IceCube
Neutrino Astronomy
at South Pole

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1912  Victor Hess showed that Cosmic Rays come from beyond the atmosphere

1938  Pierre Auger detected CR of ~PeV with two cloud chambers placed a kilometer apart in the Alps

1962  John Linsley reported an event of $10^{20}$ eV (Volcano Ranch)

What are and where are the sources of Cosmic Rays?
Why IceCube?

IceCube is a supernova detector!
High Energy Phenomena for Neutrino Telescopes

- SuperNova Explosions
- Atmospheric Neutrinos
- SuperNova Remenants
- Gamma Ray Bursters
- Active Galactic Nuclei
- Dark Matter Candidates (WIMPs)
- Magnetic Monopoles
- Topological Defects
- GZK-Neutrinos
The IceCube Detector

A cubic kilometer of ice instrumented with:

- 80 Strings (9 deployed)
- 4800 Digital Optical Modules
- 17m between Modules
- 125m between Strings

Plus an Air-Shower Array:

- 80 Pairs of Ice-tanks

Includes AMANDA:

- 19 Strings
- 677 Optical Modules

Possible Future Extension:

- 10km x 10km Radio- and Acoustic Array

A Neutrino Observatory at South Pole
Muon tracks with a pointing resolution of $\sim 2^\circ$

Cascades with a pointing resolution of $\sim 30^\circ$

CC ($\nu_e, \nu_\tau$), NC ($\nu_\mu, \nu_e, \nu_\tau$)

in addition:
- correlated noise for supernova neutrinos (low energy)
- bright events for UHE analyses
Searches for a Diffuse Flux

AMANDA:
1) upward muons (1997)
2) upward muons (2000)
3) Cascades (2000)
   Astrop Ph 22 (2004)
4) UHE (1997)
   Astrop Ph 22 (2005)
6) UHE sensitivity (2000)
7) upward muons (4 years)
   Phys Scripta T121(2005)
8) RICE (2006)

Baikal:
At > PeV huge muon range
Large energy depositions
→
very bright events

Earth opaque →
Signal concentrated at horizon

MC 2.6 · 10^{19} \text{eV}

Experiment

MC 4.4 · 10^{18} \text{eV}
Extensive investigation of systematic uncertainties. (Ice properties, CR primary composition, Muon propagation...)

Background simulation describes data on all rejection levels

1997 data:
\[ N_{\text{bgr}} = 4.6 \pm 1.2 \] events
\[ N_{\text{exp}} = 5 \] events

Current analysis with A-II (2000)
Simulated UHE event as seen in AMANDA-B10
...and in IceCube
Point Source Search – Skyplot 2000-03

4 years of data taking

3329 upward going neutrinos

small contribution from fakes (<5%)

Search for an excess of events

- from a set of 33 selected sources

- in the full northern hemisphere
Highest significance is 3.4 $\sigma$

The probability of such an excess (or higher) is 92% in this analysis

Selected source analysis:
- Highest excess (Crab Nebula): 10 events seen, 5.4 expected (64% chance probability)

Distribution of events compatible with atmospheric neutrino background
Future IceCube Extensions

For neutrino detection at extrem high energies (GZK scale) one needs $\gg 1\text{km}^3$

Radio detection:
   Attenuation length $\sim 1$ km
   **RICE** detector

Acoustic detection:
   Attenuation length up to 10 km?
   Untested in ice

**SPATS project**

1 Week System Test at Torneträsk, North Sweden
South Pole Acoustic Test Setup

3 Strings
21 Transmitters
21 Sensors
Between 80m and 400m
Parasitic in IceCube Holes

Feasibility of Acoustic Detection at South Pole

SPATS string setup
SPATS DAQ System

- Power Supply + String-PC
- Transmitters (10kHz)
- Sensors (x3)
- Experiment Control (Laptop with Physicist)
- Heavy wind protection
SPATS – Signal over 800m

Sensor at 800m distance from Transmitter
For neutrino detection at extrem high energies (GZK scale) one needs $>>1\text{km}^3$

Combine optical, radio and acoustic detection

Hybrid detector with coincident events will help to establish the new technologies

90 strings
200 acoustic and 5 radio detectors

String distance $\sim1\text{km}$

IceCube as core for a large hybrid array
After the last season we are confident that IceCube will be built on schedule

- in 2011 a cubic kilometer of ice is instrumented
- the combined instrument IceCube with AMANDA has >1200 optical modules
- Data taking of the combined detector is ongoing
- Analysis has started

AMANDA took 9 years of data

- All analysed data is compatible with atmospheric neutrinos
- Covers an energy range of 100 GeV to \( \sim 10^{18} \text{eV} \)
- Will continue as “dense” core of IceCube

An acoustic test setup was developed

- A week of successful outdoor tests has been performed
- Will be deployed this season

A hybrid detector will enable measurement of GZK neutrinos

Such an extension would turn South Pole into a large neutrino observatory
The IceCube Detector