ASPEN CENTER FOR PHYSICS
New Directions in Neutrino Physics, February 3 - 9, 2013

TECHNISCHE UNIVERSITÄT MÜNCHEN

Heisenberg-Programm
Deutsche Forschungsgemeinschaft
Bundesministerium für Bildung und Forschung

The stepping stones to proton decay:

IceCube

PINGU

MICA

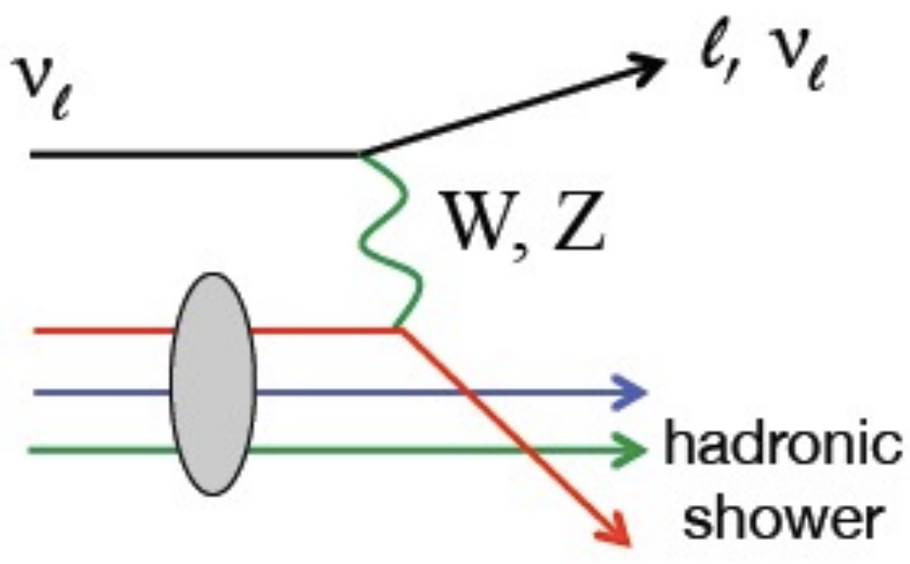
and potentially neutrinos from SN-core collapse (see Monday session)

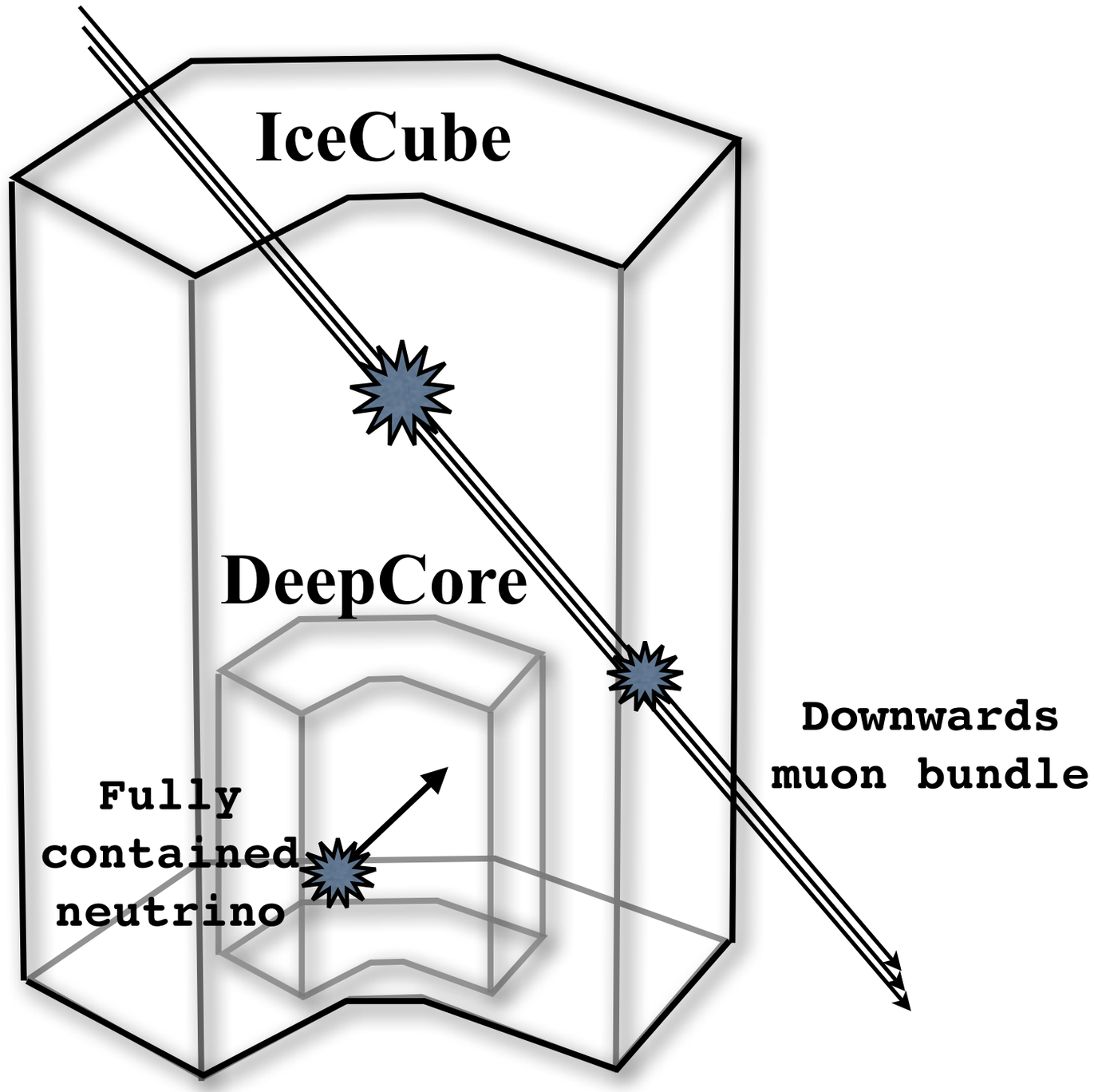
Elisa Resconi
TU Munich

IceCube

Principle of Detection

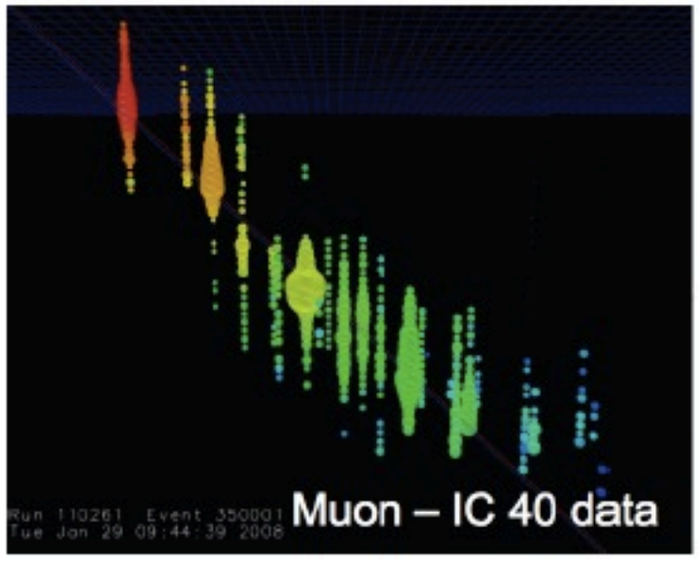
Neutrinos interact in or near the detector





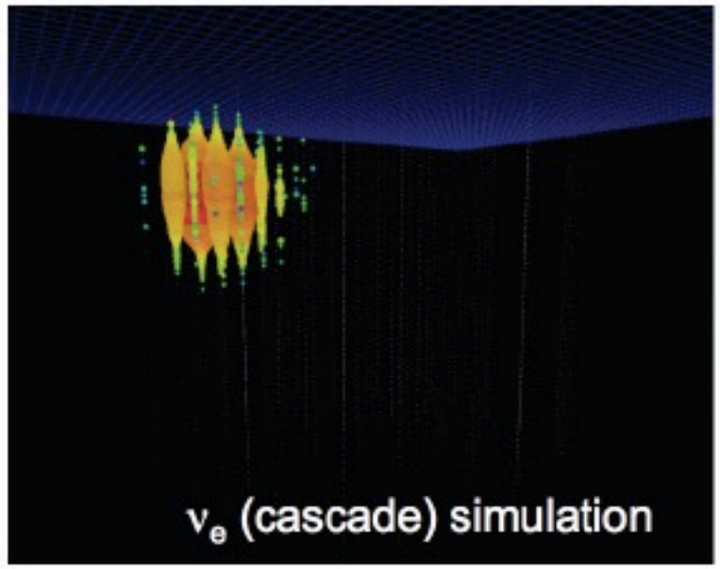
IceCube

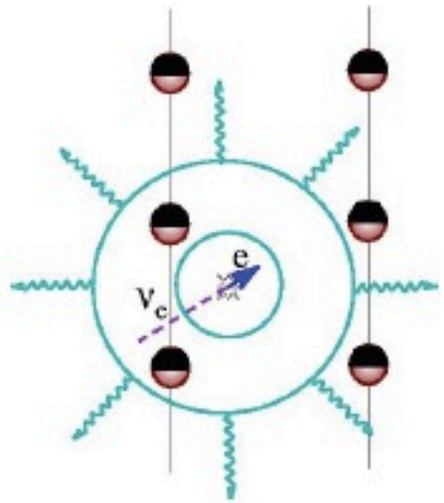
Principle of Detection



Tracks:

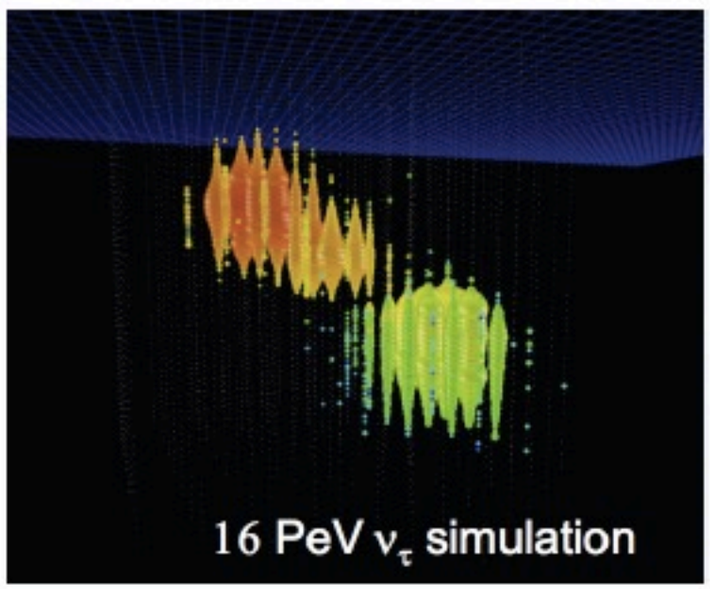
- through-going muons
- pointing resolution ~1°





Cascades:

- Neutral current for all flavors
- Charged current for ν_e and low-E ν_τ
- Energy resolution ~10% in log(E)

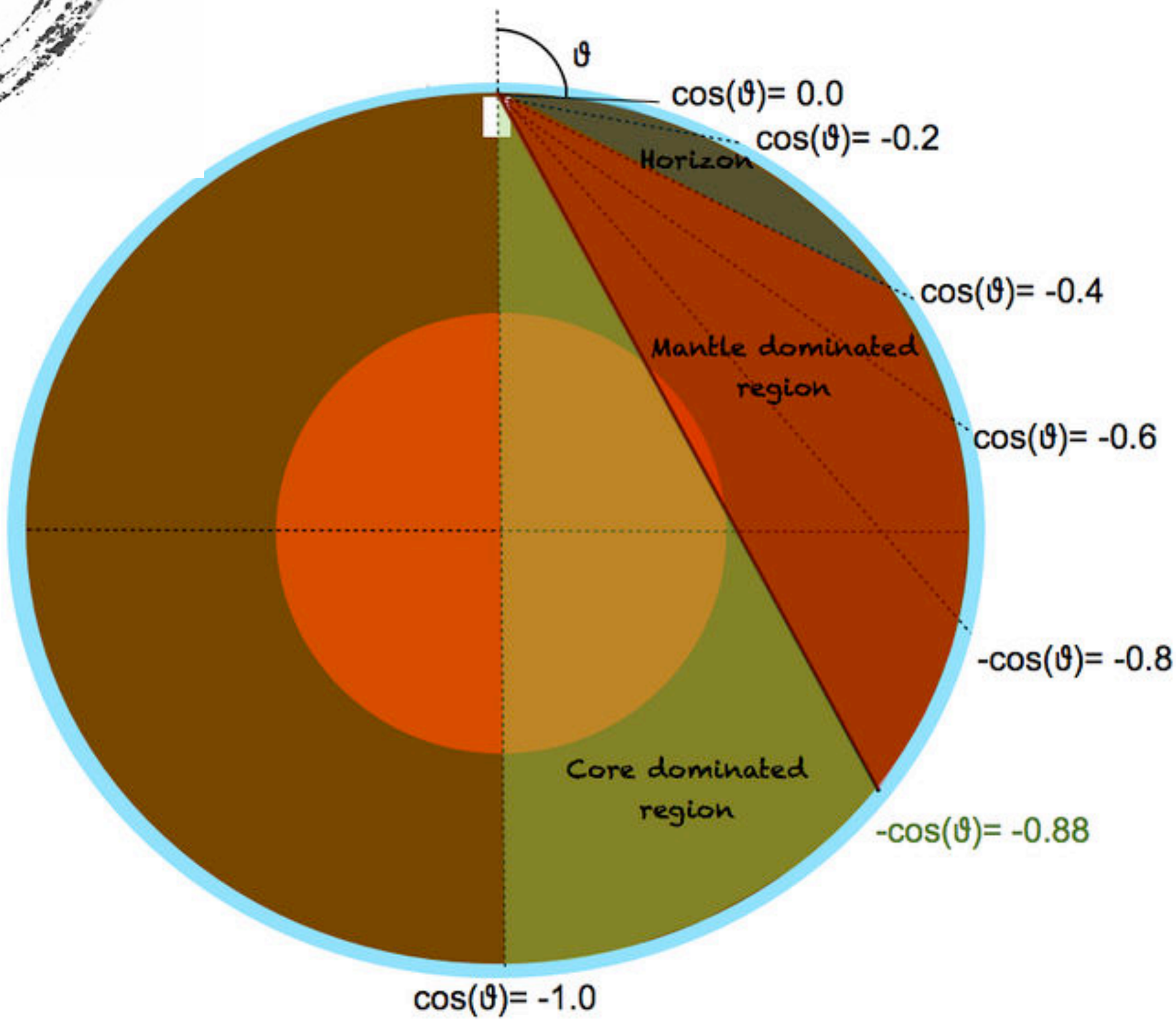


Composites:

- Starting tracks
- high-E ν_τ (Double Bangs)
- Good directional and energy resolution

