The KM3NeT Project

Design Study for a Deep Sea Facility in the Mediterranean for Neutrino Astronomy and Environmental Sciences

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for the KM3NeT Project Group

ApPEC Workshop
Munich, 25.11.2003

Physics Perspectives of KM3NeT
Status of Current Deep-Sea Projects
Objectives and Time Schedule for KM3NeT
Associated Sciences
Management and Status of Proposal

Introduction (i)

- Institutes participating in the Design Study:

Cyprus: Univ. Cyprus

France: CEA/Saclay, CNRS/IN2P3 Marseille, CNRS/IN2P3 Strasbourg, Univ. Haute Alsace

Germany: Univ. Erlangen

Greece: Hellenic Open Univ., NCSR “Demokritos”, NOA/Nestor Inst., Univ. Athens, Univ. Crete, Univ. Patras

Italy: INFN (Bari, Bologna, Catania, LNS Catania, LNF Frascati, Genova, Messina, Pisa, Roma-1)

Netherlands: NIKHEF (Univ. Amsterdam, Free Univ., Univ. Utrecht, Univ. Nijmegen)

Spain: IFIC (CSIC, Univ. Valencia), U.P. Valencia

United Kingdom: Univ. Leeds, Univ. Sheffield, Univ. Liverpool?

Coordinator: Uli Katz, Erlangen

Introduction (ii)

- What is our aim:
  a deep-sea km^3-scale observatory for high energy neutrino astronomy and associated platform for deep-sea science
- Why we need an FP6 Design Study:
  to enable the European neutrino astronomy community to prepare for the timely and cost-effective construction of the next-generation neutrino telescope
- Why we need it now:
  "... both in view of the size of the enterprise and of a timely competition with IceCube, the Committee finds it urgent that a single coherent collaboration be formed, ..."
  Recommendation from ApPEC peer review meeting, Amsterdam, 3-4 July 2003

Present and Future of Neutrino Telescopes

Fresh water

- **Lake Baikal**
  demonstrated the concept of water Cherenkov neutrino telescopes

Salt water

- **ANTARES, NESTOR**
  first data from prototype installations
- **NEMO**
  R&D towards km^3 neutrino telescope

Ice

- **AMANDA**
  data taking
- **IceCube**
  km^3 project; under construction

The Mediterranean Sea offers optimal conditions

- water quality, depth, temperature, ...
- existing infrastructure
- current expertise for sea water ν telescopes concentrated in European countries
- a perfect stage for a large Europe-led science project

Common effort needed to realise a future km^3 ν telescope in the Mediterranean Sea operated and constructed by an international collaboration

Physics Perspectives of KM3NeT

HENAP Report to PaNAGIC, July 2002:

“The observation of cosmic neutrinos above 100 GeV is of great scientific importance. ...“

“... a km^3-scale detector in the Northern hemisphere should be built to complement the IceCube detector being constructed at the South Pole.”

“The detectors should be of km^3-scale, the construction of which is considered technically feasible.”

Scientific Goals of KM3NeT

- Astronomy via high-energy neutrino observation
  - Production mechanisms of high-energy neutrinos in the universe (acceleration mechanisms, top-down scenarios, . . .)
  - Investigation of the nature of astrophysical objects
  - Origin of cosmic rays
- Indirect search for dark matter
- Associated science

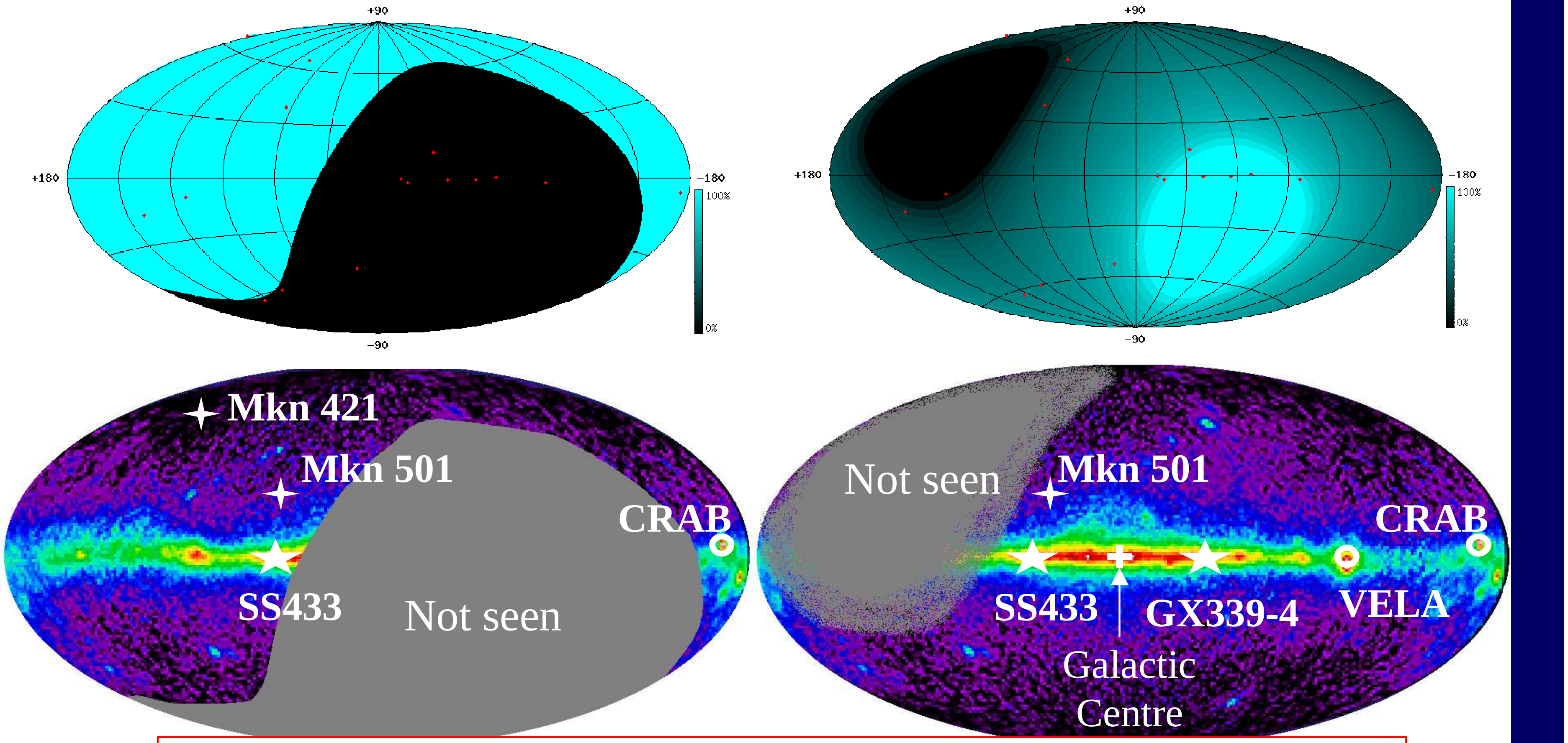
Point Sources

- Allows for association of neutrino flux to specific astrophysical objects
- Energy spectrum, time structure and combination with multi-messenger observations provides insight into physical processes inside source
- Profits from very good angular resolution of water Cherenkov telescopes
- GRBs, if simultaneously observed by space-based experiments, allow for lower thresholds and larger efficiency

