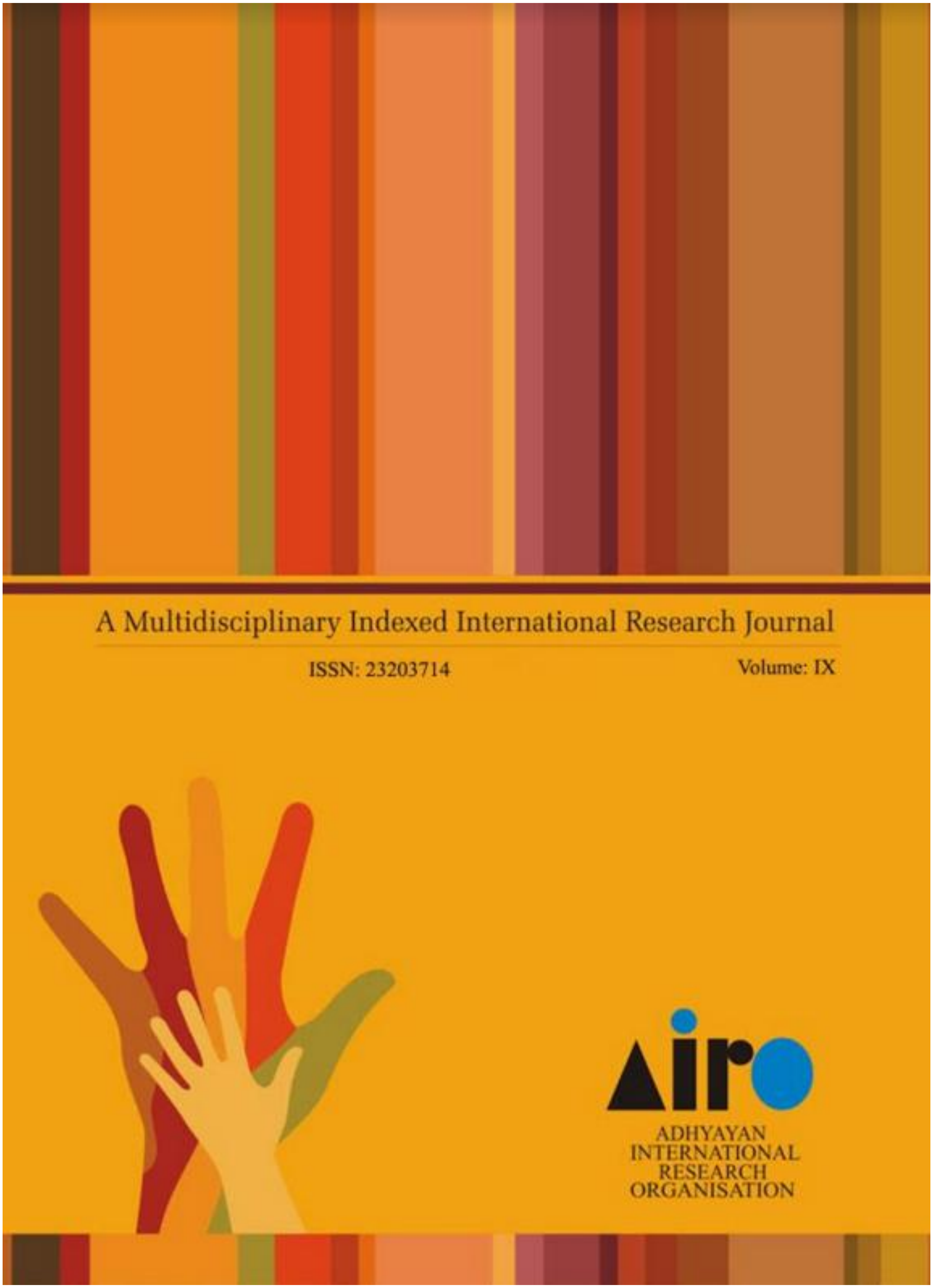
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A STUDY ON THE PROPERTIES OF NUCLEUS

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ABSTRACT

Size of a nucleus is in order of $10^{-15} \div 10^{-14}$ *m. Charge of the nucleus Z is positive and equal to serial number of current chemical element in Periodic Table of Elements. For example, charge of the nucleus of oxygen atom equal to +8. Nucleus consists of nucleons: protons and neutrons.*

