Study of the reconstructed neutrino energy and the Super Scaling Approach (SuSA)

for development of a new method for the study of neutrino oscillations.

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Introduction

T2K and NEUT

T2K

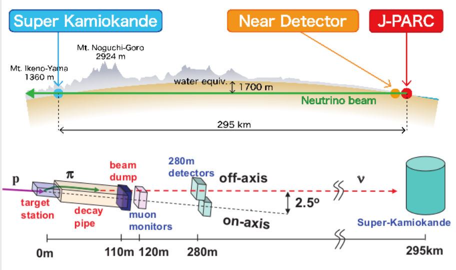
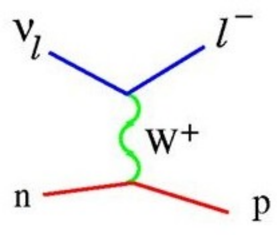


Figure 1: Schematic representation of the T2K configuration.

Using the NEUT simulation code, the reaction studied was:

- $\nu_\mu \rightarrow {}^{12}$C

CCQE or CC0π



Super Scaling Approach (SuSA)

What is the scaling variable?

The scaling variable (ψ') equation

$$\psi' \equiv \frac{1}{\sqrt{\xi_F}} \frac{\lambda' - \tau'}{\sqrt{(1+\lambda')\tau' + \kappa\sqrt{\tau'(\tau'+1)}}} \tag{1}$$

$$\xi_F = \sqrt{1+\eta_F^2} - 1;$$

$$\eta_F = \frac{k_F}{M_N} << 1;$$

$$k_F = 228\ MeV;$$

$$\kappa = \frac{q}{(2M_N)};$$

$$q = \sqrt{|\vec{k_\mu}|^2 + E_\nu^{true2} - 2\,|\vec{k_\mu}|\,E_\nu^{true}\,cos\theta_\mu}$$

$$\lambda' = \frac{\omega'}{(2M_N)};$$

$$\omega' = \omega - E_{shift};$$

$$\omega = E_\nu^{true} - E_\mu$$

$$E_{shift} = 20\ MeV;$$

$$\tau' = \kappa^2 - \lambda'^2.$$

The energy shift E_{shift}, is introduced in the theoretical description to account phenomenologically for the shift observed in the QE peak $\left(\omega = \frac{|Q^2|}{2\,M_N}\right)$ when the cross section is plotted as a function of ω.

Super Scaling Approach (SuSA)

How it behaves?

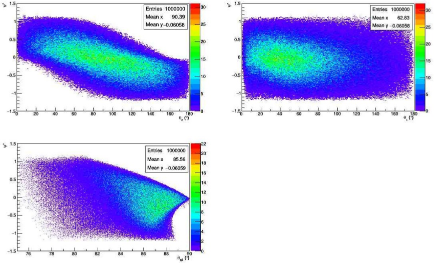


Figure 2: Scaling variable dependency with (a) the neutron angle, (b) the muon angle and (c) the transfered momentum angle.

Neutron angle:

$$\theta_n = \arccos\left(\frac{\vec{P_\nu} * \vec{P_n}}{P_\nu \; P_n}\right) \quad (2)$$

Muon angle:

$$\theta_\mu = \arccos\left(\frac{\vec{P_\nu} * \vec{P_\mu}}{P_\nu \; P_\mu}\right) \quad (3)$$

Transfered momentum angle:

$$\theta_{q2} = \arccos\left(P_n * \left(\frac{\vec{P_\nu} - \vec{P_\mu}}{|P_\nu - P_\mu|}\right)\right) \quad (4)$$

Super Scaling Approach (SuSA)

How it behaves?

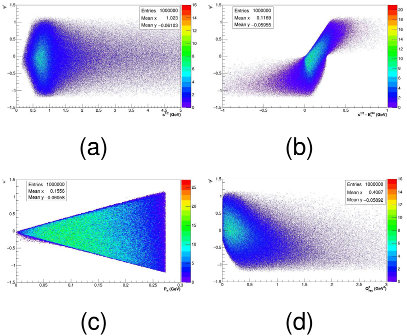


Figure 3: Scaling variable dependency with (a) the center of mass energy, (b) the center of mass energy minus reconstructed neutrino energy, (c) the neutron momentum and (d) transfered momentum.

Center of mass energy:

$$\sqrt{s} = E_\nu^{true} - P_n \quad (5)$$

$$\sqrt{s} = E_\nu^{true} - P_n - E_\nu^{rec} \quad (6)$$

Reconstructed transfered momentum:

$$Q^2_{rec} = 2\,E_\nu^{rec}\,(E_\mu - |\vec{k_\mu}|\cos\theta_\mu) - M_\mu^2 \quad (7)$$

Super Scaling Approach (SuSA)

How it behaves?

