

Dark Matter Physics Simulation and Analysis

Software Design Document

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1. Introduction

1.1 Purpose

The purpose of this software design document is to describe the architecture, data flow, and system design of the Dark Matter Physics Simulation and Analysis Pipeline. The system includes event generation, detector simulation, reconstruction, and data analysis within the EIC Shell.

1.2 Scope

The software will include scripts and other data-extraction programs to be used within the simulation pipeline. The goal is to extract data at the generator and reconstruction levels, invariant masses, compare pseudorapidity, momentum transfers, and scattered electron energies, produce graphs and histograms, and show visualizations of dark matter and its tracks. The software does not modify the EIC framework, but runs and operates within it. Another goal is

1.3 Overview

This document provides definitions of words that will be used, descriptions of the software used, and a visualization of the simulation pipeline that is being followed.

1.4 Definitions and Acronyms

Acronym	Term
EIC	Electron-Ion Collider
ePIC	Electron-Proton/Ion Collider

Term	Definition
MadGraph	Physics command-line interface modeling software
HepMC	Object-oriented C++ event record in High

	Energy Physics, which describes generated events
ROOT	Data analysis framework used to process and visualize high-energy physics data
EIC Shell	Containerized software environment for the Electron-Ion Collider
ddsim	Simulates particle interactions with detector materials

2. System Overview

2.1 Description

The simulation pipeline is a command-line and Linux-based pipeline that executes physics simulations.

2.2 Context and Design

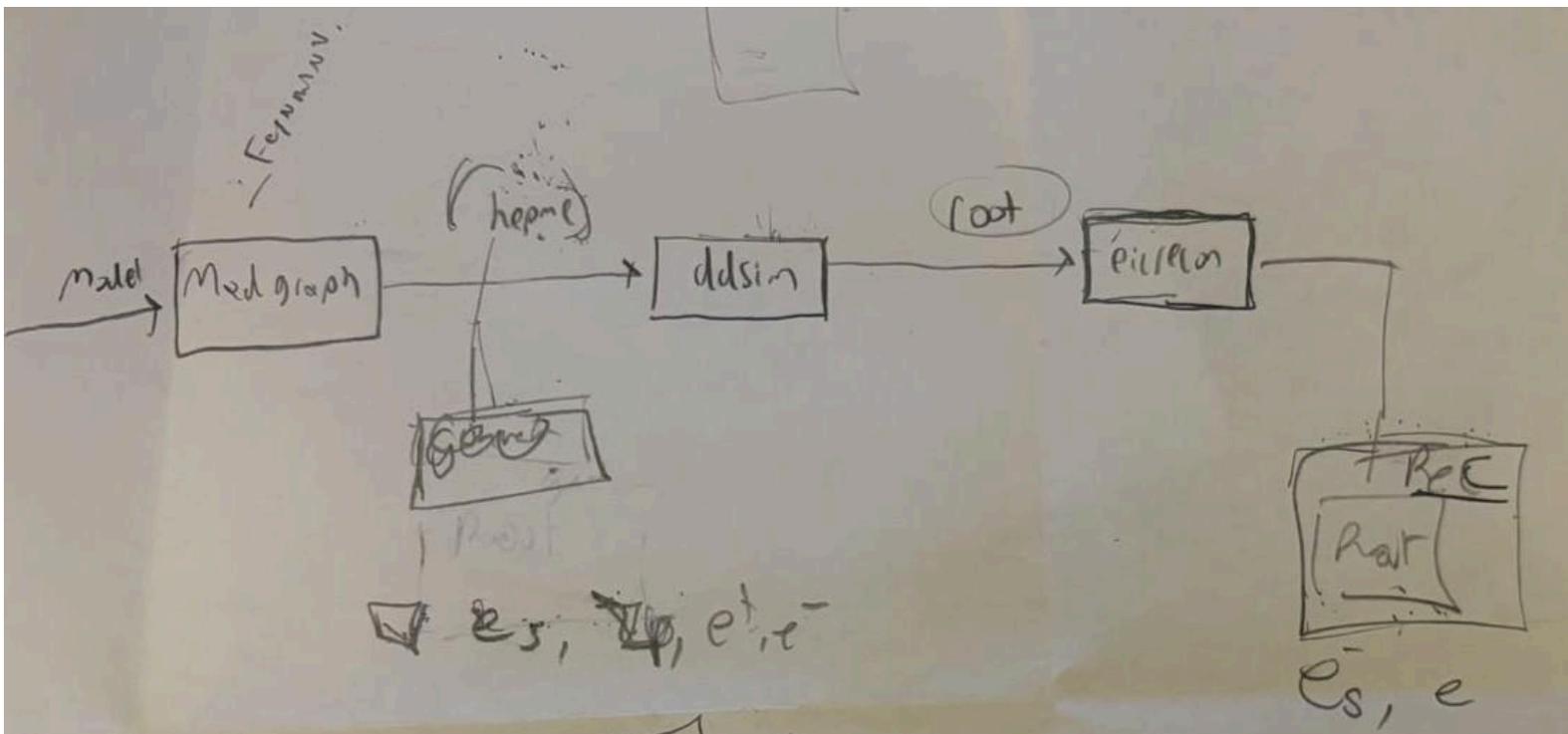
Each component of the simulation relies on the previous output as its input to output the proper information to be used by the next.

2.3 Background

Currently, there is no streamlined or effective way to test the Beyond Standard model Dark matter processes in the current EIC epic detector simulation. This software will be used to use a dark matter model, visualize it within the current EIC visualization, locate the interaction vertices, and obtain other physics quantities as needed.

3. System Architecture

3.1 Architectural Design



3.2 Decomposition Description

For event generation through MadGraph, the input is a dark matter model and particles, and the output is a HepMC file containing: event data, particle IDs/other information, and vertex information. This HepMC file will be analyzed.

For detector simulation through ddsim, the input is a HepMC file, and the output is a ROOT file, containing the reconstructed detector and other quantities. This ROOT file will also be analyzed.

Then, for reconstruction ROOT file is put through EIC for restricted tracks, momentum vectors, and vertices.

3.3 Design Rationale

It is a singular pipeline, and it can only flow in a single direction because each process relies on the last output as its input, and you have to have the same files produced through a simulation, or you risk comparing vastly different data files.

4. Data Design

4.1 Data Description

The main data files are:

HepMC - A readable text file that contains information on particles, particle collisions, events, and vertices.

ROOT - Results of the reconstruction process, transforms simulated data into physical quantities

5. Component Design

Event generation is made up of a selected model and MadGraph, which in turn outputs a HepMC file, which we get analyzed line by line, extract scattered electron energies, and keep track of the number of events to be able to calculate a mean energy.

Detector simulation is made up of the HepMC file and ddsim, which in turn outputs a ROOT file, which is also analyzed.

Reconstruction is made up of the ROOT file and EIC, which in turn will output a reconstructed ROOT file, which will be compared to the original files to ensure that it is correct and nothing happened to the data.