Tau Polarization in Novel Neutrino Event Generator

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Introduction

Particle physicists use particle event simulators to analyze and compare with results gathered from experiments. Modern accelerator event generators like those for proton-proton events are very advanced whereas event generators for neutrino events are well behind current physics, so a solution is needed. ACHILLES is a novel neutrino event generator that uses quantum mechanics to begin simulating the process that occurs when a neutrino interacts with an atom's nucleus. After this initial hit, called the primary interaction vertex, ACHILLES models the neutrino and knocked particle(s) through the nucleus using semi-classical cascaded (sort of like the balls on a billiards table). This modelling process is how the program generates properties of the final state particles.

Purpose

When there is a final state tau lepton (which decays very rapidly), the polarization of the leptons must be accurately calculated as the decay depends on the polarization. Polarization here is the spin of the particle projected along the direction of momentum. The purpose of this project is to use ACHILLES to study of the tau lepton polarization in charged-current quasielastic (anti)neutrino-nucleus scattering.

Methods

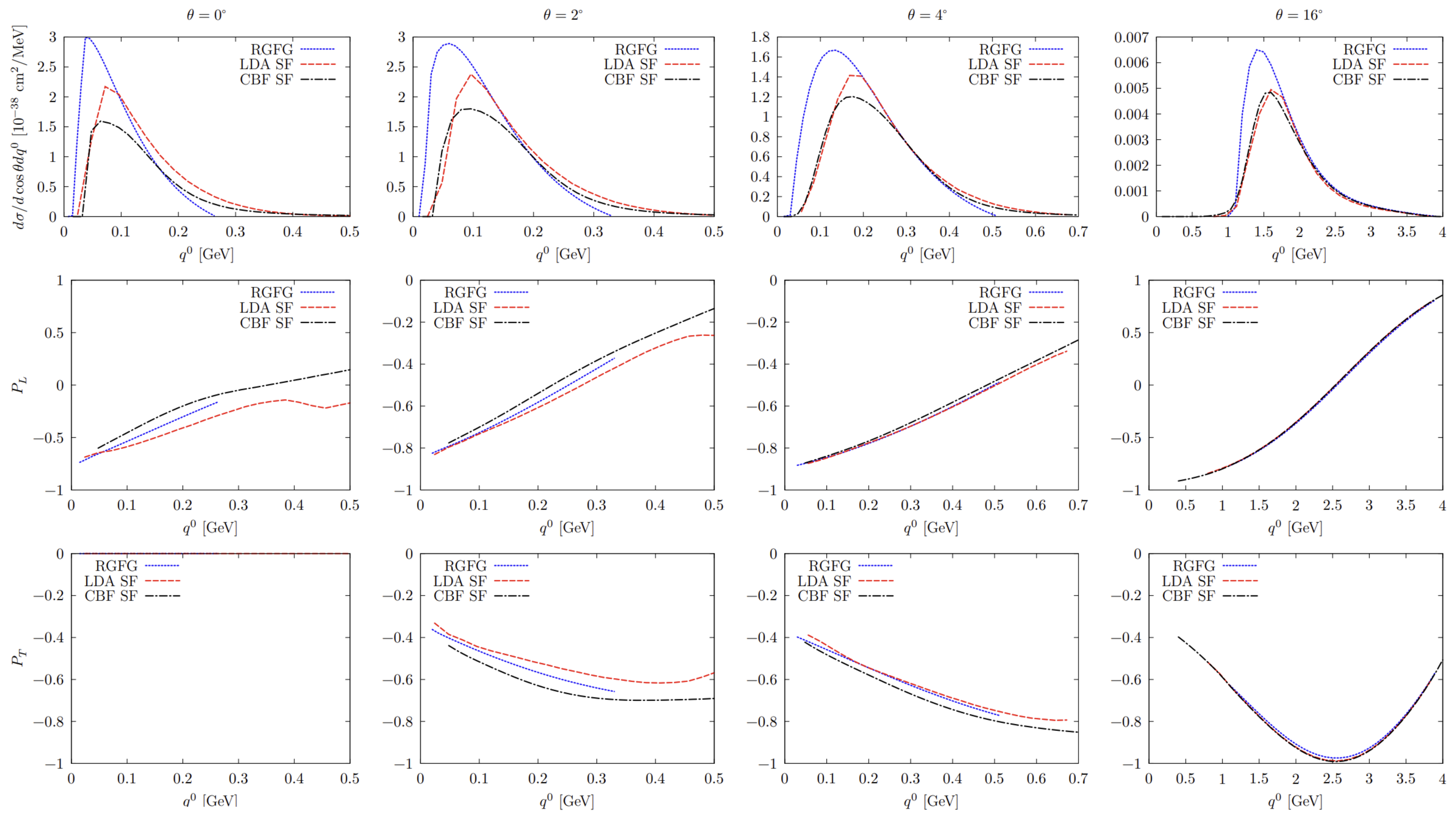
The event generator ACHILLES is written in mostly C++ but also uses Fortran, Python, CMake, and other languages. To calculate the tau lepton polarization the math and main coding was done using C++. However, to check the calculations were correct and to plot the graphs seen in this poster, I used Python and matplotlib. Less importantly, I used VS Code on a windows machine to do the work for this project.

```
if ((amps2[k] != 0) && (amps2[k] == amps2[k])) {
    double coupl2 = pow(Constant::ee/(Constant::sw*sqrt(2)), 2);
    double prefact = coupl2/pow(Constant::MW, 4);
    pL[k] += mult * prefact * constant * real((mass_out*(hLk + gkL - leviL)*hadronTensor[{-24,-24}][k][mu][nu]));
    pT[k] += mult * prefact * constant * real((mass_out*(hTk + gkT + leviT)*hadronTensor[{-24,-24}][k][mu][nu]));
}
else if (amps2[k] == 0) {
    pL[k] = 0;
    pT[k] = 0;
}
```

