110 руб.

Индекс 3649

П Р Е П Р И Н Т 94-34, И Ф В Э, 1994

INSTITUTE FOR HIGH ENERGY PHYSICS

IHEP 94-34

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ON POSSIBILITY TO STUDY NEUTRINO OSCILLATIONS BY DETECTORS LOCATED AT GRAN SASSO (ITALY) USING BEAMS FROM 600 GeV UNK-1 MACHINE

Protvino 1994

UDK 539.123 M-24

Abstract

Fedotov Yu.S., Garkusha V.I., Gershctein S.S. et al. On Possibility to Study Neutrino Oscillations by Detectors Located at Gran Sasso (Italy) Using Beams from 600 GeV UNK-1 Machine: IHEP Preprint 94-34. – Protvino, 1994. – p. 9, figs. 7, tables 2, refs.: 7.

The paper presents the results of a preliminary consideration of the possibility to form beams from the 600 GeV UNK-1 machine toward Gran Sasso (Italy) laboratory as well as to study neutrino oscillations using the ICARUS facility.

Depending on the experiment conditions the expected range for the study of the oscillation parameters is Δm^2 up to 10^{-3} eV^2 under complete mixing and $\sin^2 2\theta$ up to $6 \cdot 10^{-3}$ at $\Delta m^2 \sim 2 \cdot 10^{-2}$ eV^2.

Аннотация

Федотов Ю.С., Гаркуша В.И., Герштейн С.С. и др. К возможности изучения осцилляций нейтрино на детекторах, расположенных в Гран-Сассо (Италия), с использованием пучков от ускорителя УНК-1 на энергию 600 ГэВ: Препринт ИФВЭ 94-34. – Протвино, 1994. – 9 с., 7 рис., 2 табл., библиогр.: 7.

В работе изложены результаты предварительного рассмотрения возможностей формирования пучков от ускорителя УНК-1 (600 ГэВ) в направлении лаборатории Гран-Сассо (Италия) и изучения осцилляций нейтрино различных типов с использованием установки ИКАРУС. Ожидаемая область изучения параметров осцилляций в зависимости от условия эксперимента: Δm^2 – до 10^{-3} эВ^2 при полном смешивании и $\sin^2 2\theta$ – до $6 \cdot 10^{-3}$ при $\Delta m^2 \sim 2 \cdot 10^{-2}$ эВ^2.

INTRODUCTION

The study of neutrino oscillations becomes one of the main trends in the investigations in elementary particle physics. A wide range of the oscillation parameters is under investigation: the square of the mass difference of the bare neutrino Δm^2 is within the interval from 100 up to 10^{-8} eV^2 and the squared sin of double mixing angle $\sin^2 2\theta$ is within the interval from 1 up to $10^{-2} \div 10^{-4}$ depending on the experimental conditions (fig.1). There still exists a considerable range of the $\Delta m^2 (10^{-1} \div 10^{-4})$ values not yet studied in the neutrino beams at the accelerators, however this information may be necessary owing to a number of reasons. For the study of this range of the oscillation parameters there have been proposed a number of experiments, using 1-300 GeV neutrino beams from the CERN, FNAL, KEK, IHEP accelerators and such detectors and SOUDAN-2, ICARUS, KAMIOKANDE, DUMAND, Baikal [1,2,3].

1. DETECTOR

The ICARUS detector [2] seems to be an ideal one for the neutrino oscillation studies, since it allows one to use all possible methods for the observation of the oscillations. Among them are the study of the equilibrium muon flux; application of the NC/CC technique; selection of the CC events depending on the energy variations; and what is more important – a direct observation of the presence (or excess) of ν_e and ν_τ beams in the ν_μ beams. Besides at a distance of ~2200 km between Protvino – Gran-Sasso the MSW – effect becomes significant, which also may be of great importance for the observation of the oscillation effects.

The detector consists of three cryostat volumes (4.138 m^3, 16 m diameter, 20 m long) filled with liquid argon (each 5000 t).

2. NEUTRINO BEAM CHARACTERISTICS

Neutrino beam directed at the Gran Sasso lab (GS) may be formed with the help of the proton beams, extracted from SS-V of the UNK machine. To be aimed at GS the proton beam should be rotated in the equilibrium orbit plane of UNK by 16.3^o (northward) and then directed downward into the earth depth at 9.5^o (fig.2). The equipment of the beam extraction and transport systems, of the target station and decay channel (L_p=500 m) is similar to that used for the neutrino beam towards the Baikal [4].

