Matter and the Universe

Topic 3: *Matter and radiation from the Universe*

R&D Program for IceCube High Energy Extensions

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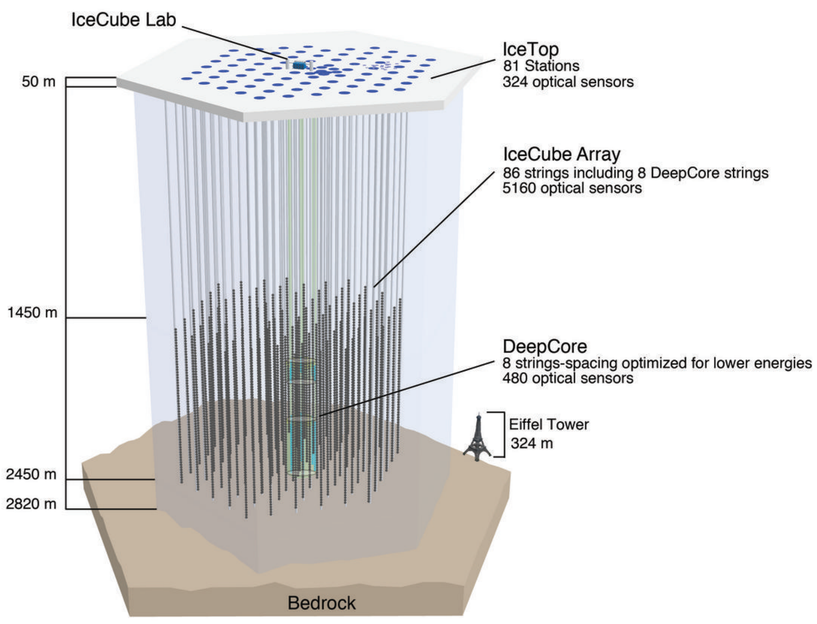
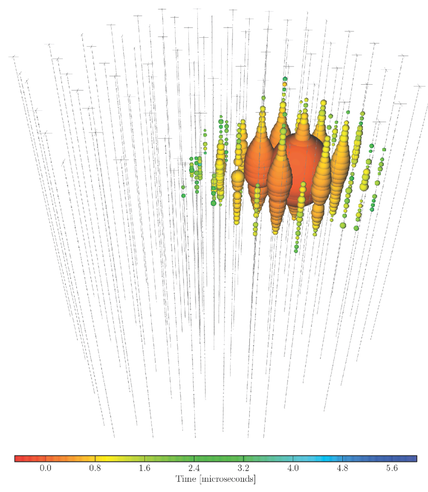
Current Status and High Energy Results

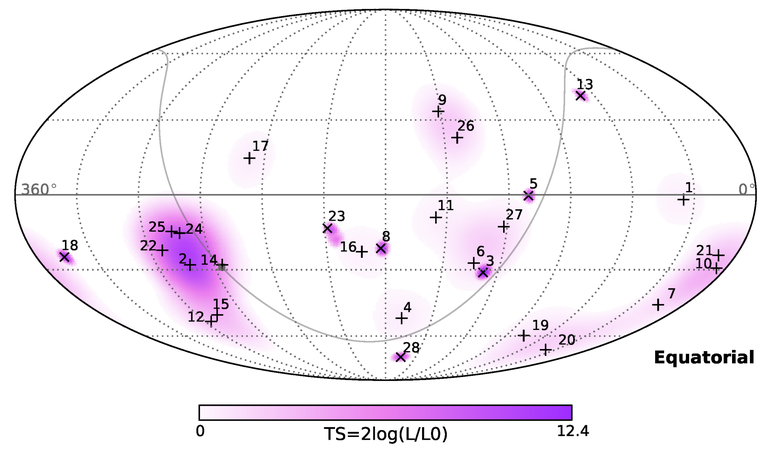


The IceCube neutrino observatory was completed in December 2010. In two years of data 28 neutrino events with deposited energy > 30 TeV were observed. A purely atmospheric origin can be rejected at the 4σ level [1].



