Ultra-High-Energy Neutrino Astronomy From ACoRνE

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Motivation For UHE Astronomy

The motivation:

Is there new particle physics ?

- It is needed if we observe particles at energies > 5×10^{19} eV
- Is it the same new physics as the LHC - here we are at CME = 200 TeV ?
- Can be used to measure the neutrino nucleon cross section at to-date unreachable energies

If there is new physics :

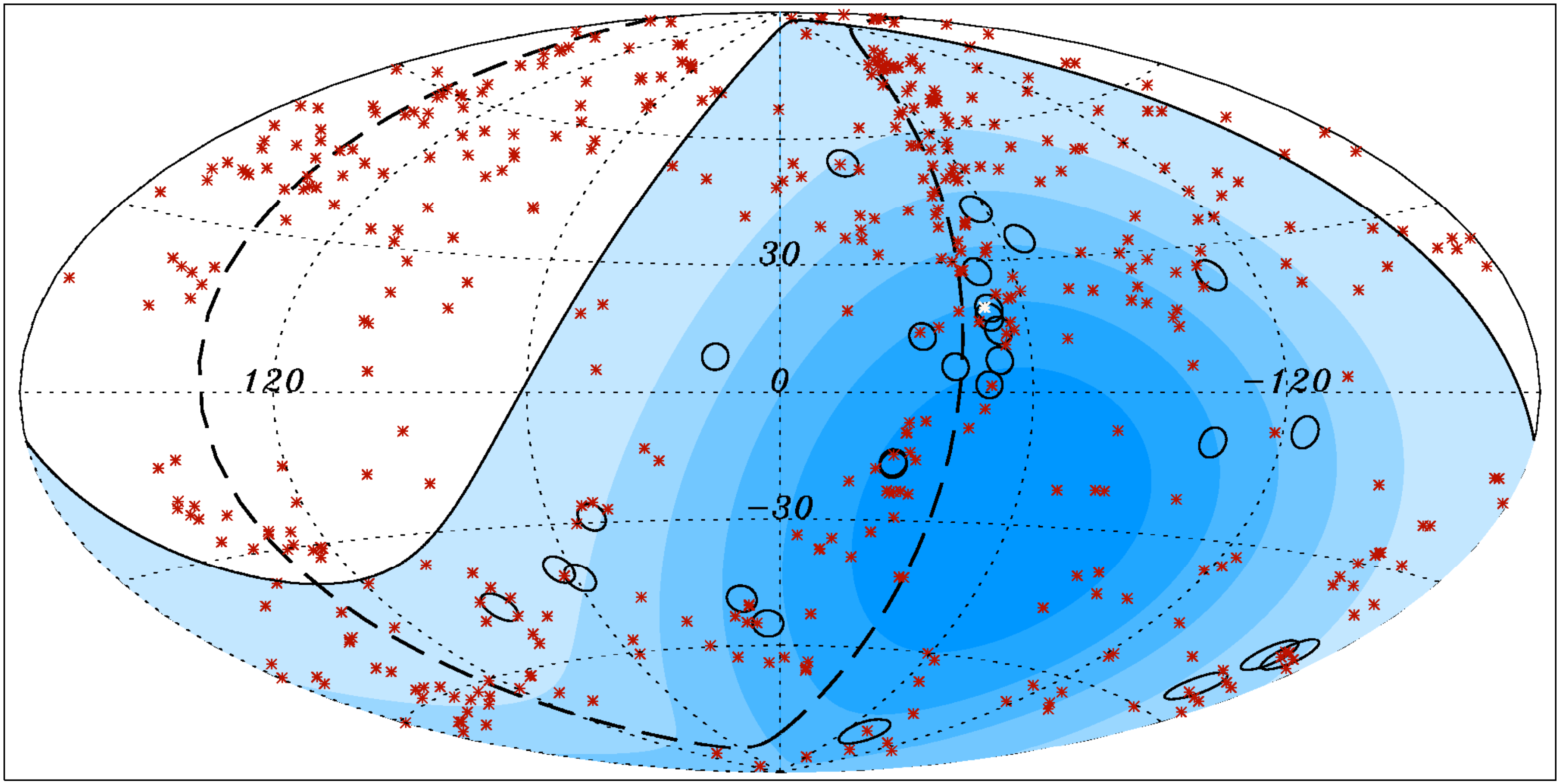
- Can it be used to explain dark matter : are LHC-astro consistent ?
- Does it fit in a GUT model ?
- Can the same GUT model explain LHC data AND ultra-high energy ν ?

