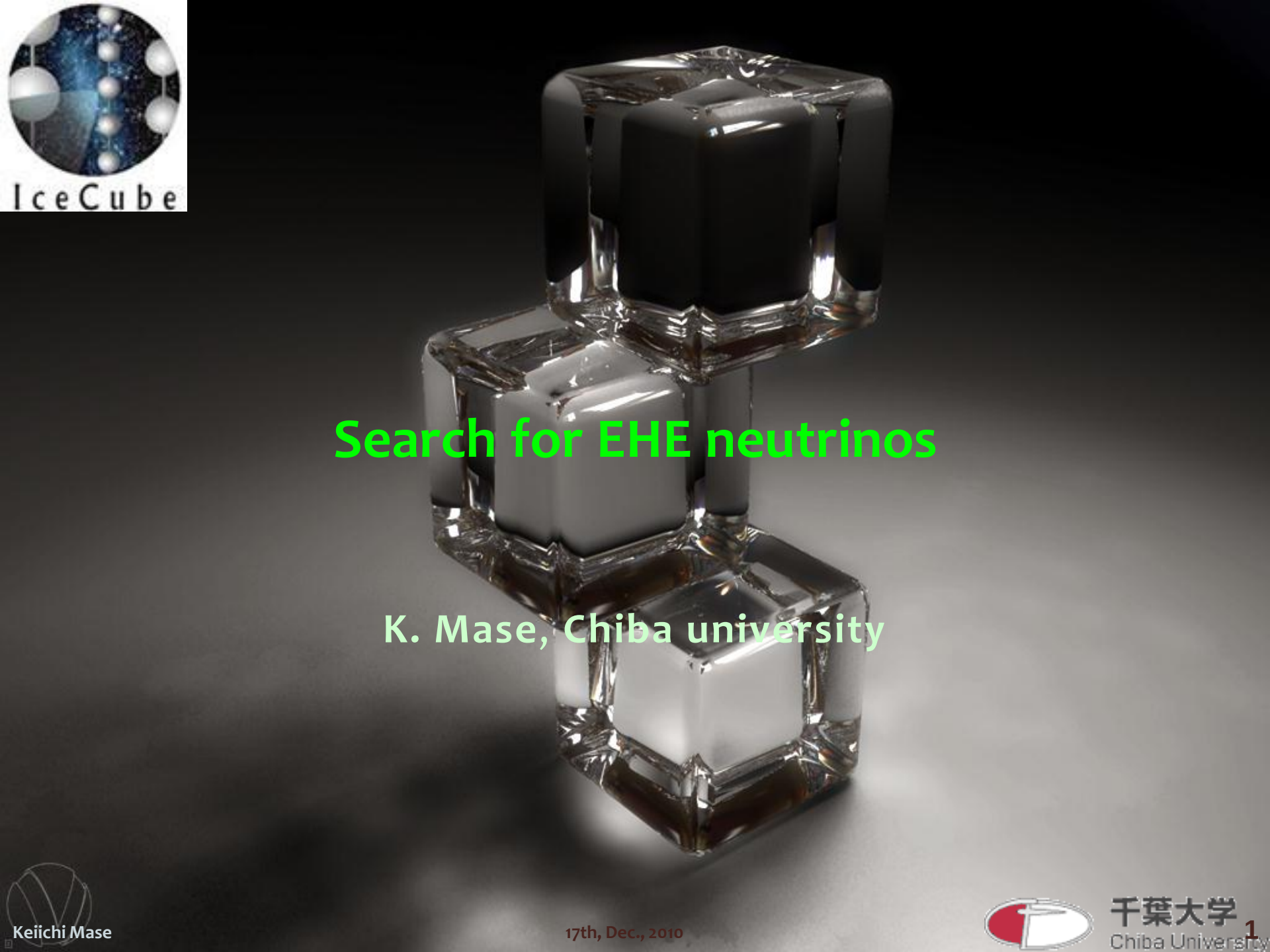


Search for EHE neutrinos

K. Mase, Chiba university

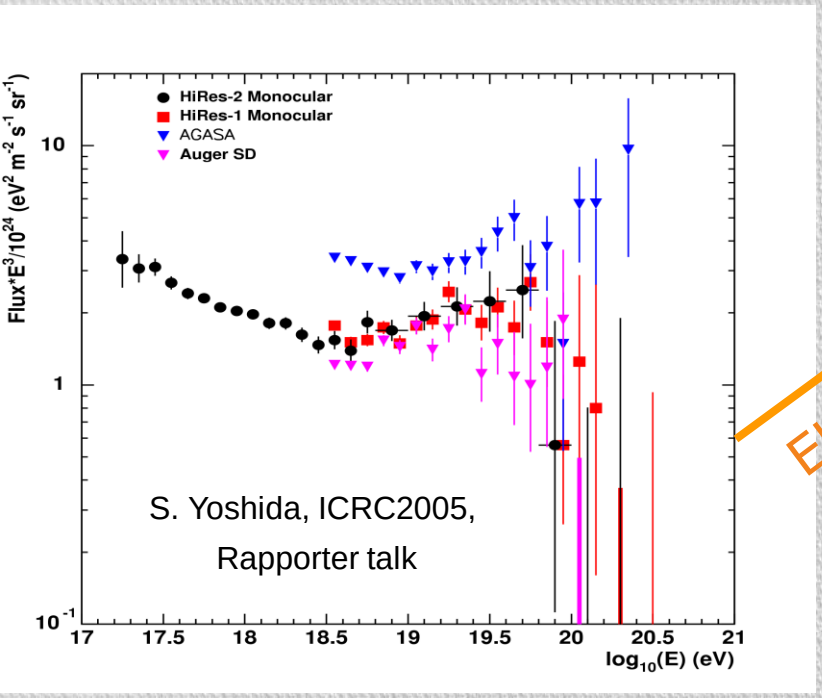
Our proposal

- PI: S. Yoshida
- Proposal: **Simulation study for the IceCube cosmic neutrino observation experiment**
- Budget: 80,000 yen

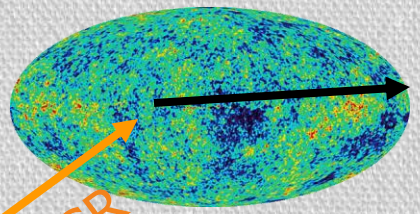
- The budget was (will be) used for
  - Travelling expense
  - Hard disks for data transfer

- Appreciate the permission of ICRR computer system use more than the budget. A part of our results owes lots to the system. (High energy cosmic ray simulation by CORSIKA)

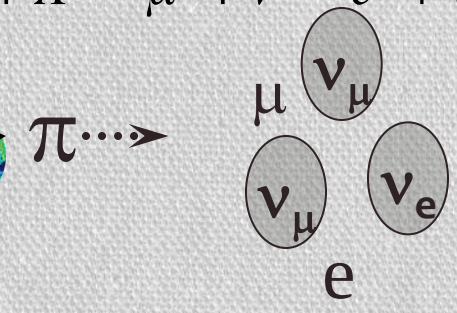
The extremely high energy (EHE) neutrinos

