Status of simulations in NEMO

- Introduction and framework
- Simulation of atmospheric μ (HEMAS and MUSIC)
- Response of a km^3 underwater Cherenkov telescope based on "NEMO towers"
  - detector lay-out, triggers, background rejection, … (OPNEMO code)
  - effective areas and angular resolutions after reconstruction, … (ANTARES software)
- Conclusions and perspectives

Introduction and framework

The NEMO activity is devoted to two main issues:

- R&D for a km^3 underwater Cherenkov detector for high energy neutrino astronomy (design, mechanics, electronic, trasmission, …)

- Search and characterization of a deep underwater site,for the installation of a km^3 Cherenkov detector

Software simulations in NEMO support these activities

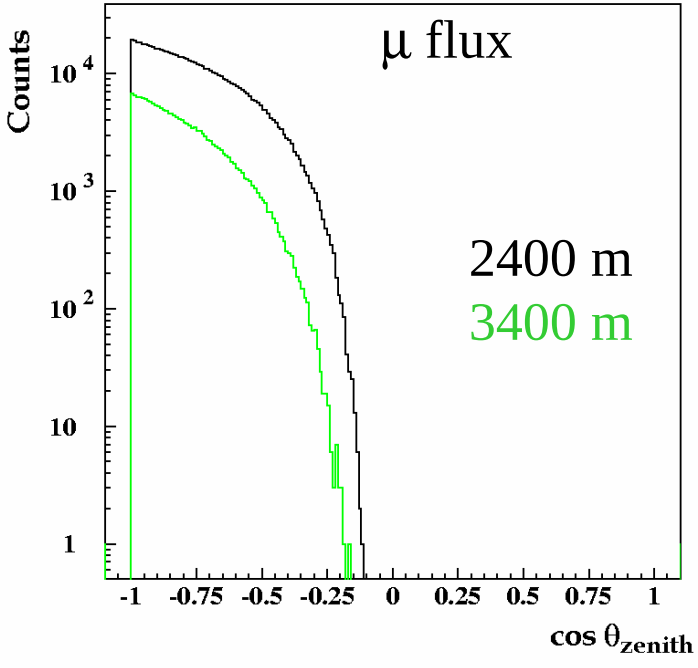
Atmospheric muon simulations

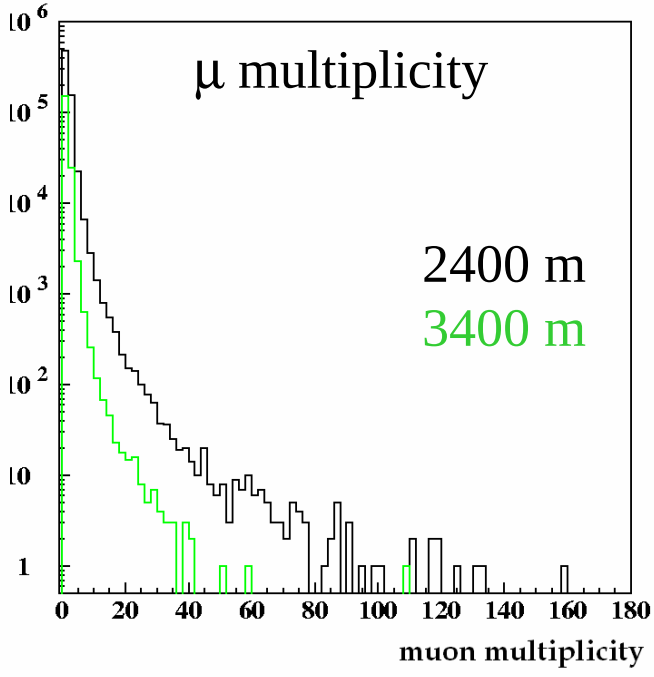
A. Margiotta et al

The depth of the site is related to the shielding from atmospheric muons

HEMAS code (vrs7-02) has been used to simulate the atmospheric down-going muon flux at sea level for zenith angles up to about 85°

MUSIC code has been used to propagate muons from sea level to the detector can at 2400 m and 3400 m underwater





Strong muon flux and multiplicty reduction at 3400 m, especially at large angle
Effect on detector performance is under investigation

