

Building the history of neutrino astronomy

1912 On a balloon at an altitude of 5,000 meters, Victor Hess discovers highly "penetrating radiation" coming from outside our atmosphere, currently known as cosmic rays.

1929 Using a newly invented cloud chamber, Dimitry Skobelzyn observes the first ghostly tracks left by cosmic rays. Walter Bothe and Werner Kolhorster verify that the tracks are curved, showing that cosmic rays are charged particles.

1930 Wolfgang Pauli postulates a new particle with no charge and no mass. This particle would carry the missing energy in beta decays measured by Otto Hahn and Lise Meitner almost 20 years previously. Enrico Fermi will later name it the "neutrino."

1949 Enrico Fermi put forth an explanation for the acceleration of cosmic rays: protons speed up by bouncing off moving magnetic clouds in space. Exploding stars are believed to act as such cosmic accelerators, but they cannot account for the highest energy cosmic rays.

1956 Frederick Reines and Clyde Cowan report the first direct evidence for neutrinos.

1960 Kenneth Greisen and Frederick Reines propose a new type of detector to search for very high energy neutrinos in an underground mine. Greisen predicts that the detection of neutrinos produced by or in coincidence with cosmic rays will become one of the tools of both physics and astronomy in the next decade.

1960 Moisey Markov proposes installing detectors in a lake or a sea to determine the direction of charged particles, such as muons produced by the interaction of incoming neutrinos, with the help of Cherenkov radiation.

1965 First detection of atmospheric neutrinos occurs almost simultaneously in a South African gold mine and in the Indian Kolar Gold Fields mine.

1968 Raymond Davis, Jr. and John N. Bahcall successfully detect the first solar neutrinos in the Homestake experiment in South Dakota.

1976 The Deep Underwater Muon and Neutrino Detector (DUMAND) project begins with the aim of building a cubic-kilometer neutrino telescope in the Pacific Ocean, off the shore of Hawaii, five kilometers beneath the surface.

1978 Baksan Neutrino Observatory begins operation in the Caucasus Mountains in Russia.

1979 Alexander Chudakov proposes using the deep water of Lake Baikal in Siberia to build a neutrino detector.

1981 The first shallow-site experiment with small phototubes is tested in Lake Baikal.

1984 The first stationary string is deployed in Lake Baikal, which records the downward moving muons produced by the interaction of cosmic rays in the Earth's atmosphere. Fifty days later, it is no longer working due to several technical issues in both the cables and the sensors.

1987 DUMAND's first single prototype string, suspended from a ship, is successfully operated.

1987 Neutrinos coming from a supernova, named SN 1987A, are accidentally observed by Kamiokande II in Japan, the Irvine-Michigan-Brookhaven detector in the US, and the Baksan Neutrino Observatory in Russia.

1988 The Baikal experiment is approved as a long-term project to build a full-scale high-energy neutrino detector via steps of intermediate detectors of growing size.

1988 Francis Halzen and John Learned propose the detection of high-energy neutrinos in deep polar ice.

1990 DUMAND is approved for construction.

1990 A fledgling collaboration of physicists, including Francis Halzen and Bob Morse at UW–Madison, proposes the Antarctic Muon and Neutrino Detector Array (AMANDA), at the South Pole.

1993/94 The first sensors of the AMANDA detector are deployed at depths between 800 and 1000 meters in Antarctica's ice sheet. Air bubbles from firn ice originally at the surface are found at this depth, which makes particle track reconstruction impossible.

1995 The DUMAND project is cancelled, after the first string of photodetectors deployed on the ocean bottom develops short circuits in the instrument that prevent communication with the installed apparatus.

1995/96 A second set of sensors for AMANDA is deployed at a depth of 1500–2000 meters, and this time AMANDA proves to be a viable option for detecting very high energy neutrinos.

1998 NT200, the first underwater neutrino telescope, is completed in Lake Baikal, an array of 192 sensors carried by eight strings.

