Studies with radioactive ion beams in the $A \sim 80$ region

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Abstract. The availability of good quality radioactive ion beams is allowing unique research in nuclear physics and nuclear astrophysics. Coulomb Excitation is a mechanism with a relatively large cross sections that allows the use of low intensity radioactive ion beams, and therefore it has become in a powerful experimental tool for the study of nuclei considerably far from stability. Among the data of interest for nuclear models that can be obtained using Coulomb excitation are: reduced transition probabilities; electric quadrupole moments; and magnetic moments. This work gives an overview of experimental studies on the mass 80 region in which I have been involved.

1. Introduction
In order to establish the structure of nuclei far from stability it is most important to obtain good-quality data on half-lives, excitation energies, transition probabilities, electromagnetic moments, one- and two-nucleon transfer cross sections, etc. The recent availability of Radioactive Ion Beams (RIBs) has made possible to perform pioneering experiments to measure some of these properties [1, 2, 3, 4, 5]. At the Holifield Radioactive Ion Beam Facility (HRIBF) in Oak Ridge National Laboratory (ORNL), we are actively involved in an experimental program to measure these important quantities in neutron-rich nuclei around mass $A = 80$.

2. Radioactive Ion Beams at HRIBF
HRIBF uses the Isotope Separation On Line (ISOL) technique to produce RIBs [6]. Basically, the $K = 100$ Oak Ridge Isochronous Cyclotron (ORIC) [7] provides an energetic intense light-ion beam (e.g. 10 $\mu$A of 50 MeV protons) to induce fission on a thick uranium carbide target. Using high temperatures, $\geq 2000^\circ$C, the fission fragments are diffused out from the target material and flow though a small transport tube that directs them across a high-resistance emission surface. Electrons emitted from this surface are then accelerated into a biased ionization chamber where a plasma is formed and electron impact ionization takes place. The integrated system target/ion source (TIS) is typically operated to $40 - 60$ kV, and it is the electric potential difference between TIS and the injector platform (typically operated to $\sim 200$ kV) what is used to extract the RIB from the plasma [8].

The injector platform has several beam optics elements and a first mass analyzing magnet (with a mass resolution $M/\Delta M \sim 1000$), and a charge exchange cell that uses re-circulating caesium vapor ($\sim 10^{-2}$ Torr). By collisioning with the Cs gas in the cell, the positive ions coming...
3. The Mass $A \sim 80$ region
Since the mechanism behind RIB production at HRIBF is the induced fission of uranium, it is intuitive that the more intense beams, produced at this laboratory, concentrate around the mass number of uranium’s fission fragments: $A \sim 80$ and $A \sim 130$. Our approach in studying exotic nuclei around mass 80, has been trying to get a comprehensive picture of the evolution of its nuclear structure by systematically measuring quantities, such as $E(2^+)$, $B(E2)$, $g$-factors, quadrupole moments and masses, along isotopic and isotonic chains using almost identical experimental conditions for both stable and radioactive nuclei. Our first step in this approach has been the measurement of the reduced transition probabilities $B(E2; 0^+ \rightarrow 2^+)$ for the neutron rich $^{78}$Ge, $^{80}$Ge and its $N = 50$ isotope $^{82}$Ge [1].

Stable germanium nuclei have a very complex structure, that is reflected in the irregular neutron-dependence of the excitation energy of the $0^+_2$ states, the $B(E2)$ values and the population cross sections in two-neutron-transfer reactions [10] (see Figure 1). The abrupt change of these quantities have suggested that this $Z = 32$ chain, undergoes a structural change around $N = 40$. Furthermore, the measured values for the electric quadrupole moments associated with the $2^+_1$ and $2^+_2$ states [11, 12], are supporting evidence that a shape transition and the coexistence of two different kinds of deformation are present in these nuclei [13].

A natural question that one might ask is how these properties evolve when more neutrons are added to the nucleus? The Coulomb excitation (CoulEx) mechanism [14] is a suitable experimental tool that can provide guidance in answering this question. By requesting a bombarding energy smaller than the Coulomb Barrier, one can make sure that the surfaces of the nuclei participating in the reaction do not touch, more precisely, this condition guarantees that the wave length of the projectile is smaller than the distance of closest approach in the head on collision, and therefore one can use a semiclassical approach to describe the process, i.e. to describe the scattering process classically, and using the formalism of quantum mechanics to describe the nuclei excitation under the assumption that the only responsible for the excitation is the time dependent electromagnetic field between the two nuclei.

