"Low energy" neutrino physics in ANTARES

Astronomy with a Neutrino Telescope and Abyss environmental RESearch

Introduction

Expected performances for low energy (E<300 GeV) neutrinos

Atmospheric Neutrino Oscillations

- *analysis method & main results*
- *systematics (tentative)*

Conclusions

for the ANTARES collaboration

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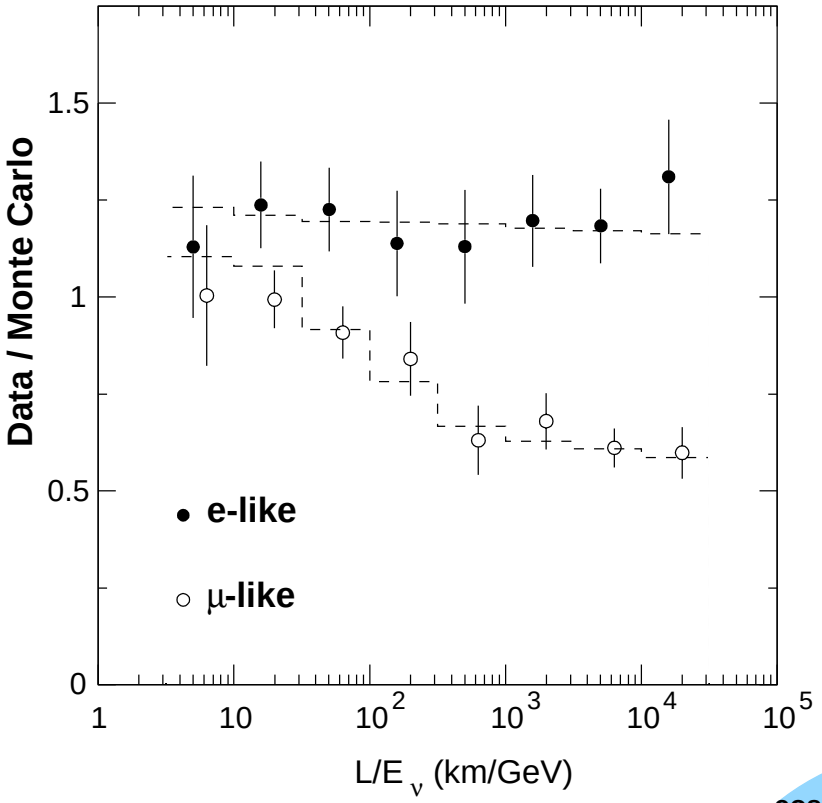
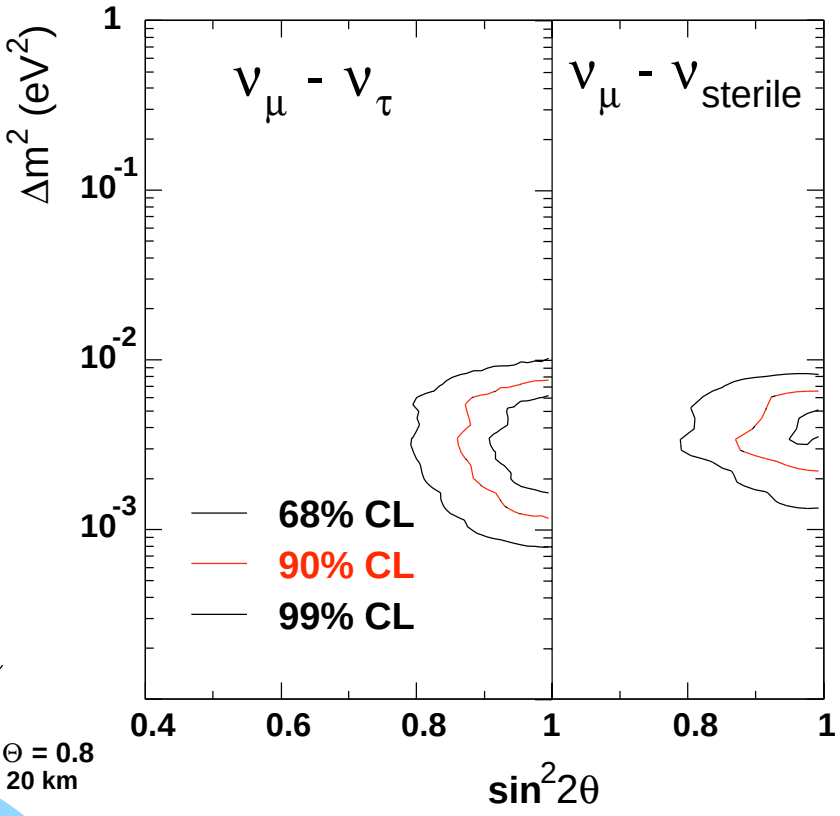
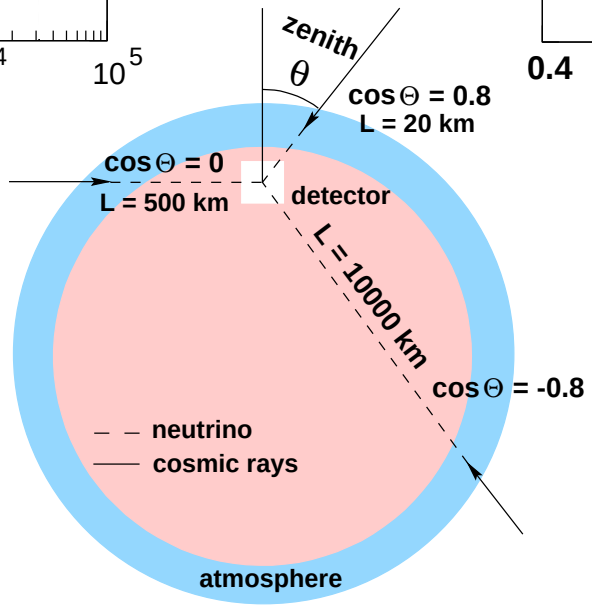
NIKHEF

SuperKamiokande, Summer 1998

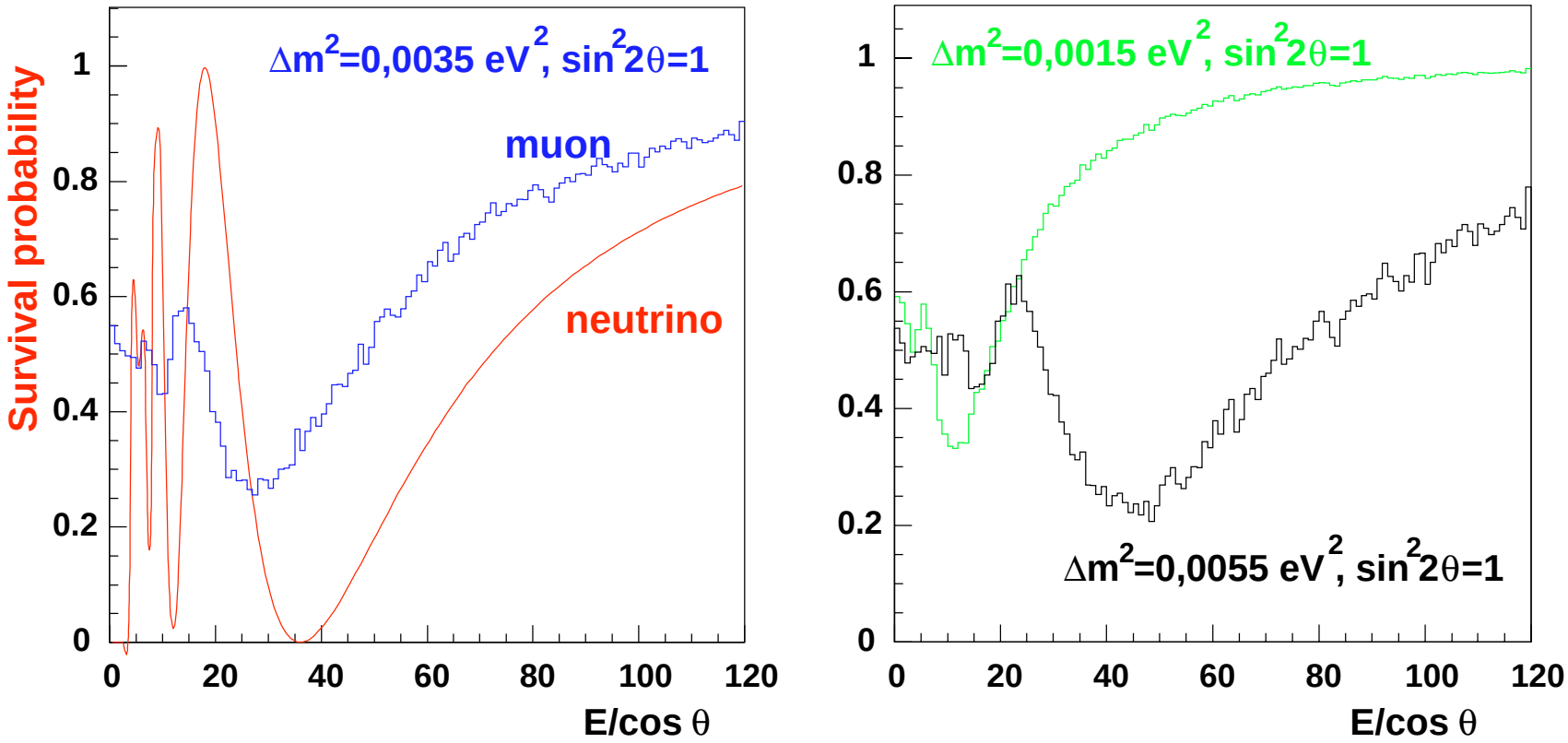






What about the neutrino telescopes ?

