Status and Recent Results of the Acoustic Neutrino Detection Test System AMADEUS

Robert Lahmann
for the ANTARES Collaboration

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Friedrich-Alexander-Universität Erlangen-Nürnberg

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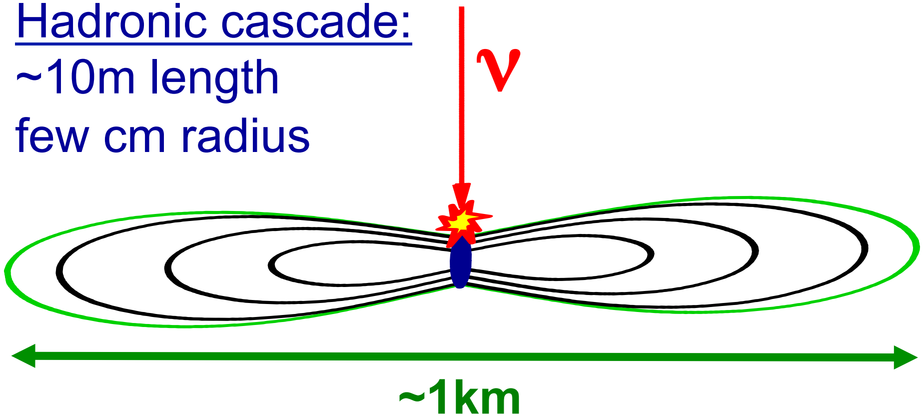
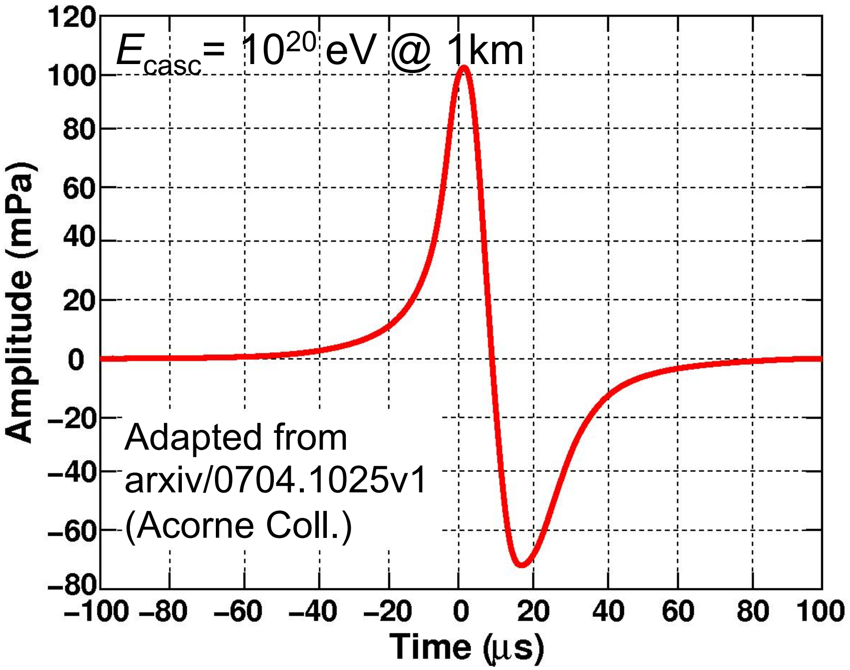
Acoustic Detection of Neutrinos

Thermo-acoustic effect: (Askariyan 1979)
energy deposition ➔ local heating (~µK) ➔ expansion ➔ pressure signal

Hadronic cascade:
~10m length
few cm radius





Pressure field:
Characteristic "pancake" pattern
Long attenuation length (~5 km @ 10 kHz)
Allows for neutrino detection at $E \gtrsim 10^{18}$eV

$$P(r = 200\,\mathrm{m}) \approx 10 \times \frac{E_{casc}}{1\,\mathrm{EeV}}\,\mathrm{mPa}$$

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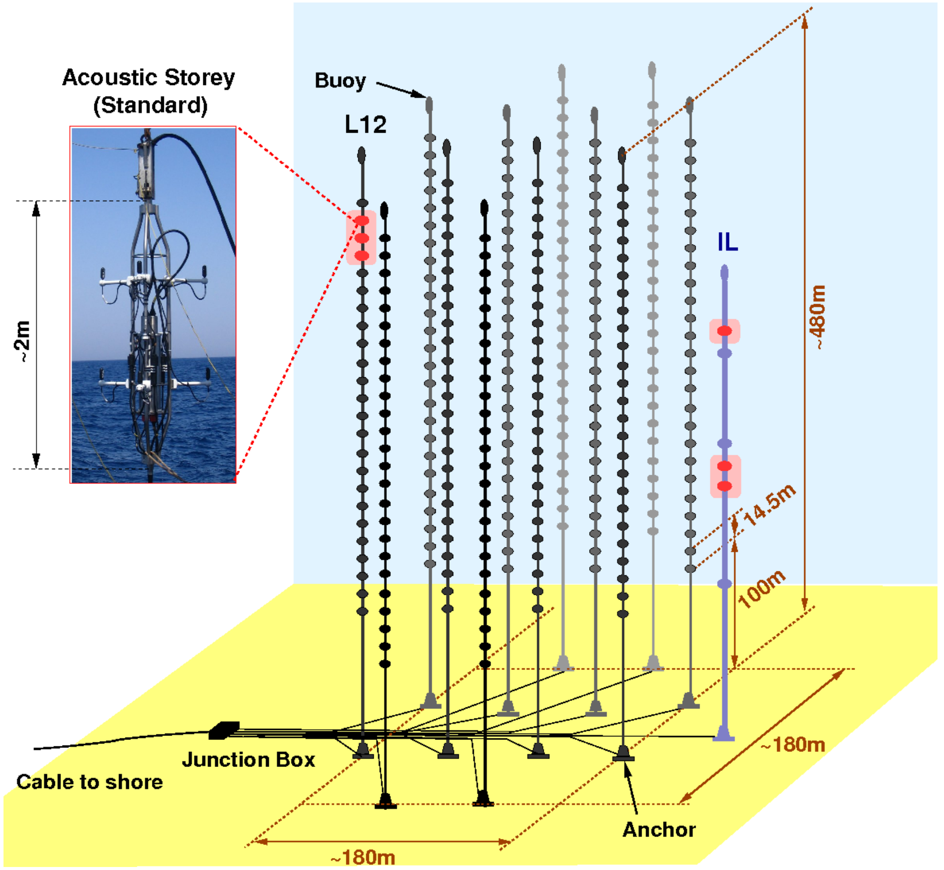
The AMADEUS System of the ANTARES detector



