New low-spin states of ^{122}Xe observed via high-statistics β-decay of ^{122}Cs

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Abstract. Excited states of ^{122}Xe were studied via the β^+/EC decay of ^{122}Cs with the 8π γ-ray spectrometer at the TRIUMF-ISAC facility. Compton-suppressed HPGe detectors were used for measurements of γ-ray intensities, $\gamma\gamma$ coincidences, and γ-γ angular correlations. Two sets of data were collected to optimize the decays of the ground (21.2 s) and isomeric (3.7 min) states of ^{122}Cs. The data collected have enabled the observation of about 505 new transitions and about 250 new levels, including 51 new low-spin states. Spin assignments have been made for 58 low-spin states based on the deduced β-decay feeding and γ-γ angular correlation analyses.

1 Introduction

It is known that nuclei in the $Z > 50$, $N < 82$ region exhibit a very smooth evolution of collectivity. This region is ideal for studying the development of collectivity but the collective properties of many nuclei in this region are not fully characterized because of a general lack of available spectroscopic data for low-spin states. This work is part of a program to systematically study collectivity in the Xe isotopes. Proton sub-shell gaps were suggested in $^{124-132}$Xe isotopes [1] based on very strong population of excited 0_3^+ states in (^{3}He,n) reactions. Recent work on ^{124}Xe [2] has refined the $B(E2)$ values and established that nearly identical quadrupole collectivity exists for the 0_3^+ band and the ground state band, and suggested that the 0_3^+ band may represent a significant fragment of the proton pairing vibration.

Our first result on ^{122}Xe [3] was the establishment of the 2^+ band members of the 0_2^+ and 0_3^+ bands and observation of important, but previously unobserved, $2_2^+ \rightarrow 0_2^+$ and $2_3^+ \rightarrow 0_3^+$ transitions. The spin of the 0_3^+ state in ^{122}Xe was suggested based on energy systematics in Ref. [2]. Our second report on ^{122}Xe [4, 5] confirmed the spins of the 0_3^+ state and of the previously suggested 2^+ members of the 0_2^+ and 0_3^+ bands using angular correlation analysis. The present work is focused on newly observed low-spin states of ^{122}Xe.

2 Experimental Detail

The high-statistics ^{122}Cs β^+/EC decay experiment was performed at the TRIUMF-ISAC facility located in Vancouver, BC, Canada. The ^{122}Cs beam was produced through spallation reactions induced by a 65-μA, 500-MeV proton beam bombarding a thick ^{nat}Ta foil target. The atoms were ionized with a Re surface-ion source and a magnetic mass separator selected the ions of interest with $A = 122$. The high-intensity beam of 1.1×10^7 ions/s of ^{122}Cs in the 1^+ ground state with a 21.2 s half life, and 2.1×10^6 ions/s of ^{122}Cs in the 8^- isomeric state with a 3.7 minute half life, was delivered to the centre of the 8π γ-ray spectrometer [6–8] and implanted into a FeO-coated mylar tape. The 8π spectrometer consisted of 20 High-Purity Ge (HPGe) detectors surrounded by bismuth-germanate (BGO) Compton-suppression shields.

Two sets of data were collected in repeated cycles for short and long durations to favour the decays of the two β-decaying states in ^{122}Cs in order to have the best sensitivity of potential excited states in ^{122}Xe. Analyses of the γ-γ matrices and fitting of the spectra were performed with the `Radware` package [9]. An example of the γ-ray coincidence data is shown in Fig. 1.

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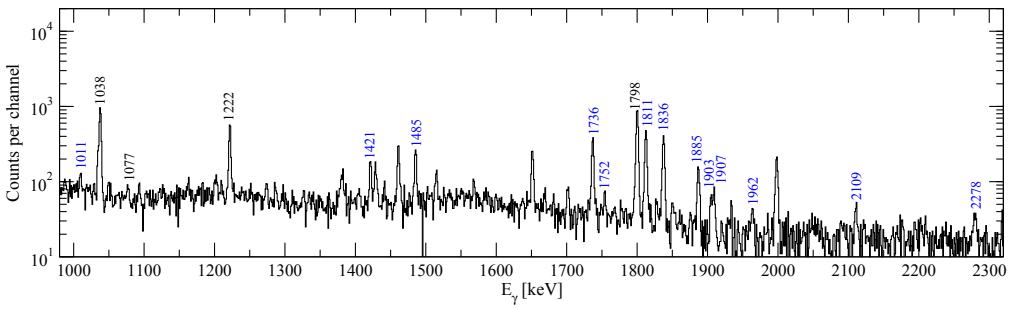

Figure 1. Portion of the γ-ray energy spectrum in coincidence with the 843-keV γ-ray $2^+ \rightarrow 0^+$ transition in ^{122}Xe. The data were taken with a short tape cycle to optimise the observation of the ground state decay of ^{122}Cs.

