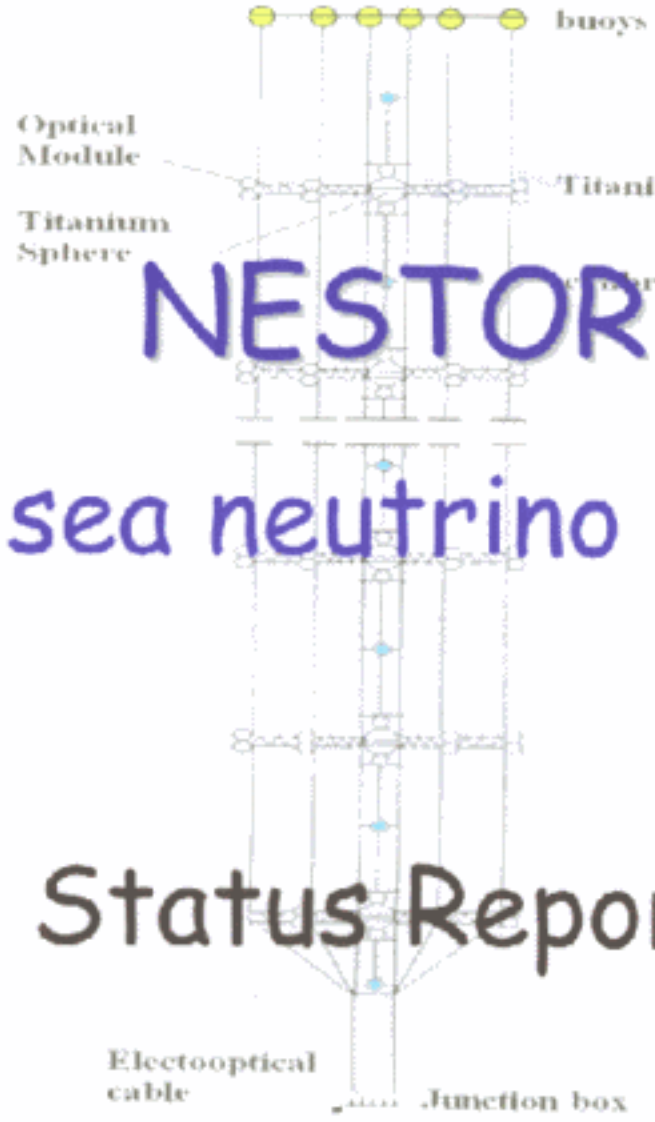
S. E. Tzamarias



NESTOR

a deep sea neutrino telescope

Status Report

NESTOR

NEUTRINO EXTENDED SUBMARINE TELESCOPE WITH OCEANOGRAPHIC RESEARC

GERMANY

Institute for Geophysics
University of Hamburg
Institute of Experimental and Applied Physics
Center for Applied Marine Sciences
Research and Technology Center West - Kueste (FTZ Buesum)
University of Kiel

GREECE

Physics Dept.
University of Athens
Institute for Geodynamics
Athens Observatory
Physics Dept.
University of Crete
Institute for Nuclear Physics
Institute of Informatics and Telecommunications
NCSR DEMOKRITOS
National Science Foundation
NESTOR Institute For Deep Sea Research, Technology
and Neutrino Astroparticle Physics
Physics and Astronomy Dept.
University of Patras
HELLENIC OPEN UNIVERSITY

RUSSIA

Experimental Design Bureau of Oceanological Engineering
Institute For Nuclear Research
Russian Academy of Sciences

SWITZERLAND

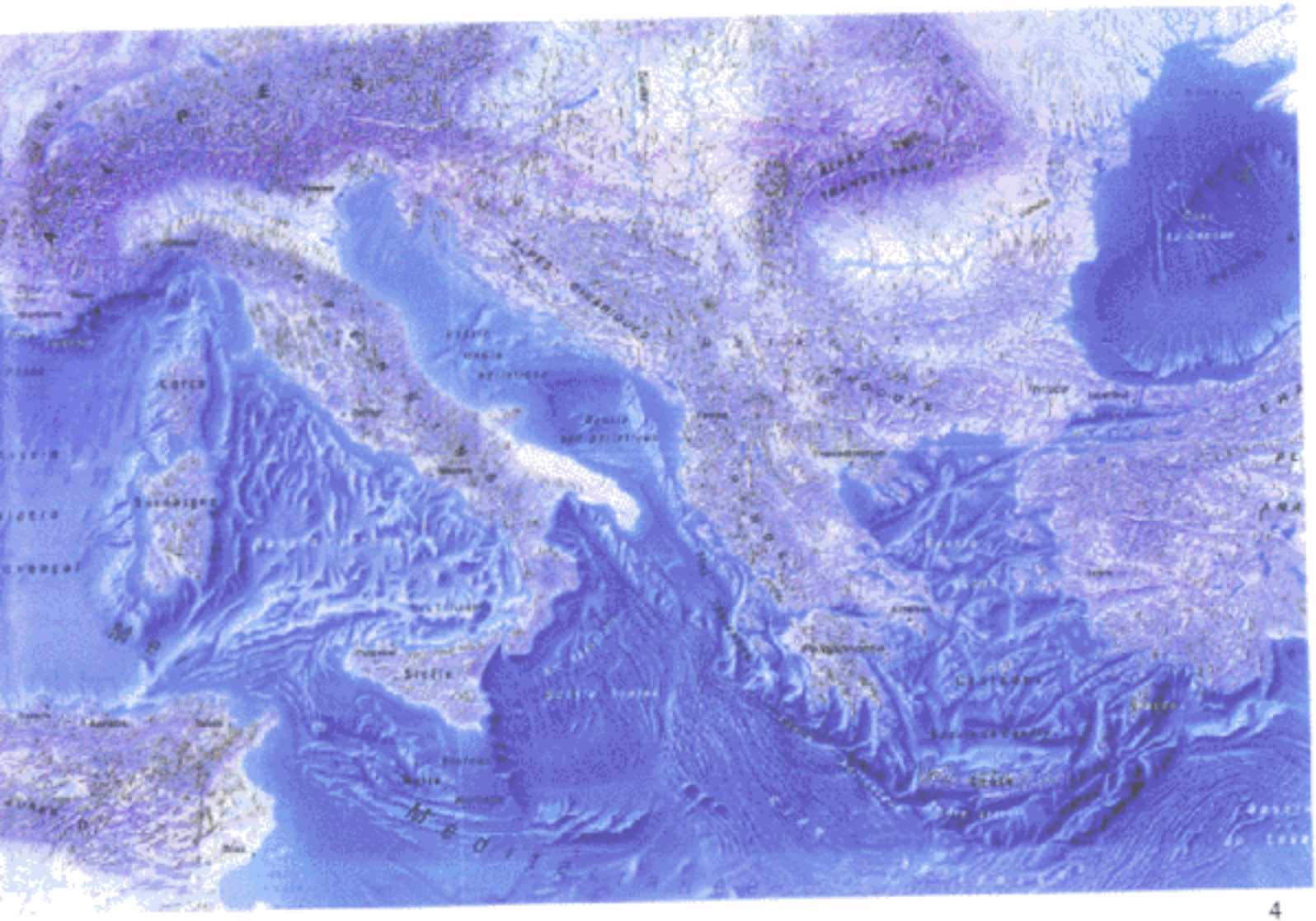
Physics Dept.
University of Bern

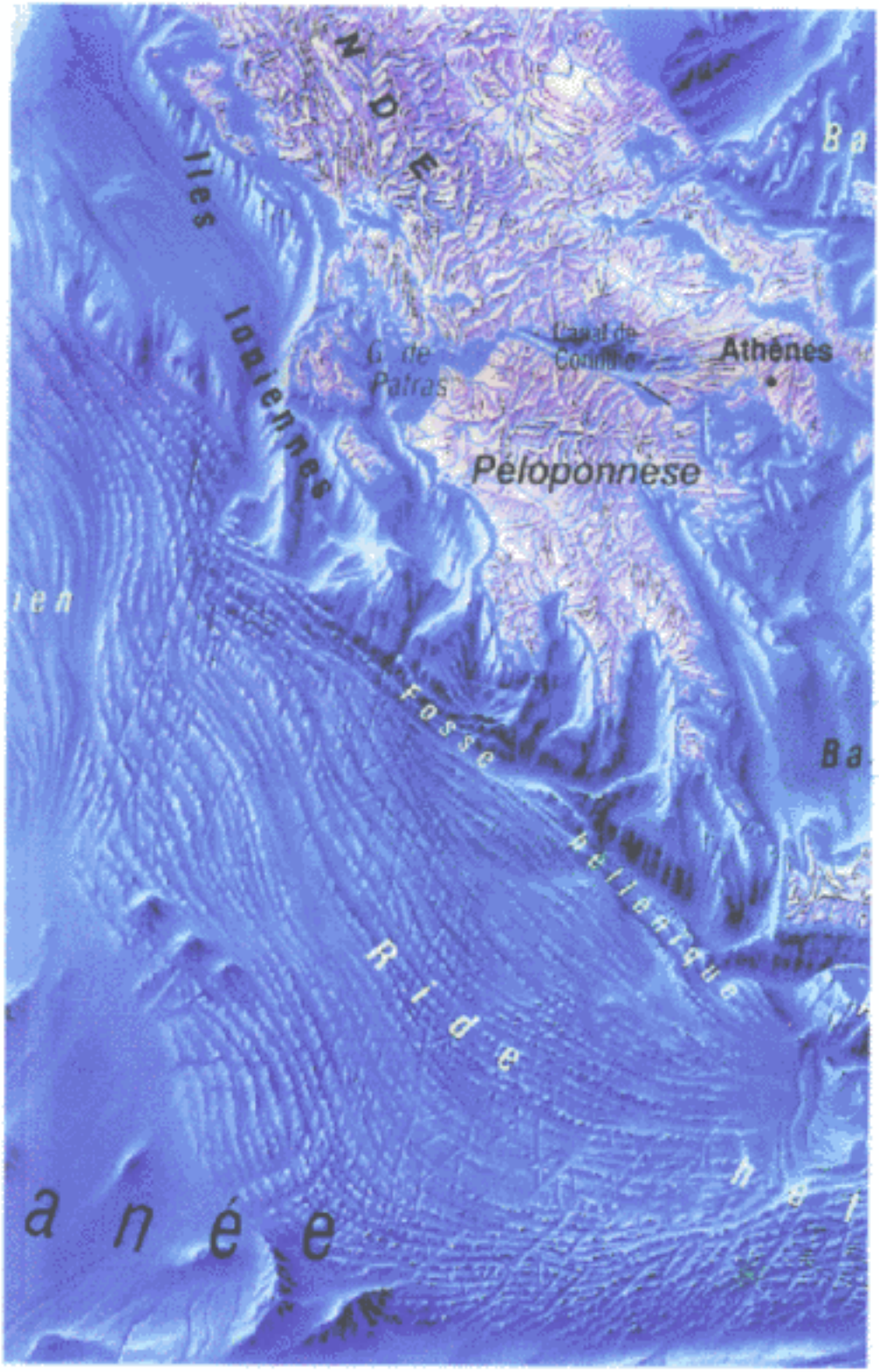
U.S.A.

