The ACORNE Project
Listening for Neutrinos

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Institute of Physics
Astroparticle Physics Meeting
Oxford
19th June 2008

ARENA 2008

3rd International Workshop on the Acoustic and Radio EeV Neutrino detection Activities

4 ACORNE talks
First ACORNE limit

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Workshop Poster
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Local Organizing Committee

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NEW Conference Program

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EPJ The European Physical Journal

ARENA 2008 will be organized at the Roma University "Sapienza" on June 25th-27th 2008. It will be the third International Conference in a series of events bringing together experts in the use of acoustic and radio techniques for the detection of ultra-high energy neutrinos.

Recent results on cosmic rays at extreme energies (HESS, MAGIC, AUGER, ...) have increased the interest in UHE astronomy (protons, nuclei, neutrinos,...) beyond the energy window usually covered by existing apparatuses leading to the exploitation of new detection techniques capable to provide huge effective areas.

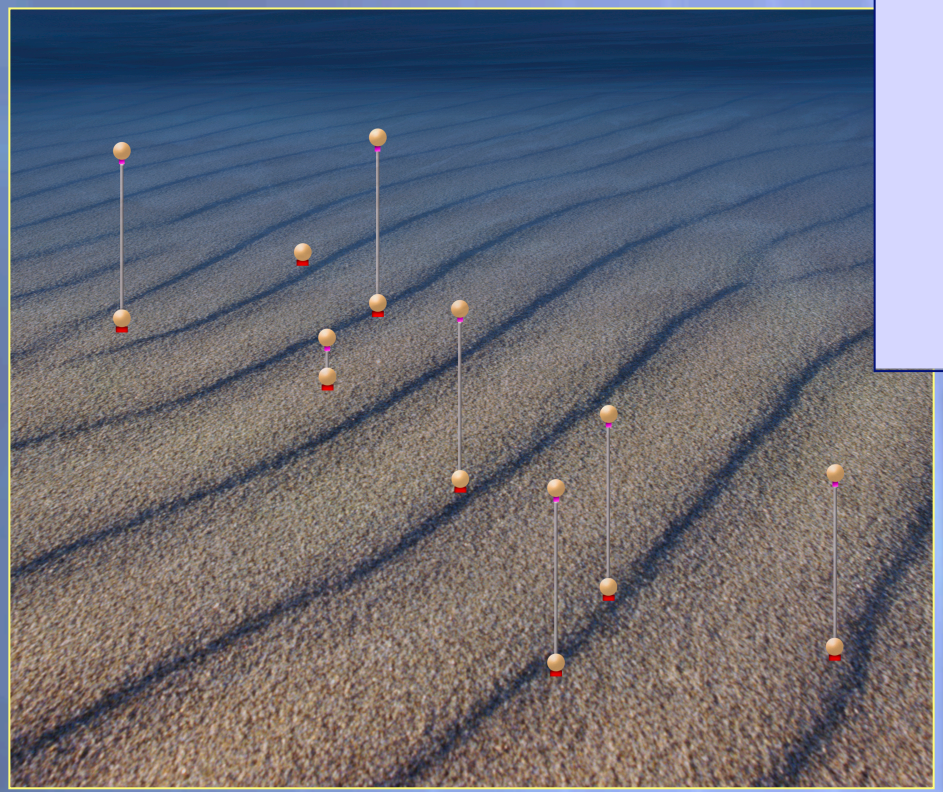
The aim of the Conference is to present the most relevant theoretical and experimental results in the field of high energy cosmic rays, to discuss theoretical prediction of fluxes, and to analyze the potentialities of new detection techniques.

Previous meetings include:

- ARENA 2006 held in Newcastle, UK, in June 2006
- ARENA 2005 held at DESY-Zeuthen in May 2005
- The Stanford Mini-Workshop on acoustic and radio detection in September 2003

ACoRNE and RONA

- Rona hydrophone array, a submarine ranging array in North-West Scotland used by the ACORNE collaboration

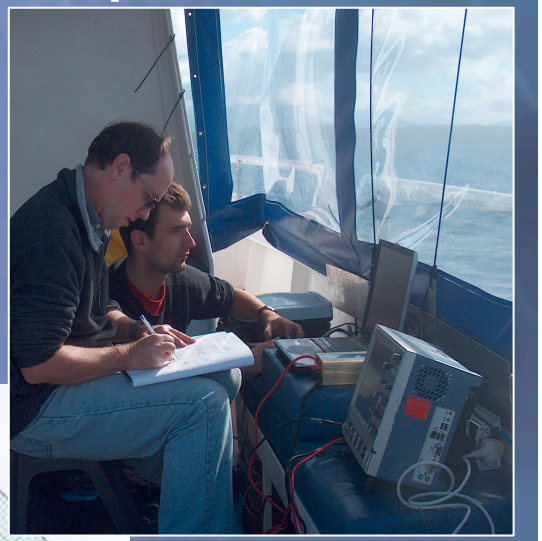


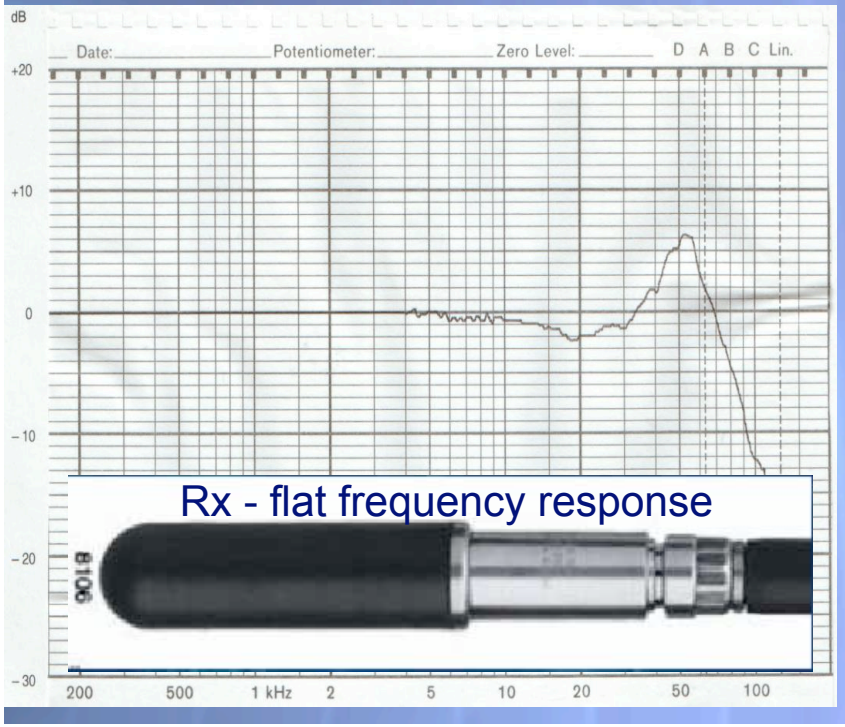
- 7 hydrophones read out continuously at 16bits,140kHz - a total of (~28 Tb uncompressed) data taken to date (since December 2005)

Play the Rona Fly-by Movie!