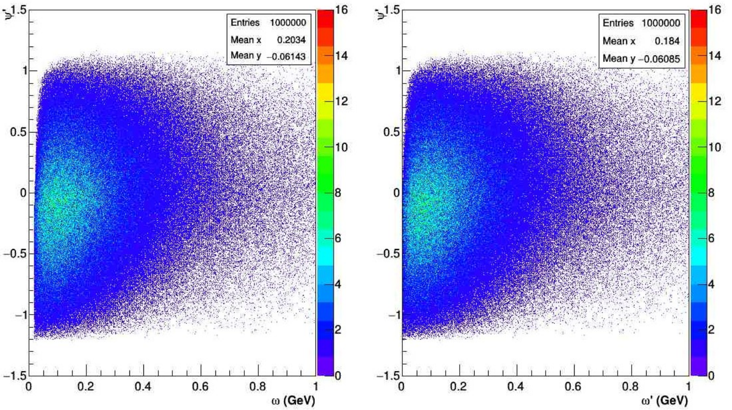


Figure 4: Scaling variable dependency with (a) the transfered energy and (b) the transfered energy shifted.

Super Scaling Approach (SuSA)

How it behaves?

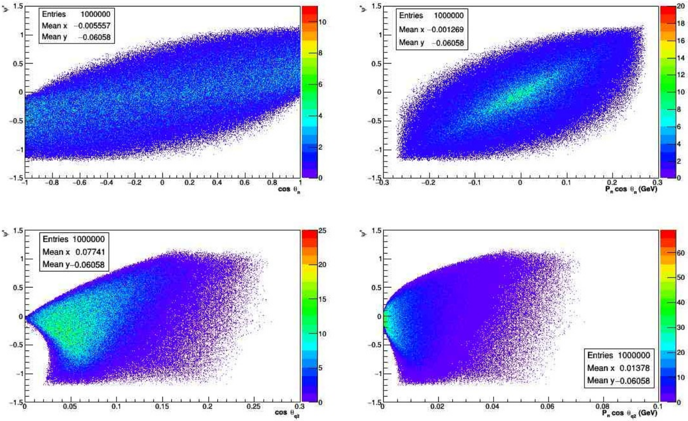


Figure 5: Scaling variable dependency with (a) cosine of the neutron angle, (b) neutron momentum per cosine of the neutron angle, (c) cosine of the transfered momentum angle and (d) neutron momentum per cosine of the transfered momentum angle.

Super Scaling Approach (SuSA)

How it behaves?

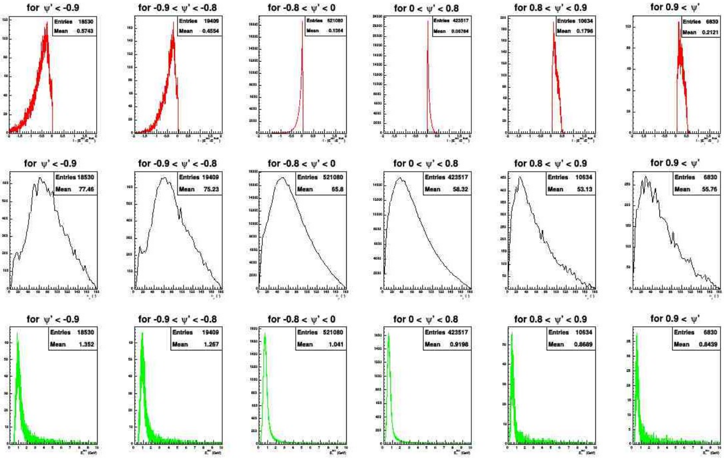


Figure 6: Study the behavior of different variables in the extreme values of the scaling variable.

Reconstructed neutrino energy

Equation for the reconstructed neutrino energy

Reconstructed neutrino energy (E_ν^{rec}) for CCQE:

$$E_\nu^{rec} = \frac{2(M_n - E_B)E_\mu - (E_B^2 + M_\mu^2 - 2M_nE_B + \Delta M^2)}{2(M_n - E_B - E_\mu + |\vec{k_\mu}|cos\theta_\mu)} \quad (8)$$

$$\Delta M^2 = M_n^2 - M_p^2$$

$$E_\mu = \sqrt{|\vec{k_\mu}|^2 + M_\mu^2}$$

- $M_n = 939.565379$ MeV;
- $M_p = 938.272046$ MeV;
- $M_\mu = 105.6583715$ MeV;
- $E_B = 24$ MeV.