Proton is nucleus of hydrogen, stable particle. Proton is stable particles and did not change own characteristics in time. Charge of one proton equal to +1. Mass of one proton equal to 1.673·10-27 kg or 1.00782 u (atomic mass unit). 1u is the same as 1/12 of mass ^{12}C *atom and equal to* $1.661 \cdot 10^{-27}$ *kg. Number of protons in nucleus equal to number of electrons in atom. Neutron is neutral particle. Neutron is unstable particle when outside of nucleus, it decay to proton, electron and antineutrino. Average life-time approximately equal 15 min. Inside stable nucleus, neutron is stable particle. Charge equal to 0 (uncharged). Mass of one neutron approximately equal to mass of one proton:* $1.675 \cdot 10^{-27}$ *kg or 1.00786 u. Proton and neutron is characterized by spin – internal moment. Charge of nucleus equal to number of protons in nucleus. Number of protons and neutrons in nucleus called atomic mass number A.*

KEYWORDS: *Charge, nucleus, proton*

INTRODUCTION

The nucleons in nucleus are in constant movement. The nucleons in nucleus have different velocity of movement and different energies. The sum of nucleon energies determines full energy of nucleus (but not equal). According to quantum laws full energy of nucleus is discrete value, nucleus can have just only certain energy values. Nucleus, which has minimally possible energy is named as nucleus in ground state, otherwise the nucleus is in excited states. Excitation energy is energy equal to difference of nucleus energy in exited state and energy of nucleus in ground state. Set of the excited states for the nucleus ^{56} Fe represented on figure 1. Zero of excitation energy on that graph represents nucleus in ground state. Electron-volt is main energy unit in nuclear physics (1eV=$1.6\cdot10^{-19}$ J, 1 MeV=106 eV, 1keV=103 eV).

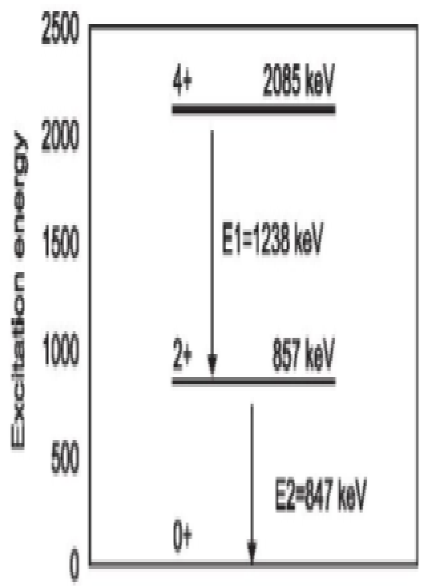
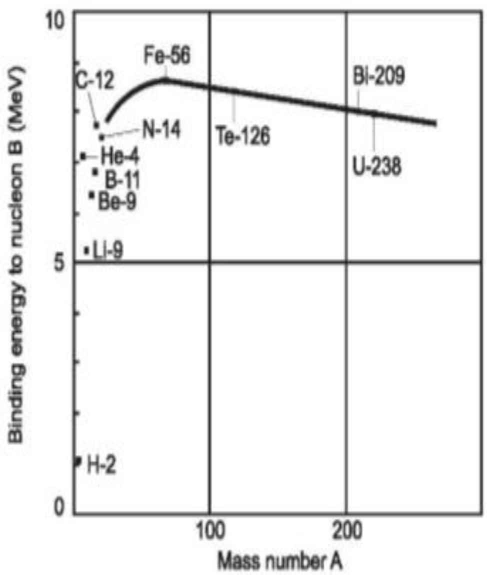


Figure 1. The excited states of Fe-56 nucleus

γ-quantum or γ-rays is electromagnetic waves having very short wavelength in comparison to other electromagnetic waves such as visible light, heat rays, and radio waves, which can be escaped from the nucleus during radioactive decay. Because of some special laws, which are not the aim of that chapter, γ-rays of certain energies will escaped from exited nucleus until nucleus become in the ground state. For example, if Fe-56 atom nucleus in excite state with excitation energy equal to 2085 keV, from that nucleus can escape γ-rays with energy equal to 1238 keV and after that γ-rays with energy equal to 847 keV or one γ- rays with energy equal to 2085 keV.

