FSI STUDIES FOR NEUTRINO ENERGY ESTIMATION

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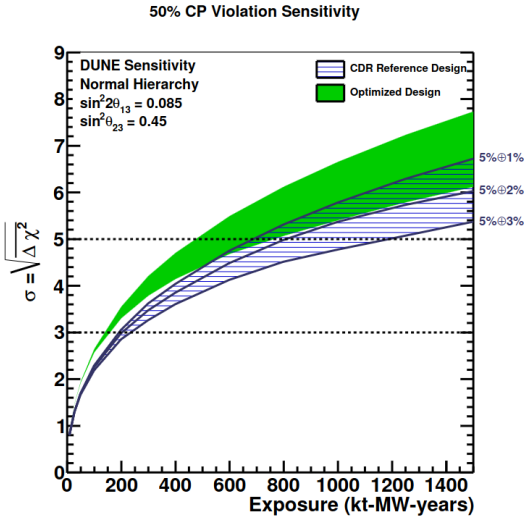
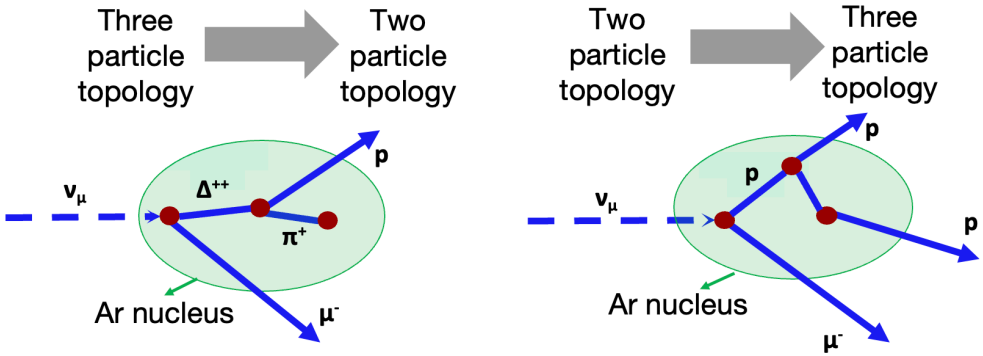
INTRODUCTION

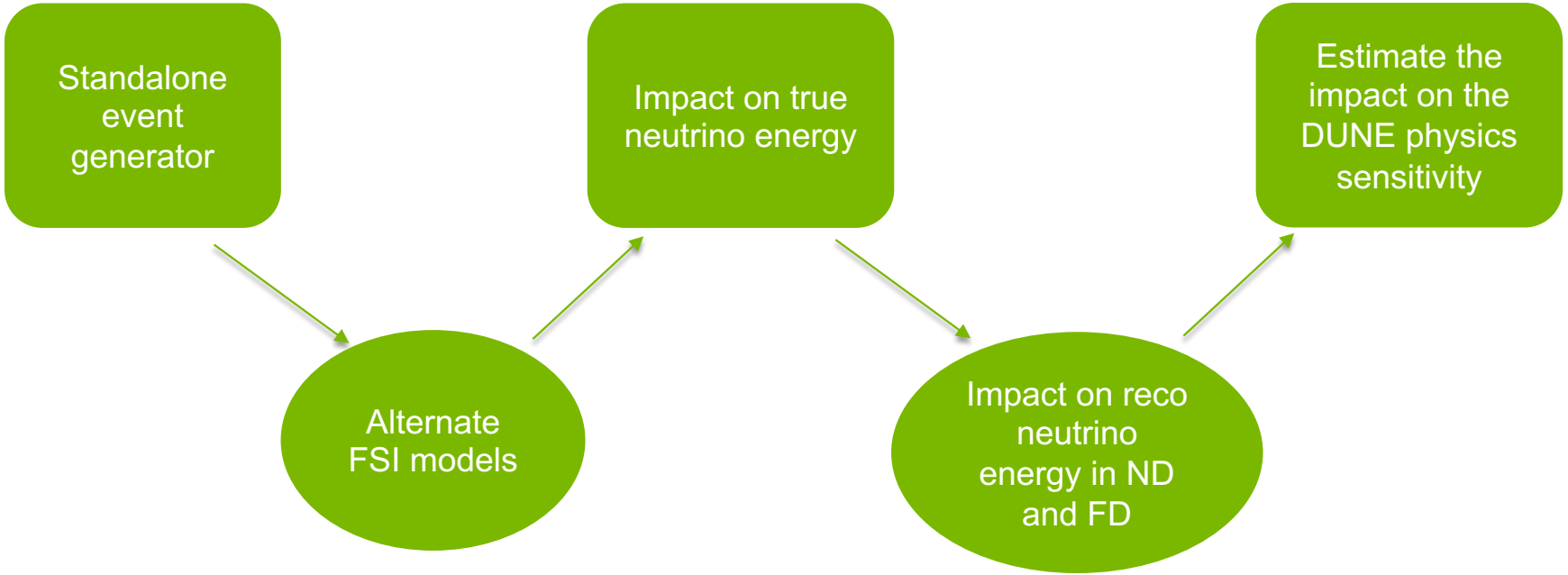
- The measurement of CP-violation phase δ_{CP} requires the accuracy of neutrino energy scale
- Neutrino energy estimation is impacted by the mismodelling in the neutrino event generator
- Final State Interactions (FSI) play an important role in understanding the neutrino event generators



