BSM searches in neutrino experiments

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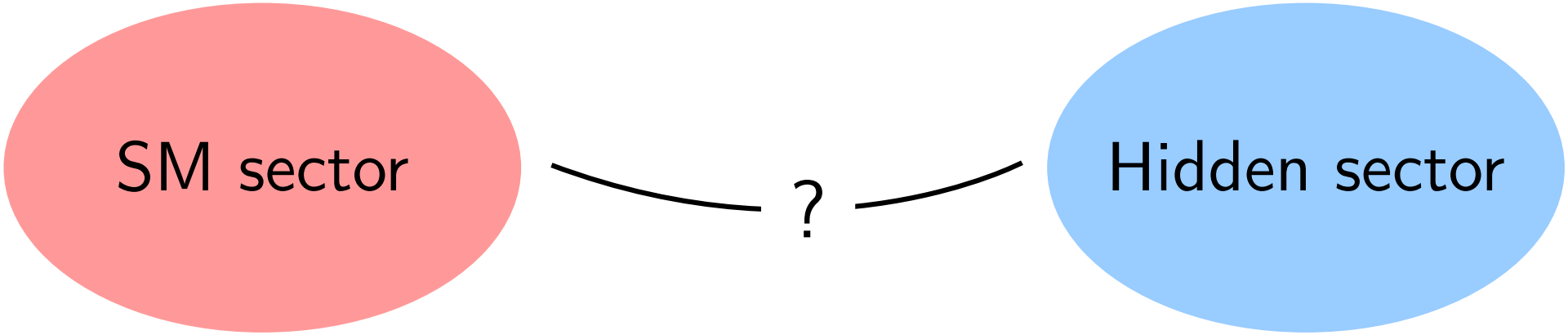
Where is the new physics?



Why neutrino experiments?

1) Underground massive detectors

2) Very powerful sources (reactors, conventional neutrino beams, spallation sources) with near detectors

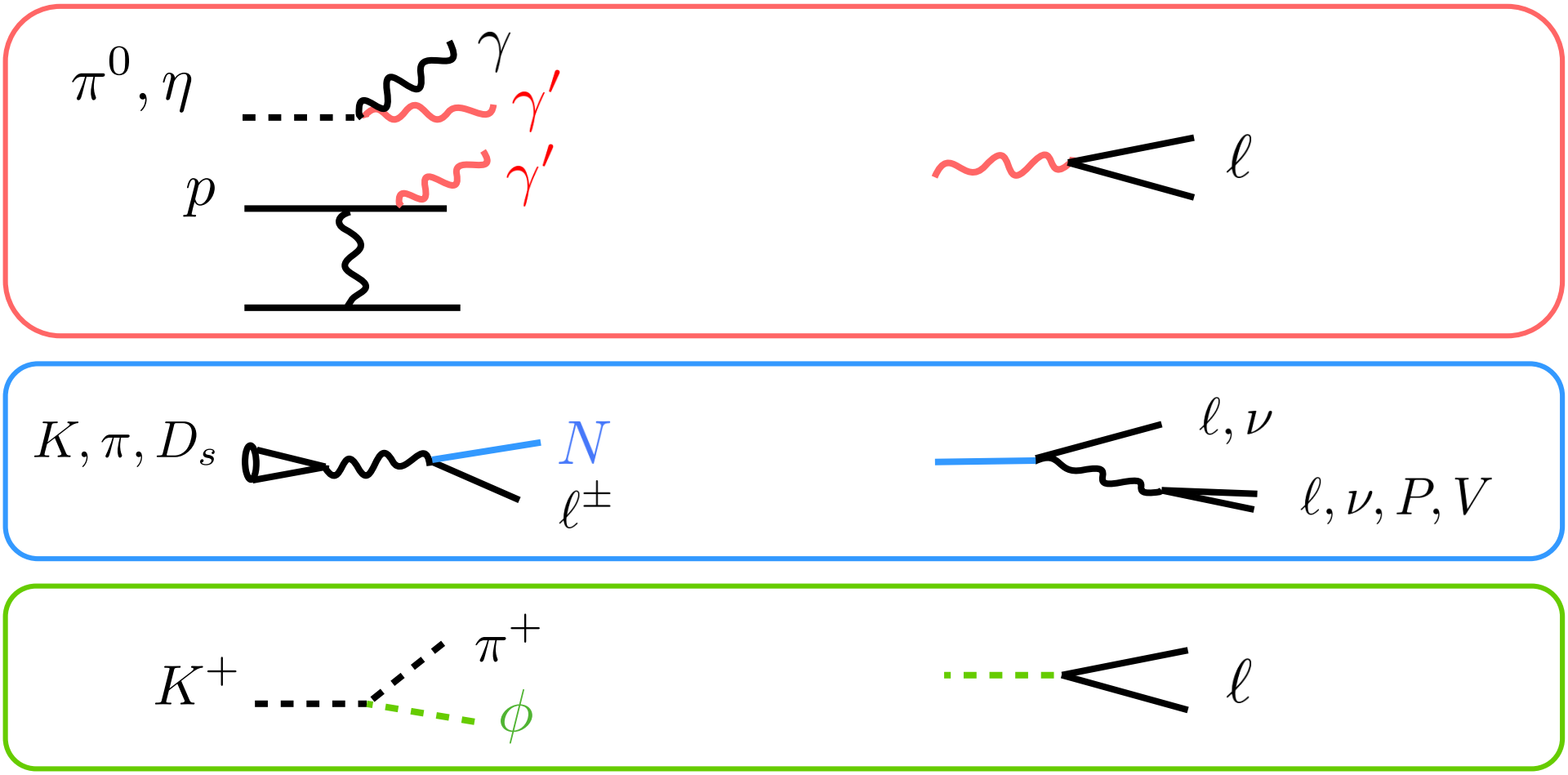
3) Neutrino oscillations: at short baselines, at very long baselines, at very different energies, in matter, in vacuum, ...

→ See talk by Ivan Esteban

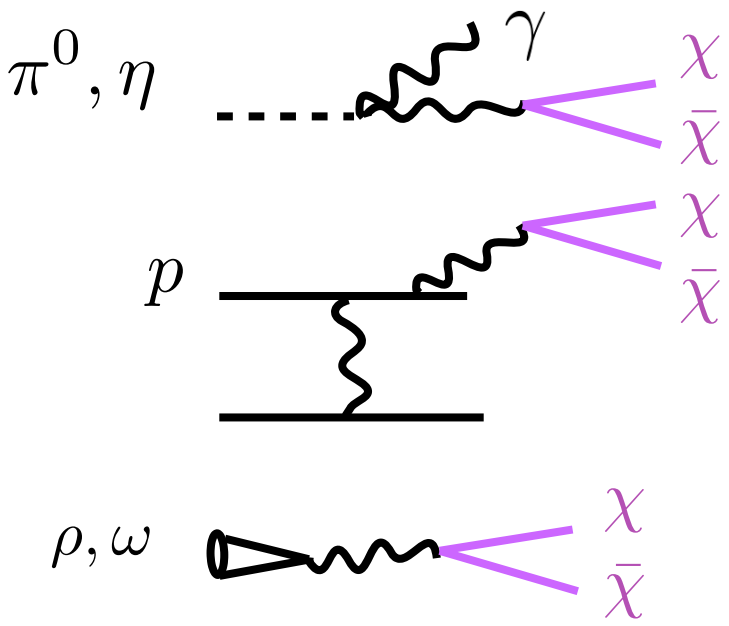
Disclaimer:

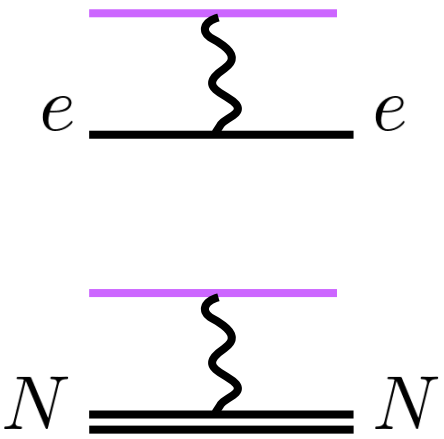
apologies if your favorite model of NP is not in this talk!

