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Requirements from $N^{O}E$ for ν_τ appearance in the NGS ν beam

Abstract

Recent claims for neutrino oscilations from atmospheric neutrino experiments suggest values of the oscillation parameters that impose tight requirements to the neutrino beam energy shape for a LBL experiment in order to maximize the ν_τ production. In this report the effect of the ν_τ cross section and oscillation probability will be discussed, and a comparison of different proposed beams will be shown.

1 General considerations

The rate of ν_τ CC events detected in $\nu_\mu \rightarrow \nu_\tau$ appearance experiments is given by

$$R_\tau = A \int \Phi_\mu(E)\sigma_\tau(E)P_{osc}(E)dE$$

where E is energy, $\Phi_\mu(E)$ is the neutrino flux, $\sigma_\tau(E)$ is the ν_τ charged current cross section, $P_{osc}(E)$ the oscillation probability and A the number of target nucleons in the target detector.

The oscillation probability $P_{osc}(E)$, in the case of mixing of two neutrinos, is given by

$$P_{osc}(E) = \sin^2(2\theta)\sin^2(1.27\Delta m^2 L/E)$$

Fig.1 shows its energy dependence for different values of Δm^2 in the range $5 \cdot 10^{-4}$ to 10^{-2} eV^2.

ν_μ and ν_τ CC cross sections (see appendix A) as a function of energy are shown in Fig.2 and 3 respectively. In particular the $\sigma_\tau(E)$ cross section grows slowly with energy above a threshold of about 3.5 Gev.

The function $\sigma_\tau(E)P_{osc}(E)$ is shown in Fig.4 for different values of Δm^2.

The shape of the energy spectrum of the neutrino beam has to be such to provide most of its flux where this function is large. One would thus maximize the rate R_τ of ν_τ CC events. It appears therefore that the optimal energy is about 15 Gev for the highest values of Δm^2 ($0.01\ eV^2$) and decreases gently with the value of Δm^2 towards a limiting value of about 10 GeV.

2 Comparison of proposed beams

As an example the rate of ν_τ CC interactions for 10^{19} protons on target and per kton has been calculated for different proposed beam configurations [1],[2],[3]. Fig. 5 shows the ν_μ CC interaction spectra for the different beams. The rate of ν_τ CC interactions is shown in Fig. 6 as a function of Δm^2. It is clear that a beam like the one proposed by Ball et al. in [1], rather narrowly peaked around an energy that better matches the requirements of section 1, gives the highest tau yield.

Fig 7 shows the rate of residual ν_μ CC interactions. From comparison of Fig. 6 and Fig. 7 one can also conclude that the beam in ref [1] has a higher ratio of oscillated to unoscillated events (the best signal to noise ratio) when compared to the one of ref [2]. In particular Fig.5 shows that the event rate of ref [1] above $\sim$ 20 GeV is only about 25% of the one of ref [2]. Therefore in ν_τ appearance

