Contribution ID: **2** Type: **not specified**

Genetic Algorithm Modeling of ^{47}Sc Production via Proton Irradiation of ^{49}Ti

Thursday 2 October 2025 17:10 (20 minutes)

The β^--emitting radionuclide ^{47}Sc is an attractive theranostic agent for nuclear medicine, offering both SPECT imaging capabilities and therapeutic efficacy for small tumors. However, its clinical deployment remains limited by production challenges, including insufficient radionuclidic purity, low yields for some reaction channels, and reliance on restricted infrastructure. In cyclotron-based irradiation of enriched ^{49}Ti, long-lived impurities such as ^{48}Sc and ^{46}Sc are co-produced through competing reactions, complicating purification compliance and increasing the dosimetric burden for patients. Reactor-based alternatives are not universally accessible and present logistical constraints.

In this study, we analyze the ^{49}Ti(p,x)^{47}Sc reaction using the TALYS 1.95G nuclear reaction code [1,2], calibrated against the only available experimental cross-section dataset for this route, recently reported by Pupillo et al. [3]. A genetic algorithm (GA) is employed to optimize twelve level-density parameters across six compound nuclei and nine reaction channels, including ^{46}Sc, ^{47}Sc, ^{48}Sc, ^{43}Sc, ^{44}Sc, ^{42}K, ^{43}K, and ^{48}V. This represents the first application of GA-based joint optimization across multiple reaction pathways for a medically relevant radionuclide, demonstrating the feasibility of integrated AI-driven calibration in nuclear modeling.

The GA-driven optimization significantly improves the agreement between TALYS description and measured data. However, the refined simulations confirm that high co-production of ^{48}Sc and ^{46}Sc are intrinsic to the proton–^{49}Ti reaction path. As a result, this route remains unsuitable for routine clinical applications.

These findings emphasize the potential of evolutionary algorithms for nuclear model tuning and underscore the need for alternative production strategies. The methodology provides a scalable framework for integrating AI into predictive nuclear theory and applied isotope research.

References

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Authors: LASHKO, Yuliia (Istituto Nazionale di Fisica Nucleare, Sezione di Padova, Italy; Bogolyubov Institute for Theoretical Physics, Kyiv, Ukraine); BARBARO, Francesca (Istituto Nazionale di Fisica Nucleare, Sezione di Padova, Italy; Dipartimento di Fisica e Astronomia, Università di Padova, Italy); ZANGRANDO, Lisa (Istituto Nazionale di Fisica Nucleare, Sezione di Padova, Italy); CANTON, Luciano (Istituto Nazionale di Fisica Nucleare, Sezione di Padova, Italy)

Presenter: LASHKO, Yuliia (Istituto Nazionale di Fisica Nucleare, Sezione di Padova, Italy; Bogolyubov Institute for Theoretical Physics, Kyiv, Ukraine)

Session Classification: Short contributions (V)