ANTARES site:

• 2500m depth, 30km offshore

AMADEUS

acoustic neutrino detection test system:

- Total of 6 "acoustic storeys"
- Total of 36 hydrophones
- Continuous sampling, >90% up-time
- Online filter selects ~1% of data volume for storage
- 3 storeys since 5-Dec-2007, full array since 30-May-2008

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Goals of AMADEUS

Main objective: feasibility study for a potential future large-scale acoustic neutrino detector

Main science case: Cosmogenic neutrinos

Main tasks:

- Determine energy threshold for neutrino detection
- Investigate background conditions
- Devise high efficiency, high purity neutrino detection algorithms

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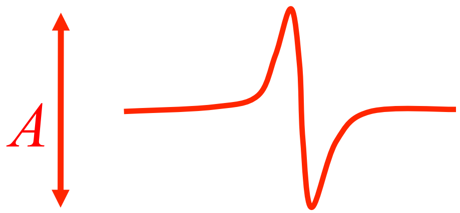
Background for Acoustic Detection in the Sea

Bipolar (BIP) events

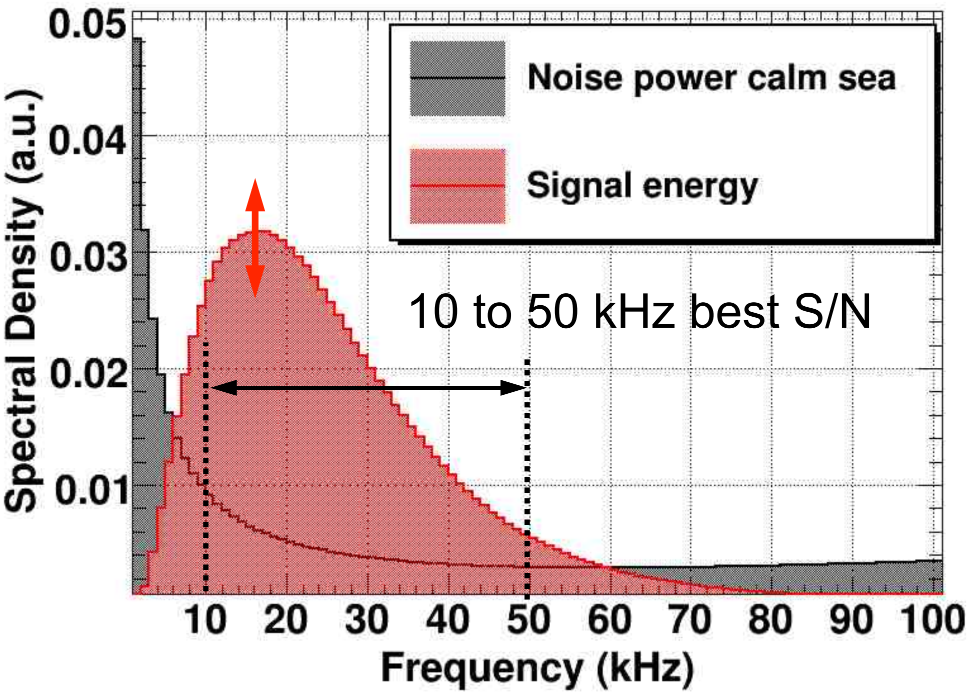


Bipolar Pressure Signals (BIPs)

Have to measure rate of BIP events: $\frac{d^3N}{dA\,dV\,dt}$

⇨**Determines fake neutrino rate**

Ambient noise



⇨**Determines intrinsic energy threshold**

Depends on "sea state" (surface agitation)
cf. Wenz, J. Acoust.Soc. Am. 34 (1962) 1936

