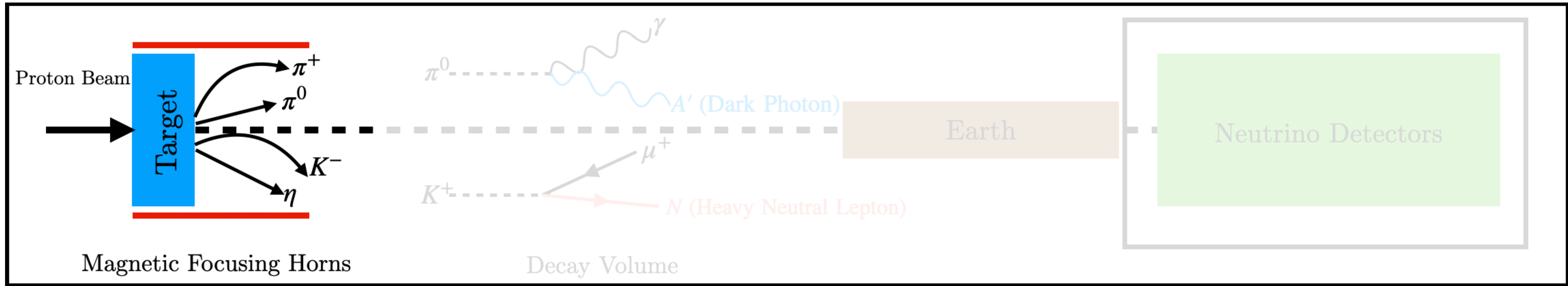


Neutrino Detectors & Dark Sectors

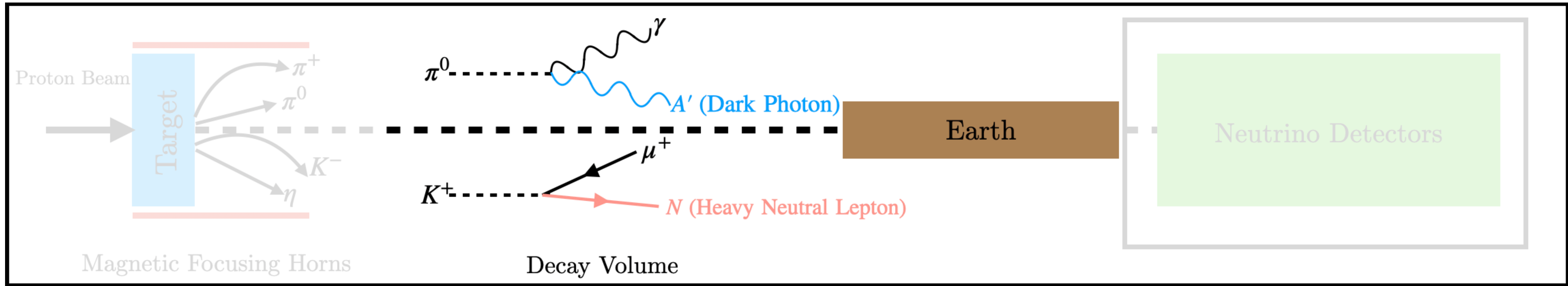
Kevin J. Kelly, Texas A&M University
YOUNGST@RS MITP — 6-9 November 2023
kjkelly@tamu.edu

Neutrino Facilities as Dark Sector Machines



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

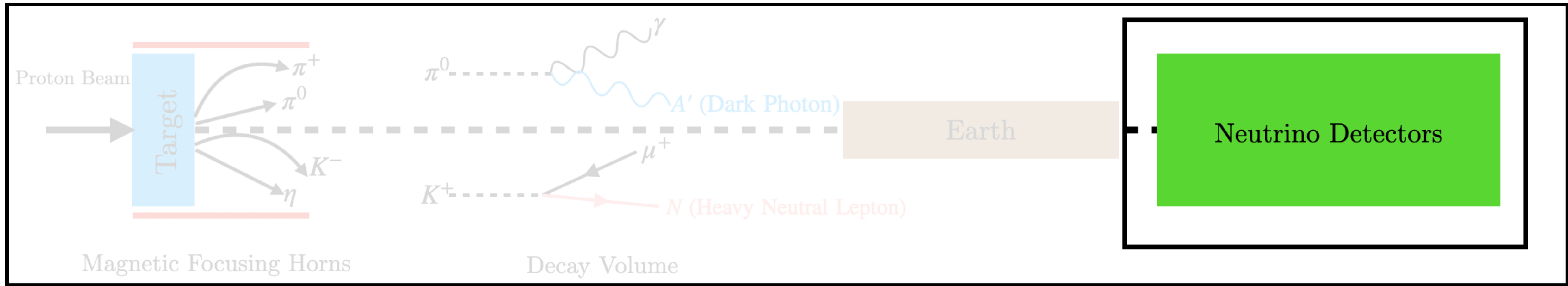
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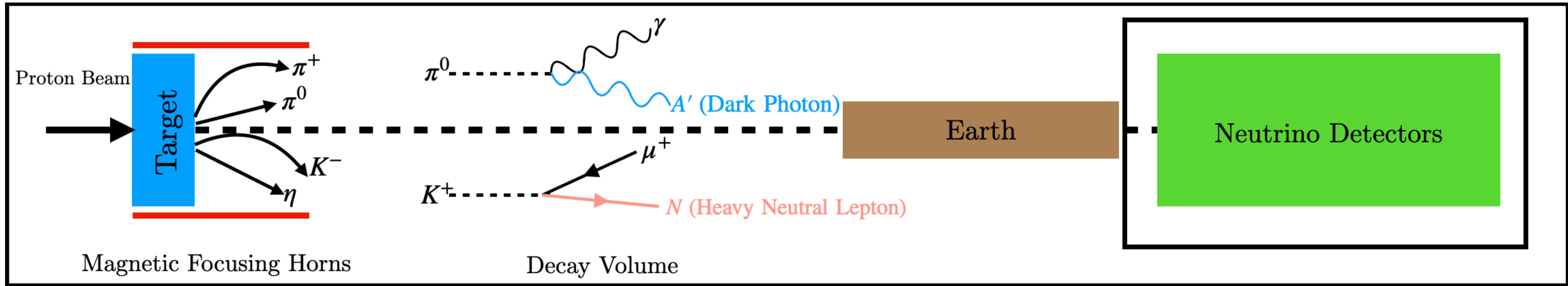


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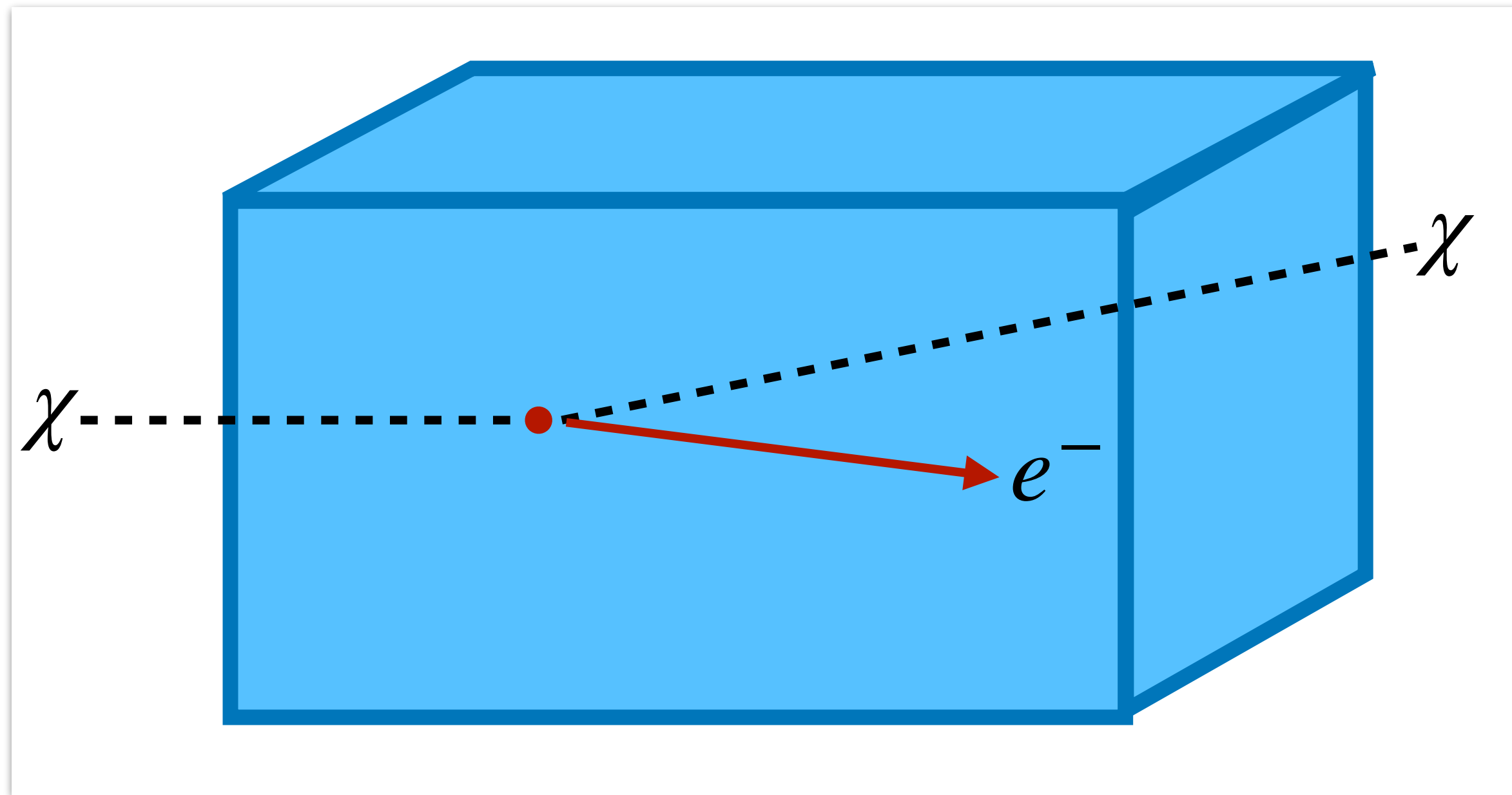
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Complementarity of Neutrino Detectors

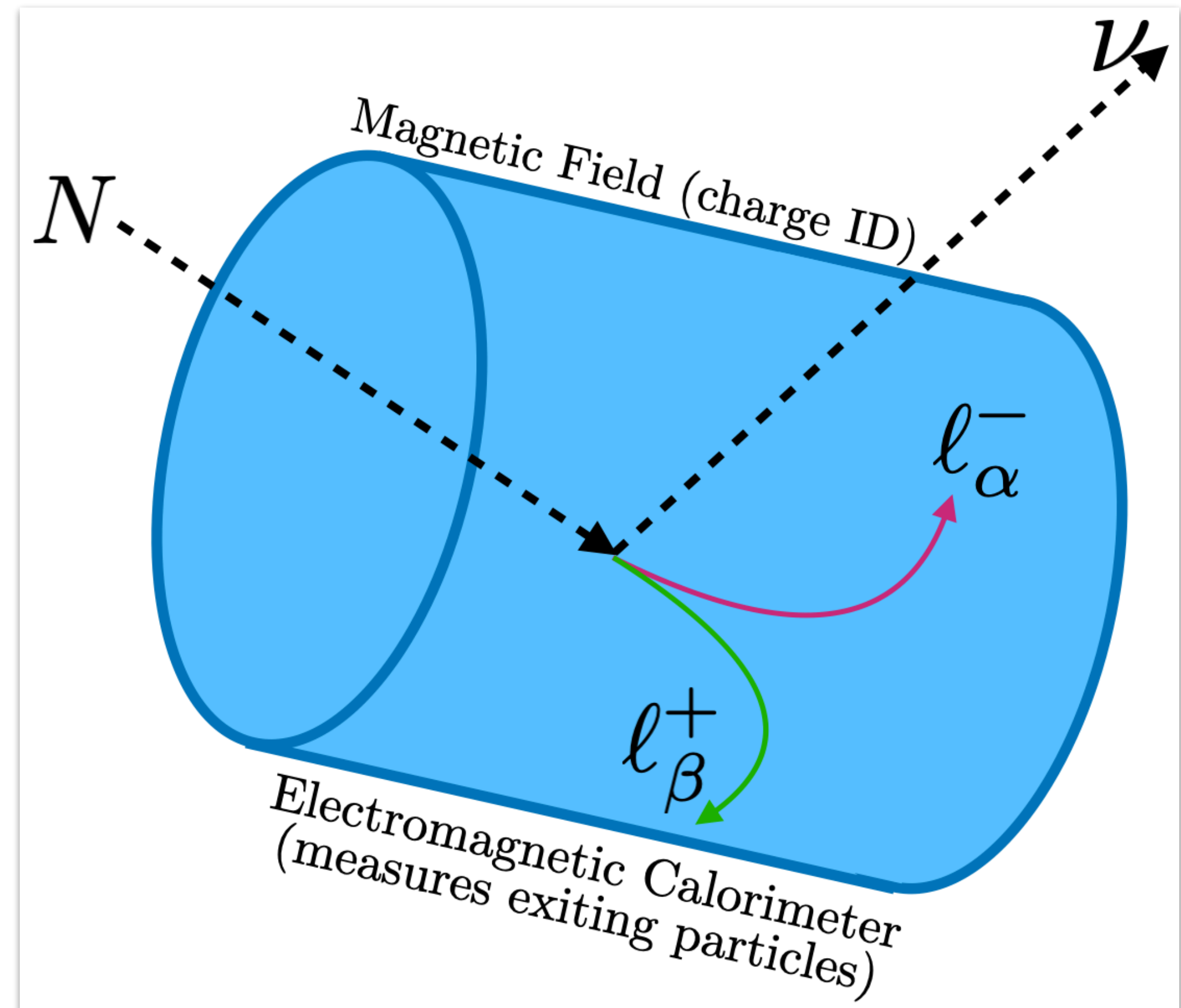
Liquid Detectors (SBND, ICARUS, etc.)



Large mass for rare-particle scattering

Excellent particle ID, energy resolution, etc.

Gaseous Detectors (DUNE NDGAr)

