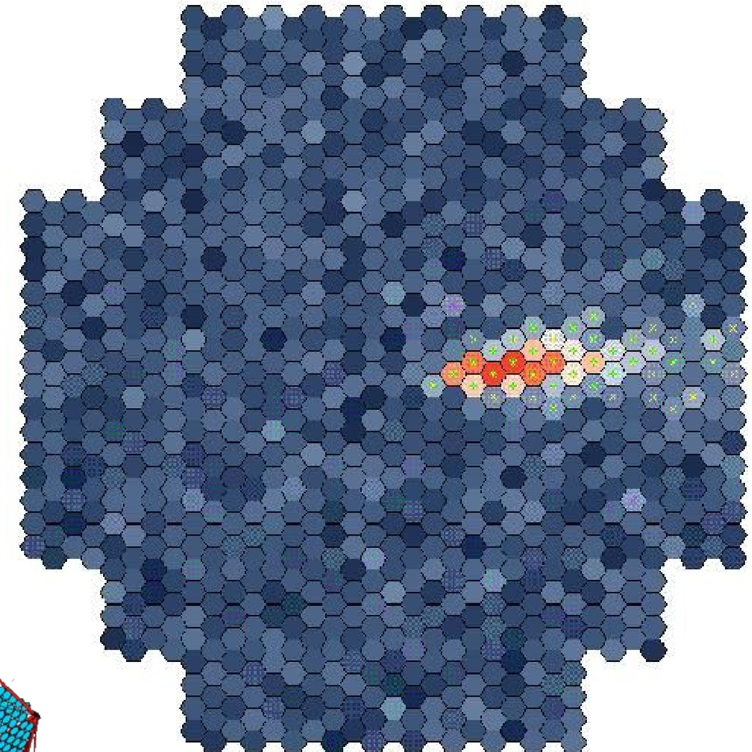
2. Particles emit Cherenkov radiation – around 100 photons per m^2 reaches the ground in a circle of 250m diameter. Flash of Cherenkov light lasts several nanoseconds.







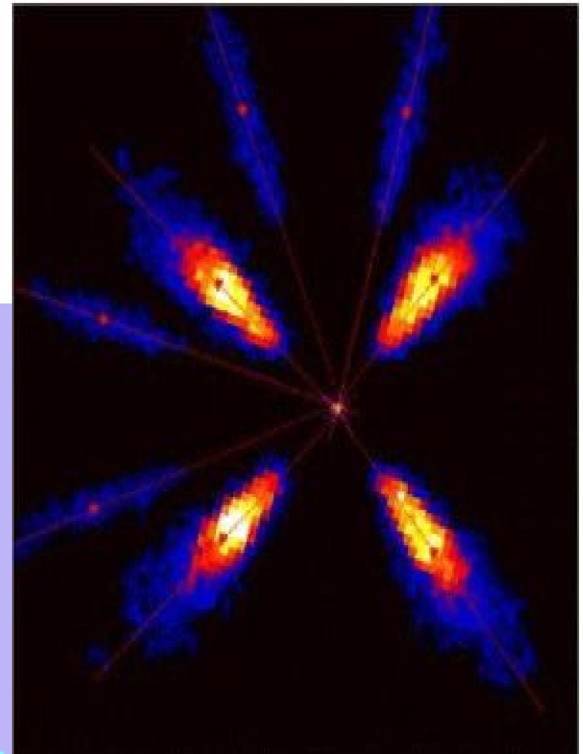
3. Cherenkov photons can be registered anywhere within the cone by an optical telescope (if enough sensitive) – this provides an effective area of **50000 m^2**

