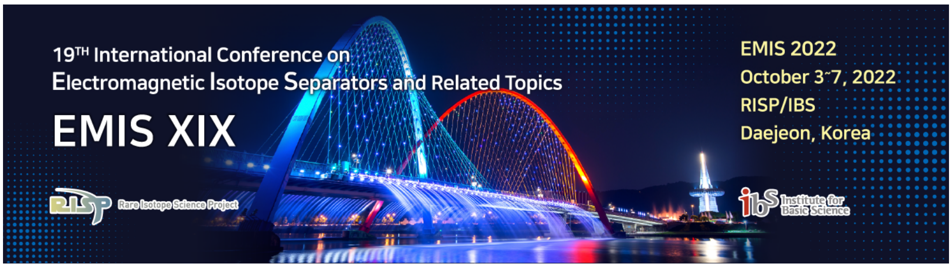

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Understanding radioactive ion beam production at TRIUMF-ISAC through yield measurements and simulations

Monday, 3 October 2022 17:26 (8 minutes)

The high-intensity proton beam of the TRIUMF H^- 500 MeV cyclotron offers unique opportunities to produce rare isotopes by irradiating a variety of targets. In particular, the ISAC (Isotope Separation and ACceleration) facility [1] provides the infrastructure to deliver customized rare ion beams to experiments in the fields of nuclear structure, astrophysics, medicine, and material science. ISAC target stations can host a wide range for targets, from graphite to uranium carbide. Each target material generates a unique set of isotopes through nuclear reactions induced by the proton beam.
A continuous effort is underway to develop new radioactive ion beams (RIB) and improve their intensity or purity, properties that depend strongly on the type of target, operating conditions, the ion source, and beam transport efficiency. However, isotopically pure RIBs are not always achievable due to limitations on the selectivity of the ion source and the resolution of mass separation. Instead, RIBs can consist of a variety of atomic and molecular isobars with beam intensities sometimes spanning over more than 10 orders of magnitude.
An important tool to characterize RIB compositions, using α, β and γ spectroscopy, is the ISAC Yield Station [2]. Most of the close to 1000 radioactive isotopes and isomers so far documented in the TRIUMF Isotope Database [3] have been identified and quantified by it. Other diagnostic tools include Faraday cups, channeltron detectors and, more recently, the TITAN MR-TOF mass spectrometer, which can identify extremely weak RIB [4].
The yield data on various target-ion-source combinations, operational settings and mass-over-charge ratios in the database is complemented by theoretical production rate simulations based on FLUKA and GEANT4 models, two of the most common tool kits for calculating the interactions of high-energy particles with matter. Both experimental and theoretical data sets provide valuable input for RIB development and experiment planning.
In this contribution we will discuss examples where the combination of yield data with GEANT4 simulations is used to determine the release time of an element from a target, to plan an experiment and understand the correlation between alternative production pathways for certain isotopes and the measured yield:

• The average release time of francium from a uranium carbide target was determined by minimizing the ratios of measured yield over calculated production rate for the relatively long-lived isotopes $^{211-213}$Fr and the short-lived ^{214}Fr to a time-dependent release model [5].
• The collection of up to 370 MBq of ^{155}Tb for nuclear medicine research showcases how simulation data helps to determine the choice of ion source to maximize the yield of precursors of ^{155}Tb and how yield results are used to determine the length of RIB collection and cool-down periods [6].
• Recent upgrades of the GEANT4 model for ISAC targets provided quantitative information on direct and indirect production channels for ^{239}Pu from ^{238}U. Comparison with the measured ^{239}Pu yield helps to gain a better understanding of the release properties of neptunium and plutonium [7].

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3. TRIUMF Isotope Database, 2022 URL: https://yield.targets.triumf.ca
4. Reiter, M. P., et. al., NIM B 463 (2020) 431–436
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