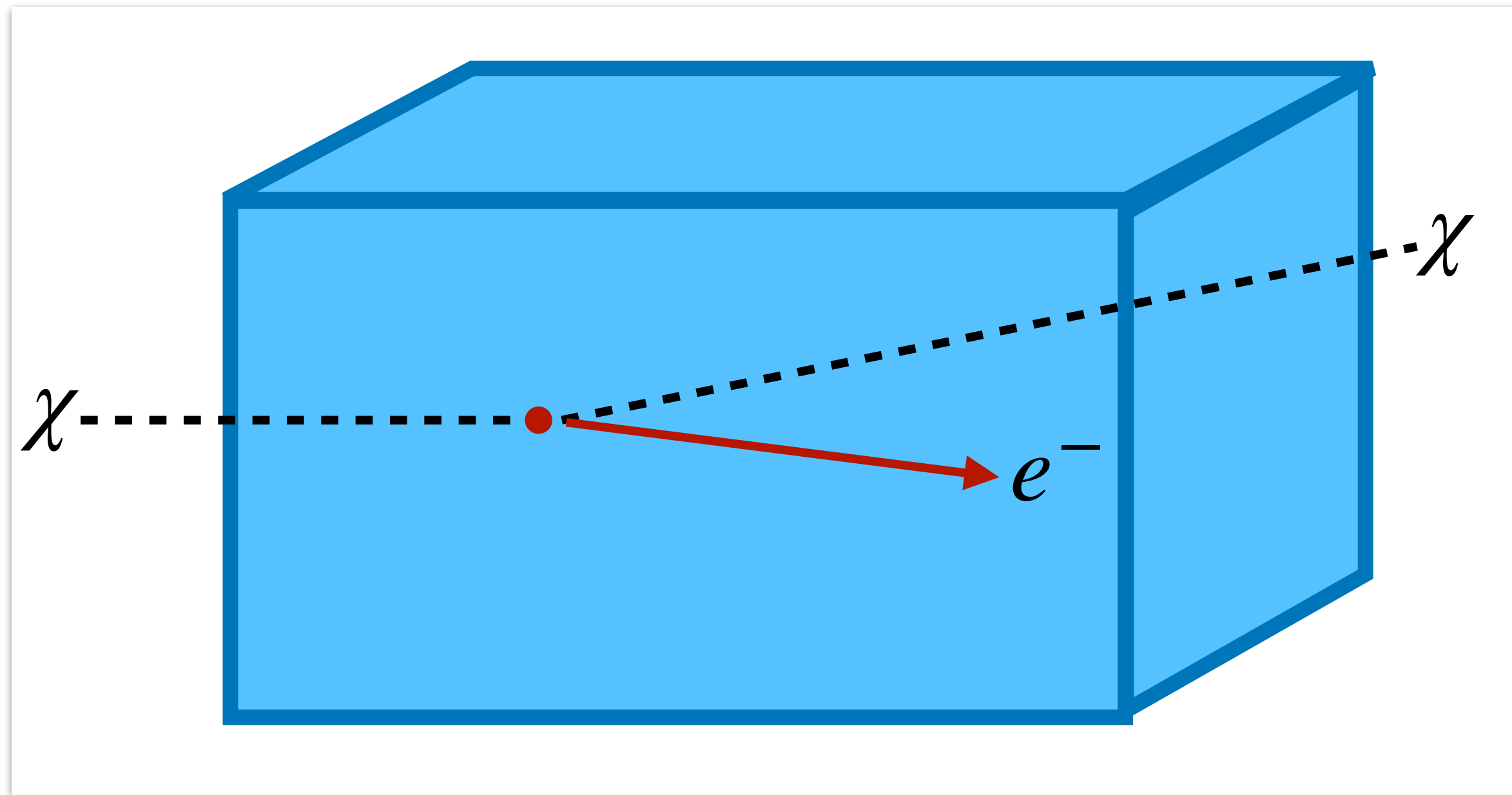


Decay Signal \propto Volume

Neutrino Scattering Backgrounds \propto Mass

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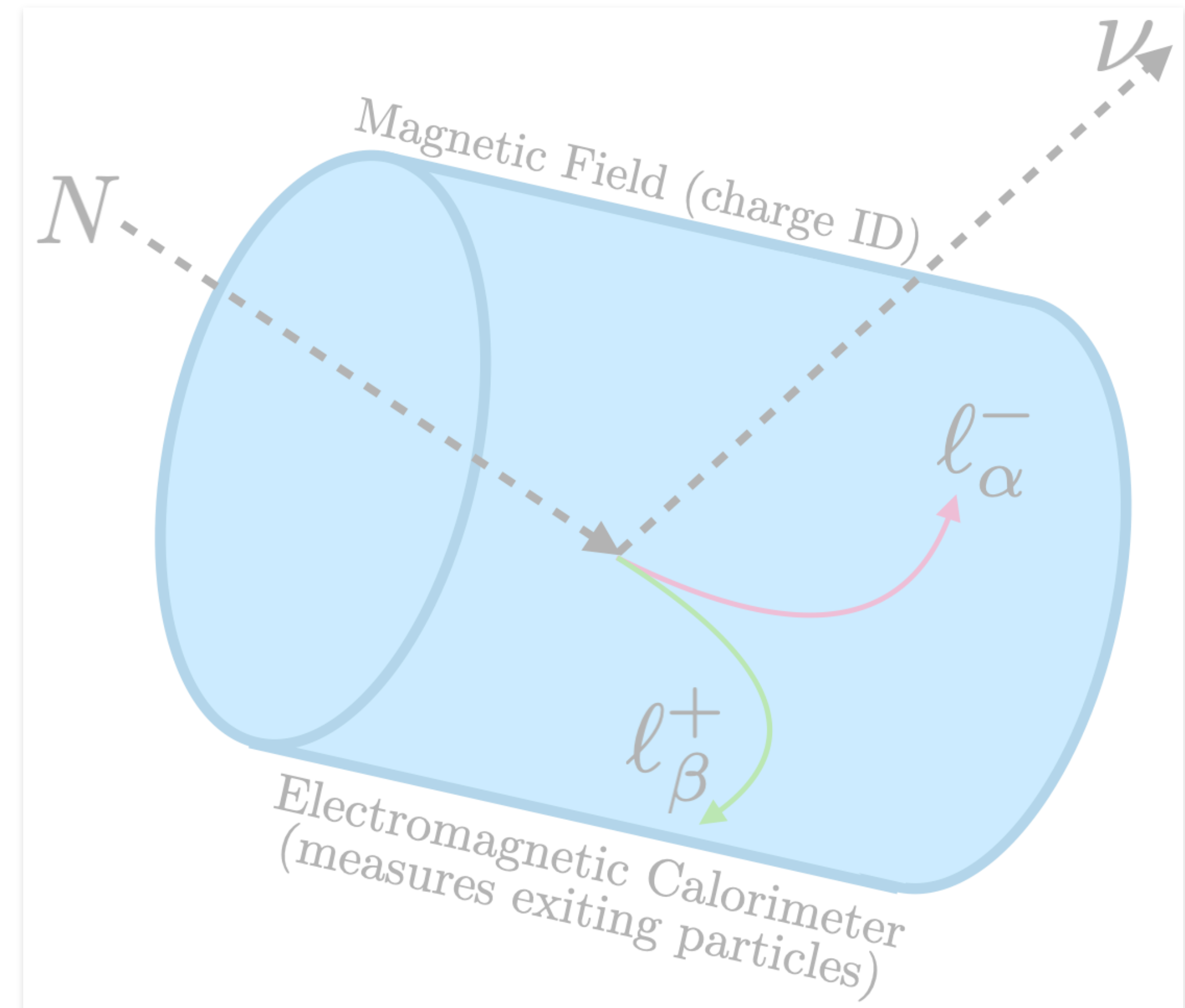
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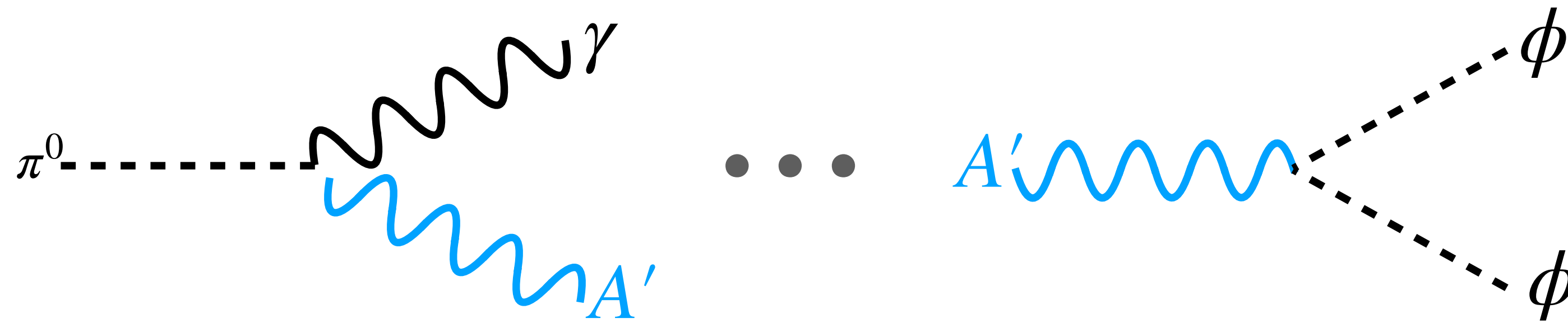


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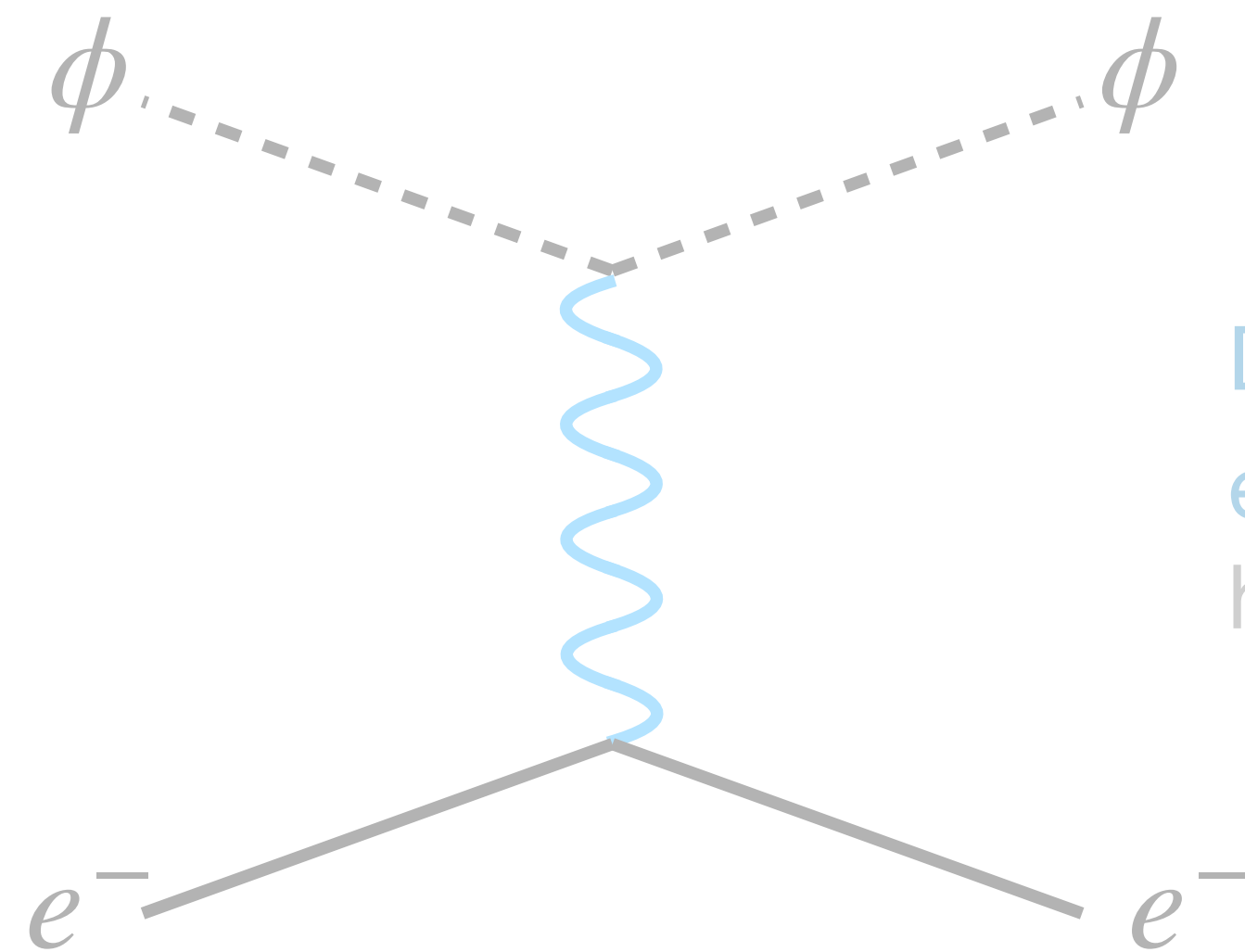
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Scattering of Dark Sectors

Example scenario: vector-coupled dark matter.



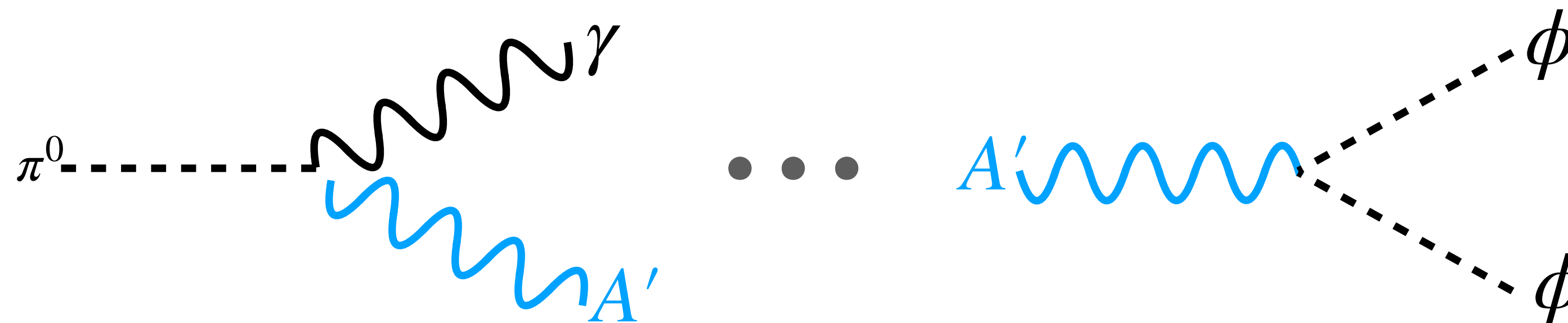
Flux will be unfocused (relative to neutrino beam), but much will be boosted forward



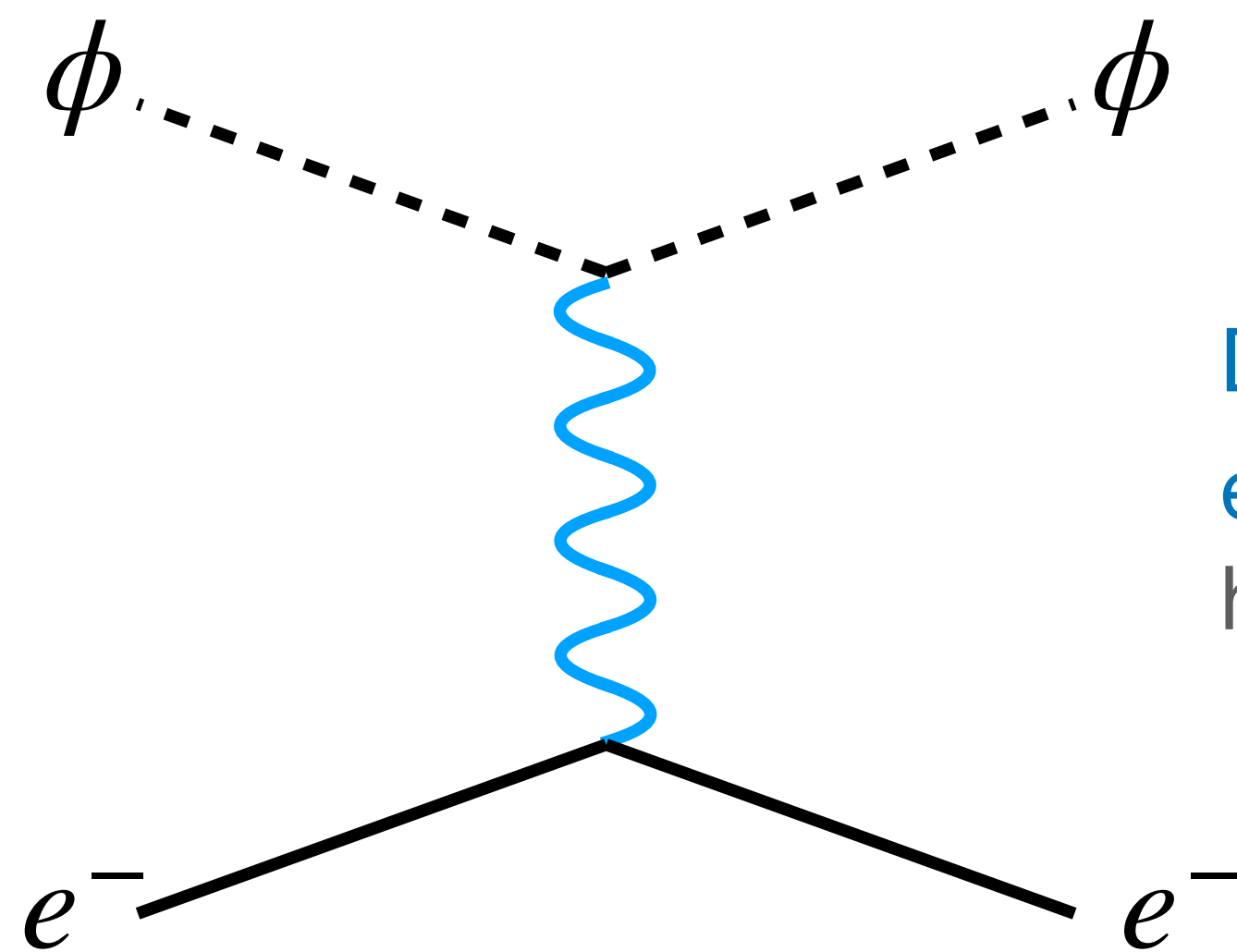
Dark-sector particle ϕ can scatter off electrons via the mediator A' :
high-energy, forward electron signature.

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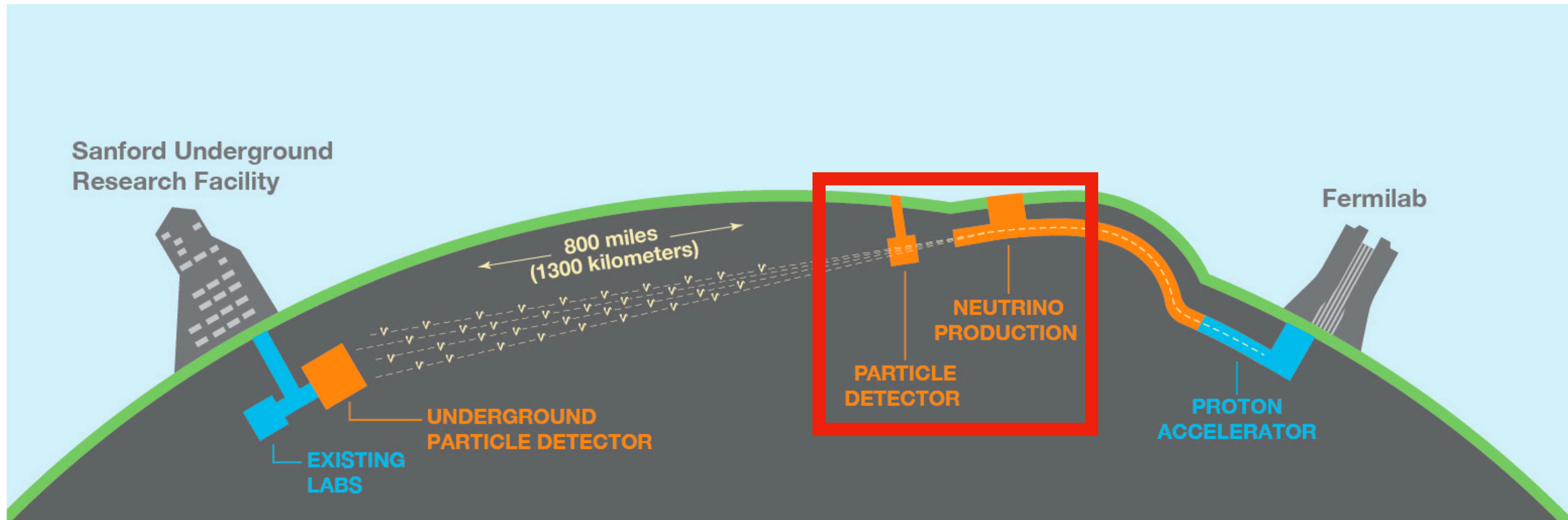


