Research Result Report
ICRR Inter-University Research Program 2023

Research Subject:
Data Taking, Calibrations, Measurements & Analysis with Super-Kamiokande I-VII

Principal Investigator: L. Labarga (University Autonoma Madrid)

Participating Researchers:
Pablo Fernández (also DIPC, San Sebastián, Spain)
Felipe Garay (PhD student, University Autonoma Madrid)
Nataly Ospina (University Autonoma Madrid)
Dustin Samudio (PhD student, University Autonoma Madrid)
Bryan Zaldivar (also IFIC, Valencia, Spain)

Summary of Research Result

The items in the title are fundamental for the collaborative work to get out the most of the Super-Kamiokande (SK) experiment, SuperK-Gd and the preparation for the next generation Hyper-Kamiokande. The period spanned by JPF2023 is characterized by Super-Kamiokande running with a ~0.06% $Gd_2(SO_4)_3$ concentration.

Also, during JPF2023 SK suffered serious incidents with its geo-magnetic compensation system; the works within this project contributed most significantly to their understanding, to quantify its impact and to gauge the need of their repair.

Calibrations and related: We are continuously evaluating with autoXenon and Nickel data the evolution with time of SK detector´s performance, mainly from the point of view of light transmission and detection. Main conclusions and results are:

- the SK water system is keeping the Top-Bottom-Asymmetry (TBA) in light transmission at less than 2% with an stability better than 0.5 % at any time. However, some very small, yet significant trend of decreasing is observed. The current value of TBA is around −0.015, close to the typical value at convection.
- The value of TBA extracted from "Nickel" data (from Compton scattered electrons by the Nickel photons) keeps steadily below that from auto-Xenon data (light with $\lambda > 400$ nm) since T1.5 loading; it happened also after T1 loading but it recovered. It coincides with a larger absorption at small wavelengths. We are in the process of studying the (non-)uniformity of that absorption along the detector's volume.
- We detect a significantly large impact of coil failures on the measured TBA with autoXenon data and to a less extent with Ni data. They are still under study. To be able to continue using this TBA in physics analysis we are investigating how to correct it to the "before coil problems" situation.

SuperK-Gd: The $Gd_2(SO_4)_3$ concentration after the second load in June 2022, a total of ~0.06%, corresponds to a ~70% neutron tagging efficiency.

- The SK detector is performing well, no deterioration has been observed after the dissolving of the Gd. The signals from the neutron capture by the Gd are very well identified in all the analysis strategies.

- Among the several publications by the Collaboration or by some of its members, I would like to highlight *Gadolinium concentration measurement with an atomic absorption spectrophotometer*; Prog. Theor. Exp. Phys. 2024 033H01; Ll. Marti & L. Labarga, February 2024.

Geo-magnetic compensation coils incident: We have studied with auto-Xenon and Nickel data the impact on the performance of the PMTs. A summary follows:

- When the coils of the geo-magnetic compensation system go off, the collection efficiency of the PMTs decrease largely: a mean / RMS decrease of ~25% / ~8% is estimated from the auto-Xenon data at the top and bottom parts of the detector, and larger ones, ~35% / ~10%, in the barrel.

- The gains of the PMTs also decrease; we estimate from the 1-photoelectron peak analysis in Nickel data mean / RMS decreases of ~2.6% / ~9% at the top and bottom parts and ~3.4% / ~11% at barrel PMTs.

- We estimate a dependence of the decrease of the collection efficiency when the coils go off on the PMT HV of approximately: − [0.013% / Volt]. To use this property to recover the collection efficiency of the PMTs we'd expect a rate of ~ 0.013% / Volt that is too slow for any realistic use: we would need ~800V, not possible without damaging the PMT, to recover just 10%

Physics Analyses: We are increasing our involvement in the main physics goal of SuperK-Gd: the search for the Diffuse Supernova Neutrino Background (DSNB).

- The first paper on DSNB search with Gd neutron was published in *APJ Letters*

- We are continuing the R&D towards reliable quantitative estimates of the uncertainties in the selection or identification procedures based on Neural Network or, in general, AI algorithms. I.e. to obtain uncertainties estimates that have a mathematically correct statistical meaning.

- Two PhD students have been incorporated to the UAM' group's push for this goal.

No.