Neutrino 2006, Santa Fe – June 19, 2006

Underwater Neutrino Detection in the Mediterranean Sea: From Presence to Future

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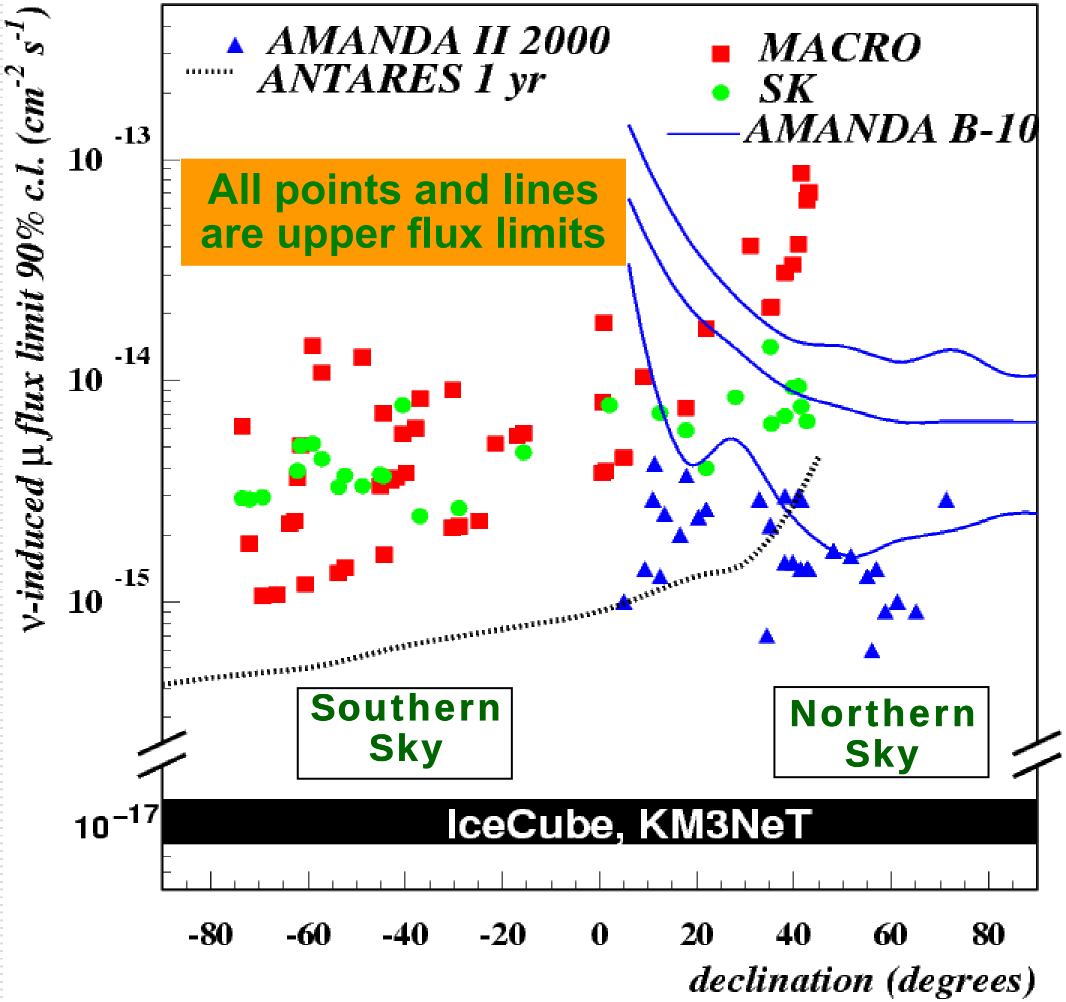
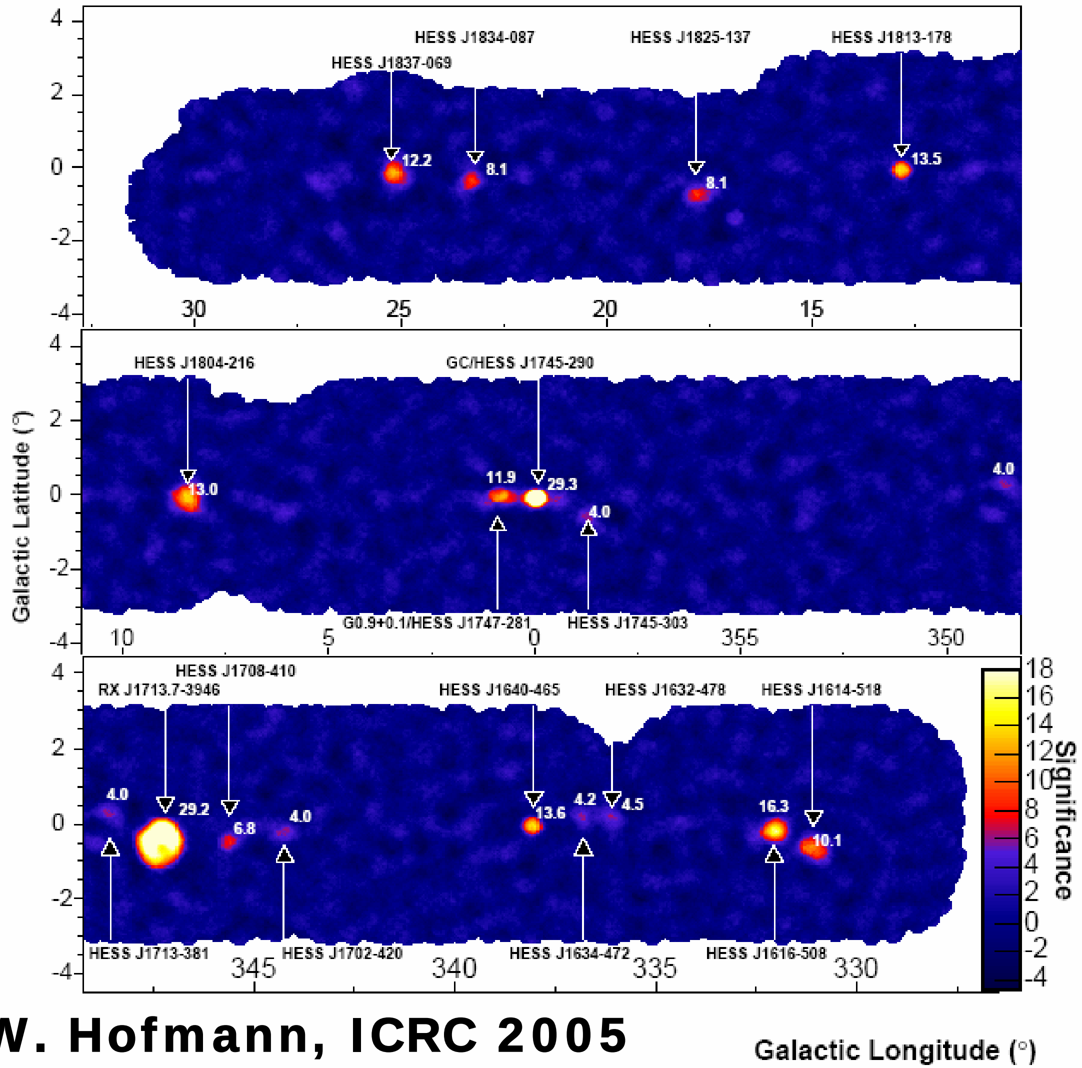
- Scientific Case: Some highlights
- Current Projects: ANTARES, NEMO, NESTOR
- The KM3NeT Design Study and Beyond
- Conclusions and Outlook

Neutrinos from Astrophysical Point Sources

- Association of neutrinos to specific astrophysical objects.
- Energy spectrum, time structure, multi-messenger observations provide insight into physical processes inside source.
- Measurements profit from very good angular resolution of water Čerenkov telescopes.
- km³ detectors needed to exploit the potential of neutrino astronomy.



