β-decay studies near $N=28$

Zhihuan Li (RIKEN)
Contents

• Motivation
  - Shell evolution in N~28
  - Low lying states of 41Si and 40Si
  - Beta decay near N=28

• Experimental method
  - Beta decay
  - Life time measurement
  - Detector setup
  - Beam estimation

• Summary
Shell evolution in N~28

The experimental $E(2_{1+}^+)$ and $B(E2)$ values in Ca Si, S isotopic chains

- The orders of their single-particle orbits may shift
- Appearance/disappearance of magic numbers
- Formation of new regions of deformation.
- New neutron magic number 14 and 16 in O isotopes
- Break down of magic number N=20 in the island of inversion region
- Disappearance of the neutron shell closure at N=28 in $^{42}$Si.
The low lying levels of $^{41}$Si

The systematic of the energies of the $3/2^-$ states relative to $7/2^-$ ones in N=27 nuclei.

Deformation - strong configuration mixing of proton and neutron excitations

The proton excitations will be hindered.?

$^4$5Ar
deflection

$^4$3S

$^{41}$Si


The strength of the mixing of the two components could be get from the lifetime of the $7/2^-$ state.
Low lying levels of $^{40}$Si

- The inelastic scattering and nucleon removal reaction on a liquid hydrogen target

- To reproduce the experimental result, the reduction of the n-n interaction at $Z=14$ is needed, but this reduction will cause the overestimating size of N=28 shell gap

- Low lying levels of $^{40}$Si and $^{41}$Si via the beta decay of $^{40}$Al and $^{41}$Al

- Beta decay of $^{40,41,42}$Si and $^{41,42,43}$P to test the shell model in wide range in near N=28 region
• The $\beta$-decay measurement for the nuclei near $N=28$ below $^{48}$Ca.

  - The parities of the ground-states of the parent and daughter are different. It will limit the possibility for direct feeding to the ground state.

  - The large $Q$-value window allows a large number of excited states to be populated.

  - Large $P_n$, $\beta$-delayed gamma and neutron measurements are needed.
The isomeric state produced in the fragmentation
The long-lived excited state populated in the $\beta$-decay

- **Time-delayed $\beta\gamma\gamma(t)$ measurement**

**Plastic scintillator: Timing (start)**
- Fast time response

**LaBr$_3$: Timing (stop)**
- Fast time response
- Poor energy resolution

**HPGe: Branch selection**
- High energy resolution
- Poor time response

$\tau > 30$ ps by fitting the slope of time spectrum

$\tau \sim 5$-10 ps by centroid shift of time spectrum relative to the prompt position

BigRIPS+ZeroDegree $^{48}$Ca beam at 350 AMeV with 200 pnA

- **PID**: event-by-event $B\rho-\Delta E$–TOF
- **$\beta$-ray**
  - plastic scintillator
- **$\beta$-delayed $\gamma$**
  - Clover Germanium detectors
  \[ \varepsilon_\gamma > 5\% \text{ @ 1 MeV} \]
- **$\beta$-delayed neutron**
  - plastic scintillation bars
  \[ \varepsilon_n \sim 5\% \text{ @ 1 MeV} \]
- **Lifetime by time-delayed $\beta\gamma\gamma(\tau)$**
  - two 1 inch $\times$ 1 inch LaBr$_3$ counters
  \[ \varepsilon_\gamma \sim 2.6\% \text{ @ 1 MeV} \]
The conditions of BigRIPS are optimized with minimal change of target and wedge configurations.
Summary

• **The goals of the experiment**
  Beta decay studies near N=28
  - low lying states of $^{41}\text{Si}$, $^{40}\text{Si}$
  - beta decay of $^{40,41}\text{Al}$, $^{40,41,42}\text{Si}$, $^{41,42,43}\text{P}$

• **Experimental method**
  - beta delayed gamma, neutron measurement
  - lifetimes for long-lived states by $\beta\gamma\gamma(t)$ measurement