

High-Energy-Resolution Inelastic Electron and Proton Scattering and the Miltiphonon Nature of Mixed-Symmetry 2⁺ States in ⁹⁴Mo

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High-energy-resolution inelastic electron scattering (at the S-DALINAC) and proton scattering (at iThemba LABS) experiments permit a thorough test of the nature of proposed one- and two-phonon symmetric and mixed-symmetric 2⁺ states of the nucleus ⁹⁴Mo. The combined analysis reveals the one-phonon content of the mixed-symmetry state and its isovector character suggested by microscopic nuclear model calculations. The purity of two-phonon 2⁺ states is extracted.

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Content

Motivation

- Experiments
- Results and microscopic interpretations
- Summary and outlook

Motivation

• *pn*-IBM-2

- \rightarrow fully symmetric states (FSS) \rightarrow isoscalar
- \rightarrow mixed-symmetry states (MSS) \rightarrow isovector

• Test case of ⁹⁴Mo:

- N. Pietralla et al., Phys. Rev. Lett. 83, 1303 (1999); Phys. Rev. Lett. 84, 3775 (2000)
- C. Fransen et al., Phys. Lett. B 508, 219 (2001); Phys. Rev. C 67, 024307 (2003)

Study of one- and two-phonon 2⁺ FSS and MSS with (e,e') and (p,p')

- \rightarrow sensitive to one-phonon components of the wave functions
- → test of fundamental phonon character
- \rightarrow isoscalar / isovector decomposition
- \rightarrow purity of two-phonon states
- Complete observation of all 2⁺ states up to 4 MeV
 → high resolution → beam matching techniques

169° Spectrometer and Focal Plane Detector System





- New Si microstrip detector system: 4 modules, each contains 96 strips, with pitch of 650 μm
- Resolution: $\Delta E/E = 4 \times 10^{-4}$
- Data rates up to 100 kHz

K600 Spectrometer and Focal Plane Detector System



Data: Weak Transitions



One-Phonon FSS and MSS



Wave Functions of One-Phonon FSS and MSS

Main config.	2 ⁺ _{1,FSS}		2 ⁺ 3,MSS	
	QPM	SM	QPM	SM
π (1g _{9/2} 1g _{9/2})	0.66	0.39	0.64	0.51
v(2d _{5/2} 2d _{5/2})	0.72	0.55	-0.71	-0.33

- FSS \rightarrow isoscalar
- MSS \rightarrow isovector

Summary

- Study of one- and two-phonon FSS and MSS 2⁺ states in ⁹⁴Mo with high-resolution (e,e') and (p,p') experiments
- Combined analysis with microscopic models reveals:
 - \rightarrow dominant one-phonon character of 2_1^+ and 2_3^+ states
 - \rightarrow isovector character of one-phonon MSS within valence shell
 - → quantitatively consistent conclusions after inclusion of two-step processes in (p,p') cross sections
 - \rightarrow two-phonon FSS quite pure
 - → about 10% one-phonon and about 17% three-phonon admixtures in two-phonon MSS → but dominant two-phonon character

Outlook

 The case of ⁹²Zr: Mixed-symmetry concept seems to fail: C.Fransen *et al.*, Phys. Rev. C71 (2005) 054304



Outlook

- Fine structure of the IVGDR
 - ⇒ (p,p´) at 200 MeV
 - \Rightarrow newly developed 0° facility at K600 magnetic spectrometer
- Information can be extracted on:
 - \Rightarrow damping mechanisms of nuclear giant resonances
 - \Rightarrow level densities \rightarrow very important for astrophysics

RCNP: ²⁰⁸Pb(p,p[']) at 0[°]





Theoretical Calculation

- Quasi-Particle Phonon Model (QPM)
 - \rightarrow full (up to 3 phonons)
 - → pure one- or two-phonon states
- Shell Model (SM)
 - \rightarrow ⁸⁸Sr core / V_{lowk}
- IBM-2
 - \rightarrow transition densities from generalized-seniority SM
 - \rightarrow U(5) limit to describe dominant transitions
- Cross Section
 - → DWBA / Love-Franey effective projectile-target interaction for (p,p²)



Coupled-Channel Analysis



pure two-phonon FSS confirmed

admixture to two-phonon MSS confirmed

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 - \rightarrow sensitive to one-phonon components of the wave functions
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 - \rightarrow purity of two-phonon states
- Complete observation of all 2⁺ states up to 4 MeV
 - \rightarrow high resolution \rightarrow beam matching techniques
- Experiments:
 - → (e,e´) at S-DALINAC
 - → (p,p') at iThemba LABS