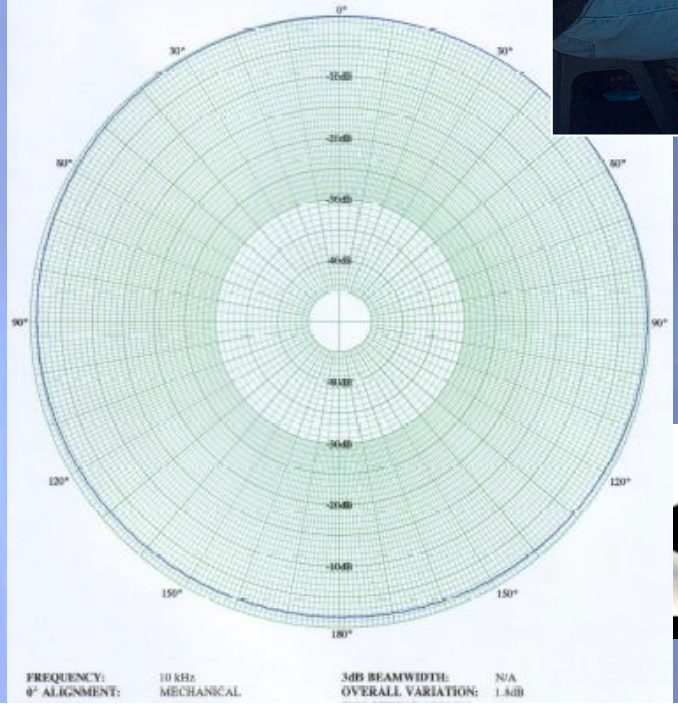
Acoustic Calibration Development

Progression: lab tank – pool – lake – open sea

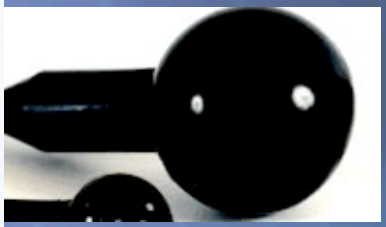




Rx - flat frequency response

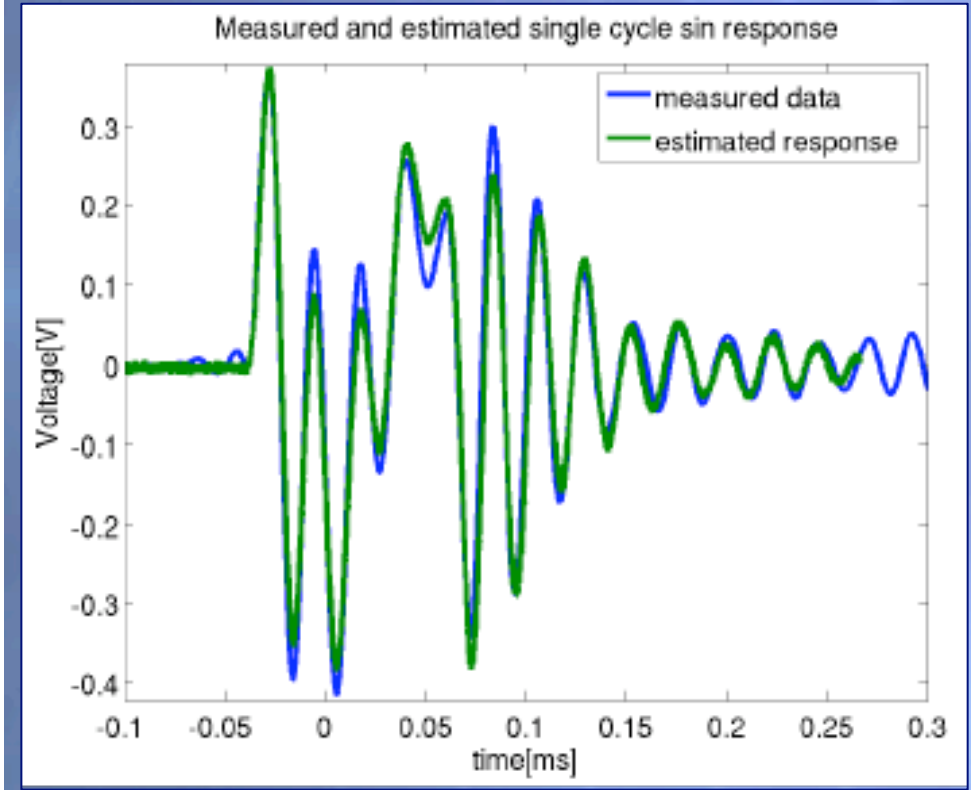


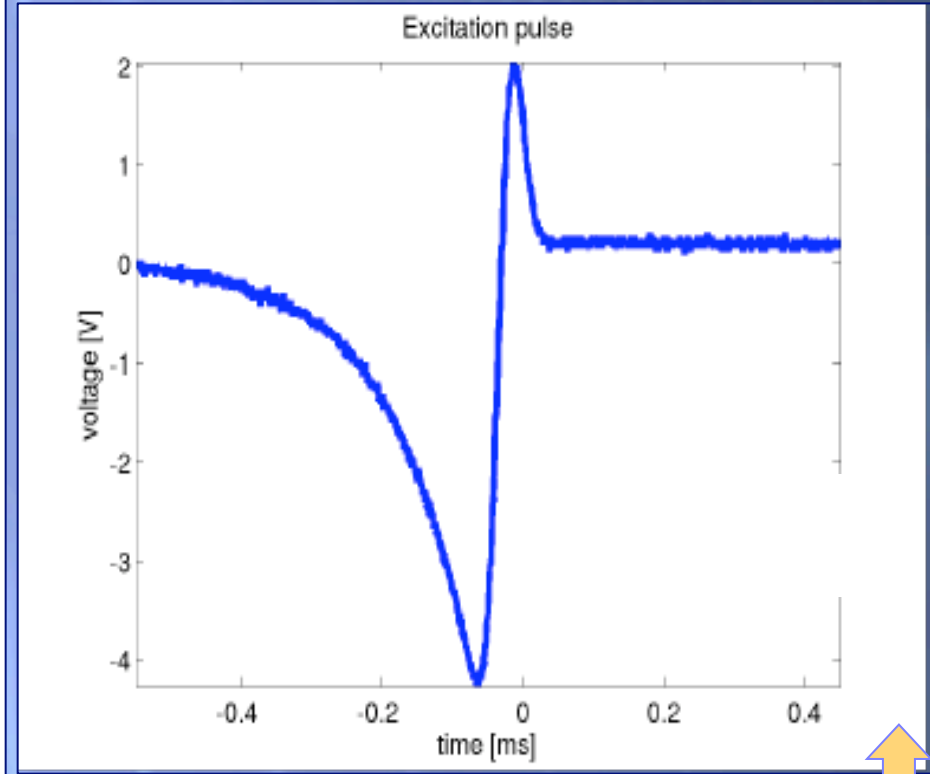
Tx - omnidirectional
± 1.8dB @ 10kHz



Acoustic Calibration

- Aim: to apply an electrical impulse to a hydrophone that will result in a bipolar pulse being created in a body of water
- *First evaluate the hydrophone response using signal processing techniques*
- Predicted (5th order LRC model) and measured response for single cycle sine wave

