Neutrino Mixing and CPT violation by 20 GeVs beaming across the Earth and atmospheric neutrino at Deep Core

Beaming neutrino and antineutrinos across the Earth … see:

arXiv:1012.3245v1

DFargion,, **Daniele D'Armiento**, **Paolo Paggi, Paolo Desiati**

arXiv:1103.2642: Foreseeing Neutrino spectra in Deep Core

Authors: Daniele Fargion, Daniele D'Armiento, Paola Di Giacomo, Paolo Paggi

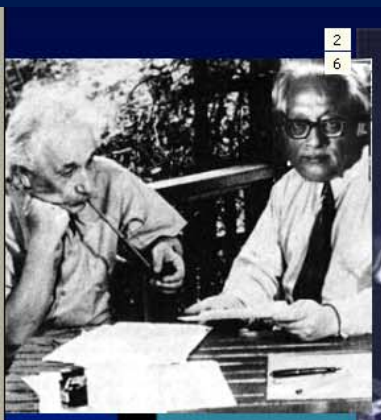
arXiv:1101.1991: A 20 GeVs transparent neutrino astronomy from the North Pole?

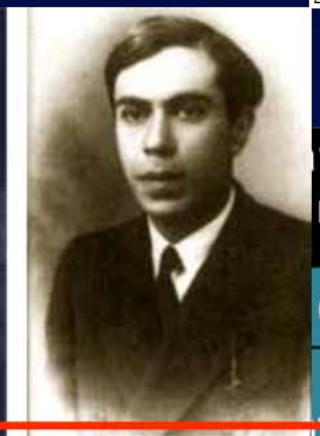
Summary

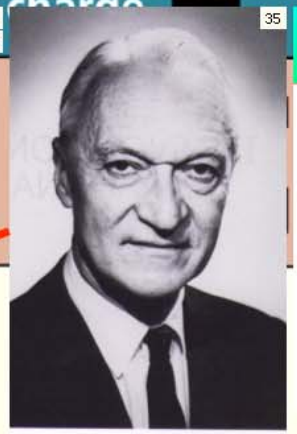
- Neutrino flavor changing may be asymmetric by CPT violation: different masses
- Muon into Tau may be different than anti-particle in oscillation (how to test it at best?)
- Beaming artificial neutrinos into Icecube Deep Core may solve the puzzle (and reveal Taus)
- Upward atmospheric neutrinos at 20 GeV may also show the CPT ..see..Deep Core soon
- Neutrino Astronomy at 20s GeV is more clean

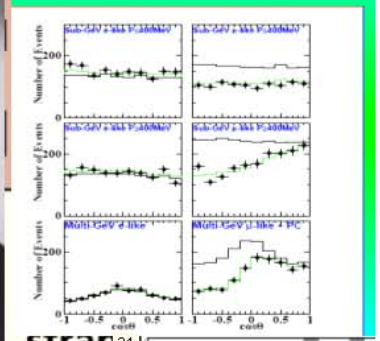
of noisy atmospheric background

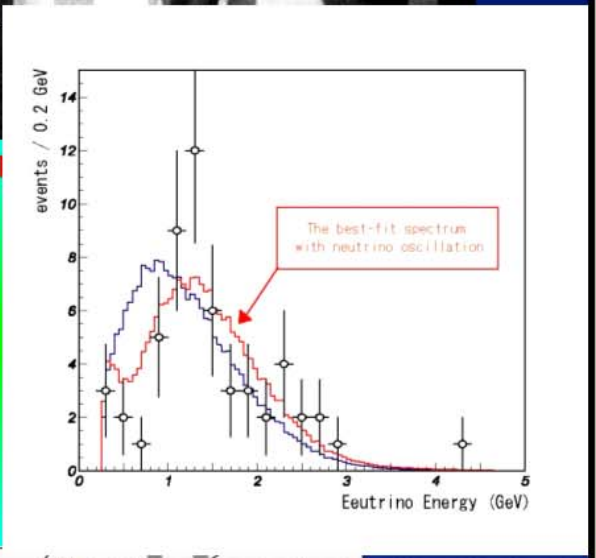
6 Neutrinos mixed among themselves

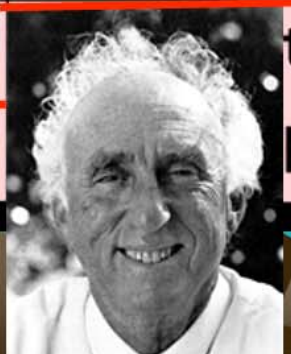


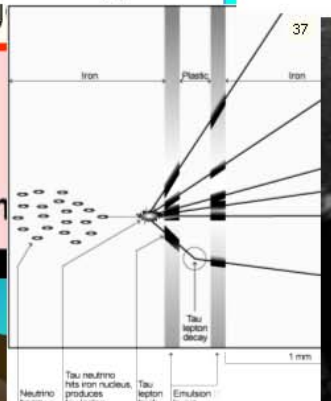




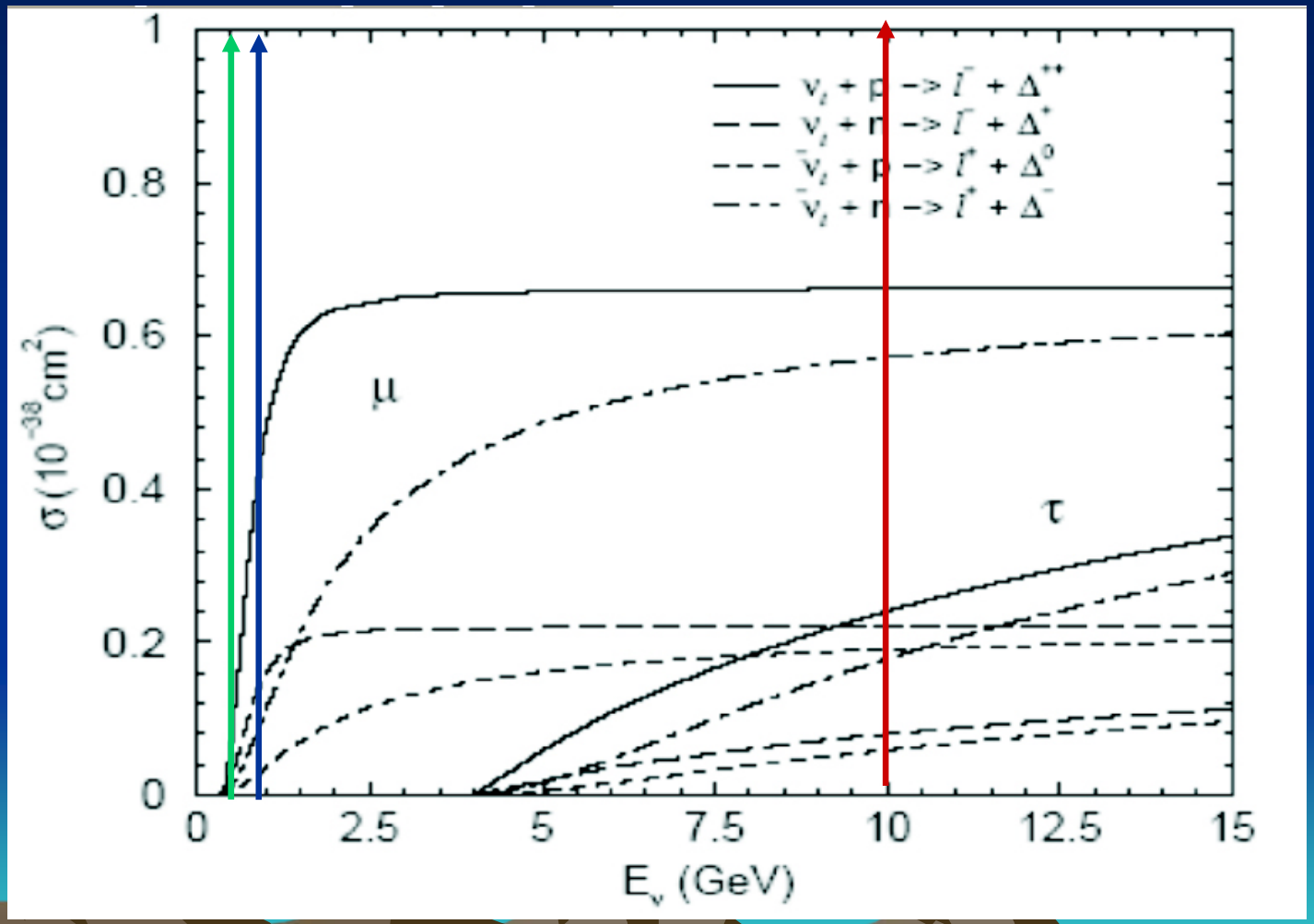




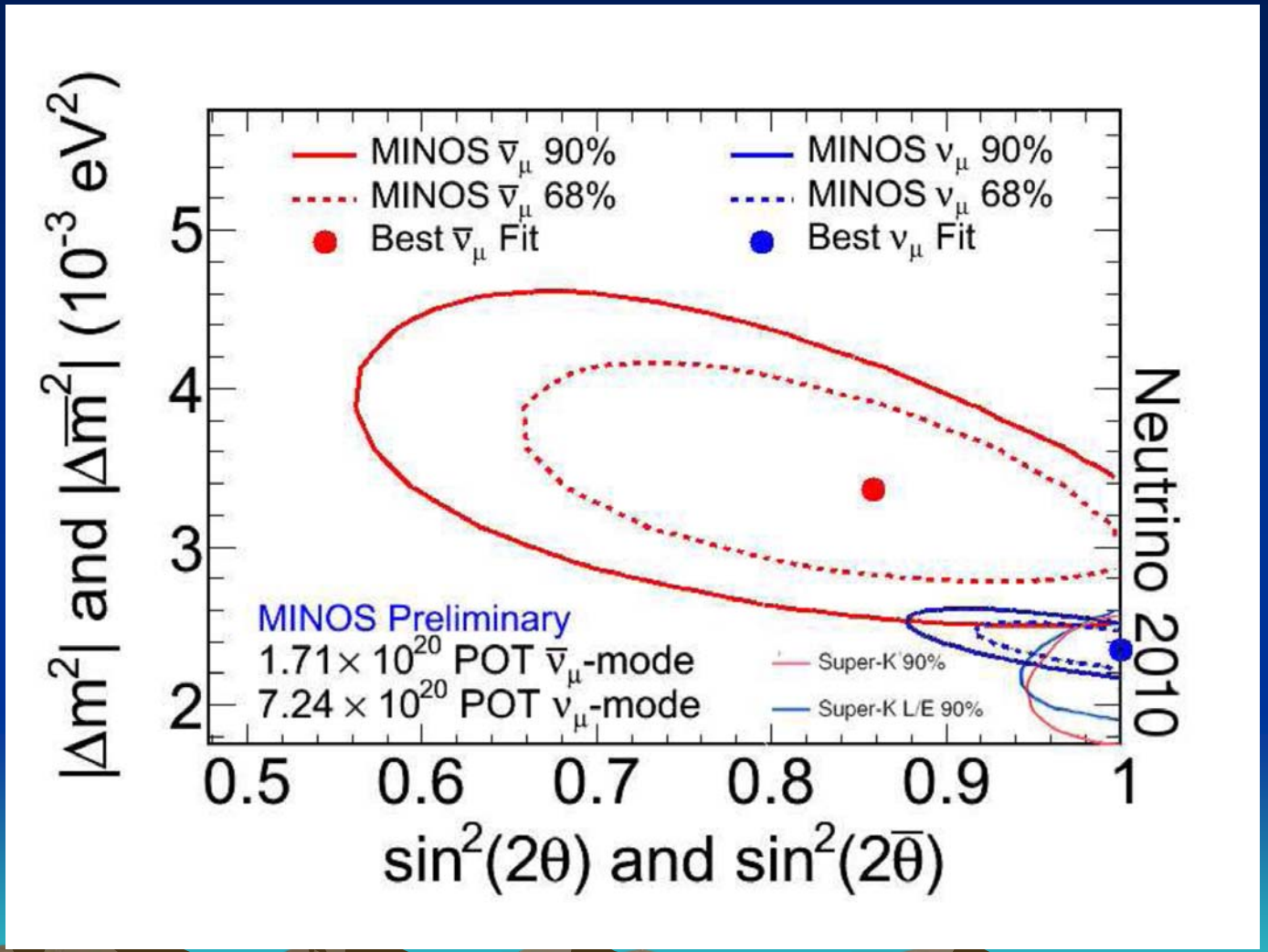




Energy threshold to each born leptons 6 different neutrino astronomy

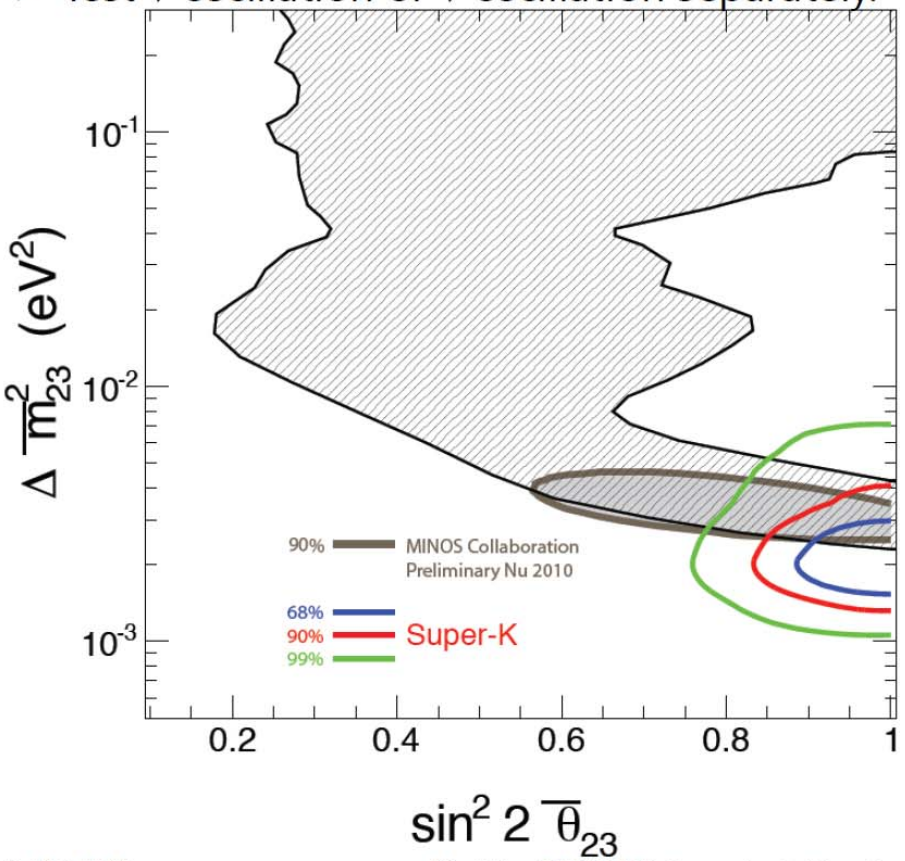


Minos , June 2010: Different anti-muon neutrino mass and mixing?



But SK ICHEP 24 july 2010 : …
No really need of any CPT violation?

- Test ν oscillation or $\bar{\nu}$ oscillation separately.



SK-I+II+III

Preliminary

Neutrino:

$\Delta m_{23}^2 = 2.2 \times 10^{-3} eV^2$

$\sin^2 2\theta_{23} = 1.0$

Anti-neutrino:

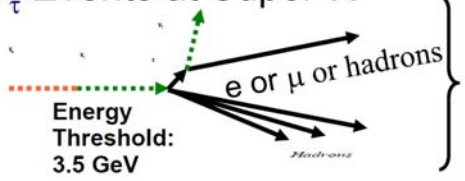
$\Delta \overline{m}_{23}^2 = 2.0 \times 10^{-3} eV^2$

$\sin^2 2\overline{\theta}_{23} = 1.0$

No evidence for CPT violating oscillations is found

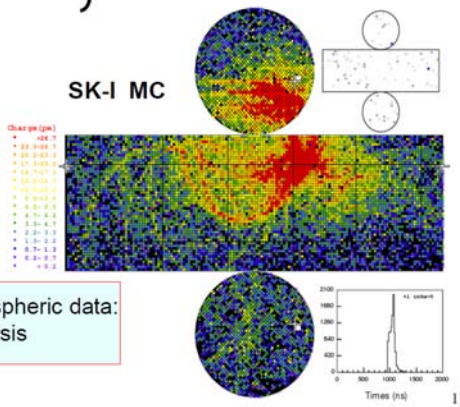
Tau Appearance in SK: still no CPT signature?

ν_τ Events at Super-K



- Many light-producing particles
- Most events are deep inelastic scattering (DIS) interactions

- Complicated event topology makes identification of the leading lepton difficult
  - Use a Neural Network
- Negligible primary flux
  - Observed tau events must be oscillation induced

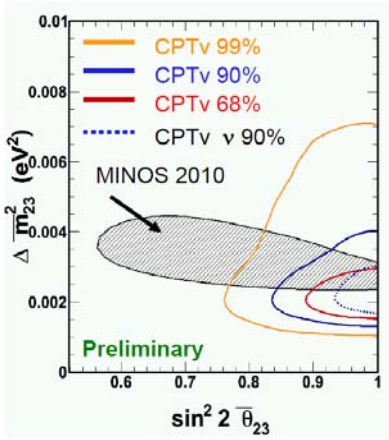


GOAL : Detect ν_τ events in SK atmospheric data: test the "no tau appearance" hypothesis

11

Antineutrino Oscillations : CPT violation

- CPT theorem: $P(\nu \rightarrow \nu)$ and $P(\bar{\nu} \rightarrow \bar{\nu})$ should be the same.
- Test ν oscillation or $\bar{\nu}$ oscillation separately.



