# Simulation studies for large scale acoustic neutrino detectors

ERLANGEN CENTRE FOR ASTROPARTICLE PHYSICS

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presented by Robert Lahmann
ARENA 2018, Catania, June 15, 2018

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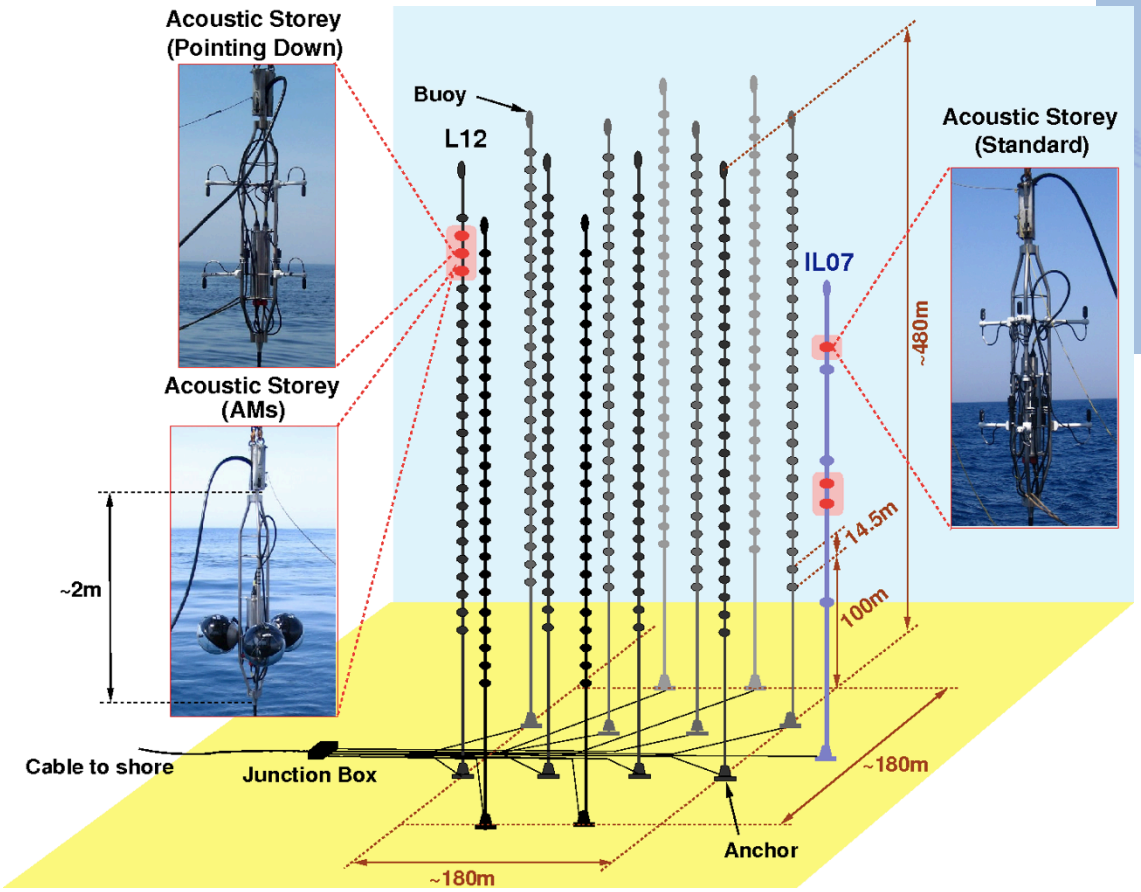
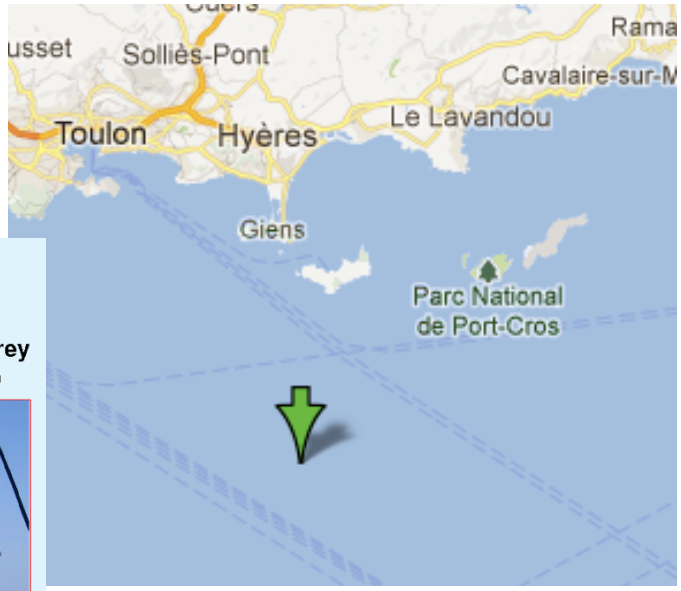
# AMADEUS – ANTARES




