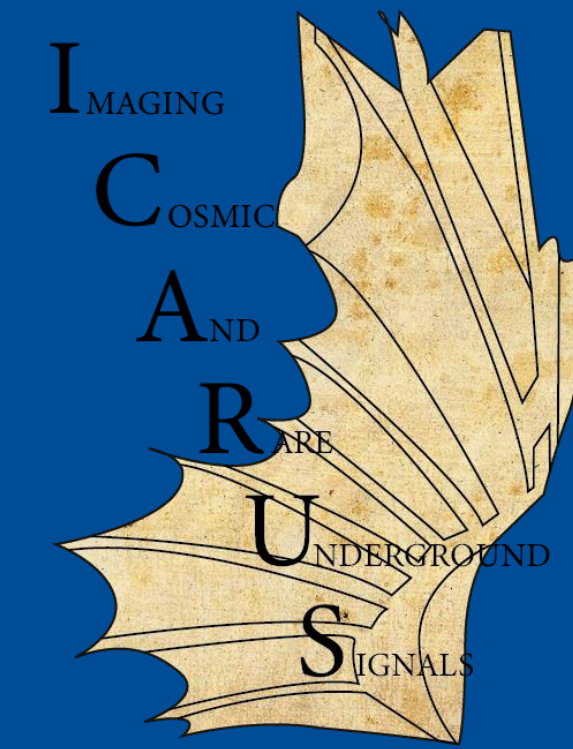


Search for a Long-Lived $\mu\mu$ Resonance in the NuMI Beam at ICARUS

Gray Putnam, Fermilab

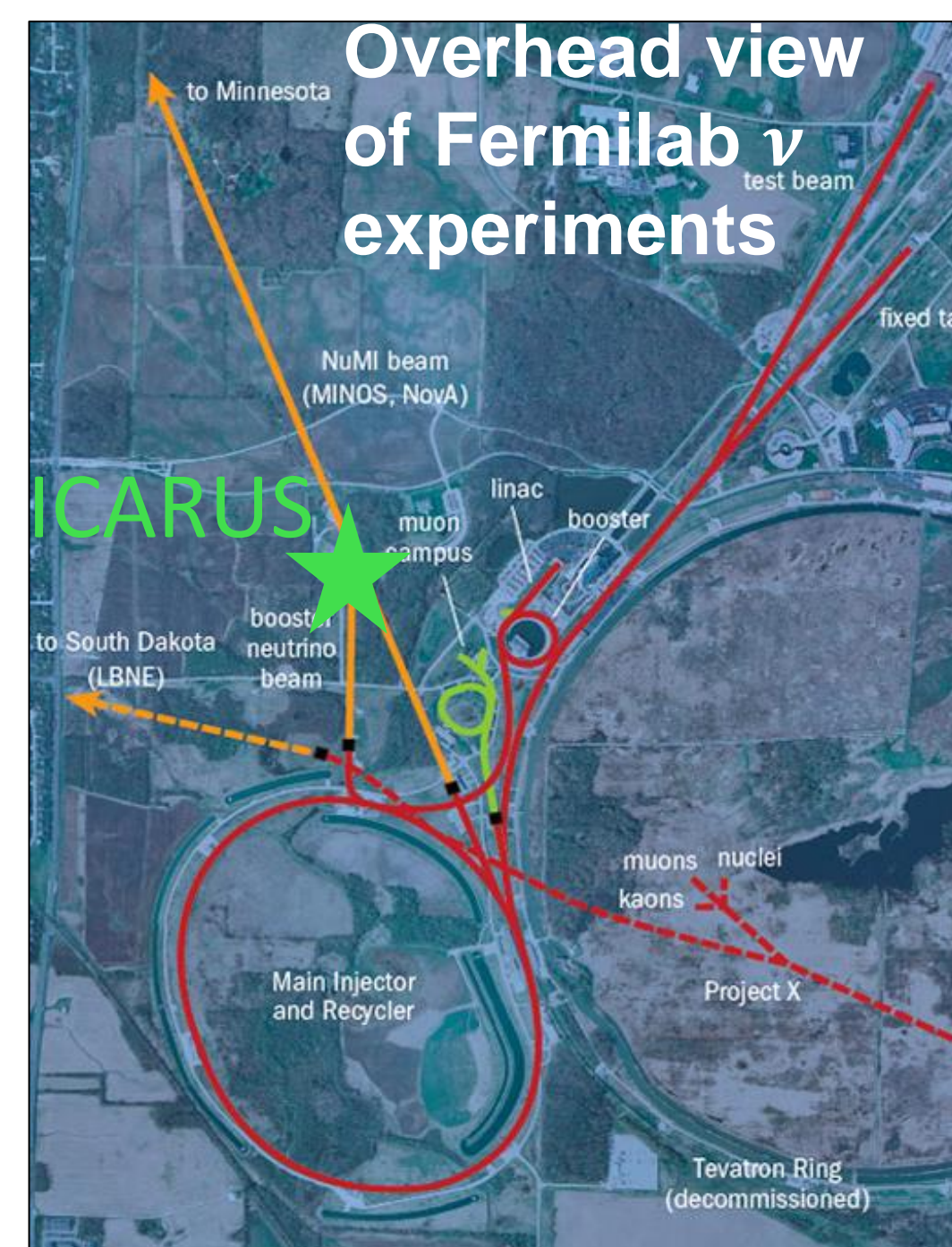
On behalf of ICARUS Collaboration



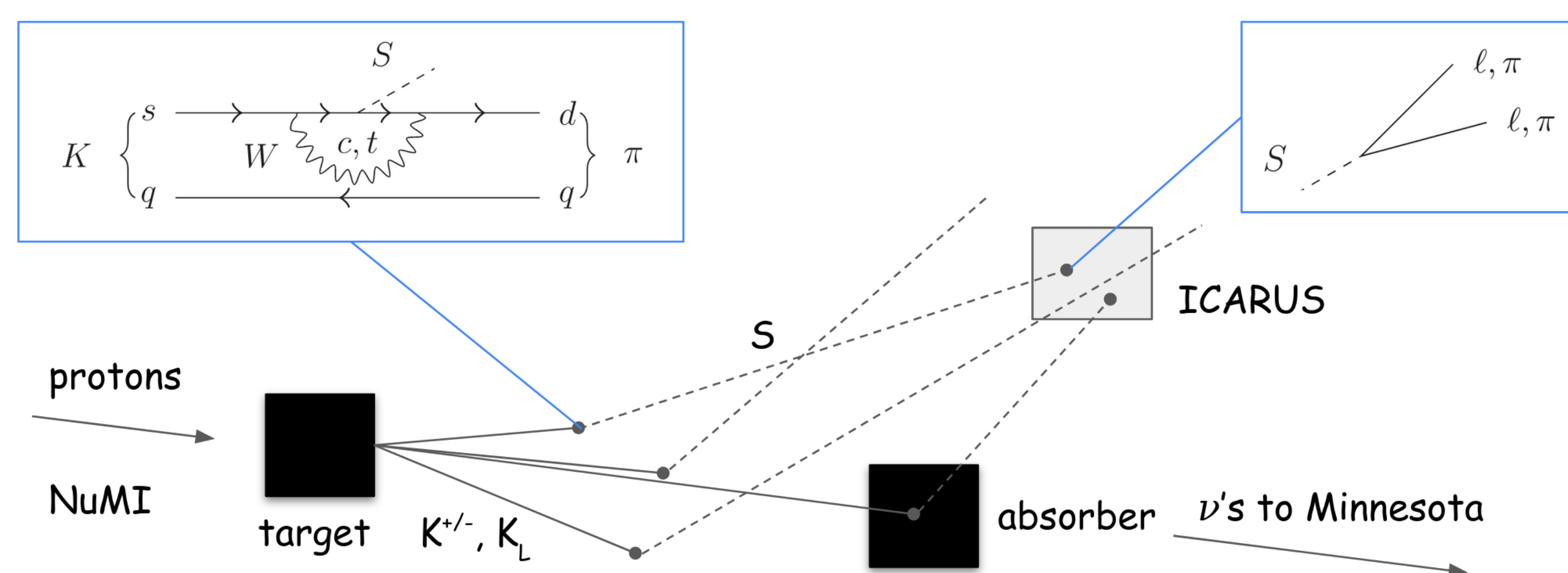