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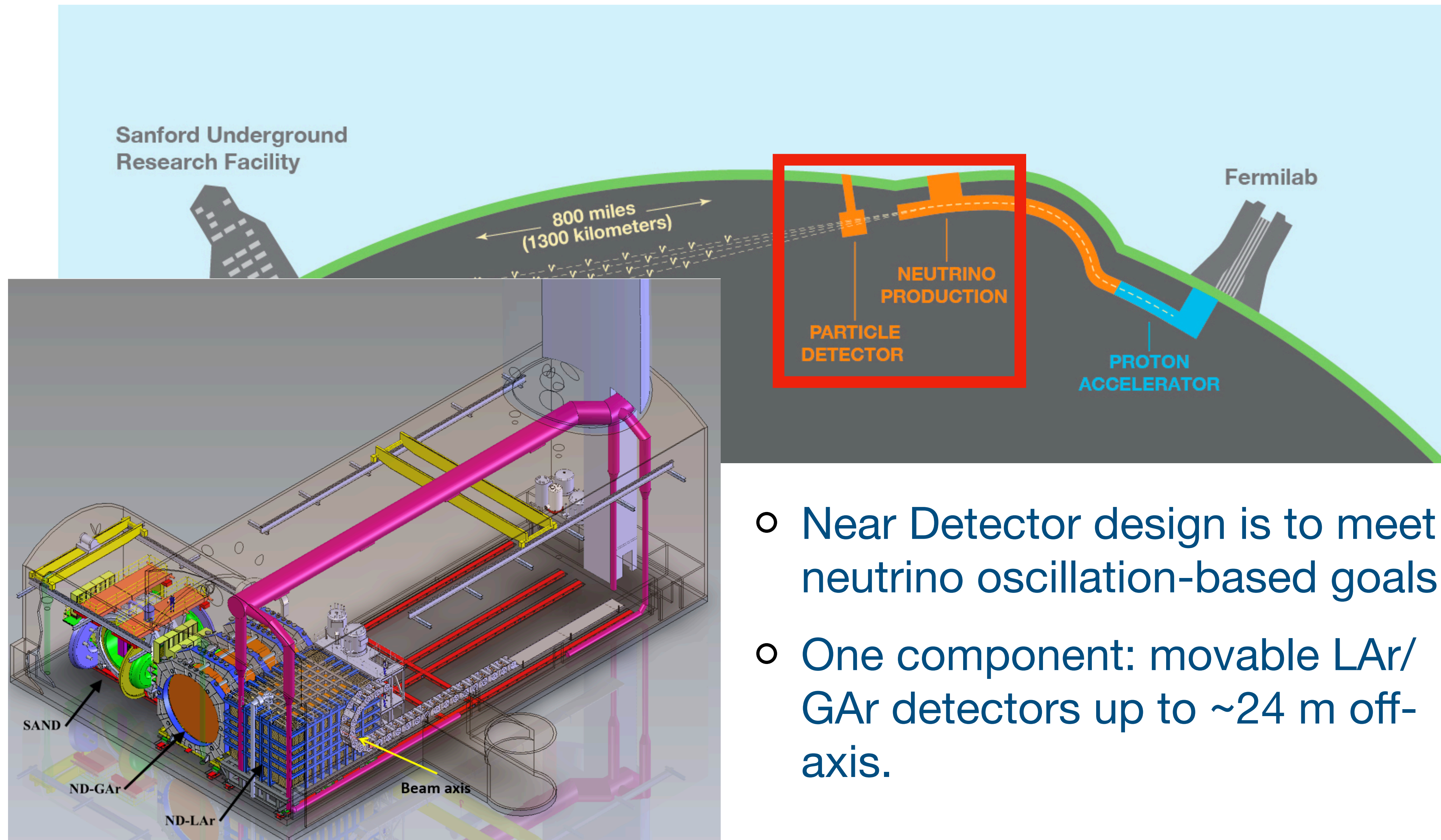


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DUNE-PRISM



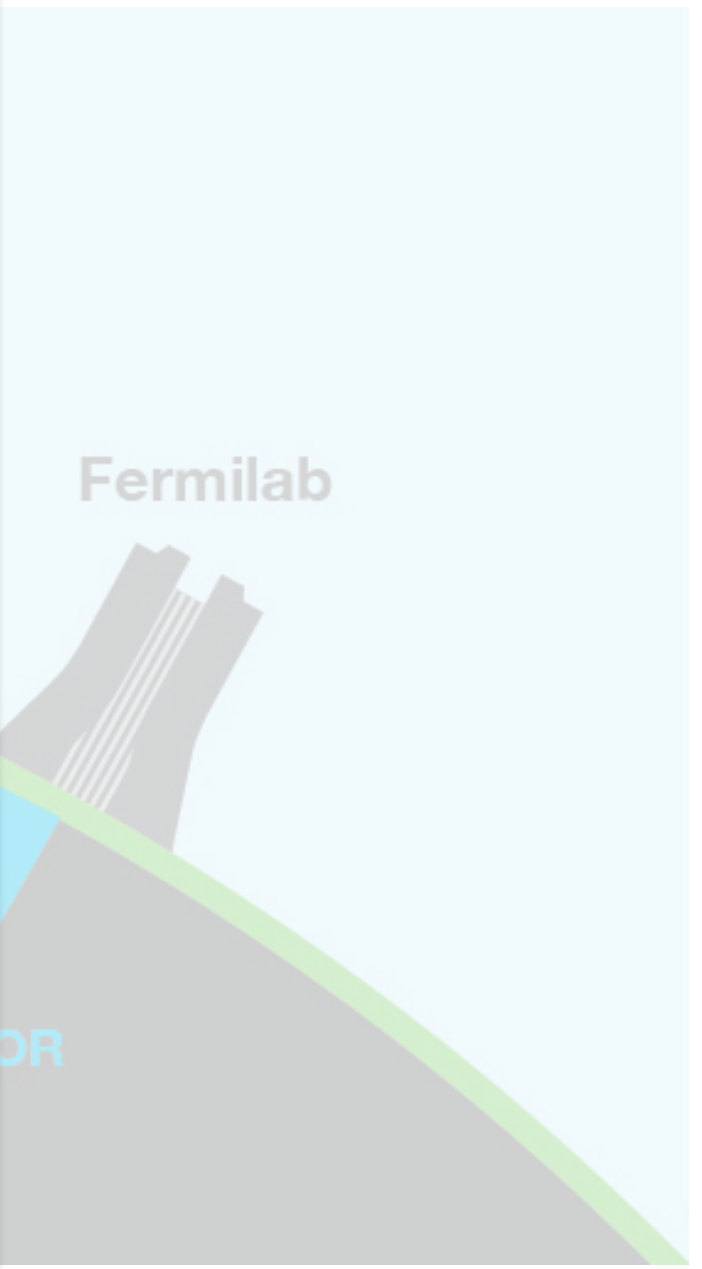
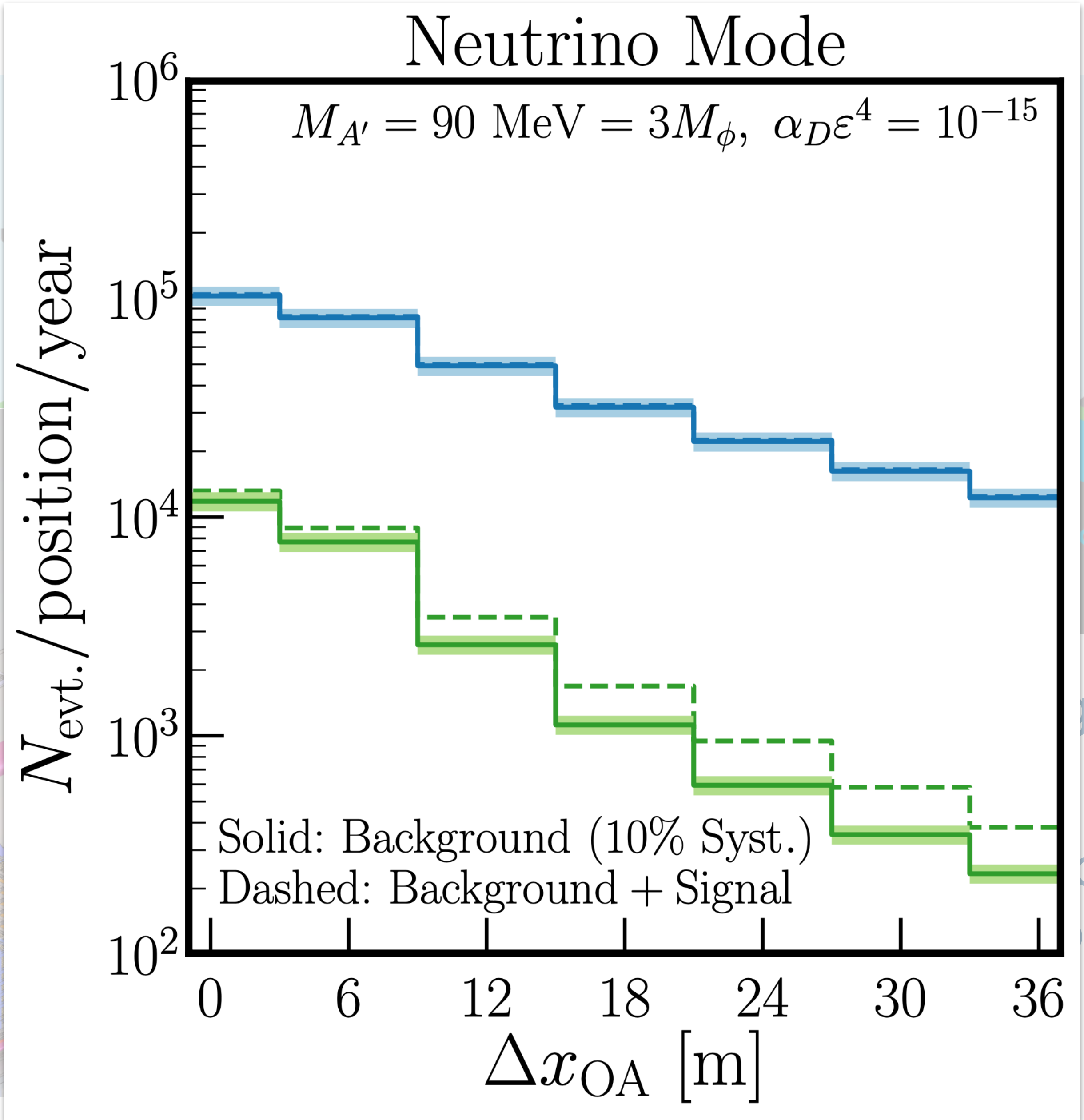
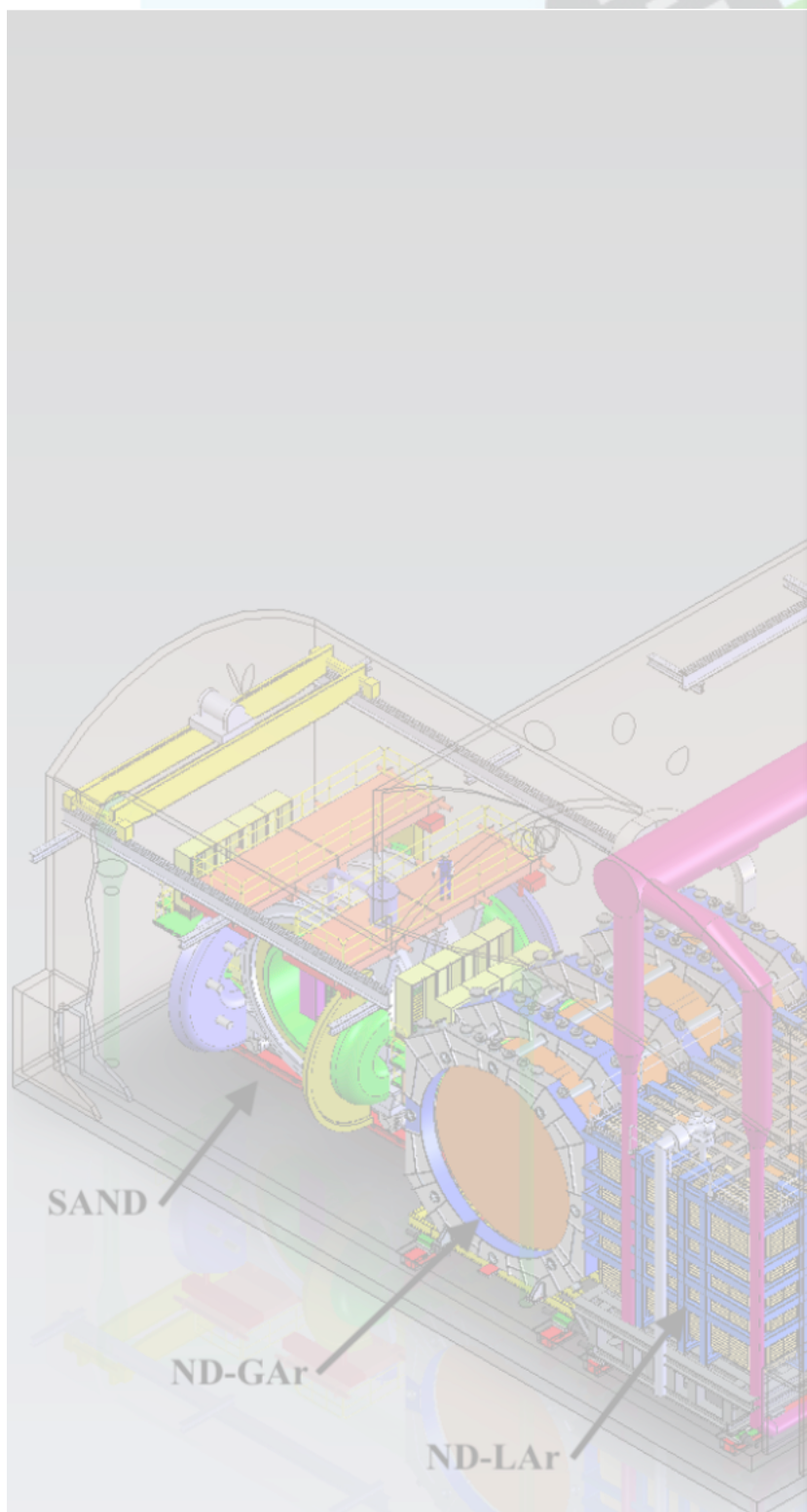
DUNE-PRISM



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

DUNE-PRISM

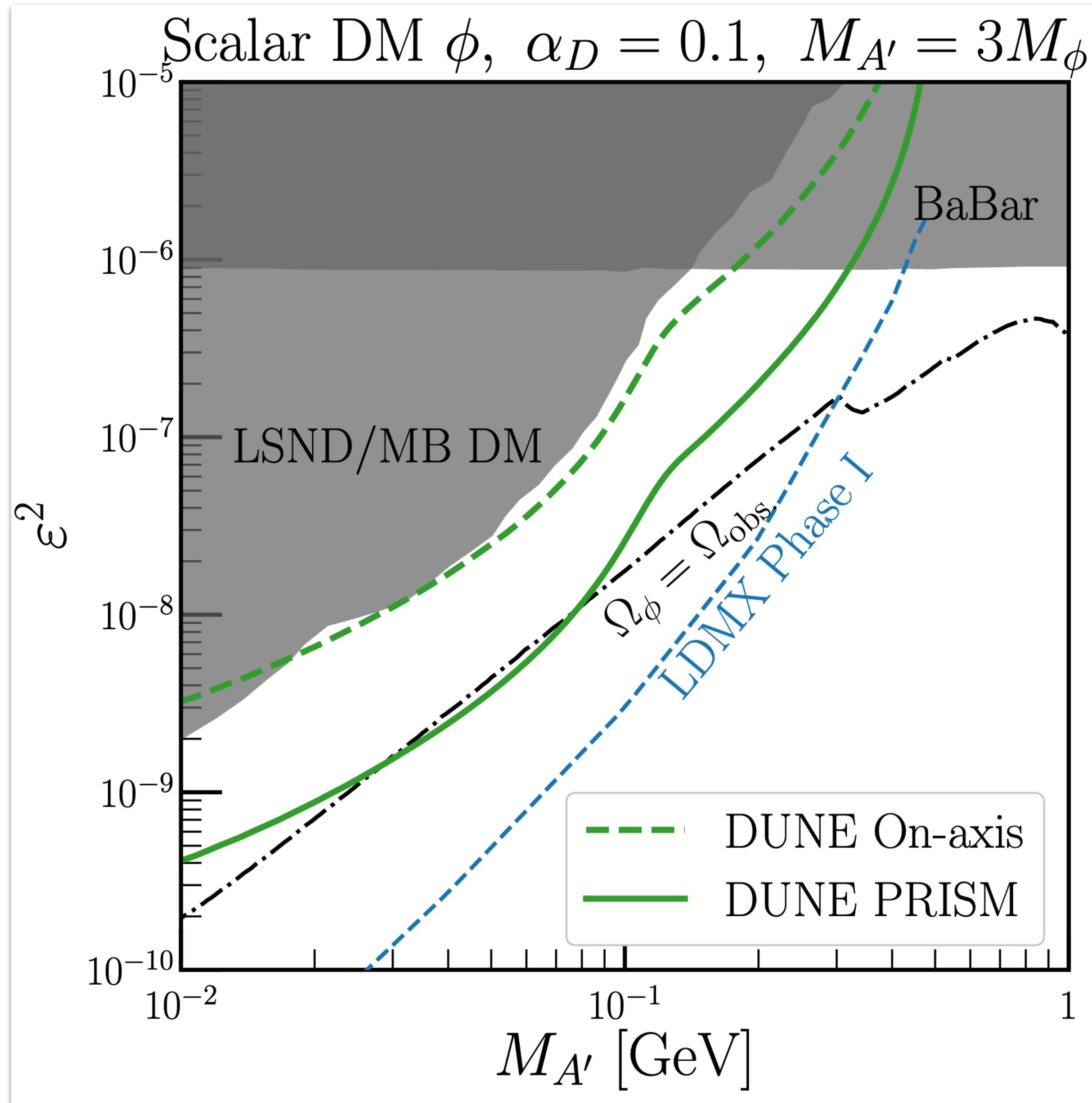
De Romeri, Kelly, Machado [\[1903.10505\]](#)



... is to meet
... based goals.

