Computational challenges for neutrino event generators

Based on the CompF2 LOI Gardiner-131 (and references therein)

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Streamlining theory improvements: the challenge

- Generators provide an essential bridge between theory and experiment
  - Exciting work by theory community on improving lepton-nucleus cross section models
  - Experiments need this physics in a generator to use it in their analyses: neutrino energy reconstruction, backgrounds, efficiencies, etc.
- "Traditional" development approach: implement one model for one process (e.g., CCQE) at a time directly in a generator
  - Labor-intensive: multiple person-years typically required for one new model
  - Ability to switch between neutrinos and electrons often neglected, hard to add later
- Creates a bottleneck for delivering the latest theory improvements to experiments
  - Reducing model uncertainties will be crucial for precision oscillation results
  - Development process must be optimized to meet growing needs

Streamlining theory improvements: possible ways forward

- Both human & technical factors likely needed for a full solution
- Relatively few active developers are trying to serve a growing community
  - Usually have other significant demands on their time
  - Diverse expertise needed: participation from theorists, experimentalists, and computing experts must be supported and incentivized
- Ideas for a “universal theory API” are under exploration but could use more attention
  - Provide a general interface for generators to “talk to” external theory models and create events using them
  - Early explorations of this idea are summarized in arXiv:2008.06566
  - Design must accommodate neutrino & electron probes, model parameter variations for systematic uncertainty assessment
  - Leveraging LHC experience looks promising, many tools available
    - Phase space generation (RAMBO, etc.)
    - Parameter variations & tuning (Professor)

Future resource needs for neutrino event generation

- Topic discussed for LHC generators in other session #99 talks
- Currently a small part of the overall CPU budget for neutrino experiments, but very likely to grow
  - Theory calculations that serve as input (e.g., via Quantum Monte Carlo techniques)
  - Generation of standard physics (possibly with multiple models/generators) and BSM events
  - Systematic uncertainty assessment and tuning
    - Recent example: tune of GENIE by NOvA (**arXiv:2006.08727**)
    - Used HPC resources from NERSC
- Quantitative estimates of related computing needs will become important for experiments like DUNE, SBN, Hyper-K
- Techniques for addressing these needs (GPUs, etc.) worth exploring
  - Input from experts in other domains (e.g., LHC experiments) helpful for moving forward