Dept. of Physics and Astronomy
University of Hawaii
Lawrence Berkeley National Laboratory

MARINE TECHNOLOGY COLLABORATORS

GERMANY	ALU-BAU, Buedelsdorf GeoPro mbH GISMA GmBH
GREECE	Hellenic Telecommunications Organization (OTE) Marine Technology Development Company (EANT) National Centre Marine Research (NCMR) Institute for Marine Biology of Crete Kourtis Salvage Ltd Naval Engineering Dept. , Athens Technical University
USA	MAKAI Engineering, Hawaii Scripps Institution of Oceanolgraphy, La Jolla, California


Alpes Transylvanie
Alpes Cimmériennes
Corse
Sardaigne
Sicile
Crète
Chypre
Mer Egée


N D E
Iles Ioniennes
G. de Patras
Canal de Corinthe
Athènes
Péloponnèse
Fosse hellénique
Ride
Ba
Ba
ien
a n é e
h e l

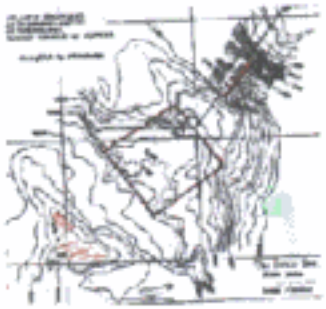
NOTE

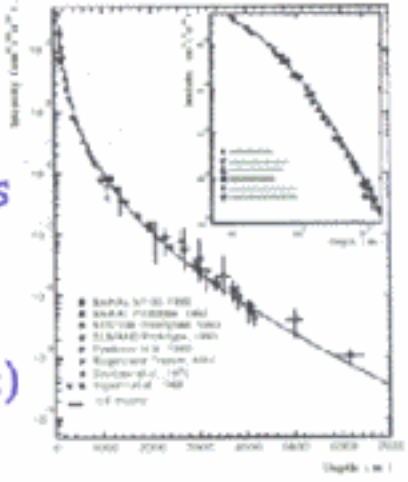
4 HARBOURS

DISTANCE 8 – 15 miles

Site characteristics

- a broad plateau: 8x9 km^2 in area, 7.5 nautical miles from shore
- depth: 3800m ± 50m
- transmission length: 55 ± 10m at λ=460 nm
- underwater currents: <10 cm/sec measured over the last 10 years
- optical background: 75 kHz/OM due to K40 decay, bioluminescence activity (1% of the experiment live time)
- sedimentology tests: flat clay surface on sea floor good anchoring ground.





ISOBATHS

CONTOURS OF EQUAL DEPTH

The lighthouse of Sapientza
will be the counting room.
Then the data will be transmitted
to PYLOS by cable or microwave link.

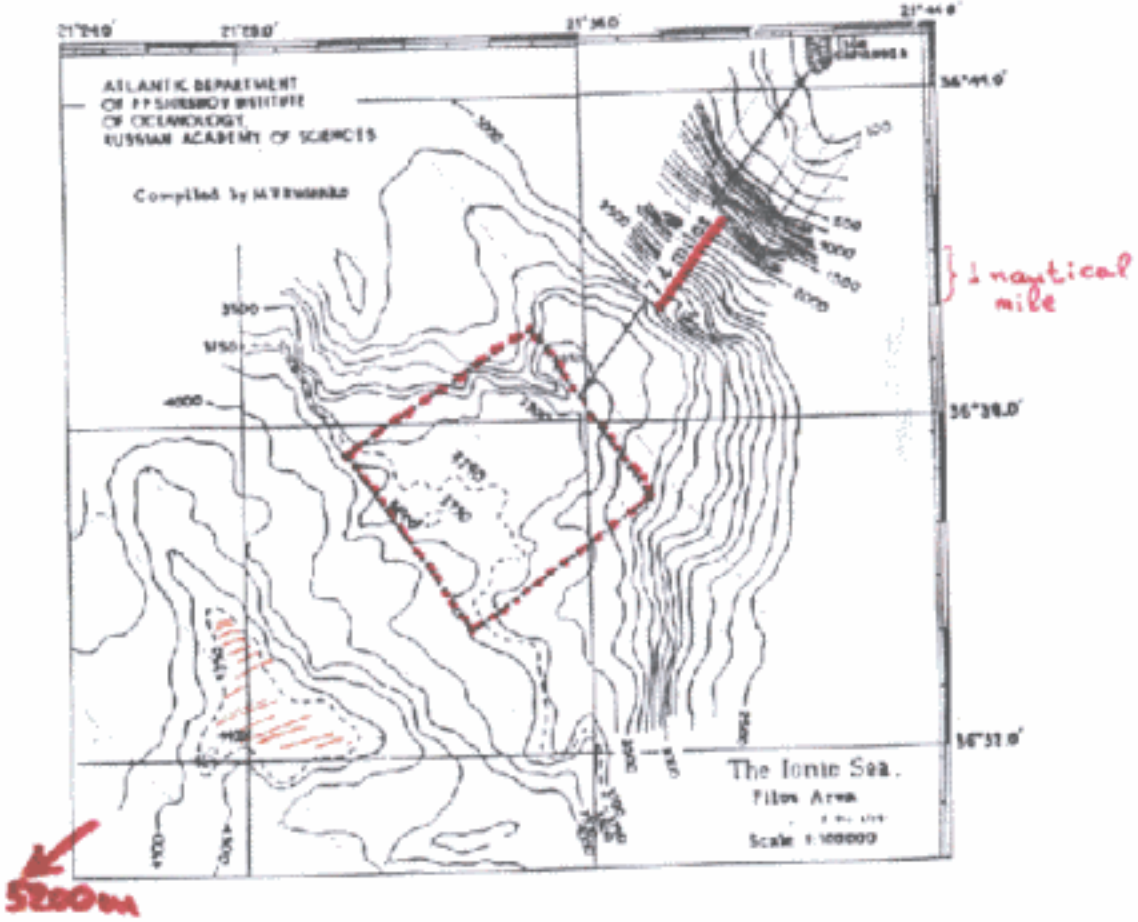


Figure 2

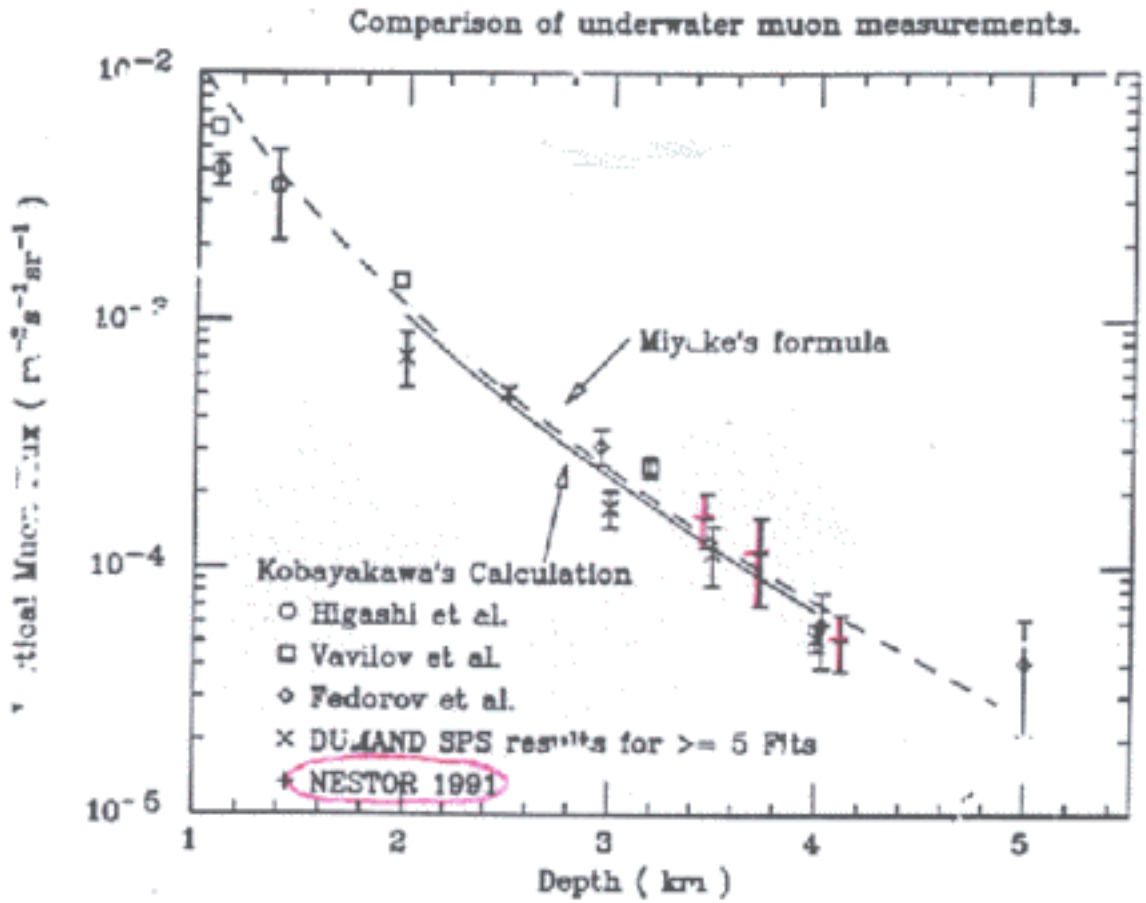

Comparison of underwater muon measurements.
Miyake's formula
Kobayakawa's Calculation
Higashi et al.
Vavilov et al.
Fedorov et al.
DUMAND SPS results for >= 5 Fits
NESTOR 1991
Depth (km)

