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A SEARCH PROGRAMME OF EXPLICIT ν- OSCILLATIONS WITH THE ICARUS DETECTOR AT LONG DISTANCES *)

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1.— INTRODUCTION

The central problem of neutrino physics is today the determination of masses through neutrino oscillations. The necessity of the phenomenon of oscillations, initially proposed by Pontecorvo [1] stemmed from the main results from the solar neutrino experiments [2], which all indicate a deficit of about a factor 2 with respect to the standard Solar Model. Though such a model is not without problems, it would seem that the most reasonable way out is the one of presuming that some depletion occurs through mixing over the path. Until sometime ago the preferred solution was the one of a relatively small mixing angle, coupled with a "mass enhancement" phenomenon in the path of neutrinos through the solar mass, the so-called MSW effect [3]. If the Sun has such a specific mechanism, one would expect that other experiments on other more conventional neutrino sources would give no major depletion in flux.

However, more recent results from atmospheric neutrino experiments [4], though with significant uncertainties, also claim a depletion factor of the same order as the solar neutrinos. It is the merit of Harrison, Perkins and Scott [5] to have pointed out that all existing data (with perhaps the exception of the early data from Davis) could be reconciled with the simple assumption of a large mixing angle and a neutrino mass difference Δm^2 of the order of 0.01 eV^2, presumably between the μ- and e-neutrinos. We refer to Figure 1, taken from Ref. [5] to visualise this point.

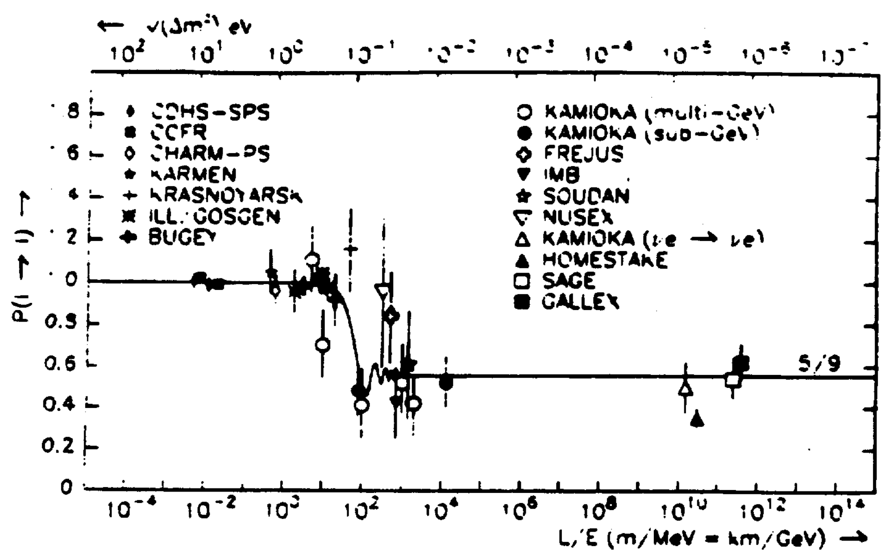

Figure 1. Compilation of disappearance rates as a function of the distance [5].

Assuming two competing neutrino species and the world's information on disappearance experiments, there is little or no room left for the oscillatory pattern except of putting it around a value of $\Delta m^2 \approx 0.008$ eV^2. In all cases, the large difference between the "depleted" long path neutrino experiments (solar & cosmic rays) and the short path results (accelerators & reactors) — which are apparently unperturbed by oscillations — suggest a large mixing angle, of the order of $\sin^2(2\theta) \approx 0.9$ [5].

We need to accommodate three neutrino species. A more rigorous treatment [6] shows that one could accommodate also LSND results and a third neutrino mass of the order of $\Delta m^2 = 1 \div 2$ eV^2, leading to an attractive scenario with $\Delta m^2_{2,1} \approx 0.01$ eV^2 and $\Delta m^2_{3,1} \approx \Delta m^2_{3,2} \approx 1$ eV^2 and a mixing matrix of the form $U_{\alpha\beta}$ between the three weak eigen-states (ν_e, ν_μ, ν_τ) and the mass eigen-states (ν_1, ν_2, ν_3):

$$P(\upsilon_\alpha \to \upsilon_\beta) = \delta_{\alpha\beta} - 4\sum_{i>j} U_{\alpha,i}U_{\beta,i}U_{\alpha,j}U_{\beta,j}\sin^2(\Delta_{i,j}/2) \quad where \quad \Delta_{i,j} = \frac{\Delta m^2_{i,j} L}{2E}$$

The best values of the mixing matrix are [6] believed to be

$$U_{\alpha,\beta} = \begin{bmatrix} 0.630 \leftrightarrow 0.764 & 0.764 \leftrightarrow 0.630 & 0.140 \\ -.776 \leftrightarrow -.645 & 0.619 \leftrightarrow 0.754 & 0.124 \\ -.010 \leftrightarrow -.028 & -.187 \leftrightarrow 0.185 & 0.982 \end{bmatrix} \quad \begin{matrix} \Delta m^2_{2,1} = 10^{-2} eV^2 \\ \Delta m^2_{3,1} = \Delta m^2_{3,2} = 1 \div 2 \ \ eV^2 \end{matrix}$$

The experimental evidence for such a pattern is, so far, purely circumstantial. It is only because of the agreement, or rather of the disagreement between different experimental results that the possible explanation through the oscillation mechanism emerges. On the other hand we expect that at the appropriate L/E distance the oscillation pattern must appear as a direct, self-contained signature. The oscillation should manifest itself as an energy dependent modulation in the appearance rate of the different neutrino flavours, starting from an initial ν_μ beam of sufficiently high energy to produce all three final leptons with appreciable cross sections. It is a fortunate circumstance that both effects are centrally located in the energy range of neutrinos produced by the CERN-SPS beam at two distances which are readily accessible: (1) at 17 km behind the Jura, using the existing neutrino beam, to explore the pattern due to $\Delta m^2_{3,1} \approx \Delta m^2_{3,2} \approx 1$ eV^2 and the 731 km from CERN to LNGS to study 10^{-3} eV$^2 < \Delta m^2_{2,1} < 0.1$ eV^2 , for which, as well known, however, a dedicated new beam has to be constructed [7].