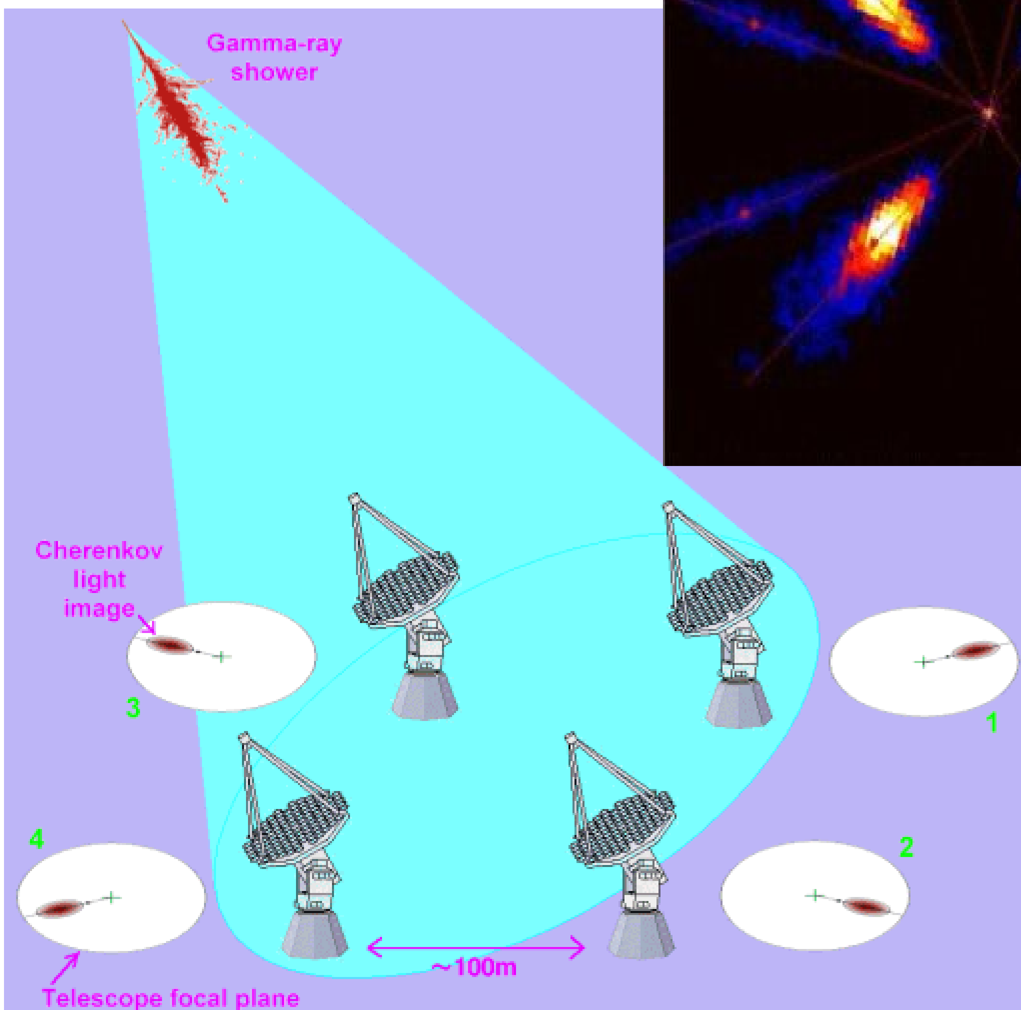


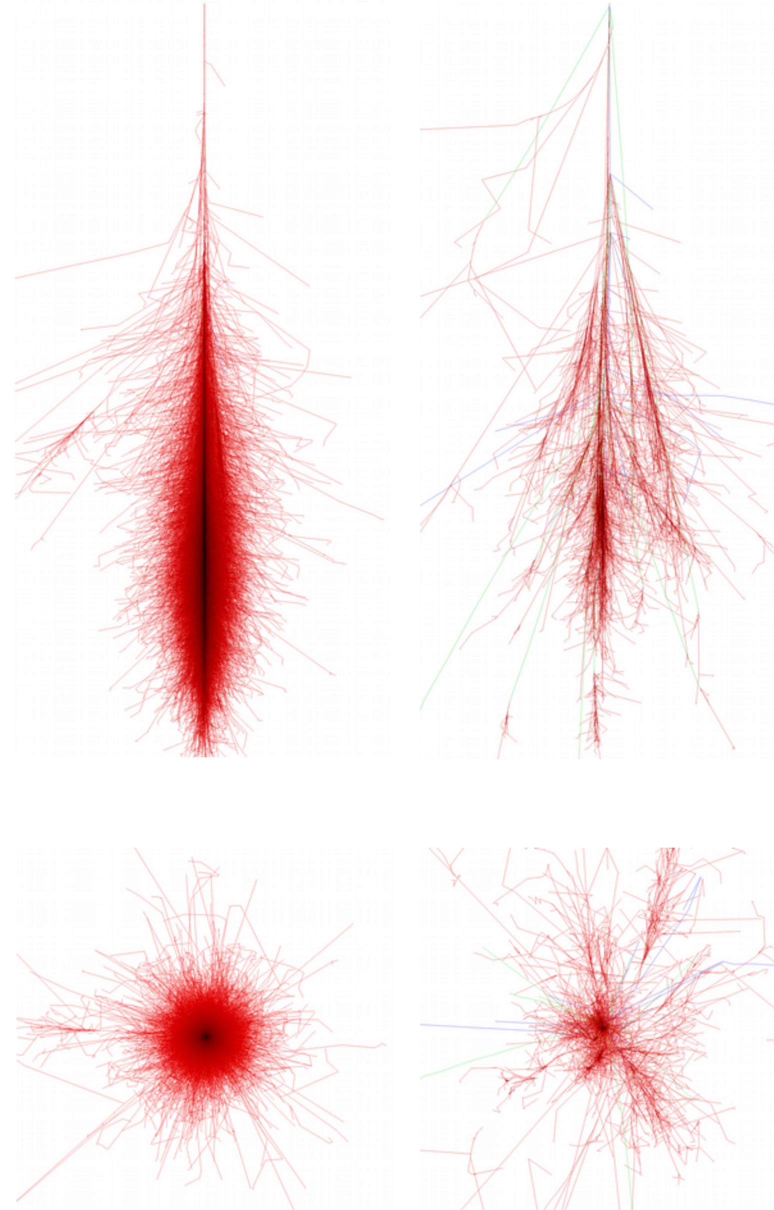
4. Image of the air shower is captured by the camera.

Cherenkov technique - stereoscopy

Use of several telescopes allows for better direction reconstruction, energy estimation, and gamma-hadron separation







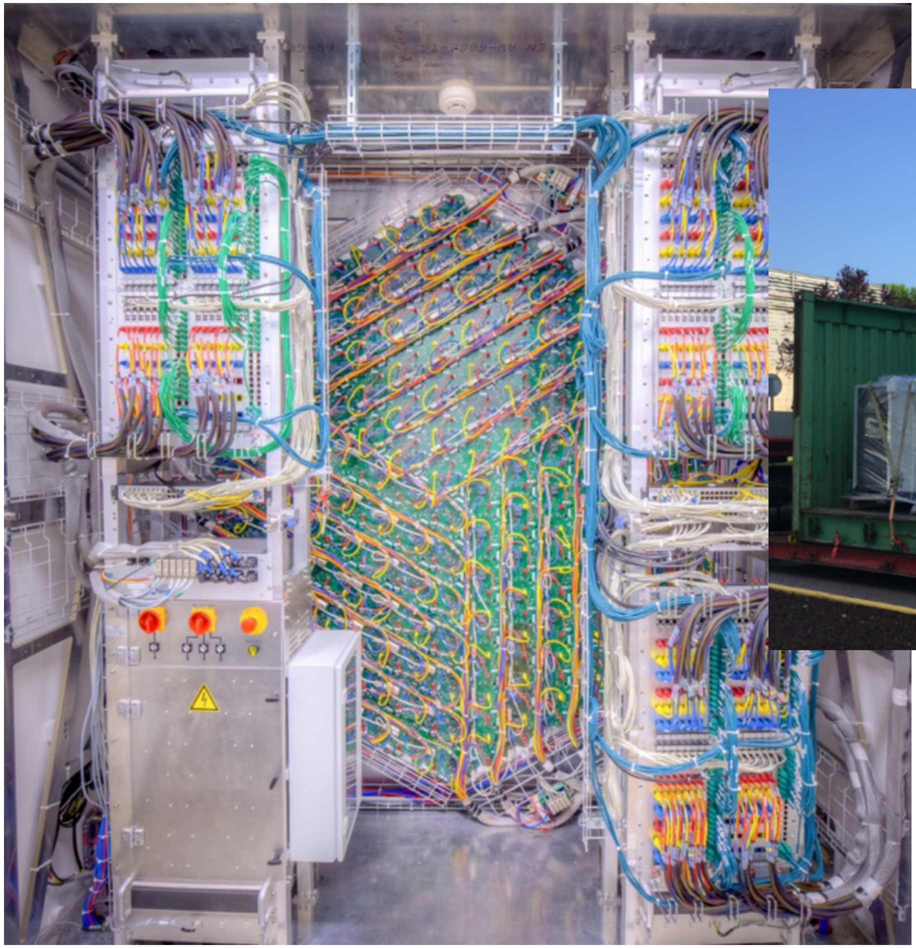
1 TeV gamma-ray induced shower

1 TeV proton induced shower

Hardware upgrades

– all CT1-CT4 cameras upgraded in 2017 to CT1U-CT4U: new electronics (NeCTAr chip), new light collectors, new ventilation system