SK 2806 Days

	Best Fit
Δm^2	2.1×10^{-3} eV^2
$\sin^2 2\theta$	1.0

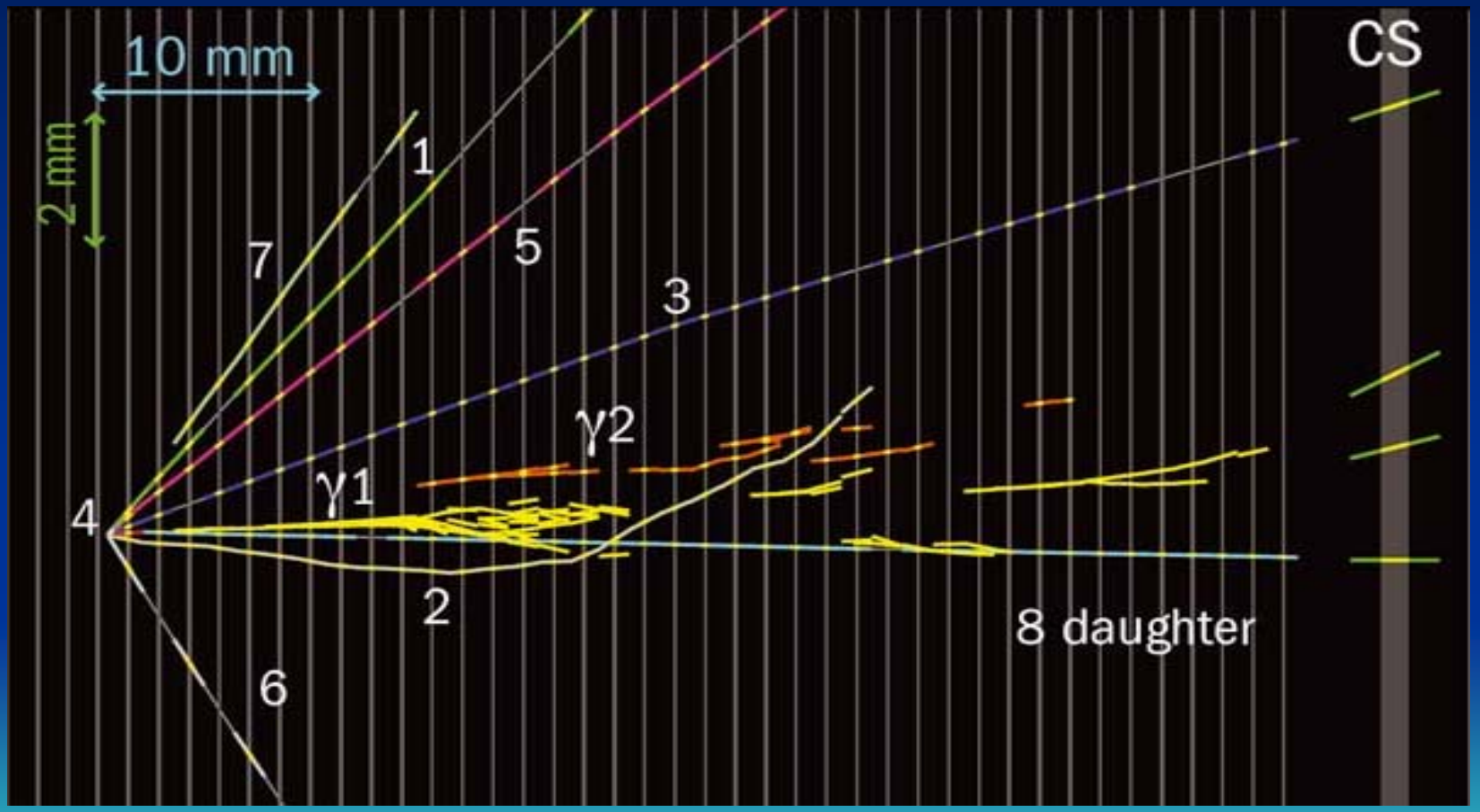
	Best Fit
Δm^2	2.0×10^{-3} eV^2
$\sin^2 2\theta$	1.0
χ^2	468.8 / 416 D.O.F

Equal neutrino and antineutrino mixing favored by the data

- No evidence for CPT violation in SK atmospheric data
- Field theories are still safe...

13

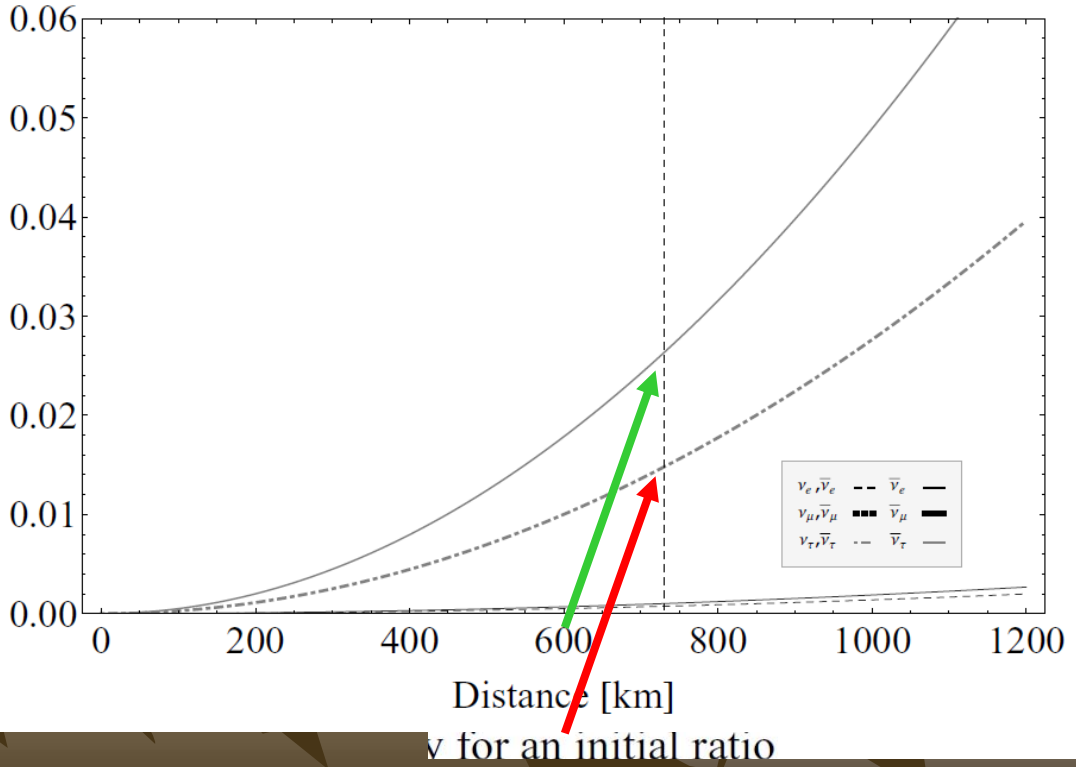
A first artificial Tau by Cern-Opera 2010 experiment



To test this CPT result by a new Anti-Opera?

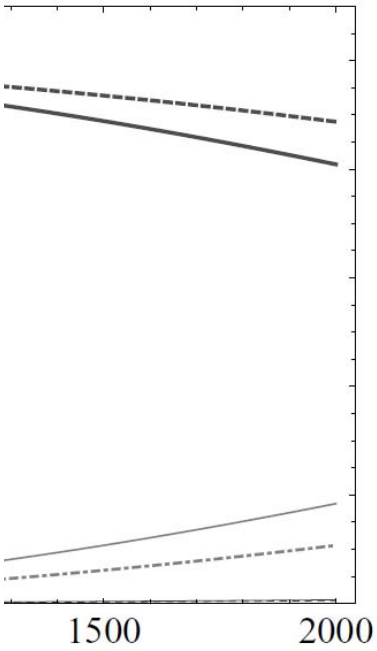
Oscillation probability for an initial ratio

$\overline{\nu}_e : \overline{\nu}_\mu : \overline{\nu}_\tau = 0 : 1 : 0$ (<E> ≈ 17 GeV)



n initial ratio

> ≈ 17 GeV)



for an initial ratio

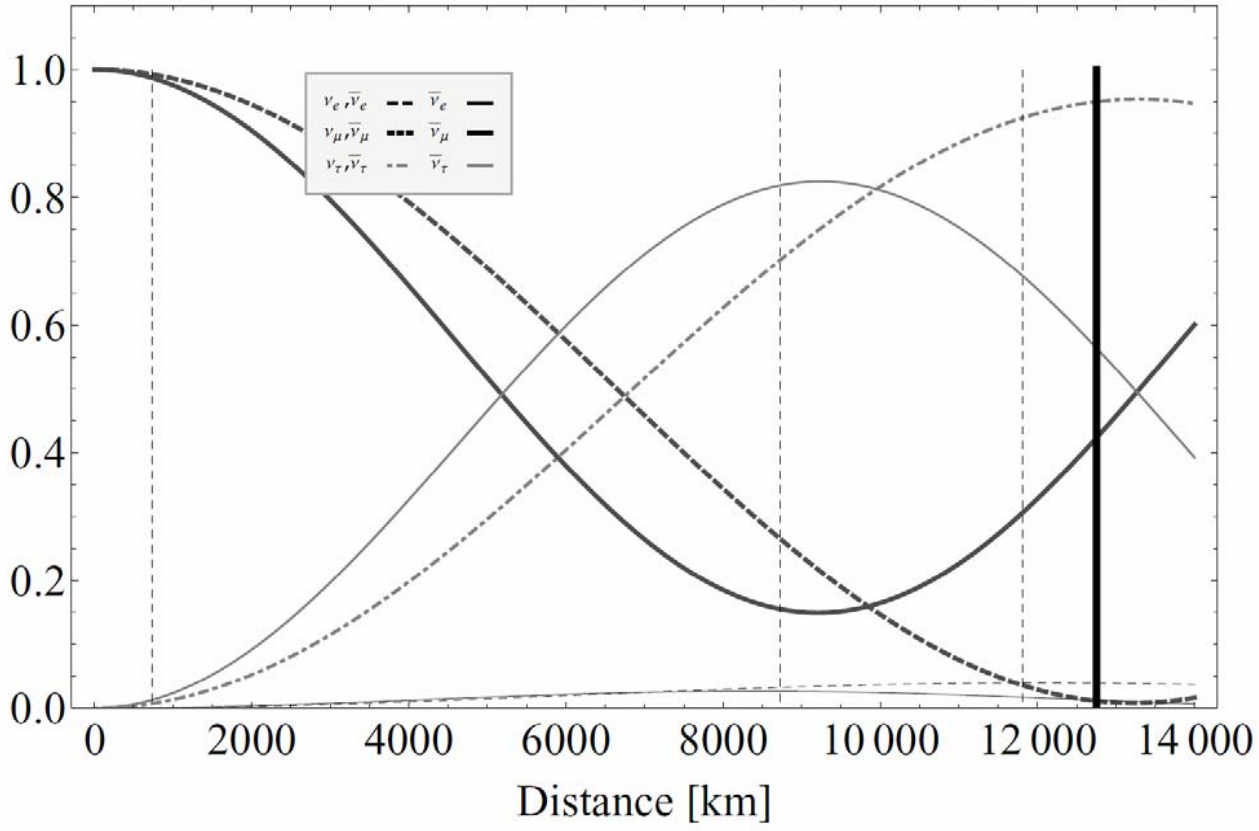
OK..from 1 tau to 1 anti-tau a year?

- Non convincing and not useful

Larger distances, better split CPT violation

Oscillation probability for an initial ratio

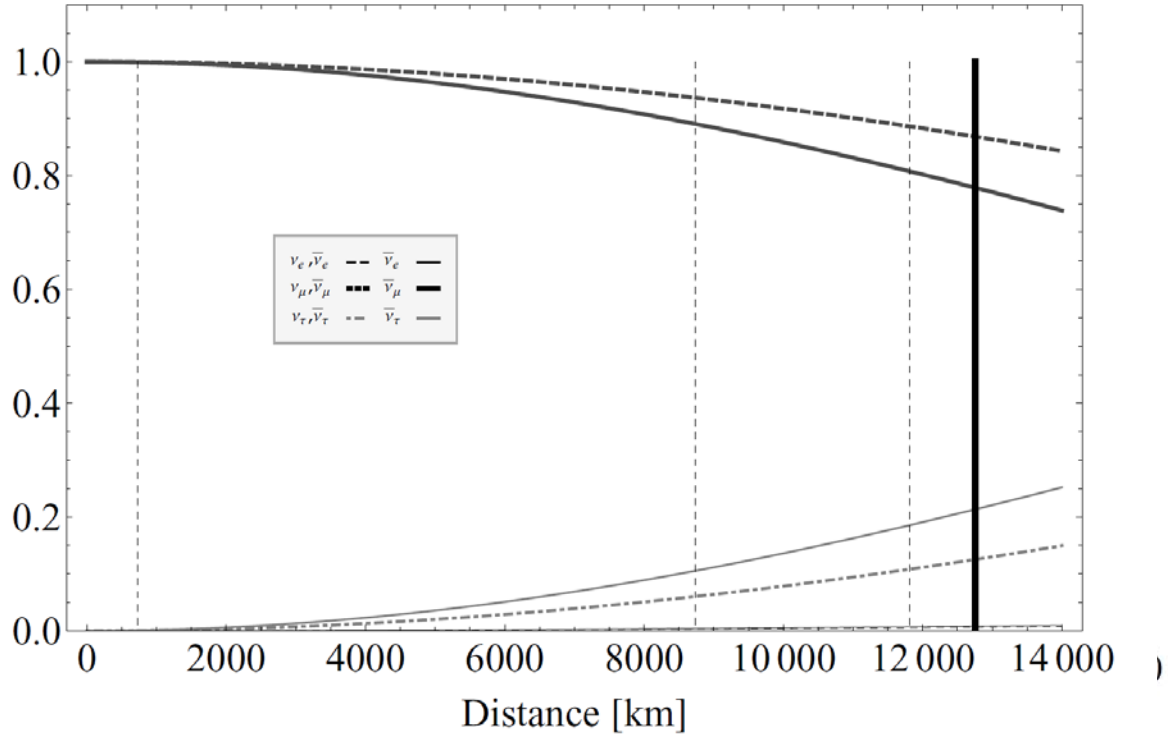
$\overline{\nu}_e : \overline{\nu}_\mu : \overline{\nu}_\tau = 0 : 1 : 0 \quad (<E> \approx 24.6\ \text{GeV})$



A larger energy..a smaller mixing and smaller anisotropy

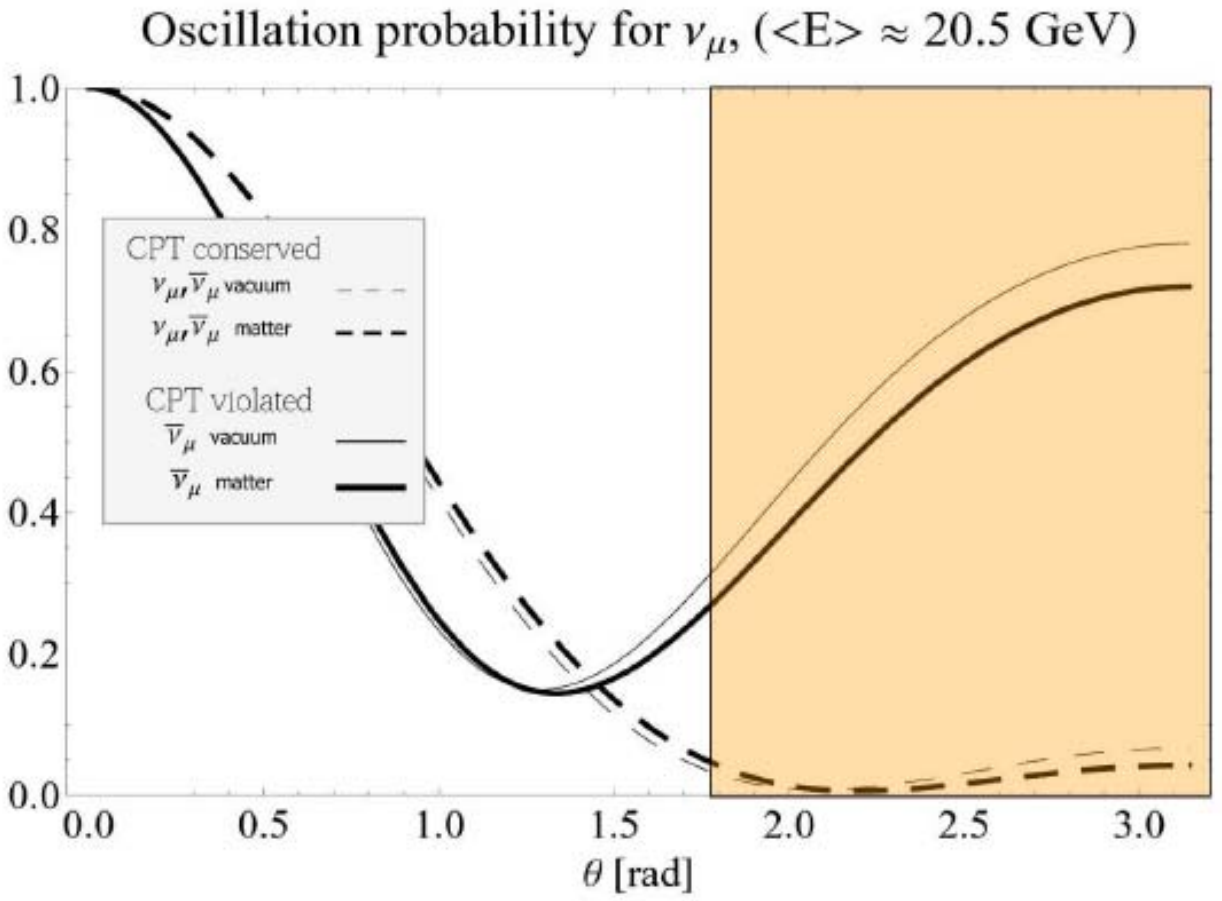
Oscillation probability for an initial ratio

$\overline{\nu}_e : \overline{\nu}_\mu : \overline{\nu}_\tau = 0 : 1 : 0$ (<E> ≈ 100 GeV)



