# Status of the CHORUS structure function measurement

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The CHORUS detector, designed to search for neutrino oscillations, was used to record a high-statistics sample of neutrino and anti-neutrino interactions during the extension of the experiment in 1998, using the lead calorimeter as a target. The measurement of the structure functions $F_2(x, Q^2)$ and $xF_3(x, Q^2)$ is underway.

## 1. INTRODUCTION

At the end of 1997 CHORUS finished a successful four-year exposure of a nuclear emulsion target. The present 90% confidence limit on the $\nu_\mu \rightarrow \nu_\tau$ oscillation probability is $4.6 \cdot 10^{-4}$ [1].

In 1998 the neutrino beam was produced for the NOMAD experiment, just behind the CHORUS set-up. This allowed CHORUS to record a high statistics sample of neutrino interactions using the 118 tons calorimeter as a target. Recording these interactions in the previous years would have caused too much dead-time for the oscillation search.

Other data taking programs in 1998 included test beam exposures of the calorimeter and the muon spectrometer, emulsion test exposures, an exposure of four light targets and a continuation of a heavy lepton search in cooperation with NOMAD.

Neutrino structure functions are valuable ingredients for constraining parton distribution functions and testing QCD. The comparison of $F_2^{\nu N}(x, Q^2)$ with charged lepton data tests the universality of parton distributions. The structure function $xF_3^{\nu N}(x, Q^2)$ represents in leading order the valence quark densities and its QCD evolution is independent of the gluon density.

The only published neutrino structure functions to date, based on samples of more than $10^5$ neutrino and anti-neutrino interactions, are from CCFR [2] and CDHSW [3]. These measurements are in disagreement. CCFR also shows at low $x$ a discrepancy with muon data.

An independent high-statistics measurement may help to clarify these disagreements. The CHORUS high resolution calorimetry makes it possible to measure at low $Q^2$. Furthermore, the different target material, lead for the CHORUS data compared with iron for CCFR and CDHSW, allows to study nuclear effects.

## 2. THE CHORUS SETUP IN 1998

### 2.1. Neutrino Beam

Neutrinos are produced using the 450 GeV protons of the CERN-SPS accelerator, extracted every 14.4 s in two 6 ms spills on a segmented beryllium target. Mesons of the selected charge are focused by two pulsed toroid magnets. Neutrinos originate predominantly from the decay of pions and kaons in a 309 m long vacuum tunnel. A shielding of 370 m iron and earth serves to stop all hadrons and most muons.

### 2.2. The Calorimeter

The 118 ton lead/scintillator calorimeter had been designed for neutrino interactions in the emulsion target upstream. In this study it serves both as a target and for measuring the shower energy of neutrino interactions.

It consists of three sectors of increasing size and decreasing granularity. The first and the second sector consist of lead modules, interspersed with 1 mm diameter scintillating fibers. The third sector consists of lead plates interleaved with scintillator plates. The total thickness corresponds to 5.5 interaction lengths, enough to contain most showers originating from neutrino interactions upstream of the calorimeter. For neutrino interactions in the calorimeter itself the shower leakage is significant and must either be measured in a tail catcher or be accurately modeled. All sectors have both longitudinal and transverse segmentation and readout at two sides, used to compensate for light-attenuation.

The resolution measured with test beam pions impinging on the front of the calorimeter is about $32\%/\sqrt{E}$ [4]. For neutrino interactions inside the calorimeter the resolution is 40-60%$/\sqrt{E}$.

### 2.3. The muon spectrometer

The muon momentum and charge is measured in a six-disk magnetized iron spectrometer. The muon trajectory is measured at seven locations between the magnets. The momentum resolution, measured using test beam muons, varies from 12% at 10 GeV to 17% at 100 GeV. The magnets are equipped with scintillators, allowing the muon spectrometer to be used as a shower tail catcher.

### 2.4. Data Collection

The data were taken during a period of about 18 weeks in the summer of 1998. For two periods of three weeks each the polarity of the beam focusing magnets was inverted to produce a beam of predominantly anti-neutrinos. A total of about $5.4 \cdot 10^6$ interactions have been recorded in neutrino mode and $1.2 \cdot 10^6$ in anti-neutrino mode. A typical neutrino event is shown in Figure 1.