Sky Observable by Neutrino Telescopes

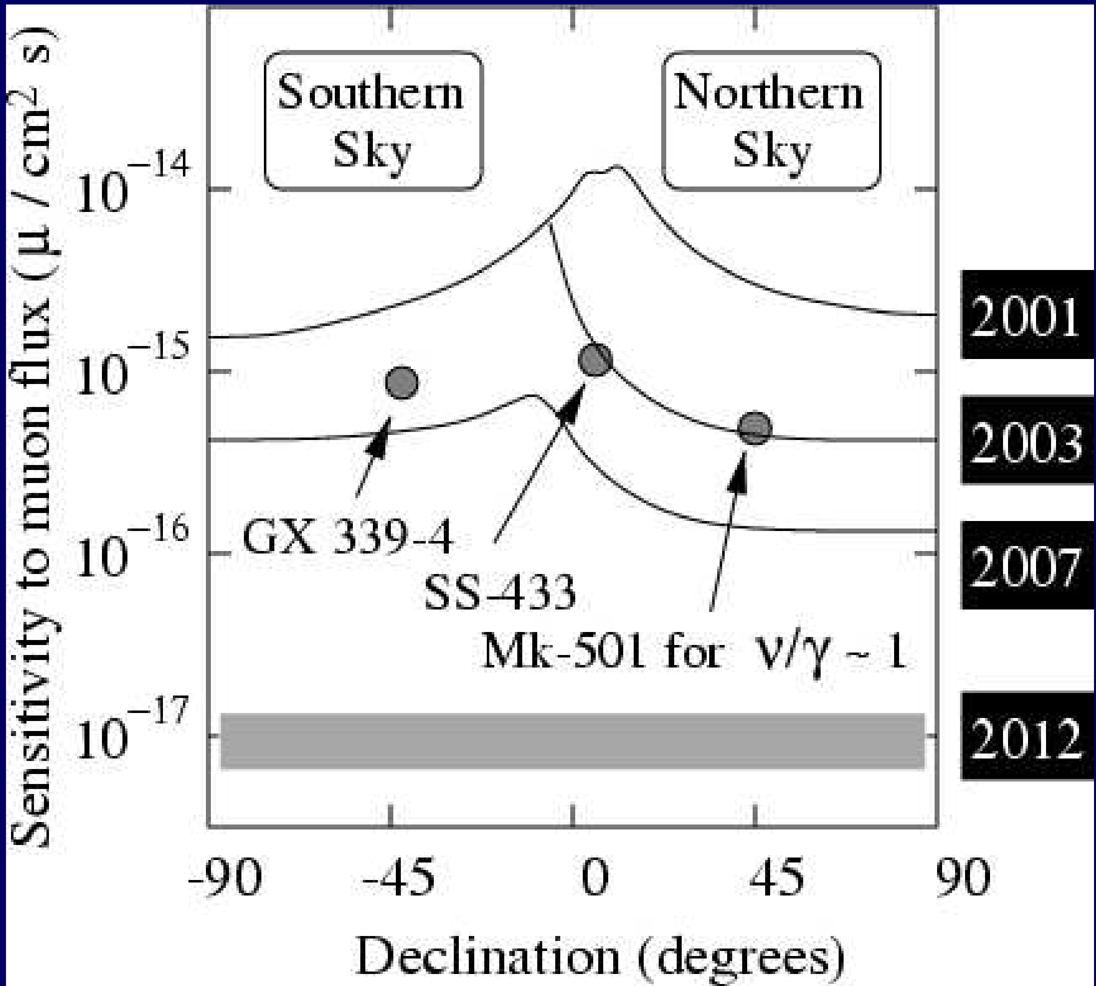
(Region of sky seen in galactic coordinate assuming 100% efficiency for 2π down)

South Pole | **Mediterranean**



Need Neutrino Telescopes in both hemispheres to see whole sky

Point Sources - Sensitivities



Ch. Spiering, astro-ph/0303068

MACRO + SK + AMANDA-B10

AMANDA

AMANDA + IceCube + ANTARES + NESTOR

IceCube + KM3NeT

Diffuse ν Flux

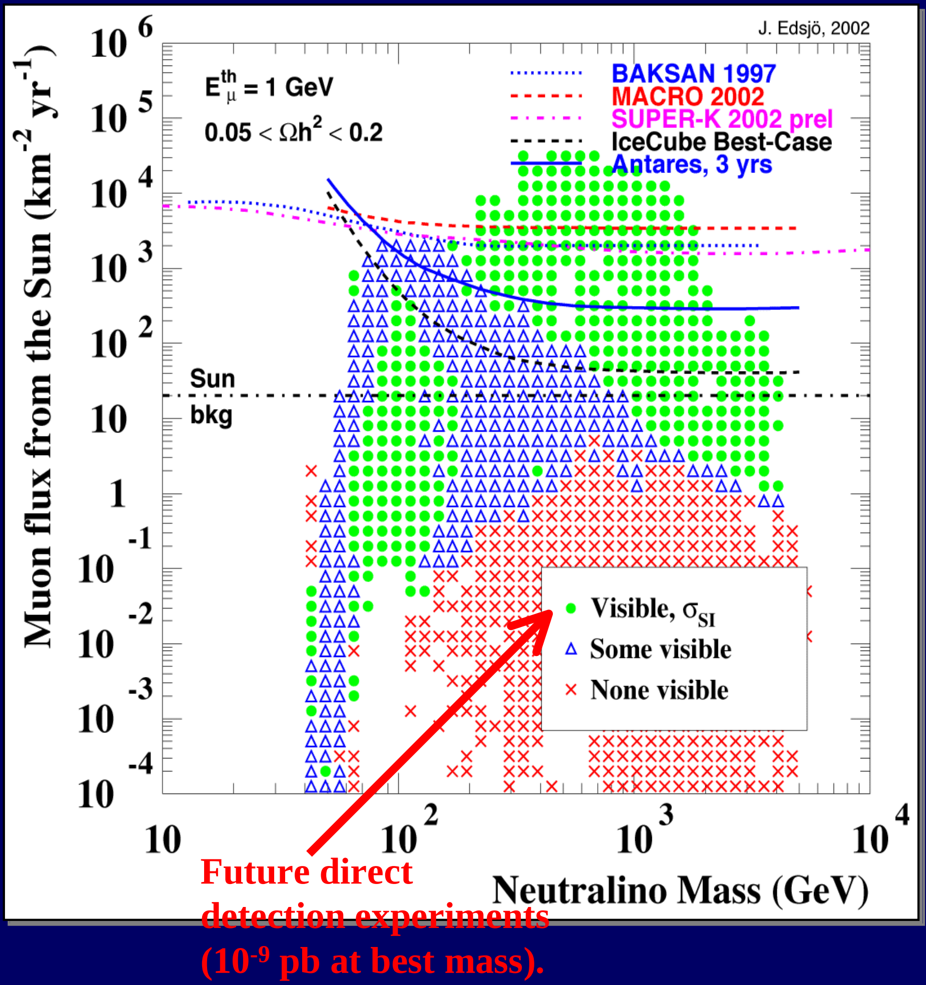
- Energy spectrum will provide important constraints on models of particle acceleration and energy budget at cosmological scales
- Present theoretical upper limits are at the edge of current experiments' sensitivities
  => Precise flux measurement needs km^3-scale detector
- Accessible energy range limited by atmospheric neutrino flux (~10^5 GeV) and detector size (~10^8 GeV)
- Measurements at these energies require sensitivity for neutrinos from above due to opacity of Earth
- Cosmic neutrinos arrive in democratic flavour mix
  Sensitivity to ν_e, ν_τ and NC reactions important

Dark Matter

- Neutrinos produced in co-annihilation of WIMPs gravitationally trapped in Earth, Sun or Galactic Centre provide sensitivity of ν telescopes to Dark Matter
- May solve long-standing questions of both particle- and astrophysics
- KM3NeT will observe Galactic Centre
  => exciting prospects

