Level-scheme investigation of ^{33}S

To cite this article: G Tz Gavrilov *et al* 2014 *J. Phys.: Conf. Ser.* **533** 012050

View the article online for updates and enhancements.

Level-scheme investigation of ^{33}S

G. Tz. Gavrilov[1], N. Goutev[1], B. I. Dimitrov[1], D. Tonev[1], P. Petkov[1], G. de Angelis[2], F. Recchia[2], E. Farnea[3], C. A. Ur[3], S. Aydin[2,4], P. G. Bizzeti[5], A. M. Bizzeti-Sona[5], I. Deloncle[6], A. Gottardo[2], H. Laftchiev[1], S. Lunardi[3], D. Mengoni[2], C. Michelangoli[2], D. R. Napoli,[2],R. Orlandi[2], E. Sahin[2], E. A. Stefanova[1], J.J. Valente-Dobon[2], Tz. K. Marinov[1], M. S. Yavahchova[1]

[1]Institute for Nuclear Research and Nuclear Energy, BAS, BG–1784, Sofia, Bulgaria.
[2]INFN, Laboratori Nazionali di Legnaro, I–35020, Legnaro, Italy.
[3]Dipartimento di Fisica and INFN, Sezione di Padova, Padova, Italy.
[4]Aksaray University, Department of Physics, 68100 Aksaray, Turkey.
[5]Dipartimento di Fisica dell'Universitá and INFN Sezione di Firenze, Firenze, Italy.
[6]CSNSM, IN2P3/CNRS et Université Paris-Sud, Orsay, France.

Abstract.
   An angular correlation experiment was carried out for ^{33}S at Laboratori Nazionali di Legnaro with the gamma-ray detector array GASP. The reaction used was ^{24}Mg(^{14}N,α p)^{33}S at a beam energy of 40MeV. An analysis of DCO ratios and triple gamma coincidences was performed. So far, a new level depopulated by 3 γ -ray transitions has been found and its spin was determined. The work for further extension of the level scheme is in progress.

1. Introduction

The investigation of nuclei along the N=Z line is of considerable interest since it directly addresses the validity of the charge symmetry of the nuclear forces and the role of the Coulomb effects on nuclear structure [1, 2]. During the last years the interst to study nuclei in the mass region A $\sim$ 30 arose significantly. This fact is due to the efficient gamma-spectrometers and large variety of beams provided by accelerators. Level-schemes and lifetimes of low-spins states in this mass-region are known, but they need to be remeasured, especially lifetimes which are derived with limitted number of detectors, in some cases with one or two germanium detectors (see e.g. [3]). For low spin states, sd-interactions are applicable but for higher spin states the fp shell has to be taken into account [4, 5, 6, 7]. One may expect a number of interesting physical phenomena that can be studied in the hypothetical superdeformed configuration of ^{32}S, like the shape coexistence, proton neutron pairing and its deformation dependence, effects related to the time-odd components of nuclear mean fields, as well as nuclear - molecular and nuclear - cluster structures [8]. The nucleus ^{33}S is well studied and the relevant spectroscopic information is summarized in [9]. Nevertheless, the data on high-spin states is scarce. The aim of the present work was to provide such new data which allow a comparison with the predictions of shell model calculations at higher spins including fp-shell effects. Using the reaction ^{24}Mg(^{14}N,αp)^{33}S excited states in ^{33}S were populated and observed. The level scheme of ^{33}S was investigated in details.

