REPORT ON THE STUDY GROUP ON ν MASSES, OSCILLATIONS, ν_e

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Introduction

The problem this group* addressed was the following: what are the areas in ν oscillations and ν_e physics in which the Tevatron can be useful, better than existing accelerators or even unique? The points which, without any claim of originality, were discussed during the group meetings are briefly outlined below.

Neutrino Oscillations

The most obvious experiments in which to look for neutrino oscillations are those which study the production of prompt neutrinos originating from the dumping of the primary proton beam. In these experiments ν_μ's and ν_e's are produced in equal number from the semi-leptonic decays of charmed particles. Present limits on the oscillations of ν_μ into any other kind of neutrinos are fairly tight, though not for small mixing angles. Thus, the observation, at a distance L from the dump, of a ν_e/ν_μ value smaller than unity would be a strong indication of $\nu_e \rightleftarrows \nu_?$ ($\nu_? \neq \nu_e$, ν_μ) oscillations.

The probability for such a process is governed by the equation

$$P(\nu_e \to \nu_?) = \sin^2 2\alpha \sin^2 \frac{(m^2_{\nu_?} - m^2_{\nu_e})L}{E},$$

where α is the ν_e, $\nu_?$ mixing angle and E is the neutrino energy.

Conclusive evidence for $\nu_e \rightleftarrows \nu_?$ oscillations would then be obtained from the observation of an oscillatory behavior of ν_e/ν_μ according to the equation above. From an experimental point of view this study seems quite feasible in a calorimeter-type set-up capable of collecting high statistics. Positive identification of electrons in ν_eCC events has been achieved in the charm experiments at CERN (utilizing the different transverse behavior of electromagnetic and hadronic showers) and is expected to be possible in the E-613 experiment at Fermilab (using the different longitudinal development of electromagnetic and hadronic showers in lead).

A typical energy dependence for the ratio of events with an electron to those with a muon, calculated for $\sin^2 2\alpha = 0.4$, $\delta m = (m^2_{\nu_?} - m^2_{\nu_e})^{1/2} = 17$ eV and L = 60 m is shown in Fig. 1.

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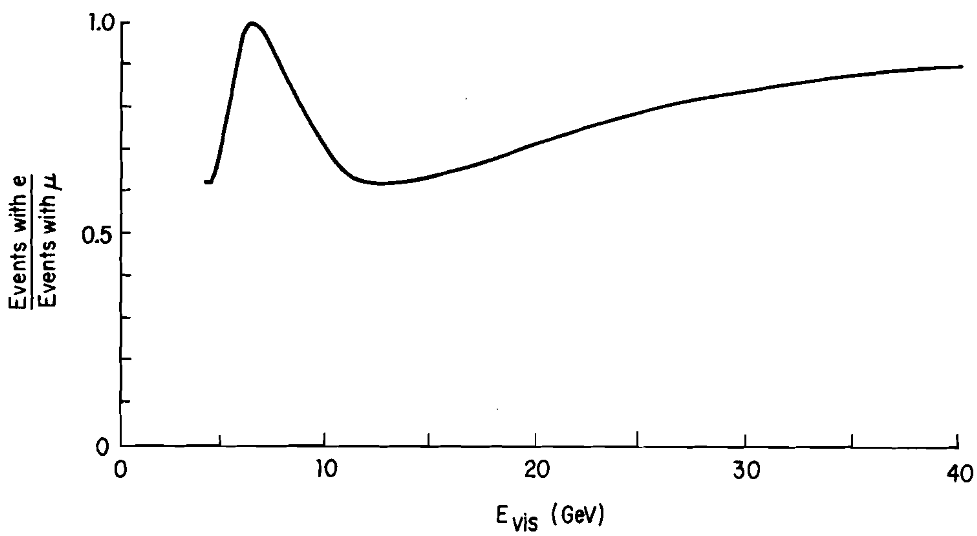

Fig. 1. This figure shows the e/μ ratio vs E_{vis} with $\sin^2 2\alpha = 0.4$; δm = 17 ev, L = 60 m; (or δm = 59 ev, L = 500m).

The advantages of performing this type of investigation at the Tevatron, with energies which are typically a factor of two high than presently available, are several:

(i) The charm production cross section is expected to increase substantially (~ ×3).

(ii) For the same apparatus, the same solid angle could be subtended at larger L. This allows extension of the sensitivity of the experiment to lower δm, or, alternatively, to study the same δm range under better experimental conditions originating from the higher neutrino energies.

(iii) The higher duty cycle of the Tevatron will allow experiments to run at higher proton beam intensity, usually limited by the muon flux originating from the dump.

The expected sensitivity of good Tevatron experiments is such that, provided δm falls in the range accessible to high energy accelerators, oscillatory phenomena should be observable even for $\sin^2\alpha \approx 0.1$. This could be very important, since many theoretical idea suggest mixing angles $\alpha \lesssim \theta_c$.

Physics of Tau Neutrinos

Convincing evidence for the detection of the ν_τ will probably have to be based on the observations of its interaction downstream of the production point. Thus, the higher energy available at the Tevatron and the corresponding high production cross section and longer decay paths will certainly be an advantage, even if the slower repetition rate of the new accelerator implies a reduction in the proton beam intensity.

The study of ν_τ induced neutral currents looks at this stage almost hopelessly difficult. It is however quite reasonable to expect the study of charged current properties to reach, in a few years of Tevatron operation, the semi-quantitative stage which was typical of ν_μ physics a decade ago and has been reached in ν_e physics at present.