Antares/Nemo

Open problems

- ***Origin and composition of cosmic rays***
- ***Gamma ray bursts***

  (GRB030329 ; Z=0.169; 805 Mpc; $E_\gamma=10^{52}$ erg)
- ***Origin of high energy gamma rays***
- ***Correlation of gamma rays with radio emission***
- ***Correlation of high energy cosmic rays with radio-loud galaxies***

- ***High energy neutrinos a clue ?***

EGRET results

- γ rays 100 MeV-20 GeV from galactic + extragalactic sources:

- 270 sources identified: LMC, 5 pulsars, a radio-galaxy (Cen A) + 66 Blazars

- ..other 27 probable blazars + 170 unidentified sources

- *Diffuse γ flux*

- Diffuse γ radiation found by EGRET. Probably extragalactic
- Arnon Dar: inverse Compton scattering of high energy electrons by background radiation ?

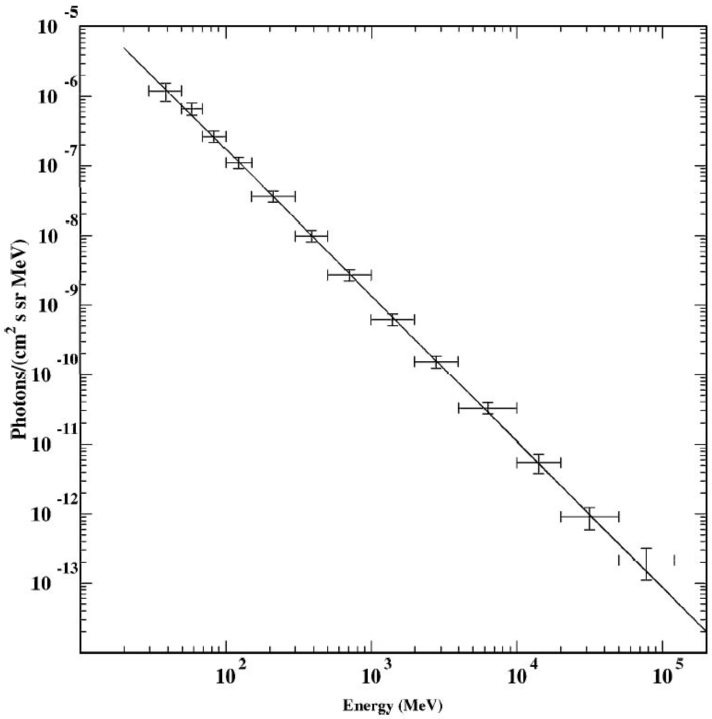
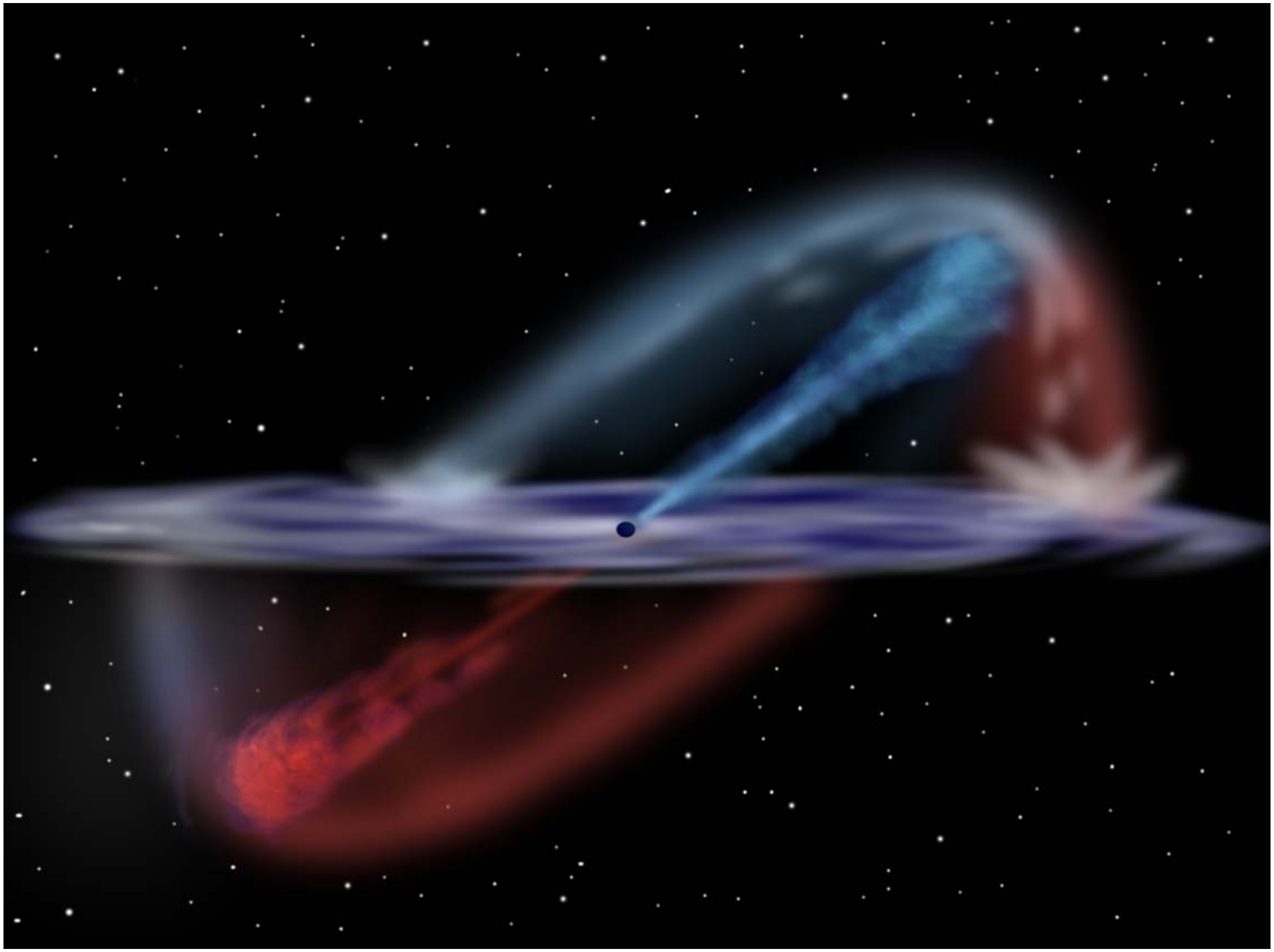


Figure 1: Comparison between the spectrum of the GBR, measured by EGRET (Sreekumar et al. 1998), and the prediction for ICS of starlight and the CMB by CR electrons. The slope is our central prediction, the normalization is the one obtained for $h_e = 20$ kpc, $\rho_e = 35$ kpc.

Active Galactic Nuclei + Blazars

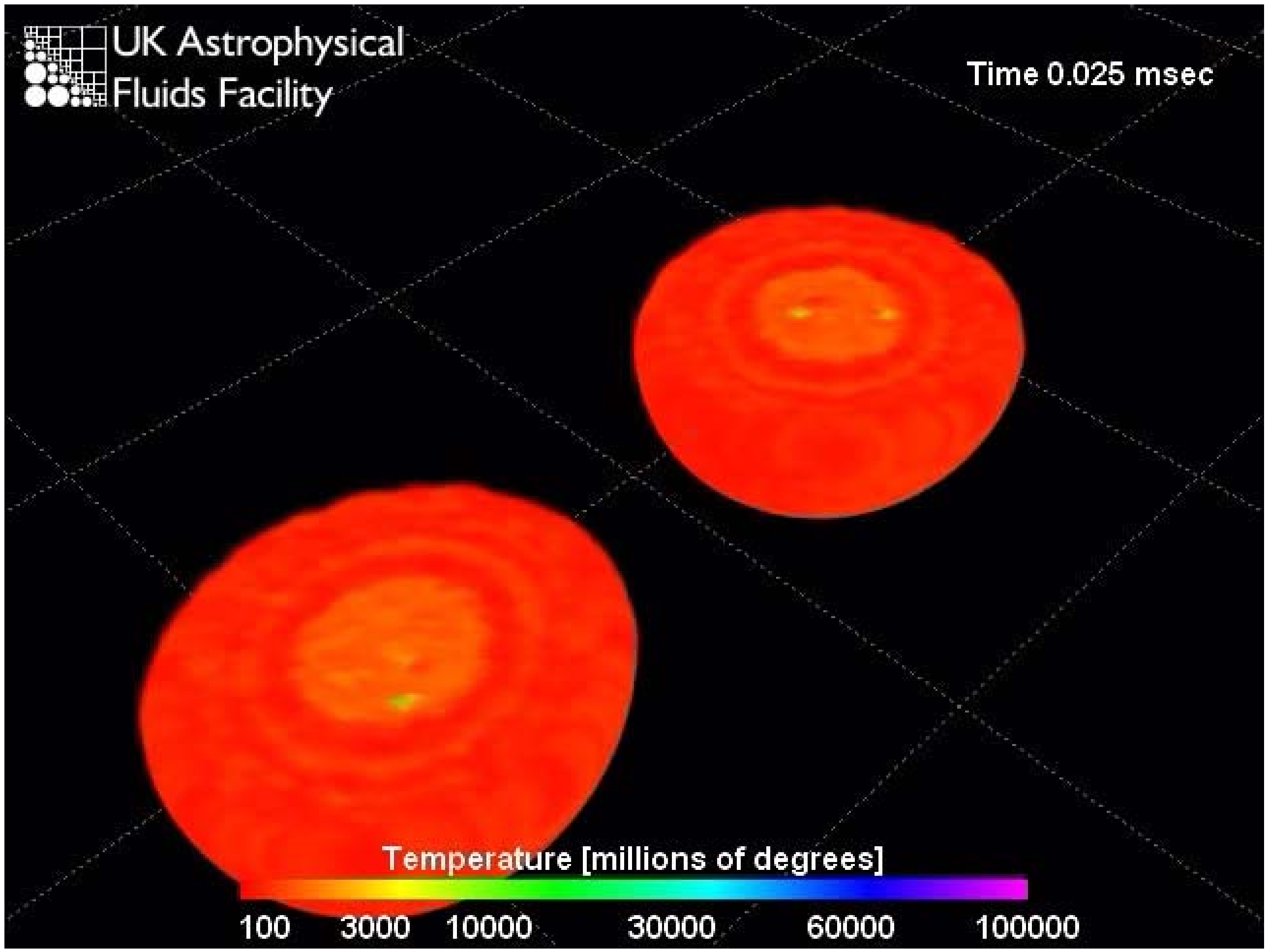
AGN => Very massive black holes causing two relativistic opposite jets to emanate

Blazars => AGN having one of the jets pointing towards the Earth



- The last de
  many calcu
  from AGN'
- Plenty of p
  of main me
- Synchrotro
  versus γ
  much dispu

Sources of high energy particles



Problems with high energy cosmic rays

- "Knee" at ~ 3 PeV
- "Second "knee" at ~ 300 PeV
- "Ankle" at $10^{18.5}$ eV
- *Cosmic ray absorption by 0.5 eV relic neutrinos ??*

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PeV cosmic rays: a window on the leptonic era?

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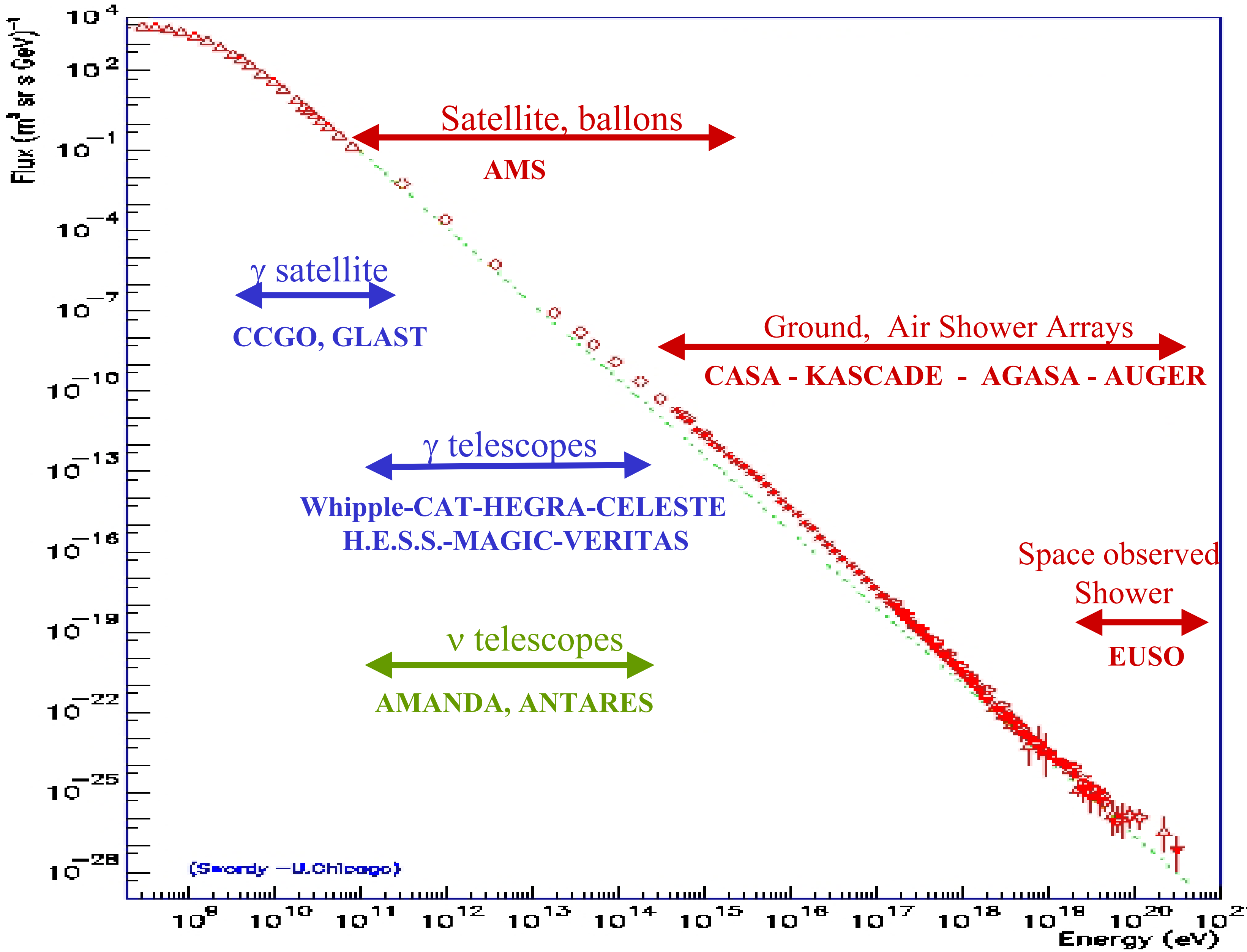
Received 30 May 2002; received in revised form 5 July 2002; accepted 5 August 2002

Abstract

It is shown that a variety of characteristic features of the high-energy hadronic cosmic-ray spectra, in particular the abrupt changes in the spectral index that occur around 3 and 300 PeV, as well as the corresponding changes in elemental composition that are evident from kinks in the $\langle X_{max} \rangle$ distribution, can be explained in great detail from interactions with relic Big Bang antineutrinos, provided that the latter have a rest mass of ~0.5 eV/c^2.

Keywords: Cosmic rays; Knee; Relic neutrinos; Neutrino mass



Flux (m² sr s GeV)⁻¹
Energy (eV)
Satellite, ballons
AMS
γ satellite
CCGO, GLAST
Ground, Air Shower Arrays
CASA - KASCADE - AGASA - AUGER
γ telescopes
Whipple-CAT-HEGRA-CELESTE
H.E.S.S.-MAGIC-VERITAS
Space observed
Shower
EUSO
ν telescopes
AMANDA, ANTARES
(Swordy – U.Chicago)

Wigmans *(Astrop. Phys. 19, 379, 2003)*

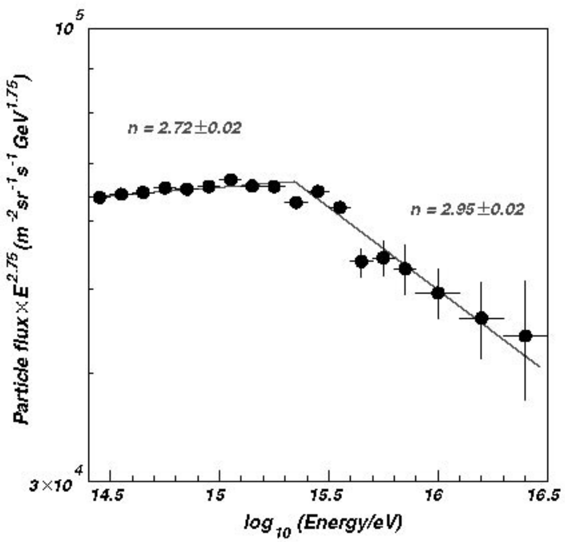


Fig. 1. The all-particle energy spectrum of cosmic rays, measured by the CASA-BLANCA experiment [3].

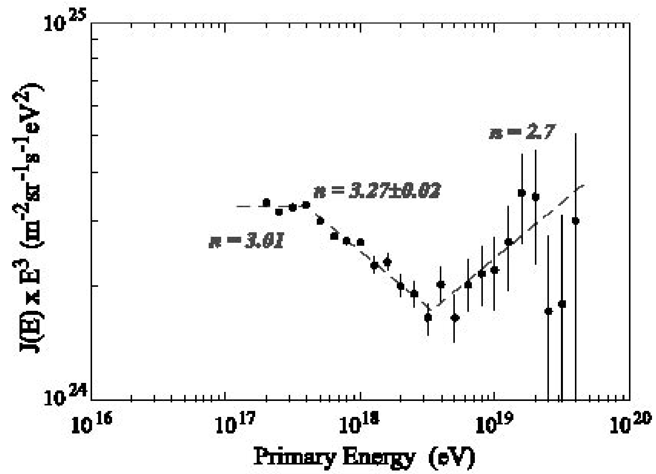


Fig. 2. The all-particle energy spectrum of cosmic rays, measured by the Fly's Eye experiment [8].

Greisen-Zatsepin-Kuzmin cutoff

$P + \gamma \rightarrow n + \pi^+$

$(E+\varepsilon)^2 - (P-\varepsilon)^2 = E^2 - P^2 + 4\,\varepsilon\,E = (940+140)^2\ \mathrm{MeV}^2 =$

$=(1.08\ \ 10^9)^2\ \mathrm{eV}^2 \Rightarrow\ E_{max} = 7\ 10^{19}\ \mathrm{eV}$

Lunghezza d'assorbimento ~ 50 Mpc (sopra i 50 EeV)

$[\lambda_{\gamma p} = (n_{CMB}\ \sigma_{p+\gamma_{CMB}})^{-1}]$

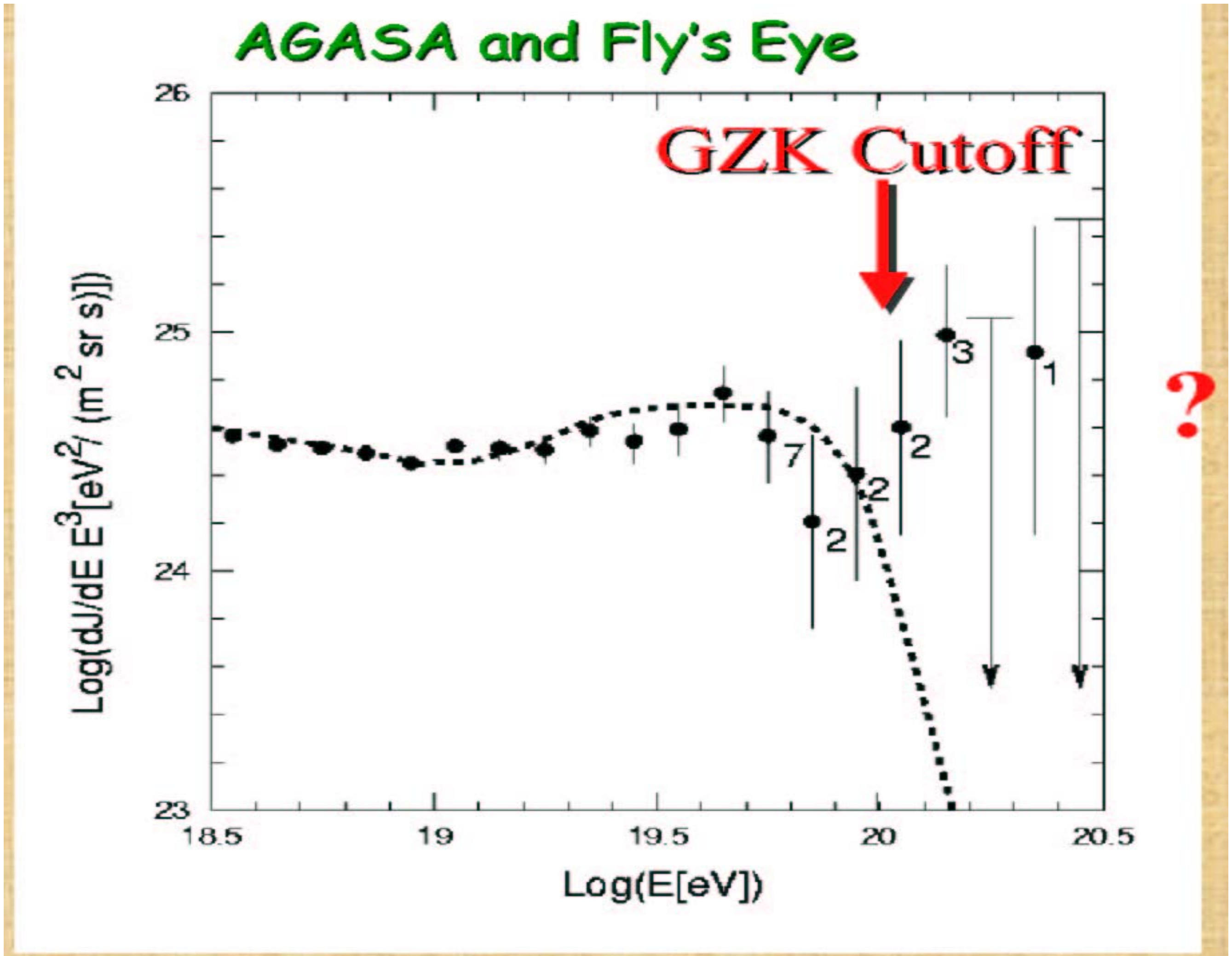
Events observed at energies larger than $2x10^{20}$ eV

Fly's Eye: 1 event, 320 EeV

Haverah Park: 6 events, 101-159 EeV

AGASA: 8 events, 101-213 EeV

GZK cutoff ?



AGASA and Fly's Eye
GZK Cutoff
Log(dJ/dE E^3[eV^2/ (m^2 sr s)])
Log(E[eV])
26
25
24
23
18.5
19
19.5
20
20.5
7
2
2
2
3
1
?

Angular correlation of ultra-high energy cosmic rays with compact radio-loud quasars

Amitabh Virmani, Astropart. Phys. 17, 489, 2002

Correlation with positions of radio-loud quasars

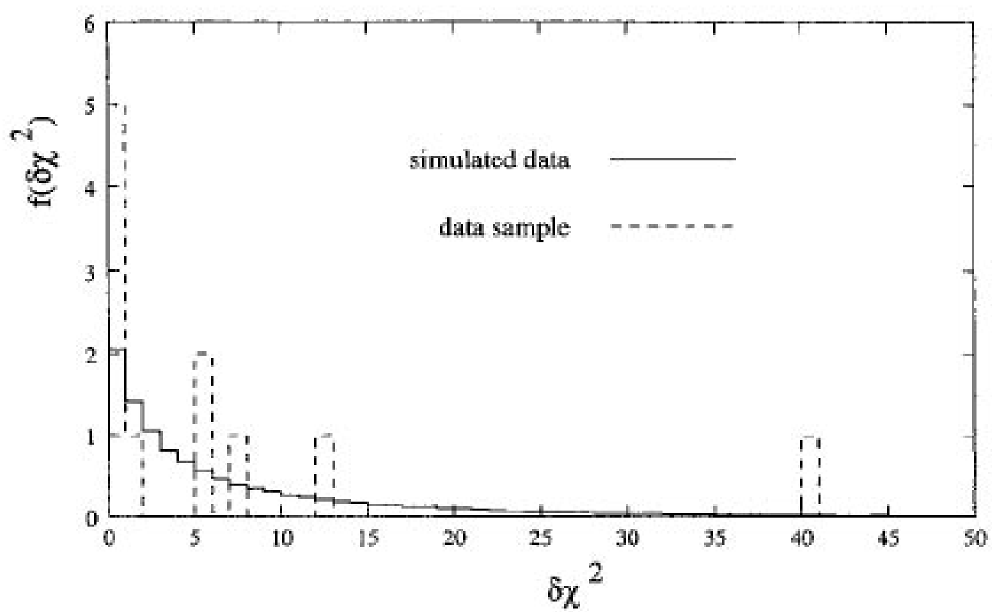


Fig. 1. The distribution of residual $\delta\chi^2$ for individual events for the data set (dashed line) and the simulated data (solid line). Both distributions are normalized to the total number of 11 events cited in the text.

Energy/distance cutoff for different probes

Probe	Cutoff energy	Mean free path
- *Protons*	*50 EeV*	*50 Mpc*
- *Nuclei*	*5 EeV/n*	*100 Mpc*
- *γ rays*	*100 TeV*	*10 Mpc*
- *ν*	*40 ZeV*	*40 Gpc*

- **[PeV=10^{15} eV; EeV=10^{18} eV; ZeV=10^{21} eV]**

Sources of high energy neutrinos

a) bottom-up models

Gamma ray bursts in collapse of massive stars

Quasars-Microquasars

Interacting neutron stars

Supernovae

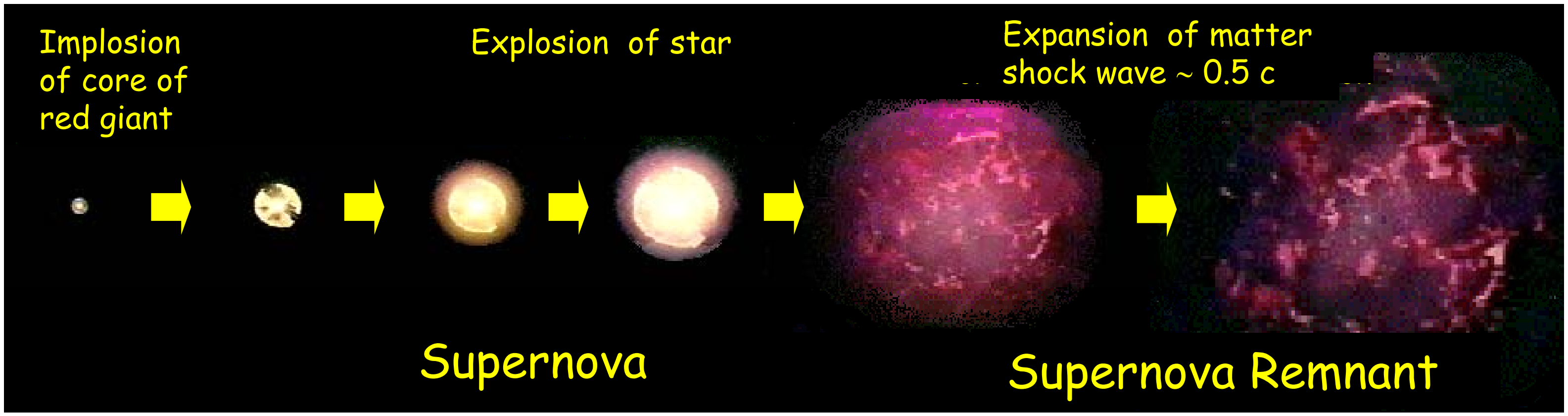
Shock waves in Supernova remnants

b) top-down models

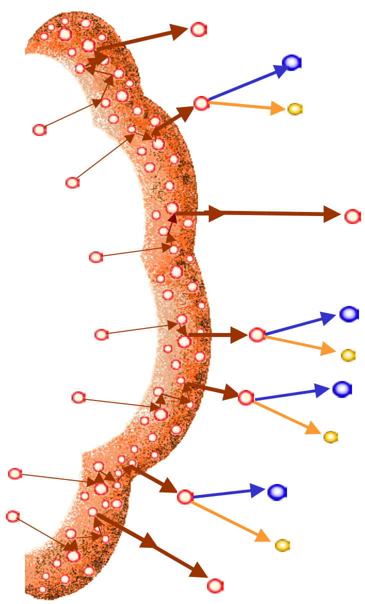
Decay of massive particles (wimps)

Production of Neutrinos in Stellar Objects

Example of Supernova Remnant



Charged particles accelerated
by Fermi process in shock wave



Neutral particles produced
in interactions and decays

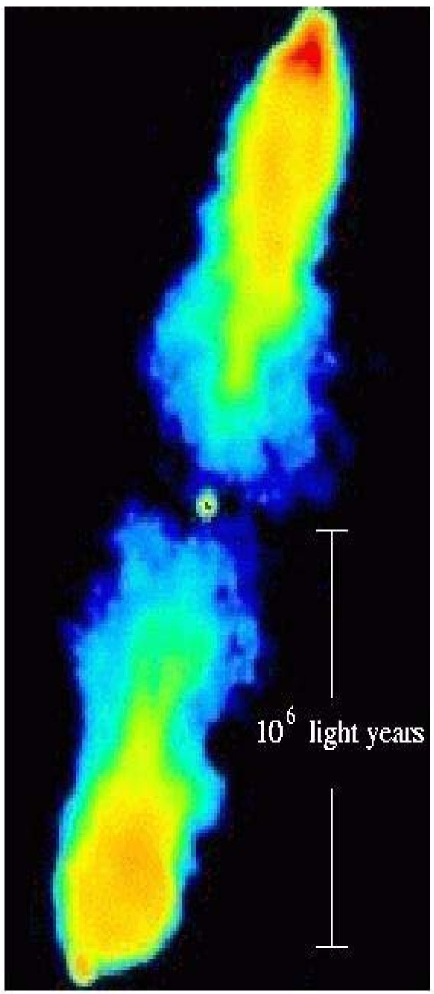
$$p/A + p/\gamma \rightarrow \pi^0 + \pi^{\pm} + \ldots$$

$$\pi^0 \rightarrow \gamma\,\gamma \qquad \pi^{\pm} \rightarrow \nu_\mu\ \mu$$

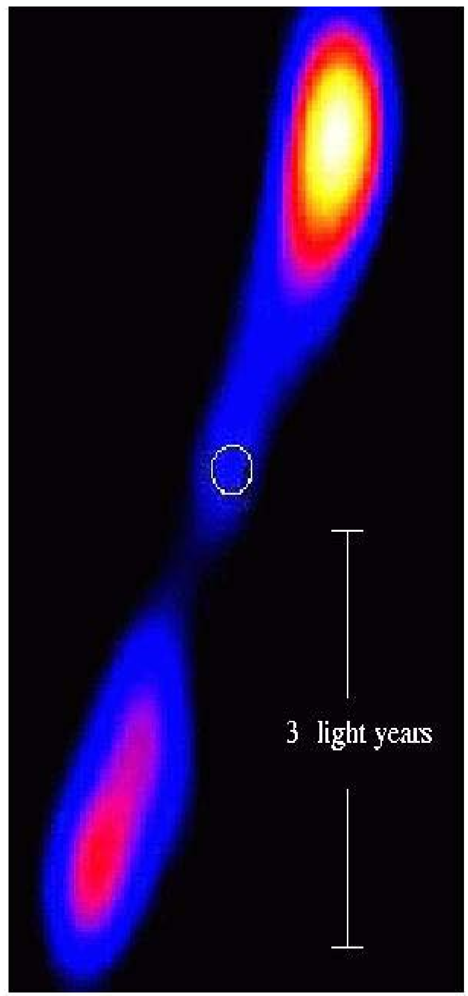
$$\mu \rightarrow \nu_\mu\ \nu_e\ e$$

QUASARS & MICROQUASARS

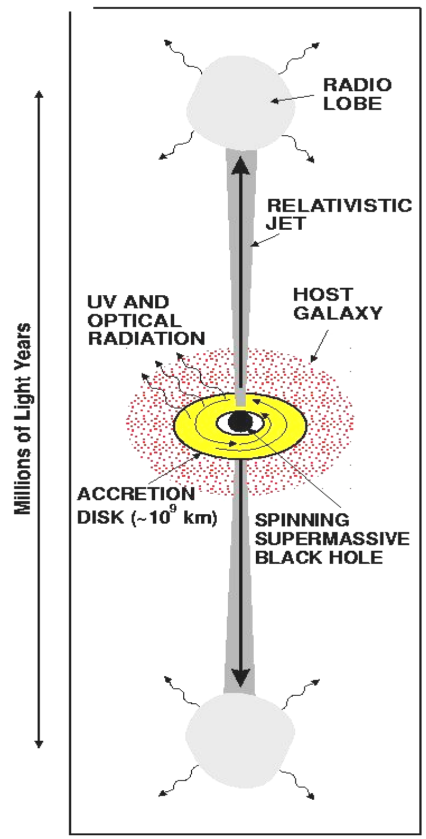
QUASAR



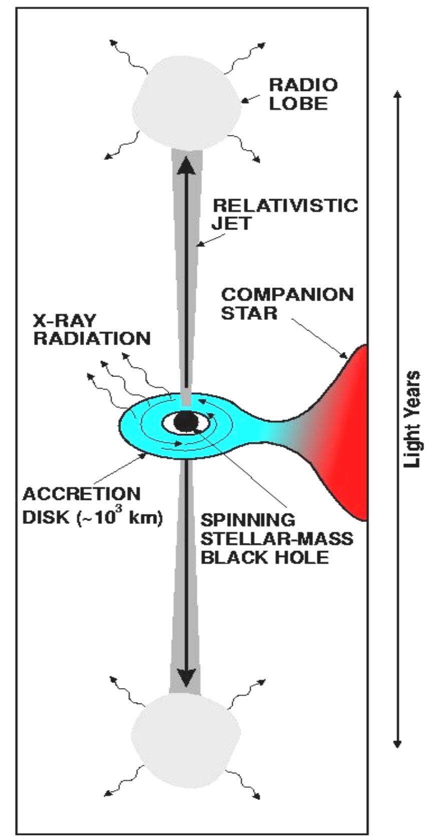
MICROQUASAR



QUASAR



MICROQUASAR

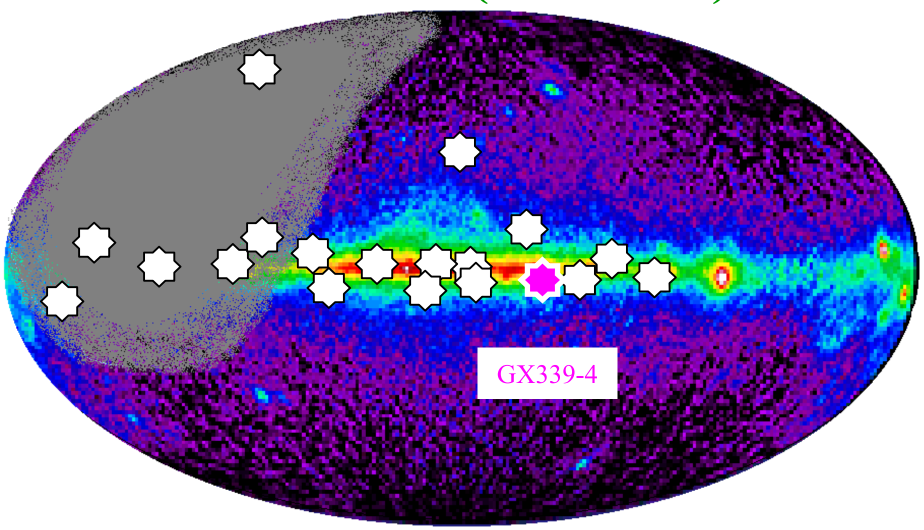


Central black hole

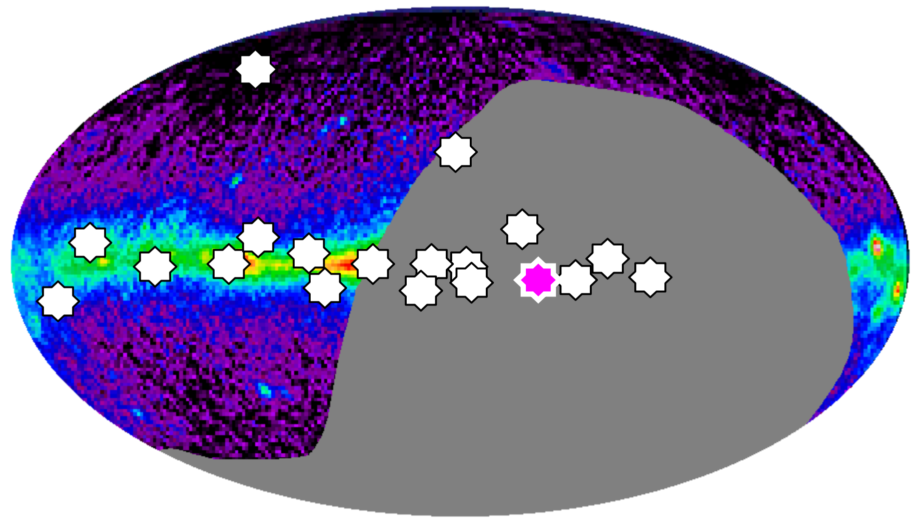
10^8- 10^9 $M_\odot$	10^2- 10^5 $M_\odot$
distant galaxies	local galaxy

View of the Sky (microquasars)

ANTARES (43° North)



AMANDA (South Pole)



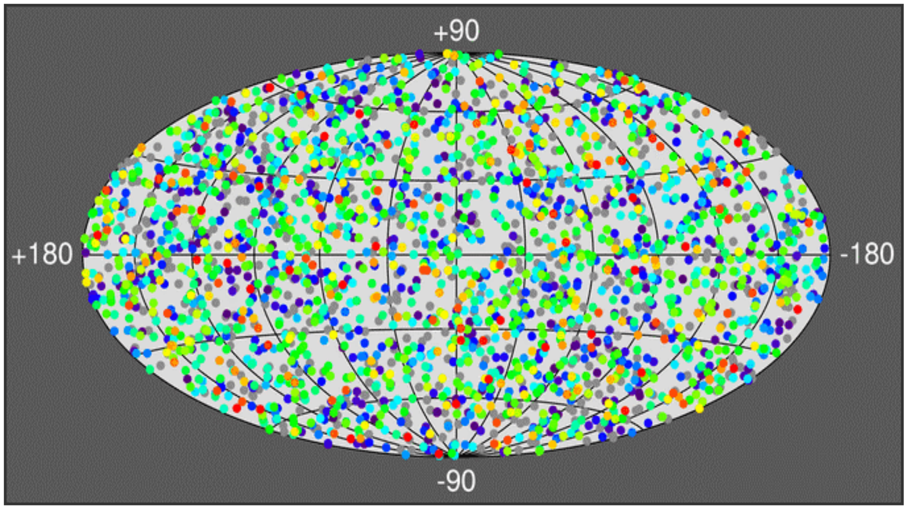
(Gamma ray flux >100 MeV observed by EGRET)

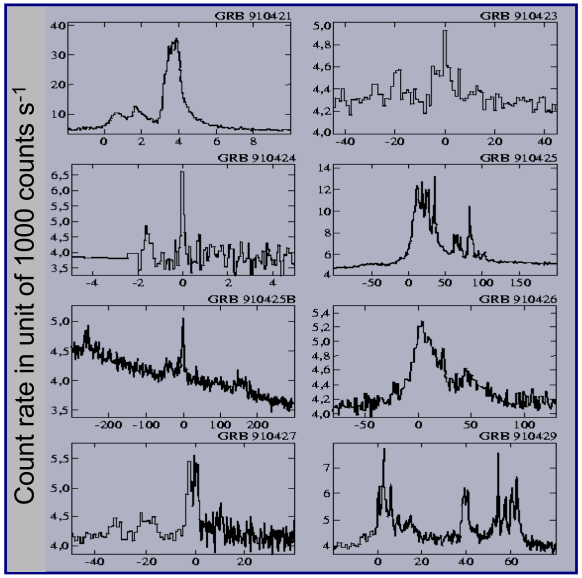
Source type	number of sources	seen by Antares
EGRET AGN	94	86%
EGRET Pulsars	5	100%
Known Microquasars	19	74%

Indicative, assumes efficiency=100% for 2π downwards

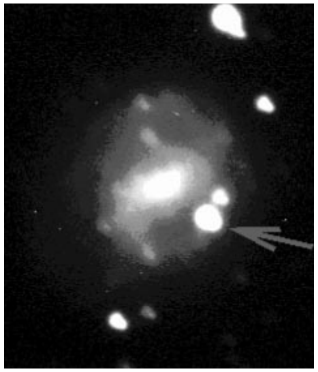
Gamma Ray Bursts : present knowledge

~1-2 / day, duration 10ms - 100s,
isotropic distribution in sky,
at extra galactic distances.