IceCube

The Detector



IceCube

recent results

cosmic rays

dark matter

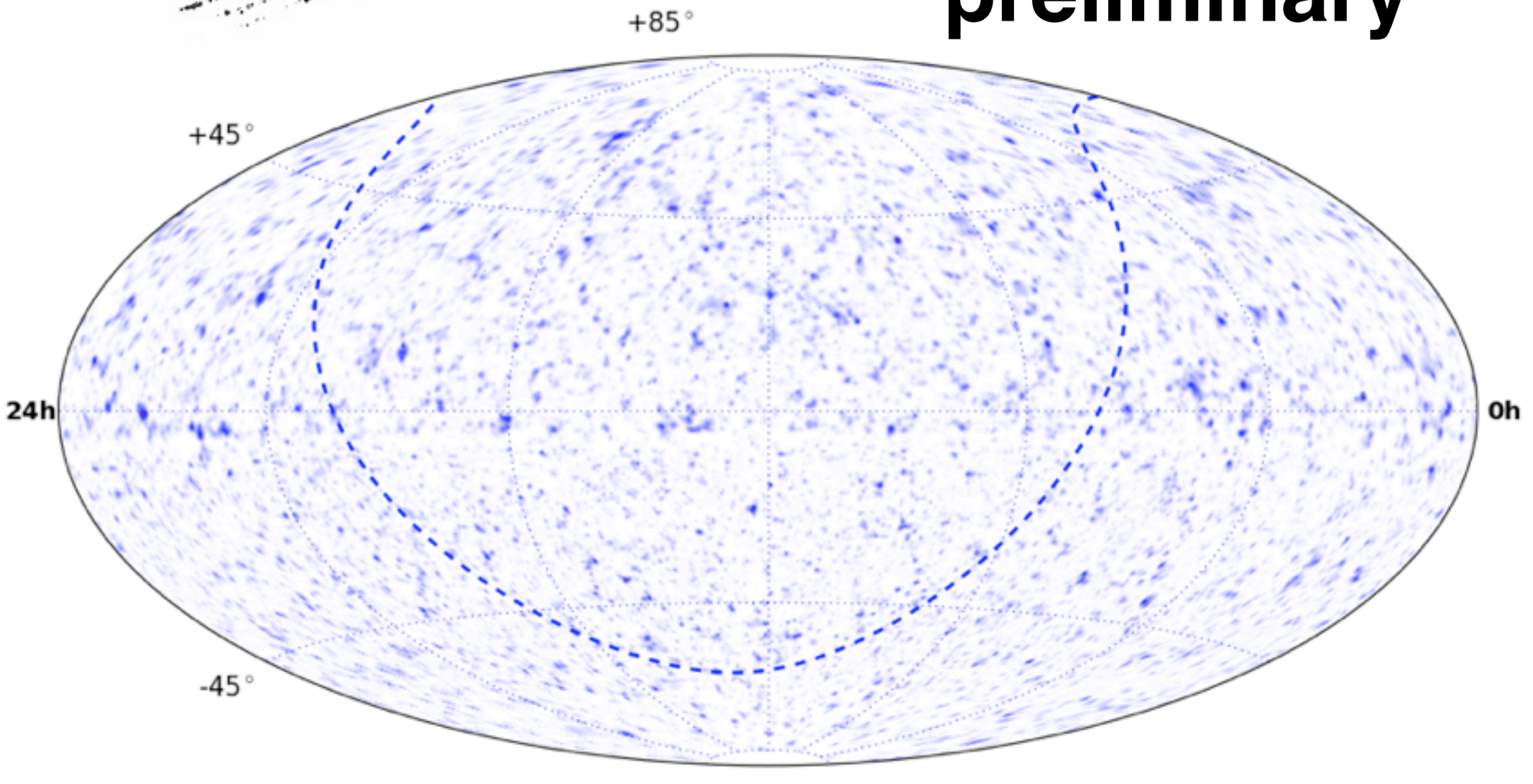
see Carsten Rott

beyond the SM

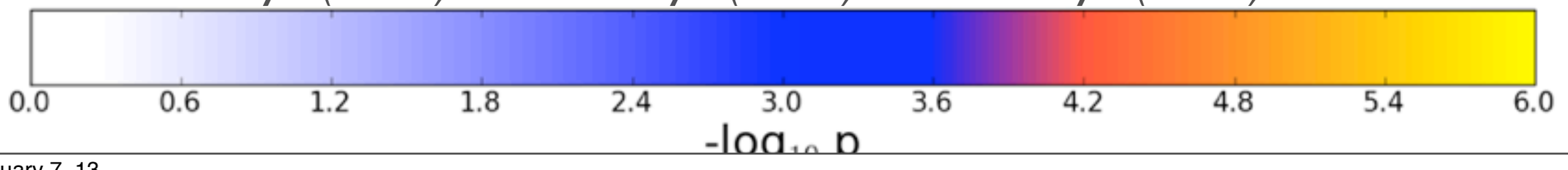
astrophysical neutrinos

IceCube point sources

preliminary

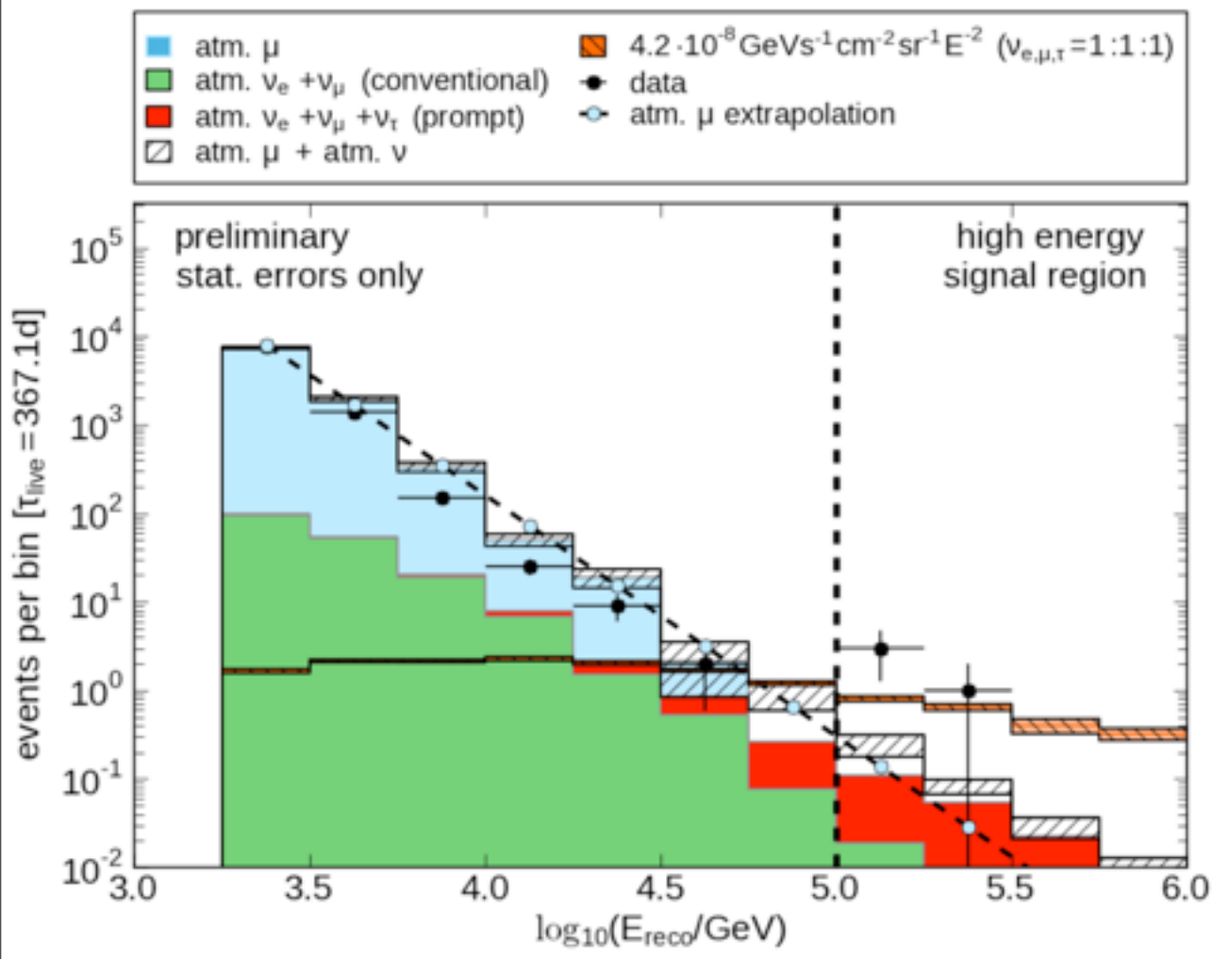


- *Total events (IC40+IC59+IC79): 1083317 (upgoing) + 146018 (downgoing)*
- *Livetime: 316 days (IC79) + 348 days (IC59) + 375 days (IC40)*

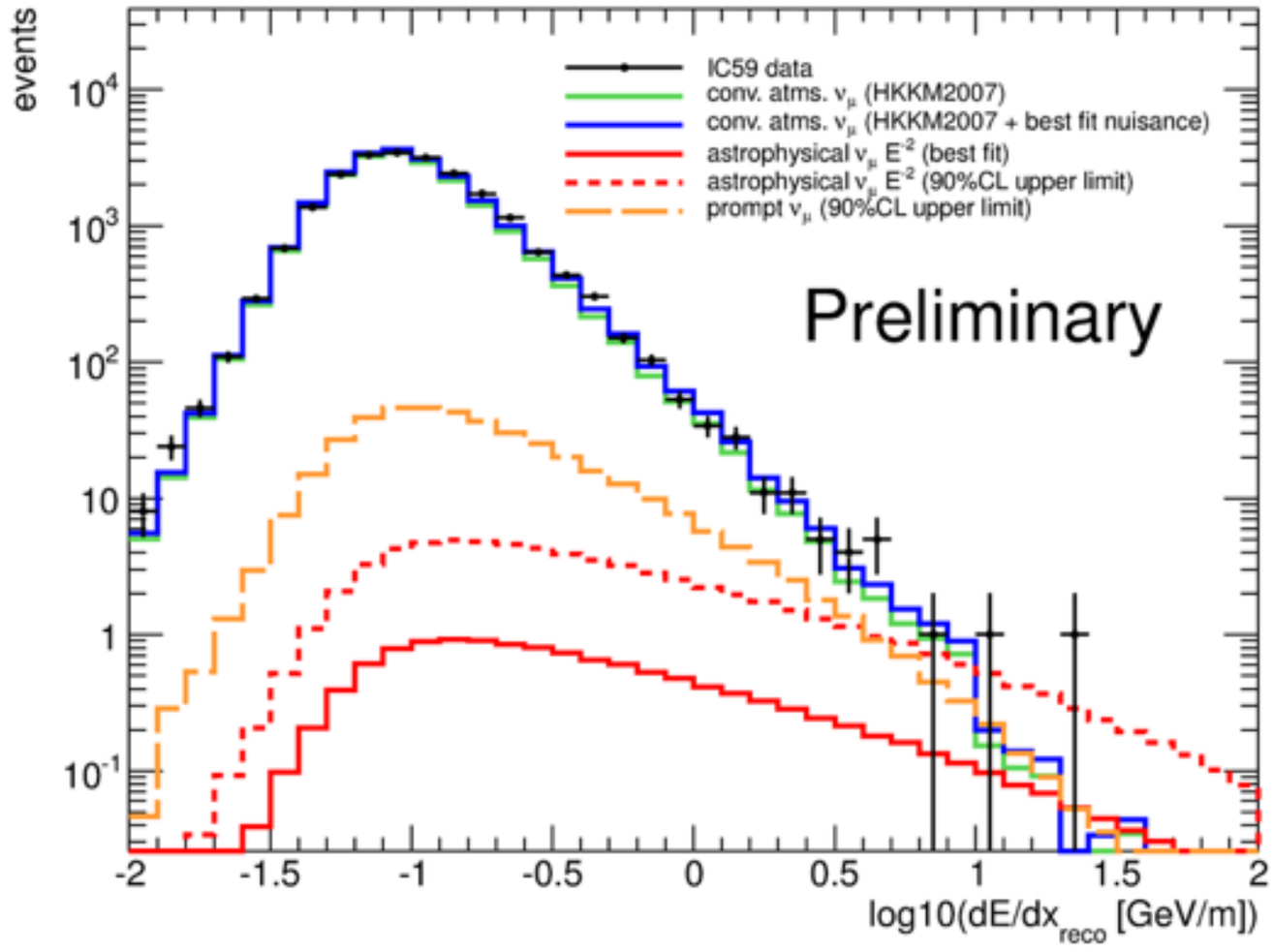


IceCube diffuse flux

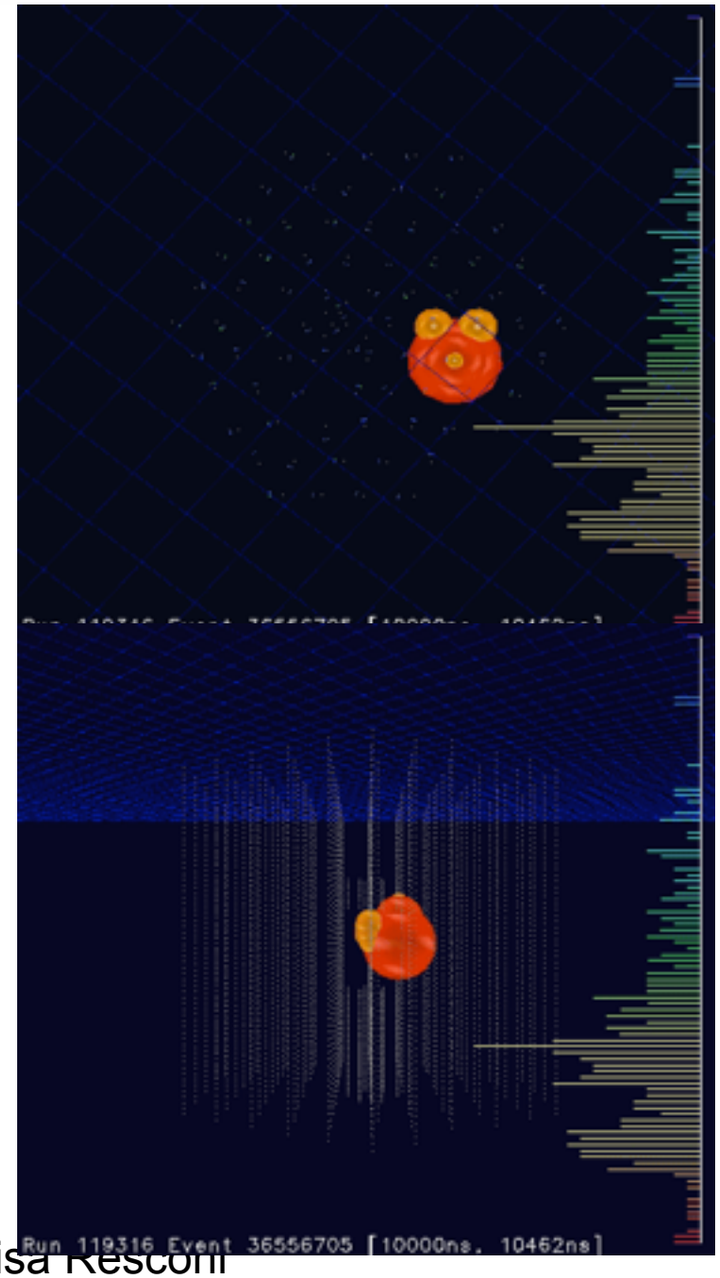
IC40 cascades

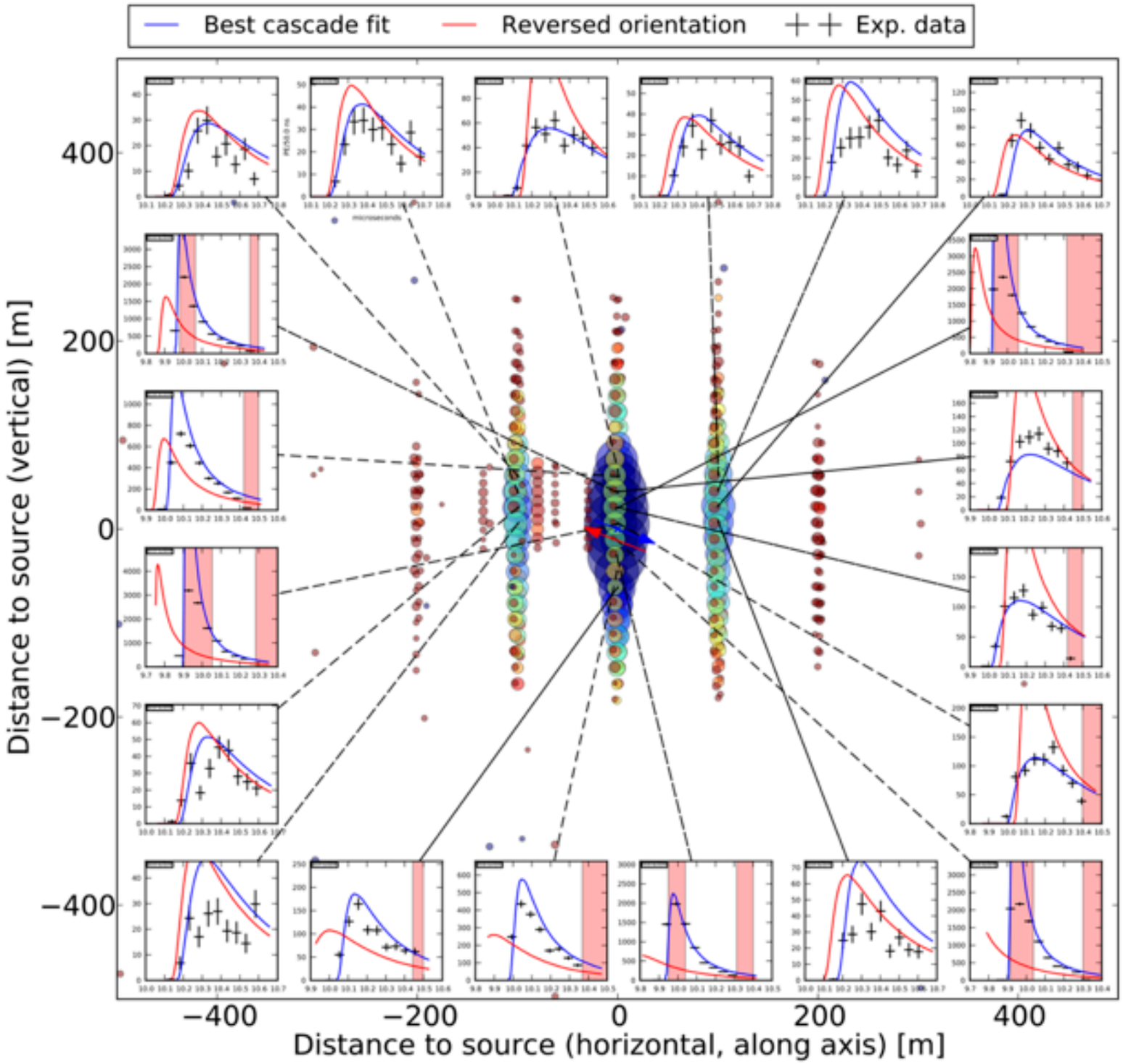


IC59 track

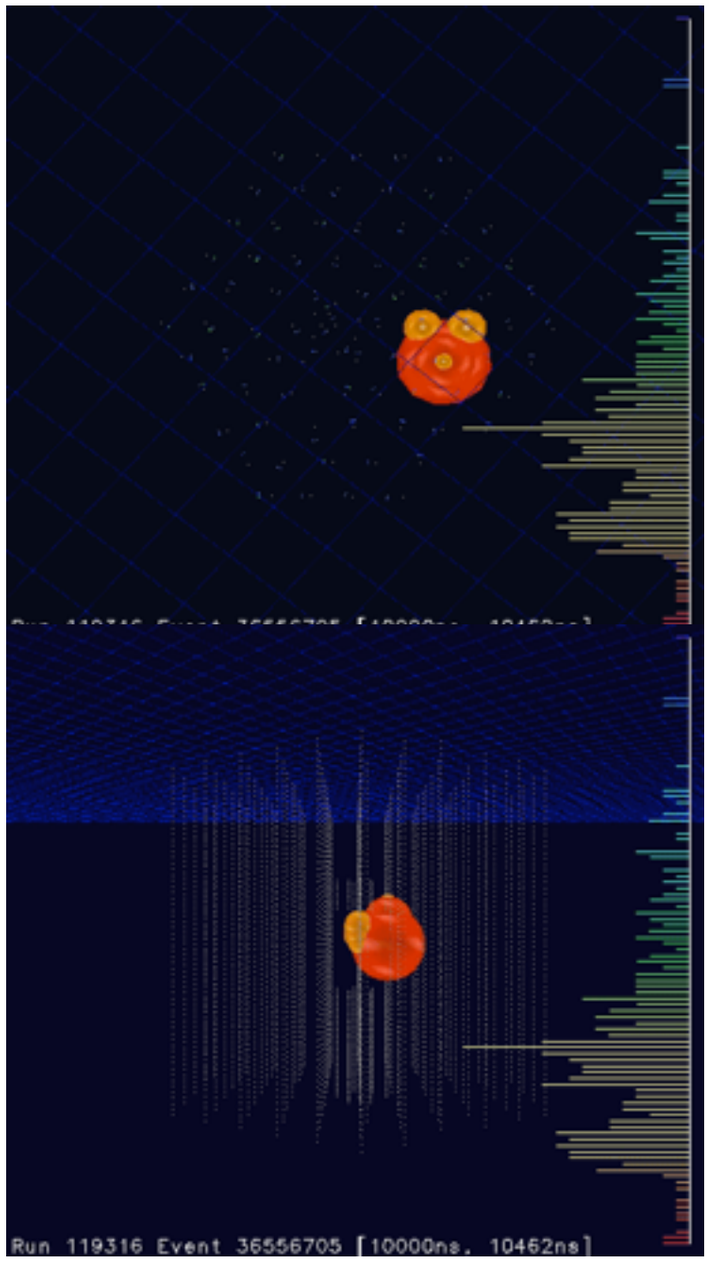


IceCube Surprises!





