Development of Paleo-detectors

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Old minerals are natural particle detectors, here called “paleo-detectors”. This is because in the mineral an atom recoiled by a particle (e.g. a dark matter particle or a neutrino) is stopped via nuclear collisions, leaving a crystal defect (i.e. event signal) that cannot be erased unless thermally annealed. While normal particle detectors have large exposure owing to their huge target mass, the paleo-detectors, in spite of their tiny mass, can have comparable exposure thanks to their very long exposure time over the geological time scale. A big issue with paleo-detectors is how to read out the “signals” recorded inside the minerals. The crystal defects made by the nuclear stopping are expected to be weak and short (O(10-100) nm). This is in contrast with the fission tracks, which are formed when daughter atoms are stopped via electronic excitation and thus are much clearer and longer (~10 micron). Therefore, it is crucial for the paleo-detectors to develop methods for reading out efficiently the weak and short defects in the mineral crystals. Paleo-detectors were firstly applied a few decades ago to search magnetic monopoles (Price and Salamon 1986) or weakly-interacting massive particles (WIMPs) (Snowden-ifft et al. 1995). Recently paleo-detectors have been focused again because of possible improvements of read-out methods (Baum et al. 2020) and their new applications to search dark matter much heavier than WIMPs (Acevedo et al. 2021). Following these new works, we have started working on the paleo-detectors. In this paper, we will introduce our initial attempts to read-out the crystal defects inside mineral samples irradiated by low-energy (~keV/amu) heavy ions or fast neutrons (O(0.1-10) MeV) to mimic the natural nuclear recoil events.