Neutrino event "Bert" with 1.04 PeV deposited energy.

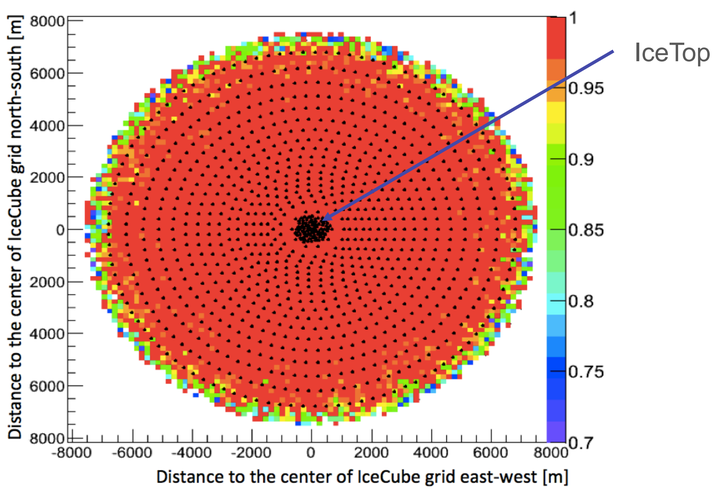
Veto techniques that utilize the outer layers of optical modules to reject atmospheric muons played a crucial role in obtaining this result. To explore the neutrino sky in more detail, a R&D program targeted towards high energy extensions of IceCube is outlined here.



Skymap of the 28 neutrino events (from [1]).

Idea 1: Large Area Surface Veto

Veto atmospheric muons in a large zenith range by detecting the associated air shower.



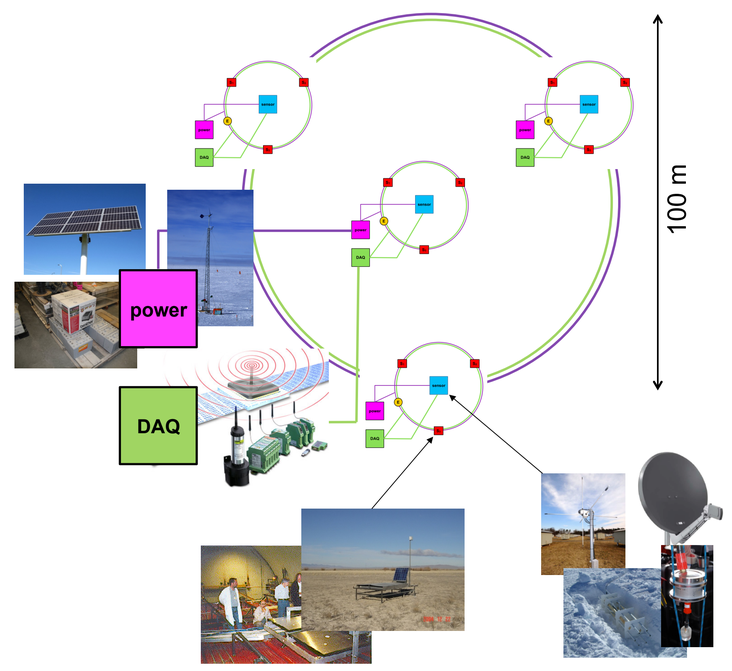
Veto efficiency for extensive air showers which deposit a total signal of > 1000 p.e. in IceCube (from [2]).

