Direct Evidence of Ground State Wave function of Neutron-rich $^{29,30}Na$ Isotope through Coulomb Breakup

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Introduction

Various measurements since 1975 [1] have confirmed large deformation in the nuclei at "Island of Inversion". Today, it is understood that this unusual deformation around $N \sim 20$ is a result of strong intruder configurations in the ground states of these nuclei. Several experimental and theoretical works in this region suggest a considerable reduction of $sd-pf$ shell gap which allows the mixing in the low lying states of those nuclei. This region has also emerged as one of the most attractive region in the chart of nuclei to understand the nucleon nucleon interaction and isospin dependent part in nuclear medium. Coulomb breakup is a very useful and well established tool to probe the quantum number of nucleon of the loosely bound nuclei [2]. Here I am going to report some interesting results of experiment s306 [3] through Coulomb breakup of the nuclei $^{29,30}Na$ in the vicinity of "Island of Inversion". Earlier measurements [4] have suggested considerable reduction in shell gap of these nuclei. When a projectile is moving with high velocity passes a target of high nuclear charge Z, it may be excited by absorbing virtual photons from the time-dependent Coulomb field. The corresponding differential cross section $d\sigma/dE^*$ for dipole excitation decomposes into an incoherent sum of components $d\sigma_c^\pi/dE^*$ corresponding to different core states with spin and parity, I^π, populated after one-neutron removal. For each core state, the cross section furthermore decomposes into an incoherent sum over contributions from different angular momenta j of the valence neutron in its initial state:

Experiment

The radioactive beam were produced by fragmentation of a primary ^{40}Ar beam with energy 530 MeV/nucleon, delivered by the synchrotron SIS at GSI, Darmstadt. A beryllium target (8.0 gm/cm^2) was used for the fragmentation. The secondary beam were separated according to their magnetic rigidities using the Fragment Separator FRS. The beam contained various isotopes with similar mass-to-charge ra-

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tios ($A/Z = 2.60 - 2.85$) for Na, Mg and Al. The separated beam were then transported to cave C where complete kinematic measurements were performed after Coulomb breakup at secondary target ^{208}Pb (2 gm/cm^2) using various tracking detectors e.g. SST(s), GFI(s), TFW, DTF, DC, LAND etc (Figure: 1). Production run using ^{12}C (935 mg/cm^2) were also taken in order to obtain absolute Coulomb part after proper scaling between C and Pb target. A Crystal Ball detector consist of 162 NaI detectors was used to detect the $\gamma - ray$ from the decay of excited core of the reaction fragments after Coulomb breakup.

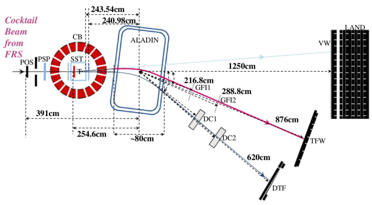

FIG. 1: Experimental setup at cave C

Analysis and Result

Incoming beam was identified on event by event basis from the magnetic rigidities, time of flight and relative energy loss measurements. Populated isotopes of interest were separated at FRS and transfered to cave C as shown in figure 2 (top panel). Event by event tracking was performed after Coulomb breakup at ^{208}Pb target. Calibration of several detectors have been presented earlier in DAE symposium. Outgoing fragments mass after the decay of neutron(s) from excited projectile were identified from the deflection angle obtained from GFI, the geometry of the setup and time of flight measurements from TFW and is shown in figure 2 (bottom panel). The timing and position of of the decay neutron(s) were obtained after calibrating the LAND detector. After proper calibration and alignment, the position of individual fragments and energy have been obtained. Using all the tracking detector and crystal ball the excitation energy E^* of the projectile is reconstructed through invariant mass [2] analysis.

Predominant ground state configurations of $^{29,30}Na$ have been shown in the table I. We have compared our experimental result with theoretically estimated value from direct breakup model and they are in good agreement.

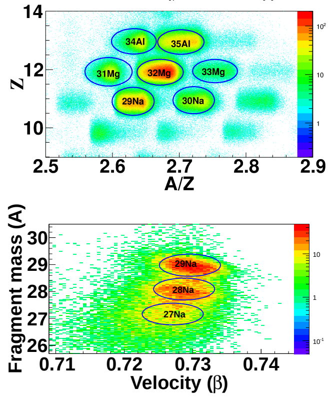

FIG. 2: Top: Incoming cocktail ion beam ; Bottom: Outgoing fragment mass distribution after Coulomb breakup for incoming ^{29}Na

TABLE I: Predominant ground state (g.s.) configuration of $^{29,30}Na$ isotopes from Coulomb breakup measurement (Experiment s306)

Isotope	Reported g.s. spin parity	predominant g.s. configuration from this experiment
^{29}Na	$3/2^+$	$^{28}Na(g.s; 1^+) \otimes \nu_{1/2}$
^{30}Na	2^+	$^{29}Na(g.s; 3/2^+) \otimes \nu_{1/2}$

$^{29,30}Na$ predominantly occupy the *sd* shell in ground state and our result is consistent with ground state spin and parity as reported in literature. It may be noted that using similar technique, it has been observed that valence neutron of the ground state of neutron-rich ^{35}Al isotope occupies $p_{3/2}$ orbital, predominantly [5].

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References

[1] C. Thibault et. al., PRC **12**, 644 (1975)
[2] U. Datta Pramanik, et al., PLB **551**, 63-70 (2003)
[3] U. Datta Pramanik, et al., Proposal for an experiment, S306 at GSI, 2005
[4] V. Tripathi et. al., PRC **73**, 054303 (2006)
[5] S. Chakraborty et. al., EPJ Contribution (INPC 2013)