Large-scale Underwater/ice Neutrino Telescopes

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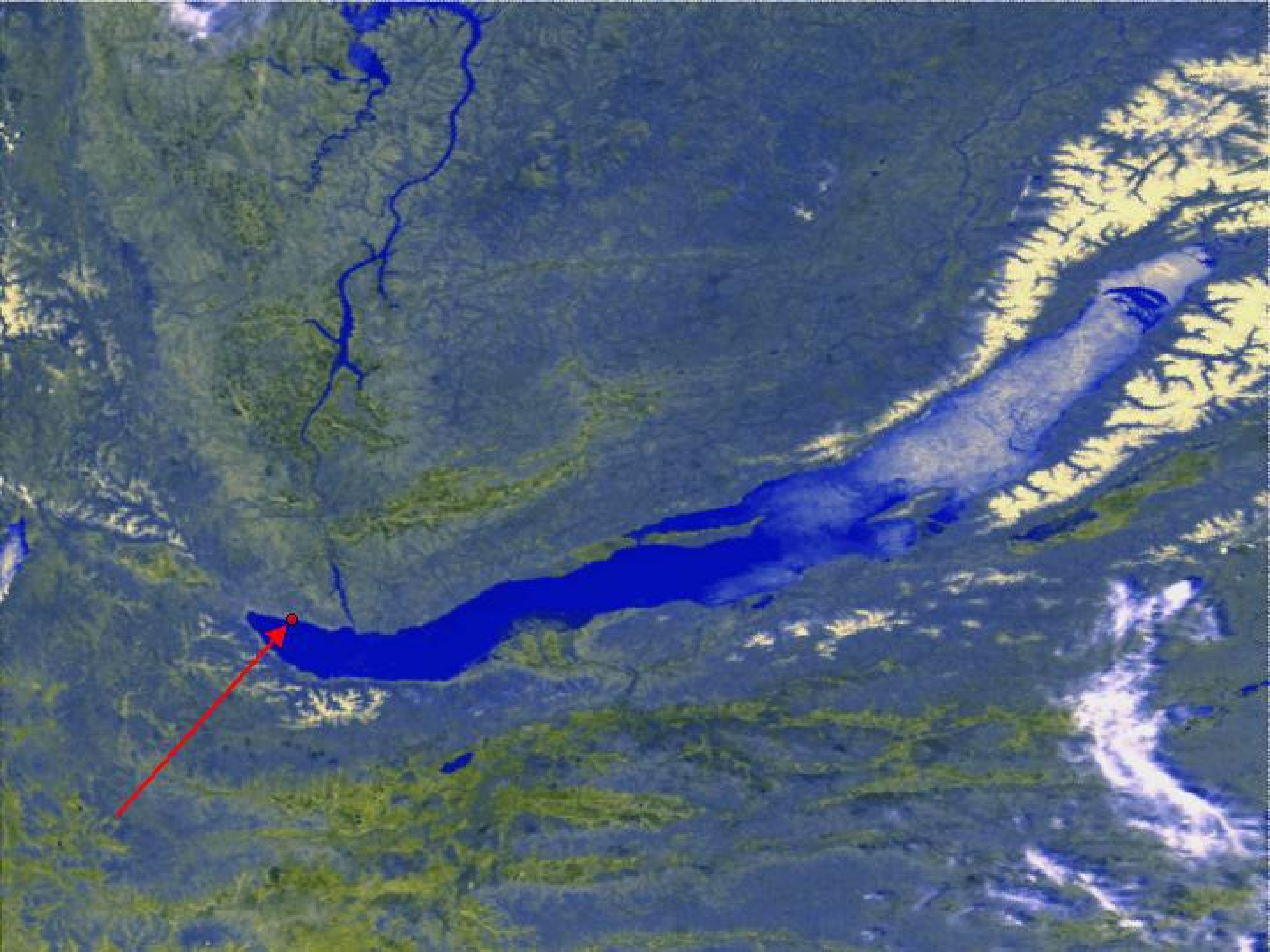
STATUS

Operating	Mounting	R&D
BAIKAL	NESTOR	IceCube (Antarctic)
AMANDA	ANTARES	km3(Mediterranean)
	NEMO	km3 (Baikal)

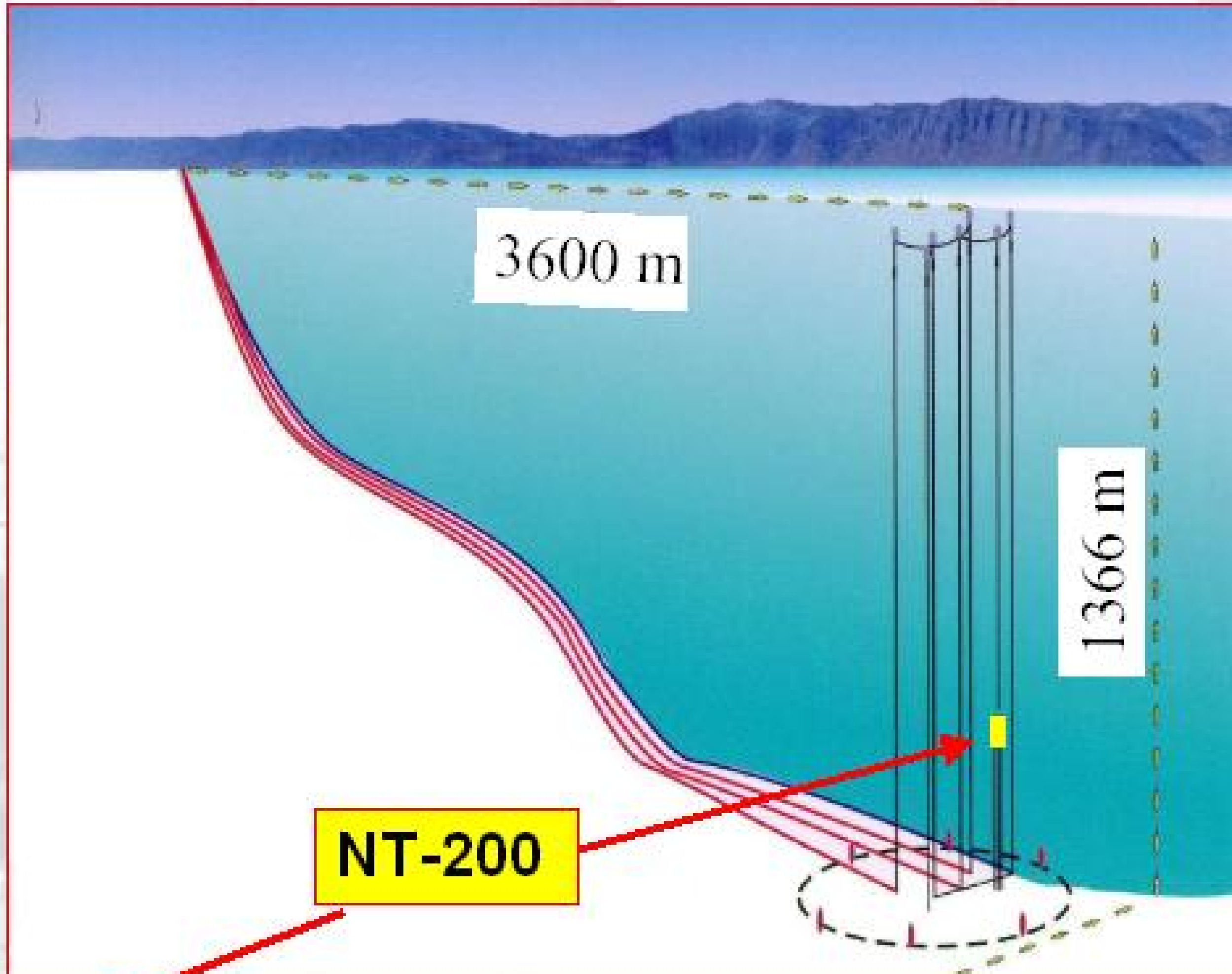
The Baikal Collaboration

1. Institute for Nuclear Research, Moscow, Russia.
2. Irkutsk State University, Irkutsk, Russia.
3. Skobeltsyn Institute of Nuclear Physics MSU, Moscow, Russia.
4. DESY-Zeuthen, Zeuthen, Germany.
5. Joint Institute for Nuclear Research, Dubna, Russia.
6. Nizhny Novgorod State Technical University, Nizhny Novgorod, Russia.

1. St.Petersburg State Marine University, St.Petersburg, Russia.
2. Kurchatov Institute, Moscow, Russia.



The Site

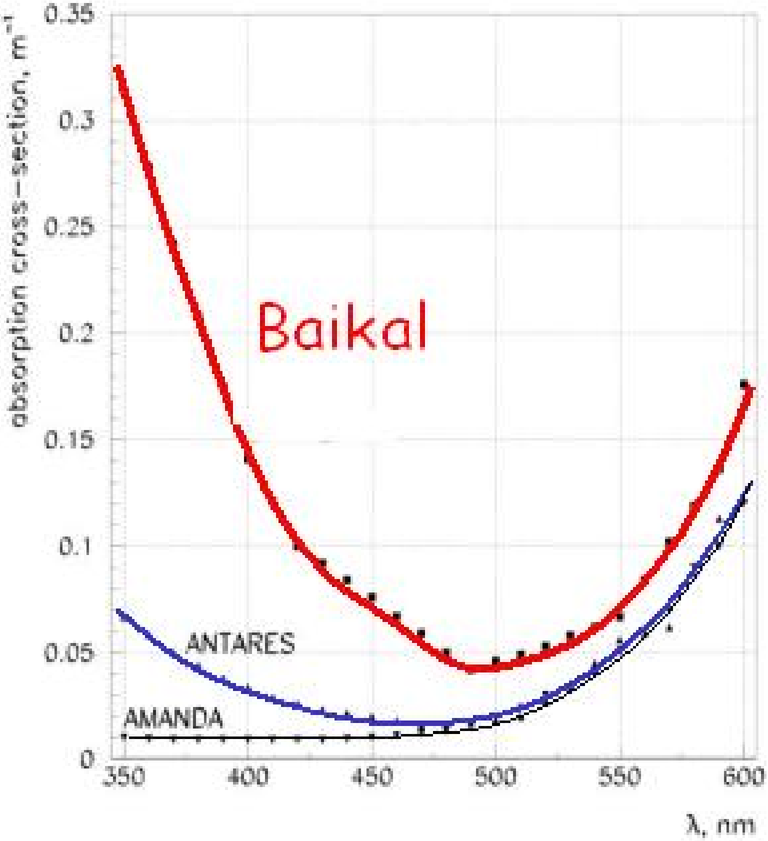


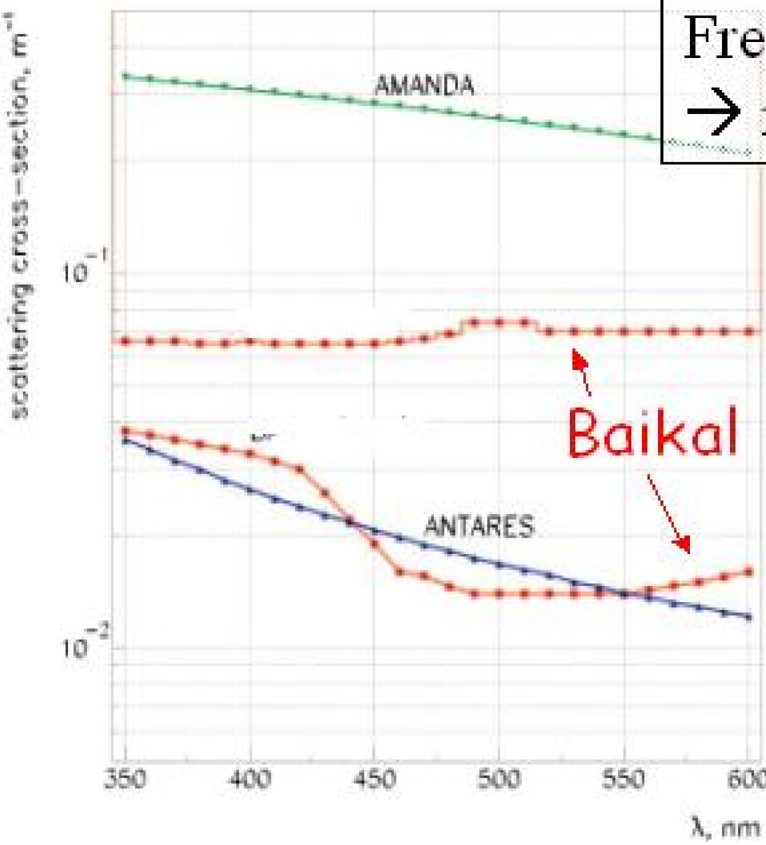
- 4 cables x 4km to shore.
- 1070m depth

Ice as a natural deployment platform

- Ice stable for 6-8 weeks/year:
  - Maintenance & upgrades
  - Test & installation of new equipment
  - Operation of surface detectors (EAS, acoustics,…)
- Winches used for deployment operations →