– CT5U upgrade in Oct 2019 – completely new camera based on FlashCAM, called NamCam



H.E.S.S. as a pathfinder project for CTA

Particle Astrophysics research

Galactic sources:

- supernova remnants (SNRs),
- pulsars and pulsar wind nebulae (PWNs),
- star clusters,
- Galactic centre,
- X-ray binaries (XRBs) and microquasars.

Extragalactic sources:

- active galactic nuclei (AGNs),
- dwarf galaxies (DSs),
- extragalactic background light (EBL),
- gamma-ray bursts (GRBs),
- clusters of galaxies.

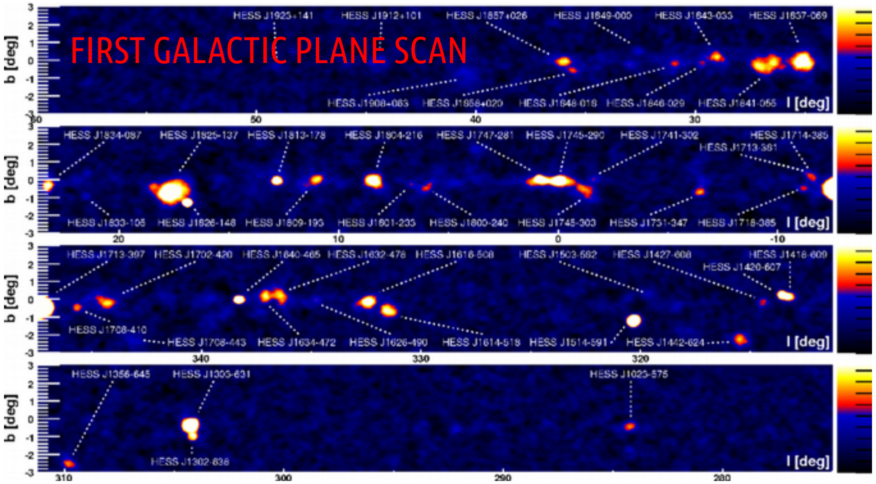
Fundamental physics:

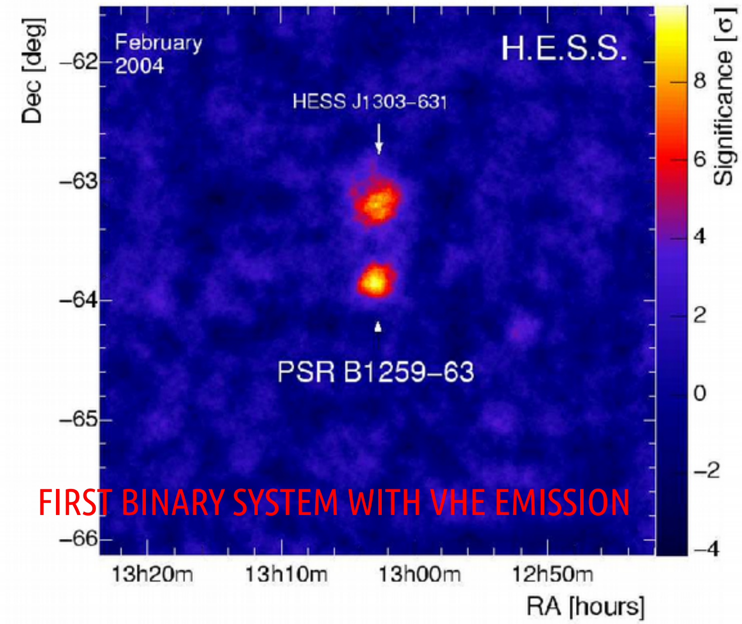
- dark matter (DM),
- Lorentz invariance violation (LIV),
- cosmic-rays (CR).

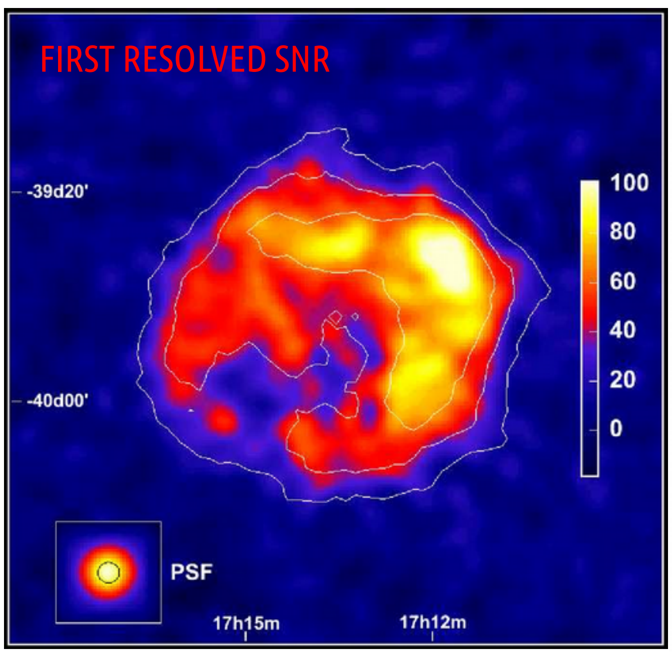
Physical processes:

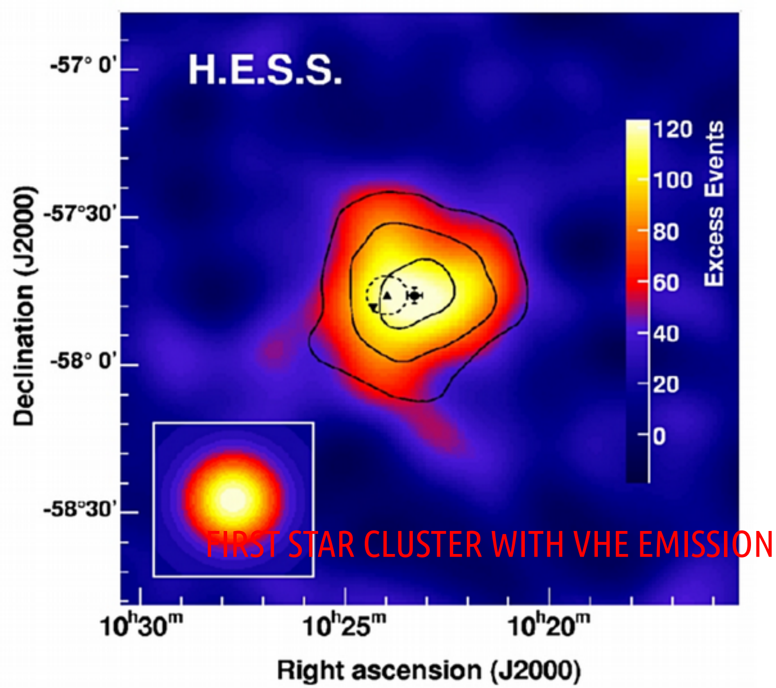
- particle acceleration to the highest energies,
- particle and radiation propagation in the intergalactic medium,
- structure of the magnetic field at different scales,
- radiation production mechanisms at high energy.

