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DUMAND-II Progress Report

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Abstract

The design, scientific goals, and capabilities of the DUMAND II detector system are described. Construction was authorized by DOE in 1990, and construction of various detector subsystems is under way. Current plans include deployment of the shore cable, junction box and three strings of optical detector modules in 1993, with expansion to the full 9-string configuration about one year later.

1 INTRODUCTION.

DUMAND-II is a water Cerenkov detector consisting of 216 hemispherical photomultiplier tubes, mounted on nine vertical strings containing 24 Optical Modules (OMs) each. Figure 1 shows the configuration of the planned ocean bottom array, sited approximately 30 km west of Keahole Point on the Island of Hawaii, at a depth of 4.7 km. A cable to shore, terminating in the Junction Box to which the strings are connected, provides power and fiber optic data communications. The DUMAND-I experiment[1,2] operated a short prototype string near this site, and verified the ability of the planned system to detect and reconstruct muon tracks.

The strings are located at the corners of an equilateral octagon, with the ninth string at its center. The active volume of the array will have a height of

230 m and a diameter of 105 m, with the lowest module 100 m above the ocean floor. Horizontal and vertical spacings between the modules are 40 m and 10 m, respectively. The geometry of the array has been chosen after extensive monte carlo studies as the simplest and least expensive configuration capable of yielding a reasonable event rate and adequate sensitivity to extraterrestrial high-energy neutrino sources at the expected flux levels. The array has been optimized for the detection of high energy (> 10 GeV) muons from neutrino interactions, as well as contained neutrino induced cascades. The detector spacings ensure that muons will be detected with high efficiency and reconstructed in direction with a median accuracy of better than 1^o. The scattering angle between the incident neutrino and the resulting muon will be within this error for neutrino energies above about 1 TeV. The site places no significant constraints on future expansion of the system. The major characteristics of the array are summarized in Table 1.

Muons generated by cosmic rays will be incident at all angles. There will be a high rate in the downward direction (zenith angles $\theta < 80^o$) due to cosmic ray muons (decay products of cosmic ray secondaries which are sufficiently energetic to penetrate the water overburden). For zenith angles $> 80^o$, the observed flux will be dominated by muons produced from the interactions of neutrinos which are the decay products of cosmic ray secondaries (atmospheric neutrinos). Atmospheric neutrinos yield a relatively low rate of background muons so that we have an excellent window for observing extraterrestrial neutrino sources for zenith angles beyond 80^o, with solid angle 2.35 π steradians. The rate for atmospheric neutrino induced muon events will be about 4500 per year, i.e., a background of about one event per $(2.3^o)^2$ per year. Thus, with the design resolution of 1 degree for muon direction reconstruction, we will be largely signal limited, rather than background limited, in the search for extraterrestrial point sources.

We expect detectable signals in DUMAND II from a number of point sources both inside and outside the galaxy. DUMAND also has a chance of seeing the diffuse background of neutrinos produced by cosmic rays passing through the denser portions of our galaxy. The work of Stecker, *et al.* on ultrahigh energy neutrino production in Active Galactic Nuclei (AGN)[3] has stimulated increased attention to possible UHE ν flux levels. Taking into account the summed flux from all AGNs, their calculations suggest that for muon energies above about 50 GeV, AGNs could be the dominant source of neutrinos, with a very hard spectrum. Current consensus of theorists[4] predicts flux levels about 1/17 those suggested in the original paper of Stecker, *et al,* but these levels are nonetheless significantly higher than any previously predicted. Muon detection rates in DUMAND for atmospheric and AGN neutrinos are shown in the Table; the figures for AGNs represent an rough average over predictions of various authors[4,5]. Atmospheric and AGN neutrinos have similar angular distributions for very different reasons: the atmospheric ν rate peaks near the horizon due to the pion decay path distribution, while the AGN rate is depressed at the nadir because the very high mean energy causes significant attenuation in the earth. If the expected fluxes are observed, we would expect about 80 neutrinos events per year from AGNs with energy over 10 TeV at the detector[5].

DUMAND will complement accelerator high energy physics research, since no currently existing or planned accelerator facility produces neutrino beams above about 600 GeV, while DUMAND explores energies above 1 TeV. The AGN model predicts substantial ν_e fluxes which may permit the observation of resonant W^- production at 6.4 PeV[6].

DUMAND will provide unprecedented opportunities for long term deep ocean observations. Of interest are the ocean currents and other physical parameters, and bioluminescence (seasonal fluctuations, diurnal variation, spatial correlations, etc.). Hydrophones on the strings will be used to provide continuous location information for the optical modules, and the data system has been designed to provide digitization of acoustical signals up to 100 kHz. Since the cable provides a high-rate data link to the shore station, sophisticated realtime processing of acoustical signals can be employed, to ensure accurate OM location and to observe the acoustical background. These data can also be used to explore the possibility of acoustic detection for ultrahigh energy neutrinos.

2 PROGRESS AND PLANS

Manufacture of the shore cable is nearly complete, and deployment of the cable with its terminating Junction Box is planned for mid 1993. The first string will be integral to the junction box and serve as the center string for the ultimate full array. The next two strings will be deployed immediately after completion of the cable laying and JB deployment operation, and will later be connected to the JB by a manned submersible. The shore station facilities at Keahole Point are in the design stage, with construction planned for early 1993. OMs using both Hamamatsu and Phillips photomultipliers have been prototyped and tested. Critical fast logic designs for the String Controllers have been finalized.