Baikal - Optical Properties



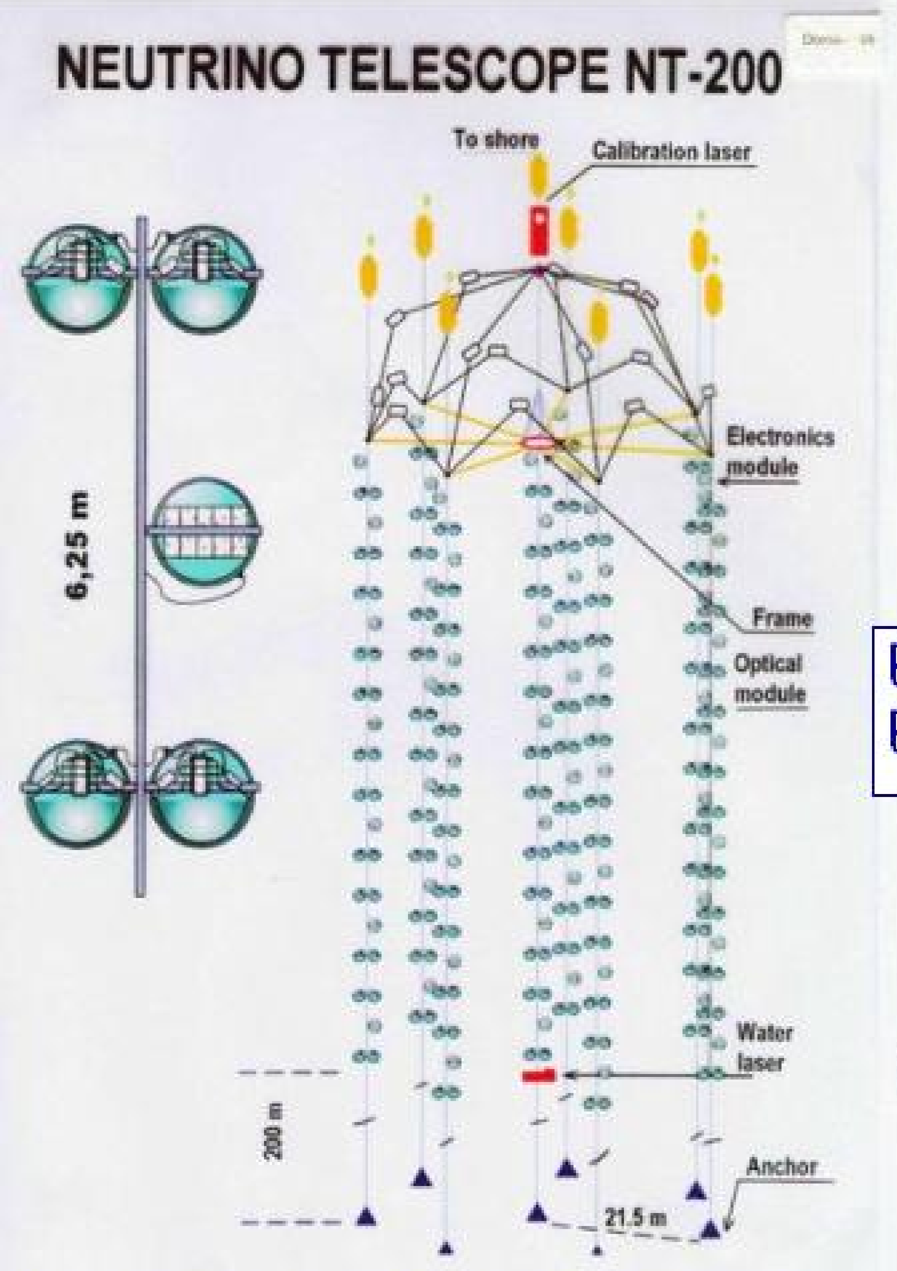


FreshWater
→ no K40 BG

Abs. Length: 22 ± 2 m

In-situ measurements

Scatt. Length (geom) ~ 30-50 m
$\langle \cos \Theta \rangle$ ~ 0.85-0.9



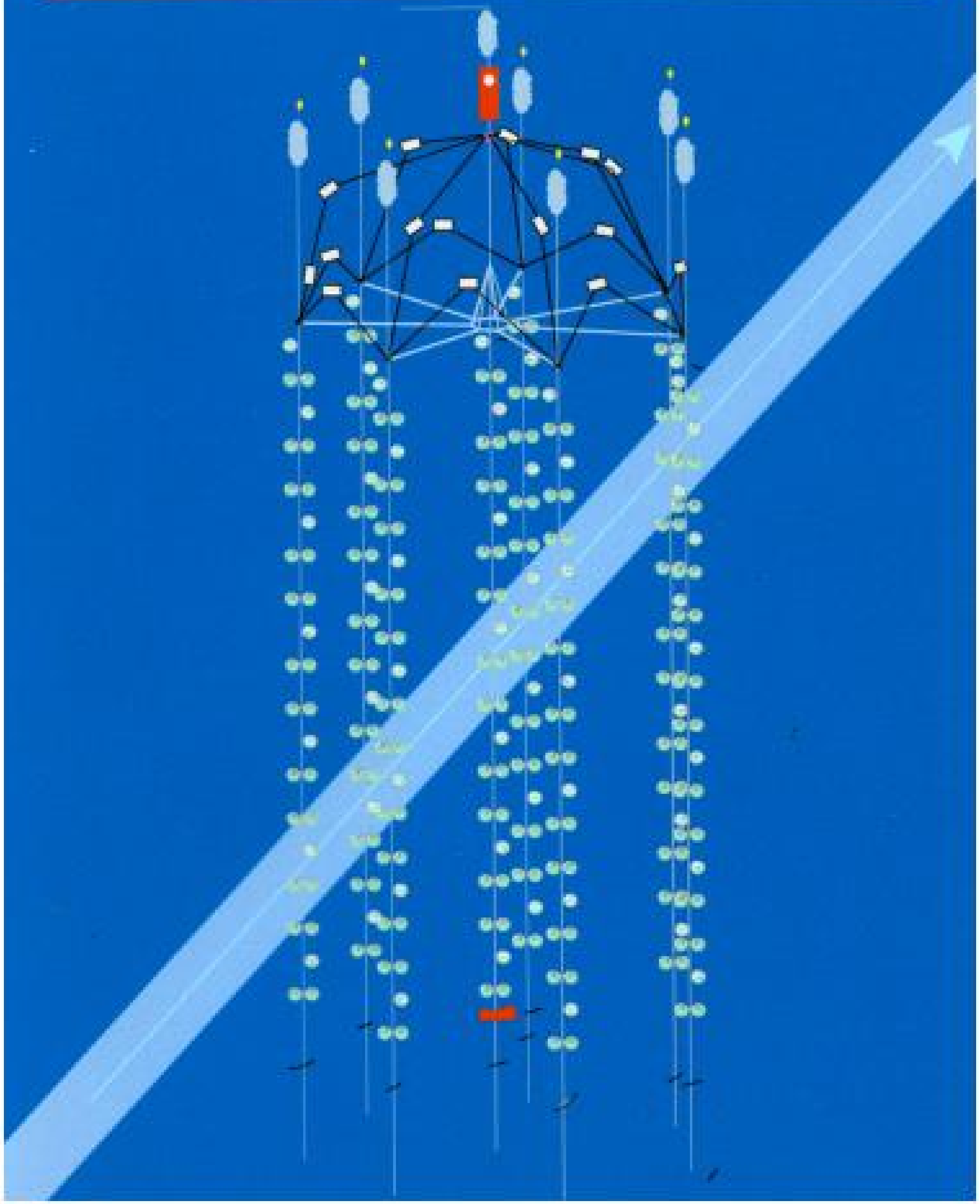
- 8 strings: 72m height
- 192 optical modules
- pairwise coincidence
  → 96 space points
- calibration with N-lasers
- timing ~ 1 nsec
- Dyn. Range ~ 1000 pe

Effective area: 1 TeV ~2000 m^2
Eff. shower volume: 10TeV ~0.2Mt

Height × & = 70m × 40m, $V=10^5 m^3$

Quasar PMT: d = 37cm

NEUTRINO TELESCOPE NT-200

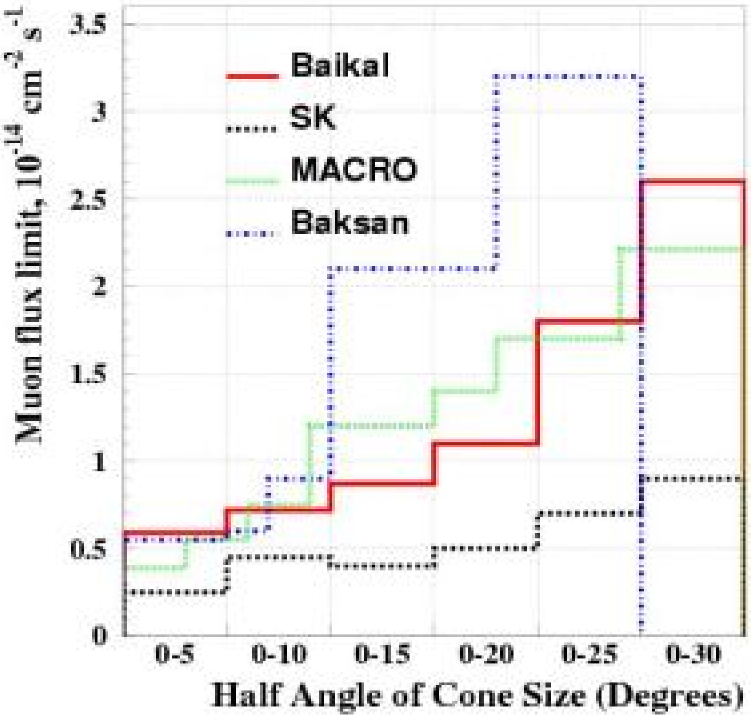


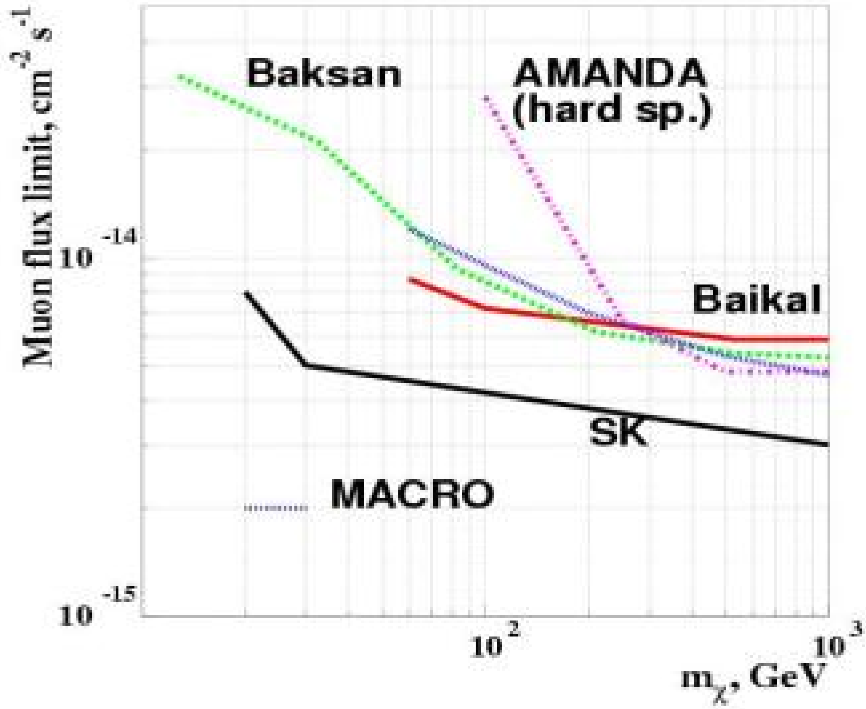
Optical Module – Pair (Coincidence)

WIMP Search

Excess neutrino induced upward muon flux 90% c.l. limits from the Earth
(502 days of NT-200 livetime, $E_\mu > 10$ GeV)

	Baikal	Amanda	SK	Baksan	MACRO
T, days	502	130	1680	5402	1298





Search for fast monopoles ($\beta > 0.8$)

$$N_\gamma(\lambda) = n^2 (g/e)^2 N_{\gamma\mu}(\lambda) = 8300\, N_{\gamma\mu}(\lambda)$$
$$g = 137/2, \quad n = 1.33$$