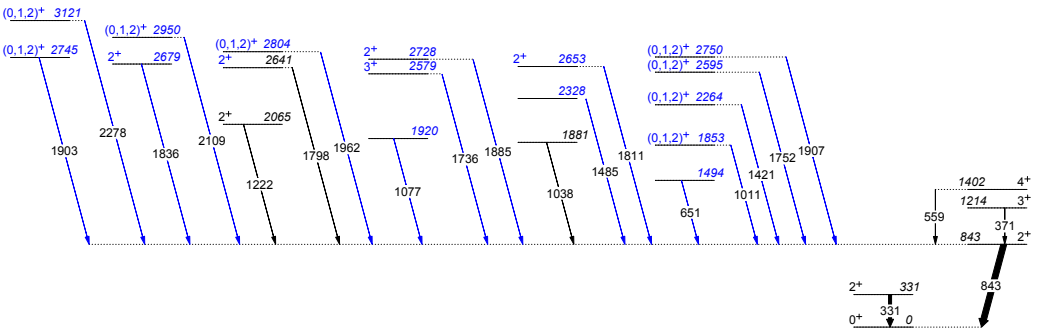

Figure 2. Partial level scheme of ^{122}Xe displaying those transitions that are in coincidence with the 843-keV $2^+ \rightarrow 0^+$ γ-ray transition. Blue colour indicates newly-observed transitions and newly-assigned labels of the states and spins.

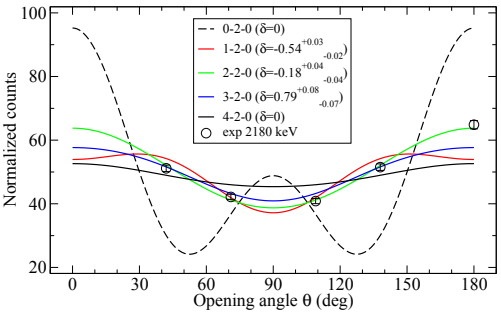

Figure 3. Angular correlation of 1798- and 843-keV γ rays.

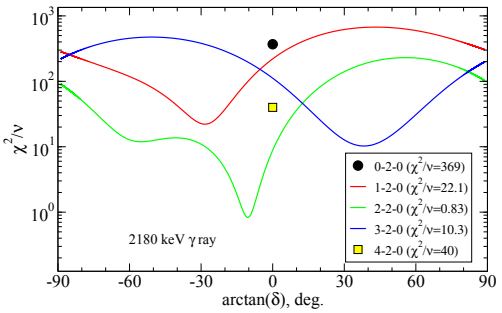

Figure 4. χ^2/ν plot of the angular correlation of 1798- and 843-keV γ rays.

3 Results and Discussions

Spin assignments have been made using data for 58 γ-ray cascades from low-spin levels using an angular correlation analysis and based on β-decay feeding. Two γ-ray coincidence gates, placed on the 331- and 843-keV γ-ray transitions, were analyzed for transitions from low-spin levels. The partial level scheme for levels decaying to the 843-keV 2^+ level is shown in Fig. 2, constructed in part using the data presented in Fig. 1. Levels are labelled with their energies in keV and their spin and parity, J^π. The transition arrows are labelled with their energies in keV and with arrow widths proportional to the intensity. Newly observed transitions and newly assigned labels of the states and spins are indicated in blue.

Spin assignments were made by γ-γ angular correlation analysis, details of which were given in Ref. [5]. As

Table 1. Newly-observed transitions with the spin assignments of the initial levels and deduced mixing ratios with 1σ uncertainty from the analyses of γ-γ angular correlations. All cascades proceed through the 331-keV $2_1^+ \rightarrow 0_1^+$ γ ray.

