

MATHUSLA

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on behalf of the MATHUSLA collaboration

LHCP 2023

LHCC LOI: [1811.00927](#)

LHCC LOI Update: [2009.01693](#)

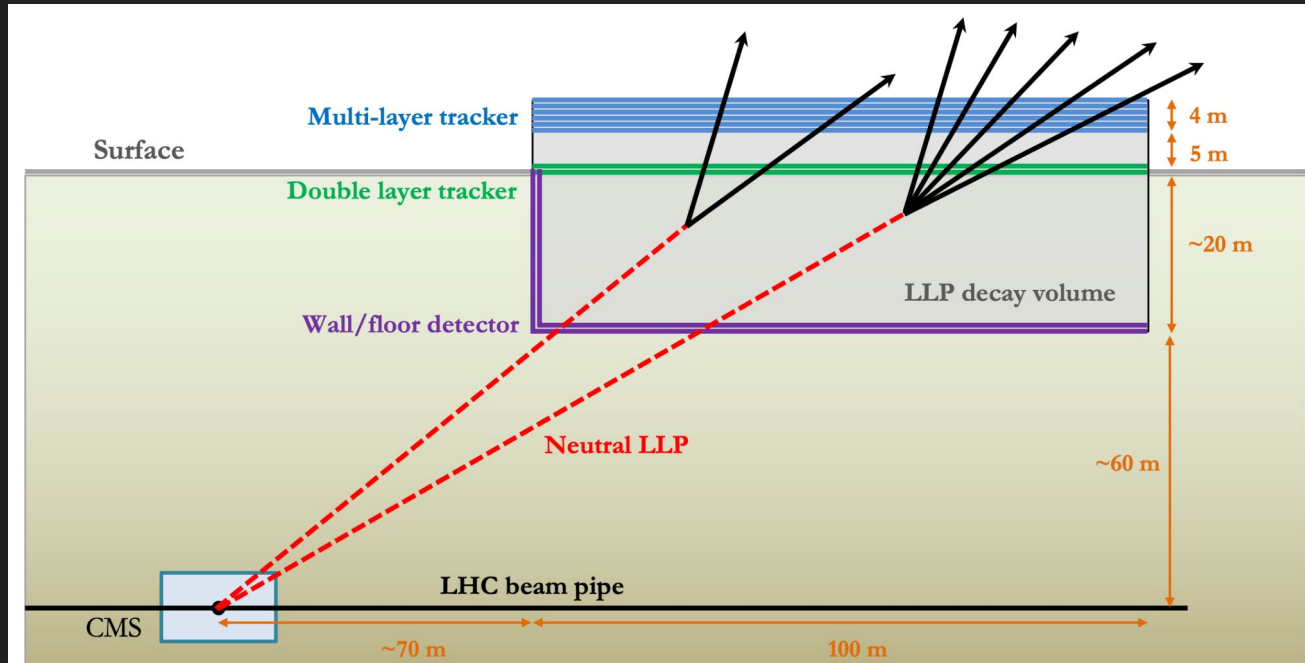
Snowmass White Paper: [2203.08126](#)



