The IceCube
Neutrino Telescope

K. Mase, Chiba univ.

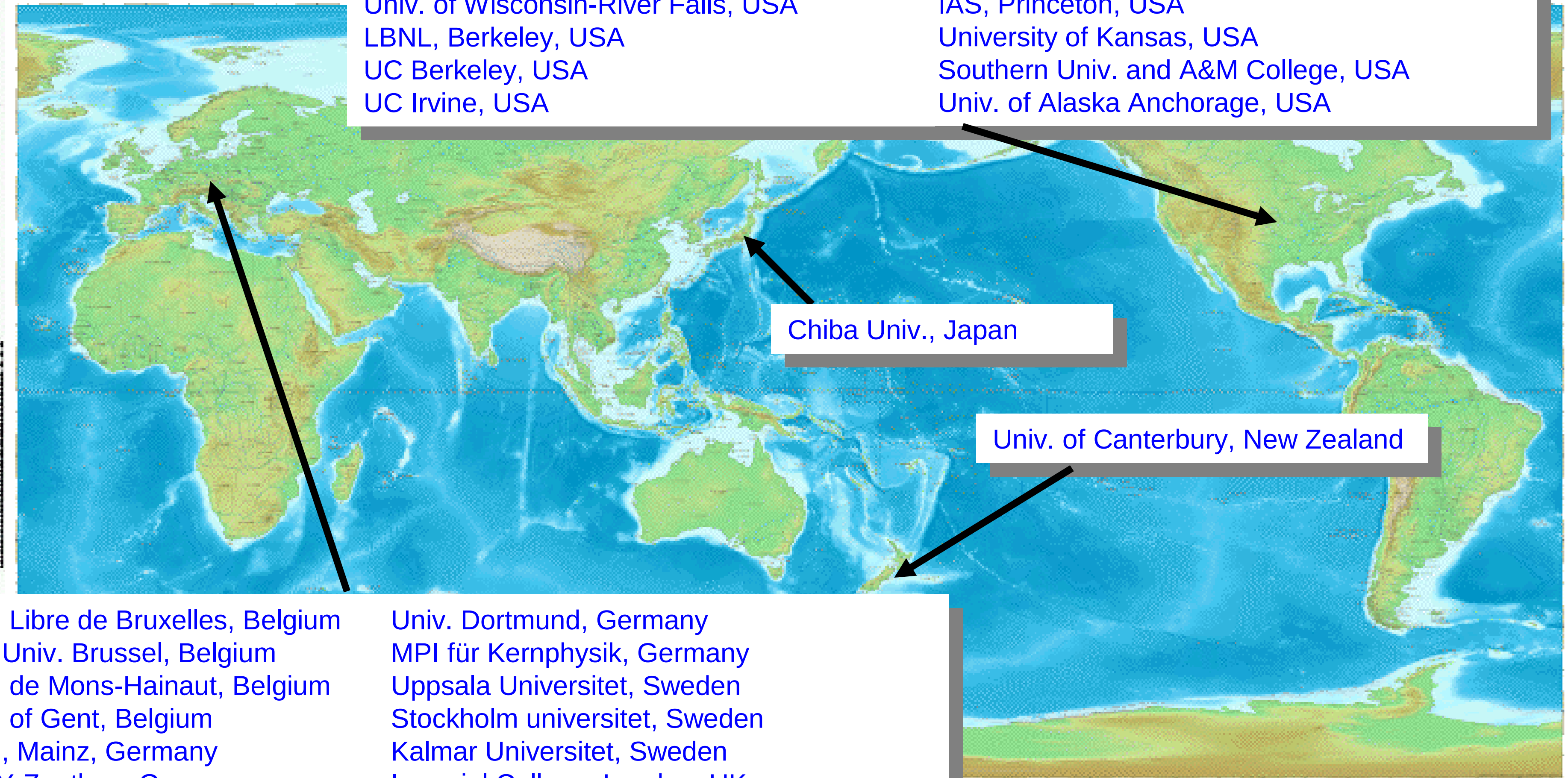
国立大学法人 千葉大学
National University Corporation
Chiba University

The IceCube Collaboration

34 institutes and >200 physists

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

Univ. of Alabama, USA
Clark-Atlanta University, USA
Univ. of Maryland, USA
IAS, Princeton, USA
University of Kansas, USA
Southern Univ. and A&M College, USA
Univ. of Alaska Anchorage, USA



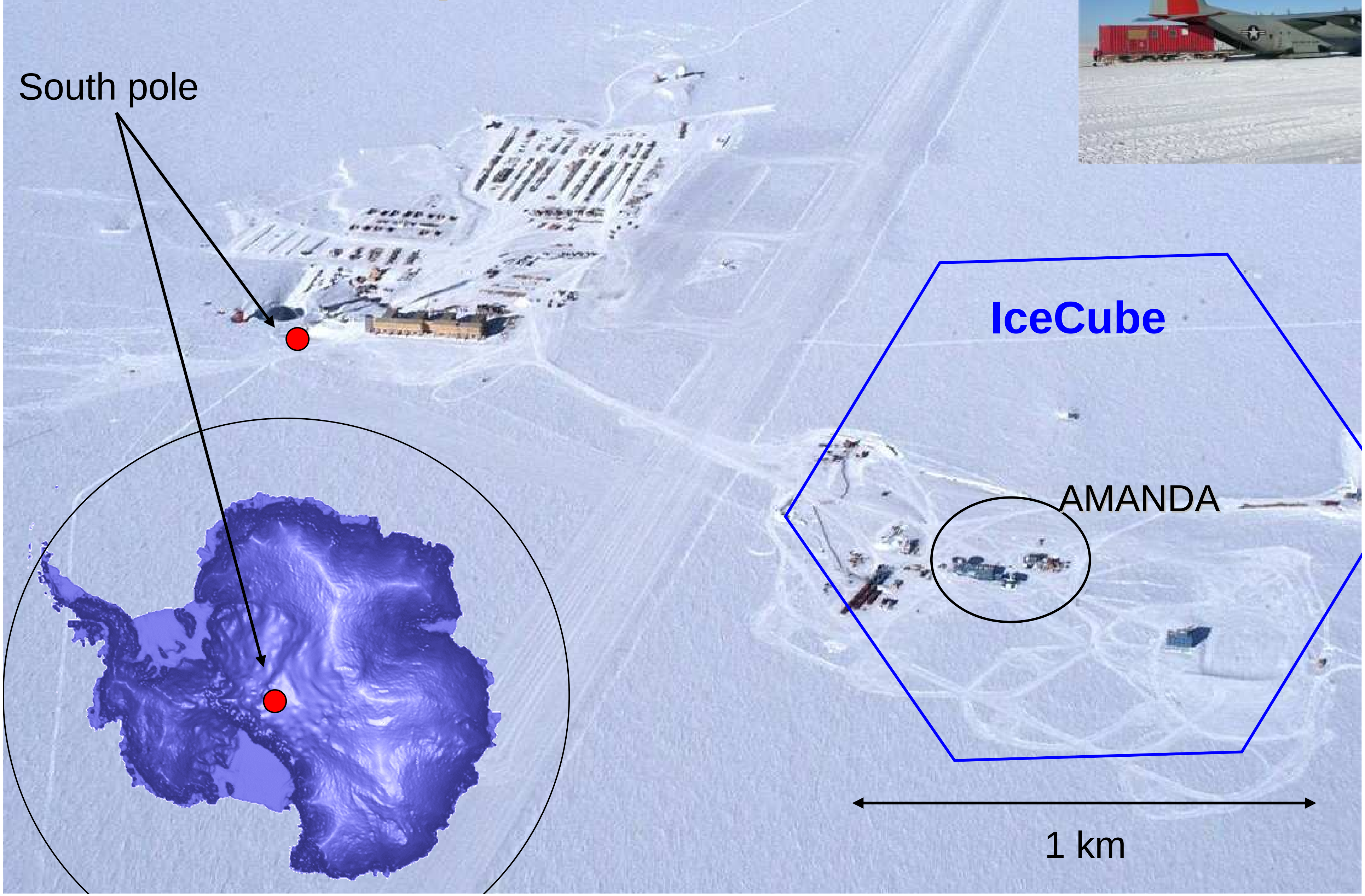
Chiba Univ., Japan

Univ. of Canterbury, New Zealand

Univ. Libre de Bruxelles, Belgium
Vrije Univ. Brussel, Belgium
Univ. de Mons-Hainaut, Belgium
Univ. of Gent, Belgium
Univ., Mainz, Germany
DESY-Zeuthen, Germany
Univ. Wuppertal, Germany
RWTH Aachen Univ., Germany
Humboldt Univ. zu Berlin, Germany

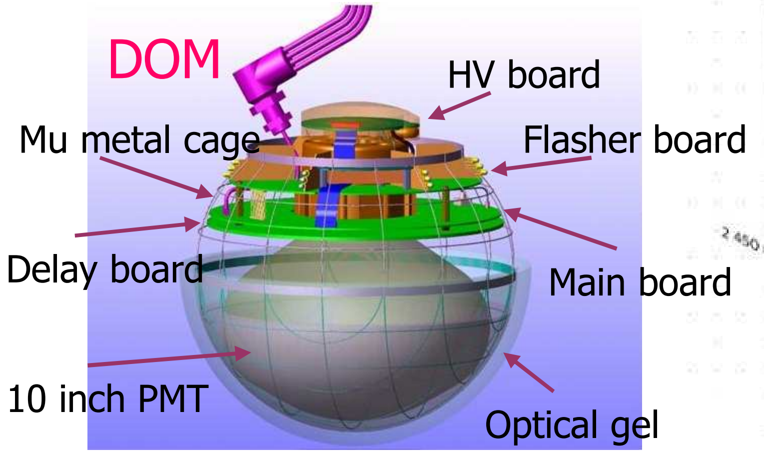
Univ. Dortmund, Germany
MPI für Kernphysik, Germany
Uppsala Universitet, Sweden
Stockholm universitet, Sweden
Kalmar Universitet, Sweden
Imperial College, London, UK
University of Oxford, UK
Utrecht University, Utrecht, NL
Ècole Polytechnique Fèdèrale, Switzerland

