Level density and $\gamma$ strength function in $^{118,119}$Sn

Heidi Kristine Toft, PhD student

Department of Physics, University of Oslo
Outline

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Motivation

- $E_\gamma$: Energy of $\gamma$ from disintegration of excited product nucleus.
- **Energy level density**: Number of energy levels of excited nucleus per MeV.
- **$\gamma$ strength function**: Probability function for $E_\gamma$ independent of level density.
- Earlier found: New, small resonance in $\gamma$ strength function for $^{116,117}$Sn.
  - Enhanced $\gamma$ emission.
  - Resonances are interesting because they indicate collective oscillations in the nucleus.
New resonance in $^{116,117}\text{Sn}$

- Detects $E_\gamma < S_n$.
- Small enhancement. “Pygmy”.
- $E_\gamma \approx 8 \text{ MeV}$.
- On the tail of GEDR (Giant Electric Dipole Resonance).
Resonances’ origins

- **GEDR**: Out of phase oscillation of clouds of all (?) protons and neutrons.
  - Many nucleons involved ⇒ High $\gamma$ strength.
  - Variation of a large charge distribution along an axis.
    - Emission of electric dipole radiation (E1 mode).
  - High frequency oscillation ⇒ Centroid $\hbar \omega \approx 15$ MeV.
- **Pygmy**: Origin unknown.
  - Theory prediction of small resonances at 8 MeV: M1 (GMDR) or E1 (neutron skin oscillations).
  - **Neutron skin oscillations**: Non-moving core of $Z$ protons and $N \approx Z$ neutrons, while excessive neutrons ($\approx A-2Z$) oscillate in nucleus’ skin.
Motivation for $^{118,119}$Sn

- Confirm pygmy.
- More excess neutrons in skin.
- Expect stronger pygmy, if skin oscillations.
  - Possibly scaled to number of excess neutrons.
Oslo cyclotron laboratory

- Norway’s only nuclear particle research accelerator.
- Makes radioactivity for research and industry.

Cyclotron
Cactus
Control room
**Experimental setup**

- **28 NaI(Tl), 1 Ge** detectors
- **$^3\text{He}$** (38 MeV)
- **$^{119}\text{Sn}$** target
- **8 Si $\Delta$E-E telescope** (Particle detectors)
Analysis overview

- Interested in particle and $\gamma$ coincidences.
  - Pick-up reaction: $^{119}\text{Sn}(^{3}\text{He},^{4}\text{He} \gamma)^{118}\text{Sn}$.
  - Inelastic scattering: $^{119}\text{Sn}(^{3}\text{He},^{3}\text{He}' \gamma)^{119}\text{Sn}$.

- Particle detectors:
  - Measure particle energy $\Rightarrow$ Estimate $E_x$.
  - Particle identification.

- $\gamma$ detectors: Measure $E_\gamma$.

- Keep only first generation $\gamma$. Matrix $(E_x, E_\gamma)$.

- Estimate level density and $\gamma$ strength function.
  - Nucleus properties.
$\Delta E$ and $E$ energy distribution depend on charge ($Z$), mass ($A$) and particle velocity.

- Distinguish $^4\text{He}$, $^3\text{He}$, $t$, $d$ and $p$. 

$\Delta E$ vs. $E$
Spectrum of added $\Delta E + E$

- $\Delta E$ detects some particle energy, $E$ detects remainder.
  - Add up to total energy.
- Better resolution than partial energy in each telescope.
  - Statistical fluctuations.
- High-energetic $p$ and $d$ do not stop in $E$.
  - Increasing particle energy $\Rightarrow$ Less total energy detection.
  - Sharp cut-off in right flank.
- Particle overlap.

Counts vs. total energy
Spectrum of $^4\text{He}$ area (zoomed)

- Energy difference of $^4\text{He}$ peaks ⇒ Must match $^{118}\text{Sn}$ energy difference in excitation levels (literature).
- Identify: Most energetic $^4\text{He}$ peak ⇔ $^{118}\text{Sn}$ ground state.
- Low cross section for $^{118}\text{Sn}$ ground state.
  - Favour of high $I$ neutron pick-ups.
  - High $Q$ value.
Spectrum $\Delta E$ telesc. thickness

- $^4$He and $^3$He overlap in total energy. How to easily gate reactions?
- Function range $R(E)$ for $^4$He in Si is known.
- Calculate $\Delta E$ thickness for $^4$He: $t = R(E+\Delta E) - R(E)$.
- Thickness:
  - Separates particles.
  - Criterion for gating on $^4$He or $^3$He particles.
Time spectrum

- **$\Delta t$:** Time from particle detection to $\gamma$ detection.
- Gated on: $^4$He particles.
- Peak: $\gamma$'s from $^4$He reactions.
- Narrow. (FWHM: 15-20 ns)
- Rest: Background of random coincidences.
  - For subtraction.

**Counts vs. $\Delta t$ (ns)**
Future work

- Estimate $\gamma$ strength function and energy level density.
- Compare results to earlier work on $^{116,117}$Sn.
- Neutron skin oscillations?
Further investigations

- Matrix of $E_x$ vs. $E_\gamma$.
- Unfolding of NaI spectra with NaI response functions.
- Spectra of first $\gamma$ emission from excited nucleus (first generation method).
- Decompose matrix $P = \rho \times T$.
- Normalisation of $\rho$ and $T$.
- Make $\gamma$ strength function.
Spectrum $\Delta E$

- $^3\text{He}$ elastic peak.
- Også inelastic område???
- No $^4\text{He}$ peak since high-energetic.
- Hvorfor ikke $^4\text{He}$ her?
- Er dette noe å vise?

$^3\text{He}$ elastic peak

# vs energy
Spectrum E

- E telescope stops particles.
- Lower-energy peak: Elastic $^3$He.
- Higher-energy peaks: $^4$He.