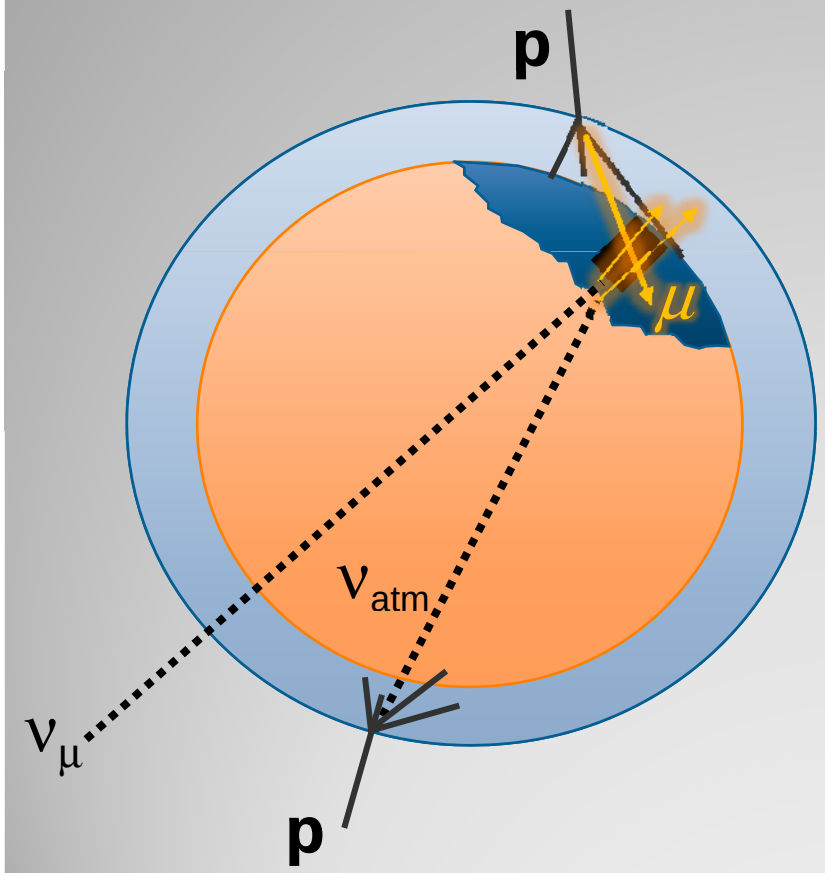
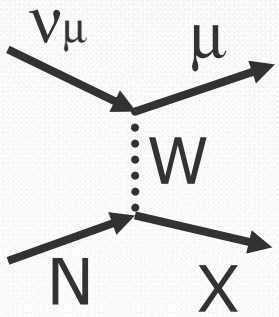
Neutrino Telescopes in the Mediterranean Sea

ANTARES and KM3NeT

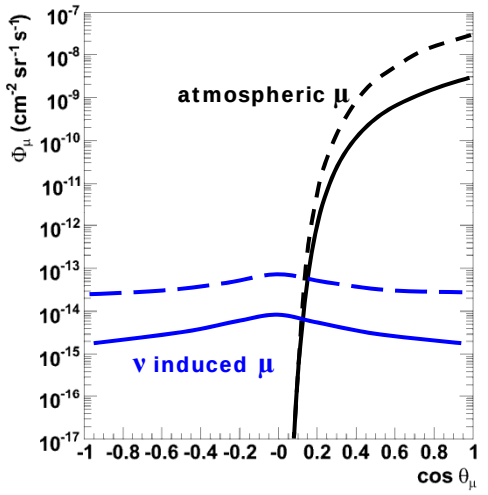
J.J. Hernández-Rey
IFIC



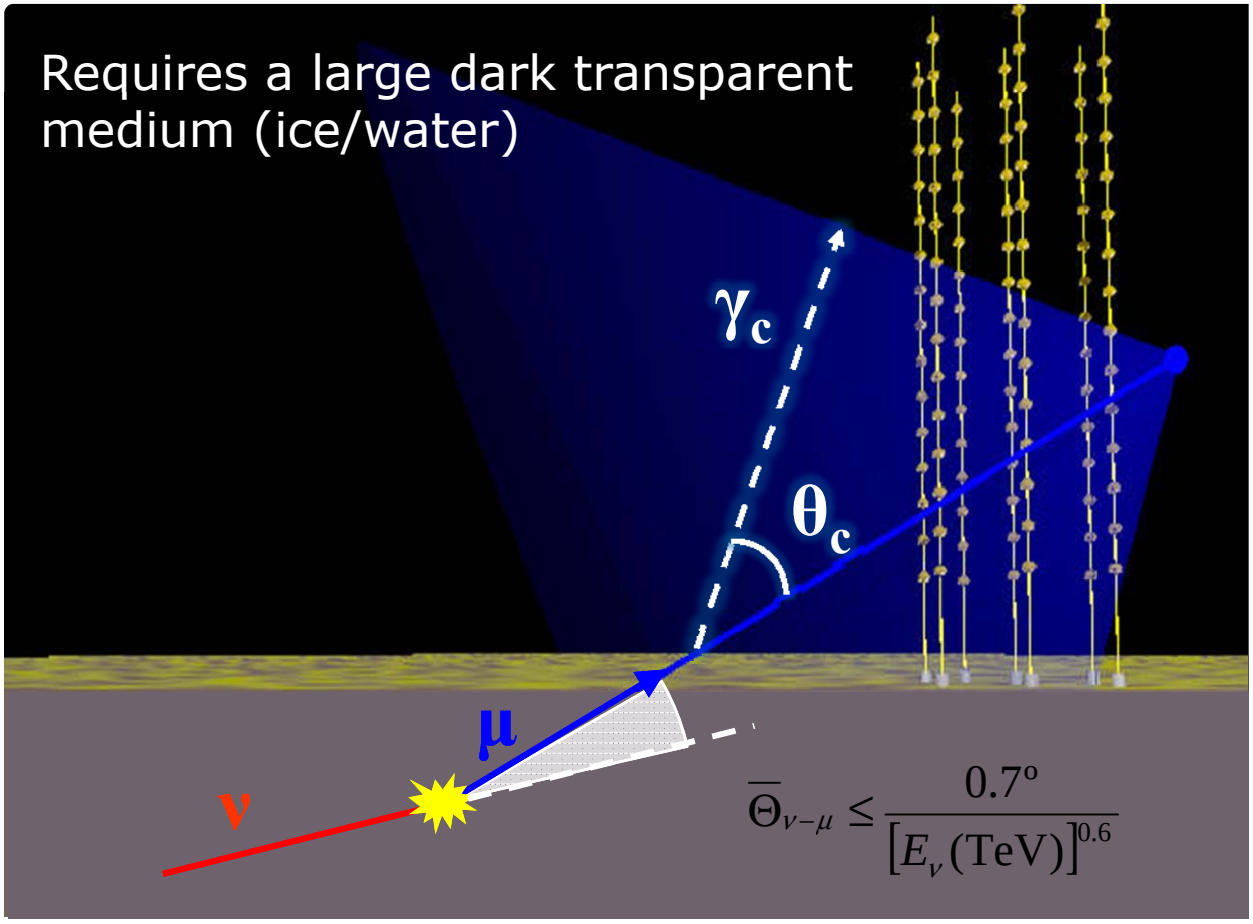


Cosmic neutrinos can interact in the Earth and release a muon

Atmospheric muons and neutrinos can also induce a signal at the detector



Detection principle



Muon neutrinos are well suited for HE detection (cross-section and muon range increase with energy)

Muons emit Cherenkov light collected by a lattice of PMTs.

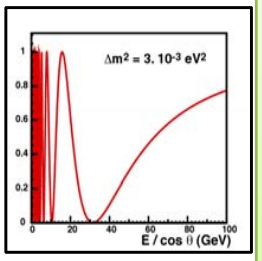
Other signatures can also be detected.

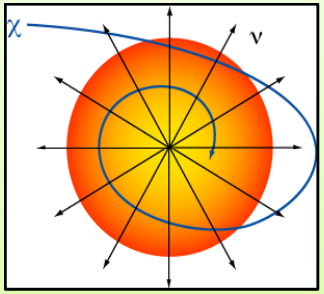
Long track ⟶ angular resolution

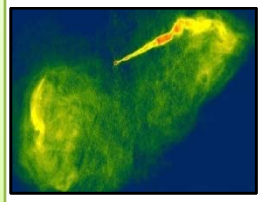
Cherenkov Neutrino detection

Scientific scope

- Less amount of light
- Lower ranges
- ^{40}K background







?

