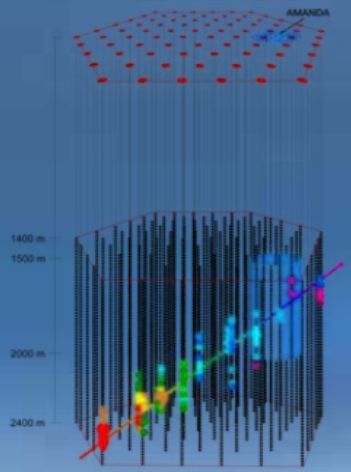
Status, Results & Prospects from IceCube at the South Pole

M.Ribordy

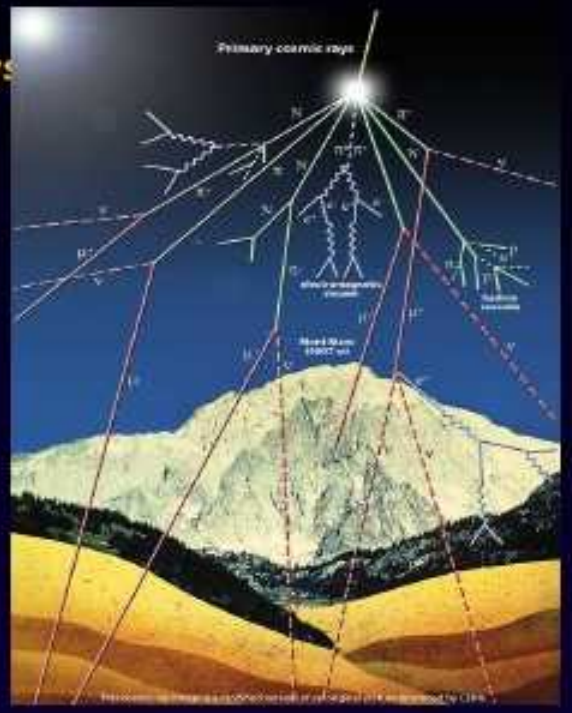


***CHIPP* plenary meeting**
PSI
15-16 Oct. 07

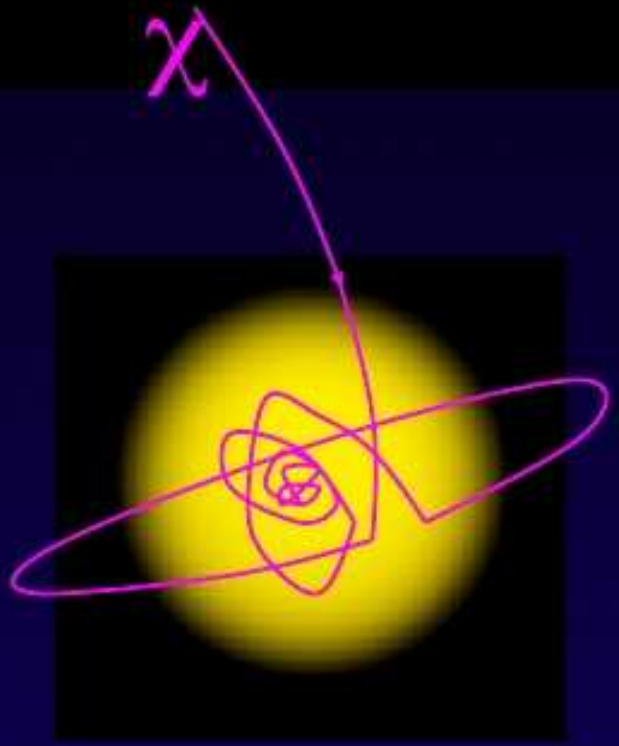
Neutrino sources @ > 100 GeV

Astrophysical Accelerators

CasA Supernova Remnant in X-rays



Cosmic Rays on atmosphere and on ISM or during propagation on CMB



DM annihilation

Neutrinos allow for observation of 'hidden regions' with possible compact accelerators (BH, pulsars, initial epochs of SN explosions). The penetrating power of νs is important also for moderately opaque sources from which we may be seeing γ spectra that are significantly distorted

The IceCube collaboration

Bartol Research Inst, Univ of Delaware, USA
Pennsylvania State University, USA
University of Wisconsin-Madison, USA
University of Wisconsin-River Falls, USA
LBNL, Berkeley, USA
UC Berkeley, USA
UC Irvine, USA

Clark-Atlanta University, USA
Univ. of Maryland, USA
University of Kansas, USA
Southern Univ. and A&M College, Baton Rouge, LA, USA
University of Alaska – Anchorage, USA
Institute for Advanced Study, Princeton, NJ, USA

EPFL Lausanne
Switzerland

DESY Zeuthen, Germany
Universität Wuppertal, Germany
Universität Dortmund, Germany
Humboldt Universität, Germany
MPIfK Heidelberg, Germany

Uppsala Universitet, Sweden
Stockholms Universitet, Sweden
University of Oxford, UK
Universiteit Utrecht, Netherland

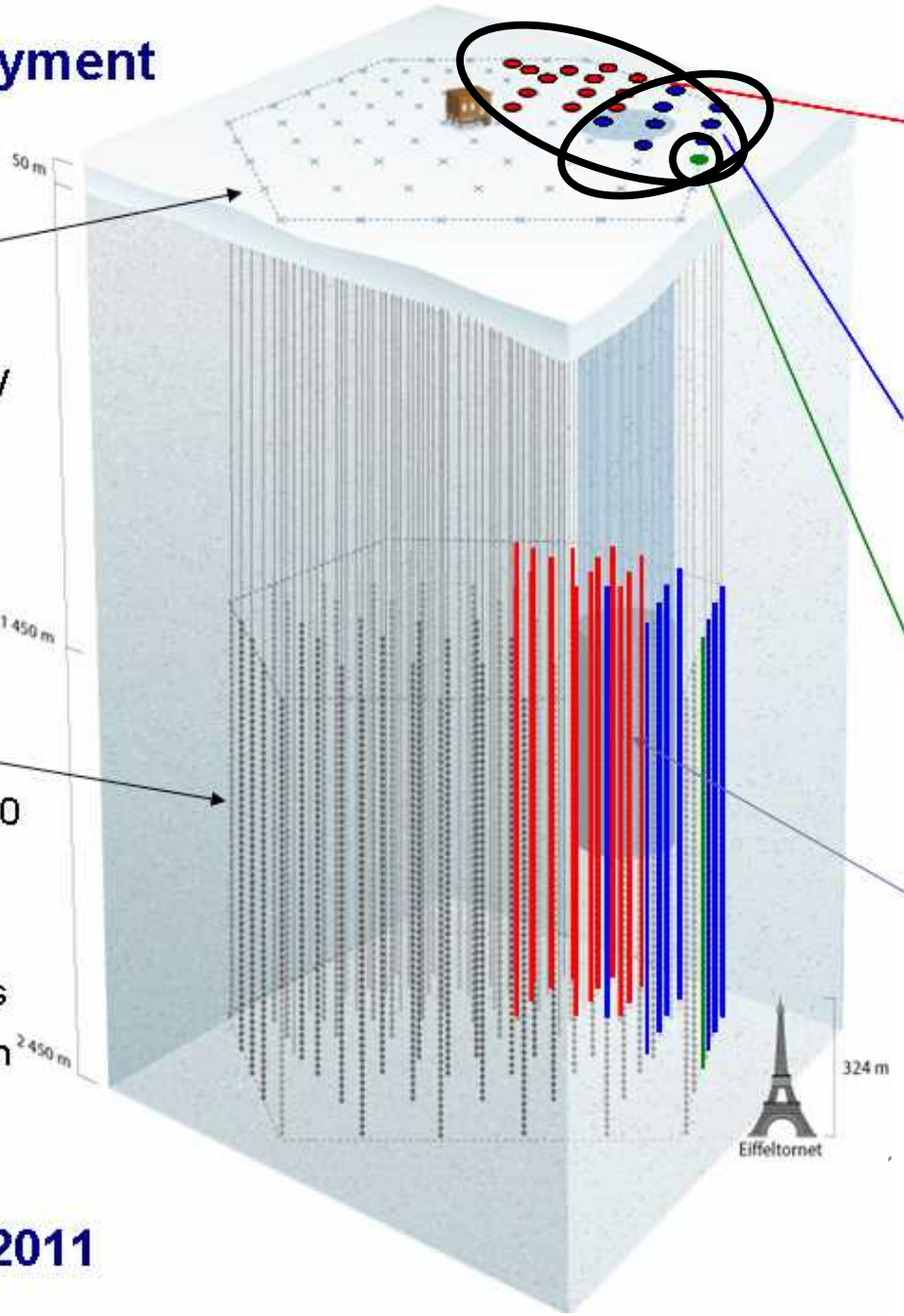
Université Libre de Bruxelles, Belgium
Vrije Universiteit Brussel, Belgium
Université de Mons-Hainaut, Belgium
Universiteit Gent, Belgium
Universität Mainz, Germany
RWTH Aachen Universität, Germany