Possible configuration [2]:
- About 1000 simple particle detectors
- Radius of 7 km covers zenith range 0 to 75° wrt. IceCube

Challenges:
- Autonomous detector stations
- Self-sustained power supply (wind, solar, …)
- Wireless communication and synchronization

Present R&D efforts at DESY:

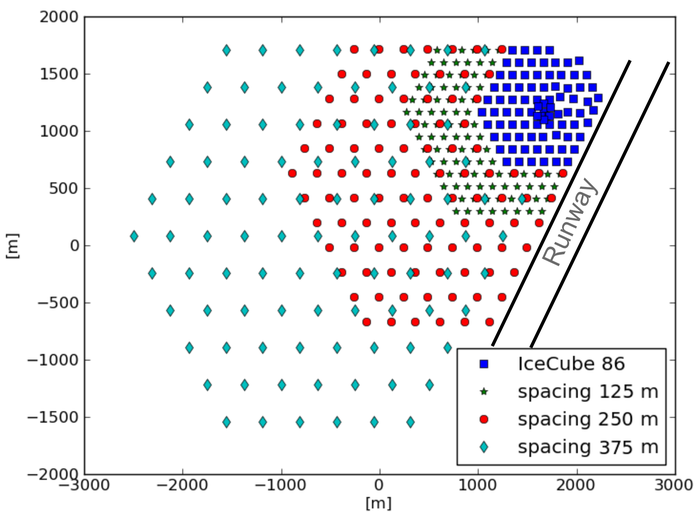
TAXI – Transportable Array for eXtremely large area Instrumentation studies:
- Array of four clusters to develop and test concepts for sensors, communication, and power supply infrastructure in-situ
- Use well-understood scintillator detectors as reference and trigger for air showers
- Provide well-defined hardware and software interfaces to test different components
- Easily transportable to allow for site studies
- Cooperation between DESY and KIT



Schematic overview of TAXI.

Idea 2: Increase Volume by Installing Additional Strings

Increase instrumented volume to ~10 km^3 by additional strings with larger horizontal spacing.



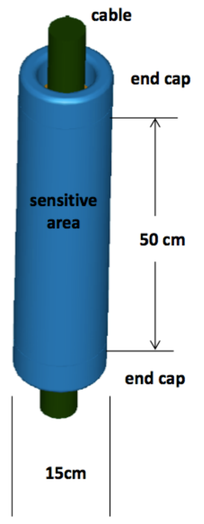
Three different detector geometries that have been studied (from [3]).

Possible configuration:
- About 100 additional strings
- Spacing and geometry to be optimized

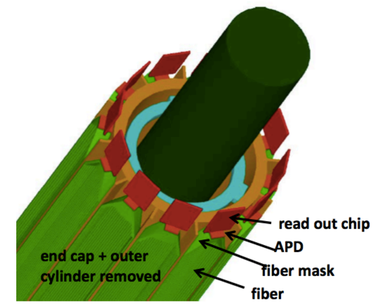
Challenges:
- New drilling and deployment procedures for large inter-hole spacing
- New, slender optical modules will allow one to drill narrower holes → cost scales with hole cross section

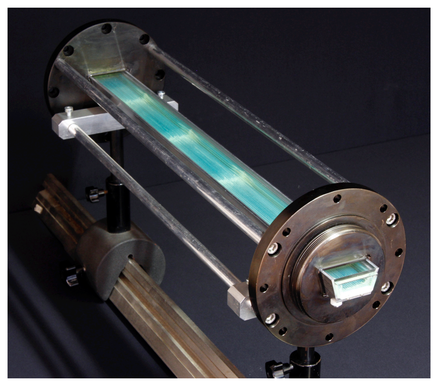
Present R&D efforts at DESY:

ZOMBI – Zeuthen Optical Module for Boreholes in Ice:
- Segmented cylinder filled with liquid wavelength shifter
- Collect more Cherenkov photons by wavelength shifting
- Light guided to photosensors in end caps
- Cylindrical design allows to feed cable through the module
- First test cell currently being characterised



Schematic overview of ZOMBI (top).