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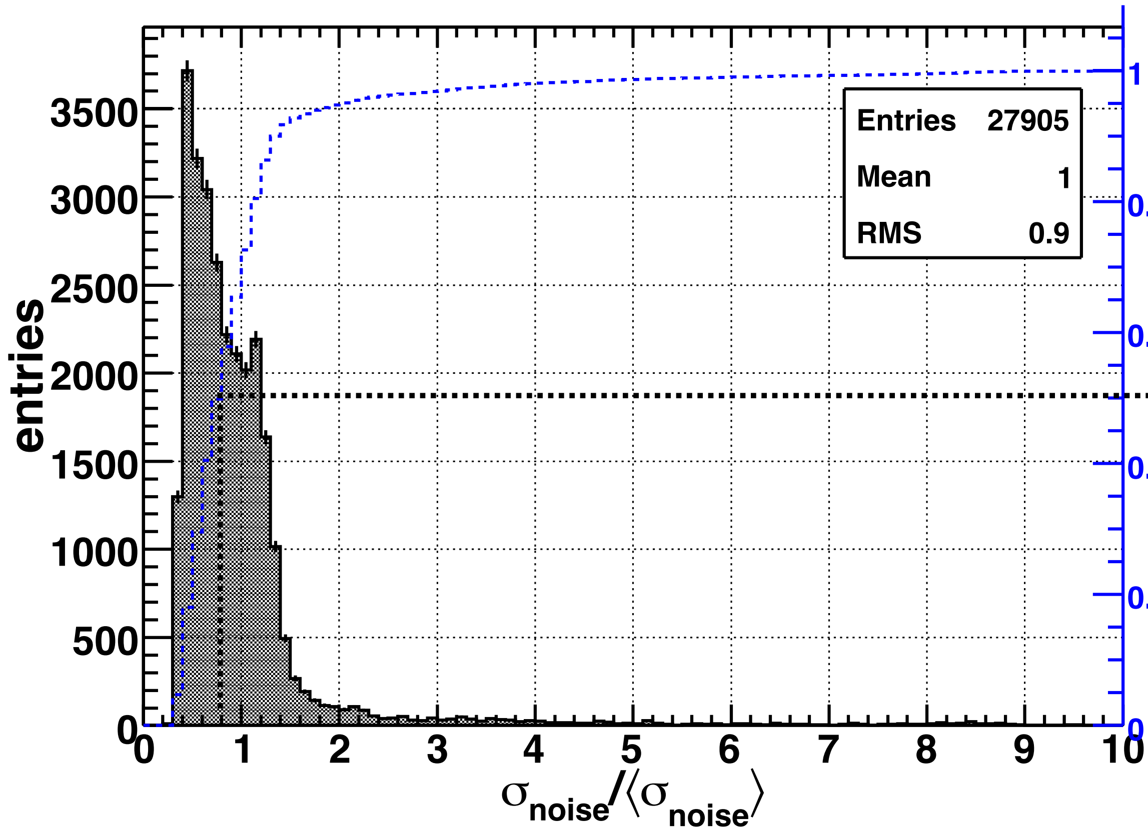
Distribution of Ambient Noise Level

1 entry = noise level (f = 10 – 50kHz) of 10s of continuous data recorded every hour with one hydrophone (2008 – 2010 data)



Median:

$$0.8\langle\sigma_{noise}\rangle$$

≈ 8 mPa

For sensor sensitivity of -145^{+2}_{-2} dB re 1V/µPa (lab calibration), the mean noise level is 10^{+3}_{-2} mPa

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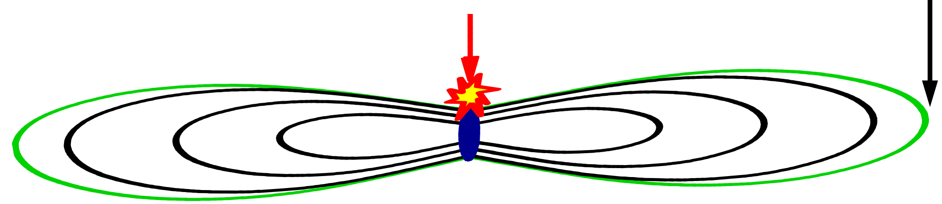
Ambient Noise: Conclusion

Evaluate for f = 10 to 50 kHz (best S/N)