Unstable particles



Stable particles





(1) Massive Underground detectors

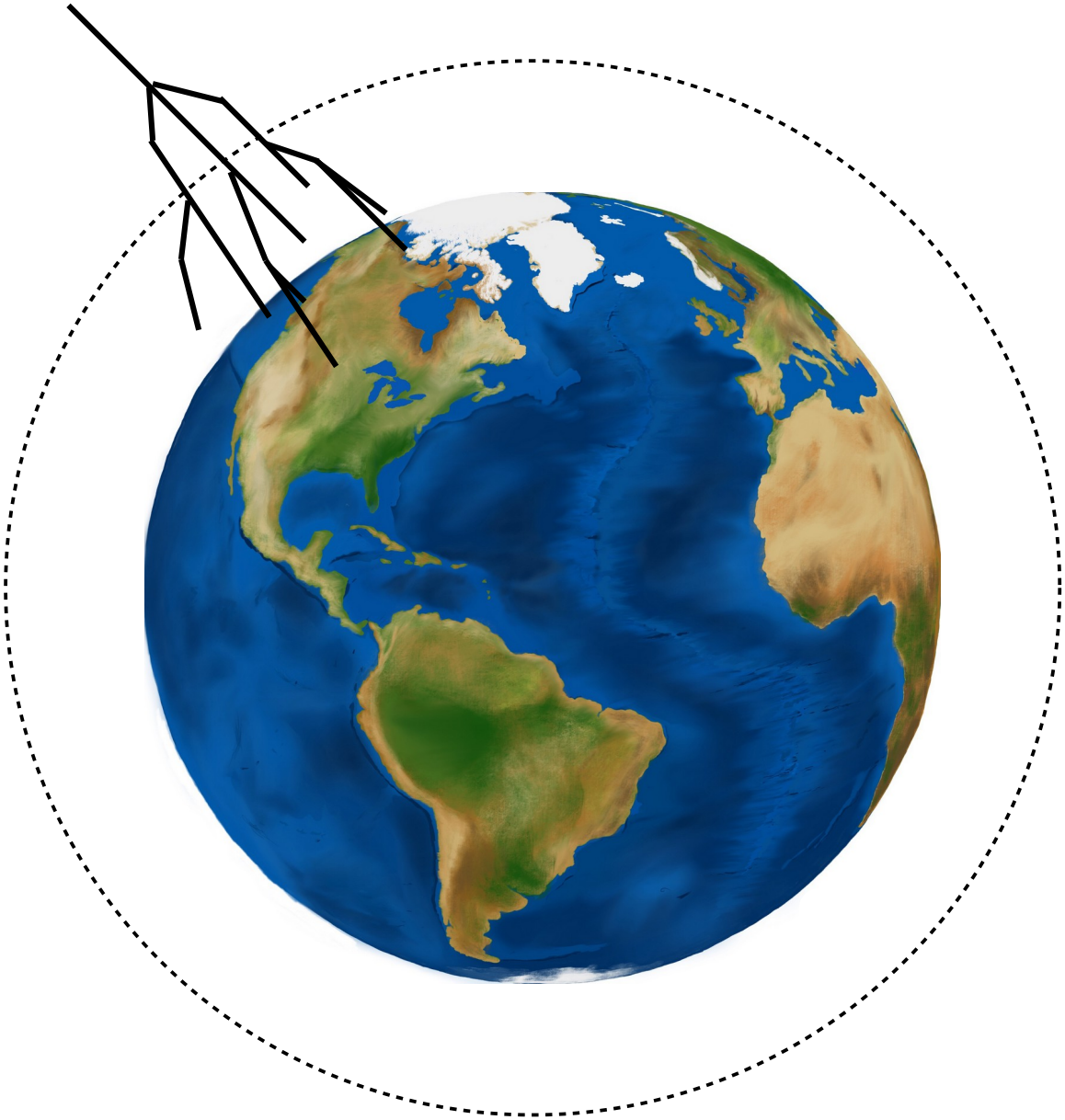


Image credit: https://mingtang.me/

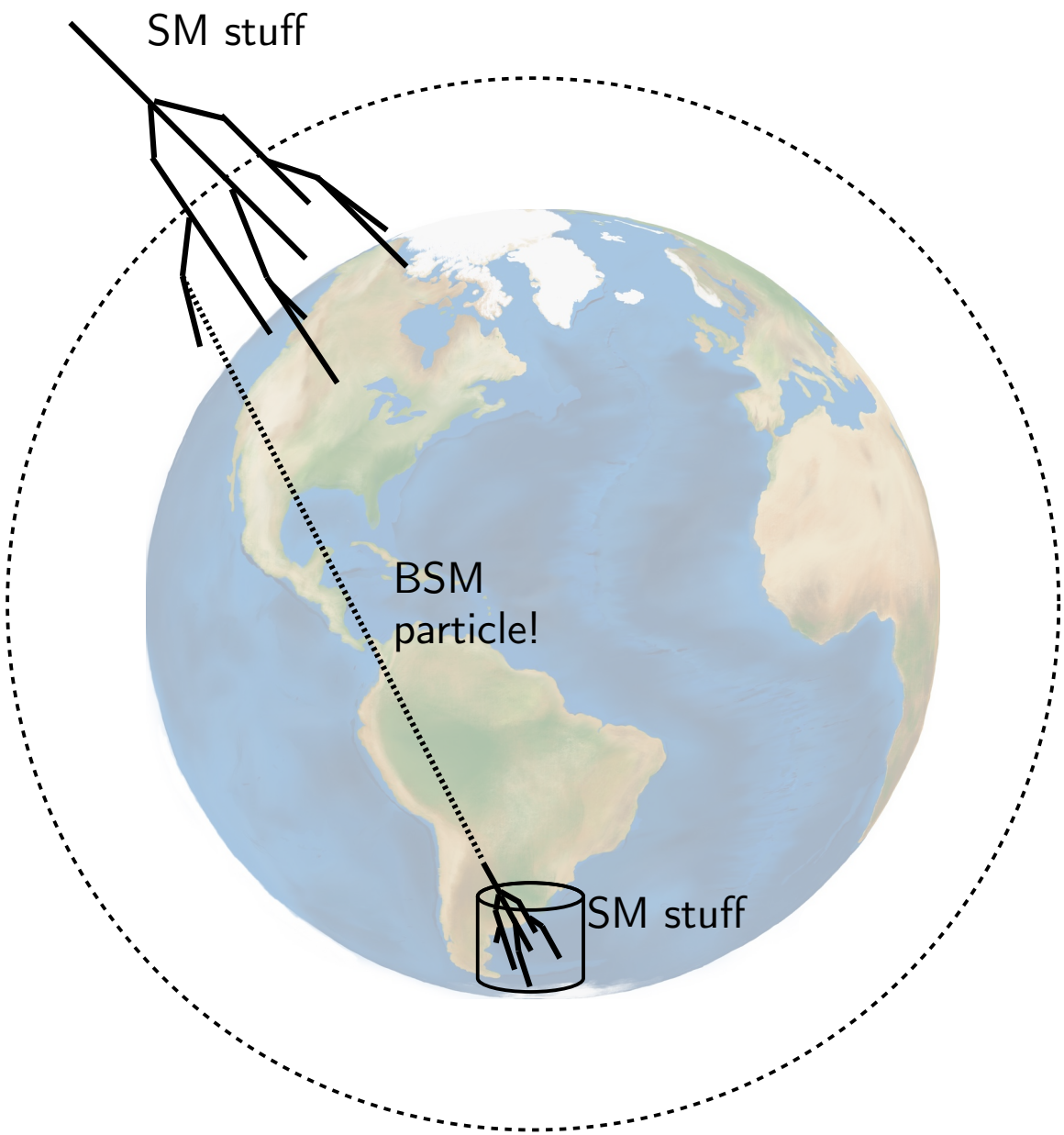
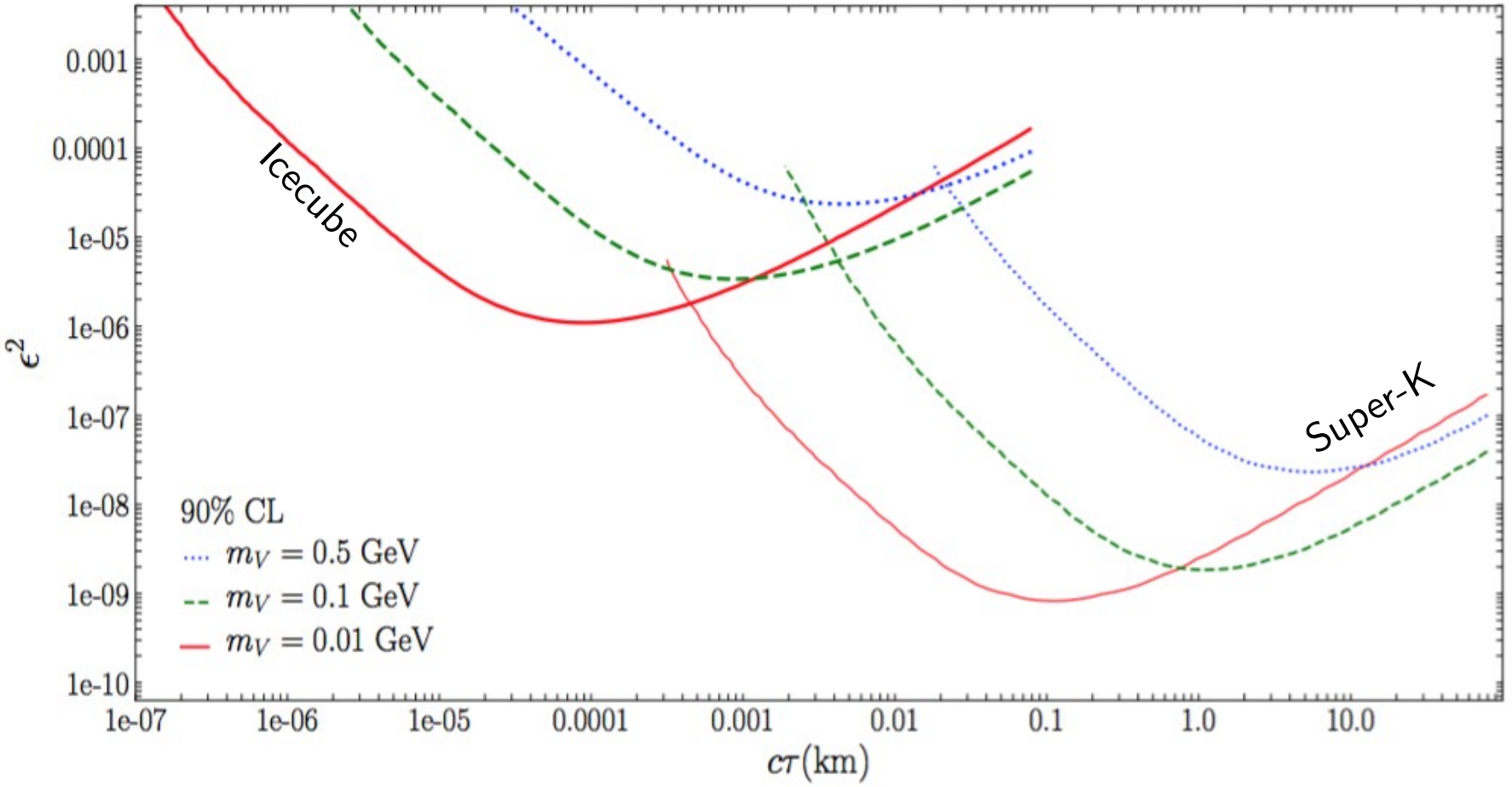