Fig. 13

DESIGN CONSIDERATIONS

NO BATHYSCAPHS - NO ROVs

NO HIGHLY SPECIALIZED SURFACE VESSELS

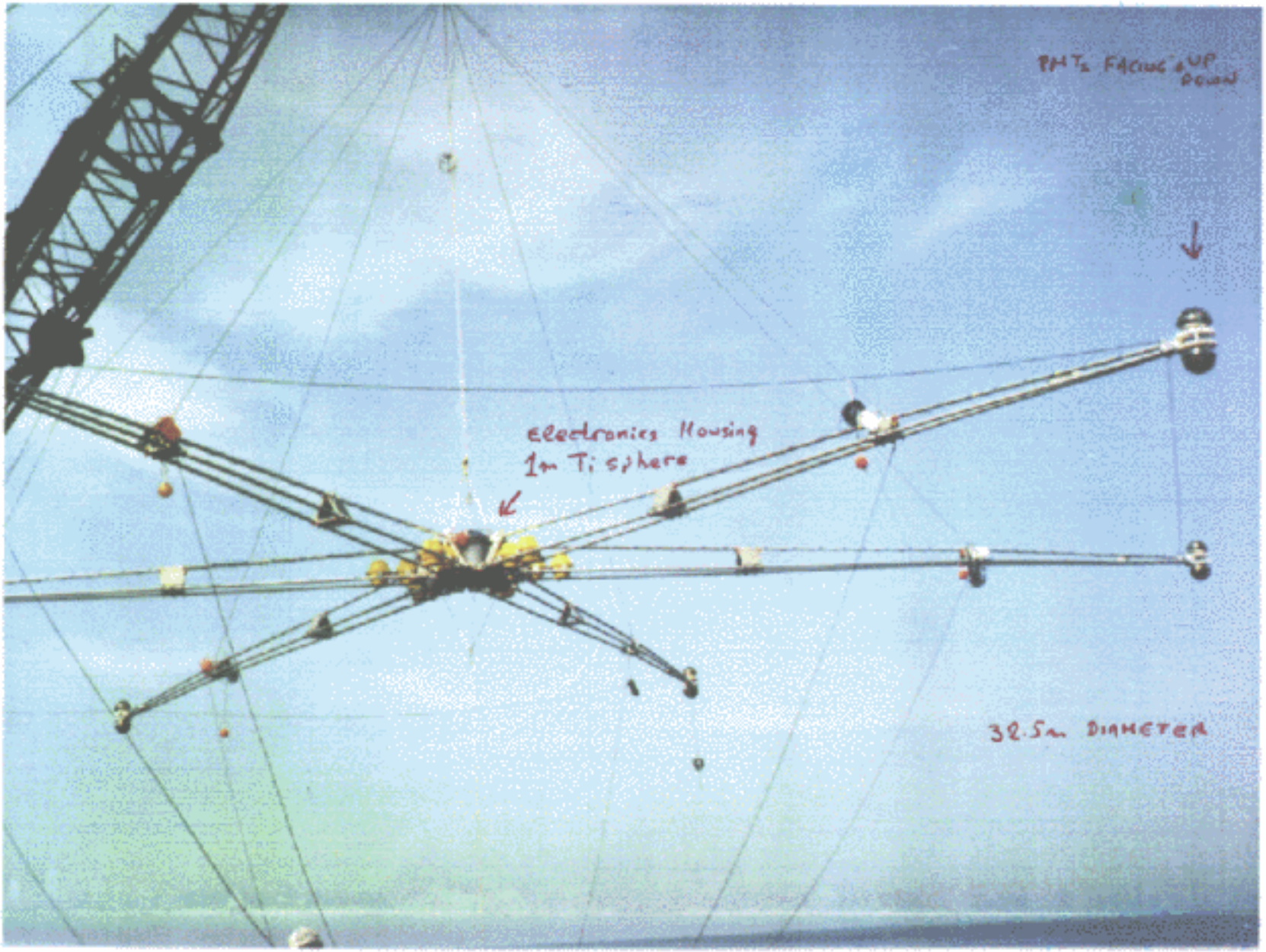
ALL CONNECTIONS TO BE MADE IN THE AIR

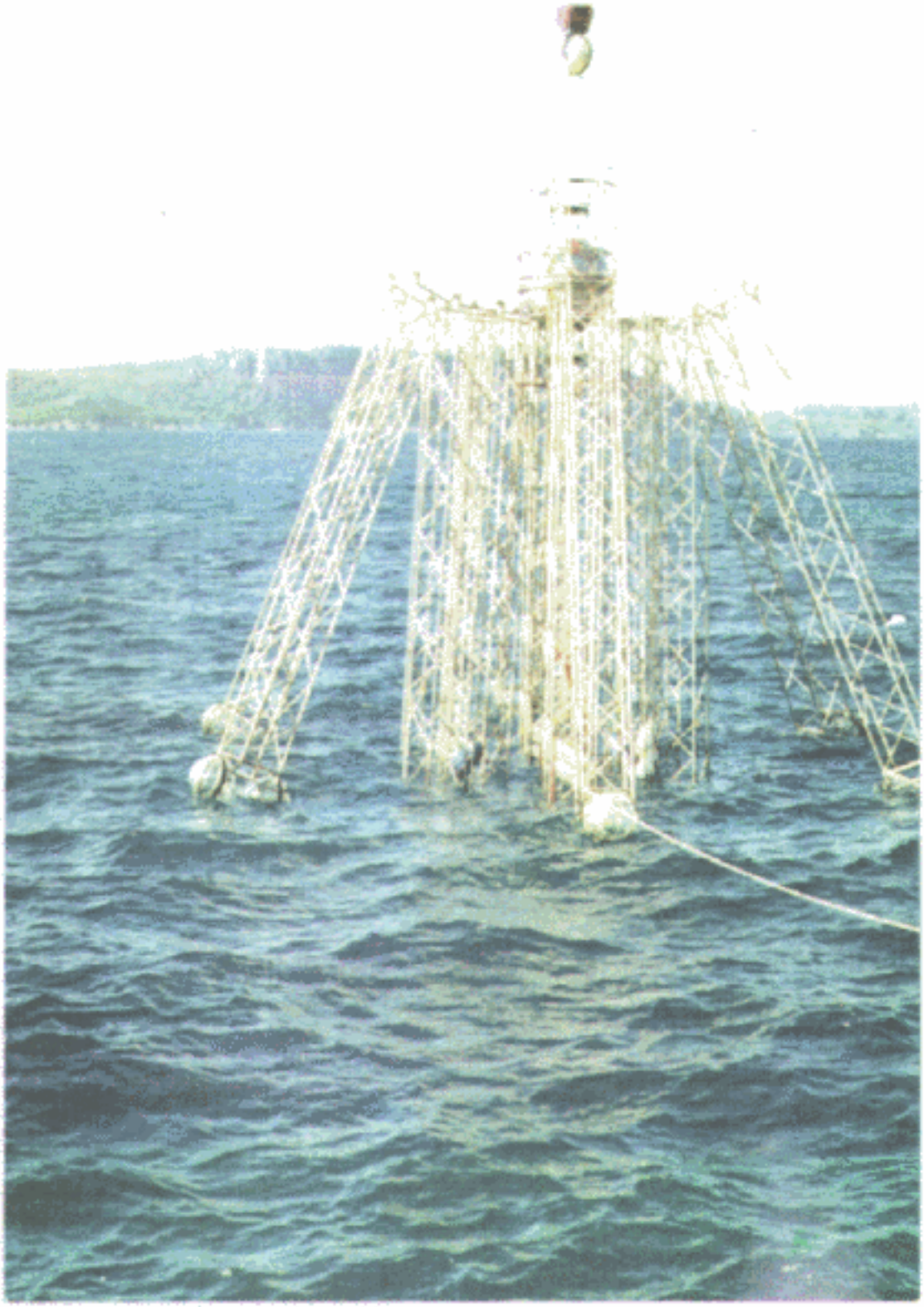
MINIMUM NUMBER OF CONNECTORS

AS PASSIVE A SYSTEM AS POSSIBLE
(Triggering on the shore)

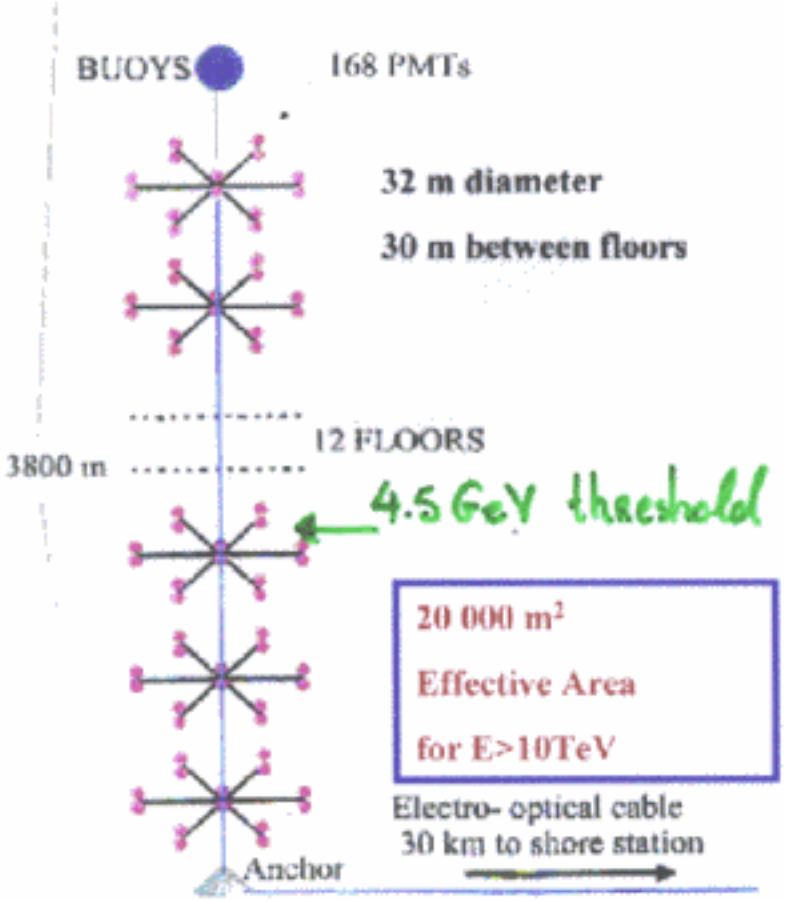
MODULAR SYSTEM WITH BUILT IN REDUNDANCY

RETRIEVABLE AND EXPANDABLE

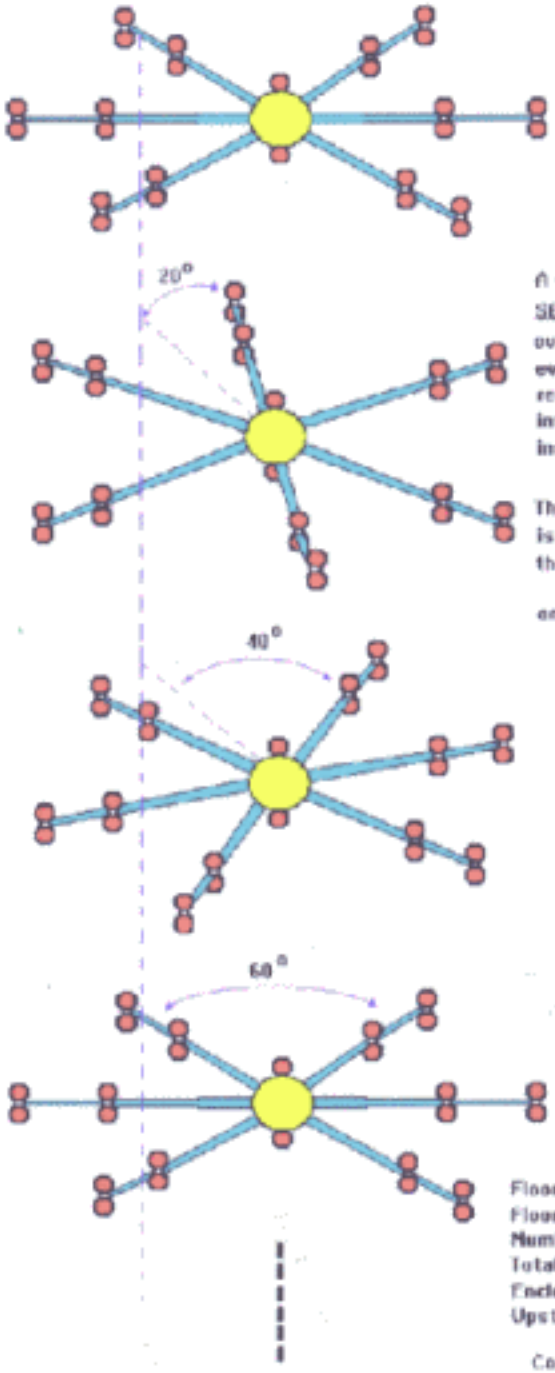

PMTs FACING UP
Electronics Housing
1m Ti sphere
38.5m DIAMETER



NESTOR TOWER



NESTOR - Part of a Twisted Tower (2 rings of PMT's)



ADD 1 RING
OF PMTs TO THE
TOWER WE HAVE
CONSTRUCTED
NOW
+
5m INTERFLOOR
SPACING
+
TWIST

NOTE

A water Cherenkov in the SEA has the advantage over other detectors that events can easily be reconstructed if they interact outside the instrumented volume

therefore:

The fiducial volume is much larger than the instrumented one

and

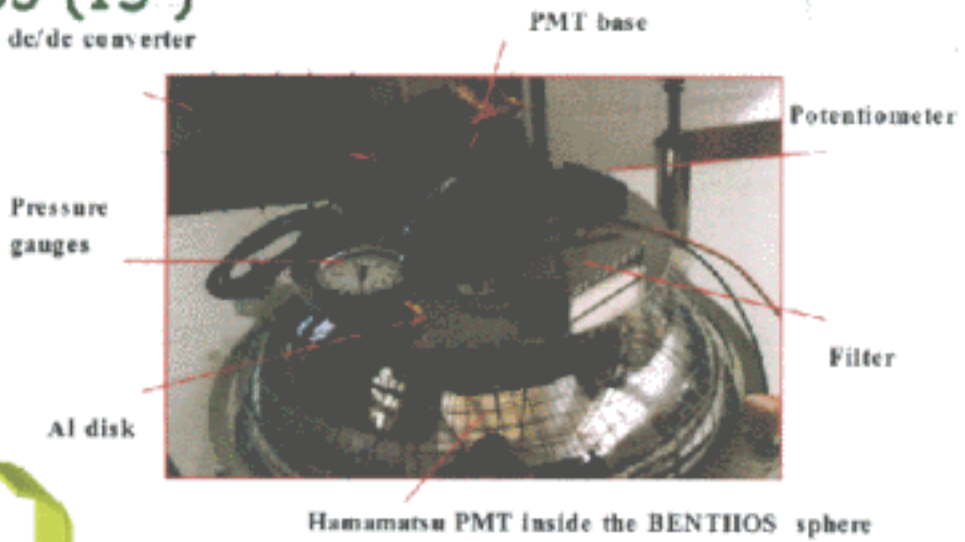
one can have an active veto

Floor radius: 16 m
Floor separation: 5 m
Number of floors: 12
Total No of PMTs: 312
Enclosed mass: 45 ktons
Upstream sensitive mass: ~ 70 ktons
Cost: ~ 4 M$

