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The Nuclear Symmetry Energy

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Abstract

The nuclear symmetry energy characterizes the variation of the binding energy as the neutron to proton ratio of a nuclear system is varied. This is one of the most important features of nuclear physics in general, since it is just related to the two component nature of the nuclear systems. As such it is one of the most relevant physical parameters that affect the physics of many phenomena and nuclear processes. This review paper presents a survey of the role and relevance of the nuclear symmetry energy in different fields of research and of the accuracy of its determination from the phenomenology and from the microscopic many-body theory. In recent years, a great interest was devoted not only to the Nuclear Matter symmetry energy at saturation density but also to its whole density dependence, which is an essential ingredient for our understanding of many phenomena. We analyze the nuclear symmetry energy in different realms of nuclear physics and astrophysics. In particular we consider the nuclear symmetry energy in relation to nuclear structure, astrophysics of Neutron Stars and supernovae, and heavy ion collision experiments, trying to elucidate the connections of these different fields on the basis of the symmetry energy peculiarities. The interplay between experimental and observational data and theoretical developments is stressed. The expected future developments and improvements are schematically addressed, together with most demanded experimental and theoretical advances for the next few years.

Keywords:

1. Introduction

The nuclear matter (NM) Equation of State (EOS) is one of the central issue in Nuclear Physics. It incorporates the fundamental properties of the nuclear medium, which is present not only in terrestrial nuclei but in many astrophysical objects and phenomena. It plays an essential role in understanding and linking an extremely wide set of data on different physical systems and processes, like nuclei in laboratory experiments, in particular exotic nuclei, heavy ion collisions, the structure and evolution of compact astrophysical objects as Neutron Stars (NS), supernovae and binary mergers, and so on. On the other hand the laboratory experiments and the astrophysical observations can put meaningful constraints on the nuclear EOS. Unfortunately a direct connection between the phenomenology and the EOS is not possible, and theoretical inputs are necessary for the interpretation of the data. In particular the EOS above saturation density is much less constrained than around or below saturation.

In recent years a great attention has been payed to one of the main feature of the EOS, i.e. the symmetry energy as a function of density [1]. A distinctive aspect of the nuclear systems is the possibility of varying the relative contents of the two particles they are composed of, the neutrons and the protons. The symmetry energy measures the change in binding of the system as the neutron to proton ratio is changed at a fixed value of the total number of particles. In nuclear matter one considers the energy per particle E/A, which is a function of the total density ρ and the asymmetry