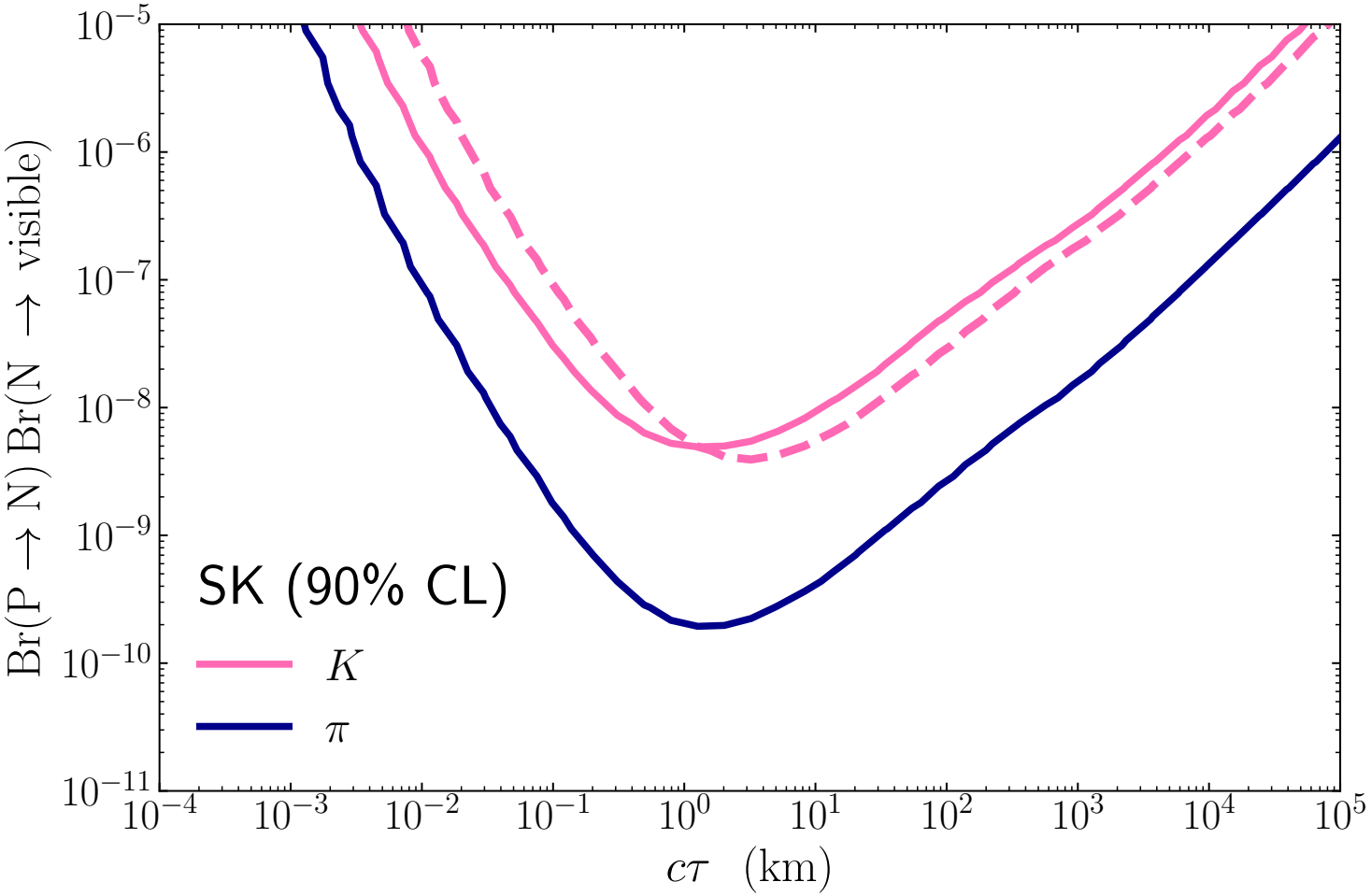
Image credit: https://mingtang.me/

Dark photons via kinetic mixing



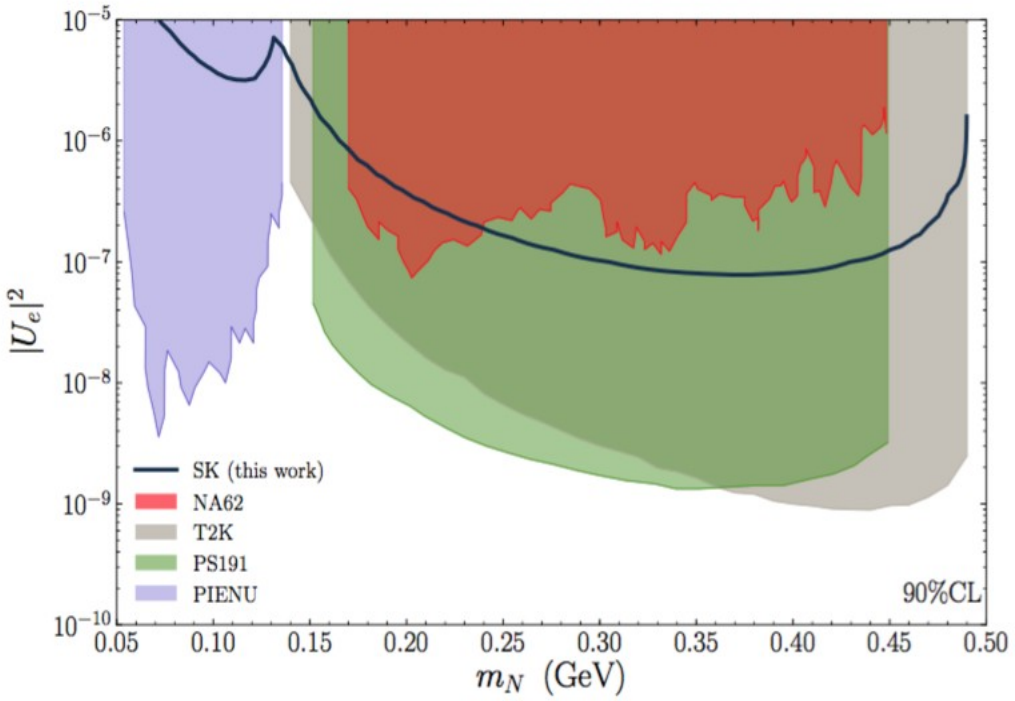
Argüelles, Coloma, Hernandez, Muñoz, 1910.12839

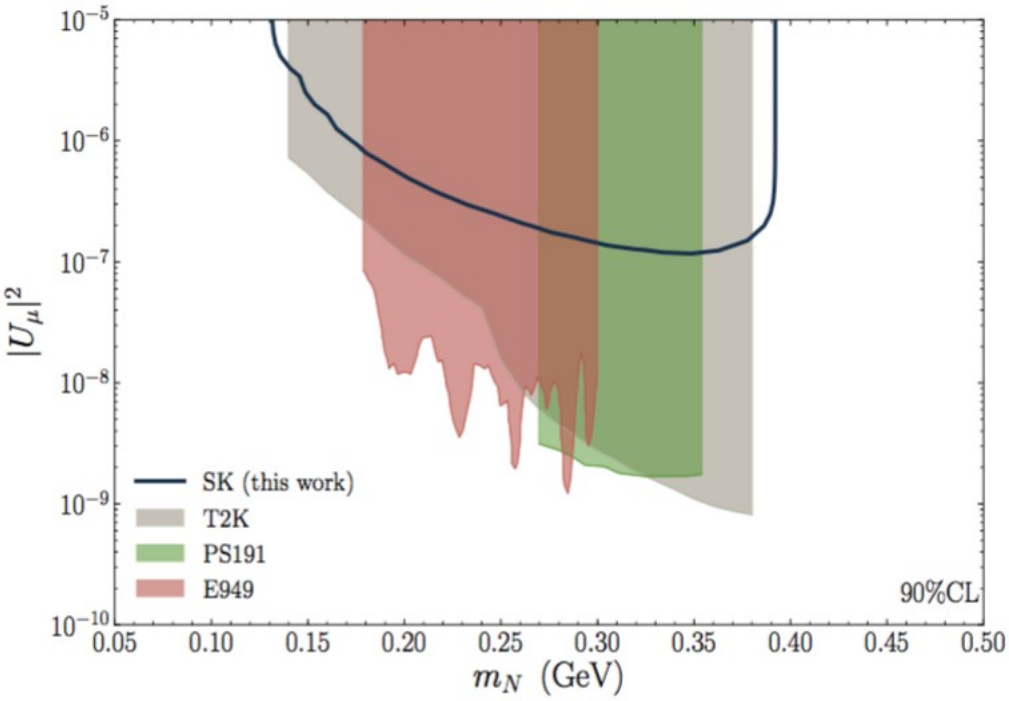
Heavy Neutral Leptons