Chiba University, Japan

University of Canterbury, Christchurch, New Zealand

Amundsen-Scott
Station, Antarctica

IceCube Deployment



IceTop

Air shower detector

Threshold ~ 300 TeV

InIce

planned 80 strings of 60 optical modules each

17 m between modules

125 m string separation

2006-2007:

13 strings deployed

Altogether: 22 strings

52 surface tanks

2005-2006: 8 strings

2004-2005 : 1 string

First data in 2005

first upgoing muon:

July 18, 2005

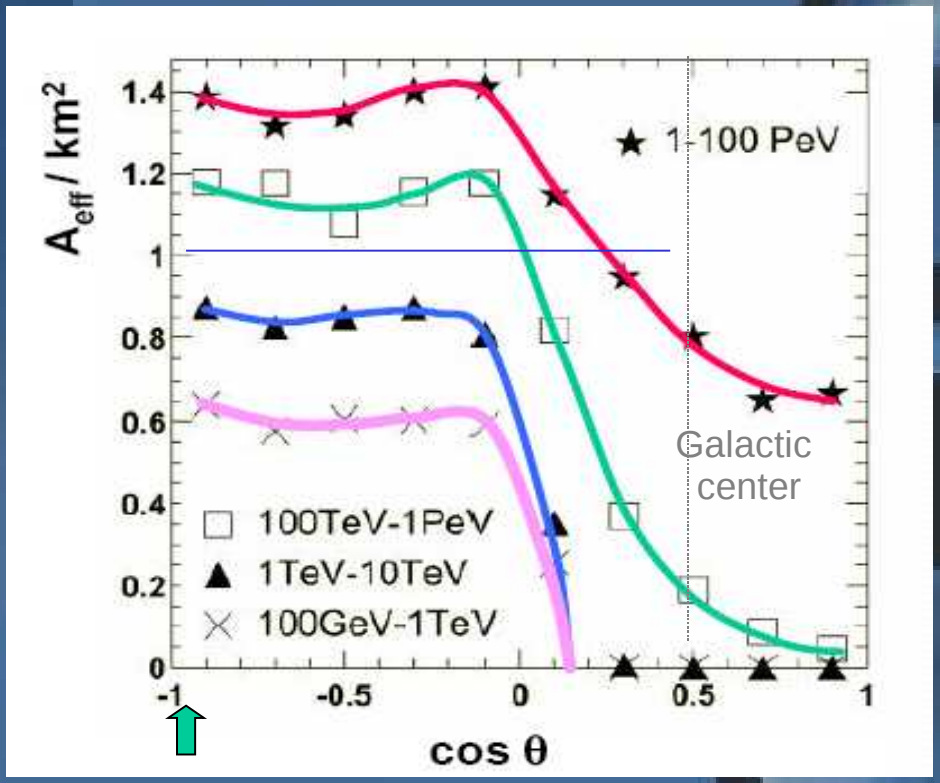
AMANDA

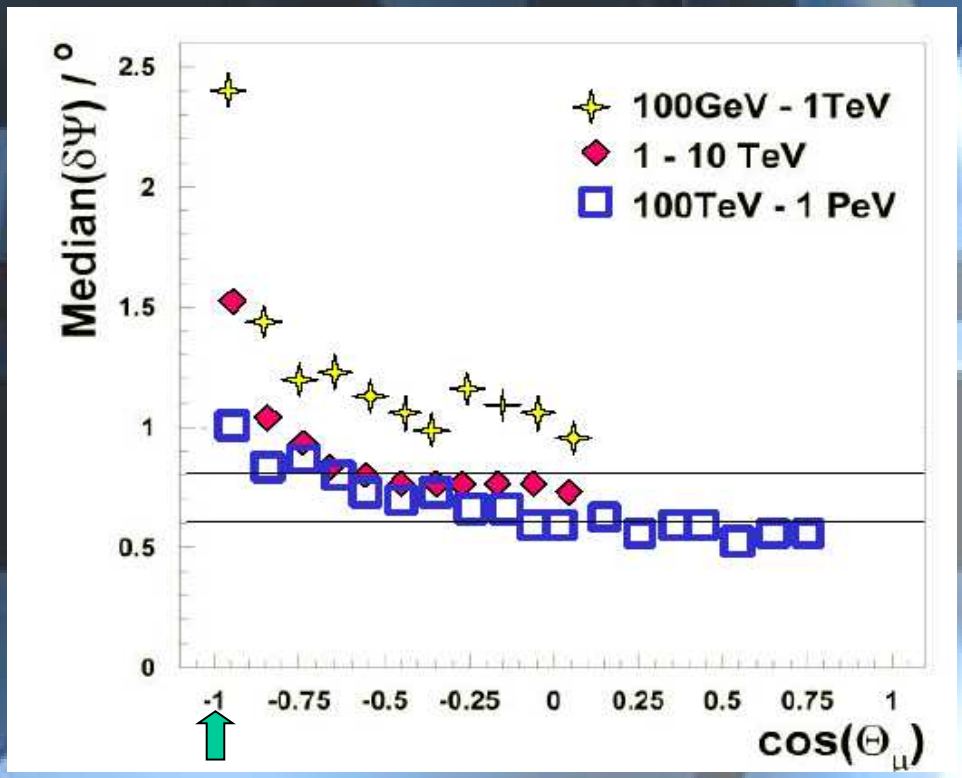
Integrated in IceCube

Completion by 2011

2007/2008: 14-18 strings & IceTop stations

