100 Years of Cosmic Rays

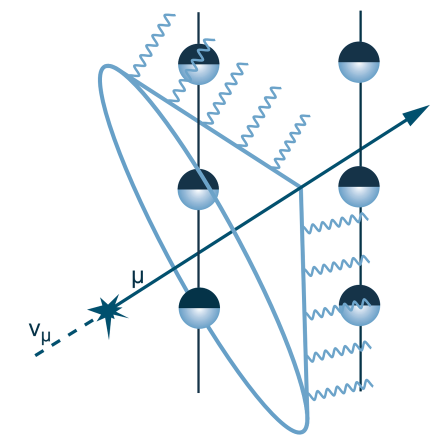
1971—1995 New Technologies

1973—1991 Fly's Eye: First fluorescence detector array

Fluorescence light is produced when cosmic particle showers excite air molecules. The pioneering work was done by a group under K Greisen in the 1960s. Initial prototype detectors measuring air fluorescence light were built and tested by the University of Utah at the beginning of the 1970s. The Fly's Eye detector array was located in the desert of Utah at an altitude of about 1370m. With 67 detector units, each consisting of a container with a 1.5m mirror and a light collection system, the array was able to register on moonless nights fluorescence light over an area of about 1000km^2. In 1991 an event was detected with $(3.2 \pm 0.9) \times 10^{20}$eV, the highest energy ever measured.

1978—1996 DUMAND project: Deep Underwater Muon and Neutrino Detector

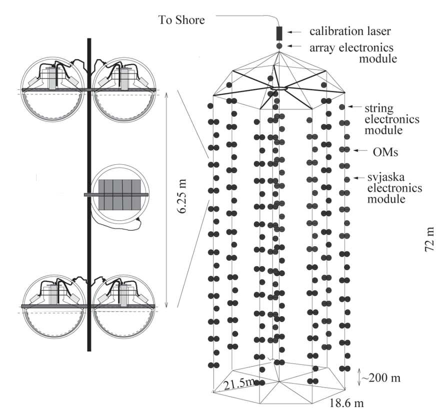
Discussions about building DUMAND began in 1973. According to the 1978 proposal, one cubic kilometre of ocean was to be instrumented at a depth of 5km near the coast of Hawaii by about 23000 photomultiplier detectors. Neutrinos produce a muon in two-thirds of their very rare interactions. Relativistic muons produce in water Cherenkov light which is measured by PMTs. The arrival time allows for reconstructing the muon track. To disentangle the large amount of high-energy atmospheric muons from the muons produced in the few neutrino interactions, one looks for upward-going muons, as only neutrinos can traverse the Earth. The giant project failed for several reasons, but the almost 25 years of R&D were a very helpful basis for subsequent projects.



Muon detection through Cherenkov light

1984 Baikal neutrino project: First stationary string

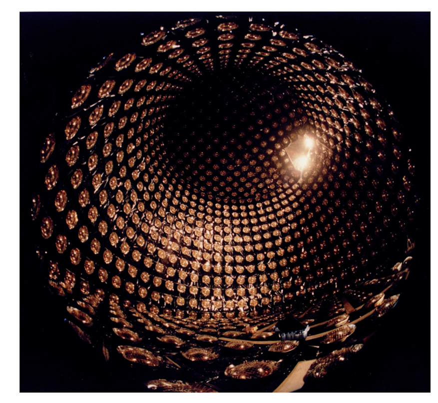
Lake Baikal in Siberia, with its clean water and stable ice in wintertime, was chosen for the installation of a water Cherenkov neutrino detector. The first string of PMT detectors, deployed at a depth of 1200m in 1984, measured atmospheric muons. Construction of the present NT-200 detector started at the end of the 1980s. An array of eight strings with 24 floors and 48 PMTs per string was planned. After several installation steps, NT-200 was completed in 1998. One of the first neutrino events with an upward-moving muon was detected in 1996.