IceCube Surprises!



expected background of 0.05 events conventional neutrinos

3.0 sigma deviation respect conventional only

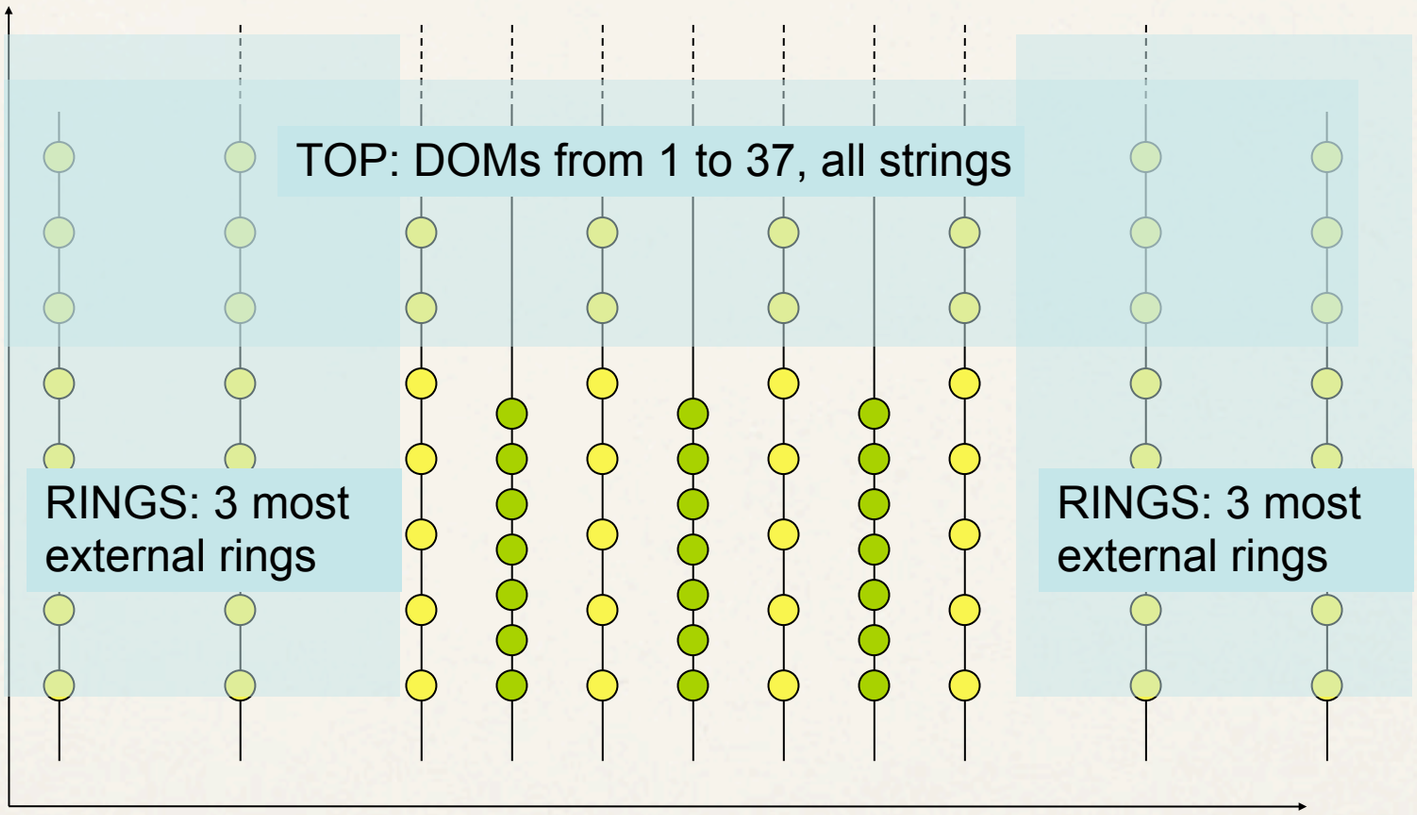
2.7 sigma when including the nominal prompt atmospheric neutrinos.

stay cool … we have new data coming in

DeepCore

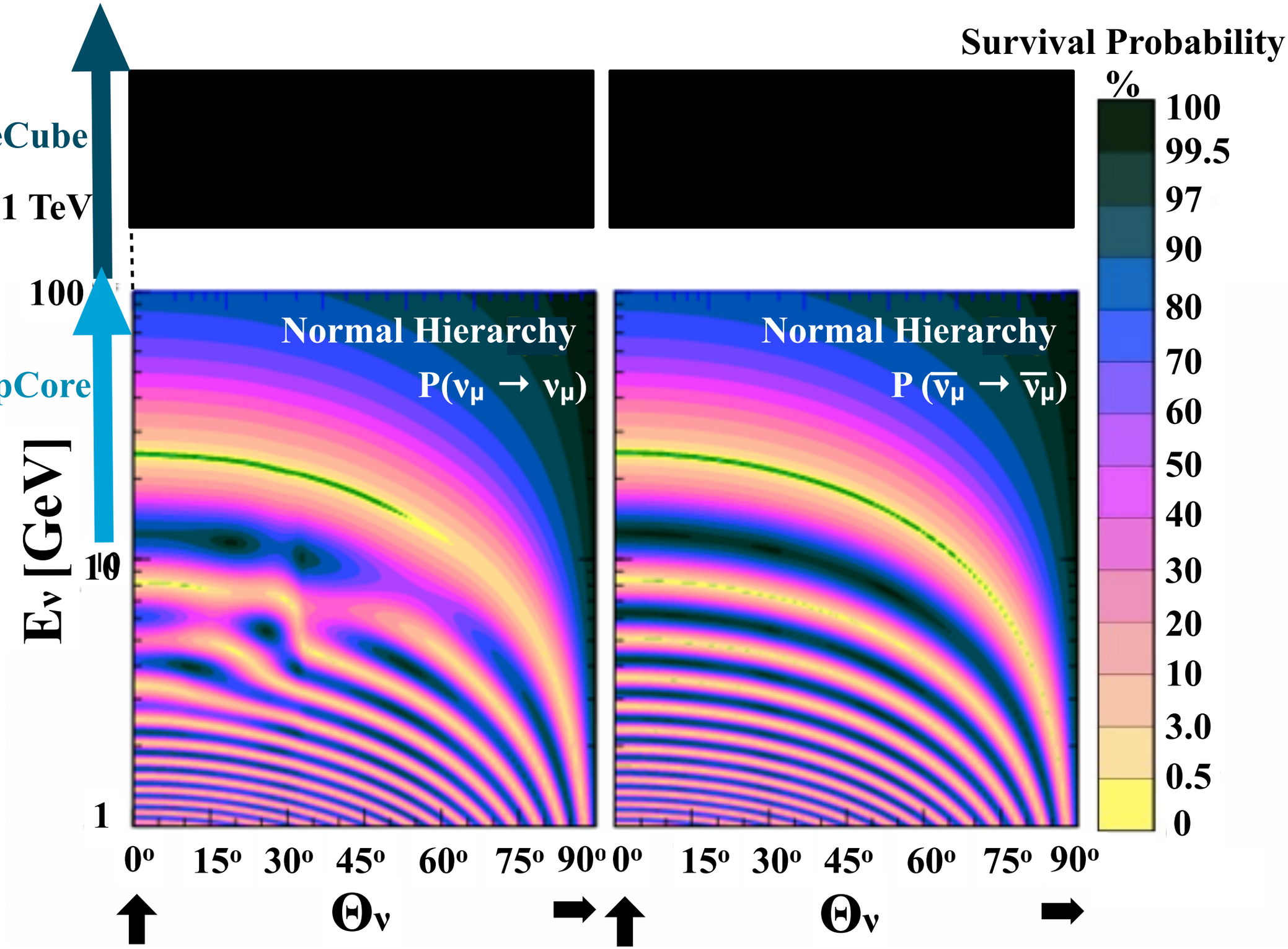
DeepCore: Rejection of atmospheric background

Containment cuts: enough for the reduction of the first 3 - 4 order of magnitude atmospheric background



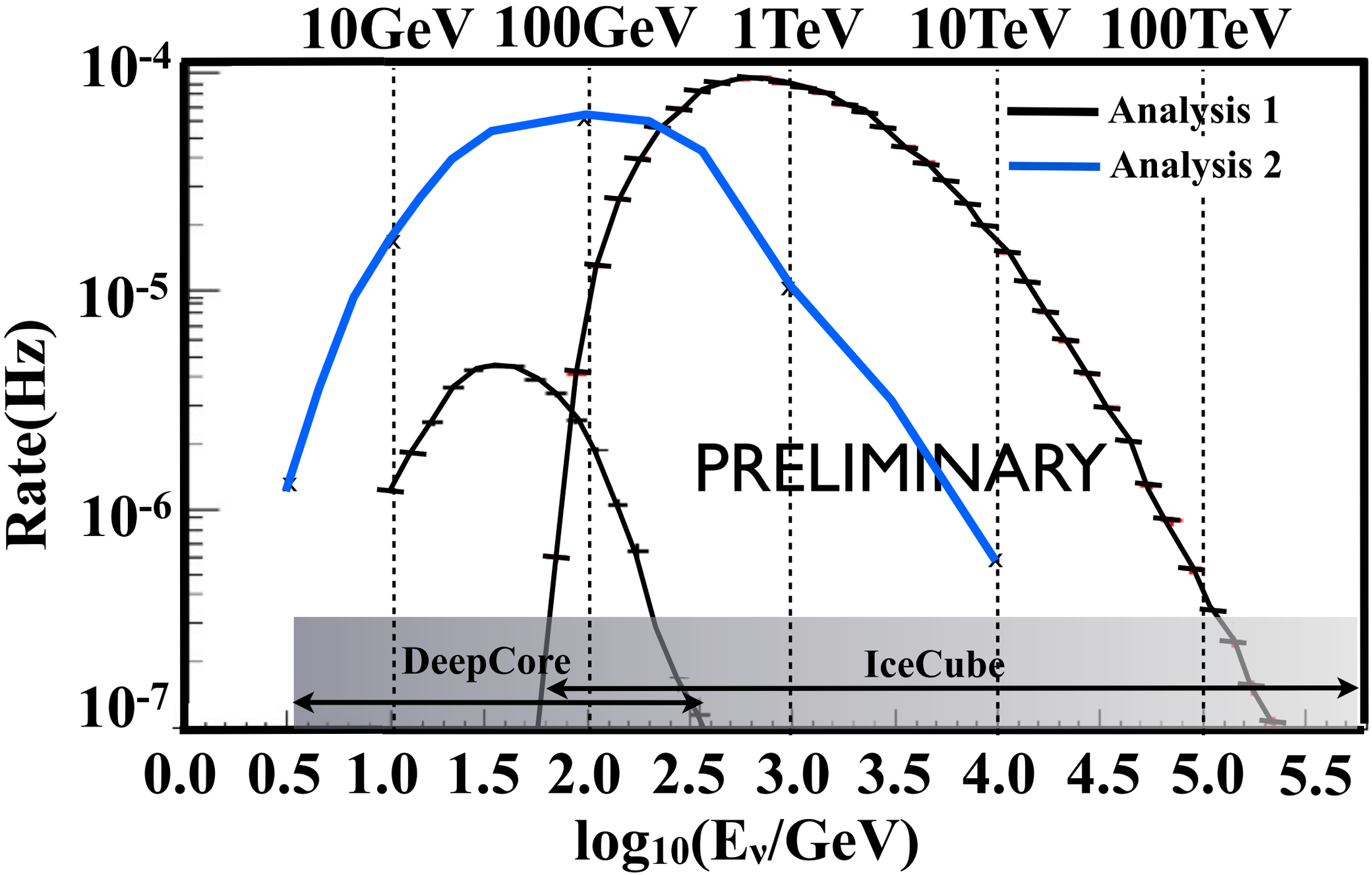
from DeepCore design study meeting in Stockholm, 2008

PINGU is IceCube + DeepCore + PINGU



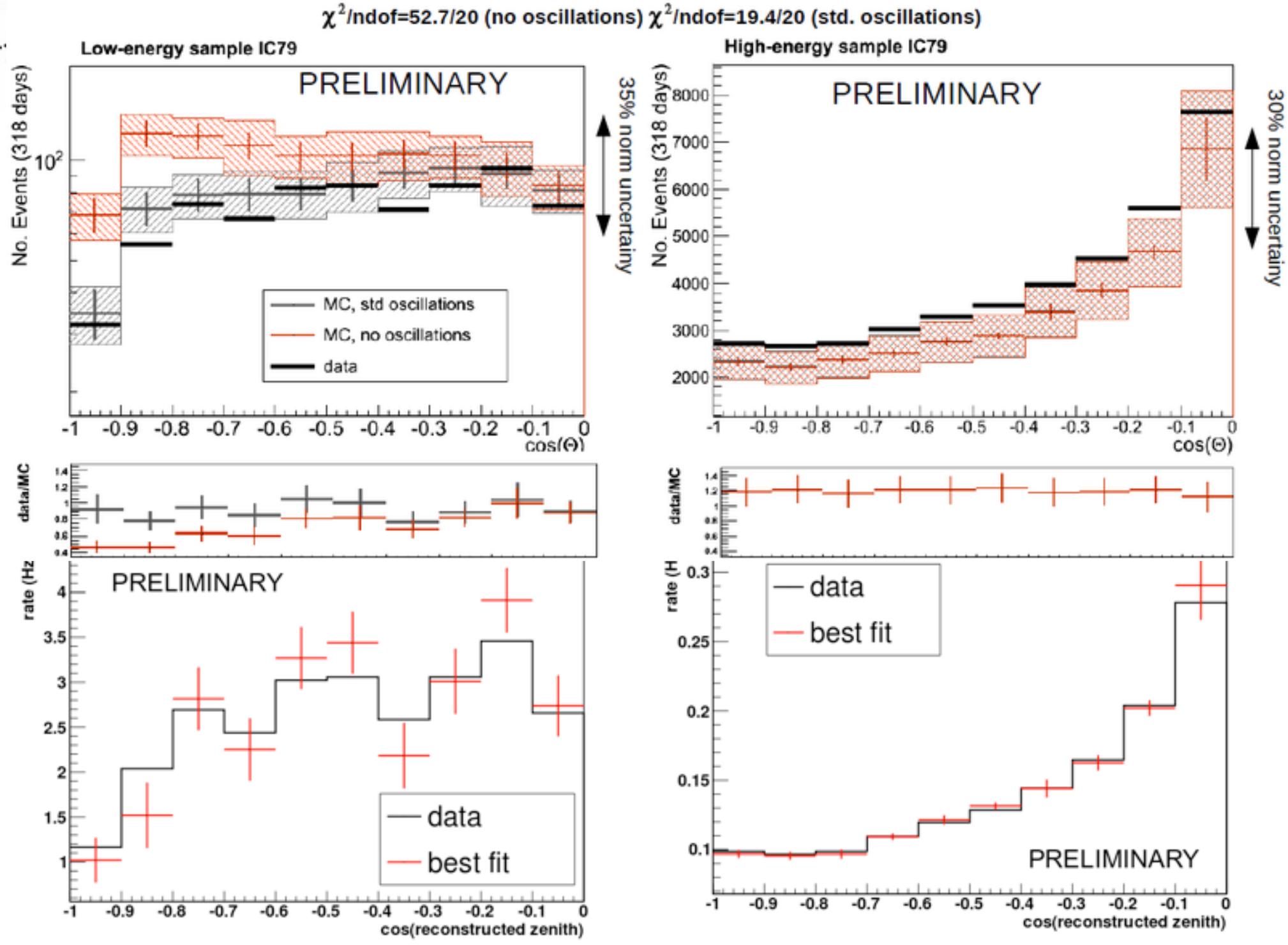
Neutrino oscillogram of the Earth from Akhmedov-Maltoni-Smirnov modified from arXiv:hep-ph/0612285v2 (private communication)