$L = L_0 \cos\vartheta$



0.1 km2 detector

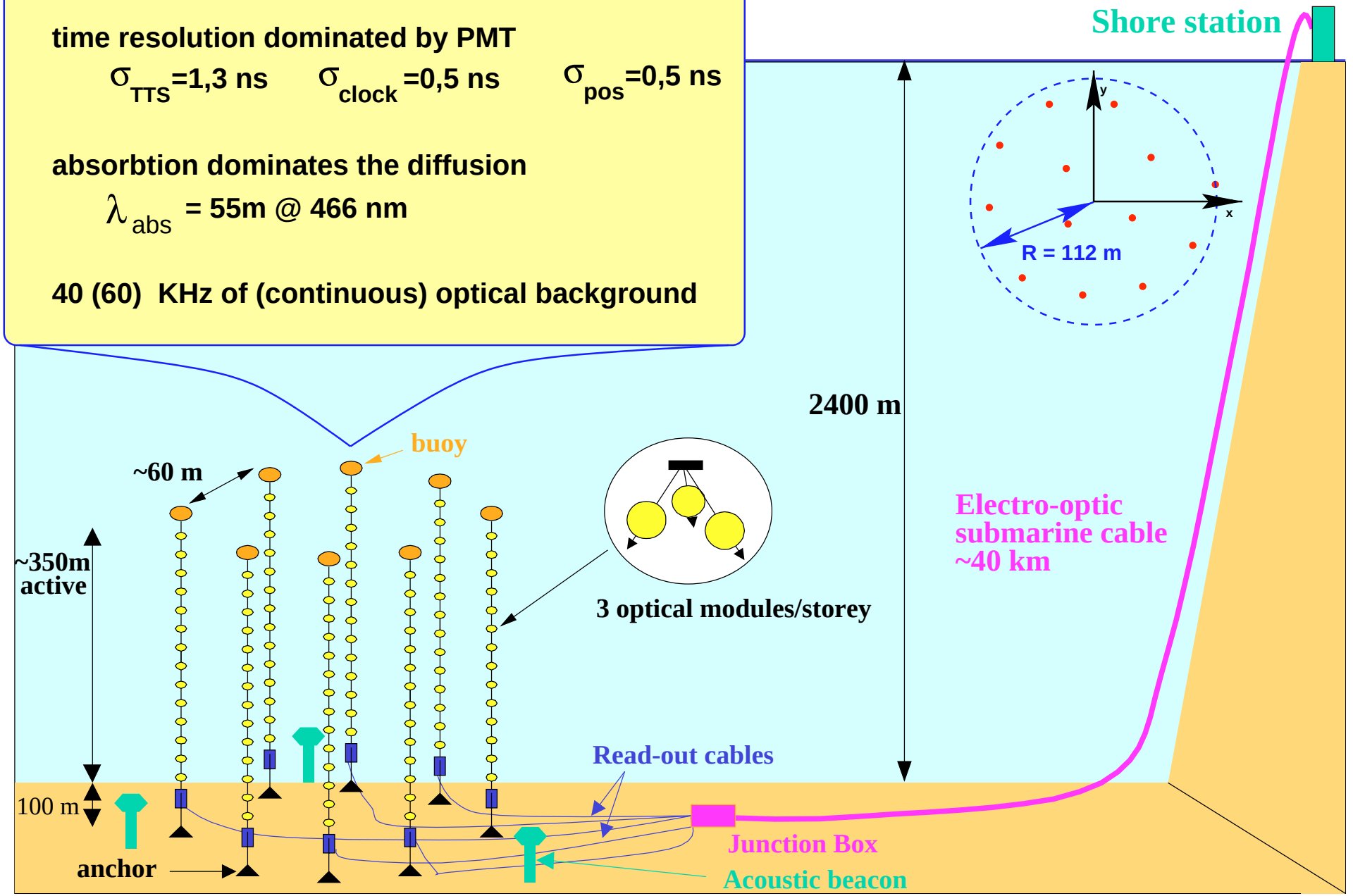
time resolution dominated by PMT

σ_{TTS}=1,3 ns σ_{clock}=0,5 ns σ_{pos}=0,5 ns

absorbtion dominates the diffusion

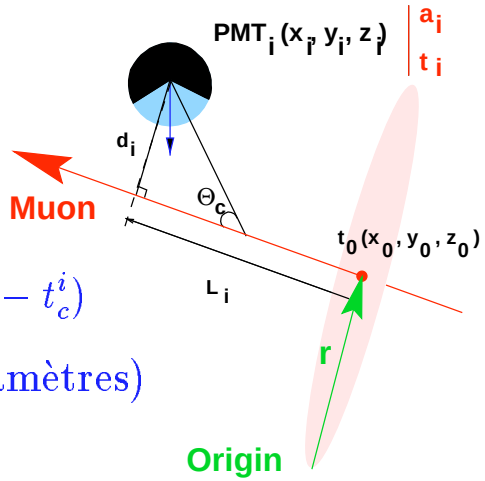
λ_{abs} = 55m @ 466 nm

40 (60) KHz of (continuous) optical background



Muon reconstruction

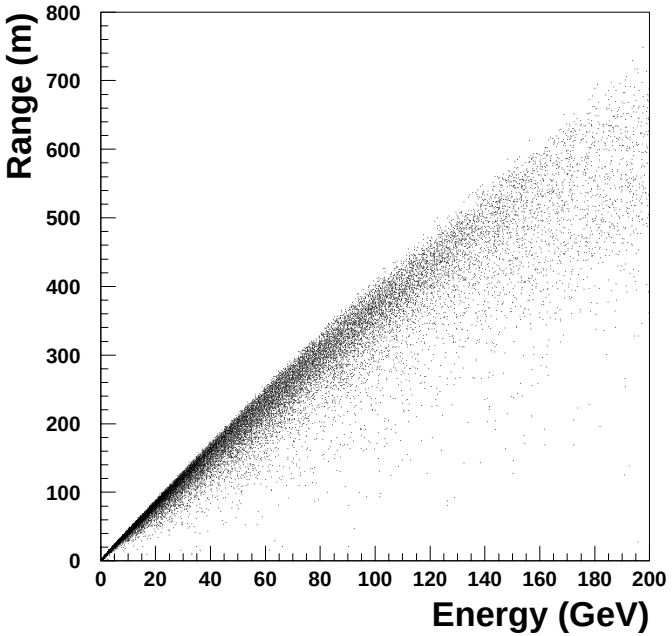
Track:



$$\mathcal{L} = \prod_i f(t^i - t_c^i)$$

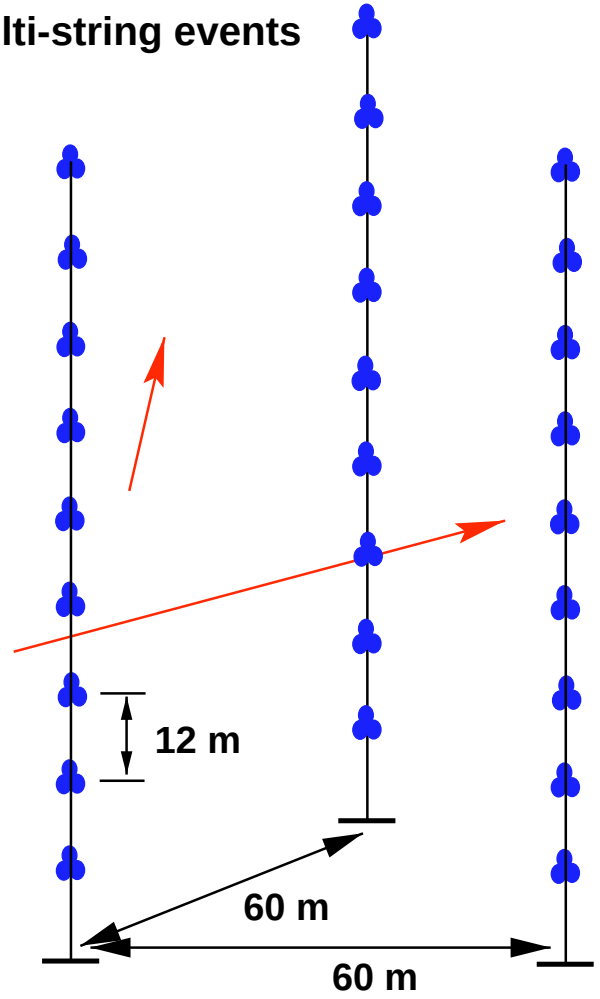
$$t_c = t_c(\text{paramètres})$$

Energy:

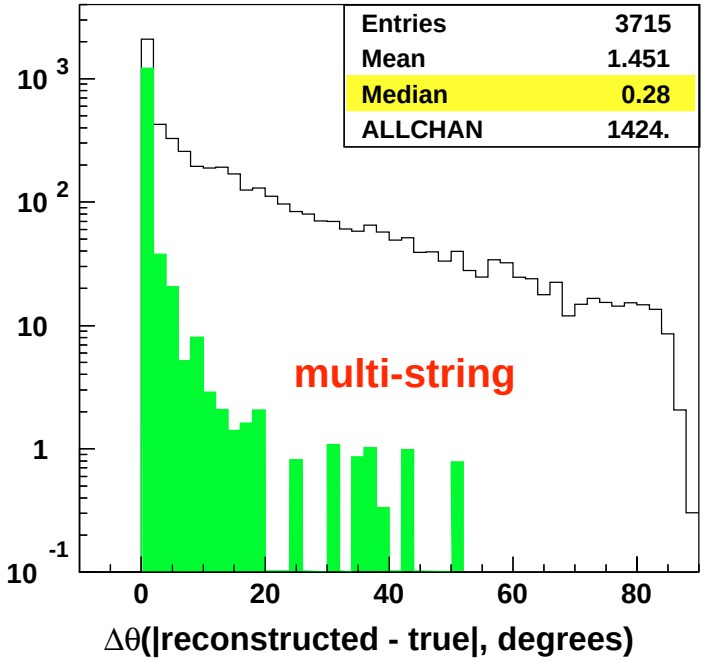


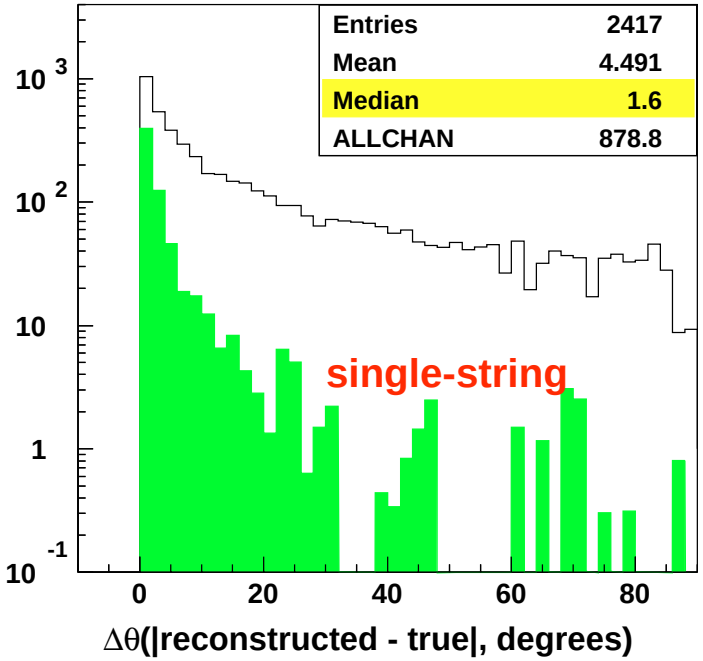
Important optical background -> filters

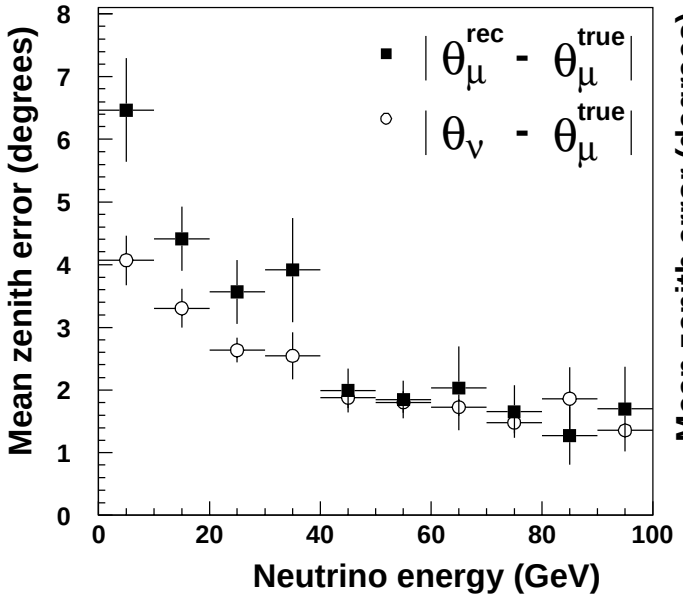
Asymmetric detector -> single & multi-string events