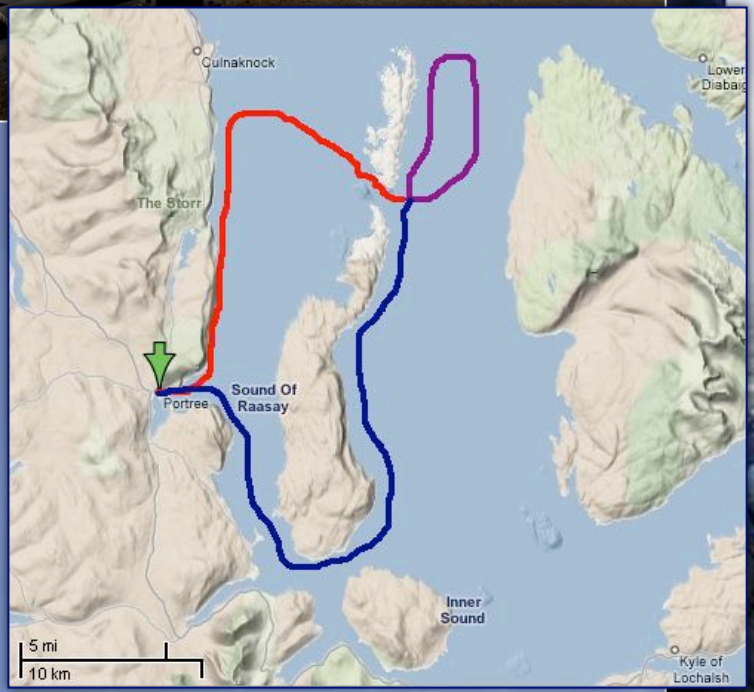




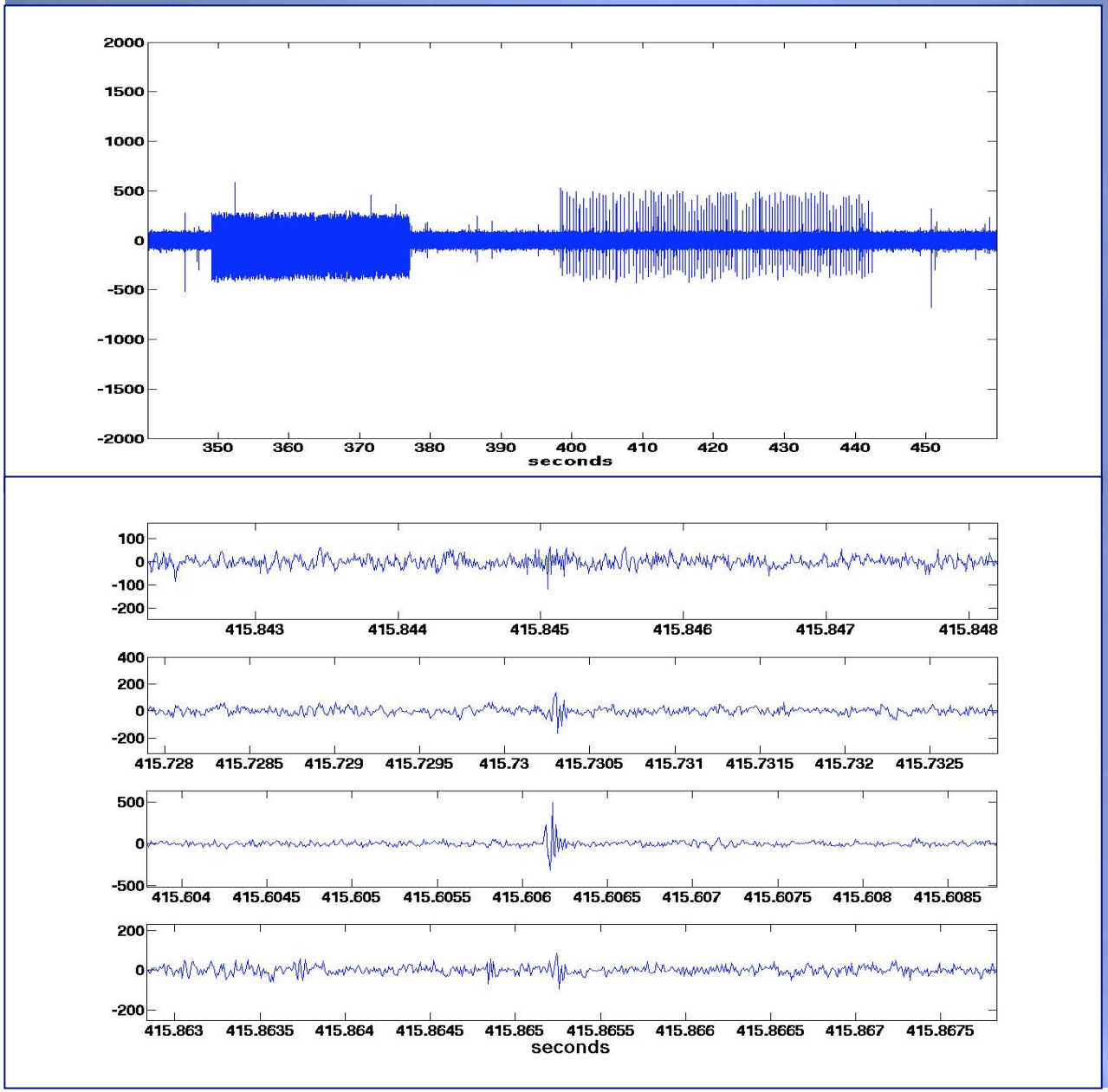
- Excitation and response pulses required to generate bipolar pulse using this method
- *Method used at Rona in summer 2007*

Rona Field Trip August

- In August 2007 we injected a number of different pulse types (sine, square, bipolar) at different frequencies and amplitudes directly above the Rona hydrophone array



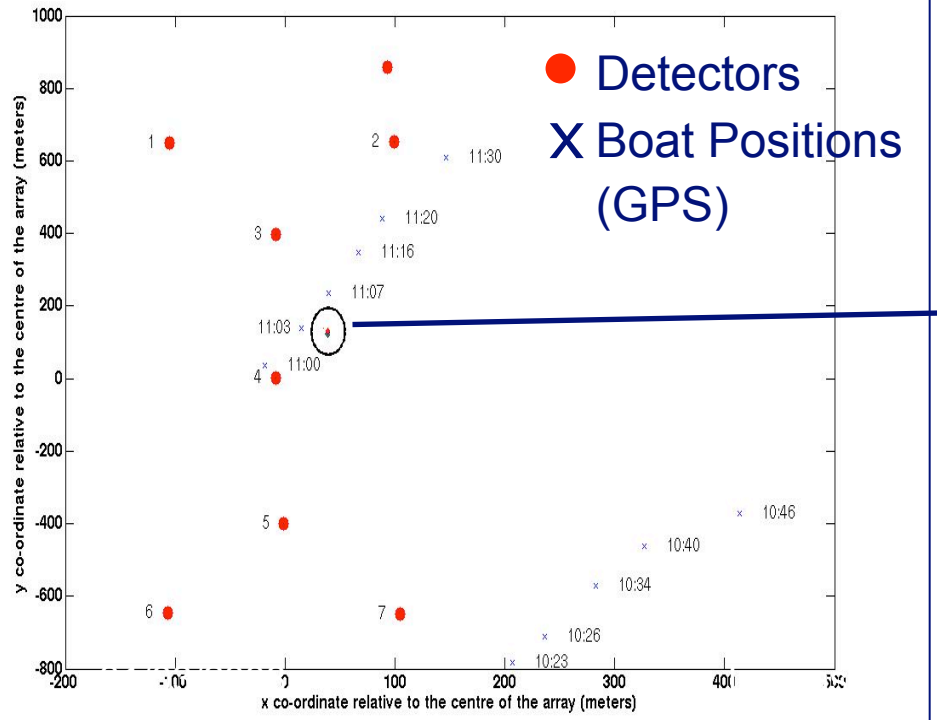
Picking Out the Pulses

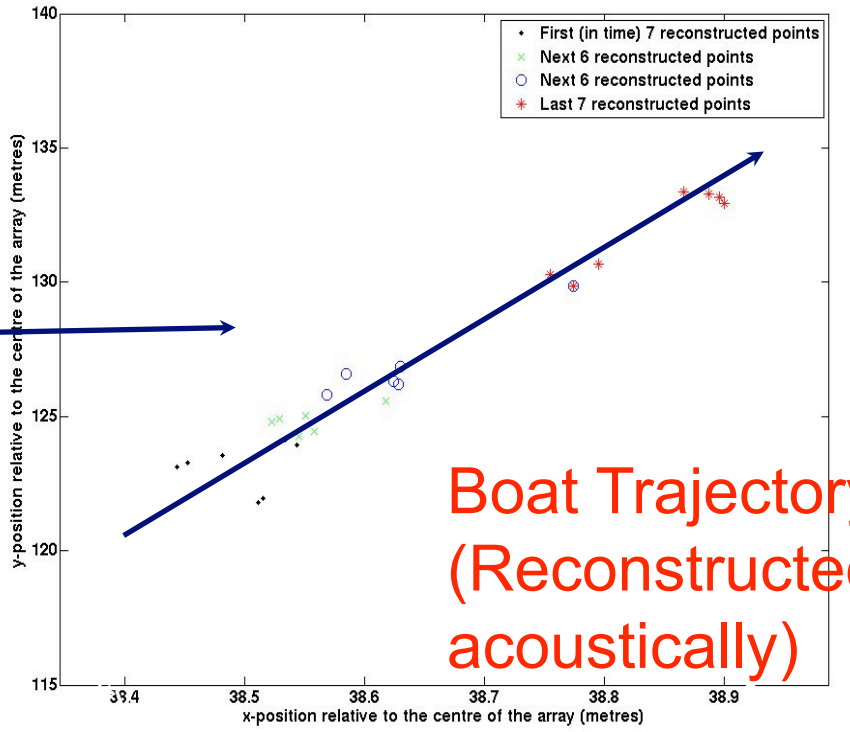


- The top plot shows raw data where 2 periods of pulse injection can be seen
- The bottom plot shows a close up of one of these pulses on the 4 nearest detectors
- Reconstructed 25% of events