100 ktons

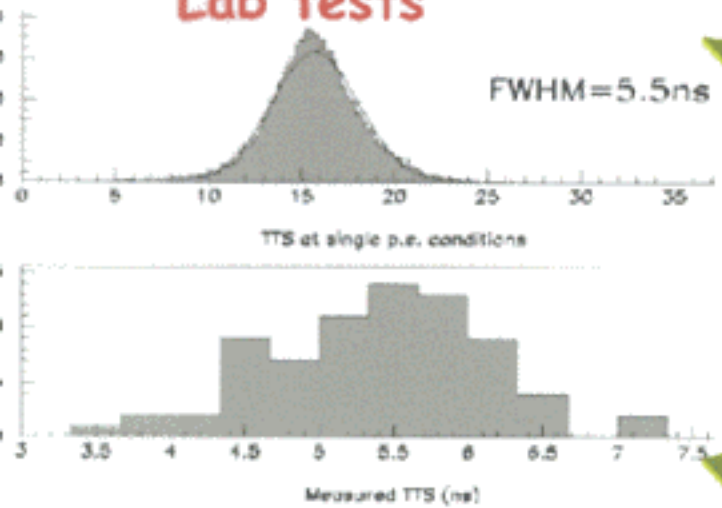
The Optical Module

- Hamamatsu PMT R2018-03 (15")
- Benthos spheres
- μ-metal cage
- power supply



Hamamatsu PMT inside the BENTHOS sphere

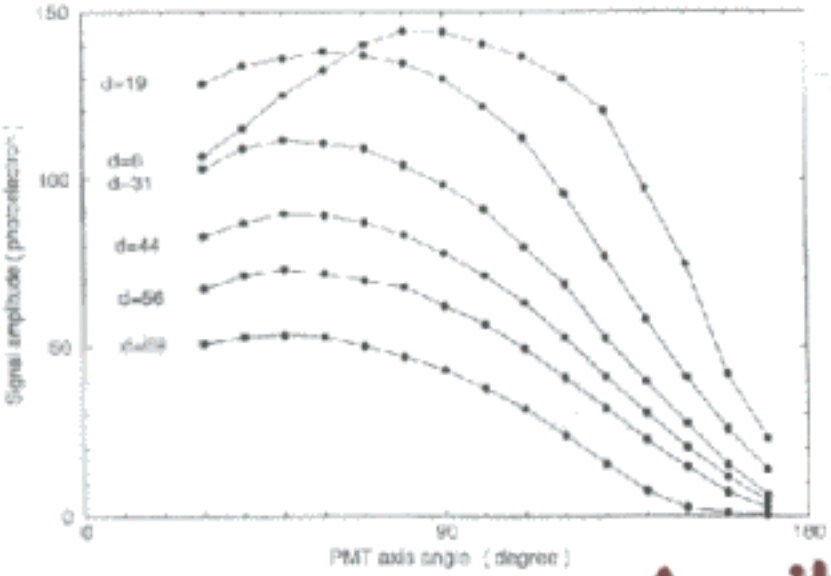
Lab tests



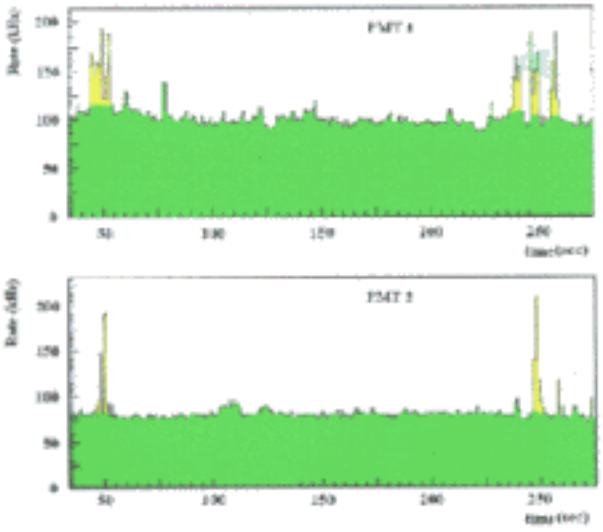
Single p.e. conditions

Beam tests

Muons CERN



Deep water tests



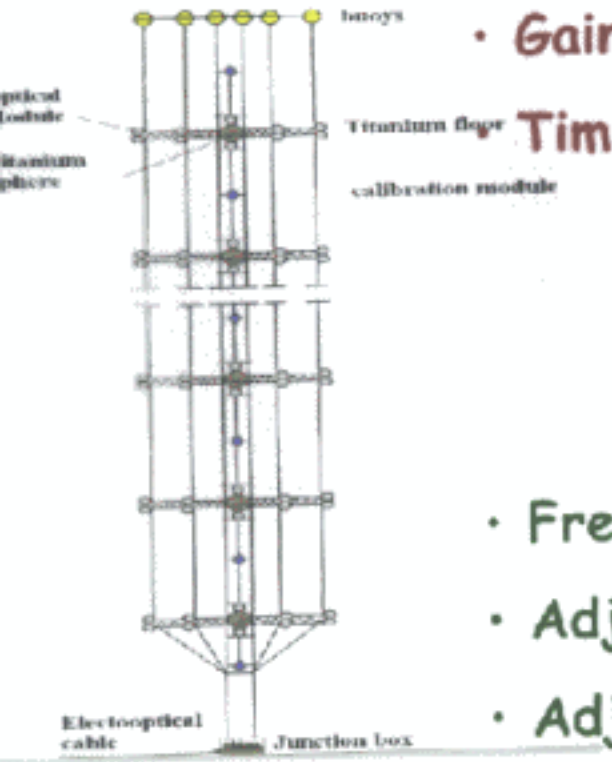
Available

248 Hamamatsu R2018-03 (15") PMT's

350 Benthos spheres

8 (3Al & 5Ti) floors

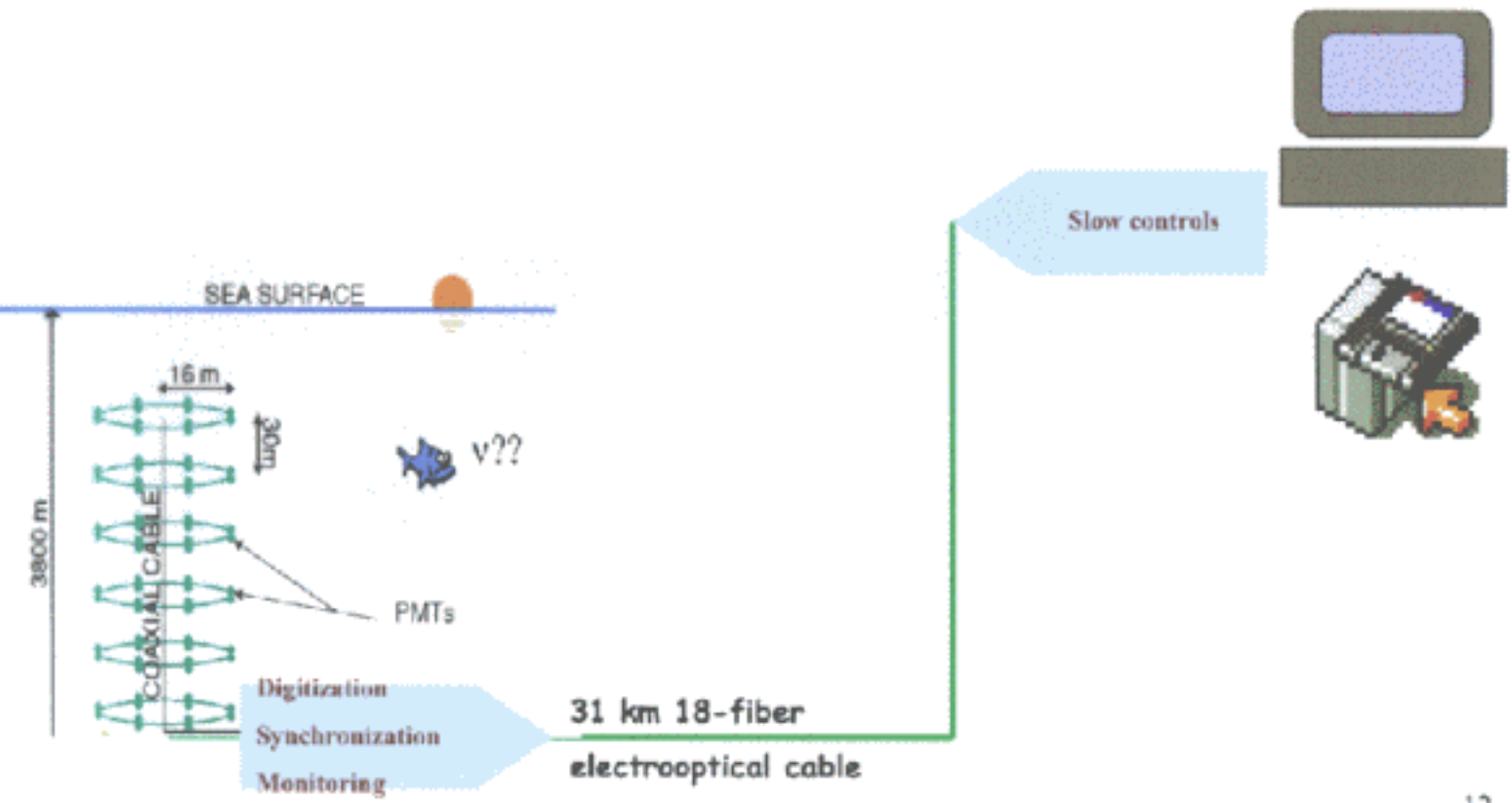
Calibration



- Gain monitoring
- Timing

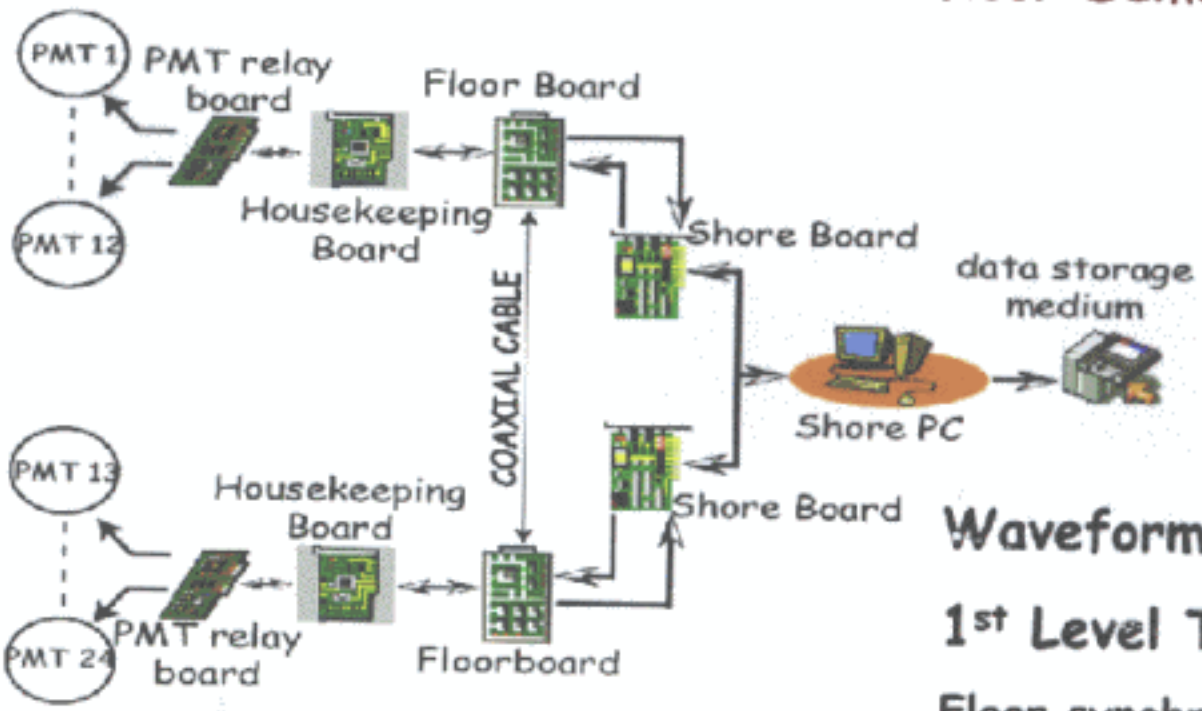
- Free running Calibration Trigger
- Adjustable Trigger frequency
- Adjustable LED's light output