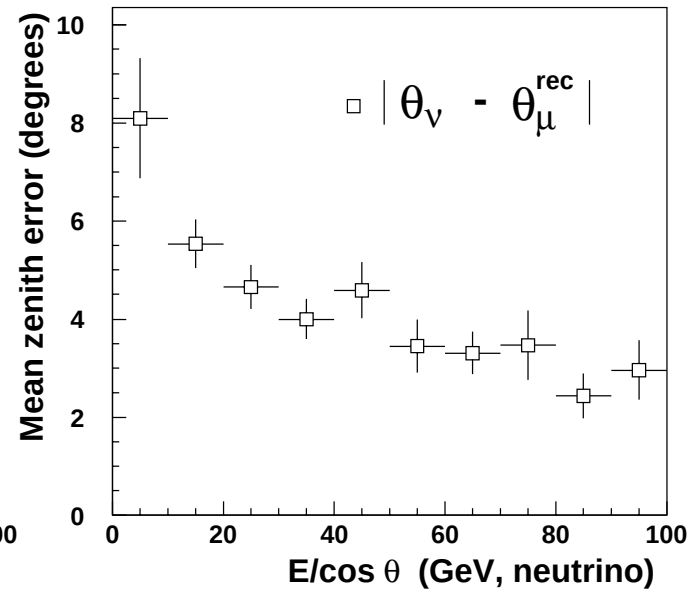


Angular resolution

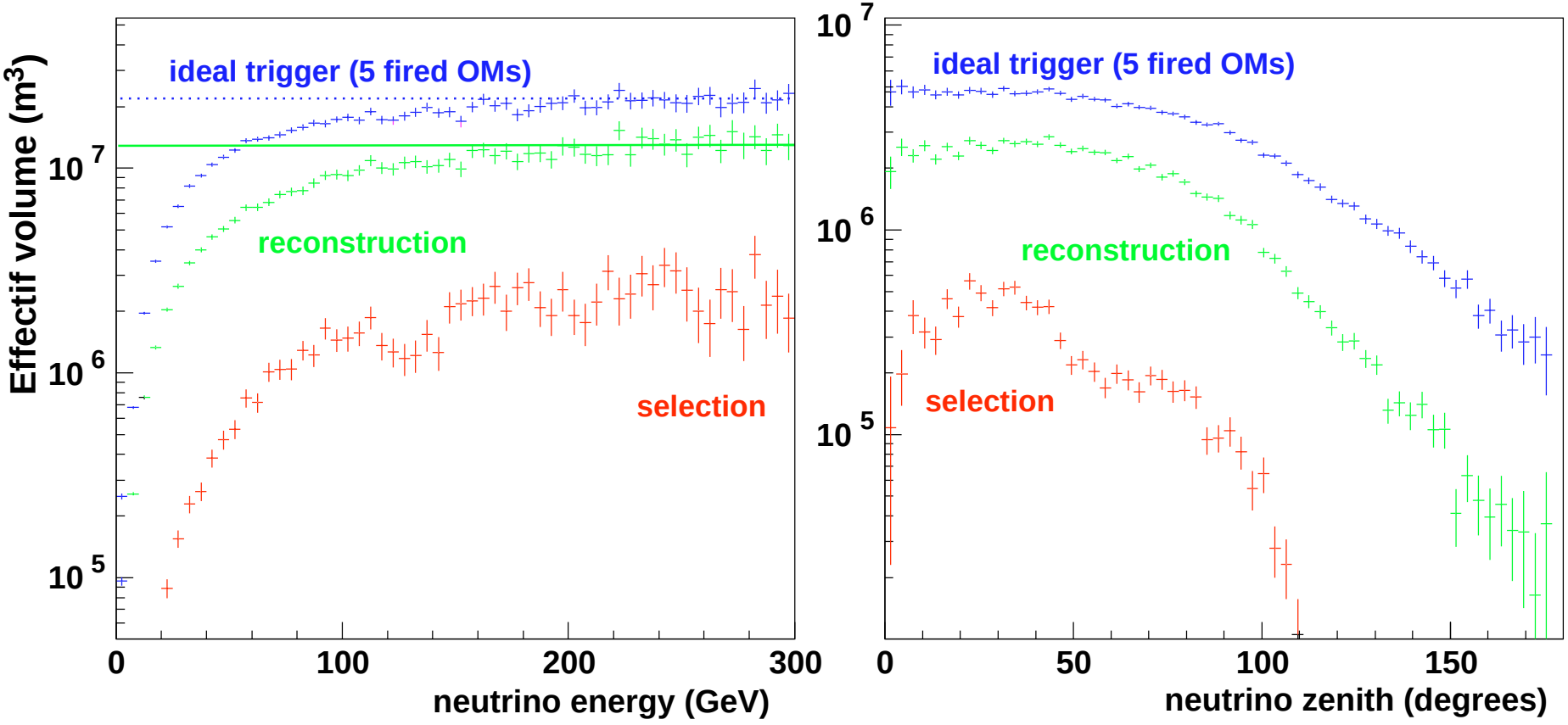








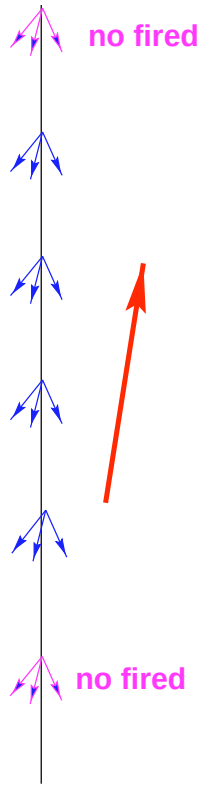
Effective Volume

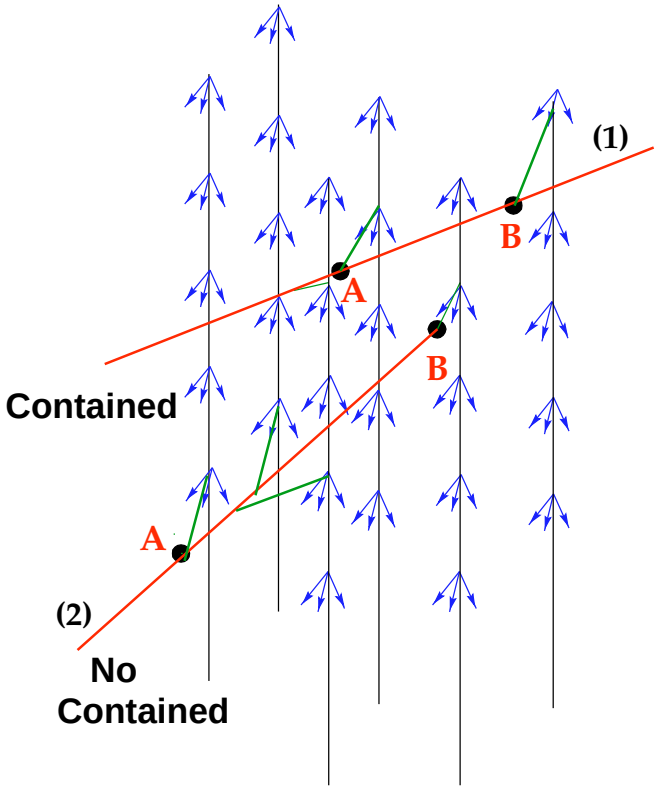


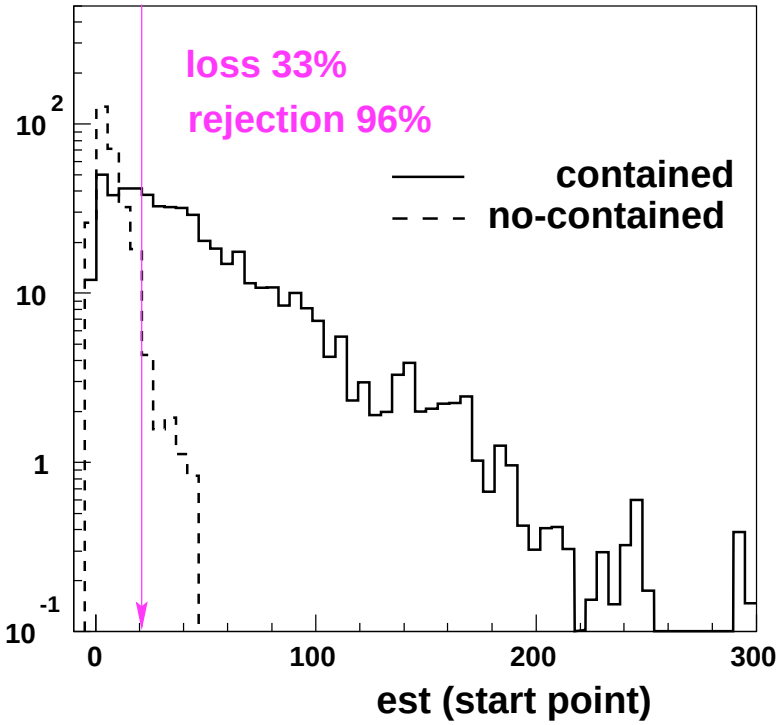
Selection = well reconstructed up going events

(single string: zenith < 45 deg, multistring: zenith < 80 deg)

