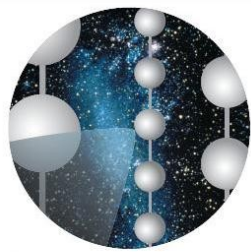




Vrije
Universiteit
Brussel



IceCube

Catching Neutrinos with an IceCube



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IceCube Collaboration



IceCube



University of Alberta



University of the West Indies



University of Alabama
University of Alaska, Anchorage
University of California, Berkeley
University of California, Irvine
Clark-Atlanta University
Bartol Research Institute, U. Delaware
Georgia Institute of Technology
University of Kansas
Lawrence Berkeley Natl. Laboratory
University of Maryland
Ohio State University
Pennsylvania State University
Southern University and A&M College
University of Wisconsin, Madison
University of Wisconsin, River Falls



Stockholms Universitet
Uppsala Universitet



Oxford University



Vrije Universiteit Brussel
Université Libre de Bruxelles
Universiteit Gent
Université de Mons



Chiba University



RWTH Aachen
Ruhr-Universität Bochum
Universität Bonn
DESY, Zeuthen
Universität Dortmund
MPIfK Heidelberg
Humboldt Universität, Berlin
Universität Mainz
BUGH Wuppertal



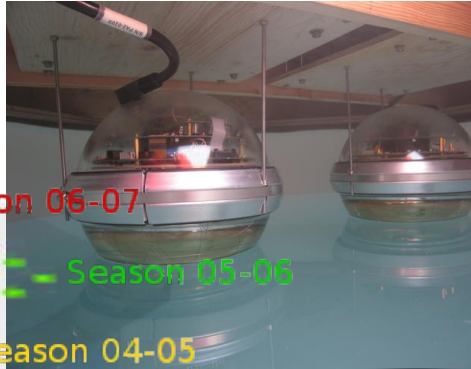
University of Canterbury



EPF Lausanne

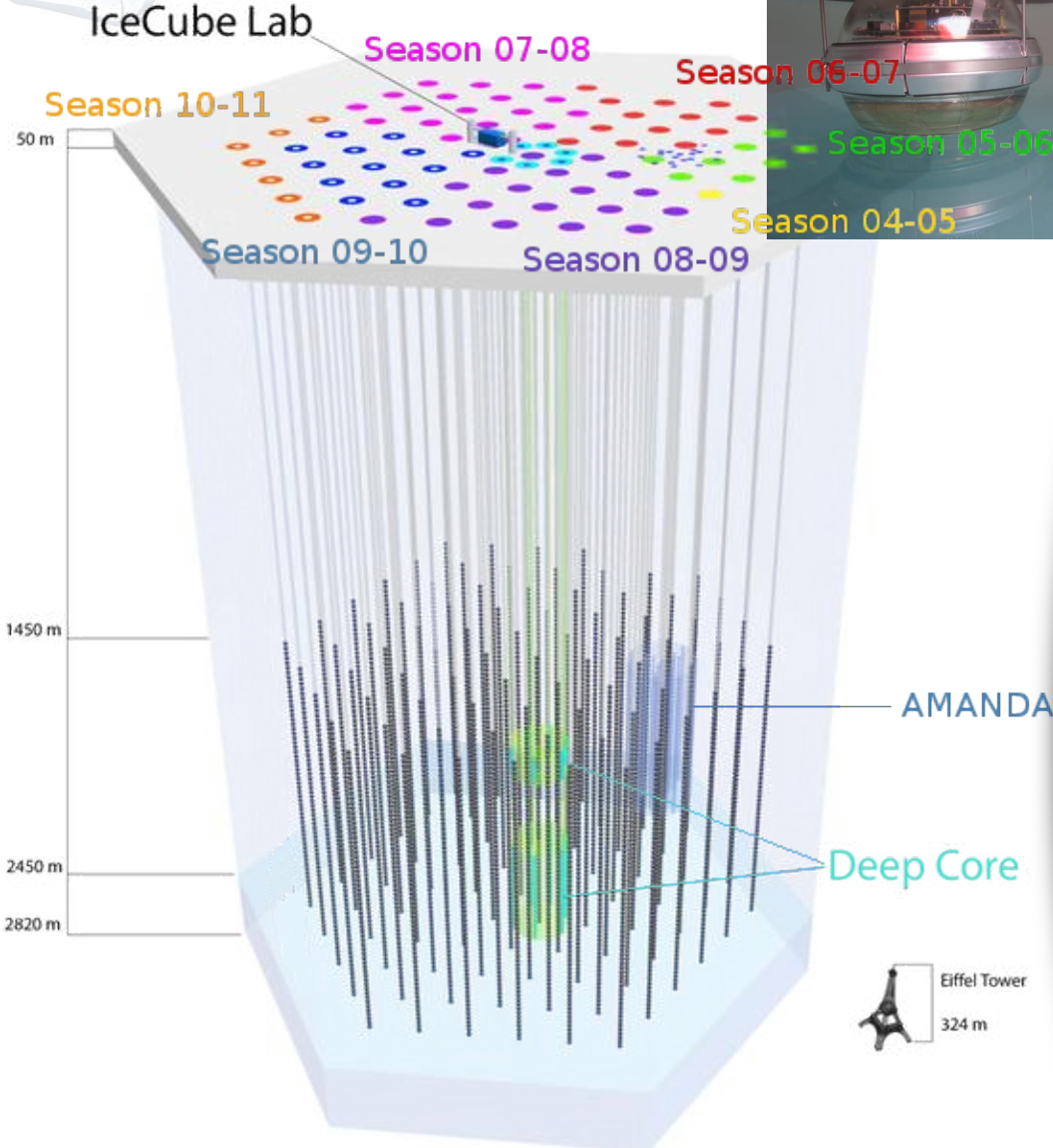


IceCube Neutrino Observatory



IceTop

80 stations composed of 2 Cherenkov tanks with 2 DOMs sensors per tank.



IceCube

86 strings of DOMs

Completed December 14th 2010 !

