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Double Calorimetry in Liquid Scintillator Detectors

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Liquid Scintillator (LS) detectors have been at the forefront of neutrino physics thanks to their scalability. Realizing large detectors has indeed been pivotal to compensate for the extremely elusive nature of neutrino interactions. The LS' capability to act at the same time as both the interaction medium and the detection medium, allowed to use LS detectors as homogeneous calorimeters with an energy resolution in the range 5%-10% at 1MeV. The experimental method used to reconstruct the energy deposited in the detector usually reflects the detector's own light level and dynamic range. In the case of a low light level, where the average number of scintillation photons detected by each photomultiplier (PMT) is less than one, the deposited energy can be inferred by the number of active PMTs in a given time window. We refer to this technique as "photon counting". On the contrary, if the average number of detected photons per PMT is larger than one, the PMT output current needs to be integrated to build an unbiased energy estimator. Both estimators have pros and cons. Photon counting is in general more robust, since it is more resilient to any feature affecting either the PMT or the readout electronics, such as a non-linear and/or unstable response. Charge integration, on the contrary, makes it possible for the detector to cover a wide dynamic range, and allows, in turn, to instrument the detector surface with fewer larger PMTs. Double Calorimetry (DC) is a novel detection concept envisioning -for the first time- both energy estimators to be implemented in the same LS detector by means of dedicated hardware. DC has been designed in particular for detectors that need to achieve an unprecedented energy resolution, for which they need to collect the largest possible amount of scintillation light, and to control to their best ability systematic uncertainties. That is, to minimize both the stochastic and the non-stochastic energy resolution terms.

Within this presentation, DC is to be realized by means of two sets of PMTs, one meant to work in photon counting mode and one in charge integration mode. We aim to show that, while the latter can be used perform the main calorimetry measurement -that is, to collect the largest fraction of scintillation light-, the former is able to provide a unique handle to better quantify and possibly reduce most of the energy-related systematic uncertainties. We conclude by showing how DC is expected to allow the largest LS detector currently under construction (JUNO) to reach the unprecedented 3% energy resolution at 1 MeV needed to determine the neutrino mass ordering.

Summary

This contribution deals with a new experimental method in the context of liquid scintillator detectors. It is suitable to be presented either as a poster or as short talk.

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