Boat Reconstruction

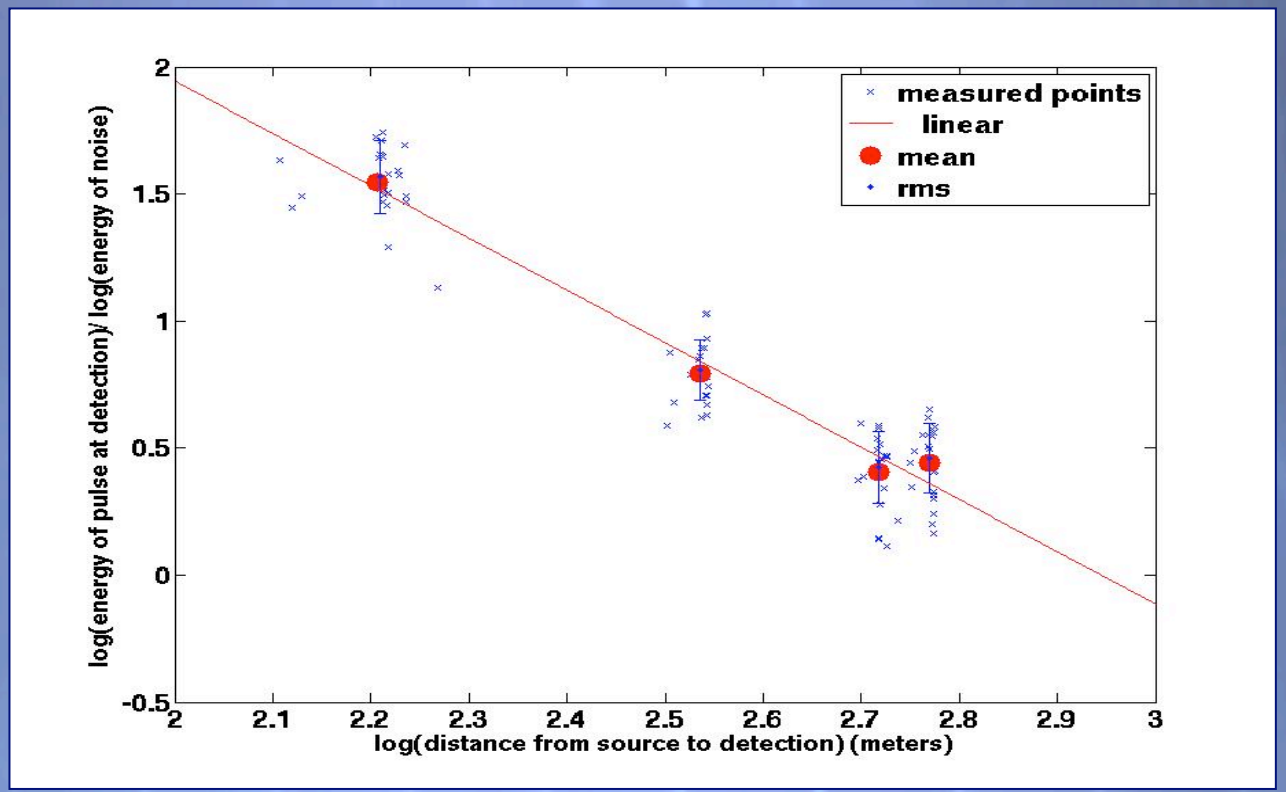
- Using the known detector positions and the time of arrival of the pulse on each hydrophone, each detected pulses' origin (if detected on > 4 detected) could be calculated.
- The boat, and drift, was successfully reconstructed
- Plots show the detector positions, the boat positions, and the reconstructed origins.



