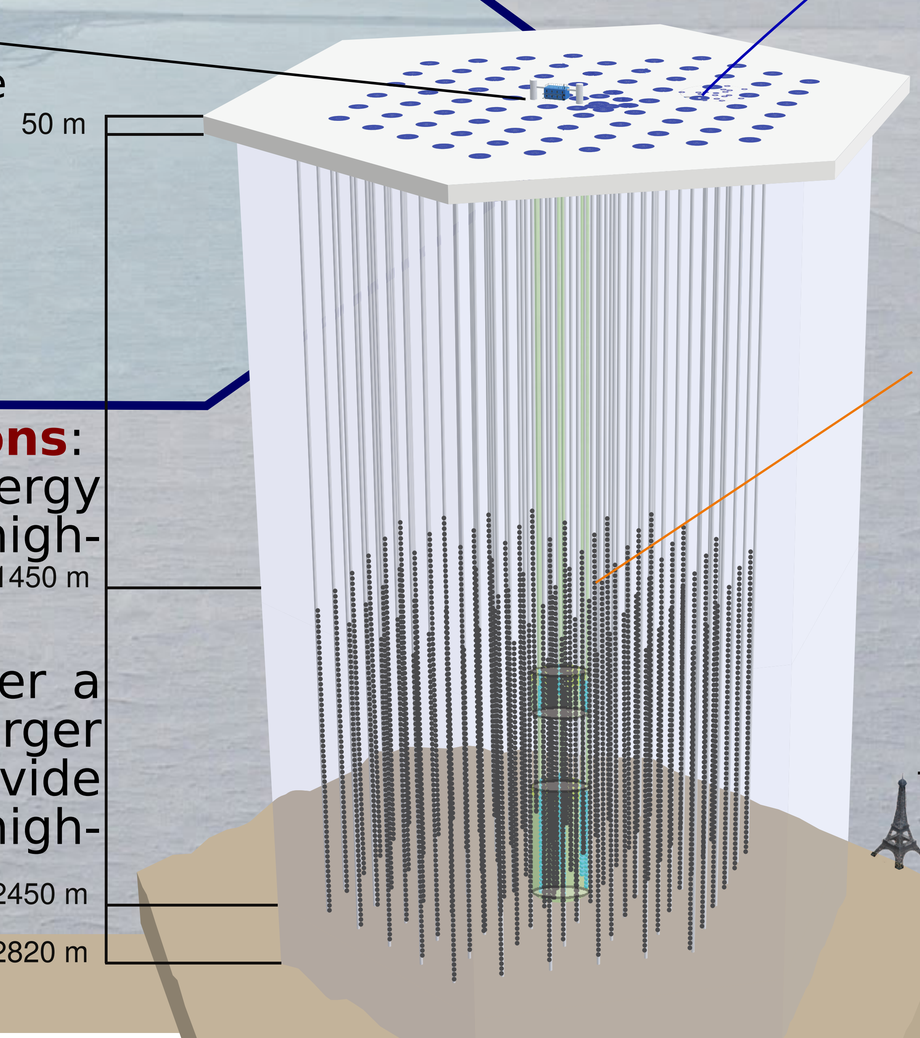
IceCube Neutrino Observatory : Particle Physics at South Pole

UNIVERSITEIT GENT

The **IceCube Neutrino Observatory** is the world's largest neutrino detector, located at the geographic South Pole, close to the **Amundsen-Scott South Pole Station.**

IceTop surface array consists of 81 stations, composed of 2 tanks equipped with pairs of Digital Optical Modules (DOMs) and spread over 1 km² on the Antarctic plateau.

All raw data are collected in one place : the **IceCube Lab.** There are first level real-time reconstruction and selection performed before sending interesting data back to North.



The **IceCube Array** consists of 5160 Digital Optical Modules (DOMs) deployed on 86 strings up to 2.5 km deep in the Antarctic Ice, covering a volume of 1 km³!

DeepCore (2009) : 8 strings with denser spacing

The IceCube future **extensions**:

- **PINGU** will be a low-energy infill extension to target high-energy neutrino oscillations.
- **IceCube-Gen2** will cover a volume of 10 km³ with larger strings spacing to provide unprecedent view of the high-energy Universe.

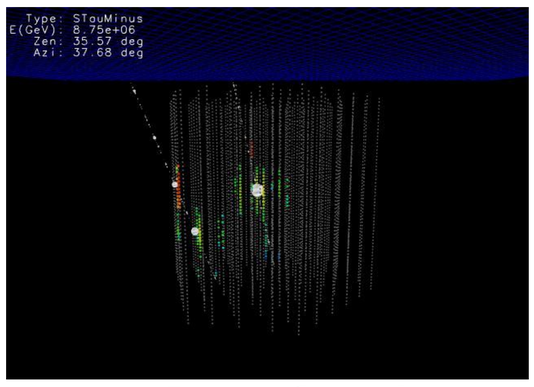
IceCube : SuperSymmetry

Supervisor: Ward Van Driessche

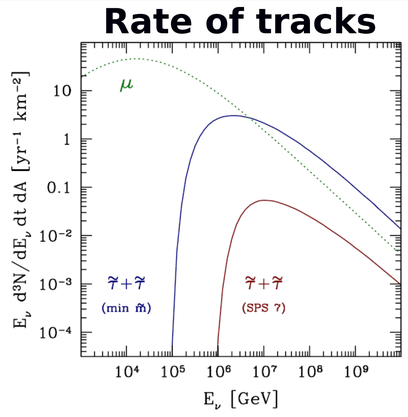
Why : Study SuperSymmetry (SUSY) theories that extend the Standard Model of Particle Physics, by searching for long-lived pairs of charged staus before they decay into stable Lightest SUSY particles.

