Neutrino-nucleus interactions

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Something about me

(Rome, 2010)

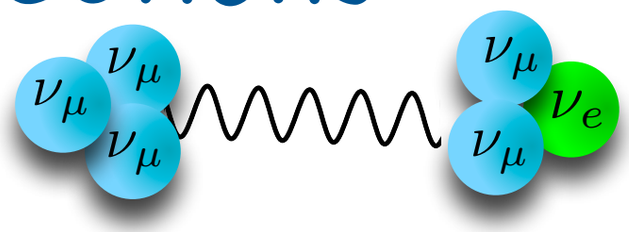
- I grew up in Terni, a small city in Italy ~100 km North of Rome
- In October 2008, I started my Physics studies at "La Sapienza University of Rome". I obtained my Bachelor (left picture) and my Master degree there
- In 2012, I started my PhD focusing on Neutrino Physics

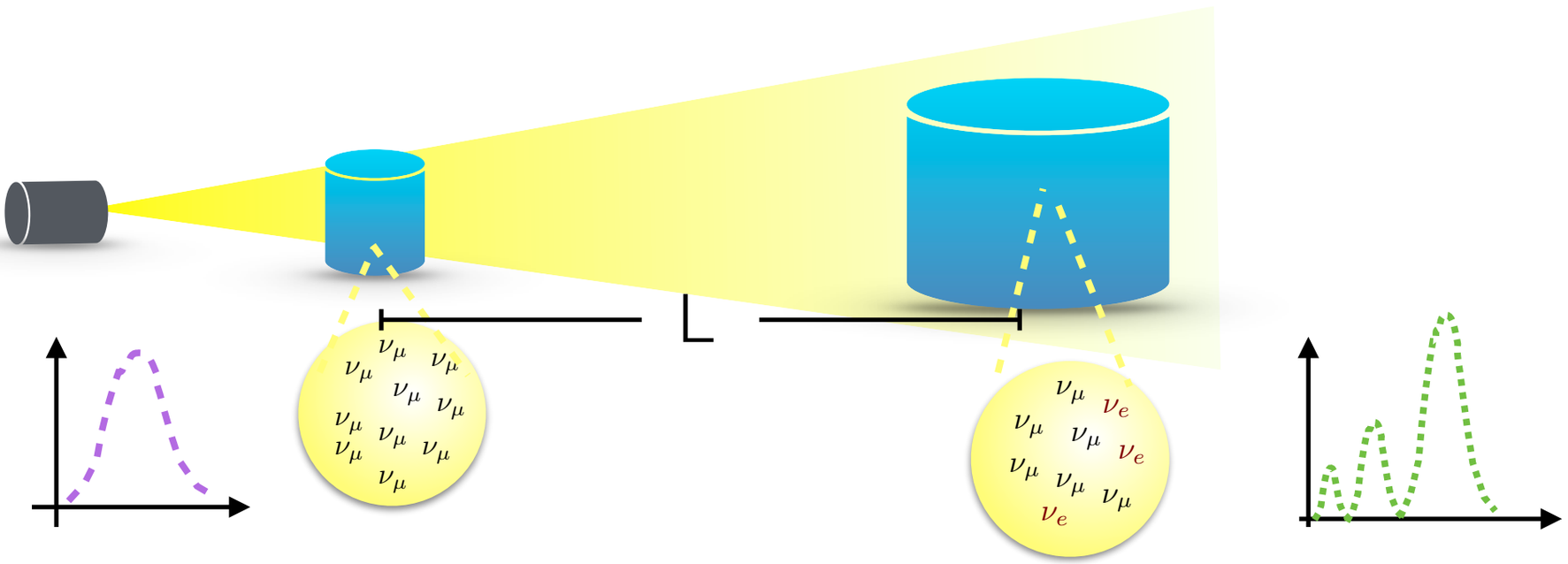
(Fermilab, 2019)

- Between 2016 to 2018 I have been traveling a lot: Canada (Triumf), Spain (IFIC), and UK (U Surrey)
- In 2018 I moved to Chicago and started working in the Theory Group at Fermilab.
- In September 2025 I joined UV

Neutrino Oscillations and cross sections

$$P_{\nu_\mu \to \nu_e}(E, L) \sim \sin^2 2\theta \sin^2 \left(\frac{\Delta m^2 L}{4E} \right) \to \Phi_e(E, L)/\Phi_\mu(E, 0)$$





