# $^{40}Ca(\alpha,\gamma)^{44}Ti$ reaction in the regime relevant for supernovae nucleosynthesis

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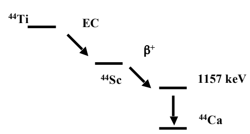
## Abstract

The $^{40}Ca(\alpha,\gamma)^{44}Ti$ reaction is the main production reaction for the radioactive nuclei $^{44}Ti$, which serves as an important diagnostic for understanding explosive nucleosynthesis. A new self-consistent measurement of this reaction is proposed to determine the integral cross section below 4 MeV. An in-beam measurement using the University of Washington FN Tandem Van de Graaf will be followed by a low-background counting of the activation product. A report on the progress of this experiment is given.

## Introduction

The observation of short lived radionuclides from supernovae provide an important diagnostic for studying explosive nucleosynthesis. The detection of $^{44}Ti$ through its 1157 keV γ-ray line by the COMPTEL observatory has generated a great deal of interest in $^{44}Ti$ since the yield of the 1157 keV provides a direct observational test for nucleosynthesis models. Currently, the observation of $^{44}Ti$ from known and unkown supernovae has a high priority for γ-ray astronomy.



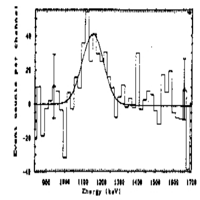



Fig. 1. Sum of the background-subtracted spectra of observation periods 34 and 211. Typical error bars are shown

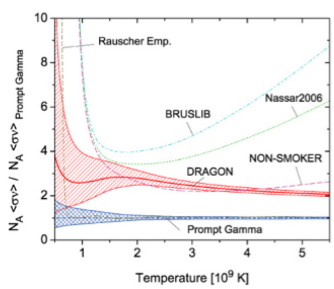
Observation of the 1157 keV gamma-ray from the decay of $^{44}Ca$ as observed by the COMPTEL gamma-ray observatory.

$^{44}Ti$ is produced primarily in the α-rich freeze-out from nuclear statistical equilibrium in core-collapse supernovae. The calculation of the the $^{44}T$ yield depends on the mass cut, the pre-supernovae composition, and the maximum temperature and density reached in the ejecta. It also depends upon the nuclear reaction rates related to $^{44}Ti$ production. All of which are quite uncertain. Since the $^{40}Ca(\alpha,\gamma)^{44}Ti$ reaction is the main reaction responsible for $^{44}Ti$ nucleosynthesis, it has a strong influence on the $^{44}Ti$ yield.

## Previous Measurements

The $^{40}Ca(\alpha,\gamma)^{44}Ti$ reaction was studied in the past by prompt γ-ray spectroscopy[1] in the energy range $E_\alpha$ = 2.7-4.6 MeV corresponding to a temperature of $T_9$ = 1.2-2.2 ($T_9 = T/10^9$ K). Recently, an off-line integral measurement[2] using Accelerator Mass Spectroscopy (AMS) for counting $^{44}Ti$ atoms following an irradiation of a He gas target by a $^{40}Ca$ beam. The AMS increased the supernovae yield of $^{44}Ti$ by a factor of ~2 compared to the prompt γ-ray result. An even more recent measurement of the reaction rate by the recoil mass spectrometer DRAGON[3] gives a reaction rate intermediate between the prompt γ-ray and the AMS reaction rates. Given that a precision of greater than ~20% is needed for this reaction additional measurements are needed to help constrain the true reaction rates.

[1]W.R. Dixon *et al.*, Phys. Rev. C **15**, 1897 (1977).
[2]H. Nassar *et al.*, Phys. Rev. Lett. **96**, 041102 (2006).
[3]C. Vockenhuber *et al.*, Phys. Rev. C **76**, 035801 (2007).




Comparison of the $^{40}Ca(\alpha,\gamma)^{44}Ti$ reaction rates relative to the rate calculated from prompt gamma-ray spectroscopy.

## Proposed Experiment

The proposed experiment would measure the integral cross-section of $^{40}Ca(\alpha,\gamma)^{44}Ti$ from $E_\alpha$ = 0 to 4 MeV in two different ways:

1. Measure the production of $^{44}Ti$ using in-beam gamma-ray spectroscopy by identifying the 1083 keV transition to the ground state of $^{44}Ti$ while also measuring the beam current.
2. Count the same target post-irridiation in a low background counting environment to measure the 1157 keV γ-ray of $^{44}Ca$. γ

**End result is an integral cross-section for $^{40}Ca(\alpha,\gamma)^{44}Ti$ measured two different ways for an uncertainty of 5% each.**

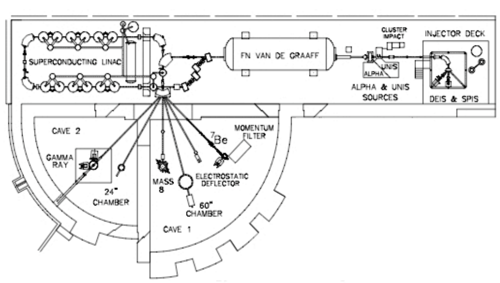



Figure 3.1: University of Washington FN Tandem Van de Graaff accelerator, located at the UW Center for Experimental Nuclear Physics and Astrophysics

## Experimental Details

- Measurement planned at the 9-MV Tandem Van de Graaf accelerator located at the Center for Experimental and Nuclear Astrophysics at the University of Washington.
- In order to reduce oxygen and carbon contaminants a calcium target will be created *in-situ* by evaporating metallic calcium onto a copper backing.
- The target thickness will be determined by measuring the range of a $H^+$ beam in the calcium target.
- Two 80% Ge detectors will be used for the in-beam γ-ray spectroscopy as well as the counting of the 1157 keV γ-ray in the post-irridiation part of the experiment.

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## Status

- Data acquisition and target development will be done at LLNL before moving to the University of Washington.
- The experiment will be performed in January/Febuary of 2008.
- The $^{40}Ca(\alpha,\gamma)^{44}Ti$ reaction possibly first in a series of a-capture reactions on self-conjugate nuclei (N=Z) that may be performed at a future Pelletron facility at LLNL.

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