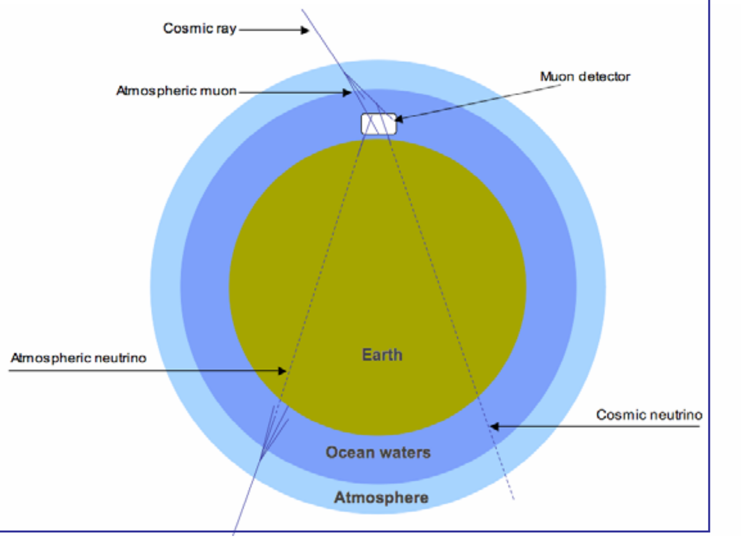
Study of the angular acceptance of a km^3 neutrino telescope in the Mediterranean Sea

Piera Sapienza and Rosa Coniglione
for the km3NeT collaboration

Outlook

- Why to "look up"?
- Effect of OM orientation on neutrino effective area and angular resolution
- Response to atmospheric muons – first results
- On the "observation of the Moon shadow"
- Conclusions and perspectives

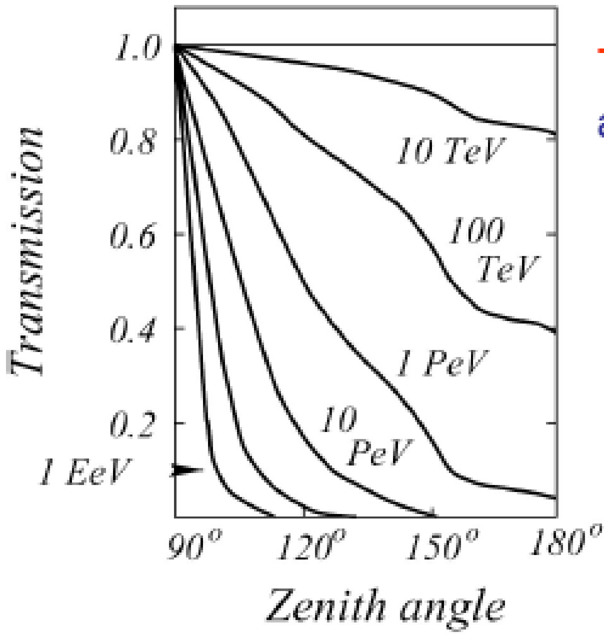
Neutrino telescopes look for point sources watching at the sky upside down. However …



Mission of the session detector design

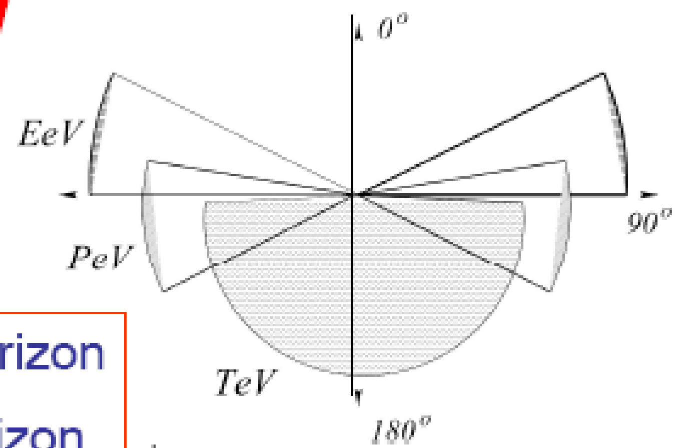
Ch. Spiering - vlvnt, Amsterdam october 2003

Diffuse flux of UHE muon neutrinos (> 1 PeV): Upward looking modules are useful ! Also for measuring shadow of moon or any other calib. with downward muons.



Transmission of Earth for Neutrinos
as a function of zenith angle and energy

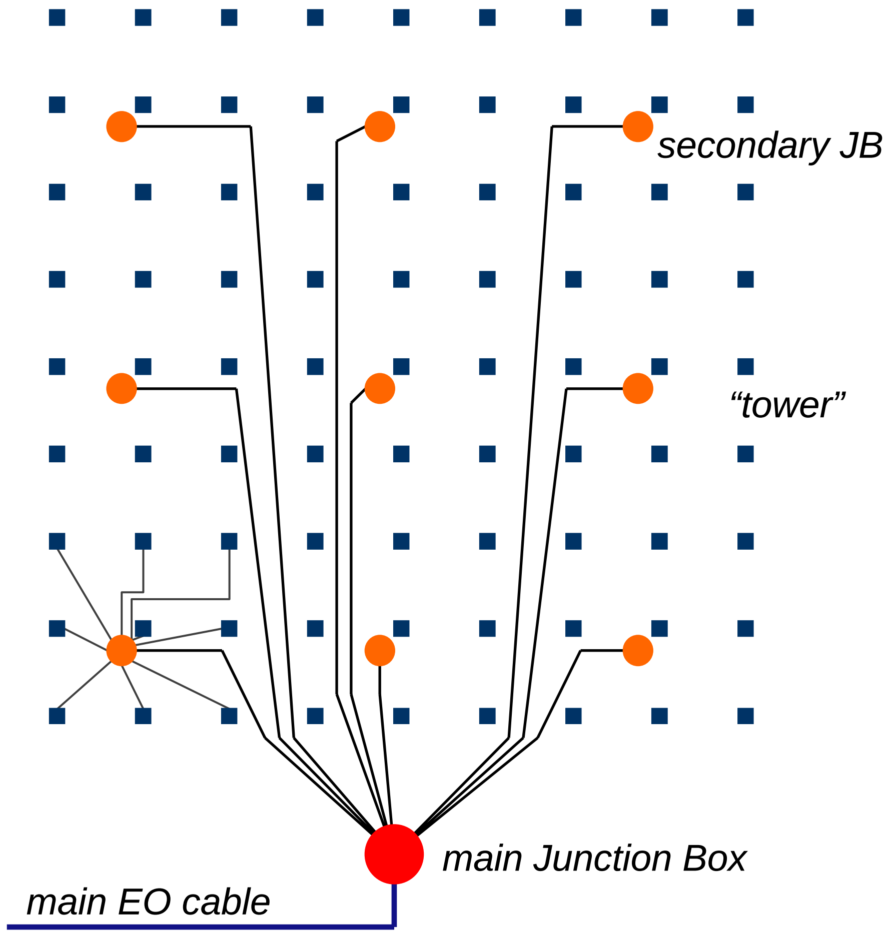
Downward-background at high energy is small.

