Recent Results of the Acoustic Neutrino Detection Test System AMADEUS

ERLANGEN CENTRE FOR ASTROPARTICLE PHYSICS

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ANTARES

Motivation

Acoustic Neutrino Detection:

Main science case: cosmogenic neutrinos

AMADEUS:

Acoustic Neutrino Test System in ANTARES

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

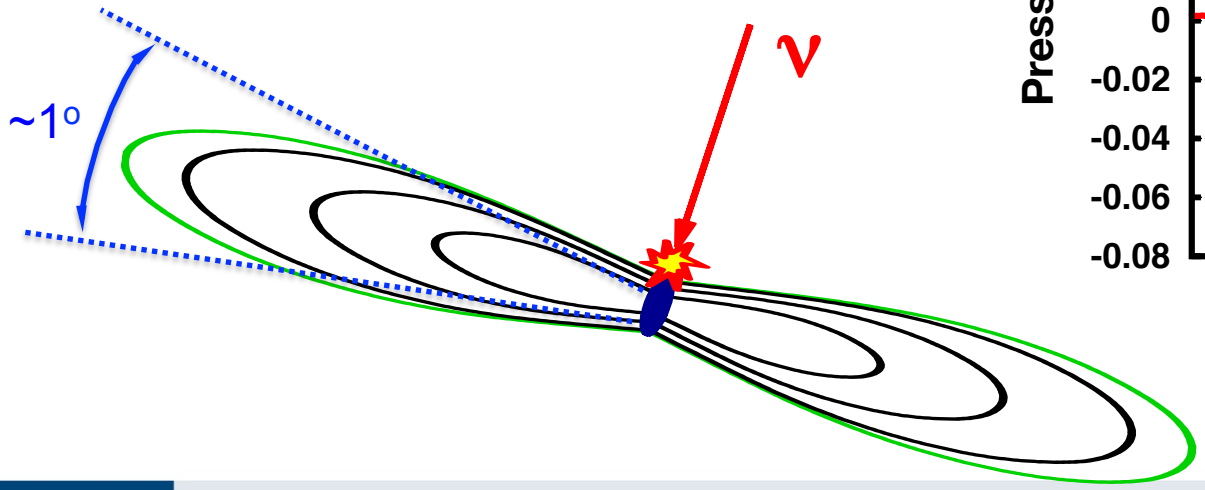
- Investigate background conditions
- Determine energy threshold for neutrino detection
- Devise high efficiency, high purity neutrino detection algorithms

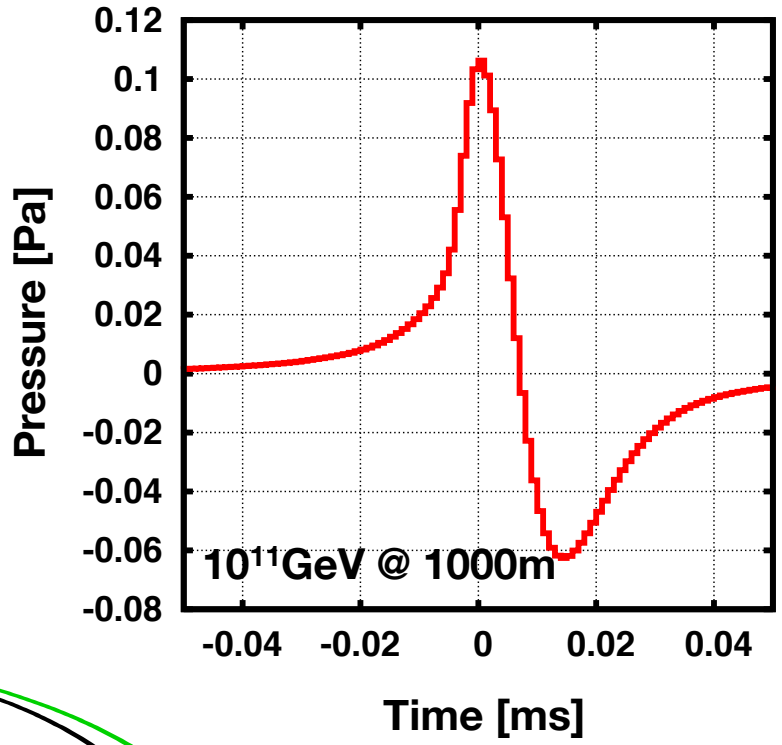
Acoustic Detection of Neutrinos

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)





