Neutrino - Tungsten interactions at SND@LHC

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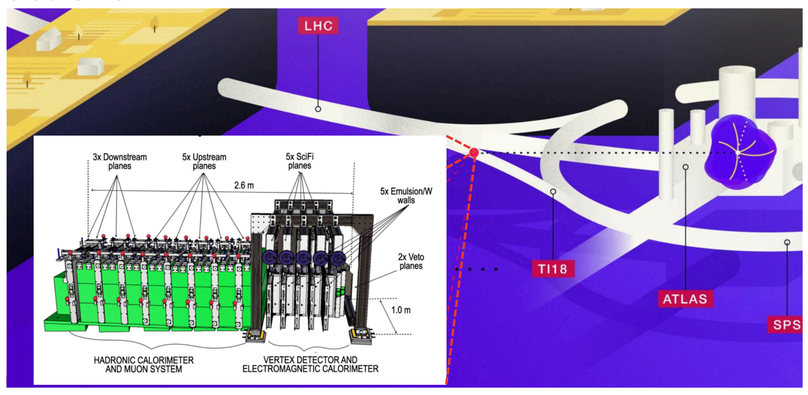
Abstract

Neutrino production from primary hadrons produced by 13TeV proton-proton collisions was studied with Pythia8.3.13 using the forward tune [2]. Hard and soft QCD physics scenarios were considered. After this production, the different interaction channels in the tungsten target were studied using Genie, for neutrino energy up to 1TeV and a target made of tungsten (W^{184}) The cross-section includes Quasi-elastic Scattering (QEL), Resonance Interactions (RES), Deep Inelastic Scattering (DIS), Coherent Pion Production (COH) and Meson Exchange Current (MEC) interactions.



Neutrino flux

Pythia8 neutrino flux predictions, using a forward-tuned configuration, are presented for the pseudorapidity region covered by SND@LHC, considering both hard and soft QCD processes

