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DUMAND II Status Report

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Abstract

The scientific goals, design, capabilities, and status of the DUMAND II detector system are described. In June, 1989, the High Energy Physics Advisory Panel recommended support for construction of DUMAND II to the U.S. Department of Energy. Funding began in 1990, and prototype development for 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, and expansion to the full 9-string configuration in 1993.

1 INTRODUCTION.

The DUMAND (Deep Underwater Muon and Neutrino Detector) Collaboration is constructing a laboratory for the study of:

1. **high energy neutrino astrophysics**, in particular the detection of galactic and extragalactic point sources of TeV neutrinos;

2. **particle physics**, via indirect observations of UHE hadronic interactions in astrophysical objects as well as direct observations of terrestrial interactions, including studies of neutrino mass and oscillations, dark matter searches and other rare phenomena;

3. **cosmic ray physics**, including single and multiple muon spectra, cosmic ray primary energy spectrum and composition studies;

4. **geophysics and ocean science** issues which can be investigated using data acquired as byproducts of the astrophysical neutrino detector operation. These physics goals have been described in detail elsewhere [1].

DUMAND-II is a water Čerenkov detector containing 9 strings of high sensitivity photomultiplier tubes (Fig. 1), capable of detecting the position and direction of single relativistic charged particles with a uniquely large sensitive volume and an angular resolution of about 1°. Construction of DUMAND II will proceed in two steps: deployment of an initial three-string array (the Triad) in 1992, followed by expansion to the planned 9-string configuration in 1993. The project will be sited in an ocean basin approximately 30 km west of the Island of Hawaii, at a depth of 4700 m.

2 HISTORY AND DETECTOR DESIGN

DUMAND-I refers to the 1987 deployment of a Short Prototype String, (SPS) which validated the basic design of the detector. Results from this experiment, which included the measurements of the depth - intensity relation of high energy cosmic ray muons and their zenith angle distribution at various depths between 2000 m and 4200 m as well as background measurements, have been published [2]. The SPS deployment demonstrated the practicability of the DUMAND system and tested detector module capabilities. In particular, bioluminescence backgrounds, a subject of early concern, were found to be insignificant.

The DUMAND Stage II proposal was submitted in August, 1988, to the US Department of Energy (DOE), and the High Energy Physics Advisory Panel recommended construction in June 1989. Funding from DOE began at the end of April 1990. Construction costs will total about 12 M$, with approximately equal shares provided by US, European and Japanese sources. US groups will be responsible for construction of the shore station, array infrastructure and deployment operations, while the European and Japanese groups will supply the Optical Modules (photomultiplier tubes and fast electronics).

Figure 1 shows the configuration of the planned ocean bottom array. It will consist of a total of 216 Optical Modules (OMs) containing Hamamatsu and Phillips 15" hemispherical PMTs, mounted on nine vertical strings of 24 modules each. The strings are located at the vertices of an equilateral octagon, with the ninth string at its center. The array will have a height of 230 m and a diameter of 105 m. Horizontal and vertical spacings between the modules are 40 m and 10 m, respectively, with the lowest OM approximately 100 m above the ocean floor. The salient features of the array are summarized in Table 1.

The size and geometry of the array have been chosen after extensive monte carlo studies, and represent the simplest and least expensive configuration capable of yielding a reasonable event rate and adequate sensitivity to extraterrestrial high-energy neutrino sources at their expected flux levels. The planned site for the array is about 32 km west of Keahole Point on the Island of Hawaii, at a depth of 4.8 km. This is the location where DUMAND-I was deployed, and the site has been extensively investigated

by ocean scientists over the last decade.

The University of Hawaii operates a laboratory at Keahole Point which will provide shore facilities for DUMAND. The shore station will have communications and control computers, power supply systems, timing standards, data harvesting computers and trigger processor hardware.

The cable, containing 12 single-mode, fully duplexed optical fibers and electrical conductors, supplies power and command signals to the array from the shore station, and transmits data from the strings. The Junction Box (JB) contains voltage regulators and underwater mateable electro-optical connectors for the individual string cables. An Environmental Module attached to the JB (JBEM) includes video cameras and lights to aid in deployment operations, as well as environmental sensors and acoustical locating equipment. Similar EM units (without video systems) are attached to the strings. A field of acoustical transponders will be laid around the array to provide fiducials for locating the strings relative to the celestial coordinate frame. The transponders will be surveyed from the surface, using acoustical ranging techniques and shipboard GPS satellite navigation equipment referenced to nearby shore sites. After deployment of the cable and JB, the strings will be deployed and connected using a Remotely Operated Vehicle (ROV), which will also be required for maintenance. Although replacement of individual OMs would be too costly, provision has been made for retrieval and replacement of strings and critical JB components, and the array will operate satisfactorily with up to 10% of the OMs down.

