Search for a Long-Lived $\mu\mu$ Resonance in the NuMI Beam at ICARUS

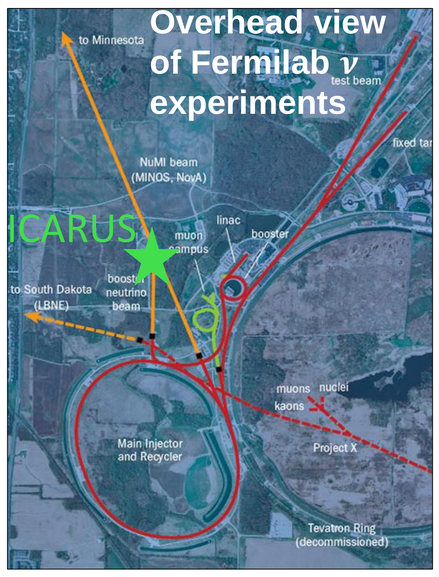
Gray Putnam, Fermilab

On behalf of ICARUS Collaboration

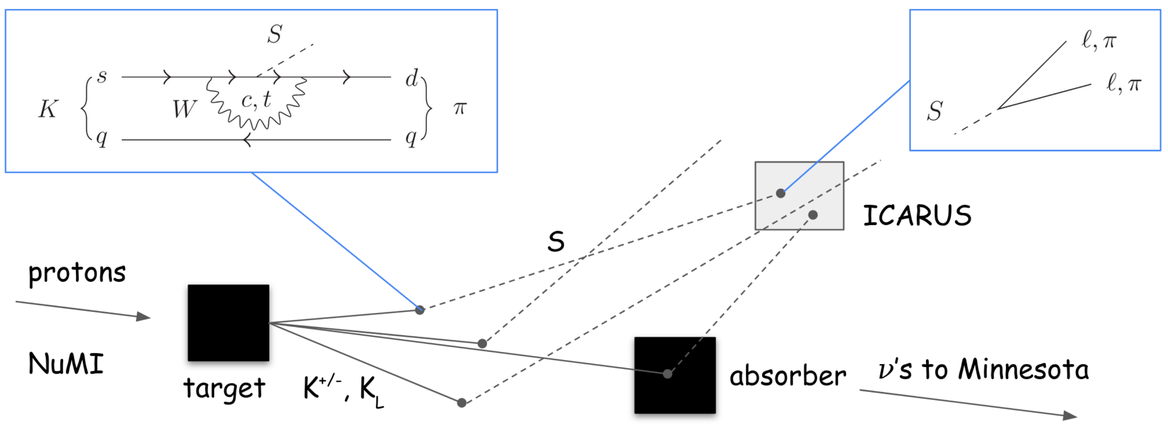
Searching for New Physics at ICARUS

The ICARUS neutrino detector[1] is at the intersection of the BNB and NuMI neutrino beams at Fermilab.

New physics particles like the **Higgs Portal Scalar**[2] **(HPS)** and an **Axion-Like Particle**[3] **(ALP)** can be produced in kaon decay in the NuMI target, travel to ICARUS, and decay into SM final states (including $\mu\mu$!)



Below: Production and decay of a Scalar particle (the Higgs Portal Scalar) in ICARUS with the NuMI beam.



Imaging $\mu\mu$ Decays with the ICARUS LArTPC

Calorimetric and topological information distinguish stopping $\mu\mu$ events. Kinematic cuts further reject the neutrino background.

The residual background is mostly: ν_μ CC Coherent-π scattering (right).

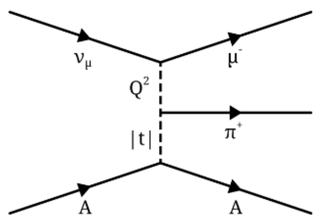
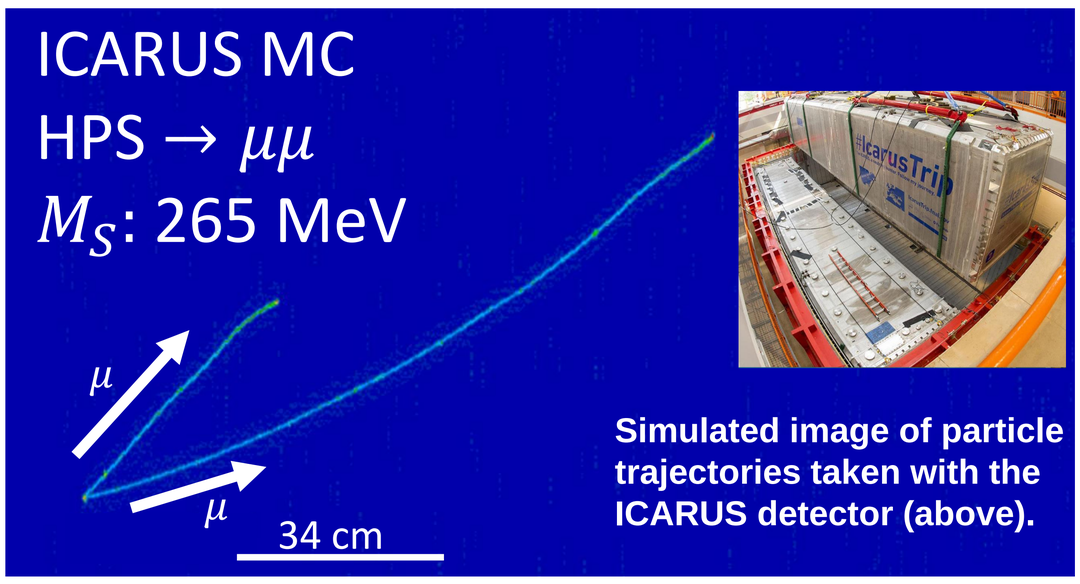
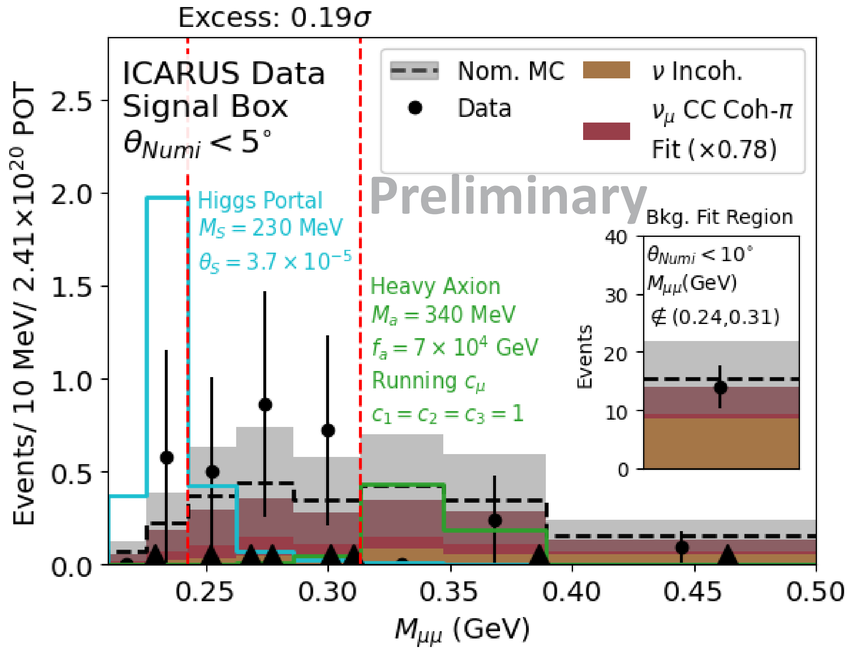


Diagram of background ν_μ CC Coh.-π scattering process.



Simulated image of particle trajectories taken with the ICARUS detector (above).