Dark Matter - Sensitivity

J. Edsjö, HENA workshop 2003 Paris



- WIMP mass = upper limit of Neutrino energy spectrum
- Detection requires sensitivity at low energies
- KM3NeT scenario: maximise efficiency in direction of potential signal sources
- Results complementary to direct searches

Additional Topics

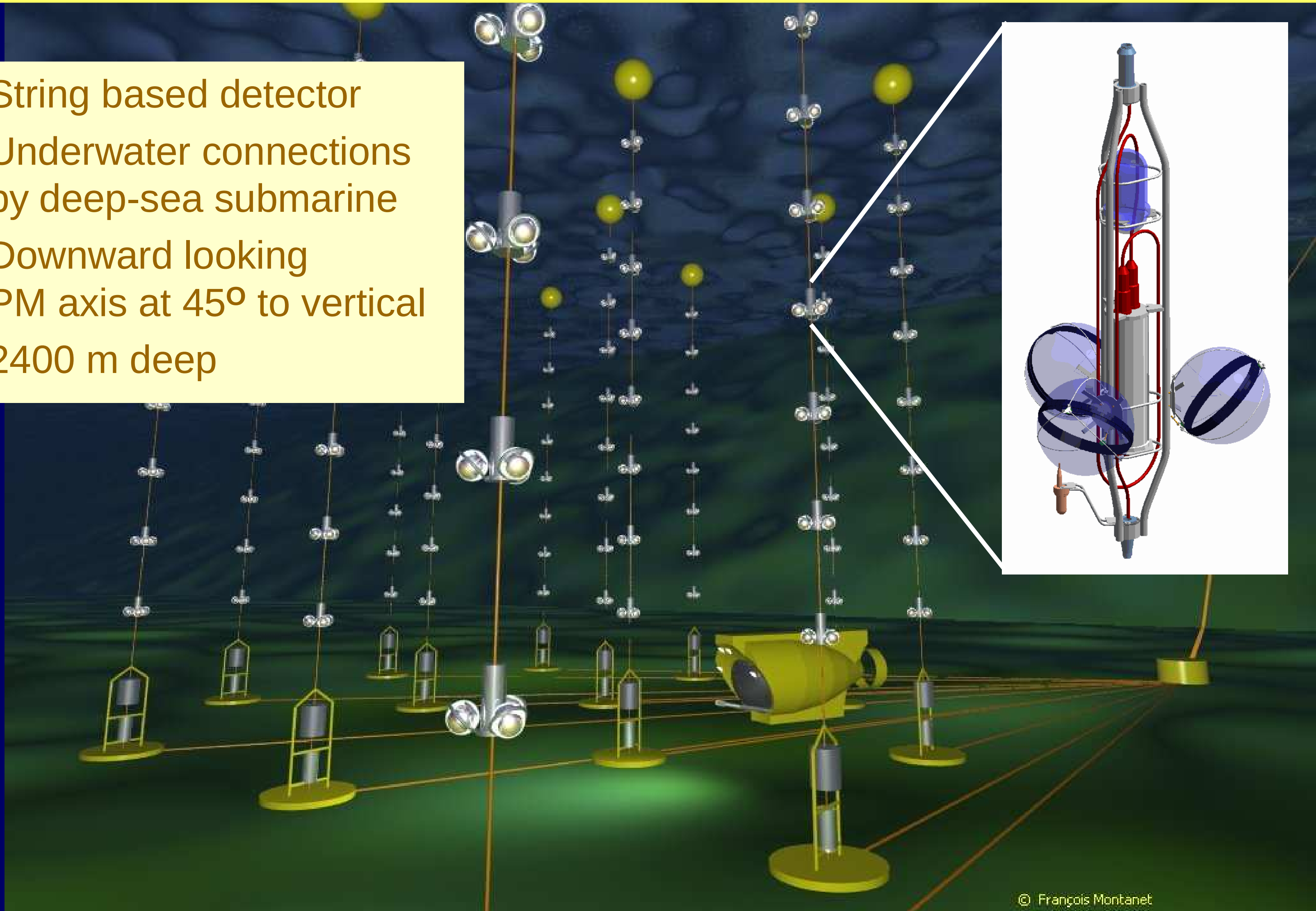
- Particle physics (flavour oscillations, cross sections)
- Top-down scenarios
- Magnetic monopoles
- **The Unexpected**

Status of Current Deep-Sea Projects

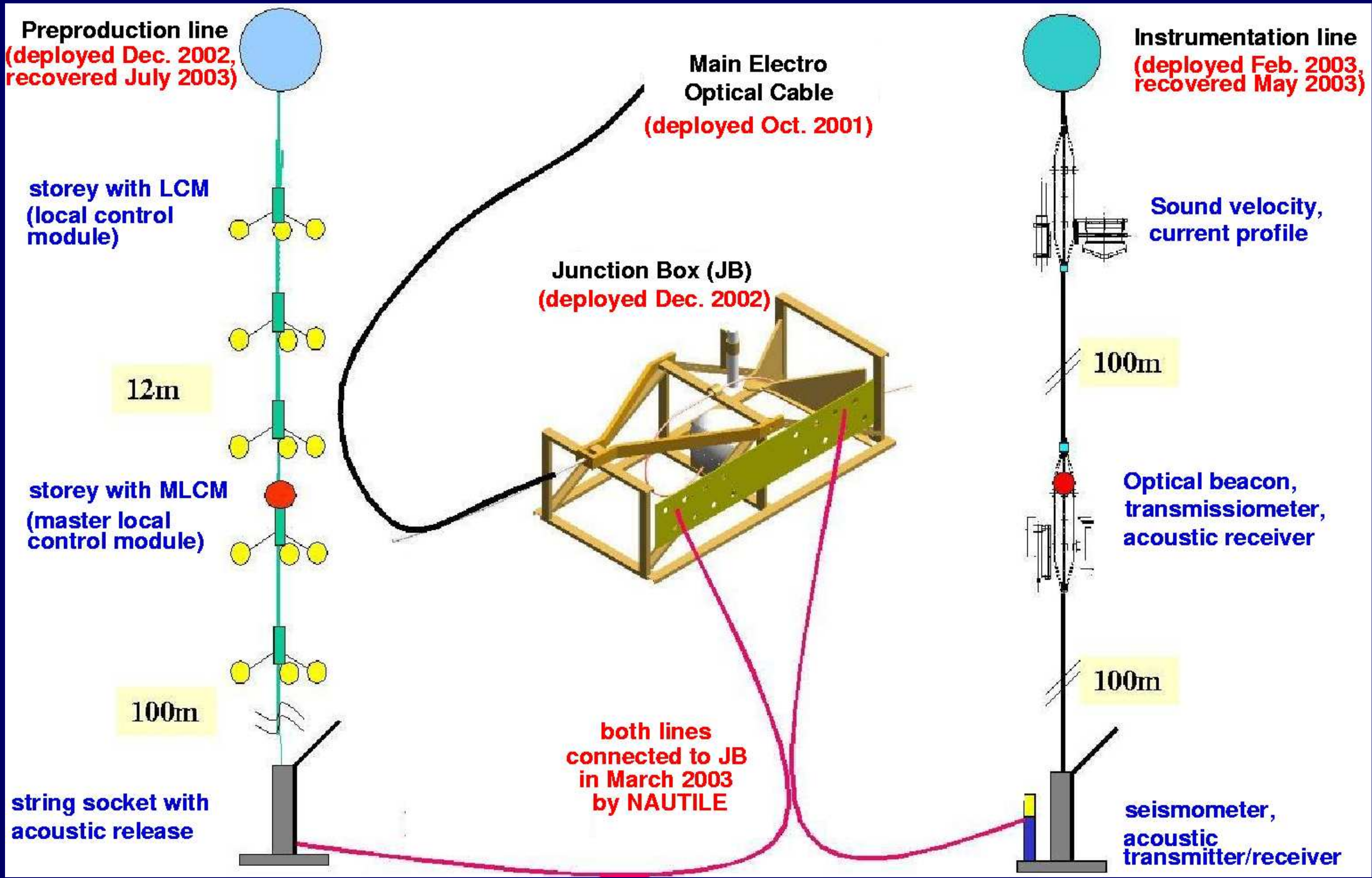
- 3 ongoing projects
- 2 detectors (ANTARES, NESTOR) and 1 prototype (NEMO) under construction
  - different technologies
  - will provide feasibility proof
- 3 possible sites identified and being further explored
- Existing installations can provide test bed for future R&D activities