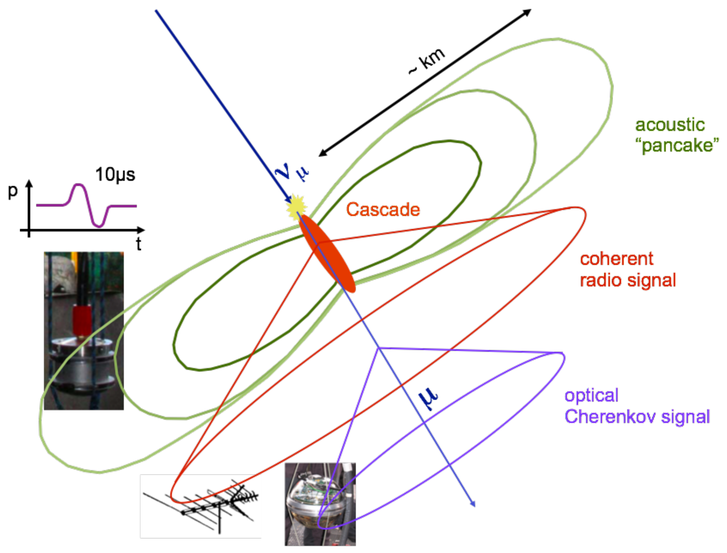




ZOMBI test cell without PMTs (right).

Idea 3 – Far Future: Hybrid Detection

Radio and acoustic techniques can be used to detect cosmogenic neutrinos at ultra-high energies ($E_\nu \geq 1$ EeV).

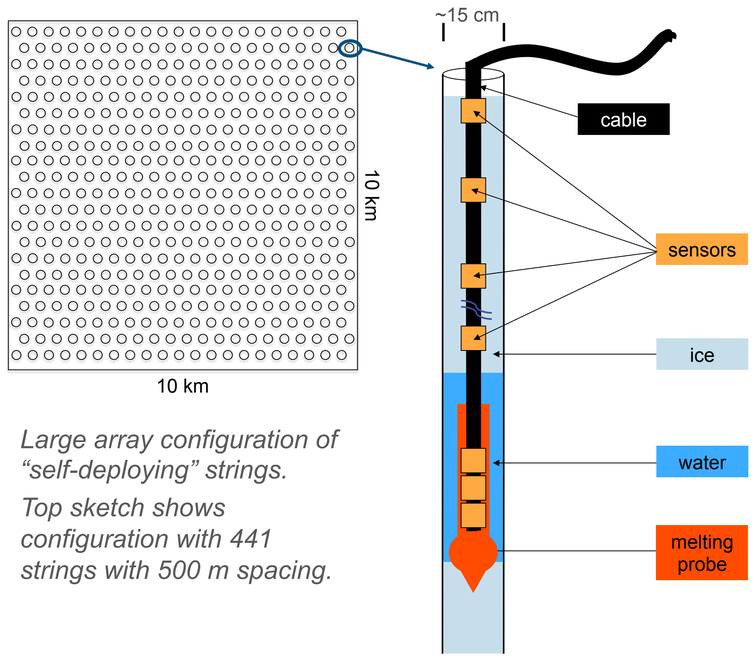


Possible configuration:
- Order of one thousand shallow strings on 100 km^2
- Radio and acoustic detectors on same string

Challenges:
- Robotic drilling and deployment techniques
- Autonomous detector stations at the surface of each string

Present R&D efforts at DESY:

Drilling and Deployment:
- Deploy sensors from payload of single-use melting probe
- Cable with sensors spooled inside probe → hole can re-freeze immediately
- Melting probes studied by glaciologists since the 1960s
- Conceptual Design Report for melting probe (without payload) prepared [4]



Large array configuration of "self-deploying" strings.

Top sketch shows configuration with 441 strings with 500 m spacing.

References

[1] IceCube coll., Science **342** (2013) 1242856.
[2] J.Auffenberg for the IceCube coll., Proc. of the 33rd ICRC (2013).
[3] D. Altmann, Master's thesis, RWTH Aachen (2011).
[4] A. Donat, TK, …, RN et al., Conceptual Design Report, DESY internal (2013).

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