Is there new astro-physics ?

- The existence, in the first place, of UHE cosmic rays is a mystery
- What is the primary composition : protons or heavier nuclei ?
- Where do they come from and how are they accelerated ?

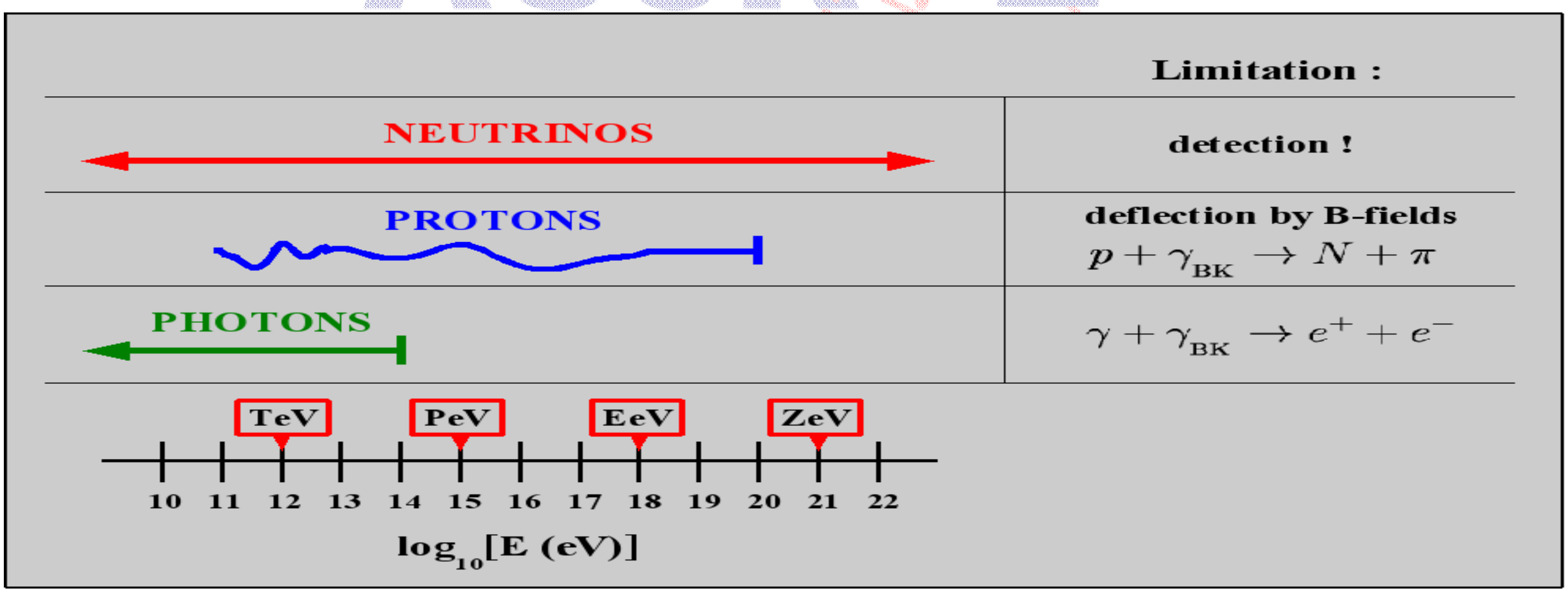
Motivation For UHE Astronomy

Pierre Auger sky map - 29 UHE particles detected



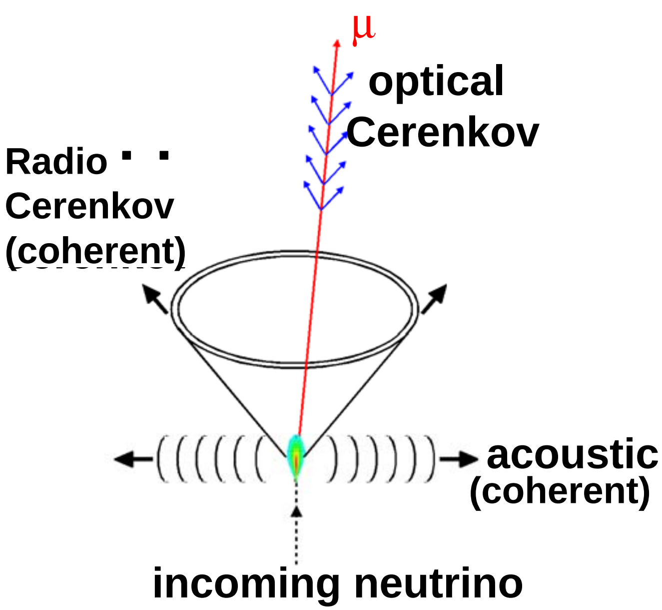
Why Neutrinos?