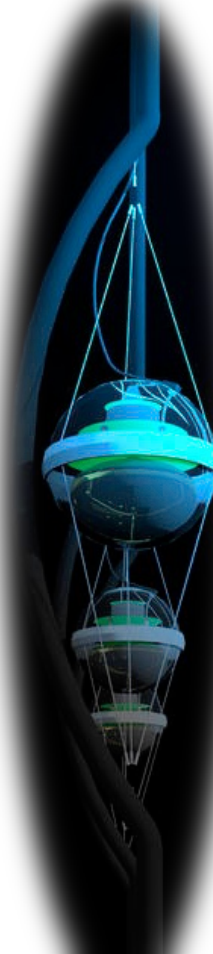
AMANDA

Shutdown in March 2009

DeepCore

8 strings of HQ-DOMs

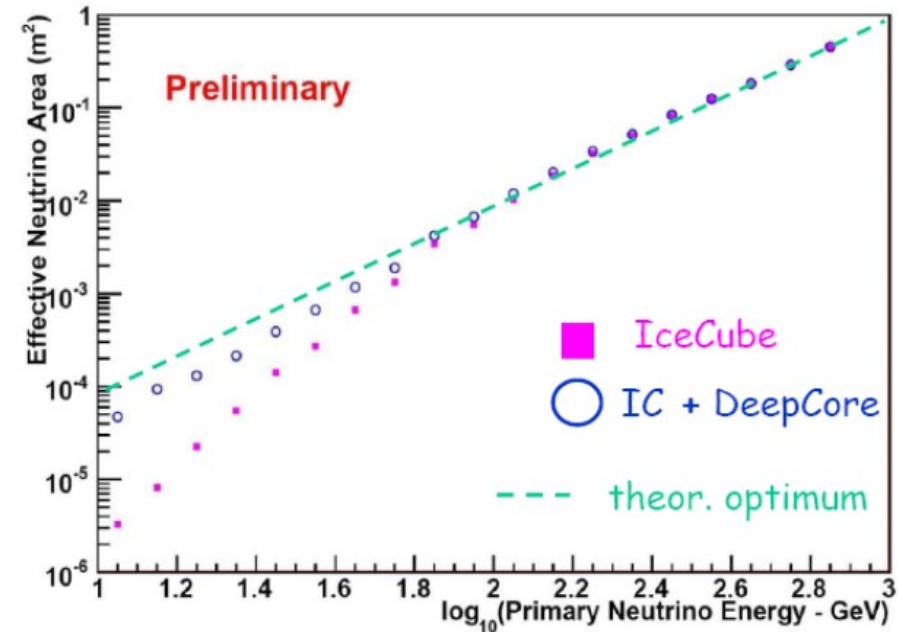
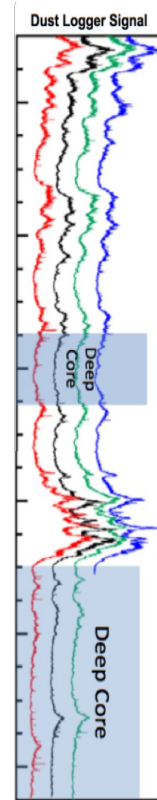
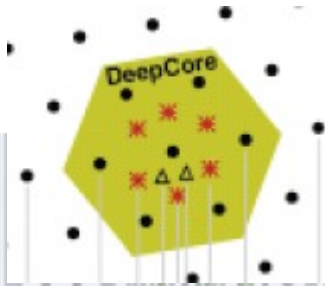
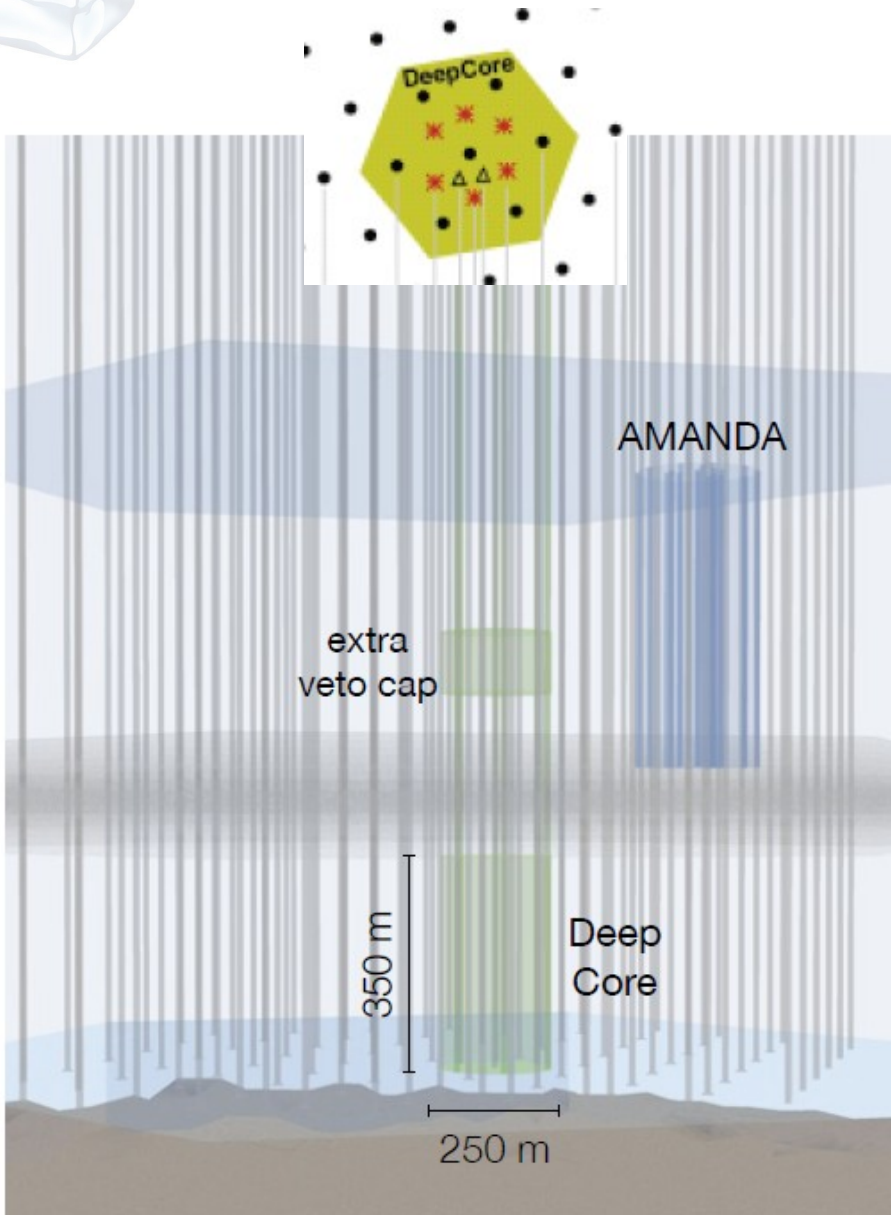
Completed in February 2010.





IceCube Neutrino Observatory

The DeepCore extension

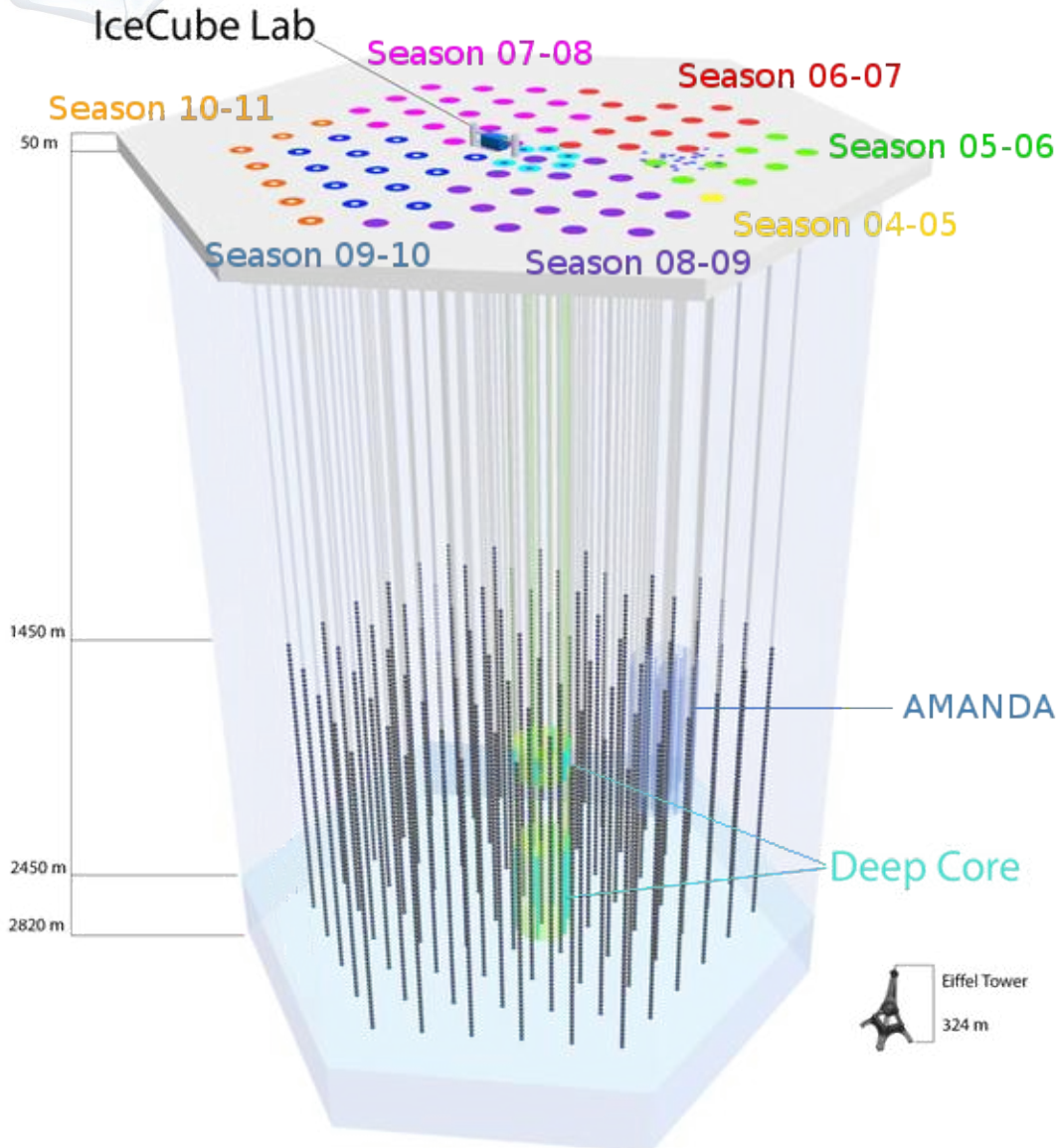


DeepCore
8 strings of HQ-DOMs
Low-Energy extension
Completed in February 2010.



IceCube Neutrino Observatory

Successive configurations



Season 04-05

First IceCube string deployed

Season 05-06 : IC-9

Season 06-07 : IC-22

- ▶ Cosmic Ray anisotropy
- ▶ Diffuse fluxes
- ▶ GRB observations

Season 07-08 : IC-40

- ▶ Moon Shadow
- ▶ Point Source search
- ▶ Diffuses fluxes (Prel.)
- ▶ GRB observations

Season 08-09 : IC-59

- ▶ GRB observations (Prel.)

Season 09-10 : IC-79

Season 10-11 : IC-86

IceCube is completed !