2. Experiment

High-spin states in ^{33}S have been populated via a fusion-evaporation reaction at 40MeV bombarding energy. A ^{14}N beam, delivered by the LNL XTU-Tandem accelerator impinged on the target with an average beam current of 5 pnA. The 99.7% isotopically enriched ^{24}Mg target, 1mg/cm^2 thick, was evaporated on a 8 mg/cm^2 gold layer. The γ rays emitted in the reaction were detected by the 4π-GASP array composed of 40 Compton-suppressed large-volume, high-purity Ge detectors arranged in seven rings at different angles with respect to the beam axis. Events were collected when at least two germanium detectors fired in coincidence. Energy and efficiency calibrations were performed with standard γ-ray sources of ^{56}Co and ^{152}Eu. The data were sorted into a symmetric γ-γ-γ cube, a symmetric γ-γ matrix, and seven asymmetric matrices having the detectors at 34°, 60°, 72°, 90°, 120°, 146°, respectively, on the first axis and all detectors on the second axis.
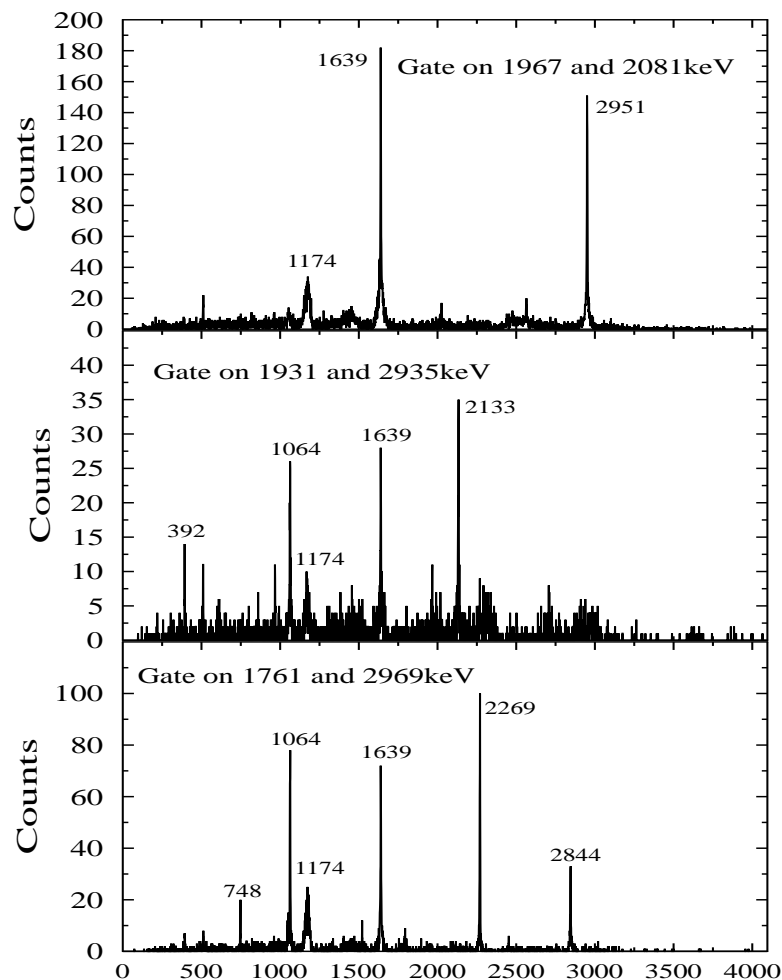

Figure 1. Examples of background-subtracted coincidence spectra obtained from the symmetric γ-γ-γ cube gated by (a) 1967- and 2081-keV γ -rays, (b) 2935- and 1931-keV γ -rays, and (c) 2969- and 1761-keV γ -rays (cf. Figure 2). The most intense peaks, taking into account the detector efficiency for the different energies, are marked and underlined (2951-, 2133- and 2269-keV). By adding their energies to the previously known levels, which are deexcited by the gated transitions, a brand new level with an excitation energy of 6999 keV was found.

The symmetric matrices have been used to study γ-γ coincidence relationships for the construction of the level scheme, while the asymmetric matrices were used to obtain information about the γ transition multipolarities and for lifetime determinations.

3. Data analysis and results

The level scheme of ^{33}S has been extended to higher spins and excitation energies with respect to previous studies. One new state and three γ-ray transitions have been added. The level scheme has been constructed based on double-gated γ-ray spectra. Typical examples of spectra obtained with double gate are shown in Figure 1.

In order to obtain information on the multipolarities and mixing ratios of the observed γ-ray transitions, an angular distribution analysis was performed by using efficiency-corrected γ-ray intensities, $I(\theta)$, obtained from the asymmetric matrices by gating on the axis where all detectors are included. The angular distributions were fitted with Legendre polynomials with free angular coefficients $A_{2,4}$. For transitions with lower intensity the multipolarity was determined by using the angular distribution ratio R_{ADO} defined by the formula in Ref. [5]:

$$R_{ADO} = (I(34.6^\circ) + I(145.4^\circ))/2I(90.0^\circ) \tag{1}$$
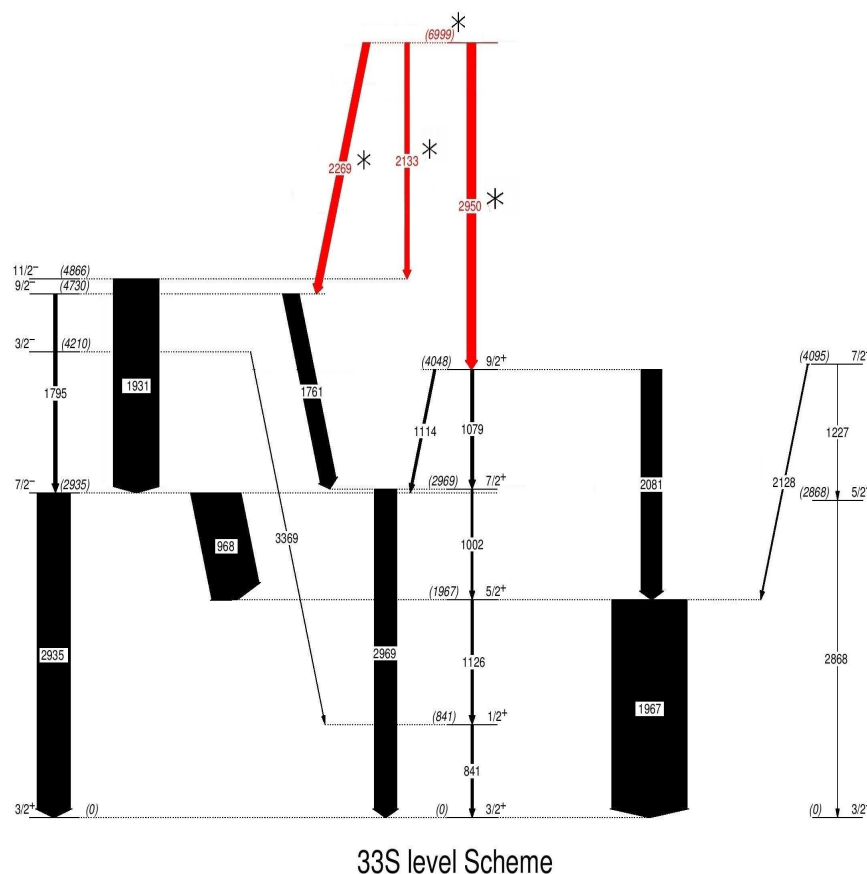

Figure 2. The extended level scheme. The new level is marked with a star as are the three new γ-ray transitions.

In the GASP geometry R_{ADO} values for stretched dipole and stretched quadrupole transitions are about 0.8 and 1.4, respectively. For transitions with mixed character the situation is not so well defined, because the angular distribution ratio depends on the value and sign of the mixing ratio δ. Using this method the multipolarities of previously known transitions have been redetermined and proved with full exactness. The multipolarities of the three new γ -ray transitions have also been determined, all leading to the conclusion that the newly found level at 6999 keV has a spin of $11/2^+$ $\hbar$.

4. Summary and conclusions

A new high-spin level with an excitation energy of 6999 keV in ^{33}S was found along with three new gamma transitions which deexcite it. Further search for higher-lying levels is in progress. The results obtained so far are promising. Rich spectra with very good statistics guarantee that more results can be expected in the near future. Comparison with shell-model calculations is also going to be performed in order to support the proposed spins.

5. Acknowledgments

References

[1] S M Lenzi *et al.* 2001 *Phys. Rev. Lett.* **87** 122501
[2] D Tonev *et al.* 2002 *Phys. Rev.* C **65** 034314
[3] J A J Hermans *et al.* 1974 *Phys. Lett.* **50B** 337
[4] M Ionescu-Bujor *et al.* 2009 *Phys. Rev.* C **80** 034314
[5] S Aydin *et al.* 2012 *Phys. Rev.* C **86** 024320
[6] S Aydin *et al.* 2014 *Phys. Rev.* C **89** 024320
[7] A Bisoi *et al.* 2014 *Phys. Rev.* C **89** 024303
[8] H Molique, J Dobaczewski and J. Dudek 2000 *Phys. Rev.* C **61** 044304
[9] J Chen and B Singh 2011 *Nuclear Data Sheets* **112** 1393