Now evidence
of GRB association
with supernova



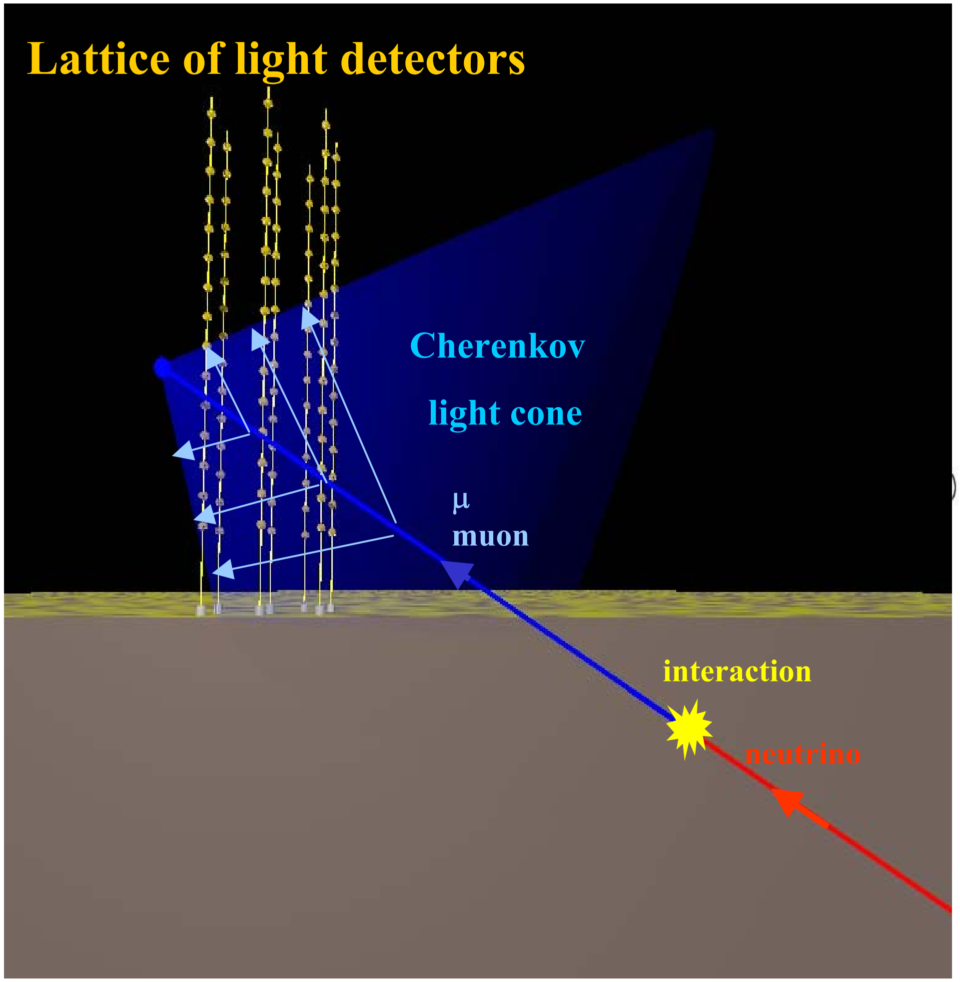
ANTARES will dump all data in ± 100 secs of gamma ray burst warning signal

Principle of H_2O Cherenkov Neutrino Astronomy

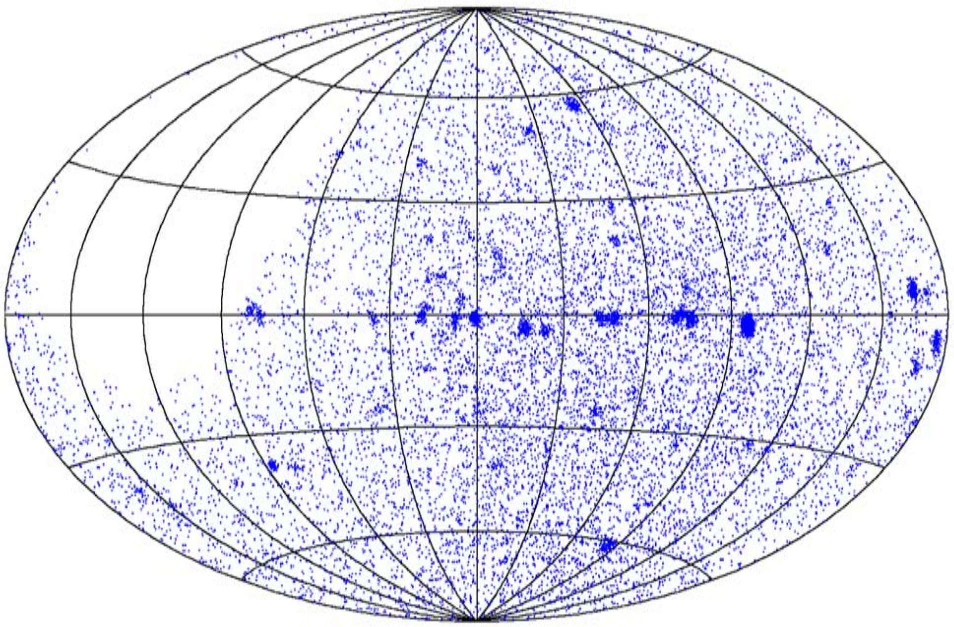
Muon track direction from arrival time of light

Neutrino direction: $\Delta(\theta_\nu - \theta_\mu) \approx 0.7^o / E^{0.6}(TeV)$

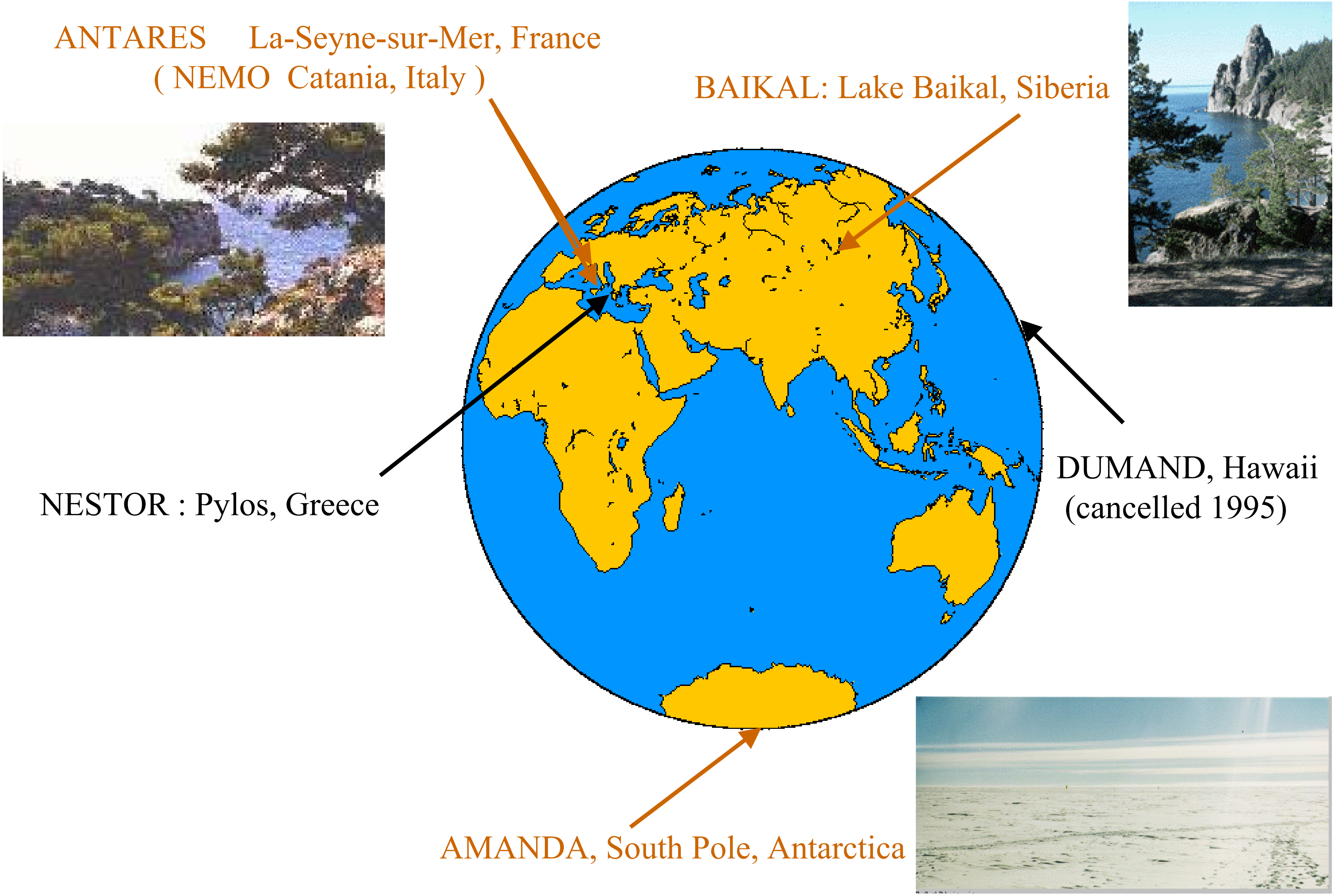
Muon energy from energy loss and range



Sky map of origins of neutrinos
(Galactic co-ordinate system)



Neutrino Telescope Projects



AMANDA

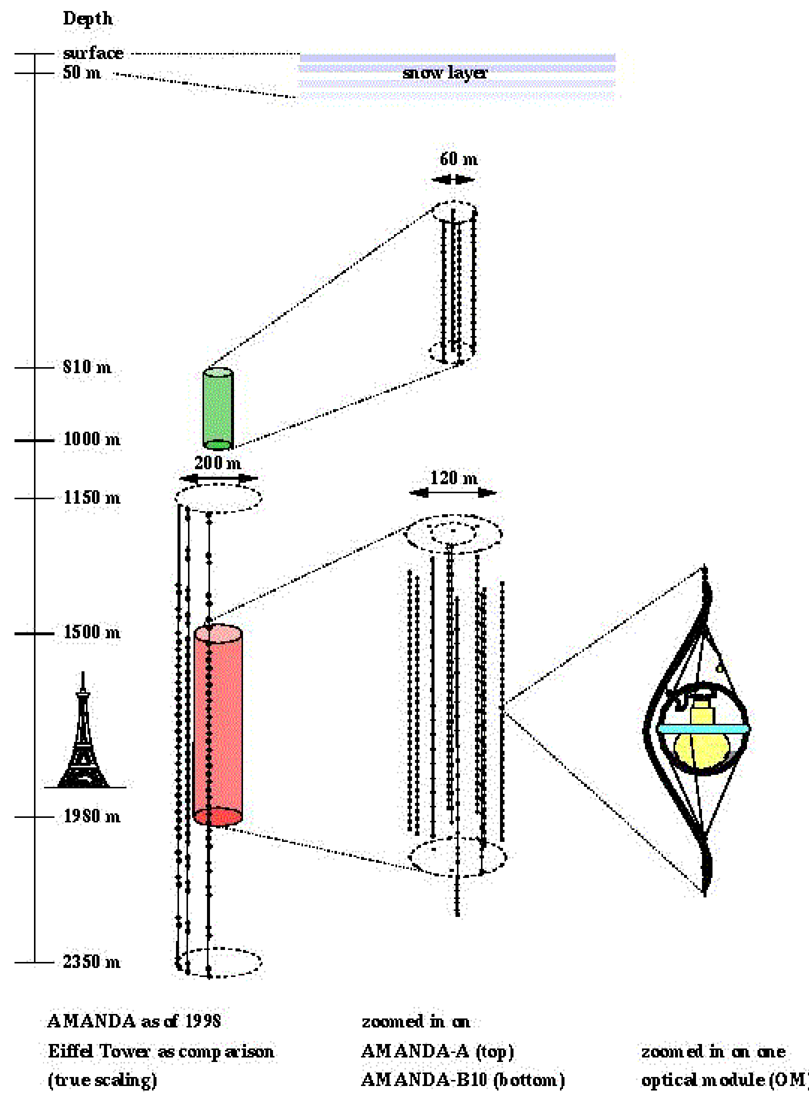
South Pole: glacial ice

1993 First strings AMANDA A

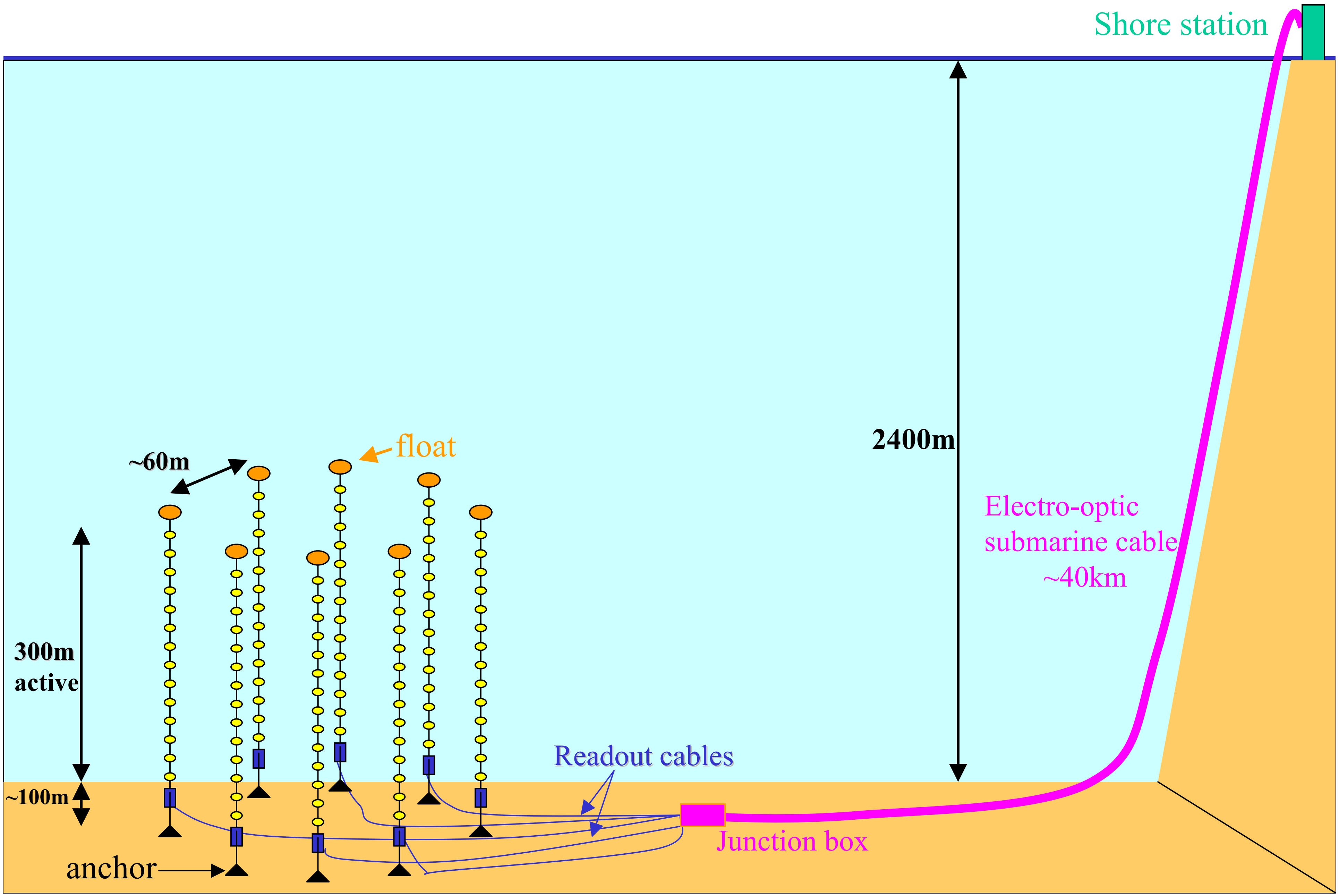
1998 AMANDA B10 ~ 300 Optical Modules

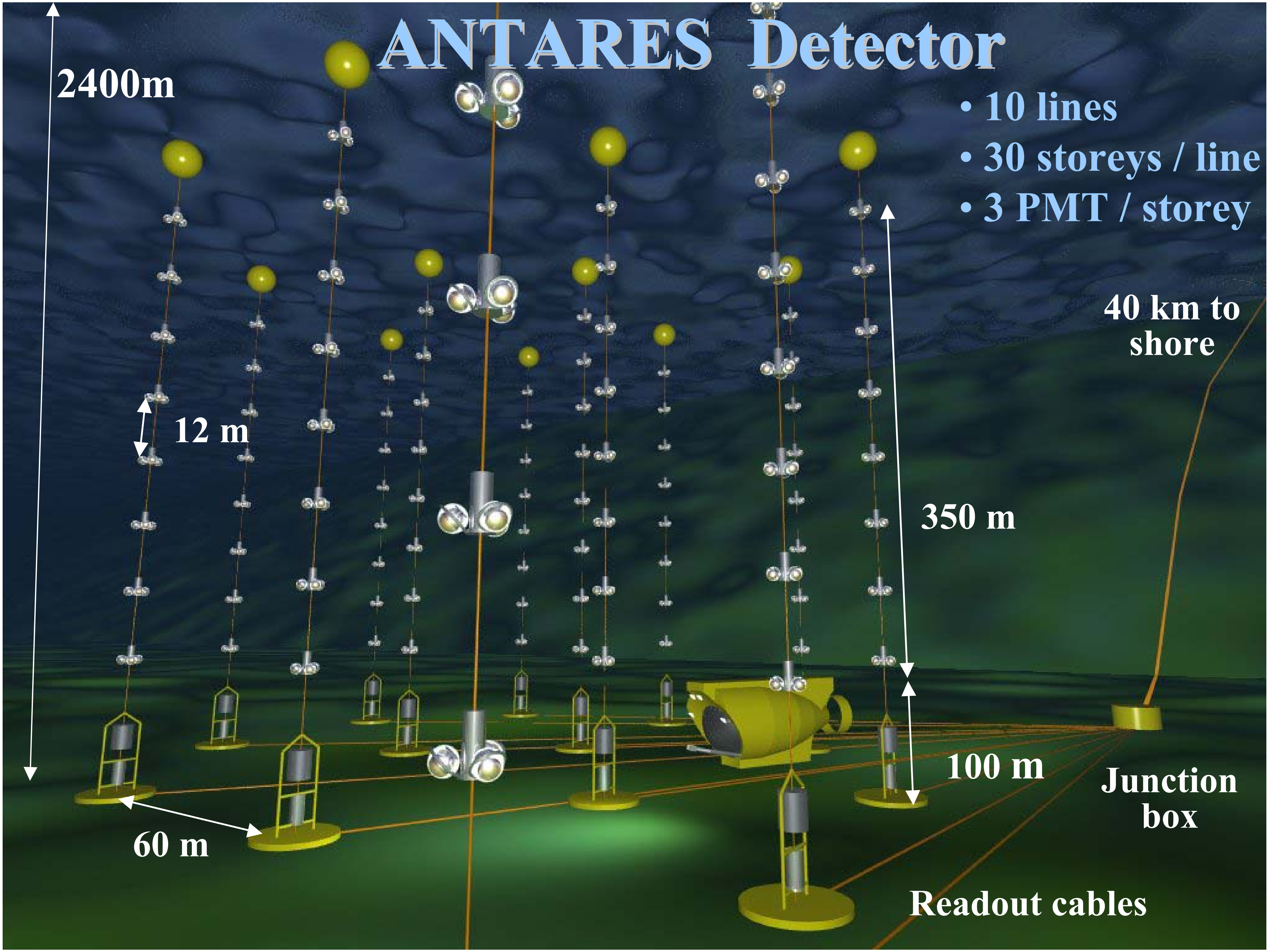
2000 ~ 700 Optical Modules

→ ICECUBE 4000 Optical Modules



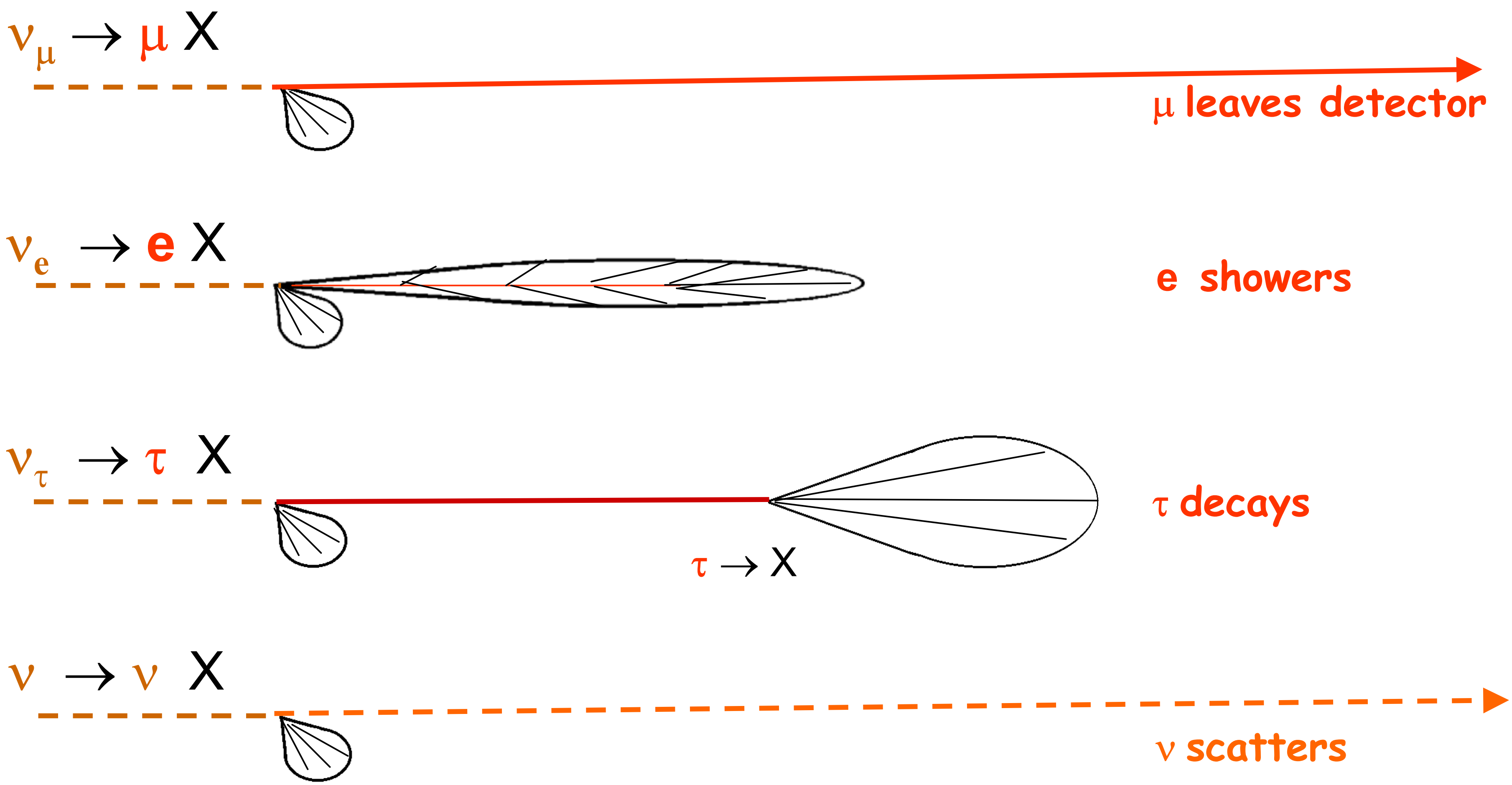
ANTARES Detector




ANTARES Detector
• 10 lines
• 30 storeys / line
• 3 PMT / storey
2400m
12 m
350 m
40 km to shore
100 m
Junction box
60 m
Readout cables

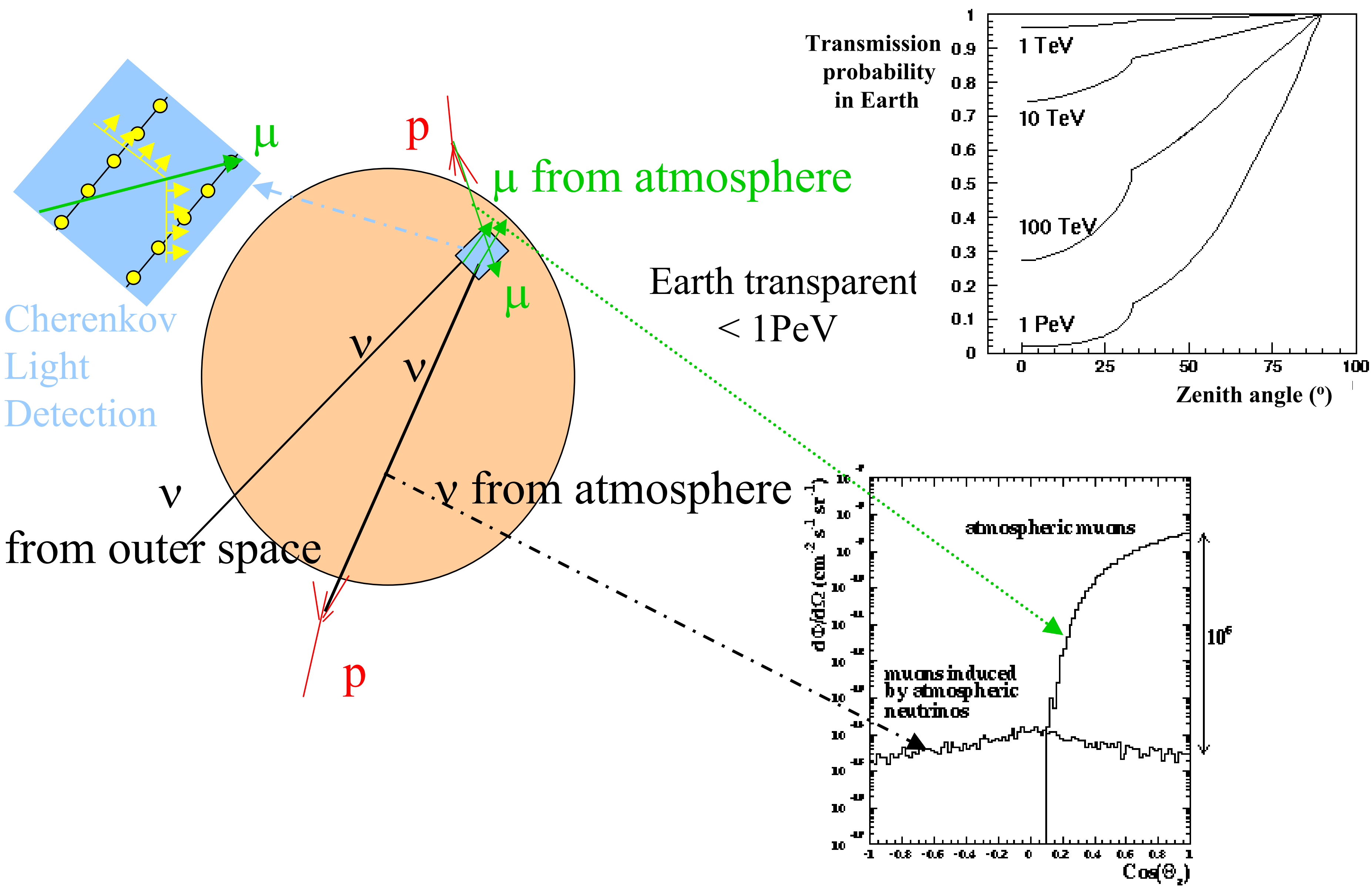
Neutrino Interactions in water

3 flavours of neutrino, 2 types of interaction:
4 topologies of light production in water



Detector optimised for $\nu_\mu \to \mu$ X, other modes have lower detection efficiency

Undersea Neutrino Telescope



Water versus Ice

Deployment

Ice gives solid platform to install detector
Sea experiments need boats/ platforms
Ice detectors worked first (Baikal deploys from ice)

Angular Resolution

Light scattering much less in water
AMANDA : ~ 3° (real detector)
ANTARES : ~ 0.4 ° (simulations)

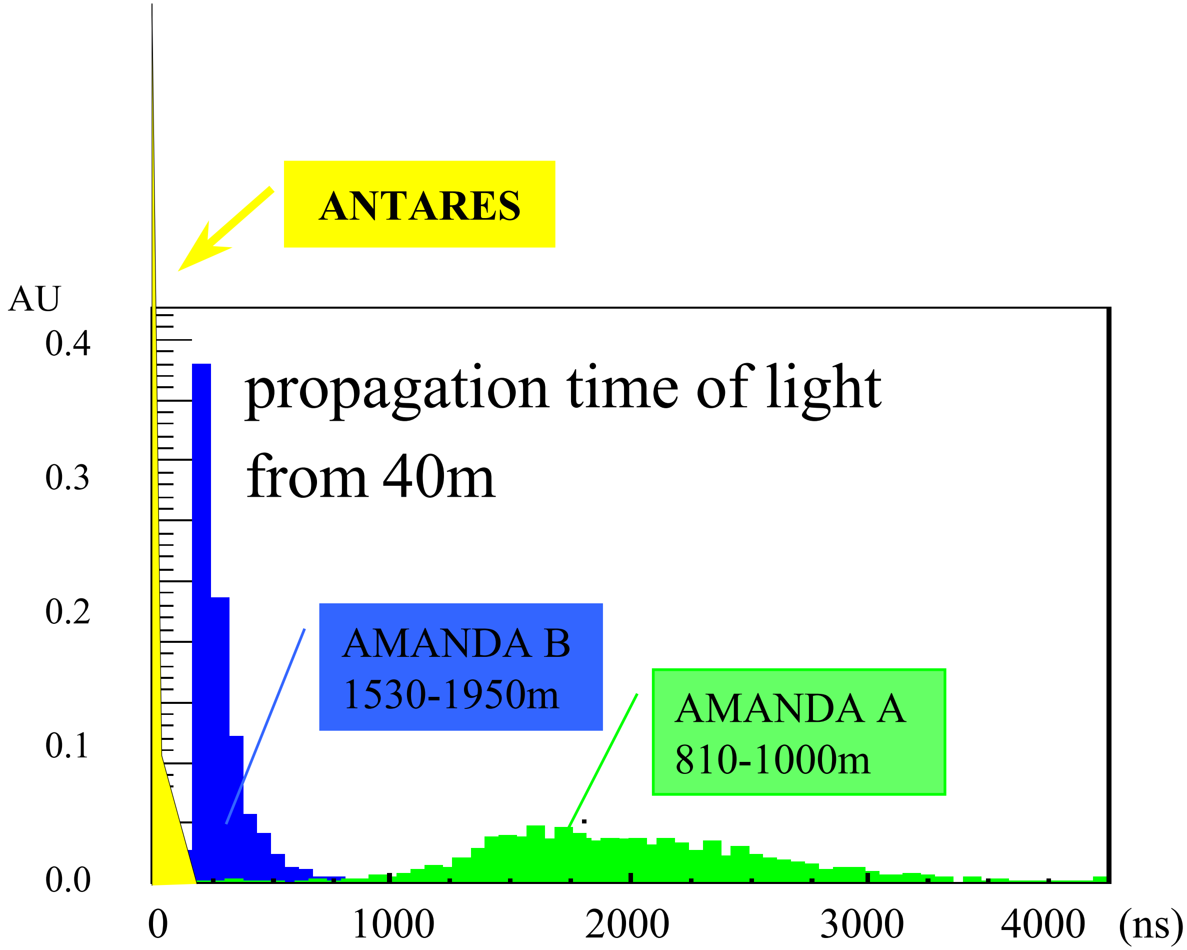
Uniformity of Detector response

Water homogeneous
Ice has dust layers, bubbles
Knowledge of efficiency simpler in water

Noise Backgrounds

Water: ^{40}K /bioluminescence ~ 60kHz / PMT
Ice: only dark tube noise ~ 500Hz / PMT
Detector design must take into account

Light Scattering: Sea Water and Ice



<u>ANTARES</u>

Absorption = 54 m

Scattering □$_{eff}$ > 100 m

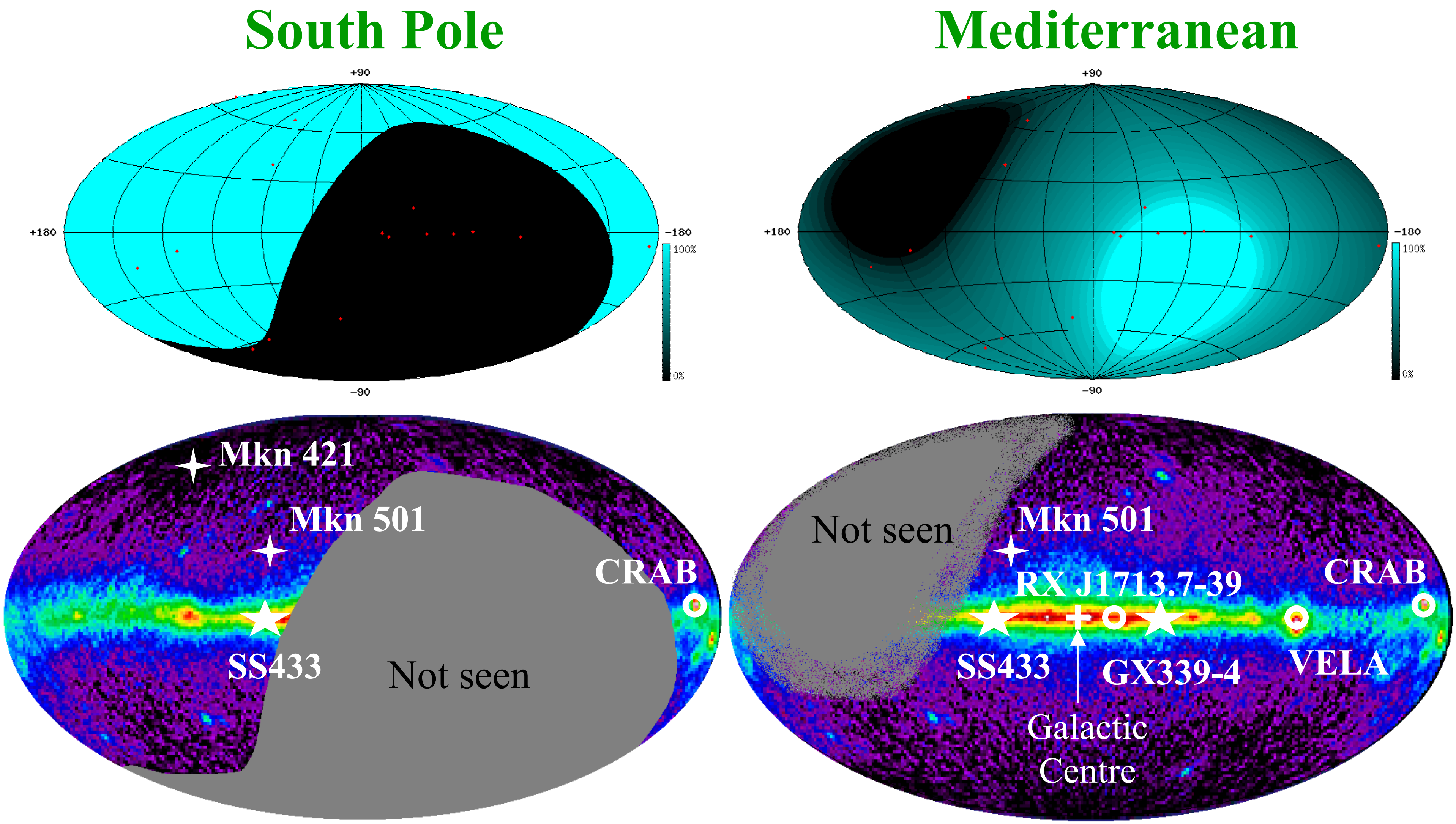
<u>AMANDA B</u>

Absorption = 100 m

Scattering □$_{eff}$ = 25 m

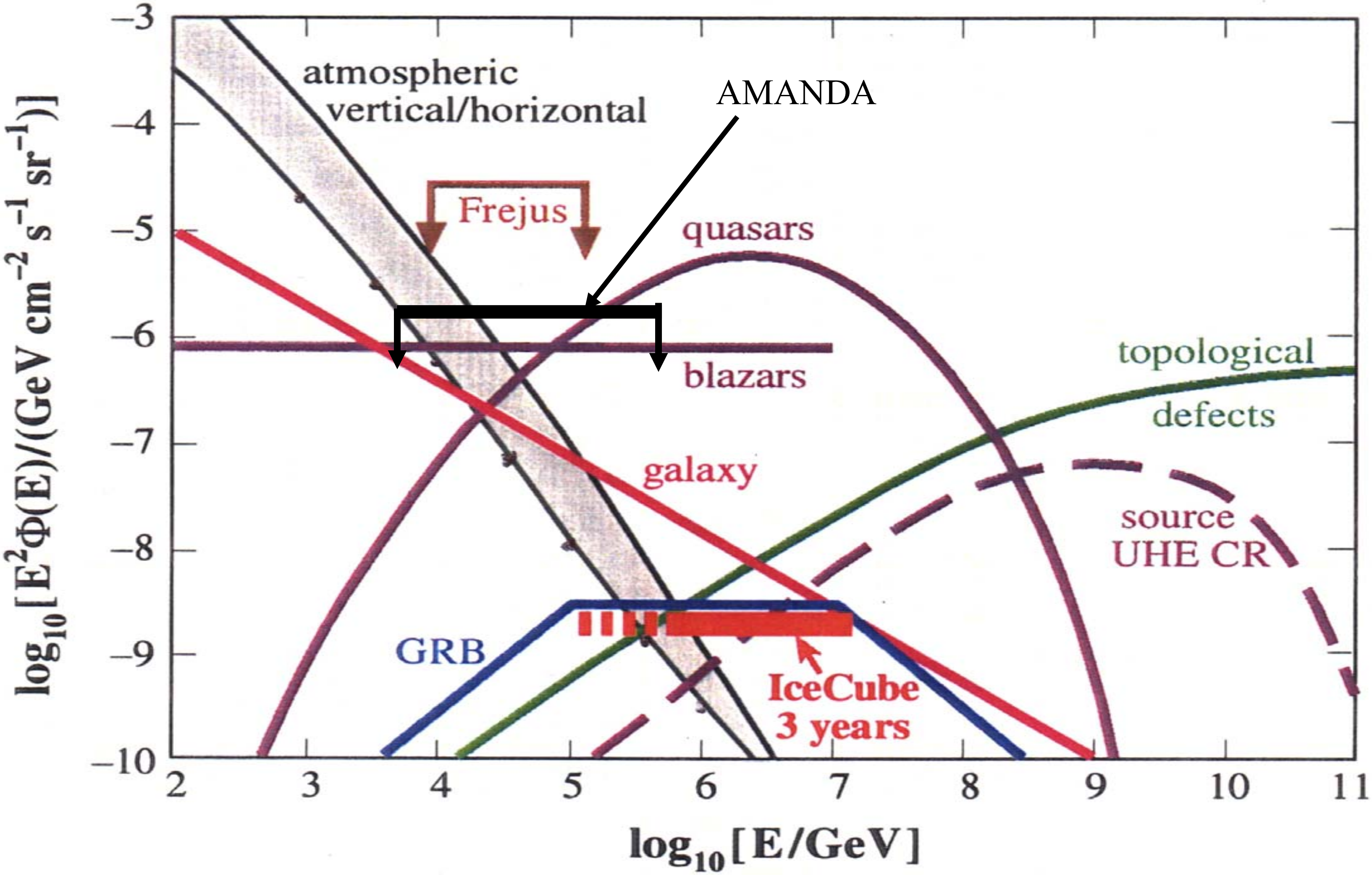
Sky Observable by Neutrino Telescopes

(Region of sky seen in galactic co-ordinate assuming 100% efficiency for 2π down)



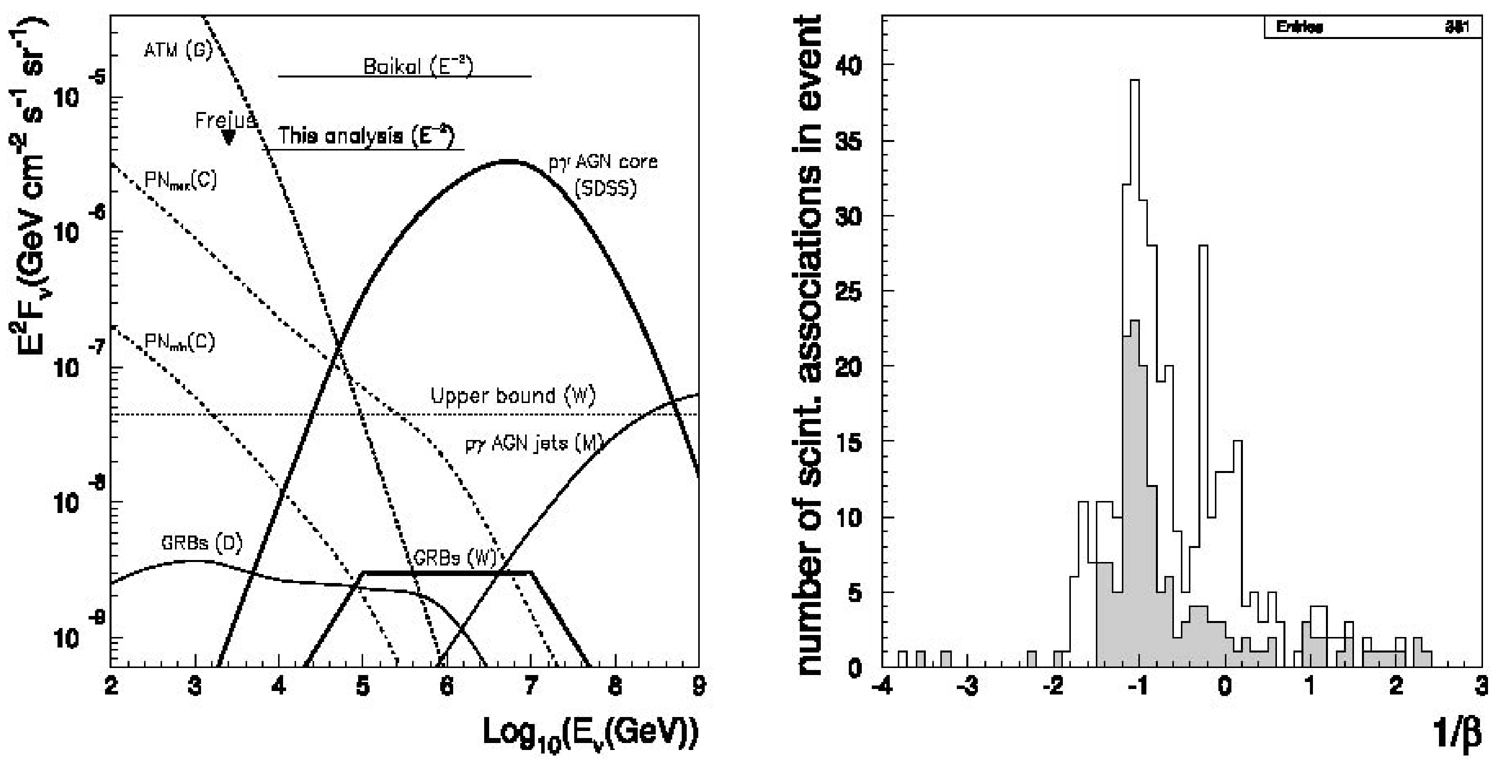
Need Neutrino Telescopes in both hemispheres to see whole sky

AMANDA Results: Diffuse Flux Limits



MACRO Limits on diffuse flux

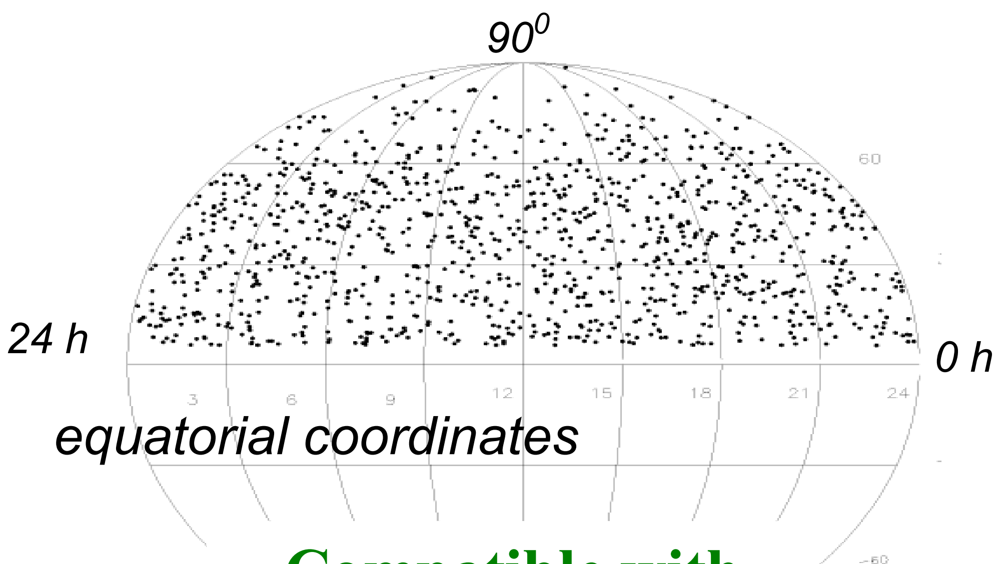
10 *M. Ambrosio et al. / Astroparticle Physics 19 (2003) 1–13*



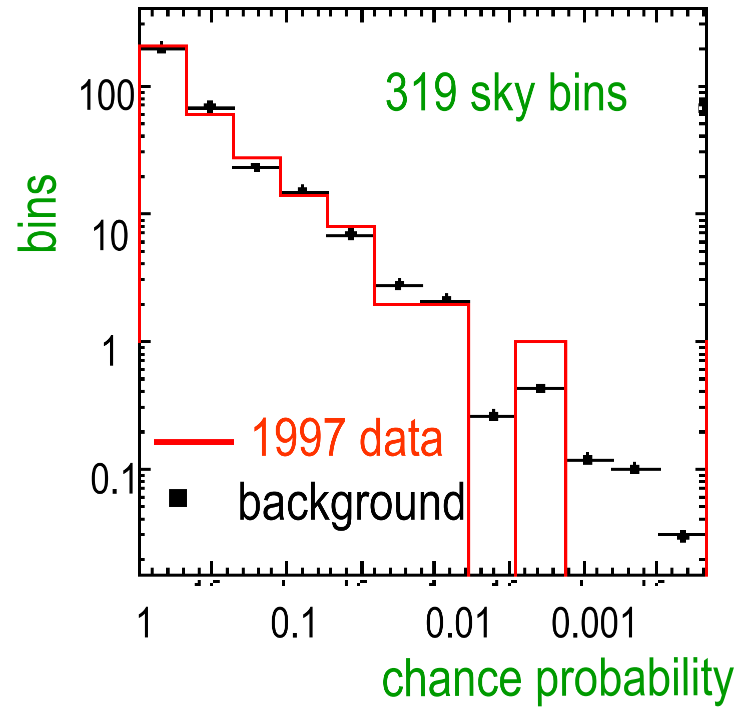
Limit: Flux · E^2 (GeV cm^{-2} s^{-1} sr^{-1}) = 4.1 10^{-6} (10 Tev – 1 PeV)

AMANDA results: Search for Point Sources

1097 events in final sample
(75% muons, 25% atmo.ν)
319 sky bins



Compatible with random distribution



Flux (>10 GeV) < 10^{-7} cm^{-2} s^{-1} @90%

Neutrino Astronomy with MACRO

Macro: underground detector array in Gran Sasso tunnel

Search among known point sources:

Make a list of 42 sources that look interesting

Look in 1.5^{o}, 3^{o}, 5^{o} around each of these sources

Macro Results on point sources

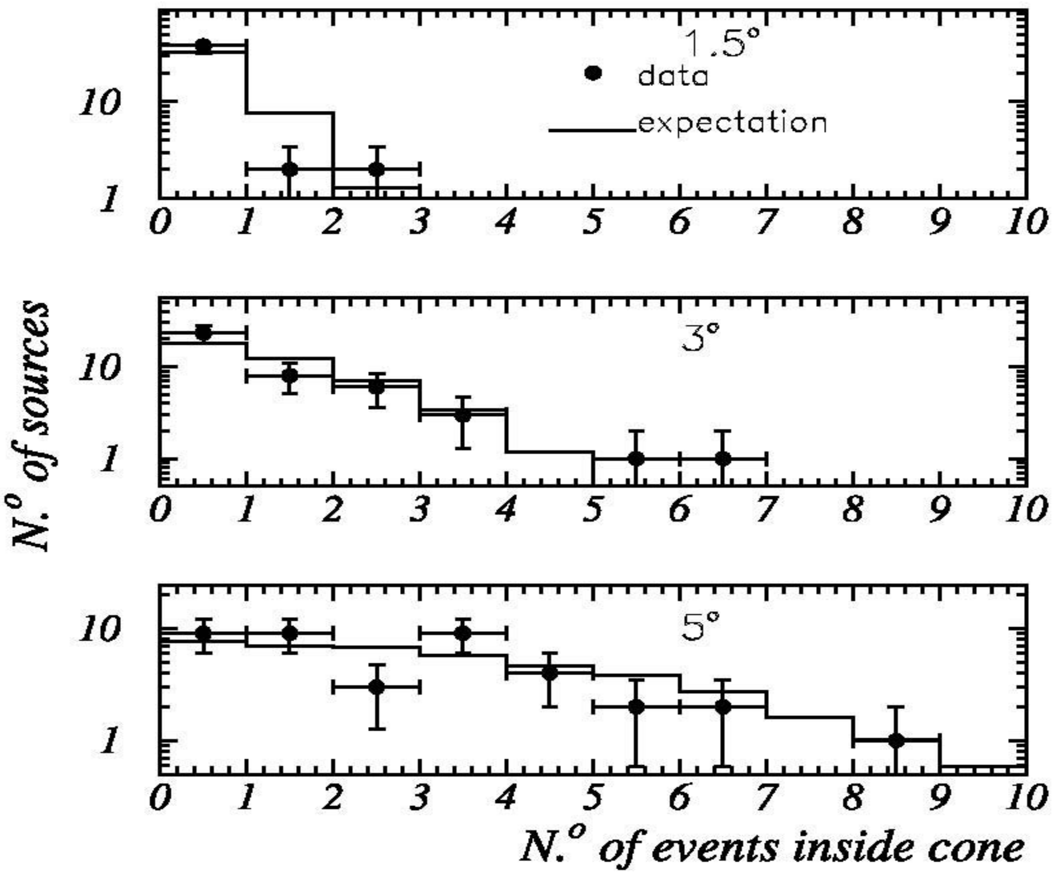
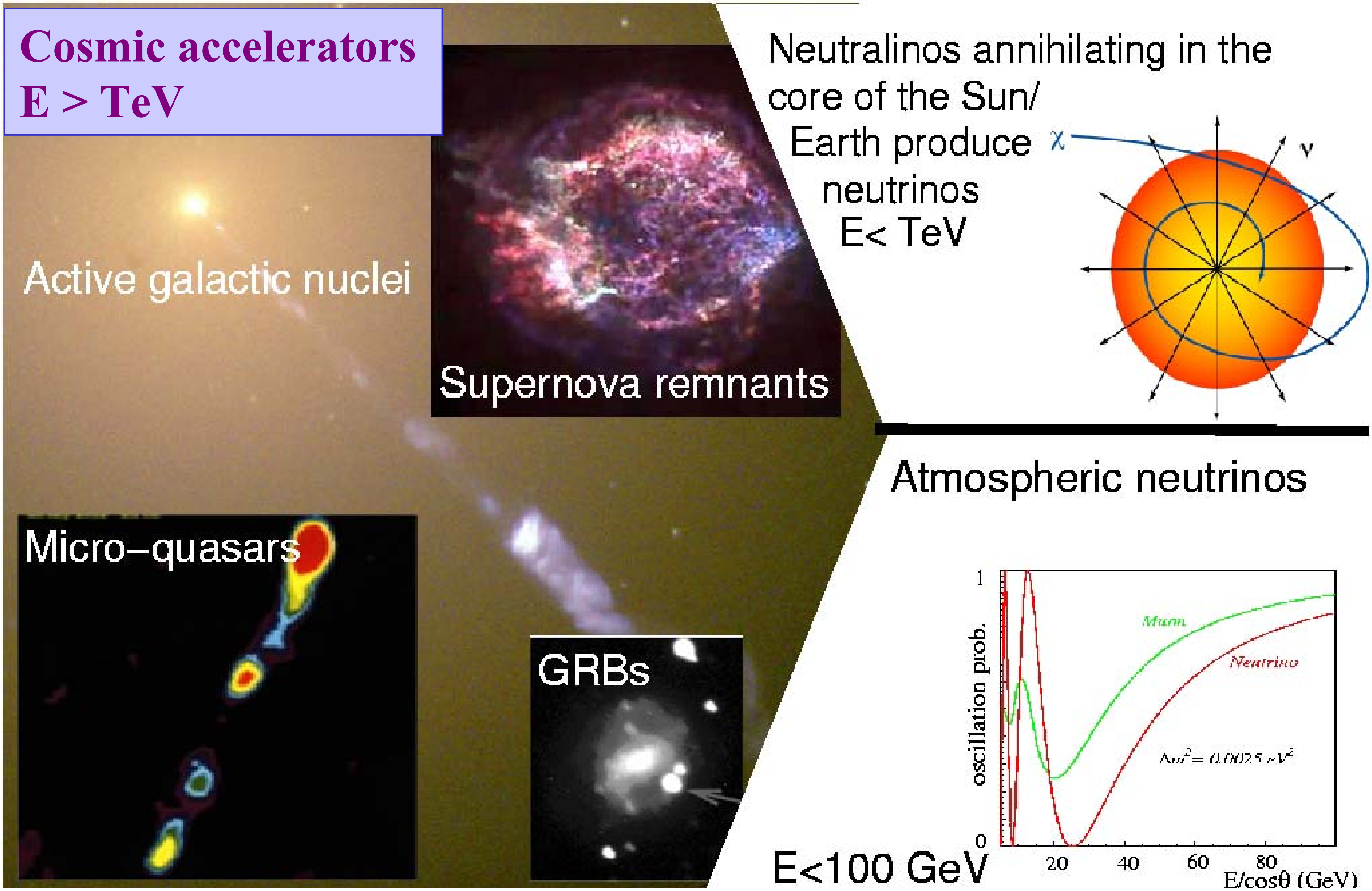


FIG. 11.—On the x-axis there are the number of events falling in cones of half-width 1°.5, 3°, and 5° (*from top to bottom*) around the direction of the 42 sources considered. The y-axis depends on the total number of sources considered. *Filled circles*: data. *Solid line*: simulation.