Emission of γ-rays from the nucleus is not unique process of changing of nucleus state. Excitation energy can be transferred to nearby atomic electron. Other fundamental value for nuclear physics is binding energy per nucleon B. Binding energy of nucleus is energy, which should be transfer to nucleus for liberation of all nucleons from nucleus. Binding energy per nucleon B is equal to binding energy of nucleus divided on number of nucleons in nucleus (atomic mass number A). Binding energy per nucleon ranged from 1 MeV for H-2 to 8.7 MeV for Fe-56. Binding energy per nucleon B is a measure of nucleus stability. If two nuclei with equal number of nucleons have different value B, than for nucleus with less B is favourably to change current state and become nucleus with higher value of B. As more energy it should be spent to liberate of all nucleons from nucleus as less energy of nucleus. During the process of energy dissemination the γ-ray will be escaped from nucleus.



The study of nuclear properties shows evidence of nuclear shells analogous to those observed in the atoms. One clear piece of evidence in the nuclear case is the sharp discontinuity in nucleon separation energies for certain numbers of N (neutron number) and Z (proton number), known as magic numbers. In the case of the electronic shells in atoms the picture is very clear, since there is a central Coulomb potential, due to the charge carried by the nucleus and electrons.

RESEARCH STUDY

In the case of the nucleus there is no such external potential but the nucleons move in the potential created by them. This potential contains many terms: central, spin-orbit, tensor, spin - spin, etc. At long distances it has a Yukawa form, while at short distances it shows an extremely repulsive core. The idea of a shell model for the nucleus may seem contradictory with these strong correlations because this rudely breaks the independent particle picture.

We shall consider the nucleus as composed of Z protons and N neutrons, that interact via two-body forces and obey the Schrodinger equation, the general time independent form of which is

$$(- h^2 \Delta^2 / 2m + V) | \psi > = E | \psi$$

where V is the potential and | i is the wave function with an associated energy E. The experimental idea of magic numbers led M. Goeppert-Mayer and H. Jensen to the construction of the nuclear mean field, a harmonic oscillator, whose main novelty was the very strong spin-orbit splitting needed to explain the experimental magic numbers. This idea originates from atomic physics in which the magnetic moment of an electron interacts with a magnetic field generated by its motion around the nucleus.

$$V(r) = ½ m w^2 r^2 + D I^2 - Cl.s$$

where 1/2m?2r2 is the kinetic energy of an harmonic oscillator with frequency ? and mass m, l is the orbital angular momentum operator, s is the spin operator, D and C are constants to fit and where,

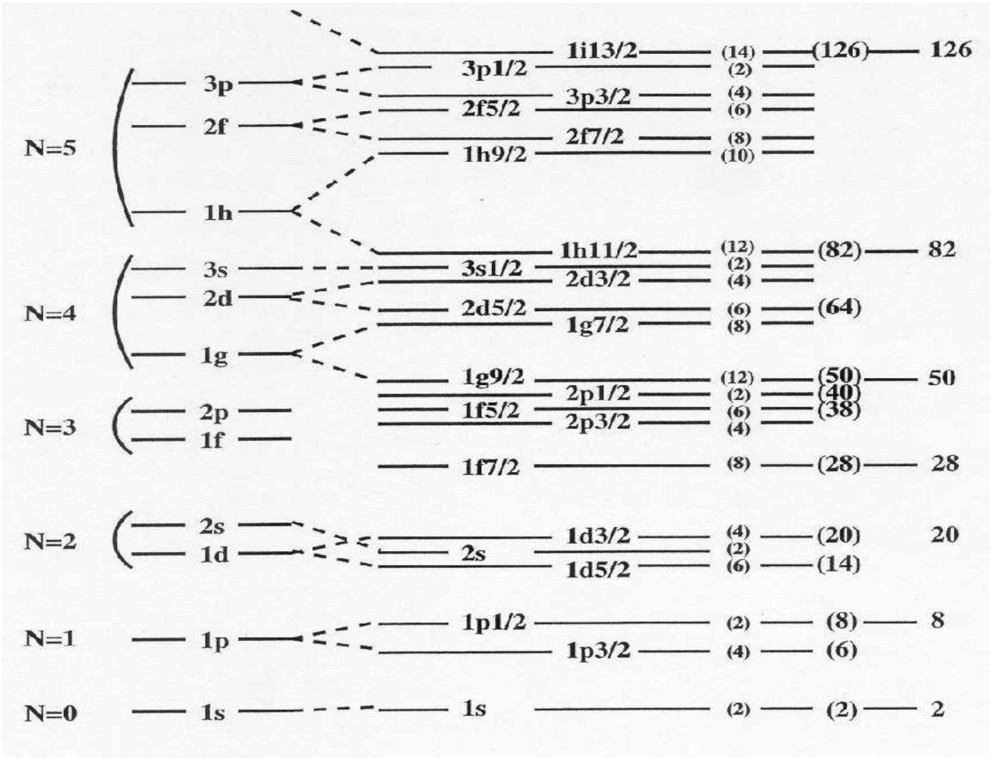
$$l.s = - ½ (j^2 – l^2 – s^2) = - ½ (j (j + 1) - l (l + 1) – ¾$$