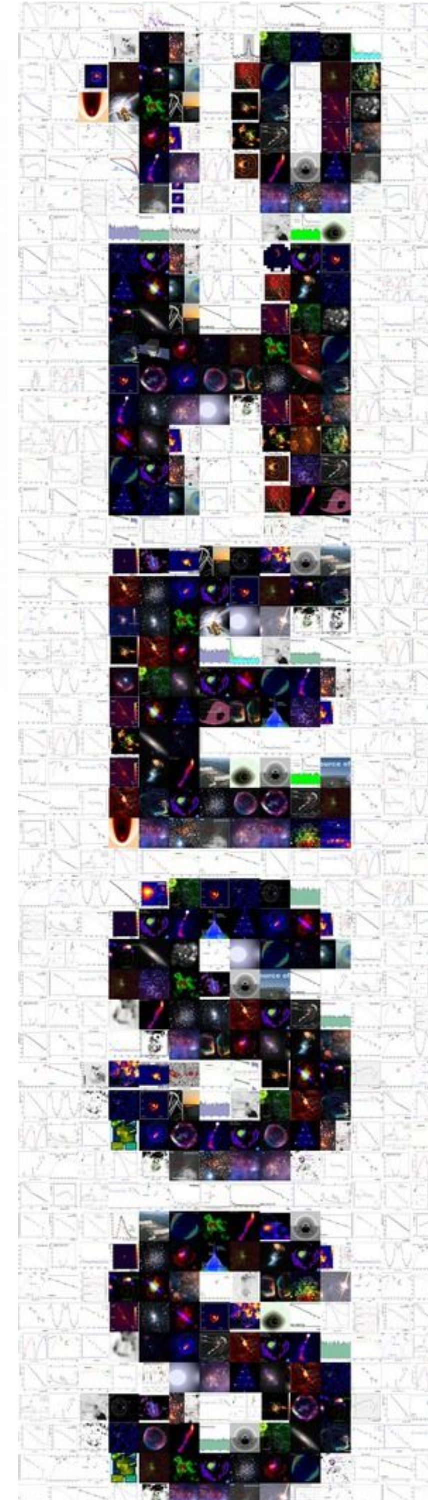
H.E.S.S. - some results





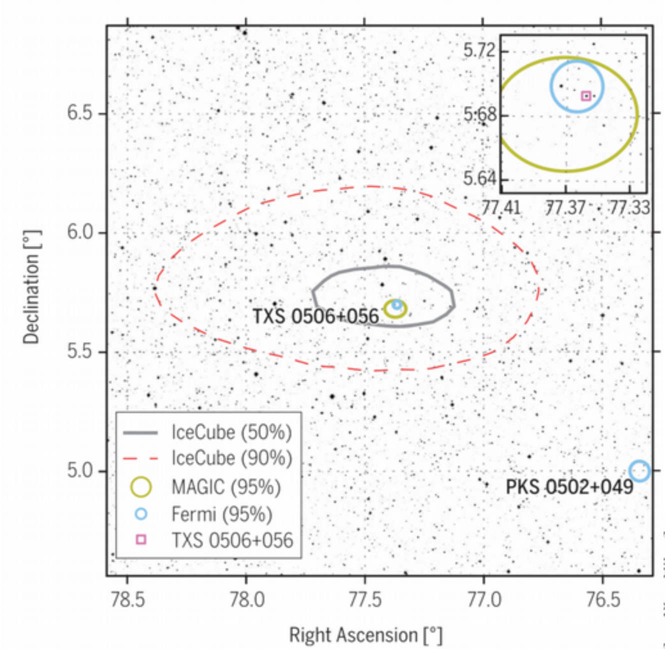




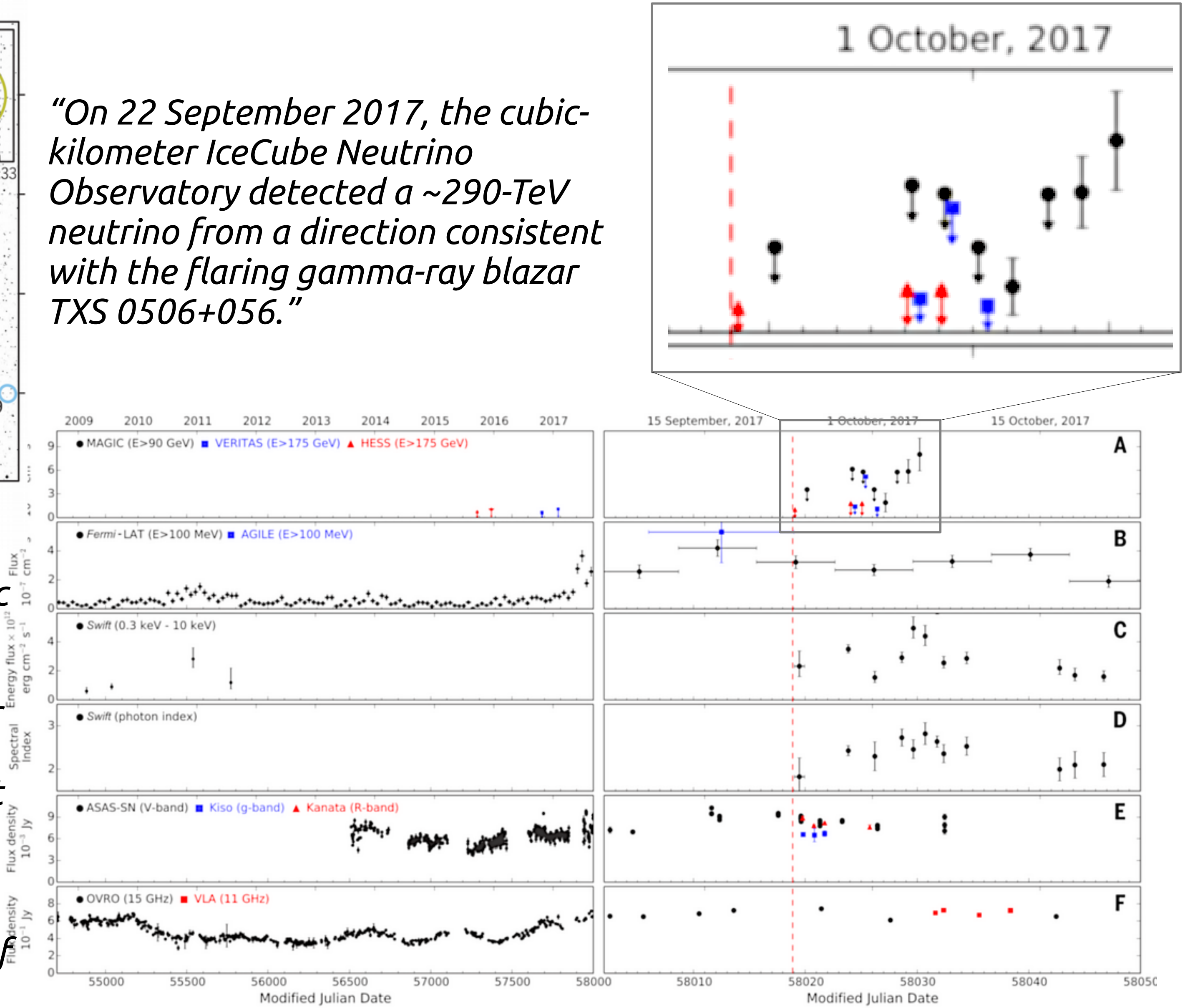


Multimessenger observations – IceCube-170922A

*IceCube Collaboration et al. , Science **361**, eaat1378 (2018)*



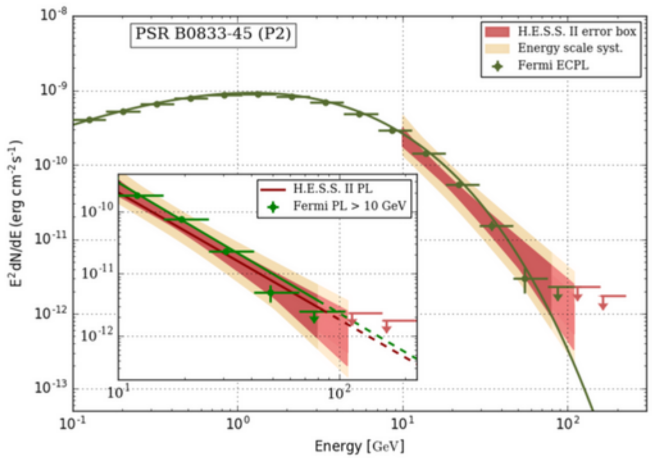
"On 22 September 2017, the cubic-kilometer IceCube Neutrino Observatory detected a ~290-TeV neutrino from a direction consistent with the flaring gamma-ray blazar TXS 0506+056."