The distance between UNK and GS is 2192 km. The IHEP systems of parabolic lenses [5] or systems of the Horn type [6] can be used to form a wide band neutrino beam. Narrow band neutrino beams may be formed by a system of quadrupole lenses [4]. The average characteristics of the formed beam are as follows:

1. A focusing system of the IHEP parabolic lenses [5] (some variants)

Table 1.

#	$< E_\nu >$, GeV	I_ν/prot	N_{ev}/day
1	19.4	$.286 \cdot 10^{-5}$	9.3
2	39.3	$.470 \cdot 10^{-5}$	30.6
3	51.6	$.397 \cdot 10^{-5}$	34.1
4	40.9	$.548 \cdot 10^{-6}$	3.7

Here the ν_μ flux I_ν is presented for the area with R ~50 m. The number of neutrino interactions N_{ev}/day is calculated for the detector with the mass $1.5 \cdot 10^4$t. There are ~720 cycles of the accelerator per day with $4 \cdot 10^{14}$ protons per pulse.

Neutrino spectra for these variants are presented in fig.3. (Variant 4 presents the parameters of the unfocused neutrino beam.)

2. The focusing system of two horns [6]:

$< E_\nu > \simeq 69$ GeV, $N_{ev}/\text{day} \simeq 30$ events.

3. Narrow band neutrino beams from decays of π^+ with $\Delta p_\pi / p_\pi$ ~20%:

Table 2.

E_π, GeV	$< E_\nu >$, GeV	I_ν/prot	N_{ev}/day
70	27.9	$1.54 \cdot 10^{-6}$	0.93
140	49.5	$4.90 \cdot 10^{-6}$	2.73
280	81.3	$4.15 \cdot 10^{-6}$	2.50

These data show that in a quite reasonable period of run (1-2 months) one can detect up to ~1000 neutrino interactions. Having a possibility to detect events from all types of neutrino, one will be able to make a reliable conclusion concerning the value of the oscillation effect in the region Δm^2-$\sin^2 2\theta$ presented in fig.1.

Fig.4 presents the dependence of $P(\nu_\mu \rightarrow \nu_e)$ versus neutrino energy, calculated for Δm^2 and $\sin^2 2\theta$ obtained in the KAMIOKANDE experiment [7]. As is seen the comparison of the detector exposure results at neutrinno energies, e.g. 30-40 GeV and ~ 80 GeV would be additional data in favour of the existence of the oscillation effect. The existence of the oscillations may change the initial neutrino beam intensity ~2-3 times.

Figs.5-7 present the sensitivity of the Protvino-Gran-Sasso experiment in the Δm^2-$\sin^2 2\theta$ plane when using narrow band neutrino beams, formed from π^+ meson beams with energies 70 (27.9), 140 (49.5) and 280 (81.3) GeV (the average neutrino energy is given in brackets).

These figures present the data for vacuum and with account of the matter effect (MSW-effect). The data are given for $P(\nu_\mu \rightarrow \nu_e)$ measured with the accuracy of 1%, 3% and 10%.

In conclusion we can say that in the Protvino-Gran-Sasso experiment will be possible to investigate the neutrino oscillation in the the interesting region of Δm^2-$\sin^2 2\theta$ with high accuracy.

Authors would like to thank A.A.Logunov and C.Rubbia for the interest to this work and simulating discussions.