High-energy γ sources in the Galactic Disk

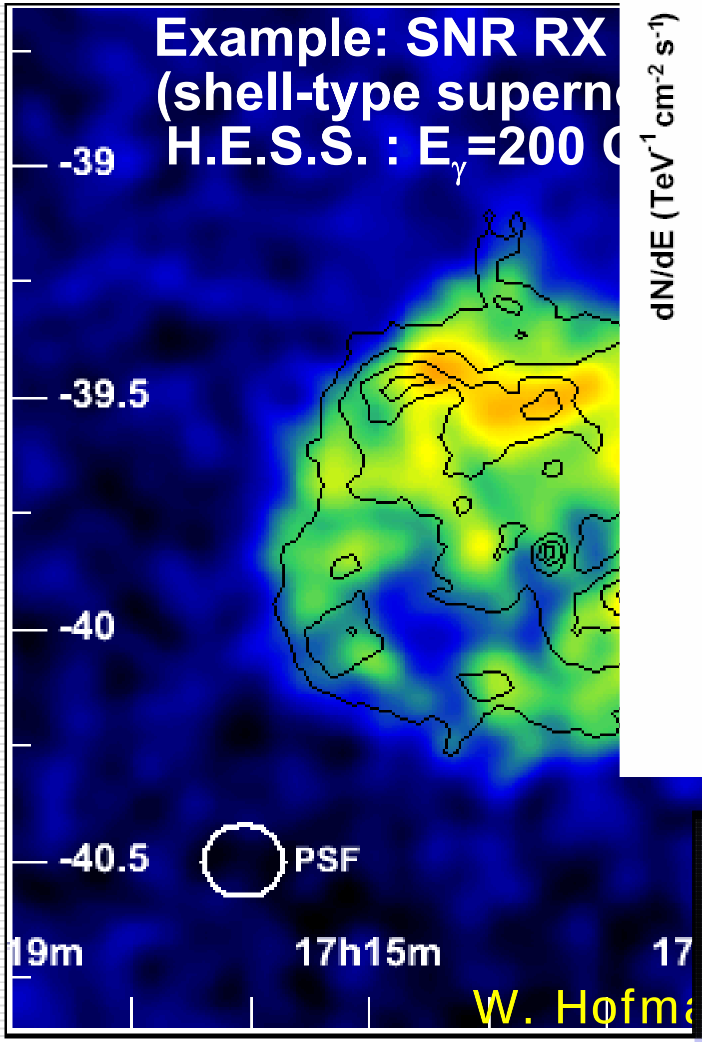


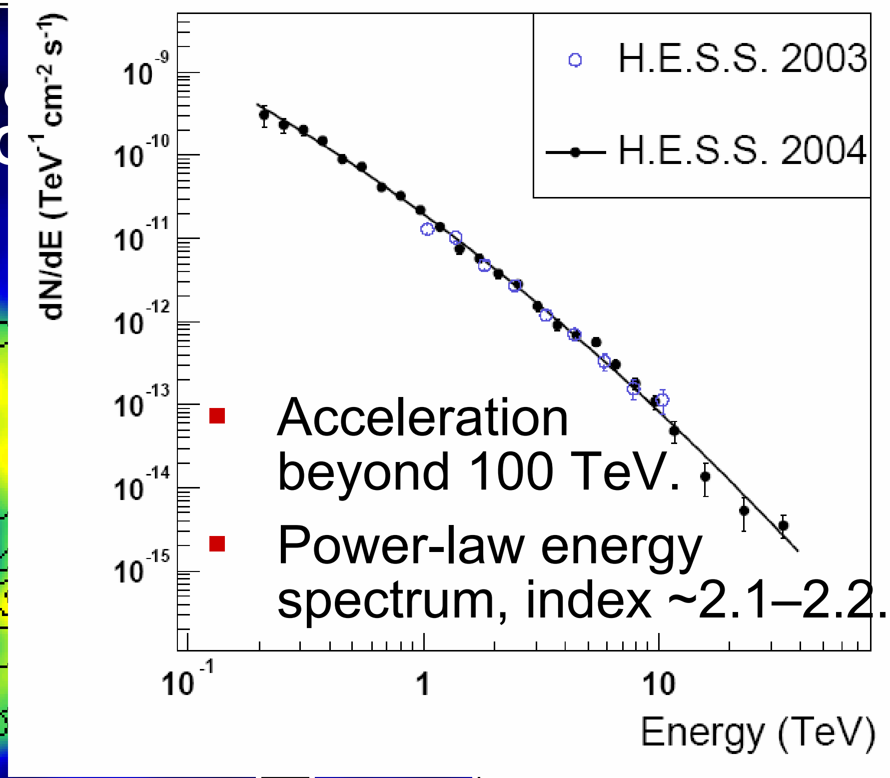
W. Hofmann, ICRC 2005

Update June 2006:

- 6 γ sources could be/are associated with SNR, e.g. RX J1713.7-3946;
- 9 are pulsar wind nebulae, typically displaced from the pulsar;
- 2 binary systems (1 H.E.S.S. / 1 MAGIC);
- 6 have no known counerparts.