Assume detection threshold for bipolar signals with S/N = 2

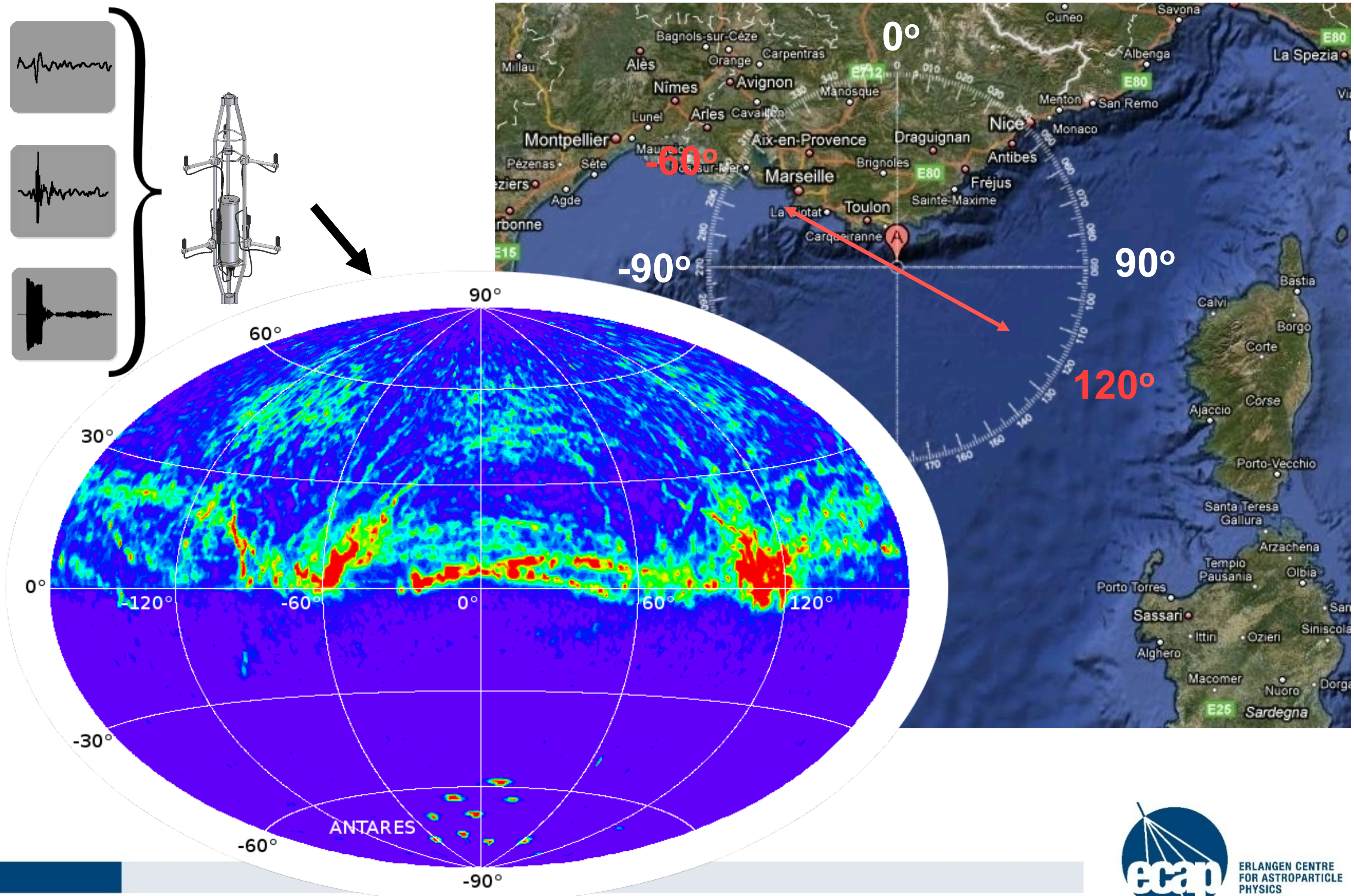
@200m along shower axis



- Median:
  P_{thd} = 16 mPa ⇨ $E_{thd} \approx$ 1~2 EeV
- 95% of time ambient noise is below $2\langle \sigma_{noise} \rangle$ (~20 mPa)
  P_{thd} = 40 mPa ⇨ $E_{thd} \approx$ 4 EeV

⇨ Good conditions for neutrino detection
(stable threshold, level as expected)

AMADEUS - Source Direction Distribution



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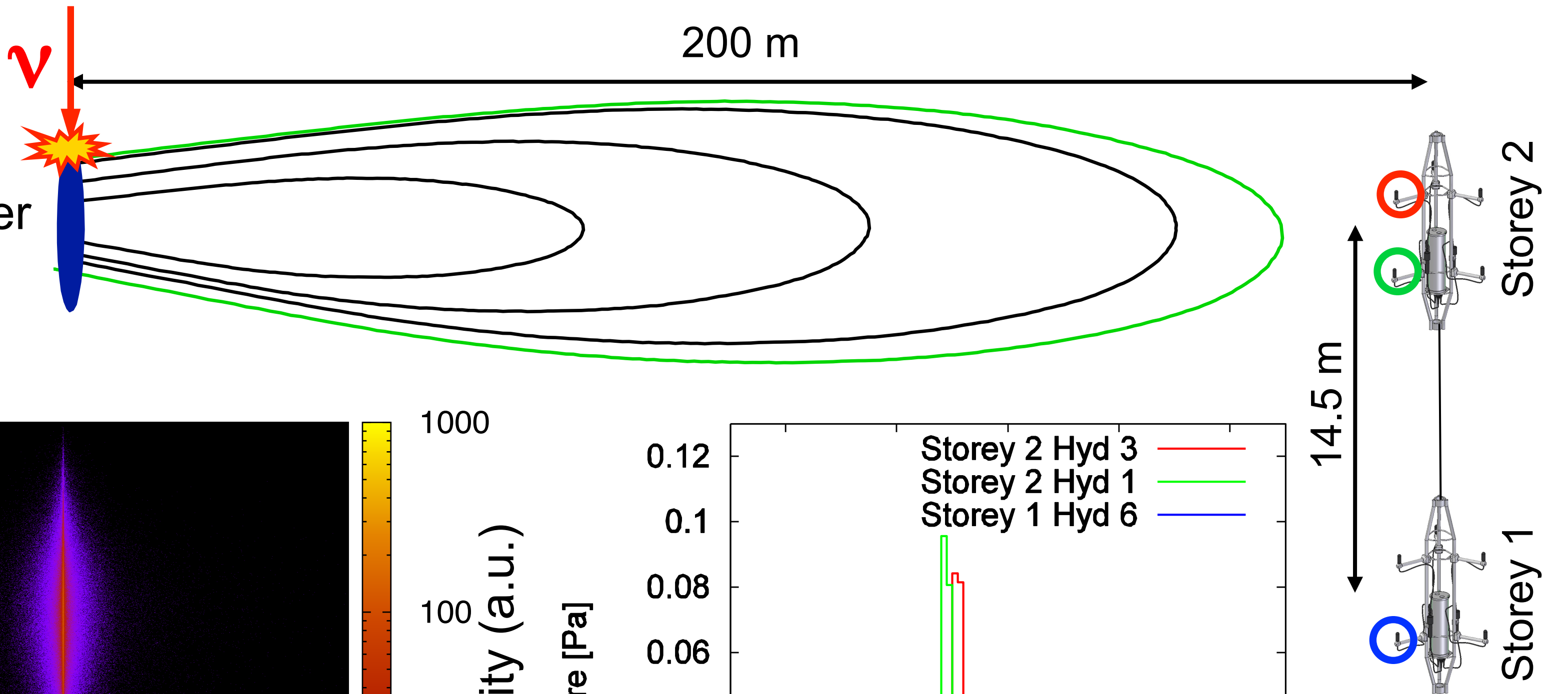
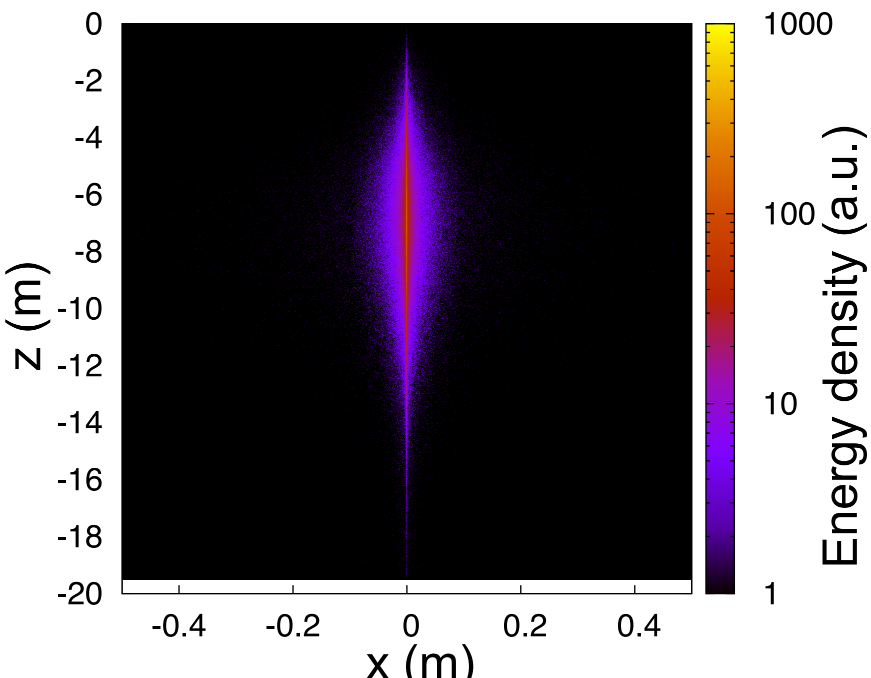
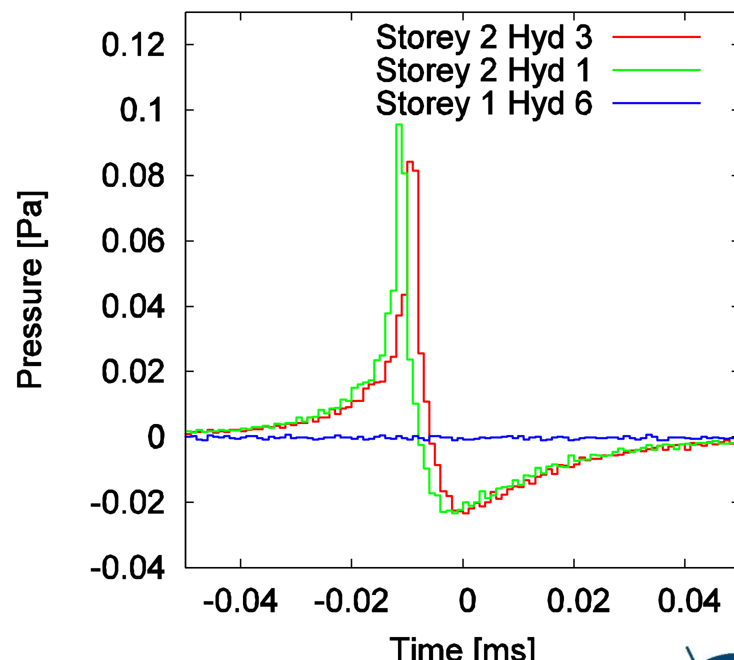
Simulation of Neutrino-Induced Acoustic Pulses