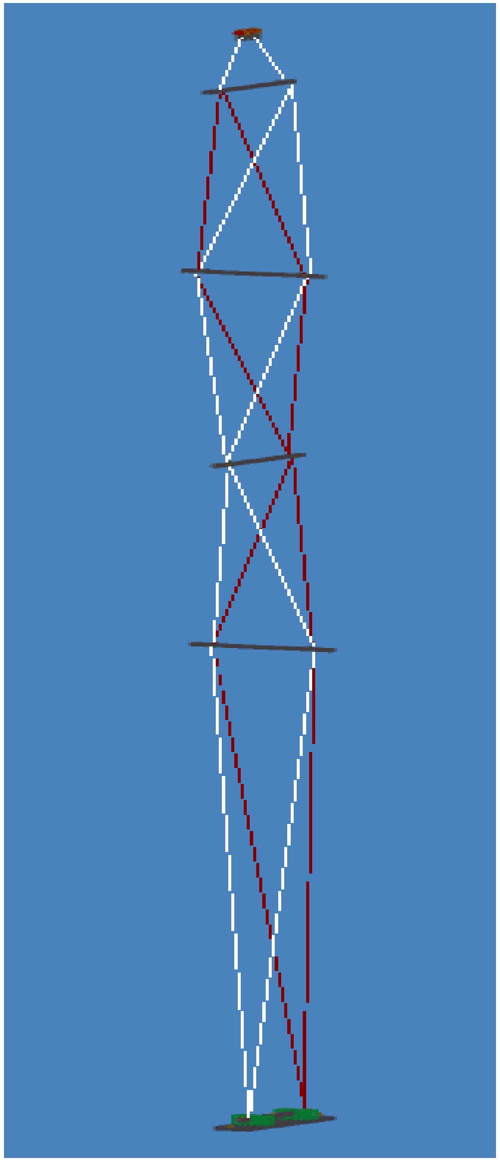


PeV acceptance around horizon

EeV acceptance above horizon

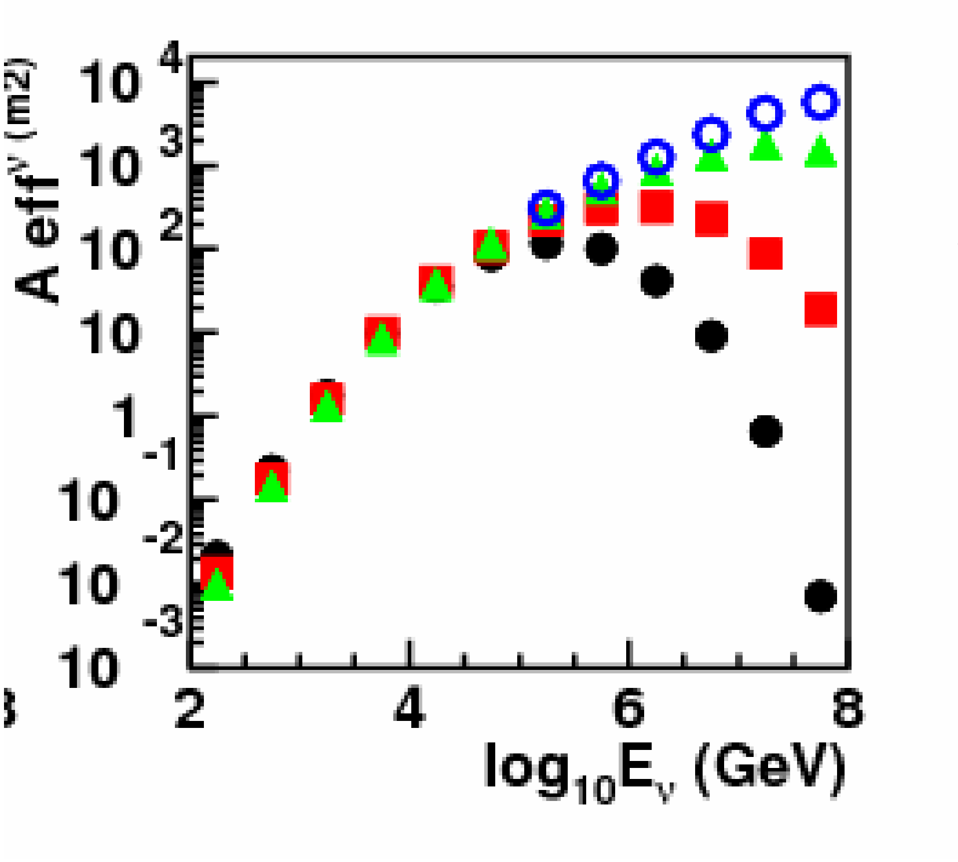
A design of a km^3 ν telescope based on flexible towers