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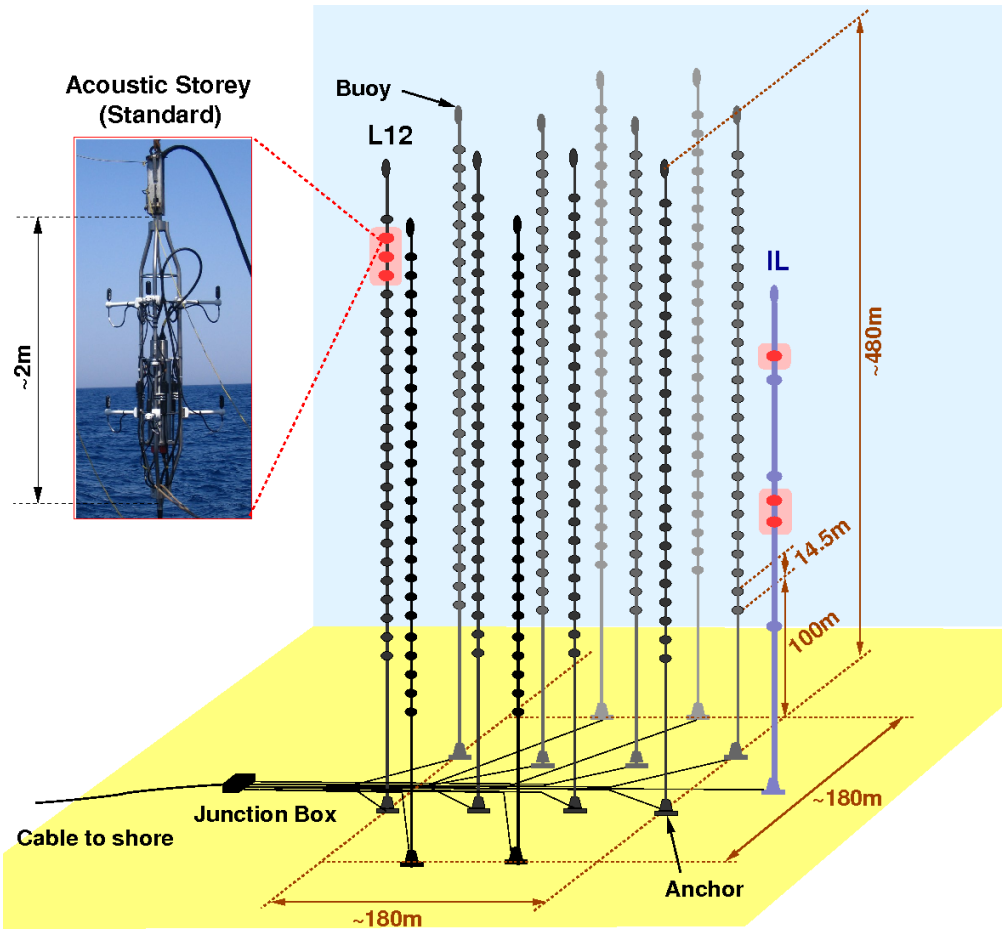
The AMADEUS System of the ANTARES detector



ANTARES site:

- 2500m depth, 30km offshore

AMADEUS :

- Total of 6 “acoustic storeys”
- Total of 36 hydrophones
- Continuous sampling
- Online filter selects ~1% of data volume for storage

