In Collaboration with I. Mocioiu and G. Giordano, Penn State U.

Non standard neutrino interactions bounds in "Icecube"

In memory of Jan Wennekers

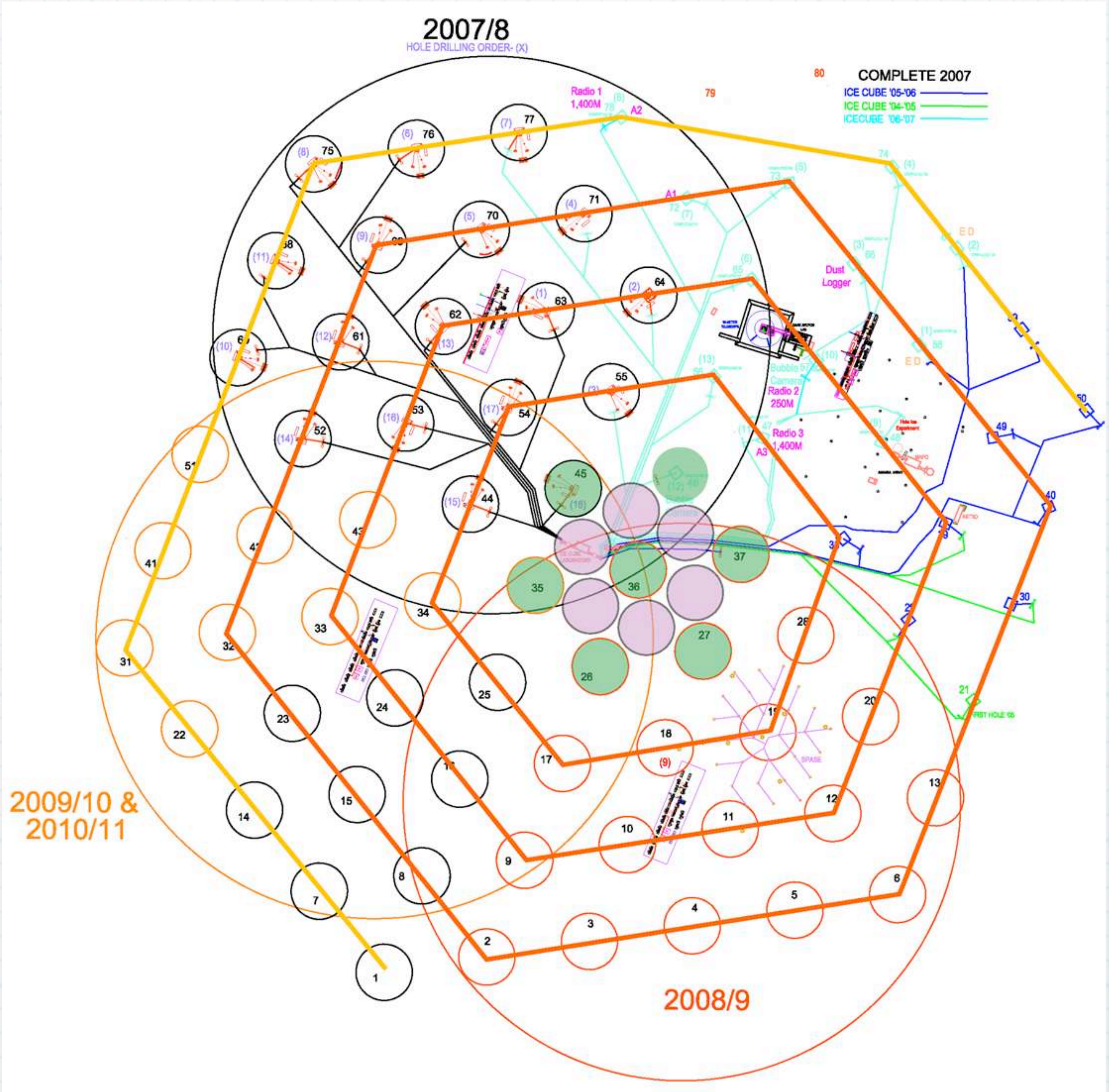
PostDoc at IFIC & Valencia University in the lattice group of Pilar Hernandez, who passed away unexpectedly on December 4th at the age of 31.
All IFIC group will miss him sadly.

Non standard neutrino interactions bounds in

“Icecube”

Low Energy Deep Core Array!

= Denser core in the center of the Icecube array



Low Energy Deep Core Array!

= Denser core in the center of the Icecube array

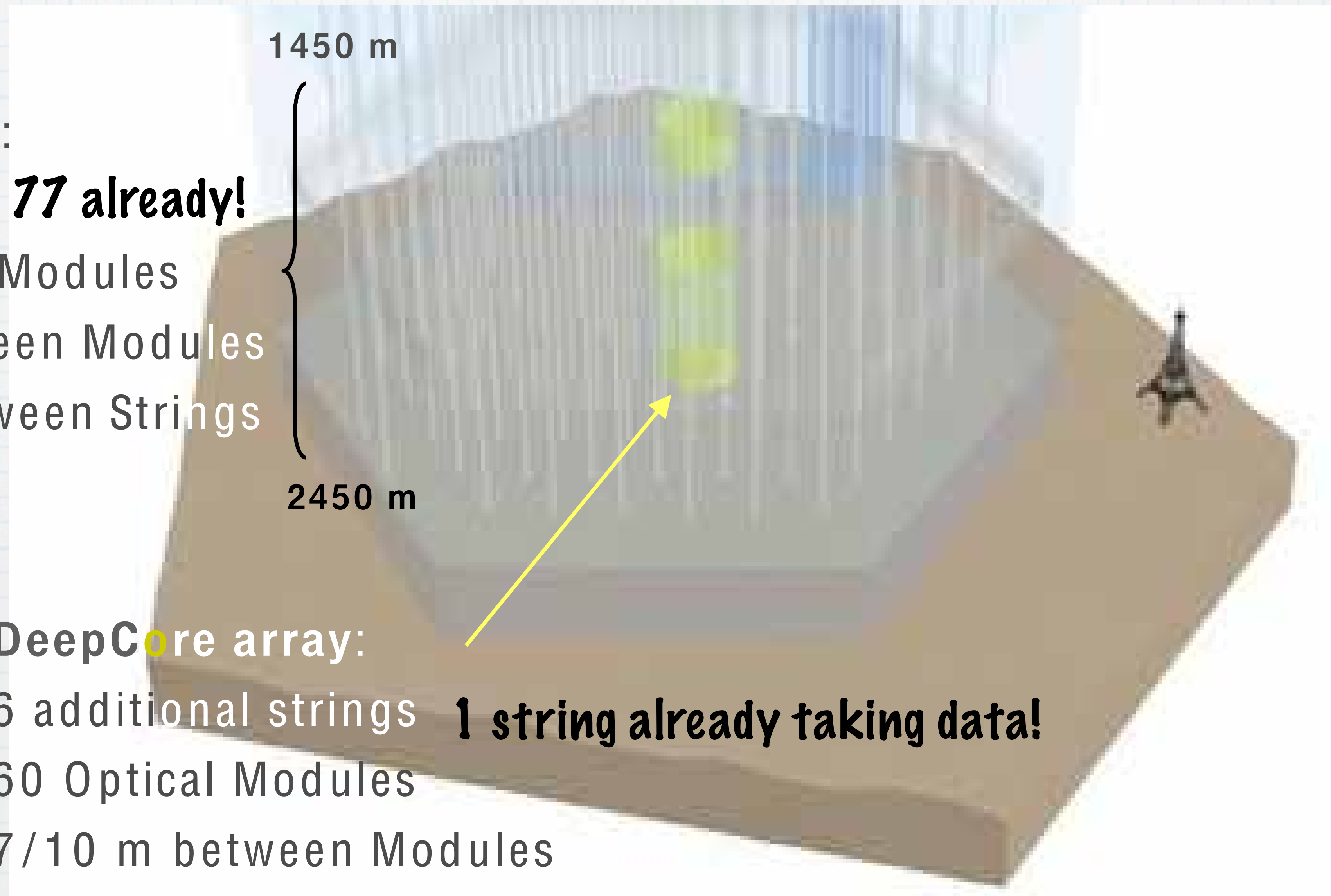
InIce array:

80 Strings **77 already!**

60 Optical Modules

17 m between Modules

125 m between Strings



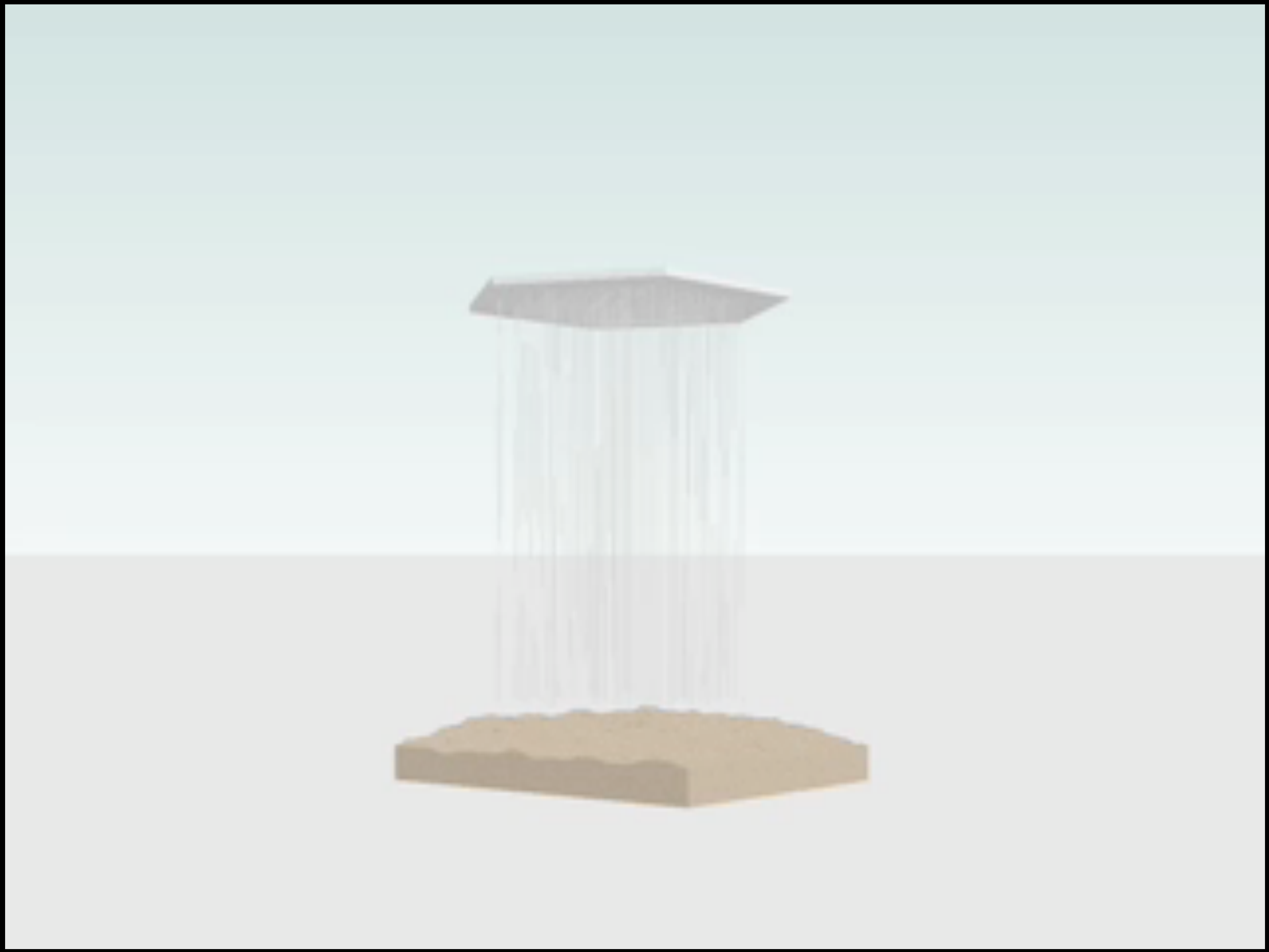
DeepCore array:

6 additional strings **1 string already taking data!**

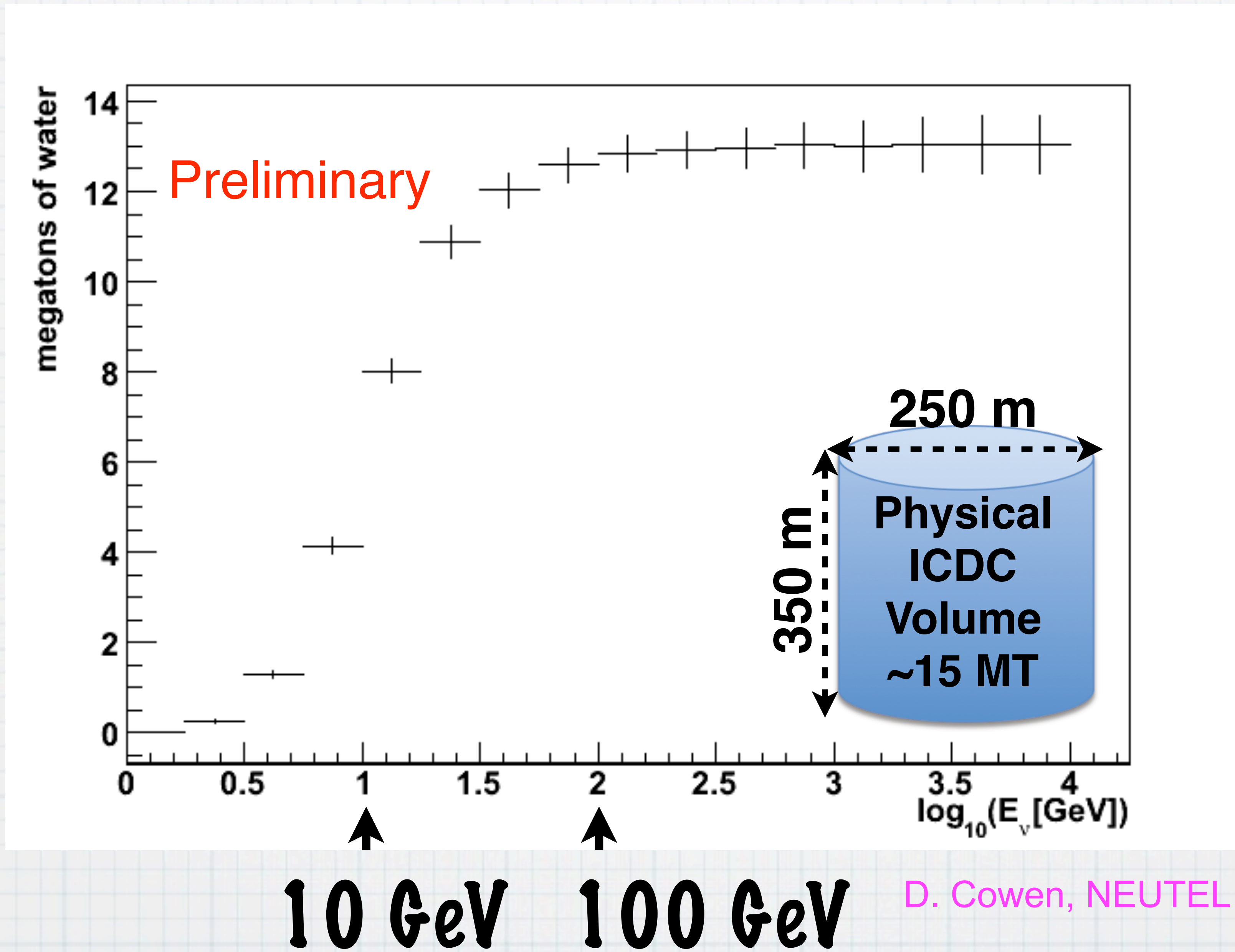
60 Optical Modules

7/10 m between Modules

72 m between Strings



Denser instrumentation= lower energy detection threshold



D. Cowen, NEUTEL 09

ICDC extends Icecube low energy reach by 1 order of magnitude!