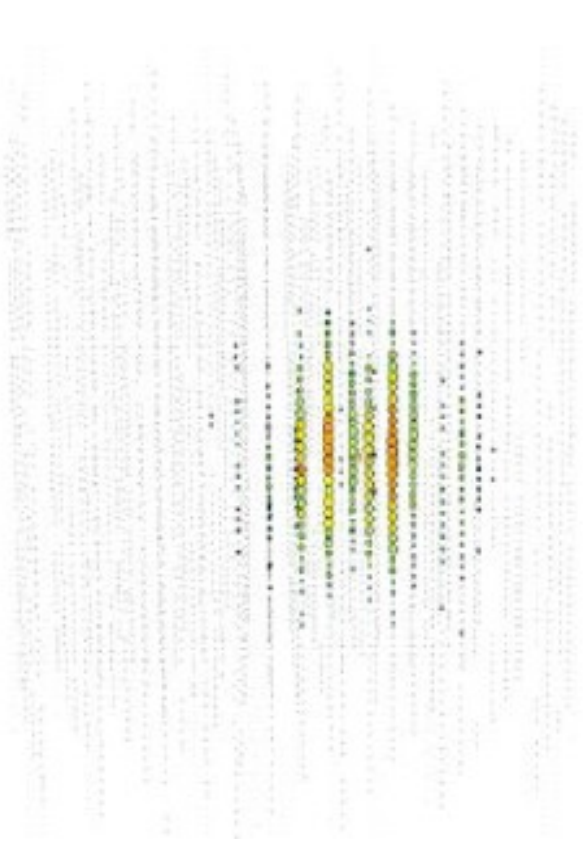
Signal in IceCube

Cherenkov radiation detected by optical sensors

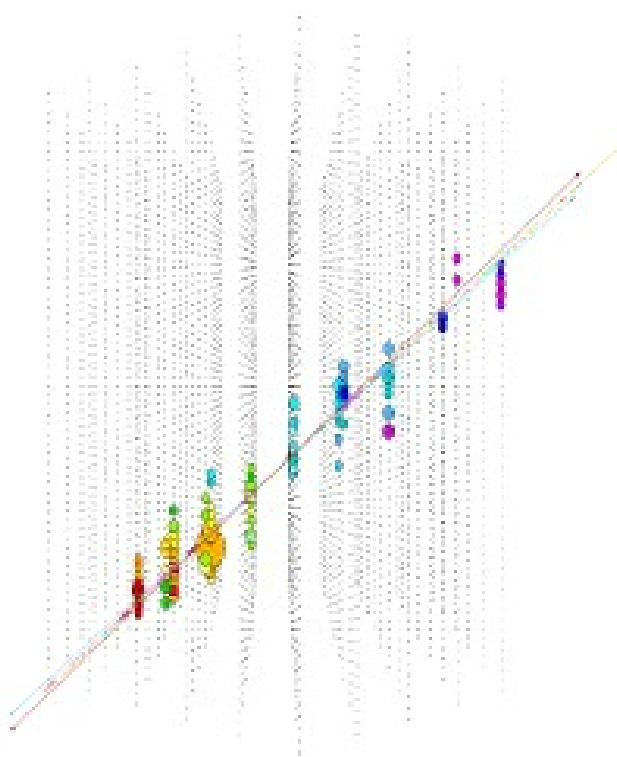
Information : Time – Intensity – Position