Electronics & DAQ



NESTOR DAQ

2-floor Demonstrator



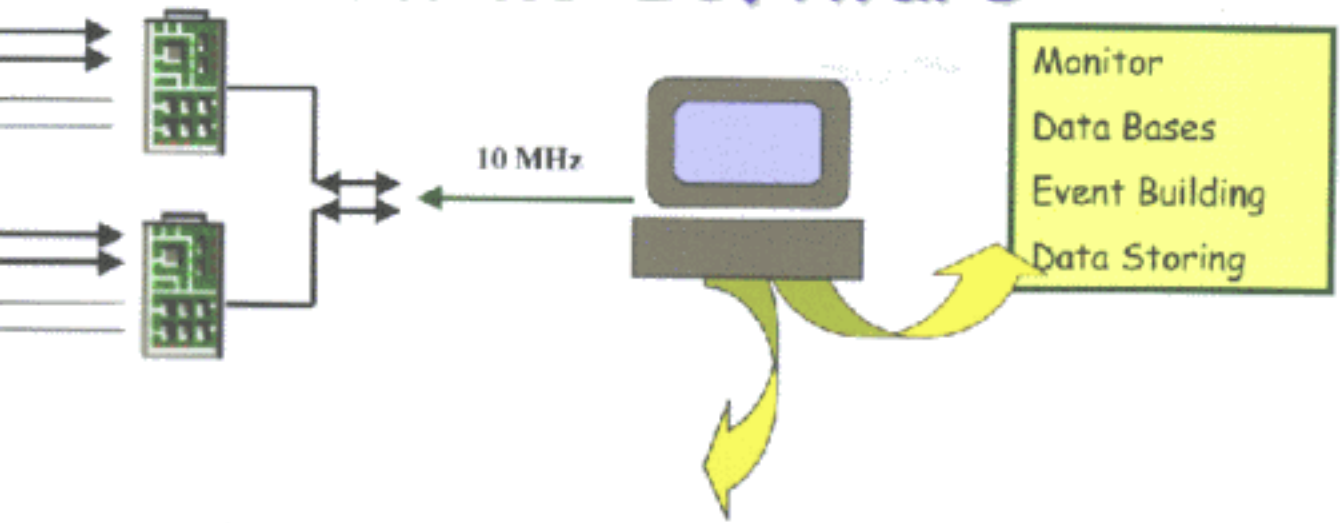
Waveform capture

1st Level Trigger (adjustable)

Floor synchronization

Slow Control/Monitoring

Online Software



Control (set the F/B registers)

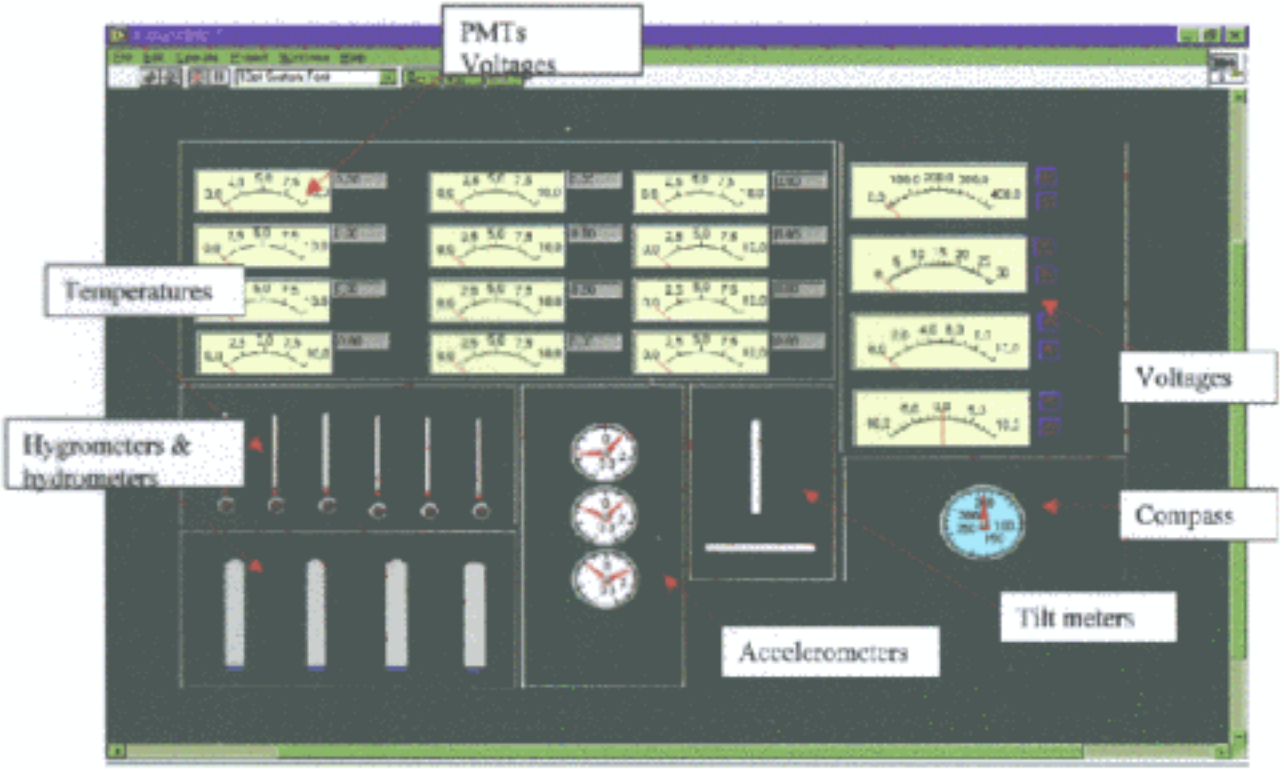
Define

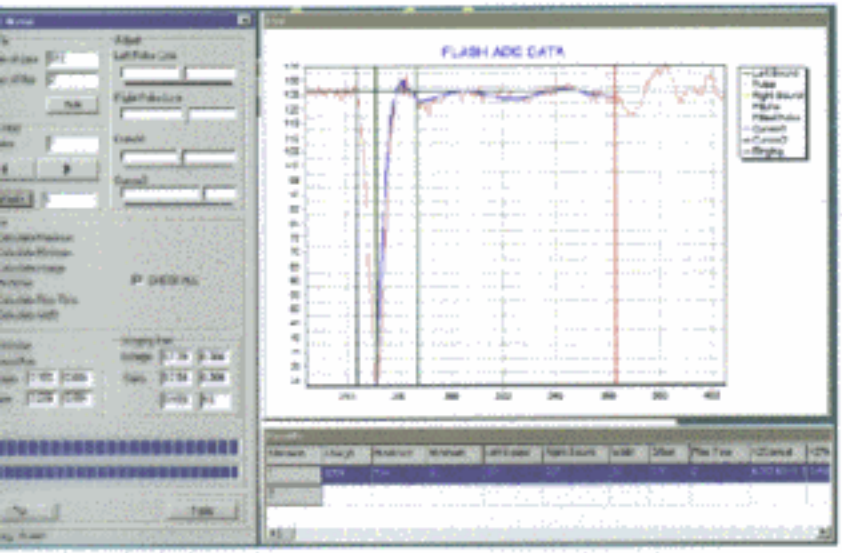
Experimental Parameters (FPGA)

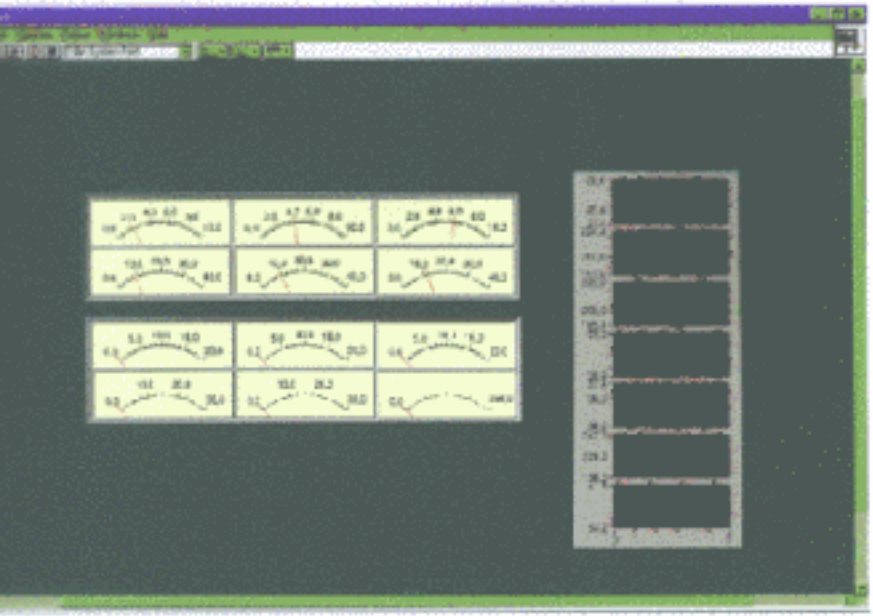
Run Status (Stop - Calibration - Run)

Update Electronic Logbook

Monitor Environmental Conditions

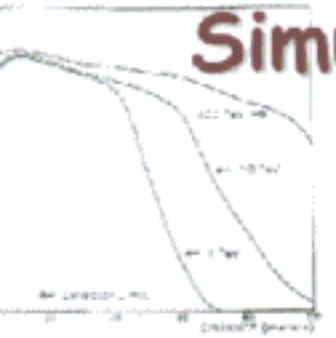






Monitor PMT Rates and PMT Performance

Simulation and Analysis Effort



BEOWULF CLUSTER

32 PCs, each one with:

dual processor INTEL III @ 500 MHz).

128 MB of RAM, 13 GB HD

2 FAST-Ethernet Cards.

Interconnection via Fast-ethernet switches

Monte Carlo Production (studies)

Transition to C++

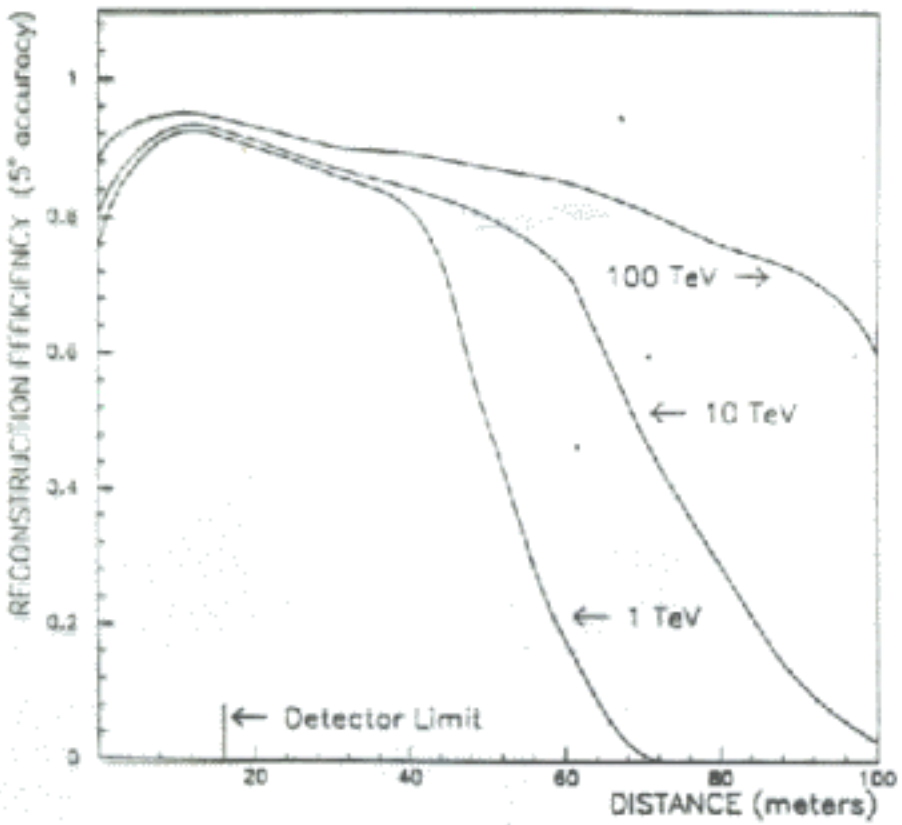


Figure 5. Reconstruction efficiency versus distance from the axis of tower (vertical incidence of muons) for one NESTOR tower (5° reconstruction accuracy).

The Real Game: Deployment

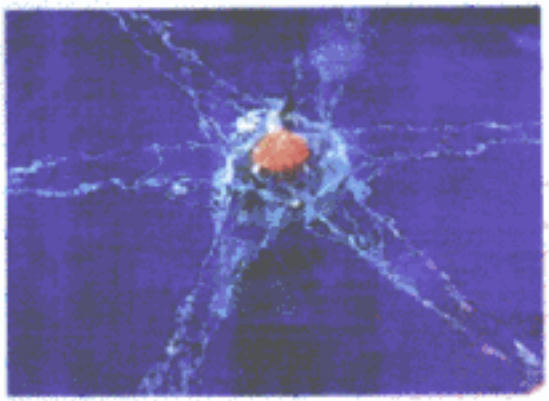
ElectroOptical cable to shore (18 fibers +1 conductor)

Deployed in June 2000 by the cableship MAERSK-FIGHTER (ALCATEL- TELEDANMARK)

Cable was damaged during laying because of ship's problems. ALCATEL accepted responsibility and will repair the cable.

