The KM3NeTdeep sea neutrino telescope project

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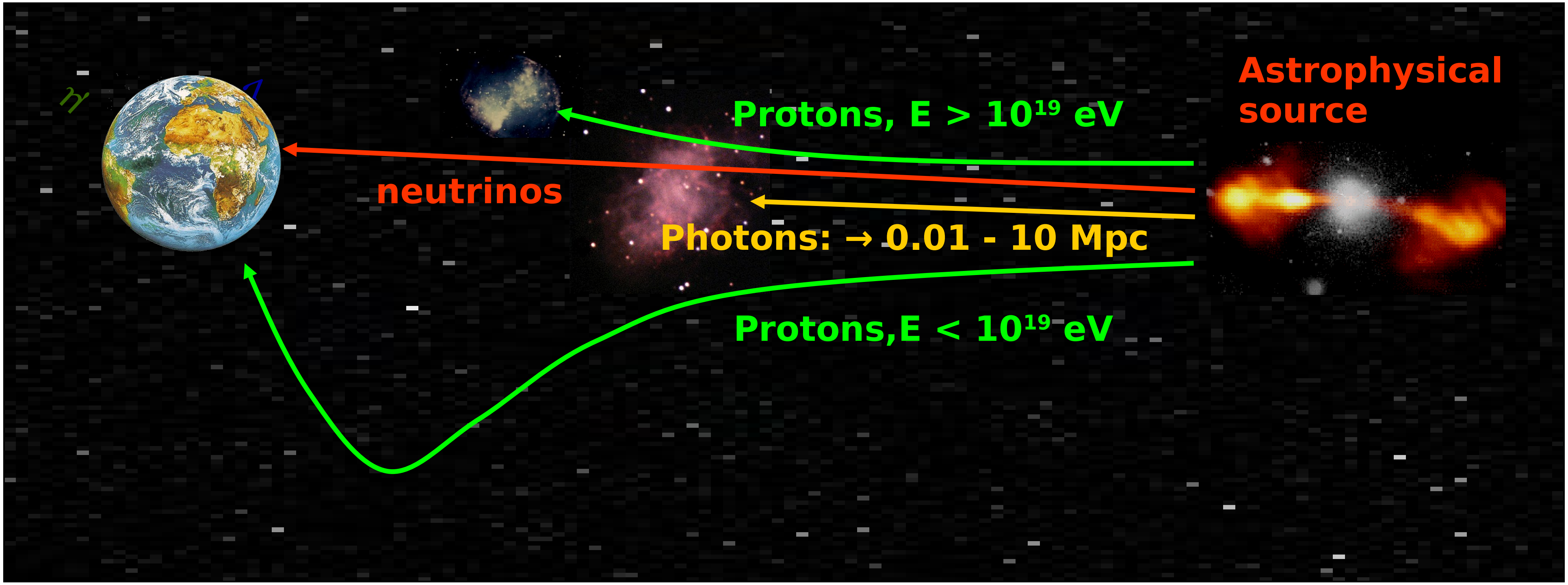
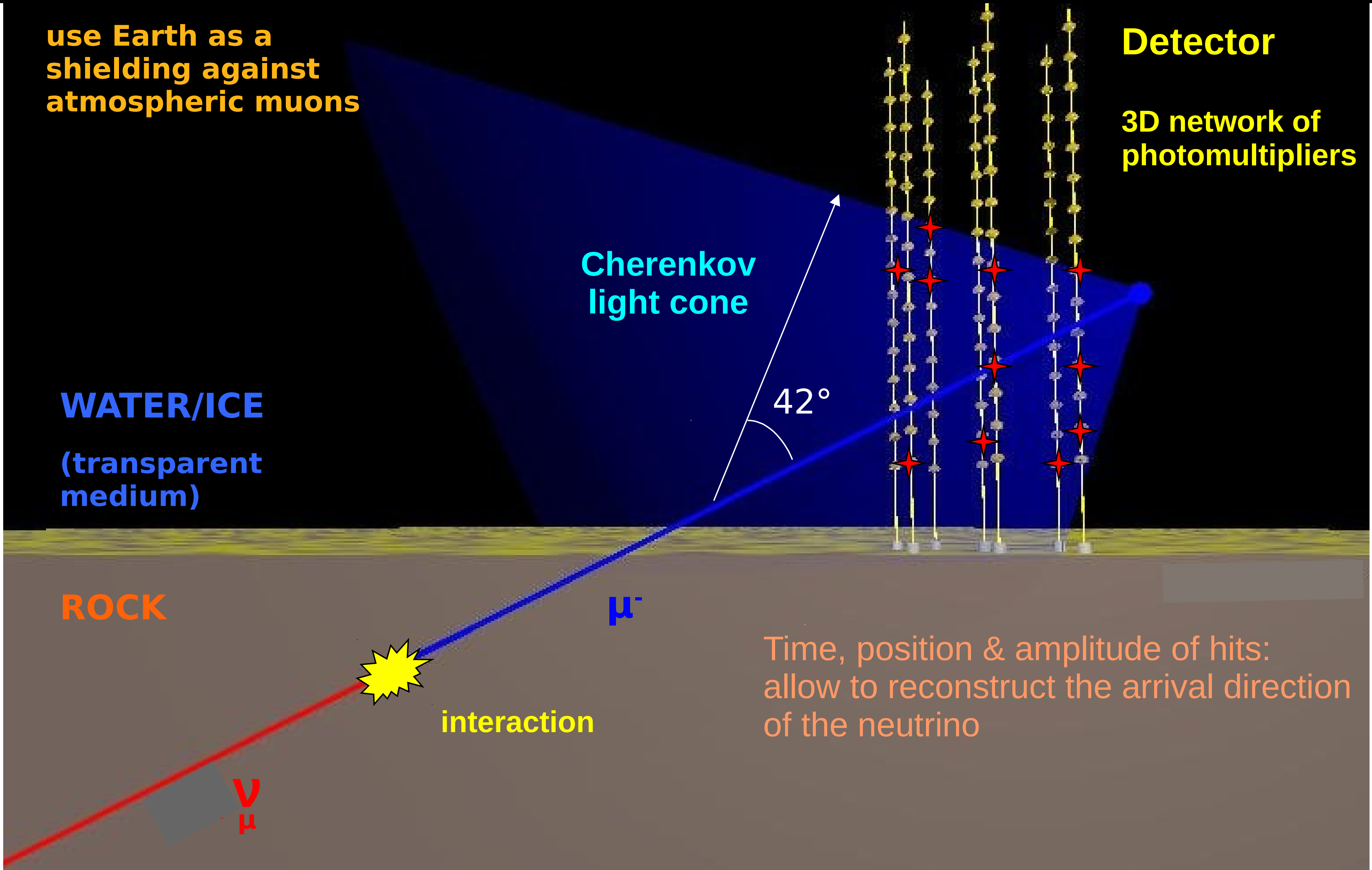
- Neutrino astronomy: why and how
- The KM3NeT project: physics goals & technical constraints
- Technical design & optimization
- Expected performance
- Timeline and perspectives

Neutrino astronomy : motivations



- Long-range, deep-source messenger:
  no interactions (or weak/gravitational ones) with ambient matter & radiation,
  no deflection by magnetic fields
  carry information on the internal processes of the astrophysical engines, unaccessible through photons or hadrons
- Unique probe of fundamental processes:
  origin of UHE cosmic rays ?
  production mechanism of HE gamma-rays (hadronic vs leptonic) ?
  nature of dark matter ?
- Discovery potential for hidden sources (not detected through E-M radiation)

