Acoustic Detection - Status

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Acoustic and Radio Detection Meeting
NIKHEF, Amsterdam

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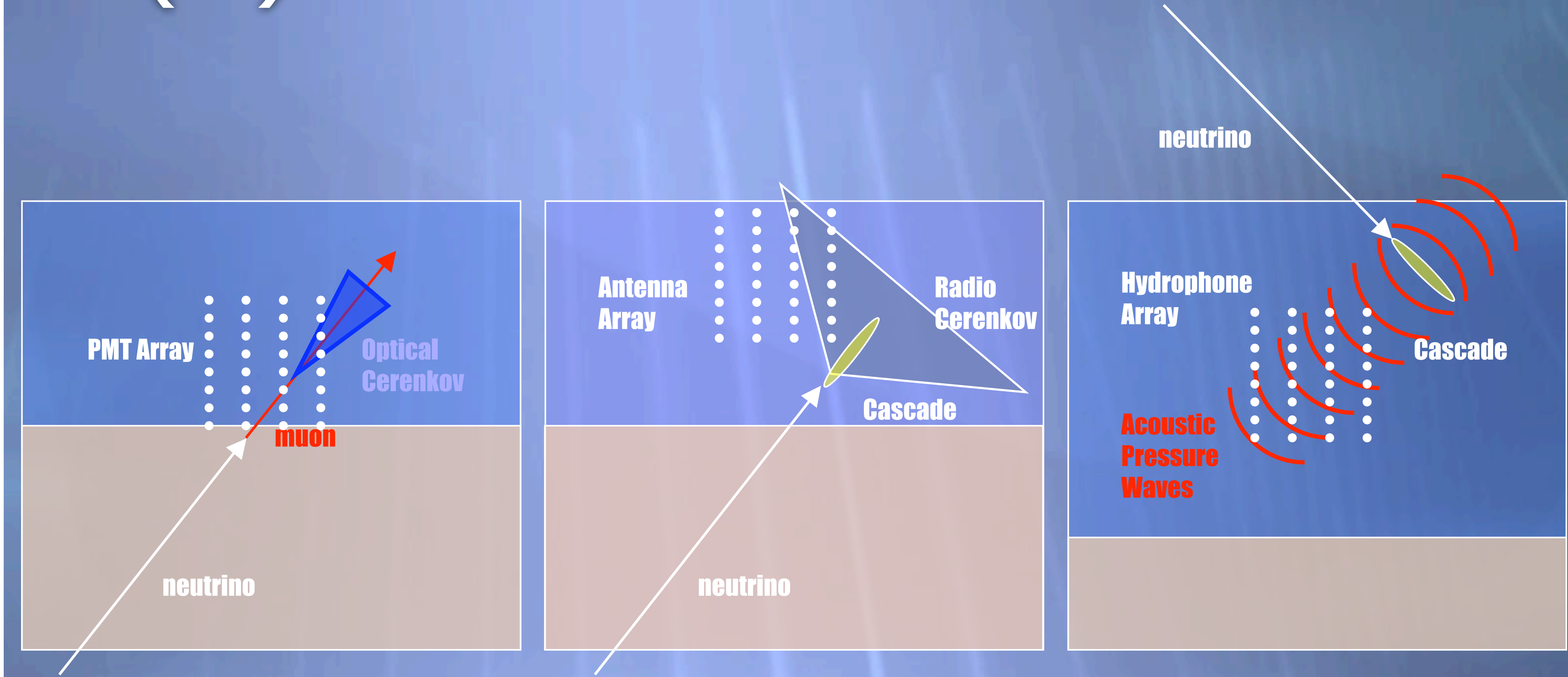
(U)HE ν Detection Methods



Optical Cerenkov

3D array of photosensors

Works well in water, ice

Attenuation lengths of order 50m to 100m (blue light)

Radio Cerenkov

3D array of antennae

Long (order km) attenuation lengths in ice and salt

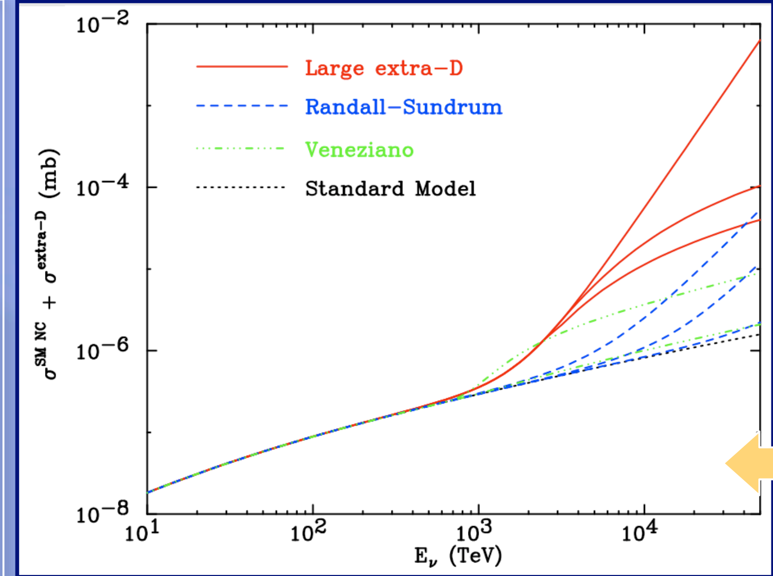
Acoustic Detection

3D array of hydrophones

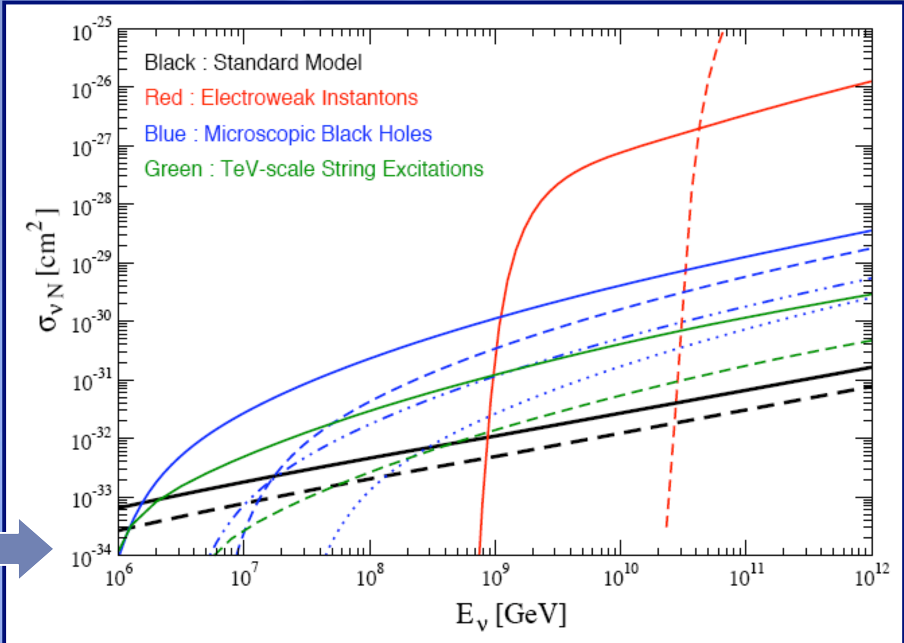
Very long attenuation lengths (order 10km) in water, ice and salt