DeepCore muon neutrinos



DeepCore muon neutrinos

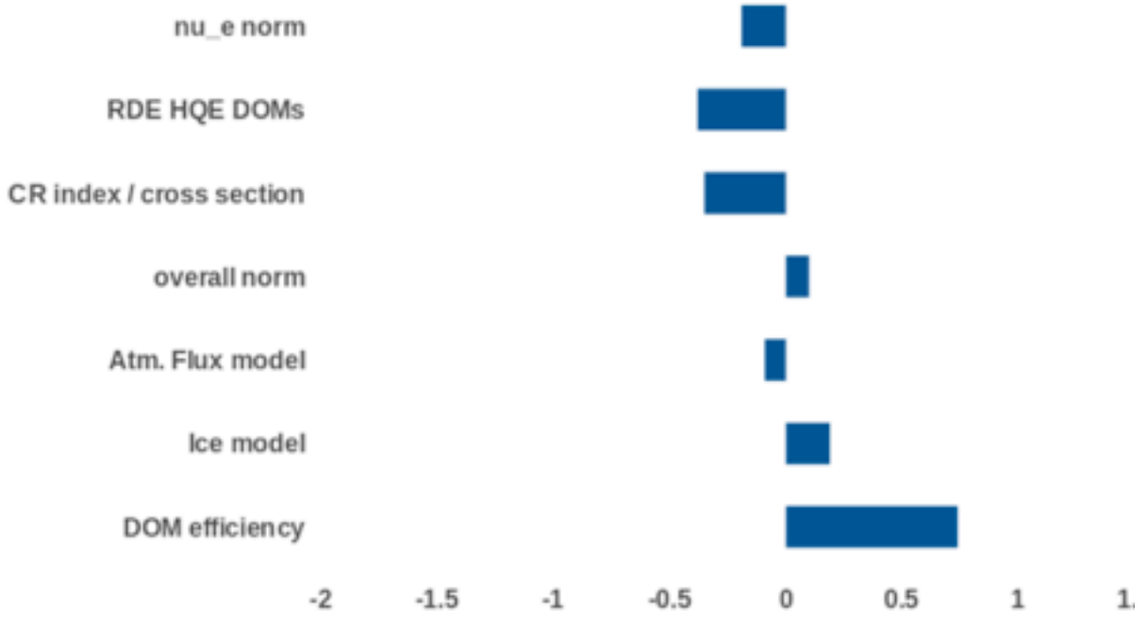
IceCube used as control region



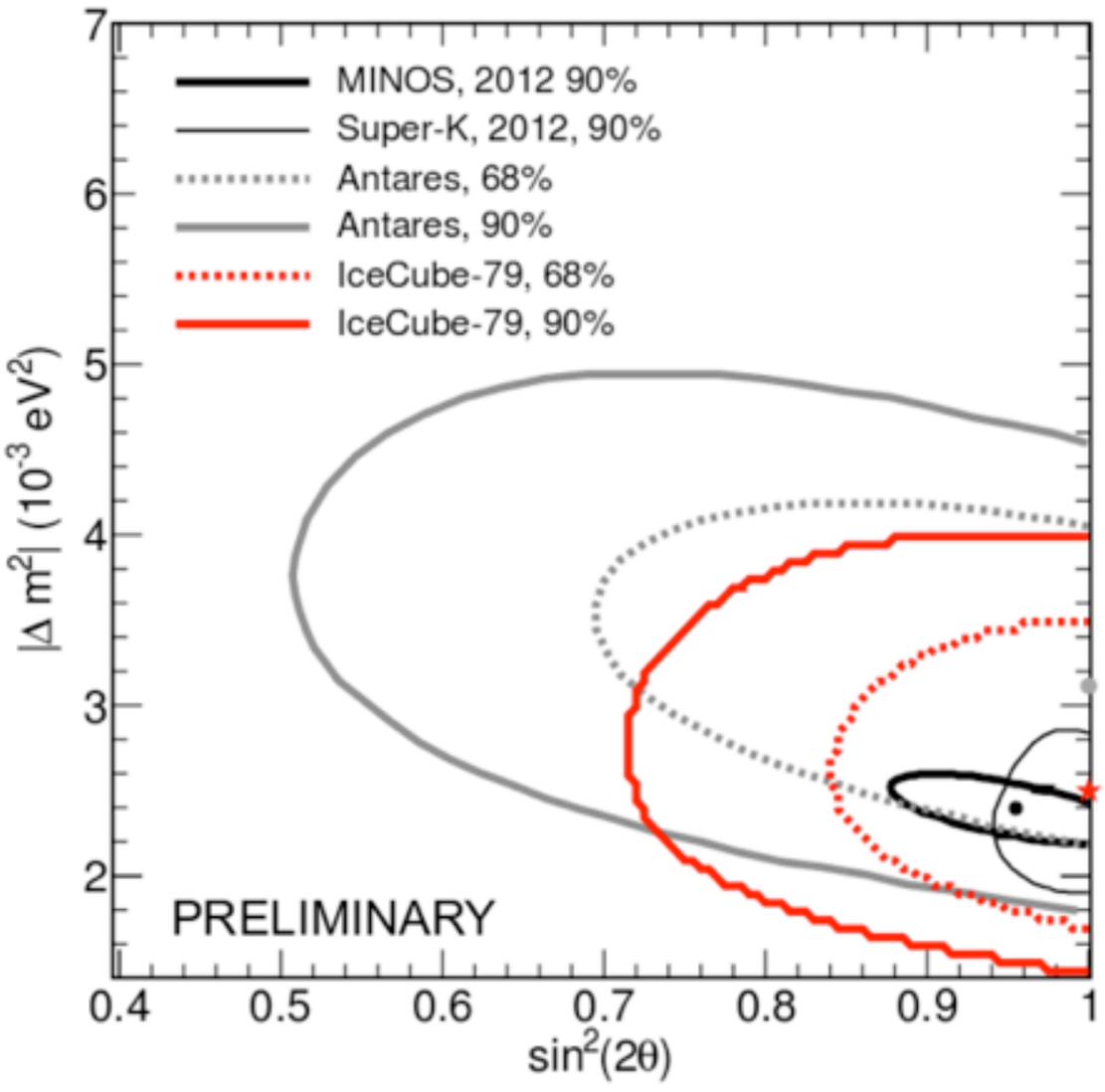
DeepCore muon neutrinos

Analysis 1

DOM efficiency	0.74
Ice model	0.19
Atm. Flux model	-0.09
overall norm	0.1
CR index / cross section	-0.35
RDE HQE DOMs	-0.38
nu_e norm	-0.19

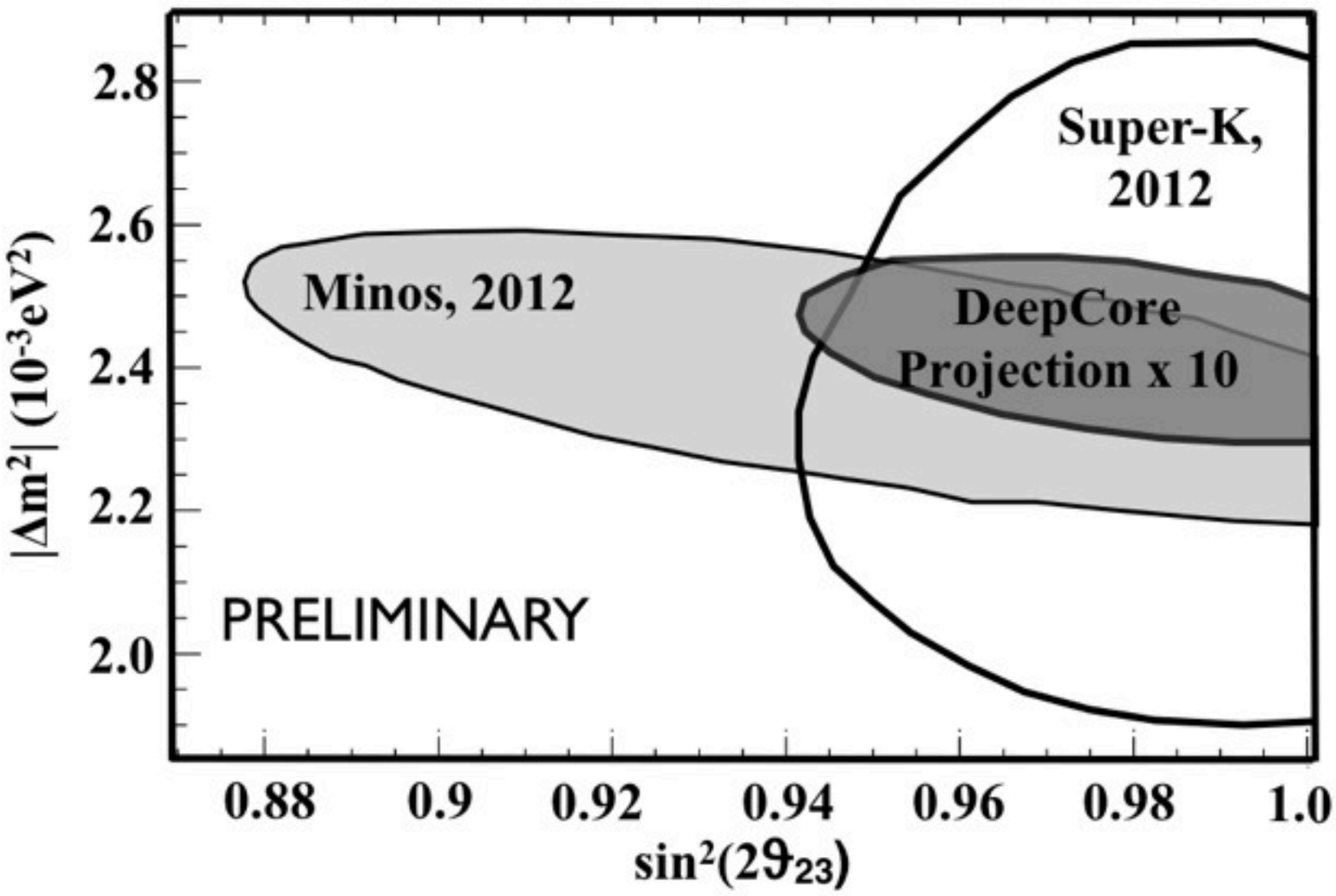


PRELIMI



DeepCore

but we want to speak about the FUTURE …



Projected sensitivity

Analysis 1 where:

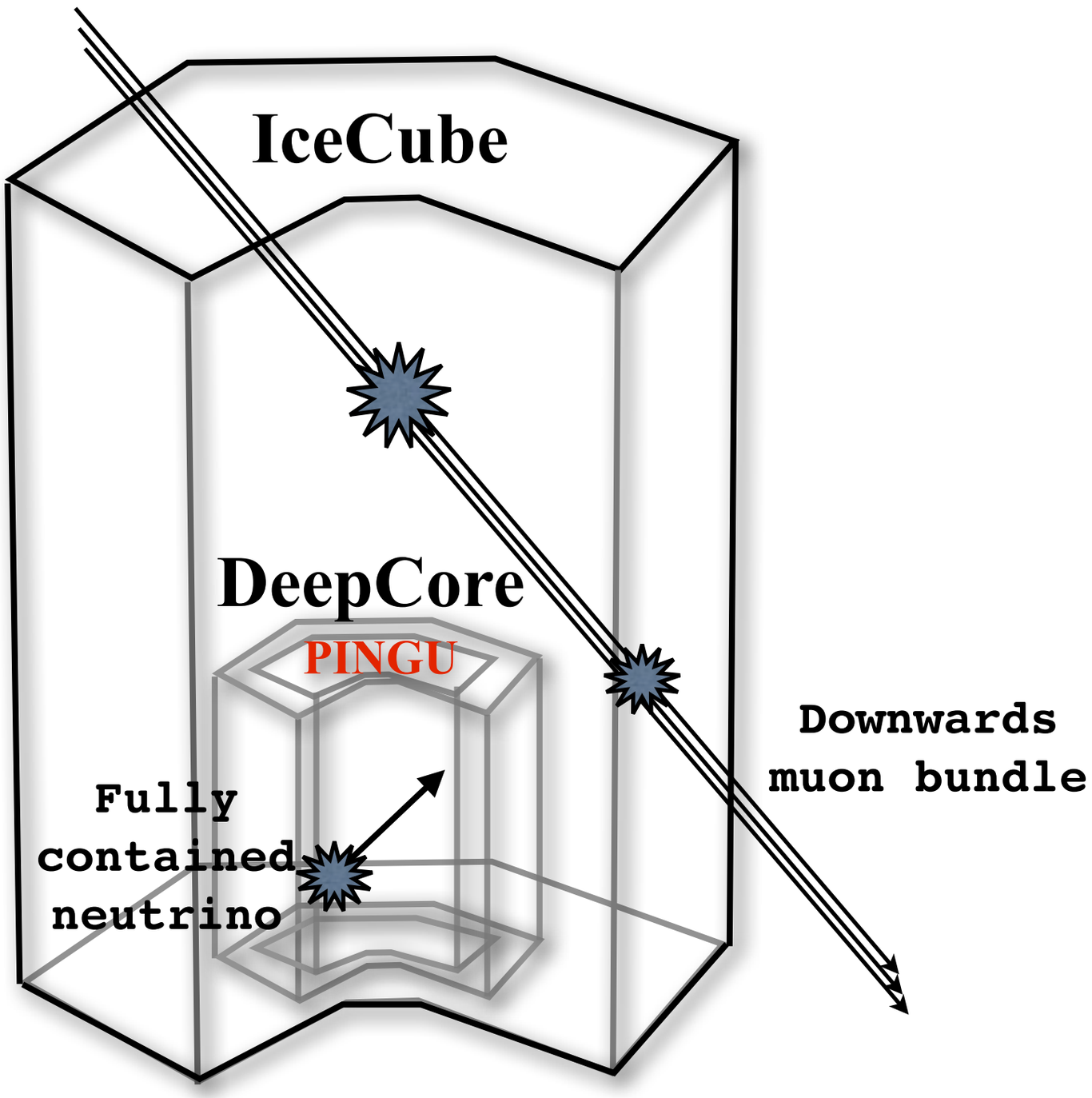
- systematics 50% reduced
- 3 bins in true energy
- 10x neutrinos

… it is all about systematic uncertainties

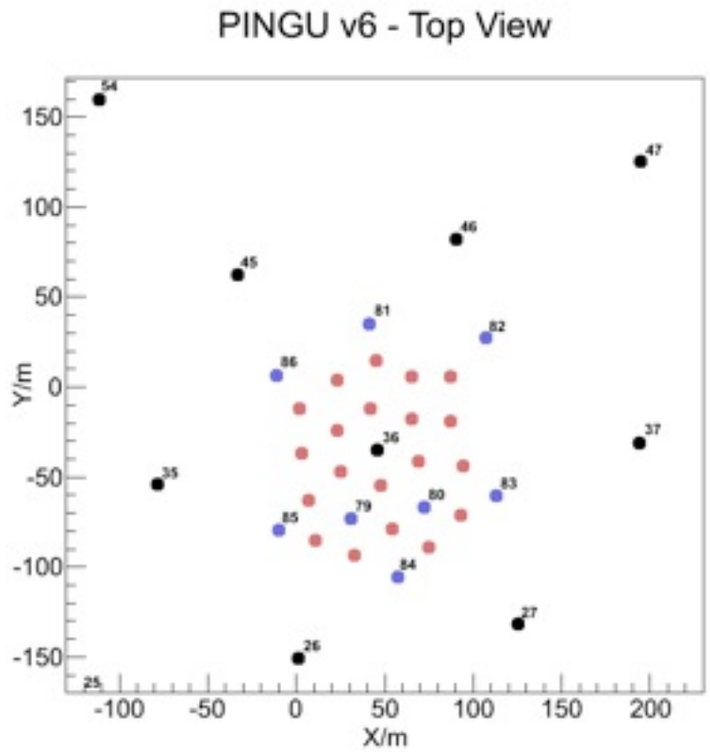
PINGU

see also Jason Koskinen

PINGU: keep on infilling ...

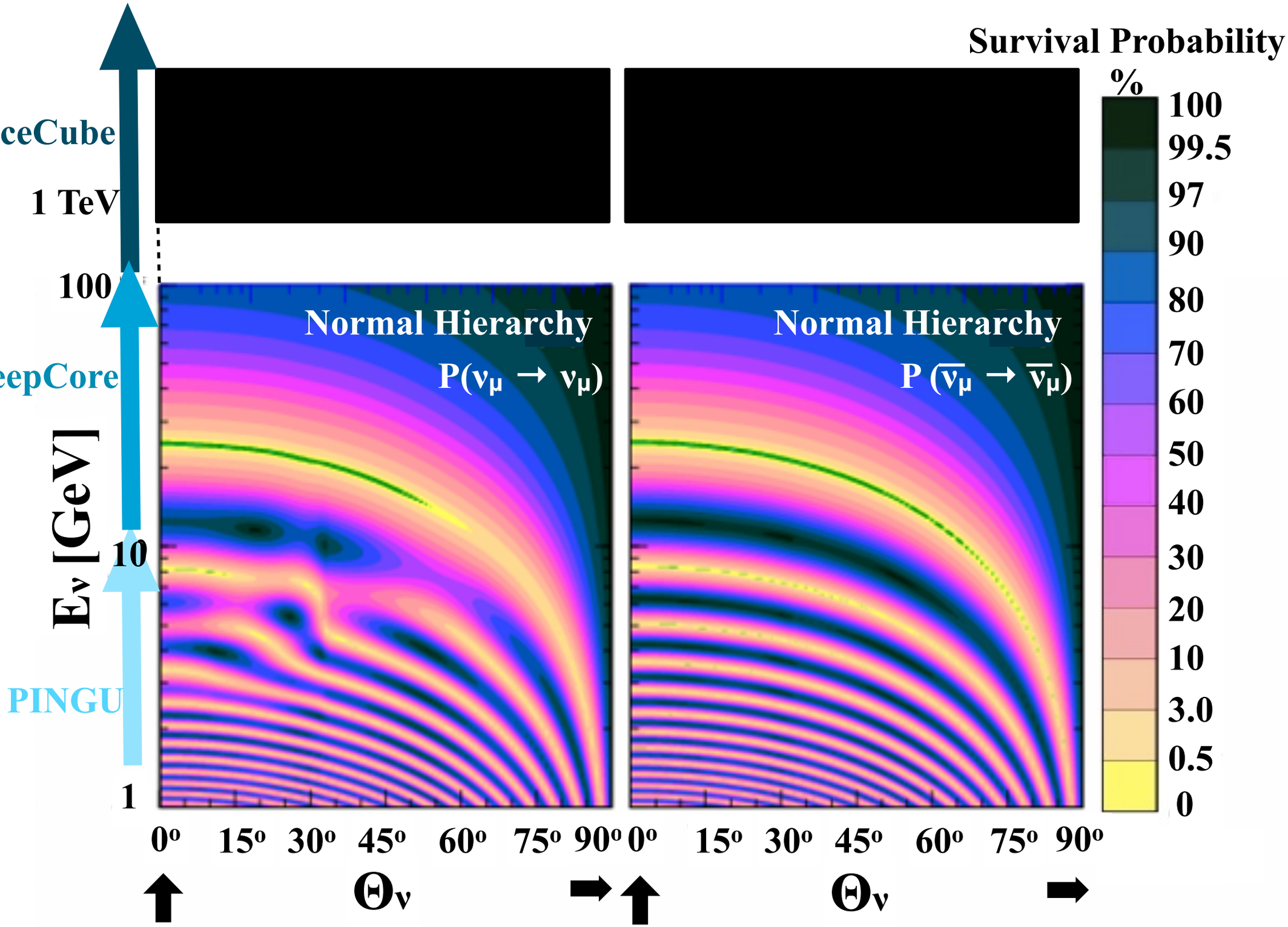


geometry under optimization



for Neutrino Mass Hierarchy

PINGU is IceCube + DeepCore + PINGU



Neutrino oscillogram of the Earth from Akhmedov-Maltoni-Smirnov modified from arXiv:hep-ph/0612285v2 (private communication)

… it is all about systematic uncertainties

… and the interplay of the IceCube components

MICA - Mega Ton Ice Cherenkov Array

- Proton decay
- Extra galactic SN detection

MICA

proton decay, why?

+ we have the MASS

+ we have the DEPTH

+ we are approaching higher precision

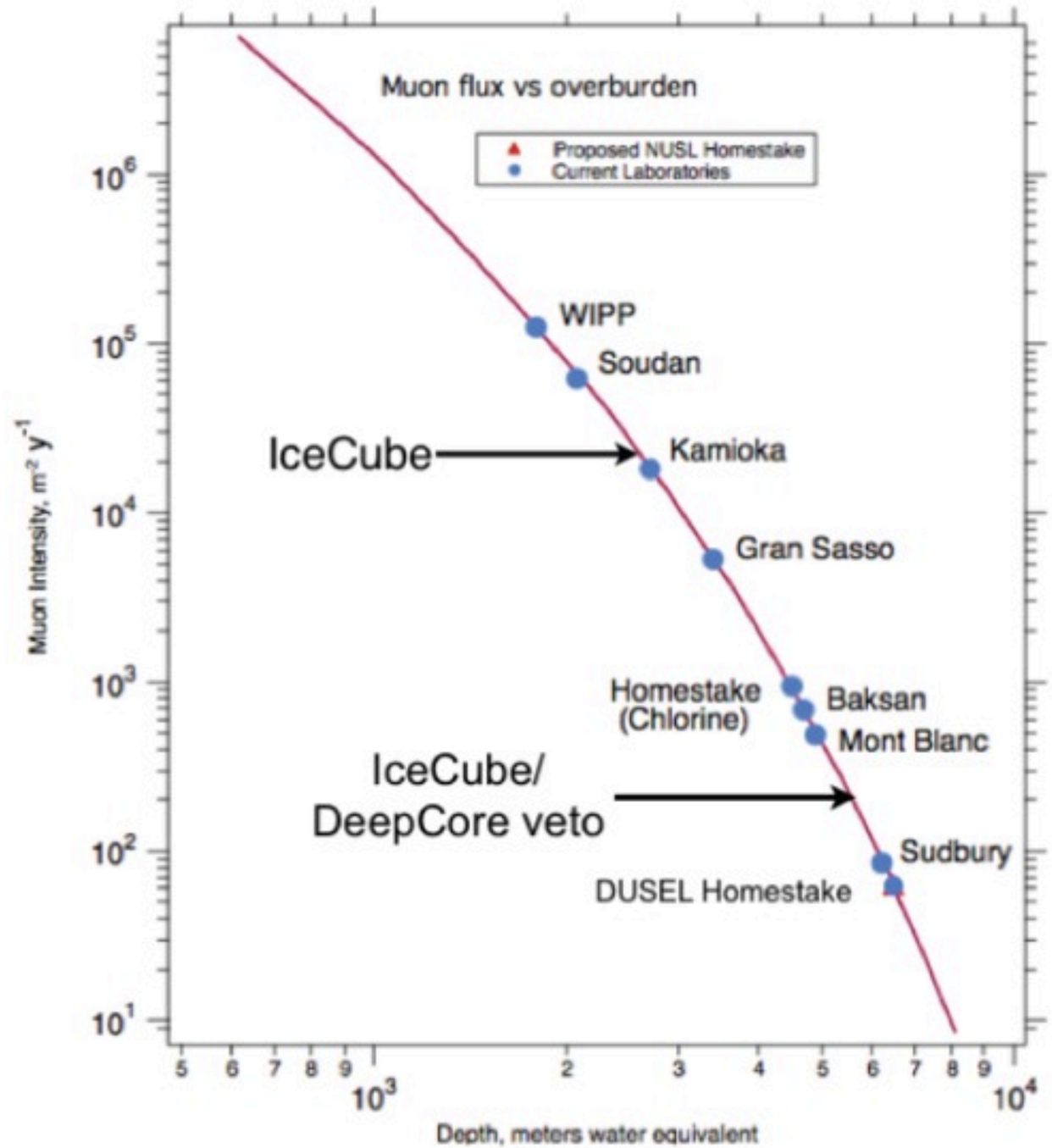
$p \rightarrow \pi^0 + e^+$
$\rightarrow \gamma + \gamma + e^+$

- can we reconstruct the Cherenkov rings?
- atmospheric neutrino background?
- photocatode area required?
- how to deploy all of this? …..