Each floor is perpendicular to the adiacent ones

Neutrino effective area vs zenith angle



- **0° - 30°**
- **30° - 60°**
- **60° - 90°**
- **90° -120°**

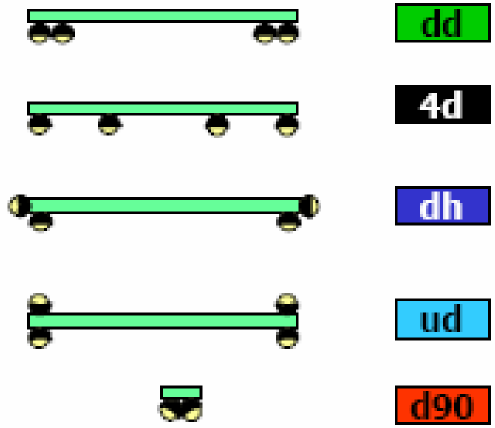
169 towers, dh configuration, no cuts

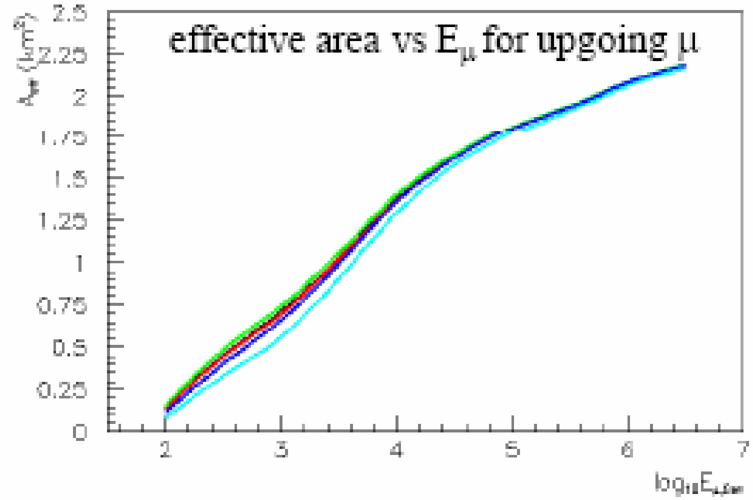
Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali del Sud

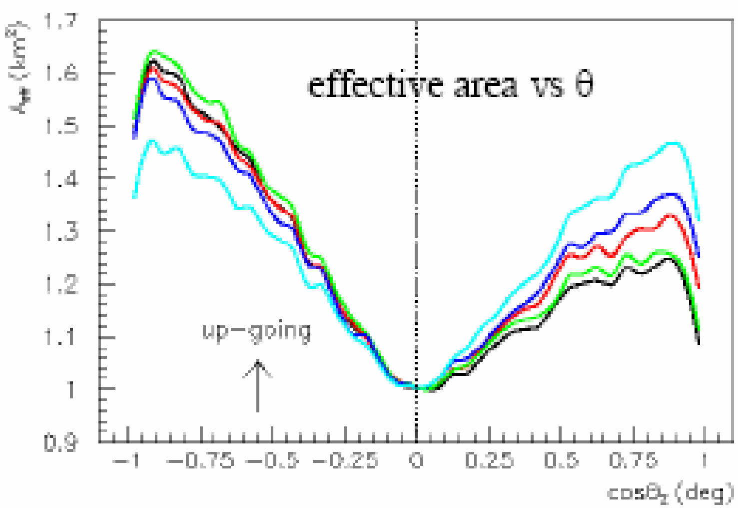
Detector configurations – *OM arrangement* –

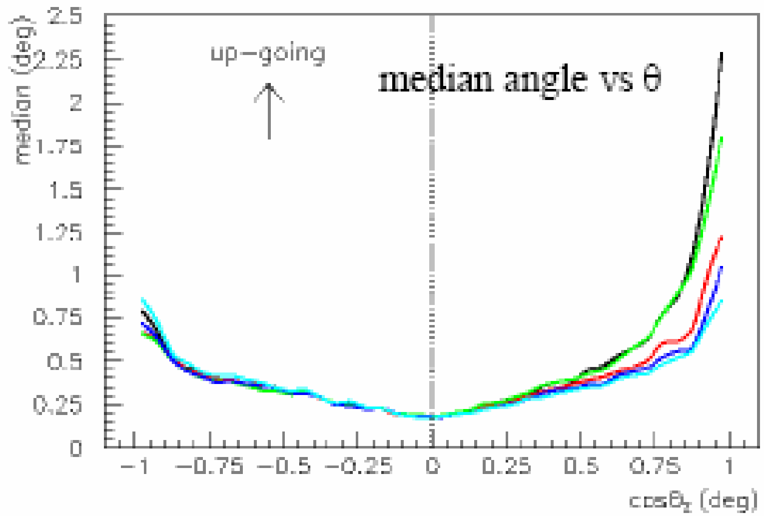
OPNEMO without optical background (C. Distefano et al)

surf. μ generation
$N_{string/tower} = 64$
$H_{string/tower} = 600$ m
$N_{PMT} = 4096$
$D_{PMT} = 10''$
$\sigma_{PMT} = 2.5$ nsec
$d_{xy} = 180$ m
$\lambda_a(450\ nm) = 40$ m