- Above $1x10^{14}$ eV photons interact with the cosmic microwave background.
- At higher energies, protons suffer due to a finite inelastic collision length of ~50Mpc with the CMB. Another major problem with using protons is they get deflected by galactic magnetic fields, making any pointing astronomy very hard.
- Neutrinos suffer no such problems….



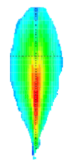
Why Acoustic Neutrinos?

- 4 ways of detecting UHE neutrinos - Optical, radio, air showers, and acoustic.
- At energies > 1 x 10^{18} eV, the magic number is 1 particle per square km per year (in dense material), so for even just a few particles many km^3 arrays are needed.
- Limits Optical and air showers, leaving acoustic and radio as two complementary techniques.

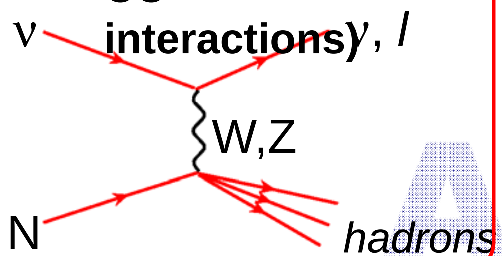


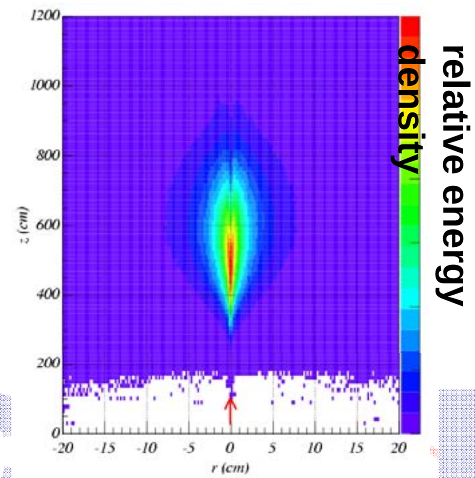
	Attenuation Length		
	water	ice	salt
EM optical (Cerenkov)	~ 50 m	~ 100 m	? (large)
EM radio (0.1-1.0 GHz)	~ 0	~ few km	~ 1 km
Acoustic (10 kHz)	~ 10 km	? (large)	? (large)