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WASHINGTON

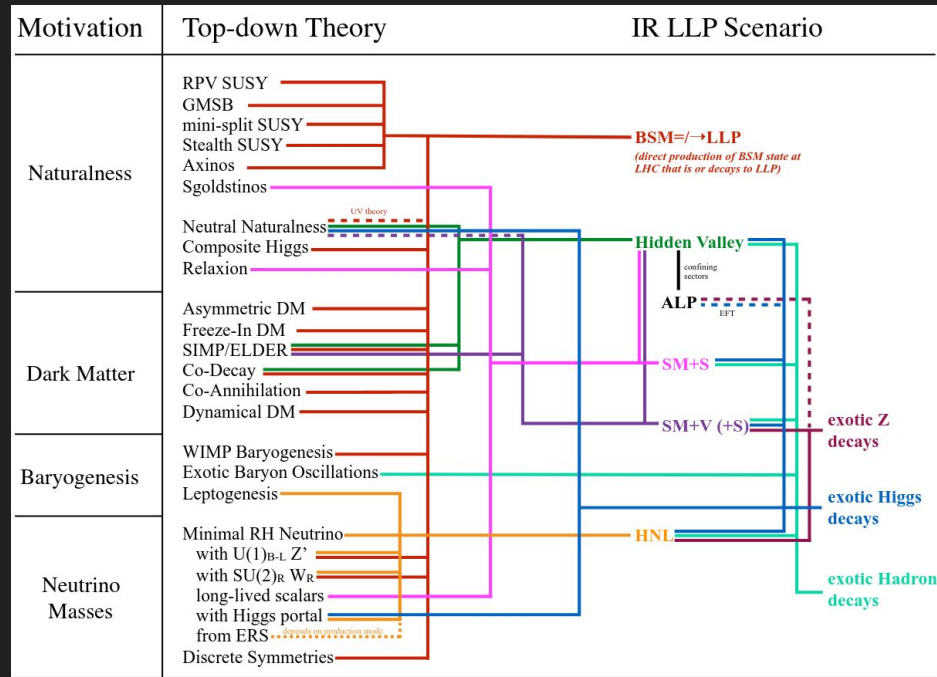
Overview

- MATHUSLA (MAssive Timing Hodoscope for Ultra Stable neutral pArticles) is a proposed experiment for detecting decays of long-lived particles (LLPs)



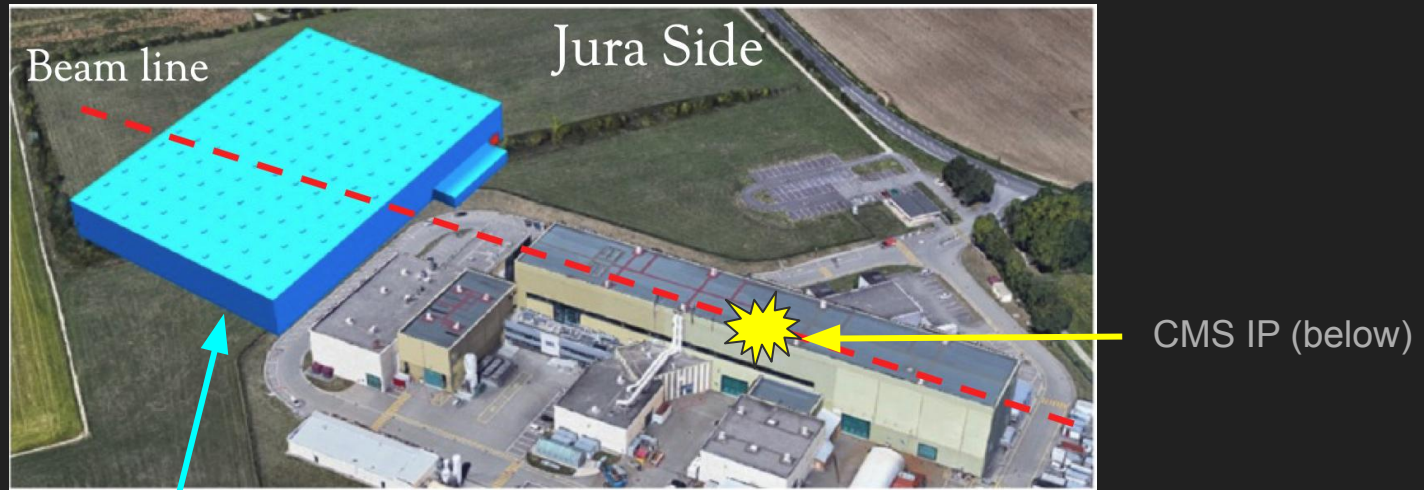
Motivation

- Very long-lived particles are a relative blind spot of the main LHC experiments and are well-motivated by both observations and theoretical considerations:



Location

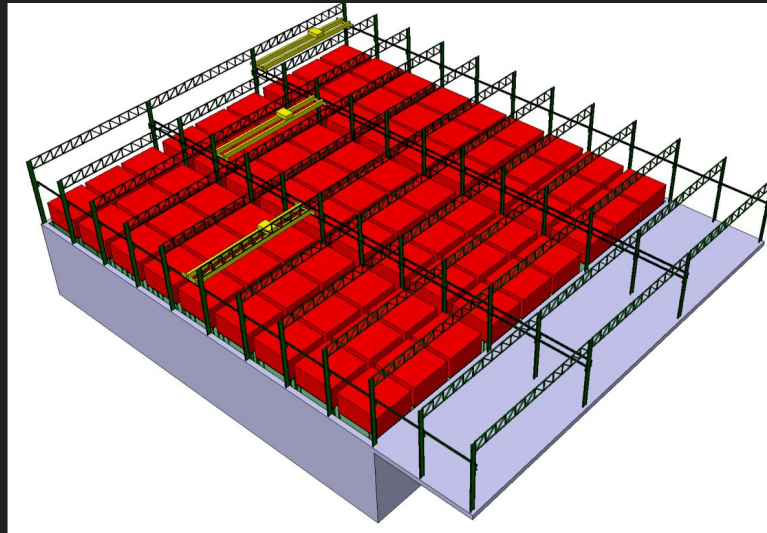
- Proposed site is at surface of LHC point 5 (CMS)
 - Naturally shielded from IP by ~100 m of rock
- Currently unused plot of land that is already owned by CERN
- Displaced ~70 m horizontally from IP along beam axis



MATHUSLA

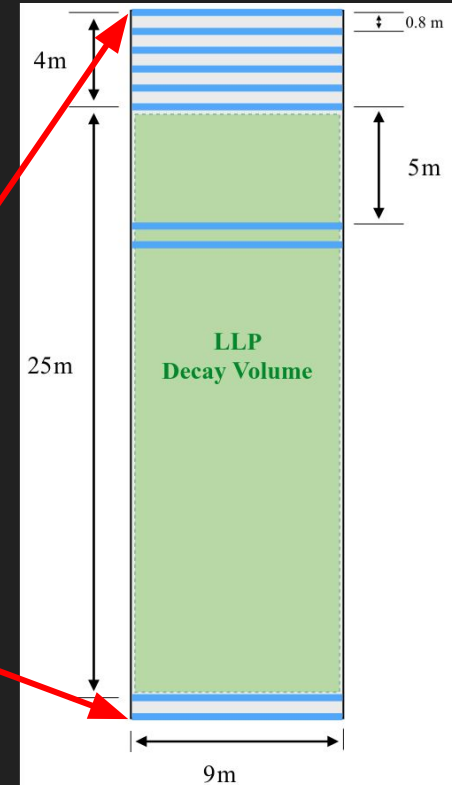
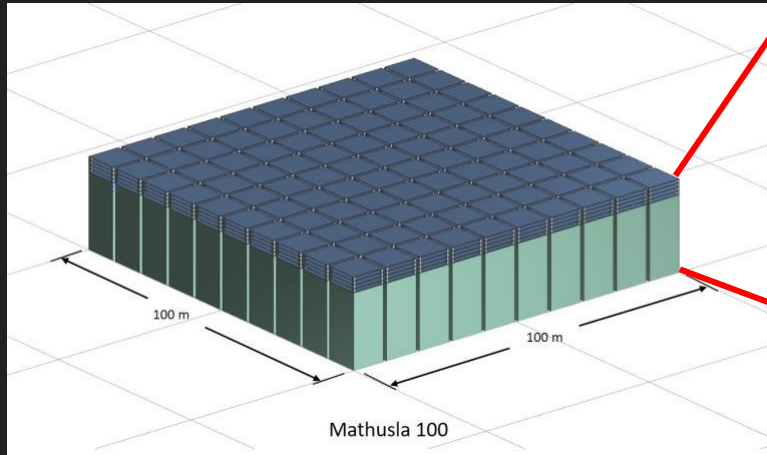
Structure