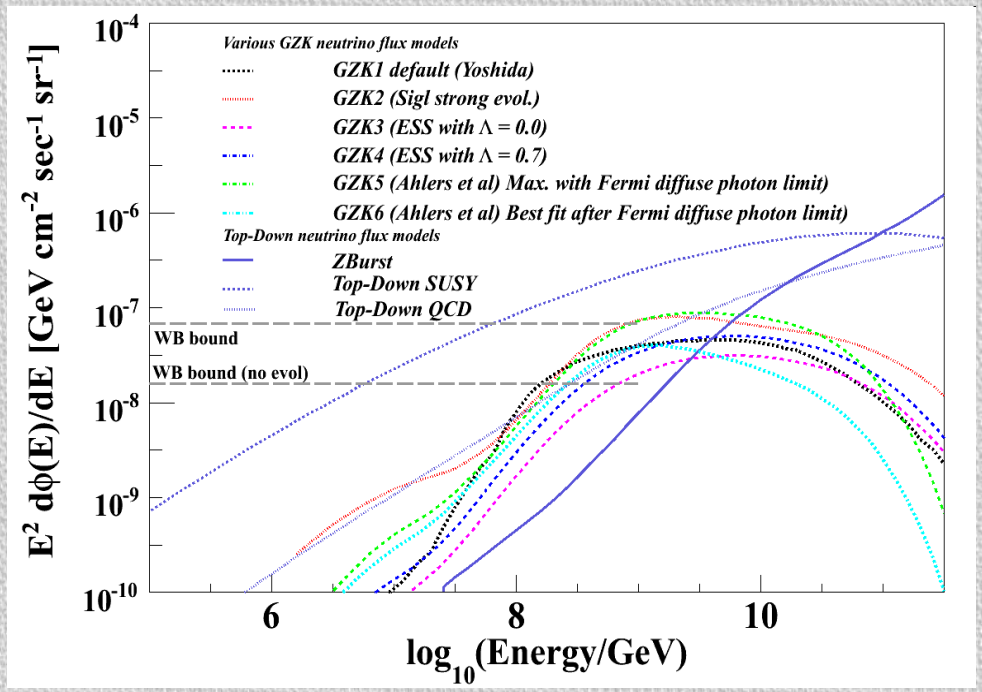


$$p\gamma_{2.7K} \rightarrow \pi^{\pm} + X \rightarrow \mu^{\pm} + \nu \rightarrow e^{\pm} + \nu' s$$



EHE-CR





Shed light on the EHECR origin

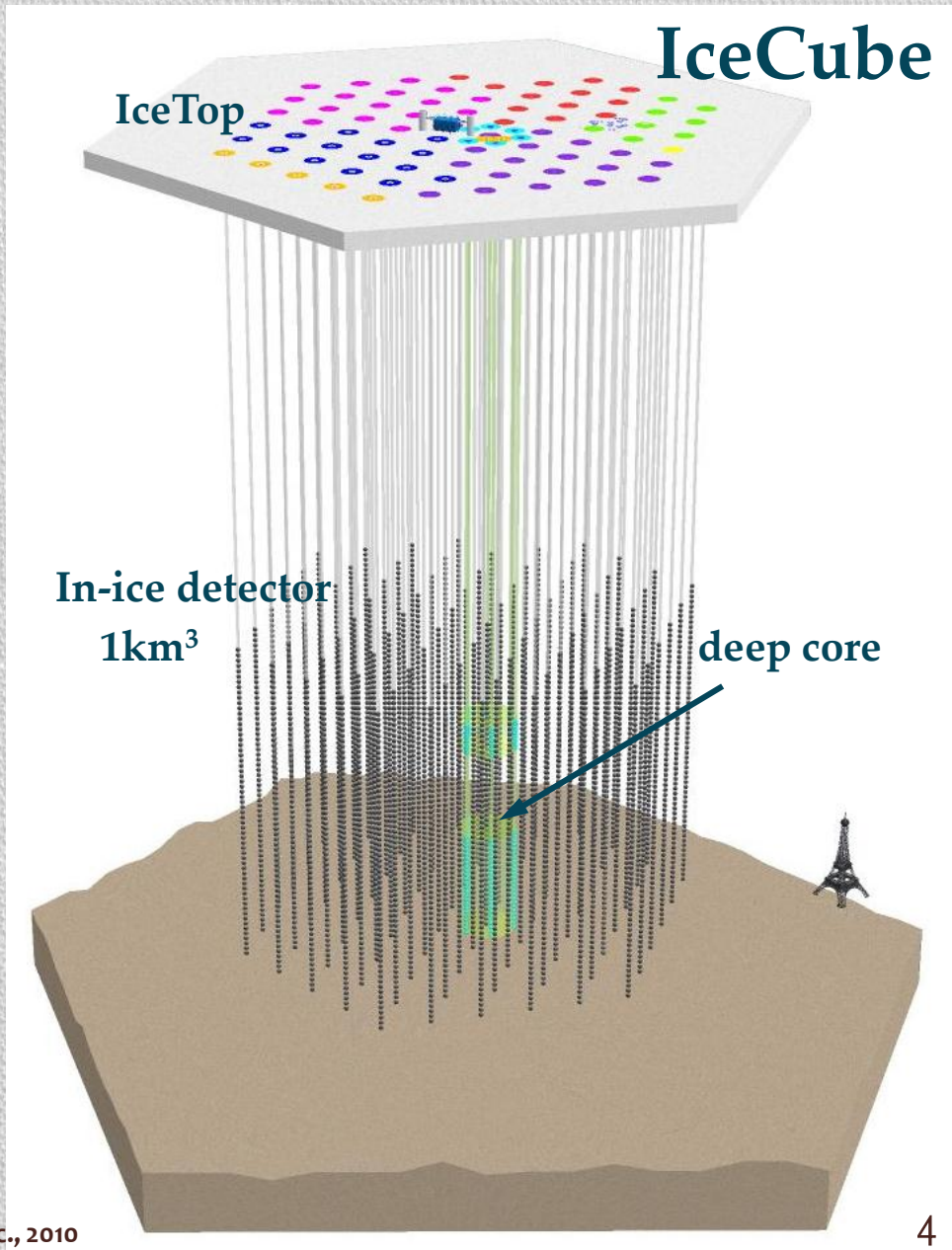
- ✧Source position
- ✧Composition (proton/iron)?
- ✧Source evolution

