Photon strength function in ^{96}Mo - is there an enhancement at low energies?

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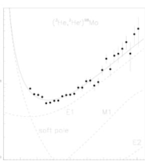
Introduction

An unusual low energy enhancement (E_γ < 4 MeV) in the γ-ray strength function has recently been observed in a series of medium mass nuclei. These observations were made by the Oslo Cyclotron Laboratory which used (^{3}He,αγ) and (^{3}He, ^{3}He'γ) reactions and the sequential extraction method to extract the γ-ray strength function and nuclear level density. In a series of nuclei ^{56,57}Fe, ^{50,51}V, $^{93-98}$Mo, and ^{44,45}Sc a U-shaped γ-ray strength function having γ energies with a minimum around E_γ = 3 MeV.



A low energy enhancement in the photon strength function is not expected by any standard theory of the nucleus and may suggest new physics. Therefore, we performed a new experiment to see if there was an evidence of a low energy enhancement in the γ-ray spectra of ^{96}Mo following neutron resonance capture.

Photon strength functions

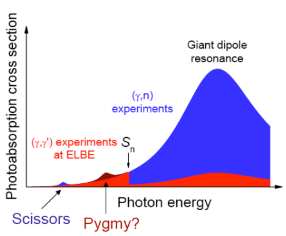
For a γ-transition of multipolarity *XL* from an initial state *i* to a final state *f*, the average partial radiation width is:

$$f_{XL}(E_\gamma) = \frac{\langle \Gamma_{\gamma f} \rangle \rho(E_i, J^\pi)}{E_\gamma^{2L+1}}$$

f_{XL} defines the photon strength function. It is related to the photon transmission function by:

$$T(E_\gamma) = 2\pi E_\gamma^{2L+1} f_{XL}(E_\gamma)$$

The photon strength function gives the probability that a γ-ray of a given multipolarity will be emitted by a nucleus.



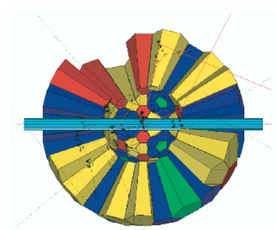
By detailed balance, the PSF is related to the photo-absorption cross section, σ_a, by:

$$f^{E1}(E_\gamma) = (3\pi^2\hbar^2c^2E_\gamma)^{-1}\sigma_\gamma(E_\gamma)$$

E1 strength can be described by a Lorentzian shape (Brink-Axel model):

$$f^{E1}(E_\gamma) = \frac{1}{3(\pi\hbar c)^2}\frac{\sigma_0 E_\gamma \Gamma_G^2}{(E_\gamma^2 - E_G^2)^2 + E_\gamma^2\Gamma_G^2}$$

Experimental Setup with DANCE



- 4π calorimetric detector to measure total energy of γ-ray cascades following neutron capture.
- Highly segmented BaF_2 array with 160 crystals.
- High efficiency. E_γ ~ 90%.
- Neutron energies 1 eV - 100 keV.
- Designed to measure (n, γ) cross sections on milligram sized radioactive targets.
- Located at the Lujan Center at LANSCE which is part of Los Alamos National Laboratory.

Spectrum fitting method

The spectrum fitting method was adopted to extract the photon strength function from the measured γ-ray spectral distribution. This indirect find the γ-ray strength function by calculating the shape of the spectral distribution until good agreement is found with the measured shape.

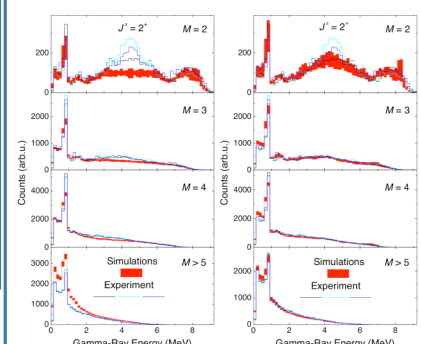
Simulating the γ-ray spectra

The Monte Carlo program DICEBOX was used to simulated the decay of the compound ^{96}Mo nucleus. To simulate γ-ray cascades DICEBOX requires the user to supply a γ-ray strength function, a nuclear level density, and nuclear level information up to a given excitation energy, E_{crit}. Above E_{crit} DICEBOX performs a random discretization of the nuclear level density and generates a series of partial widths from the capture state using the γ-ray strength function supplied. The γ-ray cascades generated by DICEBOX obey the selection rules and follow a Porter-Thomas distribution.

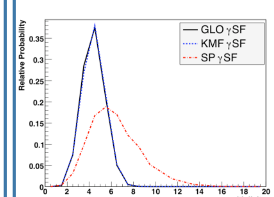
The DICEBOX γ-ray cascades served as input into GEANT simulations of the DANCE detector response. To verify that GEANT gave an accurate description of DANCE's response function numerous comparisons were made between source spectra generated by GEANT and those measured by the DANCE detector.

Results

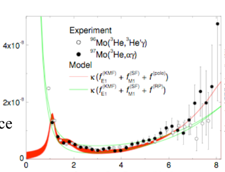
γ-ray spectra from different resonances as measured with DANCE were compared to simulations using DICEBOX+GEANT. For every resonance studied the γ-ray strength function given from (^{3}He,αγ) and (^{3}He, ^{3}He'γ) data over-estimated the intensity of high multiplicity γ-cascades and gave poor agreement with the DANCE spectra. This is easily understood since a low energy enhancement of the γSF is expected to shift the multiplicity distribution towards a higher multiplicity.



γ-ray spectra from the decay of J = 2+ resonances. The spectra are plotted according to the multiplicity of the γ-ray cascade, *M*. The spectra on the left are compared to simulations with a low energy enhancement while the spectra on the right are compared to simulations with an empirical γSF intermediate between a KMF γSF and the Oslo γSF.



Multiplicity distribution from the decay of a J = 3+ resonance in ^{96}Mo. Two standard γ-ray strength functions are compared to a γSF with a low energy enhancement. A low energy enhancement dramatically increases the γ-ray multiplicity.



The shape of the γSF which gave the best agreement with the DANCE spectra contained a low lying Lorentzian resonance centered at 1 MeV. However, the strength of the resonance is much less than the strength function found in the (^{3}He,αγ) and (^{3}He, ^{3}He'γ) data.

Conclusion

The γ-ray strength function was studied in ^{96}Mo by the ^{95}Mo(n, γ) reaction through examining the γ-ray spectra of isolated neutron resonances. Using the spectrum fitting method a γ-ray strength function was extracted. While a γ-ray strength function with a slight low energy enhancement gave the best fit to DANCE data the enhancement was much weaker than the one found in (^{3}He,αγ) and (^{3}He, ^{3}He'γ) data

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