Searching for New Physics at ICARUS

The ICARUS neutrino detector¹ 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.

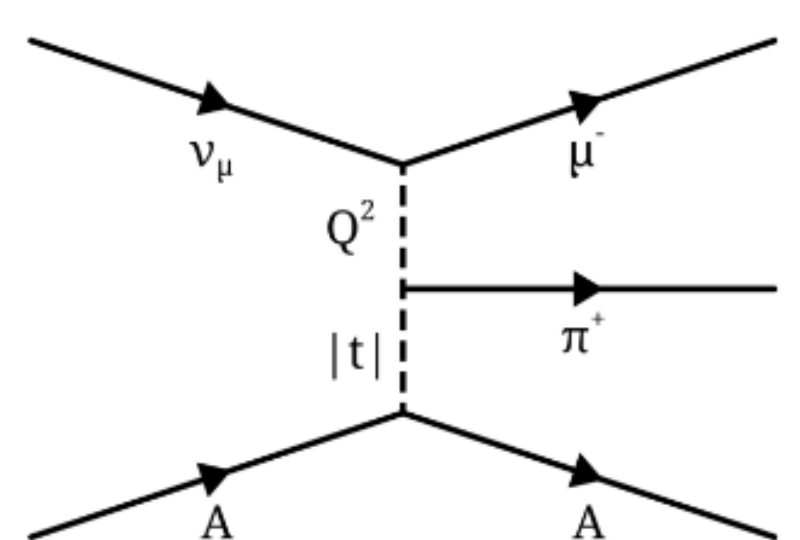


Diagram of background ν_μ CC Coh.- π scattering process.

