100 Years of Cosmic Rays

1996—2012 Gamma-Ray Astronomy

1996—2010 KASCADE & KASCADE-Grande

KASCADE detector array

With the KArlsruhe Shower Core and Array DEtector, a new generation of modern shower arrays came into operation. Some 252 stations, each consisting of four electron/gamma liquid scintillation counters and a muon counter, were arranged in an array of 200 x 200m². In the centre a hadron and muon detector system with an active area of 320m² was installed. KASCADE was extended in 2003 by 37 scintillation counter stations to become KASCADE-Grande. This allowed the study of the composition of primary cosmic particles from 10^{15}eV to 10^{18}eV, covering the “knee” and the so-called “second knee”.

1997—2006 HiRes

The High Resolution air fluorescence experiment, known as HiRes, replaced the first-generation Fly’s Eye detectors in Utah. With smaller photomultipliers and an improved data acquisition system, a higher sensitivity could be reached in order to determine the energy, direction and chemical composition of the highest-energy cosmic rays. At energies greater than 5×10^{19}eV, the decrease in the measured particle flux is in agreement with the expectations of the GZK effect.

2002 Third generation of Cherenkov telescopes

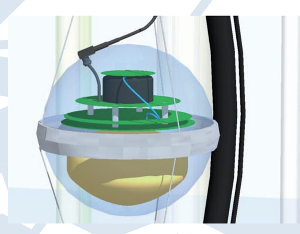
H.E.S.S.: 4 telescopes in 2003, 5 in 2012

MAGIC: 1 telescope in 2004, 2 in 2009

VERITAS: 2 telescopes in 2006, 4 in 2008

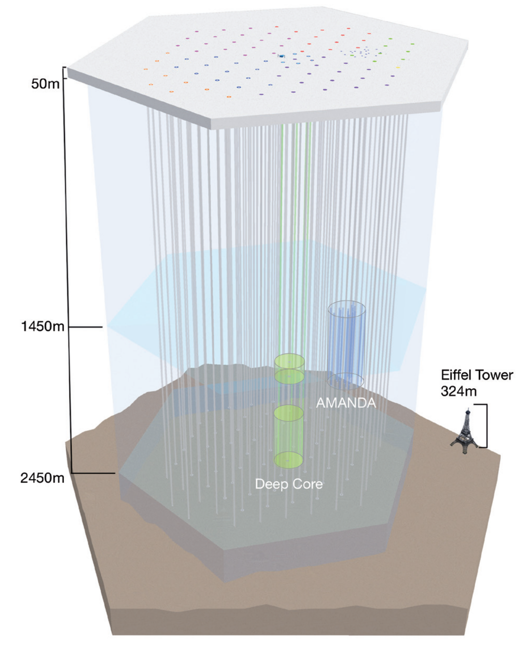
The success story of high-energy gamma astronomy began with the operation of the new generation of air Cherenkov telescopes: H.E.S.S. in Namibia, MAGIC in La Palma and VERITAS in Arizona.

2004 IceCube & IceTop



Digital optical module

From 2004—2010, the giant IceCube Neutrino Observatory was built at the South Pole. Some 86 strings with digital optical modules were installed to survey one cubic kilometre of ice to depths of 1450m to 2450m. Every hour about 10 up-going muons from neutrino interactions near the detector and about 7 million down-going atmospheric muons are reconstructed by measuring the Cherenkov light.
In addition, 81 pairs of IceTop tanks are installed on the surface to investigate air showers in the “knee” energy region.
In the data analysed so far, no neutrinos have been observed from point sources. All the neutrinos measured since 2005 were produced in the northern atmosphere.



IceCube detector

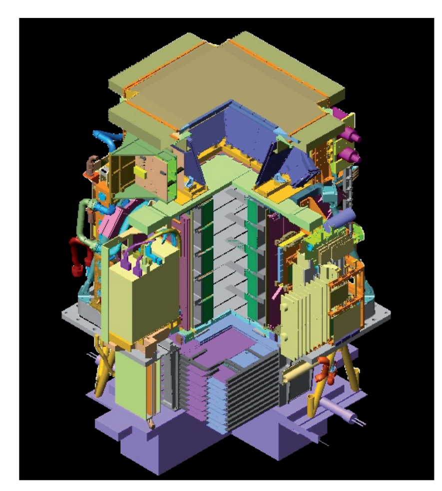
2004 Pierre Auger Observatory

The largest extensive air shower array was constructed as the first true hybrid observatory. It comprises 1600 water Cherenkov detectors distributed on a grid of 1.5km over an area of 3000km², and 27 air fluorescence telescopes erected at four stations on the periphery of the observatory. Important results include the exploration of the ultra-high-energy area with a cut-off as expected from the GZK effect; the particle composition; and a first hint of the extragalactic origin of the highest-energy cosmic particles.