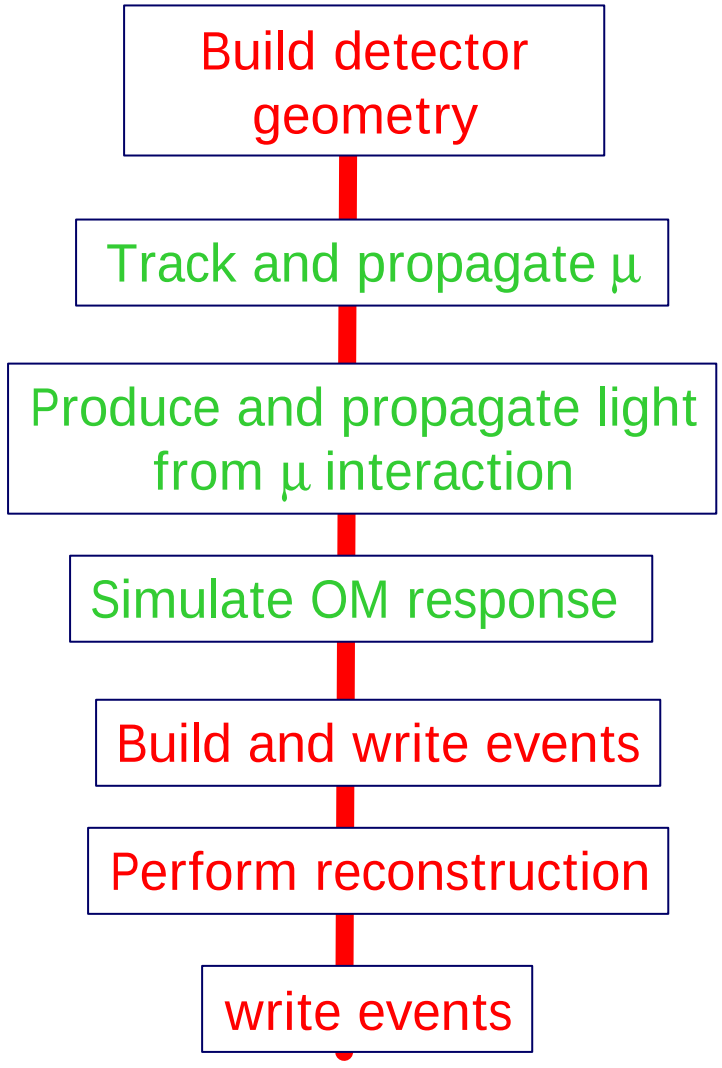
Simulation of NEMO detectors with OPNEMO

OPNEMO code (S. Bottai and T. Montaruli) is a fast first generation Monte-Carlo tool

OPNEMO has been used to define km^3 detector lay-out and triggers in the NEMO Collaboration

Main limitations:
- scattering of light not taken into account
- **track reconstruction in presence of optical background not implemented**
- …

It has provided indications for the detector lay-out



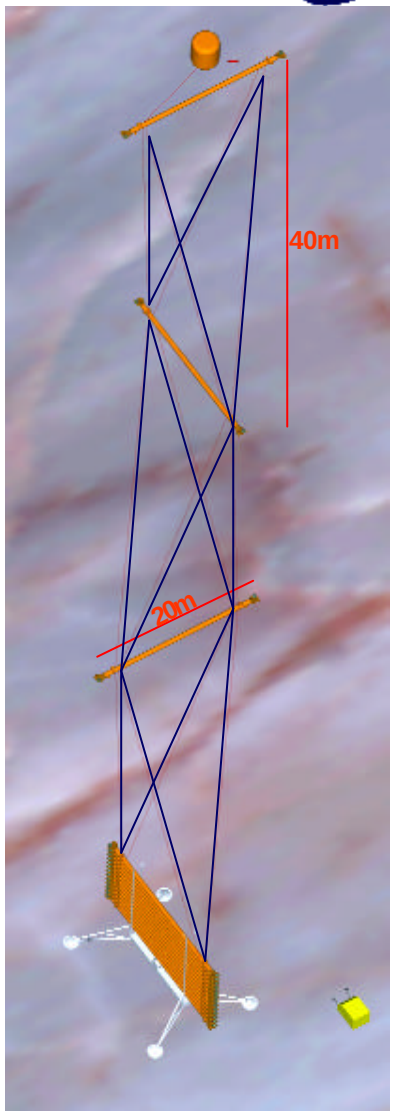
Study of detector configurations

Main constraints imposed to the detector design:
- number of PMTs < 6000
- number of strings/towers < 100
- distance between strings/towers > 100 m
- string/tower height < 1 km

