Recent Results from IceCube

Erik Blaufuss - University of Maryland for the IceCube Collaboration TevPA 08 - Beijing

University of Oxford

University Utrecht

- Univ Alabama, Tuscaloosa
- Univ Alaska, Anchorage
- UC Berkeley
- UC Irvine
- Clark-Atlanta University
- U Delaware / Bartol Research Inst
- Georgia Tech
- University of Kansas
- Lawrence Berkeley National Lab
- University of Maryland
- The Ohio State University
- Pennsylvania State University
- University of Wisconsin-Madison
- University of Wisconsin-RiverFalls
- Southern University, Baton Rouge



The IceCube Collaboration

32 Institutions, ~250 members



Neutrino detection in ice







AMANDA (1995-2000) 19 Strings 677 Modules

IceCube Neutrino Observatory



IceCube Neutrino Observatory

2004-2005 : I String



IceCube Neutrino Observatory



IceCube Neutrino Observatory









A collection of through-going muons

Tue Jan 29 08:39:34 2008





An EeV event in IceCube40





An EeV event in IceCube40













Meters

Reflected Signal



Coincident muons





- IceCube large enough to observe multiple muons from different air showers in the same event.
- Grows to ~5% of events in full lceCube.
- Two down-going tracks can easily fake an upward going track!



IceCube at the South Pole







Life at the South Pole











Digital Optical Module (DOM)





10 inch Hamamatsu PMT Autonomous data collection Self triggering with 0.25 pe threshold Waveform sampling on main board: 300 MHz for 400 ns w/ custom chip 40 MHz for 6.4 µsec w/ 'fast' ADC Digital data packets sent to surface Time calibration with surface GPS with 2 ns resolution High voltage generated internally Low power consumption (3.5 Watts) Large dynamic range (500 pe / 15 ns) Integrated flasherboard with 12 LED Self calibrating Robust design - < 1% failure Expect 97% of DOMs operating in 15y



Digital Optical Module (DOM)





10 inch Hamamatsu PMT Autonomous data collection Self triggering with 0.25 pe threshold Waveform sampling on main board: 300 MHz for 400 ns w/ custom chip 40 MHz for 6.4 µsec w/ 'fast' ADC Digital data packets sent to surface Time calibration with surface GPS with 2 ns resolution High voltage generated internally Low power consumption (3.5 Watts) Large dynamic range (500 pe / 15 ns) Integrated flasherboard with 12 LED Self calibrating Robust design - < 1% failure Expect 97% of DOMs operating in 15y



Drilling and deployment









Drilling and deployment















IceCube laboratory







- ICL is central data center for IceCube at South Pole
 - Opened in January 07
 - 17 racks of computers
- All cables and servers for IceCube DOMs, DAQ and online filtering
- All Level I filtering done at South Pole in real time and data sent north via satellite



Signal and backgrounds







Optimal detector at high energies







Effective area for neutrinos

-Sensitivity grows with detector -Not optimized for IC22/IC80 Signal begins to dominate at higher energies

Strings	Year	Livetime	µ rate	V rate
IC9	2006	I 37 days	80 Hz	1.7 / day
IC22	2007	275 days	550 Hz	28 / day
IC40*	2008	~365 days	1000 Hz	110 / day
IC80*	2011	~365 days	1650 Hz	220 / day
* Predicted				



Point sources: method and sensitivity





- Select good signal events
- Use unbinned maximum likelihood search

MACRO: ApJ 546, 2000 ANTARES, ICRC 2007 IC80, Astrop. Phys. 20, 2004





- 3.8 yr livetime
- 95% of RA-randomized skymaps have maximum significance > 3.38 $\sigma \rightarrow$ Not significant





IceCube 9 point source search



- 60% of randomized signal maps have maximum significance > 3.35
 - No significant excess found
- 26 a-priori source locations also searched, none show a significant excess



IceCube 22- Point Source Search



Hottest spot found at r.a. 153°, dec. 11° pre-trial p-value: 7×10⁻⁷ (4.8 sigma)

Accounting for all trials, p-value for analysis is 1.34% (2.2 sigma).

At this significance level, consistent with fluctuation of background. Full details are in Chad Finley's parallel presentation on Sunday



Moon shadow

IC40: April, May, June



h2 Entries 1404975

1.288

14.98

Mean

RMS

20

Cosmic Ray Flux



- Will be used to investigate detector angular resolution



10

Moon

 $(\alpha_{event} - \alpha_{moon})^* \cos(\delta_{event})$

0



- 7 year AMANDA data in good agreement with atmospheric neutrino models.
- IceCube 80 will collect ~60k atmospheric neutrinos/year
 - Study prompt high energy component of atmospheric neutrino flux
 - Search for new physics (violations of Lorentz Invariance)



Search for a diffuse flux





Search of 2000-2003 AMANDA data for an excess of cosmic neutrinos from unresolved point sources Comparing:

- Atmospheric neutrinos
- E⁻² signal

Phys. Rev. D 76, 042008 (2007)



Search for a diffuse flux





Phys. Rev. D 76, 042008 (2007)





Indirect solar WIMP searches

- Search for neutrino signal from neutralino annihilation
 - $\chi\chi \rightarrow W^+W^- \rightarrow V$
- No observed excess constrains allowed MSSM models





Preliminary



IceCube as MeV SN ν detector



...first proposed by Halzen, Jacobsen & Zas, astro-ph/9512080





IceCube as MeV SN ν detector



...first proposed by Halzen, Jacobsen & Zas, astro-ph/9512080





Future Plans - The Deep Core





- Instrument the clear ice found in lower half of IceCube volume
- Extends IceCube sensitivity to neutrino energies below ~100 GeV
 - DOMs built using high QE PMTS
 - Rest of IceCube as veto
 - Replacement for AMANDA strings



Future Plans - The Deep Core





Future plans



- IceCube on track to be completed in 2011
 - Includes 6 additional Deep Core strings
- R&D work toward new detection techniques
 - Test modules for both radio and acoustic EHE neutrino detectors have been deployed
 - See Timo Karg's talk in parallel session
- Multi-Messenger astronomy studies
 - Search for correlations of IceCube neutrino signals with observations in Fermi, Swift, ACTs, Milagro/HAWC, ROTSE, LIGO...



Other topics



- Cosmic ray physics with IceTop
 - Surface array of Ice-Cherenkov tanks
 - Study the composition and spectrum of primary cosmic rays in the knee region
- Neutrinos from GRBs
 - See talk by Erik Strahler in parallel session
- Exotic particle searches
 - See talk by Alex Olivas in parallel session





Summary



- IceCube construction is 50% complete
 - Construction of entire array, including addition of Deep Core detector, will be complete in 2011
 - IceCube40 detector currently operating and returning analysis-ready data
 - 1 km³·yr exposure in 2009
- Analysis of IceCube data already well underway
 - Some IceCube22 results ready now and many more will be available soon