ν oscillations in ANTARES

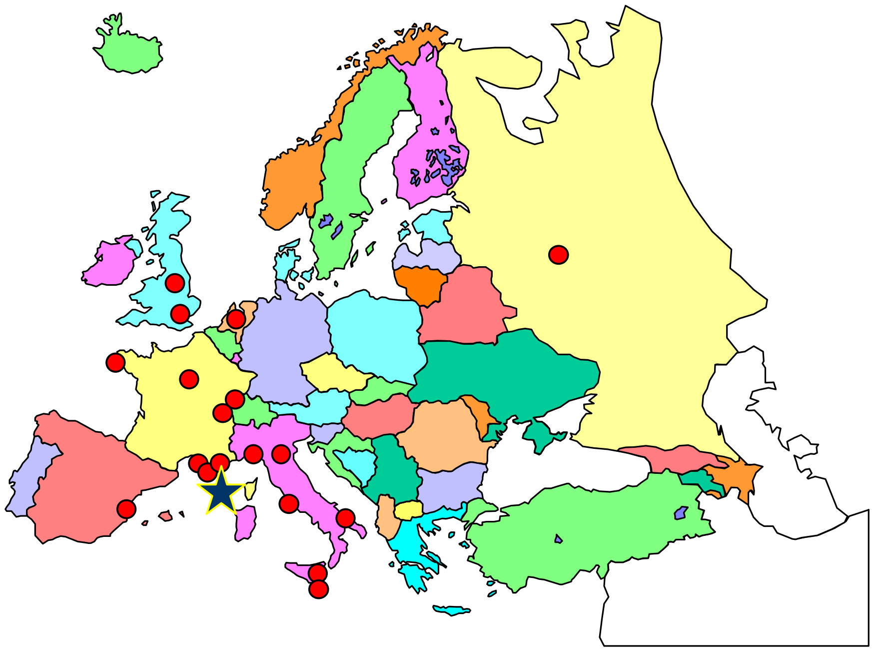
Dick Hubbard / Saclay

for the ANTARES collaboration

Antares site	**40 km off Toulon in Mediterranean Sea**
Antares detector	**Effective area 0.1 km^2, 10 strings, 900 PMTs**
Neutrino astronomy	**Sky coverage 3.6 π including galactic center**
	Amanda overlap 0.6 π
Oscillations studies	**Current analysis - partially contained events**
	Work in progress - stopping & thru-going events
Antares schedule	**1st prototype deployed Nov 1999 - June 2000**
	Full detector deployment 2002 - 2004

ANTARES collaboration

- CPPM, Marseille (IN2P3)
- DSM/DAPNIA, Saclay (CEA)
- IReS, Strasbourg
- Univ. of H.-A., Mulhouse
- C.O.M. Marseille
- IFREMER, Marseille/Brest
- IGRAP (INSU), Provence



