Fermilab U.S. DEPARTMENT OF ENERGY | Office of Science

Interfacing Electron and Neutrino Quasielastic with Spectral Function in GENIE

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Joint Meeting between Theorists and Experimentalists

Wed Dec 13th

arXiv 2308.15524[nucl-th]

Genie

UNIVERSAL NEUTRINO GENERATOR & GLOBAL FIT

Theory-Generator Interface

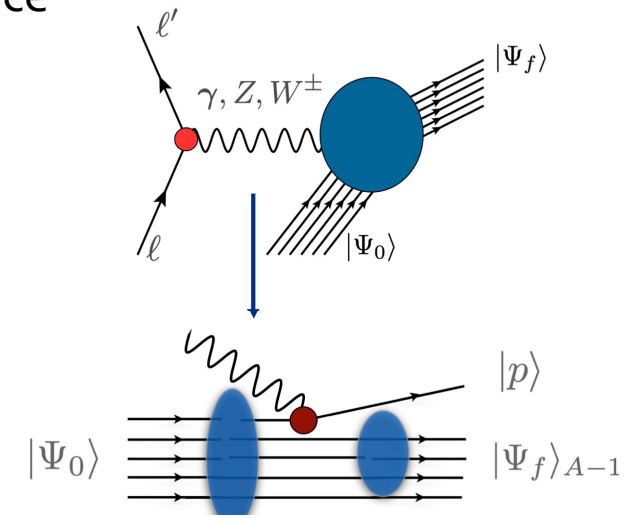
- Goal: Create a flexible interface between theorists existing and validated code and the GENIE event generator

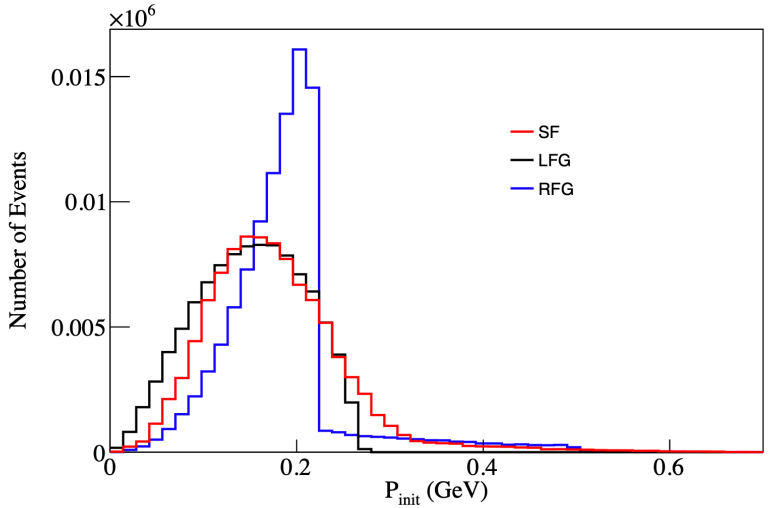
```
//Lets solve the many body problem
#include "MasterTheory.h"
#include "NuclearTheory.h"
#include "QCDTheory.h"

int main(argv,argc) {

    Nucleus Argon(40,18);
    //Now we will actually construct the nuclear current operator
    det_Ja(f1v,f2v,ffa,ffp);

    J_1_V=czero;
    J_1_A=czero;

    for(int mu = 1; mu <= 4; mu++) {
        J_1_V[:,:,mu]=czero;
        J_1_A[:,:,mu]=czero;
         for(int nu = 1; nu <= 4; nu++) {
            J_1_V[:,:,mu]=J_1_V[:,:,mu]+ci*f2v*sigma_munu[:,:,mu,nu]&
                  &     *g_munu(nu,nu)*q(nu)/2.0d0/xmn;
         }
        J_1_V[:,:,mu]=J_1_V(:,:,mu)+f1v*gamma_mu[:,:,mu];

        //Now add axial pieces of current
        J_1_A[:,:,mu]=J_1_A[:,:,mu]+ffa*(gamma_mu[:,:,mu],gamma_mu[:,:,5]);

     }

     //Applying current conservation first to the vector current before adding axial current
     J_1_V[:,:,4] = (q[1]/q[4])*J_1_V[:,:,1];
     J_1 = J_1_V + J_1_A;

}
```