Building at surface extends ~20 m below ground

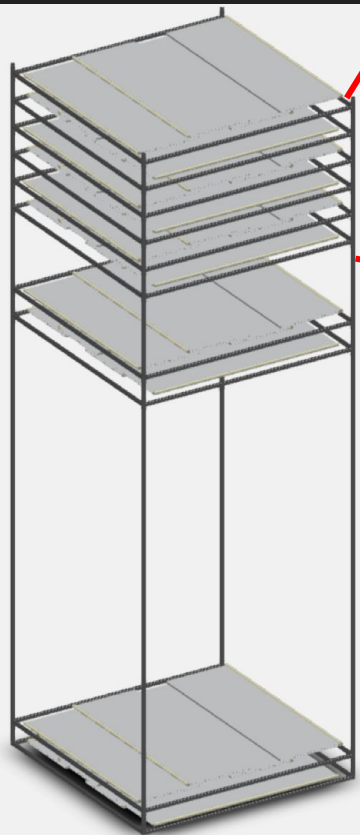


Each detector unit is 9 m × 9 m horizontally and ~30 m tall

Contains 100 detector units

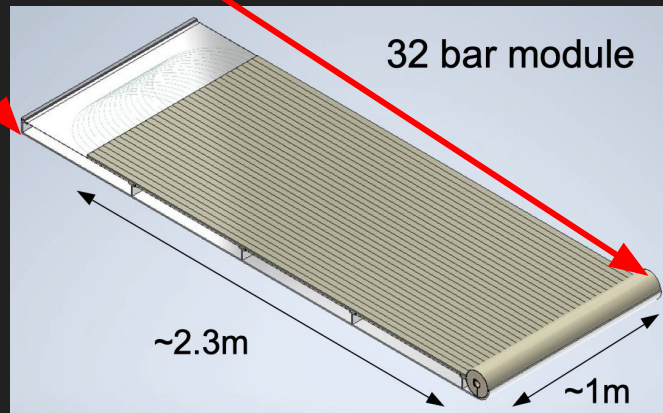


Structure



Each tracking layer is composed of 4 sub-planes

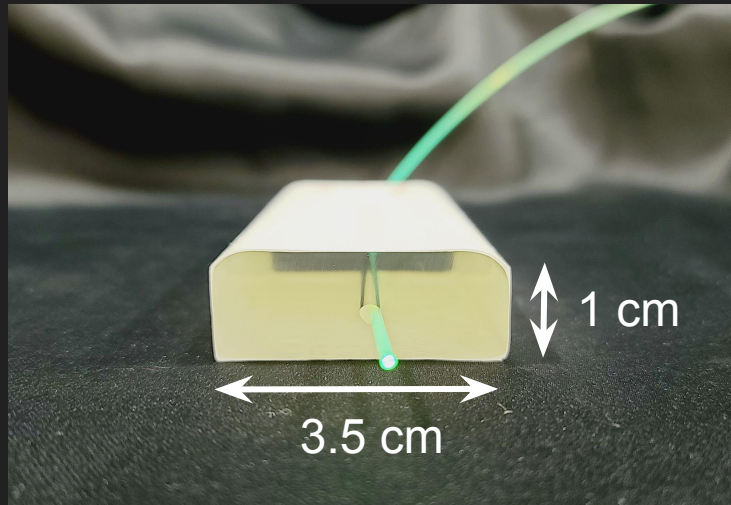
Each sub-plane consists of 8 adjacent modules



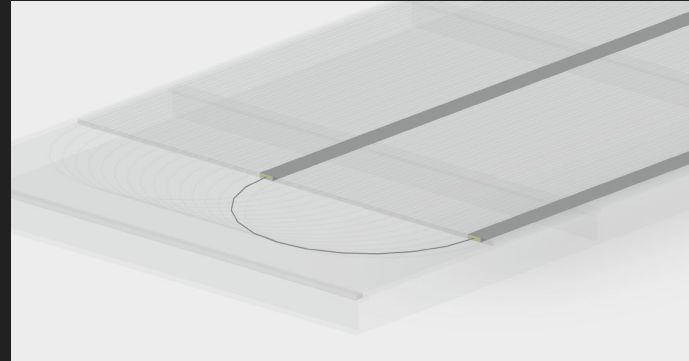
2 layers at bottom to veto incoming charged particles and 8 tracking layers at top

