The ANTARES Detector and Nuclearite Search with ANTARES

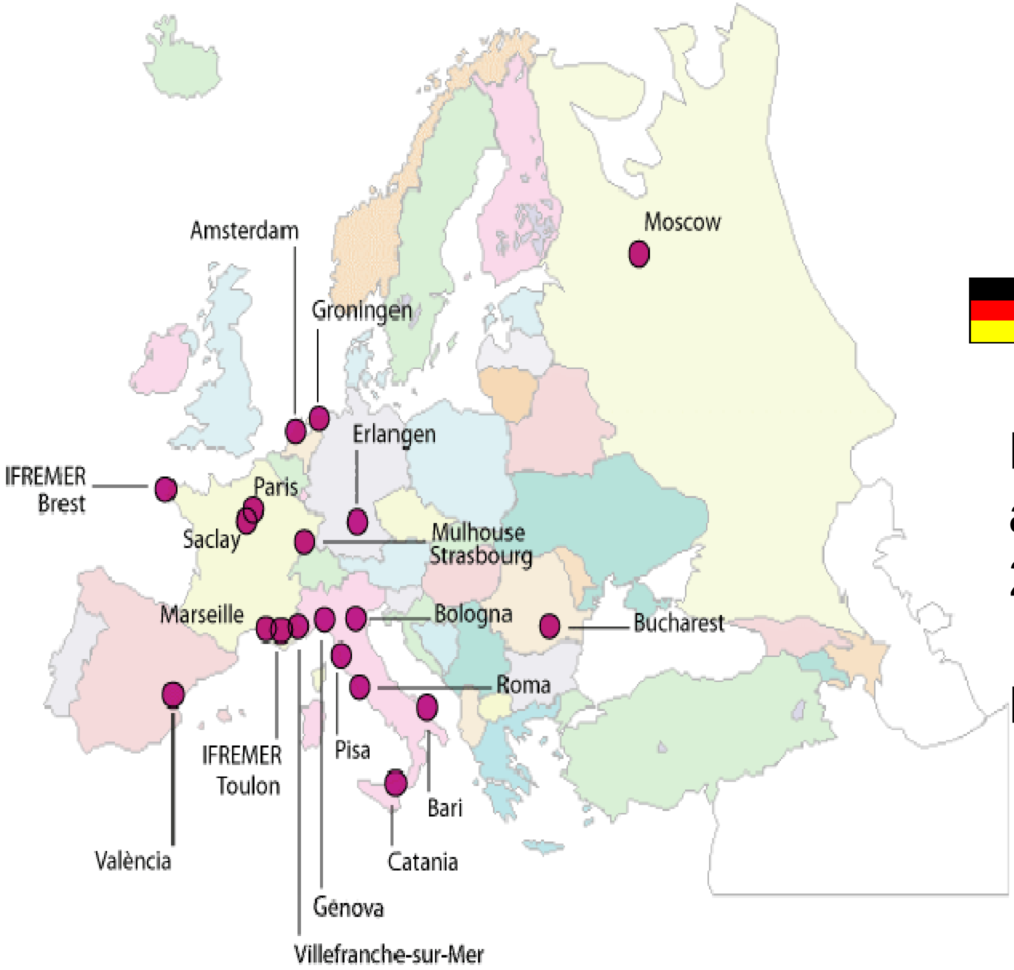
G.E. Pavalas

Institute for Space Sciences

Astrophysics, Dynamical Systems, Fractals - past and future, Magurele, 26-27 April 2007

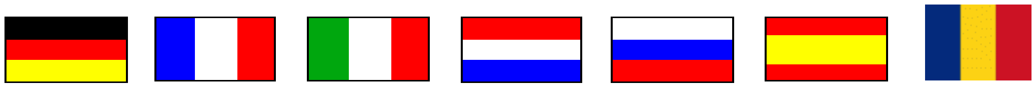
The ANTARES detector

(**A**stronomy with a **N**eutrino **T**elescope and **A**byss Environmental **Res**earch)