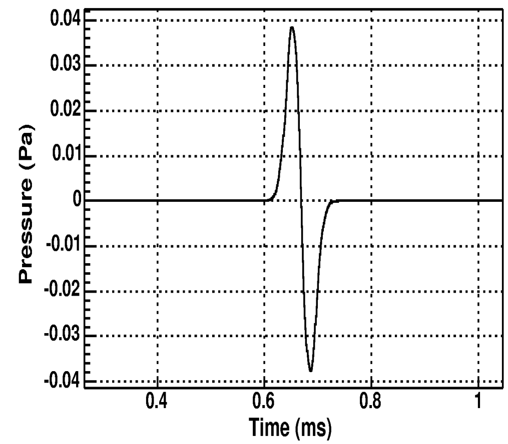
Detection of Acoustic Neutrinos



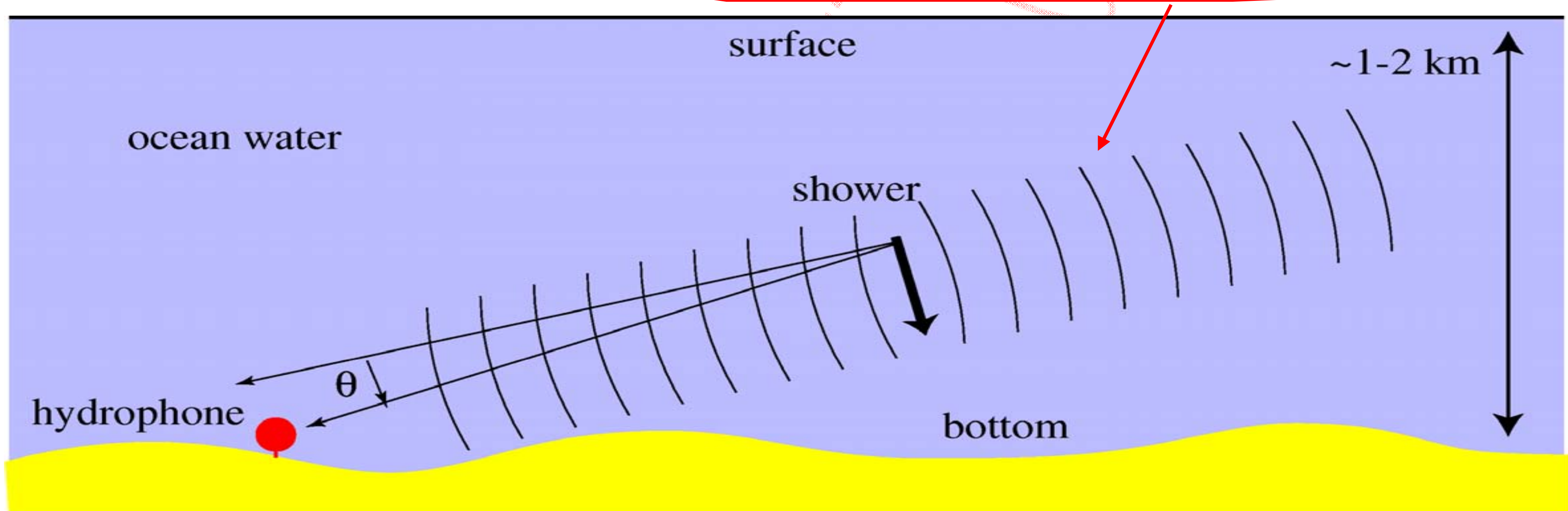
= hadronic shower (or EM shower for ν_e CC interactions)