Cable landing has been completed and first three km have been buried 2 m inside the bottom sand.

Methoni counting room is fully operational.



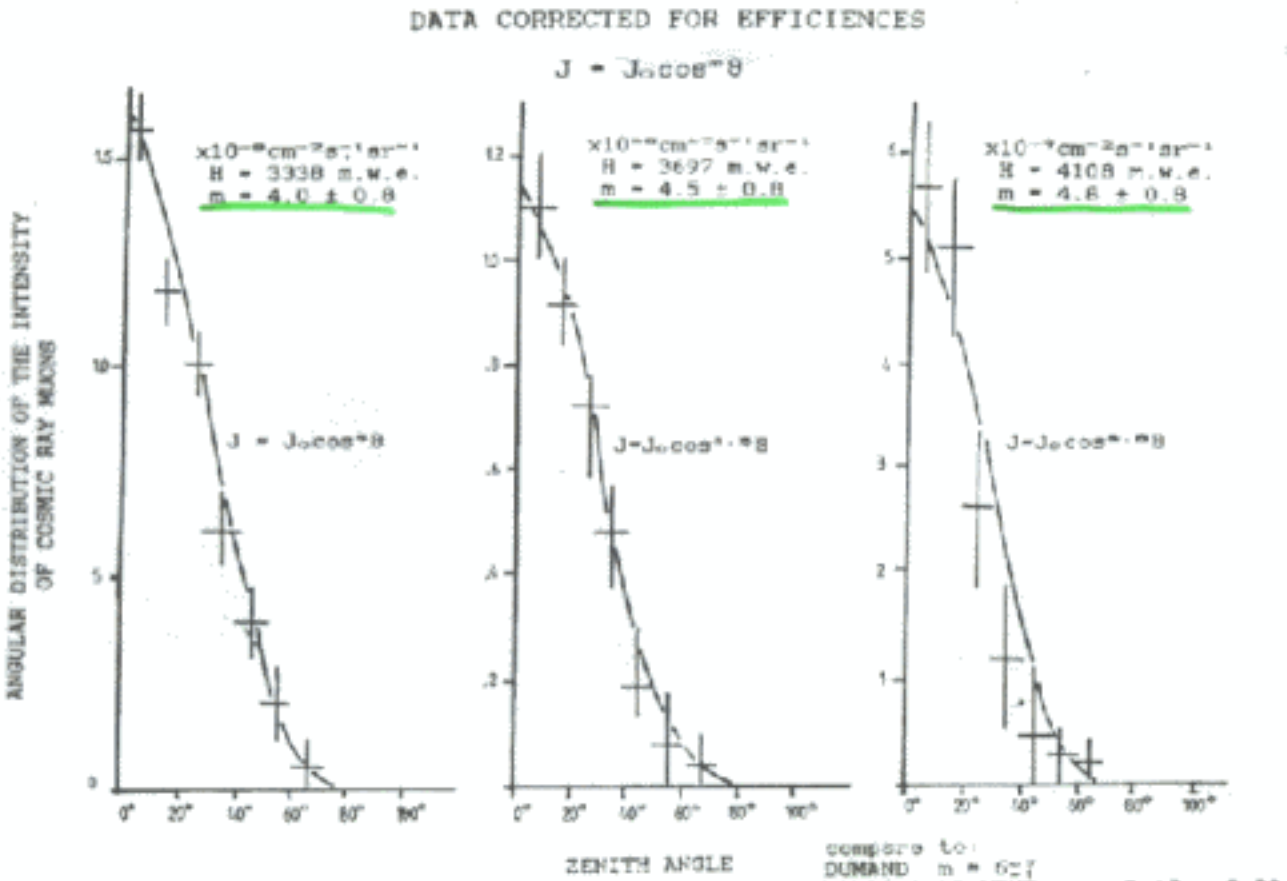
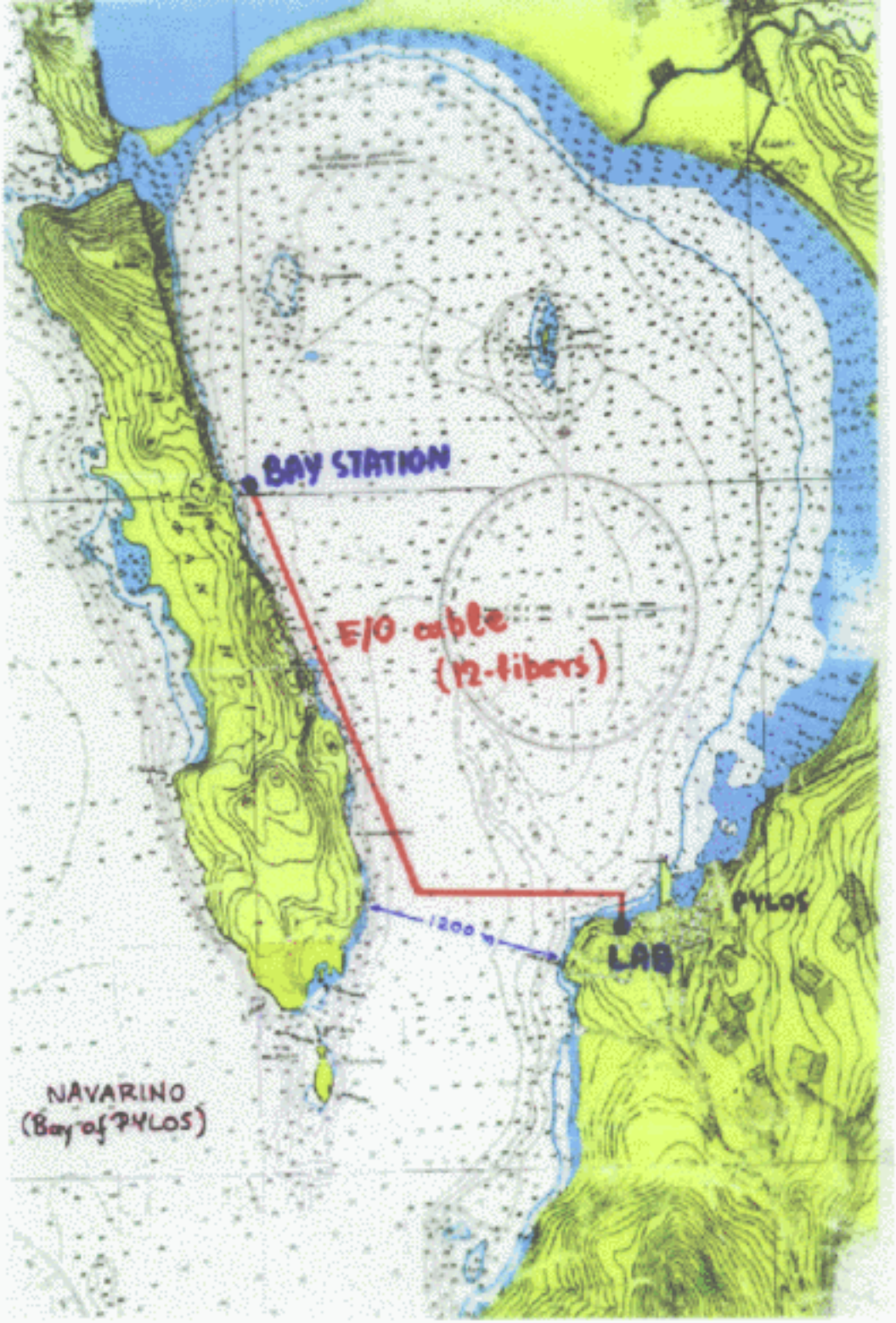

DATA CORRECTED FOR EFFICIENCES
J = J₀cos^m θ
ANGULAR DISTRIBUTION OF THE INTENSITY OF COSMIC RAY MUONS
x10^-13 cm^-2 s^-1 sr^-1
H = 3338 m.w.e.
m = 4.0 ± 0.8
J = J₀cos^m θ
x10^-13 cm^-2 s^-1 sr^-1
H = 3697 m.w.e.
m = 4.5 ± 0.8
J = J₀cos^m θ
x10^-13 cm^-2 s^-1 sr^-1
H = 4108 m.w.e.
m = 4.8 ± 0.8
J = J₀cos^m θ
0° 20° 40° 60° 80° 90°
ZENITH ANGLE
compare to:
DUMAND m = 6±7
KOLAR GOLD MINE m = 5.12 ± 0.82