Baikal NT-200 detector

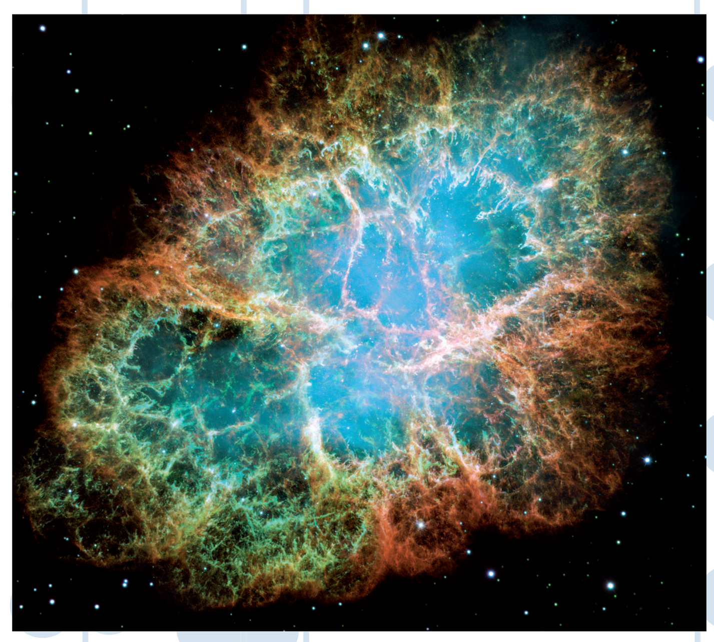
1987 Supernova 1987A: First detection of low-energy neutrinos

The neutrino window on the universe was opened by chance on 23 February 1987, when a supernova explosion in the Small Magellanic Cloud was discovered by optical telescopes. At the time several underground detectors were looking for proton decays in large volumes of water and in liquid scintillators. The data showed that three detectors observed an excess of events at the same time: the Japanese Kamiokande II detected 11 events within 13 seconds, the US IMB eight events within 6 seconds and the Soviet Union Baksan five events within 9 seconds from SN1987A.



Photomultipliers on the inner wall of Kamiokande II

1989 Whipple collaboration: Gamma rays from the Crab Nebula

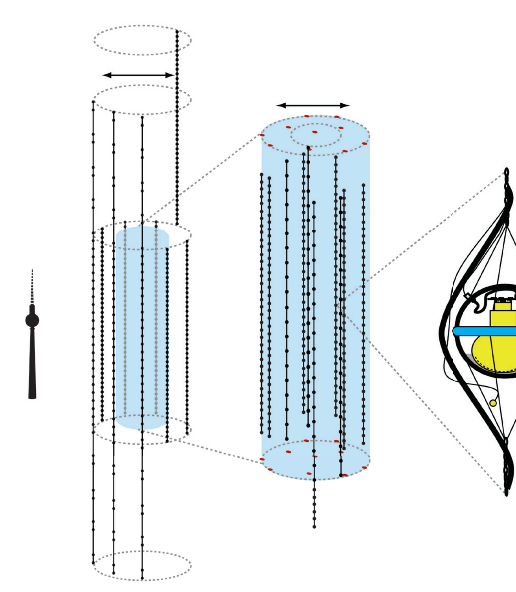


Crab Nebula

A telescope camera with 37 PMTs and an efficient analysis algorithm allowed a considerable reduction of hadronic background events. In 1989, more than 20 years after the Whipple telescope started to look for Cherenkov light flashes, the discovery of gamma rays from the Crab Nebula opened a new window into the sky: high-energy gamma astronomy.

1993—2009 AMANDA neutrino detector

The first string of photomultiplier modules was installed in the ice at the South Pole in the austral summer of 1993—1994. The AMANDA detector collected data in the final configuration of 19 strings from 2000—2009. About 1000 muon-neutrino interactions per year were measured. However, the neutrinos were produced in pion decays in the atmosphere of the northern sky. No significant neutrino signal from a galactic or extragalactic point source was found.



