Neutrino Detectors
& Dark Sectors

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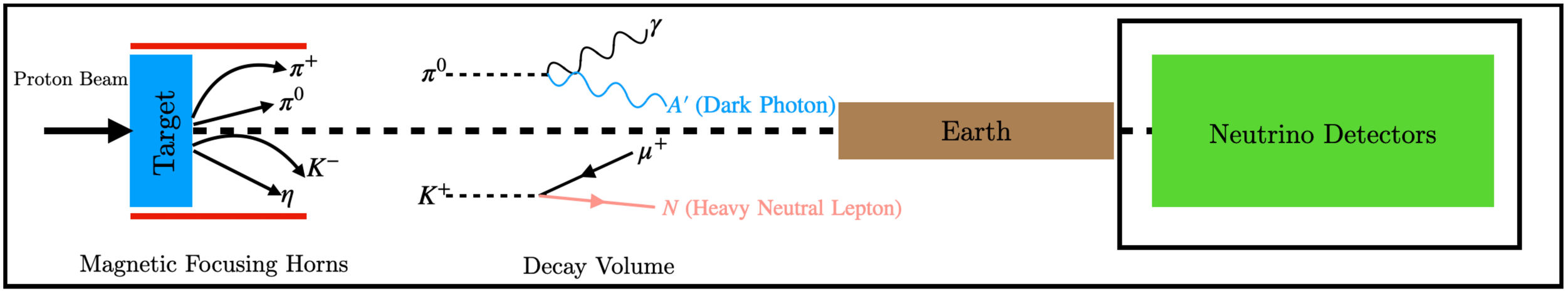
Neutrino Facilities as Dark Sector Machines



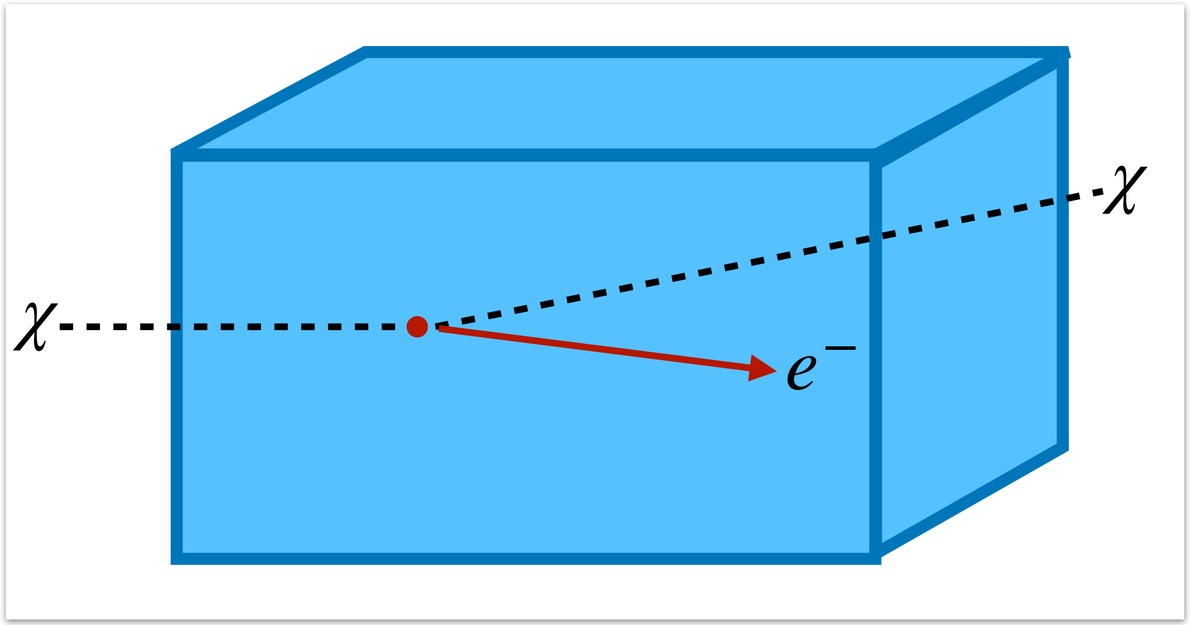
1) Charged and Neutral Mesons are produced in the high-energy/high-intensity proton collisions.

2) Mesons undergo rare decays into dark sector mediators that are long-lived. Some fraction of them travel in the forward direction.

3) Dark Sector particles decay/interact inside the neutrino detector, leaving a striking signature.

Complementarity of Neutrino Detectors

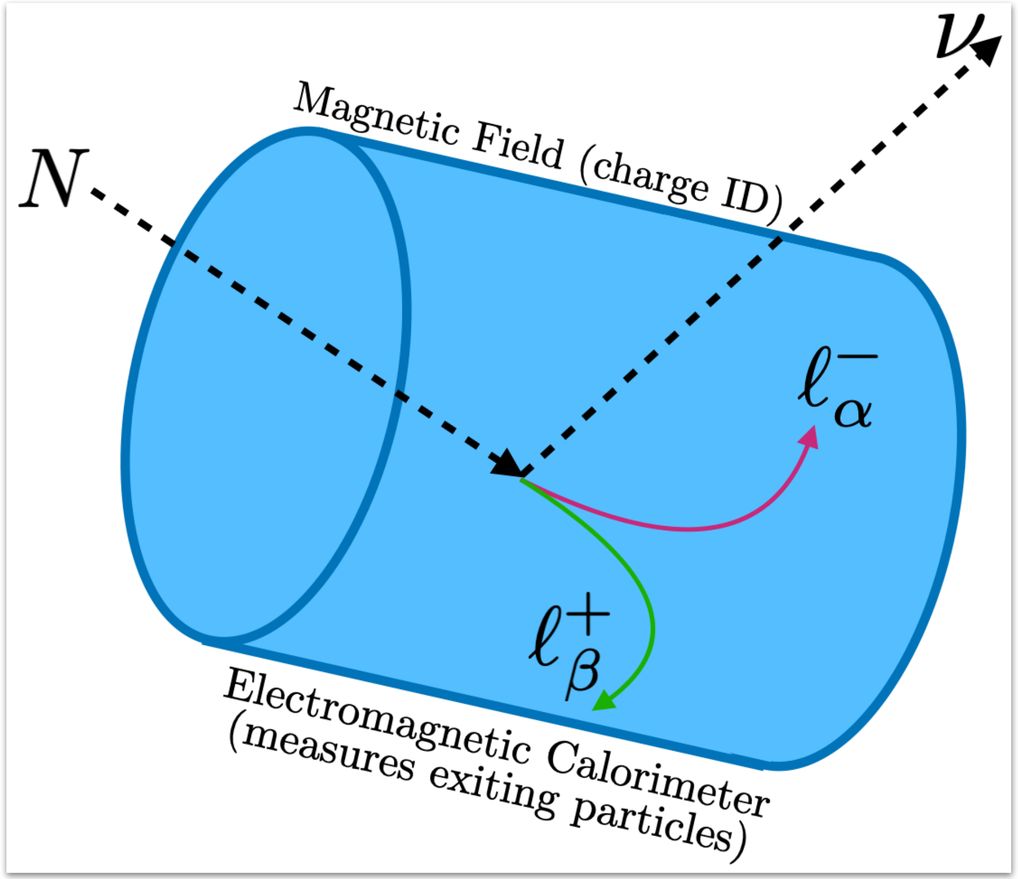
Liquid Detectors (SBND, ICARUS, etc.)



Large mass for rare-particle scattering

Excellent particle ID, energy resolution, etc.

Gaseous Detectors (DUNE NDGAr)