How : IceCube has the ability to detect the two long parallel and well-separated tracks produced by staus pairs from SUSY interaction processes and descriminate them from the muon background.

What : Unique analysis focused on investigating and tuning the search parameters to optimize the signal to background ratio.



Rate of tracks



IceTop : Cosmic Rays

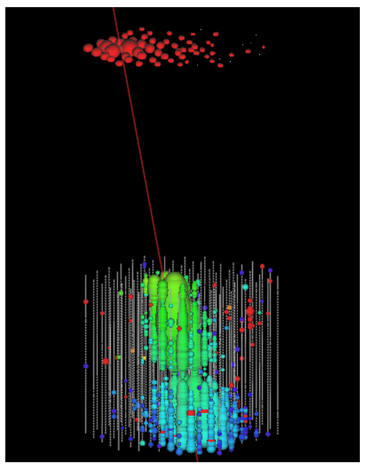
Supervisor : Mathieu Labare

Why : Study the energy spectrum and mass composition of primary cosmic rays (CR) from ~100 TeV to ~1 EeV.

How : Combining the energy deposited by CR showers in IceTop with the energy deposited by muons in IceCube.

What : Various possible contributions:

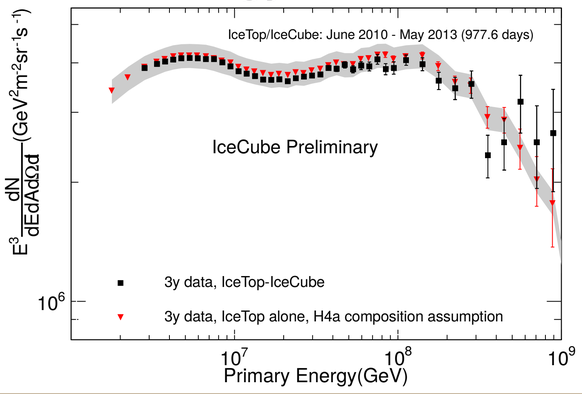
- Develop reconstruction tools.
- Investigate simulations for UHE CR
- Check sim/data agreement.



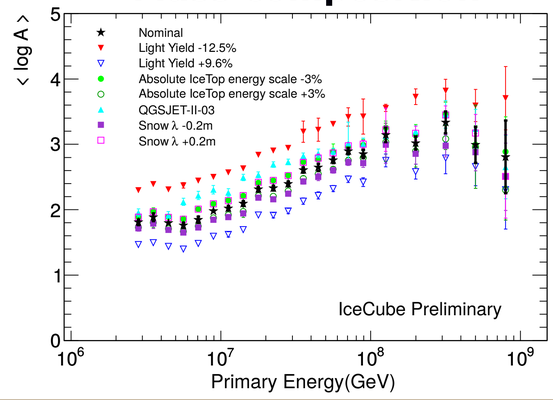
Cosmic ray event

early — Time scale — late

Energy spectrum

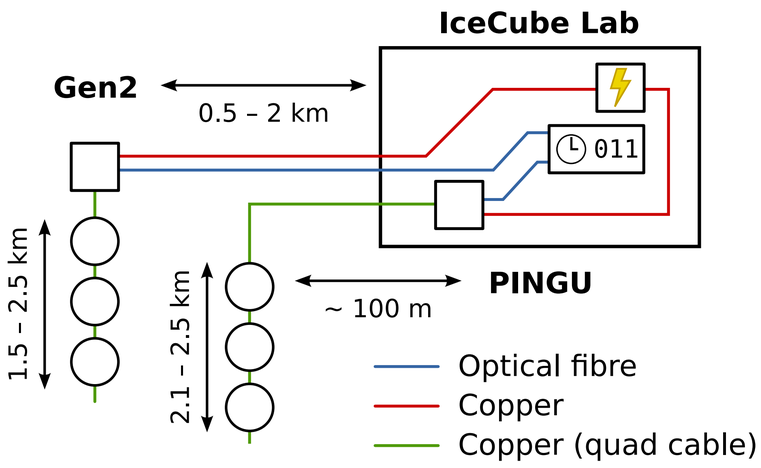


Mass composition



PINGU and Gen2 detector extensions : R&D

Supervisor: Sander Vanheule



Detector extensions require electronics update:

- More DOMs per cable, drop (noise suppressing) inter-DOM cabling,
- Frequency multiplexing and Quadrature Amplitude Modulation (QAM) to provide the needed transmission rates,
- Design implemented in firmware for new FPGA using VHDL and commercial development hardware.

Event reconstruction requires $\mathcal{O}$(5ns) timing resolution:

- Investigate new time synchronisation protocol on top of QAM,
- Implement in the FPGA firmware.