~MeV | GeV-100 GeV | GeV-TeV | TeV-PeV | PeV-EeV | ➢EeV

- Earth opacity
- Decreasing neutrino flux

The Antares collaboration

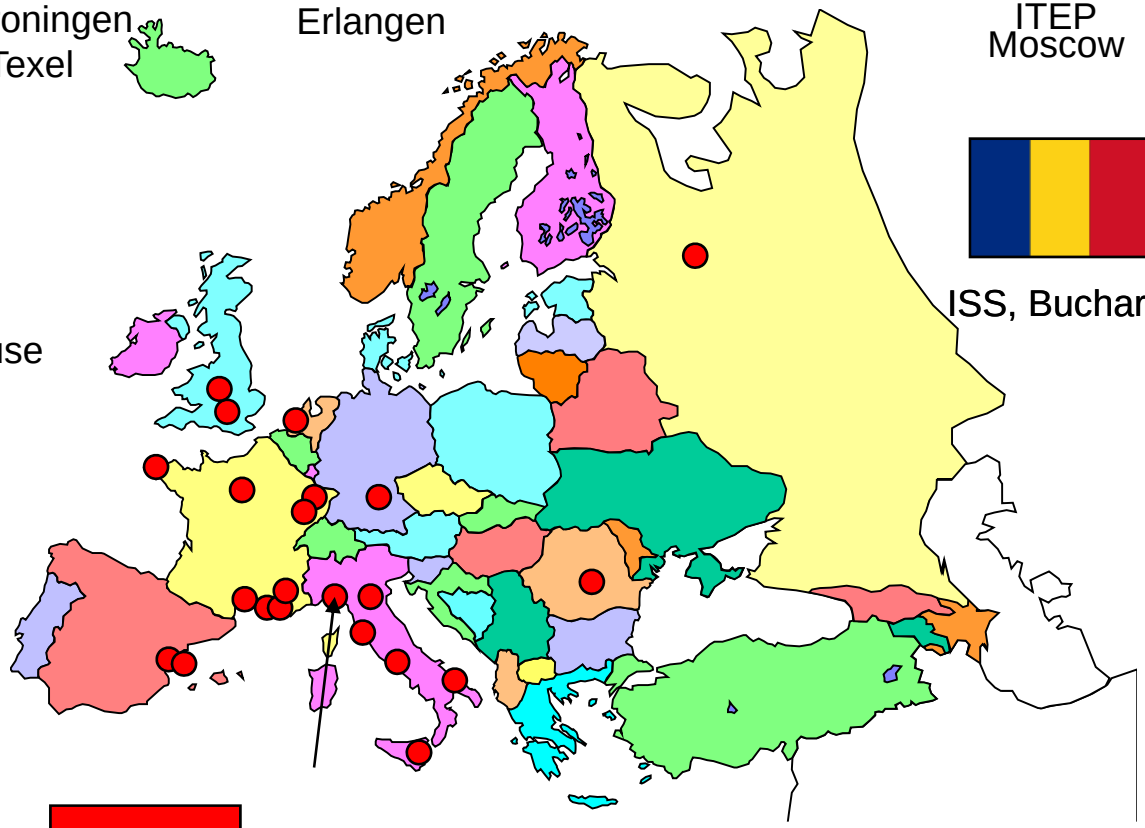
NIKHEF Amsterdam
KVI Groningen
NIOZ Texel

Erlangen

ITEP
Moscow

APC Paris
IFREMER, Brest
DAPNIA, Saclay
IReS, Strasbourg Mulhouse
CPPM Marseille
IFREMER,Toulon
COM, Marseille
OCA, Nice

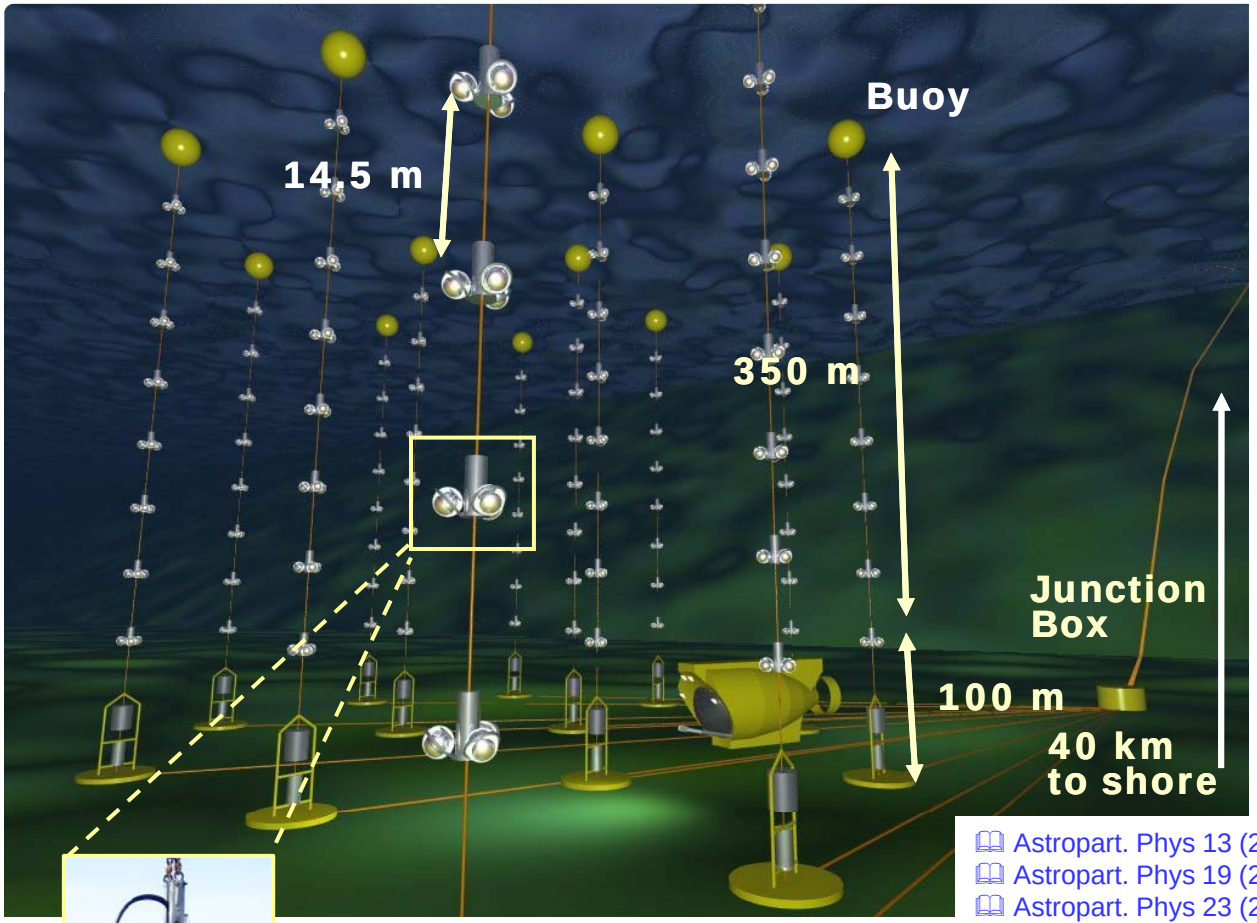
ISS, Bucharest



INFN Bari
INFN Bolgna
INFN Catania
INFN Genova
LNS
INFN Pisa
INFN Roma

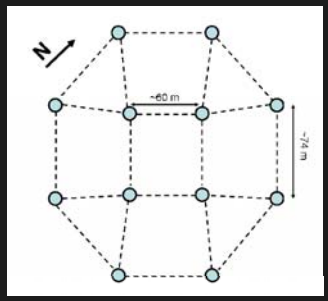
IFIC Valencia
UPV

7 countries, 25 institutes,
~150 engineers, sea scientists
& physicists

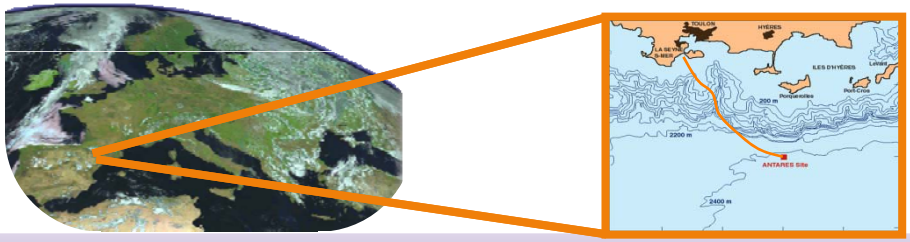


- 12 lines (900 PMTs)
- 25 storeys / line
- 3 PMTs / storey

Horizontal layout



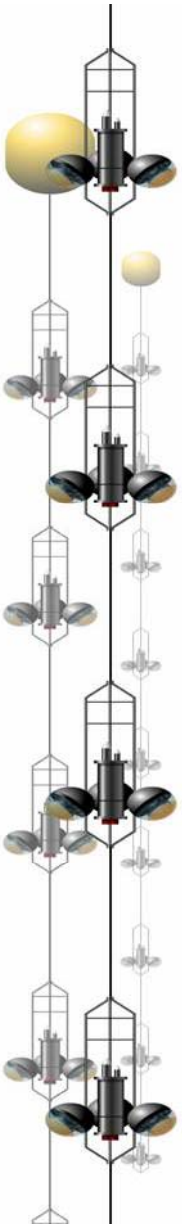
Astropart. Phys 13 (2000) 127-136 (Background light)
Astropart. Phys 19 (2003) 253-267 (Sedimentation & Fouling)
Astropart. Phys 23 (2005) 131-155 (Light transmission)



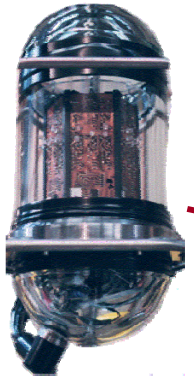
The detector is located in the Mediterranean Sea (42º50'N, 6º10'E) at **2500 m** depth, in the south coast of Toulon (France).