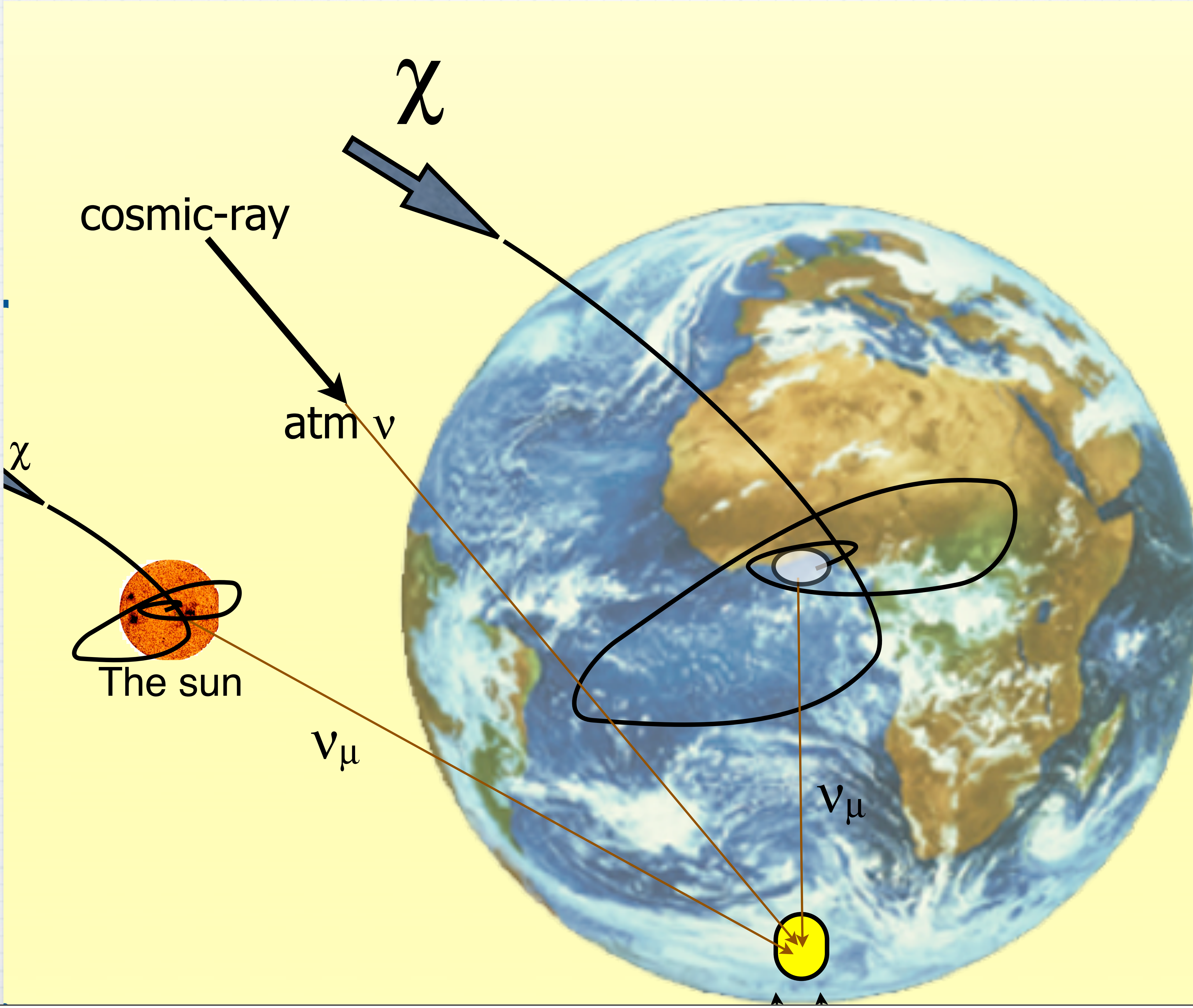
What do THEY want to look for ?

Hot topics!

Neutrinos from: Southern sky neutrino sources (AGNs, GRBs,SNRs)

Dark matter annihilations (Solar and Earth cores, Galactic center)

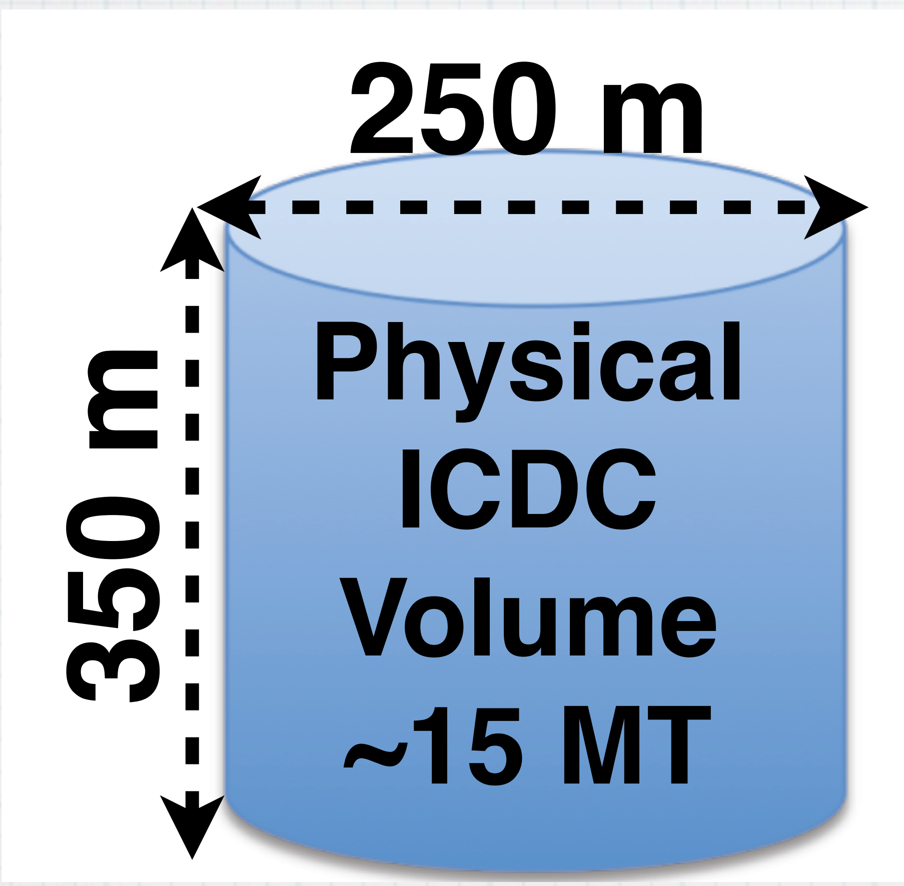
HUGE atmospheric neutrino background!!



What do WE want to look for?

Cool topics!

Their Atmospheric neutrino background is Signal for US!