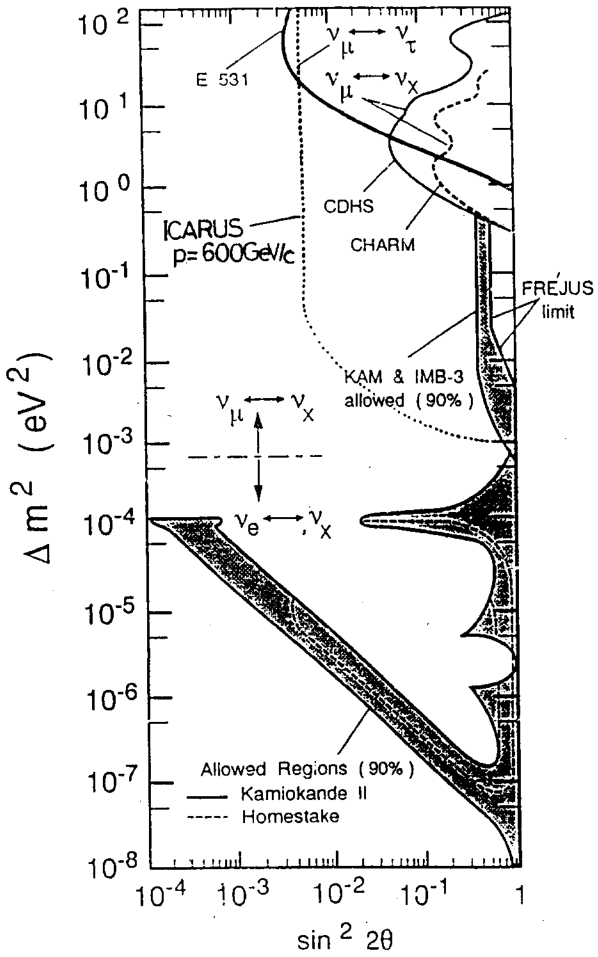

Fig. 1. Sensitivity in the Δm^2 versus $\sin^2 2\theta$ plane of some experiments using accelerator neutrino beams and using atmosphere and solar neutrinos [1] and region suitable to be investigated with UNK-ICARUS.

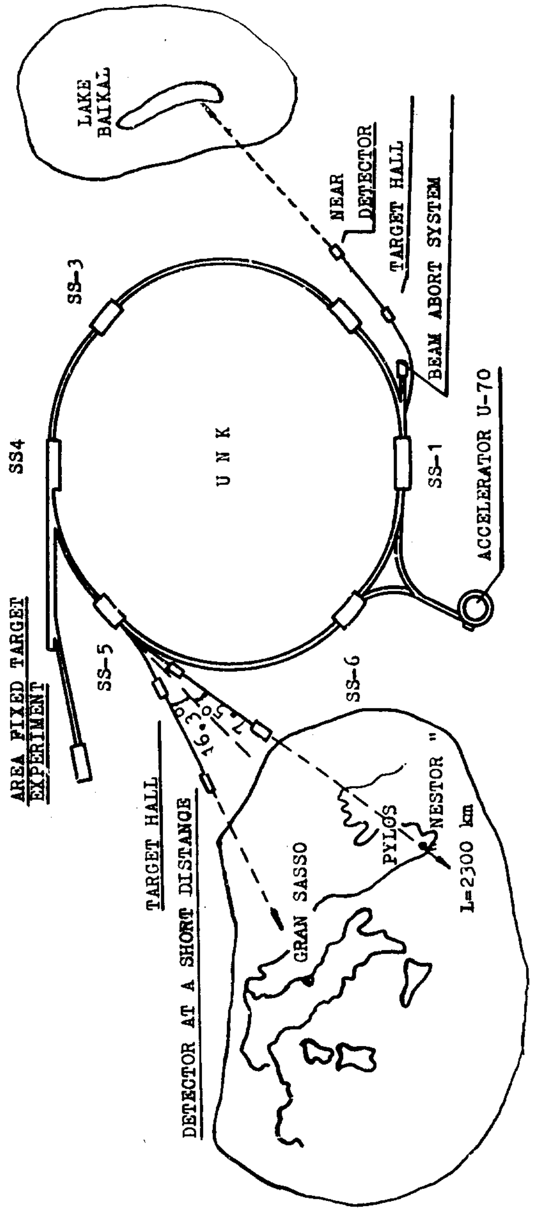

Fig. 2.
Mutual position of the UNK 54°30' N.L., 37° E.L. and Gran Sasso 42°27' N.L., 13°34' E.L. The distance is 2192 km.

