Research Report
ICRR Inter-University Research Program 2019

Research Subject:
Data taking, Calibrations, Measurements and Analysis with Super-Kamiokande and SuperK-Gd

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

Calibrations and related

We have evaluated with autoXenon and Ni data the evolution with time of the water properties of Super-Kamiokande.

- At the beginning of SK-V to understand the starting conditions and the convection period.
- During regular data taking period to monitor the detector performance and help the water team in the preparations of the water system for SK-Gd.
- At the preparation of the SK's February 2020 TOW-2, at its recovery, at the new convection period: to help in the understanding of the new performance of the water system after TOW-2 and its readiness for SK-Gd.

We have studied the gains of the ID PMTs:

- Changes from those at SK-IV to the same PMTs at SK-V with new HV settings.
- Time evolution of the mean gain during the time interval spanned by SK-V: for every PMT and grouped into a) Production Year, and b) Top/Barrel/Bottom detector parts

SuperK-Gd: For the search and quantification of critical radioactive contaminations in the $Gd_2(SO_4)_3$ to be dissolved in SK,

- we have screened with high purity Germanium Detectors in the Canfranc Underground Laboratory samples of 16 batches, out of the current 36, that are either to be loaded in the T1 phase or used for making resins for the SK-Gd water system.
- Detailed ICPM measurements of samples of those batches, are being performed at the UAM to quantify the amount of Ce and Eu (light emitters) and La (for cross checking) in the salt.

Physics Analyses:

We are rather involved in the main neutrino oscillation analysis of the experiment.

- Our main works pivot on the use of neutron tagging, for the time being with H, for better neutrino-/antineutrino separation, better determination of the incoming neutrino energy and better discrimination of Neutral Current reactions.
- The most up to date SK oscillation analysis incorporates some of these techniques (so-called Hybrid Analysis) resulting in a significant improvement of the sensitivity of SK atmospheric data to CP violation and mass hierarchy: it will be presented officially for the first time in the incoming NEUTRINO 2020 conference (June 2020).
- We continue working towards a -full data- SK-T2K joint oscillation analyses. The joint result should improve rather significantly the already very relevant, yet totally independent results by SK (atmospheric neutrinos) and T2K (beam neutrinos).

We have initiated this FY a new research program towards reliable quantitative estimates of the uncertainties in the selection or identification procedures based on Neural Network or, in general, Artificial Intelligence algorithms. I.e. to estimate 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.

- The first field of action is on the algorithms for neutron tagging, for the time being H-tagging, and soon Gd-tagging. This work is in a rather advanced state.
- We foresee next to apply it to accurately include the uncertainty in the discrimination neutrino / anti-neutrino in the main neutrino oscillation program.