- University of Oxford
- University of Sheffield

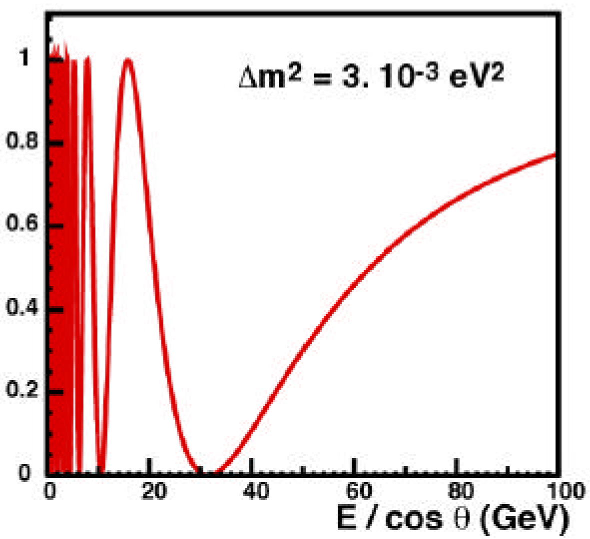
- ITEP, Moscow

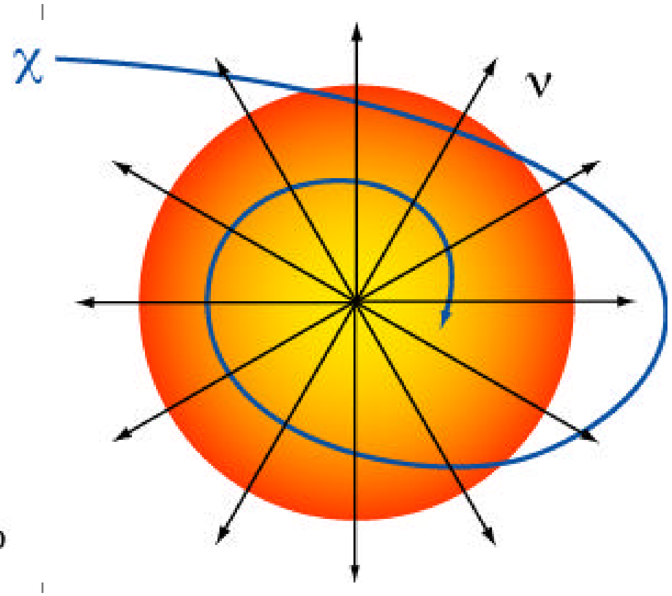
- University and INFN, Bari
- University and INFN, Bologna
- University and INFN, Catania
- INFN - LNS, Catania
- University I and INFN, Rome
- University and INFN, Genova

