Mechanical Design of the OSCURA Vessel

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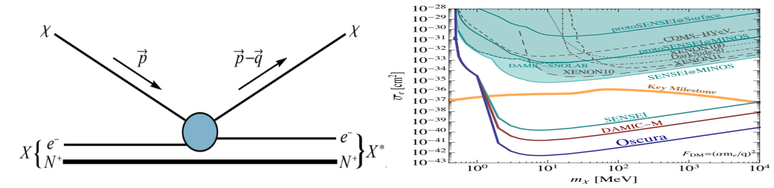
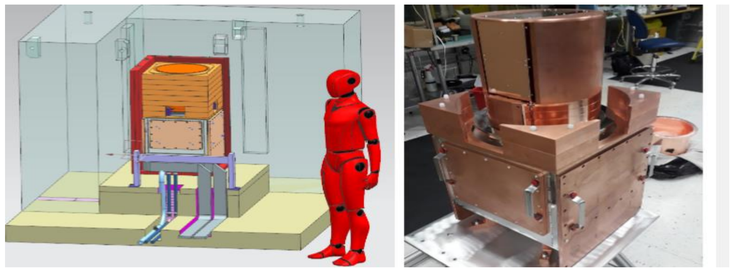
What is the Oscura/SENSEI Experiment?

A large body of evidence points to the existence of dark matter (DM), but the nature of DM remains a mystery. One of the most recent innovations in the search for DM search is the SENSEI experiment, using newly developed highly sensitive sensors with ultra-low readout noise called skipper Couple-Charged Devices (CCDs). The SENSEI experiment set world-leading limits on DM-electron scattering using one 2 g skipper-CCD operated at the MINOS cavern at Fermilab (Barak et al). SENSEI is currently taking data at SNOLAB with 100 g of skipper-CCDs and aims to improve on the previous DM limits set by SENSEI@MINOS.



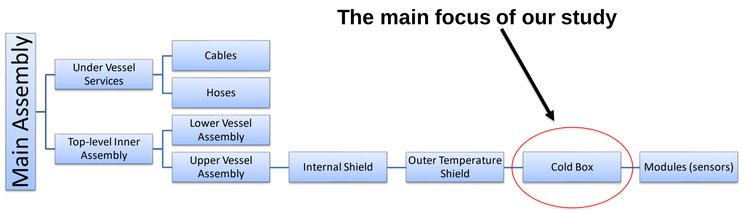
Left: The scattering of a DM particle with a bound electron
Right: Projected sensitivity to dark-matter-electron scattering of Oscura

The Oscura experiment will use a larger array with 10 kg of skipper-CCDs to provide improved sensitivity to DM particles. This study evaluates the feasibility of scaling up the existing SENSEI@SNOLAB vessel to conduct the Oscura experiment.



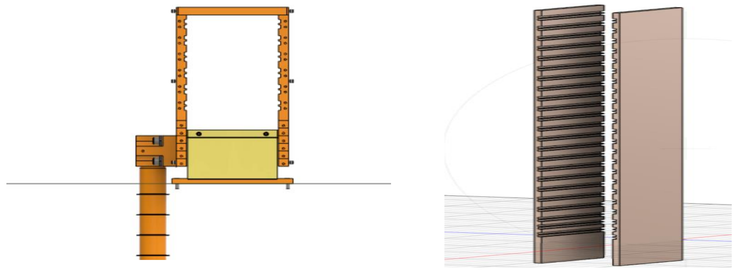
Scale of the SENSEI vessel

Understanding the Main Assembly (SENSEI)



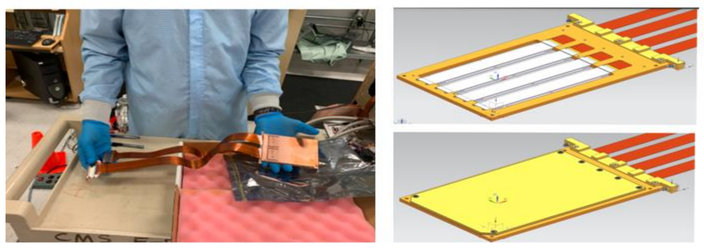
Method

In order to scale up the mass of the SENSEI detector payload, we increased the capacity of the Cold Box by increasing its height by a factor of four, and we included four modified Cold Boxes in the modified design.



Left: Side View of the Cold Box before scaling up
Right: Design Phase of the Oscura Cold Box

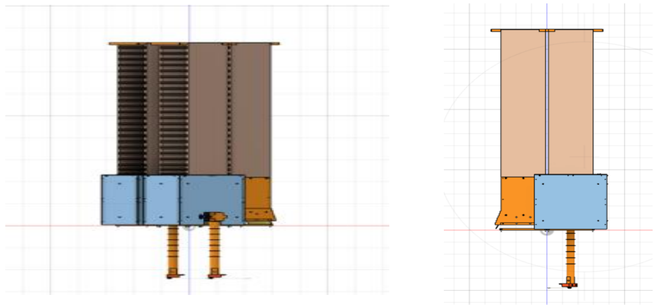
We are also using a CCD module that integrates four skipper-CCDs each to maximize space.



Left: SENSEI Experiment's modules with 2 CCDs each
Right: a modified version of the SENSEI modules with 4 CCDs each

Results

Each CCD has a mass of 1.93 g and the new design can include up to 960 CCDs for a total mass of 1.85 kg towards the intended 10 kg. The cold box height is now 825 mm so its height could be further increased while satisfying the space requirements at SNOLAB.



A scaled-up version of the Oscura Cold Box

Conclusion

This work developed a modified design for the SENSEI vessel that can house ~2 kg of skipper-CCDs for the Oscura experiment. This design can be further extended to house the full 10 kg Oscura payload. Future studies will model the thermal management of this design to ensure that it meets the thermal requirements of the Oscura experiment. Further refinements to this design will be made based on the thermal modeling results.

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References

Barak, L. et al, PRL 125 (2020) 17.
Aguilar, A. et al, arXiv:2202.10518, (2022)The Oscura Experiment. https://arxiv.org/pdf/2202.10518.pdf

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