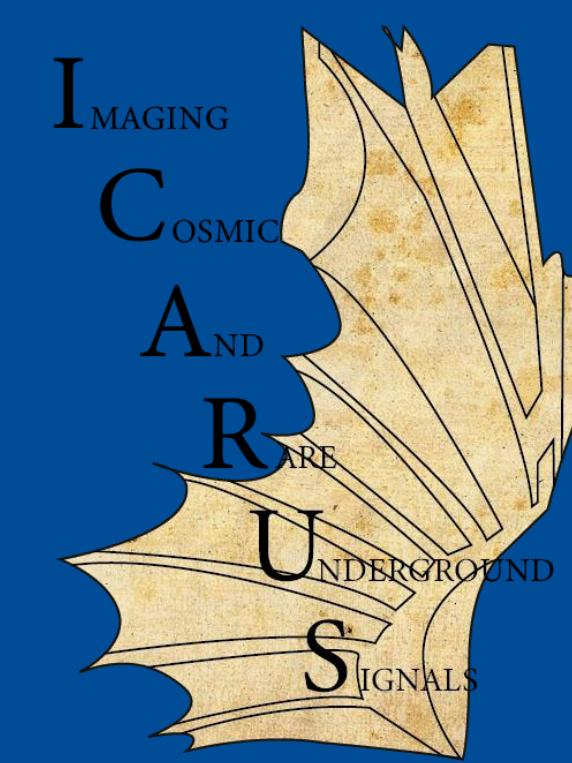


# Search for a Long-Lived $\mu\mu$ Resonance in the NuMI Beam at ICARUS

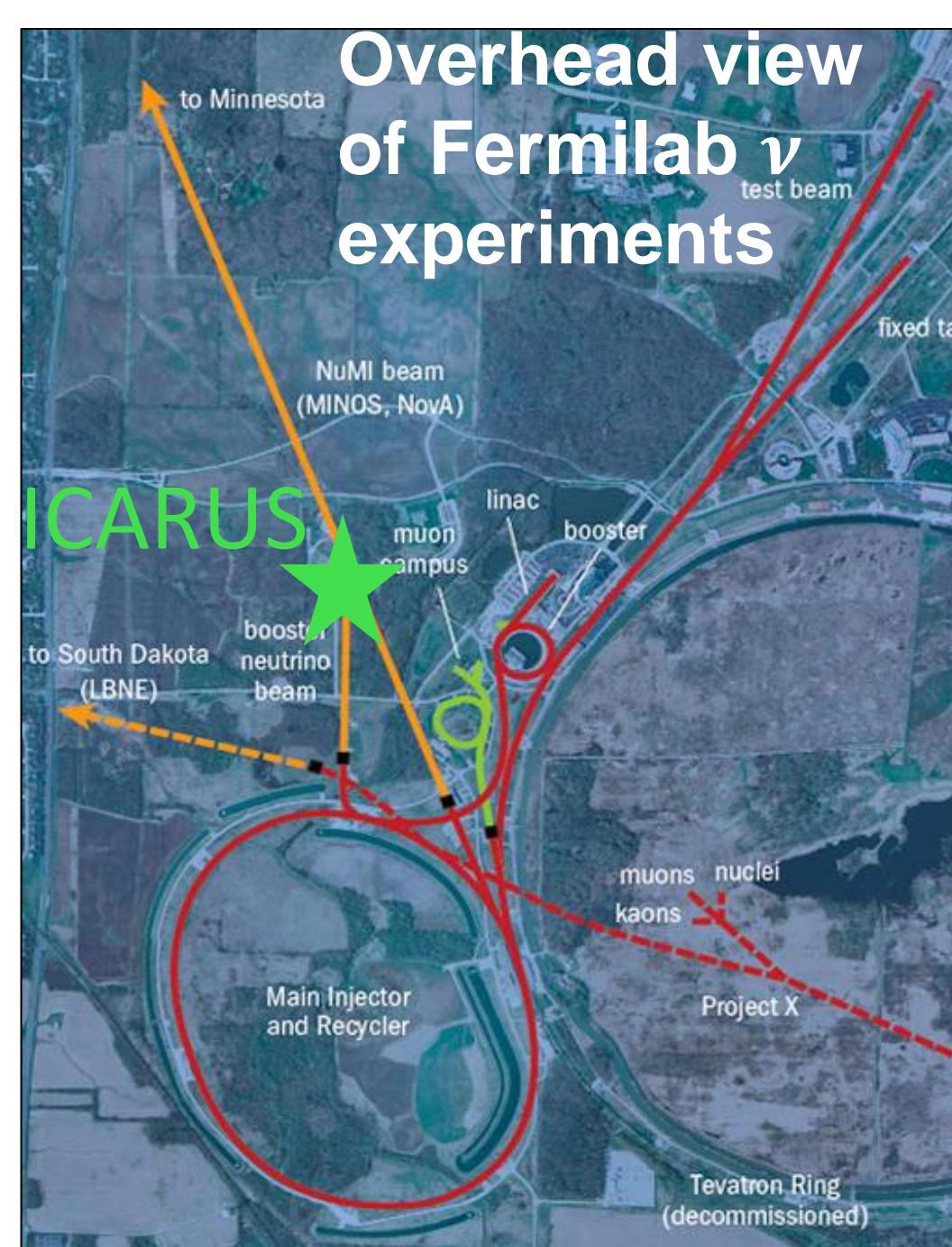
Gray Putnam, Fermilab  
On behalf of ICARUS Collaboration



