THE STATUS OF THE CHORUS $\nu_\mu \rightarrow \nu_\tau$ OSCILLATION EXPERIMENT

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Abstract

CHORUS is an experiment designed to study the neutrino oscillation using the pure and intense Wide Band ν_μ beam at the SPS (CERN). The goal is to observe the appearence of ν_τ induced events detecting both ν_τ interactions and τ decay topology.
The very short life time of the τ requires a high resolution vertex detector. This problem was solved in CHORUS by using a big active target (800kg) made of nuclear emulsions, followed by a sofisticated electronic apparatus that allows the kinematical selections of interesting events.
After the completion of the first period of data taking, we report the analysis status and the detector performances.

1 Introduction

The question about the neutrino mass and stability is still unanswered. This question is particulary relevant for the ν_τ which is, as member of the third generation of fermions, one of the most promising candidates for the dark matter in the universe.
These considerations stimulated a new generation of accelerator experiments to search, with improved sensitivities, the $\nu_\mu \rightarrow \nu_\tau$ oscillation. [1][2]
As a by-product, the identification of the τ decay topology in a neutrino beam will be a direct check of ν_τ existence.
The CHORUS experiment adopted the visual technique to identify a τ decay topology, and is taking data since april 94 in the rebuilt and optimized CERN Wide Band ν_μ[3] beam.
The new beam presents a higher intensity ($> 2 \times 10^{13}$ protons/cycle) and a higher mean neutrino energy ($< E_{\nu_\mu} > \approx 27$ GeV) compared to the past. The mean distance of the neutrino source from the detector is 600 m. This distance together with the attainable statistics and background contamination fixes the sensitivity of the experiment.
The aim is to explore mixing angles down to $sin^2(2\theta) \sim 10^{-4}$. This will set a limit, in case of unsuccessful search for oscillation events, a factor 20 better with respect to the existing one [4].

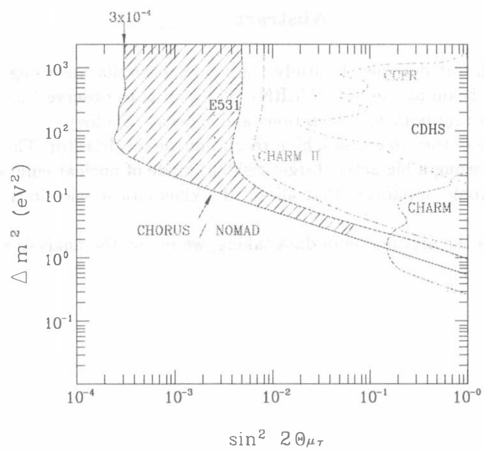

Figure 1: Exclusion Plot

2 Design and Data Selection Strategy

CHORUS is a classic appearance experiment. It is conceived to identify ν_τ by detecting the τ path and decay vertex.
In particular, the aim is to isolate few signal events coming from the charge current interaction

$$\nu_\tau N \to \tau^- X$$

followed by one of the decay topologies

$$\begin{array}{lll} \tau^- & \hookrightarrow \mu^- \nu\nu & 18\% \\ & \hookrightarrow h^- \nu + n\pi^0 & 50\% \\ & \hookrightarrow h^- h^- h^+ + n\pi^0 & 14\% \end{array}$$

from the large background of charged and neutral current interactions

$$\nu_\mu N \to \mu^- X$$
$$\nu_\mu N \to \nu_\mu X$$

Because of the very short τ^- decay length ($c\tau$=90μm), we need a precise device with a spacial resolution in the micron range. The nuclear emulsions have the required characteristics, and at the same time allow to build a massive target.
The CHORUS target was made by 800 Kg of emulsion gel segmented into four stacks, each one representing one radiation lenght.
Each stack is subdivided in 36 sheets. This configuration allows fast automatic and semiautomatic scanning techniques[5] (developed at the University of Nagoya and now under development in several italian labs) to speed-up the data analysis.
A further improvement may be obtained by reducing the scanning area. This goal is pursued by alternating the emulsion stacks with scintillating fibre tracking detectors to predict the track position at the stack boundaries.
The hybrid approch used by CHORUS, combining the use of the nuclear emulsion target with electronic counter devices, allows not only to speed up the track search in emulsion, but also to kinematically select the events, in order to optimize the ν_τ candidates sample versus scanning time. This selection, mainly based on particle energy and missing trasverse momentum, and taking into account the kinematical properties of the final state particles, allows to increase the signal/background ratio with a reduction of the data sample by a factor 5.
The detection of long lived particles is done in CHORUS using two magnetic spectrometers