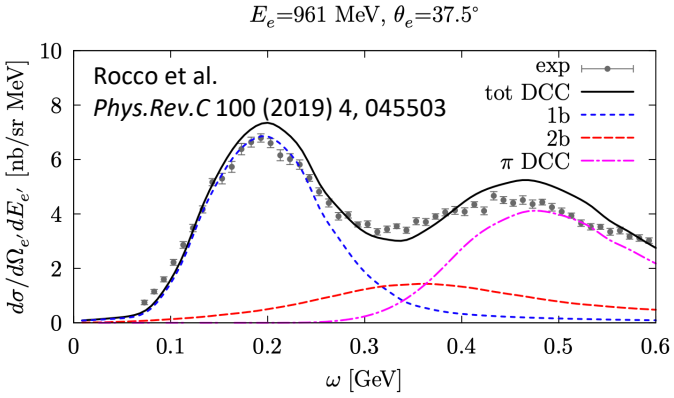
Interface

UNIVERSAL NEUTRINO GENERATOR & GLOBAL FIT

- Test Case: Implement Spectral Function model (written in Fortran) via this interface







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Interface Details:

- GENIE provides kinematic details on initial and final state hadrons

- Theory code computes un-integrated hadronic response tensor
  - Hadronic kinematics retained, useful for exclusive predictions

$$\sigma \sim L_{\mu\nu} R^{\mu\nu}$$

- Abstract base class HadronTensorInterface
  - Returns elements of hadron tensor
  - Interfaces for different languages derive from this class
    - Job is to fill the hadron tensor
    - Call necessary theory code in whichever language

- Currently only Fortran Interface exists, easy to code up in other languages

Lepton-nucleus QE Cross Section model

- Developed Unified cross section model for (e + ν)A scattering
  - Takes advantage of charged lepton & neutrino complementarity
  - Set up calculation based on probe (FF, constants, etc.)

- Hadron Tensor is computed via theory code and passed back to GENIE - Configurable

```
<param type="string" name="TensorModel"> Noemi fortran </param>
```

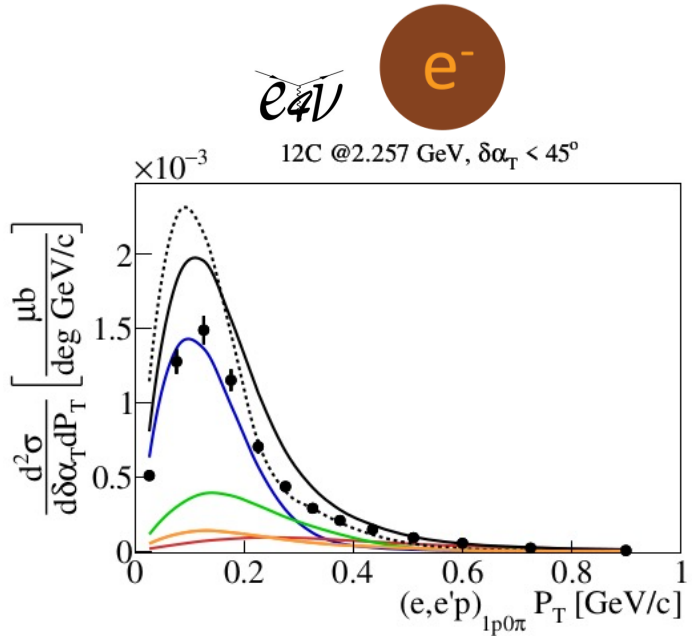
- Configuration parameter determines which theory model

