SENSEI

A Novel Search for Hidden-Sector Dark Matter

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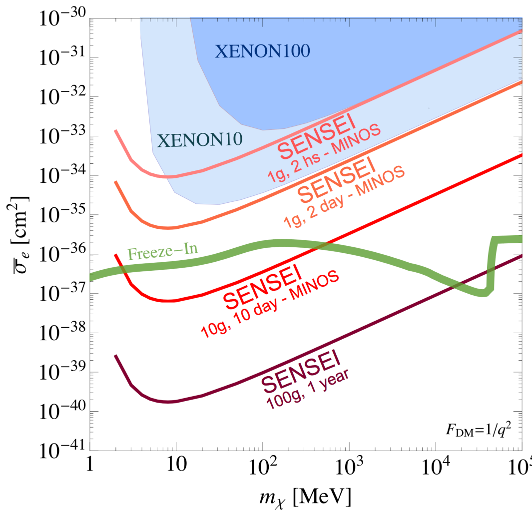
Primary physics goals: A primary goal of particle physics research today is to identify the dark matter particles that make up 85% of the Universe's matter. *Hidden-sector dark matter (including axion-like particles)* with eV-to-GeV masses is a rich but remarkably underexplored possibility that has been receiving increased attention in the last few years. Several model scenarios exist with sharp theory targets in parameter spaces. New ultra-sensitive detectors are required to probe these models.

Technological breakthrough: SENSEI is a Fermilab Laboratory Directed R&D project and a collaboration between particle theorists and experimentalists. SENSEI uses a new generation of silicon Charged Coupled Devices ("Skipper CCDs"), which were designed in collaboration with the LBL Micro Systems Lab. The CCDs consist of a ~million pixels and have an innovative readout technology. For the first time, SENSEI has demonstrated the ability to measure precisely the number of free electrons in *each* of the million pixels across the CCD.

Implications for Dark Matter Searches: SENSEI's innovative readout technology has immediate applications in searching for a broad range of hidden-sector dark matter candidates. For example, dark matter can scatter off bound electrons in the silicon CCD, creating one or more free electrons. SENSEI can measure these tiny depositions of electric charge in each pixel allowing for unprecedented sensitivity. The **Figure** shows one striking example, in which interactions between dark matter and electrons are mediated by an ultralight dark photon. A 1-gram detector taking data for only 2 hours will already probe unexplored parameter space beyond XENON10/100 (blue shaded regions). A 10-gram detector running for 10 days will probe a compelling theory target in which dark matter obtains the observed relic abundance through "freeze-in" (thick green line), while a 100-gram detector will probe this theory target over five orders of magnitude in mass. No accelerator can come close to probing this theory target.

Current Status: A 1-gram prototype detector is operating ~100 meters underground in the Fermilab MINOS Hall. The primary goal will be to demonstrate a working detector, but we expect to obtain with it also the world's leading sensitivity to certain classes of hidden-sector dark matter.

Future Plans, Experimental Approach, and Setup: We propose constructing a 100-gram detector to be operated at a deep underground site. The required shielding and support systems are analogous to the ones used by the DAMIC experiment currently operating at Snolab. All the technology has been demonstrated and no further development of the sensors, shielding, or support systems is required.



Construction can start <u>*now*</u> (in FY-18). The time scale for commissioning and taking data is 2 years. We envision a partial deployment, first placing a 10-gram detector underground in the MINOS Hall for commissioning and data taking, while preparing the 100-gram detector for deployment at a deeper underground site to avoid cosmic-ray backgrounds that would otherwise limit the sensitivity. The 10-gram detector can be operated with existing electronics, while the 100-gram detector requires improved electronics and a new vessel and support system. Each detector is expected to be almost background-free, with the 100-gram detector providing a factor of 100 in improved sensitivity to dark matter over the 1-gram detector.

Budget: The **Table** shows the funds required for a 100-gram SENSEI detector. A 10-gram detector installed at MINOS only requires the first line-item (Sensors & package).

Item	**Cost**
Sensors & package *(only item needed for 10 grams)*	\$450k
Readout electronics	\$200k
Vessel & support systems	\$215k
Installation	\$50k
Contingency	\$200k
Total	**\$1,115k**

Further impact: A 100-gram detector envisioned here is a necessary step towards developing the next generation 1-kilogram detector with the DAMIC-1K project, which will also require improved shielding and packaging to avoid radioactive backgrounds beyond what has *already* been demonstrated. Besides the search for dark matter, the SENSEI technology <u>will impact other scientific areas</u>. This includes enabling a table-top search for <u>low-energy neutrino oscillations to probe for</u> <u>sterile neutrinos</u>, new measurements of <u>coherent neutrino-nucleus scattering</u>, and a factor of two reduction in exposure times for the <u>imaging of terrestrial exoplanets in the habitable zones of nearby star</u>. The SENSEI team has established collaborations with these projects. The Skipper CCDs procured here can also be used for testing these other implementations.