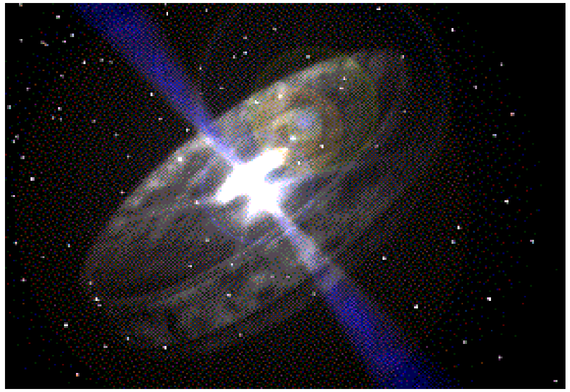
- NIKHEF, Amsterdam

- IFIC, Valencia

ANTARES scientific program







Low Energy	Medium Energy	High Energy

ν oscillations

Observation of first oscillation minimum

Neutralino search

$\chi\chi \rightarrow \nu + X$

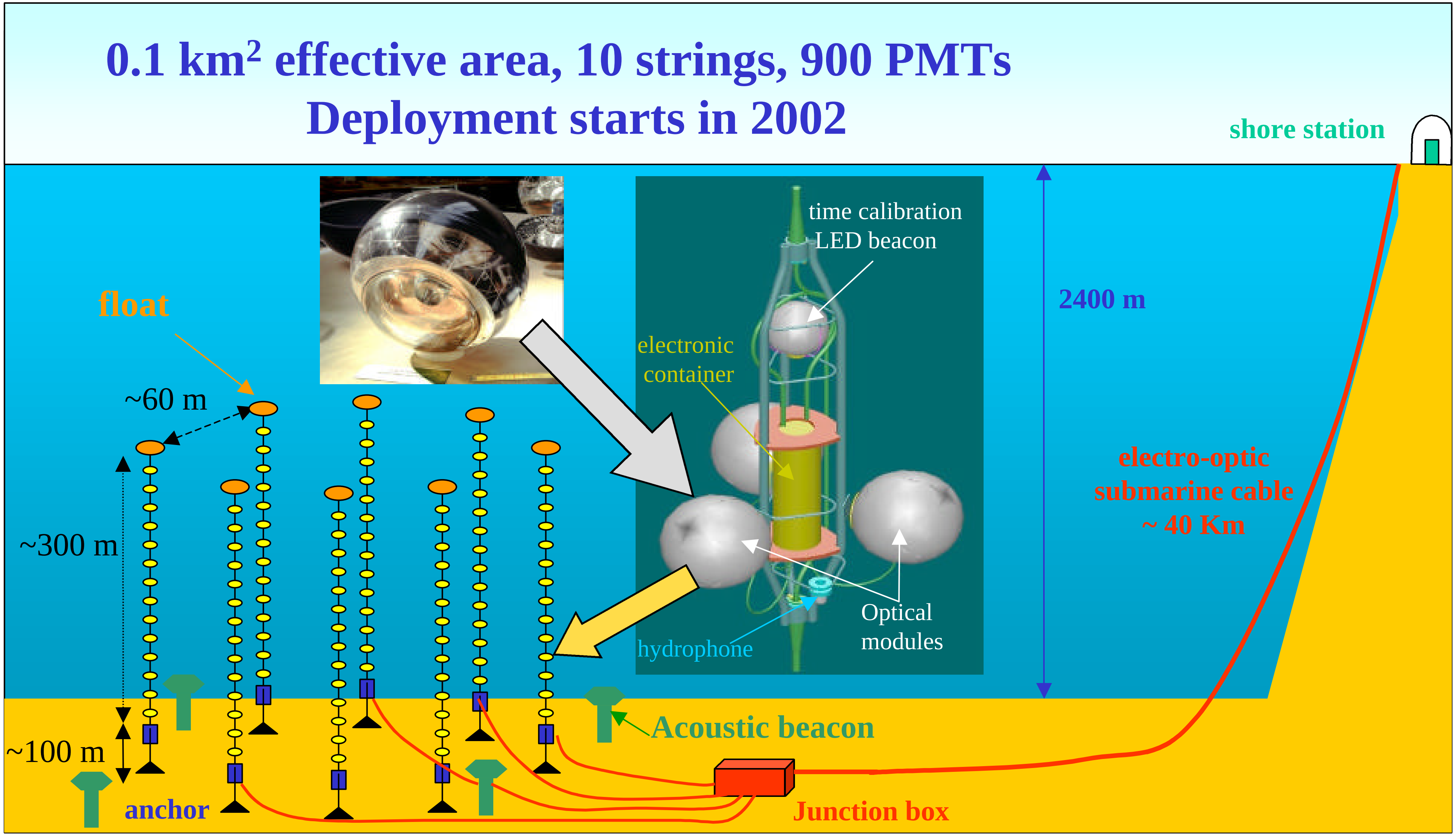
center of earth, sun, galaxy

GRB cannonballs

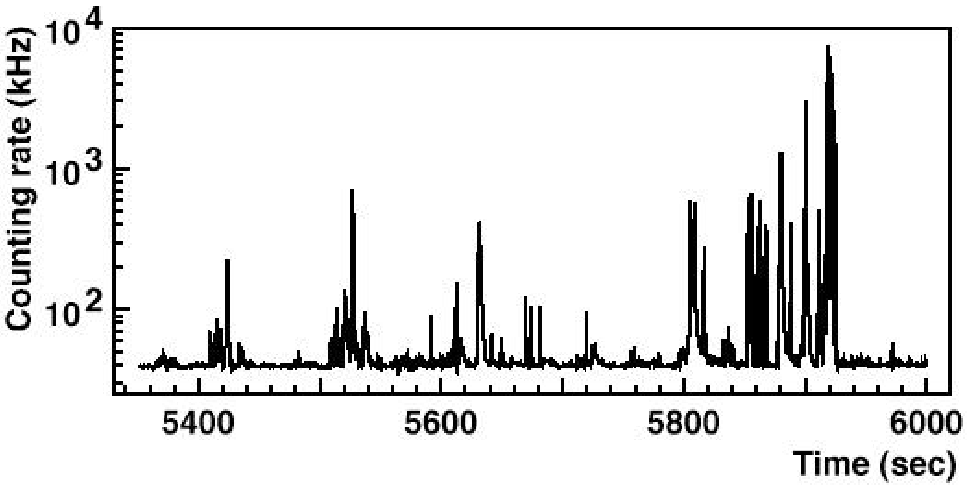
ν from (extra-) galactic sources

SN remnants, AGN, GRB, ...