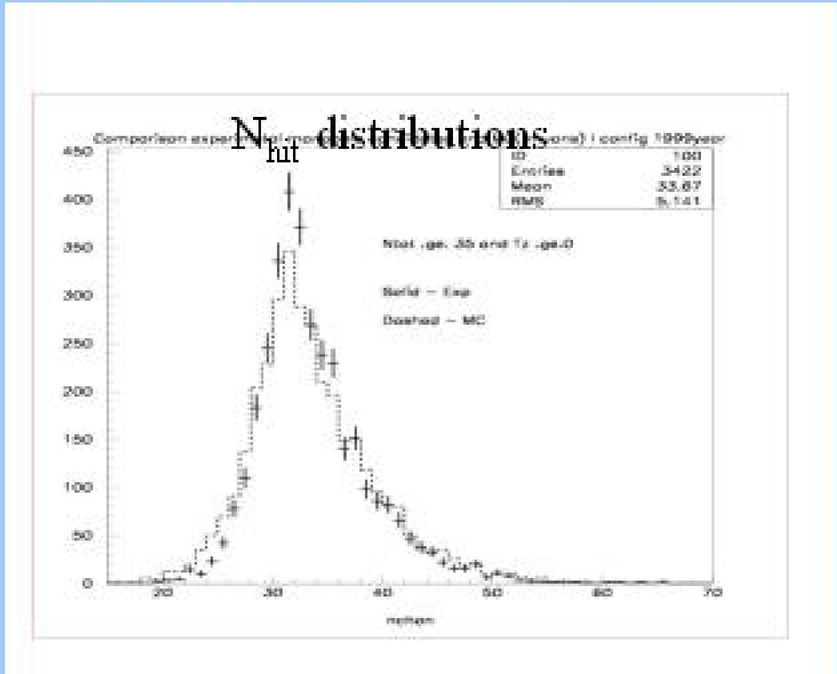
Event selection criteria:

hit channel multiplicity - $N_{hit} > 35$ ch,

upward-going monopole -

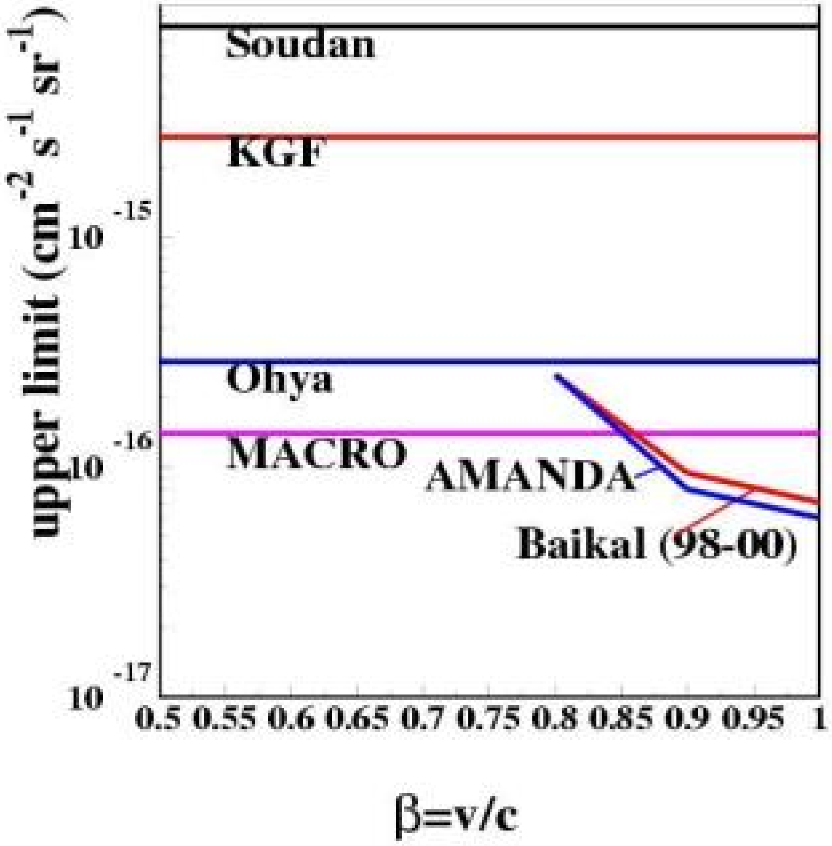
$\Sigma(z_i - z)(t_i - t)/(\sigma_t \sigma_z) > 0.45$ & $\theta > 100^o$

Background - atmospheric muons



780 livedays

Monopole limit (90% C.L.)



Search for slow massive monopoles ($10^{-5} < \beta < 10^{-3}$)

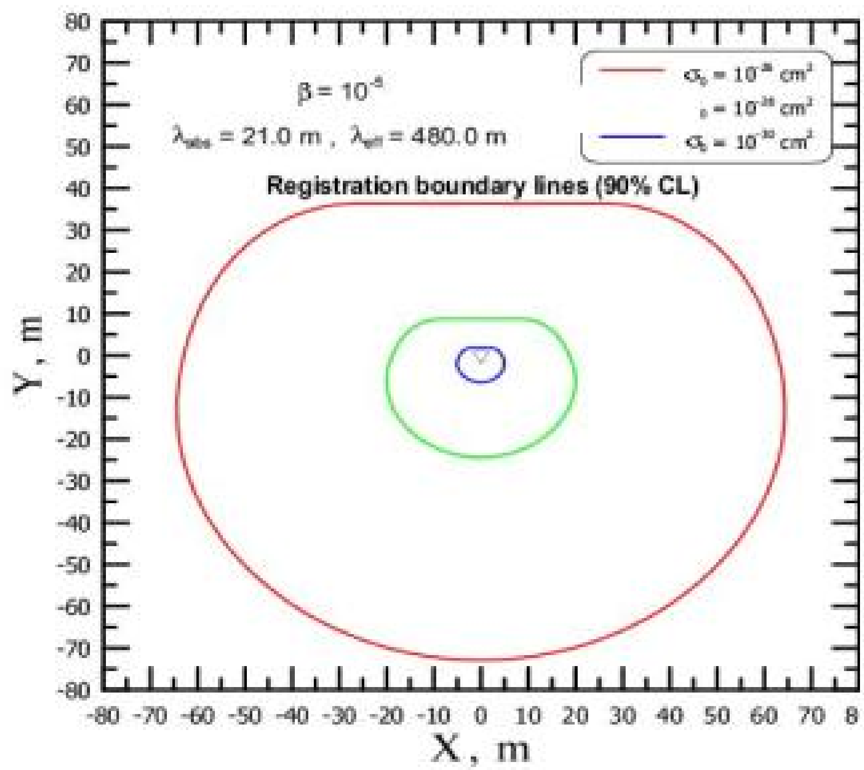
$\sigma_{cat} = 0.17\sigma_0/\beta^2$, $10^{-5} < \beta < 10^{-3}$

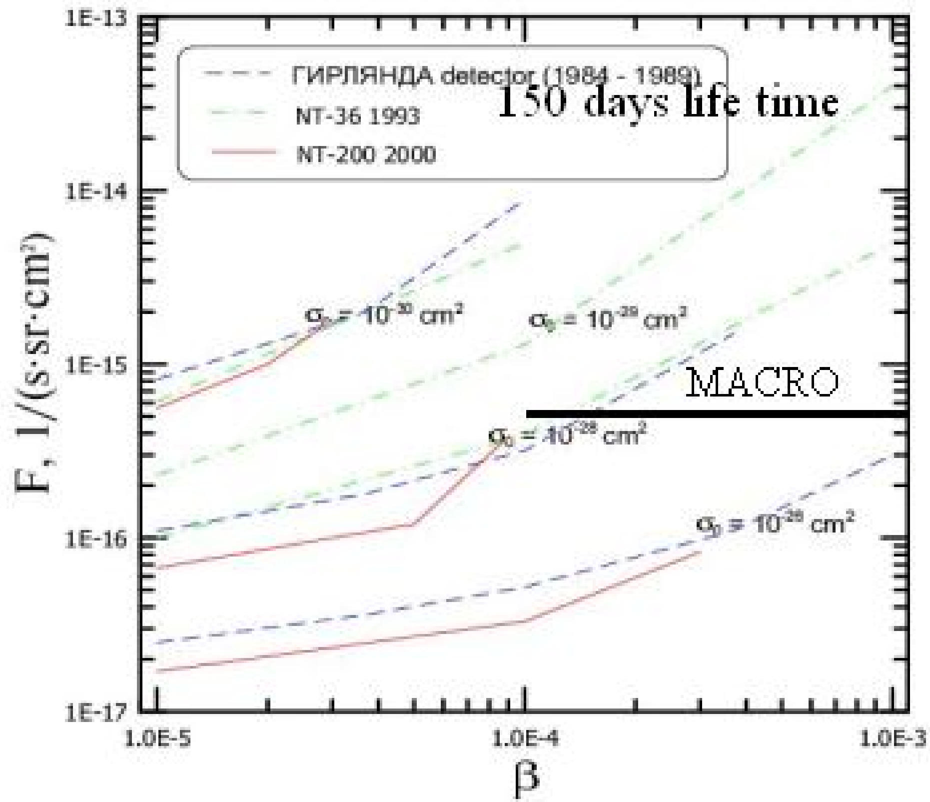
$M + p \rightarrow M + e^+ (+\pi\ldots)$, $N_\gamma \sim 10^5$

NT-200 - detection of massive bright objects (GUT-monopoles, nuclearites, Q-balls ...)

monopole trigger: $N_{hit} > 4$ within dt=500µsec

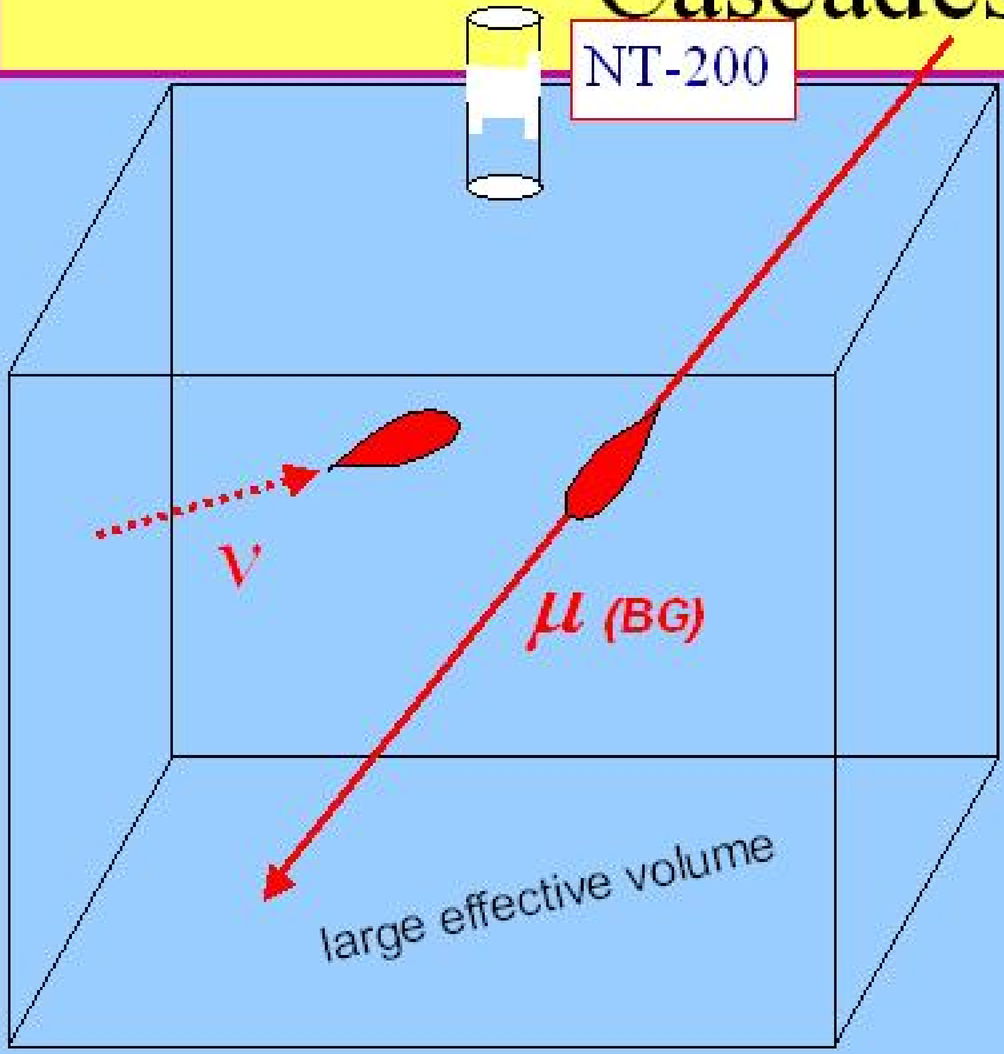
selection requirements - $N_{ch} > 1$ with $N_{hit} > 14$





Magı ɔoundaries

Search for High Energy - Cascades



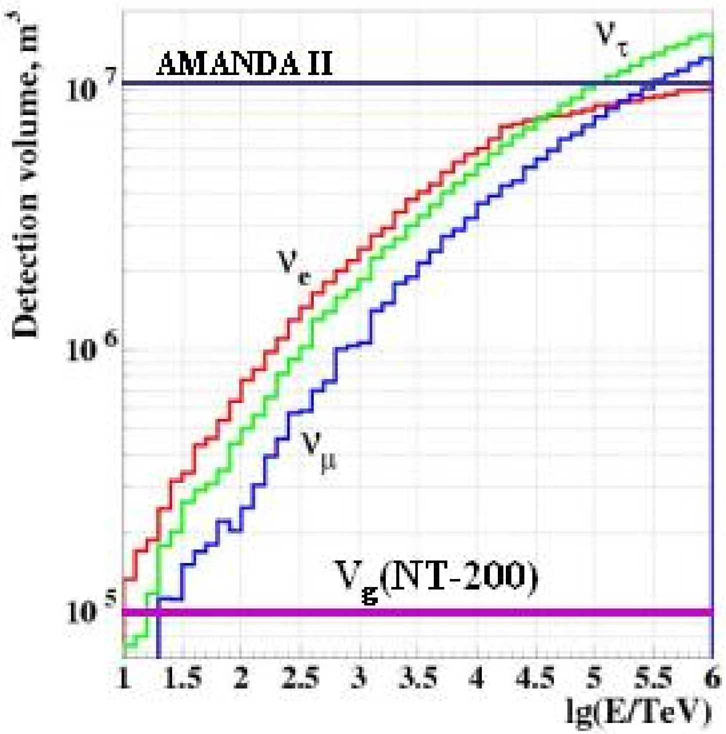
Look for upward moving light fronts.