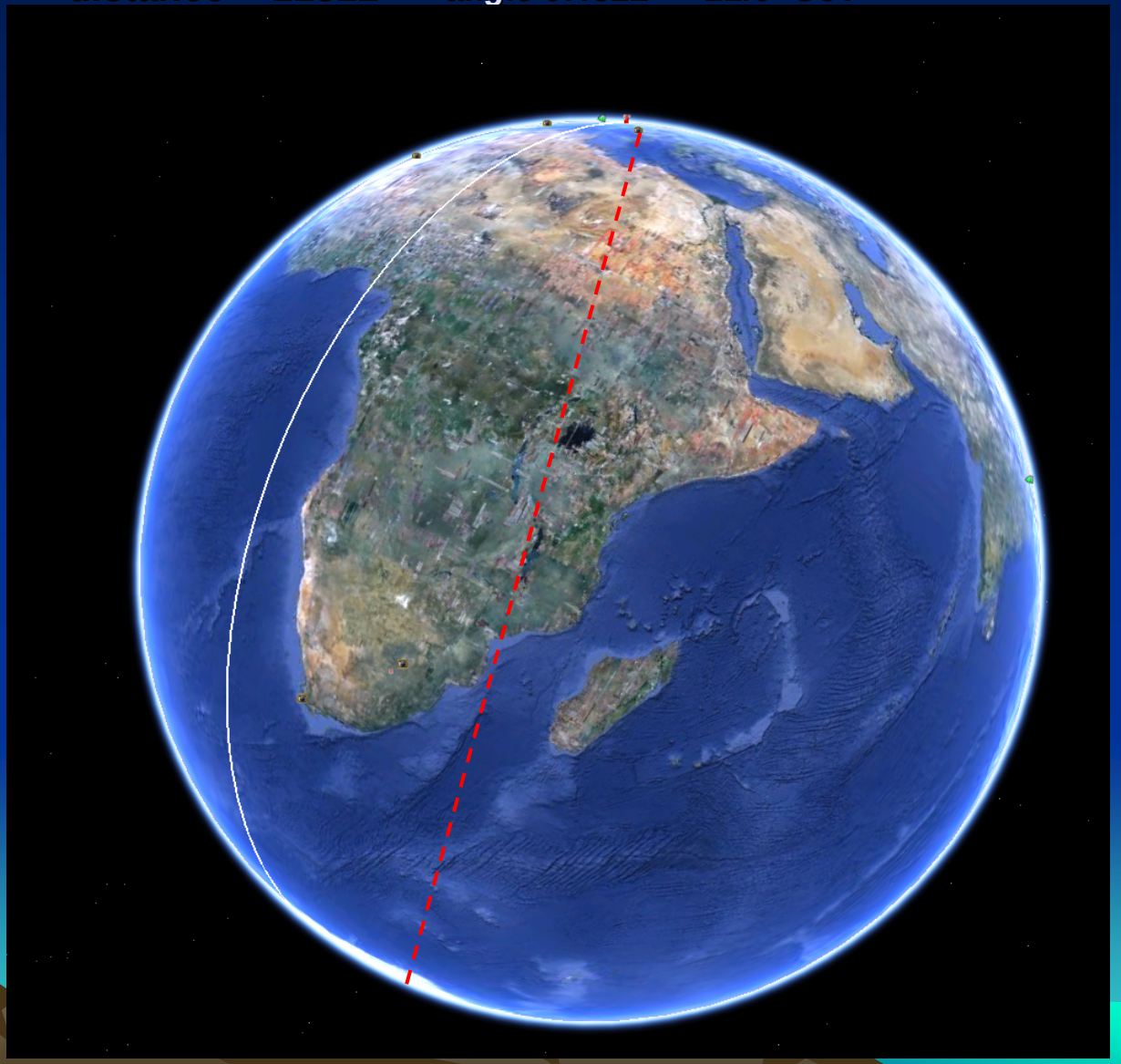
Oscillation probability for an initial ratio

Angular splitting on upward muons and CPT violated antimuons

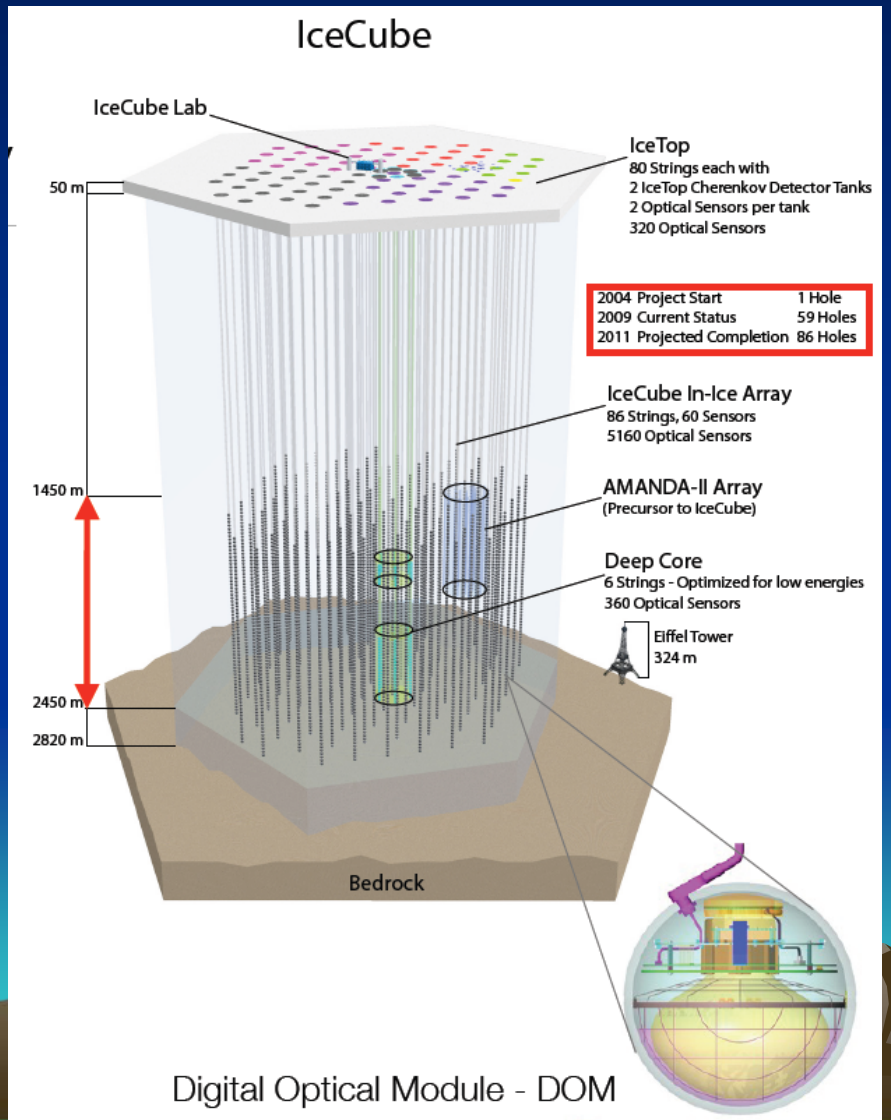


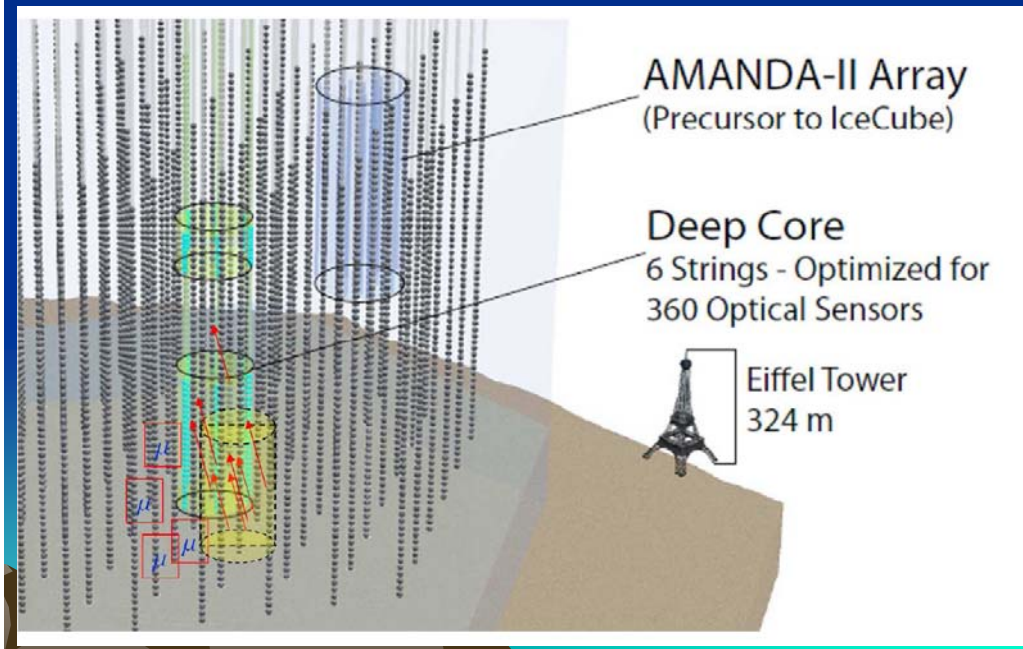
From Cern (or FNL)- to Icecube

***distance* = 11812** **angle 67:82±** **21:9 GeV**



Longest distances and largest detectors : Cern Deep Core

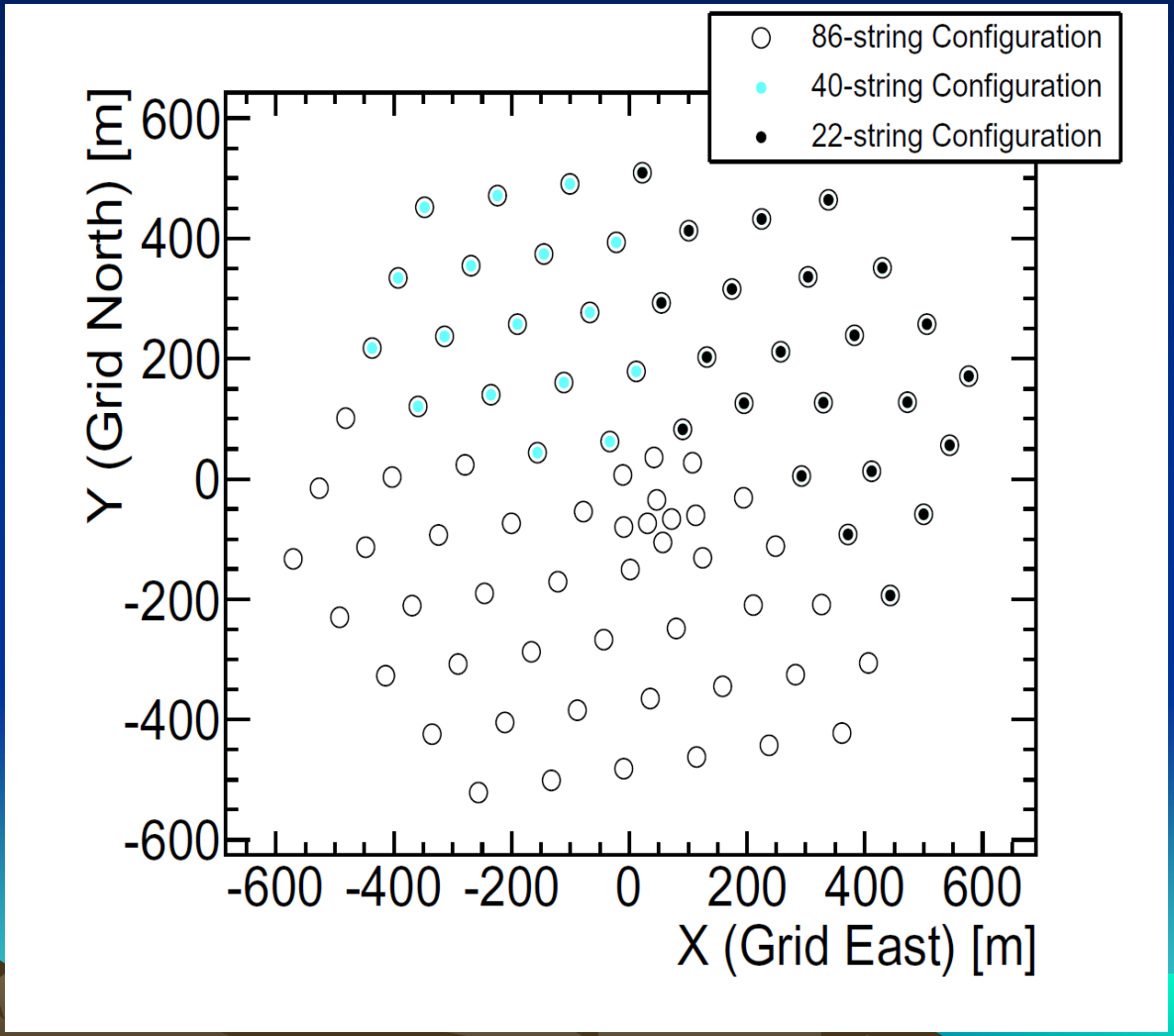




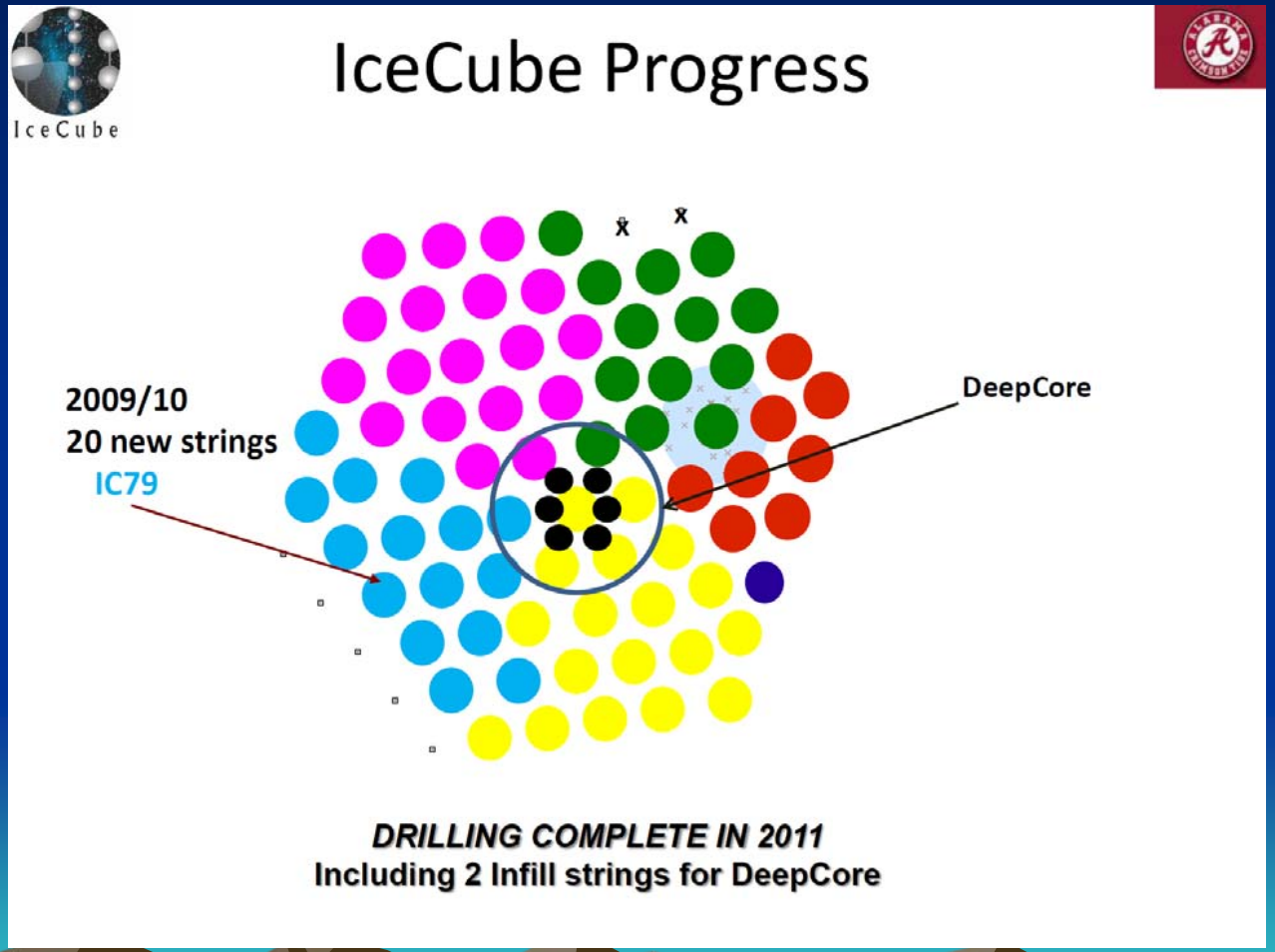
Why from Cern-Deep Core?

