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Neutrinos, Nuclei and SHERPA

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About me

Introduction

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Research interests:

- ChiPT neutrino interactions via ACHILLES, which uses a UFO plugin for SHERPA
- Nuclear modelling techniques for SHERPA
- Theory of resonance vertex structures and form factors for higher spin particles (e.g. Delta-1232)
- Machine learning applications to dark jet searches
- Higgs decay to massive quarks via HEFT in SHERPA

Neutrinos

The motivations for studying them

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- Cool science
  - RH neutrinos
  - CP violation
  - Neutrino mass hierarchy

[1] NuSTEC white paper, 2018

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- Cool science
  - RH neutrinos
  - CP violation
  - Neutrino mass hierarchy
- Current and future experiments are moving into a regime where statistical errors are small, so interaction-model and nuclear uncertainties become limiting systematics[1].
  - Past: Minerva, ANL & BNL bubble chamber, MicroBooNE
  - Present: T2K, NOvA, JUNO
  - Near Future: DUNE, Hyper-Kamiokande

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  - Near Future: DUNE, Hyper-Kamiokande
- Current MC event generators are not accurate enough for the next generation of experiments

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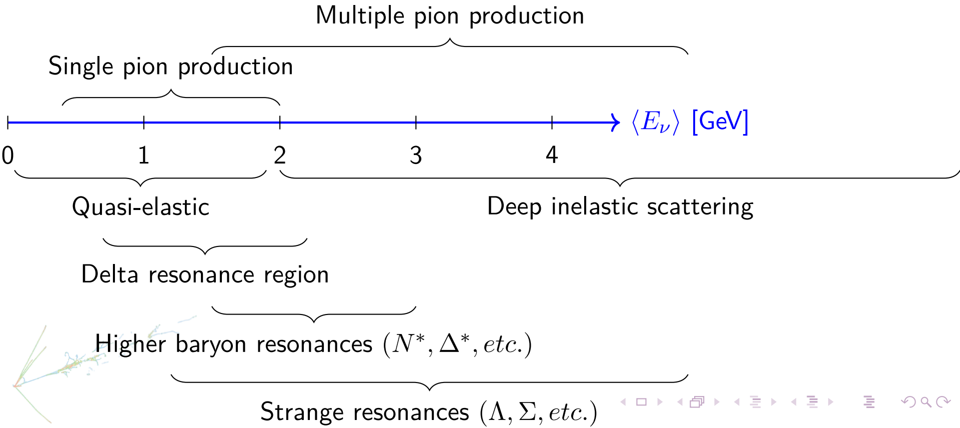

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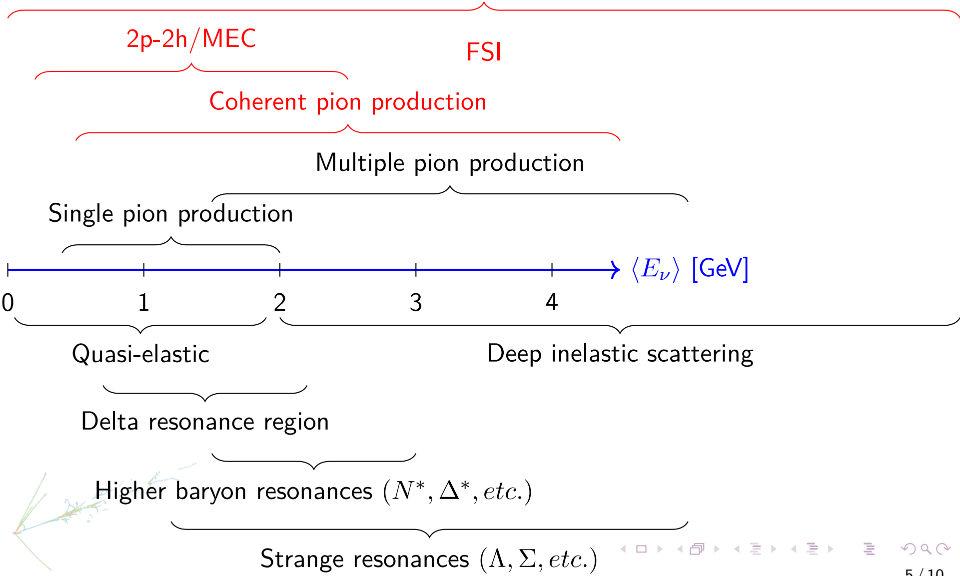