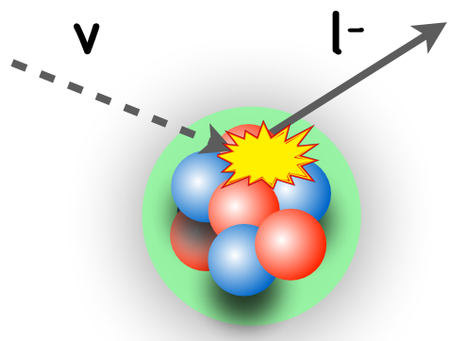
Detectors measure the **neutrino interaction rate:**

$$N_e(E_{\text{rec}}, L) \propto \sum_i \Phi_e(E, L)\sigma_i(E) f_{\sigma_i}(E, E_{\text{rec}}) dE$$

Reconstructed ν energy

Cross Section

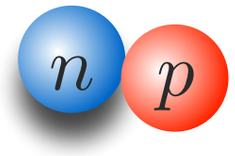
Smearing matrix



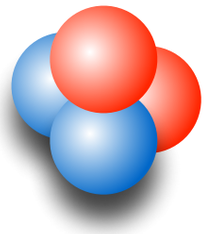
A precise determination of σ(E) is crucial to extract ν oscillation parameters

How do we describe a nucleus

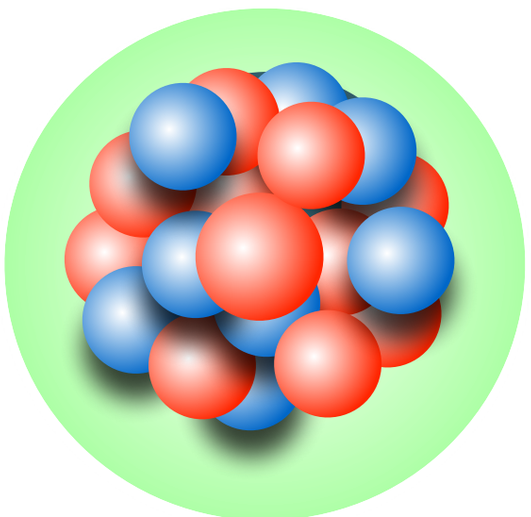
We start from the interaction between a proton and a neutron



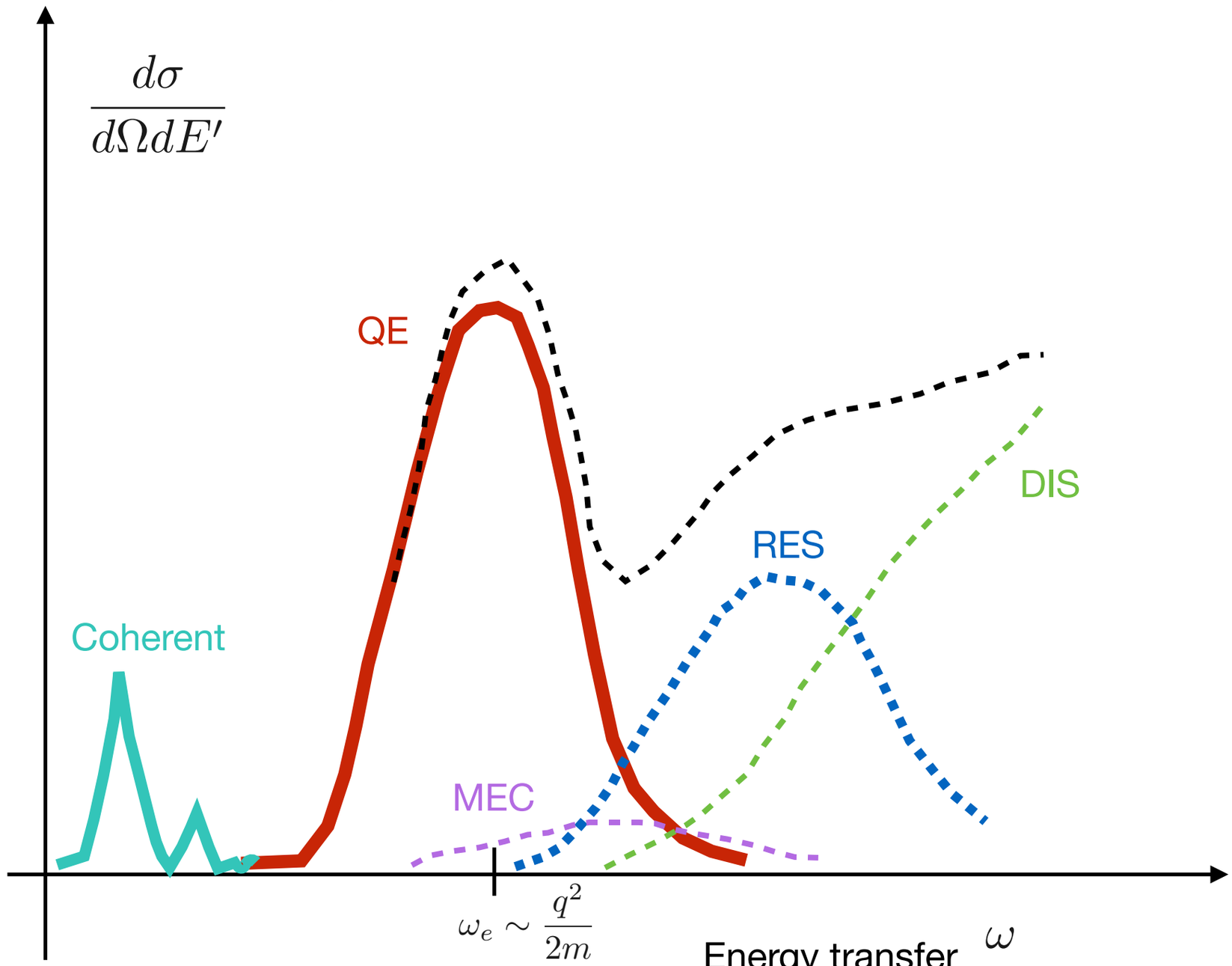
We iterate to obtain more complex structures