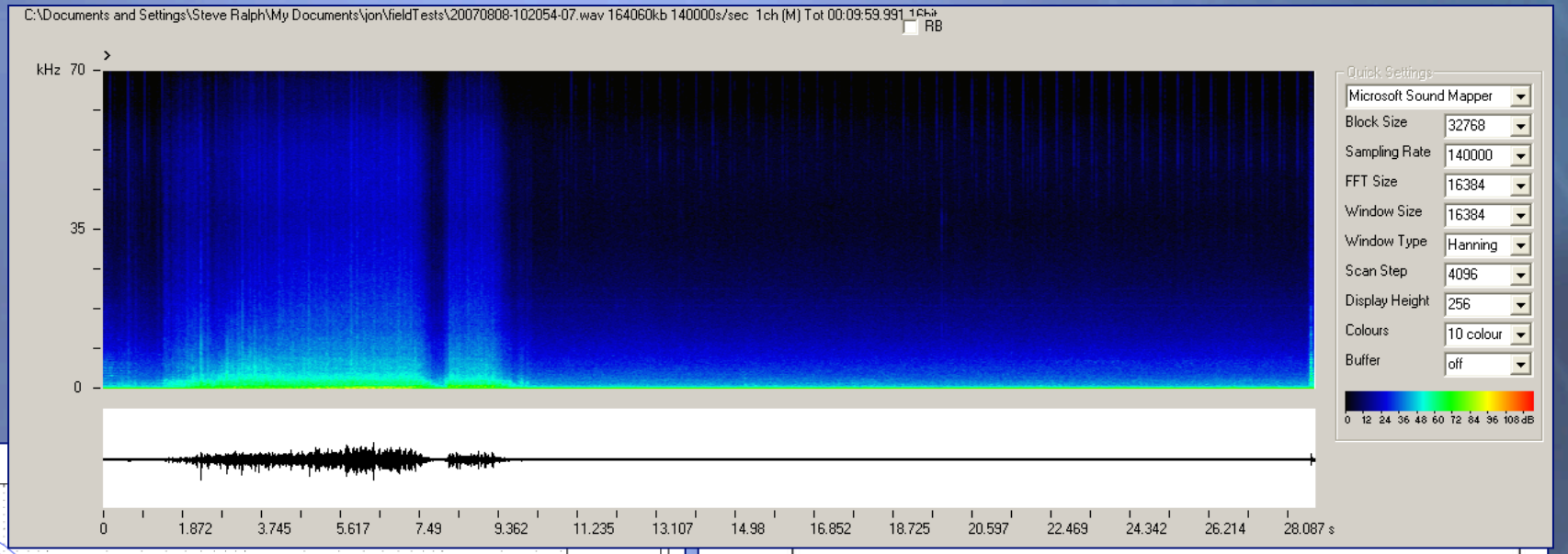


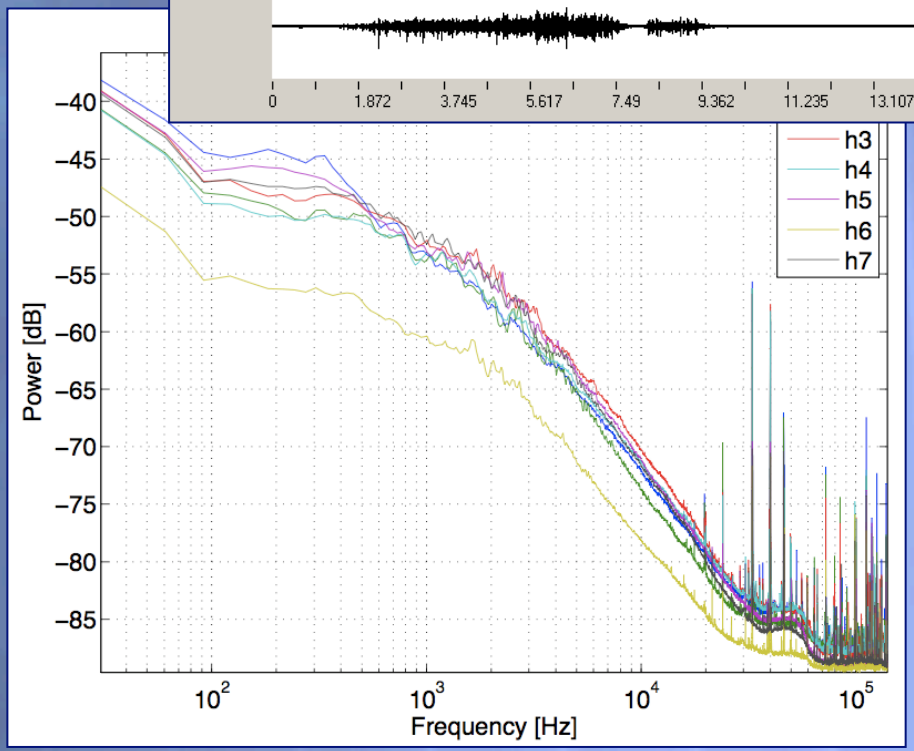
Energy Dissipation

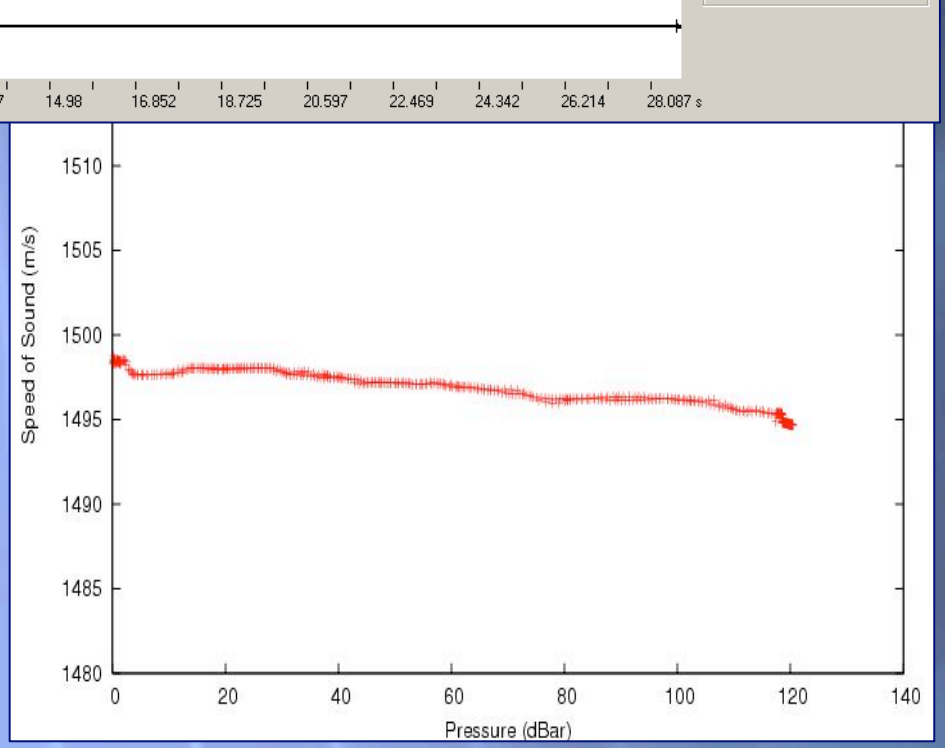
- Another test was to see if the energy of the reconstructed pulses fell as $1/r^2$.
- Again, this proved successful with the slope of the line being -2.1 ± 0.23.



Rona field trip data and spectra

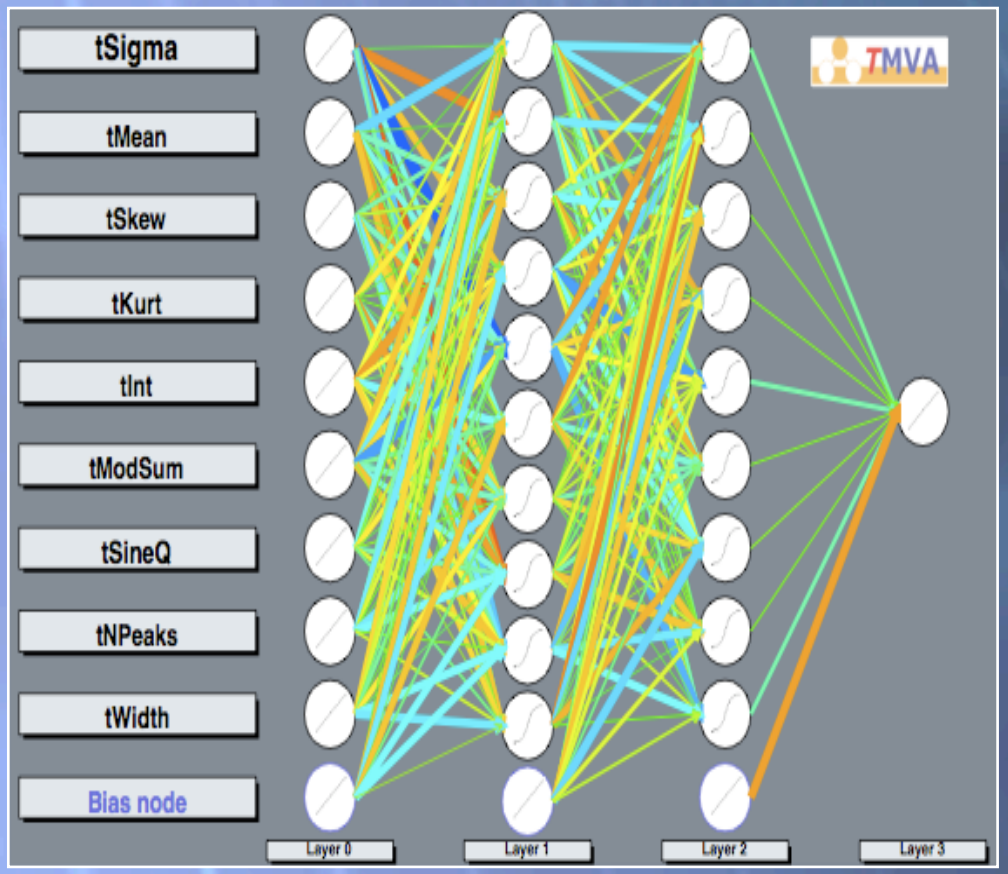






Data analysis

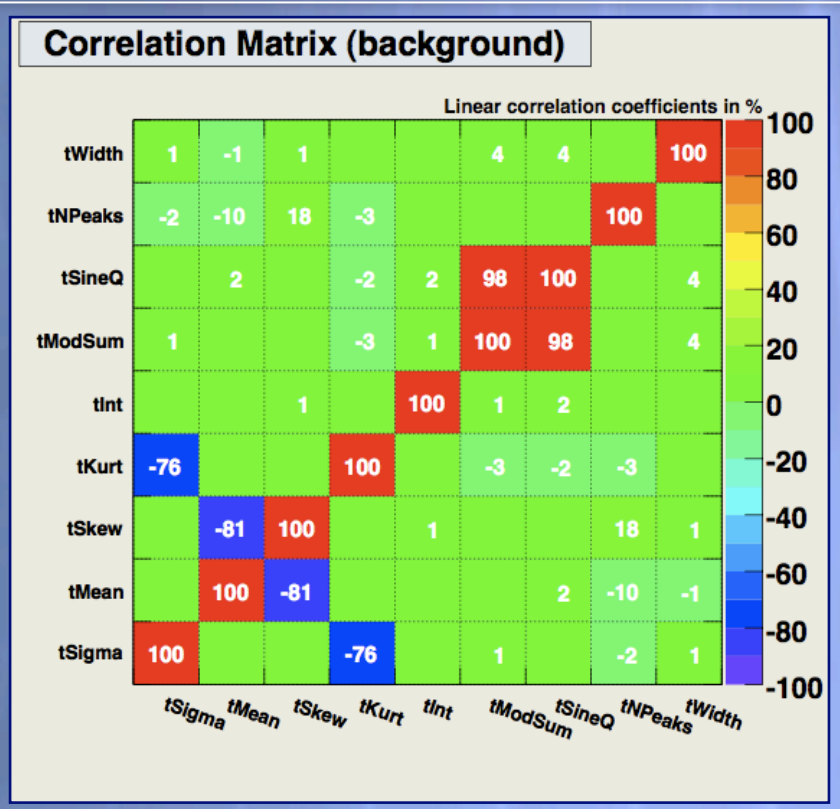
- Potential discriminators in time/frequency
  - Pulse Width
  - Pulse Periodicity
  - Relative Energy
  - Pulse Multiplicity
  - Dominant Frequency
  - Sinusoidalness
  - Bipolarity
  - Standard Deviation
  - Skewness
  - Kurtosis

