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Muonic X-rays for cultural heritage: technique overview and developments

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Muonic X-ray Emission Spectroscopy (μXES) is a novel technique in the broad field of non-destructive methods for cultural heritage analysis [1]. It relies on the interaction of a probe of negative muons with matter and the following emission of x-ray radiation. Since the muon mass is about 200 times bigger than the electron, the emitted X-rays are highly energetic and are characteristic of the emitting atom, making it possible to cover a wide part of the periodic table (from Lithium to Uranium). Thanks to the multi-elemental range, a negligible self-absorption effect of the x-rays and very low residual activity left in the sample after irradiation, μXES is a very powerful probe for material characterization, especially for historical samples [2,3]. In addition, by varying the muon beam energy, the muon stops at different sites inside the sample (in metals, up the centimeter scale), thus providing information both from the surface and from the bulk in the form of a depth profile. Given the novelty of the technique, there is a lot of room for improvements, especially for data processing and data interpretation. On this topic, Monte Carlo (MC) simulation software can provide a new way to approach the data analysis process. Among MC software, SRIM-TRIM is an established method for simulation of the interaction of particles within matter [4]. In this work, the results of simulations performed with SRIM will be presented, along with the results obtained with a Geant4 based simulation tool developed at the university of Milano Bicocca called "Arby"[5]. With Arby, it is possible to exploit all the tool provided by Geant4 in a more user-friendly approach. The simulation environment is defined by a configuration file and the simulation is run via command line. With both software, the information provided regards the number of muons topped in any given layer, that is then compared to the data collected during the real measurement. Here, results on the analysis of gilded metals will be presented. Moreover, Arby can be used not only to give an information of the number of muons stopped in each layer, but it can provide the X-ray spectra generated after the interaction of the muon with matter. However, the process is not yet reliable, since a lot of information are missing for high energy transition of high Z atoms. A solution to this issue could be provided by using another simulation software called "MuDirac"[6]. MuDirac is a Dirac equation solver that calculates the frequencies and probabilities of the transitions between levels of the muonic atoms. This software could be used to provide a database of transitions to be implemented in Arby. Here, preliminary results will be presented.

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Summary

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