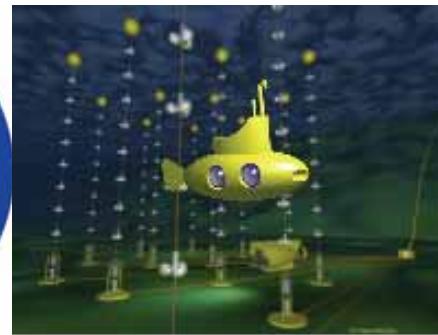


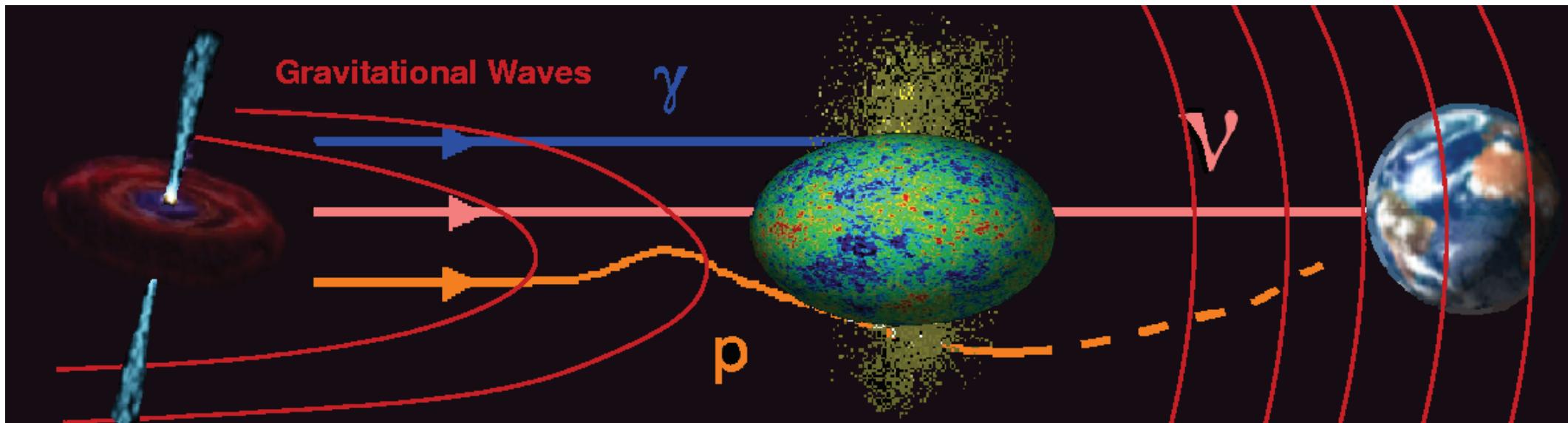
# The *Antares* Neutrino Telescope : First Results

Thierry Pradier  
for the *Antares* Collaboration

IPHC/DRS & University Louis-Pasteur Strasbourg-I



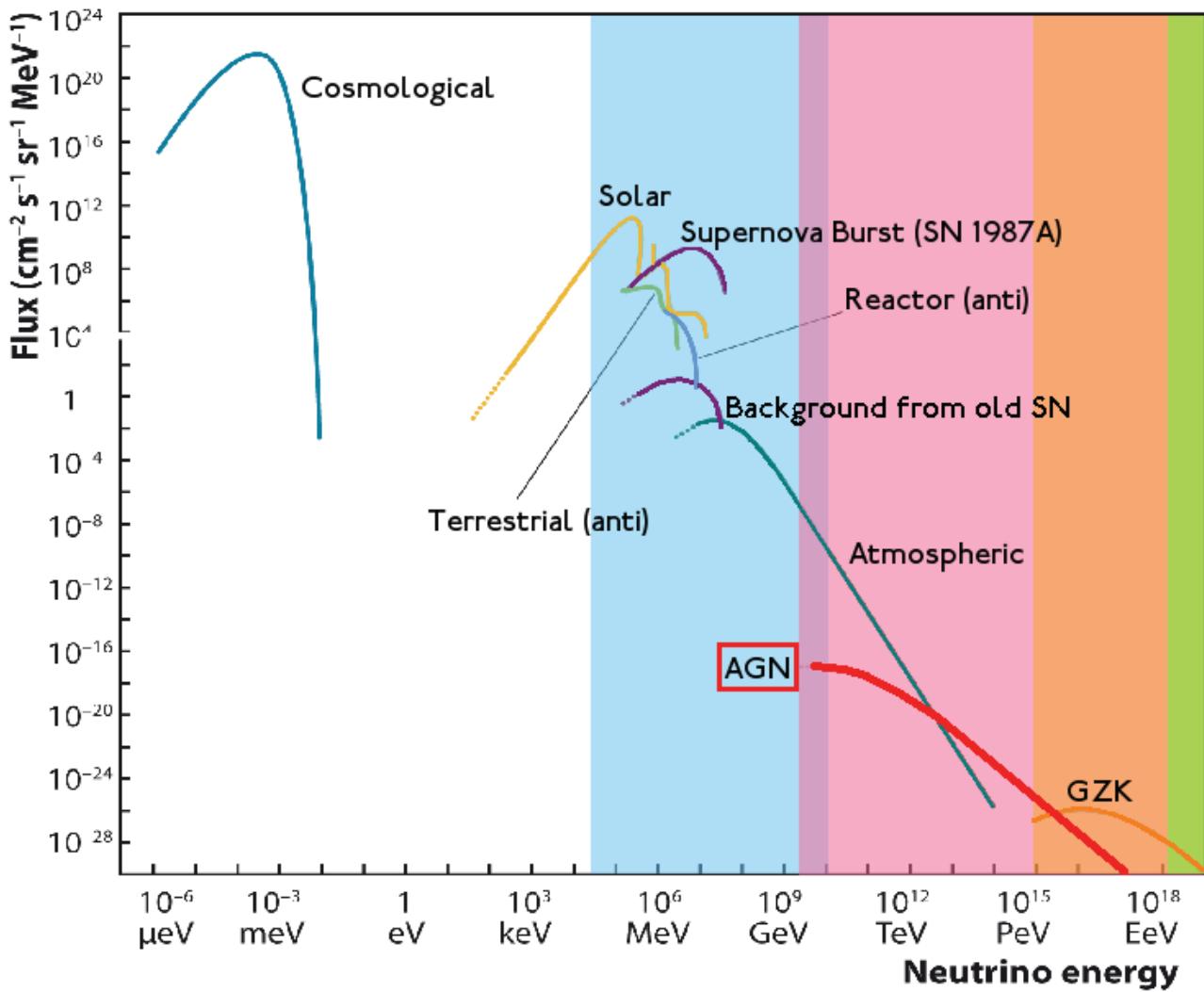
# The neutrino as a new messenger



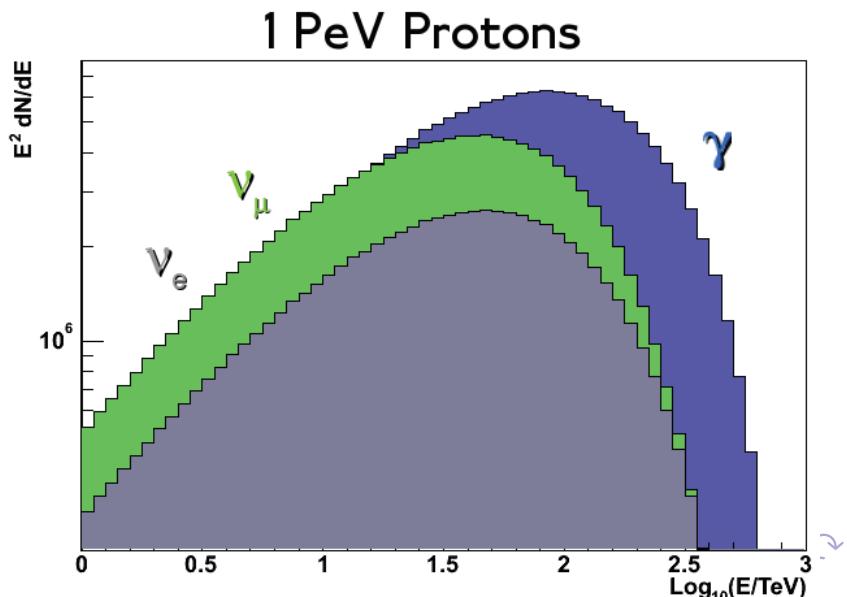
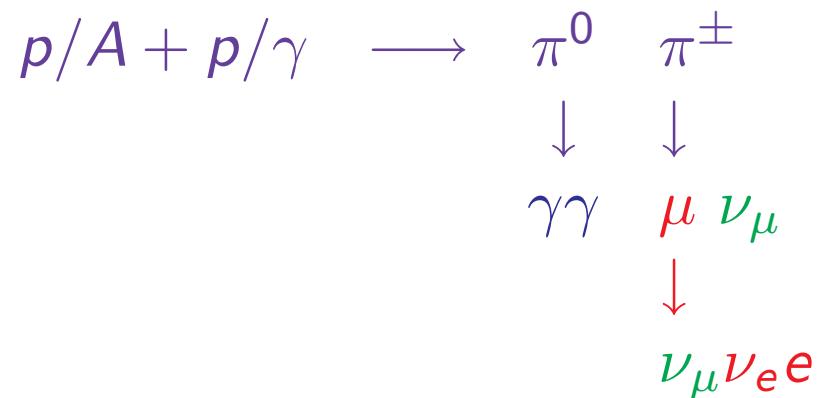
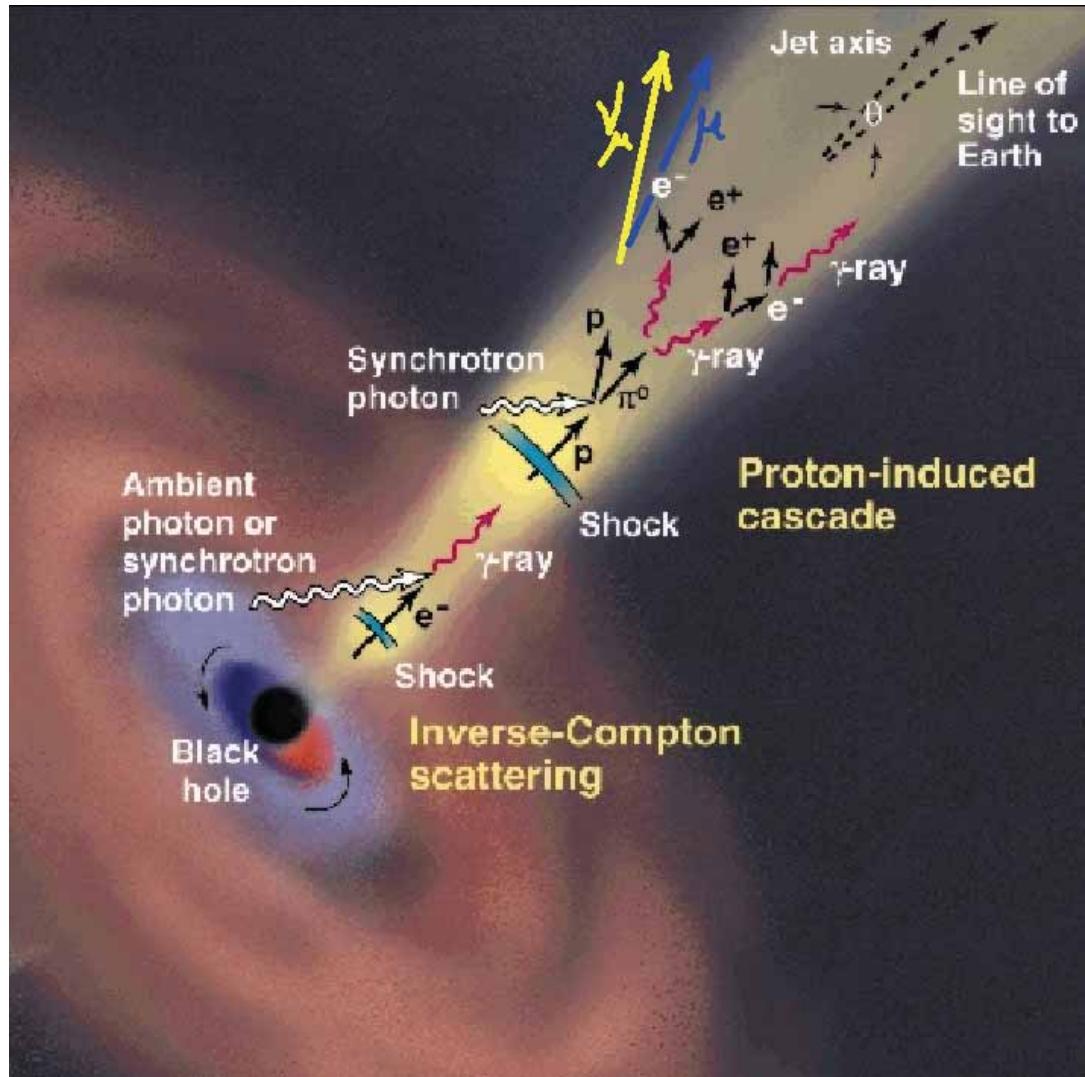
- Interaction of cosmic particles :
  - $\gamma$  : cut-off  $\sim 10^{14}$  eV, mean free path  $\sim 10$  Mpc
  - $p$  : cut-off  $\sim 5 \times 10^{19}$  eV, mean free path  $\sim 50$  Mpc
- Deflection of charged particles :
  - $\Delta\theta \sim L(kpc) \frac{Z B(\mu G)}{E(EeV)}$
  - In the Galaxy  $\Delta\theta \simeq 12^\circ$  at  $10^{19}$  eV

