Structure Around ^{100}Sn

D. Rudolph, C.Fahlander, H. Grawe, K.Schmidt, T. Faestermann

Doubly-magic nuclei are essential bench marks within the nuclidic chart. They and their near neighbours serve as sources and act as constraints for the shell-model parameter sets by providing key ingredients to any nuclear mean-field model such as single-particle energies and residual interactions. The region around ^{100}Sn is of particular interest, since it is the heaviest bound self-conjugate doubly-magic system and as such, may be susceptible for continuum and isospin effects. In addition, the structure of the region has astrophysical consequences since it is predicted that the region 'southwest' of ^{100}Sn lies on the rapid proton capture path.

RISING will open new perspectives in the spectroscopy of nuclei in the vicinity of ^{100}Sn.

1. Beta-decay information of the exotic nuclei in the region remains scarce (see, e.g., Ref [1]). In many cases even fundamental quantities such as masses or ground state half-lives are not well known. The combination of a powerful germanium-detector array with an efficient and comprehensive beta-decay set-up should provide a significant improvement in our experimental sensitivity in this area.

2. The study of quantities which are difficult (if not impossible) to access by means of other well established reaction mechanisms and techniques, such as the identification of specific single-particle states of low-spin orbits.

The very neutron deficient nature of ^{100}Sn also implies low production rates. However, this is not necessarily an experimental disadvantage, since too high rates potentially destroy correlations between implanted ions and subsequent decays. In that sense, the region around ^{100}Sn appears to be ideal for beta-delayed studies during the proposed stopped RISING campaign. Three specific physics cases are presented in some detail.

Subject	Beam	Set-Up[a]	σ_{frag}(nb)	b_{gamma}	γ-rays/min @ S4[b]
^{105}Sb beta decay	^{124}Xe	β-decay	47(15) [3]	0.01	0.13
^{86}Tc beta decay	^{96}Ru	β-decay	30	0.08	0.50
^{97}Cd beta decay	^{112}Sn	β-decay	6(3) [4]	0.1	0.16
^{96}Ag isomer decay	^{112}Sn	active stopper	200(80) [4]	0.1	5

[a] A complementing BaF_2 array for Fast Timing is also considered useful.
[b] Detected for a given transition and based on the following assumptions:
$I_{beam}=3x10^9 s^{-1}$; target 1.5g/cm^2 Be; T_{total} = 30%; gamma efficiency =5 %.

1. Neutron Single-Particle States

In the past, the main portion of nuclear structure information in the ^{100}Sn region has arisen from fusion-evaporation reactions. Recently, the splitting of the neutron d5/2 and g7/2 single-particle states has been deduced from excited states in ^{103}Sn [2]. The single-particle levels of the low-spin neutron s1/2 and d3/2 orbits, however, are basically unknown --- it is only in ^{107}Sn, seven neutrons away from the doubly-magic core, where excited states with tentatively assigned spin and parity I=3/2$^+$ are known. We suggest to measure the Gamow-Teller (GT) beta-decay of ^{105}Sb, which has a half-life of about one second. The GT decay of the proton d5/2 ground state shall mainly populate the neutron d3/2 state in the ^{105}Sn daughter. Depending on its location, a gamma-ray branch into the neutron s1/2 level may be observed as well from GT feeding of higher lying $3/2^+$ states, though this is suppressed due to the reduced phase space. Both states shall subsequently gamma-decay into the known $7/2^+$ and $5/2^+$ states in ^{105}Sn. An additional attractive aspect of such studies using fragmentation beams and Rising is that Sb-isotopes are difficult to process with ISOL techniques.

2. Fermi-Decays and Isospin Mixing

From previous campaigns at GSI (using the Cluster Cube and TAS at the Online Mass Separator) it was established that a measurement of the full Gamow-Teller strength of the decay of proton-rich nuclei is difficult to achieve solely using high-resolution gamma-ray spectroscopy. Therefore, we suggest instead a focus on Fermi decays of odd-odd N=Z nuclei below ^{100}Sn. Due to their much shorter half-lives the Fermi decays can be discriminated from beta-decaying high-spin states, which are also populated in these isotopes [1,4]. In particular we would like to search for weak branches parallel to the main super allowed Fermi decays. A measurement of the number of gamma rays in the daughter nuclei with respect to the number of incoming ions shall allow for an estimate of the isospin mixing in medium heavy N=Z nuclei.