Detection principle



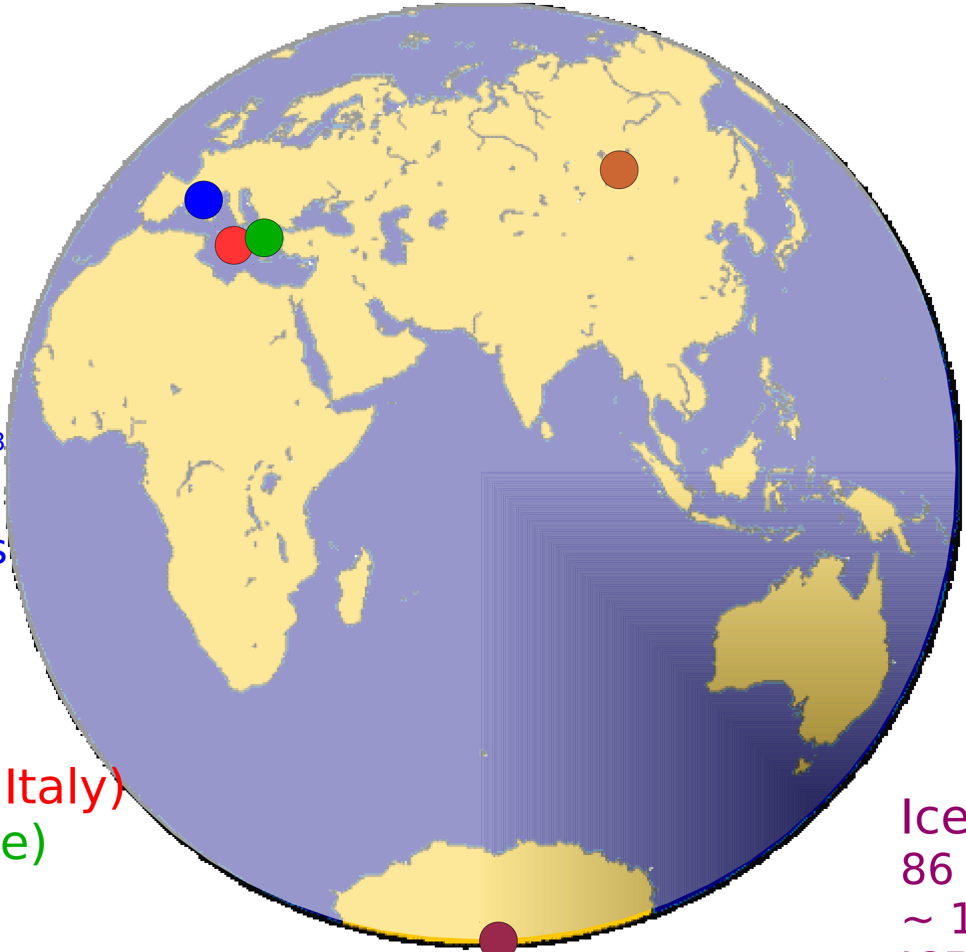
golden channel for astronomy (but ν_e,ν_τ -induced showers also interesting)

World map of neutrino telescopes

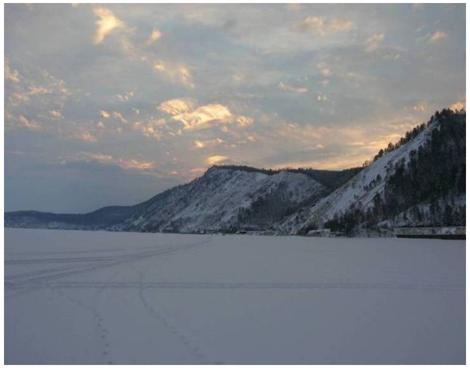
Mediterranean telescopes:

ANTARES (Toulon):
12 lines operating
since 2008, ~ 0,015 km^3
instrumented volume
2007-2009 data analysis
ongoing (5L $\rightarrow$ 12L)

NEMO (Capo Passero, Italy)
NESTOR (Pylos, Greece)
prototyping phase



Lake Baikal:
NT200+ since 2005
since 2008: 2 prototype strings
for a km^3-scale detector



Ice Cube:
86 strings in 2011
~ 1 km^3 instrumented volume
IC59 analysis ongoing

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ANTARES + NEMO + NESTOR
joined efforts to build a (few) km³-sized
neutrino telescope in the Mediterranean:

KM3NeT consortium

40 Institutes from 10 european countries
(CY,DE,F,GR,I,IR,NL,RO,ES,UK)
mainly Astroparticle Physics, but also several
Marine & Earth Science Institutes

MAIN OBJECTIVES:

- Neutrino astronomy in the Southern sky
- Exceed IceCube sensitivity by substantial factor
- > 10 yr operation without major maintenance
- Provide infrastructure for Marine & Earth Sciences