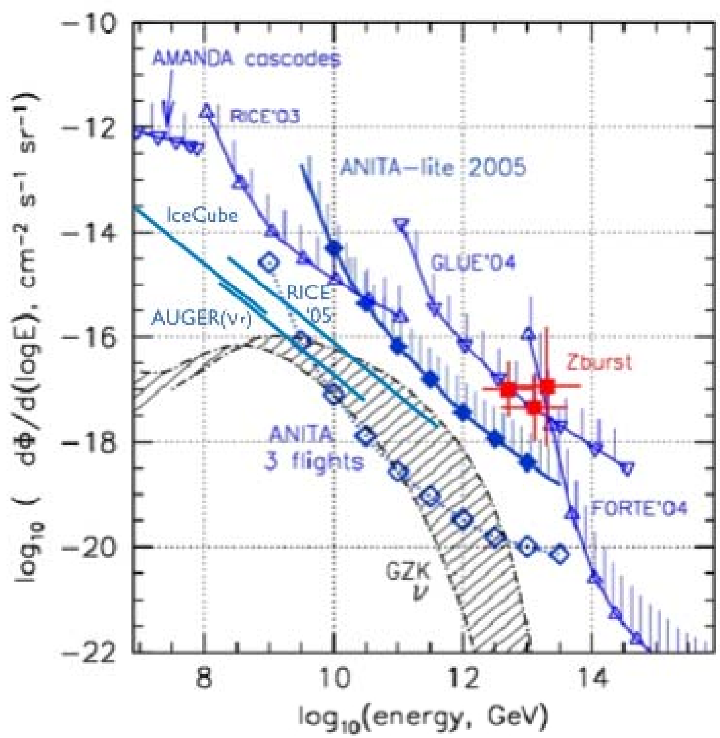


"pancake" propagates ⊥ to shower direction



Other Detection Methods

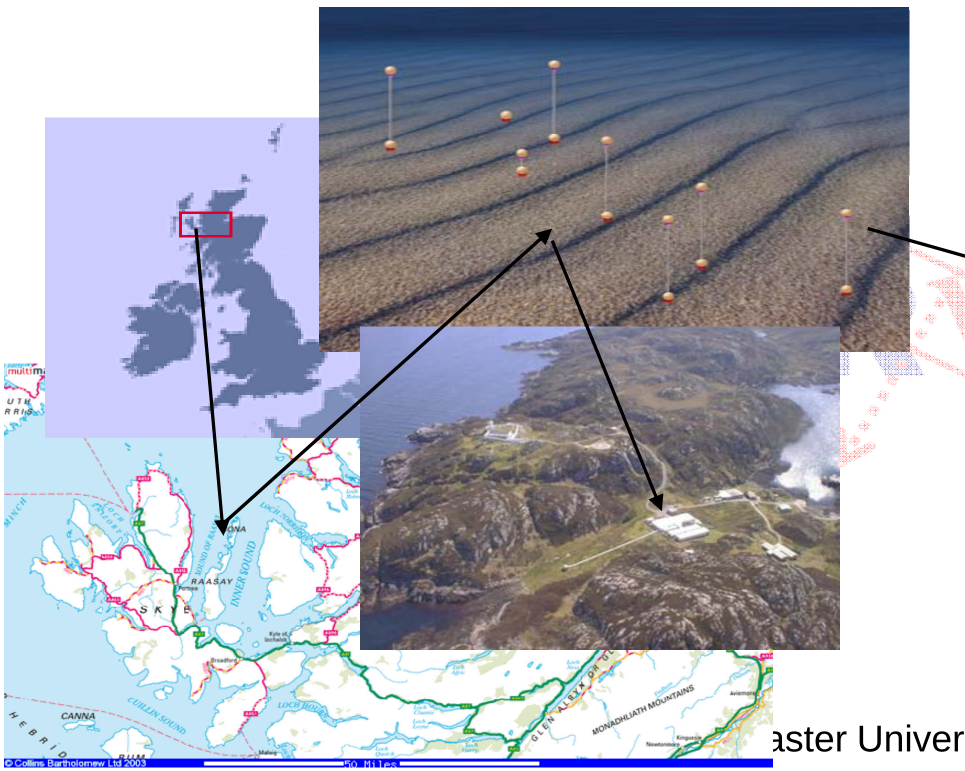
- Optical (AMANDA, ANTARES, ICECUBE) –
  - Look for upward going muons to minimise the noise from neutrinos from cosmic rays hitting the atmosphere.
  - Could detect UHE neutrinos, but not optimal as they have relatively small detection volumes
- Radio (RICE, ANITA, GLUE) –
  - Been demonstrated in lab
  - Km^3 detection volumes
  - Relatively well understood background

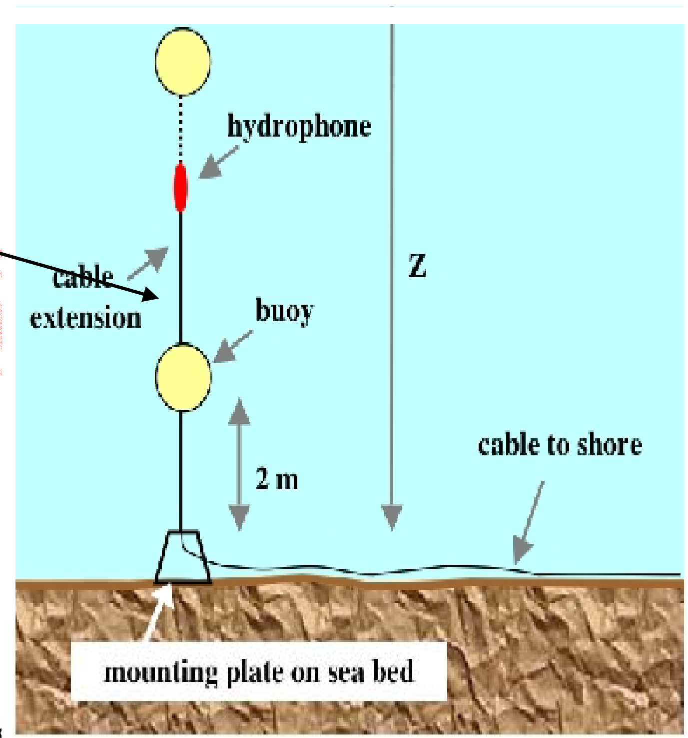


Incorporation of all three?