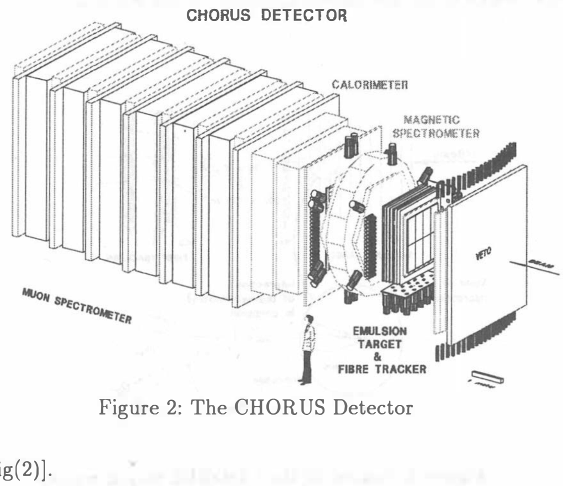

Figure 2: The CHORUS Detector

and a calorimeter [fig(2)].
The first spectrometer, placed downstream of the target, consists of an array of three diamond-shaped fiber planes in a 0.12T magnetic field, generated by a hexagonal air-core magnet[6]

operated in pulsed mode. This device determines sign and momentum of low energy particles (below 10 GeV/c).
The second is a muon spectrometer, placed downstream of the calorimeter, measuring the momentum of muons up to 100 GeV/c. Its resolution is 20% at 75 GeV/c. It consists of six circulary magnetized iron modules, producing a 1.8T field, interlived with tracking sections composed by drift chambers and streamer tube planes.
The CHORUS calorimeter is the first large-scale application of the so called 'spaghetti tecnique' [7] . The sampling is realized with a lead/scintillating fiber matrix optimized for compensation, with an equal response to electromagnetic and hadronic showers.
The energy resolution for hadrons was measured using a pion beam and turned out to be:

$$\sigma_E/E = (32.3 \pm 2.4)\%/\sqrt{E}$$

3 Topological identification

The long lived charged particles, reconstructed event by event by the electronic tracking devices, are tracked backward to the target.
The high resolution scintillating fibre detector predicts the position and angle of the track at the emulsion exit with a resolution of 200 μm and 3mrad respectively.
Two sheets of emulsions are placed between the target and the tracking section. These two sheets, obtained by double-coating thin emulsion layers (100μm) on a plastic base (800μm), are periodically changed to minimize the background in the delicate step of starting the scan-back in emulsion.
The search of candidates in these 'clean' emulsion 'chambers' allows to jump to the emulsion bulk with high precision ($\sim$ 10μm).
The high resolution delivered by the emulsions ($\sim$ 1μm) allows the scan back up to the vertex of a chosen track. Further vertex analysis is then possible. The whole process will identify the presence of a kink, which is the the tipical signature of the τ decay.

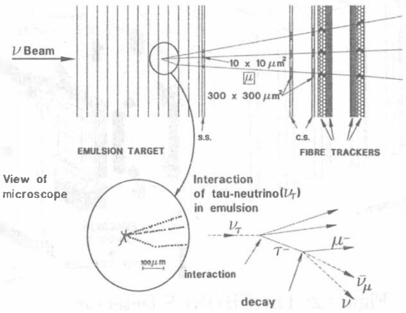

Figure 3: Layout of the CHORUS target region

4 Data Taking and Emulsion Exposures

In the first 2 years of data taking an integrated intensity of 2.01x10^{19} protons on target was achieved. Out of these, 3.2x10^{5} charged current events were recorded.
During the long shut down between 1994 and 1995 run, one of the four emulsion stack was replaced to allow the start of a pilot analysis.
This stack was succesfully developped and is now the object of the events search.
At the end of the 1995 run, all the stacks were replaced with 4 new emulsion bulks prepared for the 1996/97 data taking. Recently, the development procedure for the 4 1994/95 stacks was succesfully completed.