Coloma, Hernandez, Muñoz, Shoemaker, 1911.09129

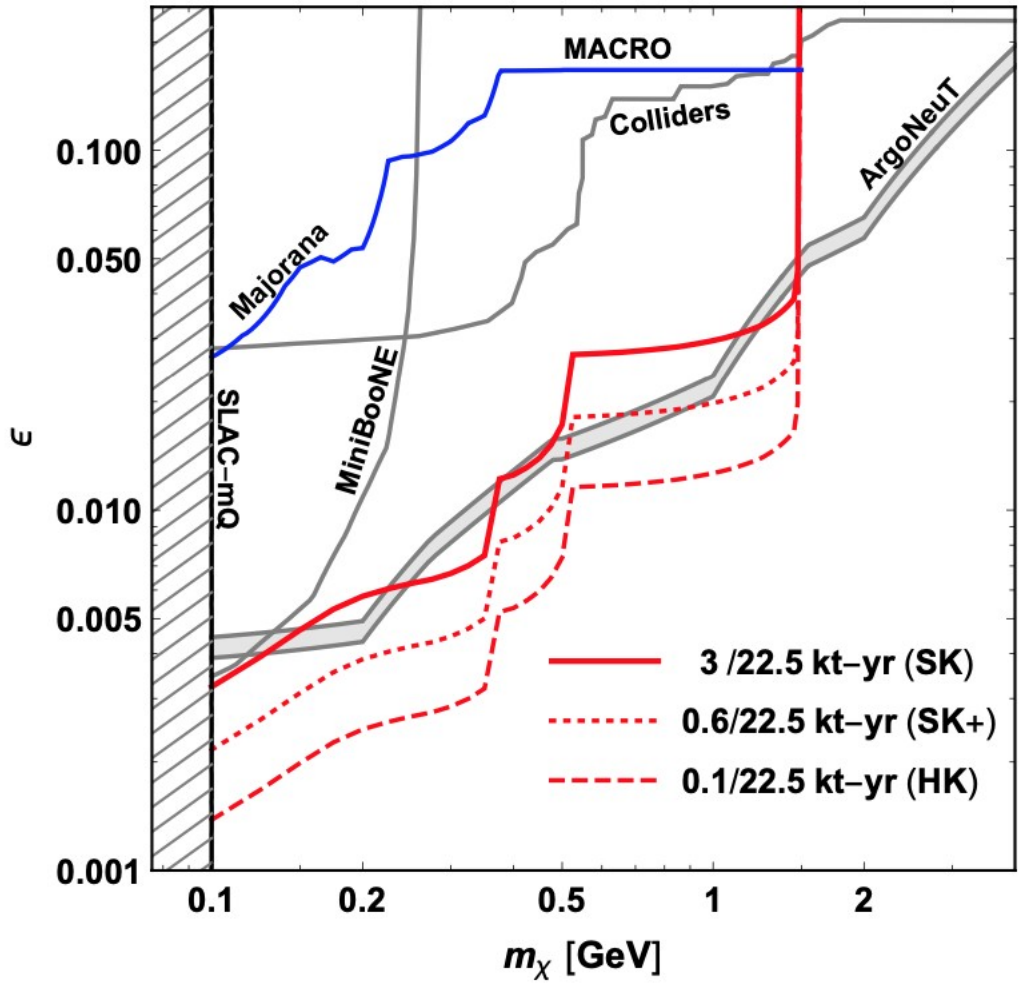
Heavy Neutral Leptons





Coloma, Hernandez, Muñoz, Shoemaker, 1911.09129
(see also Asaka and Watanabe, 1202.0725, Kusenko, Pascoli and Semikoz, hep-ph/0405198