Effective Area and Angular Resolution for Muons





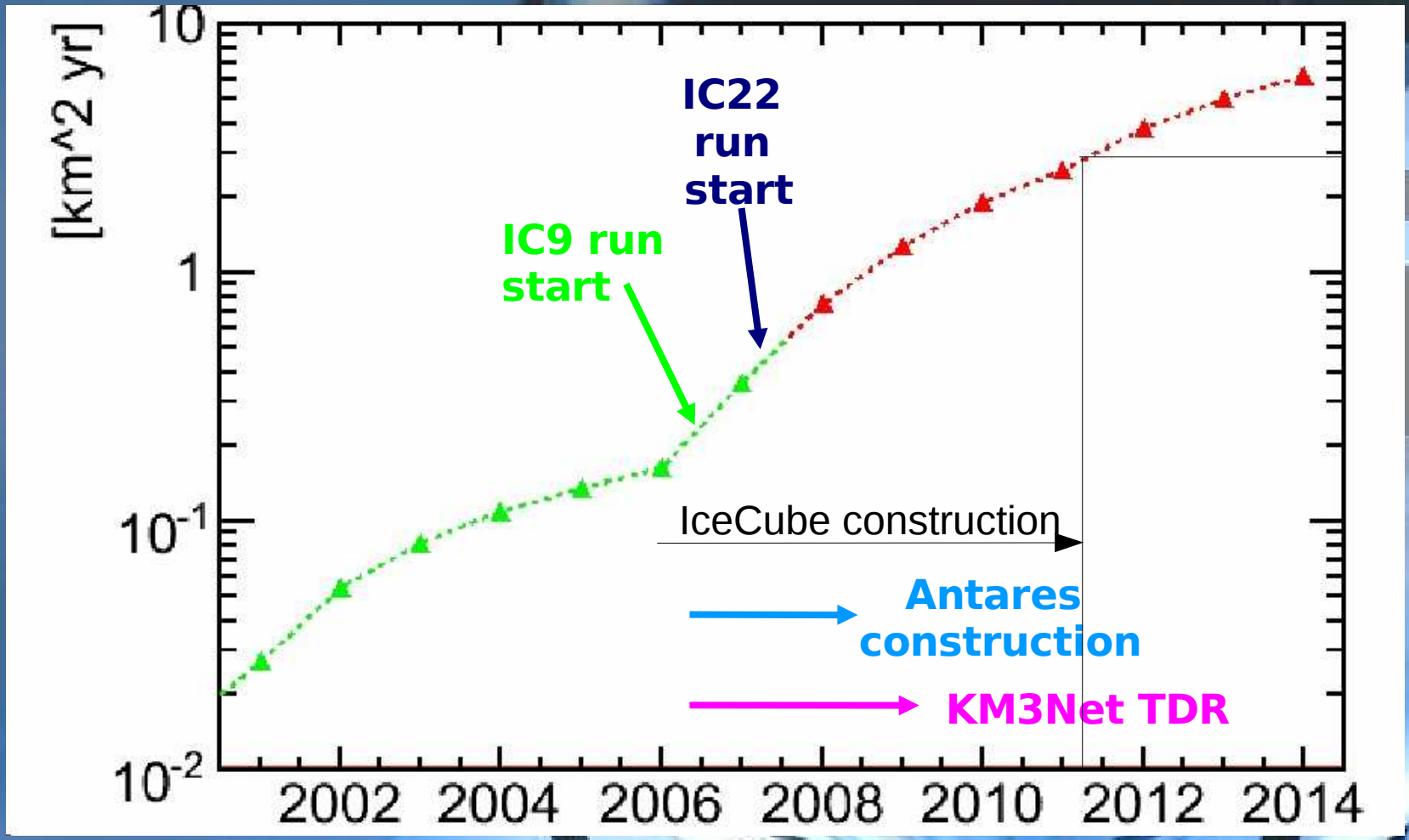
Effective Area:

- for a E^{-2} ν_μ spectrum
- at neutrino level

Energy resolution: $\sigma[\log_{10}(E_\mu)] \approx 20\% - 30\%$

Results from simulations for IceCube using the AMANDA hardware & software. Further improvment expected in near future

IceCube accumulated exposure at 100 TeV



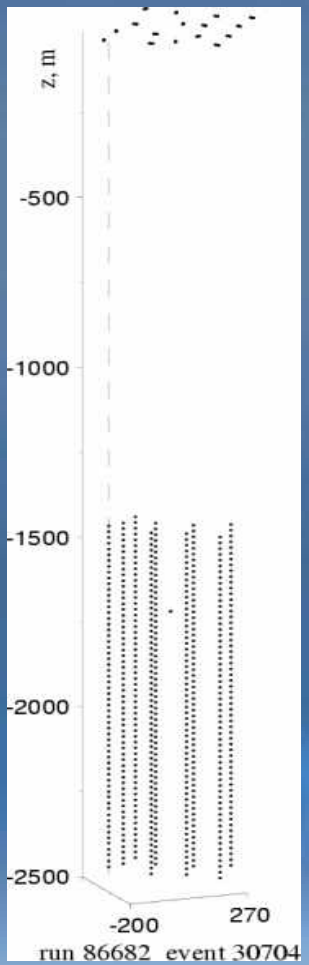
Effective area (muons)

Data Taking Status

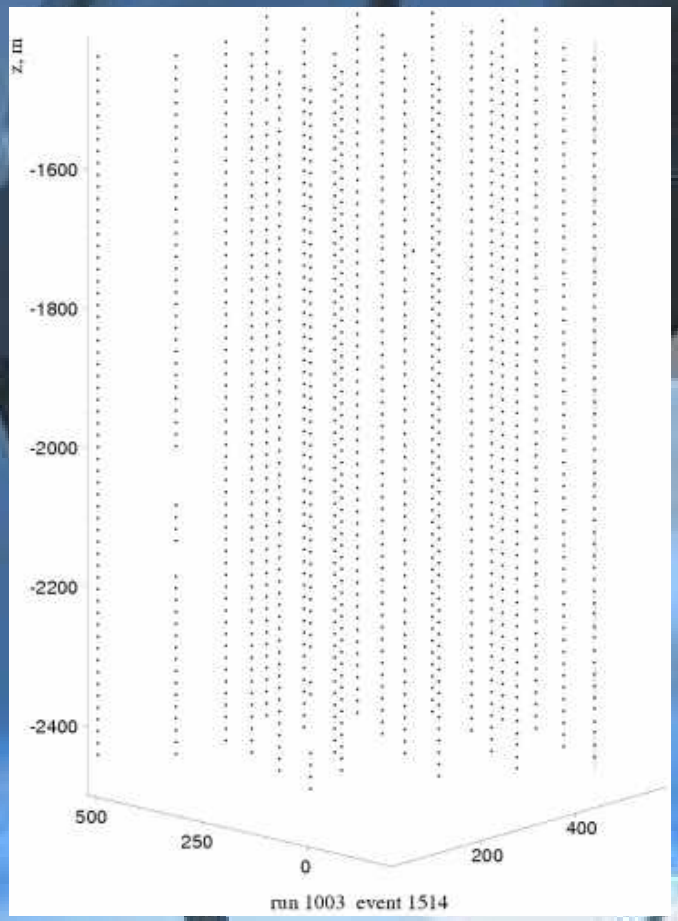
- *22 strings run since May 23, 2007*
- *98.5% of deployed DOMs are commissioned*
- *~96% live time*
- *Event rate ~600 Hz*

A few events...