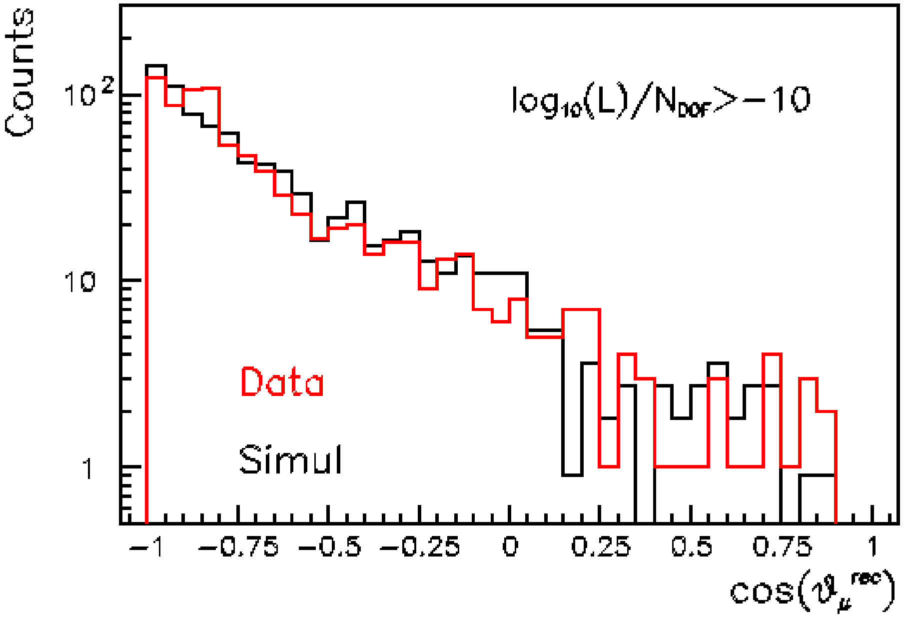
Atmospheric muons @ Nemo test site - comparison with simulations 10h-

Isabella Amore vlvnt08

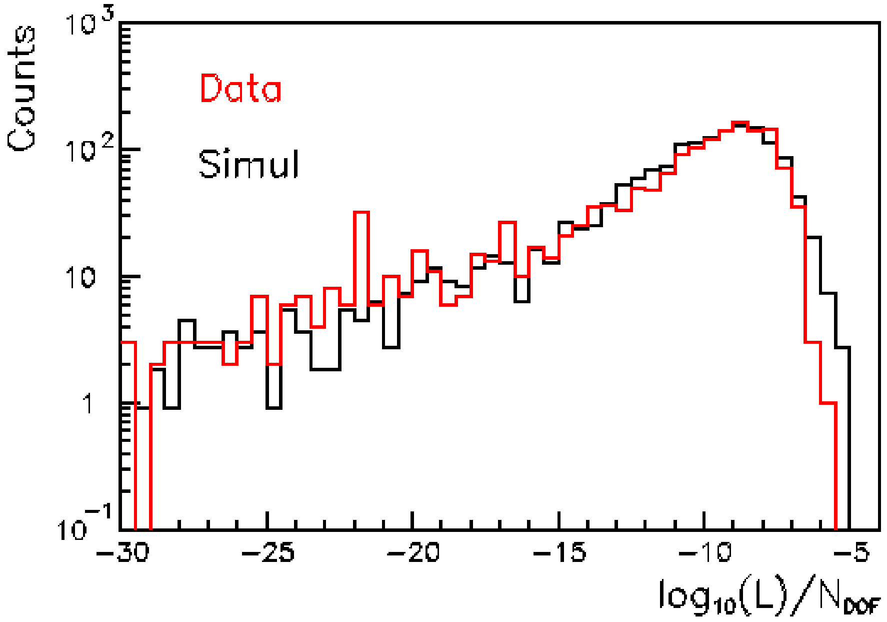
Rate Data track reconstructed = 0.047 ± 0.001 Hz

Rate Simulated track reconstructed = 0.044 ± 0.001 Hz

Cosine of angular distribution



Likelihood



Simulation input

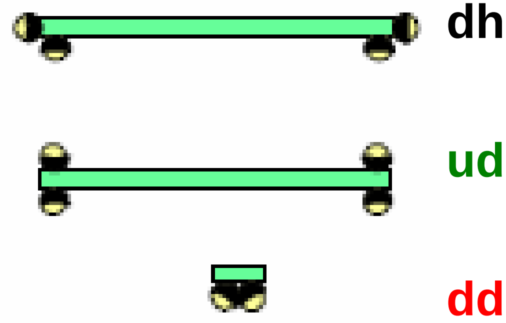
number of towers	169 (13x13)
tower distance (m)	140
PMT type & QE	10” - 23%
number of OM	12168
number of PMT	12168
storey distance (m)	40
total PMT catode area (m^2)	535
instr. volume (km^3)	1.92

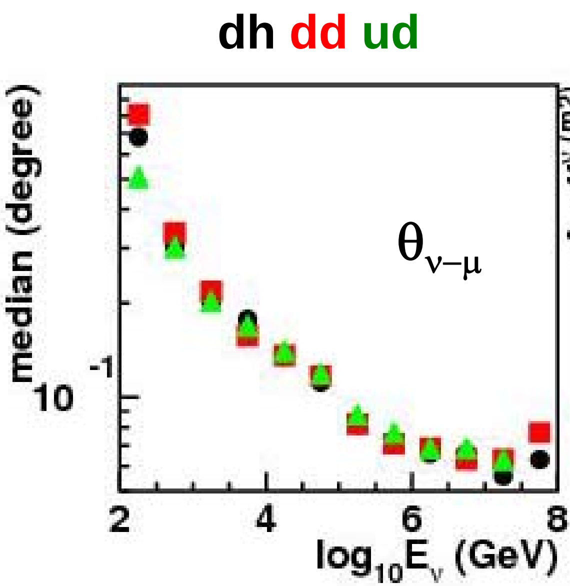
ANTARES code modified for km3 detectors

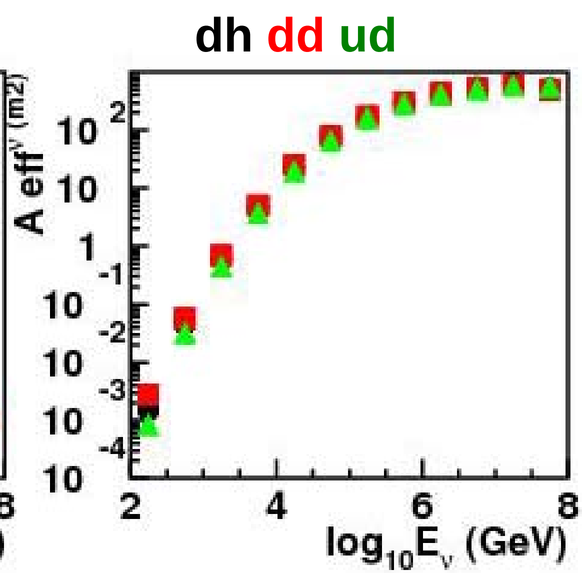
- neutrino and atm. muon generation
- water absorption and scattering
- optical background isotropic distributed around the event time window
- event trigger based on local coincidences and high charge