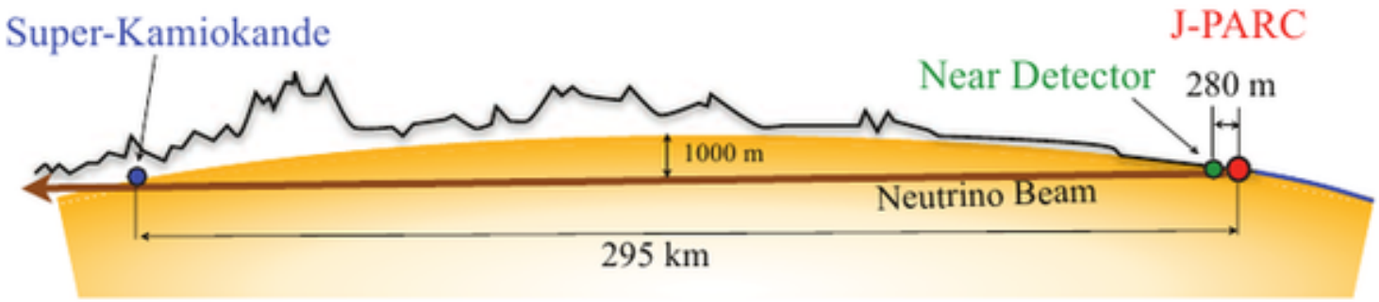
Nuclear properties are self-emerging

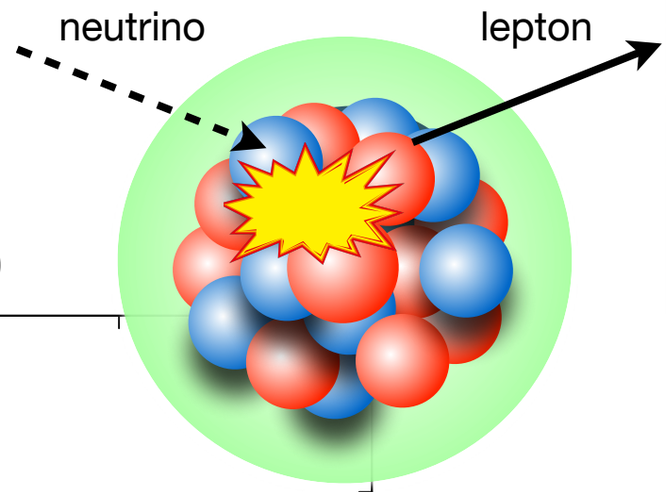


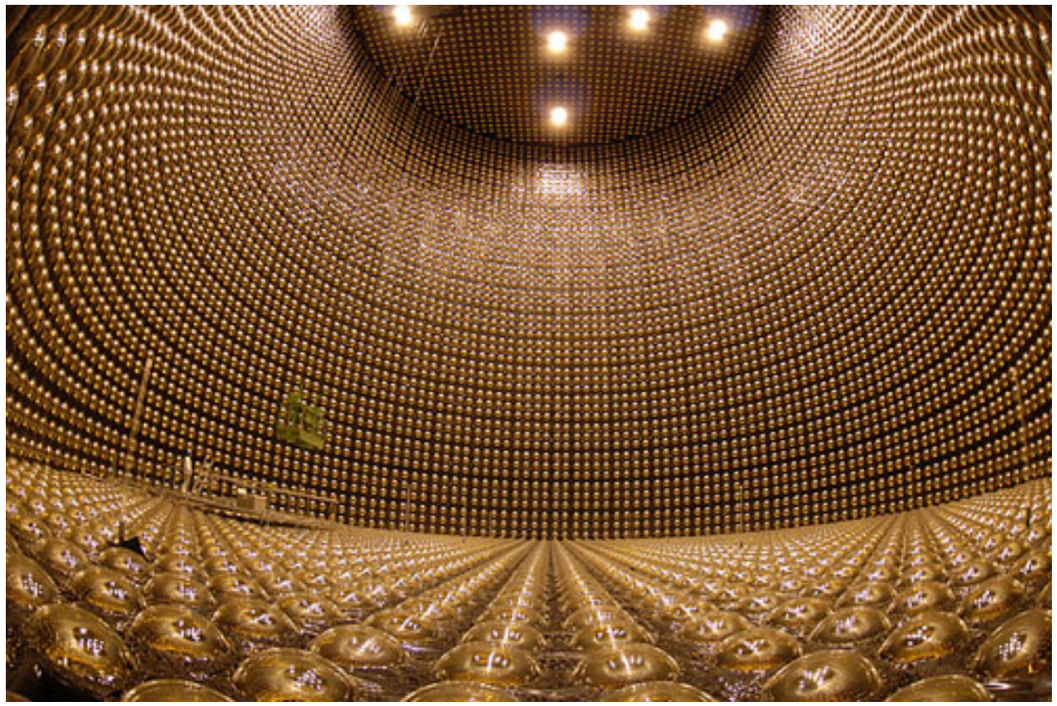
Different reaction mechanisms contributing to lepton-nucleus cross section