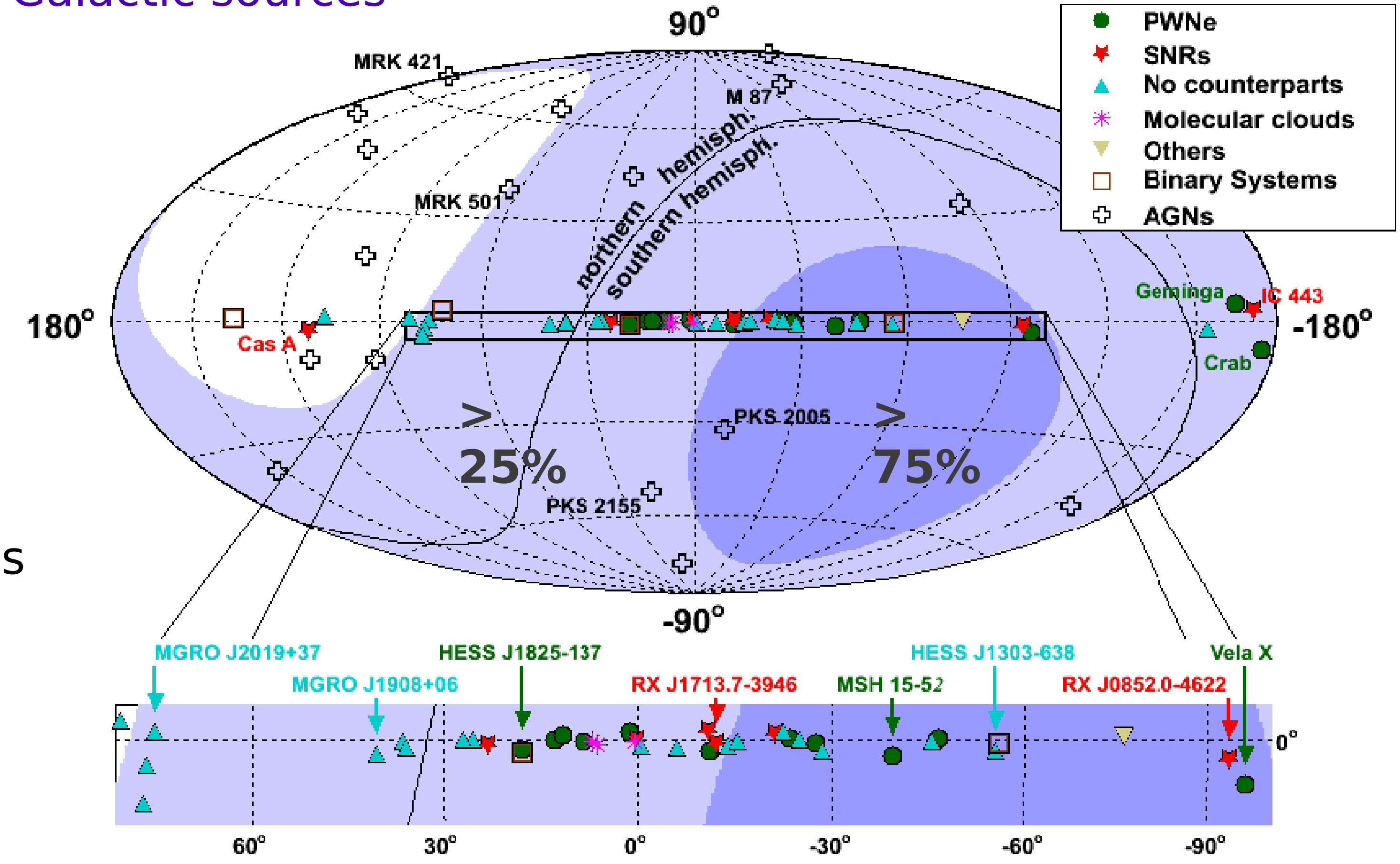
OVERALL BUDGET: ≤ 250 M€

KM3NeT: Physics goals

- Central physics goal: investigate (extra-)galactic neutrino "point sources" (steady and transients) in the energy regime 1-100 TeV
- Exceed IceCube sensitivity: several km^3 needed
- Complement IceCube field of view

integrated visibility: ~ 3,5 π (visibility of individual sources can be < 100% at KM3NeT latitude)

Optimal sensitivity for Galactic sources



(assuming instantaneous 2π downward coverage)

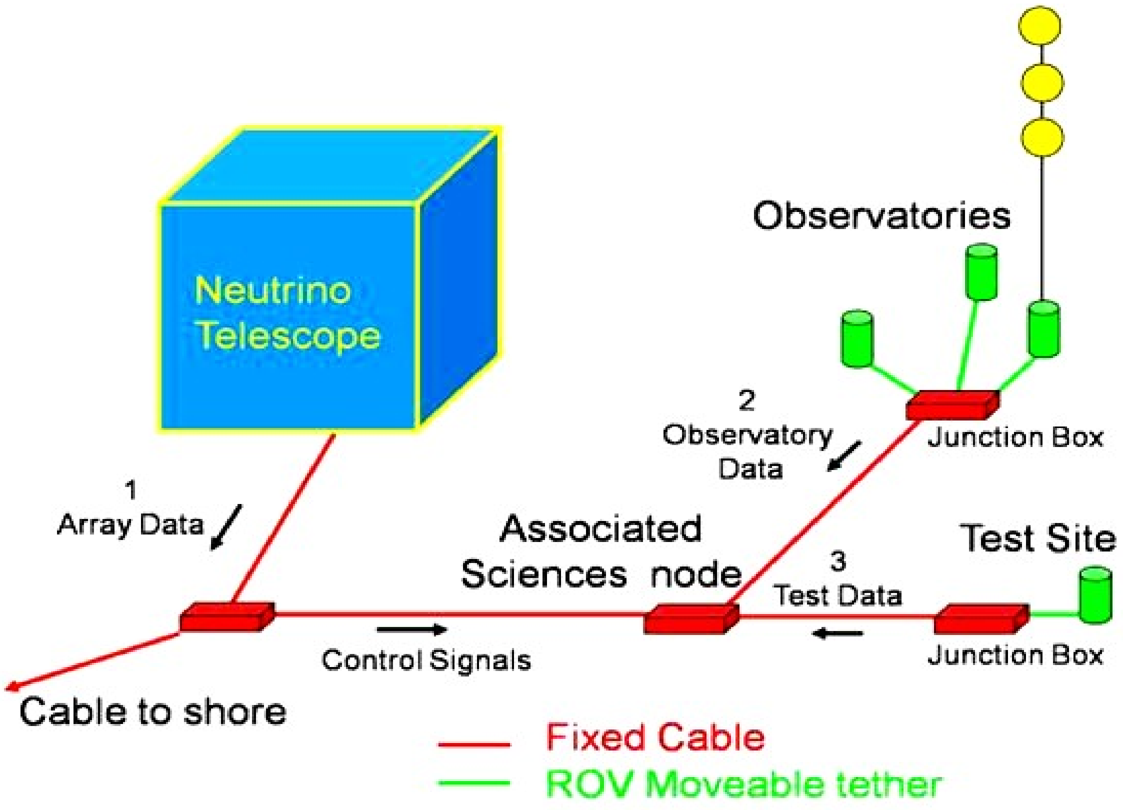
KM3NeT: Physics goals...and more

Other important physics items:

- High energy diffuse neutrino flux detection
- GZK neutrinos and link with UHE cosmic rays
- Indirect search for Dark Matter
- Neutrino particle physics aspects
- Exotics (Magnetic Monopoles, Lorentz invariance violation, ...)

Interdisciplinary research

- marine biology
- geology/geophysics,
- oceanography,
- environmental studies & alerts



Technical constraints

MAIN GOAL: mechanically support a 3D array of optical sensors and connect them to shore (power, slow control, data transmission)

- Site & environmental constraints:
  - 3–5 km depth → tests at 600 bars
  - 40-100 km offshore → long-distance data transmission
  - salinity of sea water → resistance to chemically aggressive medium
  - sea currents → flexible structure
  - optical background from ^{40}K decay → local coincidences required

- Implementation:
  - construction time < 5 years
  - reliable & efficient deployment strategy
  - operation over at least 10 years without major maintenance

- Main performance targets:
  - position resolution of optical modules < 40 cm
  - single-photon time resolution < 2 ns
  - dark noise rate < 20% of ^{40}K rate
  - optical module failure rate < 10% over 10 years

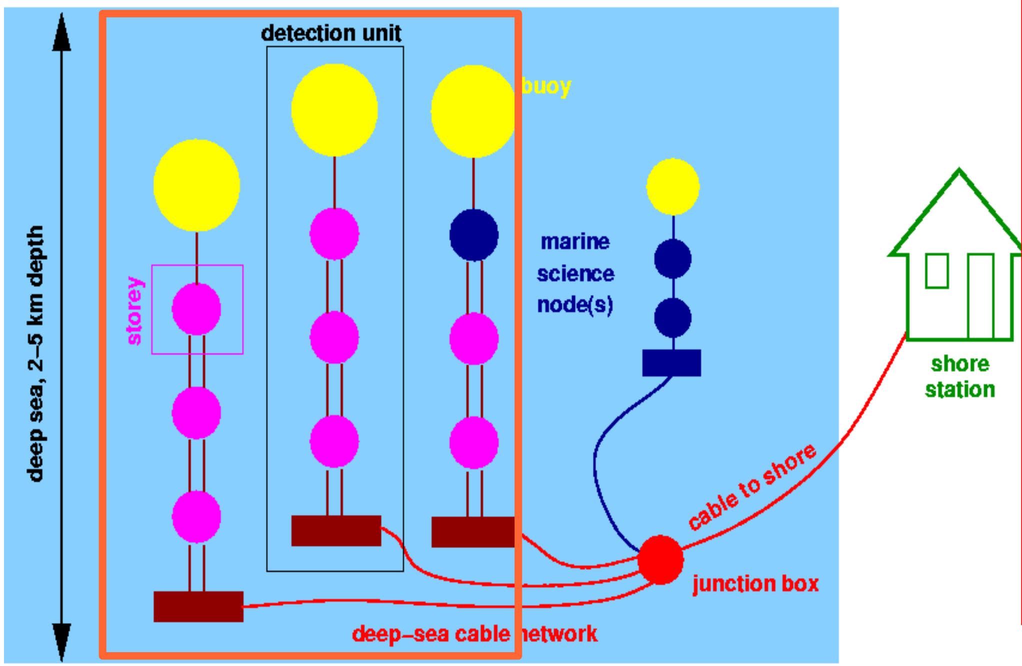
Technical design

Addressed during the KM3NeT Design Study (DS) (funded by EC FP6 2006-2009)
- 2008: Conceptual Design Report (CDR)
- 2010: Technical Design Report (TDR)