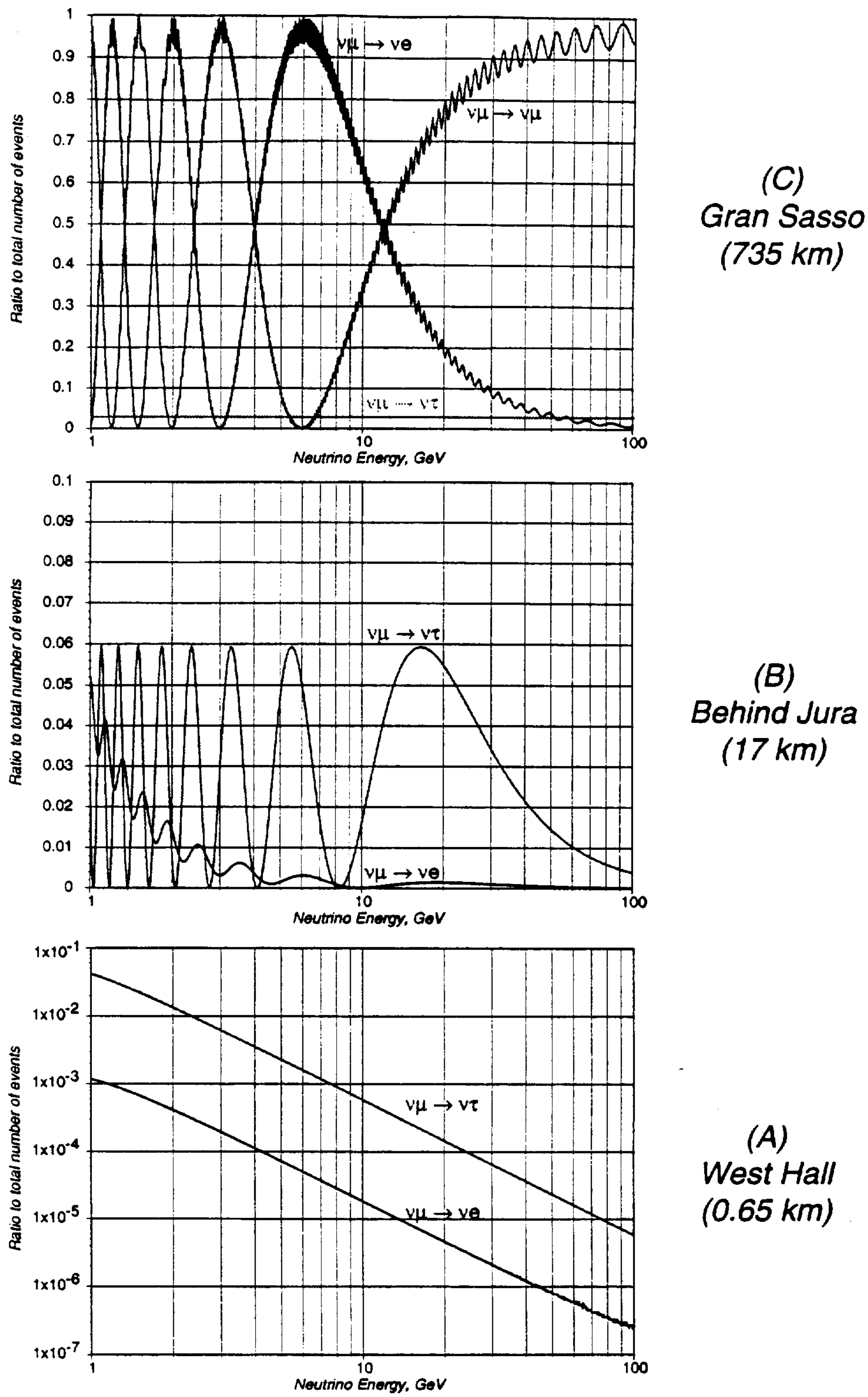

Figure 2. *The predicted [6] emergence of the oscillation pattern as a function of the distance from the source, in the case of the neutrino beam from CERN. In (A) CHORUS and NOMAD; in (B) The enhancement of $\Delta m^2 \approx 1$ eV^2 oscillations due to ν_τ behind the Jura and (C) the very spectacular ν_μ — ν_e oscillations due to the smaller mass difference ($\Delta m^2 \approx 0.008$ eV^2), modulated by the larger mass.*

The following conclusions can be drawn:

(1) At the present location (0.65[1] km) of CHORUS and NOMAD the ν_μ — ν_τ conversion is very small, of the order of 5.79×10^{-4} $[10/E_\nu(\mathrm{GeV})]^2$, presumably too tiny to be detectable by the present generation of experiments (see Figure 2a).

(2) At the Jura location (17 km) within the continuation of the present neutrino beam, one expects an oscillation into τ-neutrinos which is dominated by an effective ν_μ — ν_τ oscillatory conversion with a $\sin^2(2\theta) = 4[U_{\mu,3}\, U_{\tau,3}]^2 = 0.06$ and a negligible amount of ν_μ — ν_e conversion (see Figure 2b). The actual value of the mass difference and of the $\sin^2(2\theta)$ can both be determined from a fit of the ratio of events ν_τ / ν_μ as a function of the visible energy, since large changes are expected over the energy interval of detectable events.

(3) At the Gran Sasso location (730 km) an effective ν_μ — ν_τ steady conversion with $P_{\mu\tau} = \sum_i \left(U_{\mu,i} U_{\tau,i}\right)^2 \approx 0.028 + 0.035$ accompanied by a large oscillatory ν_μ — ν_e conversion (see Figure 2c). The effect is very spectacular in the ν_e / ν_μ ratio. While at the "resonant" energy $E_{res} = 5.9\ 10^2\ \Delta m^2\ (\mathrm{eV}^2)$ i.e. 5.9 GeV for $\Delta m^2 \approx 10^{-2}\ \mathrm{eV}^2$, the ν_μ is essentially absent to the extent of $1 - \sin^2(2\theta) \approx 0.1$, at higher energies the fraction of ν_e events is decaying smoothly (50% at $E = 2\ E_{res}$, 10% at $E = 5\ E_{res}$ and descending like $1/E^2$ for larger values). Therefore while electrons dominate at lower energies, at high energies the normal "muon-like" behaviour is re-established.

The previous discussion contains a substantial amount of theoretical prejudice and may not turn out to be entirely correct. This is particularly so for the case of the $\Delta m^2 \approx 1\ \mathrm{eV}^2$ oscillation hypothesis, stemming only from the unconfirmed result of the LNSD experiment. This is the dominant assumption on which relies the success of the measurement at the Jura position, which therefore has a lesser confidence level of leading to a positive result. More credibility can be assigned to the $\Delta m^2 \approx 10^{-2}\ \mathrm{eV}^2$ oscillation hypothesis, to be tested at the Gran Sasso position, since it relates to the rather extensive phenomenological analysis of Ref. [5]. However since it is based exclusively on disappearance data, it may well be that the oscillations are transforming incident neutrinos into ν_τ rather than into ν_e (assuming of course that the

[1] The distance is calculated from the centre of the decay path (300 m).

result of LNSD is wrong). The detection of a very large conversion into the ν_τ is possible with the ICARUS apparatus. In a first approximation these events will look like "neutral currents" and therefore will enhance the canonical ratio NC/CC of ordinary events.

