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The SVM Method for Fissile Mass Estimation through Passive Neutron Interrogation: Advances and Developments

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INTRODUCTION

Fissile mass estimation through passive neutron interrogation is now one of the main techniques for NDT of fissile mass estimation, due to the relative transparency of neutron radiation to structural materials- making it extremely effective in poorly characterized or dirty samples .

Passive neutron interrogation relies on the fact that the number of neutrons emitted (per time unit) due to spontaneous fissions from the sample is proportional to the mass of the detected sample. However, since the measurement is effected by additional neutron sources- mainly (α,n) reactions and induced fission chain in the tested sample, a naive estimation, assuming a linear correspondence between the mass of the detected sample and the average number of detections, is bound to give an over estimation of the mass. Since most passive interrogation facilities are based on ^{3}He detectors, the origin of the neutron cannot be determined by analyzing the energy spectrum (as all neutrons arrive at the detector in more or less the same energy), and a mathematical "filter" is used to evaluate the noise to source ratio in the detection signal. The basic idea behind the mathematical filter is to utilize the fact that the different neutron sources have different statistical attributes- in particular, both the source event rate and the distribution of the number of neutrons released in each event differs between the different sources. There for, by studying the higher moments of the neutron population, new information about the source to noise ration may be obtained.

The most well known method for doing so is the Multiplicity method [1], where the amplitude of the three sources (the spontaneous fission (SF) source, the (α,n) source and induced fission source) are correlated with the so called Singles, Doubles and Triples rate in the detection signal. Then, by solving a set of three equations with three unknowns, the amplitude of SF source may be isolated. Recently, the authors have introduced a new method, referred to as the SVM method (standing for Skewness, Variance and Mean), correlating between the amplitude of the three sources, and the first three central moments of the number of detections in a given (fixed) time interval [2].

While the new method has the same statistical convergence rate as the Multiplicity method (although a different random variable is sampled) , it enjoys a theoretical "flexibility", allowing us to take into consideration, with relative simplicity, physical effects that have so far been neglected in the physical models, such as the detector dead time effect.

In the present study, we introduce the reader with the SVM method from a practical point of view, demonstrate its advantages and discuss future prospects of the method.

In particular, we demonstrate the method on measurements taken at the JRC (Joint Research Center) at Ispra, Italy (and compare the results with the multiplicity method), and demonstrate how, by fairly simply modifications on the stochastic transport equation describing the dynamics of the distribution of the number of detections, we may obtain analytic formulas for dead time corrections [3] , active neutron pulsed source interrogation [4] and the effect of long fission chains on the measurement [5].

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