Exploring Electron Scattering in LDMX - Developing a Selection to Improve Neutrino Interaction Models

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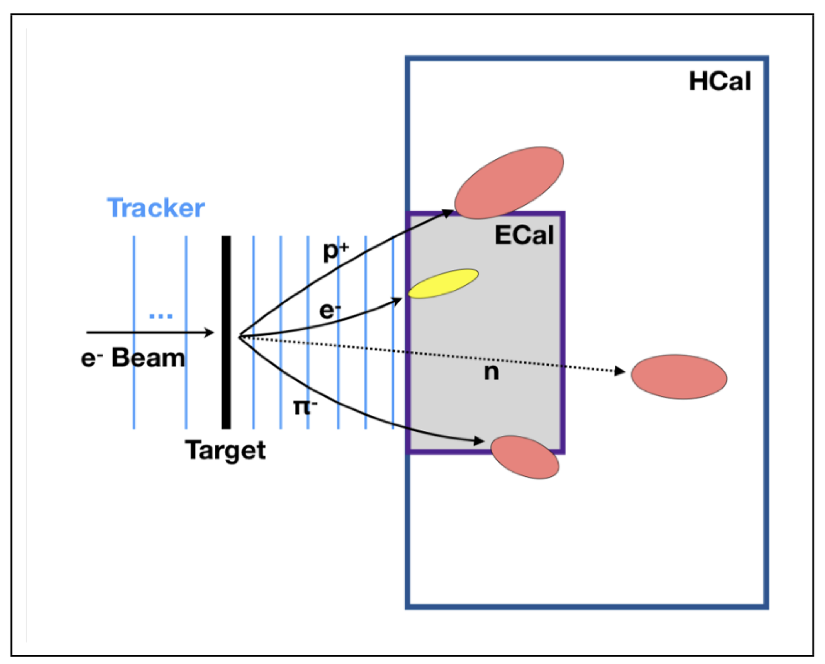
Introduction

Current and future experiments, such as SBN and DUNE, will measure neutrino oscillations to determine neutrino mass ordering and search for matter/anti-matter asymmetries. Understanding O(GeV) neutrino interactions is crucial to making these measurements and reconstructing the initial neutrino energy.

In addition to looking for dark matter, the proposed Light Dark Matter eXperiment (LDMX) [1] can measure electron scattering interactions that can be analogous to neutrino scattering to aid the development of neutrino models.



LDMX Conceptual Illustration

The LDMX's detector includes a fine tracker and a two-stage EM and hadronic calorimeter that will give precise measurements of both charged and neutral particles produced in electron interactions with the target material within the acceptance of the detector.

Background

We use the GENIE Neutrino Monte Carlo Generator [2] to simulate 4 GeV e-Ti interactions like those that could be observed with the LDMX. We consider two different model sets, G18_02a and G21_11b, from GENIE v3.2 and use their differences to illustrate our selection's sensitivity to different interaction models.

Medium Energy GENIE Configurations (100 MeV- 100 GeV)

Modelling CMC	Ground State	Quasi-elastic	Meson Exchange Current	Resonance	Shallow and Deep Inelastic	Final State Interactions
G18_02a	Relativistic Fermi Gas Model	Llewellyn-Smith QE model	Dytman	Berger-Sehgal	Bodek and Yang Model	hA18 (Effective intranuclear transport model)
G21_11b	Local Fermi Gas Model	SuSAv2	SuSAv2	Berger-Sehgal	Bodek and Yang Model	hN18 (Full intranuclear cascade)

