Effect of Pre-Equilibrium spin distribution on neutron induced cross sections

Dugersuren Dashka Dashdorj

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dashdorj1@llnl.gov

Outline

- Motivation
- Spin Distribution in the Pre-Equilibrium reaction
- Experimental setup
- Partial gamma-ray cross section results
- Comparision with model calculations
- Summary

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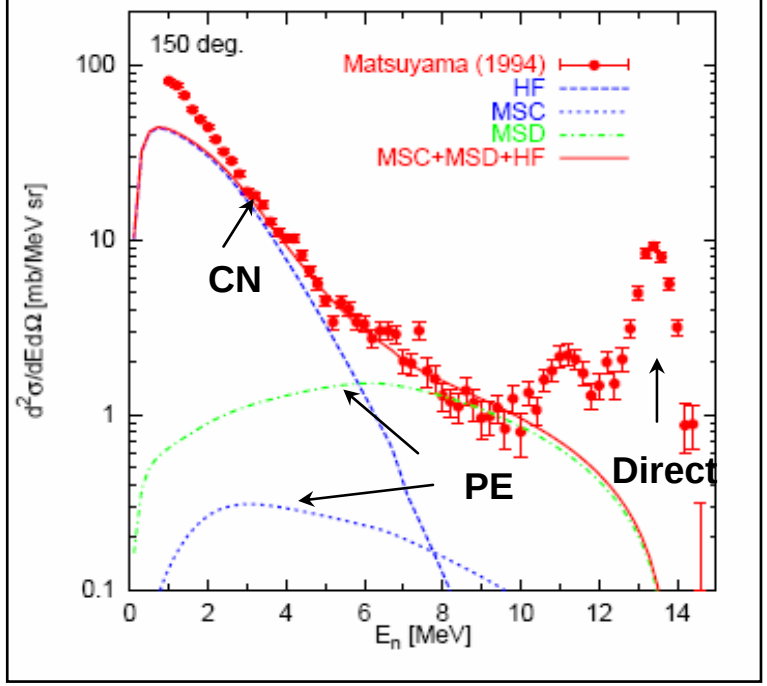
Motivation

- PE reaction mechanism is important for nuclear reaction modeling but still uncertain
  - Magnitude is not well predicted
  - Effects on outgoing neutron spectrum
  - Effects on gamma-ray cascade
- GEANIE - enables gamma-ray cascade measurements
  - Infer spin distribution of residual nucleus
- Systematic PE study as function of ^{A}Z: ^{48}Ti, ^{150}Sm, ^{194}Ir, ^{196}Pt, ^{186}W

dσ/dΩ data ^{93}Nb + n, E_n = 14 MeV



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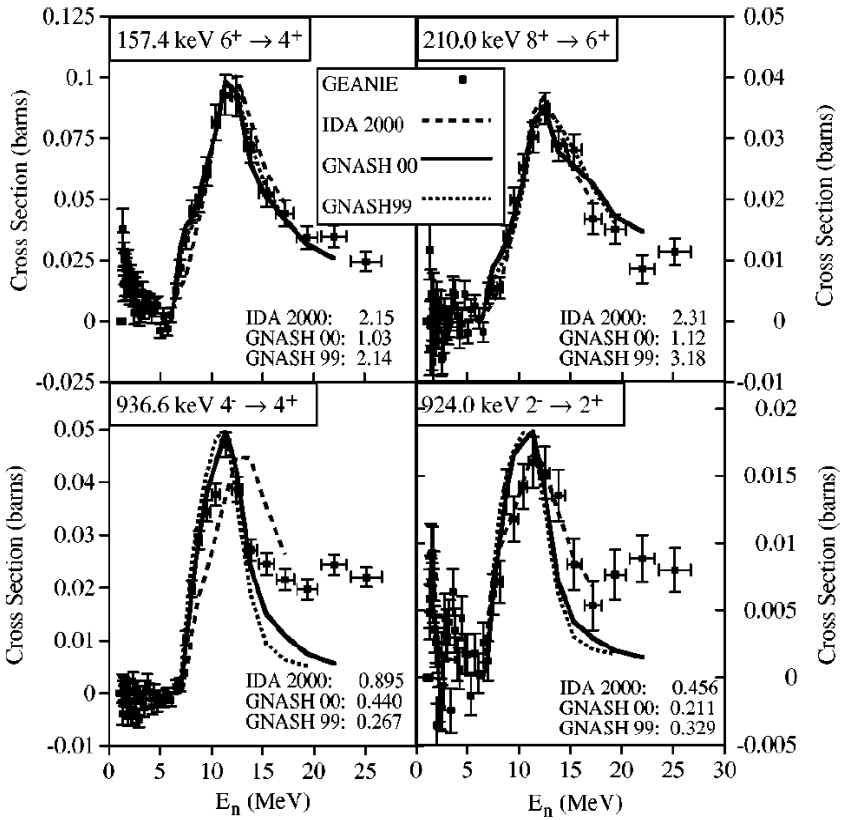
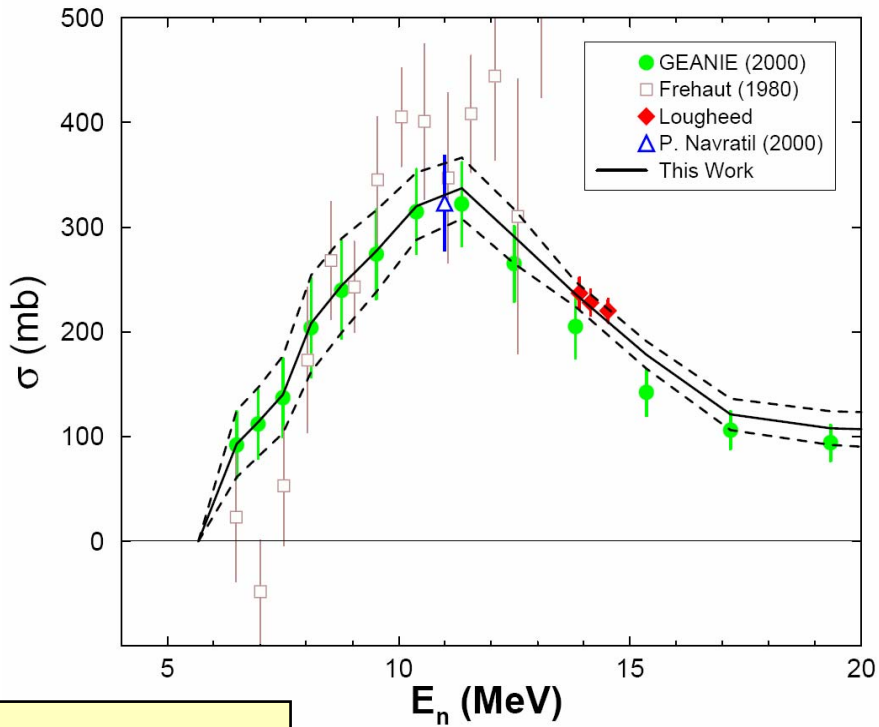
$^{239}Pu(n,2n)^{238}Pu$ cross section measurement with GEANIE L.A.Bernstein et. al. 2000



$$\sigma(n,2n) = \sum_{\gamma_i} \sigma^{exp}(n,2n\gamma_i) \times \frac{\sigma^{the}(n,2n)}{\sum_{\gamma_i} \sigma^{the}(n,2n\gamma_i)}.$$

LLNL evaluation



- Provide data to insights of PE physics
- Enable predictive capabilities for nuclear reaction model