Neutrinos from Supernova Remnants



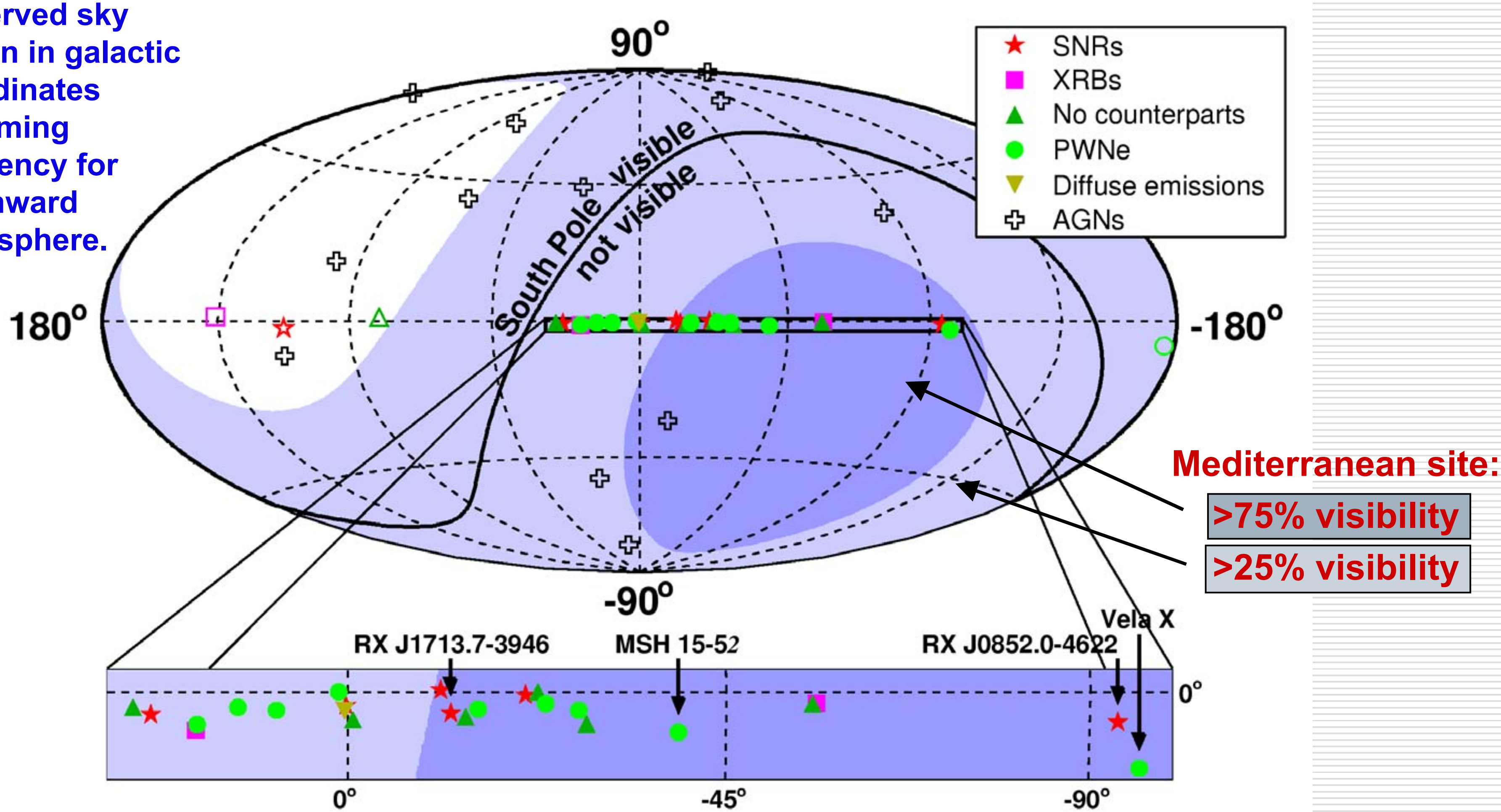


- Acceleration beyond 100 TeV.
- Power-law energy spectrum, index ~2.1–2.2.

Expected neutrino fluxes: see Felix Aharonian‘s talk

Sky Coverage of Neutrino Telescopes

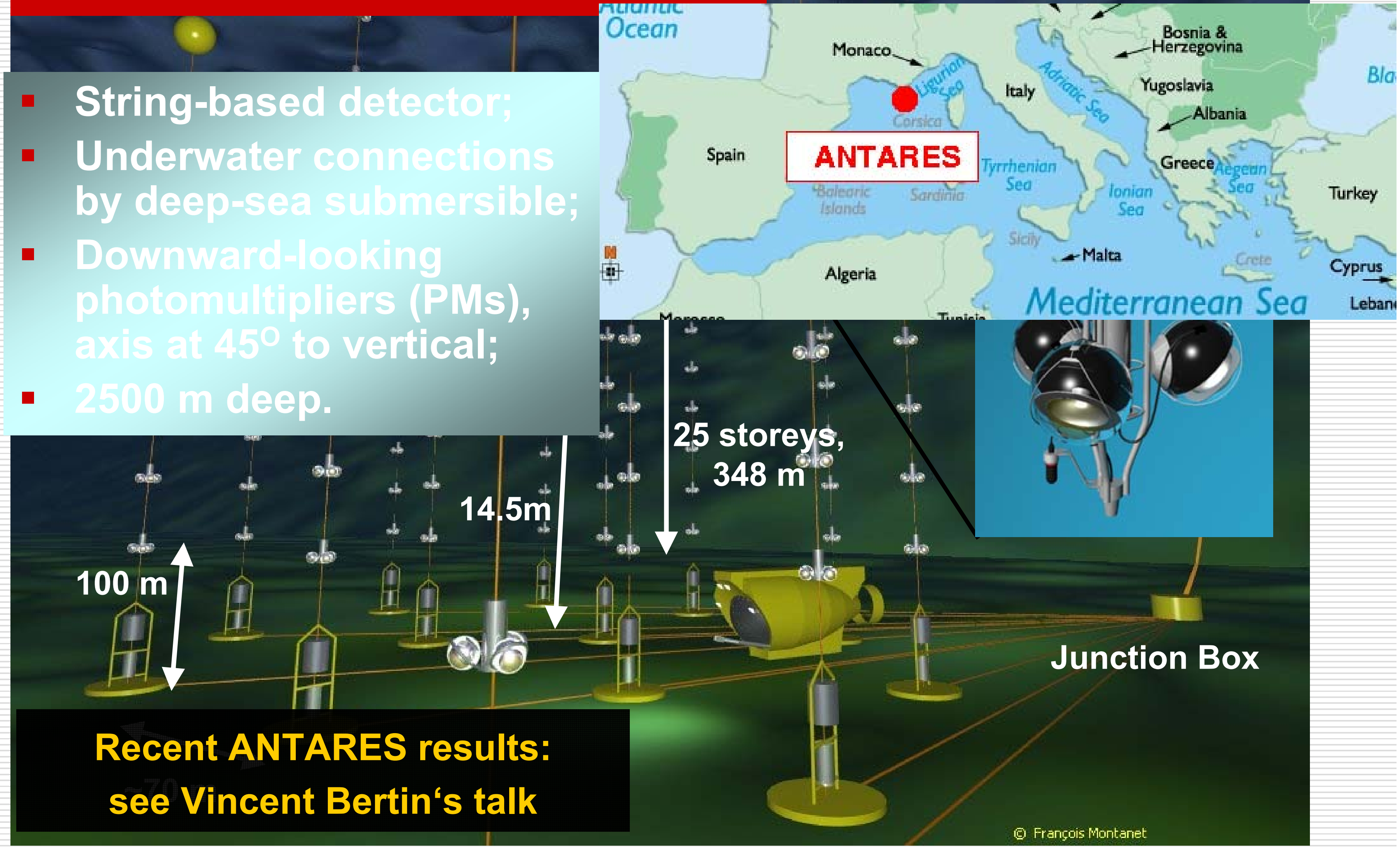
Observed sky region in galactic coordinates assuming efficiency for downward hemisphere.



→ We need ν telescopes in both hemispheres to see the whole sky

ANTARES: Detector Design

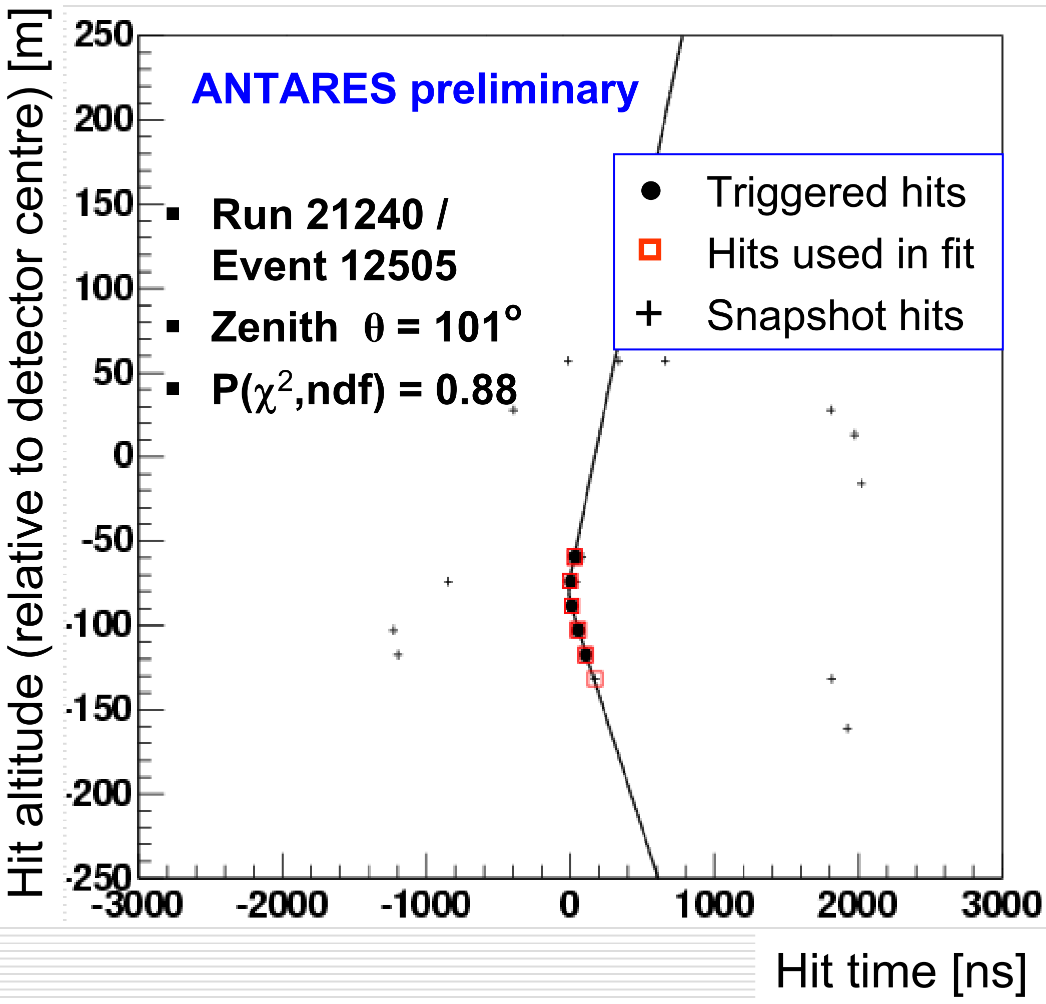
- String-based detector;
- Underwater connections by deep-sea submersible;
- Downward-looking photomultipliers (PMs), axis at 45^{o} to vertical;
- 2500 m deep.



