Computational Analysis of the Discrete Ordinates Adjoint Function Applicability in VVER Monte Carlo Modelling

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Abstract. The Monte Carlo method code MCNP has an extensive application in the nuclear physics research. It is commonly used for modelling detectors response in experiments' set-ups, cross-sections behaviour, nucleus production from different reactions, etc. This spread is due to the major advantages the Monte Carlo method has over the other methods for numerical modelling of particles transport namely: possibility to obtain identity of the source and the geometry of the model for calculations with the physical object, integrated visualization of the model's geometry; continuous energy representation of the cross sections available in the software's libraries. Important drawback of the Monte Carlo method, connected with its statistical nature, is the necessity of obtaining sufficient statistics for achieving reliable calculational results. This may not be well visible in the aforementioned cases, due to the simple geometries and high fluxes typically used in such problems, but in bigger and more sophisticated systems like nuclear reactors, radiotherapy facility, radioactive waste storage and other such complex facilities it is often impossible to reliably evaluate the particle flux. For this reason less precise numerical approaches, like the Discrete Ordinates method, are still used as a standard in these areas of nuclear physics application. In order to benefit from the advantages of the Monte Carlo method, a number of statistical techniques for reducing the uncertainty of the results have been implemented in the MCNP code, and most complex among them is the Weight Windows Variance Reduction Technique. Due to its complexity, it is not straightforward to apply it in Monte Carlo calculation and significant effort and experience is needed to properly define the weight windows' input values. The possible use of the adjoint solution of the Boltzman Equation as an automated source for weight windows generation in the case of VVER-1000 benchmark transport calculations is presented in this paper. The numerical solution of the Boltzman Equation for obtaining the adjoint function is performed using the Discrete Ordinates TORT code. Interface software is used to translate the adjoint function into weight windows' input parameters. A deep penetration problem has been modelled for the VVER-1000 Mock Up, built at the NRI/Rez's LR-0 critical assembly for VVER-1000 benchmark studies. The neutron flux is evaluated in three locations lying on the centre of symmetry in radial direction and with increased shielding from the reactor core. The calculations are performed in three different approaches: by MCNP code using the weight windows obtained through the adjoint function, by MCNP code using weight windows created by the author through the standard procedure and by the TORT code. The results are compared in terms of integral fluxes and the validity of the adjoint function as a variance reduction method for VVER reactor Monte Carlo calculations is justified. Other possible areas of its application are discussed in the conclusion of the paper.