5 Analysys of 1994 stack

The event search was started by predicting the impact points and directions of the tracks reconstructed in the electonic apparatus, and in particular in the target fiber tracker.
On this data sample, no kinematical cuts were applied, to allow an unbiased pilot study.

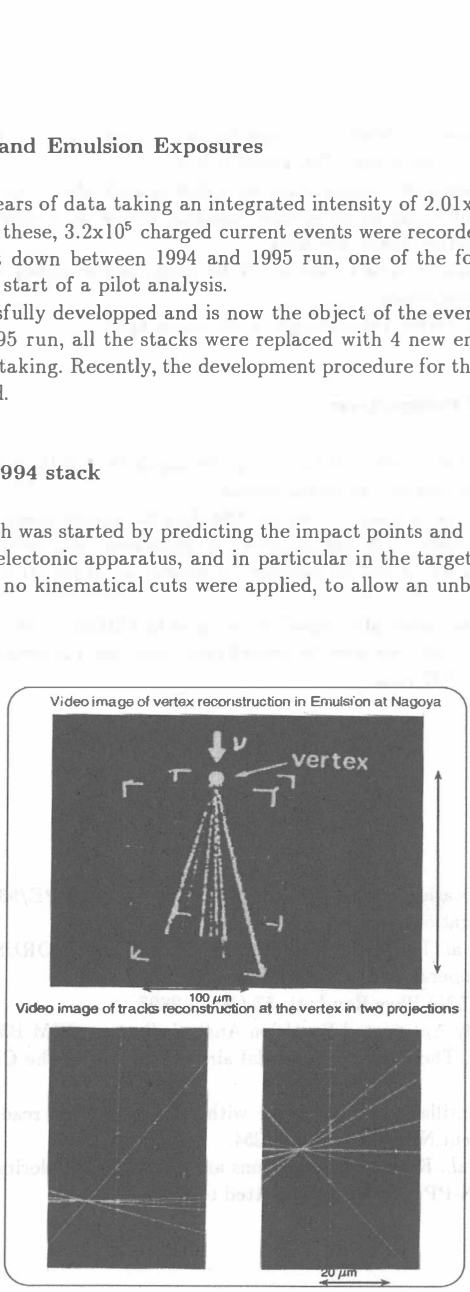

Figure 4: Layout of the vertex 3D image

About 27000 track candidates were predicted to impact on the changeable emulsion sheets.

Out of these, up to now, $\sim$ 15000 have been found in 1 mm^2 around the predicted point by using the fully automatic procedure developed in Nagoya.
In a subset of these successful candidates, we followed back the tracks from the changeable sheets to the bulk. Still using an automatic scanning device we located, up to now, $\sim$ 7000 primary interaction vertices inside the bulk.
In the case of about 300 of these events a full 3D image of the vertex region was digitized to search possible kink candidates.
One of these so called 'vertex video images' is shown in fig[4].

6 Summary and Perspectives

During the first two years of data taking the capabilites of the CHORUS detector were carefully inspected and prouved to be satisfactory.
The analysis performed on a small sub-set of 1994 data has shown that the full chain "detector $\rightarrow$ predictions $\rightarrow$ scanback $\rightarrow$ vertex analysis" is operational and delivers good data quality. With this partial data set, it will be possible to achieve an upper limit comparable with the existing one.
Taking into account the favourable signal/noise ratio in CHORUS (0.4 background events in the full 1994/1995 data set) we hope to considerably increase the sensitivity by doubling the statistics during 1996/1997 runs.

References

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