Operation from Dec. 2007 to Nov. 2015

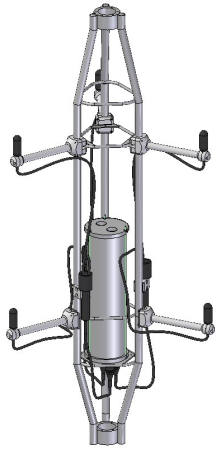
36 acoustic sensors on 6 stories

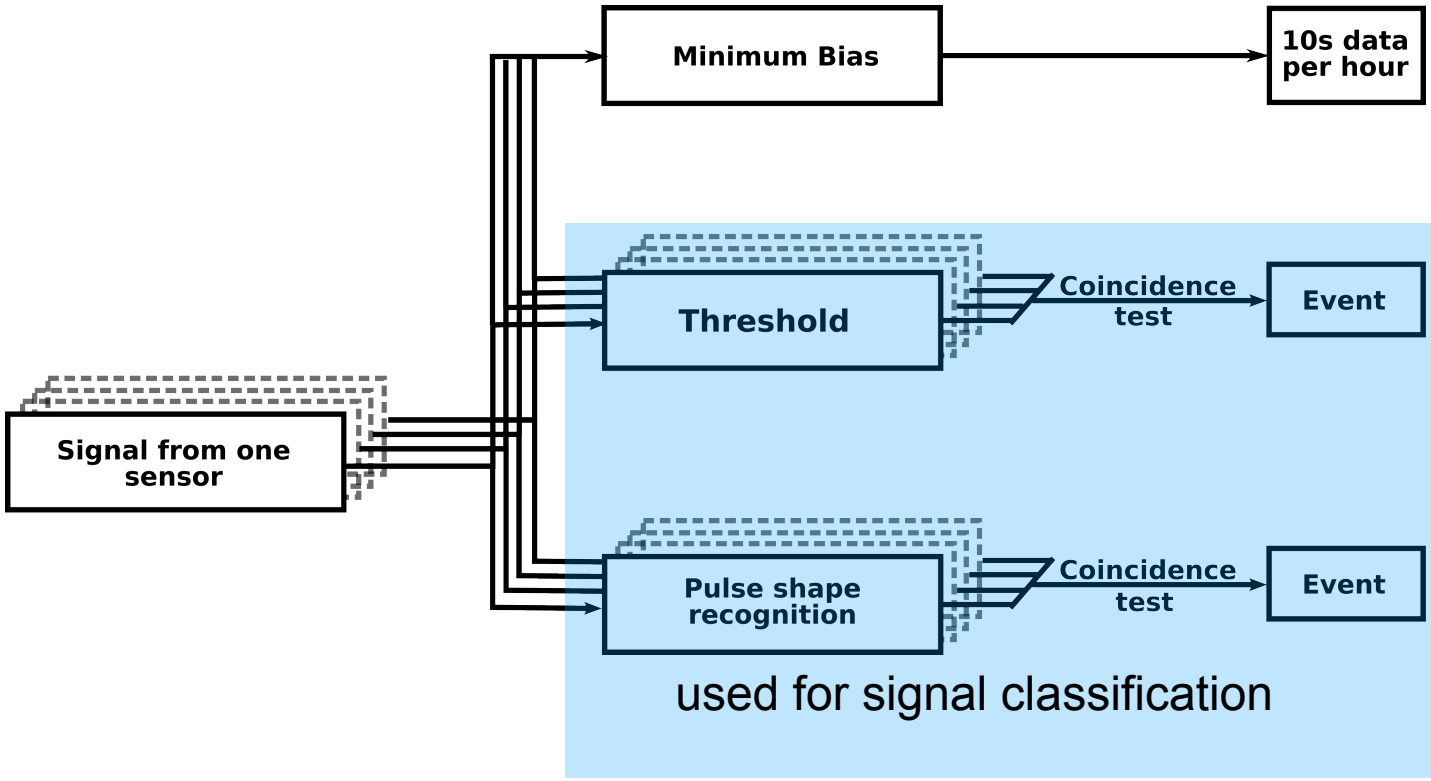
Local clusters for direction reconstruction

