

Phenomenological studies of new physics

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Outline

- Why should we care?
- Flavour violation
- Unitarity tests
- Damping effects
- Summary

Disclaimer: This is not intended to be a review, just a few examples...

Why should we care?

If you believe there is new physics in neutrinos

- Neutrinos have already surprised us
- Neutrino mass seems to be closely related to GUT scale physics
- Neutrinos are much less constrained than other fermions
- If there are more surprises someone is going to Stockholm

Why should we care?

If you don't believe there is new physics in neutrinos

- Neutrinos have already surprised us
- Neutrino mass seems to be closely related to GUT scale physics
- Neutrinos are much less constrained than other fermions
- We want to measure the oscillation parameters
- If someone wants to go to Stockholm, there better should be no surprises

Flavour violation

- New four-point vertices
- can be (V-A), but also more general

Ota, Sato, Yamashita 2001

- CP conserving/violating

Gonzalez-Garcia, Grossman, Gusso, Nir 2001

Bounds on flavour violation

Stringents bound for charged leptons from the first and second family. No direct bounds for neutrino-only vertices, but elektroweak symmetry allows to put bounds on these, too. Typically one has in units of G_F :

$$\epsilon^\mu < \mathcal{O}(10^{-5}), \quad \epsilon^\tau < \mathcal{O}(10^{-2})$$

Vertices containing only ν_e and ν_μ can be very well tested by the near detector complex at a neutrino factory. But the ν_τ vertices remain a problem, even at a neutrino factory.

Davidson, Peña-Garay, Rius, Sanatamaria 2003

Flavour violation

Direct searches usually are sensitive to $\epsilon^2 \Leftrightarrow$
 oscillation enhanced searches are sensitive to ϵ via
 interference effects