Containment Estimators



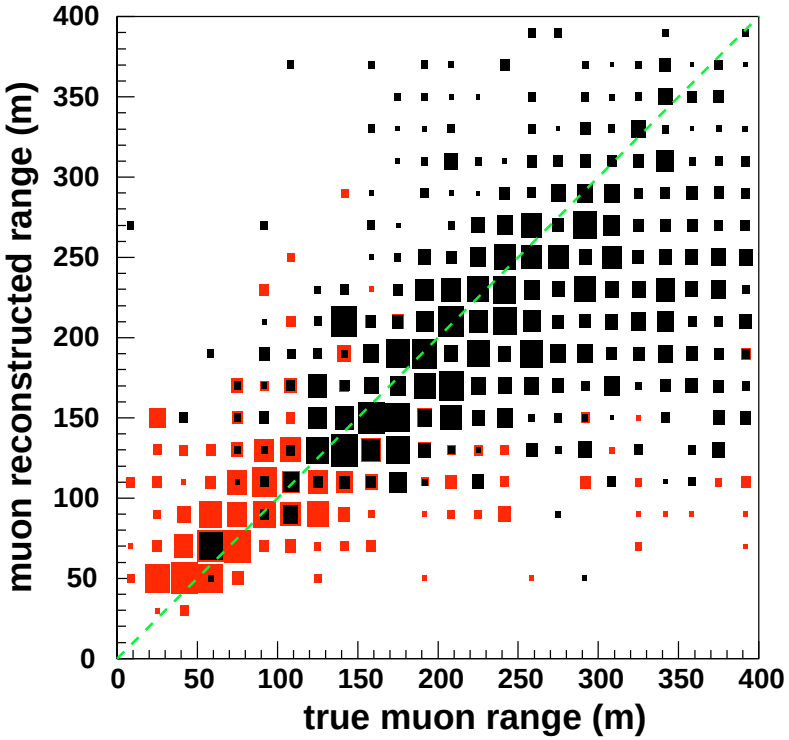


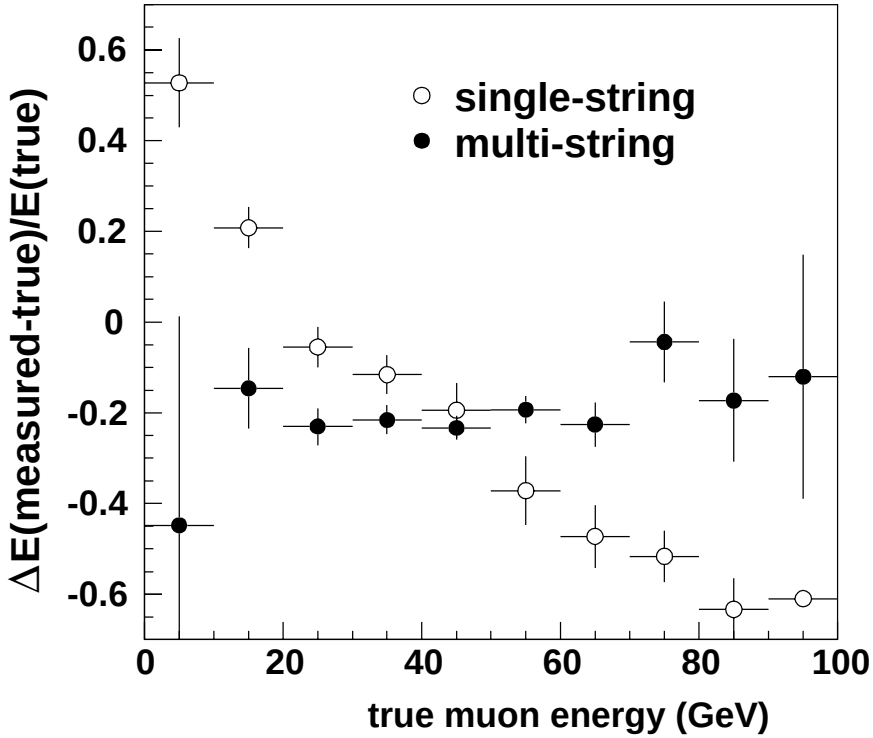


Single-string events

Multi-string events

Energy Resolution





Potential Backgrounds

electron neutrinos

non contained muon neutrinos

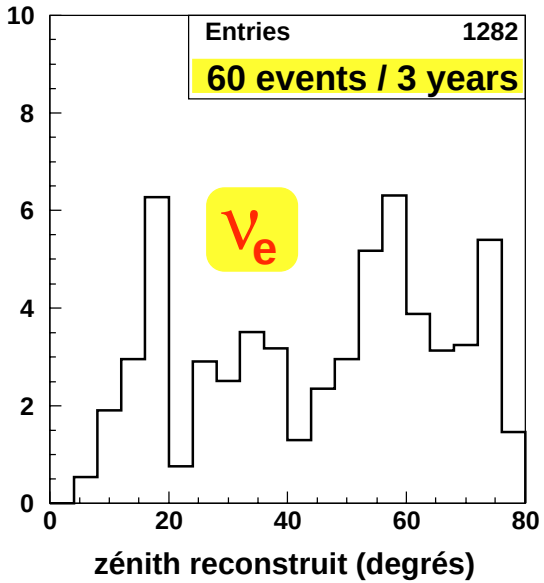
atmospheric muons (mono & multi)

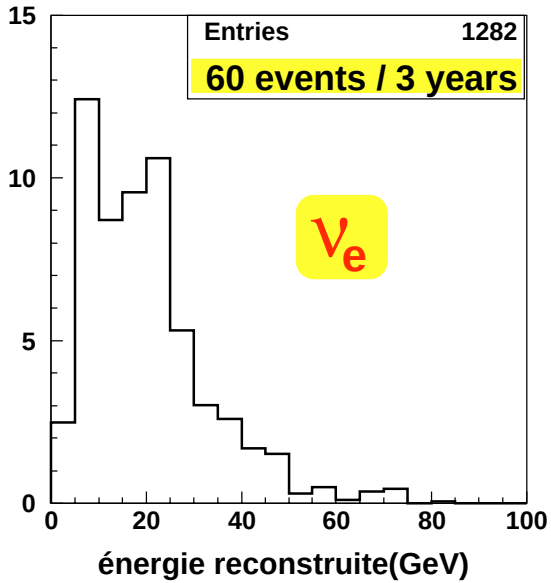
~ 10 days of multi-muons

< 90 evt / year @ 90% CL

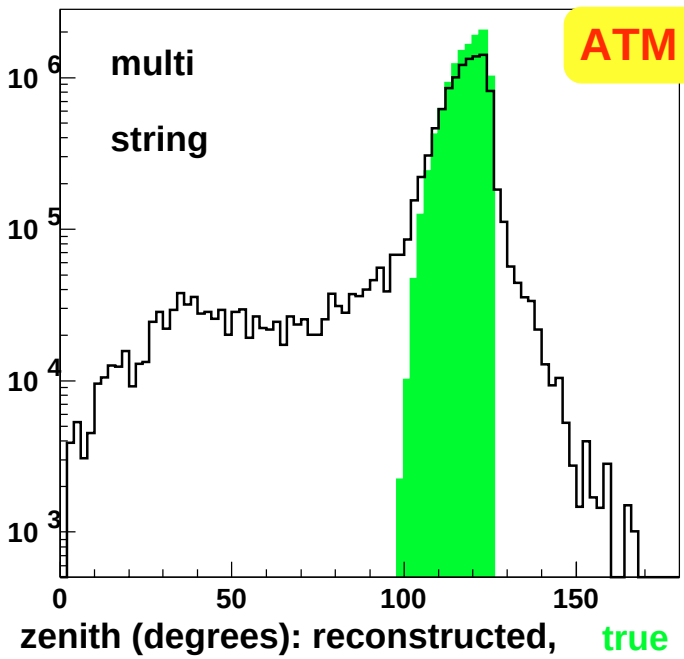
random optical background (K40)