Recent ANTARES results: see Vincent Bertin‘s talk

ANTARES: Status and Outlook

- Deployment and operation of several prototype lines in 2003-2005 confirm expected functionality and help to fix last design issues.
- First full line deployed and connected, taking data since March 2, 2006.
- All subsystems operational. Time and position calibration verified.
- First muons reconstructed.
- Detector completion expected by end of 2007.



NESTOR: Rigid Structures Forming Towers

- Tower based detector (titanium structures).
- Dry connections (recover − connect − redeploy).
- Up- and downward looking PMs (15’’).
- 4000 m deep.
- Test floor (reduced size) deployed & operated in 2003.
- Deployment of 4 floors planned in 2007

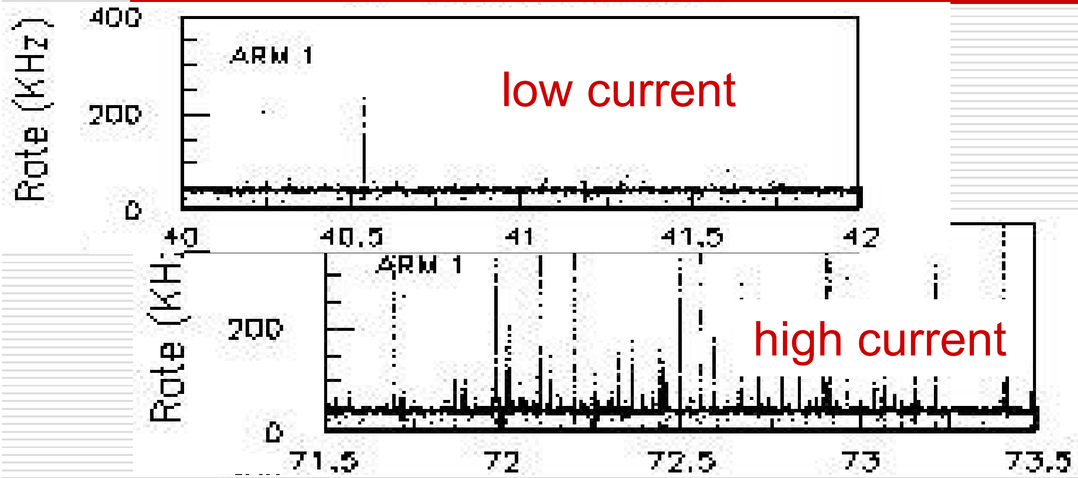
Plan: Tower(s) with12 floors

→ **32 m diameter**

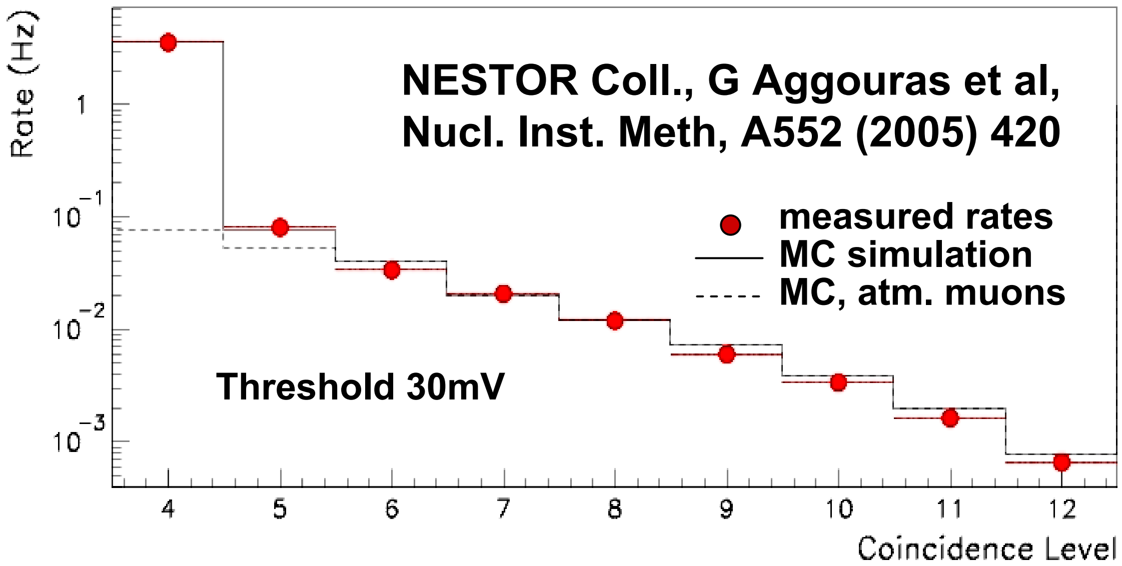
→ **30 m between floors**

→ **144 PMs per tower**

NESTOR: Data from the Deep Sea