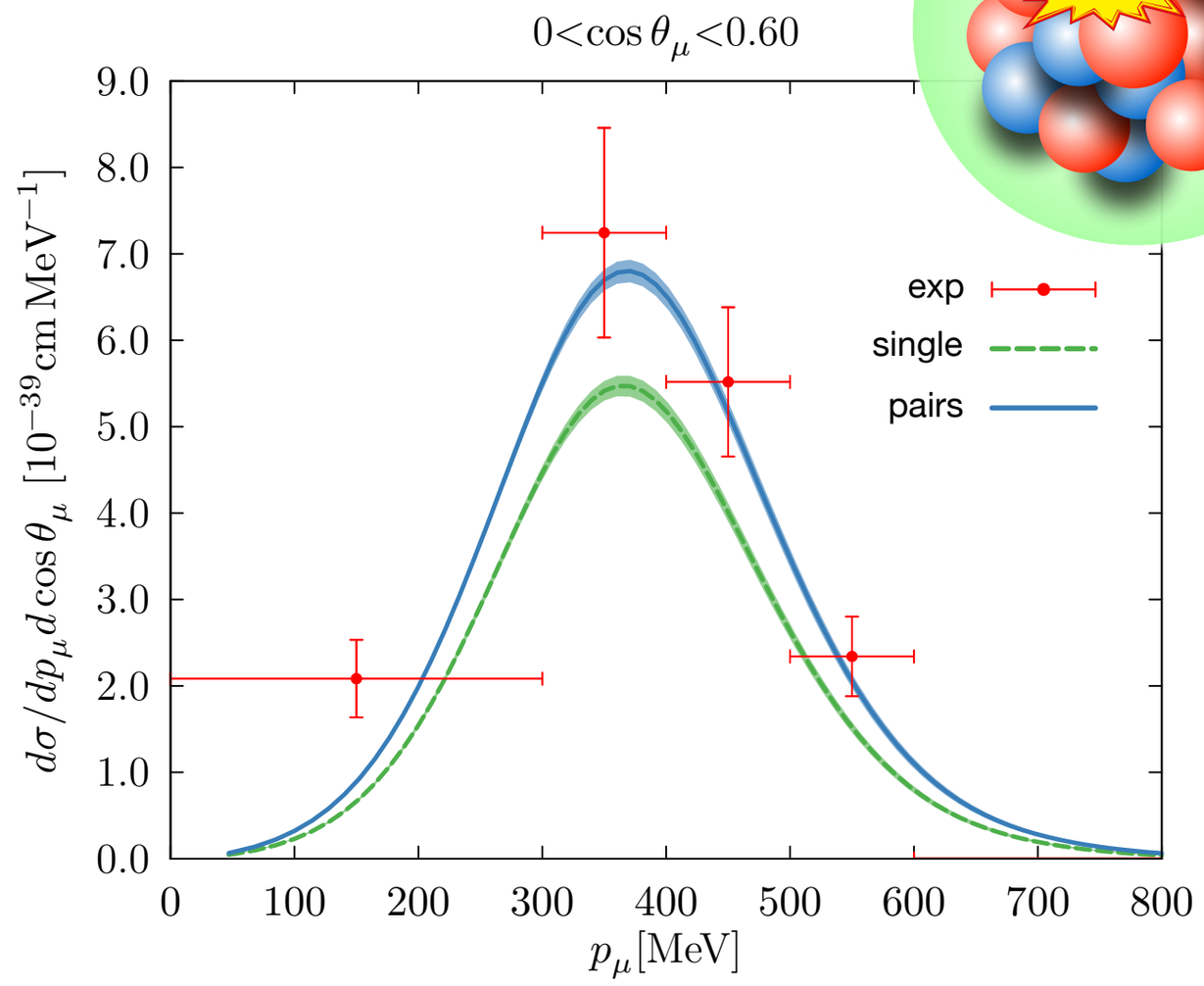


A closer look to our Results





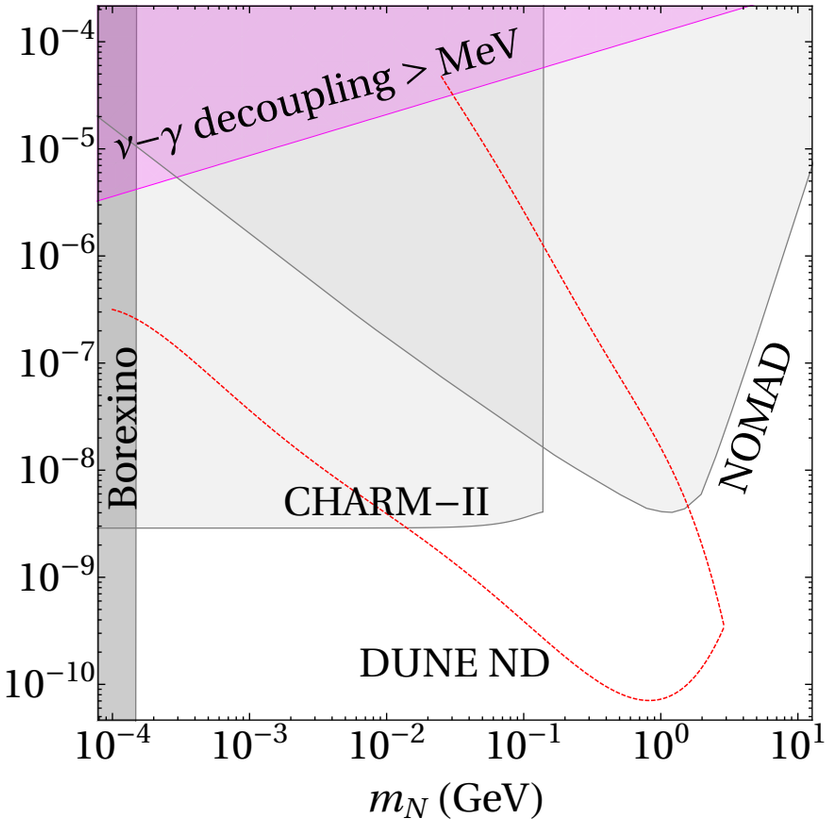


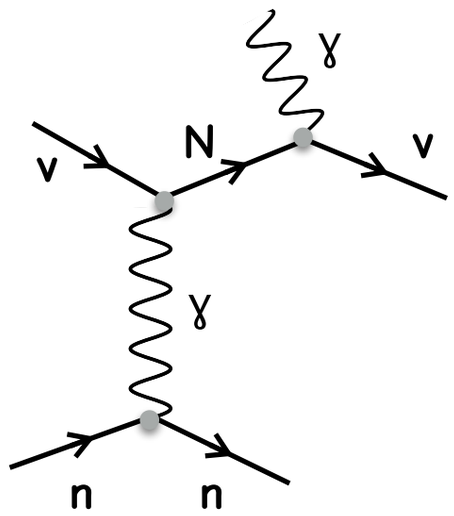


Super-Kamiokande Detector: 50 kton water, ~11000 photomultiplier tubes (PMT) placed 1000 m underground

Our results for the T2K experiment. **We compared theoretical calculations with experimental data** of neutrino interactions with nuclei in the SK detector

Interplay with BSM scenarios

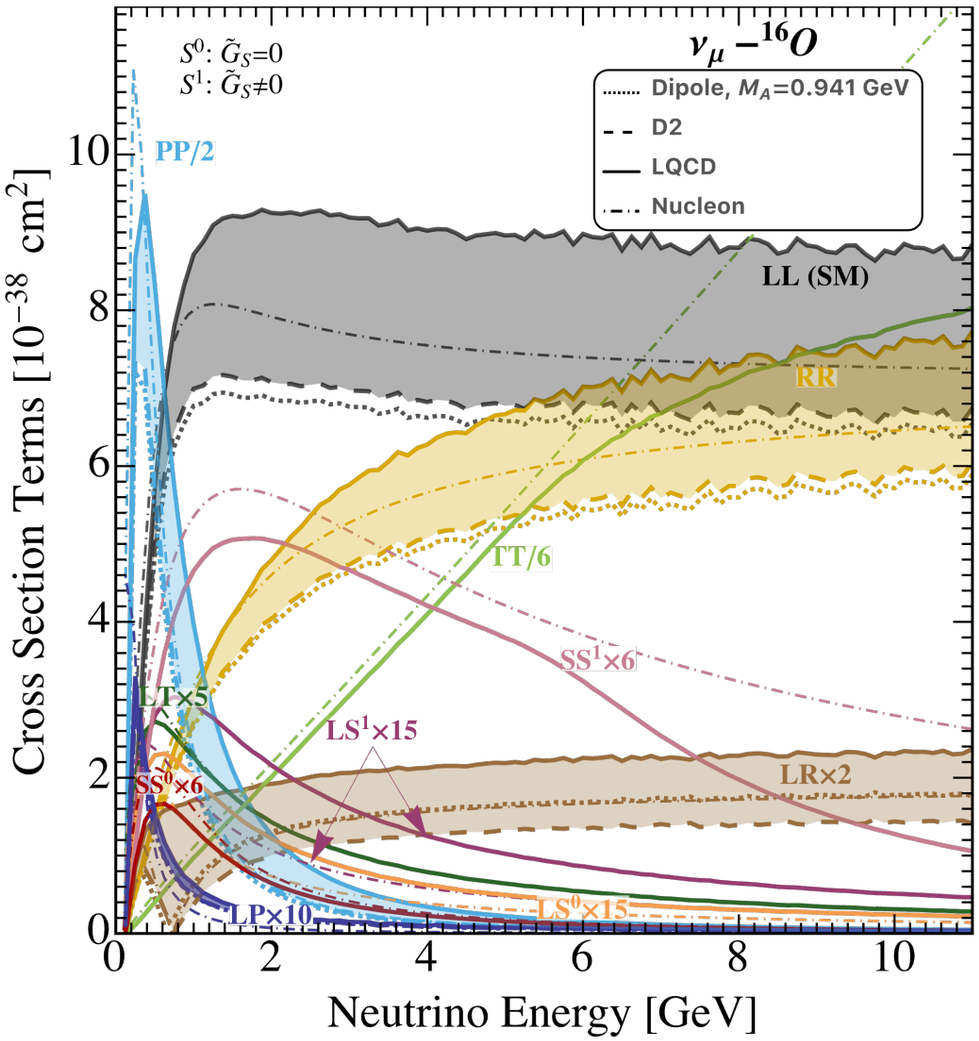




Expected sensitivity to the transition magnetic moment νμ – N from DBs signals in the DUNE LAr near detector

M.Atkinson, P. Coloma, I. Martinez-Soler, NR, I Shoemaker, JHEP 04 (2022) 174

Neutrino cross sections in the quasi elastic regime, for arbitrary Weak EFT interactions



Z. Tabrizi, J. Kopp, NR, JHEP 08 (2024) 187