Experiments presently in progress will soon be able to establish on a firmer ground the likelihood of observing the oscillation:

(1) the future reactor experiments such as CHOOZ [8] and Palo Verde [9] which observe ν_e survival probability and will be sensitive to $\Delta m^2 \approx 10^{-3}$ eV^2. They should see a large effect $P_{ee} \approx 0.48 \div 0.50$, thus confirming the interest in the Gran Sasso position.

(2) the upgraded KARMEN experiment [10] will verify the result from LNSD and therefore may give more strength to the measurement in the Jura position. Note that both experiments "see" the ν_τ indirectly, through a small effect in the $\nu_\mu - \nu_e$ conversion. The Jura position measurement will instead see the oscillation directly in the ν_τ channel.

To conclude, there is a substantial body of data leading to a theoretical prejudice which suggests that likely the Jura and most probably the Gran Sasso positions, coupled with the SPS neutrino beam could be the real "focal point" of the neutrino oscillation search. Spectacular conversion $\nu_\mu - \nu_\tau$ is expected behind the Jura, where the neutrino event rate is very high (≈ 1 event/pulse in the ICARUS detector) and a monumental conversion in $\nu_\mu - \nu_e$ or alternatively $\nu_\mu - \nu_\tau$ is expected at the Gran Sasso position, with rates which are , as we shall show, quite acceptable (≈ 1600 events for $4\ 10^{19}$ pot).

Finally we would like to put forward the pragmatic consideration that the L/E interval covered by the two proposed positions is not yet well studied and that the simultaneous, possible $\nu_\mu - \nu_\tau$ and $\nu_\mu - \nu_e$ oscillatory conversions can be observed very cleanly with high energy SPS-neutrino interactions in ICARUS.

We believe that both positions should be explored with the same detector as a part of a same programme. If the same neutrino beam configuration is used, the Jura and Gran Sasso represent respectively the "near" and "far" positions of the experimental programme.

2.— SHORT DESCRIPTION OF THE ICARUS DETECTOR

ICARUS is now an approved experiment of the Gran Sasso Laboratory (LNGS). We refer to the original ICARUS proposal [11] for further details. Note that in this proposal we have already discussed the possibility of a neutrino beam from CERN in order to study neutrino oscillations, including the characteristics of the required ν-beam.

ICARUS is the outcome of a graded, careful strategy of R & D to develop a new experimental technique which could offer "bubble chamber like" quality of events for non-accelerator experiments and neutrino physics. As in the case of bubble chambers[2], the ICARUS technology:

1) permits to record unbiased events in three dimensions and with high spatial resolution and precision (There is the possibility of adding a magnetic field);
2) because of the high density of the liquid medium, can combine target and detector functions;
3) is capable of unambiguous discoveries with only few events produced inside its volume, as has been the case for neutral currents, Ω^-, hadron spectroscopy (SU-3) etc.

However, unlike bubble chambers, the ICARUS detector is (1) continuously sensitive and self-triggerable, (2) cheap and simple to build in modular form and (3) sufficiently safe to be located underground (no pressure). The feasibility of these goals has been amply demonstrated by an extensive R & D programme, namely :

1) ten years of studies on small volumes: proof of principle, purification methods, read-out schemes, mixtures of Argon-Methane, diffusion coefficients, electronics;
2) five years of studies with a 3 ton detector at CERN: purification technology, real events, pattern recognition, event simulations, long duration tests, doping, read-out technology.

An example of a recorded track in the 3 ton detector is shown in Figure 3. The successful completion of the R & D programme has led to the approval of a first 600 ton module. Such a full scale module is presently under

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[2] We are aware of the fact that this reference to Bubble Chamber may be a bit old fashioned. Indeed some younger people may ask:" but what <u>is</u> a bubble chamber ?"

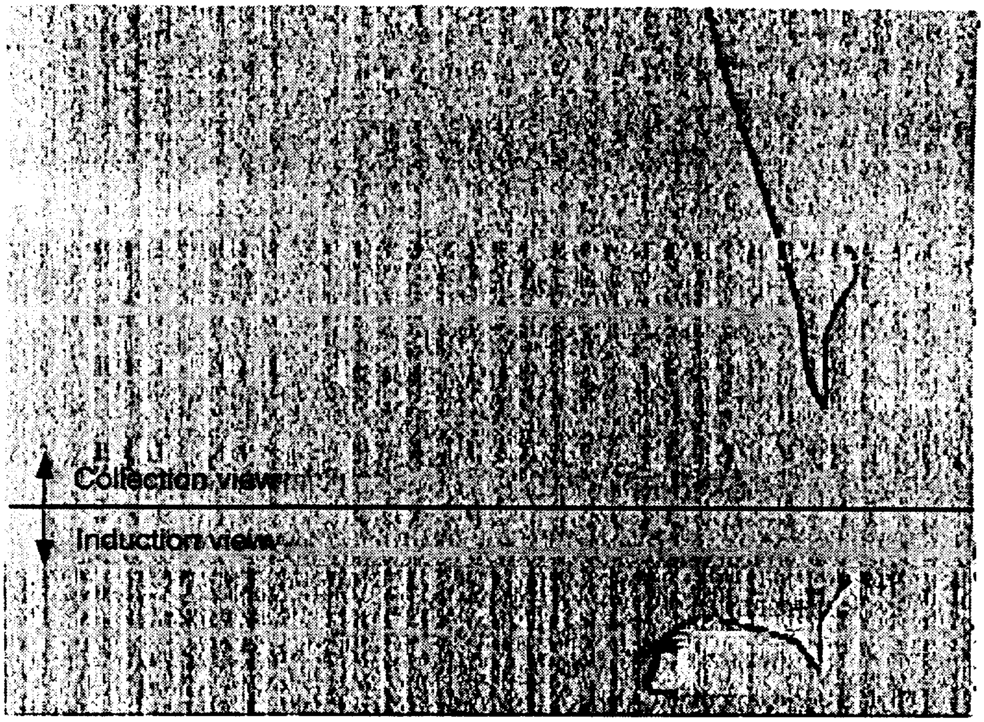

Figure 3. Recorded muon stopping in the 3 tons prototype. Both views (induction and charge collection are shown).We remark the ionisation information proportional to the grey level. The actual drift distance in argon is about 50 cm.

construction and it will be assembled and tested in Pavia during the latter half of 1998, before being installed in the Lab C of the Gran Sasso Laboratory in the course of 1999. This module, which is transportable, will be realised fully in Italy with a strong industrial involvement.