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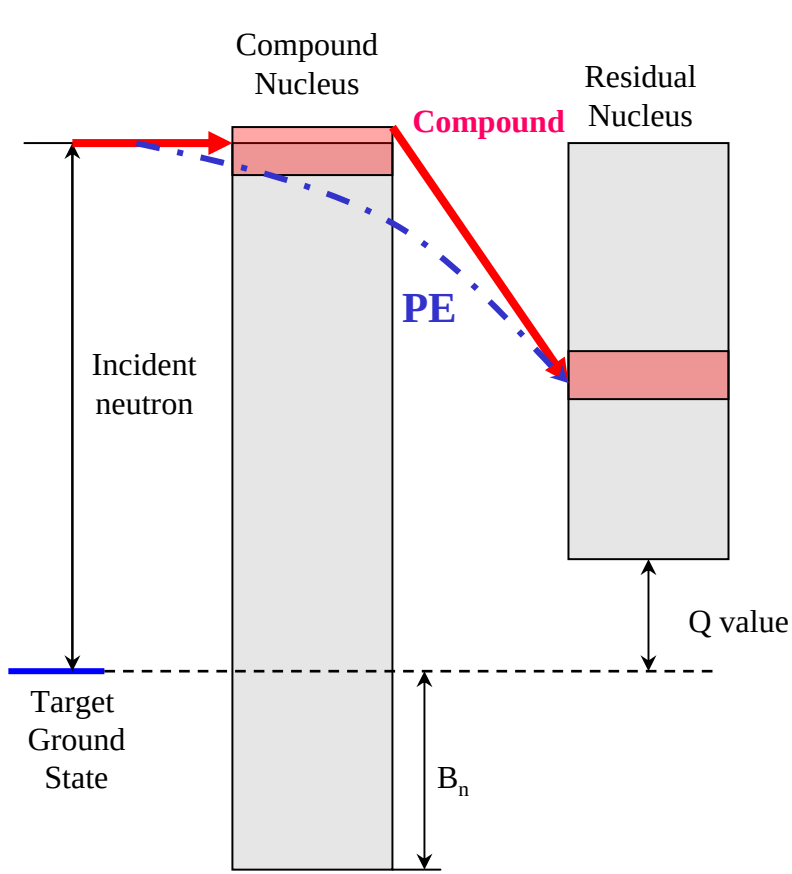
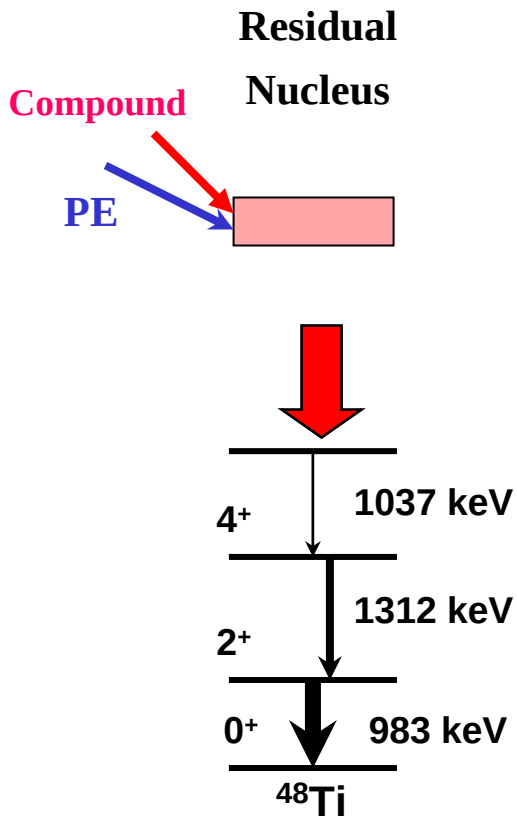
New approach to study PE reaction mechanism

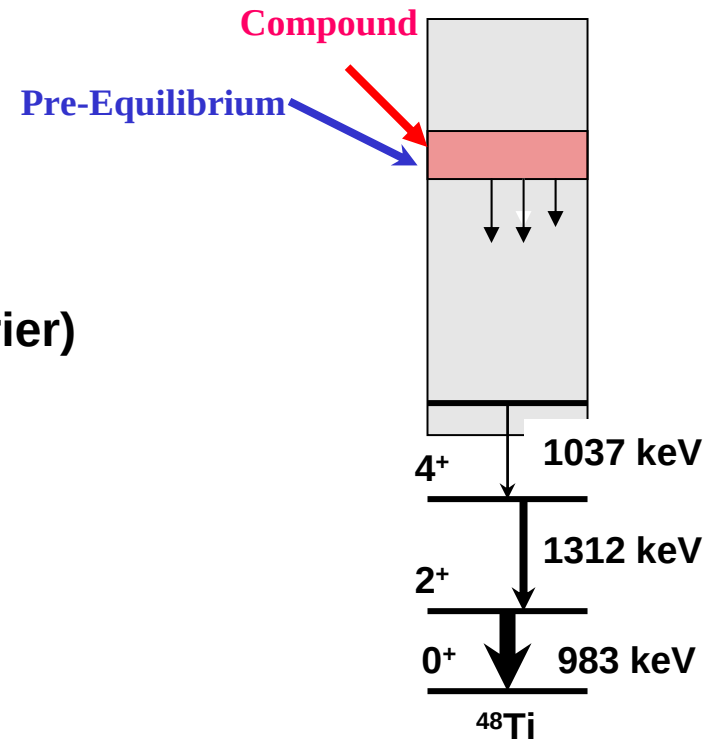
- **Previously, charged particle and fast neutron spectroscopy to study reaction mechanisms, especially PE reaction**
- **We adopt an approach to look at gamma-rays to study PE**





GEANIE at LANSCE offers a new way: γ-rays

- PE leaves residual nucleus in low spin states
- GEANIE spectrometer
  - high γ-ray energy resolution
  - precise γ-ray yield
- Energetic neutrons at LANSCE
  - a good projectile (no Coulomb barrier)
- Implementation of FKK in GNASH
  - Allows direct calculation of spin distributions in residual nucleus following PE emission
  - Allows direct comparison of the partial γ-ray production cross sections with GEANIE data



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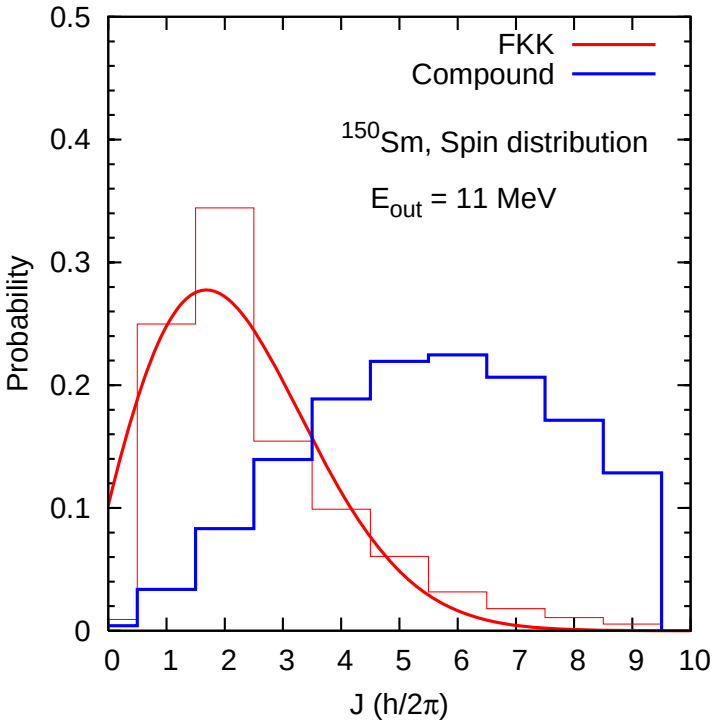
Spin-distribution for E_n = 20 MeV and E_{out} = 11 MeV



$$R_{MSD}(J) = \frac{J+1/2}{\sigma^2}\exp\left\{-\frac{(J+1/2)^2}{2\sigma^2}\right\}$$

σ^2 spin cut-off parameter

FKK gives a significantly different spin cut-off parameter than CN.