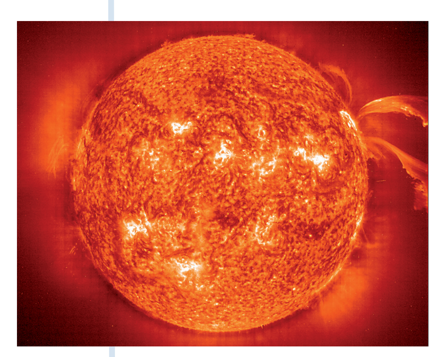
Schematic view of the 19-string AMANDA detector mostly installed at a depth of 1400m—2000m

1993 AGASA: Highest-energy event

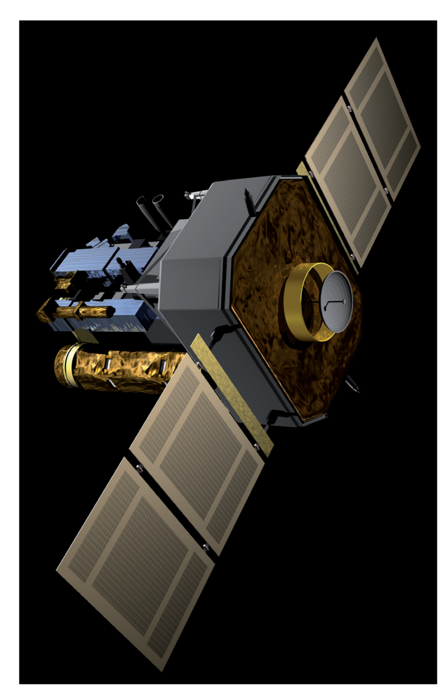
The Akeno Giant Air Shower Array (AGASA) operated in Japan from 1990—2004. It consisted of 111 scintillation and 27 muon detectors distributed over an area of 100km^2. The event with the highest energy of 2×10^{20}eV was measured in December 1993. The particle shower was distributed over an area of 6×6km^2. In total, 11 events with an energy greater than 10^{20}eV were detected; this did not show the decrease expected for the GZK effect observed in other experiments.

1995 Start of SOHO: Solar and Heliopheric Observatory

SOHO is a joint project of NASA and ESA to study the sun and the solar wind.
Originally designed to operate for two years, it still provides important information about the structure of sunspots and the temperature profile and gas flow in the corona over a complete sun cycle of 11 years.
SOHO is also a very important detector for space weather, providing alerts in the case of sun bursts directed at the Earth.



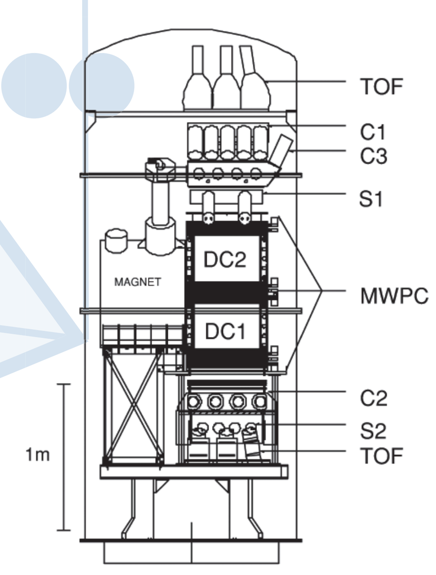
Solar burst seen by SOHO



SOHO satellite

1995 Detection of antiprotons in primary cosmic rays

In the 1970s, NASA began the exploration of primary cosmic rays with balloon experiments at very high altitudes. Particle detectors weighing more than 1000kg measured particle energies and the composition of the primaries, and searched for antimatter.
Three experiments launched in the early 1990s, IMAX, BESS and CAPRICE, published the discovery of antiprotons.



IMAX magnet spectrometer. TOF - time of flight, C1/C3 - Cherenkov detectors, S1/S2 - scintillators, MWPC - multiwire proportional chamber, DC1/DC2 - drift chambers.

DESY ASPERA Durham University