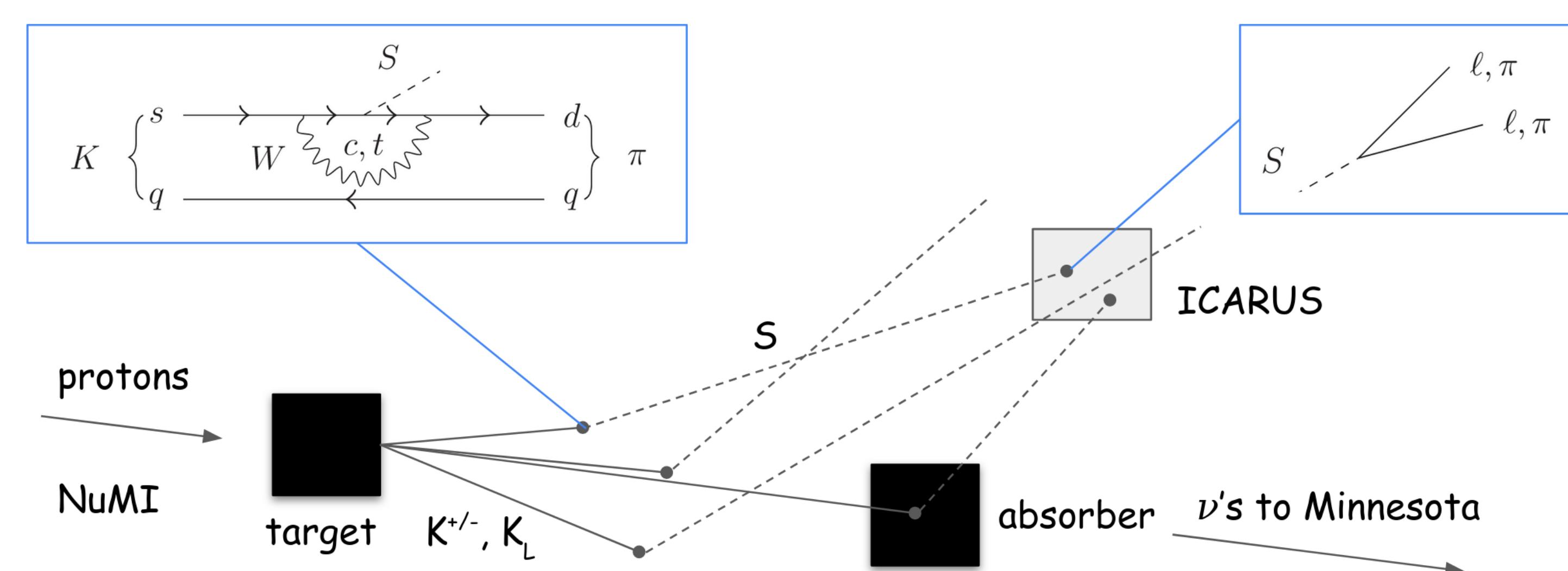
## Searching for New Physics at ICARUS

The ICARUS neutrino detector<sup>1</sup> is at the intersection of the BNB and NuMI neutrino beams at Fermilab.