<u>Signal:</u>
isolated cascades from neutrino interactions

<u>Background:</u>
Bremsshowers from h.e. downward muons

Final rejection of background by „energy cut" ($N_{channel}$)

Diffuse flux of ν_e, ν_τ, ν_μ: cascades



The 90% C.L. Limits Obtained With
NT-200 (780 days)
DIFFUSE NEUTRINO FLUX
($\Phi_\nu \sim E^{-2}$, 10 TeV < E < 10^4 TeV)

$\nu_e : \nu_\mu : \nu_\tau = 1 : 2 : 0$ (AGN)

$\nu_e : \nu_\mu : \nu_\tau = 1 : 1 : 1$ (Earth)

$E^2 \Phi_\nu < 1.0 \cdot 10^{-6}$ GeV cm^{-2} s^{-1} sr^{-1}

$E^2 \Phi_\nu < 8.6 \cdot 10^{-7}$ GeV cm^{-2} s^{-1} sr^{-1} (AMANDA04)

W-RESONANCE
(E = 6.3 PeV, $\sigma = 5.3 \cdot 10^{-31}$ cm^2)

$\Phi_{\nu e} < 4.2 \cdot 10^{-20}$ (cm^2 · s · sr · GeV)$^{-1}$

$\Phi_{\nu e} < 5.0 \cdot 10^{-20}$ (cm^2 · s · sr · GeV)$^{-1}$ (AMANDA04)

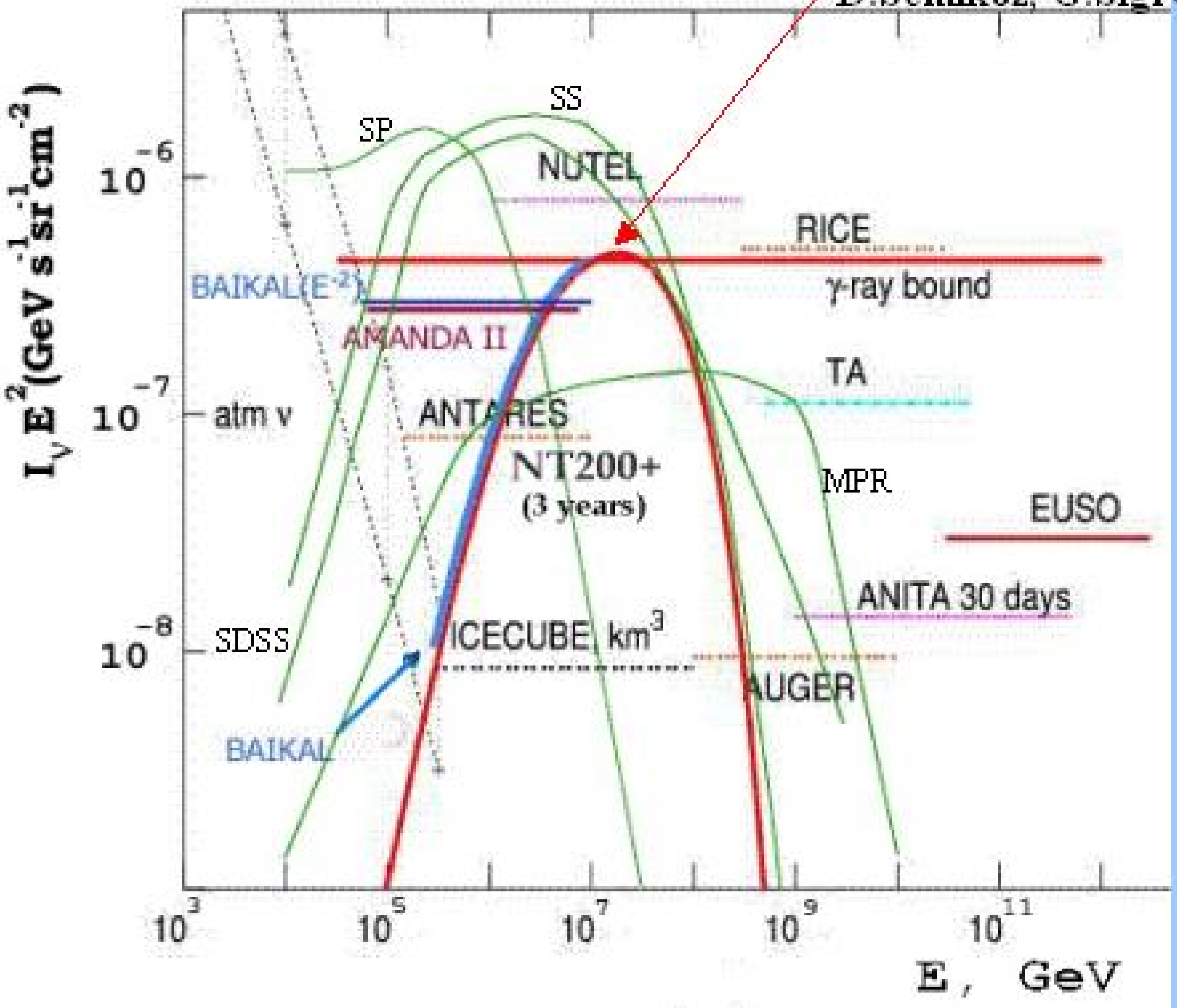
Diffuse flux of ν_e, ν_τ, ν_μ: cascades

Experimental limits and theoretical predictions

Models ruled out by AMANDA04 and BAIKAL04
SDSS - Stecker et al.92
SS - Stecker, Salamon964
SP - Szabo, Protheroe92

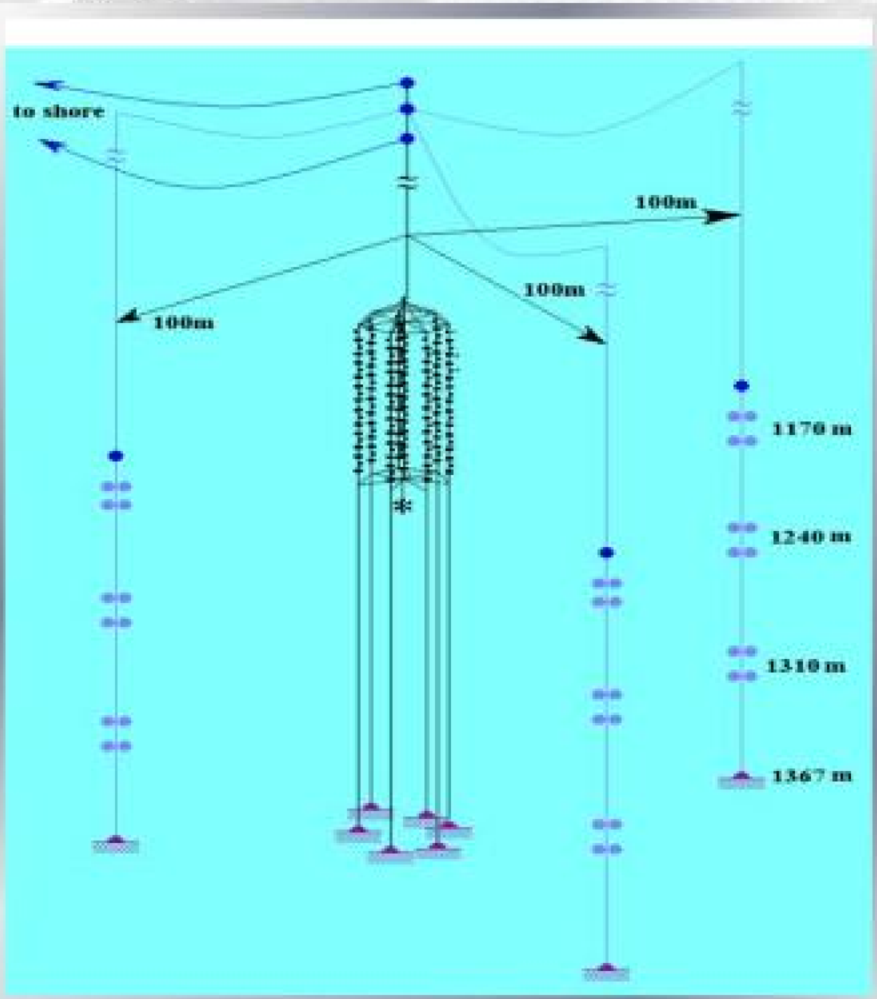
MPR - Mannheim, Protheroe, Rachen

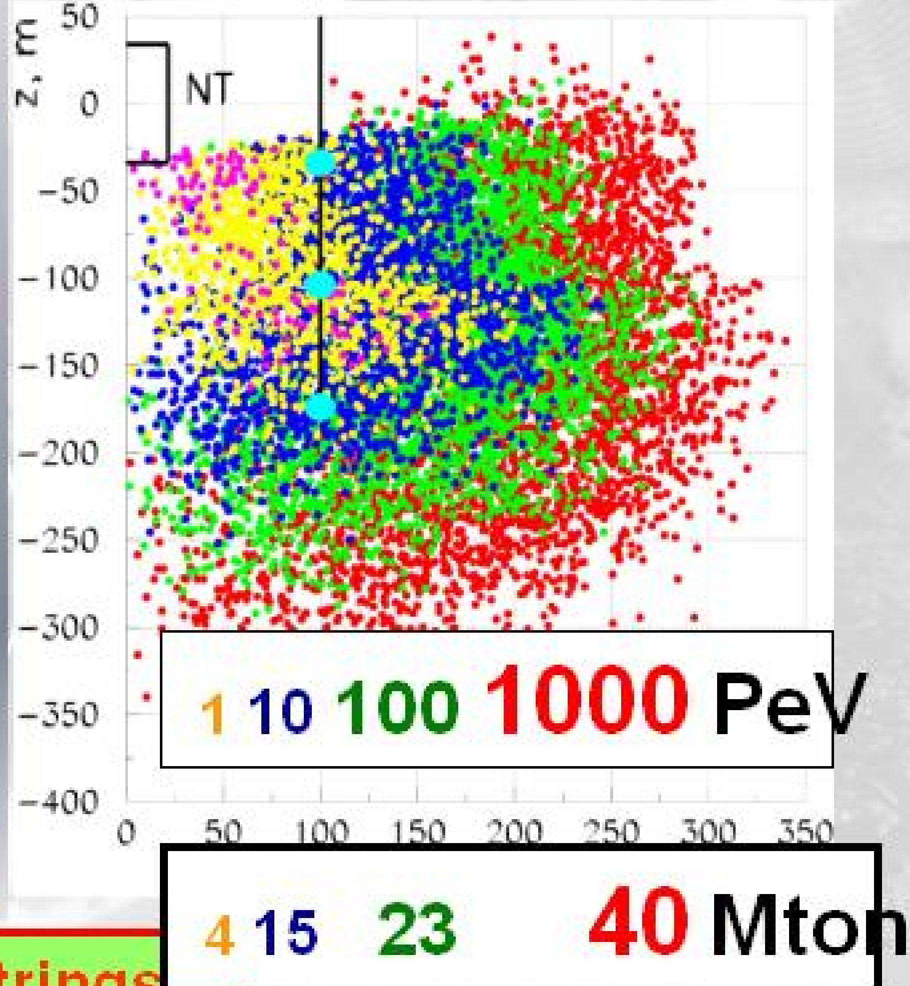
D.Semikoz, G.Sigl 04



Upgrade to NT-200+

2004: two distant test string
2005: completion

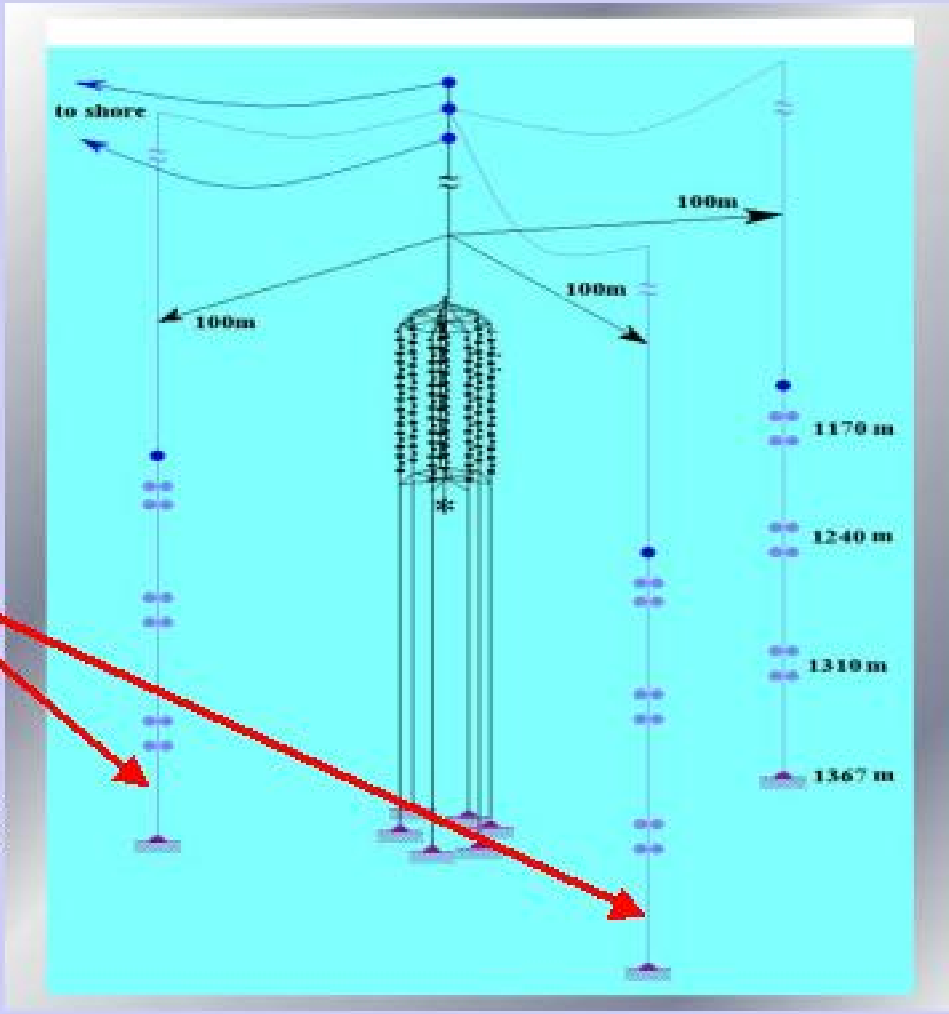




36 additional PMTs on 3 far 'strings'
$\rightarrow$ 4 times better sensitivity !