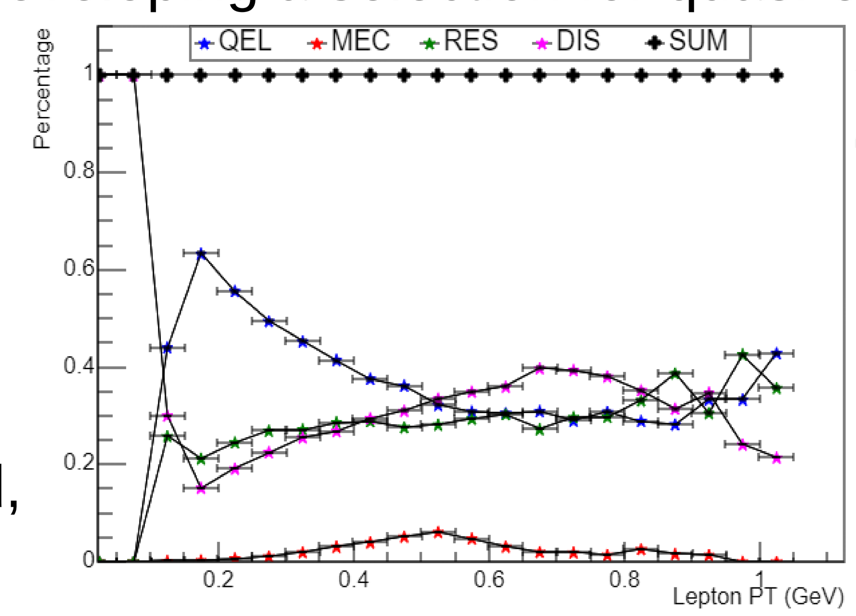
Table excerpt taken from GENIE's online database elaborating the fundamental differences in models G18_02a and G21_11b [2]
https://hep.ph.liv.ac.uk/~costasa/genie/tunes.html (accessed July 28, 2022)

Results

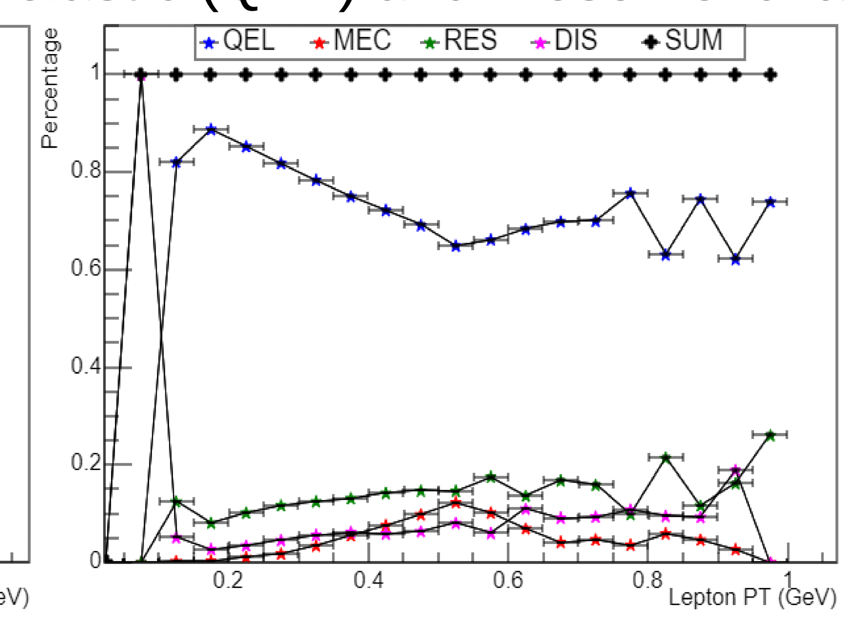
We simulate 10 million e-Ti events for each of the model sets and we require lepton p_T >400 MeV/c and θ_e<40° to model the effects of a trigger and lepton acceptance.

In this study, we focus on developing a selection for quasi-elastic (QEL) and meson exchange current (MEC) events.