The Antares Telescope

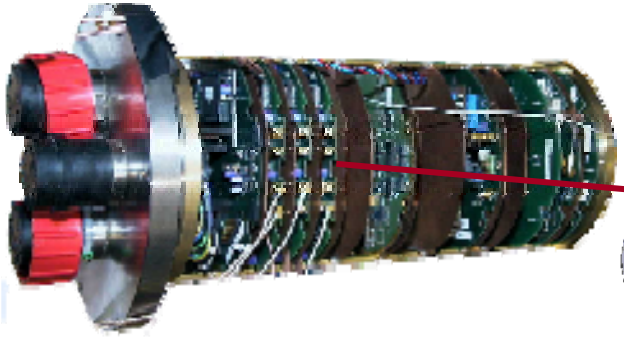
Basic detector element: storey



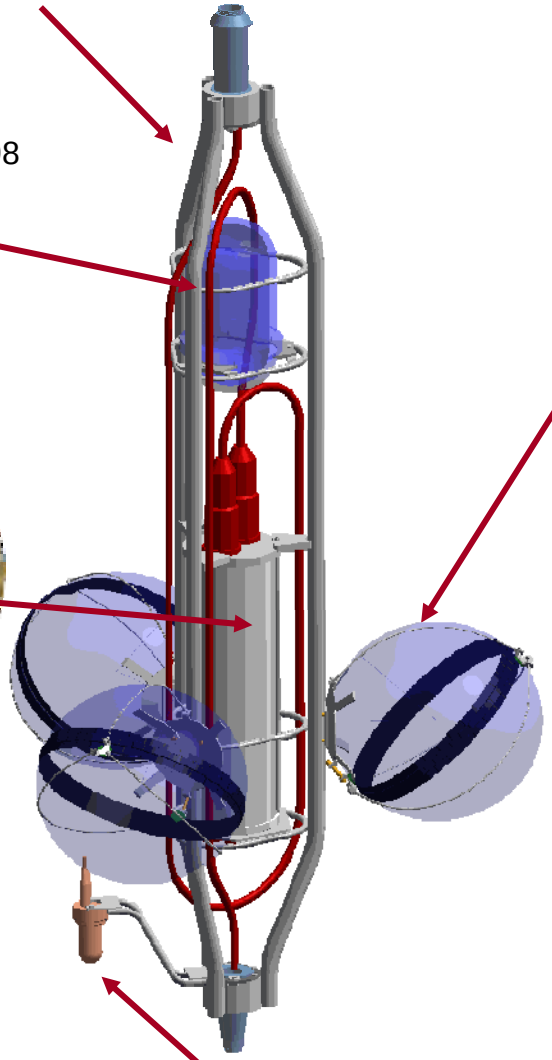
Titanium frame: *support structure*

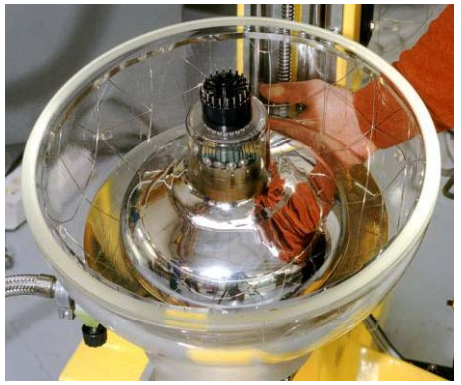


Optical Beacon
with blue LEDs:
timing calibration
📖 NIM A578 (2007) 498



Local Control Module (Ti):
Front-end ASIC, DAQ/SC, DWDM,
Clock, tilt/compass, power distribution…

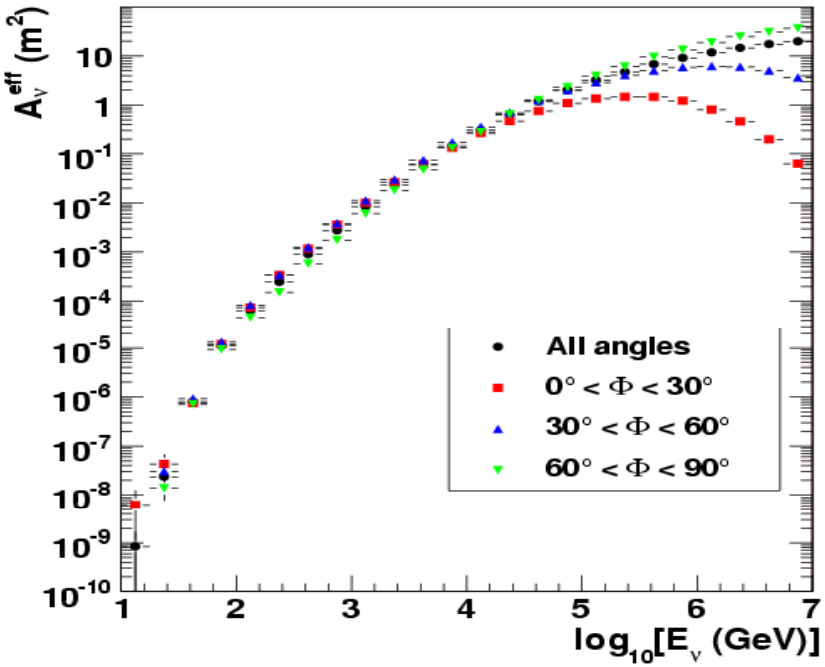


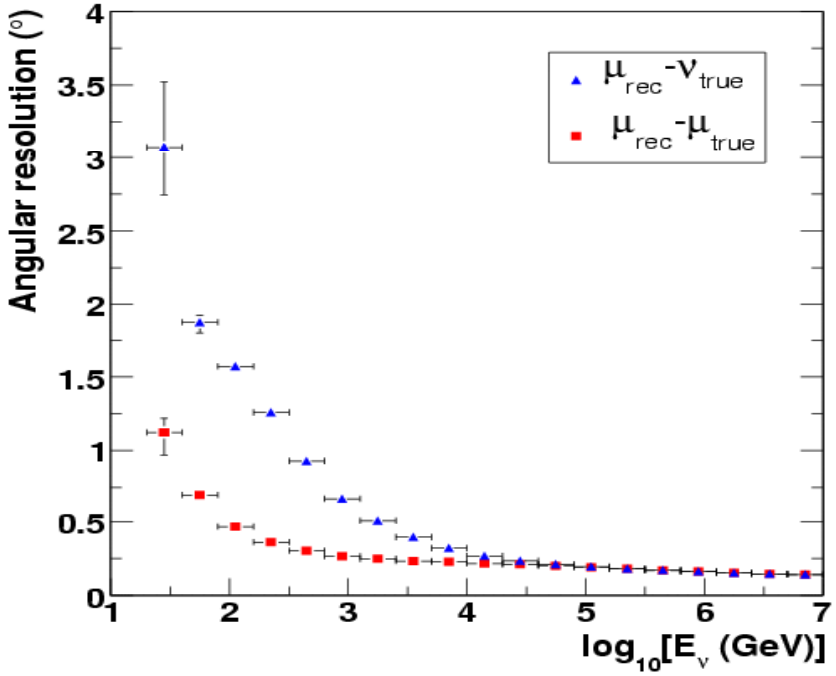


Optical Module:
10” Hamamatsu PMT in 17” glass sphere
photon detection
📖 NIM A484 (2002) 369
📖 NIM A555 (2005) 132

Hydrophone:
acoustic positioning

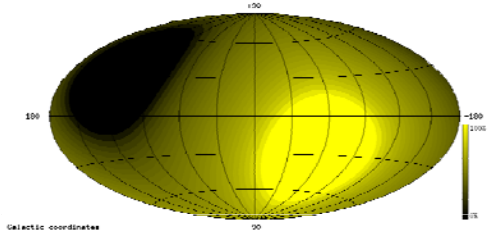
Detector performance



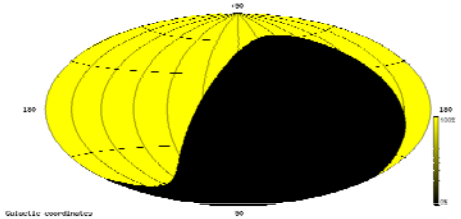


- Neutrino effective area is > 1 m^2 for energies > 100 TeV
- Angular resolution better than 0.3° above a few TeV,.