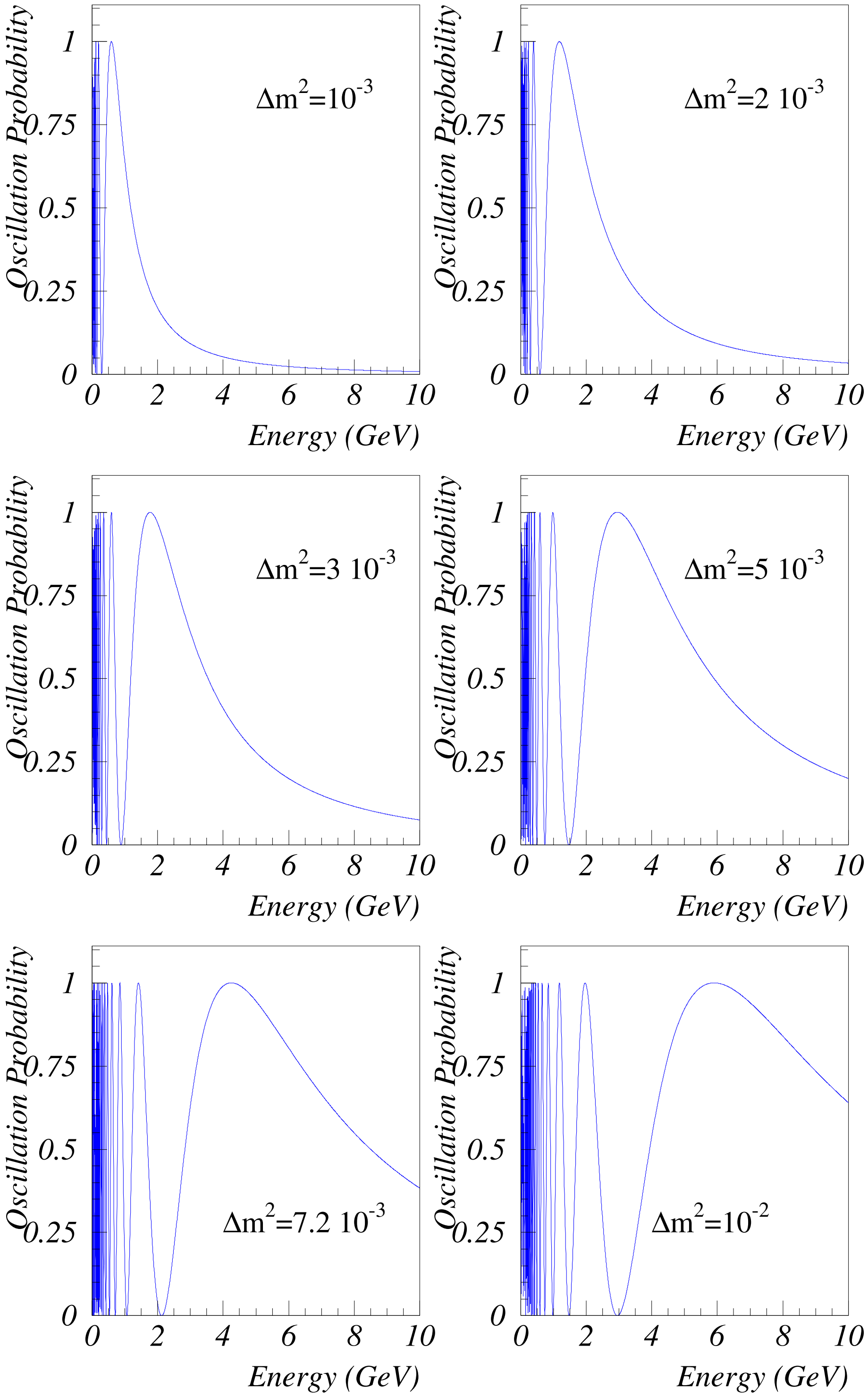

Figure 1: Oscillation probability at Gran Sasso for different values of Δm^2

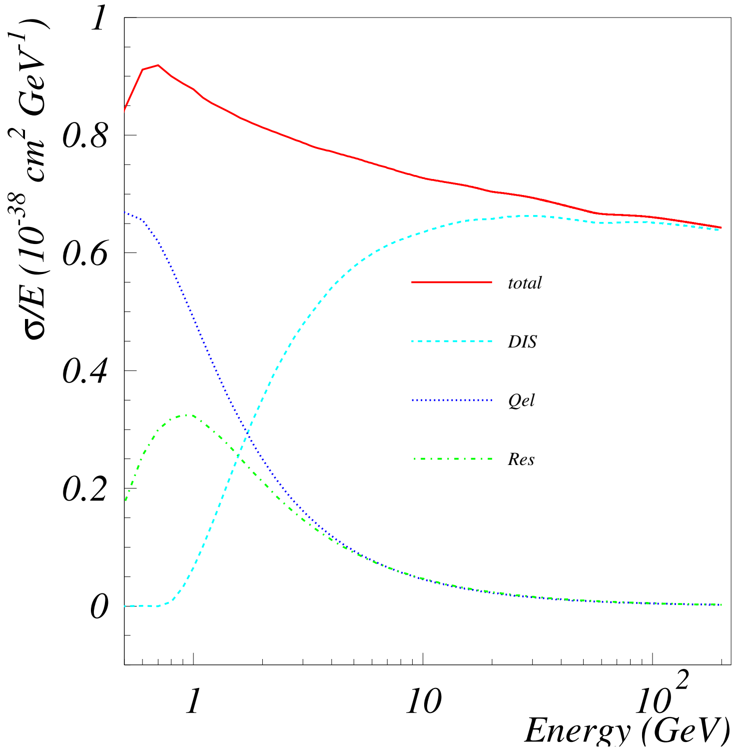

Figure 2: Ratio of ν_μ CC cross section over its energy

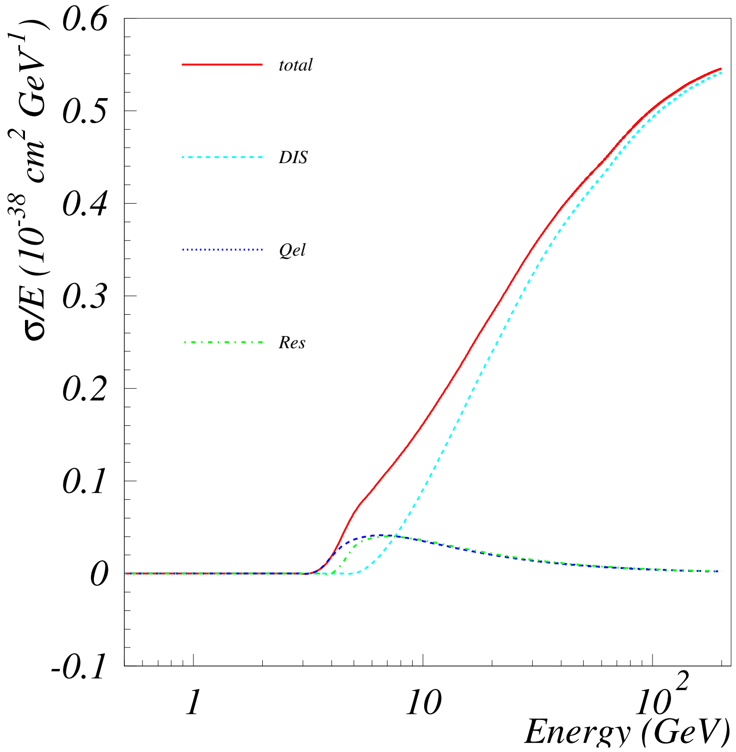

Figure 3: Ratio of ν_τ CC cross section over its energy

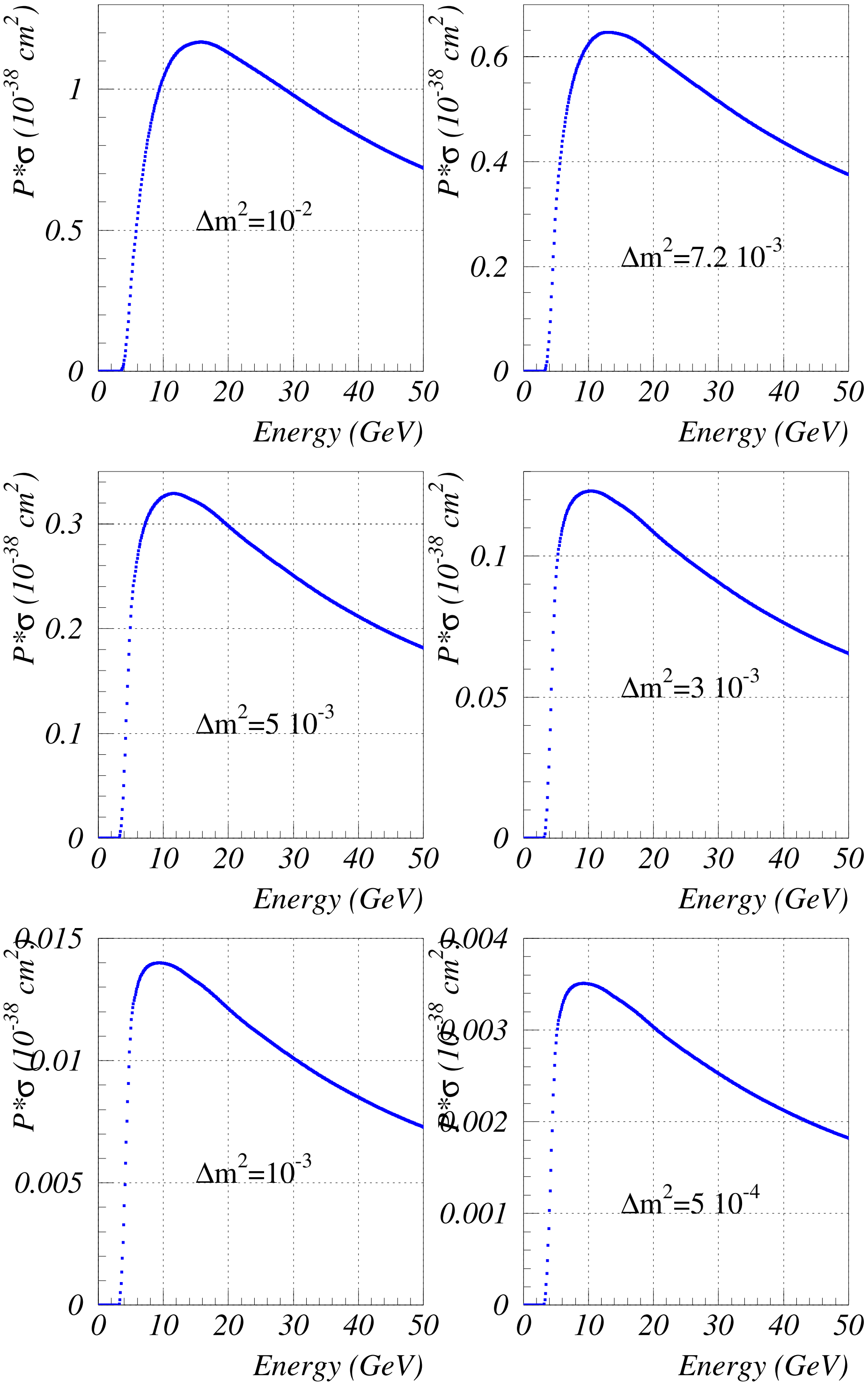

Figure 4: ν_τ CC cross section times oscillation probability at Gran Sasso for different values of $\Delta \mathrm{m}^2$