- ▶ Energy and/or direction reconstruction

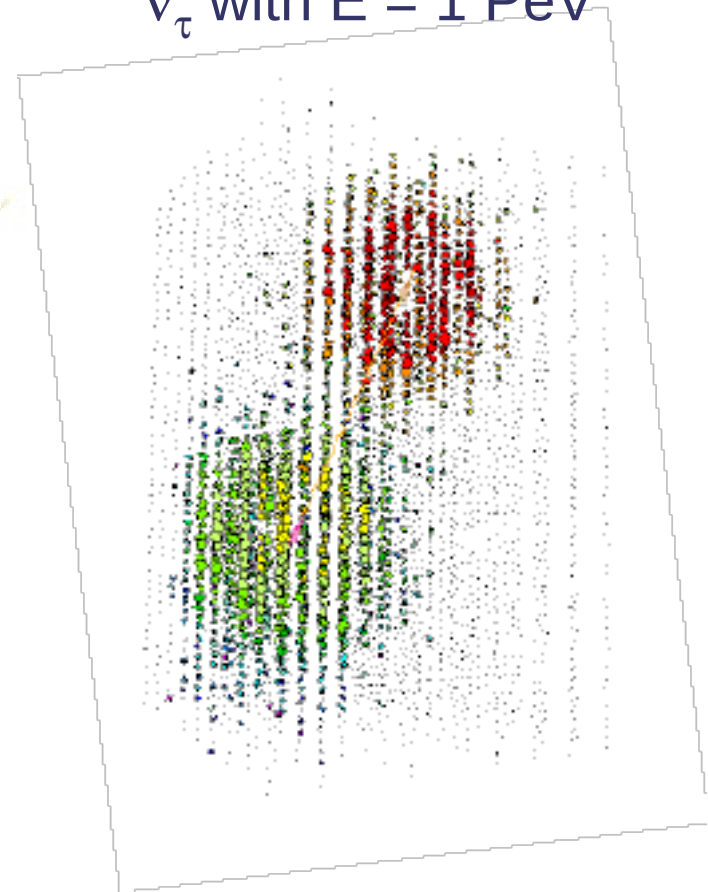
ν_e with $E = 375$ TeV



ν_μ with $E = 6$ TeV



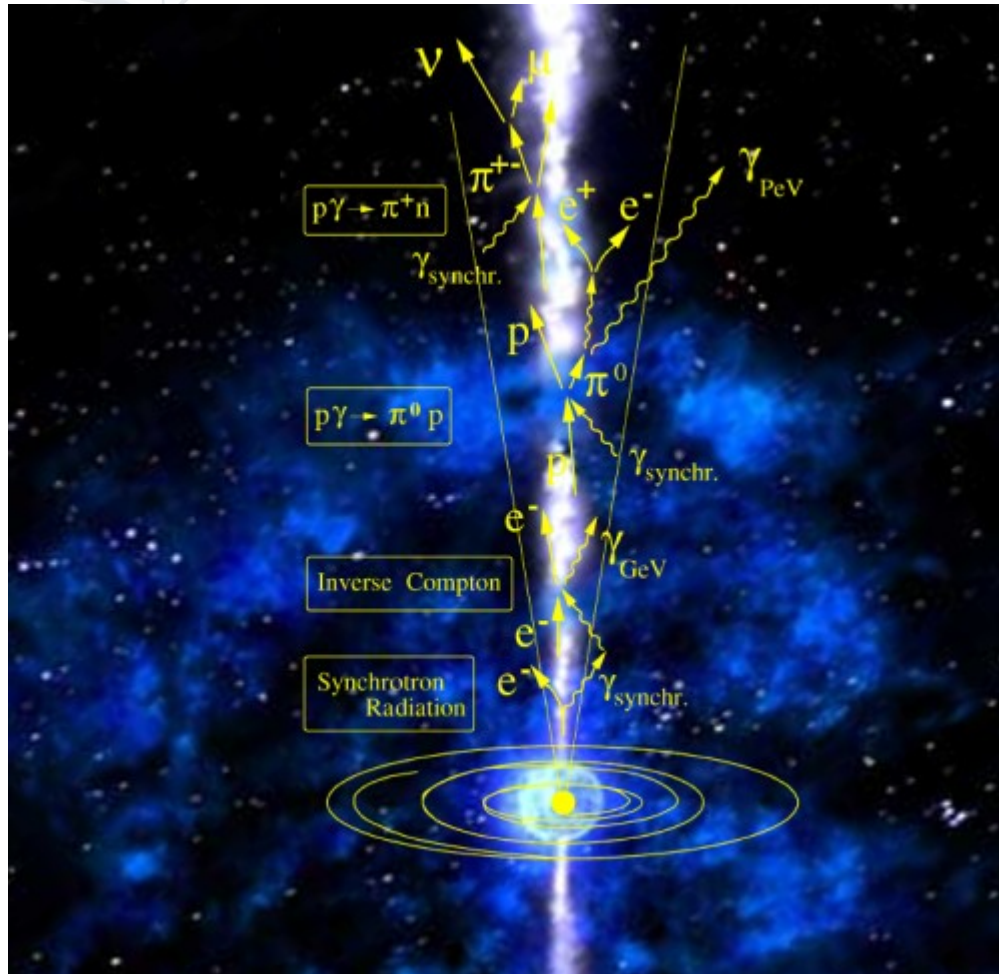
ν_τ with $E = 1$ PeV





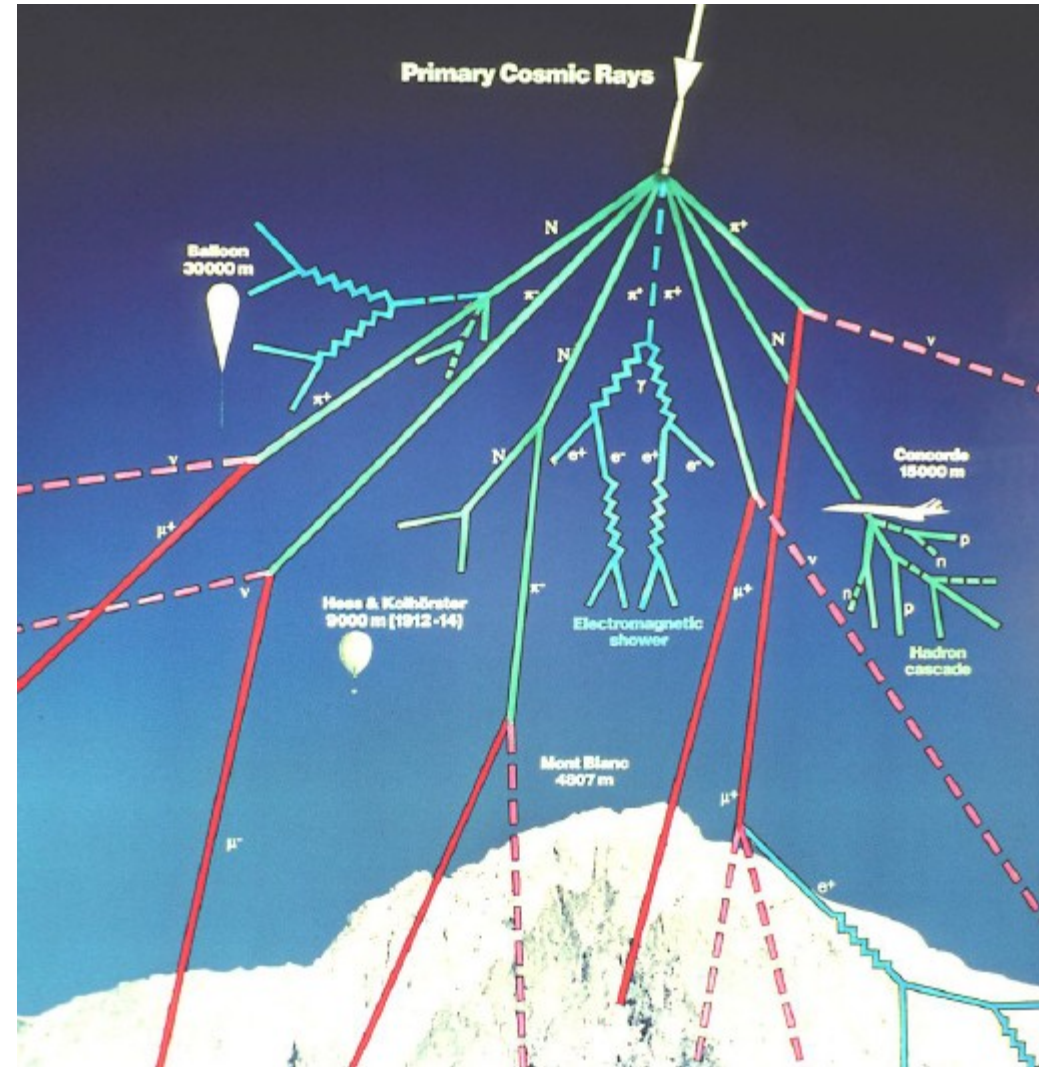
Signal in IceCube

Cosmic



$$\sim E^{-2}$$

Atmospheric



$$\sim E^{-3.7}$$



IC-40 The Moon Shadow

Verification of the IceCube pointing accuracy

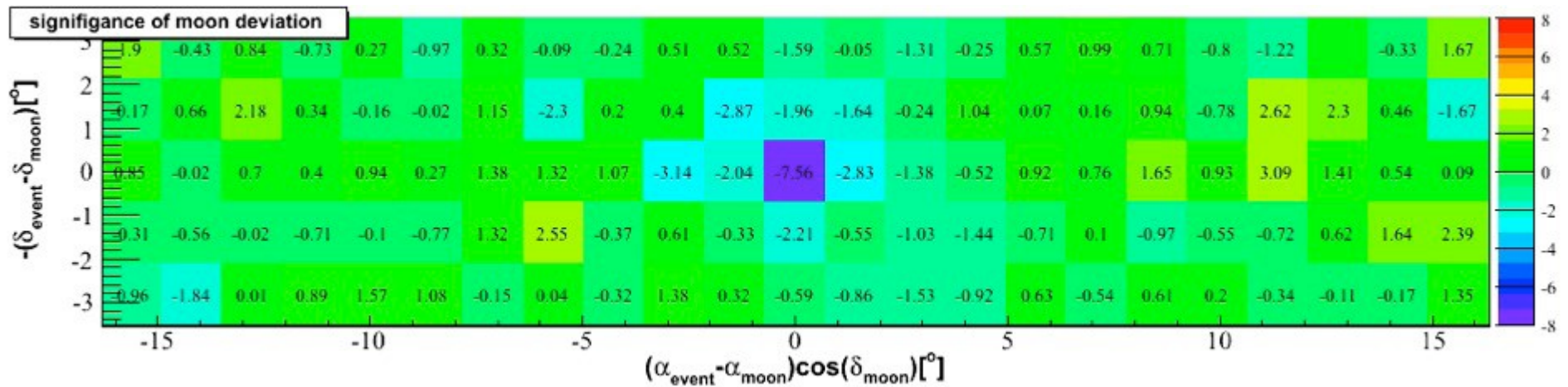
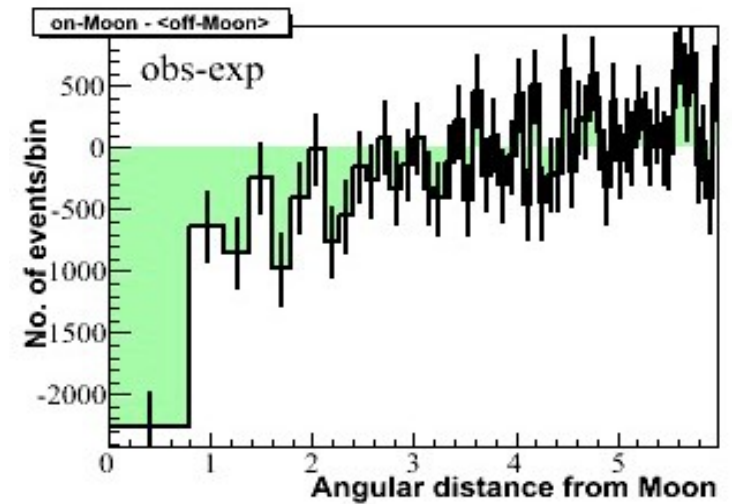
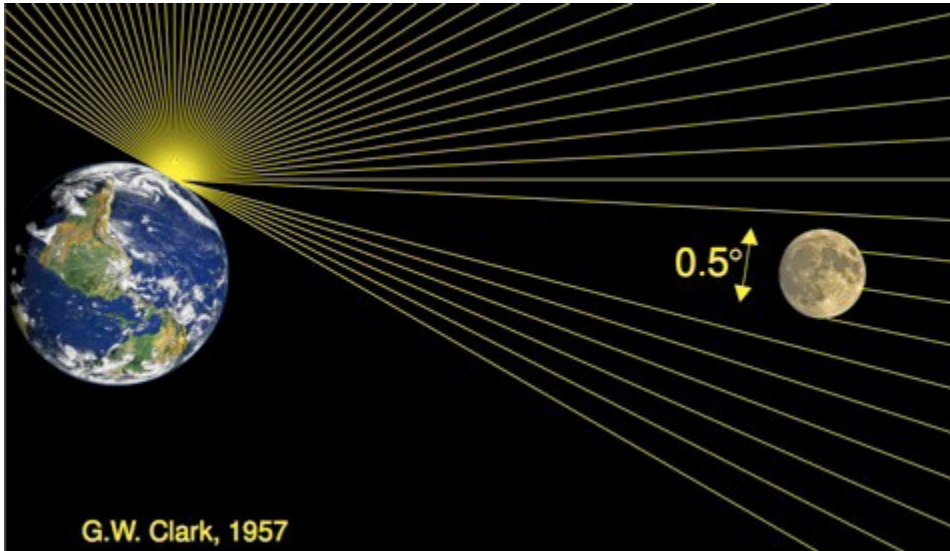
observed: 7.173×10^4 events