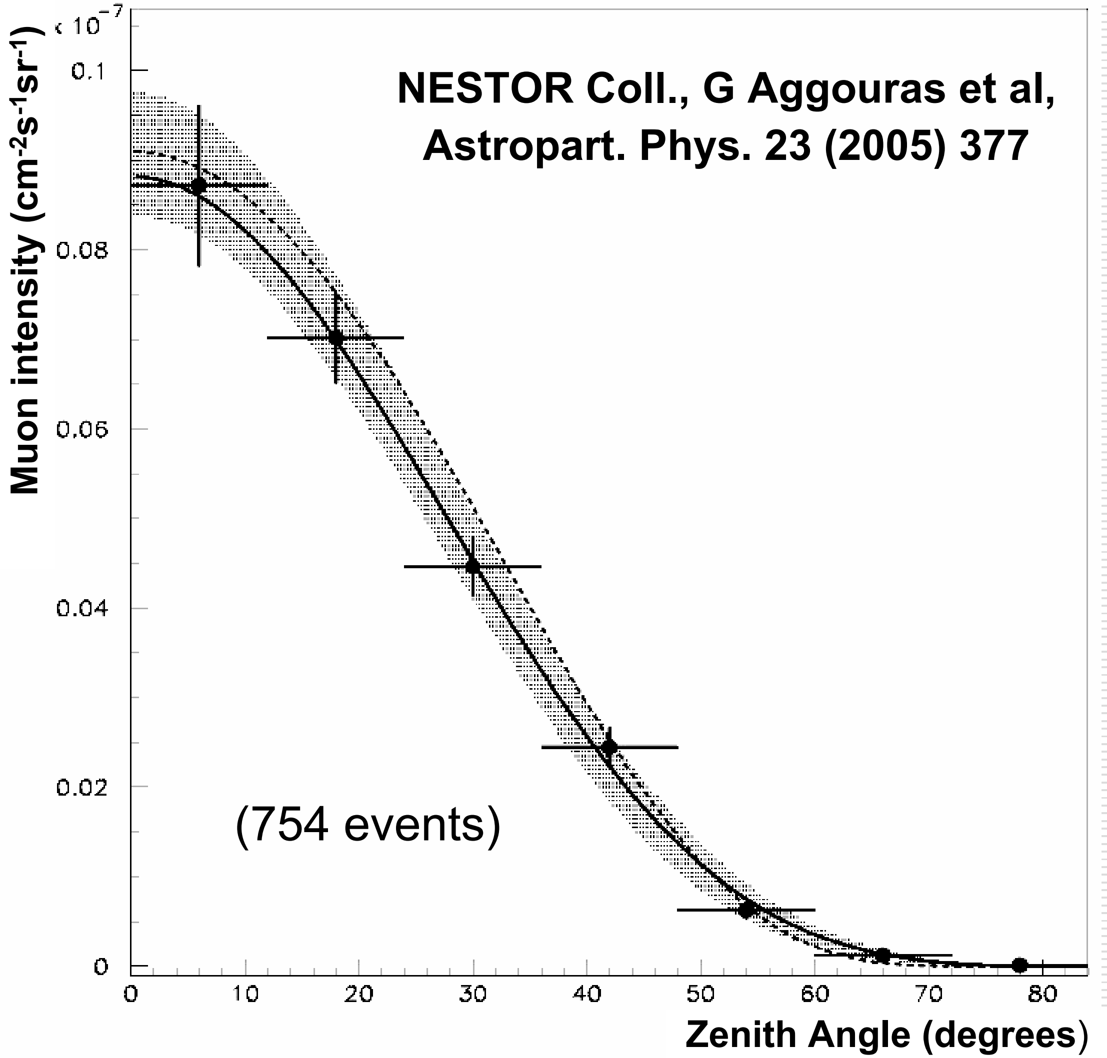


- Background baseline rate of 45-50 kHz per PM
- Bioluminescence bursts correlated with water current, on average 1.1% of the time.



- Trigger rates agree with simulation including background light.
- For 5-fold and higher coincidences, the trigger rate is dominated by atmospheric muons.

NESTOR: Measurement of the Muon Flux



Atmospheric muon flux determination and parameterisation by

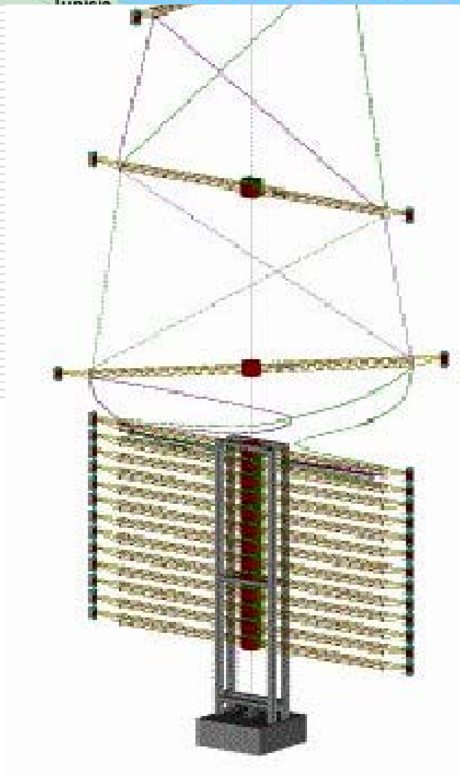
$$\frac{dN}{d\Omega \cdot dt \cdot ds} = I_0 \cdot \cos^{\alpha}\theta$$

α = 4.7 ± 0.5(stat.) ± 0.2(syst.)
I_0 = 9.0 ± 0.7(stat.) ± 0.4(syst.) x 10^{-9} cm^{-2} s^{-1} sr^{-1}

Results agree nicely with previous measurements and with simulations.

The NEMO Project

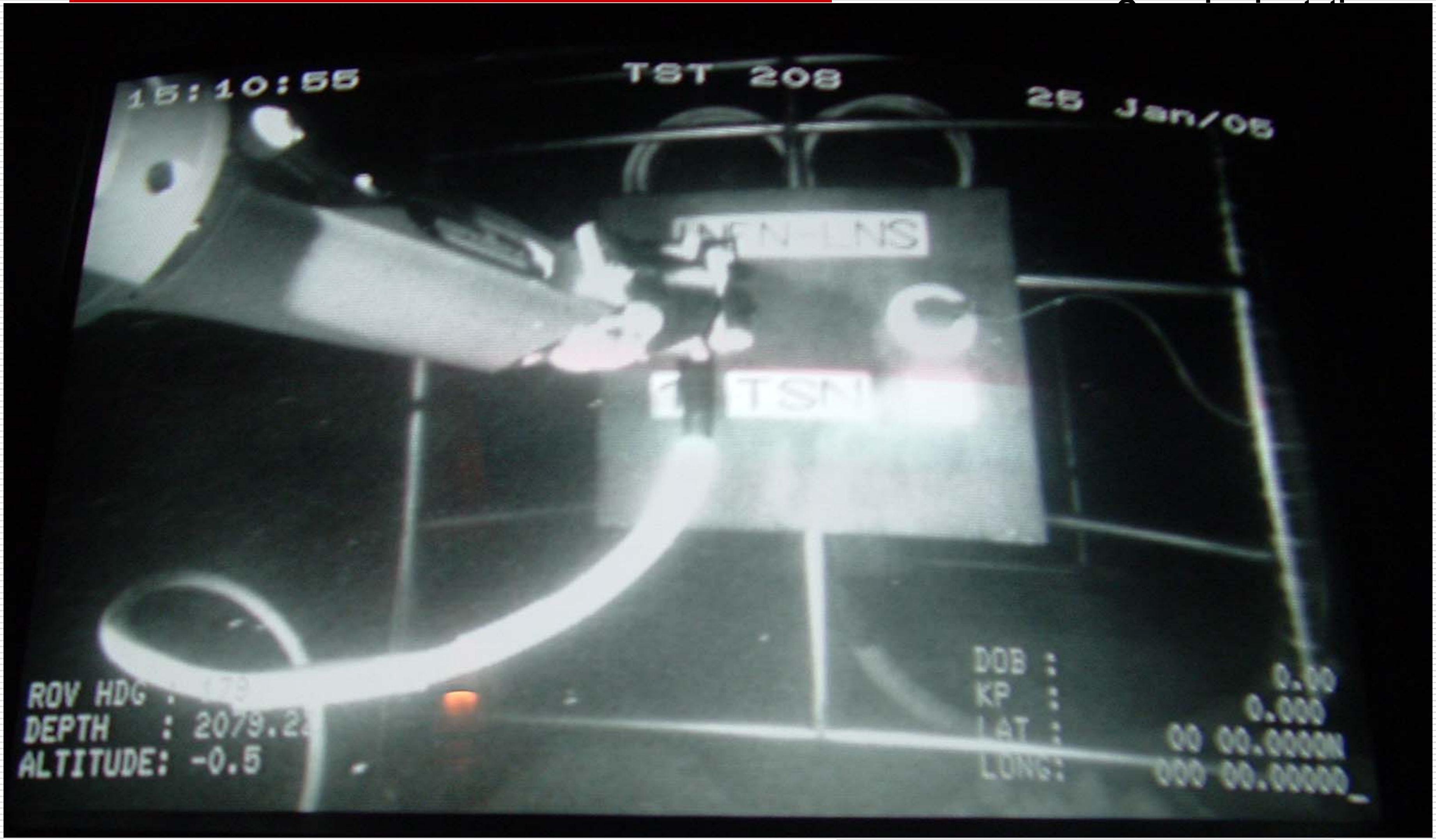
- Extensive site exploration (Capo Passero near Catania, depth 3500 m);
- R&D towards km^3: architecture, mechanical structures, readout, electronics, cables ...;
- Simulation.



