# Isomer population control via direct irradiation of solid density targets using a compact laser-plasma accelerator


NSSC Nuclear Science & Security Consortium

R. E. Jacob[1,2], S. M. Tannous[1], L. A. Bernstein[1,2], J. Brown[1], T. Ostermayr[2], Q. Chen[2], D. H G. Schneider[3], C. B. Schroeder[2,1], J. van Tilborg[2], E. H. Esarey[2], C. G R. Geddes[2]

[1]University of California, Berkeley, [2]Lawrence Berkeley National Laboratory, [3]Lawrence Livermore National Laboratory


Poster #9

## Introduction

Long-lived nuclear isomeric states are difficult to access directly due to their narrow energy widths. Multi-MeV nuclear excitation into the "quasicontinuum" coupled with nuclear plasma interactions (NPIs) may provide means of manipulating populations of large ΔJ isomers. Relevant QC properties include:

- Gamma Strength Functions ($\gamma$SFs)
  - Ability to emit or absorb a photon of a given energy
- Nuclear Level Densities (NLDs)
  - Density of available states in #/MeV

An interesting case: $^{242m}$Am, nuclear fuel cycle byproduct

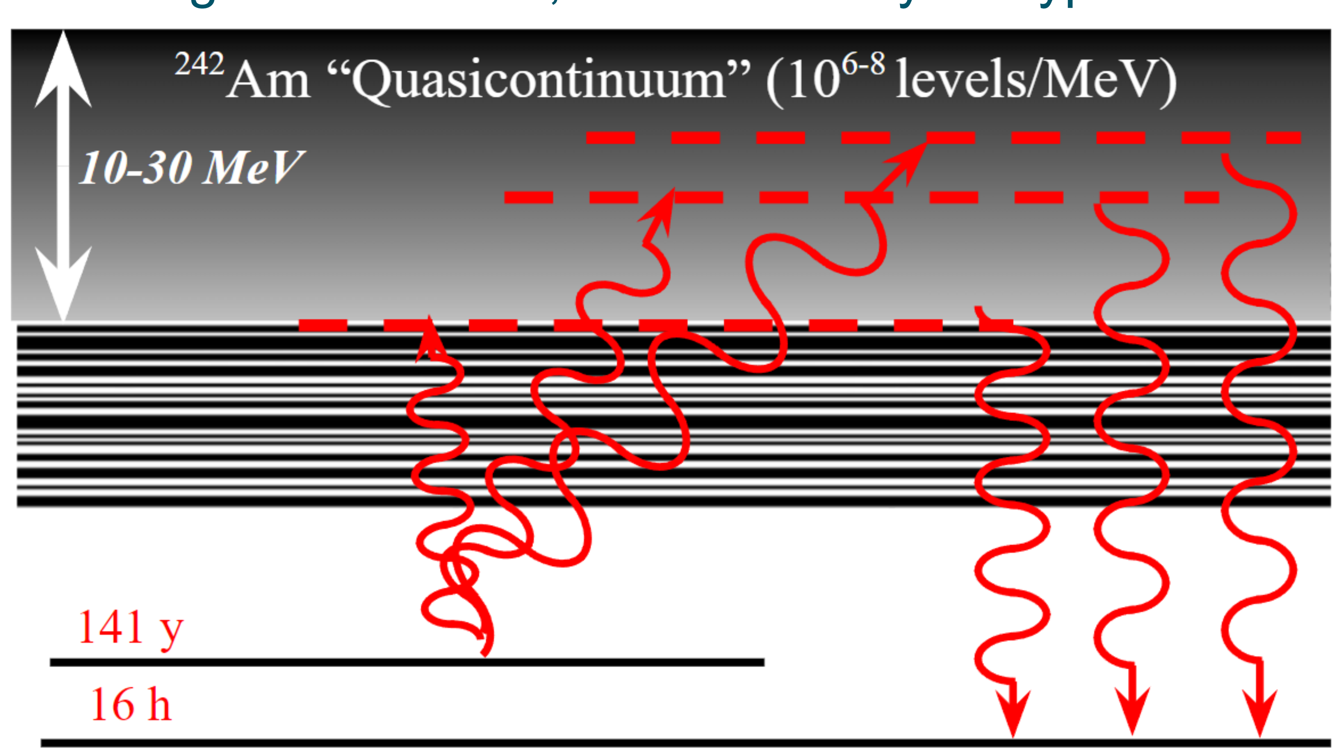


Figure 1: $^{242m}$Am isomer depopulation via excitation into the quasicontinuum followed by de-excitation to the ground state

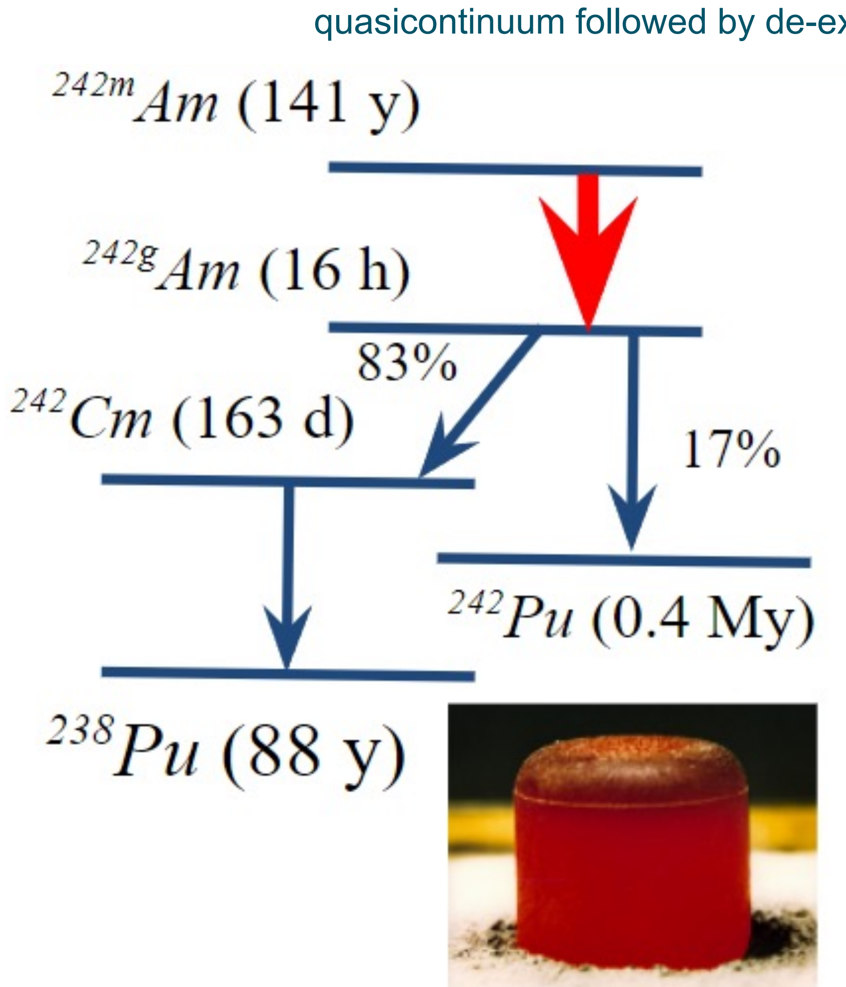


Figure 2: $^{242m}$Am decay chain, resulting in the formation of $^{238}$Pu, an isotope useful for radioisotope thermal generators