Neutrino Fluxes From

- Galactic Microquasars (G. Distefano, D. Guetta, E. Waxman, A. Levinson)
- GRB (A. Dar, A. De Rujula. D. Guetta…)
- Galactic Cosmic rays (F. Halzen..)
- WIMPS

Scientific Program



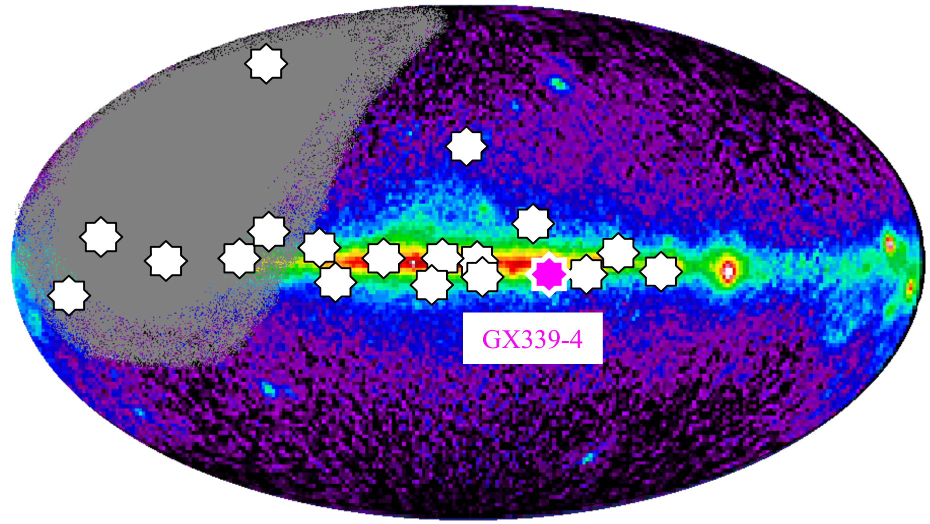
Oceanographic interest (exploration of new environment…)

Rates of Neutrinos from Microquasars

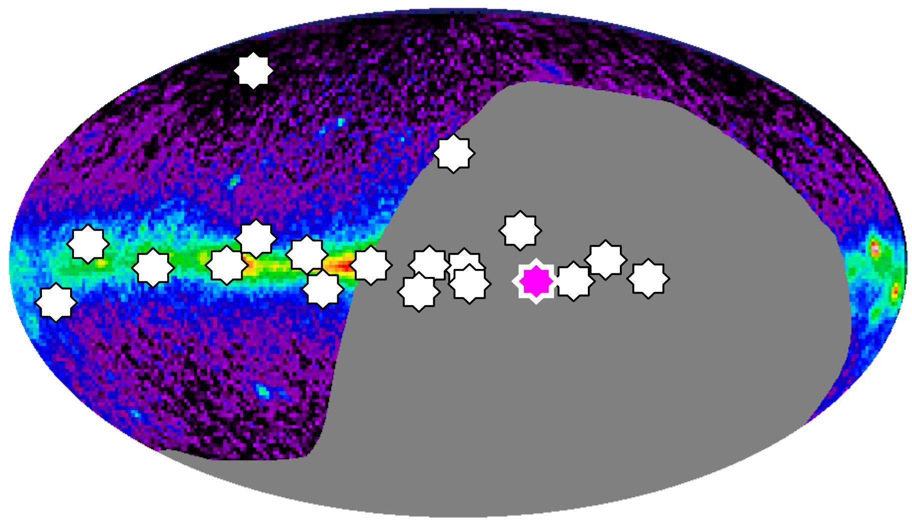
Point-Source Microquasar	Event rate/yr
XTEJ1748-288	1.1
CygnusX-3	5.1
LS5039	$5 \cdot 10^{-3}$
GROJ1655-40	3.0
GRS1915+105	0.5
CircinusX-1	0.6
XTEJ1550-564	0.1
V4641Sgr/1	0.8
V4641Sgr/2	109.3
ScorpiusX-1	$2 \cdot 10^{-2}$
SS4333	4.3
GS1354-64	0.1
GX339-4	6.5
CygnusX-1	$3 \cdot 10^{-2}$
GROJ0422+32	0.4

(Waxman et al.)

ANTARES (43° North)

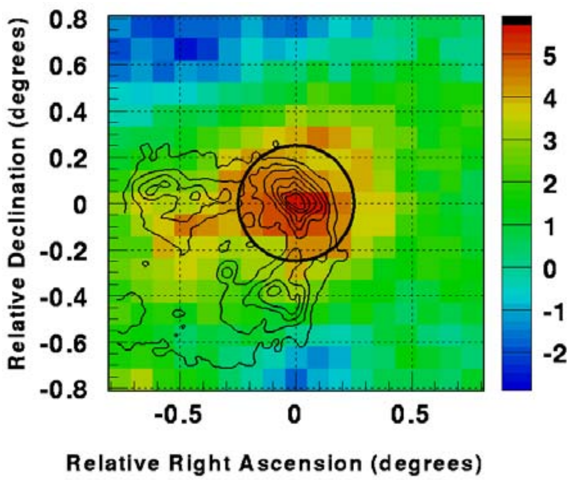


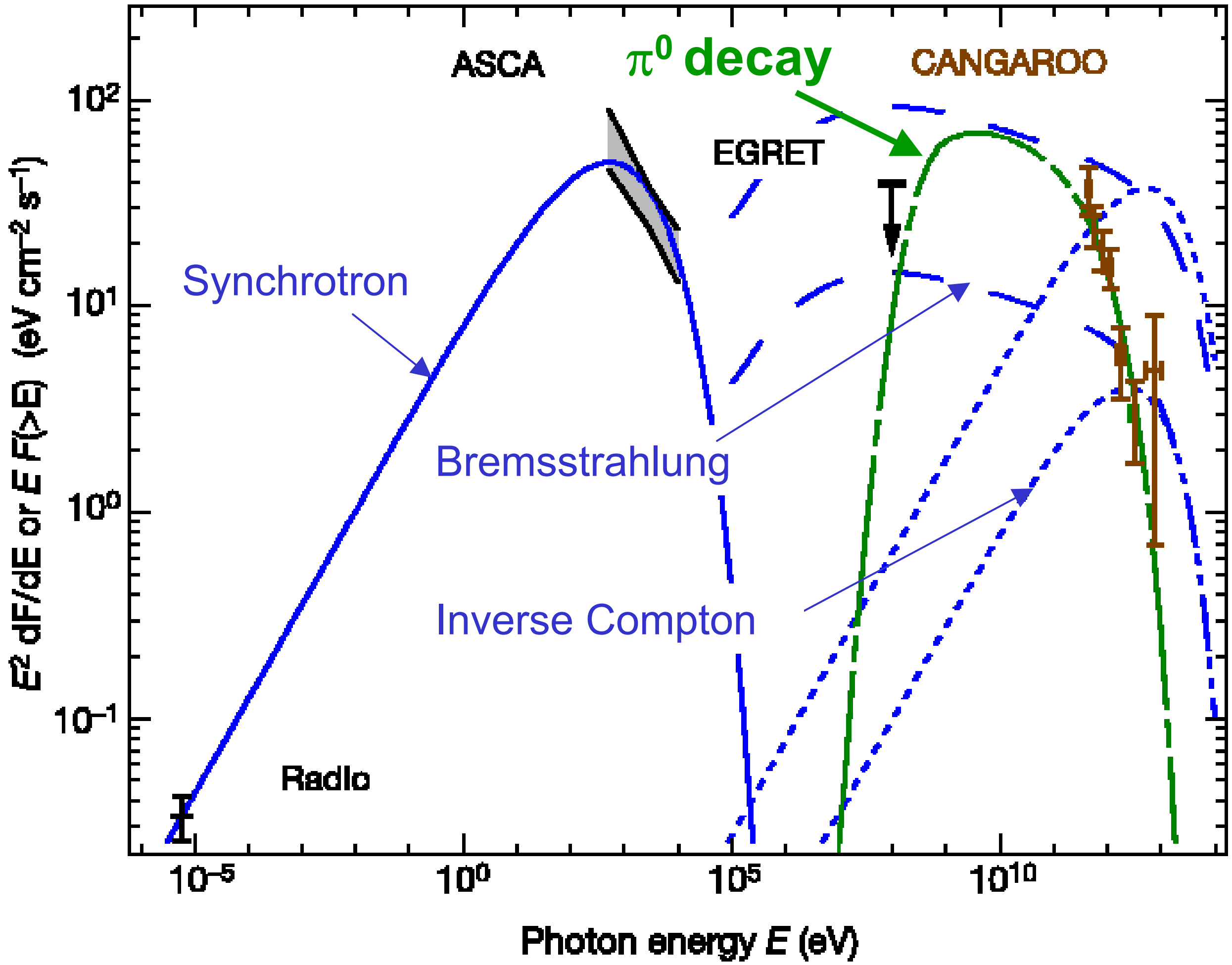
AMANDA (South Pole)



The Acceleration of cosmic-ray protons in the supernova remnant RX J1713.7-3946

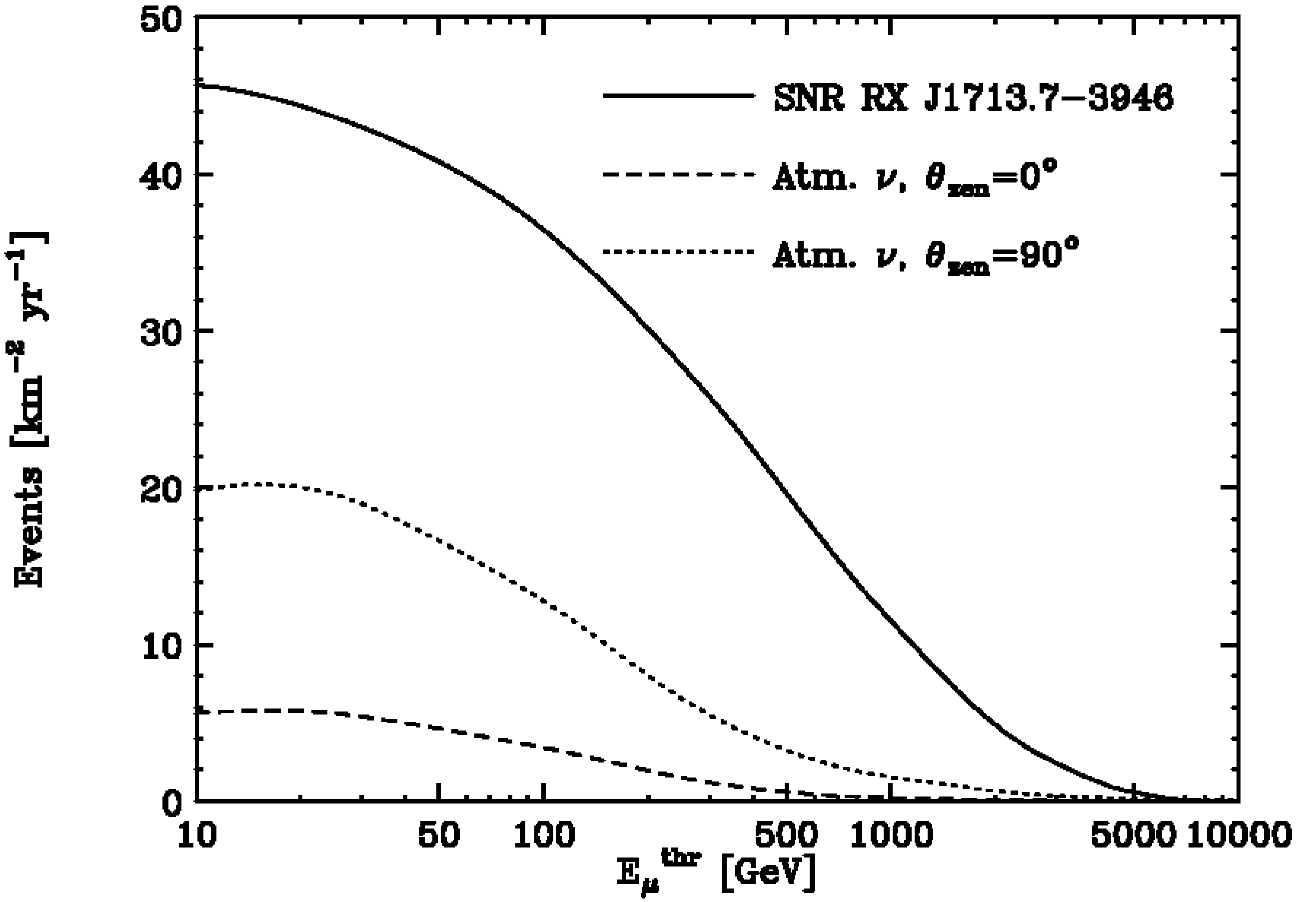
R. Enomoto et al., Nature, v416, p823,25 April 2002





High Energy Neutrinos from the Cosmic Accelerator RX J1713.7-3946

J. Alvarez-Muñiz and F. Halzen (astro-ph/0205408)

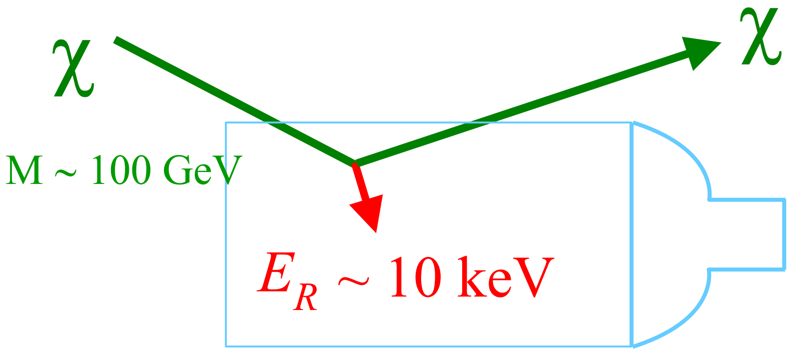


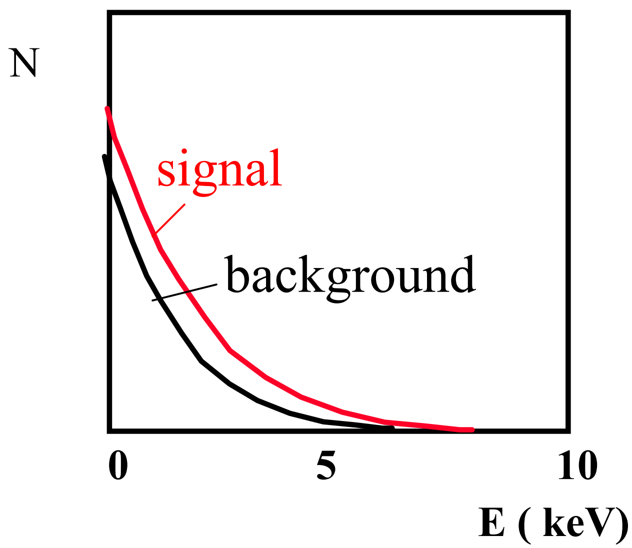
Clear signal for Northern Hemisphere Neutrino Telescope

Detection of WIMPS

Direct

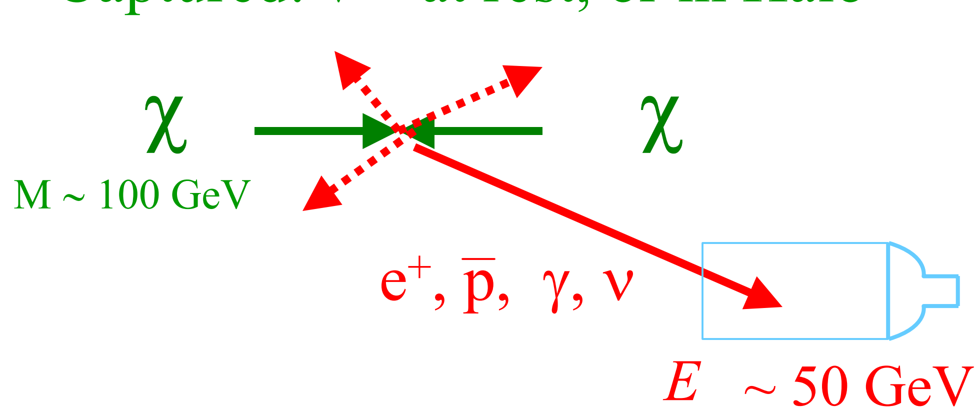
Halo: v ~ 300 km/sec

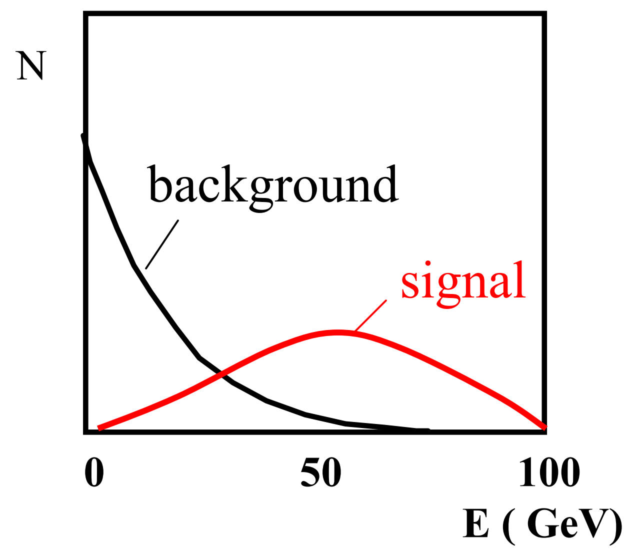




Indirect

Captured: v ~ at rest, or in Halo





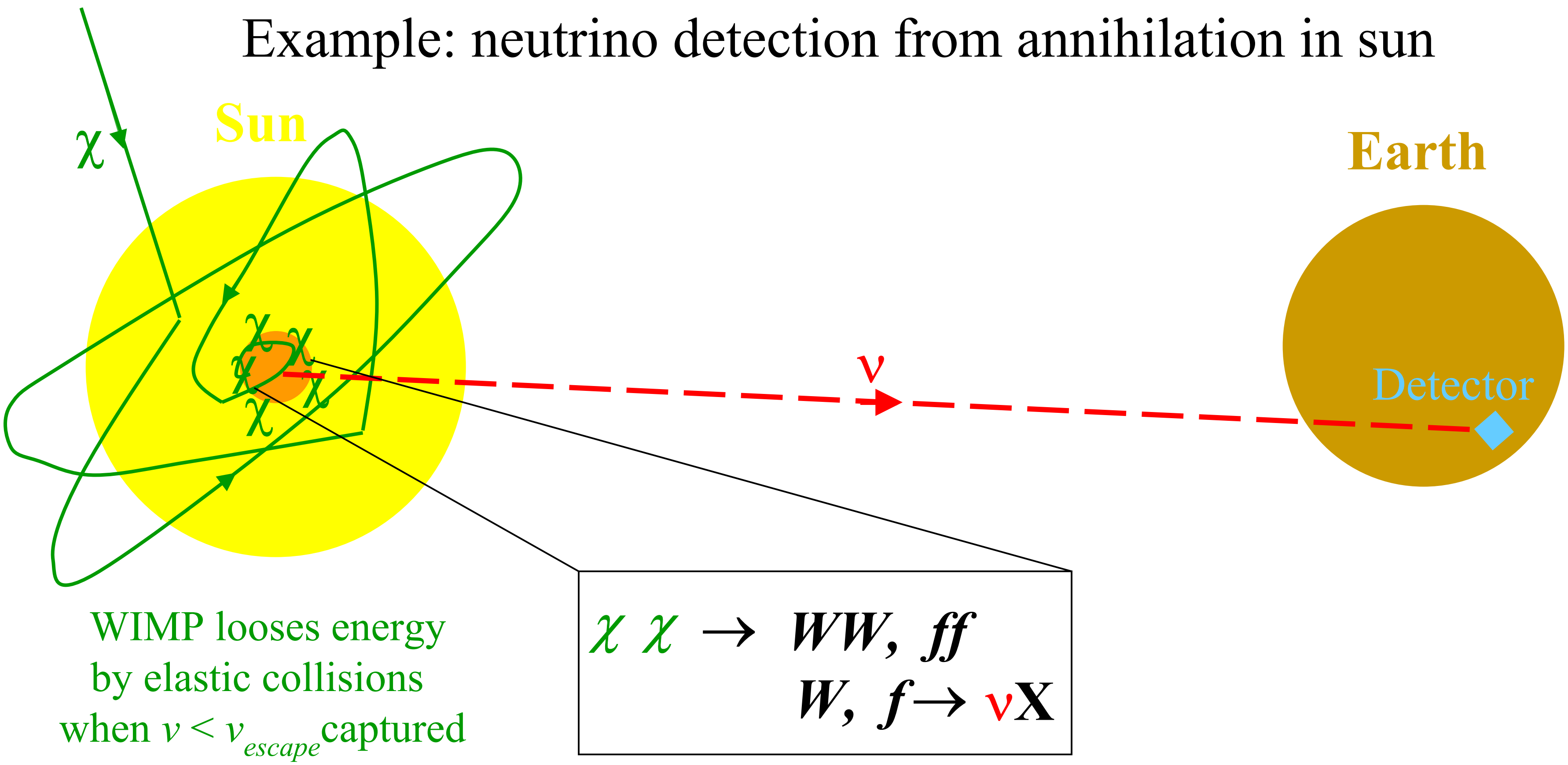
Indirect detection of WIMPS

Searches for annihilation in

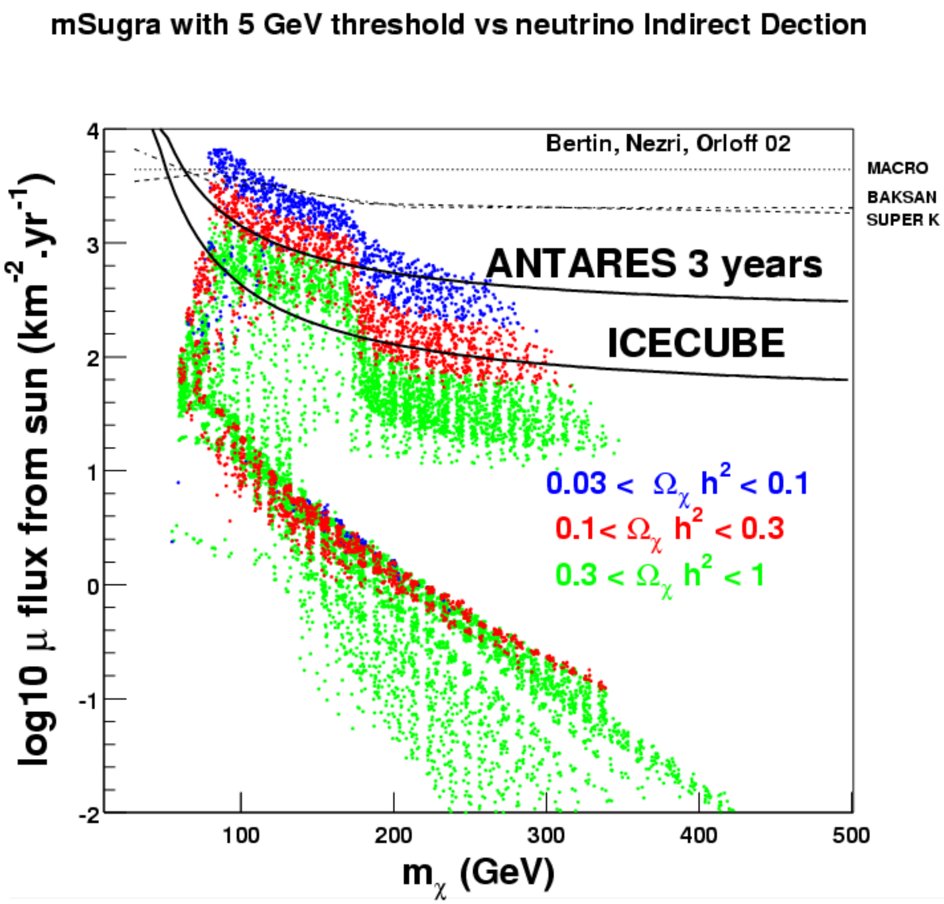
Halo, Earth, Sun , Galactic Centre, other galaxies, …

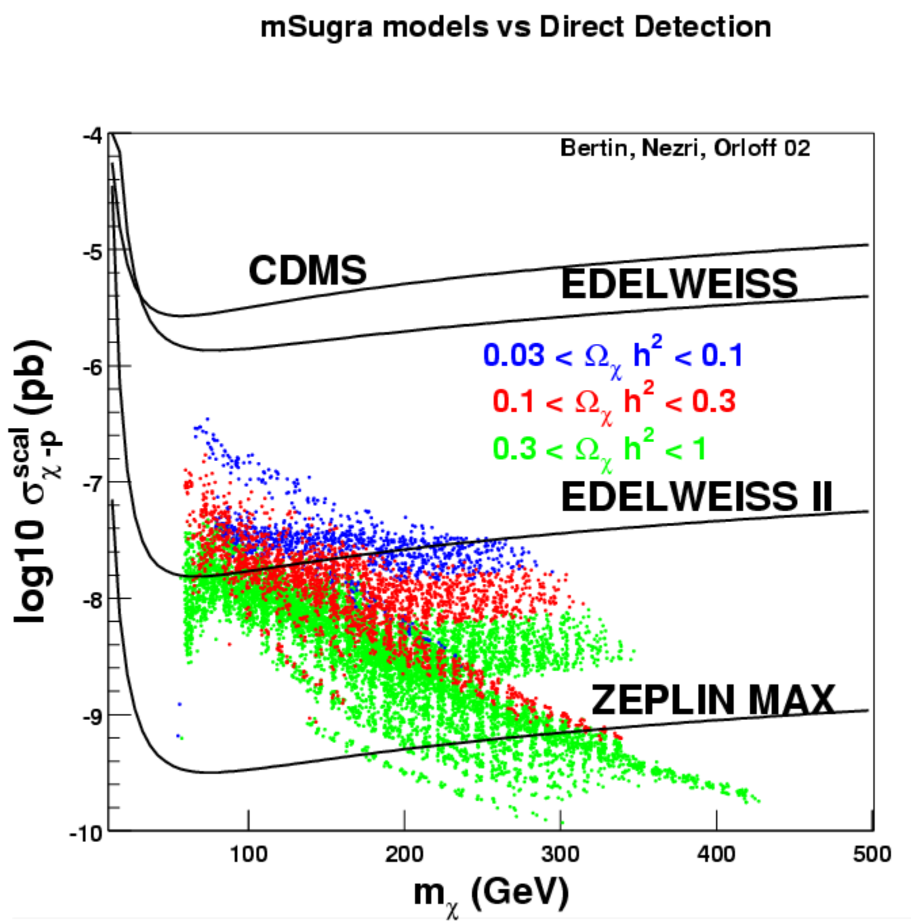
various secondary particle signatures: e^+, $\bar{p}$, D, γ, ν

Example: neutrino detection from annihilation in sun

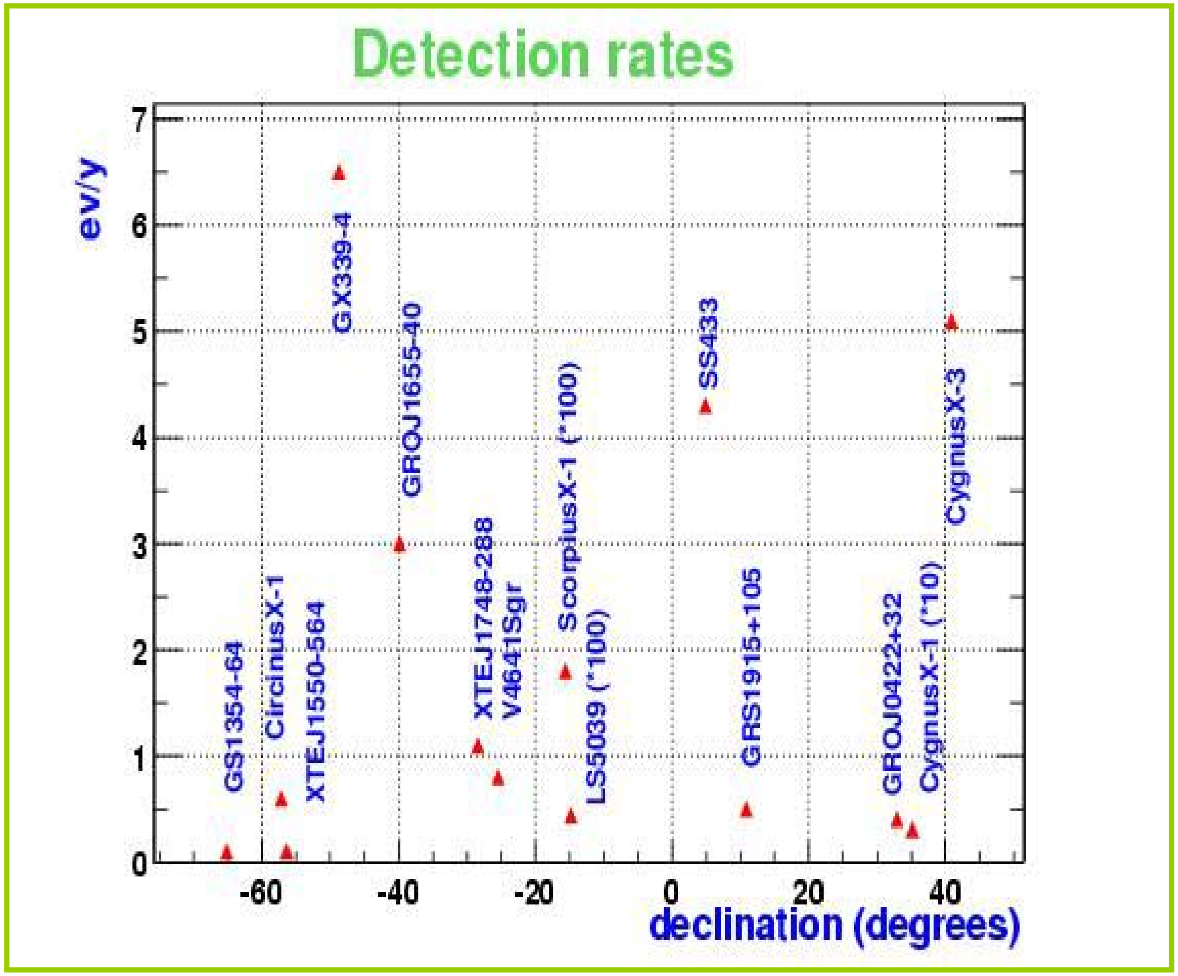


ANTARES WIMP Sensitivity
Indirect Neutrino vs. Direct





Event rates from Galactic models



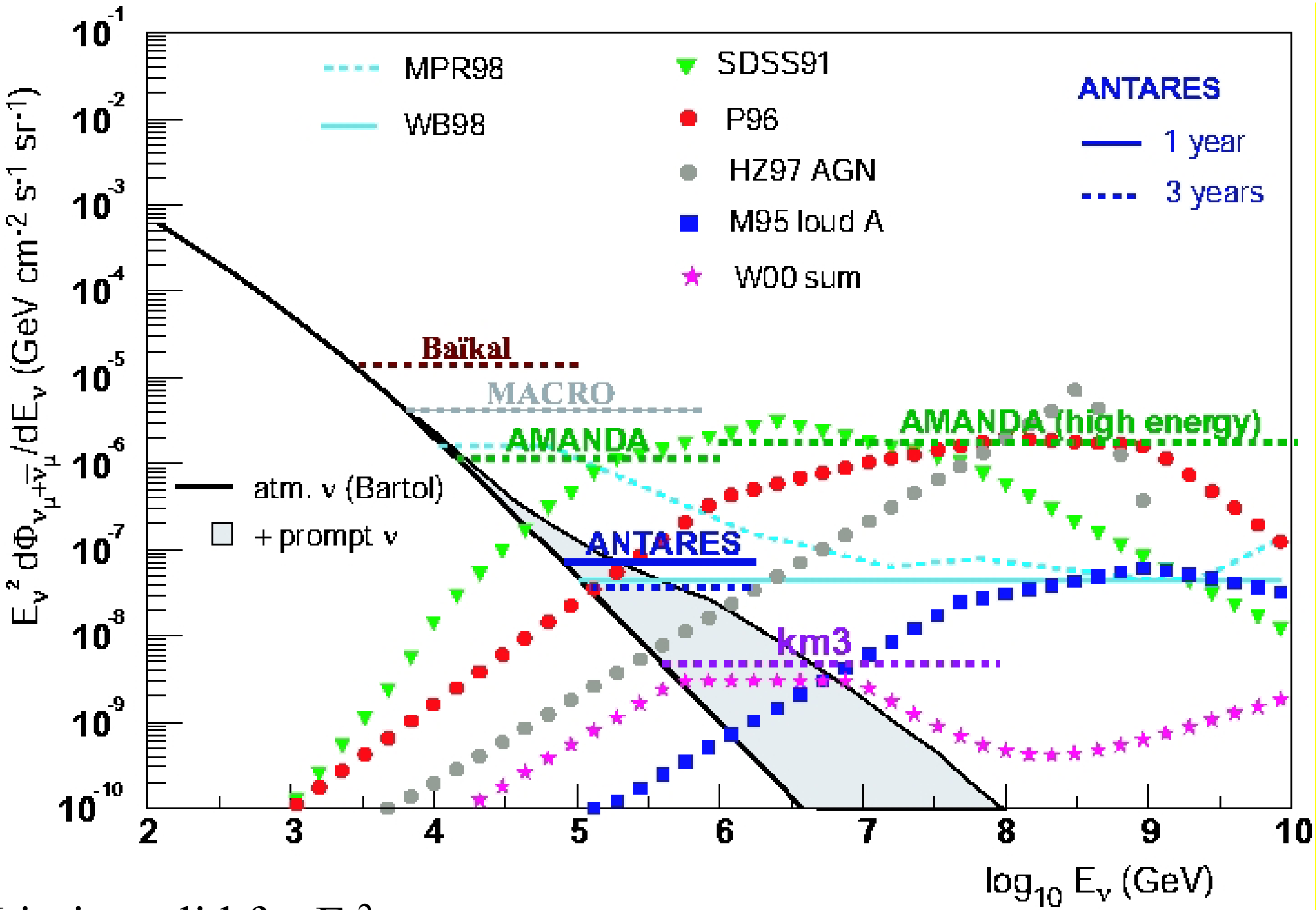
OK for young SNRs : ~10 events/year

OK for microquasars : ~ 3-6 events/year

Bad detection rates for plerions & magnetars.

Alain Juande

Diffuse fluxes



Limits valid for E^{-2}

No oscillations for models

10 strings

ANTARES 20 times better SDSS9 in 1 yr

AMANDA (ν_μ) 130 d (astro-ph/030328): 8.4 10^{-7} GeV cm^{-2} s^{-1} sr^{-1}

AMANDA UHE >10^{16}eV: 4.8 10^{-6} GeV cm^{-2} s^{-1} sr^{-1}

MACRO: 4.1 10^{-6} GeV cm^{-2} s^{-1} sr^{-1} Astrop Phys 19 2003

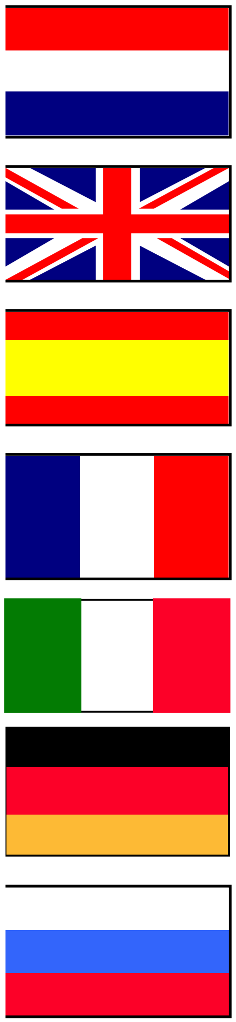
Baikal: 1.4 10^{-5} cm^{-2} s^{-1} sr^{-1} Astrop Phys 19 2000

km3 (ICECUBE): expected sensitivity

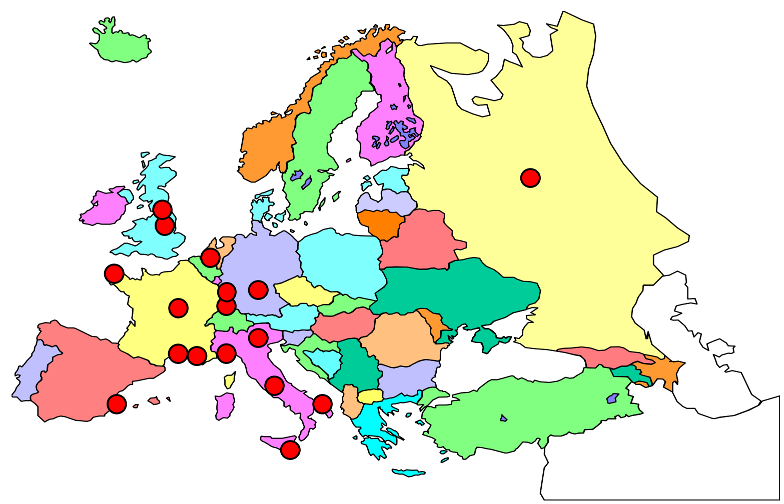
ANTARES Project History

	1996 - 2000	R&D, Site Evaluation
January	2000	Operation of ‘Demonstrator’ line
	2001	Start of construction at Toulon site
December	2002	Deploy prototype line
March	2003	Connection with Nautile submarine
March	2003	Start operation of prototype lines
May	2004	Start final assembly 12 line production
December	2005	ANTARES 12 line detector finished
	2005	Design for 1km^3 Detector

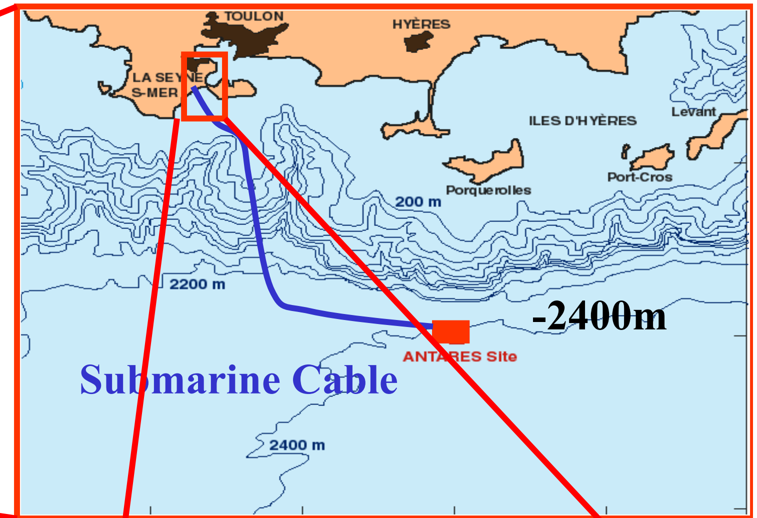
ANTARES Collaboration

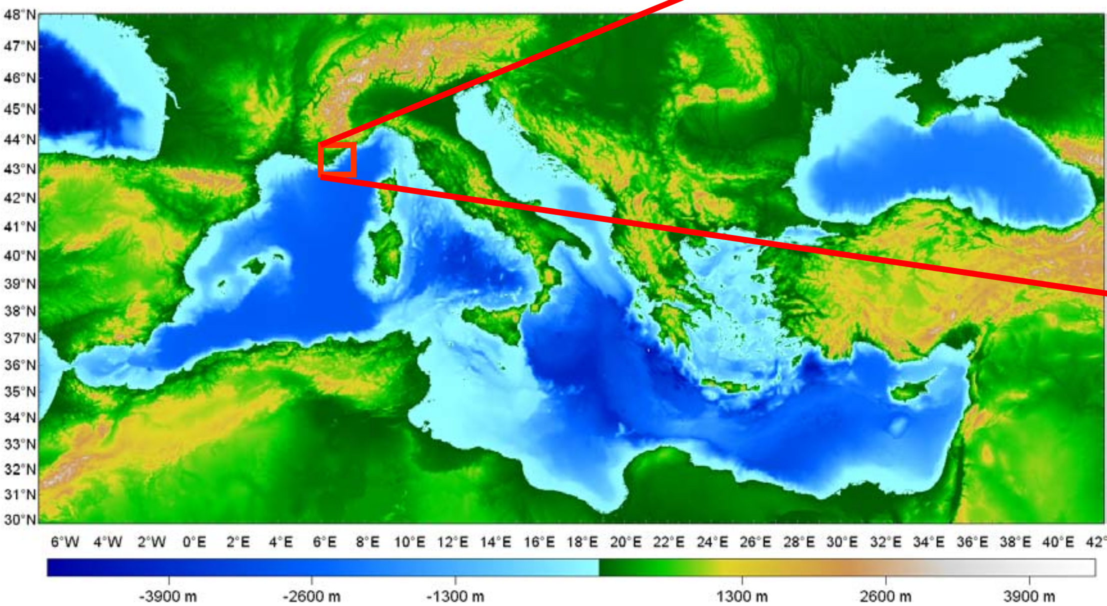


- NIKHEF, Amsterdam
- University of Sheffield
- University of Leeds
- IFIC, Valencia
- CPPM, Marseille
- DSM/DAPNIA/CEA, Saclay
- C.O.M. Marseille
- IFREMER, Toulon/Brest
- LAM, Marseille
- IReS, Strasbourg
- Univ. de H.-A., Mulhouse
- ISITV, Toulon
- LOV Villefranche
- University of Bari
- University of Bologna
- University of Catania
- LNS – Catania
- University of Rome
- University of Genova
- University of Erlangen
- ITEP, Moscou



ANTARES Site





Shore Station

ANTARES Test Sites

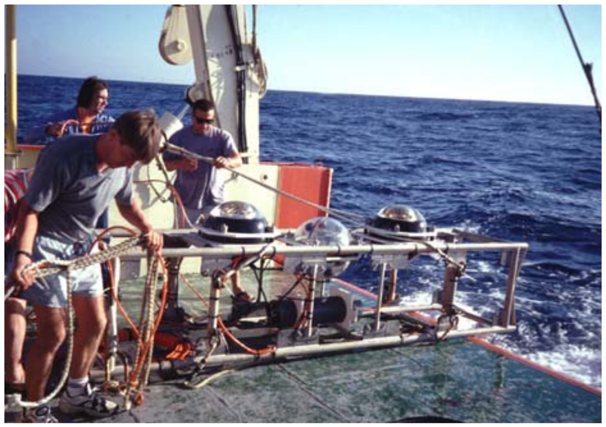
~ 40 deployments and recoveries of test lines for site exploration

