Coulomb excitation of $^{66}\text{Ge}$

Or How I Learned to Stop Worrying and Love Ge

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Overview

- Shape Conundrum in $^{70}\text{Se}$ (IS569)
- Beam profile favours $^{66}\text{Ge}$
- Experiments carried out during 13-17 July 2017
- Data analysis
- Conclusions
Angular distribution would tell us precisely static quadrupole moment of the first $2^+$

Shape Coexistence in $^{70}$Se: **What about the second $2^+$?**

Enough statistics (~100-200 counts) @ HIE-ISOLDE to determine the sign of $Q_s(2^+)$ with complementary measurements @ iThemba LABS.

Lifetime and mixing-ratio measurements for $2^{nd} 2^+$ @ iThemba LABS using the GAMKA array

- e.g., $^{58}$Ni($^{14}$N,pn) reaction at 39 MeV (Heese *et al* 1986) to avoid yrast population
Shape coexistence in the neutron deficient region A ~ 70

$^{66}$Ge and $^{70}$Se present a very similar “anomalous” behaviour

Mixing of $0^+$ states leads to anomalous rotational behaviour of first $2^+$ state. Tentative 2nd $0^+$ state @ 2010.3 keV in $^{70}$Se. No 2nd $0^+$ state in $^{66}$Ge (new proposal by G. O’Neill et al)
The original Physics goal changed by the existing sulfur in the ZrO$_2$ target, which allowed for the production of $^{66}$GeS molecules in greater proportion than $^{70}$SeCO molecules.

Particle hits on Q2 quadrant in MINIBALL as a function of time (similar pattern in all quadrants)

The primary target is heated by an extra 15 A up to 555 A

The beam current decreased very rapidly over time despite efforts from the accelerator group.

Beam composition from CD upstream: estimated $^{70}$Se/$^{66}$Ge ~0.1

Implantation data under analysis to estimate beam composition.

The good news: first time an unstable Ge isotope is accelerated!
Experiments carried out during 13-17 July 2017

- $d(^{22}\text{Ne},^{23}\text{Ne})p$ @ 4.48 MeV/u to determine MINIBALL crystal angles

- $^{66}\text{Ge}(^{196}\text{Pt},^{196}\text{Pt}^*)^{66}\text{Ge}^*$ Coulomb excitation reaction @ 4.395 MeV/u

- $^{66}\text{Ge}$ beam in the ionization chamber downstream the MINIBALL array to estimate beam energy losses and $^{196}\text{Pt}$ target thickness.

- Implantation and beta decay to study the beam composition and nuclear structure of daughter nuclei (C. Mehl PhD thesis)
$^{66}\text{Ge}(^{196}\text{Pt}, {}^{196}\text{Pt}^*^{66}\text{Ge}^*)$ Coulomb excitation reaction $\@ 4.395 \text{ MeV/u}$

- Eight MINIBALL detectors + double-sided CD detector
- $^{66}\text{Ge}$ beam bombarded onto a $^{196}\text{Pt}$ target (97.25% enriched)
- $^{196}\text{Pt}$ target thickness = 4 mg/cm$^2$ @ Heavy Ion Laboratory, Warsaw
- Starting $^{70}\text{Se}^{12}\text{C}^{16}\text{O}$ yield = 1.1E5/uC (free of isobars?) vs $^{70}\text{Se}$ 9.7E4/uC
- Actually, it was mostly $^{66}\text{GeS}$!
- Beam energy = 4.395 MeV/u
- Target - CD distance = 27.4 $\pm$ 0.3 mm
- CD angular coverage: [18.2°, 56.2°] in the lab frame
Beam composition from in-beam $\gamma$-ray data: $I(^{66}\text{Ge})/I(^{70}\text{Se})$

The composition of $^{66}\text{Ge}$ is stronger than $^{70}\text{Se}$, as agreed by the accelerator group.

Data are, however, not conclusive as there is a decay/time dependence in the $\gamma$-ray peaks. The activation/decay data will confirm the beam composition.
Preliminary Doppler-corrected $\gamma$-ray spectrum

355.7 keV

956.9 keV

$\sim$700 counts

Enough statistics to determine $Q_s(2^+)$ from normalization method
Implantation + beta decay study
beam composition + nuclear structure

A promising data set collected with $10^6 \gamma-\gamma$ coincidences (C. Mehl, PhD Thesis)
$E_\gamma$ – time matrix + pile up + dead time (ongoing analysis)
CONCLUSIONS

- Efficiencies and Calibration of the clusters and CD detector
- Geometry characterisation
- In-beam composition supports a larger $^{66}\text{Ge}/^{70}\text{Se}$ beam composition
- Static quadrupole moment will be determined using the Normalization technique
- Beam composition under analysis from activation+beta decay data collected at the end of the experiments
- A new proposal to study shape coexistence in $^{66}\text{Ge}$ will be submitted to the next INTC + we expect to run $^{70}\text{Se}$ (IS569).
- Beam development is required to study the $^{66}\text{Ge}/^{70}\text{Se}$ beam profile and enhance production for either of them.
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