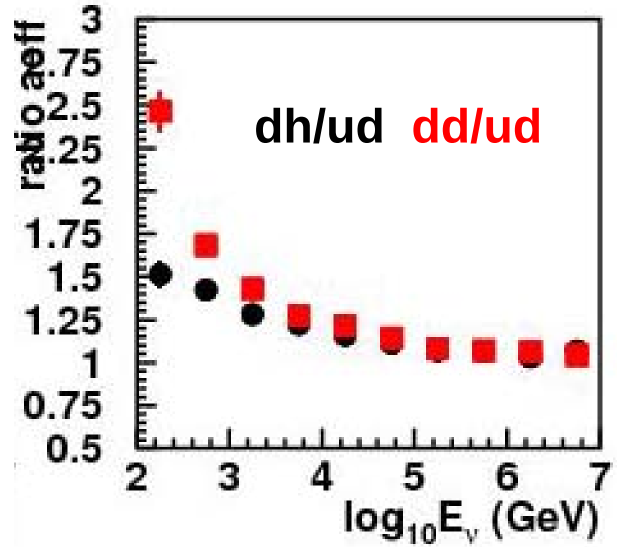
Median and effective areas

- Up-going neutrinos, E-2 spectrum
- quality cuts for point source search applied



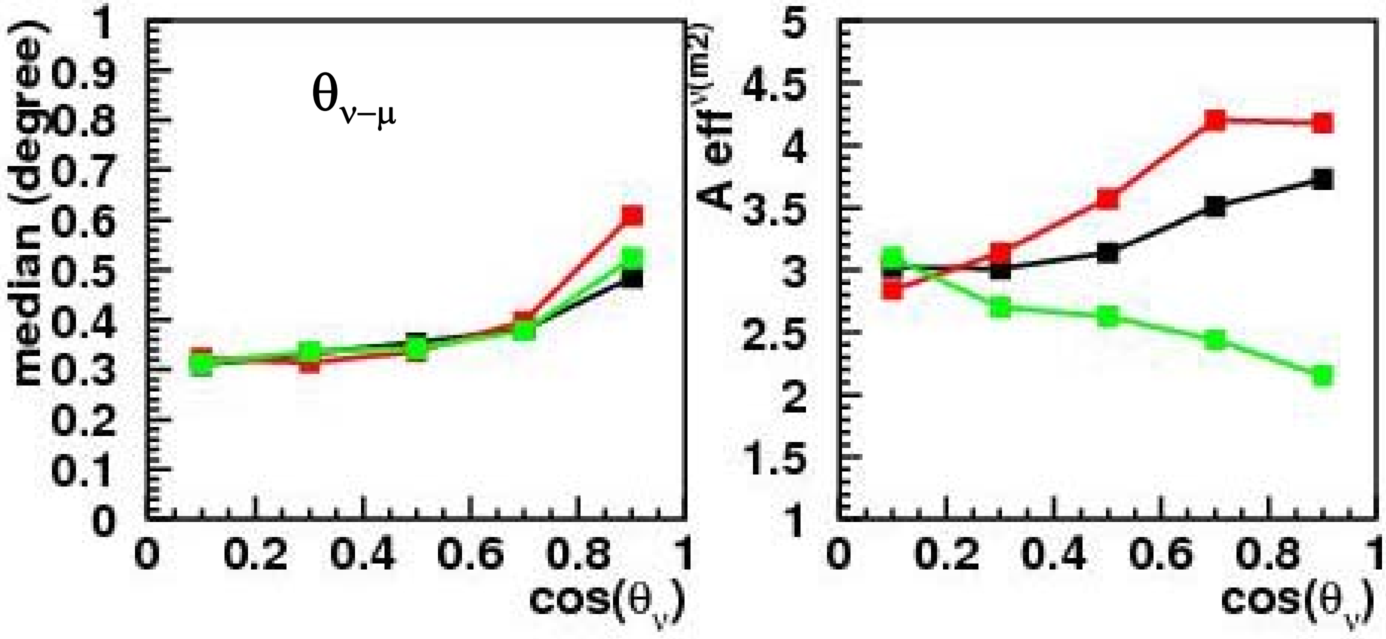






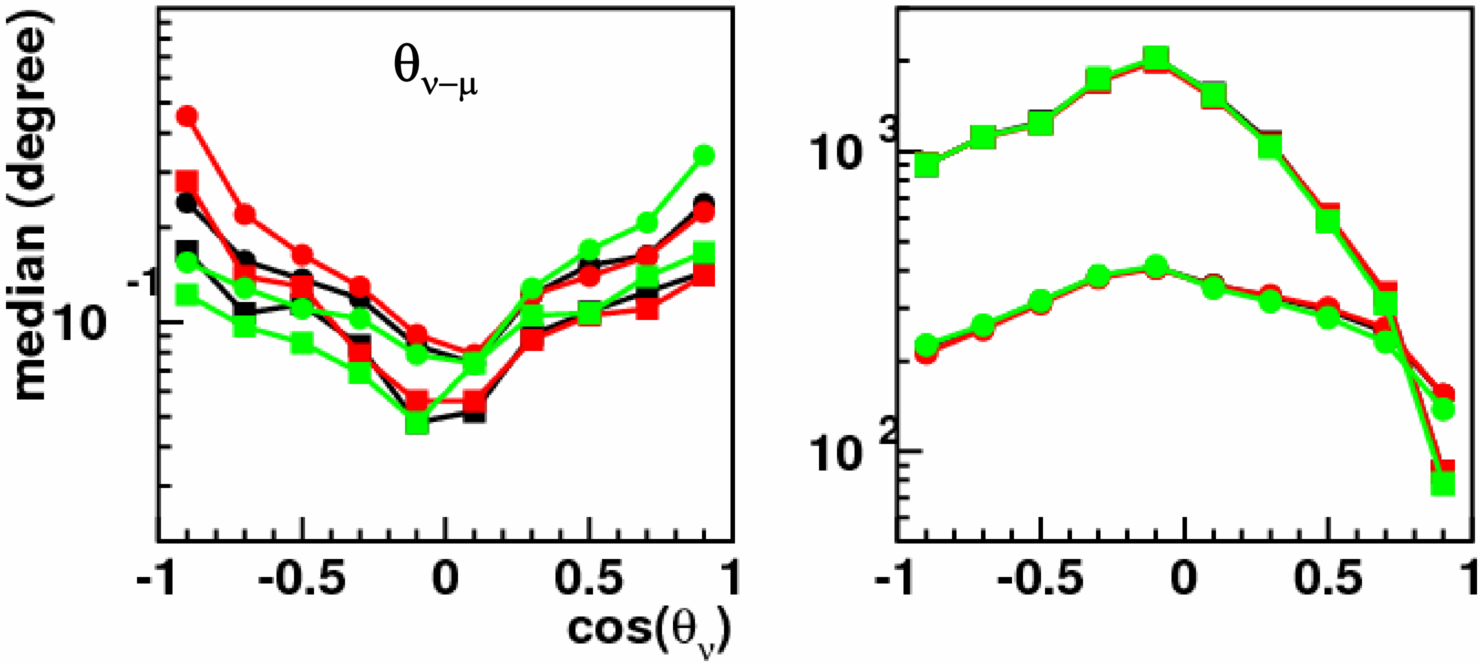