Depth 2300 – 2100 m

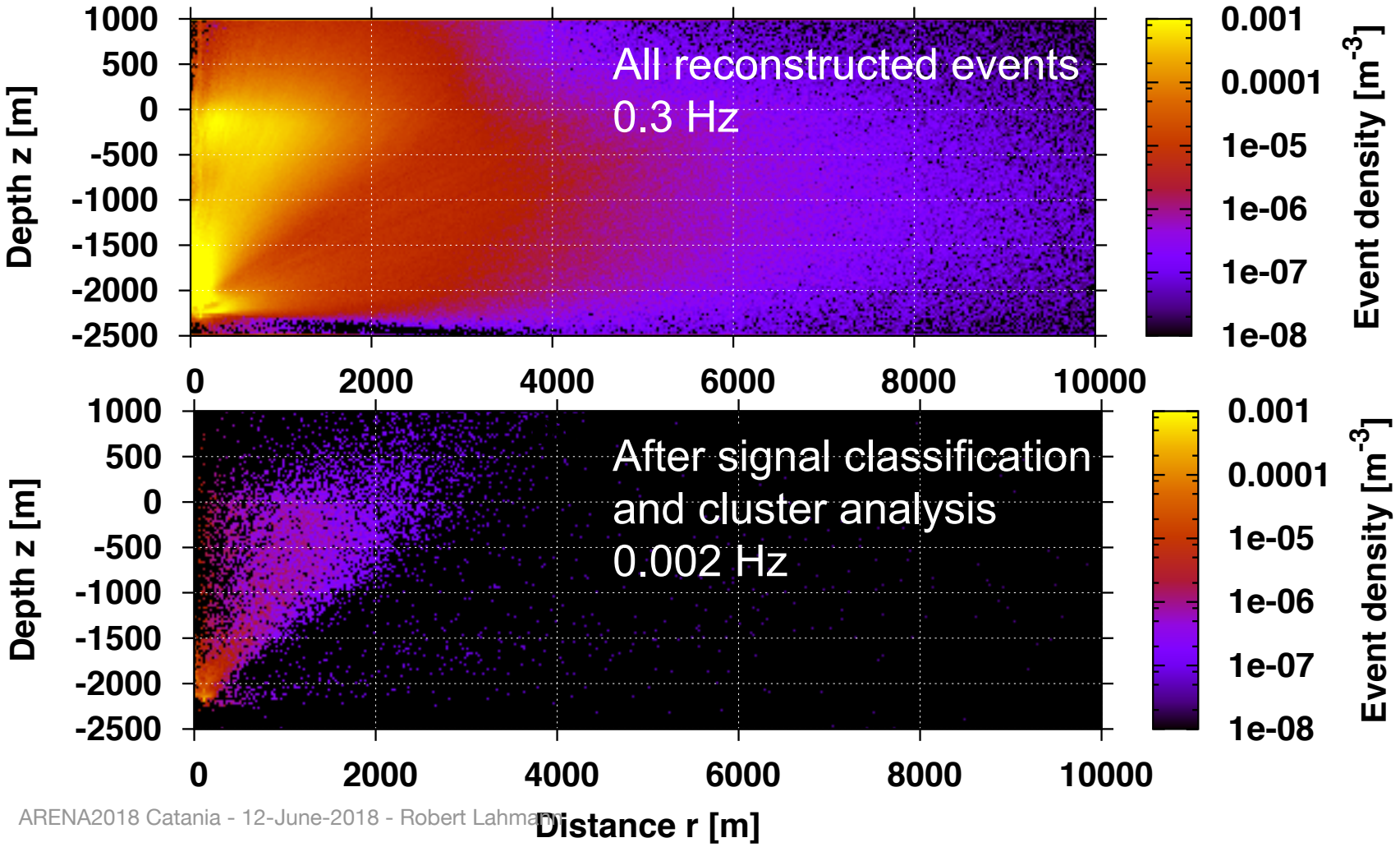
# The onshore filter system

Task: Reduce incoming data rate of ~1.5 TByte/day to ~15 GByte/day



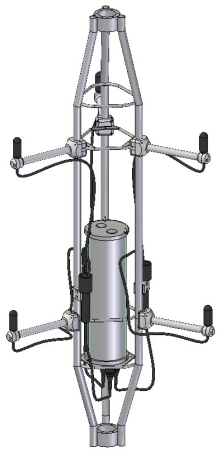


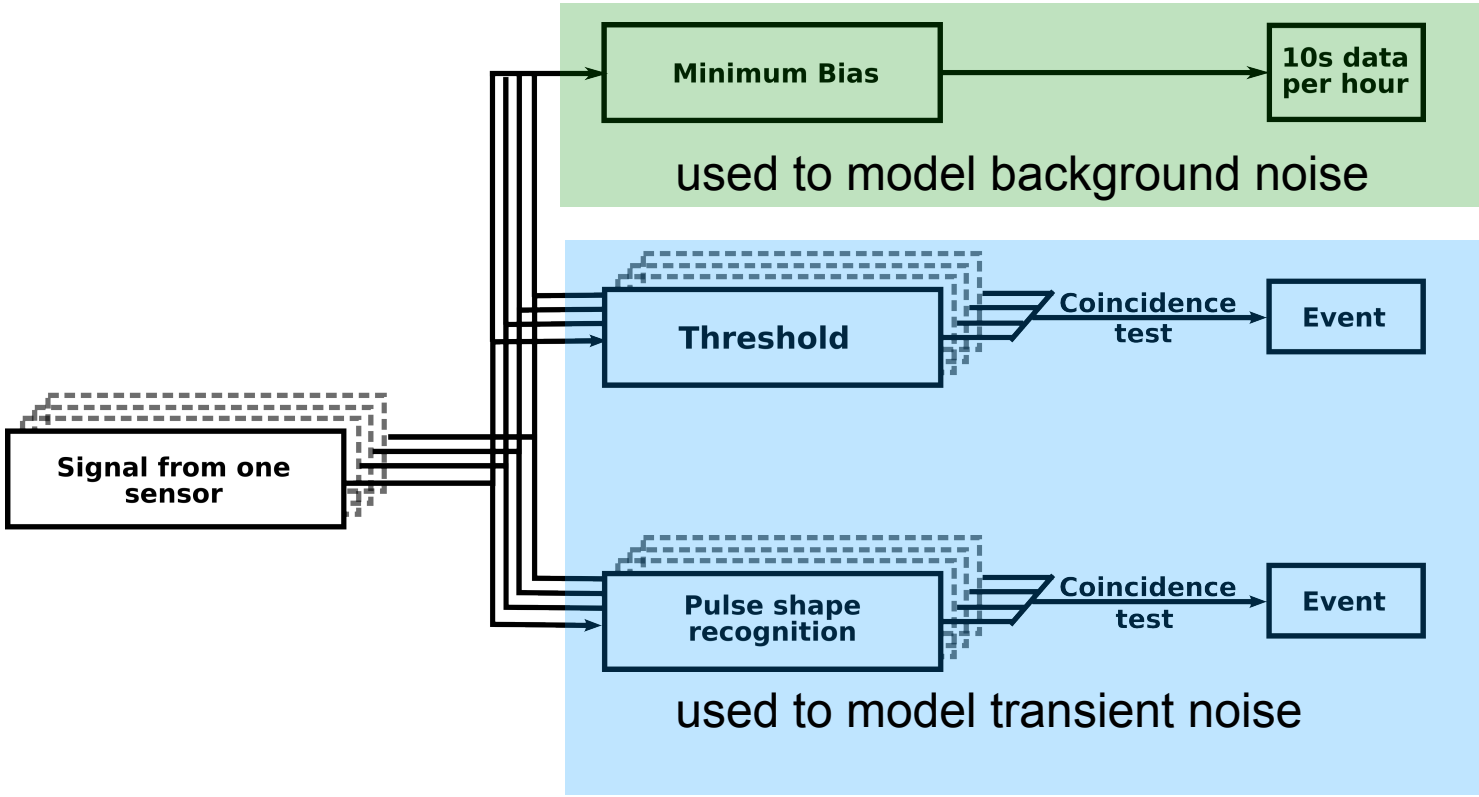
# Spatial distribution of transient background



# ANTARES data as input for simulations

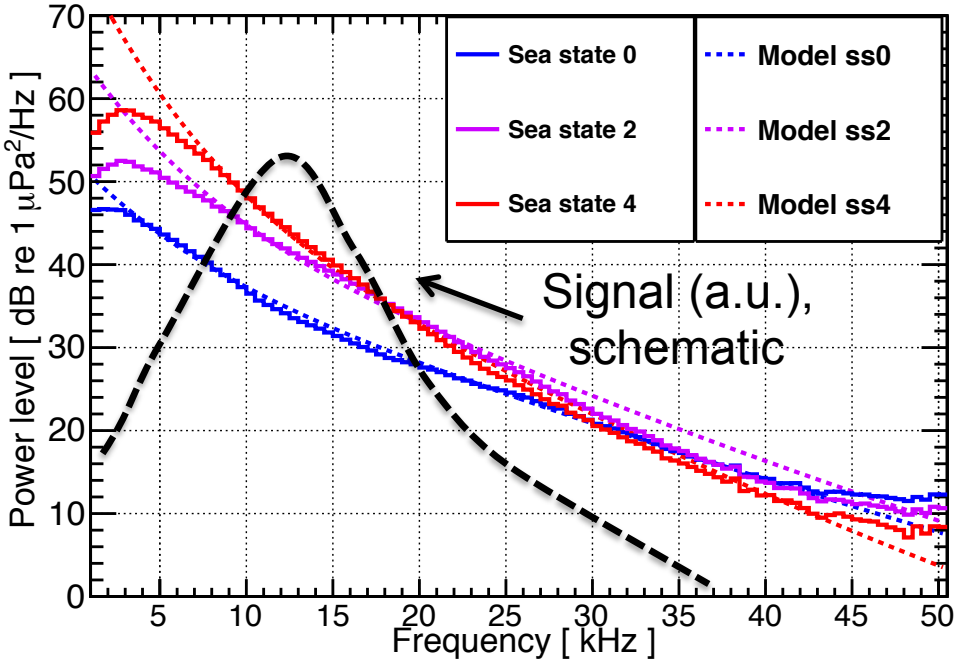
Task: Reduce incoming data rate of ~1.5 TByte/day to ~15 GByte/day





# Background for acoustic detection in the sea

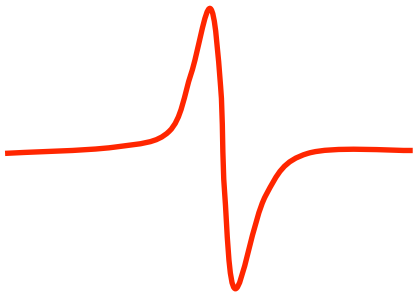
## Ambient noise




⇨**Determines intrinsic energy threshold**

Depends on “sea state”
(surface agitation and precipitation)

