Radiative Correction Framework
A Quick Start Guide

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February 23, 2022

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0.1 Introduction

This document will walk you through how to use and modify the radiative correction framework starting from creating the particle guns till producing the efficiency ratios required for a fake data study.

The full code is accessible at:
`https://github.com/f-shaker/radiative_correction`
and the generated root files for the analysis are available at:
`https://yuoffice-my.sharepoint.com/:f:/r/personal/fshaker_yorku_ca/Documents/radcorr_root_files?csf=1&web=1&e=BsrP6P`

0.1.1 Framework Overview

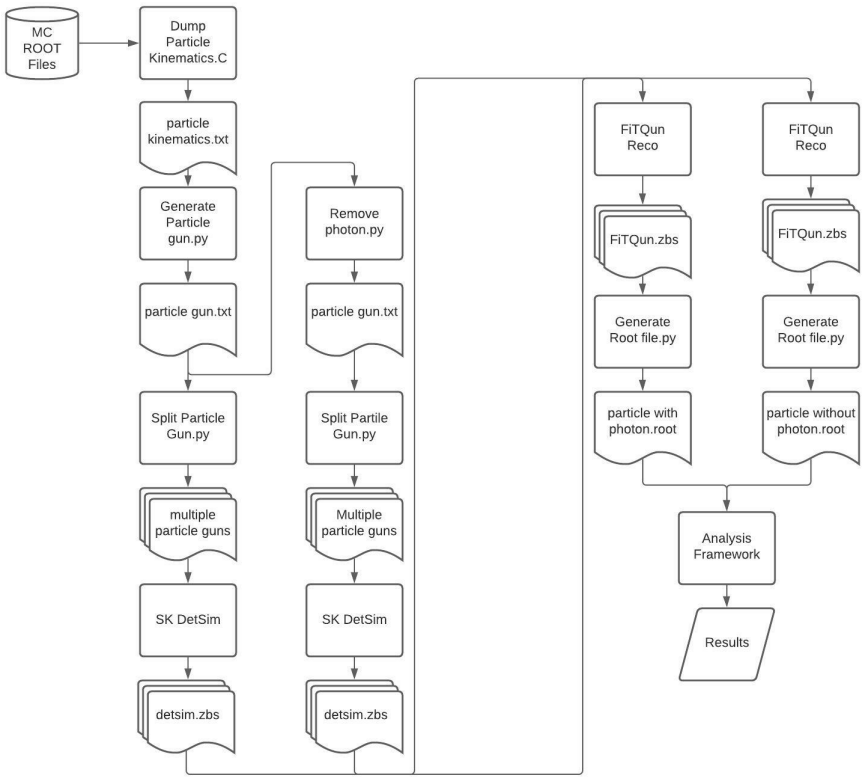

Figure 1: Radiative Correction Framework

0.2 Creating a Particle Gun

0.2.1 Dumping Particle Kinematics

In order to create a realistic particle gun, covering the full SK detector volume, the vertex position and output lepton (μ^-, e^-, μ^+, e^+) kinematics are read for the unoscillated SK MC files. This operation is done on two steps:

1. Adding the MC files to create a single root file through hadd

Listing 1: Combining MC ROOT files

```
python hadd_nu.py --particle=<particle type>
```

where <particle type> can be "nue", "nuebar", "numu" or "numubar" .

2. Dump the content of the single root file into a text file containing the vertex position of a specific interaction (NEUT code) and output lepton total energy and direction. Change the dump_particle_kinematics.C configurations (e.g. input and output files). Then, from ROOT run

Listing 2: Dumping Particle Kinematics

```
dump_particle_kinematics(particle_pdg)
```

At the end of this step, we will have a text file with the following format: Energy dir_x dir_y dir_z vertex_x vertex_y vertex_z

0.2.2 Adding the Photon

The particle kinematics produced from the above step, does not contain any photons. Now, we will add a photon associated with that lepton at the same vertex and conserve energy, so the final output lepton energy = initial output lepton energy + photon energy.

0.3 ROOT Analysis

0.3.1 Creating the Weight Branches

The main idea is to merge the two root files: lepton kinematics with photons (radiative) and lepton kinematics without photon (non-radiative) to produce a realistic particle gun. The created mixed-weighted root file must, at least, has a new branch that indicate if this event is radiative or not. It can also calculate the correct radiative (non-radiative) weight as well as the oscillation probabilities. However this functionality is currently overwritten in the main code. To produce the mixed weight files, use the following function

Listing 3: Creating Weight Branch Example

```
/*void create_weight_branches(std::string in_file_name,
bool is_sim_gamma,
fq_particle i_particle,
bool is_antiparticle)
*/
create_weight_branches("muplus_ginft180_5e4.root",
true, MUON, true);
create_weight_branches("muplus_init_5e4.root",
false, MUON, true);
/* then use hadd -f muplus_g_weighted.root
muplus_ginft180_5e4.root muplus_init_5e4.root */
```

Bibliography

[1] Konosuke Iwamoto. *Neutrino Oscillation Measurements with An Expanded Electron Neutrino Appearance Sample in T2K, 2017.*

[2] Kevin McFarland and Konosuke Iwamoto. *Radiative CCQE and T2k's Oscillation Analyses, 2018*

[3] A. De Rujula, R. Petronzio and A. Savoy-Navarro *Radiative Corrections to High-Energy Neutrino Scattering. Nucl.Phys. B154 (1979) 394. CERN-TH-2593.*