By carefully choosing the bombarding energy one can use CoulEx as a clean tool to measure
excitation energies and transition probabilities of previously unknown nuclei, meaning that one rules out the nuclear interaction and the only responsible for the excitation is the well understood electromagnetic interaction.

4. Detection Systems
Following this idea, we used even-even $A \sim 80$ germanium RIBs produced at HRIBF to bombard light-$A$ targets and study the Coulomb excitation of the projectile nuclei. Detecting the gamma-rays (emitted when the excited nuclei returns to their ground states) in coincidence with the scattering target-like nuclei we were able to measure projectile’s lowest energy levels and transition probabilities. Figure 2 shows an aerial view of the detectors at the experimental station, used in the measurement of the $B(E2)$ of $^{80}$Ge. The first detector seen by the reaction products is the charge particle array, which is surrounded by a gamma-ray spectrometer. The experimental setup is completed by a beam monitor system located upstream.

Two different technologies in charge particle detectors have been used for CoulEx experiments at HRIBF. One of them is illustrated in Figure 2 by the detector called HyBall [15], which is built of 96 individual elements arranged in 9 rings. Each element consists on a thin CsI(Tl) crystal, optically coupled to a trapezoidal prism of lucite. This geometry is used to guide the scintillation light (generated when a charge particle hit the CsI crystal) towards the readout element consisting on a 1 cm$^2$ silicon photodiode. The electronic signal is preprocessed using a charge sensitive preamplifier and the final particle identification (PID) is obtained using pulse shape discrimination techniques [16]. For HyBall, the frontal face of each CsI crystal is covered by an absorber foil of lead or tin, and the lateral faces of the lucite prism are wrapped up using aluminized mylar (to minimize scintillation light losses). A new version of this array,
called BareBall, has been developed more recently with the idea of being used, exclusively, in experiments that involve RIBs. In contrast with HyBall, the angular coverage of BareBall is restricted to forward scattering angles and in order to extend the detection threshold towards low energies, the frontal face of each element is covered with a very thin layer of aluminized mylar. The second type of charge particle detector consisted on a planar double sided silicon strip detector, S2, designed by Micron Semiconductors [17]. The active region of the detector (35 cm$^2$) is limited between an inner diameter of 22 mm and an outer diameter of 70 mm. The frontal face of this detector is segmented in 48 concentric rings whereas the back face is divided in 16 sectors, providing $\Delta E$, $E$ signals respectively.

For the detection of the de-excitation gamma-rays, we also explored the use of two different kinds of spectrometers. The one shown in Figure 2 is called CLARION [18], and consists on eleven hyper-pure germanium clover detectors. Each detector is formed of four n-type individual crystals segmented into two halves and sharing a common cryostat. Seven electronic signals can be readout for each clover: four channels of high resolution that are obtained from the central electrode of each crystal (and digitize the energy and time of the gamma-ray detected), and three low resolution channels that come from the external electrode that surrounds each half of the crystal (and can be used to get information about the position of the first interaction hit in the detector and also to reduce the Doppler broadening of the gamma-peak). Clover detectors are placed at 25 cm from the target at backward angles to avoid positrons and annihilation radiation background (511 keV). A different spectrometer, operated in coincidence with the double sided silicon strip detector (DSSD) was the so called ORNL-MSU-TAMU barium fluoride array, consisting on 150 elements arranged in four sets of 19 (two of them placed at 90° and two at 135°), and two sets of 37 elements (placed at 89°). Each element is formed by a BaF$_2$ crystal coupled to twelve-stage, high-gain photomultiplier tubes with a quartz window, which provides a good transmission of the UV-components of the scintillation light.