- New proposal: to disentangle the different CPT mass splitting by the use of largest oscillation distances and largest detection energy of Deep Core, largest dilution but even more larger detection masses
- L (opera) 730 km ---L(Icecube) 12000 km
- M(Opera Kton) --M(Icecube) 4 -8 Mton
- Conversion mix (Opera 1.5%)---(Icecube 100%)

Icecube 1 april 2011



News from the ice

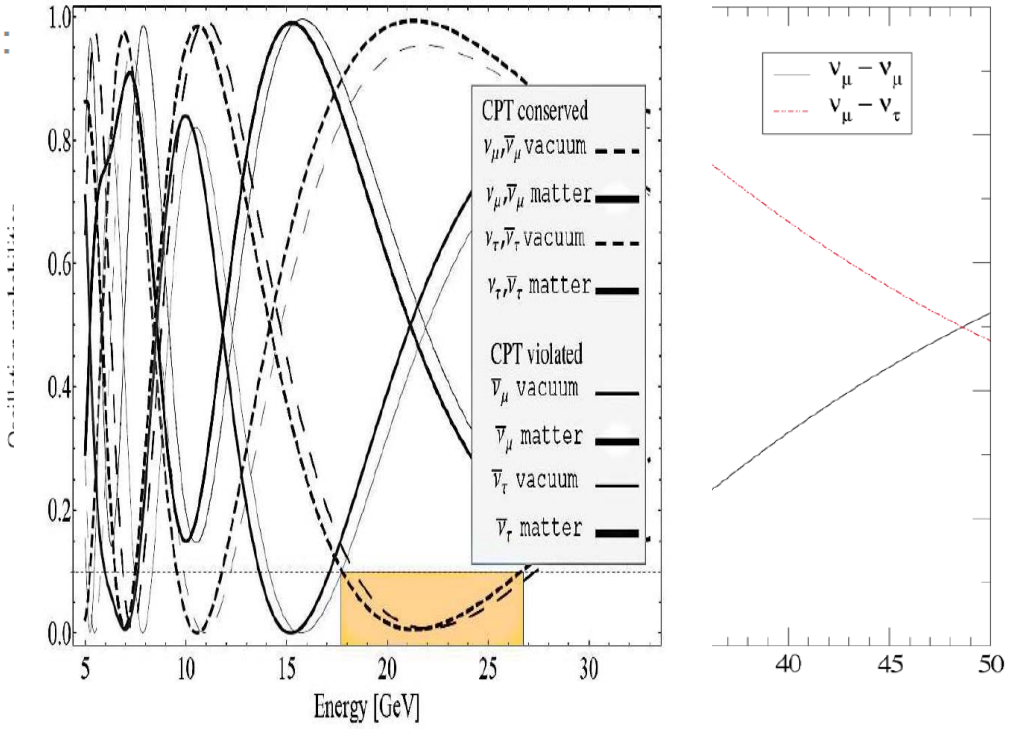


Why Deep Core? Icecube-us

Deep Core : fundamental physics

- muon neutrino disappearance : feasable
- tau neutrino appearance : reasonable
- neutrino mass hierarchy : difficult

ν hierarchy
($\sin^2(2\theta_{13})=0.1$)



inos

baseline = Earth's diameter

Why Deep Core? Icecube-us

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- tau neutrino appearance :
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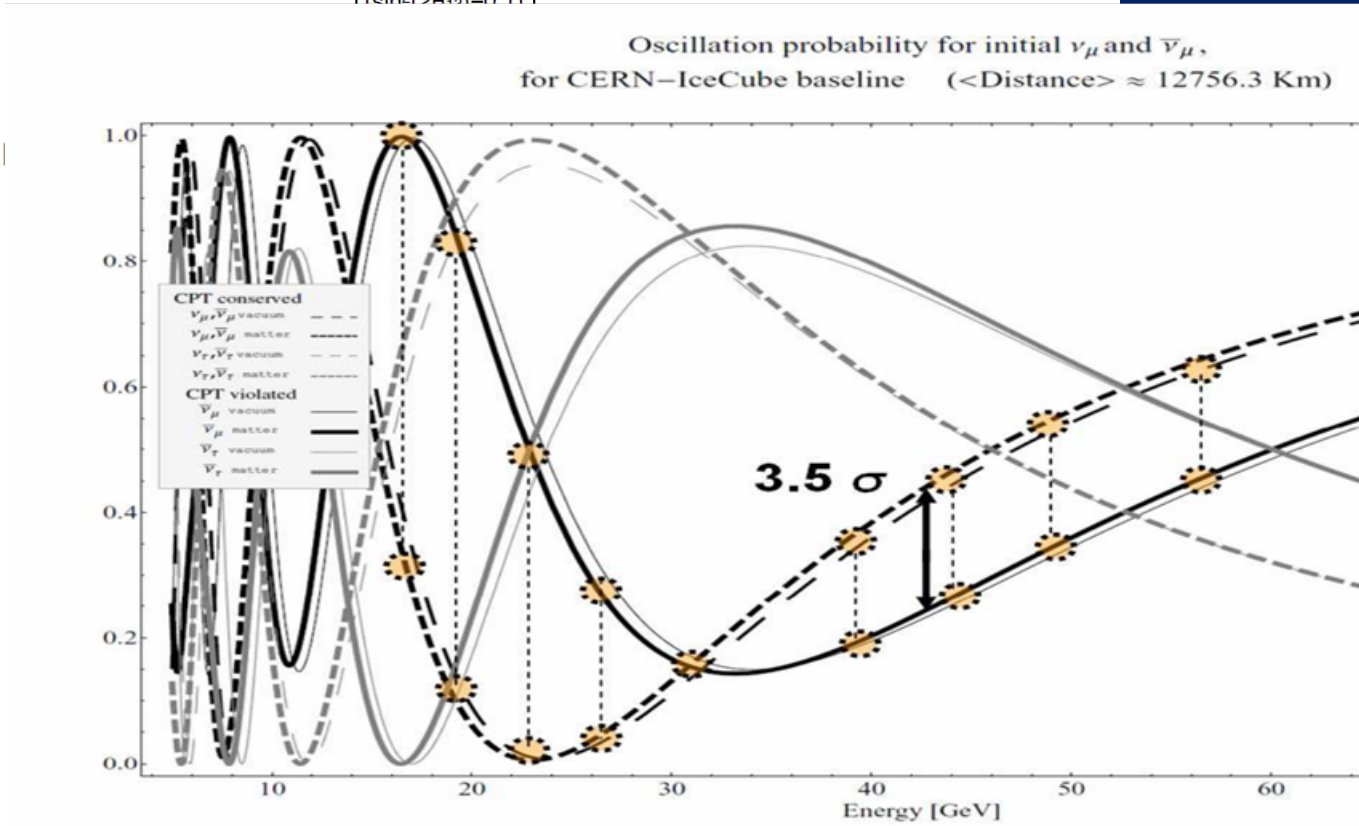
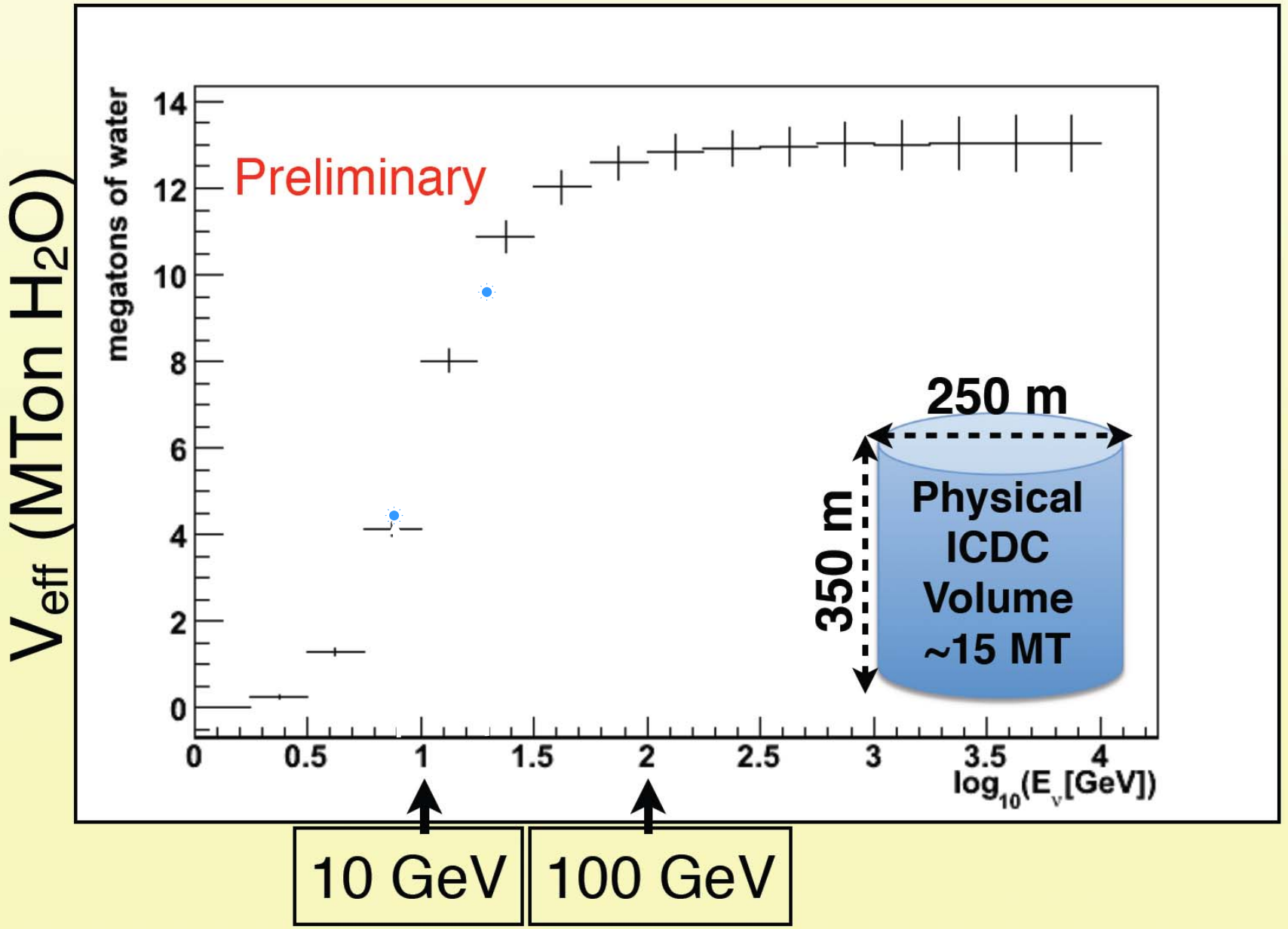
ν hierarchy
($\sin^2(2\theta_{13})$=0.1)

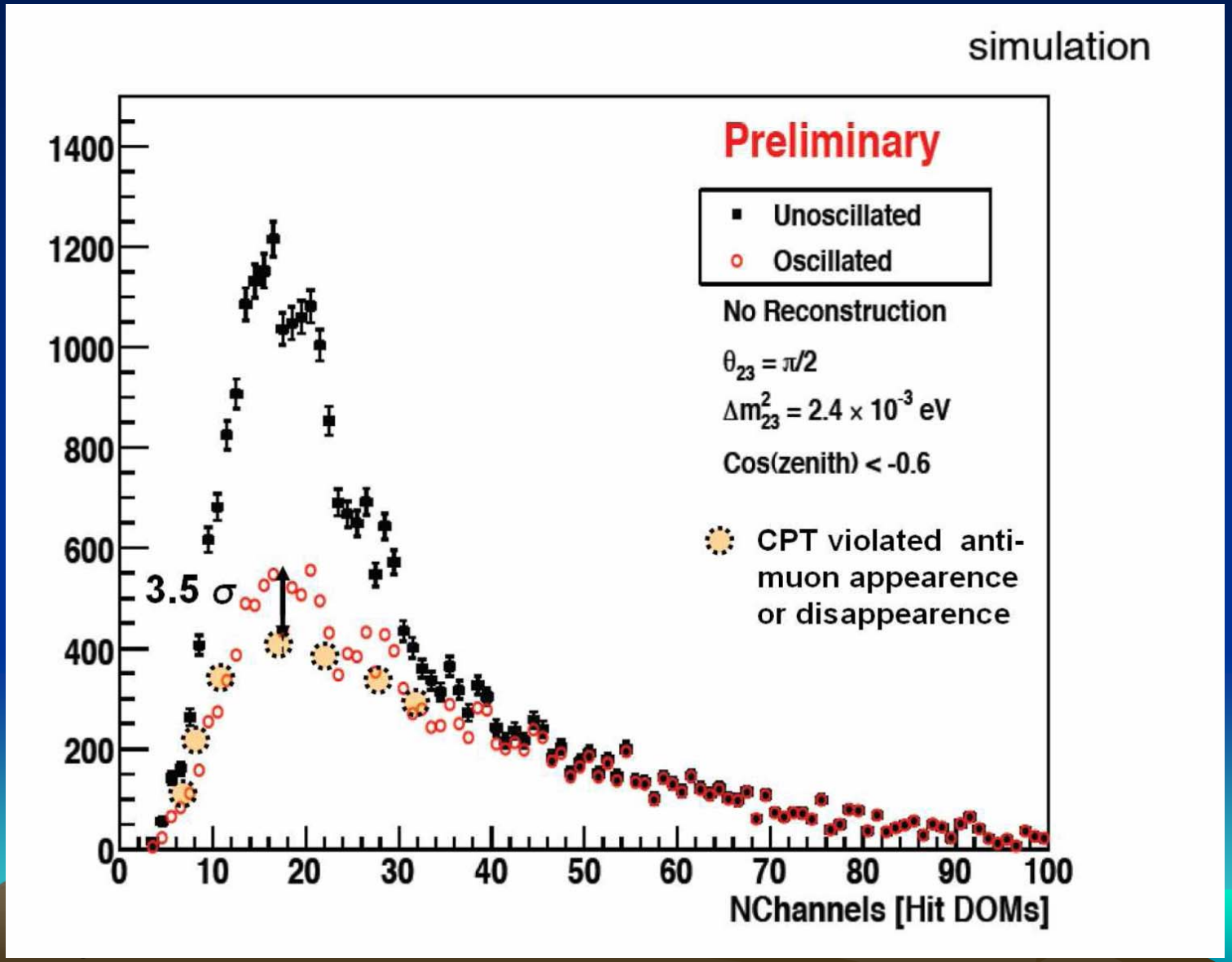


for vertically up-going neutrinos

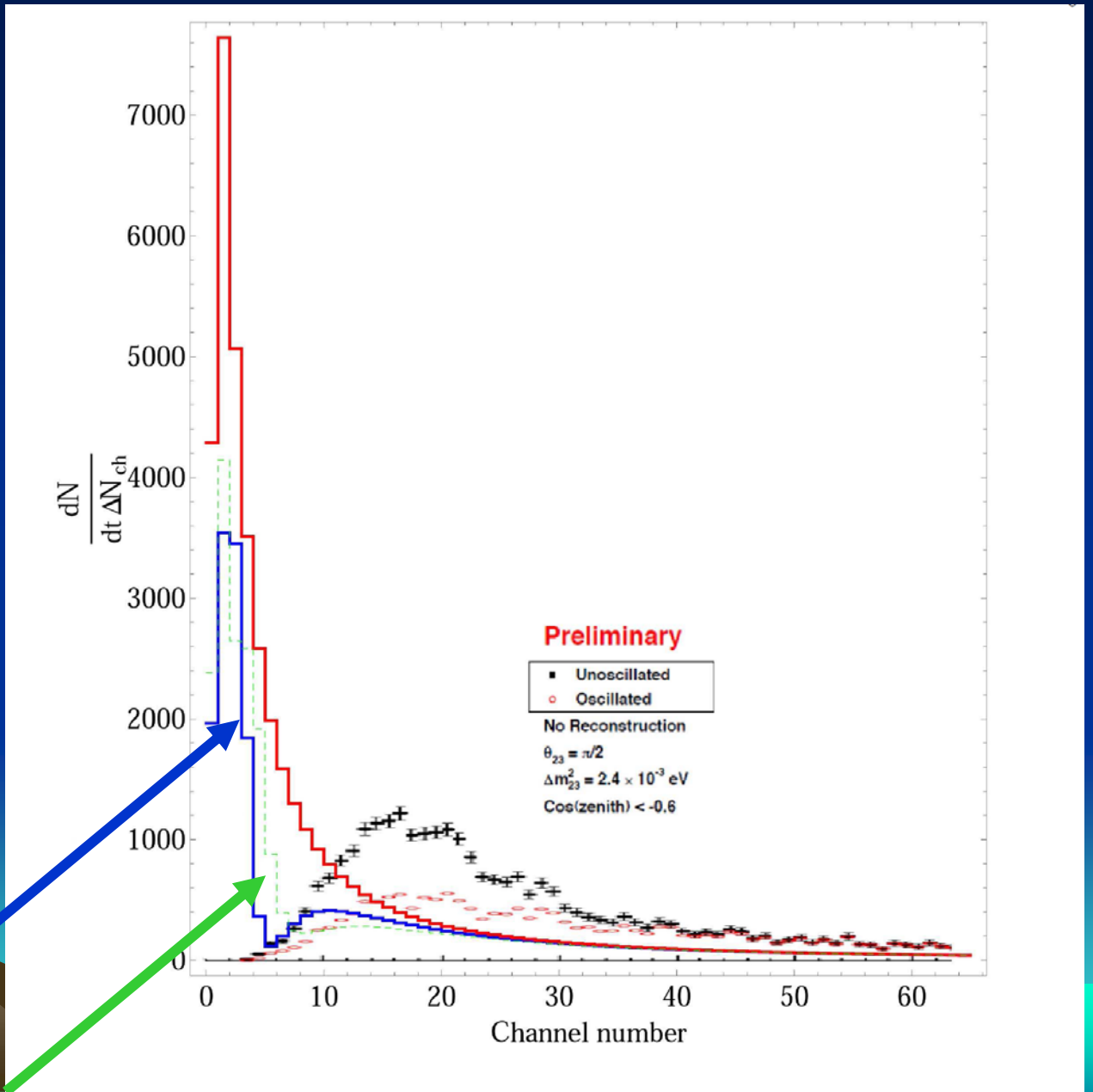
baseline = Earth's diameter


V_{eff} (MTon H_2O)
megatons of water
Preliminary
250 m
350 m
Physical
ICDC
Volume
~15 MT
$\log_{10}(E_\nu$[GeV])
10 GeV
100 GeV

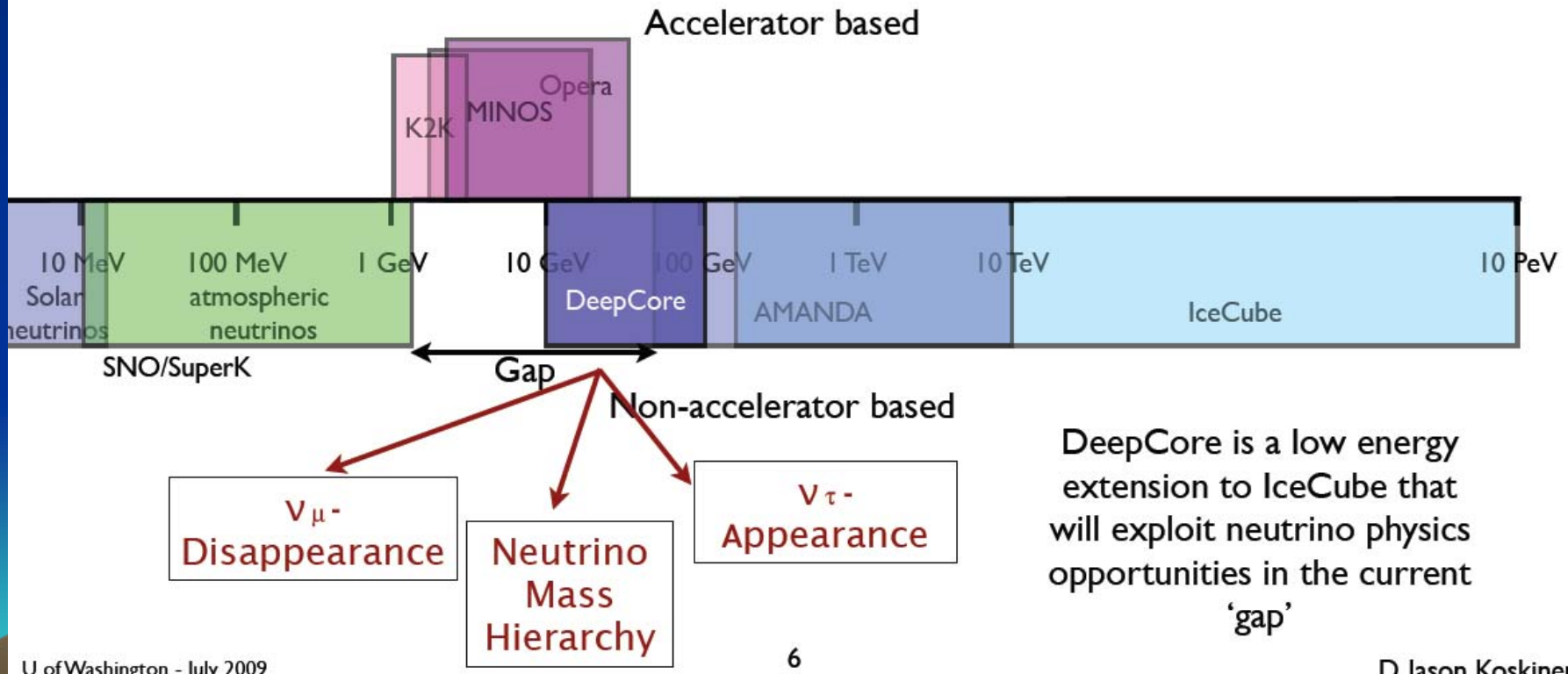
A First use of Deep Core simulation for atmospheric neutrino rate signals in Deep Core