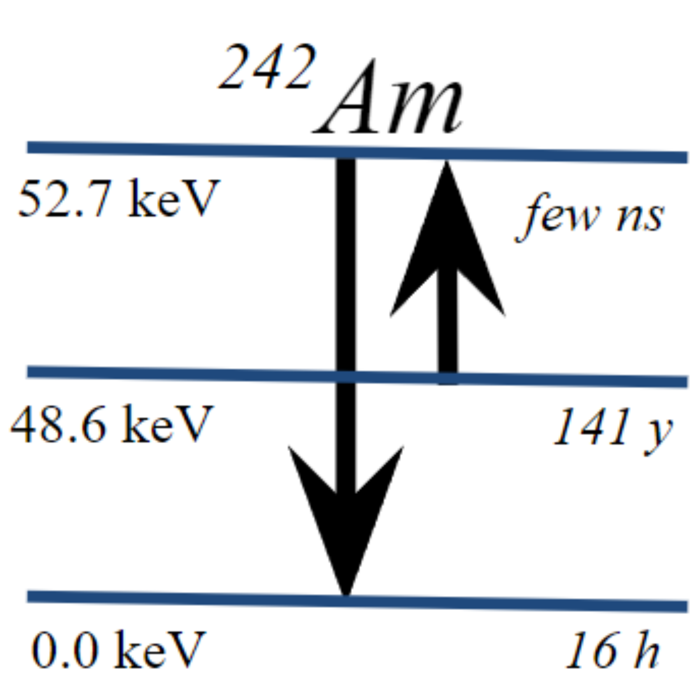


Figure 3: Example traditional excitation scheme, with direct excitation to next available level, followed by de-excitation to the ground state

## Proof of Concept with $^{79}$Br in an $LaBr_3$ Detector

- Primary Goal: Observe population of the 4.85 s half-life isomer in $^{79}$Br nuclei after exciting nuclei into the quasicontinuum
- Direct irradiation of solid density $LaBr_3$ "active targets"
  - Electron beam at 35 MeV
  - Bremsstrahlung photons
- Performed at the BELLA 100 TW laser-plasma accelerator, part of a DNN R&D developed mono-energetic photon source facility
- Ultrashort (<100 fs) electron pulses can enable nuclear-plasma interactions to occur within the active targets