3. Spin-Gap Isomeric or Beta-Decaying States

Near doubly-magic nuclei spin-gap isomers may arise from specific couplings of a few valence nucleons or holes (e.g., $19/2^-$ states in the A=53 mirror nuclei ^{53}Co and ^{53}Fe), which will de-excite by gamma- and/or beta-decay. By studying their properties valuable information on the neutron-proton part of the nucleon-nucleon interaction can be obtained. A spin-gap isomer is predicted to exist in $^{96}Ag_{49}$, and the beta-delayed proton decay observed in $^{97}Cd_{49}$ is thought to originate from a $25/2^+$ high-spin state. Similarly, the N=Z isotope ^{96}Cd is expected to reveal a highly excited, energetically favoured, beta-decaying 16^+ state. The latter isotope has been identified in projectile fragmentation reactions (see, e.g., Ref.~[1]), however to date, no spectroscopic information has been observed. In ^{95}Pd only the $21/2^+$ spin-gap decay has been observed. Currently, nothing is known on the decay of the $9/2^+$ ground-state.

Clearly, delayed high-efficiency gamma-ray detection will help to (I) discover isomers in the 'southwest' of ^{100}Sn, and (II) establish a comprehensive decay scheme of, for example, ^{97}Cd.

[1] Proceedings Pingst2000 --- Selected Topics on N=Z Nuclei, Lund, Sweden, June 2000, Eds. D.Rudolph and M.Hellstroem, (Bloms i Lund, 2000), chapter 4.
[2] C. Fahlander et al., Phys. Rev. C63, 021307(R), (2001).
[3] R. Schneider, PHD-thesis, TU-Muenchen, 1996.
[4] A. Stolz, PHD-thesis, TU-Muenchen, 2001

g-Factor Measurements

G. Neyens, D. Balabanski, M.Hass, R.Grzywacz, G. Georgiev

RISING will allow the measurement electromagnetic moments of isomeric states in nuclei far from stability. These experiments will utilise the alignment of fully stripped projectiles from fragmentation reactions at GSI. The intention would be to carry out the experiments into several phases. The initial phase concentrate on measurements of magnetic moments of isomers in neutron rich nuclei near N=50, which would include a study of the spin-orientation of the projectiles in fragmentation reactions. (The orientation of the isomers of interest is a stringent requirement for these experiments, but information on this aspect of the reaction process in the energy regime of the GSI beams is very scarce.) In a later phase of the project we aim to study the quadrupole moments of the nuclei of interest, as well expanding these studies towards the neutron-rich nuclei along the N=82 shell for which no data are available at present.

The present project is a continuation of the experiments which were initiated at Louvain-le-Neuve, which studied the deformations and the effective charges of isomers near the N=50 shell closure in proton mid-shell mass A~80 nuclei. In the current letter of intent, we propose the study of g-factors of the isomers in this region for the first time. Numerous new isomers have been discovered recently in this region in heavy ion fragmentation reactions [grz95], produced following the fragmentation of a ^{112}Sn beam at GANIL with primary beam energies of 58 A.MeV and 63 A.MeV on a natural nickel. The experiments which are suggested will focus on understanding the properties of the N=50 shell.

The experimental method of the Time-Dependent Perturbed Angular Distribution (TDPAD) applied to the isomeric beams will be utilized. The feasibility of these experiments for the GSI energy regime has been demonstrated Schmidt-Ott et al. [sch94]. Also, the present collaboration has performed recently a successful experiment at GANIL to study isomers close to ^{68}Ni [geo01].

In order to carry out these experiments, a dedicated magnet system up to 1 T will be developed. With this aim, contacts and discussions with DANSKFYSIK and the GSI RISING group have already been carried out. The feasibility of the project has been justified. DANSKFYSIK provided a first set of technical drawings for the magnet and the details about its installation are under discussion with the GSI RISING group. This magnet will allow to build up two experimental set-ups:

(a) for g-factor measurements, for which only the EUROBALL detectors around the magnet at S2 will be needed; and

(b) a experimental set-up to allow beta-gamma coincidences and measurement of quadrupole moments with the LEMS technique.

As first experiments we would like to suggest to fragment the ^{98}Mo beam in order to study the N=50 mass A~80 nuclei. These experiments will provide two-fold information: (a) on the spin-alignment of the secondary isomeric beams as a function of the abraded nucleons; and (b) on the g-factors of the isomers in the vicinity of the N=50 shell.