ANTARES - Layout

- String based detector
- Underwater connections by deep-sea submarine
- Downward looking PM axis at 45º to vertical
- 2400 m deep



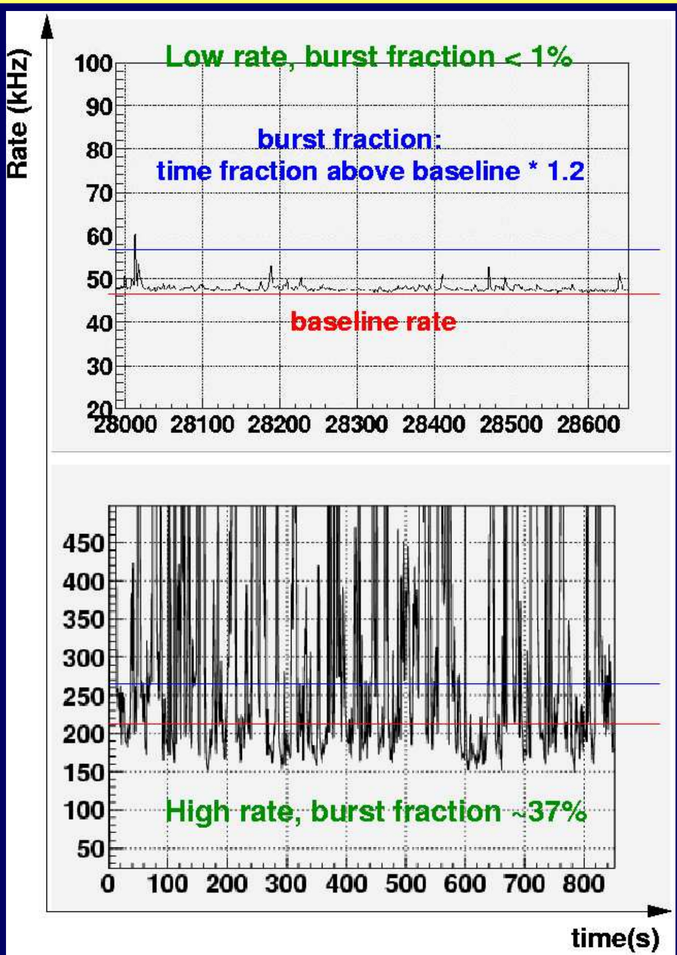
ANTARES - Status

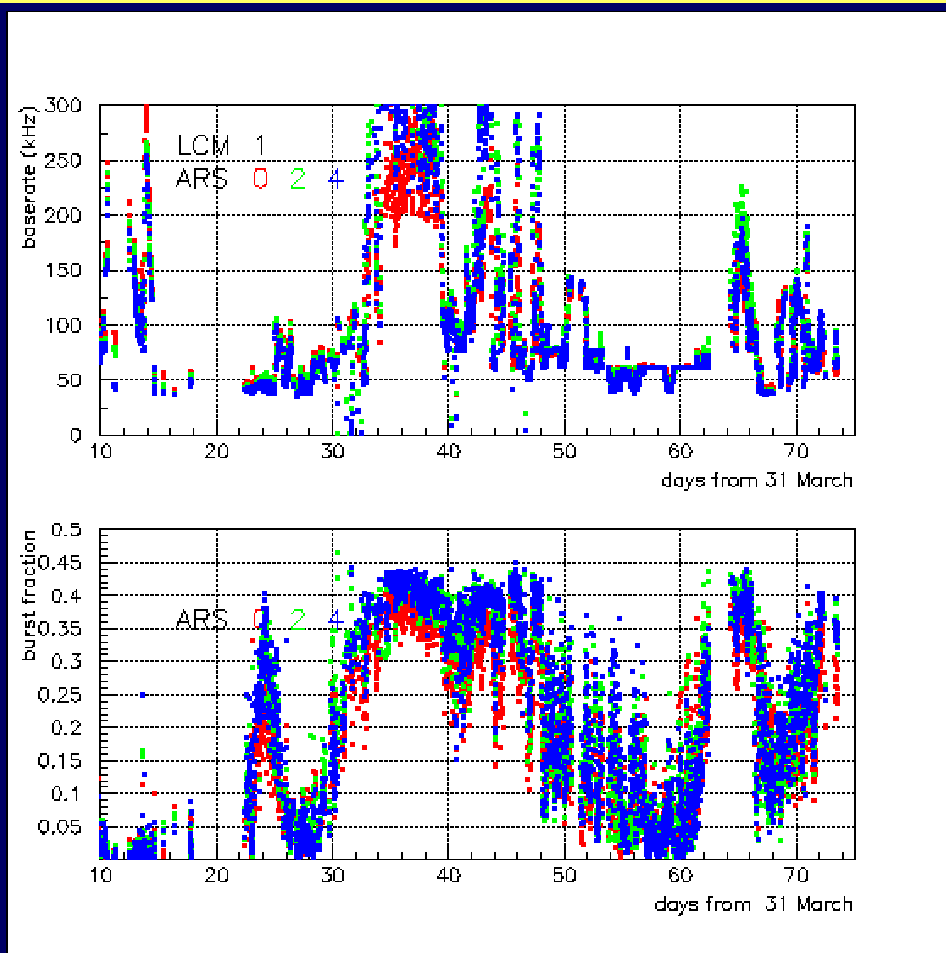


ANTARES - Results

- Junction box successfully deployed and continuously operating for over 11 months in stable condition
- Detector line and instrumentation line successfully deployed, connected and recovered
- Data taking over 5 months
(rate monitoring and environmental data)
- Important conclusions for future detector operation; analysis is ongoing
- Problems (timing signal, water leak) prohibited data taking at ns precision => no muons reconstructed
(modest design modifications will avoid these failures)