ANTARES collaboration

21 institutes, 7 European countries

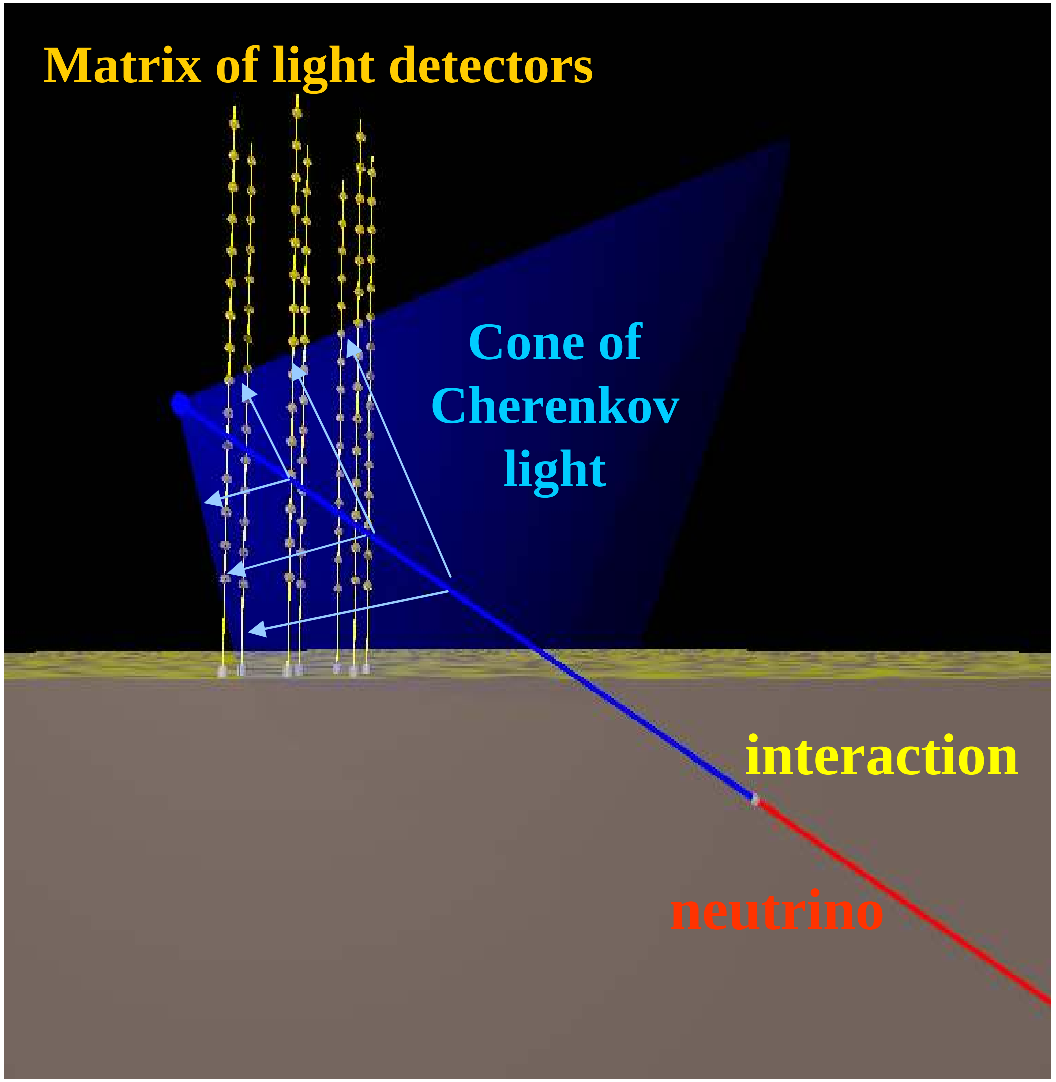


Detector site in the Mediterranean Sea,
about 40 km off the southern French coast
2007 Completion of the detector

Physics goals:

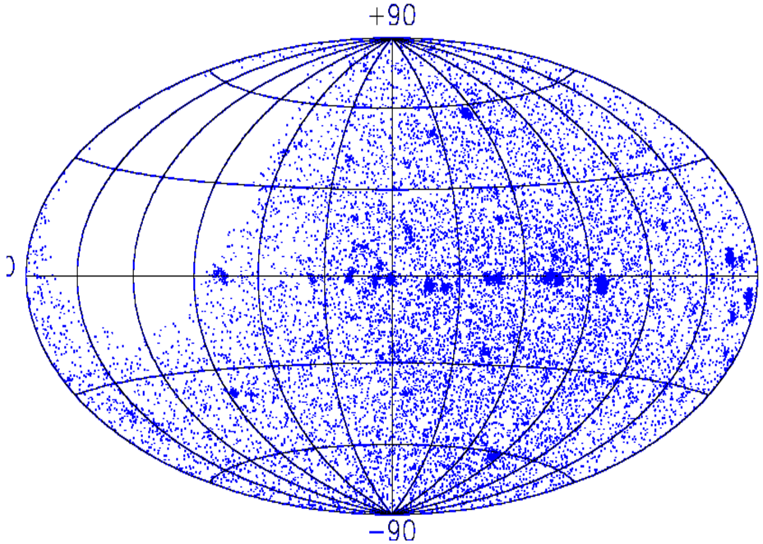
- Detection of cosmic neutrinos
- Search for astrophysical neutrino sources
- Indirect neutralino detection
- Search for exotic particles

