Genie

v3.4.0

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Marco Roda
marco.roda@liverpool.ac.uk

on behalf of the GENIE collaboration

GENIE Forum
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UNIVERSITY OF LIVERPOOL

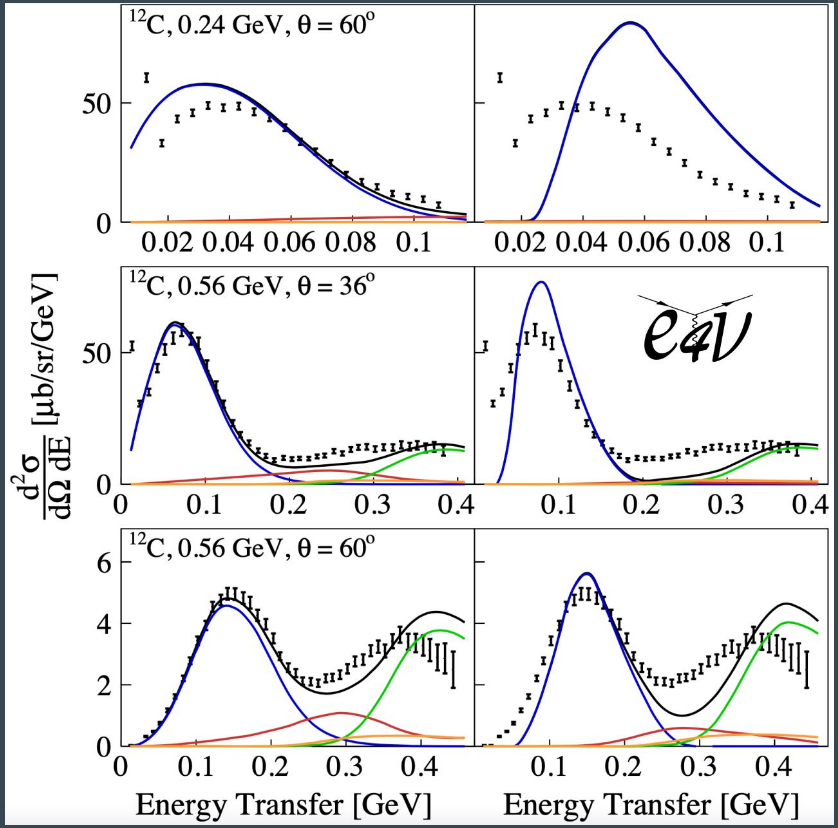
Genie
UNIVERSAL NEUTRINO GENERATOR & GLOBAL FIT

[Phys. Rev. D 103, 113003 (2021)](https://doi.org/10.1103/PhysRevD.103.113003)

SuSAv2 - electron scattering

- Consistent with neutrino version
- Benchmarked against inclusive (e, e') data
  - by members of the e4ν collaboration
- Improvement with respect to G18_10a_02_11a
  - Which is not a tune used electrons
  - Rosenbluth + Empirical MEC (with no tuning)
- Contributors:
  - Afroditi Papadopoulou
  - Alon Sportes

SuSAv2 G18_10a_02_11a



(blue) QE, (red) MEC, (green) RES and (orange) DIS

Initial state: Correlated Fermi Gas

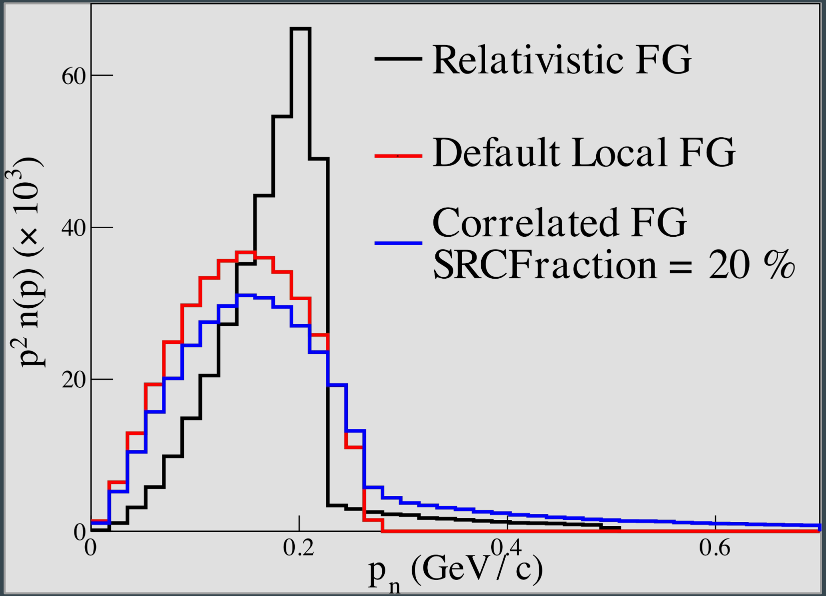
- Attempt to model the high energy tail
  - Measured at electron scattering
    - Phys. Rev. C 68, 014313
  - expected from two-nucleon short range correlations