The Rona Array

- Off the Isle of Skye we have an 8 detector array
- We have been taking since December 2005





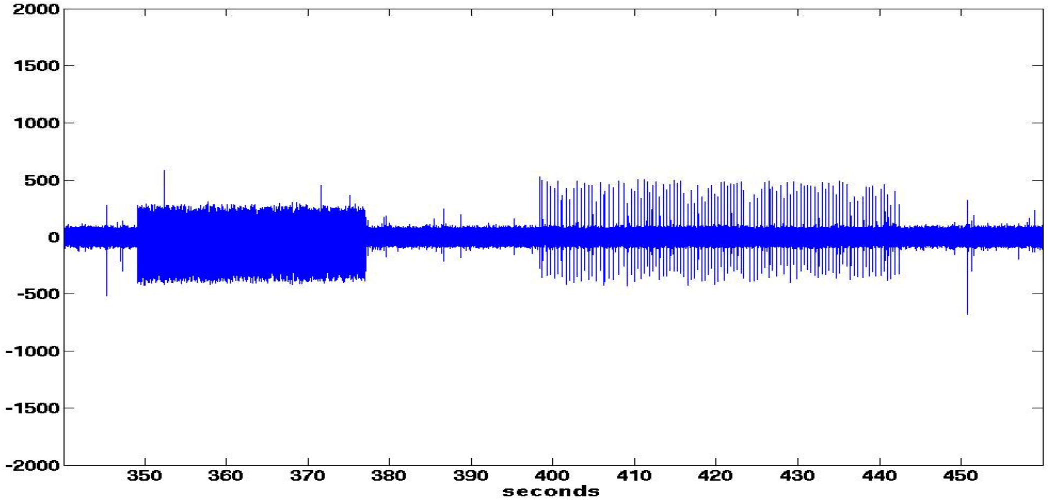
Animation

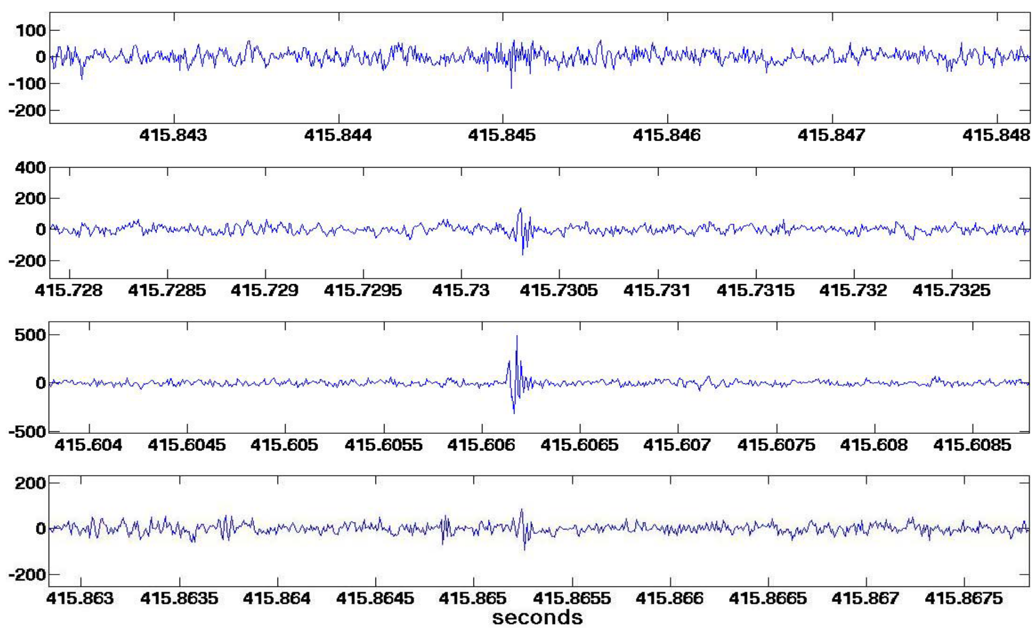
QuickTime™ and a
mpeg4 decompressor
are needed to see this picture.

Rona Field Trip

- In August 2007, we went to Rona and placed (after a few stomach churning days!) a selection of pulses (including predicted neutrino like pulses) above the detector array.
- The data was collected from our DAQ and run through the analysis code to see if we could successfully pick out the pulses, ▪ ▪ and reconstruct the boat position.

