FISSION STUDY USING SAMURAI SPECTROMETER AT RIKEN

Masami Sako @ Kyoto Univ. (RIKEN)
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# Collaborators

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Contents

• Motivation: potential surface study with fission
• New and powerful method: (p,2p) (p,pn) (p,n) reaction with SAMURAI
• Uniqueness of our project
  Current status of the project
  test experiment
• Summary
Potential surface: $^{180}$Hg

- Beta-delayed fission from $^{180}$Tl
- The fission fragment distribution is asymmetric mass pattern
- $\text{Ex} < Q_b \sim 10 \text{ MeV}$ -> symmetry fission cannot be occurred

fission fragment distribution as a function of Ex

Fission probability as a function of Ex

Earlier fission barrier studies at low energies employing direct nucleon-transfer reactions

Recent Experimental Data
SAMURAI experiment

- New and powerful method with SAMURAI

  - Inverse kinematics with \((p,2p), (p,pn), (p,n)\) reaction
    -> decide the excitation energy by missing mass spectroscopy

  - large acceptance and good resolution
    -> charge\((Z)\) and mass\((A)\) distribution of fission fragment
Our Experiment Outline

- experiment @ RIBF + BigRIPS + SAMURAI magnet
  beam : neutron-rich heavy RI beam @ ~300 AMeV

- method : inverse kinematics with (p,2p)

- measurement : Excitation energy <- missing mass spectroscopy
  -> fission barrier
  -> charge(Z) and mass(A) distribution of fission fragments
Inverse kinematics with (p,2p) reaction

- **proton knockout (p,2p) reaction**
  - cross section: large
  - high momentum transfer
  - 2 proton measurement -> low background

- We can decide excitation energy directly with missing mass spectroscopy
RIBF and BigRIPS and SAMURAI magnet

primary beam: $^{238}\text{U} @ 345$ AMeV

production target: Be

large acceptance high resolution
SAMURAI (Superconducting Analyser for Multi-particle from Radio Isotope beam) magnet
Test Experiment

- Beam: $^{238}$U @ $\sim$300 AMeV, $\sim$$10^4$ pps
- Target: liquid H

- Purpose
  - 2 proton trigger
  - Experimental challenge: detector operation
    - $Z$ of beam = 92, minimum $Z$ of fragment $\sim$ 30
  - 2 fission fragments measurement and
    charge($Z$) and mass($A$) separation

- Beam Time
  - 1 day @ 3/31 – 4/1

- There is no resolution for excitation energy
Charge(Z) and Mass(A) can be separated by $B_p \angle E$-ToF(E)
Target Chamber and proton counter

- 2p trigger: multiplicity = 2
- UP and DOWN counters or LEFT and RIGHT counters

Neutron det. for 20 – 80 degs (2-deg steps)
ICF, hodoscope and TED

- ICF: multilayer Ion Chamber for PID of fragment -> Z
  - active area (80cm × 40cm) is divided to 4 parts
  - charge resolution $\sigma_z \approx 0.17$ between Z=8 and 36 @250 AMeV

- hodoscope: ToF counter -> Q/A
  - consist of 7 bars (10cm × 45cm × 5mm) with double side PMTs
  - time resolution $\sigma_t \approx 2$~300 ps
  - we can use fission trigger: multiplicity=2

- TED: total energy counter -> A
  - consist of 32 pure CsI crystal (10cm × 10cm, 8 × 4) with PMTs
  - mass resolution $\sigma_A \approx 0.15$ up to mass=80 @250 AMeV
SAMURAI and fragment counters
Histogram of Simulation

- The magnetic setting and counter setting for test Experiment was decided with Geant4
  -> Almost of all fission fragments can enter the counters!

ICF is divided to 4 parts
-> fission fragments can be detected
Exp.) Histogram of Simulation
Exp.) Histogram of Simulation

$\Delta E$ @ Ion Chamber

$E$ @ total $E$ counter

$\propto Z$

$\propto Q/A$

large

$\propto Z$

small
Development for Next Experiment

- New Detector 1
  - Segmented Ion Chamber
  - Sasano-san@RIKEN got the RIKEN internal fund for this counter
  - I will develop this counter!

- New Detector 2
  - Hodoscope which has good time resolution and thin plastic (vertical and horizontal bar)

- 2 proton Detector
  - Drift Chamber(position and angle) and NaI(energy)
  - Already Existed

- Ge-counter of in-flyght $\gamma$ emission for particle tagging.
Next Experiment

• Beam: $^{210}$Bi (300 pps) $^{213}$Po (270 pps) $^{219}$At (130 pps)
  -> Total Beam rate $\sim 4 \times 10^3$ pps by LISE++

• Target: Solid H

• Estimation
  • $N = 1.1 \times 10^7$ fragment events per day for $^{218}$Po
  • (p,2p) cross section $\sim 100$ ub/MeV at 1g/cm$^2$ H$_2$ target
  -> $5 \times 10^2$ events/day $\cdot$ MeV
Summary

• Our goal of fission experiment
  • charge and mass distribution and fission probability as a function of excitation energy
• New and powerful method at SAMURAI with (p,2p)
• Current status of our project
• Test experiment will be start
• New detector development
• Next experiment
Thank you