Double giant dipole resonance in ^{136}Xe and ^{238}U

T. Aumann[1], K. Boretzky[3], J. Cub[4], W. Dostal[3], B. Eberlein[3], Th.W. Elze[2], H. Emling[1], J. Gerl[1], A. Grünschloß[2], J. Holeczek[8], R. Holzmann[1], S. Ilievski[2], M. Kaspar[1], C. Kozhuharov[1], J.V. Kratz[3], R. Kulessa[6], Y. Leifels[1], A. Leistenschneider[2], E. Lubkiewicz[6], S. Mordechai[7], T. Ohtsuki[9], I. Peter[1], P. Reiter[5], M. Rejmund[11], H. Simon[4], K. Stelzer[2], J. Stroth[2], K. Sümmerer[1], A. Surowiec[10], E. Wajda[6], W. Walus[6], S. Wan[1] H.J. Wollersheim[1]

[1]GSI Darmstadt, [2]Univ. Frankfurt, [3]Univ. Mainz, [4]TU Darmstadt, [5]LMU München, [6]Univ. Kraków, [7] Univ. Beer-Sheva, [8]Univ. Katowice, [9]Univ. Tohoku, [10]GFE Darmstadt, [11]Univ. Warsaw

Large electromagnetic cross sections (σ_{EM}) in heavy-ion collisions at relativistic energies (700 AMeV) allow for the study of the double giant dipole resonance (DGDR). Excitation and decay of this two-phonon process was investigated for the semi-magical nucleus ^{136}Xe and for the deformed and fissile nucleus ^{238}U using the LAND-Setup (Large Area Neutron Detector). Investigations of the DGDR are connected with the question of harmonicity of multistep excitations. An anharmonic behaviour of the nuclear response in the multiple excitation may be reflected in the spectral distribution, the excitation probability or the decay characteristics of the resonance. In former experiments [1] the spectral distribution of the DGDR could be understood in the framework of an harmonic process, whereas the results on the cross section of the DGDR were conflicting. Especially for ^{136}Xe σ_{DGDR} was observed in a first LAND Experiment [2] with a factor 2–3 higher than the harmonic limit, whereas for ^{238}U no deviations in σ_{DGDR} could be derived from inclusive measurements [3].
The excitation spectra were determined via the invariant mass method using projectile excitation and measurement of all outgoing particles with high efficiency. Compared to our earlier measurements the setup was improved substantially.

The use of a ^{136}Xe beam of low emittance as well as high resolution Si-μ-strip detectors allowed for the first time to measure angular distributions of Xe fragments produced in peripheral collisions on thin Pb (Fig. 1) and Sn targets. Equivalent sharp-cutoff minimum impact parameters (b_{min}) were derived on the basis of a semi-

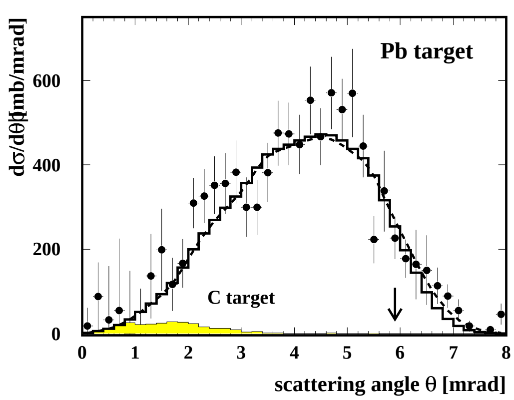

Figure 1: Differential cross section $d\sigma/d\theta$ for Xe fragments (700 AMeV). The result of a semi-classical calculation using the best choice of sharp-cutoff minimum impact parameters $b_{min} = 14.5 fm$ is shown by the histogram, the result using the soft-spheres model by the dashed curve. The arrow indicates θ^{LAB}_{max} corresponding to the fitted b_{min} value. Nuclear contributions can be estimated from the corresponding measurement with the C target (shaded).

classical description of the electromagnetic excitation of the one- and two-phonon giant resonances. The spectrum is well reproduced within this approach and leads to an experimental value of $b^{exp}_{min} = 14.5 \pm 0.2 \pm 0.25\ fm$ in case of the Pb target. In comparison with current parametrisations [4,5] of b_{min} and with the soft-spheres model [6] using realistic mass density distributions for projectile and target it is shown, that the soft-spheres model and the Benesh et al. parametrisation with a value of $b^{BCV}_{min} = 14.5\ fm$ are in good agreement with the experimental value, whereas b^{Kox}_{min} of Kox et al. is too large. For details see [7].
The analysis of the excitation spectra results in an observation of the DGDR with an harmonic mean energy and width and an enhancement factor for the σ_{DGDR} of X=1.63(25). Together with the results on ^{208}Pb (X=1.33(16)) [8] this could be explained assuming rather small anharmonicities (≤ 1 MeV) of the DGDR energy as predicted from microscopic calculations [9] and its mass dependence.

In a second experiment, the DGDR in ^{238}U was studied and both, the neutron and fission decay were investigated. Compared to the above measurement, the setup was modified to allow, in addition, for a simultaneous measurement of the two fission fragments in coincidence with emitted pre- and postfission neutrons. In the neutron decay channel, only a rather weak cross section for the DGDR is observed as expected because the relatively high-lying DGDR mainly undergoes fission. The primary excitation energy distribution leading to fission cannot be obtained directly. Instead, we utilize the well-known (linear) relationship between primary excitation energy and the mean neutron multiplicity [10]. The neutron multiplicity distributions are measured with LAND and are finally compared with calculated ones, obtained from a transformation of excitation energy distributions (of one and two-phonon states) into the respective neutron multiplicity distribution. A first analysis shows a considerable contribution to the fission channel arising from excitation energies in the DGDR domain. Similar effects were observed in an independent measurement using different methods [11].

References

[1] T. Aumann, P.F. Bortignon, H. Emling, Ann. Rev. Nucl. Part. Sci. **48** (1998) 351
[2] R. Schmidt et al., Phys. Rev. Lett. **70** (1993) 1767
[3] T. Aumann et al., Z. Phys **A352** (1995) 163
[4] C.J. Benesh et al., Phys. Rev. C **40** (1989) 1198
[5] S. Kox et al., Phys. Rev. C **35** (1987) 1678
[6] T. Aumann, C.A. Bertulani and K. Sümmerer, Phys. Rev. C **51** (1995) 416
[7] A. Grünschloß et al., Phys. Rev. C **60** (1999) 051601
[8] K. Boretzky et al., Phys. Lett. B **384** (1996) 30
[9] C.A. Bertulani, V. Ponomarev, Phys. Rep. **321** (1999) 139
[10] M. Soleihac et al., Journal of Nucl. Energy **23** (1969) 257
[11] K.H. Schmidt et al., GSI-Preprint 99-30; and refs. cited therein