outlines the main technological options for the construction, deployment and maintenance of a deep-sea neutrino telescope

see http://www.km3net.org/public.php

Research Infrastructure:
building blocks (BB) made of detection units (DU) made of storeys



building block

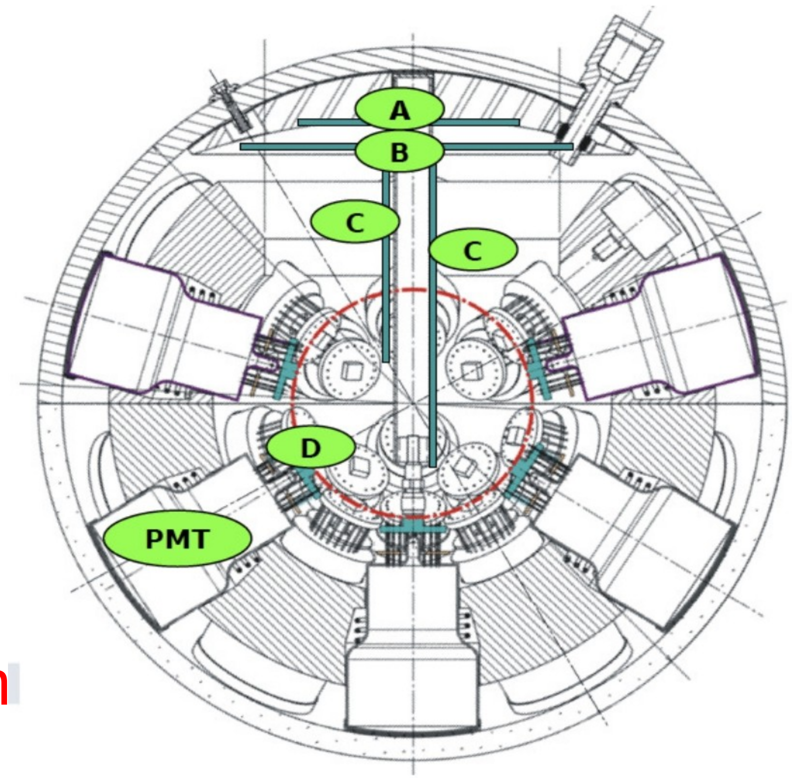
Technical items:

- Optical Modules
- Front-end electronics
- Readout, data acquisition, data transport
- Mechanical structures, backbone cable
- General deployment strategy
- Sea-bed network: cables, junction boxes
- Calibration devices
- Shore infrastructure
- Assembly, transport, logistics
- Risk analysis and quality control

Multi-PMT Optical Module

31 small PMTs (3”) inside a 17” (~ANTARES) glass sphere

- 31 PMT bases
  (total ~140 mW)
- cooling shield and stem
- single penetrator
- readout electronics inside OM
- total photocathode area equivalent to 3 x 10” PMTs

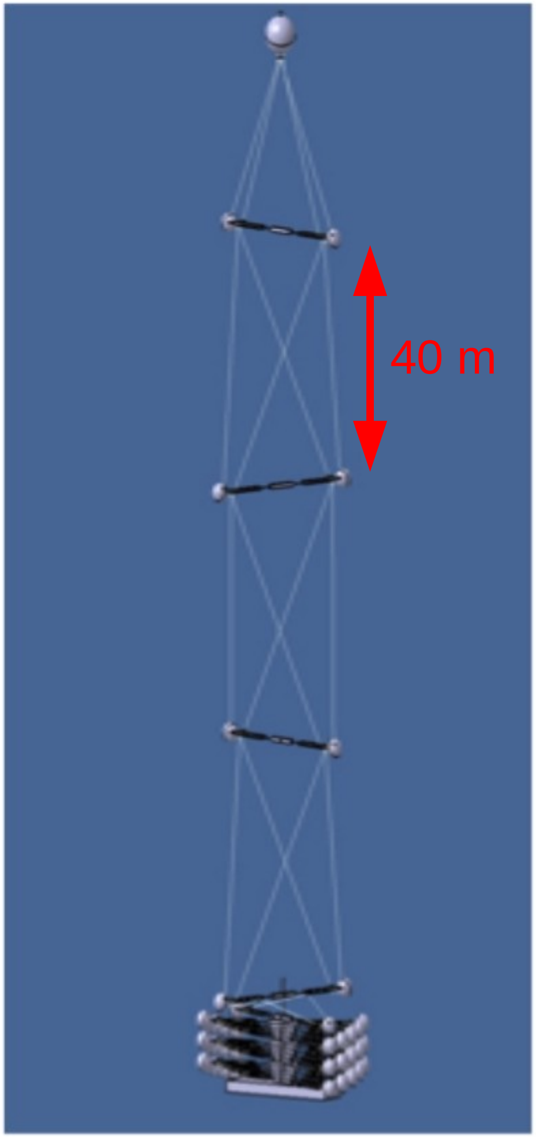


local coïncidences, directional information

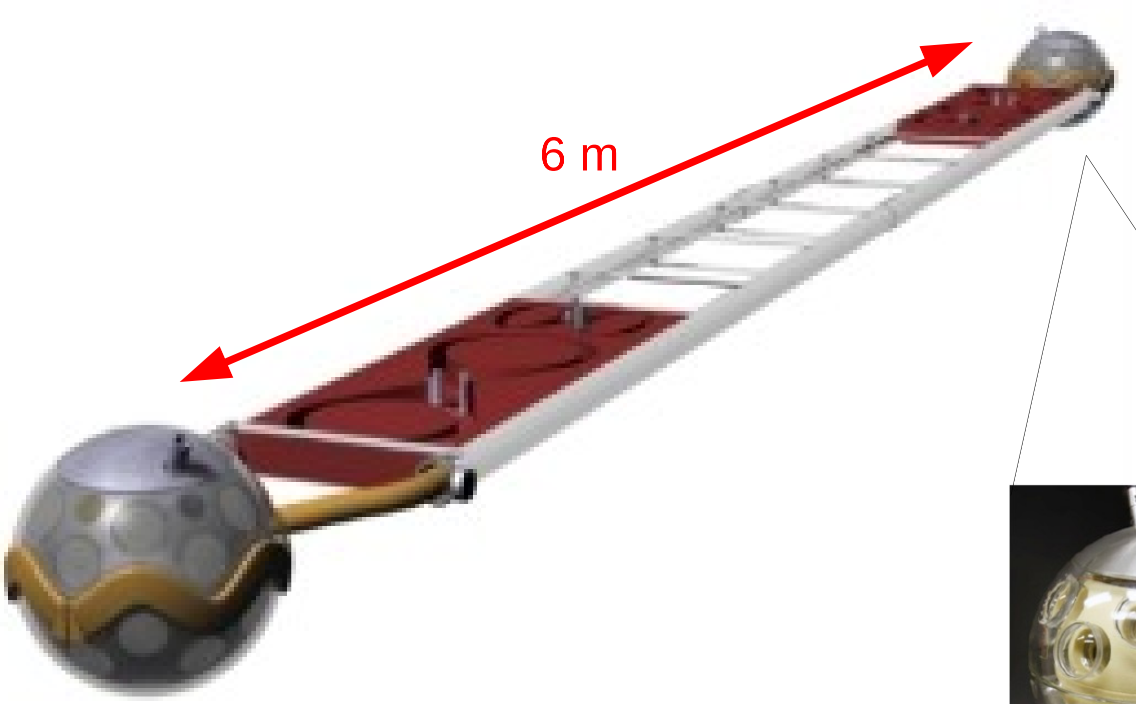
In situ tests on ANTARES Instrumentation Line
In summer 2011