Sky view



Antares/KM3NeT



Amanda/IceCube

Deployment

Data taking periods:

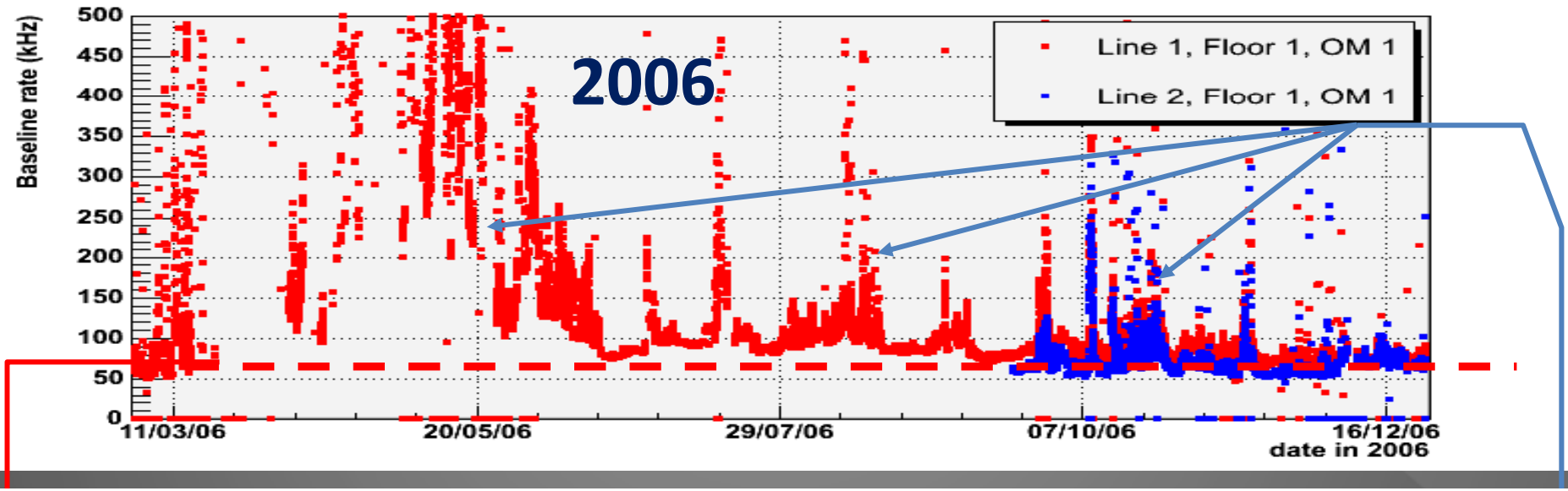
- ***MILOM : Mar '05 – Mar '06***

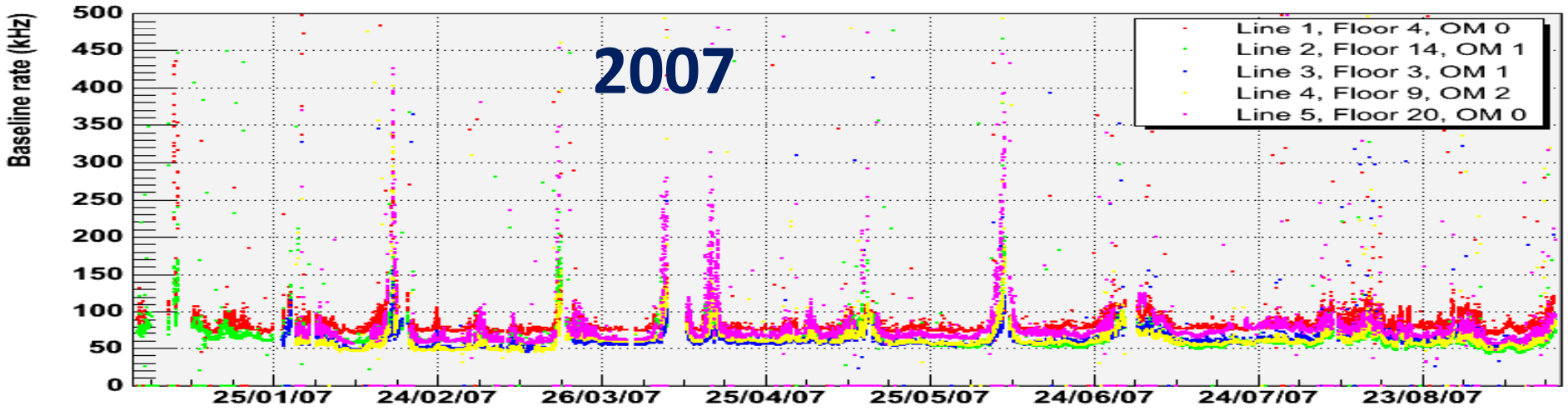
La Seyne-sur-Mer

(40 km)

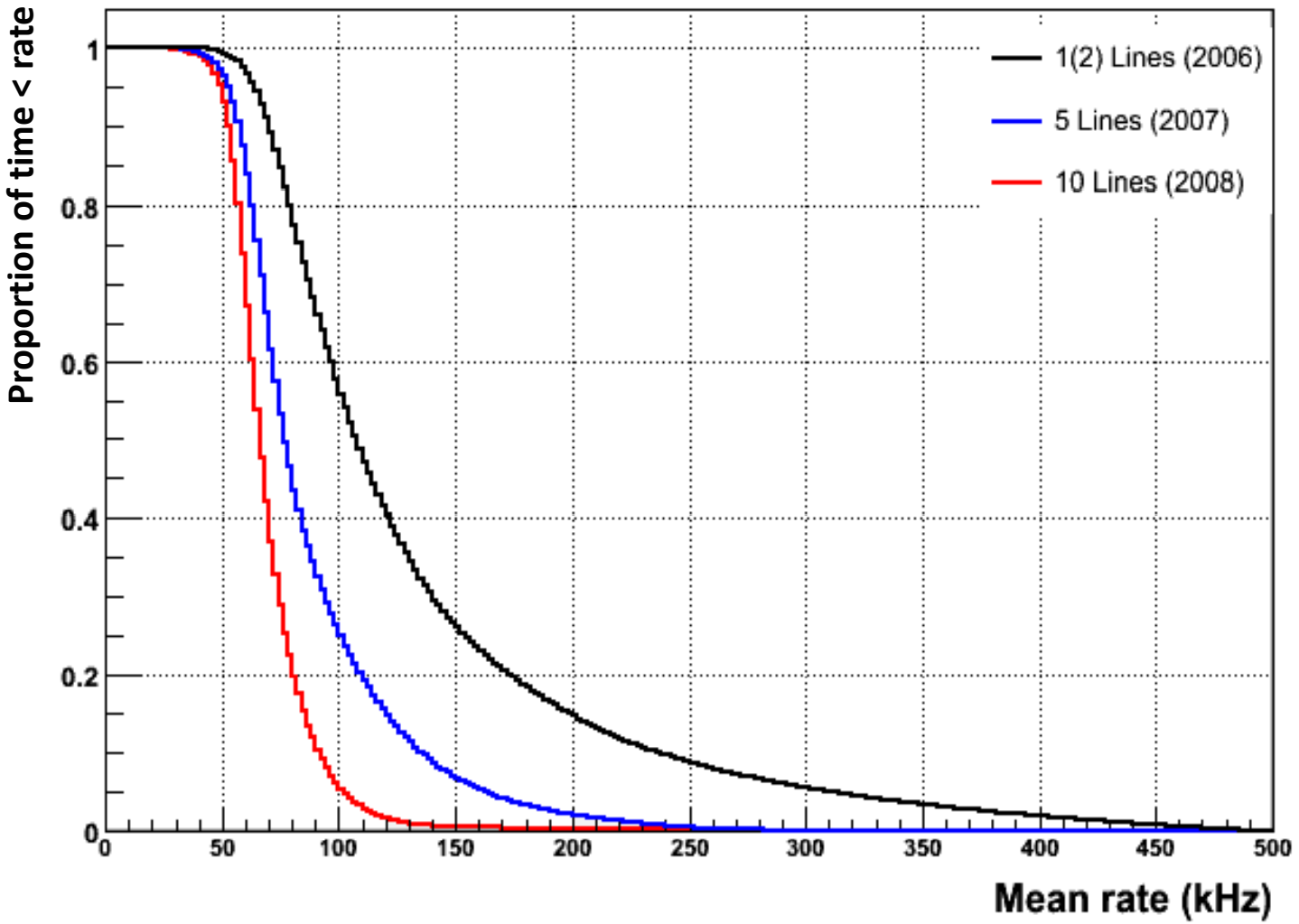
(2.5 km depth)