Motivation

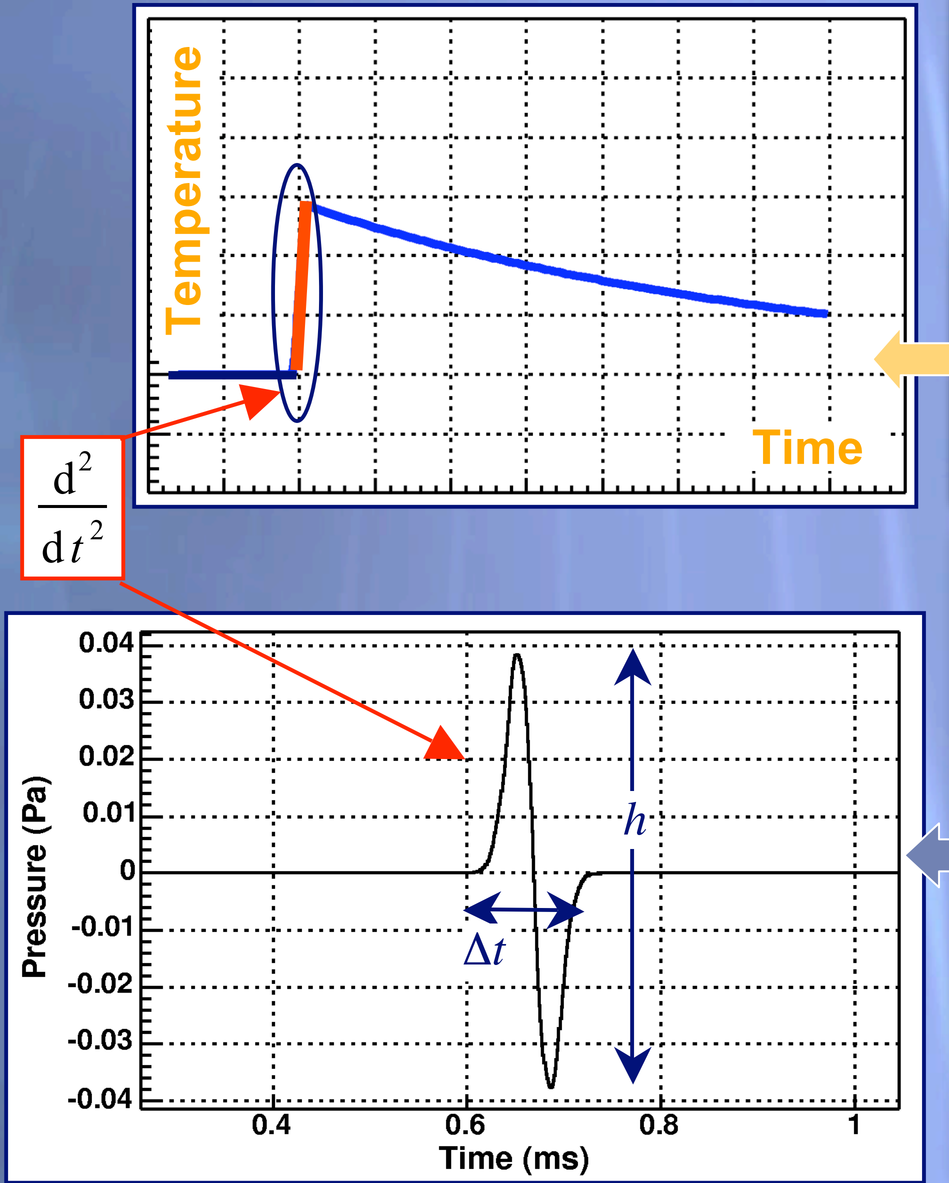
- Probing Ultra High Energies with neutrinos
- *In addition to cosmogenic neutrinos other theories such as:*
  - Strongly interacting neutrinos
  - *New neutral primaries*
  - Violation of Lorenz invariance
  - *Decaying supermassive dark matter*
  - Instantons, excitons
  - *etc…*
- Many of these models predict, e.g. enhanced neutrino cross-sections at ultra high energies



Neutrino-nucleon cross-sections for low- scale models of quantum gravity involving e.g. extra dimensions



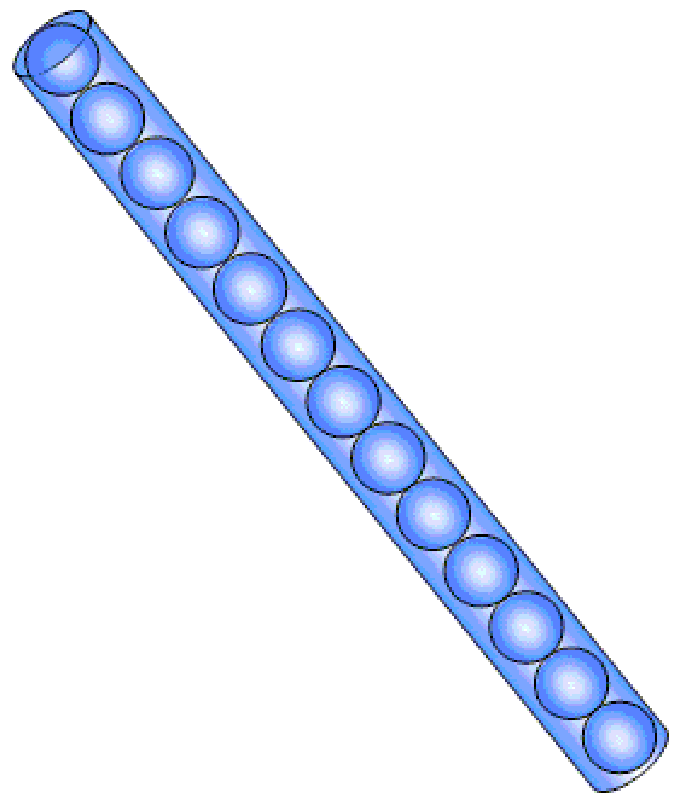
Acoustic Detection Principle



- Fast thermal energy deposition (followed by slow heat diffusion)
- *Results in a quasi-instantaneous temperature increase and expansion of the medium leading to "acoustic shock" sound pulse*