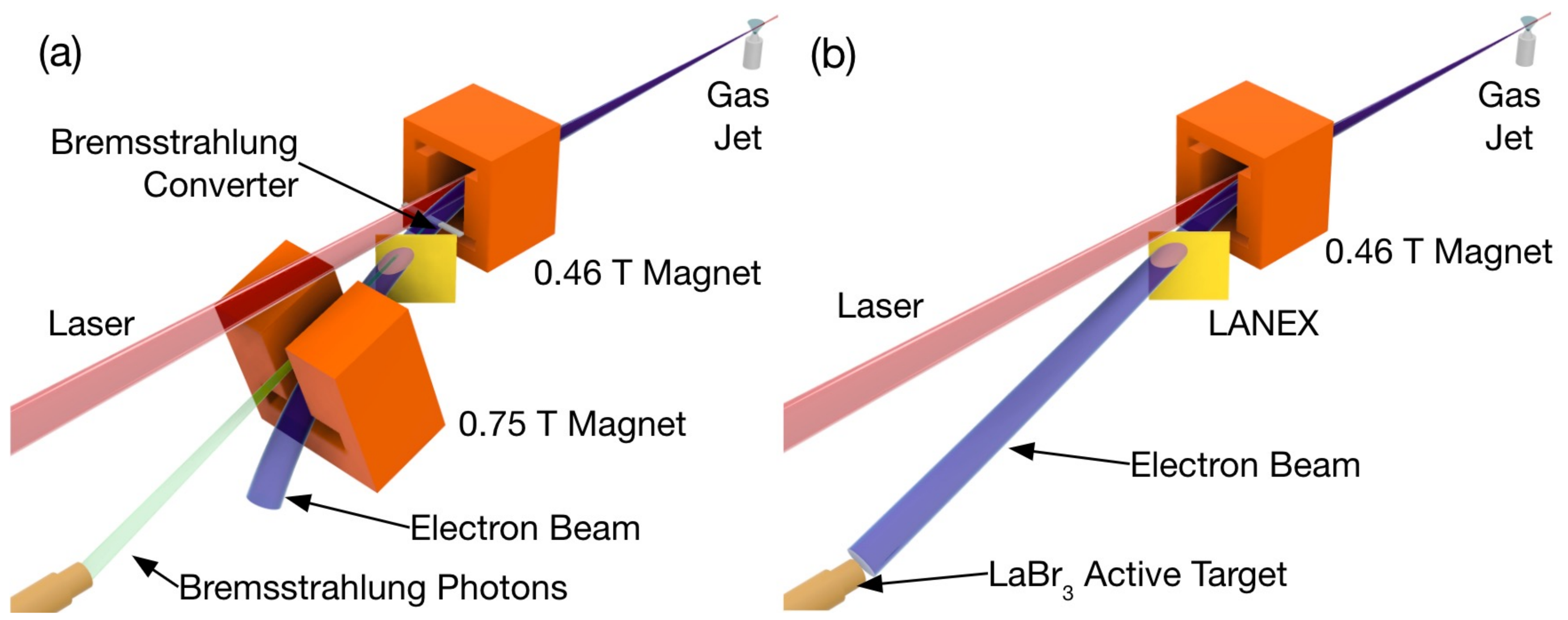


Figure 4: Experimental layout with (a) showing the bremsstrahlung irradiation case, and (b) showing the electron irradiation case. Note the LANEX screen was motorized to allow for characterization of the electron beam without producing unwanted bremsstrahlung photons

## Analysis

- Identified decay signals from $^{79m}$Br and $^{80m}$Br for both cases of irradiation
  - $^{79m}$Br (207.6 keV $\gamma$): $^{79}$Br($\gamma$, $\gamma$')$^{79m}$Br, $^{81}$Br($\gamma$,2n)$^{79m}$Br
  - $^{80m}$Br (85.84 keV $\gamma$): $^{81}$Br($\gamma$, n)$^{80m}$Br
- Determined activation/shots and activation ratios for each case, to remove dose dependency
- These ratios were compared with TALYS calculated $^{79m}$Br/$^{80m}$Br values

| Case | $^{79m}$Br [#/Shot] | $^{80m}$Br [#/Shot] | $^{79m}$Br/$^{80m}$Br |
|---|---|---|---|
| Photons | 13.21±1.29 | 566.23±17.48 | 0.023±0.0024 |
| Electrons | 26.25±0.80 | 787.50±26.10 | 0.033±0.0015 |

Table 1: Calculated number of activations/shot for each irradiation case, with the $^{79m}$Br/$^{80m}$Br ratio of these values shown.

## Results

- TALYS calculations were performed for all combinations of NLDs and $\gamma$SFs to generate $^{79m}$Br/$^{80m}$Br activation ratios
- Best matches (~0.07) were further adjusted within TALYS parameters in an attempt to approach experimental observations, but only changed ~10%
- Direct manipulation of microscopic level density distributions was performed, via spin-distribution shifts
- Best match (0.03) to experimental data was achieved with a +5$\hbar$ shifts for $^{79}$Br, $^{80}$Br, and $^{81}$Br
- Required shifts may indicate influence from the g9/2$^+$ orbital near the fermi surface in Bromine nuclei