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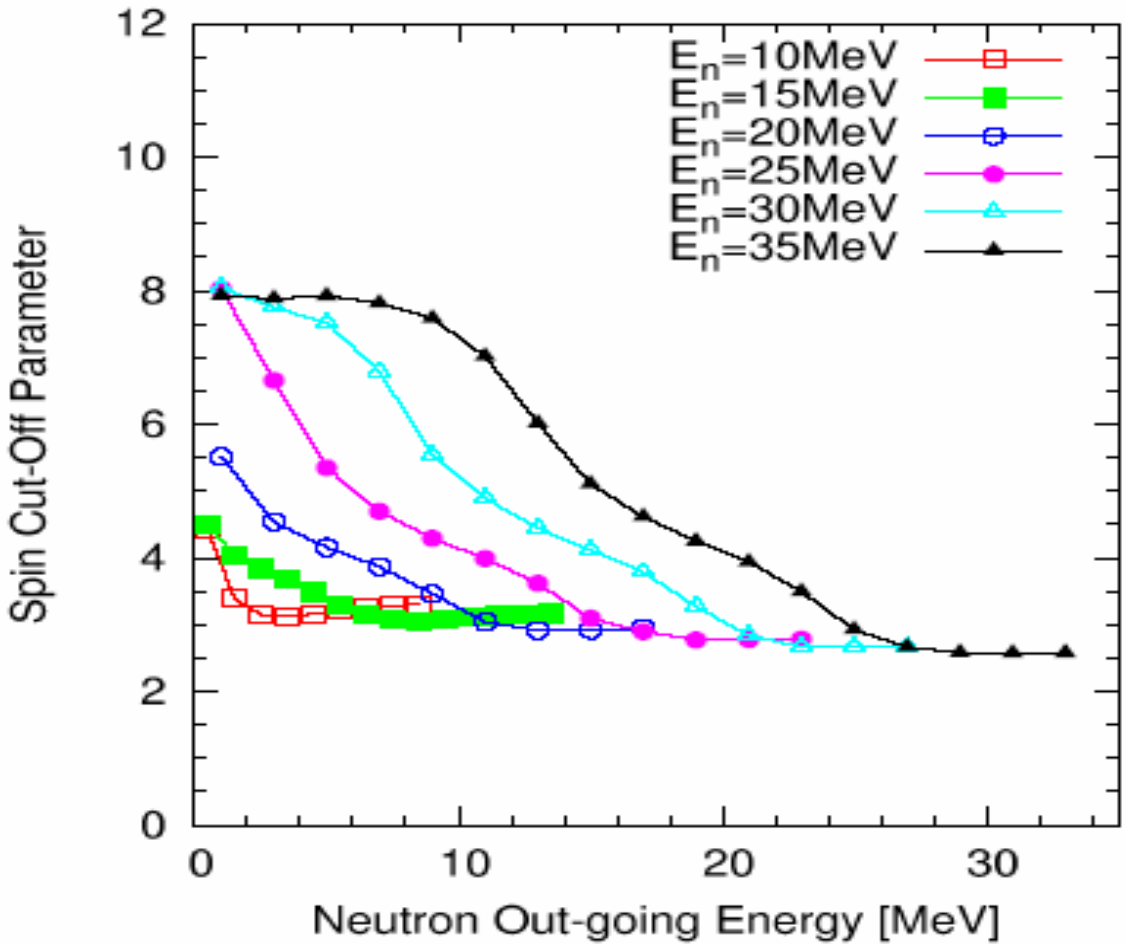
Spin cut-off parameters



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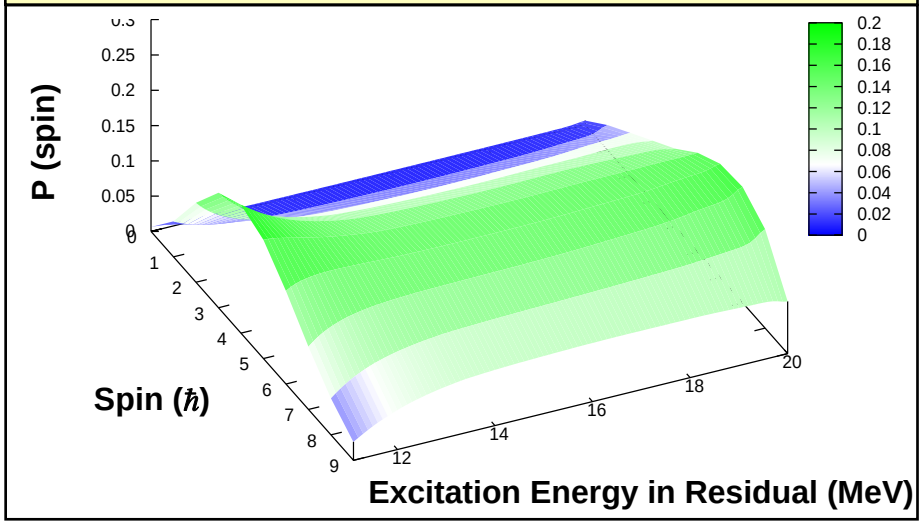
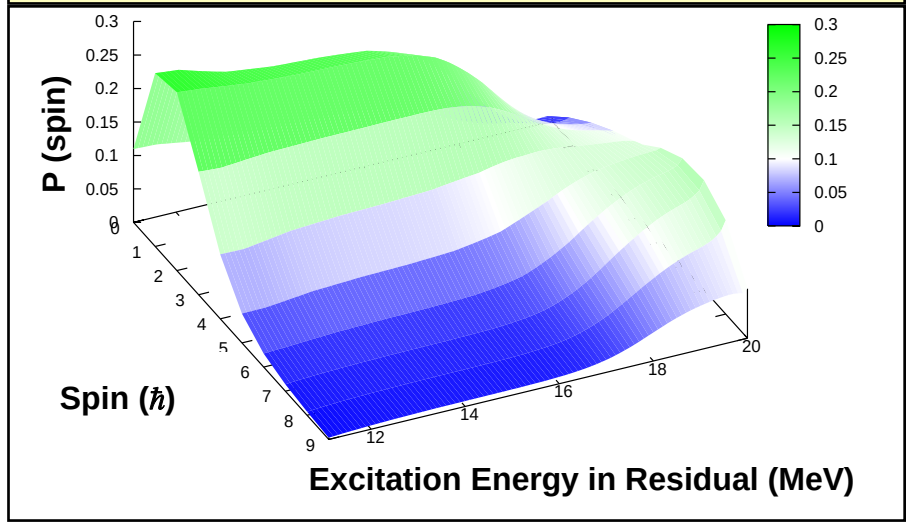
Spin distribution in the continuum of ^{48}Ti E_n = 20 MeV

Without FKK



With FKK



Pre-Equilibrium shifts the spin distribution in residual nucleus to lower spins

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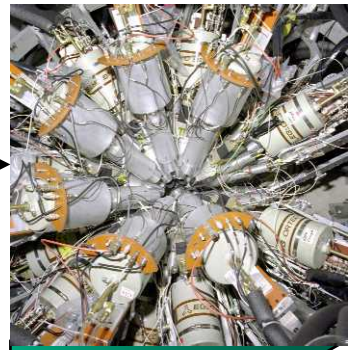
Cross Section Measurements using γ - ray spectroscopy coupled to a spallation neutron source



GEANIE

GEANIE consists of 11 planar and 15 coaxial Ge detectors.

All planar and 9 of coaxial detectors are equipped with BGO shield.

