FIRST RADIOACTIVE BEAM COULOMB EXCITATION EXPERIMENT ON SPIRAL*

E. Bouchez[a], A. Chatillon[a], A. Hürstel[a], W. Korten[a], Y. Le Coz[a], Ch. Theisen[a], J.M. Casandjian[b], G. de France[b], F. Becker[c], J. Gerl[c], T. Czosnyka[d], J. Iwanicki[d,e], M. Zielińska[d,f], P. Butler[e], R. Herzberg[e], D. Jenkins[e], G. Jones[e], G. Sletten[g], W. Catford[h], and C. Timis[h]

[a]CEA Saclay, France
[b]GANIL Caen, France
[c]GSI Darmstadt, Germany
[d]Heavy Ion Laboratory, Warsaw, Poland
[e]Oliver Lodge Laboratory, Liverpool, UK
[f]Intitute of Experimental Physics, Warsaw, Poland
[g]Niels Bohr Institute, Copenhagen, Denmark
[h]University of Surrey, UK

(Received December 2, 2002)

We report on the first Coulomb excitation experiments of a radioactive beam provided by the Spiral facility at GANIL (France) to study the shape of the unstable isotope ^{76}Kr.

PACS numbers: 25.70.De, 21.10.Ft, 29.25.Rm

1. Introduction

Low energy Coulomb excitation is the only way to determine the parameters of shape of a nucleus, *i.e.* the quadrupole moment, of short-lived excited states.

It was proposed to apply the Coulomb excitation technique to study the shape evolution in the krypton nuclei, which (according to previous measurements and theoretical predictions, see [1] and references therein) exhibit the phenomenon of *shape coexistence.* This means, that the shapes of the nucleus in the states of similar energy differ significantly. An exhaustive discussion of the shape coexistence phenomenon may be found in a review article of Wood *et al.* [2].

---

* Presented at the XXXVII Zakopane School of Physics "Trends in Nuclear Physics", Zakopane, Poland, September 3–10, 2002.

Using a post-accelerated low energy beam is essential to achieve multi-step Coulomb excitation of an unstable nucleus. Deexcitation γ-ray yields depend on the quadrupole moments of the excited states, which can then be derived.

The quadrupole moment of the first excited 2^+ state affects the population cross-section of this state as well as higher-lying states and the γ-ray angular distributions. The first effect may be analyzed either by an absolute cross section measurement or by fitting the ratio of $\frac{4^+\to 2^+}{2^+\to 0^+}$ transition yield. The second effect is usually very weak and requires high statistics data.

2. Secondary post-accelerated krypton beams

The ^{76}Kr beam was obtained from the fragmentation of a primary high intensity ($\approx$3 pμA) 68.5 MeV/A ^{78}Kr beam provided by coupled GANIL cyclotrons, which was bombarding the high power carbon target of the Spiral facility. Reaction products were thermalized, bred to the +15 charge state in an ECR ion source and post-accelerated by an additional cyclotron Cime, dedicated to secondary beam acceleration.

As a result, low intensity (5×10^5 pps) post-accelerated secondary beam of unstable ($T_{1/2}$ $\approx$14.8 h) ^{76}Kr could be focussed at the target position.

The Spiral facility has the ability to change the accelerated ion species in a relatively short time, so at the end of the experiment a short run with a 10^4 pps ^{74}Kr beam ($T_{1/2}$ $\approx$11.5 min) was performed.

3. Targets and detector set-up

To obtain different Coulomb excitation conditions, two targets were used and the beam energy was adjusted according to the atomic number of the target.

We have used ^{208}Pb target to excite 4.4 MeV/A beam and ^{48}Ti target to excite 2.6 MeV/A beam. Targets of the thickness close to 1 mg/cm^2 were transparent to both the beam and recoiling target nuclei. The second target was used to excite both ^{76}Kr and ^{74}Kr beams of the same energy.

Forward-scattered beam particles as well as forward going recoils were detected in a round, double-sided Si strip detector (16 angular & 16 radial, equidistant strips) placed at forward angles and surrounding the outgoing beam (see Fig. 1).

The angular coverage of the silicon detectors was adjusted by selecting the detector–target distance.

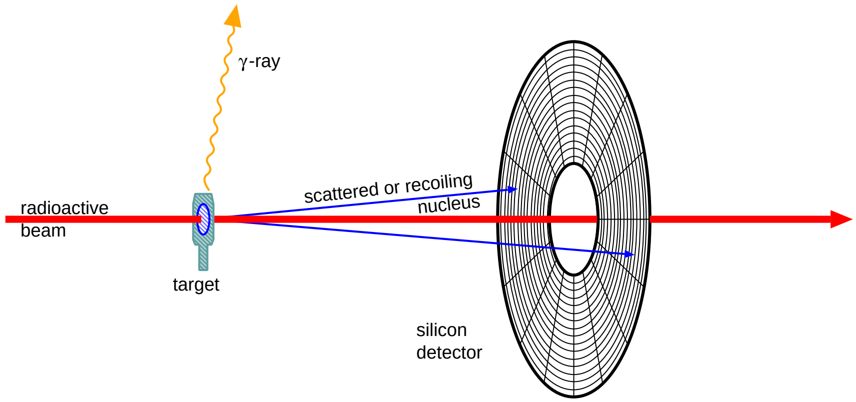

Fig. 1. Target and particle detection set-up.

