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Tata Institute of
Fundamental Research
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Tau-Contamination in the golden channel at the Neutrino Factory

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&
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Based on the work of
A. Donini, D. Meloni and J.J. Gómez Cadenas
arXiV: 1005.2275 [hep-ph]

The golden channel

$$\mu^+ \to e^+ \nu_e \bar{\nu}_\mu$$

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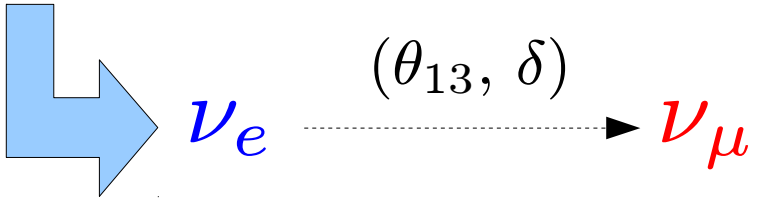

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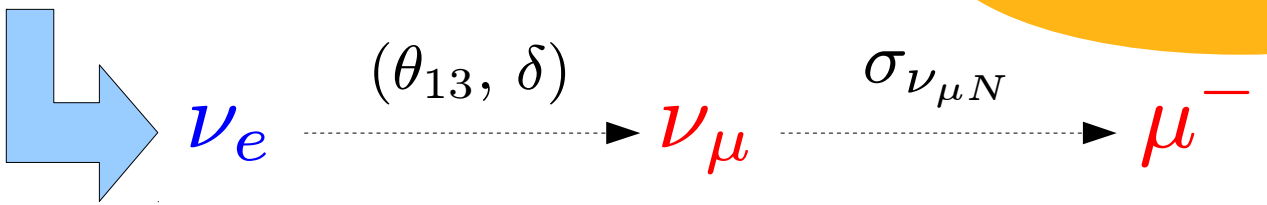
Wrong sign muons:
Golden signal



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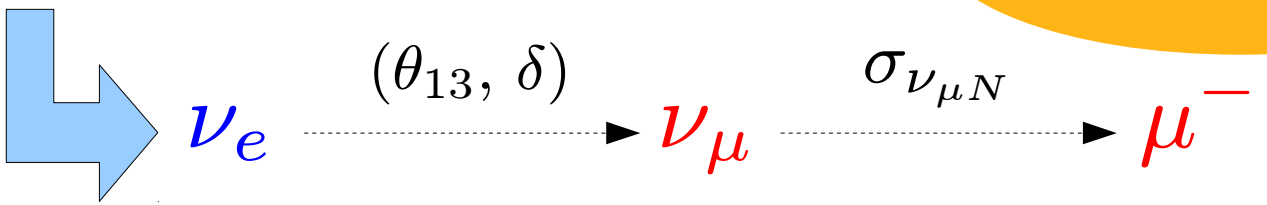
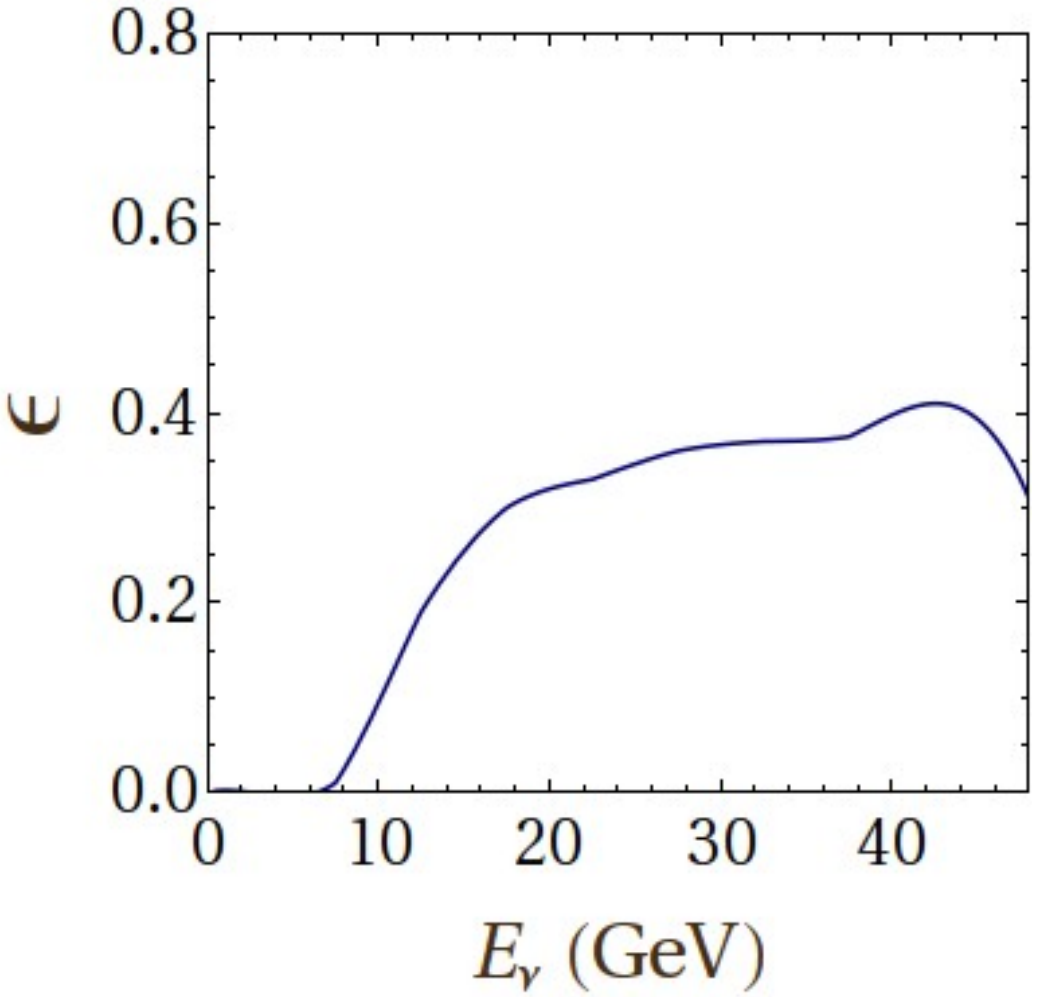


- Best channel to measure θ_{13}, δ and $sgn(\Delta m^2_{31})$
- However, correlations & degeneracies appear for the 25 GeV NF.
- Ways to solve them:
  - Two detectors at different baselines;
  - Info at different energies.
- Main backgrounds:
  - Right sign-muons;
  - CC with missed lepton + fake muons from hadrons;
  - NC + fake muons from hadrons.

MIND (old) efficiencies

Tight kinematic cuts give a very low background fraction

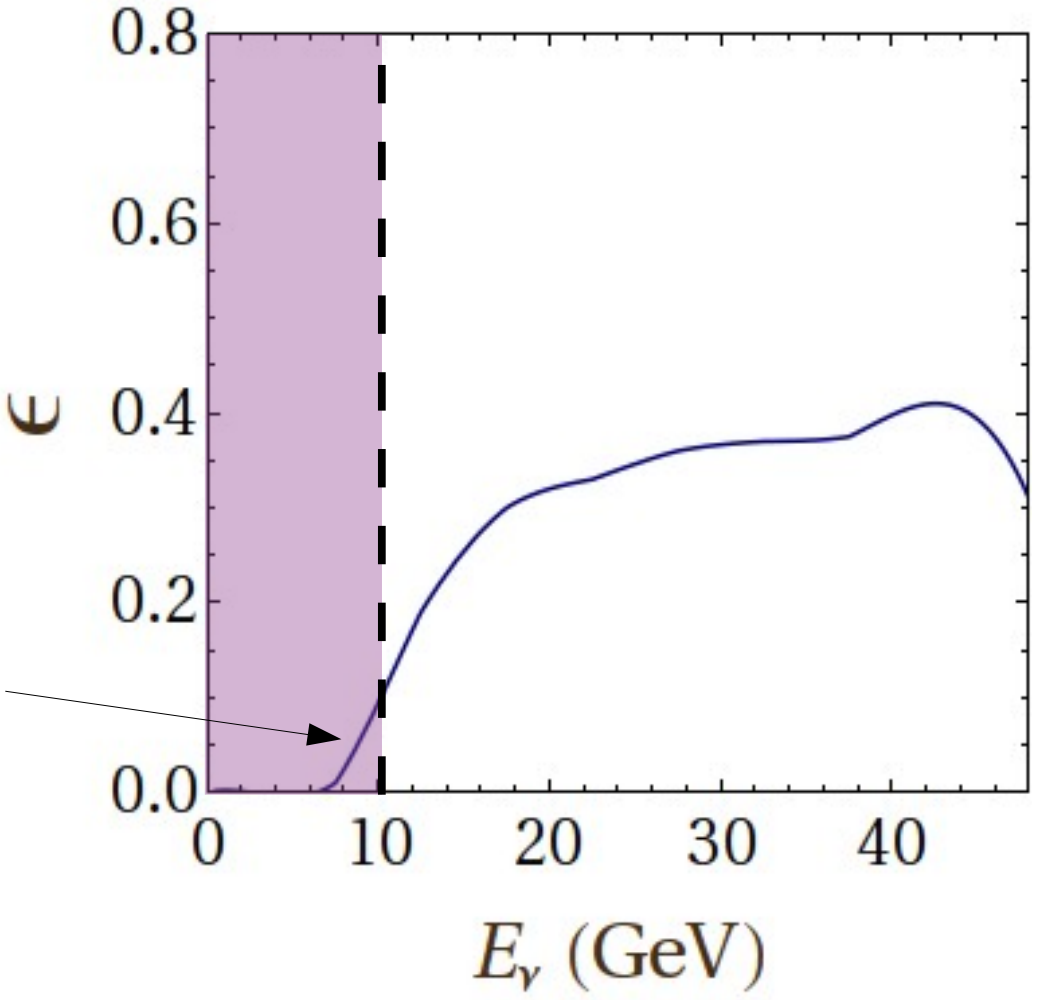


Cervera et al, hep-ph/0002108

MIND (old) efficiencies

Tight kinematic cuts give a very low background fraction

But these give very low efficiencies below 10 GeV, too...



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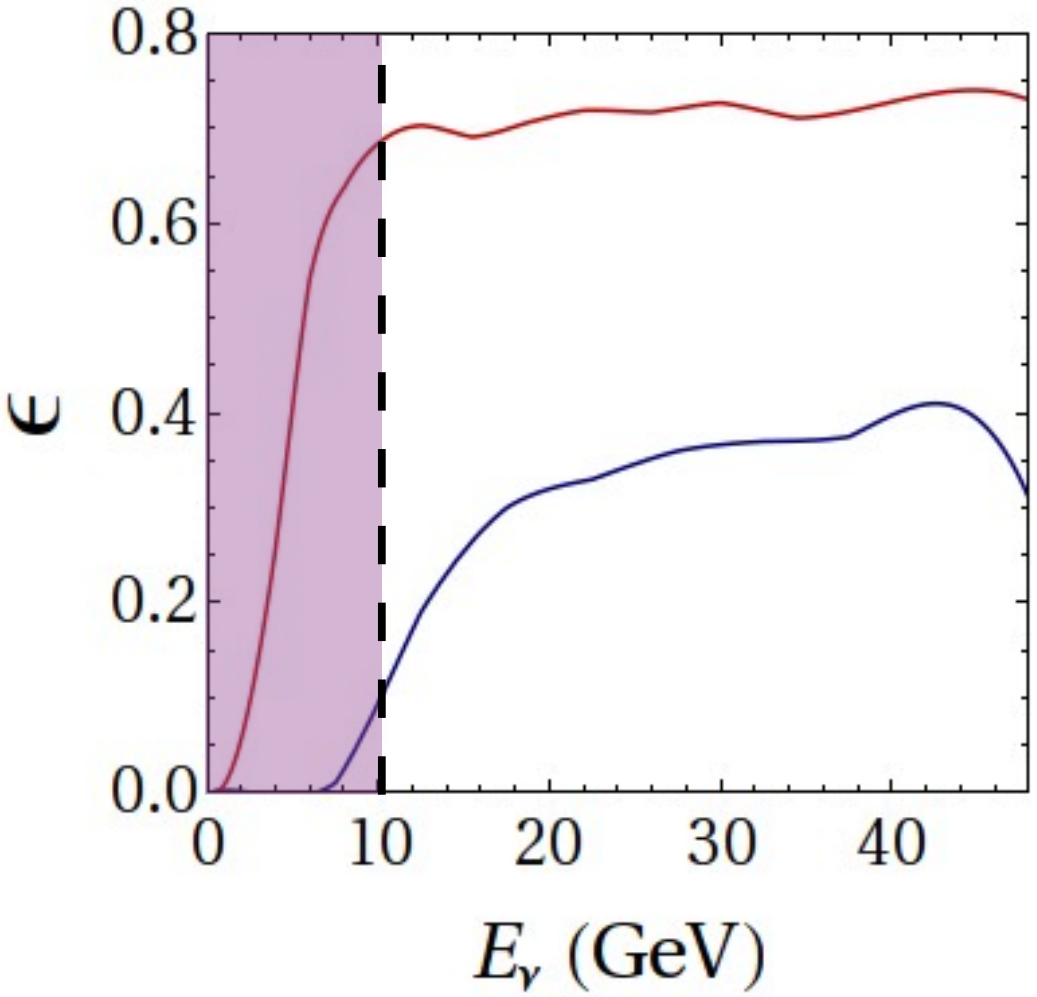
MIND (new) efficiencies