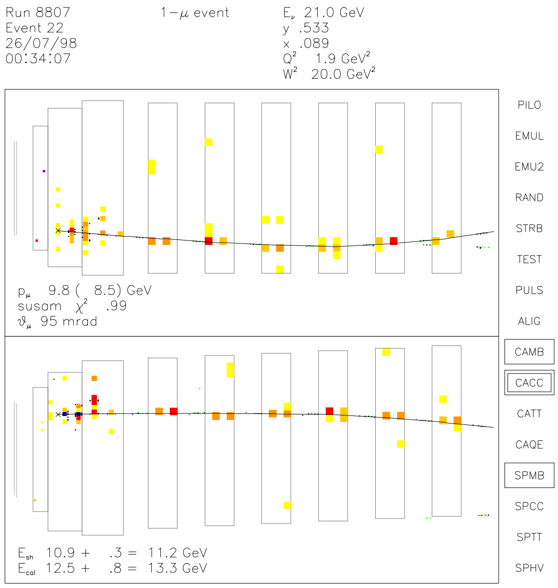


Figure 1. Top-view and side-view of a typical charged-current interaction.

## 3. ANALYSIS METHOD

The selected events are required to have a muon with reconstructed momentum larger than 4 GeV and a scattering angle below 300 mrad. The hadronic energy deposit must be at least 4 GeV and the neutrino energy between 10 and 240 GeV. Furthermore the event vertex is required to be in a central area of $200\times200$ cm$^2$ upstream in the calorimeter, corresponding to a fiducial volume of 18.4 tons.

After these cuts the event sample is reduced to $1.6 \cdot 10^6$ neutrino interactions and $0.2 \cdot 10^6$ anti-neutrino interactions.

Presently the information from the shower tail catcher is not taken into account. Therefore additional cuts are applied that require a hadronic energy deposit of less than 100 GeV, and the vertex reconstructed in the upstream half of the fiducial volume. This way an event sample with reduced shower leakage is selected.

A Monte Carlo sample is generated using a cross-section model according to the GRV94 LO [5] parton distributions, the measured beam spectrum and a parameterization of the detector response. The MC sample is used to correct the data for the above cuts, the trigger inefficiency, the reconstruction inefficiency and the resolution smearing.

In a first step of the analysis the neutrino flux is determined for both beam polarities. The data are divided in $E_\nu$ bins and corrected with the MC sample. The neutrino flux is then determined from the interaction rate using a world average inclusive charged-current cross-section for neutrinos and anti-neutrinos [6]. The result is shown in Figure 2.

Except for a 10-20% difference in the normalization, the measured fluxes are in agreement with the beam simulation. In neutrino mode the beam is more intense, has higher average interaction energy and lower contamination than in

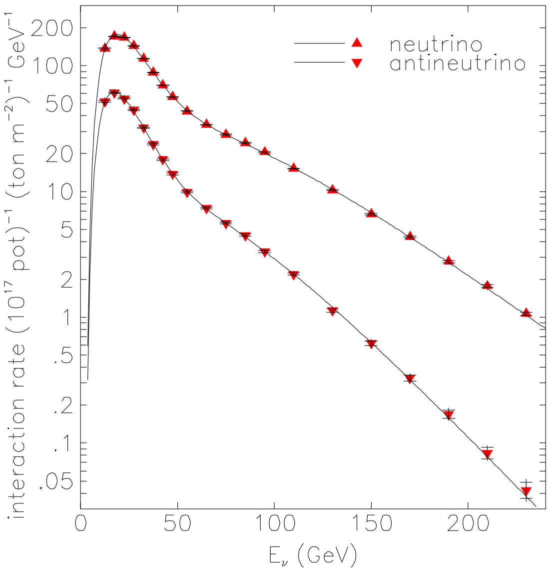


Figure 2. Measured interaction rate normalized to the number of protons on target (pot). Superimposed is a 6-parameter fit used for the MC generation.

anti-neutrino mode.

The structure function extraction is based on the general formula for neutrino charged-current cross-section:

$$\frac{d\sigma^{\nu N}}{dx\,dy} = \frac{G_F^2 M_N E_\nu}{\pi}\left(\frac{m_W^2}{Q^2+m_W^2}\right)^2 \times \left\{(1-y+\frac{y^2}{2(1+R)})F_2 \pm (y-\frac{y^2}{2})xF_3\right\}$$

The data are divided in bins of $x$ and $Q^2$ and corrected with the MC sample. Additional corrections are needed for the non-isoscalarity of the target, radiative effects, non-zero strange sea and the charm production suppression. The value of $F_2(x,Q^2)$ and $F_3(x,Q^2)$ are then calculated using the corrected number of neutrino and anti-neutrino interactions, the measured fluxes, and an external measurement of the longitudinal cross-section.

Current results of the analysis are under study. Some changes are foreseen for the event reconstruction and modeling. Not all systematic uncertainties have been evaluated yet.

## 4. CONCLUSIONS AND OUTLOOK

A high-statistics sample of neutrino and anti-neutrino interactions has been recorded during a relatively short run. The results may shed new light on the present discrepancy between neutrino and charged lepton structure functions. The comparison between this experiment and others may reveal nuclear effects in neutrino interactions.

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