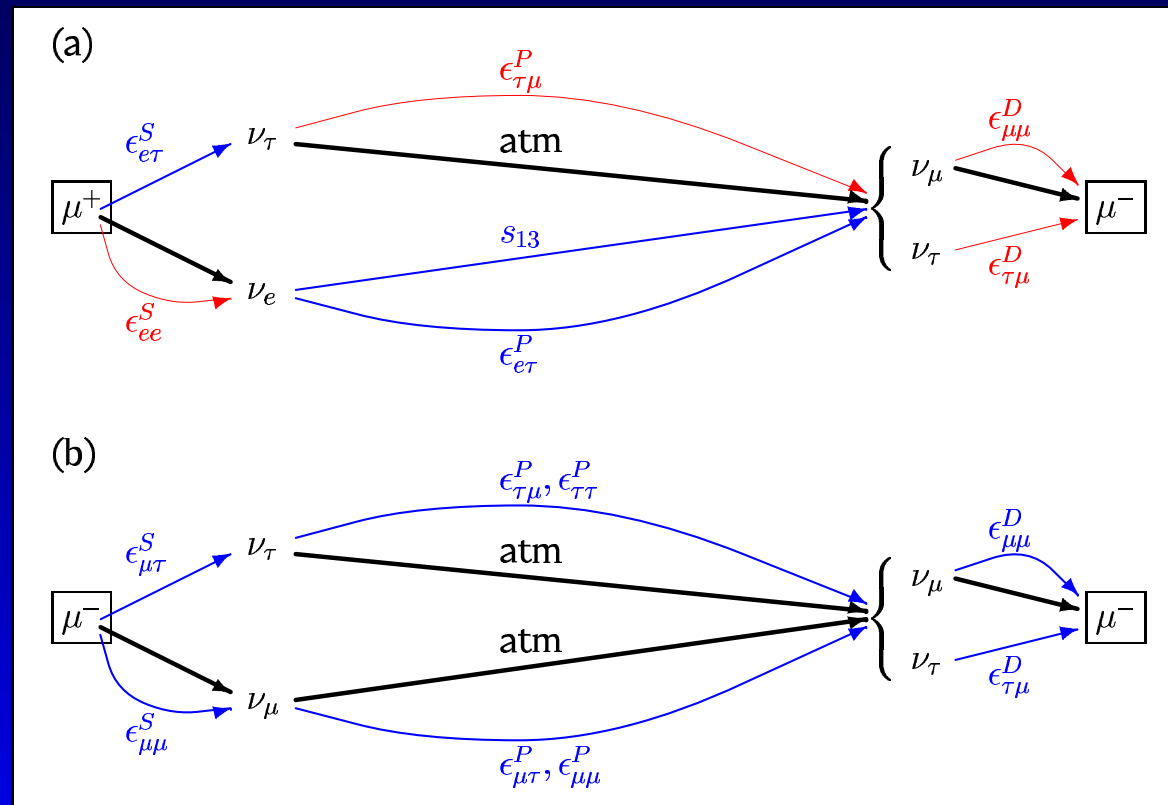
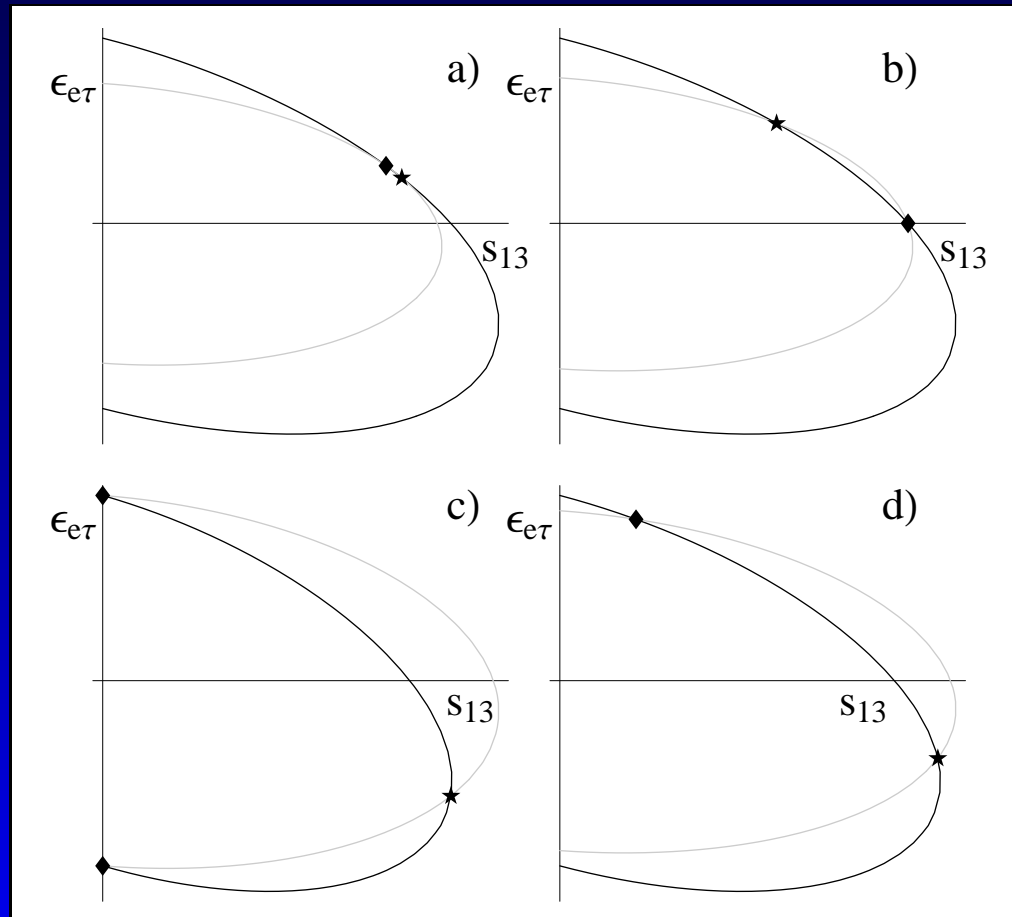


figure from Huber, Schwetz, Valle 2002

Flavour violation

The problem usually is that the new physics and θ_{13} can be both small and thus are very difficult to separate



Flavour violation – an example

The oscillation probability takes following form:

$$\mathcal{R} \sim A s_{13}^2 + B s_{13} \epsilon_P + C \epsilon_P^2 + D \epsilon_P \epsilon_S + E \epsilon_S^2 + F s_{13} \epsilon_S$$

it can be shown that

$$\mathcal{R}_{e\mu}^{NSI}(r \times \epsilon_P, \epsilon_P) = \mathcal{R}_{e\mu}^{osc}(s_{13})$$

for a specific choice of r , which only depends on ϵ_P , θ_{13} and θ_{23} .