Relaxing cuts, we get better efficiencies at low energies



ISS Detector Report, Abe *et al*, JINST 4 (2009) T05001

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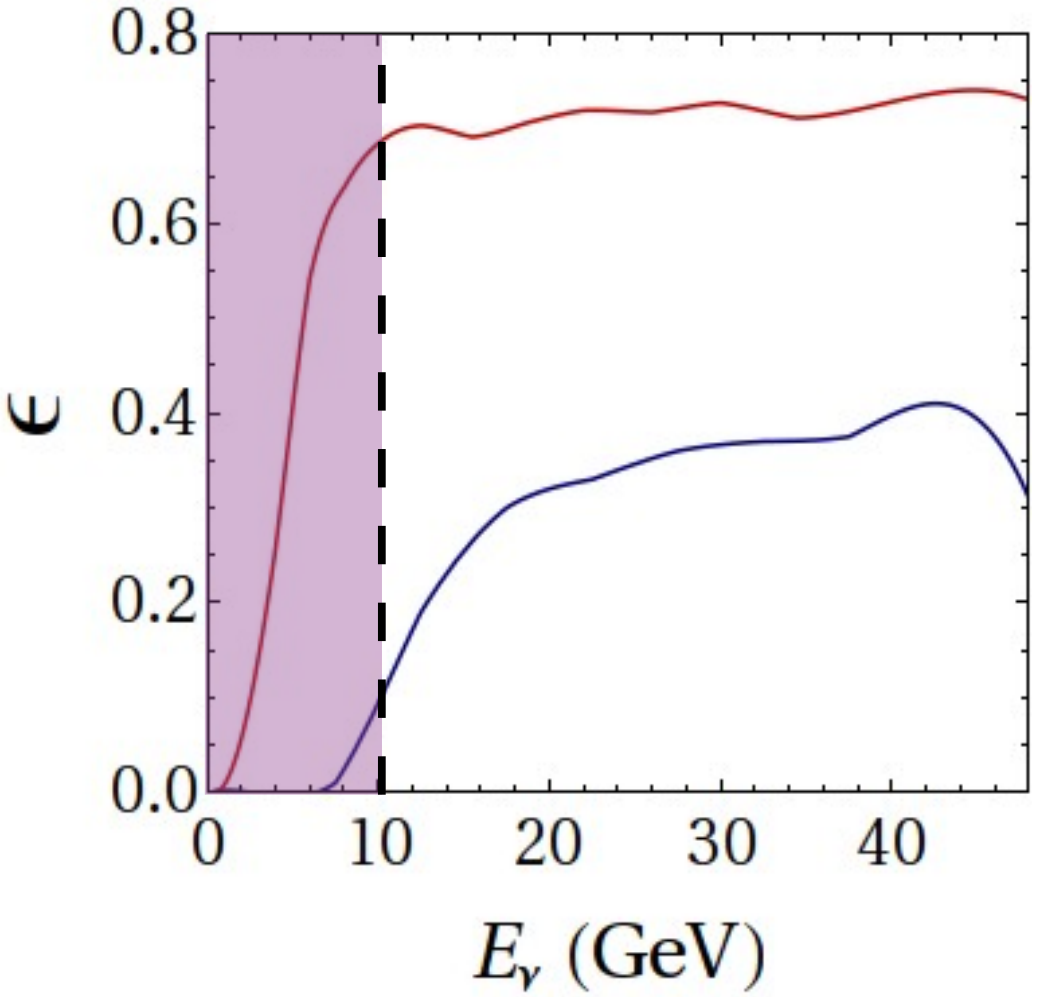
Relaxing cuts, we get better efficiencies at low energies

We solve degeneracies better!



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Golden signal again??

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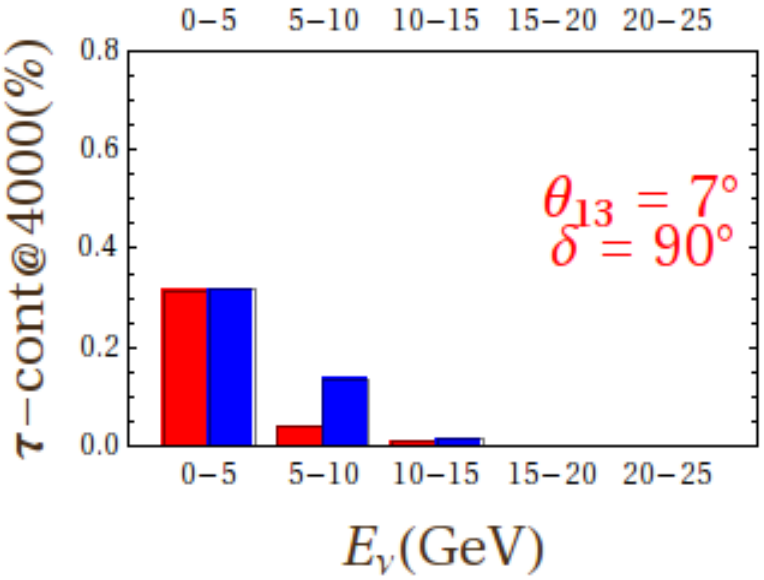
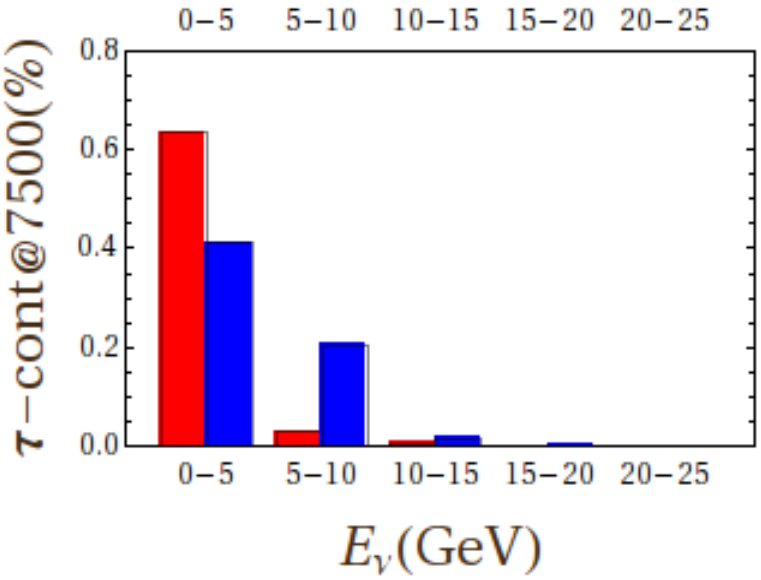
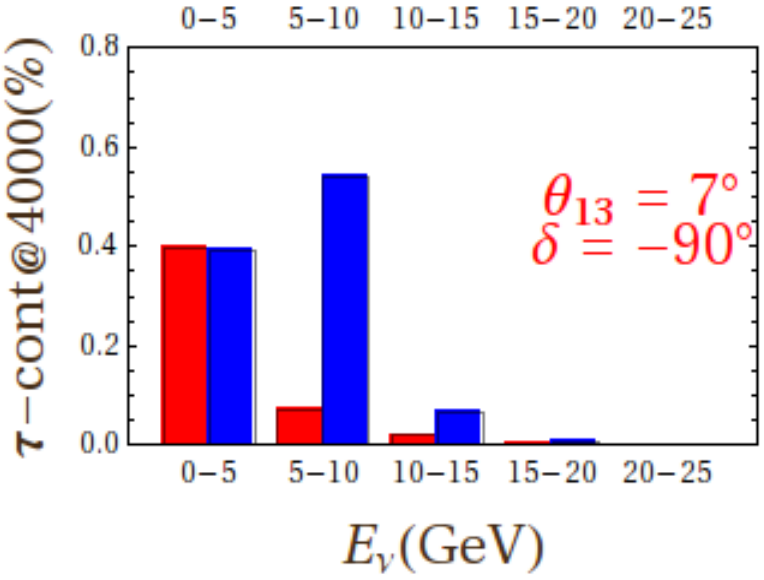
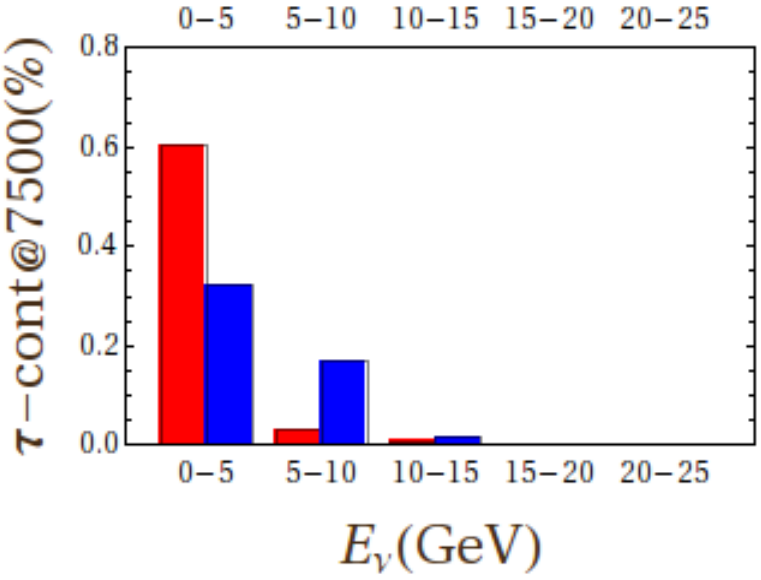
- In MIND, we cannot distinguish these from the "true" golden muons
- Larger number of events than expected ⇒ fake measurements on θ_{13}, δ
- Low energy bins will be the most affected due to spectral change after the decay
  - Notice that now we have better muon efficiencies for E < 10 GeV.

How many of these will we have?