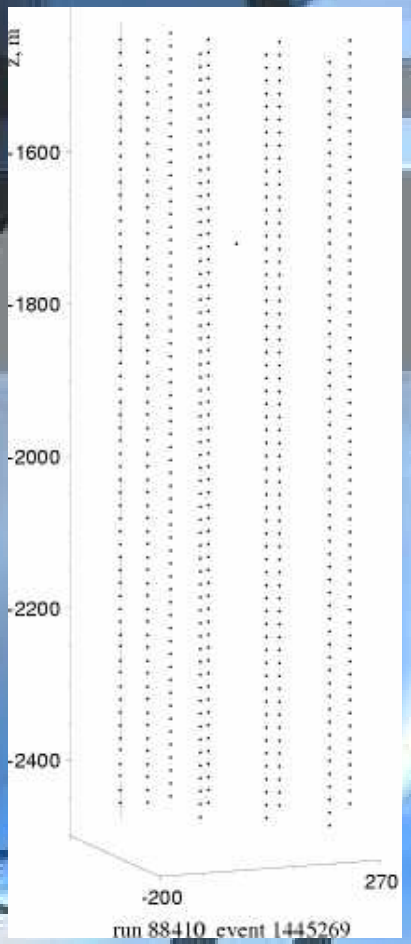
IceTop/in -ice coincidence



Muon event in IC22



ν candidate in IC9



Atmospheric neutrinos with IC-9

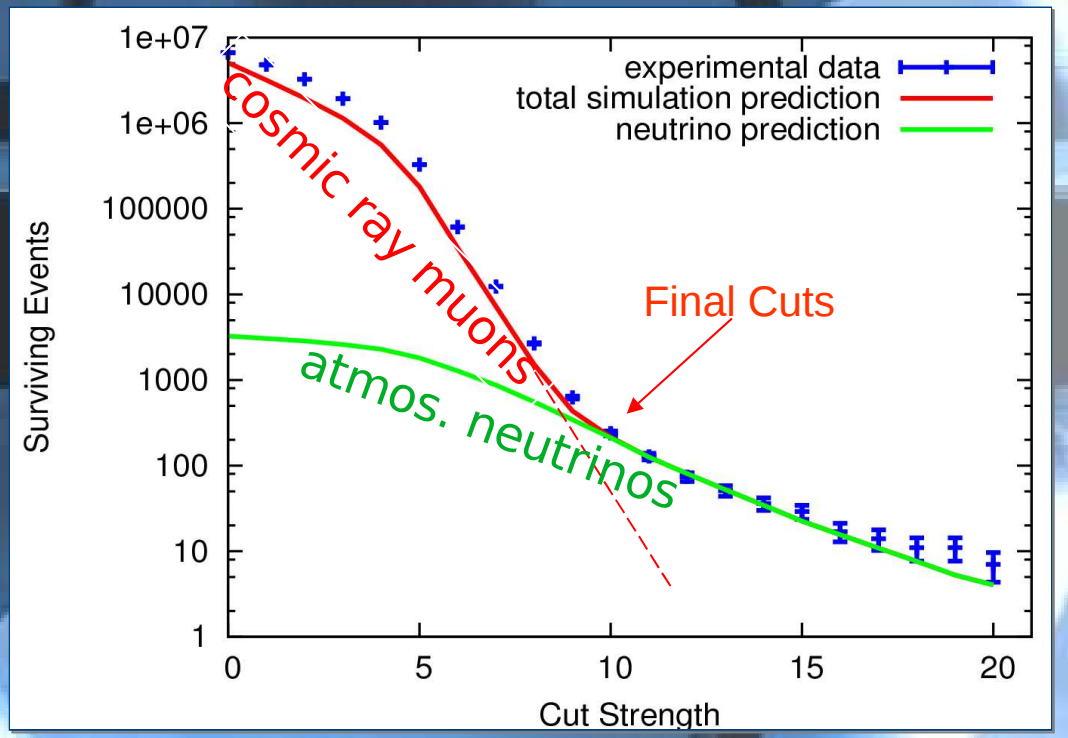
This analysis was an important step in qualifying IceCube:

- Hardware
- Offline software
- DAQ chain

Analysis:

- 137.4 days of live time (June – November '06)
- **Online filter:** Only up-going neutrino candidates sent North
- Waveform not exploited
- Simple quality selection parameter S:

$$S = \{ L_{track} , N_{direct\ hits} \}$$



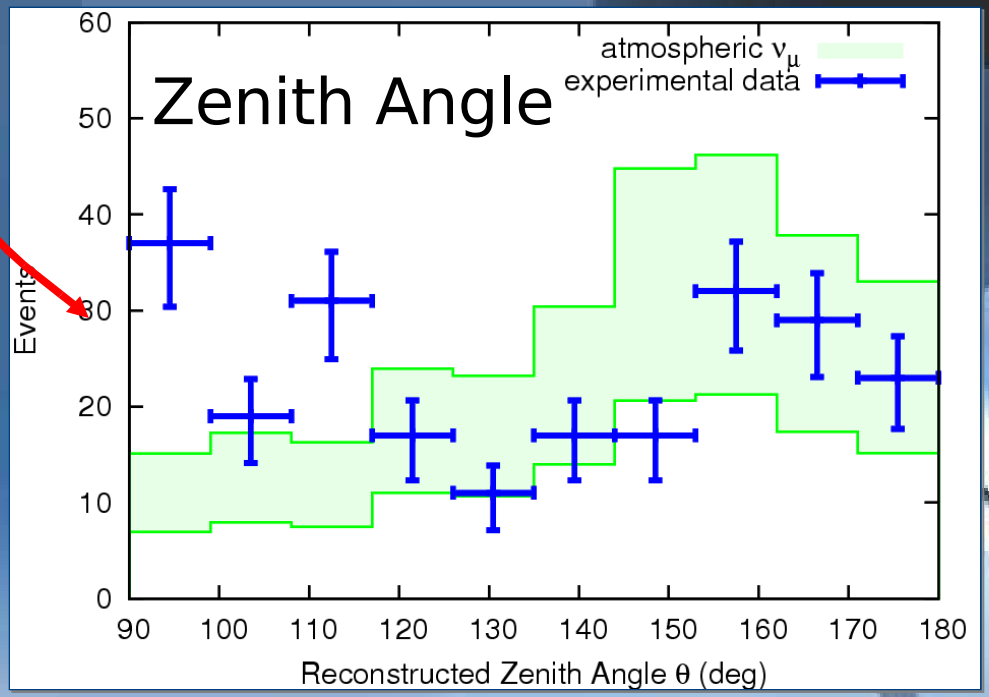
Results:

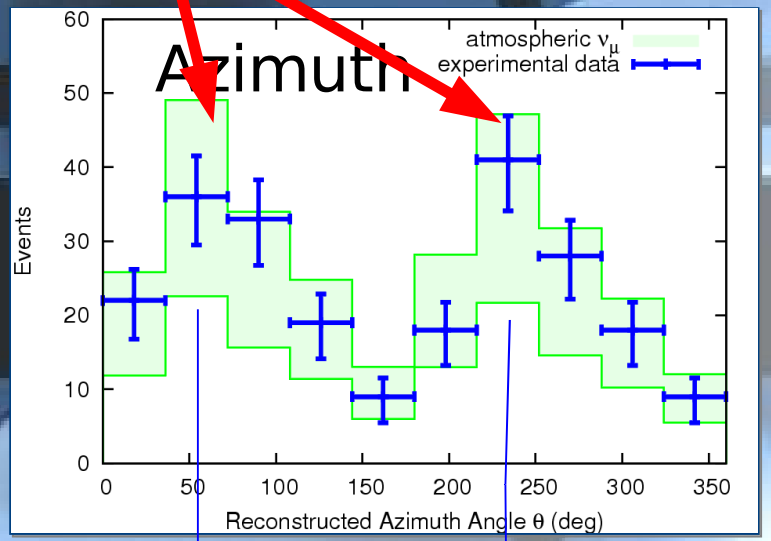
- 234 neutrino events (211 ± 76.1$_{syst}$ ± 14.5$_{stat}$ expected)
- Agreement in event rate over 6 decades

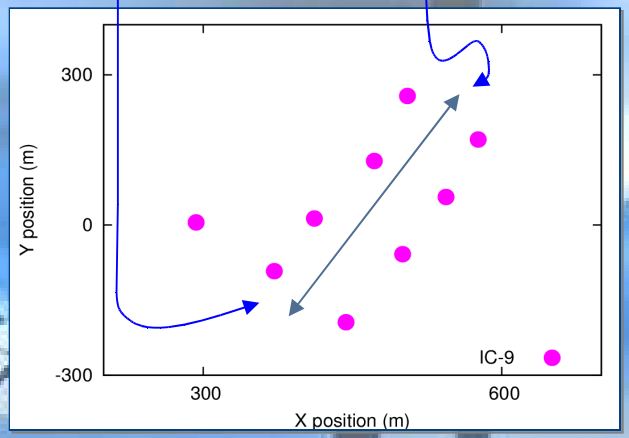
Atmospheric neutrinos with IC-9

- *Residual background near horizon (~10 % of total set), mostly coincident muons*
- *Peaks in azimuth along detector long axis*

Detector asymmetry







Point source search with IC-9

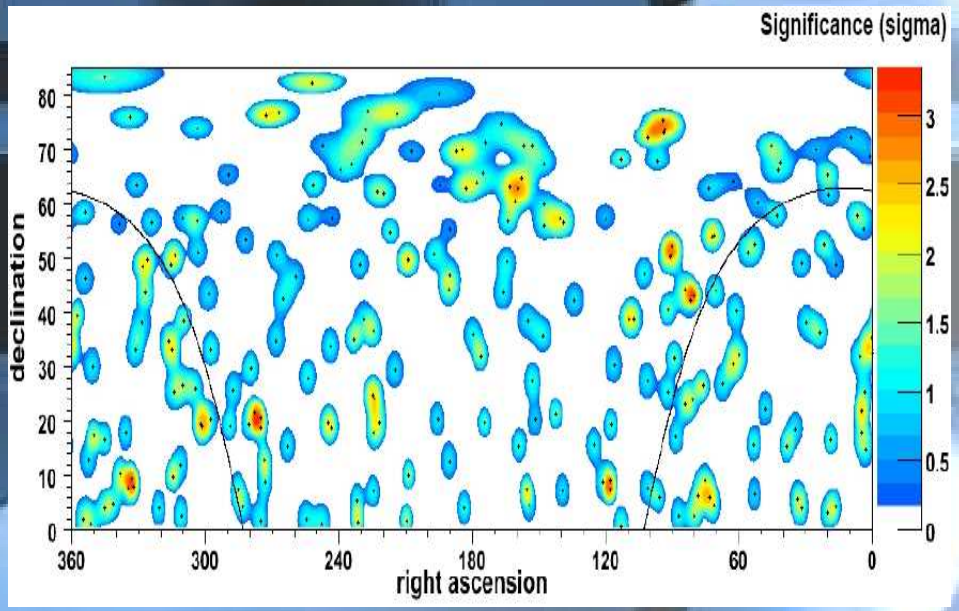
- same online filtering as previously
- neutrino event selection based on # of direct hits & angular res.
- optimized for max. discovery potential

Results:

- 232 isolated up-going neutrinos (~90% purity) --> No significant excess
- sky averaged sensitivity (E^{-2} spectrum):

$$d\Phi/dE = 1.2 \cdot 10^{-10}\ TeV^{-1}\ cm^{-2}\ s^{-1}\ (E/TeV)^{-2}$$

comparable to AMANDA ($V_{IC-9} \cong V_{AMANDA}$) for equivalent livetime given the detector configuration