ANTARES - Rates

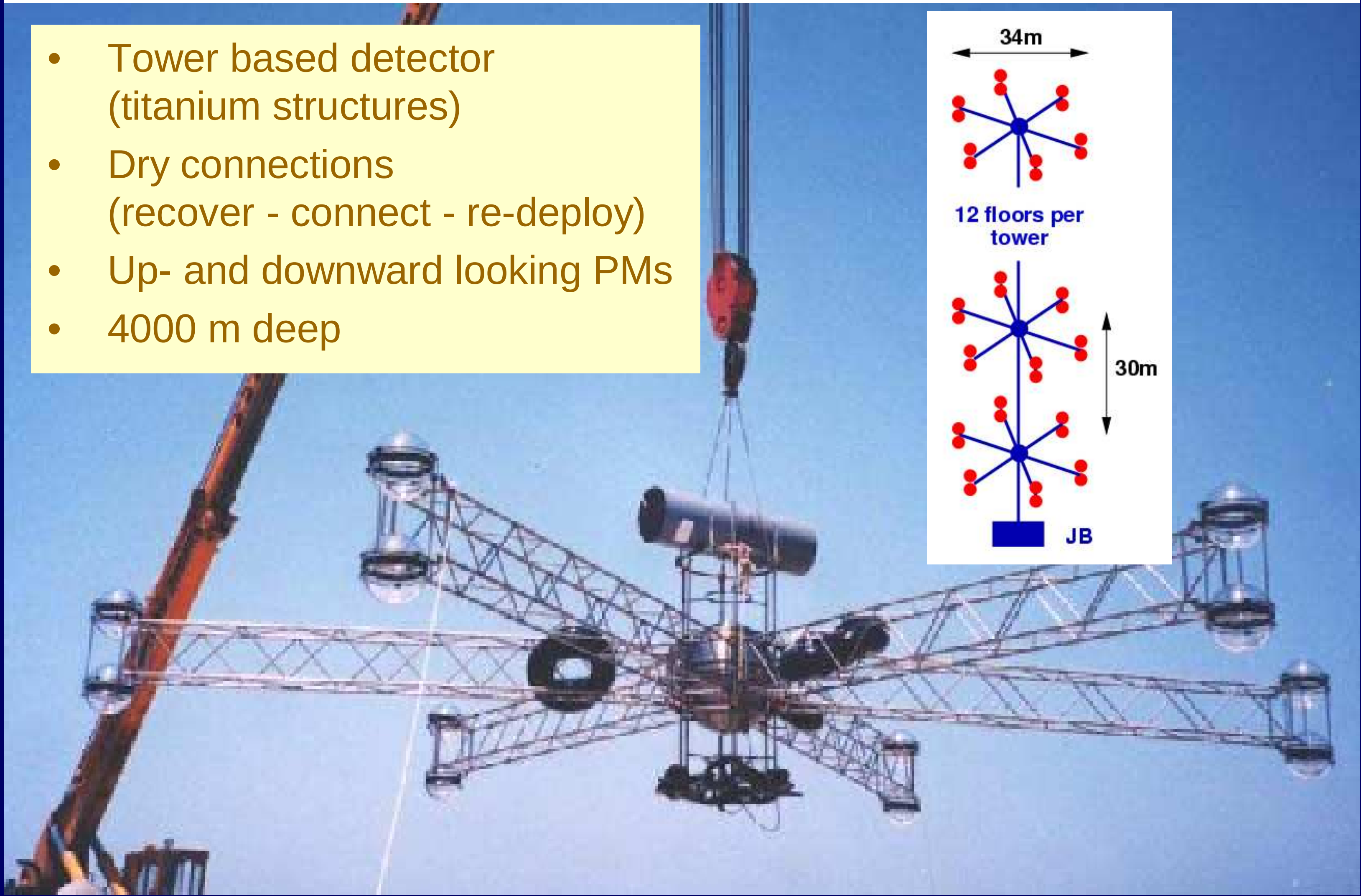




Strong variability of bioluminescence rates

NESTOR - Layout

- Tower based detector (titanium structures)
- Dry connections (recover - connect - re-deploy)
- Up- and downward looking PMs
- 4000 m deep