An element that has been crucial for the nuclear structure research program at HRIBF, is what we called monitor systems. The basic idea of these ancilliary detectors is to perform a measurement of the isobaric beam composition by continuously sample the beam, after it has interacted with the target. It is worth to emphasize that although desirable, at this point we are not tagging our events using the beam component information, instead we are only getting a rough idea of the isobaric composition by sampling part of the beam. Two ideas have been tested at HRIBF with this purpose: a projectile X-ray system and a Bragg Curve Detector. The projectile X-ray system consisted on a single coaxial HPGe detector placed at 90 degrees relative to the incoming beam direction, which is used to detect the X-rays generated when the beam passed through a thick ($\sim$ 4 mg/cm$^2$) palladium foil. The advantage of this technique is that the isobaric separation does not depend on the energy loss by the projectile, its drawback is however, that the physical process is not well characterized in the range of beam energies that we are interested (2–5 A MeV). An alternative monitor system is a Bragg Curve Detector (BCD) [19], that consisted on an cylindrical geometry ionization chamber holding an homogeneous electric field in the direction of the incoming particle. The $Z$ identification of the projectile can be done characterizing the amount of ionization (created by the heavy ion in the gas contained inside the chamber), as a function of the projectile position along its slowing-down path. A limitation of a BCD is that it can not hold large count rates, and it easily reach saturation if the incoming beam intensity is larger than a few times 10$^5$ pps.

5. CoulEx experiments
Stable ion beams of the even-even $^{70-76}$Ge, $^{74-82}$Se plus the RIBs of mass $A = 78$ and $A = 80$ were produced and accelerated to 2.4 A MeV, at HRIBF. These beams were used to bombard a $\sim$ 1 mg/cm$^2$ carbon target [1].

Typical beam intensities of $1.4 \times 10^6$ pps and $1.4 \times 10^5$ pps were measured at the target position
for RIB $A = 78$ and $A = 80$, respectively. Using projectile X-rays, the beam composition for RIB $A = 78$ was determined to be 57.1% of $^{78}$Ge, 28.1% of $^{78}$SGe, 9.9% of $^{78}$As and 4.9% of $^{78}$Ga. For $^{80}$Ge, extracting the atomic species from the ion source was not as favorable as it was for $^{78}$Ge. Preliminary tests indicated that, only 2.2% of the total X-ray yield was associated with $^{80}$Ge, while the $^{80}$Se component was 96% and the remanent 1.8% corresponded to $^{80}$As, making unfeasable the measurement. It was found that, a good solution to this problem can be acheived by adding sulfur gas (H$_2$S) to the UC$_2$ production target, and extracting a molecular beam of GeS$^+$ (instead of an atomic one: Ge$^+$) from the ion source. The advantage of doing so was that (because of their chemical properties) the molecular ions of the contaminants: SeS$^+$ and AsS$^+$, were suppresed. This effective purification technique, was crucial in the measurement of the $B(E2)$ of $^{80}$Ge. After purification, the $^{80}$Ge beam component was determined to be 95.3% when measured in the BCD.

The $B(E2)$ measurement of the $N = 50$ nucleus $^{82}$Ge was performed using a completly different approach. Based on theoretical predictions it was expected that the reduced transition probability had a lower value compaired with the previously mesure $B(E2)$s. Also since we were moving farther from stability an unavoidable decrease on the beam intensity was expected, and a non-favorable chemistry turned out on a non-significant improve in purity using the sulfur molecule. Given the fact that the excitation energy of the first 2$^+$ state of $^{82}$Ge and its more abundant stable contaminant $^{82}$Se can be clearly separated, for this measurement we decided to change the good resolution of the HPGe-based gamma-spectrometer by the larger efficiency of the BaF$_2$ array, and in order to increase the CoulEx cross section we decided to replace the light carbon target for a heavier $^{48}$Ti target, whic also has a well determined $B(E2)$ value.

Figure 3 present the experimental mesurement of the $B(E2)$ values for the radioactive $^{78,80,82}$Ge isotopes compaired with the adopted values for the heavier isotope chains of $^{34}$Se, $^{36}$Kr, and $^{38}$Sr, it is important to notice that the behavior of germanium isotopes around $N = 50$ appears to be similar to the plateau exhibited by the isotopic chains with higher-$Z$. 

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{figure3.png}
\caption{Comparison between the mesured $B(E2)$ values for the radioactive $^{78,80,82}$Ge [1] and the trend follow by the adopted values of heavier isotope chains of $^{34}$Se, $^{36}$Kr, and $^{38}$Sr [20].}
\end{figure}
6. Theoretical Models