$$= l + 1 \text{ for } j = l – ½$$

$$= - l \text{ for } j = l + ½$$

The single-particle levels of the nuclear mean field are represented in Fig. The left-hand side shows the shell structure of the isotropic harmonic oscillator, then the splitting due to the l2 term and finally the single-particle levels taking into account the spin-orbit splitting. To the right are the predicted magic numbers. Therefore, due to the l.s term in the potential, the total degeneracy becomes (2j+1). This means that, for example, a 1p level, with a total degeneracy of 2(2l + 1) = 6, will split into two levels according to Equation, 1p1/2 and 1p3/2 with degeneracy’s 2 and 4 respectively.

For a given nucleus (N,Z) the mean field dictates which levels are occupied (those below the Fermi level) and which are empty (those above). However, these



states can be close enough in energy or have a structure such that the residual twobody interaction can mix them to produce correlated states. Therefore, the infinite set of mean-field orbits will be divided in three parts:

i) Inert core: the orbits that are forced to be always full. Imagine that the core consists of Nc neutrons and Zc protons, thus if we are studying a nucleus (N,Z) there will remain nv = N ? Nc valence neutrons and zv = Z ? Zc valence protons.

ii) Valence space: the orbits available to the valence particles, that will be partially occupied by them according to the effective interaction.

iii) External space: the remaining orbits that are always empty.

In a binary reaction, the γ rays detected in each event can come from one or both of the fragments and a priori, there is no way to assign a γ ray to a specific fragment. In the case of prompt γ rays it is possible to distinguish whether the γ ray comes from TLFs or BLFs. Therefore it is possible to study the distribution of the binary partners using delayed-prompt coincidences. An isomer in one of the binary partners and prompt feeding in the other is needed, a situation which is quite likely for the region of nuclei populated in the reaction studied. Here the way to proceed is to gate on delayed γ-ray transitions from well-known isomers and project the prompt γ rays from the binary fragment. For this purpose a delayed-prompt matrix was produced, where the prompt γ rays are Doppler corrected for TLFs.

ANALYSIS

The spherical shell model does not describe well those nuclei far from closed shells. For these regions a deformed potential has to be assumed. The assumption of a deformation is able to explain some experimental facts such as rotational bands and very large quadruple moments.

The nuclear surface of a non-spherical nucleus can be mathematically described by

$$R(\theta, \varphi) = R_0 (1 + \sum \sum Y (\theta, \varphi)$$

where α _ μ are the coefficients of the spherical harmonics Y_μ(θ, φ). The terms with λ = 1 are not included since they correspond to a translation of the centre of mass. R0 is the average radius. For axially symmetric nuclei (independent of φ) the radius is defined,

$$R(\theta) = R_0 (1 + \beta Y_{20} (\theta, \varphi))$$

where the deformation parameter β2 = α20. If β2 < 0 the nuclear shape is called oblate ("spaceship" shaped), if β2 > 0 the nuclear shape is called prolate ("cigar" shaped), if β2 = 0 then the nucleus is spherical. The larger the value of β2, the more deformed the nucleus.

The nuclei can be axially asymmetric (λ = 2), in this case a new deformation parameter γ enters into the description of the nuclear shape, where the γ deformation is related to the α_μ coefficients as follows ,

$$\alpha_{20} = \beta_2 \cos \gamma$$

The γ deformation goes from 0◦ to 60◦ corresponding to prolate and oblate shapes respectively. A completely tri-axial nucleus has a γ = 30◦.

The different nuclear interactions between heavy ions can be, broadly speaking, divided into three main categories, depending on the energy involved in the interaction. Nevertheless, a nuclear reaction is determined in addition to the centre-of-mass energy by the impact parameter b and the nature of the projectile and target.