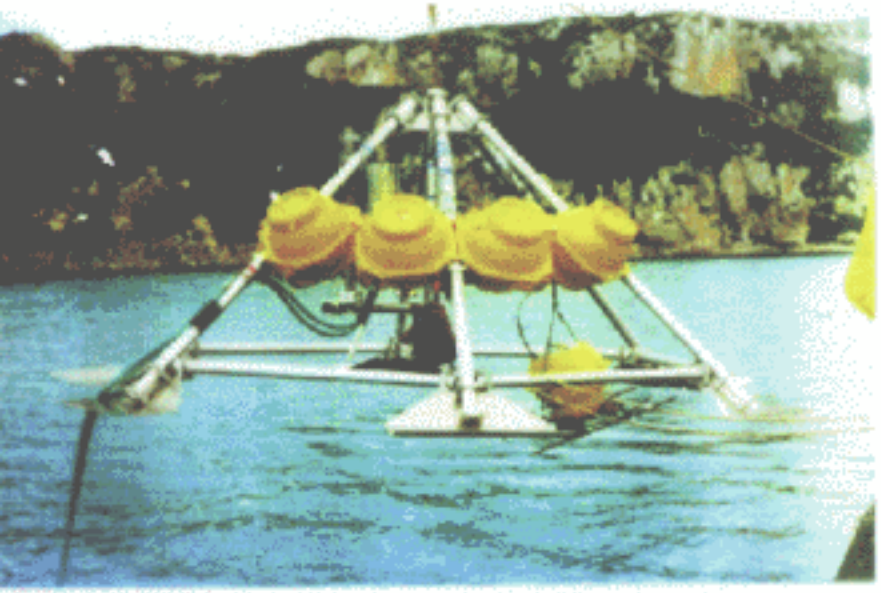
Fig. 11

NESTOR Institute

for Deep Sea Research, Technology and Neutrino Astroparticle Physics

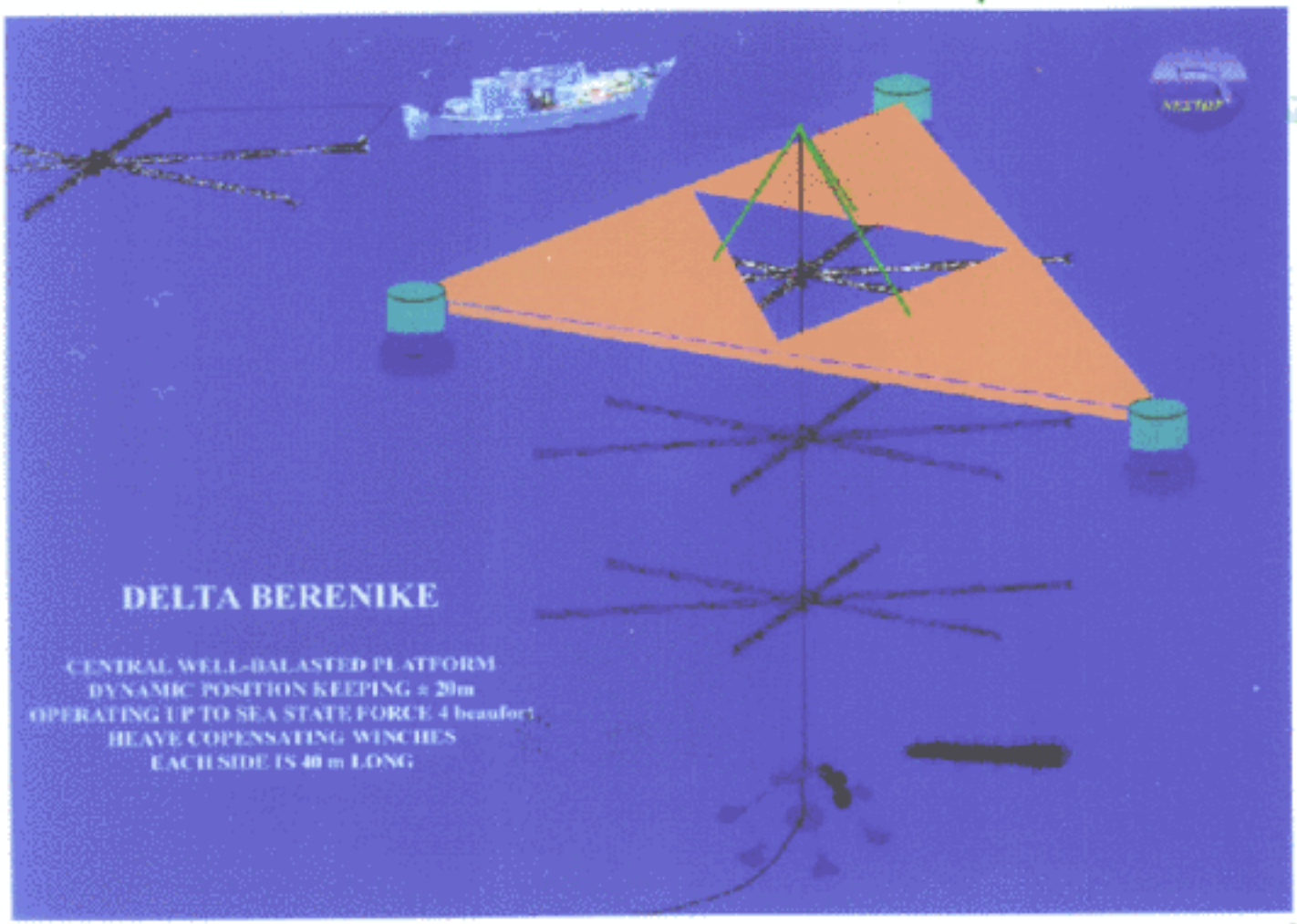
- Bay Test Station
- Counting Rooms
- Vessel Infrastructure
- Electronics Lab
- ElectroOptics Lab
- Full Machine Shop
- Computing Facilities

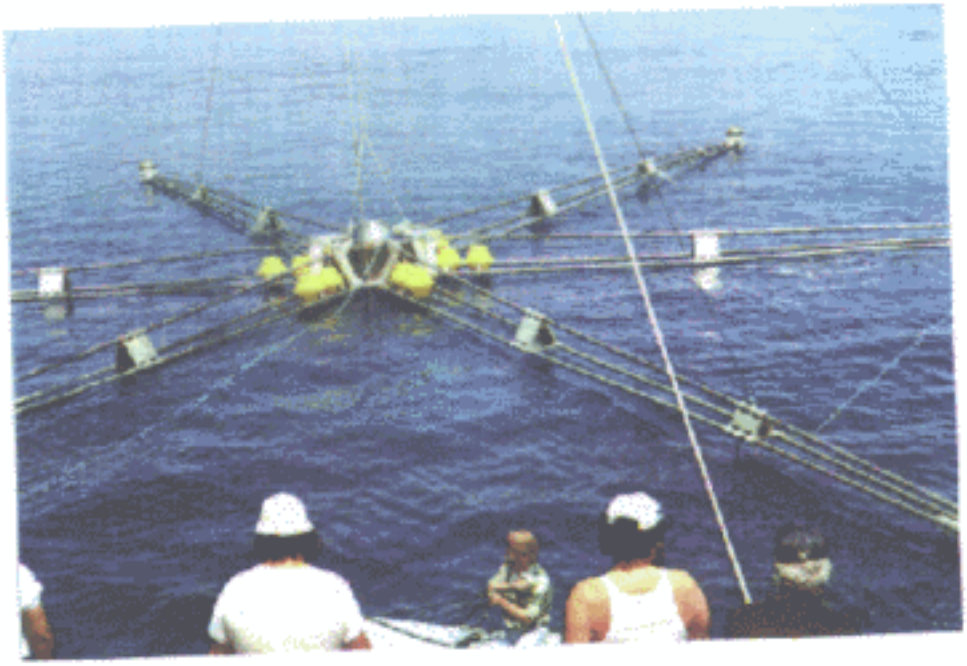

BAY STATION
E/O cable
(12-fibers)
1200
PYLOS
LAB
NAVARINO
(Bay of PYLOS)



Bay Test Station

Under Construction (will be operational at Pylos this summer)





Full Machine Shop

Ti floor

Status

Main Components	Need (1 tower)	Have
PMTs (15")	168	248
Benthos spheres	268	350
Mechanics (floors)	12	8 (3 Al & 5 Ti)
Electronics (floor module)	12	Production phase
ElectroOptical cable to shore 18 fibers+1 conductor	1	Will be rectified by Spring 2001

3 built in Pylos

Time Scale

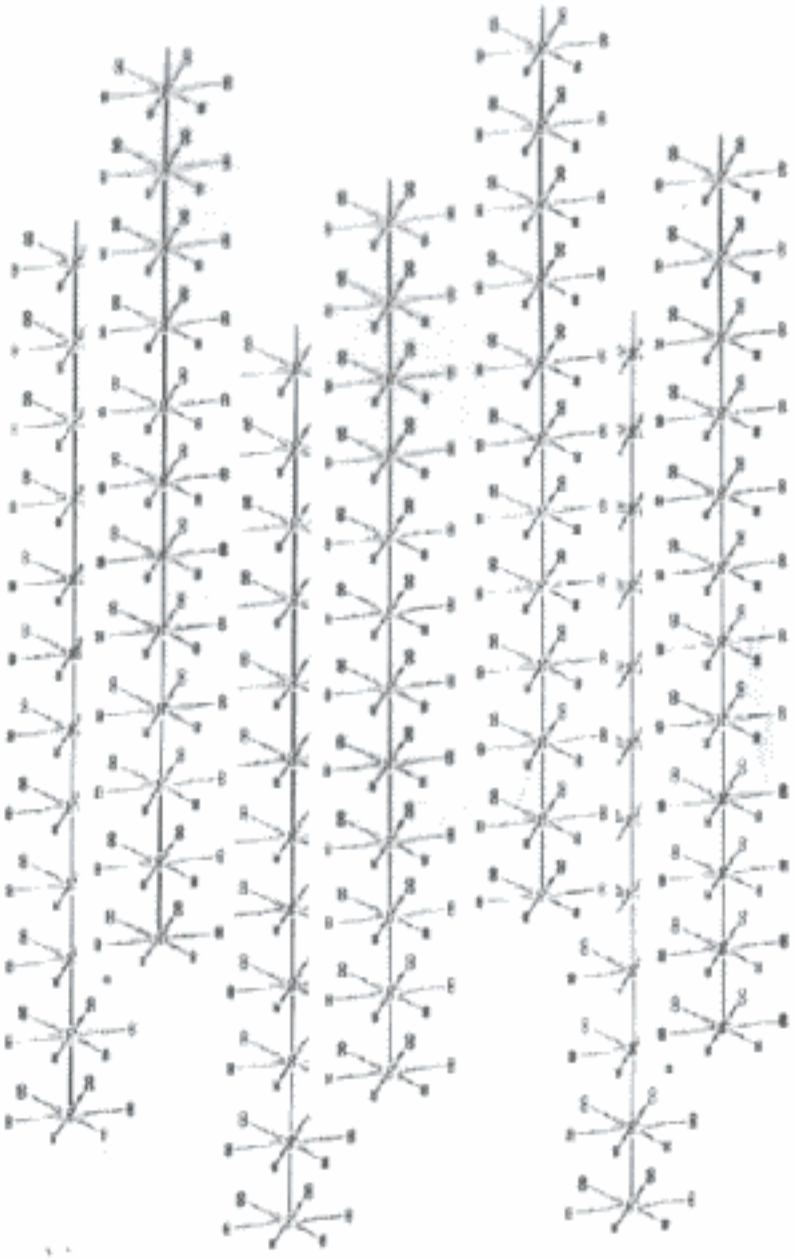
Spring 2001
Cable rectification & acceptance tests (OTE/ALCATEL)
Electronics tests in Lab & Bay Test Station

Summer 2001
Deep-sea deployment & run 2-floors
Physics Test Run

Autumn 2001
Recovery & re-deployment with 4-floors
Physics Run

2002
Full tower deployment in deep sea
Physics Data Taking
Enlarge collaboration

2003 ⟶
Deployments of more towers
e.g. 7 towers (1176 PMT's)
- 1.8 Megatons of DENSILY instrumented mass within the 7 towers (i.e. few GeV threshold)
- 25 Megatons of enclosed mass