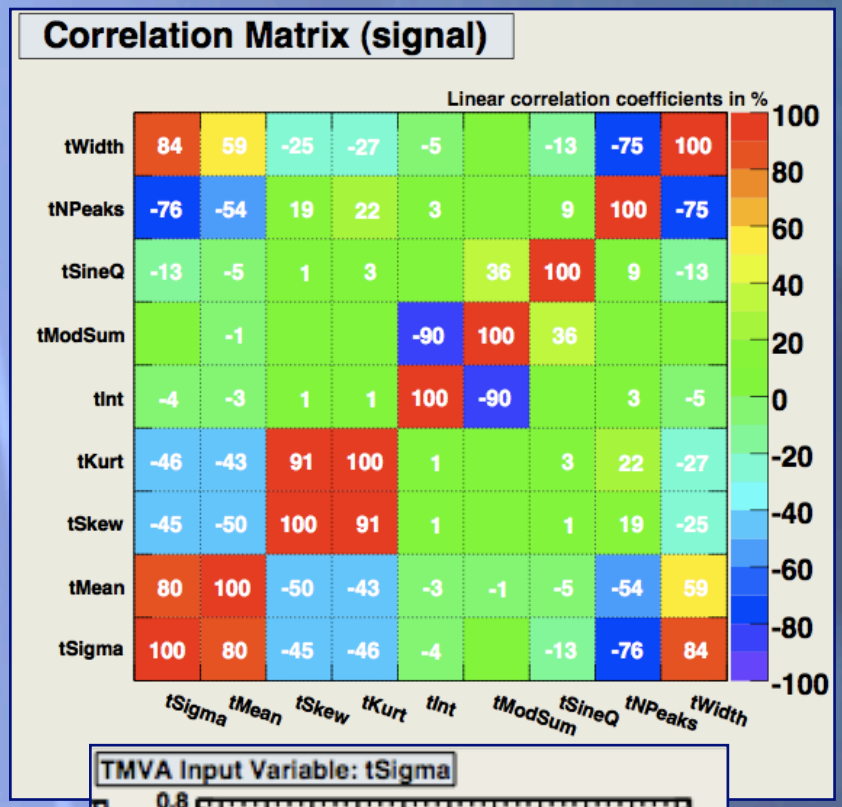


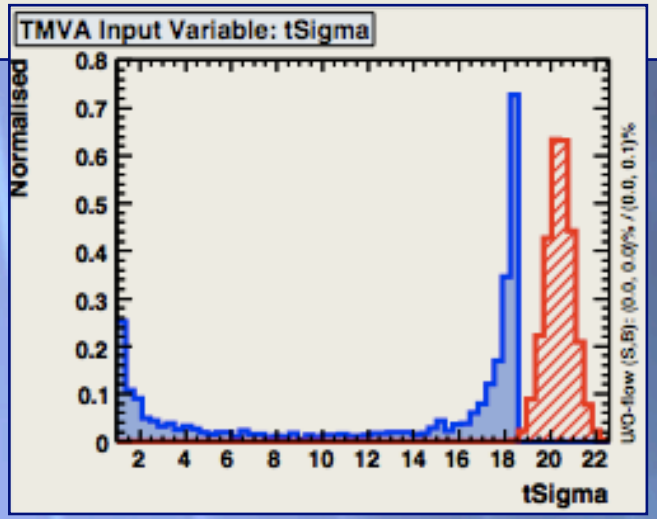
  - … all fed into a neural network

Neural Network

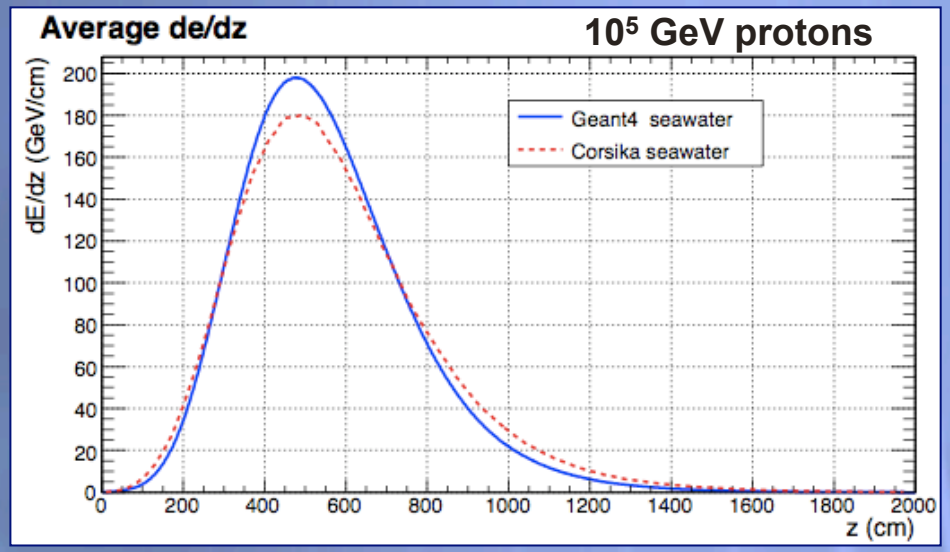
- Correlation matrices: red strong correlation, blue: strong anti-correlation, green: no correlation

