CRPA via Reweighting in GENIE

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Introduction

- We have a number of options for the initial nucleus state model (LFG, SF, CRPA, …) across neutrino event generators – can we use phase space reweighting as a tool to switch between these options quickly and conveniently?

- I'll be presenting observations from initial studies – work still ongoing!

GENIE Models

- DUNE baseline model (version 3.4.2 tune AR23_20i_00_000) CCQE model uses NievesQELCCPXSec/ZExp module, which uses LFG

- CRPA and SF implemented in a feature branch, not yet integrated into develop

Reweighting Approach

- Benchmarked the T2K approach of reweighting the muon phase space for inclusive CCQE events (thanks to Stephen Dolan for the guidance)
  1. Build a 3D histogram from CCQE MC events (1M for each Enu bin) using the baseline model (Enu, cos, p), using bin width (100 MeV, 2pi/50 rad, Enu/50)
  2. Get corresponding cross section for that variable from CRPA hadron tensor calculations
  3. For each MC event, get the (Enu, cos, p) values, apply CRPA/baseline value as reweight (value capped at 10)

- T2K did SF -> CRPA, I tried FG -> CRPA

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Example: Monoenergetic Flux (Enu=400MeV)

Wide regions of phase space not described well due to the insufficient overlap between the covered phase spaces of AR23 and CRPA
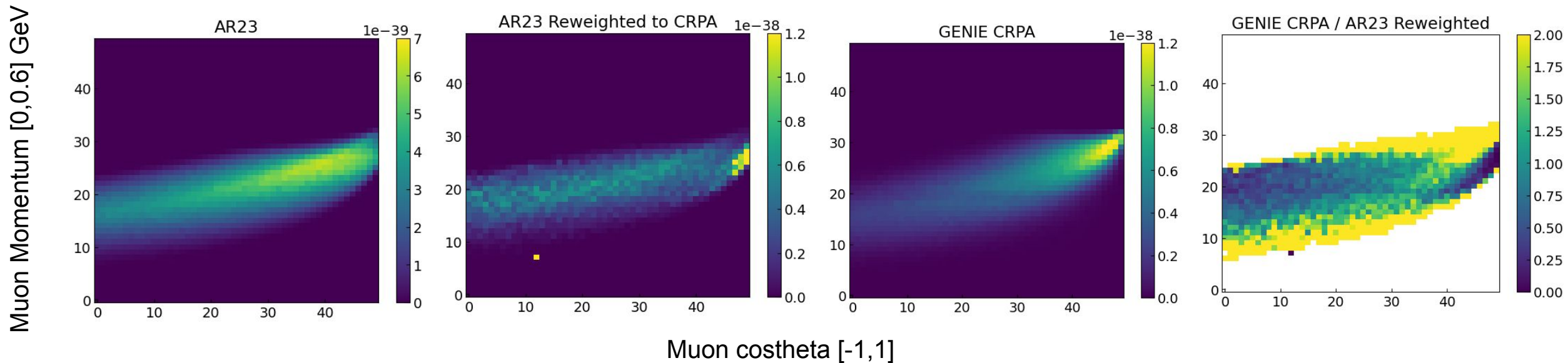
Example: Broadband Flux (SBND)

Works well for a wider range of phase space for a broadband flux due to the larger overlap between the covered phase spaces
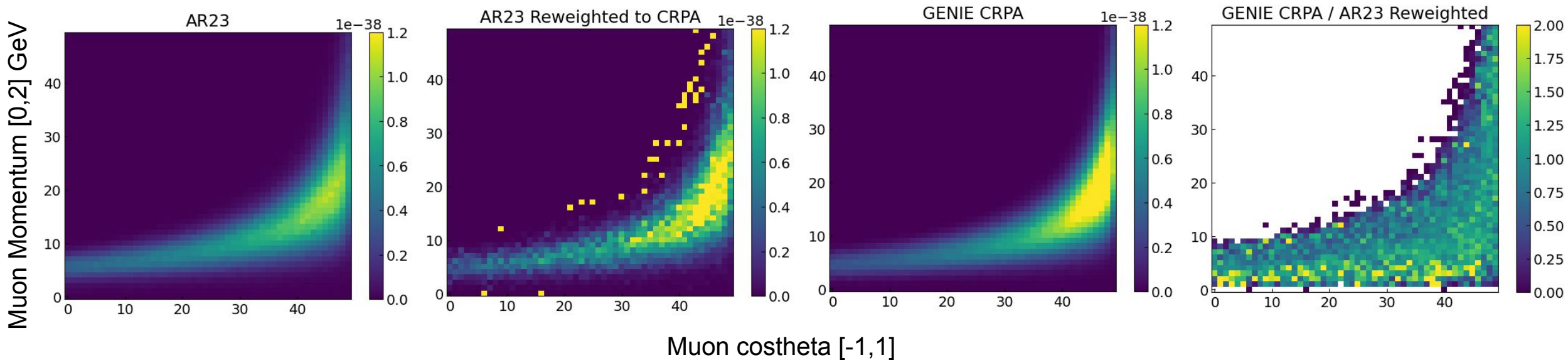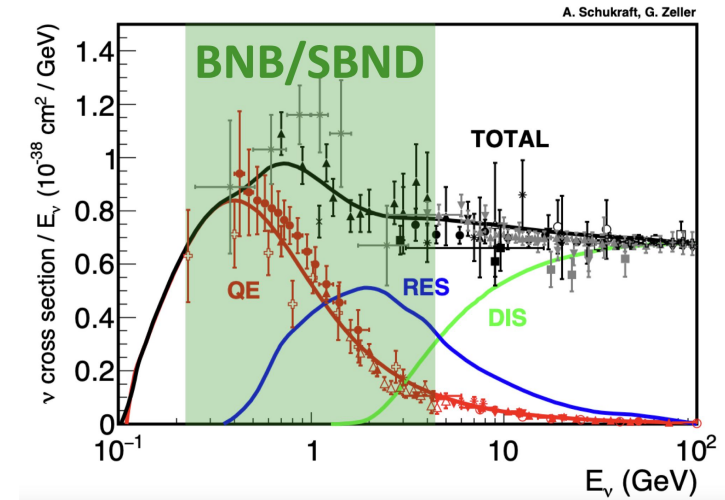
Access Through a Systematic Dial

