New (sub) shell closures – Relativistic Coulex of neutron-deficient and neutron-rich Ca isotopes

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At N $\gg$ Z the disappearance of the familiar Woods-Saxon shell closures and their reappearance as harmonic oscillator magic numbers is a burning question, which is strongly related to the dilute neutron density and the decoupling of proton and neutron motion in weakly bound systems [1]. In the region of neutron-rich nuclei beyond the "halo" region double shell closures are unambiguously identified for ^{34}Si/^{36}S at N=20, Z=14/16, and the well known $^{48}_{20}Ca_{28}$ and $^{132}_{50}Sn_{82}$. There is incomplete or controversial evidence for ^{52,54}Ca and ^{68}Ni [2].

Signatures for (sub)shell closures can be derived from binding energies as the differences δ_{2n} resp. δ_{2p} of the two-neutron (proton) separation energies, the excitation energies of $I^{\pi}=2^+$ states E(2^+) and the γ-transition strength B(E2;$2^+ \rightarrow 0^+$) . There are four regions of interest within reach for RISING to study the development of shell structure via the latter signatures by relativistic Coulomb excitation:

- the Sn isotones with N>82 and the Z<50 isotones of $^{132}_{50}Sn_{82}$, which can be abundantly produced in ^{238}U fission;
- the Ni isotopes with N$\geq$40 and the Z>28 isotones of $^{78}_{50}Ni_{50}$, which can be reached via fragmentation of ^{86}Kr, ^{82}Se and ^{76}Ge (see H. Scheit);
- the neutron-rich Ca isotopes with N$\geq$30, produced in fragmentation of ^{76}Ge or ^{82}Se (see below); and
- the neutron deficient ^{36}Ca, mirror to ^{36}S produced in fragmentation of ^{40}Ca (see M. Bentley et al.).

The study of these nuclei will address the question of shell quenching in neutron-rich nuclei and provide a test ground for the isovector part of the nuclear mean field. For the production by fragmentation the following table gives typical beam intensities I_{RIB} and γ-ray count rates N_γ, assuming a primary beam intensity of 3×10^9 /s, a target thickness of 1 g/cm^2 for the Be fragmentation and Pb Coulex targets, a B(E2;$2^+ \rightarrow 0^+$) = 4 Wu and $\epsilon_\gamma = 5\%$.

RIB	Beam	σ_{Frag} (b)	I_{RIB} (p/s)	σ_{Coul} (mb)	N_γ (1/min)
^{84}Se	^{86}Kr	4.7[-4]	9.4[+3]	340	25
^{82}Ge	^{86}Kr	8.7[-7]	1.7[+2]	320	0.42
^{70}Ni	^{76}Ge	4.0[-5]	8.0[+2]	240	1.50
^{74}Ni	^{86}Kr	2.5[-6]	5.0[+1]	260	0.10
^{50}Ca	^{82}Se	4.5[-6]	9.0[+2]	180	1.26
^{52}Ca	^{82}Se	1.4[-7]	3.0[+1]	190	0.04
^{36}Ca	^{40}Ca	1.4[-6]	2.8[+2]	120	0.26

[1] T. Werner et al., Z. Phys. A358 (1997) 169
[2] H. Grawe, M. Lewitowicz, preprint GANIL P 01 03 and Nucl. Phys. A, in print