[grz95] R. Grzywacz et al., Phys. Lett. B355 (1995) 439
[sch94] W.D. Schmidt-Ott et al Z. Phys. A 350 (1994) 215
[geo01] G. Neyens et al. Acta Physica Polonica B Vol. 32 (2001) 1061

Proton Drip line physics around A~130

D.M. Cullen, A.M. Bruce

Of particular interest for the stopped beam program using RISING are deformed isomers which lie in the vicinity of the proton drip-line, specifically, the case of the N=74 nucleus $^{140}Dy_{74}$. The analogous Z=75 region of deformed W, Re and Os nuclei is particularly rich in energetically favoured high-K states which often lead to the existence of isomeric levels [1]. More recently, a programme of work to study analogous states in the N=74 series of nuclei has produced some intriguing results about the 'robustness' of the K quantum number across this range of isotones [2]. The observed isomers have K=8 and are interpreted as being based on the two quasi-neutron 7/2+[404] x 9/2-[514], Nilsson structure which couples to produce a $K=8^-$ state. The quadrupole deformation of the N=74 isotones increases with increasing mass (see e.g. [3]) and the nominally 'K-forbidden' decay to the (K=0) ground-state band should become more hindered as the K quantum number becomes more defininitive. In fact the opposite is observed and two theories have been proposed [2] to explain this anomaly. Currently the heaviest N=74 isotone whose spectroscopy has been studied is ^{138}Gd which was investigated at the Australian National Laboratory and Jyvaskyla using fusion evaporation reactions. The production of $^{140}Dy_{74}$ and (possibly) heavier N=74 isotones could best be done using a fragmentation reaction, in particular we would propose the fragmentation of a ^{208}Pb beam.

The initial aim would be to identify the gamma-decay of the isomeric state in ^{140}Dy (which is expected to have a half-life of about 5miroseconds). This would automatically give information about the low-lying states in the ground-state band, allowing an estimate of the deformation to be obtained using the Grodzin's formula. The deformation of the ground-state of ^{140}Dy has a special relevance because its value has an effect on the analysis of recent measurements [4] on the proton radioactivity from the highly deformed nucleus ^{141}Ho (to ^{140}Dy). Under the assumption that the deformation of the parent and daughter nucleus are the same, the authors of [4] calculate a quadrupole deformation parameter for the $7/2^-$[523] state in ^{141}Ho of between 0.27 and 0.33. This essentially agrees with the value of 0.26 calculated in [3] but neither value has yet been verified experimentally.

Following the gamma-ray study, it would be of interest to consider the possibility of observing proton decay from the isomeric state. Although the probability of this obviously depends on the lifetime of the isomeric state, it should not be too readily dismissed since it was the search for two-proton decay from an isomeric state in a nucleus not lying beyond the proton drip-line which led to the first example of one-proton radioactivity being serendipitously discovered [5].

Another intriguing possibility in this mass region is the nuclei at the proton drip line in the cerium (Z=58) region, which are predicted to possess large ground-state quadrupole deformations. As a consequence, the high-Ω $[404]9/2^+$ proton orbital approaches the Fermi surface and it may be possible to form two-quasiproton high-K isomeric states similar to the two-quasineutron isomers seen in the N=74 isotones. In addition, doubly odd nuclei of this neutron-deficient region would be expected to form low-lying high-j isomeric states.

[1] P.Walker and G.D.Dracoulis, Phys. Scr. **T5**, 29 (1983) and Nature **399**, 35 (1999).
[2] A.M.Bruce et al., Phys. Rev. **C55**, 620 (1997).
[3] F.R.Xu et al., Phys. Rev. **C59**, 731 (1999).
[4] C.N.Davids et al., Phys. Rev. Lett. **80**, 1849 (1998).
[5] K.P.Jackson et al., Phys. Lett. B33, 281 (1970).

Fission fragment studies: Opportunities with RISING

M. Hellstrom

One of the advantages of GSI is the availability of isotopically separated secondary beams of neutron-rich reaction fragments produced by in-flight fragmentation or fission of heavy projectiles. In particular, the use of relativistic fission opens up many interesting possibilities to study the evolution of nuclear structure in medium-mass nuclei far from stability as a function of the increasing neutron-to-proton ratio. The in-flight fission process has been studied in detail at GSI, and cross sections have been measured [Bernas,Engelmann,Donzaud]. The kinematics of the process is well understood, allowing accurate predictions of both production yields and the transmission throughout the fragment separator.