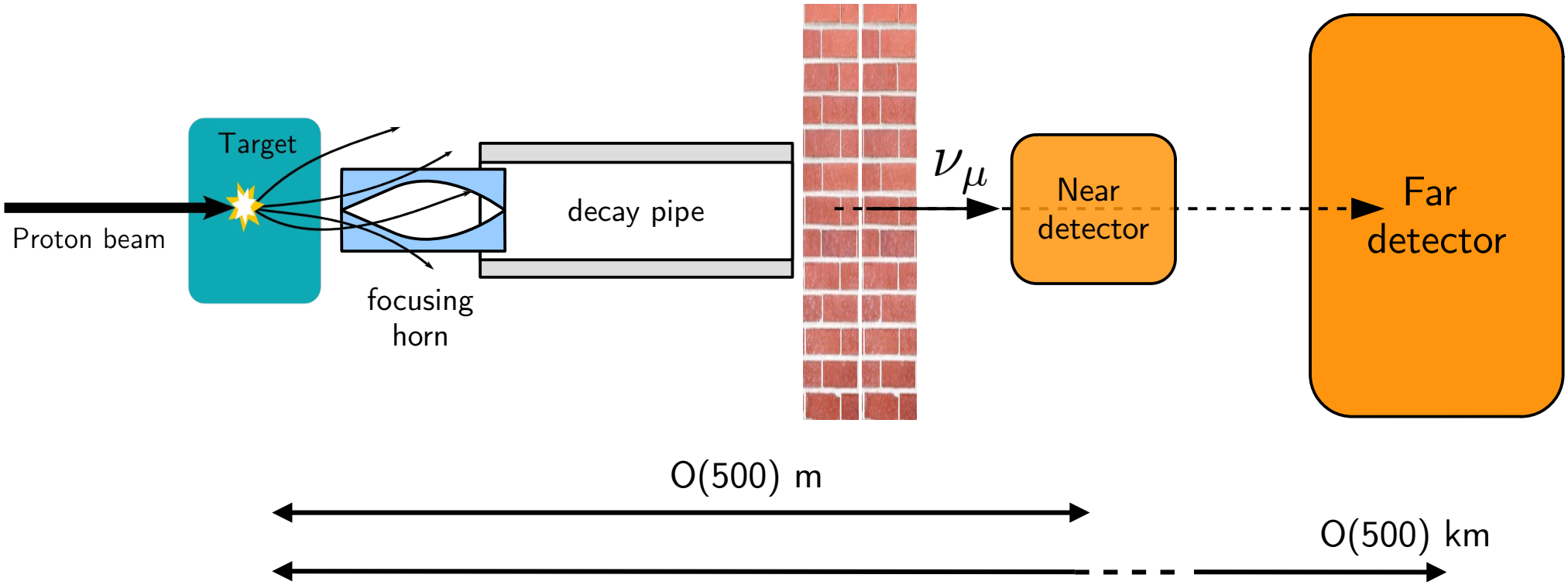
Milli-charged particles



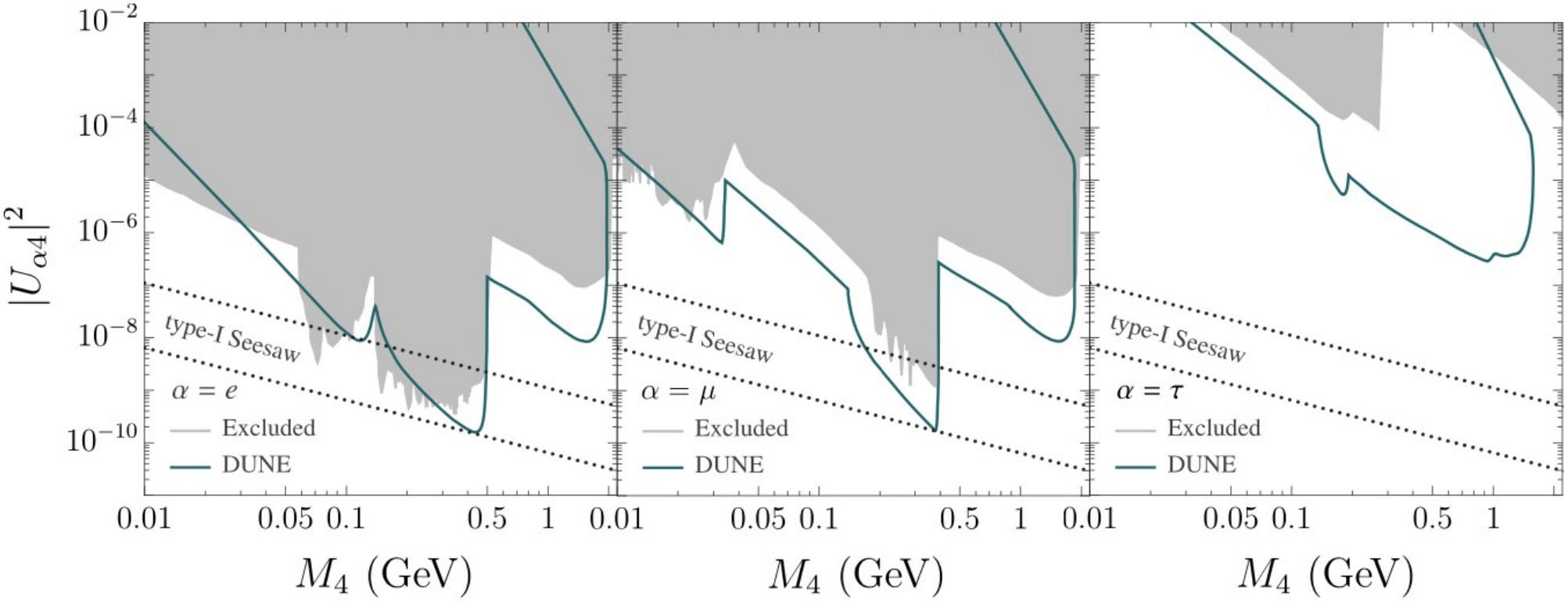
Plestid, Takhistov, Tsai et al, 2002.11732
See also Harnik, Plestid, Pospelov and Ramani, 2010.11190, and Kachelriess and Tjemsland, 2104.06811