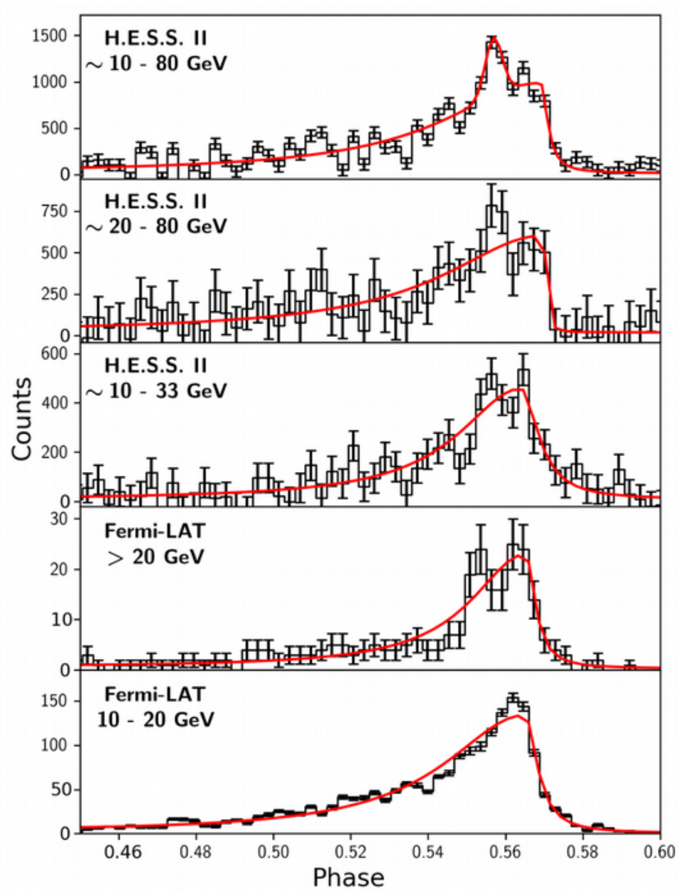


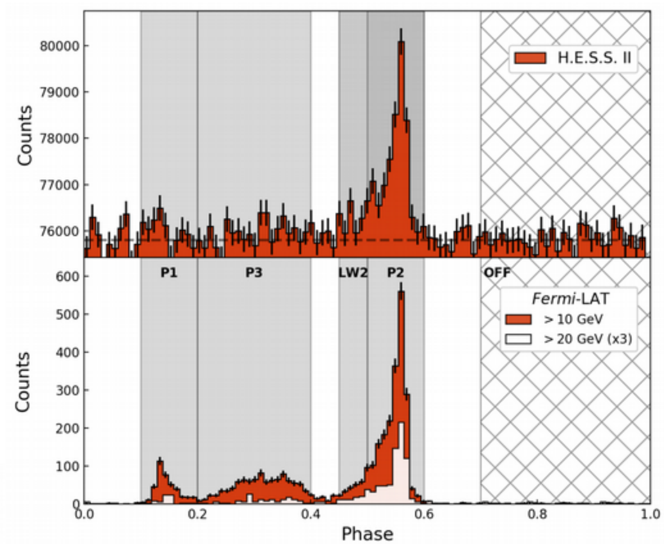
– blazar jets may accelerate cosmic rays to at least several PeV
– the observed association of a high-energy neutrino with a blazar during a period of enhanced gamma-ray emission suggests that blazars may indeed be one of the long-sought sources of very-high-energy cosmic rays, and hence responsible for a sizable fraction of the cosmic neutrino flux observed by IceCube

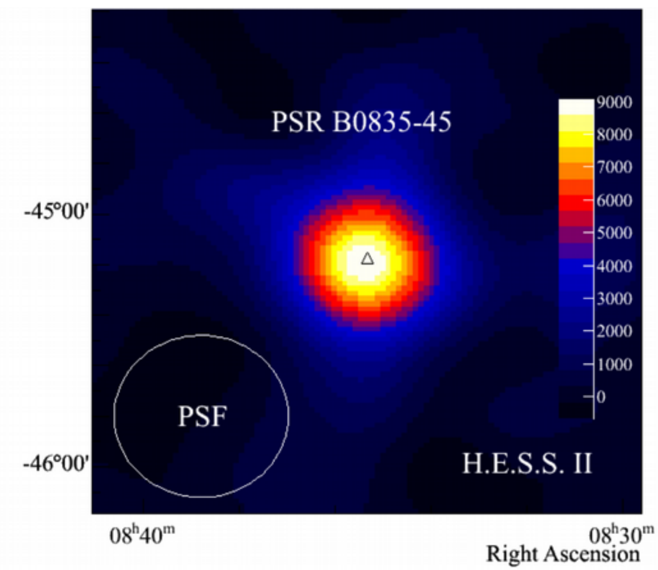
Vela pulsar with CT5 in mono mode

*HESS Collaboration, A&A **620**, A66 (2018)*







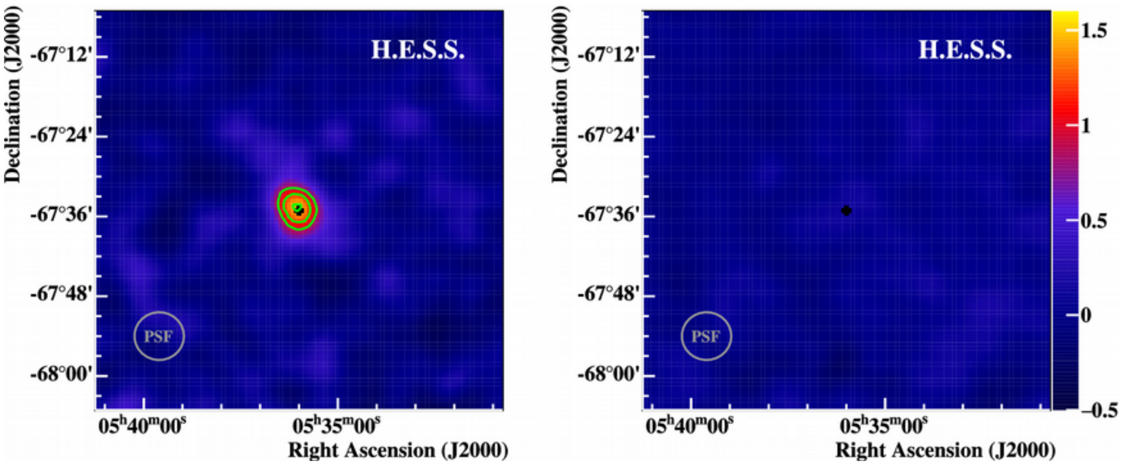


Left: γ-ray phasogram of the Vela pulsar from H.E.S.S. II-CT5 data (top panel) and 96 months of Fermi-LAT data above 10 and 20 GeV (bottom panel). Right: Gaussian-smoothed excess map for the CT5 data in the P2 phase range.

– pulsed high-energy γ-ray emission from the Vela pulsar, PSR B0833−45, based on 40.3 h observations with the largest telescope of H.E.S.S., CT5, in monoscopic mode
– a pulsed γ-ray signal at a significance level of more than 15σ is detected from the P2 peak of the Vela pulsar light curve
– of a total of 15 835 events, more than **6000 lie at an energy below 20 GeV**
– CT5 data show a **change in the pulse morphology of P2**, i.e. an extreme sharpening of its trailing edge, together with the **possible onset of a new component** at 3.4σ significance level

LMC P3 – γ-ray binary in the Large Magellanic Cloud

– past observations led to the discovery of three individual very-high-energy (VHE, >100 GeV) γ-ray-emitting sources (H.E.S.S. Collaboration et al. 2012, 2015a): supernova remnant, pulsar wind nebula and a superbubble



H.E.S.S. excess count rate maps for the on-peak (left panel) and off-peak (right panel) regions of the orbit.