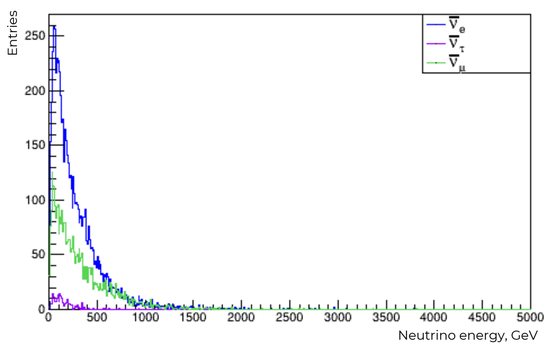


Fig. 1. Anti-Neutrino Fluxes with Hard QCD

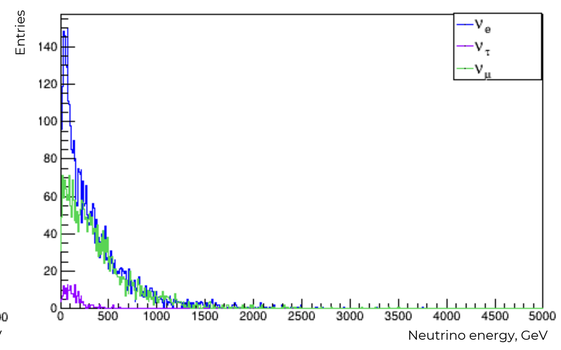


Fig. 2. Neutrino Fluxes with Hard QCD

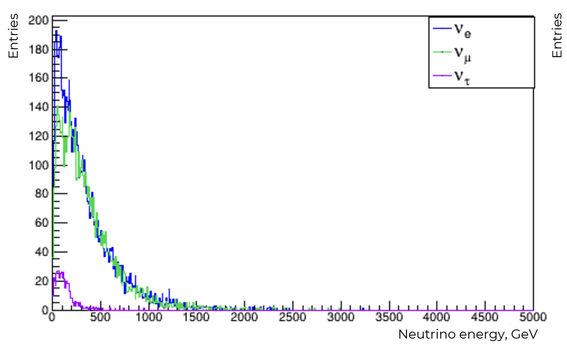


Fig. 3. Neutrino Fluxes with Soft QCD

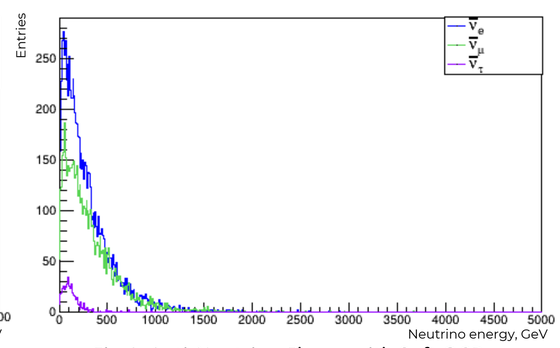


Fig.4. Anti-Neutrino Fluxes with Soft QCD

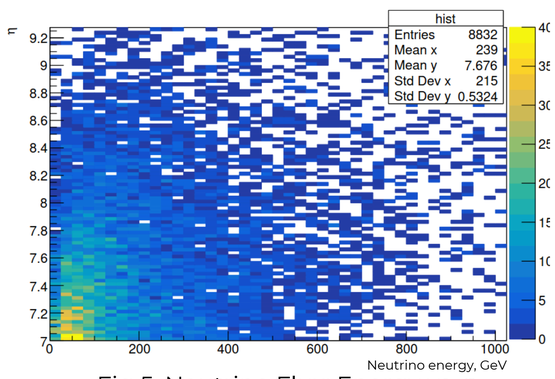


Fig 5. Neutrino Flux: Energy vs η

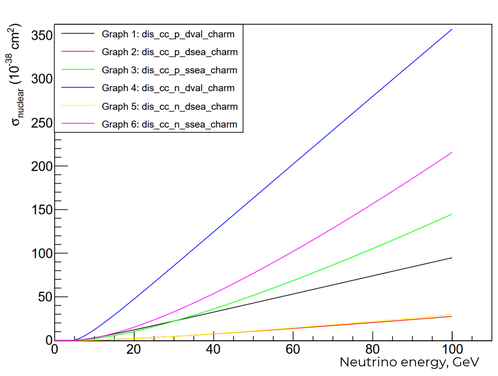


Fig 6. Total cross-section for electron neutrino deep inelastic scattering (DIS) off charm quarks in tungsten

The total cross sections were estimated with GENIE_3.06, fig. 6 shows some DIS cases.

The expected no. of ν+W interactions is estimated as:

$$N_{\nu+W} = N_{W_{nuclei}} \times N_{\nu}[1/cm^2] \times \sigma_{Total}[cm^2]$$

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The following tables present the predicted number of events for 10^8 p+p collisions, based on a selection of Genie's interaction models. Generalized Resonance processes, Pion-Hadronic Resonance interactions, the Interference model for DIS, are excluded. The errors in the prediction, derived from the variation in neutrino fluxes described in [2].

Table 1 and 2, ν_τ interactions for Hard and Soft QCD respectively.

Interacción	Nro. Eventos	Porcentaje
QEL	$5{,}88^{+0{,}42}_{-0{,}15} \times 10^{-3}$	0.106 %
MEC	$2{,}21^{+0{,}26}_{-0{,}06} \times 10^{-3}$	0.0400 %
COH	$5{,}09^{+0{,}32}_{-0{,}04} \times 10^{-4}$	0.00922 %
RES	$2{,}88^{+0{,}21}_{-0{,}06} \times 10^{-2}$	0.522 %
DIS	$3{,}28^{+0{,}05}_{-0{,}03} \times 10^{0}$	59.4 %
Total	5.52	-

Interacción	Nro. Eventos	Porcentaje
QEL	$1{,}35^{+0{,}05}_{-0{,}04} \times 10^{-2}$	0.118 %
MEC	$5{,}09^{+0{,}16}_{-0{,}16} \times 10^{-3}$	0.0448 %
COH	$1{,}10^{+0{,}04}_{-0{,}04} \times 10^{-3}$	0.00969 %
RES	$6{,}60^{+0{,}22}_{-0{,}23} \times 10^{-2}$	0.581 %
DIS	$6{,}60^{+0{,}22}_{-0{,}21} \times 10^{0}$	58.1 %
Total	11.36	-

Table 3 and 4, ν_e interactions for Hard and Soft QCD respectively.