60°

Fission Chamber

800 MeV protons

LANSCE Linac

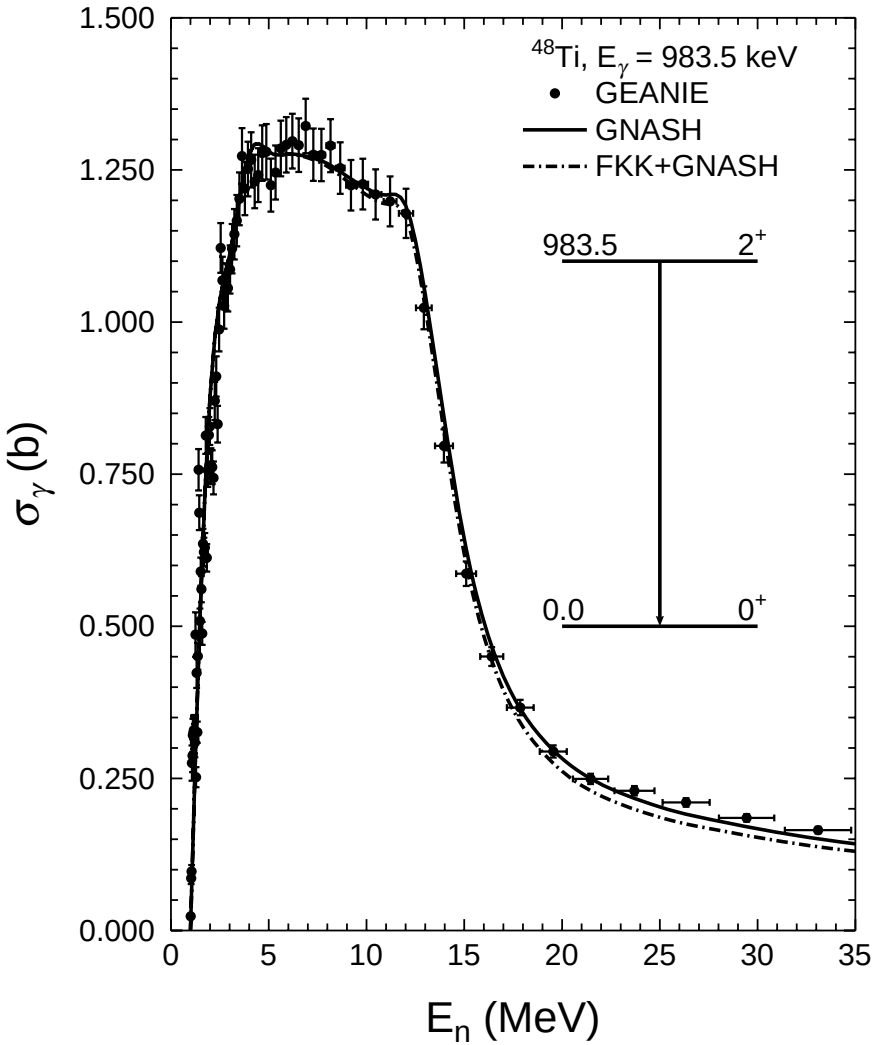
18.3 m

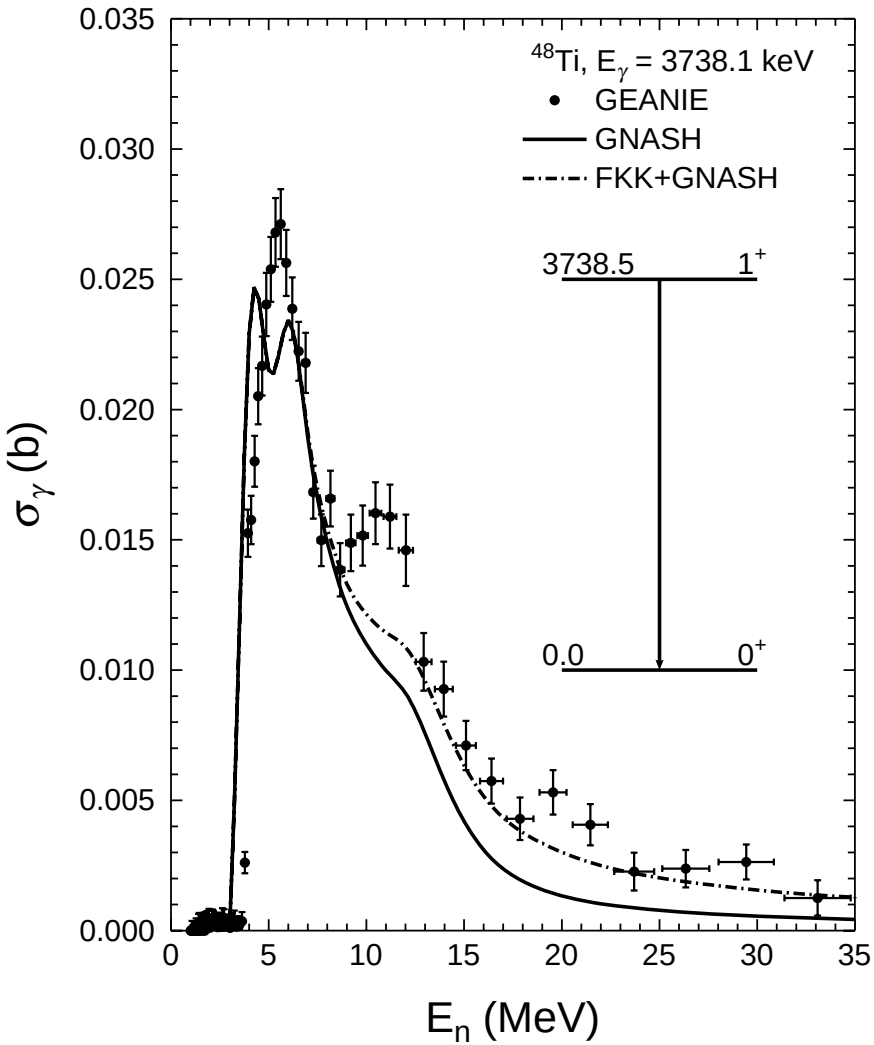
20.3 m

W spallation target

http://www.geanie.lanl.gov

Partial gamma-ray reaction cross section for the $^{48}Ti(n,n'\gamma)^{48}Ti$ transition to ground state





γ–ray transitions from low-spin states are enhanced.