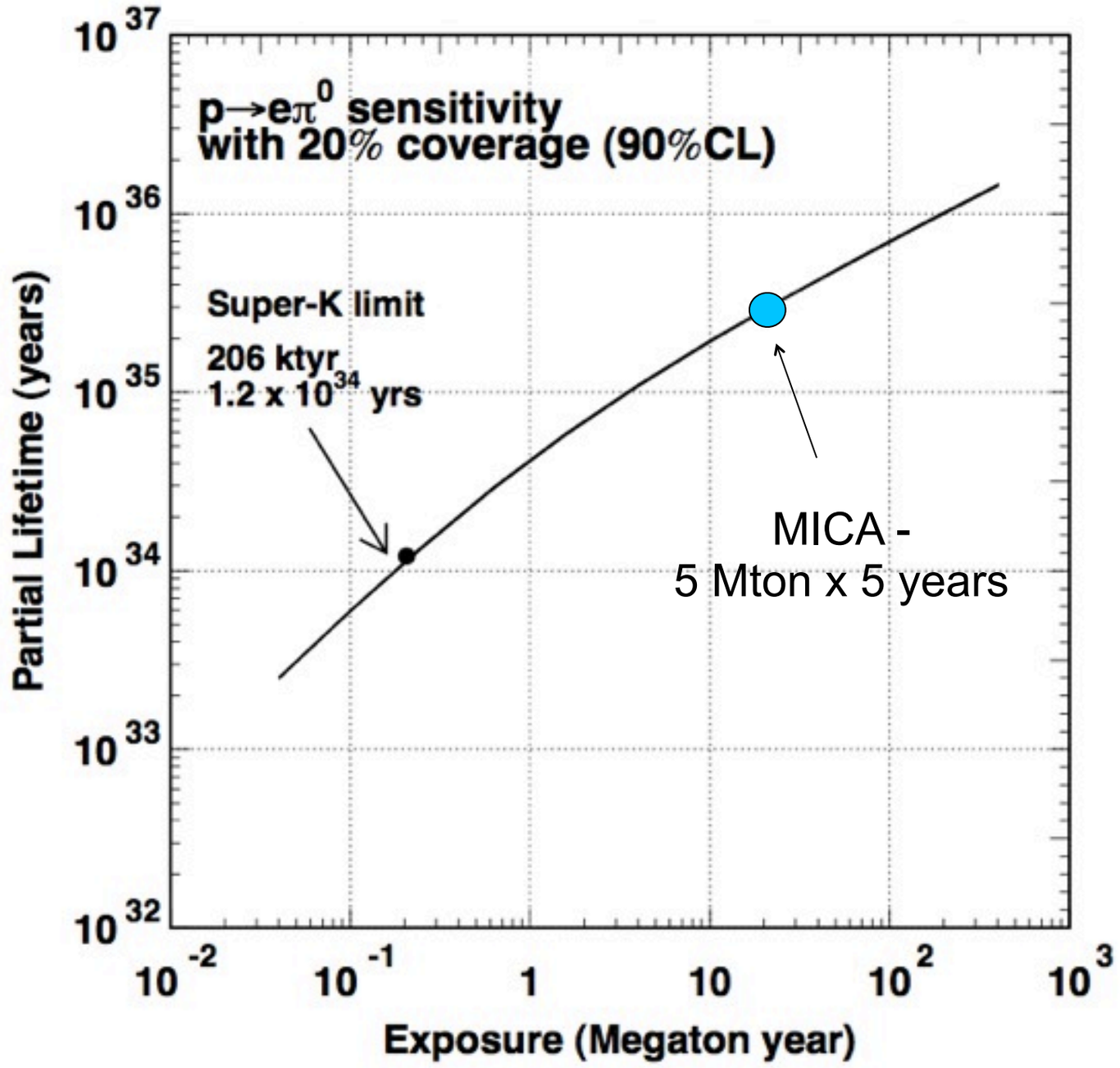
MICA

proton decay, why?

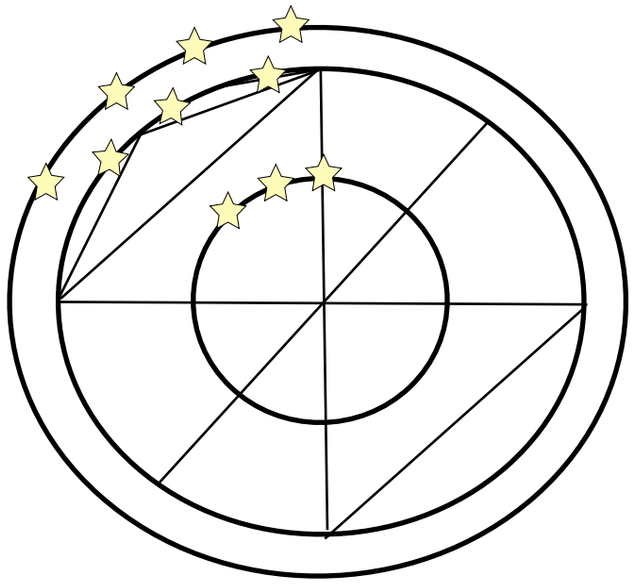
+ we have the DEPTH



MICA proton decay, why?



Geometry:
Tank-like and strings-like are in the same geometry family



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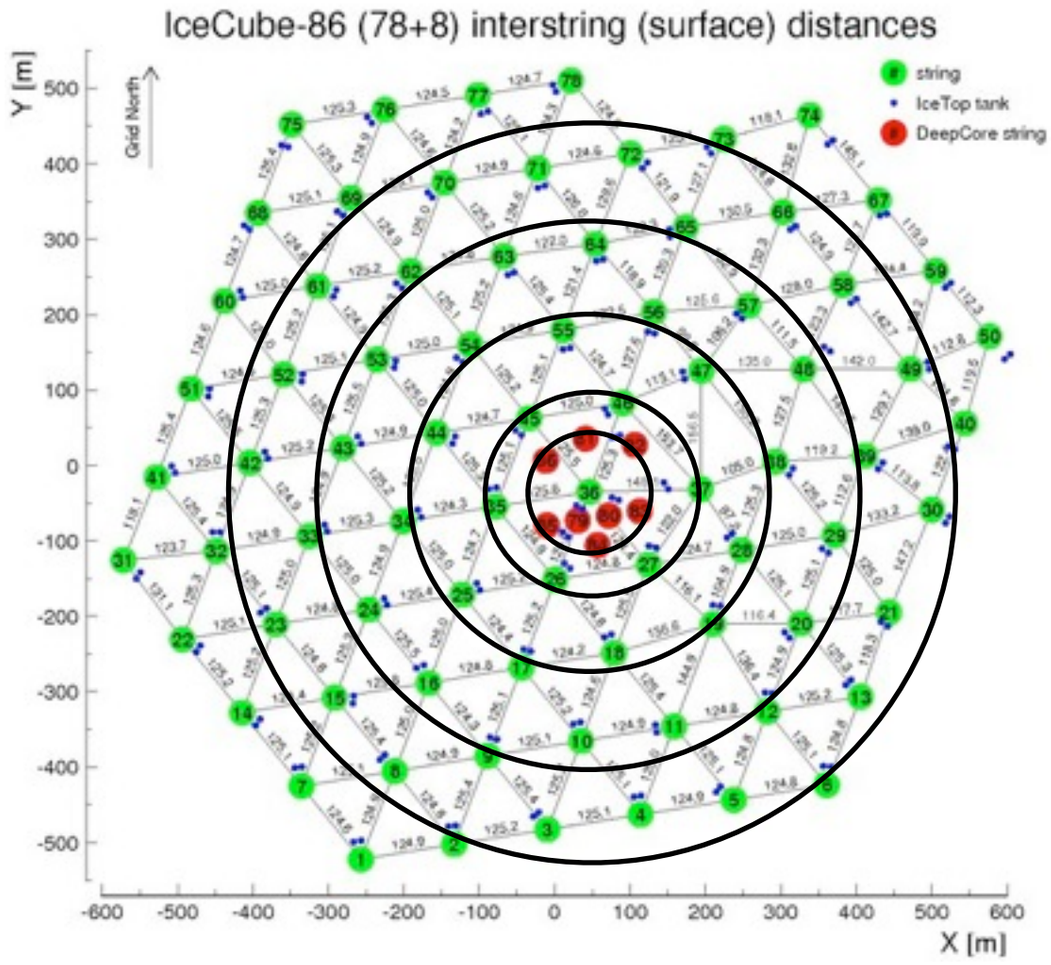
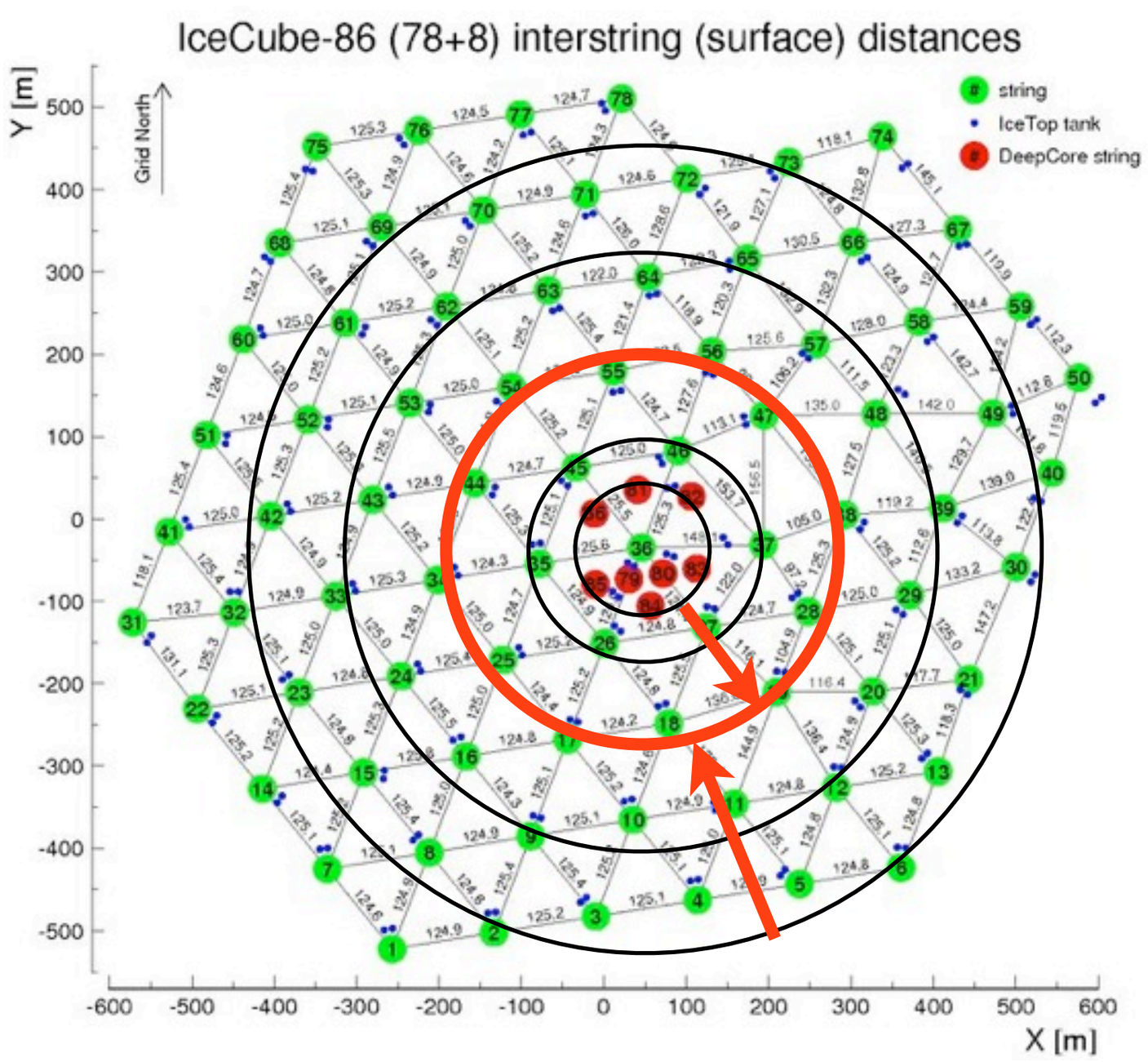


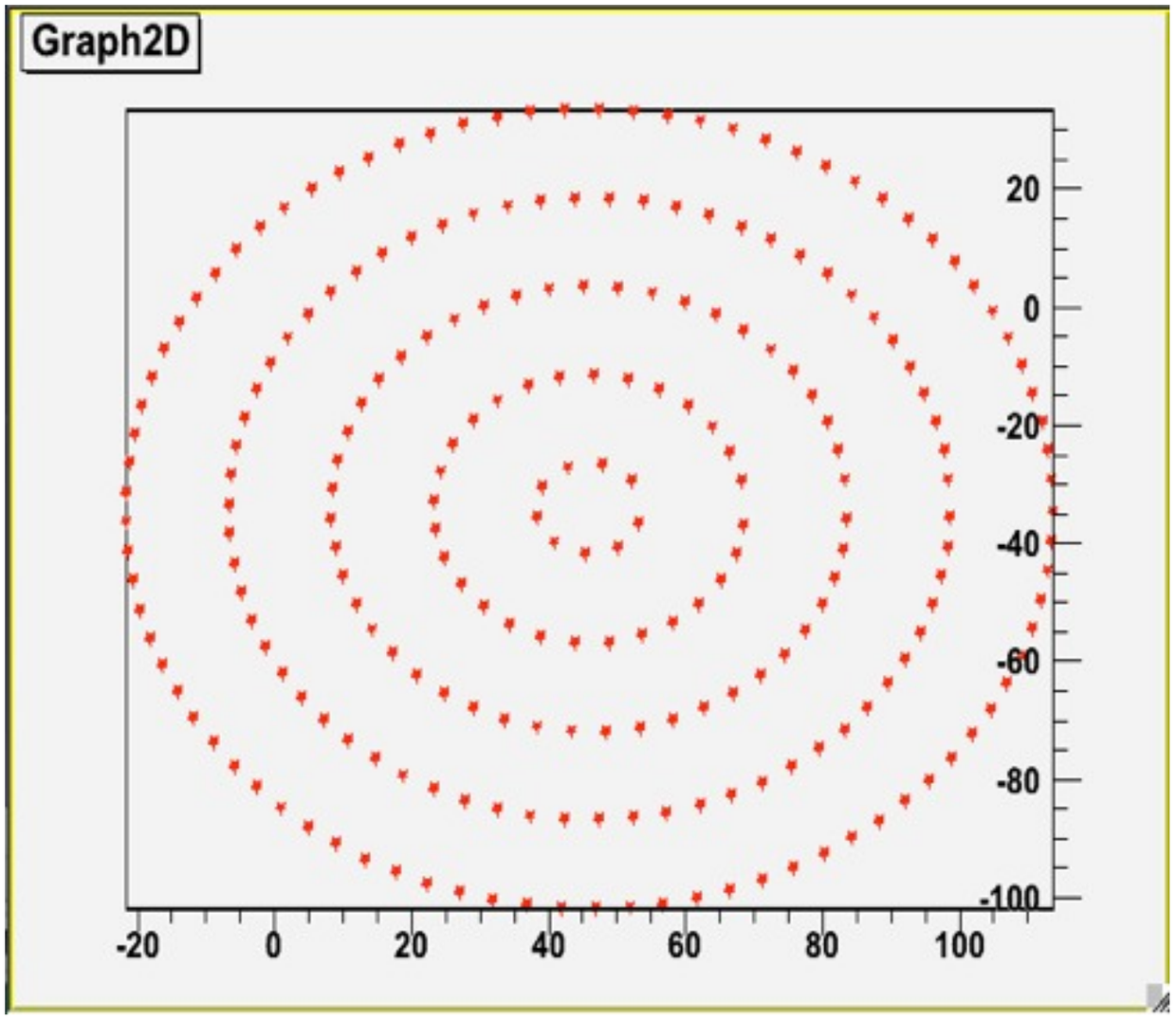
$$\frac{\text{photocathode area}}{\text{surface area}} \sim 0.26$$