2000 AMANDA is completed, with 19 strings and about 700 sensors buried below 1,500 meters of Antarctic ice.

2004 The construction of the IceCube Neutrino Observatory begins. The transition from AMANDA to the first cubic kilometer neutrino detector has already begun.

2006 The new Gigaton Volume Detector (GVD) for Lake Baikal is designed, which could become the first underwater cubic-kilometer detector.

2009 AMANDA is switched off after over a decade of data-taking, having provided record limits on fluxes for cosmic neutrinos and excluded the most optimistic models for neutrino production in cosmic sources.

2010 IceCube is completed at the South Pole, with over 5,000 sensors distributed on 86 strings and deployed at depths between 1,500 and 2,500 meters.

2013 The IceCube Collaboration announces the observation of the first flux of extraterrestrial high-energy neutrinos.

behind 1912 This is where our story starts.

behind 1929 Over 70 years later, muons produced by cosmic rays are observed in Lake Baikal.

behind 1930 A bit more than 25 years later, neutrinos are detected.

behind 1949 This happens 11 years before Greisen predicts that neutrinos could become a new tool for both physics and astronomy.

behind 1956 Nine years later, the first atmospheric neutrinos are observed.

behind 1960 Almost 20 years later, Chudakov proposes using the deep water of Lake Baikal as a detector.

behind 1960 And almost 30 years later, Halzen and Learned propose the same technique but in the polar ice.

behind 1965 A little more than 50 years earlier, radiation coming from outside our atmosphere is first detected with a balloon.

behind 1968 Three years earlier, atmospheric neutrinos are detected, but it takes another 19 years to observe neutrinos from a supernova and still 26 more years to record the first flux of extraterrestrial high-energy neutrinos.

behind 1976 IceCube, the first cubic kilometer detector ever built, is completed 34 years later.

behind 1978 This is the first neutrino observatory built in Russia, almost 20 years after M. Markov proposes using Cherenkov radiation to build underwater neutrino detectors.

behind 1979 Approval for the Lake Baikal experiment, home of the second neutrino observatory in Russia, comes about nine years later.

behind 1981 It takes another 12 years to deploy the first sensors in the polar ice.

behind 1984 This is 35 years after Fermi proposes a mechanism for very high energy cosmic rays.

behind 1987 This is 11 years after the project begins, and 27 years after the oceans are proposed as great locations for neutrino detectors.

behind 1987 This happens at the same time that the first prototype string for DUMAND is deployed from a ship, and 26 years before IceCube announces the observation of the first flux of very high energy neutrinos.

behind 1988 DUMAND is approved two years later, and IceCube construction starts in 16 years.

behind 1988 This is the beginning of IceCube's history. First there is AMANDA, then IceCube. Amanda is completed 12 years later, and IceCube 10 years after AMANDA.

behind 1990 Fourteen years have passed since the project's beginning, and only five years later it is cancelled.

behind 1990 This is year 78 of our history, still 23 more years until the end.

behind 1993/94 One or two years later, DUMAND also faces problems, which end in the cancellation of the Russian cubic-kilometer neutrino detector.

behind 1995 First is DUMAND, then Baksan, followed by Baikal. All of these projects start within a few years of each other, about 20 years before now.

behind 1995/96 In five years, AMANDA is completed.

behind 1998 Markov first proposes building this underwater detector 38 years earlier.

behind 2000 This happens 70 years after Pauli predicts the existence of neutrinos.

behind 2004 This is 56 years after the first neutrinos are detected, and still nine years before the announcement of the first flux of very high energy neutrinos.

behind 2006 Twenty-seven years prior, Chudakov proposes Lake Baikal as a great location for a neutrino detector, just after the Baksan Neutrino Observatory starts operations.

behind 2009 DUMAND, starting deployment on the ocean bottom at the same time as AMANDA, is cancelled 14 years earlier.

behind 2010 This happens exactly 22 years after a neutrino detector in the polar ice is first imagined.

behind 2013 The success of IceCube builds on the success of AMANDA, whose first sensors are deployed 20 years before this discovery.