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Probing beneath the surface without a scratch: Developments of elemental analysis using muons at ISIS

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Using negative muon emission spectroscopy (μXES) can yield unique information by determining the composition beneath the surface whilst being completely non-destructive and has been shown to be a powerful technique for non-destructive analysis of the elemental composition of precious/rare samples. The characteristic muonic X-rays emitted after muon implantation can be used as fingerprints to assign the presence and depth of a given element in a sample. The use of negative muons for elemental analysis has seen a rapid increase in demand, from cultural heritage, advanced manufacturing to energy materials, even though the instrument at ISIS is still under development.

In the past few years there has been some developments in data acquisition electronics, analysis techniques, and future instrument design and in this paper we will review some of the science highlights, and the recent developments, including:

New software has been developed (EVA) to assist in the understanding, this includes easy peak identification, composition analysis and data correction.

Mudirac: A Dirac equation solver for elemental analysis with muonic X-rays is being extended to include the probability of transition, thus potentially making an automatic efficiency and absorption correction.

In addition, a machine learning (mulspec_ml) based technique for analysing and classifying elemental composition from μXES experiments has been developed (see abstract Butler).

Finally, studies for the next generation instrument are in place. The current set-up is composed by four HPGe detectors: the new detector array is expected to increase the solid angle coverage and optimisation which should yield an increase in rate of 10-100x (momentum dependent) and a decrease in measuring time. To evaluate the best geometry, Monte Carlo simulations are performed with the GEANT4 toolkit. Simulations are peformed to evaluate the capabilities of seven hexagonally shaped germanium crystals, placed around the sample stage in a packed geometry.

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