0.1 km² Detector with 900 Optical Modules , deployment 2002- 200

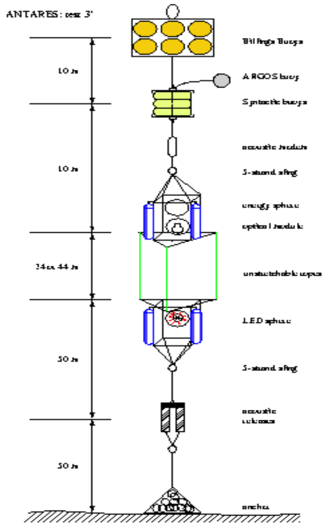
Site Explorations

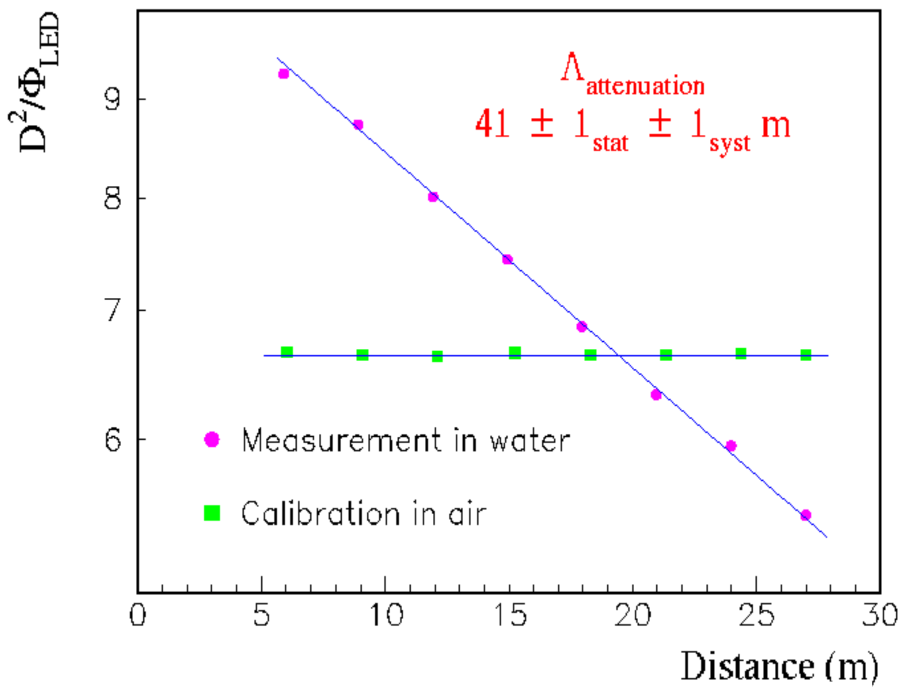
1) Optical background study:	15 deployments
2) Biofouling-sedimentation study:	4 deployments
3) Optical properties study:	28 deployments

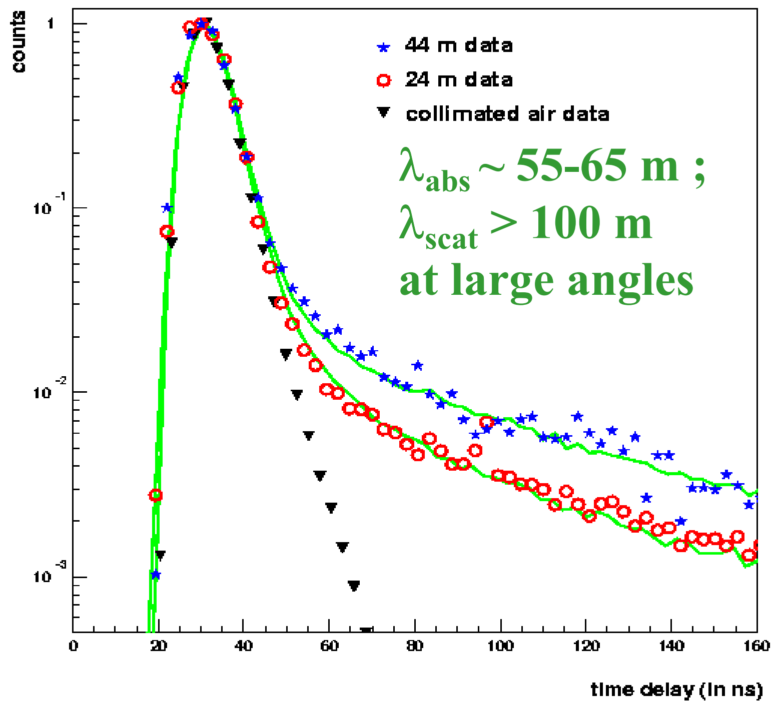




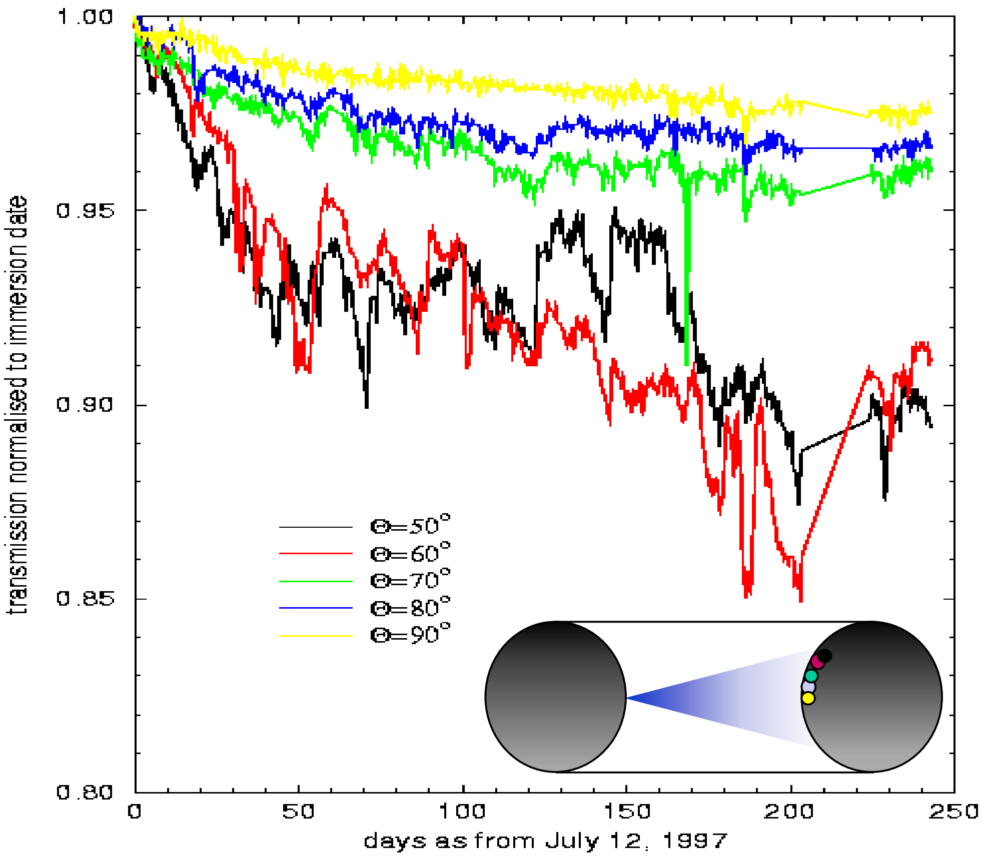

Water Transparency





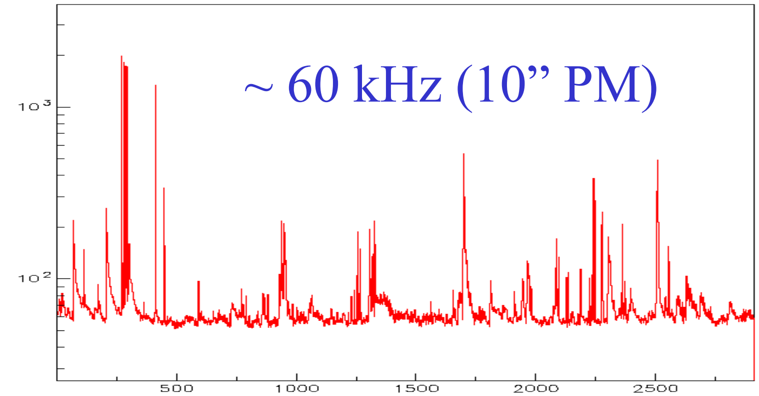


Biofouling

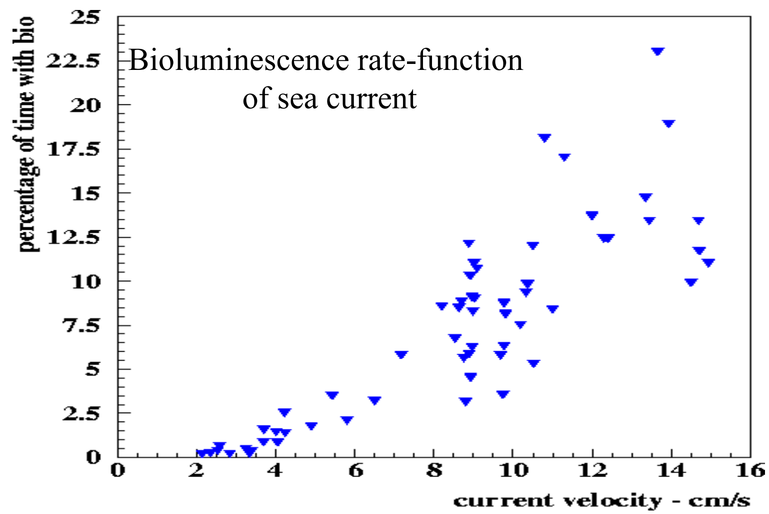


For θ > 90° transmission loss
< 1.5% in 1 yr (and saturates)

Optical Backgrounds

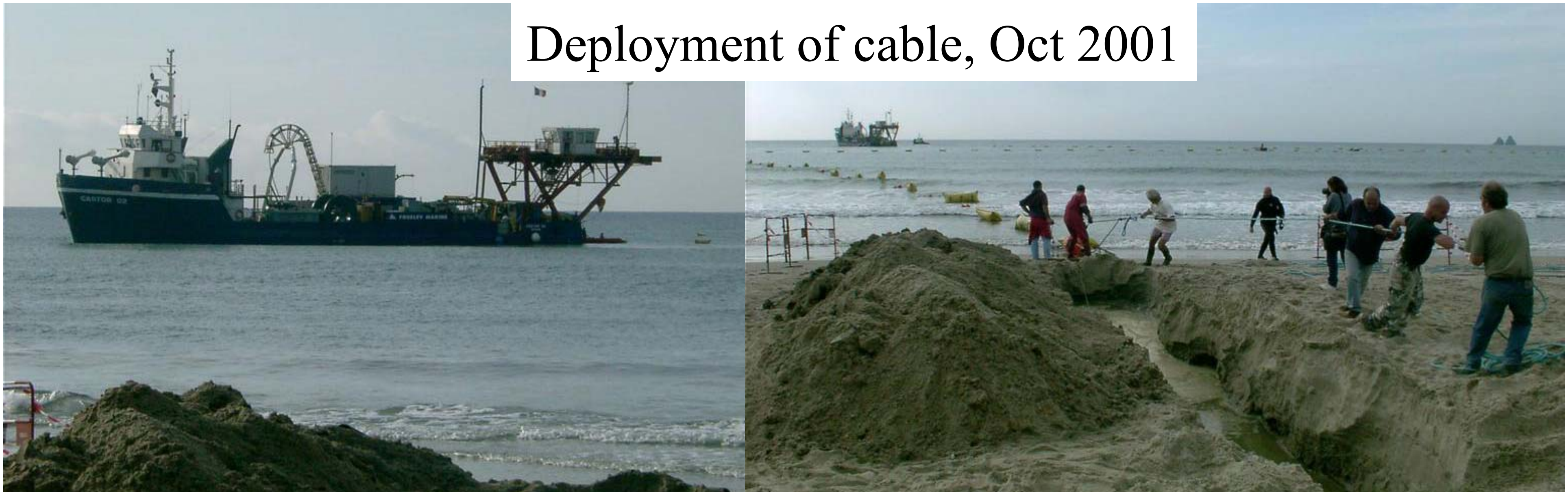


Short bursts (bioluminescence) over a continuous background (^{40}K).



~5% of time a PMT is unusable

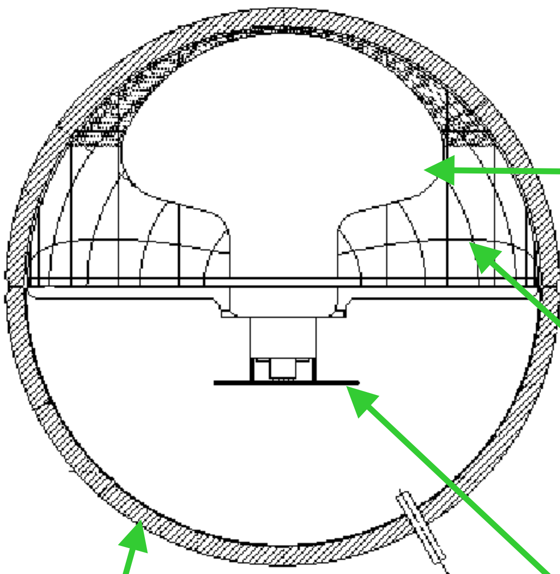
Construction of ANTARES Detector



Deployment of cable, Oct 2001

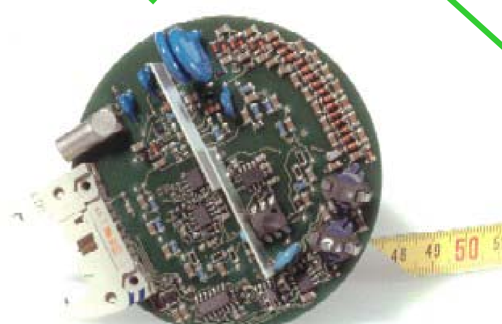
Test of line deployment, Nov 2001

Optical Module



Photomultiplier: 10 inch Hamamatsu

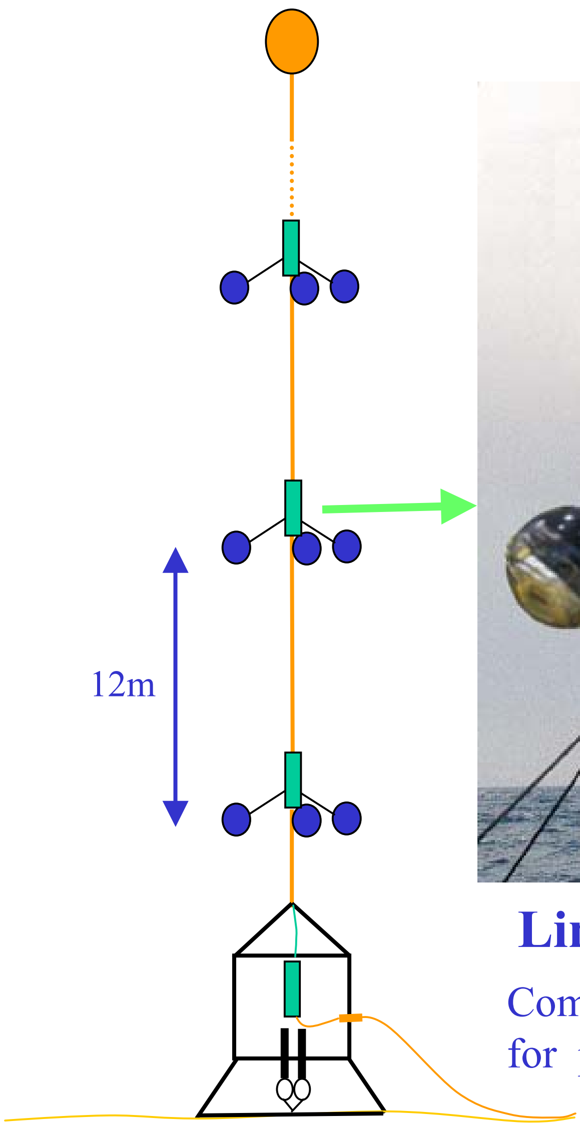
Glass sphere: Nautillus

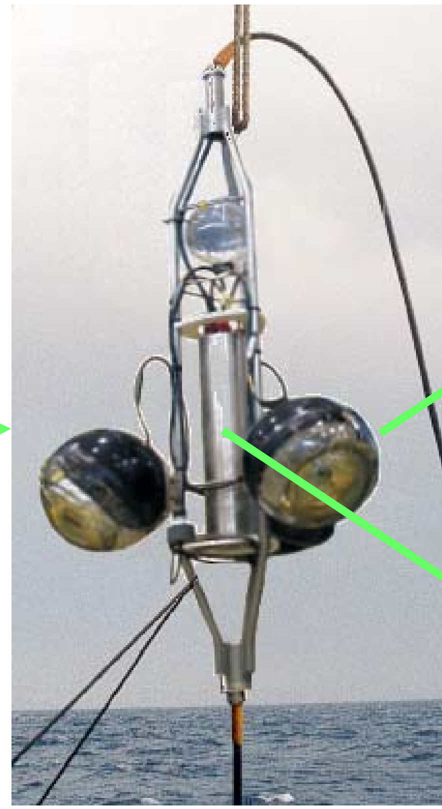


Active PMT base

Mu metal magnetic shield

Detector Line





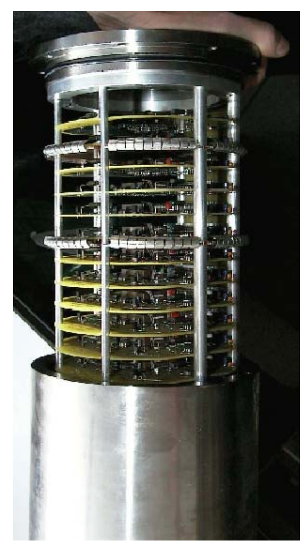
Line mechanics

Components available
for prototype line

Optical Module

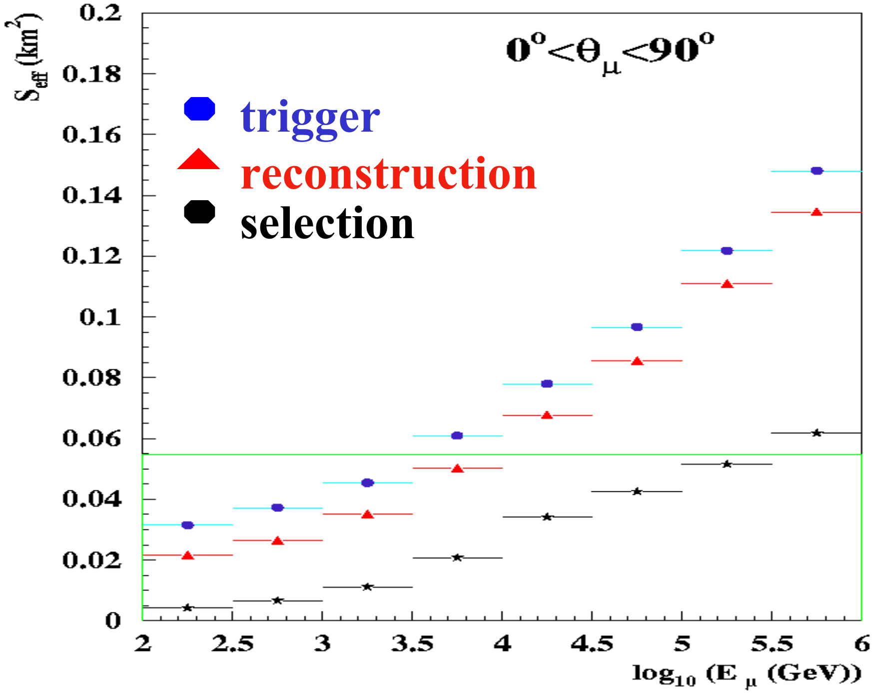
All components ordered
arriving 100 / month
90% available end 2001
production starts oct 2001

Sea Electronics



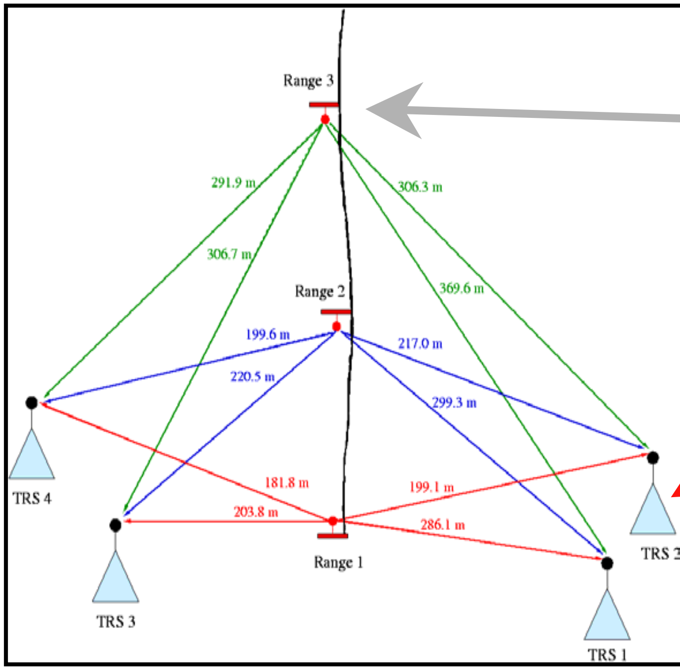
most cards working in prototype
complete system test Nov 2001

Effective Detection Area

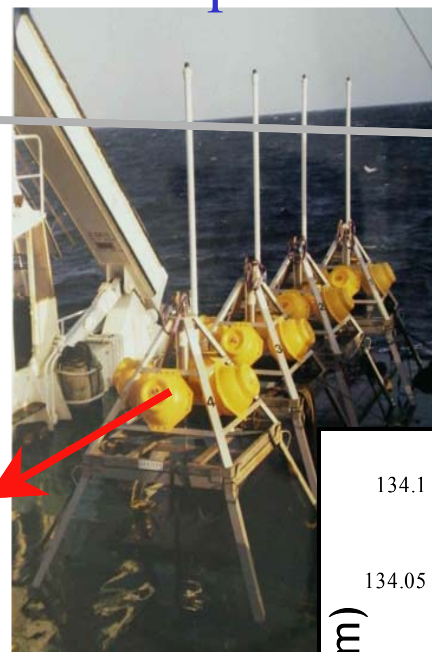


Expérience	Propriétés optiques	Précision angulaire	Surface effective $E_\mu = 1$ TeV	Surface effective $E_\mu = 100$ TeV
Antarès 10 lignes	$\lambda_{abs} \approx 55$ m $\lambda_{diff} \approx 52$ m	$\sim 0,2°$	~ 10000 m^2	~ 55000 m^2
AMANDA II 19 lignes	$\lambda_{abs} \lesssim 100$ m $\lambda_{diff} < 25$ m	$\sim 3,0°$	~ 30000 m^2	~ 50000 m^2
Baikal 8 lignes	$\lambda_{abs} \gtrsim 15$ m $\lambda_{diff} \lesssim 50$ m	$\sim 1,5°$	~ 800 m^2	~ 1360 m^2

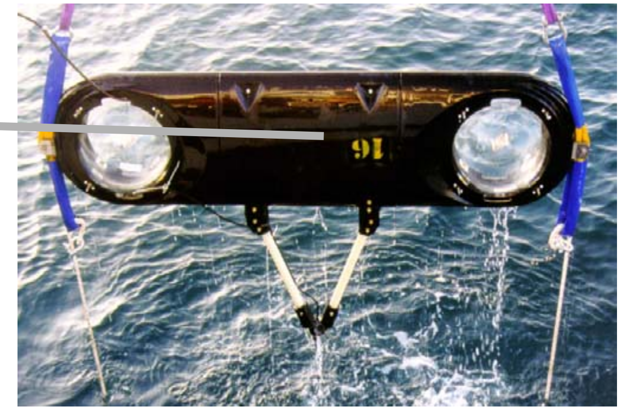
Acoustic Positioning Prototype

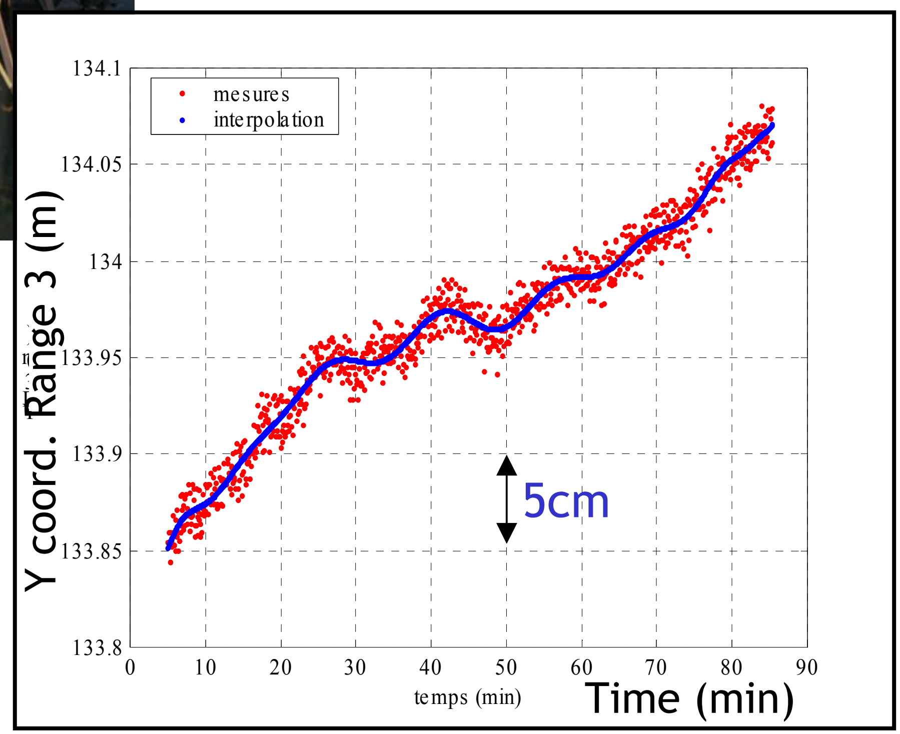


4 transponders



3 distancemeters

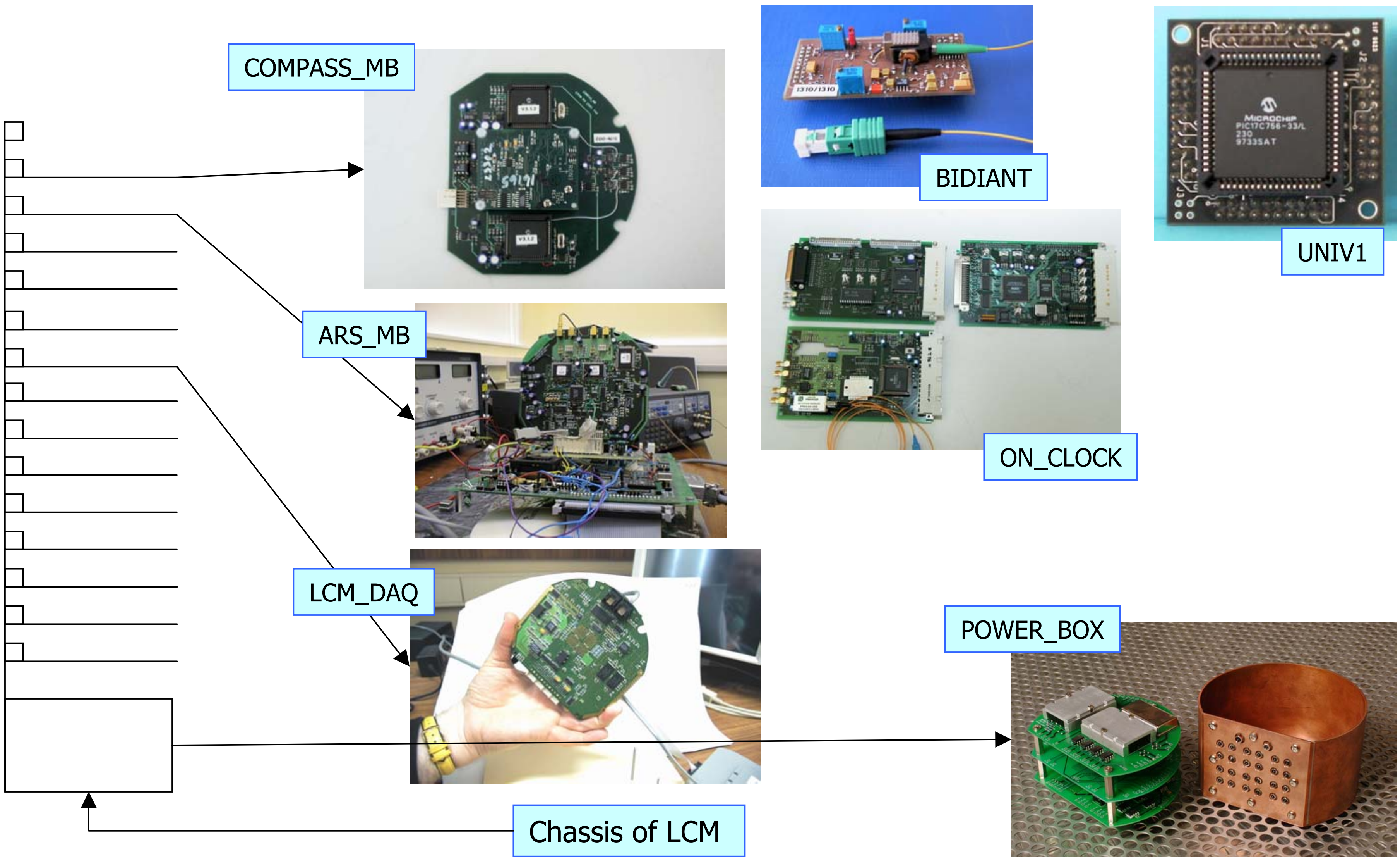




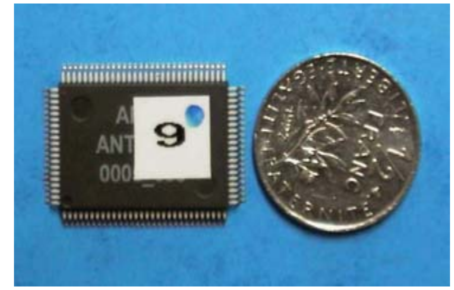
distance	Precision (σ)
Inter-distancemeter	~ 1 cm
Inter-transponder	~ 1 cm
Range-Transponder	≤ 3 cm

Triangulation → ~5 cm final precision

Electronics



ARS: The front-end digitizer



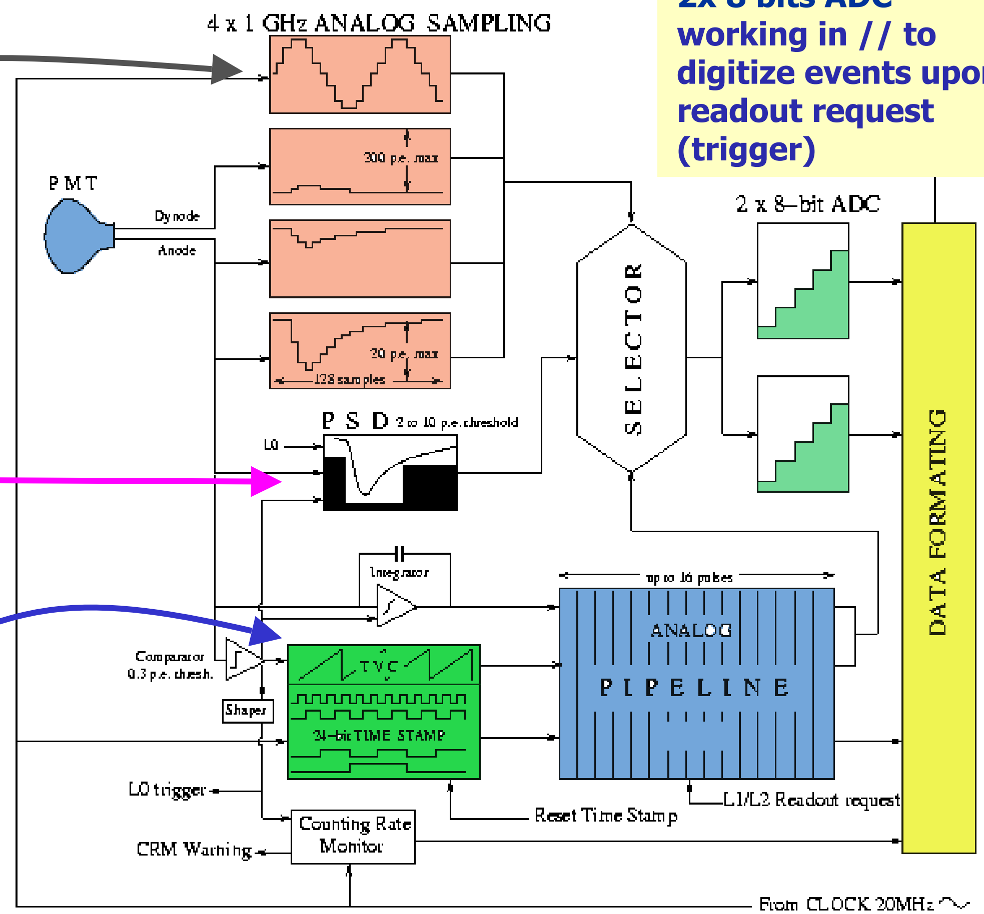
The Analog Ring Sampler (ARS) chip performs the complex front-end functions: ~10$/chip, 250mW

Constant 1GHz analog sampling of PMT's Anode, A/5, Dynode 11, and CLOCK signals Dynamic: 4V (~60spe)

Configurable pulse-shape discrimination to tag complex shapes (Waveform) which will be fully digitized.

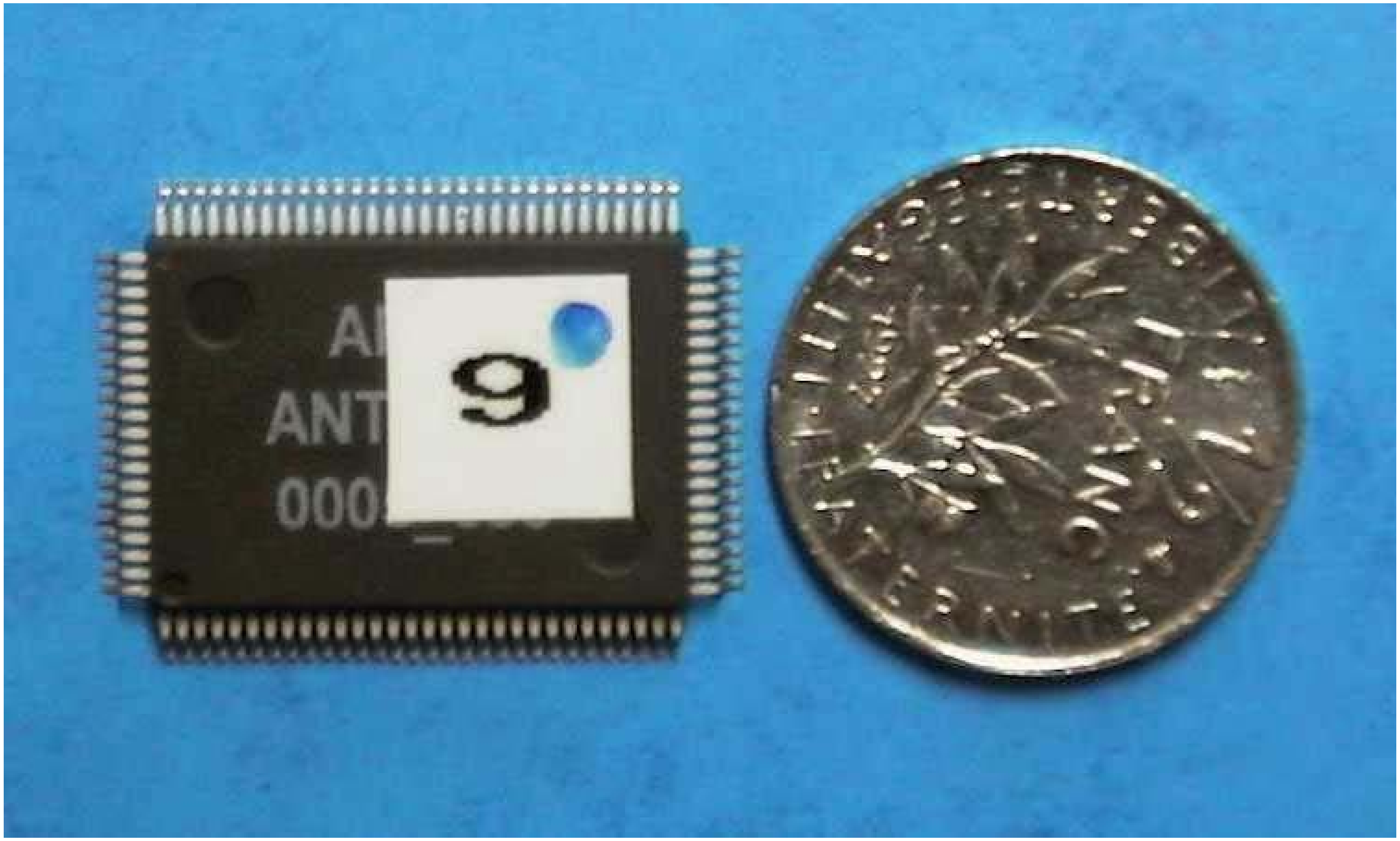
For simple pulses (SPE like) only Charge and Time information is measured.
σ_t ~400 ps

2x 8 bits ADC working in // to digitize events upon readout request (trigger)

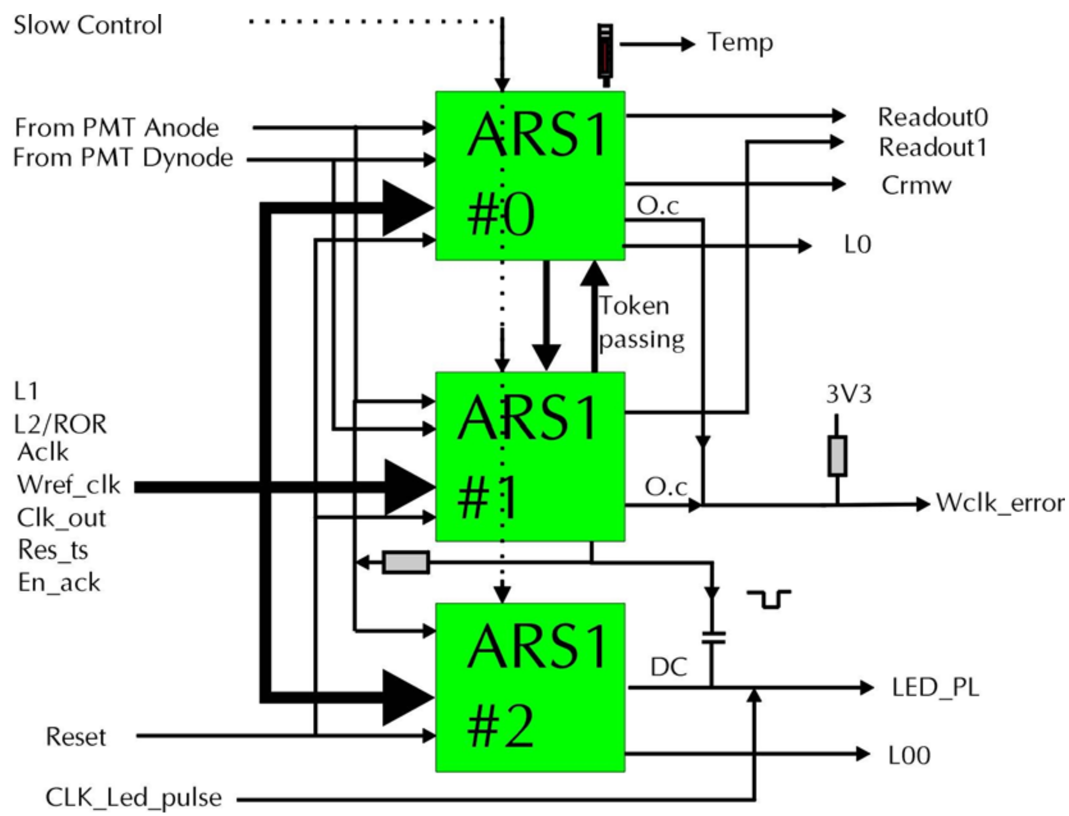


A high speed (20Mb/s) serial port is used to transfer digitized events to the central daqLCM processor.