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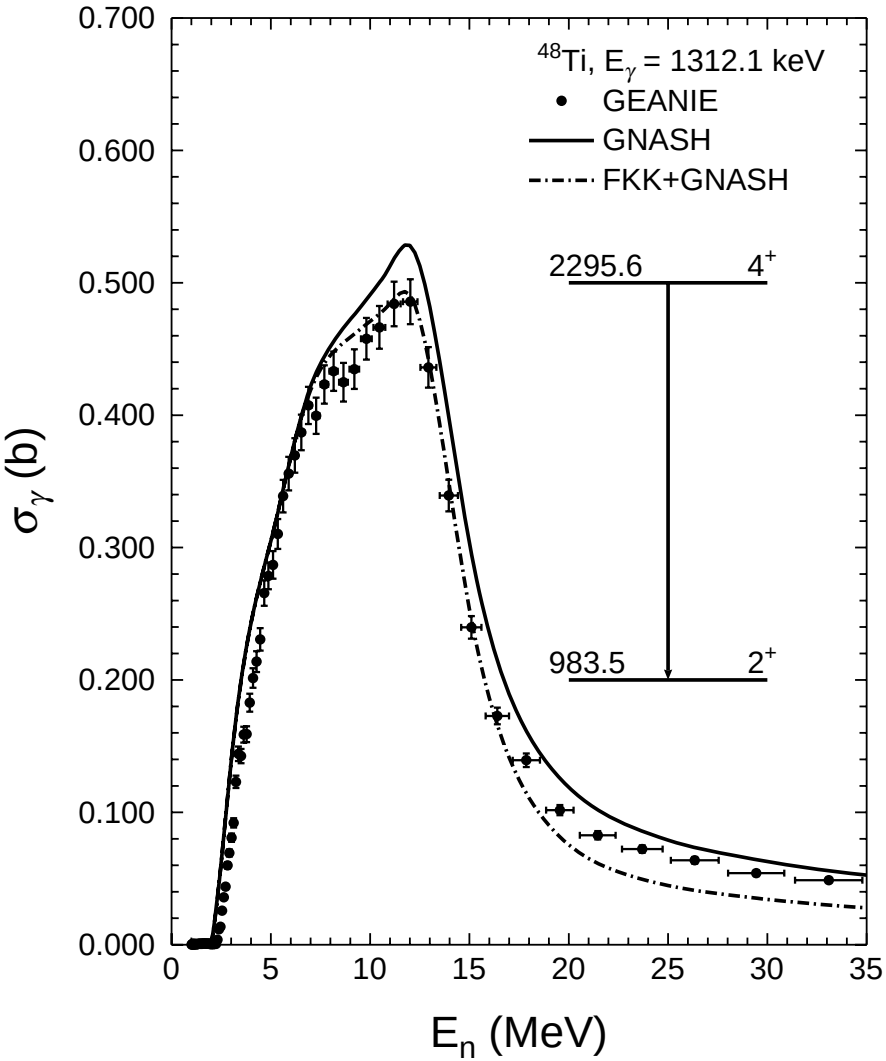
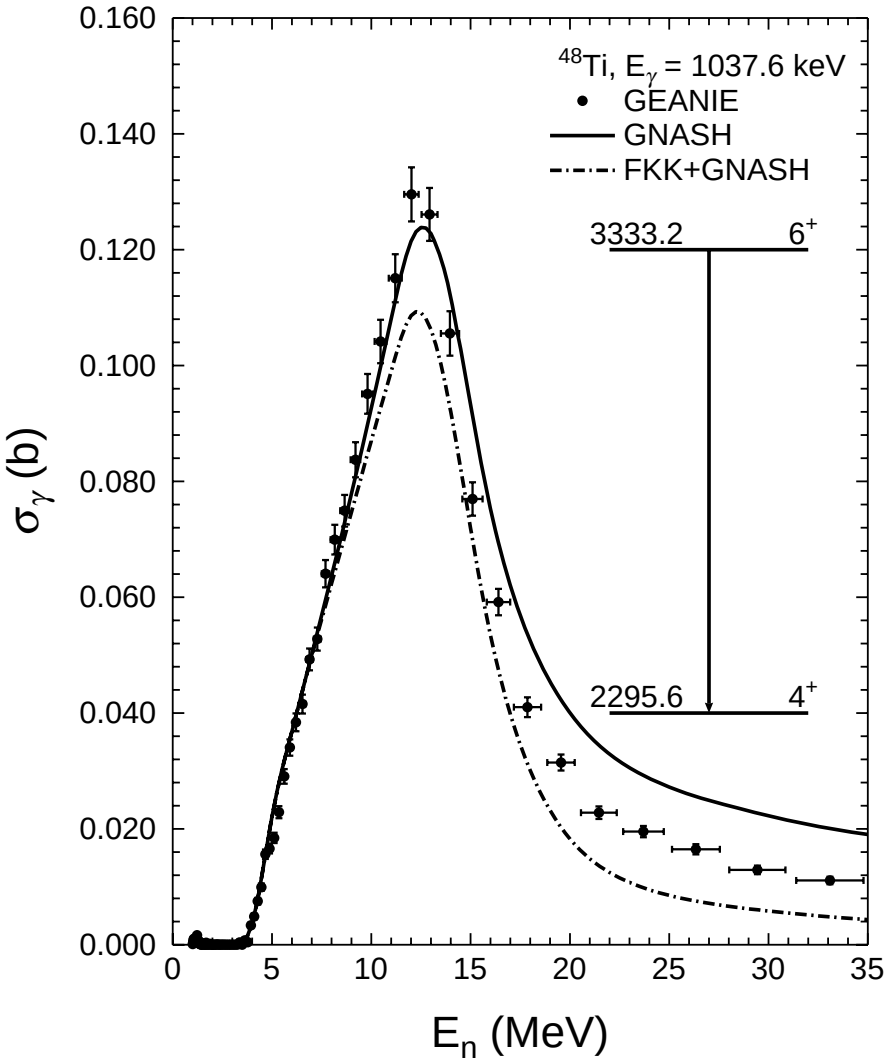
Partial gamma-ray reaction cross section for the $^{48}Ti(n,n'\gamma)^{48}Ti$ transition (yrast band)





γ–ray transitions from high-spin states are suppressed.