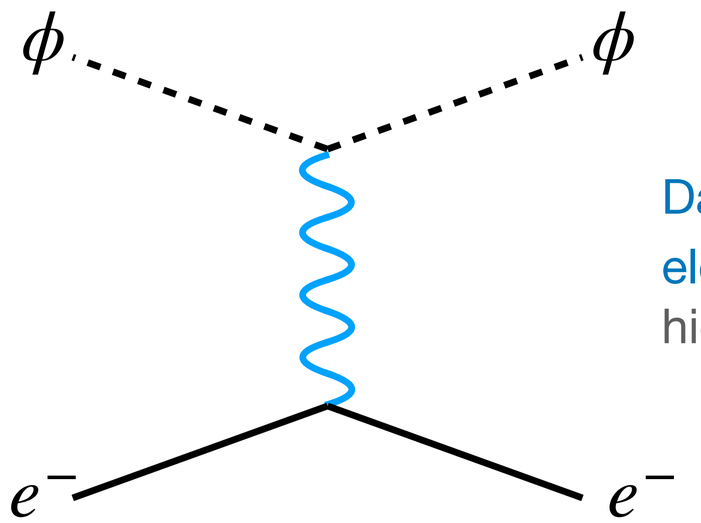
Decay Signal $\propto$ Volume

Neutrino Scattering Backgrounds $\propto$ Mass

Scattering of Dark Sectors

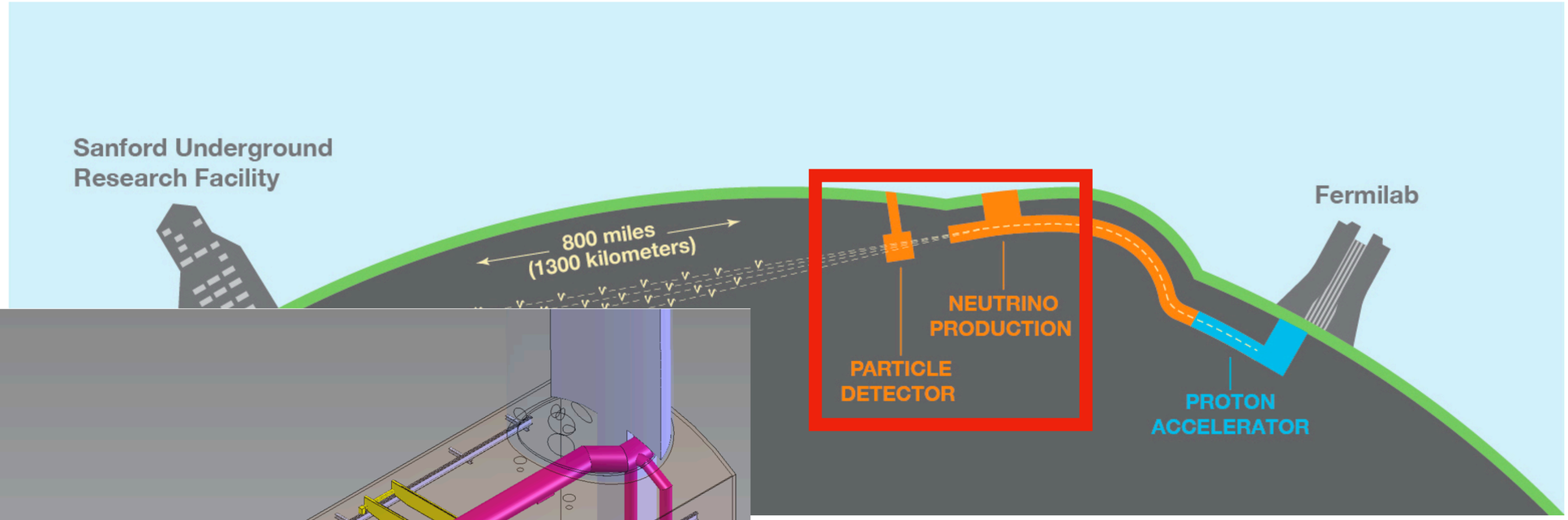
Example scenario: vector-coupled dark matter.

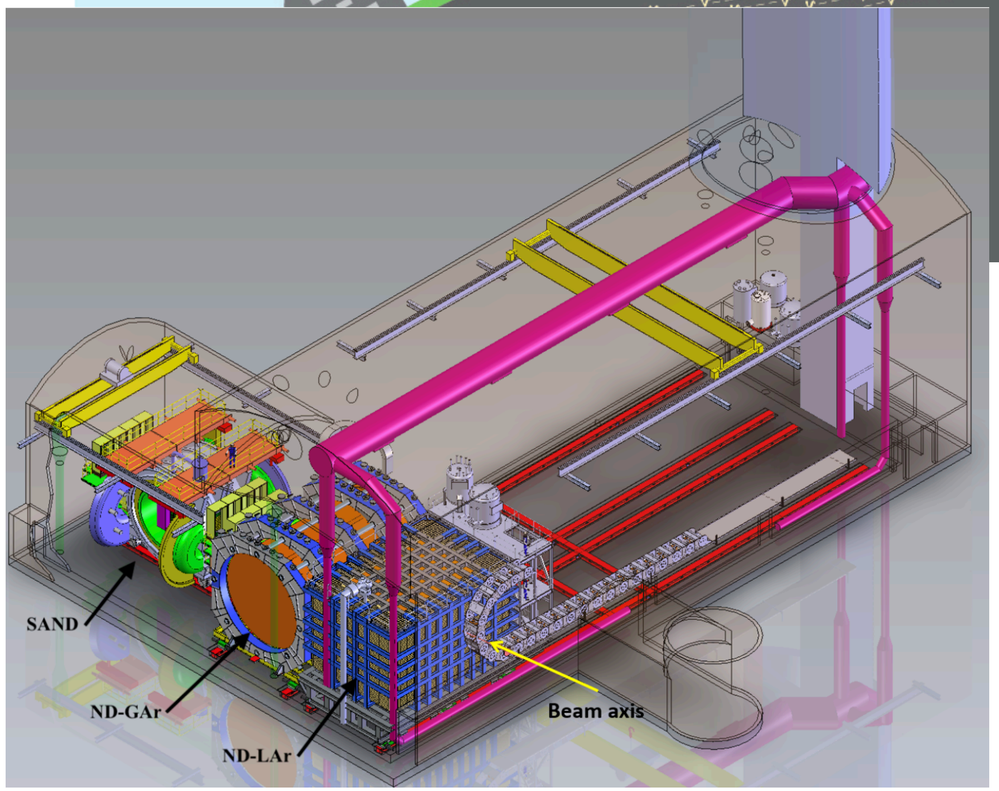
Flux will be unfocused (relative to neutrino beam), but much will be boosted forward



Dark-sector particle ϕ can scatter off electrons via the mediator A':
high-energy, forward electron signature.