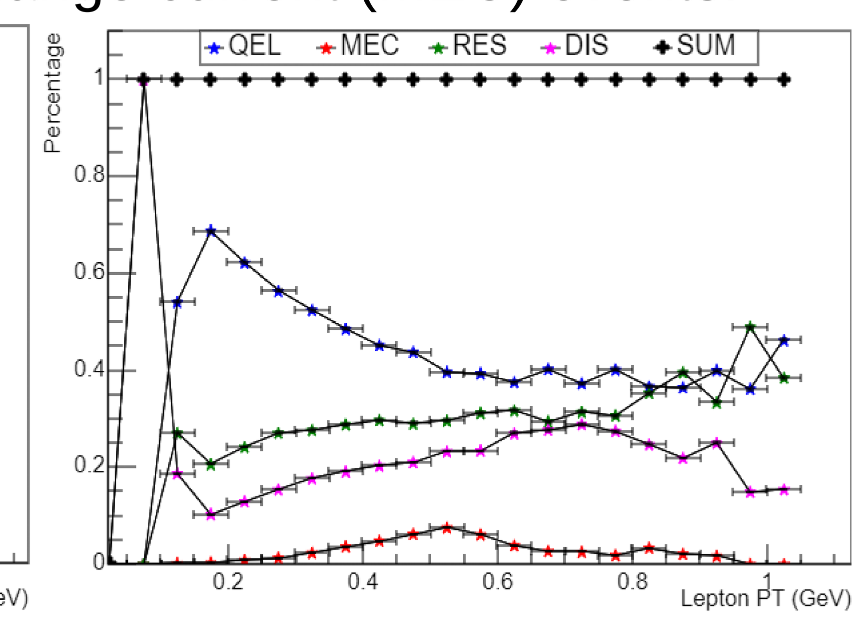
First, we remove resonant (RES) and deep inelastic scattering (DIS) events by vetoing events with charged/neutral pions. We found if all final state pions could be well reconstructed, vetoing pions would give a clean QEL/MEC selection. Furthermore, requiring energy transfer < 300 MeV effectively removes RES/DIS events and allows us to investigate hadronic kinematics.