Detector units

- Local 3D arrangement of optical modules help resolve ambiguities in the reconstruction of the muon track



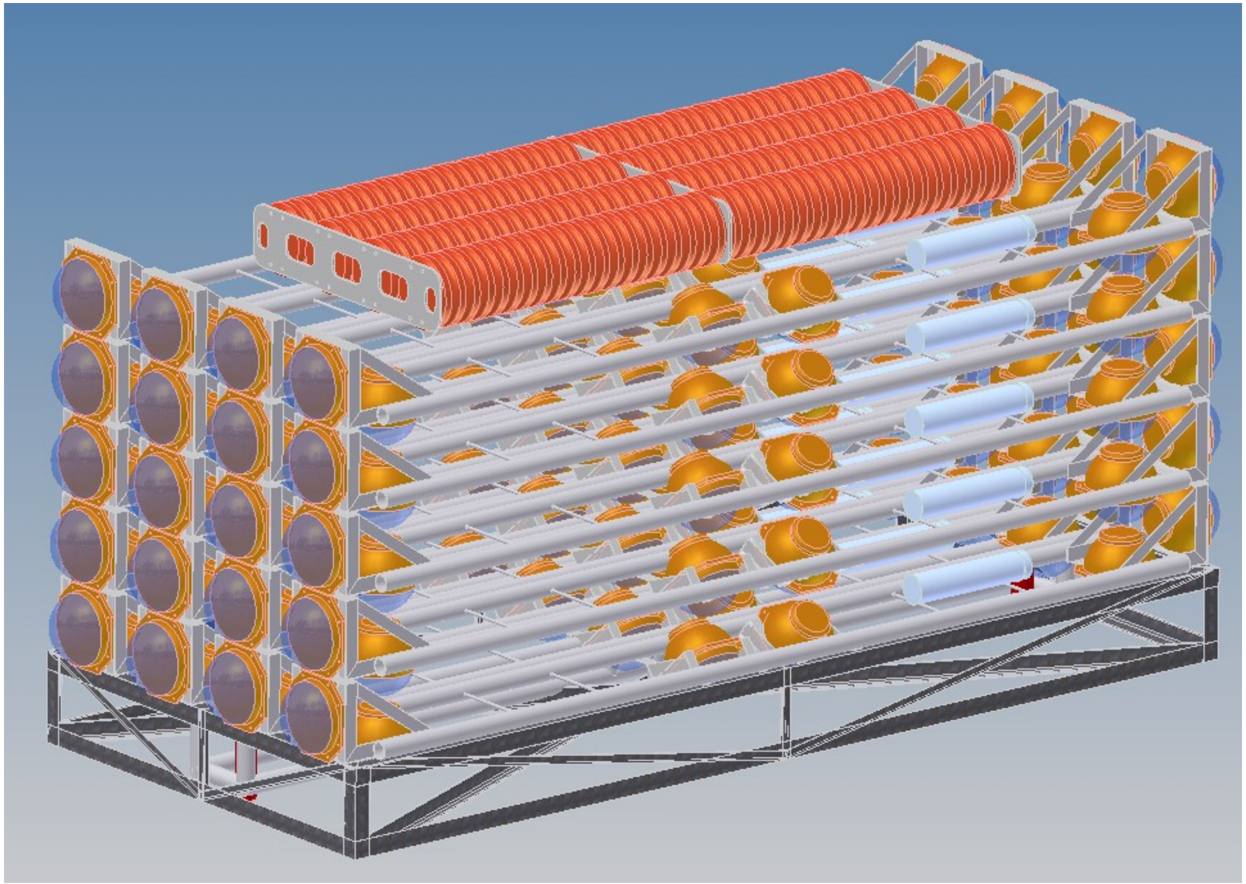
Flexible tower with horizontal bars



20 bars equipped with
2 multi-PMT OMs:

Deployment strategy

- Requirements:
  - compact package
  - self-unfurling
  - connection to seabed network by remotely operated vehicle (ROV):



Packaged bars:
unfurling « «from top to bottom »

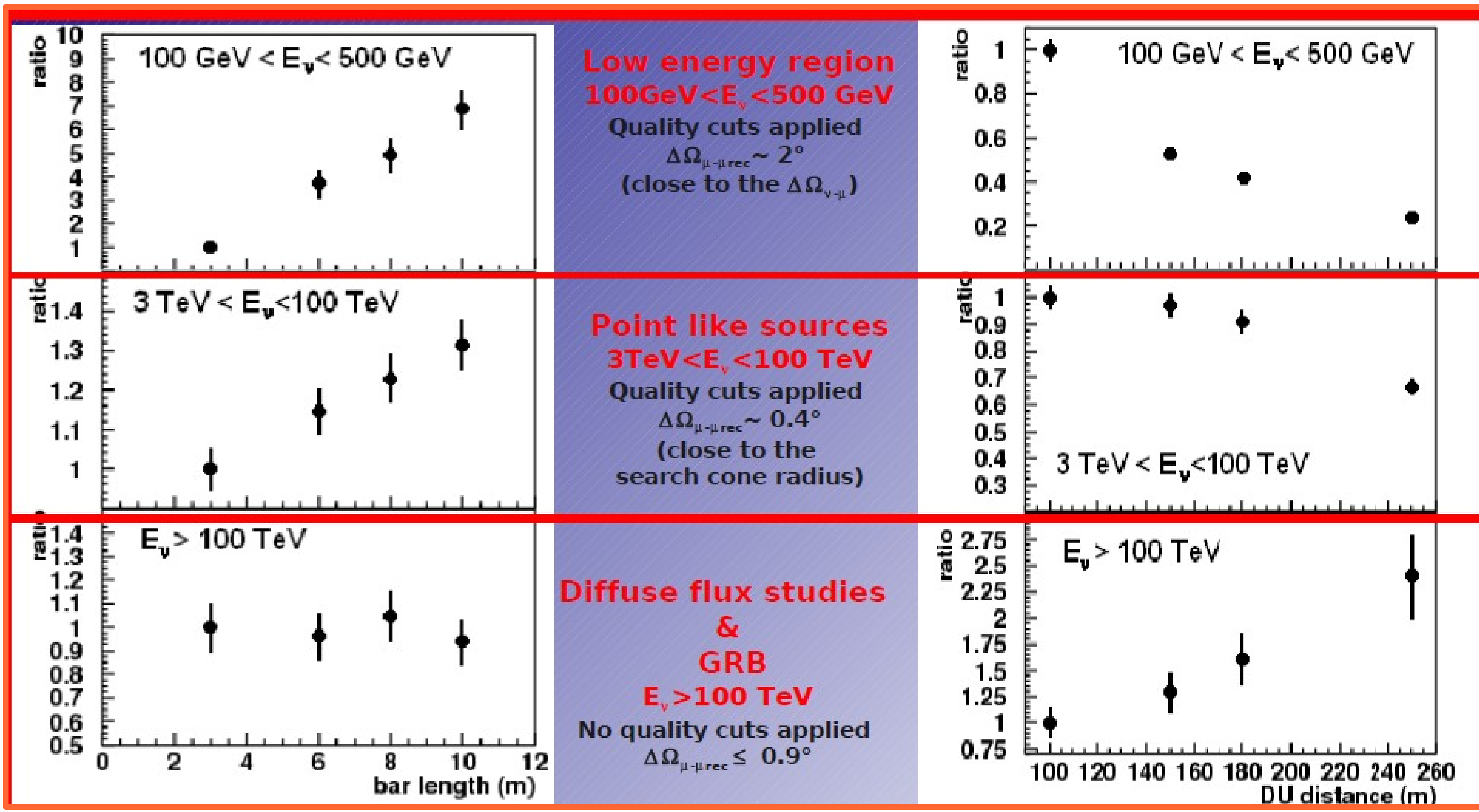
successfull deployment test
in February 2010:

Optimization studies

★ Critical parameters: size and spacing of the detector units

Bar length — ratio of effective areas wrt. 3 m bar

DU separation — ratio of effective areas wrt. 100 m spacing



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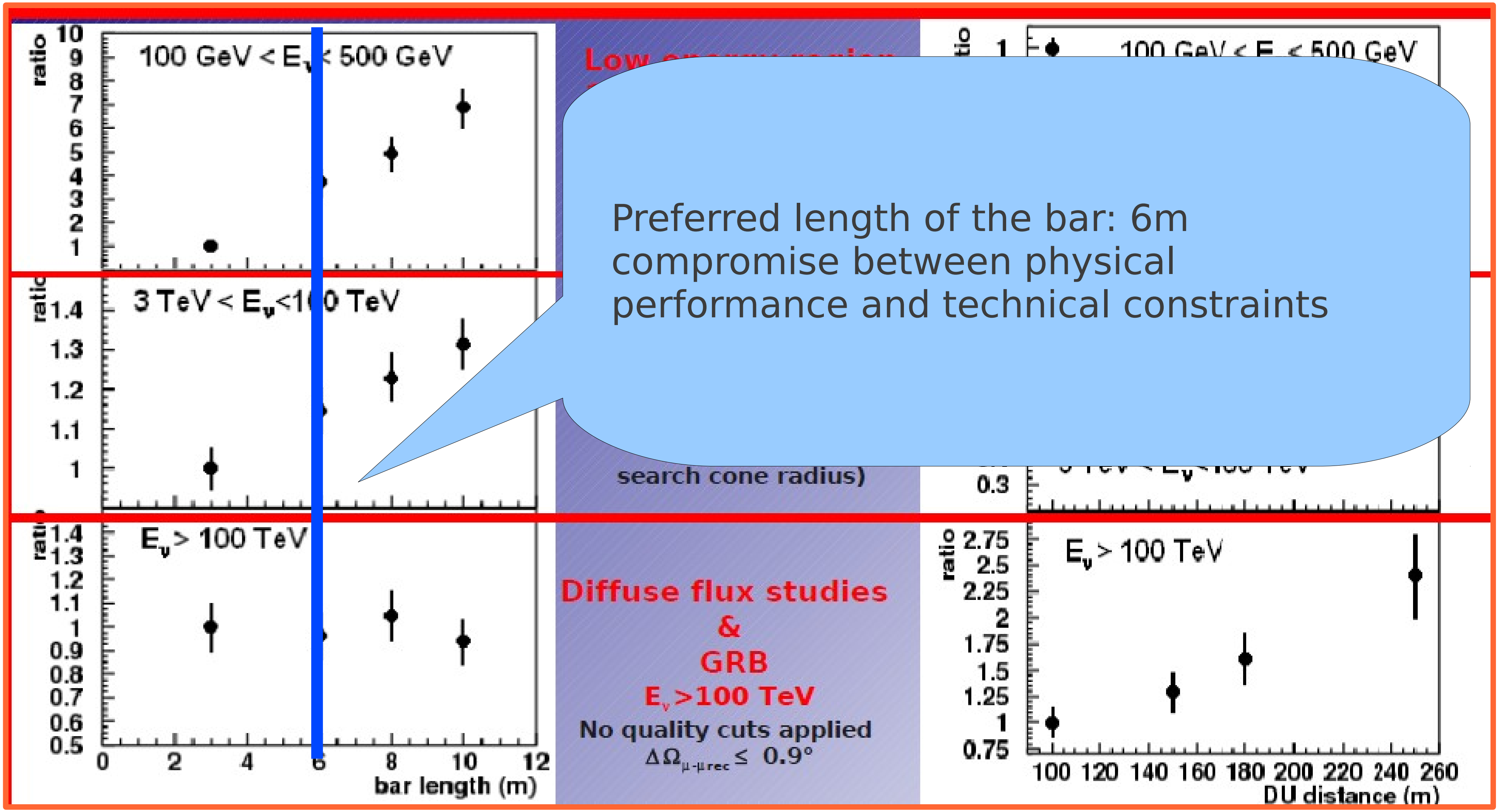


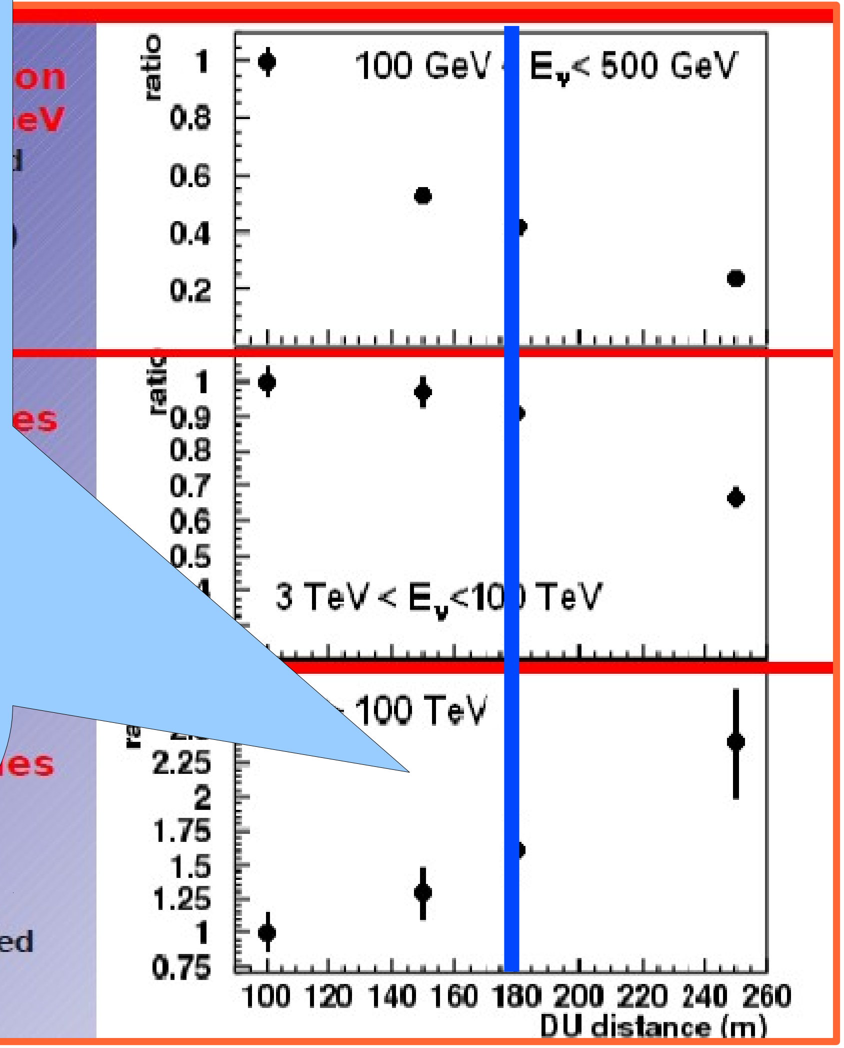
Preferred length of the bar: 6m
compromise between physical
performance and technical constraints