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These all model IS with upgraded local fermi gas model and FSI modelled using semi-classical cascade model

- GENIE
  - Some interaction models (Resonance, DIS) are outdated
  - Global fit is tuned against data
- NuWro
  - Motivated by T2K energy scales, and has energy inputs between QE and DIS
  - Flexible modelling options (nuclear and resonance)
- NEUT
  - Developed for Japanese water Cherenkov experiments
  - Not built for electron scattering

Neutrino Event Generators

non-exhaustive list

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- GiBUU
  - Nuclear model based on transport model i.e. propagation of hadrons in the nucleus and FSI dynamically modelled
  - IS and FS modelled in a unified way
- ACHILLES
  - IS via explicit configuration of nucleons (spectral functions)
  - FSI using impact-parameter cascade nuclear model
  - Amplitude based, using COMIX (SHERPA module)
  - Electron scattering natively supported

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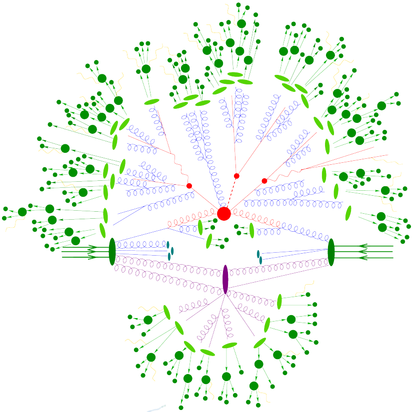
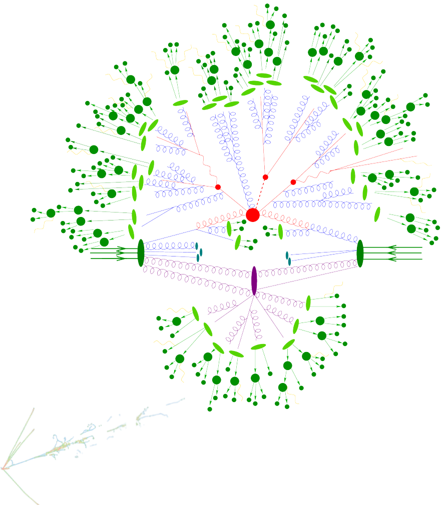


$$d\sigma \sim d\sigma_H(Q) \times \mathsf{PS}(Q \to \mu) \times \mathsf{MPI}$$

$$\times\ \mathsf{Remnants} \times \mathsf{QED\text{-}radiation}$$

$$\times\ \mathsf{Hadronization}(\mu \to \Lambda)$$

$$\times\ \mathsf{HadronDecays} \times \ldots$$



- lepton-lepton collisions, as explored by the CERN LEP experiments,
- lepton-photon collisions,
- photon-photon collisions with both photons either resolved or unresolved,
- deep-inelastic lepton-hadron scattering, as investigated by the HERA experiments at DESY, and,
- hadronic QCD interactions as studied at the Fermilab Tevatron or the CERN LHC.

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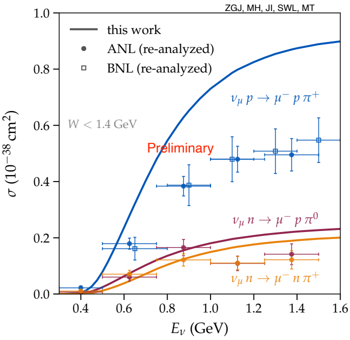

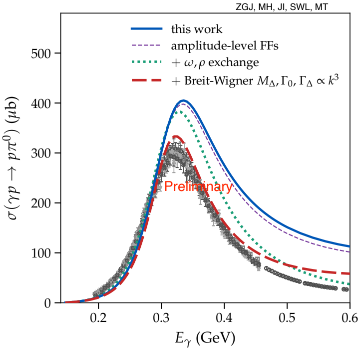

(a) Total cross sections for charged-current single-pion production on free nucleons, computed with the automated pipeline in SHERPA and compared to re-normalized ANL and BNL data.

(b) The $\gamma p \to p\pi^0$ channel with the modifications, applied one after another.

What's next?

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- More particles
  - vector mesons
  - multi-pion final states
  - Strange chiral theories
  - higher resonances
- More nuclear effects
  - 2p-2h
  - MEC