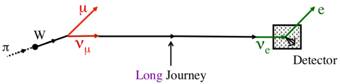
Reconstructed neutrino energy

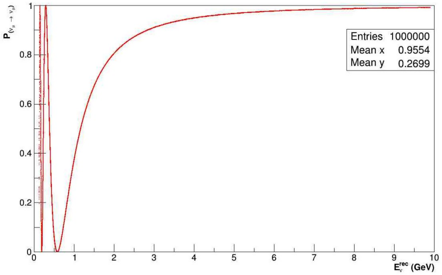
Equation for the ν_μ probability of disappearance

ν_μ probability of disappearance:

$$P_{\mu\mu} \equiv P_{(\nu_\mu \to \nu_\mu)} = 1 - sen^2(2\,\theta_{23})\; sen^2\left(1.267\,\frac{\Delta M^2_{32}\,L_{far}}{E_\nu^{true}}\right) \tag{9}$$

- $sen^2(2\,\theta_{23}) \approx 1$;
- $\Delta M^2_{32} = 2.44 \times 10^{-3}\ \mathrm{eV}^2$;
- $L_{far} = 295$ km.





Reconstructed neutrino energy

E_ν^{rec} dependency with θ_μ

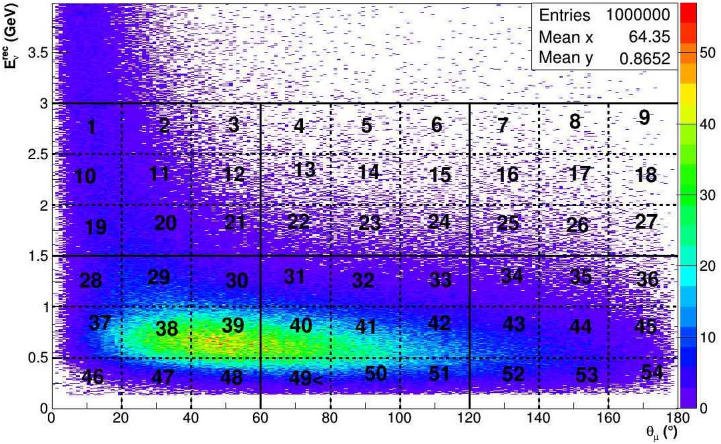


Figure 7: Reconstructed neutrino energy vs. muon angle matrix with bins of 0.5 GeV for E_ν^{rec} and 20° for θ_μ.

Reconstructed neutrino energy

E_ν^{rec} dependency with θ_μ

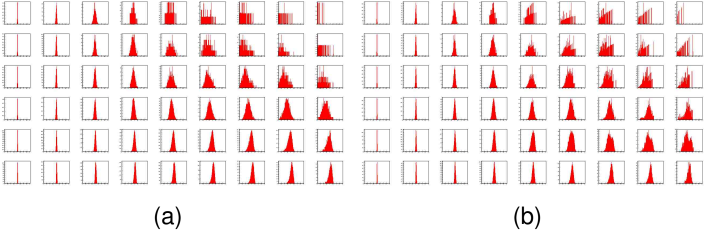
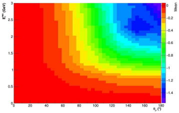
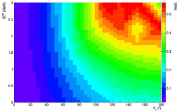


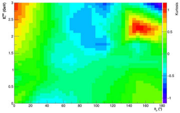
Figure 8: (a) No. of ν_μ events vs. $1 - \left(E_\nu^{rec}/E_\nu^{true}\right)$ for each block of the matrix and (b) appalling probability of disappearance of the ν_μ.

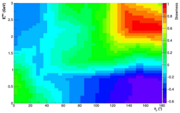
Reconstructed neutrino energy

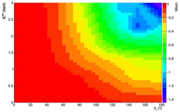
E_{ν}^{rec} dependency with θ_{μ}

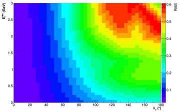

(a) Mean

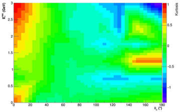

(b) RMS


(c) Kurtosis


(d) Skewmess


(e) Mean


(f) RMS


(g) Kurtosis

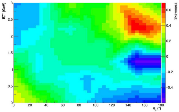

(h) Skewmess

Figure 9: Comparison data of each distribution before (a,b,c,d) and after appalling probability of disappearance of the ν_{μ} (e,f,g,h).

