Looking for Low-Mass WIMPs with TREX-DM

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TREX-DM is a low-mass WIMP detector: a gas time projection chamber (TPC) equipped with novel micromesh gas structures (Micromegas) readout planes. In the fiducial volume of $\sim$20 litres and a pressure of 10 bar, there will be approx. 0.160 kg of Ne, or alternatively 0.300 kg of Ar. The energy threshold foreseen is well below 0.4 keVee and the expected background level is better than 10 counts $\mathrm{keV^{-1}kg^{-1}d^{-1}}$, and could give competitive results in the search for low-mass WIMPs. The experiment has recently been approved by the Laboratorio Subterrneo de Canfranc and is expected to be commissioned by the end of the current year. We report on the status of the project.

1 Introduction

The Weakly Interacting Massive Particles, which appear in supersymmetric extensions of the Standard Model, are one of the strongest candidates to form the Dark Matter of the Universe. The lack of a positive signal during the last 30 years in the search of “standard WIMPs”, during which the experimental efforts have reached remarkable levels of sensitivity, and the lack of proof of Supersymmetry in the data of LHC so far, have made the lower end of the WIMP mass attractive. Looking for low-mass WIMPs (<10 GeV) requires the use of light elements and a low energy threshold, aspects for which the current experiments are not optimized, but which are met by a gaseous Time Projection Chamber.

The Canfranc Underground Laboratory in the Spanish Pyrenees (Laboratorio Subterráneo de Canfranc, LSC) will host a high pressure TPC, called TREX-DM, with the primary goal of searching for low-mass WIMPs.

2 TREX-DM status and prospects

The TREX-DM detector, built and commissioned at University of Zaragoza, is described in detail in [1]. It is designed to host aprox. 20 L of pressurized gas up to 10 bar in the fiducial volume, which corresponds to 0.160 kg of Ne or 0.300 kg of Ar. The detector is equipped with novel microbulk Micromesh Gas Structures (Micromegas) (see Fig.1).

The overall concept has been developed as part of the T-REX project [2, 3], in which an intensive R&D has been done on low-background application of gaseous TPCs. Similar technology is in use to search for axions in the CAST experiment, and considered for the future IAXO experiment, in which low background at keV energies (although at surface level) is the

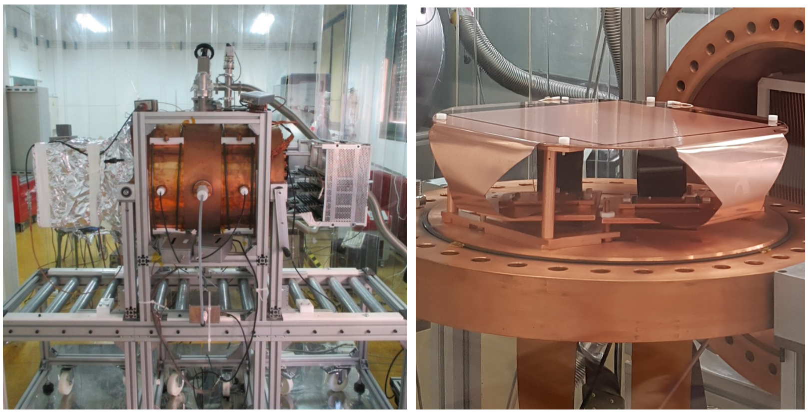

Figure 1: Left: A picture of the TREX-DM detector sitting on a platform in the laboratory in Zaragoza. Right: One of the two microbulk Micromegas recently installed.

main experimental requirement [4]. The key aspect of the detection concept is that microbulk Micromegas readouts can be built with extremely low levels of intrinsic radioactivity, that have been found to be less than $0.1\mu\text{Bq/cm}^2$ of the natural Th and U chains. Considering, in addition: the high-granularity that the Micromegas planes can have, that with the help of high-density readout electronics provide rich event information; the intrinsic amplification of gaseous ionization detection, which, combined with the high granularity, makes feasible effective thresholds of less than 1 keV; and the flexibility in the choice of target gas and pressure, that allows to tune the experiment for low-mass WIMP sensitivity and provides a unique tool for background study and identification, the choice of a gaseous TPC detector to explore the low-mass WIMP frontier is very appealing and clearly appropriate.

The microbulk Micromegas of TREX-DM are the largest area built with the microbulk technique, featuring an active area of 25×25 cm^2. They present a high granularity (256 channels in the x direction and 256 in the y) and are to be read with a self-triggered TPC data acquisition (based on the AGET electronics); the effective threshold is expected to be well below 1 keVee [1], probably down to 100 eVee.

