Analysis & Dark Matter Physics Simulation for the Dark Photon

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Faculty Advisor and Client

- Dr. Marcus Hohlmann - Physics Professor

- Pietro Iapozzuto - Graduate Student with Dr. Hohlman

Goal and Motivation

- Creating a software program that Analysis Dark Matter Photon searches for the EIC ePIC detector.

- Currently there is no streamline or effective way to test Beyond Standard model Dark matter processes in the current EIC epic detector simulation . The client would like to be able to have software that can use a dark matter model, visualize it in the current EIC visualization, locate vertices of the interaction and obtain other physics quantities needed.

Approach

1. Visualize the decay products of the dark matter interaction in the EIC Geometry. (Create HEPMC files)
2. Find the most probable dark matter signal (invariant mass, pseudorapidity (eta), location).
3. Correctly perform background subtraction for competing processes (ie Pions).
4. Correct signal matching for the dark matter e+ e-.

Novel Features

- Visualization of the dark matter tracks that is able to be shown and explained to a customer or nontechnical person.
- Background subtraction of user specific dark matter process allowing for matching of dark matter between simulation and real data.

Algorithms and Tools

- Github - Host as our website and version control
- Mad Graph - CLI Modeling Software
- HepMC - Object oriented C++ event record in High Energy physics
- ROOT - Data analysis framework to create histograms, can work as a python library
- EIC Shell - Containerized software environment for the Electron-Ion Collider
- Python - Programming language
- Fortran Compiler - To run “launch” inside of Mad Graph
- Discord and Google Chat - Group communication

Technical Challenges

- We will use a lot of commands through the CLI and will have to manage them so we use the right commands with the software we are working with at that time
- It will be necessary to use Mad Graph, HepMC, and EIC and the processes between them to create diagrams of particles, but we will need to learn completely from scratch on how to use these
- Also necessary to use ROOT and identify Dark photon and decay products, will need to understand how to use this software

Milestone 1

- Learn and understand how to use Mad Graph, HepMC, and ROOT
- Read HepMC files
- Use ROOT to identify particle id numbers ie 1023 is dark photon candidate as a parent particle and its decays (children) and graph physics related quantities ie Momentum of scattered particle
- Install EiC RECO and use EIC Geometry, NPSIM to output reconstruction root file
- Use ROOT to graph signals of initial proton and electron, the scattered electron and decay products at the madgraph generator level, and compare it to the EIC reconstruction level.
- Produce EIC visualization using inner detector obtaining dark matter decay product e-e+ tracks
- Using HepMC file data, produce a Python script that works along with ROOT to produce histograms of scattered electron energy
- Create Requirement Document
- Create Design Document
- Create Test Plan

Milestone 2

- Complete graph of background subtracted signal of dark matter at the end of the EIC pipeline.
- Explore 10-20 different invariant masses, running them through simulation pipeline, visualization to identify most probable dark matter invariant mass, and incorporating the background subtracted

Milestone 3

- Streamline the process
- Get cross section comparison at generator level, at reconstruction level, Pseudorapidity (Eta), momentum transfer for each invariant mass that is put in pipeline and a visualization of tracks

Milestone 1 Task Matrix

Task	Nikhil	Sam	Jacob
Learn and understand how to use Mad Graph, HepMC, and ROOT	1/3	1/3	1/3
Start reading HEPMC files	1/3	1/3	1/3
Use ROOT to identify particle id numbers ie 1023 is dark photon candidate as a parent particle and its decays (children) and graph physics related quantities ie Momentum of scattered particle	1/3	1/3	1/3
Install EiC RECO and Use EIC Geometry, NPSIM to output reconstruction root file	1/3	1/3	1/3
Use ROOT to graph signals of initial proton and electron, the scattered electron and decay products at the madgraph generator level, and compare it to the EIC reconstruction level	1/3	1/3	1/3
Produce EIC visualization using inner detector obtaining dark matter decay product e- e+ tracks	1/3	1/3	1/3
Using HepMC file data, produce a Python script that works along with ROOT to produce histograms of scattered electron energy	1/3	1/3	1/3
Requirement Document	1/3 *	1/3	1/3
Design Document	1/3	1/3 *	1/3
Test Plan	1/3	1/3	1/3 *

Any Questions?