Our recent simulation on atmospheric muon neutrino based on SK data..different **arXiv:1103.2642: Foreseeing Neutrino spectra in Deep Core**

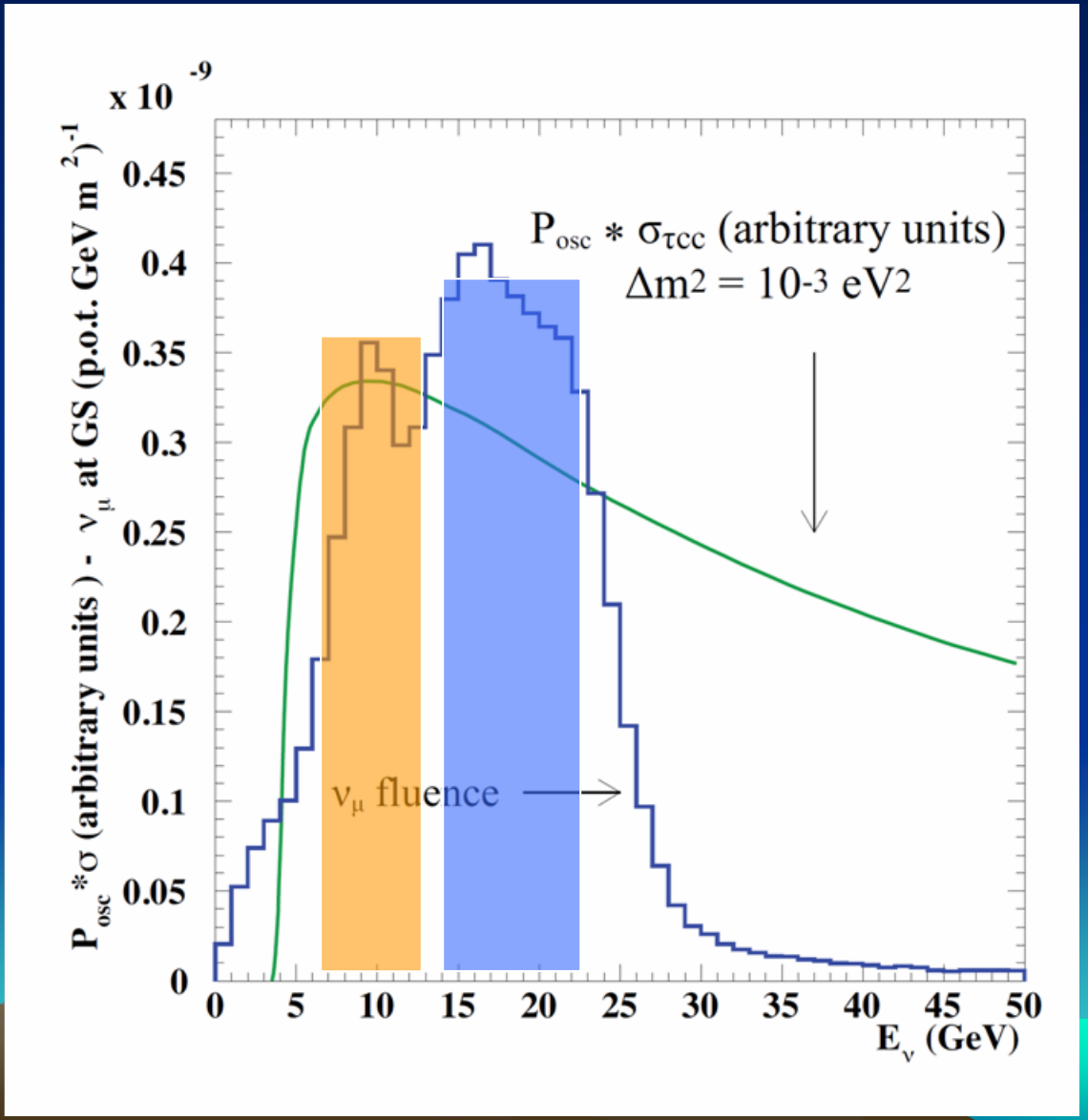


The Energy Gap in neutrino physics...



BEAMING FROM CERN TO OPERA

Journal of Physics: Conference Series **203** (2010) 012013



Atmospheric Neutrino in Deep Core with mixing and flavors

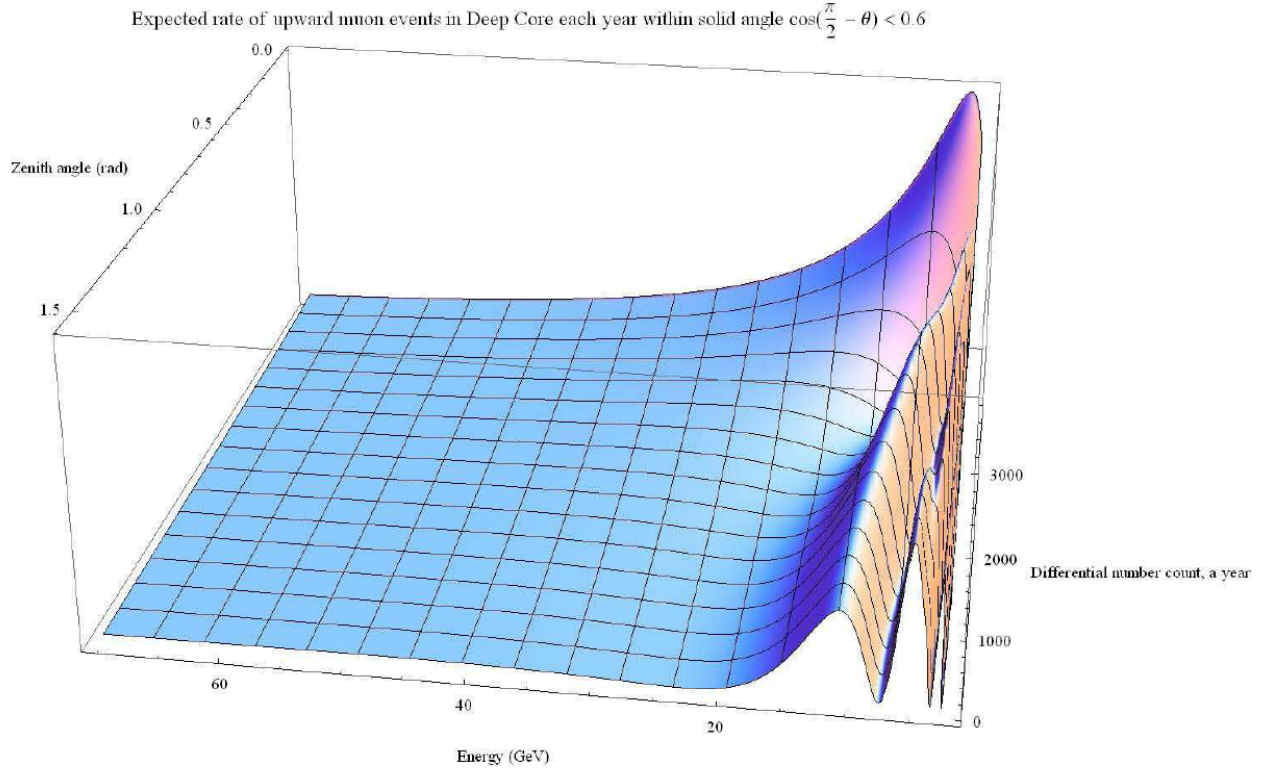
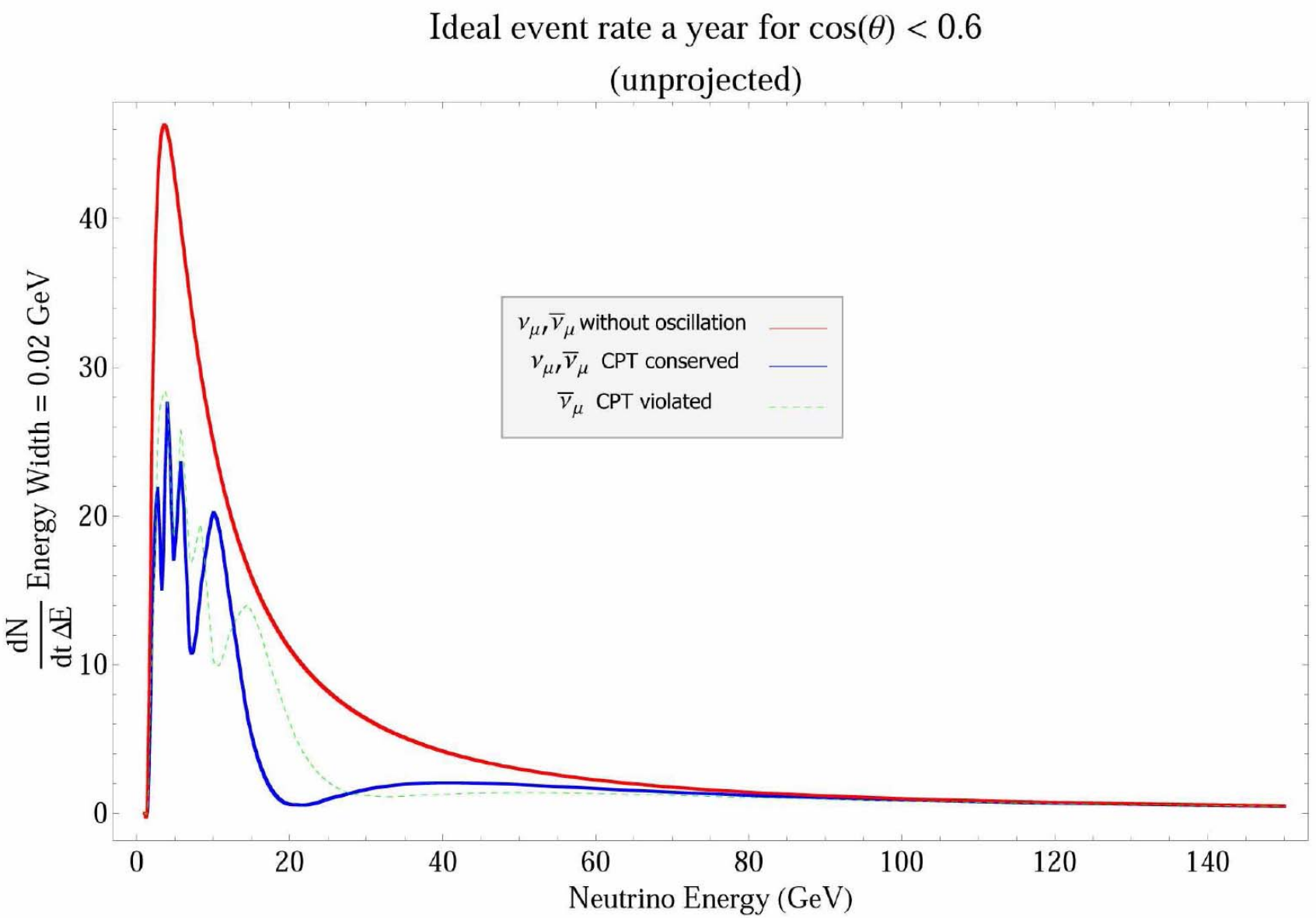


Figure 2. As above the differential number event count a year in Deep Core as a function of the muon neutrino energy and angle, observable in wide scale (top, 3–65 GeV) assuming an average Earth density $\rho = 7$ during up-going neutrino flight within Earth.The horizontal axis is the energy in GeV, the vertical one is the event rate a year in Deep Core, the depth axis is the zenith angle variable in radiant. Most of the inner oscillating structure is lost because of the Deep Core un-ability to reveal a few GeVs muon track. The last longest flux suppression at 20 GeV survive and is source of a spectra deepening in Channel 6–9


Ideal event rate a year for cos(θ) < 0.6
(unprojected)
$\frac{dN}{dt\,\Delta E}$ Energy Width = 0.02 GeV
Neutrino Energy (GeV)
$\nu_\mu, \overline{\nu}_\mu$ without oscillation
$\nu_\mu, \overline{\nu}_\mu$ CPT conserved
$\overline{\nu}_\mu$ CPT violated
0
10
20
30
40
0
20
40
60
80
100
120
140