- Implemented the reweight functionality as a single continuous on (CRPA) and off (LFG) dial in the GENIE Reweight package

- Apart from being used to reweight the CV, can also be used as a model-variance uncertainty

```
double fRPATwkDial; ///< 0 = default, 1 = RPA off (changes Nieves CCQE only)
double fCRPATwkDial; ///< 0 = default, 1 = fully reweighted to CRPA (changes Nieves CCQE only)
```

Summary

- Working on implementing a switch between CCQE models that use different initial nucleus state models, specifically for LFG->CRPA through reweighting

- This approach has the potential usage for comparison studies and convenient switches between models

- At a first glance, observed reasonable performance for a broadband flux, while the performance was unreliable for monoenergetic flux due to the insufficient overlap of phase space

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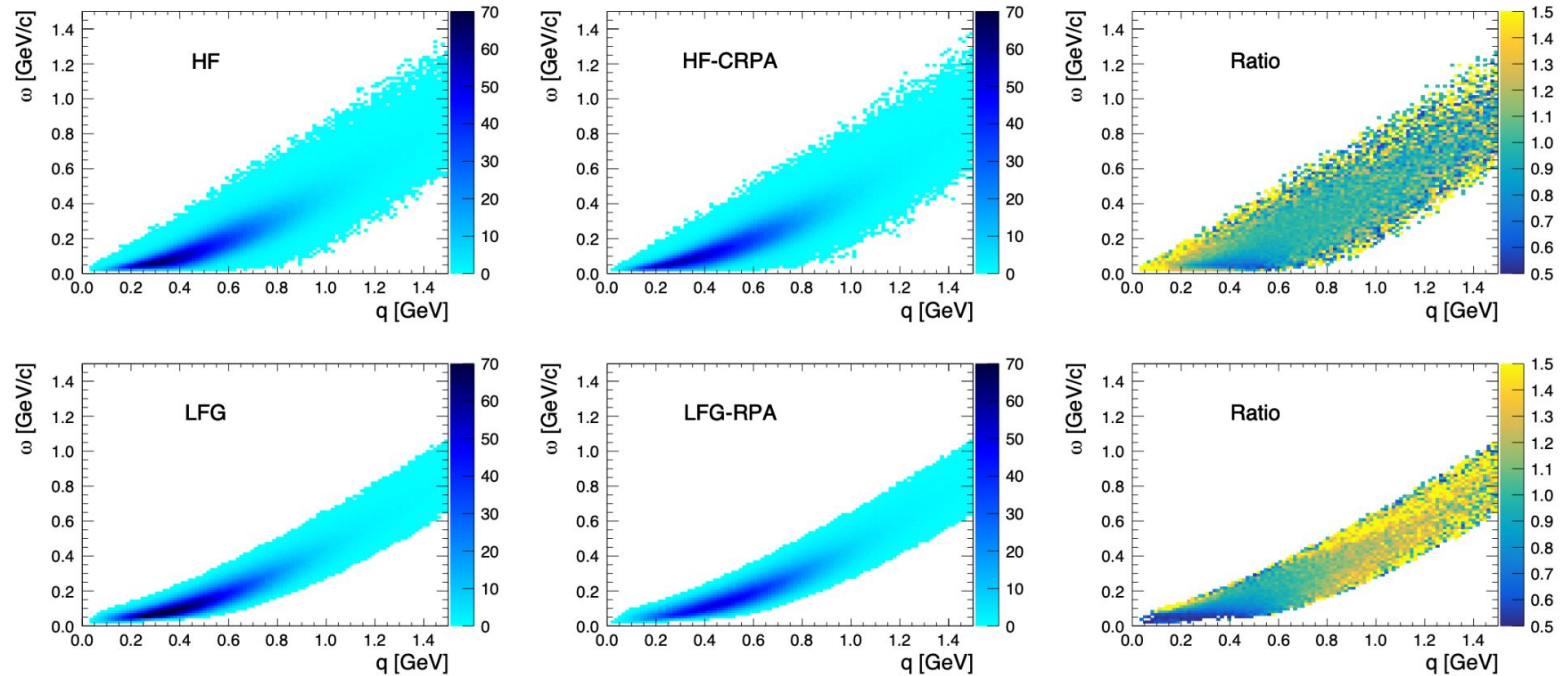
CRPA   https://arxiv.org/pdf/2110.14601

FIG. 4. The left and centre T2K muon neutrino flux (peaking at 0.6 GeV) averaged double differential cross section on carbon as a function of the energy (ω) and momentum transfer (q) shown (on the z-axis) 10^{-39} cm^2 GeV^{-2}/c per nucleon with and without (C)RPA corrections. All plots are produced with GENIE. The plot on the right shows the impact of the corrections as a ratio. The upper row shows predictions from HF/HF-CRPA model whilst the the lower row shows the same for the Valencia LFG/LFG-RPA model. White regions indicate regions in which no events were generated.