Huber, Schwetz, Valle 2002

Flavour violation – an example

It was later shown that although $\mathcal{R}_{e\mu}^{NSI} = \mathcal{R}_{e\mu}^{osc}$ that the increase in $R_{e\tau}^{NSI}$ can be seen, even if only muons are visible in the detector, via the leptonic decay of τ .

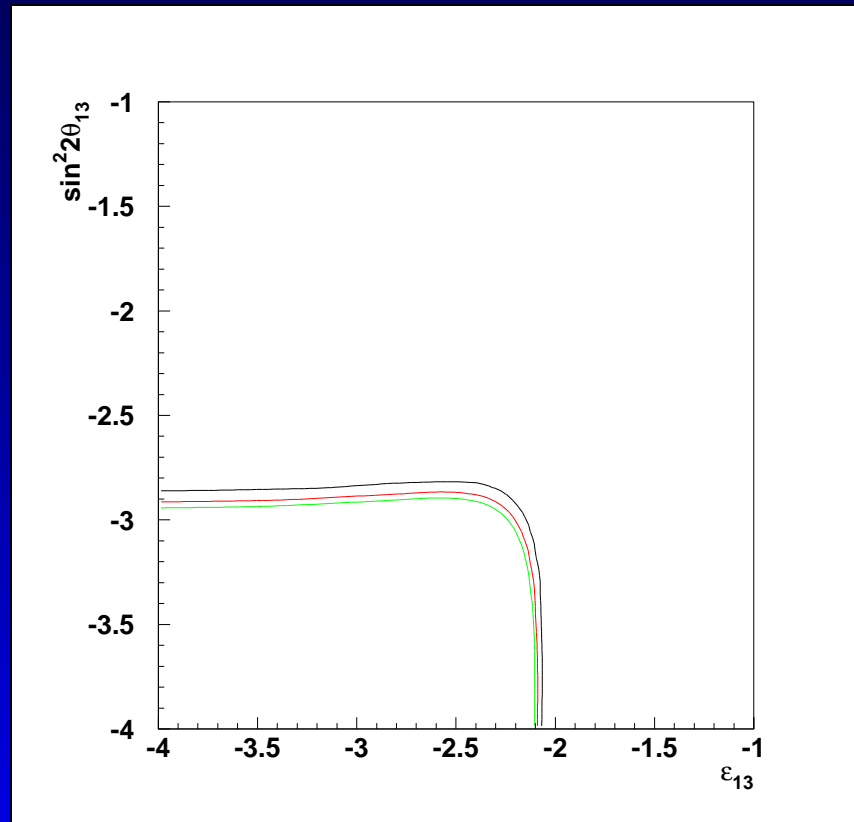


figure taken from Campanelli, Romanino 2002

Unitarity tests

If all flavour transitions we see in neutrino are described by a CKM-like mechanism with 3 active neutrinos, we have

$$P_{xe} + P_{x\mu} + P_{x\tau} = 1$$

There are two approaches to test this relation

- Measure P_{xe} , $P_{x\mu}$, $P_{x\tau}$ individually by charged current
- Measure $P_{xe} + P_{x\mu} + P_{x\tau}$ by neutral current

Unitarity tests – CC

- relatively simple to determine P_{xe} and $P_{x\mu}$,
- in principle can be done with the same detector
- Particle ID and x-sections may be the limit
- maybe \sim % level accuracy
- $P_{x\tau}$ is very hard to measure
- τ -ID is tough.
- requires a high-energy beam
- dedicated detector.

$\implies P_{x\tau}$ dominates the error budget.