MC according to arxiv/0704.1025v1 (Acorne Coll.)

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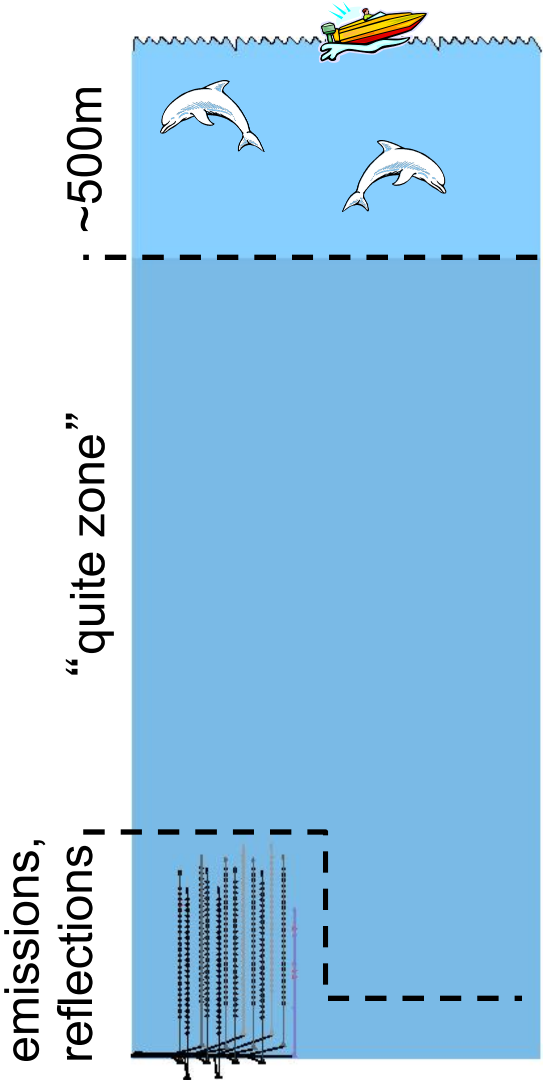
Transient Background Conclusions

- Exclude region near surface
- Very diverse transient background, signal classification crucial
- Cut on pattern of pressure field (“pancake”)



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Conclusions and Outlook

- The AMADEUS system has all features of an acoustic neutrino telescope (except size)
- Ambient background: Stable, level as expected
- Transient background: Several methods for suppression developed, work in progress
- Monte Carlo simulations and algorithms for neutrino selection under development
- KM3NeT: Combined system for acoustic positioning and neutrino detection planned

Funded by:
Bundesministerium
für Bildung
und Forschung

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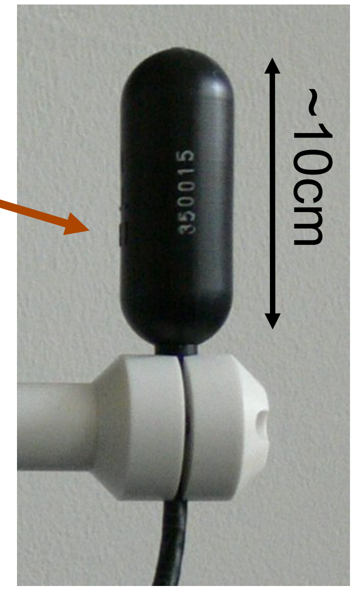
Backup transparencies