Optimization studies

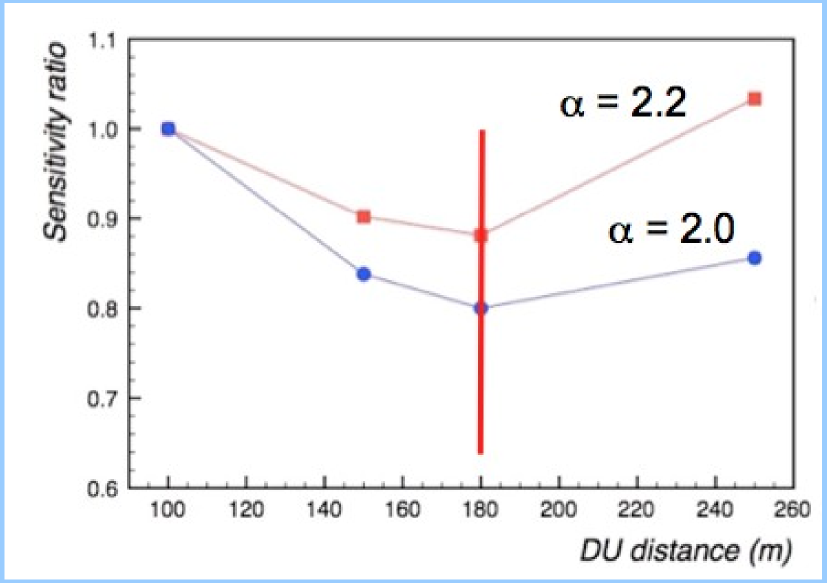
- Critical parameters: size and spacing of the detector units

DU separation

ratio of effective areas wrt. 100 m spacing



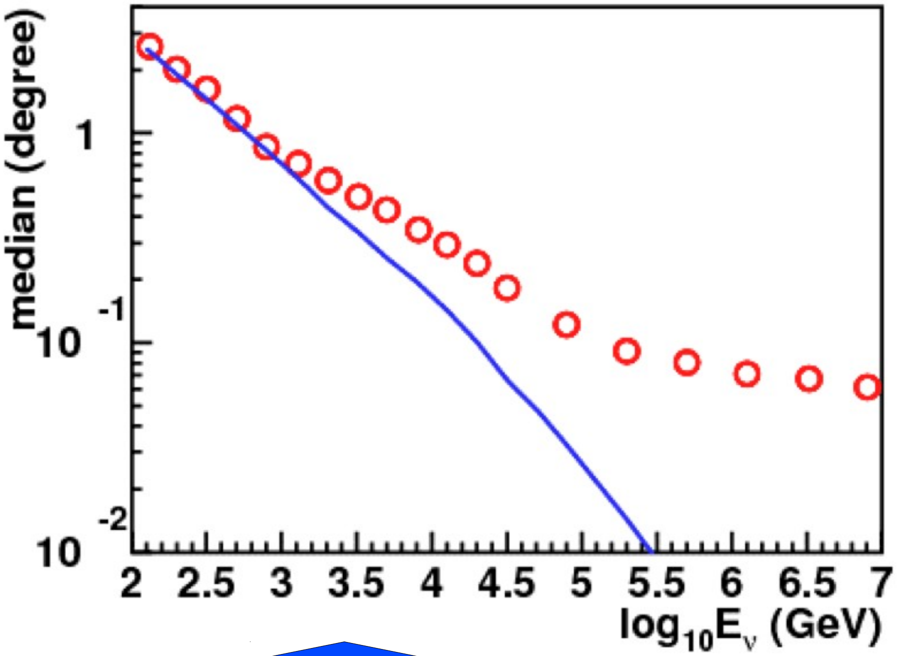
Preferred distance between DU: 180 m



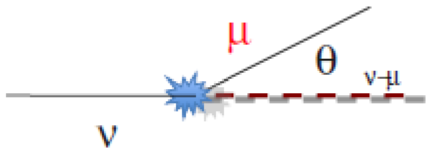
(neutrino flux ~$E^{-\alpha}$, all energies, no cut-off)

Ecpected preformances

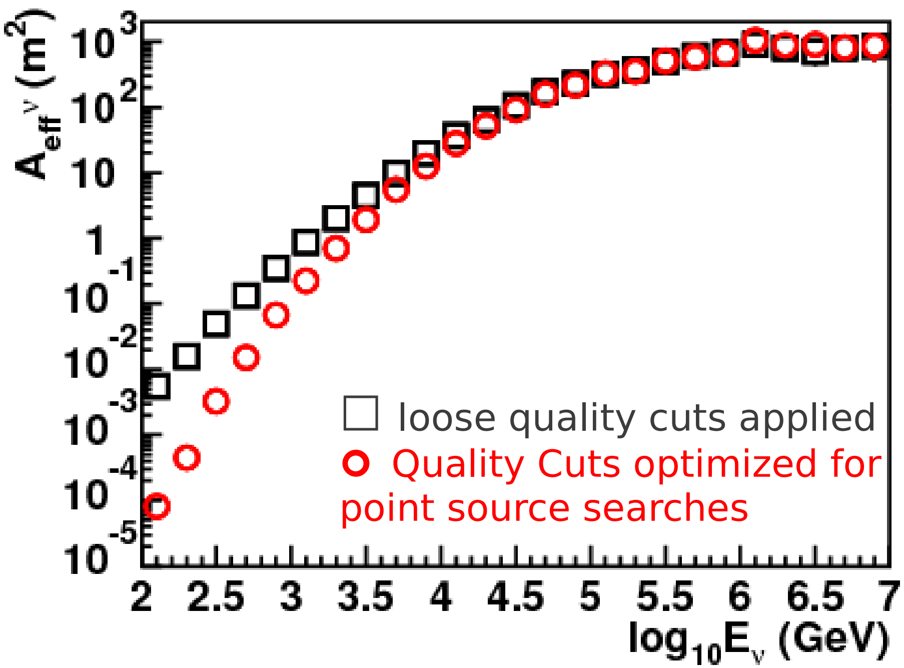
Angular resolution
(median of ΔΩ ν-μ rec.)