Predicted, but never detected

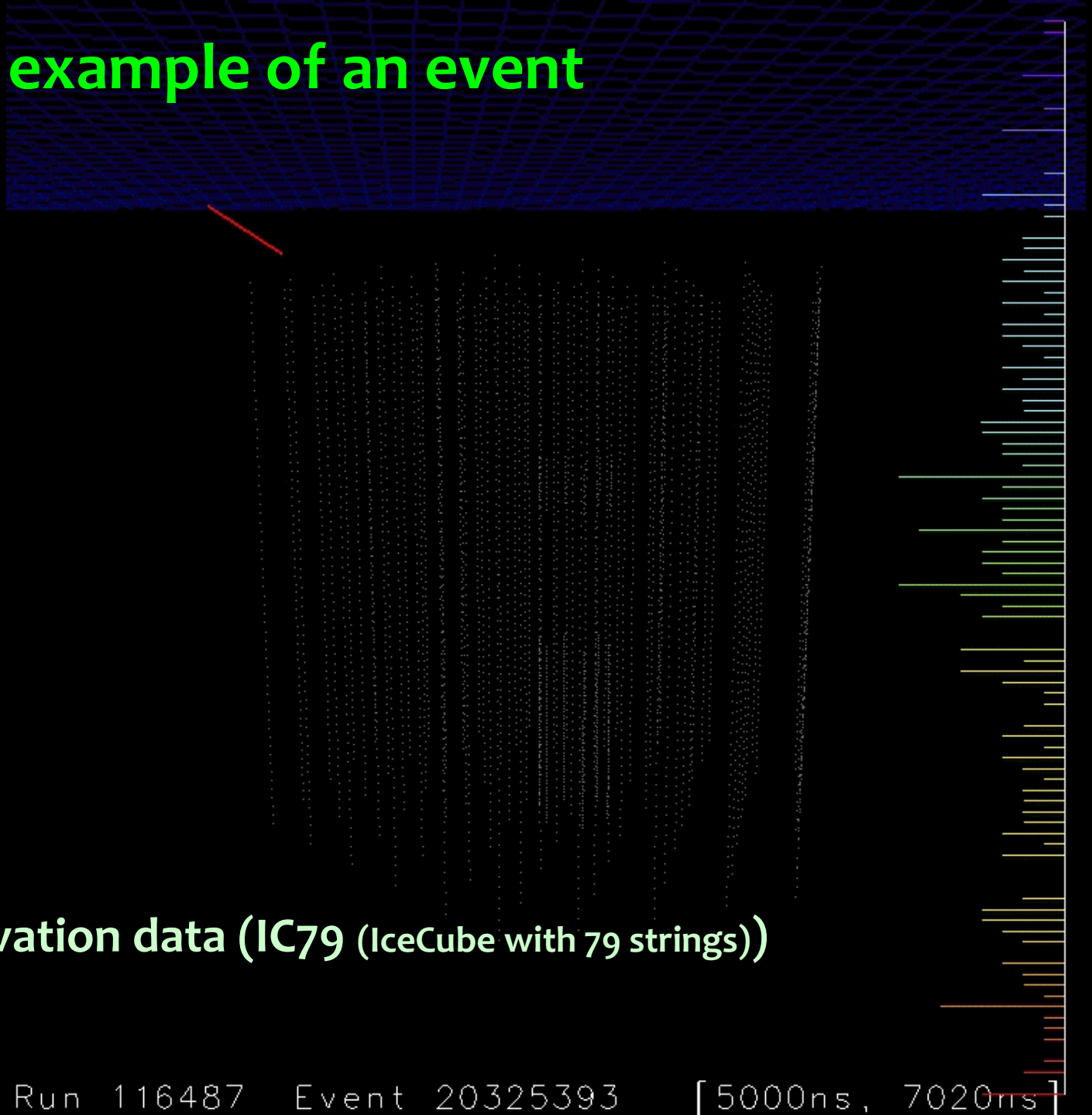
→ detectable with IceCube

The IceCube experiment

- Deployed in the Antarctica glacier
- In-ice + IceTop + deep core
- 86 strings (completed this season!)
- ~ 5000 photo-multiplier tubes (PMTs)
- Detector volume: ~ 1 km^3
- ATWD 300MSPS
  3 different gains (x16, x2, x0.25)
- FADC for long duration pulse
- Targets for high energy neutrinos
  (>~ 100 GeV)



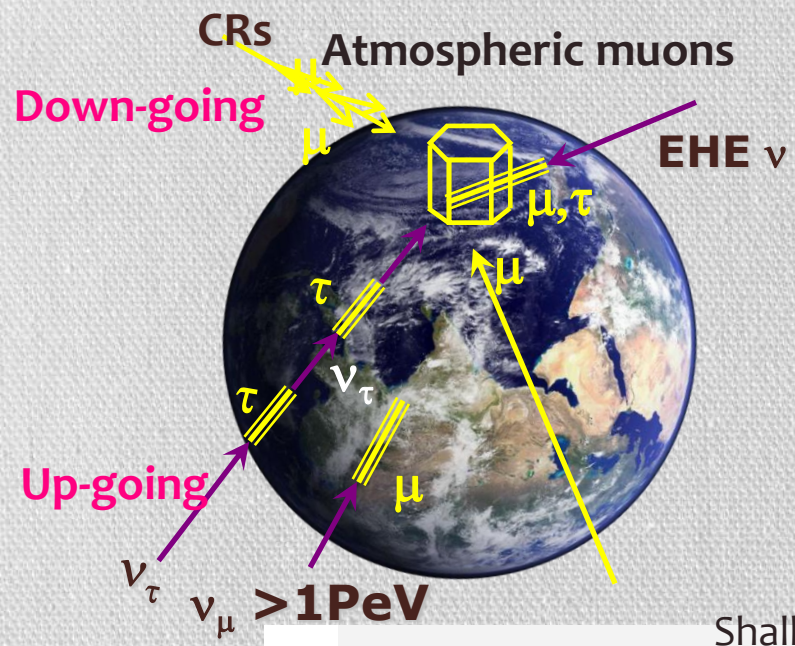
An example of an event



Observation data (IC79 (IceCube with 79 strings))

The detection principle

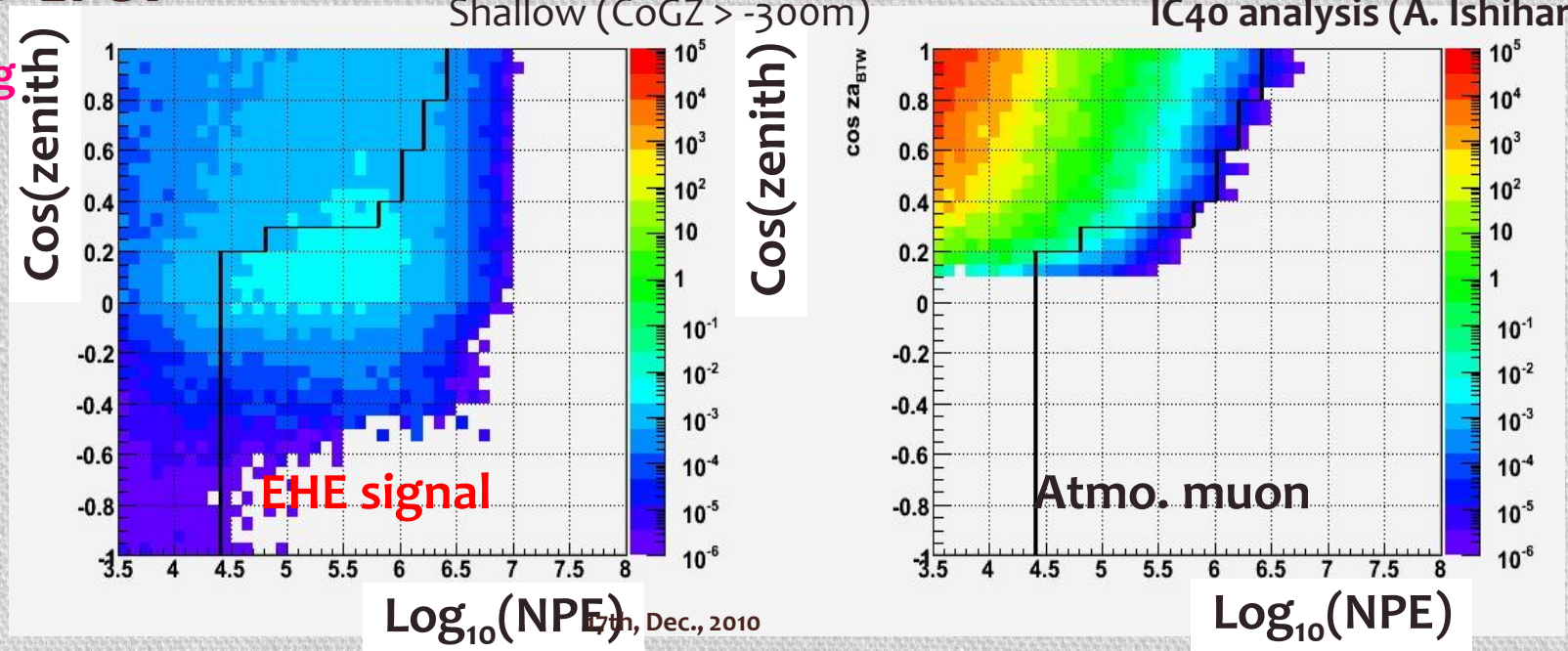
Simple but robust analysis



- **EHE neutrino signal**
  - horizontal (opaque to the earth)
  - high energy
- **Atmospheric muon background**
  - down-going
  - low energy (the energy spectrum is steep ($E^{-3.7}$))