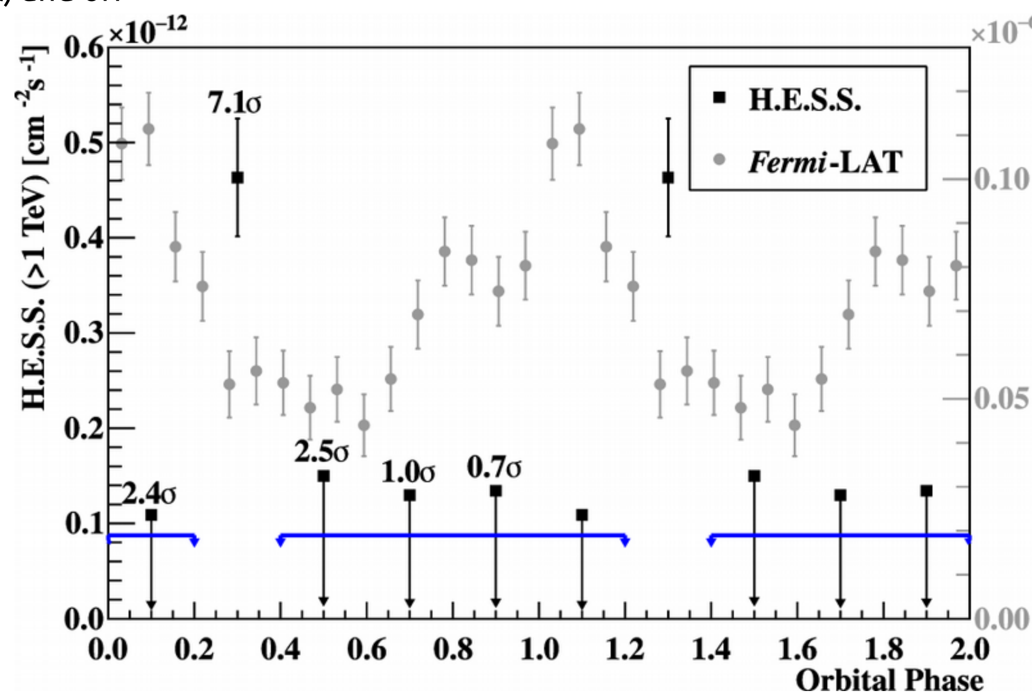
the high-energy γ-ray emission from the object LMC P3 in the Large Magellanic Cloud (LMC) has been discovered to be modulated with a 10.3-day period, making it **the first extra-galactic γ-ray binary**

– LMC P3 is the most luminous γ-ray binary known so far

*HESS Collaboration, A&A **610**, L17 (2018)*

– two scenarios proposed for γ-ray binaries are that the γ-ray emission can be powered either by the **spin-down of a pulsar** or by **accretion of the stellar wind onto the compact object**

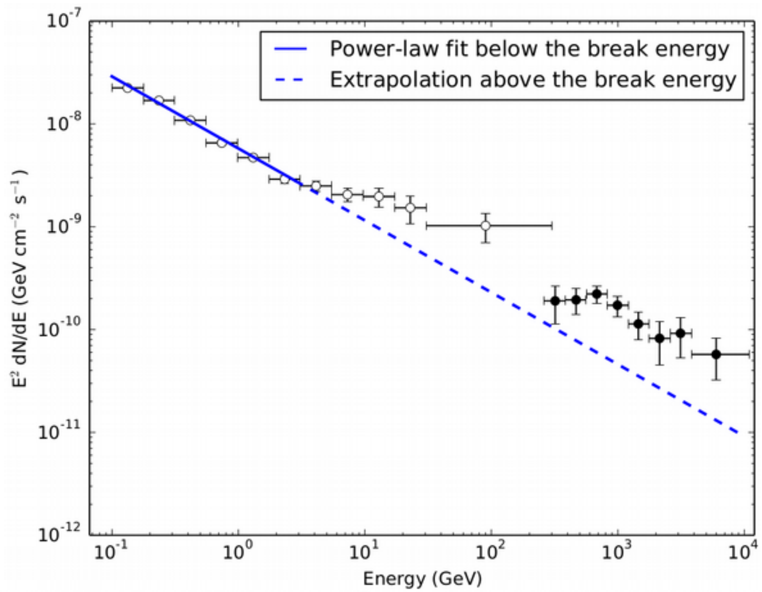
– **VHE emission is out of phase with the HE** emission which may be explained by **absorption due to pair production**, or by **different particle distributions** responsible for the HE and VHE γ-ray production

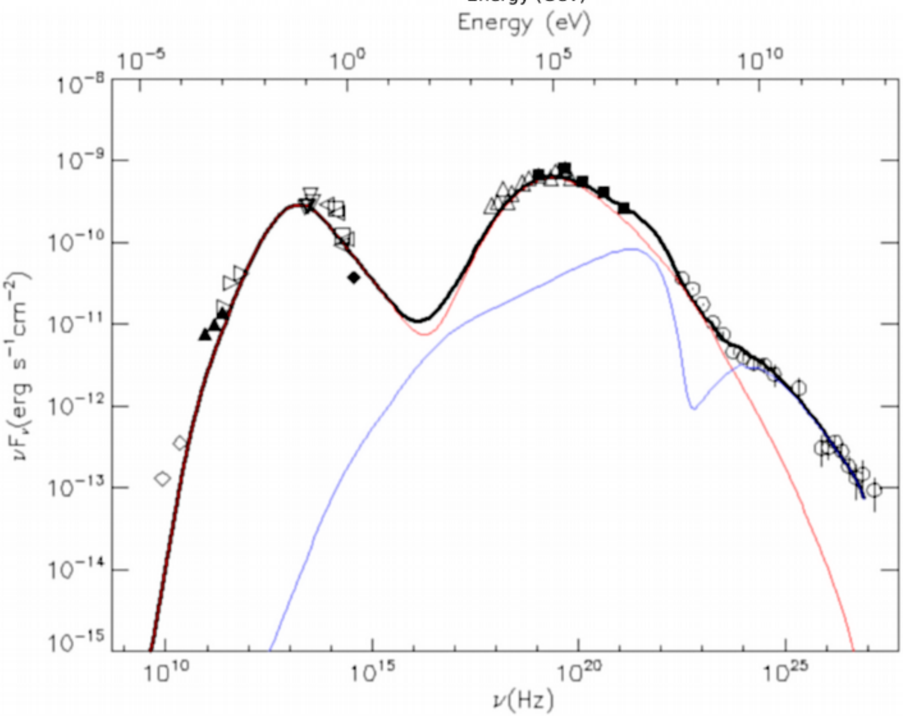


Folded γ-ray light curves with orbital phase zero at the maximum of the HE γ-ray emission (MJD 57 410.25)

Centaurus A observed with H.E.S.S.