Setup of Acoustic Storey with Hydrophones

Hydrophone:
Piezo sensor with pre-amplifier and band pass filter in PU coating

Typical sensitivity: -145 dB re 1V/ μPa



Titanium cylinder with electronics

3 custom designed Acoustic ADC boards 16bit @ 250kHz

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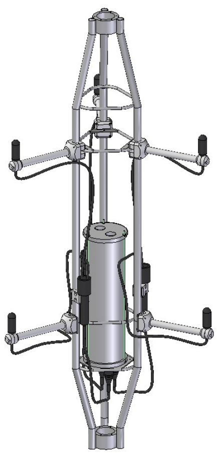
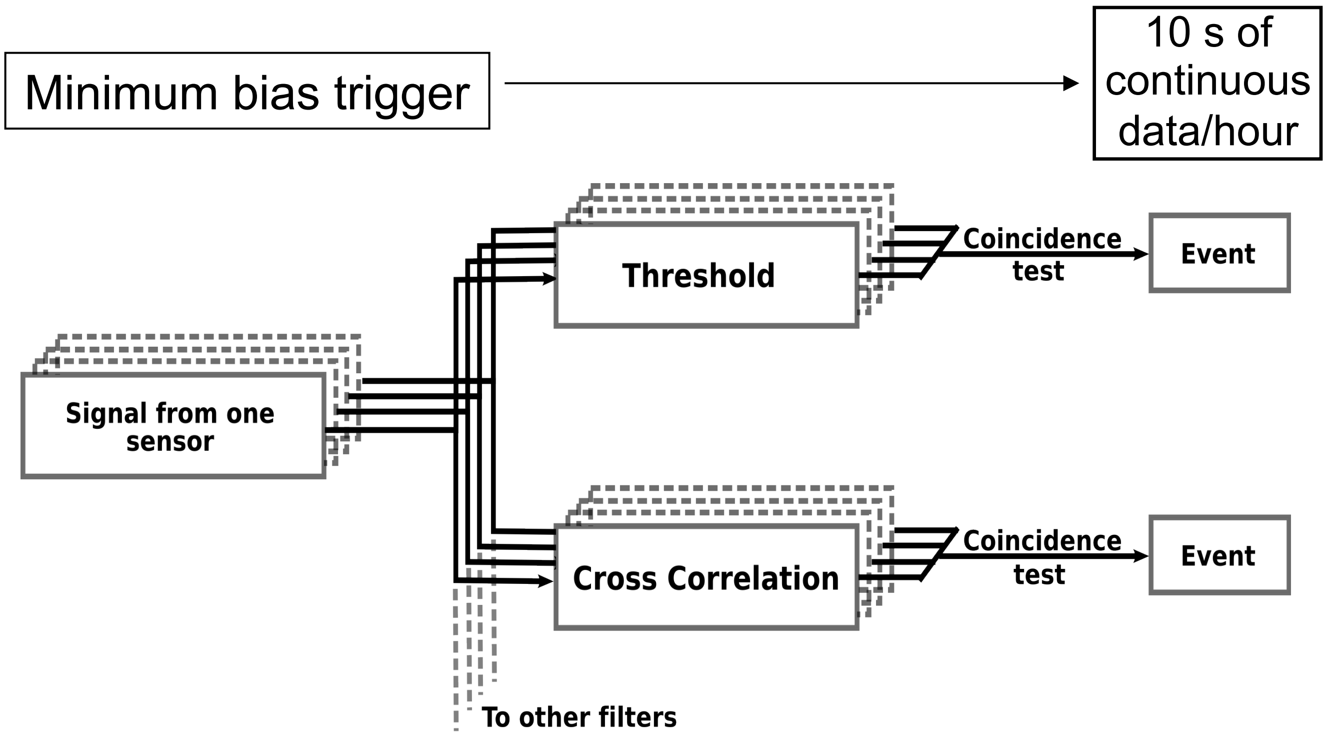
The Onshore Filter System

