# Leveraging nanomechanical membrane resonators for new fundamental physics searches

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**Abstract**

Recent years have seen rapid development of chip-scale mechanical oscillators, particularly silicon nitride thin-film resonators. These nanomechanical systems exhibit ultra-low mechanical loss, corresponding to exceptionally high mechanical quality factors (Q), which makes them highly sensitive platforms for precision sensing applications such as force measurements [1] and pressure sensing [2,3]. Furthermore, these sensors are now being explored as tools for detecting new fundamental physics, including high-frequency gravitational waves and dark matter candidates [4]. All these applications benefit from increasing both the mass of the membrane, which enhances coupling to target signals, and its mechanical Q factor, which suppresses thermal noise.

The goal of this project is to fabricate and characterize nanomechanical silicon nitride membranes that are an order of magnitude larger in lateral dimensions (up to 8 cm) than current state-of-the-art devices. This increase in size is expected to enhance the membrane mass by approximately two orders of magnitude while further reducing mechanical loss, as both quantities scale favorably with membrane dimensions [4].

In the context of our recent proposal for a membrane-based detector targeting high-frequency gravitational waves and vector dark matter (see Fig. 1), such scaling is expected to translate into a sensitivity improvement exceeding two orders of magnitude.

We will first summarize the established fabrication processes for millimeter-scale silicon nitride membrane resonators with ultra-low mechanical loss. Building on this foundation, we will then present our approach to extending these techniques toward the controlled fabrication of centimeter-scale devices, including the associated fabrication challenges.

**References (maximum: 4)**

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## Figures (max 1 page)

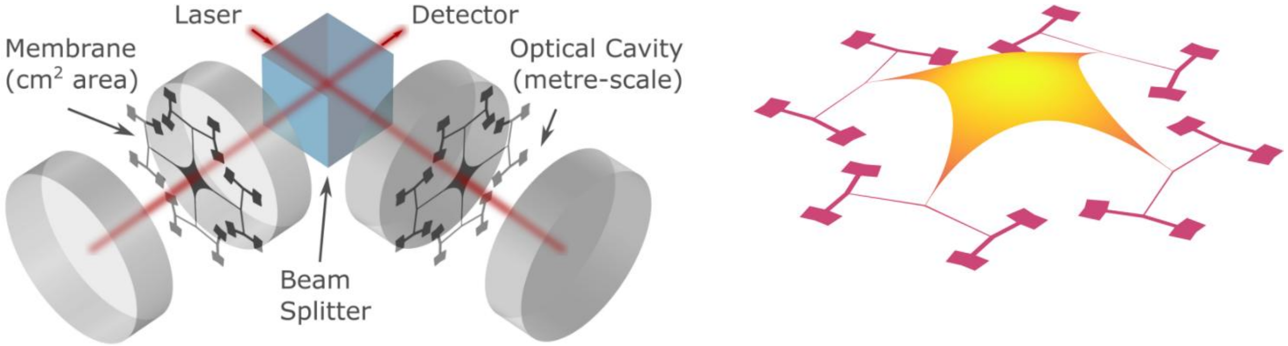


*Fig.1: (left) Conceptual layout of the NEST (Nano-membrane Experiment for Space-time Tremors) detector prototype: a Michelson interferometer with two meter-scale cavities containing optically-trapped cm²-scale membranes that transduce high-frequency gravitational-wave or vector dark matter signals. (right) Fundamental oscillation mode of a branched silicon nitride trampoline membrane, as simulated in Comsol Multiphysics.*