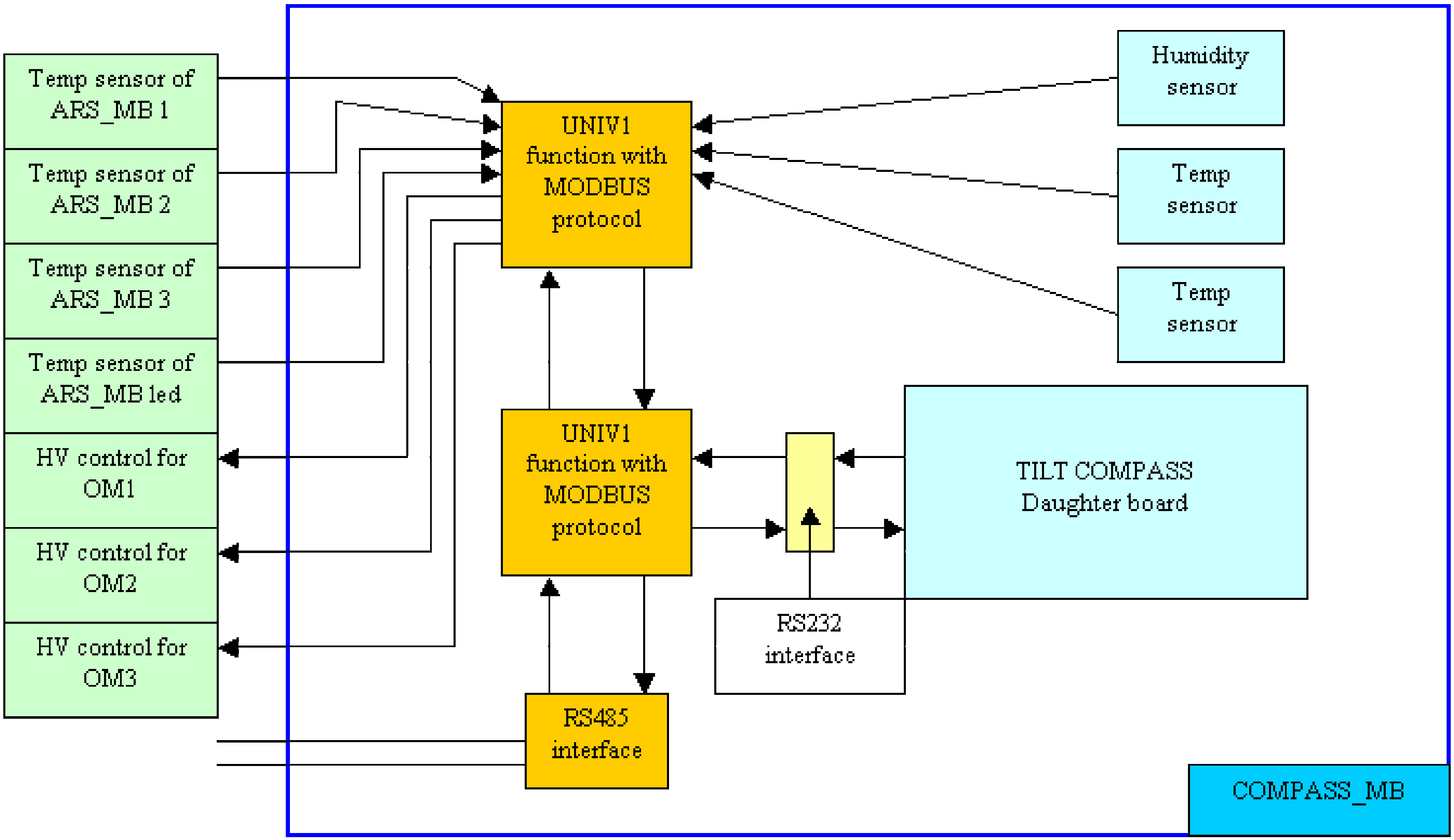
Ars1



Ars Structure

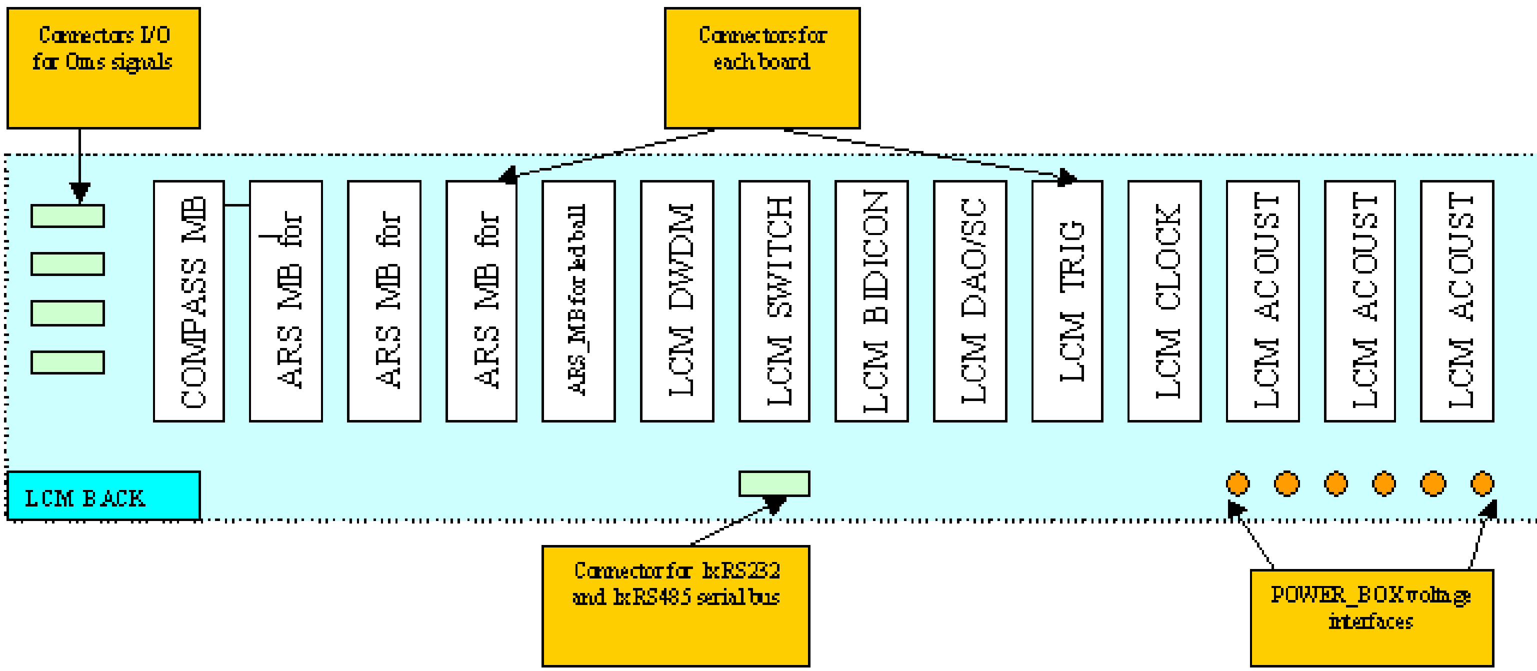


COMPASS_MB

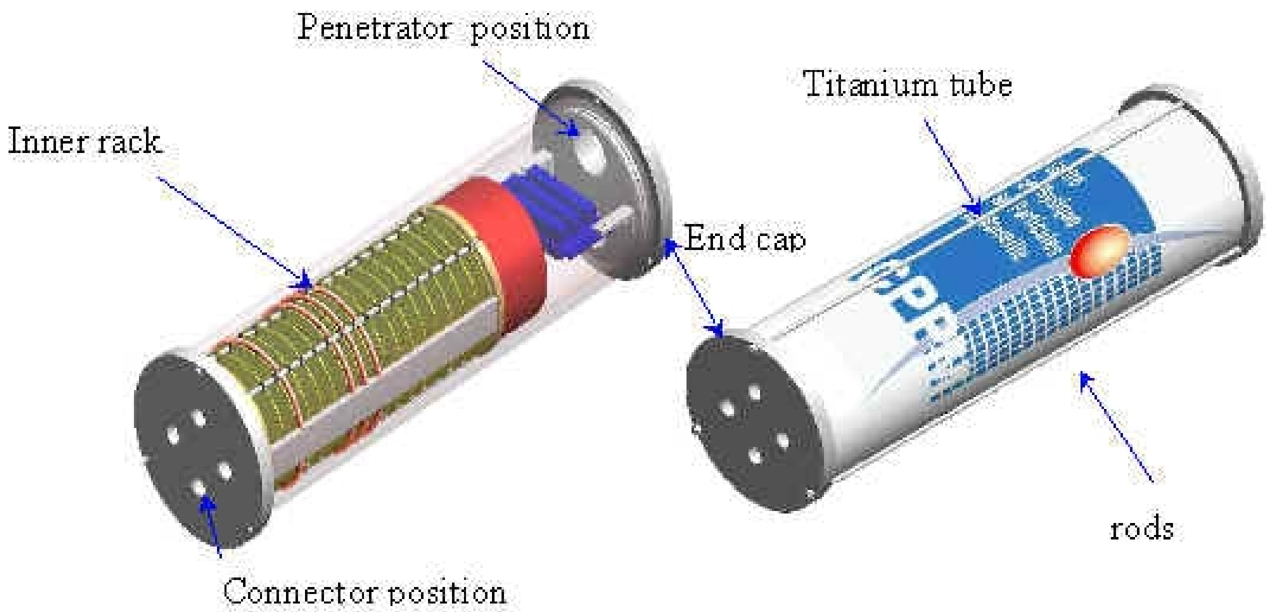


Temp sensor of ARS_MB 1
Temp sensor of ARS_MB 2
Temp sensor of ARS_MB 3
Temp sensor of ARS_MB led
HV control for OM1
HV control for OM2
HV control for OM3
UNIV1 function with MODBUS protocol
UNIV1 function with MODBUS protocol
RS485 interface
RS232 interface
Humidity sensor
Temp sensor
Temp sensor
TILT COMPASS Daughter board
COMPASS_MB

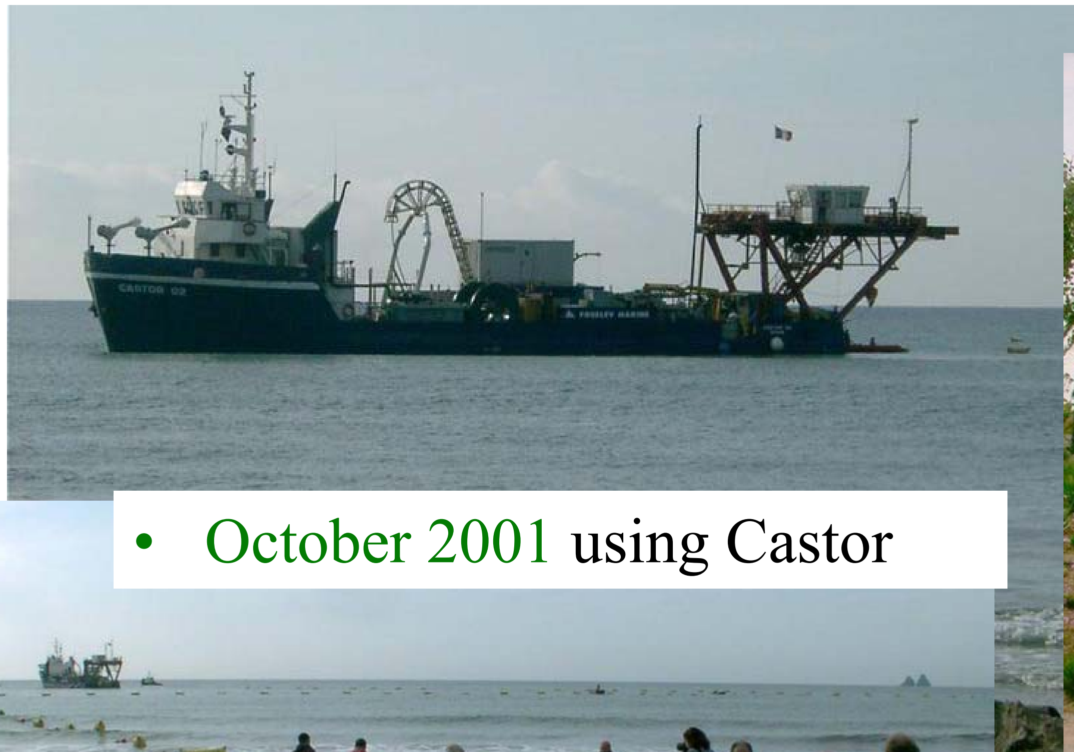
Backplane


Connectors I/O for Oms signals
Connectors for each board
COMPASS MB
ARS MB for
ARS MB for
ARS MB for
ARS_MB for led ball
LCM DWDM
LCM SWITCH
LCM BIDICON
LCM DAQ/SC
LCM TRIG
LCM CLOCK
LCM ACOUST
LCM ACOUST
LCM ACOUST
LCM BACK
Connector for 1xRS232 and 1xRS485 serial bus
POWER_BOX voltage interfaces

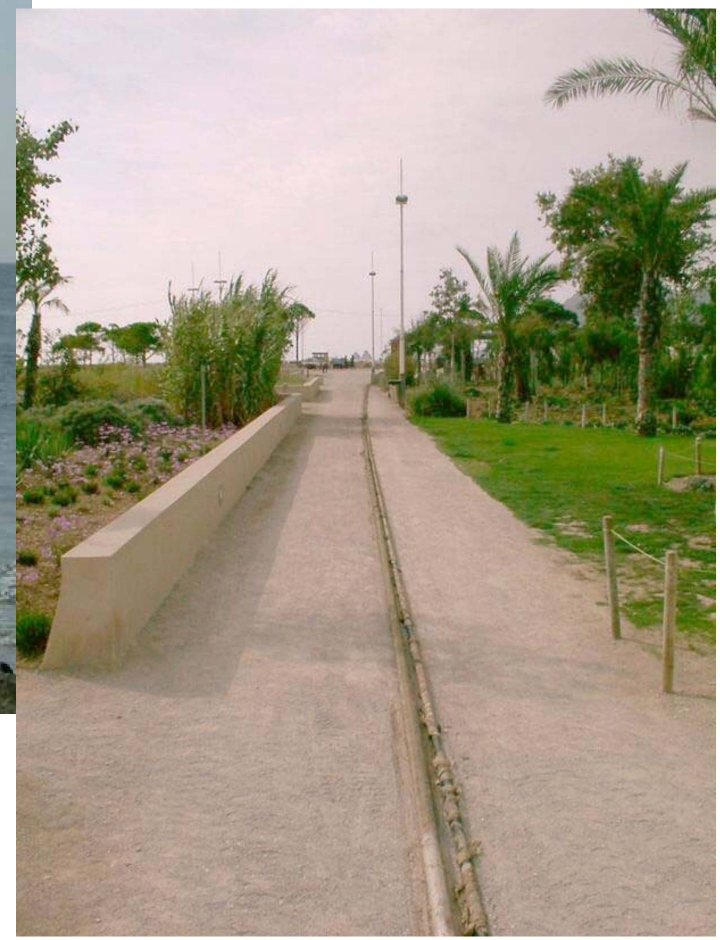
LCM


Penetrator position
Inner rack
Titanium tube
End cap
rods
Connector position

Deployment of Electro-Optical Cable



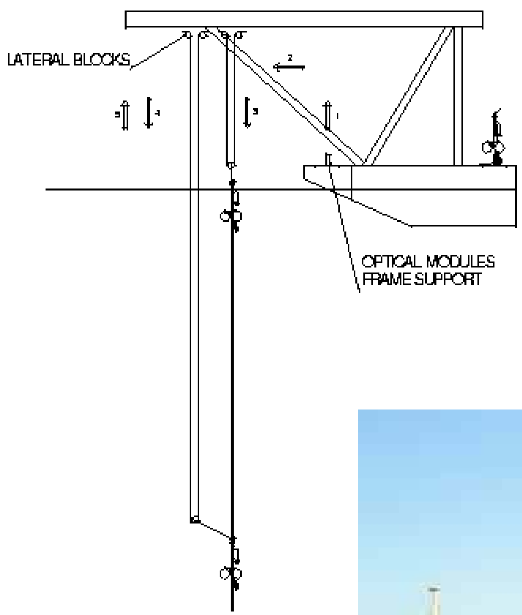
- October 2001 using Castor



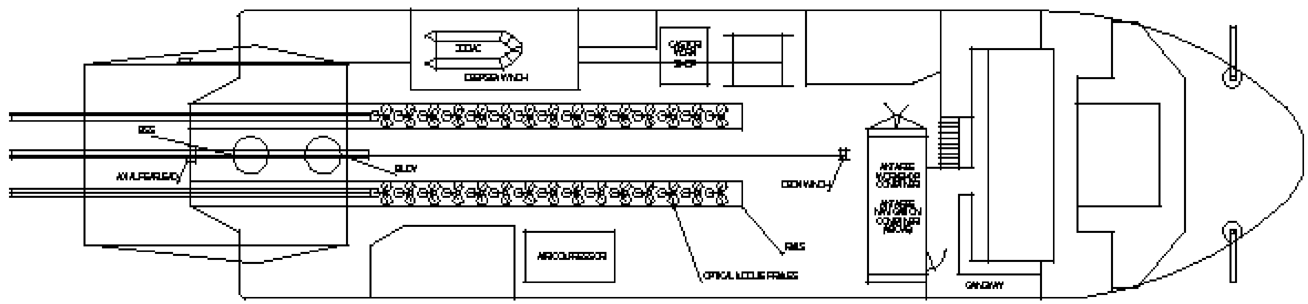
- Important milestone successfully completed

Line Deployment 0.1km^2 Detector

Storeys deployed two by two

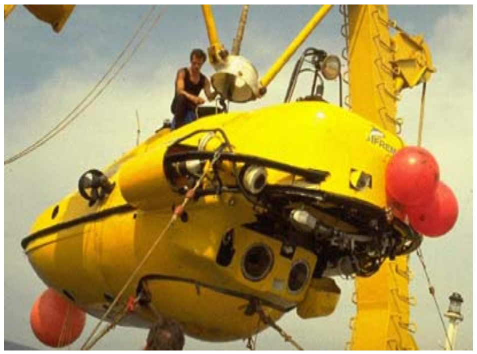


Storeys stored on deck of Castor

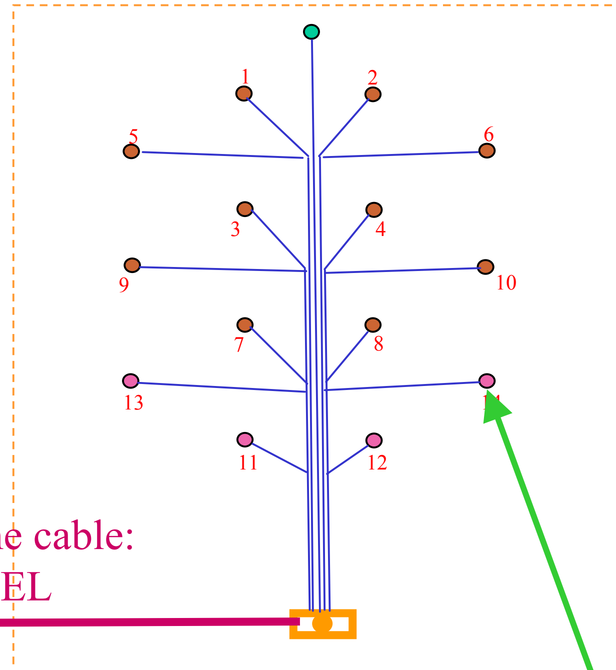


Sea Floor Layout

Site inspection
Cyana

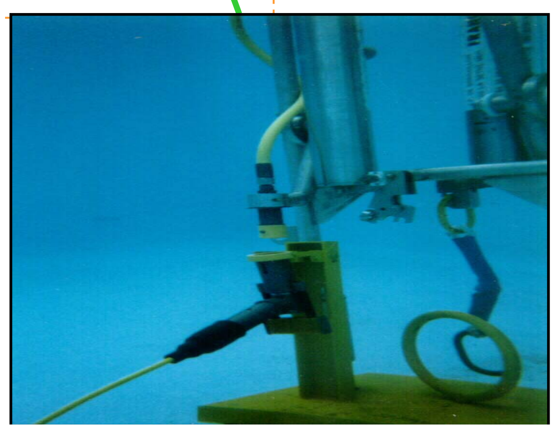


Line sea floor
configuration



Line connections
Victor

Submarine cable:
ALCATEL



Nautile

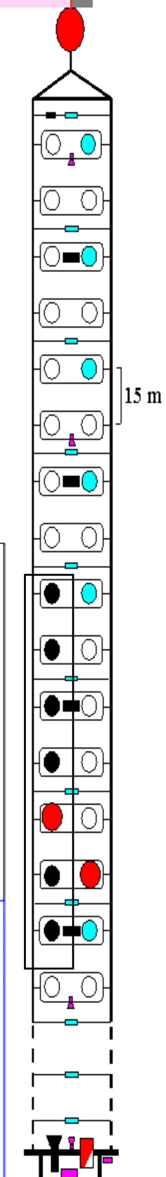
Nautile1

Demonstrator string: atmospheric μ measurement

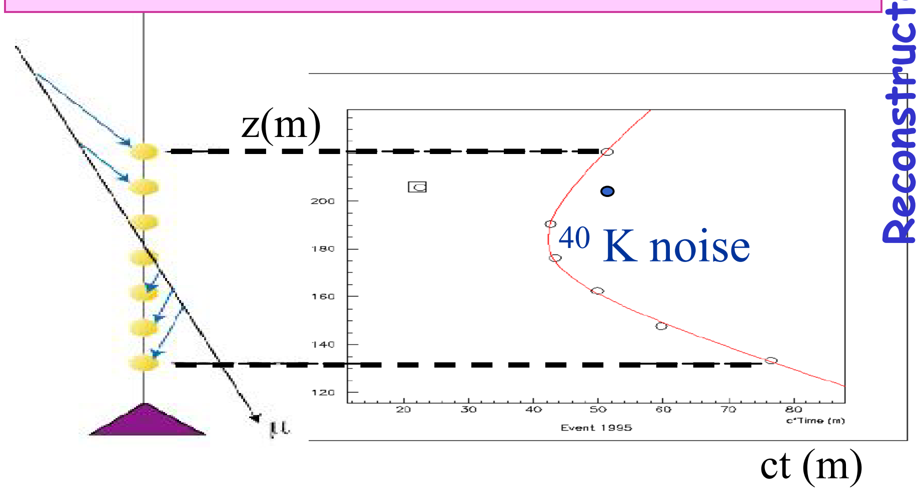
Nov 99-Jul 2000: 1200 m deep, 350 m string, 7 PMTs, prototype acoustic system

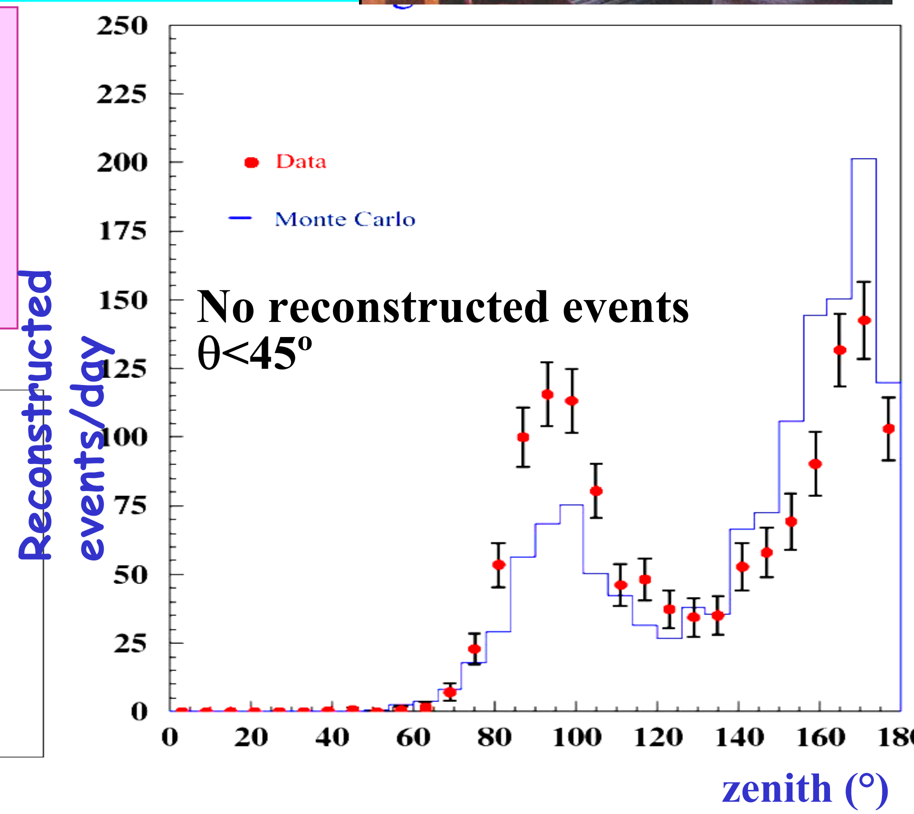
Site properties (temperature, salinity, pressure, currents, bioluminescence)

Relative Positioning Accuracy: precision ~5 cm
acoustic emitters/receivers+celerimeter+tiltmeters
⇒reconstruction of string profile , string stability

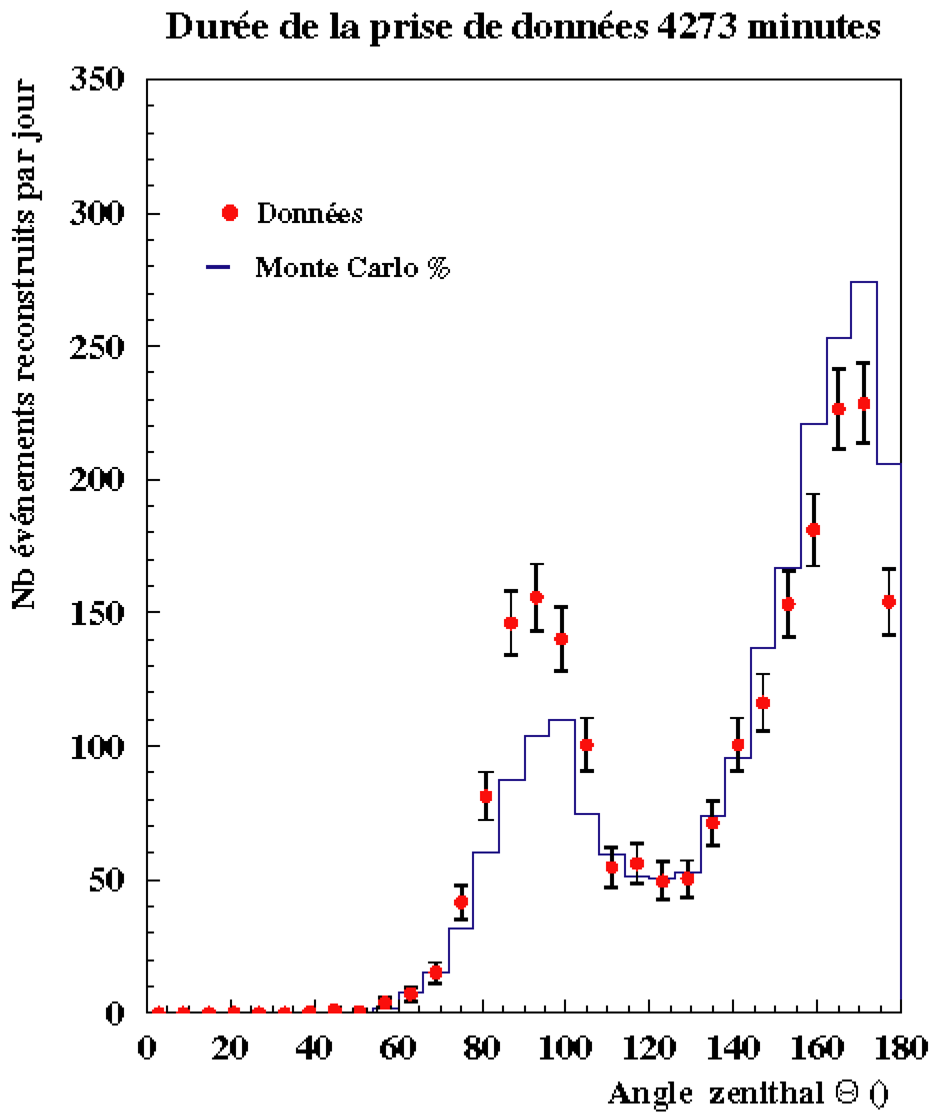


- 50 000 7-fold coincidences recorded
- zenith from hyperbolic fit PMT height +times
- ^{40}K hits filtered out by reconstruction





Muon angular distribution



Data rates

Off-shore

- Background rate/OM from ^{40}K : ~ 70 kHz   SPE = 6B/hit
- SPE rate for 900 OMs before *software trigger* ~ **1 GB/s**

  (rate doubles assuming 2% of WFD events (=260 B/hit))

Typical raw data: 1 Gb/s to 100 PC farm on shore ⇒

Trigger Software (= 100 CPU farm)

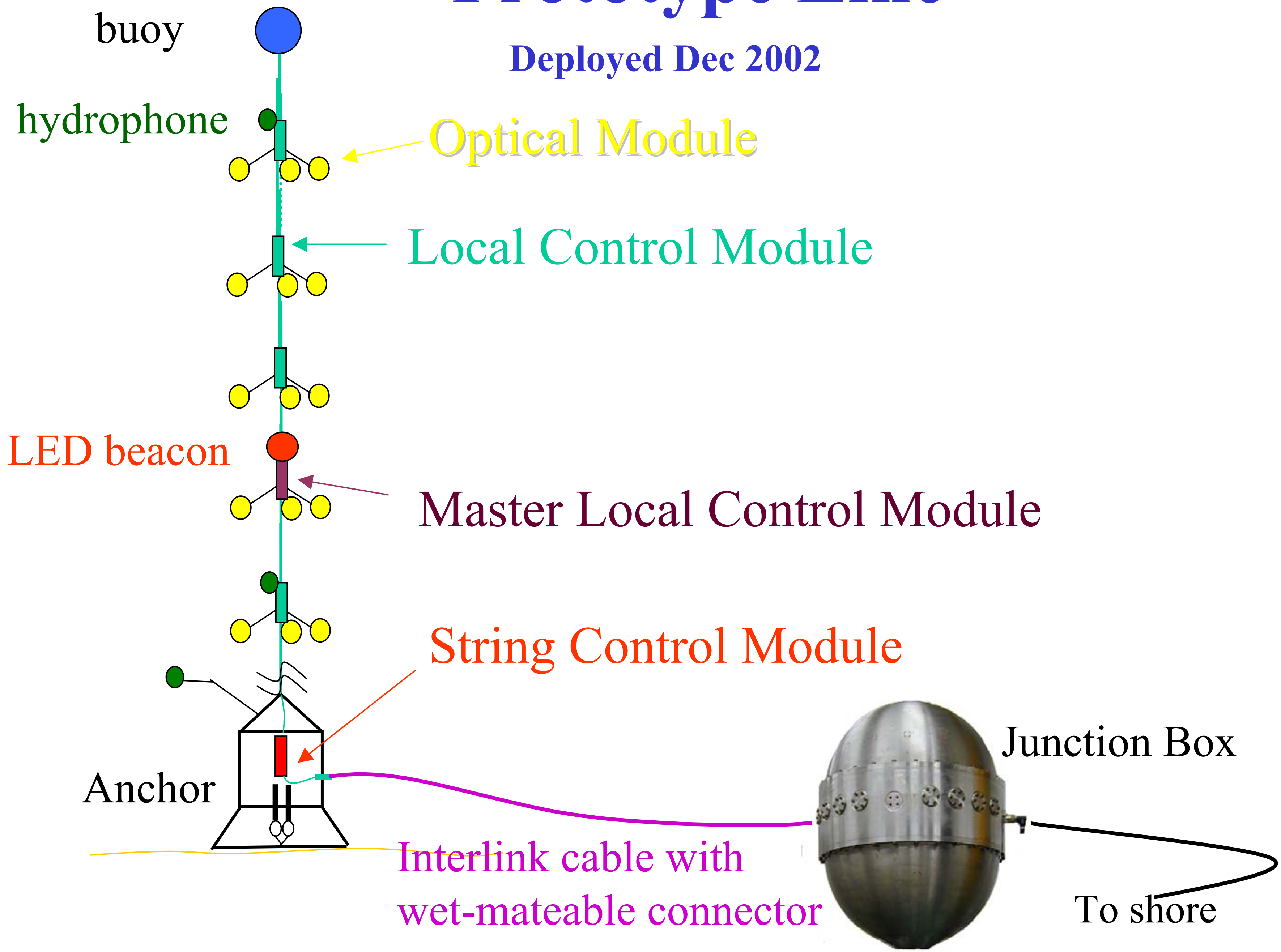
A 'trigger' (3D for > 1 string, 1D in one string) included hits in about ±2 μs

After data reduction 20 TB/yrSPE :

Data on Tape ~ **20 TB/y**

Prototype Line

Deployed Dec 2002

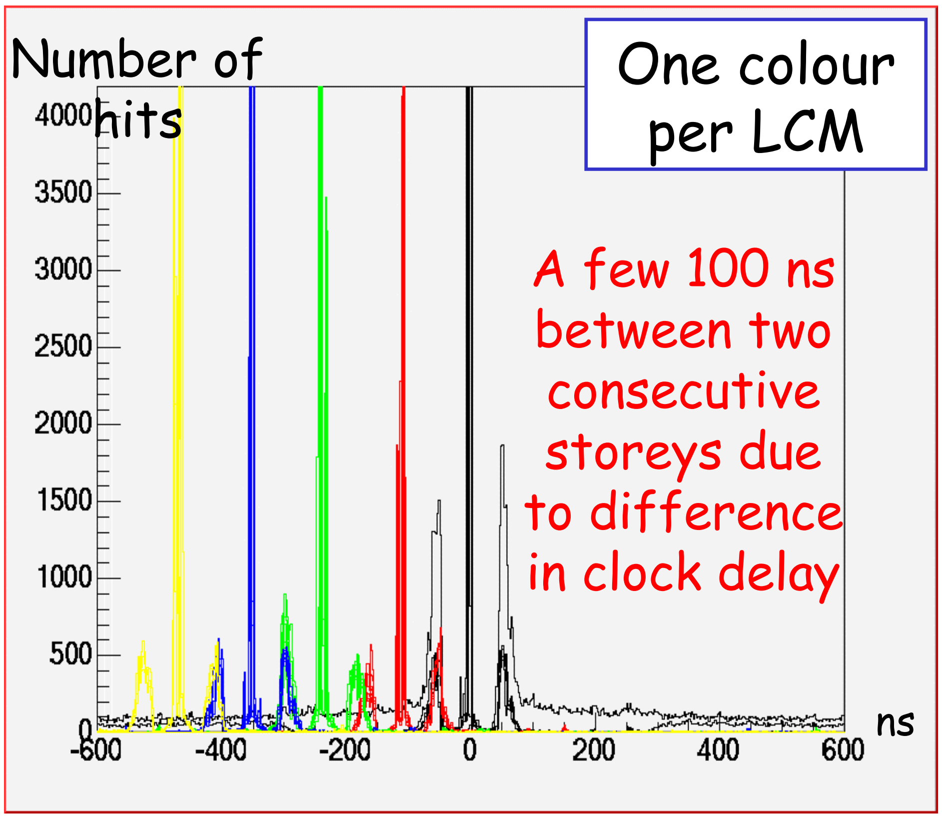


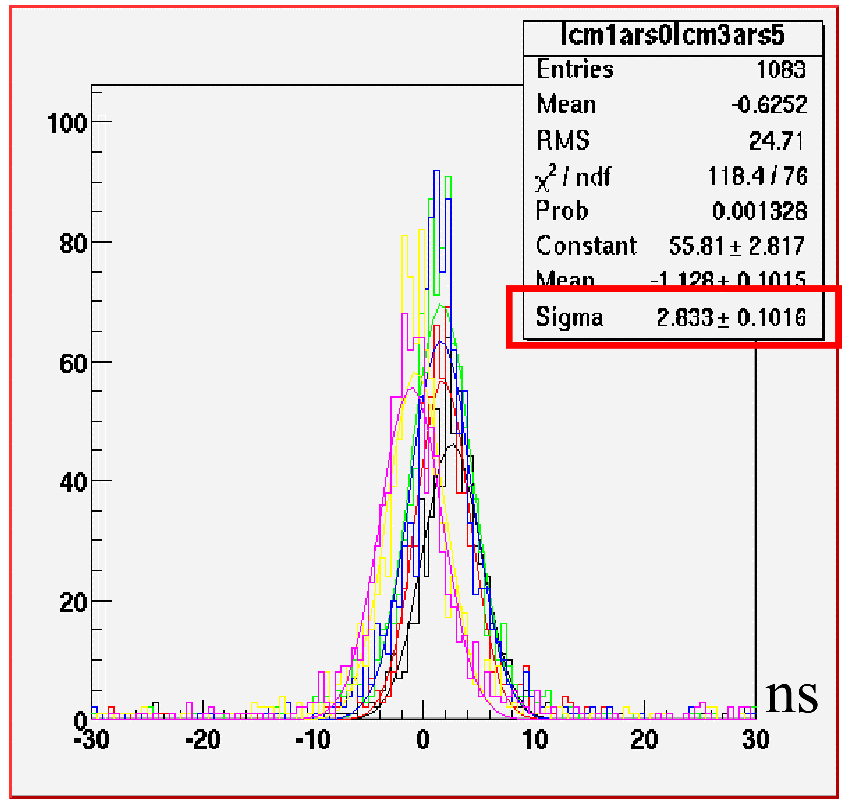
Prototype Line ready: Nov 2002

Time calibration in lab

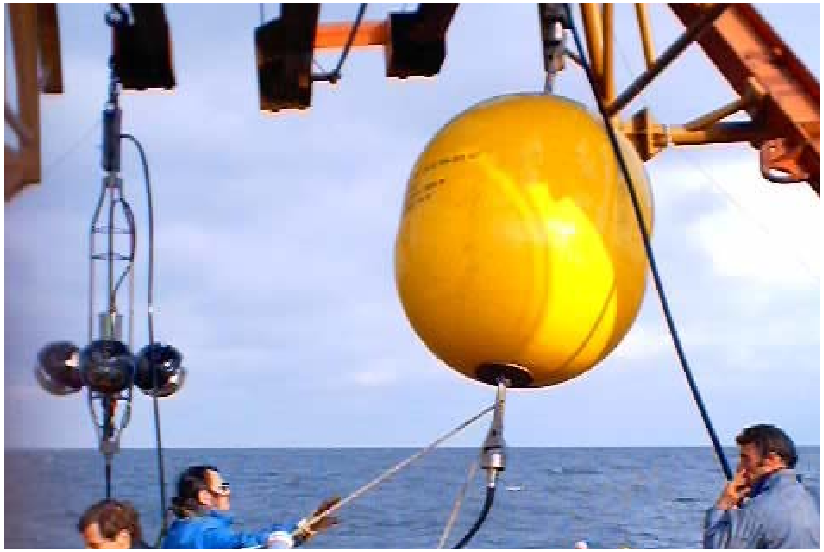
Time difference of laser pulses between one PM and others

before correction of clock delay after





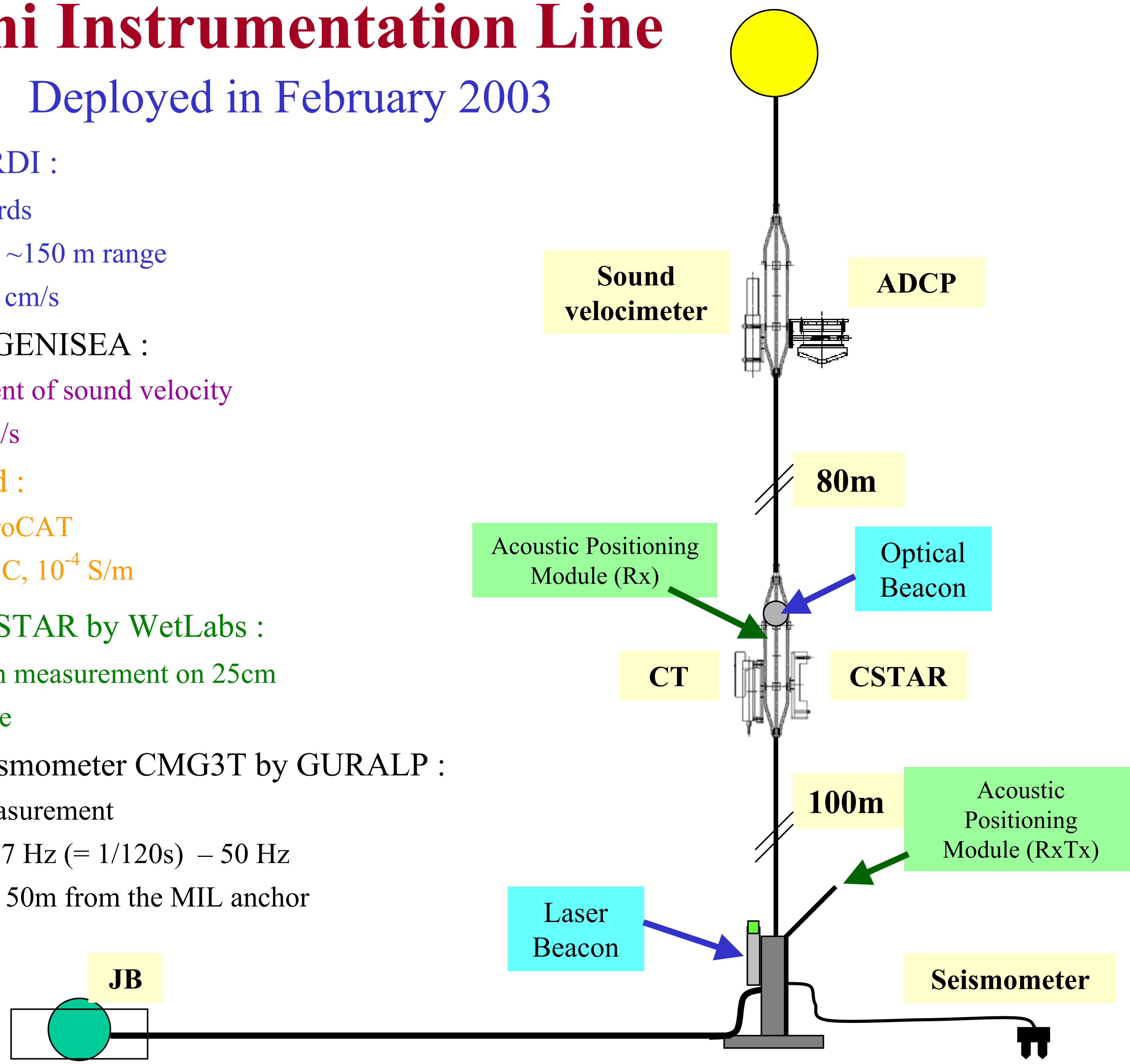
Deployment Prototype Line, Dec 2002



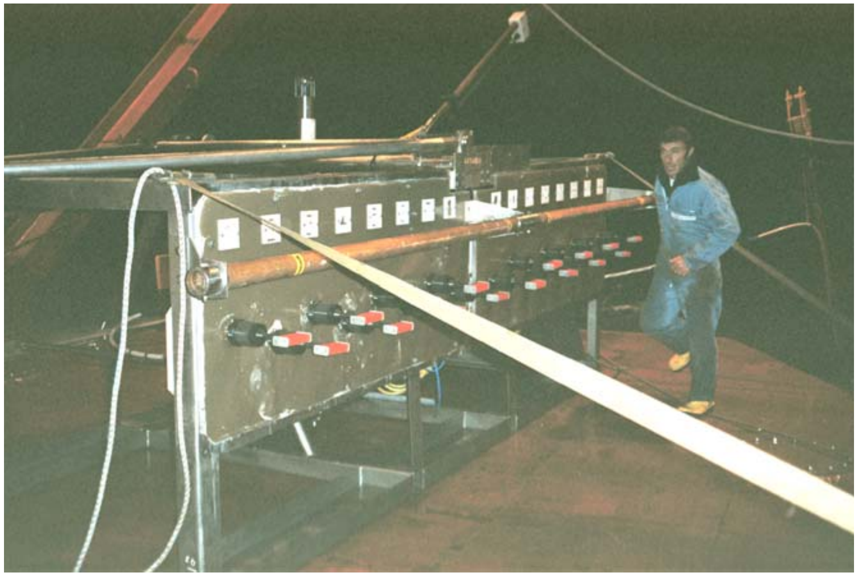
Mini Instrumentation Line

Deployed in February 2003

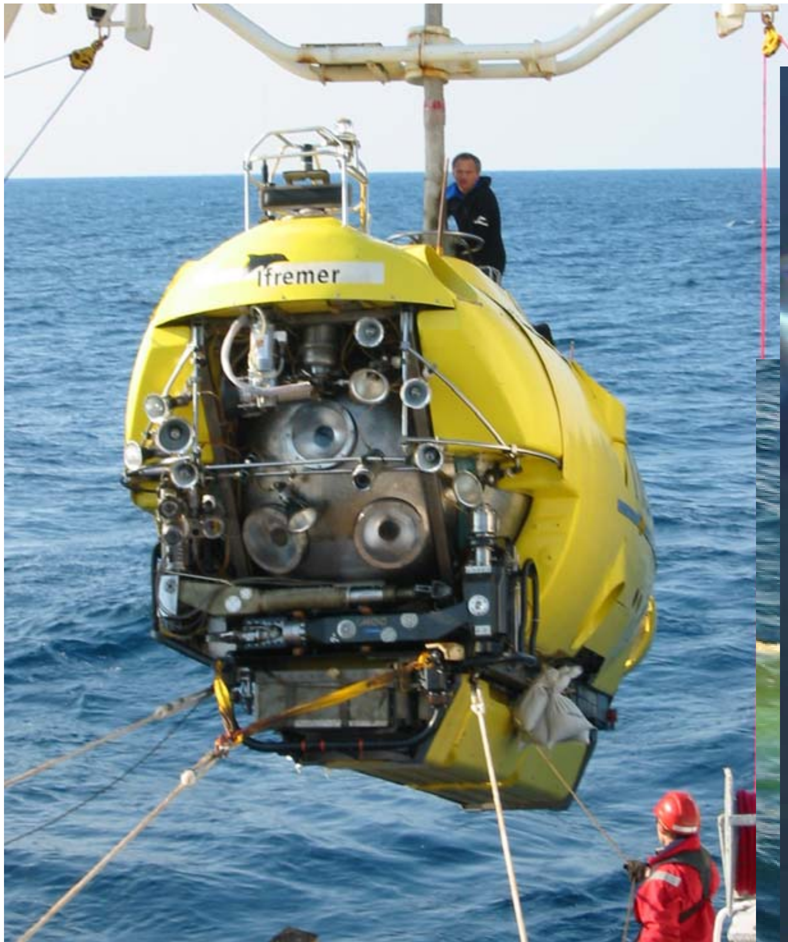
- ADCP 300 kHz by RDI :
  - Emitting downwards
  - Current profile on ~150 m range
  - Resolution : ~ 0.5 cm/s
- Sound Velocimeter GENISEA :
  - Direct measurement of sound velocity
  - Precision : ~ 5 cm/s
- CT probe by SeaBird :
  - Model 37-SI MicroCAT
  - Resolution : 10^{-4} °C, 10^{-4} S/m
- Transmissiometer CSTAR by WetLabs :
  - Light transmission measurement on 25cm
  - Analogue response
- Large bandwidth seismometer CMG3T by GURALP :
  - 3 components measurement
  - Sensitivity 0.00277 Hz (= 1/120s) – 50 Hz
  - Put in sediment at 50m from the MIL anchor