Example: Flexible tower

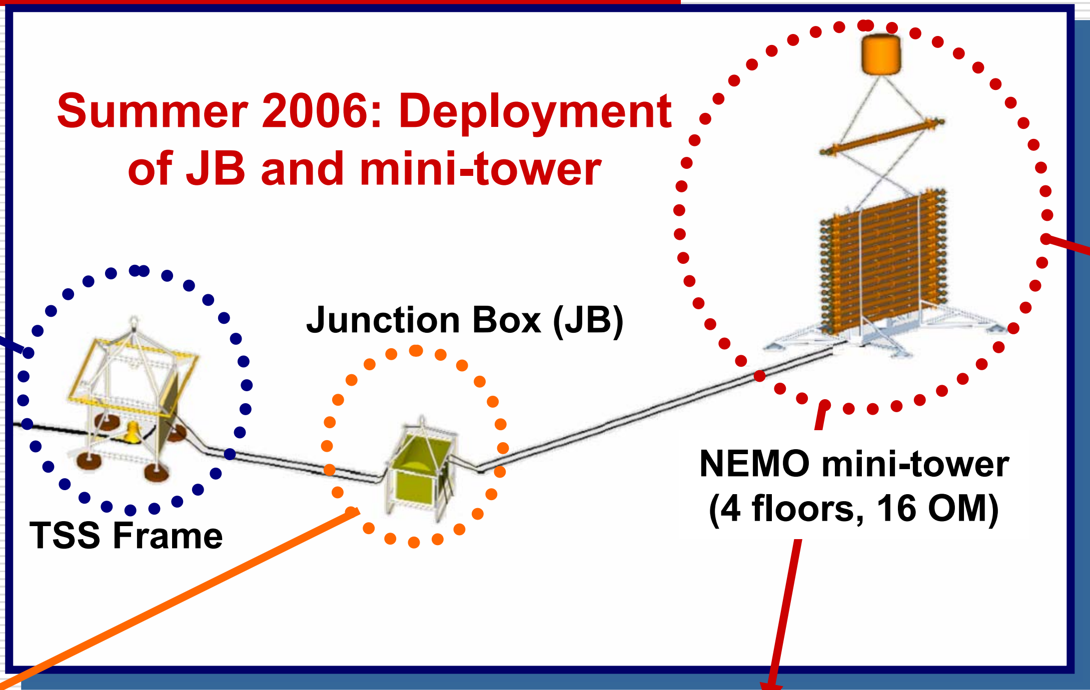
- 16 arms per tower, 20 m arm length, arms 40 m apart;
- 64 PMs per tower;
- Underwater connections;
- Up- and downward-looking PMs.

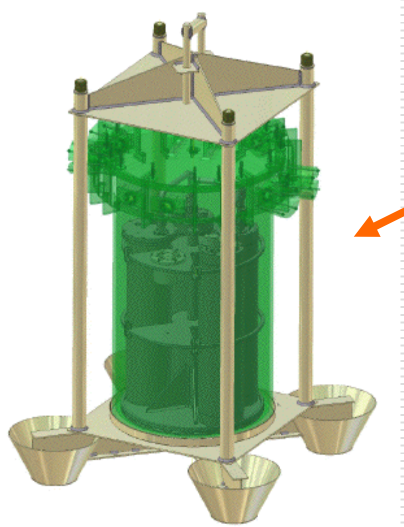
NEMO Phase I: Current Status

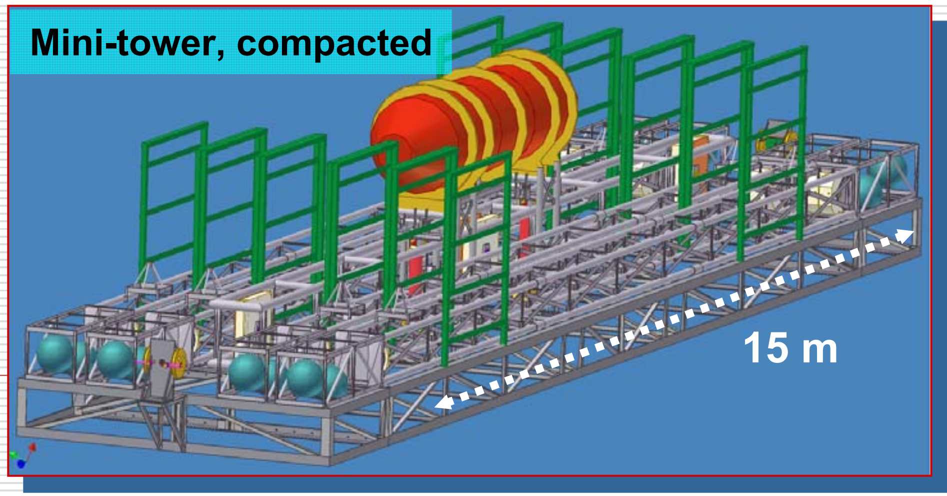


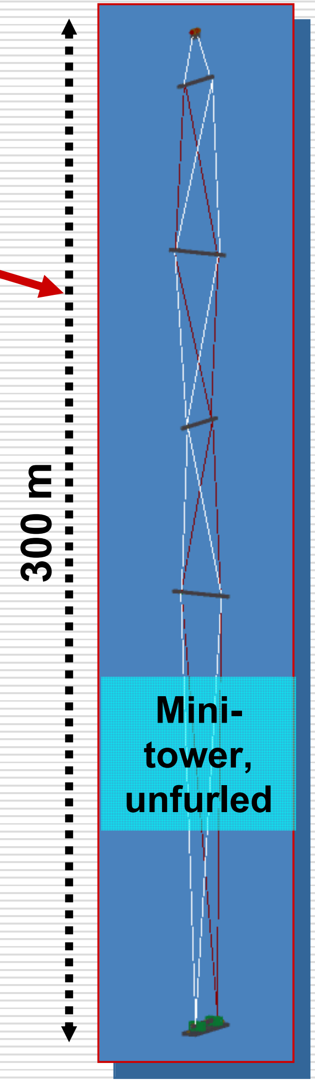
NEMO Phase-1: Next Steps

Deployed January 2005

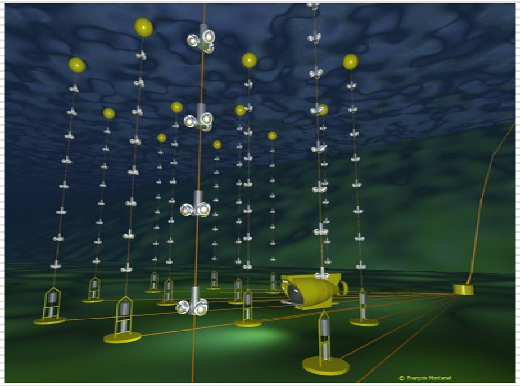








KM3NeT: Towards a km^3 Deep-Sea ν Telescope



~~scale up~~

~~dilute~~

new design

Existing telescopes “times 30” ?

- Too expensive
- Too complicated
  (production, maintenance)
- Not scalable
  (readout bandwidth, power, ...)

R&D needed:

- Cost-effective solutions
  to reduce price/volume by factor ~2
- Stability
  goal: maintenance-free detector
- Fast installation
  time for construction & deployment
  less than detector life time
- Improved components

Large volume with same number of PMs?