Relevant performance for point-like source neutrino detection

Λ>-6.2 e 1 TeV<E_ν<100 TeV



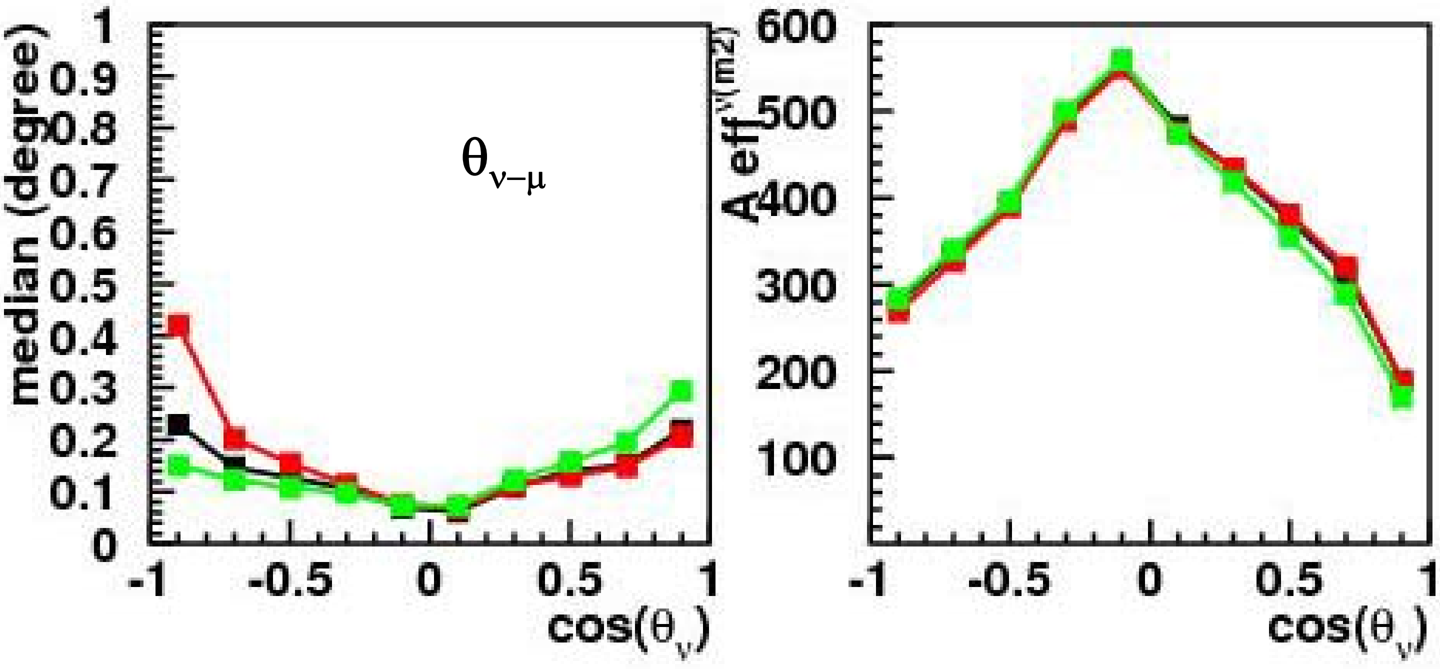
High energy neutrino detection

- E^{-2} neutrino spectrum
- circles 100 TeV < E_ν < 1 PeV
- squares 1 PeV < E_ν < 100 PeV