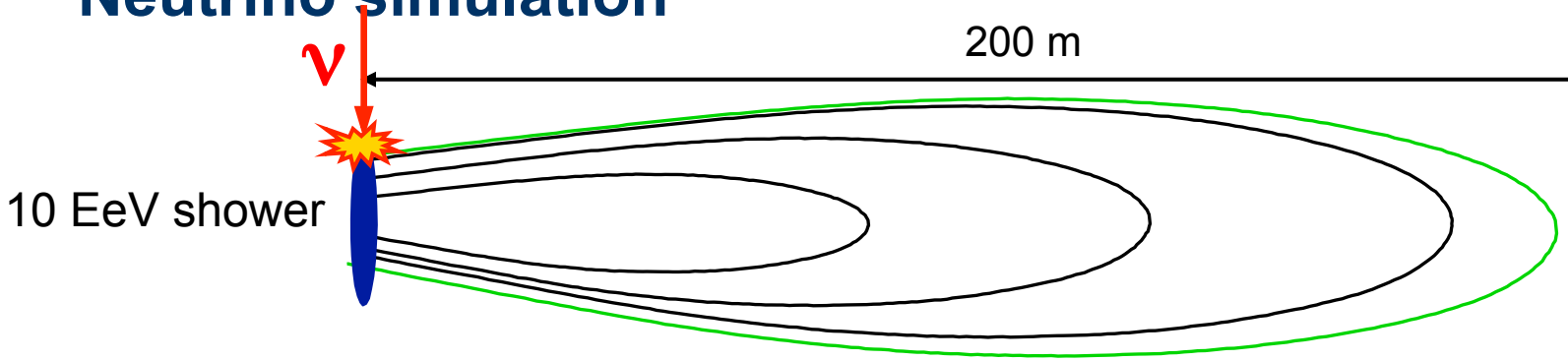
## Transient background

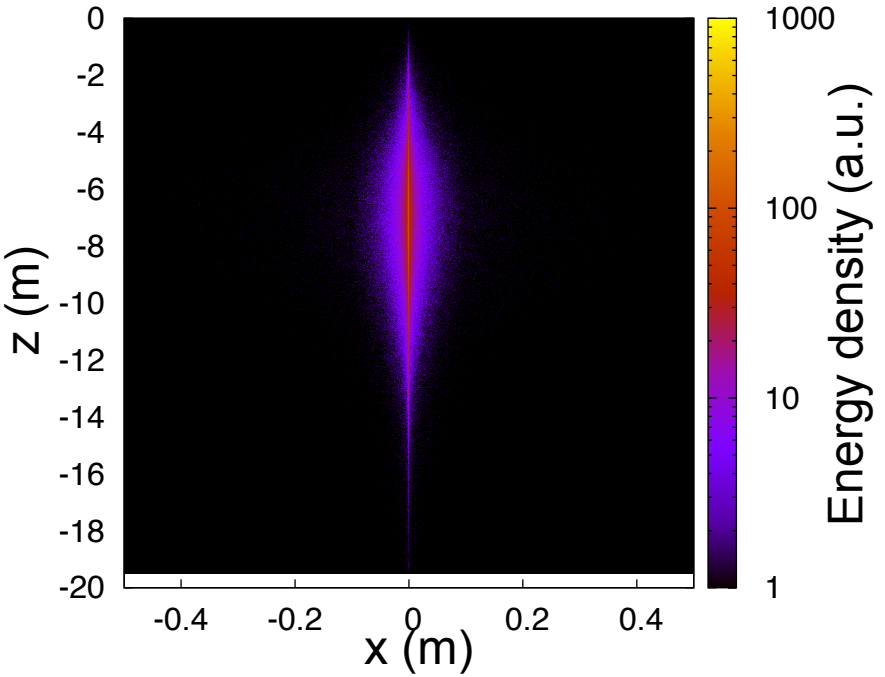


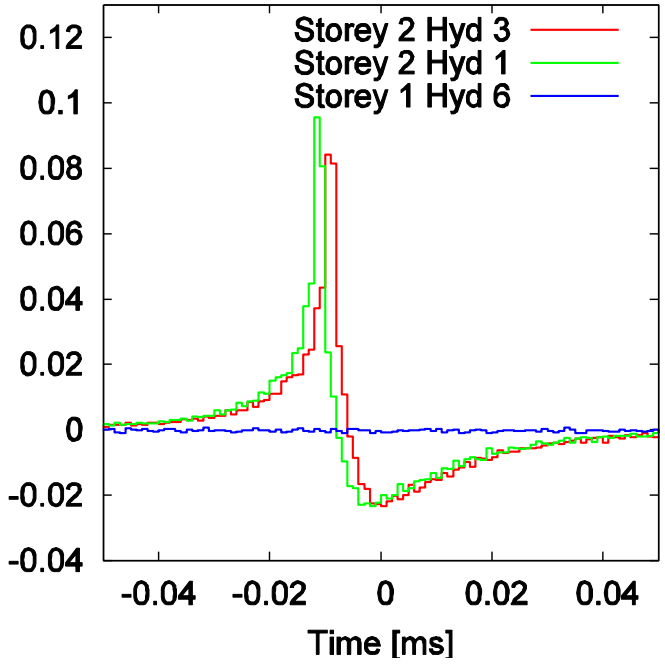
Bipolar Pressure Signals (BIPs)