... available LAr/
... ~24 m off-

Search Sensitivity

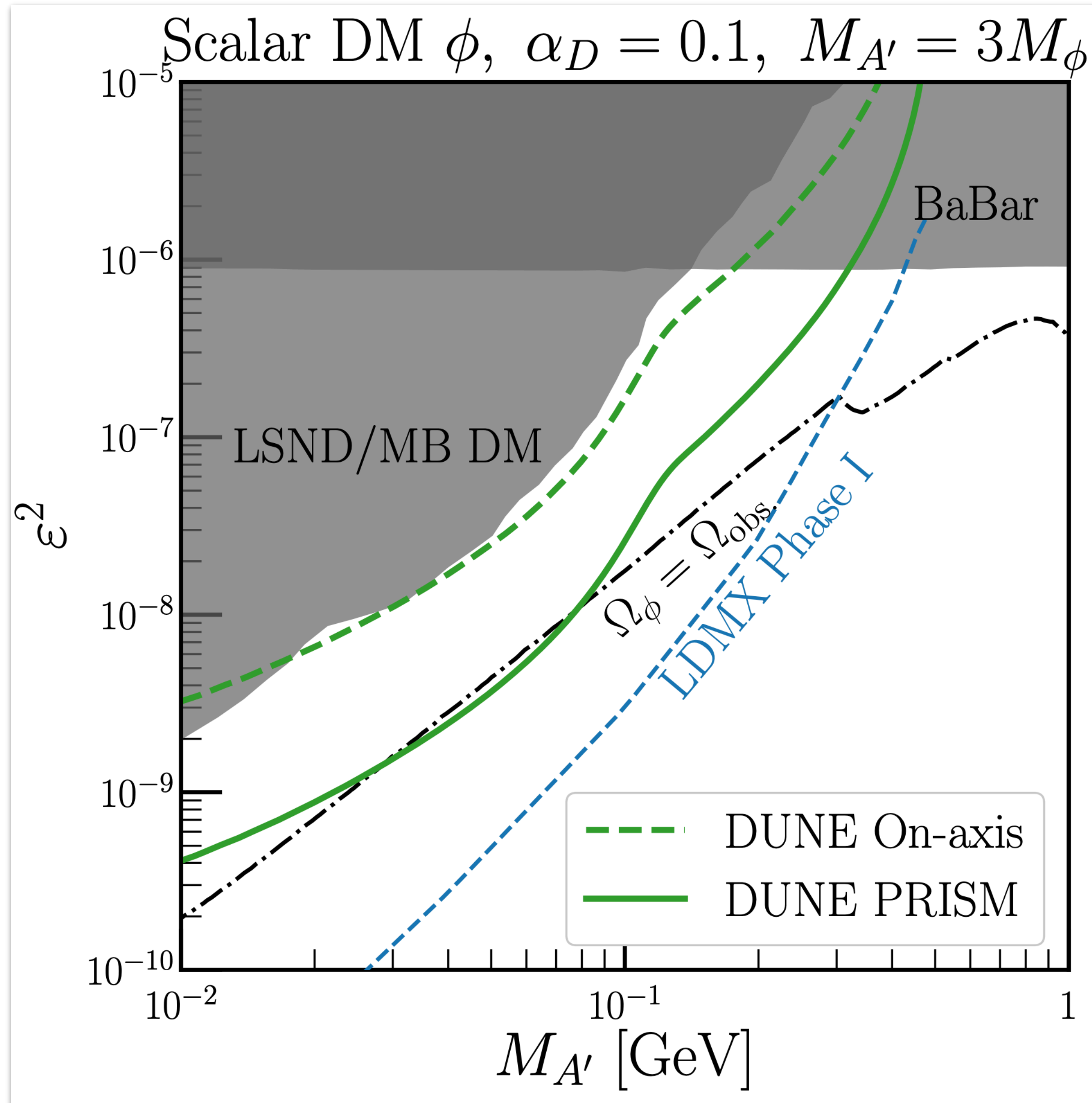


- Combining on- and off-axis searches allows to reduce systematic uncertainties.
- This allows for searches in novel parts of parameter space preferred if ϕ comprises the dark matter.
- Seven years' data at DUNE, reasonably competitive with LDMX Phase I.

Similar study incorporating spectral measurements, etc.:
Breitbach et al [\[2102.03383\]](#)

Consideration of a DUNE Off-Target mode:
Brdar et al [\[2206.06380\]](#)

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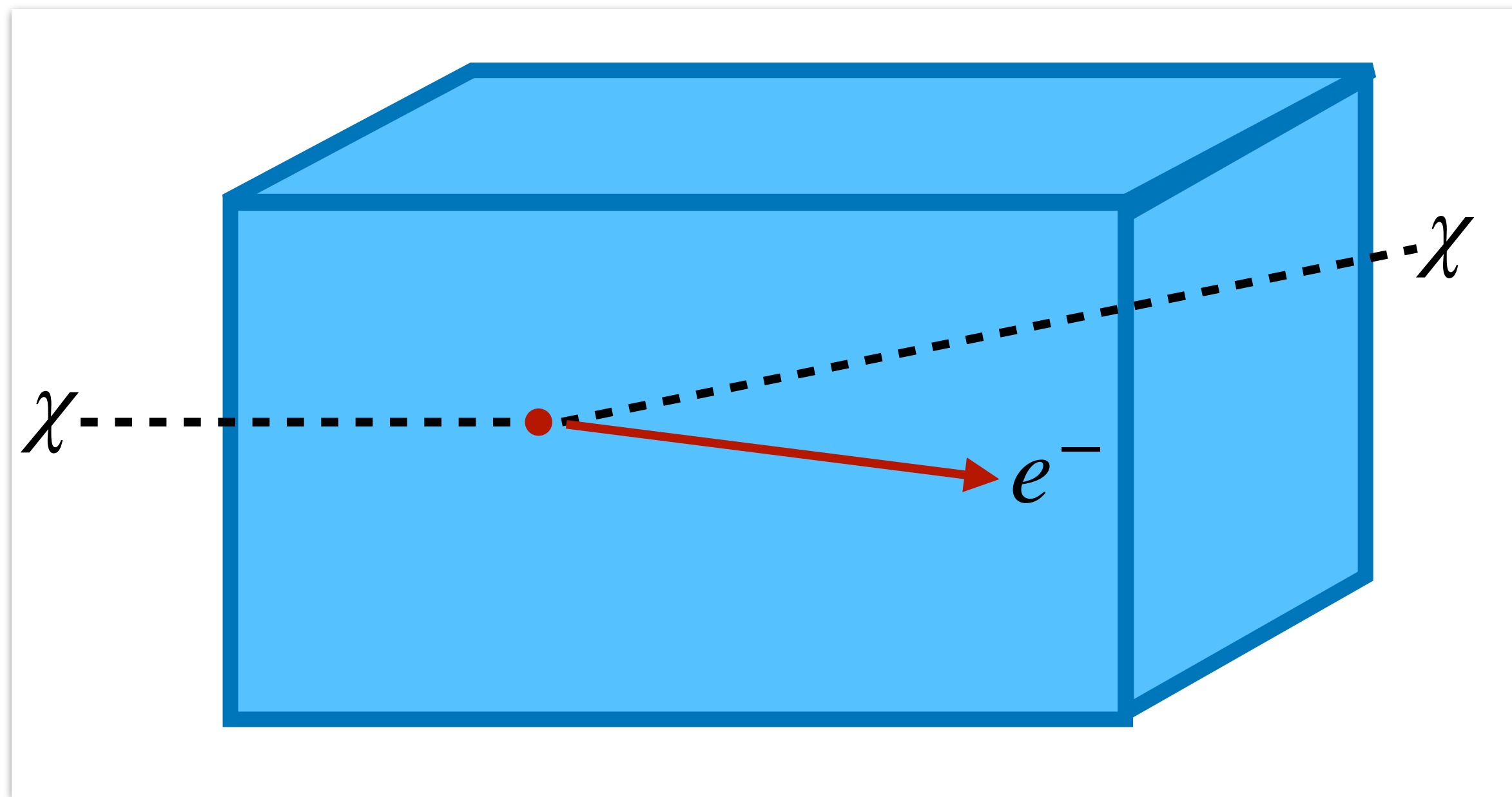
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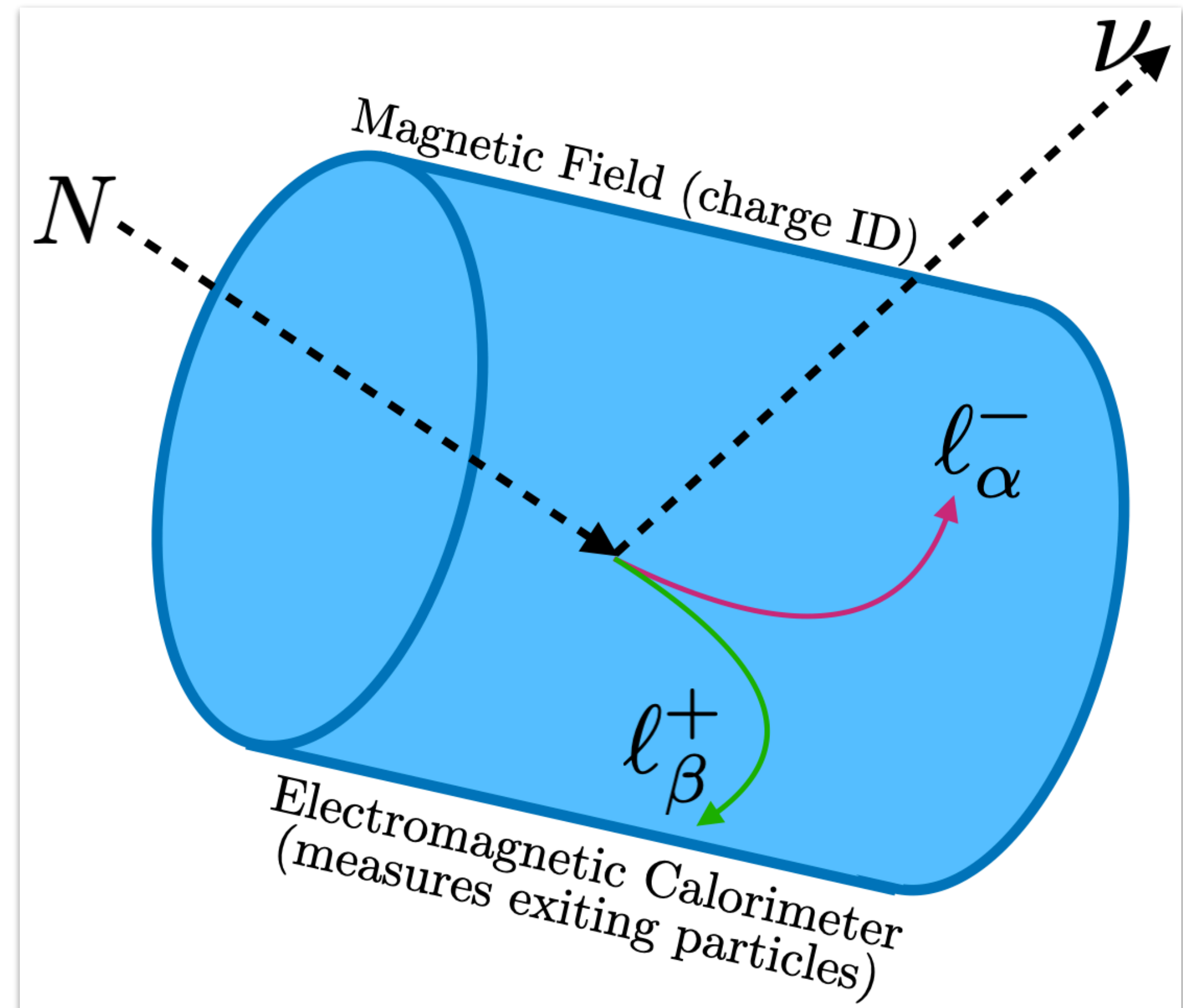
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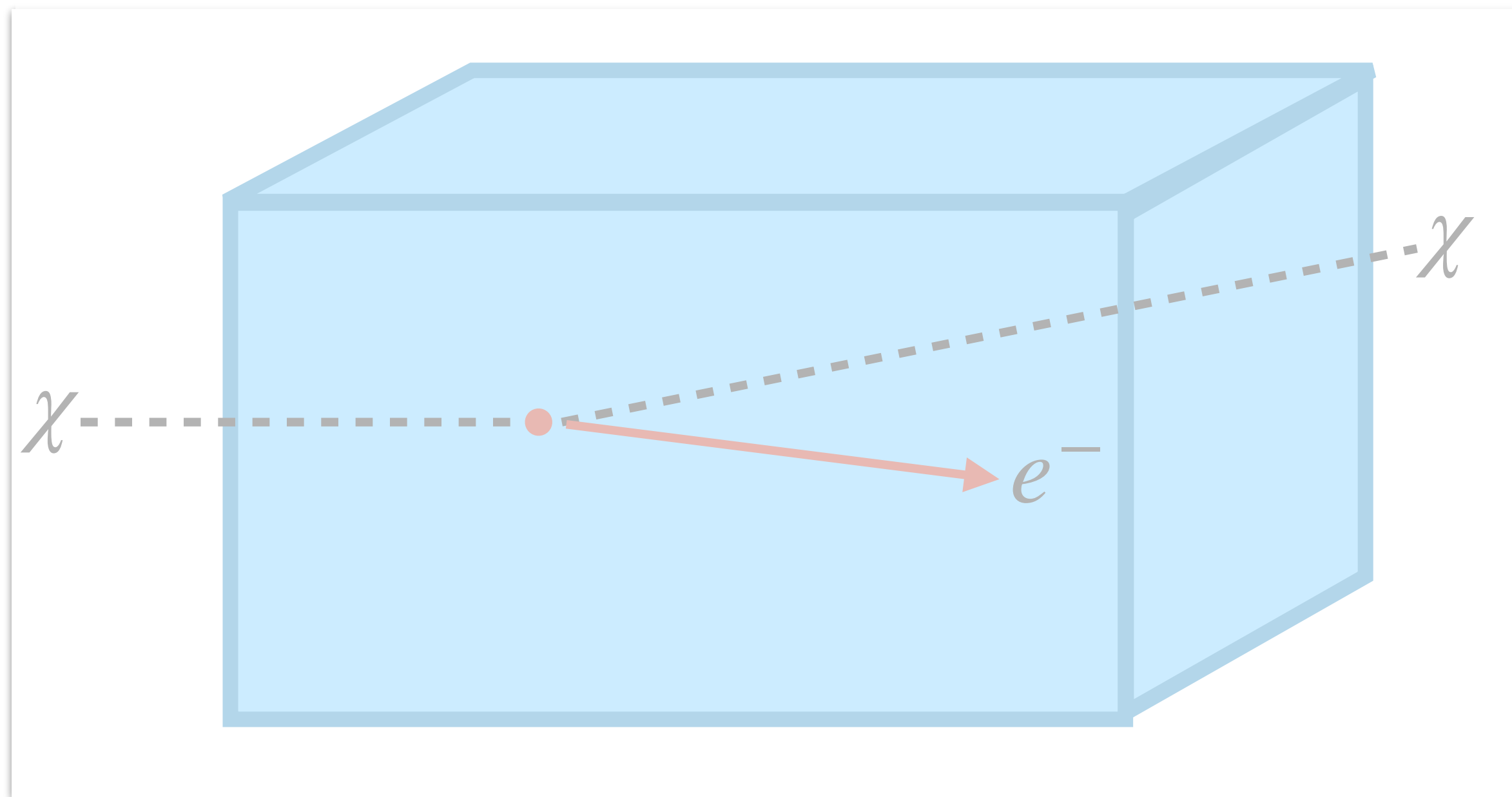


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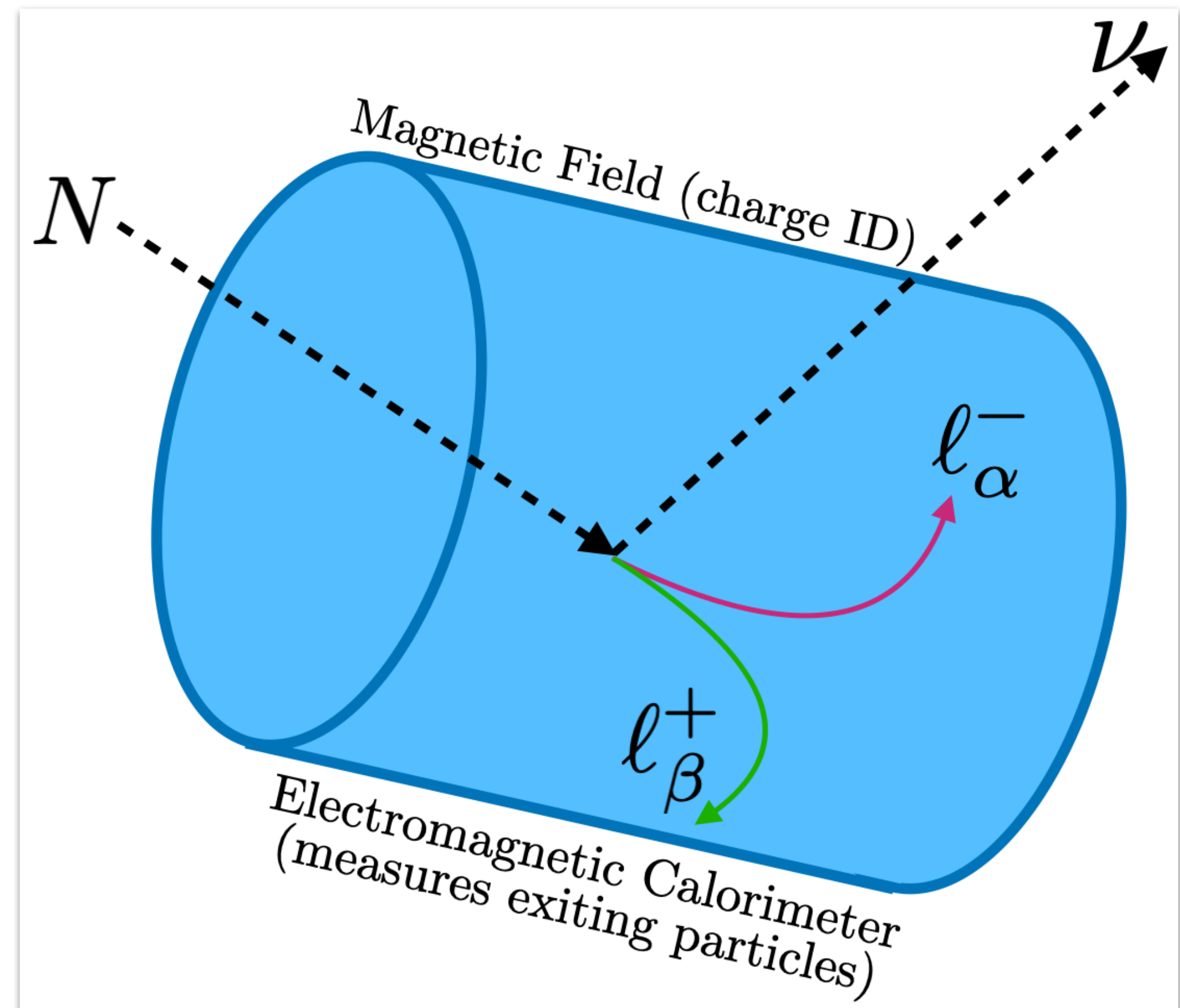
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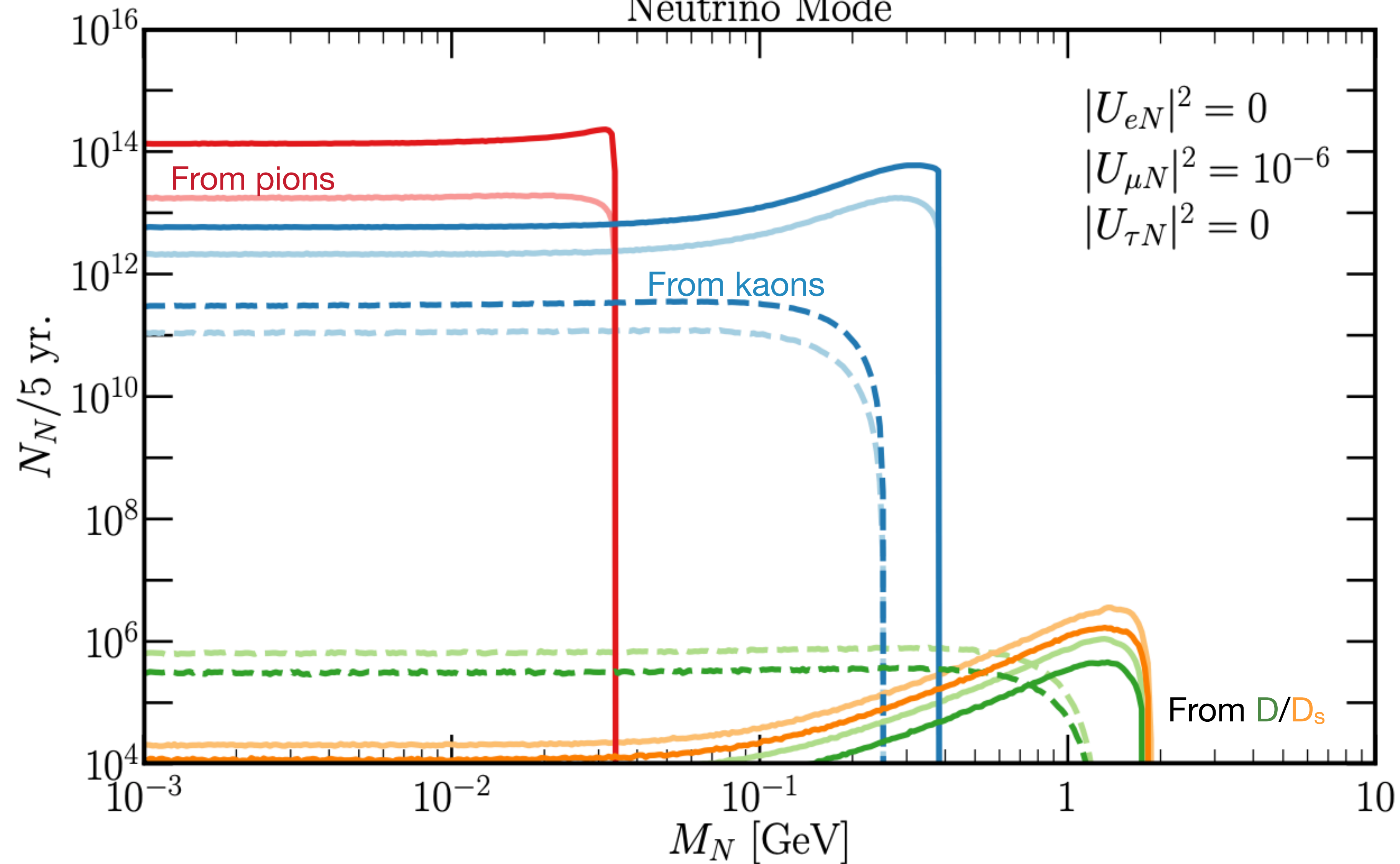
HNLs in the DUNE Beam