Mechanics by G. Raia, M. Musumeci et al
Simulations with OPNEMO

Characteristics of the NEMO tower for km^3:

- total height	750 - 830 m
- instrumented	600 - 680 m
- number of bars	16 - 18
- number of PMTs per bar	4
- number of towers	64-81
- number of PMTs	4096-5832
- bar length	20 m
- bar vertical distance	40 m



Detector configuration - *dependence on the tower distance* -

OPNEMO **without** optical background (C. Distefano et al)

Simulation inputs:

surf. μ generation

N_{tower}= 64

H_{tower}= 600 m

N_{PMT} = 4096

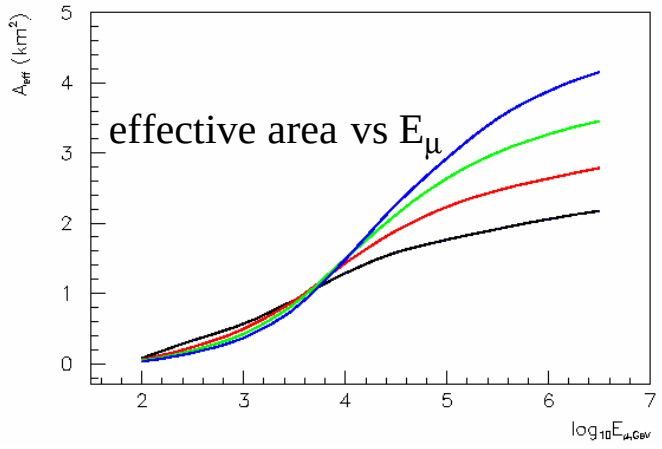
D_{PMT} = 10”