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

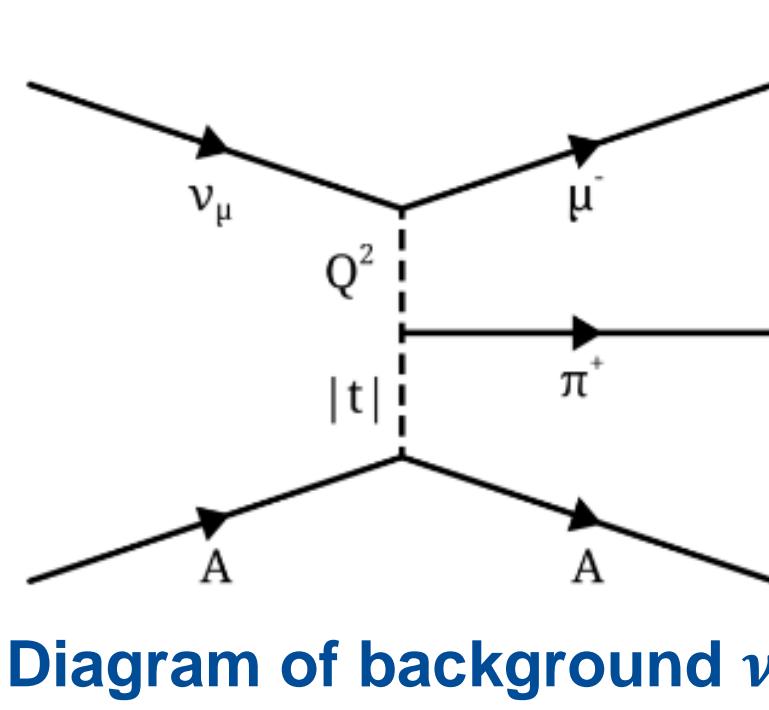


Below: Production and decay of a Scalar particle (the Higgs Portal Scalar) in ICARUS with the NuMI beam.

