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DUNE and CPT-violating neutrinos

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In this work we present bounds on CPT invariance using global neutrino oscillation data and then analyze how much DUNE could improve these bounds. We also find that if CPT is not conserved in nature, we are actually obtaining fake solutions for the neutrino oscillation parameters. To give a concrete example we show that, if the recent results from the T2K collaboration turn out to be the true values of neutrino and antineutrino oscillations, DUNE would measure CPT violation at more than 3σ. We also show that these results could not be obtained by neutrino non-standard interactions.

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1. Introduction and current bounds from neutrino oscillation experiments

CPT invariance is one of the most important predictions of local, relativistic quantum field theory. One of the predictions of CPT invariance is that particles and antiparticles have the same masses and, if unstable, the same lifetimes. Proving the CPT theorem requires only three ingredients: Lorentz invariance, Hermiticity of the Hamiltonian, Locality. Therefore, a violation would result in a huge impact on particle physics. Here we will see how well neutrinos can test the predictions of the CPT theorem by comparing neutrino and antineutrino oscillations. A different pattern would be an indication of CPT violation. To compute current bounds, we preform a global fit to neutrino and to antineutrino data [1] and then calculate $\chi^2(\Delta x) = \chi^2(|x - \bar{x}|) = \chi^2(x) + \chi^2(\bar{x})$, where x is any of the oscillation parameters. To calculate these bounds we use the same data as in version 1 of Ref. [2], excluding atmospheric data. The current 3σ bounds are summarized in Tab. 1. With the data considered here it is not possible to set any bound on $|\delta - \overline{\delta}|$, since all possible values of δ or $\overline{\delta}$ are allowed.

$\Delta(\Delta m^2_{21})$	$\Delta(\Delta m^2_{31})$	$\Delta \sin^2\theta_{12}$	$\Delta \sin^2\theta_{13}$	$\Delta \sin^2\theta_{23}$
$4.7 \times 10^{-5}\,\text{eV}^2$	$3.7 \times 10^{-4}\,\text{eV}^2$	0.14	0.03	0.32

Table 1: Current 3σ bounds on CPT violation in neutrino oscillation parameters.

2. Sensitivity to CPT violation at DUNE

To study the sensitivity of DUNE we can repeat the calculation of the previous section in the context of DUNE. We assume DUNE to run 3.5 years in both neutrino and antineutrino mode. The true values of the oscillation parameters are the ones in Tab. 2. Note that we consider three different values for the atmospheric angles. We obtain interesting results for $\Delta(\Delta m^2_{31})$ and $\Delta(\sin^2\theta_{23})$, as seen in Fig. 1. The different lines refer to the different assumed values of the atmospheric angle. Regarding mass splittings, DUNE can put stronger bounds, namely $\Delta(\Delta m^2_{31}) < 8.1 \times 10^{-5}\,\text{eV}^2$. For the atmospheric angle we obtain different results depending on the true value assumed in the simulation of DUNE data. The second minimum for the non-maximal values appears due to the octant degeneracy. Note that these curves have a maximum close to $\Delta \sin\theta_{23} \approx 0.08$. A difference of this size was obtained by T2K [3]. Performing an analyzes of DUNE assuming these parameters measured by T2K (different angle and mass splitting) DUNE could actually rule out $\Delta \sin\theta_{23} = 0$ at close to 5σ [1]. Note, that although matter effects can induce a fake CPT violation through NSI, in this special case DUNE could distinguish it from actual CPT violation [4].

Δm^2_{21}	Δm^2_{31}	$\sin^2\theta_{12}$	$\sin^2\theta_{13}$	$\sin^2\theta_{23}$	δ
$7.56 \times 10^{-5}\,\text{eV}^2$	$2.55 \times 10^{-3}\,\text{eV}^2$	0.321	0.0215	0.43/0.5/0.60	1.5π

Table 2: Oscillation parameters used to create the fake data in DUNE.

3. Imposter solutions

We have also shown, that if CPT is violated in nature, we can obtain fake solutions in our data analyzes. Assuming for example different values of the atmospheric angles in the fake data, but

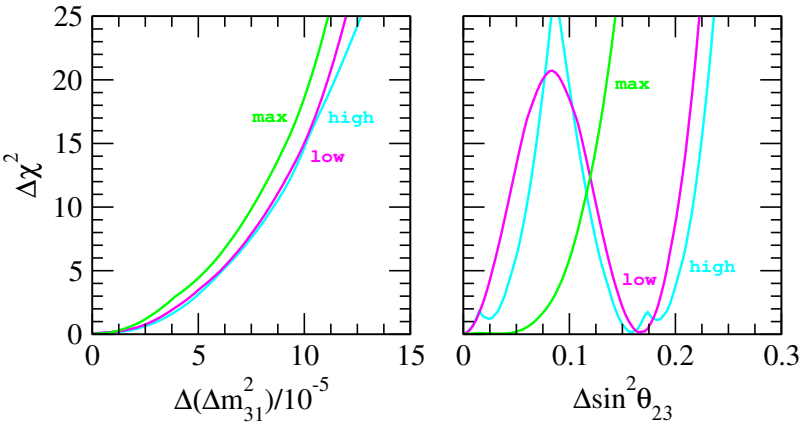

Figure 1: The sensitivity of DUNE to the difference of oscillation parameters.

analyzing the data in a CPT-conserving manner, we can create fake true values, as shown in Fig. 2. Here we see, that the combined analyzes excludes the true values at close to 3σ in one case and more than 5σ in the other.

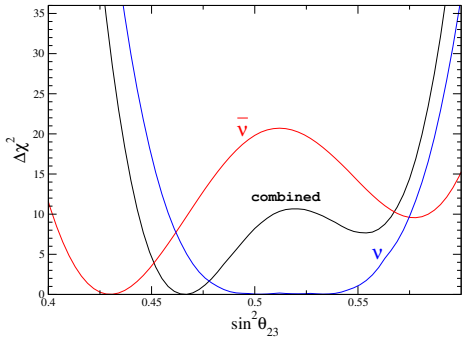

Figure 2: DUNE sensitivity to the atmospheric angle for neutrinos (blue), antineutrinos (red) and to the combination of both under the assumption of CPT conservation (black).

References

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