s_{PMT} = 2.5 nsec

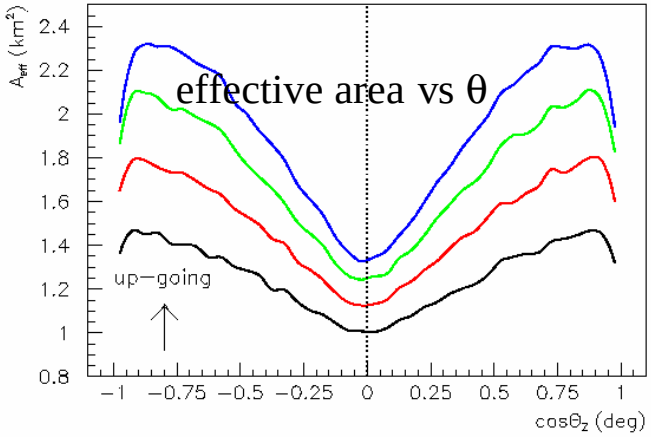
λ_a(450 nm) = 40 m

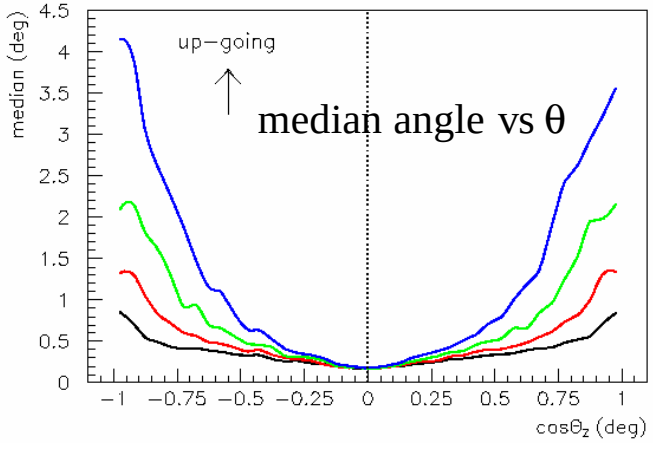
OM up-down

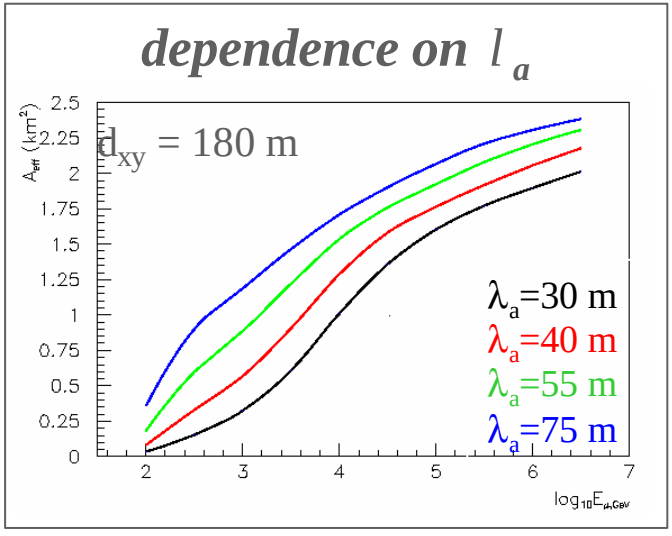
180 m 220 m 260 m 300 m



Rather good perfomances are obtained for distances of about 180 m.
However, more accurate simulations including the effect of the optical background are needed.







Detector configurations – *OM arrangement* -

OPNEMO without optical background (C. Distefano et al)

surf. μ generation

$N_{string/tower}$ = 64

$H_{string/tower}$ = 600 m

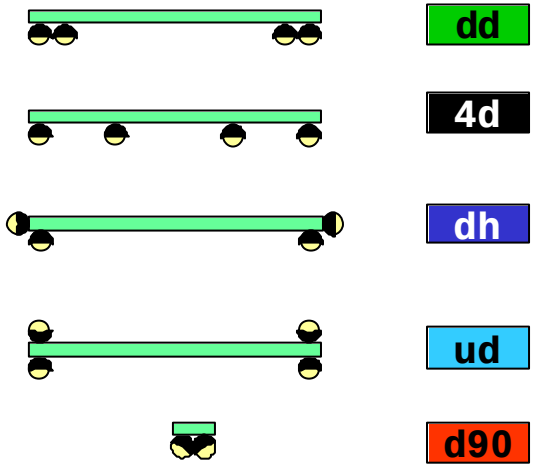
N_{PMT} = 4096

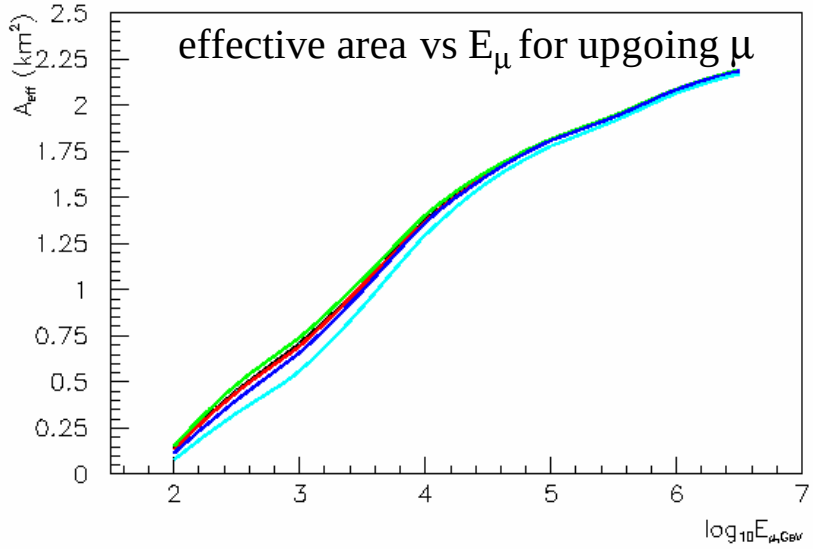
D_{PMT} = 10”