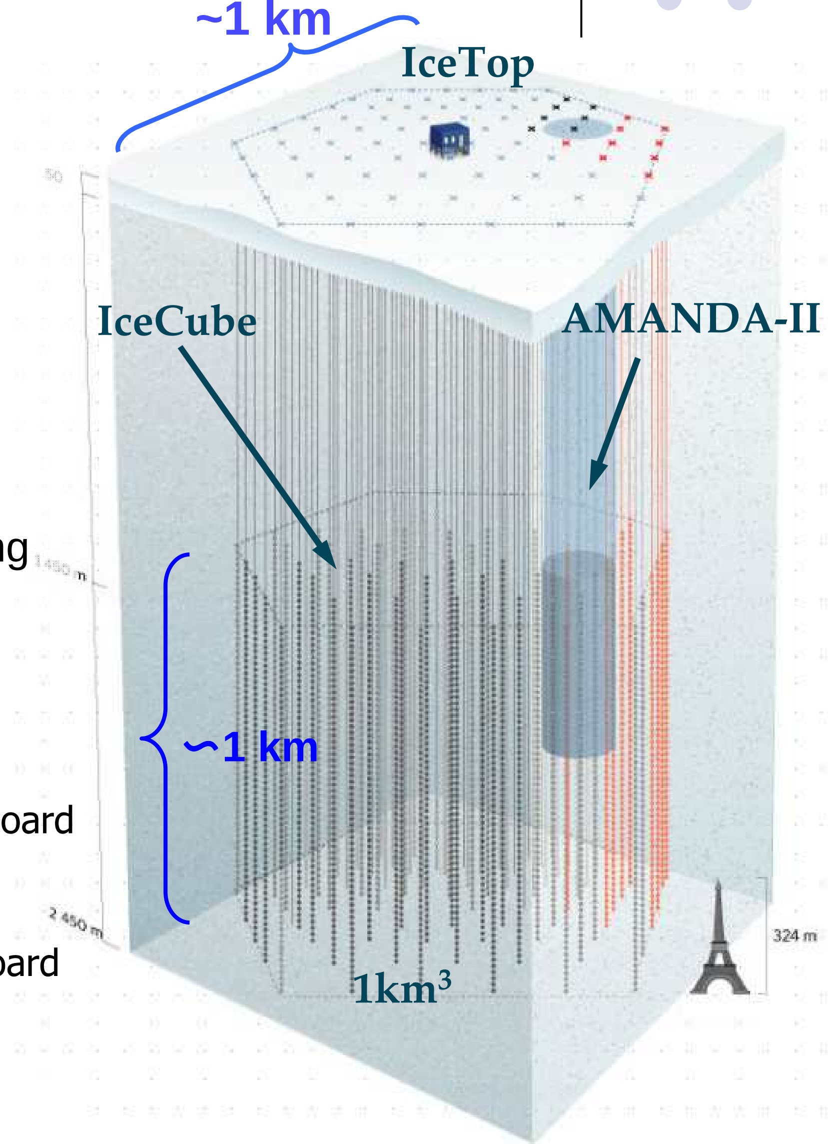
The south pole



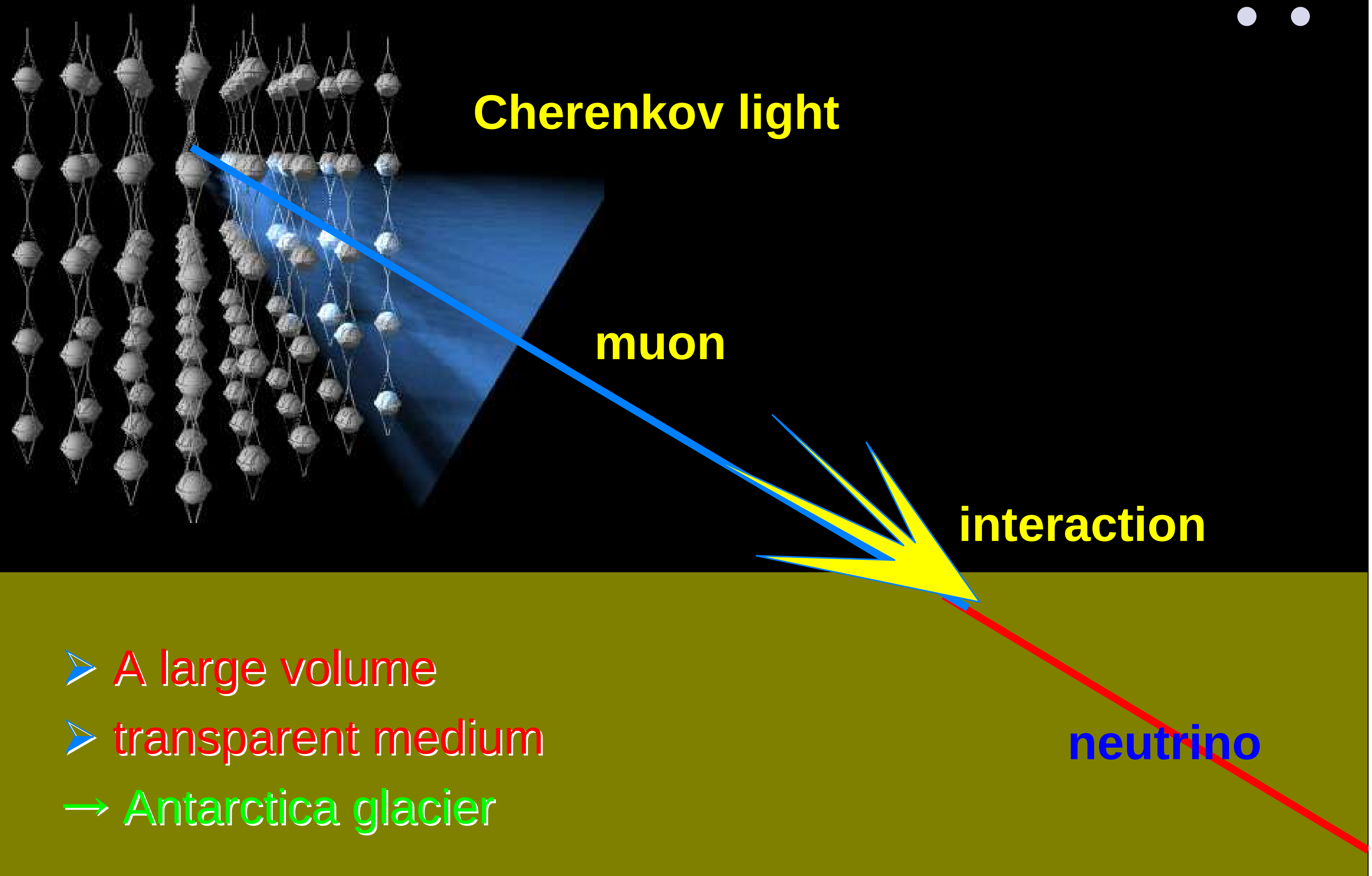
The IceCube experiment

- to detect VHE neutrinos from astrophysical sources
- deployed in the Antarctica glacier
- >70 strings
- >4200 photo-multiplier tubes (PMTs)
- Detector volume: ∽$1km^3$
- ATWD 300MHz, effectively 16 bits
- 3 different gains (x16, x2, x0.25)
- 10 bits FADC for long duration pulse
- Neutrino energy of above 100 GeV is detectable.
- 22 strings are deployed so far, and taking data as the biggest neutrino detector.





