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## Probing nonstandard interactions with reactor neutrinos\*

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New limits on the weak mixing angle and on the electron neutrino effective charge radius in the low energy regime, below 100 MeV, are obtained from a combined fit of all electron-(anti)neutrino electron elastic scattering measurements. We have included the recent TEXONO measurement with a CsI (Tl) detector. Only statistical error of this measurement has been taken into account. Weak mixing angle is found to be  $\sin^2 \theta_W = 0.255^{+0.022}_{-0.023}$ . The electron neutrino effective charge radius squared is bounded to be  $\langle r_{\nu_e}^2 \rangle = (0.9^{+0.9}_{-1.0}) \times 10^{-32} \text{ cm}^2$ . The sensitivity of future low energy neutrino experiments to nonstandard interactions of neutrinos with quarks is also discussed.

### 1. Introduction

Current and future measurements of elastic neutrino scattering off electrons and quarks in reactor and accelerator experiments are getting more and more precise. This opens a possibility to search for possible nonstandard neutrino interactions (NSI) in such experiments.

Nonstandard neutrino interactions with quarks and electrons are still allowed to be rather large. It was shown recently that coherent neutrino nuclei scattering is a very sensitive probe to NSI [1, 2]. The sensitivity to some specific NSI models, such as extra heavy neutral gauge bosons, leptoquarks, supersymmetry with broken R-parity, could be better than present constraints and,

therefore, could give complementary bounds to future LHC limits [2].

Here we focus on the NSI effects in neutrino detection at low energies [1–5]. We will present the limits on the weak mixing angle,  $\sin^2 \theta_W$ , and on the electron neutrino effective charge radius,  $\langle r_{\nu_e}^2 \rangle$ , obtained from the combined analysis of all available low energy (anti)neutrino-electron elastic scattering experiments including recent  $\nu$ - $e$  cross section measurement by TEXONO [6].

### 2. Weak mixing angle and effective electron neutrino charge radius

The straight-forward definition of a neutrino charge radius in the Standard Model has been proved to be gauge-dependent and, hence, unphysical. There have been discussions in the literature on the possibility to define and to calculate a physically observable neutrino charge radius [7–10]. All relevant references can be found in Ref. [4] and in the recent review [11]. A more general interpretation of the experimental results which we adopt here is that they are limits on cer-

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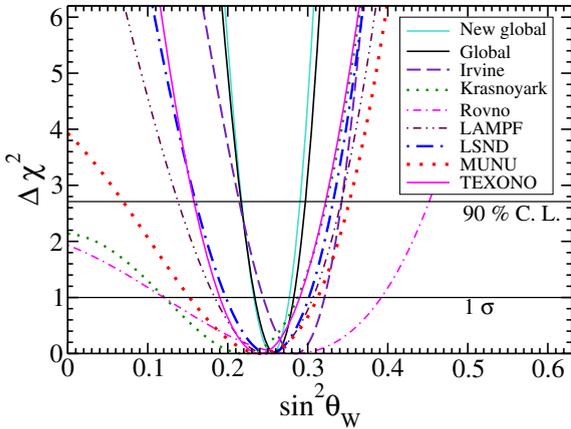


Figure 1.  $\chi^2$  fits of the weak mixing angle for various experiments are shown. “New global” means with TEXONO 2008, while “global” means without TEXONO 2008.

tain nonstandard contributions to neutrino scattering.

All available data of the (anti)neutrino-electron scattering from the following reactor and accelerator experiments were analyzed: first measurement of neutrino-electron scattering made by Reines, Gurr and Sobel (Irvine), the Kurchatov institute group at the Krasnoyarsk reactor, the group from Gatchina at the Rovno reactor, MUNU at the Bugey reactor, recent TEXONO measurement [6], LAMPF and LSND. All references to the experimental data used in the analysis are given in Ref. [4], except the recent talk by the TEXONO Collaboration at the ICHEP 2008 Conference [6]. The measurement presented by TEXONO Collaboration was obtained using CsI(Tl) detector at Kuo-Sheng Nuclear Power Plant in Taiwan [6]

$$\sin^2 \theta_W = 0.24 \pm 0.05 \text{ (stat)}. \quad (1)$$

We would like to note that only statistical error was presented by now, therefore our new global limits should be considered as the preliminary ones.