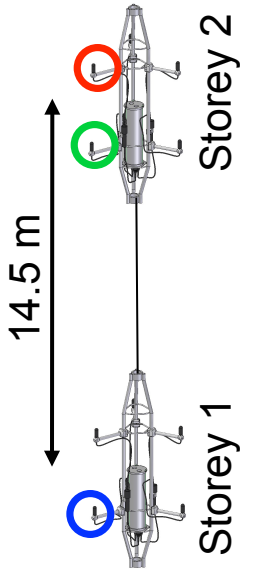
⇨**Determines fake neutrino rate**

# Neutrino simulation



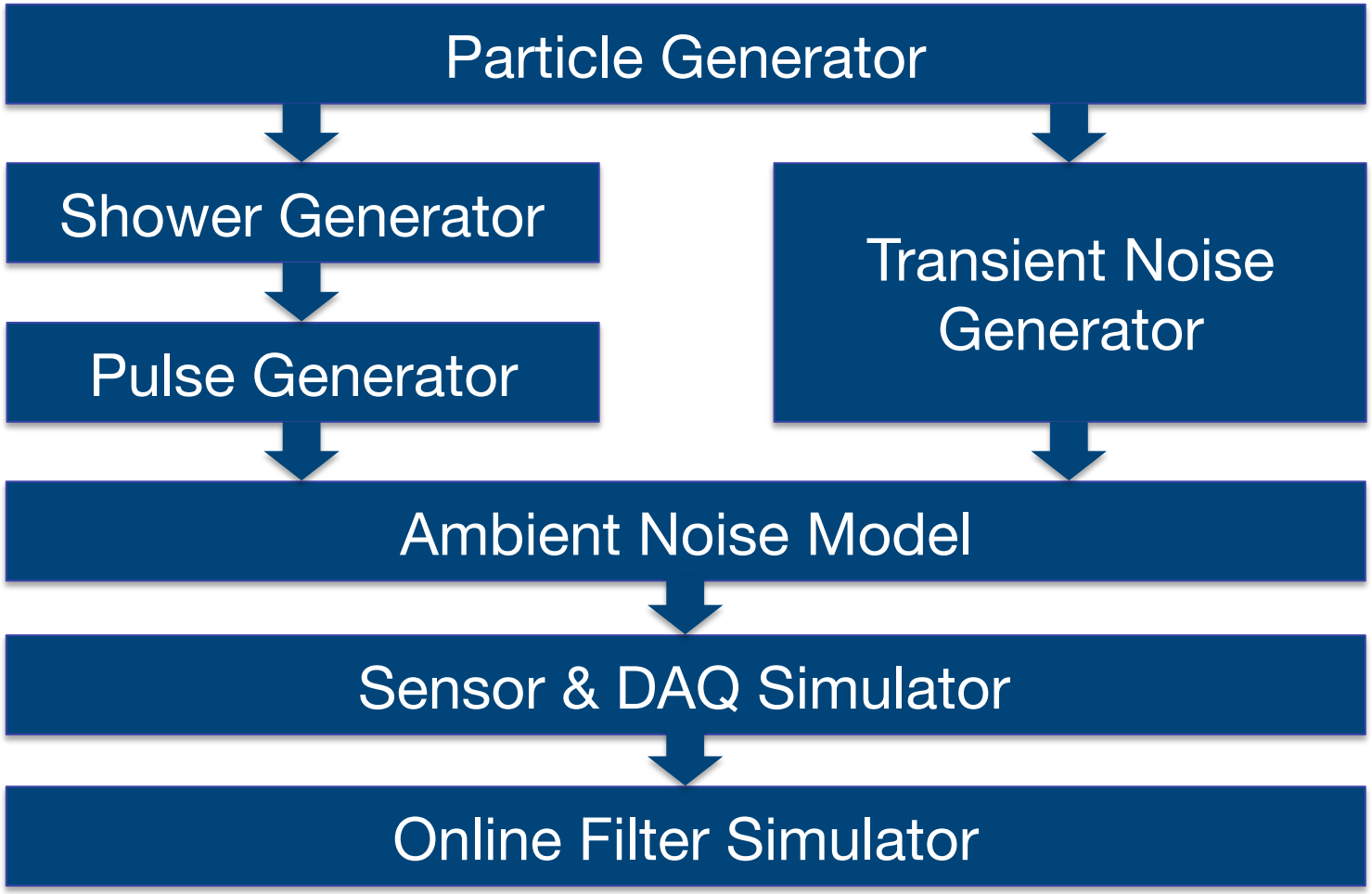




MC according arXiv:0903.0949v2 to (Acorne Coll.)

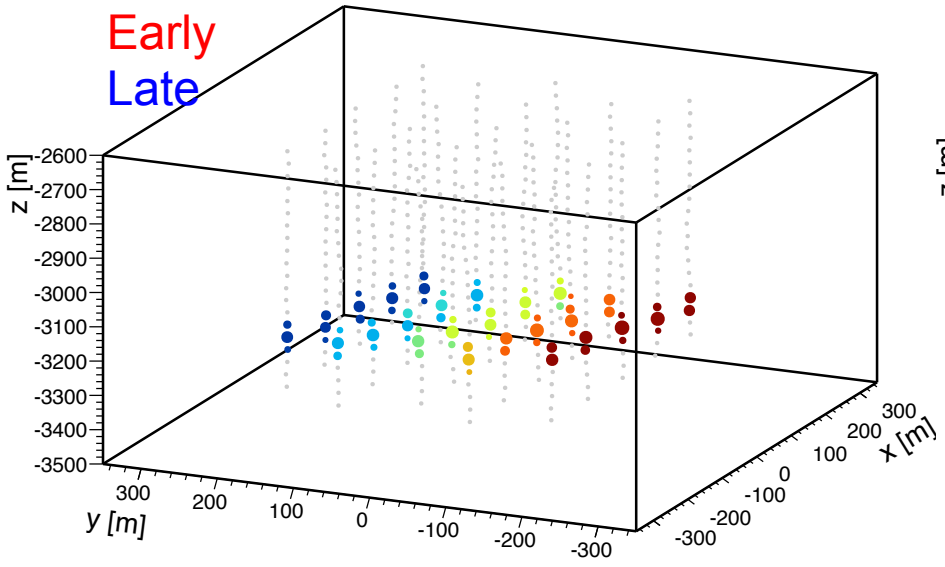
# Simulation Chain Modules



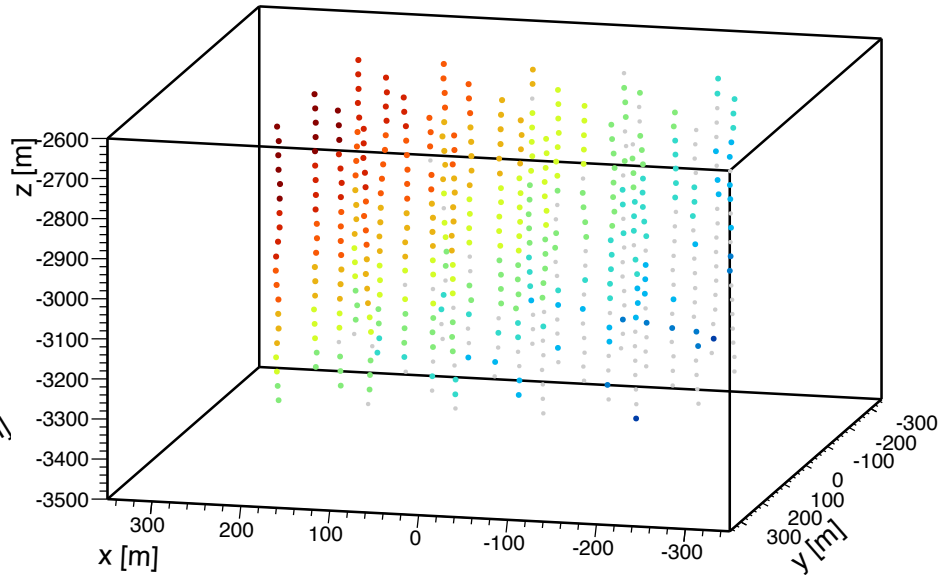

Work & graphic by Max Neff

# Simulated Events

Neutrino @ 1.8 km, E=$10^{21}$eV, Θ=16°




Spherical background (e.g. ship)