# Neutrinos in the Universe

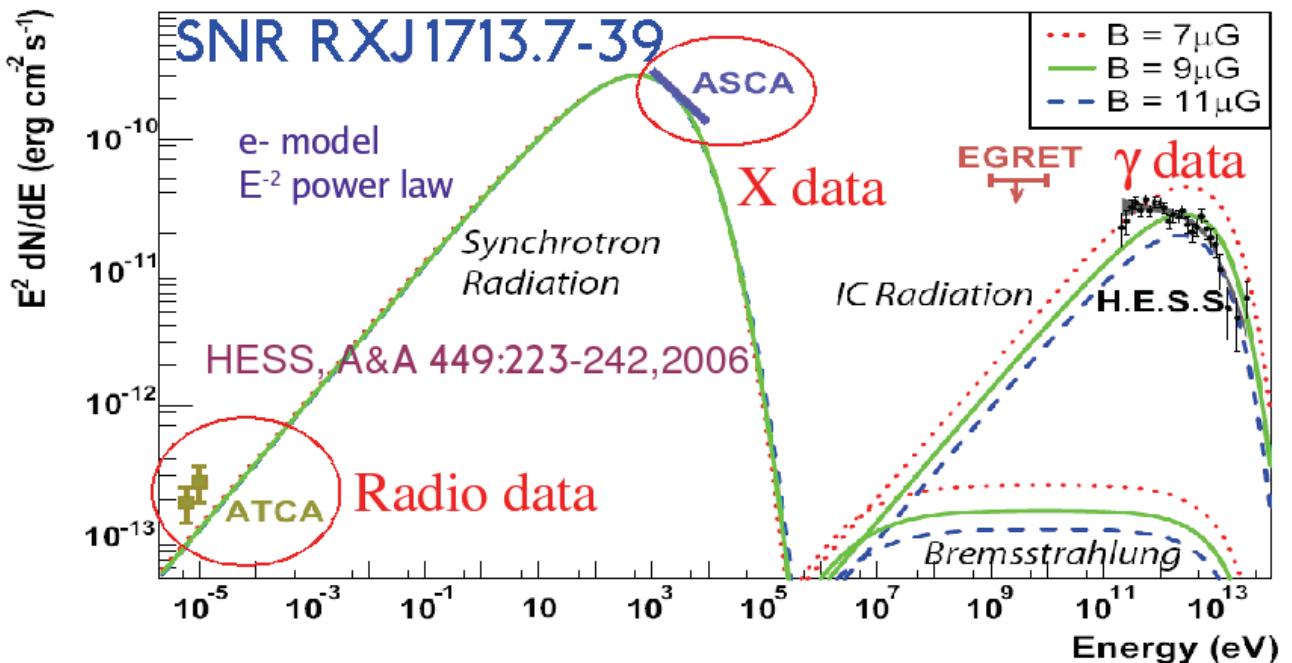
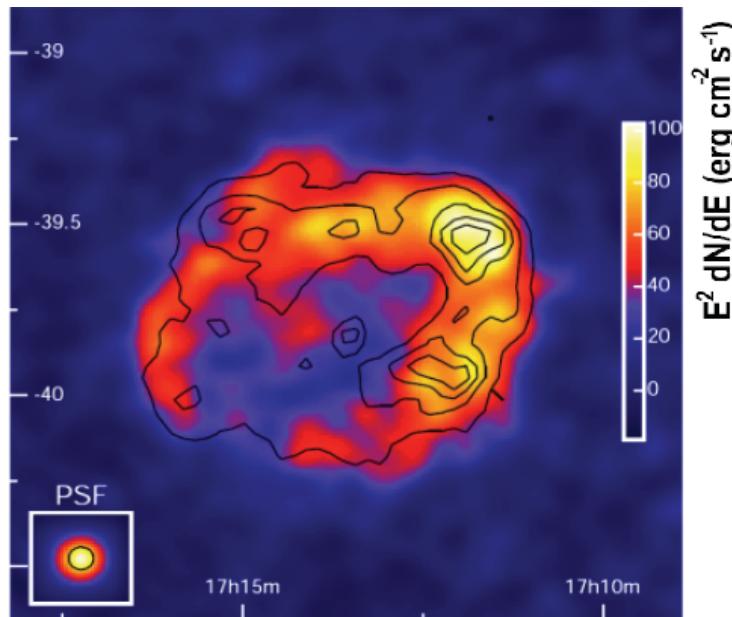
- Under Rock
- Under water/ice
- Acoustic/Radio
- Air Showers



# Origin of Cosmic TeV Neutrinos



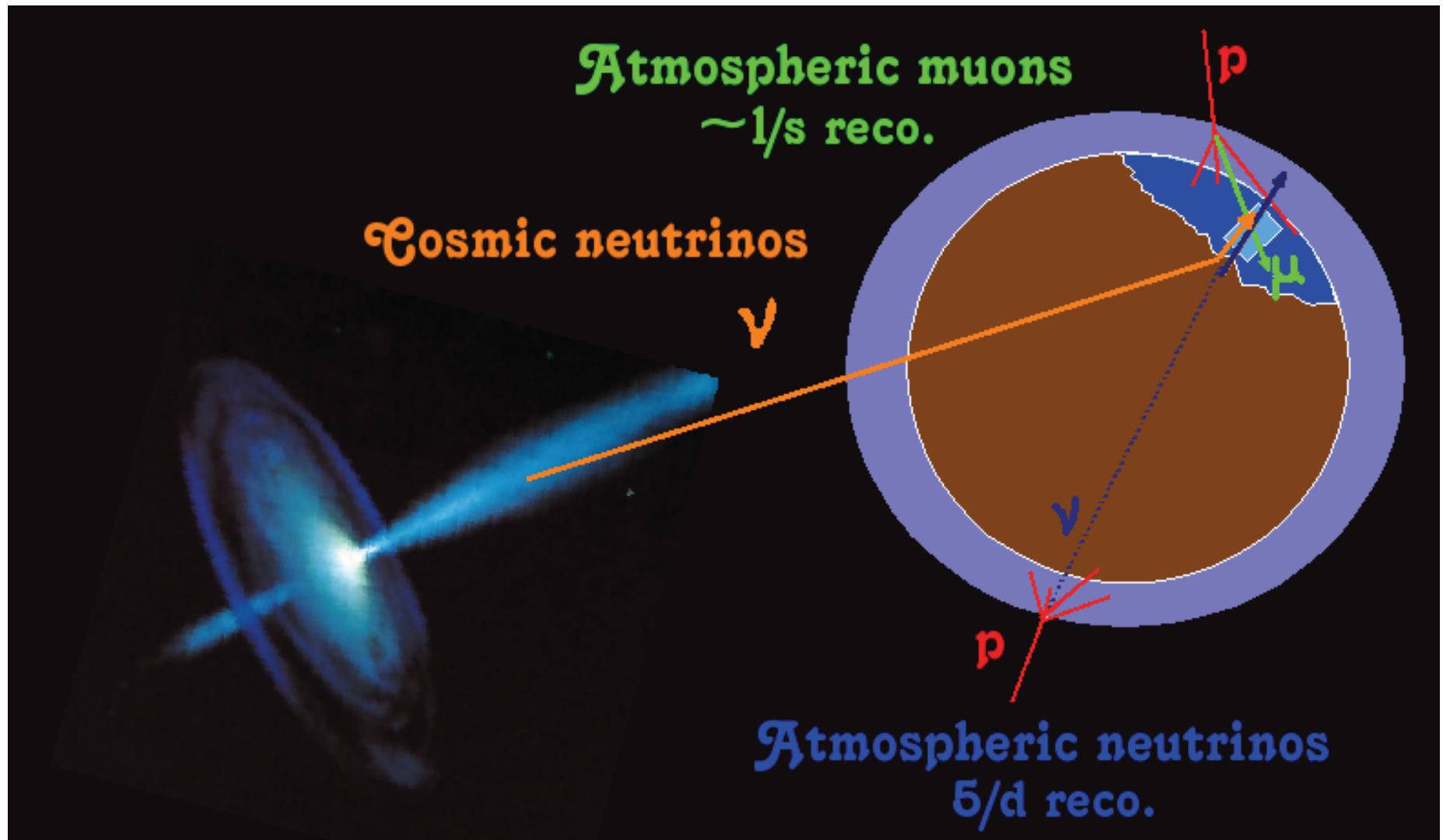
# A Hadronic origin for $\gamma$ emission ?



## The case of RXJ 1713-3946

- Purely leptonic models not satisfactory

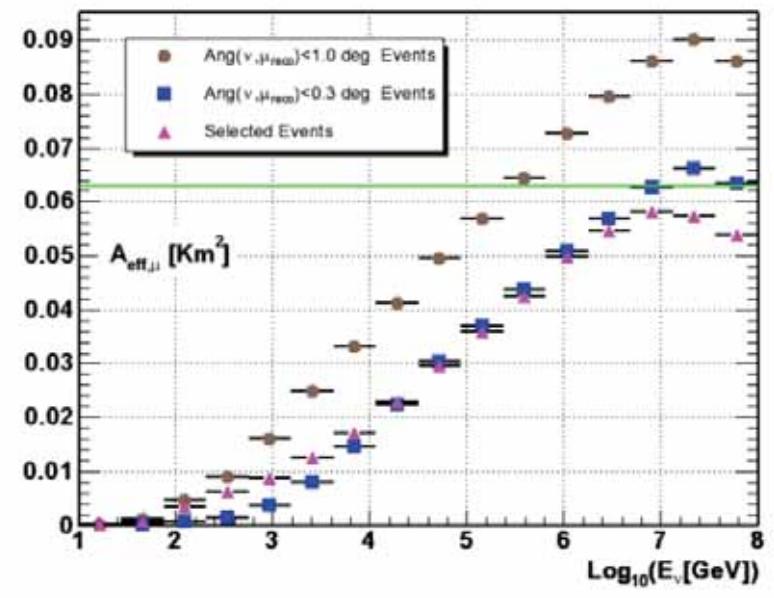
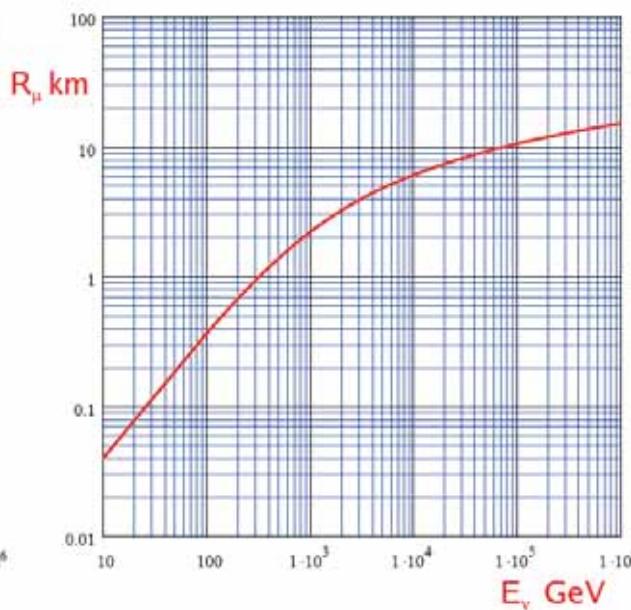
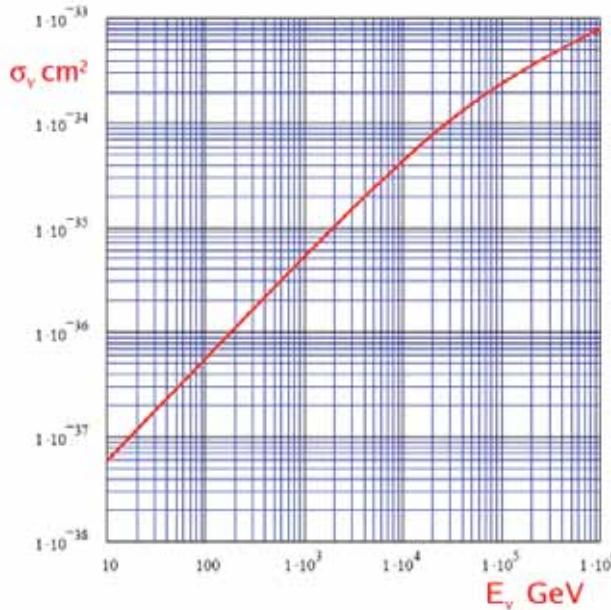
# Detection of Cosmic TeV Neutrinos



# Event Rate & Detector Size

## Event Rate $N_\nu$ & Luminosity needed

$$N_\nu \propto \Phi_\nu \times P_{\text{absorption}}(\theta, E) \times \underbrace{\sigma_\nu}_{\text{cross-section}} \times \underbrace{R_\mu}_{\mu \text{ range}} \times \underbrace{A_\mu}_{\text{Effective Area for } \mu}$$



