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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 development 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 1992, with expansion to the full 9-string configuration about one year later.

DUMAND-II is a water Cerenkov detector for high energy astrophysical neutrinos. Nine vertical strings each contain 24 hemispherical photomultiplier tubes, for a total complement of 216 Optical Modules (PMTs and associated fast electronics in glass pressure housings). The ocean bottom array is 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 confirmed 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. Array geometry has been optimized for the detection of high energy (> 25 GeV) muons from neutrino interactions, as well as contained neutrino induced cascades. Muons will be detected with high efficiency and reconstructed in direction with a median accuracy of about 1°. 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.

There will be a high rate in the downward direction (zenith angles  $\theta < 80^\circ$ ) due to cosmic ray muons (decay products of cosmic ray secondaries which are sufficiently energetic to penetrate the water overburden). For zenith angles > 80°, the observed flux will be dominated by neutrinos produced in cosmic ray interactions in the atmosphere. For zenith angles beyond 80°, with solid angle  $2.35 \pi$  steradians, the rate for atmospheric neutrino induced muon events will be about 4500 per year, i.e., a background of about one event per  $(2.3^\circ)^2$  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. Recently, a new model for ultrahigh energy neutrino production in Active Galactic Nuclei (AGN) has been described[3]. Taking into account the summed flux from all AGNs, calculations suggest that for muon energies above about 50 GeV, AGNs may be the dominant source of neutrinos. Muon detection rates in DUMAND for atmospheric and AGN neutrinos are shown in figure 1a as a function of detected muon energy; in figure 1b we show the expected zenith angle distribution. Note that atmospheric and AGN neutrinos have similar angular distributions for very different reasons: the atmospheric  $\nu$  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 fluxes predicted in ref. [3] are observed, we would expect about 3500 neutrino events per year from AGNs, nearly half with energy over 10 TeV at the detector[4]. At these rates, the angular distribution might permit a 5% determination of the earth's core density in one year.

DUMAND will complement accelerator research, since no currently existing or planned accelerator facility produces neutrino beams above about 600 GeV. The AGN model predicts substantial  $\nu_e$  fluxes which may permit the observation of resonant  $W^-$  production at 6.4 PeV[4]. A proposal to Fermilab (P824) requests that construction of the new 150 GeV proton injector include facilities for directing a neutrino beam toward the DUMAND site to permit long baseline neutrino oscillations studies.

DUMAND will provide unprecedented opportunities for long term deep ocean observations. Hydrophones on the strings will digitize 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.

Construction of the shore cable is under way, and deployment of the cable and its terminating Junction Box (along with associated environmental monitoring equipment) is planned for mid 1992, followed later in the year by deployment and connection of the first three strings. The shore station facilities at Keahole Point are in the design stage, with construction to begin in early 1992. OMs using both Hamamatsu and Phillips photomultipliers have been prototyped and tested, including a recent underwater test of Phillips units near the Canary Islands. Critical fast logic designs for the String Controllers have been finalized. Workshops on triggering and ocean engineering aspects of DUMAND held recently in Madison and Seattle indicate that development of the various subsystems is proceeding on schedule.

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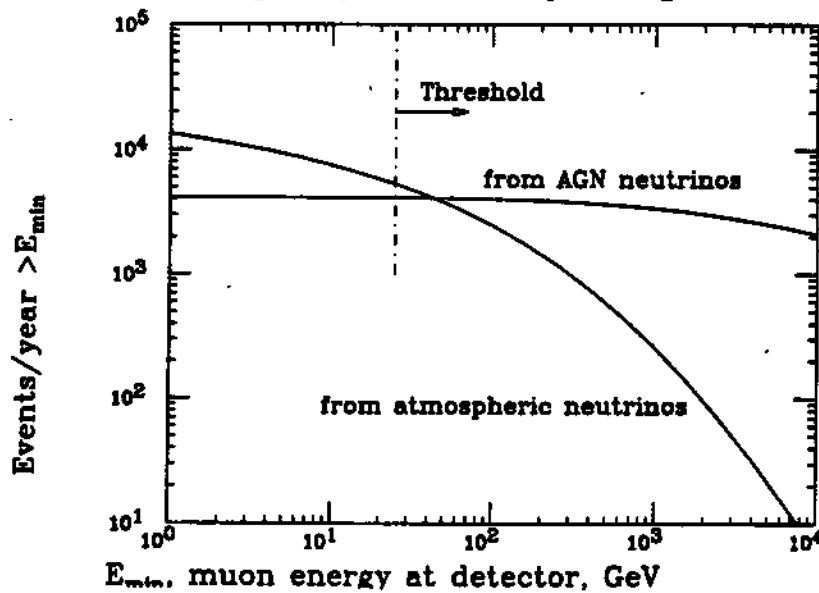
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Figure 1: Calculated muon rates in the DUMAND-II array from atmospheric and AGN neutrino events, as a function of the a) muon energy; b) muon zenith angle  $\theta_\mu$ .

a) DUMAND-II: Integral spectrum of upcoming muons



b) DUMAND-II: Muon angular distributions

