Research Report
ICRR Inter-University Research Program 2021

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

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Summary of Research Result
The items listed in the title are fundamental for the collaborative work to get out the most of the Super-Kamiokande experiment, SuperK-Gd and the preparation for the next generation Hyper-Kamiokande.

Calibrations and related
We have evaluated with autoXenon and Ni data the evolution with time of Super-Kamiokande detector' performance, mainly from the point of view of light transmission and detection. The period spanned by JPF2021 is characterized by:

- it starts after ~10 months of running with a ~0.02% $Gd_2(SO_4)_3$ concentration (nominal is 0.2%) dissolved in the water, with no major change being carried out in SK's water system. The SK detector is performing well in this conditions.
- there is a small but significant increase of Dark Noise that varies along time, mostly after modifications in the water system settings; neither the DN increase, nor the variations are understood.

Main conclusions, results are:

- Top - Bottom asymmetry in light transmission is at a reasonably ≈ 3% (except at changing water conditions for reducing DN). A good relative behavior between auto-Xenon data results and "Nickel" data results is observed.
- Light transmission at different detector heights is reasonably stable with time, with only minor relative variations (except at changing water conditions for reducing DN). In general light transmission is larger than that at end of the SK-V period. However, contrary to previous periods, a regime close to stagnant seems to be present in the middle-lower part of the detector.

- A different gain evolution of the PMTs at the top, barrel, and bottom parts in SK-V, -VI is seen. But the increase of the gains themselves with time are significantly slower than in SK-I

SuperK-Gd:

The SK detector with ~0.02% $Gd_2(SO_4)_3$ is performing well, no deterioration is observed after the dissolving of the Gd. The signals from the neutron capture by the Gd are identified well in all the analysis strategies. The intermediate step in loading (T1.5) consists in dissolving another 26 tons of $Gd_2(SO_4)_3$ that, with the previous Gd loaded will add up to ~0.06%, corresponding to a ~70% neutron tagging efficiency. T1.5 loading has finished at beg. July 2022. Every production batch consisted of 1 ton (it was 0.5 tons for T1); all batches must be carefully screened.

- We have screened with high purity Germanium Detectors in the Canfranc Underground Laboratory eight T1.5 samples. No Radioactive Isotope other than small amounts of ^{176}Lu were seen (no harm for physics from this isotope is known).
- 3 additional samples will be screened soon (a quick check of their quality has been performed in Kamioka before their loading).
- Another related topic is the resins used in the water purification system that are key to handle the presence of Gd in the water. The [cation Gd] resin used up to now, AJ1020 (Gd), is discontinued. For its replacement seven new resins have been studied. A sample of each one has been screening for RI in Canfranc. All of them show similar RI pattern: only limits for the radioactive chains and ~1 Bq of +K. All of them are OK for the resin's purpose. The one chosen was AL IR120B(Gd) (mostly from commercial considerations).

Physics Analyses

We aim to get further involvement in the main neutrino oscillation analysis of the experiment and on the search for the Diffuse Supernova Neutrino Background. Our works pivot mainly on neutron tagging.

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. These works are intended to significantly improve the precision of the systematic error estimates of our measurements.