Eur. Phys. J. A **25**, s01, 431–432 (2005)
DOI: 10.1140/epjad/i2005-06-155-4

EPJ A direct
electronic only

Spectroscopy of Ne and Na isotopes: Preliminary results from a EUROBALL + Binary Reaction Spectrometer experiment

K.L. Keyes[1,a], A. Papenberg[1,b], R. Chapman[1], J. Ollier[1], X. Liang[1], M.J. Burns[1], M. Labiche[1], K.-M. Spohr[1], N. Amzal[1], C. Beck[2], P. Bednarczyk[2], F. Haas[2], G. Duchêne[2], P. Papka[2], B. Gebauer[3], T. Kokalova[3], S. Thummerer[3], W. von Oertzen[3], and C. Wheldon[3]

[1] The Institute of Physical Research, University of Paisley, Paisley, PA1 2BE, UK
[2] IReS, 23 Rue du Loess, 67037, Strasbourg, France
[3] Hahn-Meitner-Institut, Glienicker Str. 100, 14109 Berlin-Wannsee, Germany

Received: 23 December 2004 / Revised version: 20 April 2005 /
Published online: 4 July 2005 –

Abstract. The gamma-decay of fragments from deep-inelastic and multi-nucleon transfer processes which occur when a beam of ^{26}Mg at 160MeV is incident on a thin ^{150}Nd target was studied using the EUROBALL IV array of escape suppressed Ge detectors at Strasbourg. The good resolving power of EUROBALL IV was further increased by combining it with the Binary Reaction Spectrometer (BRS), used for the detection of projectile-like fragments. The BRS allows full kinematic reconstruction of the binary reaction allowing crucial Doppler corrections of gamma-ray spectra to be performed. Some preliminary results are presented.

PACS. 23.20.Lv γ transitions and level energies – 25.70.Lm Strongly damped collisions – 27.30.+t $20 \leq A \leq 38$

A beam of ^{26}Mg at 160MeV incident on a target of ^{150}Nd of thickness 0.4mg/cm^2 was used to initiate deep-inelastic and multi-nucleon transfer reactions in order to populate nuclei in the vicinity of the projectile and target. These are good methods of populating yrast and non-yrast states of projectile-like and target-like nuclei.

Very little is known of the higher spin states of nuclei in the projectile-like region. Their study was a primary objective of the experiment. Measurements using the BRS also allow kinematic reconstruction of the binary reaction channels to be made thus allowing the γ-decay of both projectile-like and target-like species to be investigated.

The Vivitron accelerator at IReS, Strasbourg, France, was used to accelerate a beam of ^{26}Mg ions to an energy of 160MeV. The highly efficient γ-ray spectrometer EUROBALL IV was used in conjunction with the BRS. The array consisted of 26 Ge clover detectors, 15 Ge cluster detectors and an inner BGO array. A previous set-up had included tapered detectors at forward angles but these had been removed prior to the run to allow for the installation of the BRS.

The BRS comprises two large-area heavy-ion detection telescopes either side of the beam axis covering 21% of the full solid angle $\Theta = 12°–46°$ [1]. The BRS was used to measure the energy and (Θ, Φ) coordinates of the projectile-like reaction fragments in coincidence with γ-rays detected by EUROBALL. Z-identification was based on data in the form of a 2-dimensional plot of Bragg peak versus ion energy. Mass identification by time of flight was not possible for this experiment. This was the first experiment which had employed the BRS with an array such as EUROBALL to study the γ-decay of deep-inelastic fragments.

The trigger conditions for an event corresponded to two or more Compton-suppressed Ge signals and particle detection in the BRS. The data were sorted into Z-gated two dimensional γ-γ matrices using the highly sophisticated Data8m [2] and Datajo [3] sorting programs. The matrices thus generated were compatible with the RADWARE analysis package [4] which is currently being used to analyse the data.

Two dimensional γ-γ matrices were generated for each projectile-fragment Z value from $Z = 3$ to $Z = 15$. Our attention so far has been focused on matrices corresponding to Mg, Na and Ne. Figure 1 shows an example of γ-ray spectra for Ne. The top spectrum corresponds to a gate at 2.97 MeV, the first 6^+ to 4^+ transition of ^{22}Ne. The transitions up to the 6^+ to 4^+ are known and can be clearly identified. Various experiments have identified the 8^+ state (possibly yrast) located at an energy of 11.03 MeV [5,6,7], in agreement with shell model calculations of Preedom

[a] Conference presenter;
e-mail: kirstine.keyes@paisley.ac.uk
[b] e-mail: andre.papenberg@paisley.ac.uk

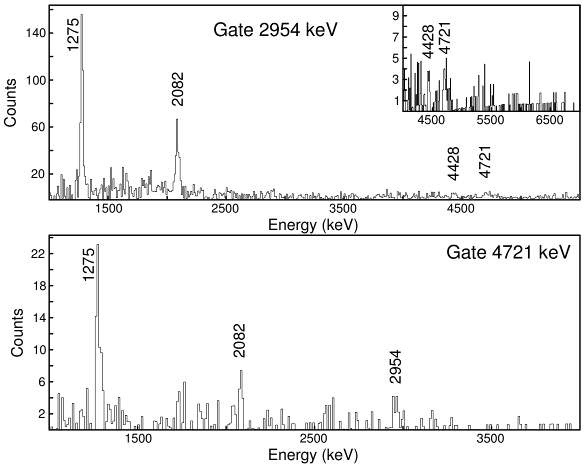

Fig. 1. Spectra obtained from a gate on $Z = 10$.