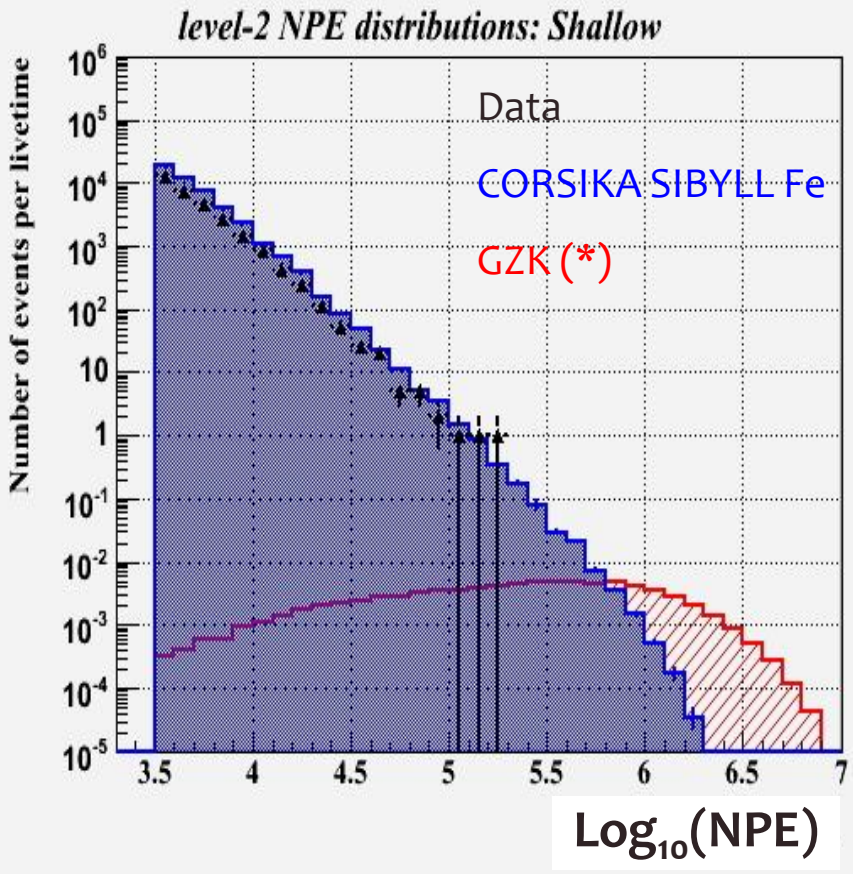
Shallow (CoGZ > -300m)

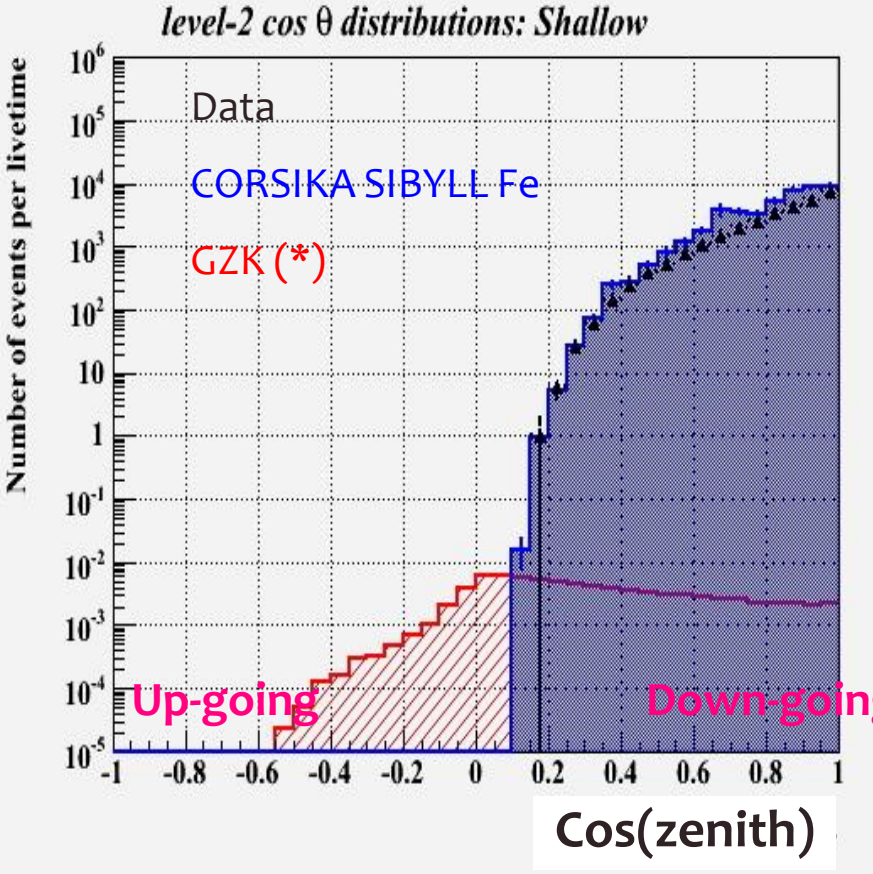
IC40 analysis (A. Ishihara)



Agreement between data and MC

Shallow (CoGZ > -300m)

