Study of cross-shell excitations in ^{28}Mg and ^{32}Si using Doppler shift methods

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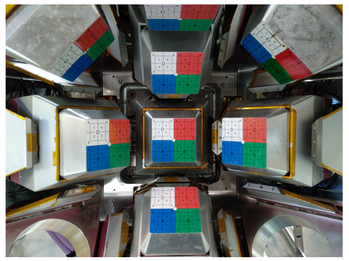
Motivation

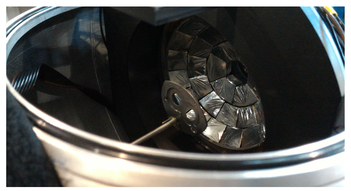
The 'island of inversion' centered on ^{32}Mg is characterized by ground-state configurations with an inverted ordering of *sd* and *pf* (intruder) neutron orbitals due to nucleon-nucleon interactions. For nearby species outside of the 'island of inversion', similar configurations occur in levels with high energy and spin via cross-shell excitations.

These intruder configurations were studied in **^{28}Mg** using a fusion-evaporation reaction, which preferentially populates higher spin and energy states which are likely to result from cross-shell excitations. An upcoming experiment will study **^{32}Si** in similar fashion.

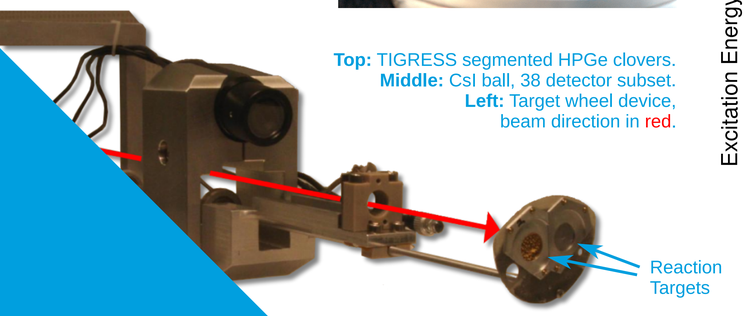
Experiment

The ^{12}C(^{18}O, 2p)^{28}Mg reaction was used (E_{18O} = 48 MeV, ~10^{10} pps. Charged particles were identified using a CsI(Tl) scintillator array. Time coincident γ rays were detected using the TIGRESS spectrometer.





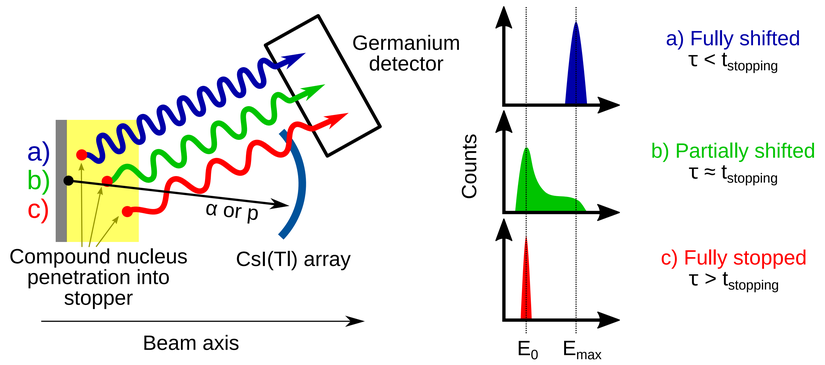
Top: TIGRESS segmented HPGe clovers.
Middle: CsI ball, 38 detector subset.
Left: Target wheel device, beam direction in red.



Doppler Shift Attenuation Method (DSAM)

A method to measure lifetimes of very short lived (< 1 ps) excited states in nuclei.

- Measured Doppler shifts of γ-rays emitted from the ^{28}Mg residual nucleus as it slowed in a thick target backing.
- Lineshapes of γ-rays were compared to simulations to extract lifetimes of excited states.

