13 May 2010

Recommendations from the Review Committee on Acoustic Detection R&D at DESY

Background:

Detection of neutrinos at ultra high energies (> 10^{17} eV) in the ice of the South Pole requires the instrumentation of hundreds of km^3 of ice. Given the sensor spacing implied by the optical properties of the south polar ice, a detector entirely based on optical detection techniques is unrealistic for this purpose. Two alternative techniques, the detection of coherent radio emission from neutrino-induced hadronic showers, and the detection of thermo-acoustic signals generated by interactions in dense media have been proposed, both predicted to have attenuation lengths in the km range. R&D towards these techniques has been conducted for several years by part of the IceCube collaboration and other groups. The DESY group has been the driving force in the field of acoustic detection[1] and has attracted other groups from Europe and the US to join the effort, which culminated in the acoustic test setup SPATS inside the IceCube detector.

SPATS allowed for measuring the acoustic ice properties like the sound speeds of pressure waves and shear waves, dispersion and attenuation. Unfortunately, the attenuation length in the upper 500 m of the ice sheet, averaged over the interval 5 kHz-30 kHz, turned out to be about 300m, thus an order of magnitude smaller than expected, a finding which still remains to be understood in detail. This makes a purely acoustic neutrino detector in ice unrealistic but still leaves the option of hybrid radio/acoustic detectors.

The mandate:

Astroparticle physics at DESY concentrates on two main projects, the physics analysis in the context of the IceCube experiment and the preparation of a next-generation Cherenkov telescope array for very high energy gamma ray astronomy. Given the unfavorable attenuation length of acoustic signals in south polar ice and the small size of the DESY group in the acoustic R&D project, a future involvement of DESY in a possible next generation neutrino experiment in the ice of Antarctica is questionable. The Helmholtz Senate Commission for the evaluation of the DESY proposal for astroparticle research in the funding period 2010-2014 therefore recommended:

For evaluating the acoustic detection activities in IceCube a specific review called by the DESY management in the beginning of 2010 is recommended. A continuation of these

[1] It may be that acoustic detection has some potential applications in glaciology. In the past half-century, radar soundings have been the usual technique employed to infer glaciological parameters, such as the ice crystal orientation fabric (COF). Knowledge of COF then provides information on ice flow, which then provides information on glacial mass balance, for instance. In the case that acoustic waves can scatter off of COF, a new field of acousto-glaciology could be opened up in the future as power complement to the radio soundings.

activities beyond that review should be subject to its outcome and to a "critical mass" of partner institutes ready to participate in such a programme.

DESY passed this mandate to a committee consisting of several members of the DESY PRC and experts from the field of acoustic detection, radio detection and astroparticle theory. The review took place on April 28, 2010. The agenda and the members of the review committee are listed in the annex.

Results:

The committee formulated the following six questions to be answered:
Q1: *Is the physics case (for neutrinos with $E > 10^{17}$ eV) convincing?*
Q2: *How does the physics case compare/relate to that of IceCube and CTA?*
Q3: *Is acoustic detection in ice still a viable technique for a 100(0) km^3 neutrino detector at the South Pole (or elsewhere)?*
Q4: *What are the benefits of acoustic detection in large hybrid radio/acoustic/optical arrays?*
Q5: *Is there sufficient interest ("critical mass") within the community (esp. IceCube) to allow for a design study and a systematic R&D program towards a major radio/acoustic/optical detector at the South Pole (or elsewhere)?*
Q6: *Could DESY play an adequate role in such a program and what are the resources needed to achieve this?*

After the presentations of German representatives of the research on acoustic and radio detection in ice, and after in depth discussion within the review committee, the following answers to these questions were formulated:

Q1: The physics case as such is clear, at least on the qualitative level. Highly interesting fundamental aspects are addressed, like the origin of the highest energies cosmic rays, the measurement of neutrino cross sections at these energies, constraining cosmological parameters, measuring neutrino masses and the search for exotic phenomena. The existence of neutrinos with energies above 10^{17} eV is guaranteed by the GZK mechanism for the attenuation of ultra high energy cosmic rays; however, the flux of these neutrinos is still uncertain by at least one order of magnitude and requires a deeper understanding of the cut-off in the cosmic ray spectrum, as observed by cosmic ray air shower experiments. Moreover, detailed studies, including detector sensitivities and resolutions, of how precisely the various physics signatures can be accessed and interpreted, are still lacking.

