

The GENIE-Geant4 Interface

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Motivation

- Geant4 does not currently support neutrino interactions
 - they are produced but do not interact
- Eventual goals:
 - add native processes, models and cross sections to handle this
 - use new biasing tools to make possible Geant4-style tracking through detectors
- First step
 - interface to an existing neutrino generator to leverage work already done

Genie

- Genie is the code chosen for the interface
 - currently used as neutrino interaction generator by many experiments (DUNE, etc.)
 - DUNE also uses Geant4 to do propagation of secondaries through detector
 - written in C++
 - interest from Genie side to use Geant4 final state interaction models (Bertini, etc.)

Genie

- Genie mode of operation
 - scans the detector geometry to find maximum neutrino interaction probability for given beam
 - scales probability of all other neutrino interactions w.r.t max value
 - uses neutrino beam profile and cross sections to sample the point of interaction in detector
 - performs neutrino-nucleus interaction by selecting nucleon within target nucleus
 - off-shell neutrino-nucleon interaction performed using
 - Woods-Saxon model of nucleus
 - Fermi motion

Genie

- Genie mode of operation
 - several types of interaction available:
 - neutral current elastic (NCEL)
 - charged current quasi-elastic (CCQE)
 - resonance reactions (pion produced)
 - single kaon production
 - deep inelastic scattering (DIS)
 - **final state interaction**: propagate secondaries through nucleus using Gheisha-like models
 - send output particles to user (or Geant4) for tracking through detector

Interface

- Substitute Geant4 hadronic model (Bertini) to handle final state interaction
- Currently interfacing Geant4 10.3 with Genie R-2.12.2 (close to latest version)
 - wrapper model developed to make Bertini look like Genie final state model
 - Bertini takes hadrons from neutrino interaction and propagates them through nucleus, performs nuclear de-excitation, then returns resulting particles to Genie
 - xml scripts allow Genie user to select final state interaction model

Running the Interface

- Genie event record
- Plots of secondaries and comparison of models

Event Record for Single Kaon on ^{12}C

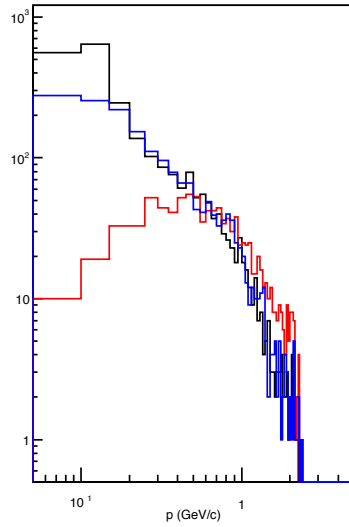
GENIE GHEP Event Record [print level: 3]												
Idx	Name	Ist	PDG	Mother	Daughter	Px	Py	Pz	E	m		
0	nu_mu	0	14	-1	-1	4	4	0.000	0.000	2.000	2.000	0.000
1	C12	0	1000060120	-1	-1	2	3	0.000	0.000	0.000	11.175	11.175
2	proton	11	2212	1	-1	5	6	-0.114	0.115	0.068	0.955	0.938
3	B11	1	1000050110	1	-1	7	15	0.114	-0.115	-0.068	10.220	*10.253
4	mu-	1	13	0	-1	-1	-1	0.214	0.098	0.473	0.539	0.106
5	proton	14	2212	2	-1	-1	-1	-0.708	0.068	0.905	1.485	0.938
6	K+	14	321	2	-1	-1	-1	0.380	-0.051	0.689	0.930	0.494
7	He4	1	1000020040	3	-1	-1	-1	-0.059	-0.198	-0.172	3.737	3.727
8	He4	1	1000020040	3	-1	-1	-1	0.293	0.166	0.011	3.743	3.727
9	proton	1	2212	3	-1	-1	-1	-0.678	0.064	0.862	1.445	0.938
10	proton	1	2212	3	-1	-1	-1	0.205	-0.085	0.872	1.300	0.938
11	K0	1	311	3	-1	-1	-1	-0.122	0.032	-0.091	0.521	0.498
12	neutron	1	2112	3	-1	-1	-1	0.095	0.009	0.046	0.946	0.940
13	proton	1	2212	3	-1	-1	-1	0.052	-0.086	-0.002	0.944	0.938
14	gamma	1	22	3	-1	-1	-1	-0.001	0.001	-0.000	0.001	0.000
15	gamma	1	22	3	-1	-1	-1	-0.000	-0.000	0.000	0.000	0.000
Fin-Init:								0.114	-0.115	-0.068	10.220	
Vertex:		nu_mu @ (x = 0.00000 m, y = 0.00000 m, z = 0.00000 m, t = 0 s)										
Err flag [bits:15->0] : 0000000000000000				1st set:				none				
Err mask [bits:15->0] : 1111111111111111				Is unphysical: NO		Accepted: YES						
sig(Ev) =		2.6554e-40 cm^2		dsig(Ev;{K_s})/dK =		1.6985e-41 cm^2/{K}		Weight =		1		