expected: 7.4×10^4 events

deficit: -2262 events

error: 285 events

significance: -7.9σ





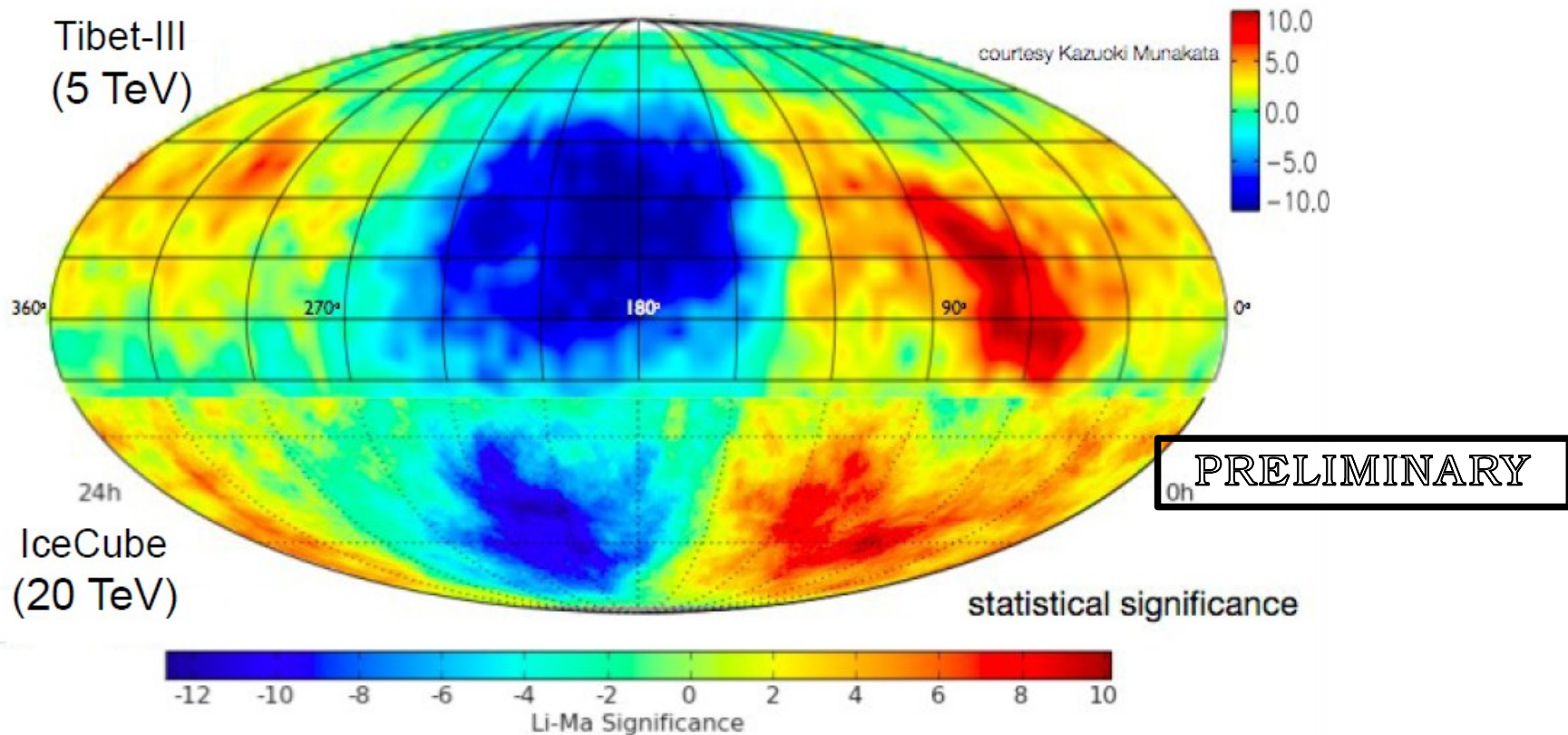
IC-22 Cosmic Ray Anisotropy

ApJ Letters, 718 (2010) L194

June, 2007 - March, 2008
4.3 10^9 atm. μ $\langle E \rangle = 14$ TeV

Very first measurement for Southern Hemisphere

- ▶ Anisotropy up to 100 TeV
- ▶ Energy dependence





IC-40 All sky Point Source Search

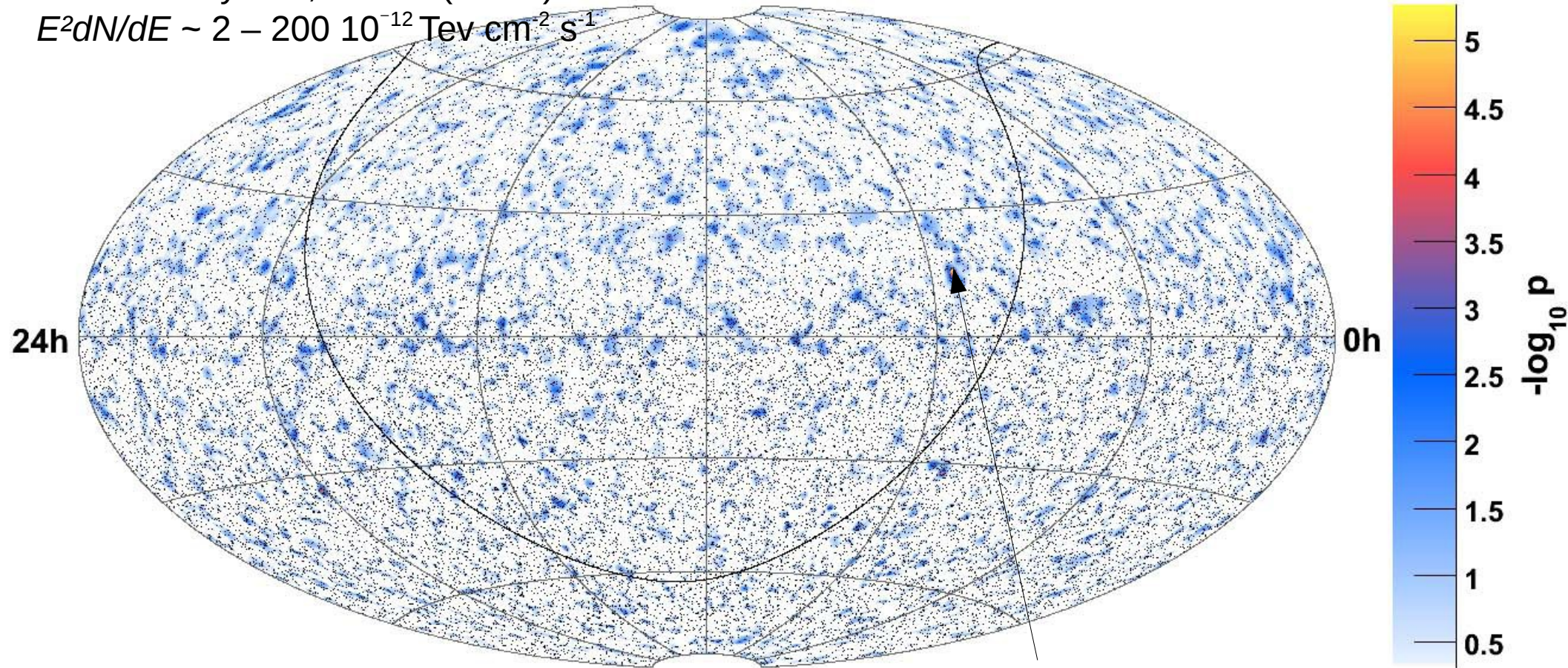
ArXiv:1012.2137 (To be published in ApJ.)

375.5 days livetime

$3 \cdot 10^{10}$ ev. → 36,900 events

Northern sky : 14,121 ev. (atm- ν)

$E^2 dN/dE \sim 2 - 200 \cdot 10^{-12} \text{ Tev cm}^{-2} \text{ s}^{-1}$



Southern sky : 22,779 ev. (atm μ)