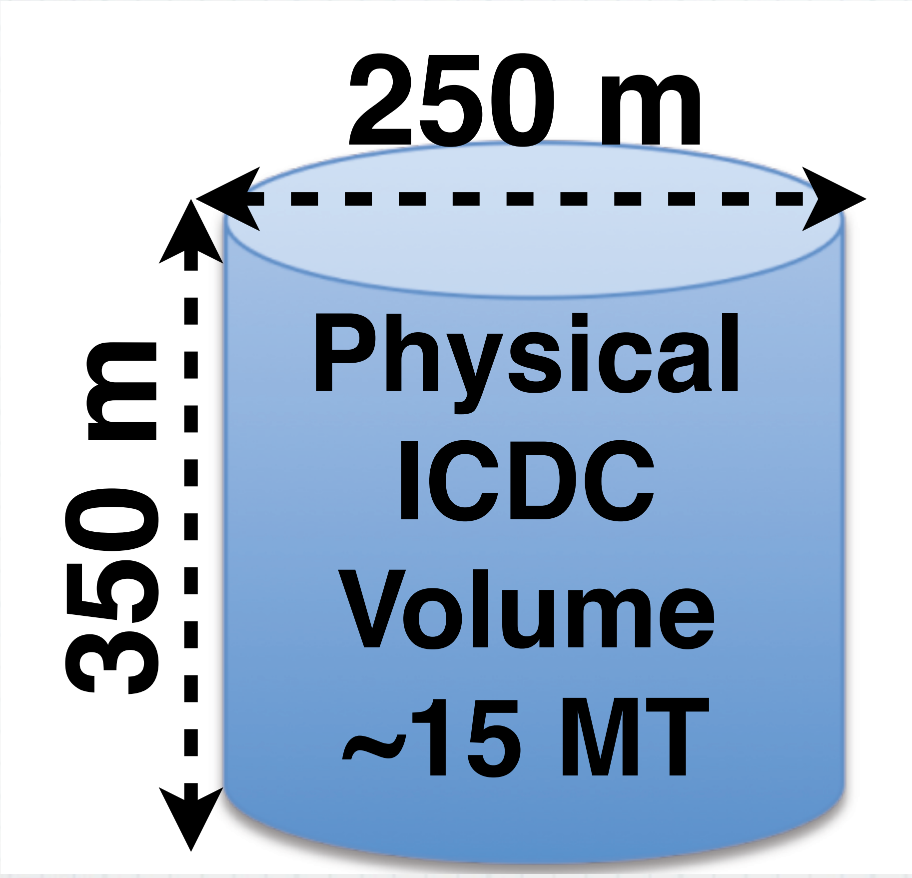


= 300 SKs!

What do WE want to look for?

Cool topics!

Their Atmospheric neutrino background is Signal for US!



= 300 SKs!

What can we do with these atmospheric neutrinos?

Muon tracks: muon events coming from CC muon neutrino and antineutrino interactions

$$N_{i,j,\mu} = \frac{2\pi N_{\rm T}\, t}{V_{\rm det}} \int_{E_i}^{E_i+\Delta_i} dE_\nu \int_{c_{\nu,j}}^{c_{\nu,j}+\Delta_j} dc_\nu V_\mu \times \left(\frac{d\phi_{\nu_\mu(\nu_e)}}{dE_\nu d\Omega}\, \sigma^{\rm CC}_{\nu_\mu(\nu_e)} P_{\nu_\mu(\nu_e)\to\nu_\mu} + \frac{d\phi_{\bar\nu_\mu(\bar\nu_e)}}{dE_\nu d\Omega}\, \sigma^{\rm CC}_{\bar\nu_\mu(\bar\nu_e)} P_{\bar\nu_\mu(\bar\nu_e)\to\bar\nu_\mu} \right)$$

$$V_\mu(E_\mu,\theta) = 2hr^2 \arcsin\left(\sqrt{1-\frac{R_\mu^2(E_\mu)}{4\,r^2}\sin^2\theta}\right)\left(1-\frac{R_\mu(E_\mu)}{h}|\cos\theta|\right)$$

We exploit the energy and angular dependence of the physics we are interested in measuring...

Energy distribution

E< 50 GeV Neutrino oscillations

50 GeV < E < 5 TeV Flux normalization

E> 10 TeV Earth Profile

M.C.Gonzalez-Garcia, et al PRL'08

Angular distribution

0 <cos t<1 Flux normalization

-1 <cos t<0 Atmospheric mixing parameters

-1 <cos t<-0.7 Matter effects

Cool topic: Non standard neutrino interactions "in matter":

$$H_{\mathrm{mat}} = \sqrt{2} G_F n_e \begin{pmatrix} 1+\epsilon_{ee} & \epsilon^*_{e\mu} & \epsilon^*_{e\tau} \\ \epsilon_{e\mu} & \epsilon_{\mu\mu} & \epsilon^*_{\mu\tau} \\ \epsilon_{e\tau} & \epsilon_{\mu\tau} & \epsilon_{\tau\tau} \end{pmatrix}$$

Cool topic: Non standard neutrino interactions "in matter":

$$H_{\rm mat} = \sqrt{2}G_F n_e \begin{pmatrix} 1+\epsilon_{ee} & \epsilon^*_{e\mu} & \epsilon^*_{e\tau} \\ \epsilon_{e\mu} & \epsilon_{\mu\mu} & \epsilon^*_{\mu\tau} \\ \epsilon_{e\tau} & \epsilon_{\mu\tau} & \epsilon_{\tau\tau} \end{pmatrix}$$

Biggio, Blennow & Fernandez-Martinez, JHEP'09

Cool topic: Non standard neutrino interactions "in matter":

$$H_{\rm mat} = \sqrt{2} G_F n_e \begin{pmatrix} 1+\epsilon_{ee} & \epsilon^*_{e\mu} & \epsilon^*_{e\tau} \\ \epsilon_{e\mu} & \epsilon_{\mu\mu} & \epsilon^*_{\mu\tau} \\ \epsilon_{e\tau} & \epsilon_{\mu\tau} & \epsilon_{\tau\tau} \end{pmatrix}$$

$$\left|\varepsilon^{\oplus}_{\alpha\beta}\right| < \begin{pmatrix} 4.2 & 0.33 & 3.0 \\ 0.33 & 0.068 & 0.33 \\ 3.0 & 0.33 & 21 \end{pmatrix}$$

Biggio, Blennow & Fernandez-Martinez, JHEP'09

Cool topic: Non standard neutrino interactions "in matter":

$$H_{\text{mat}} = \sqrt{2} G_F n_e \begin{pmatrix} 1+\epsilon_{ee} & \epsilon_{e\mu}^* & \epsilon_{e\tau}^* \\ \epsilon_{e\mu} & \epsilon_{\mu\mu} & \epsilon_{\mu\tau}^* \\ \epsilon_{e\tau} & \epsilon_{\mu\tau} & \epsilon_{\tau\tau} \end{pmatrix}$$

set to 0
in the following!

Cool topic: Non standard neutrino interactions "in matter":

$$H_{\rm mat} = \sqrt{2} G_F n_e \begin{pmatrix} 1+\epsilon_{ee} & \epsilon^*_{e\mu} & \epsilon^*_{e\tau} \\ \epsilon_{e\mu} & \epsilon_{\mu\mu} & \epsilon^*_{\mu\tau} \\ \epsilon_{e\tau} & \epsilon_{\mu\tau} & \epsilon_{\tau\tau} \end{pmatrix}$$

set to 0 in the following!