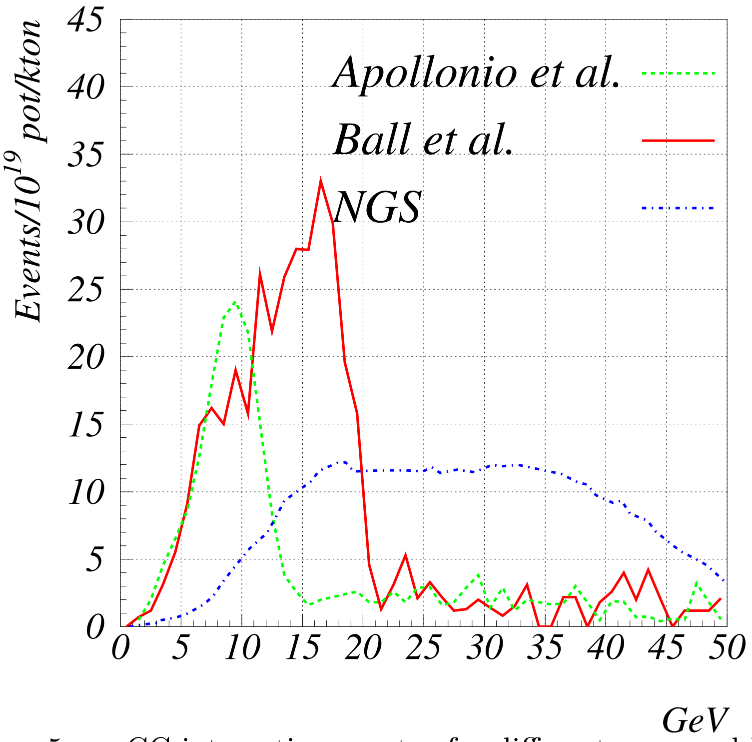

Figure 5: ν_μ CC interaction spectra for different proposed beams

searches in the $\tau \rightarrow e$ channel, the contribution of NC (π^o) will be reduced by the same amount.

Appendix A: ν interaction cross-sections

The cross sections used here are derived from the MonteCarlo code of Lipari-Sartogo [4] [5], developed mainly for the MACRO experiment analysis. It includes also processes which are of relevance at low energies (few GeV). The total cross-section is the sum of three contributions: quasi elastic scattering (QEL), single pion production (RIS) and deep inelastic scattering (DIS). The DIS is considered only for $W_c > 1.4$ GeV, and RIS for $W_c < 1.4$ GeV to avoid double counting.

1. QEL - Nuclear effects are included ($p_{\text{Fermi}} = 0.220$ GeV/c) and the lepton masses are taken into account. So are the effects due to binding energy [6].

