

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

**Measurements of octupole collectivity in  
odd-mass Rn, Fr and Ra isotopes**

*CERN-ISOLDE* (J. Pakarinen, T. Stora, D. Voulot, F. Wenander)

*TU Darmstadt* (Th. Kröll)

*GANIL* (E. Clément)

*U Groningen KVI* (K. Jungmann, J. Van de Walle, L. Willmann, H.W. Wilschut)

*U Jyväskylä* (T. Grahn, P. T. Greenlees, R. Julin, P. Nieminen)

*U Kentucky* (S.W. Yates)

*U Köln* (A. Blazhev, N. Warr)

*Lawrence Livermore L* (E. Kwan, M. A. Stoyer, C.-Y. Wu)

*KU Leuven* (M. Huyse, P. Van Duppen)

*U Liverpool* (P.A. Butler, R.-D. Herzberg, D.T. Joss, R.D. Page, P. Papadakis, M. Scheck)

*U Lund* (J. Cederkäll)

*U Michigan* (T. Chupp, W. Lorenzon)

*TU München* (V. Bildstein, R. Gernhäuser, R. Krücken, D. Muecher, N. Nowak, K. Wimmer)

*U Oslo* (A. Bürger, M. Guttormsen, A.-C. Larsen, H.T. Nyhus, S. Siem, H. Toft, G. Tveten)

*U Rochester* (D. Cline, A. Hayes)

*HIL U Warsaw* (K. Hadynska-Klek, J. Iwanicki, P. Napiorkowski, D. Pietak, J. Srebrny, K. Wrzosek-Lipska, M. Zielinska)

*U West Scotland* (A. Andreyev, J.F. Smith)

Spokesperson: **P.A. Butler** (*Liverpool*)

**Abstract**

It is proposed to study octupole correlations in odd-mass Rn, Fr and Ra isotopes using Coulomb excitation at 4.5-5 MeV.A. These data are necessary to interpret EDM measurements in terms of time-reversal violating interactions.

## Physics case

There is considerable theoretical and experimental evidence that atomic nuclei can assume reflection asymmetric shapes that arise from the octupole degree of freedom [1]. The strongest correlations occur near the proton numbers 88 and the neutron numbers  $N=134$ , where octupole deformation can occur in the ground state. The only observable that provides unambiguous and direct evidence for enhanced octupole correlations in these nuclei is the E3 matrix element and the measure of octupole correlations in the ground state is the  $B(E3, 0^+ \rightarrow 3^-)$ .

Beyond nuclear physics, atoms with octupole-deformed nuclei are very important in the search for permanent atomic Electric-Dipole Moments [2]. The observation of a non-zero EDM indicates T-violation beyond the Standard Model. Measurements that give a limit on the EDM provide the most important constraints on the many proposed extensions of the Standard Model. Octupole-deformed nuclei will have large nuclear ‘‘Schiff’’ moments due to the presence of nearly degenerate parity doublets (seen in odd mass nuclei) and large collective octupole deformation. Since the Schiff moment induces the atomic EDM, the sensitivity over non-octupole systems such as for  $^{199}\text{Hg}$ , currently providing the most stringent limit on an EDM, can be improved by a factor of 100-1000. Essential in the interpretation of such limits in terms of new physics is a detailed understanding of the structure of these nuclei.

We propose here to initiate a programme to study odd-mass Rn, Fr and Ra isotopes with  $A \sim 220$  by employing Coulomb excitation. The yields of states of both parities in candidate parity doublet bands will be optimised by using bombarding energies of 4.5-5 MeV.A. The experiments will allow previously unobserved parity doublet bands (e.g. in the odd Rn isotopes) to be identified and the parity splitting measured. The  $B(E3)$  values of transitions connecting the parity doublet partners in these nuclei will also be determined, giving a measure of the octupole deformation.

Experiments designed to study octupole correlations in even-mass Rn and Ra isotopes using Coulex at 3 MeV.A have been approved (IS475) and should run during 2010.

## Experimental setup

Figure 1 shows a typical level sequence observed in these odd-mass octupole nuclei. The experiments will require a germanium array that has high  $\gamma$ -ray efficiency at low energy (e.g. MINIBALL[3]-like) and a means to detect conversion electrons (e.g. SACRED[4]-like), in coincidence with detection of the scattered ions. The electron spectrometer could be simplified as the flux of delta-electrons is small compared to stable beam experiments. Event-by-event identification of the  $Z$  of the scattered ions (beam-tagging) would eliminate background from isobaric contamination.

## Beam requirements

Typical isotopes of interest are  $^{219-225}\text{Rn}$ ,  $^{221-227}\text{Fr}$  and  $^{221-227}\text{Ra}$ , accelerated to 4.5-5 MeV.A For these Coulomb excitation experiments, integrated beam-on-target of  $10^5/\text{s.day}$  is the minimum. The purity should be greater than 10% if beam-tagged, otherwise greater than 50%.

## Safety aspects

The major safety concern is the build-up of long-lived activity from the long decay chains of these radioisotopes.

## References

- [1] P. A. Butler and W. Nazarewicz, (1996) Rev. Mod. Phys. **68**, No.2, 349.
- [2] J. Dobaczewski and J. Engel, (2005) Phys. Rev. Lett. **94**, 232502.
- [3] N. Warr *et al.*, (2004) Eur. Phys. J. **20**, 65
- [4] P.A. Butler *et al.*, (1996) Nucl. Instrum. Meth. A **381**, 433

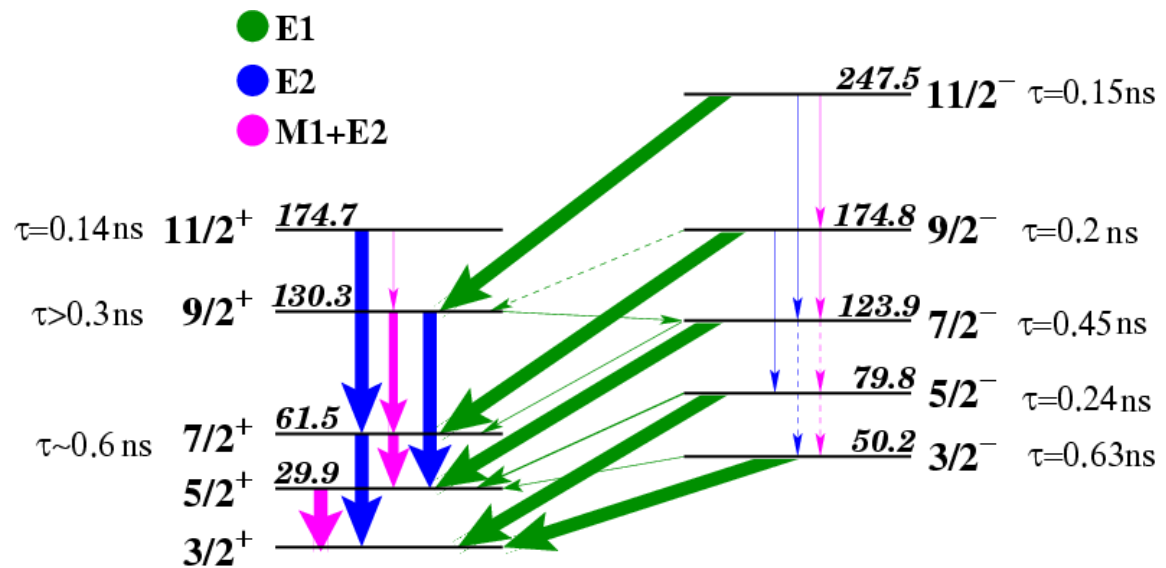


Fig. 1. Part of the level scheme of  $^{223}\text{Ra}$ . Energies are in keV. The thickness of the arrows is proportional the relative intensity, normalized to 100% for the strongest transition from the state. Transitions with less than 1% are dashed.