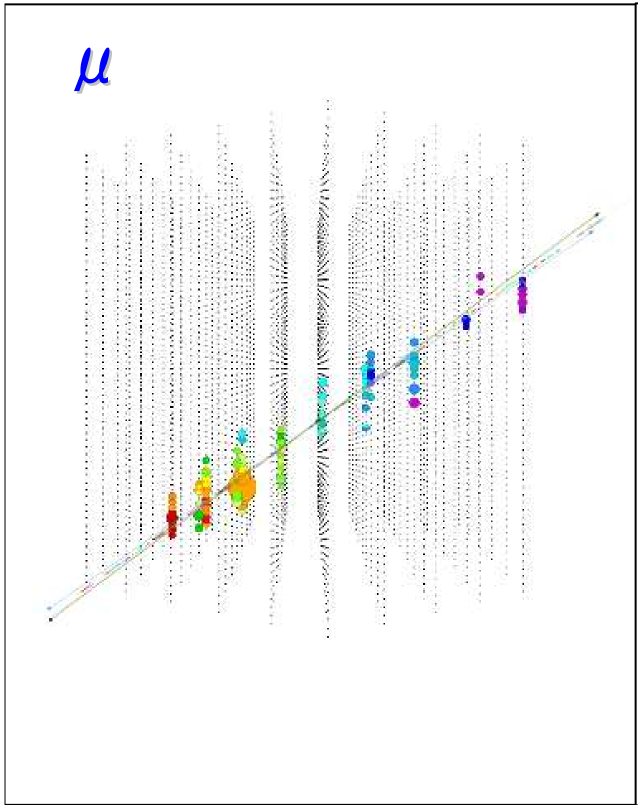
The detection principle

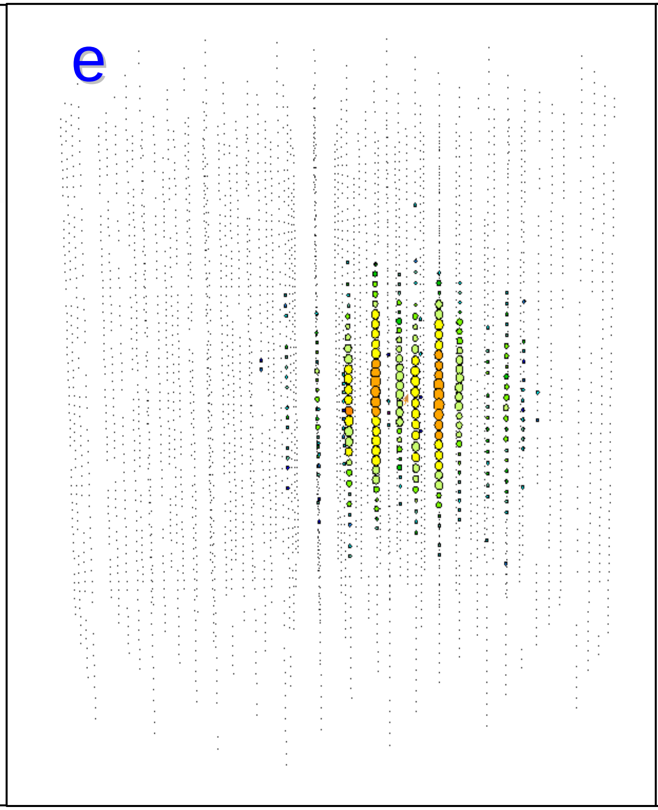


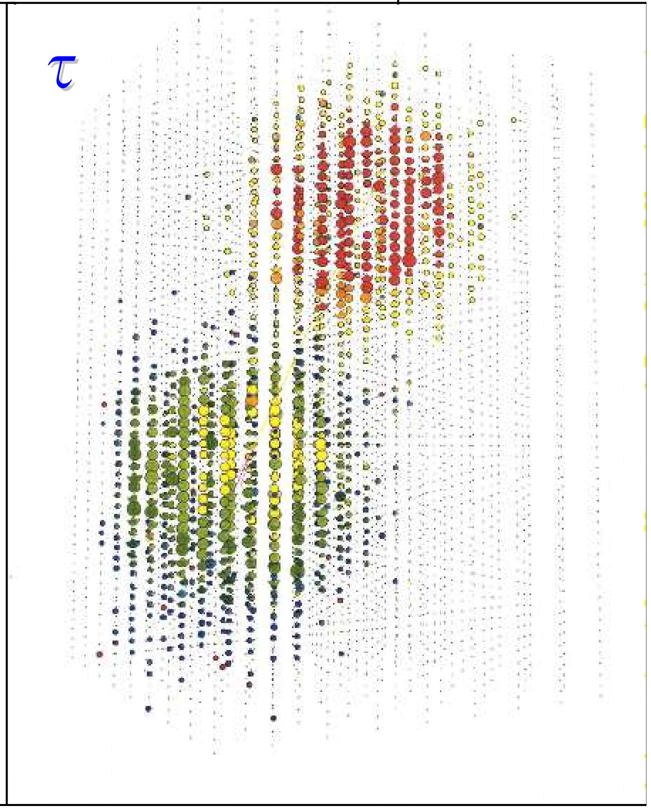
- A large volume
- transparent medium

→ Antarctica glacier

Particle identification



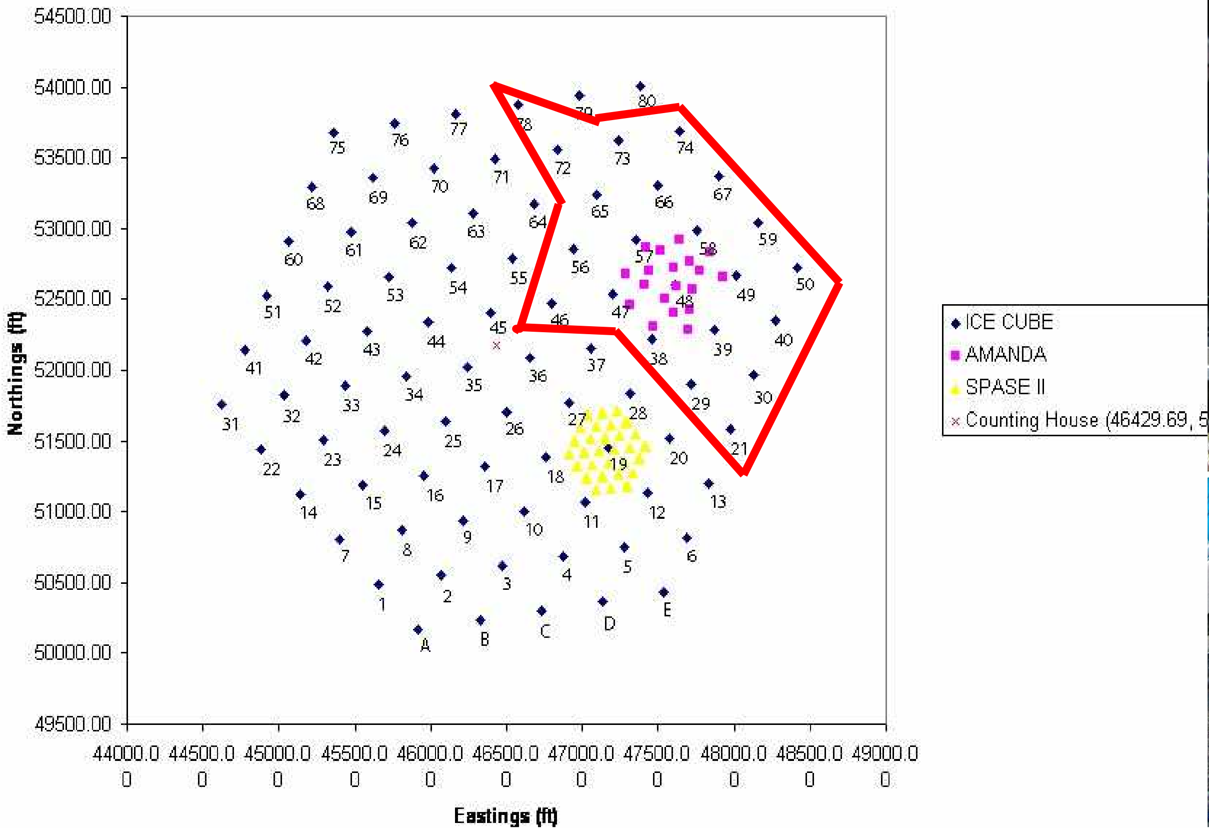




Particle identification possible from the shape

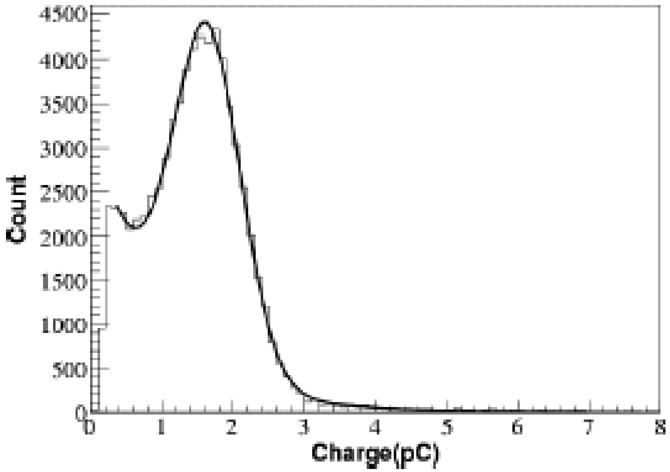
The deployment

22 strings deployed!