Legend for Following Plots

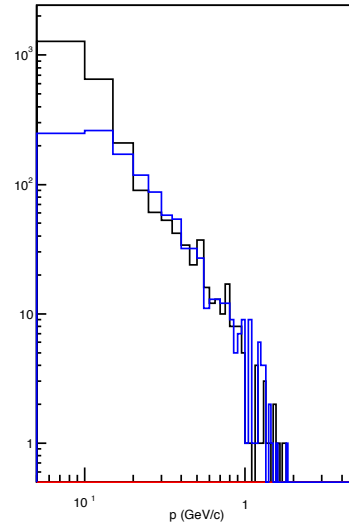
- Black: runs with G4BertCasclnInterface (the Genie class calling Geant4 Bertini)
 - CCQE, NCEL, SingleKaon and DIS event types
 - ^{40}Ar target
- Blue: runs with HAlntranuke (a Genie final state interaction model)
 - otherwise same conditions as above
- Red: runs with no FS interaction
 - otherwise same conditions as above

CCQE

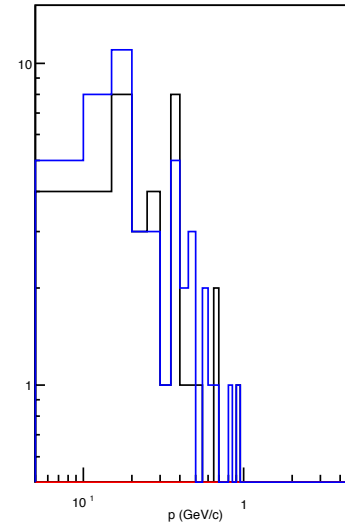
Final State p Momentum



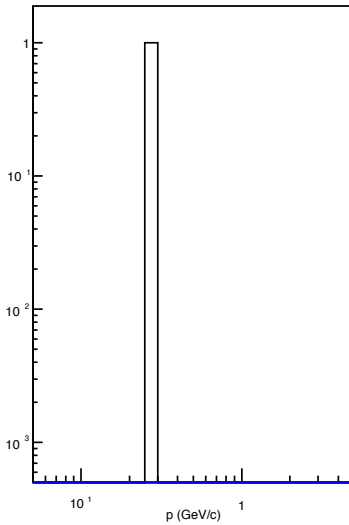
Final State n Momentum



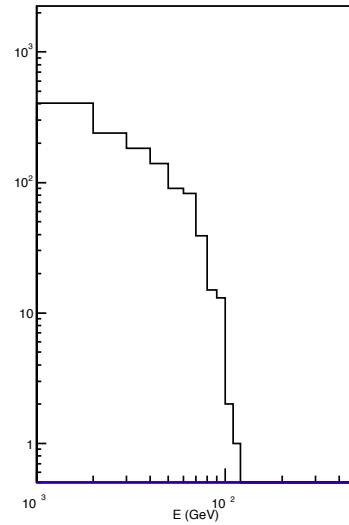
Final State Momentum (pi+, pi-, pi0)



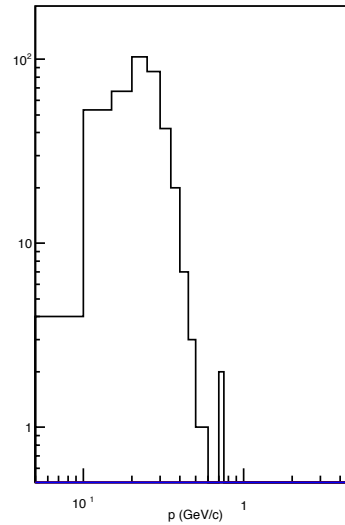
Final State Momentum (K+, K-, K0, K0b)