The physics programme for the first module is primarily

1) decay- independent proton decay search at $\tau \geq 10^{32}$ years.
2) cosmic rays neutrino events and oscillations.
3) model independent Solar neutrino flux measurements > 5 MeV.

Once the first module has been completed and tested and some early physics has been produced, we plan to increase the installed mass to some 5000 tons of liquid Argon with the addition several (8?) of such modules.

The main cryostats for the ICARUS 600 ton module are being developed by Air Liquide-Italia (Figure 4). Each volume is roughly a parallelepiped of 3.6 x 3.9 x 19.9 m^3. Its main walls are made of Aluminium honeycomb panels. The main parameters are listed in Table 1.

Table 1 Main parameters of the cryogenic s of the ICARUS module

Number of independent containers	2
Single container internal dimensions:	
length	19.9 m
width	3.6 m
height	3.9 m
Internal Volume	279 m^3
Single container external dimensions:	
length	20.2 m
width	3.9 m
height	4.2 m
Container's walls thickness	153 mm
Container material	Aluminium Honeycomb structure
Design pressure	1.5 bar (abs)
Working pressure	1.25 bar (abs)
External insulation thickness	600 mm
Insulating material	Aramid Fibre Honeycomb flushed with Nitrogen gas
Nominal heat losses at regime	≈ 15 W / m^2
Cooling liquid	LN_2 @ 3.6 bar
Single container own weight	19.6 ton
Limits for transportability on the Italian highways:	
length	25 m
width	5.9 m
height	5.2 m
Minimum cross section of the entrance doors to the Gran Sasso laboratories	
width	4.95 m
height	4.67 m
Total external dimensions:	
length	21.4 m
width	9.0 m
height	5.4 m
Total internal volume (completely occupied by LAr)	**559 m^3**
Total LAr mass	**782 ton**

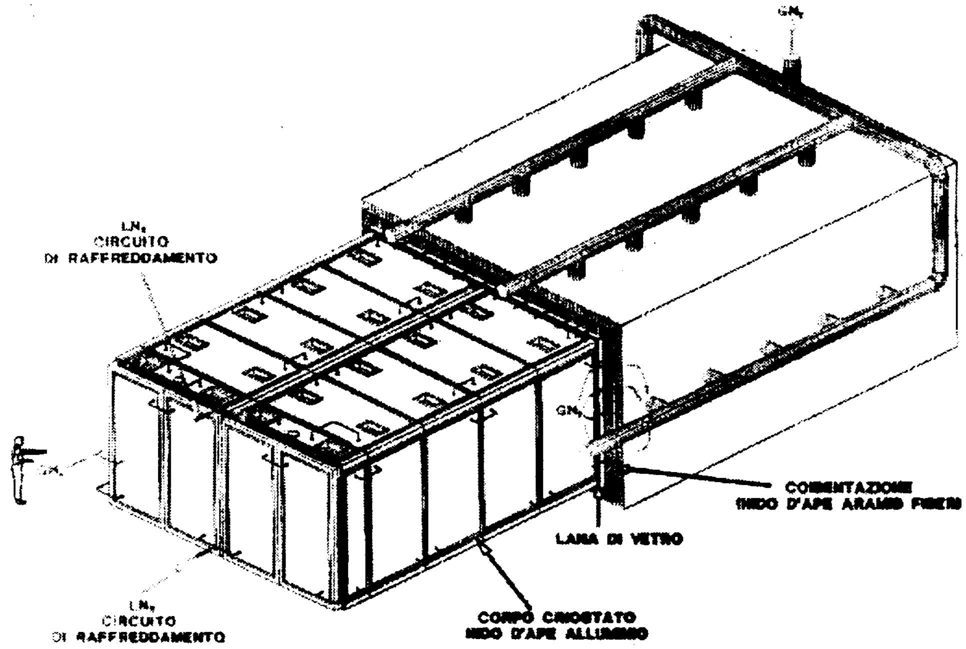

Figure 4. General layout of the cryostat, according to the design of Air Liquide Italia.

The thermal insulation is an innovative method requiring no vacuum and it is based on a 60 cm thick honeycomb insulating material with gas flowing through the cells and adiabatically rising its temperature to the room value. Two cryostat units bolted side to side are enclosed in the same insulating envelope. The cryogenic and the Argon purification system as well as the operational maintenance are also directly supplied by Air Liquide-Italia.

Each cryostat has two read-out planes, one at each edge of the volume, a high voltage plane at the centre, to be set to a nominal voltage of 75 kVolt and a maximum drift length of 1.50 m. Race-track electrodes ensure appropriate uniformity to the electric field. The maximum collection time of the electrons (drift speed 1.5 mm/μs) is of the order of 1.0 ms for a specified free electron lifetime in the Argon of about 5 ms. Each readout plane has three read-out co-ordinates at 60° from each other (horizontal, +60°, -60°) and a read-out wire pitch of 3 mm [3]. Scintillation light from Argon (eventually doped with

[3] This corresponds to a "bubble" diameter of about 3 mm, which was for instance the case of Gargamelle. Note also that the radiation length and density of liquid Argon are the same as heavy Freon, used currently for neutrino experiments in Gargamelle.

Xenon) is detected by two PM's arrays behind the transparent wire planes in order to determine the t = 0 internally[4] and eventually other trigger purposes.