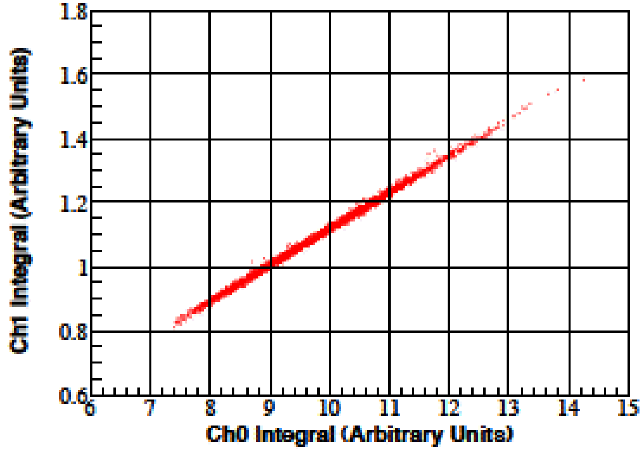


The perfomance

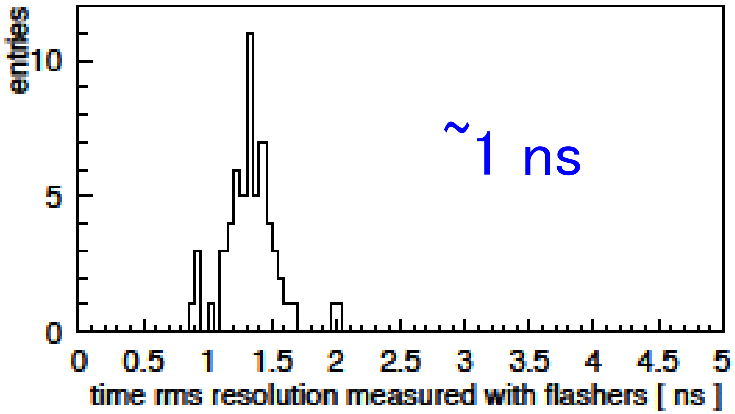
1 p.e. distribution



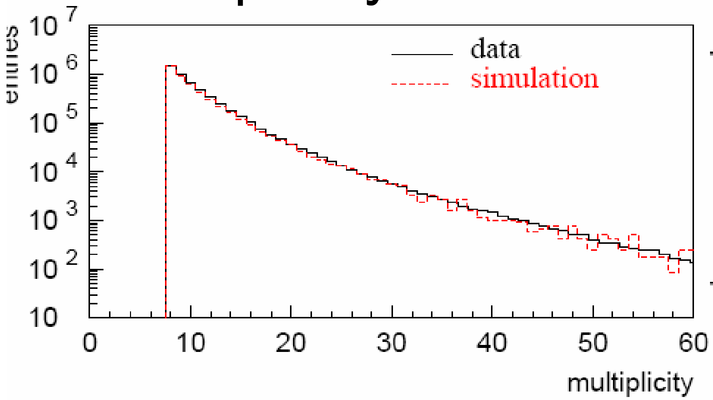
Gain check

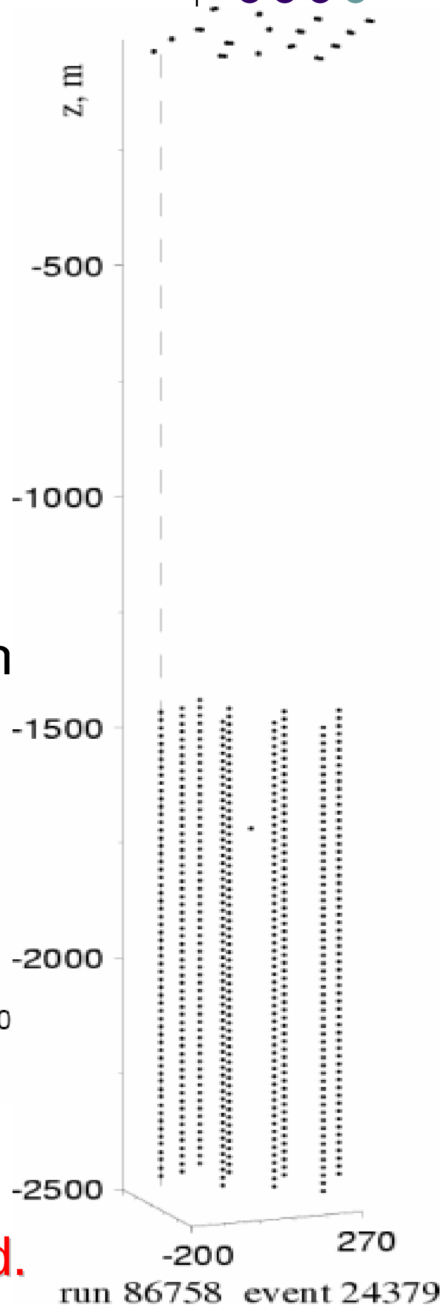


Time resolution



Multiplicity distribution

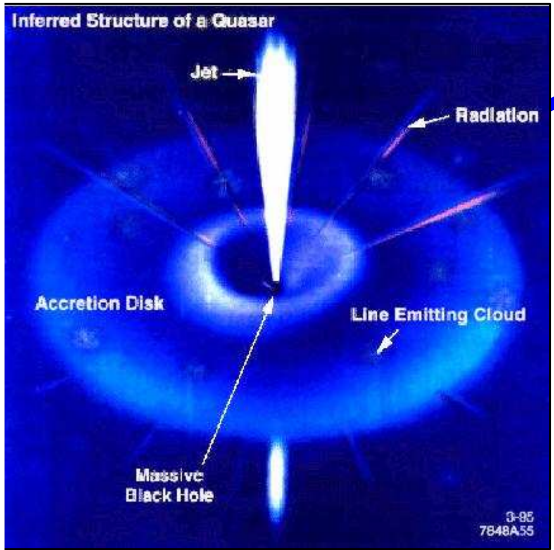




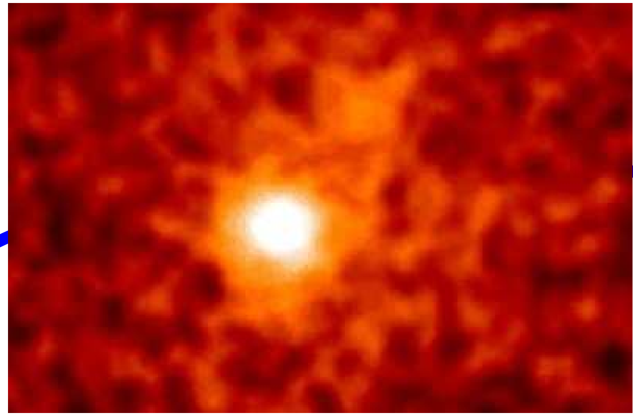
A. Achterberg et al., Astropart. Phys., 26, 3, 155-173 (2006)

The IceCube detectors are working as expected.

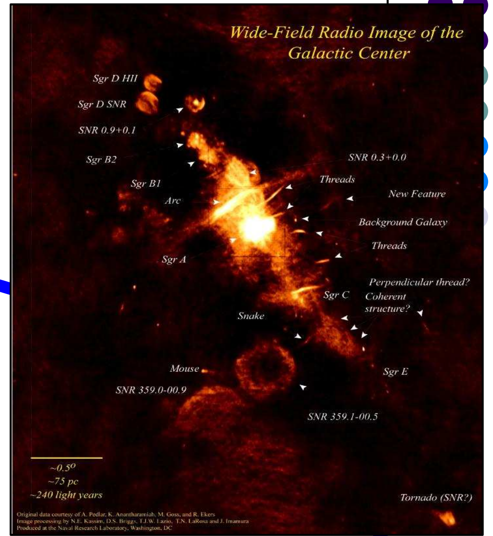
The physics of IceCube



- AGNs

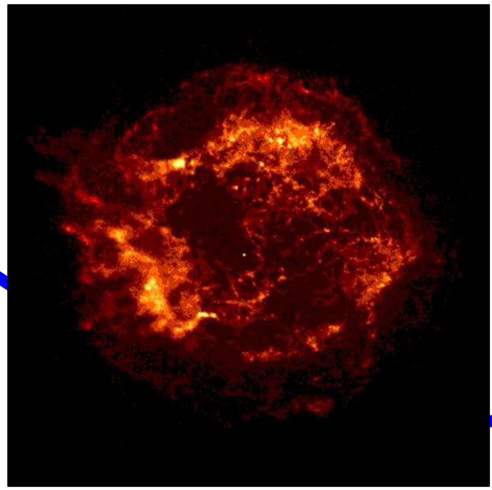


- GRBs



- Dark Matter

- **Cosmic ray origin**



- Supernova

- Extremely high energy (EHE) neutrinos

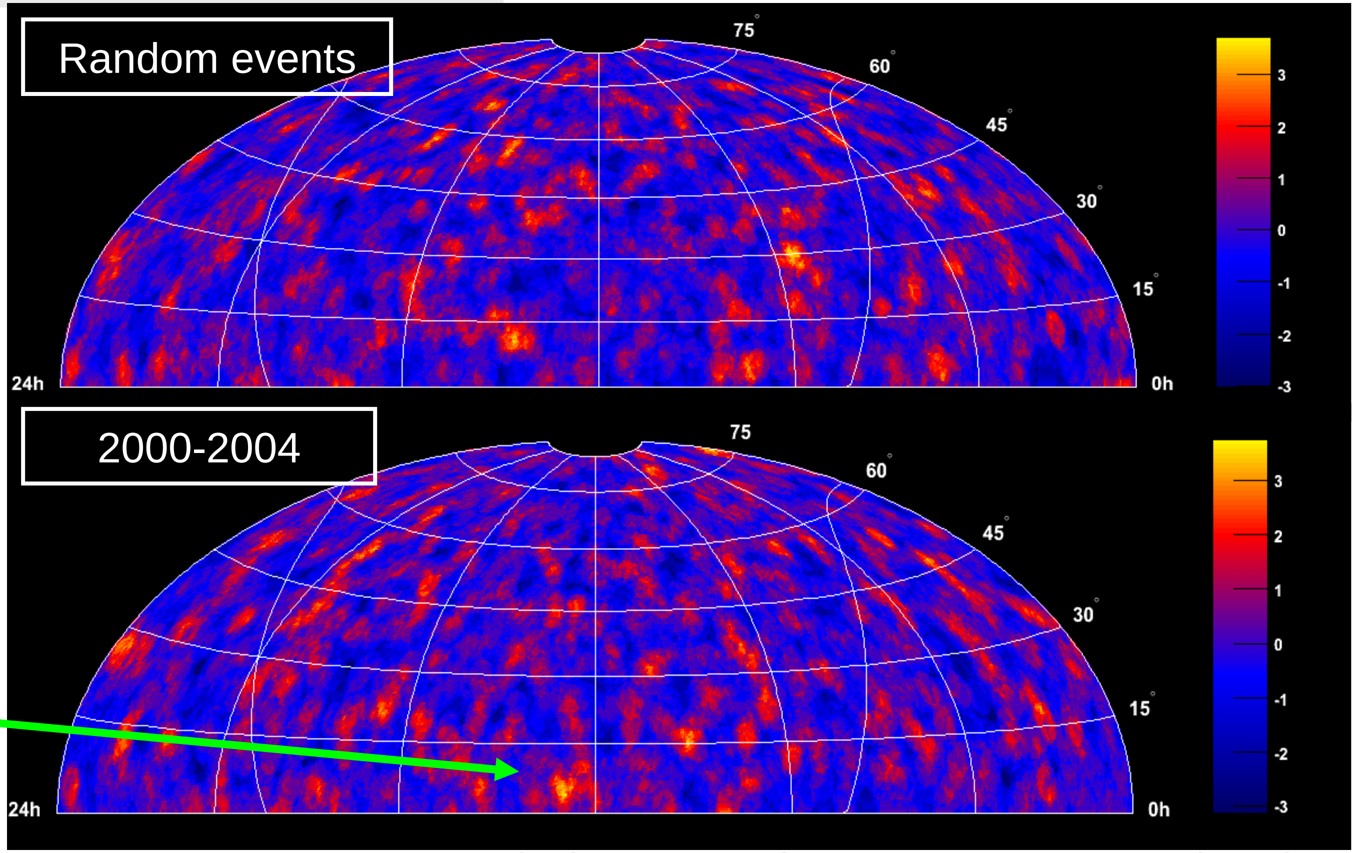
GZK, Z-burst, TDs

Point source search by AMANDA II

Unfortunately, no signal so far…

Search for clustering in northern hemisphere
- compare significance of local fluctuation to atmospheric ν expectations

2000-2004 (1001 days)
4282 ν from northern hemisphere
4600 ν expected from atmosphere



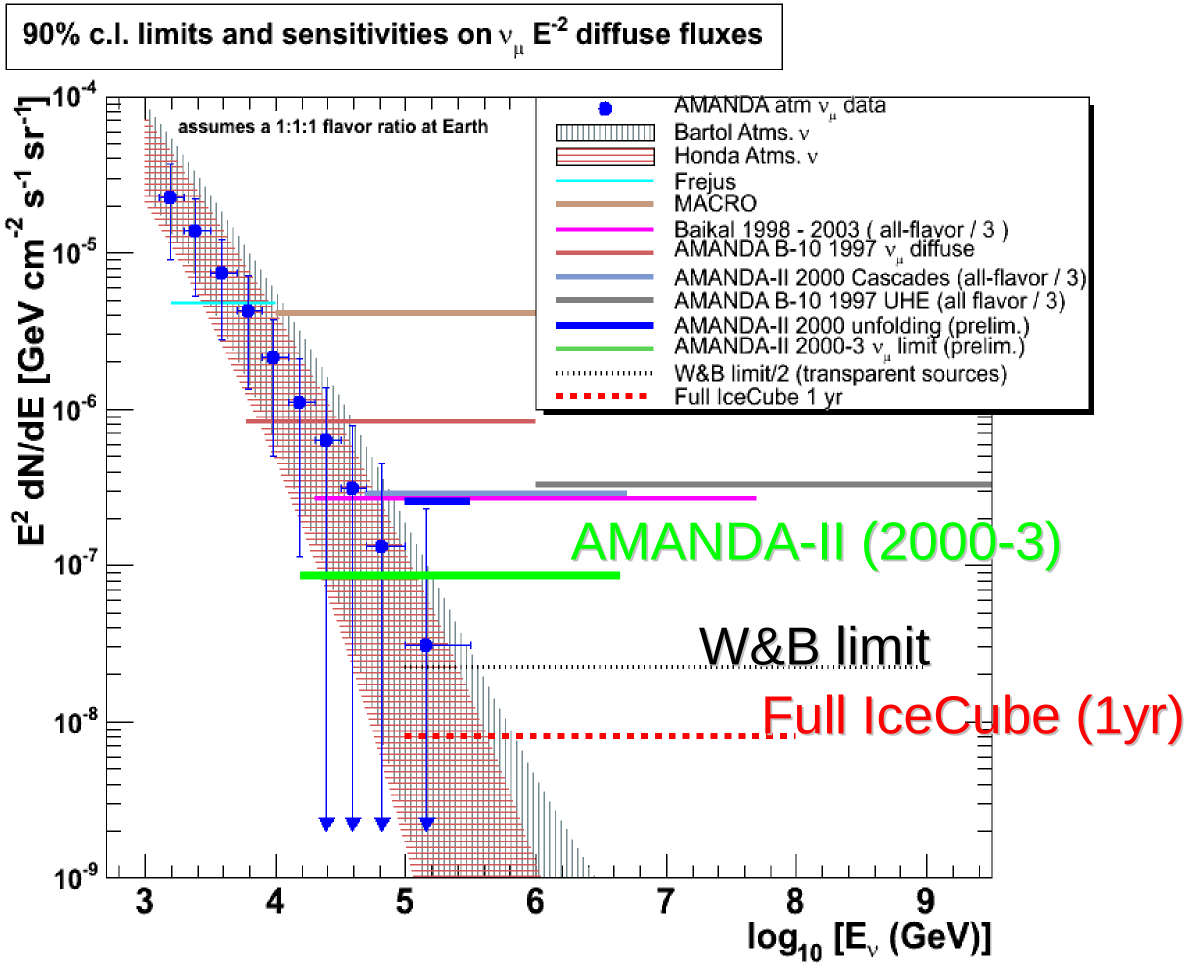
Maximum significance 3.7 σ
compatible with atmospheric ν