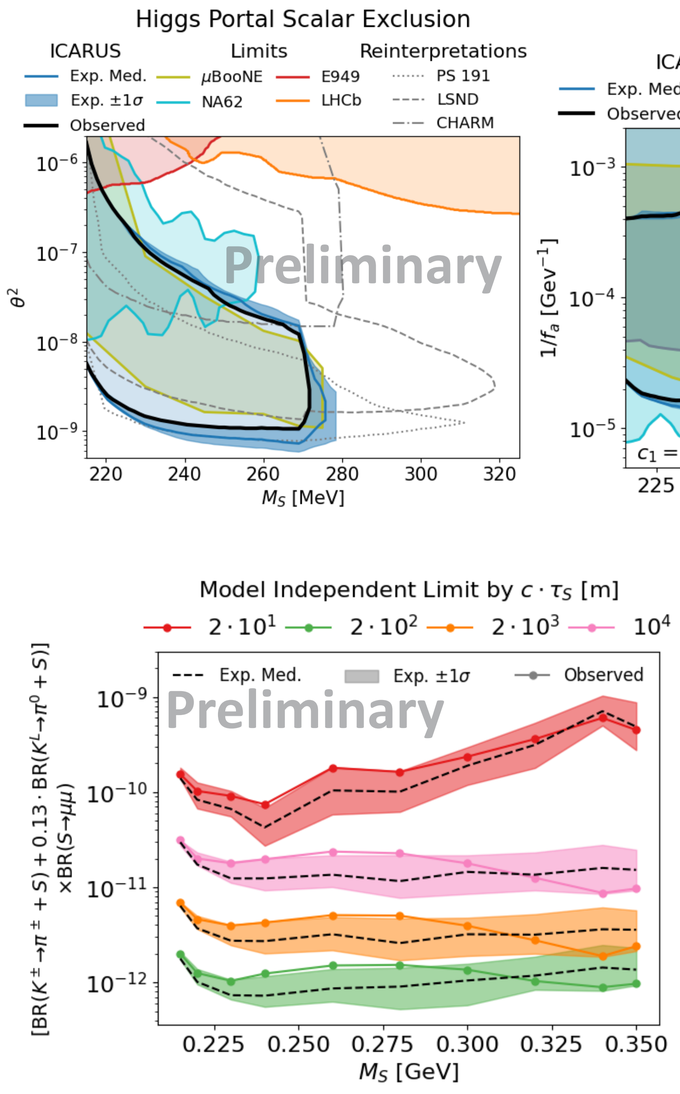
Signal Box Result

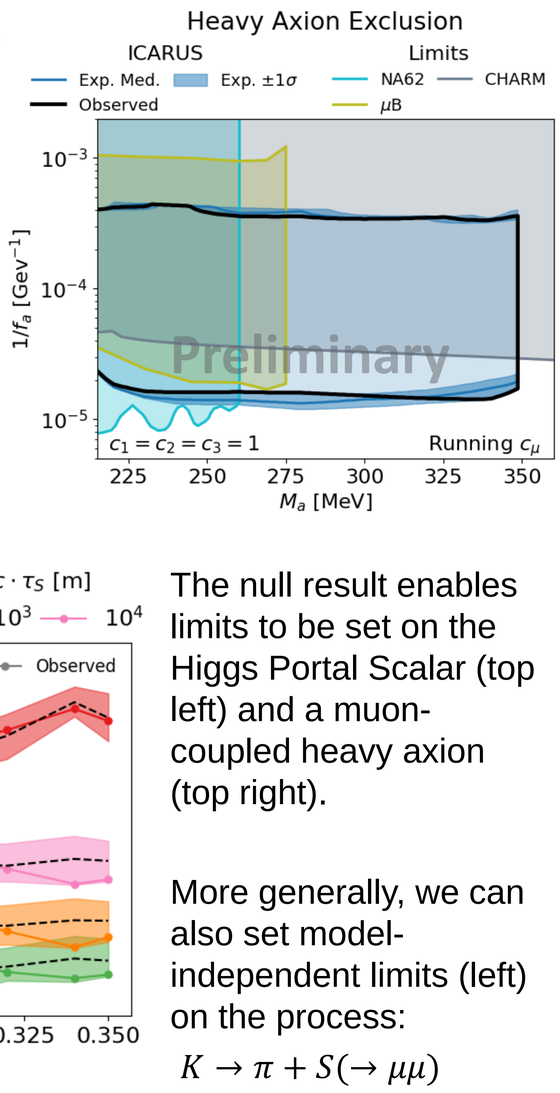


A scale factor is fit to the ν_μ CC Coh.-π rate in a control region and simultaneously a bump-hunter algorithm identifies the significance of any excess.

No new physics is found. The biggest excess is 0.19σ.

Limits on LLP Models





The null result enables limits to be set on the Higgs Portal Scalar (top left) and a muon-coupled heavy axion (top right).

More generally, we can also set model-independent limits (left) on the process:

$K \to \pi + S(\to \mu\mu)$

This is the first particle physics result at ICARUS!

Future searches are planned and ongoing, including with other final states and using the NuMI beam structure timing.

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1: P. Abratenko, *et al., Eur. Phys. J. C* 83, 467 (2023).

2: B. Batell, J. Berger, and A. Ismail, Rev. D 100, 115039 (2019)

3: J. Berger and G. Putnam, arXiv:2405.18480