A number of state of the art, mean-field calculations predict that when the nuclear system become more weakly bound on the neutron rich side of the valley of stability, their spatial extent increases as neutron skins develop and the surface becomes more diffuse [Werner,Dobaczewski]. The resultant decoupling of proton and neutron motion, as well as the influence of levels in the particle continuum, is predicted to strongly affect the spin-orbit interaction, causing a 'rearrangement' of the standard shell model single particle orbitals. The result could be the disappearance or quenching of the standard magic shell gaps and possibly, the reappearance of harmonic-oscillator magic numbers. Although the heavy neutron drip-line will not be directly accessible with RISING, studies of nuclei at the edge of what is currently known will help locate the onset of such effects. (Recent results from ISOLDE [Shergur] indicate that nuclei close to ^{132}Sn could already be influenced)

The connection to nuclear astrophysics is also strong: the rapid n-capture process paths are thought to proceed through nuclei "below" ^{78}Ni and ^{132}Sn. The importance of the properties of these exotic systems is illustrated by the strong dependence of nucleosynthesis abundance calculations on the choice of mass surface – mass models including the above mentioned shell quenching lead to a superior reproducibility of observed solar system abundances compared to those that preserve near-to-stability magic numbers. [Kratz].

Systematic studies of fission fragment angular momentum will also give important insights on the neck formation and scission of the fissioning system, as well as "temperature" information (because of the correlation between average fragment spin and excitation energy). Up to now, data on angular momentum aspects of fission are relatively scarce, and mostly originate in studies of low-energy processes, such as spontaneous fission [Ahmad]. The measurement of isomeric ratios of especially high-spin (I>10 hbar) isomeric states would be extremely useful

With the arrival of RISING, it will be possible both to continue the isomer spectroscopy studies, not only of nuclei close to the doubly-magic fix-points ^{78}Ni and but also in new areas, including the potential region of new (doubly) "K-magic" nuclei [Walker]. This possibility is very exciting, and should offer a unique probe into the development of deformation as the number of valence particles increases in the mass ~120 region. In addition, efficient beta-decay studies of also very rare fission product isotopes become possible. Here the nuclei of interest would be implanted in an active catcher and the subsequent gamma-radiation in coincidence with beta-particles recorded – the betas in the catcher system and the gammas in the surrounding germanium detectors (as demonstrated in the Munich ^{100}Sn-experiment at GSI [Schneider]). This technique can be applied to any region of the nuclidic chart accessible with fission. Both of these measurement types can be combined with "fast timing" [Mach], using ancillary BaF_2-arrays, and this possibility should not be forgotten. Using either the isomeric or the beta transition as trigger, the much shorter (down to picosecond) lifetimes of lower-lying states populated in the (isomer) decay can be measured, adding useful nuclear structure information (transitions, multipolarities etc.).

[Bernas] M. Bernas et al., Phys. Lett. B331, 19 (1994).
[Engelmann] Ch. Engelmann et al., Zeitschrift für Physik A 352 (1995) 351.
[Donzaud] C. Donzaud et al., Eur. Phys. J. A 1 (1998) 407.
[Werner] T. Werner et al., Z. Phys. A 358 (1997) 169.

[Dobaczewski] J. Dobaczewski et al., to be published in Nucl. Phys. A (2001).
[Shergur] J. Shergur et al., Nucl. Phys. A682 (2001) 492.
[Kratz] K.-L. Kratz et al., Hyp. Interact. 129 (2000) 185, and references therein.
[Ahmad] I. Ahmad and W.R. Phillips, Pep. Prog. Phys. 58 (1995) 1415.
[Mineva] M.N. Mineva et al., to be published in Eur. Phys. J. A (2001).
[Ameil] F. Ameil et al., Eur. Phys. J. A 1 (1998) 275.
[Schatz] H. Schatz et al., GSI experiment E040.
[Walker] P.M. Walker, private communication (2001).
[Mach] H. Mach et al., in *Proceedings of the International Workshop on Selected Topics on N=Z Nuclei*, June 6-10, 2000, Lund, Sweden, p. 295-299.
[Schneider] R. Schneider et al., Nucl. Phys. A583, 853c (1995).