ANTARES detector



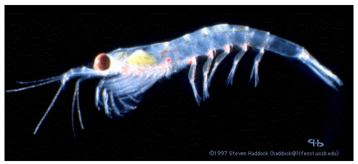
Water optical properties



Optical background:

~ 60 kHz on 10” PMT mainly ^{40}K

+ bioluminescence bursts



$\Rightarrow$ < 5% dead time / PMT

Water transparency:

- Blue light 470 nm

λ_{abs} ~ 55 m

$\lambda_{scat\ eff}$ ~ 300 m

- UV light 370 nm

λ_{abs} ~ 25 m

$\lambda_{scat\ eff}$ ~ 120 m

$$\lambda_{scat\ eff} = \frac{\lambda_{scat}}{1 - \langle \cos\theta \rangle}$$

Oscillations analyses

Current analysis   Contained events and leaving muons

10 string detector : generate ν 's with $E_\nu = 4 - 300$ GeV

Atmospheric neutrino flux from Bartol : statistical errors only

Large hadronic showers rejected by quality cuts

Work in progress

Hadronic showers for partially-contained events

Shower energy precision ~ factor 2 at $1\,\sigma$

Minimum error ~ $\pm$ 10 GeV $\Rightarrow$ poor for Super-K parameters

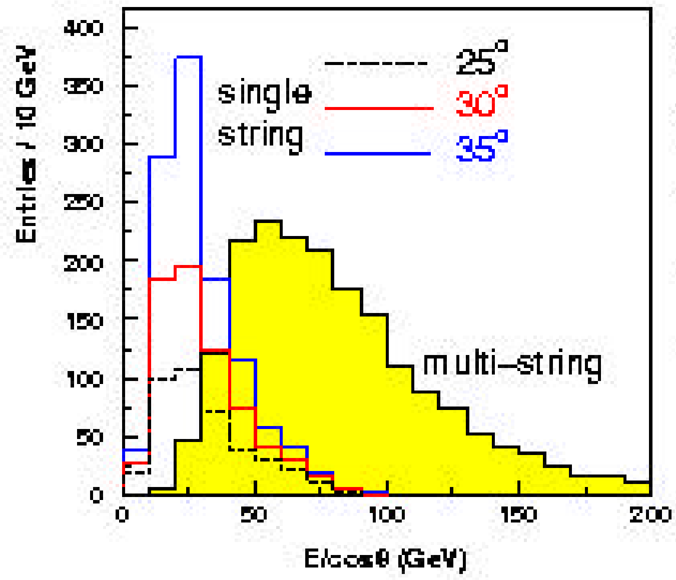
Analysis of stopping and through-going muons

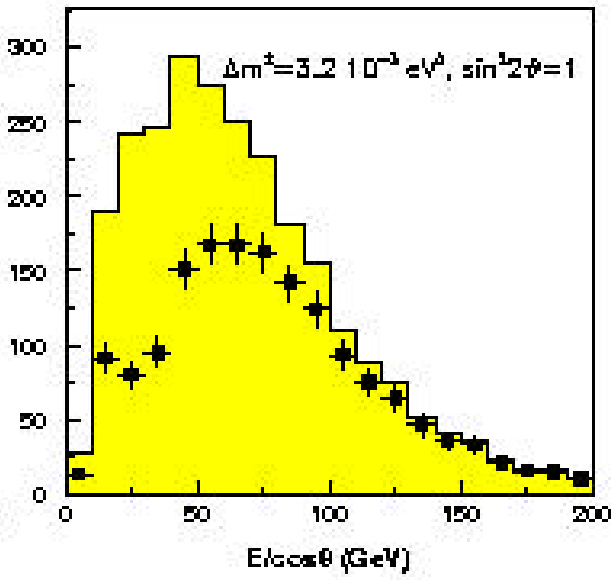
Generate neutrinos with E_ν = 4 GeV - 100 TeV

Two analyses using visible E/L or zenith-angle distribution

ν flux normalization from data : fitted as 3rd parameter

ν oscillations : partially-contained events





Bartol atmospheric ν flux

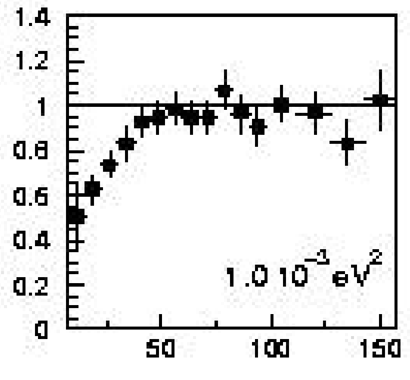
4 years, 90% C.L.