dominated by kinematics
at low energy



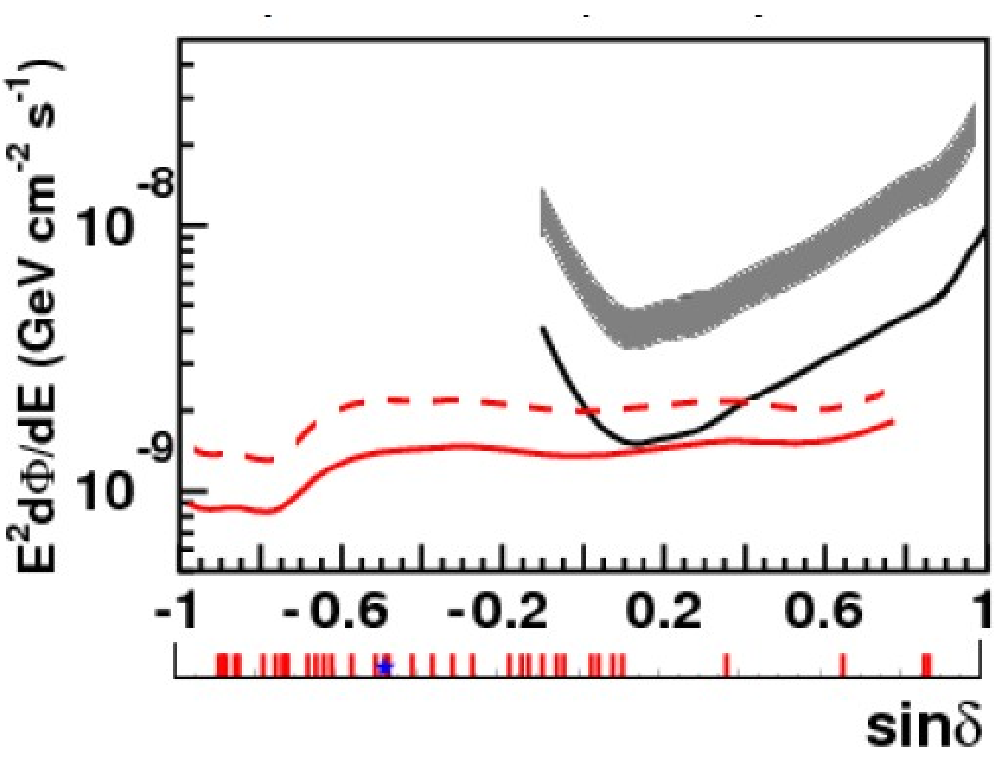
Neutrino effective area



Expected performances

- Sensitivity to neutrino point sources, flux ~ E^{-2}

1 year operation



KM3NeT sensitivity 90%CL

KM3NeT discovery 5σ 50% prob.

IceCube sensitivity 90%CL

IceCube discovery 5σ 50% prob. 2.5÷3.5 above sensitivity flux (extrapolation from IceCube 40 string configuration)

Observed galactic TeV γ-ray sources

F. Aharonian et al. Rep. Prog. Phys. (2008)

Abdo et al., MILAGRO, Astrophys. J. 658 L33-L36 (2007)

★: Galactic Center

Expected performances

- Expected number of events in 5 years observation time for some Galactic sources: (inside optimized cone)

Source Name	Source radius (°)	Visibility	Number of events For E_ν > 5 TeV	
			Signal ν	Atm ν
RX J1713.7−3946	0.7	0.74	4 − 11	6.4
RX J0852.0−4622	1.0	0.84	2 − 6	17
HESS J1745−303	0.2	0.66	0 − 22	1.4
HESS J1626−490	< 0.1	0.91	4 − 9	1.6
Vela X	0.4	0.81	4 − 15	3.5
Crab Nebula	< 0.1	0.39	1 − 3	0.8

- Expected number of events for 2 very energetic GRBs detected by Fermi:

GRB	Signal	Background
GRB080319B	2.6	5×10^{-4}
GRB080916C	2.7	5×10^{-4}
100 typical GRB	12	6×10^{-2}

(with reference Waxman-Bahcall flux)

requiring a time coincidence drastically reduces background

~ yearly detection rate with future satellites

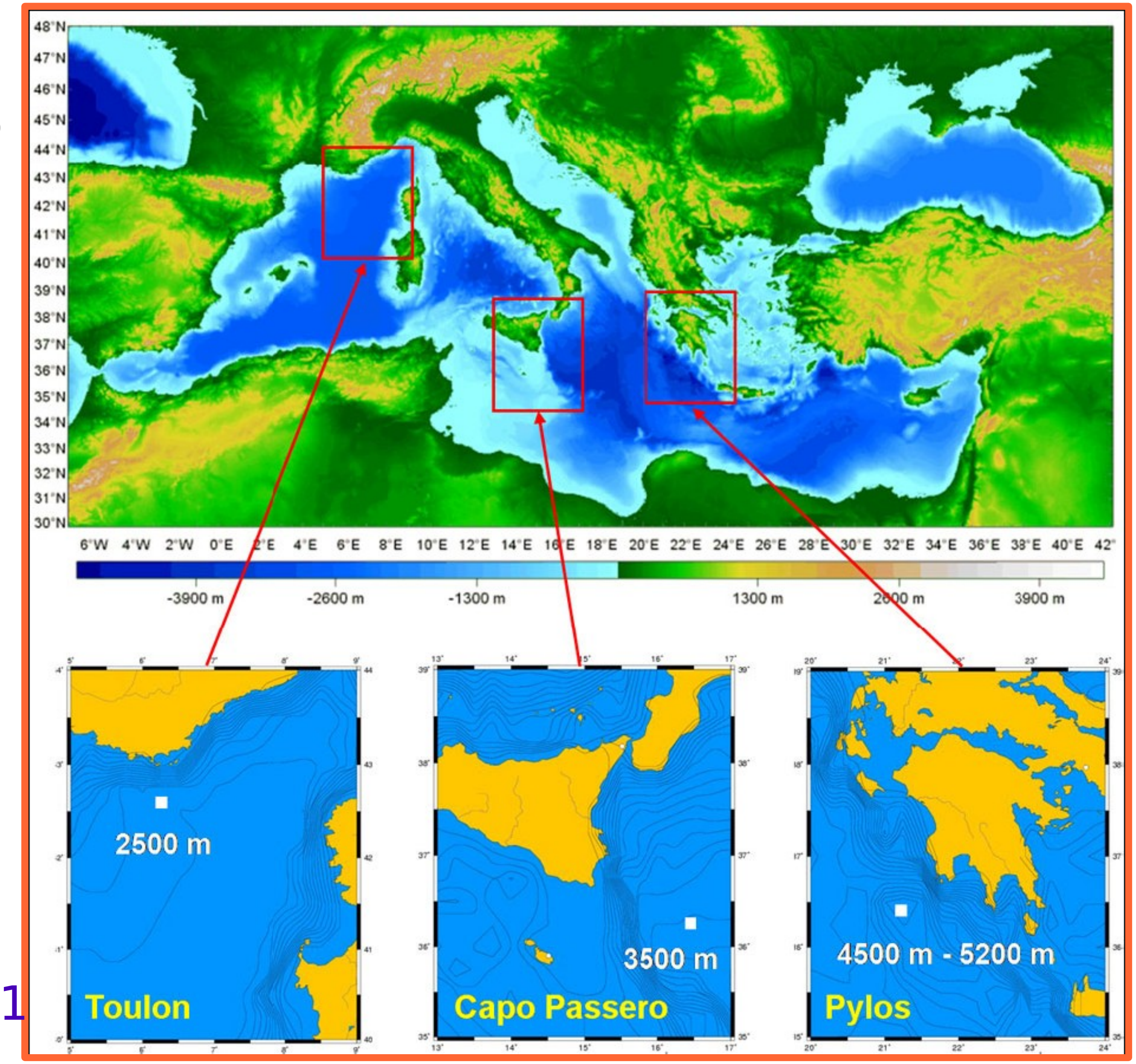
Candidate sites

- Locations of the 3 pilot projects:
  - ANTARES: Toulon (France)
  - NEMO: Capo Passero (Sicily, Italy)
  - NESTOR: Pylos (Greece)

- Long-term measurements performed for site characterization

- Main issues for site decision:
  - scientific performance
  - technological aspects (deployment, maintenance)
  - funding opportunities
  - political convergence

Final decision to be taken by end 2011



Summary and outlook

- KM3NeT: ~5 km³ neutrino telescope in the Mediterranean, complementing IceCube field of view and substantially surpassing its sensitivity:
  overall budget needed ~250 M€
- Convergence process towards a unique technical design is underway
- Readiness for construction expected at the end of Preparatory Phase (March 2012)
- Deployment could start in 2013 and data taking soon after