Mixing in Matter MSW

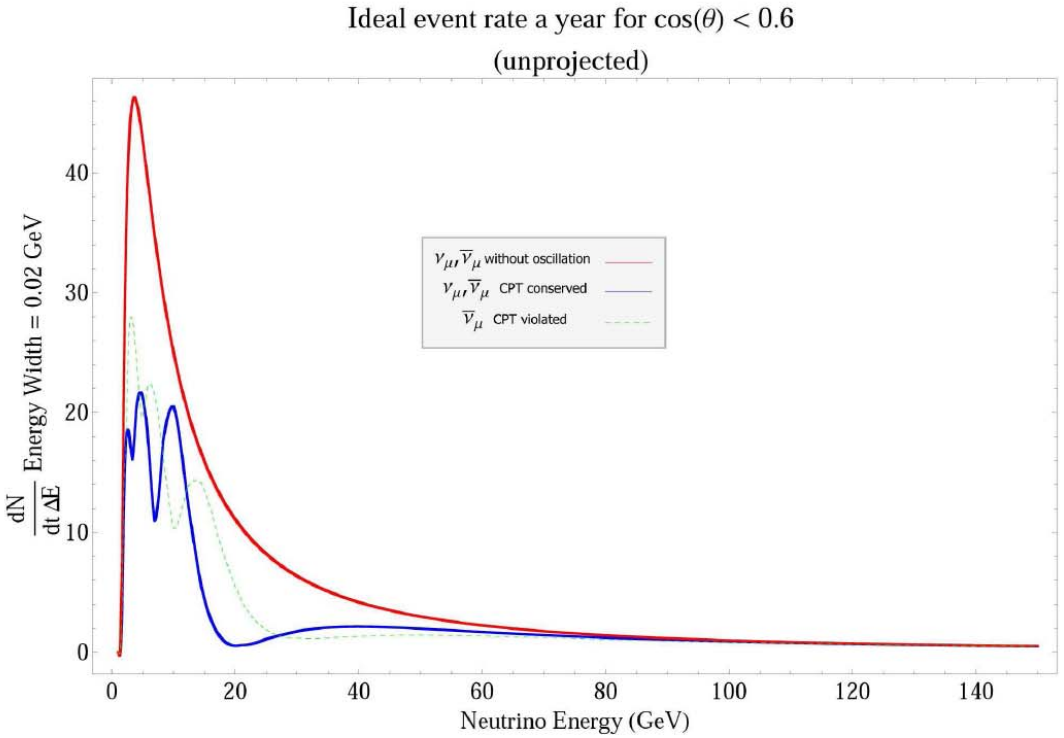
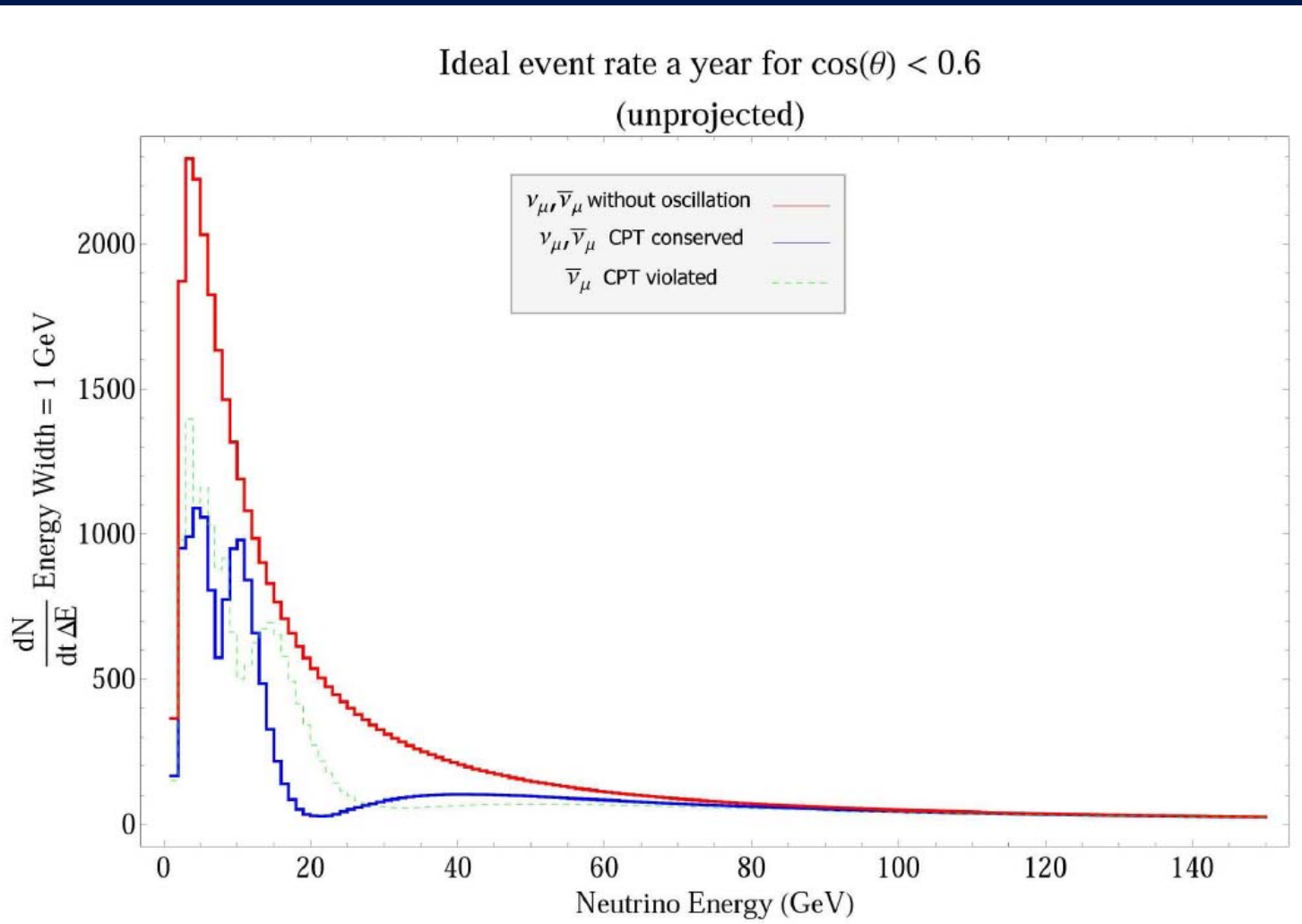
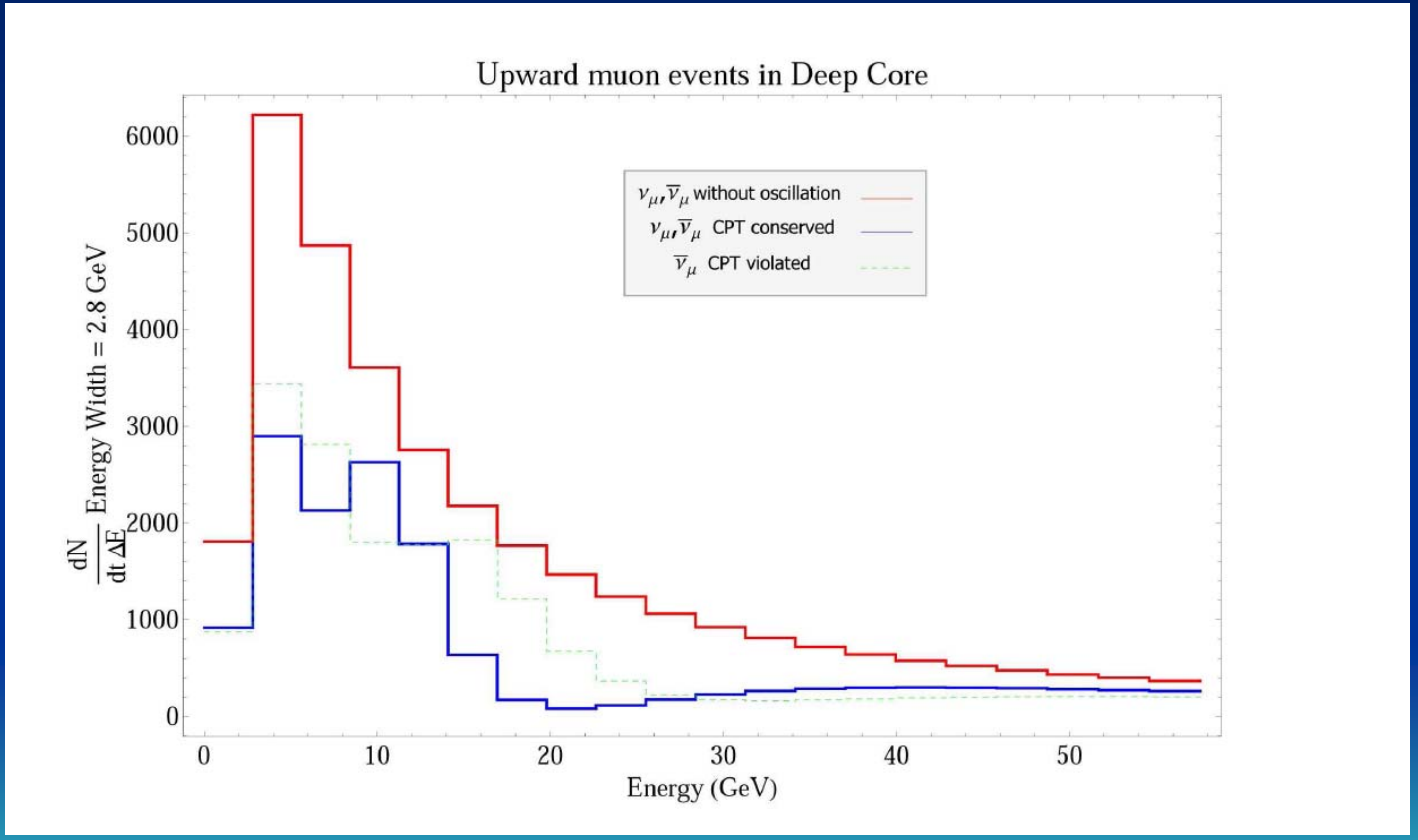


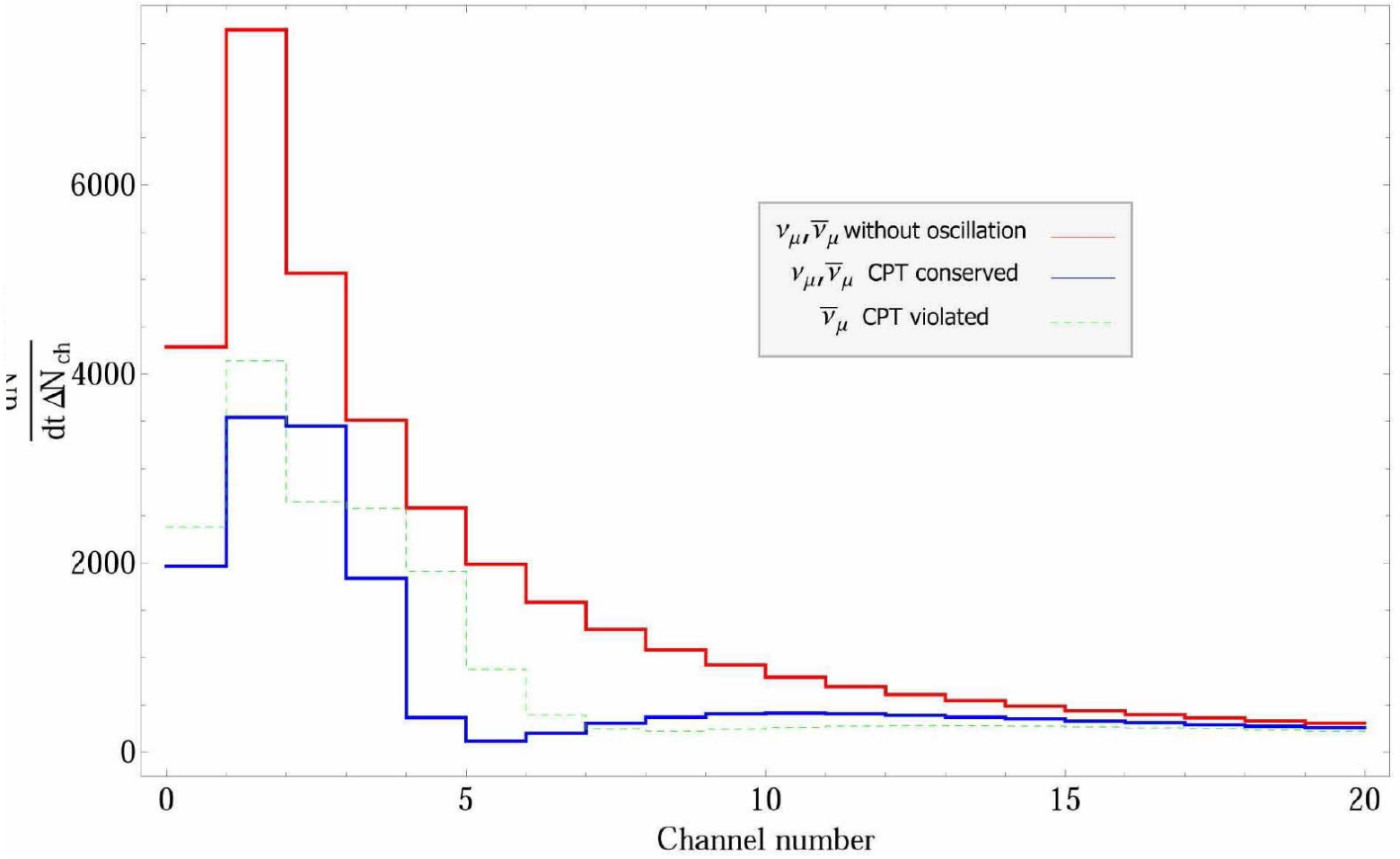
Figure 4. As previous figure, where neutrino mixing occurs in matter. Note the little difference in spectra at the very low energies.


Ideal event rate a year for cos(θ) < 0.6
(unprojected)
$\nu_\mu, \overline{\nu}_\mu$ without oscillation
$\nu_\mu, \overline{\nu}_\mu$ CPT conserved
$\overline{\nu}_\mu$ CPT violated
$\frac{dN}{dt\,\Delta E}$ Energy Width = 1 GeV
2000
1500
1000
500
0
0
20
40
60
80
100
120
140
Neutrino Energy (GeV)

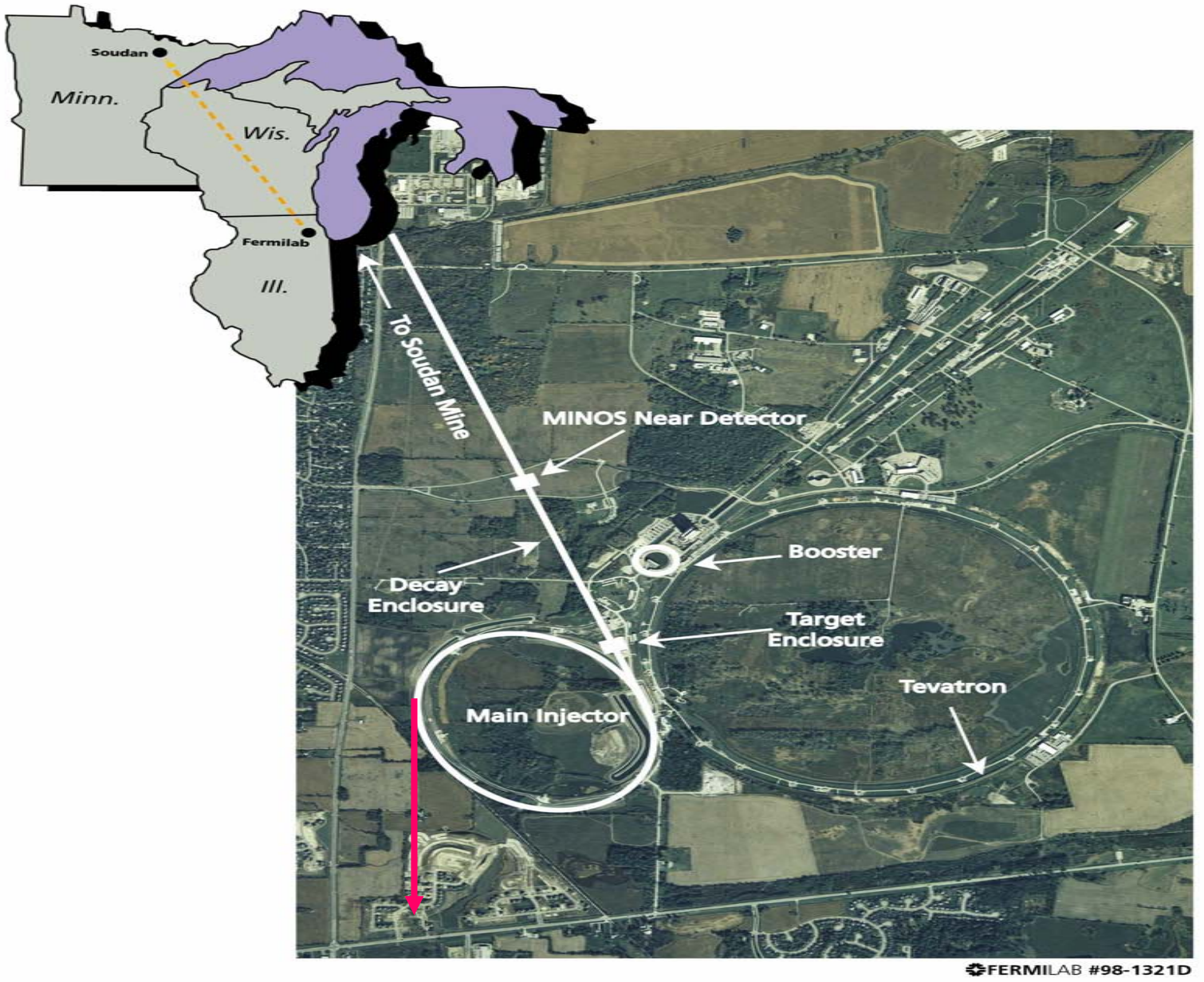
unprojected



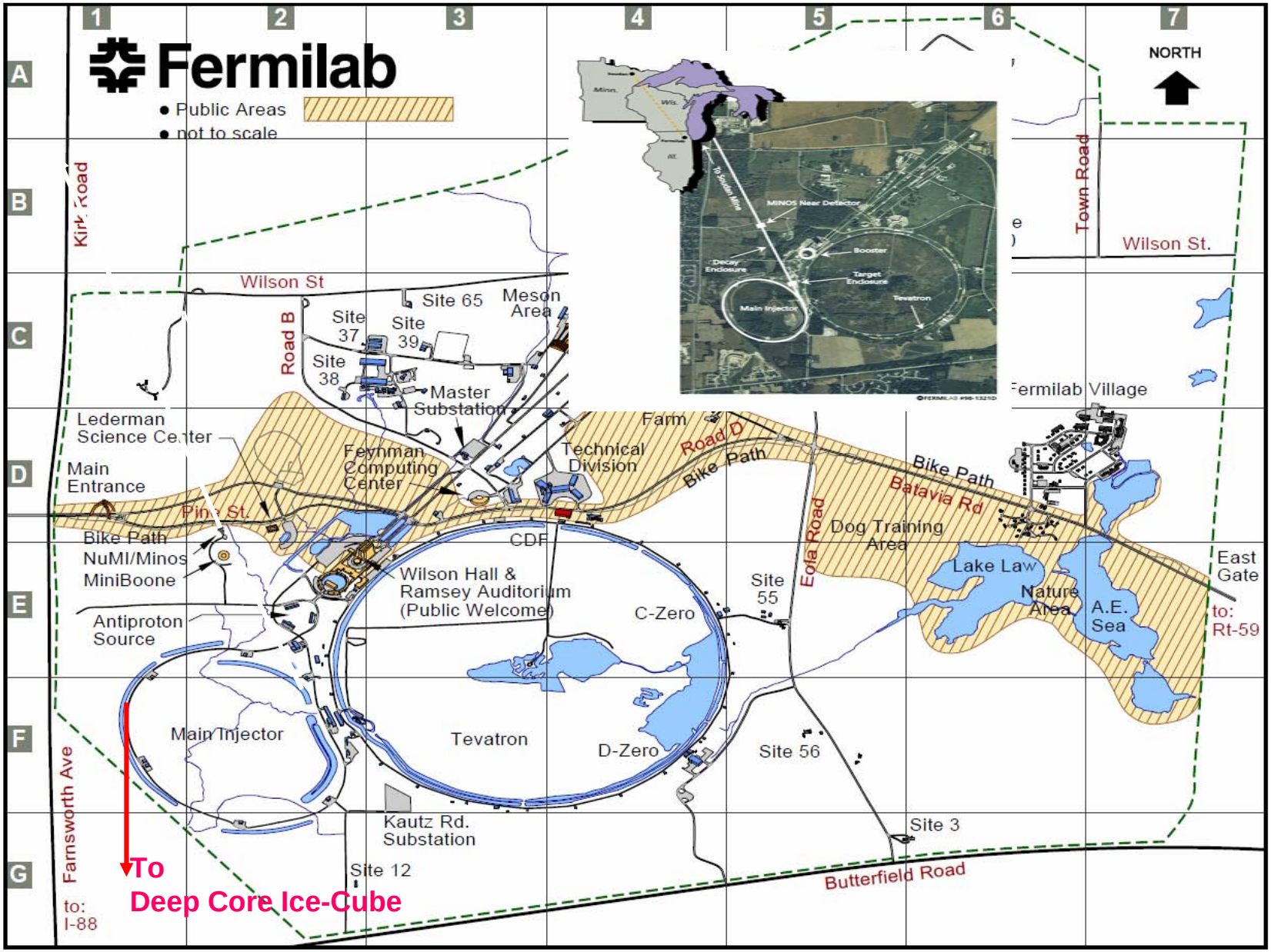
(projecting on average on vertical axis)