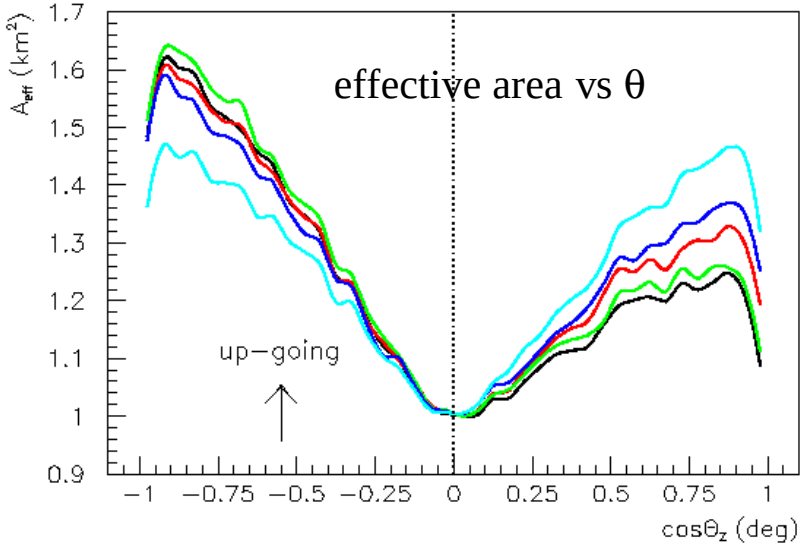
s_{PMT} = 2.5 nsec

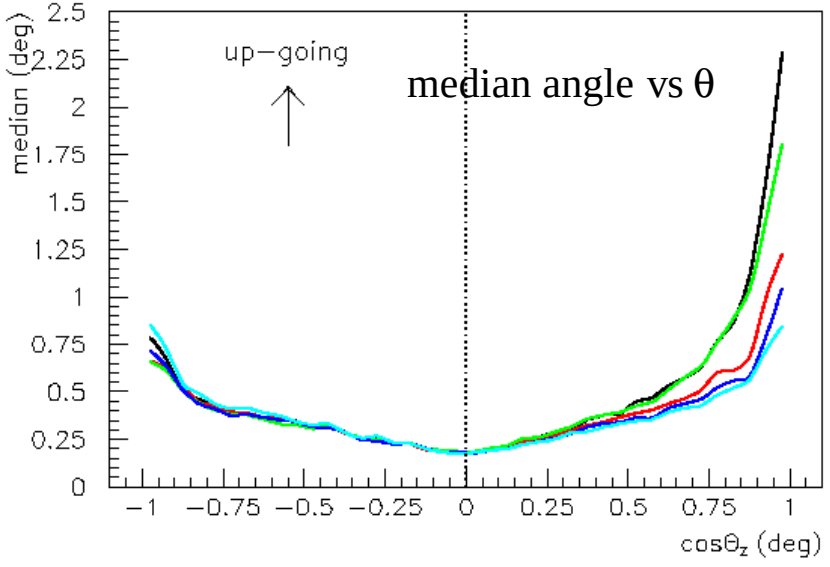
d_{xy} = 180 m

λ_a(450 nm) = 40 m









Simulations of NEMO detectors with the ANTARES software package (R. Coniglione, P.S. et al)

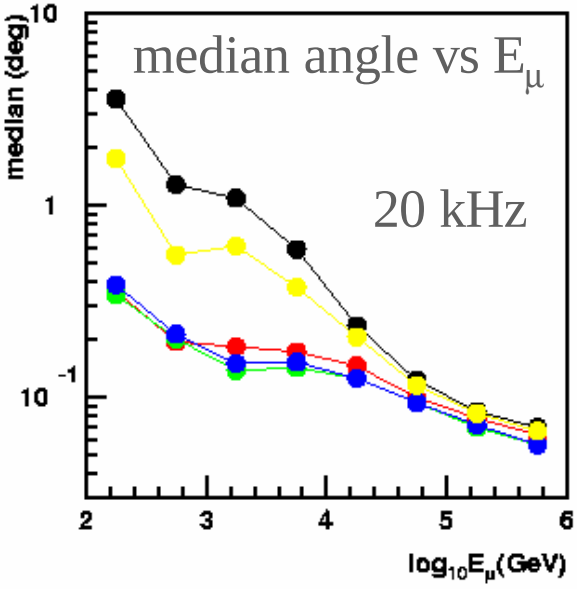
During the ANTARES meeting held in Catania on september 2002, the ANTARES and NEMO collaboration agreed to start a stronger cooperation towards the km^3.
In particular, activities concerning site characterization and software were mentioned.
By the end of 2002, ANTARES software was installed in Catania by D. Zaborov.

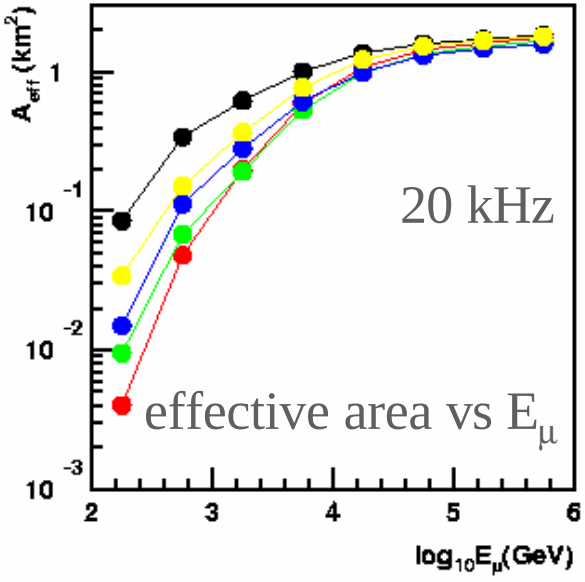
Detector configuration
NEMO10dh140
number of PMTs 5832
number of towers 9x9=81
distance between towers 140
tower height 680 (830 total)
bar length 20 m
bar distance 40 m
instrumented volume 1140 x 1140 x 680
PMT diameter 10”
OM down-horizontal

