Exploration of new opportunities at the NA62 experiment at CERN

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Kaon decay studies have played a unique role in the establishment of the Standard Model (SM) of particle physics over the past 70 years: CP violation, the suppression of flavour changing neutral currents (FCNC) and the GIM mechanism have been discovered in the kaon system. Because of the relatively small number of decay modes, simple final states, and availability of high-intensity kaon beams leading to very large datasets, kaon decay experiments continue to be in many ways the quintessential intensity-frontier experiments. At present, kaon physics is focused on precision measurements of highly suppressed loop-induced FCNC processes that may reveal the effects of new physics beyond the SM description at the 100 TeV scale, above the scale that can be explored directly by the LHC or even a next-generation hadron collider.

The NA62 experiment at CERN is world's leading precision kaon facility. The NA62 physics programme includes studies of the quark flavour dynamics and CP violation in rare kaon decays, searches for lepton flavour and number violation, and searches for feebly interacting dark sectors. The NA62 Run 1 dataset collected in 2016–18 represents world's largest sample of K^+ decays. The first measurement of the ultra-rare process $K^+ \to \pi^+\nu\nu$ (with a SM branching ratio below 10^{-10}) based on this dataset was published in 2021, making it one of the rarest particle decays to be ever observed. Collection of the NA62 Run 2 dataset started in 2021 and will continue until at least 2025.

We offer a flexible computing-based research project aligned with the responsibilities and physics interests of the Birmingham NA62 group. You will work using the NA62 data analysis software installed on a computing cluster at CERN. Familiarity with the Linux operating system and Python/C++ programming languages is required. Full access to NA62 software, datasets and simulated samples stored at CERN is provided. Two possible projects are described below.

- **Ultra-rare decays.** The enlargement of the NA62 dataset during Run 2 opens unique opportunities for discovery of new ultra-rare kaon decay modes (including those violating lepton flavour or number conservation), with branching ratios at the level of 10^{-12}. The project is focused on sensitivity studies for ultra-rare decays, for example $K^+ \to \pi^+\gamma\mu^+\mu^-$, and involves acceptance and background evaluations.
- **Kaon identification.** Measurements of ultra-rare processes at NA62 rely on the efficient performance of the Cherenkov kaon tagger detector (KTAG) constructed and operated by the Birmingham team. The excellent time resolution (70 ps) provided by the KTAG is of key importance. A four-fold increase in the kaon beam intensity (to 3 GHz) foreseen towards the end of the decade necessitates improvements of the KTAG event reconstruction to enable resolution of pairs of K^+ particles separated by O(100ps) time intervals. The project includes development of new reconstruction algorithms, and tests of these algorithms with data and simulated samples.