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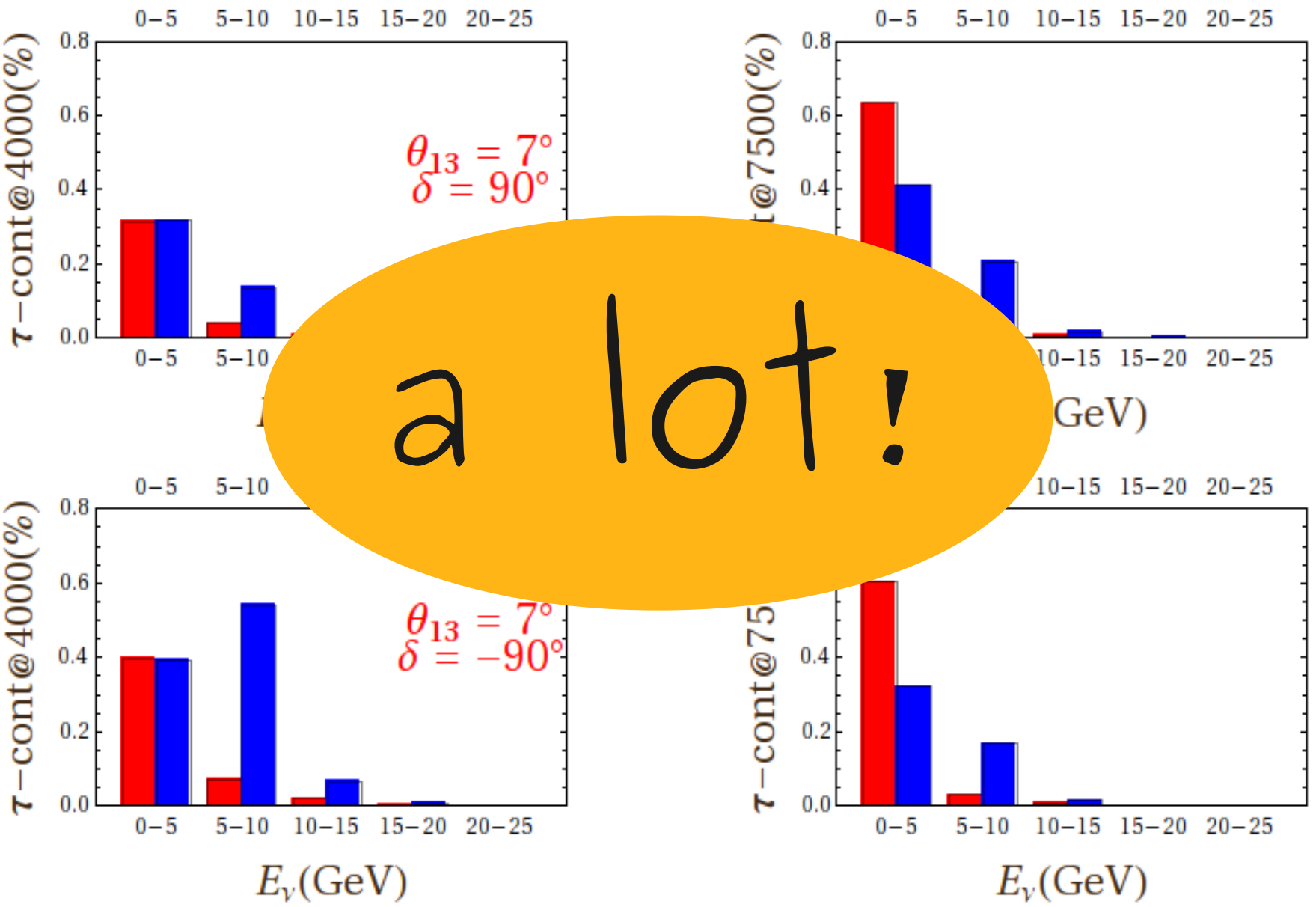
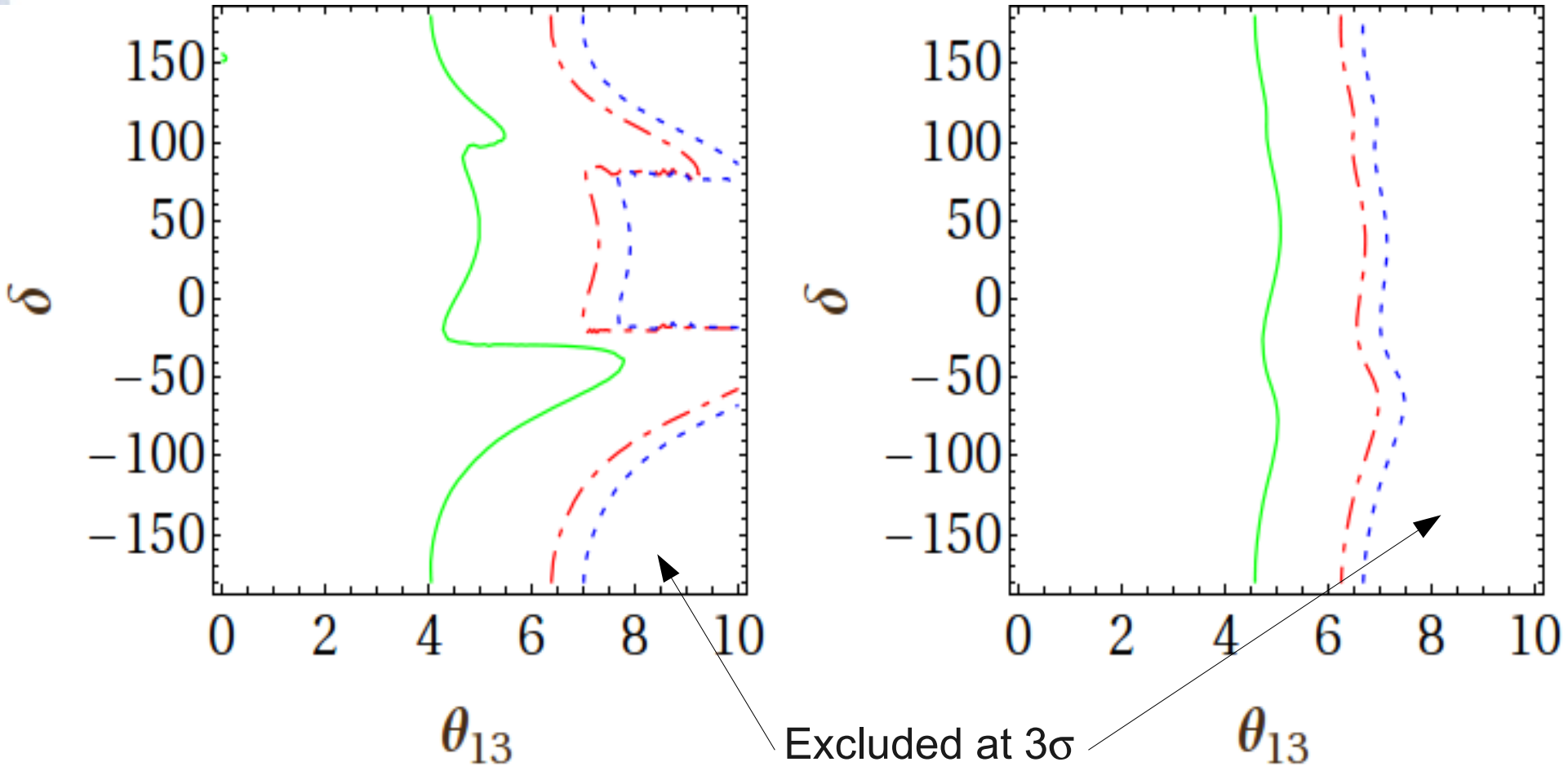


What if we do not take these events into account in the analysis?

Can we fit the data?



L=4000 km

L=4000+7500 km

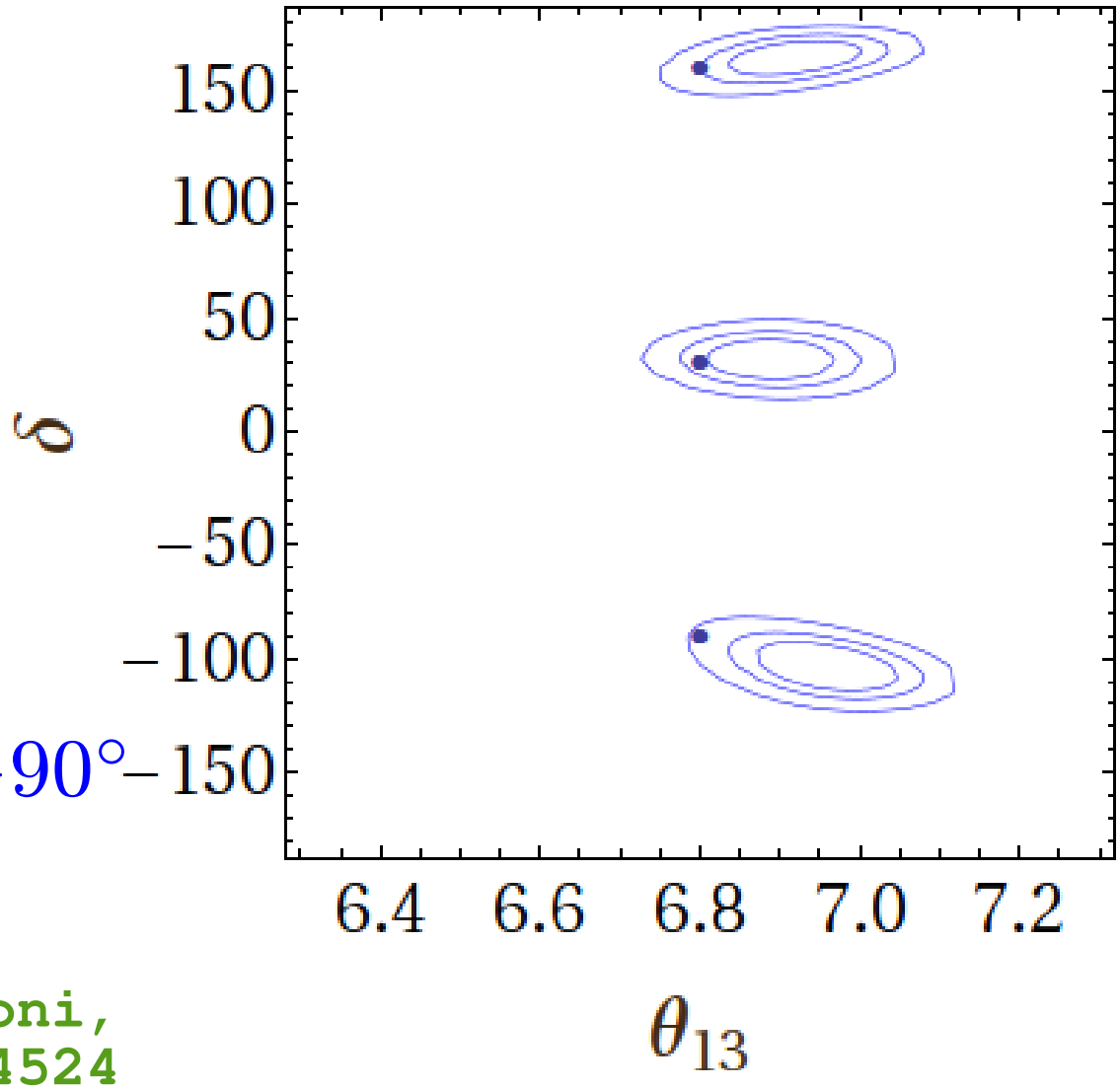
Can we fit the data?

Trying to fit the data without taking the taus into account...