DUNE-PRISM



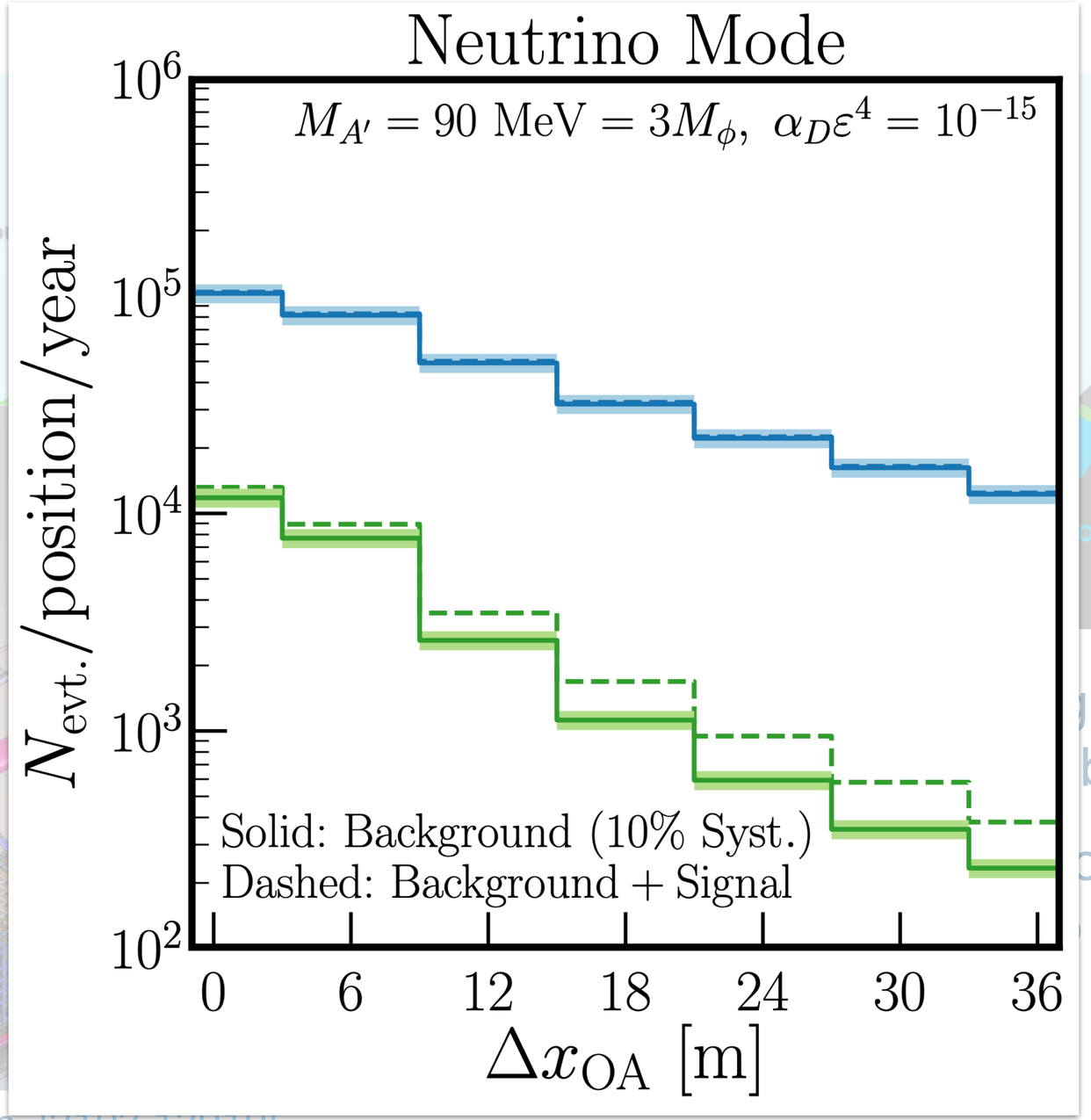


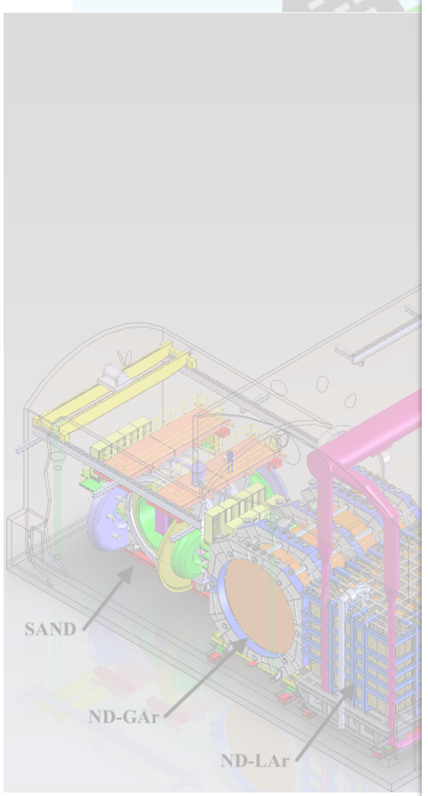
DUNE Collaboration, [2103.13910]

- Near Detector design is to meet neutrino oscillation-based goals.
- One component: movable LAr/GAr detectors up to ~24 m off-axis.

DUNE-PRISM

De Romeri, Kelly, Machado [1903.10505]





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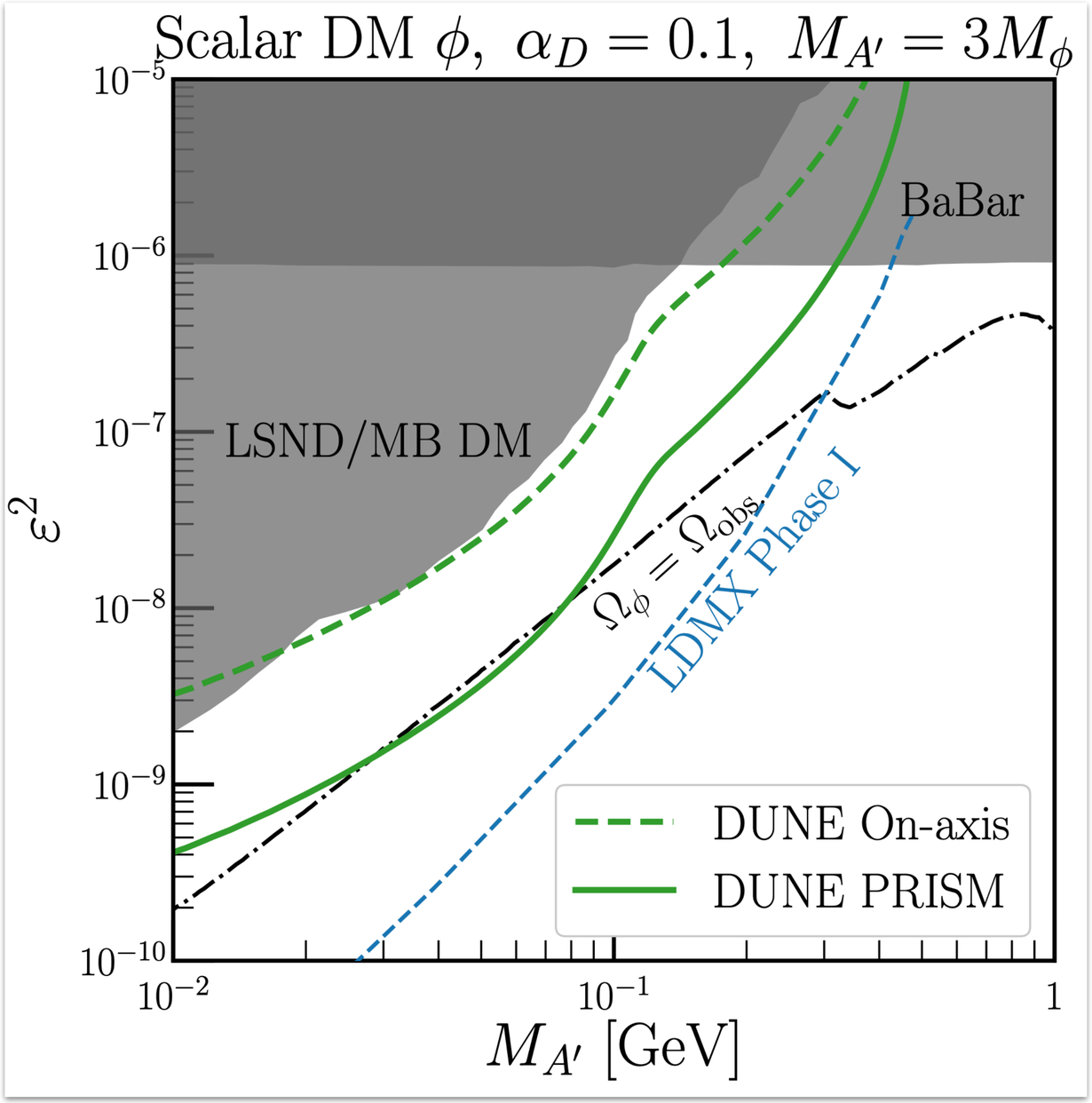
Search Sensitivity



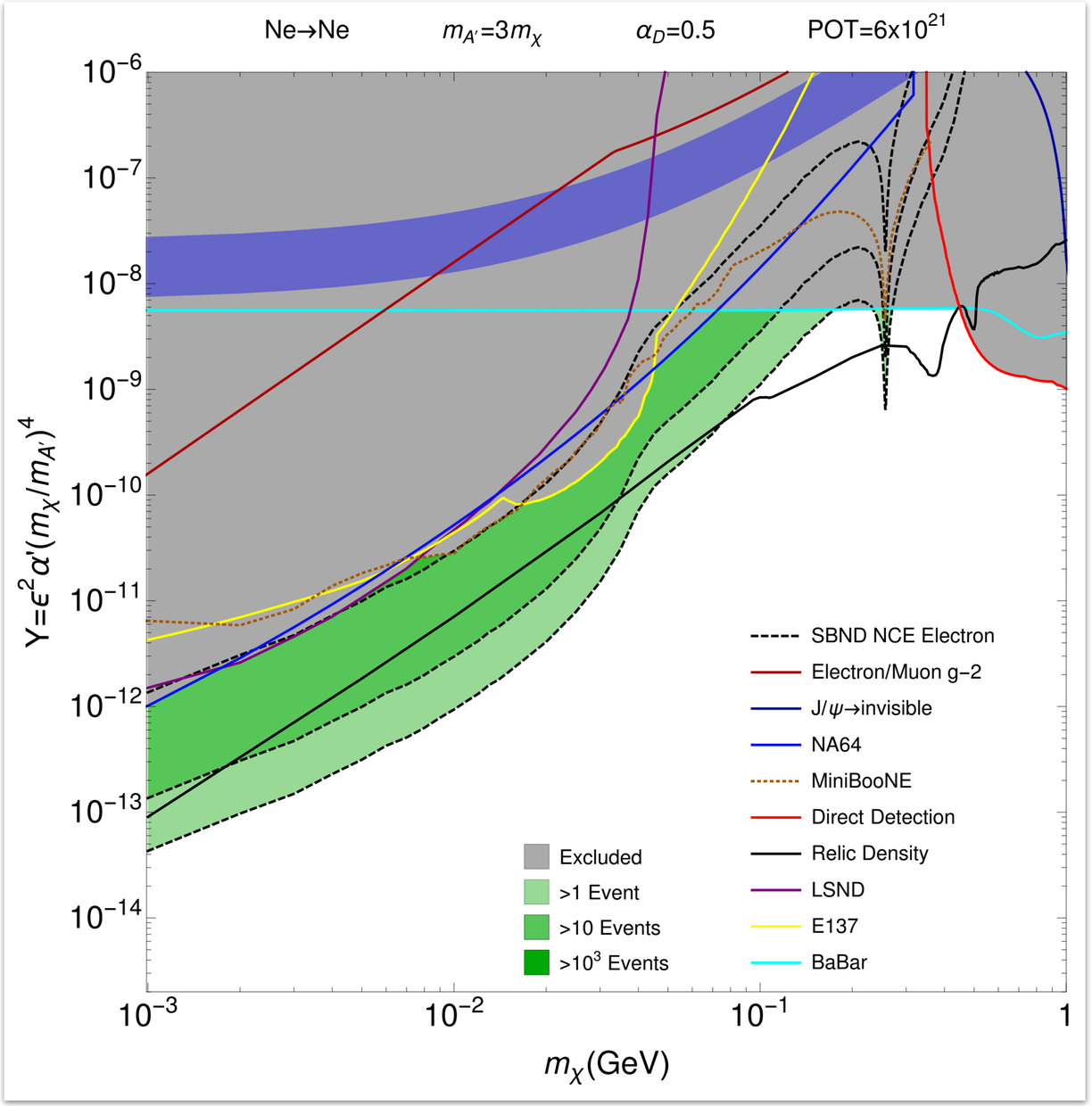
- Combining on- and off-axis searches allows to reduce systematic uncertainties.
- This allows for searches in novel parts of parameter space preferred if ϕ comprises the dark matter.
- Seven years' data at DUNE, reasonably competitive with LDMX Phase I.