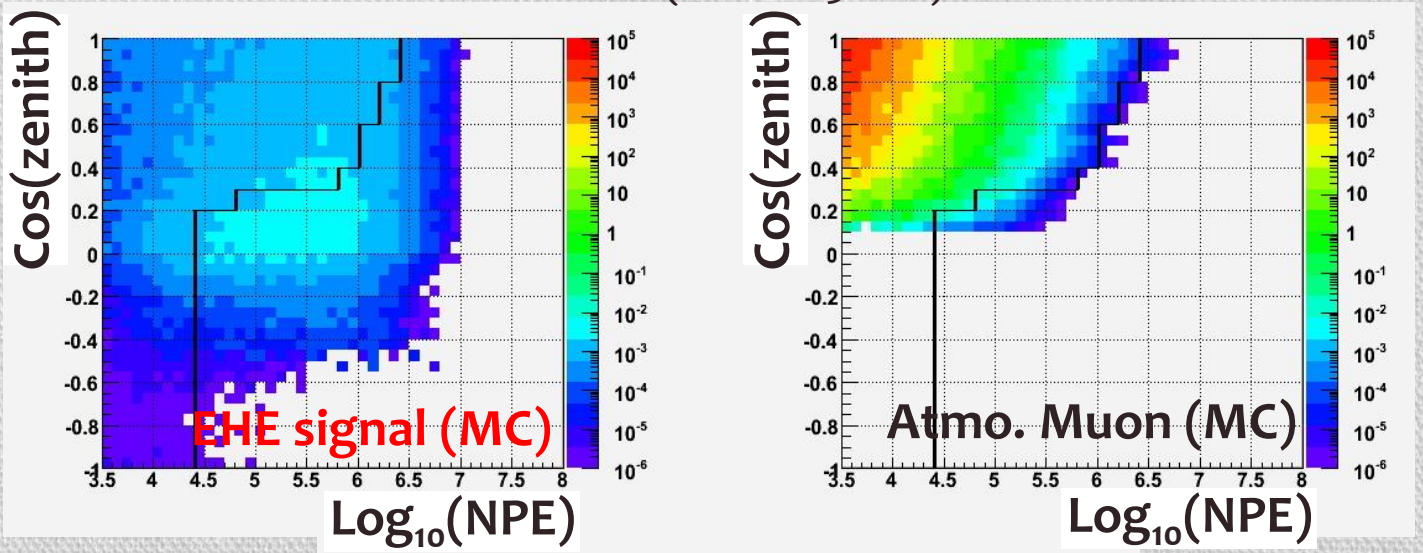


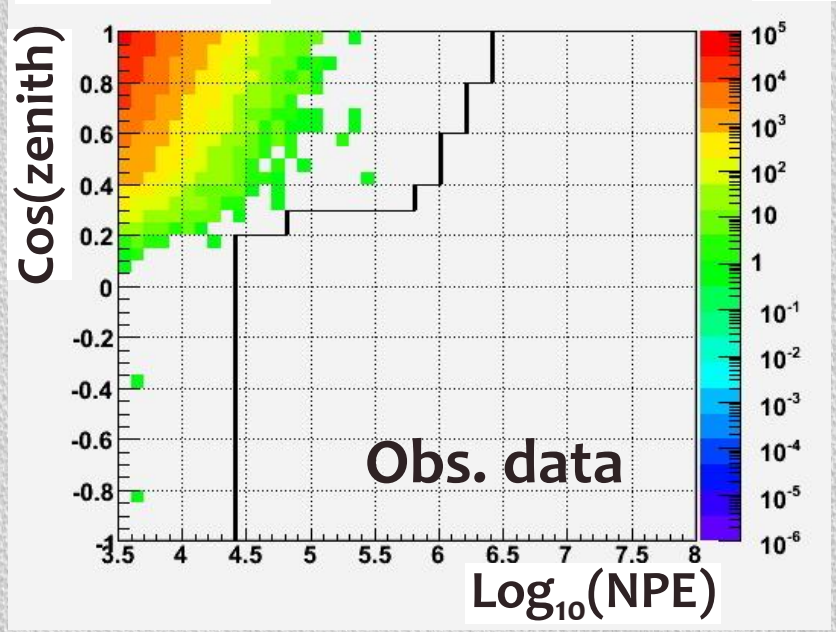


(*) Yoshida et al., ApJ, 1997, m=4, Z_{max}=4

The result

Shallow (CoGZ > -300m)





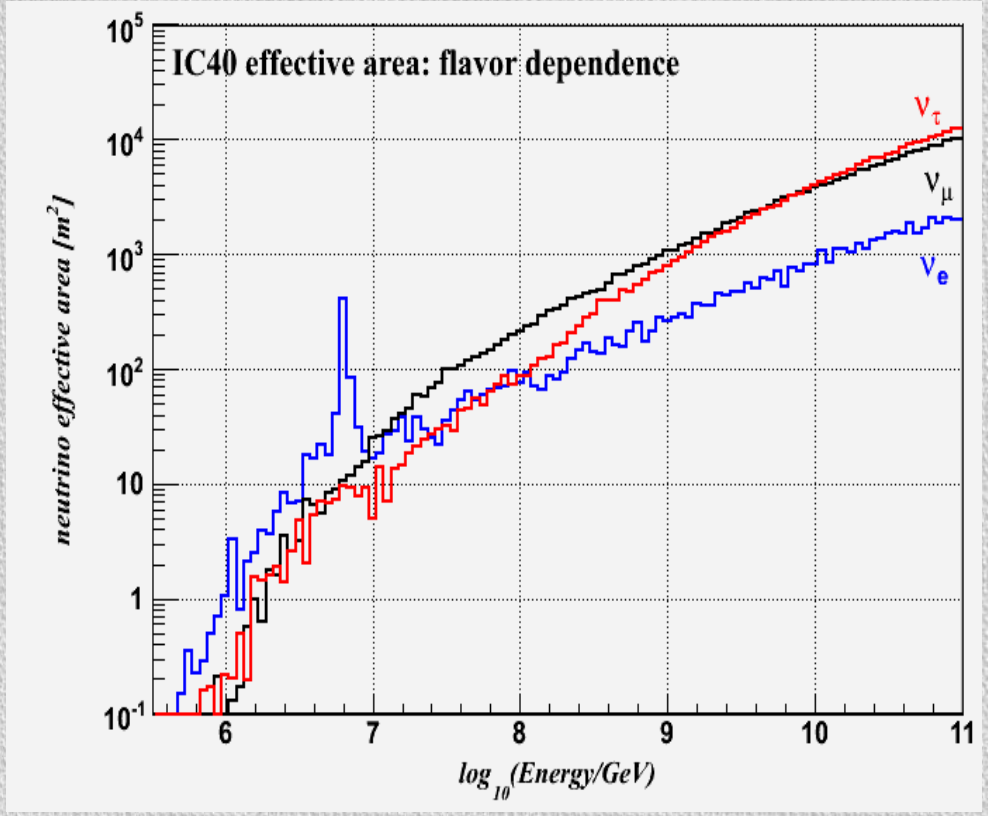
BG is kept to
0.1 event / 335.5 days

IC40 analysis (A. Ishihara)