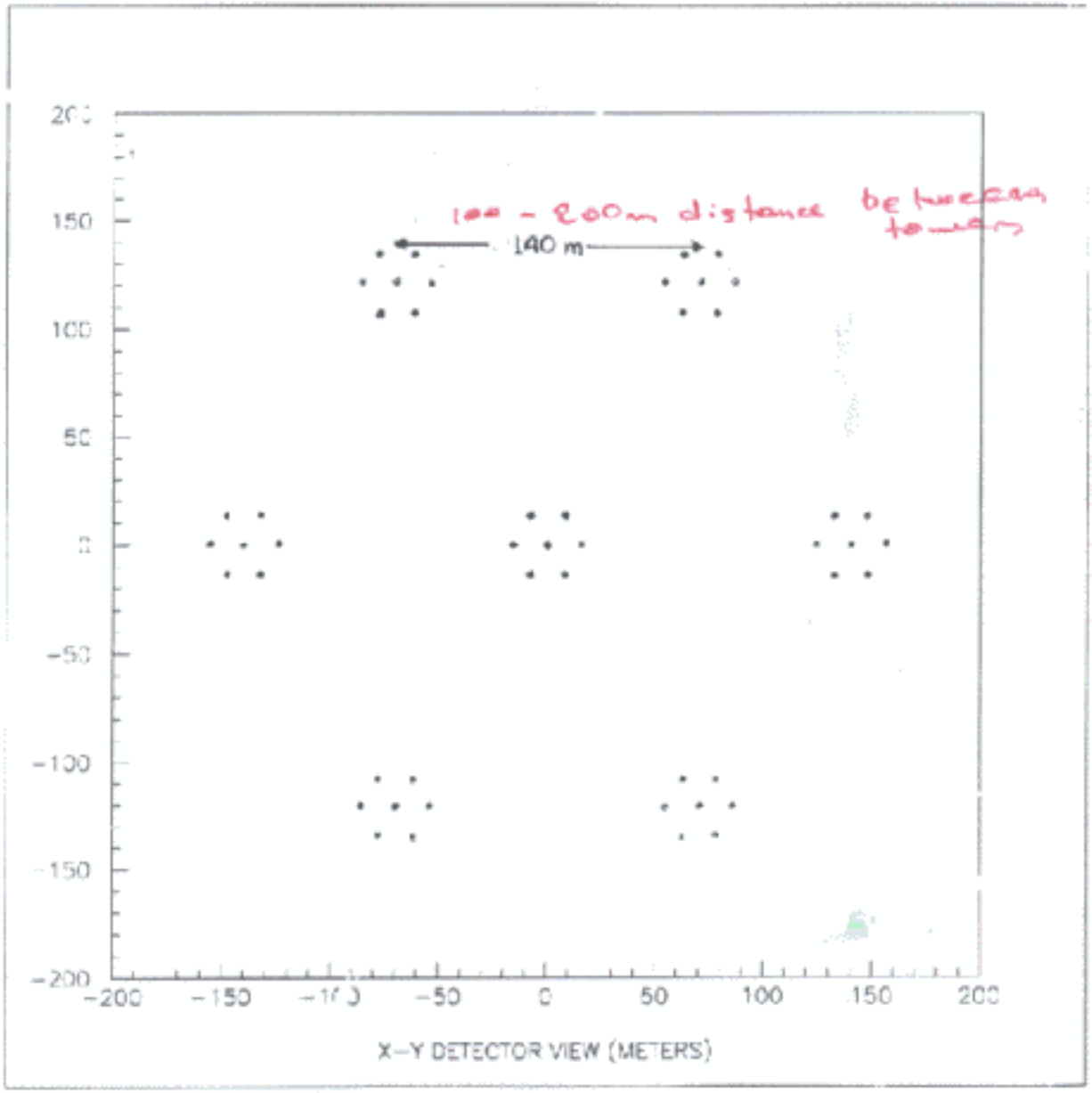


NESTOR

7 TOWERS, 1176 PHOTOMULTIPLIERS

1.8 MEGATONS OF DENSELY INSTRUMENTED MASS WITHIN THE 7 TOWERS i.e. FEW GeV THRESHOLD

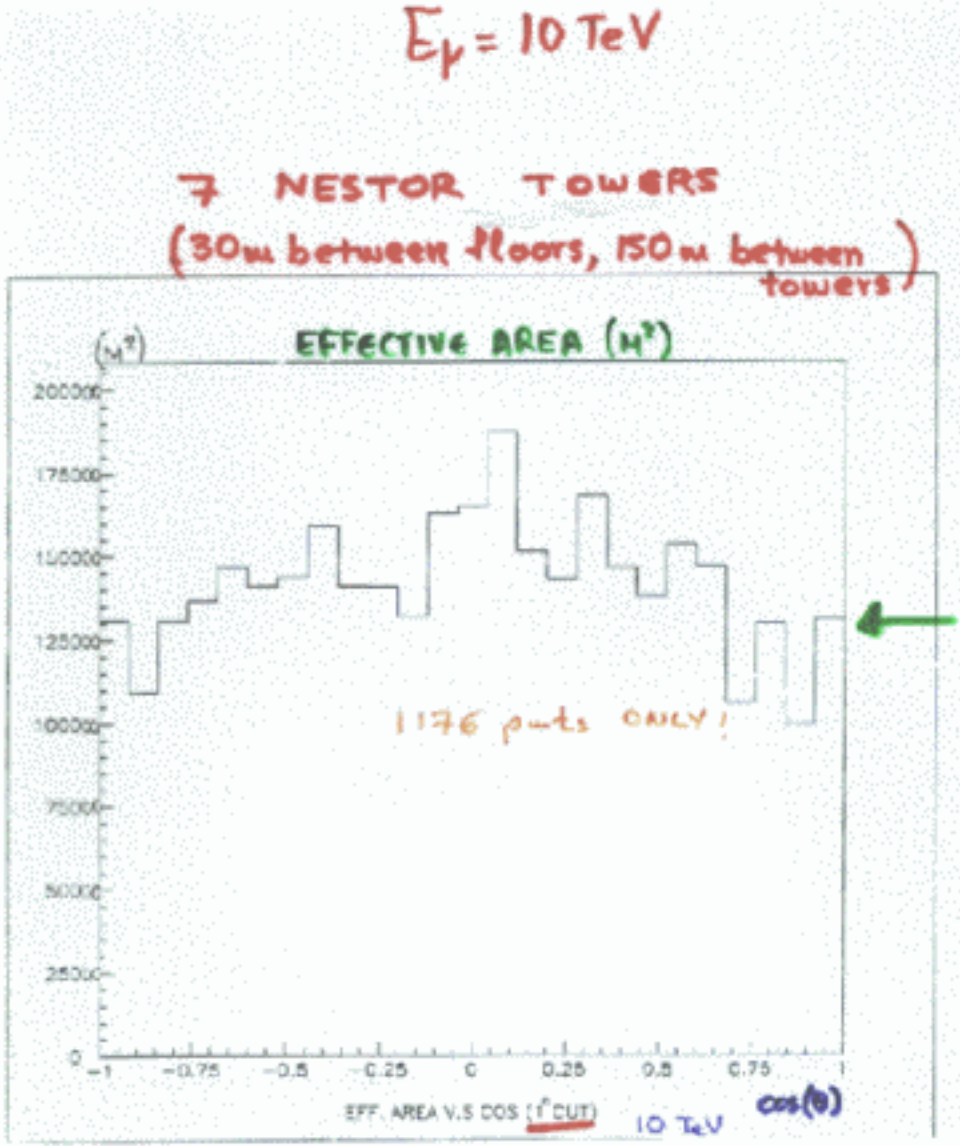
25. MEGATONS OF ENCLOSED MASS



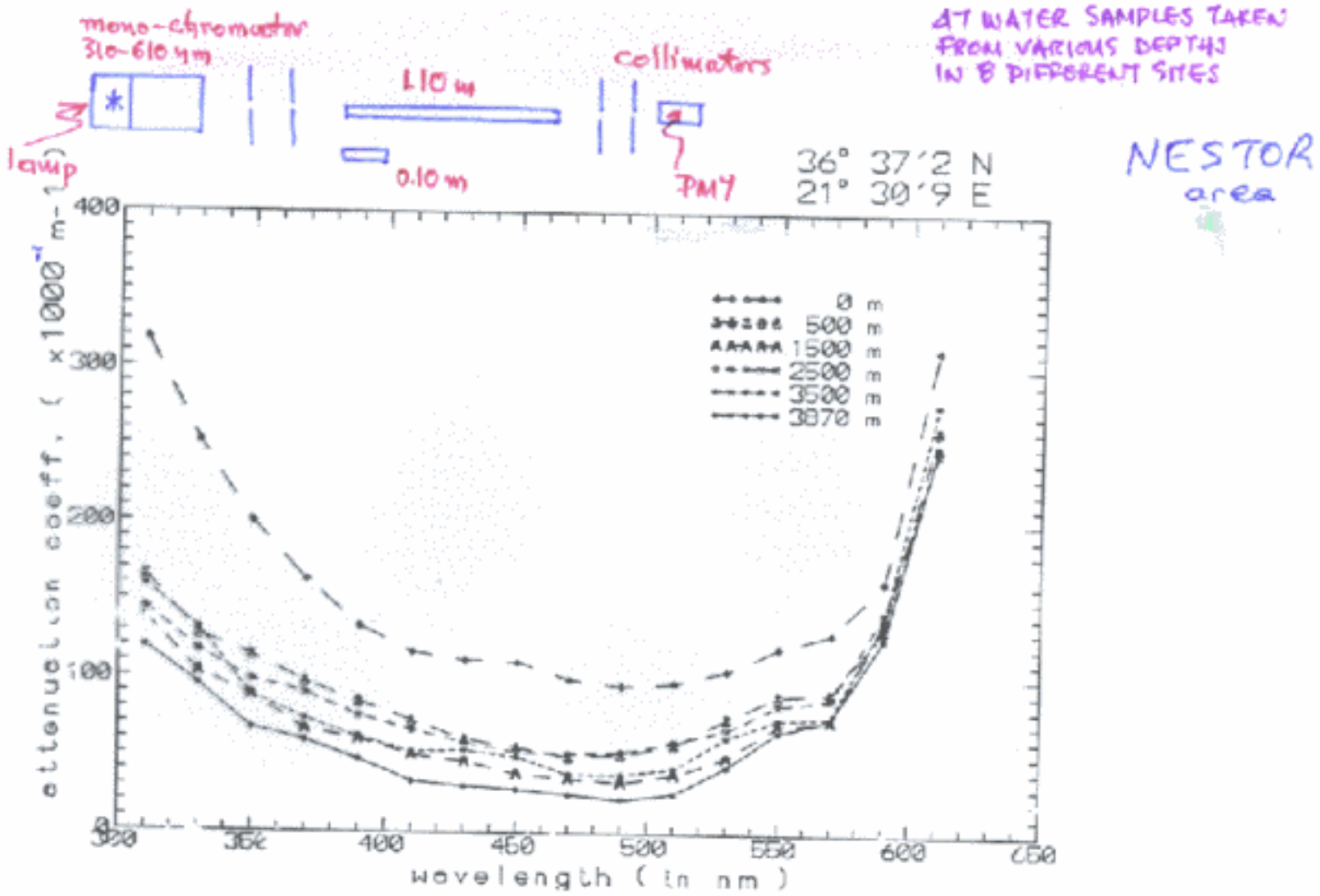
$E_\mu = 10$ TeV

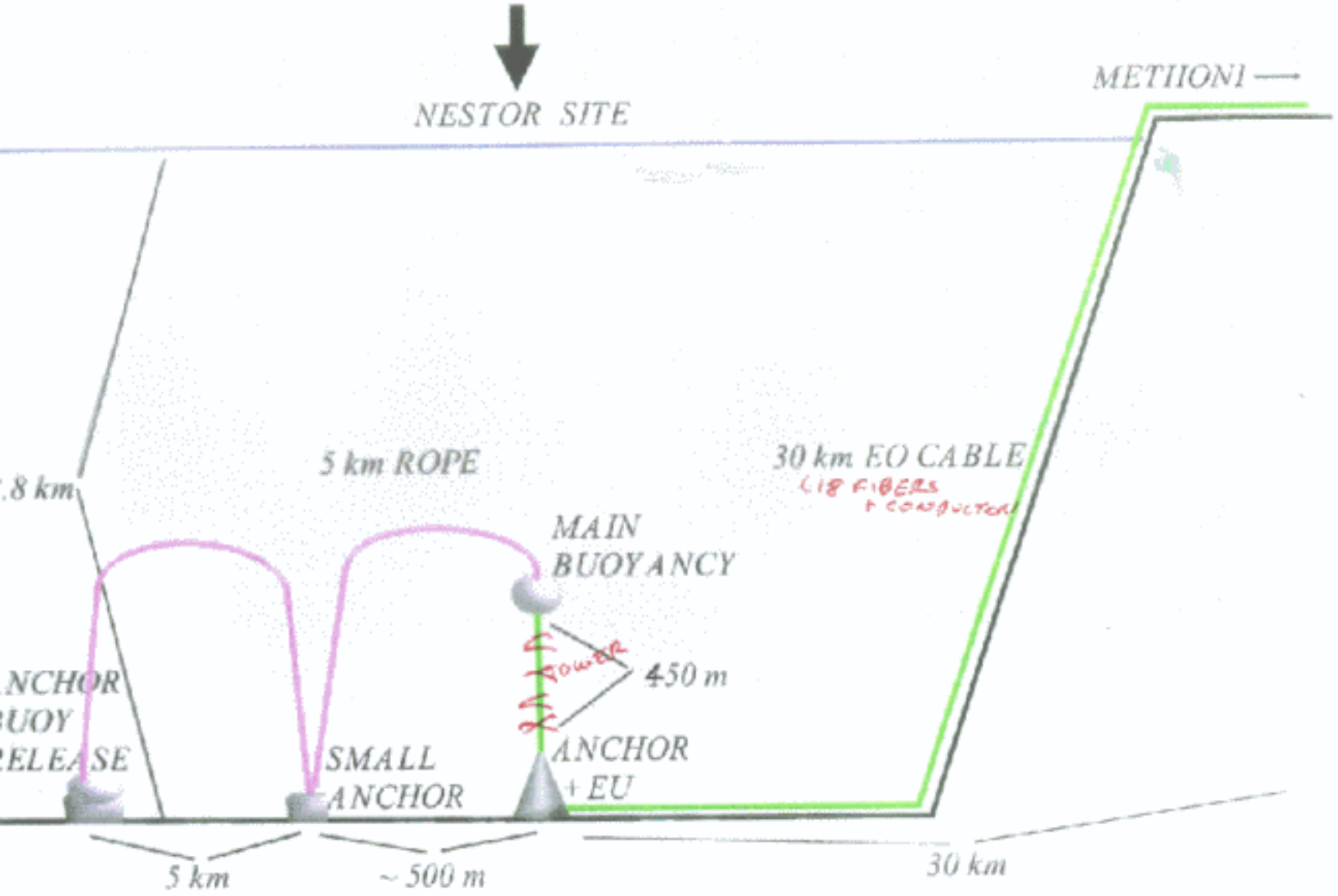
7 NESTOR TOWERS

(30m between floors, 150m between towers)



← 1/8 of the km²


mono-chromator
310-610 nm
lamp
1.10 m
0.10 m
collimators
PMT
AT WATER SAMPLES TAKEN
FROM VARIOUS DEPTHS
IN 8 DIFFERENT SITES
36° 37'2 N
21° 30'9 E
NESTOR
area
attenuation coeff. (x1000 m-1)
wavelength (in nm)
0 m
500 m
1500 m
2500 m
3500 m
3870 m
S. KHANAEV and A. KULESHOV


NESTOR SITE
METIONI
5 km ROPE
30 km EO CABLE
Lig FIBERS
+ CONDUCTOR
MAIN
BUOYANCY
450 m
ANCHOR
+ EU
SMALL
ANCHOR
5 km
~ 500 m
30 km

Dense Wavelength Division Multiplexing

- ANALOGUE SIGNAL TRANSMISSION
- ONE WAVELENGTH / PMT
- 1.6 nm BETWEEN ADJACENT PMTs