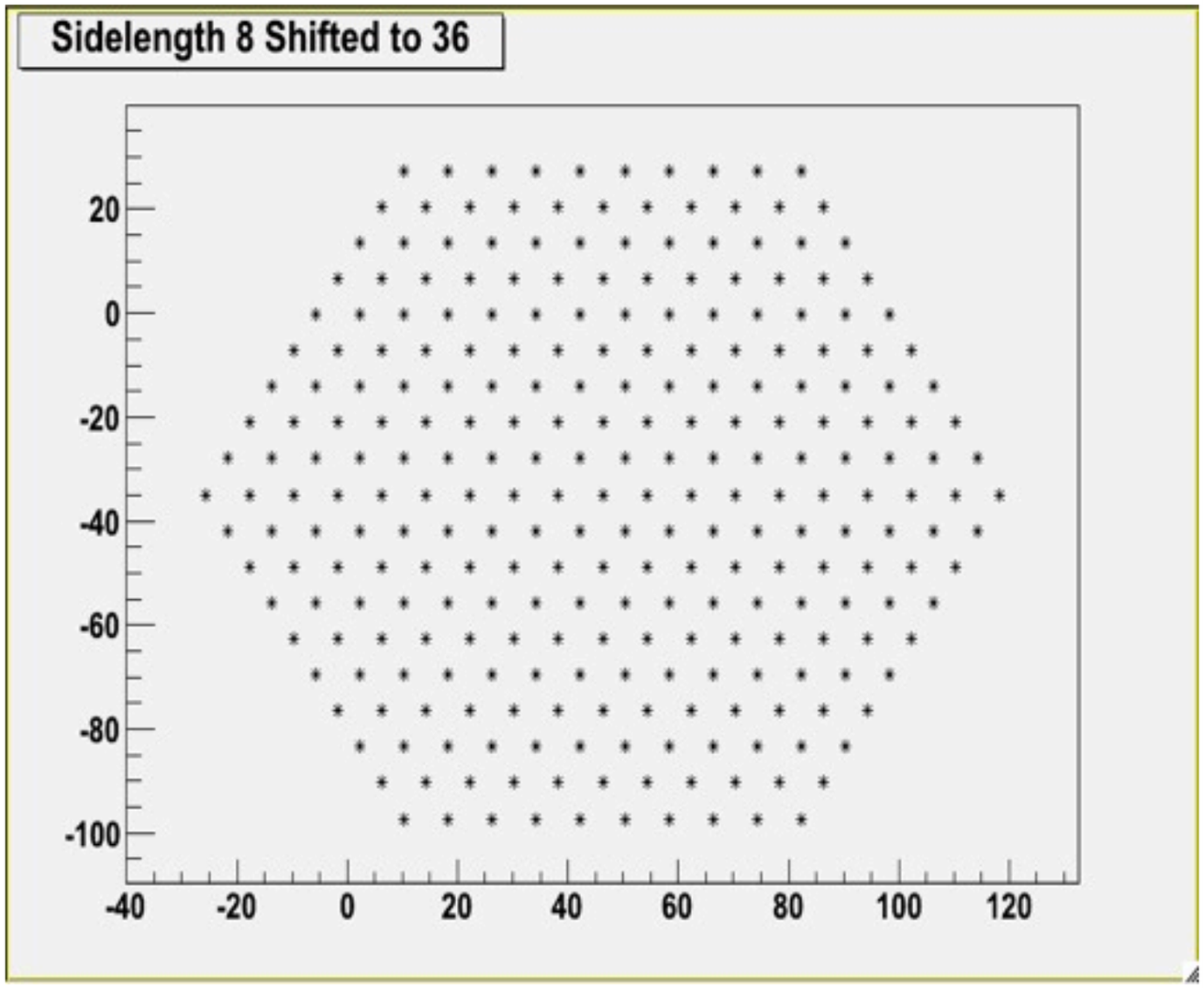


ϕ(500 m) X h(1000 m) 60DOMs/string, 1 string / 18.25 m

$$\frac{\text{photocathode area}}{\text{surface area}} \sim 0.15 \times 10^{-3}$$

MICA: considered geometries





Nested Cylinders

- 120 strings of 125 composite DOMs each
- Instrumented volume of 250 m height, ~40 m radius

Hexagon (Triangular)

- 1 MegaTon fiducial volume, at depths of 2200-2450 m

MICA: considered geometries

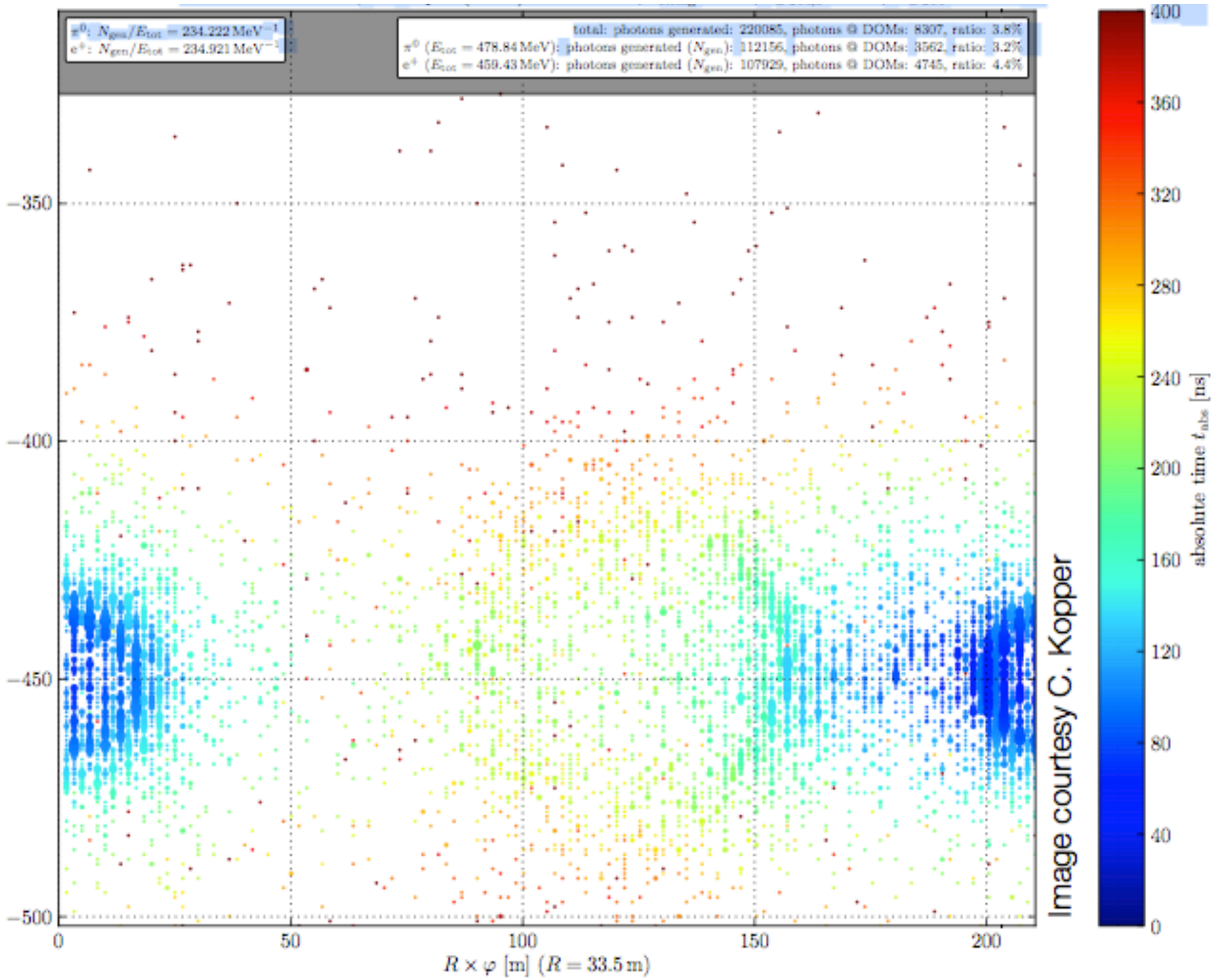
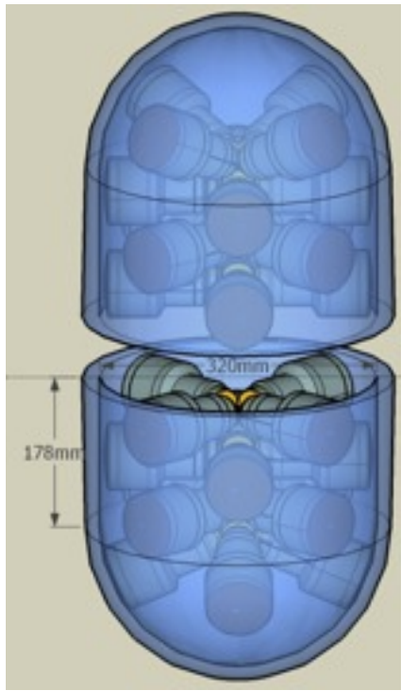


Image courtesy C. Kopper

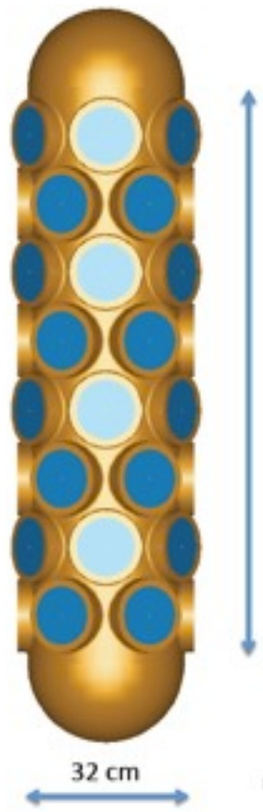
Claudio Kopper

MICA: hardware developments

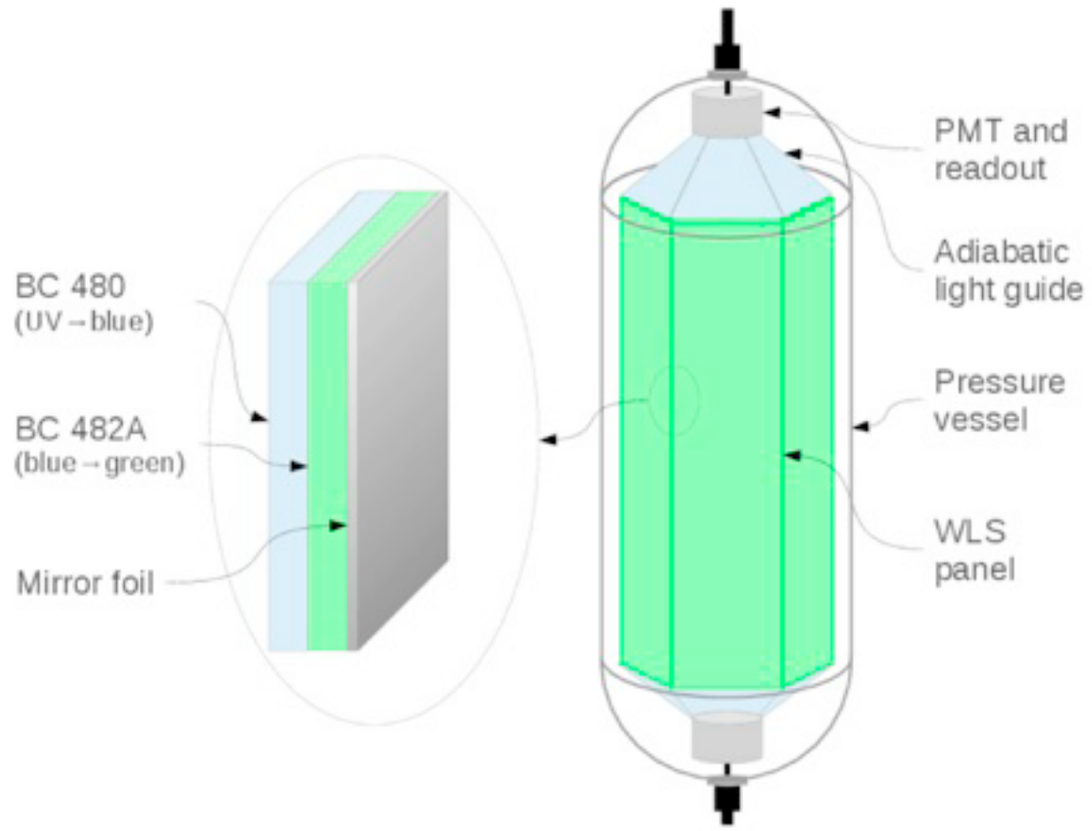


Courtesy P. Kooijman

3.4x that of standard 10” IceCube PMT



Courtesy P.O. Hulth



Courtesy M. Kowalski

possible test modules in PINGU

IceCube is heading off to

1- solve the cosmic ray puzzle

2- measure the atmospheric mixing parameters with high precision

3- test sterile neutrinos

4- observe a detailed neutrino light curve from the next core collapse supernovae

with the addition of PINGU

5- measure the neutrino mass hierarchy (I beat is inverted)

with MICA

6- see that proton is …. just stable!!!
but by then we will be able to do neutrino astronomy of supernovae

good enough for a joke in the "Big Bang Theory" … Dave?

Proton life time (τ_p)

thanks to Goran Senjanovic (ICTP, Trieste)
http://arxiv.org/pdf/0912.5375

What can we learn in case of non detection?

- life time of the proton difficult to be determined: uncertainty in the masses of particles that lie at the large (GUT) scale

- minimal SU(5) [H. Georgi, S.L. Glashow (1974)] is a completely predictive theory but requires extensions (neutrino masses = 0, not unified gauge couplings)

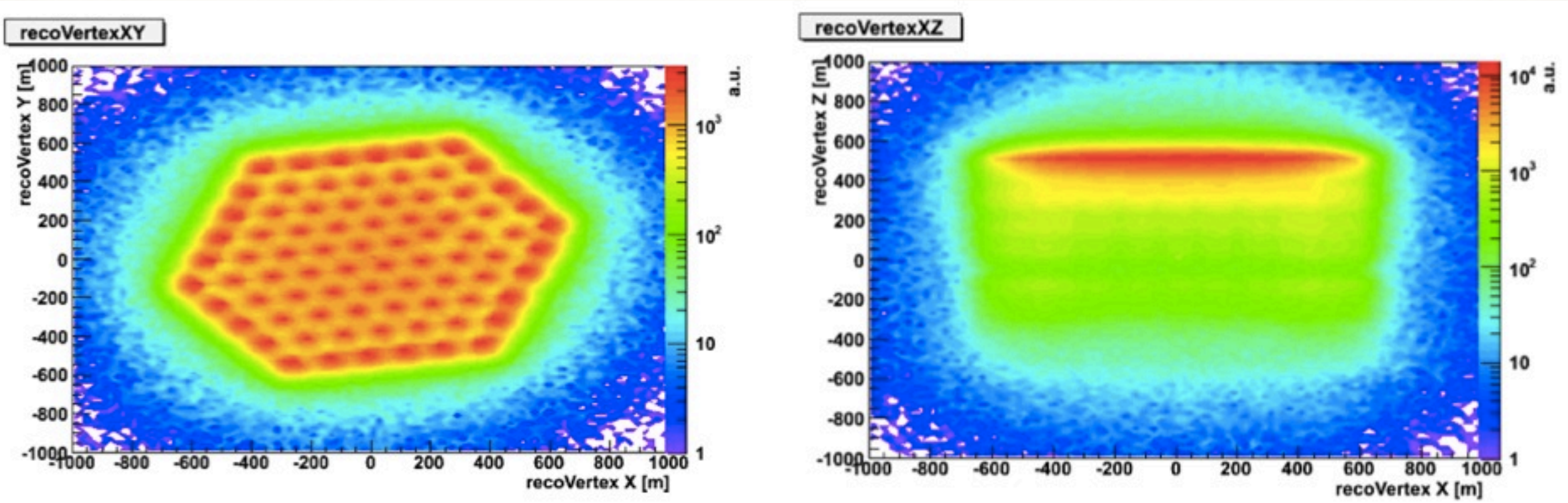
- ordinary extension of SU(5): $\tau_p < 10^{36}$ years

- supersymmetric extension of SU(5), less predictions, depend on mass of supersymmetric particles (LHC)

if mass of supersymmetric particles < TeV then $\tau_p < 10^{32}$ years

DeepCore: Rejection of atmospheric background

Corsika background (IC80) reconstructed vertex

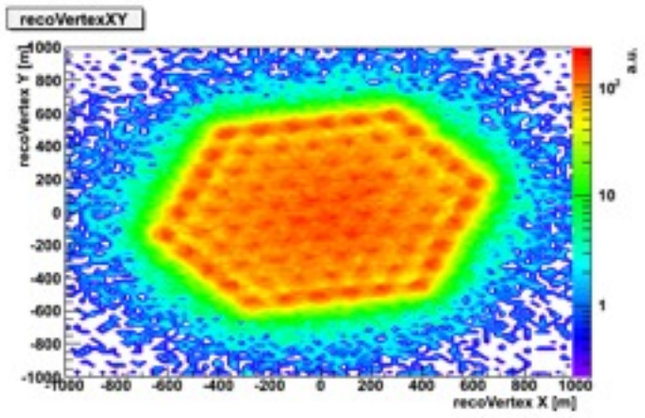


from DeepCore design study meeting in Stockholm, 2008

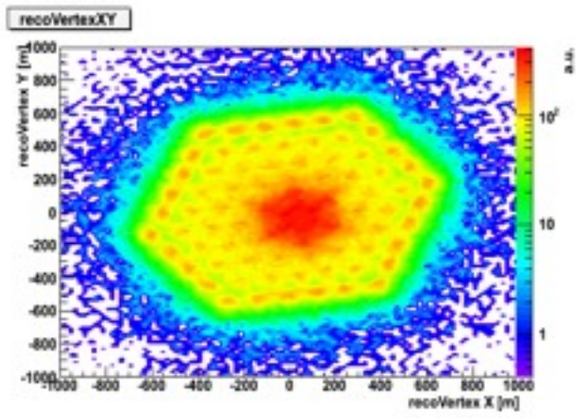
DeepCore: Rejection of atmospheric background