The Neutron-rich Hf-Pt region

Z. Podolyak, P.M.Walker, J. Jolie, H. Mach, R. Lieder

The region of the neutron-rich Hf-Pt nuclei is an established testing ground for a number of nuclear structure phenomena, including K-isomerism, configuration dependent pairing effects, gamma softness, hexadecapole deformation, and subshell effects. However, our current knowledge of the neutron-rich isotopes of these elements is severely limited due to the difficulty in synthesising these species in an environment which allows detailed spectroscopy. Recent experiments have shown that the structure of neutron-rich nuclei can be studied using the novel technique of fragmentation reactions. Technically the most straightforward is to obtain structural information from the delayed radiation originating from isomeric states (with no Doppler broadening, and almost no background).

The structure of nuclei in the Yb-Hf-W-Os (Z=70-76) region of deformed nuclei is characterised by the presence of K-isomeric states [walk00]. These are multi-quasiparticle states formed by orbitals with large angular-momentum projections (Ω) on the symmetry axis ($K=\Sigma_i\Omega$). The isomers present in the chain of the heavy Pt (Z=78) isotopes are of different nature. They are spin traps, deexcited by low energy transitions. The overall presence of the isomers in the Hf-Pt region almost guarantees a plethora of new spectroscopic information using the projectile fragmentation method. Not only are K isomers of interest in themselves, but they also serve as a tool, giving access to excited states in these very neutron-rich nuclei where novel subshell structures may be manifest.

A significant amount of information on the global behaviour of nuclei can be obtained from the energy spacing of the lowest lying states. In even-even systems the excitation energy of the first 2^+ state can be used to infer the extent of quadrupole deformation. Similarly, the ratio of the excitation energies of the first 4^+ and 2^+ states can be used to distinguish between an axially symmetric deformed rotor, a spherical, vibrational nucleus and a triaxial rotor. In general, for nuclei, where the spectroscopic information is available, the systematics follow smooth trends, providing sub-shell closures are taken into account. The experimental data obtained on the neutron-rich ^{190}W isotope (following the highly successful experiment at GSI in April 1999 investigating isomeric decays following the fragmentation of a 1GeV.A ^{208}Pb beam) suggests a new subshell effect for heavy neutron-rich systems [pod00]. The energy ratio of the first two excited states, for this nucleus shows a striking deviation from the pattern for the lighter isotonic chains, a feature which is not currently understood. The deviation at ^{190}W is reminiscent of the systematics representing the breakdown of the Z=64 subshell gap for neutron numbers between N<78 and N>88. More data on the ground state bands of neutron rich even-even nuclei in this region are needed, and we propose to study nuclei such as ^{186,188}Hf and ^{192}W to address this question.
The high efficiency of RISING will also significantly improve statistics, allowing detailed gamma-gamma coincidence information to be obtained. This is crucial in the case of the odd-odd and odd-A nuclei, from which the proton-neutron interaction and single-particle energies can be extracted.

Another major question to be addressed is the underlying reason for the shape transitions between axially deformed, triaxial and spherical nuclei. This can be investigated by studying nuclei close to the spherical ^{208}Pb nucleus via previously inaccessible neutron-rich nuclei. The first choice is the ^{204}Pt nucleus, where a 7^- spherical isomer is expected. Recently a similar isomer in ^{202}Pt was identified [caam01], with a lifetime four orders-of-magnitude longer than those of similar states in the lighter platinum isotopes, caused by the lowering of the $(h^{-1}_{11/2}d_{3/2})$ 7^- two-proton state below the (most likely 2 proton $h^{-1}_{11/2}s_{1/2}$) 5_- level.

The most favoured conditions for the formation of K isomers are when the neutron and proton Fermi levels are high, but not too high, in their respective shells. Thus, Z=72 (about 70 percent through the Z=50-82 shell) is strongly favoured, and so is N=116. These nucleon numbers could be described as "K magic". However, to combine simultaneously optimum proton and neutron numbers requires the study of nuclei that have to date been inaccessible, such as ^{188}Hf, ^{146}Hf, ^{118}Ru – nuclei that may be termed "doubly K magic". The ground state of the "doubly K magic" ^{188}Hf (Z=72) has recently been identified following relativistic projectile fragmentation performed at GSI (caam01). We propose the study of its excited collective and multi-quasiparticle structures.