Optical background

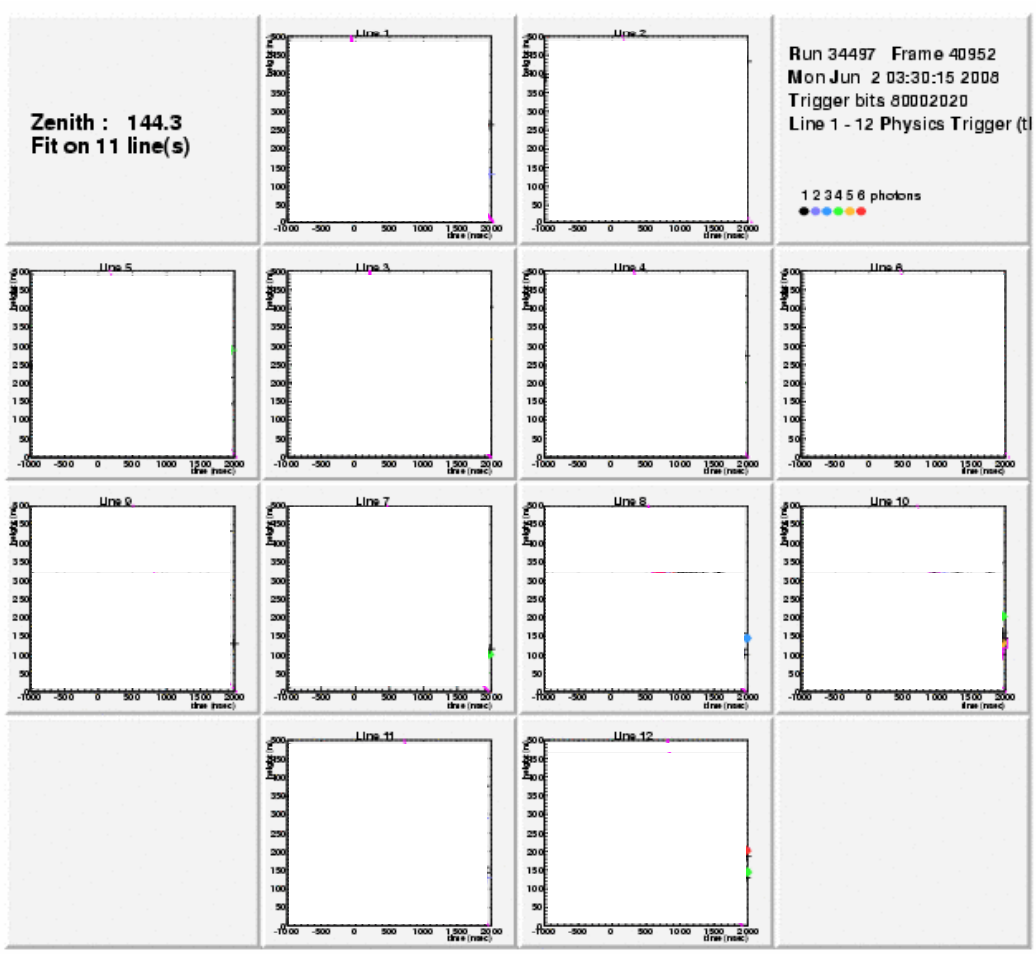




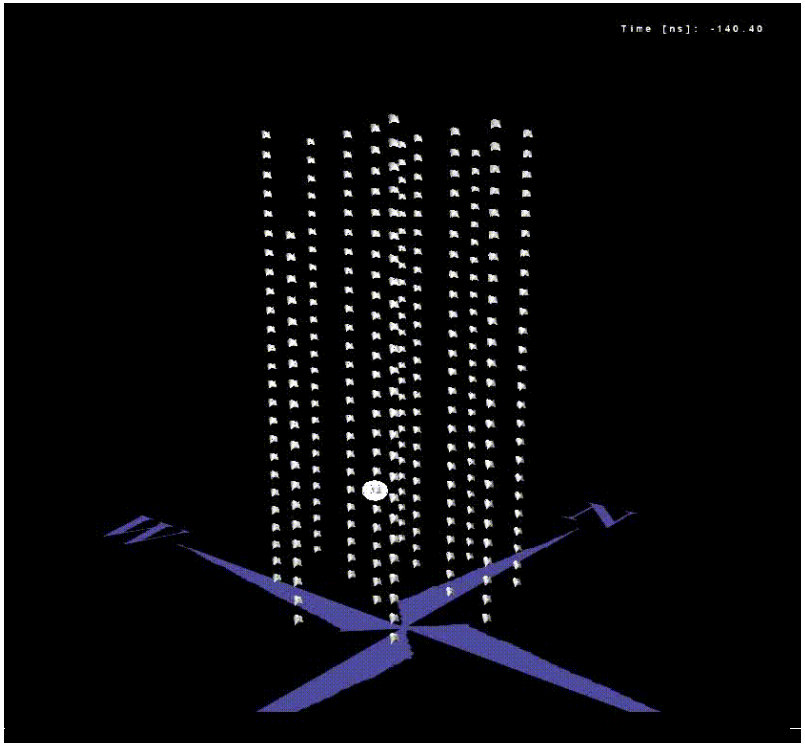
Optical background



(multi-) Muon Event

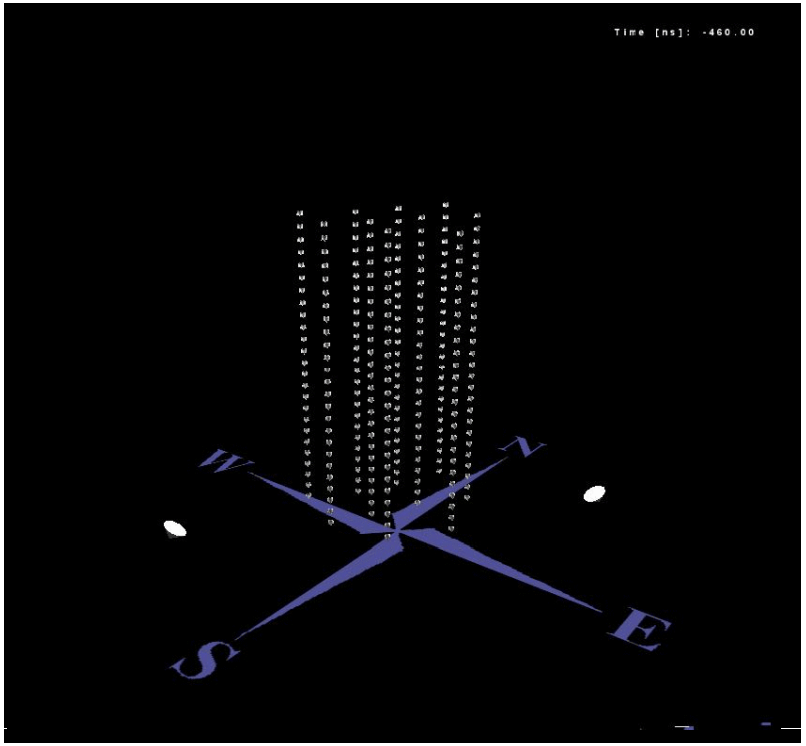


Example of a reconstructed down-going muon, detected in all 12 detector lines:

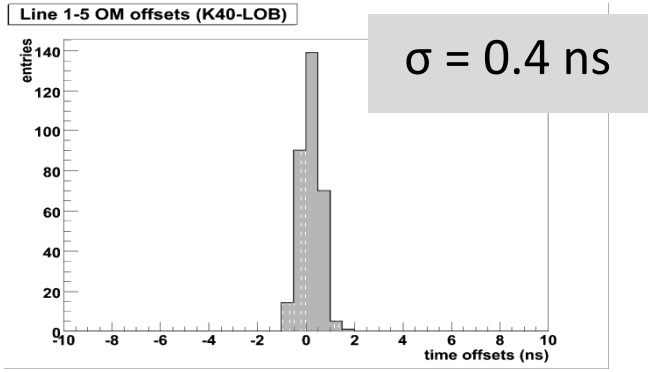


Neutrino candidate

Example of a reconstructed up-going muon (i.e. a neutrino candidate) detected in 6/12 detector lines:

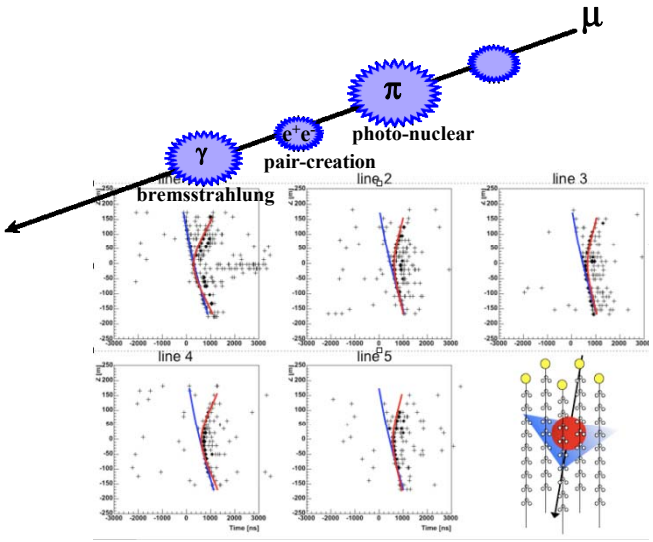


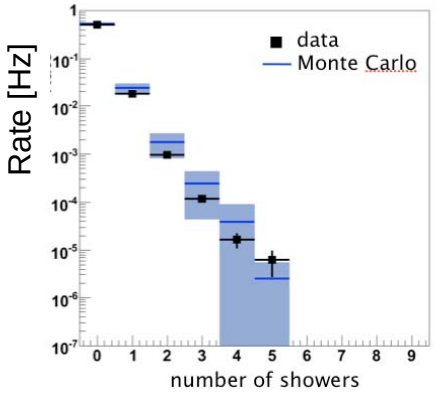
LED beacons – K40



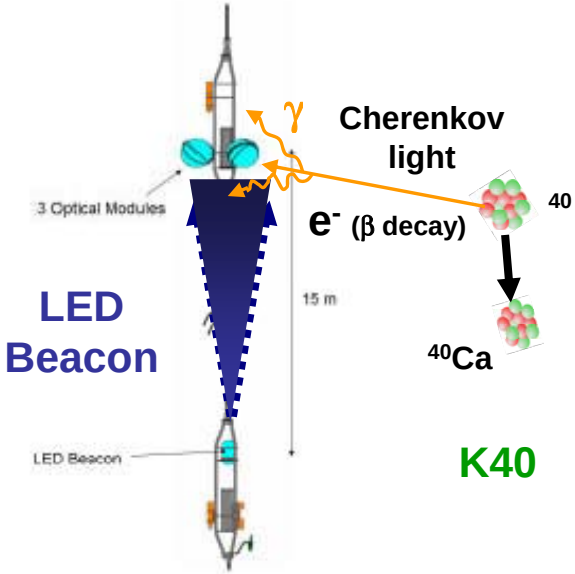
σ = 0.4 ns

Showers from μ's can be reconstructed

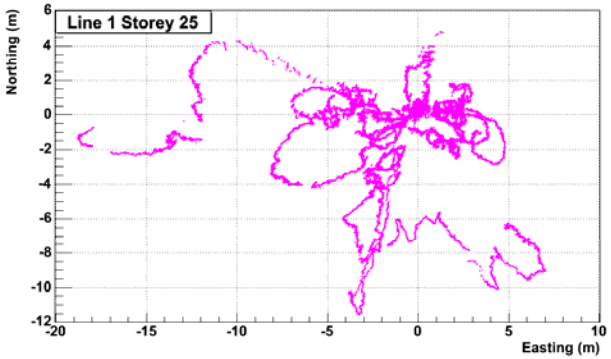




Time calibrated to < 0.5 ns

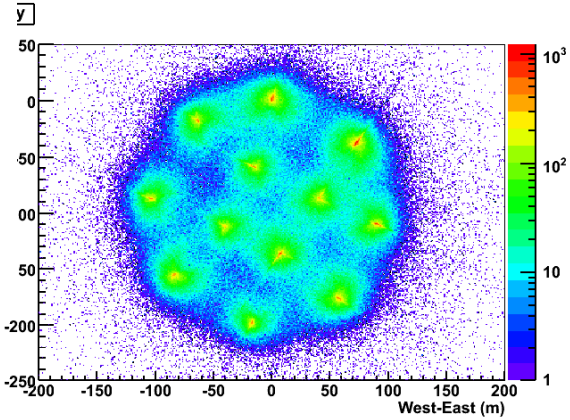


K40



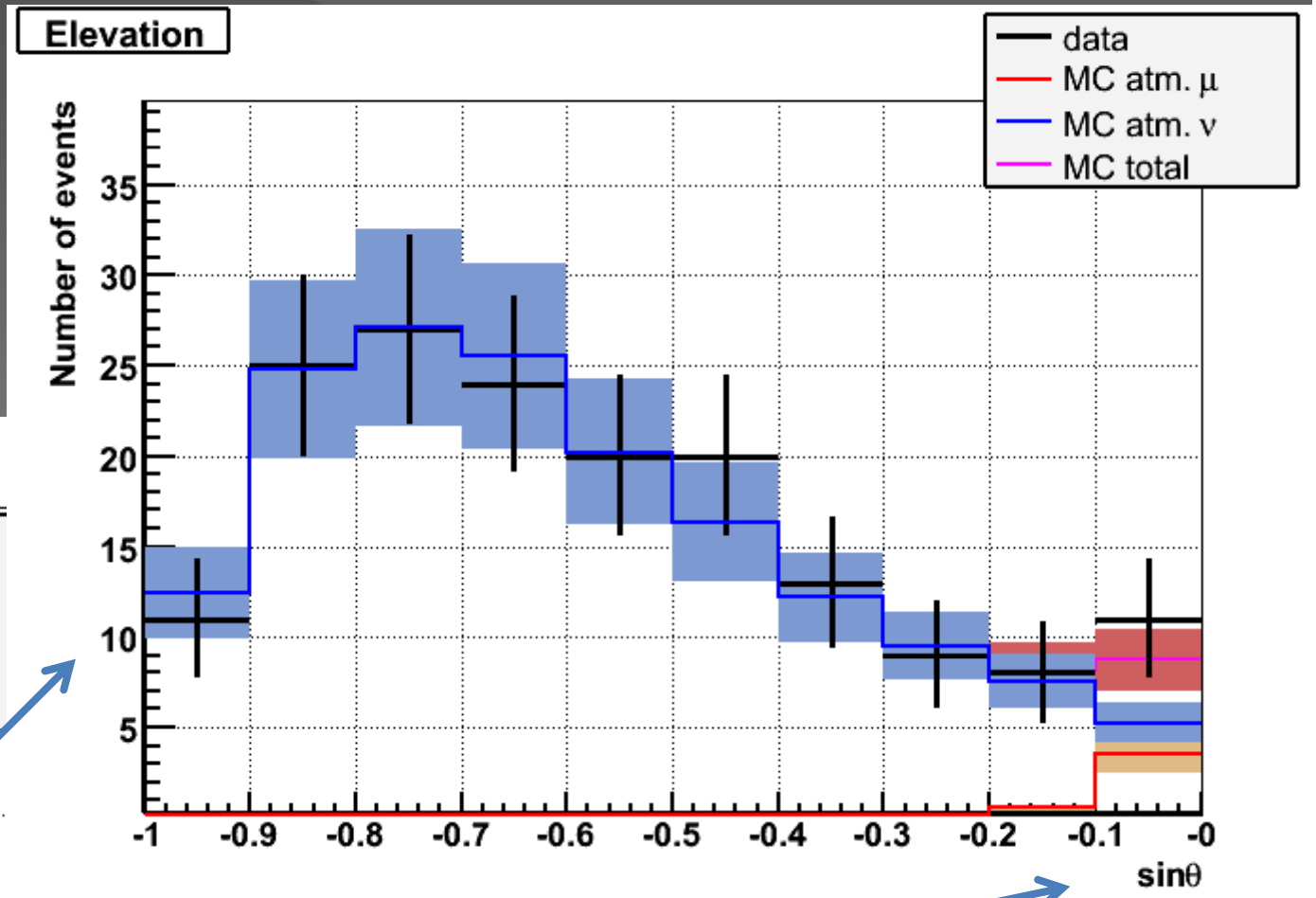
Positioning ~ 10 cm

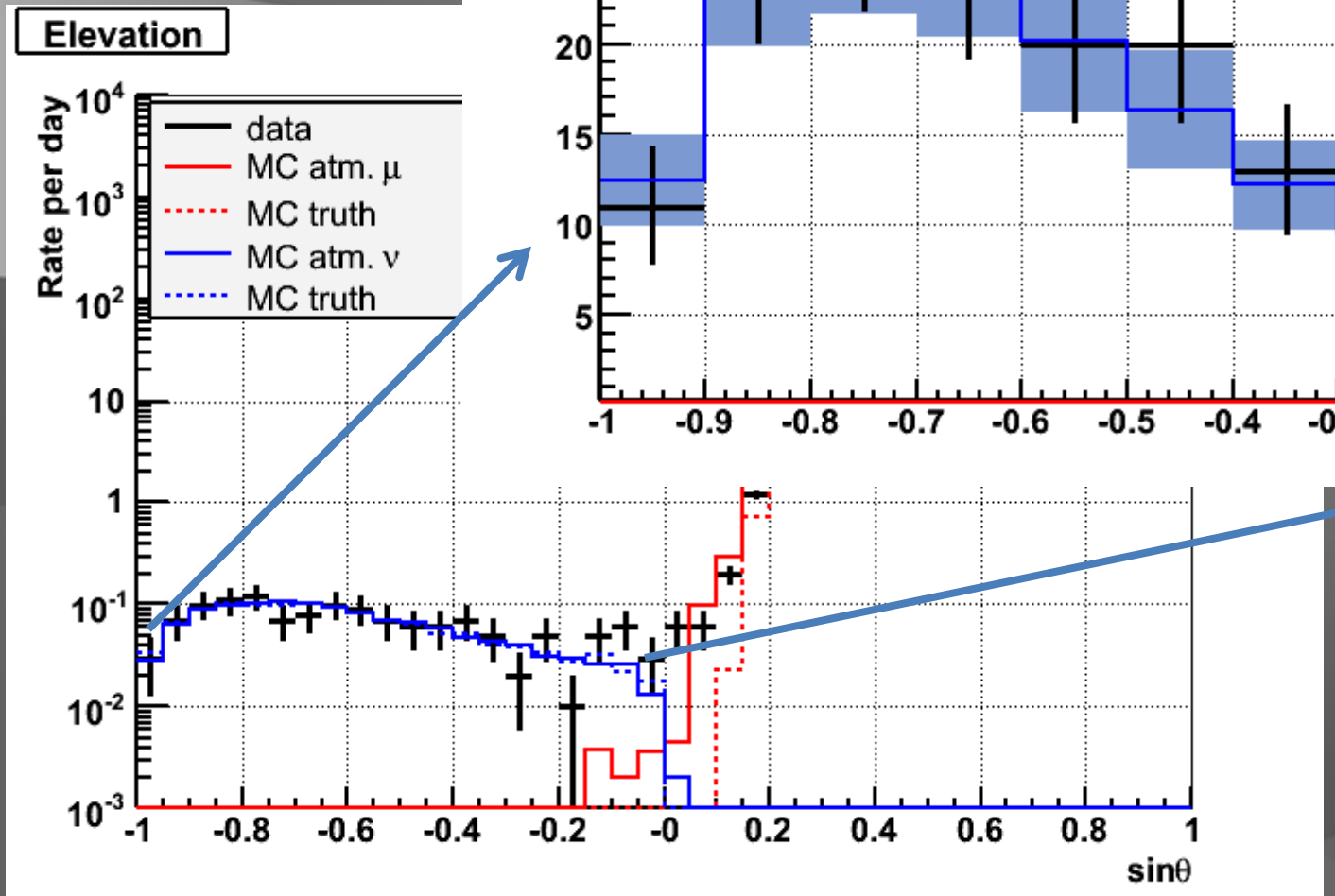
ANTARES as seen by atmospheric muons

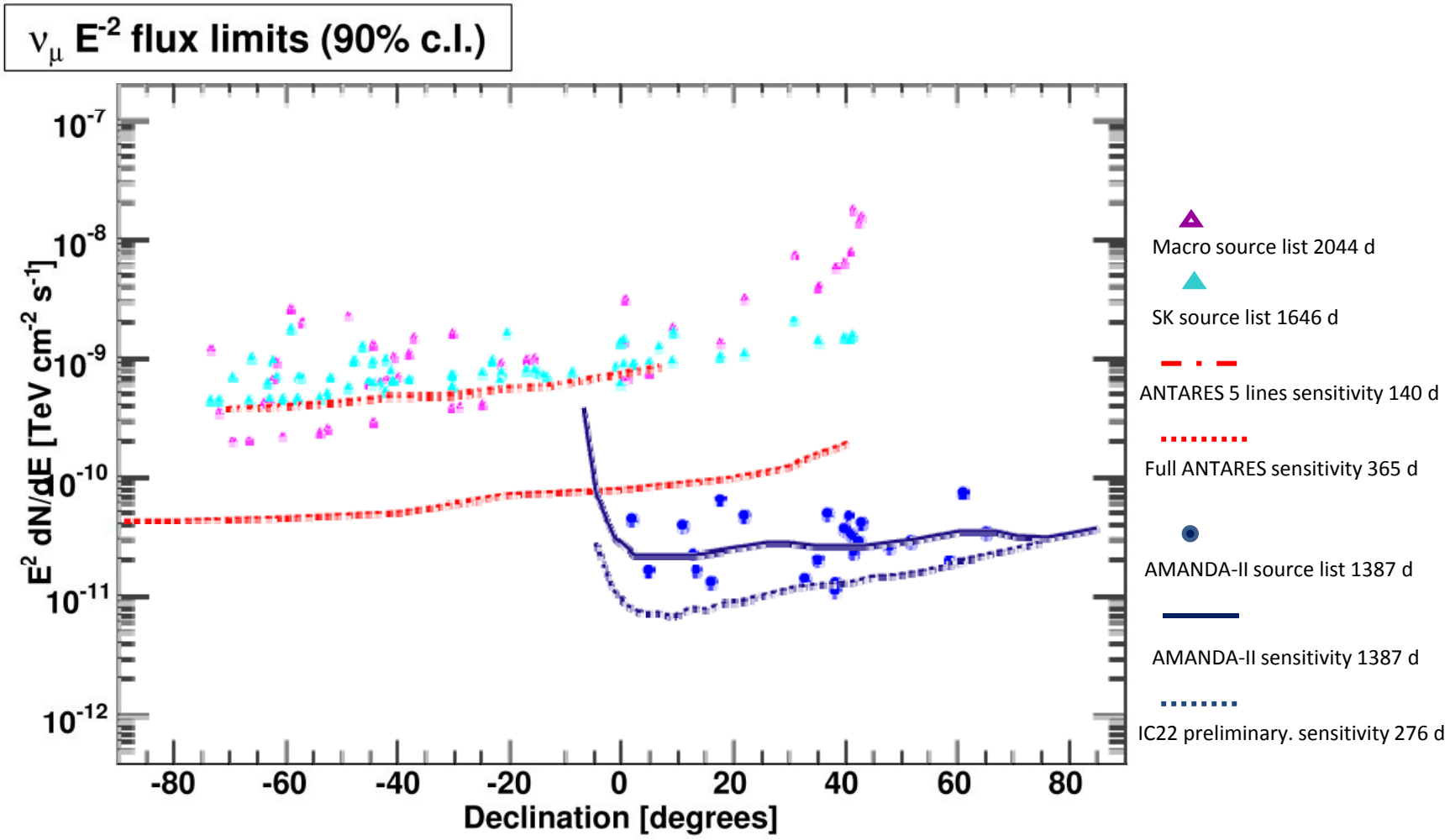


5-line data

1.3 events/day

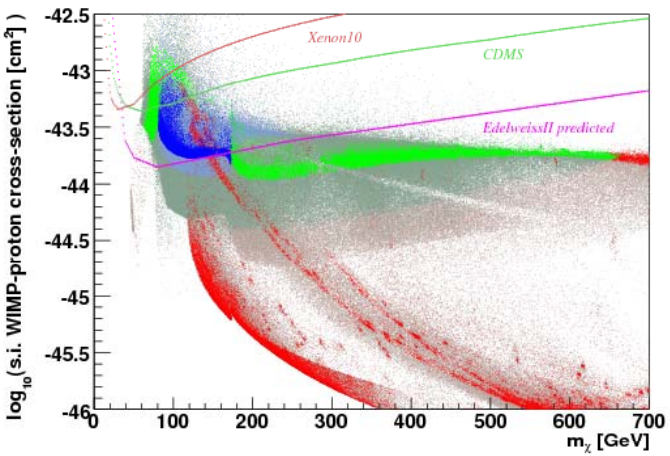




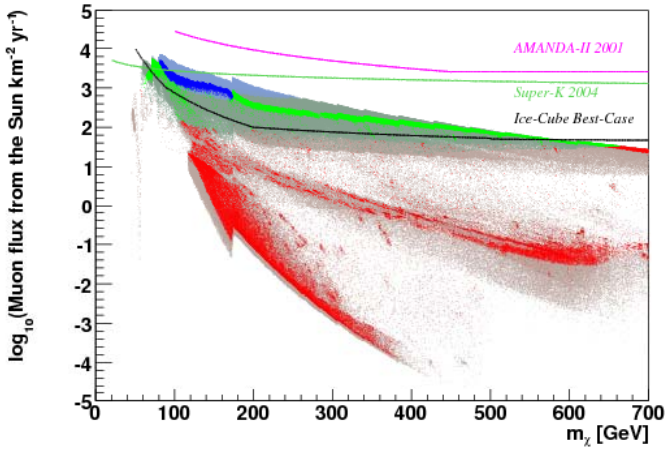

ν_μ E^{-2} flux limits (90% c.l.)
E^2 dN/dE [TeV cm^{-2} s^{-1}]
10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^{-11}
10^{-12}
-80
-60
-40
-20
0
20
40
60
80
Declination [degrees]
Macro source list 2044 d
SK source list 1646 d
ANTARES 5 lines sensitivity 140 d
Full ANTARES sensitivity 365 d
AMANDA-II source list 1387 d
AMANDA-II sensitivity 1387 d
IC22 preliminary. sensitivity 276 d

Dark Matter Search

S.I. WIMP-proton x-section (cm^2)



Muon flux (km^{-2} yr^{-1})



ANTARES and KM3NeT
3 year data taking
(From the Sun)

mSugra models favoured by WMAP
- 90% CL excludable by ANTARES
- 90% CL excludable by KM3NeT