FNAL Minos to Icecube



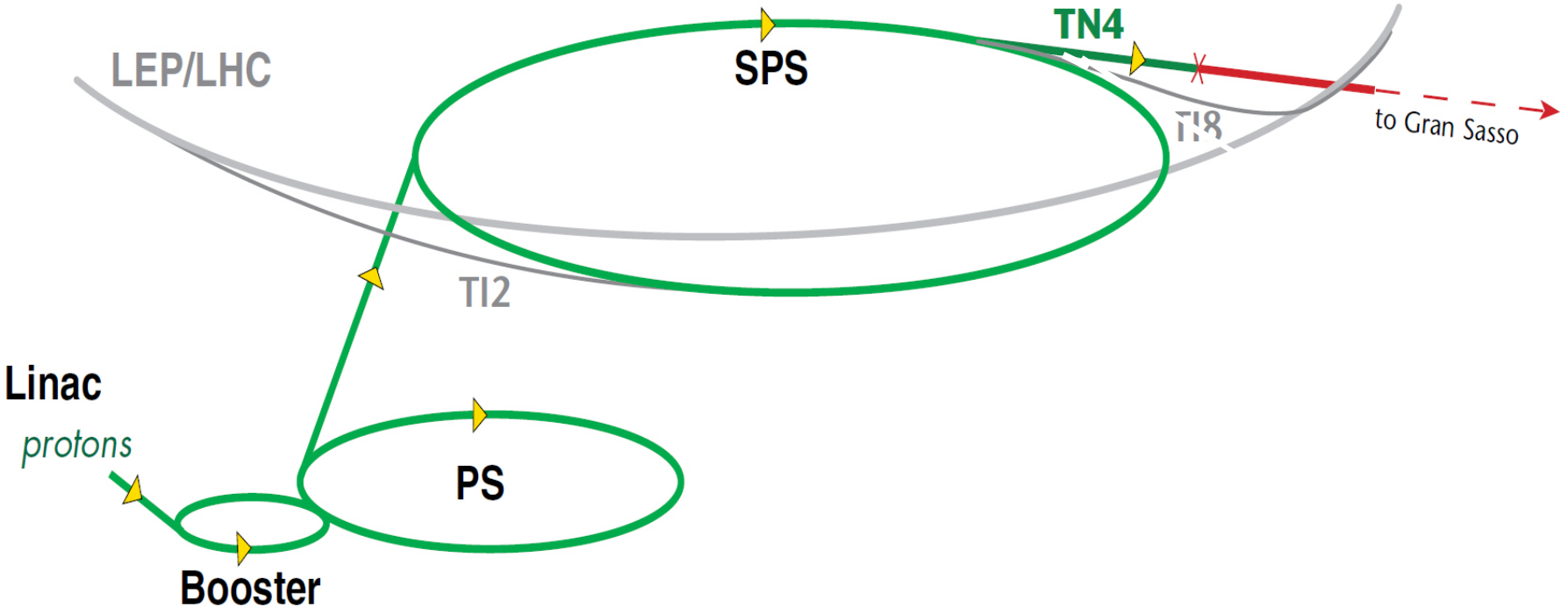
Fermi Lab Minos Soudan



maps

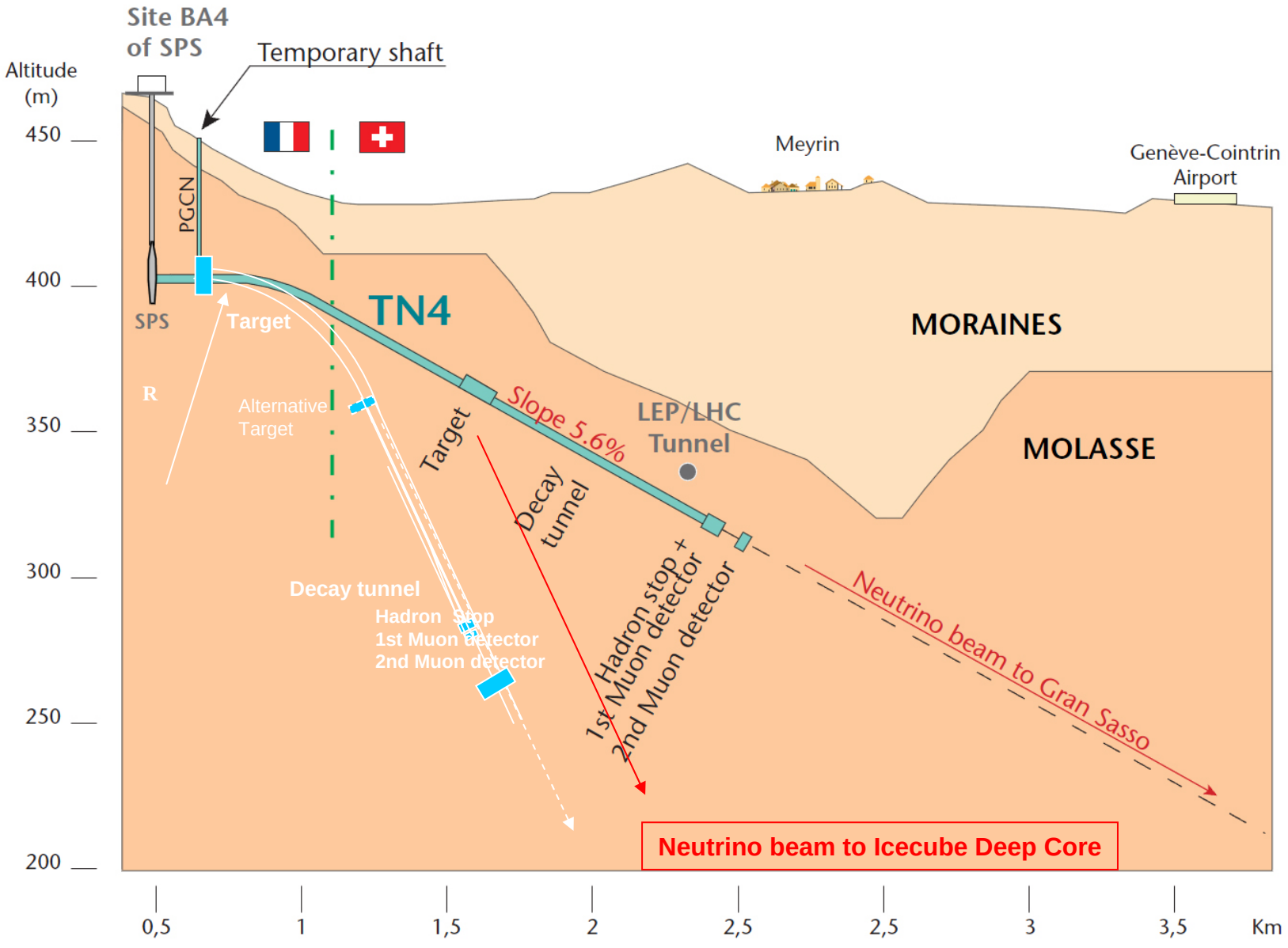

N
Prévessin-Moëns
SPS/BA4
/ECA4
Temporary shaft PGCN
Access gallery
SPS
Proton beam tunnel (TN4)
Decay tunnel
LEP/LHC
TI8
Target
Decay tunnel
To Gran Sasso
To ICE-CUBE
Connection gallery LEP/LHC
Hadron stop and 1st muon detector
2nd muon detector
Meyrin

Geometry cern icecube



PS : Proton Synchrotron
SPS : Super Proton Synchrotron
LHC : Large Hadron Collider

Cern---IceCube --- Tunnel :92m depth: 85m

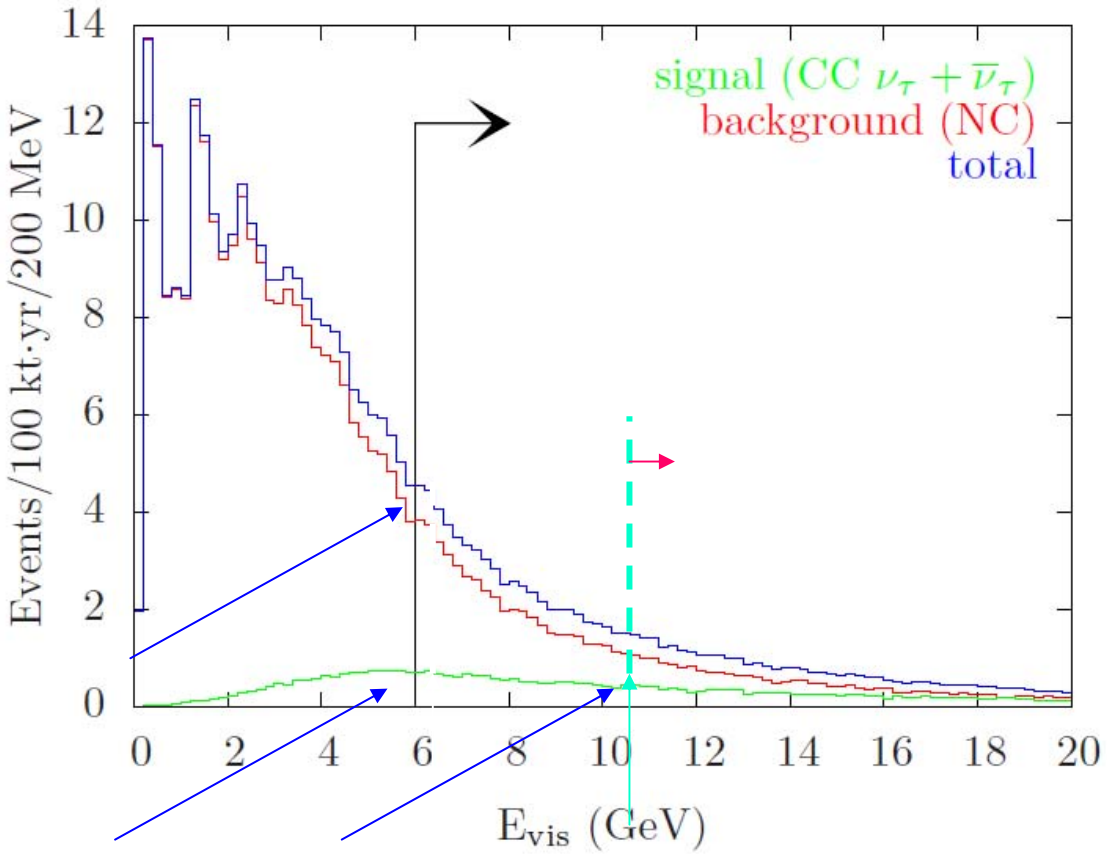


Tau and Muon mixing along the Earth: Atmospheric Neutrinos

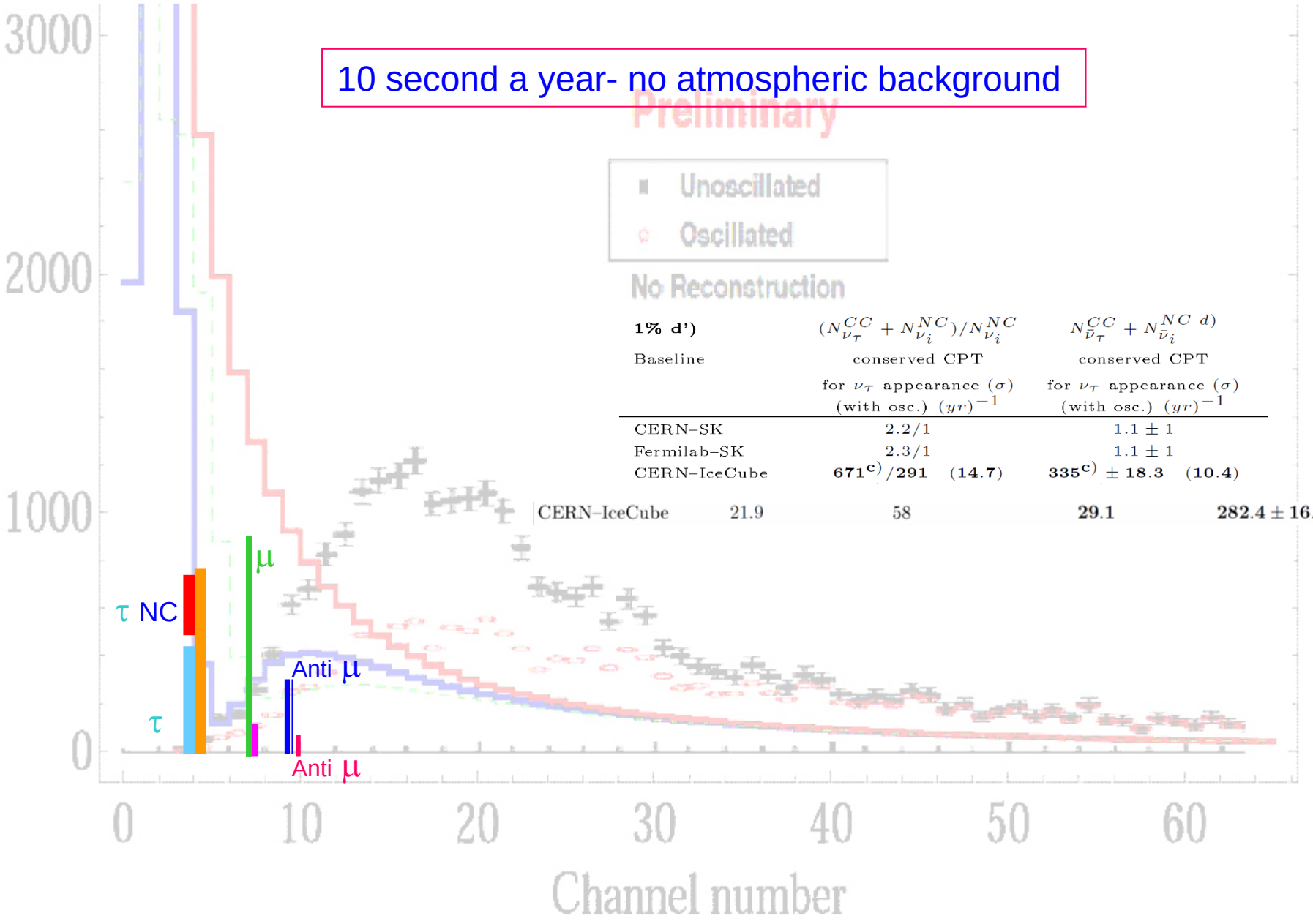
NUHEP-TH/10-11

Atmospheric Tau Neutrinos in a Multi-kiloton Liquid Argon Detector

Janet Conrad,[1] André de Gouvêa,[2] Shashank Shalgar,[2] and Joshua Spitz[3]
[1]*Massachusetts Institute of Technology, Cambridge, MA 02139, USA*
[2]*Department of Physics & Astronomy, Northwestern University, IL 60208-3112, USA*
[3]*Department of Physics, Yale University, New Haven, CT 06520, USA*
(Dated: August 25, 2010)



10 second a year- no atmospheric background



1% d')	$(N^{CC}_{\nu_\tau} + N^{NC}_{\nu_i})/N^{NC}_{\nu_i}$	$N^{CC}_{\bar{\nu}_\tau} + N^{NC\ d)}_{\bar{\nu}_i}$
Baseline	conserved CPT	conserved CPT
	for ν_τ appearance (σ) (with osc.) $(yr)^{-1}$	for ν_τ appearance (σ) (with osc.) $(yr)^{-1}$
CERN–SK	2.2/1	1.1 ± 1
Fermilab–SK	2.3/1	1.1 ± 1
CERN–IceCube	**671**[c)]**/291** **(14.7)**	**335**[c)] **± 18.3** **(10.4)**

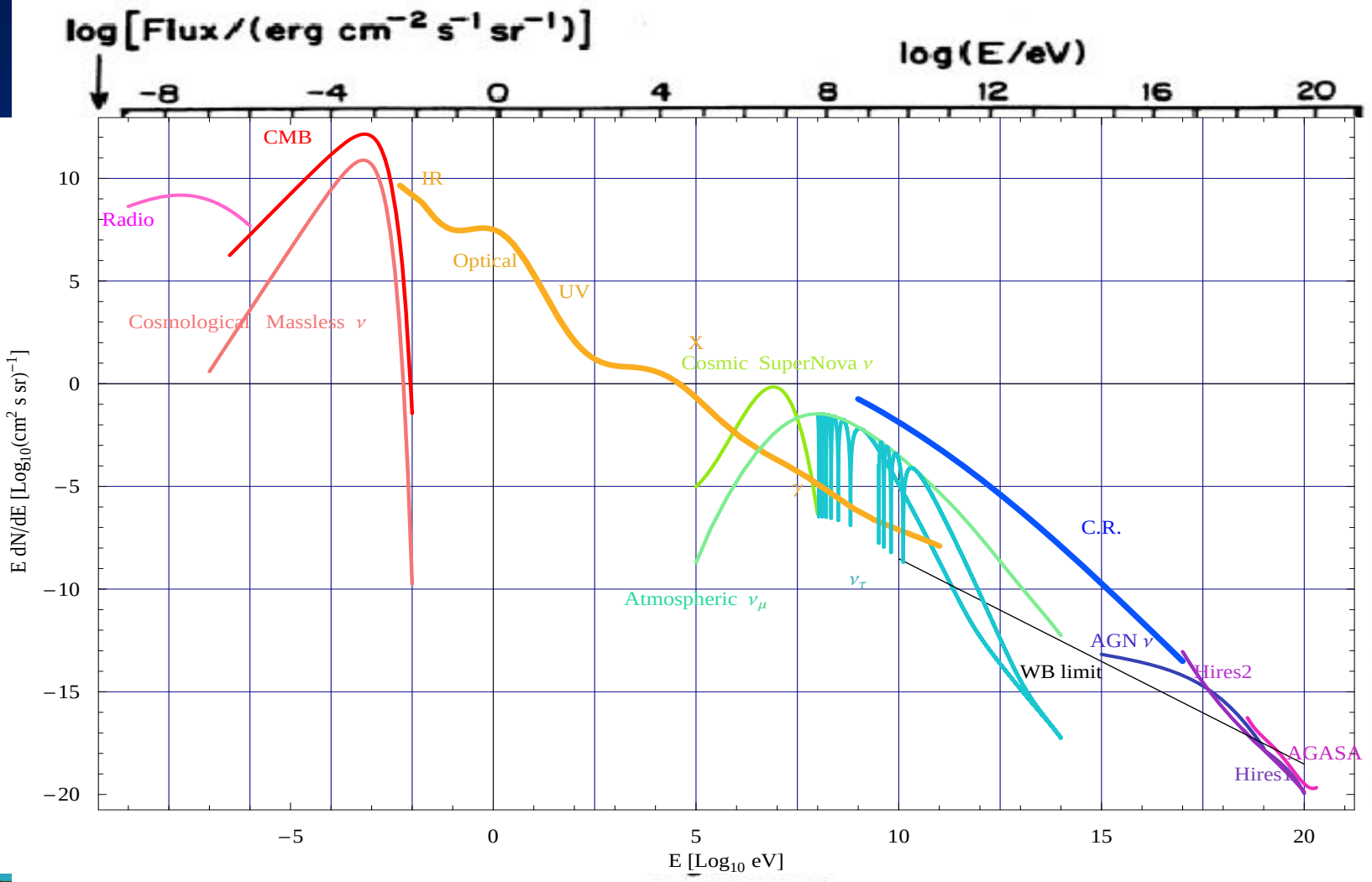
CERN–IceCube	21.9	58	**29.1**	**282.4 ± 16.8**