# Event Rate & Detector Size

## Event Rate $N_\nu$ & Luminosity needed

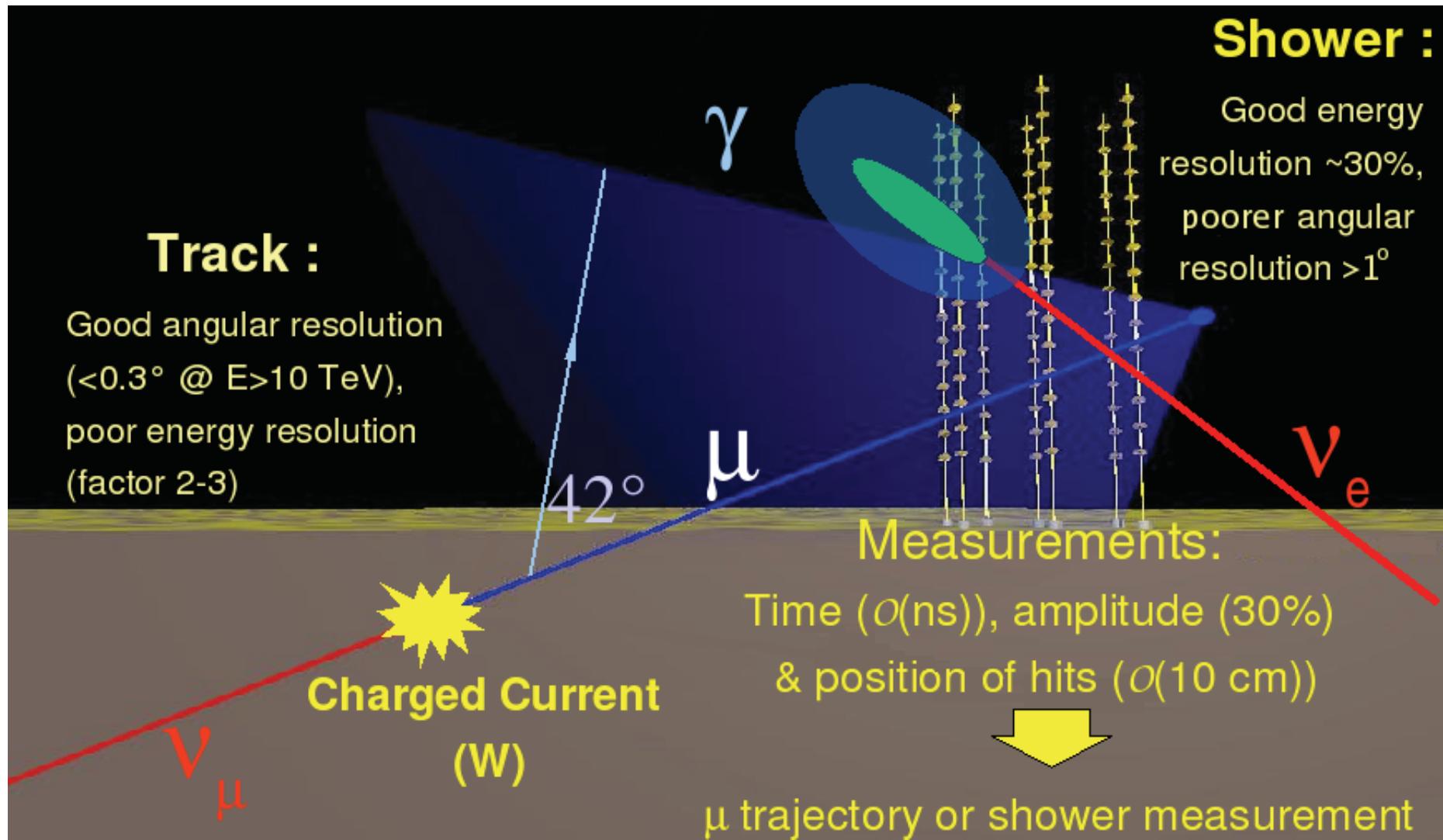
$$N_\nu \propto \Phi_\nu \times P_{\text{absorption}}(\theta, E) \times \underbrace{\sigma_\nu}_{\text{cross-section}} \times \underbrace{R_\mu}_{\mu \text{ range}} \times \underbrace{A_\mu}_{\text{Effective Area for } \mu}$$

$$L_\nu = 4\pi d^2 \Phi_\nu \approx 10^{46} N_\nu \left( \frac{d}{4 \text{Gpc}} \right)^2 \left( \frac{E_\nu}{100 \text{TeV}} \right)^{1-\alpha} \left( \frac{A_\mu T}{\text{km}^2 \text{yr}} \right)^{-1} \text{erg/s}$$

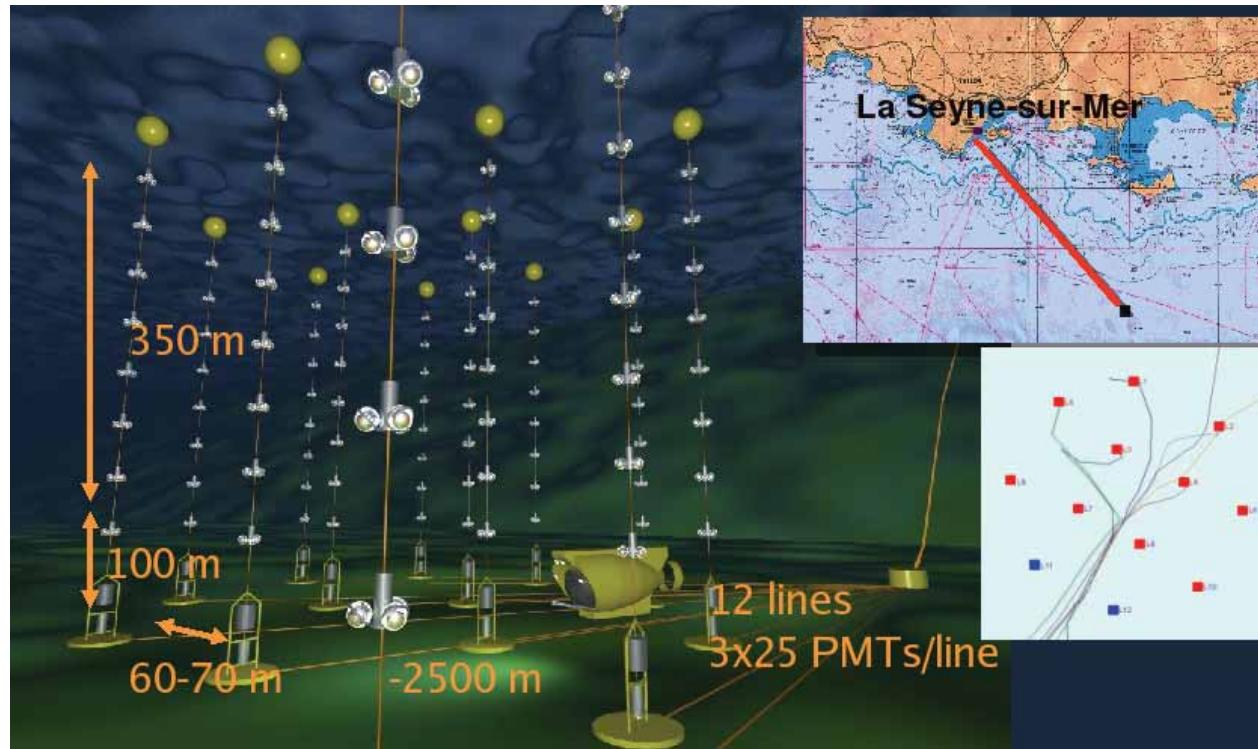
- $\alpha \sim 1$  for  $E_\nu < 100 \text{TeV}$ ,  $\alpha \sim 0.5$  above 100 TeV
- Blazars  $\sim \text{Gpc}$ ,  $L \sim 10^{47} \text{ erg/s} \Rightarrow A_\mu \sim 1 \text{ km}^2$
- Galactic Sources  $L_\nu \simeq 10^{35} \text{ erg/s}$  for  $A_\mu \sim 0.1 \text{ km}^2$



# Antares Detection Principles



# Antares Layout

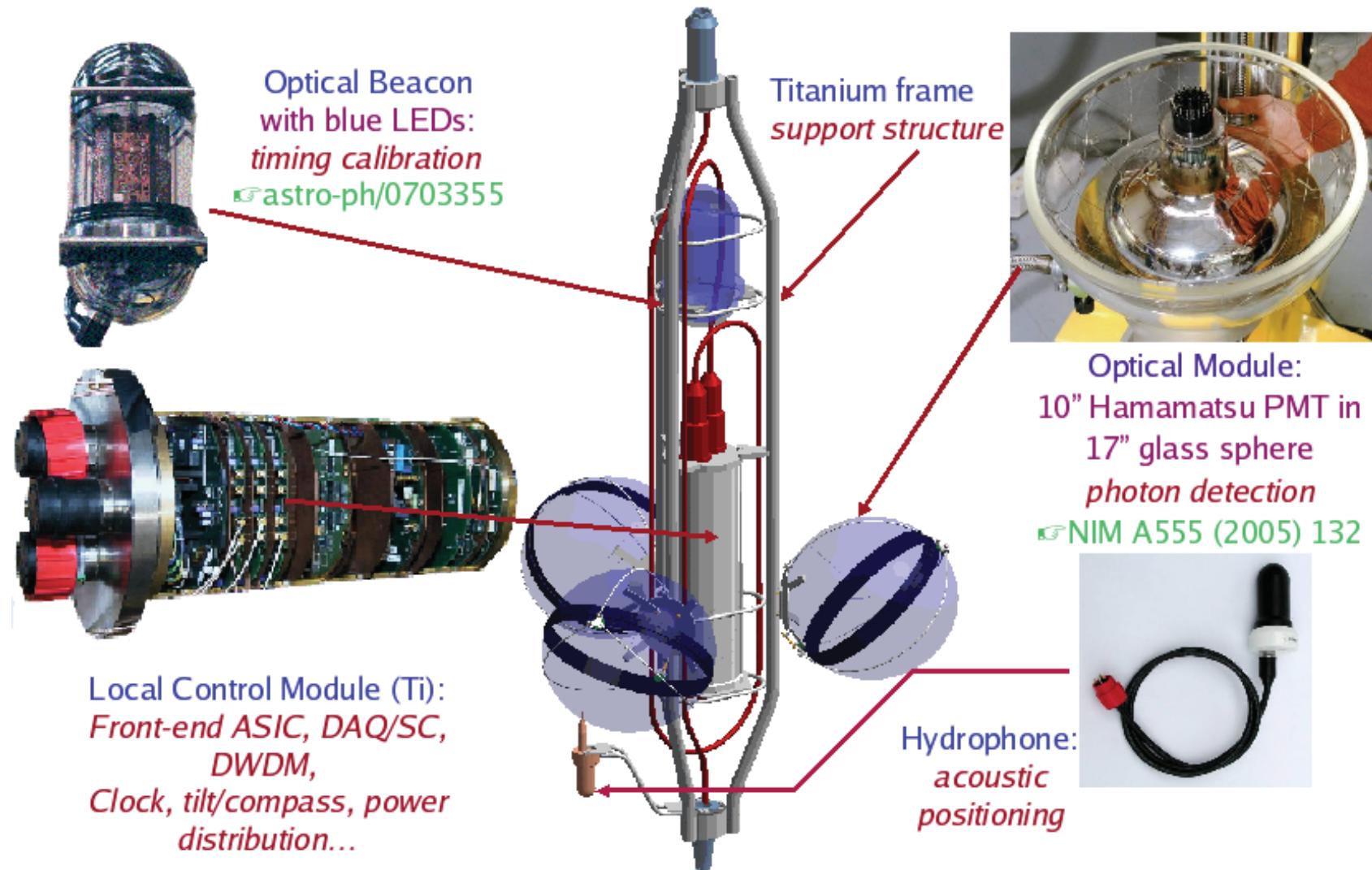


Full Completion in 2008

- March 2006 : Line 1 → September 2006 : Line 2
- January 2007 : Lines 3-5 → 10 Lines in December 2007