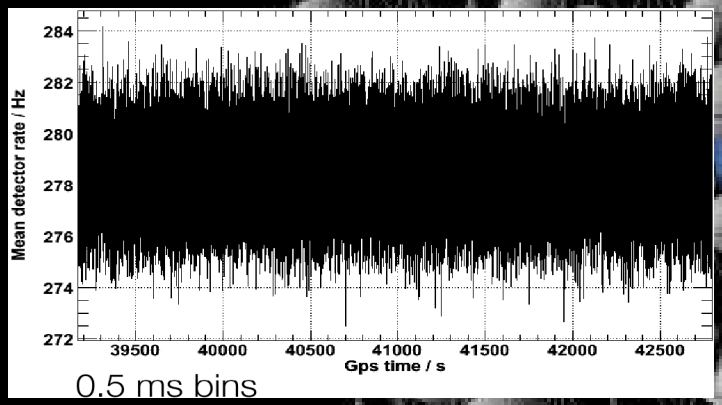


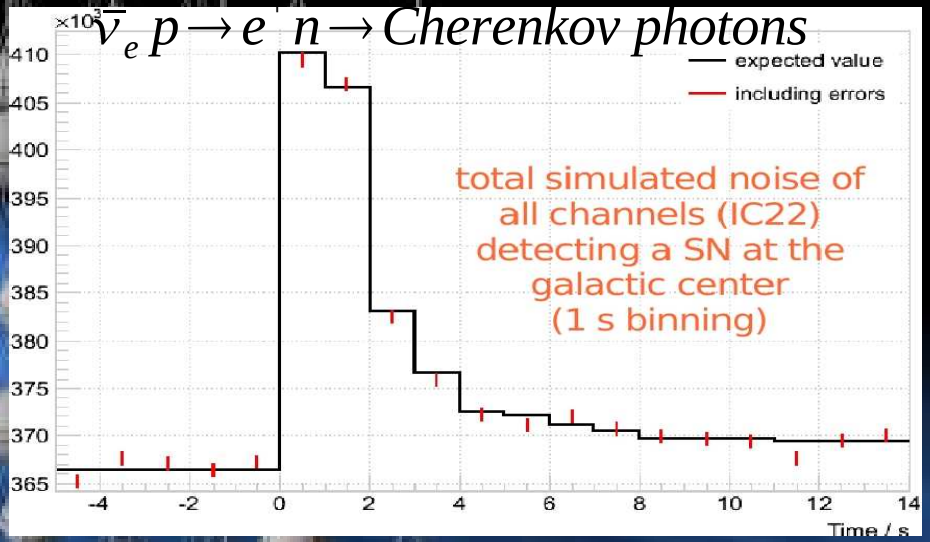
IC-22 is greatly improving that situation thanks to:
- the integration of AMANDA as a dense core
- a more uniform coverage & 4x larger instrumented volume

--> improvement of the neutrino selection efficiency

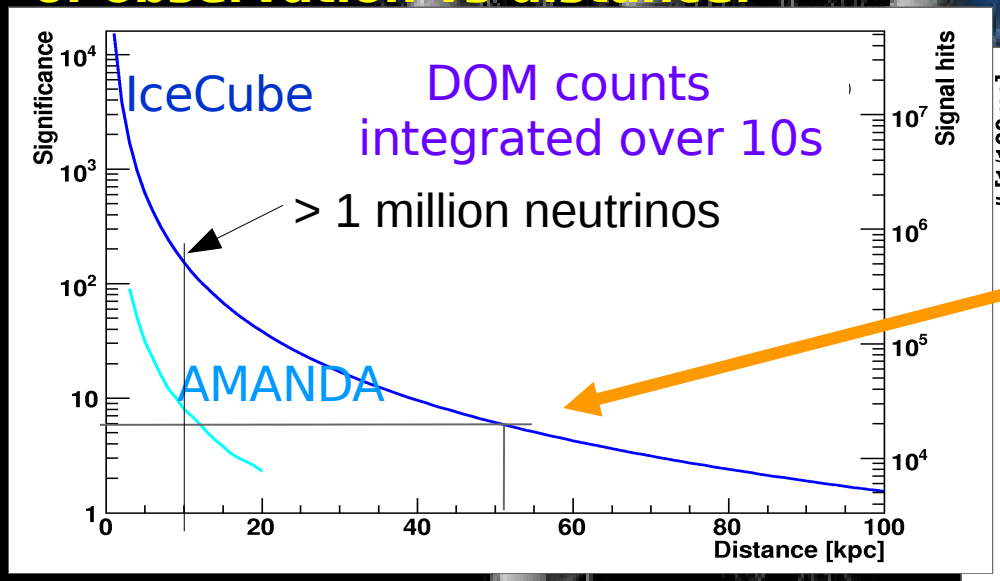
Supernovae

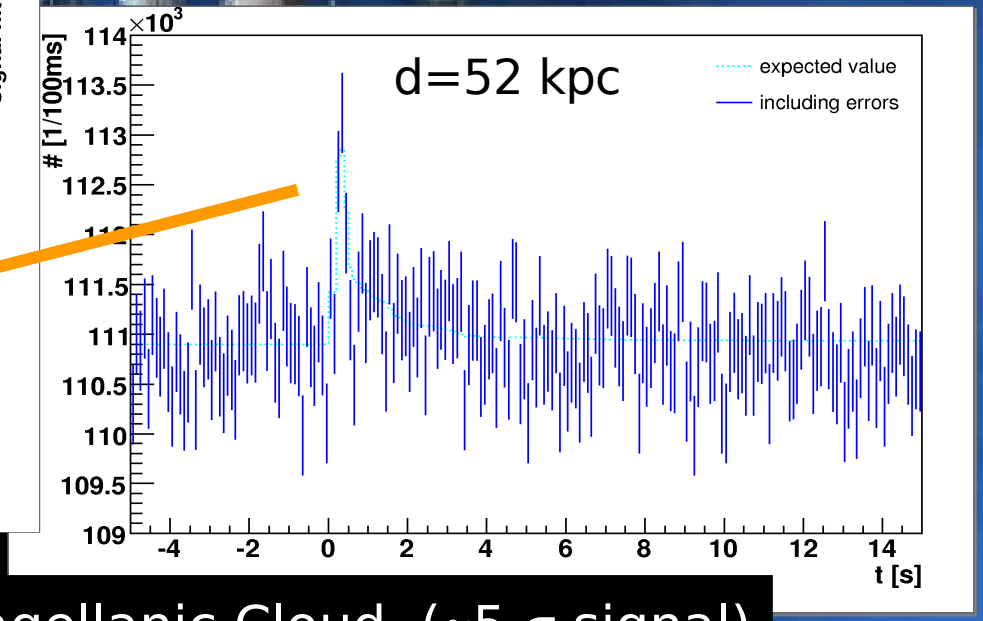
Noise profile (IC-22, April '07)





Significance of observation vs distance:





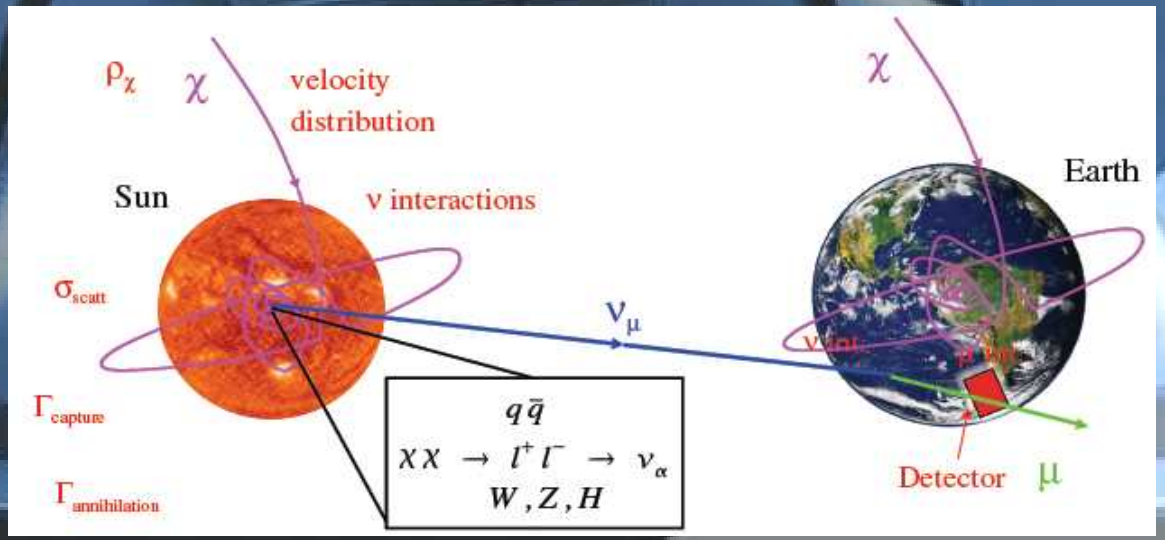
Visibility out to Large Magellanic Cloud (~5 σ signal)