Berryman, de Gouvêa, Fox, Kayser, **KJK**, Raaf [[1912.07622](#)]
Neutrino Mode

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.

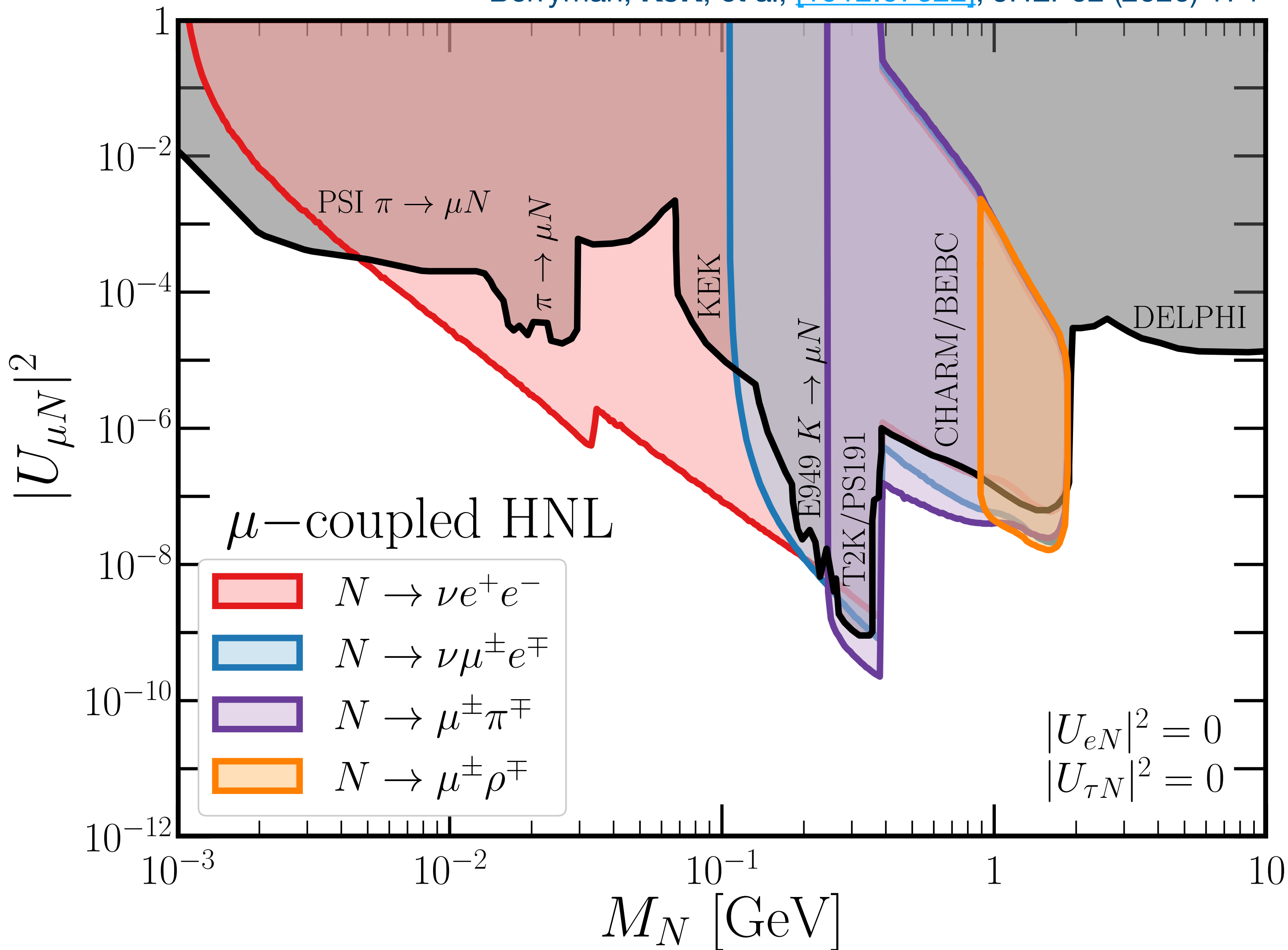
Similar fluxes are easy* to simulate for different target/detector configurations.



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

Discovery Potential at DUNE-NDGAr

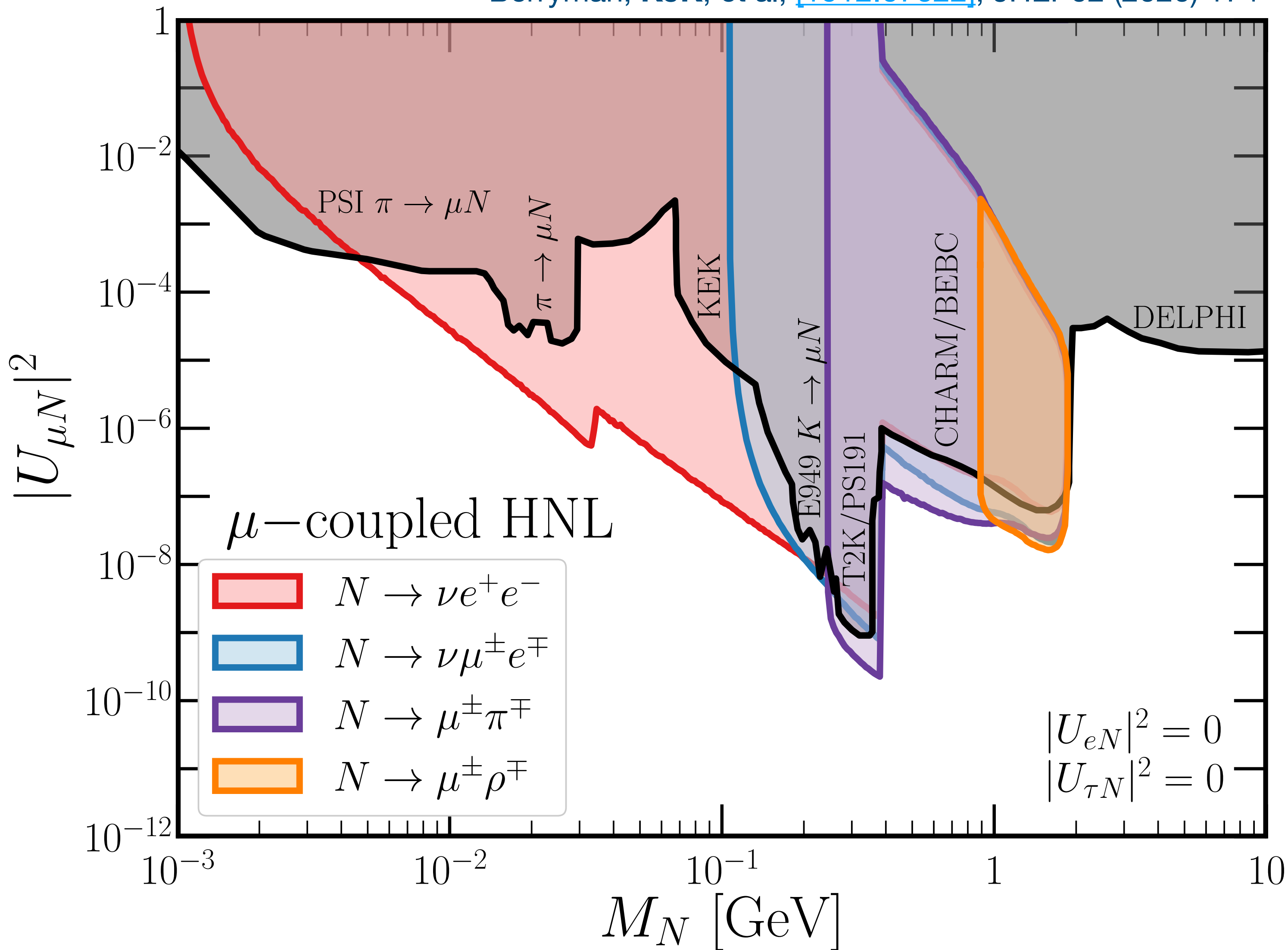
Berryman, **KJK**, et al, [1912.07622], JHEP02 (2020) 174