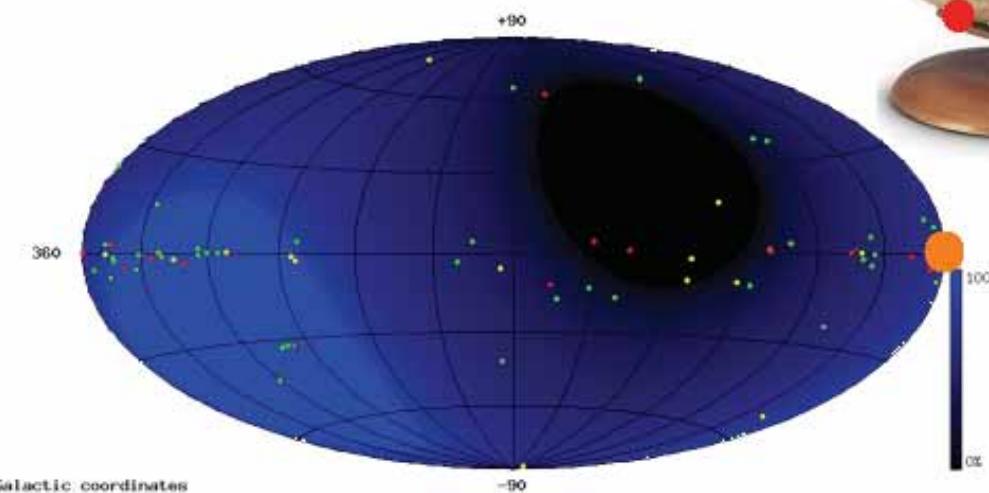


# Antares basic element : a storey

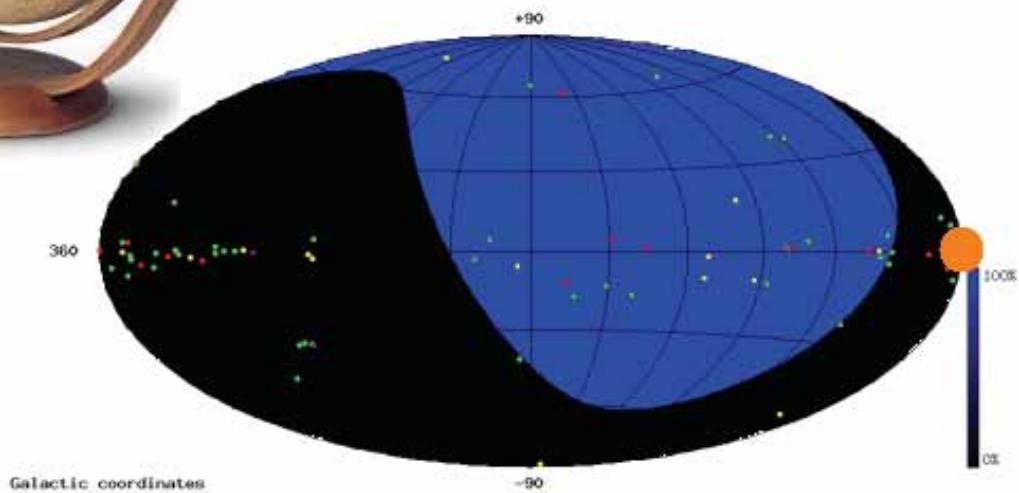


# Sky Coverage & Sensitivities

● Galactic Centre

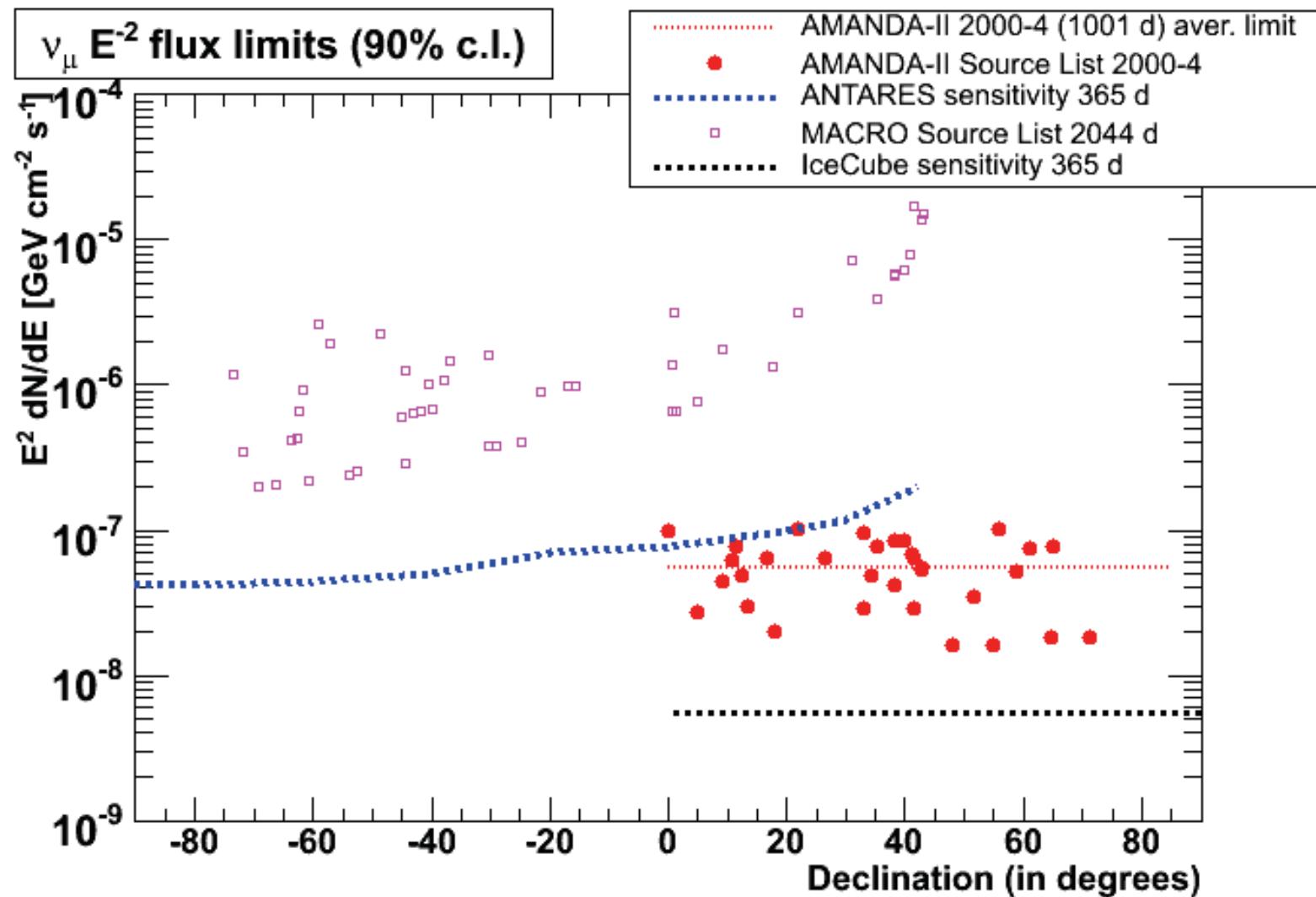


ANTARES ( $43^\circ$  N)  $3.5\pi$  sr

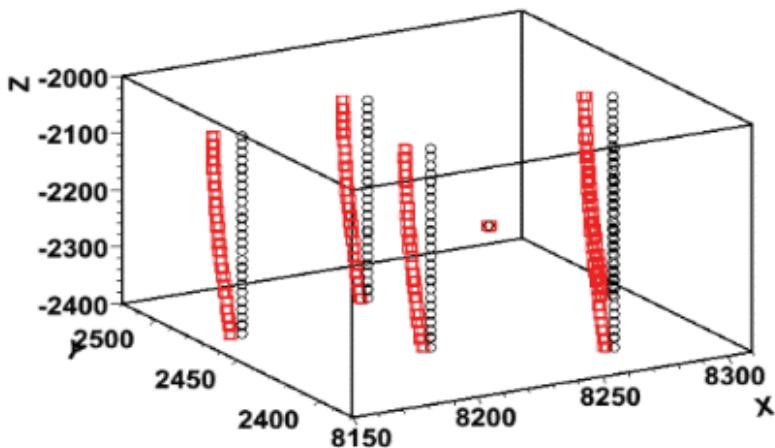
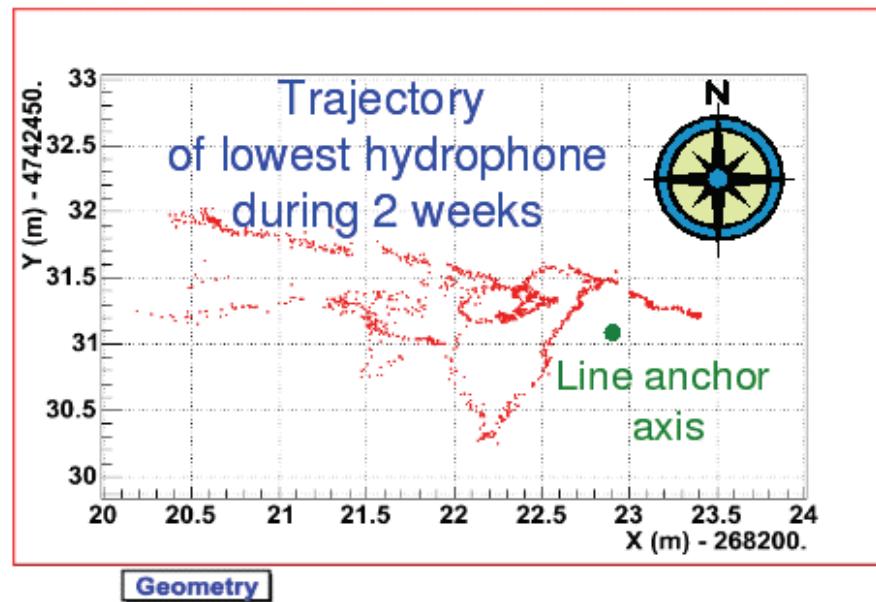
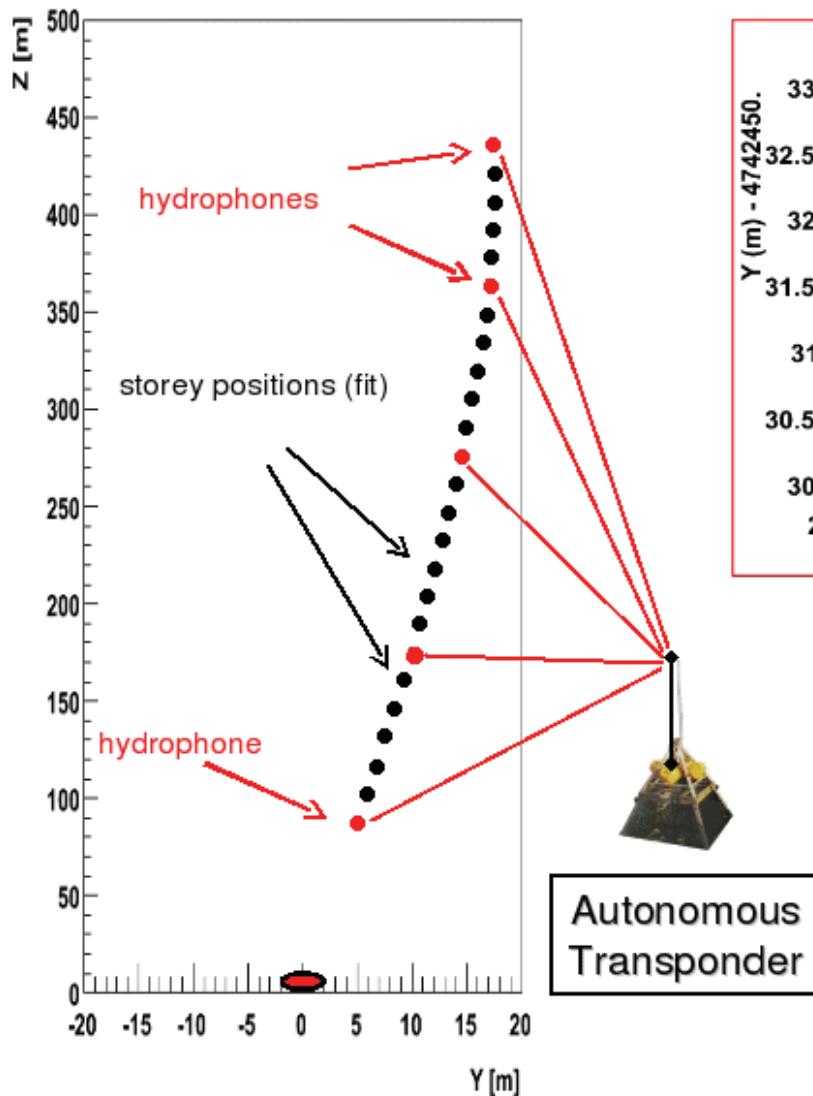