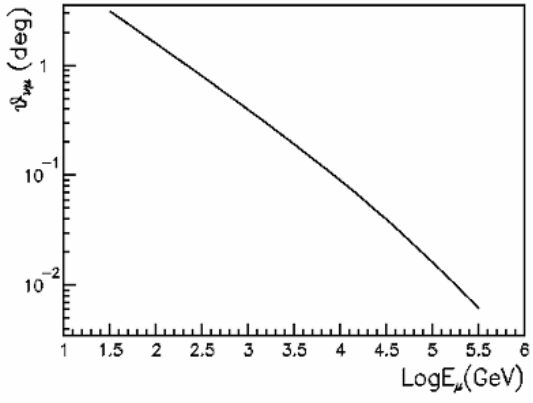
Simulation inputs
Zaborov version for km^3 detectors
surface μ generation
can radius $d_{max}/2$ + 100 m
Upgoing muons with E^{-1} spectrum
ANTARES water parameters
0.5 p.e. threshold
2.5 p.e. trigger
opt. back. 500 nsec -> 1000 nsec offset
20, 45, 60, 120 kHz
reconstrution with “Aart strategy”

Simulations of NEMO detectors with the ANTARES software package (R. Coniglione, P.S. et al)

Requirements for detector performance has to be defined.
To fulfil the requirements both design optimisation and tuning of trigger and reconstruction are needed.
In the following, a s.p.e. uncorrelated optical background of 20 kHz is considered. This value is close to values measured in Capo Passero (G. Riccobene talk).
An amplitude trigger based on the presence of at least three signals above 2.5 p.e. was used (Zaborov).



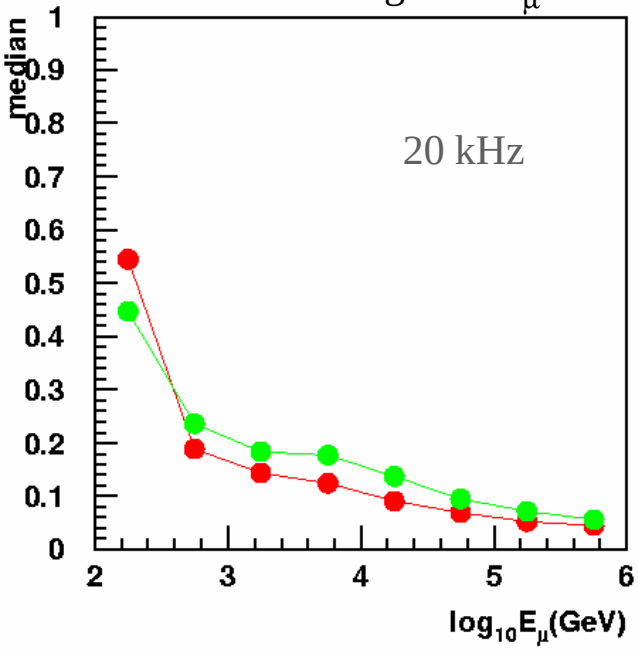




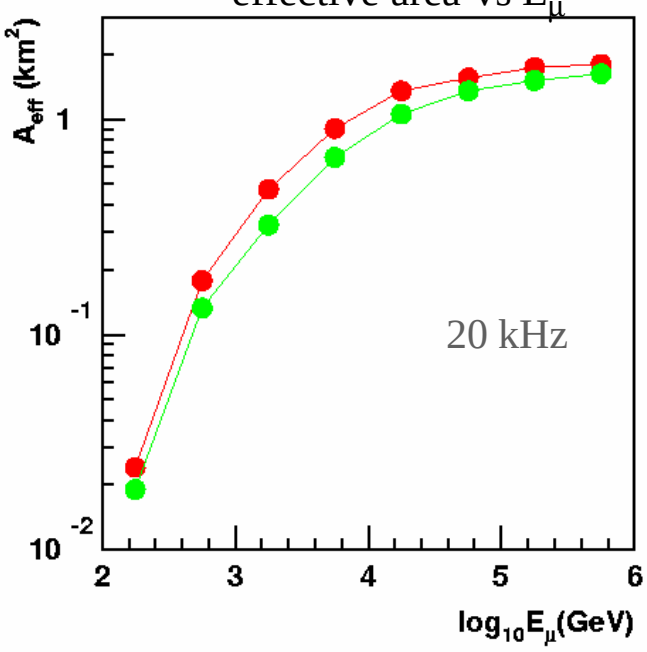
original
our conditions + quality cuts
our cond. + coincidences
our cond. + coinc. + quality cuts

