(1)

MPHYCC-13 (Nuclear and Particle Physics)

P.G. Sem. -III.

Dr. Sanjeet Kumar; Assistant Professor, Dept. of Physics, H.D. Jain College, VKSU, Ara.

Two Body Problem and Nuclear Forces

Two Body Problem and Nuclear Forces (contd.)

The only way out then is to recognise the existence of another fundamental interaction — the nuclear interaction(force). Since nuclei are composed of protons and neutrons only, which are packed very densely within the small volume of the nucleus, the heavier nuclei will be subjected to very strong coulombian repulsive forces — the ones, acting between the positively charged protons, which tends to tear the nucleus, apart. The fact that nuclei stay as bound systems even in the wake of these strong repulsive Coulombian forces, is a sufficient proof of the great strength of the nuclear forces and that at distances of the order of nuclear dimensions, it should be attractive in nature. A great deal of effort has gone into the investigation of the characteristics of this nuclear force and it has turned out to be a truly monumental task — perhaps more man hours of work have been devoted to it than to any other scientific question in the history of mankind and even now it is not fully understood. Our task here and quite a formidable one, is to compile sequentially the progress made in this direction so far.

In atomic physics, the forces between the atomic nuclei and the electrons, are known to be of electromagnetic origin and accessible to direct macroscopic measurements. The force law being precisely known (inverse-square law) and therefore all that was needed was the correct mechanics viz, quantum mechanics to account for the observed properties with maximum refinement. However in nuclear physics, the situation is somewhat different in that we do not know the force law even approximately what to say of precisely and that unlike electromagnetic force, the nuclear force is inaccessible to direct macroscopic measurements. The success with which quantum mechanical considerations have accounted for experimental results in atomic physics tempts us to adopt the tacit assumption that nuclei are also quantum mechanical systems.

As a general rule, the wave nature of matter (quantum mechanical principles) is relevant where the de Broglie wavelength of the particles is of the order of the size of the system to be studied. So let us compare nuclear size with the wavelength of a nucleon of energy 10 MeV.

$$\lambda = \frac{h}{M_N v} = \frac{h}{\sqrt{2M_N E}} = \frac{[6.625\times10^{-27}\,erg\text{-}sec]}{[2\times1.67\times10^{-24}\,gm\times10^{6}\times1.6\times10^{-12}\,erg]^{1/2}}$$

$$= 9.1\times10^{-13}\,cms. = 9.1\ fermi\ [\because 1\ fermi = 10^{-13}\,cms = 10^{-15}\,m]$$

or, In S.I. units,

$$\lambda = \frac{h}{\sqrt{2M_N E}} = \frac{(6.6256\times10^{-34}\,J\text{-}s)}{[2\times(1.67\times10^{-27}\,Kg)(10^{6}\times1.6\times10^{-19})]^{1/2}}$$

$$= 9.1\times10^{-15}\,meters = 9.1\ fermi$$

which is obviously of the order of the size of the nuclei and hence quantum mechanical considerations are indeed relevant to the study of nuclei.

Having ascertained that nuclei are quantum mechanical systems composed of nucleons, it is quite plausible to study the nuclear force under the simplest possible conditions. The simplest case in which the nuclear force is effective is when there are only two nucleons present and interacting. With a two-nucleon system there are two experimentally

achieva

(1) When

Of t

system,

deuteron

the deu

(2) When

one is

scatterin

neutron-

are limi

and for

achievable situations.

(1) When the two nucleons are bound together.

Of the three possible bound states of a two nucleon system, di-neutron (nn), di-proton (pp) and deuteron (np) nature has provided us with only the deuteron and the other two are unstable.

(2) When the two nucleons are in free state and one is made to impinge on the other, i.e the scattering processes.

In practice, it is not possible to make a neutron-target and therefore scattering experiments are limited only to neutron-proton (np) scattering and proton-proton (pp) scattering.