A. Achteberg et al., Phys. Rev. D, 75, 102001 (2007)

Diffuse neutrinos

Even though we can't resolve signals from each source, we can integral signals in all sky and should see some excess.

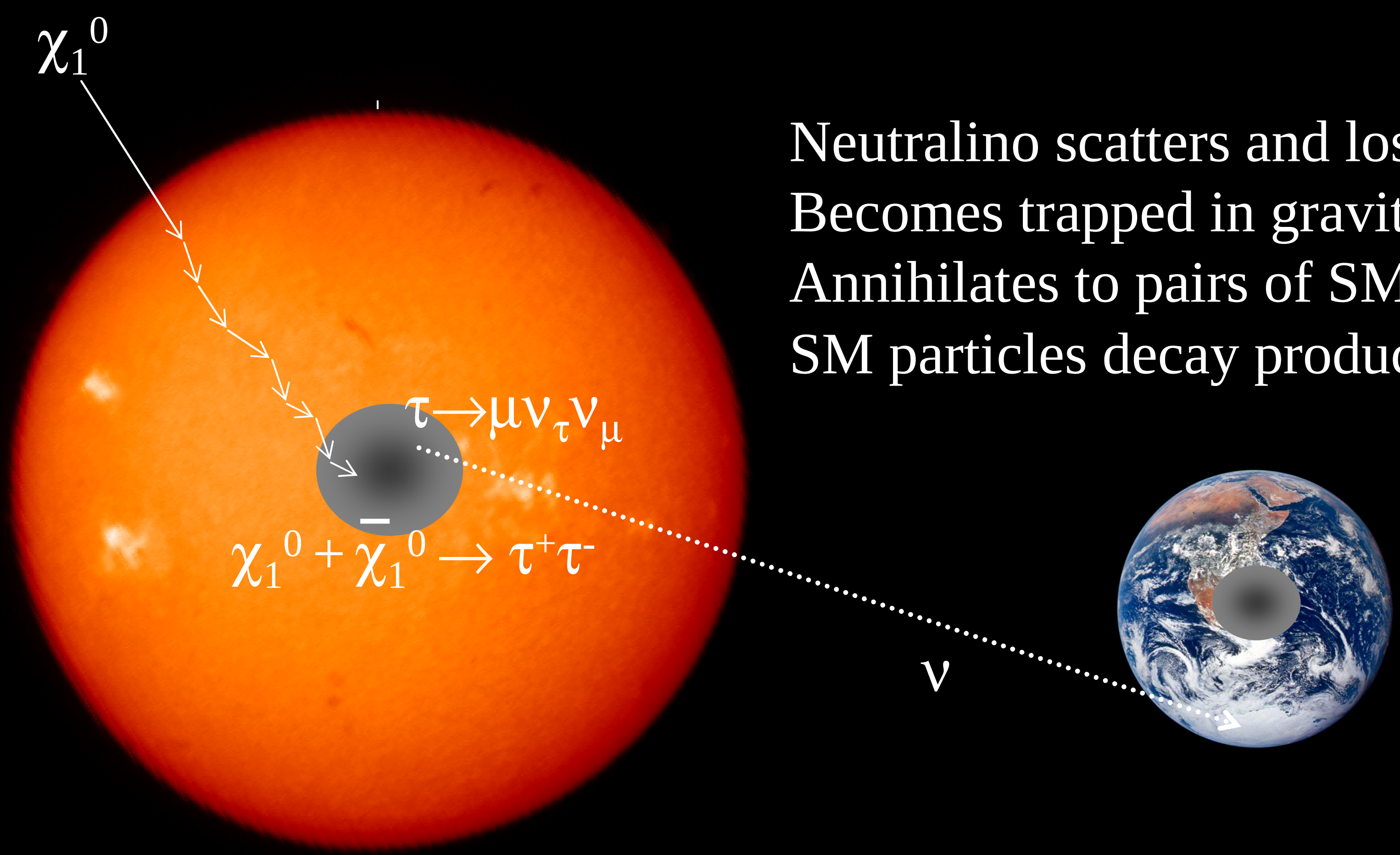
But, no excess so far



A. Achteberg et al., astro-ph 0705.1315 (2007)

❑ WIMP Search

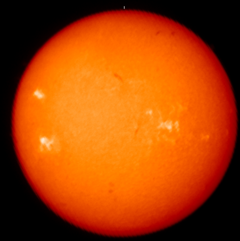
Neutralino scatters and loses energy
Becomes trapped in gravity well
Annihilates to pairs of SM particles
SM particles decay producing ν

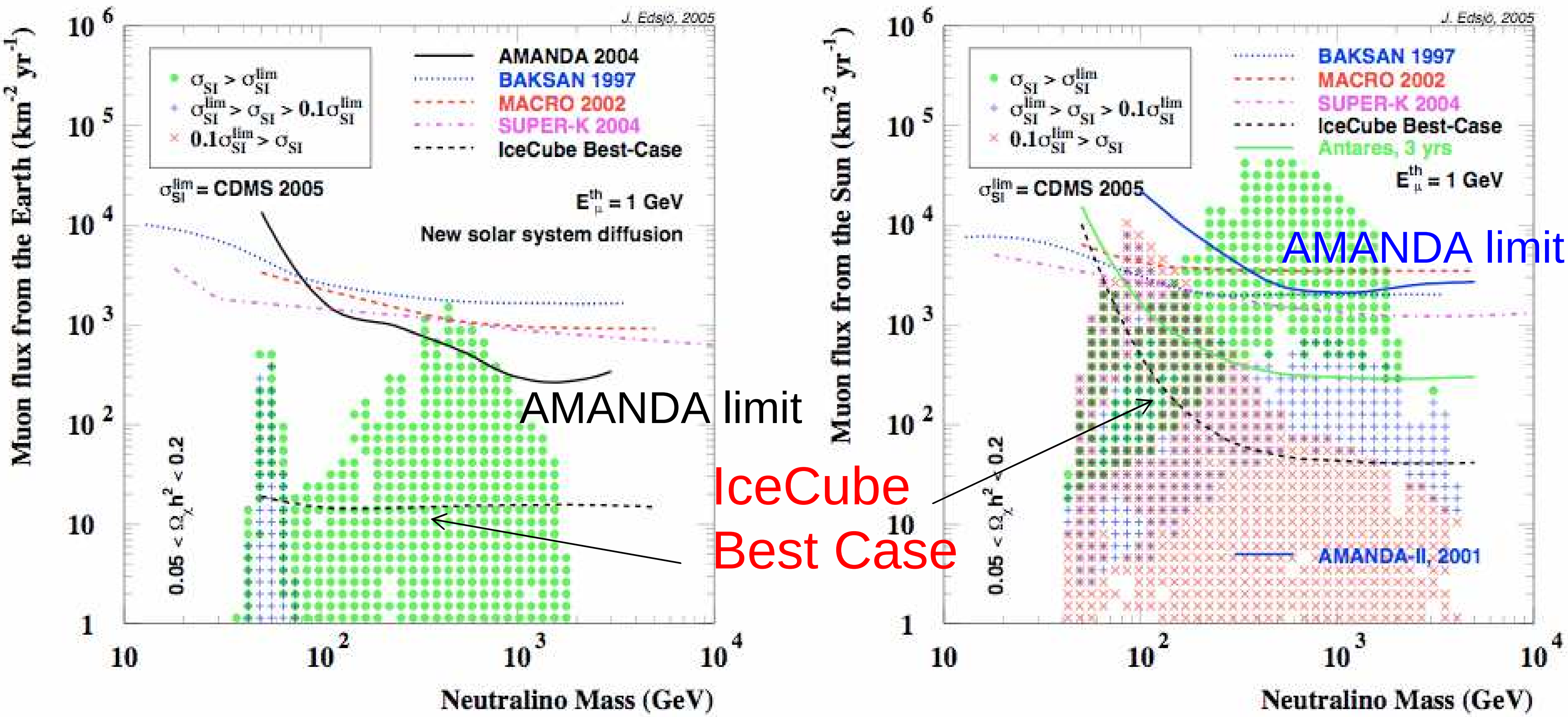


$\chi_1^0 + \chi_1^0 \rightarrow l^+l^-, q\bar{q}, W^+W^-, Z^0Z^0$

$\chi_1^0 + \chi_1^0 \rightarrow H^0_{1,2}\ H^0_3, Z^0H^0_{1,2}, W^+H^-, W^-H^+$

❑ WIMP Search Limits





■ The extremely high energy (EHE) neutrinos (>10^7 GeV)