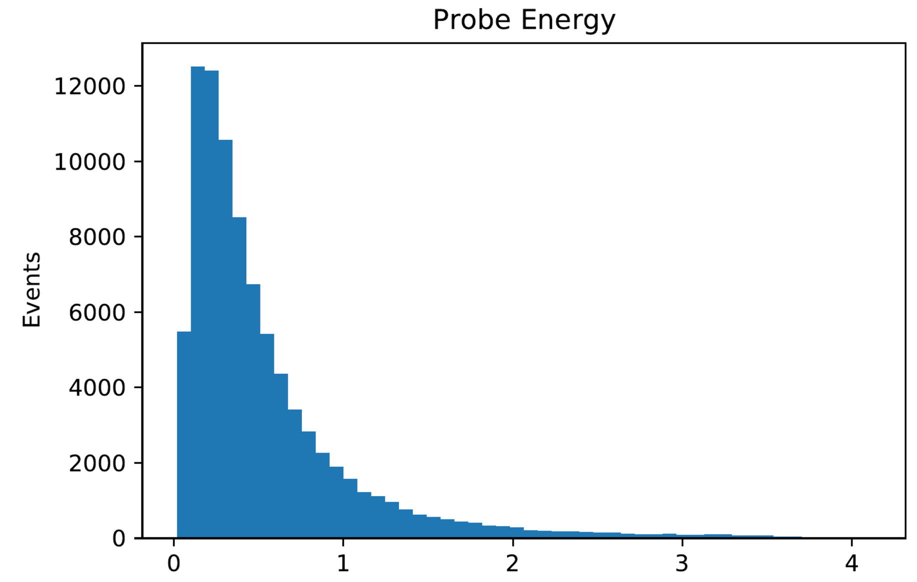
This is a brief snippet of code from the code that calculates longitudinal and tangential polarization

Results and Conclusions

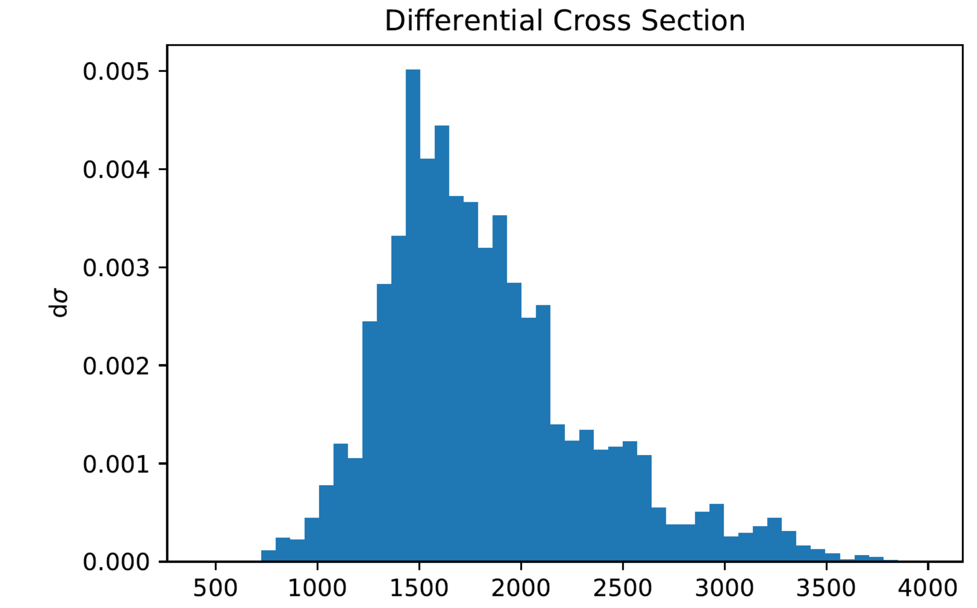
To check if the polarization was calculated correctly, histograms for prob energy, scattering angle, and both tangential and longitudinal polarization as a function of probe energy are currently in the process of being made. Complete and correct plots for these values have not bee completed in time for this poster because of numerous difficulties with the code. These difficulties include getting the units correct for each plot, the learning curve associated with the methods used in this project, and the time constraint of the project. Additionally, the average degree of polarization is being calculated and plotted against neutrino energy. These were cross checked with a paper published by my advisor Noemi Rocco and her collaborators, whose plots are also shown below, so we could see if what I was doing was correct.



Beam, or incoming neutrino energy, is 6 GeV



q_0 is energy of the incoming neutrino minus the energy of the outgoing lepton in GeV.



q_0 is in MeV. Here theta = 16, this is black line of top right plot

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