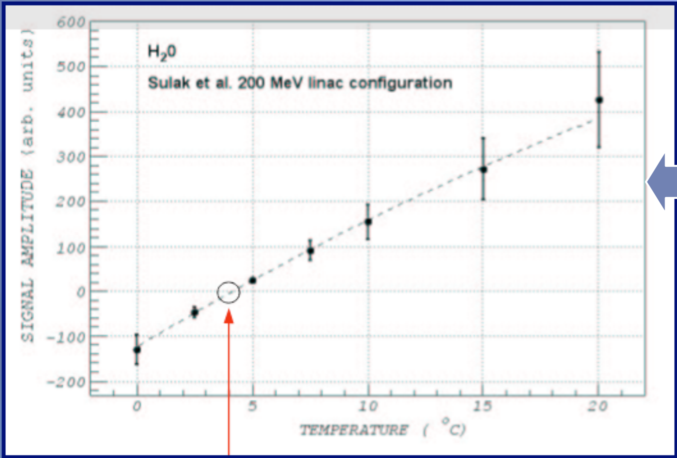
- Double derivative leads to classic bipolar pulse shape
- *Pulse width Δt is related to the **transverse** shower spread*
- Pulse height h is defined by the medium: $h \propto \beta / C_p$ where b is the co-efficient of thermal expansivity and C_p is the specific heat capacity

Acoustic Detection Principle



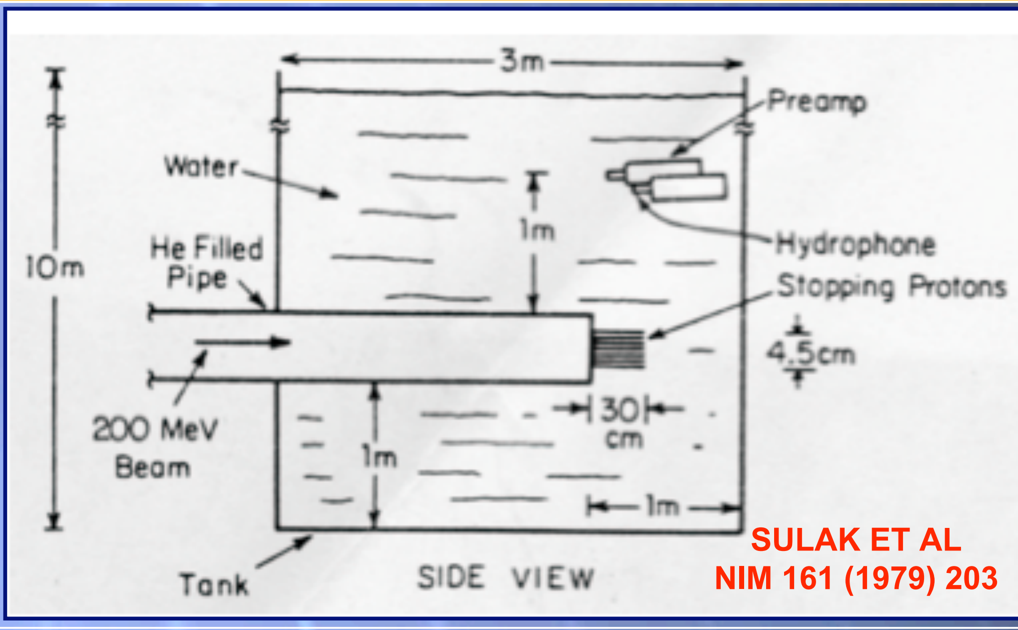
- Cylindrical volume over which the hadronic energy is deposited is typically 10m-20m long and a few centimetres wide
- *In analogy with light diffraction through a slit the acoustic signal propagates in a narrow "pancake" perpendicular to the direction of the shower*

Confirmation of Technique



- Signal amplitude vs. water temperature - warmer is better!
- P proportional to β(T) - thermo-acoustic origin

- Results from experiments in late 1970s confirmed bi-polar acoustic pulse in a test beam at Brookhaven



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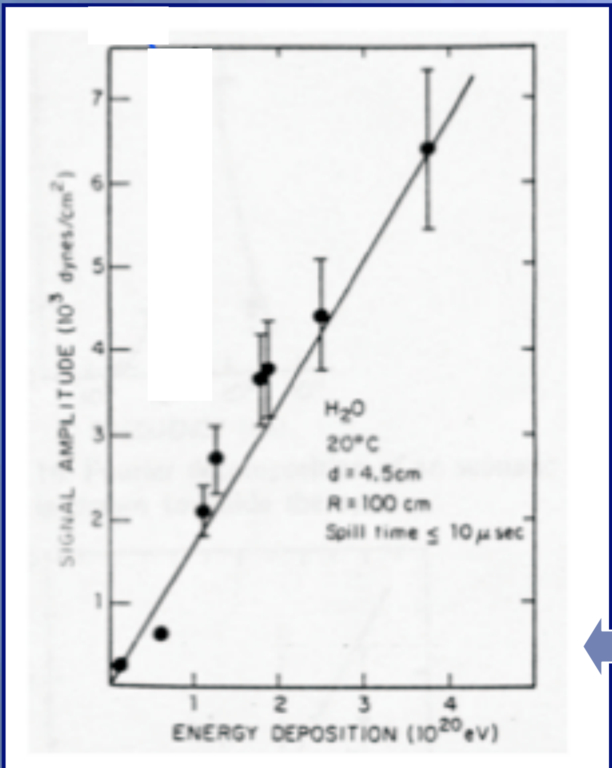


- Signal amplitude vs. energy deposition
- Pressure proportional to Energy - proves predicted coherent effect