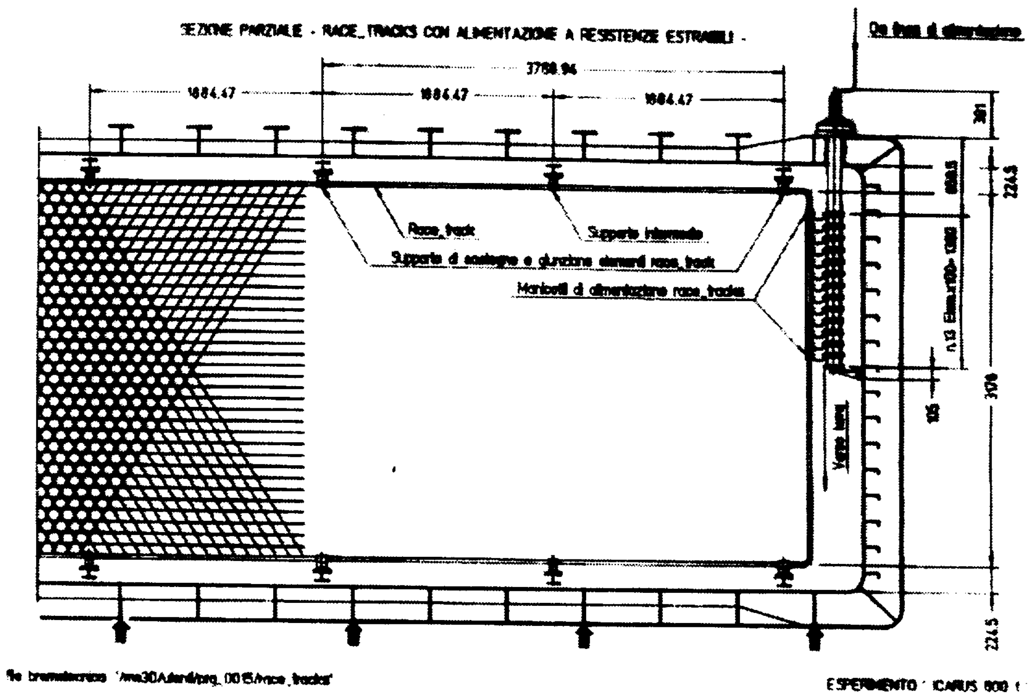

Figure 5 General layout of the wire planes. Note the three wire orientations. The high voltage feedthrough is also shown.

The mechanics of the wire planes (Figure 5), which has been already extensively tested in liquid Argon, is designed with industrial support (Breme-Industries) and has the interesting feature of having a moving mechanism to ensure the constant wire tension to the wires even during the cool-down process, since significant deformations due to thermal contraction are likely to occur (Figure 6).

The read-out electronics, also extensively tested, consists of an appropriate low noise amplifier followed by a ADC which samples and stores in a digital memory of each wire signal approximately every 400 ns. The read-out system has an appropriate processor to compress the information before read-out, keeping only the relevant hits. It will be produced with the help of industry (CAEN). The detector module has about 46,000 pre-amplifiers and 46,000/16 = 2875 ADC's, because of analogue signal multiplexing before digitisation. Main parameters are listed in Table 2.

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[4] The t = 0 timing is also available as a signal from the HV- cathode.

Table 2. Main parameters of the read-out planes of the ICARUS module.

Number of readout chambers	4
Number of wires planes	3 (all readout)
Wires orientation respect to horizontal	0° , ± 60°
Wires pitch	3 mm
Wires length:	
horizontal wires	9.37 m
wires @ ± 60°	3.76 m
Wires diameter	150 μm
Wires nominal tension	12 N
Number of wires / construction module	32
Number of modules / chamber:	
Horizontal wires	33
Wires @ ± 60°	2 x 162
Number of wires / chamber:	
horizontal	1056
@ ± 60°	2 x 5184
Total	11424
Total number of wires	45696
Maximum drift length	1.5 m
Maximum drift time @ 500 V / cm	1.0 ms
Distance between race tracks	50 mm
Number of race tracks / sensitive volume	29
Sensitive volume / chamber:	85.1 m^3
length	17.95 m
width	1.5 m
height	3.16 m
Nominal drifting field	500 V / cm
Maximum voltage on the cathode	75 kV
Number of analogue channels	45696
Analogue multiplexing factor	16
Number of digital channels	2856
Sampling time for the single analogue channel	400 ns
ADC range	12 bit
Estimated signal to noise ratio	
Induction wires	10
Collection wires	15
Total sensitive volume	**340 m^3**
Total sensitive LAr mass	**476 ton**

Spatial resolution and geometrical accuracy of the ICARUS detector is comparable to the one of a large freon-propane bubble chamber. However, unlike a bubble chamber, the ICARUS detector can also provide very accurate calorimetric measurements of contained events. The calorimetric volumes can of course be defined "à la carte" in each event. In the energy range of interest of the present proposal we expect a relative energy resolution of $0.03/\sqrt{E}$ for electrons (γ) and about $0.08/\sqrt{E}$ for hadrons[5]. Stopping particles can be easily identified in μ/π, K and protons from the residual ionisation losses versus range. Primary electrons are very easily separated from early π^0 conversion pairs because of the factor 2 in the ionisation losses.

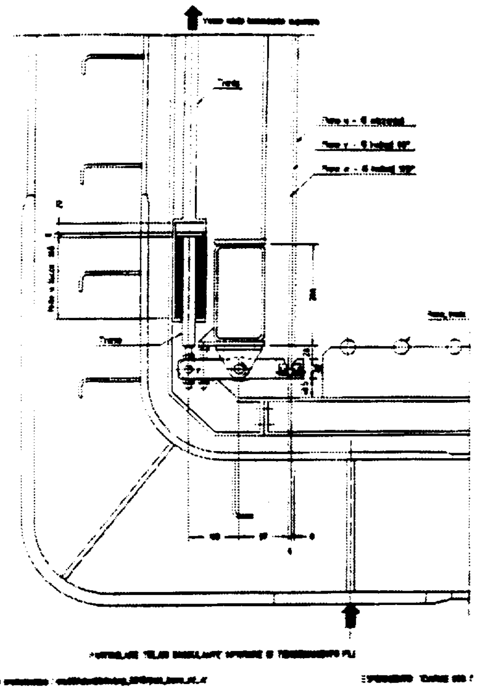

Figure 6. *Detail of moving wire supports to compensate for thermal contractions during cool-down (BREME Industries).*

The determination of the total energy of the neutrino events requires the measurement of the muon momentum. In view of the higher energy of the events from the SPS, when compared for instance to cosmic ray neutrinos, an external muon momentum analyser is required. A conventional magnetised iron core of some 4-5 m diameter, about 3 m thick, segmented in few sub modules with wire chambers planes in between is the obvious addition[6]. The Gran Sasso Laboratory is already oriented in the direction of the CERN neutrino beam.

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[5] Such an excellent energy resolution will be for instance used to identify proton decays by the proton mass peak. For instance simulations show that 95% of the events $p \rightarrow \pi^0 e^+$ in Argon will fall within 30 MeV of the proton mass, including the effects of the Fermi motion and nuclear excitation.

[6] We are considering the possibility of "recycling" some existing iron cores and chamber modules. More details on the spectrometer will be given at the end of this search.

3.— EVENT RATES

The experimental programme consists in two exposures of two similar ICARUS modules with an external muon detector at the positions of 17 km (Jura) and 730 km (Gran Sasso) from the source. These two measurements complement each other ("near" and "far" positions, distance ratio 43 : 1) and provide a full exploration of the L/E interval , taking into account the energy spectrum of the wide band neutrino beam from CERN (5 $\leftrightarrow$ 100 GeV). The complementarity of the two position measurements is evidenced in Figure 7.