Task: Reduce incoming data rate of ~1.5 TByte/day to ~10 GByte/day

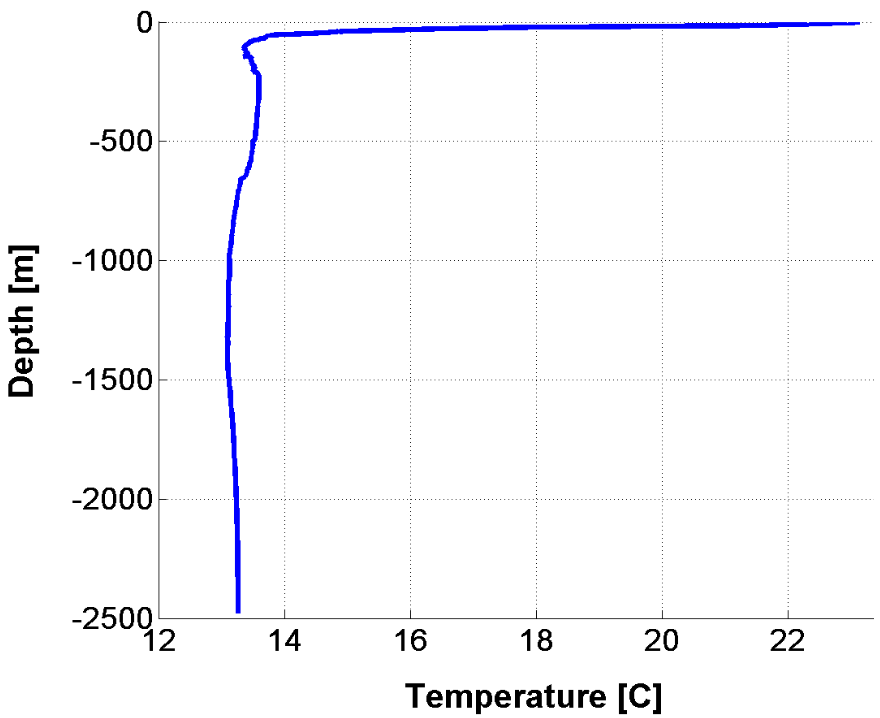


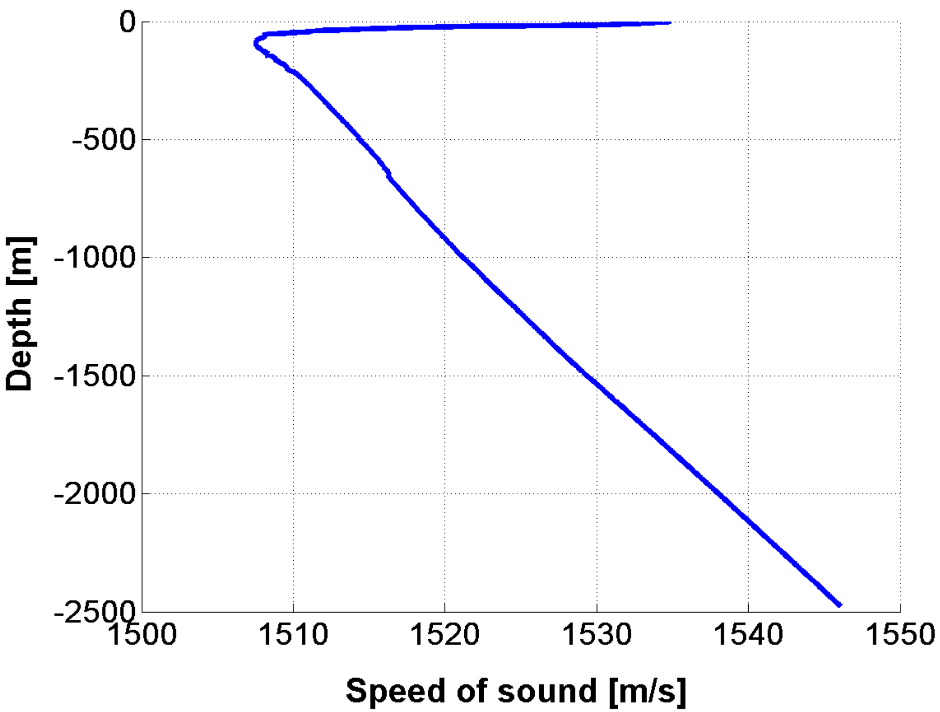


System extremely flexible, all components scalable

Local clusters (storeys) big advantage for fast (on-line) processing

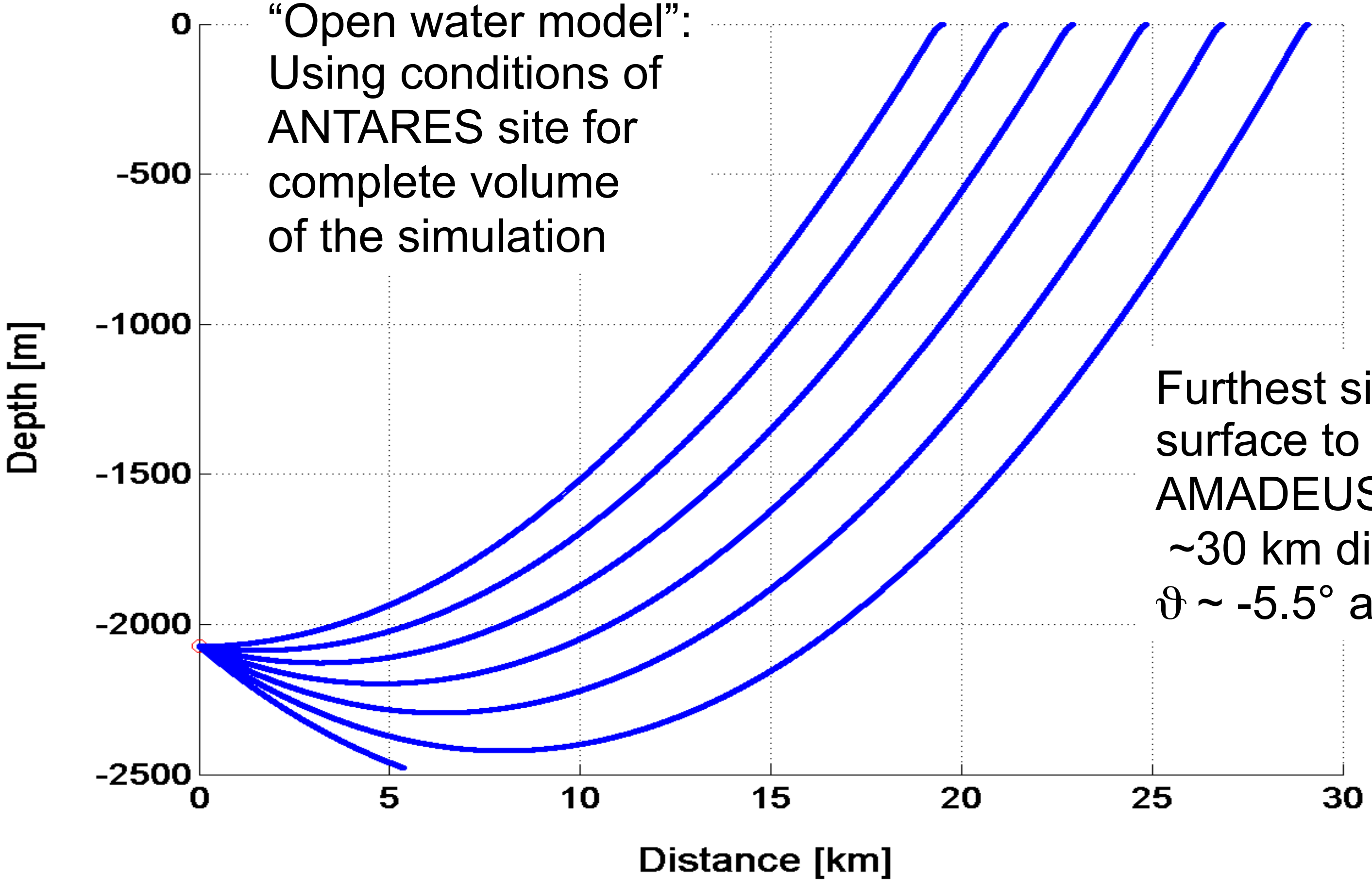
Properties of the Mediterranean Sea (ANTARES site)