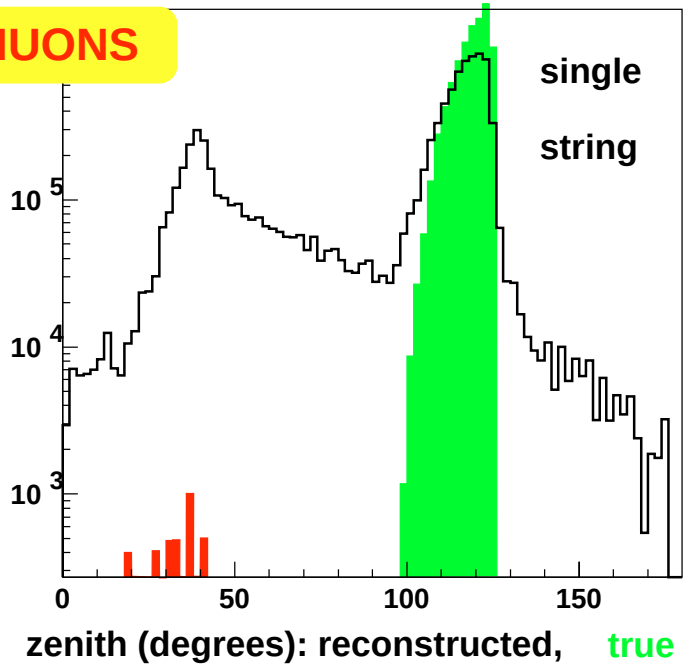
more statistics is needed





ATM MUONS



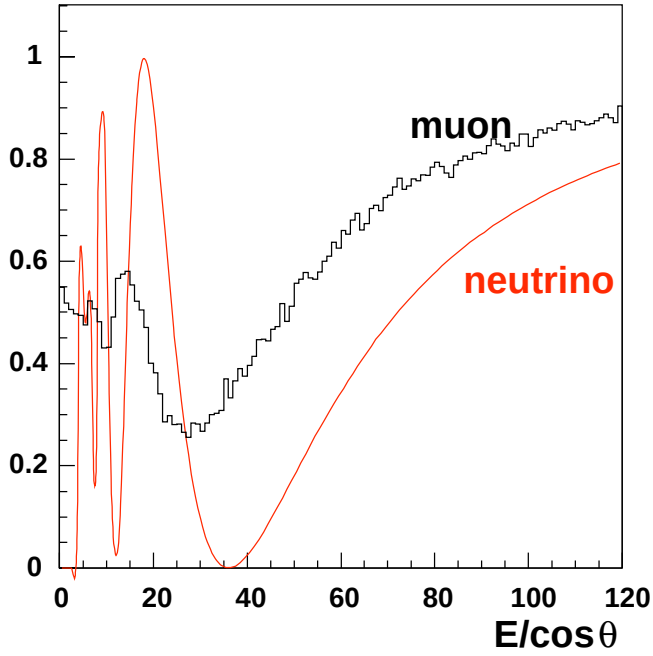


RELAXED CUTS

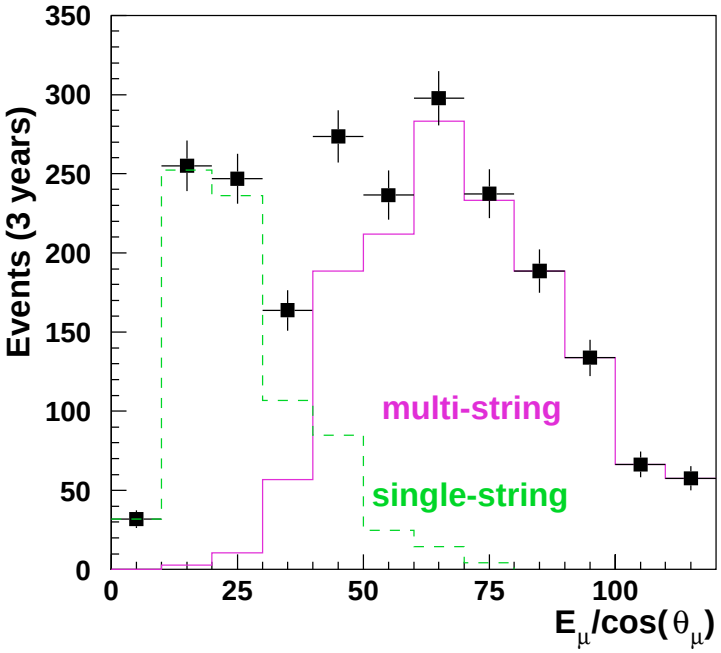
Oscillation Analysis

Survival probability of muon neutrinos

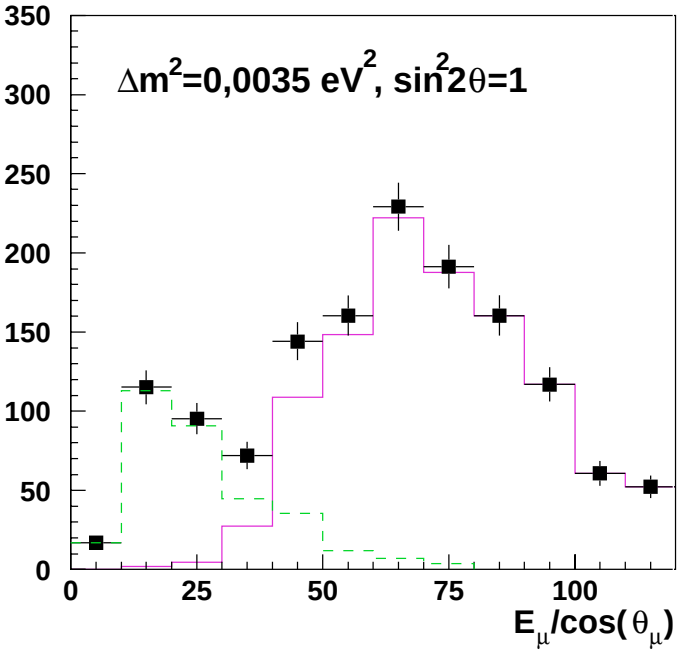
Δm^2=0,0035 eV^2, $\sin^2 2\theta$=1



multi-string: zenith < 80 deg

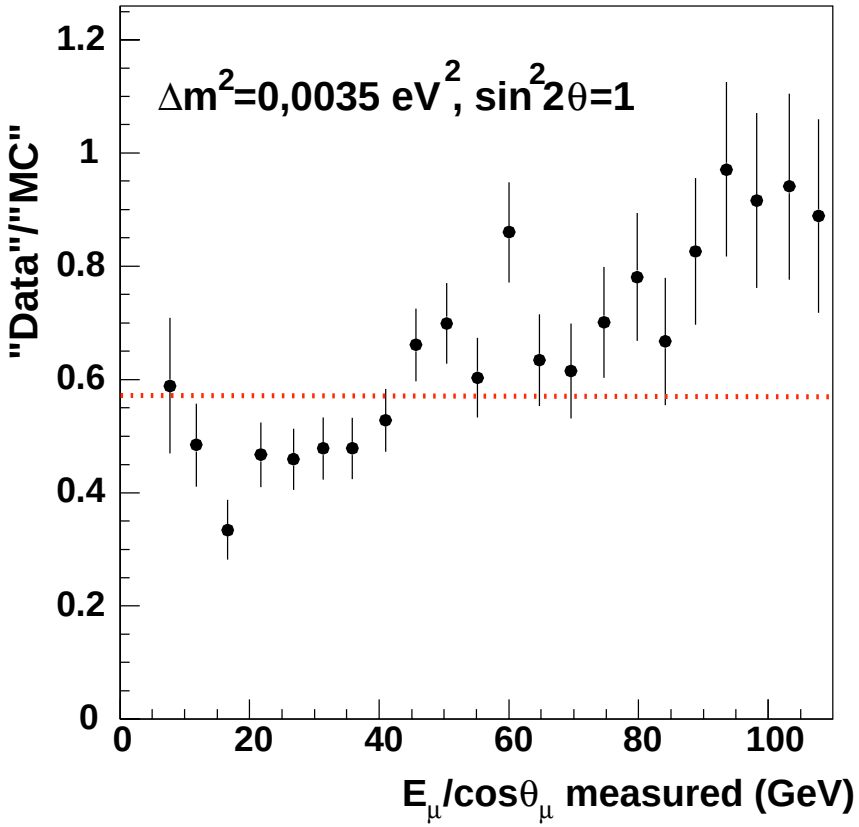


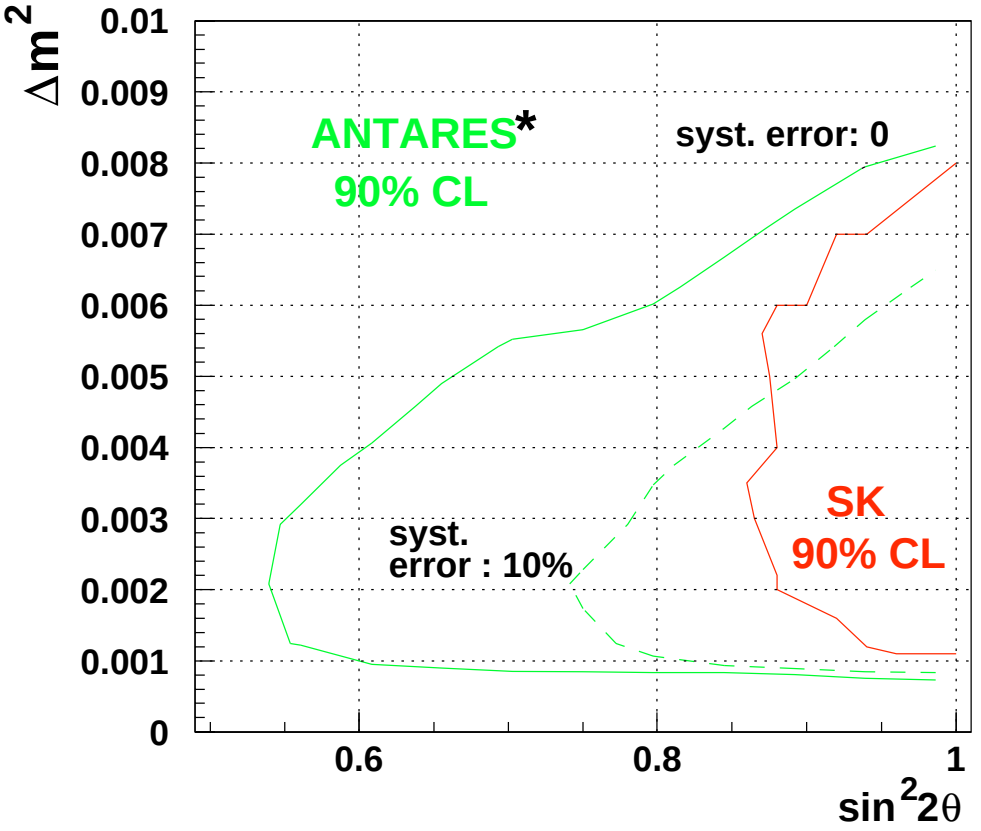
single-string: zenith < 30 deg



Exclusion Plots

- Simulate 1 high statistics experiment: ‘‘Monte Carlo’’ (no oscillations)
- Simulate many experiments with the ANTARES statistics (oscillations)
- Fit the oscillation spectrum with a straight line (normalisation free)

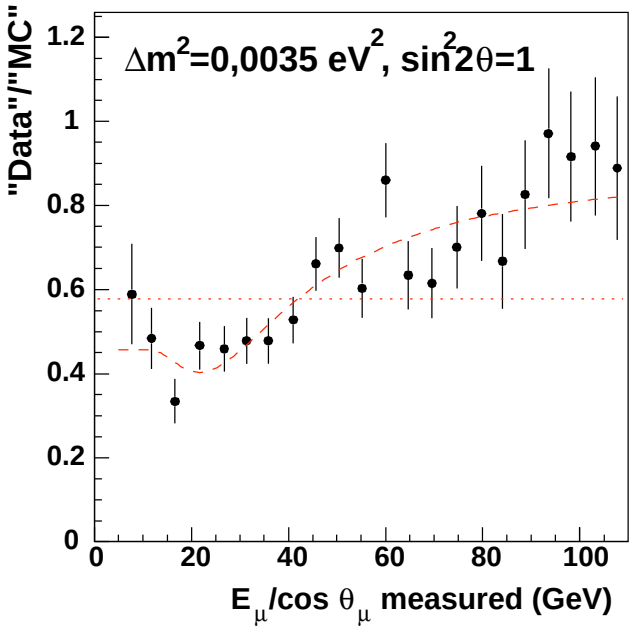




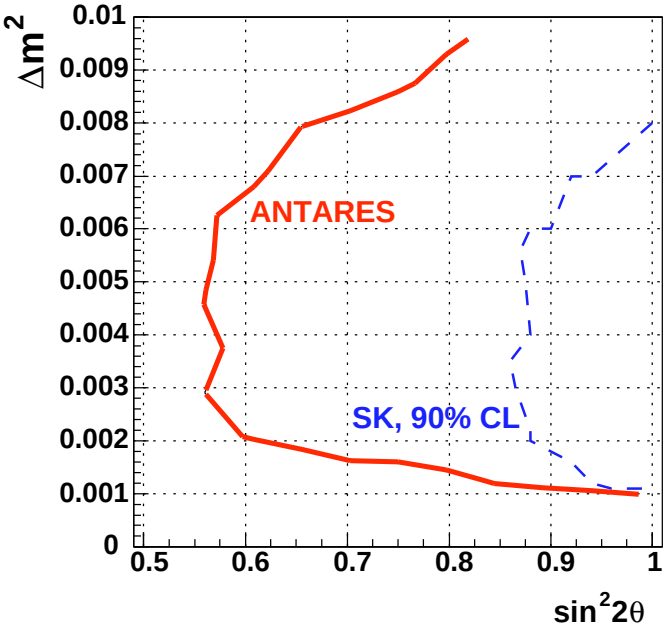
*ANTARES, 90% CL = 90% CL in 80% of the experiments