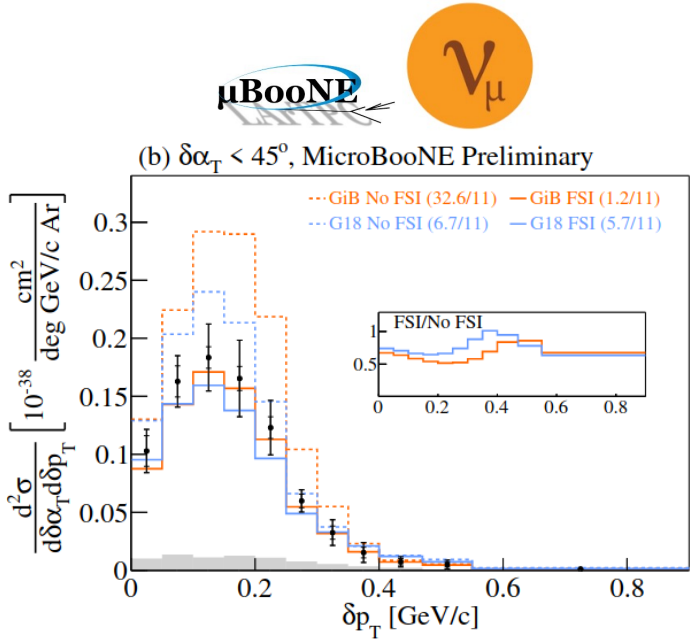
```
if(fTensorModel.find("fortran") != std::string::npos) {

    ATilde_munu = std::make_shared<HadronTensorFortInterface>(qP4.E(),
xmn, p4Ni, p4Nf, fFormFactors, fTensorModel);  }


if (fModel == "Noemi fortran") {

          compute_hadron_tensor_SF(&mNi, &w, &wt, &pNix, &pNiy, &pNiz,
&qtx, &qty, &qtz, &f1v, &xif2v, &fa, &fp, hadron_tensor);}
```