Individual OM signals provide pulse arrival time (with 1 ns resolution) and integrated charge via fast electronics attached to each tube. The OMs are interfaced to the shore cable by a String Bottom Controller (SBC) which merges these data into the string's 625 Mbd optical fiber data stream, along with environmental sensor data and digitized hydrophone signals from the positioning system.

3 DETECTOR PERFORMANCE AND CAPABILITIES

Muons with energy greater than 50 GeV which pass through the sensitive volume 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 ~1 TeV. Muons will be detected with reduced efficiency and resolution down to about 10 GeV. Contained neutrino induced cascades with energy > 10 GeV will also be detected and reconstructed.

There will be a high rate in the downward direction (zenith angles $\theta <$ 80°) due to cosmic ray muons – decay products of cosmic ray secondaries which are sufficiently energetic to penetrate the water overburden (> 1 TeV at sea level). For zenith angles > 80°, the observed flux will be dominated by muons produced from the interactions of *neutrinos* from the decays of cosmic ray secondaries. These 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°, with solid angle 2.35π steradians. The OMs will thus be optimized for the detection of upward-going events; with the site at latitude 19.6°N, only a small region around the north pole will be permanently obscured by the 80° cut. The

rate for muon events induced by atmospheric neutrinos of energy > 100 GeV will be ~3500 per year, i.e., a background of about one event per $(2.8°)^2$ per year. Thus, with the calculated 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.

Although optimized for up-coming muons from neutrinos, DUMAND will still have a subtantial effective area for downward-going muon events; of these about 2% will be simultaneous multiple muons. Moreover, there are significant daily duty cycle overlaps between DUMAND looking downward and detectors in other parts of the world looking upward, permitting simultaneous observation of astrophysical source candidates in neutrinos, muons and gamma rays [3].

4 STATUS

Current plans call for deployment of the cable, JB and three strings by mid-1992, with the remaining 6 strings to be deployed about a year later. The shore cable was ordered recently and will be delivered in 1991. Prototype PMTs and fast electronics for the OMs are being tested in Japan and Germany. SBC digitizer design is in the final stages in Boston, and JB development is proceeding in Hawaii. Trigger processor hardware and software development is under way in Wisconsin, and prototype calibration modules (scintillator illuminated by pulsed nitrogen lasers, for OM relative timing and water transparency determination) are being tested at Vanderbilt. In Seattle, we are developing environmental module subsystems (hydrophone digitization, JB video system, and environmental sensor readouts) and expect to begin underwater testing of prototypes in early 1991.

5 ACKNOWLEDGMENTS:

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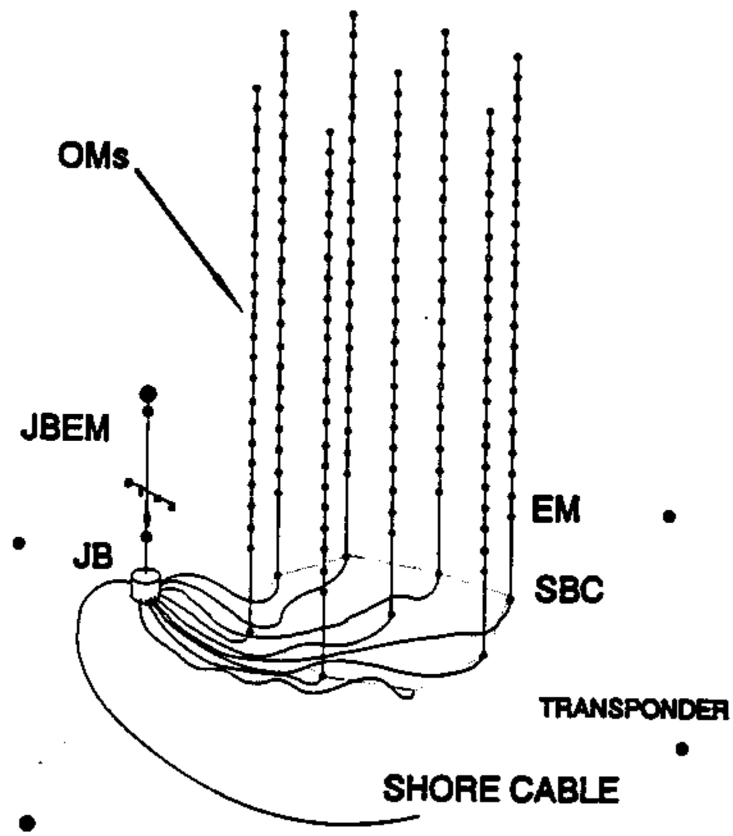

Figure 1: The Dumand II Octagon Array

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
Sensitivity (> 1 TeV, in 1 yr):	
Point sources	$4-7 \cdot 10^{-10}\ cm^{-1}s^{-1}$
Contained events	$1 \cdot 10^{-8} cm^{-2}s^{-1}$