Similar study incorporating spectral measurements, etc.:
Breitbach et al [2102.03383]

Consideration of a DUNE Off-Target mode:
Brdar et al [2206.06380]

Complementarity with PIP-II Beam-Dump Proposals

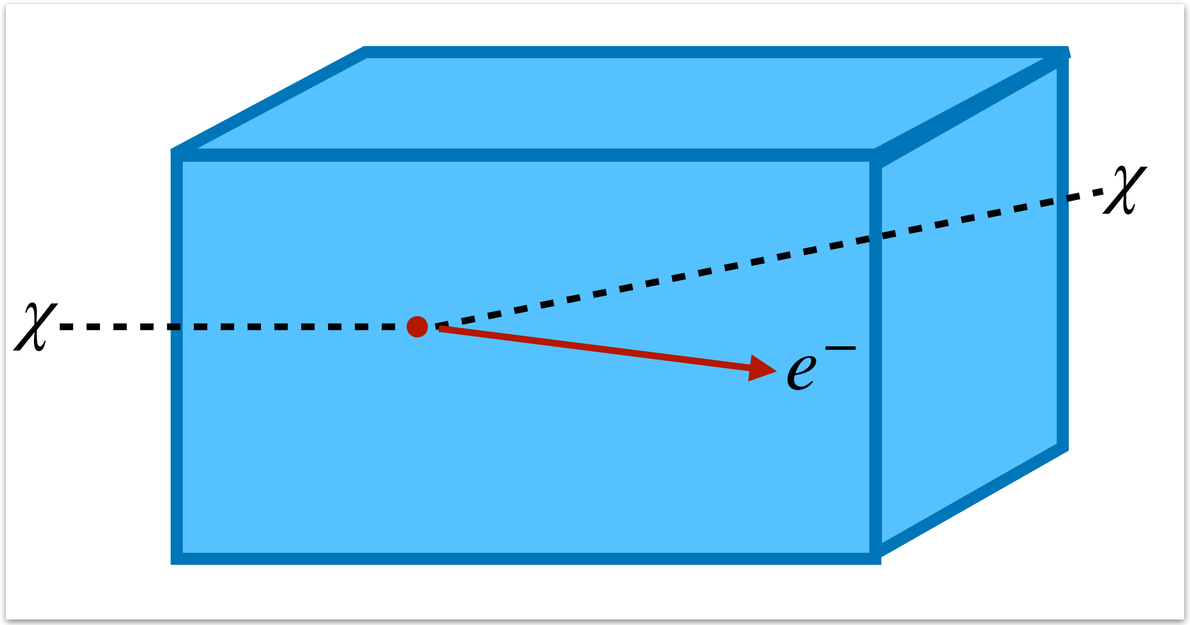
Toups et al [2203.08102]



- Utilizing SBND with a new dump running in the PIP-II era (five years).
- Same production mechanism and detection idea as proposed for DUNE-PRISM.

Complementarity of Neutrino Detectors

Liquid Detectors (SBND, ICARUS, etc.)



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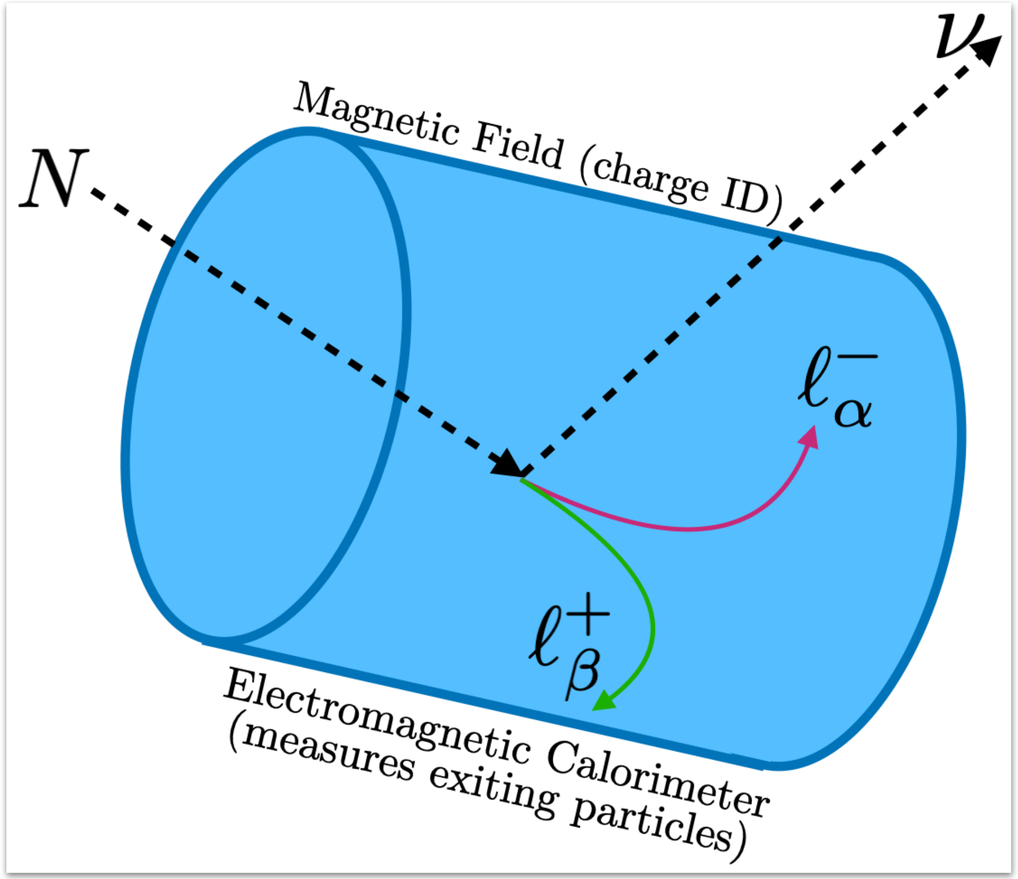

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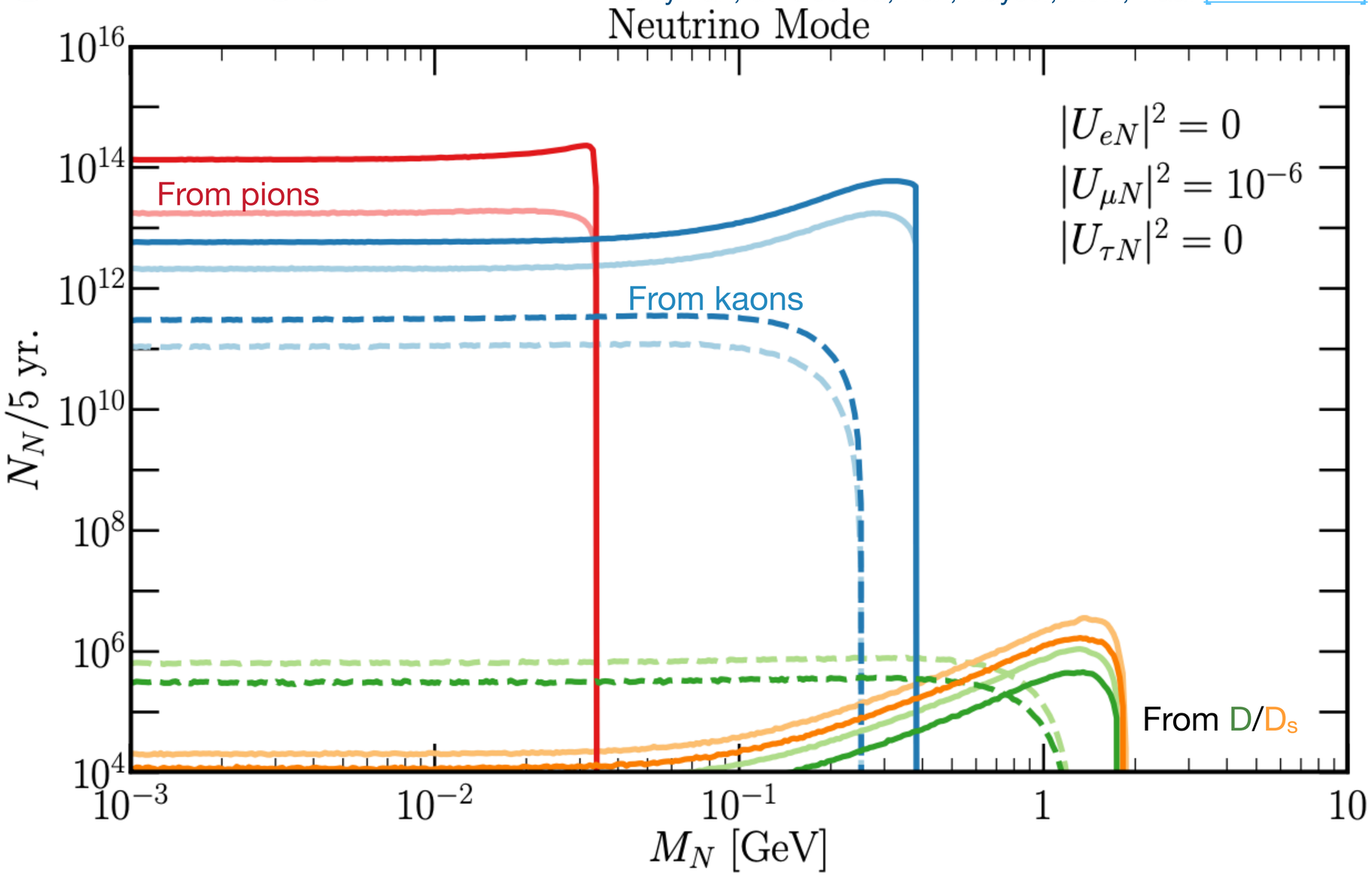
HNLs in the DUNE Beam