Picking Out the Pulses

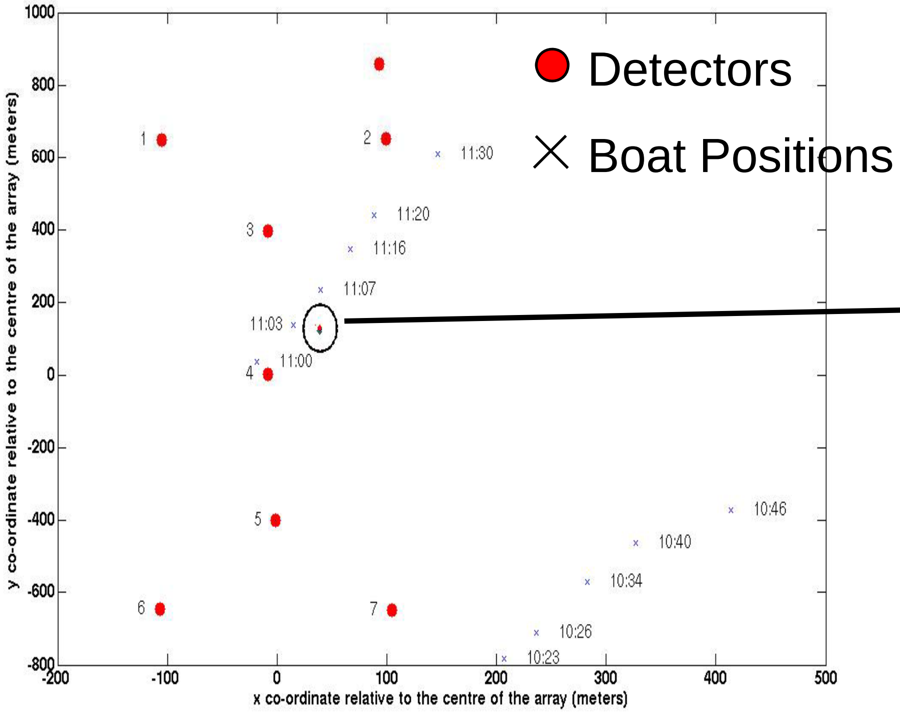


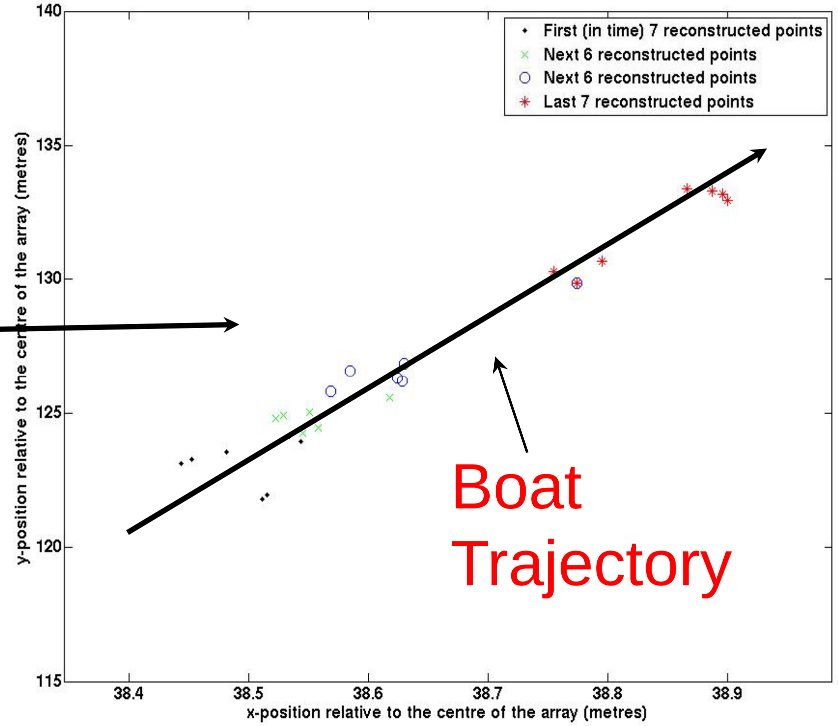


- The top plot shows raw data where 2 periods of pulse injection can be seen
- The bottom plot shows a close up of one of these pulses on the 4 nearest detectors
- Reconstructed 25% of events