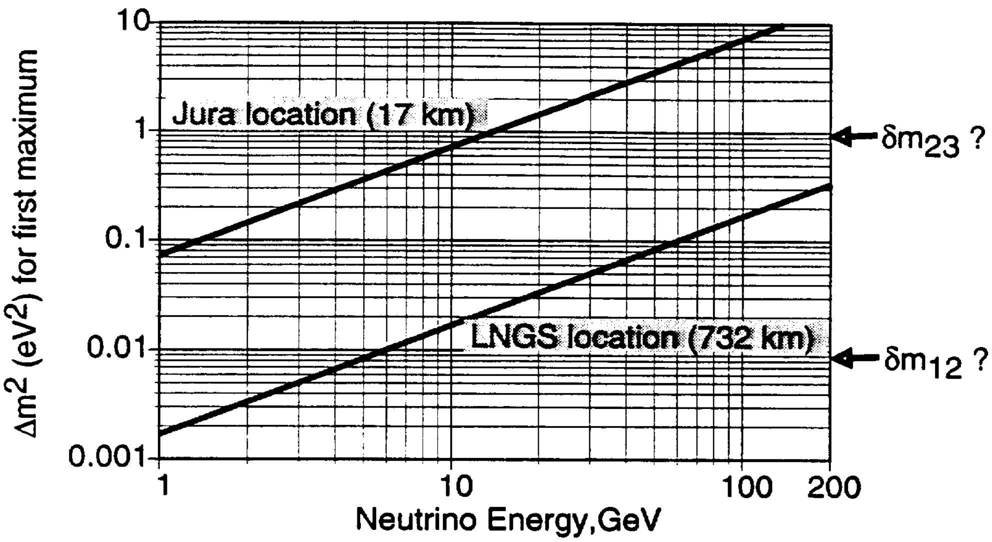

Figure 7. Mass difference for the first maximum of oscillations as a function of the neutrino energy, for the "near" and "far" position of our Proposal.

The neutrino energy of the SPS beam is sufficient in order to produce directly a large number of τ-events. Therefore the measurement will be an appearance measurement, starting with an initially clean ν_μ beam converting over its path into the ν_e and ν_τ channels. No absolute knowledge of the neutrino flux is then needed. Because of the higher event rate we plan to run primarily on neutrinos, though some verification with anti-neutrinos may be of considerable value.

Events rates for the near (Jura) and far (Gran Sasso) positions have been estimated. The parameters and fluxes of the present neutrino beam have been assumed for the near position. Incidentally in view of the substantial cosmic muon flux through the module in the essentially unshielded position of the Jura ($\approx$ 10 kHz) the duration of the beam burst should be as short as possible (fast extraction). We note that the memory time of the detector (max.

drift time) is of the order of 1 ms and therefore we expect of the order of 0.1 stray muon tracks over the full detector volume. The trigger could be simply based on energy deposition, with a threshold of the order of 1-2 GeV, gated over the neutrino burst and it is sufficiently high to remove most of the cosmic ray triggers[7]. Therefore we expect a smooth operation even if the detector is not housed underground.

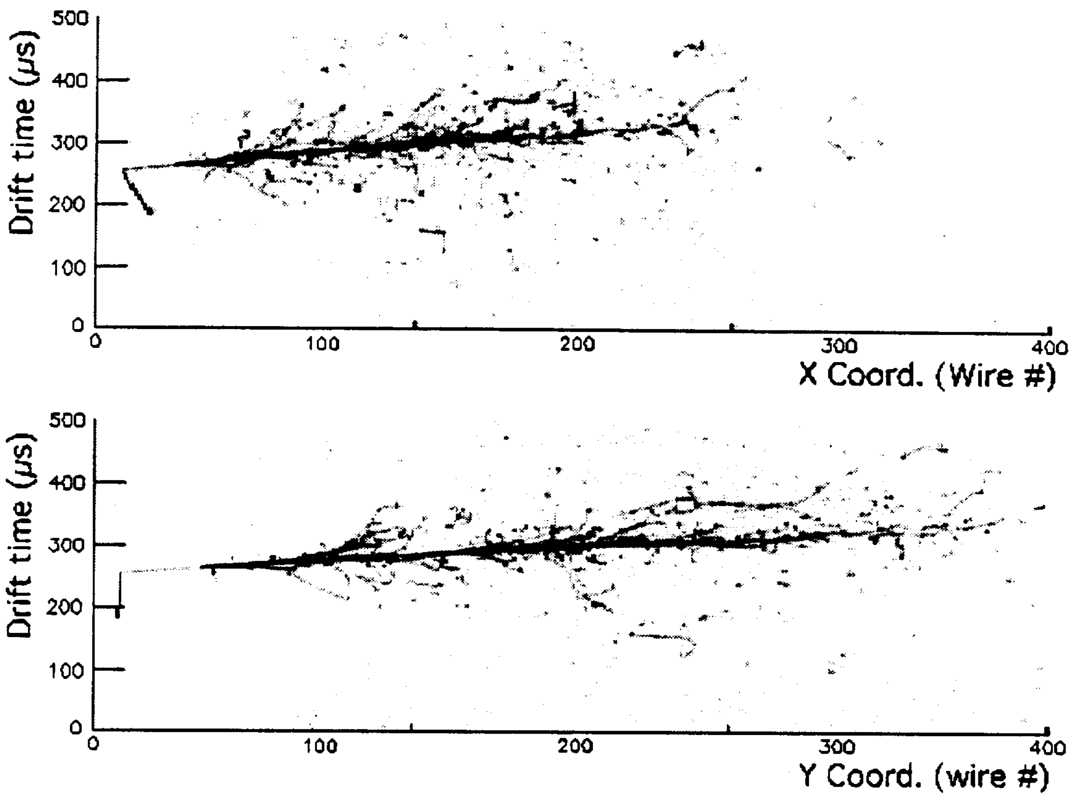

Figure 8. Simulated ICARUS event of quasi-elastic ν_τ interaction on a neutron of Argon and subsequent $\tau^- \rightarrow e^- \nu \nu$. The incoming neutrino energy is 10 GeV. The recoil proton has a kinetic energy of 96 MeV and the electron has 3.88 GeV. Note the minimum ionising behaviour in the initial part of the electron track, before showering. The event is widely unbalanced (2.33GeV).

