THE DUMAND II EXPERIMENT

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ABSTRACT
A deep-ocean muon and neutrino telescope is now being built for installation near Hawaii. A brief description of this undersea physics and astrophysics laboratory is presented.

INTRODUCTION

A deep-ocean laboratory for the study of neutrino astrophysics and particle physics is under construction. Phase II of the Deep Underwater Muon and Neutrino Detection (DUMAND) experiment is scheduled for initial deployment during summer of 1992. The experiment detects Čerenkov radiation from high energy muons, and hadronic and electromagnetic cascades, using a volume array of photomultiplier tubes (PMTs) buoyed off the ocean bottom. Deep ocean water serves as target mass for neutrino interactions, the Čerenkov radiator for charged particles, and shielding from the cosmic ray muon flux. Event energies and muon trajectories are reconstructed using timing and pulse-height information from the PMTs. Through the study of high energy muons ($E_\mu > 50\ GeV$) and cascades ($E > 1\ TeV$) the primary scientific goals of DUMAND are achieved. These are:

- the search for and study of astrophysical point sources of TeV muon neutrinos;
- the investigation of neutrino interactions at energies ($0.6 < E_\nu < 10\ TeV$) far beyond the range of present and planned accelerators;
- the study of the spectrum and composition of the primary cosmic radiation.

The possibility of neutrino astrophysics has been discussed for at least three decades[1]. Neutrinos are an excellent astrophysical probe. They interact only via the weak nuclear force and are stable. Hence they provide direct views of astrophysical processes hidden by material too thick for the escape of photons ($\sim 100\ g\ cm^{-2}$). For this same reason neutrino detectors are typically extremely massive.

The motivation to search for sources of high energy neutrinos is prompted by the discovery of VHE and UHE galactic sources of γ-rays[2] and the exciting prospect of exploring a new view to the universe. Although possible sources are distant ($\sim 10\ kpc$) and neutrino cross sections are small ($\sim 10^{-36}\ cm^2$), the effective target volume of an undersea or underground detector is enhanced by the long range of muons produced by charged current ν_μ interactions in the surrounding earth or water. Sources are observed while near or below the horizon by a clustering on the celestial sky of upward-going muon tracks. At large zenith angles the signal is well separated from the cosmic ray muon flux and competes only with the near isotropic flux of muons from atmospheric neutrinos.

Searches for point sources of high energy neutrinos have been performed using underground water Čerenkov detectors with typical exposures of $\sim 1000\ m^2\ yr$ and $\sim 5^o$ angular resolution[3]. These have resulted in upper limits to high energy neutrino radiation ($E_\nu > few\ GeV$) from a host of candidate γ-ray sources. The total integrated neutrino flux measured by these detectors is consistent with that expected from atmospheric neutrinos.

With $\sim 20,000\ m^2$ effective area and $\sim 1^o$ angular resolution DUMAND II will achieve a sensitivity to high energy neutrinos ~ 1000 times that of previous searches. A point source producing a flux of $> 5 \times 10^{-10}\ cm^{-2}\ s^{-1}$ above $1\ TeV$ would be detected in one year of operation.

THE SITE AND PROTOTYPE EXPERIMENT

The Kahoolawe Deep ($19.6^o N, 156.5^o W$), a $4.8\ km$ deep subsidence basin $35\ km$ west of Keahole Pt. on the island of Hawaii, is the site of the DUMAND experiment. From 1980 to 1986 eight oceanographic cruises were chartered to study its physical characteristics. The basin sediment is silty clay, flat to $1\ m$ in $1\ km$, and well suited for moorings. Measured ocean currents did not exceed $11\ cm\ s^{-1}$, had typical values of $4-5\ cm\ s^{-1}$, and had an average value of $2\ cm\ s^{-1}$. An unplanned $1.5\ yr$ exposure of a prototype optical module revealed negligible biofouling and sedimentation. Water clarity is as good as the clearest ocean water measured, with attenuation lengths in the blue-green exceeding $40\ m$.

Background light has been extensively studied and is understood. The ambient background flux of about $200\ photons\ cm^{-2}\ s^{-1}$ is dominated by radioactive β-decays of ^{40}K. Decays which produce a > 1 photoelectron signal in a single optical module or correlated signals in multiple modules are rare.

During November of 1987, a Short Prototype String (SPS) of DUMAND optical modules[4] measured the vertical intensity and angular distribution of cosmic ray muons in the deep ocean of the Kahoolawe Deep[5]. This shipboard test demonstrated proof of the DUMAND experimental technique. Pulse-width encoded PMT signals were digitized and multiplexed in a String Bottom Controller (SBC). Detector triggering and data recording were effected aboard the SSP Kaimalino. All data were transmitted via optical fiber.

DUMAND II

The design goal for DUMAND II[6] was 20,000 m^2 of muon area and an angular resolution of order of 1°. The configuration arrived at is an octagon of moored strings, with a ninth string in the center. Each string consists of 24 optical modules, plus laser calibration units, 3 hydrophones, and environmental monitoring instruments. String instrumentation begins 100 m off the bottom with optical modules every 10 m for 230 m and a float package for tension at the string top some 350 m off the bottom.

The 216 optical modules will be a mix of Hamamatsu R2018C and Phillips XP2600 PMTs with 40 cm hemispherical photocathodes, housed in 1.5 cm thick pressure tolerant glass spheres. Each module will have an electronics package with networked reprogrammable microprocessor. PMT high voltage and discriminator settings may be adjusted and verified. Remote monitoring of module conditions, including PMT noise rate, will be provided.

The fast PMT data streams, consisting essentially of time-over-threshold pulses, will travel in parallel down each string riser cable on a multi-mode fiber optic link to a string bottom digitization and multiplexing package (SBC). Pulse start and stop times will be encoded to a 1 ns precision. The signals, including data from hydrophones and calibration modules, will be sent shoreward on single-mode fibers (one per string) at 500 Mbd per channel.

The 12 mm diameter shore cable will have 12 fibers in an insulated and armor jacketed (2 mm diameter) tube, which conductor also serves to transport power to the array (370 VDC delivered, 5 kW with seawater return). Two fibers will be dedicated to the command and control network. All nine strings will be attached to a junction box at the terminus of the 32 km cable which connects the array to the Keahole Point laboratory.

In summer 1992 it is planned to place the first 3 strings on the ocean bottom, employing the SSP Kaimalino, as used for the prototype tests. A subsequent operation, to be carried out with a remotely operated vehicle (ROV), or a research submarine, connects the strings to the junction box. Strings will be removable to facilitate service or replacement. The final

6 strings will be connected the following summer, by which time the software should be well tested on 3 strings, so that data taking should proceed immediately. If all goes as planned, the first high energy neutrino sources could be reported by 1994.

REFERENCES

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