Measurement of the oscillation parameters

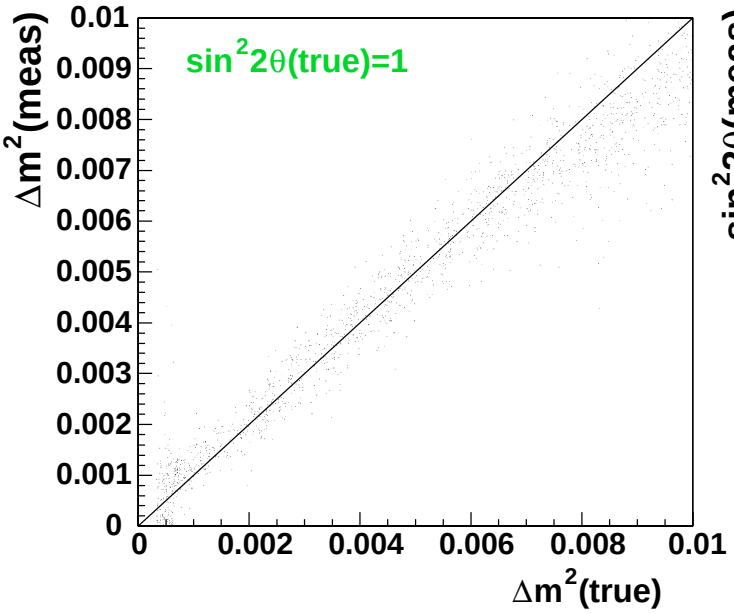
$$< \mathcal{P} >= 1 - \sin^2 2\theta < \sin^2 \left(1,27 \Delta m^2 \frac{L_\nu}{E_\nu}\right) >$$

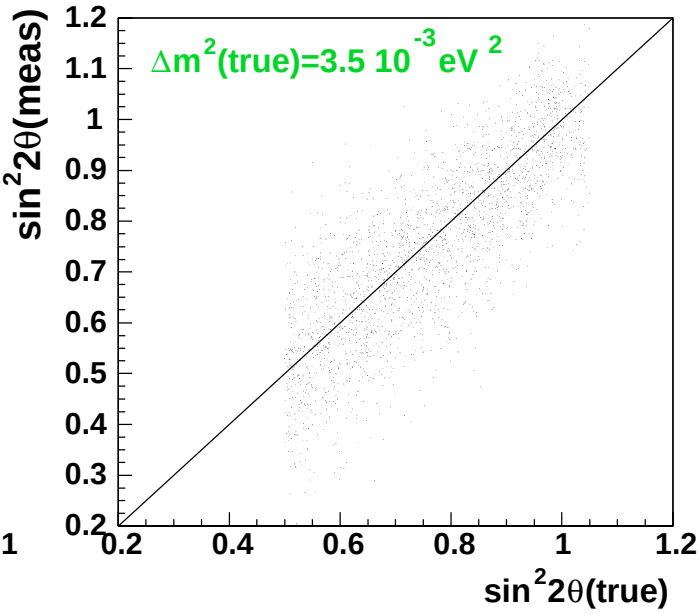


3 years of data taking



Independent measurement of each oscillation parameter with a relative precision better than 33 %





Systematic uncertainties

Detector environment
- **water transparency**
- **optical background level**

} *rate of events*

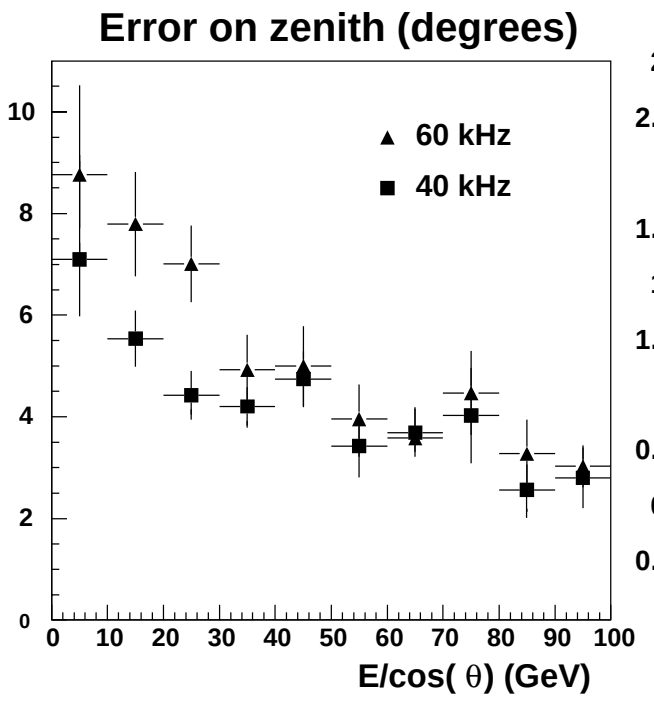
The detector
- **OMs positioning**
- **timing resolution**

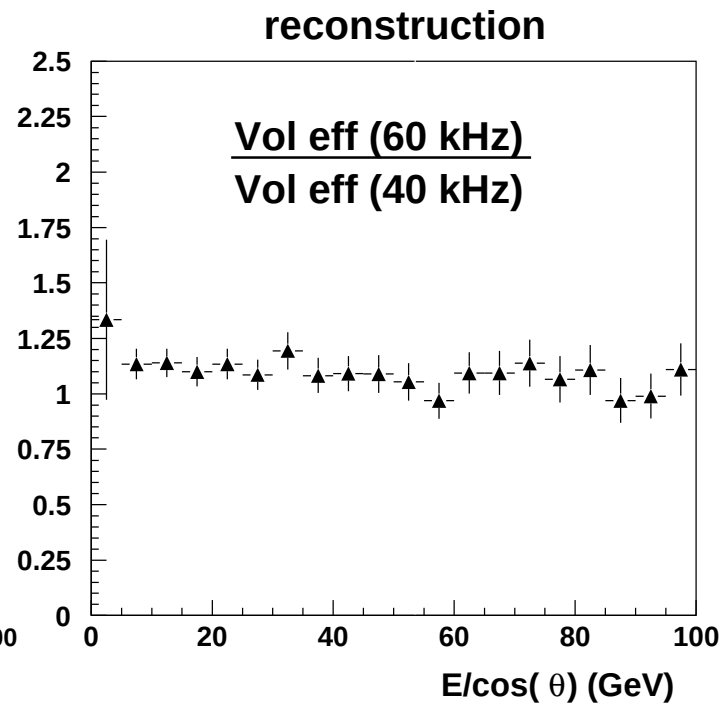
} *oscillation spectrum deteriorated (“washed out”)*

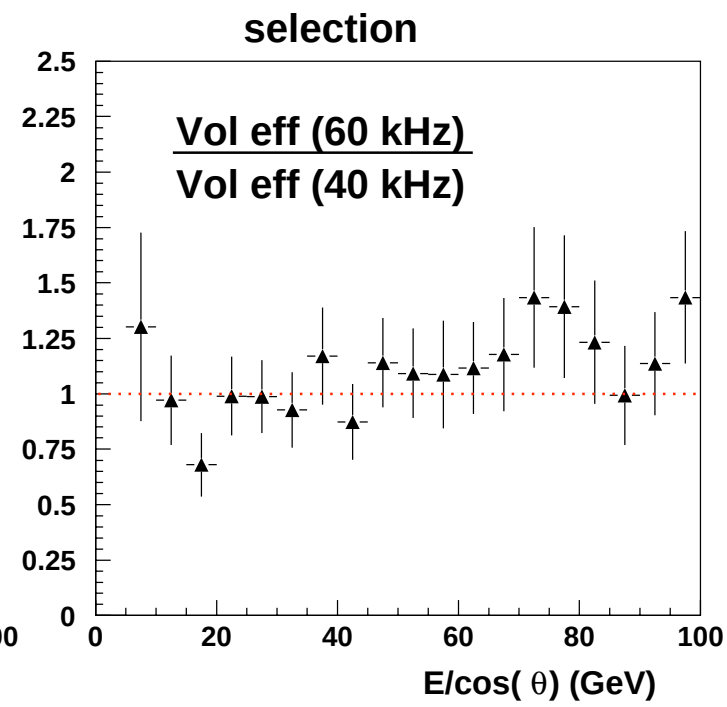
Atmospheric neutrino flux
- **normalisation** *-> rate of events*
- **shape** *-> systematics for parameter measurement*

how important ??