Lets focus on ν_μ-ν_τ Kopp, Ota & Winter PRD'08

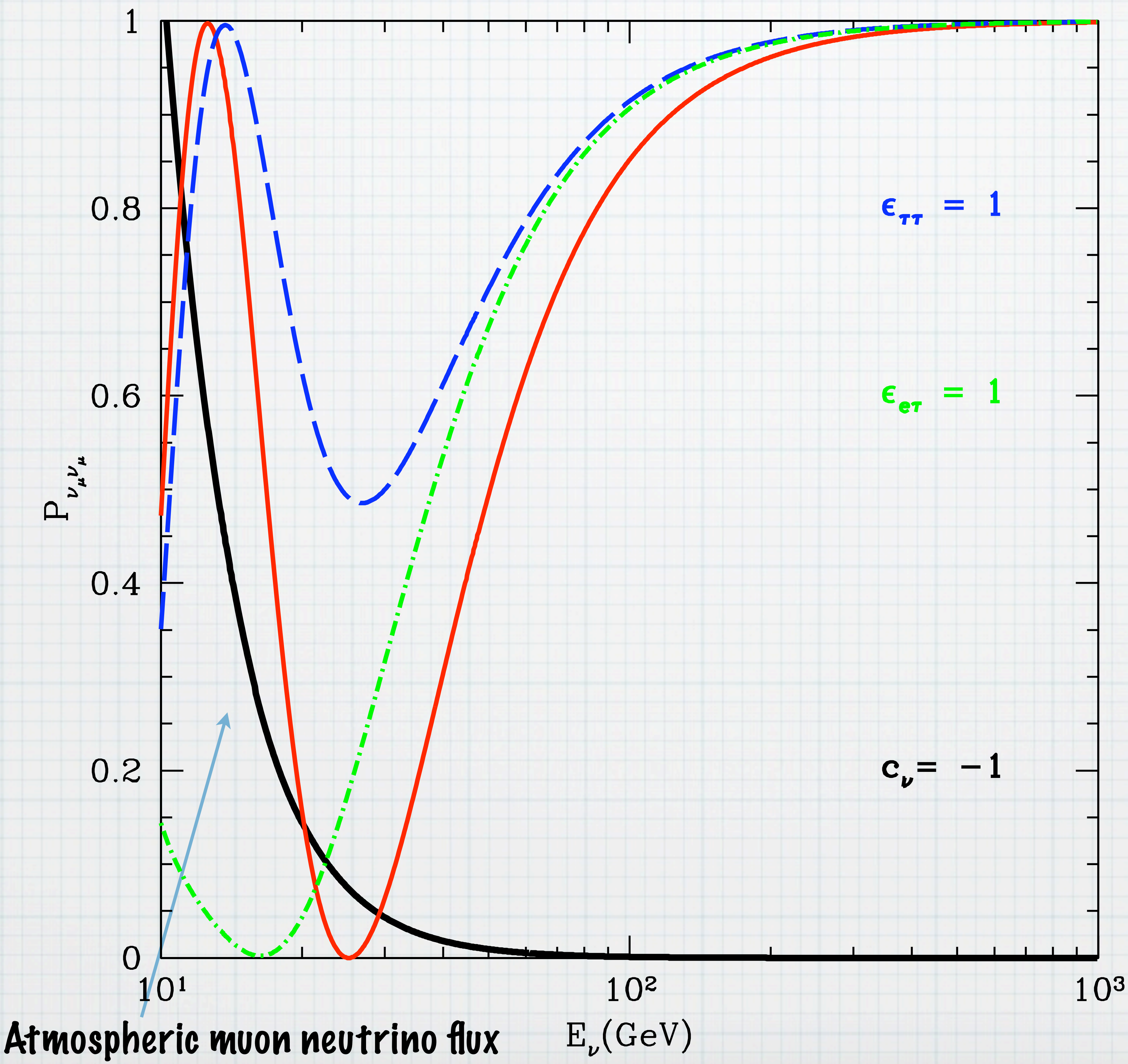
$$\Delta \tilde{m}^2_{31} = \Delta m^2_{31} \sqrt{\sin^2 2\theta_{23} + (\hat{A}\epsilon^m_{\tau\tau} + \cos 2\theta_{23})^2}$$

$$\sin^2 2\tilde{\theta}_{23} = \frac{\sin^2 2\theta_{23}}{\sin^2 2\theta_{23} + (\hat{A}\epsilon^m_{\tau\tau} + \cos 2\theta_{23})^2}$$

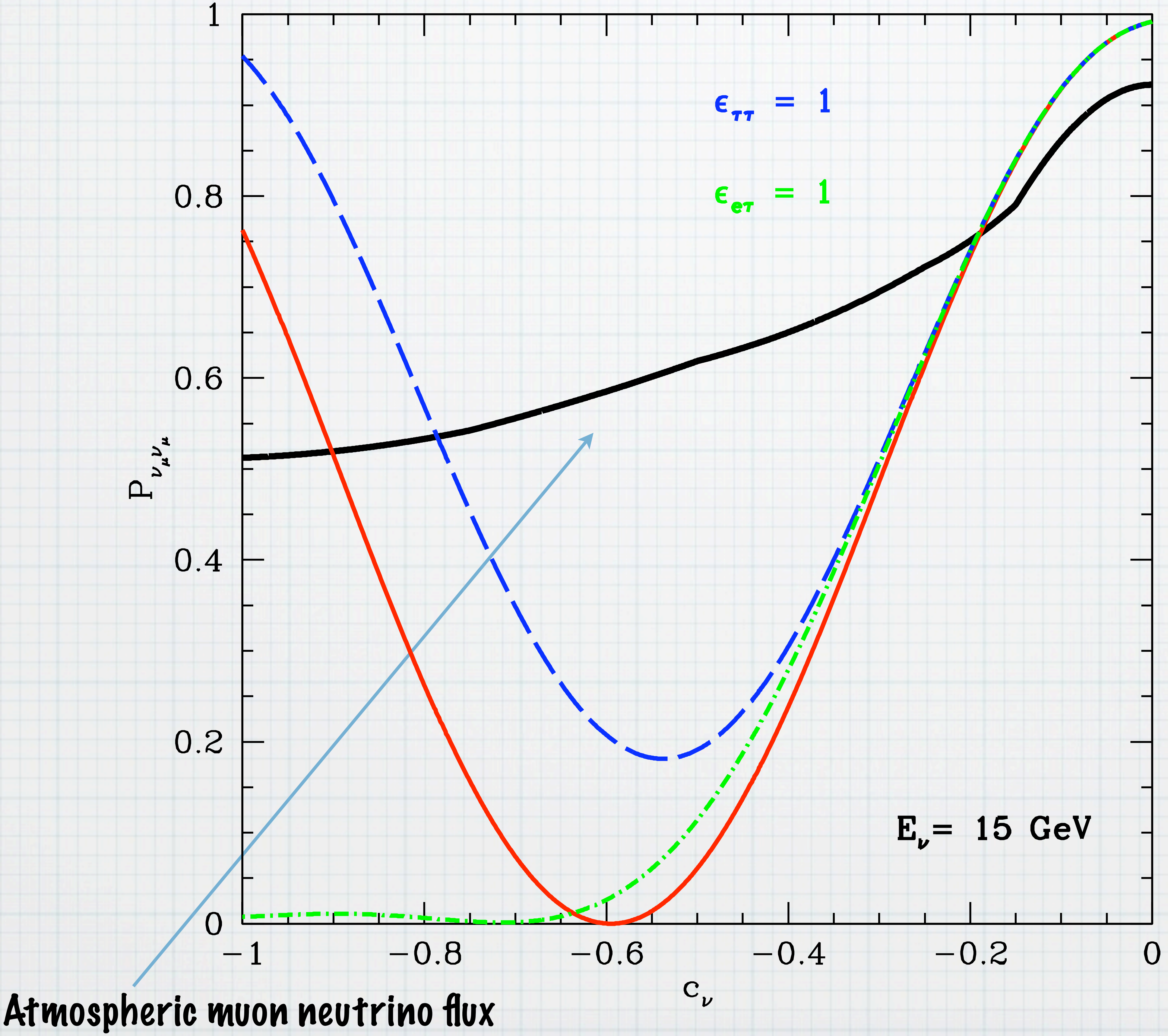
where $\hat{A} \equiv \dfrac{2\sqrt{2} E G_F N_e}{\Delta m^2_{31}}$

Gonzalez-Garcia et al PRL'99
Bergmann, Grossman&Pierce PRD'00
Fornengo et al PDR'01
Gonzalez-Garcia & Maltoni PRD'04
Friedland, Lunardini & Maltoni PRD'04