Conclusions for 1% Opera like beaming Cern or FNL to Icecube

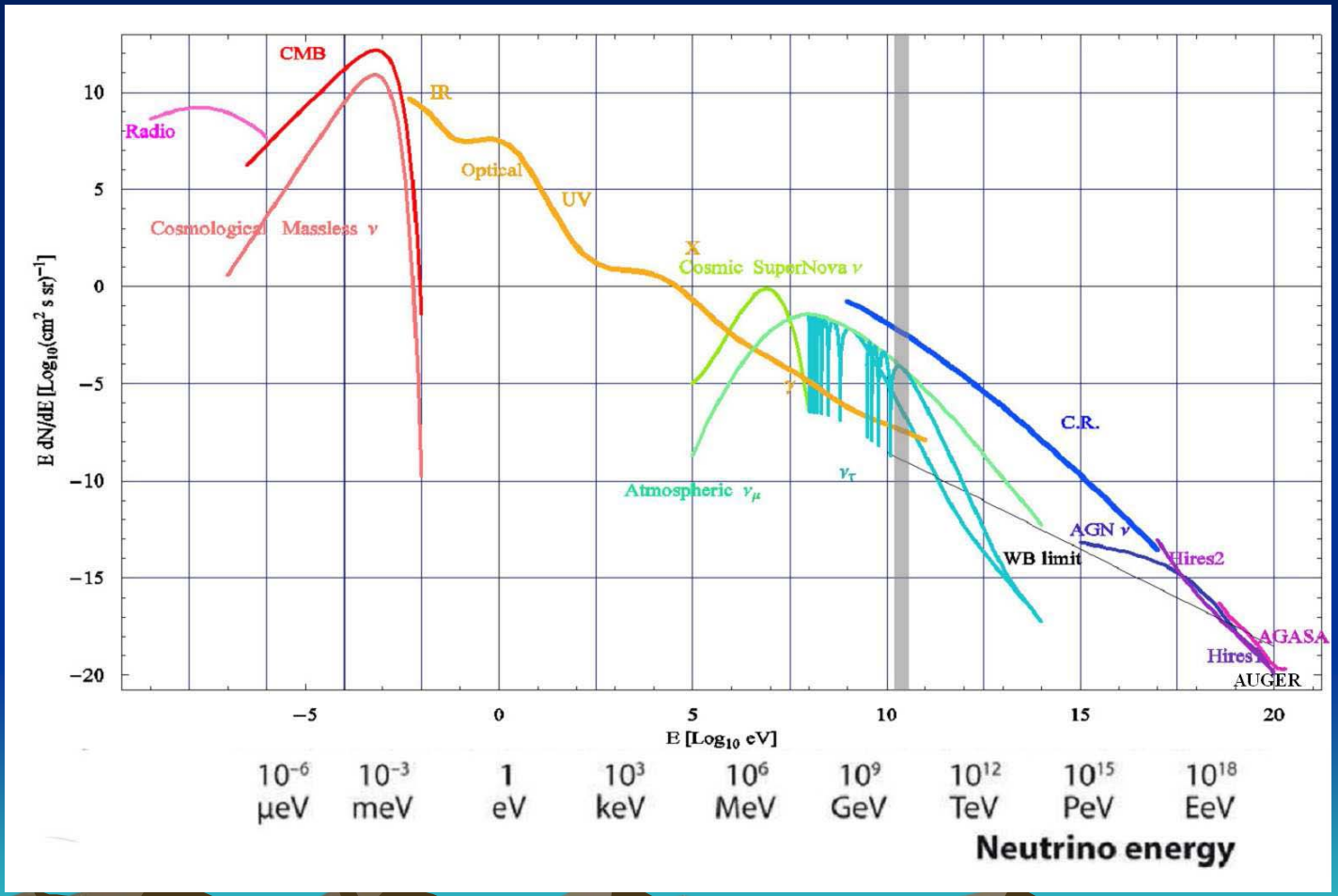
- As shown in tables 6, 7, 8, we expect for CERN - IceCube-DeepCore scenario, even at 1% of Opera efficiency, a rate of 671 tau like events (291 noise + 380 signal) a year, offering 14 sigma in one year of

  experiment for tau neutrino appearance.
- On the other side the beaming of anti muon primary (as shown in tables 6,7,8) are leading to make very different signals: 337 conserved versus 243 violated anti-tau scenario, with 145 neutral current noise events, offering a 5 sigma test of CPT
- At the same time we will observe in the same detector positive (anti) muons either in suppressed oscillations, or enhanced for the the CPT violating mixing parameters: 29 events (CPT conserved) versus 282 (CPT violated), leading toat least 15 *sigma* signicance to test of CPT

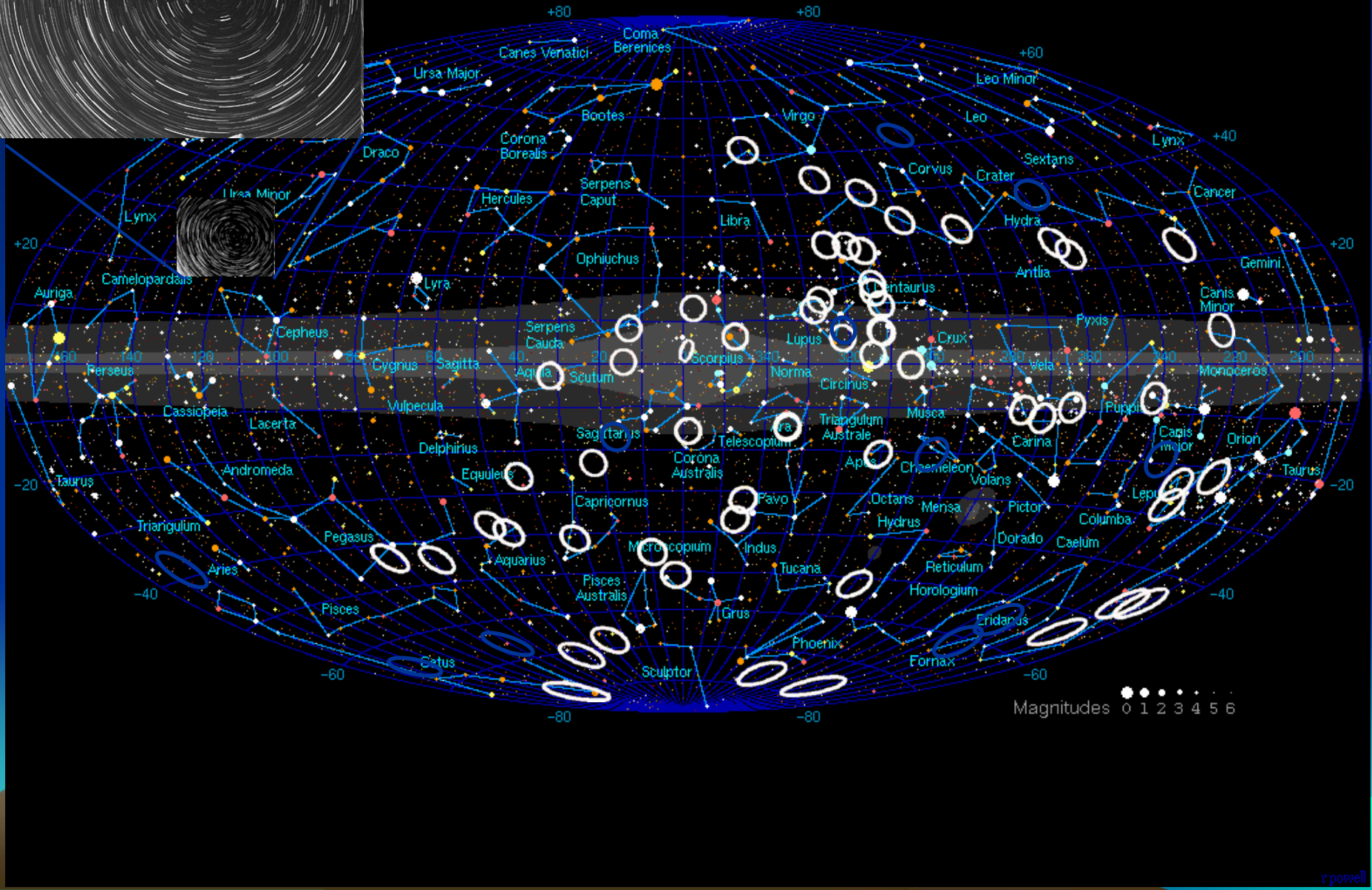
Flux Number


log [Flux / (erg cm^{-2} s^{-1} sr^{-1})]
log (E/eV)
-8
-4
0
4
8
12
16
20
CMB
IR
Radio
Optical
UV
Cosmological Massless ν
X
Cosmic SuperNova ν
γ
C.R.
ν_τ
Atmospheric ν_μ
AGN ν
WB limit
Hires2
AGASA
Hires1
E dN/dE [Log$_{10}$(cm^2 s sr)$^{-1}$]
10
5
0
−5
−10
−15
−20
−5
0
5
10
15
20
E [Log$_{10}$ eV]

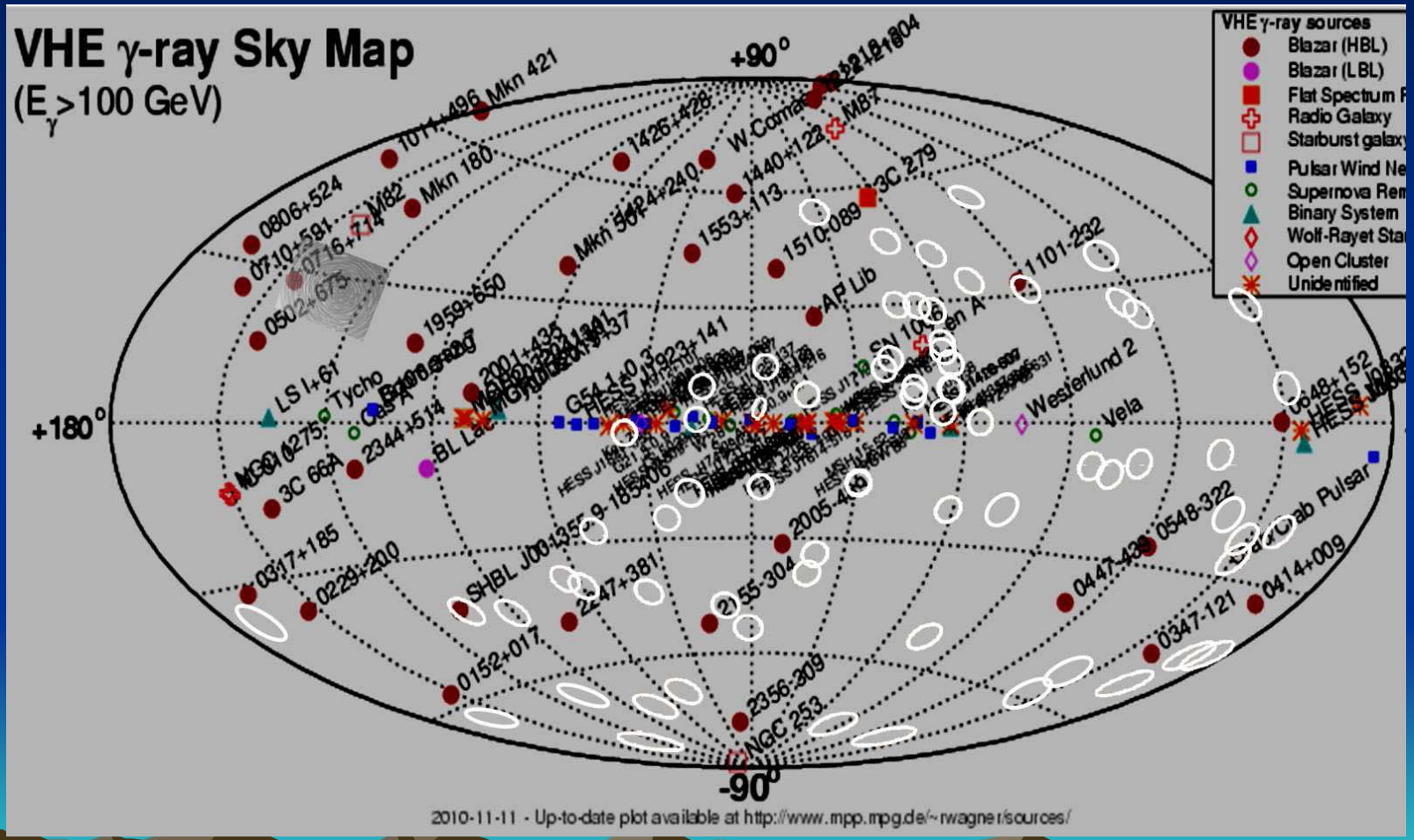
A new energy windows

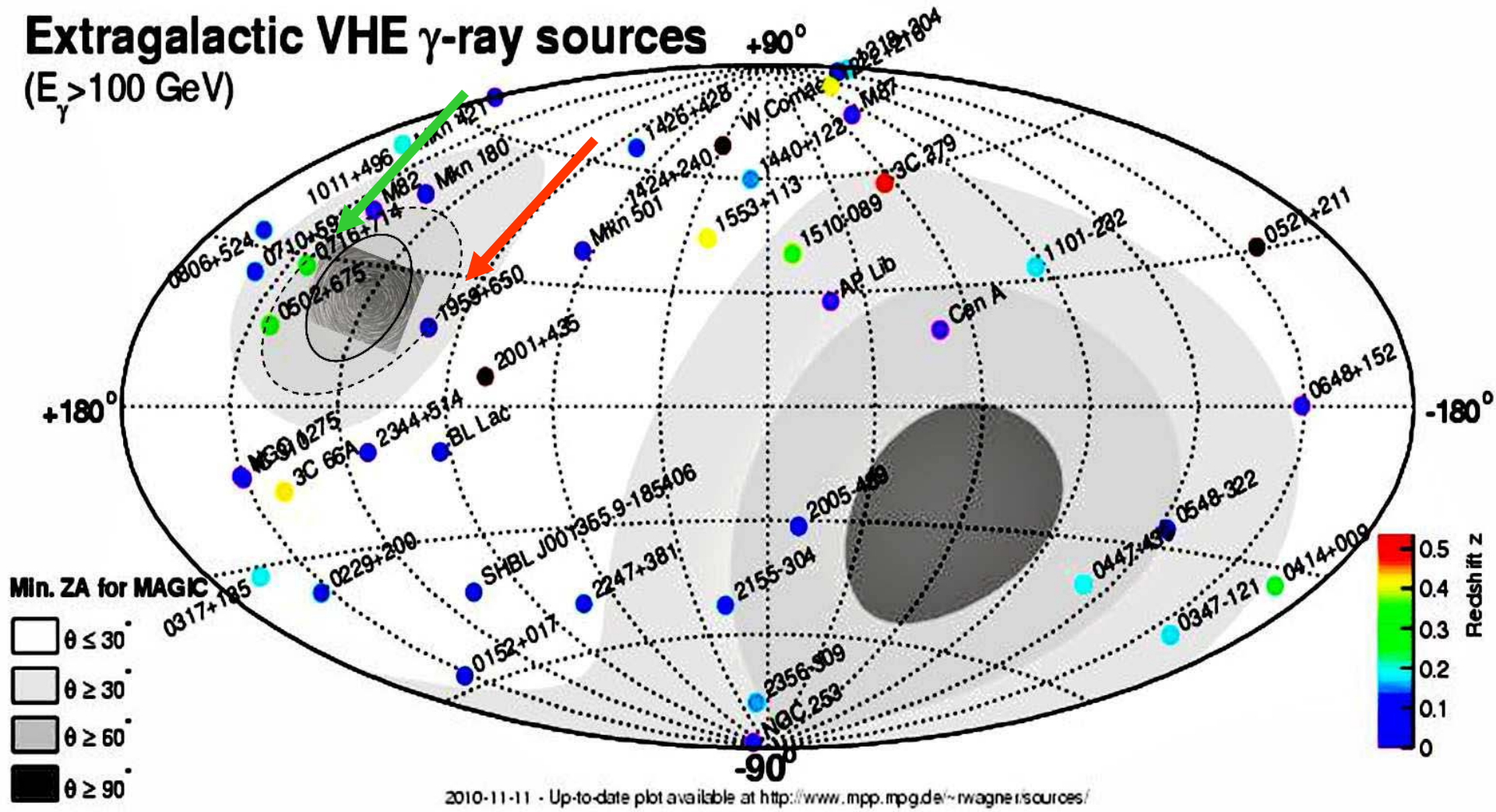


versus 69 UHECR



Where to look in




Extragalactic VHE γ-ray sources
(E_γ>100 GeV)
+90°
+180°
-180°
-90°
1011+496
Mrk 421
M82
Mkn 180
1426+428
W Comae
M87
1440+122
3C 279
1424+240
Mkn 501
1553+113
1510-089
0806+524
0710+59
0716+714
0502+675
1959+650
2001+435
AP Lib
Cen A
1101-232
0521+211
0648+152
2344+514
BL Lac
3C 66A
1ES 0229+200
SHBL J001355.9-185406
2005-489
0548-322
2247+381
2155-304
0447-439
0414+009
0347-121
0152+017
2356-309
NGC 253
0317+185
Min. ZA for MAGIC
θ ≤ 30°
θ ≥ 30°
θ ≥ 60°
θ ≥ 90°
Redshift z
0.5
0.4
0.3
0.2
0.1
0
2010-11-11 - Up-to-date plot available at http://www.mpp.mpg.de/~rwagner/sources/

Conclusion 2

- **In conclusion let us remind that the whole IceCube contain an order of magnitude more photomultipliers (nine times Deep-Core). They may also play an additional amplify role. Beaming neutrino along the Earth may become a day, a new "faster than light" telegraph able to inform within 0.04 seconds a message across the Earth, three times faster other radio-optical signals. Different application as the economy one may be of interest. Finally it may sound fun or ironic that the most largest experiments on Earth are needed to beam at longest distance, neutrino to largest detector in order to reveal tiniest lepton mass splitting, or the inner CPT secrets. However such an experiment even at 1% of Opera size, seem to us still an attractive and economic solution.**

- Thank you for the attention