Berryman, de Gouvêa, Fox, Kayser, **KJK**, Raaf [1912.07622]

Operating with a 120 GeV proton beam, DUNE will produce a bevy of SM mesons.

Includes acceptance efficiency — small solid angle for a detector like DUNE-ND.

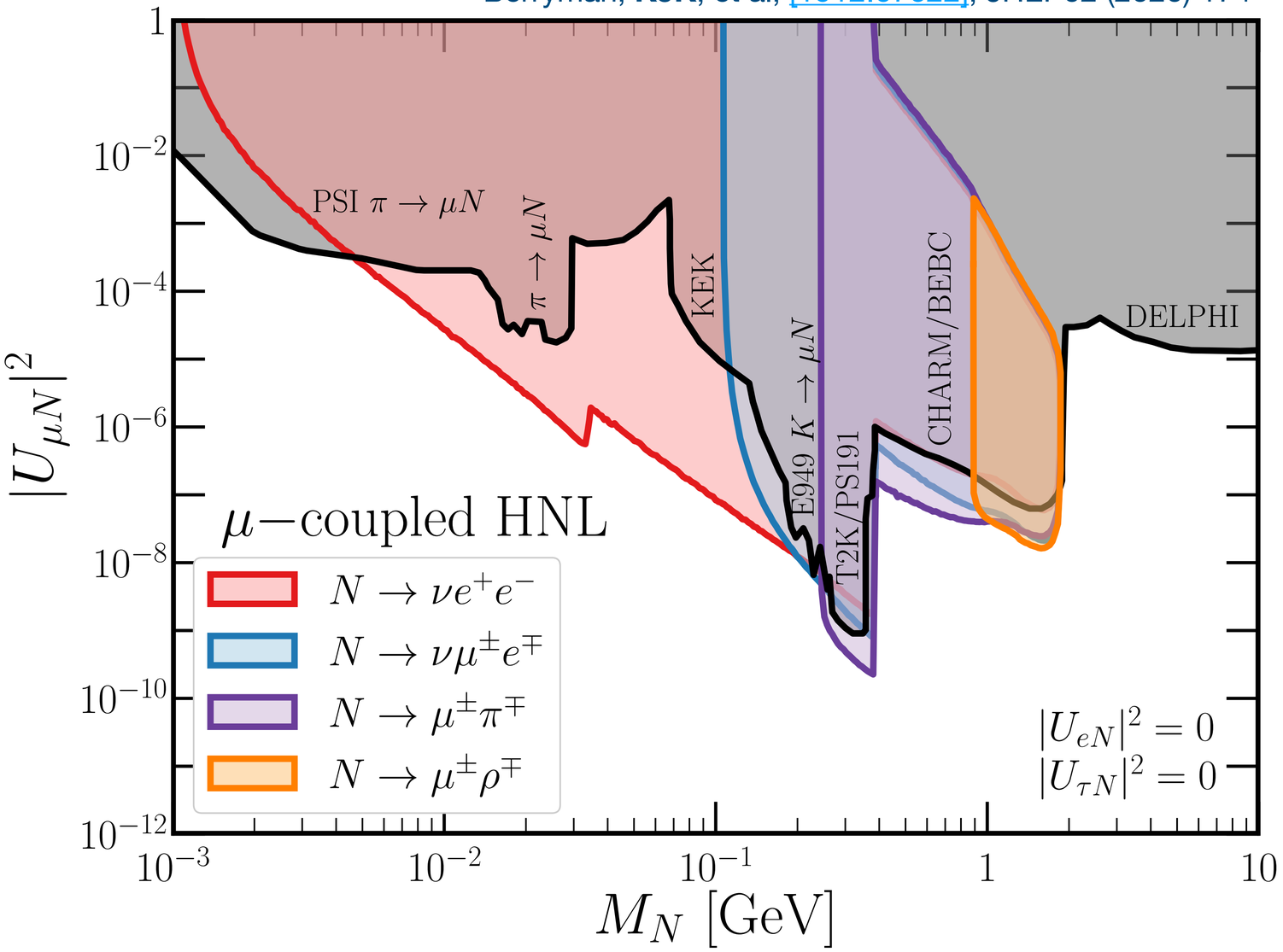
Similar fluxes are easy* to simulate for different target/detector configurations.



Mass-reach of HNLs limited by beam energy: what SM mesons can be produced?

Discovery Potential at DUNE-NDGAr

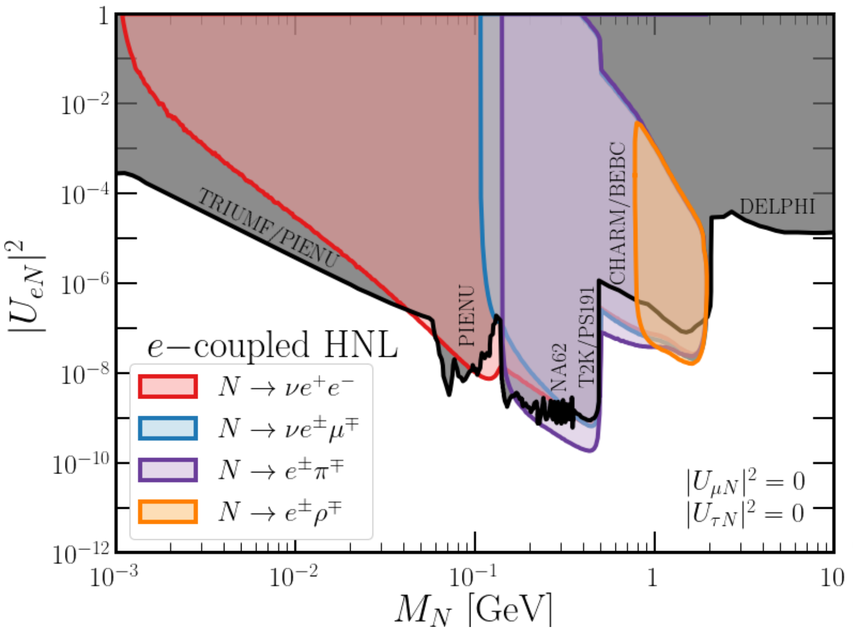
Berryman, **KJK**, et al, [1912.07622], JHEP02 (2020) 174