Current Activities

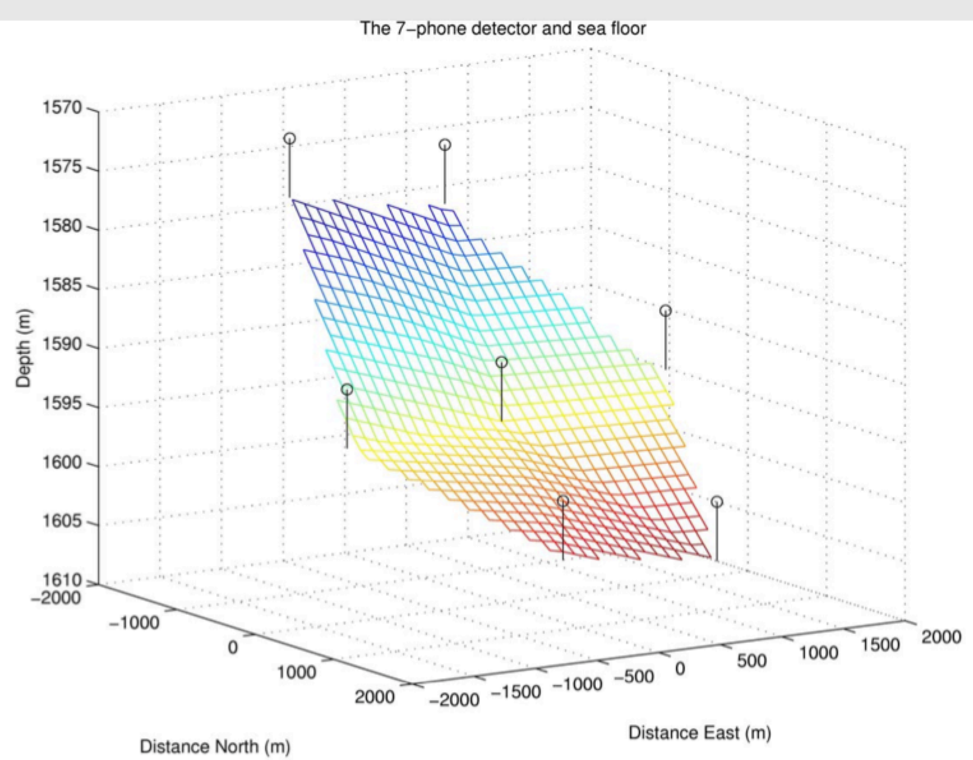
- Mostly in the form of feasibility studies and/or R&D programmes
- Following is an arbitrary classification (personal)
- Activities around already funded optical Cerenkov telescopes
  - AMADEUS at ANTARES ✓
  - SPATS at ICECUBE ✓
  - Lake Baikal ✗
- Activities around pre-existing (military) hydrophone arrays
  - SAUND ✗
  - ACORNE ✓

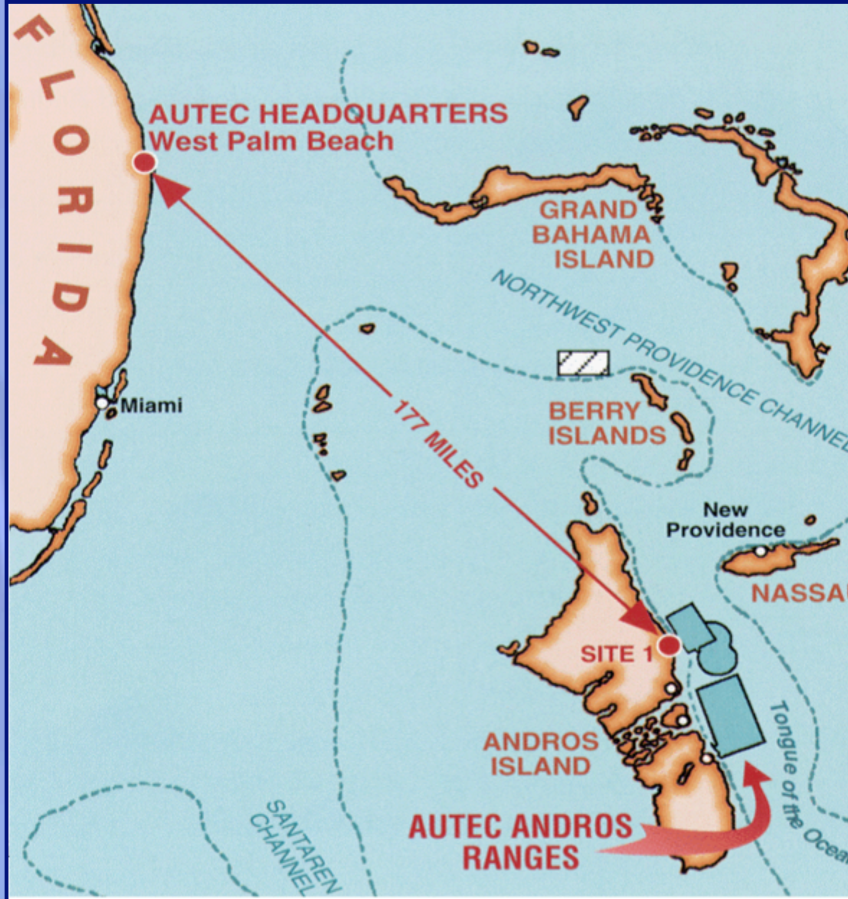
Current Activities (cont.)

- Other test sites and environment monitoring
  - ONDE at NEMO ✗
- Sensor development
  - Erlangen group (Ceramics) ✗
  - Pisa group (Optical fibre) ✓
- Calibrators
  - ACORNE group ✓
  - Valencia group ✗
  - (others)
- Signal processing, sensitivity calcs
  - All!

Stanford Acoustic Underwater Neutrino Detector (SAUND)

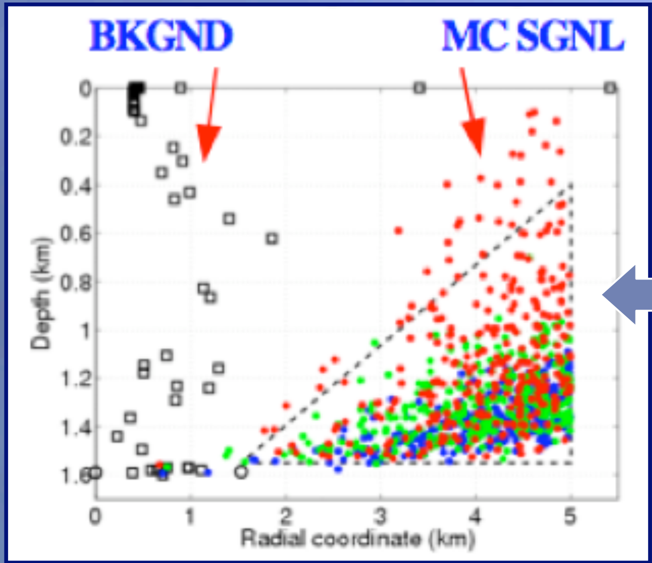
- The SAUND experiment
- *Stanford based venture using the AUTEC array, naval hydrophones in the Bahamas*