NT-200+ status

2004:
- new cable to shore
- DAQ system has been improved
- two of three outer strings are installed



$2.3\ 10^4$ common events are taken during 364 hours life time (0.017 Hz)

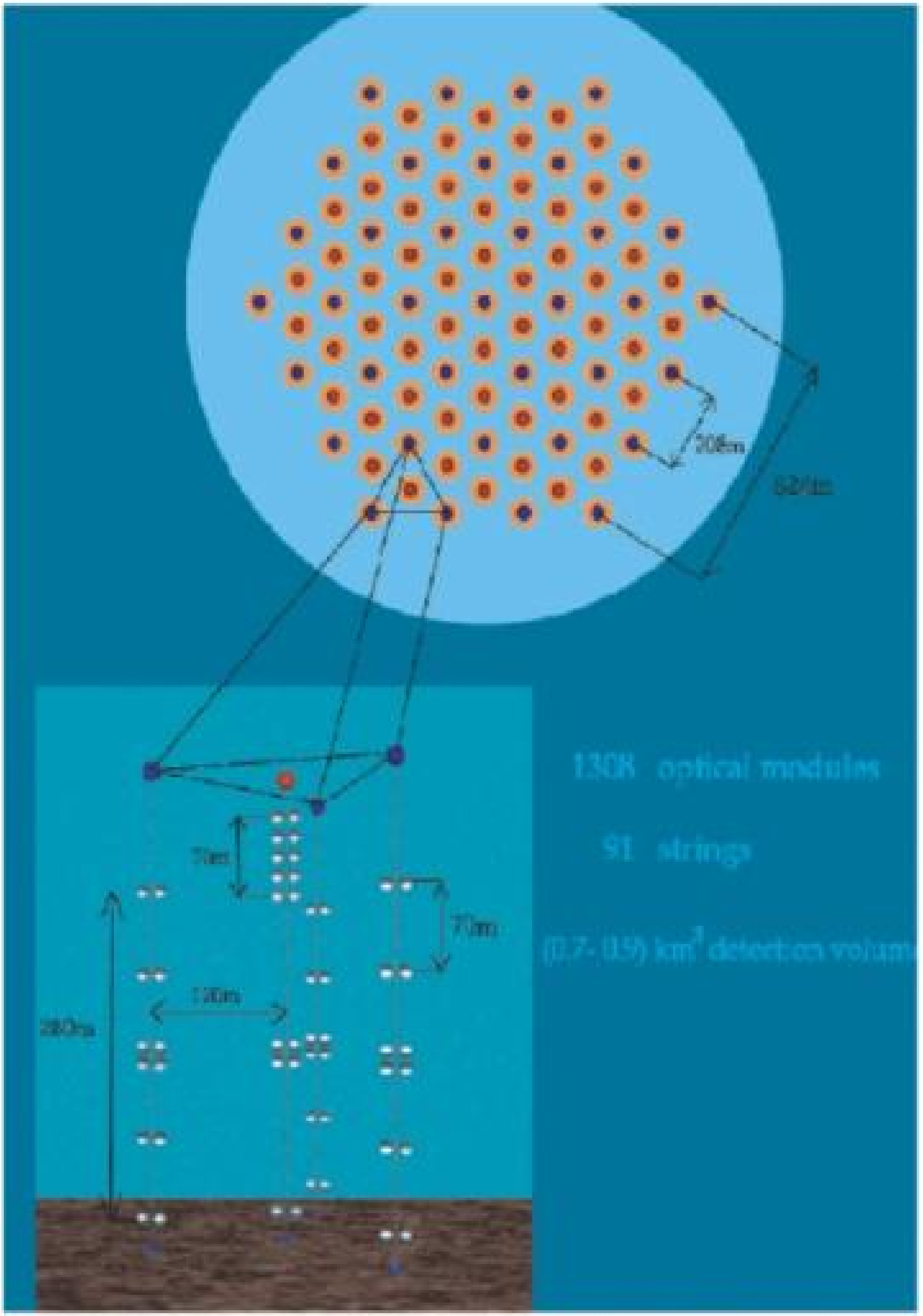
A Gigaton (km3) Detector in Lake Baikal.

Sparse instrumentation:

91 strings with 12 OM
= 1308 OMs

→ effective volume for
100 TeV cascades
~ 0.5 -1.0 km^3!

→ muon threshold
between
10 and 100 TeV



BAIKAL
CONCLUSION

- strong in HE-diffuse search (shower) and exotic particles (monopoles): “Mton detector”
- good GRB-sensitivity, complementary to AMANDA
- relevant other results: WIMP
- upgrade to NT-200+ in 2005
- R&D Gigaton Volume Detector (km3)


AMANDA

AMANDA Collaboration

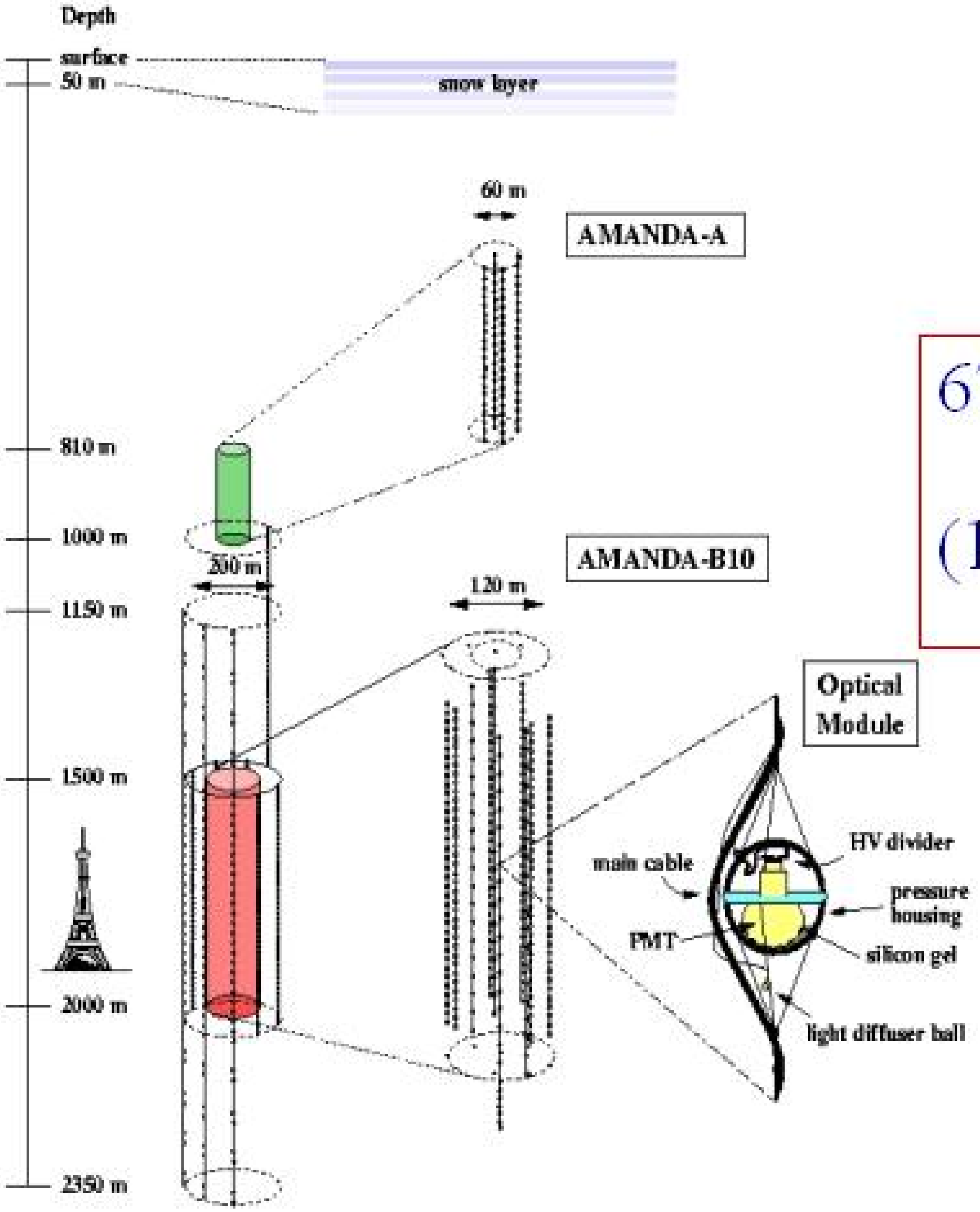
Bartol Research Institute, University of Delaware, Newark, USA
BUGH Wuppertal, Germany
Universite Libre de Bruxelles, Brussels, Belgium
Universidad Simon Bolivar, Caracas, Venezuela
DESY-Zeuthen, Zeuthen, Germany
Dept. of Technology, Kalmar University, Kalmar, Sweden
Lawrence Berkeley National Laboratory, Berkeley, USA
Dept. of Physics, UC Berkeley, USA
Institute of Physics, University of Mainz, Mainz, Germany
University of Mons-Hainaut, Mons, Belgium
University of California, Irvine, CA
Dept. of Physics, Pennsylvania State University, University Park, USA
Physics Department, University of Wisconsin, River Falls, USA
Physics Department, University of Wisconsin, Madison, USA
Division of High Energy Physics, Uppsala University, Uppsala, Sweden
Fysikum, Stockholm University, Stockholm, Sweden
Vrije Universiteit Brussel, Brussel, Belgium
Imperial College, London, United Kingdom
NIKHEF, Utrecht, Netherlands

Groups:
7 x US
11 x Europe
1 x South America
~110 Authors

- successfully running since 10 years

677 PMTs at 19 strings

(1996-2000)

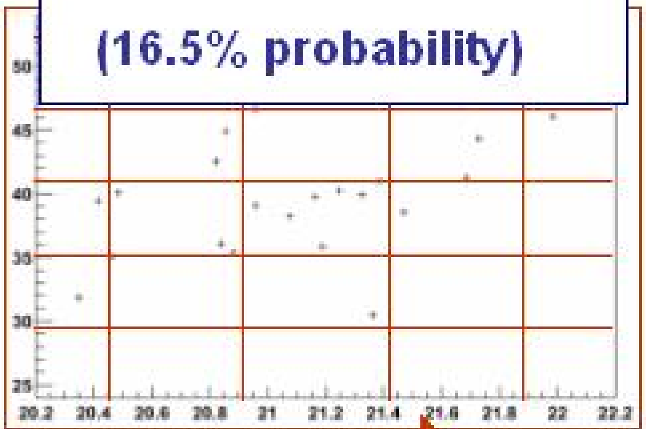


AMANDA as of 2000
Eiffel Tower as comparison
(true scaling)

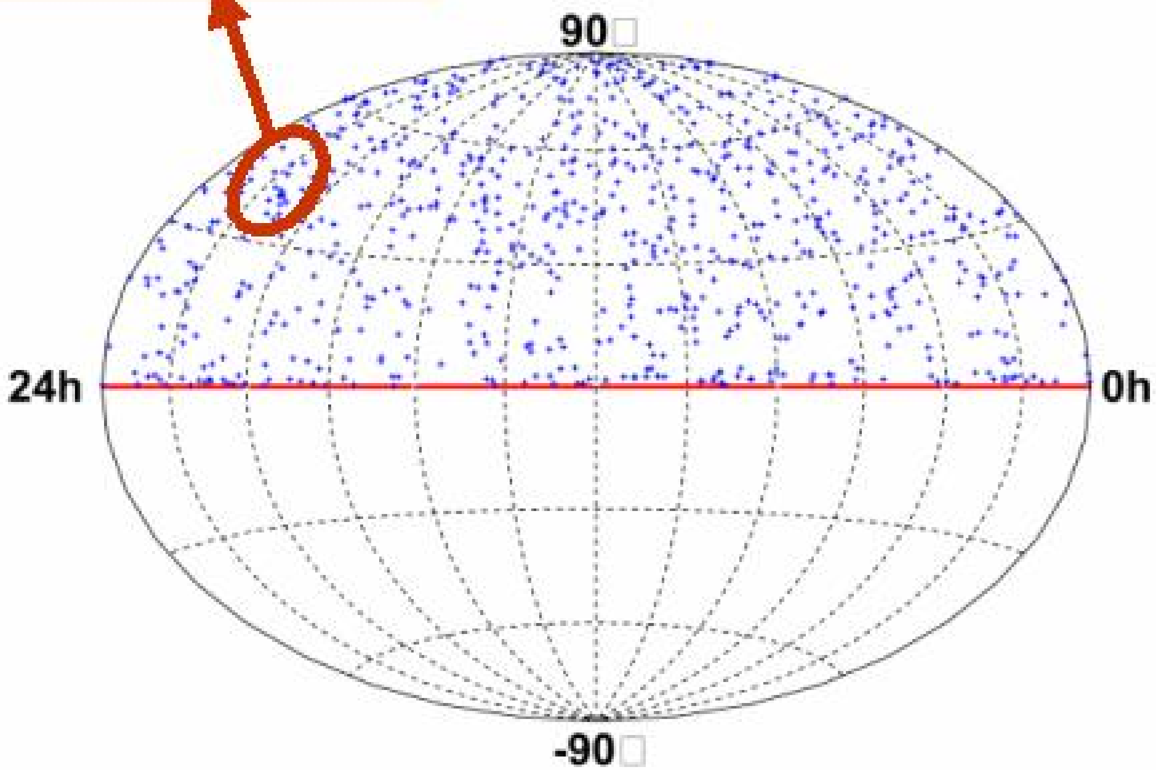
zoomed in on
AMANDA-A (top)
AMANDA-B10 (bottom)

zoomed in on one
optical module (OM)