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

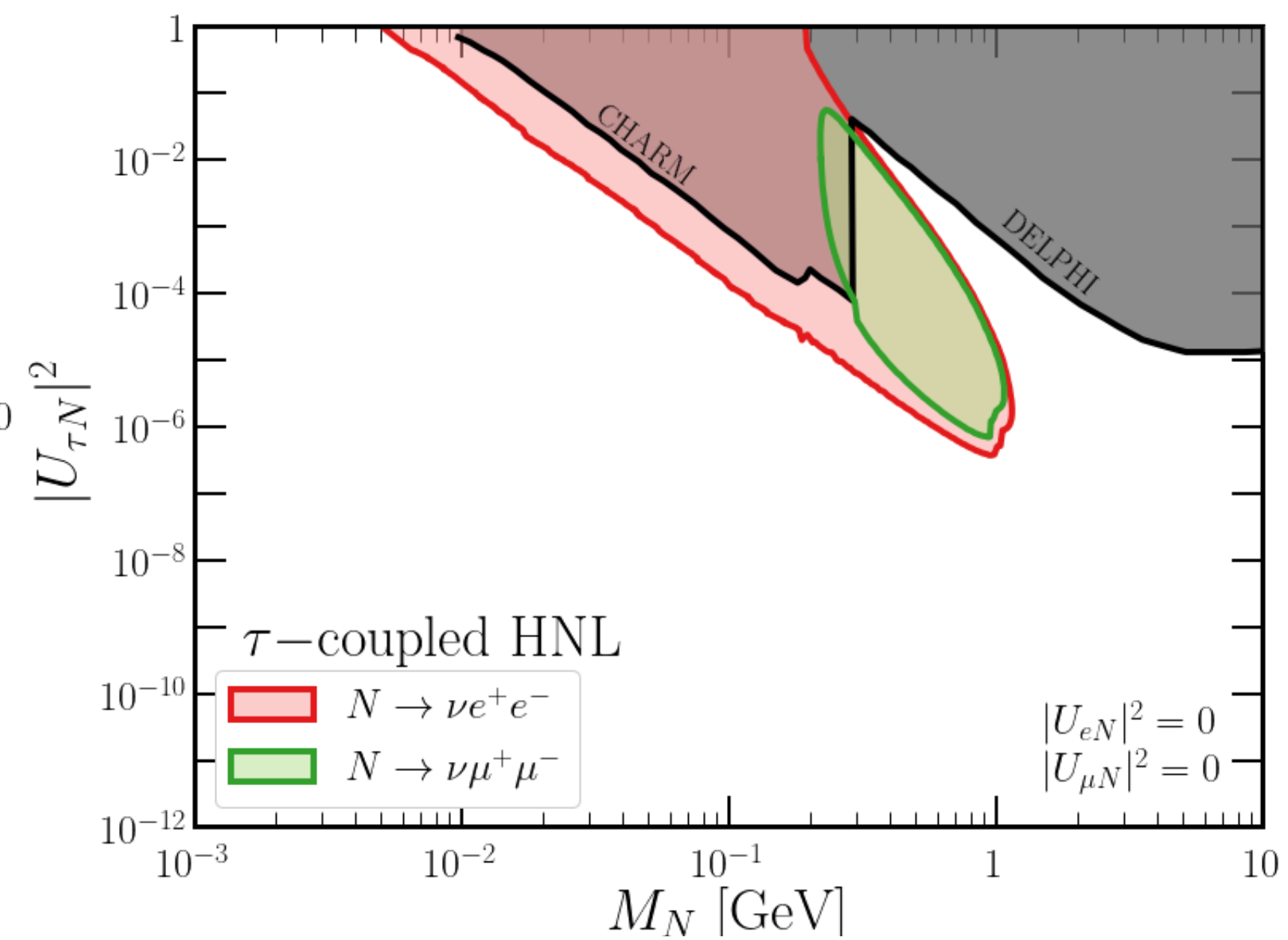
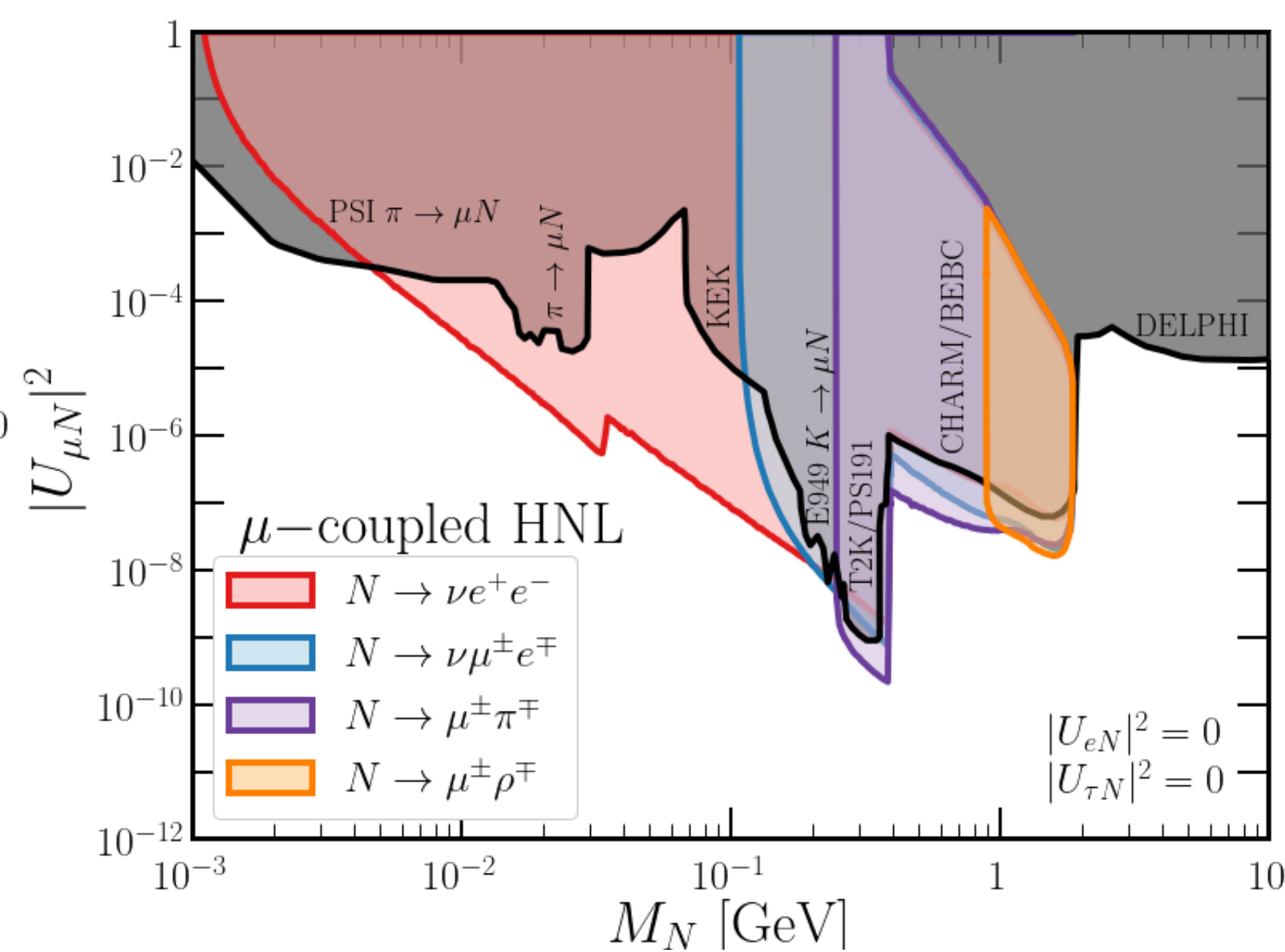
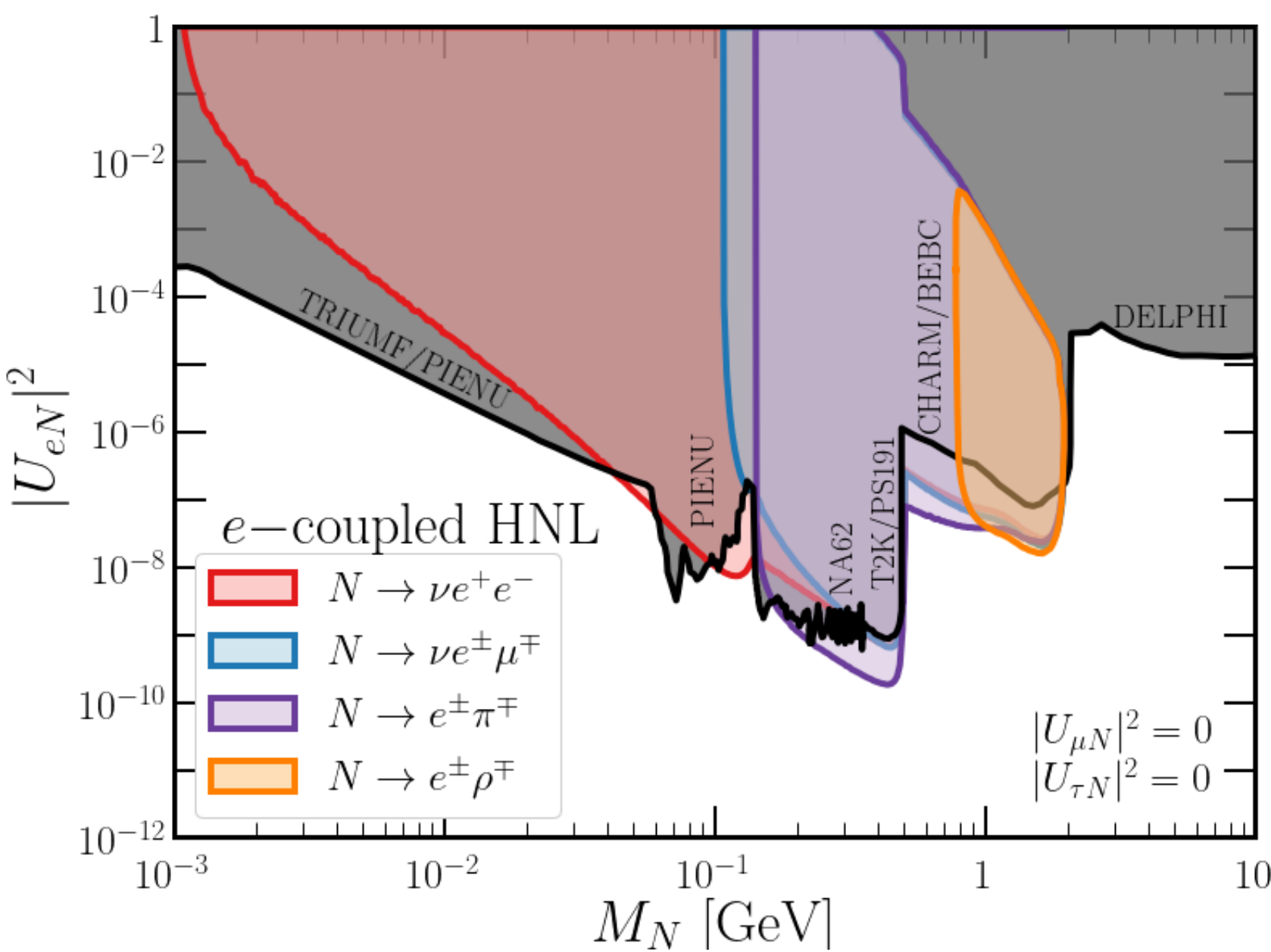
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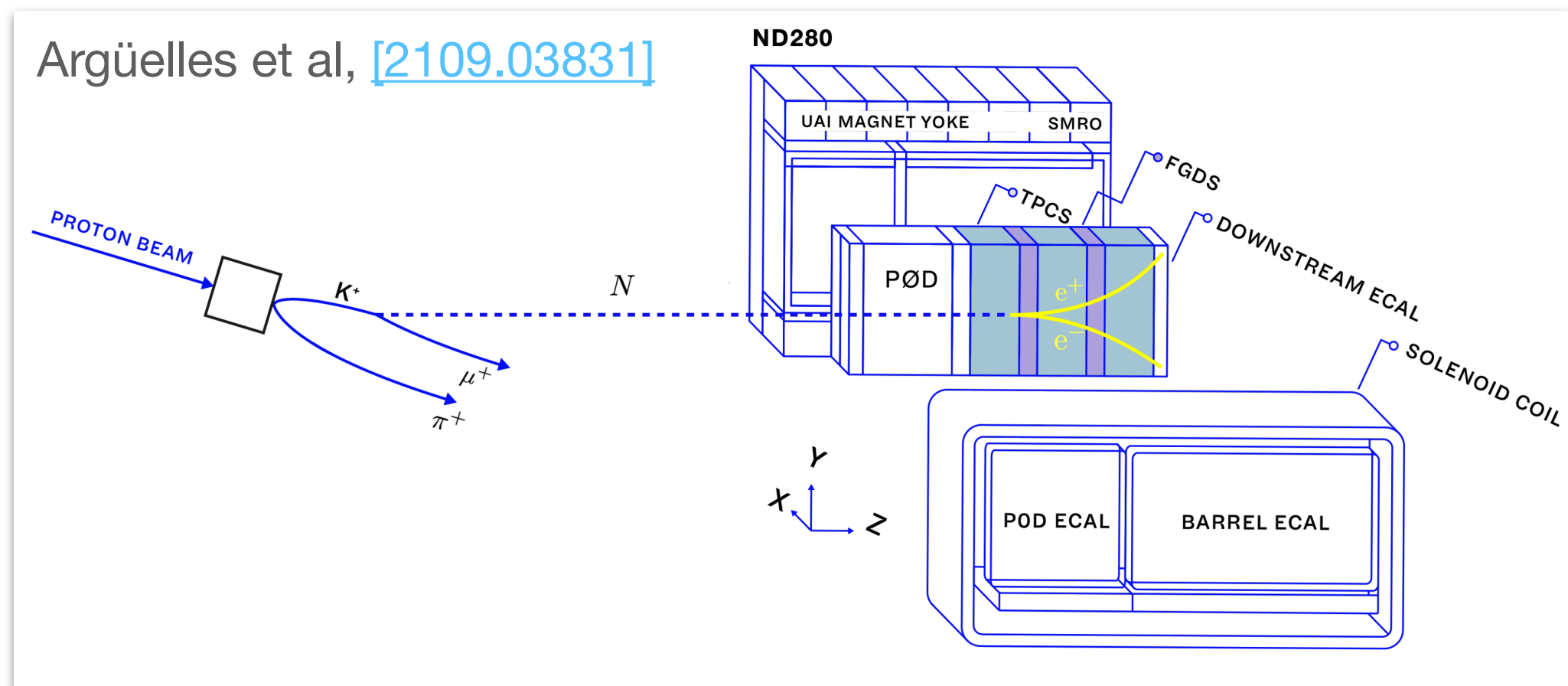


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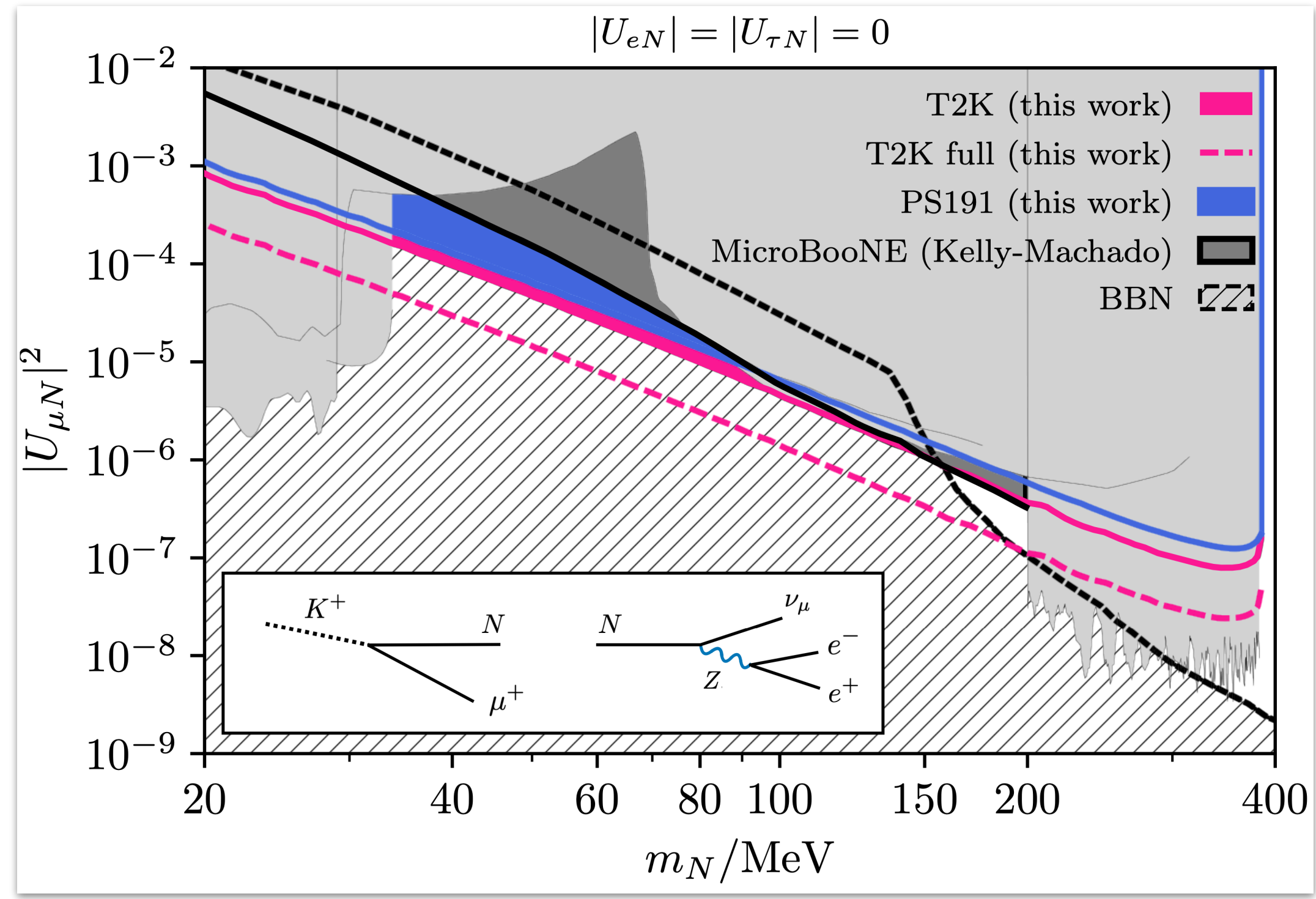
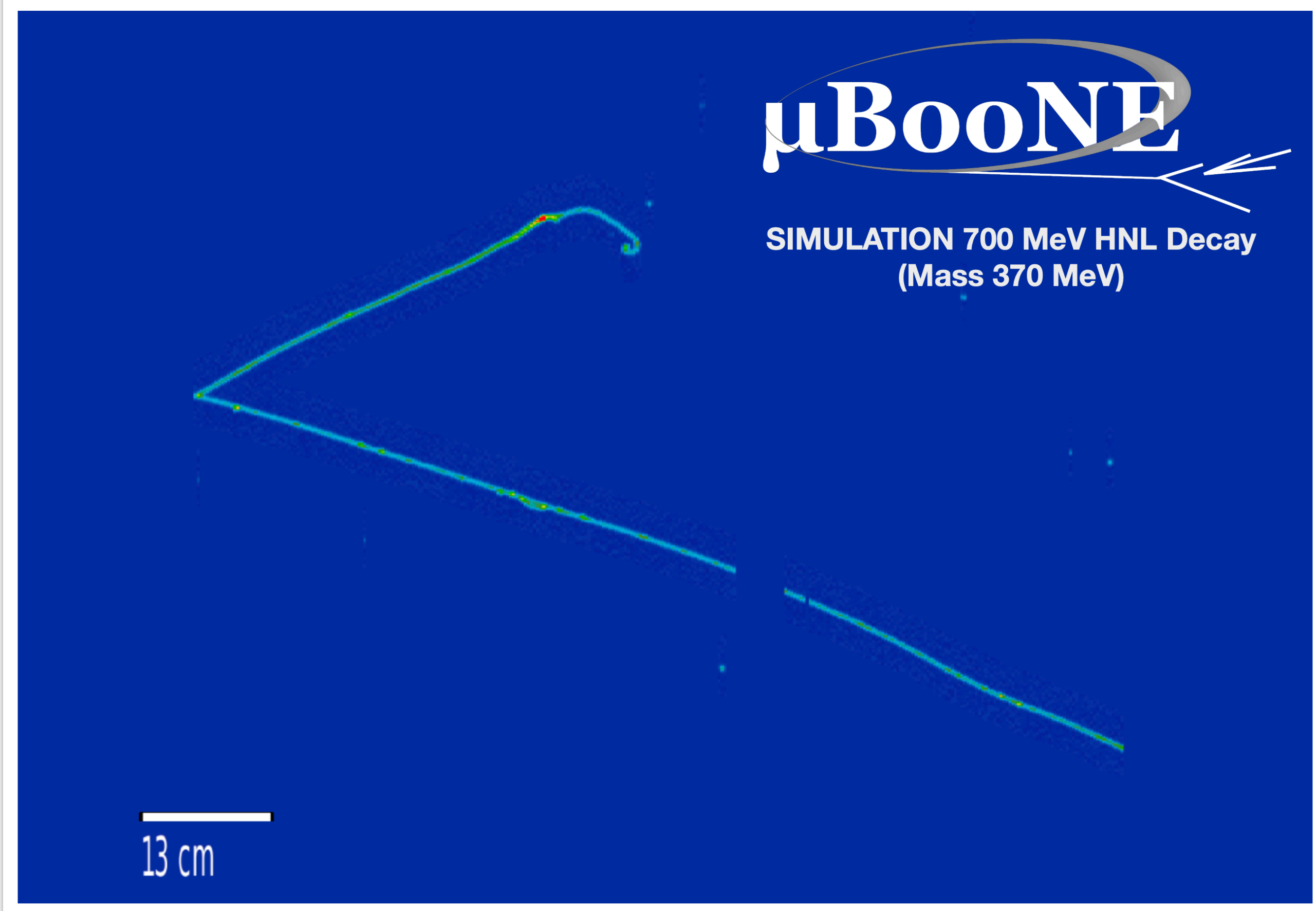
All single-mixing sensitivity



Current Searches — T2K & MicroBooNE



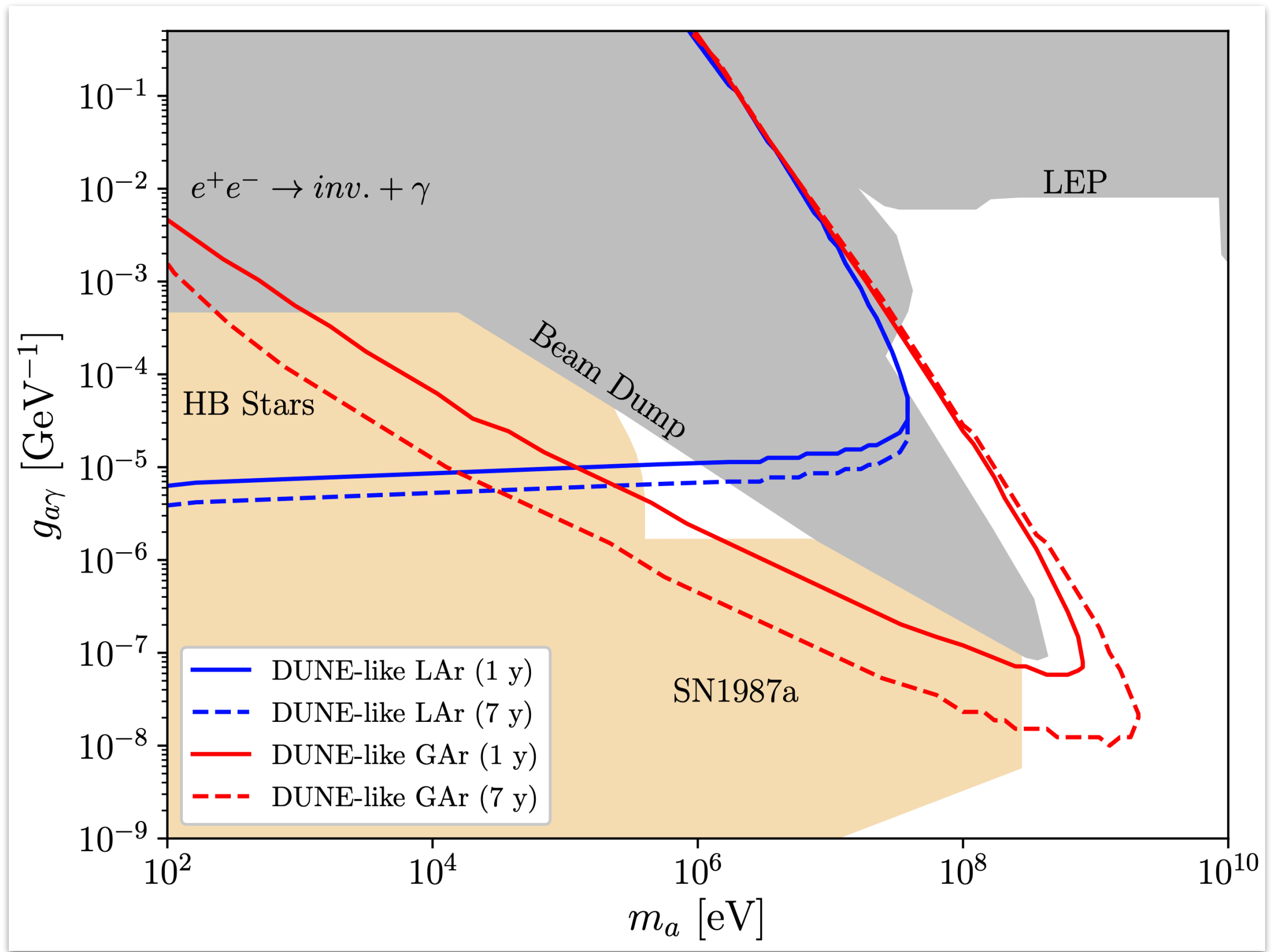
MicroBooNE collaboration, [\[1911.10545\]](#)