The ANTARES telescope detection principle



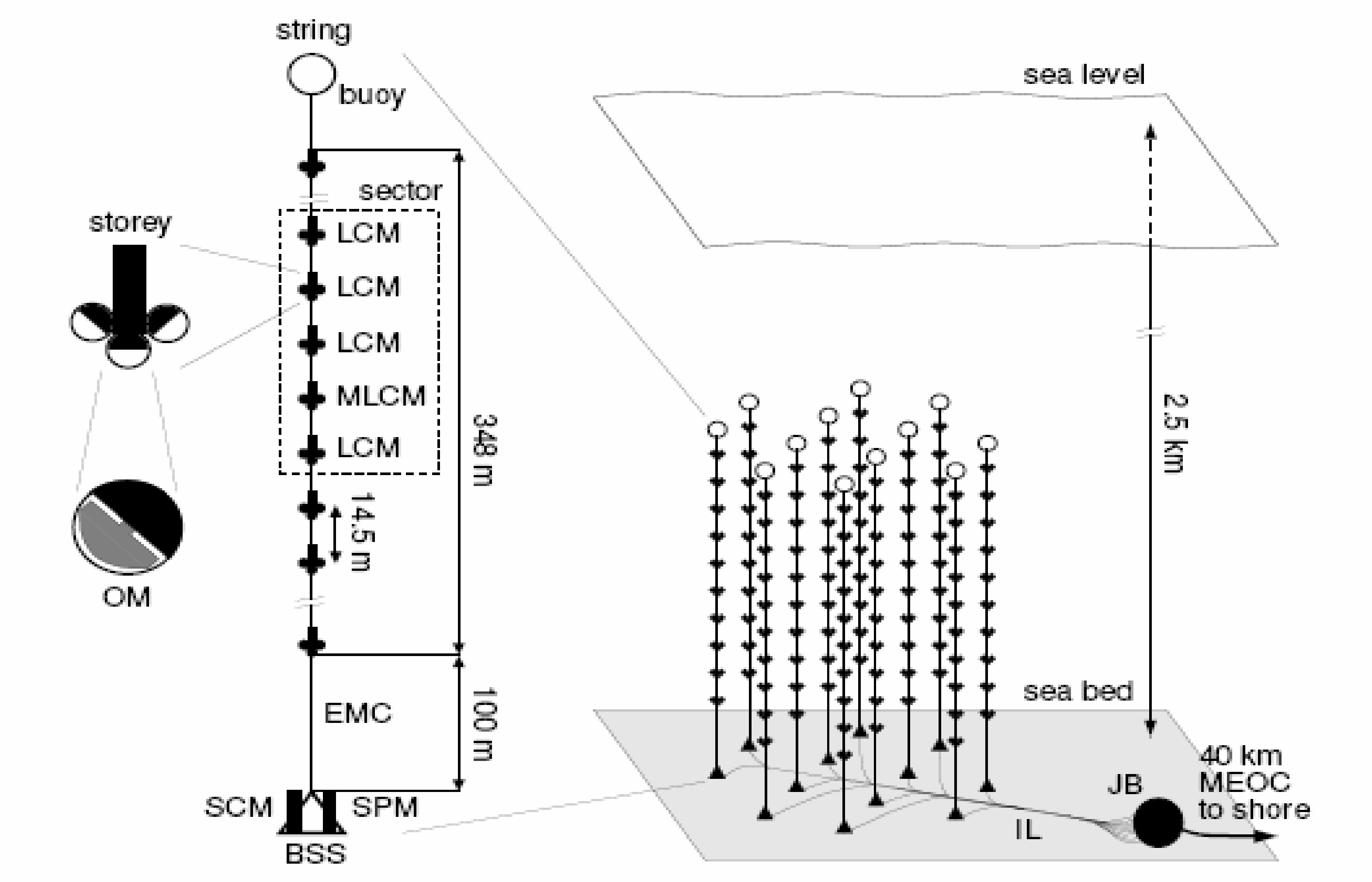
$$\nu_\mu + N \rightarrow \mu + X$$

Sky Map
Regions observable by ANTARES



Simulation

The ANTARES detector



The ANTARES detector: DAQ and Online Filter

Data acquisition:

- digitization *in situ* (Analog Ring Sampler, ARS);
- single photon electron (SPE) and wave form modes;
- all-data-to-shore concept:
  all hits above low threshold (~0.3 p.e.) sent to shore;
- no hardware trigger;

Online filter:

- raw data rate ~1GB/s reduced to ~1MB/s by online filter (PC farm);
- criteria:
  - → local coincidences,
  - → signal amplitudes,
  - → causality.