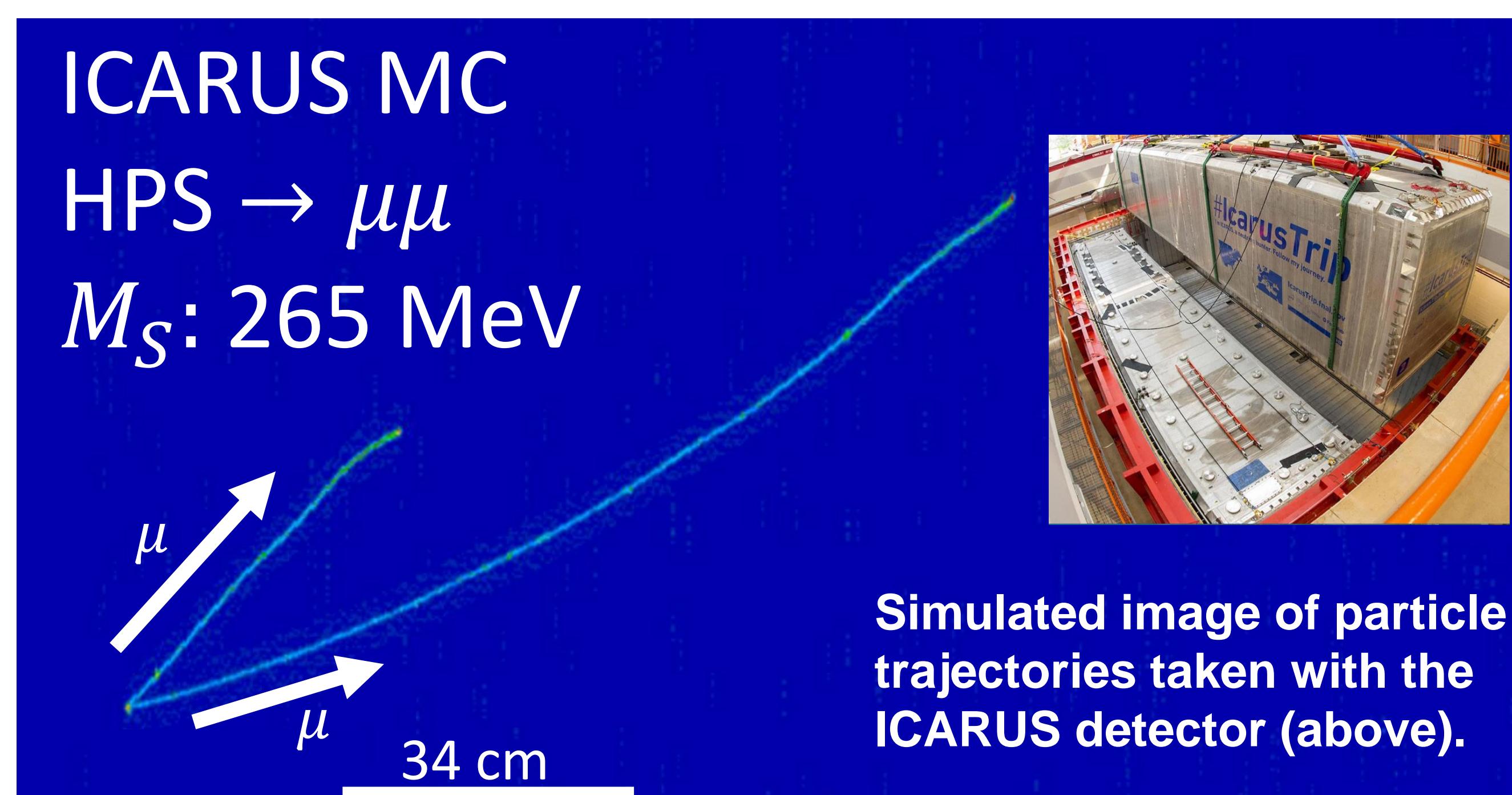


## Imaging $\mu\mu$ Decays with the ICARUS LArTPC

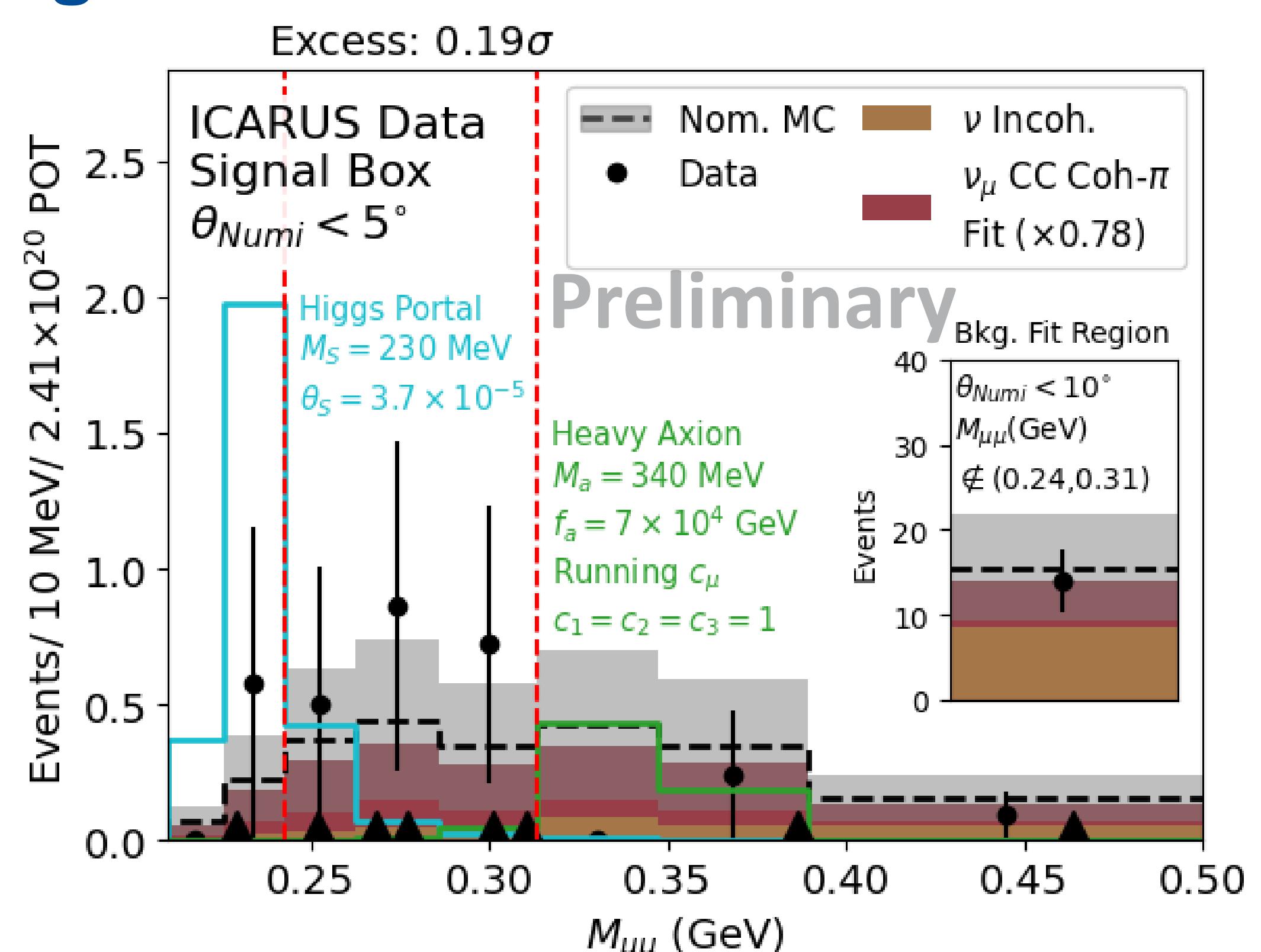
Calorimetric and topological information distinguish stopping  $\mu\mu$  events. Kinematic cuts further reject the neutrino background.