See also: T2K collaboration, [\[1902.07598\]](#)

Many searches/models being proposed/explored actively.
Suggestion for model-independent frameworks: Batell, Huang, Kelly, [\[2304.11189\]](#)

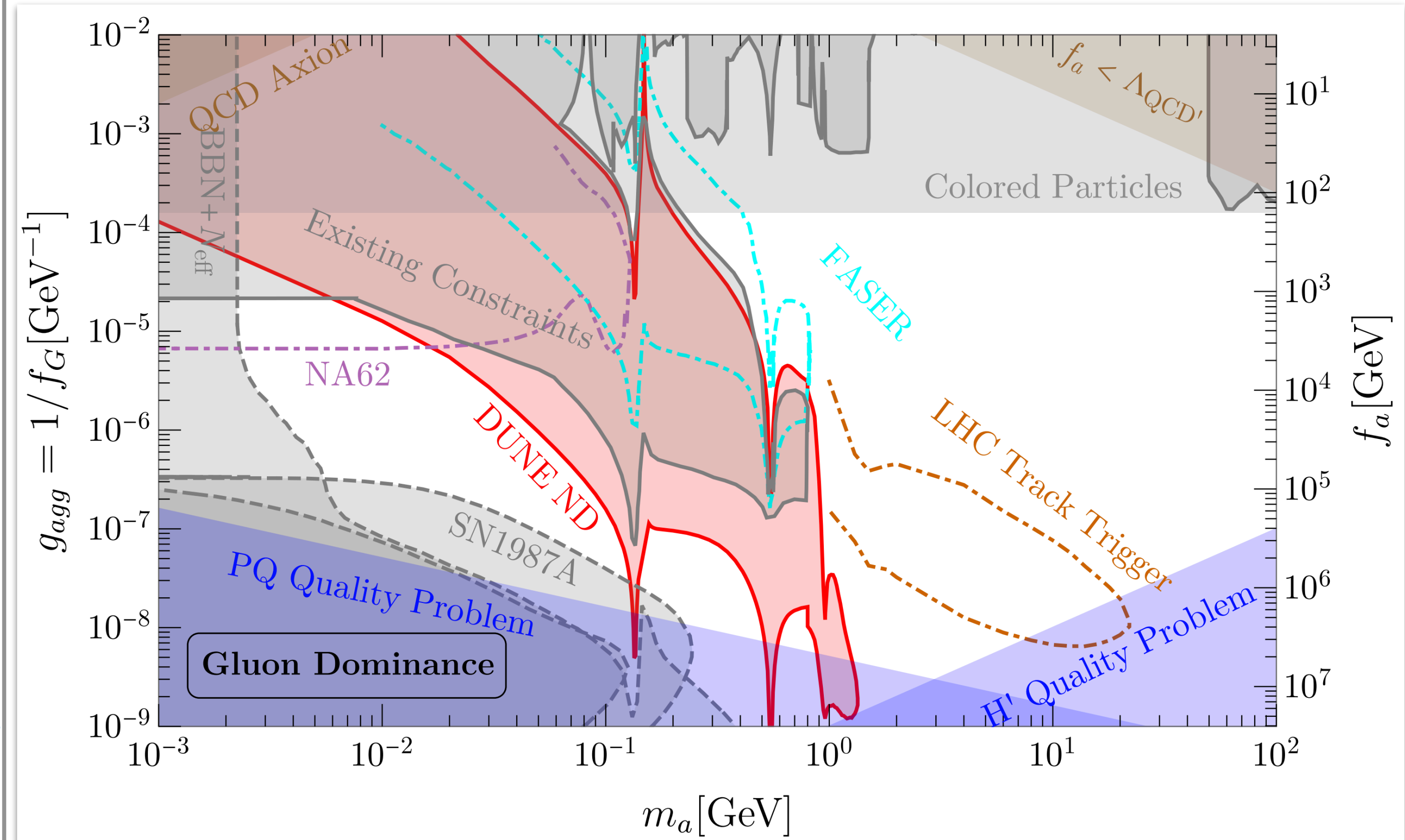
Other Models?



Brdar et al [\[2011.07054\]](#)

Axion-like particles

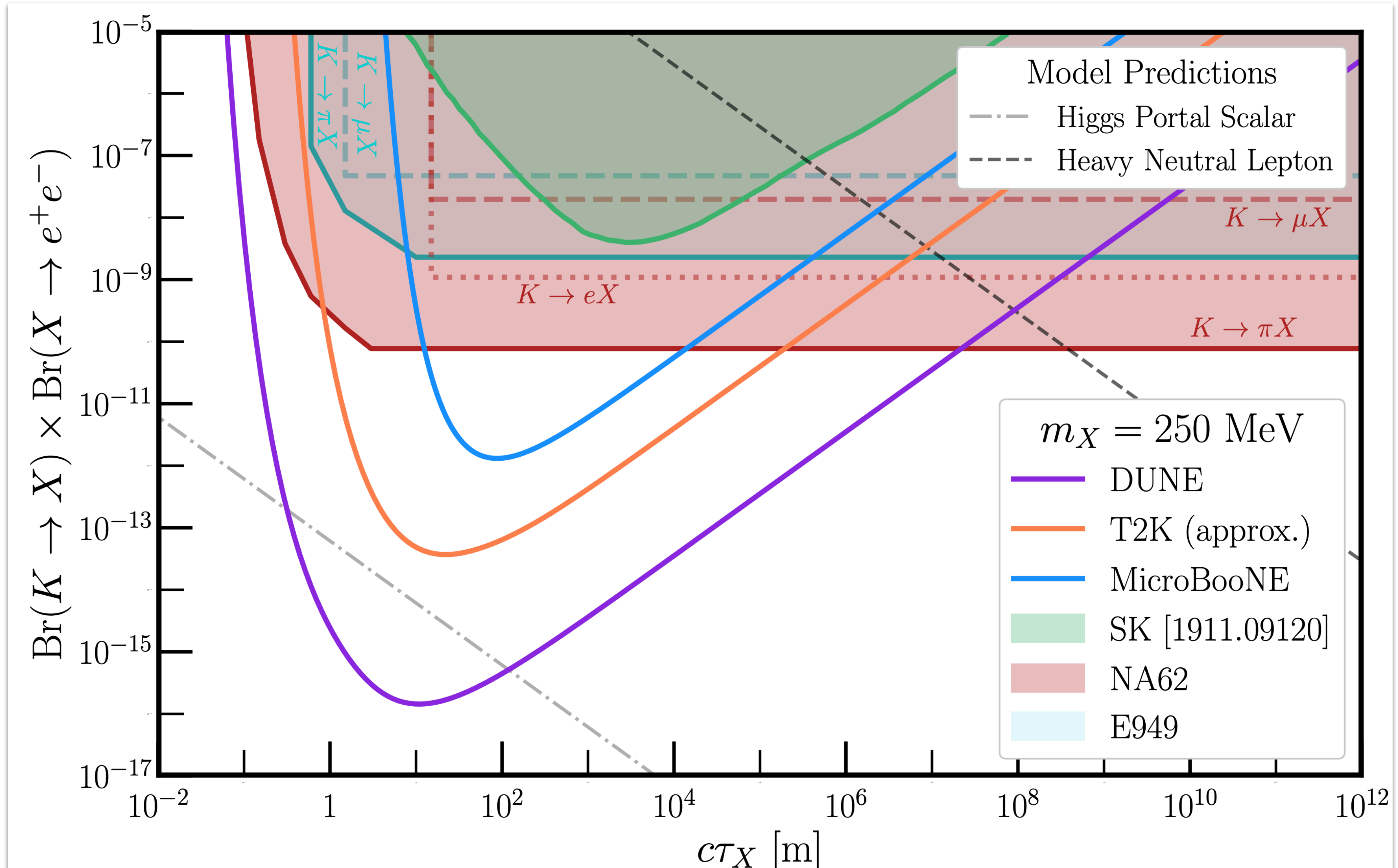
Heavy QCD axions



Kelly, Kumar, Liu [\[2011.05995\]](#)

Model-Independence in LLP Searches

Batelli, Huang, Kelly, [2304.11189]



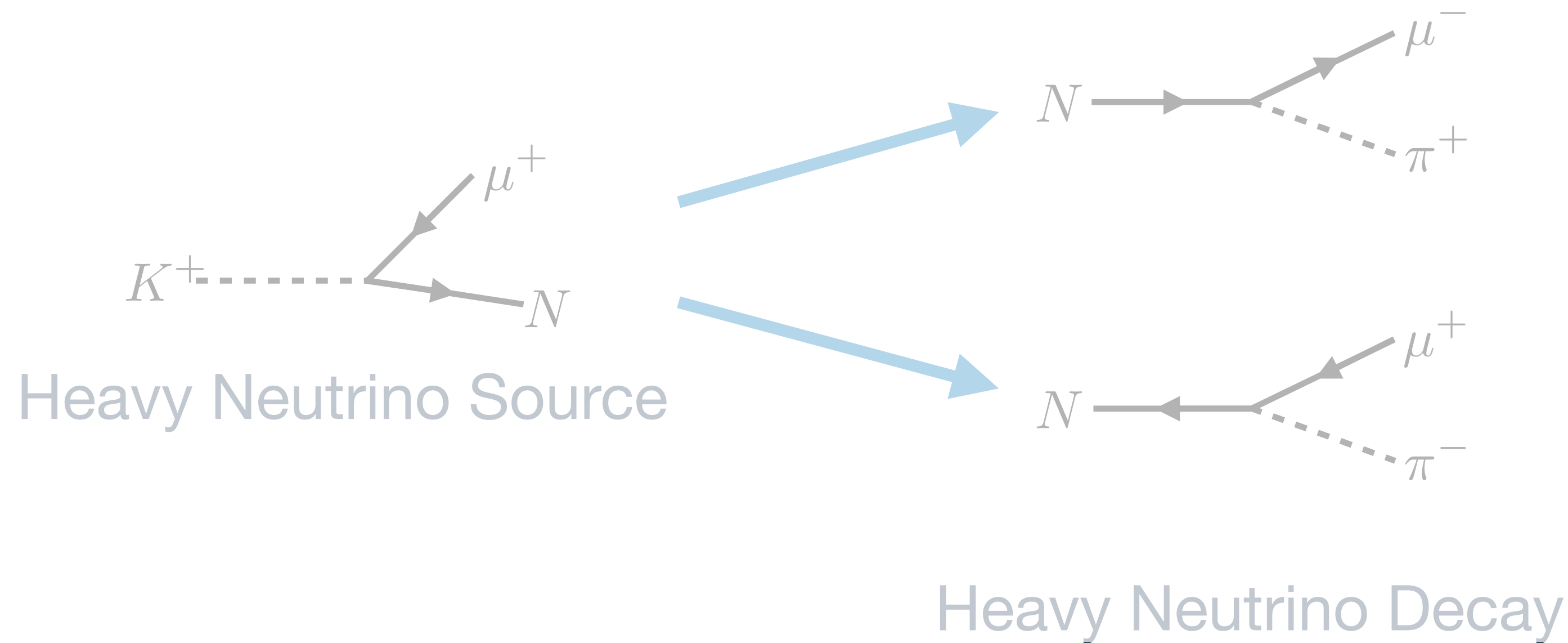
What do we do with a discovery?

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?



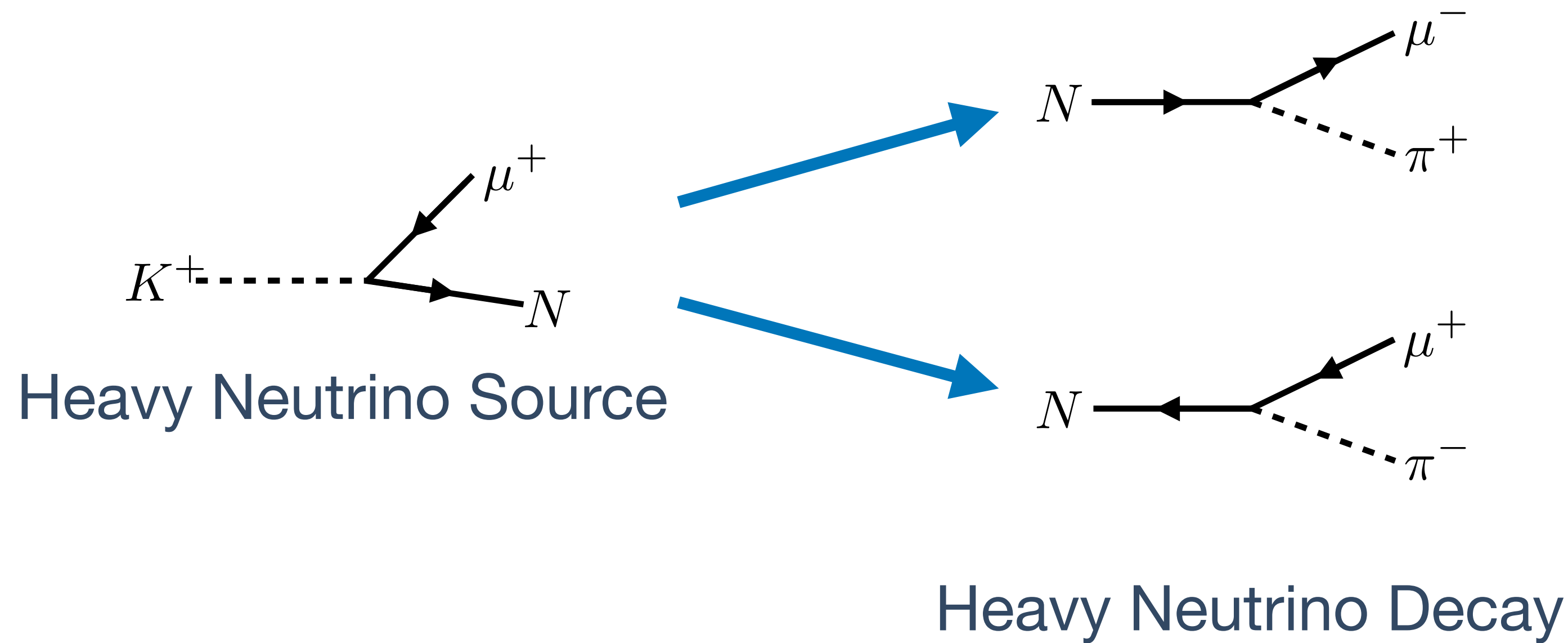
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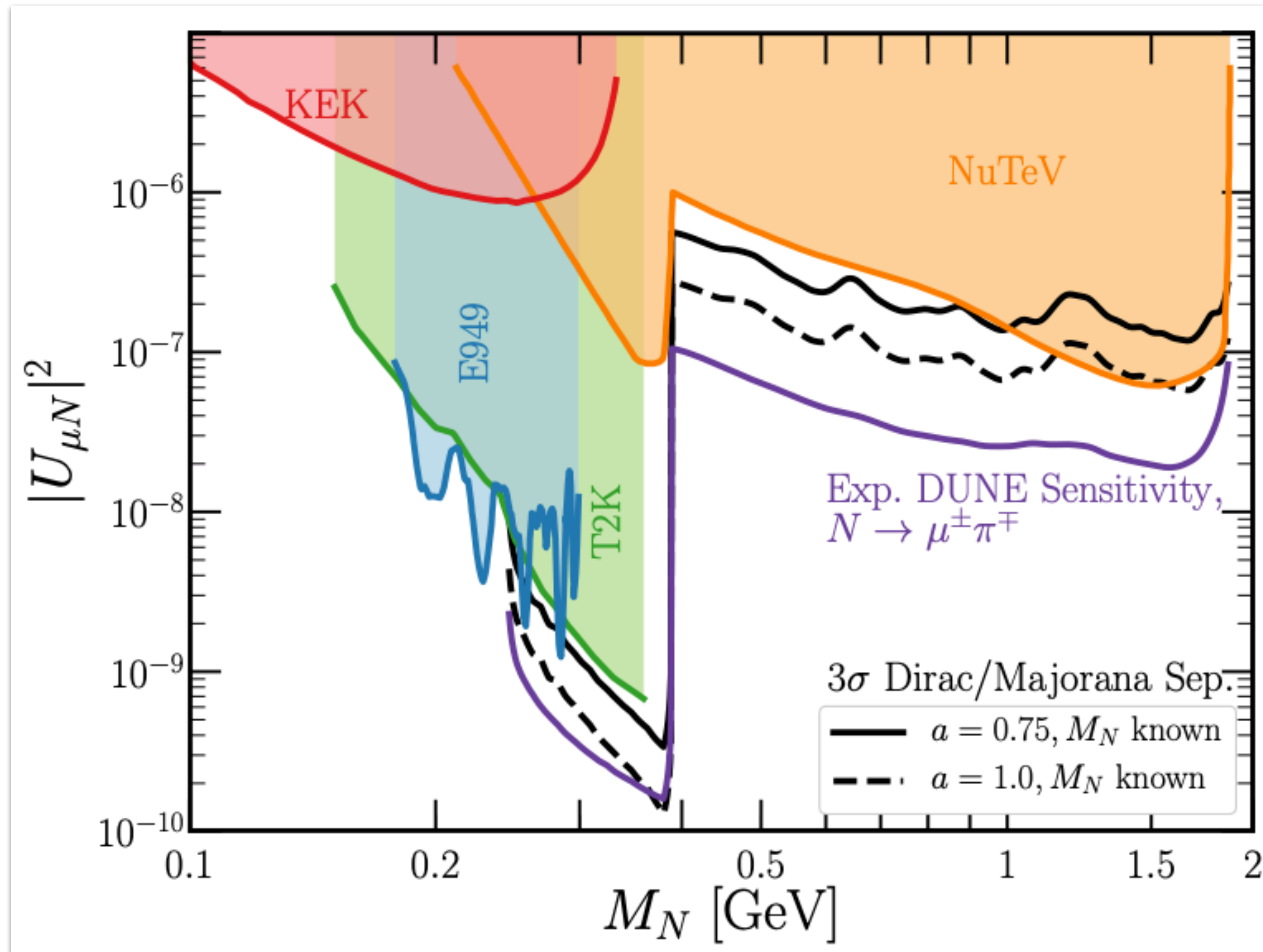