*HESS Collaboration, A&A **619**, A71 (2018)*





– Centaurus A (Cen A) is the nearest radio galaxy discovered as a very-high-energy γ-ray source by H.E.S.S.

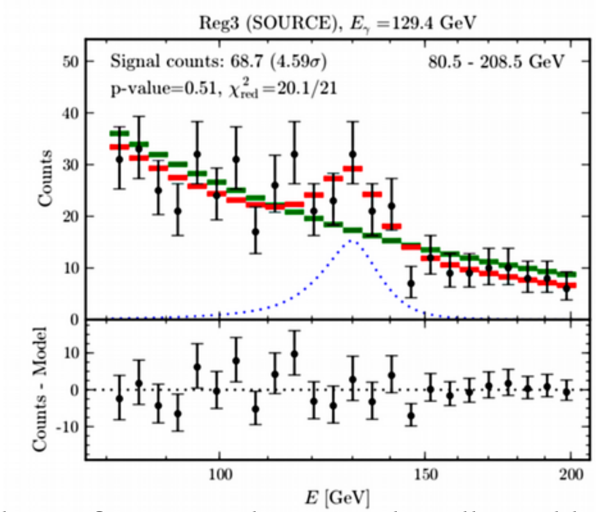
– VHE flux exceeds both the extrapolation from early Fermi-LAT observations as well as expectations from a (misaligned) single-zone synchrotron self Compton (SSC) description

– a representative, contemporaneous γ-ray **core spectrum of Cen A over almost five orders of magnitude in energy** has been constructed **for the first time**

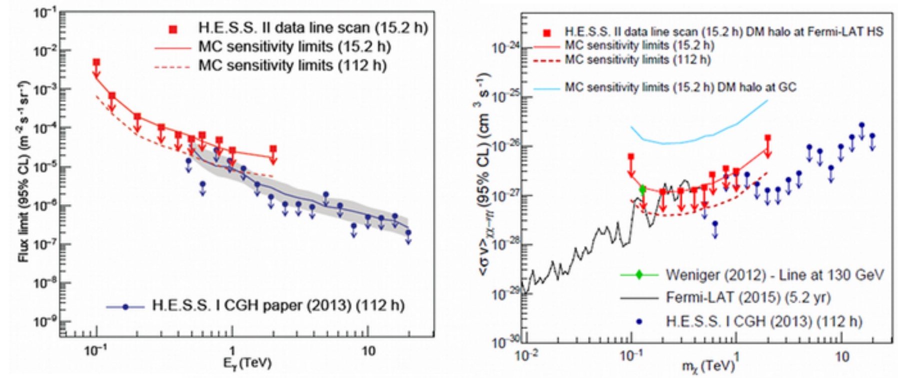
– a **new γ-ray emitting component** connecting the high-energy emission above the break energy to the one observed at VHE energies

Search for γ-rays from annihilation of dark matter

C. Weniger, J. Cosmol. Astropart. Phys. 08 (2012) 007.



– an analysis of a 5-year data sample collected by Fermi-LAT in a sky region close to the Galactic Center resulted in a hint for a line-like signal at an energy of 130 GeV



– in the past a search for dark matter line-like signals in the vicinity of the Galactic Centre was performed with the complete HESS-II array
– a new analysis of the HESS-I data was performed resulting in 254 h of total data time

– no significant excess associated with dark matter annihilation was found in any of the analysed ROIs, nor in energy range between 100 GeV and 2 TeV, nor in range 300 GeV – 70 TeV
– the limits obtained significantly improve over the strongest constraints so far from 112 hours of H.E.S.S. observations towards the GC region in the TeV mass range

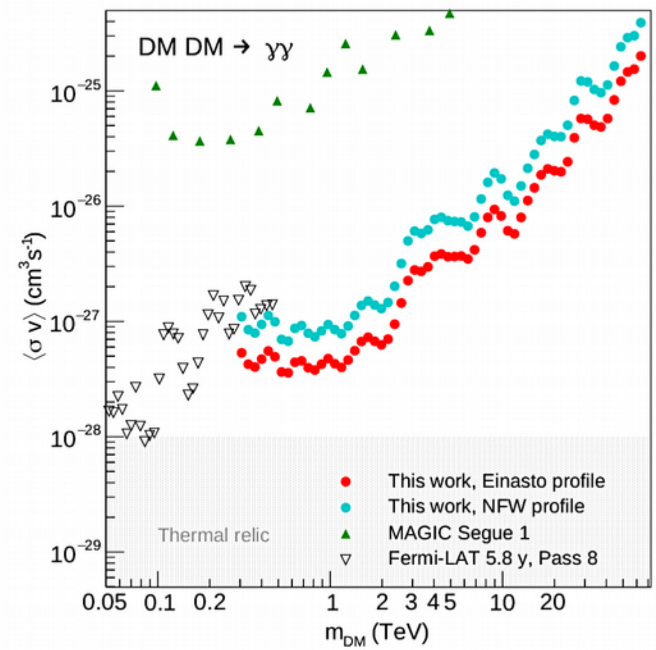


FIG. 3: Comparison of constraints for prompt annihilation into two photons obtained by H.E.S.S. for the Einasto (red dots) and NFW (cyan dots) profiles, respectively, with the limits from the observations of the Milky Way halo by Fermi-LAT [35] (black triangles) as well as the limits from 157 hours of MAGIC observations of the dwarf galaxy Segue 1 [36] (green triangles). The grey-shaded area shows the natural scale for a monochromatic γ-ray line signal.

Abdallah et al. Phys. Rev. D Lett. ***120****, 201101 (2018)*

SUMMARY

– H.E.S.S. still performs very well in many aspects of very high energy astronomy and particle astrophysics research

– systematic upgrades (addition of CT5 telescope, mirror re-coating and camera upgrade) and new analysis methods allow for constant improvement in the system performance

– H.E.S.S. is still the only hybrid system – a pathfinder for the Cherenkov Telescope Array (CTA) and a test bed for CTA technologies

– the future of H.E.S.S. in “the CTA era” under discussion