Largest excess:
8 evt vs. 2.1 evt BG
(16.5% probability)



First data from AMANDA-II:
No Indication for a Point-Source found



IceCube

2004-2010

Installation:

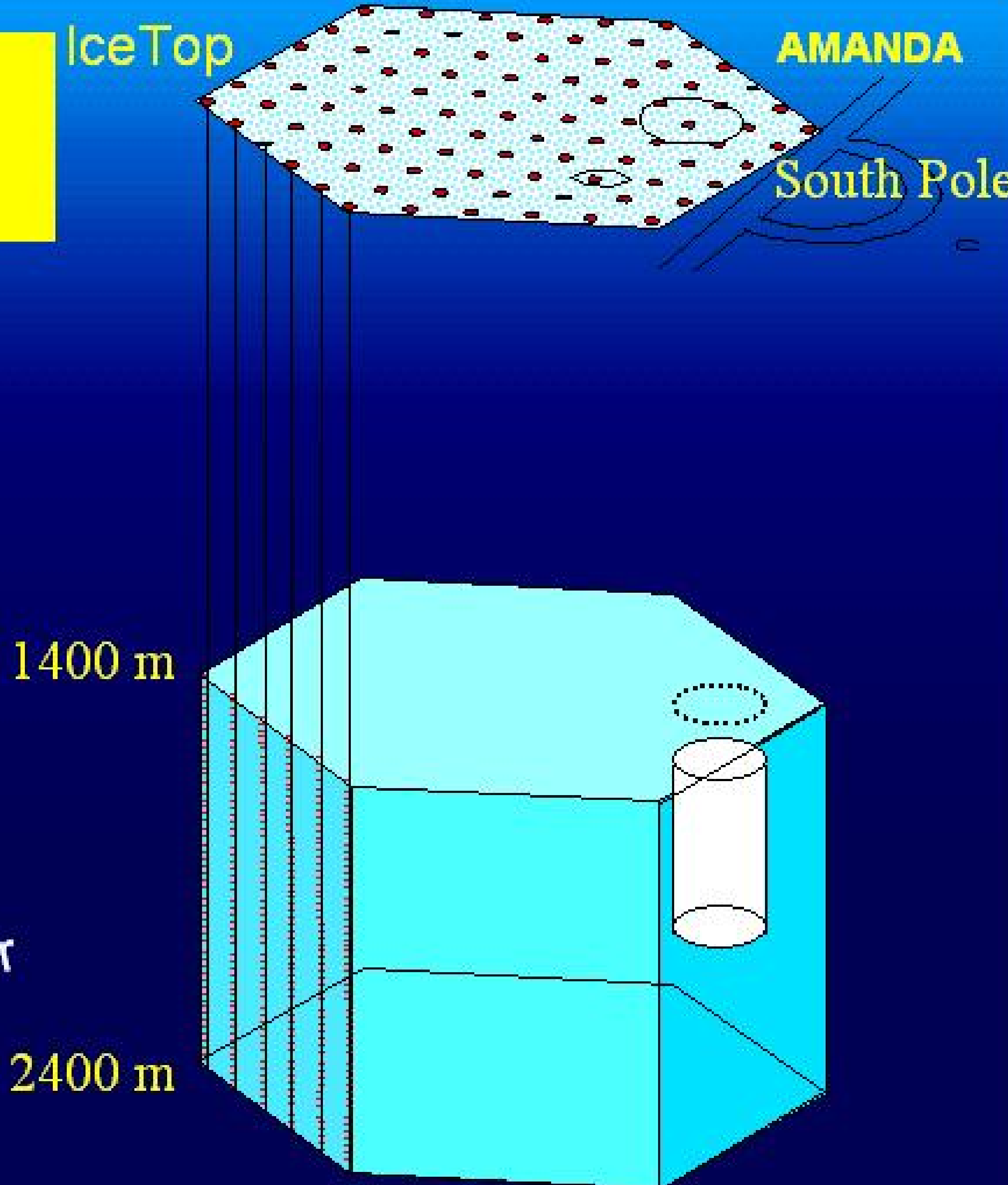
Instrumented volume: 1 km^3

- 4800 PMT

AMANDA-II

- 80 Strings

~ 80.000 atm. ν per year

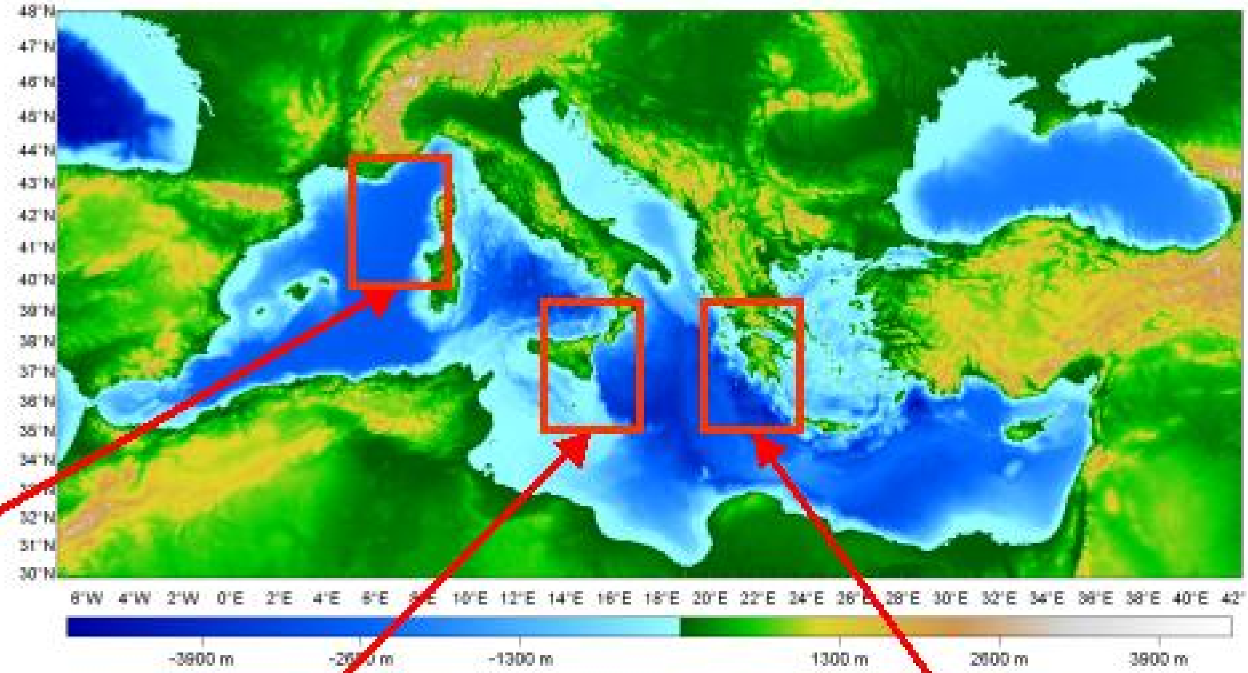



South Pole
Dark sector
Skiway
AMANDA
Dome
IceCube

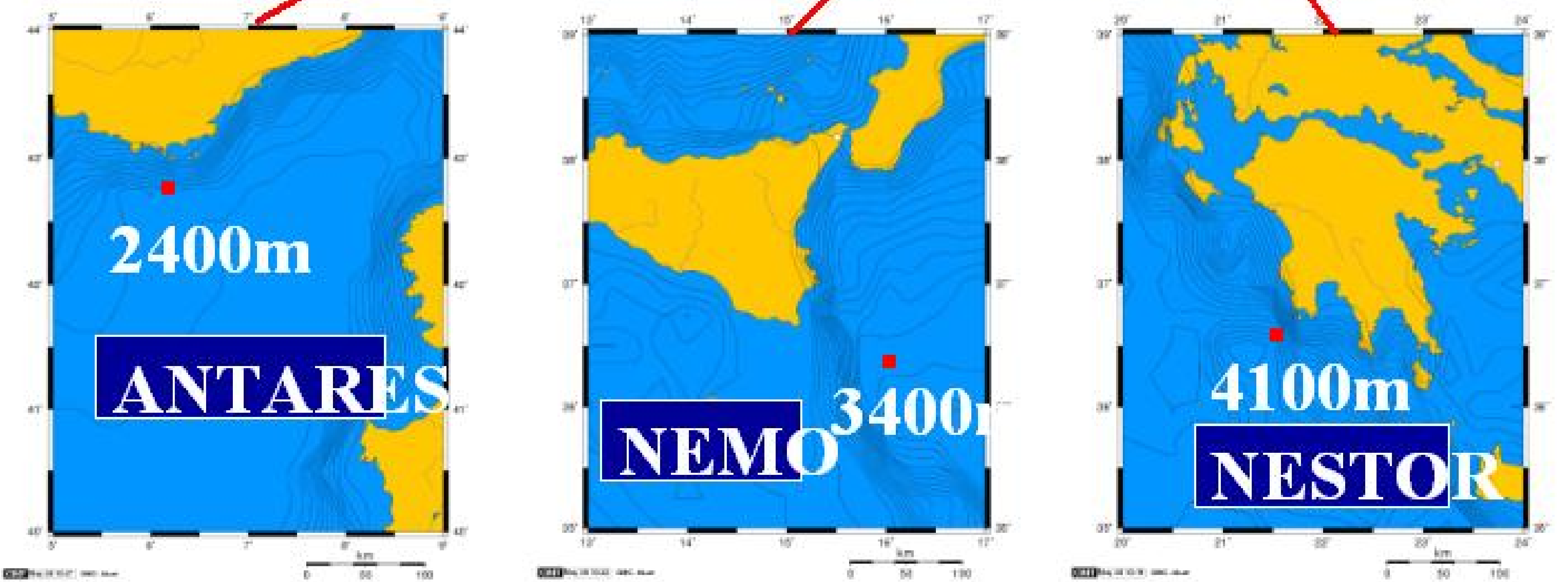
Schedule

03-04	drill equipment to Pole
04-05	first strings (proof that 16/season are feasible, prepare 6 full strings)
05-06	12 strings
06-07	16 strings
07-08	16 strings
08-09	16 strings
09-10	remaining strings