Relative fraction of events per lepton p_T

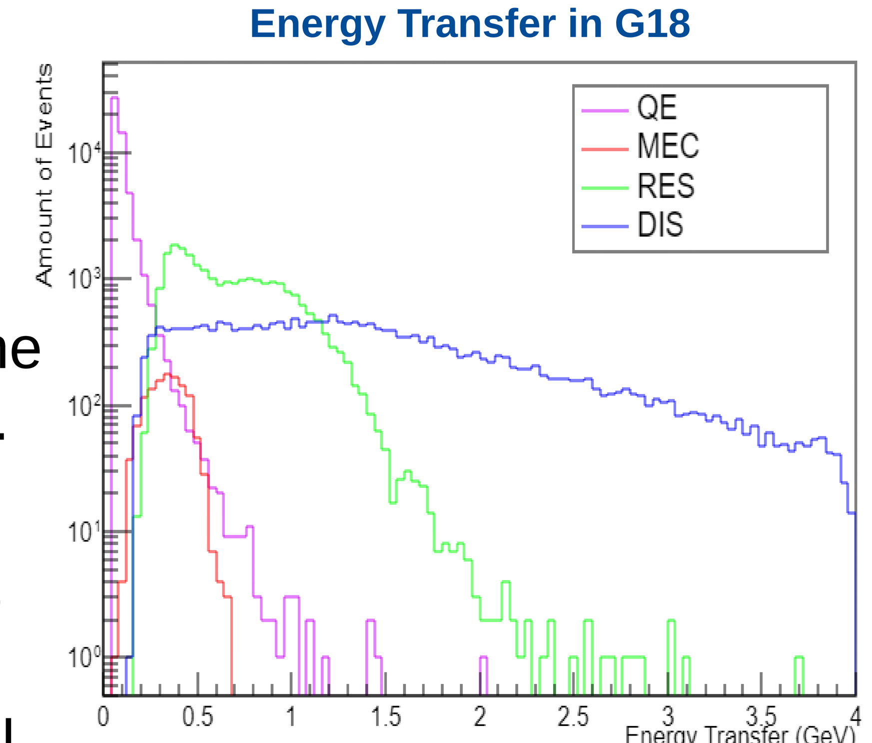


Relative fraction of events per lepton p_T without final state pions

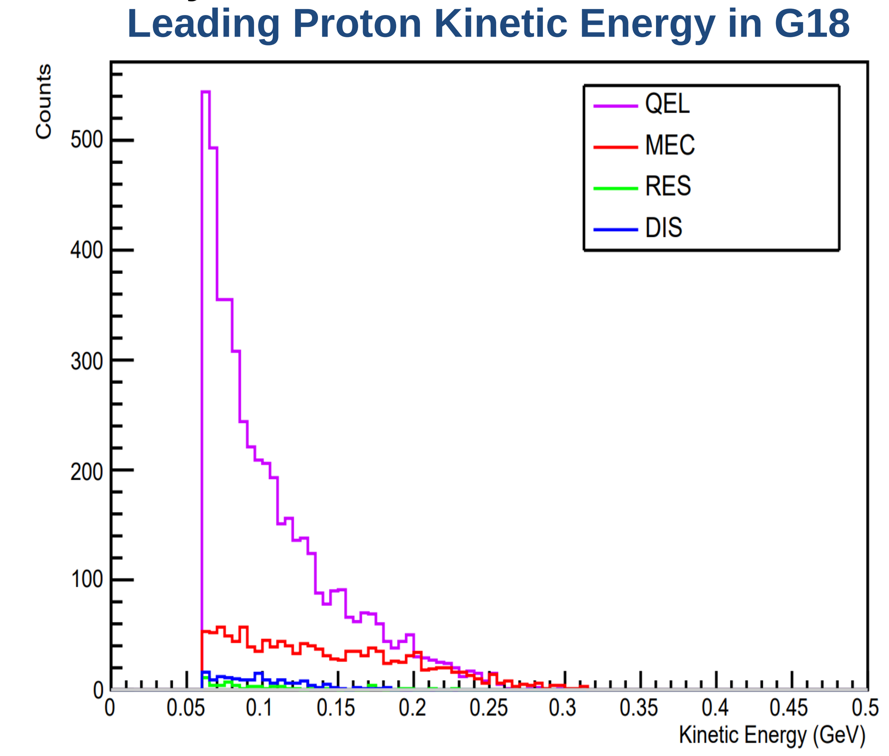


Relative fraction of events per lepton p_T without well-reconstructed final state pions