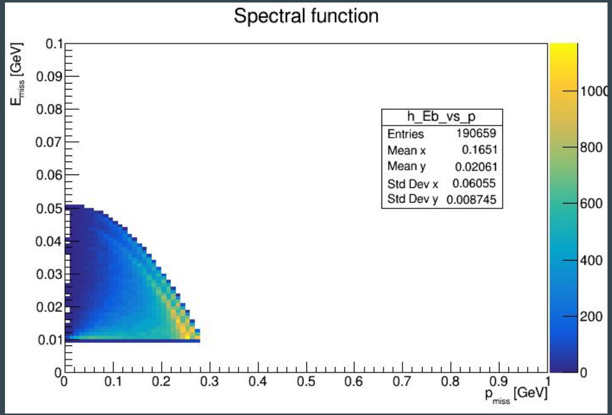
- Implementation inspired by
  - https://arxiv.org/abs/1710.07966

- Final result: extension of the Local FG
  - Fraction of nucleons are above Fermi momentum

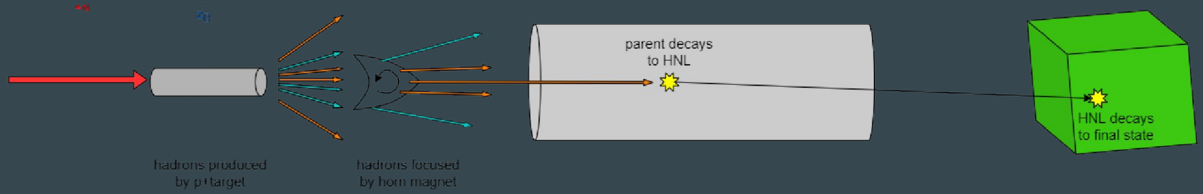
- In v3.4.0 we also added the possibility for the binding energy to be a function of the nucleon momentum
  - We call it spectral-function-like approach
  - It's not a full implementation of the spectral function
    - It just populates the space
      - A reweight module can use this as an input to proper SF distribution

- Contributor
  - Afroditi Papadopoulou
  - Steven Dolan and Laura Munteanu





Heavy neutral lepton



- neutrino mass eigenstates with masses O(MeV)
  - In our implementation $m_4 < m_K$
  - Lagrangian implemented according to Eur. Phys. J. C 81, 78 (2021)
    - With caveats for some decay channels: link to code review for details
      - The link contains all the instructions to run etc

- HNL are produced in same beam as SM neutrinos
  - Use dk2nu flux files as simulation input
- • HNL decay to some appropriately selected decay channel
  - Particle stack constructed appropriately
    - Probe is the decaying HNL particle
- • Decay vertex assigned along HNL trajectory inside detector
  - Detector ROOT geometry used as simulation input

- Provides tools for POT accounting
  - usually intended to generate weighted events

- This is a huge amount of work
  - Started from a MINERvA development
  - That has been generalised to be used by other experiments

AR23_20i_00_000 - SBN/DUNE tune

- Nuclear model: Local Fermi gas with Spectral function like approach
  - And correlated tail fraction set to 12 %, instead of the 20 %
  - The emission of the correlated nucleon is disabled
- CC 1p1h: Valencia model with z-expansion for the nucleon form factor
- CC 2p2h: SuSAv2 model
- Photon emission from nuclear de-excitation from Argon nuclei enabled
  - According to Marley distribution

AR20i_00_000 - SBN/DUNE tune

- The rest of the configuration is similar to G18_10a_02_11b

- The parameters for pion production are tuned according to free nucleon data
  - The tune was done using M_A as a nuisance parameter (not used in this 1p1h configuration)

TABLE I: Complete list of models used for the G18_10a_02_11a tune in GENIE v3 [5].