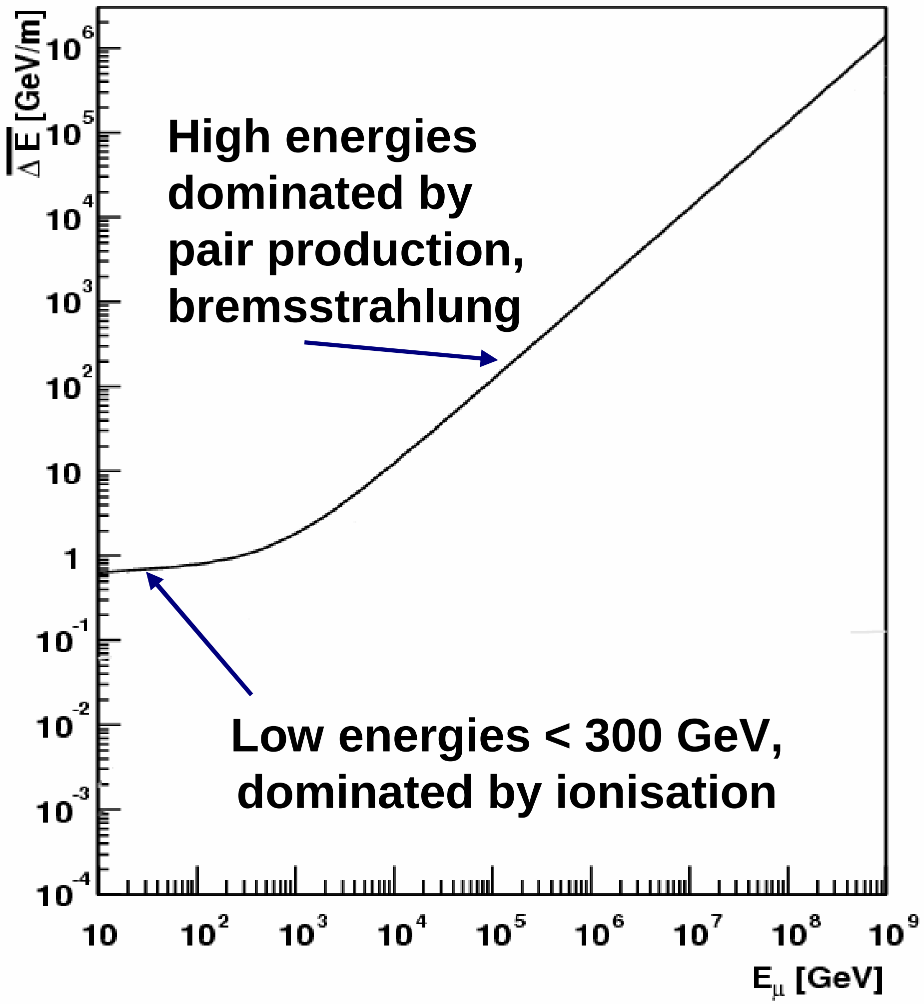
ANTARES: Expected Performance (μ Events)

Angular resolution:

- E_ν < 10 TeV: dominated by angle(ν,μ);
- E_ν > 10 TeV: dominated by the reconstruction accuracy; better than 0.3 degrees.

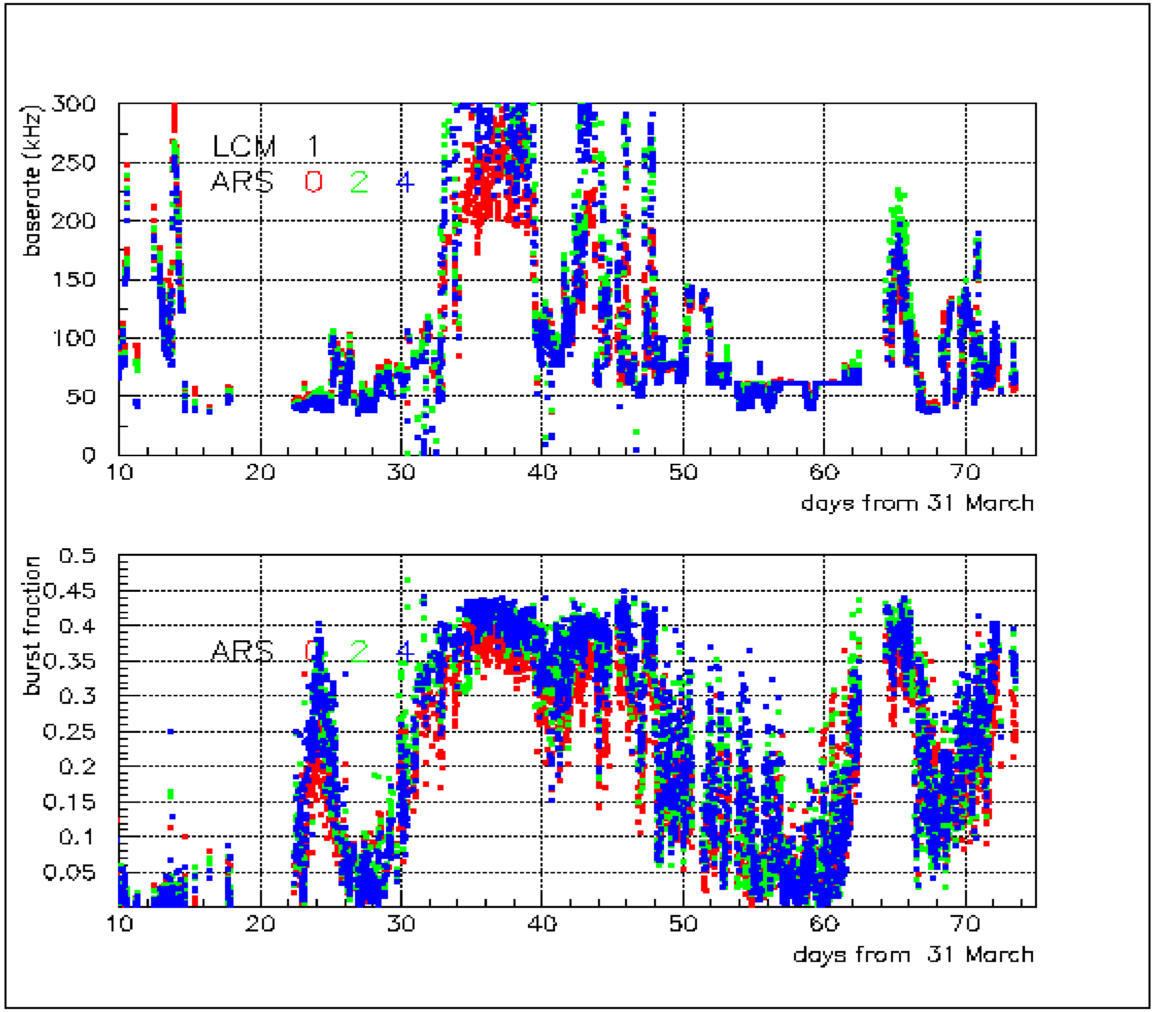
Energy reconstruction:

- E_μ < 1 TeV: muon range;
- E_μ > 1 TeV: Čerenkov light yield from radiative losses (small elm. showers);
  - μ energy resolution:
    ~ 2 at 1 TeV
    ~1.6 at 10 PeV



The ANTARES detector - Background

- Decay of ^{40}K - constant contribution to the counting rate (~27 KHz)
- Bioluminescence - large fluctuations in time
- Down-going atmospheric muons



Nuclearite characteristics

- Origins: the early universe, SNe, neutron stars
- Nuggets of strange quark matter, composed of nearly equal amounts of up, down and strange quarks, could be present in the cosmic radiation
- $\rho_N \approx 3.6 \times 10^{14}$ g cm^{-3}
- Nuclearites *could* be stable for any mass larger than some critical value (about 250 GeV)
- Typical velocities in the Galaxy $\beta \approx 10^{-3}$
- Dominant interaction: elastic collisions with the atoms in the medium

$$\sigma = \begin{cases} \pi (3M / 4\pi\rho)^{2/3} & M \geq 1.5 ng\,(8.4 \times 10^{14} GeV) \quad (e^{-} inside) \\ \pi \times 10^{-16} cm^2 & M < 1.5 ng \quad (e^{-} cloud) \end{cases}$$

- Dominant energy losses:

$$\frac{dE}{dx} = -\sigma \rho_{med.} v^2$$

Nuclearite characteristics

- They *could* contribute to the dark matter (DM)
- Phenomenological flux limit from the local density of DM:

$$\Phi(\mathrm{km}^{-2}\mathrm{yr}^{-1}(2\pi \mathrm{sr}^{-1})) \leq 7.8(1\mathrm{g}/\mathrm{M})$$

- Essentially neutral (most if not all e- inside)
- For $3\times 10^{13} \leq M \leq 10^{22}$ GeV, they could reach the ANTARES depth from above
- Better flux limit from MACRO:

$$\Phi \leq 2\times 10^{-16} cm^{-2} s^{-1} sr^{-1} \text{ for M} \geq 10^{14} \text{ GeV}$$

M. Ambrosio et al., Eur.Phys. J. C13 (2000) 453; L. Patrizii, TAUP 2003

A little more on dE/dx…

$$\frac{dE}{dx} = -\sigma\rho_{med.} v^2$$ → For $M \leq 8.4 \times 10^{14}$ GeV it depends only on v^2