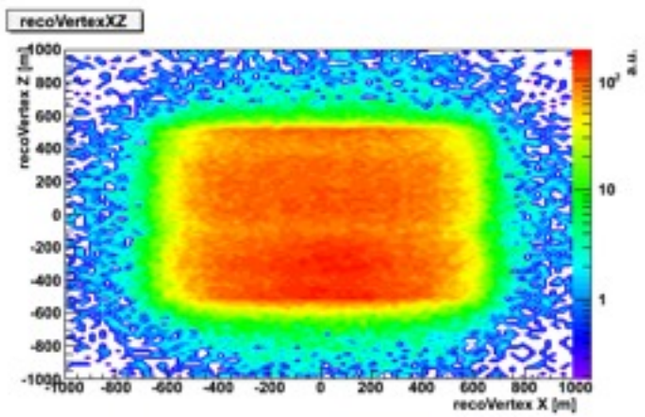
IC80 ν - vertex

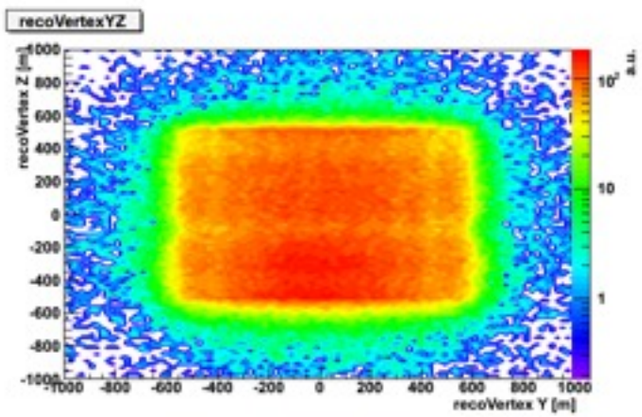
IC80 + 12 strings DeepCore
ν - vertex

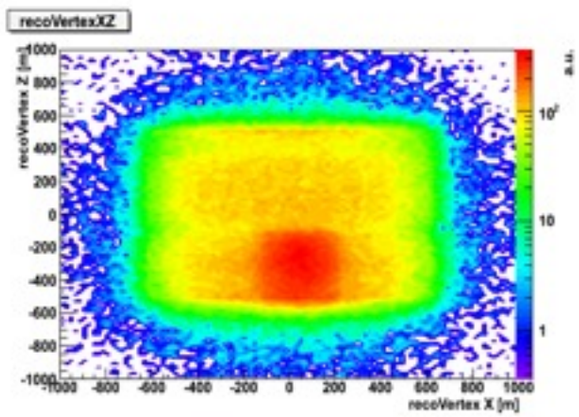


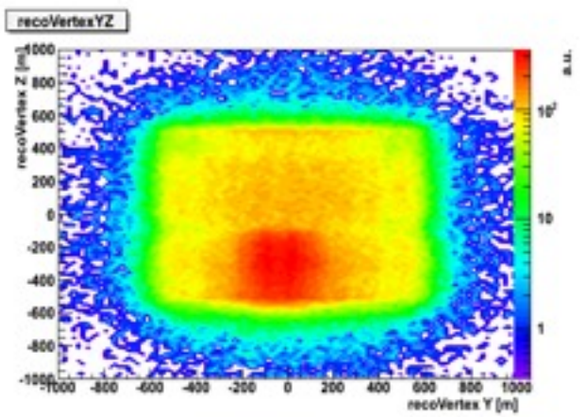
- MonteCarlo simulation
- 4π neutrino simulation
- E [5 GeV – 50 TeV]
- E^{-2} spectrum









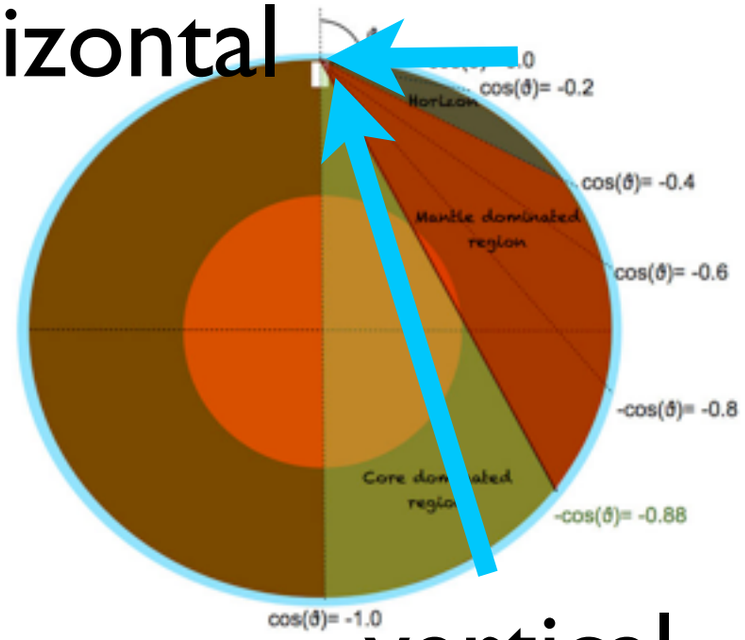


Actual DC: 8 strings

from DeepCore design study meeting in Stockholm, 2008

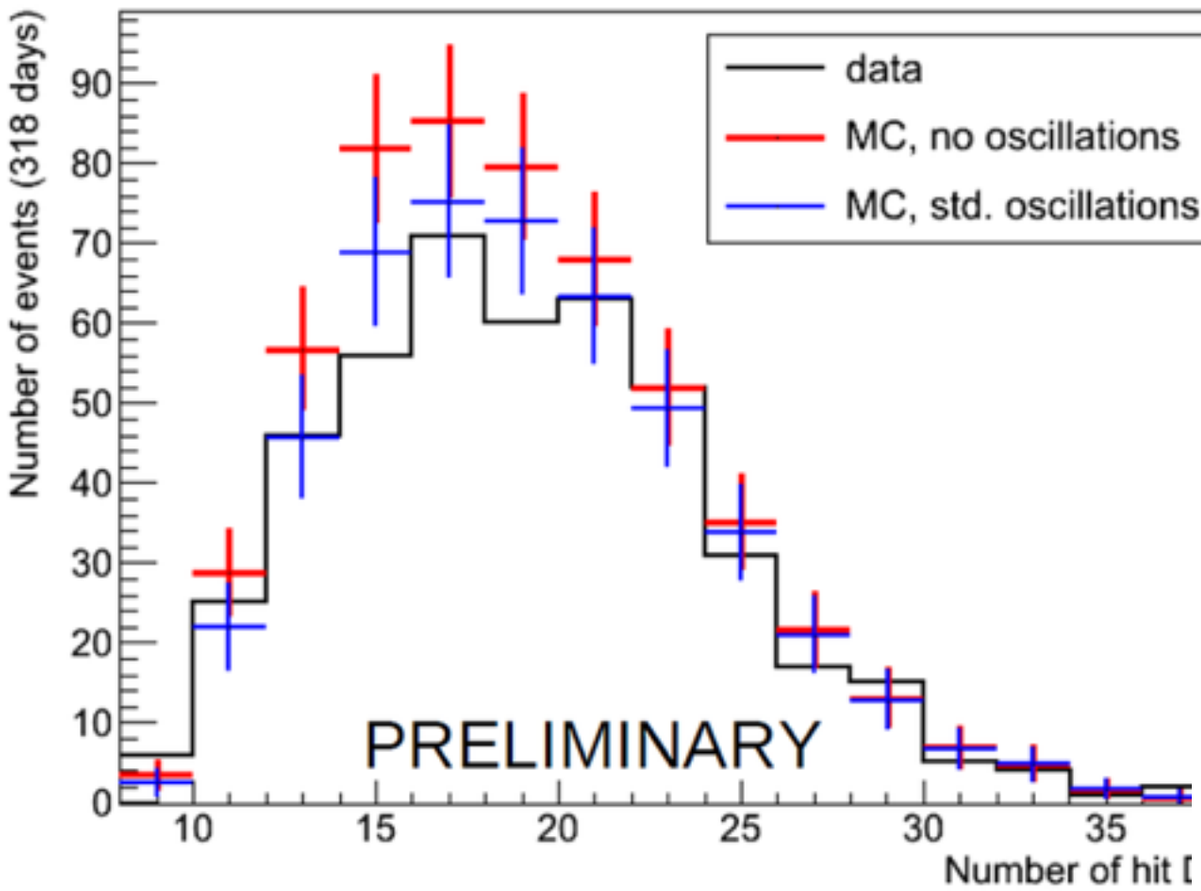
DeepCore

horizontal

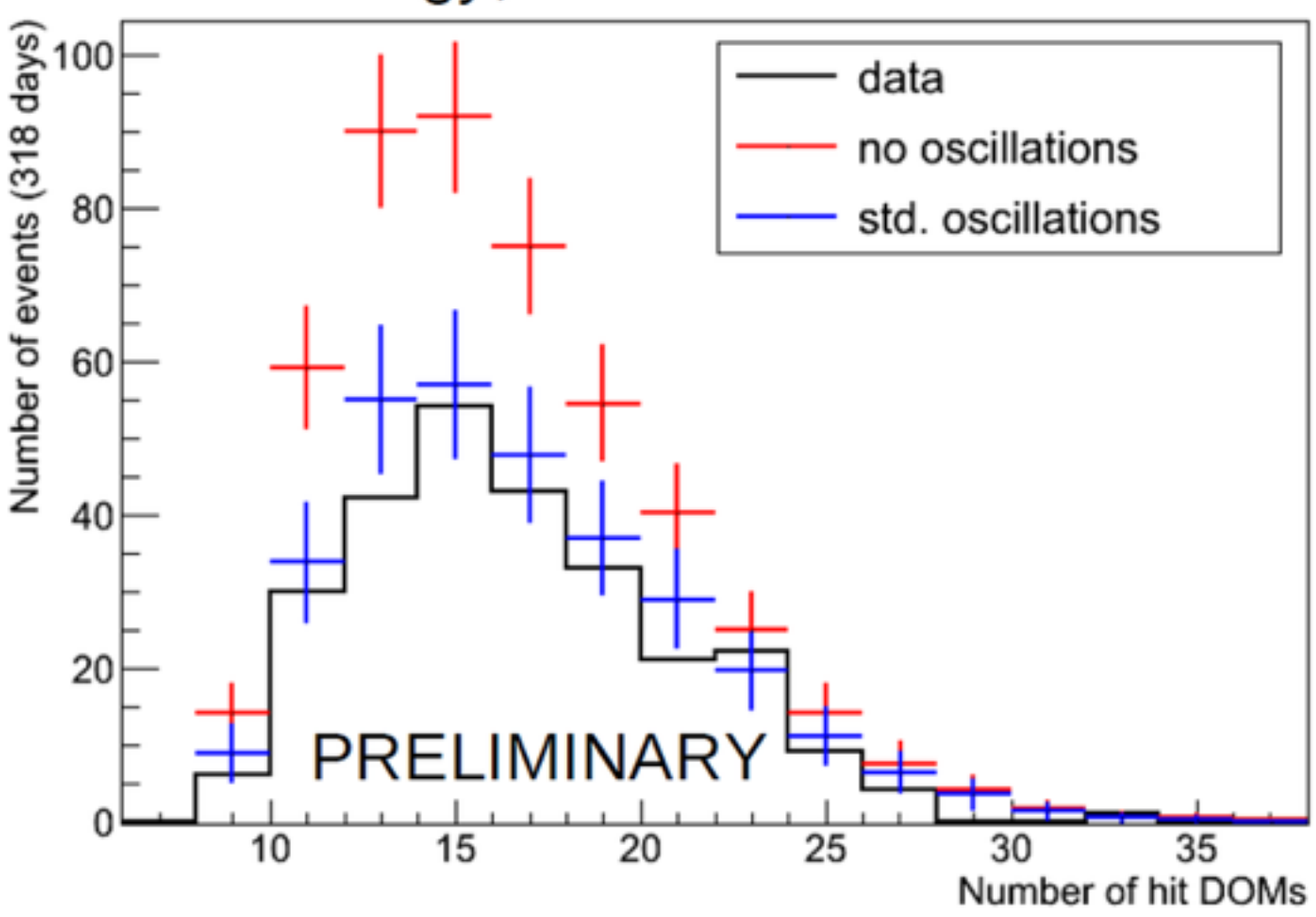


vertical

Low energy, horizontal



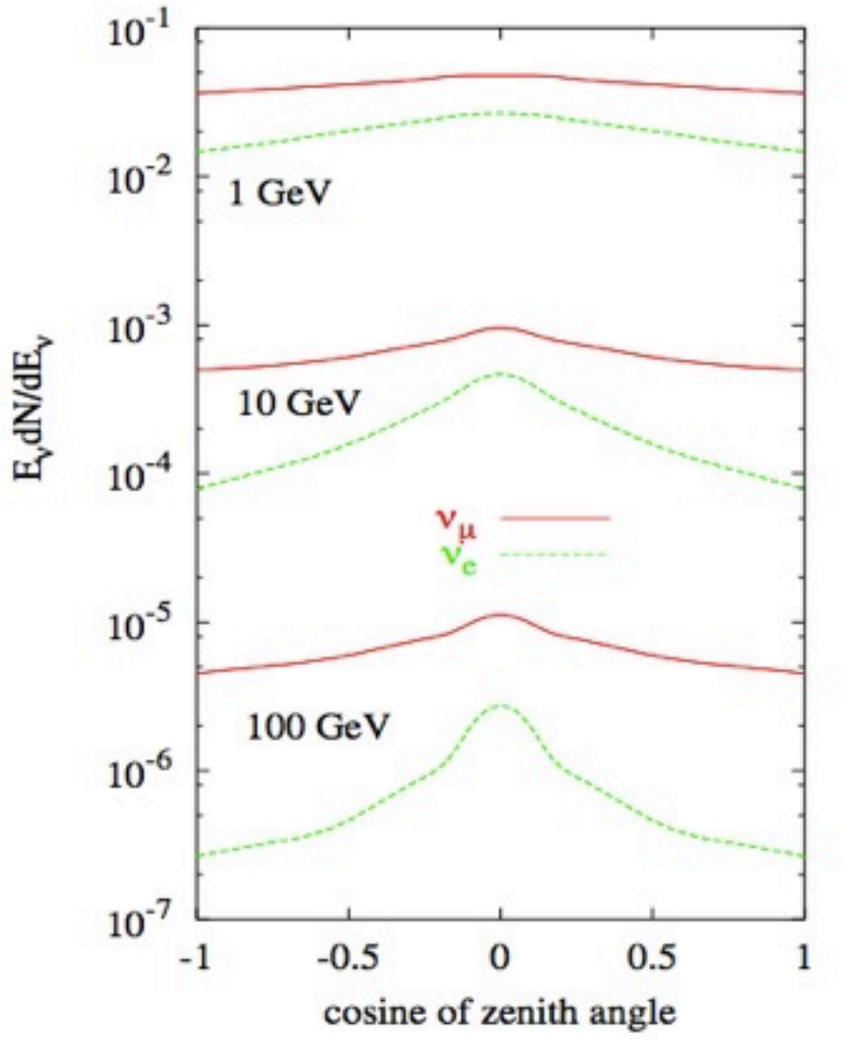
Low energy, vertical



Analysis 1 doesn't use energy!