High energy neutrino detection

100 TeV < E < 100 PeV



- Response to high energy neutrinos not very sensitive to OM orientation

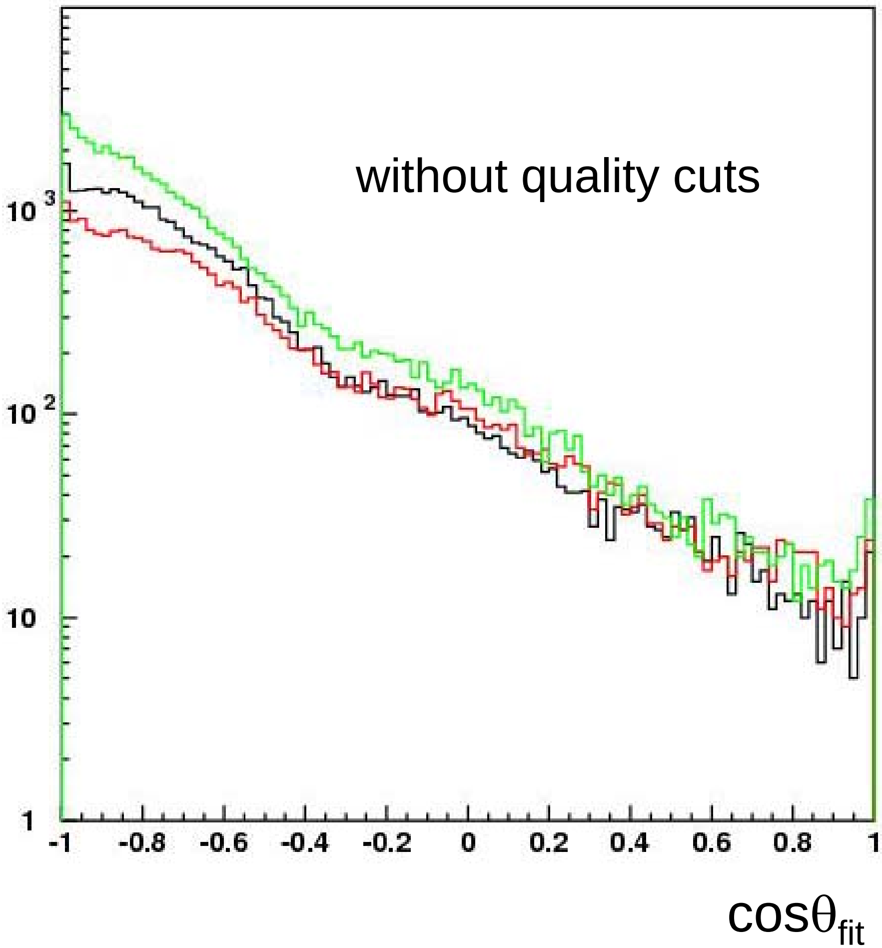
Atmospheric muon simulation (work in progress)

- Rejection of atmospheric muons mis-reconstructed as up-going

- Detection of the moon shadowing for absolute pointing

- Code Mupage
- Depth 3400 m
- 100 GeV th @ can
- Livetime 2.6 min

Atmospheric muon simulation



Events with $\cos\theta_{fit}$ >0 are mis-reconstructed as up-going

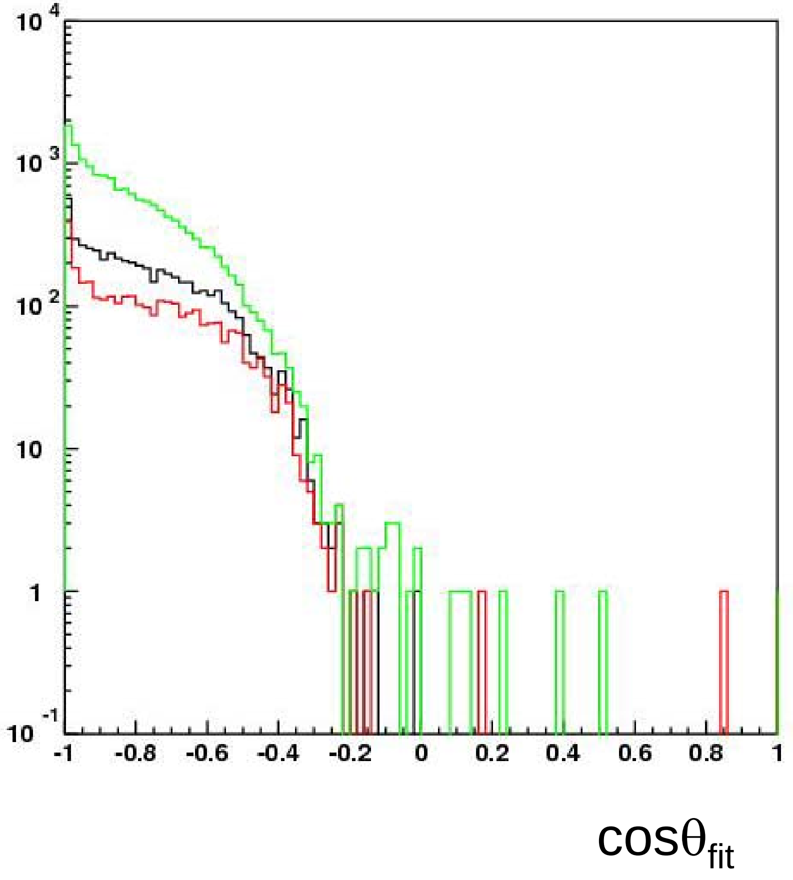
if we apply quality cuts …

orient.	Λ	counts
ud	>-7.3	93
dd	>-7.0	40
dh	>-7.0	24

Atmospheric muon simulation

Quality cuts for point source sensitivity

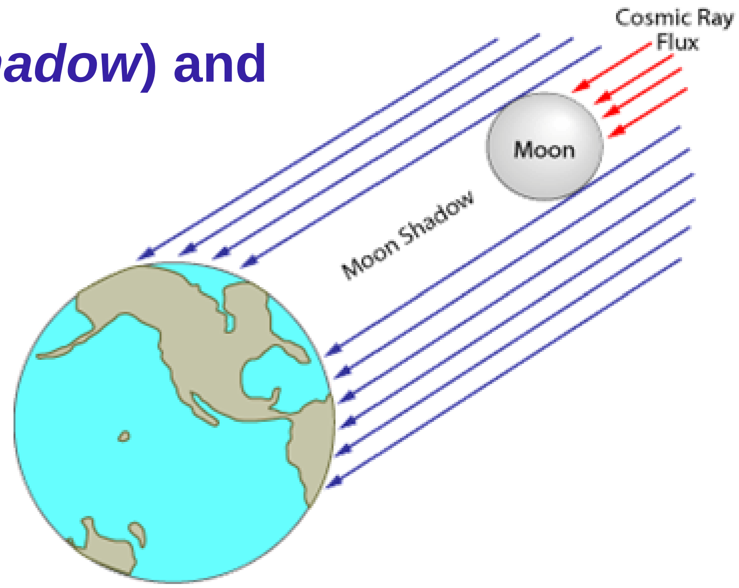
orient.	Λ	counts
ud	>-6.4	6
dd	>-6.2	2
dh	>-6.2	0