2% systematics

$\theta_{13} = 6.8°$

$\delta = 160°, 30°, -90°$



González-García, Maltoni, Salvado, arXiV: 1001.4524

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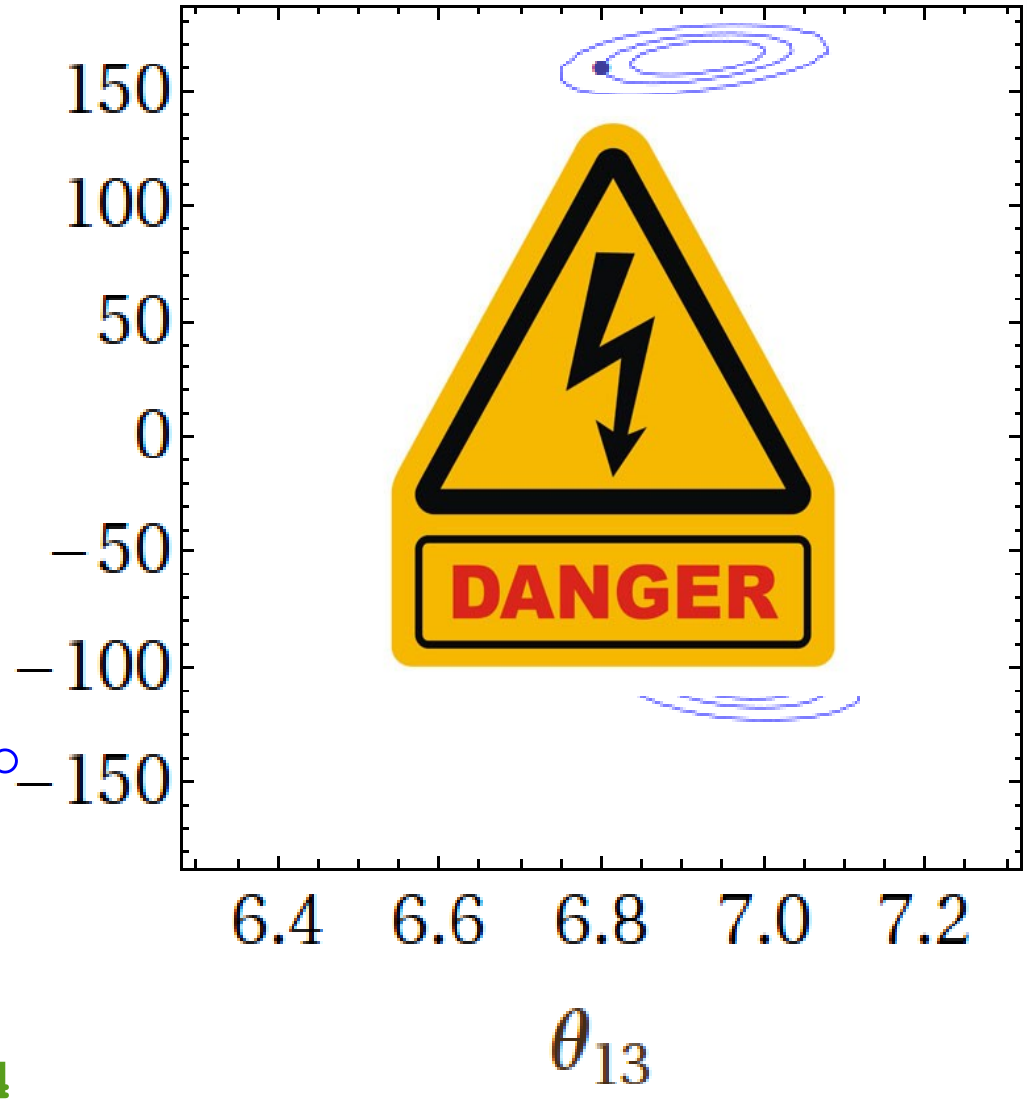

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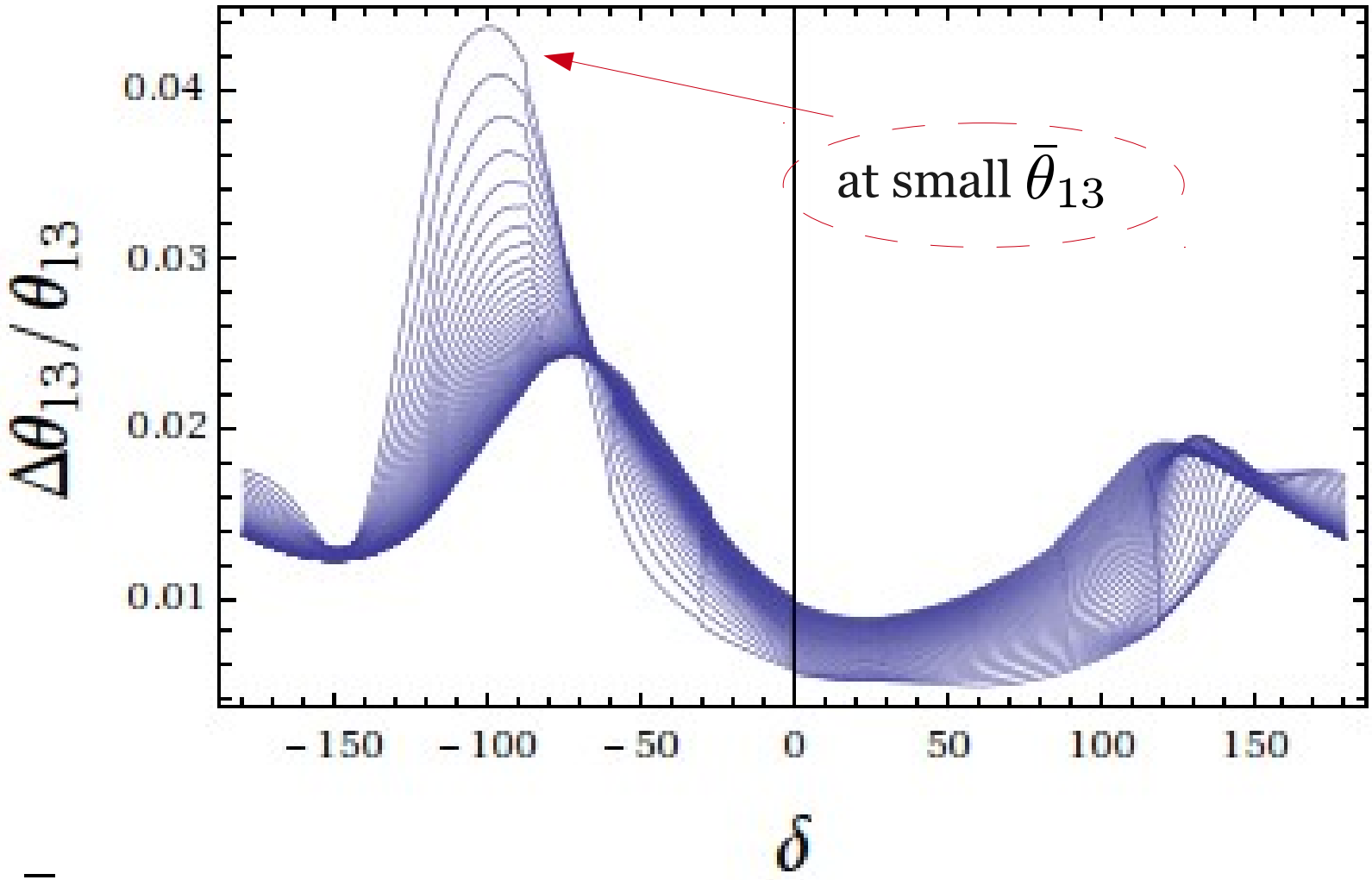
Shift in best-fit values in θ_{13}



$\bar{\theta}_{13} \in [1°, 5°]$

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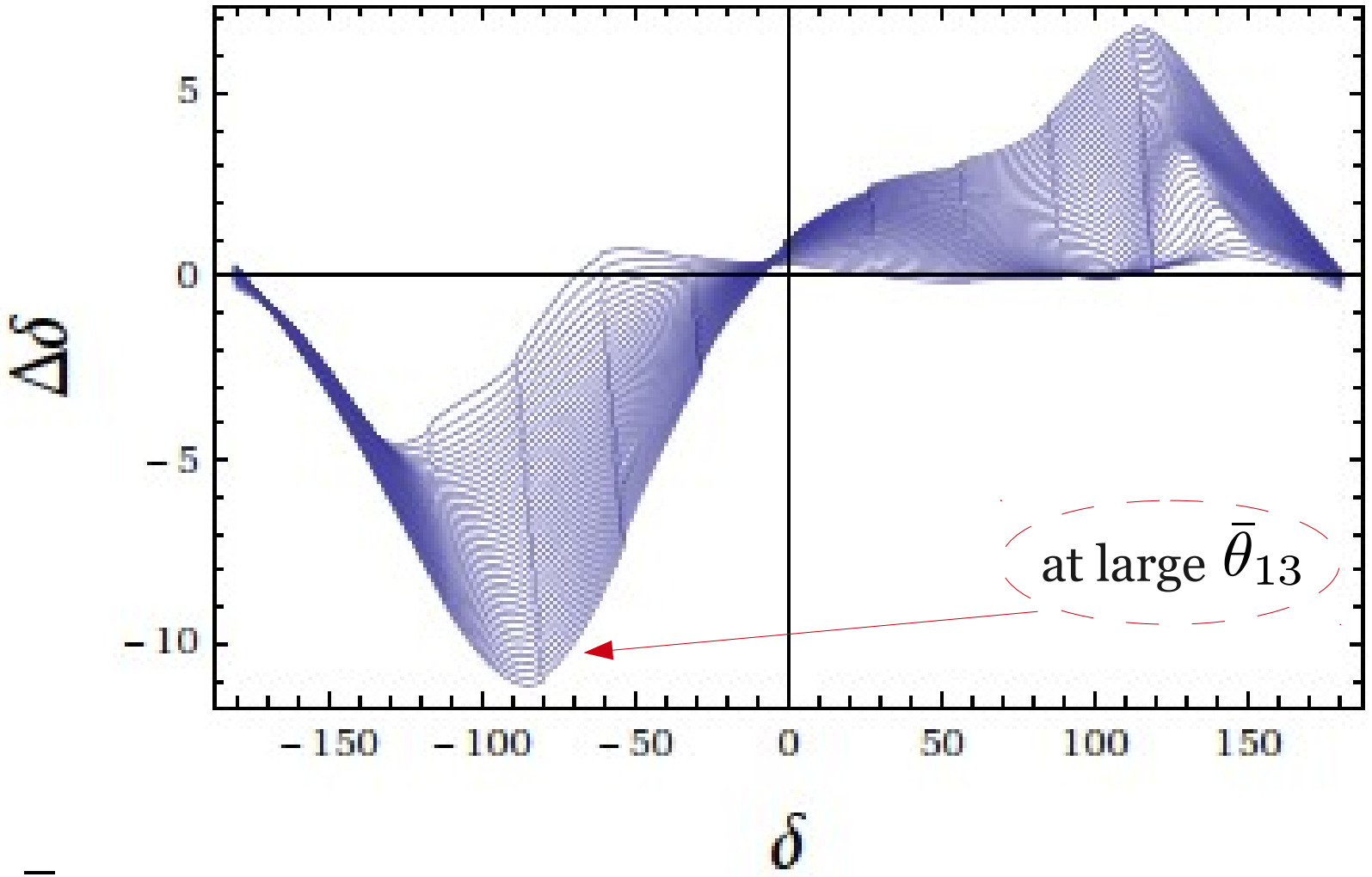
Shift in best-fit values in δ



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Ok, this doesn't seem to be working...

Let's take taus into account!