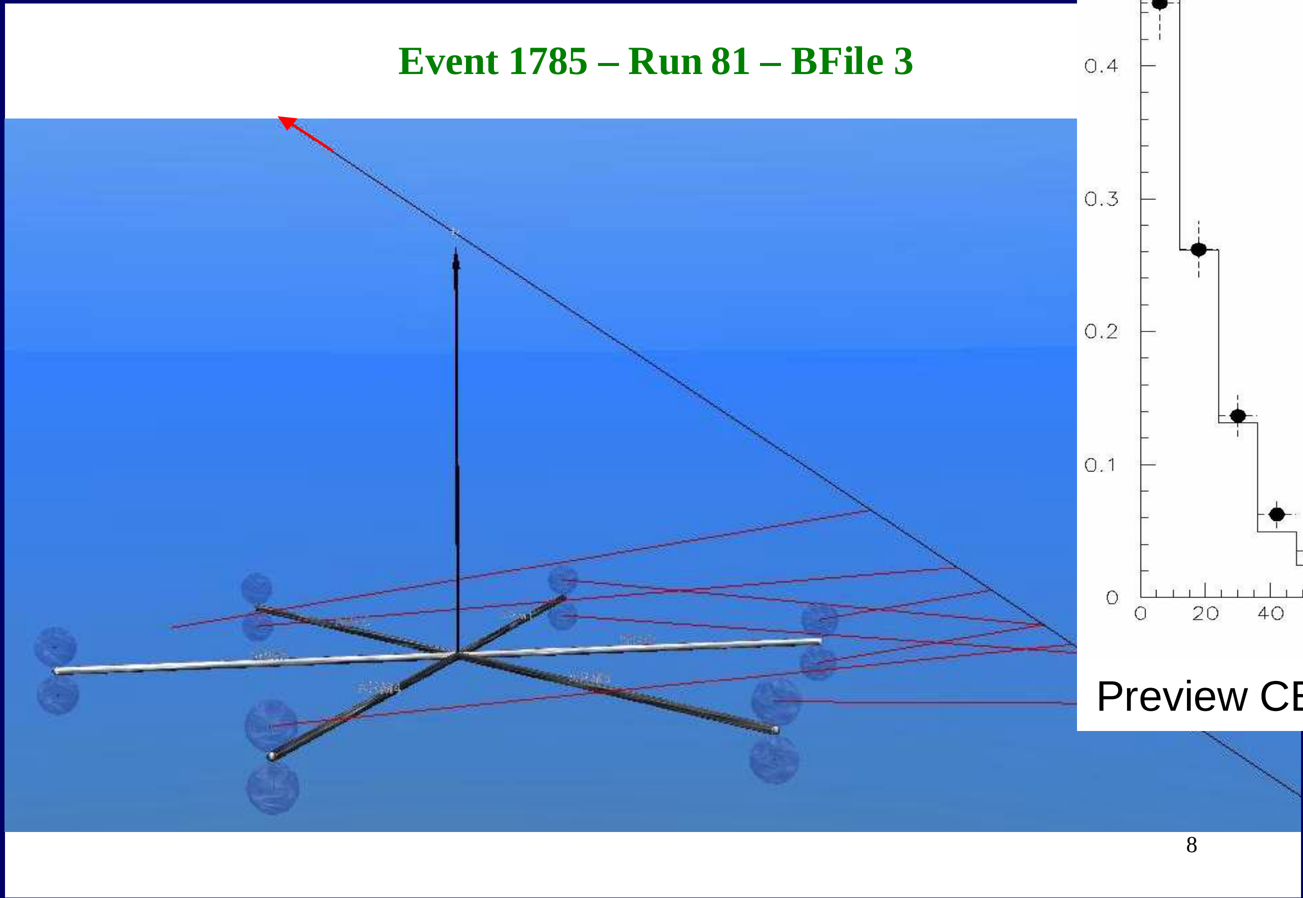


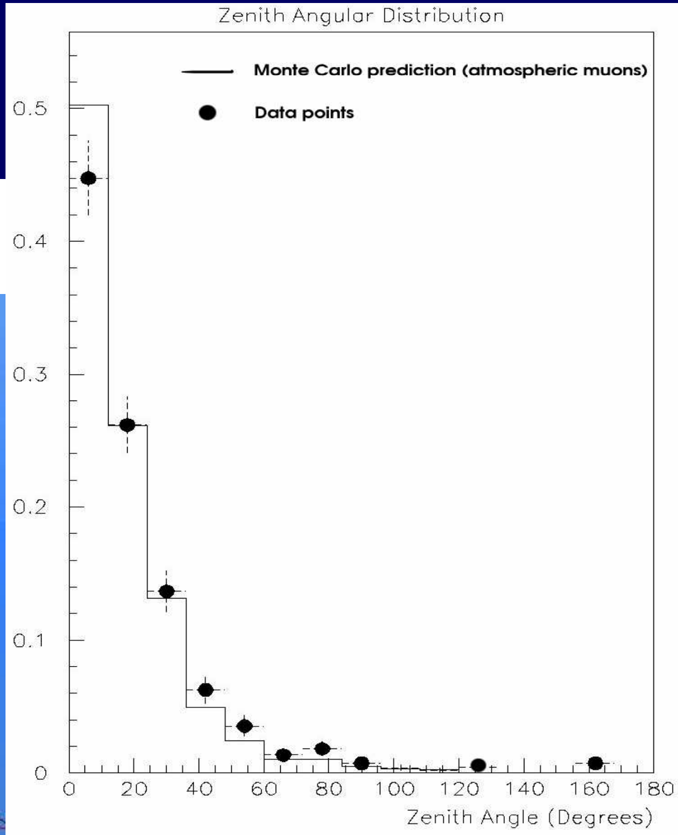
NESTOR - Status

- January 2002: deployment of LAERTIS at 4200 m depth; successfully taking of environmental data
- March 2003: deployment of first prototype floor (reduced size)
- Acquisition of > 5 million event triggers; data taking suspended due to cable problems
- Muon tracks identified and reconstructed

NESTOR - Results

Muons identified and reconstructed

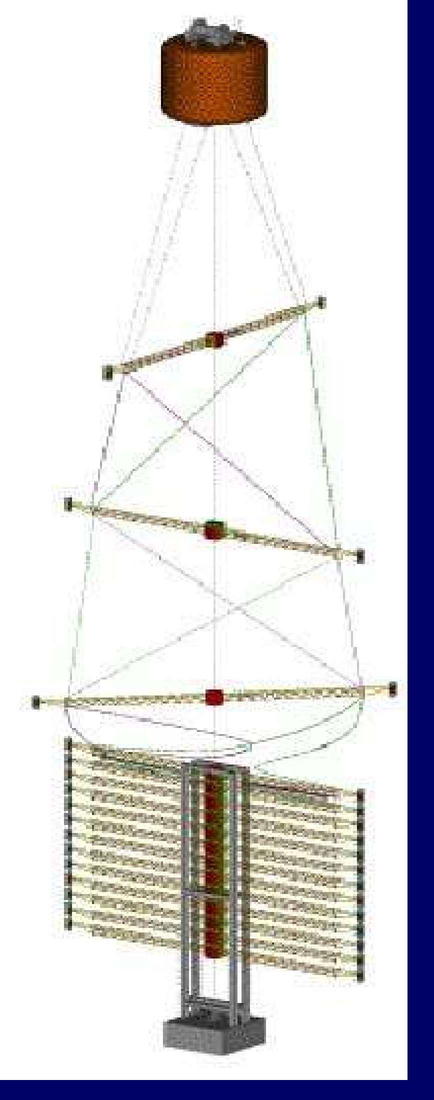




Preview CERN Courier Nov. 2003

The NEMO Project

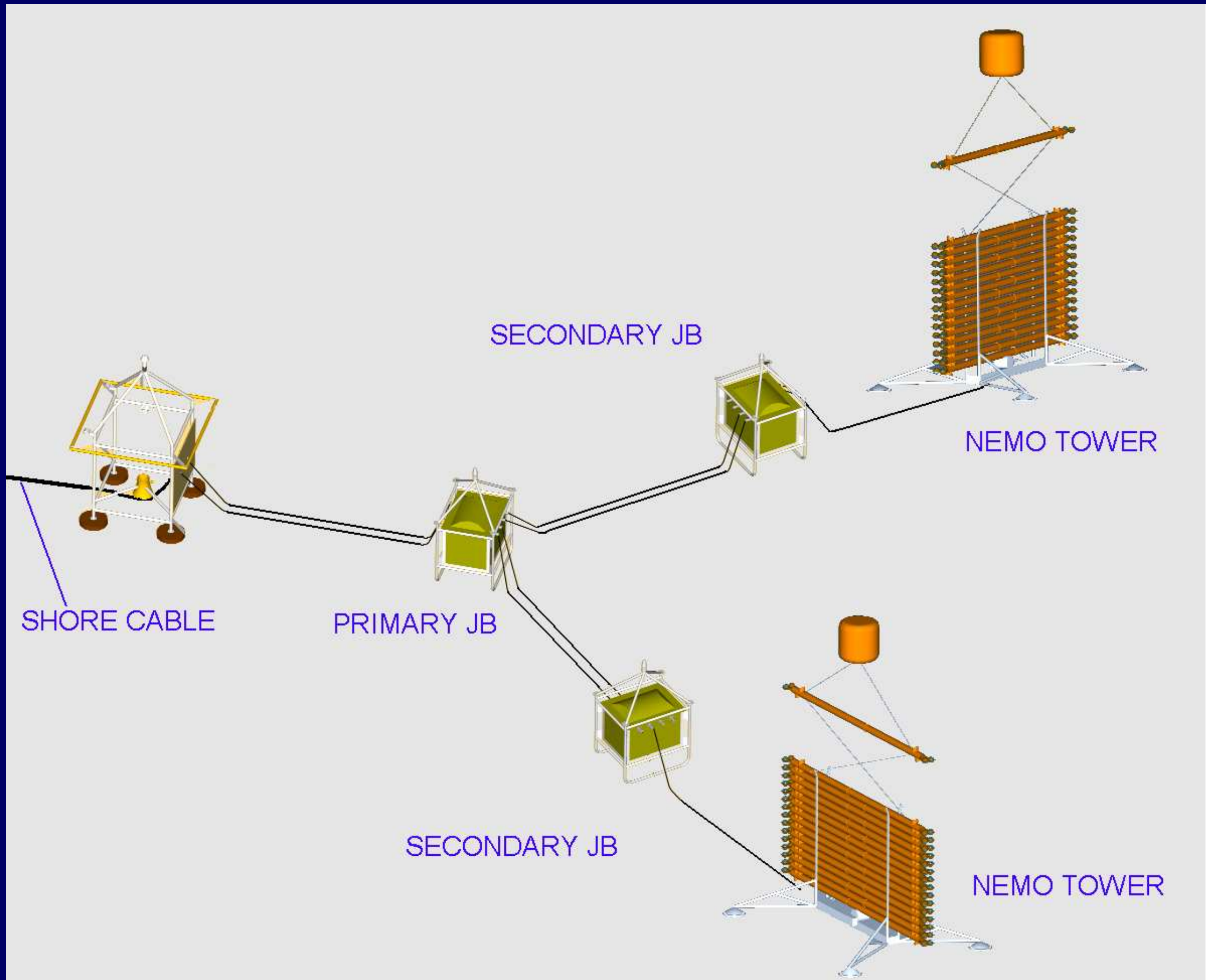
- Extensive site exploration (Capo Passero near Catania, depth 3340 m)
- R&D towards km^3: architecture, mechanical structures, readout, electronics, cables ...