(2) Neutrino beams as fixed target exps

Neutrino beams



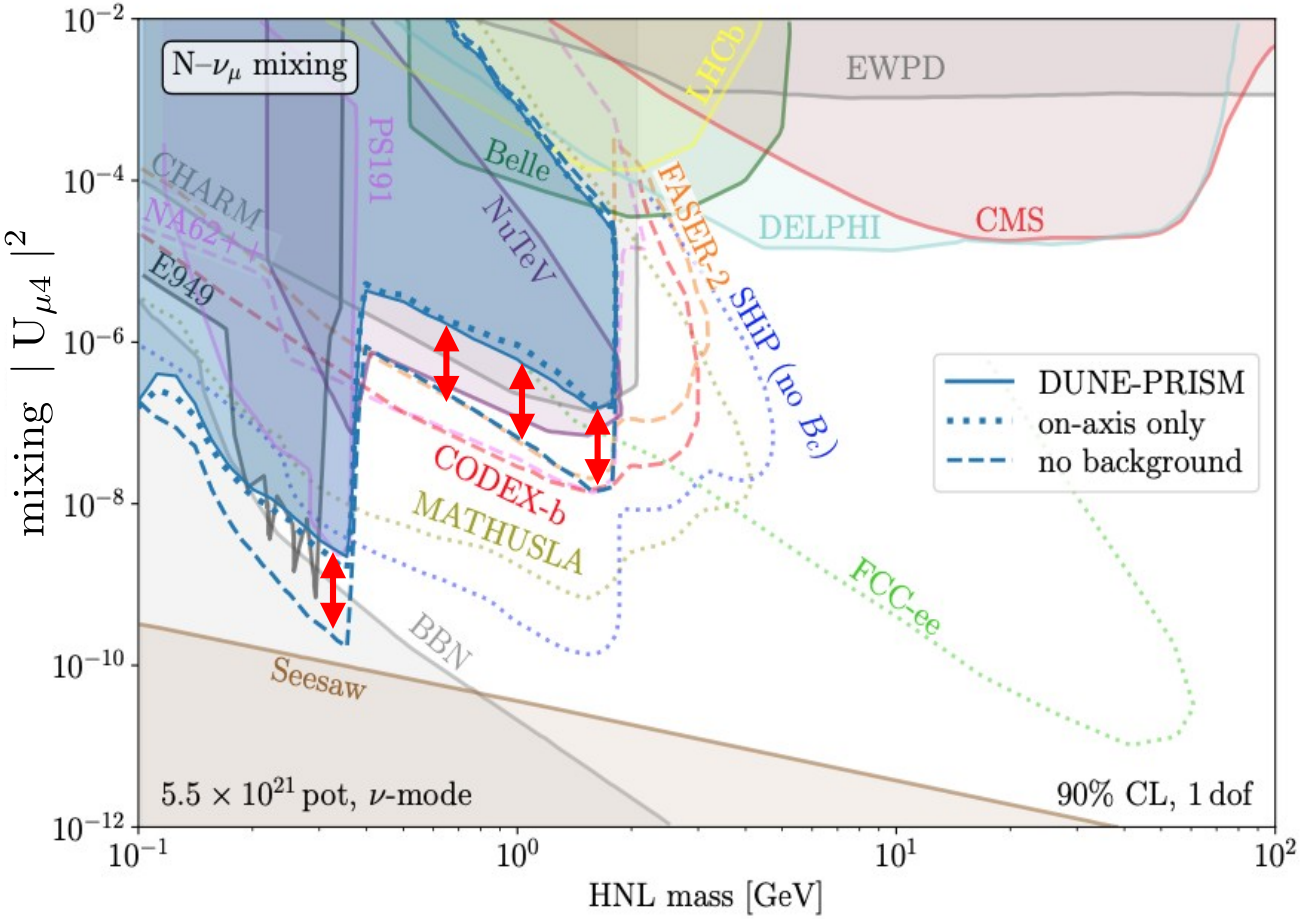
Signal looks great...



Coloma, Fernandez-Martinez, Gonzalez-Lopez, Hernandez-Garcia and Pavlovic, 2007.03701

(See also Bondarenko et al, 1805.08567, Krasnov, 1902.06099; Ballett, Boschi, Pascoli, 1905.00284; Berryman et al, 1912.07622; Breitbach et al, 2102.03383, ...)

...but what about backgrounds?

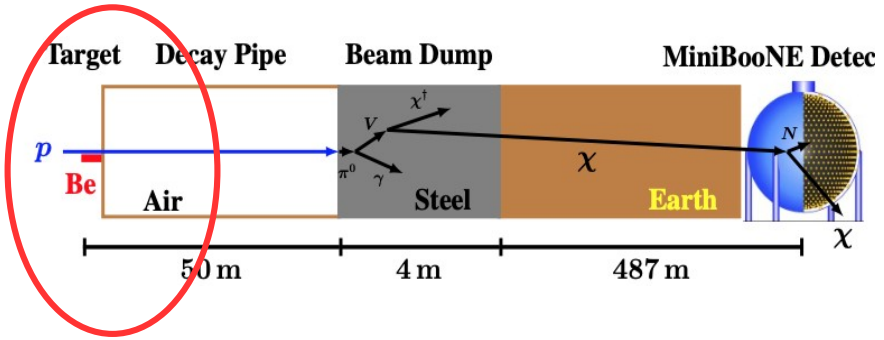


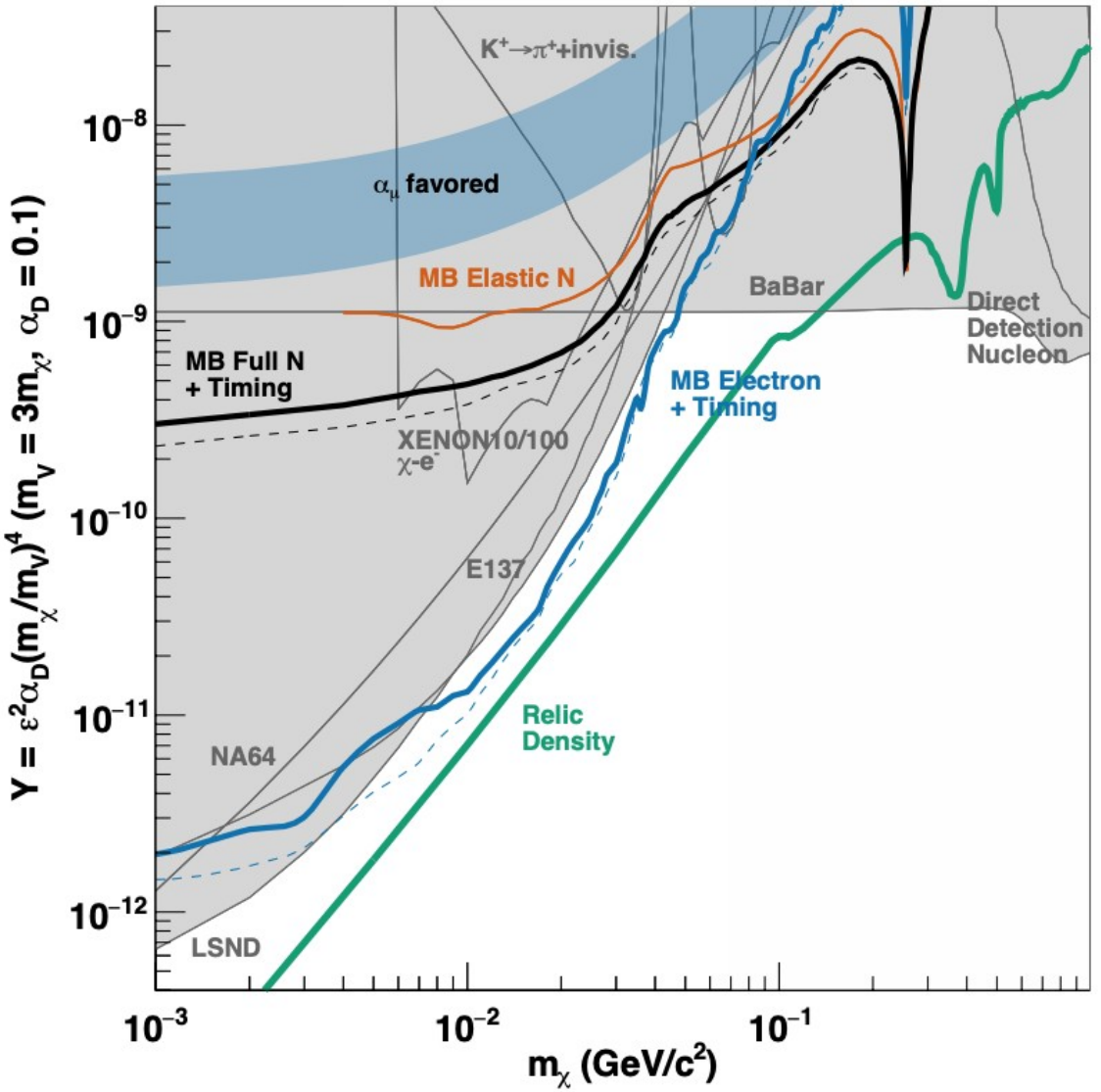
Breitbach, Buonocore, Frugiuele, Kopp and Mittnacht, 2102.03383

...but what about backgrounds?

