Low-lying dipole strength of neutron-rich 'Island of inversion' nuclei around N ~ 20

U. Datta Pramanik[1],* S. Chakraborty[1], T. Aumann[2] , S.Beceiro[3], K. Boretzky[2], M. Chartier[4], C.Caesar[2], D.Cotrina-Gil[3], G.de Angelis[5], P.Diaz[3], O.Ershova[2], H. Emling[2], L.M.Fraile[6], H. Geissel[2], M. Heil[2], C. Justyna [2], B. Jonson[7], H. Johansson[7], R. Krücken[8], A.Kelic[2], T.Kroll[8], C.Langer[2], K.Larsson[2], T.LeBleis[2], R.Lemmon[9], O.Lepyoshkina[8], K.Mahata[10], G. Münzenberg[2], C. Nociforo[2], Valerii Panin[2], R.Plag[2], S.Paschalis[11], H.Alvarez Pol[3], R.Reifarth[2], D.Rossi[2], V.Ricciardi[2], I. Ray[1], A.Rahaman[1], K. Sümmerer[2], S. Schwertel[8], C. Scheidenberger[2], H. Simon[2], B.Streicher[2], J.Stroth[12], S. Typel[2], J.Taylor[4], H.Weick[2], A. Wagner[13], C.Wimmer[12], F. Wamers[2], D.Yakorev[13],

[1] Saha Institute of Nuclear Physics, Kolkata -700064, INDIA
[2]Gesellschaft für Schwerionenforschung (GSI), D-64291 Darmstadt, Germany
[5] Univ. Santiago Compostela, E-15782 Santiago de Compostela, Spain
[4]Department of Physics, University of Liverpool, UK
[5] INFN,Laboratori Nationali di Legnaro, legnaro, Italy
[6]Universidad Complutense,Madrid, Spain
[7]Fundamental Fysik, Chalmers Tekniska Högskola, S-412 96 Göteborg, Sweden
[8]Physik Department E12, Technische Universität München, Garching, Germany
[9]STFC, Daresbury Laboratory, Daresbury, U K
[10] Bhaba Atomic Research Centre, Mumbai, India
[11]Lawrence Berkeley National Laboratory, Berkeley, California 94720, USA
[12] Johann-Wolfgang-Goethe-Universität, Frankfurt, Germany
[13]Ins. Fur Kern and Hadron Physik, Rossendorf, Germany
*. * email: ushasi.dattapramanik@saha.ac.in*

Introduction

Magic numbers are the basic building blocks of nuclear structure since last fifty years. Recently, through various experimental results using Radioactive Ion Beam (RIB) facilities, it has been observed that those long cherished magic numbers are not valid anymore in the neutron rich nuclei like ^{32}Mg etc. The breakdown of magic number was hinted in the late 1980's by Thibault et. al.[1] in sodium nuclei (^{31,32}Na). Motobayashi et. al.[2] showed large deformation for ^{32}Mg which leads to the failure of magic number at N = 20. Exploration into the cause of this breakdown shows the filling of higher *pf* orbitals rather than the pure lower *sd* orbitals in the ground state of the neutron-rich nuclei like Ne, Na, Mg in the region N~20. Thus there is obviously an inversion in nuclear orbitals and hence the so-called name "island of inversion".

This year, we have performed an experiment at GSI, Darmstadt. The measurement of dipole threshold strength of neutron-rich nucleus (N~20) through electromagnetic excitation was done using LAND-FRS setup (fig.1). Through this dipole strength, we would like to probe directly the quantum numbers of the valence neutrons in neutron rich nuclei like $^{31-33}$Mg, $^{33-,35}$Al, $^{29-30}$Na, $^{25-27}$Ne, ^{24}F etc.

Experiment

The radioactive beams were produced by fragmentation of a primary ^{40}Ar beam (522 MeV/A) delivered by the SIS facility at GSI, Darmstadt. The secondary beams were separated according to their magnetic rigidities using the Fragment Separator FRS. Since only a thin degrader (scintillator) was used, the beam contained various isotopes with similar mass to charge ratios (A/Z = 2.4 to 2.8). As a result the secondary beam (fig.2) contained $^{22-24}$F, $^{25-27}$Ne, ^{29,30}Na, $^{31-33}$Mg etc. at energies around 450 MeV/A. The secondary beam was identified uniquely by means of energy-loss and time-of-flight measurements. The trajectories of the particles were measured with position-sensitive silicon diodes placed before and after the secondary target. Behind the target, the fragments were deflected by a large-gap dipole magnet (ALADIN). By using energy-loss and time-of-flight measurements as well as position measurements before and after the