These experimental results were compared with the shell-model theory using a recently derived effective interaction [21, 22]. The calculations were performed in a configuration space that included the orbitals $p_{3/2}$, $p_{1/2}$, $f_{5/2}$ and $g_{9/2}$ [1]. The neutron-neutron ($nn$) part of such interaction was obtained fitting for nickel isotopes with emphasis on the neutron-rich $^{66-74}$Ni, while the proton-proton ($pp$) part was obtained fitting the $N = 50$ isotones. The $T = 1$ proton-neutron ($pn$) part was taken to be identical to $nn$ part, while the $T = 0$ component of such interaction was taken as a $G$-matrix with modified monopole terms fitted to reproduce the known excitation energies in odd-$A$ Cu isotopes. Full space calculations were performed for $^{82}$Ge and $^{80}$Ge while no proton excitations to the $g_{9/2}$ orbital were allowed for $^{78}$Ge. The theoretical results within the framework of the shell model well reproduced the experimental trend observed for the neutron-rich $^{78-82}$Ge, suggesting that $N = 50$ persists as a good magic number for the germanium chain.

To have an idea on how the shape evolves as we approach to $N = 50$ we also studied of the germanium chain using the Interacting Boson Model (IBM-2) with configuration mixing [23]. In this model, each nucleus is thought as formed of two configurations: normal (spherical) and intruder (prolate), based on the states $0^+_1$ and $0^+_2$. The normal configuration space consists of two proton-bosons, whereas the intruder has four proton-bosons: one boson-hole in the 20-28 shell and three boson-particles in the 28-50 shell. The calculation proceed by describing each configurations with an independent IBM-2 Hamiltonian of the form

$$H = \varepsilon n_d + \kappa Q_{\pi} \cdot Q_{\nu} + M_{\pi\nu},$$

where $n_d = \sum_{\mu, \nu} (d_{\mu\nu}^d)^2$ denotes the number operator of $d$-bosons, $Q_\rho$ represents the quadrupole operator for protons and neutrons

$$Q_\rho = (s_{\pi}^d \tilde{d}_\rho + d_{\mu}^d s_{\rho})^{(2)} + \chi_{\rho}(d_{\mu}^d \tilde{d}_{\nu})^{(2)},$$

and $M_{\pi\nu}$ is the Majorana interaction

$$M_{\pi\nu} = \xi_2 (s_{\pi}^d d_{\nu}^d - d_{\mu}^d s_{\rho})^{(2)} \cdot (s_{\pi} \tilde{d}_\nu - \tilde{d}_{\pi} s_{\nu})^{(2)} + \sum_{K=1,3} \xi_K (d_{\mu}^d d_{\nu}^d)^{(K)} \cdot (\tilde{d}_{\pi} \tilde{d}_\nu)^{(K)}$$

after diagonalizing each Hamiltonian in its appropriate space, one constructs a new basis by putting together the five lower energy eigenvectors for each configuration. The mixing calculation consist then in the diagonalization of the Hamiltonian:

$$H_{\text{mix}} = \alpha_0 (s_{\pi}^d s_{\pi}^d + s_{\pi}s_{\pi}) + \alpha_2 (d_{\pi}^d \times d_{\pi}^d + \tilde{d}_{\pi} \times \tilde{d}_{\pi})^{(0)}.$$
with the electric quadrupole transition operator given by

\[ T^{(E2)} = e_2(Q_{π2} + Q_{ν2}) + e_4(Q_{π4} + Q_{ν4}), \]

being \( Q_{ρj} \), the quadrupole operator defined in equation (2) for the normal \( (j = 2) \) and intruder \( (j = 4) \) configurations. Since in this phenomenologic model we have to use the experimental \( B(E2; 2^+_1 \rightarrow 0^+_1) \) values to determine the boson effective charges \( e_2 \) (following the work of Sambataro and Molnar [25] we fix \( e_4 = 2e_2 \) for all isotopes) the actual predictions of this model are quantities such as transition probabilities between higher excitation energy levels, electric quadrupole moments and two nucleon transfer reactions.

7. Present and future research in this region

Three natural extensions of these pioneering studies, which actually define our current research efforts in \( A \sim 80 \) are: i) the measurement of the \( B(E2) \) value for the \( N = 50 \) nucleus \( ^{84}\text{Se} \); ii) the direct measurement of the electric quadrupole moment of \( ^{78}\text{Ge} \); iii) the measurement of the \( g \)-factor for \( ^{80}\text{Ge} \) using the Recoil in Vacuum (RIV) technique.