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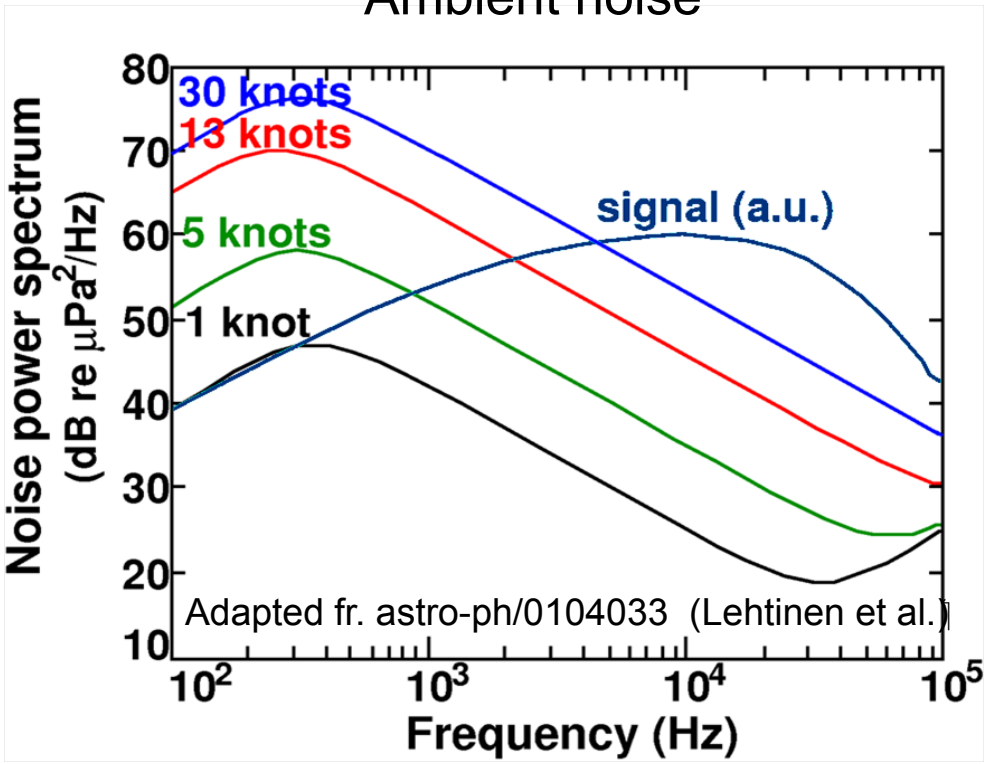
Background for Acoustic Detection in the Sea

Ambient noise

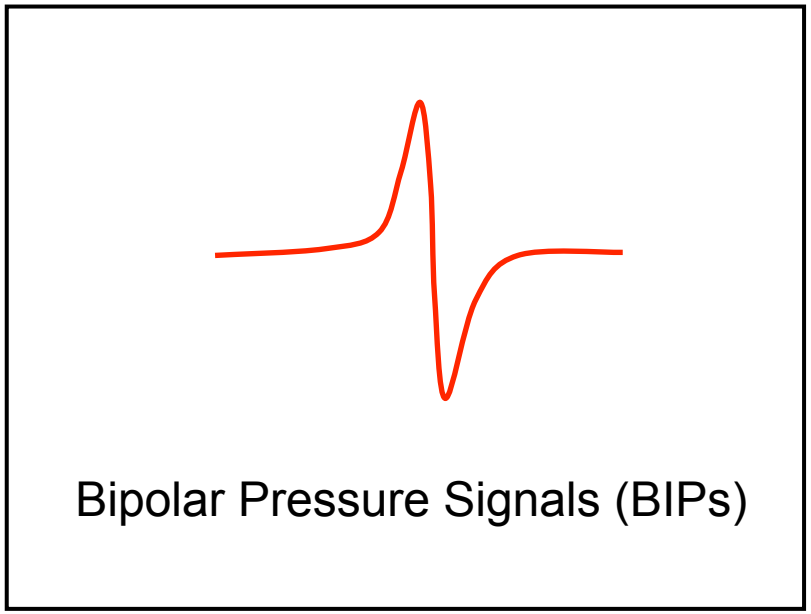


⇨**Determines intrinsic energy threshold**

Depends on "sea state" (surface agitation)