No signal unfortunately → upper limit

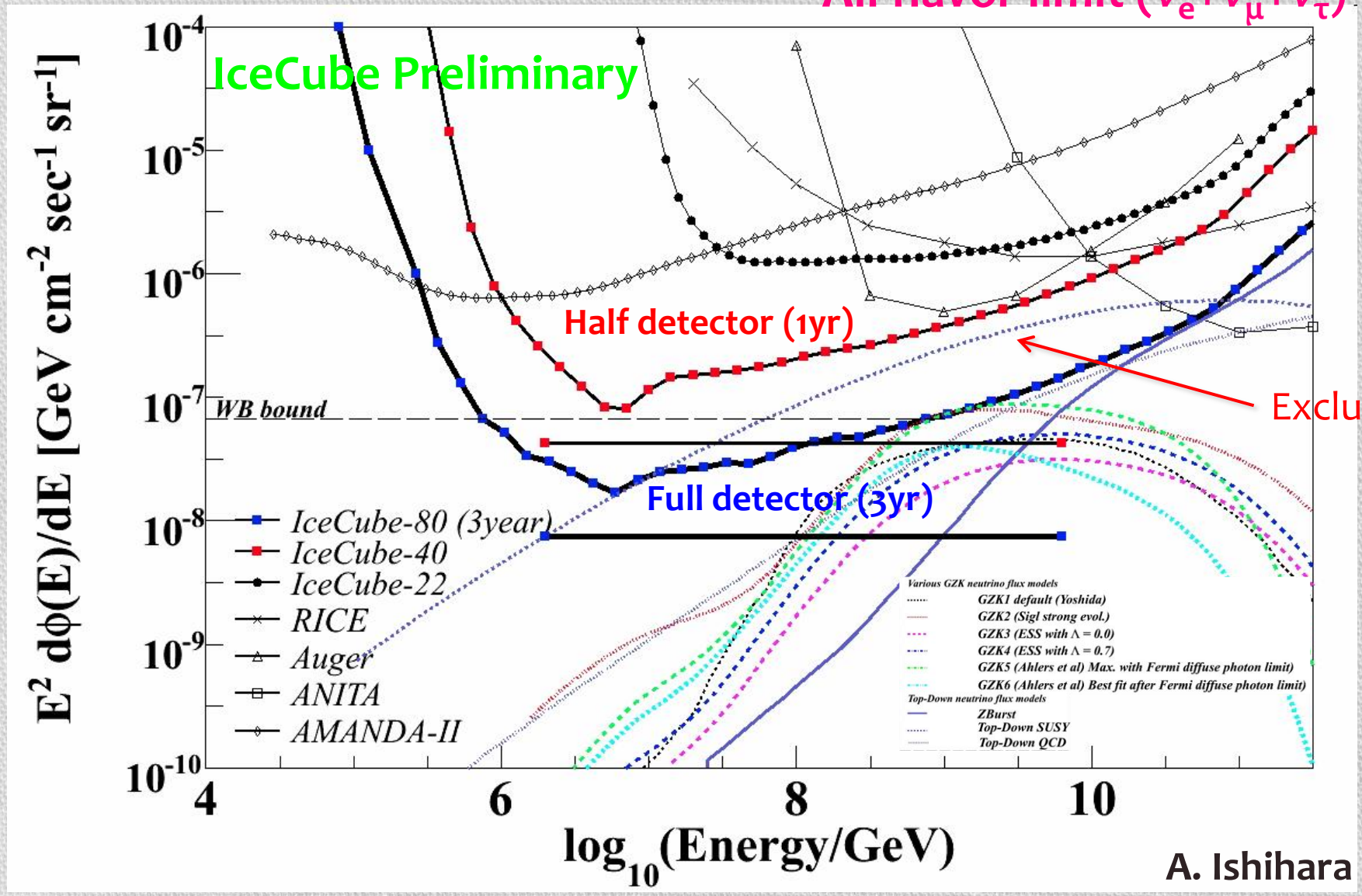
The effective area and event rates (IC40)

model	Event rate (/335.5 days)
GZK (m=4, Z_{max}=4, Yoshida et al., ApJ, 1997)	0.57
GZK (m-5, Z_{max}=2, Kalahsev et al., PRD, 2002)	0.91
GZK (Λ=0.7, Engel et al., PRD, 2001)	0.47
GZK (m=4.45, Ahlers et al., AstroP, 2010)	0.89
GZK (γ=2.5, Ahlers et al., AstroP, 2010)	0.43
Z-burst (Yoshida et al., PRL, 1998)	1.03
Top-down SUSY (Sigl et al., PRD, 1998)	5.68

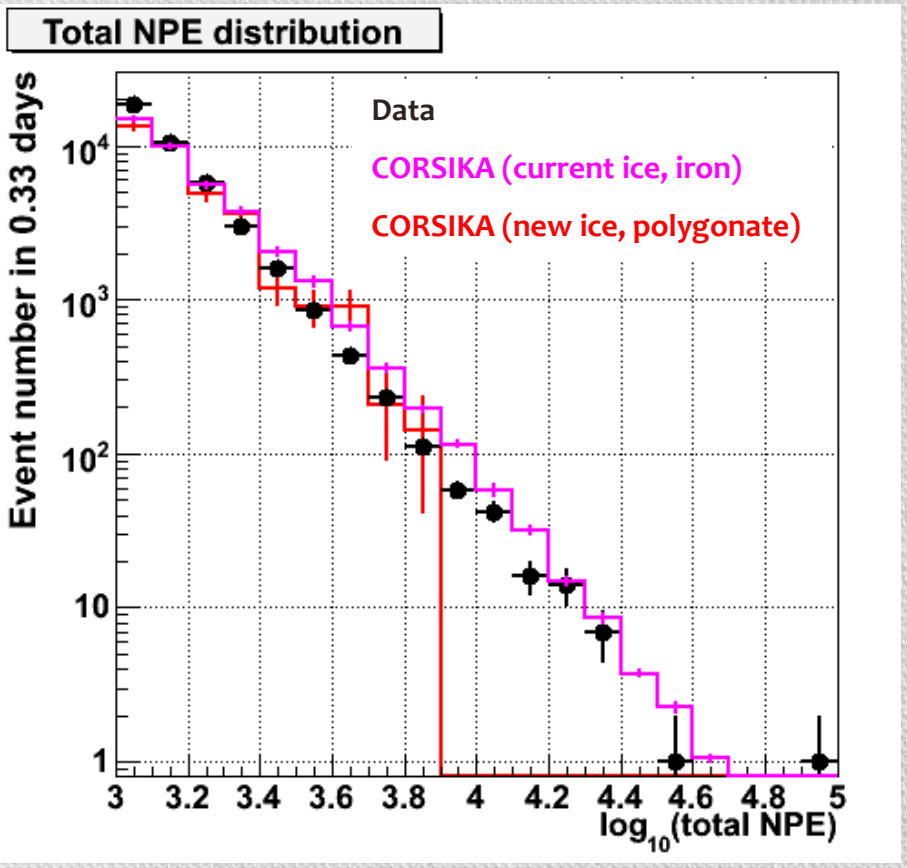


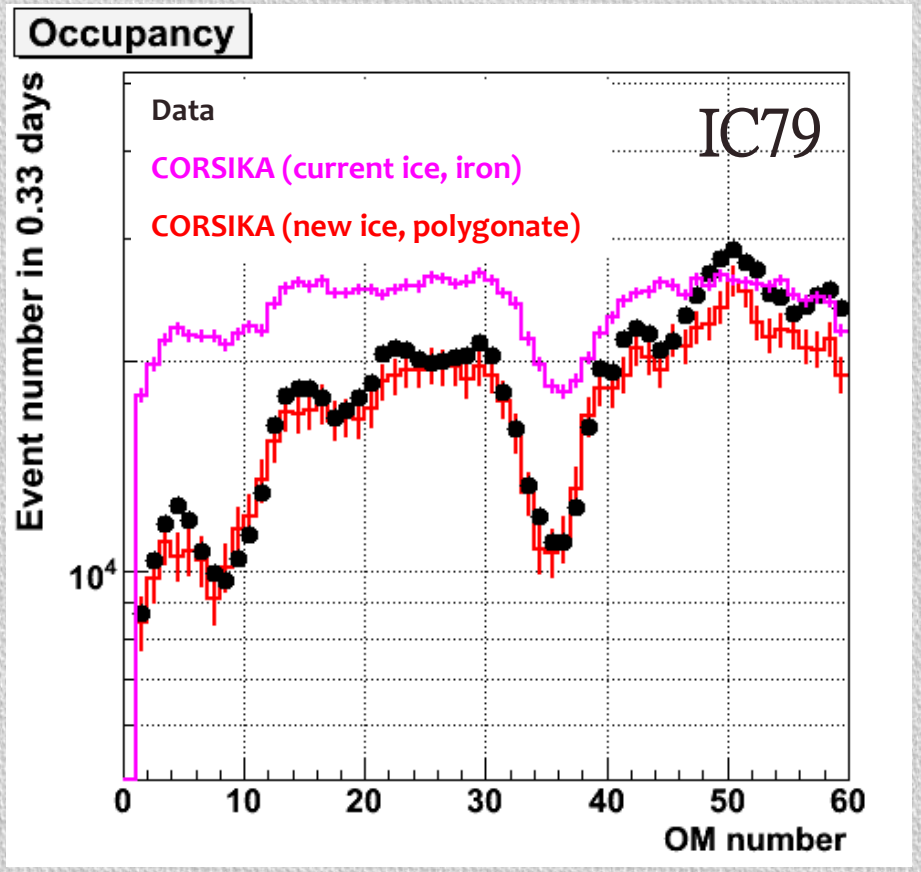
← Excluded by 99.6% C.L.

