HIGH SPIN STATES IN NEUTRON RICH Ni ISOTOPES*

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The neutron rich Ni isotopes have been studied using the quasi- and deep-inelastic reactions in ^{64}Ni bombardments of the thick ^{208}Pb target at 350 MeV. The γ-γ coincidence analysis and half-life measurements provided new spectroscopic information for heavy, $A = 64$ to 67 Ni isotopes with particular emphasis on the high spin states and the role of the $g_{9/2}$ neutron orbital.

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In the closed $Z = 28$ proton shell Ni isotopes the neutron Fermi level is localized within the low j negative parity orbitals $p_{3/2}$, $f_{5/2}$ and $p_{1/2}$, and with increasing neutron number it moves towards the higher lying $g_{9/2}$ orbital. In heavier Ni isotopes this high j positive parity intruder $g_{9/2}$ neutron level should feature prominently in the structure of high spin yrast states.

Until recently this effect could not be studied in any systematic fashion since the heavy ($A \geq 64$) Ni isotopes could not be reached in processes suitable for gamma spectroscopy. Only few results are available which, exploiting the particle detection techniques, attempted to detect high spin states in nickel isotopes heavier than ^{64}Ni. A recent $(\alpha, 2p)$ reaction study [1] which

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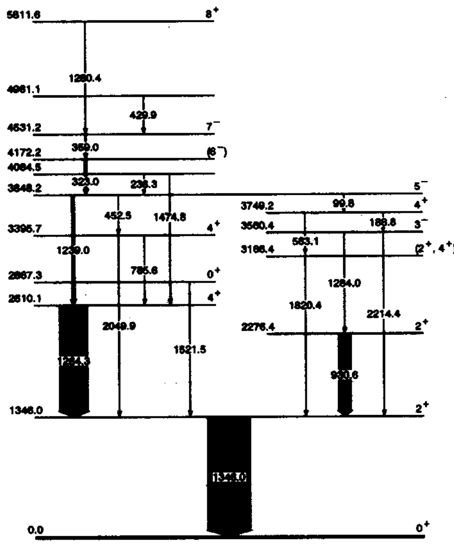
led to important findings for the ^{64}Ni and ^{66}Ni isotopes represents interesting example of such an attempt. Nevertheless, the gamma spectroscopy data are limited to a few states populated in radioactive decays. In this case the neutron rich parents have been selected with the mass separator from the large number of products formed in bombardment of tungsten target with ^{76}Ge [2] beam.

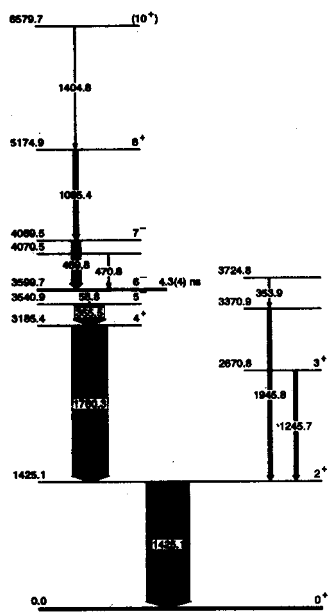
The new and promising way to extend Ni isotopes study involving the in-beam gamma spectroscopy is offered by the superior resolving power of multidetector gamma coincidence arrays. The high quality coincidence data obtained with such arrays in a thick target experiments allow to resolve the discrete radiation from the individual nuclei present in a complex assembly of heavy-ion collision products. Moreover, the observation of cross coincidences between the gammas emitted by the two partner nuclei which arise simultaneously in the exit channel can provide [3] means to make an isotopic identification of a specific nucleus. Exploiting this selectivity we analysed the γ-γ coincidence data collected with the OSIRIS γ-array during the bombardment of the ^{208}Pb target (98.7% enriched) with ^{64}Ni beam from the VICKSI accelerator at HMI Berlin with the aim to extract the spectroscopic information on neutron rich Ni nuclei produced in damped reactions. The natural pulsing of the cyclotron beam gave 69 ns spacing between the in-beam events, which was enough to separate in a clean way the off-beam events and allowed to determine the short < 30 ns half-lifes. The same ^{208}Pb+^{64}Ni experiment data have been already analysed in some other aspects and provided important spectroscopic information on the ^{207}Pb [4] and ^{208}Pb [5] nuclei as well as preliminary results on damped reaction mechanism [6]. In the present work we report the results concerning the spectroscopy of Ni isotopes with $A \geq 64$.

