PrimaPagina N. 67 - Luglio 2019
FISICA Physics

COSINUS: a NaI-ce cryogenic frontier for dark matter search

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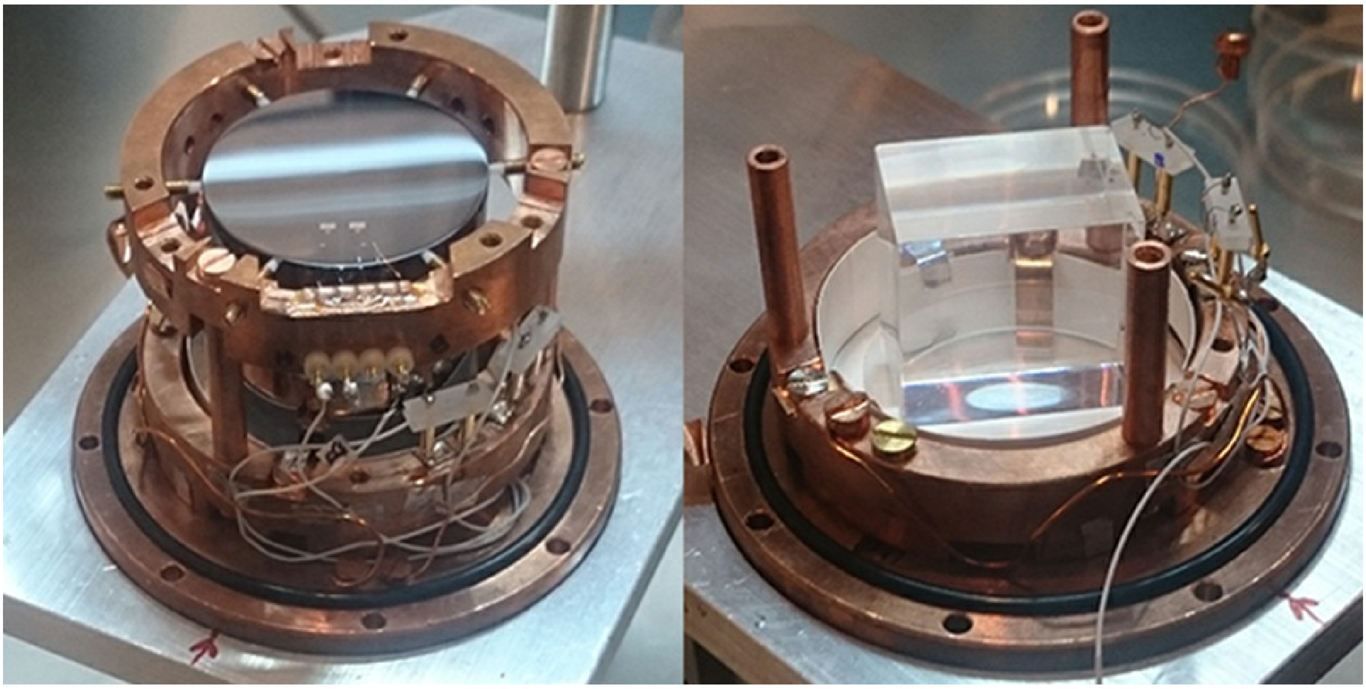

COSINUS module prototype. Left: NaI crystal in the copper housing. Right: silicon beaker (the light absorber) encapsulating the NaI crystal, instrumented with a TES and mounted in the copper housing. (Photo: Karoline Schäffner).

COSINUS will be a cryogenic observatory for dark matter particles. Its main goal is to provide a decisive answer to the long-standing results of the DAMA/LIBRA collaboration, which since 1997 has been detecting a time-dependent signal compatible with the expectation for dark matter particles present in our galaxy. The result is under debate because it is in tension with practically all other experiments, whereby all others are using different target nuclei.

Cosmological and astrophysical evidences suggest the existence of a halo of dark matter particles on average at rest surrounding our galaxy. The relative velocity between the Solar System and the dark matter halo, combined with the revolution of the Earth around the Sun, provides the chance of detecting a time-dependent signal produced by the interaction of dark matter particles with a target located on the Earth. The rate of interaction and, as a consequence, the observation of the signal depends on the interaction cross-section. Both confirmation and rejection of the interpretation of the DAMA/LIBRA result as the signature of dark matter would give fundamental information for the search of this hypothetical new particle.

COSINUS is based on NaI crystals working at mK temperature. The detection principle is analog to the CRESST experiment and relies on the collection of both the scintillation light and the heat produced by a particle interacting with the target material. The temperature increase caused by the deposited energy is measured by superconducting temperature sensors (TES: Transition-Edge-Sensors). The double-channel read-out of heat and light is the basis of the particle discrimination provided by cryogenic scintillating calorimeters. X-ray and Auger-electron atomic-relaxation-emission from ^{40}K or ^{128}I are a relevant source of background because they fall in the region of interest of the DAMA signal. In COSINUS they can be identified and rejected.

Employing NaI crystals as cryogenic calorimeters is an experimentally demanding task as their hygroscopic nature and low Debye temperature are not ideal properties for a high-performing low-temperature detector. However, the requirement for a target-independent comparison of the DAMA/LIBRA result has motivated Karoline Schäffner and Florian Reindl, who are the initiators of the COSINUS project, to accept the challenge of the employment of NaI crystals at mK temperature. The effort paid off when already the first prototypes showed a light detector energy threshold below the one of DAMA/LIBRA, that is ~1 keV. In COSINUS the energy released in the detector is reconstructed using the phonon channel. In fact the energy converted in phonons is almost particle independent, therefore the phonon energy threshold refers to both beta/gamma and nuclear recoil events (both Na and I). For scintillators like DAMA/LIBRA, the energy threshold for scintillation light has instead to be rescaled by the light quenching factor, which shifts the threshold for nuclear recoils to higher energies. The phonon detector energy threshold achieved so far by COSINUS is ~5-6 keV: the goal is to reach ~1 keV.

The detector performance is currently being optimised by initiating new theoretical studies on a more fundamental level using solid state physics insights. In the meantime the building construction project is actively going on to arrange a cryostat in a 7x7 m water-shielding working as active Cherenkov veto. The work for the realisation of this new cool dark matter underground observatory is in progress!