↓

The passage of a nuclearite in matter produces heat along its path

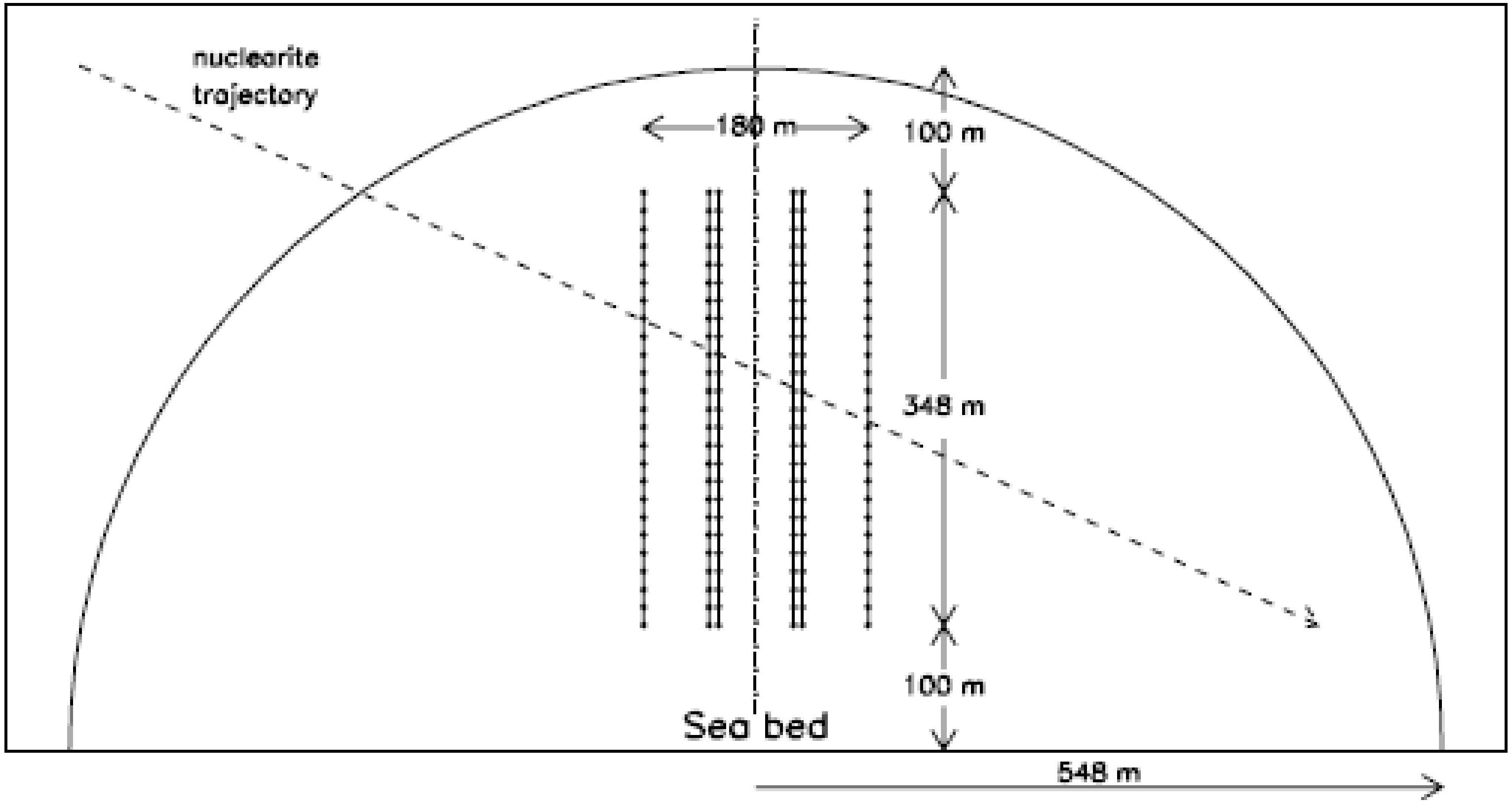
$10^4 - 10^5$ K !!! ↓

In transparent media some of the energy dissipated could appear as visible light (black body radiation)

The "optical efficiency" = the fraction of dE/dx appearing as light in water estimated to be $\eta = 3 \times 10^{-5}$ (lower bound)