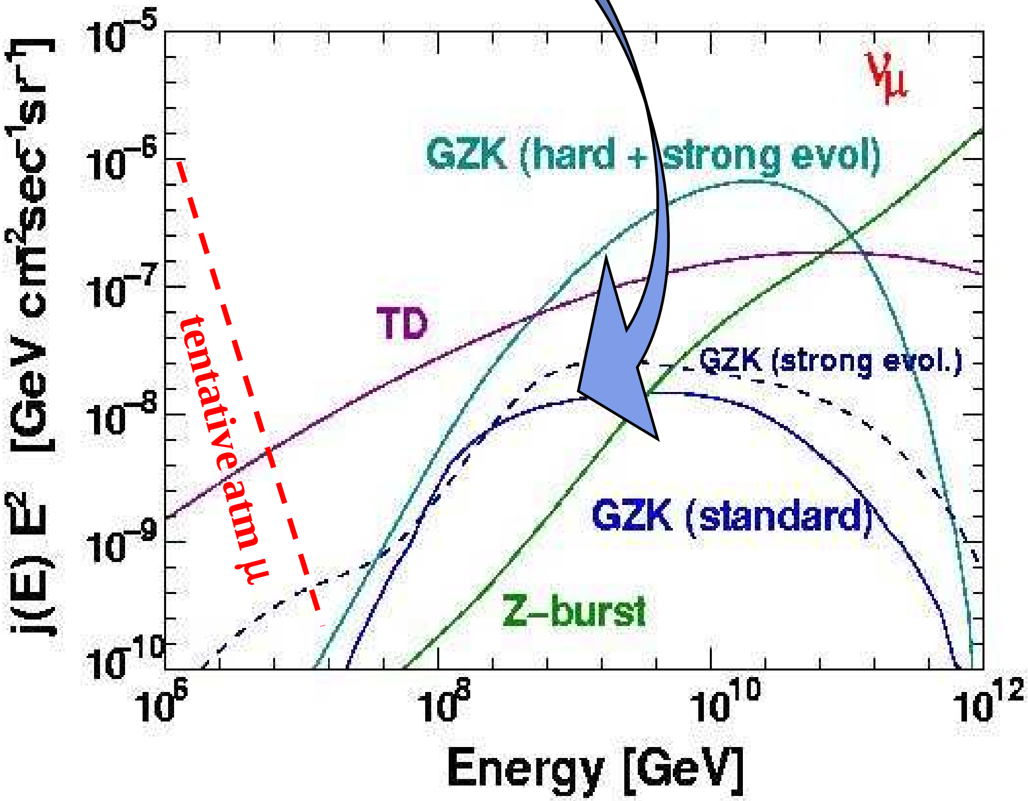
GZK neutrinos as a benchmark

The origin of the EHECRs:

- Bottom up model (AGNs, GRBs…)
- Top down model (super heavy particles, cosmic strings…)
- Z-bursts

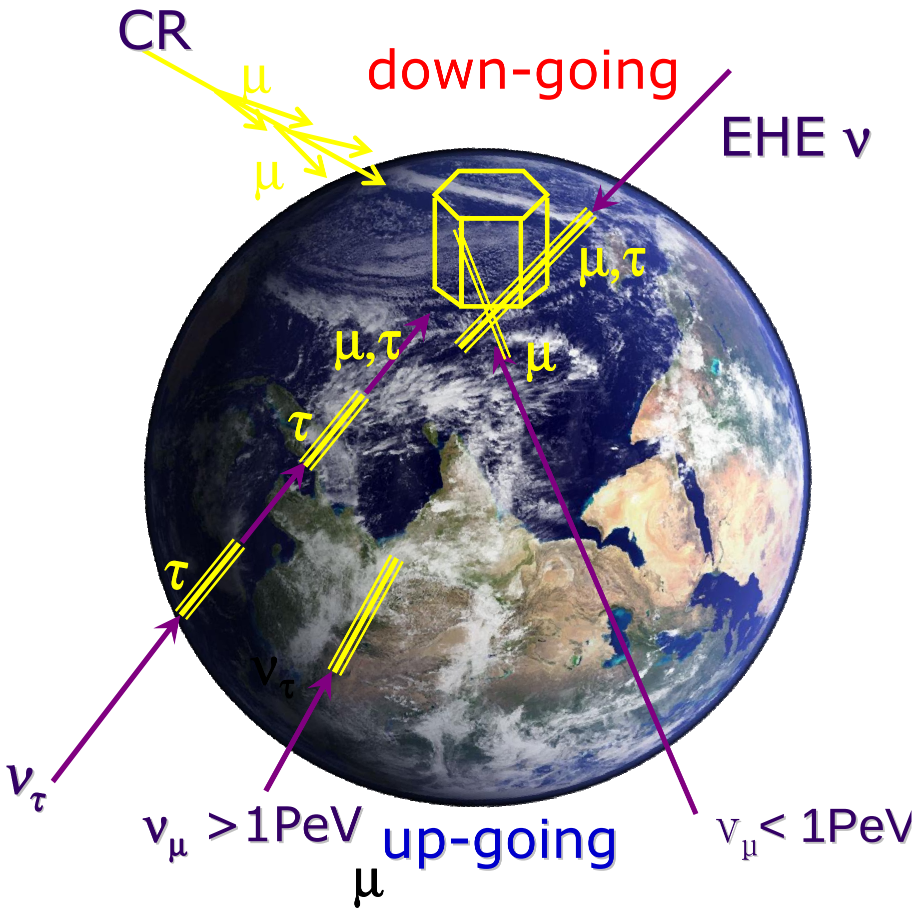
→ **In either case, neutrinos**

We test GZK ($p+\gamma \rightarrow N+\pi$): conventional

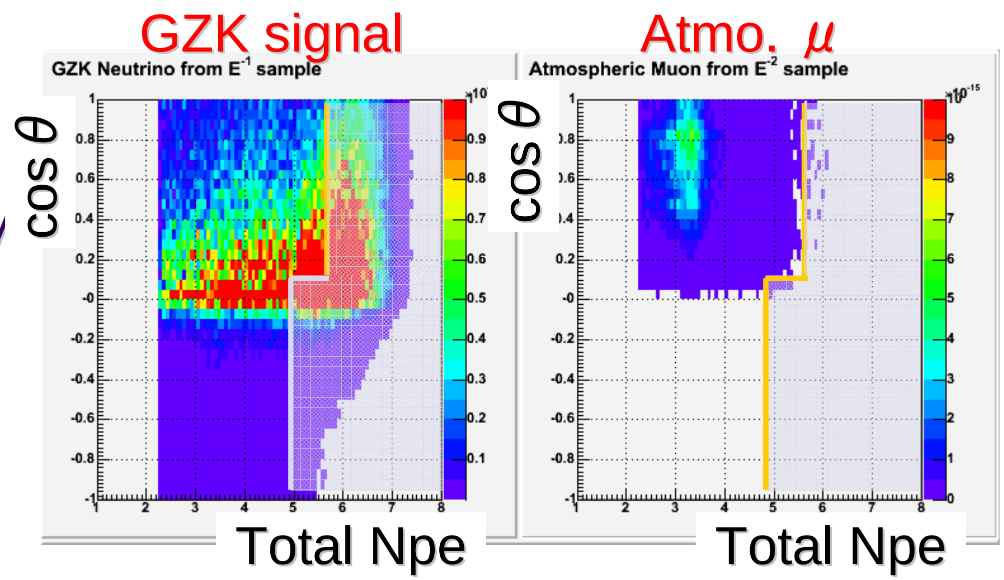


GZK: S. Yoshida et. al. (1997) ApJ 479:547,
TD: Sigl et. al.(1999), $n_{UHE}n_{2K}$: S.Yoshida et al.(1998),