The chamber is built with state-of-the-art radiopurity specifications, as the target background level of the experiment is of <1 counts keV^{-1}kg^{-1}day^{-1}. This number is obtained by a preliminary background model based on GEANT4 simulations and using the outcome of an exhaustive screening campaign of all the elements entering the detector construction, as well as the measured fluxes of backgrounds from environmental sources at the LSC (namely gamma-rays, neutrons and muons). Table 1 summarizes the contribution to the background budget of selected components of the experiment. This result should be validated experimentally, as simulations at very low energy (especially below 1 keV) may not be totally reliable, and the appearance of unforeseen background sources cannot be excluded. The main goal of the proposal is to confirm this prospect, and in general to get experimental insight on the origin of backgrounds at such low energies. This understanding is *per se* a very interesting quest; very few high sensitivity measurements at these energies have been done (even with other technologies) elsewhere. The precise sensitivity to the WIMP-nucleon cross-section will depend on the final

[1] Electron equivalent energy.

Component	Argon	Neon	Main contribution
Vessel (cosmogenic)	1.25	1.50	^{60}Co
Copper Boxes (cosmogenic)	0.034	0.046	^{60}Co
Field Cage (PTFE)	<0.033	<0.051	^{238}U
Field Cage (resistors)	<0.35	<0.63	^{238}U
Field Cage (kapton-Cu PCB)	<1.06	<1.81	^{238}U
Cathode (copper)	<0.0081	<0.012	^{238}U, ^{40}K
Cathode (PTFE)	<0.064	<0.085	^{238}U
Readout Planes	<1.24	<1.14	^{40}K
Connectors	<0.19	<0.24	^{238}U
Epoxy	<0.0044	<0.0056	^{232}Th
Target	0.15		^{39}Ar
Neutrons at LSC	$(2.52\pm0.22)\times10^{-2}$	$(7.06\pm0.61)\times10^{-2}$	
Muons (+ muon-induced neutrons)	0.205±0.021	0.336±0.034	
^{210}Pb in Pb shielding (*)	<0.12		
^{222}Rn in air	0.1495±0.0024	0.0841±0.0013	

Table 1: Background rates (in counts keV^{-1} kg^{-1} d^{-1}) expected in 2-7 keV$_{ee}$ from selected components inside, close to or outside the vessel and backgrounds at LSC using Ar or Ne mixtures in TREX-DM. The dominant contributions are indicated in the last column, while contributions marked with (*) are 90% C.L. limits when no event was registered in preliminary simulations. More results can be found in [1, 2, 5].

effective threshold and background achieved but, if the predictions of the model are realized experimentally, the sensitivity of TREX-DM could easily reach, and likely improve, the current bounds for WIMPs of masses of 0.1–10 GeV.

A definite, but flexible, experimental plan for TREX-DM at LSC is proposed, with a tentative temporal horizon of 3 years. After installation and commissioning during the first year, a 2-year campaign of physics runs at LSC is foreseen. The latter includes a set of runs with Ne- and (depleted) Ar-based mixtures at increasing pressures (from 1 bar to 10 bar). The number, duration and type of runs may be adapted depending on the intermediate results achieved. Figure 2 shows the projected sensitivity of TREX-DM (exclusion at 90% C.L.) in the direct detection of WIMPs, for both Ar- and Ne-based gas mixtures at 10 bar, for three different cases of background, energy threshold and exposure. If the background expectations are fulfilled, the experiment could provide a competitive result for low-mass WIMPs already in the 3-year time-span considered.

The detector is now getting adapted to the requirements for underground operation: a couple of provisional components need to be replaced by definitive radiopure versions. Its installation underground is foreseen for the end of this year.

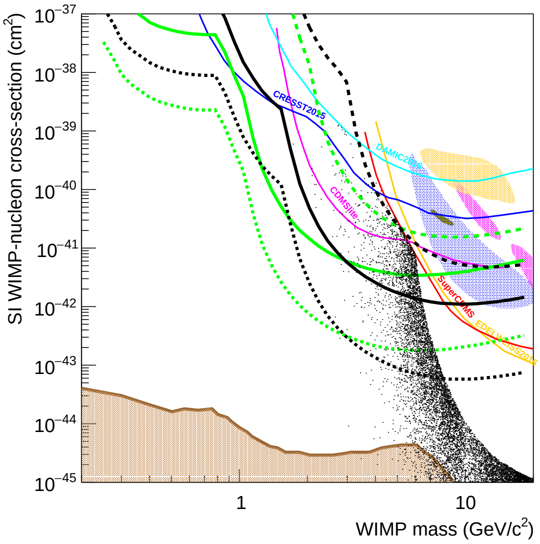

Figure 2: Projected sensitivity (90% C.L.)of TREX-DM for different assumptions (for an exposure of 0.3kg·y) for both Ar-1%C_4H_{10} (black thick lines) and Ne-2%C_4H_{10} (green thick lines): solid lines correspond to background levels of 1keV^{-1}kg^{-1}d^{-1} and a threshold of 0.4keVee (nominal scenario) while the combination of 10 keV^{-1}kg^{-1}d^{-1} and 0.4keVee (conservative scenario) is shown with dashed lines.

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