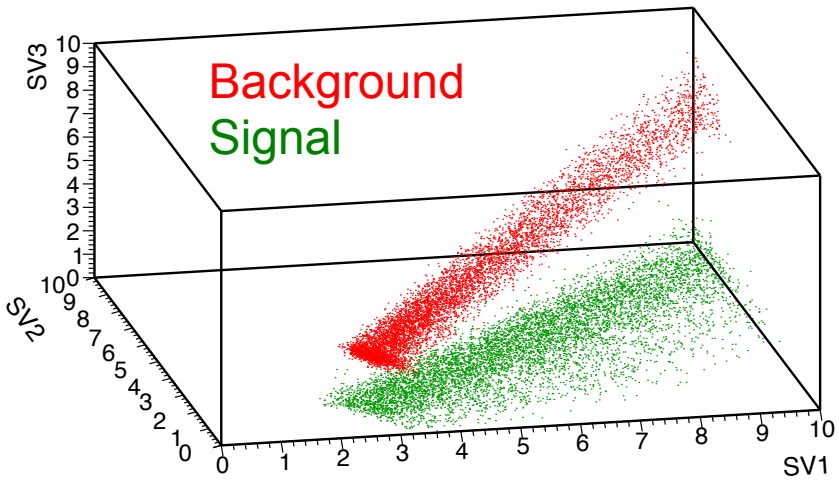



- Neutrinos (Energy $10^{18}$ – $10^{21}$ eV)
- Signals of the positioning system
- Spherically emitting sources
- Random coincidences

# Characteristic traits of neutrino signatures

- Good candidates for machine learning features are:
  - Singular values from distribution of hits in detector (Pancake reconstruction as by-product)
  - Correlation coefficient of the amplitude and the distance to the pancake
  - “likelihood” of the event
- “Boosted Decision Trees” (bdt) well suited from OpenCV*
  - Recognition rates ~99%

Distribution of the singular values




*http://opencv.org

# Classification results

Classification based on 3D signal shape:

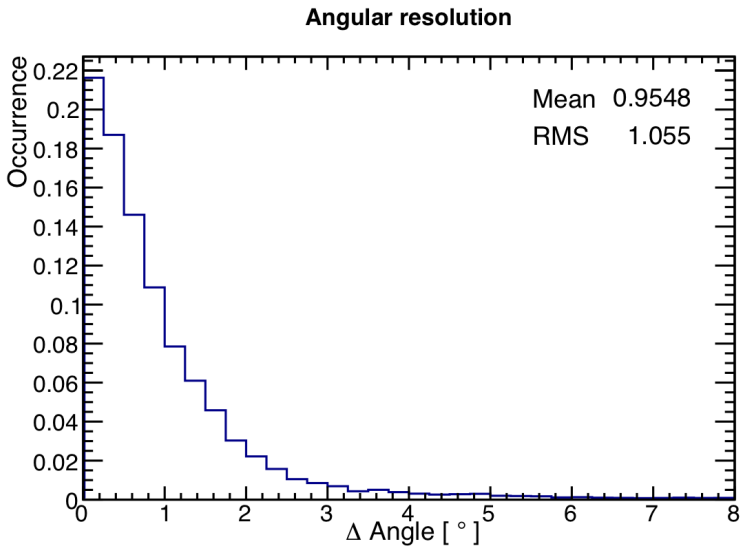
| | Neutrino | Background |
|---|---|---|
| Neutrino predicted | 99.1% | 0.0007% |
| Background predicted | 0.9% | 99.9993% |

Using background rates (after storey-based classification) from AMADEUS:

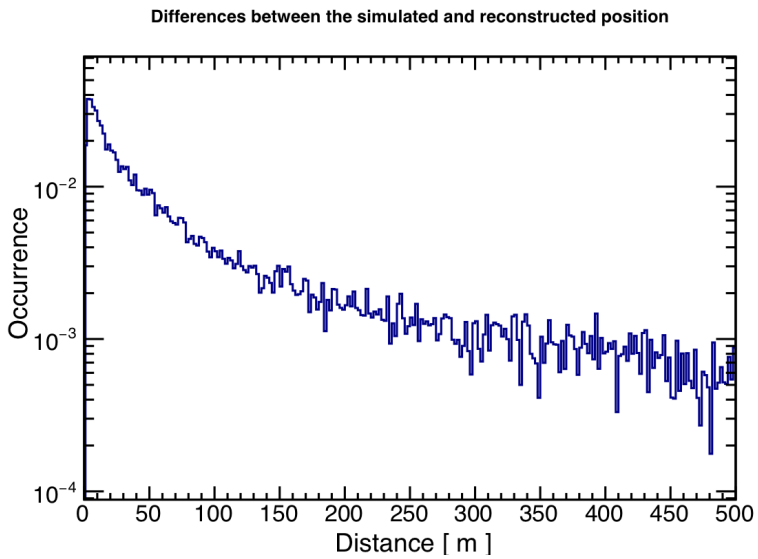
O(1) bkgr event/year classified as neutrino

# Combined fit to energy, direction and interaction vertex

- Signal amplitude depends on distance of source, hence energy reconstruction of neutrino depends on vertex reconstruction
- Combined fit (log likelihood )