Boat Reconstruction

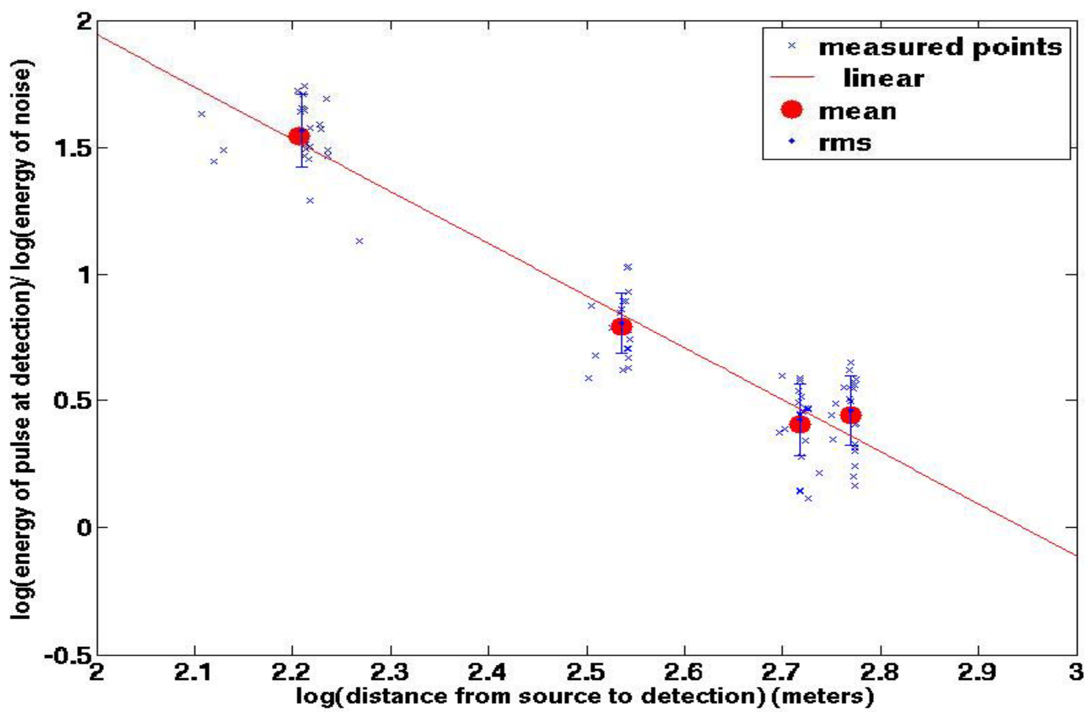
- Using the known detector positions and the time of arrival of the pulse on each hydrophone, each detected pulses' origin (if detected on > 4 detected) could be calculated.
- The boat, and drift, was successfully reconstructed
- Plots show the detector positions, the boat positions, and the reconstructed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





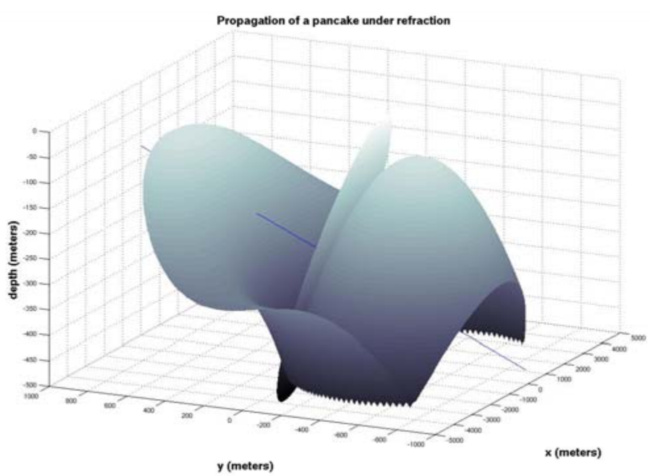
Energy Dissipation

- 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 .



Other Work

- Rona Monte Carlo - Pulse simulation, propagation, detection.
- Co-incident detector neutrino signal search in 2 years worth of data, using a specifically designed set of matched filters, a neural network.
- Using the Monte Carlo and result of the neutrino search to set the worlds first Scottish limit!



- Acoustic Detection in Ice
    - Ray tracing
    - Detector Monte Carlos.
    - Efficiency limits

Conclusion

- Neutrino astronomy is one of the most exciting fields in the search for new physics, also allowing us to answer some of the unknowns of astrophysics.
- Acoustic detection offers one of the most promising ways to search for these particles.
- Field tests and much simulation has been undertaken in the area, and the method seems realistic.
- We can successfully detect a boat, a few orders of magnitude lower in size and we are there…..

BACKUP