Detector technology

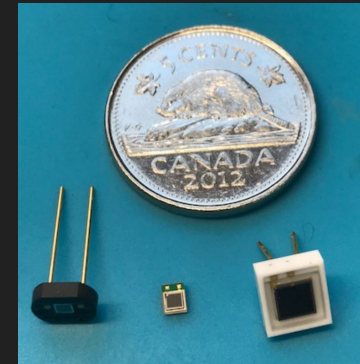
- Bars in tracking layers are extruded scintillators
- Light is carried through a wavelength-shifting (WLS) fiber running through bar
- Detected by silicon photomultipliers (SiPMs) on both ends of fiber
 - Hit resolution: $\sim 1 \text{ cm} \times \sim 15 \text{ cm} \times \sim 1 \text{ ns}$



Extruded scintillator bar with WLS fiber through center



Each WLS fiber loops through two bars



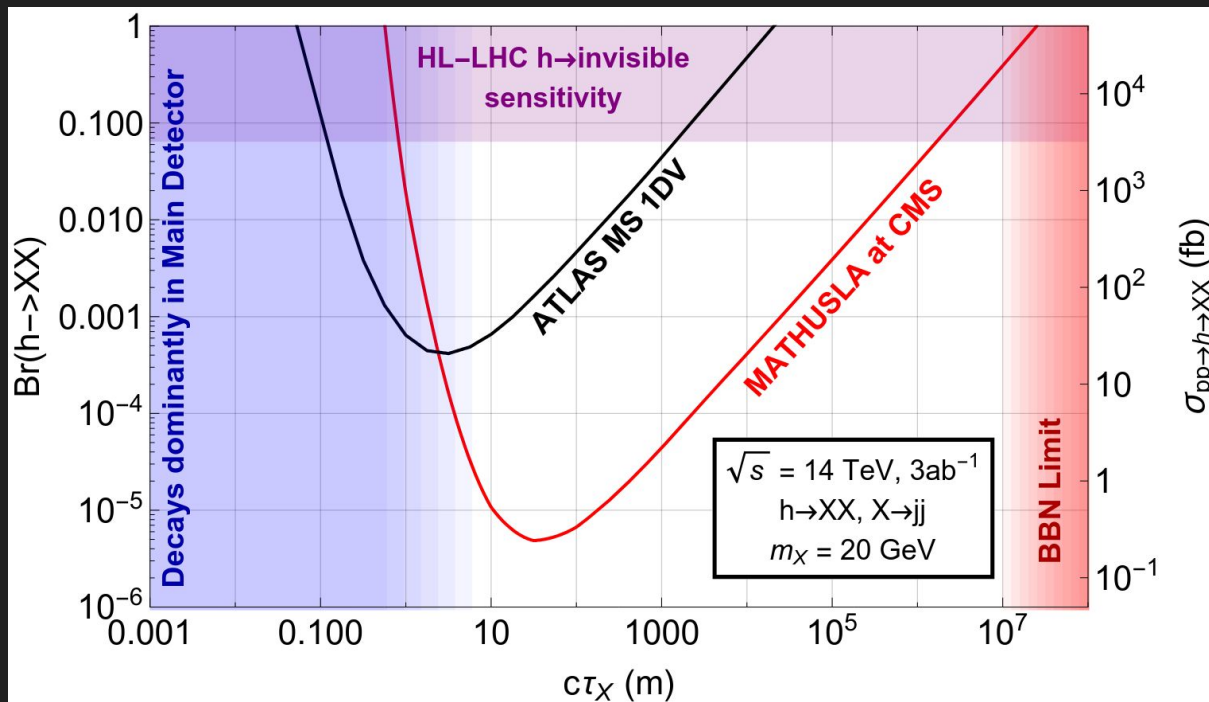
Example SiPMs that have been tested

Trigger and data acquisition

- Naturally shielded from IP, so hit rates are dominated by cosmic rays
- Plan to use commodity hardware for trigger and data acquisition
 - Stream all hits to a buffer storage
 - Relevant hits selected for permanent storage by a high-level trigger
- Able to trigger CMS readout
 - Allows matching to 4π event information
 - Can check missing transverse momentum in CMS collisions, for example
 - Challenging due to tight latency requirements
 - Feasibility has been confirmed in detailed study

