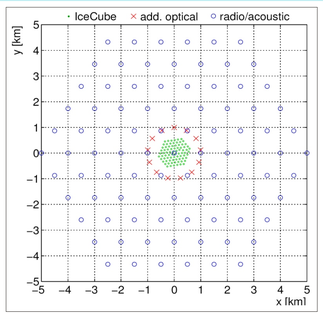
Acoustic neutrino detection at South Pole

S. Boeser,[1] C. Bohm,[2] F. Descamps,[3] J. Fischer,[1] A. Hallgren,[4] R. Heller,[1] S. Hundertmark,[2] K. Krieger,[1] R. Nahnhauer,[1] M. Pohl,[1] P.B. Price,[5] K. -H. Sulanke,[1] D. Tosi,[1] J. Vandenbroucke[5]

1) DESY, Platanenallee 6, D-15738 Zeuthen, Germany; 2) University of Stockholm, Fysikum, SE-10691; 3) University of Ghent, Department of Subatomic and Radiation Physics, Belgium;
4) University of Uppsala, Department of Radiation Sciences, Box 535 SE-751 21 Uppsala, Sweden; 5) Department of Physics, University of California, Berkeley, CA 94720, USA

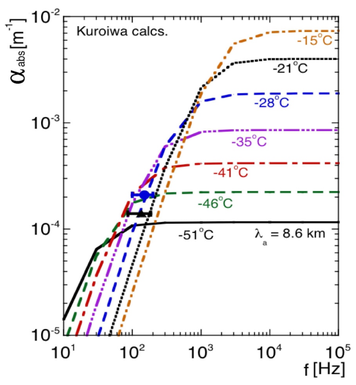
Hybrid detection of high energy neutrinos

Detection of ultra high energy neutrinos will provide valuable information concerning astrophysics (cosmic ray sources), cosmology (relic particles) and particle physics (neutrino-nucleon cross sections). In order to determine distributions, 100 km³ - scale detectors are needed. An optical/radio/acoustic hybrid detector of such a scale is predicted to detect more than 10 cosmogenic neutrinos each year [1].



[1]

SPATS goals



[2]

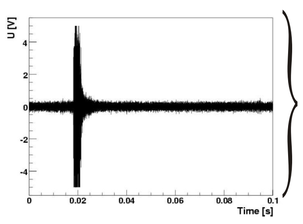
Until now only theoretical estimates [2] exist for the acoustic properties of the South Pole ice in the [0-100 kHz] range.

- attenuation
  absorption + scattering
- speed of sound
  refraction
- background noise level
  energy threshold
- background event rate

How feasible is acoustic neutrino detection at South Pole?

Status

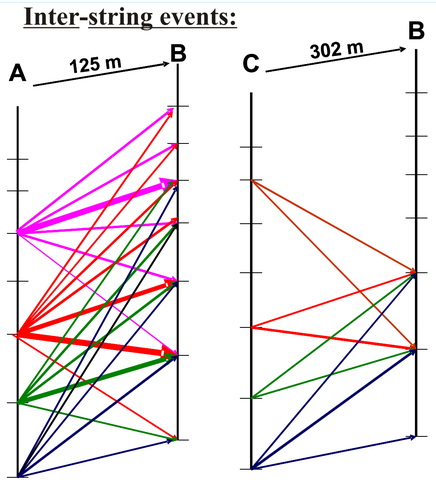
Commissioning:



Inter-stage event:
string-B
-100m to -80m

- Commissioning while stages still in water, intra-string events were observed.
- 53 out of 63 sensor channels are operational:.
  - 3 failed after deployment;
  - 3 failed during freeze-in.
- All transmitters are working.

Inter-string events:



Visualization of detected inter-string events

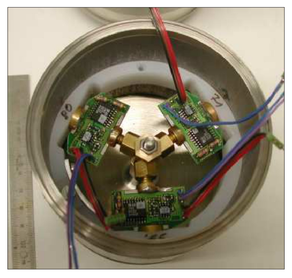
- Non-stop data-taking for 6 months, except during power failures at South Pole: cold reboot is no problem for the embedded computer buried in the snow.
- 150 Mb/day of data is transferred north.
-Transmitter signals between all three strings are seen.

