Evaluating the detectability of fissile material

Geant4 Monte-Carlo simulation in the context of nuclear disarmament verification

Manuel Kreutle, Gerald Kirchner

Universität Hamburg
Carl Friedrich von Weizsäcker-Centre for Science and Peace Research, Hamburg, Germany

Introduction

Key challenges of nuclear disarmament verification (NDV):

- Develop measurement procedures and devices to determine the **presence or absence of fissile material** (and shielding)
- Problem: Information only partially available due to **shielding** and **proliferation concerns**
- Simulations (verified with experimental data) can help to assess questions which are experimentally difficult to execute due to **resource limits, restricted access to fissile material, safety risks and radiation protection**

Method

At SCK-CEN in Mol, Belgium, close-to-weapons-grade plutonium, present as unirradiated plutonium-uranium mixed oxide (MOX) fuel rods, was investigated:

- **Different shielding materials in varied thickness, fuel amounts and isotope vectors** were examined
- For these configurations **spontaneous fission** (SF) and **(α,n) spectra** were calculated with Geant4

Results

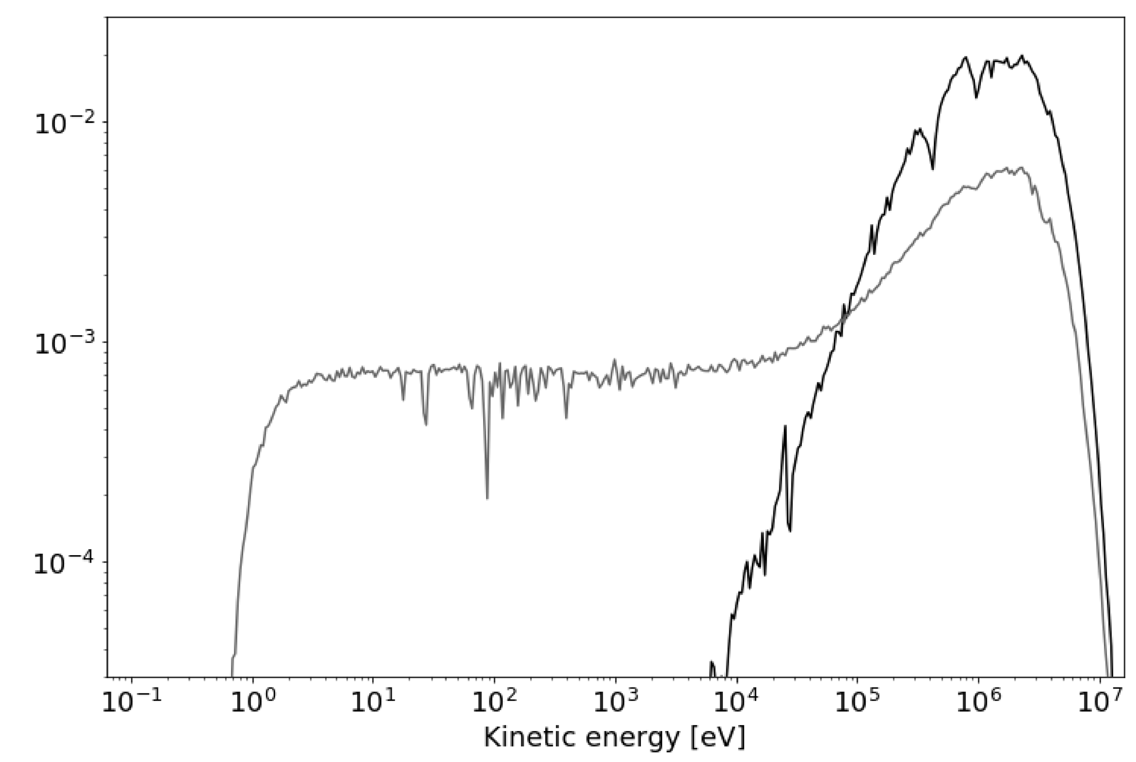


Figure 1: Comparison of bare (black) and 5 cm Polyethylene, 0.11 cm Cadmium, 1 cm Lead shielded (gray) SF neutron spectrum.