- PM distance:
  given by absorption length in
  water (~60 m) and PM properties
- Efficiency loss for larger spacing

The KM3NeT Design Study

Scope and consortium:

- Design Study supported by the European Union with 9 M€, overall volume ~20 M€.
- Participants: 29 particle/astroparticle physics and 7 sea science & technology institutes from 8 European countries (coordinator: Univ. Erlangen).
- Started on Feb. 1, 2006; will run for 3 years.

Major objectives:

- Conceptual Design Report by summer 2007;
- Technical Design Report by February 2009;
- Limit overall cost to 200 M€ per km^3 (excl. personnel).

The KM3NeT Vision

- KM3NeT will be a multidisciplinary research infrastructure:
  - Data will be publicly available;
  - Implementation of specific online filter algorithms will yield particular sensitivity in predefined directions
    → non-KM3NeT members can apply for observation time;
  - Data will be buffered to respond to GRB alerts etc.
  - Deep-sea access for marine sciences.
- KM3NeT will be a pan-European project
  - 8 European countries involved in Design Study;
  - Substantial funding already now from national agencies.
- KM3NeT will be constructed in time to take data concurrently with IceCube.
- KM3NeT will be extendable.

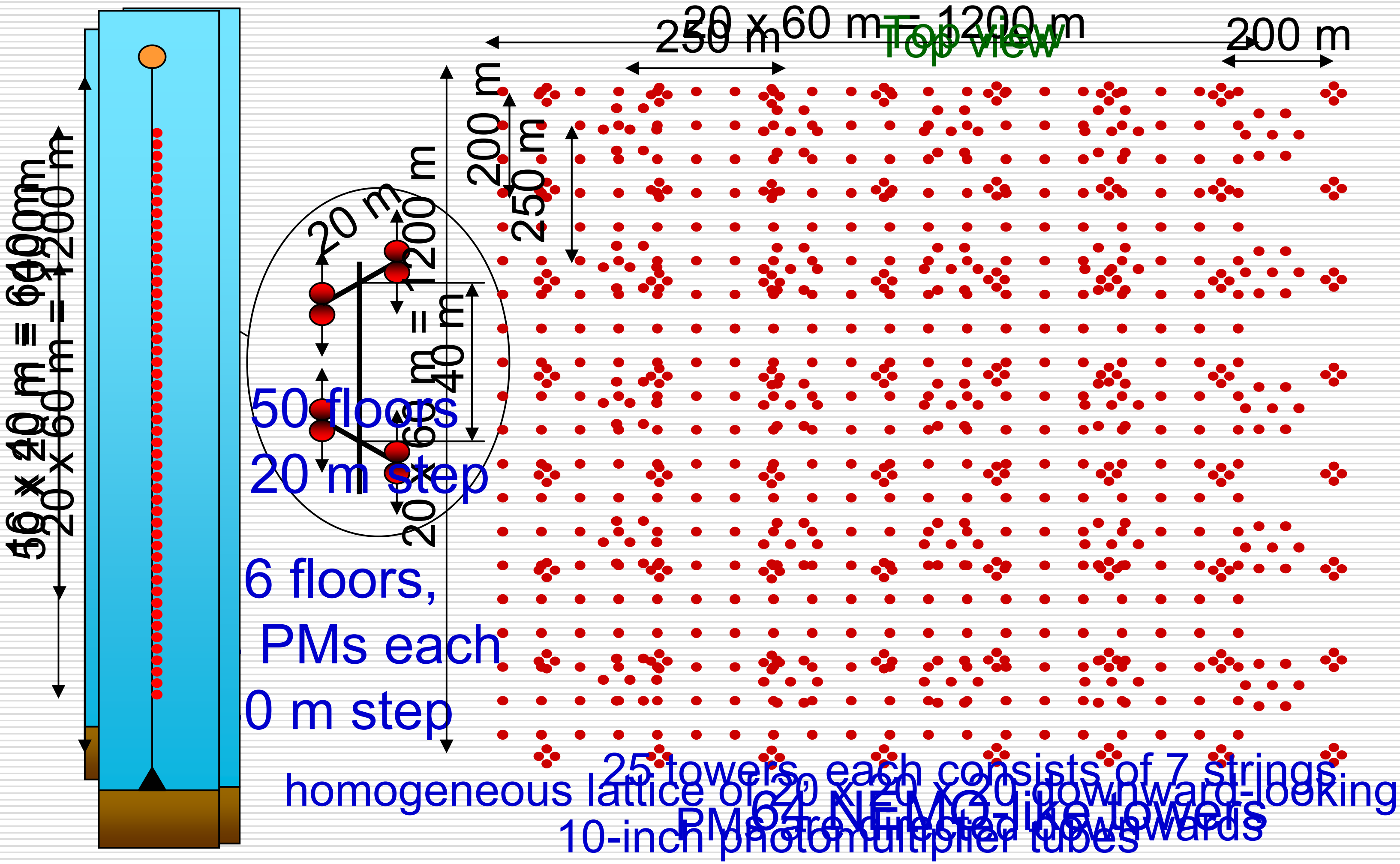
Some Key Questions

All these questions are highly interconnected !

- Which architecture to use?
(strings vs. towers vs. new design)
- How to get the data to shore?
(optical vs. electric, electronics off-shore or on-shore)
- How to calibrate the detector?
(separate calibration and detection units?)
- Design of photo-detection units?
(large vs. several small PMs, directionality, ...)
- Deployment technology?
(dry vs. wet by ROV/AUV vs. wet from surface)
- And finally: path to site decision.

Detector Architecture

(D. Zaborov at VLVνT)



Sea Operations

- Rigid towers or flexible strings?
- Connection in air (no ROVs) or wet mateable connectors?
- Deployment from platform or boat?