720 single-string events

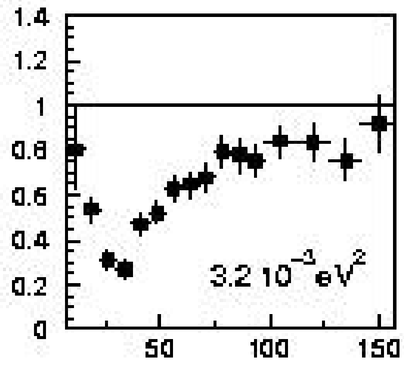
2100 multi-string events

Statistical errors only

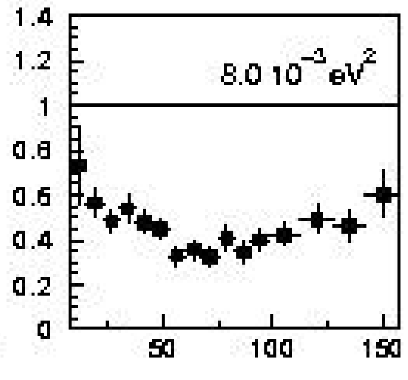
Oscillations analysis : ratio with and without oscillations



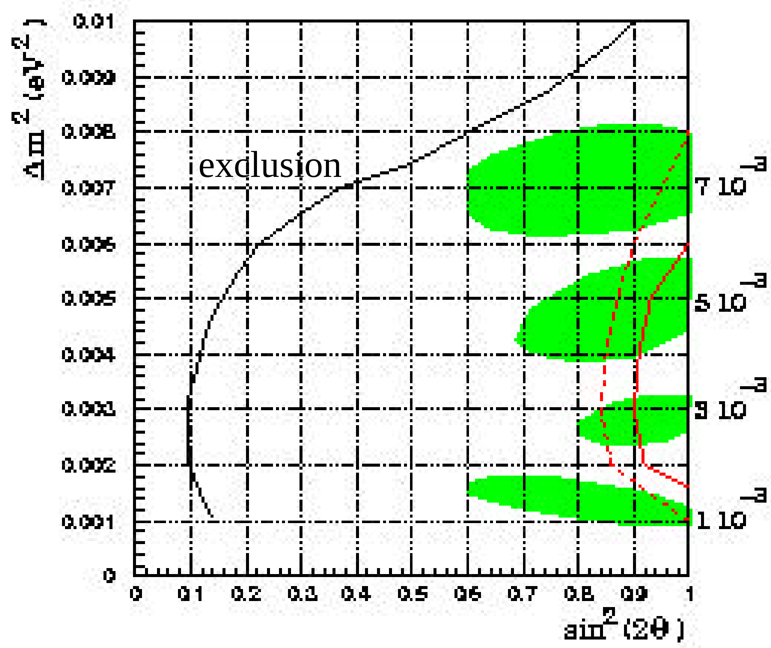
E / cos θ



E / cos θ

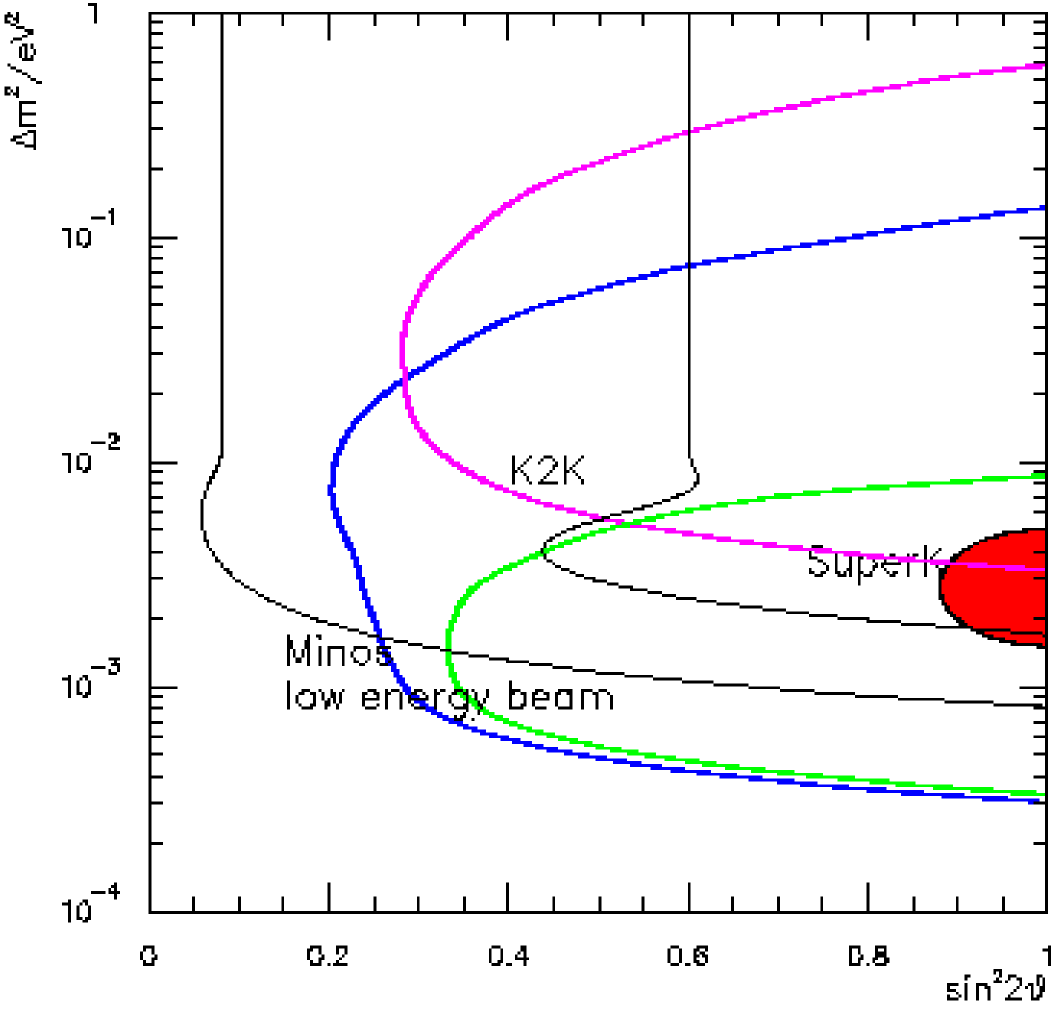


E / cos θ



ν oscillations : all events

90% C.L exclusion after 3 years



Atmospheric ν flux = 3rd parameter

Zenith angle distribution
Multi-string events - no containment cuts

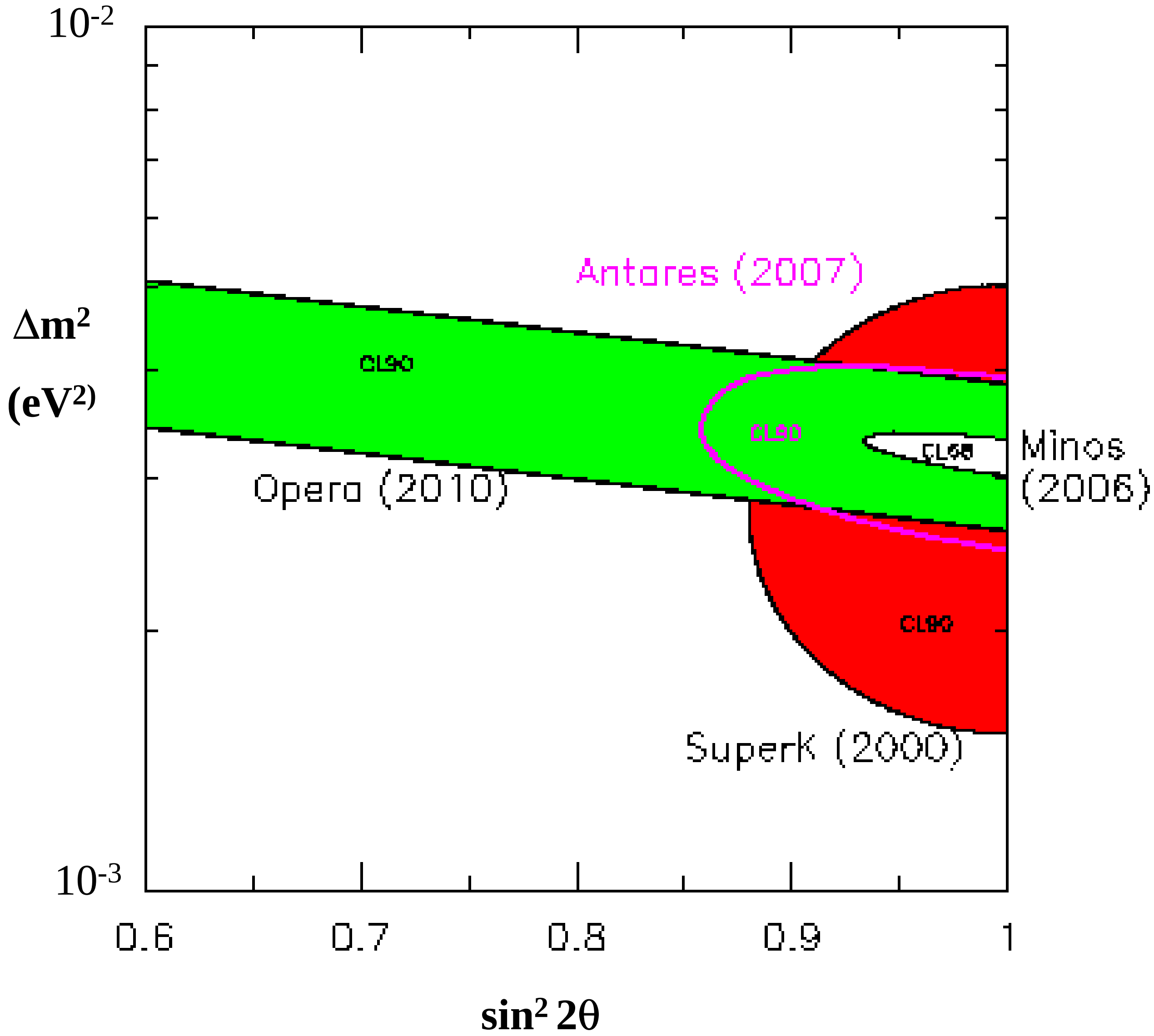
E/L distribution - no containment cuts
Single- and multi-string events

E/L distribution - partially-contained only
Single- and multi-string events