A deeper insight into the the wave-function of individual states can be obtained by measuring lifetimes. Lifetimes of the states down to the sub-nanosecond regime can be determined by electronic timing methods using fast-response BaF_2 detectors. This technique will be used to determine the lifetime of the first excited states (most importantly, the 2^+ states) in the nuclei connected to the proposed subshell effect around ^{190}W. Lifetimes of short-living isotopes will be measured as well. Previous experiments identified such isomers in the ^{200,201}Pt [caam01] isotopes with lifetimes below the time resolution of germanium detectors.

The nuclei of the neutron-rich Hf-Pt region will be populated using ^{208}Pb and ^{238}U primary beams. Generally speaking, the former will give higher cross sections, the latter will populate higher spins. Previous experiments showed that stopped isomeric beams can be successfully used to study the neutron-rich rare-earth nuclei. The increased sensitivity of the Ge detectors (RISING) gives the possibility to push further the limit of known nuclei and to investigate some of the above issues that we only glimpsed at present.

[Walk99] P.M. Walker and G.D. Dracoulis, Nature vol. 399 (2000) p35
[pod00] Z. Podolyak et al. Physics Letters B491 (2000) p225
[caam01] M.Caamano et al. Nuclear Physics A682 (2001) p223

Isomer and Particle Decay Probes of Shape Coexistence Around Z=82

A.N. Andreyev, R.D. Page, R. Wadsworth, R. Herzberg, M. Huyse, W. Korten, K.Van de Vel, P. Van Duppen

Neutron-deficient lead isotopes close to the neutron mid-shell near N=104 represent a particularly important example of the quantum mechanical mixing of nearly degenerate eigenstates characterised by different intrinsic shapes [1,2]. Calculations predict three different shape configurations at relatively low excitation energies, arising from the excitation of pairs of protons from the closed shell core: the spherical ground state, associated with the Z=82 shell closure (0p-0h configuration), along with an oblate 2p-2h and more strongly deformed 4p-4h or even 6p-6h prolate configurations [3,4]. Furthermore, new shapes, including a highly deformed oblate configuration at an excitation energy of ~2.5 MeV are also predicted for extremely light lead isotopes [3].

As an example, unique cases of *triple* (prolate-oblate-spherical) shape coexistence have recently been observed in the very neutron-deficient isotopes ^{186,188,190}Pb [2,4,5]. Pb nuclei of interest have been produced in the complete fusion reactions with heavy ions and studied by means of in-beam gamma and conversion electron spectroscopy [4-7] or via α-decay of parent Po nuclei [2,8]. However, quite often these states are not (or only weakly) populated in the in-beam and/or α-decay experiments. An alternative approach to investigate these structures is the studies of high-K μs isomers, the decay of which may cascade through the states of interest. As discussed in [4], high-K states have the robust characteristics of a well-defined axially-symmetric deformation, both prolate and oblate. Such isomers are known in many even-mass lead nuclei, down to ^{188,190}Pb [4] and the intensity distributions of the recently observed yrast bands in the lighter even-mass lead isotopes [7] also suggest existence of similar isomers. Unfortunately, the production yields of these nuclei in traditional complete fusion reactions plummet with decreasing neutron number, see Figure, making these studies with conventional techniques very difficult or even impossible.

Using RISING, we propose to considerably extend these studies towards more neutron-deficient lead isotopes for which only scarce information on some of the yrast states is available [7]. In particular, we suggest the exploitation of the unique possibilities arising from the use of intense radioactive beams of Pb from the fragmentation of relativistic 1 AGeV ^{238}U beam at the FRS. The figure shows the measured and expected yields for Pb isotopes from the reaction ^{238}U(1AGeV)+C. Note the rather good agreement between the measured and calculated yields for $^{188\text{-}190}$Pb, which gives us confidence in predicting yields for lighter isotopes. The Figure clearly shows the advantage of fragmentation reactions for this case, providing a luminosity of up to 10^{32} (based on 10^9 ^{238}U ions/s and 5 g/cm^2 C target), compared to a luminosity of 10^{29}-10^{30} for the typical complete fusion reactions used previously. We therefore expect an intensity increase of produced $^{182\text{-}186}$Pb isotopes by at least two orders of magnitude, compared to complete fusion reactions. A similar high intensity gain is also predicted for Tl, Bi and Po nuclei, which we plan to investigate in the complimentary studies in the future.

