The HUNTER Sterile Neutrino Search Experiment: Progress Towards a ^{131}Cs Decay Source

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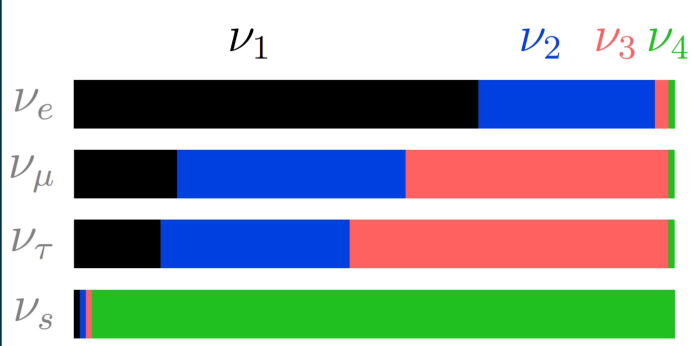
Introduction

Right-handed neutrinos are a candidate extension to the Standard Model (SM) which would facilitate generation of sub-eV neutrino masses

They would not participate in SM interactions – 'sterile.' Their discovery would indicate new physics beyond the SM

They could be detected by possible mixing with active (e, μ, τ) neutrinos

Three active neutrinos + one sterile:



$$\begin{pmatrix}\nu_e\\ \nu_\mu\\ \nu_\tau\\ \nu_s\end{pmatrix} = \begin{pmatrix}|U_{e1}| & |U_{e2}| & |U_{e3}| & \cdots\\ |U_{\mu 1}| & |U_{\mu 2}| & |U_{\mu 3}| & \cdots\\ |U_{\tau 1}| & |U_{\tau 2}| & |U_{\tau 3}| & \cdots\\ \cdots & \cdots & \cdots & \cdots\end{pmatrix}\begin{pmatrix}\nu_1\\ \nu_2\\ \nu_3\\ \nu_4\end{pmatrix}$$

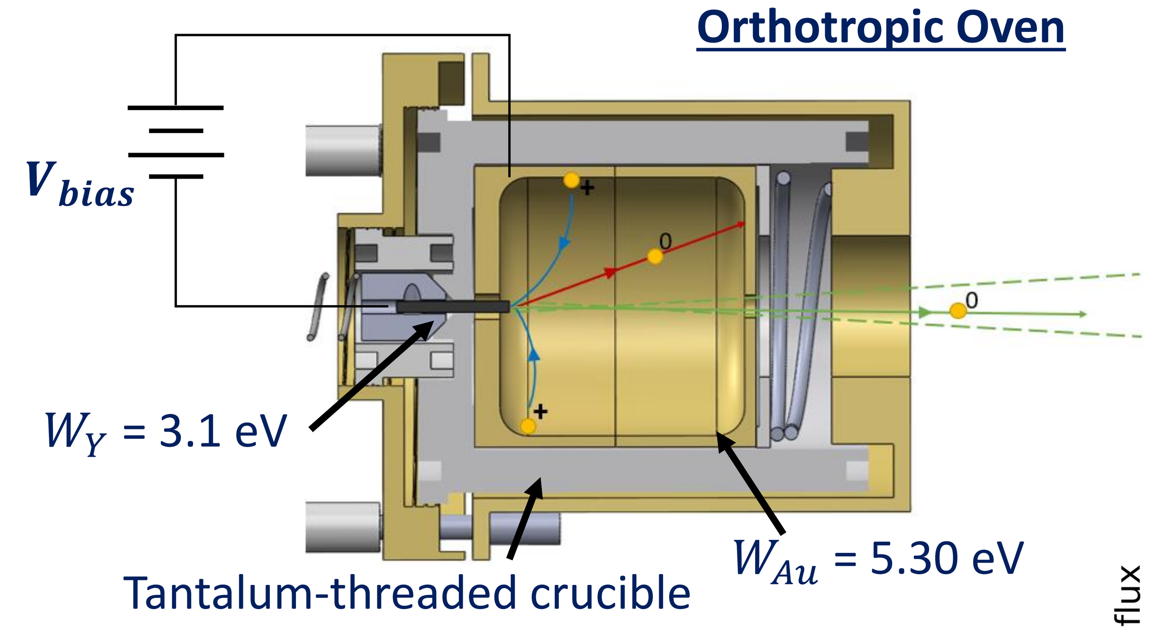
HUNTER (Heavy Unseen Neutrinos by Total Energy-Momentum Reconstruction) is a laboratory search for sterile neutrinos. Proof-of-concept Phase I will be sensitive to ν_s with $30 \lesssim m_\nu \lesssim 300\ \mathrm{keV}/c^2$.

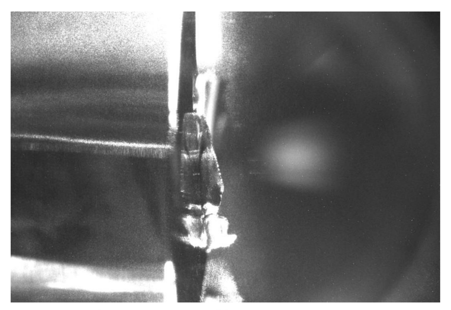
Atomic Cs Source

Develop an atomic Cs source for loading a trap with ~10 μg ^{131}CsCl refill every few weeks. 10 μg ^{131}CsCl: ~1 Ci ($t_{1/2}$ = 9.7 d), 3 x 10^{16} Cs atoms

We chose a thermionic emission-based source, which emits a directional, voltage-controlled atomic beam with geometry-determined divergence and recovers atoms which do not clear the exit aperture [3]

Orthotropic Oven





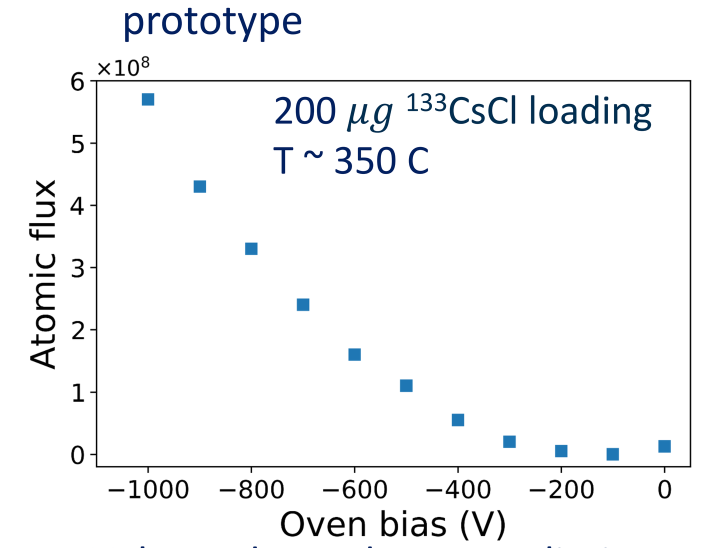
Atomic beam fluorescence, prototype

Saha-Langmuir equation

$$\frac{n_+}{n_0} = \frac{g_+}{g_0} e^{-\frac{(I-W)}{kT}}$$

I_{Cs} = 3.89 eV

$W > I$ for large ionic emission ratio



Voltage dependence, preliminary

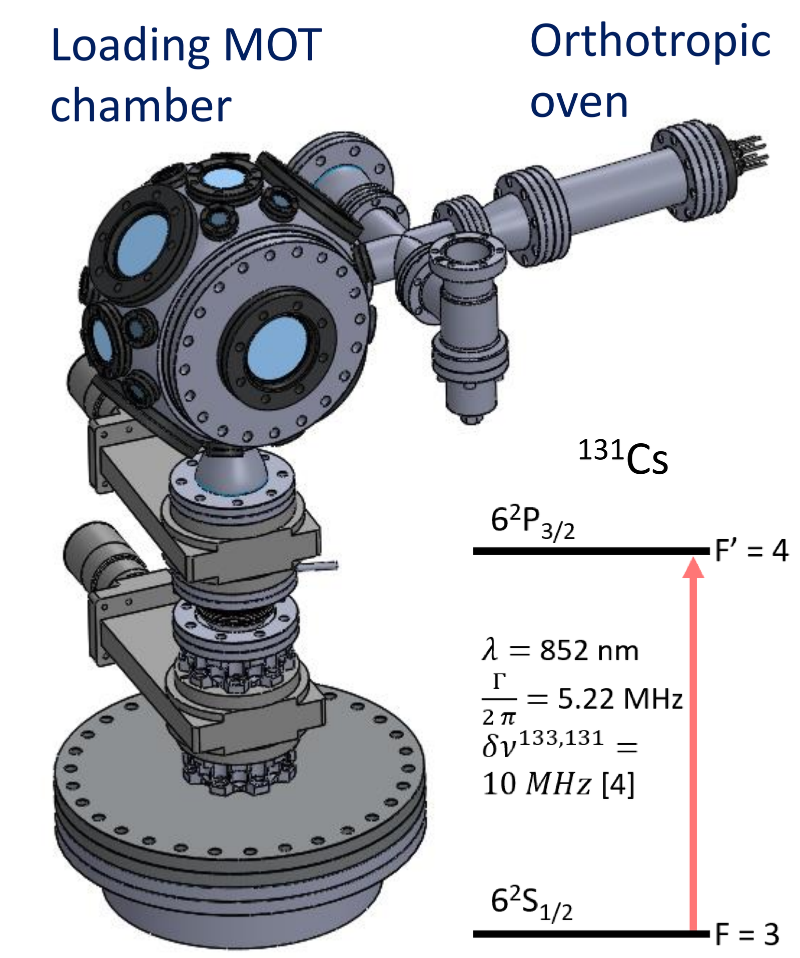
Decay Source Details

^{131}Cs trapped in a MOT provides a sufficiently low-temperature (20 μK) and spatially localized (1 mm) decay source

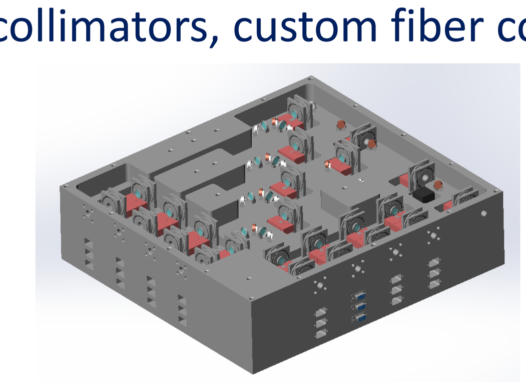
Continuously maintain decay source cloud with N > 10^8 for $t \approx 1$ yr, while running a data collection sequence involving switched MOT field

Load with a second MOT through gravity aided transfer. Separation of loading and experiment regions reduces reconstruction background

Stable and/or automated assemblies desired: custom beam control boxes, kinematic 50 mm beam collimators, custom fiber coupling

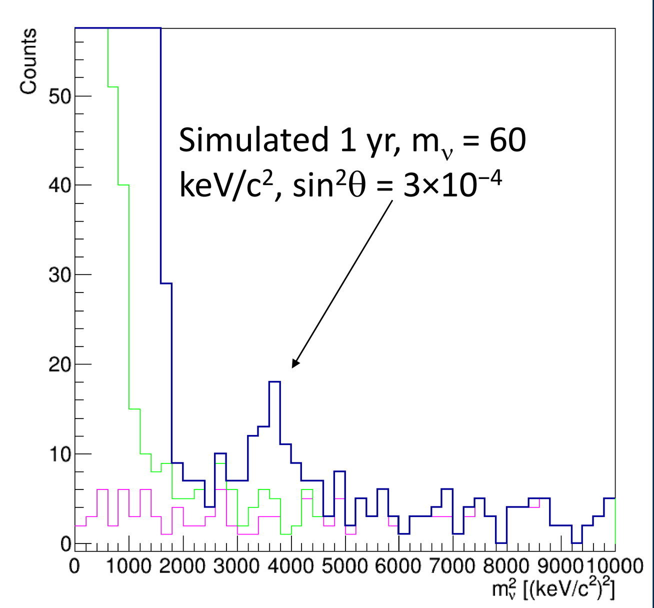


2.5 m drop to decay source MOT



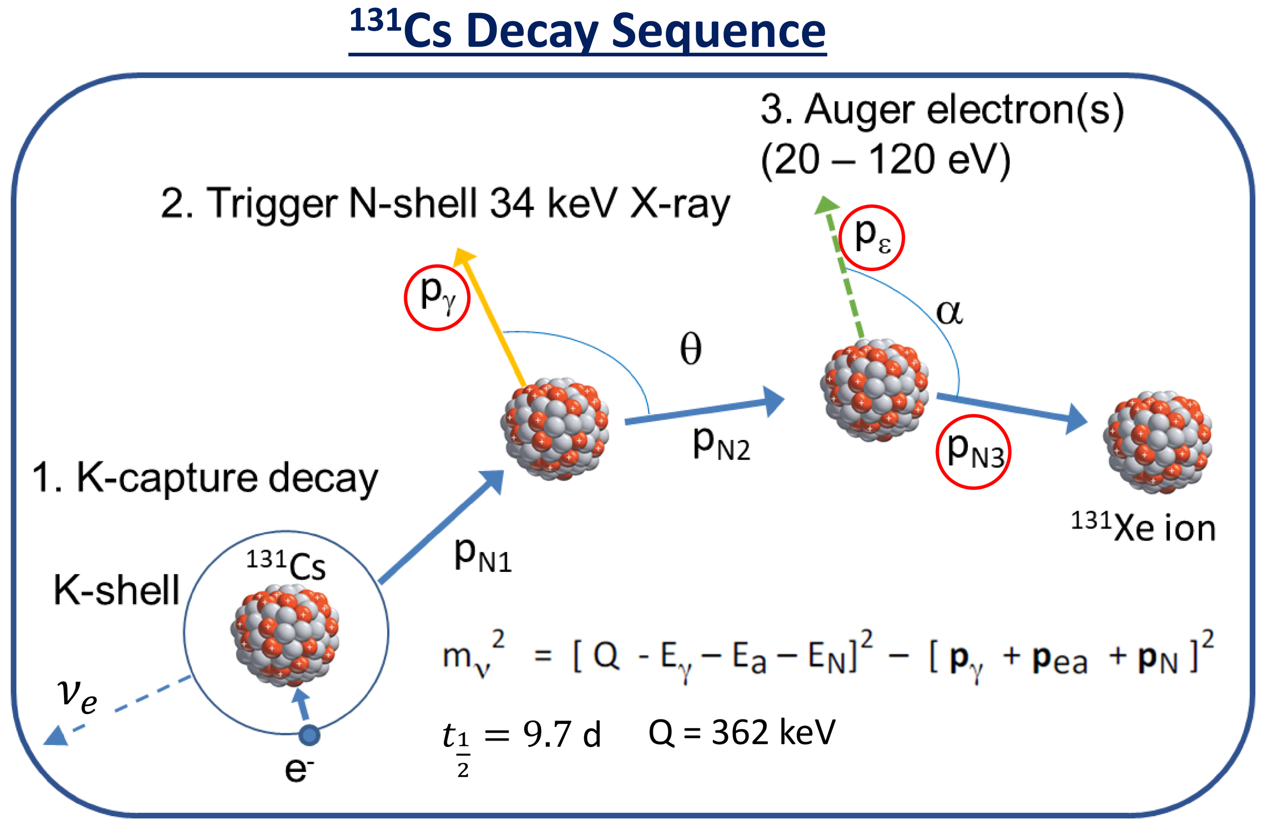
HUNTER Principle

Reconstruct vector momenta of ^{131}Cs decay products using precision timing and position sensitive detectors, and calculate the missing neutrino mass [2]

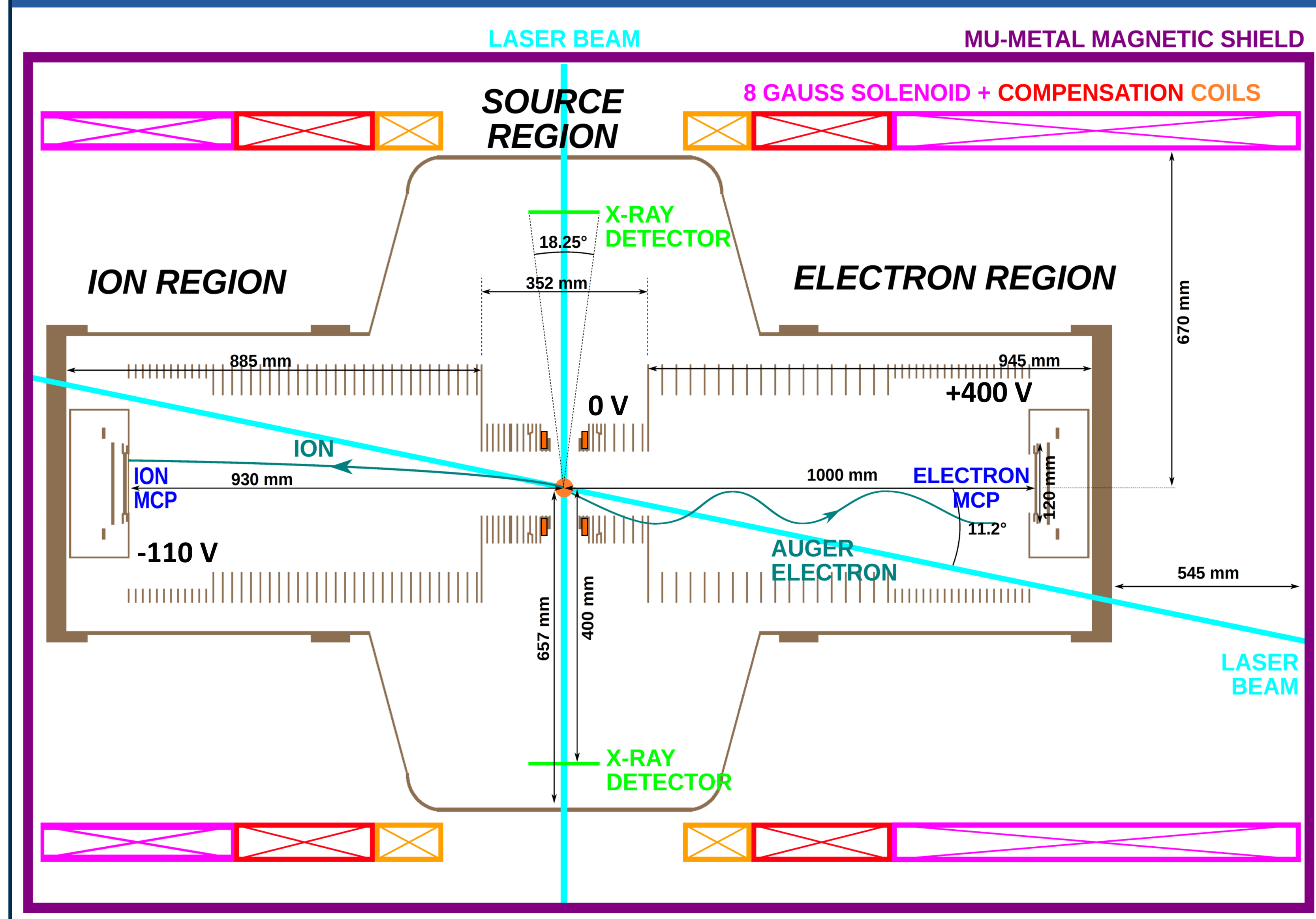


^{131}Cs: 100% electron capture decay, non-penetrating radiation, no additional gamma from daughter, alkali level structure

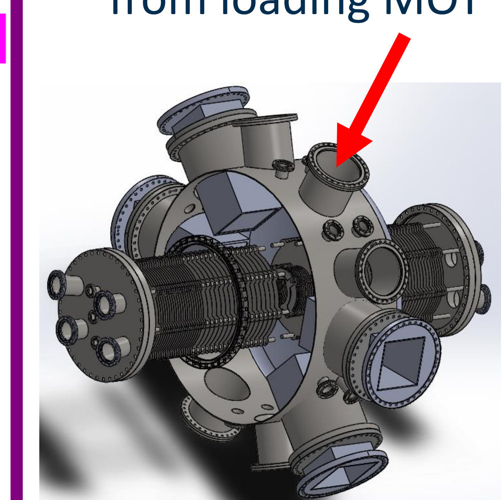
^{131}Cs Decay Sequence



MOT Reaction Microscope Layout



Transfer cloud from loading MOT

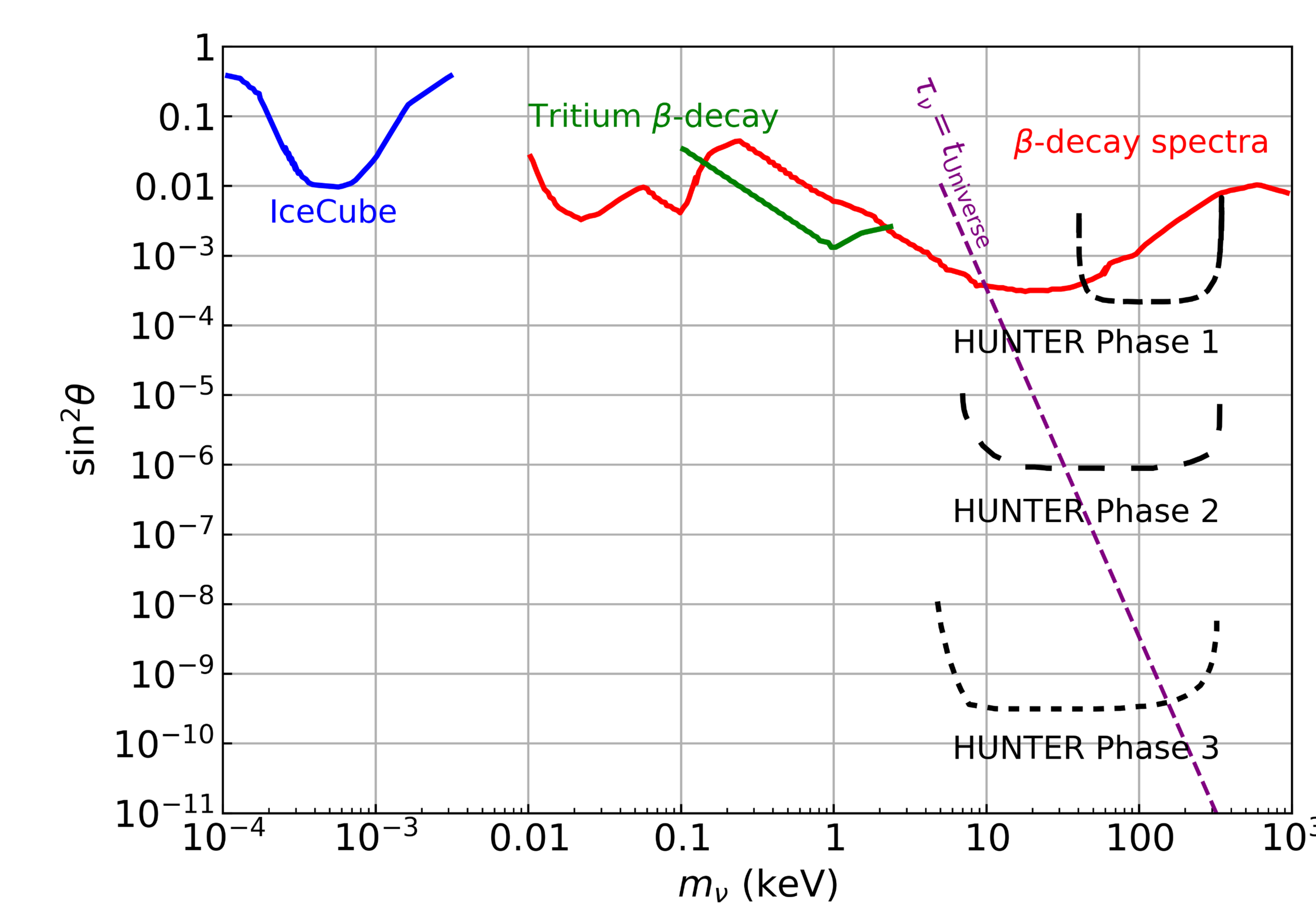


Vacuum vessel and spectrometer construction in progress

Reaction microscope arms use static E- and B-fields to detect Auger electrons and ^{131}Xe$^{(+)}$ with high collection efficiency

Four 250 x 250 mm panels detect x-rays using LYSO scintillator and silicon photomultiplier readout, providing TOF trigger for charged particle detection. X-ray subsystem in development.

Projected Sensitivity



Solid lines are existing experimental bounds. Dotted lines are projected HUNTER sensitivities for a 1-year runtime.

Phases 2 and 3 feature upgrades that will increase energy and coupling resolution: increased MOT population, greater x-ray collection solid angle, larger MCP area

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