Final State Gamma Energy

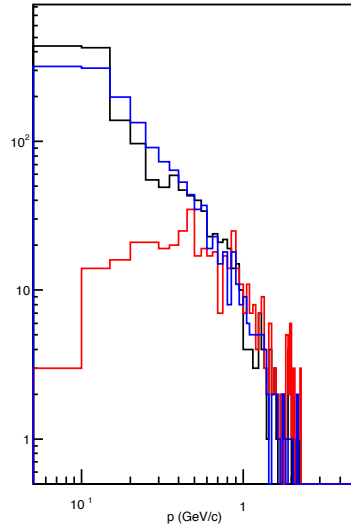


Final State Momentum (d, t, 3He, alpha)

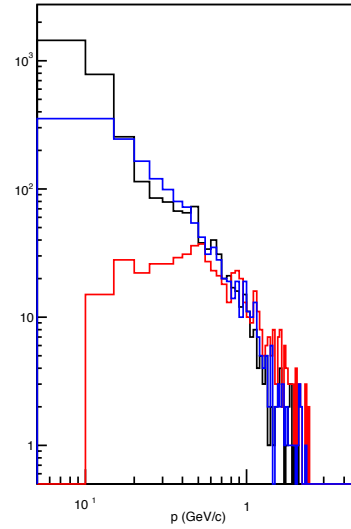


NCEL

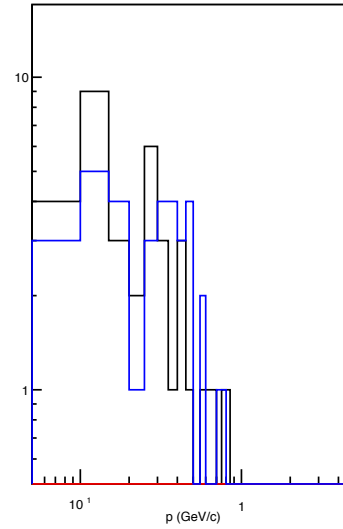
Final State p Momentum



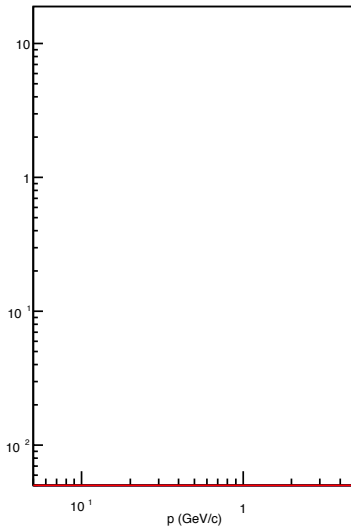
Final State n Momentum



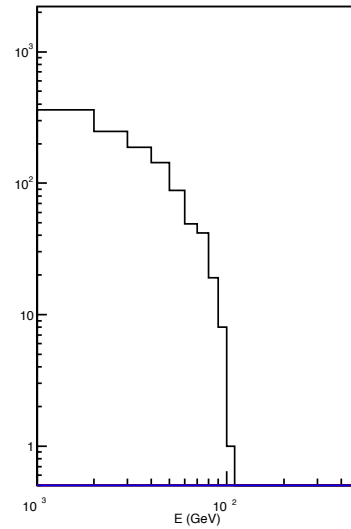
Final State Momentum (pi+, pi-, pi0)



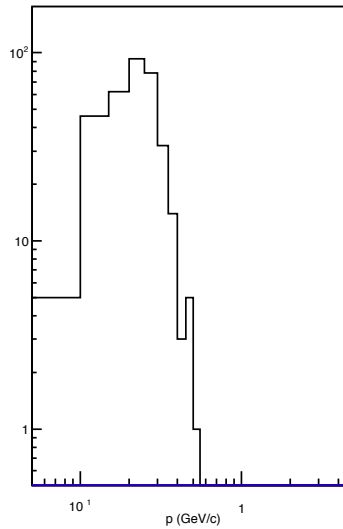
Final State Momentum (K+, K-, K0, K0b)



