

Research Result Report
ICRR Inter-University Research Program 2023

Research Subject: Constraining systematics at T2K and SuperKamiokande oscillation analyses using neutrino-nucleus interaction models

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Summary of Research Result :

Progresses on the development and optimization of neutrino interaction models (SuSAv2-MEC and RMF models) for the analysis of data from T2K and other experiments have been published in FY2023 together with other T2K papers in common with ICRR members:

- Weak Neutrino (Antineutrino) Charged-Current Responses and Scaling for Nuclear Matter in the Relativistic Mean Field. Sara Cruz-Barrios, Guillermo D. Megias, Juan A. Caballero. *Universe* 2023, 9(5), 240 (2023).

- Superscaling in the resonance region for neutrino-nucleus scattering: The SuSAv2 dynamical coupled-channels model. J. Gonzalez-Rosa, G. D. Megias, J. A. Caballero, M. B. Barbaro, J. M. Franco-Patino. *Phys. Rev. D* 108, 113008 (2023).

- New model comparison for semi-inclusive charged-current electron and muon neutrino scattering by ^{40}Ar in the energy range of the MicroBooNE experiment. J. M. Franco-Patino, S. Dolan, R. Gonzalez-Jimenez, M. B. Barbaro, J. A. Caballero, and G. D. Megias. *Phys. Rev. D* 109, 013004 (2024).

- K. Abe et al. (T2K Collaboration), *Measurements of neutrino oscillation parameters from the T2K experiment using 3.6×10^{21} protons on target*. *Eur. Phys. J. C* 83, 782 (2023).

- K. Abe et al. (T2K Collaboration), *First measurement of $\nu_{\mu} \rightarrow \nu_{\tau}$ CC interactions on hydrocarbon without pions in the FS using multiple detectors with correlated energy spectra at T2K*. *Phys. Rev. D* 108, 112009 (2023).

Work is in progress with Prof. Hayato-san (ICRR) to include the DCC model from the Osaka group in the SuSAv2 model and subsequently implement it in the NEUT event generator used in T2K and SuperKamiokande. This will allow to use different approaches to analyze the resonant regime in neutrino-nucleus reactions. Also, in collaboration with Hayato-san and other T2K members, a first implementation of the inclusive and semi-inclusive SuSAv2 and RMF-1p1h models in NEUT is also in progress. This will allow the reweight of several parameters for the oscillation analysis, the study of nuclear-medium effects, and a comparison between nuclear

optical potentials and cascade models in generators, among other issues. Some outcomes of this research have been recently published and additional works are expected to be published in coming months. They have been also presented at several conferences and meetings, such as:

- G. D. Megias: The theory experience using experimental data, NuXtract workshop at CERN (Geneva, Switzerland), October 2023.
- G. D. Megias: Uncertainties in superscaling models: quasielastic, meson exchange currents and inelastic regimes. Workshop: "Theoretical Physics Uncertainties to Empower Neutrino Experiments", Institute of Nuclear Theory, University of Washington, Seattle (USA). October-November 2023
- J. Gonzalez-Rosa: Superscaling in the inelastic region: The SuSAv2-inelastic model. NuInt24: 14th International Workshop on Neutrino-Nucleus Interactions. Sao Paulo (Brazil), April 2024

With regard to the ICRR Research Program, the Univ. of Seville group has a 3-year R&D project of the Spanish Ministry of Science in which Prof. Hayato-san (ICRR) participates as collaborator. A continuation of this project for the next 3-years has been recently submitted to the Spanish Ministry of Science, which includes Prof. Hayato-san and Prof. Okumura-san as collaborators. The Univ. of Seville consider all these projects a research line of strategic interest, having approved a special allocation to support the participation of their researchers in T2K.

We will also continue these projects on FY2024 under the ICRR Inter-University Research Program 2024.

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