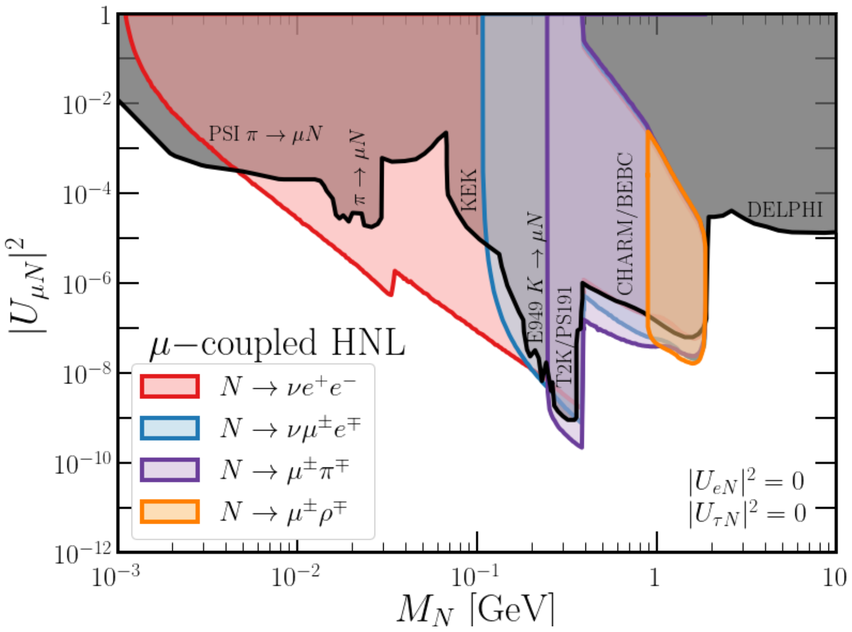


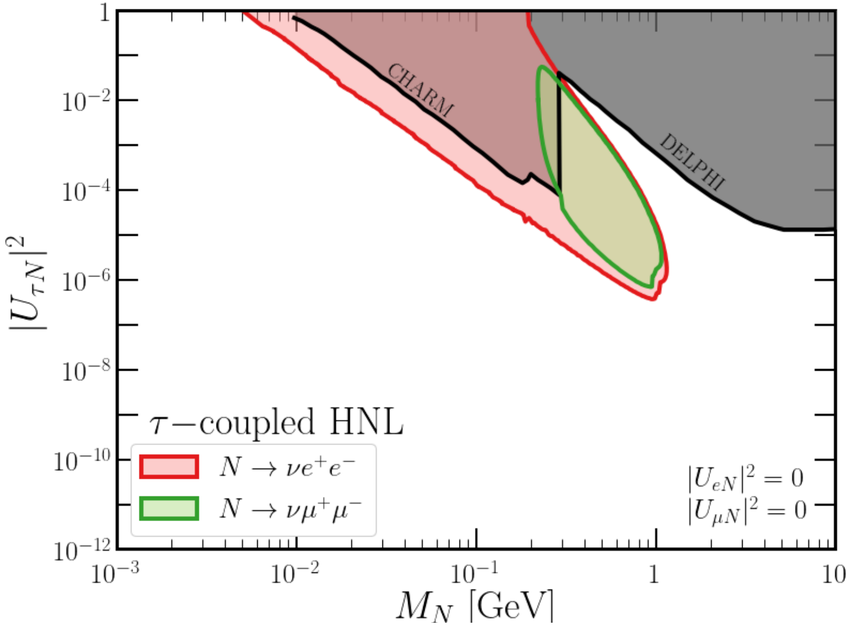
- Tons of parameter space for a potential discovery!
- Searches for different final states (or incorporating other mixing patterns) can extend reach.

More on HNLs at DUNE? Ballett et al [1905.00284], Coloma et al [2007.03701], Breitbach et al [2102.03383]

All single-mixing sensitivity



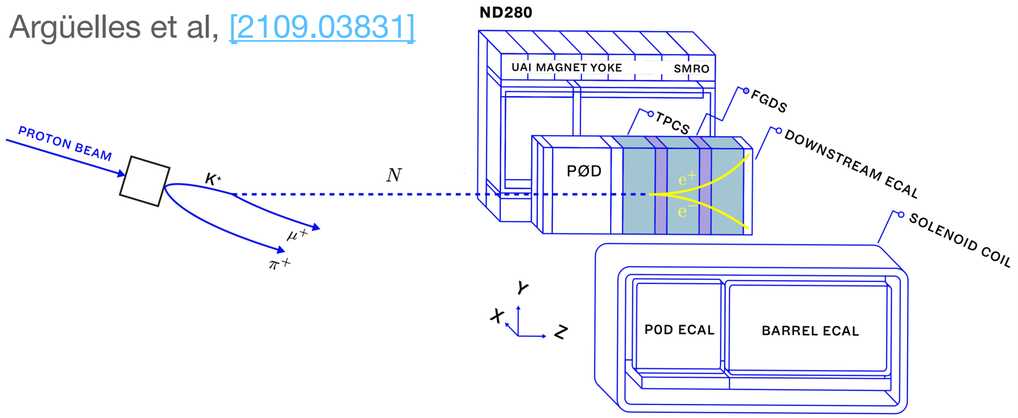


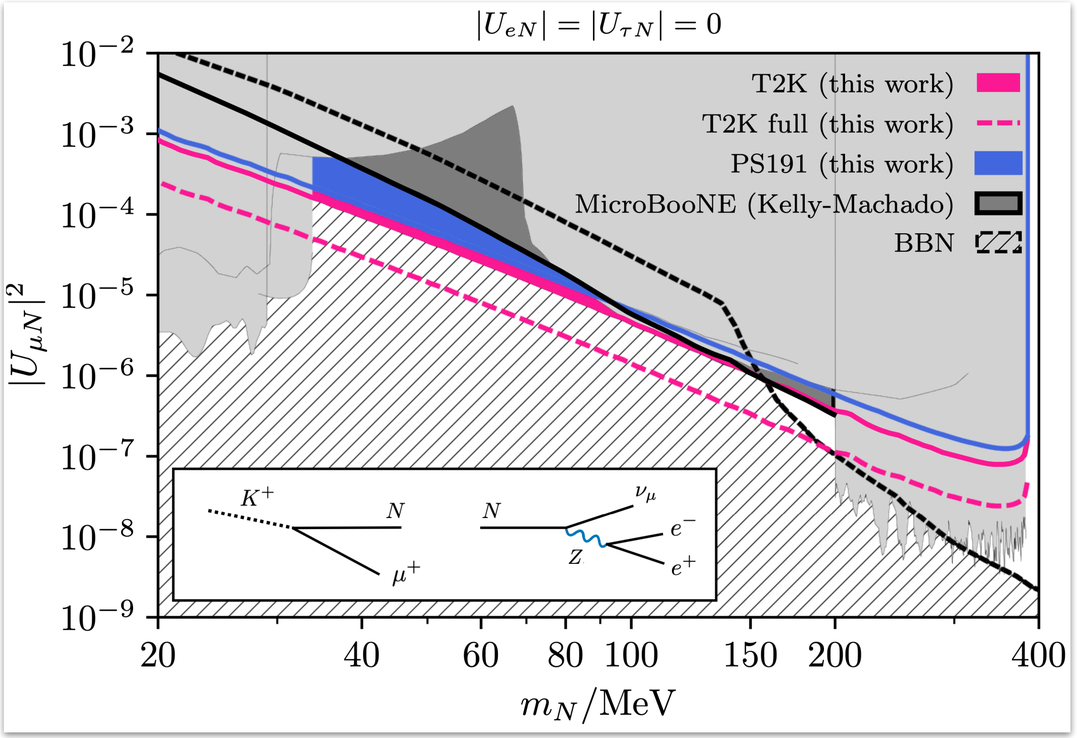


Berryman, de Gouvêa, Fox, Kayser, **KJK**, Raaf [1912.07622]

Current Searches — T2K & MicroBooNE

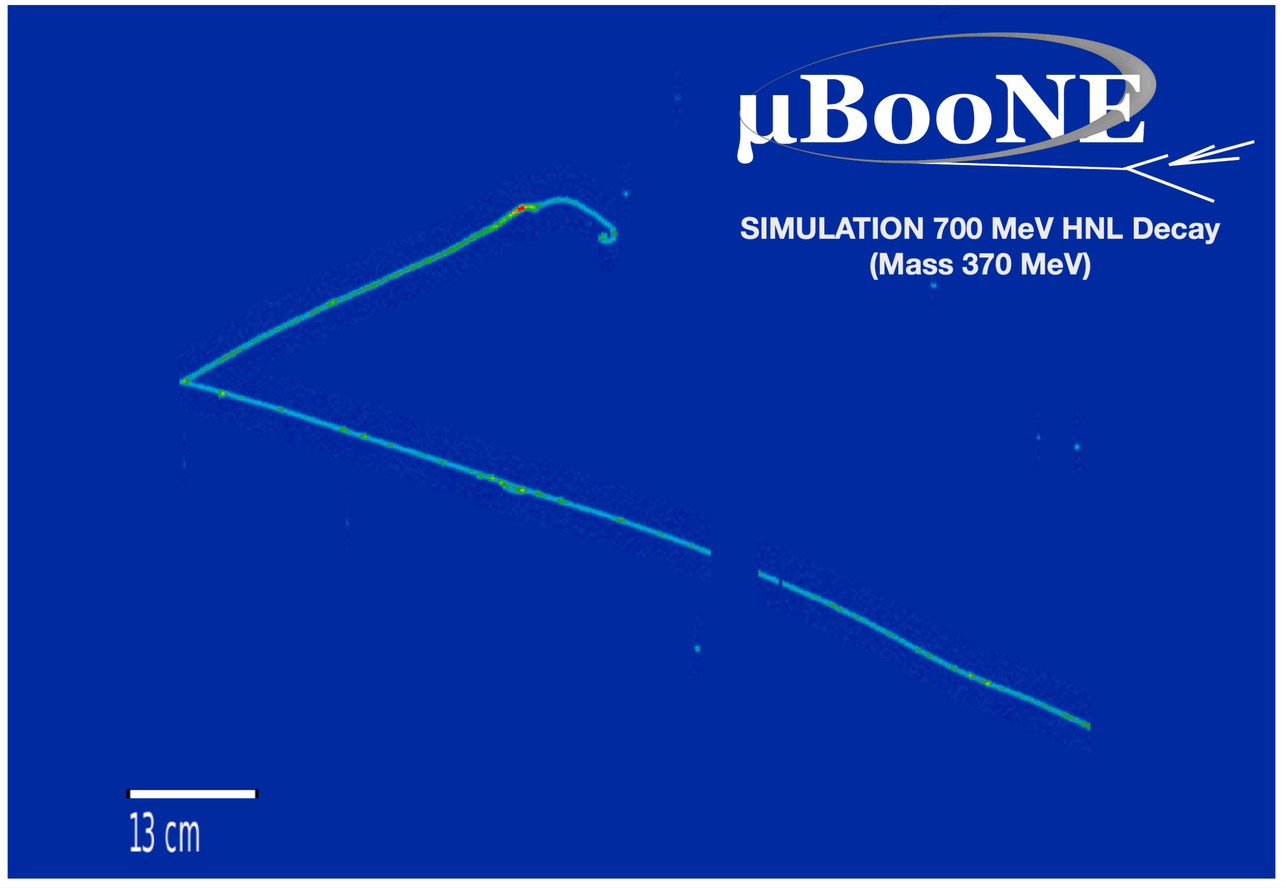
Argüelles et al, [2109.03831]