Final State Gamma Energy

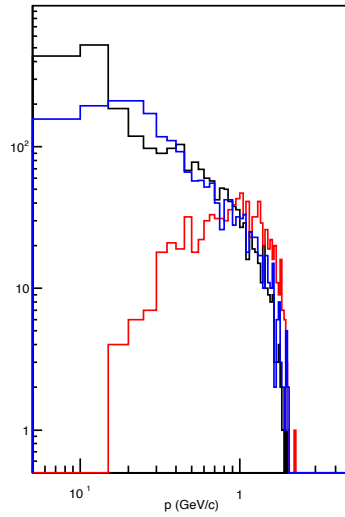


Final State Momentum (d, t, 3He, alpha)

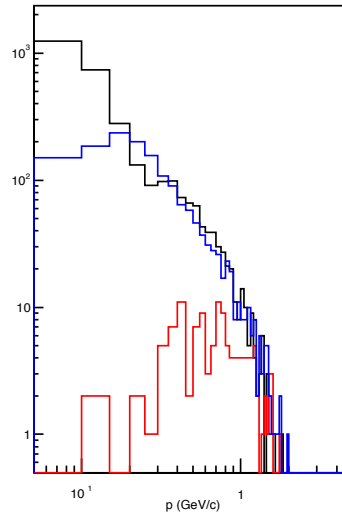


SingleKaon

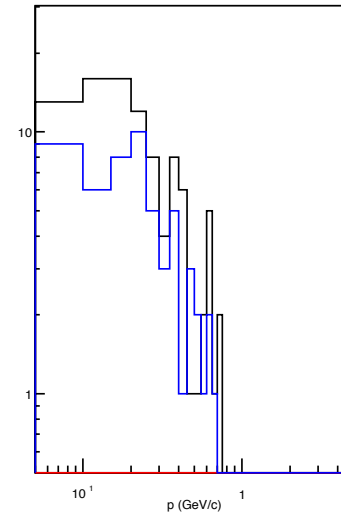
Final State p Momentum



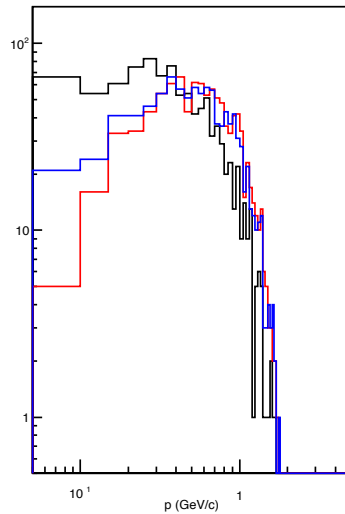
Final State n Momentum



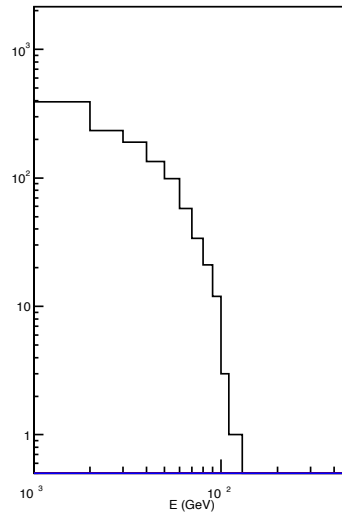
Final State Momentum (pi+, pi-, pi0)



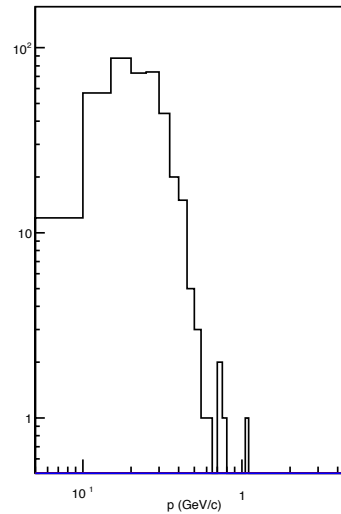
Final State Momentum (K+, K-, K0, K0b)



