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IS IT POSSIBLE TO TEST THE LSND PARAMETERS AT REACTORS?

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This report describes a part of the programme that was reported at the conference NANPino 2000. We propose a two-detector experiment at Krasnoyarsk for studying small mixing parameters at atmospheric neutrino mass range. As a first stage we consider here an experiment with two much smaller detectors that can test the LSND region. In the framework of our programme we also study the reactor antineutrino energy spectrum.

Доклад является частью нашей программы по поиску осцилляций на реакторе, которая уже докладывалась на конференции NANPino-2000. Мы предлагаем провести эксперимент в Красноярске с использованием двух детекторов для изучения малых параметров смешивания в области масс атмосферных нейтрино. В качестве первого шага мы рассматриваем эксперимент с детекторами, меньшими по размерам, который мог бы проверить области параметров LSND. В рамках нашей программы продолжается исследование и энергетического спектра антинейтрино от ядерного реактора.

INTRODUCTION

Today we have at least three evidences of neutrino oscillations [3–5] or the so-called hints on existing the neutrino mass. They are listed in Table 1. This requires four neutrino types. One of them is sterile [3].

Table 1. **Mass oscillation parameters**

Source of ν	Δm^2, eV^2
Solar [3]	$\sim 10^{-5}$
Atmospheric [4]	$\sim 10^{-3}$
Accelerator (LSND) [5]	~ 1

The first two mass parameters in Table 1 are well known and physicists believe them. The problem is in the third. The LSND experiment gives enough wide region for oscillation parameters $0.2 \leq \Delta m^2 \leq 0.6$ eV^2 at the level of Bugey3 limitations at $\sin^2 2\theta \approx 0.02$.

Are the LSND parameters real or not? Is it possible to test them in another experiment, for example, at reactors? Below we consider some aspects of detecting neutrino in a reactor experiment.

1. REACTOR EXPERIMENT

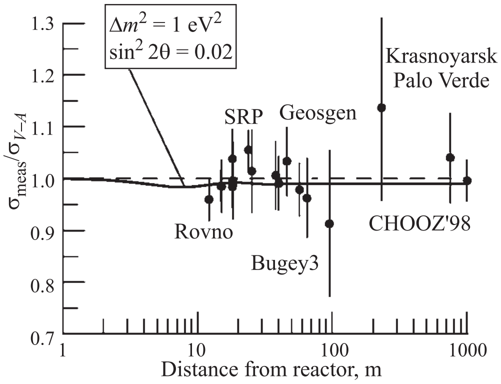

Fig. 1. Experimental ratios of measured to expected cross sections for inverse beta-decay reaction as a function of distance

Usually at reactors one can measure cross section of $\bar{\nu_e} p$ reaction (1).

$$\bar{\nu_e} + p \rightarrow n + e^+. \quad (1)$$

The cross section is measured through registration of positrons and neutrons that are products of this reaction. So one can get a positron energy spectrum that is a convolution of neutrino energy spectrum $\rho(E)$ and differential cross section $\sigma(E)$

$$S_e(T) = \int \rho(E)\sigma(E)\epsilon R(E,T)dE, \quad (2)$$

where ϵ is registration efficiency and $R(E,T)$ is a response function of the detector. After measuring the energy spectrum of positrons it is easy to calculate the cross section of reaction (1) by integrating e^+ spectrum $S_e(T)$

$$\sigma_{\nu p} = \int S_e(T)dT. \quad (3)$$

Then measured values of cross section and/or positron spectrum may be compared with the expected ones in no-oscillation case.

In Fig. 1 one can see the ratios of measured and expected values of cross sections in numerous experiments at a different distances from the reactor core. They can be easily described by LSND parameters.

In Fig. 2 the ratios of spectra at two distances from reactor obtained in two experiments (Bugey3 [6], Rovno [7]) are shown. The solid line in the figure is calculated ratios of spectra at the same distances with appointed parameters. It is well seen that LSND parameters also satisfy these experimental results. So we can conclude that existing reactor oscillation experiments do not exclude completely oscillations in LSND mass parameter region. Oscillation parameters that are the best fits of experiments at reactors are presented in Table 2.

Table 2. **Oscillation parameters as fits of experimental spectra ratios**

Experiment	Δm^2, eV^2	$\sin^2 2\theta$
Geosgen, 1986 [8]	0.88	0.1–0.06
Rovno, 1987 [7]	0.9	0.09
Bugey3, 1995 [6]	0.45–1.6	0.03–0.09
ILL, revised in 1995 [10]	2.2	0.48–0.2
SRP, 1996 [9]	3.84	0.085

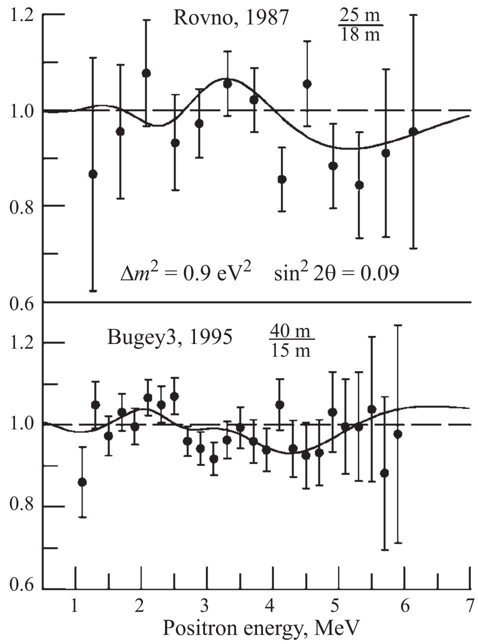

Fig. 2. Experimental ratios of positron spectra from two experiments [6, 7]. The solid line in the figure is calculated ratios of spectra at the same distances with appointed parameters