https://arxiv.org/pdf/1512.06148.pdf

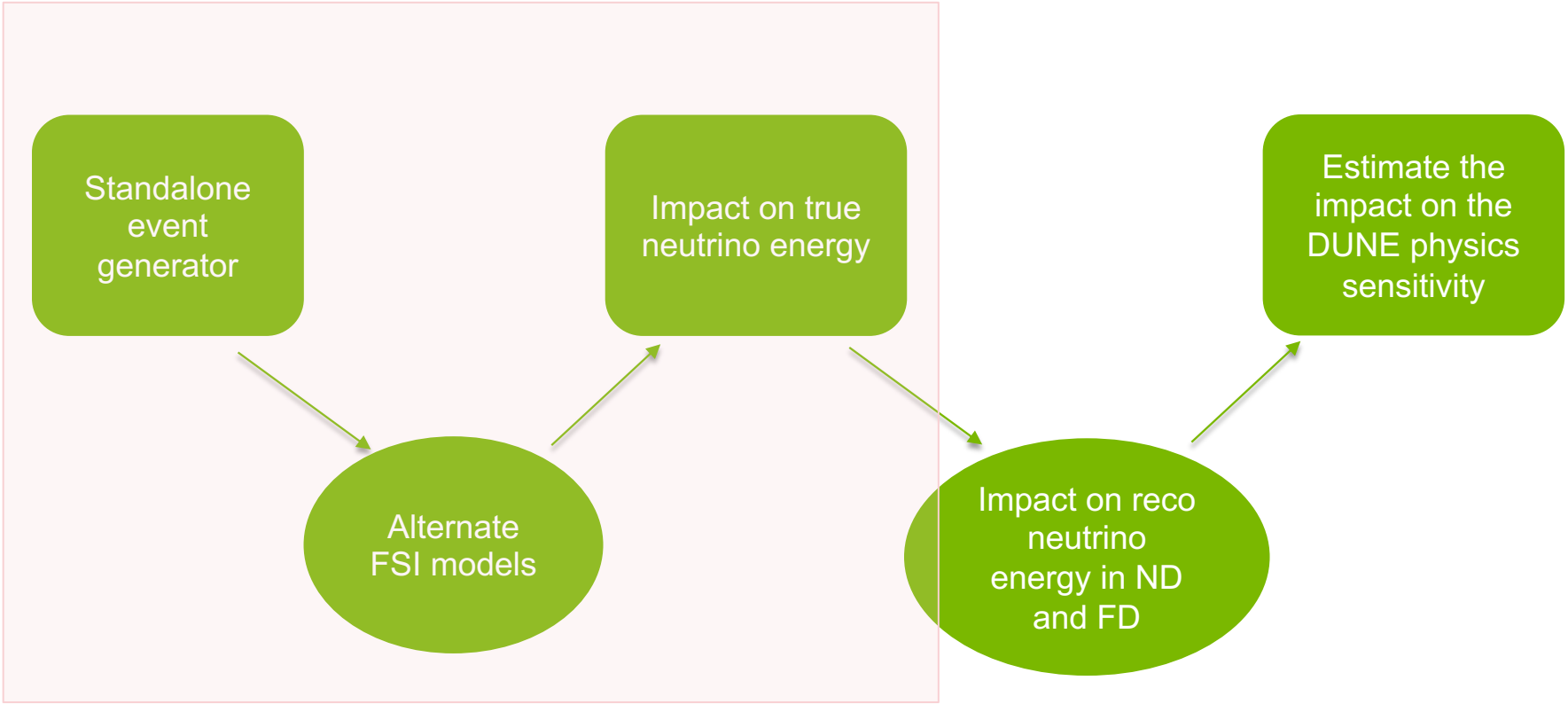


WORKFLOW


Standalone event generator
Alternate FSI models
Impact on true neutrino energy
Impact on reco neutrino energy in ND and FD
Estimate the impact on the DUNE physics sensitivity