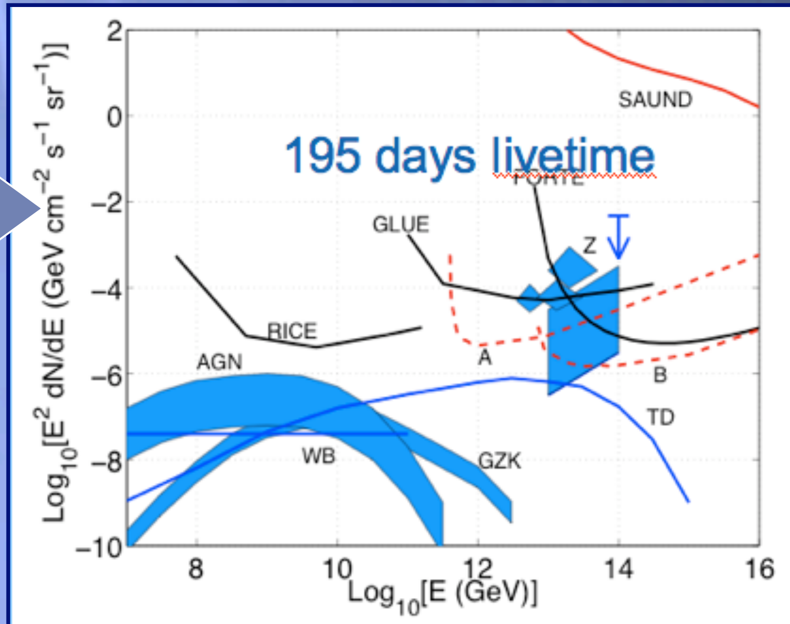
- SAUND I: 7 hydrophones read out
- *Raw data filtered before acquisition*

SAUND

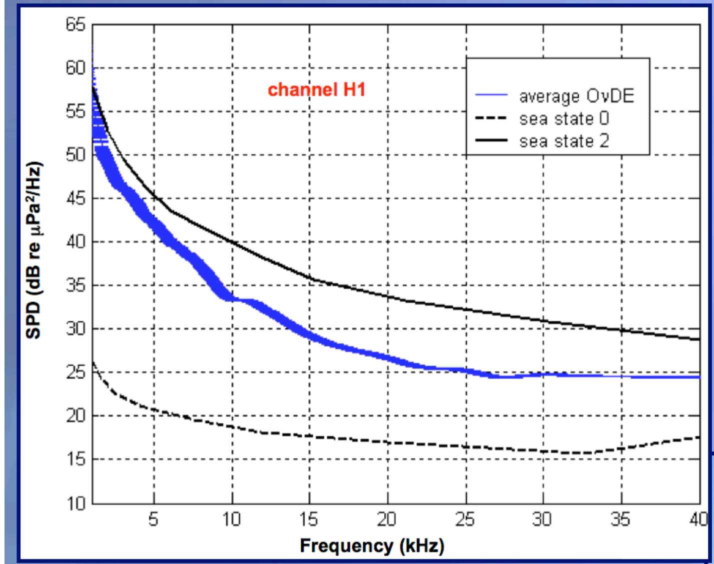


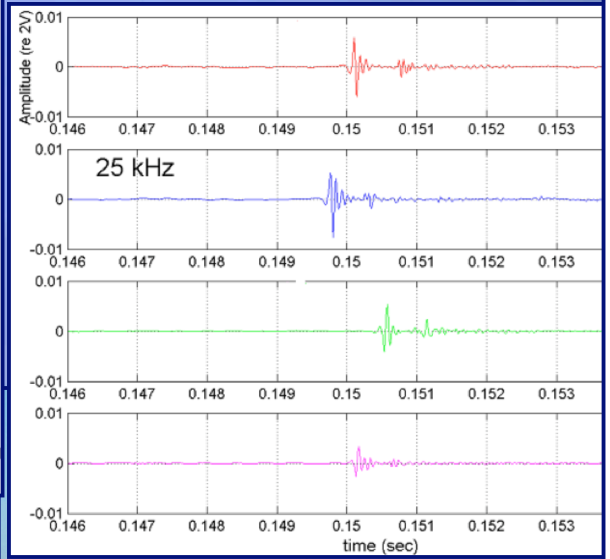
- SAUND analysis requires multi-phone co-incidences and fiducial cuts to remove the remaining multi-polar backgrounds

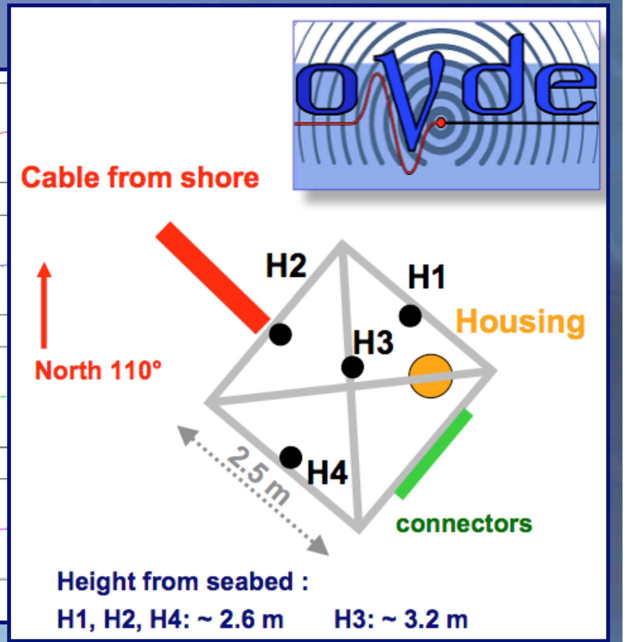
- Published sensitivity for 195 days of data with SAUND I
- SAUND II is reading out ~56 hydrophones and started data taking in summer 2006



Ocean Noise Detection Experiment (ONDE)