How to detect EHE neutrinos

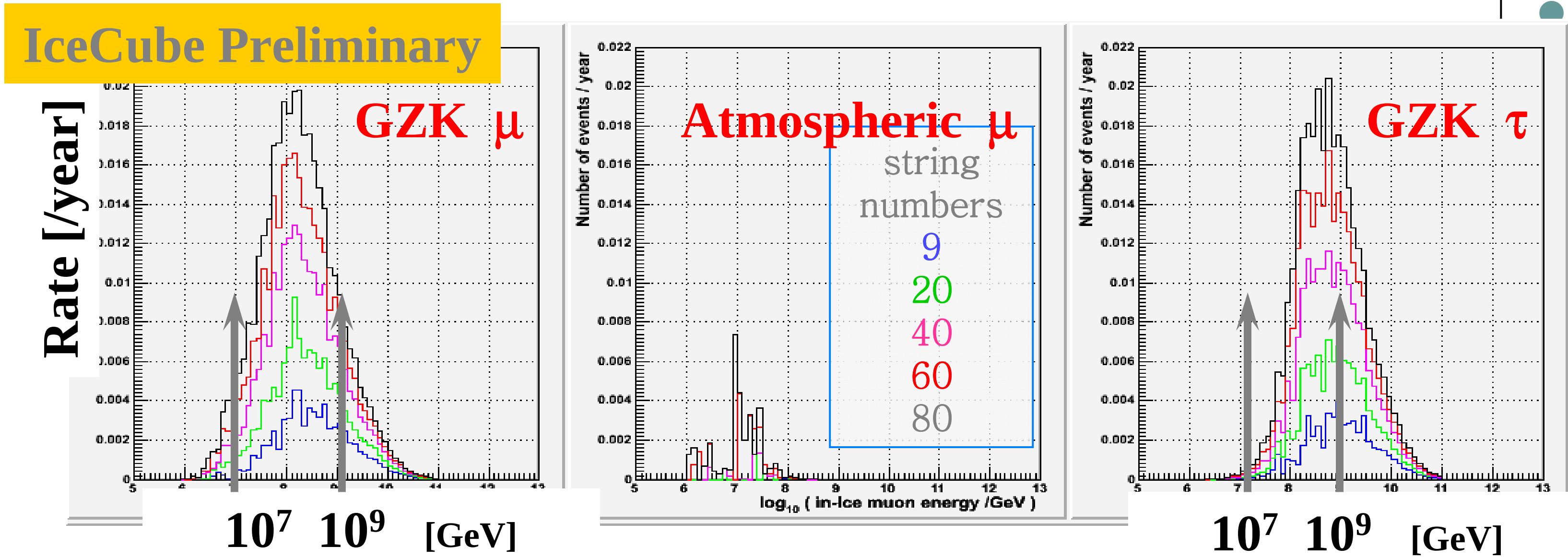


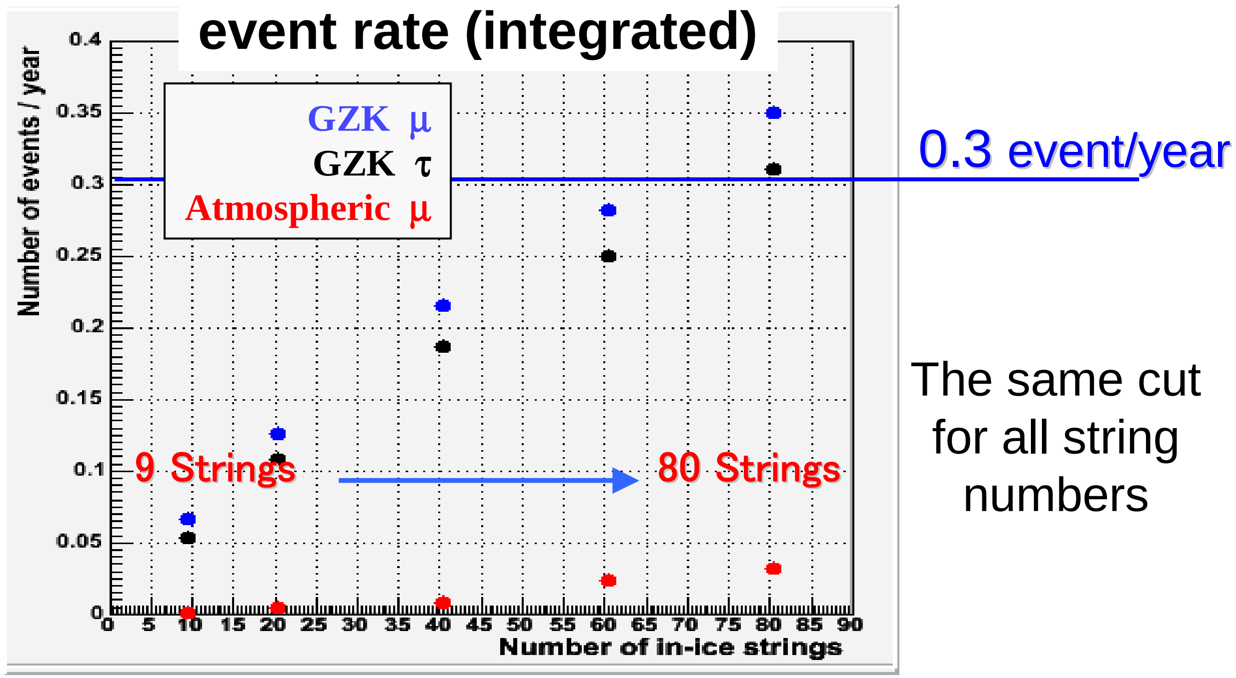
- Earth is opaque for EHE neutrinos. (The cross section increase lineally with the energy.)
- Therefore, EHE neutrinos come from above horizontal.



A. Ishihara, astro-ph/0611794

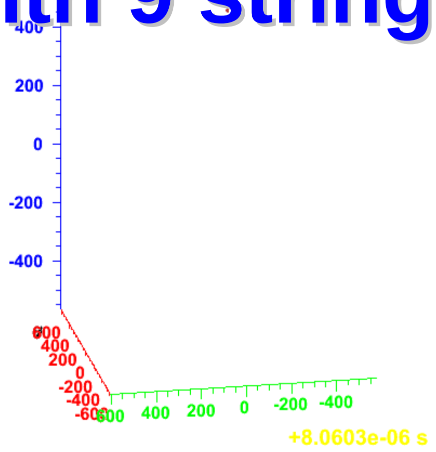
The event rate (MC study)

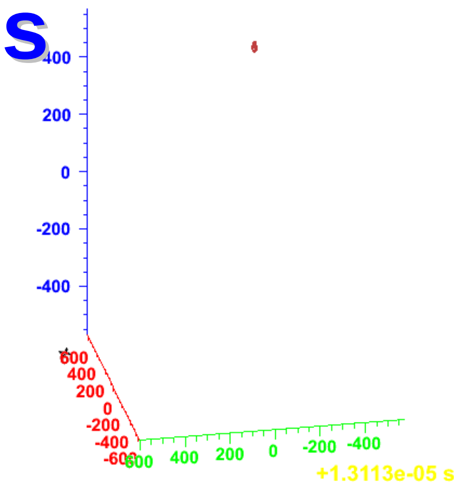




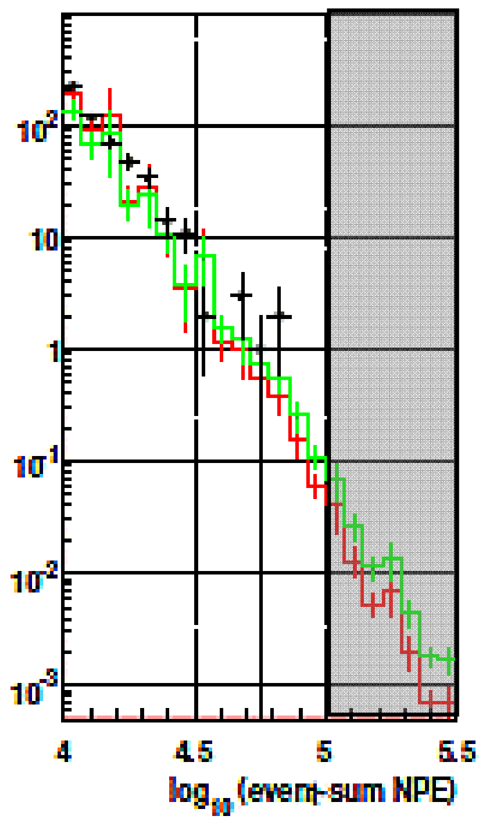
The same cut for all string numbers

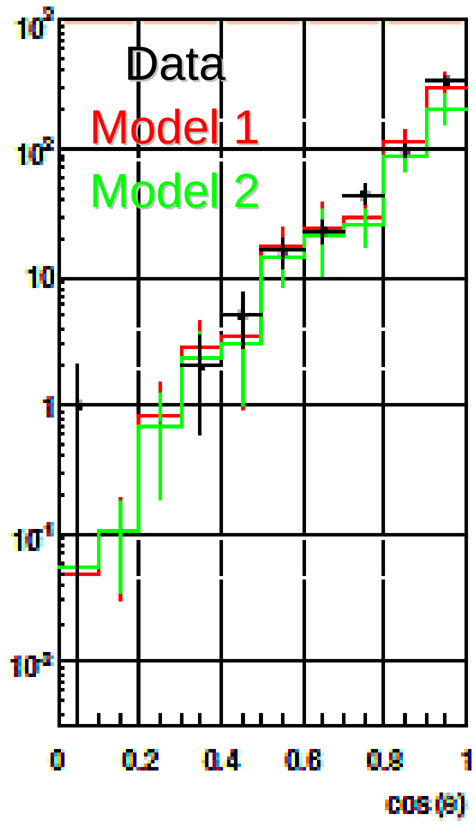
EHE analysis 2006 with 9 strings





- Live time ~ 124 days
- Npe based study
- The signal region (Npe>10^5) is blinded
- The backgrounds agree well with the MC
- The signal region will be unblinded soon



