

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

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

In-beam electron spectroscopy at HIE-ISOLDE

CERN-ISOLDE (J. Pakarinen, D. Voulot, F. Wenander)
STFC Daresbury Laboratory (J. Simpson)
TU Darmstadt (Th. Kröll)
U Edinburgh (T. Davinson)
GANIL (E. Clément)
U Jyväskylä (T. Grahn, P. T. Greenlees, P. Jones, R. Julin, J. Konki, P. Rahkila, J. Sorri)
U Köln (A. Blazhev, J. Jolie, P. Reiter, N. Warr)
KU Leuven (M. Huyse, P. Van Duppen, I. Darby)
KVI Groningen (J. Van de Walle)
U Liverpool (P.A. Butler, R.-D. Herzberg, D.T. Joss, R.D. Page, P. Papadakis, M. Scheck)
U Lund (J. Cederkäll)
IEM CSIC Madrid (R. Orlandi)
TU München (V. Bildstein, R. Gernhäuser, R. Krücken, K. Wimmer)
LMU München (P. Thirolf)
U Oslo (A. Bürger, M. Guttormsen, A.-C. Larsen, H.T. Nyhus, S. Siem, G.M. Tveten)
U Rochester (D. Cline, A. Hayes)
CEA Saclay (A. Goergen, W. Korten)
HILU Warsaw (K. Hadynska, J. Iwanicki, P. Napiorkowski, D. Piętak, J. Srebrny, K. Wrzosek, M. Zielinska, M. Palacz, G. Jaworski)
U West Scotland (A. Andreyev, J.F. Smith)
U York (C. Barton, D.G. Jenkins, R. Wadsworth)

Spokesperson: J. Pakarinen (janne.pakarinen@cern.ch)

Abstract

The advent of HIE-ISOLDE post-accelerator will extend regions in the chart of nuclei that can be studied with radioactive beams. It will provide higher cross-sections for multistep Coulomb excitation processes, transfer reactions and fusion-evaporation reactions. The increased transition multiplicities stress the importance of coincidence measurements. The purpose of this Letter of Intent is to initiate investigation to find optimum method for in-beam conversion electron-spectroscopy with radioactive beams at ISOLDE and how to combine that with the existing MINIBALL Ge-detector array for γ -electron cross-coincidence measurements.



1. Introduction

The interplay between single-particle motion, collectivity and pairing in atomic nuclei results in a rich tapestry of coexisting nuclear shapes and exotic excitations. For decades, in-beam γ -ray and electron spectrometers have been important tools in nuclear structure research to study these interesting phenomena. The MINIBALL array at REX-ISOLDE, consisting of segmented Ge-detectors has been the working horse in radioactive beam experiments for several years and has provided excellent in-beam γ -ray data, whereas electron spectroscopy with radioactive beams has not been exploited to great extent. However, γ -ray or electron spectrometer alone can provide only partial information of nuclear de-excitation processes. Generally, experimental set-ups for simultaneous in-beam observation of γ rays and conversion electrons have been optimized to observe either one or the other. In this Letter of Intent we propose to investigate various methods to carry out electron spectroscopy employing radioactive beams at ISOLDE and how they could be combined with the existing MINIBALL array for simultaneous electron γ -ray spectroscopy measurements.

2. Physics cases

Throughout the nuclear chart, there exist physics cases where combined electron γ -ray spectroscopy would shed light on intriguing open questions. For example, the $0^+ \rightarrow 0^+$ transitions can only proceed via the E0 transitions i.e. via conversion electron emission. These transitions are typically present in nuclei exhibiting shape coexistence [1]. Moreover, the interband transitions between states of the same spin and parity and involving shape transition have enhanced E0 strengths [2]. Shape coexistence is established, for example, in neutron-deficient lead and neutron-rich $A \sim 100$ regions [2,3]. To probe the E0 transitions, the 0^+ states and non-yrast band levels can be populated via multistep Coulomb excitation (Coulex). Since multistep Coulex process is strongly dependent on bombarding energy, these experiments will hugely benefit from HIE-ISOLDE beams.

Converted transitions play important role especially in heavy nuclei. There the internal conversion coefficients of the low-energy M1 and E2 transitions are high, which can even make the internal conversion the dominant decay mode. Some of these very heavy nuclei, namely radon and radium, have recently become available as radioactive beams and a programme to investigate the degree of octupole deformation in the $A \sim 222$ mass region employing Coulex technique has been initiated [4]. However, there again a complete picture can only be achieved via simultaneous electron- γ -ray spectroscopy. The improved beam intensity and higher beam energy will make such studies more feasible. More physics cases that could benefit from electron spectroscopy at HIE-ISOLDE can be found in other Letter of Intent [5-8].

3. Experimental setup

The challenge in in-beam electron spectroscopy arises from the fact that the electron detector must be in the same vacuum chamber with the target. The target region is a hostile environment due to high fluxes of particles, especially delta-electrons, produced when beam collides with target particles. Therefore, conversion electrons are often transported away from target by means of magnetic fields and various techniques to filter out delta-electrons have been used [9,10]. However, the intensity of radioactive beams is only a small fraction of the typical beam intensity of stable-beam experiments. Thus, delta-electrons may not pose a big problem, which would simplify the set-up. The proposed electron spectrometer will be used in conjunction with MINIBALL and either the Coulex or the transfer reaction particle detector set-up. Requesting prompt coincidences with γ -rays and/or particles will reduce the random background of a β -decay origin. The spectrometer is envisaged to cover a broad energy range to enable studies from light to heavy nuclei. In light and medium mass nuclei, typical transition energies of 1-2 MeV set requirements for the detector thickness. However, at this stage, we will investigate three different in-beam methods for electron spectrometry:

- 1) electron detection at the target; e.g. backward CD
- 2) electron transportation with permanent magnets; Mini-Orange

3) electron transportation with solenoid magnet; SAGE

The first two methods do not set major infrastructural requirements, unless combined with a high voltage electrode for delta-electron suppression. The third option, electron transportation employing a solenoid magnet, would set a few infrastructural requirements. Typical solenoid currents in similar applications are few hundred amperes, solenoids being water-cooled (see Fig. 1). Therefore, power and cooling water resources at MINIBALL should be investigated. In addition, delta-electron suppression by employing a high-voltage electrode would also require new arrangements at MINIBALL.

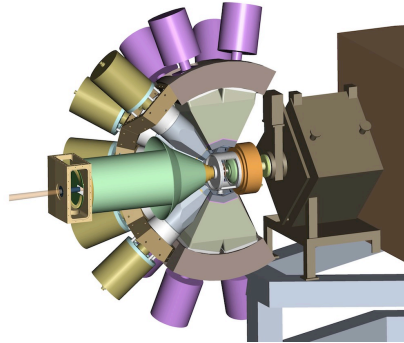


Figure 1. The recently commissioned SAGE spectrometer enables, for the first time, efficient simultaneous electron - γ -ray spectroscopy [11]. On the right hand side, the RITU separator is shown.

4. Beam requirements

As already mentioned, the proposed electron spectrometer can be employed to investigate many regions of the nuclear landscape. Therefore it is not discussed explicitly what beams are required, instead we refer to other HIE-ISOLDE Letter of Intents [4-8]. Just for example, in Coulex experiments a beam energy of ~ 5 MeV/u is needed to achieve an adequate Coulex cross-section. Concerning the beam intensity, a SAGE type of spectrometer can typically take 10^{10} ions/second, whereas rate limitations for mini-Orange or backward CD configurations are not foreseen. Thus, in principle the maximum intensity available from HIE-ISOLDE can be exploited. Concerning other beam parameters like energy resolution, beam emittance and time structure of beam, it is envisaged that similar parameters compared to in-beam γ -ray spectroscopy at MINIBALL will also satisfy requirements of in-beam electron spectroscopy. Moreover, it is estimated that requested beam times will be similar to γ -ray experiments at MINIBALL (up to ~ 30 shifts/isotope).

5. Safety aspects

The use of high voltage for delta-electron suppression must be considered a safety hazard and would probably limit access to MINIBALL target area when in operation.

6. References

1. J.L. Wood, K. Heyde, W. Nazarewicz, M. Huyse and P. Van Duppen, Phys. Rep. **215**, 101 (1992)
2. C.Y. Wu, H. Hua and D. Cline, Phys. Lett. B **541** (2002) 59
3. A.N. Andreyev *et al.*, Nature **405** (2000) 430
4. P. Butler *et al.*, Letter of Intent to the INTC for HIE-ISOLDE (2010).
5. N. Warr *et al.*, Letter of Intent to the INTC for HIE-ISOLDE (2010).
6. P. Van Duppen *et al.*, Letter of Intent to the INTC for HIE-ISOLDE (2010).
7. T. Grahn *et al.*, Letter of Intent to the INTC for HIE-ISOLDE (2010).
8. D. Jenkins *et al.*, Letter of Intent to the INTC for HIE-ISOLDE (2010).
9. P.A. Butler *et al.*, Nucl. Instrum. Meth. A **381** (1996) 433
10. J. Van Klinken and K. Wisshak, Nucl. Instrum. Meth. **98** (1972) 1
11. P. Papadakis *et al.*, AIP Conf. Proc. **1090** (2009) 14