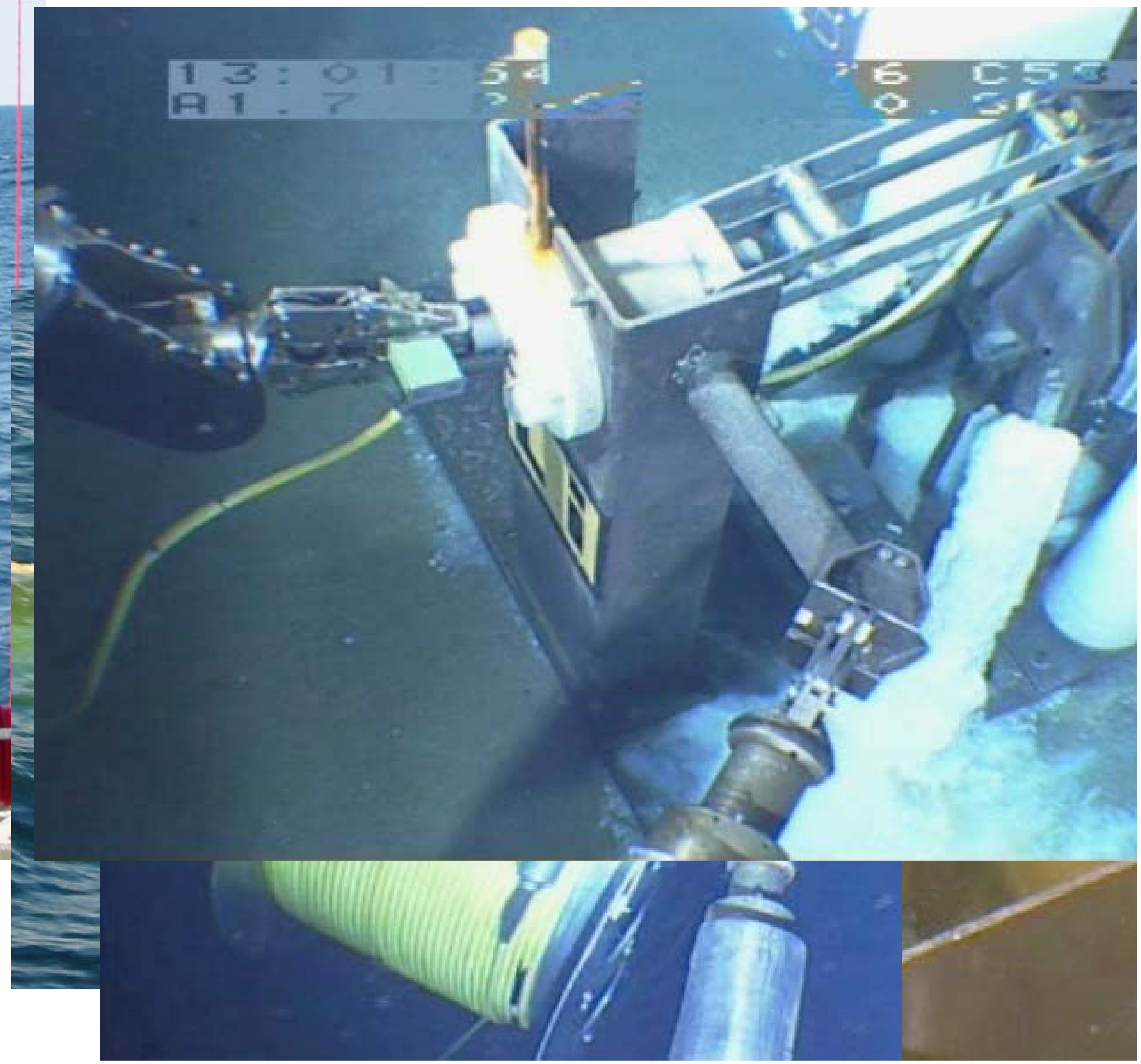


Deployment of Junction Box , Dec 2002

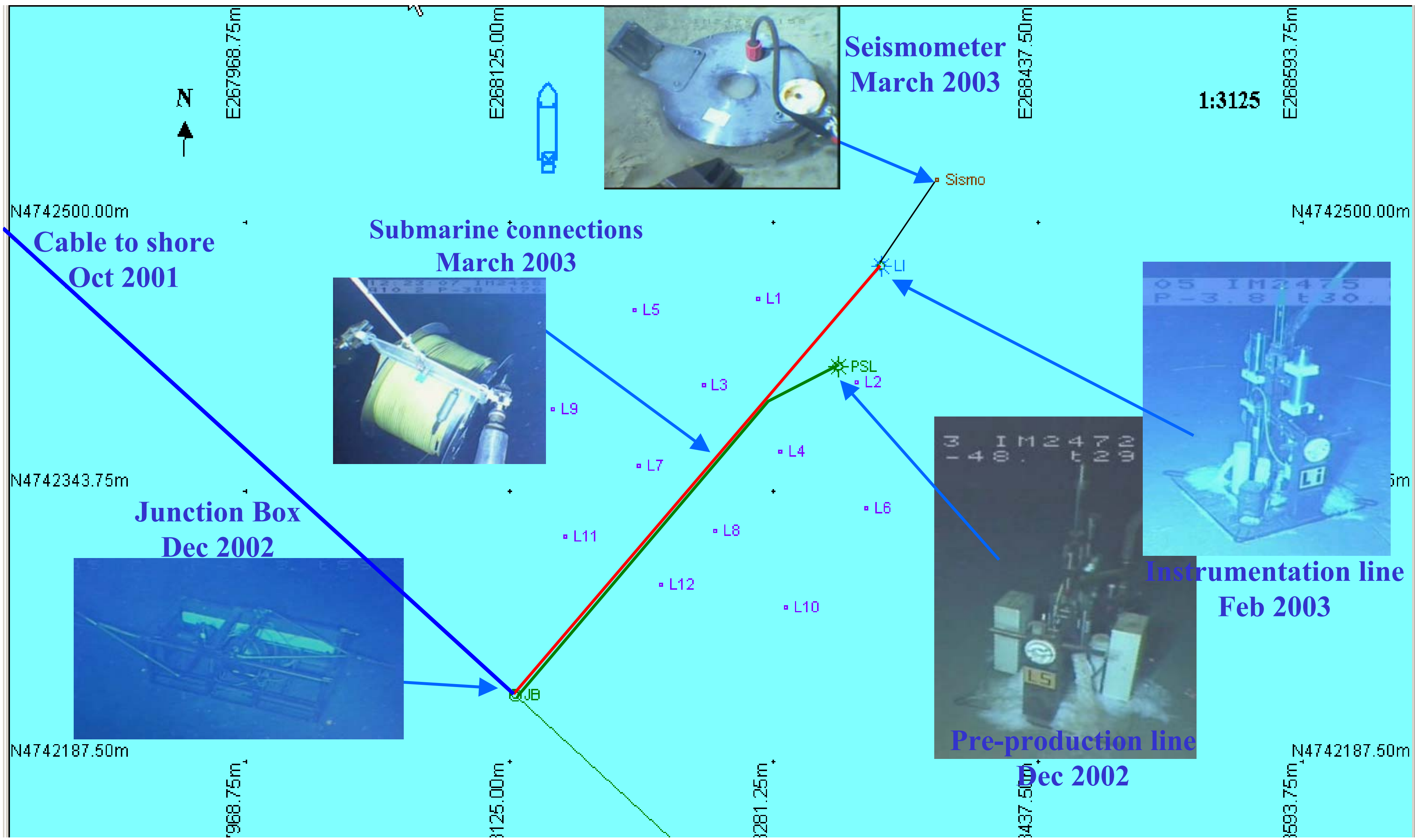


Submarine cable connection



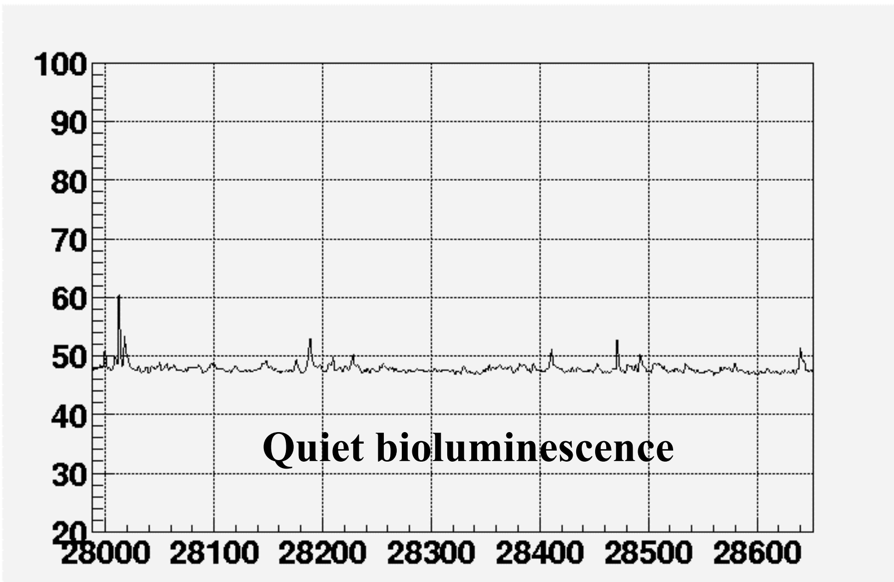


Current Layout of ANTARES site



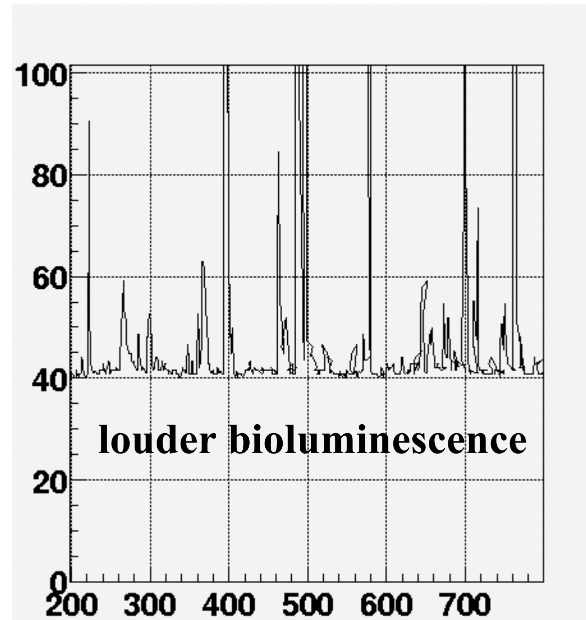
Rates in PMT

Rate
Khz



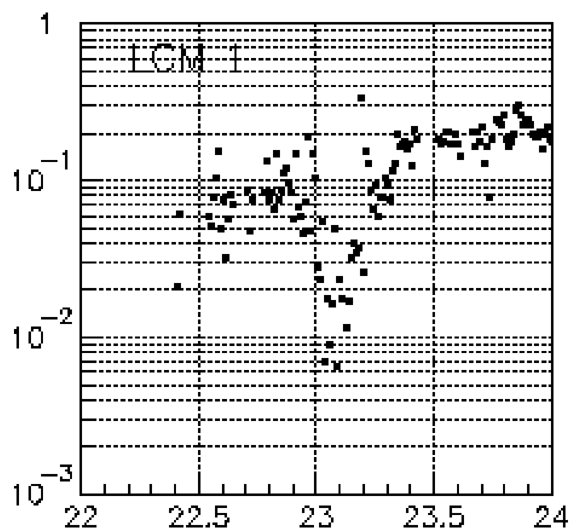
Time (sec)

Rate
Khz



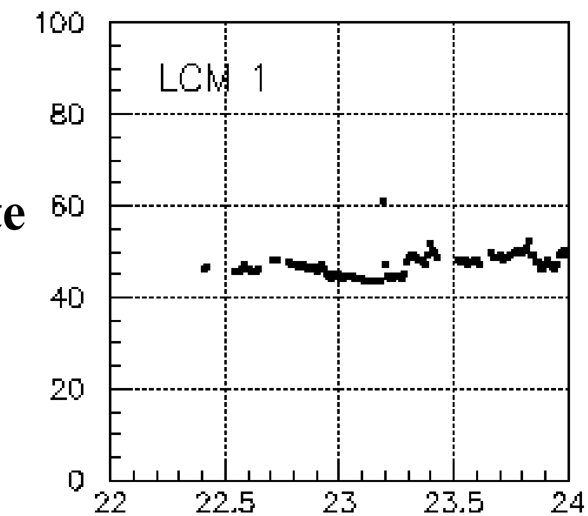
Time (sec)

Burst
fraction



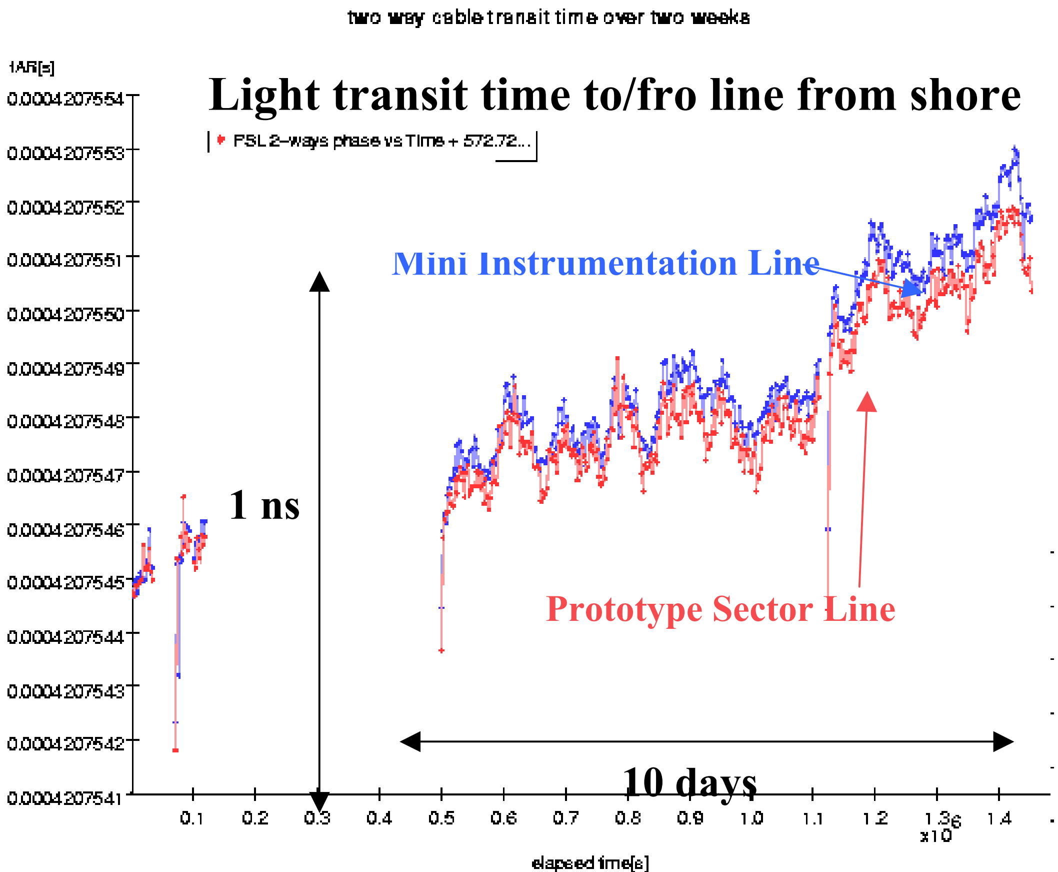
Time (day)

Base rate
Khz

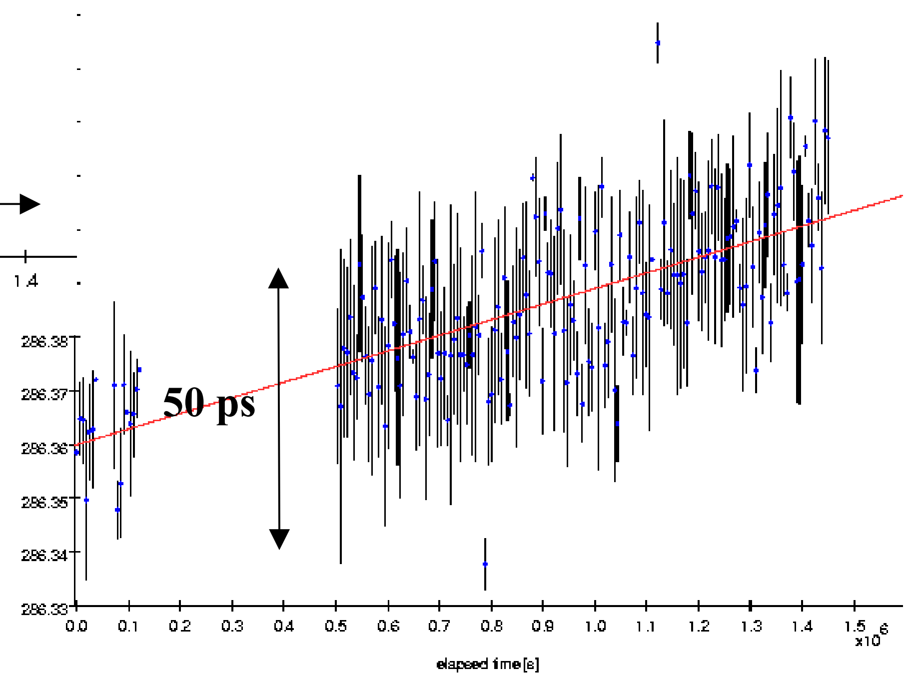


Time (day)

Clock time reference system

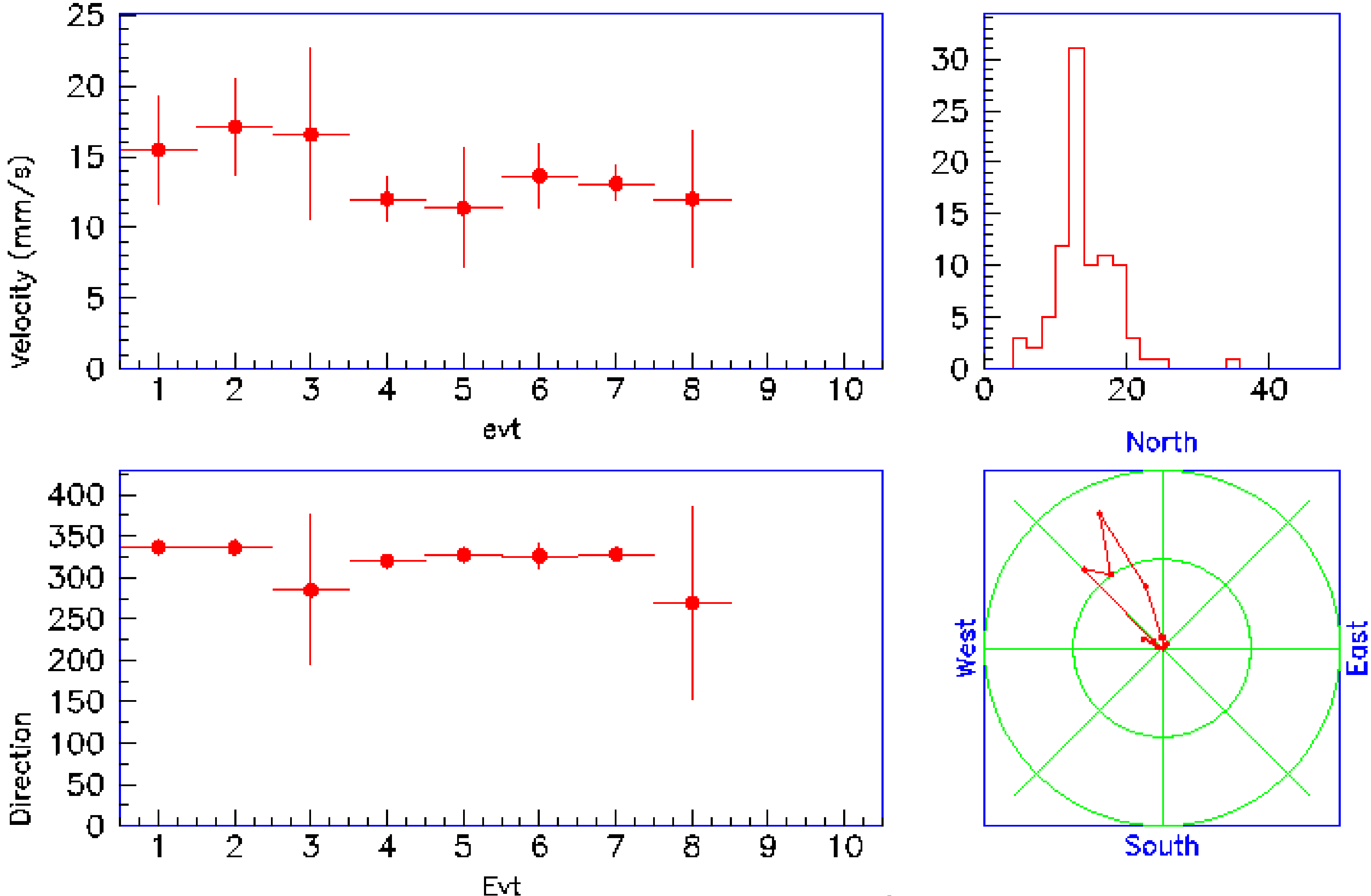


Difference in transit times for two lines



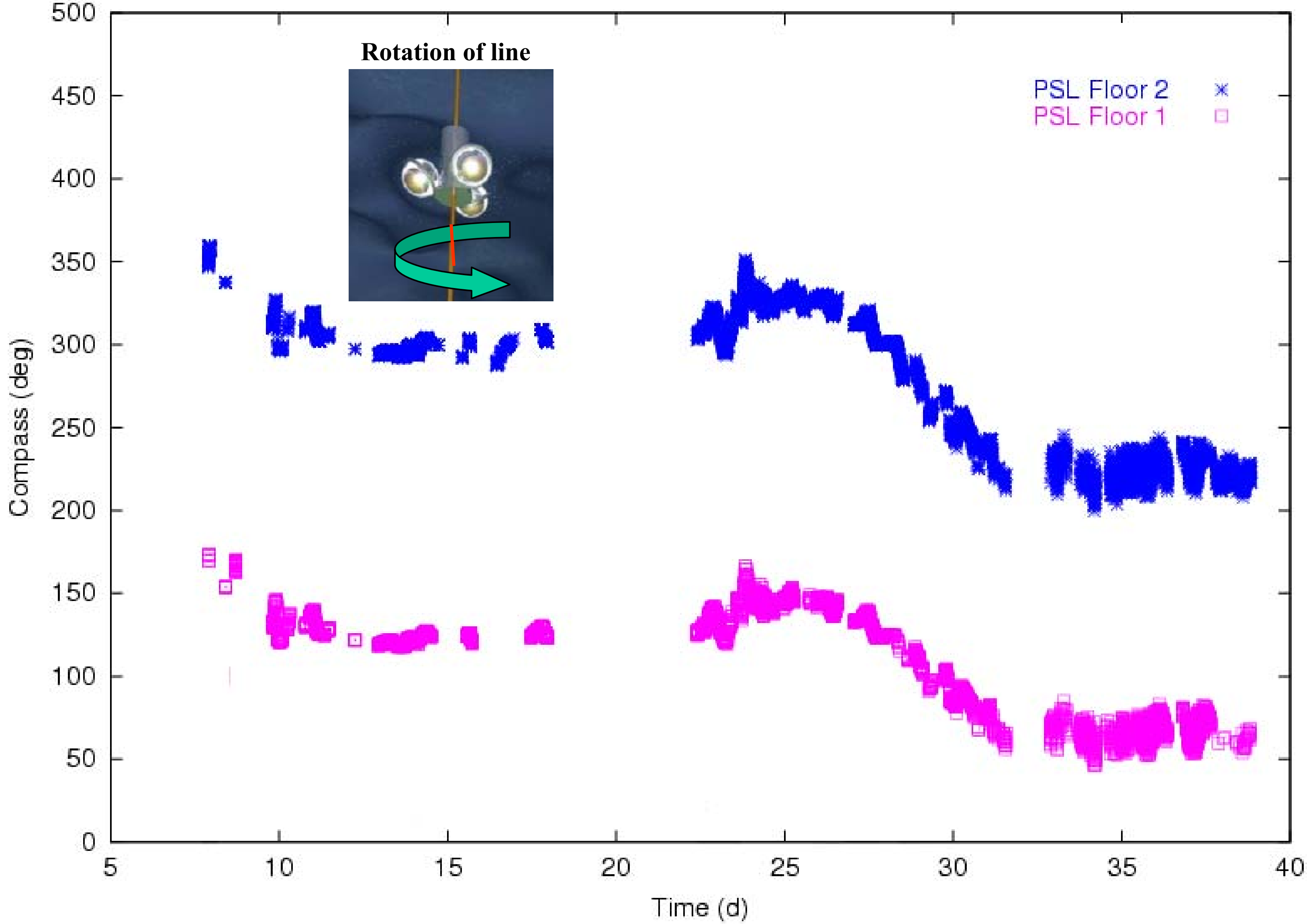
Current Mesurements

Current velocity (mm/s)



Current direction

Movement of line



Construction Schedule

March	2003	Start operation PSL and MIL lines
May	2003	Recover MIL for debug
Sept	2003	Recover PSL for evaluation
Dec	2003	Final electronics tests in lab
May	2004	Start assembly of 12 lines
Dec	2005	12 line detector operational

MoU

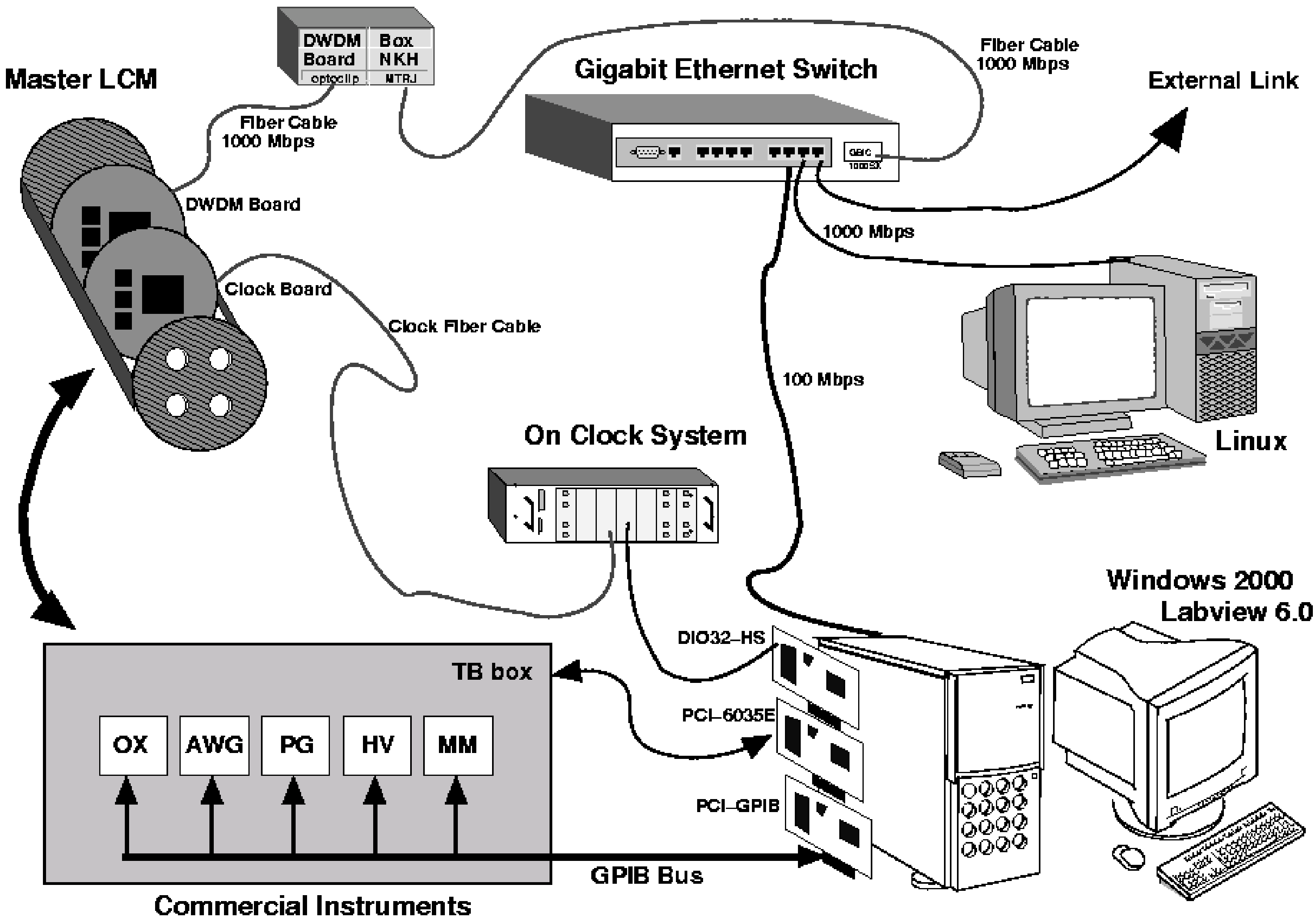
Source of Finance	Contribution (kEuro)	
CEA/ DSM/ DAPNIA , France	2300	11950
CNRS/ IN2P3, France	2300	
| CPER	250	
| Region PACA (not yet agreed)	2300	
| La Seyne sur Mer	100	
| Departement du VAR	1500	
| EU FEDER	3200	
NIKHEF, The Netherlands	3600	
ERLANGEN, Germany	2400	
INFN, Italy	2150	
IFIC, Spain	410	
TOTAL FINANCE	**20510**	

LCM Test Bench

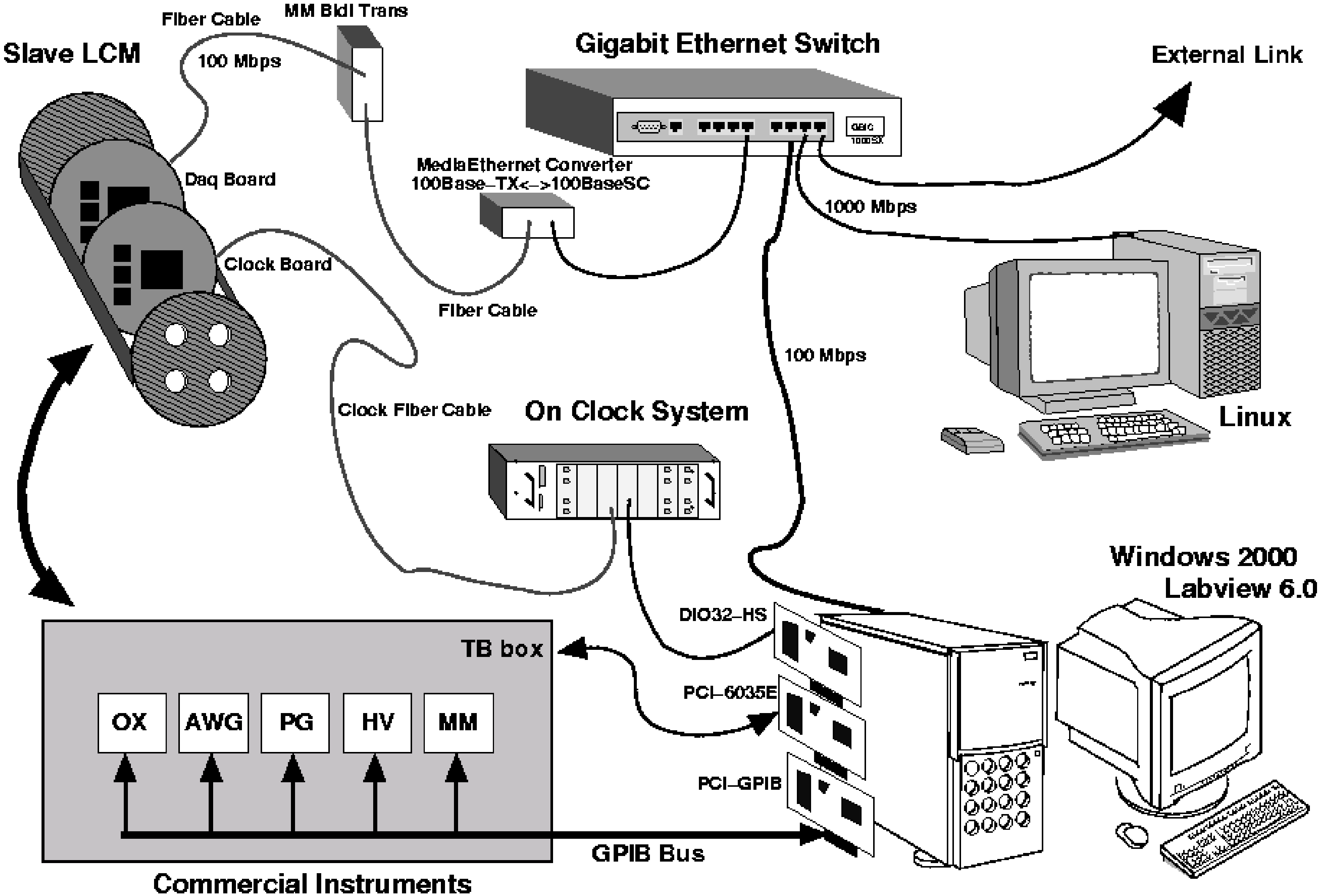
- Lo scopo del Test Bench è provare la funzionalità dell'intero sistema costituito dal Local Control Module e non di ogni sua singola parte.
- Il test dovrà essere quanto più possibile automatizzato, affidabile e semplice dal punto di vista dell'operatore.

Foto LCM

Setup Master LCM



Setup Slave LCM



PC Configurations

Two PCs are used:

- 1 PC Windows 2000, Labview

  National Instruments PCI-DIO32HS (ON_CLK System communication)
  National Instruments PCI-GPIB (commercial instruments communication)
  National Instruments PCI-6035E (Test Bench Box communication)
  Ethernet 100BASE-TX

- 1 PC Linux

  Ethernet 1000BASE-T

Commercial Instruments

- Arbitrary Waveform Generator: Sony Tektronix AWG 520
- High Voltage Power Supply: ….
- Pulse Generator: Stanford DG 535
- Oscilloscope: Tektronix DSA 602
- Multimeter: Agilent 34401A

All the instruments have GPIB port.

Network Devices and Cables

- Gigabit Ehternet Switch:

  Allied Telesyn AT-9410GB + GBIC Module AT-G8SX

Minimal requirements: 1 fiber gigabit port (1000Base-SX)
1 copper gigabit port (1000Base-T)
2 copper 100Mbps ports (100Base-TX)

- Ethernet Media Converter:

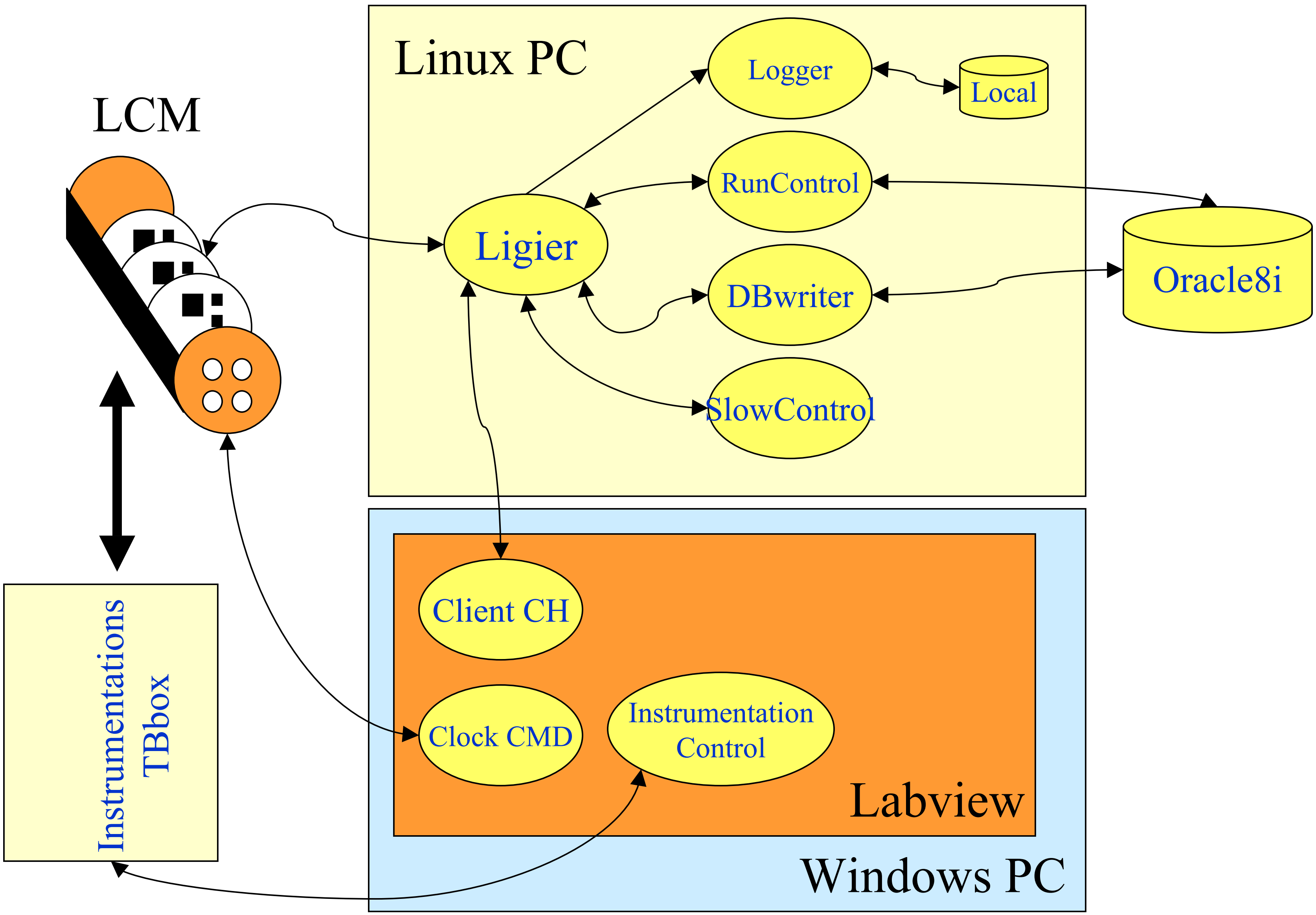
  D-Link DMC-300SC

Requirement: 100Base-TX to 100Base-FX media converter

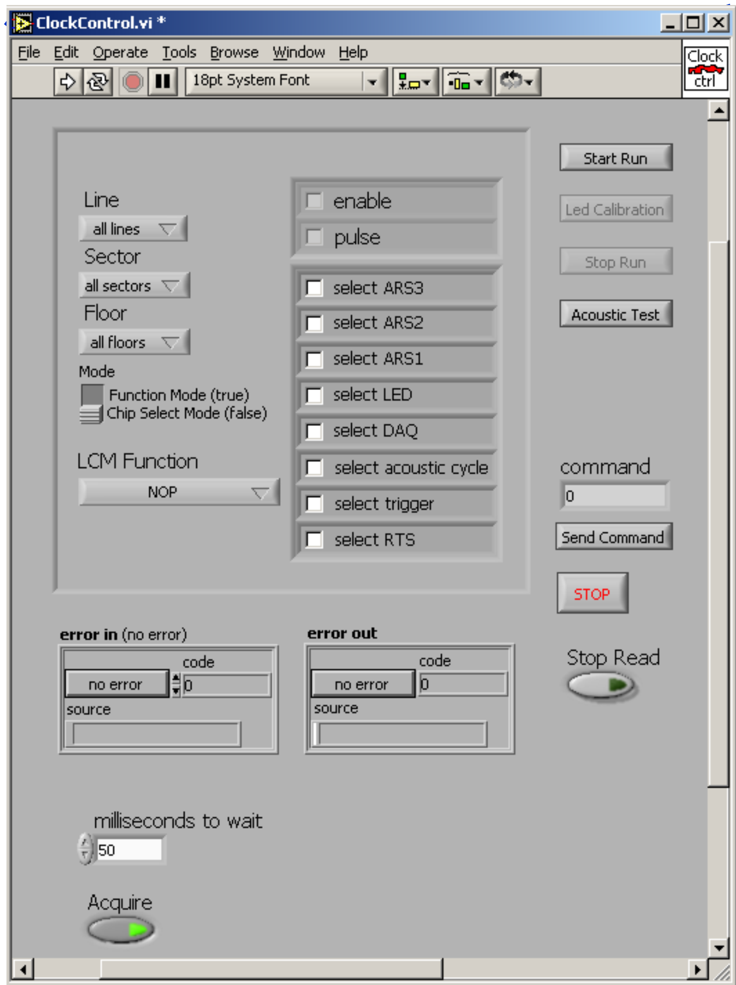
- Fiber Patchcords:

  MTRJ-SC 50/125 and 62.5/125
  SC-SC 50/125 and 62.5/125

Communication Schematic

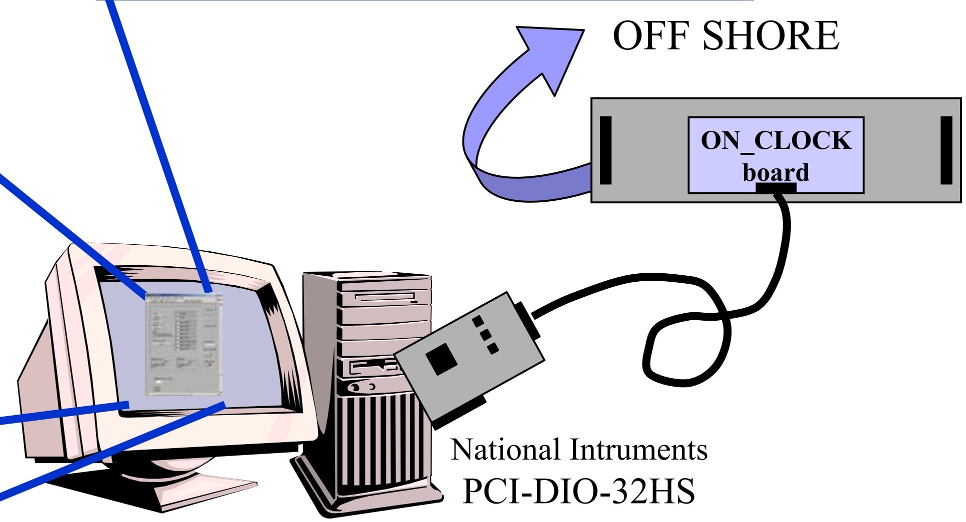


Clock Software Labview

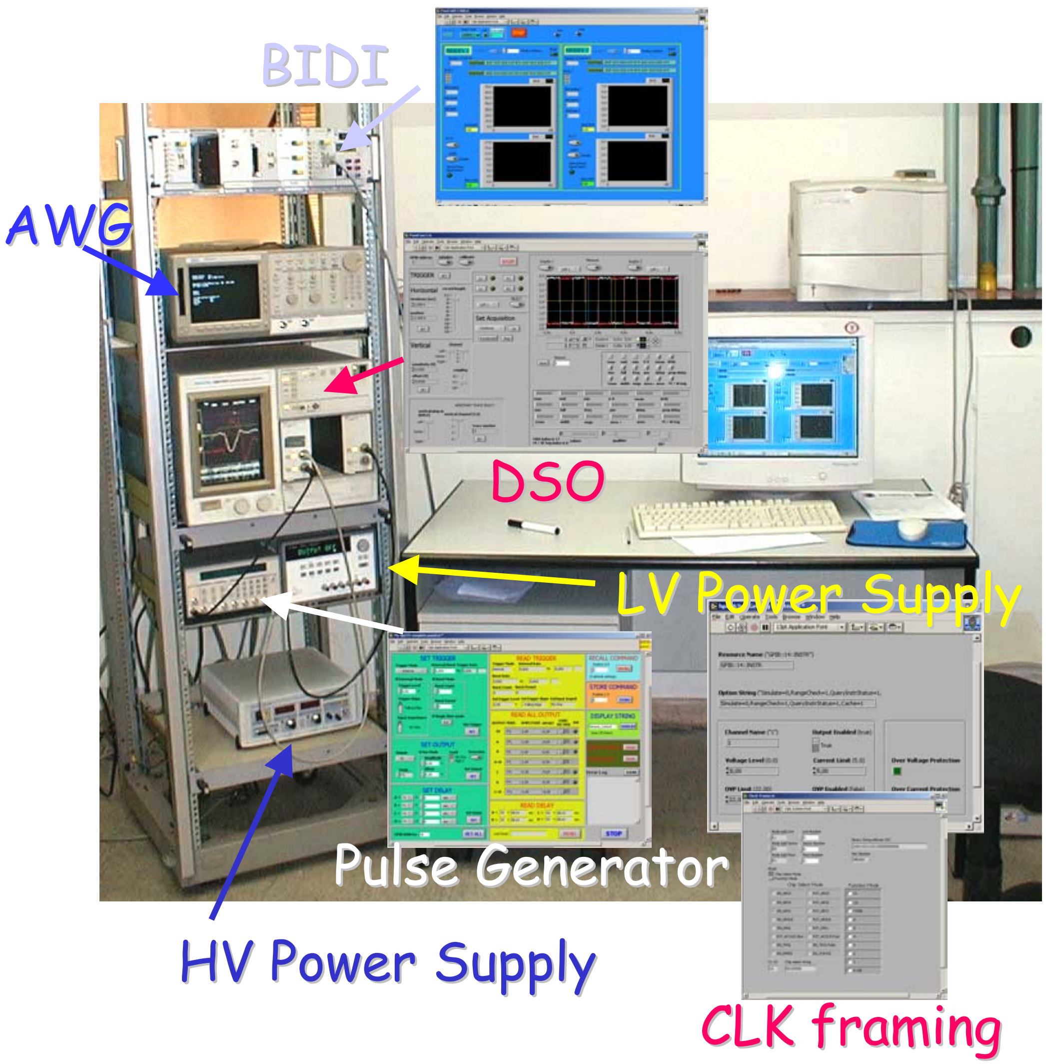


The CLOCK system fits up both the distribution of a clock signal to all the LCMs, and the two-way communication between the onshore base and the LCMs.

The communication consists in sending the proper commands of control to one or more LCMs, and in receiving the informations concerning the state of each one of them (LCMs).



Instrument VIs



Programma previsto per Pisa

- *2003: Acquisto componenti ed assemblaggio test-bench*
- *Gennaio-Marzo 2004: prime prove sul test bench*
- *inizio assemblaggio LCM*
- *Aprile 2004..: Assemblaggio LCM e tests*

Impegno della Sezione

- *Persone interessate* (al 28 Maggio):
- **Bigi, Cavasinni, Flaminio, Galeotti, Morganti, Roda**

- *Per gli aspetti astrofisici:*
- **Scilla Degl'Innocenti**

- **Richieste di tecnici:**
- **1 tecnico elettronico per 1 anno**

Richiesta finanziaria 2003

- Inventariabile: 60,000 Euro
- Consumo: 23,000 Euro
- Viaggi e Missioni: 3 m.u. (Italia) + 3 m.u. (Estero)

- (Circa 220,000 Euro sono gia’ disponibili all’interno della collaborazione
- ANTARES Italia)

MoU

SUB SYSTEM	France	Italy	Nether - lands	Germ- any	Russia	Spain	UK	Resources (kEuro)
Mechanics	50 %	17 %	8 %	25 %	#			5640
Electronics	57 %	37 %	6 %				@	2340
Readout	22 %		78 %					2720
Optical Modules	68 %		17 %	15 %	#			3110
nstrumentation	50 %	12 %		25 %		13 %	@	1935
nfrastructure	94 %		6 %					2305
ntegration	53 %		20 %			27 %		575
Sea Operations	97 %	3 %						1885
TOTAL	58.3 %	10.5 %	17.5 %	11.7 %		2 %		20510

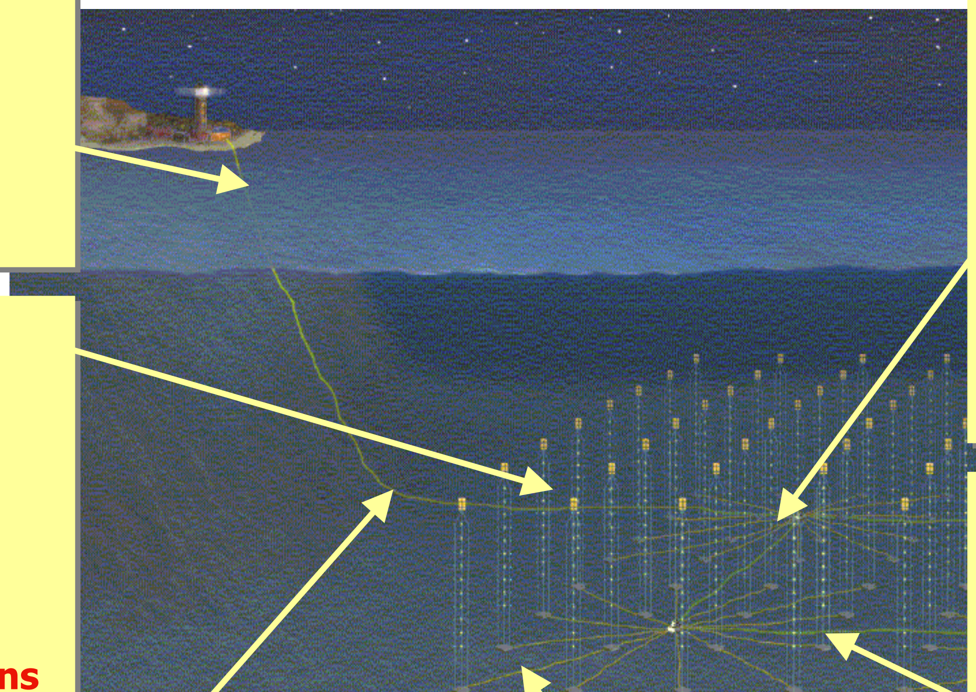
@ Research and Development contributions

In-kind contributions

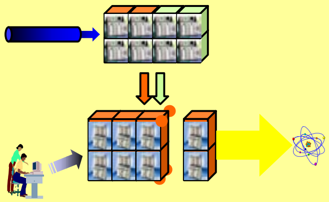
Note: The fractional distribution of tasks is indicative only.