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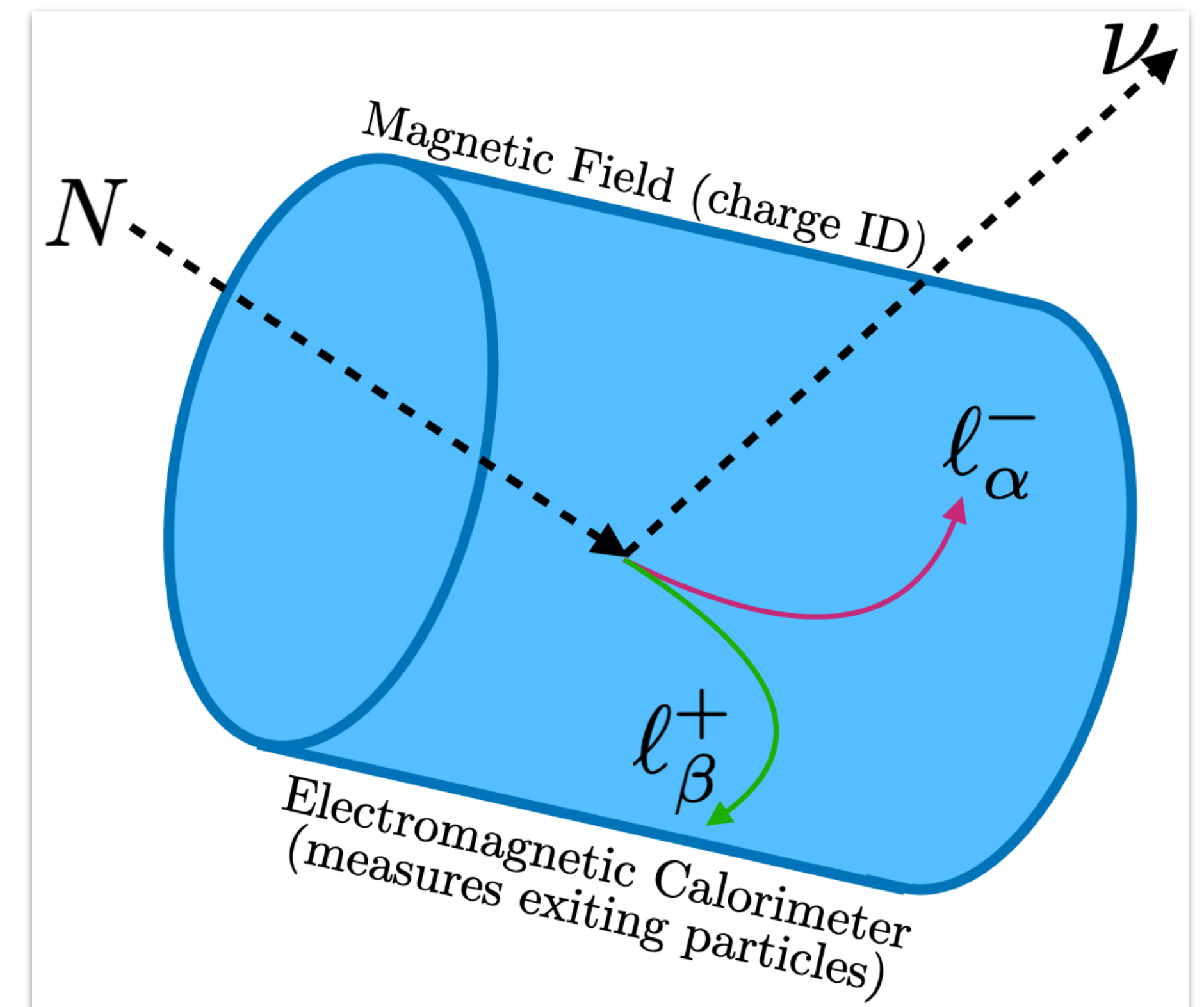
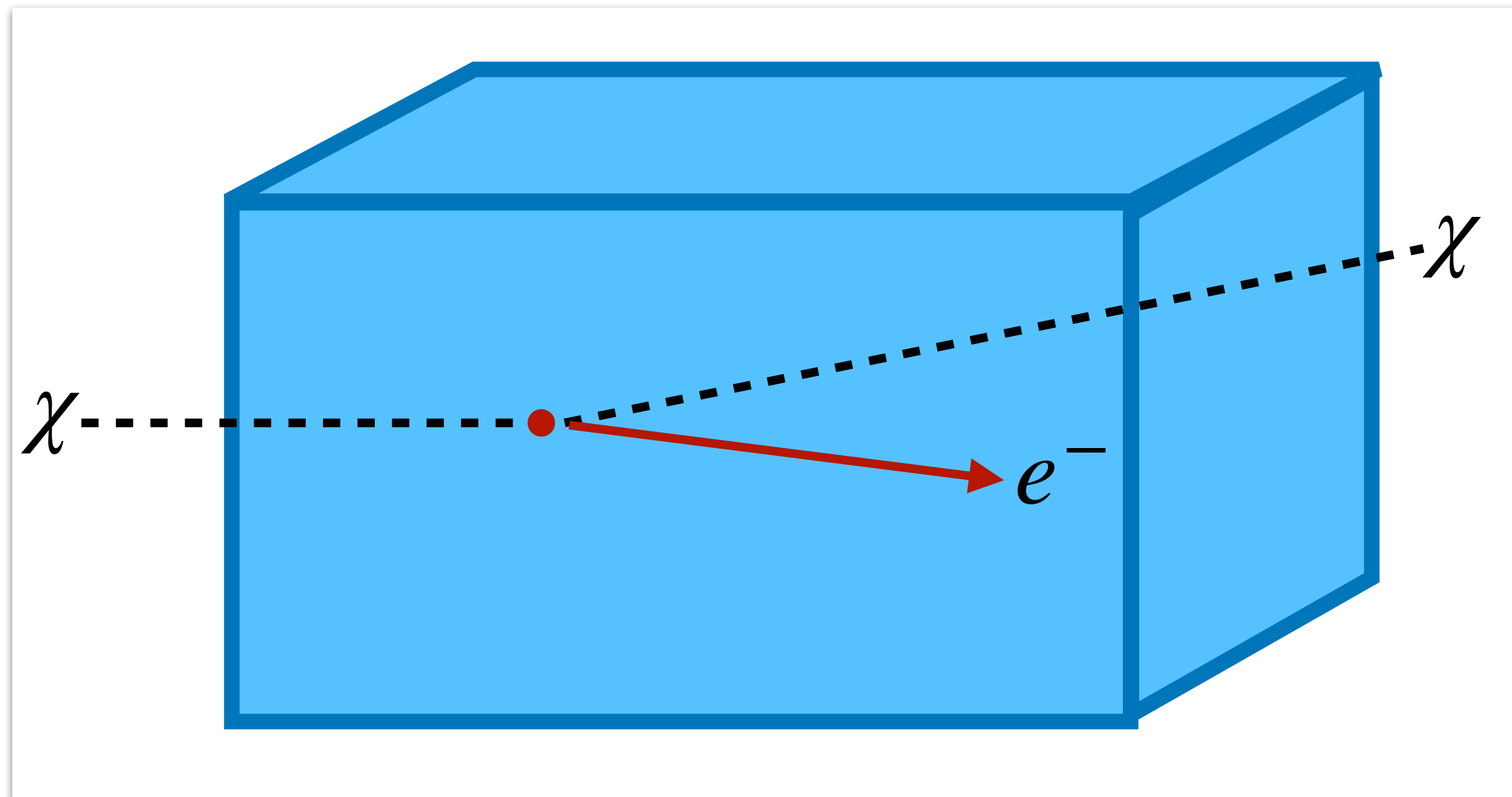
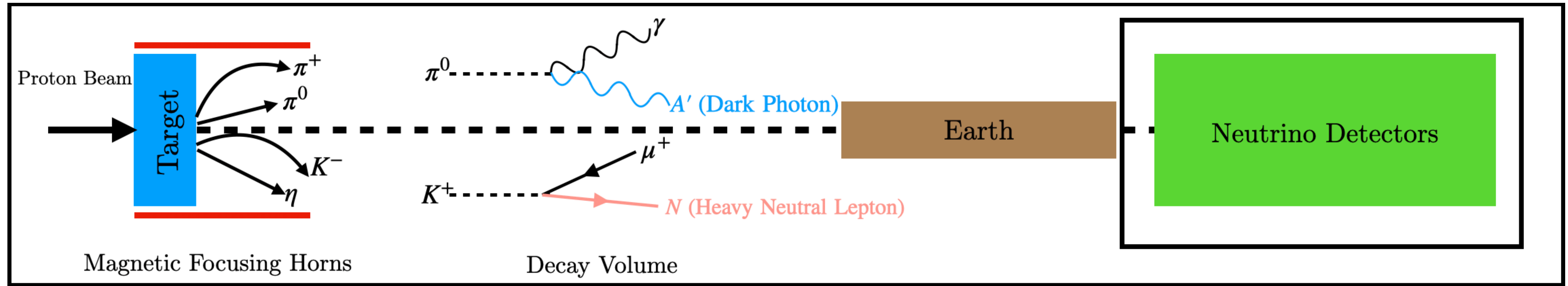


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Next-Generation Prospects

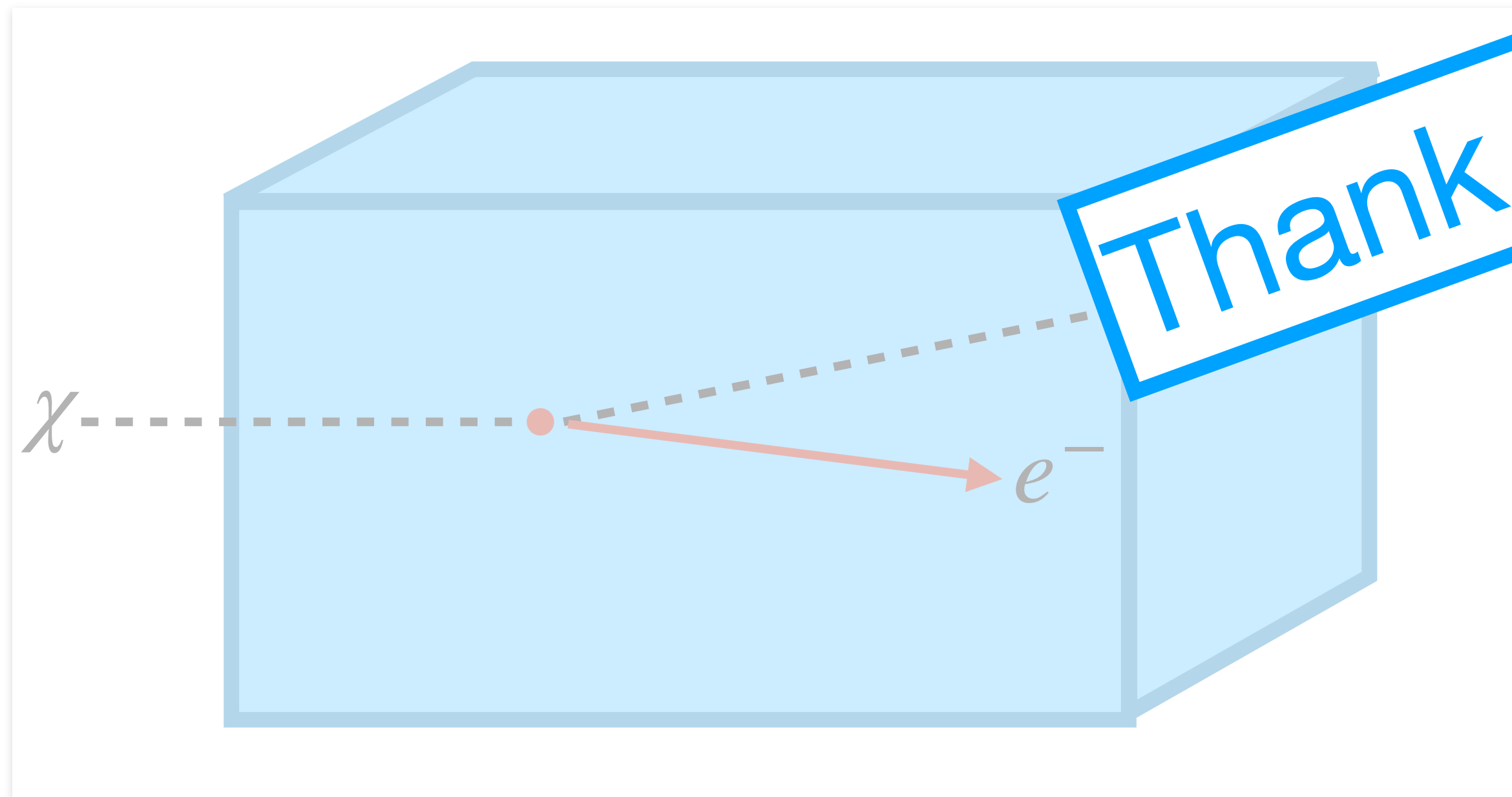
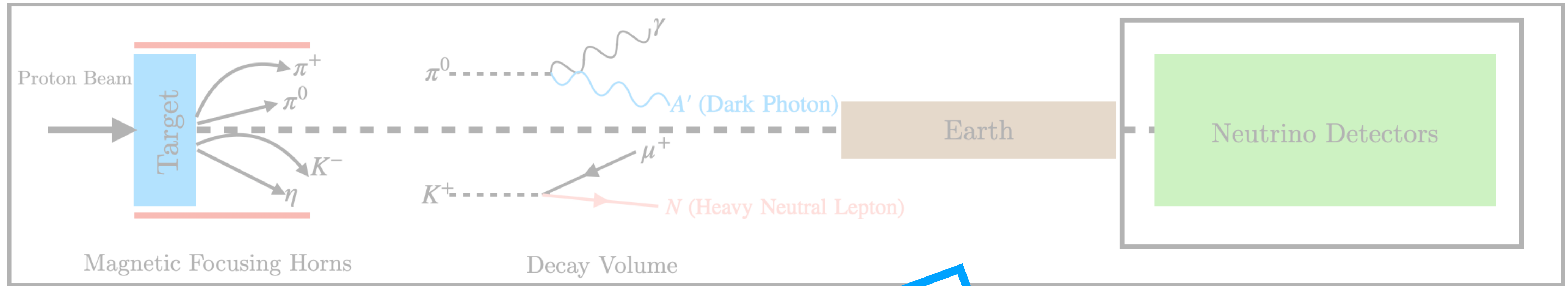


Takeaways

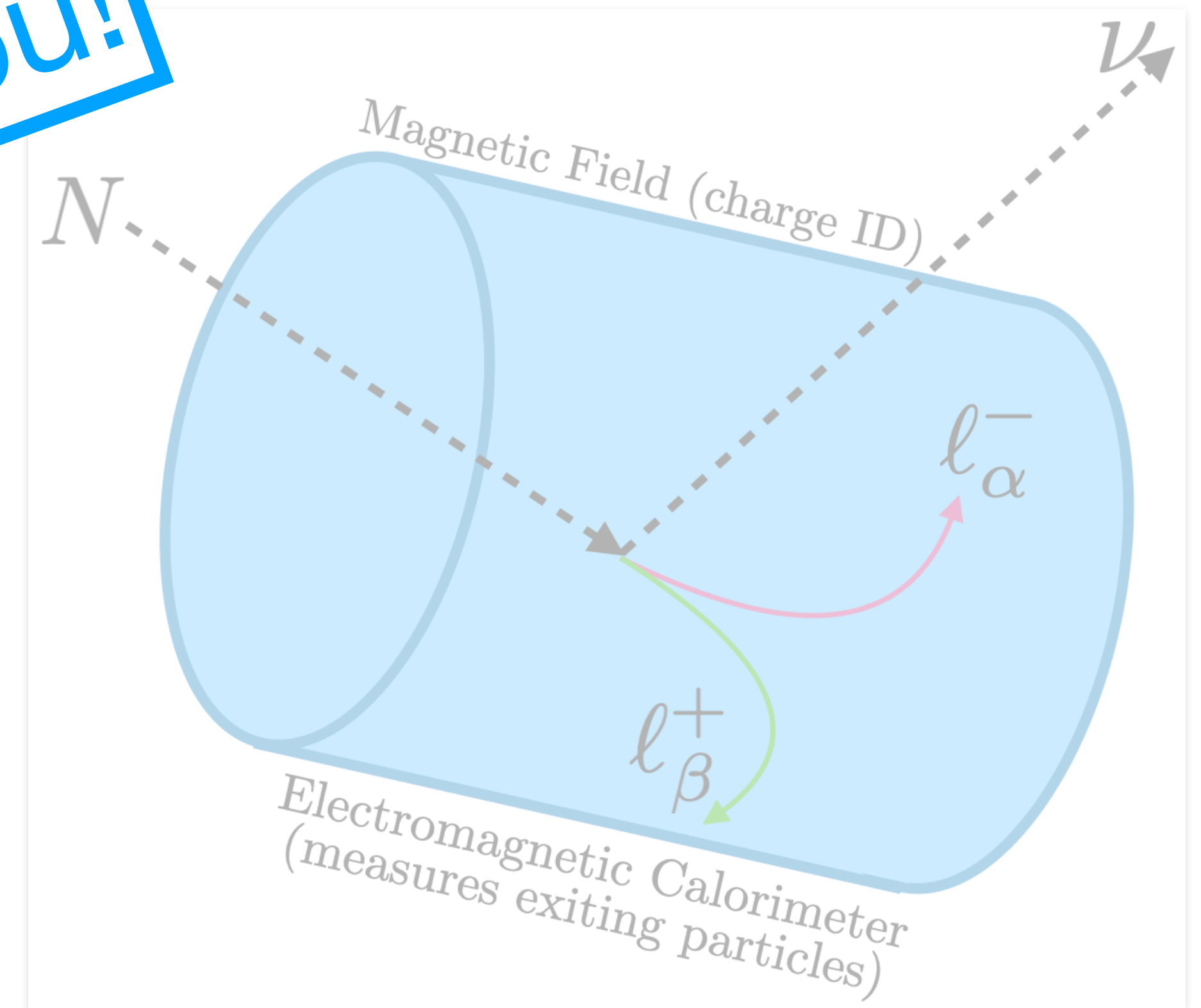


- Neutrino facilities can search for a variety of dark sectors, often simultaneously with their neutrino “mission”

Takeaways



Thank you!



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