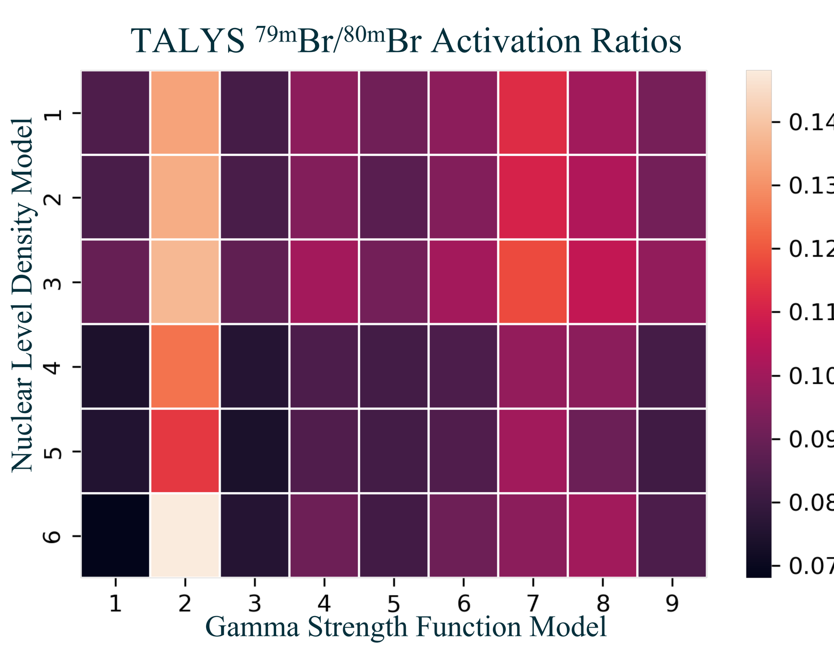


Figure 5: Heatmap of $^{79m}$Br/$^{80m}$Br activation ratio for all combinations of NLD and $\gamma$SF models in TALYS

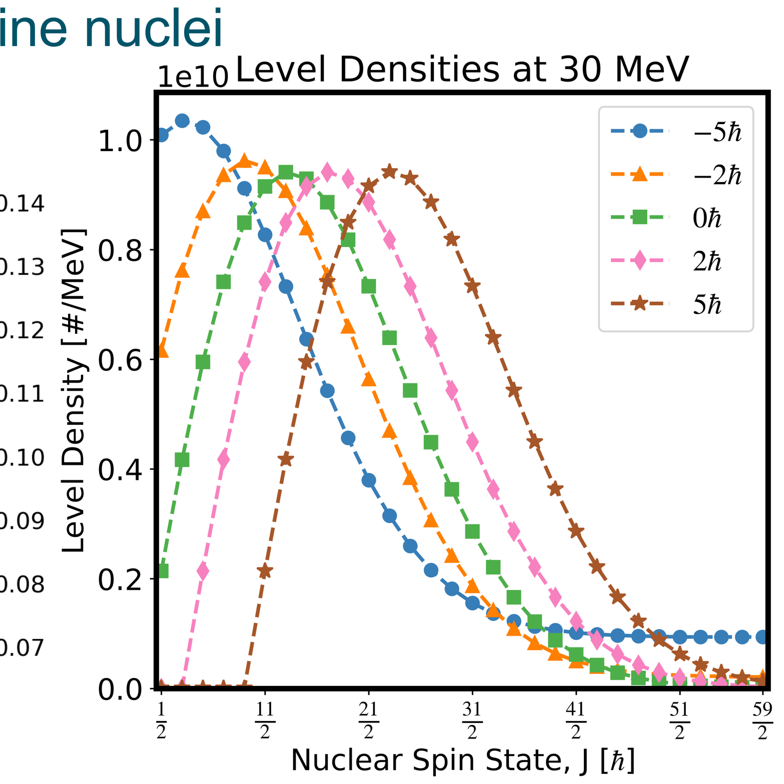


Figure 6: Example of spin shifted nuclear level density distributions performed

## Mission Relevance

- Experimental data for comparison to nuclear structure models
- Progress towards measuring the impacts of nuclear-plasma interactions in high energy density environments
- Time delayed signals for nondestructive photon interrogation

## BELLA 100 TW Thomson Laser System for NSSC Goals

- Platform for the development of non-destructive target evaluation methods using a compact laser-plasma accelerator based quasi-monoenergetic MeV photon source
- Source can enhance and enable metal target radiography, computed tomography, single-sided 3D imaging, photofission, and nuclear resonance fluorescence material identification methods


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