# A Comparison of Stable and Reaccelerated Radioactive Beams to Produce Nuclei at High Angular Momentum

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Future radioactive beam facilities will provide intense (~pnA) neutron-rich beams at Coulomb barrier energies (4-6 MeV/A), opening the way to study nuclear phenomena in a new “spin regime” and in neutron-rich nuclei. It is at the very highest spins and in the more neutron-rich nuclei that we may expect to observe new phenomena such as hyperdeformed shapes. In this report we compare the use of stable beams and reaccelerated neutron-rich beams to produce nuclei at high angular momentum, specifically in the context of the maximum spin that can be reached.

The top panel of the figure shows the calculated maximum spin that a given isotope can sustain from Cd (Z=48) to Hf (Z=72). The maximum spin ($I_c$) was estimated by comparing the height of the fission barrier to the neutron separation energy, as a function of angular momentum. $I_c$ then corresponds to the spin at which the fission barrier ($B_f$) is equal to the neutron separation energy ($S_n$). The fission barrier was calculated using the analytic expressions of W. Swiatecki and W.D. Myers (see the discussion in Ref [1] for relevant formulae and references). While the absolute $I_c$ values depend on the form of the fission barrier and $S_n$ values, for example, the relative $I_c$ values within an isotopic chain will be less sensitive.

For each isotope we then determine the most neutron-rich compound system that could be produced with either (i) a stable beam on a stable target or (ii) a radioactive beam on a stable target. The list of potential radioactive beams was taken from the estimates for RIA and limited to those with predicted intensities of ~1pnA (examples of n-rich RIBS include; $^{94}$Kr, $^{132}$Sn, $^{136}$Te, $^{142}$Xe). In many cases the use of RIBS results in a compound system that has 6-8 more neutrons (bottom panel of the figure). The maximum spins that can be accessed using either stable beams or radioactive n-rich beams are marked as lines in the upper panel. In general, the availability of a neutron-rich beam increases the spin window by 6-10 $\hbar$ . This is a significant increase and opens up a new spin regime for future study throughout this whole region.

Hyperdeformation is one clear physics example where the availability of neutron-rich reaccelerated beams will provide significant gains. These very deformed nuclei with axis ratios of c/a > 2:1 have been predicted for many years but a hyperdeformed band has yet to be observed. The neutron rich Cd isotopes are calculated to be among the best candidates to observe hyperdeformed nuclei. With stable beams the heaviest Cd isotope that can be produced at high spins is $^{112}$Cd ($^{48}$Ca+$^{64}$Ni) leading to the final nucleus $^{108}$Cd with 60 neutrons. However, while very deformed structure with ~2:1 axis ratios have been observed in $^{108}$Cd [2], the hyperdeformed states are predicted to remain energetically unfavored below a spin of ~65 $\hbar$ (and are most likely beyond the reach of today’s experimental sensitivity). However, for neutron numbers N=64 and greater the hyperdeformed states will become the favored configuration at lower spins and hence these few extra neutrons may make all the difference. With a RIB beam of $^{95}$Kr on a $^{26}$Mg target it will be possible to produce $^{121}$Cd as the compound system. Even allowing for the evaporation of 7 neutrons this still brings us to $^{114}$Cd, which is 6 neutrons beyond where we can go today and into the region of predicted hyperdeformed shapes.

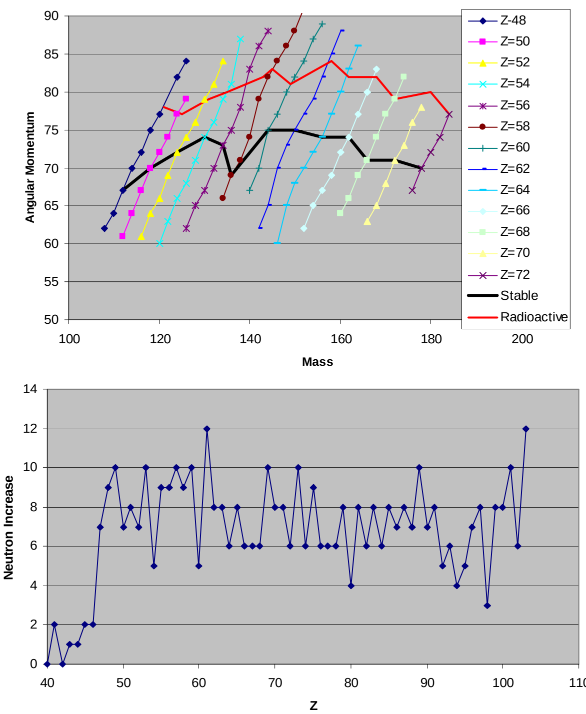


Figure 1: Upper panel shows the calculated maximum spin that a given isotone can sustain from Cd (Z=48) to Hf (Z=72). Lower panel shows the number of extra neutrons, as a function of the atomic number of the compound nucleus, which can be obtained using intense n-rich radioactive beams.

## REFERENCES

[1] D. Ward et al., Phys. Rev. C66, 024317 (2002)
[2] R. M. Clark et al., Phys. Rev. Lett. 87 (2001) 202502
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