cf. Wenz, J. Acoust.Soc. Am. 34 (1962) 1936

Transient background



⇨**Determines fake neutrino rate**

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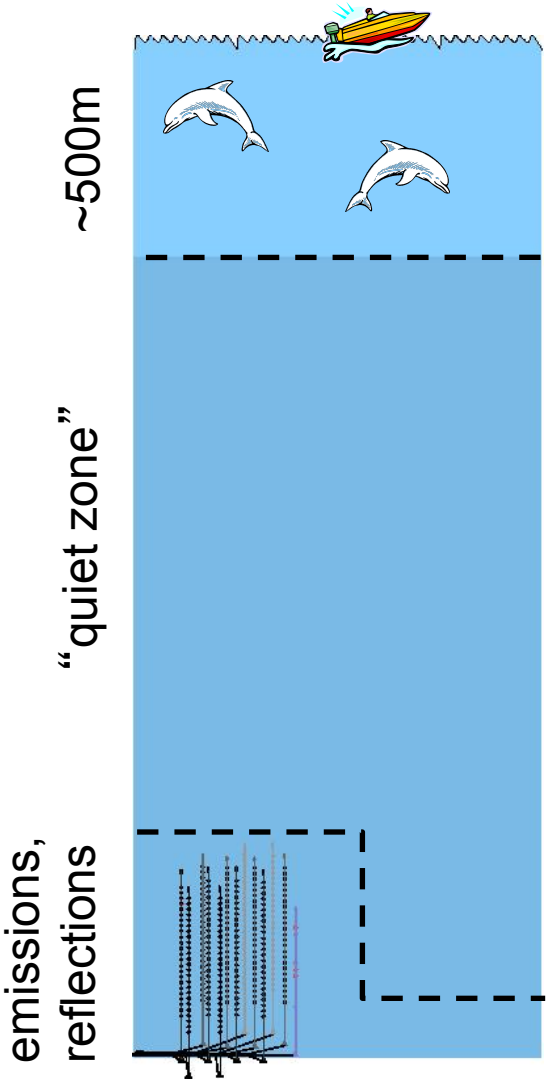
Transient Background: Properties

- Very diverse
  Shipping traffic, marine mammals, …
  ⇨ perform signal classification
- Mostly originating from near surface
  ⇨ Impose cut based on source location



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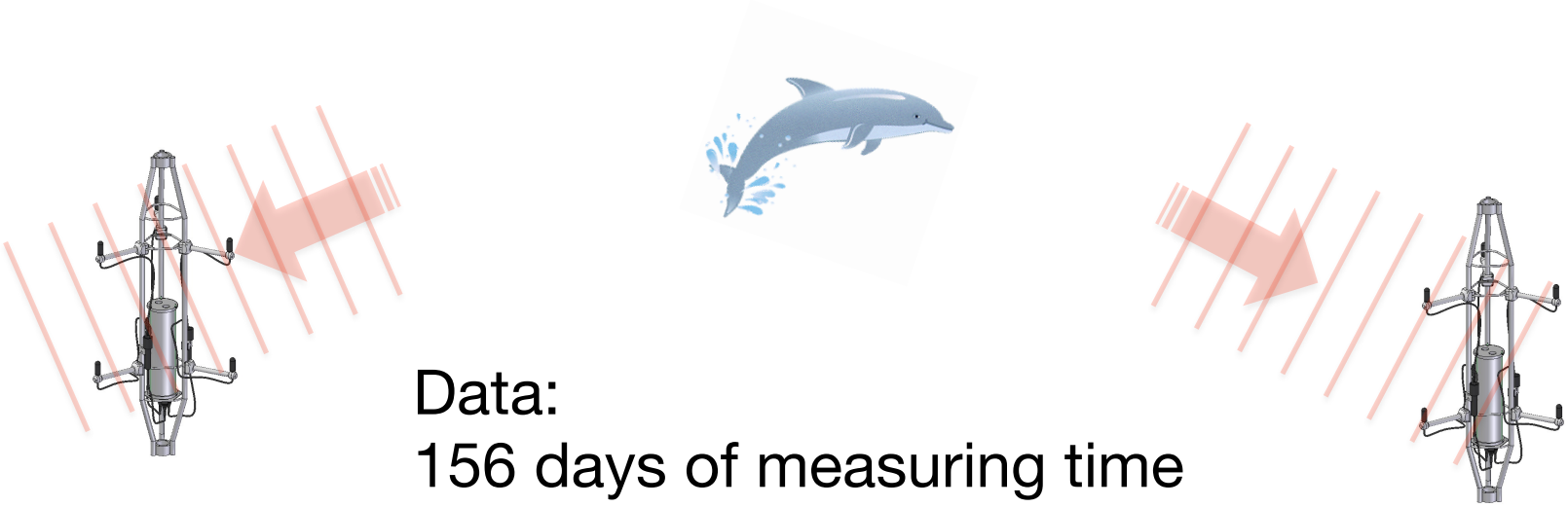
Transient Background: Position Reconstruction