2. RIS - We used Fogli and Nardulli [7] instead of the more common (see NOMAD and MINOS) Rein and Segal approach. Mass effects are included.

3. DIS - Parton density functions: GRV-LO Q^2min=0.25 GeV^2 called through the PDF library - Mass effects are included.

Satisfactory qualitative comparisons were made with other cross section sets from NOMAD (A.Marchionni) and from MINOS [8].

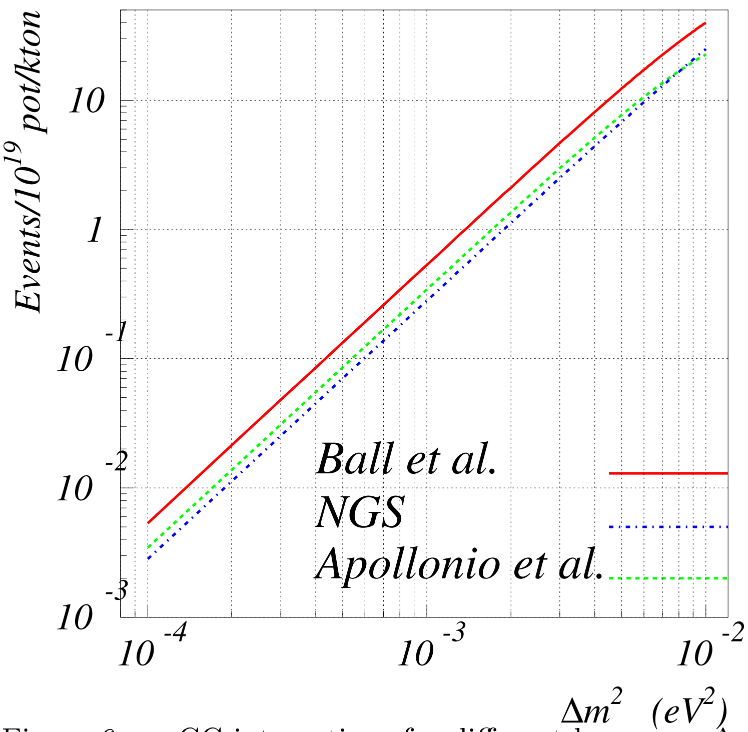

Figure 6: ν_τ CC interactions for different beams vs Δm^2

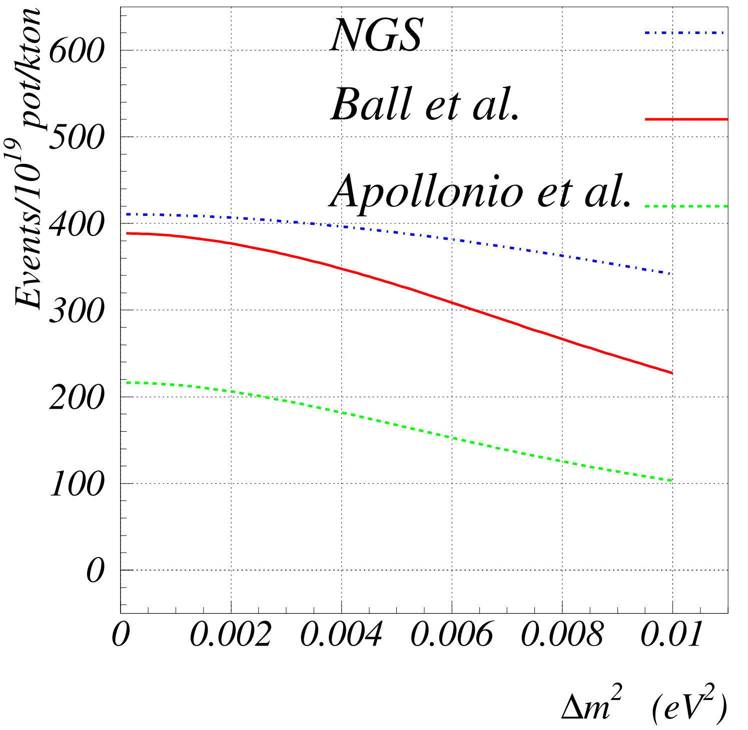

Figure 7: Residual ν_μ CC interactions for different beams vs Δm^2 in the range $0 \leq E_\nu \leq 50$ GeV.

References

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