- Possible handles include:
  - going off-axis
  - beam-dump mode
  - time of flight
  - empty decay volume detectors
  - reconstruct event tracks, particle identification for decay products
  - apply clever geometric cuts

Dark matter production

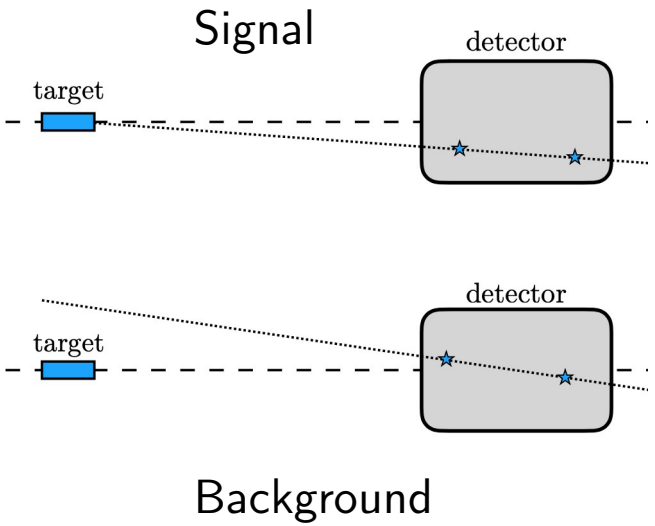


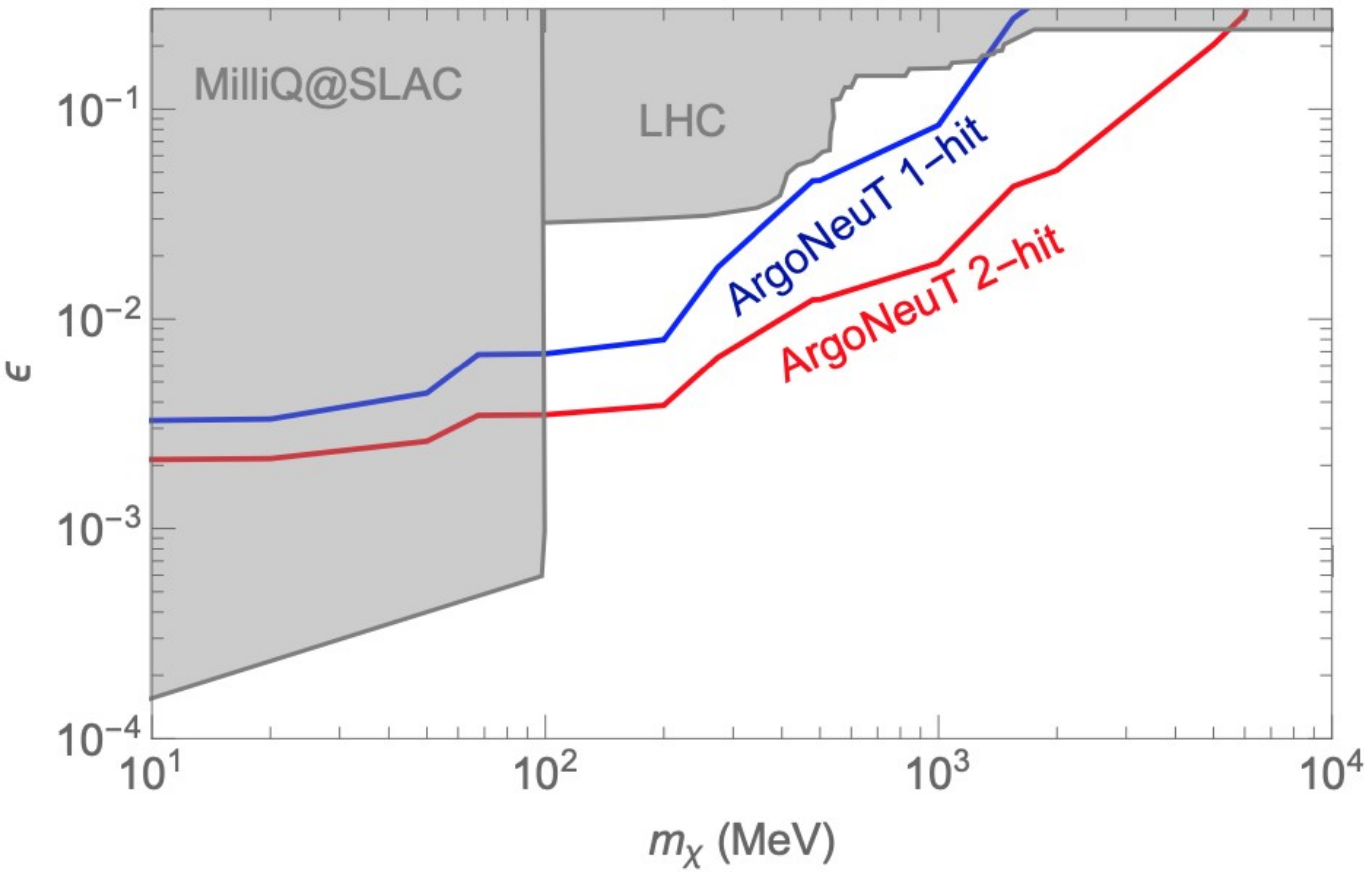


MiniBooNE coll., 1807.06137 and 1702.02688

See also e.g. Batell, Pospelov and Ritz, 0906.5614; Batell, deNIverville, McKeen, Pospelov, Ritz, 1405.7049

Milli-charged particles

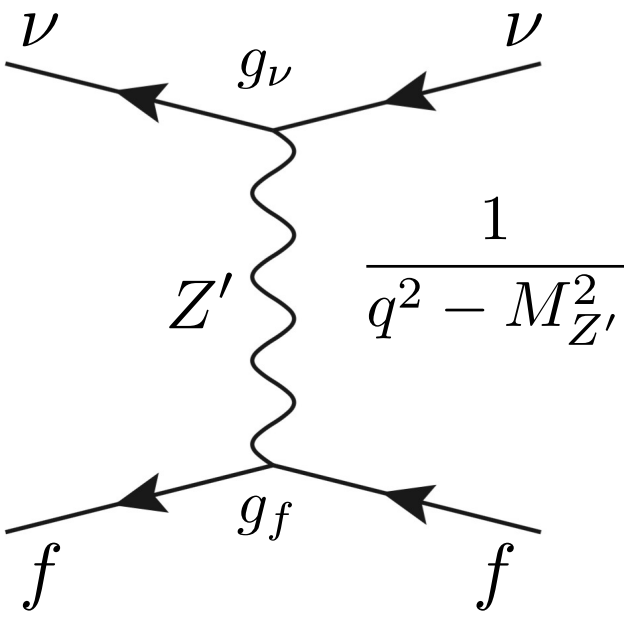




Harnik, Liu, Palamara, 1902.03246
For the limit from the Argoneut coll., see 1911.07996
(see also, e.g., McGill, Plestid, Pospelov, Tsai, 1806.03310)