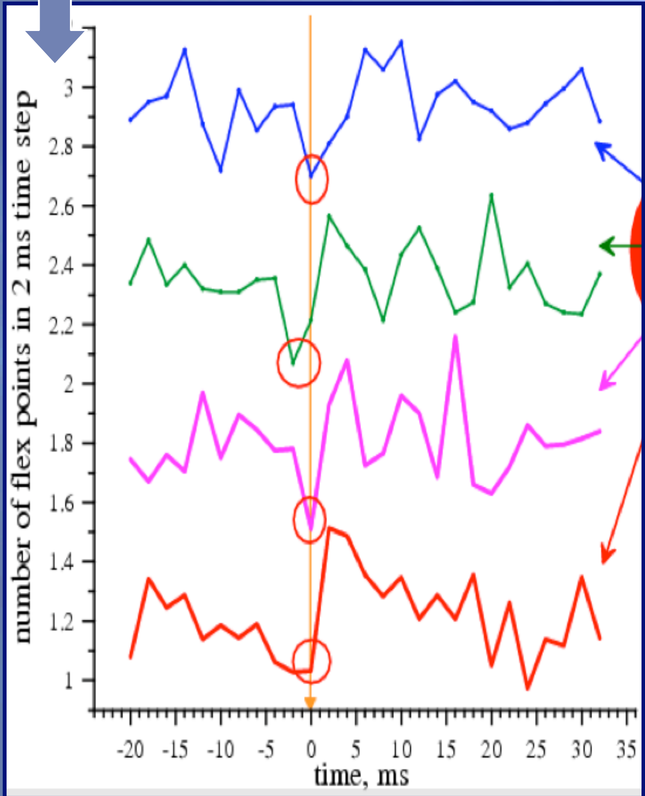


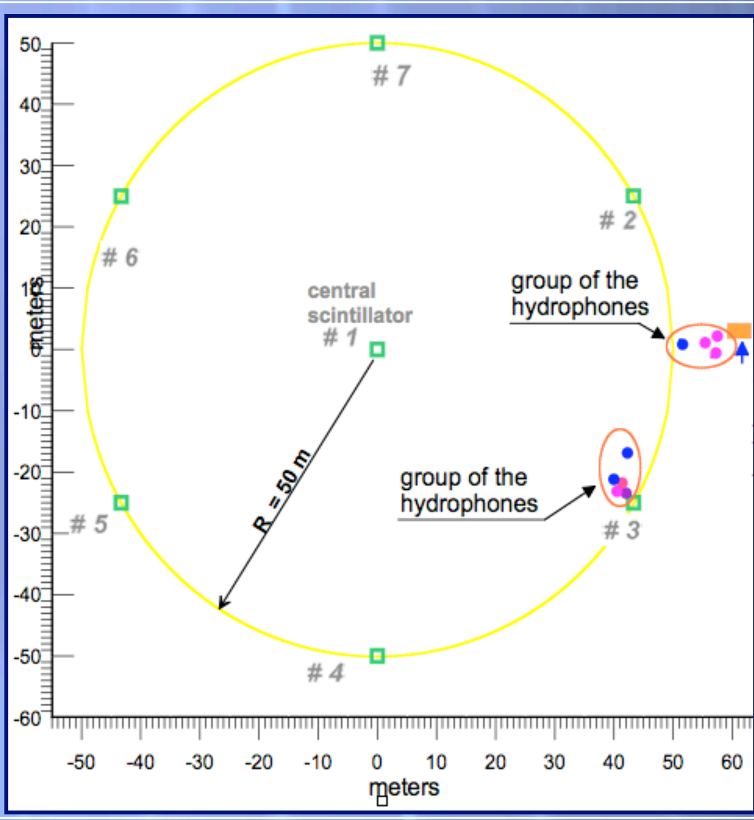


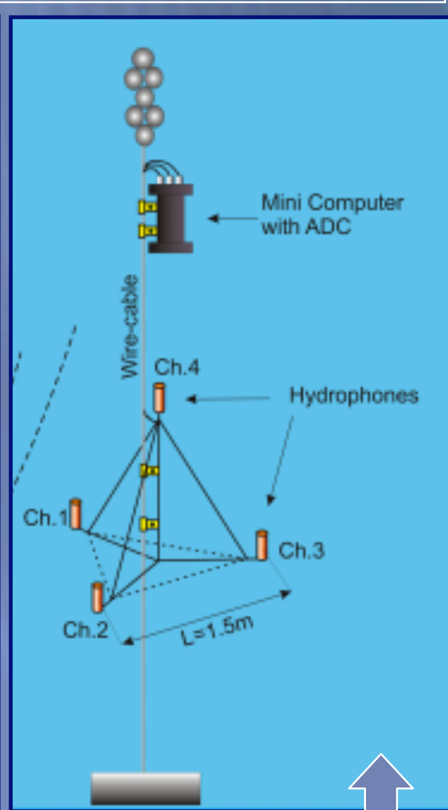
- ONDE was deployed in January 2005 at the NEMO Test Site in Sicily
- *4 hydrophones werer read out (5′ per hour) for ~2 years*
- Full analysis of noise (by hour, month, etc.)
- *Bio coincidences seen*

Lake Baikal

- Co-incidence of surface (ice) based scintillators and hydrophones
- *Data taken at the Lake Baikal NT-200 site during spring ice cover 2002 and 2003*
- Analysis in progress looking for features in acoustic signals in coinc. with EAS