A particle detector, measuring particle energies and angles, was operated in coincidence with the EXOGAM γ-ray detection array, in a configuration of six (out of sixteen designed) high efficiency, segmented Clover detectors and additional one smaller Clover detector. The coincidence condition was sufficient to suppress the background from the natural radioactivity of the beam.

4. Results

Cumulative γ-ray energy spectra originating from the Coulomb excited beams of unstable ^{76,74}Kr ions are presented in figures 2 and 3. The spectra are not corrected for the Doppler shift. In the spectrum for ^{76}Kr+^{48}Ti case the $2^+ \rightarrow 0^+$ transition peak contains about 10^4 counts (this is not the full statistics collected during the run), which is promising for further analysis. Also the $4^+ \rightarrow 2^+$ transition is clearly visible, which should allow for a relative cross section analysis, independent from the total detection efficiency.

The spectrum of Coulomb excited ^{74}Kr beam (Fig. 3) shows that succesful measurement in this case is also possible, but the statistics collected in this first short ($\approx$12 h) run with this beam are not yet sufficient for a detailed analysis.

The SPIRAL experiment, one of the first of its kind in Europe, shows that Coulomb excitation of an unstable beam is possible and gives a new outlook on the spectroscopy of the nuclei not accessible by classical methods.

Post-accelerated beam, contrary to other secondary beams techniques like in-flight separation, offers very clean experimental conditions without beam contaminants and the choice of the appropriate, well defined beam energy.

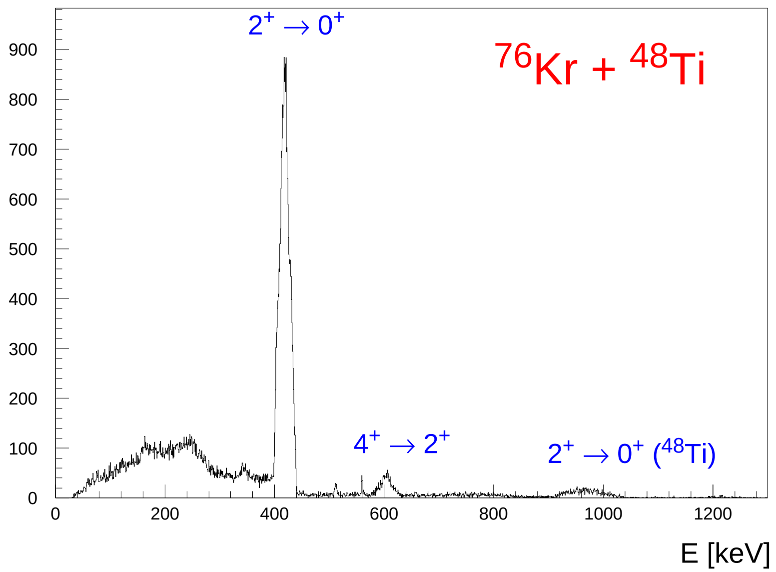

Fig. 2. Gamma-ray energy spectrum of Coulomb excited ^{76}Kr beam.

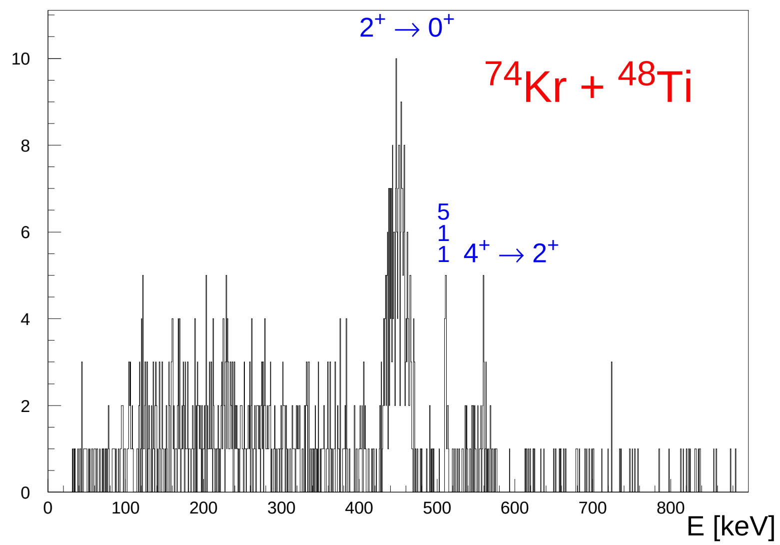

Fig. 3. Gamma-ray energy spectrum of Coulomb excited ^{74}Kr beam.

REFERENCES

[1] W. Korten, *Acta Phys. Pol. B* **32**, 729 (2001).
[2] J.L. Wood *et al.*, *Phys. Reports* **215**, 101 (1992).