Final Muon energy

- Fitting in the final muon energy (see talk by Sinha):
  - Add the two samples: more signal
  - No hadronic calorimeter info: more background

Indumati and Sinha, arXiV: 0910.2020

Neutrino energy reconstruction

- Fitting in the reconstructed neutrino energy:

$$E_{\nu_\mu} \quad = \quad E_\mu + E_{hadr} \qquad \text{(Golden muons)}$$

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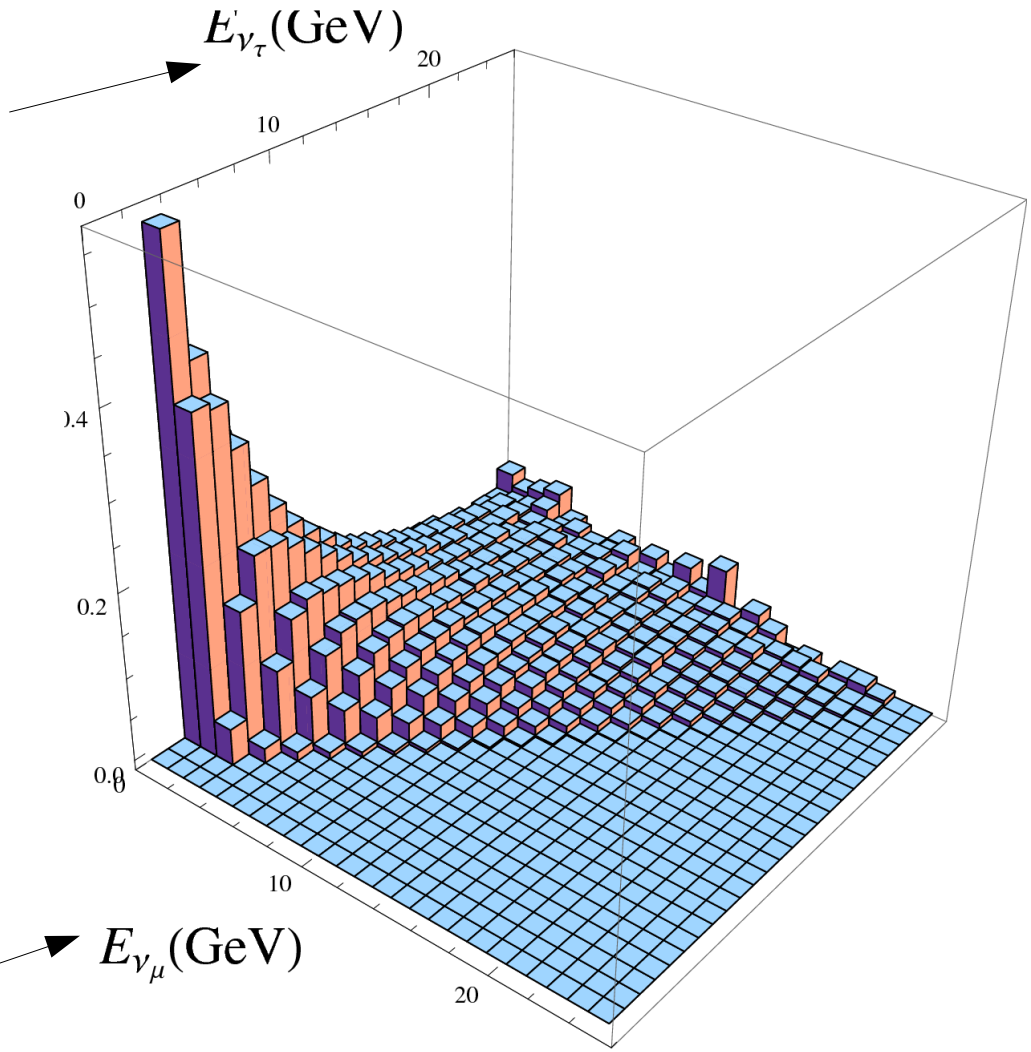
$$\text{“}E_{\nu_\mu}\text{”} = E_\mu + E_{hadr} < E_{\nu_\tau}$$

The neutrino energy is wrongly reconstructed!

Migration matrix

True energy



- 10^6 ν_τ per energy bin
- Cross section and differential decay width $\tau \to \mu$ with GENIE

(Andreopopoulos *et al*, arXiV:0905.2517)

Fake energy

The whole signal

- Once we have computed the migration matrix M_{ij}, we can compute theoretically the entire signal:

$$N_i^{tot} = N_i^{\mu} + \sum_j M_{ij} N_j^{\tau \to \mu}$$

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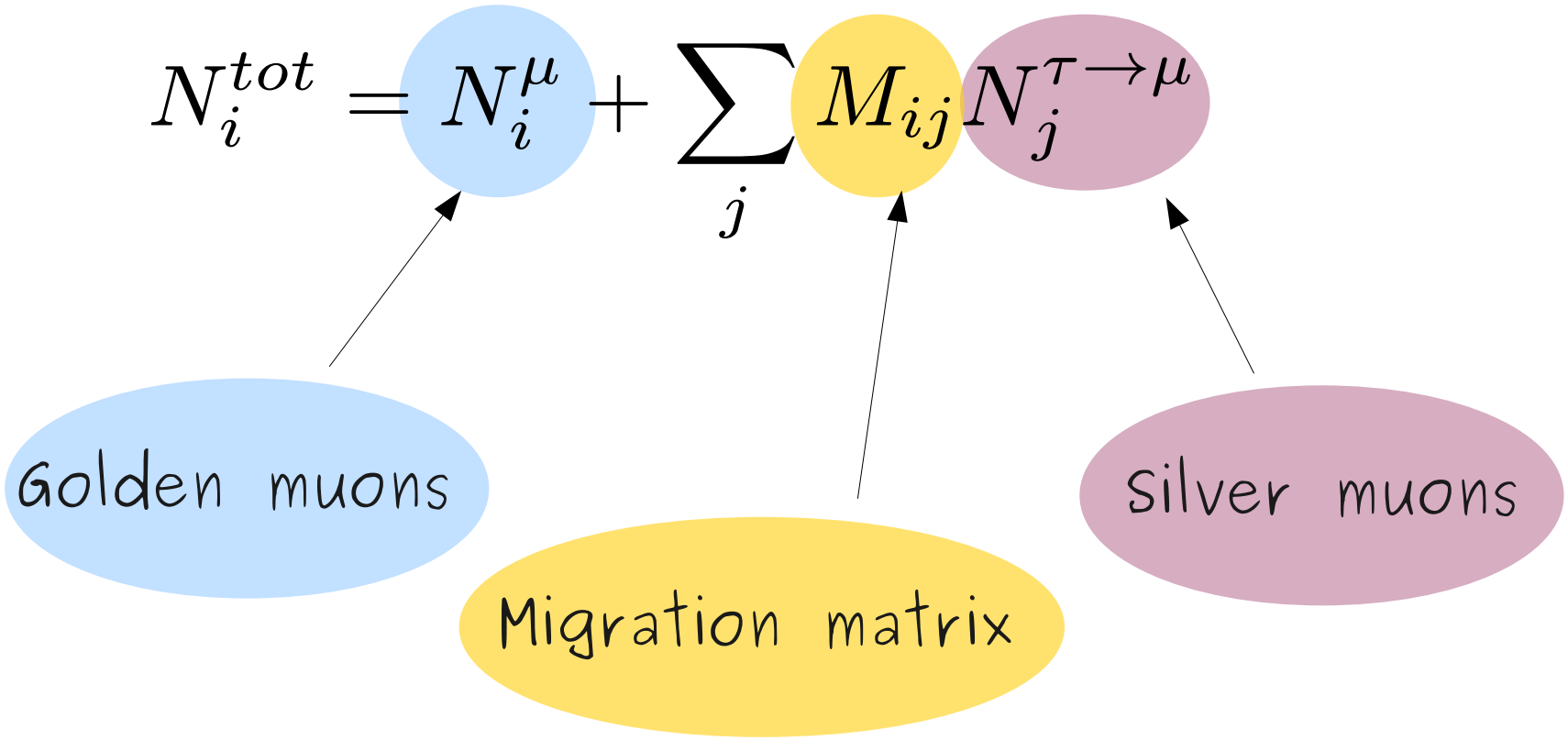

Can we fit the data now?

Fitting the data including the events coming from true contamination

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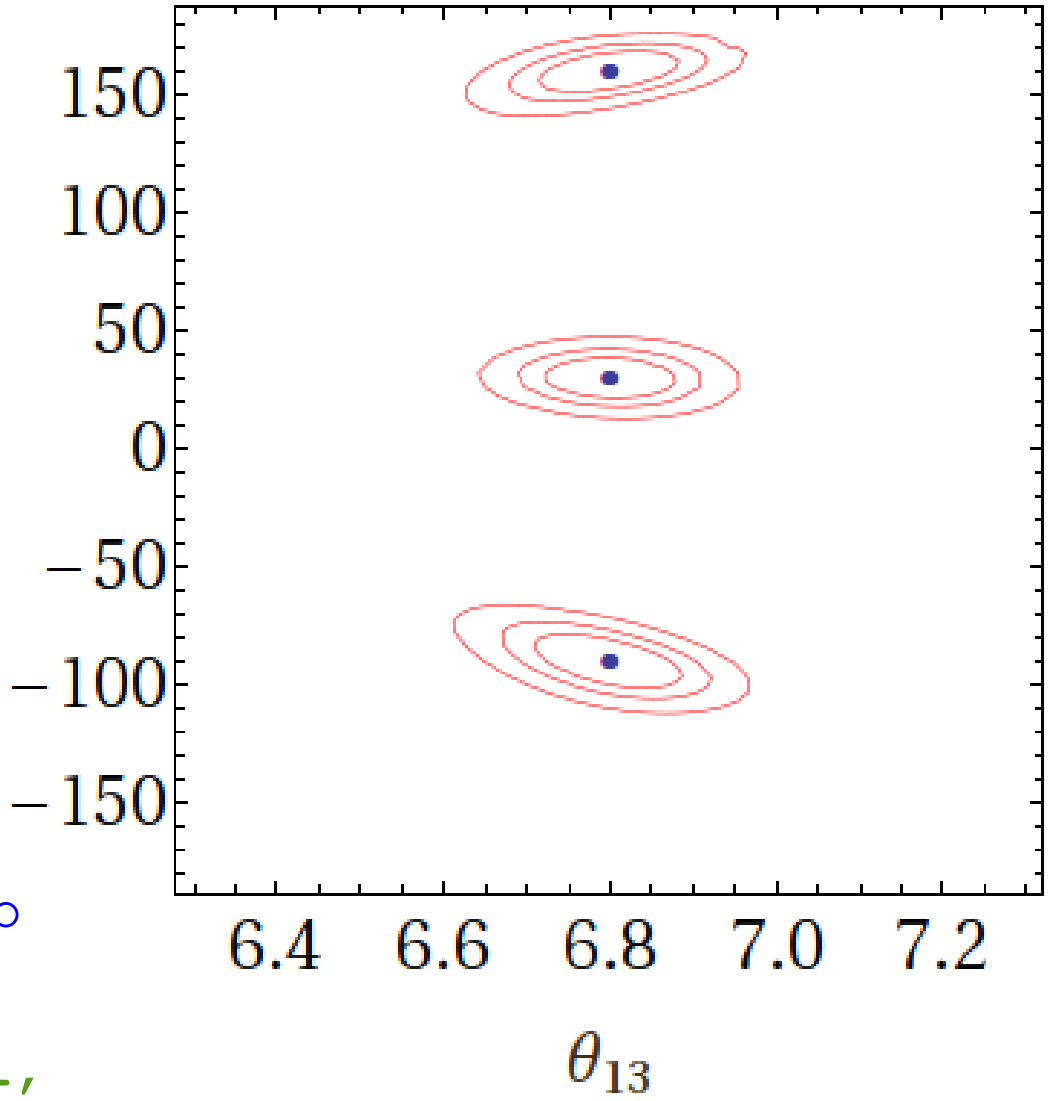