Final State Gamma Energy

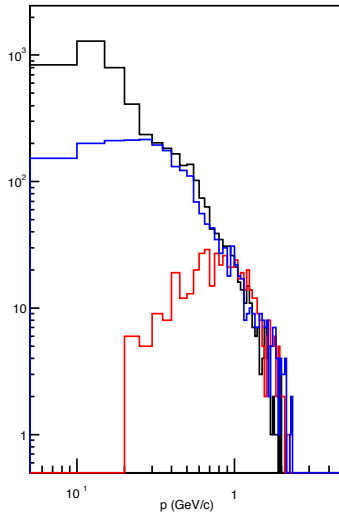


Final State Momentum (d, t, 3He, alpha)

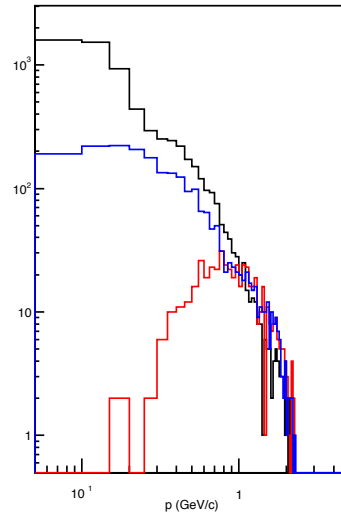


DIS

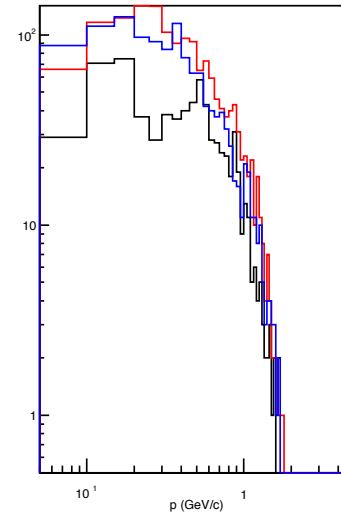
Final State p Momentum



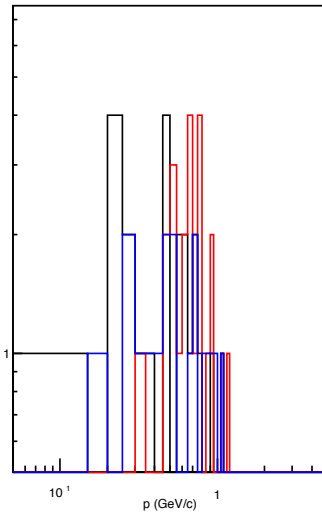
Final State n Momentum



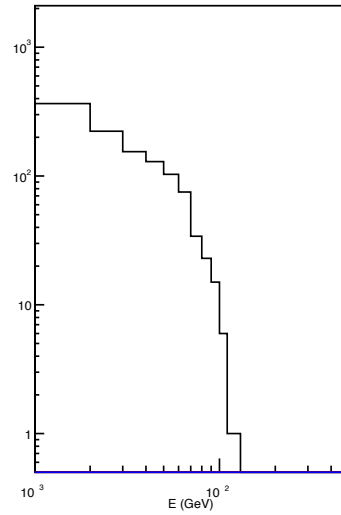
Final State Momentum (π^+ , π^- , π^0)



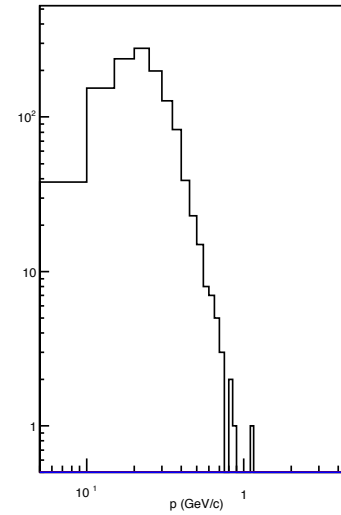
Final State Momentum (K+, K-, K0, K0b)



Final State Gamma Energy



Final State Momentum (d, t, 3He, alpha)



Observations

- For final state nucleons Bertini produces more low energy particles
 - but agreement between Bertini and Genie models is quite good at higher energies
- Final state pion and kaon distributions are in rough agreement
 - except for DIS where pions from initial neutrino interaction are re-absorbed in nucleus in Bertini, but not in Genie model
- Bertini produces final state gammas and nuclear fragments while Genie does not

Next Steps

- Continue testing
 - so far, so good
- Set up scripts so that interface can be easily built and run by Genie users
- Start work on reverse interface: using Genie interactions as Geant4 processes