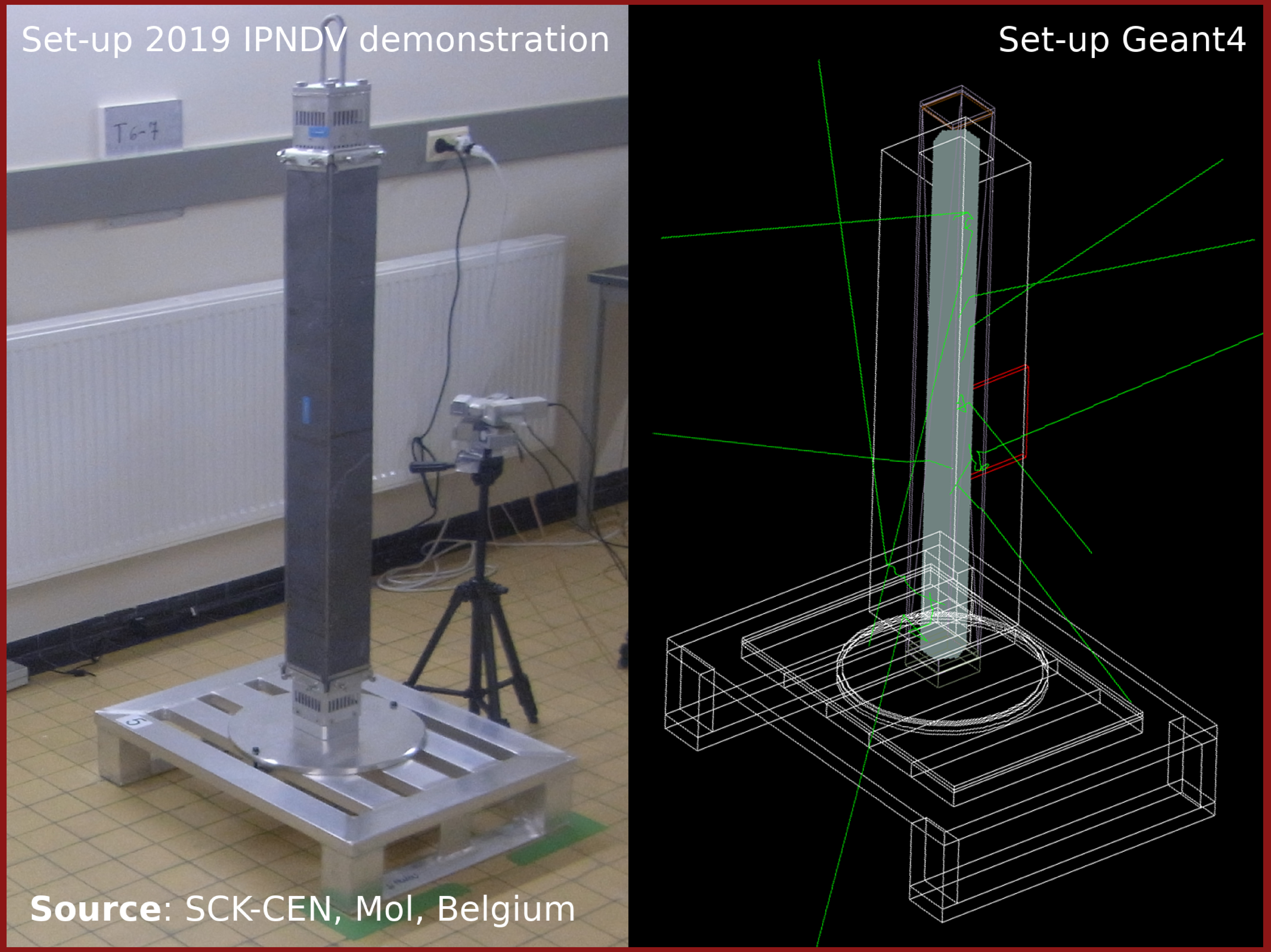
Conclusion:

- strongest signal reduction for PE+Cd+Pb shielded configuration
- neutron signal: variations in isotope composition only detectable trough change in flux (due to change of activity)

Perspectives

→ Simulate **floor and walls** to calculate neutron reflection
→ Include **effect of various detectors** on signals
→ **Evaluate further methods**, e.g. active measurement techniques

Monte-Carlo simulations of the 2019 Mol configuration allow to evaluate the **detectability of fissile material** in various scenarios.



The poster and the whole study are available at:
www.znf.uni-hamburg.de/forschung/publikationen

Geant4: Open-source toolkit for simulation of particle passage through matter, **developed at CERN** (Geneva, Switzerland)
→ most common databases were used (ENDF/B-VIII, ENSDF, ...)

Data output: **neutron multiplication factor k_{eff}**, neutron **spectrum and flux** in reference area (20 cm x 20 cm in 10 cm distance from centre of element)

Shielding:

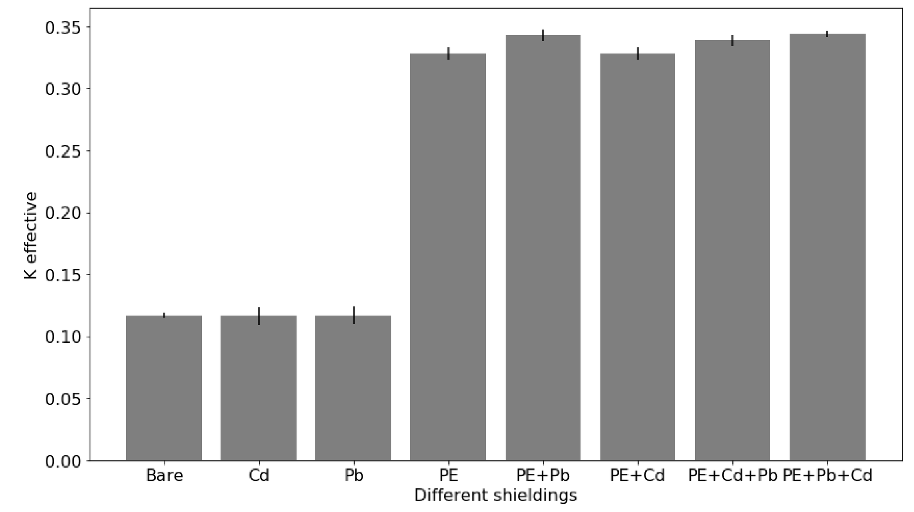


Figure 2: Different shielding and corresponding k_{eff}.

