Evidence of rotational behavior in ^{120}Te isotope

M. Saxena[1], P. Napiorkowski[1], R. Kumar[2] , L. Próchniak[1], A. Stolarz[1], S. Dutt[3], M. Komorowska[1], K.Wrzosek-Lipska[1], M. Matejska-Minda[1], M. Palacz[1], J. Srebrny[1], H.J. Wollersheim[4] and the EAGLE collaboration
[1]Heavy Ion Laboratory, University of Warsaw, Pasteura 5a, 02-093 Warsaw, Poland
[2]Inter-University Accelerator Centre, New Delhi 110067, India
[3]Department of Physics, Aligarh Muslim University, Aligarh 202002, India
[4]GSI Helmholtzzentrum fur Schwerionenforschung GmbH, D-64291 Darmstadt, Germany
. * *email:msaxena@slcj.uw.edu.pl*

Numerous experimental and theoretical studies are currently focused on nuclear shell structure far from the line of stability [1] . In particular, the evaluation of nuclear properties, e.g., the energy of the first excited 2^+ state and the reduced transition probabilities across closed shell Z = 50 are area of great interest. The Te nuclei with 52 protons lie in the transitional region between the spherical nuclei, and deformed Xe and Ba nuclei. The energies of the first excited 2^+ and 4^+ states reveal vibrational patterns almost throughout the isotopic chain except in the vicinity of A = 134. The B(E2↑) values for the $2^+ \rightarrow 0^+$ transitions are predicted to follow a parabolic behavior around the neutron mid shell, reaching their maximum at ^{118}Te[2]. This observation is quite in contrast to the measured quadrupole moments Q_2^+ for the doubly even Te isotopes [3,4]. These quadrupole moments can reach 60% of the one predicted by the symmetric rigid rotor.

In our recent Coulomb excitation experiment [5] at IUAC, New Delhi we used ^{58}Ni beam @ 175MeV to excite ^{120,122,124}Te isotopes. In these measurements the scattered particles were detected at forward angles. The B(E2; $0^+ \rightarrow 2^+$) value in ^{120}Te was re-measured with a much higher precision to allow a comparison with the predictions of the large scale shell model calculations (LSSM). Based on all experimental findings including the excitation of higher excited states for ^{120,122,124}Te one obtains the best agreement with an asymmetric rotor behavior. Calculations were performed using the Davydov-Filippov model which reproduce the reduced transition probabilities with β=0.19 and γ~27°. But, microscopic calculation (using the Skryme effective interaction) performed point towards a vibrational structure with a mean value of γ~30°. The most sensitive probe to characterize a nuclear excitation is via the measurement of quadrupole moments.

Therefore, to further investigate the second order effects (diagonal matrix elements) in ^{120}Te, an experiment was performed at Heavy Ion Laboratory, Warsaw, where particle detectors are in the backward direction enabling a more precise and sensitive measurement of the quadrupole moments.

The measurement was carried out using a highly enriched ^{120}Te target (~ thickness 0.150mg/cm^2) and a ^{32}S beam @ 90 MeV from the U-200P cyclotron at HIL. Simulations were performed using the GOSIA code [5] and assuming a set of matrix elements that optimally reproduced lifetimes, branching ratios and mixing ratios in ^{120}Te that were known from earlier measurements [5].

The gamma rays emitted by the ^{120}Te recoils after Coulomb excitation were detected by the EAGLE array consisting of 15 HPGe detectors of 70% efficiency equipped with anti-Compton BGO shields. A compact Coulex chamber (the so-called Munich Chamber), equipped with 48 PIN-diodes of 0.5 x 0.5 cm^2 active area, was used for the detection of backscattered ^{32}S ions to select particle-gamma coincidences in order to perform event by- event Doppler shift correction. The PIN-diodes were placed at angles from 110 to 152 degrees to enhance the probability of double-step excitation.

A multi-step Coulomb excitation of ^{120}Te was observed up to 4^+ state in the ground state band. Along with second 0^+ and second 2^+ states were also populated.

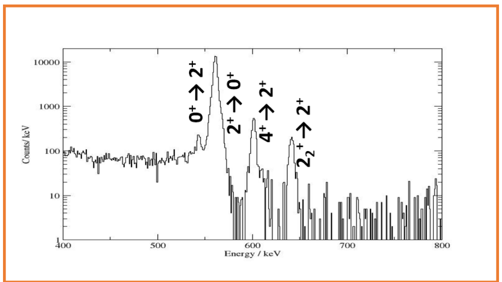

Fig- 1. Background subtracted Doppler shift corrected γ-ray spectra summed over all Ge detectors for the $^{32}S+^{120}Te$ system at 90 MeV.

The offline data analysis was performed using the GO4 analysis software. The data analysis required determination of scattering angles to perform precise Doppler correction on an event by event basis. The background subtracted doppler corrected spectra for ^{120}Te is shown in Fig.1.

In a multiple Coulomb excitation process several levels are observed and number of unknown matrix elements affects Coulomb excitation cross sections in a complicated nonlinear way. Subdivision of the experimental data based on the projectile scattering angle makes it possible to disentangle contributions from various excitation paths. While performing the analysis it was decided to sum all the individual Ge spectras and sub divide it into two sets for different projectile scattering ranges.

The Coulomb excitation least squares search code – GOSIA [6] was used to determine the reduced matrix elements. The code fits a set of reduced matrix elements to the measured gamma-ray yields taking into account known spectroscopic data related to electromagnetic matrix elements: branching ratios, lifetimes, E2/M1 mixing ratios, as well as previously measured matrix elements.

The relative signs and magnitude of the transitional matrix elements between populated states were determined. The diagonal matrix element for the 2^+ state was determined and has significant value different from zero with a negative sign, which shows a rotational character of the collective structure of ^{120}Te (See Table 1).

Table1. Set of BE(2) values (e^2b^2) obtained from GOSIA code are compared with theoretical predictions from Davidov Fillipov Model and Interacting Boson Approximation.

$I_i \rightarrow I_f$	**BE(2) e^2b^2 (Exp)**	**D.F. Model (ß = 0.18;γ = 27°)**	**IBA**
$2^+ \rightarrow 0^+$	0.121 ± 0.01	0.125	0.135
$2_2^+ \rightarrow 0^+$	0.004 ± 0.0002	0.0008	0.002
$4^+ \rightarrow 2^+$	0.199 ± 0.02	0.172	0.205
$0_2^+ \rightarrow 2^+$	0.058 ± 0.005	-	0.0943
$2_2^+ \rightarrow 2^+$	0.251 ± 0.02	0.137	0.212
***Q.M.* (2^+)**	***-0.614* ± *0.24***	**-0.348**	**-0.075**

The project is fulfilled with in the research grant from National Science Center-POLONEZ-1(2015/19/P/ST2/03008). The project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agrrement No 665778

References

[1] H. Grawe and M. Lewitowicz, Nucl. Phys. A693, 116 (2001), and references therein.
[2] https://www.nndc.bnl.gov/endsf
[3] A. Bockisch and A. M. Kleinfeld Nucl. Phys. A261 498-510 (1976).
[4] J. Barrette *et al.*, Phys. Rev. C 10, 3 (1974)
[5] M. Saxena *et al.*, Phys. Rev. C **90**, 024316 (2014).
[6] T. Czosnyka, D. Cline, and C. Y. Wu, Bull Am. Phys. Soc. 28 , 745 (1982), Coulomb excitation data analysis code GOSIA :http://www.slcj.uw.edu.pl/gosia