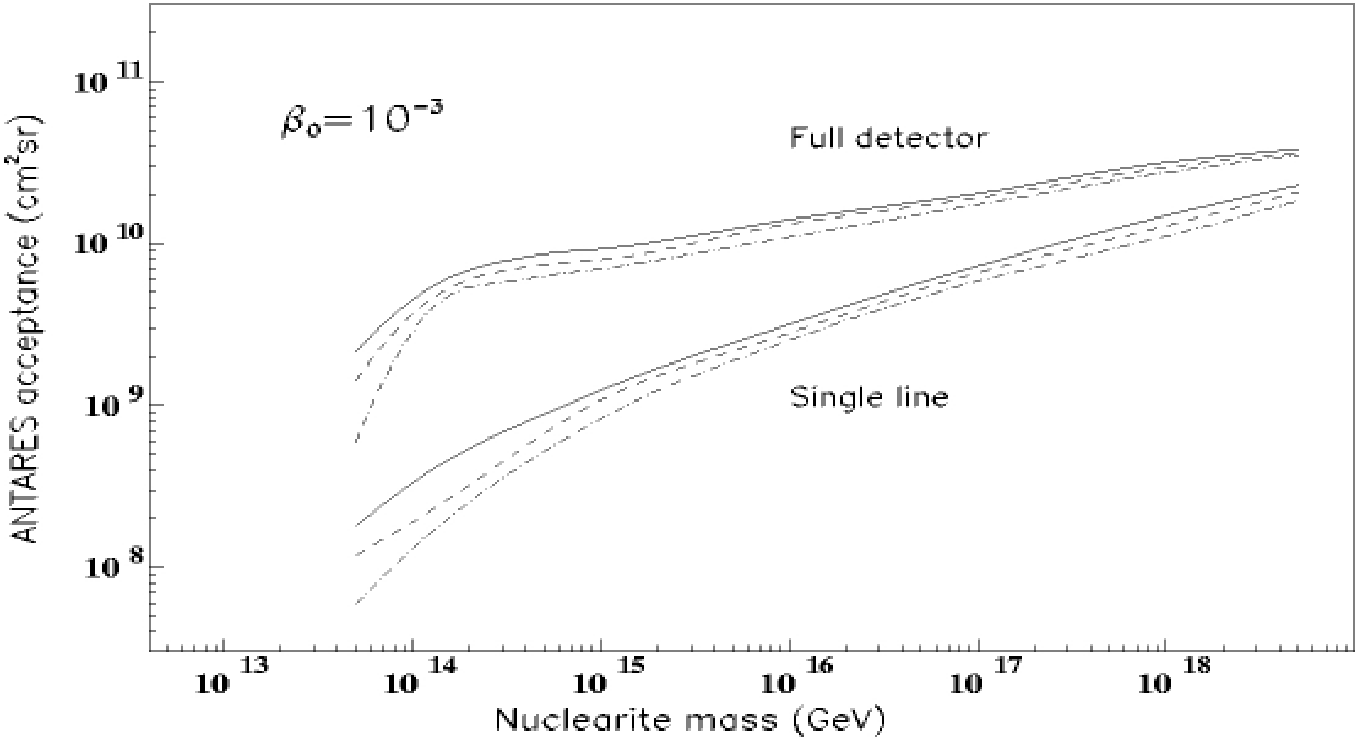
(A. De Rùjula, S.L. Glashow, Nature **312** (1984) 734)

MC simulation of an isotropic flux of down-going nuclearites in ANTARES



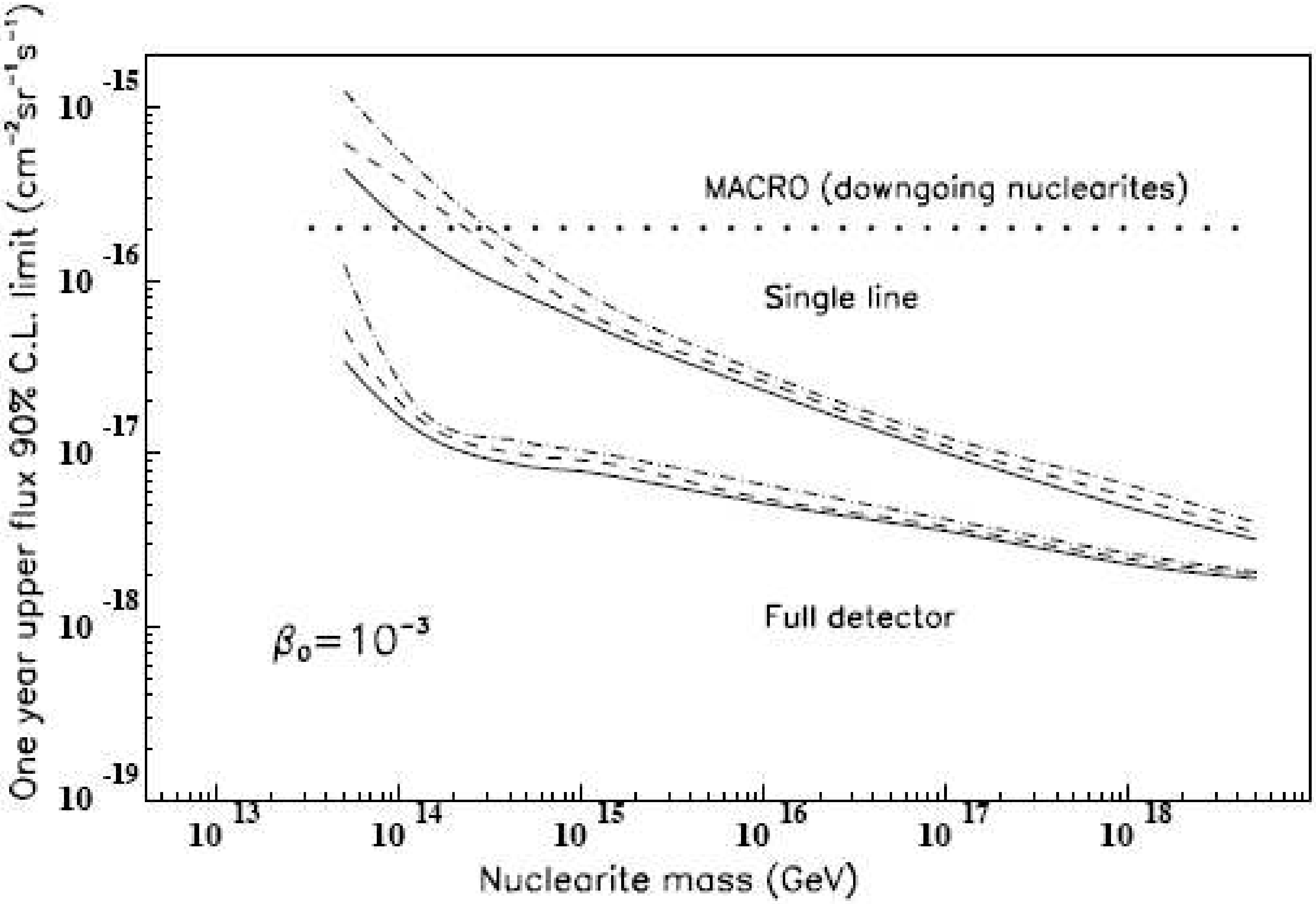
Simplified geometry: sea bed flat, all perfectly aligned
128 ns integration time
L0 triggers only