- For events selected by online filter, reconstruct direction for individual storeys
- When directions reconstructed by more than one storey get source location



Data:
156 days of measuring time
from Nov. 2009 to Oct. 2010

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Source Localization

Problem:

Small size of AMADEUS device

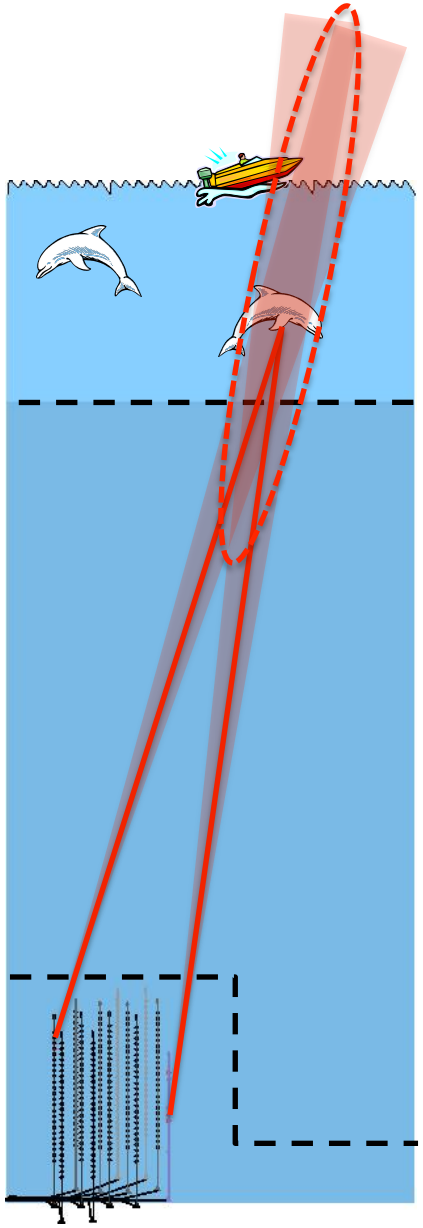
⇨ large errors in *z*, despite good angular resolution for direction reconstruction:

$\Delta\theta = 0.6 \pm 0.2^{\circ}$ in zenith

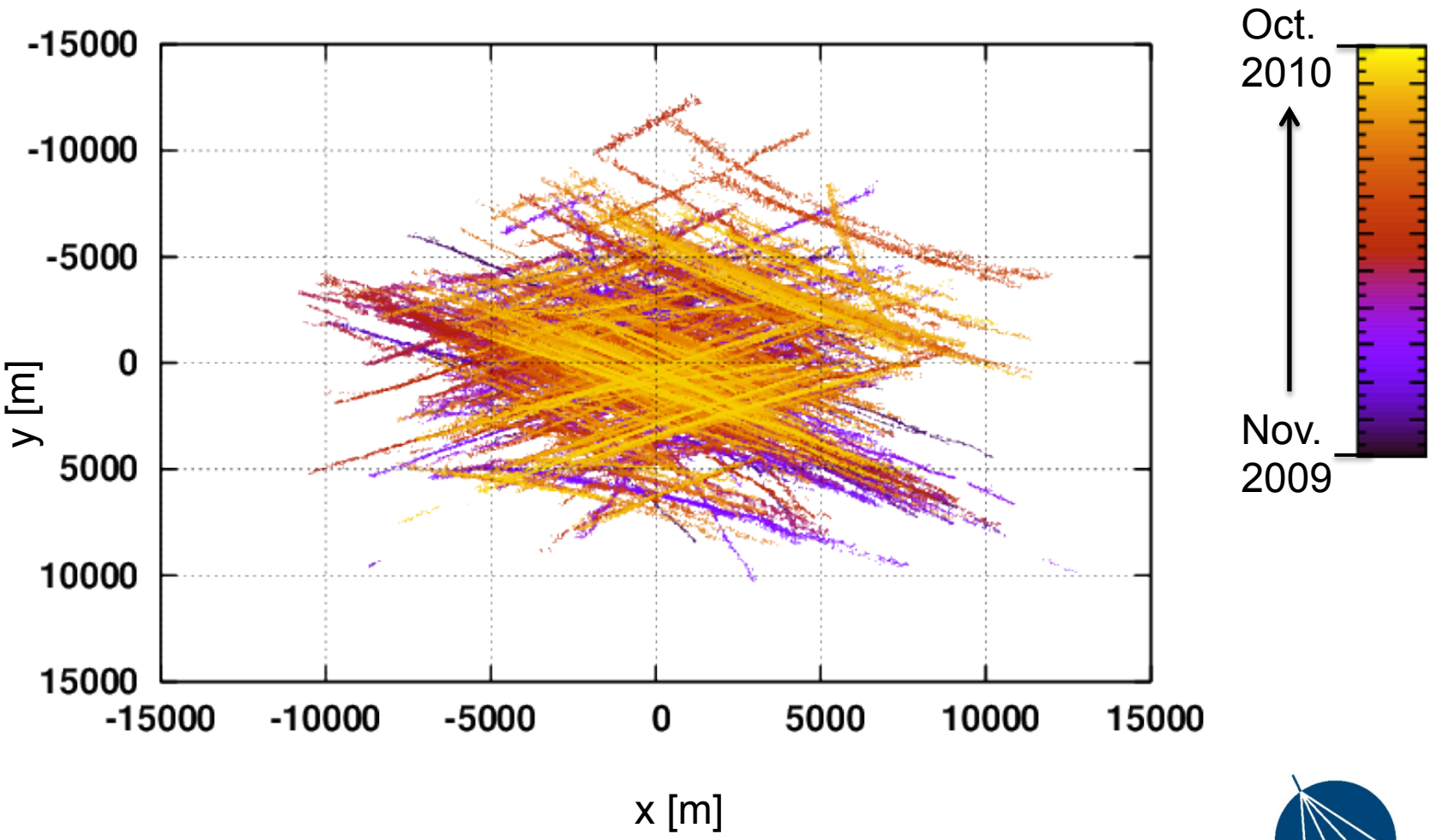
$\Delta\varphi = 1.6 \pm 0.2^{\circ}$ in azimuth

Solution:

Project positions to sea surface and remove event clusters from moving sound emitters