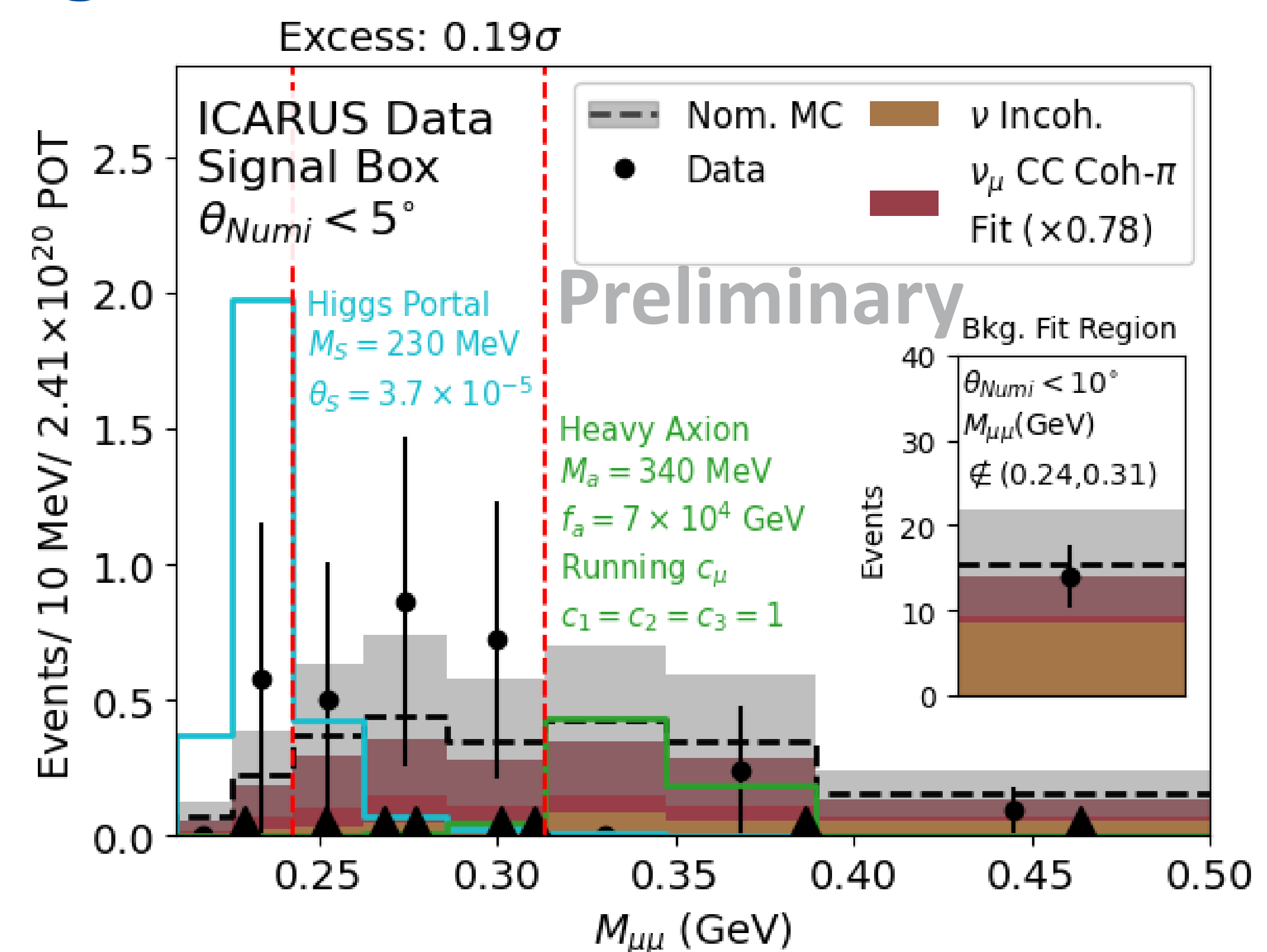
The residual background is mostly: ν_μ CC Coherent- π scattering (right).