DeepCore electron neutrinos

T.K. Gaisser and M. Honda, arxiv.org/pdf/hep-ph/0203272v2.pdf



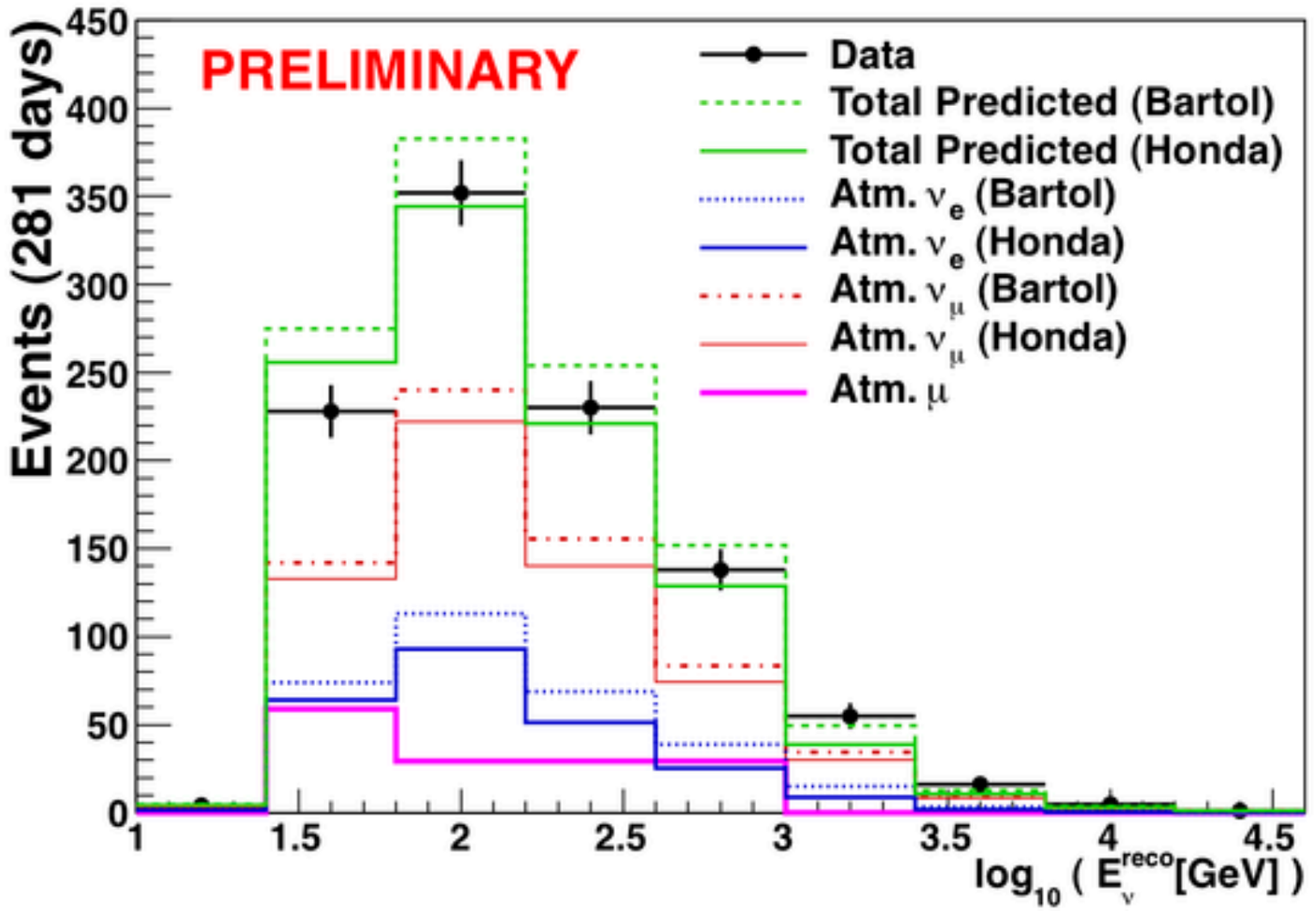
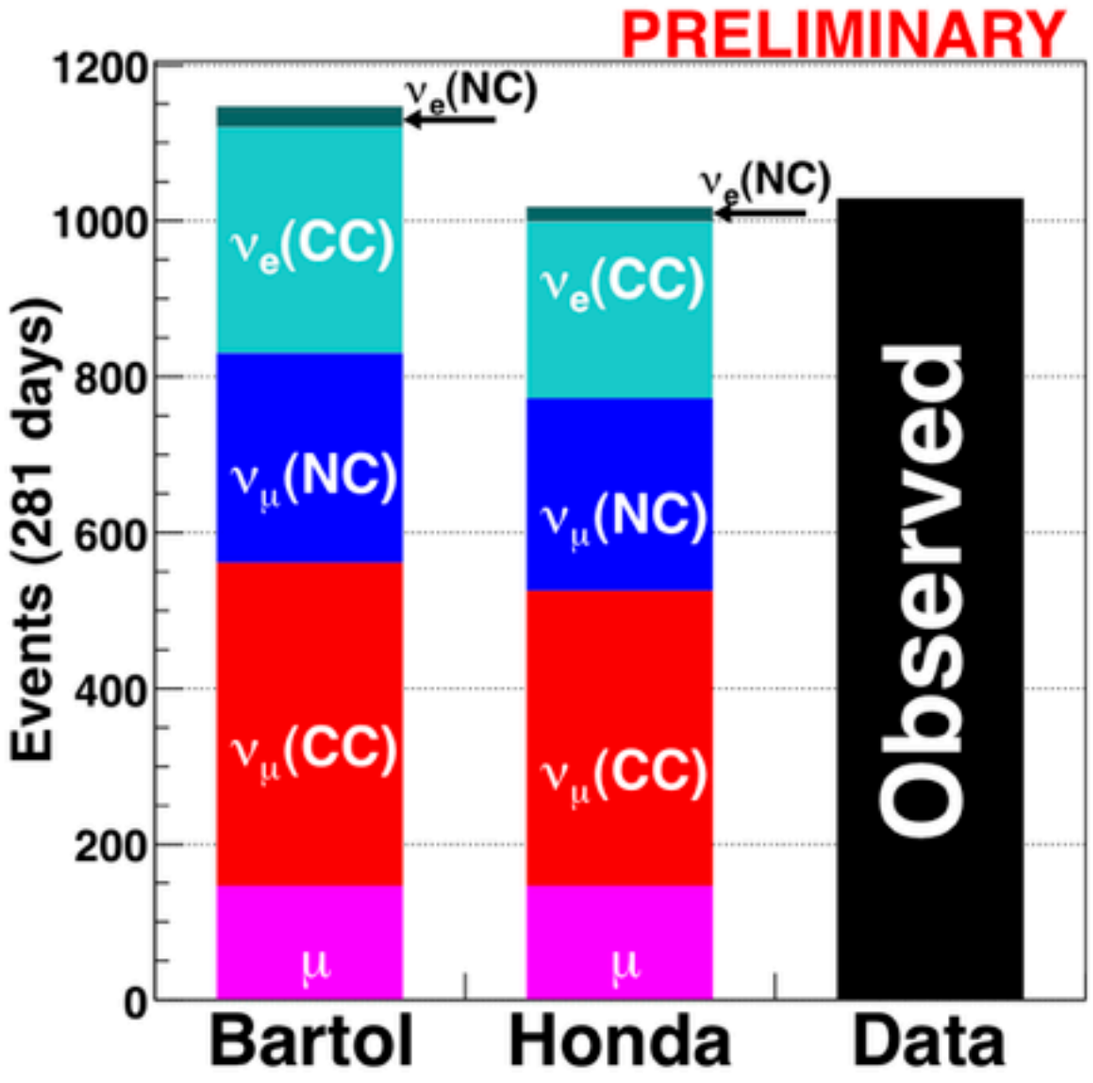
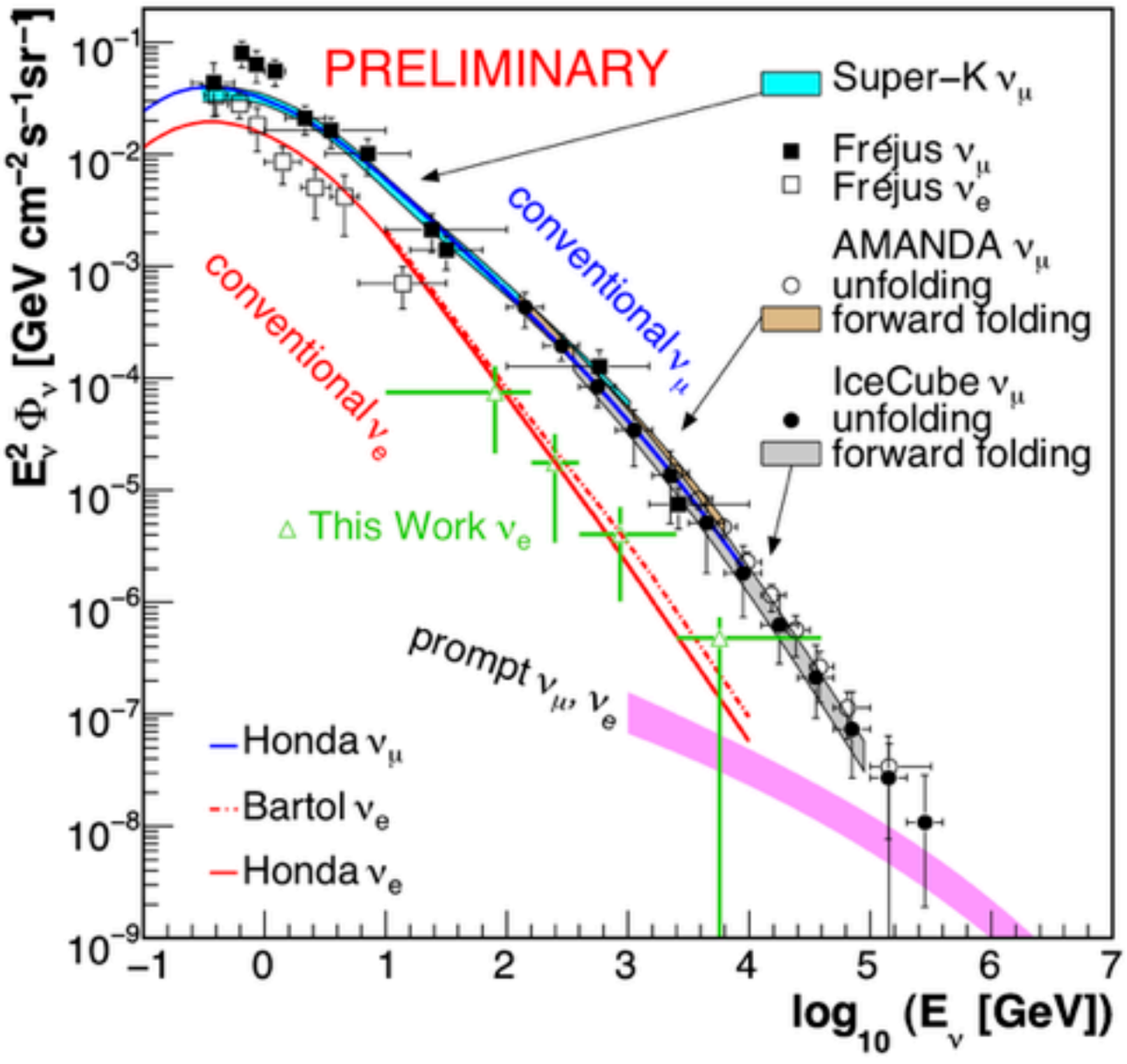


Figure 3: Left panel: Zenith-angle dependence of $\nu + \bar{\nu}$ calculated in the absence

DeepCore electron neutrinos





IceCube recent results

astrophysical neutrinos

→ **point sources**

GRBs

core collapse SN

→ **diffuse flux**

→ **surprises ...**

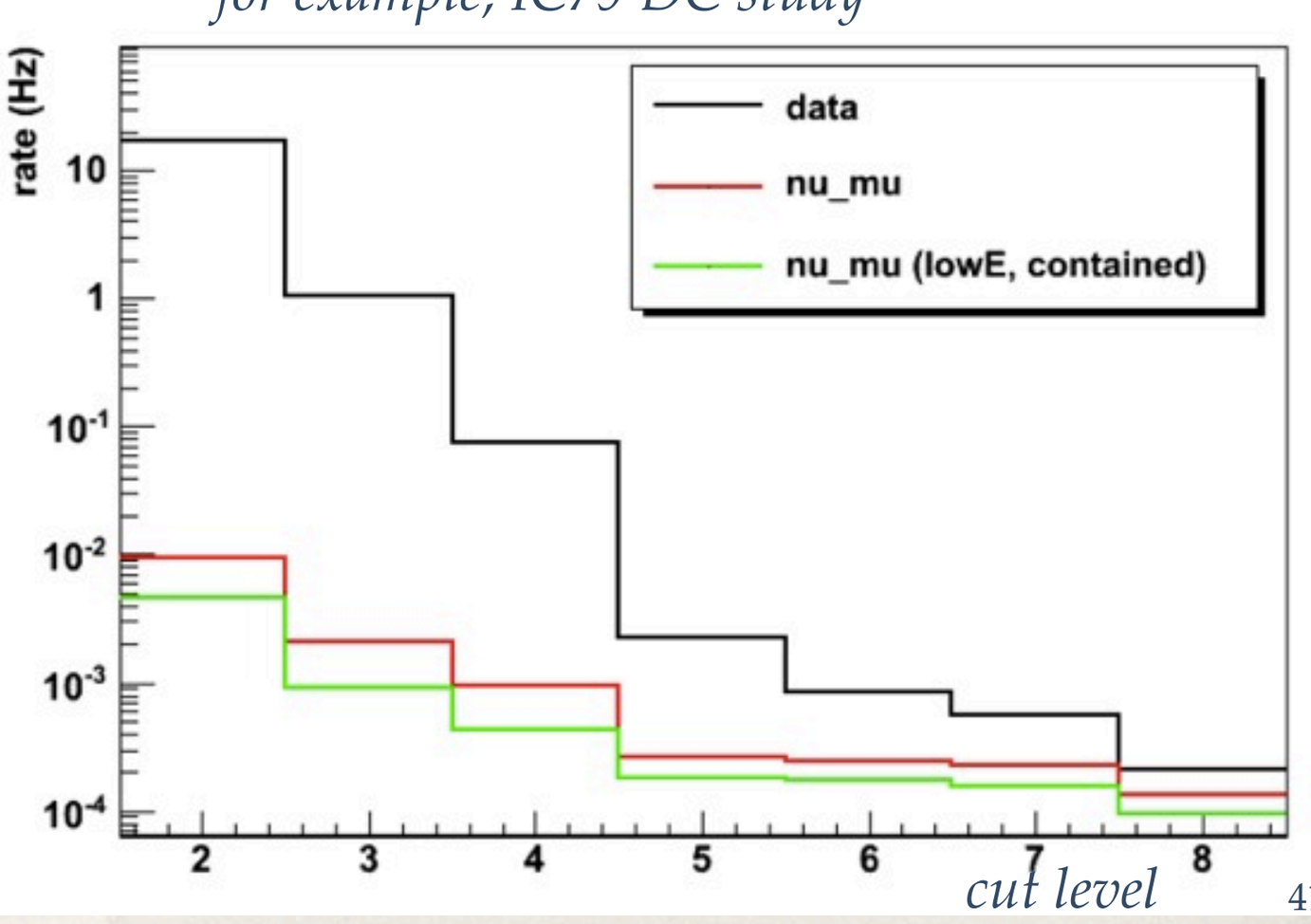
DeepCore: Rejection of atmospheric background

Containment cuts: reduction of the first 3 - 4 order of magnitude atmospheric background.
Various study performed in this direction, new variables at mature stage.

Example of analysis progression:
Up to L5, with containment only

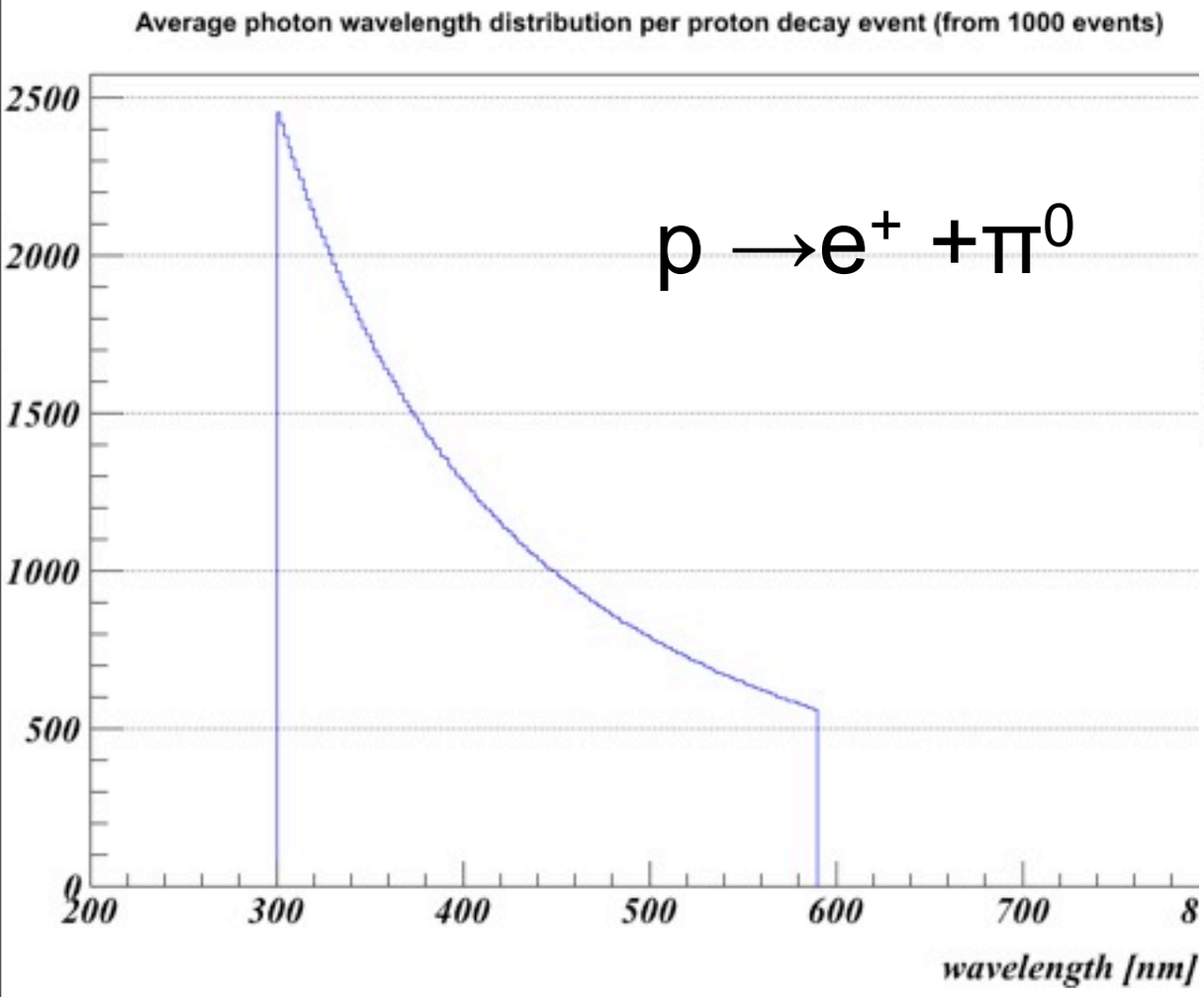
Signal efficiency in DC:
~10-20% for a high pure sample (>95%).

for example, IC79 DC study

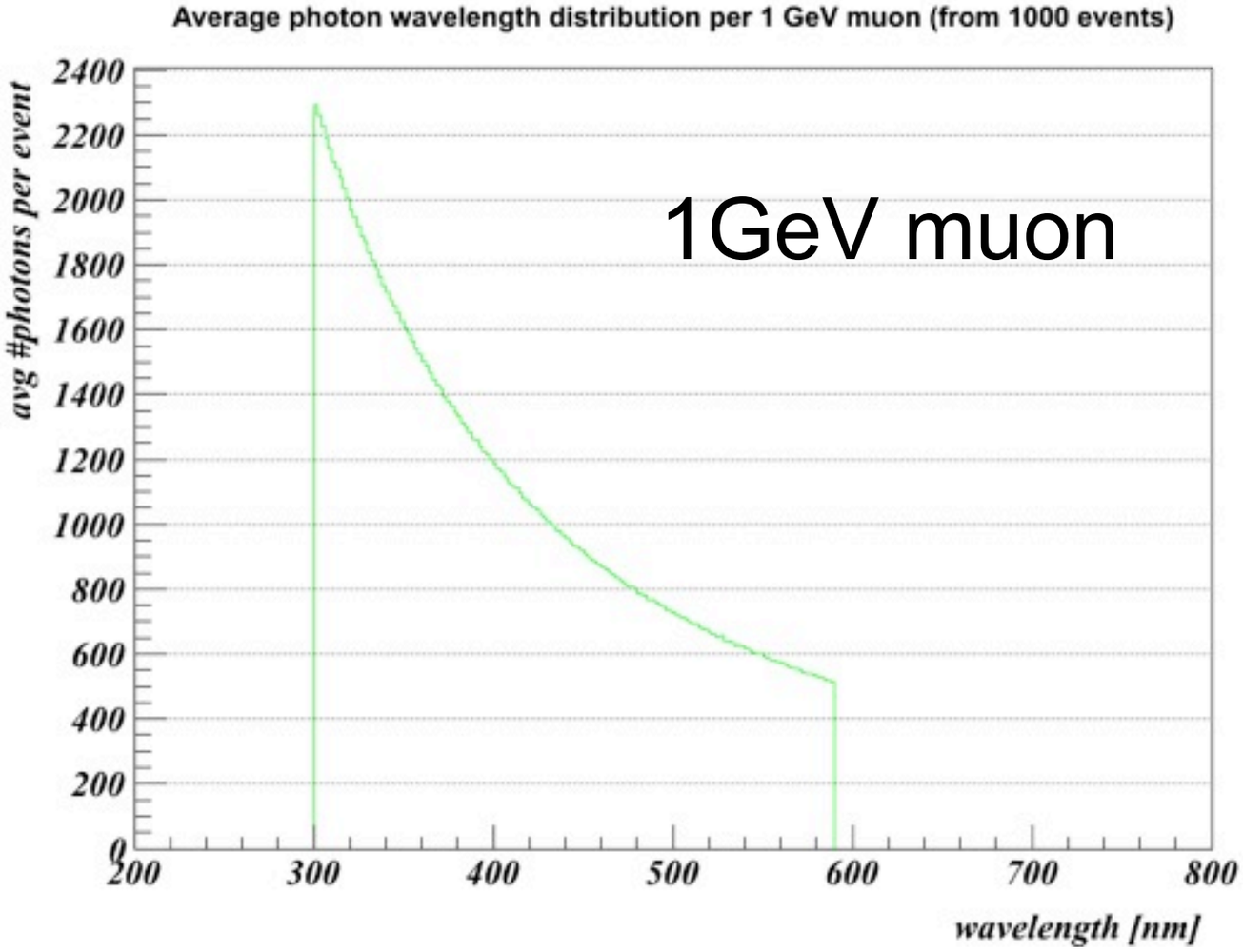


MICA proton decay

Photon yield for p-decay ~ 1GeV muons



$p \rightarrow e^+ + \pi^0$



1GeV muon

photocathode area coverage needed?

from Kamiokande: the most serious background for proton decay searches was atmospheric neutrino events, at a rate of approximately 10^2 events/kt/yr

… it is all about atmospheric neutrinos

In this talk

AMANDA-B10

AMANDA-II

IceCube

DeepCore

PINGU

MICA

see also Jason Koskinen