Cluster Analysis of Moving Sound Emitting Objects



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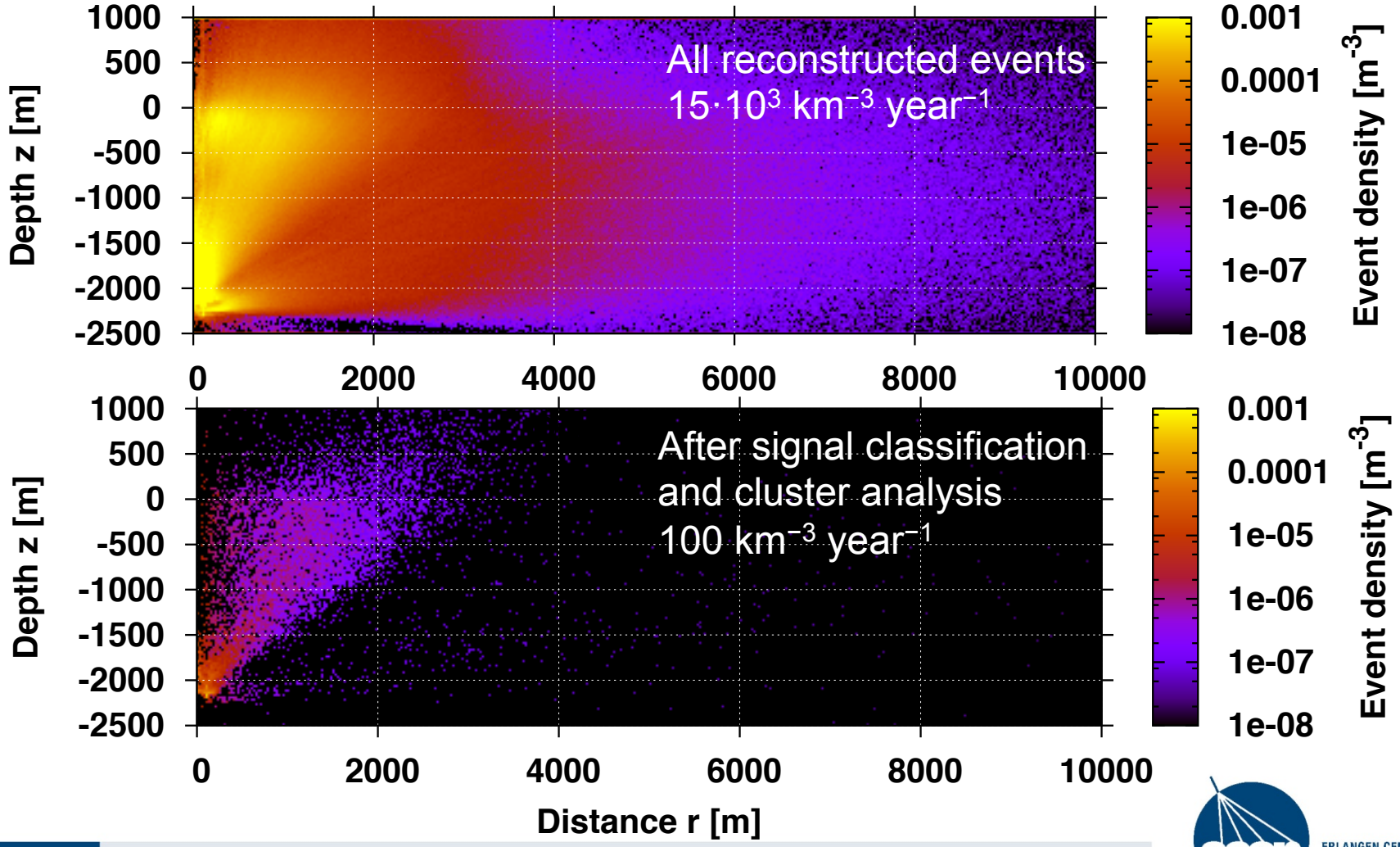
Signal Classification with Machine Learning Algorithms

- Different algorithms have been investigated:
  - Random Forest
  - Boosted Trees

  } best performance
  - Naïve Bayes
  - Decision Tree
  - Support Vector Machine

- Recognition Error:
  - For individual sensors < 10%
  - For clusters of sensors < 2%

Spatial Distribution of Transient Background



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Further Reduction of Transient Background

Search for characteristic geometry of pressure field from neutrino interaction (“pancake”)

- AMADEUS too small
- investigations with Monte Carlo simulations (input from AMADEUS)
- KM3NeT: Combined system for acoustic positioning and neutrino detection planned

AMADEUS Effective Volume

Probability of the neutrino reaching the vertex

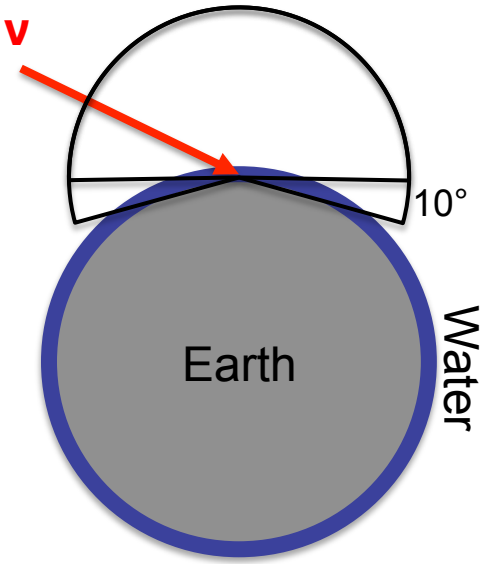
only counted if signal is detected;

$$V_{\text{eff}} = \frac{\sum p(\mathrm{E}, \mathbf{x}, \mathbf{e}_p)\delta_{\text{sel}}}{N_{\text{gen}}} V_{\text{gen}}$$

Effective Volume

Number of Neutrinos: 10^7

Volume in which the Neutrinos are generated: 1200km^3



Earth density model (PREM)