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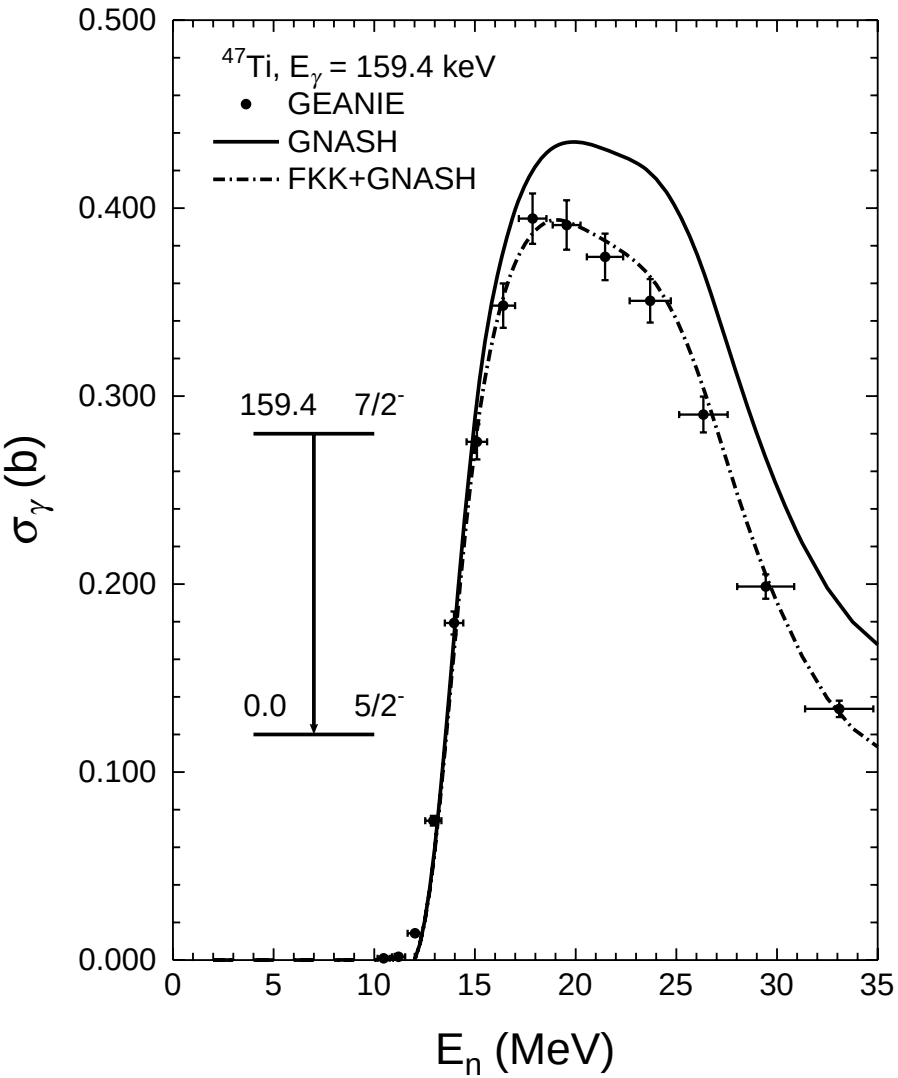
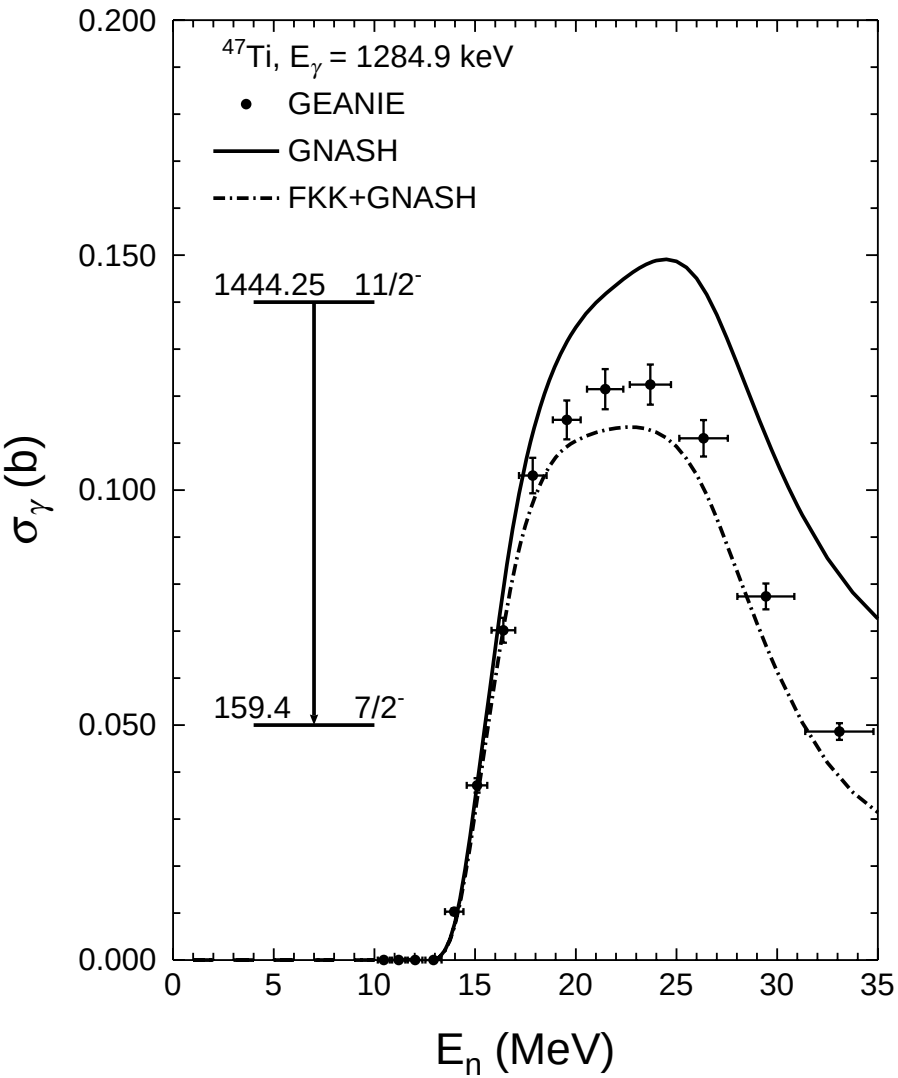
Partial gamma-ray reaction cross section for the $^{48}Ti(n,2n\gamma)^{47}Ti$ transition to ground state





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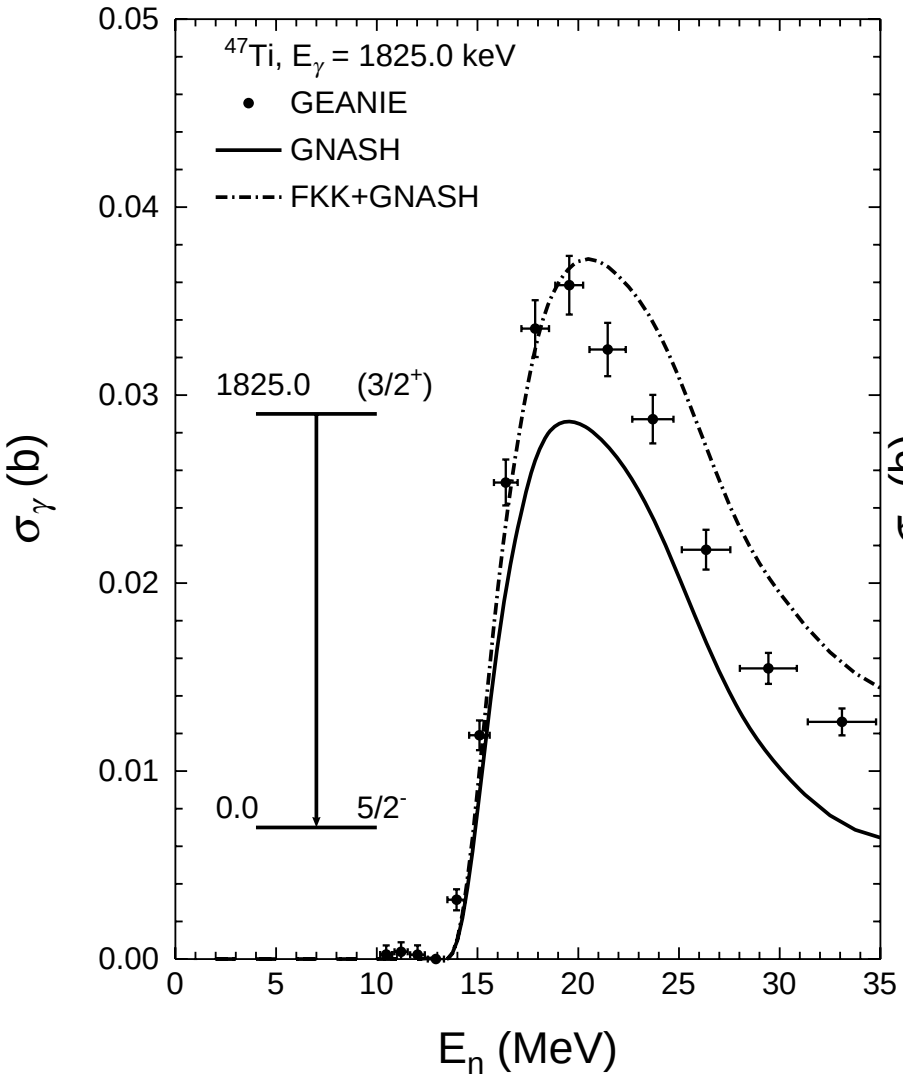
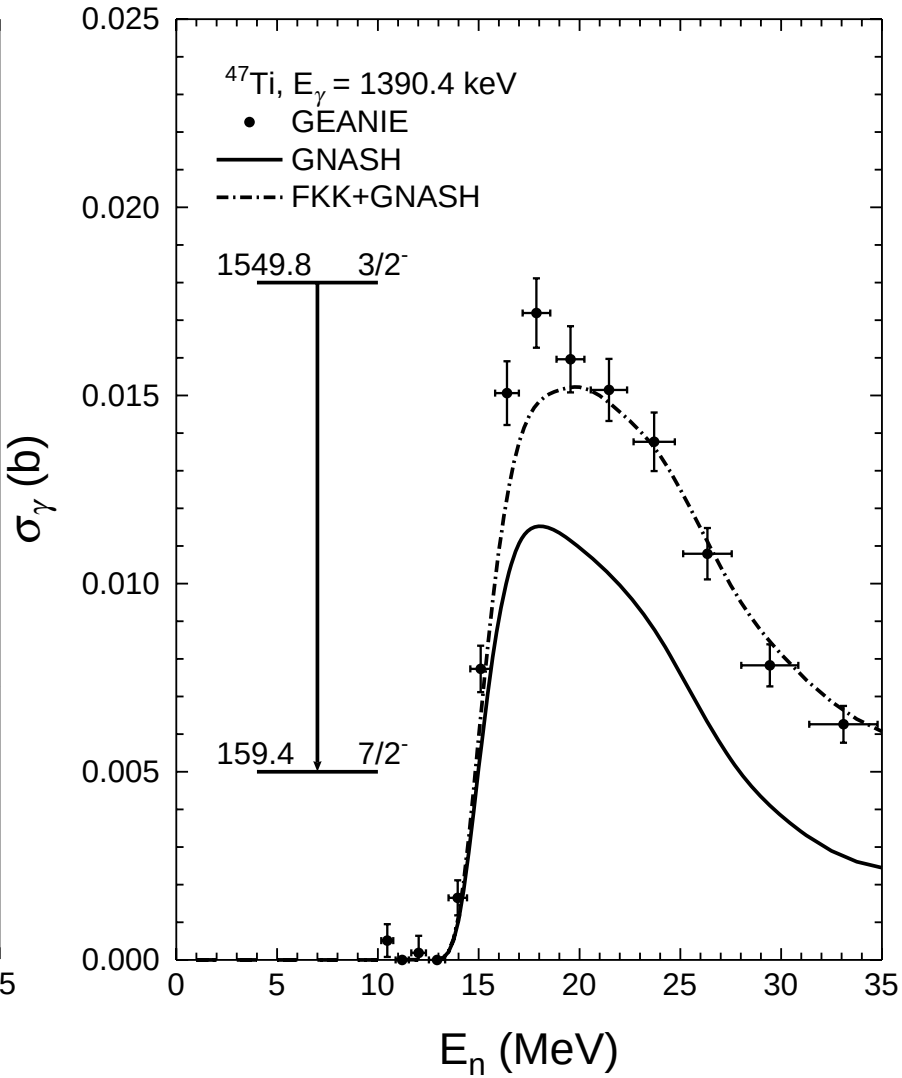
Partial gamma-ray reaction cross section for the $^{48}Ti(n,2n\gamma)^{47}Ti$ transition to ground state