Reconstructed neutrino energy and SuSA

E_ν^{rec} dependency with ψ'

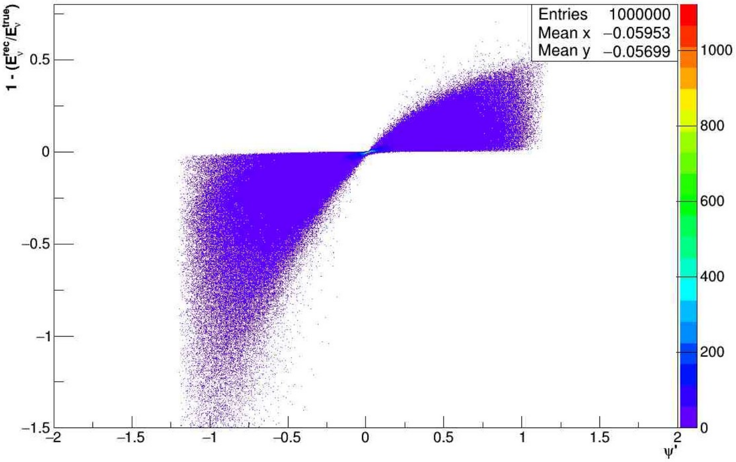


Figure 10: $1 - (E_\nu^{rec}/E_\nu^{true})$ vs. scaling variable.

Reconstructed neutrino energy and SuSA

E_ν^{rec} dependency with $\psi^{'}$

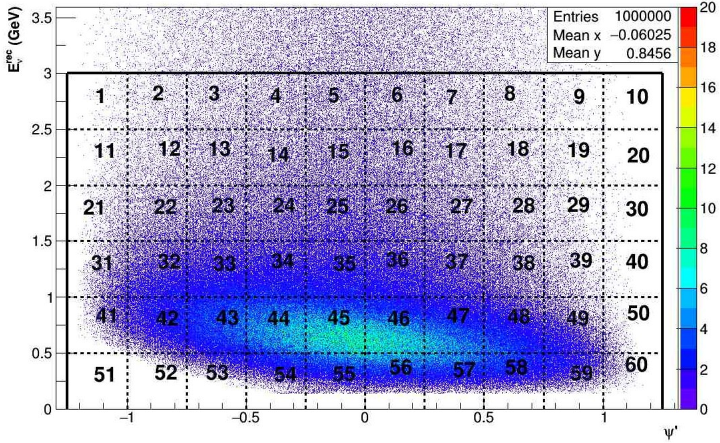
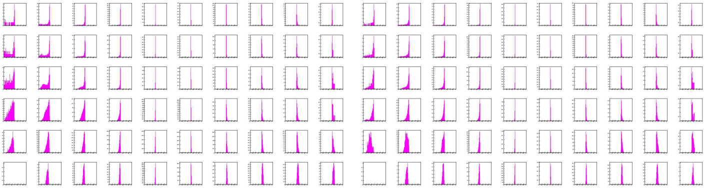


Figure 11: Reconstructed neutrino energy vs. scaling variable matrix with bins of 0.5 GeV for E_ν^{rec} and 0.25 for $\psi^{'}$.

Reconstructed neutrino energy and SuSA

E_ν^{rec} dependency with ψ'

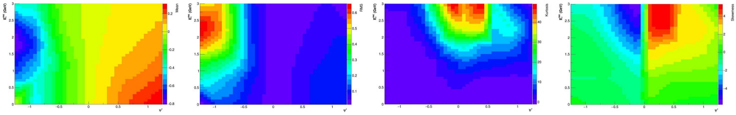


(a) (b)

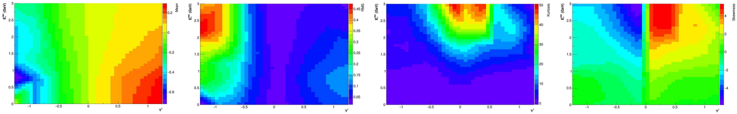
Figure 12: (a) No. of ν_μ events vs. $1 - \left(E_\nu^{rec}/E_\nu^{true}\right)$ for each block of the matrix and (b) appalling probability of disappearance of the ν_μ.

Reconstructed neutrino energy and SuSA

E_ν^{rec} dependency with ψ'



(a) Mean (b) RMS (c) Kurtosis (d) Skewmess



(e) Mean (f) RMS (g) Kurtosis (h) Skewmess

Figure 13: Comparison data of each distribution before (a,b,c,d) and after appalling probability of disappearance of the ν_μ (e,f,g,h).

Thank you!!!

Group Meeting 14/12/2017

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