DUMAND Note 80-18

Recent Evolution of the DUMAND Array, and Consequences For Sensor Design

by

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The 1978 Standard Array (1), which represents the principal line of thought in DUMAND until the middle of 1979, contains 22,695 optical sensors, and its cost is entirely dominated by that component (2). Thus, in searching to decrease the overall cost of DUMAND, improvements in sensitivity and reductions in sensor cost have long dominated our thinking. Higher sensitivity means wider spacing, and thus fewer sensors; lower cost per sensor has an enormous multiplier. A savings of $1000 per sensor means a total of $22.6M saved for the 1978 array. Consequently we set ourselves the goals of reducing the cost of each sensor to $1000 (a factor of 2) and increasing the sensitivity to the range of 5-6 photoelectrons per 100 quanta/m^2 incident flux. The Sea Urchin has just about reached those goals, and represents a major technical achievement. Why, then, are we reconsidering more expensive, less sensitive detectors?

The correct answer has nothing to do with the deployment of Sea Urchin*, but rather with the shifting nature of the DUMAND arrays now being considered. Since last summer we have been discussing a mini-DUMAND, which meant a DUMAND small enough to be affordable, but capable of sufficient physics to be worth building. We have now seen that such a design can be achieved, but probably at the cost of giving up extra-terrestrial neutrino astronomy as one of the goals.

As the need to reduce the size and cost of DUMAND grew more urgent, progressively smaller versions have been proposed. The largest size now being contemplated (and generally regarded as too large) is DUMAND G2, with 6615 sensors in an array with about half the data rate of the original DUMAND G, but costing only under $20M (4) At this level, the sensor cost, instead of dominating the whole has dropped to about a third of the total. It is accordingly less critical, although it would certainly make a considerable difference if it were doubled. As the size decreases further, fixed costs assume a larger and larger fraction of the total. At the level of 1000 - 1500 modules, the sensor cost is only one item among many.

Until the 1980 Workshop, systems smaller than G2 had not been considered in detail (they still have not); in fact, it was not until the July 28 meeting of the Steering Committee that the idea was put forth that an upper limit to the cost of DUMAND in the forthcoming proposal should be in the range $5M-10M. It is therefore not surprising, in retrospect, that none of us working on DUMAND noted the important <u>qualitative</u> change in sensor cost requirements implied by the quantitative reduction in number.

*The objections raised to date have been to deployment with the Sea Urchin in the fully extended position; if they prove insurmountable, we need simply return to the original proposal (3) of deployment in a folded position.

Thus, when the new direct-view sensor was proposed (actually, a resurrection of the Learned-Davisson 1975 model) my own reaction was negative, because it clearly did not satisfy the requirements formulated in 1978 on which the Sea Urchin design is based. It was much more expensive, used PMT's that do not exist, and was proposed for the wrong reason: the alleged undeployability of Sea Urchin.

Now, however, having recovered from the initial shock, and having examined the idea in more detail, my attitude has changed; I believe it should be retained as an alternate sensor design to Sea Urchin which, under certain circumstances, might compete seriously with the latter - especially if the required sensitivity for a particular array turns out to be low.* The increase in cost, which I now estimate as at least $1000-1500 per sensor - which would be intolerable in DUMAND G2 or anything larger - can perhaps be tolerated in systems with 1500 sensors or less; it may be partially compensated by increased ease of packaging and handling.

The biggest drawback to our maintaining two lines of approach to the sensor design lies in our severely limited manpower. A way out of that dilemma stems from the need to deploy sensors in the ocean as soon as possible. The direct-view PMT is ideally suited to that, and has been tacitly assumed as the vehicle for that purpose for some time.

Sensor Sensitivity. It will be instructive to list the sensitivities of Sea Urchin and several direct-view sensors. The table which follows has been calculated on the assumption that the sensitivity is defined to be that value of light flux at which the module has a 90% probability of triggering. That is a somewhat more stringent definition than the one we have been using, but it seems more appropriate. We have assumed that the WLS sensor a photocathode efficiency of 10%, and for the direct-view tubes a value of 20%; these are both conservative values. Then, if the threshold for triggering is set at 2 photoelectrons (pe's) we want to know the mean value of a photoelectrons signal for which the chance of not triggering (i.e. getting zero or one pe) is 10%. That value turns out to be 3.9 pe's. For the WLS, with 10% efficiency, this requires 39 photons to reach the PMT photocathode; for the direct-view sensor, with twice the efficiency, only 19.5. Then, knowing the photocathode area (or equivalent area for the WLS sensor) we can find the required incident light flux for triggering.

Table 1 lists for several detectors the cathode areas, incident flux for triggering, resulting sensitivity (defined as pe's/100 quanta/m^2) and also the radial distance R from a minimum-ionizing muon track at which the light flux is just sufficient for triggering. The direct-view PMT's are assumed to have the two PMT's in parallel, not in coincidence. It is readily shown that if they are connected in coincidence, the efficiency for detection, if each tube threshold is set at one pe, drops to 75%.

Table 1. Sensitivity and Triggering Level for Several Sensors.

Sensor	Photocathode area. m^2	Minimum Flux F to trigger (q/m^2)	Sensitivity pe/100 q/m^2	Radius R from minimum ionizing track at which flux = F (m)
WLS				
Sea Urchin	0.6 (equiv.)	65.	6.0	15.5
Direct-View				
2 x 20"	0.395	50	7.85	16.7
2 x 13"	0.161	121	3.22	11.5
2 x 8"	0.0628	310	1.26	7.0
1 x 6"	0.0165	1180	0.331	3.3

There may be some problem in persuading the PMT manufacturers to carry out development of as many as three different research projects for DUMAND: the original high-gain first-dynode 8" hemispherical PMT for Sea Urchin (which is now well advanced); a 20" hemispherical tube for a high-sensitivity direct-view PMT sensor; and the proposed cylindrical "hot-dog" tube.

References

1. "1978 Standard Array", by A. Roberts and G. Wilkins, Vol.3, p. 9, Proc. 1978 DUMAND Summer Workshop, LaJolla, CA., 1979, G. Wilkins, ed.

2. Ibid.,"Workshop Summary and Array Costs," by G. Wilkins, Vol. 3, p.171

3. "The Sea Urchin Module I. Survey of Design Problems", D. McGibney and A. Roberts, DUMAND Note 80-13, July 1980.

4. Proposed 1980 DUMAND Standard Array", by A. Roberts and G. Wilkins, DUMAND Note 80-11, Hawaii DUMAND Center, July 1980.

*More attention needs to be given to the proposed coincidence mode of operation, which results in a high background rate more difficult to handle than the large-pulse background of single-tube detectors.