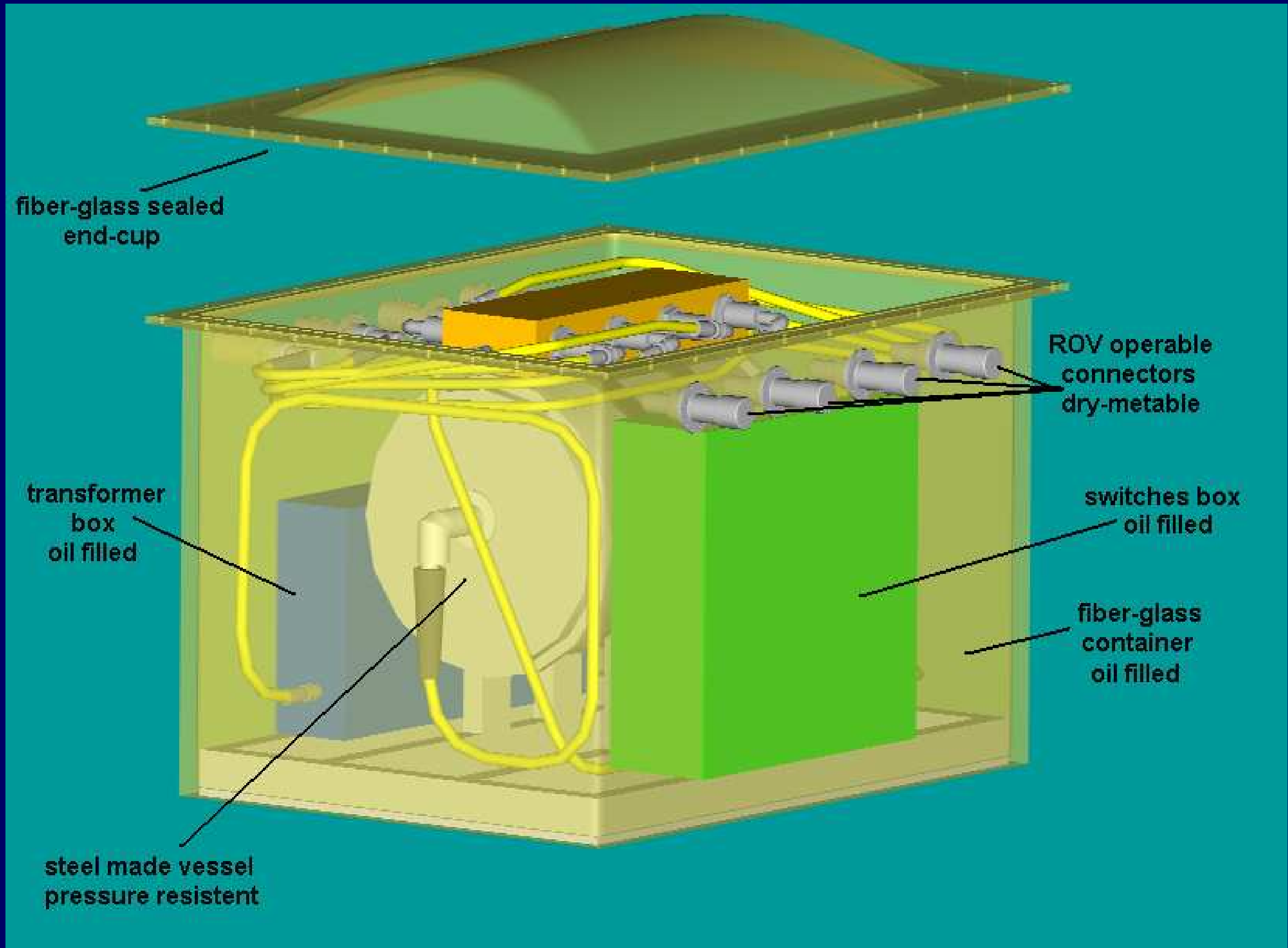
- 16 arms per tower, 20 m arm length, arms 40 m apart
- 64 PMs per tower
- Underwater connections
- Up- and down-looking PMs

The NEMO Project

NEMO test site approved and funded (depth 2000 m)



NEMO - Composite Junction Box



Towards a Collaboration

- Cooperation ANTARES-NEMO:
  - majority of NEMO institutes participating in ANTARES
  - common site-exploration campaigns
- KM3NeT project group (ANTARES, NEMO, NESTOR):
  - 4 meetings of KM3NeT coordination group (first meeting in January 2003, Munich)
  - agreement to proceed with the KM3NeT in a common coordinated effort
- VLVνT Workshop Amsterdam, Oct. 2003
- Next steps:
  - formalise collaboration
  - writing of the Design Study proposal

Objectives and Scope of the KM3NeT Design Study

Establish path from current projects to KM3NeT

- critical review of current technical solutions
- thorough tests of new developments
- assessment of quality control and assurance
- explore and establish possible cooperation with industry

envisaged time scale of design, construction and operation poses stringent conditions

Design Study Target Values (i)

- Detection principle:
  water Cherenkov
- Location in Europe:
  in the Mediterranean Sea
- Detection view:
  maximal angular acceptance for all possible detectable neutrino signals including down-going neutrinos at VHE
- Angular resolution:
  close to the intrinsic resolution
  (<~0.1 degrees for muons with E_ν >~ 10 TeV)
- Detection volume:
  1 km^3, expandable

Design Study Target Values (ii)

- Lower energy threshold:
  a few 100 GeV for upward going neutrinos with possibility to go lower for ν from known point sources
- Energy reconstruction:
  within factor of 2 for muon events
- Reaction types:
  all neutrino flavours
- Duty cycle: close to 100%
- Operational lifetime: >= 10 years

But these parameters need optimisation !

Technical Design of the ν Telescope

- Cost-effectiveness: <~ 200 MEuro per km^3
- Architecture: strings vs. rigid towers vs. flexible towers vs. new solutions
- Photo detectors
- Mechanical solutions
- Readout: electronics, data acquisition, data transport
- Calibration and slow control
- Cables and connectors: dry vs. wet
- Simulations: design optimisation and assessment; impact of environmental conditions

Production and Assembly

Construction of the telescope within
5 years after end of the Design Study

- Detailed assembly procedures
  Distributed production lines
- Evaluation of logistics needs
- Quality control and assurance model

Installation and Maintenance

- Deployment: fast procedures; parallelisation of operations
- Shore infrastructure: supply units; on-shore computing; internet connection
- Maintenance: flexible, low-cost access to sea-operation equipment; rapid recovery procedures; cost-effective repair options

Exploitation Model

Goal: facility exploited in multi-user and interdisciplinary environment

- Reconstructed data will be made available to the whole community
- Observation of specific objects with increased sensitivity will be offered
  (dedicated adjustment of filter algorithms)
- Close relation to space-based observatories will be established (alerts for GRBs, Supernovae etc.)
- "Plug-and-play" solutions for detectors of associated sciences

Operation Model

<u>Goal:</u> centralised services for tasks exceeding the capacity of single institutes

- Maintenance centre for detector components
  (closely related to sea-operation base)
- Computer facilities allowing for external operation and control
- Data storage and distribution
  (relation to GRID?)
- Software development and maintenance, in particular for on-line filter

Funding and Governance

<u>Goal:</u> establish legal foundation for the project

- Invite and coordinate world-wide participation
- Explore national, European and regional funding sources
- Assess and study models for contractual structures
- Address legal questions related to the international structure and in particular to a possible detector deployment in international waters

Work Packages

- WP1: coordination and project management
- WP2: science
  (physics, simulation, architecture and calibration)
- WP3: industry
  (materials, power, cables, connectors, photo detectors)
- WP4: technology
  (signal detection and transmission, digitization,
  data processing and distribution)
- WP5: infrastructure
  (deployment and recovery base, shore station, European
  data network, European science network)
- WP6: associated sciences
- WP7: governance, legal and funding aspects

Why us, why now, why an FP6 Design Study?