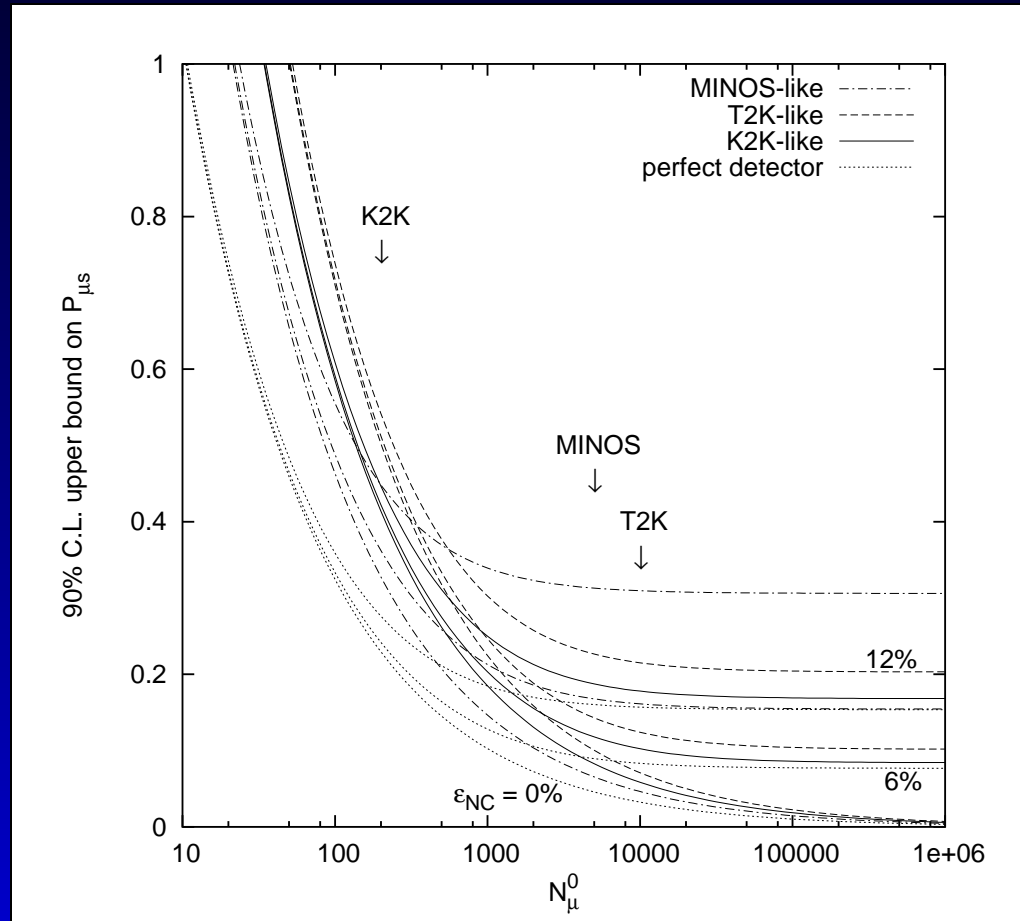
Unitarity tests – NC

- directly probes $P_{xe} + P_{x\mu} + P_{x\tau}$
- NC/CC confusion in the detector
- absolute NC x-section
- absolute flux
- fiducial volume

Unitarity tests – NC

Barger, Geer, Whisnant 2004

- $x = \mu$
- K2K
- T2K
- MINOS



Very difficult to achieve 1% unitarity test!

Damping signatures

Blennow, Ohlsson, Winter 2005

Neutrino decay, wave packet decoherence, oscillation to ν_s *asf.* may all alter the typical oscillatory energy dependence.