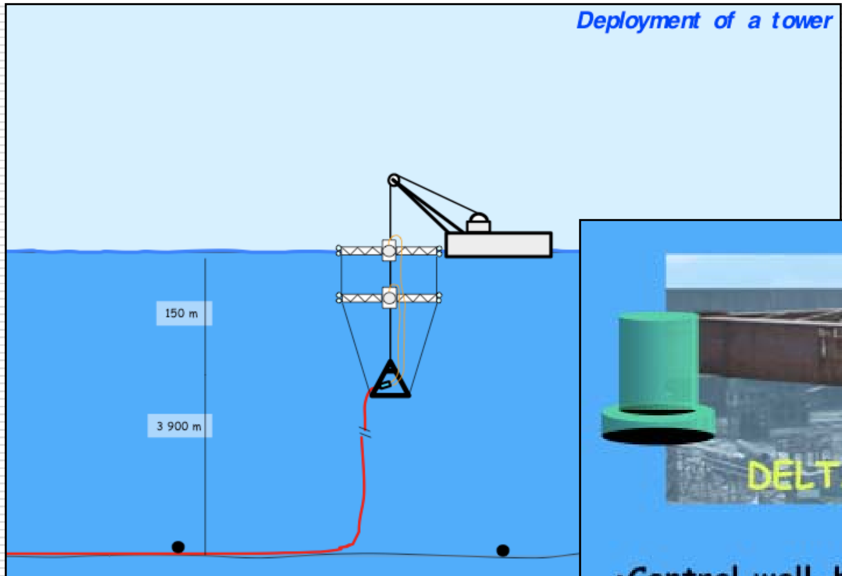
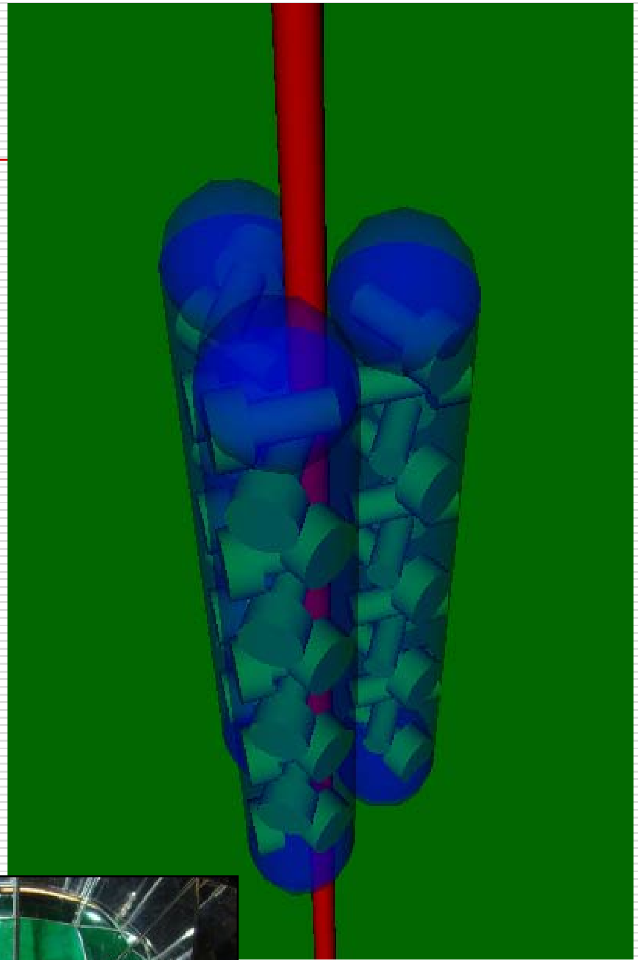
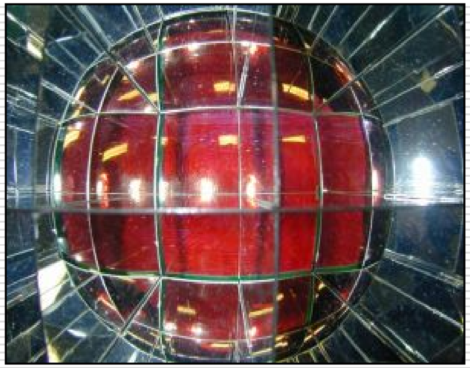
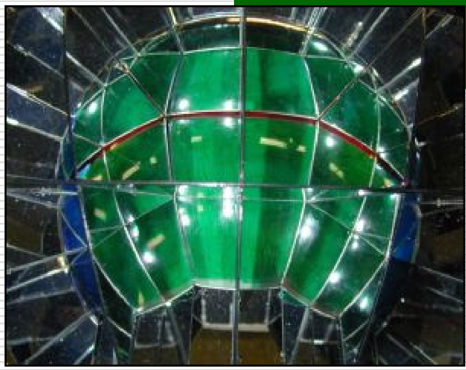


Photo Detection: Options

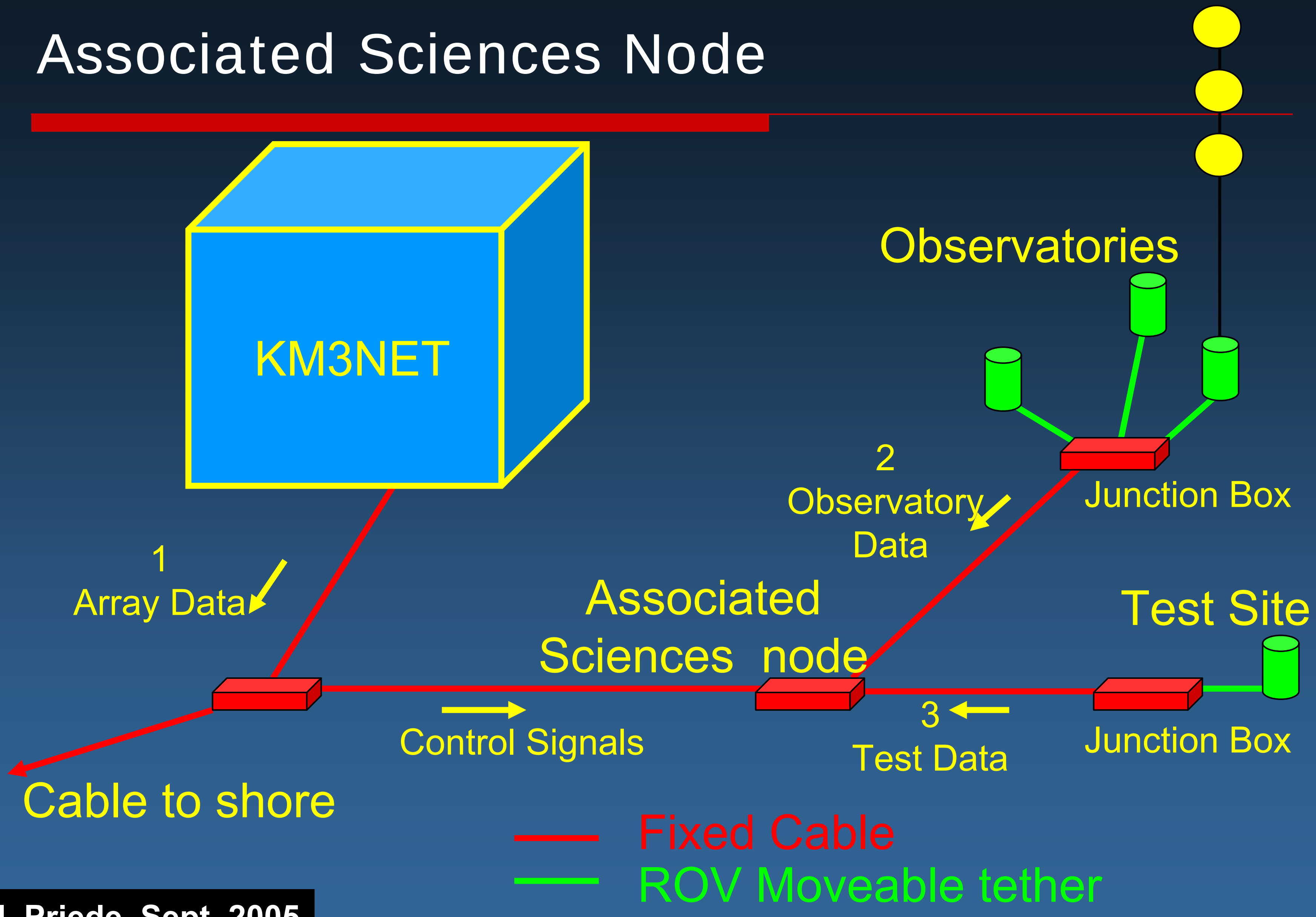
- Large photocathode area with arrays of small PMs packed into pressure housings – improved timing and amplitude resolution.
- Determination of photon direction, e.g. via multi-anodic PMs plus a matrix of Winston cones.
- But: phase space for developments from scratch is tight.







Associated Sciences Node



M. Priede, Sept. 2005

KM3NeT: Path to Completion

Time schedule (partly speculative & optimistic):

01.02.2006	Start of Design Study
Mid-2007	Conceptual Design Report
February 2009	Technical Design Report
2009-2010	Preparation Phase (possibly in FP7)
2010-2012	Construction
2011-20xx	Data taking

Conclusions and Outlook

- The Mediterranean-Sea neutrino telescope projects ANTARES, NEMO and NESTOR have proven the feasibility of large-scale deep-sea neutrino telescopes.
- Exciting data from these experiments can be expected in the near future.
- ANTARES, NEMO and NESTOR have united their efforts to prepare together the future, km^3-scale deep-sea detector.
- The EU-funded KM3NeT Design Study (2006-09) provides substantial resources for an intense 3-year R&D phase.
- Major objective: Technical Design Report by end of 2008.