Research Report
ICRR Inter-University Research Program 2020

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 for 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 Gd-loading process (beginning of SK-VI) to understand the impact of the Gd salt in the water properties and light transmission at different wave lengths.
- Significant information has been obtained from the comparison of autoXenon and Nickel results based on their different wavelength ranges (autoXenon mostly above 400 nm , Nickel large fraction below 400 nm)
- Further insight has been gathered from the comparison of Xe and Ni results to those on light transmission at different wavelengths and at different part of the detectors extracted by the Korean laser system.
- After Gd stabilization, i.e. at the regular data taking period, to monitor the detector performance and help the water team in the understanding of the observed steady increase of Dark Noise, and the preparation of the -already proven successful- counter measures by the water system.

We have studied the gains of the ID PMTs:

- Time evolution of the mean gain during the time interval spanned since the beginning of SK-V for PMTs grouped into a) Production Year, and b) Top/Barrel/Bottom detector parts.
- An increase with time, different for those subgroups, is observed. However, in the already two-year time interval studied, those increases are significantly slower than then mean in SK-IV (> 2 times). We are studying this effect.

SuperK-Gd: For the search and quantification of critical radioactive contaminations in the $Gd_2(SO_4)_3$ to be dissolved in SK-Gd, phase T1.5

- we are screening with high purity Germanium Detectors in the Canfranc Underground Laboratory samples of different ion exchange resins to be used in the enlargement of the SK-Gd water purification system needed for T1.5, in which another set of ~20 tons of Gadolinium Sulfate will be dissolved in SK water.
- We are starting the preparation at the Canfranc Lab. of the procedures for the intense screening campaign of the produced Gd salt expected for the T1.5 phase.

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 has been presented officially for the first time in the NEUTRINO 2020 conference.
- 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 are continuing the 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 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.

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

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