Studies of Spin Cutoff Parameters for Platinum Isotopes

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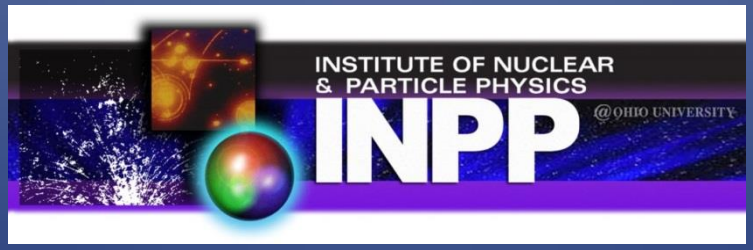

6TH Workshop on Nuclear Level Density and Gamma Strength, Oslo, May 8-12, 2017

Bethe Parameterization

- Bethe introduced the spin cutoff (σ)
- $\sigma = \langle {J_z}^2 \rangle^{1/2}$
- $\rho(J) = \frac{N(J+\frac{1}{2})}{\sqrt{2\pi}\,\sigma^3}\, e^{-J(J+1)/2\sigma^2}$
- Affects angular distributions in compound nuclear reactions.
- Affects isomeric ratios
- Needed to convert s-wave neutron resonance count to level density (all J) at neutron binding energy

- Recent paper has calculated σ for nuclei with $20 \leq A \leq 240$ (S. M. Grimes PRC **94**, 014308)
- Used BCS model with statistical mechanics
- Used single particle energies from:
  - S. G. Nilsson, Mat. Fys. Medd. K. Dansk. Vid. Sel. **29**, 16 (1955)
  - P. A. Seeger and R. G. Perisho, LA-3751, Los Alamos Report (1967).
  - P. A. Seeger and W. M. Howard, Nucl. Phys. A238, 491 (1975).

Results

- The value of σ was the rigid body value for $10 \leq u \leq 20\ MeV$ for all A.
- The value of σ was ≈ $\frac{1}{3}$ of rigid body at about 3-4 MeV.
- After pairing disappears (≈ 5 MeV), shell effects are found.

In some regions σ is above rigid body value for $6 \leq u \leq 10\ MeV$

Atomic Number	Behavior of σ^2
A ~ 30	Below Rigid Rotor
A ~ 45	Above Rigid Rotor
A ~ 65	Below Rigid Rotor
A ~ 95	Above Rigid Rotor
A ~ 200	Below Rigid Rotor

- Calculations also suggest $\pm 15\%$ deviations of σ from rigid body for excitation of 6-10 MeV in some mass regions.
- If σ changes by $\sim 15\%$, σ^2 changes by $\sim 30\%$.

Measurements of σ

- Measurement of angular distributions of (α,α'), (α,p), (α,n) reactions.
- Most measurements for $45 \leq A \leq 65$.
- Measurements confirm that σ at $A \sim 50$ is larger than σ at $A \sim 60$ for 6 – 9 MeV.

Related Issues

- Is $\rho_+(u)$ equal to $\rho_-(u)$ at the neutron binding energy?

- Is $\sigma_+(u)$ equal to $\sigma_-(u)$ at the neutron binding energy?

σ^2 Sensitivity to Orbit

J	Occupancy					
	1	2	3	4	5	6
$^1/_2$	0.25	0.0				
$^3/_2$	1.25	1.67	1.25	0.0		
$^5/_2$	2.92	4.67	5.26	2.92	0.0	
$^7/_2$	3.25	9.00	11.25	12.0	11.25	0.0
$^9/_2$	8.25	11.0	19.25	22.0	22.92	22.0

Placement of large J orbital in energy is crucial for the calculation of σ.

Note that 4 particles in the $J = 9/2$ orbital produces a much larger σ^2 than 4 particles in the $J = 7/2$ or 4 particles spread over $J = 3/2$ and $J = 1/2$.

Two Approaches to Calculations

- Statistical Mechanics
  - L.G. Moretto, Nucl. Phys. A182, 64, (1974).
  - This includes BCS.
- Odometer Method
  - Does not have BCS but avoids errors in the parity ratio caused by averaging in the statistical mechanics approach.
  - The value of σ^2 can be calculated separately for the positive and negative parity states.

Calculation Details

- Energy range $0 \leq u \leq 20$ MeV
- The calculations at 7.5 MeV were compared for ^{194}Pt, ^{196}Pt and ^{198}Pt.
- Calculations based on single particle energies from:
  - Nilsson
  - Seeger-Perisho
  - Single particles from a Wood Saxson potential with R=1.25$A^{1/3}$, V= -50 , W =0,8, and V_{so} =6.2and a = 0.65.
  - S. Goriely et al., PRC **78**, 064307 (2008)

Comparison of $\sigma^2/\sigma_{rb}{}^2$ at 7.5 MeV

Single Particles Source	Isotope		
	^{194}Pt	^{196} Pt	^{198}Pt
Nilsson	1.07	1.02	1.04
Seeger-Perisho	0.94	0.92	0.97
Seeger-Howard	0.87	0.89	0.92
Potential	0.90	0.89	0.94
Goriely	0.85	0.88	0.95

- The five calculations range over 15%.
- The results trend to 0.9 $\sigma_{rb}{}^2$
- The calculations do not show sharp oscillations.
- Tentative indication that ^{194} Pt and ^{196}Pt have spin cutoffs slightly smaller than ^{198}Pt.

Results in other regions

- For $A \sim 30$ there are indication that $\sigma^2/\sigma_{rb}{}^2$ is less than $A \sim 22$ or $A \sim 38$.
- The $\sigma_+{}^2$ and $\sigma_-{}^2$ are equal to within 5% as are ρ_+ and ρ_- at 7.5 MeV for the platinum examples.
- For $A \sim 30$, ρ_+ and ρ_- differ by ~ 15% at 7.5 MeV, $\sigma_+{}^2$ and $\sigma_-{}^2$ vary by ~ 20% at 7.5 MeV.

Results in Other Regions (cont.)

- For $A \sim 30$ the σ and the ρ_+ to ρ_- ratio may change off the line of stability.
- ^{24}Mg has a of $\sigma^2/\sigma_{rb}{}^2$ of 1.35 at 7.5 MeV.
- ^{32}S has a of $\sigma^2/\sigma_{rb}{}^2$ of 0.78 at 7.5 MeV.

Summary

- Future work
  - Look at sensitivity for nearby nuclei.
  - Look at spin cutoff behavior for deformed nuclei.
  - Look at σ, ρ_+/ρ_- and σ_+/σ_- off the line of stability near $A\sim30$ and $A\sim50$.
  - More measurements of the spin cutoff parameter are needed.