Simulation domain	Model
Nuclear model	Local Fermi Gas [14]
QEL and 2p2h	Valencia [13, 15]
QEL Charm	Kovalenko [16]
QEL $\Delta S = 1$	Pais [17]
RES	Berger-Sehgal [18]
SIS/DIS	Bodek-Yang [19]
DIS $\Delta S = 1$	Aivazis-Tung-Olness [20]
Coherent π production	Berger-Sehgal [18]
Hadronization	AGKY [21]
FSI	INTRANUKE hA [22]

Future developments

- Getting close to the release of Minoo's model for single pion production

- upgrade for the **ν**-e elastic scattering to include electron initial distribution
  - This will require a change in the data model we write in the file
  - Probably a dedicated presentation will happen at a forum

- COH single gamma production is also getting close to completion

Take away

- Lots of new models and configurations
  - Plenty choice and we are happy to receive requests and inputs

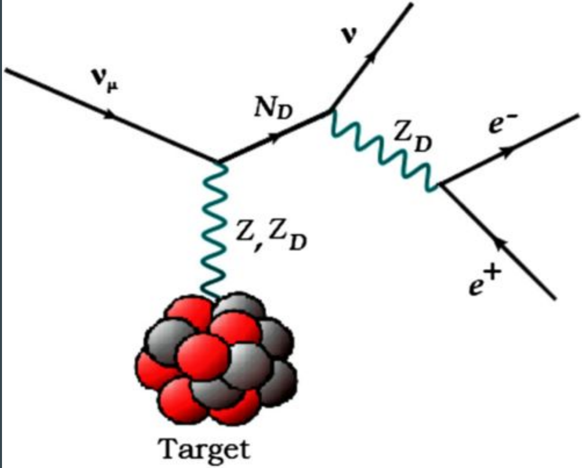
- New models are being in the process of being merged
  - Incubators are the way we track new code
  - When things are discussed in advance it's easier to include new processes

- Tuning campaign ongoing
  - Julia will go into details tomorrow

Backup

Dark neutrinos

$$\nu_\alpha = \sum_{i=1}^{3} U_{\alpha i}\nu_i + U_{\alpha 4} N_{\mathcal{D}}, \quad \alpha = e, \mu, \tau, \mathcal{D}$$



$$\mathcal{L}_{\mathcal{D}} \supset \frac{m_{Z_{\mathcal{D}}}^2}{2} Z_{\mathcal{D}\mu} Z_{\mathcal{D}}^{\mu} + g_{\mathcal{D}} Z_{\mathcal{D}}^{\mu} \bar{\nu}_{\mathcal{D}} \gamma_\mu \nu_{\mathcal{D}} + e\epsilon Z_{\mathcal{D}}^{\mu} J_\mu^{\mathrm{em}} + \frac{g}{c_W} \epsilon' Z_{\mathcal{D}}^{\mu} J_\mu^{Z},$$

- Model to explain EM excess
  - Main reference paper https://doi.org/10.1103/PhysRevLett.121.241801
- Neutrino interaction via exchange of a light dark boson (Z_D)
  - light compared to Z and W
  - producing dark neutrino with non-zero mass (ν_D)
- The dark neutrino then decays
  - In either neutrinos and/or electron pairs
    - Only tree-level decays are allowed so far
      - We can add more but we need the decay amplitudes
  - The decay length is visible in our detectors!
    - varies a lot with couplings and mixings but it can be of the order of mm
- The dark boson exchanged with the nucleus can give rise to all NC scattering mechanisms
  - The main process would be the coherent production (implemented in GENIE now)
  - The second leading process would be the QE process, not implemented yet
- Contributions by Iker de Icaza (Sussex)
  - Inputs from Pedro Machado (FNAL)