See also: T2K collaboration, [1902.07598]

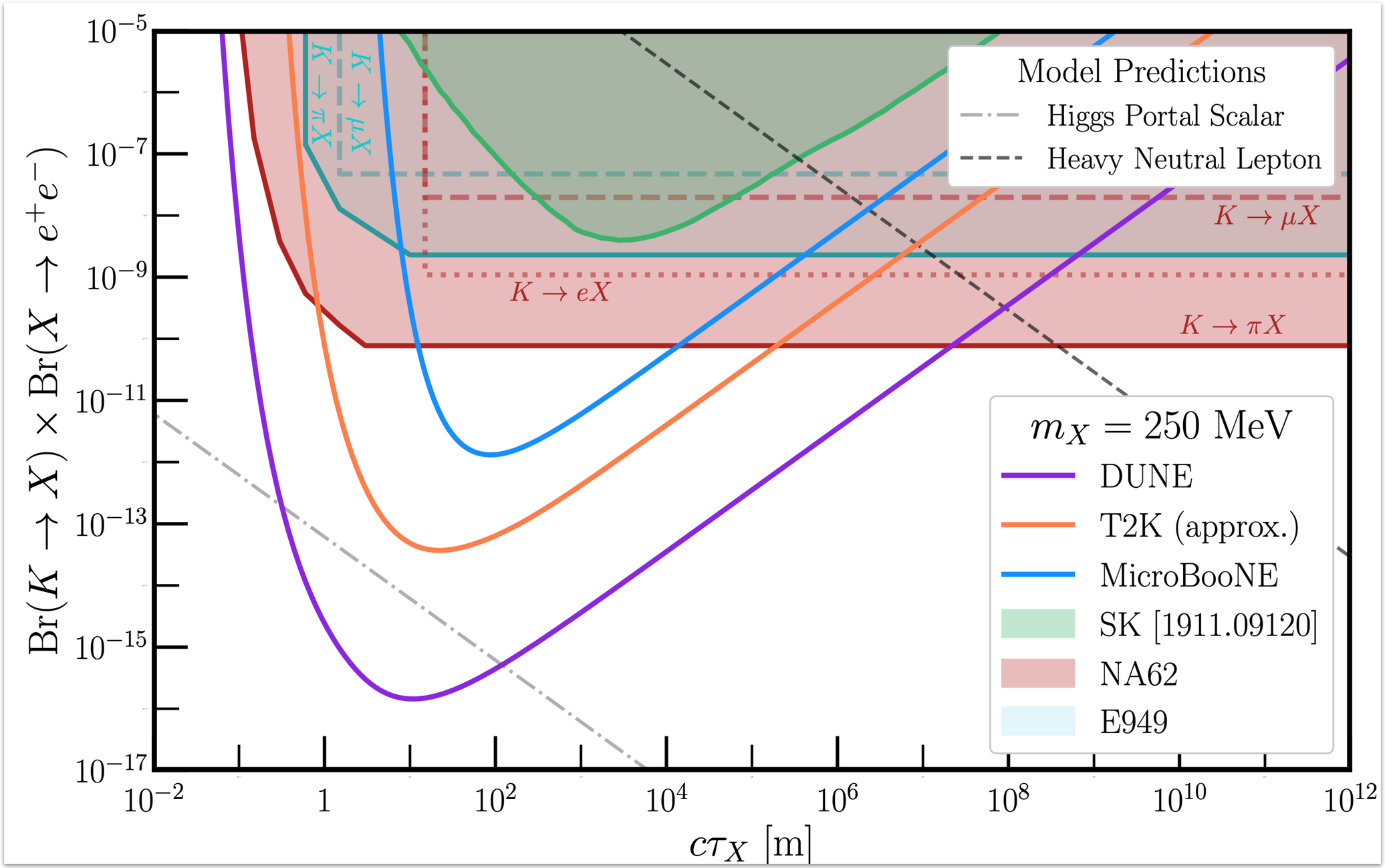
MicroBooNE collaboration, [1911.10545]



Many searches/models being proposed/explored actively.

Suggestion for model-independent frameworks: Batell, Huang, Kelly, [2304.11189]

Model-Independence in LLP Searches

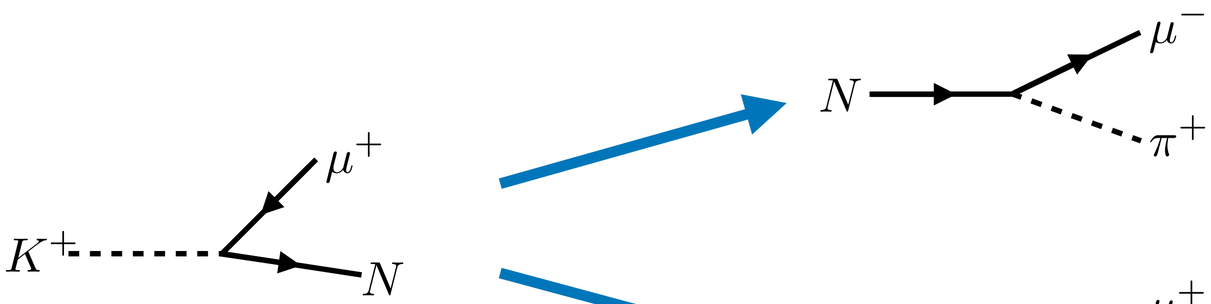


Batell, Huang, Kelly, [2304.11189]

Lepton-Number-Violation in a (Heavy) Neutrino Beam

Is the new particle a Dirac or Majorana Fermion?

Do the new particle's interactions preserve or violate Lepton Number conservation?