IceCube, AMANDA (South Pole)  $2\pi$  sr

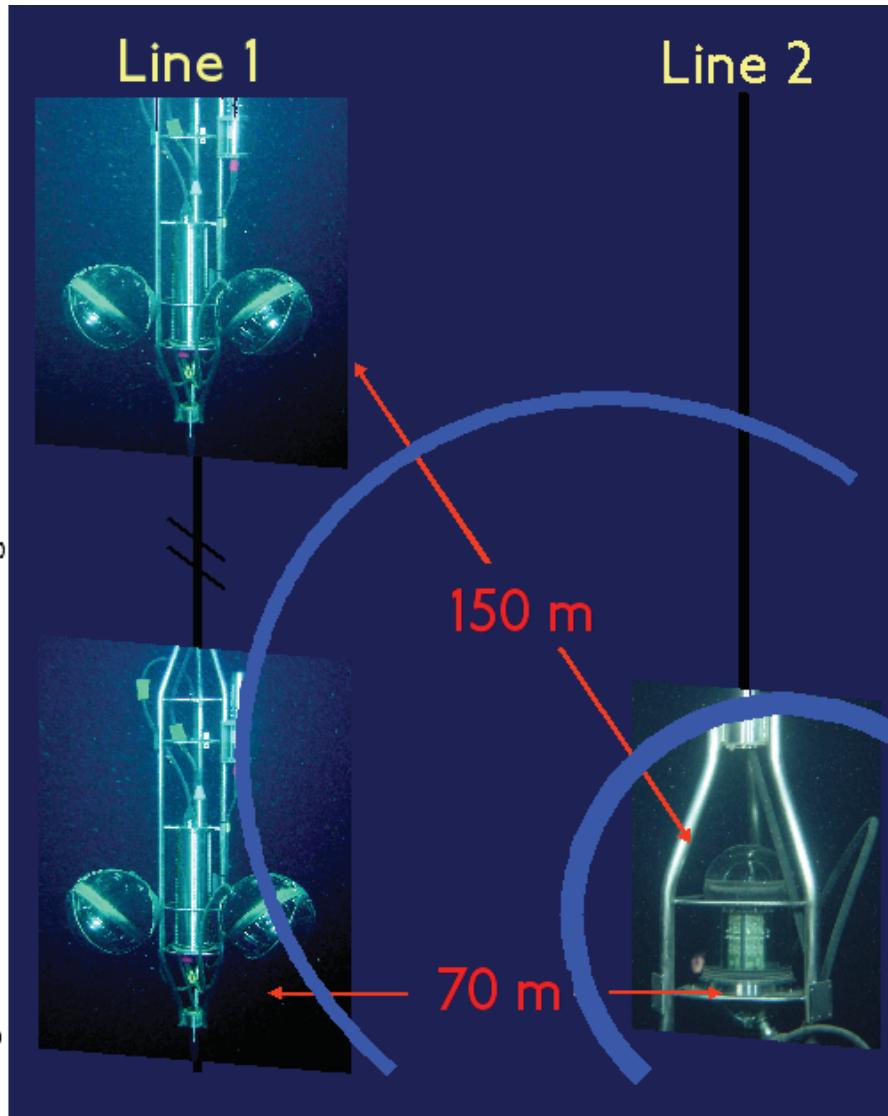
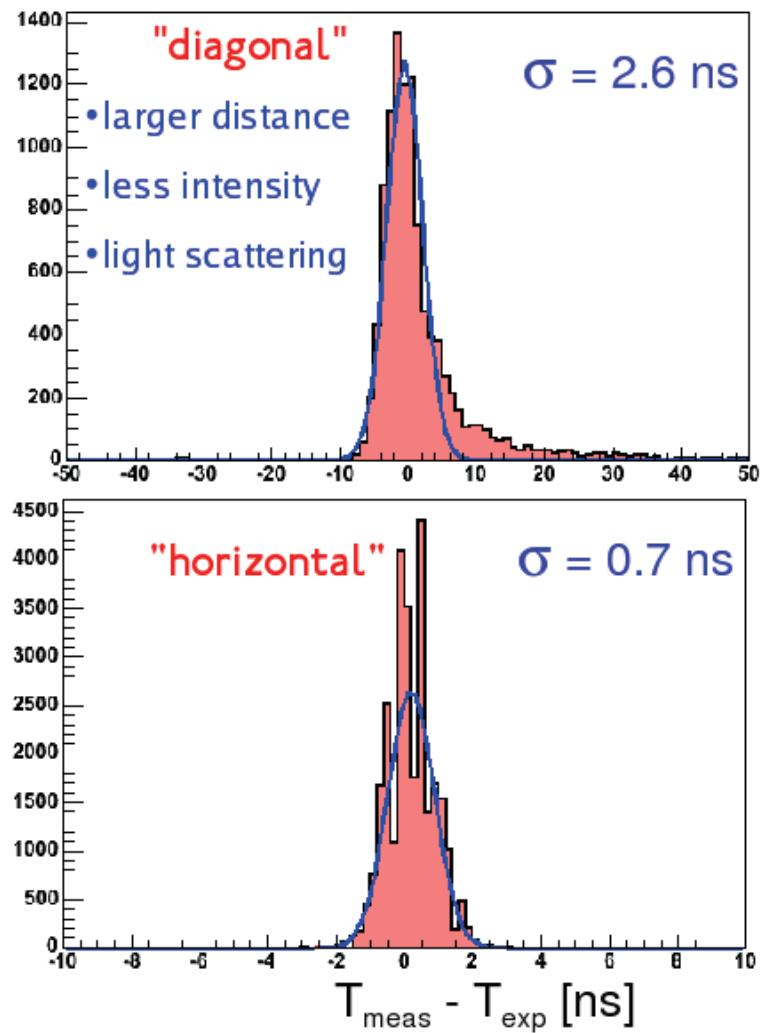
# Sky Coverage & Sensitivities