Comparison of NEMO detector with a homogenous lattice detector

median angle vs E_μ



effective area vs E_μ



NEMO 140 dh 9x9 with quality cuts 5832 PMTs

Regular lattice 400strings 60m x 60m 5600 PMTs

NEMO140dh at 20kHz has perfomance comparable to a 60x60m lattice detector

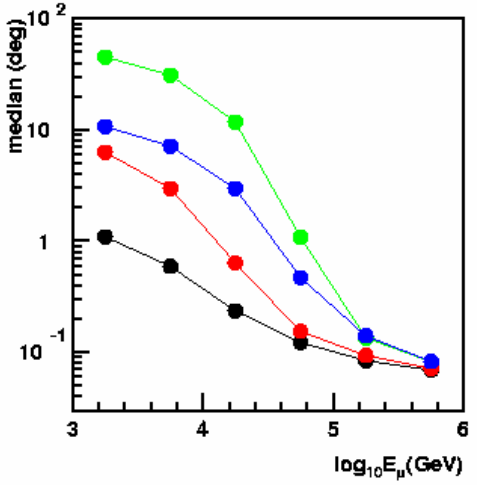
Optical background dependence

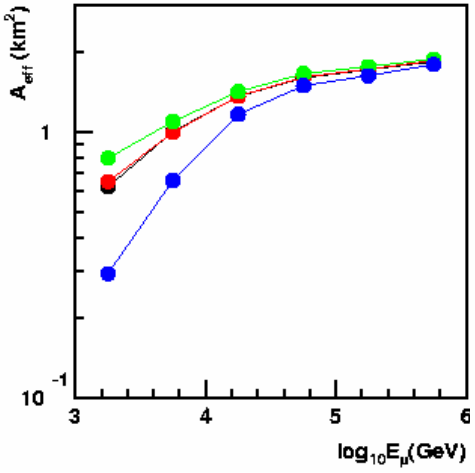
Optical background dependence

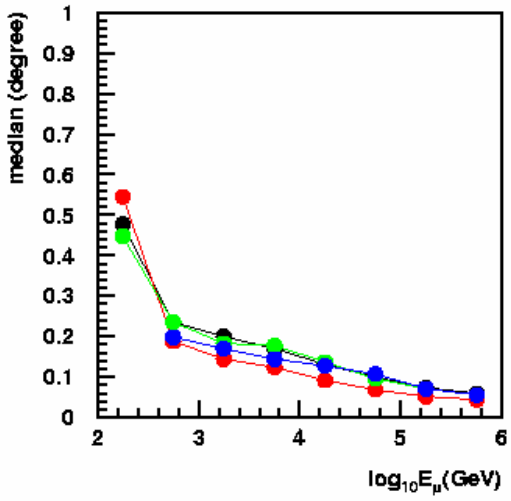
In order to make comparisons for the same angular resolution quality cuts must be applied

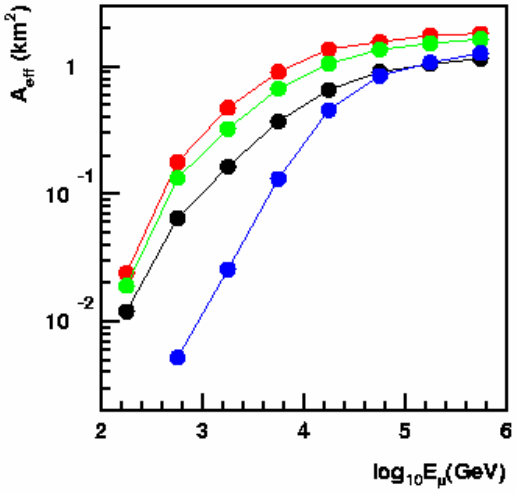
median angle vs E_μ

effective area vs E_μ









NEMO 140 dh 9x9 20 kHz
NEMO 140 dh 9x9 60 kHz
NEMO 140 dh 9x9 120 kHz
NEMO 140 dh 9x9 120 kHz th. 1.5 p.e.