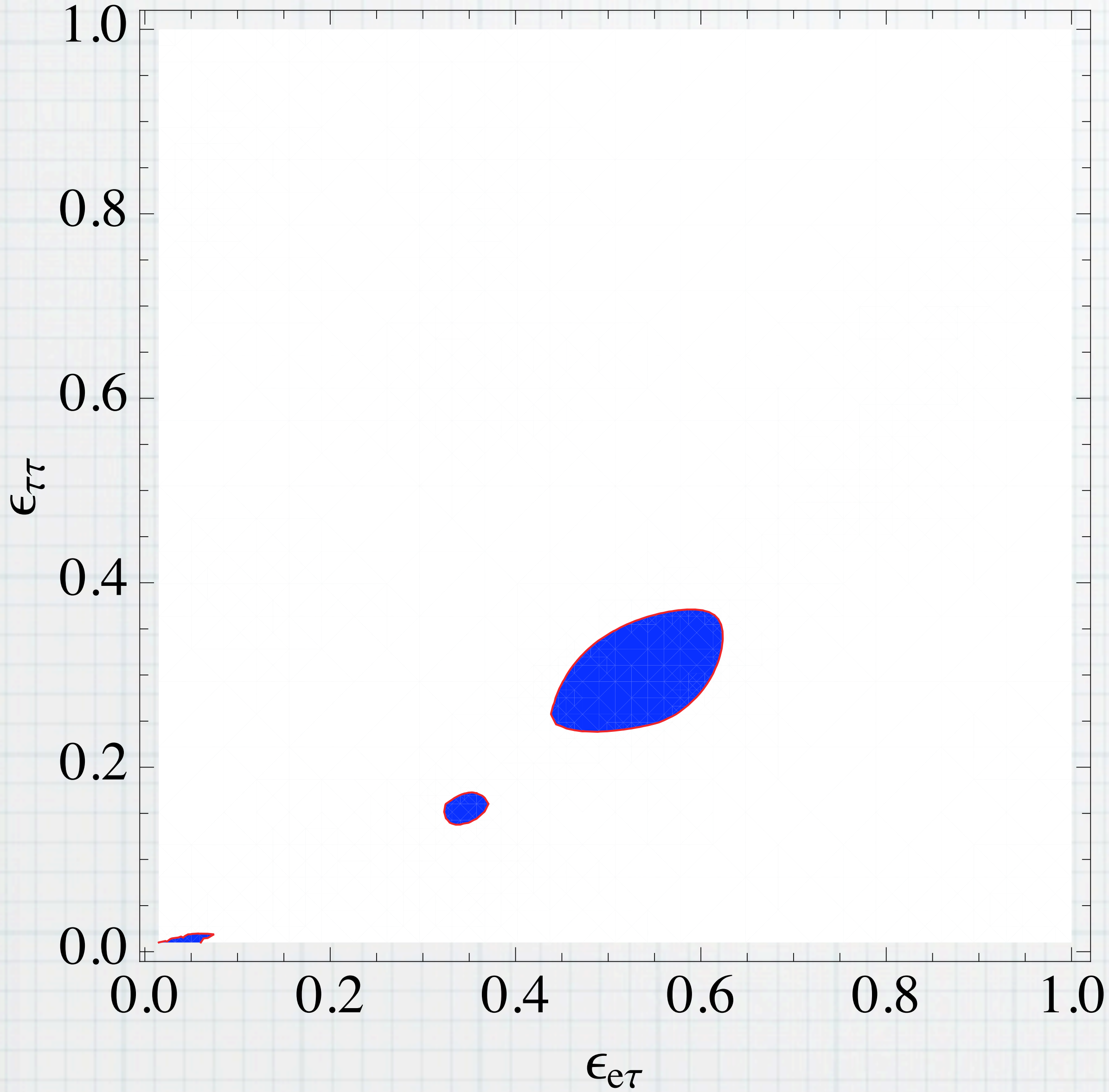
A non vanishing NSI parameter decrease the effective mixing in matter @ energies at which the matter effects are important, for a given matter density

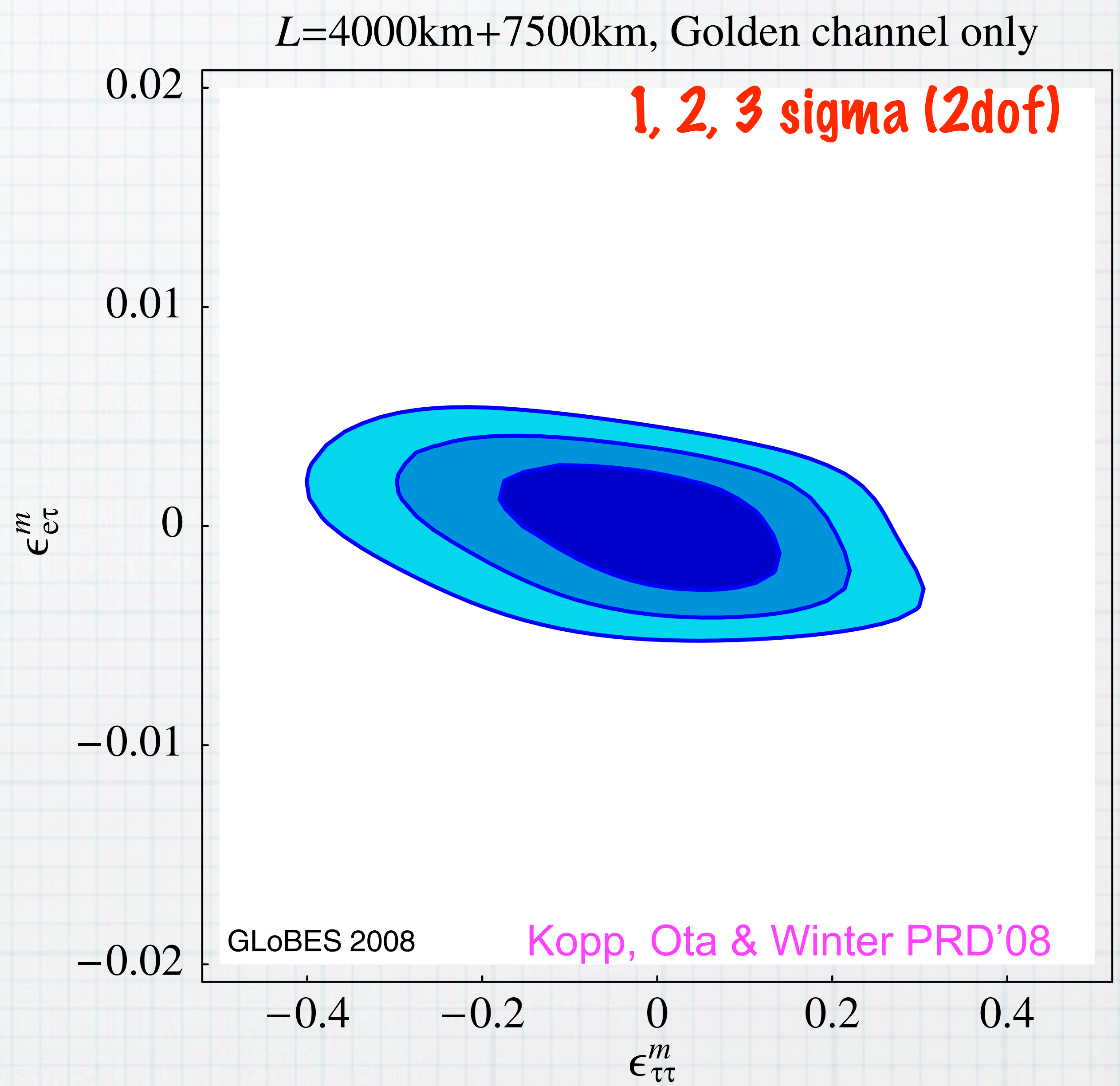


A non vanishing NSI parameter decrease the effective mixing in matter @ angles at which the matter effects are important, for a given energy



We assume all NSI to be real. We marginalize over the remaining NSI parameters.
90% CL (2 dof) for 10 years muon track statistics contours:

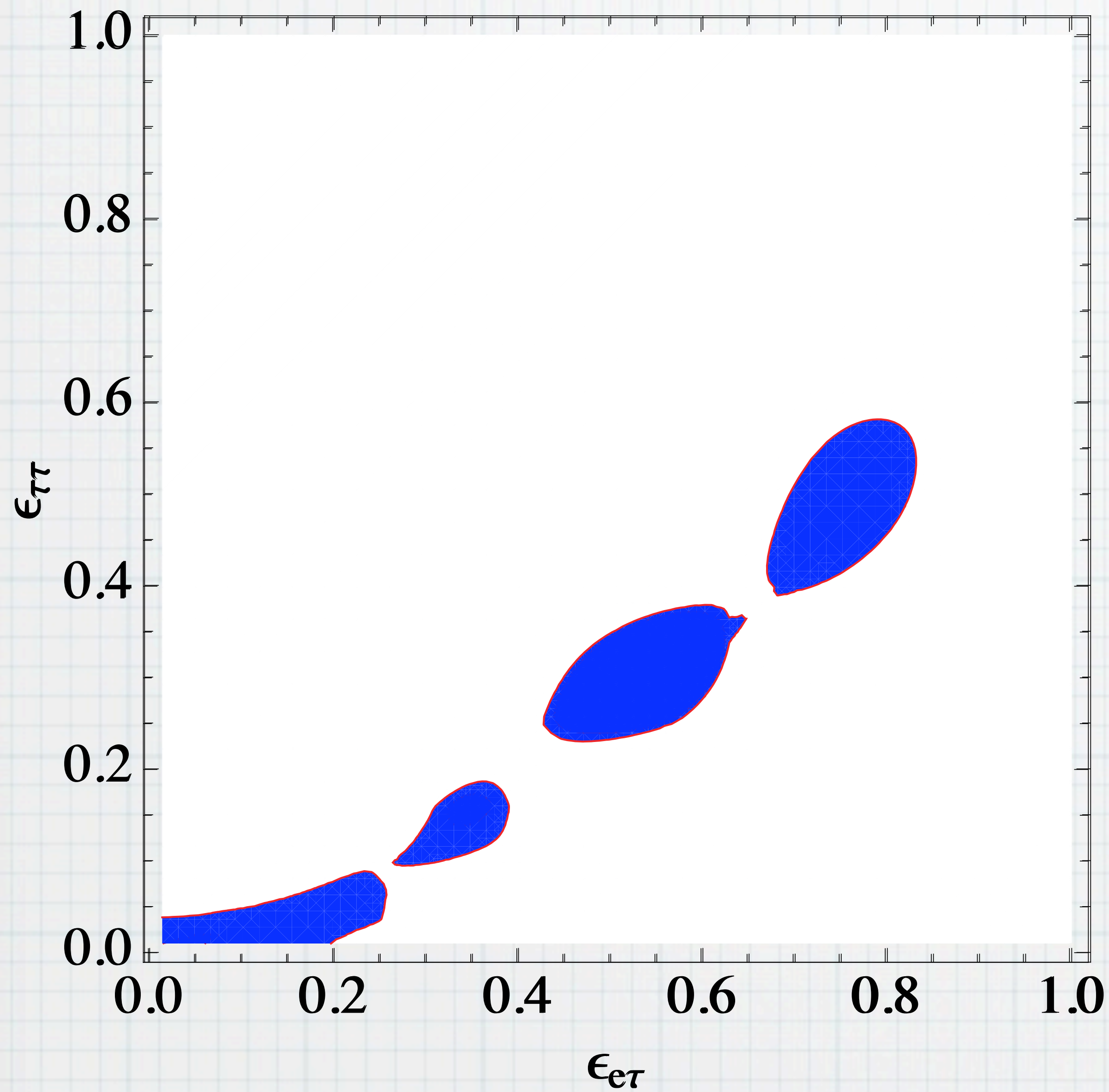


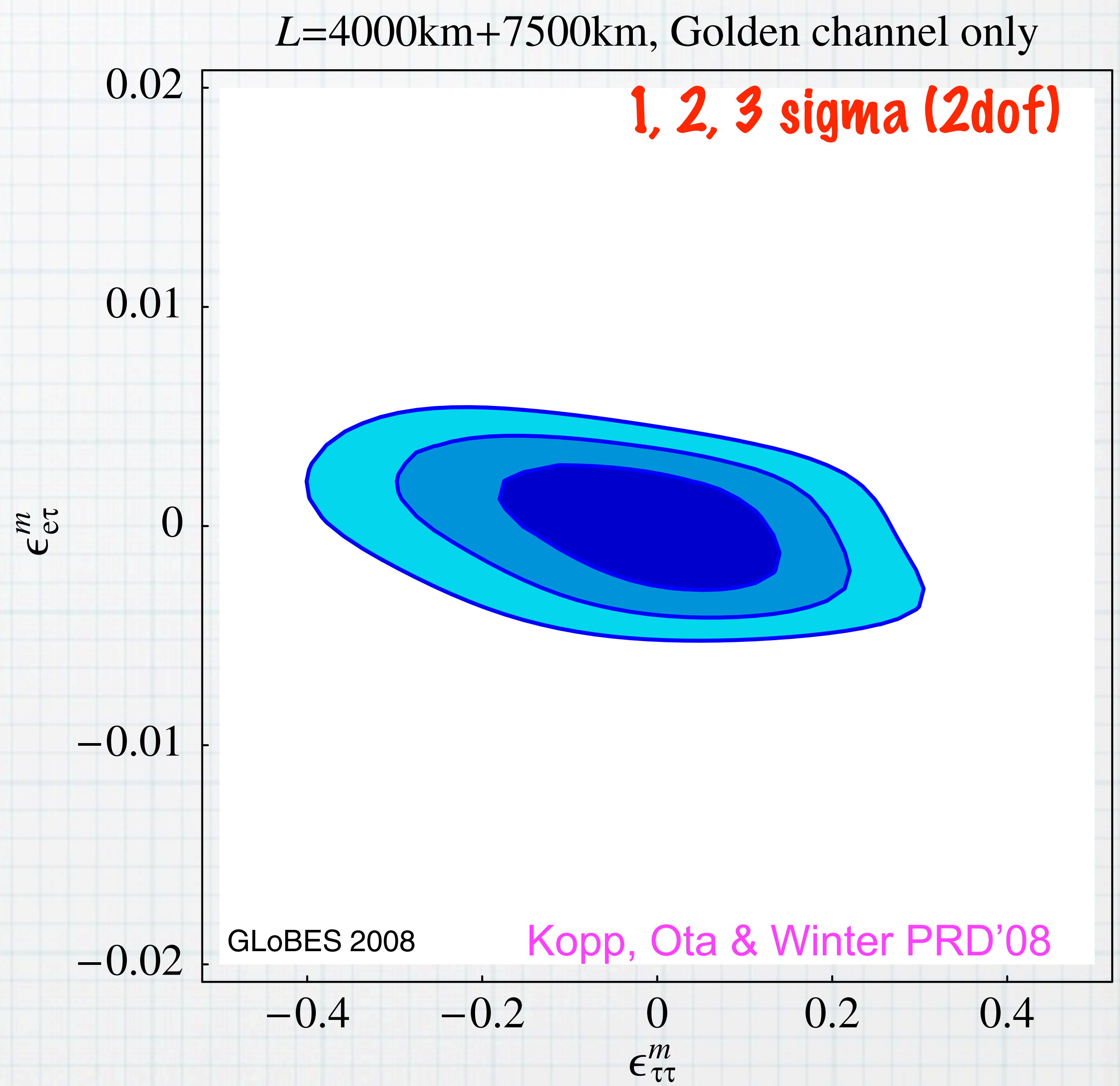


Current NSI limits could be improved by one order of magnitude, but not much better than those found @ Friedland, Lunardini & Maltoni PRD'04, DUSEL?

$$\left|\varepsilon^{\oplus}_{\alpha\beta}\right| < \begin{pmatrix} 4.2 & 0.33 & 3.0 \\ 0.33 & 0.068 & 0.33 \\ 3.0 & 0.33 & 21 \end{pmatrix}$$ **@ 90%CL**

We assume all NSI to be real. We marginalize over the remaining NSI parameters.
90% CL (2 dof) for 10 years muon track statistics contours:

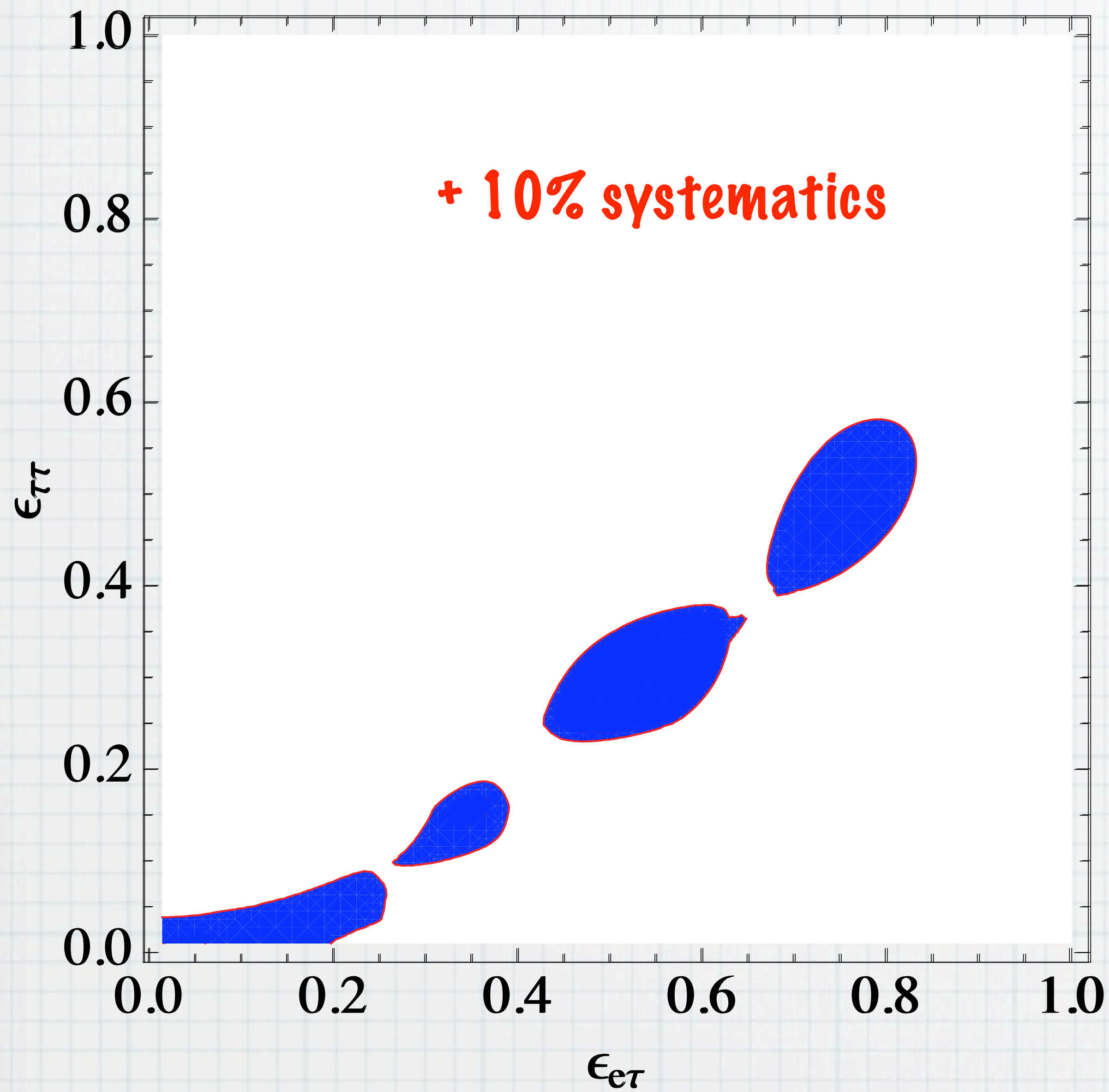


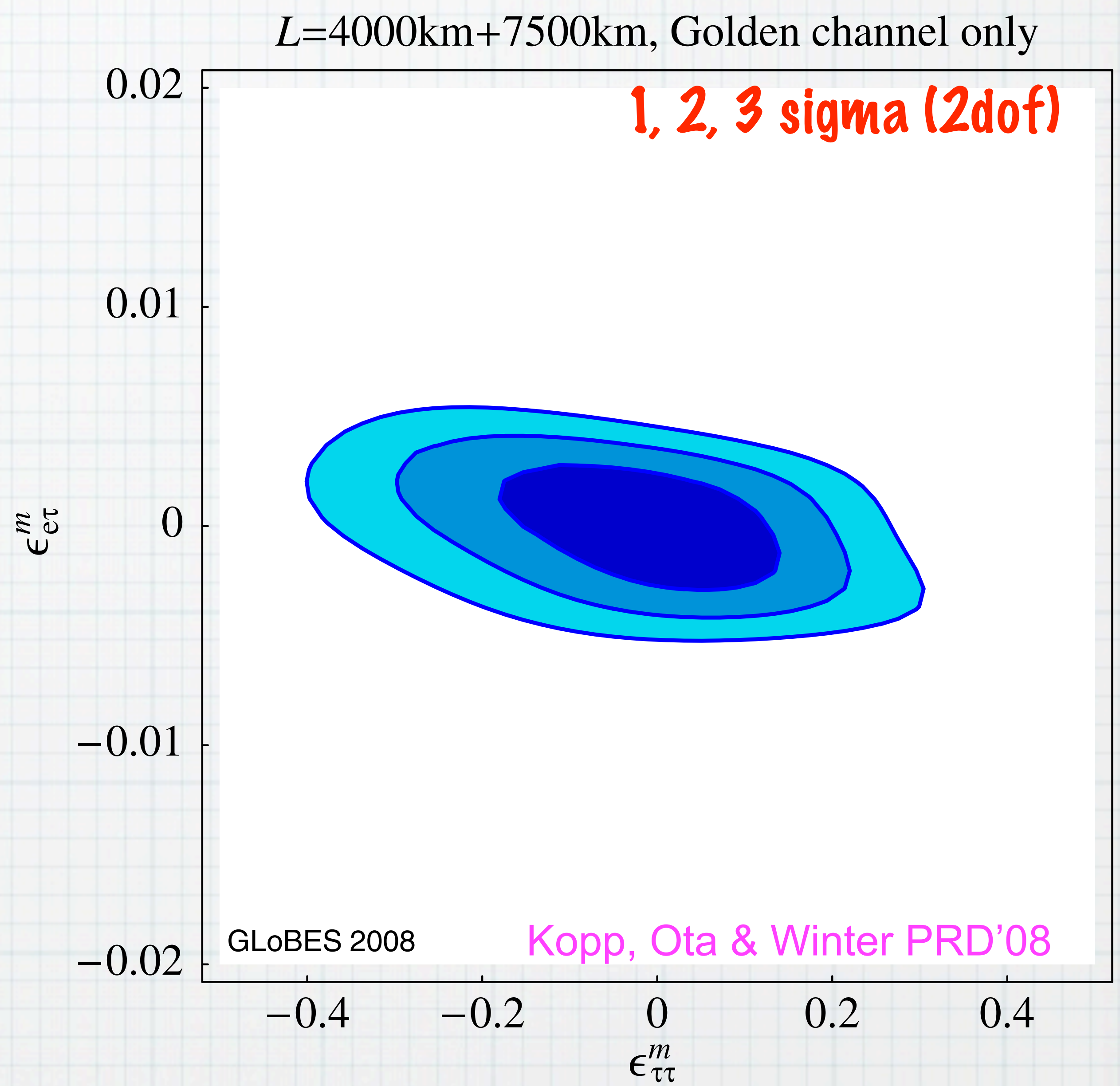


Current NSI limits could be improved by one order of magnitude, but not much better than those found @ Friedland, Lunardini & Maltoni PRD'04, DUSEL?

$$\left|\varepsilon^{\oplus}_{\alpha\beta}\right| < \begin{pmatrix} 4.2 & 0.33 & 3.0 \\ 0.33 & 0.068 & 0.33 \\ 3.0 & 0.33 & 21 \end{pmatrix}$$ @ 90%CL

We assume all NSI to be real. We marginalize over the remaining NSI parameters. 90% CL (2 dof) for 10 years muon track statistics contours:





Current NSI limits could be improved by one order of magnitude, but not much better than those found @ Friedland, Lunardini & Maltoni PRD'04, DUSEL?

$$\left|\varepsilon^{\oplus}_{\alpha\beta}\right| < \begin{pmatrix} 4.2 & 0.33 & 3.0 \\ 0.33 & 0.068 & 0.33 \\ 3.0 & 0.33 & 21 \end{pmatrix} \quad \text{@ 90\%CL}$$


"That's
all
folks!"
Thank you!

What can we do with these atmospheric neutrinos?

Cascades

EM

Tau decay: $\tau \rightarrow e + \bar{\nu}_e + \nu_\tau$

ν_e CC interactions: $\nu_e + N \rightarrow e + X$

Hadronic

Tau decay: $\tau \rightarrow \nu_\tau + X$

ν_τ NC interactions: $\nu_\tau + N \rightarrow \nu_\tau + X$

ν_τ CC interactions: $\nu_\tau + N \rightarrow \tau + X$

$\nu_{e,\mu}$ NC and CC interactions

We assume all NSI to be real. We marginalize over the remaining NSI parameters.
90% CL (2 dof) for 10 years muon track statistics contours: