Lake and Surface-Based Detectors for Forward Neutrino Physics

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Overview

We propose two medium-baseline, kiloton-scale neutrino experiments to study neutrinos from LHC proton-proton collisions:

SINE: the Surface-based Integrated Neutrino Experiment (CMS)

- Scintillator panels in shipping containers measuring up-going muons from ν_μ interactions in the surrounding bedrock

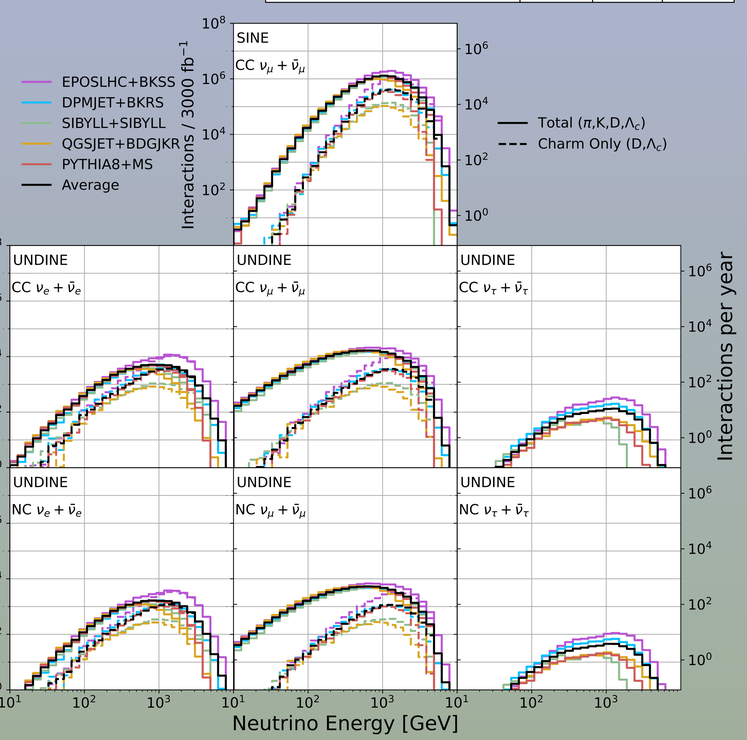
UNDINE: the Underwater Integrated Neutrino Experiment (LHCb)

- Water-Cherenkov detector in lake Geneva observing all-flavor neutrino interactions using CHIPS sub-detectors [1]

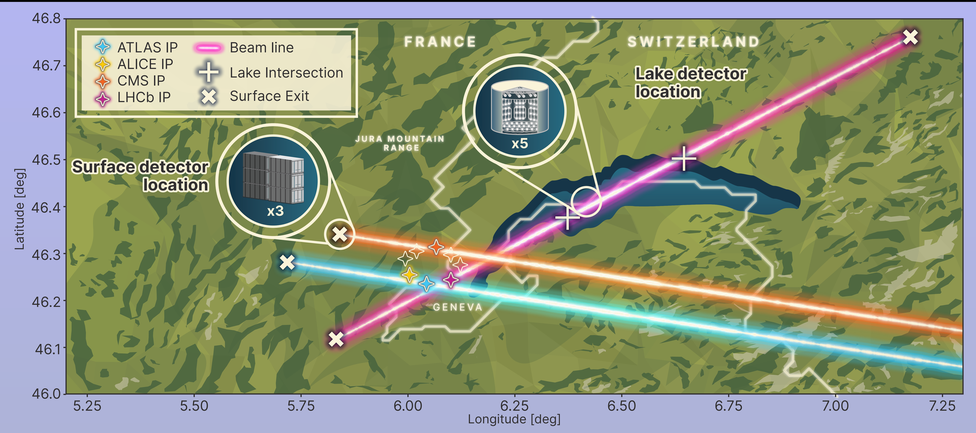
Neutrino Event Rates

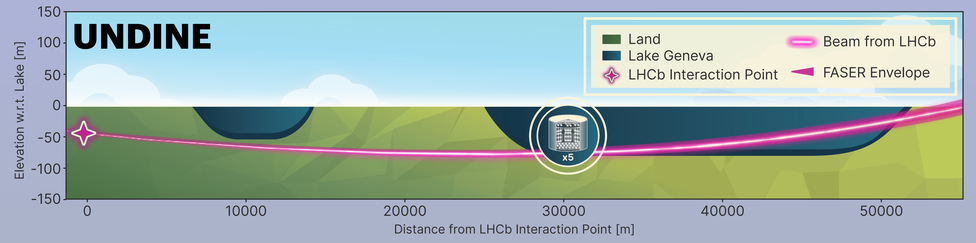
Number of neutrino interactions in each detector throughout the High-Luminosity LHC

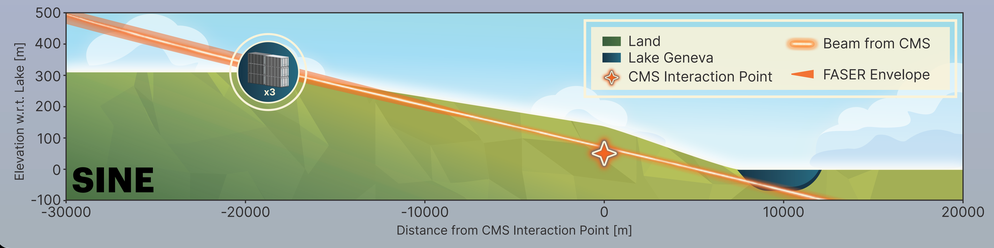
Dataset	**Total**	π, K	D, Λ_c
SINE (CC $\nu_\mu + \bar{\nu}_\mu$)	$10^{6.98}$	$10^{6.84}$	$10^{6.40}$
UNDINE (CC $\nu_e + \bar{\nu}_e$)	$10^{4.68}$	$10^{4.32}$	$10^{4.42}$
UNDINE (CC $\nu_\mu + \bar{\nu}_\mu$)	$10^{5.27}$	$10^{5.20}$	$10^{4.41}$
UNDINE (CC $\nu_\tau + \bar{\nu}_\tau$)	$10^{3.07}$	0	$10^{3.07}$
UNDINE (NC $\nu_\alpha + \bar{\nu}_\alpha$)	$10^{4.87}$	$10^{4.76}$	$10^{4.24}$



Experimental Configuration



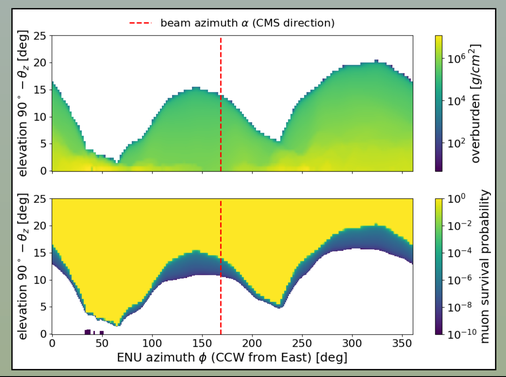


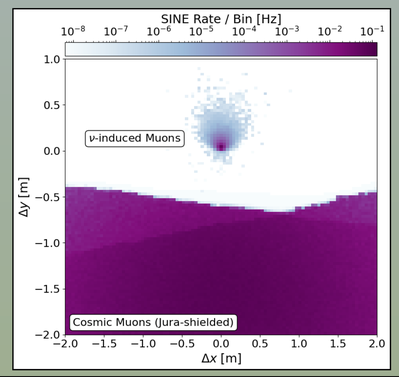


Natural Background Suppression

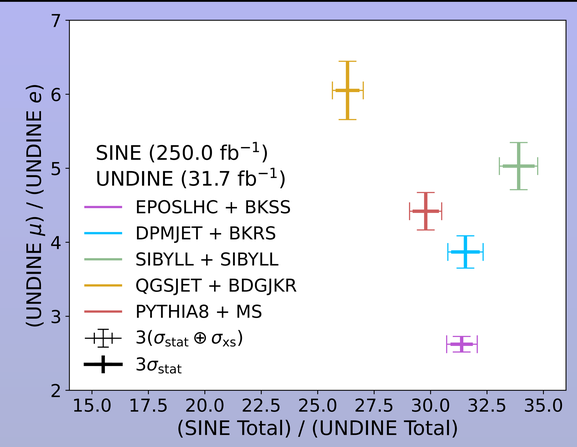
SINE: the surrounding Jura mountains shield cosmic muon backgrounds, which can then be eliminated with a vertical spatial resolution of $\mathcal{O}(0.5\,\mathrm{m})$ [2]

UNDINE: the $\mathcal{O}(50\,\mathrm{m})$ of water overburden is sufficient cosmic muon shielding [1]

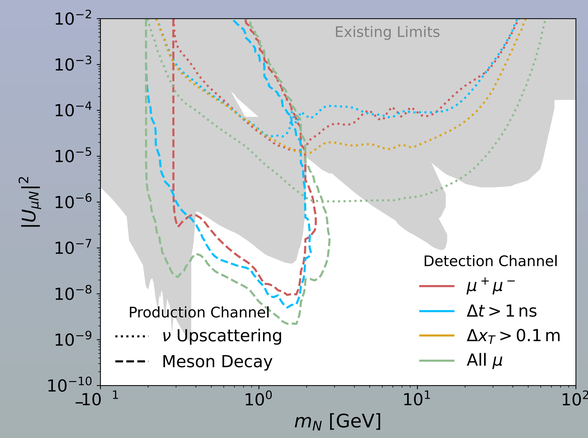




Rich SM and BSM Physics Program



SM example: forward charm production. Ratio measurements can distinguish between forward charm production models, which is sensitive to the intrinsic charm of the proton [3] and the prompt atmospheric neutrino flux [4]



BSM example: heavy neutral leptons. SINE can search for right-handed partners of the active neutrinos via three strategies: di-muon pairs, delayed muons, and high transverse-momentum muons

Outlook

SINE and UNDINE are **unique, cost-effective** collider neutrino detectors that **leverage the natural environment** to instrument large volumes while minimizing cosmic muon backgrounds. These detectors have a **rich physics program** and, along with the independent work of Ref. [6], offer a promising avenue for **medium-baseline forward neutrino physics during the HL-LHC.**

References

[1] CHIPS Collab. 2024
[2] github/jlazar17/CORSIKA-terrain
[3] Maciula+ PRD 2023
[4] Jeong+ ICRC 2023
[5] Albrecht+ Astrophys. Space Sci. 2022
[6] Ariga+ JHEP 2025

Acknowledgments

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