Speed of sound depends on temperature, salinity, pressure (depth); temperature gradient only relevant up to ~100m below surface

Refraction of Signals Reaching AMADEUS



“Open water model”: Using conditions of ANTARES site for complete volume of the simulation

Furthest signals from surface to reach AMADEUS:
~30 km distance,
ϑ ~ -5.5° arrival angle

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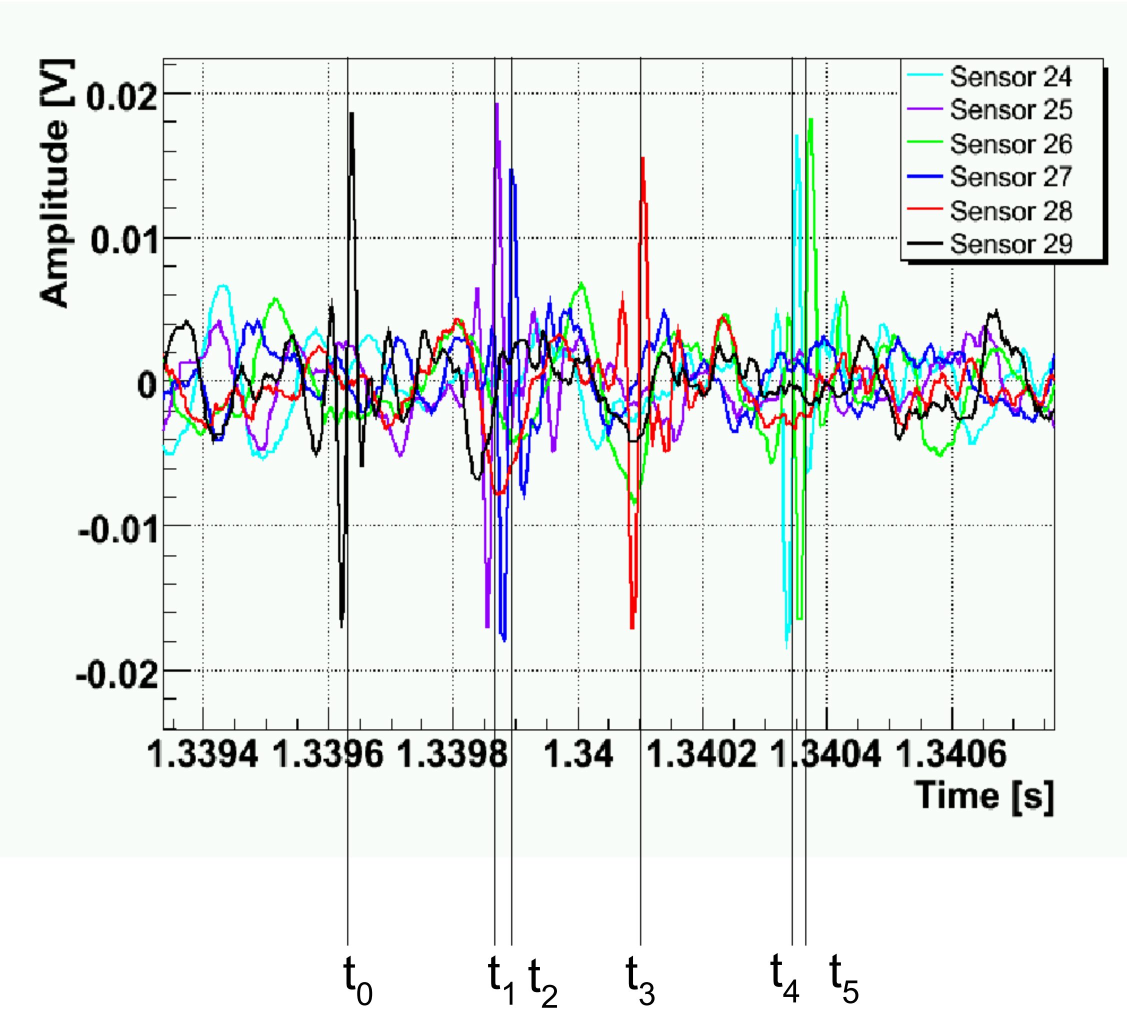
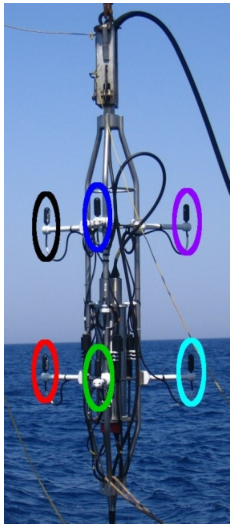
Source Direction Reconstruction



Error: ~3° in φ, < 1° in ϑ



minimize

$$\sum_i \left(t_{i_{\text{measured}}} - t_{i_{\text{expected}}}(\vartheta,\varphi)\right)^2$$