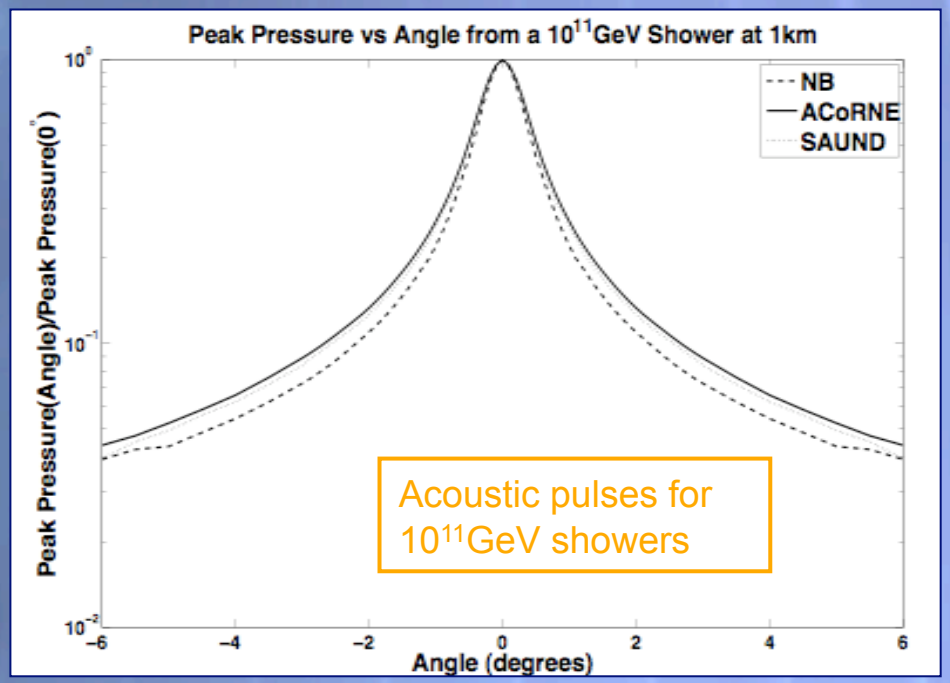




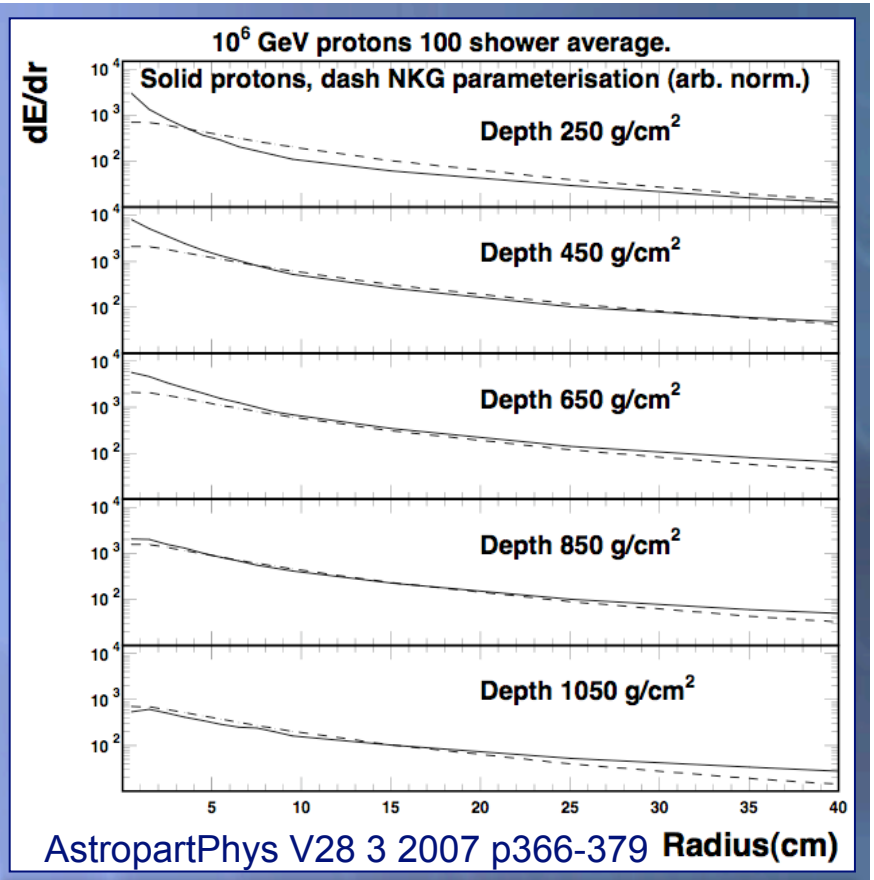


Simulation Work





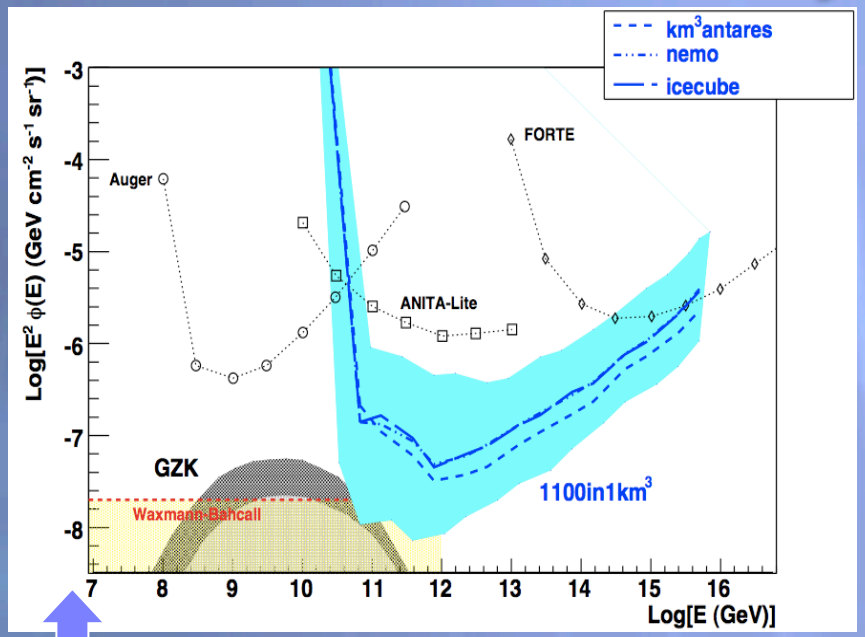
Acoustic pulses for 10^{11}GeV showers



AstropartPhys V28 3 2007 p366-379

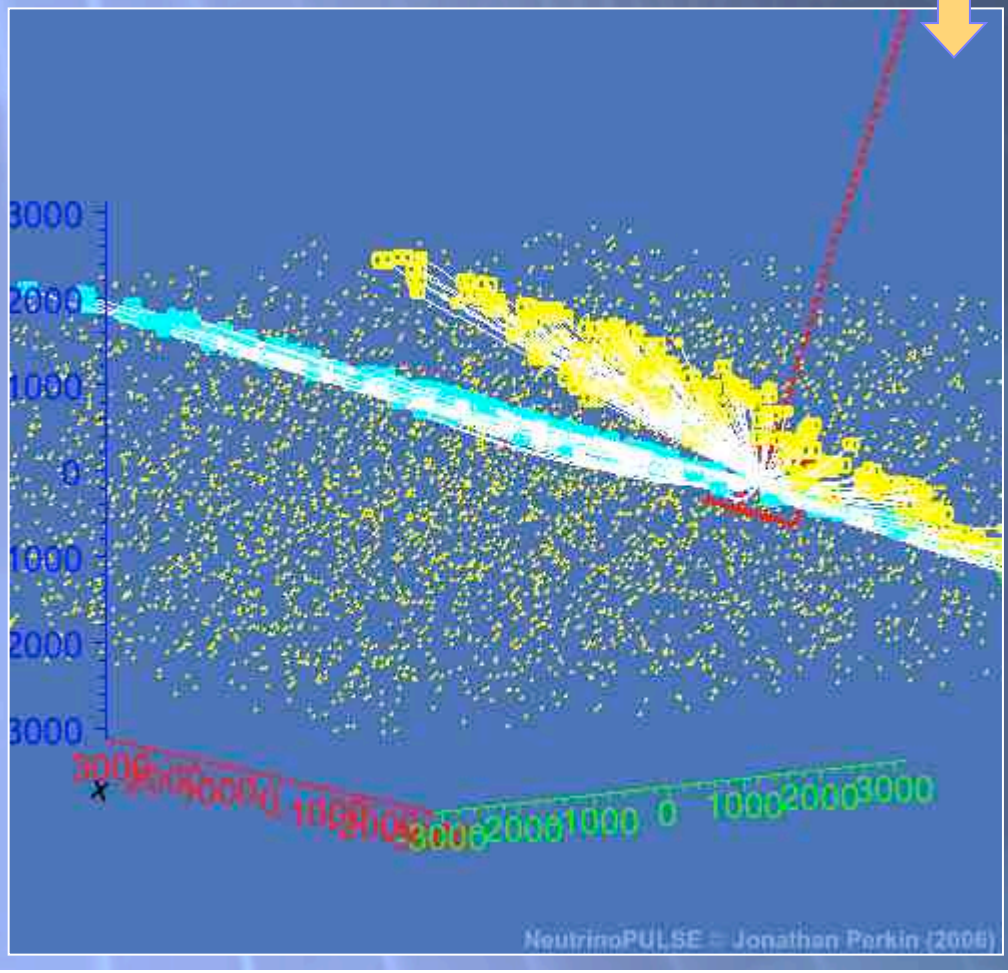
- CORSIKA has been modified to make it work in water
- *Comparisons with GEANT*
  - *~ 10% lower at peak*
  - *Showers broader*
- NKG parametrisation gives less energy at smaller radii - may be important for acoustic/radio
- *A neutrino pulse simulator based on CORSIKA param. is available*