Regular lattice 400 strings 60m x 60m
NEMO 140 dh 9x9 20 kHz with qual. cuts
NEMO 140 dh 9x9 60 kHz with qual. cuts
NEMO 140 dh 9x9 120 kHz th. 1.5 p.e. & q. c.

Search for triggers – local coincidences in the towers

OPNEMO **with** optical background (V. Valente and T. Capone)

The NEMO tower lay-out allows space-time coincidence between PMTs in the bar and between adiacenti bars. The possibility of using these coincidences as trigger is under investigation. Preliminary results are promising.

TRIGGER: 3 PMTs hits on a bar or 2 PMTs + 2 PMTs hits in nearby bars with space-time correlation plus a threshold on total charge

Simulation inputs:

surf. μ generation

N_{tower} = 64 (8x8)

H_{tower} = 600 m

N_{PMT} = 4096

D_{PMT} = 10”

s_{PMT} = 2.5 nsec

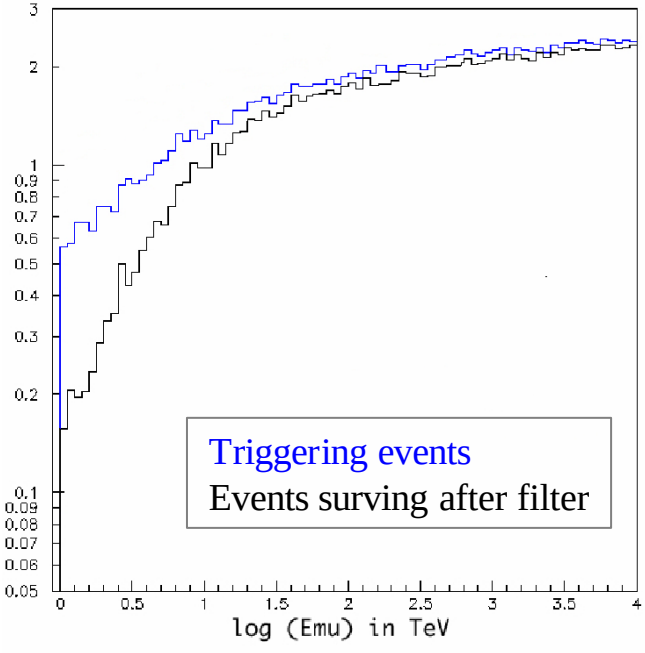
d_{xy} = 200 m

λ_a(450 nm) = 55 m

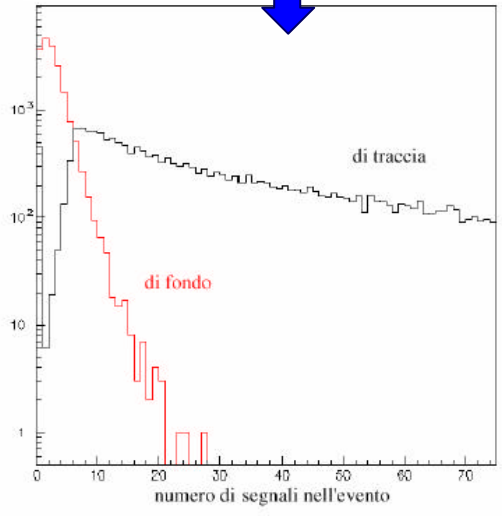
threshold 0.25 p.e.

opt. back. rate = 44 kHz

effective area



Number of background and muon signals in the events



Conclusions and perspectives

- **Strong muon flux and multiplicity at the can of a km3 NEMO detector at 3400 m respect to 2400 m, especially close to horizon (HEMAS and MUSIC). Effect on the detector performance understudy.**

- **Effect of the optical background rate on the detector performances has been simulated with the ANTARES package.**

- **A down-horizontal arrangment of the 4 PMTs at the edges of the bar seems a good compromise (OPNEMO).**

- **Tuning of triggers and reconstruction parameters on detector design and enviromental conditions is necessary.**

Angular dependence - *Nemo10dh140 20 kHz*
1 TeV < E < 1 PeV

without quality cuts

with quality cuts