Fig. 1 and Fig. 2 display the level schemes of even ^{64}Ni and ^{66}Ni isotopes, correspondingly. They include all excitations observed in the present work and populated predominantly *via* inelastic scattering (^{64}Ni) and the two neutron pick-up (^{66}Ni). In ^{64}Ni only five and in ^{66}Ni only three low lying γ transitions have been observed previously. However, particularly in ^{64}Ni, most of the observed levels and spin assignments were known from other studies [7]. Of special interest are the 8^+ $\nu g_{9/2}^2$ and 7^- $\nu g_{9/2} f_{5/2}^{-1}$ high spin states revealed earlier by the $(\alpha, 2p)$ study [1] in both ^{64}Ni and ^{66}Ni nuclei. Their exact energies and γ–decay are now established. Considering the two transitions connecting in the yrast decay 7^- $g_{9/2} f_{5/2}^{-1}$ and 5^- $g_{9/2} p_{1/2}$ states we tentatively assign the 6^- $g_{9/2} f_{5/2}^{-1}$ to the intermediate state. In the ^{66}Ni case this 6^- state becomes isomeric and the measured half-life of 4.3(4) ns reflects the forbidden character of the low energy 59 keV M1 transition $f_{5/2}^{-1} \rightarrow p_{1/2}$. In analogy to the ^{64}Ni levels the states at 3541



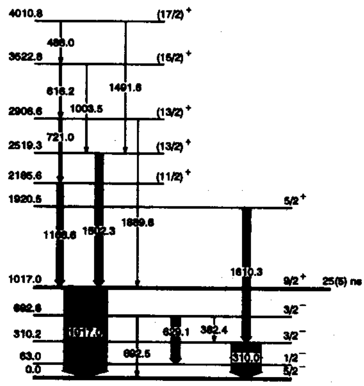
$^{64}_{28}Ni_{36}$

Fig. 1.



$^{66}_{28}Ni_{38}$

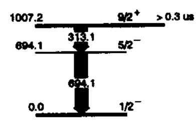
Fig. 2.



$^{65}_{28}Ni_{37}$

Fig. 3.

and 3185 keV in ^{66}Ni, which are strongly populated in the yrast decay, are most likely the 5^- and 4^+ states, respectively.



$^{67}_{28}Ni_{39}$

Fig. 4.

The level schemes for odd ^{65}Ni (Fig. 3) and ^{67}Ni (Fig. 4) nuclei represent excitations observed in $1n$ and $3n$ transfer, correspondingly. The predominant part of the $1n$ transfer takes place via quasielastic process, and consequently few, previously known low spin non-yrast states are populated in ^{65}Ni. The assignment of the 1017 keV $g_{9/2}$ 25 ns isomer was already discussed together with the identification of new levels in ^{207}Pb [4]. However, some part of the one neutron transfer proceeds via the damped reaction mechanism and leads to population of high spin states. Thus it was possible to construct the level scheme above the $9/2^+$ isomer for which the tentative spin-parity assignments are suggested considering the γ-decay and theoretical expectations. In the ^{67}Ni the $1/2^-$ g.s. and 694 keV $5/2^-$ excited states were known from radioactive decay data[2]. We observed a long lived isomer decaying via 313 keV–694 keV cascade, for which the intensity and expectations from systematics strongly suggests the $\nu g_{9/2}$ nature. The expected half-life is about 8 μs, as can be deduced from the corresponding M2 transitions in ^{63}Ni [8] and ^{65}Ni that scale well with transition energies.

Restricted by the present experimental conditions we can give only the lower limit of 0.3 μs; the determination of this half-life is planned in the future experiment.

REFERENCES

[1] U. Fister, R. Jahn, P. von Neumann-Cosel, P. Schenk, T.K. Trelle, D. Wenzel, U.Wienands, *Phys. Rev.* **C42**, 2375 (1990).
[2] U. Bosch, W.-D. Schmidt-Ott, E. Runte, P. Tidemand-Petterson, R. Koschel, F. Meissner, R. Kirchner, O. Klepper, E. Roeckl, K. Rykaczewski, D. Schardt, *Nucl.Phys.* **A477**, 89 (1988).
[3] R. Broda, M.A. Quader, P.J. Daly, R.V.F. Janssens, T.L. Khoo, W.C. Ma, *Phys. Lett.* **B251**, 245 (1990).
[4] M. Schramm, H. Grawe, J. Heese, H. Kluge, K.H. Maier, R. Schubart, R. Broda, J. Grębosz, W. Królas, A. Maj, J. Blomquist, *Z.Phys.* **A344**, 121 (1992).
[5] M. Schramm, H. Grawe, J. Heese, H. Kluge, K.H. Maier, R. Schubart, R. Broda, J. Grębosz, W. Królas, A. Maj, J. Blomquist, *Z.Phys.* **A344**, 363 (1993).
[6] W. Królas, R. Broda, J. Grębosz, A. Maj, T. Pawłat, M. Schramm, H. Grawe, J. Heese, H. Kluge, K.H. Maier, R. Schubart, IFJ Kraków Annual Report 1992, p.43.
[7] *Nuclear Data Sheets* **62**, 614 (1991).
[8] W. Müller, H.H. Bertschat, H. Haas, B. Spellmeyer, W.-D. Zeitz, *Phys.Rev.* **C42**, 7633 (1989).