IceCube is joining the Supernova alert system (SNEWS) this Winter

Prospects for IndirectDark Matter Seach

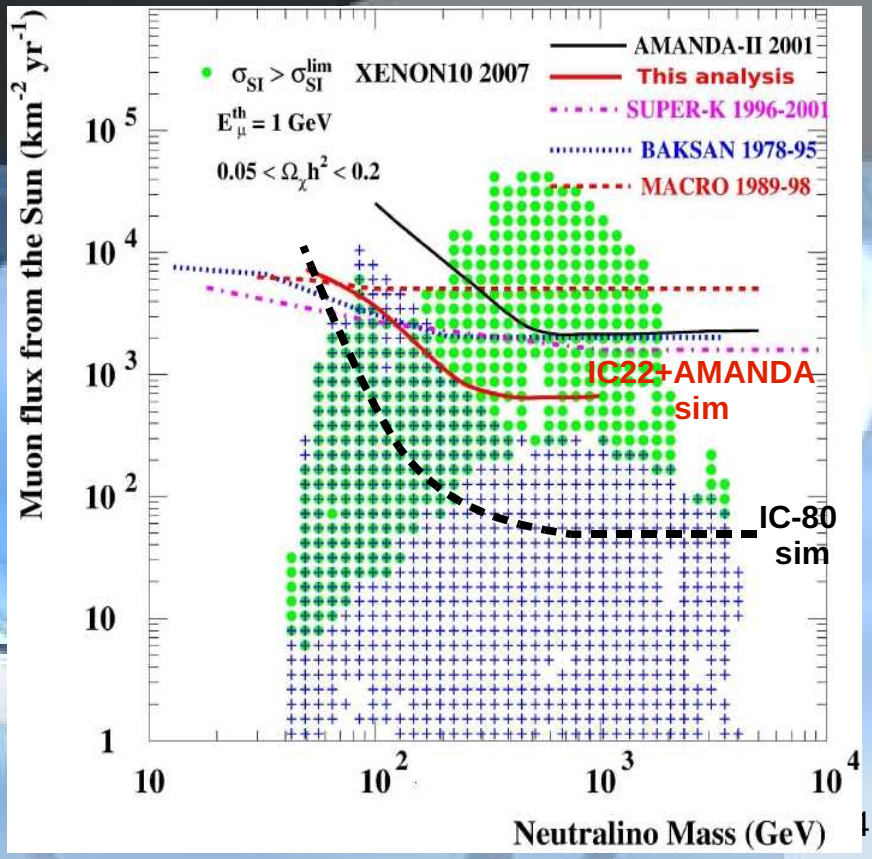
MSSM framework: neutralinos as CDM candidate

- Gravitationally trapped over astronomical time
- Pairwise annihilate in the center of the Sun

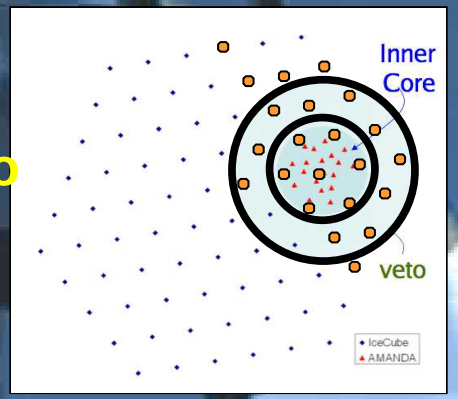


IC-22 + AMANDA II projection:

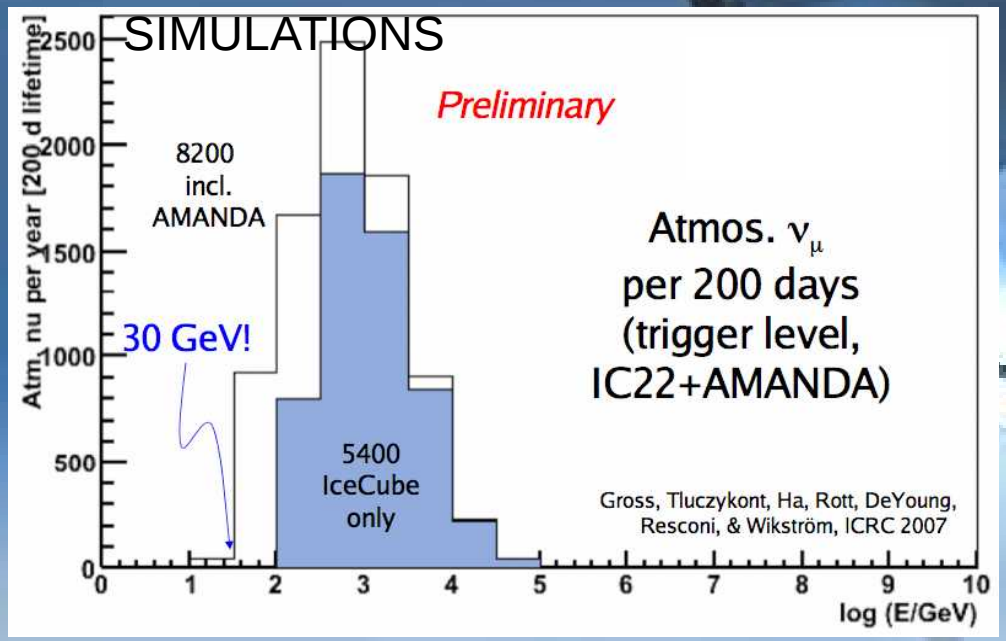
- Sensitivity enhancement to lower mass
- Scan over SUSY models & resulting muon flux (E_μ>1 GeV)
- IceCube best results