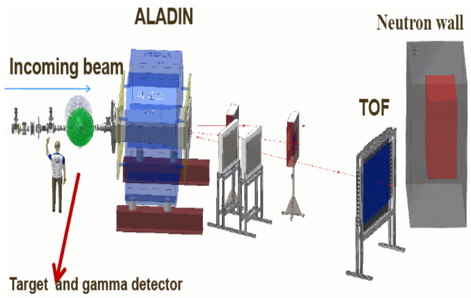

Fig. 1 Schematic diagram of experimental setup.

dipole magnet, the nuclear charge, velocity, scattering angle, and the mass of each fragment were determined. The positions of the fragments behind the dipole magnet were measured by scintillating fiber detectors. The neutrons emitted from the excited projectile or excited projectile-like fragments were kinematically focused into forward direction and were detected with high efficiency in the neutron detector LAND.

In order to detect γ-rays, the target was surrounded by the 4π Crystal-Ball gamma-ray spectrometer consisting of 160 NaI detectors. Other than lead target (0.98 gm/cm^2) data were also taken for carbon target (0.5 cm) for nuclear contribution. The backgrounds due to reactions with various detector materials were subtracted by taking data without any target.

Discussion

Various studies have been done regarding the low-lying dipole strength of neutron-rich carbon, oxygen, neon and tin isotopes. Experimentally, low-lying dipole strengths were observed in the light halo nuclei ^{6}He[3], ^{11}Li[4], ^{11}Be[5], ^{15,17}C[6], ^{19}C[7], and also in more tightly bound isotopes $^{17-22}$O[8], ^{23}O[9], ^{26}Ne[10], $^{130-132}$Sn[11] etc. Though in lighter neutron-rich nuclei, those strengths were single particle in nature but for heavier nuclei, the dipole strength were collective in nature. It would be interesting to explore these strengths in medium mass nuclei.

Inelastic scattering of ^{27,29}Ne suggested a *2p-2h* intruder states (*sd-pf* shell) configuration for the ground state. Recent direct measured ground state spin of ^{33}Mg [12] is in contradiction with that obtained from recent beta-decay measurement[13]. The present experiment aims in validating the correct one. Fig. 2 shows a plot of atomic number Z against A/Z values of incoming radioactive beams.

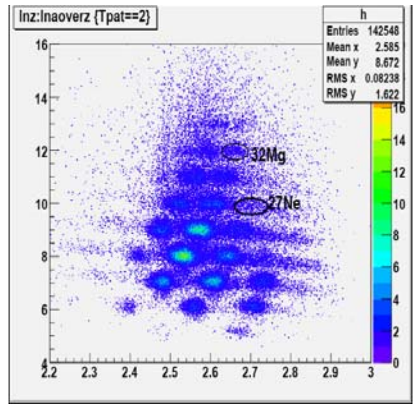

Fig. 2 Plot of the composition of the mixed radioactive beam impinging onto the secondary targets where y-axis is denoting atomic number (z) of the isotopes and x-axis is denoting ratio between mass number and atomic number of the isotopes.

Through this experiment it will be possible to study experimentally the neutron-rich nuclei in the “island of inversion” region such as $^{25-27}$Ne, ^{29,30}Na, $^{31-33}$Mg, ^{34}Al etc. where lots of contradictory experimental and theoretical studies have already been done.

Very preliminary results of the data analysis of this experiment will be presented.

References:

[1] C. Thibault et al., PRC 12, 644 (1975).
[2] T. Motobayashi et al., PLB 346:9(1995
[3] T. Aumann et al., PRC 59 (1999) 1252.
[4] D. Sackett et al., PRC 48 (1993) 118.
[5] T. Nakamura et al. , PLB 331 (1994) 296,
[6] U. DattaPramanik et al., PLB 551, 63 (2003).
[7] T. Nakamura et al. , PRL 83 (1999) 1112.
[8] A. Leistenschneider et al., PRL 86,5542
[9] C.Nociforo et al., PLB605, 79 (2005)
[10] J.Gibelin et al., PRL101, 212503 (2008)
[11] P.Adrich et al, PRL 95, 132501 (2005)
[12] O.Yordanov et al. PRL 99,212501 (2007)
[13] V. Tripathi et al . PRL 101, 142504 (2008)