4063 events per year including
294 partially-contained single-string
428 partially-contained multi-string
3341 thru-going + stopping multi-string

Systematic errors ± 5% bin-to-bin

Comparative precision



Sensitivity for 3 years data

Assuming Super-K parameters

from Neutrino-2000 conference

90 % C.L. for Antares,

Opera and Super-K

68 % C.L. for Minos

Sources of systematic errors

Background sources

Electron- and tau-neutrino backgrounds negligible

Atmospheric single- and multi-muon backgrounds small

Detector acceptance and calibration

Relative timing and relative positions should be O.K.

Calibrate efficiencies for single-string and multi-string events ?

Atmospheric neutrino flux

Flux normalization fit as 3rd parameter in oscillations analysis

Flux shape uncertainties influence mainly $\sin^2 2\theta$ determination

Conclusions

Three low-energy ν studies for Antares $E_\nu < 1$ TeV

Neutrino oscillations	- guaranteed physics result
Dark matter	- only if favorable DM parameters
Cannonballs	- possible early astrophysics result

Oscillations parameters : work in progress

Δm^2 precision improved throughout Super-K allowed region

for $\sin^2 2\theta = 1$ exclusion zone covers $\Delta m^2 = 3\times10^{-4} - 0.6$ eV^2

for $\Delta m^2 = 3.5\times10^{-3}$ eV^2 exclusion zone covers $\sin^2 2\theta > 0.25$

Systematic errors important

Flux shape and differential efficiency mainly affect $\sin^2 2\theta$