The residual background is mostly:  $\nu_\mu$  CC Coherent- $\pi$  scattering (right).



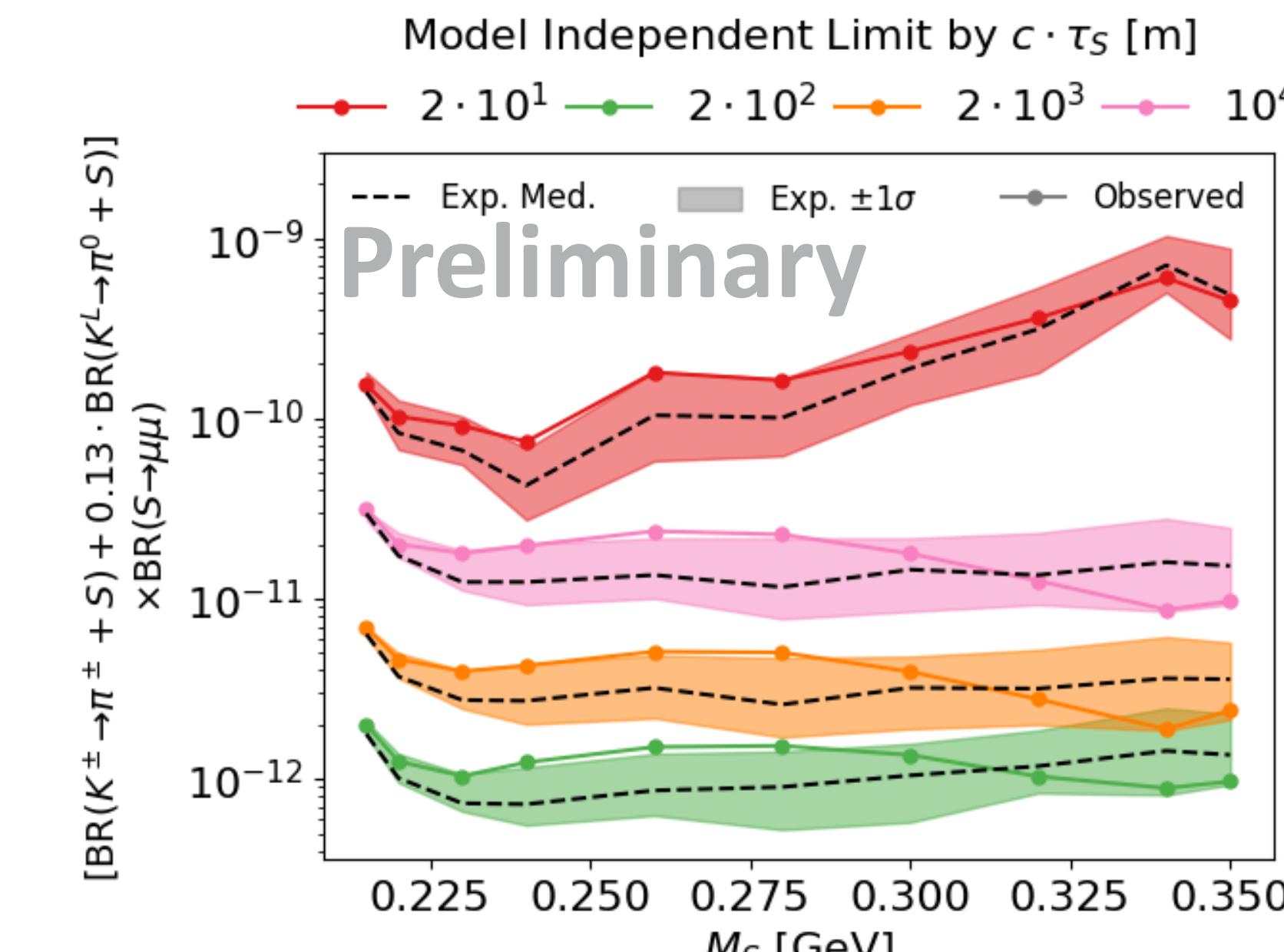
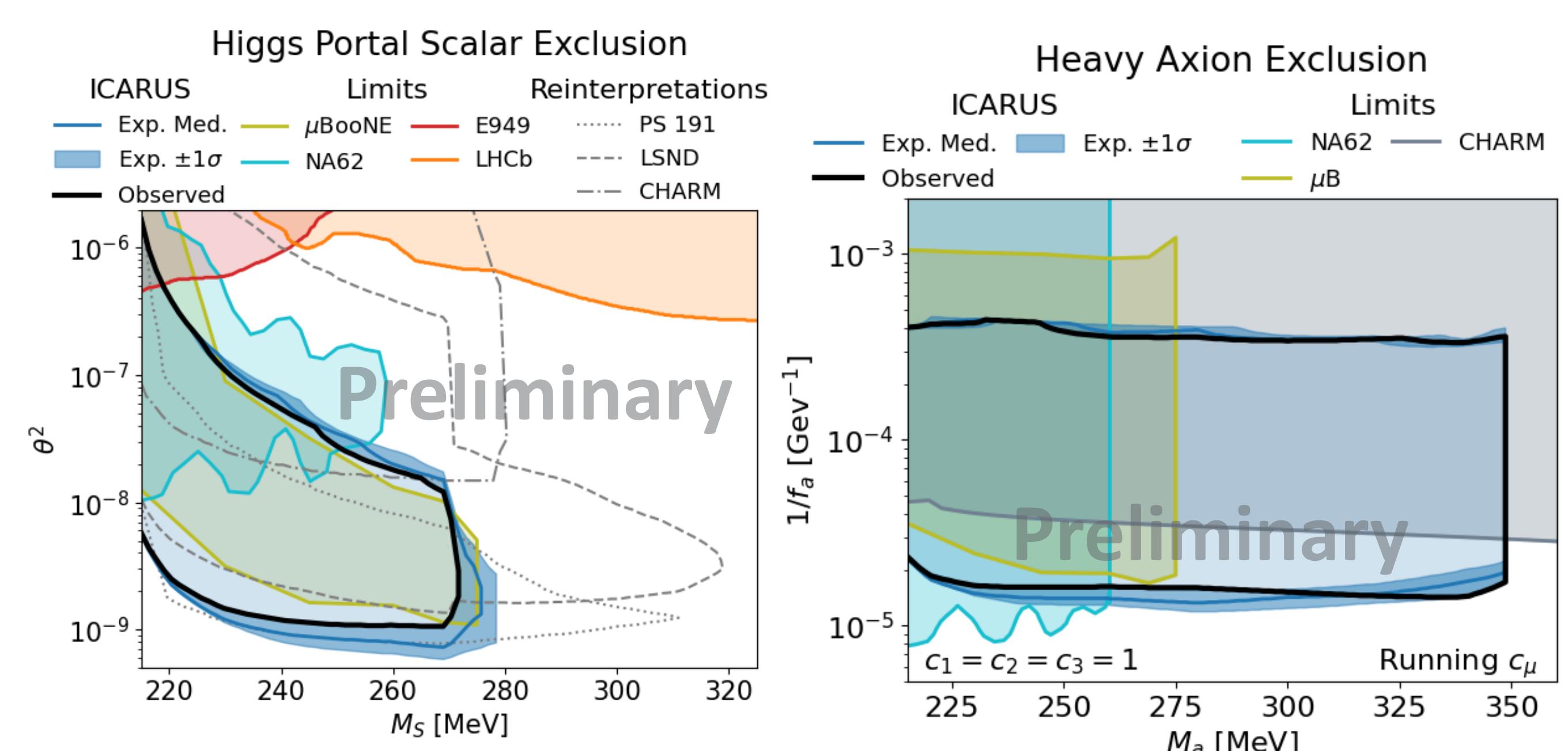
## Signal Box Result



A scale factor is fit to the  $\nu_\mu$  CC Coh.- $\pi$  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  $0.19\sigma$ .

## 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.

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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