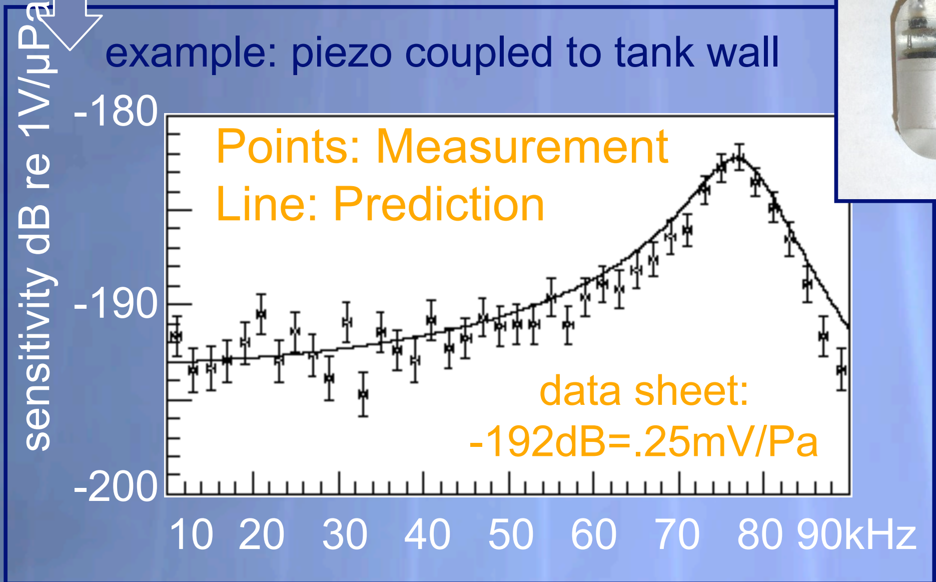


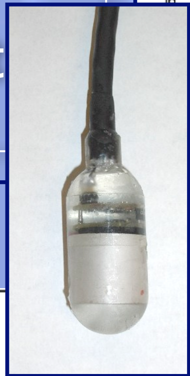


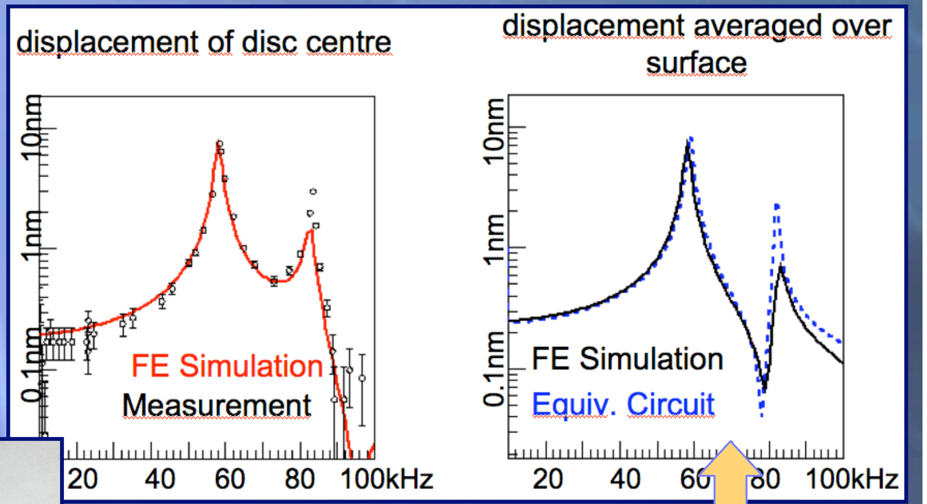
- New acoustic module with 4 hydrophones deployed in April 2006
- *100m, autonomous, self-triggered, on-detector processing*
- First results to be presented at ICRC conference

Sensor Development

- Can we design and build bespoke acoustic sensors with performance well-matched to expected signal?
- *Requires a good theoretical model of piezo and the coupling*
- Predictions using equivalent circuits





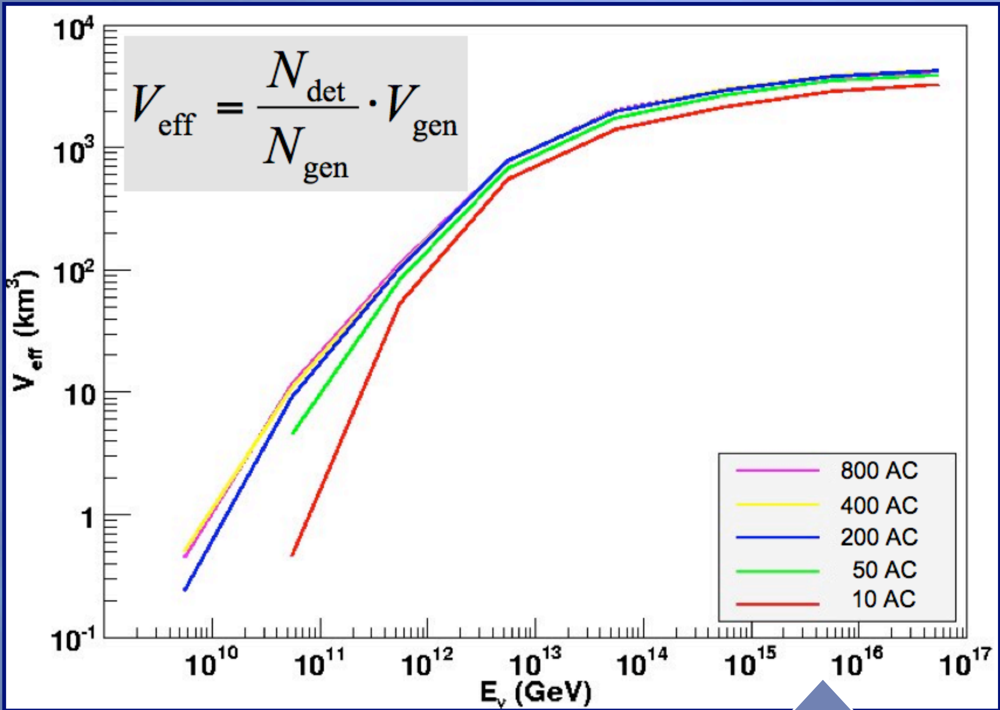


Further detailed understanding of piezos is under study

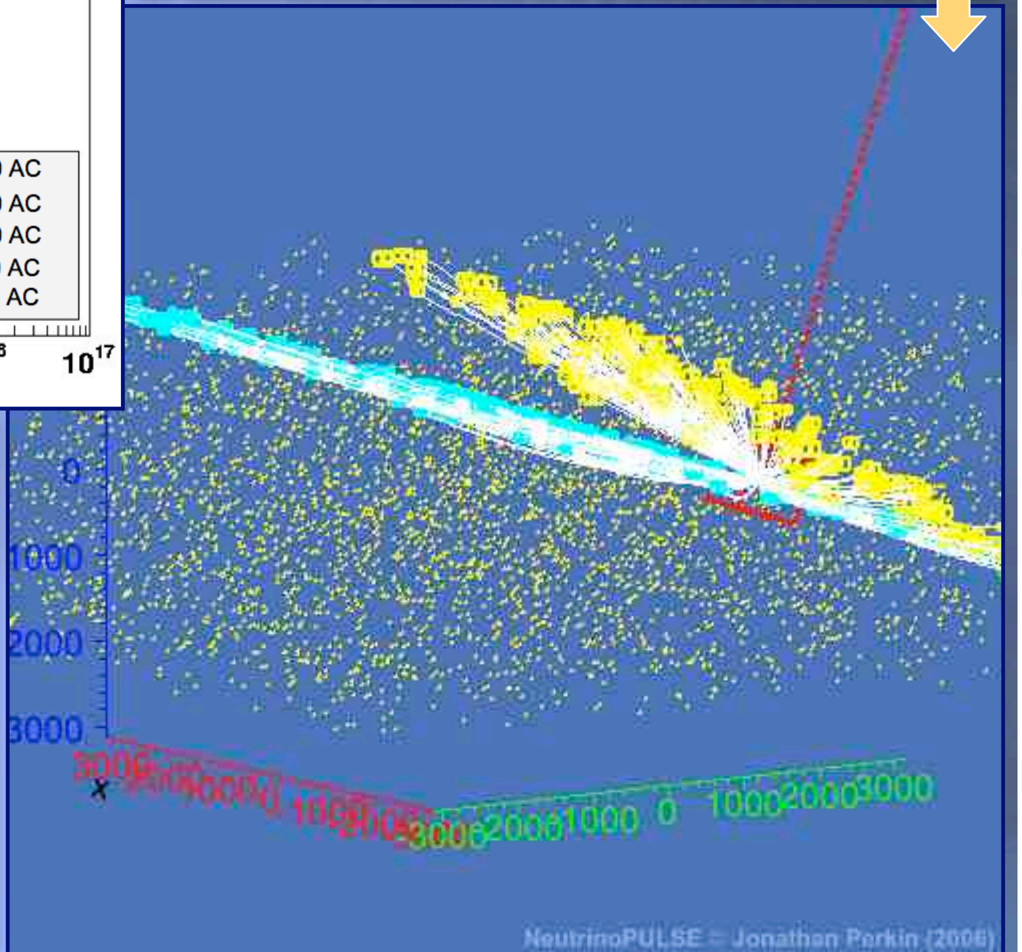
*At the **microscopic** level piezos can be modelled using PDEs for an anisotropic material*

