The (weighted) Levenberg-Marquardt algorithm for curve-fitting problems in nuclear physics

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The current methodologies for assessing nuclear reaction data, particularly for medium to heavy nuclei, utilizes the Hauser-Feshbach (HF) statistical model [1]. This model is often used to calculate an energy-averaged nuclear reaction cross section, where resonances overlap significantly. The HF model incorporates width fluctuation correction to account for these overlaps.

The CoH_3 code [2,3] implements the coupled-channels optical model in the HF framework and is designed to address reactions within the keV to tens of MeV energy range. Due to its dependence on optical potentials, single particle densities, level densities and strength functions, the CoH_3 code contains 30 different parameters which should be determined by minimization techniques for each nucleus independently. The minimization problem is exacerbated by the fact that the measurements are not (or cannot be) performed for every reaction channel and excitation energy of interest.

We compare the minimization obtained via the standard Levenberg-Marquardt[4,5] (LM) algorithm to the extended weighted Levenberg-Marquardt (wLM) algorithm that is weighted over different reaction channels and data sets from available experiments. The weighting method that was first developed to jointly analyze different cosmological data sets [6] was employed to address the systematics arising from utilizing multiple different reaction channels measured by different research groups. The collected parameters of the fitted isotopic chains will later be used to make uncertainty quantification by extrapolating their values for the nuclei that have no data.

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