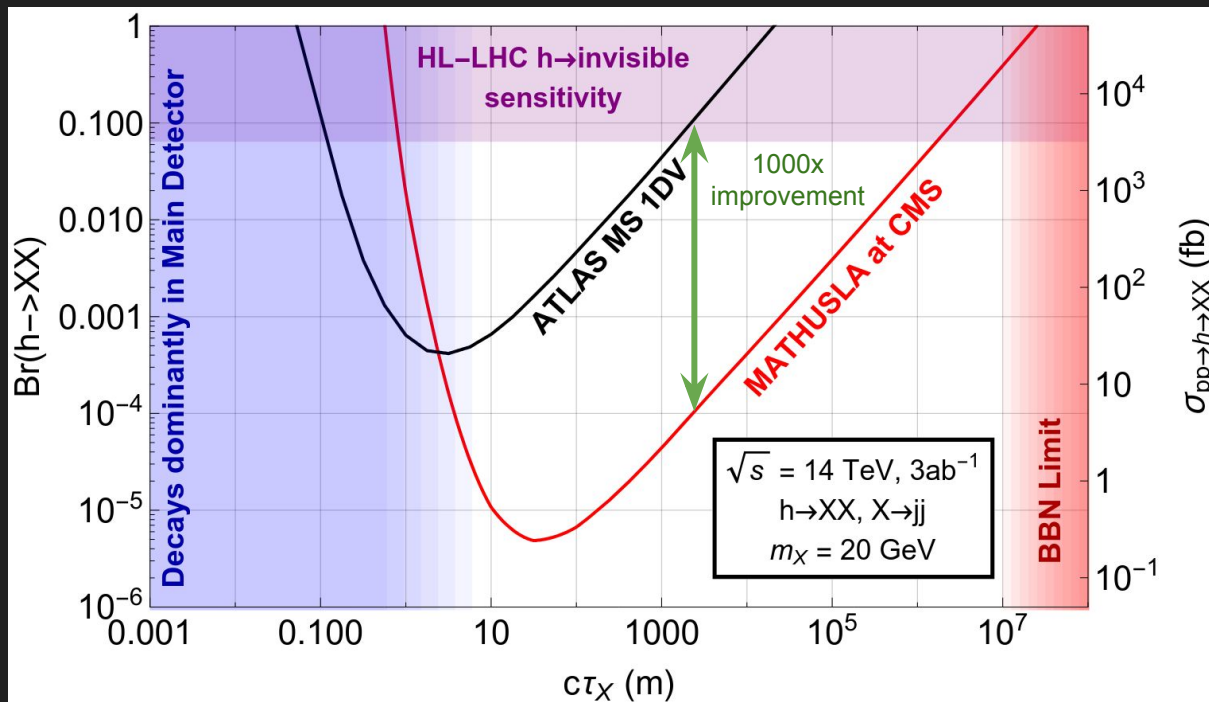
Expected sensitivity

- Primary physics case: hadronically decaying $O(10-100 \text{ GeV})$ LLPs
 - For example, from exotic Higgs decays:



Expected sensitivity

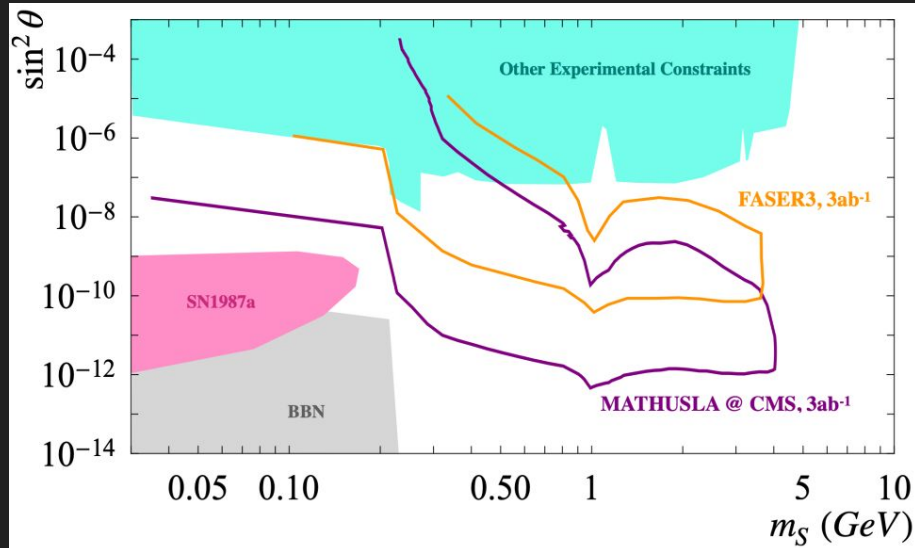
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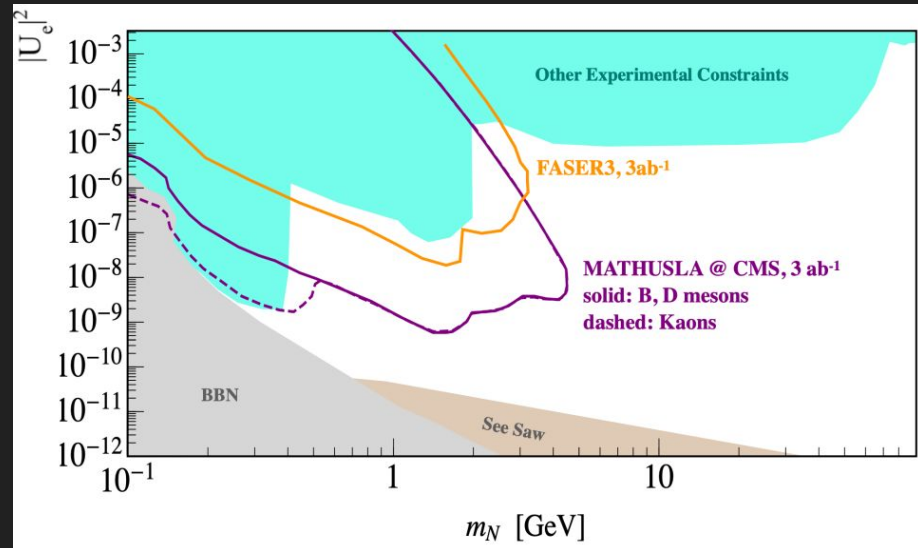
Expected sensitivity

- Secondary physics case: GeV-scale LLPs

Singlet scalar

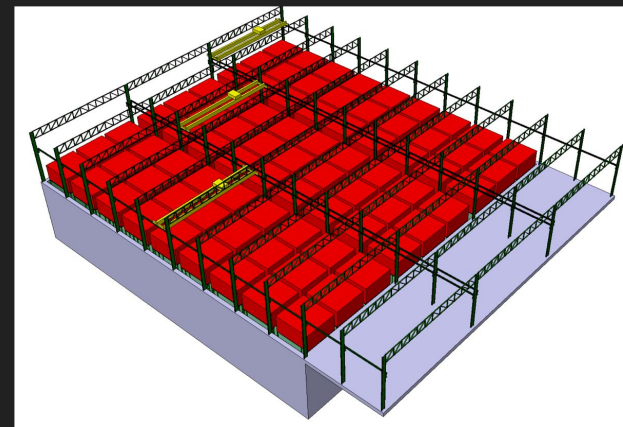


Right-handed neutrino



Status and outlook

- Current status:
 - Detector technology has been studied extensively
 - Small lab-scale prototype units are under construction
 - Conceptual design report (CDR) is in preparation
- Looking ahead:
 - Full detector can be installed in stages (i.e., per detector unit)
 - Can begin taking data before all units are installed
 - Goal is to be ready for the start of HL-LHC running



Summary

- MATHUSLA is a proposed surface-level LHC experiment that extends neutral LLP decay sensitivity up to cosmological limits on lifetime
- A growing collaboration:
(and new collaborators welcome!)

<https://mathusla-experiment.web.cern.ch/>

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