- Solve using Finite Element Analysis
- *Use Laser Interferometry to compare results*

Sensitivity Calculations

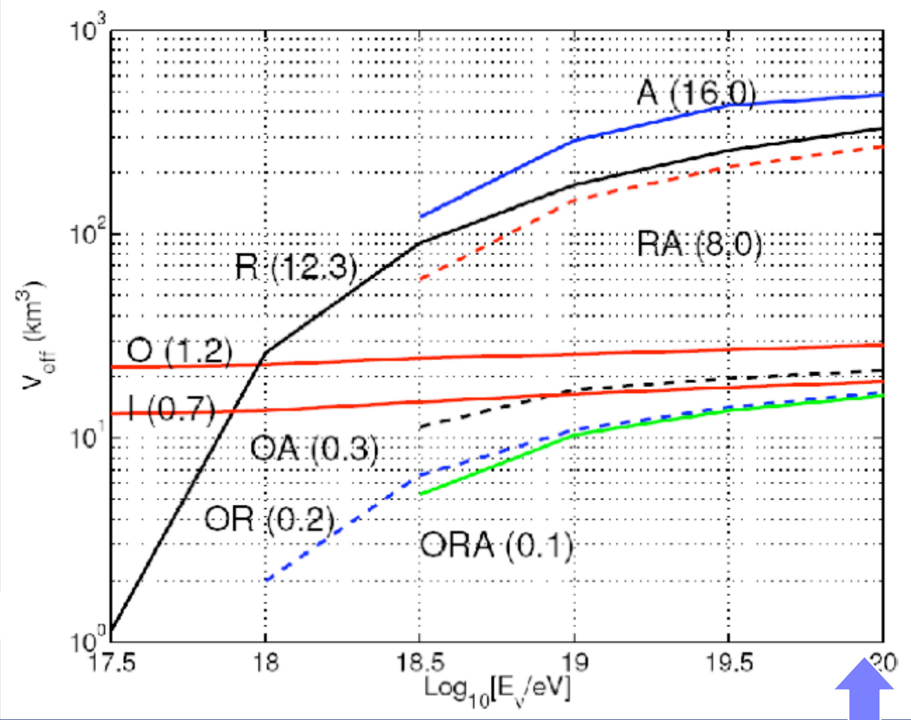


- Current studies are concentrating on the effects of refraction
- *Linear Sound Velocity Profile (SVP) distorts the acoustic pancake into a hyperbola*



- Effective volume for a 1 km^3 array instrumented with different numbers of ANTARES-style *acoustic storeys*
- *No improvement in effective volume above 200AC/km^3*
- Detection threshold 5mPa

Sensitivity Calculations



✦ Considering Hybrid arrays incorporating optical, radio and acoustic technologies

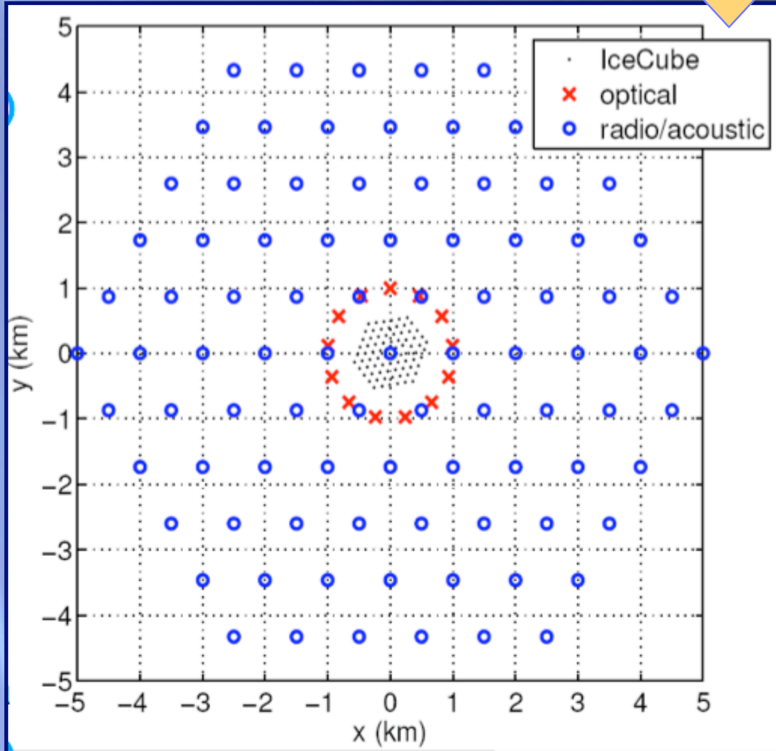
✦ *Cross-calibration between technologies should be possible*

✦ Yields up to 20 events per year

✦ Effective volume for hybrid arrays involving extending beyond IceCube with strings of radio and acoustic sensors

✦ *IceCube plus 5x2 radio and 300 acoustic sensors per string*

✦ See D. Besson, astro-ph/0512604



In Summary …

- *The acoustic detection of UHE neutrinos is a promising technique that would complement high energy neutrino detection using the optical and radio techniques*
- It is likely that any development of a large volume acoustic sensor array would be in parallel with the infrastructure of first and second generation optical Cerenkov neutrino telescopes
- *This is already starting to happen (ANTARES-AMADEUS, IceCube-SPATS-AURA)*
- Multi-messenger observations of astrophysical objects clearly provide valuable information, this is also true at ultra high energies
- For a future Astroparticle Physics I3 (HEAPNET) it will be important to identify and stress these synergies and complementarities