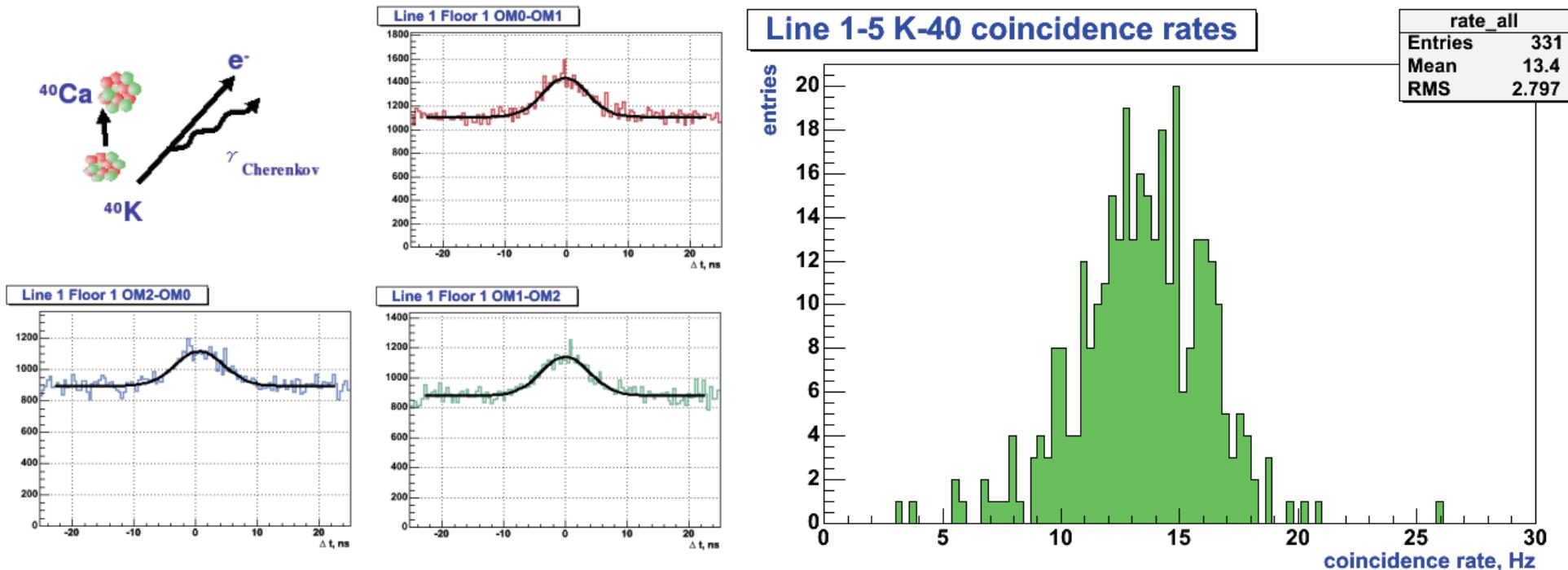
# Acoustic Triangulation



# Time Calibration with LED Beacons



# Calibration with $^{40}K$ decay

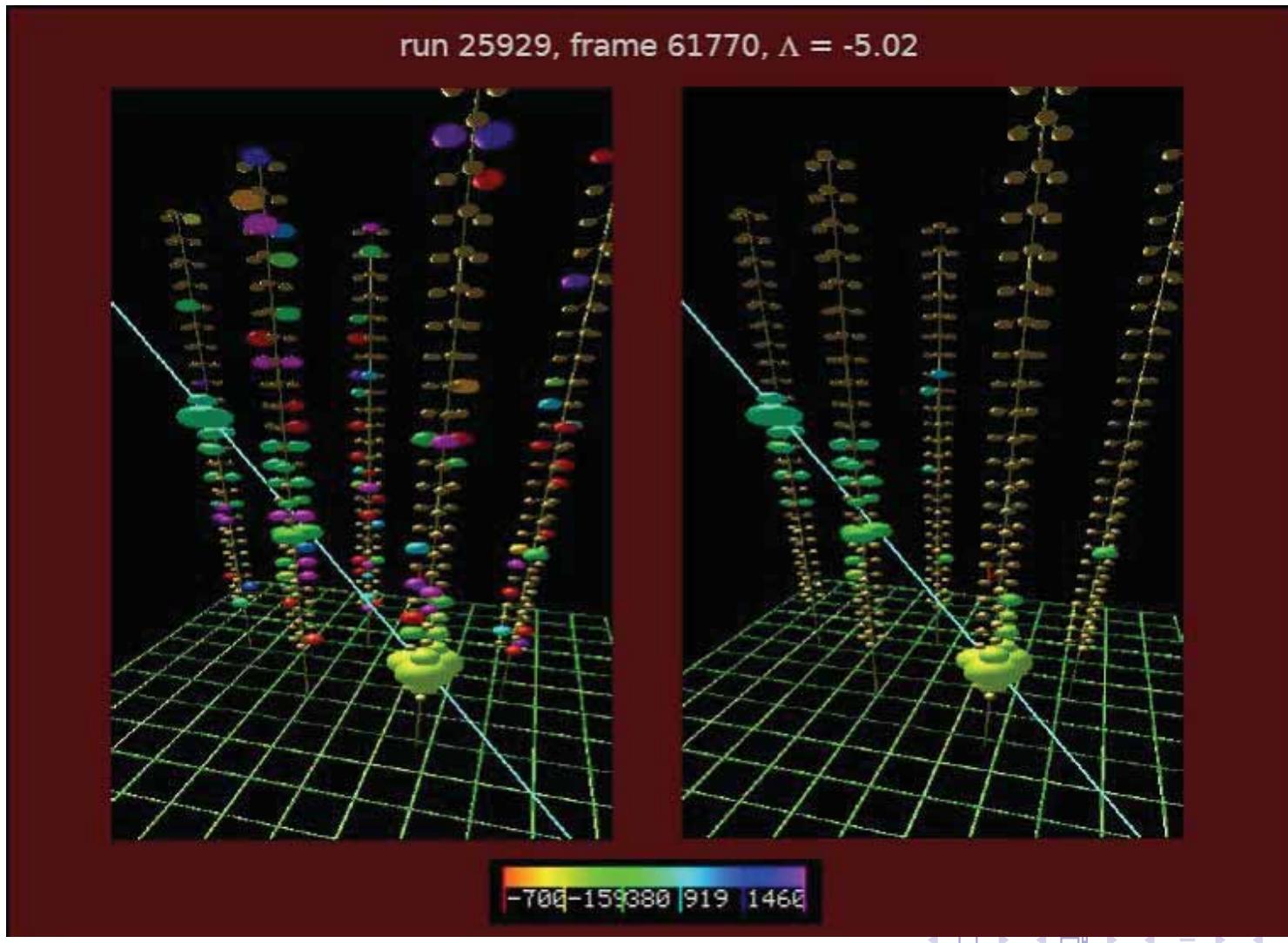


Consistent with Simulations

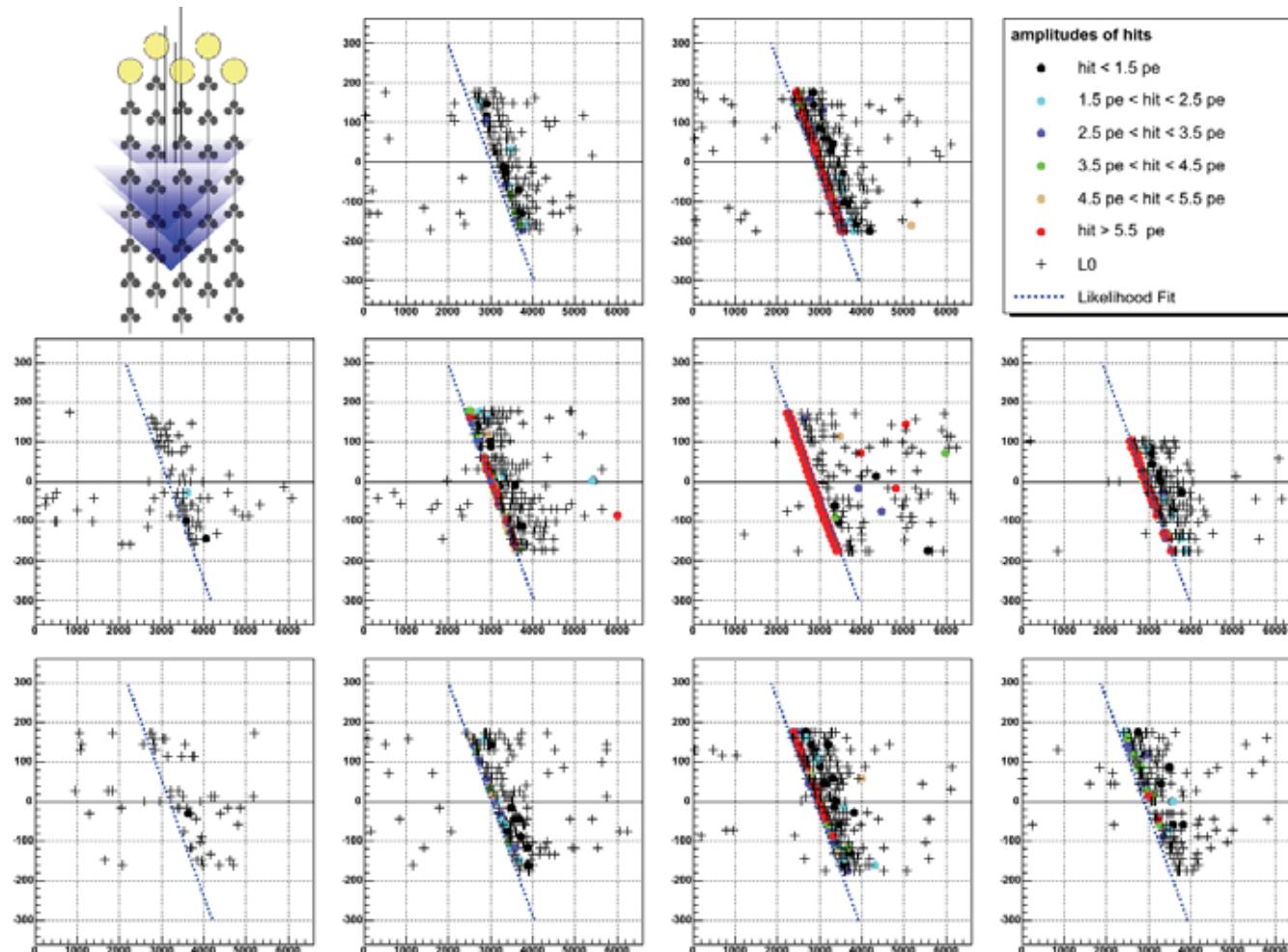
MC : 13 Hz  $\pm$  4 Hz

D. Zaborov, *Coincidence studies in ANTARES : K-40 and muons,*  
*Young Scientists Forum - 2*

# 3D view of a real upward event

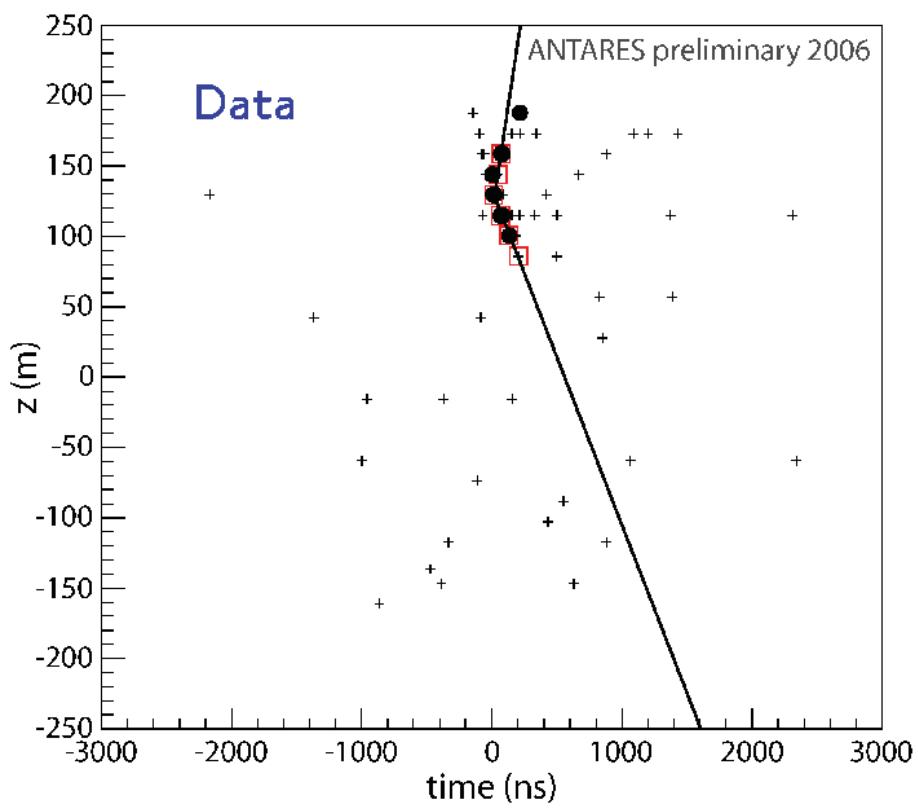
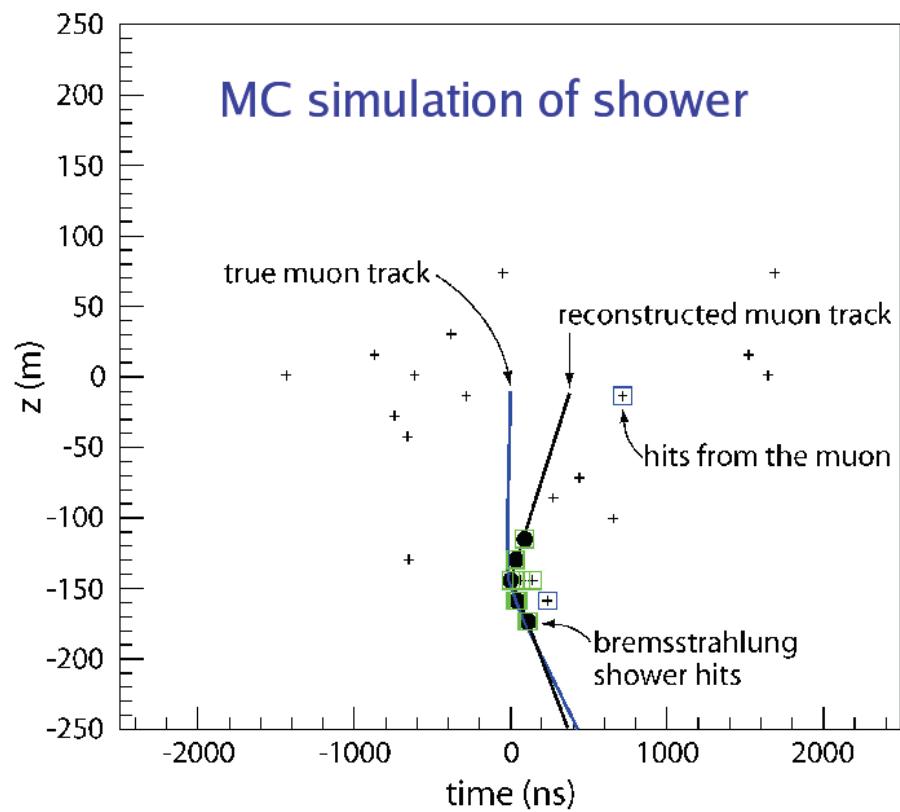


# Muon Bundles

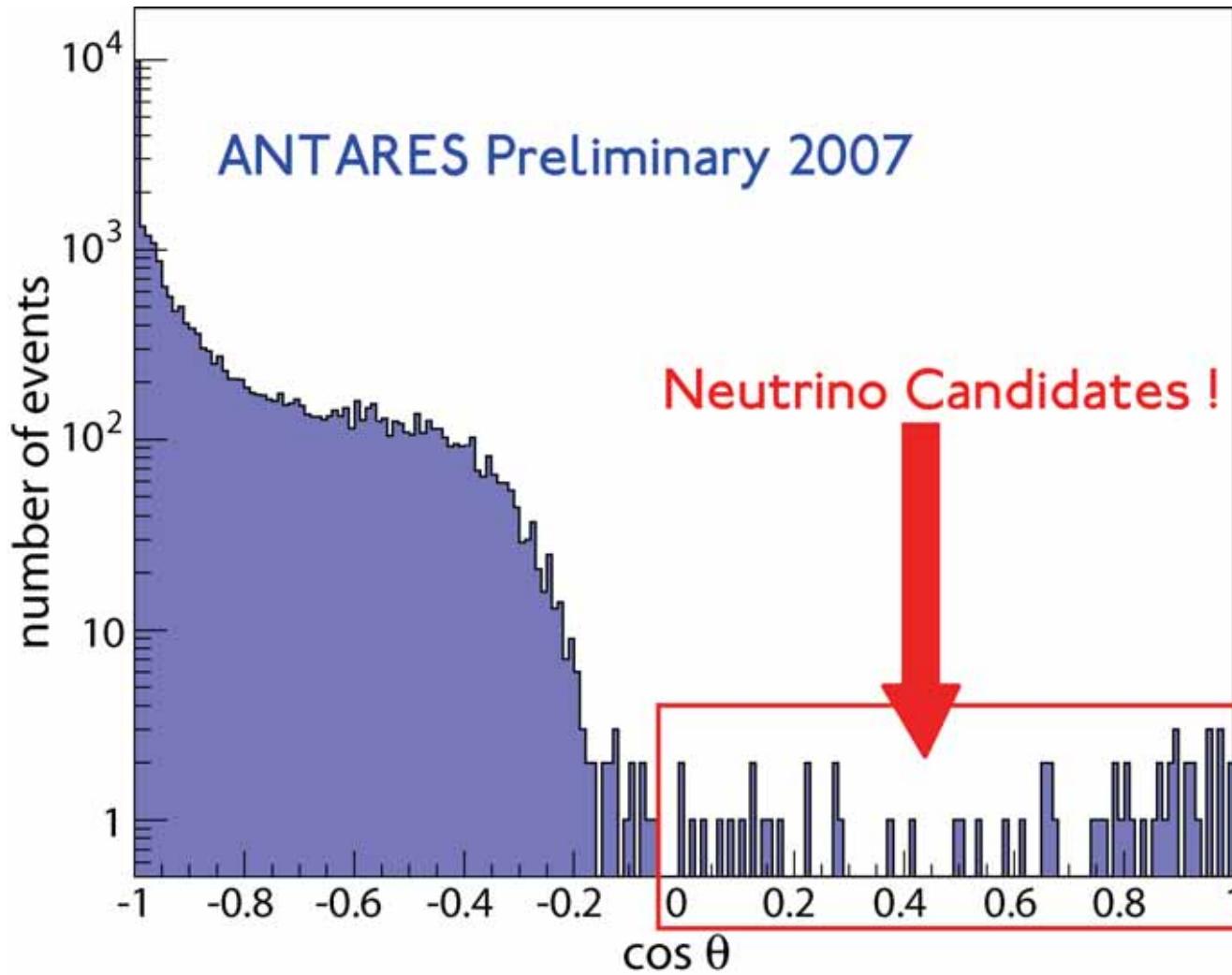


**C. Picq, Determination of cosmic muon multiplicity in ANTARES,**  
**Young Scientists Forum - 2**

# Showers

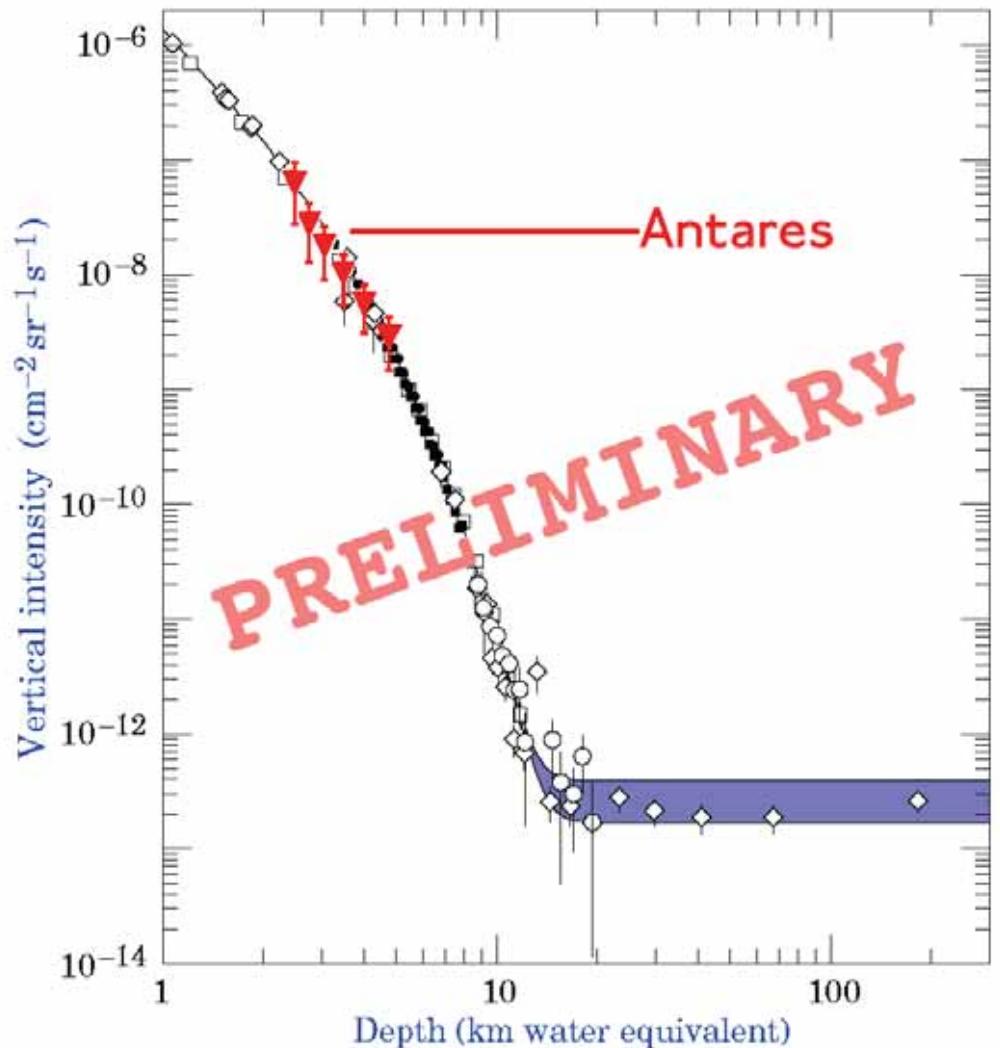


# Zenith Angle Distribution



- 5 Lines data
- Feb-May 2007
- $\sim 5 \times 10^6$  evts
- 54 days integrated time
- Trigger rate  $\sim Hz$
- Quality cut
- 20 000 evts left
- 55 upgoing muons