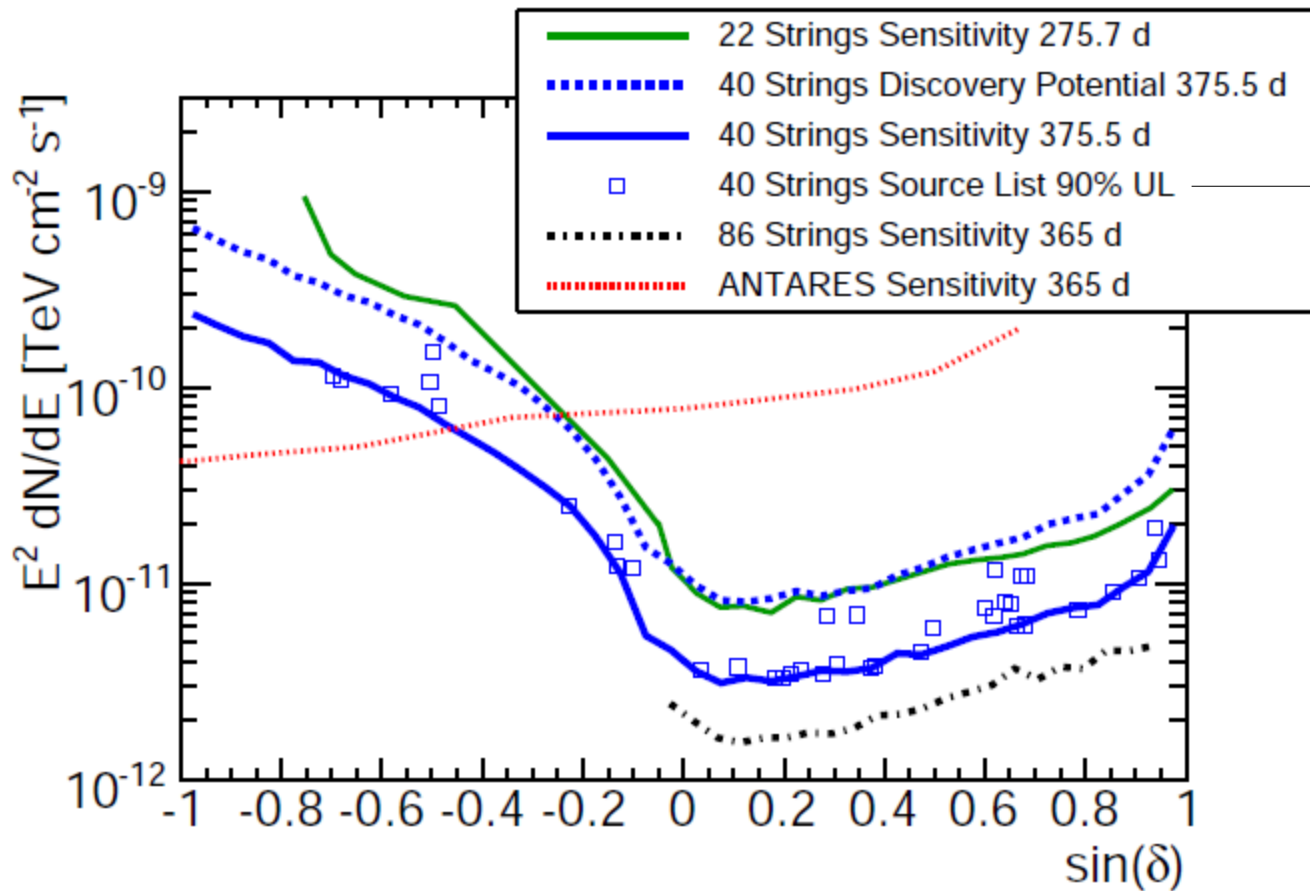
$E^2 dN/dE \sim 3 - 700 \cdot 10^{-12} \text{ Tev cm}^{-2} \text{ s}^{-1}$

113.75°ra , 15.15°dec
Post-trial proba : 18%



IC-40 All sky Point Source Search

ArXiv:1012.2137 (To be published in ApJ.)



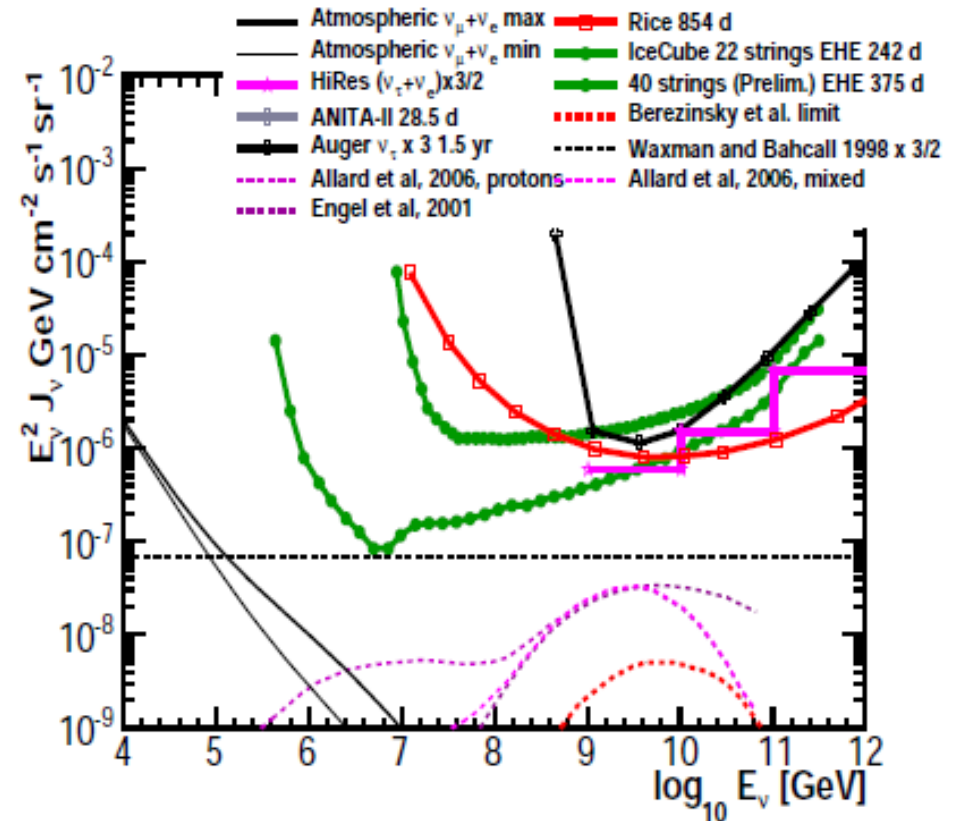
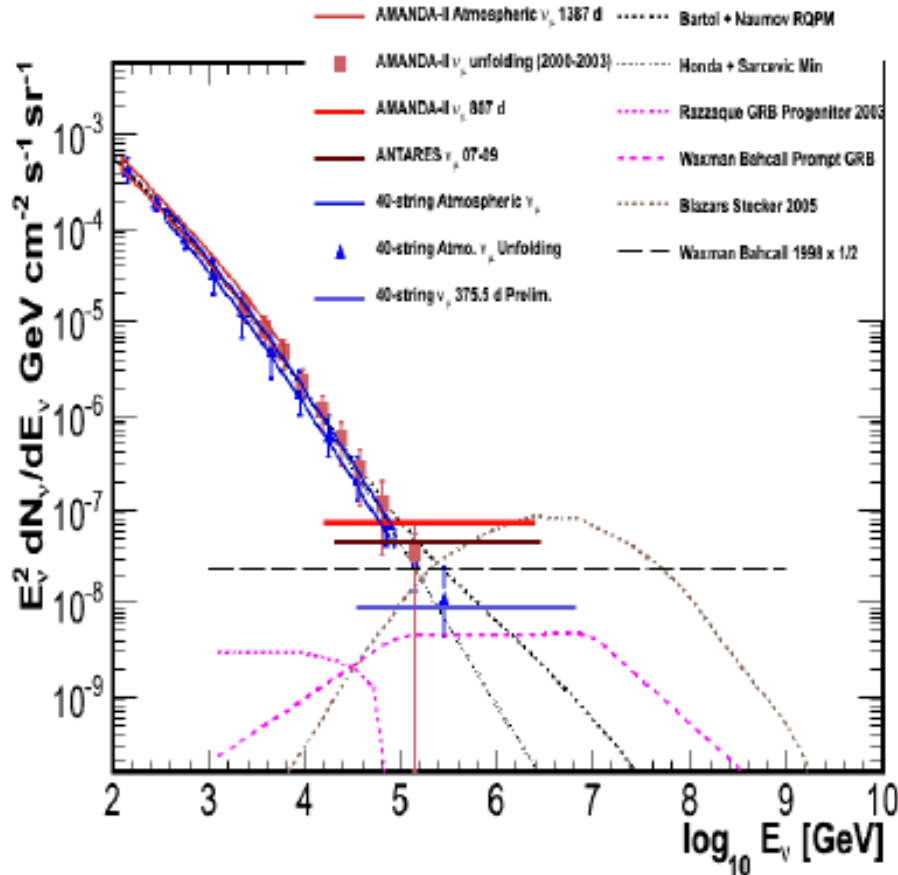
	$\Phi_{\nu_\mu}^{90}$	$\Phi_{\nu_\mu+\nu_\tau}^{90}$	p-value
Cyg OB2	6.04	10.54	–
MGRO J2019+37	7.50	13.3	0.44
MGRO J1908+06	3.73	6.82	0.43
Cas A	9.04	15.92	–
IC443	3.80	6.62	–
Geminga	3.91	6.66	0.48
Crab Nebula	3.70	6.58	–
1ES 1959+650	10.74	19.18	–
1ES 2344+514	7.24	12.96	–
3C66A	10.89	19.70	0.24
H 1426+428	6.14	10.94	–
BL Lac	10.80	18.70	0.25
Mrk 501	8.11	14.14	0.41
Mrk 421	11.71	20.14	0.15
W Comae	4.46	8.06	–
1ES 0229+200	6.89	12.06	0.19
M87	3.42	5.98	–
S5 0716+71	13.28	23.56	–
M82	19.14	32.84	0.4
3C 123.0	5.59	10.66	0.44
3C 454.3	3.42	5.92	–
4C 38.41	6.77	11.86	0.48
PKS 0235+164	6.77	11.62	0.15
PKS 0528+134	3.63	6.72	–
PKS 1502+106	3.26	5.78	–
3C 273	3.61	6.54	–
NGC 1275	6.04	10.54	–
Cyg A	7.84	13.44	0.46
IC-22 maximum	3.26	5.86	–
Sgr A*	80.56	139.26	0.41
PKS 0537-441	113.90	201.82	–
Cen A	109.51	191.56	–
PKS 1454-354	92.56	156.74	–
PKS 2155-304	105.41	182.90	0.28
PKS 1622-297	152.28	263.86	0.048
QSO 1730-130	24.83	43.30	–
PKS 1406-076	16.04	28.72	0.42
QSO 2022-077	12.18	21.78	–
3C279	11.94	21.36	0.33