The South Pole Acoustic Test Setup

SPATS:

3 strings: (A,B,C)
-7 acoustic stages
with:
1 transmitter
1 sensor module:
3 piezo channels

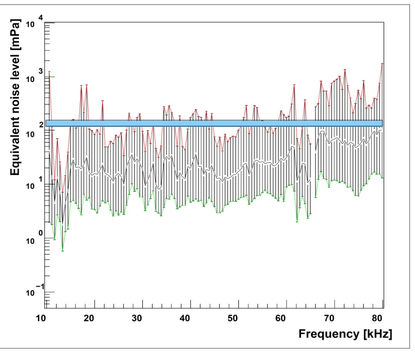
The SPATS sensor



Equivalent noise level

What is the lowest detectable pressure pulse (determines the energy threshold)?

Equivalent noise level of all SPATS sensor module channels; the bars indicate the range over which all the sensors are spread. The curved black line corresponds to the mean value. The level of a commercial hydrophone is indicated by a thick band.

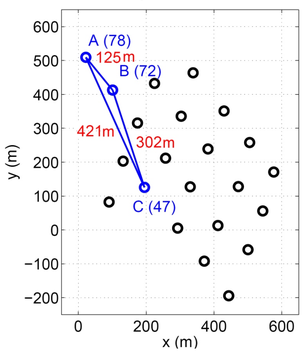


SPATS deployment

Successful deployment in January 2007 in upper 400 m of IceCube holes:
- after deployment of optical modules
- team ~ 4 people
- time ~ 4 hours

String B, 72	: 01/11/07
String A, 78	: 01/14/07
String C, 47	: 01/22/07

Current layout:



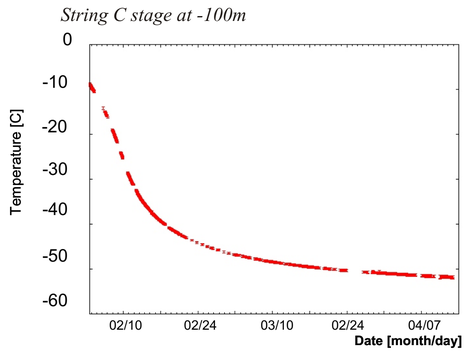
A stage going down ....

Results

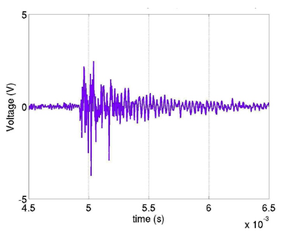
Pressure and temperature monitoring:

Commercial absolute pressure sensors were used during deployment for monitoring and positioning of the string.
All strings were placed at -400 m within 2 m precision.

Temperature sensor results:



Transient events:

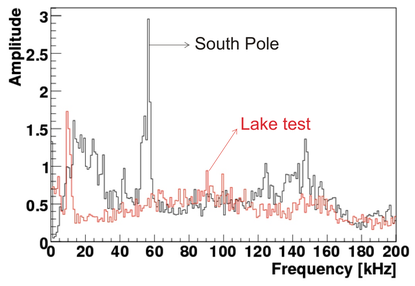


Transient background events are recorded above the Gaussian background.
Origin unknown, rate is roughly 1 per minute per channel

Background noise:

Acoustic noise floor:

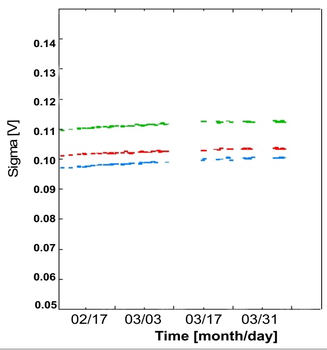
Gaussian and stable in time.