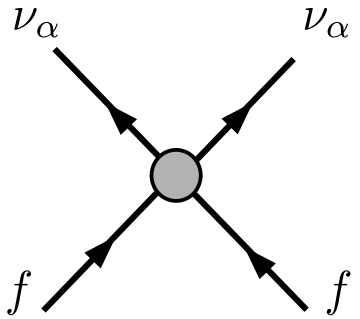
(3) Neutrino Oscillations

Oscillations vs scattering



$q^2 \ll M_{Z'}^2$

$\propto \frac{g_f g_\nu}{M_{Z'}^2}$

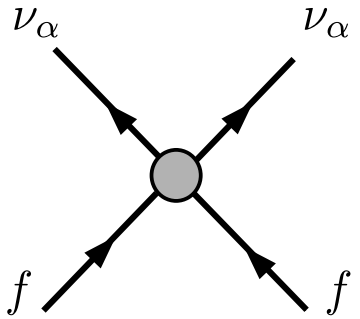


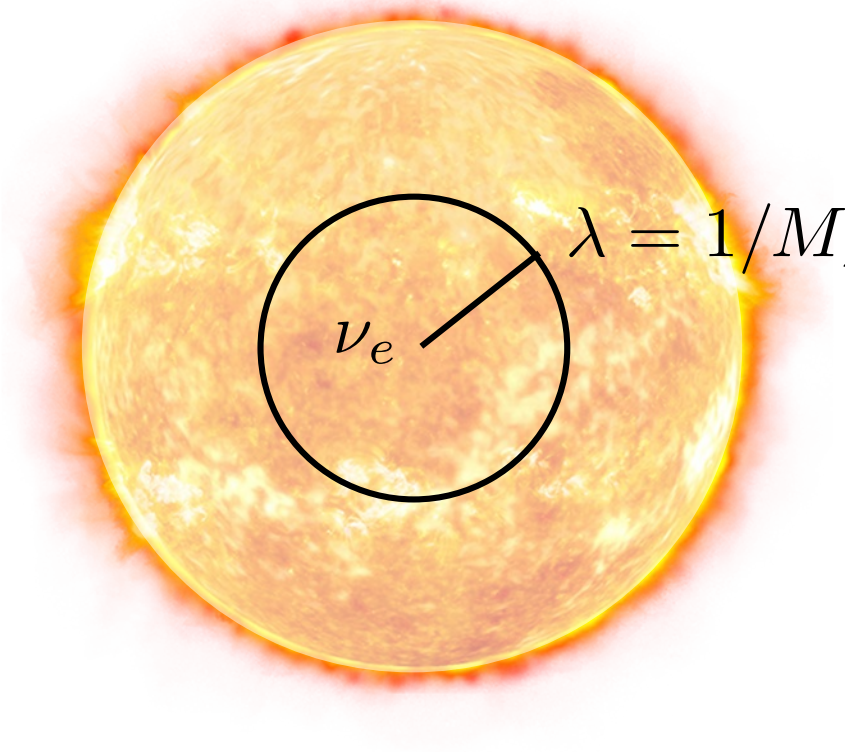
$q^2 \gg M_{Z'}^2$

$\propto \frac{g_f g_\nu}{q^2}$

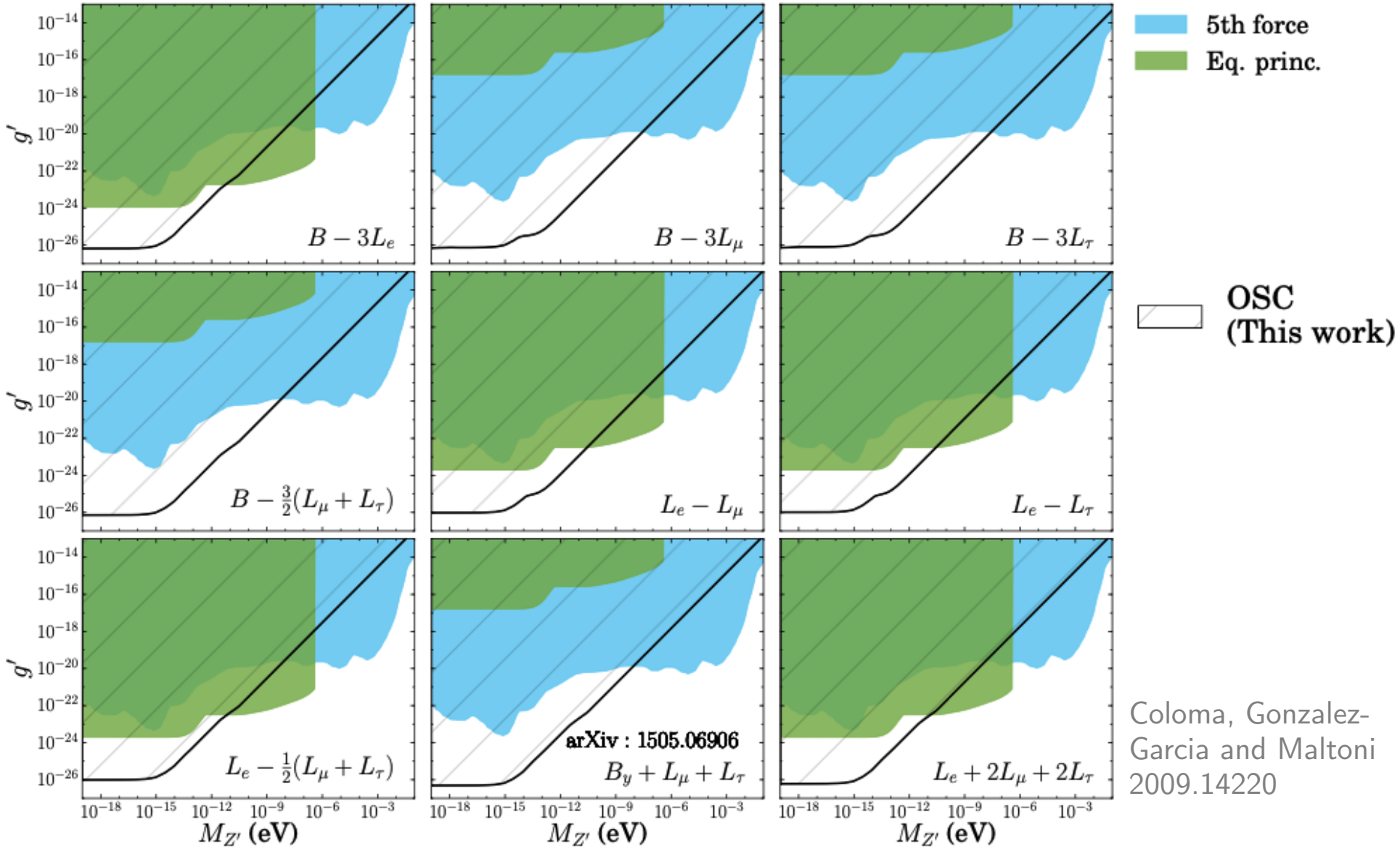
Long-range forces

$$\propto \frac{g_f g_\nu}{M_{Z'}^2}$$





Long-range forces



Coloma, Gonzalez-Garcia and Maltoni 2009.14220

Summary and conclusions

- Neutrino experiments have a great potential to constrain new particles weakly coupled to the SM
- Where/how?
  - Atmospheric production of new particles
  - Fixed target searches using near detectors
  - Precision tests of the three-neutrino oscillation picture

$\rightarrow$ Other scenarios not discussed here include: sterile neutrino oscillations, neutrino decoherence, CPT violation, neutrino decay, axion-like particles, dark matter interactions with neutrinos...

Thank you!!