WORKFLOW

Performed more simulation-based work until now



COMPUTING RESOURCES AT ANL

Argonne Leadership Computing Facility

Resource	Description
Theta	11.7-petaflops supercomputer based on Intel processors
ThetaGPU	NVIDIA DGX A100-based
Cooley	GPU based visualisation cluster
Argonne AI-Testbed	machine learning based high-performance computing applications
Polaris	44-petaflop peak performance CPU/GPU, platform to test and optimize codes for Aurora.
Aurora	Argonne's first exascale supercomputer, projected peak performance of 2 exaflops.

Laboratory Computing Resource Center

Resource	Description
Bebop	Intel Xeon CPUs with 1024 public nodes
Swing	NVIDIA A100 GPUS with 6 public nodes

Yellow boxes represent the resources we currently have allocations on for DUNE

COMPUTING RESOURCES AT ANL

2x2 detector production work

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This work!

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SAMPLE GENERATION

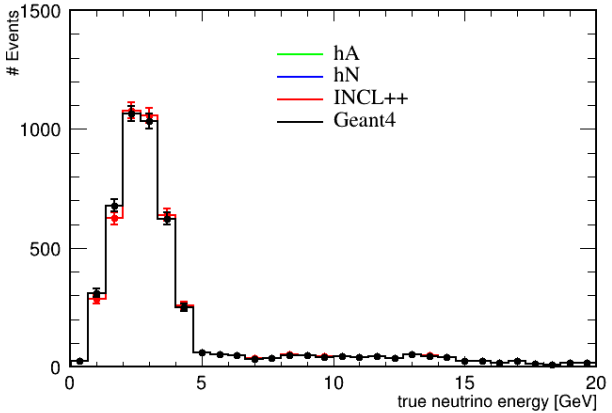
- GENIE (version 3.4 AR23_20i)
- Started with Afroditi P. repository “BuildEventGenerators”
  - https://github.com/afropapp13/BuildEventGenerators
- Changed some parameters (target, neutrino etc) in “run_genie.sh” script
- Provided flux and cross section files:
  - Flux:/pnfs/dune/persistent/users/arafique/DUNEND/DUNE_OptimizedEngineeredNov2017_REGULAR.root
  - Cross section: /pnfs/dune/persistent/users/arafique/2x2/flux_files/gxspl-NUsmall.xml

SAMPLE GENERATION (CONT.)

- Generated 5k GENIE events using ANL LCRC (bebop) machine
  - Fathima:https://indico.fnal.gov/event/62096/contributions/279136/attachments/172719/233437/XhGdMy-2x2Sim%26Calib_Fathima_Updated.pdf
- Then created tunes with alternative FSI models:
  - hA (default), hN, INCL++, GEANT
  - Richie:https://indico.fnal.gov/event/60397/contributions/270456/attachments/168488/225718/Options%20for%20Alternative%20GENIE%20Samples.pdf
- Generated 5k GENIE events for each sample

TRUE NEUTRINO ENERGY

- Generated the same set of “initial” neutrino interactions between all four samples
  - INCL++ have 2% less events, a few crashed
  - Using the same random number seed in GENIE results in different initial interactions if event generation is prompted via a single command
  - We had to generate each event individually to get the same set for the relative comparison
  - This requires additional computing time and resources. Therefore, the work is done locally at ANL.