# Atmospheric muons flux

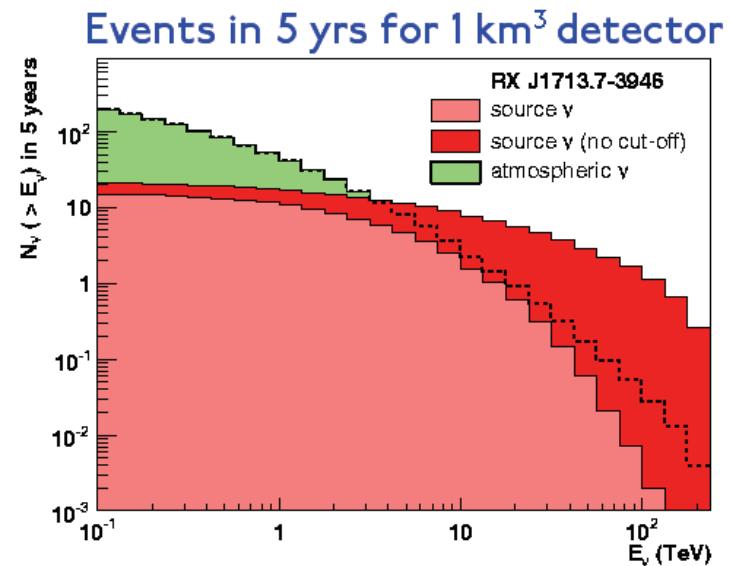


## Vertical Intensity vs Depth

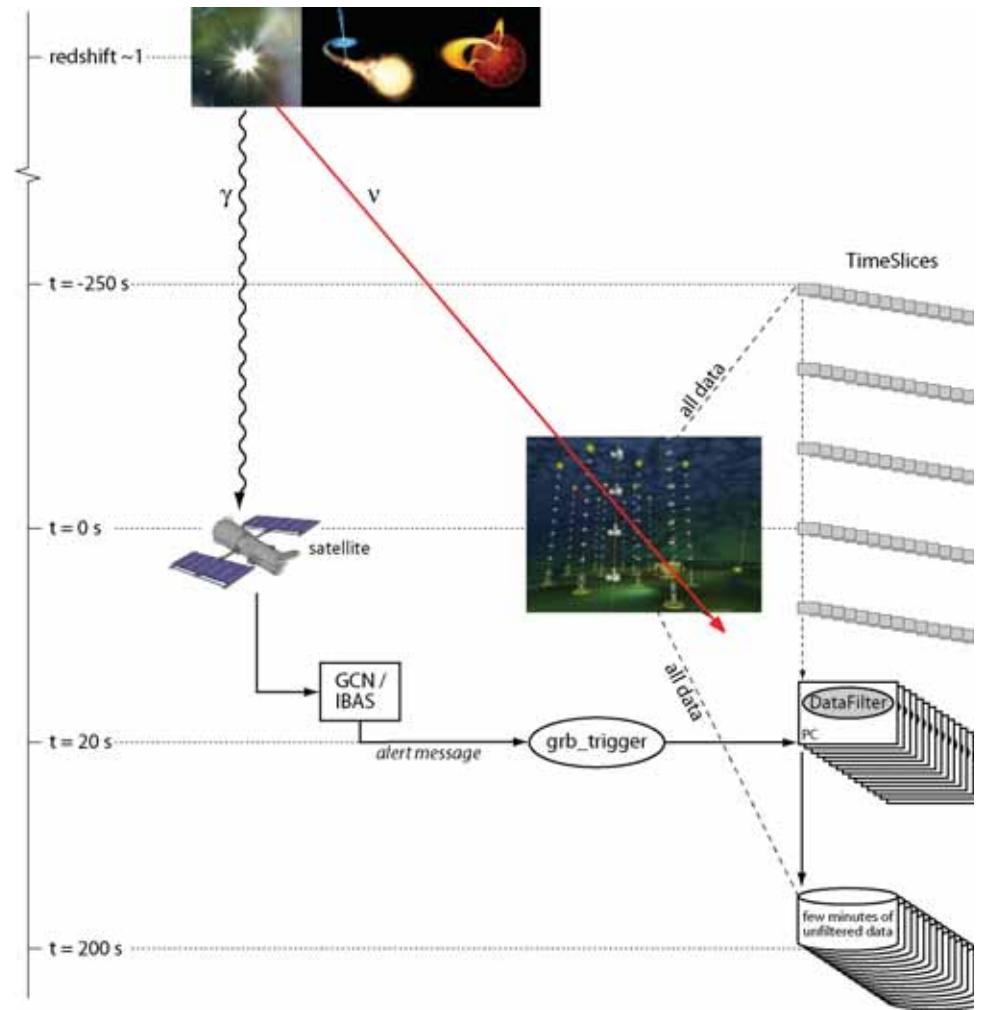
- Only Line 1 data :
  - May-September 2006
  - Quiet* runs only (low currents)  
 $\Rightarrow \sim 10$  days equivalent
- Zenith angle  $\Leftrightarrow$  slant depth

# Conclusions & Perspectives

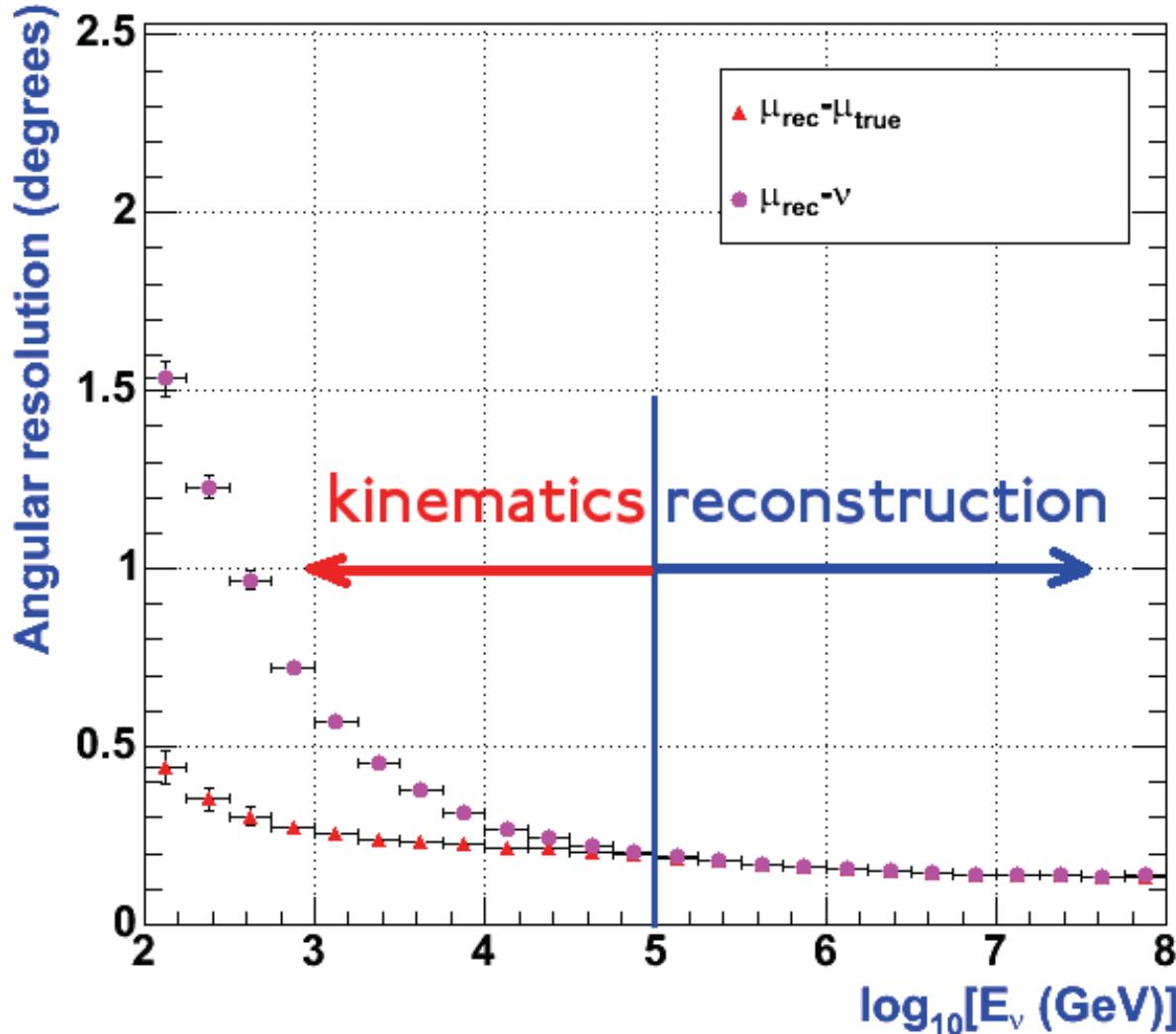
- Antares is working and taking data !  
but...



- ...HESS Sources may not be visible ?  
 ⇒ Time+Direction needed (flares)  
 ⇒ KM3NeT



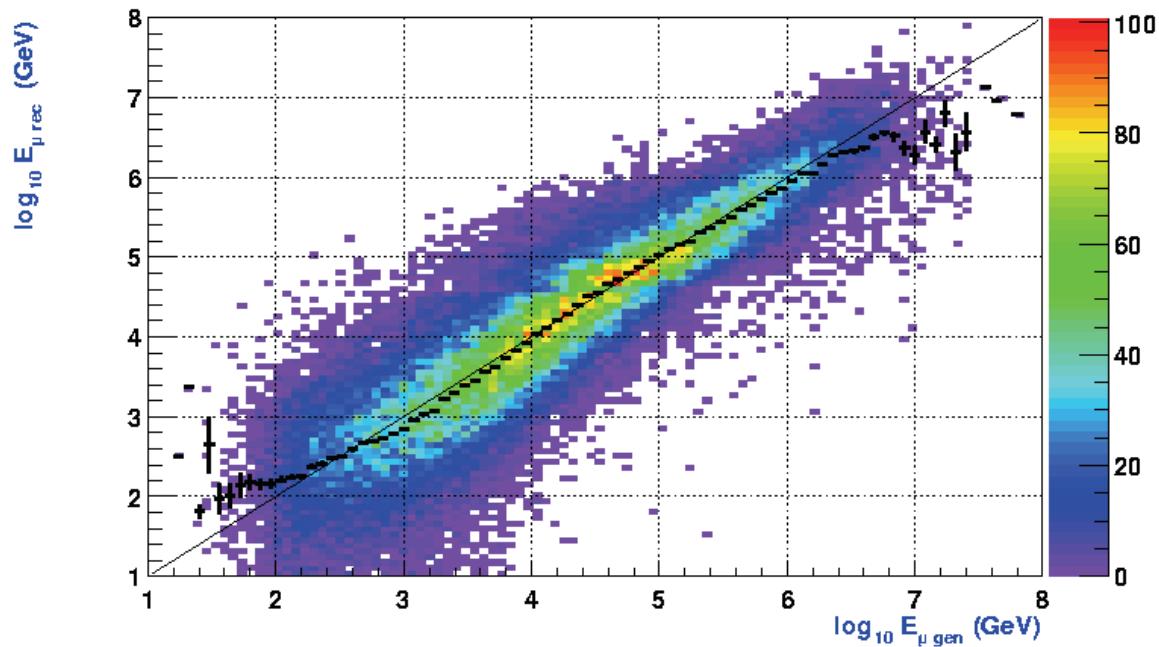
# Back-up : Angular & Spectral Resolution



## Angular Resolution

- $< 10-100 \text{ TeV} :$   
Kinematics
- $> 10 \text{ TeV} :$   
Reconstruction  
 $\Rightarrow \Delta\theta \approx 0.2^\circ$