Using projectile Coulomb excitation in inverse kinematics, we have measured the \( B(E2) \) value of the radioactive nucleus \( ^{84}\text{Se} \). With \( Z = 34 \), \( ^{84}\text{Se} \) is the \( N = 50 \) isotope that lies right in the middle between \( Z = 28 \) and \( Z = 40 \) and therefore is expected to have maximum sensitivity to constrain the shell model effective interaction. This value, together with our previously measured \( ^{82}\text{Ge} \) [1], and the recent result on \( ^{80}\text{Zn} \) from ISOLDE [4], are providing basic experimental information needed for a better understanding of the neutron-rich nuclei around \( A \sim 80 \).

One of the most important high-order effects in CoulEx, is perhaps the so called reorientation effect [26], which is a second-order process that consists in the reorientation of the nuclear spin of the Coulomb-excited nucleus caused by the electric field of its reaction partner. This effect can be observed as an interference in the \( 0^+ \rightarrow 2^+ \) transition, and is well described considering that in addition to the direct excitation, the \( 2^+_1 \) state is excited through itself (\( i.e. \) the \( 2^+_1 \) itself acts as intermediate state). The change in the nuclear spin direction affects the angular distribution of \( γ \)-rays, and what is important is that the additional contribution to the excitation probability of the \( 2^+_1 \) coming from the reorientation effect, is proportional to the static quadrupole moment of the excited state. This for instance, gives a measurement of the deviation of the nuclear charge distribution from a spherical symmetry. Following this idea, at HRIBF we have used a purified \( A = 78 \) RIB at a bombarding energy of \( 2.3A \) MeV to sequentially excite \( ^{78}\text{Ge} \) in two thin targets of \( ^{24}\text{Mg} \) and \( ^{12}\text{C} \). The data, currently under analysis, are being used to calculate the ratio of the CoulEx probabilities for the two different targets, making use of the previously known value of the \( B(E2; 0^+ \rightarrow 2^+) \) such ratio will give us a measurement of the quadrupole moment of \( ^{78}\text{Ge} \).

The measurement of the magnetic moment for a short-lived excited state is based in determining the precession of the magnetic moment by measuring changes in the angular distribution of the de-exciting \( γ \)-radiation. In particular, for the RIV technique, the beam ions after Coulomb excitation emerge into the vacuum, with a total electronic angular momentum, \( \mathbf{J} \), that has no directional constrictions. As a consequence the total angular momentum of the nucleus, \( \mathbf{I} \), starts to precess about the randomly oriented resultant \( \mathbf{F} = \mathbf{I} + \mathbf{J} \). The average over all the ions leads to an attenuated angular correlation between the recoil target ion and the de-excitation \( γ \)-emission. When used in combination with RIBs the Recoil in Vacuum technique has proved [27] to have advantages compared with the Transient Field technique for measuring the magnitudes of \( g \)-factors, as it does not require a specific optimal positioning for the \( γ \)-ray detectors (higher efficiency can be achieved) or the use of a thick target (beam radioactivity does not accumulate).
Table 1. A comparison between the experimental and theoretical $B(E2)$ values and quadrupole moments are given for the Ge isotopes from $A=68$ to $A=82$. The units of the $B(E2)$ values are given by $10^{-3} e^2 b^2$ while for the quadrupole moments one uses $10^{-2} eb$.

|       | $^{68}$Ge |       | $^{70}$Ge |       | $^{72}$Ge |       |
|-------|-----------|-------|-----------|-------|-----------|-------|
|       | EXP.      | TH.   | EXP.      | TH.   | EXP.      | TH.   |
| $B(E2; 2^+_1 \rightarrow 0^+_1)$ | 29(3)    | 27.2  | 36 (4)    | 35.9  | 40 (3)    | 39.0  |
| $B(E2; 2^+_1 \rightarrow 0^+_2)$ | 4.8      | 4.8   | 13 (3)    | 16.5  | 41 (4)    | 18.4  |
| $B(E2; 2^+_2 \rightarrow 2^+_1)$ | 0.8(3)   | 4.2   | 49.7 (189)| 68.2  | 114 (12)  | 59.4  |
| $B(E2; 4^+_1 \rightarrow 2^+_1)$ | 22.9(30) | 41.0  | 18.9 (34) | 68.1  | 64.1 (71) | 80.0  |
| $Q(2^+_1)$               | 4.6      | 3 (6)  | 2.1       |       | -12 (8)   | -6.1  |
| $Q(2^+_2)$               | -0.3     | 9.8   |           |       | 23 (8)    | -19.3 |

