Cross-validation of quenching factor methodology between the COSINUS and ANAIS experiments

Jeff Schymiczek
ParAs-seminar presentation 14.1.2026

The COSINUS and ANAIS collaborations are dark matter detector experiments using large sodium iodide scintillators. Both were created to perform a model-independent cross-check of the apparent detection of an annually modulated signal consistent with that expected from WIMP dark matter by the DAMA/LIBRA experiment. Recently, both COSINUS and ANAIS performed quenching factor measurements using the neutron beam of the Triangle Universities Nuclear Laboratory. The quenching factor measures the ratio of light yields produced in the scintillator crystal by some particles species (usually ions) relative to the light yield produced by particles interacting only with the electronic system of the crystal (usually taken to be electrons). Analogous data acquisition and event isolation schemes were employed by both collaborations to measure histograms of luminosity produced in the crystal at different neutron scattering angles. In both cases, simulated probability density functions for the expected amount of energy deposited for each angle were created. These simulated functions needed to be scaled to the histogram, smeared with the expected detector resolution and quenched by the quenching factor.

ANAIS employed least squares curve fitting to fit their data, while COSINUS used Monte Carlo sampling. This work verifies the fitting procedure of both groups by using the COSINUS Monte Carlo methodology to recreate the observed ANAIS quenching factors. Additional parameters for the resolution were required, since the smaller energy range of COSINUS allows for approximations in the resolution function that are not possible for the ANAIS dataset. To accommodate the larger parameter space, the fitting code was migrated to a more powerful Bayesian analysis package, which enabled the use of Hamiltonian Monte Carlo. Using Hamiltonian Monte Carlo's fast convergence, correlations between the histograms measured at different energies could be exploited to fit multi-parameter resolution functions.

Most data points are faithfully recreated, with divergences being greatest towards the edges of the investigated energy range. Possible reasons for these divergences lie either with a poor understanding of the resolution function for nuclear recoils or differences in background modelling. Reapplying the updated code to the COSINUS dataset led to improved accuracy also for the original COSINUS measurements.