As a first approach we propose to study the γ-ray decay of μs isomers in the very neutron-deficient isotopes ^{182,184,186}Pb in order to search for the hitherto unobserved non-yrast transitions. Expected counting rates of up to a few thousand per second are high enough to perform a detailed spectroscopy of yrast and non-yrast states in these nuclei. The isomeric states will be identified by standard isomer tagging technique.
S*imultaneously* with the study of the isomeric states in ^{182,184,186}Pb nuclei we propose to perform a search for the fine-structure α-decays of these isotopes to unknown low-lying (~400-600 keV) excited 0^+ prolate band heads in the daughter ^{178,180}Hg. The prolate rotational bands are known in these nuclei, but due to decay-out no 0^+ band heads have been observed yet. As shown in [2,8], α-decay is especially suited for such studies. The experimental signature for identification of an excited 0^+ state in the daughter nucleus is the observation of a fine structure ΔL=0 α-decay of the parent nucleus, feeding this excited level in the daughter isotope, which de-excites further by a prompt fully converted transition to the 0^+ ground state.

To perform this study, ions of interest, after slowing down to an energy of ~10 AMeV will be stopped in an active stopper, composed of a set of position-sensitive Si-detectors, where their subsequent α-decays will be measured. To register conversion electrons the Si-detectors will be surrounded in a backward/forward hemisphere by a set of Si-detectors/PIN-diodes which will allow to achieve an efficiency of ~30-40% for α-e^- coincidences. The method is well established by now and was earlier used, for example, to identify such 0^+ states in ^{182,184}Hg [8] and recently – to identify 0^+ prolate and oblate states in ^{186,188}Pb [2].

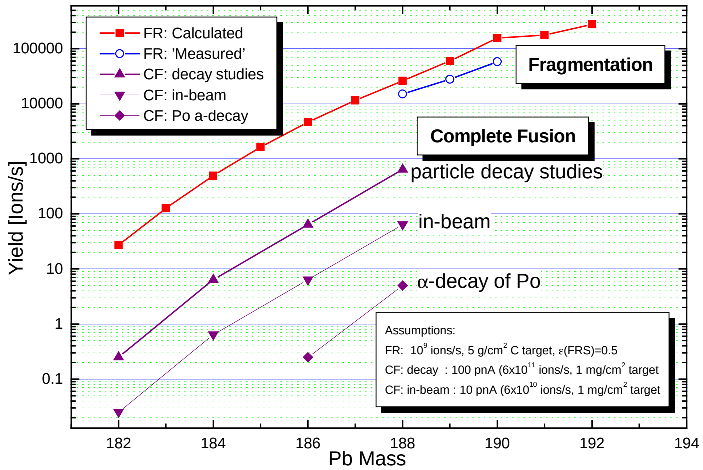

Figure. *Measured and calculated yields of Pb isotopes, produced in fragmentation reactions (FR) and in typical complete fusion reactions (CF). For complete fusion reactions 3 types of typical measured yields are shown: direct production of Pb isotopes with the high beam intensity (for particle decay studies); direct production with lower beam intensity (in-beam studies [4-7]); and production via the α-decay of parent Po nuclei [2,8]. The calculated and measured data for fragmentation reactions are taken from [9].*

In summary, the identification of non-yrast 0^+ band head states of coexisting configurations is of particular importance since it provides a constraint on the unmixed band head energies and the mixing strengths between the structures in these nuclei. Furthermore, the development of the shape isomerism beyond the neutron mid-shell at N=104 along with identification of higher-spin, non-yrast states would provide a sensitive test of the shell-model and mean-field calculations.

[1] J.L. Wood *et al.*, Phys. Rep. **215** (1992) 101.
[2] R.G. Allatt et al., Phys. Lett. **B437** (1998) 29; A.N. Andreyev *et al.*, Nature **405** (2000) 430.
[3] W. Nazarewicz, Phys. Lett. **B305** (1993) 195.
[4] G. D. Dracoulis *et al.*, Phys. Rev**. C60** (1999) 014303; Phys. Lett. **B432** (1998) 37.
[5] Y. Le Coz *et al.*, Eur. Phys. J. Direct **A3** (1999) 1.
[6] A.M. Baxter *et al.*, Phys. Rev. **C48** (1993) 2140; J. Hesse *et al.*, Phys. Lett. **B302** (1993) 390.
[7] J.F.C.Cocks *et al*, Eur. Phys. J. **A3** (1998) 17; D.G. Jenkins *et al.*, Phys. Rev. **C62** (2000) 021302.
[8] J. Wauters *et al.*, Phys. Rev. Lett. **72** (1994) 1329.
[9] http://www-wnt.gsi/kschmidt/