IC-22 (IC-40) Astroph. ν diffuse fluxe

IC-22 : 333,3 days lifetime

IC-40 : 375.5 days livetime





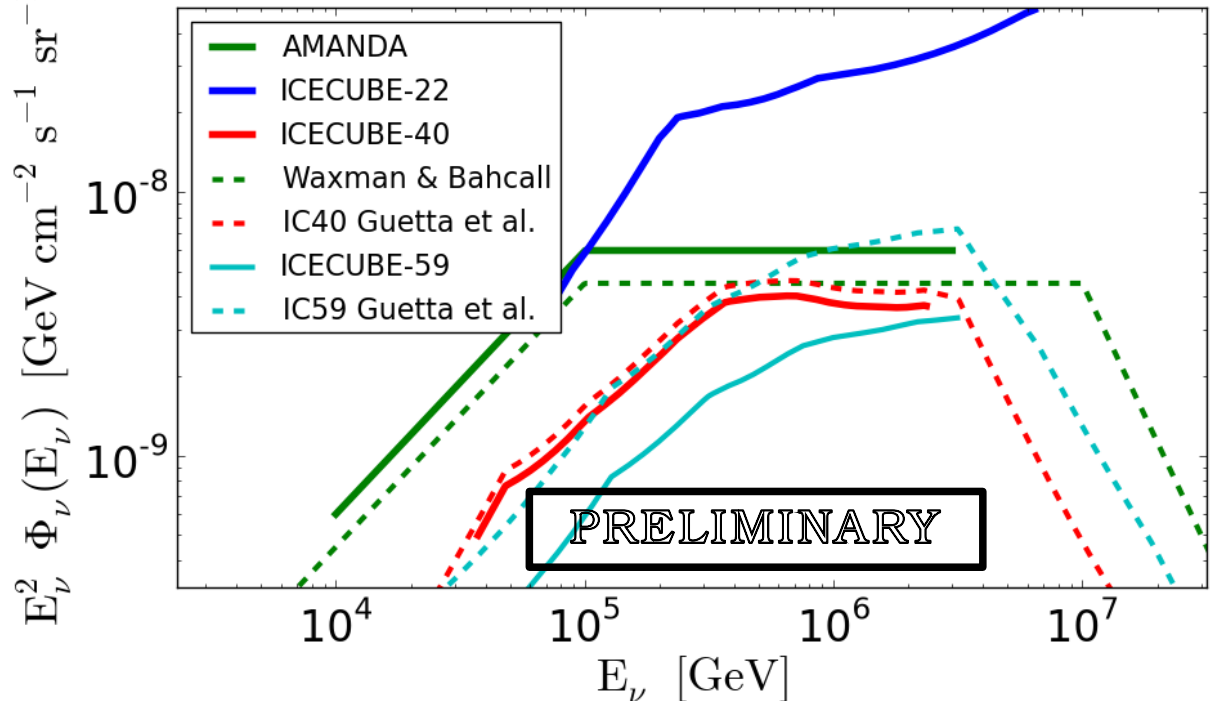
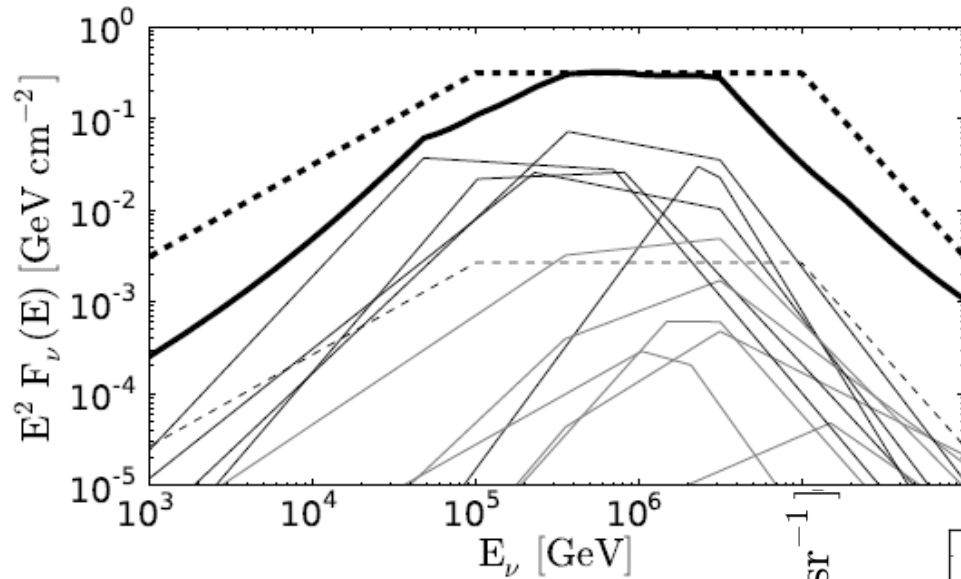
IC-40(IC-59) : Search for GRB ν signal

ArXiv:1101,1448v2

From April 5, 2008 till May 20, 2009
129 GRBs (GCN) \rightarrow 117 GRBs

Model-dependant : Unbinned LLH
Direction – arrival time – muon energy
No event observed (2.99 expected)

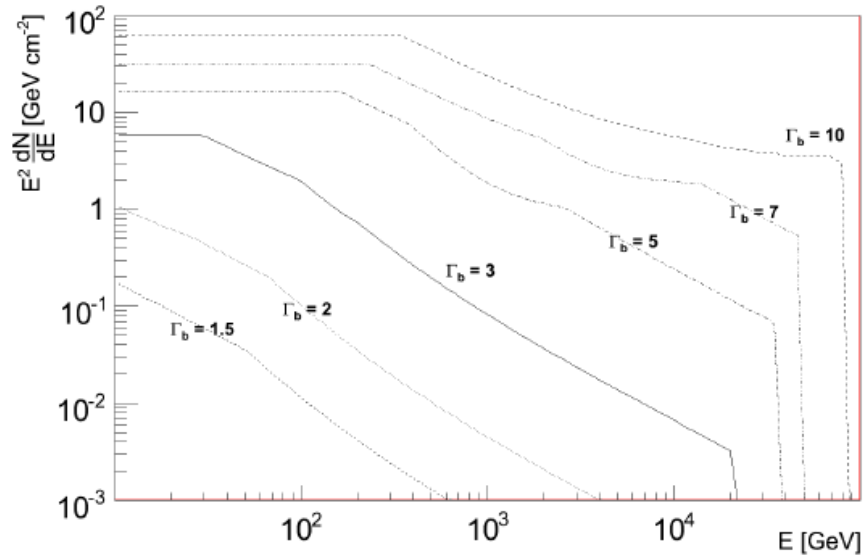
Model-independant : time window search
[-10s ; +10 s] \rightarrow [-1 day ; +1 day]
No candidate event in ± 2248 s (4.2 expected)





IC-22 : Constraint on HE ν from SN2008D

A&A, n.15770



January, 9 2008

SWIFT X-Ray flash detection

09h09m30.70s ra ; 33°09'19,1" decl.