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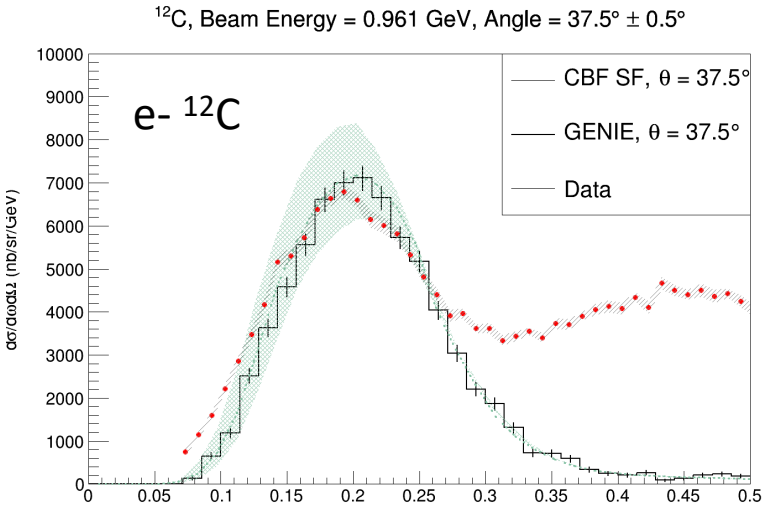
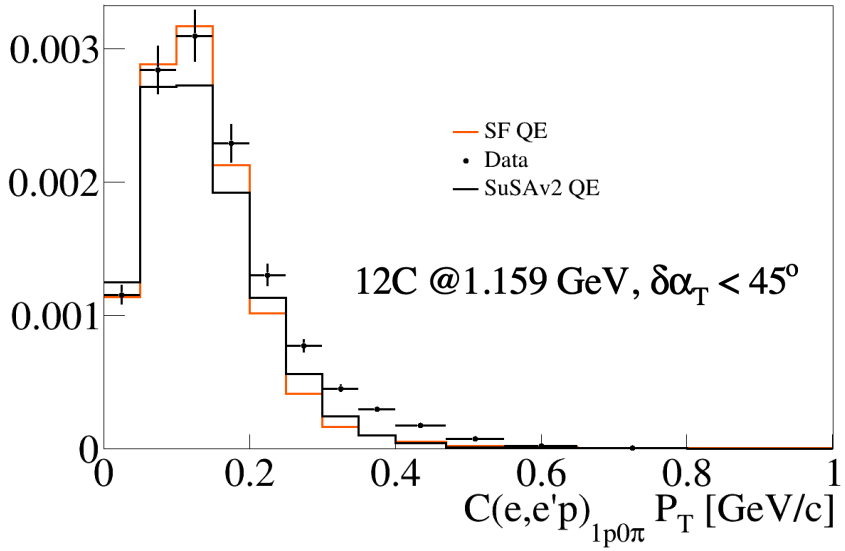
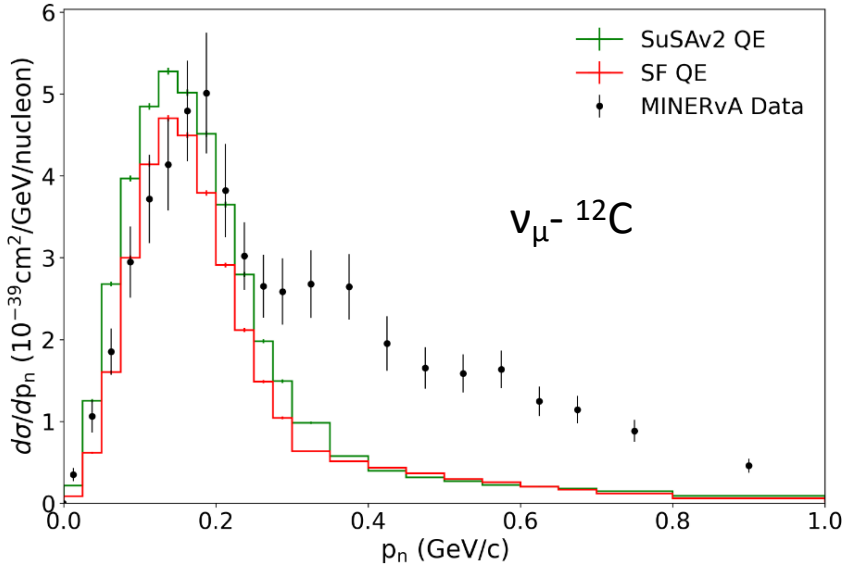
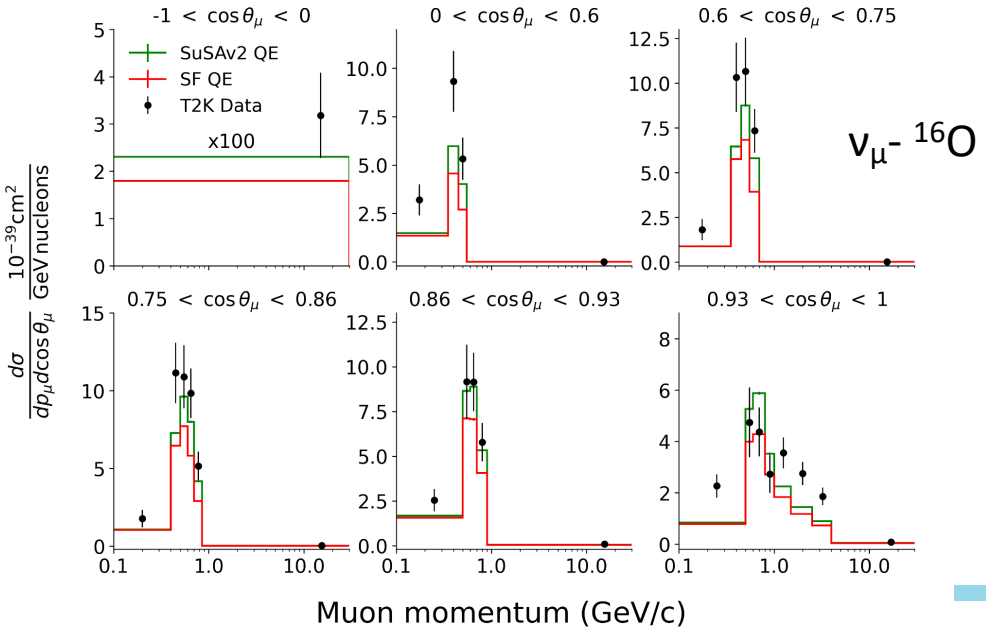
Validation – Inclusive and Exclusive Observables









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Path to Inclusion in Offical GENIE Release

- GENIE leadership have been throughout the development of this work
- Expressed support for inclusion in official release
- Requested to make interface more general for other languages

- Continuing to work with leadership (guided by Steven Gardiner)

Summary

- Created an interface between theorists codes and GENIE for lepton-nucleus QE Scattering

- SF QE model implemented and validated using this interface
  - Spectral Functions for ^{12}C, ^{16}O, ^{56}Fe included

- Details on implementation and physics model accepted for publication in PRD

- Working towards release in an official GENIE version