R&D for 1km^3

The technological challenges

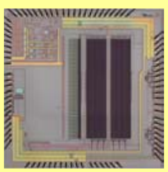


Data transmission



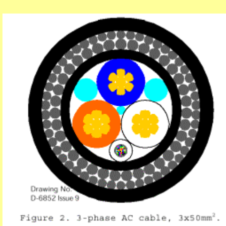
High bandtwidth data transmission

Electronics



Low power microelectronics for underwater applications

Underwater cable network

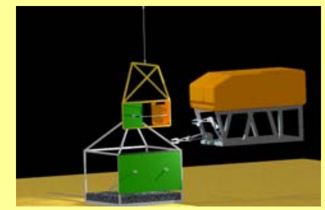


High power load electro-optical cables for deep sea applications

Connections

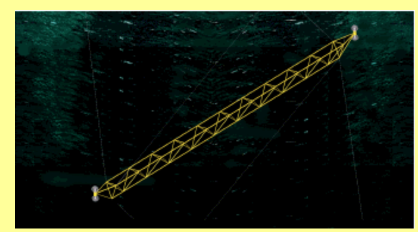
Underwater electro-optical connections

Deployment



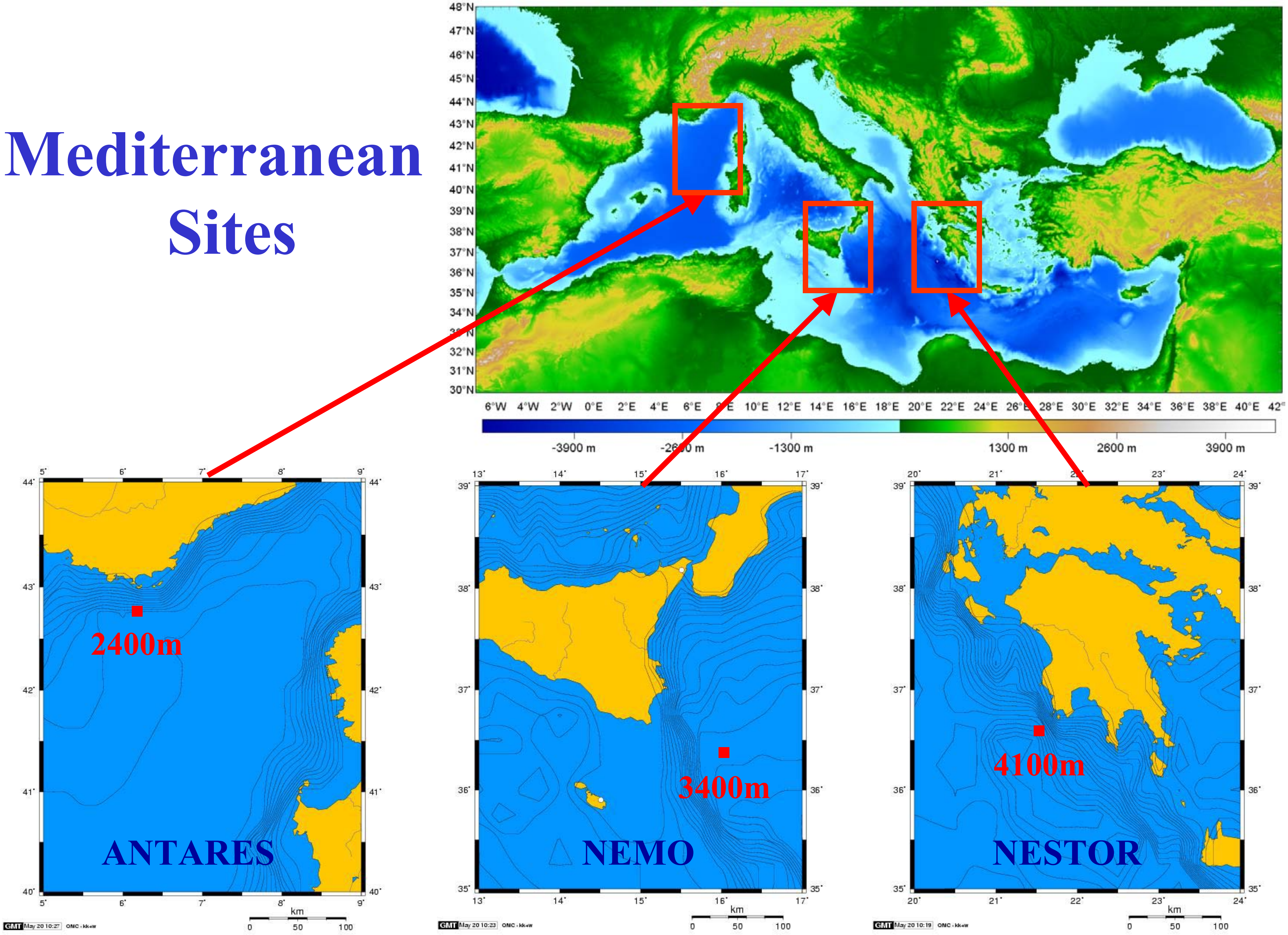
Deployment and connection of the structures with underwater vehicles

Mechanical structures



Innovative materials for deep sea applications

Mediterranean Sites



Conclusions

- Construction of the first deep sea Neutrino Telescope well underway
  technology under control, funding available

- Extensive science program:
  particle physics, astrophysics ,…….oceanography

- Further R&D necessary to build a second generation detector
  must reduce the cost

Evolution of Mediterranean Projects

NESTOR

	1991 -	R & D, Site Evaluation
Summer	2002	Deep-sea deployment (4100m) & run 2-floors
Winter	2003	Recovery & re-deployment with 4-floors
Autumn	2003	Full Tower deployment in the deep sea
	2004	Add the three DUMAND strings around tower
	2005 - ?	Deployment of more NESTOR towers e.g. 7

ANTARES

	1996 - 2000	R&D, Site Evaluation
January	2000	Data from Demonstrator line
	2001	Start Construction of ~ $0.1km^2$ at Toulon site
December	2002	Deploy pre-production prototype line
December	2005	12 line detector complete
	2005 - ?	Construction of $1km^3$ Detector

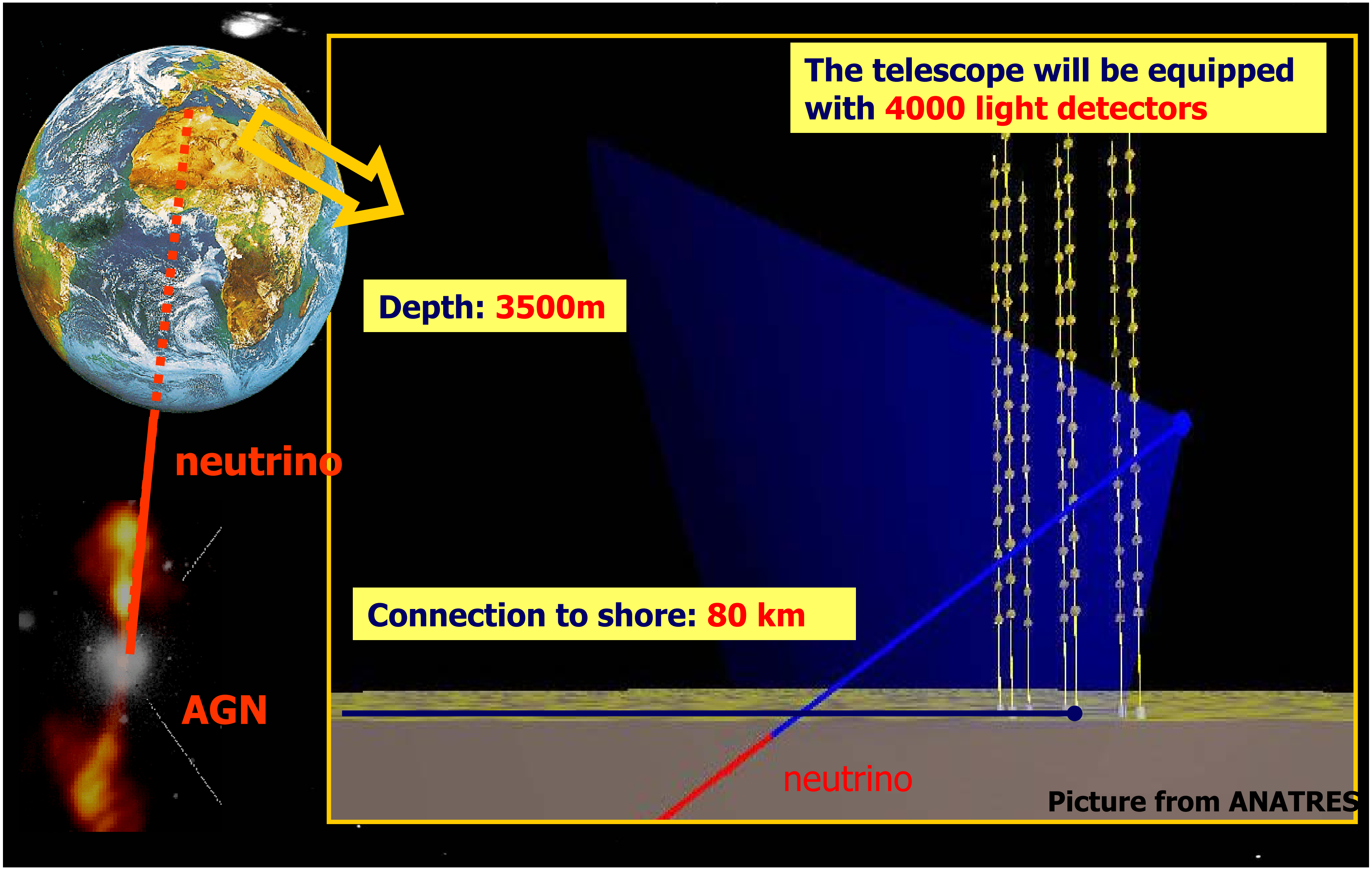
NEMO (Neutrino Mediterranean Observatory)

1999 - 2001	Site selection and R&D
2002 - 2004	Advanced R&D and prototyping at Catania Test Site
2005 - ?	Detector realization

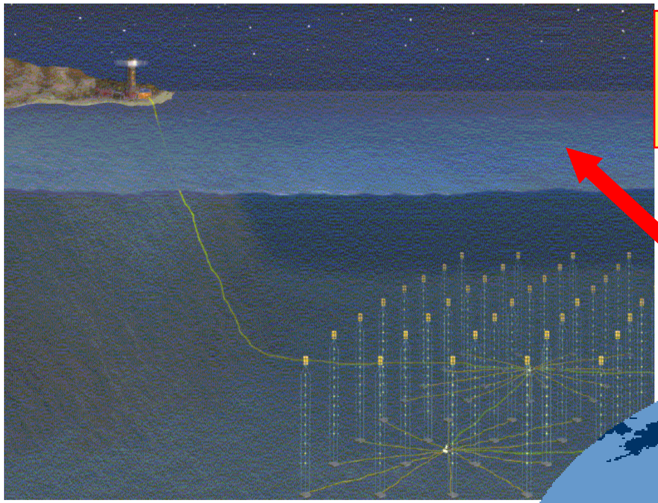
NEMO and ANTARES collaborating since 2000

work together to build $0.1km^2$ at Toulon site with agreement to choose best site for future detector

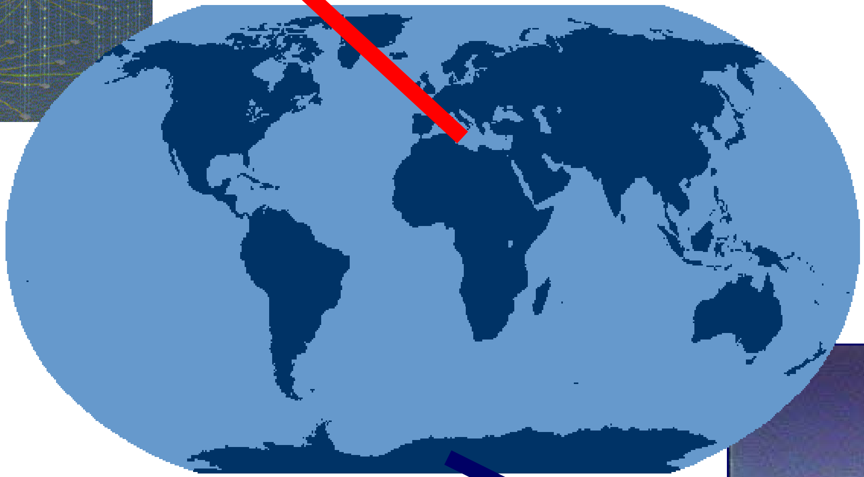
How we see neutrinos ? In the Sea !

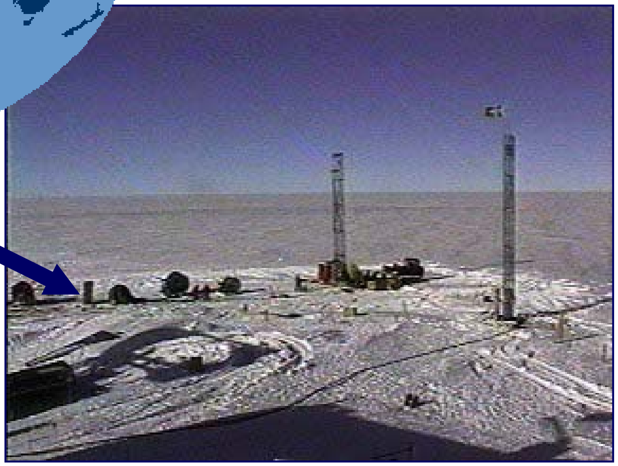


The Present Projects



Northern Hemisphere:
The Mediterranean km³





Southern Hemisphere:
AMANDA-ICECUBE

The NEMO Collaboration

INFN:

Bari, Bologna, Cagliari, Catania, Genova, LNF, LNS, Messina, Roma

CNR:

Istituto di Oceanografia Fisica (La Spezia)
Istituto di Biologia del Mare (Venezia)
Istituto Talassografico (Messina)
Istituto GEOMARE-SUD (Napoli)

Istituto Nazionale di Geofisica e Vulcanologia

Istituto Nazionale di Oceanorafia e Geofisica Sperimentale (Trieste)

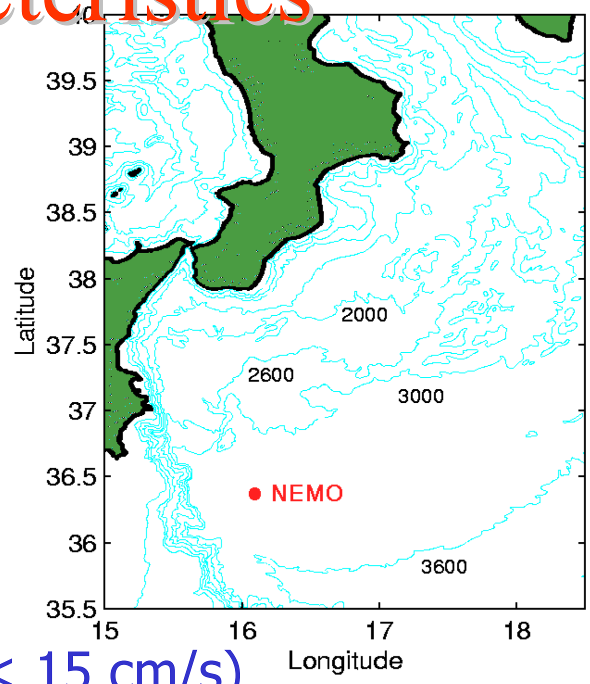
Centro Interdisciplinare di Bioacustica e Ricerche Ambientali (Pavia)

Marina Militare Italiana

Saclant NATO Undersea Research Centre

Capo Passero characteristics

distance from the coast ~ 80 km

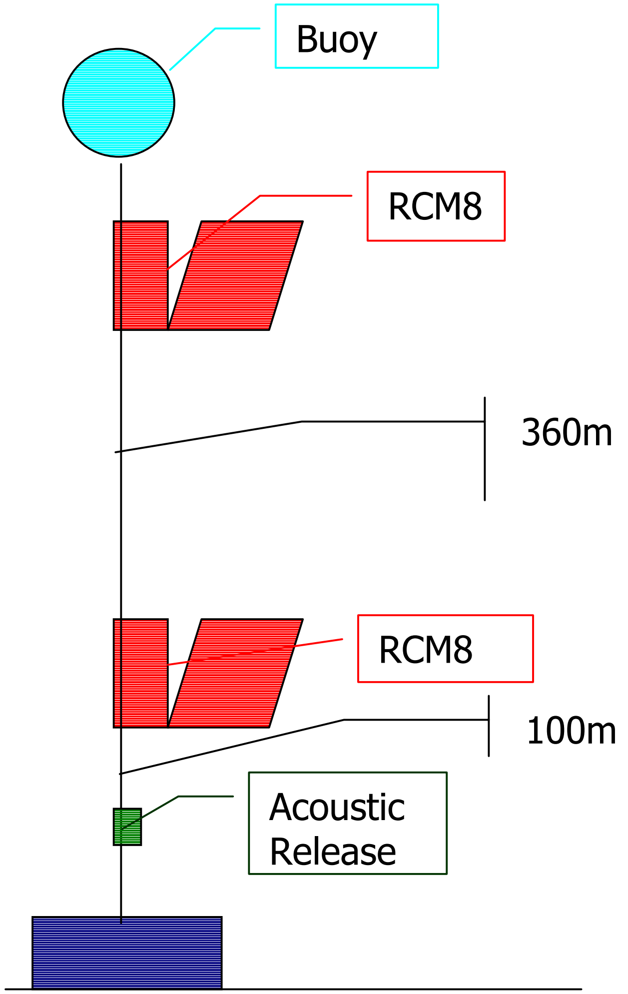


- distance from shelf break >40 km
- close to ports, international airport, Labs
- depth > 3300 m
- bathimetric profile is flat over 10 km^2
- average current Intensity ~ 3 cm/sec (max < 15 cm/s)
- light attenuation length ~ 35 m (42 m in March)
- light absorption length ~ 70 (100 m in March)
- biological activity is low
- measured sedimentation rate and fouling rate are low

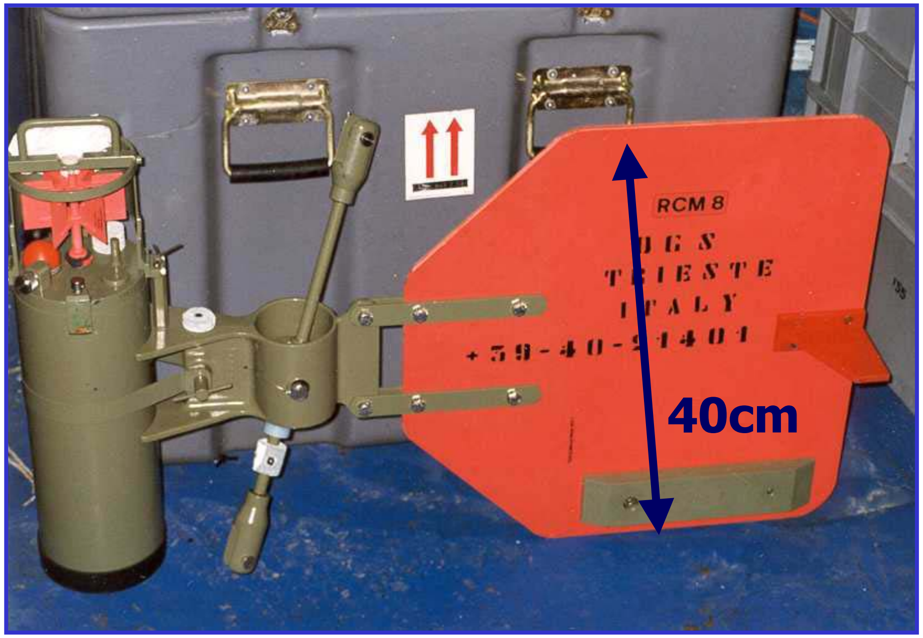
Capo Passero

- **KM2 36°10′ N 16°19′E, depth 3350m (1: Jan '99)**
- **KM3 36°30′ N 15°50′E, depth 3345m (1: Feb '99, 1: Aug'99, 2: Dec '99)**
- **KM4 36°19′N, 16°04′E, depth 3341m (2: Dec '99, 2: March '00, contiuing)**

Current metres



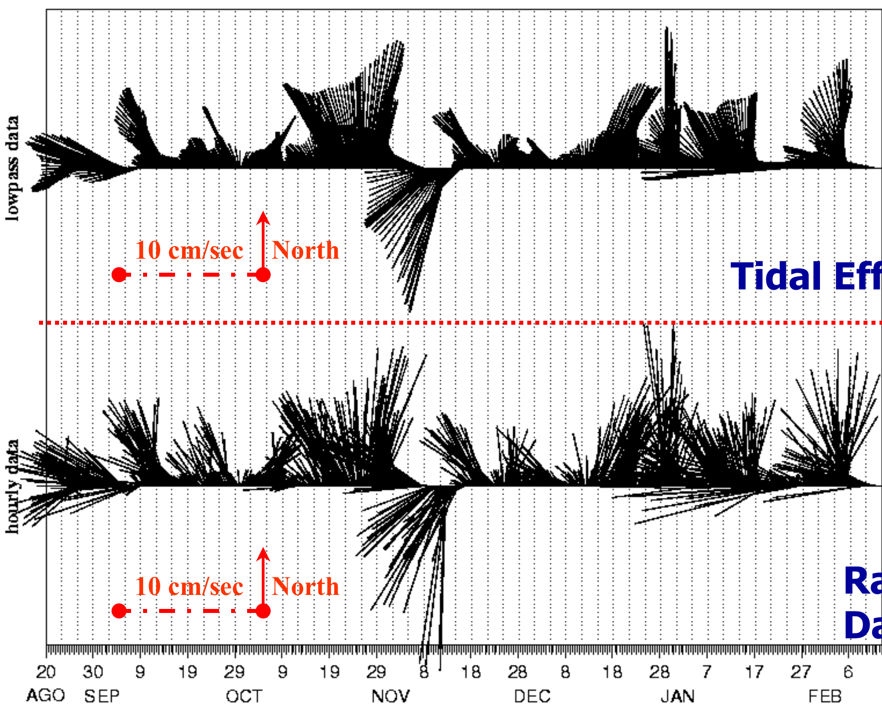
Current metre and sediment trap chain moored in Capo Passero



Current Metre Aanderaa RCM8

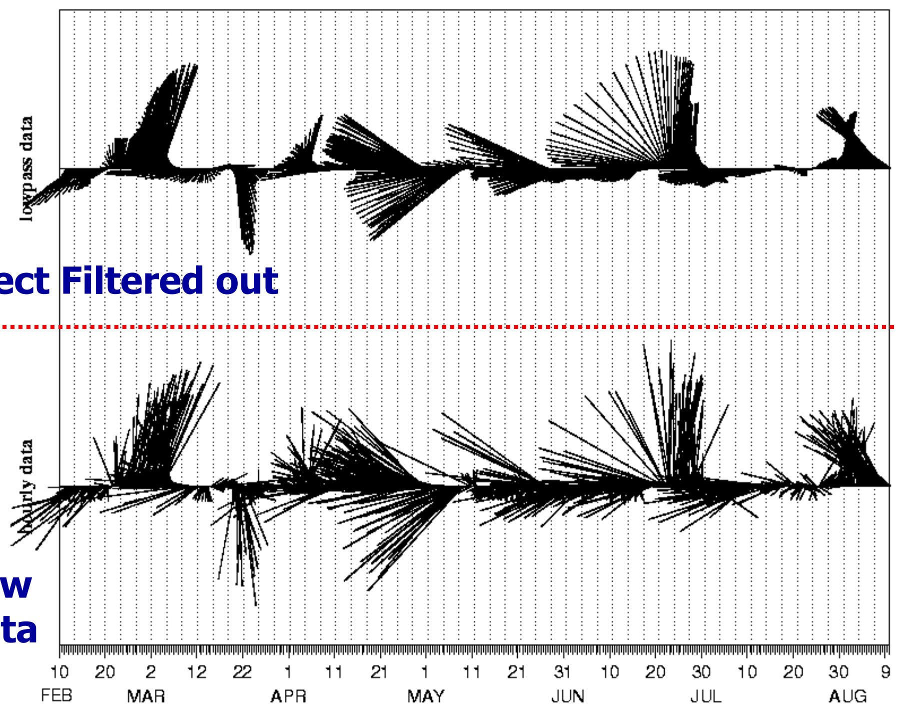
Deep Sea Current Measurements (August 1998 - running)

Detailed report available at OGS



Tidal Effect Filtered out

Raw Data



Lat:36°30'N Long:15°50'E Depth: 3350m

current meter moored @ -3325m

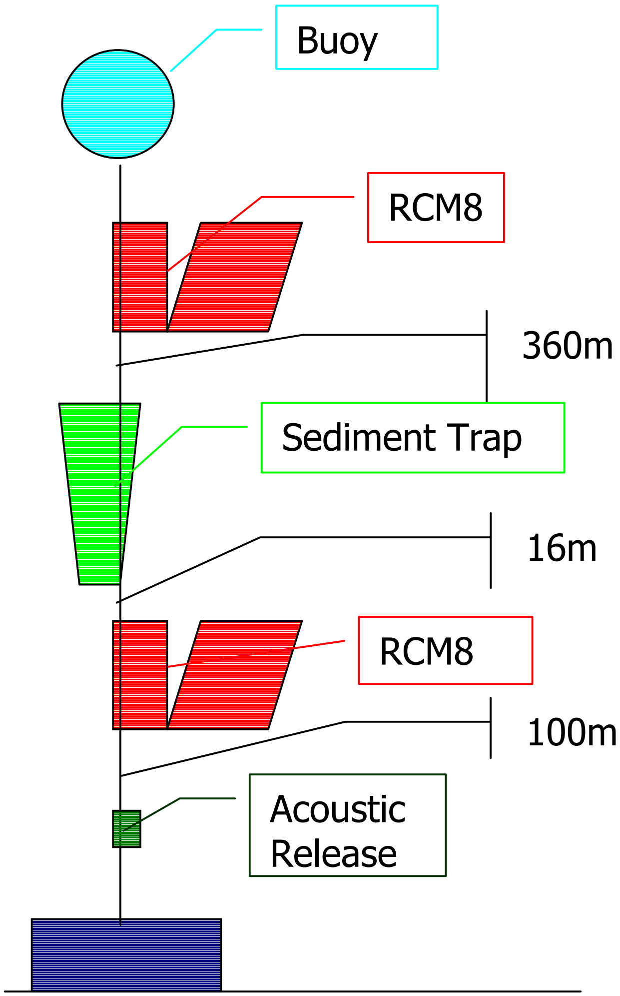
Average current intensity: 3.6 cm/sec

RMS: 2.5 cm/sec

Average angle: 8° NW

Sediment Trap

Current metre and sediment trap chain moored in Capo Passero KM4



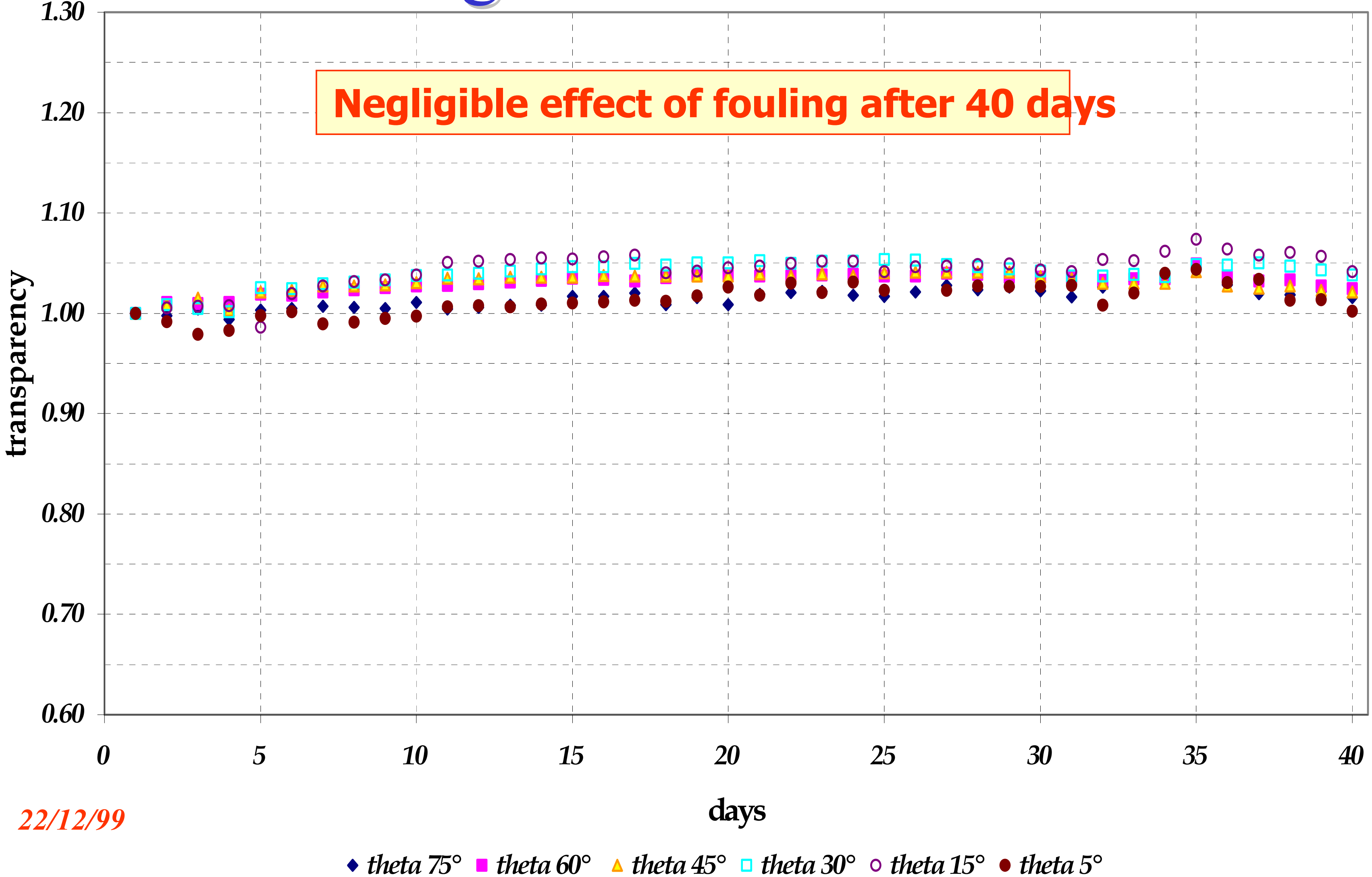
The Jonian Sea has a low biological activity

trap moored @ -3210m

Collected data are integrated over a 15 days period.

<u>**Sediment Trap re-deployed in August 2001,**</u>

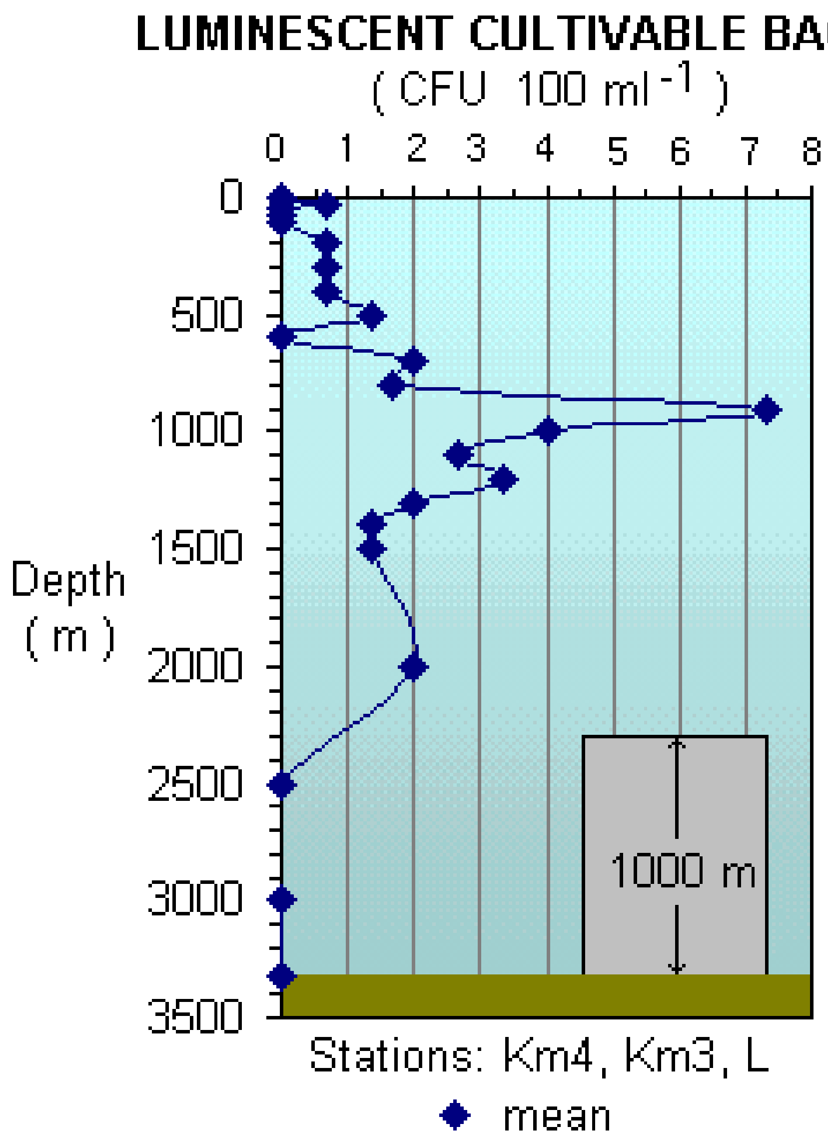
Biofouling short term measurement

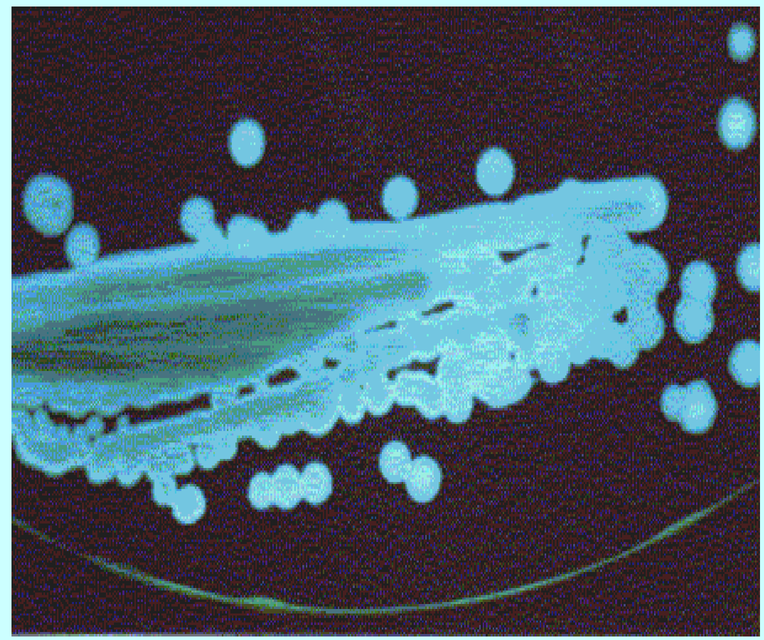


22/12/99

Transparency =(PD/reference)$_t$ / (PD/reference)$_{day\#1}$

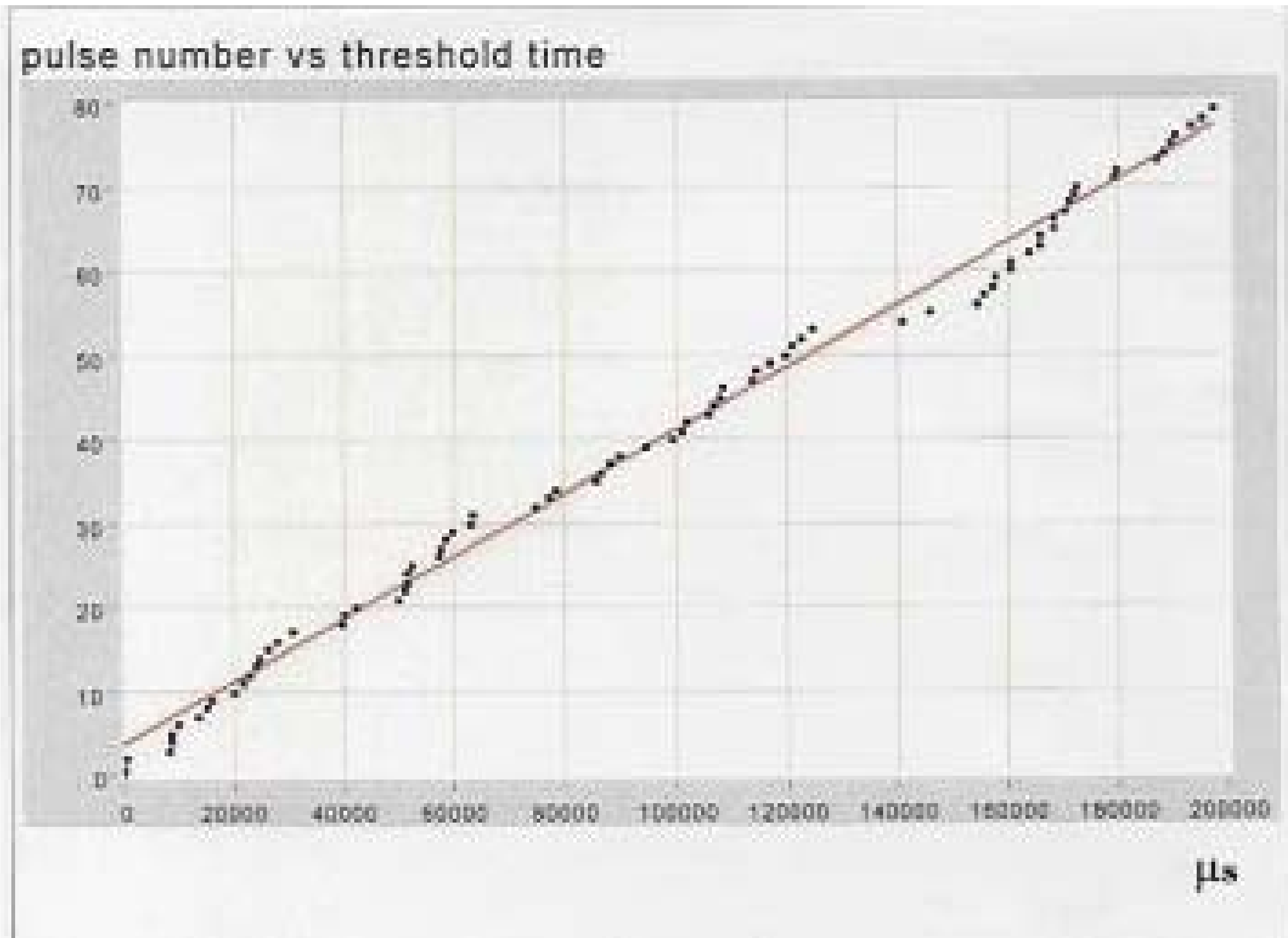
Bioluminescent bacteria





Bioluminescent bacteria on SWC

Optical Background data



PMT: **2″ EMI**

Thershol d: **.16 p.e.**

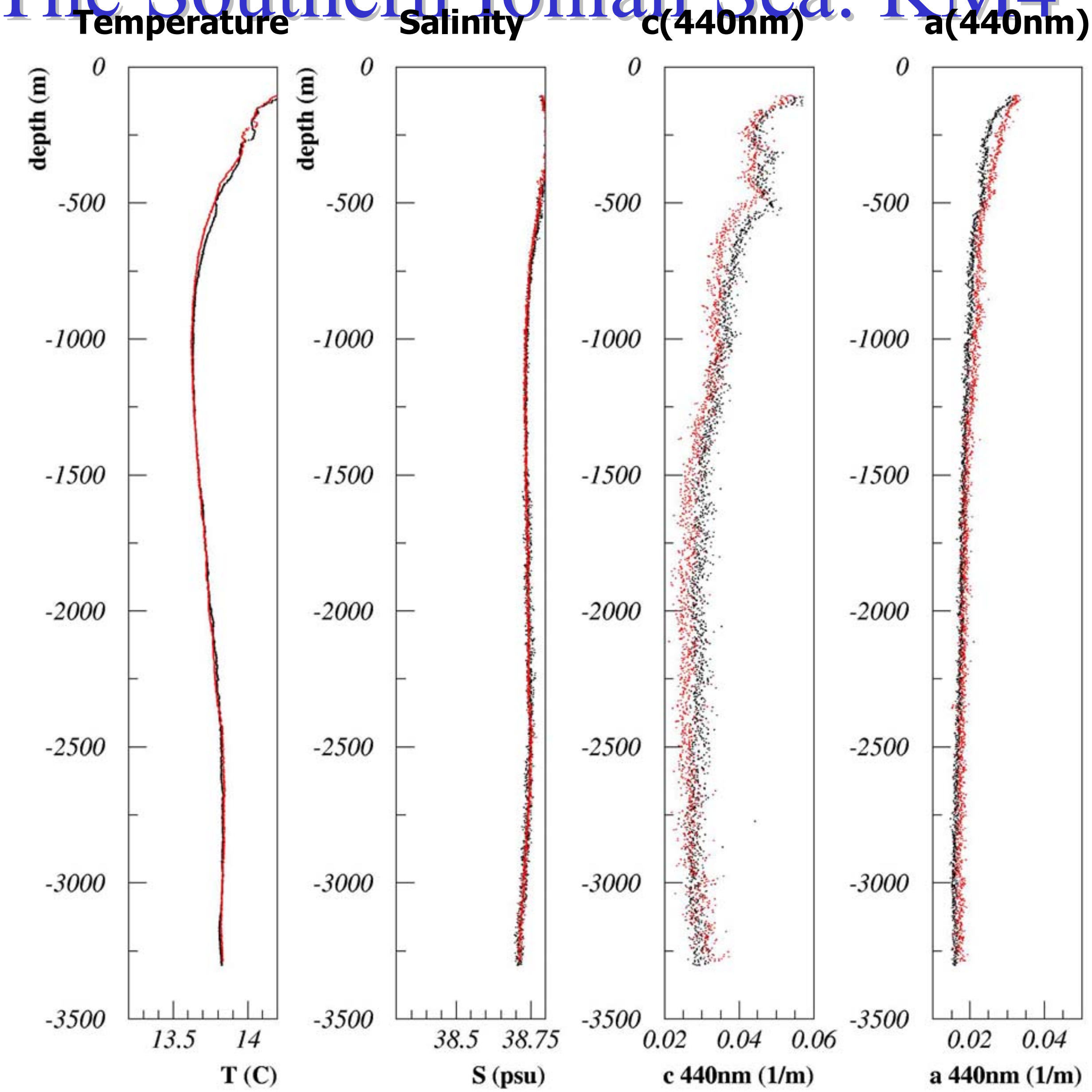
PMT noise: **50 Hz**

Capo Passero (March 2000)

