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PII: S0146-6410(17)30034-0
DOI: http://dx.doi.org/10.1016/j.ppnp.2017.03.003
Reference: JPPNP 3639

To appear in: *Progress in Particle and Nuclear Physics*

Please cite this article as: F. Vannucci, Interactions of neutrinos with matter, *Progress in Particle and Nuclear Physics* (2017), http://dx.doi.org/10.1016/j.ppnp.2017.03.003

Interactions of neutrinos with matter

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February 28, 2017

Abstract

Neutrinos are elementary particles electrically neutral which belong to the family of leptons. As a consequence and in first approximation they only undergo weak processes. This gives them very special properties. They are ideal tools to study precisely the weak interactions, but there is a price to pay: neutrinos are characterized by extremely low probabilities of interactions, they easily penetrate large amount of matter without being stopped. Consequently, it is hard to perform neutrino physics measurements. In practice the difficulty is twofold: in order to accumulate enough statistics, experiments must rely on huge fluxes traversing huge detectors, the number of interactions being obviously proportional to these two factors. As a corollary, backgrounds are difficult to handle because they appear much more commonly than good events. Nevertheless, neutrino interactions have been detected from a variety of sources, both man-made and natural, from very low to very large energies.

The aim of this review is to survey our current knowledge about interaction cross sections of neutrinos with matter across all pertinent energy scales. We will see that neutrino interactions cover a large range of processes: nuclear capture, inverse beta-decay, quasi-elastic scattering, resonant pion production, deep inelastic scattering and ultra-high energy interactions.

All the gathered information will be used to study weak properties of matter but it will also allow to explore the properties of the neutrinos themselves. In particular, the known three different flavors of neutrinos have different behaviours inside matter and this will be relevant to give some precious understanding about their intrinsic parameters in particular their masses and mixings.

As a second order process, neutrinos can undergo electromagnetic interactions. This will also be discussed. Although the corresponding phenomena are not yet experimentally proven by actual measurements, the theory is able to calculate them and it is useful to discuss the topic since it may become an important issue to test ideas of cosmological relevance.

This review will mainly adopt an experimental point of view. Strong emphasis will be placed on important detectors which have illustrated the challenging progresses in neutrino physics; they will be described and their results confronted to theoretical predictions.