Interacción	Nro. Eventos	Porcentaje
QEL	$1{,}16^{+0{,}01}_{-0{,}04} \times 10^{-1}$	0.0519 %
MEC	$4{,}33^{+0{,}07}_{-0{,}14} \times 10^{-2}$	0.0194 %
COH	$2{,}33^{+0{,}04}_{-0{,}08} \times 10^{-2}$	0.0104 %
RES	$5{,}90^{+0{,}06}_{-0{,}20} \times 10^{-1}$	0.264 %
DIS	$1{,}33^{+0{,}04}_{-0{,}08} \times 10^{2}$	59.6 %
Total	223.24	-

Interacción	Nro. Eventos	Porcentaje
QEL	$1{,}96^{+0{,}01}_{-0{,}13} \times 10^{-1}$	0.0492 %
MEC	$7{,}33^{+0{,}04}_{-0{,}46} \times 10^{-2}$	0.0184 %
COH	$4{,}08^{+0{,}03}_{-0{,}31} \times 10^{-2}$	0.0102 %
RES	$1{,}00^{+0{,}01}_{-0{,}64} \times 10^{0}$	0.251 %
DIS	$2{,}37^{+0{,}03}_{-0{,}24} \times 10^{2}$	59.5 %
Total	398.27	-

Table 5 and 6, ν_μ interactions for Hard and Soft QCD respectively.

Interacción	Nro. Eventos	Porcentaje
QEL	$8{,}63^{+0{,}27}_{-0{,}20} \times 10^{-2}$	0.0448 %
MEC	$3{,}23^{+0{,}10}_{-0{,}07} \times 10^{-2}$	0.0168 %
COH	$1{,}83^{+0{,}08}_{-0{,}04} \times 10^{-2}$	0.00950 %
RES	$4{,}41^{+0{,}14}_{-0{,}10} \times 10^{-1}$	0.229 %
DIS	$1{,}15^{+0{,}05}_{-0{,}04} \times 10^{2}$	59.7 %
Total	192.70	-

Interacción	Nro. Eventos	Porcentaje
QEL	$1{,}75^{+0{,}01}_{-0{,}11} \times 10^{-1}$	0.0458 %
MEC	$6{,}57^{+0{,}03}_{-0{,}43} \times 10^{-2}$	0.0172 %
COH	$3{,}74^{+0{,}01}_{-0{,}30} \times 10^{-2}$	0.00979 %
RES	$8{,}98^{+0{,}04}_{-0{,}60} \times 10^{-1}$	0.235 %
DIS	$2{,}28^{+0{,}01}_{-0{,}24} \times 10^{2}$	59.7 %
Total	382.23	-

Discussion

In the Pythia8 fluxes for the ν_τ we can see that the amount of events that we can see in the flux are not many, this later reflects at the number of events on Table 1.

On the other hand for ν_e and ν_μ we can pass onto directly the tables. Where we can see how DIS interactions have the most amount of events for each neutrino. Rounding up the 60% of the expected events.

This aligns with the filtering applied to the fluxes, where only neutrinos with a primary particle as their mother were considered. This is because the interactions we expect to study are predominantly of this type. Specifically, to analyze interactions leading to the production of charm quarks c, we should focus on DIS

As DIS are the most predominant process present in this work. For future reference, to have a better study on these types of interactions at SND it would be good to consider a larger range of energy for the cross-splines, up to 5 TeV rather than 1 TeV.

References

[1] Rivière, C., Redford, S., Oide, K., Apsimon, R., Bruning, O., Holzer, E., & Zimmermann, F. (2023). Study of neutrino interactions at SND@LHC. https://cds.cern.ch/record/2876147.

[2] Fieg, M., Kling, F., Schulz, H., & Sjöstrand, T. (2023). Tuning Pythia for Forward Physics Experiments. https://arxiv.org/abs/2309.08604.