- The KM3NeT group comprises the current expertise for design, construction and operation of sea-water Cherenkov neutrino telescopes
- The KM3NeT project aims at achieving the timely construction of a km^3-scale ν telescope in the Northern hemisphere
- Extensive preparatory studies required for KM3NeT with substantial need for manpower and investments. An FP6 Design Study offers the chance to pursue a common European effort.

Requested Funding

- Detailed evaluation of financial needs still ongoing
- Estimated overall budget of Design Study of the order 15 MEuro.

  Amount requested from EU:

  6 - 8 MEuro over 3 years

Time Schedule of KM3NeT

Time scale given by "community lifetime" and competition with ice detector

- Experience from current first generation water neutrino telescopes is a solid basis for the design of the KM3NeT detector
- interest fades away if KM3NeT comes much later than IceCube (ready by 2010)

Initiative for km^3 water detector has to be consolidated now

KM3NeT Milestones

End 2004	Start design study
Mid 2006	Conceptual design ready
End 2007	Technical design ready
2008 – 2012	Construction
2009 – XXXX	Operation

Associated Sciences

- Great interest in long term deep-sea measurements in many different scientific communities:
  - Biology
  - Oceanography
  - Environmental sciences
  - Geology and geophysics
  - . . .
- Communication with ESONET established
- Plan: include the associated science communities in the design phase to understand and react to their needs

Management, Political Issues and Status of Proposal Preparation

- Writing group for Design Study proposal established
- Assembly of institution representatives as major decision body
- Administrational and legal support by Erlangen University
- Target for complete application draft: Jan. 2004

Summarising Remarks

- Exciting physics perspectives of neutrino telescopes
- A km^3-scale telescope in the Northern hemisphere is needed to complement IceCube in sky-coverage and to exploit the full potential of neutrino astronomy
- The Mediterranean offers optimal conditions.
  The current expertise in water Cherenkov neutrino telescopes is united in Europe
- The European groups have agreed on a common coordinated effort towards KM3NeT
- This effort has to be consolidated now in order to achieve a timely construction of the detector.
  An FP6 Design Study offers optimal conditions to proceed

Let's Go For It !

Discussion (i)

- **Comment:** The mentioned point sources are probably not good candidates for sources of high-energy neutrinos.

  Answer U.Katz: These sources are examples representing models that were assumed to be promising at some point. However, there is a large variety of models predicting neutrino fluxes from different kinds of point sources that will be well in the sensitivity of KM3NeT.

- **Comment:** No sensitivity of KM3NeT to top-down scenarios due to high neutrino energy

  Answer U.Katz: Shows plot with a possible top-down scenario (last transparency of this file: thick red curve) with expected sensitivity of IceCube and emphasises that KM3NeT may have even higher sensitivity.

Discussion (ii)

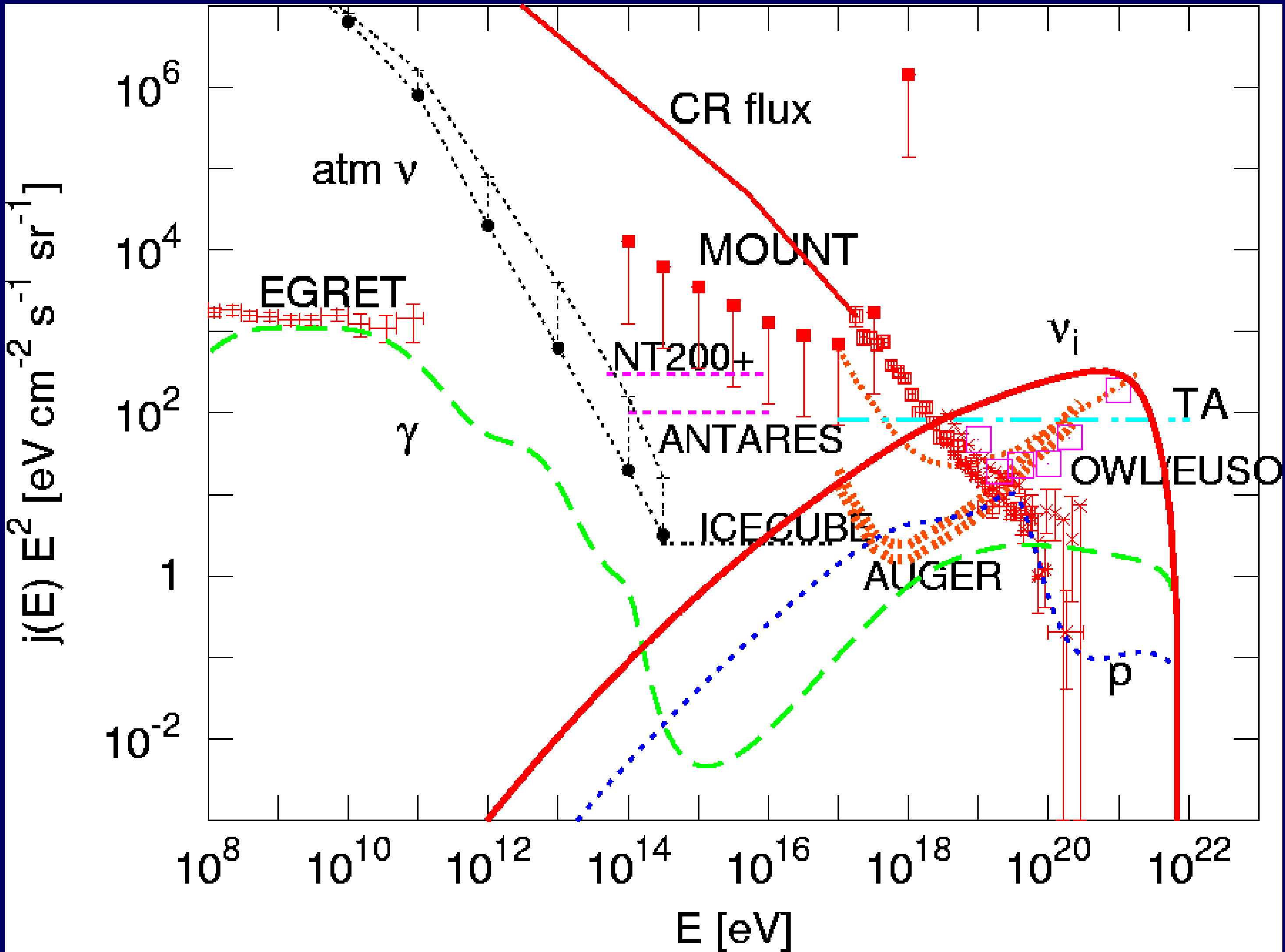
- **Question:** Is there enough manpower for the KM3NeT Design Study in view of the commitments for the ongoing construction of the current neutrino telescopes?

  Answer U.Katz: Additional manpower is one of the main objectives of the requested funding.

  Comment J.Carr: After the start of mass production of ANTARES components in 2004 manpower for development tasks becomes available.

  Comment I.Siotis: The new project attracts a lot of young scientists. In case of the successful start of KM3NeT NESTOR could stop at 4 floors instead of heading for the full 12-floor tower, thus making additional manpower available.

Top-Down Scenarios - Signal fluxes



G. Sigl, HENA workshop 2003 Paris