1. The sites



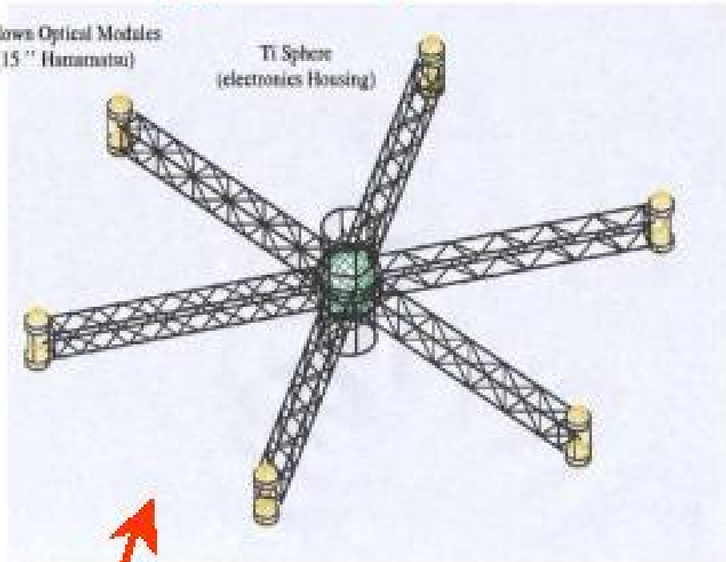
-3900 m
-1300 m
1300 m
2600 m
3900 m



2400m
ANTARES
3400
NEMO
4100m
NESTOR

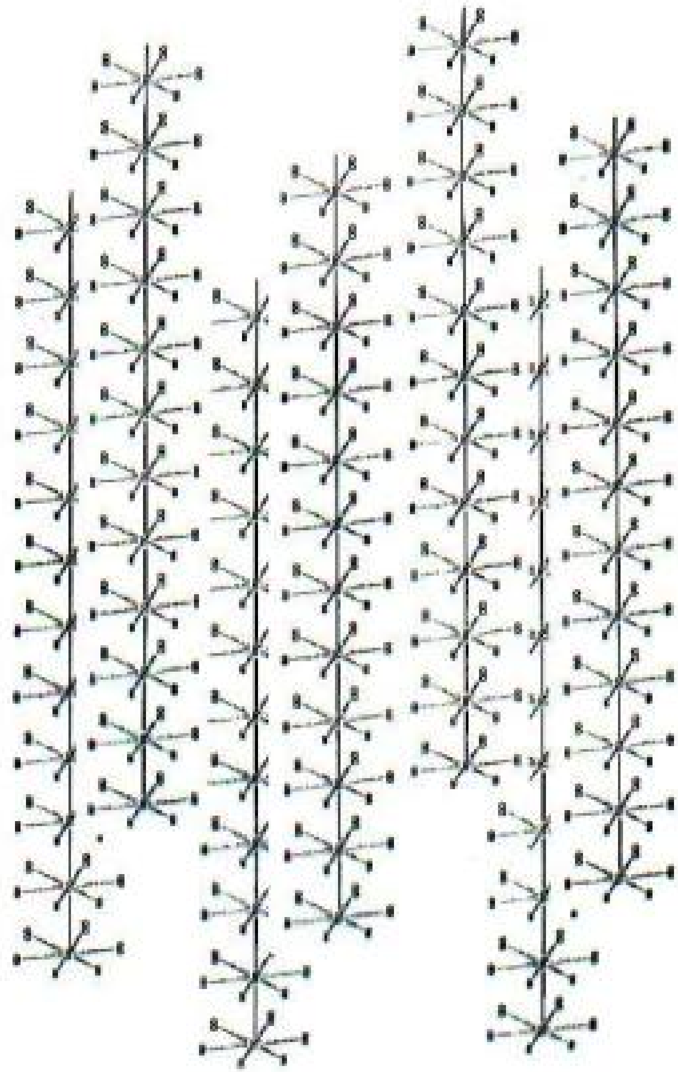
NESTOR

towers of 12 titanium floors
each supporting 12 PMTs



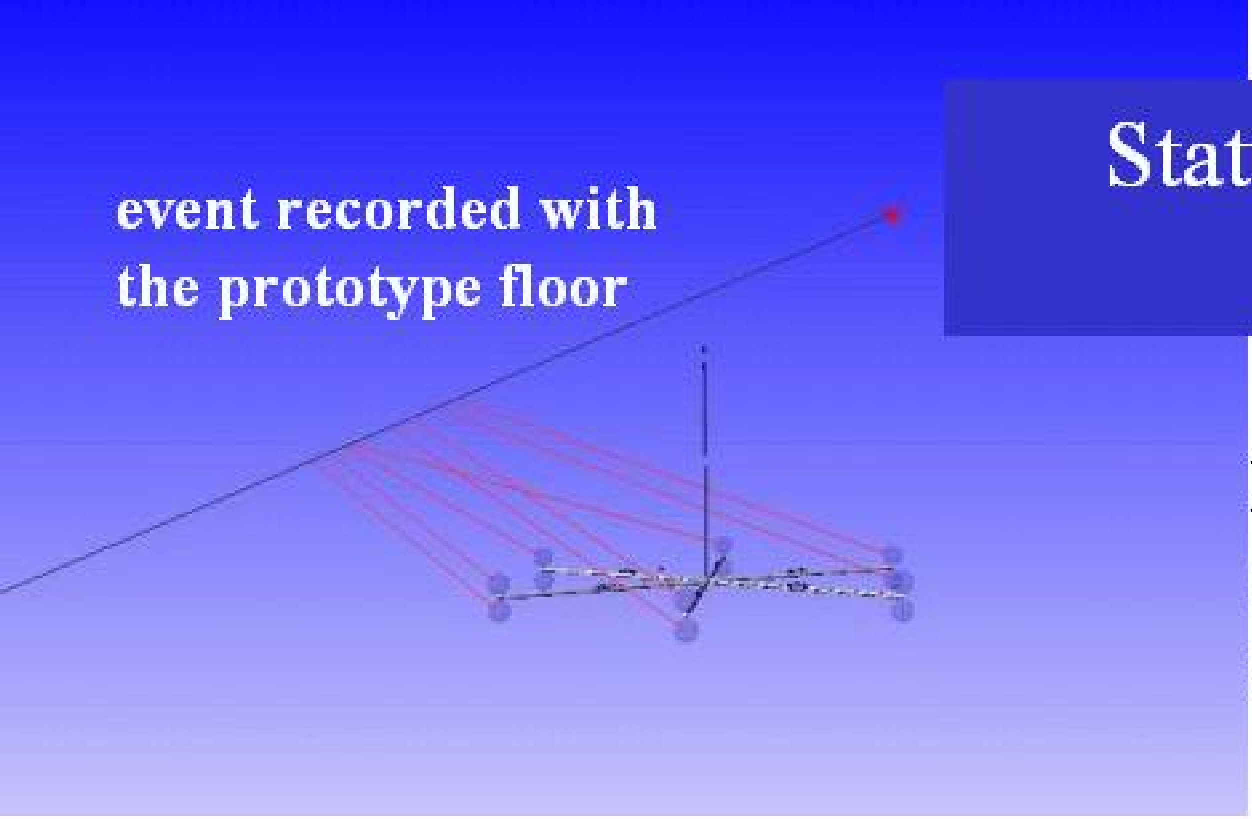
SHORT ARM (1/3 the usual diameter)
HEXAGONAL TITANIUM FLOOR

Presently deployed



7 NESTOR towers , 1008 OMs
→ 75 000 m² at 1 TeV, 1° resolution

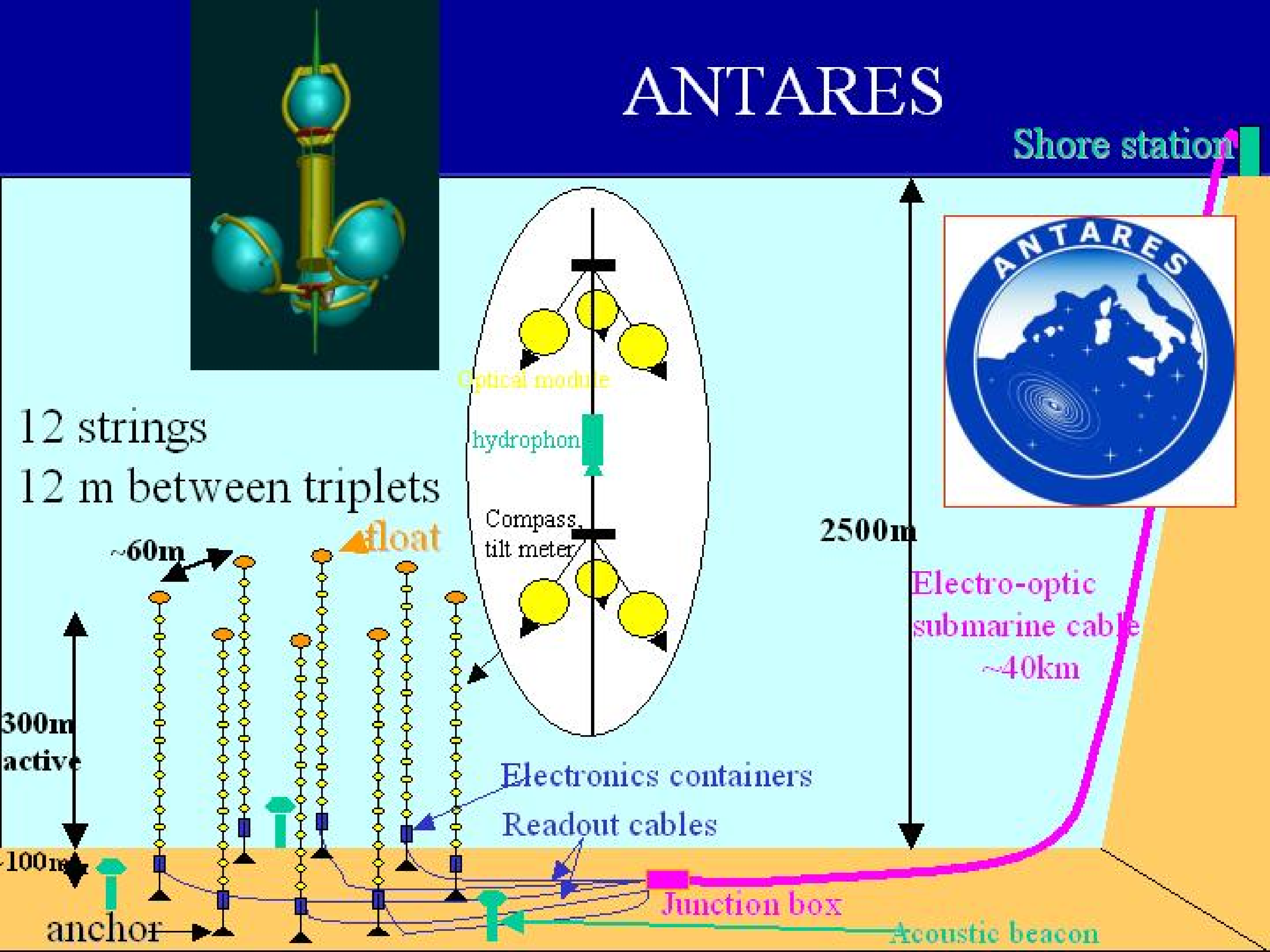
Status and Plans Nestor



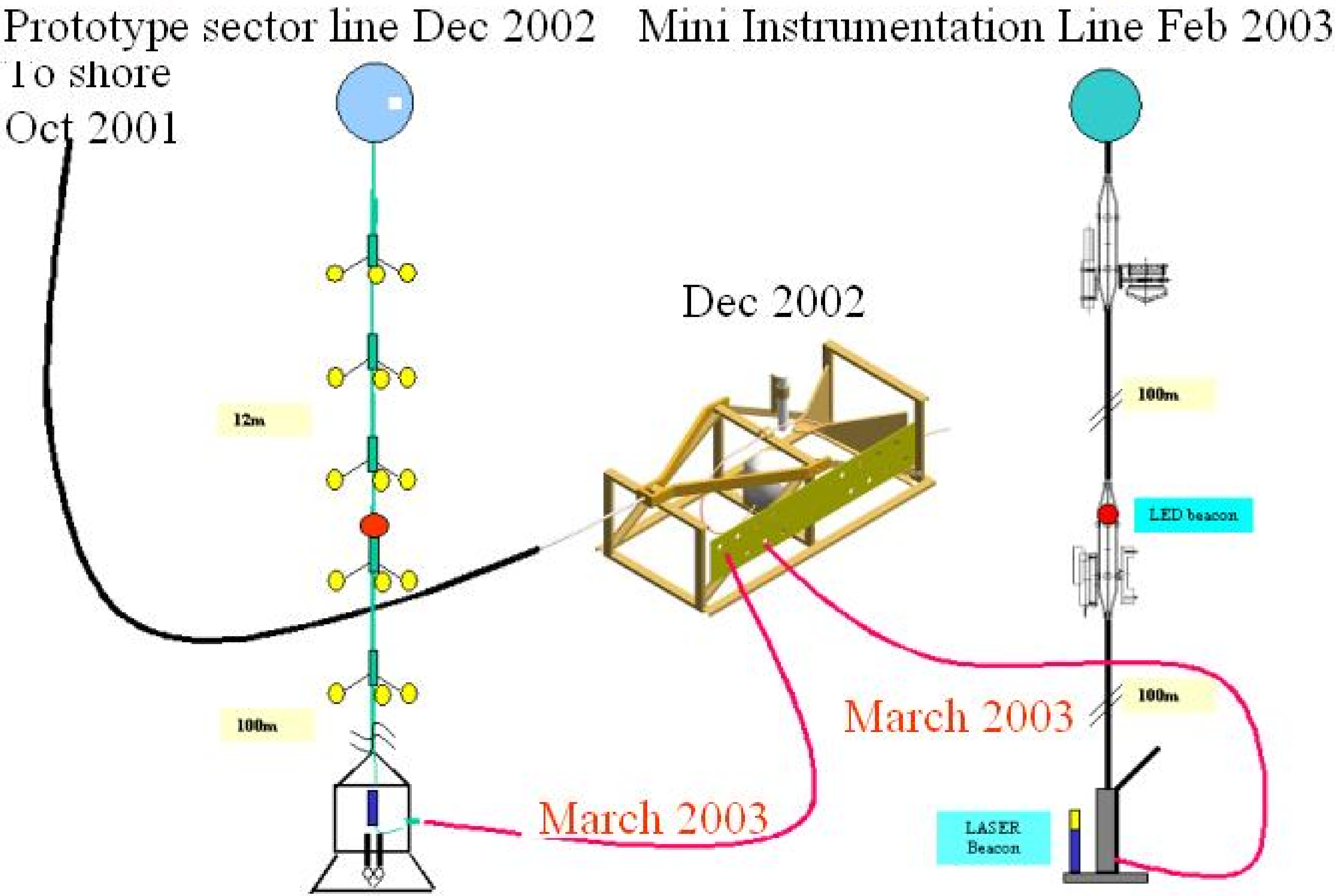
Except electronics, all components for a full tower in Pylos

Jan 2002: deployment of LAERTIS at 4200 m depth
March 2003: deployment of first prototype floor (reduced size
April 2003: high current → interruption of data taking

