EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

Letter of Intent to the ISOLDE and Neutron Time-of-Flight Experiments Committee for experiments with HIE-ISOLDE

Magnetic moment measurements in A ~ 140 Te, Xe, Ba and Ce isotopes using the Transient Field technique

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Abstract

It is intended to investigate the isospin structure of excitation in the nuclear valence shell of isotopes in the mass region A ~ 140 by the measurement of magnetic dipole moments using the Transient Field technique. The targeted energy upgrade of the HIE-ISOLDE project would increase the detection efficiency by a factor of 4 – 5. The resulting experimental data will be used for the comparison of theoretical models in case of the unresolved behavior of the B(E2) values in ^{132,134,136}Te

1. Introduction

In the mesoscopic quantum systems of real nuclei many experimental observations reflect the complex interplay between neutron and proton degrees of freedom. The rearrangement of single-particle orbits and evolution of shell structure for instance can be attributed to the monopole part of the pn interaction whereas in open-shell nuclei with a large number of valence nucleons its multipole part starts to govern the nuclear shape and is identified to drive the development of deformation and collectivity. Ideal observables for the investigation of isospin-related nuclear structure phenomena are magnetic dipole moments. The single-particle nature of the magnetic moment operator together with the anomalous spin-g-factors of protons (g_π = + 5.586) and neutrons (g_ν = - 3.826) give rise to its unique sensitivity to the microscopic structure of the nuclear wave function. For short-lived excited nuclear states with lifetimes in the range of several 100 femtoseconds up to a few picoseconds solely the well-established Transient Field (TF) technique gives experimental access to the value and sign of the magnetic moments.

2. Physics case

The complementary information from nuclear magnetic moments can be indispensable namely in cases where the composition of the wave function can't be resolved from other nuclear structure observables. Typical examples can be found in the mass region in the vicinity of the doubly magic ^{132}Sn which is known for many unexpected experimental findings. One of them is the surprisingly small B(E2;$0^+ \rightarrow 2^+$) value in ^{136}Te [1] (Z = 52, N = 84) which clearly contradicts the expectation from quadrupol-collectivity. In contrast to the B(E2;$0^+ \rightarrow 2^+$) values in the neighbouring Xe (Z = 54), Ba (Z = 56) and Ce (Z = 58)-isotones which follow well the expectations from the systematic Grodzins relation [2] or the refined version from Raman [3] in ^{132,134,136}Te a different pattern was found. With 0.103(15) e^2b^2 the reported B(E2) value from [1] in ^{136}Te is smaller than that in ^{132}Te with 0.172(17) e^2b^2 [1] whereas the first 2^+ in ^{136}Te is 370 keV lower than the 2^+ in ^{132}Te. This surprising behaviour could not be explained by shell-model calculations using realistic effective interactions [1]. Calculations using the quasiparticle random phase approximation (QRPA) on the other hand were more successful to describe the observed behaviour and trace the origin to a reduced neutron paring gap above N = 82 [4].

Nevertheless the composition of the 2^+ wave function in ^{136}Te seems still to be undefined since predictions from calculations for the g factor vary between g(2^+) ~ -0.2 [4] and g(2^+) ~ + 0.4 ([1] and Fig.1) corresponding to dominating neutron or proton components respectively. In order to resolve this intriguing puzzle the measurement of this value is required of the utmost urgency. Within the campaign IS415 at CERN the authors have measured in a series of three subsequent measurements the g(2^+) factor in the neighbouring ^{138}Xe, an isotone of ^{136}Te, in a first application of the Transient Field Technique with post-accelerated ISOL beams [5]. It is intended to expand the investigations to other isotopes in this mass region, e.g. ^{134,136}Te and ^{140}Ba where the energy upgrade from the HIE-ISOLDE project is considered as essential.

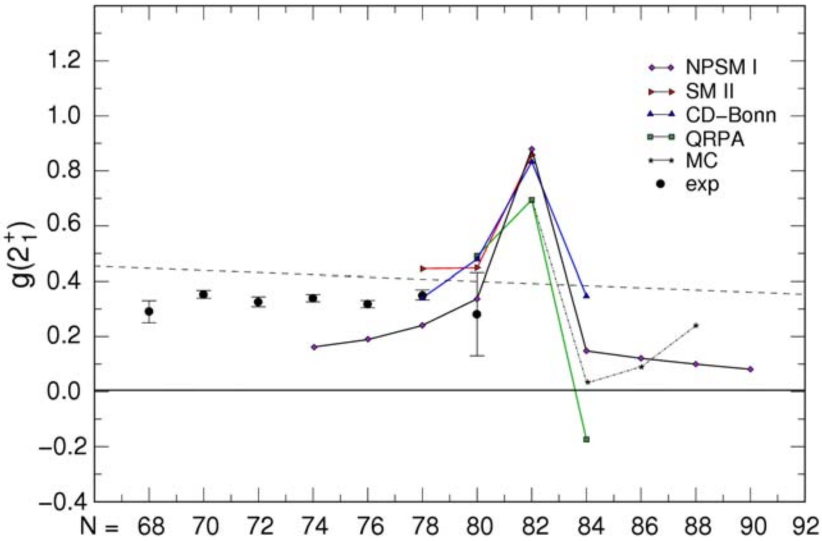

Fig. 1. Comparison of experimental g(2^+_1) factors (black circles) in even-A Te isotopes with predictions from calculations using different approaches. The picture is taken from Ref [6] and data from references therein. Lines are drawn to guide the eye.

- The Coulomb-cross section would increase by 50% since experiments can be done close to the Coulomb barrier.
- Since the TF technique requires rather thick multi-layered targets the beam straggling for isotopes with A~140 in the target can't be neglected. Straggled beam ions would damage the particle detectors and have to be removed by additional shielding. Higher energies close to the Coulomb barrier would reduce the number of straggled beam ions in the sensitive area of the particle detector by a factor of 3 compared to the present situation at 2.8 MeV/u. As a consequence background

radiation from β -decay will be reduced significantly. In addition, the shielding required at 2.8 MeV/u also stops a large fraction of scattered target-like particles which have to be detected for the coincidence measurement. At higher energies all particles will pass through the shielding and increase the detection efficiency by a factor of 2.5.

From the energy upgrade g factor measurements with the TF technique in the mass region A~140 would therefore gain a factor of 4 - 5 in the figure of merit.

3. Experimental setup

The TF technique requires a specific evacuated target chamber with a liquid-nitrogen cooled electromagnet serving as target holder, particle detector array and appropriate shielding as well as the MINIBALL detector array. Although the target chamber used in IS415 is available, a refined version is presently under construction which will comprise a position sensitive ion beam monitor and better shielding adapted to the requirements of experiments with higher beam energy.

4. Beam requirements

The isotopes of interest are mainly ^{134,136}Te, and ^{140}Ba. In a later step also neutron rich Ce isotopes will be addressed. Further investigations would address other physics cases also in the mass region around ^{132}Sn. The following list summarizes other beam related requirements.

- Beam purity: not very important (except for overlapping γ energies)
- Beam intensity : > $4*10^5$/s on target
- Beam time duration: depends on size of g factor, 5 – 7 days
- Beam energy: 3.8 – 4 MeV/u for A ~ 140, 4 – 4.5 MeV for A > 140
- Energy resolution: as good as possible
- Time structure (important): pulses as long as possible, preferably 1 ms or longer
- Beam spot size: preferably < 5 mm

5. Safety aspects

The target has to be cooled with liquid nitrogen. Other safety issues are calibration measurements with sealed γ-sources and high-voltage power supplies for the Ge detectors (MINIBALL).

6. References

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