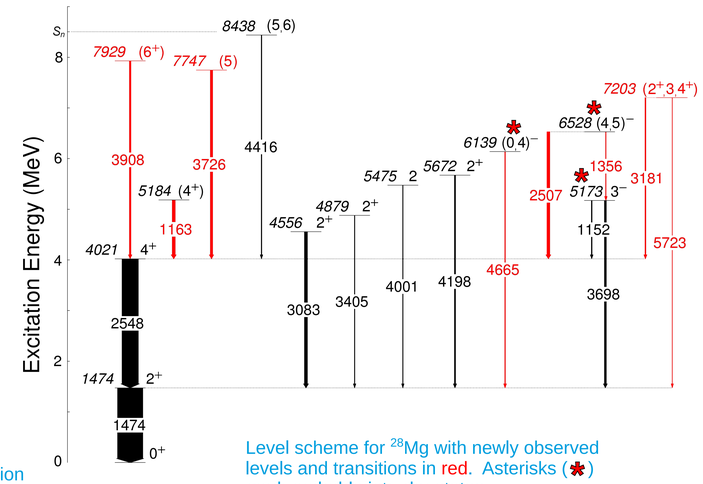


Doppler Shift Attenuation Method (DSAM) schematic.

γ-γ spectroscopy

Data from a thin ^{12}C target was used to obtain γ-γ coincidences (following Doppler correction) and construct a level scheme for ^{28}Mg.

- Several transitions and excited states first observed in this data, due to the novel choice of reaction mechanism.

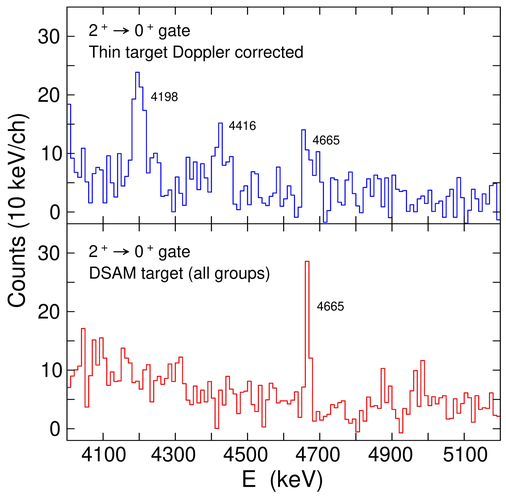


Level scheme for ^{28}Mg with newly observed levels and transitions in red. Asterisks (*) mark probable intruder states.

The picosecond state in ^{28}Mg

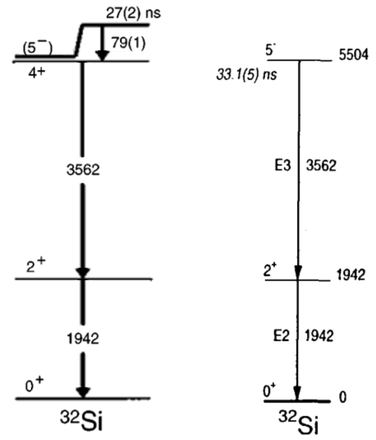
We identified a long-lived state (τ_{mean} > 1 ps) de-populated via a 4665 keV transition, likely resulting from neutron cross-shell excitation.

- Lifetime TBD from plunger data (currently under analysis at SFU).
- Unusual, but similar to an isomeric state in ^{32}Si (see right).

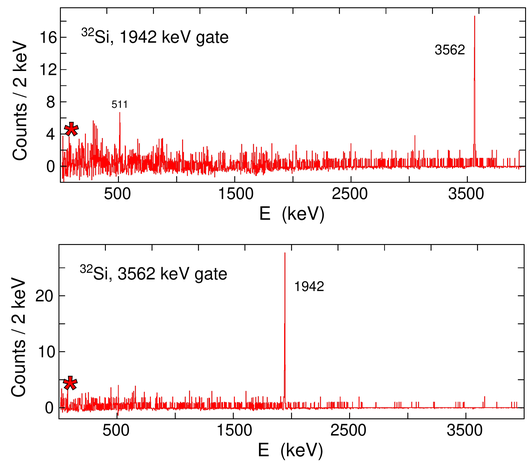


Next steps - ^{32}Si

The nearby nucleus ^{32}Si will be investigated (beamtime scheduled for December 2022) to obtain improved lifetime measurements and determine the placement of its I^{π} = (5^-) *nanosecond isomer*.



Above: Proposed decay schemes of the ^{32}Si nanosecond isomer in the literature.
Below: Preliminary data for ^{32}Si which suggests absence of the 79 keV line (asterisked).



Discovery, accelerated