Sensitivity Calculations

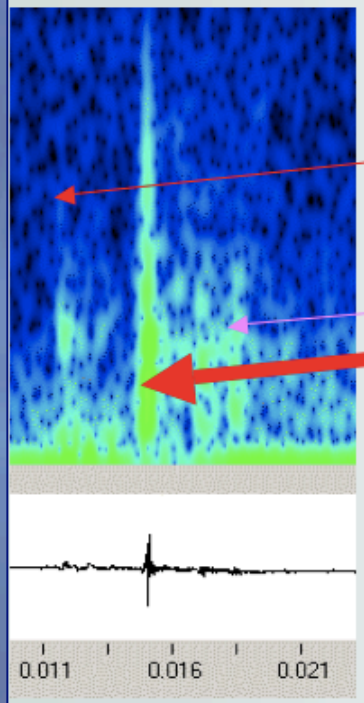


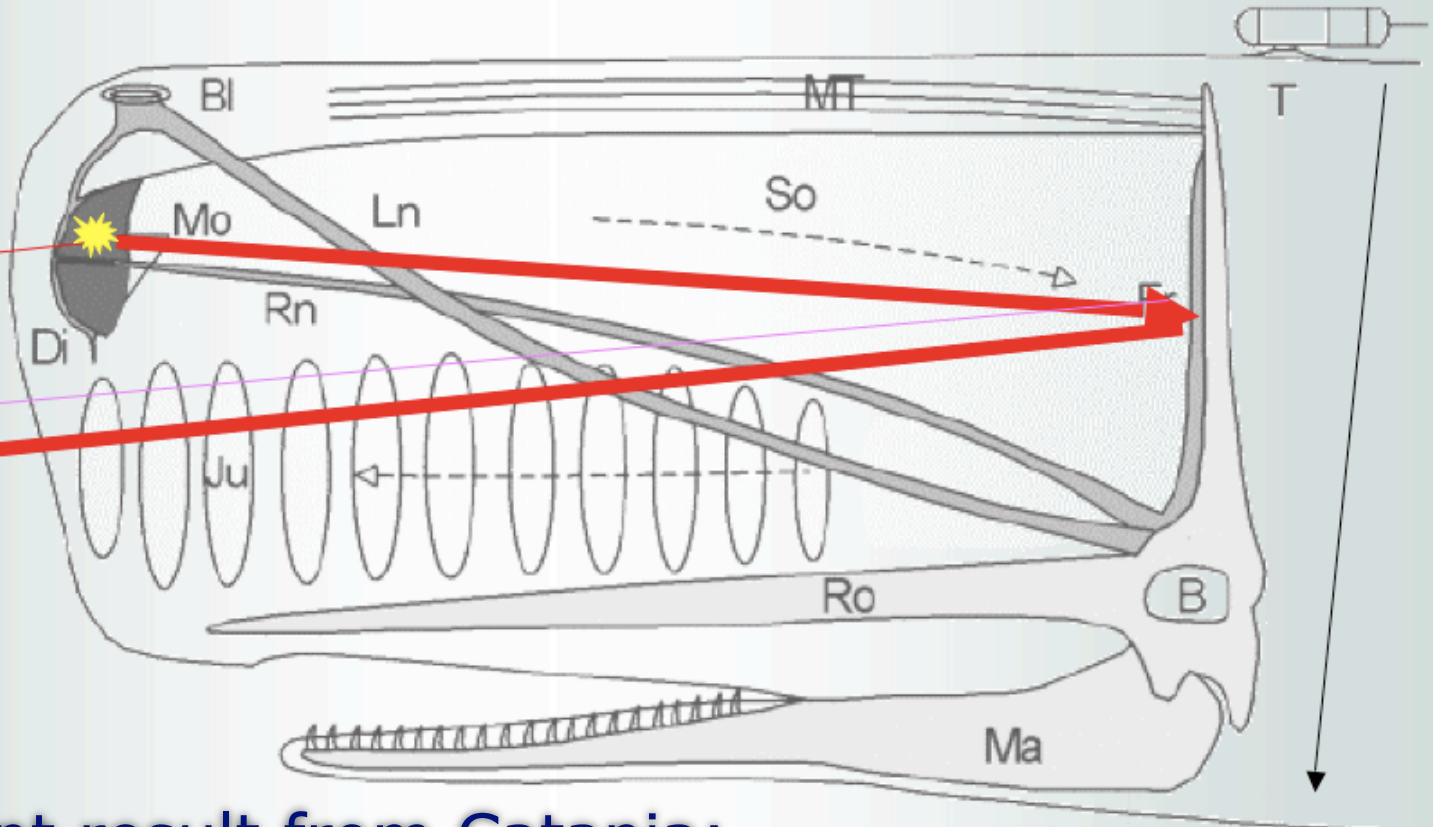
- Sensitivity of a large acoustic array to the hadronic component of neutrino induced cascades
- *1100 acoustic sensors per km³*
- 1-10 years of operation
- *35-5mPa sensor threshold applied*
- Maybe some sensitivity to GZK
- *NB no refraction in here*

- Studies on the effects of refraction
- *Linear SVP distorts the acoustic pancake into a hyperbola*

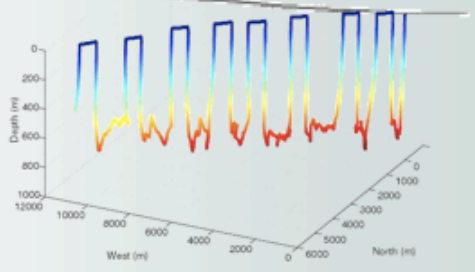


Observation of bio-activity

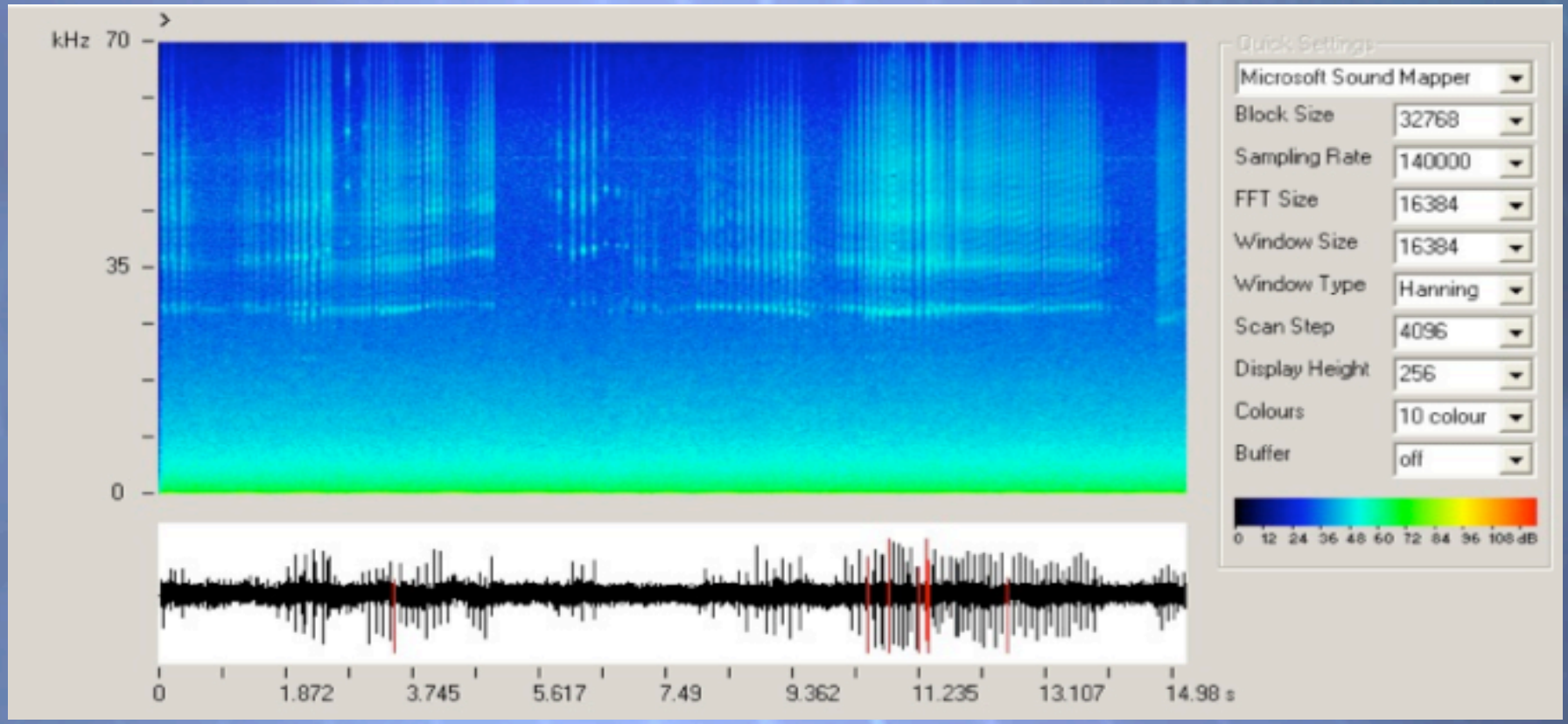




- Important result from Catania: sperm whale transits more frequent than previously believed



Dolphin “clicks” at Rona



Summary

- Multi-messenger observations of astrophysical objects clearly provide valuable information, this is also true at ultra high energies
- *Acoustic detection of UHE neutrinos is a promising technique that would complement high energy neutrino detection using the optical and radio techniques*
- ACORNE is an R&D project to assess the potential of this technique
- *A number of activities - calibrator, simulation, sensitivity assessment, data analysis successfully completed*
- Next steps: work with EU colleagues to bring the technique to maturity within KM3NeT