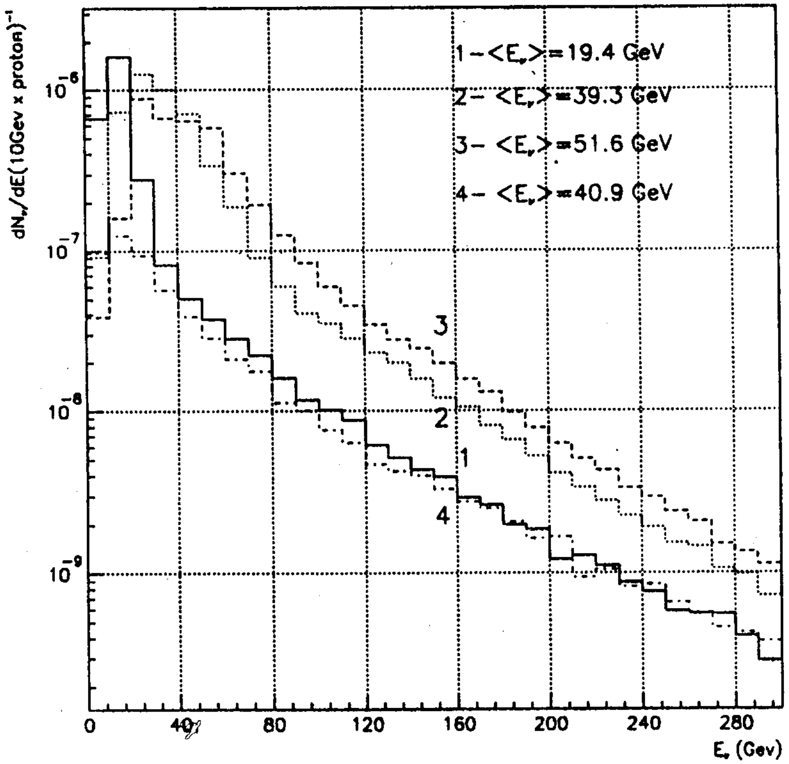

Fig. 3: **Energy spectra of wide band neutrino beams from UNK-1, formed by a focusing system of the IHEP parabolic lenses. (Variant 4 presents the parameters of the unfocused neutrino beam.)**

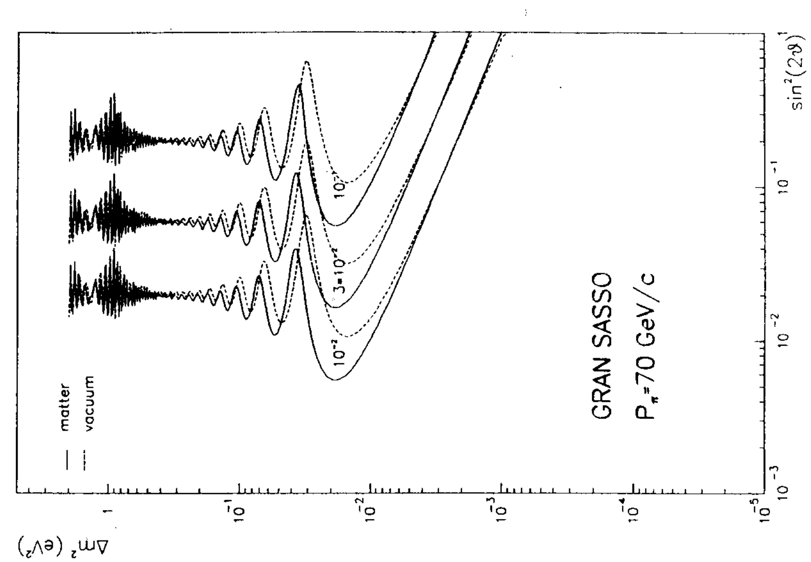

Fig.5. Sensitivity of the Protvino-Gran-Sasso experiment when using a narrow band neutrino beam with E_ν $\sim$27.9 GeV, p_{π^+}=70 GeV. $P(\nu_\mu \to \nu_e)$ measured with the accuracy of 1%, 3% and 10%.

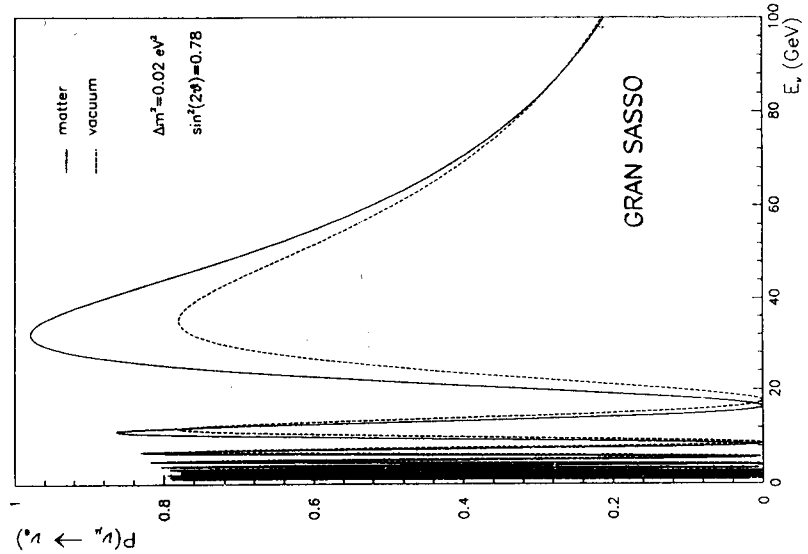

Fig.4. The $P(\nu_\mu \to \nu_e)$ dependence on energy calculated for the Protvino-Gran-Sasso experiment at $\Delta m^3 = 0.02$ eV^2, $\sin^2 2\theta$=0.78 (KAMIOKANDE [7]).