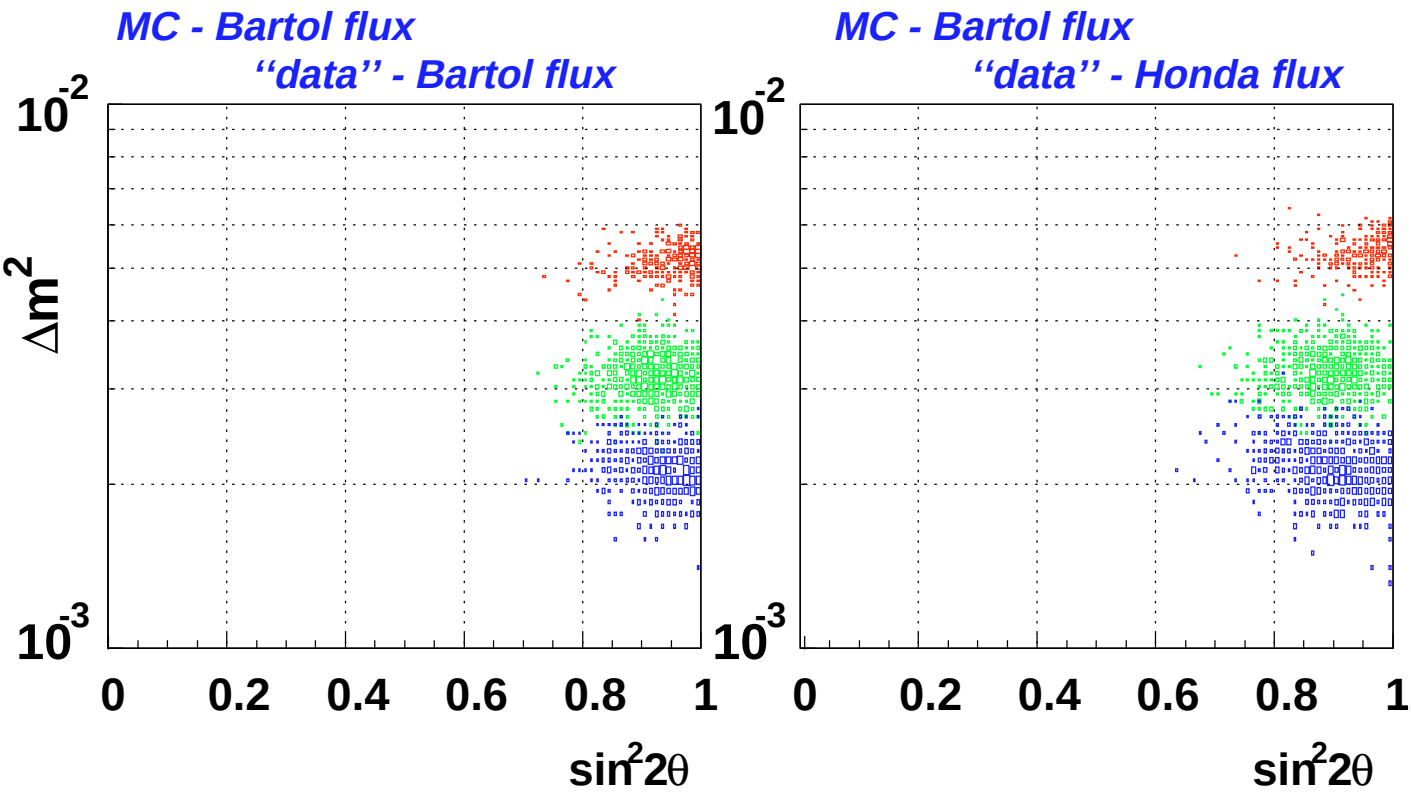
Optical Background Rate

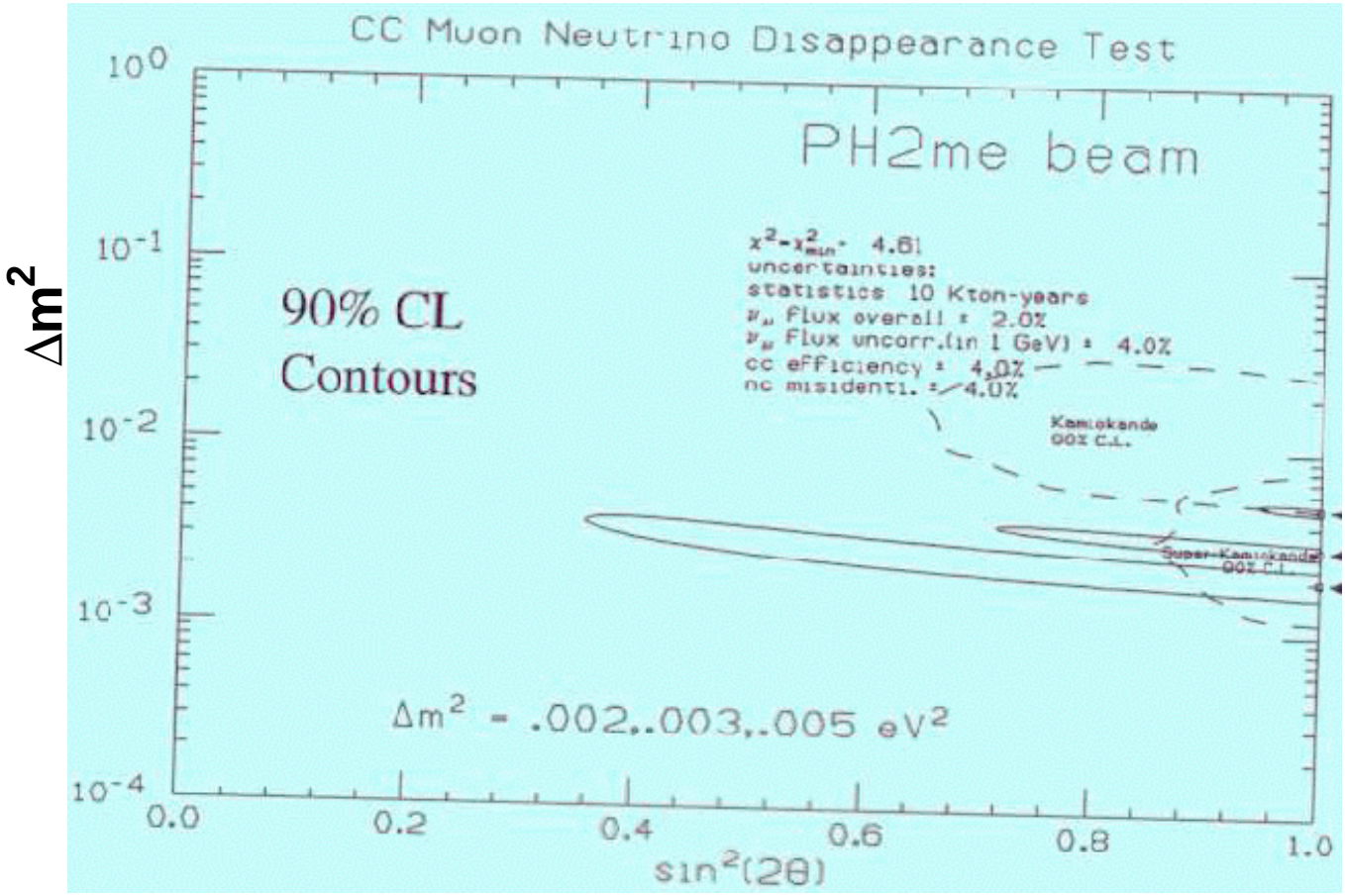






Oscillation Parameters Measurement





Conclusion

Good performances for the detection of the low energy neutrinos (E < 300 GeV)

* mean error on the neutrino zenith improves from 5 deg @ 20 GeV to 3 deg above 40 GeV
* effective volume for upgoing events: from ~10^5 m @ 20 GeV to ~ 2 10^6 above 100 GeV
* relative energy resolution better than 30% (E_μ > 20 GeV)

A first analysis shows that with 3 years of data ANTARES is sensitive to the atmospheric neutrino oscillations:

* it could exclude oscillations with the SK favoured parameters if no signal
* it could measure independently Δm^2 and $\sin^2 2\theta$ with a precision better than 33% over a large region of parameters, if oscillation signal

... but systematic effects have to be considered carefully