Nuclear Verification and Disarmament Group

Bachelor’s and Master’s theses topics 2021

Precise and correct nuclear material accounting is crucial for the management of radioactive substances such as uranium, plutonium and nuclear waste. While peaceful uses of these materials exist (e.g., nuclear power plants), uranium and plutonium are also the main components of nuclear weapons. Thus, reliable scientific methods are needed to prevent or detect diversions of nuclear material.

This working group seeks to develop new methods to reconstruct past and verify current fissile material production and inventories. Such methods can for example be used to independently assess the fissile material stocks of states such as North Korea or they can be used by state officials to estimate their own stocks.

Uranium enrichment

- Bachelor’s thesis:

  Uranium is mainly composed of two isotopes, U-235 and U-238, and the process of increasing the relative U-235 content of uranium is called enrichment. This is required for nuclear weapons, but also for reactor fuel. The most efficient enrichment process, the ideal process, is described by an analytical model and it does not exist in reality. In this thesis, you will investigate some of the assumptions used in this model. For this, you will implement and use a more precise simulation model, calculate various enrichment processes and compare these results to the ideal process.

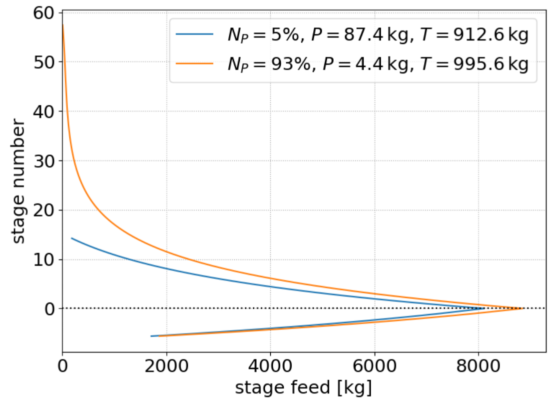

Figure 1: Material flow per stage in an ideal enrichment process

Antineutrino measurement for the monitoring of nuclear waste repositories

- Bachelor’s and Ḿaster’s theses:

  Neutrinos below 5 MeV are of particular interest in neutrino physics, e.g. for the study of solar neutrinos and geoneutrinos. This also applies to a new concept for monitoring radioactive waste repositories, in which we measure the neutrinos produced by the radioactive isotopes present in the waste. For this purpose, a Time Projection Chamber is being developed that uses an organic liquid to detect low-energy neutrinos. During your thesis, you will simulate antineutrino interactions in the detector and you will simulate the

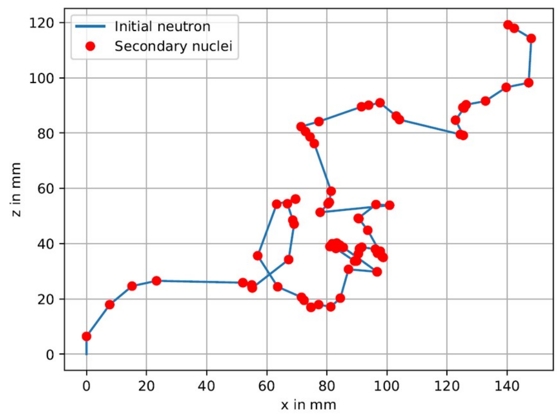

Figure 2: A trajectory of a neutron in the Time Projection Chamber, which was produced by an antineutrino interaction.

monitoring of a nuclear repository with said detector. Alternatively, you could be part of the construction of a prototype detector.

Reactor simulation

- Master's thesis:

  The plutonium production of a nuclear reactor can be reconstructed using trace isotope measurements of reactor elements. In this thesis, you will create a model of a nuclear reactor and use this in an (already existing) Monte Carlo Reactor Physics code. Thus, you can study the time evolution of trace isotopes and validate your model and results by using available data. Finally, you will learn to use sensitivity analysis to evaluate the impact of various simulation parameters on the output of the model.

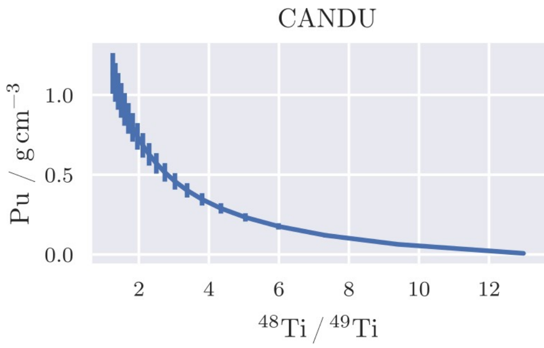

Figure 3: Determining the plutonium production using the isotopic ratio of Ti-48 and Ti-49 in a CANDU nuclear reactor

Concerning all topics: no prior knowledge on enrichment, nuclear reactors, or specific software is required. You will learn about these topics, about numerical simulations and statistical methods over the course of your thesis.

Contacts Prof. Malte Göttsche: goettsche@aices.rwth-aachen.de

Website: https://www.nvd.rwth-aachen.de/