Absolute pointing of the telescope
- detection of the Moon shadow -

The Moon is opaque to Cosmic Rays. A deficit in the atmospheric muon flux reaching the detector should be observed.

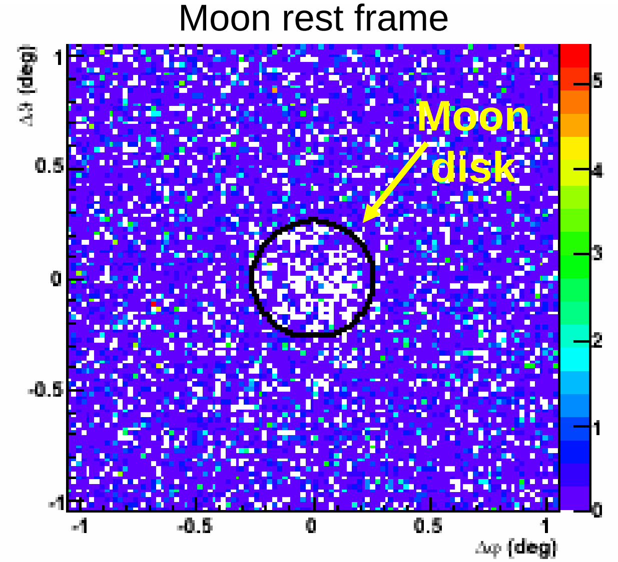
The "detection" of the deficit (*The Moon Shadow*) and of its position in the sky allows to measure the detector angular resolution and the detector absolute orientation.

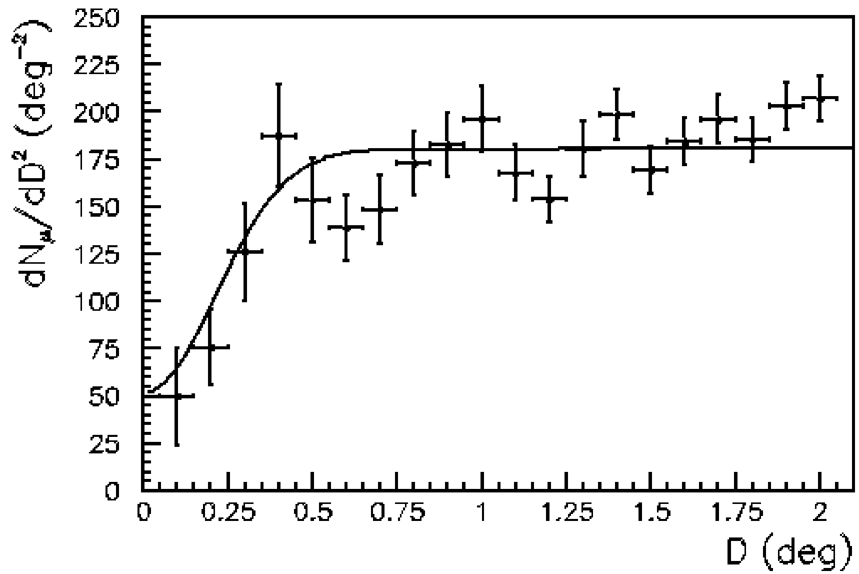


This approach has been already adopted in several cosmic ray experiments as MACRO, SOUDAN, MILAGRO, ARGO….

Observation of the Moon shadow

81 Nemo towers - Carla Distefano





Event Selection:

N_{fit}^{min}= 26

Λ_{cut}= -7.2

S_{1year}=5.5

$$\frac{dN_\mu}{dD^2} = k\left(1 - \frac{\vartheta^2_{moon}}{2\sigma^2} e^{-\frac{D^2}{2\sigma^2}}\right)$$

From the fit:

k= 195 ± 1 deg^{-2}

σ= 0.19 ± 0.02 deg

median angle:

σ= 0.22 deg

Minimum time needed for observation:

$$t_{\min}(S_{\min} = 3) = t_{gen} \cdot \left(\frac{S_{\min}}{S}\right)^2 \sim 120 \text{ days}$$

Observation of the Moon shadow

•In order to detect the Moon shadow the angular resolution (median) after cuts has not to exceed 0.2

•A first guess about performance was obtained by selecting atm. muon events with an angular resolution betteer than 0.2

• Full calculations have to be performed

orient.	Λ	counts
ud	>-6.75	118
dd	>-6.7	23
dh	>-6.0	81

Nfit>65

Conclusions and perspectives

- Sensitivity to high energy neutrinos (> 100 TeV) almost independent of the PMT orientation
- Atmospheric muon rejection and Moon shadow “detection”
- OM orientation studies indicate that the dh configuration represents a good compromise
- Moon shadow should be “detected” by the km^3 Mediterranean neutrino telescope in a time of the order of one month
- Sensitivity estimate for dd, dh, ud with high q. e. needed
- Performance of multi-PMT OM detector to be investigated
- Overall detector lay out to be optimized also taking into account deployment and maintaince procedures
- Atmospheric muon mass production
- Moon shadow calculations has to be optimised (direction, PMT acceptance, …)