- Noise level is 50 % higher than in the lake test.
- The frequency spectrum at South Pole shows following features:
  - 'bump' at ~150 kHz, believed to be acoustic,
  - 'spike' at 55-59 kHz, likely electromagnetic interference.

Noise evolution in time:

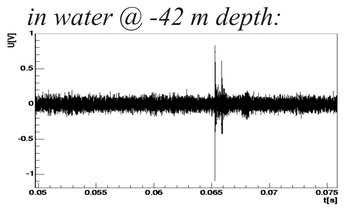
Noise increases in time. This suggests a better acoustic coupling of the hole ice to the bulk ice during the pressure relaxation period.



Inter-string:

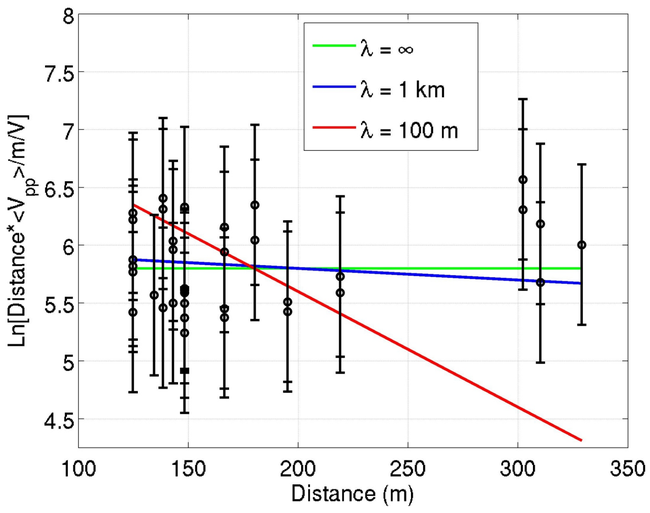
Water long range test in lake covered with 90 cm of ice: a clear signal was seen at 800 m distance between sensor and transmitter

in water @ -42 m depth:



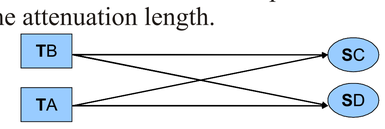
S/N ~10 @ 800 m ⟷ S/N < 1 at 400 m at South Pole! ⟶ Recorded transmitter signals are an order of magnitude lower at South Pole than in the lake test.

Attenuation length:



=> Systematic errors included.
=> Large scatter due to module-to-module variations.

No in-ice calibration of the sensors ad transmitters has been possible so far. Increasing statistics will allow us to build ratios of sensor-transmitter pairs and fit for the attenuation length.



$$\frac{d_{AC}/d_{BC}}{d_{AD}/d_{BD}} \frac{A_{T_A S_C}/A_{T_B S_C}}{A_{T_A S_D}/A_{T_B S_D}} = e^{-\alpha((d_{AC}-d_{AB})-(d_{AD}-d_{BD}))} = e^{-\alpha \Delta x}$$

Conclusions

SPATS status:
- The South Pole Acoustic Test Setup was successfully installed and commissioned in the 06/07 polar season.
- All 21 transmitters are working.
- 53 out of 63 sensor channels are operational.

Results:
- Ambient noise is stable and Gaussian.
- Transmitter signals have been recorded between all strings. Amplitudes are an order of magnitude lower than expected.
- The current data determine a lower limit on the attenuation length.

Outlook:
- With increased statistics, we will be able to constrain attenuation length.
- Implementation of precise timing will allow us to determine the speed of sound and study refraction.

Acknowledgments

The deployment and success of the South Pole Acoustic Test Setup would not have been possible without the support of the IceCube collaboration.

References

[1] Besson, D. et al., Simulation of a hybrid optical/radio/acoustic extension to IceCube for EHE neutrino detection. ICRC 2005, astro-ph/0512604.
[2] Price, P.B., Attenuation of acoustic waves in glacial ice and salt domes. J. Geophys. Research, volume 111 (B02201), 2006.

Contact: Freija@inwfsun1.ugent.be