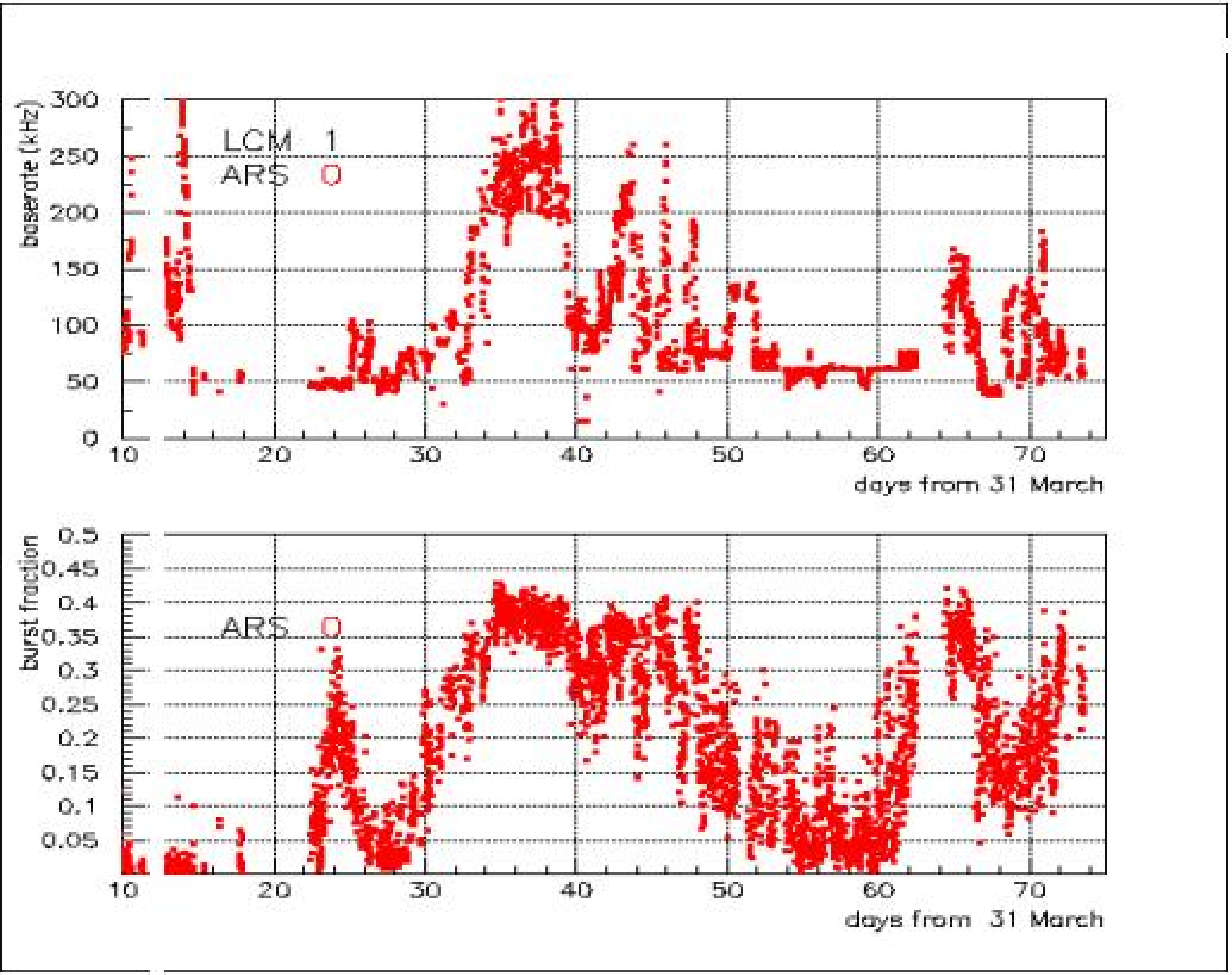
Autumn 2003: recover floor
Spring 2004: deploy first 2, then 4 floors


ANTARES
Shore station
12 strings
12 m between triplets
Optical module
hydrophon
Compass,
tilt meter
float
~60m
2500m
Electro-optic
submarine cable
~40km
300m
active
~100m
Electronics containers
Readout cables
Junction box
anchor
Acoustic beacon
ANTARES

Status and Plans Antares



Summary of variation of Bioluminescence, Antares

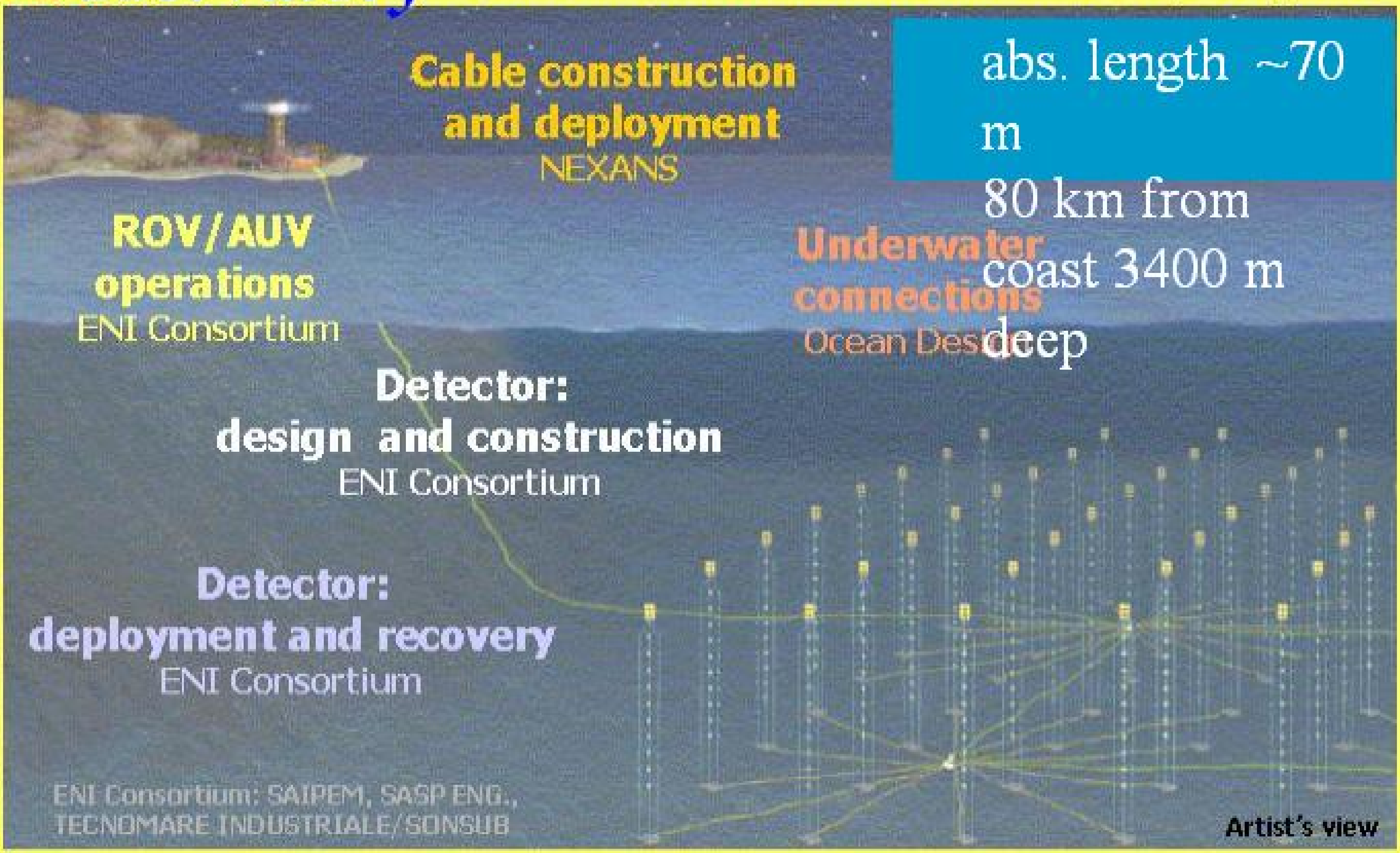


Schedule

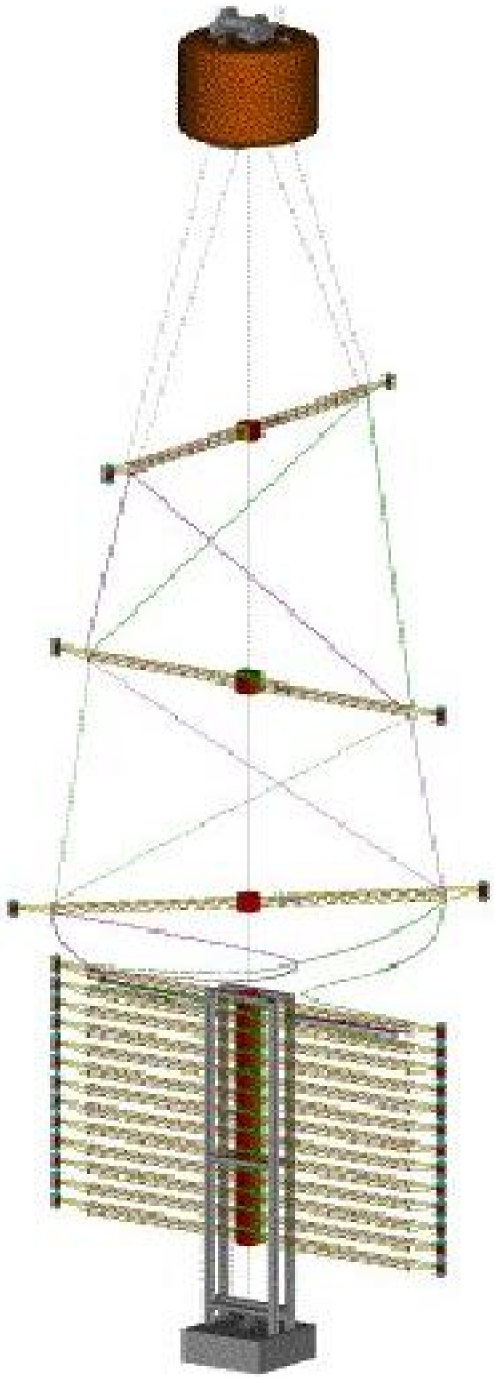
March	2003	Start operation PSL and MIL lines
May	2003	Recover MIL
July	2003	Recover PSL for evaluation
June	2004	Start assembly of production detector
end	2004	Connect first production line
	2006	12 line detector complete

NEMO *Neutrino Mediterranean Observatory*

Coordinated by INFN in collaboration with SACLANTcen-NATO, CNR, OGS



abs. length ~70 m
80 km from coast 3400 m deep

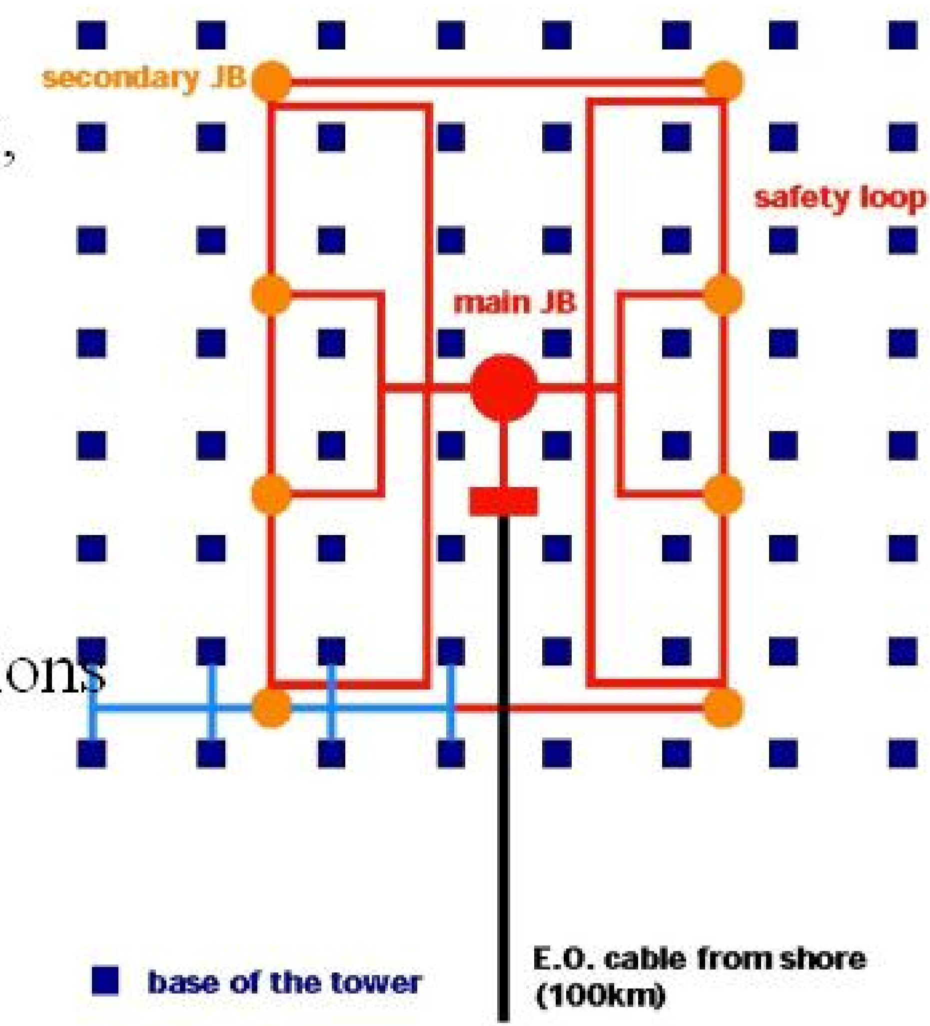


Up-down symmetry

64 towers,
each 16 arms,
20 m long
40 m apart

4096 PMTs

Wet connections
by ROV



Status and Plans Nemo

→ Repeated environmental studies since 1998 (more than 20 campaigns)

→ 25 km electro-optical cable to NEMO Phase-1 test site neighbored by Geostar lab

At present: work on a detector subsystem including all critical components

NESTOR

	1991 - 2000	R & D, Site Evaluation
Summer	2002	Deployment 2 floors
Winter	2003	Recovery & re-deployment with 4 floors
Autumn	2003	Full Tower deployment
	2004	Add 3 DUMAND strings around tower
	2005 - ?	Deployment of 7 NESTOR towers

ANTARES

	1996 - 2000	R&D, Site Evaluation
	2000	Demonstrator line
	2001	Start Construction
September	2002	Deploy prototype line
December	2004	10 (14?) line detector complete
	2005 - ?	Construction of km^3 Detector

NEMO

1999 - 2001	Site selection and R&D
2002 - 2004	Prototyping at Catania Test Site
2005 - ?	Construction of km^3 Detector

CONCLUSION

- REASONABLE PREDICTION:

- 2010 - 2020 years one or two detectors of
- volume ~ 1 cubic km