PRC 01/01

Proposal

Participation of DESY-Zeuthen in the IceCube Project

*The DESY Neutrino Astrophysics Group **
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** Presently, the following persons are contributing to the Amanda/IceCube effort in Zeuthen: A.Biron, S.Böser, P.Desiati, M.Gaug, T.Hauschildt, M.Kowalski, H.Leich, M.Leuthold, M.Ribordy, T.Schmidt, C.Spiering, P.Steffen, P.Sudhoff, K.H.Sulanke, C.Wiebusch, R.Wischnewski, H.Wissing.*

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IceCube proposal of the US institutions from Nov.1999.

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Recent publication in Nature on the observation of high energy atmospheric neutrinos with Amanda, Nature 410 (March 2001), 441.

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Brief version of a detailed technical report on the DESY analysis of atmospheric neutrinos (1997 data).

Appendix 4
Preliminary results from the DESY analysis of the year-2000 Amanda-II data.

Appendix 5
Amanda status report at "Neutrino 2000" (Sudbury, June 2000).

Appendix 6
Paper on the search for Supernova bursts, submitted to Astroparticle Physics Journal in March 2001.

More information is compiled on the DESY IceCube web page:

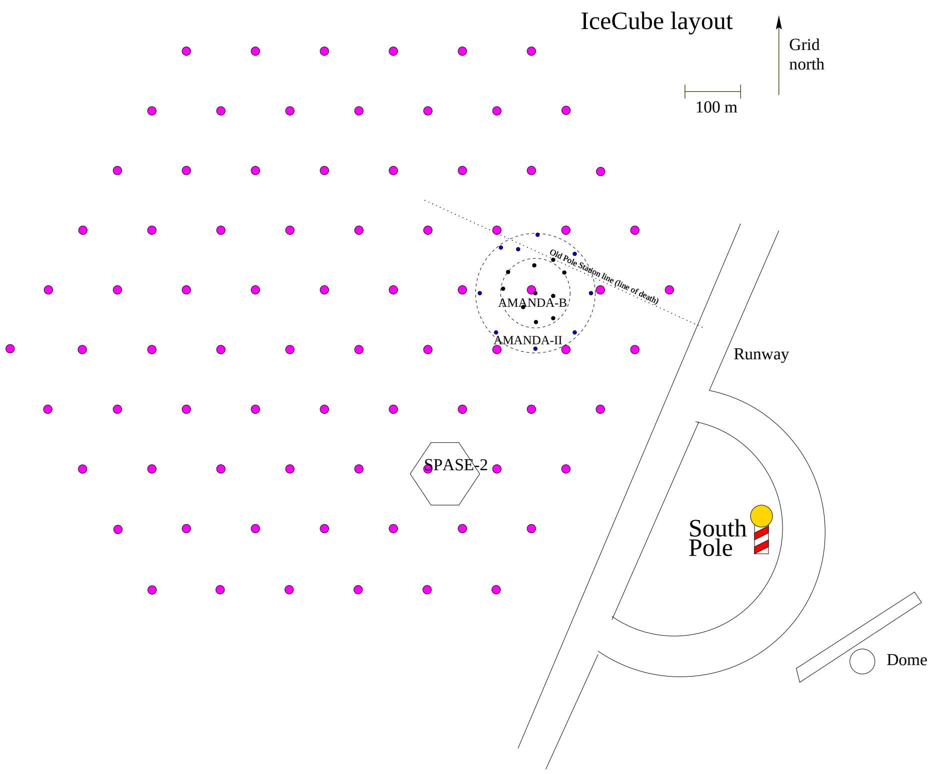
http://www-zeuthen.desy.de//nuastro/ice3_proposal/

Introduction

This document is presented to the DESY Physics Research Committee and the DESY directorate by the members of the DESY AMANDA group. We ask for approval of our participation in the construction and operation of the IceCube neutrino telescope. The IceCube project is a logical extension of the research and development work performed over the past several years by the AMANDA collaboration. The detection of high energy neutrinos has been demonstrated with the existing detector which represents a proof of concept for commissioning a new instrument with superior technical performance and an effective telescope area at the kilometer scale.

The design for IceCube is an array of 4800 photomultiplier tubes (PMTs) each enclosed in a transparent pressure sphere to comprise an optical module (OM) similar to those in AMANDA. Eighty strings are regularly spaced by 125 m over an area of approximately one square kilometer, with OMs at depths of 1.4 to 2.4 km below surface. A hot-water drill creates holes in the ice to a depth of about 2.4 km, and strings with 60 OMs spaced by 17 meters are deployed into the holes before the water column freezes. The signal cables from all strings are brought to a central location, which houses the data acquisition electronics and computing equipment.