The calculated rate of all neutrino charge current events (CC) in the Jura position (in absence of oscillations) is 5.07 10^5 for 10^{19} pot and 1 kton target, of

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[7] Note that the read-out system of ICARUS is essentially deadtime-less, since the decision of retaining the event is taken at the end of the potential drift time stopping the pulse acquisition process. During this time it is possible, if needed, to introduce some rough event selection, to further eliminate the cosmic background (showers).

which 1.47 10^4 are quasi elastic (2.9 %). In view of the simplicity of kinematic for this type of events (Figure 8) they are of the "gold-plated" kind[8].

The energy spectrum of the recorded events is shown in Figure 9. Assuming a fiducial volume of 400 tons, we predict therefore $0.40 \times 5.07\ 10^5 \times 2\ 10^{13}/10^{19}$ = 0.40 eve/pulse (1 event every 2.5 pulses). The rate of quasi-elastic is of 1 event every 85 pulses. Therefore an exposure based on an effective 2 10^{19} pot and a single ICARUS module would lead to about 400,000 events (11,000 quasi elastic).

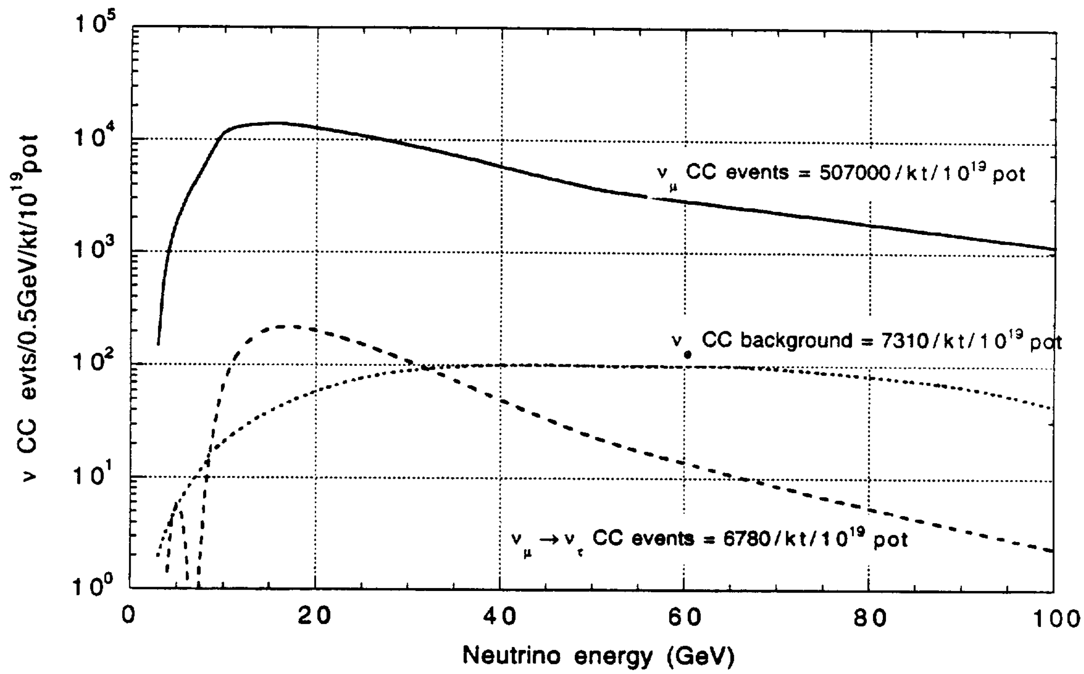

Figure 9. Expected deep-inelastic neutrino events spectra at the Jura location assuming the oscillation parameters: Δm^2_{32} = 1.5 (eV^2), $sin^2(2\theta)_{eff.} \approx 0.06$

The ν_τ-oscillated events in the case of the idealised "target" parameters Δm^2 = 2.0 [1.5] (eV^2), $sin^2(2\theta) \approx 0.06$ are 7.76 [6.8] 10^3 for 10^{19} pot and 1 kton target, of which 426 [442] are quasi-elastic). Again for an exposure of 2 10^{19} pot, we expect about 6200 [5500] ν_τ-oscillated events, of which some 340 [350]

[8] The cross section for quasi-elastic events is relatively large in the energy range in which the maximom of the tau signal is expected (10-20 GeV). At higher energies, where the muon signal is expected to be dominant, deep inelastic events are dominant.

are quasi-elastic. Even assuming kinematics cuts etc. which reduce the signal by a factor 3, we predict comfortable, realistic rates.

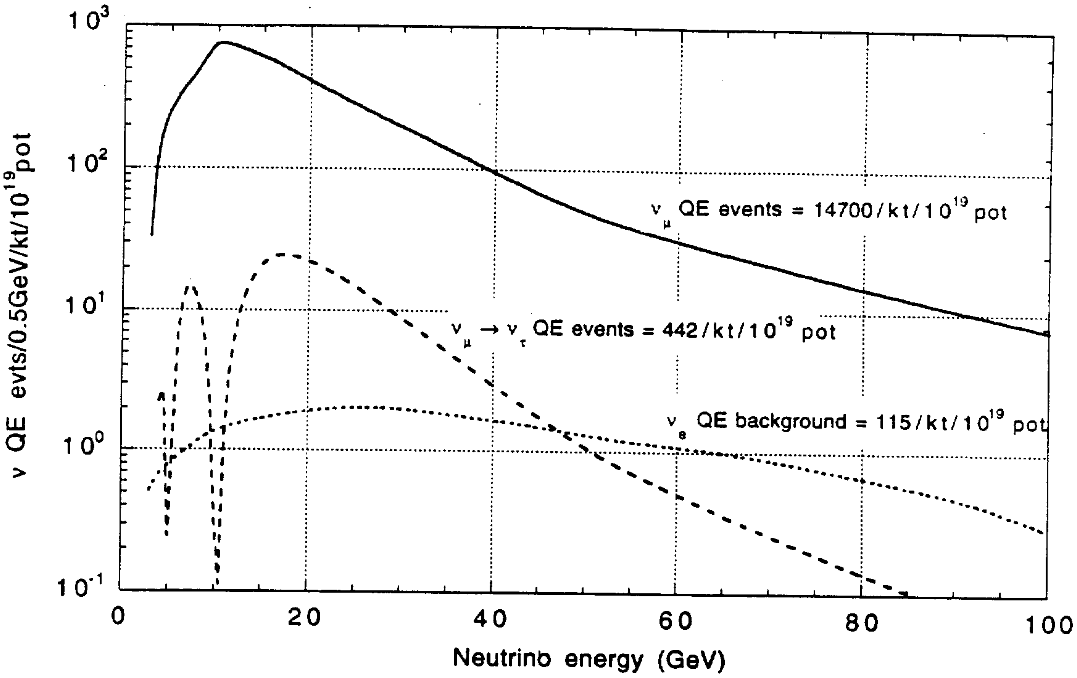

Figure 10. Same as Figure 9 but for quasi-elastic events.

