In-beam γ-ray spectroscopy of ^{55}Sc

D. Steppenbeck,*1 S. Takeuchi,*2 N. Aoi,*1,*3 P. Doornenbal,*1 M. Matsushita,*4 H. Wang,*1 H. Baba,*1 S. Go,*5 J. Lee,*1,*6 K. Matsui,*7 S. Michimasa,*4 T. Motobayashi,*1 D. Nishimura,*1,*8 H. Sakurai,*1,*7 Y. Shiga,*1,*9 P.-A. Söderström,*1 T. Sumikama,*1 R. Taniuchi,*1,*7 J. J. Valiente-Dobón,*10 and K. Yoneda*1

The study of the evolution of shell structure has played an important role in the fields of experimental and theoretical nuclear physics over recent decades. On the experimental front, significant advances have been made owing to progress in the production rates of exotic nuclei at radioactive isotope beam facilities worldwide. A few noteworthy examples of shell evolution include the onset of the neutron magic number $N = 16$ in exotic oxygen[1,2], and the weakening of the traditional magic number $N = 28$ approaching the neutron drip line[3]. Moreover, in the pf shell, the onset of a new subshell closure at $N = 32$ has been reported along the Ca[4,5], Ti[6,7], and Cr[8,9] isotopic chains owing to the migration of the $\nu f_{5/2}$ orbital as protons are removed from the $\pi f_{7/2}$ state[10]. More recently, the robustness of the $N = 32$ subshell closure below the $Z = 20$ core, namely, in K[11] and Ar[12] isotopes, has been highlighted. An additional subshell closure was predicted[13] to occur at $N = 34$ in Ti and Ca isotopes; however, the experimental data provided no evidence for this shell gap in ^{56}Ti[7,14]. Later work on the spectroscopy of ^{54}Ca did, however, indicate the presence of a sizable subshell closure at $N = 34$ from the energy of the first 2^+ level[15]. The present work on ^{55}Sc aims at the study of the significance of the $N = 34$ gap along the $Z = 21$ isotopic chain, and the evolution of this neutron magic number as protons are added to the $\pi f_{7/2}$ orbital.

The experiment was performed using ^{70}Zn^{30+} ions with the BigRIPS separator to provide a fast radioactive beam—optimized for the transmission of ^{55}Sc—that was focused on a 10-mm-thick ^{9}Be reaction target at the eighth focal plane of the spectrometer. The beam constituents were identified on an event-by-event basis using particle magnetic rigidities ($B\rho$), times of flight (T), and energy losses in an ionization chamber (ΔE)[16]. The target at F8 was surrounded by the DALI2 γ-ray detector array to measure transitions from nuclear excited states populated by the reactions; ions emerging from the target position were identified by the ZeroDegree spectrometer using the same general ($B\rho$–T–ΔE) techniques as for BigRIPS.

*1 RIKEN Nishina Center
*2 Dept of Physics, Tokyo Institute of Technology
*3 RCNP, Osaka University
*4 Center for Nuclear Study, University of Tokyo
*5 Dept of Science and Engineering, University of Tennessee
*6 Dept of Physics, University of Hong Kong
*7 Dept of Physics, University of Tokyo
*8 Dept of Physics, Tokyo University of Science
*9 Dept of Physics, Rikkyo University
*10 Laboratori Nazionali di Legnaro

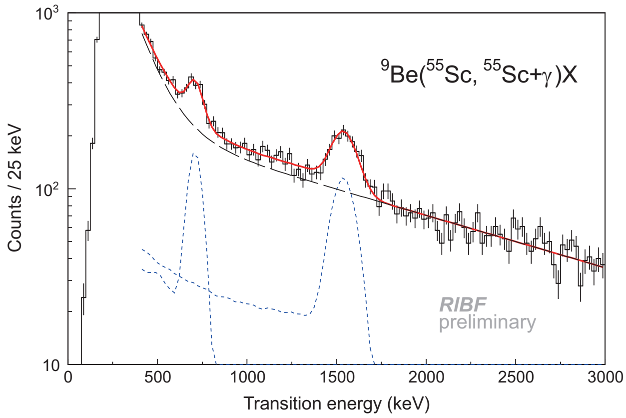

Fig. 1. (colour) Doppler-corrected γ-ray energy spectrum deduced from the inelastic scattering of ^{55}Sc on a ^{9}Be target. The black dashed line is a double exponential fit to the background and the blue dashed lines are the results of GEANT4 simulations; the solid red line is the total (sum) fit. Results are preliminary.

The γ-ray energy spectrum deduced from the ^{9}Be(^{55}Sc, ^{55}Sc+γ)X inelastic scattering reaction is presented in Fig. 1. This work was previously reported, amongst other results, in Ref.[17]. No results on excited states in ^{55}Sc were available prior to the present experiment. From the spectrum in Fig. 1, we report new transitions in ^{55}Sc at energies of 0.71(1) and 1.54(2) MeV. Additional results on the low-lying structure of ^{55}Sc will be reported elsewhere.

References

1) R. Kanungo *et al.,* Phys. Rev. Lett. **102**, 152501 (2009).
2) C. R. Hoffman *et al.,* Phys. Lett. B **672**, 17 (2009).
3) B. Bastin *et al.,* Phys. Rev. Lett. **99**, 022503 (2007).
4) A. Gade *et al.,* Phys. Rev. C **74**, 021302(R) (2006).
5) F. Wienholtz *et al.,* Nature **498**, 346 (2013).
6) R. V. F. Janssens *et al.,* Phys. Lett. B **546**, 55 (2002).
7) D.-C. Dinca *et al.,* Phys. Rev. C **71**, 041302(R) (2005).
8) J. I. Prisciandaro *et al.,* Phys. Lett. B **510**, 17 (2001).
9) A. Bürger *et al.,* Phys. Lett. B **622**, 29 (2005).
10) T. Otsuka *et al.,* Phys. Rev. Lett. **95**, 232502 (2005).
11) M. Rosenbusch *et al.,* Phys. Rev. Lett. **114**, 202501 (2015).
12) D. Steppenbeck *et al.,* Phys. Rev. Lett. **114**, 252501 (2015).
13) T. Otsuka *et al.,* Phys. Rev. Lett. **87**, 082502 (2001).
14) S. N. Liddick *et al.,* Phys. Rev. Lett. **92**, 072502 (2004).
15) D. Steppenbeck *et al.,* Nature **502**, 207 (2013).
16) T. Kubo *et al.,* Nucl. Instrum. Meth. B **204**, 97 (2003).
17) D. Steppenbeck *et al.,* JPS Conf. Proc. **6**, 020019 (2015).