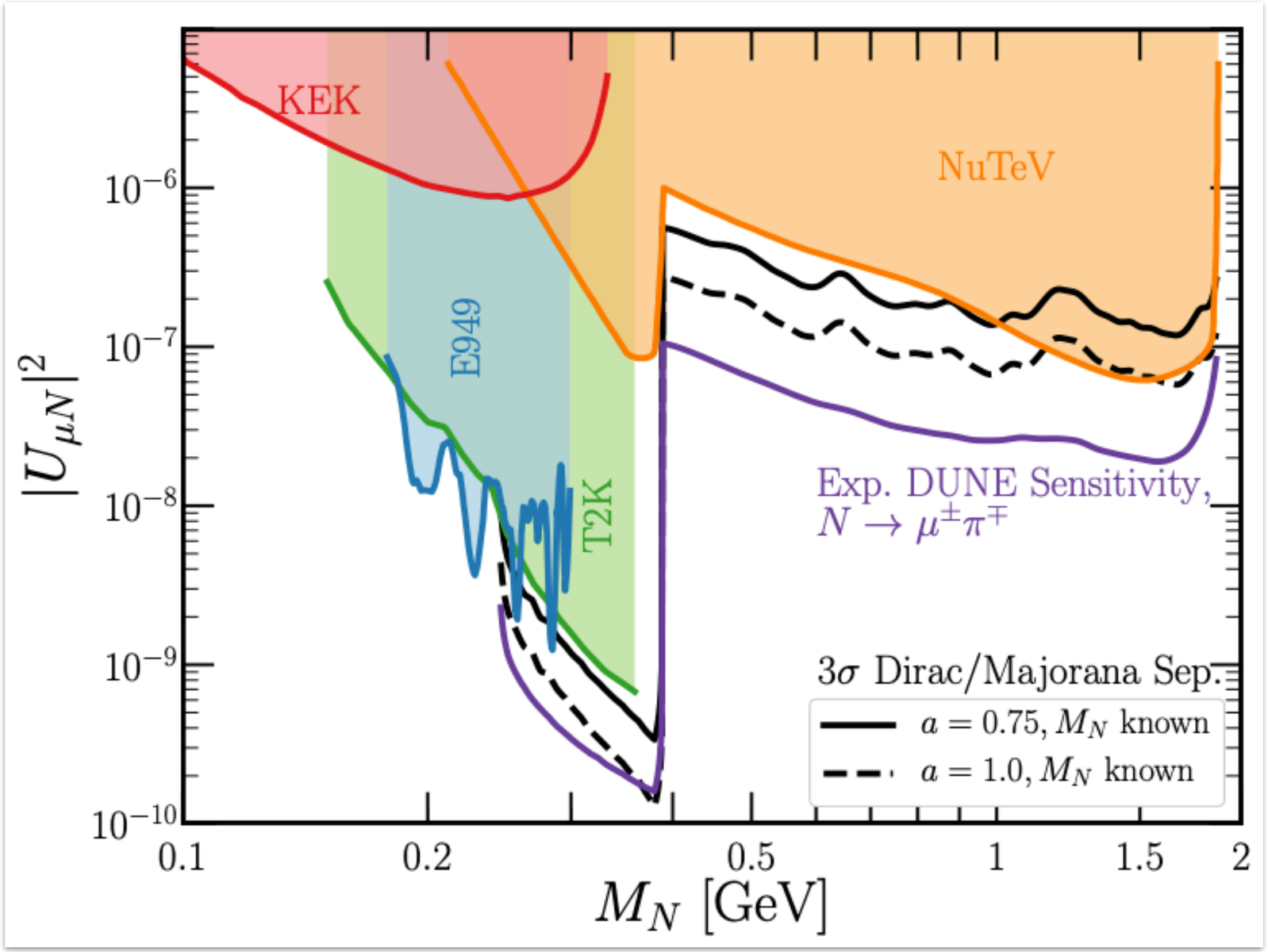


Heavy Neutrino Source

Heavy Neutrino Decay

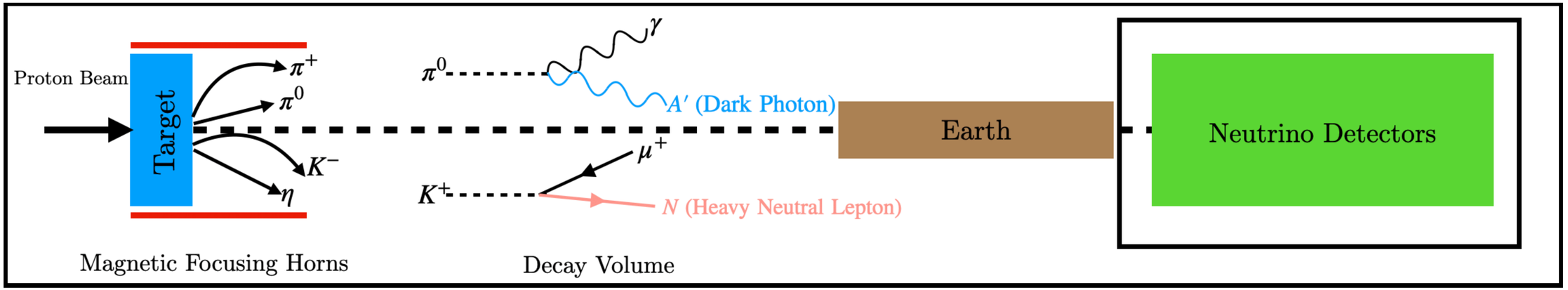
- Do these two chains occur with equal probability?

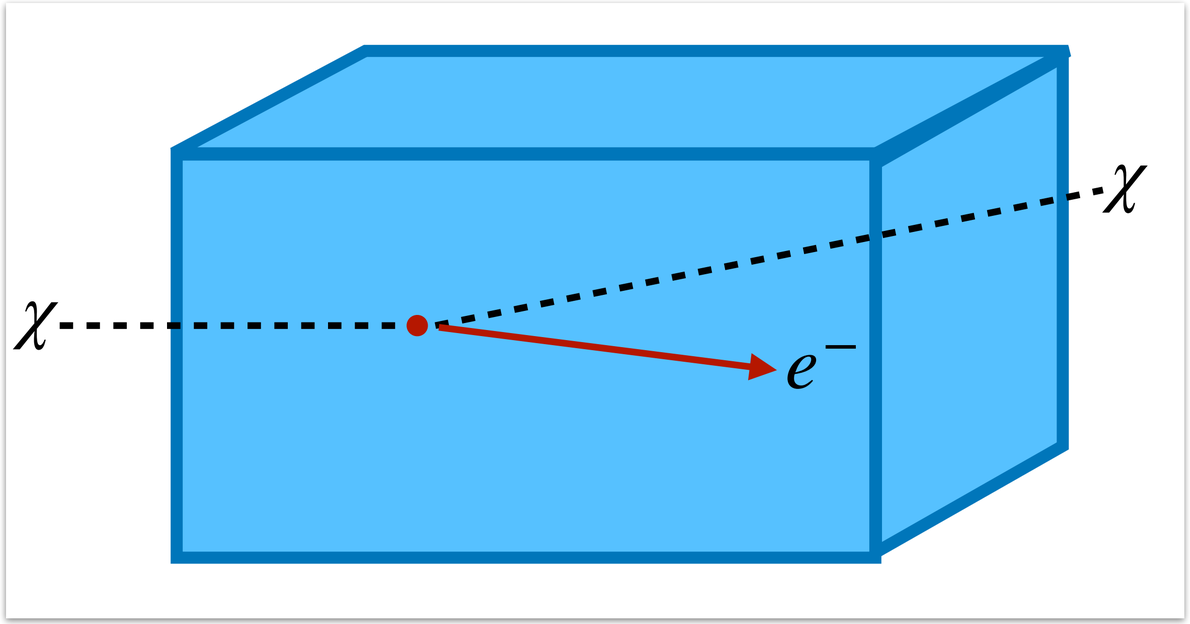
Next-Generation Prospects

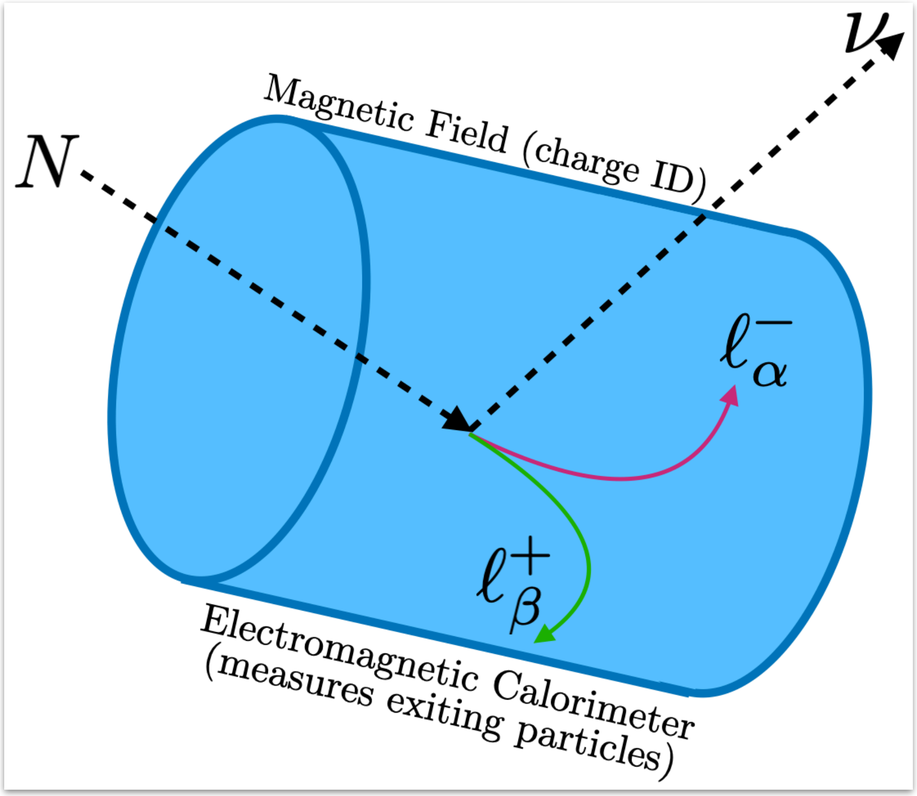


Berryman, de Gouvêa, Fox, Kayser, **KJK**, Raaf [1912.07622]

Takeaways







- Neutrino facilities can search for a variety of dark sectors, often simultaneously with their neutrino “mission”