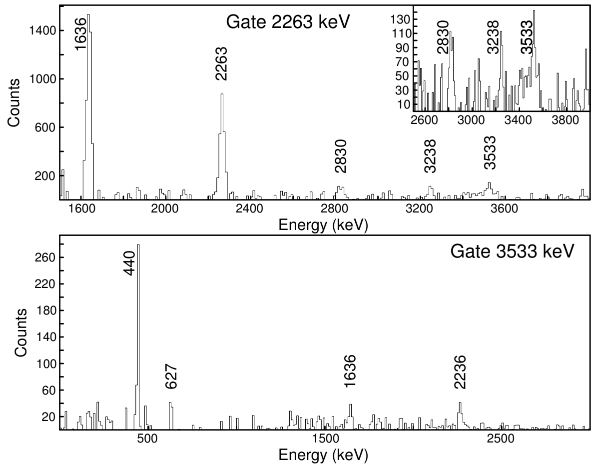

Fig. 3. Spectra obtained with a gate on $Z = 11$.

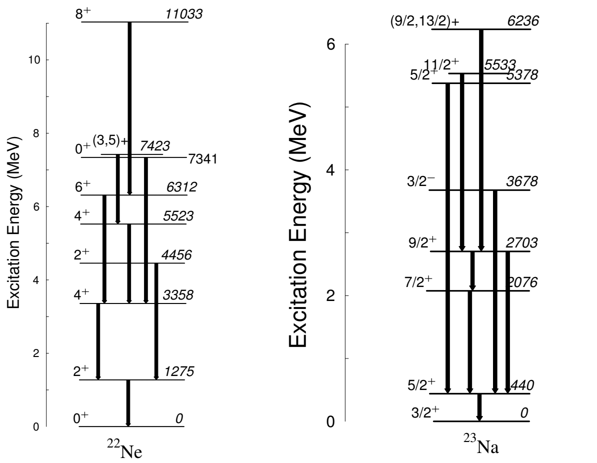

Fig. 2. Level schemes for ^{22}Ne and ^{23}Na showing states seen in this experiment.

and Wildenthal [8]. This is confirmed by the results of the present experiment which indicate the presence of a photopeak at 4.72 MeV which decays to the yrast 6^+.

Figure 2 shows the partial level scheme for ^{22}Ne from the present work. An experiment performed by Szanto *et al.* in 1979 [9] observed the 10^+ yrast state at an energy of 15.46 MeV. This was used to confirm a backbend in ^{22}Ne at around spin 8. However this state has not been referred to in subsequent papers and no evidence for it has been seen in this work.

Figure 3 shows γ-ray spectra with a gate on $Z = 11$. ^{23}Na is known up to the $11/2^+$ state. A possible $13/2^+$ state has been observed [10] at an energy of 6.23 MeV. The same publication, in agreement with other works [11, 12], presents evidence for an additional state at $15/2^+$ [9.038 MeV]. Gomez del Campo *et al.* also tentatively suggests states at $17/2^+$ [13.82 MeV], $19/2^+$ [14.24 MeV] and $21/2^+$ [14.70 MeV], however these states have not been referred to in subsequent compilations. The present experiment confirms the existence of the $13/2^+$ state. The top spectrum of fig. 3 is gated on the $9/2^+$ to $5/2^+$ transition of 2.26 MeV. The peak at 3.53 MeV is associated with the $13/2^+$ to $9/2^+$ transition and is consistent with shell model predictions and previous work. The bottom spectrum is gated on this transition and the the decay sequence down to the ground state can clearly be seen.

Preliminary results have been presented from an experiment to study the spectroscopy of fragments from multi-nucleon transfer/deep-inelastic collisions initiated by a beam of 160 MeV ^{26}Mg incident on a thin target of ^{150}Nd. The use of the Binary Reaction Spectrometer leads to the Z-identification of projectile-like species and allows Doppler corrections to be made to the γ-ray energies. So far, only those nuclei close to the projectile have been partially studied.

M.J. Burns, K.L. Keyes, A. Papenberg acknowledge support from the EPSRC during the course of this work.

References

1. S. Thummerer, PhD Thesis, Freie Universität Berlin, unpublished (1999).
2. `http://www.hmi.de/people/beschorner/data8m/html/data8m.html`.
3. J. Ollier, private communication.
4. D.C. Radford, Nucl. Instrum. Methods Phys. Res. A **361**, 306 (1995).
5. C. Broude *et al.*, Phys. Rev. Lett. **25**, 14 (1970).
6. C. Broude *et al.*, Phys. Rev. C **13**, 3 (1976).
7. H.P. Trautvetter *et al.*, Nucl. Phys. A **297**, 489 (1978).
8. B.M. Preedom, B.H. Wildenthal Phys. Rev. C **6**, 5 (1972).
9. E.M. Szanto *et al.*, Phys. Rev. Lett. **42**, 10 (1979).
10. G.J. KeKelis *et al.*, Phys. Rev. C **15**, 2 (1977).
11. J. Gomez del Campo *et al.*, Phys. Rev. C **12**, 4 (1975).
12. D.E. Gustafson *et al.*, Phys. Rev. C **13**, 2 (1976).