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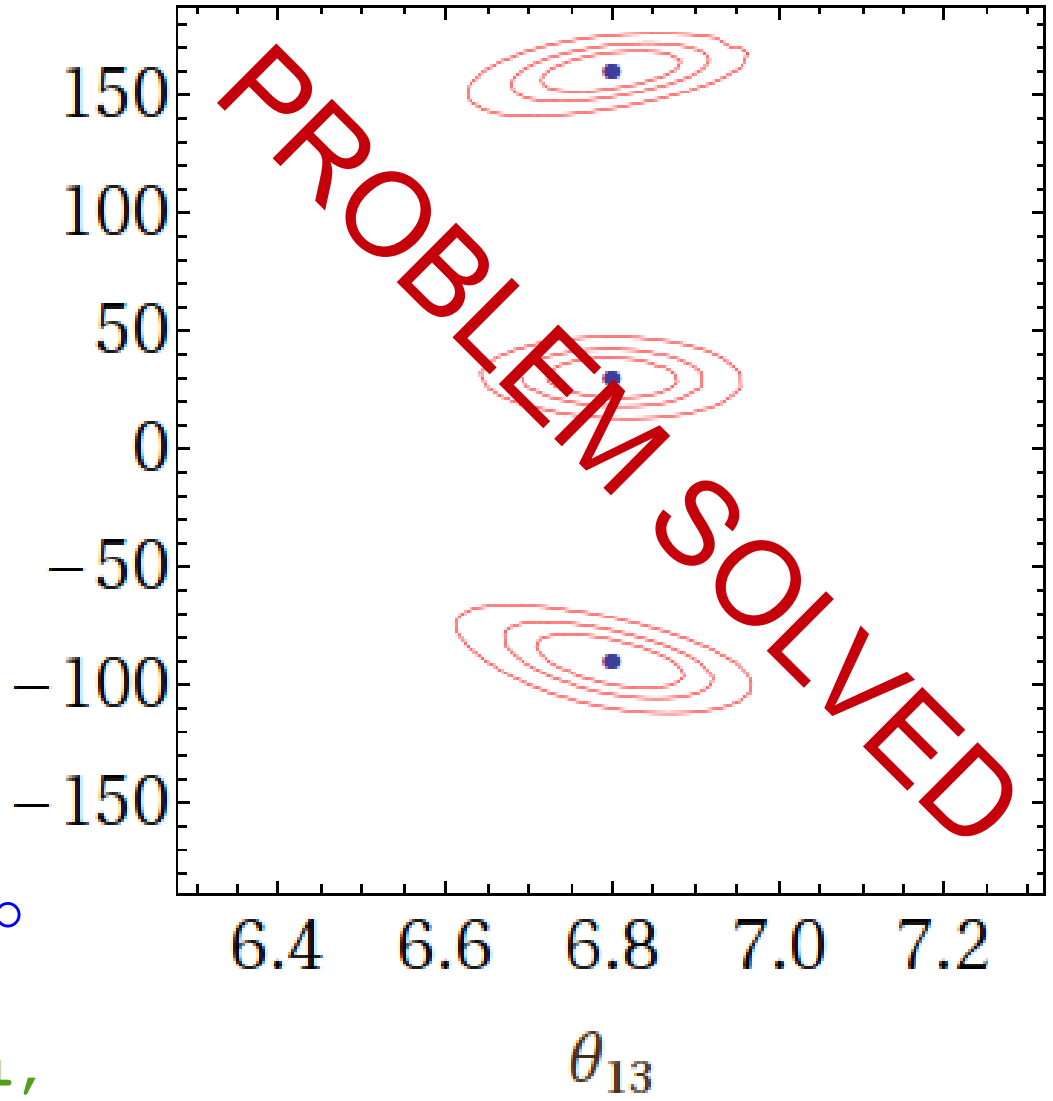
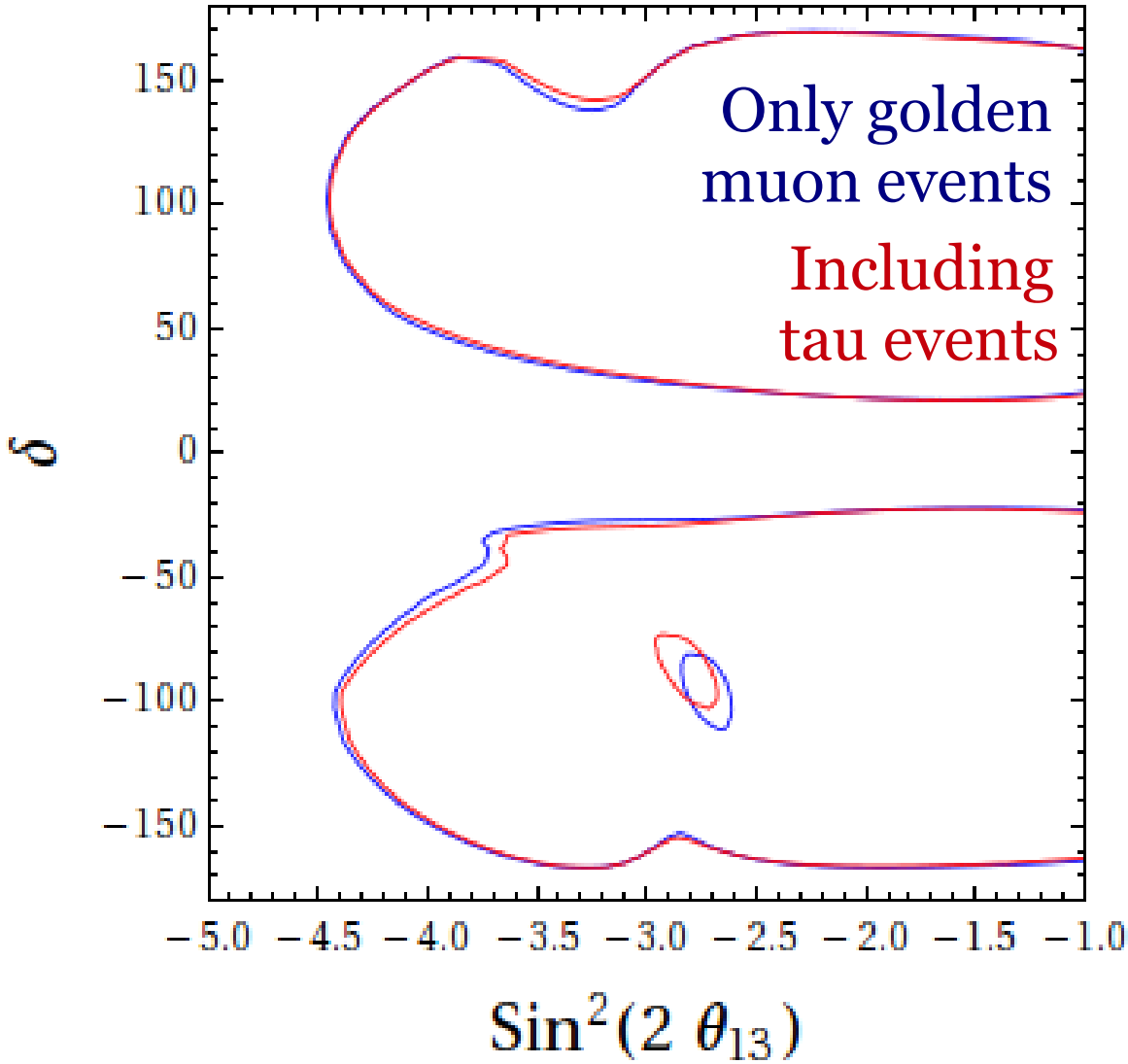


CP discovery potential

Mild effect on CP violation discovery potential

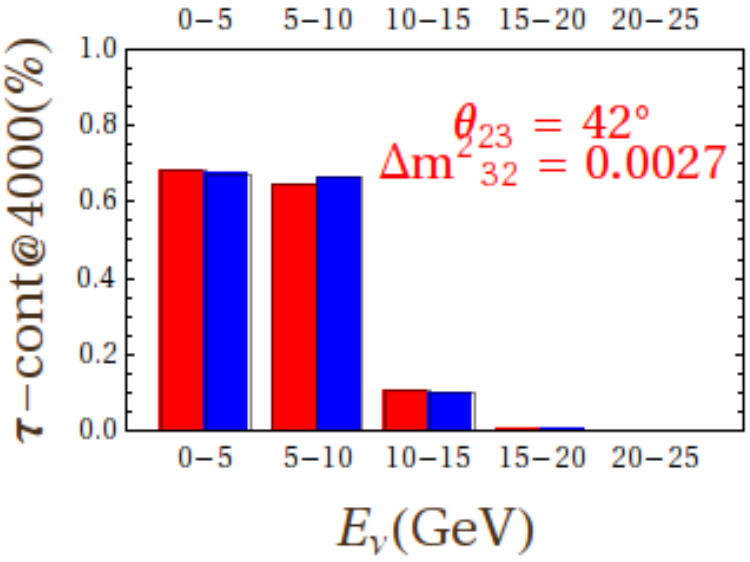


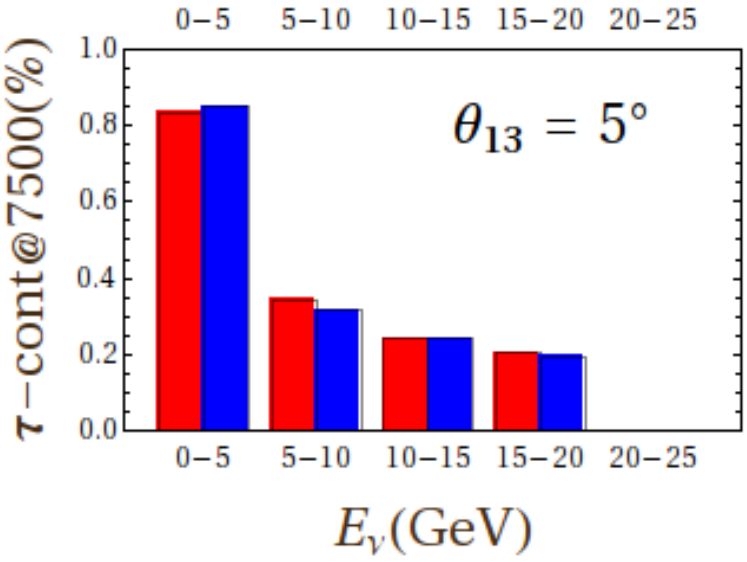
4000 +7500 km

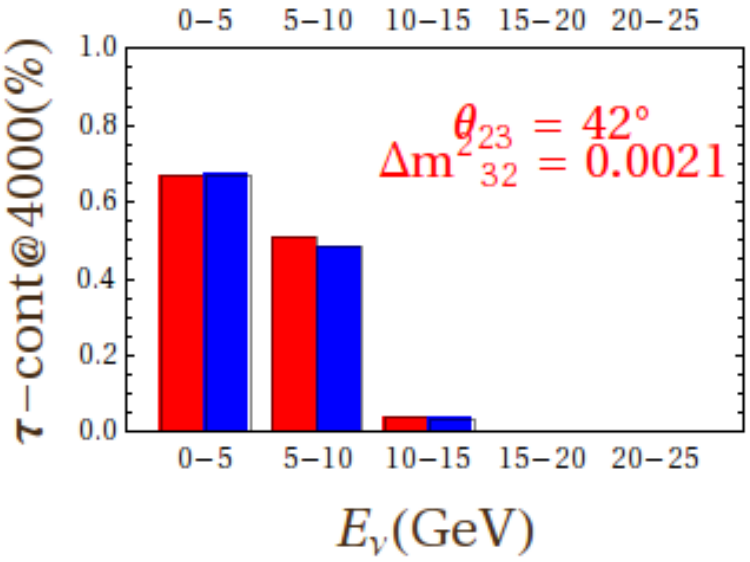
Some results on disappearance too…

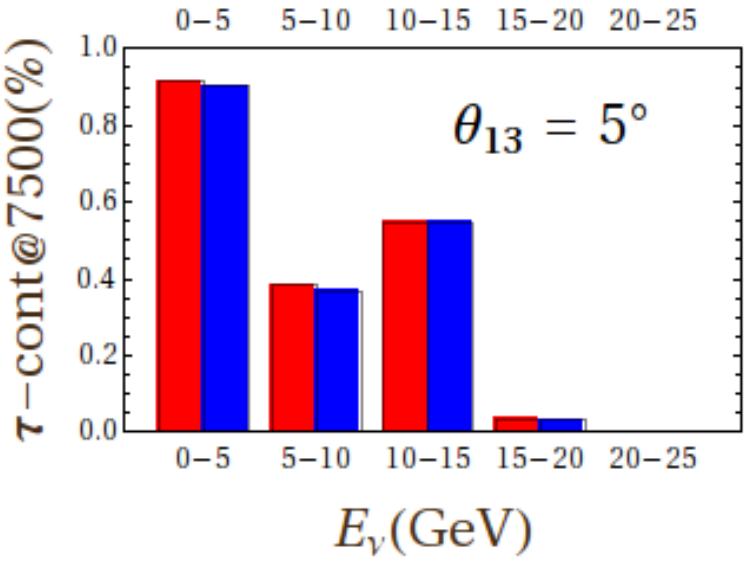
Work in progress:
P. Coloma, A. Donini, J.J. Gómez Cadenas, D. Meloni