ICARUS MC
HPS $\rightarrow \mu\mu$
 M_S : 265 MeV



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

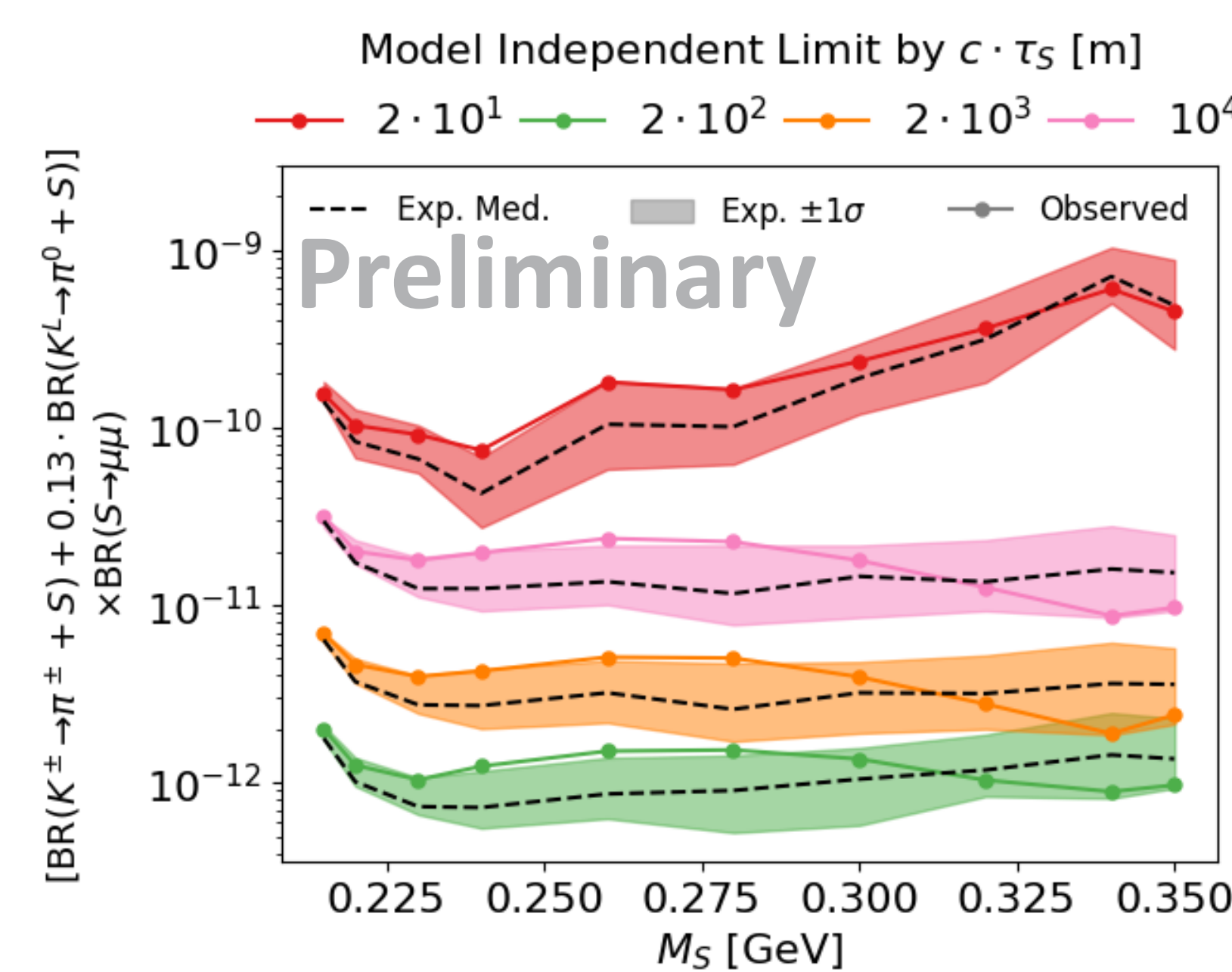
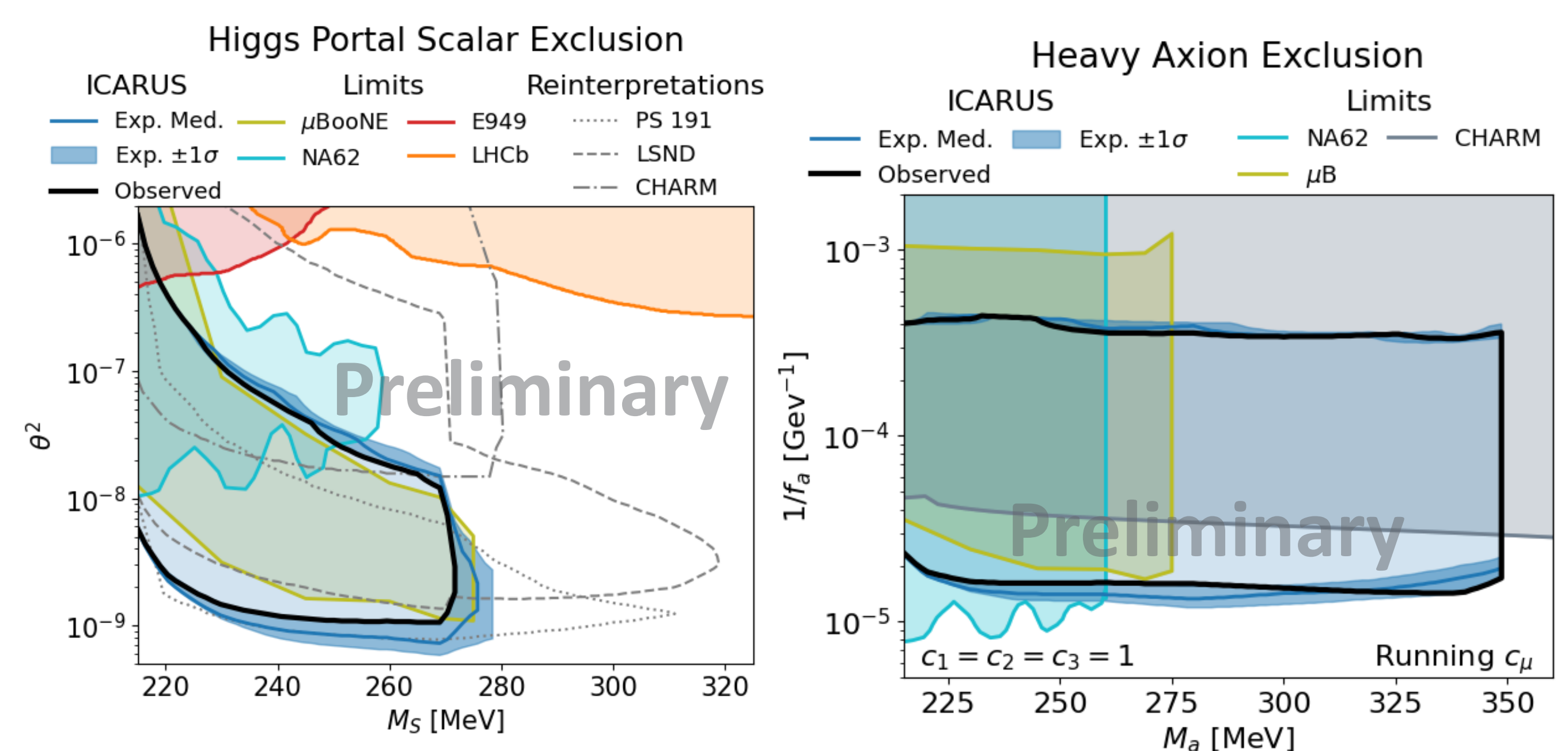
Signal Box Result