E_i (lit.)	E_i (new)	J_i^π (lit.)	J_i^π (new)	E_γ	δ (new)
1214.3	1213.5	$(3)^+$	$1^+, 3^+$	882.4	
1495.0	1493.8	2^+	2^+	1163.0	$5.1^{+1.0}_{-0.74}$
	1853.0		$(0,1,2)^+$	1522.1	
1882.3	1881.0		2^+	1550.0	$-1.18^{+0.12}_{-0.11}$
	1919.7		$(0,1,2)^+$	1588.9	
	2046.6		2^+	1715.1	$-0.45^{+0.07}_{-0.09}$
2065.5	2064.6	2^+	2^+	1733.8	0.10(3)
2264.4	2263.8	$0^+, 1, 2$	2^+	1932.4	$-0.84^{+0.23}_{-0.16}$
2343.1	2342.4	2^+	$3^+, 1^+$	2010.0	
	2406.4		$2^+, 4^+$	2074.9	
	2511.4		2^+	2180.0	0.18(4)
	2596.6		2^+	2265.2	0.32(5)
	2619.7		$(0,1,2)^+$	2288.4	
	2642.8		2^+	2311.6	$1.86^{+0.14}_{-0.15}$
	2654.9		2^+	2323.8	$22^{+\infty}_{-9}$
	2680.0		2^+	2349.2	$0.45^{+0.08}_{-0.09}$
	2705.2		$(0,1,2)^+$	2374.2	
	2730.3		2^+	2398.8	$0.05^{+0.03}_{-0.02}$
	2752.5		$(0,1,2)^+$	2421.1	
	2806.9		$2^+, 3^+, 4^+$	2475.8	
	2842.7		$(0,1,2)^+$	2511.2	
	2858.8		$(0,1,2)^+$	2527.6	
	2898.0		$(0,1,2)^+$	2566.4	
	2935.5		2^+	2604.4	0.15(4)
	2979.2		$(0,1,2)^+$	2647.7	
	3002.0		$(0,1,2)^+$	2670.6	
	3014.6		$3^+, 1^+$	2683.5	
	3047.4		$(0,1,2)^+$	2716.7	
	3070.8		$(0,1,2)^+$	2939.1	
	3085.2		$(0,1,2)^+$	2754.1	
	3097.5		$(0,1,2)^+$	2766.4	
	3111.4		$(2)^+$	2780.4	-1.17(12)
	3139.5		$(0,1,2)^+$	2808.3	
	3180.5		$(2)^+$	2848.8	$-0.52^{+0.10}_{-0.25}$
	3205.2		$(0,1,2)^+$	2874.5	
	3243.3		$(0,1,2)^+$	2912.3	
	3256.7		$(0,1,2)^+$	2925.7	
	3271.0		$(0,1,2)^+$	2939.1	
	3275.2		$(0,1,2)^+$	2944.7	
	3306.3		$(0,1,2)^+$	2975.4	
	3438.5		$(0,1,2)^+$	3107.4	
	3450.0		$(0,1,2)^+$	3118.8	
	3550.8		$(0,1,2)^+$	3220.3	
	3664.2		$(0,1,2)^+$	3333.7	
	4136.4		$(0,1,2)^+$	3805.0	
	4140.9		$(0,1,2)^+$	3810.6	

an example, the plots for the angular correlation of the 1798- and 843-keV γ-ray cascade, and minimization of the χ^2/ν as a function of the $E2/M1$ mixing ratio, are given in Fig. 3 and Fig. 4, respectively. The sign convention of the mixing ratio follows Ref. [10].

Despite the high statistics obtained in the experiment, spin assignments by angular correlation analysis is limited to the intense γ-γ cascades. For levels that were weakly populated, spin assignments were made based on the direct β-decay branch to the level of interest. The investigated γ-ray transitions are tabulated in Table 1 and Table 2 for γ-ray cascades involving the 331- and 843-keV γ rays, respectively.

Table 2. Newly-observed transitions with the spin assignments of the initial levels and mixing ratios with 1σ uncertainty deduced from the γ-γ correlation analysis. All cascades proceed through the 843-keV $2_2^+ \rightarrow 0_1^+$ γ ray.

E_i (lit.)	E_i (new)	J_i^π (lit.)	J_i^π (new)	E_γ	δ (new)
1495.0	1493.8	2^+		651.4	
	1853.0		$(0,1,2)^+$	1010.7	
1882.3	1881.0			1038.2	
	1919.7		$(0,1,2)^+$	1076.8	
2065.5	2064.6	2^+	2^+	1222.1	$-3.4^{+0.32}_{-0.39}$
2264.4	2263.8	$0^+, 1, 2$	$(0,1,2)^+$	1421.2	
	2327.7			1485.0	
	2578.8		3^+	1735.7	$-5.2^{+0.49}_{-0.60}$
	2595.5		$(0,1,2)^+$	1752.2	
2642.3	2641.4	1,2	2^+	1798.5	$-0.58^{+0.08}_{-0.09}$
	2653.3		2^+	1810.8	$35^{+\infty}_{-18}$
	2678.6		2^+	1835.7	$-0.12^{+0.04}_{-0.03}$
	2727.8		2^+	1885.2	-1.38(11)
	2745.2		$(0,1,2)^+$	1902.7	
	2750.3		$(0,1,2)^+$	1906.7	
	2804.1		$(0,1,2)^+$	1961.8	
	2949.8		$(0,1,2)^+$	2109.0	
	3121.3		$(0,1,2)^+$	2278.3	

Levels that are fed from the 1^+ ground state of ^{122}Cs and appear to have no discrete γ-ray feeding from higher-lying levels are assigned spins of $(0,1,2)^+$ based on the assumption of allowed β decays.

4 Conclusions

The level structure of ^{122}Xe was studied via the β^+/EC decay of ^{122}Cs. The data were analyzed using $\gamma\gamma$ coincidence and angular correlation methods. To date, about 505 new transitions and about 250 new levels have been observed. Among them, spin assignments have been made for 58 low-spin states. For weakly populated levels that are directly fed from the β-decaying state, suggested spin assignments were made assuming allowed transitions.

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