Results on disappearance









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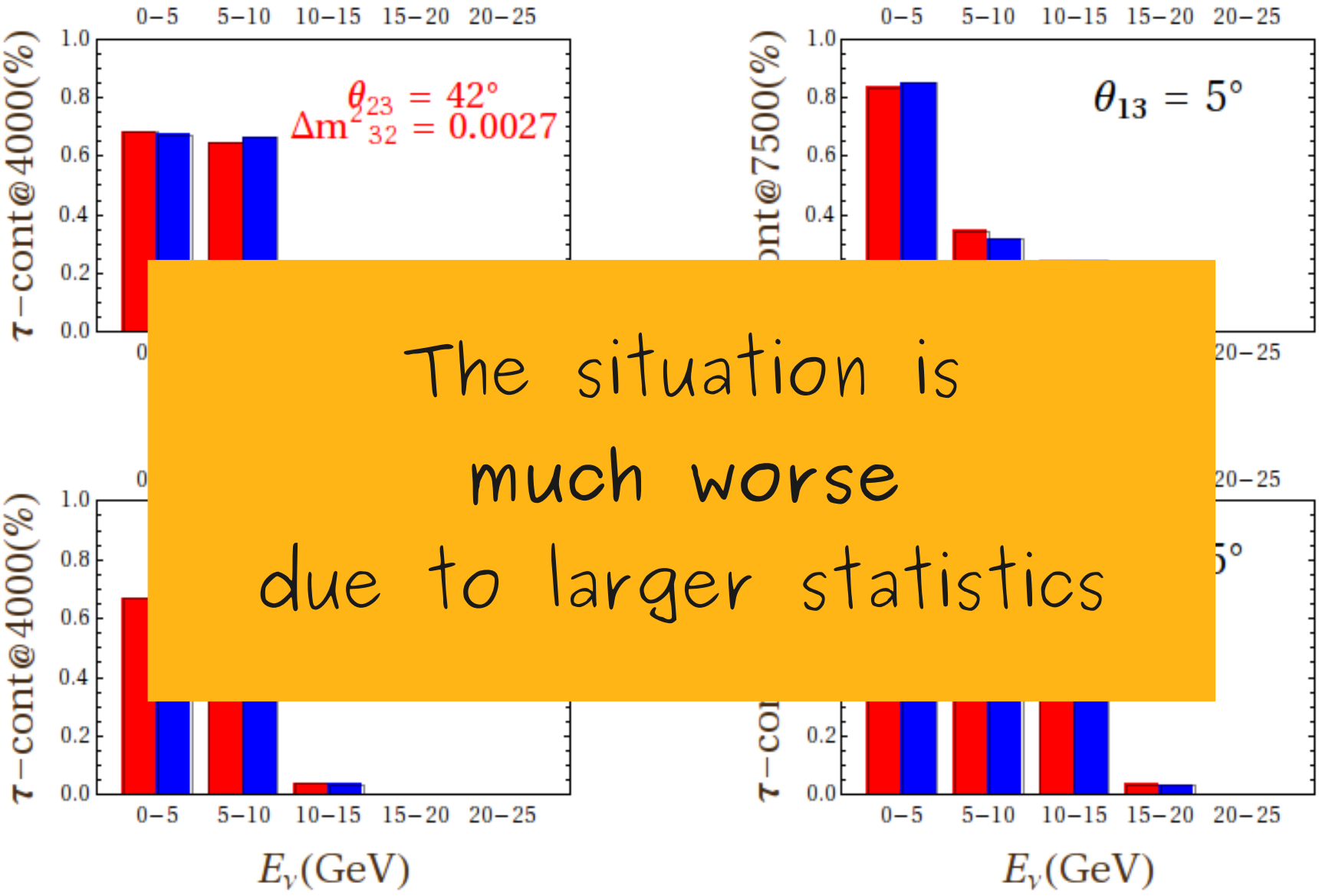
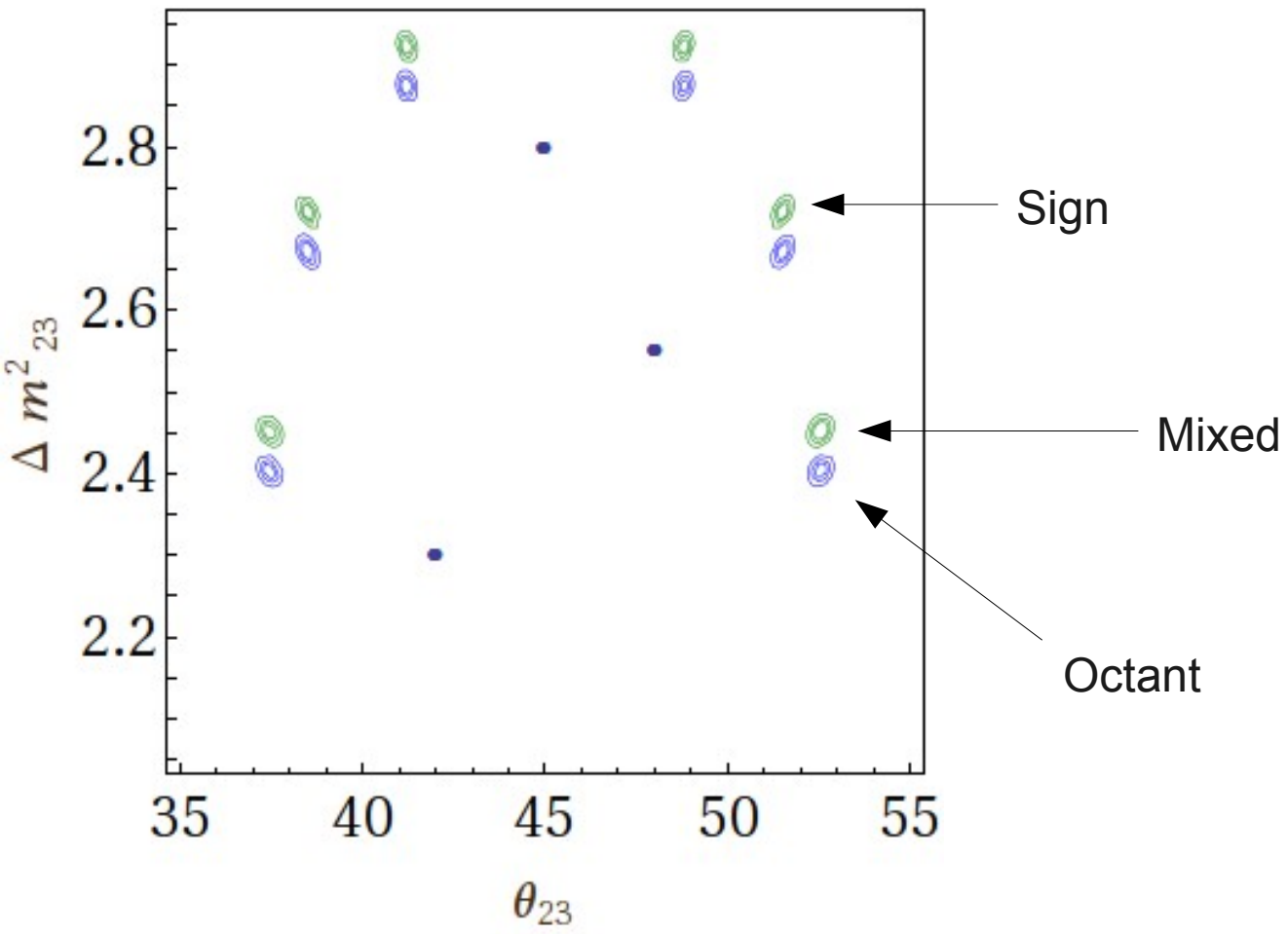


