PROCEEDINGS OF SCIENCE

NUCLEUS: recent results and perspectives

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Coherent Elastic Neutrino-Nucleus Scattering (CEvNS) is an interaction well predicted by the Standard Model. Its relatively large cross-section with respect to other weak processes allows to study neutrinos with relatively small detectors. Precision measurement of the CEvNS cross-section is a way to study neutrino properties and search for new physics beyond the Standard Model. The NUCLEUS experiment aims to detect and characterize CEvNS using reactor neutrinos, in low background environment. The NUCLEUS target detector will be a 10g array of cubic CaWO4 and Al2O3 crystals with 5mm side. The experiment will be installed between two 4.25 GW reactor cores at the Chooz-B nuclear power plant in France. The experiment is currently under commissioning at the 15 m.w.e. underground lab at TUM (Munich) and will move to Chooz in 2025. Here the recent results and perspectives of NUCLEUS will be shortly summarized.

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1. Introduction

The aim of the NUCLEUS experiment is to provide a measure as precise and accurate as possible of the coherent elastic neutrino-nucleus scattering (CEvNS) cross section. This physical process was predicted for the first time by Freedman in 1973 within the Standard Model (SM) but it was observed for the first time only in 2017 by the COHERENT collaboration [1]; the reason for this delay is the very low nuclear recoil energy involved (sub keV range) which is the physical observable ("direct detection").
For what said before, the study of this process requires an intense source of (anti-)neutrinos in MeV energy range, a detector with a very low energy threshold (at least under 50 eV) and an as low as possible background in the region of interest (sub keV range). CEvNS study can deepen our knowledge on neutrinos properties and can be useful to explore physics beyond the SM.

2. NUCLEUS experiment

NUCLEUS final goal is to provide a 5-10% precision measurement of CEvNS cross section exploiting the intense anti-neutrinos flux (order of 10^{20} neutrinos per GW per second) produced by Chooz-B Nuclear Power Plant reactors (Ardennes, France) [2][3]. CEvNS expected counting rate in $CaWO_4$ between 20 and 100 eV is around 30 $\nu/(kg \cdot day)$ and so a maximum of around 100 counts/(kg day keV) is required in the region of interest to be able to identify this contribution in the energy spectrum. Since the experiment will be placed at ground level with only a 3 m.w.e. overburden, cosmic and environmental background (mainly muons, neutrons and their secondaries) needs to be well suppressed by the very complex NUCLEUS vetoing system made both of active and passive shielding [4][5][6].

2.1 NUCLEUS detector

NUCLEUS target detector is composed by two 3x3 crystal matrices (each one of 0.5x0.5x0.5 cm^3) made of $CaWO_4$ (~6g) and Al_2O_3 (~4g); they are cryogenic calorimeters working at mK temperatures. To read them, Transition Edge Sensors made of Tungsten (W-TES) are used; as their name suggests, these sensors work ideally at the maximum slope of Tungsten transition curve, allowing to convert the slightest temperature variation into a resistance change inside the sensor. TES internal resistance is of the order of 0.1 Ω and needs to be read with a precision below the mΩ: this fact, together with a maximum ten of μA for the reading current, makes the readout of these sensors very complicated and possible only using SQUIDs (Superconducting Quantum Interference Devices) which are extremely sensitive magnetometers magnetically coupled to TES circuits [7][8]. The latest results have shown an energy threshold of NUCLEUS target detector of around 30 eV, with some improvement margin still possible.

3. Current status and perspectives

3.1 Current status

Now the experiment is finishing its commissioning phase at the Under Ground Laboratory (UGL) inside the Technical University of Munich (TUM); we are at the end of a long background run (2 months) with more than 800 hours of data collected in total. The aim of this run was to operate in minimal configuration and simultaneously some detectors plus reduced veto systems and collecting high statistics measurement of the background (although in a different condition wrt the final site of the experiment); up to now the data collection in different experimental configurations has been carried successfully. The present experimental setup is composed by 2 crystals working simultaneously, only one over six Germanium crystal of the Cold Muon Veto (COV) and the full Muon Veto System (MV). The external and cryogenic passive shield is in place while the B_4C neutron shield has not been installed [4][5][6].

3.2 Perspectives

The next step of the experiment will be to move the setup from Munich to Chooz power plant; we plan to transfer it and make some measurements there in the first three months of 2025 with the anti-neutrinos source of the nuclear reactors.

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