The first steps toward deployment were taken in September, 1992, when an oceanographic expedition aboard the University of Hawaii vessel *RV Moana Wave* for site preparation was successfully completed. Acoustical transponders were deployed and surveyed to mark the site, data logging current meters were retrieved, water samples, temperature profiles, and photographs were taken. In addition, a practice dive at the site using the Navy manned deep submersible *DSV Sea Cliff* will be undertaken in October, 1992; this submarine or its equivalent will be used to connect strings to the Junction Box following their deployment.

3 ACKNOWLEDGMENTS:

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Table 1
Summary of DUMAND-II Array Characteristics

Contained volume of array	$1.8 \cdot 10^6\ m^3$
Target area for through-going muons	$23{,}000\ m^2$ horizontal $7{,}850\ m^2$ vertical upward $2{,}500\ m^2$ vert. downward
$S\Omega$ for ν-induced muons	$148{,}000\ m^2$ sr
Effective target volume for 2 TeV μ's	$1.0 \cdot 10^8\ m^3$
V_{eff} for 1 TeV cascades	$7.0 \cdot 10^5\ m^3$
Muon energy threshold	10 to 50 GeV
Track reconstruction accuracy	1.0°median
Cascade detection threshold	$\sim$ 10 GeV
Muon rate, down-going	3 per minute
Atmospheric neutrino detection:	
Rate for through-going muons	3500 /year
Rate for contained events > 1 TeV	50 per year
AGN neutrino detection:	
Through-going muons > 100 GeV	300 /year
Through-going muons > 10 TeV	80 /year
Sensitivity (> 1 TeV, in 1 yr):	
Point sources	$4 - 7 \cdot 10^{-10}\ cm^{-1}s^{-1}$
Contained events	$1 \cdot 10^{-8} cm^{-2}s^{-1}$

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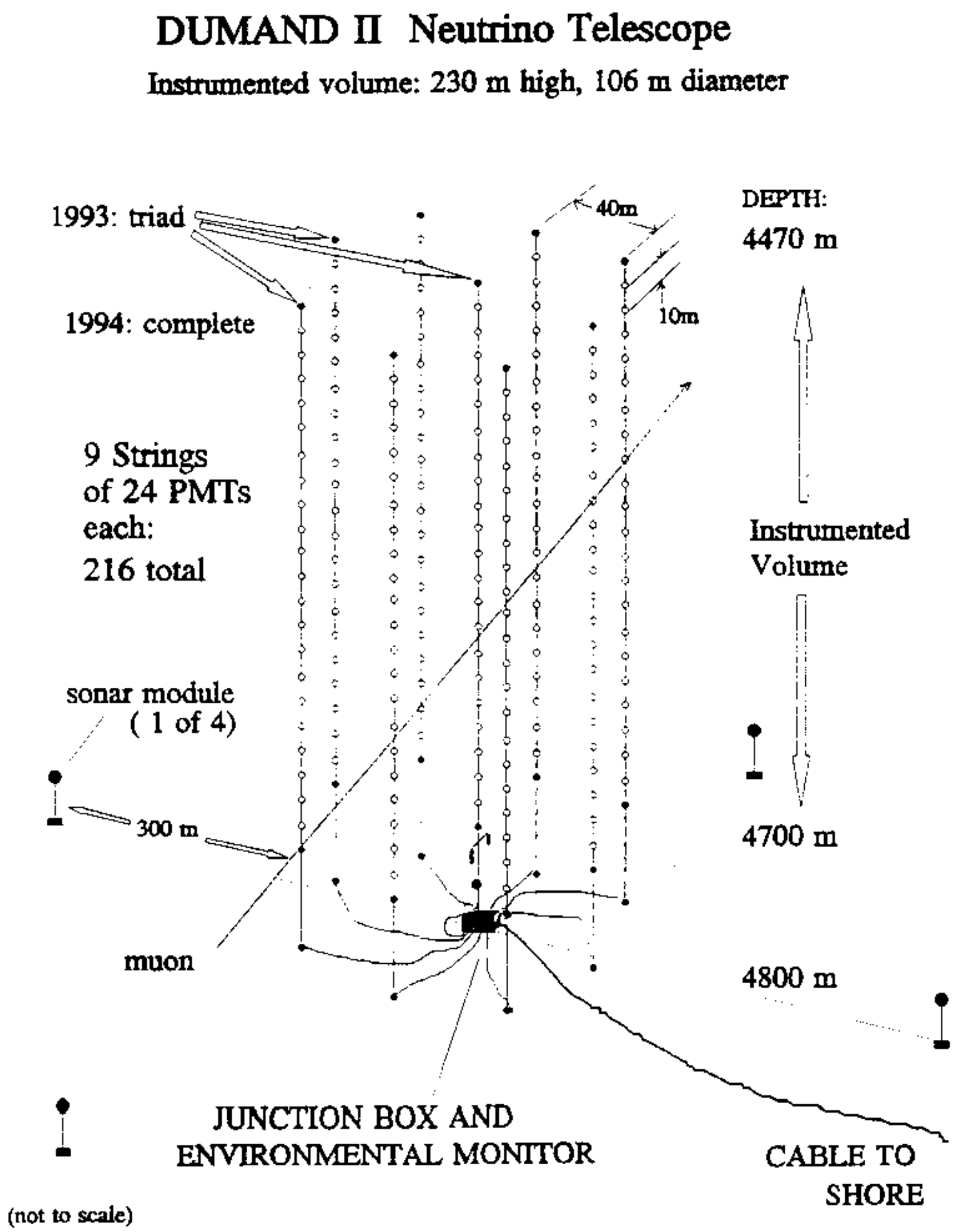

Figure 2: 1. The Dumand II Octagon Array