The situation is
much worse
due to larger statistics

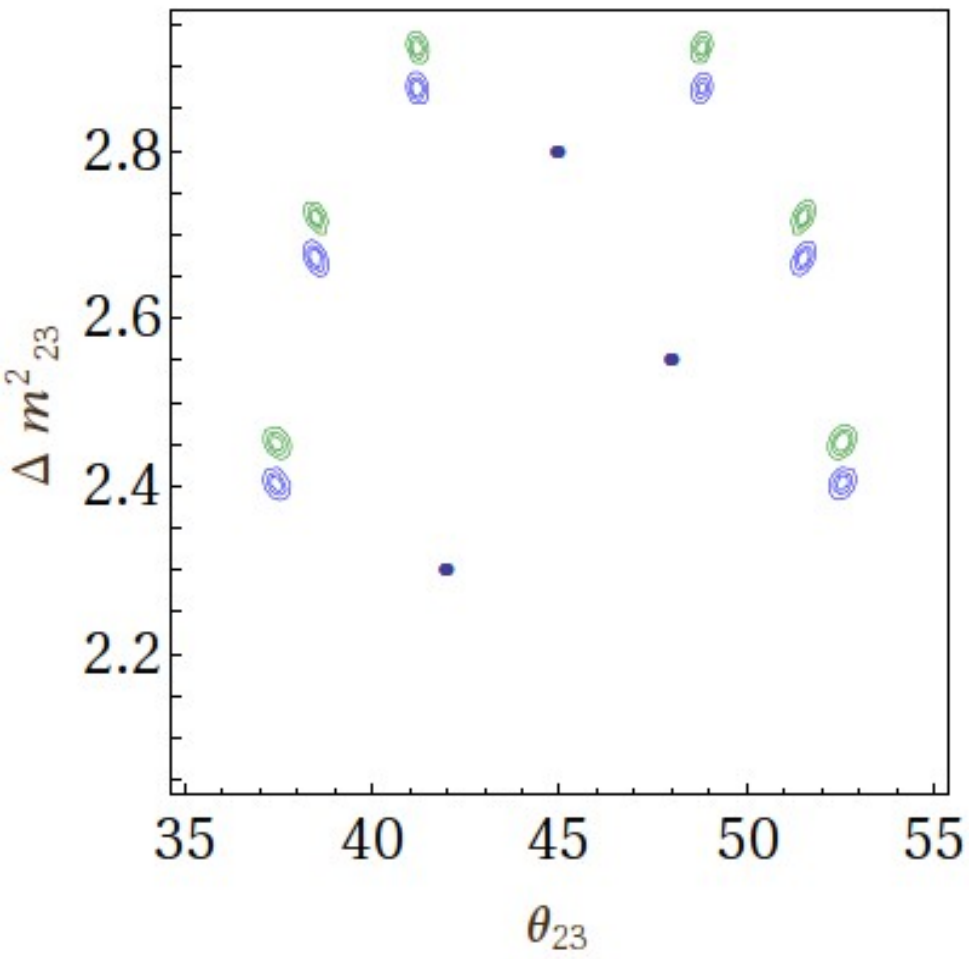
Results on disappearance

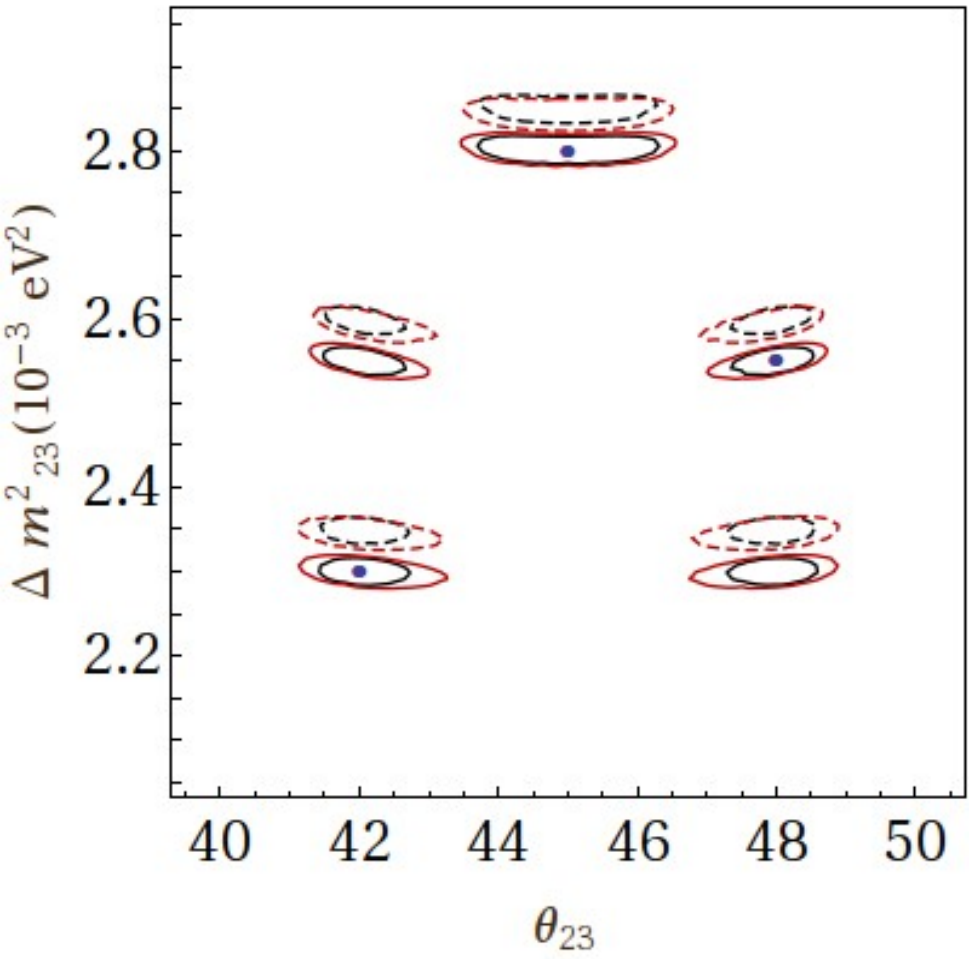


$\theta_{13} = 1^\circ$

4000 +7500 km

Results on disappearance





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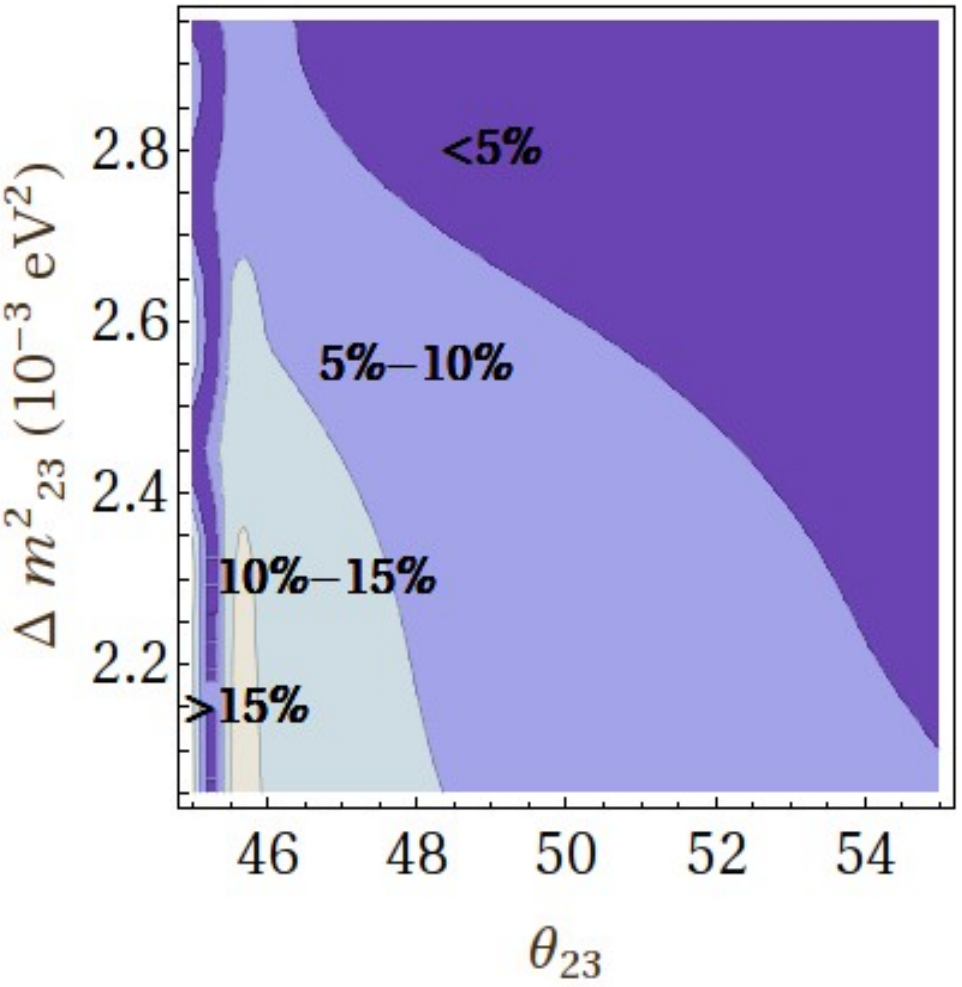

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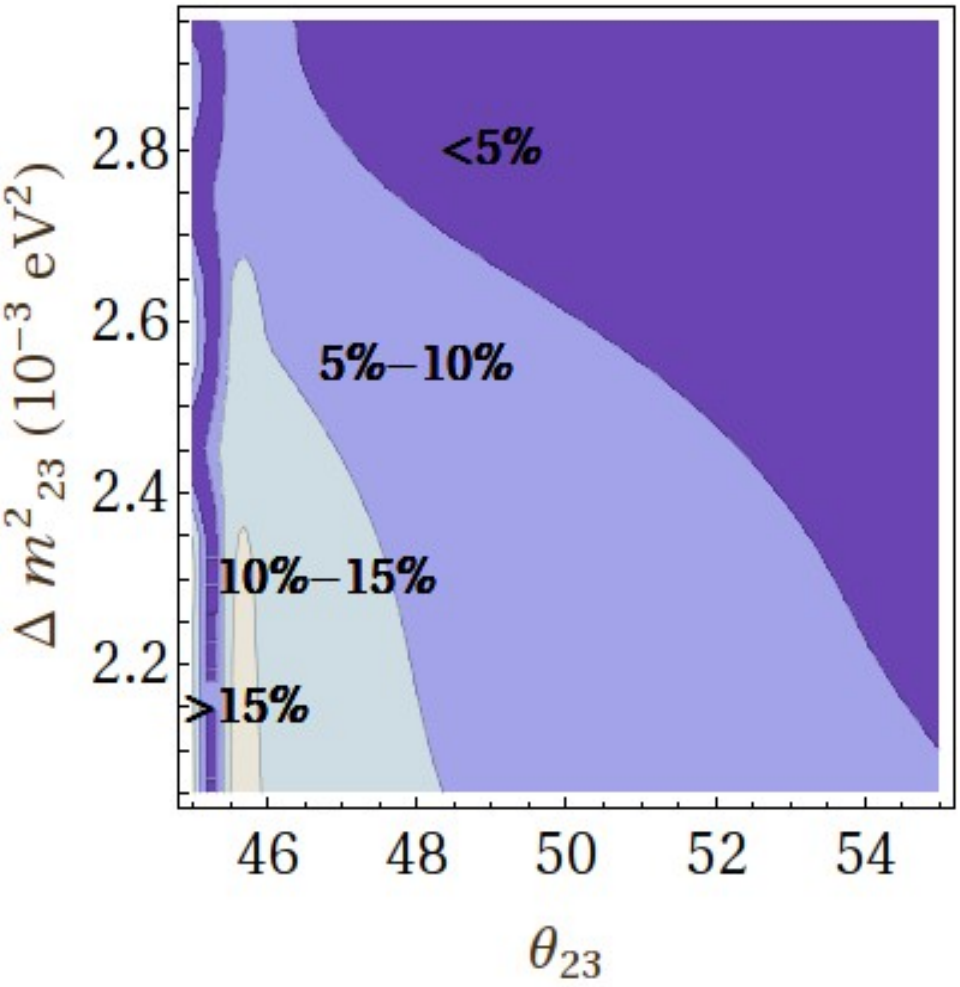

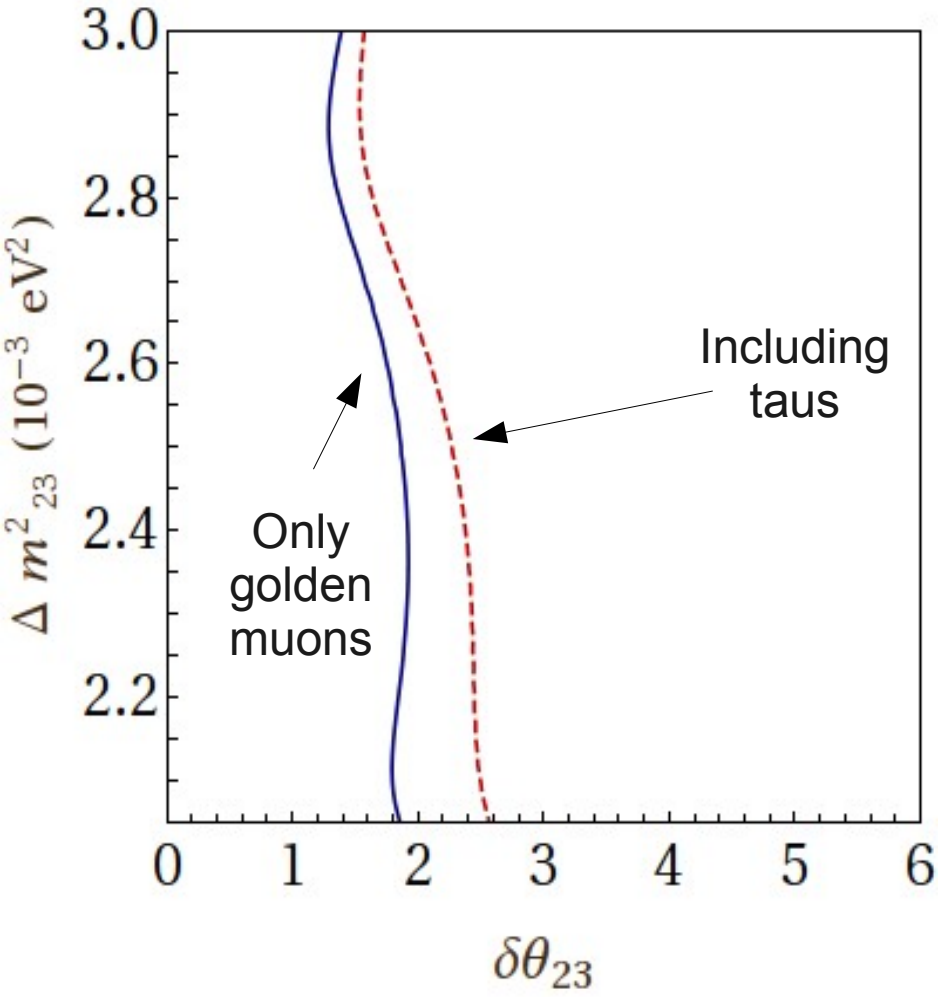

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Conclusions

- Wrong-sign muons from wrong-sign taus represent an unavoidable component of the signal at MIND
- Using the final muon energy: larger backgrounds
- Using the reconstructed neutrino energy, but not including this component, gives either:
  - An awful fit for $\theta_{13} > 5^\circ$
  - A wrong measurement of θ_{13}, δ (for $\bar{\theta}_{13} \in [1^\circ, 5^\circ]$)

Conclusions

- We have statistically computed the migration matrix that assigns muon-from-tau events corresponding to a given E_{ν_τ} to bins in fake E_{ν_μ}
- When theoretical distribution of expected events take into account this component, the problem is solved
- Situation is not much worsened due to tau-contamination for the golden channel, but it is for disappearance.
- We must include M_{ij} in GLoBES

BACKUP

How many of these will we have?