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



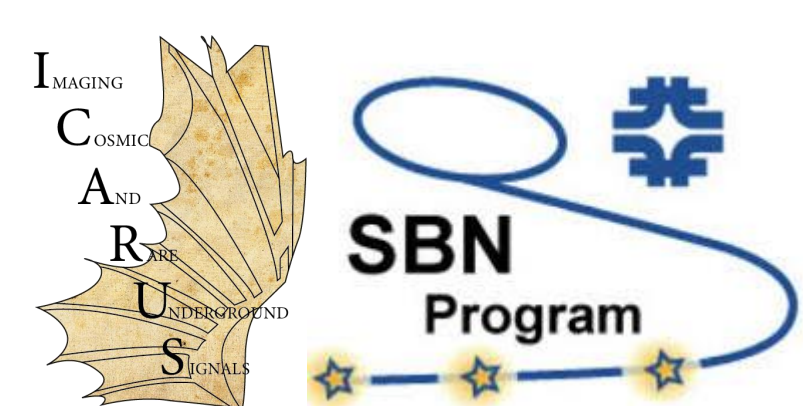
The null result enables limits to be set on the Higgs Portal Scalar (top left) and a muon-coupled heavy axion (top right).

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

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

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.



Fermilab



GRFP

This material is based upon work supported by the National Science Foundation Graduate Research Fellowship under Grant No. DGE-1746045. It will be part of the UChicago thesis: Search For A Long-Lived Di-Muon Resonance in The NuMI Beam at The ICARUS Experiment.

- 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