# Back-up : Angular & Spectral Resolution

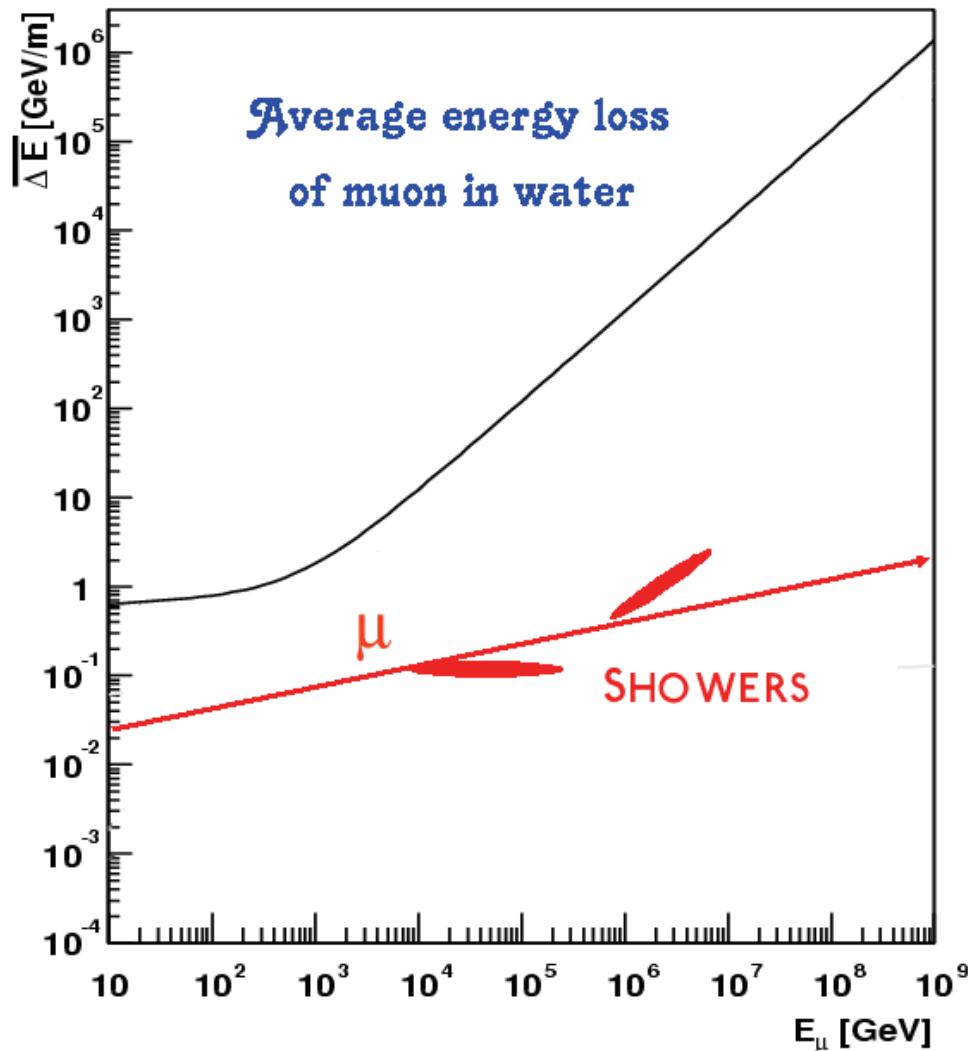


## Energy estimation

- $< 100 \text{ GeV}$  :  $\mu$  path
- $> 1 \text{ TeV}$  : amount of light

$$\Rightarrow \frac{\Delta E_\nu}{E_\nu} \approx 2 - 3.$$

# Back-up : Angular & Spectral Resolution

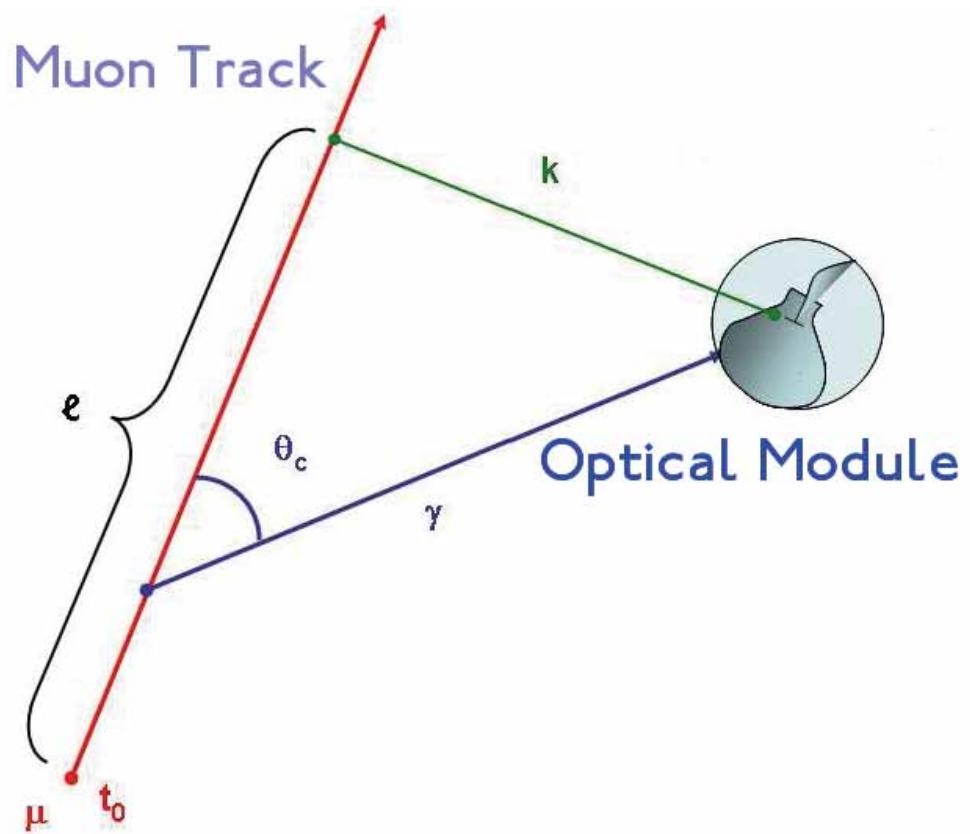


Energy estimation

- $< 100$  GeV :  $\mu$  path
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$$\Rightarrow \frac{\Delta E_\nu}{E_\nu} \approx 2 - 3.$$

# Back-up : 3D Reconstruction

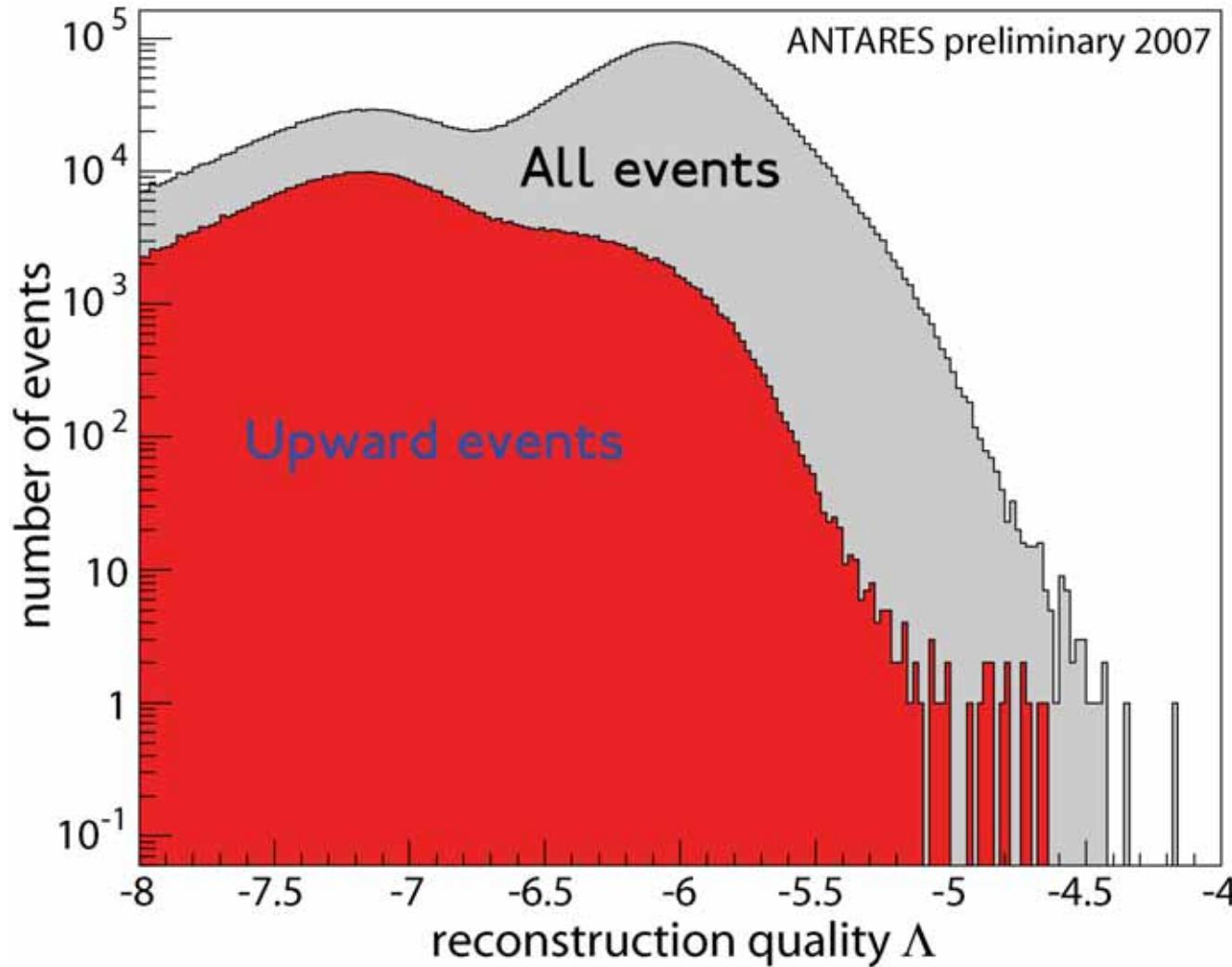


5 parameters fit :  $\chi^2$  minimisation

$$t_{\text{theory}} = t_0 + \frac{1}{c} \left( l - \frac{k}{\tan \theta_C} \right) + \frac{1}{v_g} \left( \frac{k}{\sin \theta_C} \right)$$

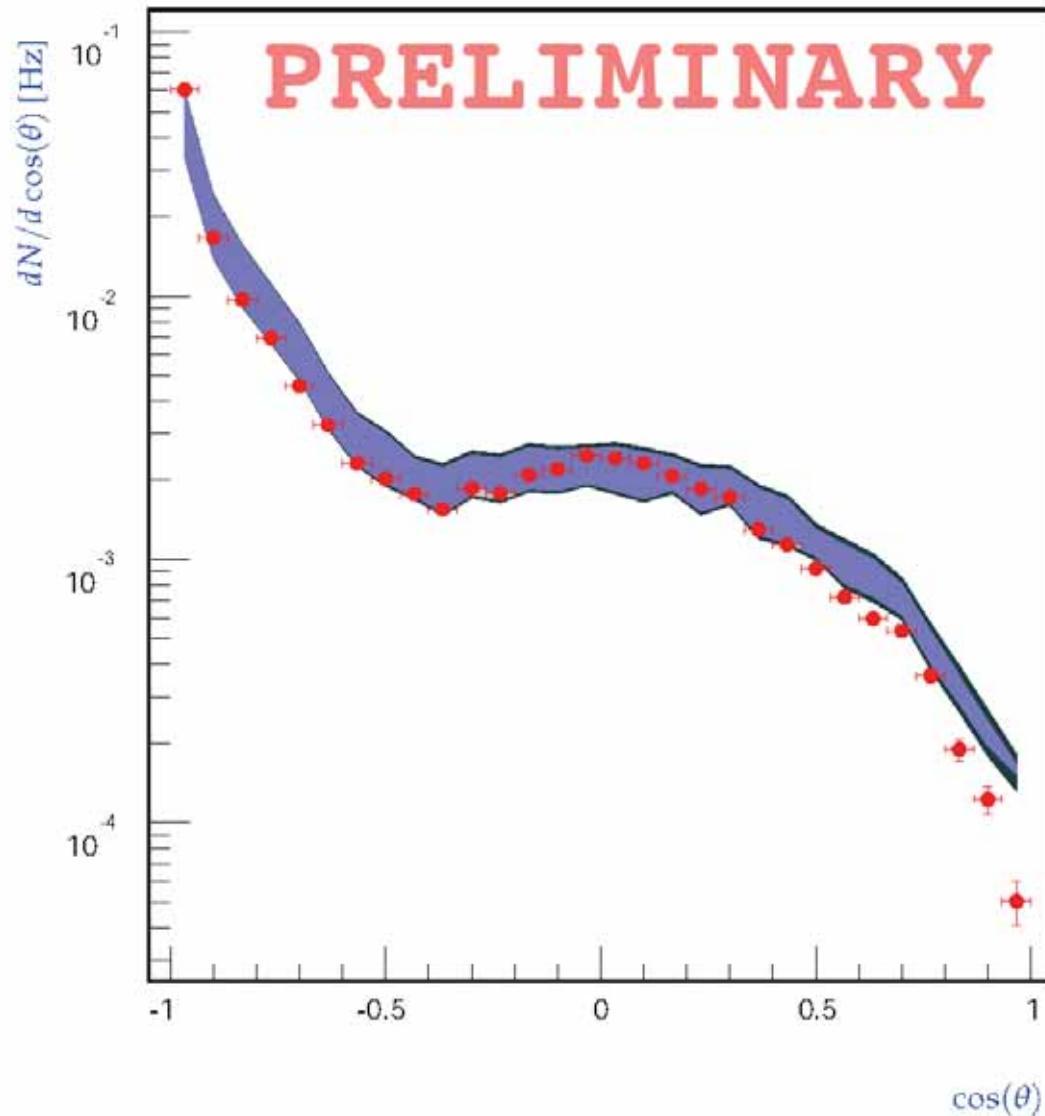
- $t_0, \theta, \phi, x_0, y_0$

# Back-up : Reconstruction Quality



- Reco. Quality Factor  $\Lambda$  :  
$$\Lambda = \frac{\log(\mathcal{L})}{N_{DOF}} + 0.1(N_{\text{solutions}} - 1)$$
- $\mathcal{L}$  Maximum Likelihood

# Back-up : Comparison Data-MC, Line 1 data



## Back-up : Comparison Data-MC, Lines 1-5 data