The upper limit and sensitivity



Better understanding of the detector



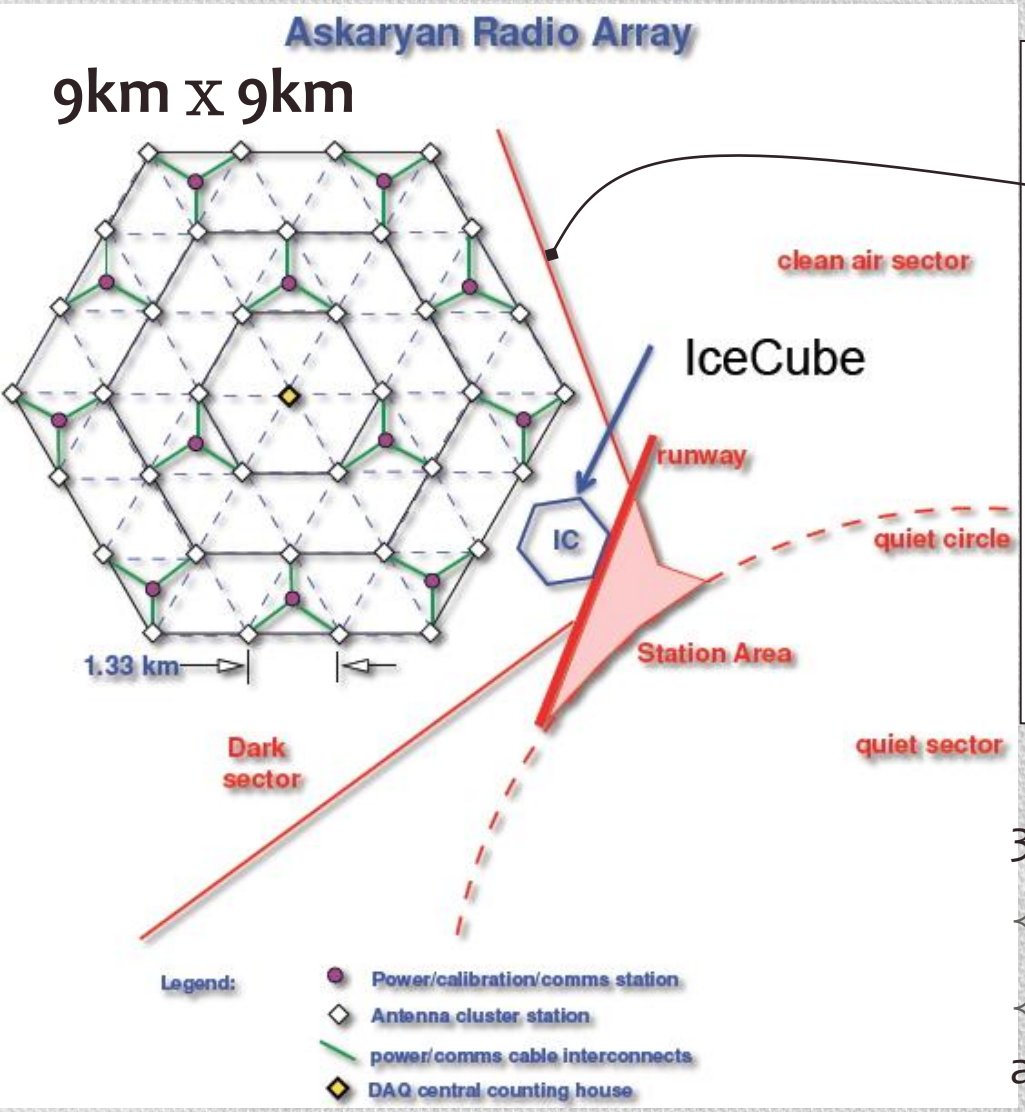


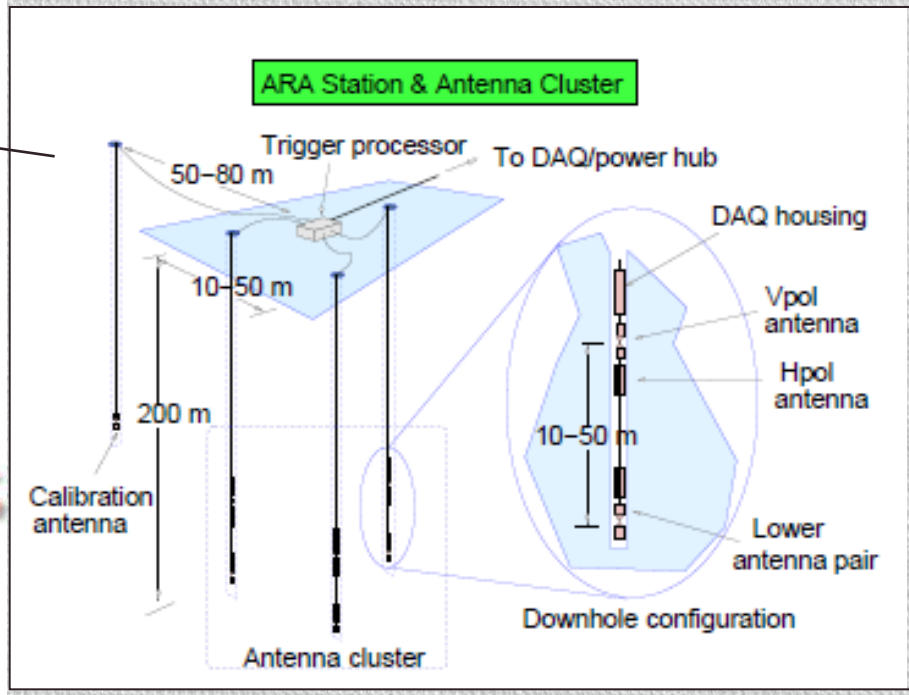
- Event-wise total NPE is robust

→ current analysis is simple but robust

- DOM occupancy is sensitive to the ice model
- New ice model has a better agreement with data → **understanding better the detector**
- More sophisticated analysis possible

Next plan - Askaryan Radio Array (ARA)