|       | $^{74}$Ge |       | $^{76}$Ge |       | $^{78}$Ge |       |
|-------|-----------|-------|-----------|-------|-----------|-------|
|       | EXP.      | TH.   | EXP.      | TH.   | EXP.      | TH.   |
| $B(E2; 2^+_1 \rightarrow 0^+_1)$ | 60 (3)   | 62.2  | 46 (3)    | 52.2  | 44 (3)    | 40.3  |
| $B(E2; 2^+_1 \rightarrow 0^+_2)$ | < 7.8    | 3.0   | < 2.8     | 1.3   | =7 (1.5)  | 3.0   |
| $B(E2; 2^+_2 \rightarrow 2^+_1)$ | 99.7 (203)| 91.5  | 74.6 (96) | 73.9  | 39.6 (139)| 53.2  |
| $B(E2; 4^+_1 \rightarrow 2^+_1)$ | 66.4 (55)| 91.8  | 73 (13)   | 74.5  | > 21.8    | 57.4  |
| $Q(2^+_1)$               | -19 (2)  | -15   | -14 (4)   | -15.3 | -18.3     |       |
| $Q(2^+_2)$               | 26 (6)   | 13.0  | 28 (6)    | 11.7  | 11.9      |       |

|       | $^{80}$Ge |       | $^{82}$Ge |       |
|-------|-----------|-------|-----------|-------|
|       | EXP.      | TH.   | EXP.      | TH.   |
| $B(E2; 2^+_1 \rightarrow 0^+_1)$ | 28 (5)   | 27.6  | 25 (5)    | 27.6  |
| $B(E2; 2^+_1 \rightarrow 0^+_2)$ | 3.5      | 3.5   | 3.5       | 3.5   |
| $B(E2; 2^+_2 \rightarrow 2^+_1)$ | 39.2     | 39.2  | 39.2      | 39.2  |
| $B(E2; 4^+_1 \rightarrow 2^+_1)$ | 39.0     | 39.0  | 39.0      | 39.0  |
| $Q(2^+_1)$               | -13.6    |       | -0.3      |       |
| $Q(2^+_2)$               | 5.2      |       | 0.2       |       |

For an even-even nucleus the $g$-factor is sensitive to the way in which angular momentum is shared between all of the protons and all of the neutrons. Since the magnetic properties of protons and neutrons are different from each other, an accurate determination of the $g$-factors for a series of isotopes offers a unique possibility for studying the influence of the proton-neutron degree of freedom in collective states.

For stable germanium isotopes the $g$-factor of the $2^+_1$ states has been measured using the ion Implantation Perturbed Angular Correlation [28, 29, 30] and the Transient Field Technique [31, 32]. Recently a systematic analysis of the $g$-factors around $A=80$ has been carried out [33]. In the left hand side of Figure 4 the experimental values for the $g$-factors of stable Ge nuclei have
Figure 4. Experimental values for $g(2^+_1)$ of the even-even $^{70-76}$Ge isotopes (left). Systematic behavior of five isotopic chains around $A = 80$ (right).

been plotted, including the average values given in [33]. A very slight variation across the four isotopes is seen, and in general a consistent agreement with the simple hydrodynamic estimate for collective motion, $g = Z/A$ (dashed line) is reached. On the right hand side of Figure 4 the systematic trend for the chains of Zn, Ge, Se, Kr and Sr isotopes is presented as a function of neutron number. It is clear, from this plot, that between $N = 46$ and the shell closure $N = 50$ a dramatic change occurs.

To explore this region in the germanium chain, experimental data using a purified RIB of mass $A = 80$ on a $^{24}$Mg target have been taken at HRIBF, to try to measure the $g$-factor of $^{80}$Ge.

8. Conclusions
Since the 60’s, CoulEx has been a well known mechanism to study nuclear structure. In recent years, it has received renew interest as a powerful tool to measure transition probabilities, quadrupole moments and magnetic moments of radioactive nuclei. To reach a succesful measurement in combination with RIBs, several challenges associated to the low intensity, isobaric contamination, and intrinsec radioactivity of the beam had to be overcome. However the possibility of using the bombarding energy to select the electromagnetic field as the only responsable for the nucleus excitation makes of CoulEx a valuable and free of ambiguitie tool to study the nucleus. With the second generation of RIB facilities already under construction it is our hope to continue the exploration of more exotic nuclei in region $A \sim 80$ using CoulEx.

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