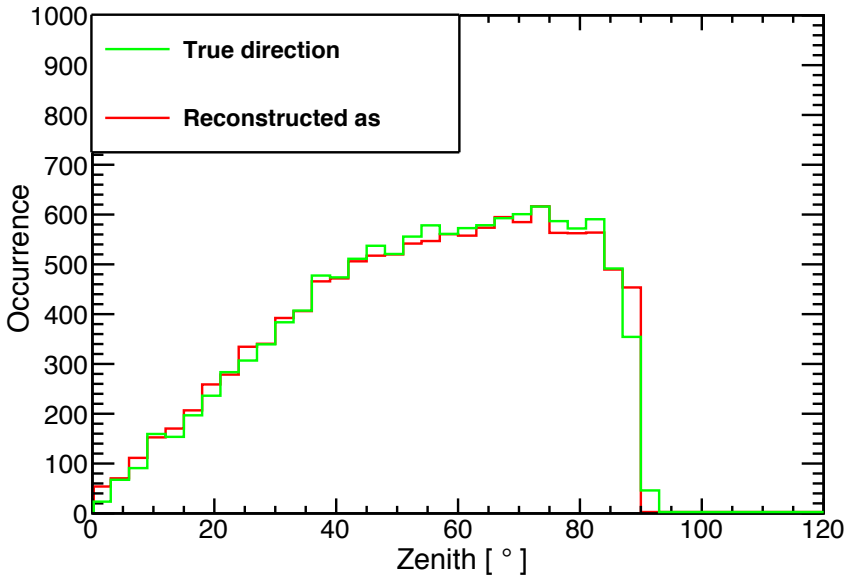



(a) Angular resolution

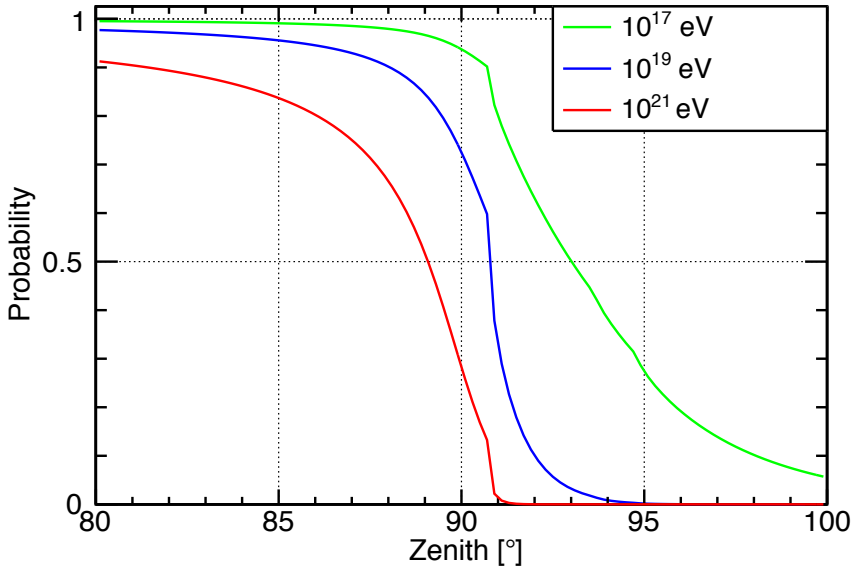



(b) Vertex resolution

# Direction ambiguity near horizon

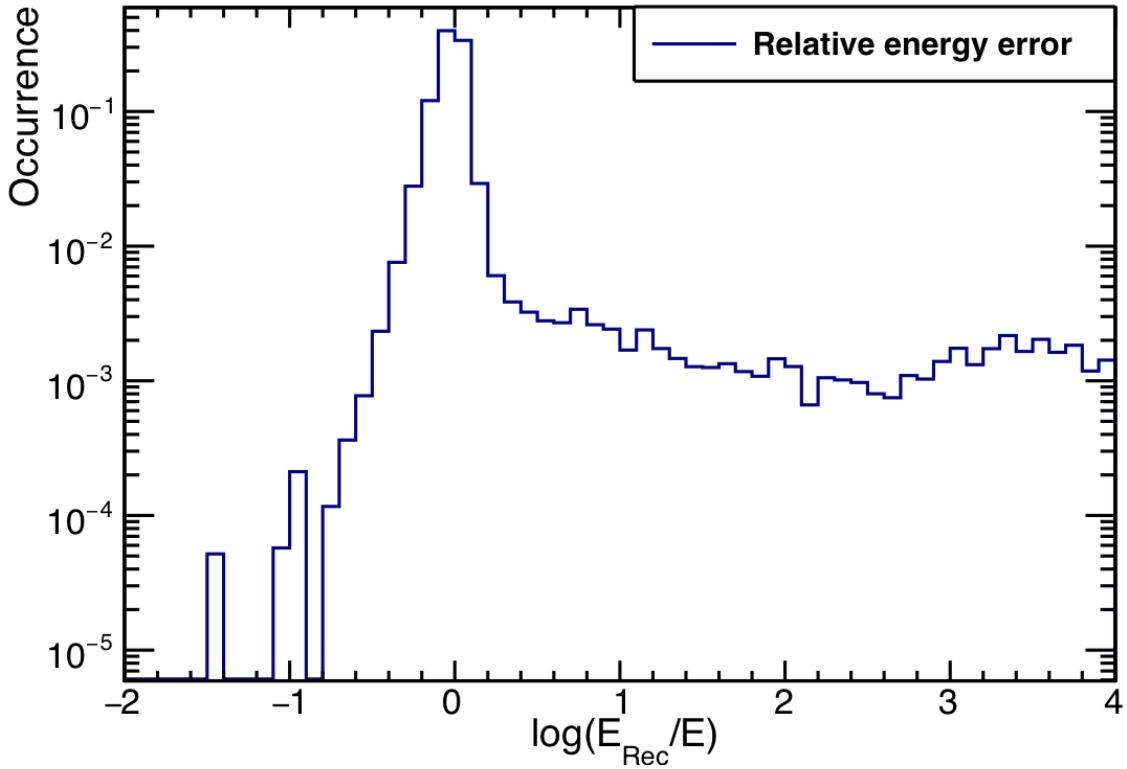



(a) Zenith angle of events



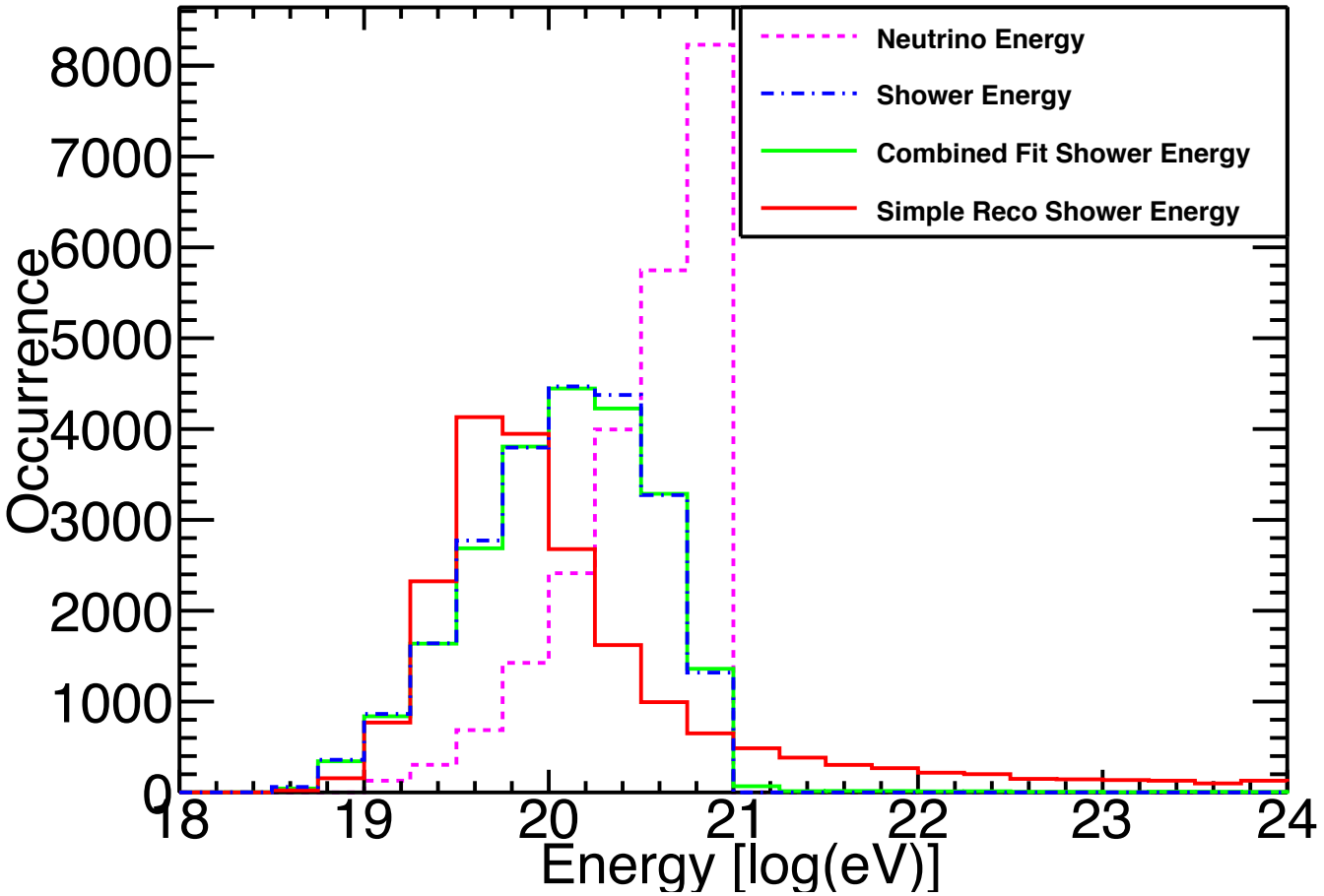

(b) Chance for a neutrino to reach the vertex

# Energy reconstruction from combined fit

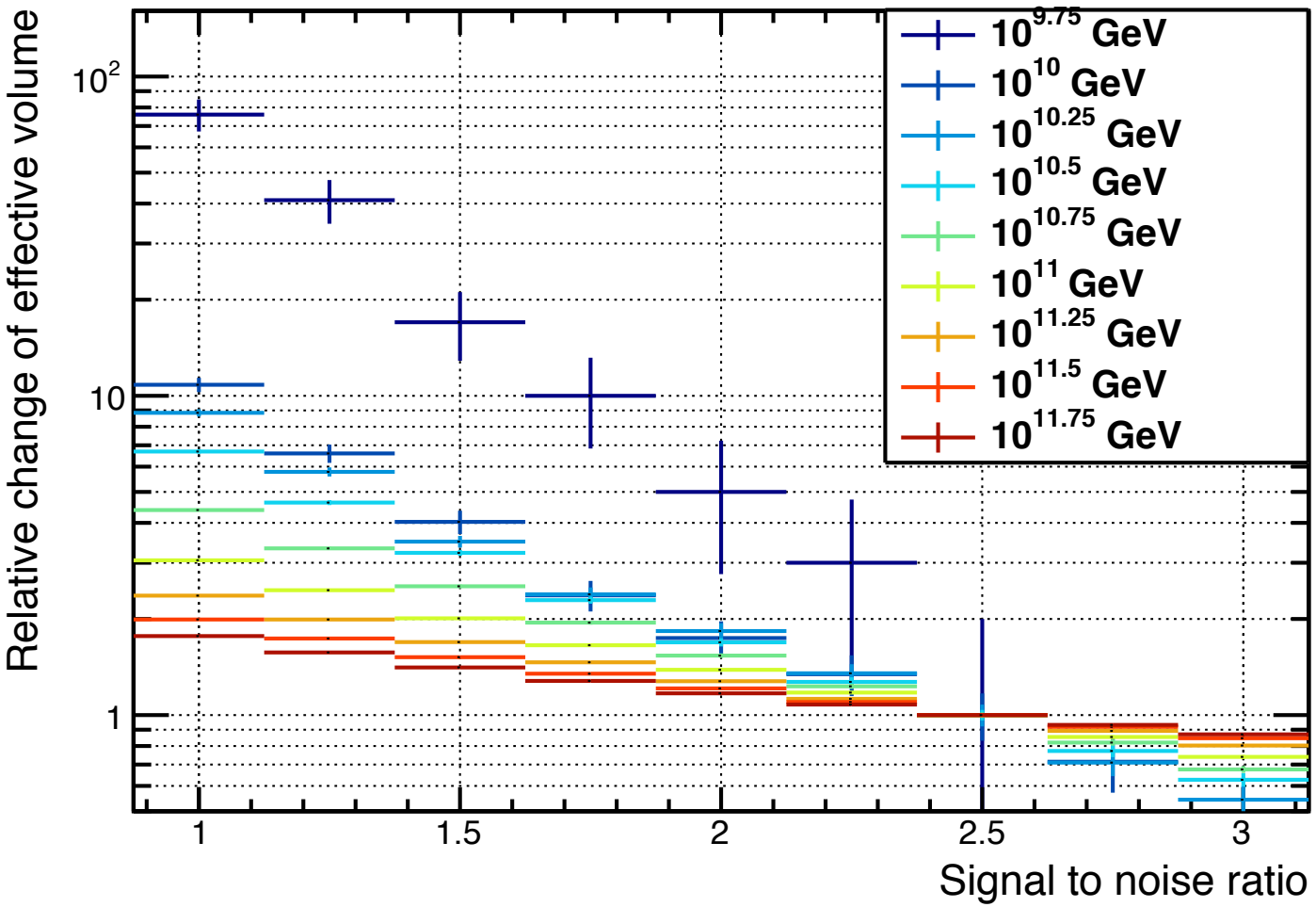



For 90% of 20000 reconstructed neutrinos, the error on the reconstructed energy is less then 75% of the energy

# Energy reconstruction



# Effect of SNR on effective volume



# Summary and conclusions

- Signal classification based on 3D signature of pressure field is promissing approach for KM3NeT
- Combined fit of vertex, direction and energy yields excellent results
- Cutting on the quality parameters of the combined fit reduces the rate of background events to ~0.5/year
- Reduction of energy threshold crucial

Bundesministerium für Bildung und Forschung