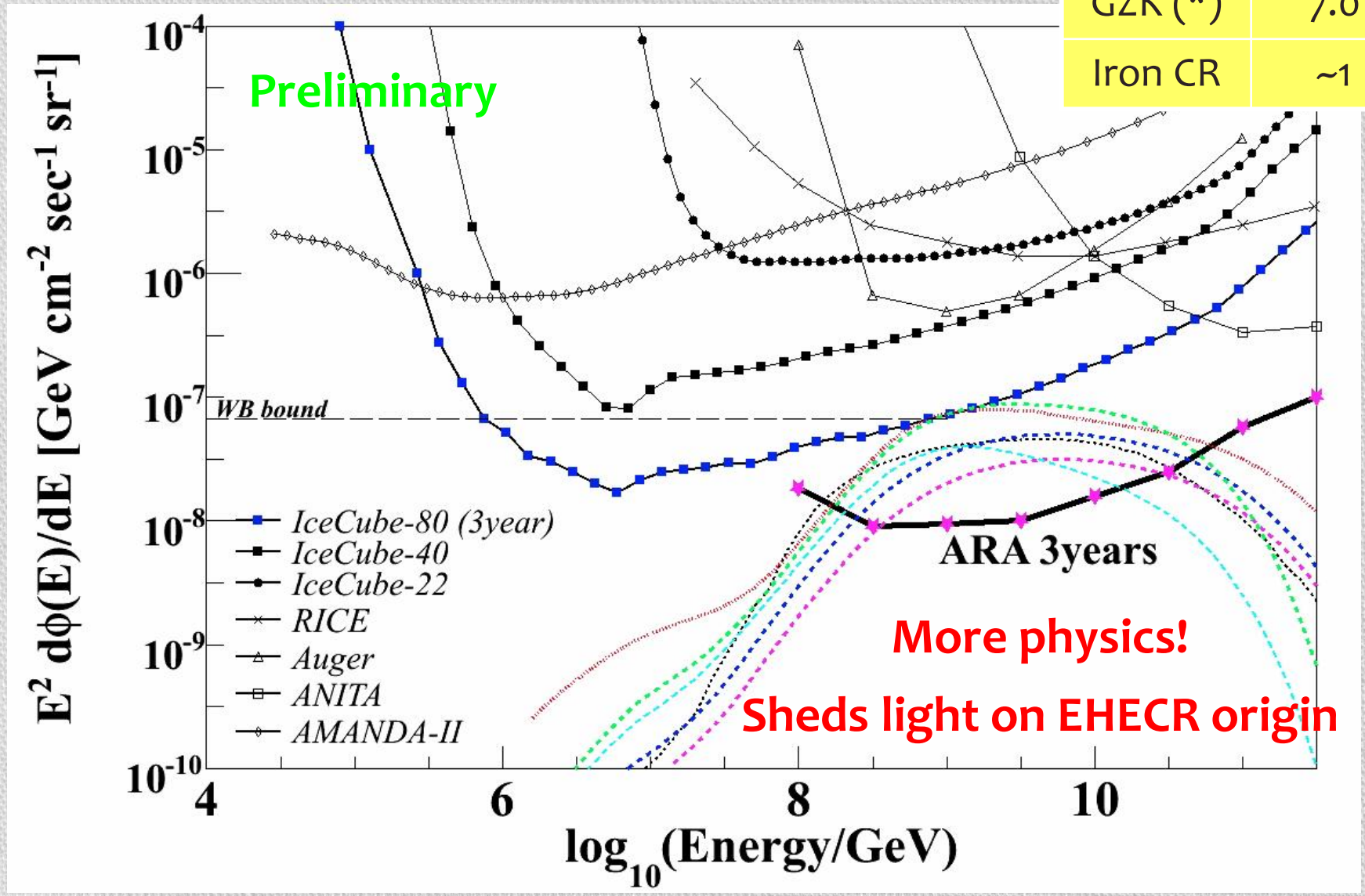


37 string clusters

- Each cluster has 4 strings of 200m depth
- Each string has 2 Vpol + 2Hpol broadband antennas (200 MHz - 1 GHz)
- Total surface area ~80 km^2

The ARA sensitivity

Model	#/year
GZK (*)	7.0
Iron CR	~1



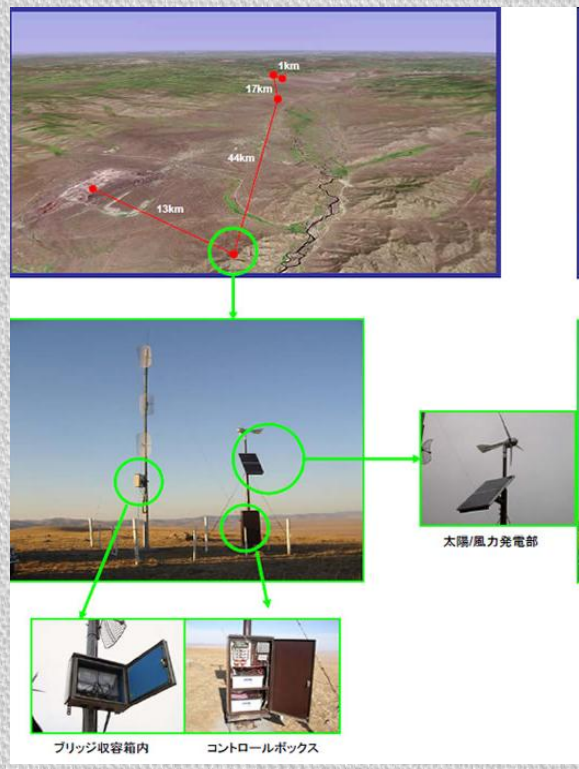
(*) Yoshida et al., ApJ, 1997, m=4, Z_{max}=4

Chiba contributions to ARA

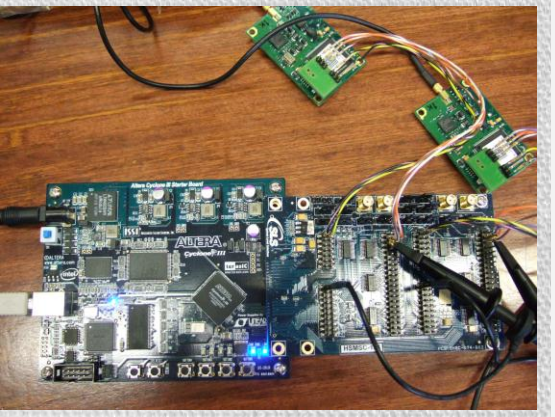
- Timing system for the DAQ (GPS and Rb clock)
- Wireless LAN for communication
- Antenna response function calibration
- IceCube and ARA coincident event analysis

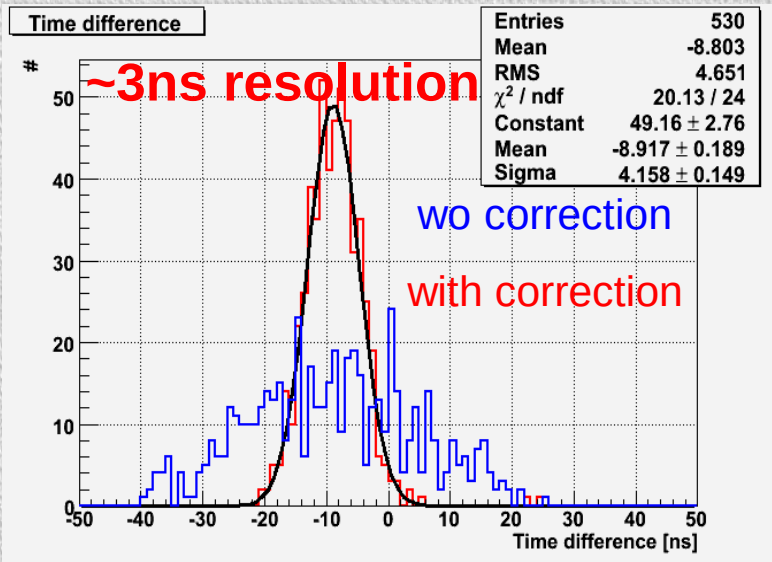
Wireless communication system

The experimental set-up



GPS test





Summary

- IceCube is increasing the detector volume and will be completed in this season (21st, Dec.,2010 planned).
- So far, no neutrino signal yet.
- In 2-3 years, within reach to the GZK fluxes.
- Understanding the detector better.
- Next plan of ARA in order to shed light on the EHECR origin.