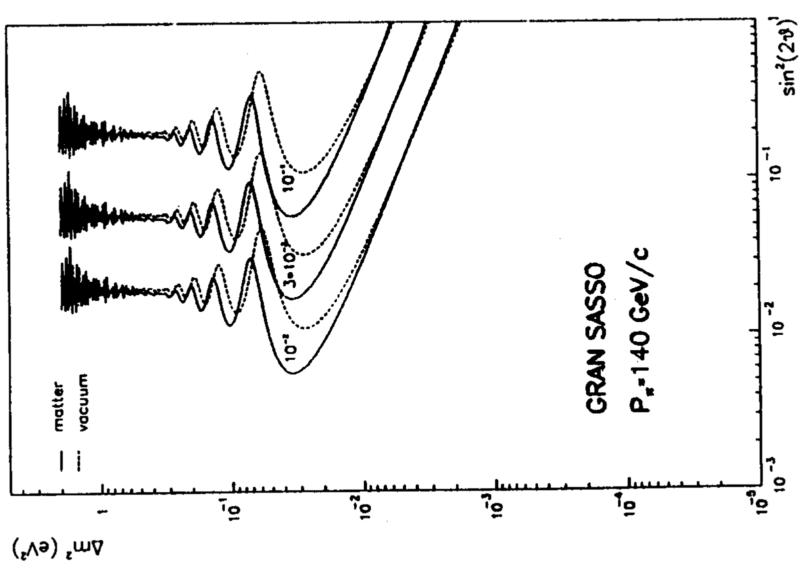

Fig.6.
The same as in Fig.4, but $< E_\nu >\sim 49.5$ GeV, $p_{\pi^+}=140$ GeV.

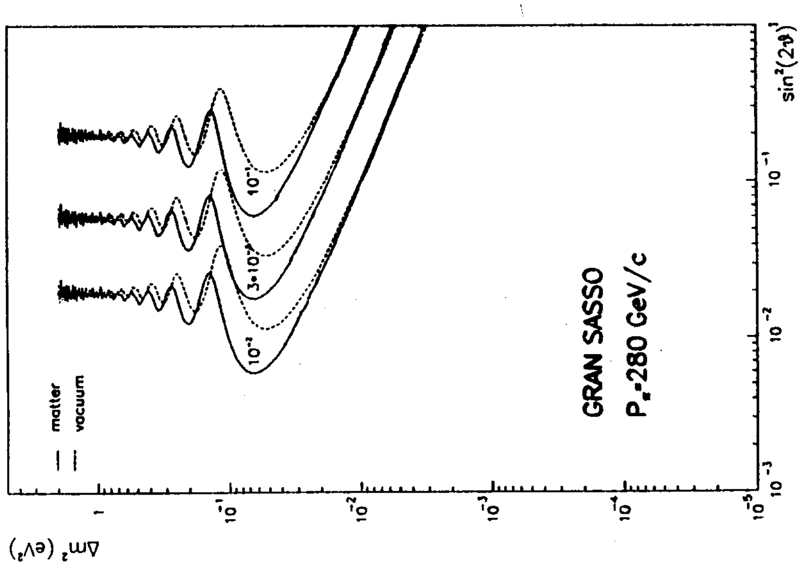

Fig.7.
The same as in Fig.4, but $< E_\nu >\sim 81$ GeV, $p_{\pi^+}=280$ GeV.

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Received March 15, 1994

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К возможности изучения осцилляций нейтрино на детекторах, расположенных в Гран-Сассо (Италия), с использованием пучков от ускорителя УНК-1 на энергию 600 ГэВ.

Оригинал-макет подготовлен с помощью системы LaTeX.
Редактор А.А.Антипова. Технический редактор Н.В.Орлова.
Корректор Е.Н.Горина.

Подписано к печати 25. 03. 1994 г. Формат 60 × 90/16.
Офсетная печать. Печ.л. 0,56. Уч.-изд.л. 0,73. Тираж 240.
Заказ 1069. Индекс 3649. Цена 110 руб. ЛР №020498 06.04.1992.

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