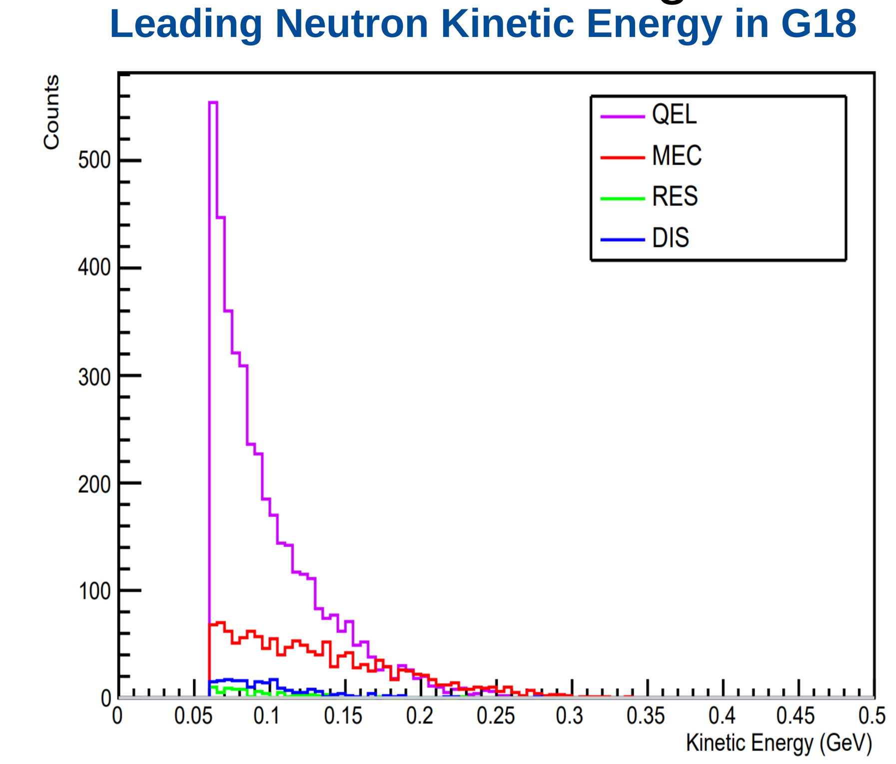
Energy Transfer in G18



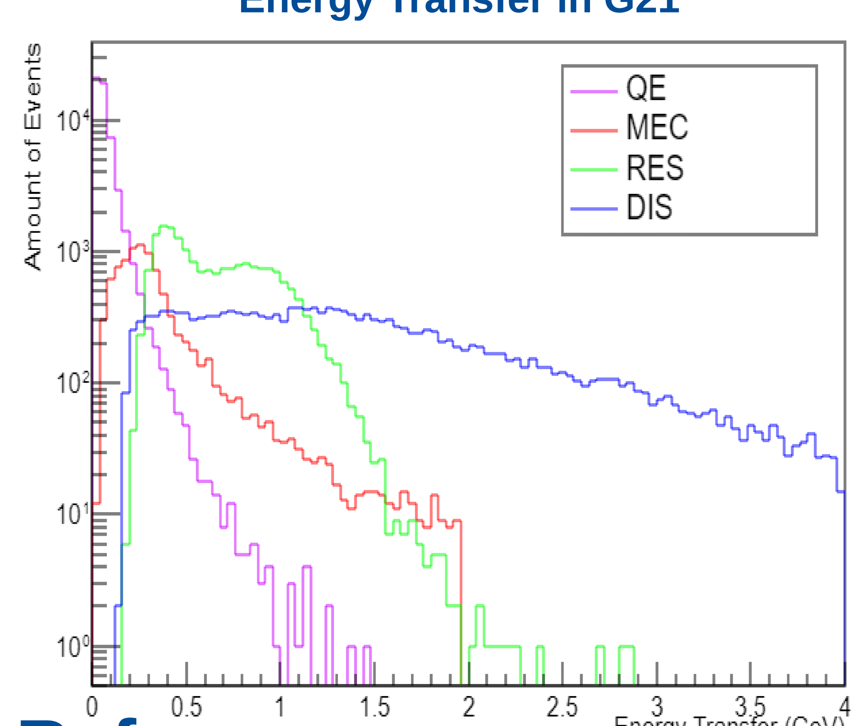
Leading Proton Kinetic Energy in G18



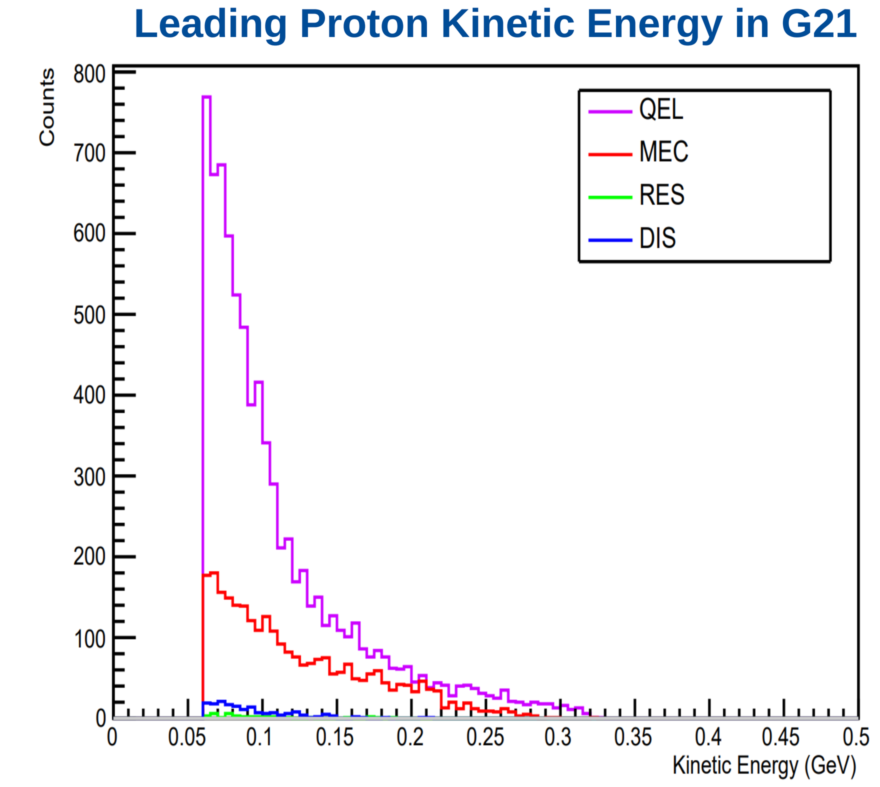
Leading Neutron Kinetic Energy in G18



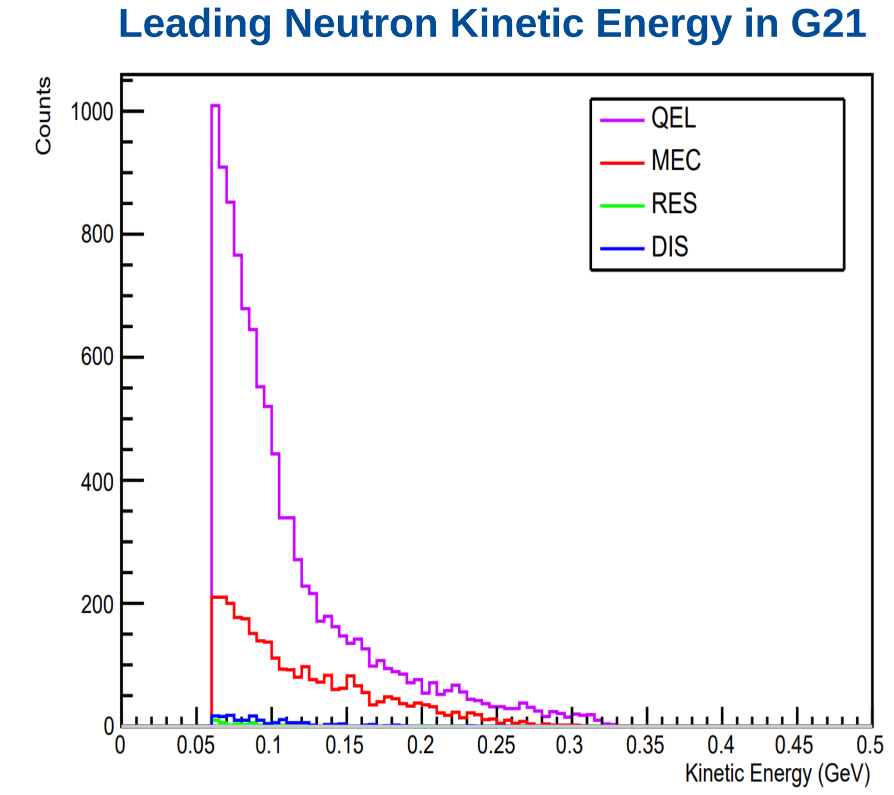
Energy Transfer in G21



Leading Proton Kinetic Energy in G21



Leading Neutron Kinetic Energy in G21



Selections: Lepton p_T [0.4-0.5] GeV   Angle < 40°
Kinetic Energy > 60 MeV   Energy-transfer < 300 MeV

References

[1] Åkesson et al, arXiv:1808.05219

[2] Alvarez-Ruso, L. et al. Eur. Phys. J. Spec. Top. 230, 4449–4467 (2021).

Conclusions

With a selection on energy transfer, we can select largely pure QEL and MEC event samples in LDMX. Future work will include more detailed model comparisons, expansion of the detector trigger for these events, and further work on reconstructing and vetoing final state pions.

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