Narrowing of the neutron sd-pf shell gap in ^{29}Na*

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The wave-function composition for the low-lying states in ^{29}Na was explored by measuring their electromagnetic properties using the Coulomb-excitation technique. A beam of $^{29}\text{Na}^{5+}$ ions, postaccelerated to 70 MeV using ISAC-II at TRIUMF, bombarded a ^{110}Pd target with a rate of up to 600 particles per second. Six segmented clover detectors of the TIGRESS γ-ray spectrometer were used to detect deexcitation γ rays in coincidence with scattered or recoiling charged particles in the segmented silicon detector, BAMBINO. A reduced transition matrix element $|\langle \frac{5}{2}^+_1 || E2 || \frac{3}{2}^+_{\rm gs} \rangle| = 0.237(21)$ eb was derived for ^{29}Na from the measured γ-ray yields for both projectile and target, shown in Fig. 1. This first-time measured value is consistent with the most recent Monte Carlo shell-model calculation (MCSM) of Utsuno *et al.*, predicted to be 0.232 eb [1]. This is sugggestive of a strongly-mixed first-excited state comprising a 30 $\sim$ 40 % admixture of 2p-2h configurations in the wave function, and also provides evidence for the narrowing of the sd-pf shell gap from $\sim$ 6 MeV for stable nuclei to $\sim$ 3 MeV for ^{29}Na.

This result can also be interpreted at the phenomenological level. Within the framework of the rotational model and assuming a prolate deformation, the transition quadrupole moment, $Q_t = 0.524(46)$ eb, is deduced from the measured transition matrix element for ^{29}Na. This value also bears good agreement with the above MCSM calculation, $Q_t = 0.513$ eb [1]; a calculation utilising an effective interaction based on a shell-model space incorporating the full sd space and the two lower orbits of the pf space, with the inclusion of the cross-shell mixing terms in the effective Hamiltonian. Contrasting behaviour in the static and dynamic-nuclear properties of ^{29}Na, arising from differences in the underlying single-particle configurations of the ground and excited states, may explain the difference between the present measurement and that of an earlier experimental result using β-NMR spectroscopy, $Q_0 = 0.430(15)$ eb [2]. This intrinsic quadrupole moment, derived from the ground-state spectroscopic quadrupole moment, 0.086(3) eb, also compares well with the MCSM calculation, $Q_0 = 0.455$ eb.

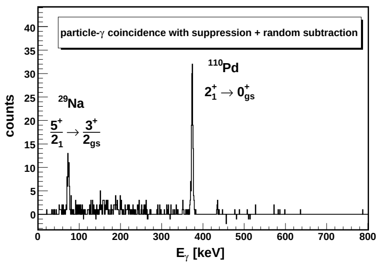

FIG. 1: γ-ray spectrum for ^{110}Pd(^{29}Na,^{29}Na*) at $E_{\rm lab}(^{29}\text{Na}) = 70$ MeV with a beam intensity of up to $\sim$ 600 pps; the particle angular coverage was between $20.1^\circ - 49.4^\circ$.

[1] Y. Utsuno *et al.*, Phys. Rev. C **70**, 044307 (2004).
[2] M. Keim *et al.*, Eur. Phys. J. A **8**, 31 (2000).

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