For low energy reactions (1-10 MeV/A) fusion evaporation type reactions might happen. These reactions occur at small values of the impact parameter and the projectile and target stay together for enough time (from 10−18 s to 10−16 s) to form a hot compound nucleus. In this case the resulting nuclei can be formed in a high spin state, thus allowing the nuclear spectroscopy of nuclear states at extremes of angular momentum . As the beam energy increases the reactions become more peripheral and the reaction times are much faster, ~ 10−22 s, and the impact parameter is extended compared to fusion-evaporation reactions. Nucleon transfer or deep inelastic reactions (DIC) can occur in which a few nucleons are transferred but the beam and target retain their original character .

SIGNIFICANCE OF THE STUDY

A prototype, highly segmented, coaxial hyper-pure n type germanium detector has been constructed by EURISYS measures (EGC 60-90 SEG36), with the aim of testing the applicability of γ-ray tracking and ultimately improving the sensitivity of nuclear spectroscopic studies. The crystal has an external diameter of 60 mm and the length is 90 mm. The outer p-type ion-implanted contact of the crystal is segmented into 6 segments in both the longitudinal and radial direction, the disks are 15 mm long. The inner contact is n+ lithium diffused. This inner contact is not segmented and can be used to provide a total energy signal for the full crystal. The impurities are not homogeneneously distributed, 0.67 1010 at/cm3 at the top coaxial part and 2.4 1010 at/cm3 at the closed end part. A schematic labeled view of the detector is shown in Fig. The cryostat has 3.0 litre capacity and it keeps the crystal at Liquid Ni temperature for 36 hours.

The outer contact is grounded, each segment goes to ground through a DC coupled preamplifier, while the inner contact is positive polarized at 3500 V. The energy signal is collected through an AC coupled preamplifier. The signals from the

Figure: EURISYS measures (EGC 60-90 SEG36) prototype.

CONCLUSION

The signal from the preamplifiers goes into a cM62 module where 3 AD40 (Very- High-Speed Data Acquisition Module) are attached to it. The AD40 module has two channels for signal digitation. These modules have been provided by OMNIBUS. Each of the cM62 modules, with only one DSP (Digital Signal Processor), comprises six channels for pulse signal digitalisation. The boards are controlled by a host computer. In the schematic block diagram A.3 two channels are shown. After passing throught a Low Distortion Input Amplifier, the signal is digitised by a 12 bit, 40 MHz ADC and the digitised signal is sent to a FIFO (First In First Out), circular buffer. The signal from the inner contact is used as external trigger. A second computer allows on-line analysis using MIDAS.

The heaviest β-stable platinum isotope, ^{198}Pt, was used as a target for the reaction to populate neutron-rich nuclei around mass 190. This nucleus was studied looking at both in-beam and out-of-beam γ-γ coincidences. The former allowed the study of the highest spins populated and the latter allowed the identification of a new high spin isomer.

REFERENCES

- A. Messiah, Quantum Mechanics, North-Holland, Amsterdam(2011).
- A. Poves and F. Nowacki, Lecture Notes in Physics, Springer, 2012.
- A.V. Davydov, G.R. Kartashov, Y.V. Khrudev, Physics Nuclear A 7, 447 (2008)
- B. Balko, G.R. Hoy, Phys. Rev. B 10, 36 (2004).
- B.V. Narasimha Rao, S. Jnanananda, Proc. Physics. Soc. 87, part 2, 455 (2012).
- E.E. Berlovich, Yu.K. Gusev, V.V. II'in, M.K. Nikitin, Soviet JETP 43, 1625 (2012).
- F. Iachello and A. Arima, Phys. Lett. B 53, 2009 .
- J. Lindskog, T. Sundström, P. Sparrman, Z. Physics 170, 347 (2012)
- K.S. Krane, At. Data Nucl. Data Tables #2,137 (2010)
- K. Higashiyama, N. Yoshinaga and K. Tanabe, Phys. Rev. C 65, 2010 .
- M.G. Mayer et al., Phys. Rev. 75, 2009 .
- M. Eisenberg and W. Greiner, Microscopic Theory of the Nucleus, North- Holland Publishing Company, 2012.
- R.F. Casten, Nuclear Structure from a Simple Perspective, Oxford Science Publications 2010.
- P.P. Craig, J.C. Dash, A.D. McGuire et al., Physics Rev. Lett. 3, 221 (2009)
- P. Steiner, E. Gerdau, W. Hautsch, D. Steenken, Z. Physics 221, 281 (2009)
- S.G. Malmskog, A. Bäcklin, Ark. Physics 39, 411 (2012)
- W. Greiner, Nuclear Models, Springer-Verlag Berlin Heidelberg New York, 2011.