# Monte Carlo method in applications of nuclear techniques

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## Introduction

The Monte Carlo calculation technique can be applied to a wide variety of applications in the radiation field, such as radiological protection, nuclear installations, volume fraction in multiphase flows, shielding of radiation and to calculate efficiency of detectors, among several others purposes. The Monte Carlo technique is a widely used simulation tool for radiation transport, mainly in situations where measurements are inconvenient or impracticable, including gathering data for artificial neural networks input.

## MCNP-X mathematical code

The MCNP-X code [1] is a general purpose Monte Carlo radiation transport code designed to track different types of particles (neutrons, electrons, gamma rays, etc.) over a broad range of energies. The code rather obtains the solution of the problem by simulating individual particle trajectories and recording some aspects of their average behavior (it does not solve the Boltzmann particle transport equation). The individual probabilistic events that comprise a process of interaction of nuclear particle with material are simulated sequentially. The probability distributions governing these events are statistically sampled to describe the total phenomenon and the sampling process is based on the selection of pseudo-random numbers. The process consists of following each of many particles since its emission from a source until it reaches an energy threshold; the particle energy is transferred to the medium by absorption, escape, physical cut-off, etc. Probability distributions are randomly sampled using transport data to determine the outcome at each step of its trajectory. The quantities of interest are tallied, along with estimates of the statistical precision of the results. The MCNP-X code can be used to simulate gamma-rays interactions which comprise: i) incoherent and coherent scattering; ii) the possibility of fluorescent emission after photoelectric absorption; iii) pair production with local emission of annihilation radiation and *Bremsstrahlung* effect. Additionally, electron trajectories were tracked.

## Results and Conclusions

- A procedure for simulation of a NaI(Tl) detector has been presented with the MCNP-X computer code. It consists of measuring two point sources at different locations around the detector and compared to the simulation results; the crystal dimensions was then adjusted accordingly until a match between the experimental and simulated results. The parameters of the real energy resolution of the detector obtained by experimental measurements were considered in the simulation. The photon detection efficiency curve was used for the validation of the mathematical model developed in the code. The efficiency curve was obtained both experimentally and by simulation; the results were compared and showed a good agreement. The methodology using two radioactive sources, a low and one high-energy photon, was found to be satisfactory to fit the dimensions of the crystal to be used in the detector's simulation [2].

- The use of code MCNP-X played a very important role in data generation for ANN training. It eliminates problems associated with availability of radioactive sources, detectors and representative test section of each flow regime in the initial phase of the project. Moreover, it allowed parameter optimization (system's geometry, energies, number of detectors, etc.), which may facilitate an initial development of an experimental arrangement with the proposed methodology. The ideal and static theoretical models for annular, stratified and homogeneous regimes in multiphase flows have been developed using MCNP-X code, which was used to provide training, test and validation data for the ANNs, avoiding the use of experimental data [3].

## References

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