The Gran Sasso exposure requires the construction of a new neutrino beam. We assume the same focusing system as the one for the Jura position, but a longer (1 km) and wider (2 m) neutrino decay path. These new parameters significantly increase the neutrino flux, but they do not modify significantly the spectrum[9]. Therefore the "near" and "far" positions are truly comparable.

The event rate at the Gran Sasso position are (in absence of oscillations) 1007 for 10^{19} pot and 1 kton target, corresponding to 800 events for a single ICARUS module and effective exposure of 2 10^{19} pot. The rate, as expected is not very large, but it should be sufficient, since the ν_μ — ν_e conversion is expected to be large[10], i.e. 125 ν_e for 10^{19} pot and 1 kton target (12.5%) and

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[9] At the Jura position (17 km) the solid angle subtended by the detector is already infinitesimal.

[10] The beam contamination due to ν_e is very small corresponding to the expectation of 0.8 % in flux. The energy spectrum of of these events is very different than the one of the oscillated component.

idealised "target" parameters $\Delta m^2 = 0.008$ (eV^2), $\sin^2(2\theta) \approx 0.9$. In the ICARUS programme we foresee to operate with several modules, especially in view of the proton decay search. It would be of course valuable to exploit also at least in part this planned mass upgrade for the neutrino oscillation search, *though we believe that already a single module suffices for the "proof of existence" of the expected effect.* The expected energy spectra of the recorded events are shown in Figure 11. We remark the striking difference of the spectra for the transmitted ν_μ and oscillated ν_e events.

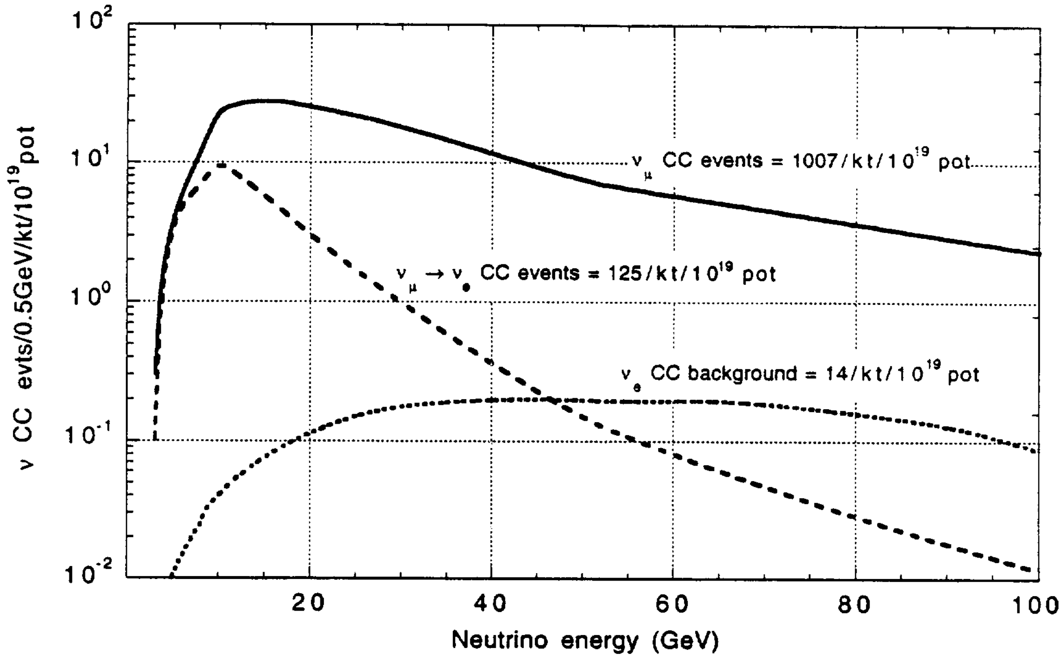

Figure 11. Expected deep-inelastic neutrino events spectra at the Gran Sasso location assuming the oscillation parameters: $\Delta m^2_{12} = 0.008$ (eV^2), $\sin^2(2\theta)_{eff.} \approx 0.9$

In the alternative that the anomaly observed by the cosmic ray neutrino experiments are instead due to ν_τ, the expected event rate at the Gran Sasso is smaller, due to the differences in cross sections, but still substantial, 120 for 4 10^{19} pot and 1 kton target. We expect no difficulty in identifying their presence in the event samples, since they will in first approximation "mimic" NC events, but with very different kinematics.

The main expected events rate are listed in Table 3.

Table 3: *Expected events rate for 2 10^{19} pot at the Jura (one ICARUS module) and 4 10^{19} pot at the Gran Sasso (one and three ICARUS modules) locations with the oscillations parameters $\Delta m_{12}^2 \approx 10^{-2}\ eV^2$ and $\Delta m_{32}^2 \approx 1.5\ eV^2$*

	Jura 1 *module*	*Gran Sasso* 1 *module*	*Gran Sasso* 3 *modules*
ν_μ CC (no oscillations)	4.06 10^5	1600	4800
ν_μ CC QE (no oscillations)	1.18 10^4	48	144
ν_e CC beam contamin.	5800	22	66
ν_e CC QE beam contamin.	92	< 1	< 1
ν_e CC oscillated	—	200	600
ν_e CC QE oscillated	—	12	34
ν_τ CC oscillated ($\nu_\mu \rightarrow \nu_e$)	5500	20	62
ν_τ CC QE oscillated ($\nu_\mu \rightarrow \nu_e$)	350	< 1	4

4.— MACHINE TIME REQUEST

The experiment is based on two exposures, one in the Gran Sasso Laboratory and the other behind the Jura. A new neutrino beam must be constructed for the first case.

Our machine time requests are therefore:

1) $2\ 10^{19}$ pot delivered with the present beam to the Jura position on a single ICARUS module, complemented by an external muon identifier
2) $4\ 10^{19}$ pot delivered to the Gran Sasso position to a minimum of 1 ICARUS module with an added muon identifier. More modules would be welcome, since they increase the economy of the run. It is likely that also other experiments in the Gran Sasso laboratory could profit from the exposure.

The competition of other experiments must be kept in mind when scheduling the programme. In particular the "competition" from SUPER-KAMIOKANDE is considered very serious, since its Δm^2 range overlaps with the Gran Sasso programme. The first ICARUS module could be operational by beginning 1999. It is essential that the scheduling of the exposures be matched to the construction schedule, especially taking into account the existence of competing programmes elsewhere.

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