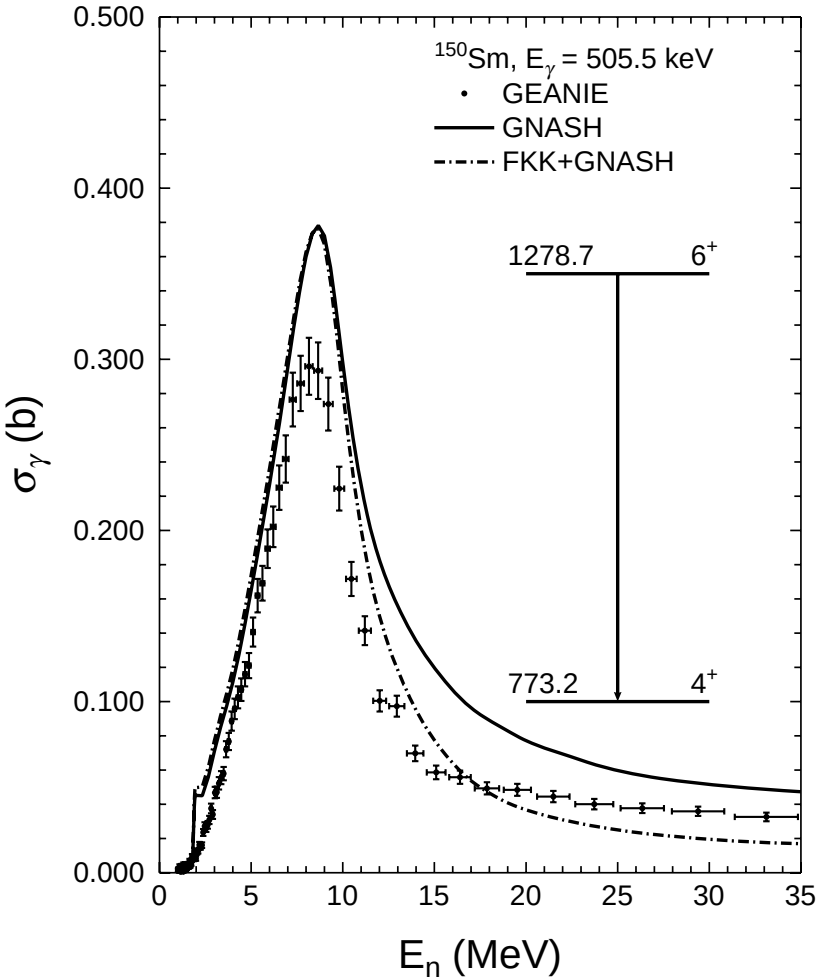


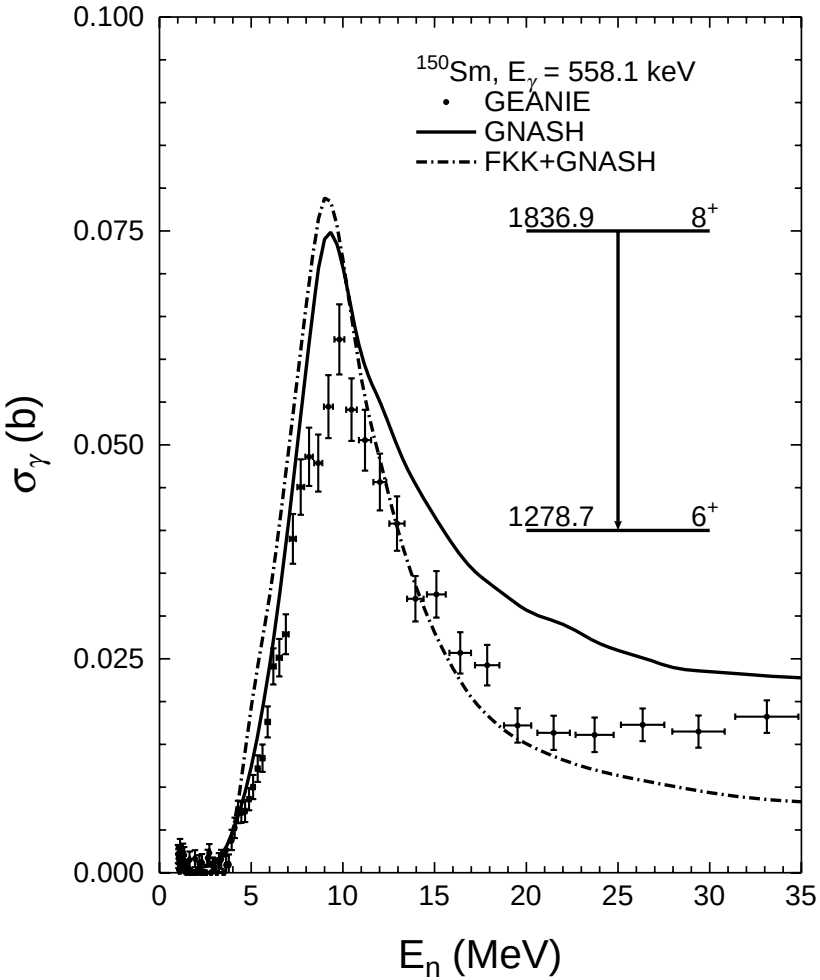


γ–ray transitions from low-spin states are enhanced.

dashdorj1@llnl.gov

Partial gamma-ray reaction cross section for the ^{150}Sm(n,n'γ)^{150}Sm transitions in ground state band