2. PROPOSED EXPERIMENT

The goal of proposed in this article new experiment at Krasnoyarsk reactor is an attempt to test directly the parameters of LSND. We propose to measure the positron spectrum from reaction (1) simultaneously by two identical detectors located at distances 20 and 35 m from a reactor. Each detector consists of three parts. The central volume is filled with liquid scintillator on the base of mineral oil about 3 tons in mass. It is surrounded by buffer volume of pure mineral oil. Both volumes are viewed by photomultipliers and all this construction is immersed in oil active veto shielding.

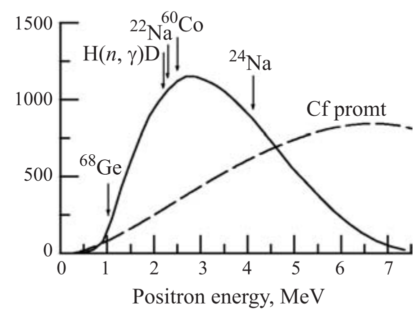

Fig. 3. Sources for detector calibrations. The solid line is the positron energy spectrum, the dashed line is the spectrum generated by Cf source

In no-oscillation case the ratio of two simultaneously measured positron spectra is energy independent. Small deviations from the constant value are searched for oscillations. The measured ratio is also independent of the exact knowledge of reactor antineutrino flux and energy spectrum, burn up and the reaction cross section, the numbers of the target protons, etc. But the difference in detector characteristics should be controlled. For this purpose we plan to do necessary calibration during the data taking. As control ratio we plan to use the spectrum of prompt gamma-rays of ^{252}Cf. This spectrum and the spectrum of positrons is shown in Fig. 3. The arrows indicate the energy position of calibration sources.

3. EXPECTED RESULTS AND CONCLUSIONS

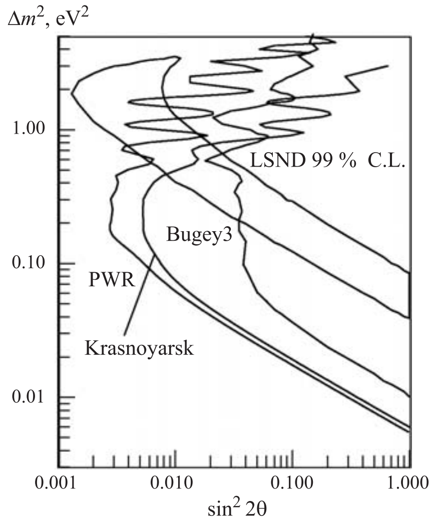

Fig. 4. Limits on oscillation parameters and LSND (99 % C.L.) parameter region

The expected rates of detecting neutrino events at 20 and 35 m are $\sim 5 \cdot 10^3\ \mathrm{d}^{-1}$ and $1.5 \cdot 10^3\ \mathrm{d}^{-1}$, respectevely. So one can achieve statistics about 3 million events at 20 m and 1 million at 35 m during two years of data taking time. It will give statistical uncertainty less than 0.5 %. We expect also to acheive sysematic uncertainty of about 0.5 % using calibration procedures described above.

There were done some Monte Carlo calculations of positron spectra accounting the finite reactor and detector dimensions. Using this spectra we have calculated expected limits on oscillation parameters. They are shown in Fig. 4. In mass parameter region heigher than 1 eV^2 there is strong influence of reactor dimensions. The same procedure was used to calculate a parameter limits with another reactor type (PWR). It is shown also in the same figure.

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REFERENCES

1. *Mikaelyan L.A.* // Talk at this Conference.
2. *Kopeykin V.I., Sinev V.V.* // Talk at this Conference.
3. *Bilenky S.M., Guintu C., Grimus W.* // Eur. Phys. J. C. 1998. V.1. P.247;
   Bilenky S.M. et al. // Phys. Rev. D. 1999. V.60. P.073007.
4. *Fukuda Y. et al. (Super-Kamiokande Collab.)* // Phys. Lett. B. 1998. V.436. P.33.
5. *Athanassopoulos C. et al. (LSND Collab.)* // Phys. Rev. Lett. 1998. V.81. P.1774.
6. *Achkar B. et al.* // Nucl. Phys. B. 1995. V.434. P.503.
7. *Afonin A.I. et al.* // JETP Lett. 1987. V.45. P.247.
8. *Zacek G. et al.* // Phys. Rev. D. 1986. V.34. P.2621.
9. *Greenwood Z.D. et al.* // Phys. Rev. D. 1996. V.53. P.6054.
10. *Hoummada A. et al.* // Appl. Radiat. Isot. 1995. V.46. P.6.