Q2: The physics of neutrinos with energies above 10^{17} eV is mostly complementary to that studied by IceCube and CTA and would therefore significantly broaden the scope of astroparticle physics at DESY. Of course, IceCube and CTA are advanced devices of second or third generation with physics programs worked out in much more depth than is presently the case for acoustics detectors.

Q3: Assuming that the current results that indicate a shorter than expected attenuation length persist, a purely acoustic detector in ice is probably excluded. However, acoustic detection is still an interesting technique for hybrid radio/acoustic detectors, the strength of acoustic detection being the very low noise levels in ice which are expected theoretically, but still have to be demonstrated. Although a first set of essential acoustic ice properties have been determined in situ, including the real and imaginary components of the permittivity, a more comprehensive suite of measurements are needed to draw firm conclusions.

Q4: Acoustic detection is an important add-on to large radio detectors to establish or verify signals. The two techniques enhance each other, e.g. by using cross-triggering techniques to extract signals with a small signal to noise ratio, or by improving the energy resolution through cross-calibration.

Q5: On a world wide scale, sufficient experience and manpower exists for R&D towards a hybrid radio/acoustic detector. DESY has played a pioneering role in acoustic detection in ice and has attracted German universities to this research direction. These universities, in turn, have made substantial contributions to the field. The resulting accumulated know-how and experience is a good basis for future acoustic R&D at DESY in close collaboration with German universities.

Q6: Given the unknowns described above, it is neither possible nor wise to try to give an answer to this question at this point in time. It seems obvious that the field has not yet reached the level of maturity to embark on the design and preparation phase for a major neutrino detector for ultra high energies. Continued R&D may change this picture and it is desirable that DESY and German universities continue to play an important role in this field.

Recommendations:

Given the present level of understanding of acoustic detection techniques in ice, it is premature to draw firm conclusions towards the feasibility of a major neutrino experiment at ultra high energies. The committee recommends that R&D activities are continued at DESY with adequate resources. DESY should continue its close collaboration with German (and other) universities. The committee suggests pursuing site studies, considering the measurement of attenuation length as function of depth and frequency and aiming at an in-situ (South Pole or alternative locations) calibration of acoustic sensors and absolute determination of noise levels. The results should be reported back in about two years' time to serve as a basis for further discussions.

13 May 2010

Annex:

Acoustic Detection R&D Review, 28 April 2010, DESY Hamburg – Agenda

Time	**Session**	**Topic**	**Speaker/Participants**
13:00	Closed Session	Review Committee	
14:00	Open Session	The scientific case for acoustics/radio detection at IceCube	R. Nahnhauer/DESY
14:30		Status of acoustics R&D	T. Karg U Wuppertal
15:15		Status of Radio R&D and interplay of radio/acoustics detection techniques	K. Helbing U Wuppertal
16:00		Coffee Break	
16:30		The future R&D plans and DESY's role	R. Nahnhauer/DESY
17:00	Closed Session		Review Committee
18:00	Executive Session	Questions and Discussions	Review Committee plus Speakers
~19:00	End of Review		

Talks are available at
https://indico.desy.de/conferenceOtherViews.py?view=standard&confId=2843

Committee Members:

Internal PRC Members:
Thomas Lohse (HU Berlin) - Chair
Gisela Anton (U Erlangen) – Co-Chair
Andy White (U Texas)
Peter Buchholz (U Siegen)
Joachim Mnich, Ulli Gensch (ex-officio, DESY)

External Members:
Acoustics: Uli Katz (U Erlangen)
Lee Thompson (U Sheffield)

Radio: Dave Besson (U Kansas)
Andreas Haungs (KIT, Karlsruhe)

Theory: Günther Sigl (U Hamburg)

Scientific Secretary: Frank Lehner, DESY