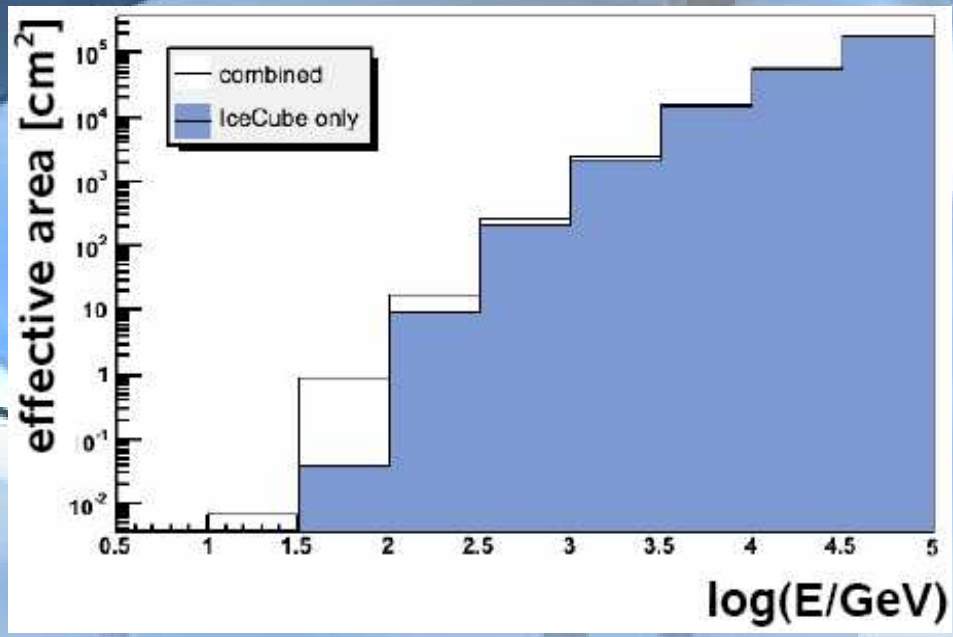


Low energy prospects

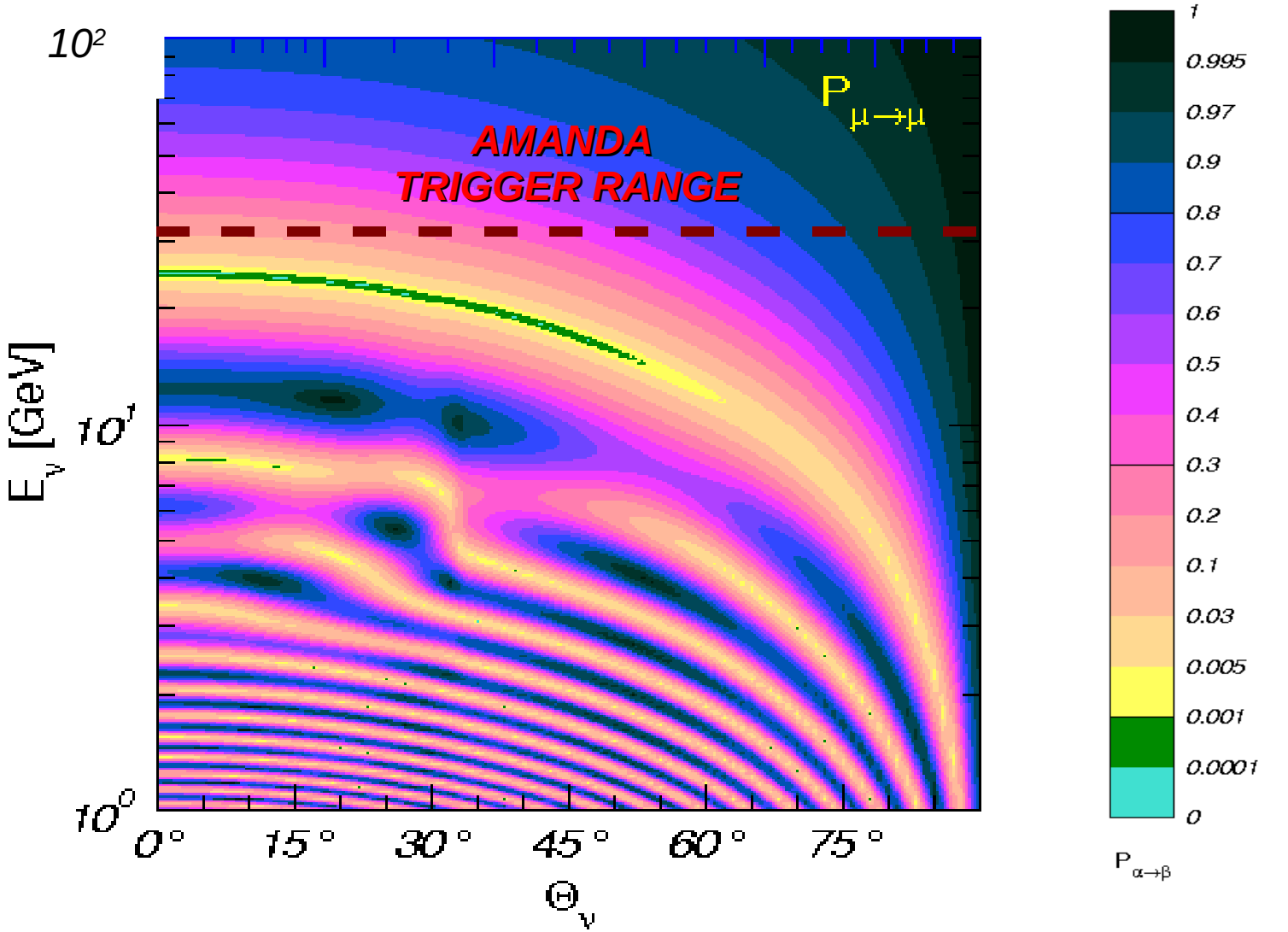


- **IceCube inner core (I7+All) for improved low *E* neutrino**
- **detection capabilities (E_ν > 30 GeV)**
- **Multiple physics interests, most notably:**
- - WIMPs search extended to low mass
- - Oscillations studies (access to LE, up VS down flux flux)
- - Point source in the Southern Sky in principle
- - Point source Search (source with steep spectra &/or cutoff at O(<10 TeV))
- - Variable point source by using time/space localization to reduce the LE background
- **using external IceCube strings (and upper sensor) as VETO & dense core for isolation of (partially) contained tracks or cascade**





Low Energy Prospects
Atmospheric Neutrino oscillations



Akhmedov, Maltoni & Smirnov, hep-ph/0612285

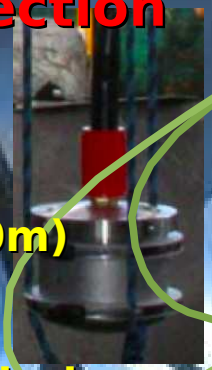
Beyond IceCube

Limited IceCube sensitivity to the guaranteed cosmogenic neutrino flux (N_{GZK} ~ 0.5 / yr)

Characterizing the cosmogenic flux is the key to understanding the UHECR:

- Distinguish between astrophysical and cosmological scenarios of UHECR origin
- UHECR observation alone does not uniquely determine injection spectrum & source evolution model

--> Extension of the detection volume to V ~ 100 km³



Prerequisites: large signal attenuation length (optical ~ 100m)

Possible solution:

- Coherent radio Cherenkov emission
- Ultrasonic acoustic pulse emission

with typical attenuation length of order km allowing for sparse instrumentation

Conclusions

- ***IceCube is running well:***
- ***- AMANDA integrated in DAQ chain***
- ***- Low energy potential is investigated***
- ***- R&D towards an hybrid radio-acoustic extension***
- ***- First atmospheric neutrino analyses published***
- ***- (Transient) point source, multimessenger analyses, ... will follow***
- ***- Can expect 250 days of livetime with IC-22***
- ***And a lot more neutrinos coming soon,***
- ***so... stay tuned***

IceCube discovery potential will be maximal in the next few years, as the statistics will dramatically increase during that time: by May 2011, the integrated effective area will correspond to ~3 years of the fully deployed array (including AMANDA as a dense low energy threshold embedded array)