Contribution ID: **0** Type: **not specified**

Role of the neutron d5/2 sub-shell in the evolution of Ge and Se isotopes

Monday, 12 September 2011 13:00 (15 minutes)

Recent data on Ge and Se isotopes above the N=50 shell closure has led to the discussion of a weakening of the Z=28 proton shell, based on relatively low first excited 2+ energies in the N=52 Ge and Se isotones. Further discussion relates to the possible emergence of a new neutron sub-shell closure at N=58, based on the evolution of single particle energies in N=51 isotones. Both effects would arise from tensor forces that result in shifts of single-particle energies, and which hence play a crucial role in the predictions of structure of neutron rich isotopes far above N=50.

Whereas the possibility of a N=58 sub-shell seems more likely for nuclei below the Z=28 shell, above Z=28 data seems to indicate the possibility that the neutron 2d5/2 sub-shell closure reappears in Se isotopes. The closure of this orbital is responsible for the nearly doubly-magic character of 96Zr, but becomes more washed out in Sr and Kr isotopes with only a modest rise of the 2_1+ energy at N=56. In all cases, that is in the Zr, Sr, and Kr isotopes, the 2_1+ energy drops slightly from N=52 to N=54. Recent data on the neutron-rich 88Se, however, indicates a vast change in structure. The 2_1+ energy in the N=54 88Se lies considerably higher than in it's N=52 neighbor isotope. This may be indicative of approaching a pronounced recurrence of a sub-shell closure which may occur at N=56. Another possibility would be the occurrence of a neutron sub-shell at N=54, which seems unlikely since it would afford a dramatic drop of the energy of the neutron 2d3/2 orbital.

We are particularly interested in obtaining data on the N=56 88Ge and 90Se isotopes in order to probe whether their 2_1+ energies indeed raise toward this neutron number. Also the 2_1+ energies of the N=54 86Ge and 88Se need to be measured - in order to track the structural evolution in those isotopes and identify a possible sub-shell closure. Only one experiment so far has identified the energy of the 2_1+ state in 88Se, in the other isotopes mentioned these energies are unknown. The RIBF facility offers the unique possibility to produce neutron-rich nuclei in the A~90 mass region in fission with sufficient yields to perform gamma-spectroscopy with a large HPGe detector array. Spectroscopy can be done after beta-decay, relating gamma-rays to implants in a focal plane detection system.

The most challenging isotope in the context is 88Ge, to be probed via beta-decay from 88Ga. The production rate that can be expected for this isotope lies truly on the frontier. The fission yields for the other isotopes needed for the beta-decay study, that is 86Ga, 88As, and 90As, should be more than sufficient. It may even be possible to have even heavier As isotopes in the fission cocktail, which would allow to track the onset of deformation beyond the possible neutron sub-shell. Likely, more than the first excited state can be observed for nuclei like 88,90Se and 86Ge, which will give further evidence for their structure, e.g., through the energy ratio of the first two excited states, R4/2 = E(4_1+)/E(2_1+).

There is some overlap in interest with the proposal on 92-94Se by Krücken et al., which is particularly focused on the onset of deformation in the more neutron-rich Se isotopes.

Summary

We propose to test the d5/2 sub-shell closure in the N=56 isotopes 88Ge and 90Se by measuring the energies of the respective first excited 2+ states. This study is motivated by the rise in 2_1+ energy that has been observe in 88Se, giving rise to a recurrence of a pronounced shell gap, which is known to be strong in Zr isotopes, but has been washed out at lower Z.

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Session Classification: Neutron-Rich I