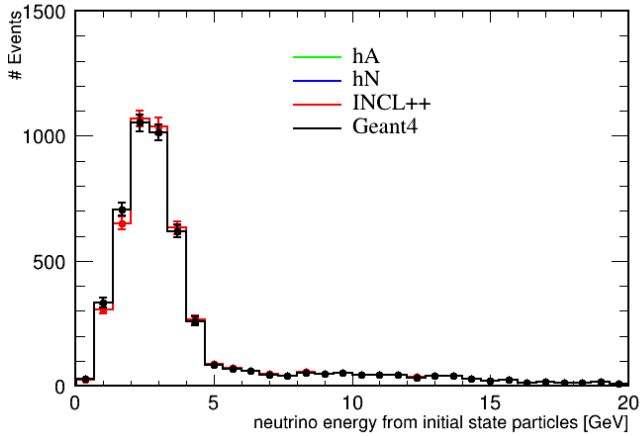
INITIAL STATE ENERGY

- The sum of all the true initial state particle energies

  $E_i = E_h + E_l - E_n$

  Where E_i is the initial state particle energies; E_h is the initial state hadronic energy sum; E_l is the primary lepton energy; and E_n is the hit nucleon energy

- We see that there is an excellent agreement in all four tunes

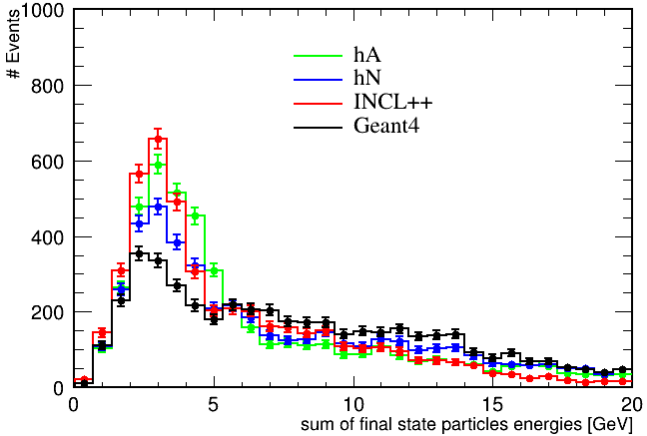


FINAL STATE ENERGY

- The sum of all the true final state particle energies

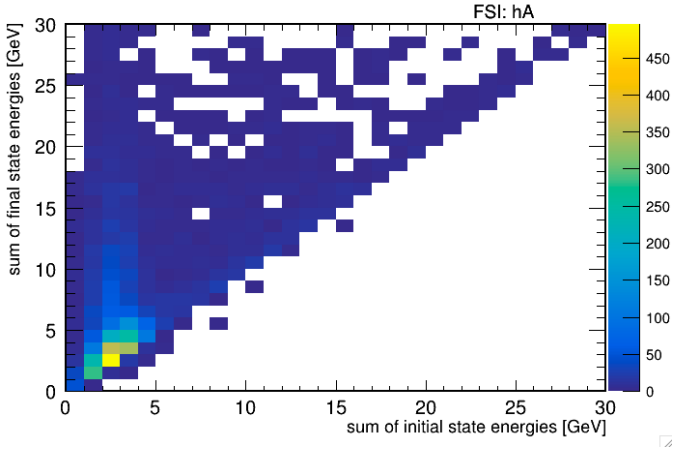
$$E_f = E_h + E_l - E_n$$

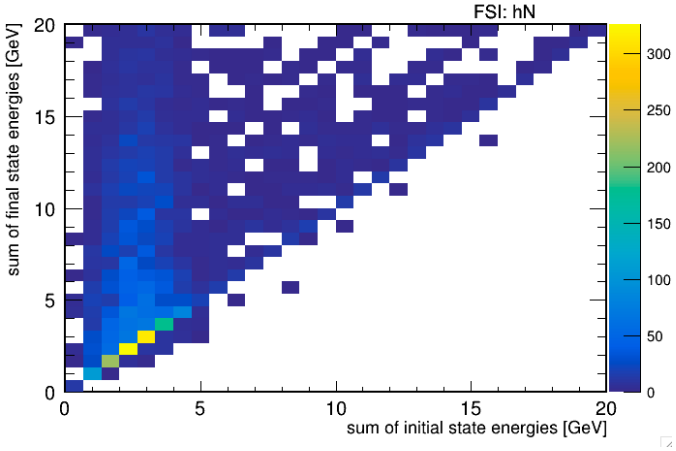
Where E_f is the final state particle energies; E_h is the final state hadronic energy sum; E_l is the primary lepton energy; and E_n is (hit or other) nucleon energy