- not excludable

mSugra models disfavoured by WMAP
- 90% CL excludable by ANTARES
- 90% CL excludable by KM3NeT
- not excludable

$0 < m_0 < 8$ TeV ; $0 < m_{1/2} < 2$ TeV
$0 < \tan\beta < 60$; $0 < A_0 < 3m_0$

Upper branch: Focus point region
$m_0 > 2$TeV; $m_{1/2} > 200$ GeV to right upper corner

Middle branch: A-annihilation
$\tan\beta = 50\text{-}60$

Lowest branch: co-annihilation-region
Low m_0 ; $m_{1/2} < 1.5$ TeV

Results from the unblinding of the 5-line data (~140 live days) are expected very soon (steady point sources, GRBs and neutralino search).

A variety of activities under way:

-Analysis of 10 line data is proceeding (~100 live days). Full detector (12 lines) since May 2008. **Hectic activity** on diffuse flux (including UHE ν's), point sources, GRBs and transient sources, etc

- Multi-messenger capabilities being pursued:
  - -ANTARES alerts to be sent to optical telescopes.
  - - Talks with VIRGO/LIGO soon to start for two-way alerts.
- Other searches ongoing (monopoles, nuclearites)

KM3NeT

A research facility in the Mediterranean Sea

- A next generation neutrino telescope
- Cabled observatory for Earth and Marine sciences

+

+

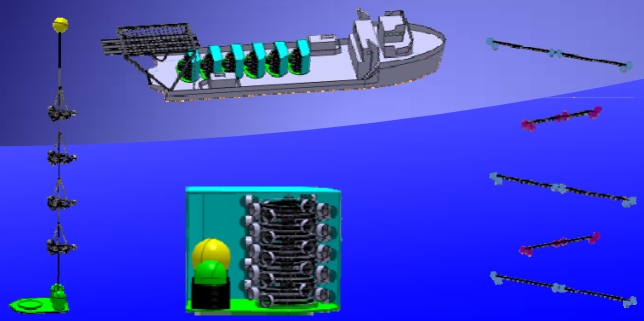
+...