The data of (anti)neutrino-electron scattering experiments listed above were used (see Figure 1 and 2) to obtain a new limit on the weak mixing angle with better than 10% precision at energies

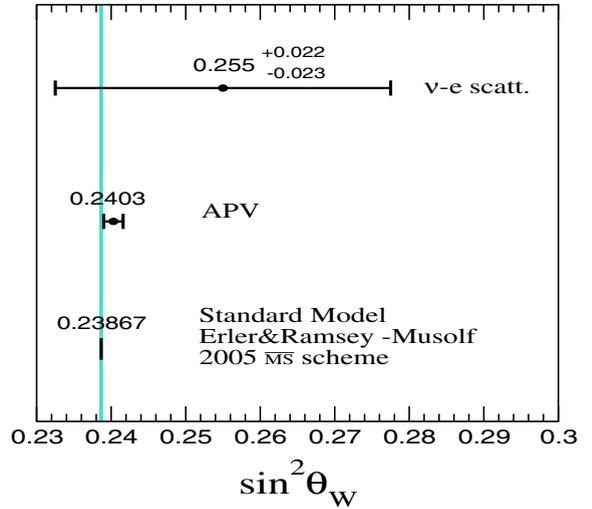


Figure 2. The weak mixing angle in low energy regime below 100 MeV is shown. For comparison the atomic parity violation (APV) measurement [13] and the Standard Model prediction [16] are also presented.

below 100 MeV

$$\sin^2 \theta_W = 0.255^{+0.022}_{-0.023}. \quad (2)$$

This limit slightly improves our previously published result obtained in Ref. [4] due to the inclusion of recent TEXONO 2008 measurement with CsI(Tl) detector [6]. It is not competitive with the current best measurements at low energies of the atomic parity violation [13] and of the Møller scattering by SLAC E158 [14], both experiments have a precision better than 0.5%. However, it is derived from a different channel and it could therefore give new information about other effects, such as the electron neutrino effective charge radius.

This value of the weak mixing angle, Eq. (2), and the Standard Model prediction [16]

$$\sin^2 \theta_W = 0.23867 \pm 0.00016 \quad (3)$$

were used to set a new limit to the electron neutrino effective charge radius squared

$$\langle r_{\nu_e}^2 \rangle = (0.9^{+0.9}_{-1.0}) \times 10^{-32} \text{ cm}^2. \quad (4)$$

This result improves previous bounds [15,4]. We

remind that only statistical error for the TEXONO measurement [6] was taken into account.

One can conclude, that from the measurement of the weak mixing angle with 1% precision it is possible to find a strong evidence for the electron neutrino charge radius, which is estimated theoretically to be of the order of  $0.4 \times 10^{-32} \text{ cm}^2$  [7–9].

### 3. Neutrino-quark NSI

We have demonstrated that neutrino coherent scattering off nuclei has a lot of potential to make precision tests of new physics, in particular, to probe NSI [1,2] that naturally appear in many extensions of the Standard Model. A new experiment would be able to test large NSI parameters and therefore may exclude new solutions to the solar neutrino data [12].

As concrete proposed experiments, we have discussed [2]: TEXONO [17], the stopped pion source with a noble gas detector [18] and the beta beams [19]. We would like to note that currently there are other experimental proposals [20], which are not covered by our analysis.

### 4. Summary

The weak mixing angle with precision better than 10% at energies below 100 MeV was obtained using all (anti)neutrino electron scattering measurements. To get this result the combined set of all available data from accelerator (LSND and LAMPF) and reactor (Irvine, Rovno, Krasnoyarsk, MUNU and TEXONO) experiments was used. This analysis was also applied to set a new limit to the electron neutrino effective charge radius squared which improves previous bounds.

We have discussed that neutrino coherent scattering off nuclei has a lot of potential to make precision tests of new physics, in particular, to test nonstandard neutrino-quark interactions.

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