A New Candidate for 0^+ Two-Phonon Octupole Excitation in ^{208}Pb $^\diamond$

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Using different techniques a number of searches [1–3] has been performed to identify two-phonon octupole vibrational excitations (2-POV) $|\,(3^- \otimes 3^-); \mathrm{J}^+\rangle$ in ^{208}Pb. but no clear-cut identification has emerged up to now. Of special interest are 6^+ and 0^+ states. A proposed 6^+ candidate at 5689(1) keV, identified by Wollersheim et al. [2], was dicussed in subsequent papers, e.g. [4–6]. The nature of the two excited 0^+ states, known from conversion electron spectroscopy - the neutron pairing vibration state (PV) at 4866 keV, and the proton PV and/or 2-POV at 5237(5) keV - has been discussed by R. Julin et al. [1] and others. A few months ago M. Yeh et al. [3] reported on the deexcitation of a level at 5241(1) keV via a cascade of E3 transitions (2626 keV and 2614 γ-rays) from a (n,n'γ)-reaction study. From the exclusive decay (observed also by M. Schramm et al. in (d,pγ) [4]) of this state to the 1-POV $3_1{}^-$ state, from angular correlations and the non observation of a respective decay of the 0^+ state at 4866 keV they assign this state as first observation of the 0^+ member of the 2-POV quartet.

To obtain information on the 2-POV strength of this state (mixing with the proton PV state may contribute), we discuss observation and strength of this state in high energy resolution proton inelastic scattering from ^{208}Pb. In a spectrum at $\theta_{lab} = 50°$, the only one with sufficient statistics and resolution, we identify a state at $\mathrm{E_X} = 5240.8(10)$ (see fig.1). Assuming pure $|\,(3^- \otimes 3^-); \mathrm{J}{=}0^+\rangle$ configuration and comparing with coupled-channel calculations (CC) [7] (see fig.2), including also first order transitions, resulting from second order effects in the expansion of the transition operator, this level shows about 40% of the strength predicted in the calculation (the solid line in fig. 2). Considering the uncertainties in the model calculation, this observation may be taken as further support of the assignment of this state.

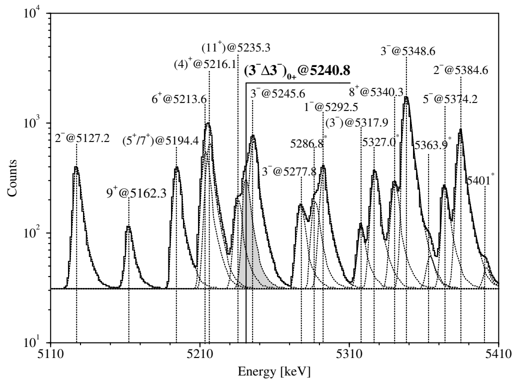

Fig. 1: Part of an excitation energy calibrated spectrum observed in (p,p') with a self-supporting 231 μg/cm^2 ^{208}Pb target at E_p = 22 MeV and $\theta_{lab} = 50°$. The proposed 0^+-member of the 2-POV quartet at 5240.8 keV shows up in peak fitting, overlapping with the much sronger excited and well known $\nu\ |3\mathrm{d}_{3/2}3\mathrm{p}_{1/2}^{-1}; 3^-\rangle$ state at 5245.6 keV [6] and a state at 5235.3 keV, assigned in ref. [4] as a 11^+ yrast state.

Experiments have been performed at incident proton energies of 20 and 22 MeV, respectively, at the Q3D magnetic spectrograph with the 1.6 m active length position sensitive detector [8] using different targets in the 200 μg/cm^2 range. In the excitation energy range between 4842 keV and 7239 keV we observed in spectra with line widths of 4 to 5 keV FWHM 192 levels, 75 more than obtained in ref. [4].

In the depicted energy range of fig.1 between 5110 keV and 5410 keV we observe 18 levels, 12 of them agree within ± 0.8 keV with those listed in ref. [4], 8 of them within ± 1 keV with those observed in ($\vec{\mathrm{d}}$,p) [9]. The levels in fig.1 marked with an asterix (at 5286.8, 5327.0 and 5363.9 keV) are not yet reported in the literature. The multiplet including the 5240.8 keV state shows up at several scattering angles. However only the run with very high statistics at $\theta_{lab} = 50°$ allows in the GASPAN fit routine [10] the resolution of this multiplet in levels reported in ref. [4] without any help of a peaklist-procedure. It remains unclear whether the detected level at 5235.3 keV is the proposed 11^+ yrast state with unnatural parity or a lower spin state not yet identyfied. At 4865.3 keV, the energy of the neutron PV state (4866 keV), we observe a peak with about the same cross section as the peak at 5240.8 keV. This energy however coincides with the $\nu\ |1\mathrm{j}_{15/2}3\mathrm{p}_{1/2}^{-1}; 7^+\rangle$ state observed in refs. [4,9], thus only an upper limit about the strength of this lower O^+ state is obtained.

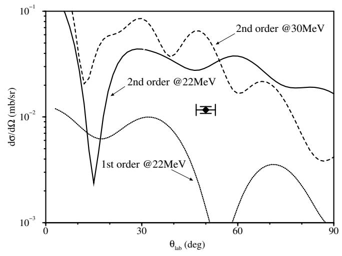

Fig. 2: Comparison of calculations in the CC approach with the measured cross section at $\theta_{lab} = 50°$ of the 5240.8 keV level. The experimental value exceeds the first order prediction (dotted curve) by an order of magnitude and carries about 40 % of the strength obtained in second order (solid curve).

At higher bombarding energies close to 30 MeV the stronger oscillating shape of the predicted cross section (dashed curve in fig. 2) might be helpful to resolve better the 2-POV nature of the 5240.8 keV level.

References

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