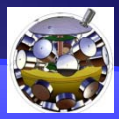
40 institutes from 10 European countries

Design goals

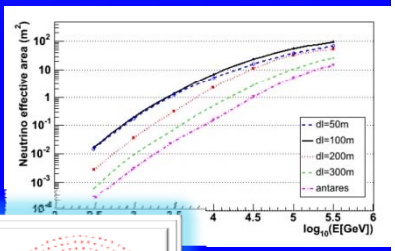
- Substantially better sensitivity than IceCube
- > 1 km^3
- Core process:
  $\nu_\mu + N \rightarrow \mu + X$ at neutrino energies above 100 GeV
- Construction and deployment < 4 years
- Data taking period > 10 year
- Optimized for energy range 1 TeV – 1 PeV
- Angular resolution < 0.1^o
- Zenith angle:
  - Full acceptance for neutrinos originating from directions up to at least 10^o above the horizon
  - For energies > 100 TeV angular acceptance limited only by the absorption of the Earth

Design proceeding well…

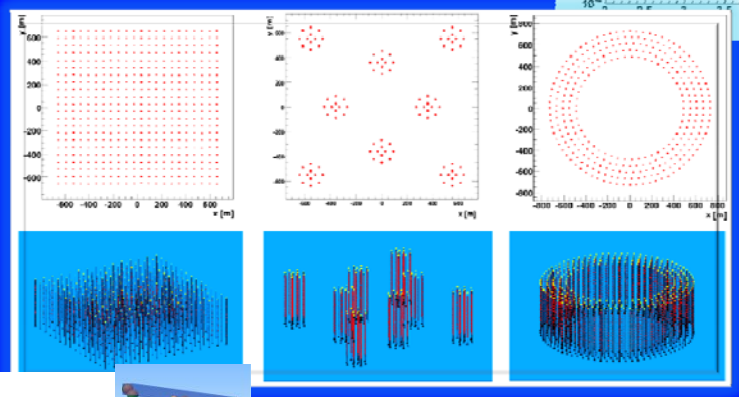




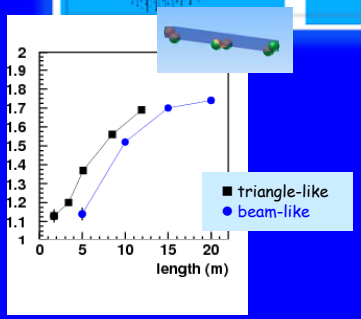
Several photo-sensors and optical module arrangements studied.



Self-unfolding structures for massive deployment



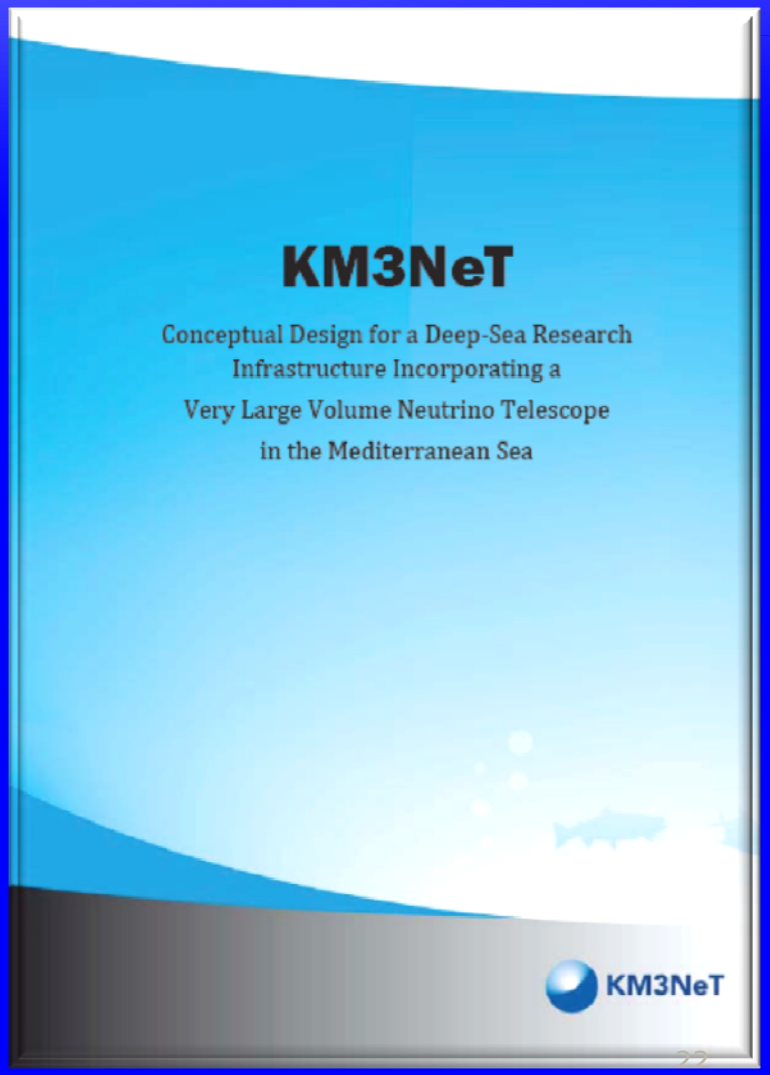
… + studies on data transmission, power distribution, time calibration and positioning, marine operations,



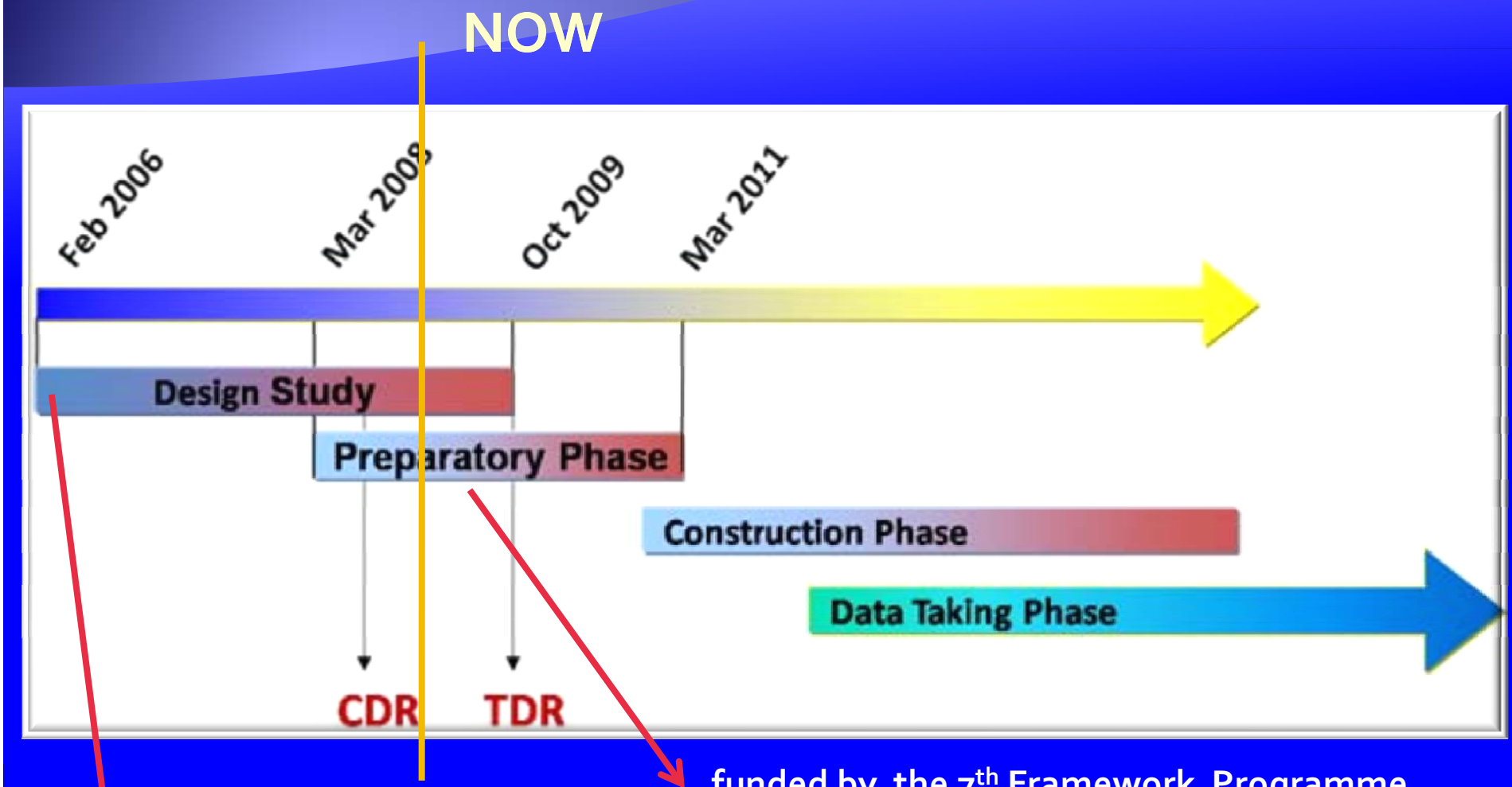
Performance in terms of effective area and resolution for different configurations have been studied

Conceptual Design Report

- Released on April 2008
- Available at **www.km3net.org**
- Includes:
  - Science case
  - Site studies
  - Design goals
  - Technical implementation
- Design Study funded by the 6th Framework Programme of the European Commission



KM3NeT project timeline



Conclusions

• ANTARES completed. The largest neutrino telescope in the Northern Hemisphere. Results from the 5-line configuration very soon.

• KM3NeT Conceptual Design Report ready. Technical Design Report next year.

– Supported by ESFRI, ASPERA and ASTRONET.

– Design Study and Preparatory Phase funded respectively by the 6th and 7th Framework Programmes of the European Commission

– Construction could start as early as 2011