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Study sets the first germanium-based constraints on dark matter

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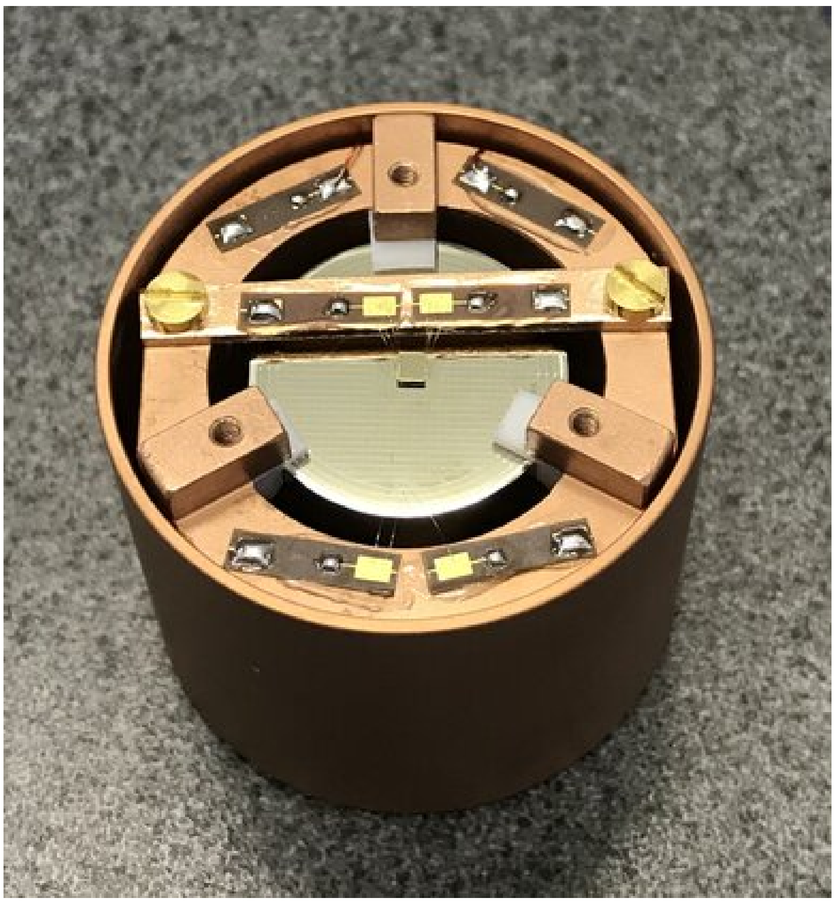

Picture of the RED30 detector that the researchers used for the dark matter searches. The orange part is the Copper casing. The cylinder inside is the ~33 g Germanium crystal. The square on top is the NTD (thermal sensor). The 3 white pieces are Teflon supports to maintain the crystal inside. Aluminum electrodes are lithographed on both planar surfaces in a grid scheme, we can see the grid on top of the crystal in the picture. Credit: EDELWEISS Collaboration.

Cosmological observations and measurements collected in the past suggest that ordinary matter, which includes stars, galaxies, the human body and countless other objects/living organisms, only makes up 20% of the total mass of the universe. The remaining mass has been theorized to consist of so-called dark matter, a type of matter that does not absorb, reflect or emit light and can thus only be indirectly observed through gravitational effects on its surrounding environment.

While the exact nature of this elusive type of matter is still unknown, in recent decades, physicists have identified many particles that reach beyond the standard model (the theory describing some of the main physical forces in the universe) and that could be good dark matter candidates. They then tried to detect these particles using two main types of advanced particle detector: gram-scale semiconducting detectors (usually made of silicon and used to search for low-mass dark matter) and ton-scale gaseous detectors (which have higher energy detection thresholds and are better suited to perform high-mass dark matter searches).

The EDELWEISS Collaboration, a large group of researchers working at Université Lyon 1, Université Paris-Saclay and other institutes in Europe, recently carried out the first search for Sub-MeV dark matter using a germanium(Ge)-based detector. While the team was unable to detect dark matter, they set a number of constraints that could inform future investigations.

"EDELWEISS is a direct dark matter search experiment. As such, our primary goal is to detect dark matter to bring irrefutable proof of its existence," Quentin Arnaud, one of the researchers who carried out the study, told Phys.org. "Still, the absence of detection is an important result itself, because this allows us to test and set constraints on existing dark matter particle models."

There are two key reasons why dark matter particles have so far eluded detection. First, the probability that these particles will interact with ordinary matter, such as the one inside conventional particle detectors, is extremely small.

Second, the signal that researchers expect would arise from a dark matter particle impinging the detector is several orders of magnitude lower than the signals produced by natural radioactivity. Detecting these signals would thus require very long detector exposure times and the use of instruments that are made of radio-pure materials, but that are also adequately shielded and operated deep underground, as this prevents them from picking up ambient radioactivity and cosmic rays.

"Eventually (in spite all our efforts), there will always be some residual background that we need to be able to discriminate against," Arnaud explained. "Therefore, we develop detector technologies with the capability to determine whether the signals we detect are induced by a dark matter particle or are originating from the radioactive background."

Arnaud and his colleagues were the first to search for sub-MeV dark matter using a 33.4g germanium cryogenic detector instead of a silicon-based particle detector. They specifically searched for dark matter particles that would interact with electrons. The detector they used was operated underground at the Laboratoire Souterrain de Modane, in France.

"The energy deposited in our detector following a dark matter particle interaction is expected to be extremely small (