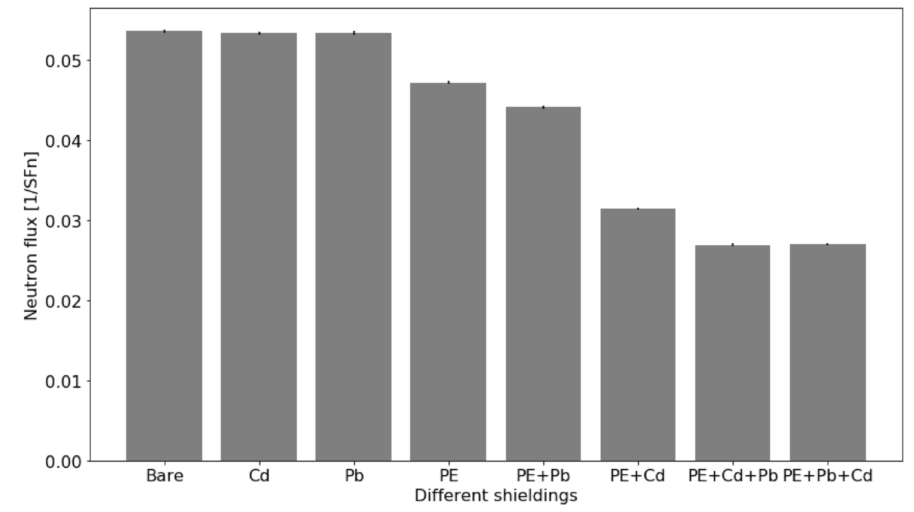


Figure 3: Different shielding and corresponding neutron fluxes.

Isotope vector:

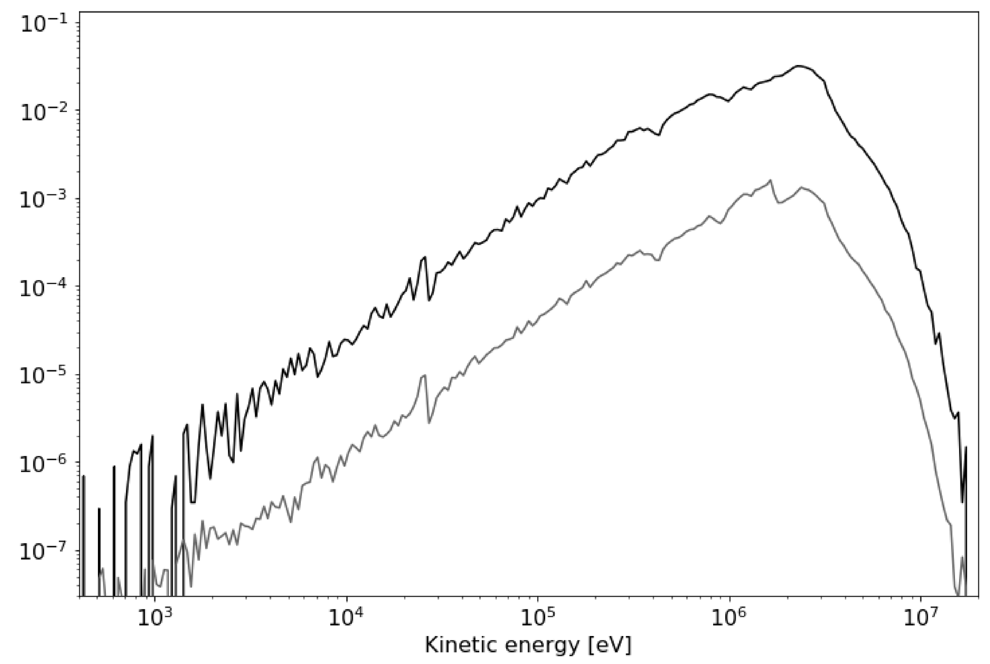


Figure 4: Superposed SF and (α,n) neutron spectra for Long (black) and short configuration (black).

Interpretation:

- All changes within limits of given configuration lead to significant change in neutron signals
- Varying isotope composition while changing amount to maintain flux might lead to very small change in neutron signals

Extension and outlook:

- Work will be extended by **gamma signal contribution** to investigate effect of combined measurements
- Interesting to study: **small variation scenarios** with strong shielding
  → if signal changes still too small: active measurements?