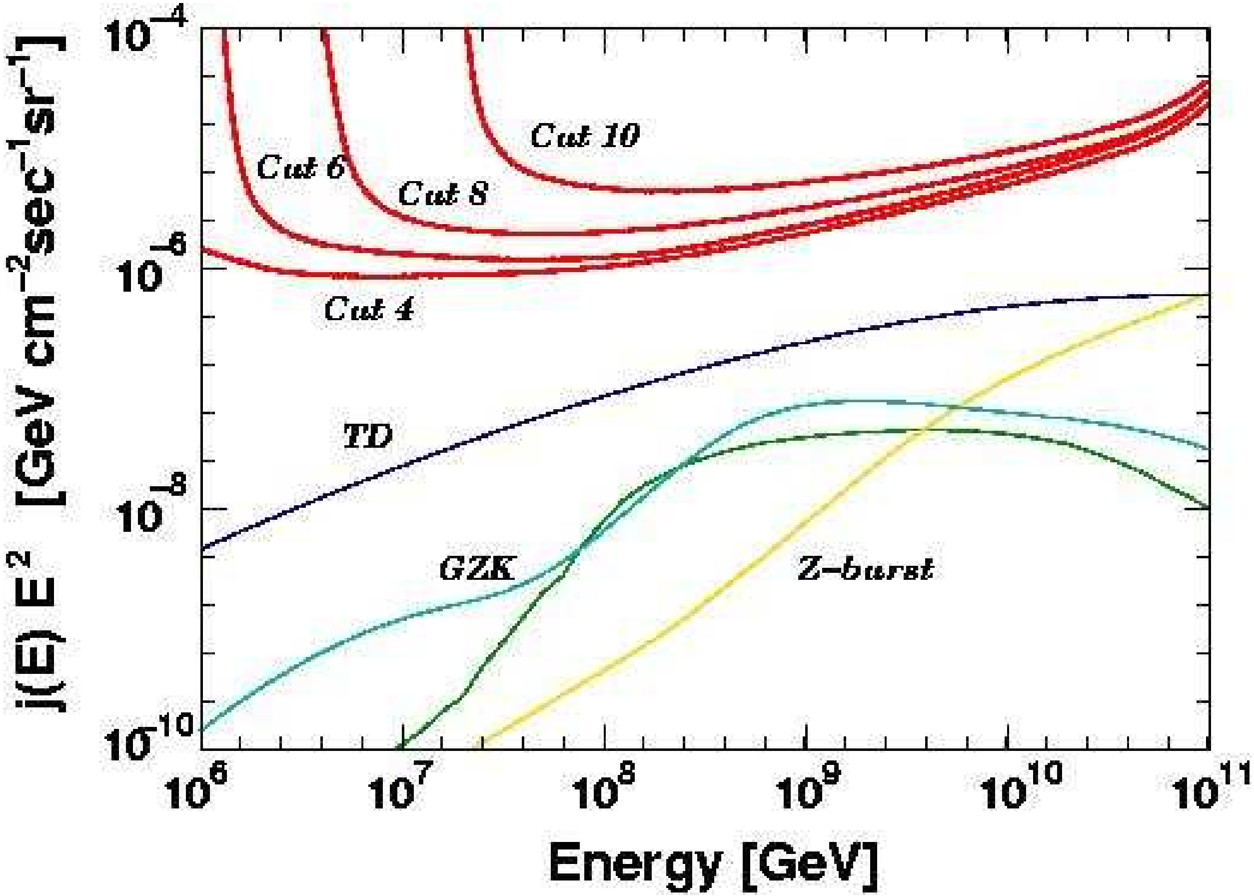


The expected rate (/124 days) in the signal region

GZK $\mu + \tau$	0.027
GZK $\nu_\mu + \nu_\tau$	0.024
Atmospheric μ	$<10^{-4}$

The sensitivity with 9 strings

If there is no signal

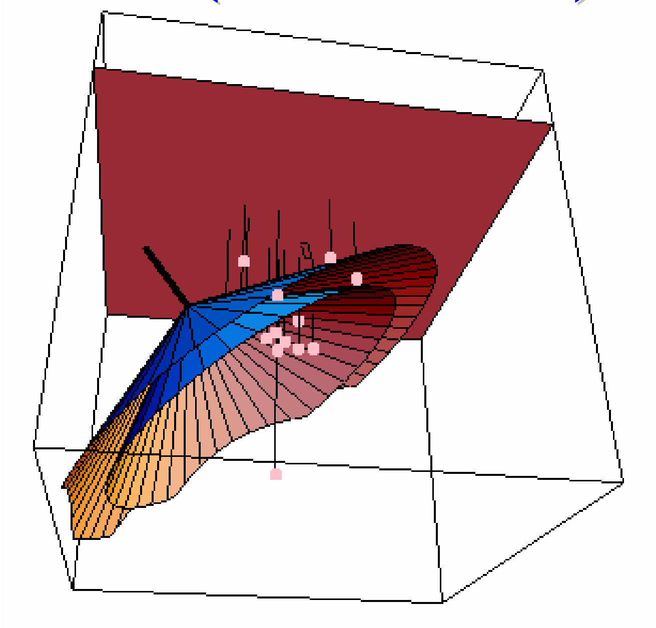


The sensitivity becomes better as the string number increases.

Beyond IceCube (R&D)

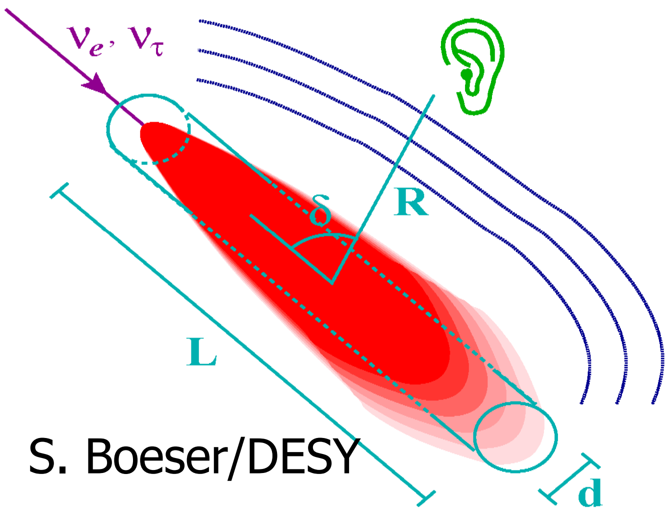
	Cherenkov Light	Cherenkov Radio	Acoustic
Attenuation length	~30 m	~1 km	~10 km

RICE (radio detector)



- The Cherenkov radiation is also emitted at radio wavelength. (Askaryan effect)

SPATS (acoustic detector)

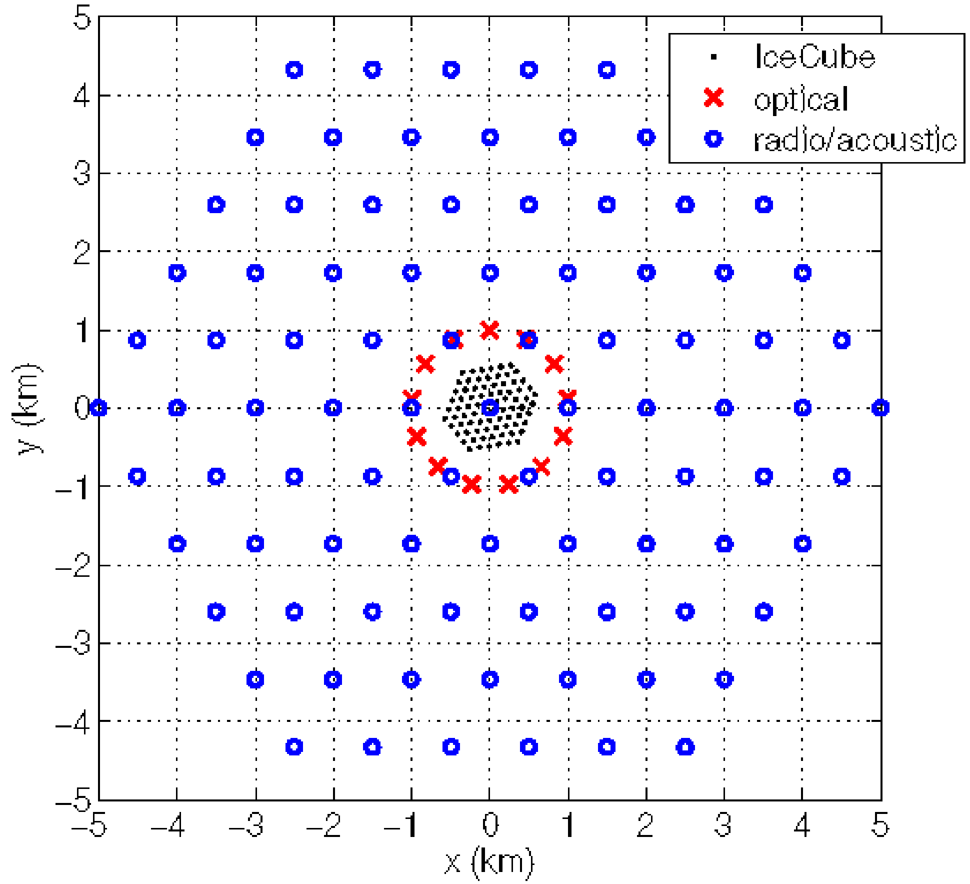


- A ν -induced cascade will produce localized heating in the medium, creating a pressure wave

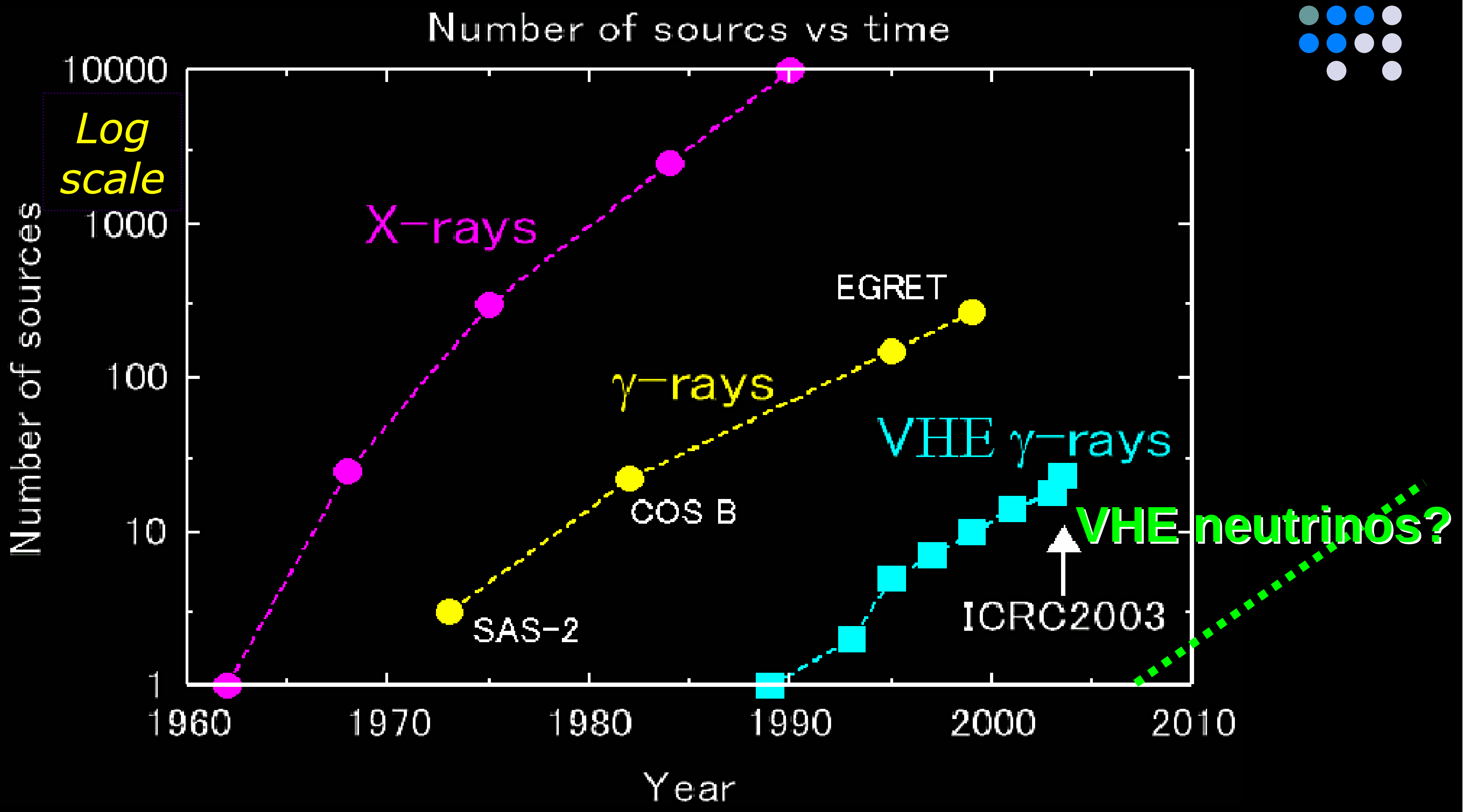
Beyond IceCube (plan)

Hybrid IceCube+Radio+Acoustic (IRA)

- ~100 km^3 effective volume at GZK energies
- ~100 strings on 1 km spacing grid



How Kifune plot will be for VHE neutrinos?



"Kifune plot" ©Rene Ong 2002

Summary

- IceCube is working as expected as the biggest neutrino detector in the word with 22 strings.
- AMANDA detector does not see any signal from sources so far.
- We hope IceCube see a signal from a source, which will open the neutrino astronomy.
- We are also planning for the next generation detector.


Illustration by Guy Billout