Antares acceptance to down-going nuclearites

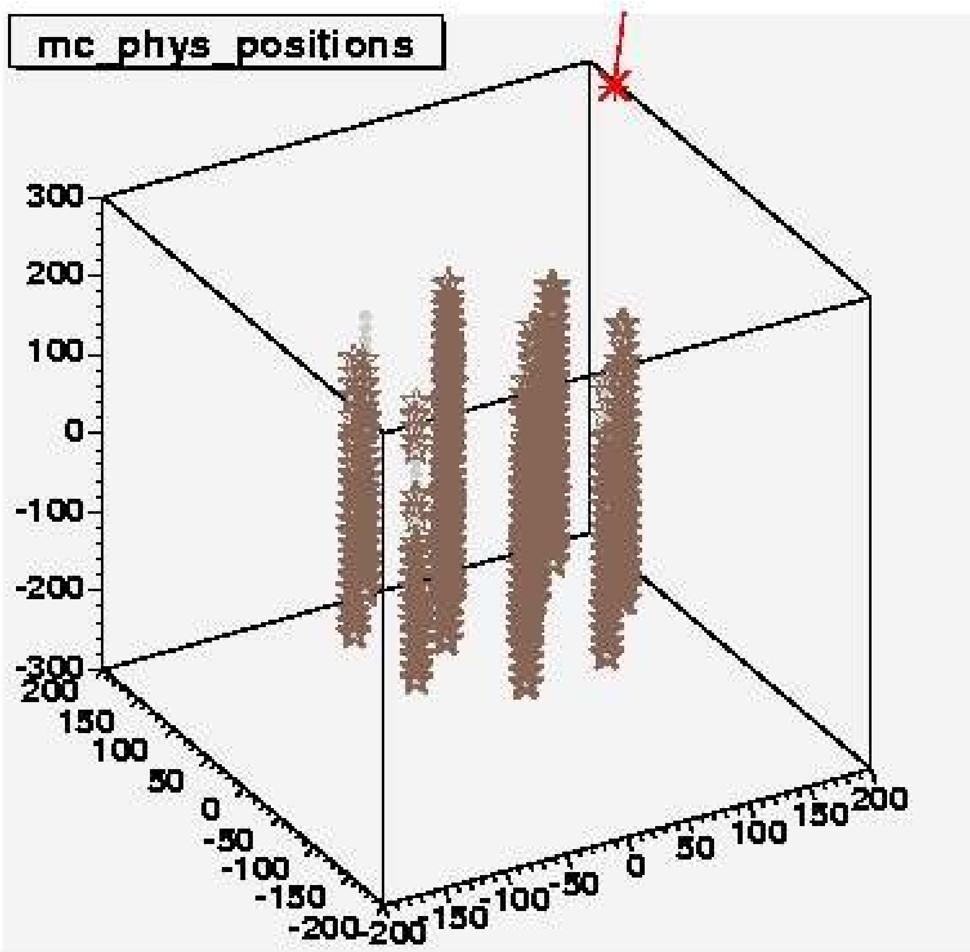


$$A = 2\pi \cdot S_{hemisphere} \cdot \frac{N_{detected}}{N_{simulated}}$$

Antares 1 year sensitivity to a down-going flux of nuclearites



Distribution of hits from a sample event



A sample event :

M = 10^{16} GeV

$\beta_0 = 10^{-3}$

$\beta_{entry\ point} = 9.75\times10^{-4}$

-huge input rates ~ GHz!

Y. Becherini Event Processor

Work to do

- Compatibility between the output of MC simulation program and the ANTARES data analysis software
- An algorithm for slow moving particles (nuclearites) to include in the DataFilter program
- Flux limits on the real data

ANTARES detector

(**A**stronomy with a **N**eutrino **T**elescope and **A**byss Environmental **Res**earch)