Soft jet model

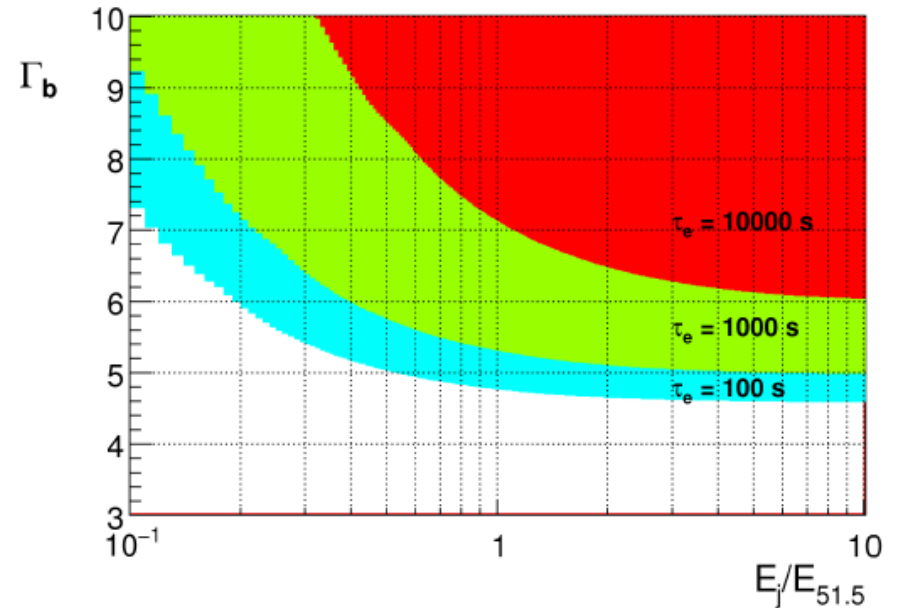
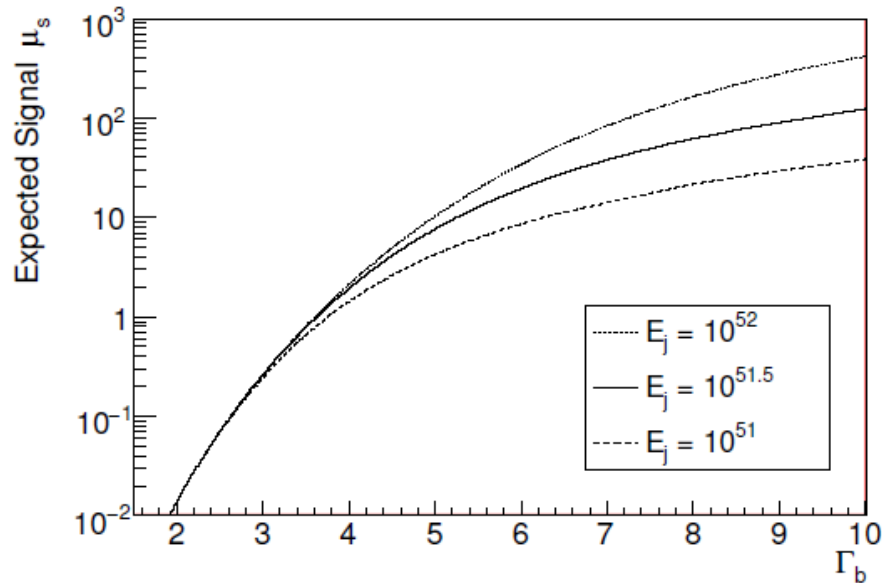
massive star collapse -> neutron star or B.H.

$\Gamma_b \sim 1 - 10$ $\theta_j \sim 5^\circ - 50^\circ$ $E_j \sim 3 - 6 \cdot 10^{51}$ erg

IC-22 : 275,72 days

Time range : [-9.5h ; +1.8h]

Bg rate : 0.03 Hz 0.26 signal ev. expected





Summary

IceCube is completed after 7 years of deployment!

▶ 86 strings with more than 5000 sensors for the biggest neutrino telescope in full activity.

▶ **DeepCore** extension : 8 densely instrumented region lowering the energy threshold @ 10 GeV

Data has been taken during construction phase

- ▶ 1st observation of CR anisotropy in the Southern Sky (IC-22)
- ▶ Limits for Point Source (IC-40)
 - NS : $\sim 2 - 200 \text{ } 10^{-12} \text{ Tev cm}^{-2} \text{ s}^{-1}$
 - SS : $\sim 3 - 700 \text{ } 10^{-12} \text{ Tev cm}^{-2} \text{ s}^{-1}$
- ▶ Limits for Atm. Neutrino diffuse flux (IC-22/IC-40)
 - We're under the WB limit !!
- ▶ Search for GRB signal (IC-22/IC-40/IC-59)
 - No event observed
 - Constraints on soft jet models
 - Optical Follow-up with SWIFT, Fermi, ROTSE,...



Summary

Additional topics :

- ▶ DarkMatter
- ▶ Exotic particles
- ▶ Electronic cascades
- ▶ Tau physics

Additional detectors for new channels :

- ▶ SPATSE
- ▶ Antarctic Radia Array (ARA) will start soon.

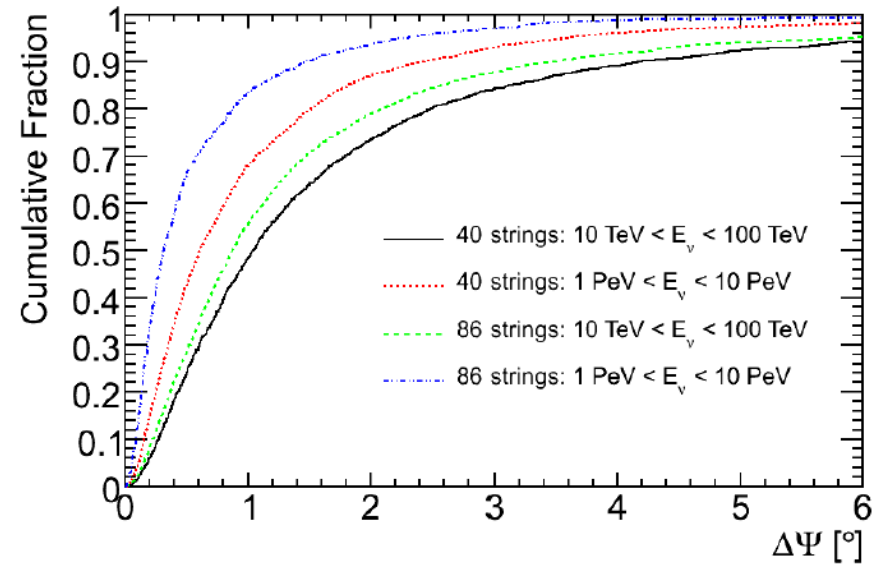
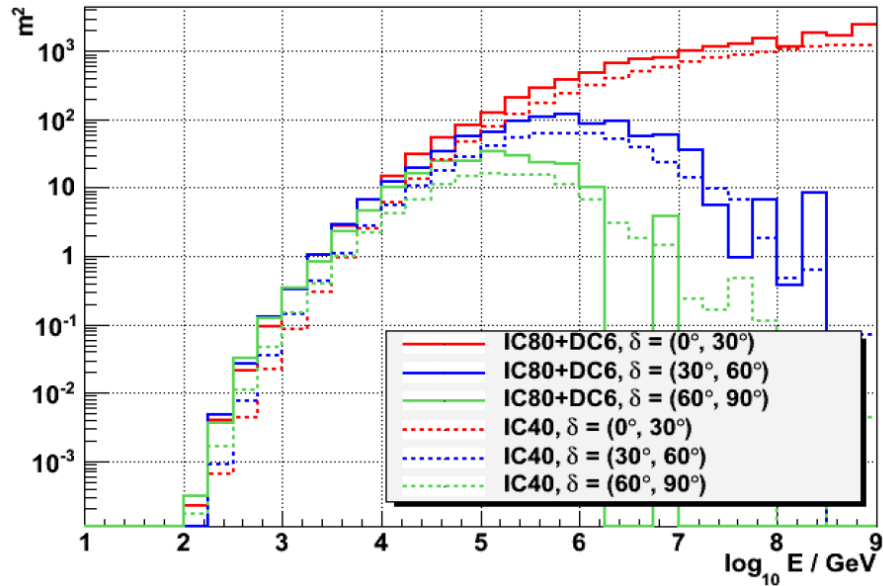
**Analyses with partialy built detector
have been successful**

**The full km³-sized detector will provide
an important increase in sensitivity for future analyses**

NEW DISCOVERIES ?



Detector characteristics (Back-up)

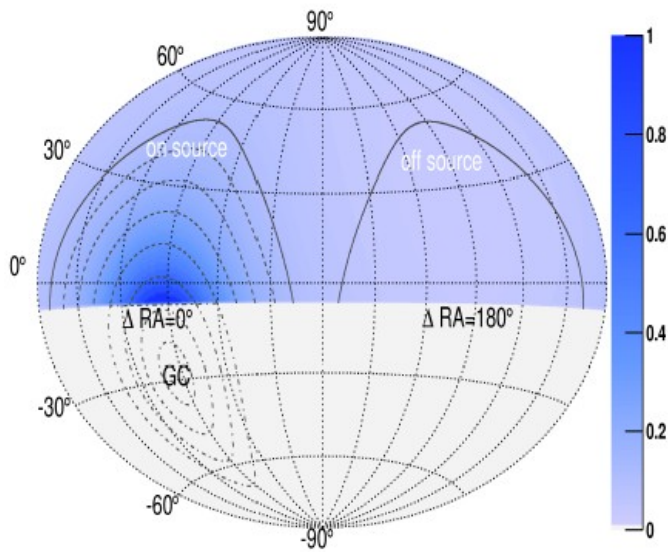




Searches for Dark Matter (Back-up)

Indirect detection of ν from DM annihilation

Phys.Rev.Lett. **102**, 201302 (2009)



Galactic Halo observation

ArXiv : 1101.3349v1