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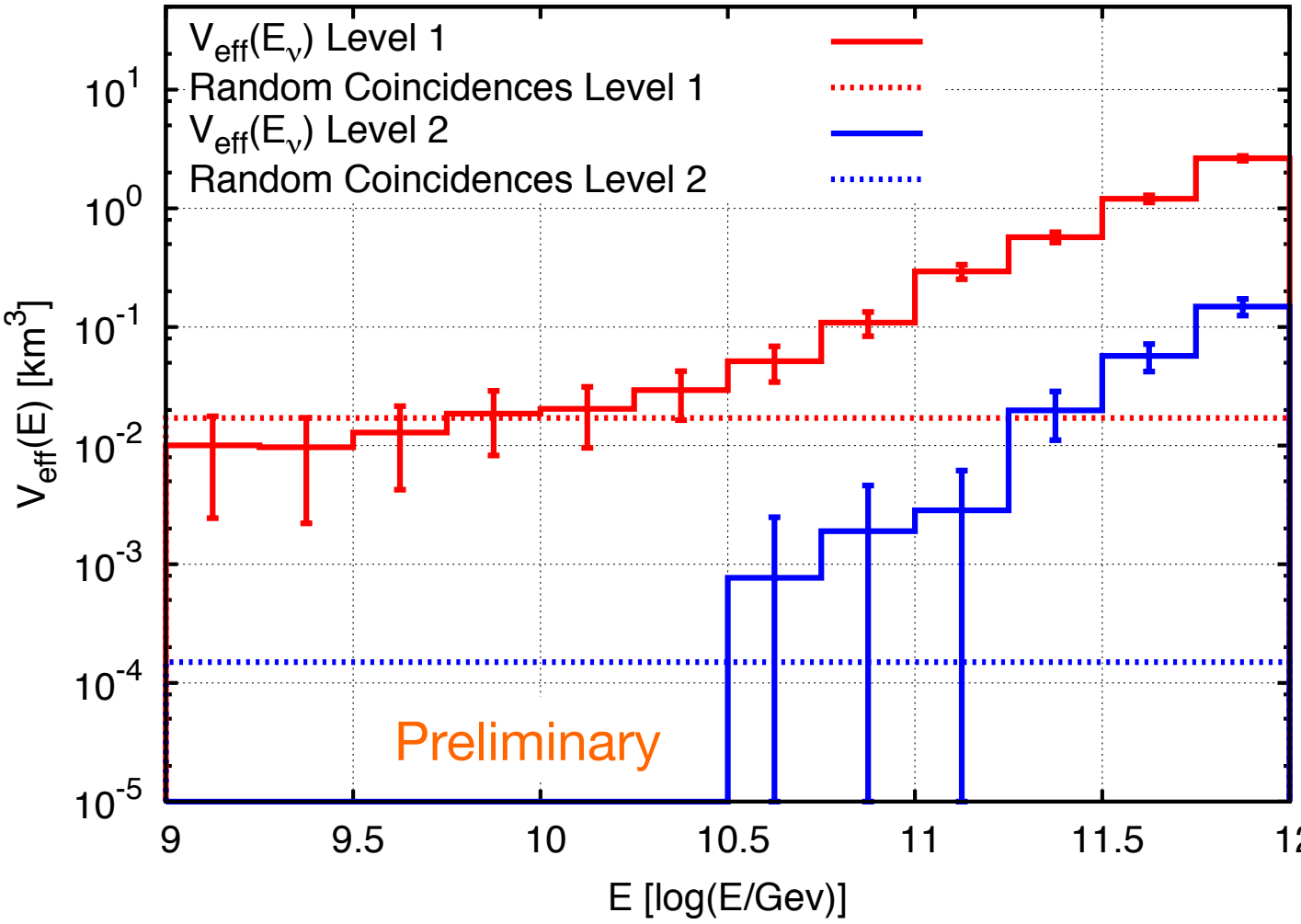
AMADEUS Effective Volume



Level 1:
- low ambient noise
- minimal filter

Level 2:
- noise model
- std. filter

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Conclusions and Outlook

- The AMADEUS system has all features of an acoustic neutrino telescope (except size)
- Transient background: Strong suppression achieved, further reduction much easier with larger (3D) detectors
- Monte Carlo simulations developed and effective volume for AMADEUS derived
- KM3NeT: Combined system for acoustic positioning and neutrino detection planned

GEFÖRDERT VOM

Bundesministerium
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