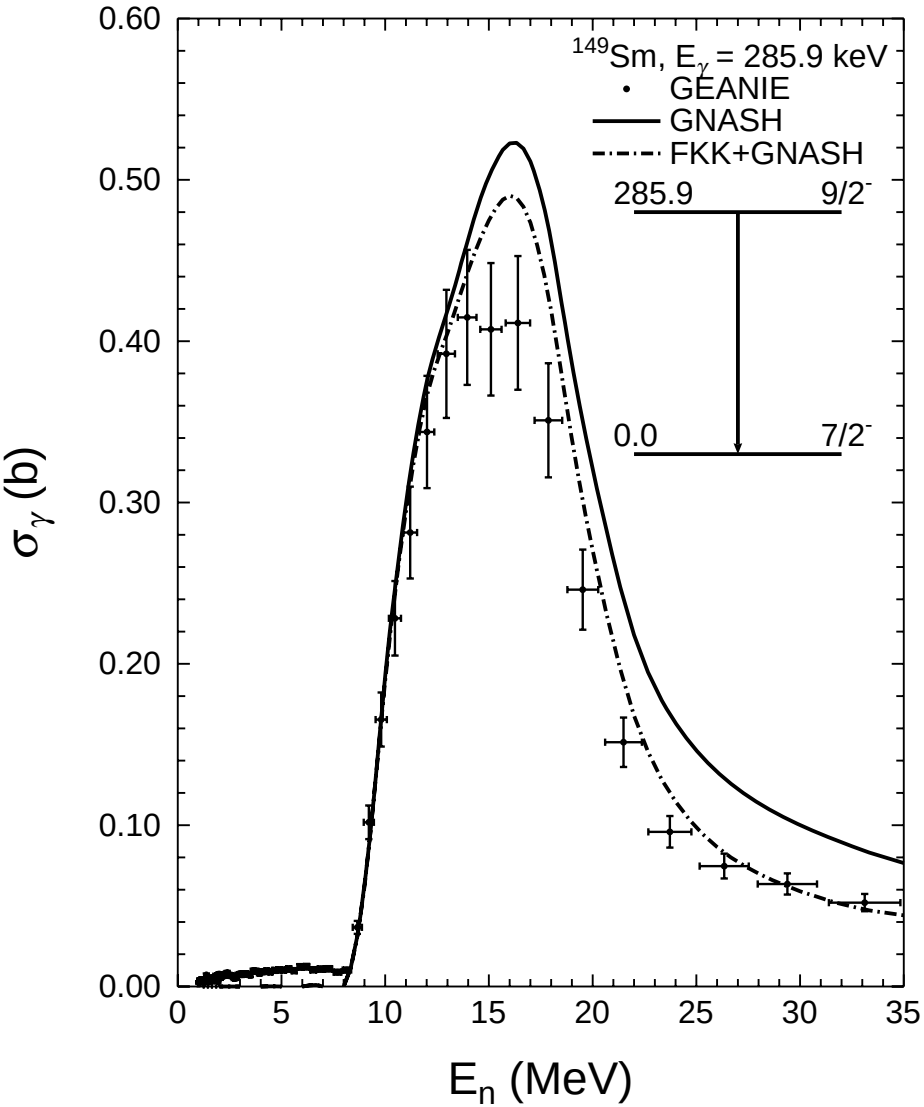


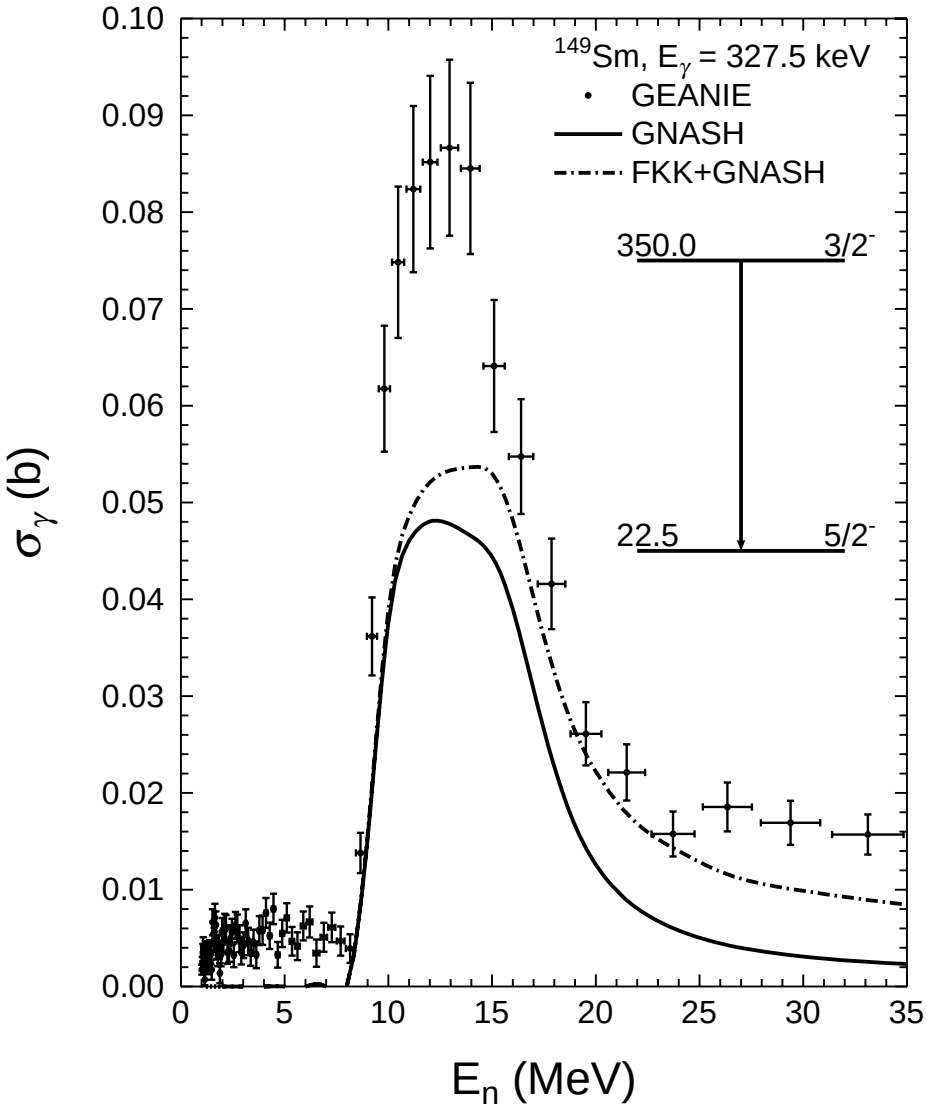


γ–ray transitions from high-spin states are suppressed.

dashdorj1@llnl.gov

Partial gamma-ray reaction cross section for the $^{150}Sm(n,2n\gamma)^{149}Sm$ transitions





dashdorj1@llnl.gov

Summary

- **Absolute partial γ-ray cross sections were measured as a function of incident neutron energies**
- **Spin distribution of the PE reaction was calculated using the FKK quantum mechanical theory**
- **The FKK spin distribution of PE was incorporated into GNASH calculation, and γ-ray production cross sections were calculated and compared with experimental data**
- **A probability of γ transition from a high-spin state is strongly suppressed and a low-spin state is enhanced because of PE spin distribution, in good agreement with the experimental data**
- **GEANIE combined with WNR is powerful tool to study reaction dynamics, gives unique opportunity to check reaction models**

dashdorj1@llnl.gov

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G. E. Mitchell
North Carolina State University, Raleigh, NC and
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J. A. Becker, C. Y. Wu, W. Younes
Lawrence Livermore National Laboratory, Livermore, CA.

M. B. Chadwick, M. Devlin, N. Fotiades, T. Kawano, R. O. Nelson
Los Alamos National Laboratory, Los Alamos, NM.

P. E. Garrett
University of Guelph, Ontario, Canada