Those effects can be described by introducing quantities D_{ij} , which modify the oscillation probability in the 2-flavour limit like this

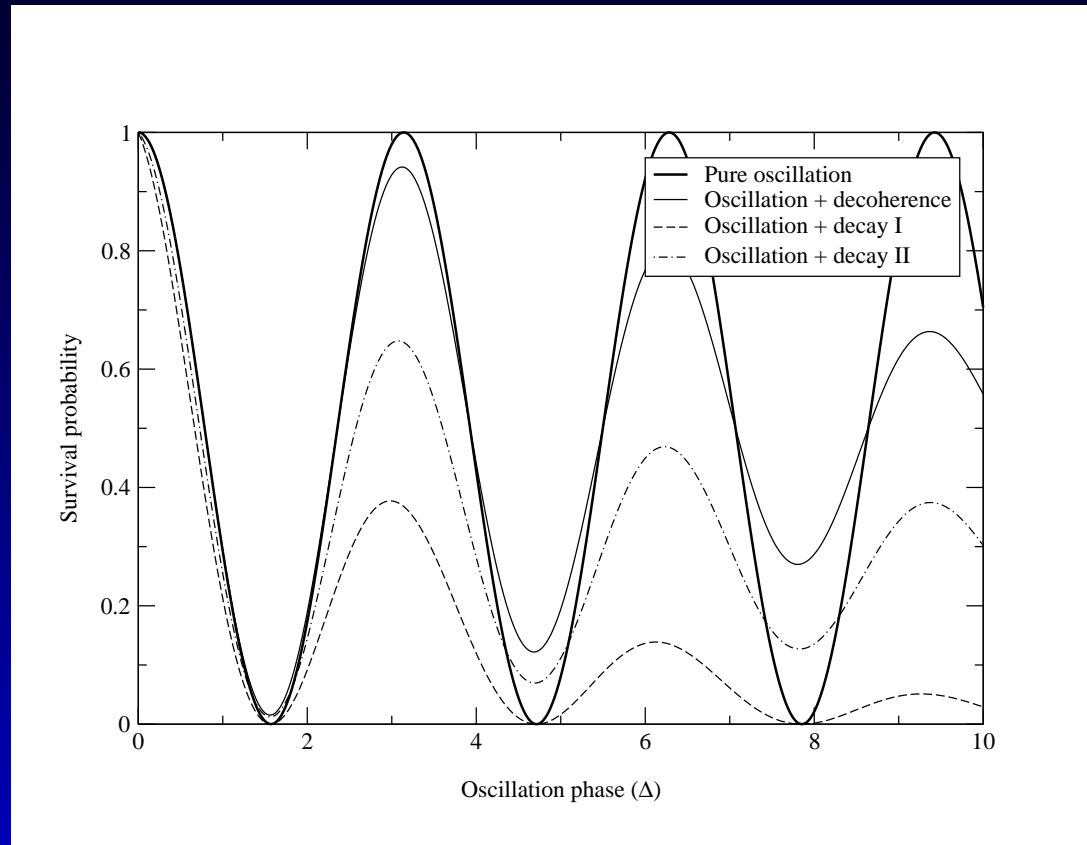
$$P_{\alpha\beta} = \frac{1}{4} \sin^2 2\theta [D_{11} + D_{22} - 2D_{21} \cos 2\Delta]$$

Damping signatures – examples

Blennow, Ohlsson, Winter 2005

Damping type	Signature D_{ij}	Unit for α
Wave packet decoherence	$\exp\left(-\sigma_E^2 \frac{(\Delta m_{ij}^2)^2 L^2}{8E^4}\right)$	MeV ² or GeV ²
Decay	$\exp\left(-\alpha \frac{L}{E}\right)$	GeV · km ⁻¹
Oscillations to ν_s	$\exp\left(-\epsilon \frac{L^2}{(2E)^2}\right)$	eV ⁴
Absorption	$\exp(-\alpha LE)$	GeV ⁻¹ · km ⁻¹
Quantum decoherence I	$\exp(-\alpha LE^2)$	GeV ⁻² · km ⁻¹
Quantum decoherence II	$\exp\left(-\kappa \frac{(\Delta m_{ij}^2)^2}{E^2}\right)$	eV ⁻²

Damping signatures – examples



Blennow, Ohlsson, Winter 2005

Difficult to distinguish different modes in the first oscillation maximum

Summary

- a number of studies
- most of them are not that recent
- leptonic CP violation or new physics?

Personal comments

- model independent – too many parameters
- specific model – effects usually small
- confounded by correlation of oscillation and new-physics parameters

Can we learn from B-physics?