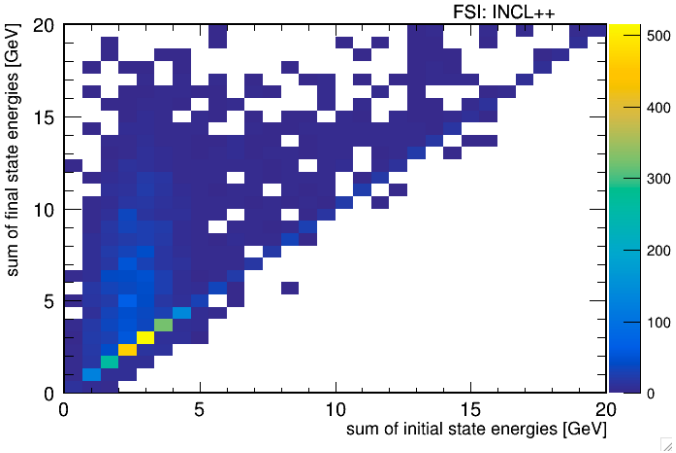


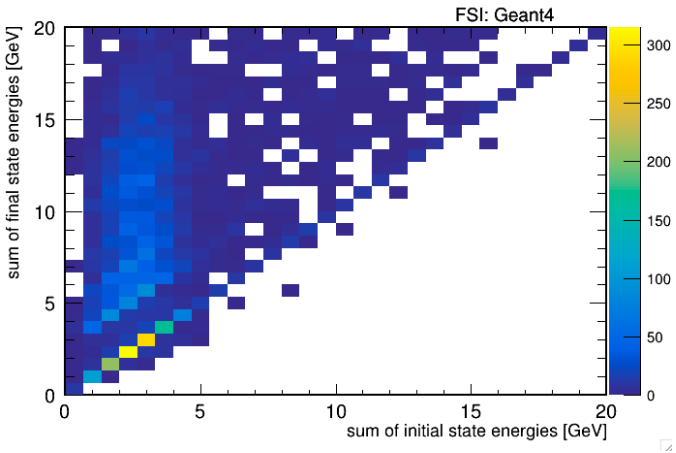
- We see that there is a discrepancy from the default tune as large as ~45%
  - These discrepancies limit our model understanding and will impact the reconstruction

INITIAL VS FINAL STATE ENERGIES



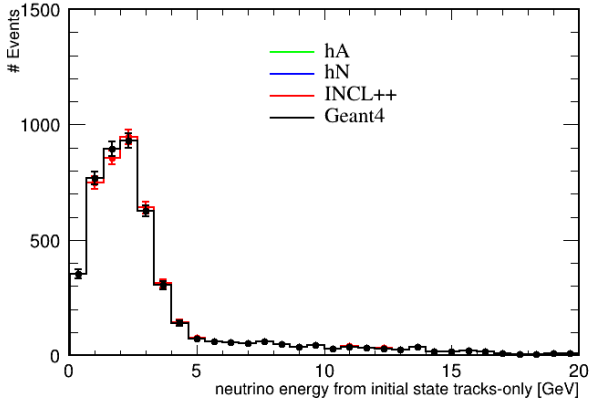


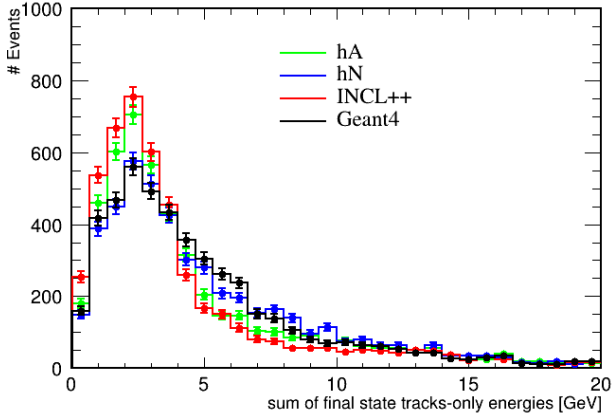




TRACK-ONLY ENERGIES

- The initial and final state track-only energies are presented
  - Considering only μ, π, p, K
- The discrepancy reduces to ~23%
  - It means that shower modelling is mostly different between different tunes





NEXT STEPS

- Look into the dependence of the energy difference between different neutrino interaction types (QE, RES, DIS etc).
- Reconstruct the neutrino energy by running these samples via FD reconstruction
  - I would like to be consistent with the FD production team to use the up-to-date flux and geometry files
  - I plan to also generate samples with various kinematics (momenta and angles) to understand how well we can estimate the reconstructed neutrino energies
- Calculate the effect of these uncertainties on the CP violation sensitivity studies