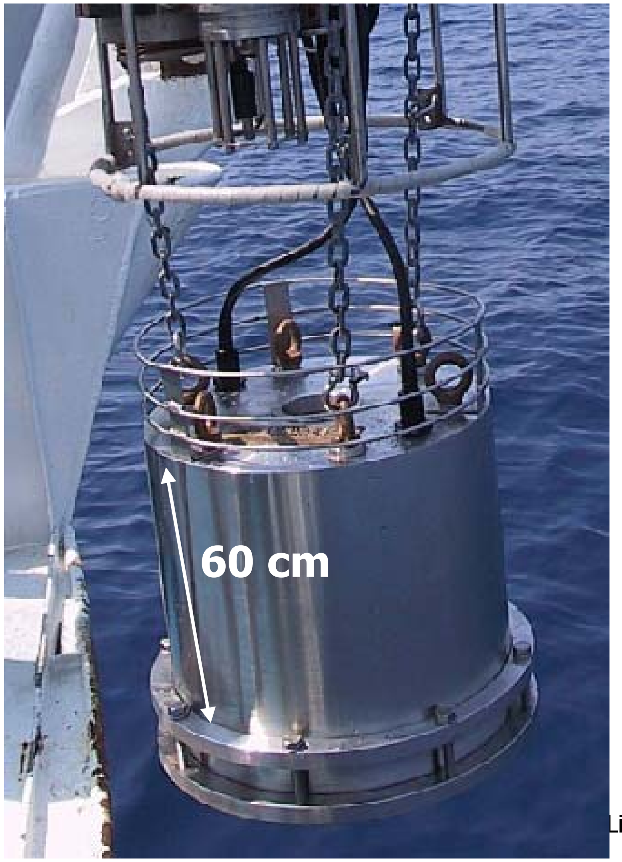
Measured Rate: ~300÷350 Hz

Compatible with expected rate from ^{40}K only

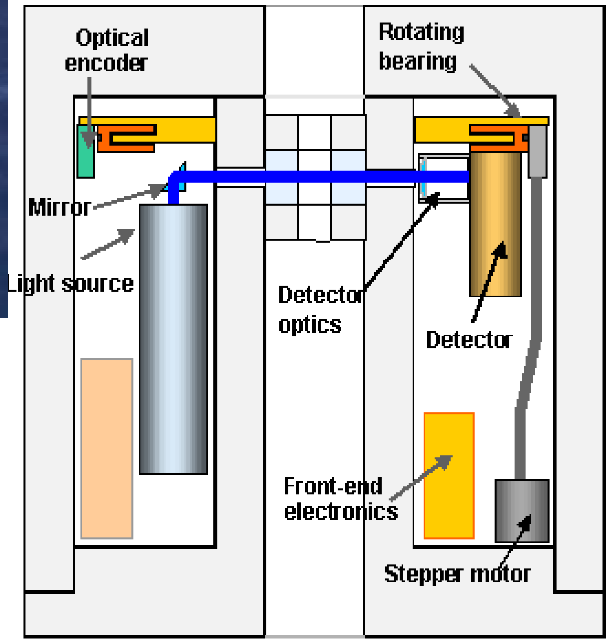
The Southern Ionian Sea: KM4

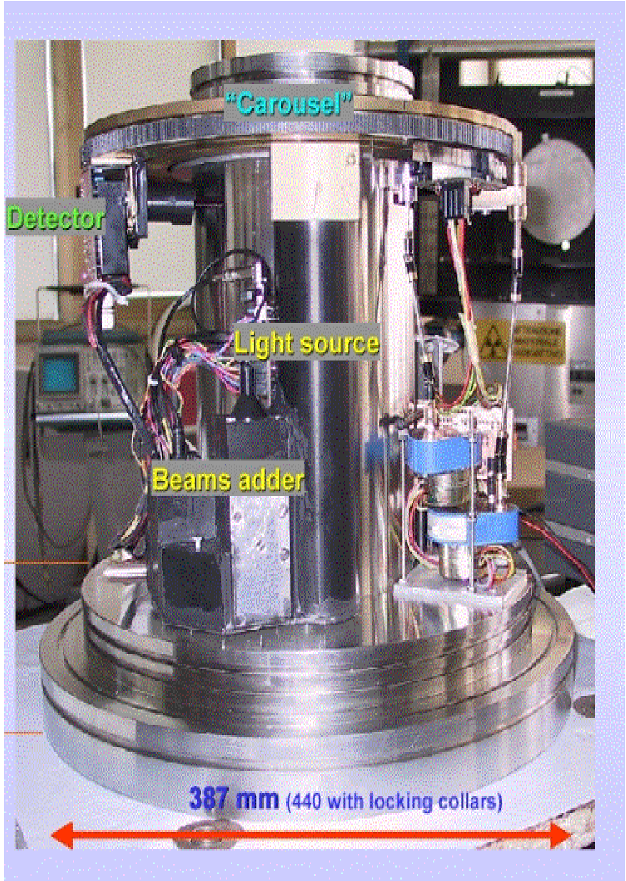


DEep WAter Scatteringmetre

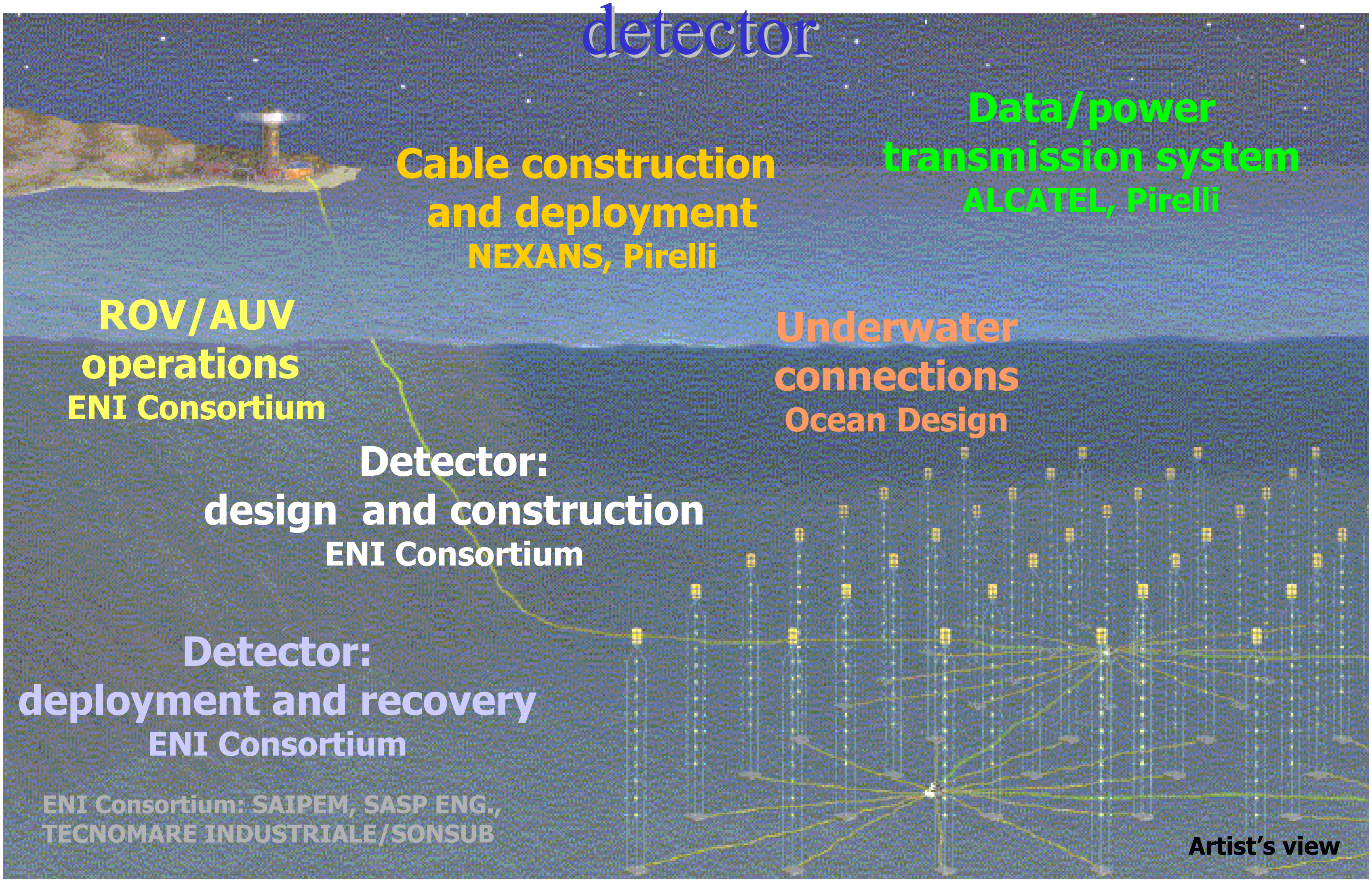


In situ measurement of the volume scattering function

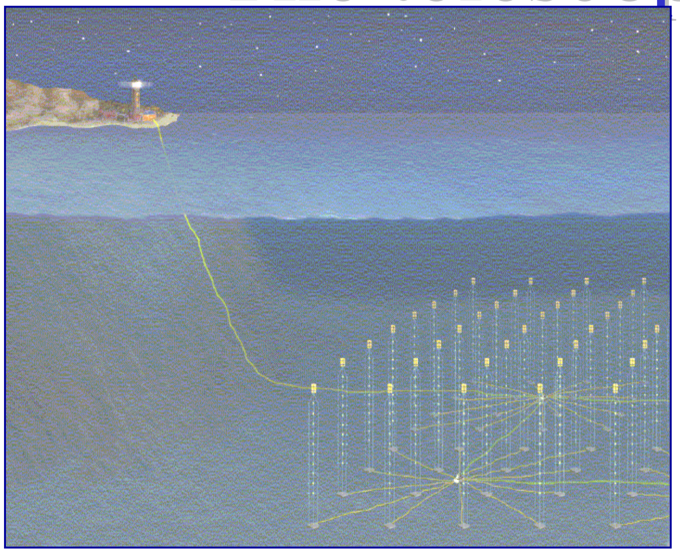




Coordinated Feasibility Study for a km3 detector

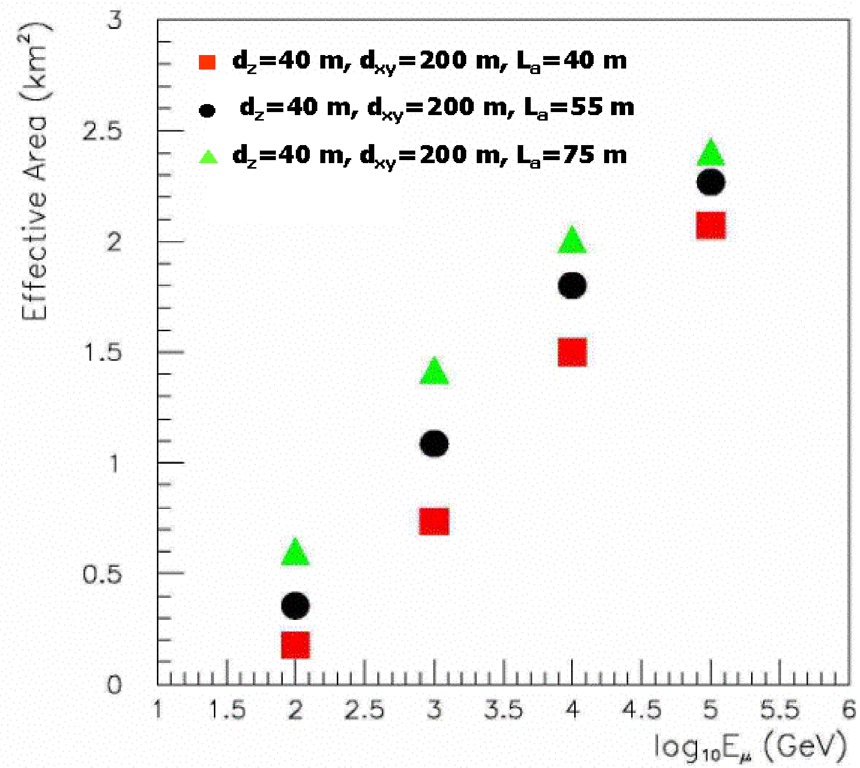


The telescope proposed by NEMO



fast montecarlo code is designed to study the telescope performance as a function of:

- **detector geometry**
- **PMT dimensions, TTS**
- **water optical properties**



Simulations show that a detector of:

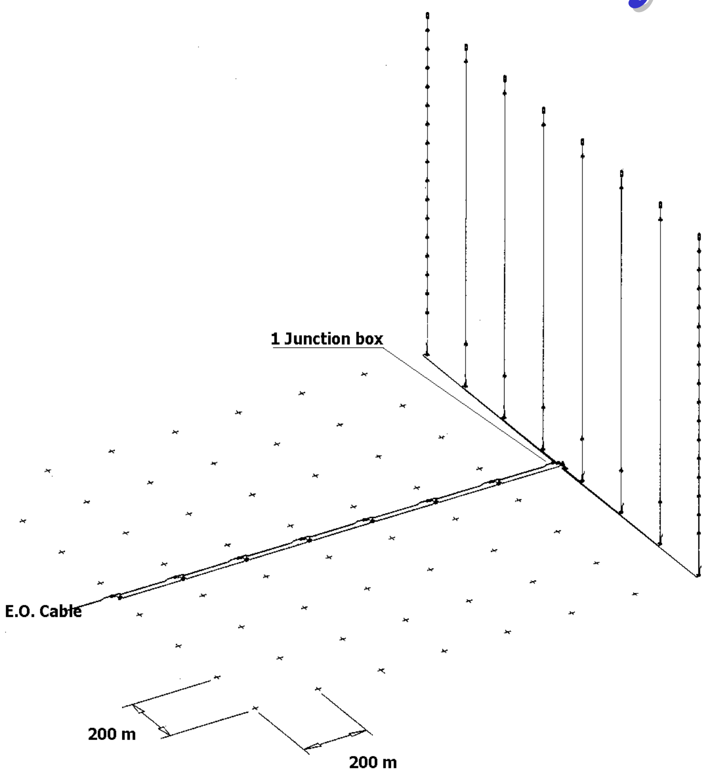
4096	**Optical Modules**
64	**Towers**
600m	**height**
200m	**distance between towers**
75m	**L_a (Capo Passero)**

May achieve:

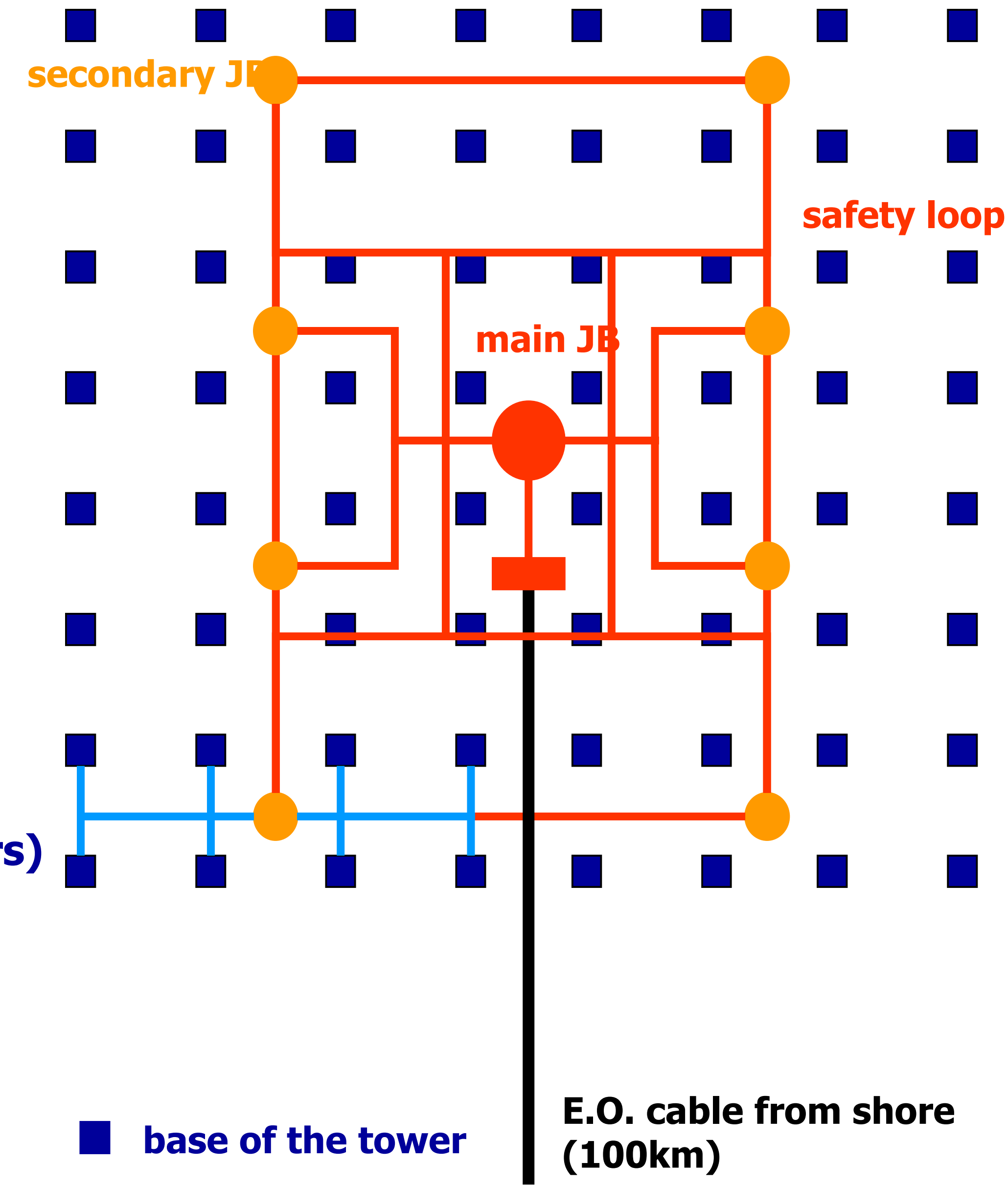
>2km² trigger area

<0.3° angular resolution (median angle)

The layout of the telescope

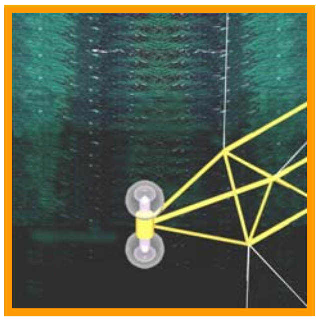


4096	Optical Modules
64	vertical structures (towers)
200m	distance between towers
1	main Junction box
1	main panel
8	secondary junction boxes (each serves 8 towers)

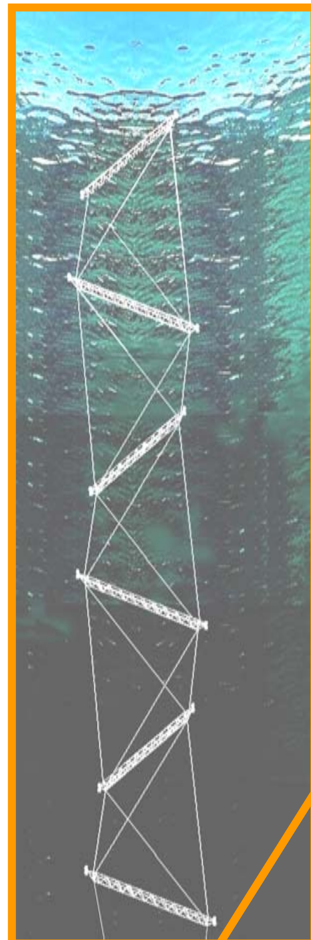


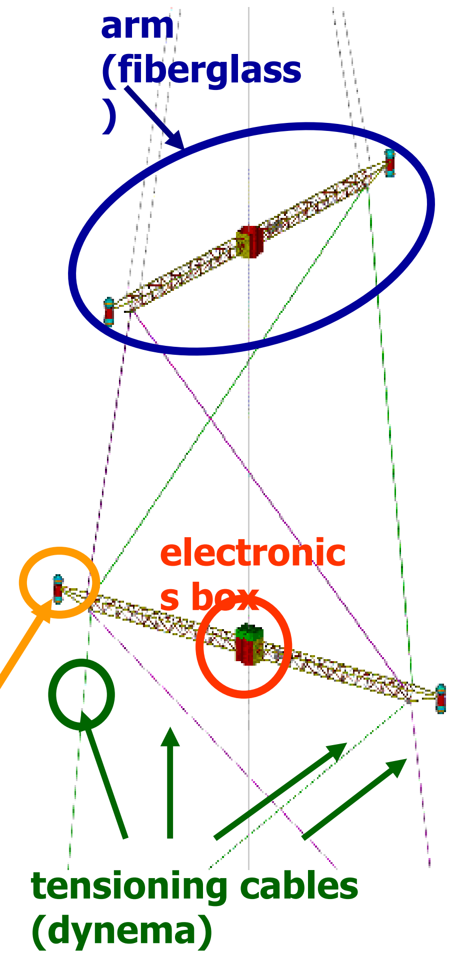
The NEMO tower

The tower designed by NEMO is a flexible structure tobe constructed in composite material: fiberglass and dynema



Optical Modules

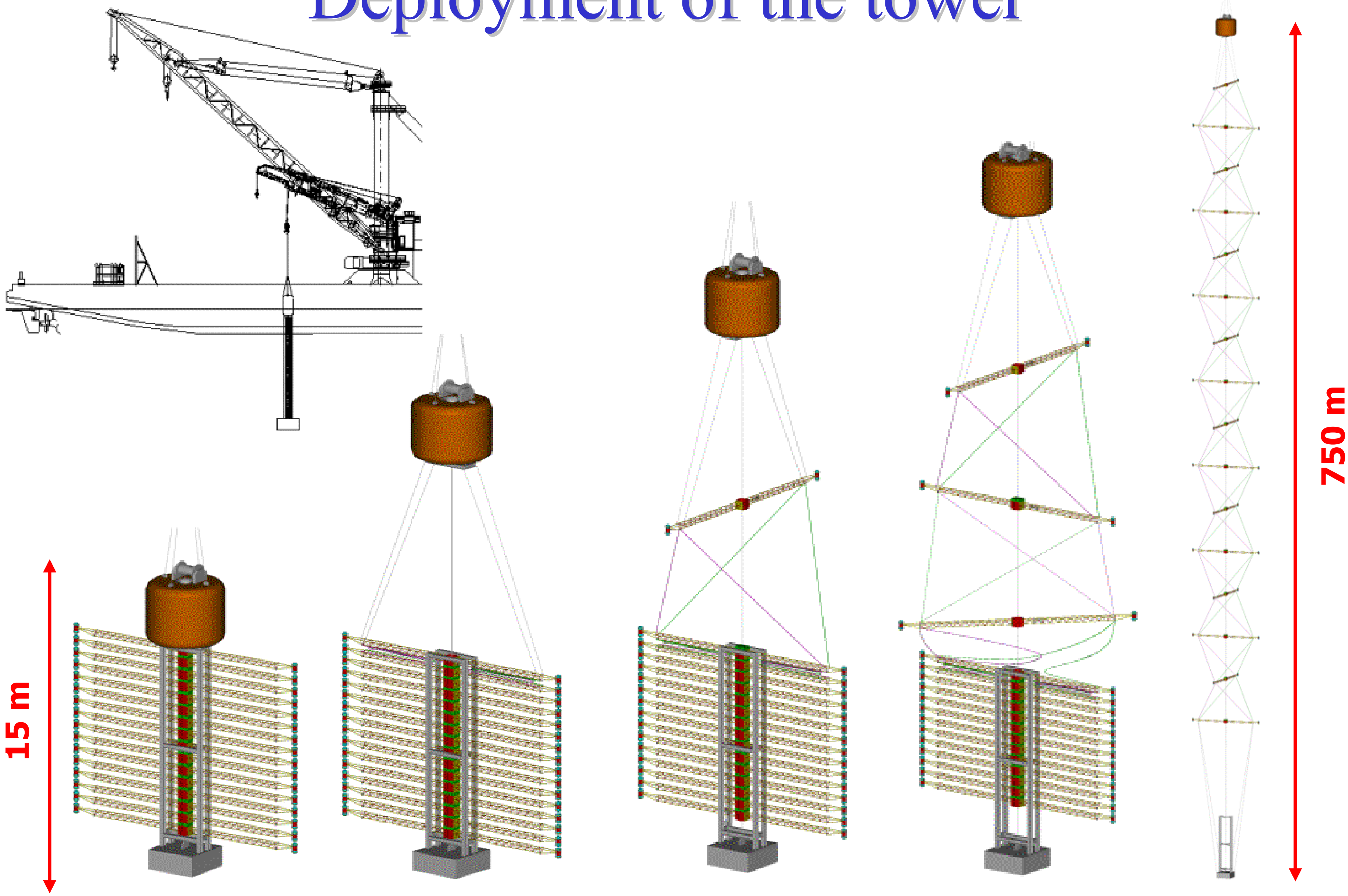




Structure of NEMO towers

tower height	750m
distance between the top and the bottom arm	600m
number of arms	16
distance between seabed and lowest arm	150m
arm length	20 m
distance between arms	40 m
OM per arm (downward and upward directed)	4
OM per tower	64

Deployment of the tower



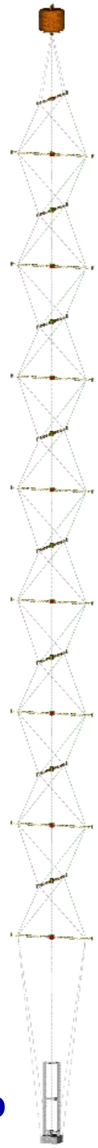
The data transmission system

ALCATEL Italia in collaboration with INFN proposes a commercial, high speed telecommunication system.
The system provides:

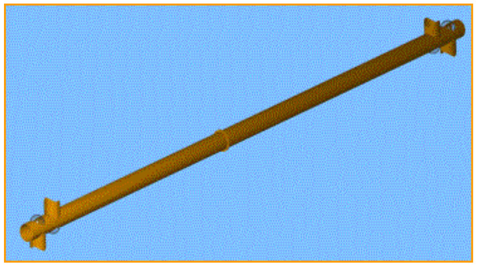
• high reliability and MTBF
• use of standard telecommunication protocols
• high speed (40 Gbps per line)
• auto re-configuration in case of failure

digital signals from 4 OM (one arm) are grouped into one S1.1 electro optical converter

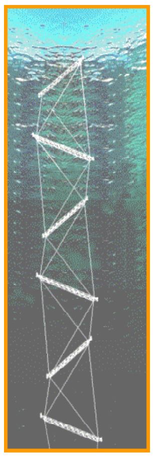
The base of the tower host the module 1660-SM equipped with:
• 16 STM-1 modules (one per arm)
• 1 STM-16 (+1 for redundancy).
This module groups the 16 optical signals from 16 arms into 1 wavelength,



Data transmission rate

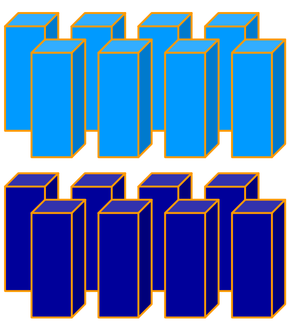


1 arm (4 OM)
S1.1 + STM1
155 Mbps



1 tower (64 OM)
STM16 + 1660 SM
2.5 Gbps in one λ (DWDM)

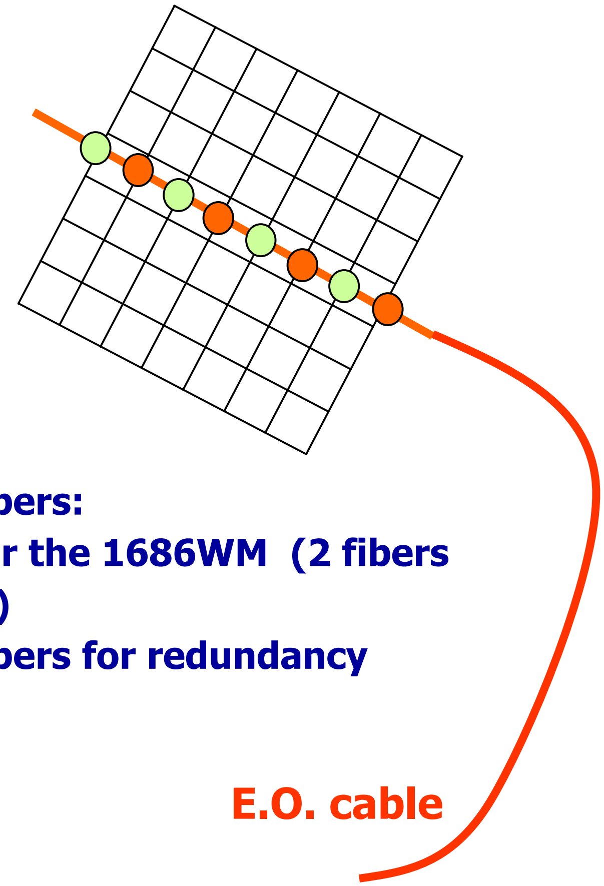
(total redundancy)



16 towers (4096 OM)
1686 WM
40 Gbps in 16 λ (DWDM)

(total redundancy)

8 Junction Boxes, 8 modules 1686 WM:
4 for data transmission, 4 for redundancy
16 λ each (DWDM)

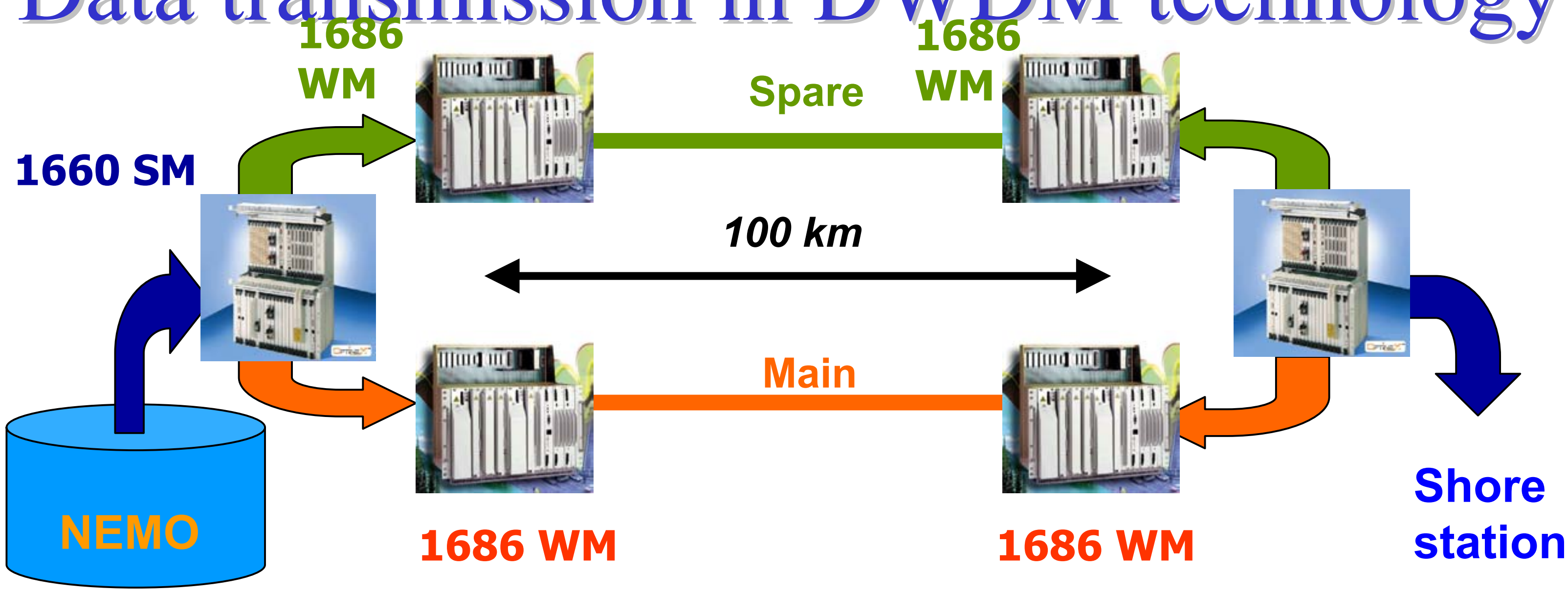


48 fibers:
16 for the 1686WM (2 fibers each)
32 fibers for redundancy

E.O. cable

Shore station

Data transmission in DWDM technology



data packing (underwater):

4096	OM	(electric)	custom board
1024	arm	(optical)	S1.1+ STM1
64	tower	(optical)	1660 SM + STM16
4	J Box	(DWDM)	1686 WM

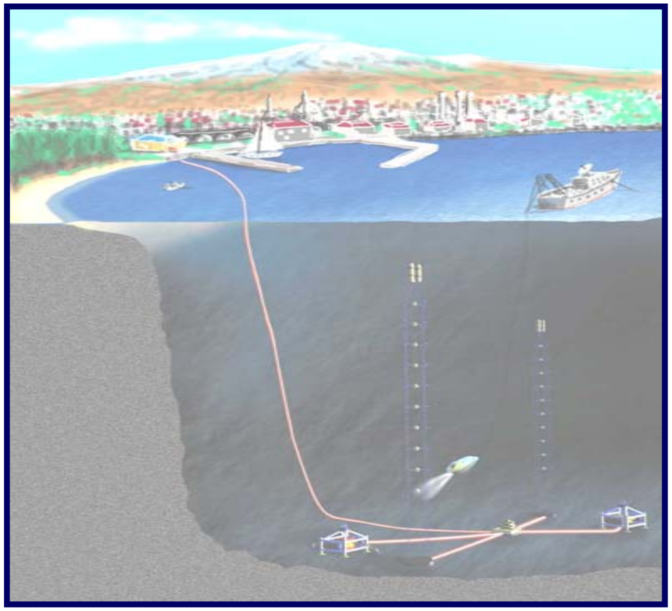
data unpacking (shore laboratory):

4	1686 WM
64	1660 SM + STM16
1024	S1.1+ STM1
4096	OM signals to be acquired

No data compression
Trigger on shore

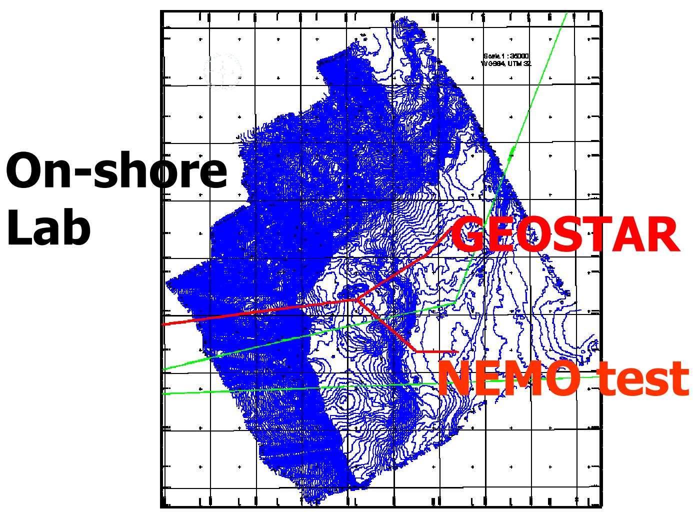
The shore station is equipped with the Network Management System for the data stream control

Test Site Lab at port of Catania



From lab to Test site
28 km optical fibres

Deep sea (2000 m) test for:
- **electronics**
- **connectors**
- **optical modules, acoustic modules**
- **deployment and recovery procedures**



Geostar (INGV):

Oceanographic and environmental survey.

Permanent on-line seismic monitoring connected to POSEIDON network.

The underwater cable at the NEMO test site

20 km electro-optical cable:
10 optical fibers
6 electrical conductors

GEOSTAR 2150 m depth

5 km E.O. cable

Junction Box

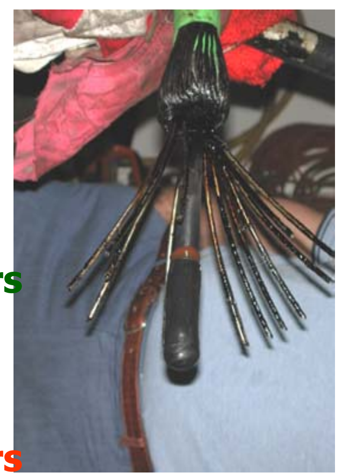
NEMO 2050 m depth

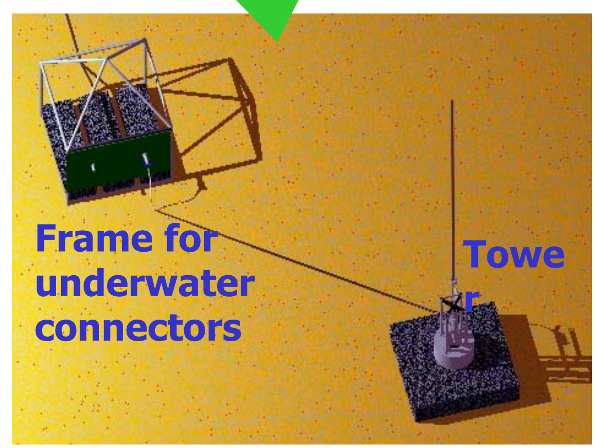
Deployed in September 2001

E.O. Cable details:

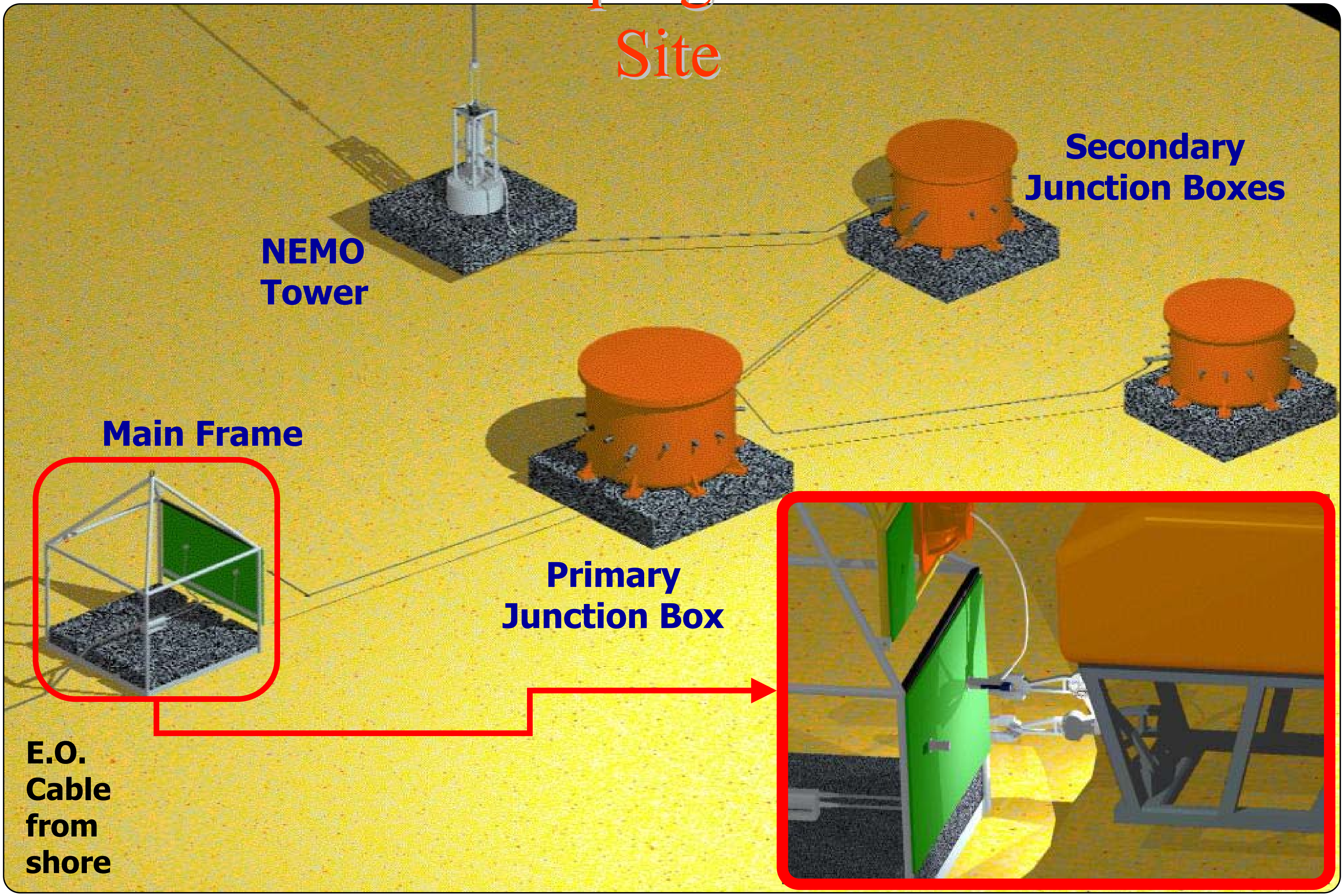
NEMO:
6 fibers
4 electrical conductors

GEOSTAR:
4 fibers
2 electrical conductors





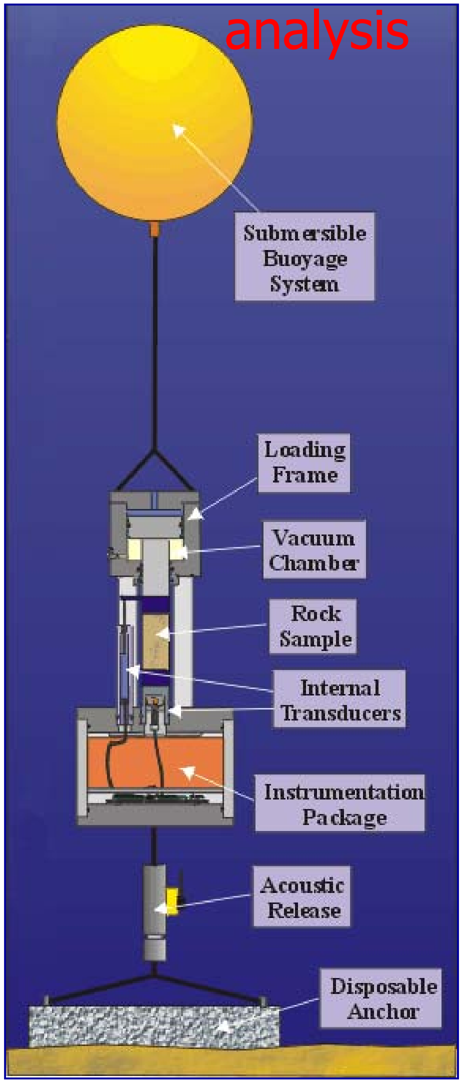
Advanced R&D programme at the Test Site



Underwater multidisciplinary laboratory

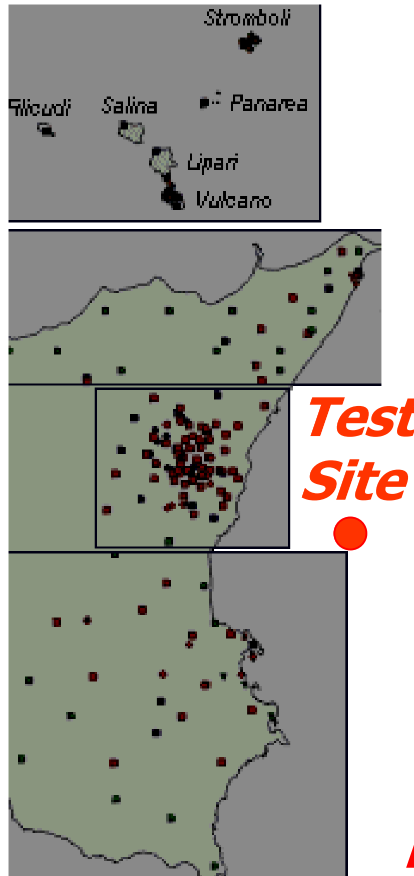
CREEP (UCL)

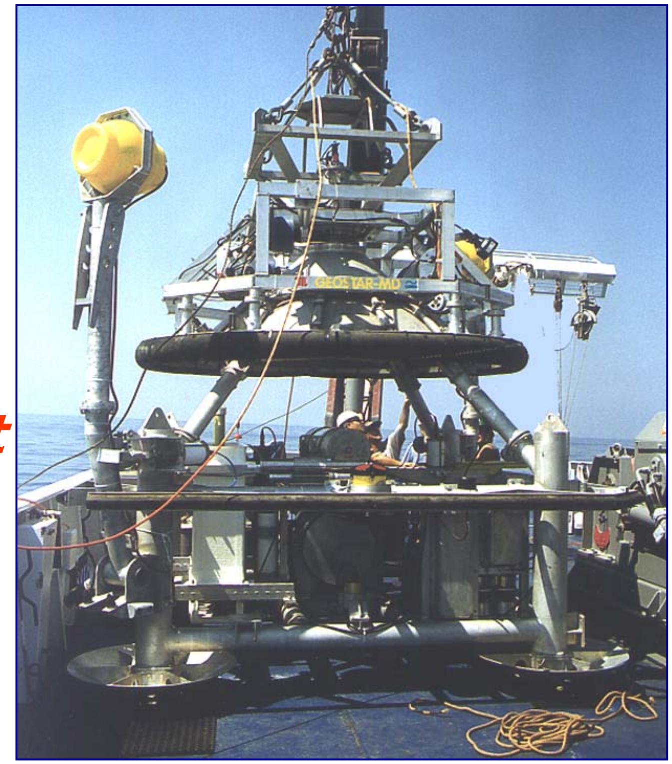
Long term rock fracture analysis



POSEIDON - GEOSTAR

Submarine seismic survey station

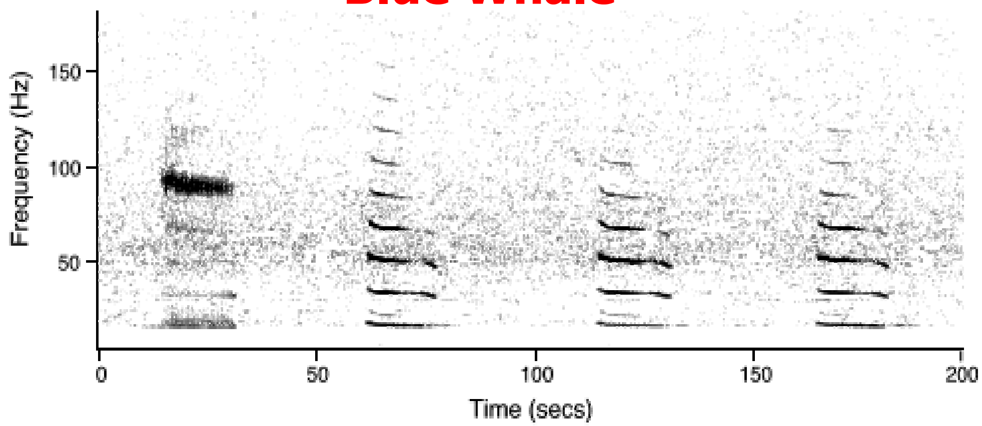


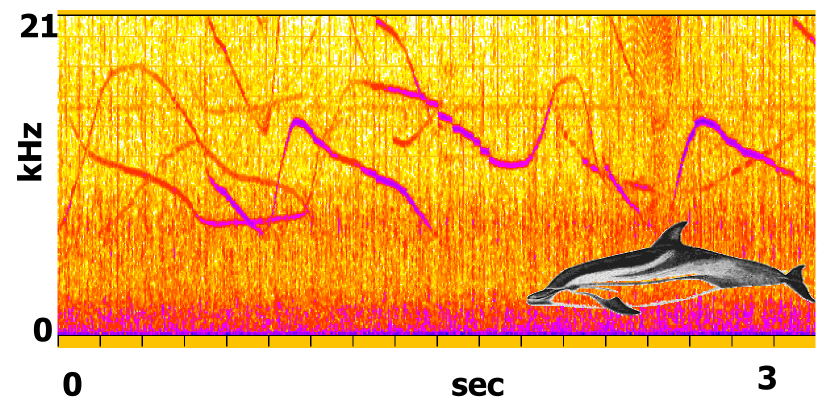


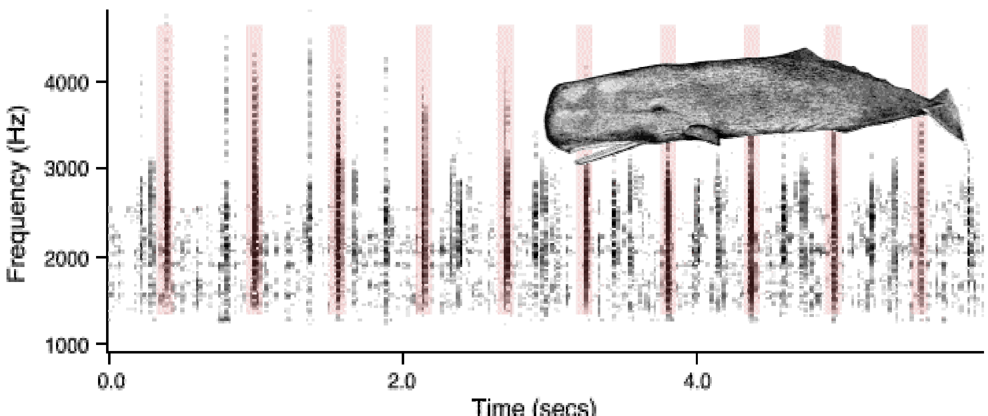
NEMO-Site

Acoustic Search for cetaceans

Blue Whale







Pavan et al. 2000

e	User	date	Intended Use
	Galileo	1608	Navigation
	Hubble	1929	Nebulae
	Jansky	1932	Noise
e	Penzias, Wilson	1965	Radio-galaxies, noise
	Giacconi ...	1965	Sun, moon
	Hewish, Bell	1967	Ionosphere
	[illegible]	[illegible]	Thermonuclear

The End