One of the air fluorescence light detector stations on the hill and a water Cherenkov tank on the right

2006 PAMELA mission

The Italian-Russian satellite was launched with the goal of antimatter-matter exploration in primary cosmic rays. PAMELA measured an unexpected increase in the positron fraction at energies between 10^{10}eV and 10^{11}eV which was later established by Fermi LAT at even higher energies. Further investigations will answer whether this effect opens a window on a “new physics”.



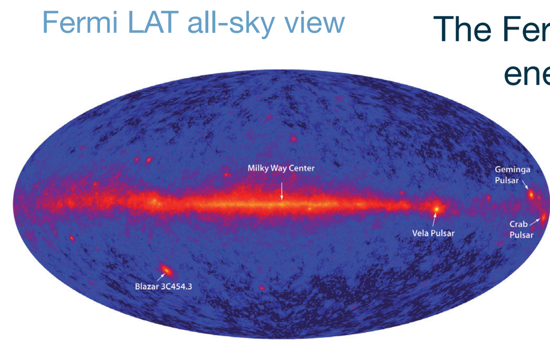
Schematic view of the PAMELA detector

2008 Telescope Array

The Telescope Array project in Utah combines the successful tradition of Fly’s Eye and HiRes air fluorescence shower detection with a ground array of scintillator counters distributed over an area of about 500km². The experiment is complemented by a low-energy extension. Both the particle flux and composition can be studied for primary particle energies above 3×10^{16}eV.

2008 Fermi Large Area Telescope and Burst Monitor

Fermi LAT all-sky view

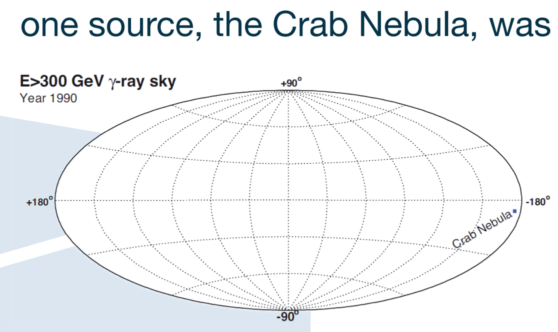


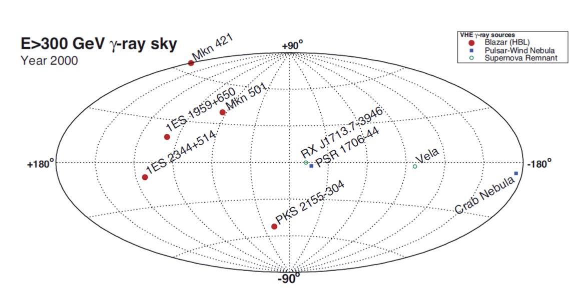
The Fermi satellite carries two experiments, the Large Area Telescope (LAT) to measure high-energy gamma rays up to energies of 10^{11}eV and the GLAST Monitor for the detection of gamma-ray bursts. The high sensitivity of both instruments allowed the detection of many new galactic and extragalactic gamma-ray sources (with LAT) and gamma-ray bursts (with GLAST). With the LAT electromagnetic calorimeter, the electron flux was measured up to energies of 10^{12}eV. For positrons, the energy range from 2×10^{10}eV to 2×10^{11}eV was investigated and an increase in the positron fraction observed.

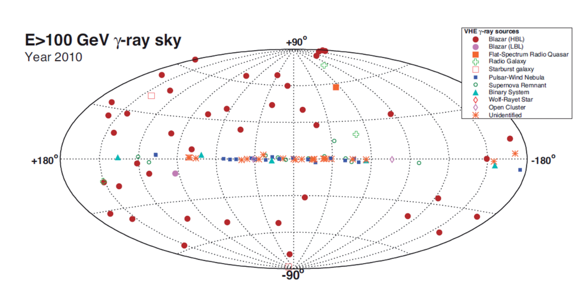
2010 Evolution of the gamma-ray sky

The progress of very high-energy gamma ray astronomy with ground-based air Cherenkov telescopes over the last two decades can be seen in the sky plots of detected sources. With the second-generation Whipple telescope, one source, the Crab Nebula, was observed until 1990.

Ten years later, Whipple and HEGRA had seen nine sources. And from 2003—2010, the third-generation telescopes H.E.S.S., MAGIC and VERITAS detected about 110 gamma sources.







2011 Launch of the Antimatter-Matter Spectrometer

The AMS cosmic particle spectrometer installed at the International Space Station was designed to search for cosmic particles and antiparticles up to energies of 10^{12}eV. A further goal is the indirect search for dark matter.
To search for possible anti-matter concentrations in the universe predicted by some theories, the sensitivity for measuring the anti-helium/helium fraction was improved by a factor of 1000.

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