The overall IceCube design is described in the IceCube-Proposal of the US Institutions to NSF, from Nov. 1999. We attach this proposal as *Appendix 1*. The following figure gives a top view of the IceCube array.



There have been yearly improvements in the system, especially the OMs, and in the overall quality of the information obtained from the detector. Initially, AMANDA OMs were completely passive, with the high voltage and the analog anode signal both transmitted on a single coaxial cable. Later, the coaxial cable was replaced by a twisted pair cable. In a next significant step, the analog PMT pulses have driven a LED and have been transmitted via optical cable. This resulted in greatly reduced distortion of the signal compared to electrically transmitted pulses. Most recent versions of the so-called analog OM (AOM) contain active components for the local generation of high voltage, for setting bias currents for the LED or laser diode, for reading control quantities etc. Finally, in January 2000 a string was deployed with OMs containing digitization electronics inside the module (DOM). The information is sent digitally to the surface over twisted-pair cable. This option eliminates the need for optical fibers and simplifies calibration of the detector. After recent tests in the laboratory and at the South Pole, the DOM technology has been given preference and adopted as baseline technology for IceCube. This decision was supported by an experts commission in March 2001. Note that the US proposal in Appendix 1 is based on the analog technology. We describe the DOM technology in Part-II of this proposal.

With the determination of a baseline technology, the basic conditions to start IceCube construction are met:

1. The detection of high-energy neutrinos has been demonstrated with the data taken in 1997.

2. New best limits on the neutrino flux from steady extraterrestrial sources like Active Galactic Nuclei (AGN), on the neutrino flux from transient sources like Gamma Ray Bursts (GRB), and on the flux of relativistic magnetic monopoles have been derived from the analysis of the 1997 data. It has been demonstrated that Amanda is monitoring about 70% of the Galaxy for supernova bursts. Also, a limit on neutrinos from WIMP decays in the Earth has been obtained which is close to limits obtained from underground experiments over many years of operation.

3. In January 2000, AMANDA-II with 19 strings and an effective area of 25,000 m^2 for 1 TeV muons has been completed.

4. The optical properties of ice deep below the Pole have been established over more than four years of iteration. After having spent an enormous effort to fully understand the detector on the basis of the 1997 data, the analysis of data taken in 1998/99 and in 2000 has been started.

5. First methodical results obtained from the ongoing analysis of 2000-data confirm expectations.

6. A baseline read-out technology for IceCube (DOM) has been determined.

7. Drill equipment has been designed which allows us to drill 16 holes per season, making the deployment of IceCube over 6 seasons possible (assuming a ramp-up phase with 6 and 12 strings in the first two seasons).

8. Monte Carlo simulations have been refined over the past year and clearly demonstrate that with respect to high energy neutrinos from extraterrestrial sources, IceCube has a sensitivity of 1-2 orders below theoretical bounds and can prove current models for the sources of high energy cosmic rays.

The construction of IceCube is overwhelmingly motivated by its potential to discover high energy neutrinos from extraterrestrial sources and to contribute to the question of the origin of cosmic rays. Apart from neutrino astronomy, IceCube will also cover other questions of highest interest for astrophysics as well as particle physics - ranging from the search for dark matter candidates or for magnetic monopoles to the monitoring of the Galaxy for supernova bursts. We give an overview over the scientific goals and the physics capabilities of IceCube in Part I of this proposal.

Part II describes the DOM technology. This includes the results from the last Pole season which led to the decision to establish the DOM read-out as baseline technology for IceCube. For all other technical questions - like e.g. the general detector design, description of the photomultiplier, expected data rates, the IceTop surface array - we refer to the appended US proposal from Nov.1999 (appendix 1).

Part-III gives a an overview over organisation, schedule and budget of the IceCube project.

Part-iV presents the planned contributions of the DESY group.

We note that the following conditions for a final committment have still have to be met:

1. The IceCube project has not yet passed approval as Major Research Equipment (MRE) project in the US. This appears to be a principal condition for a full approval in other countries.

2. At present, a Preliminary Design Document (PDD) for a NSF baseline review at the end of June 2001 is being prepared by the collaboration. Therefore some of the numbers given in this report to the PRC may change, with the overall change expected to be smaller than 10%. We will submit the PDD to the DESY directorate for the final definition of requests on manpower and budget.