Probing the Internal Structure of the Proton

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Introduction

Atoms are made of **protons**, **neutrons**, and **electrons**. In the 1960s, physicists discovered that protons and neutrons were not fundamental particles, but rather made up of **quarks**. Quarks are fundamental particles described by the **Standard Model of Particle Physics.** Here we are interested in studying the distribution of quarks within protons (relative position, momentum, spin...)

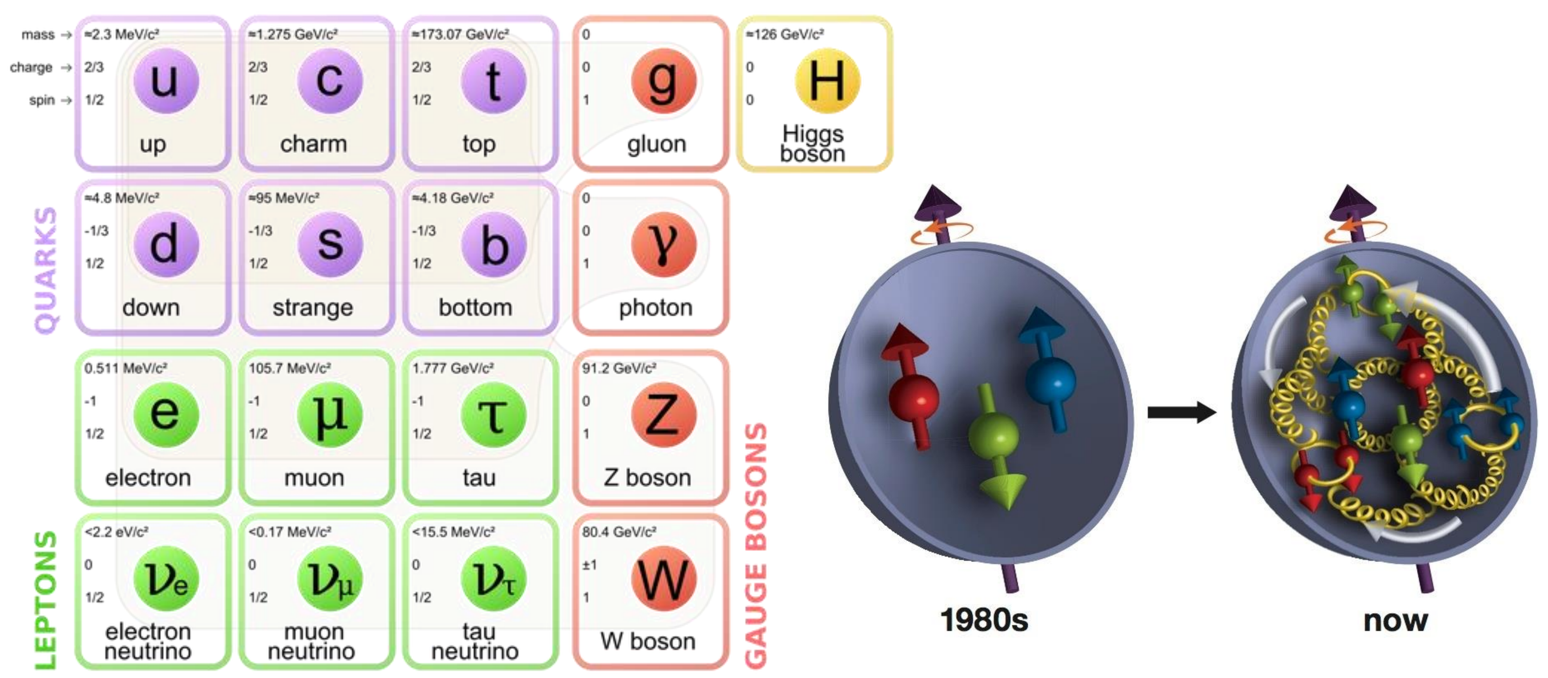
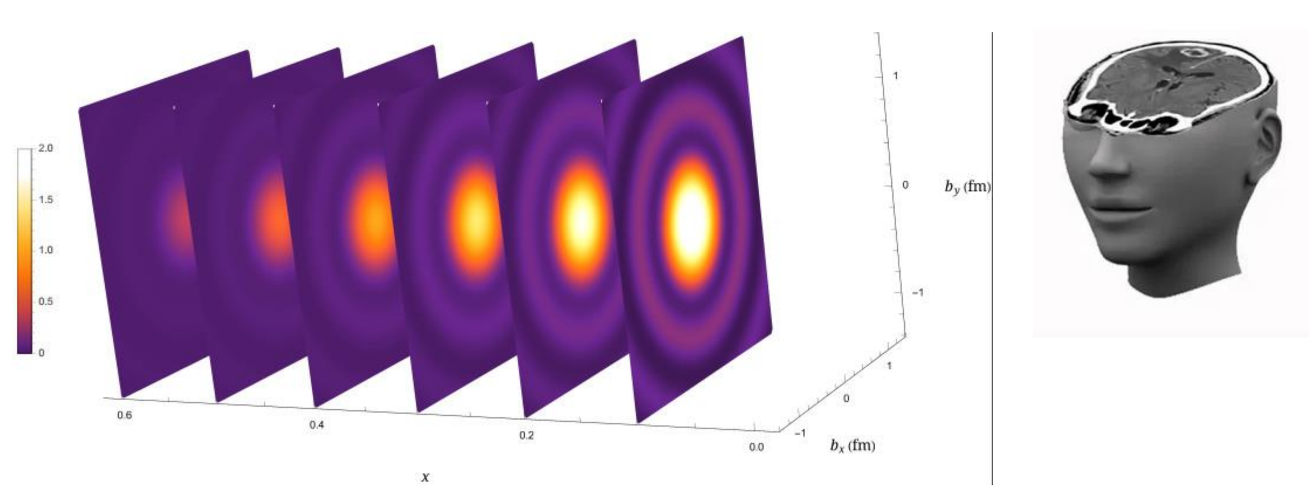


Figure 1. The Standard Model of Particle Physics with a diagram of quarks inside a proton.

Generalized Parton Distributions (GPDs)

- Goal: multidimensionnal parametrization of the proton's internal structure in terms of quarks and gluons ("proton imaging")
- "Structure functions" can be measured in high energy reactions. For instance, GPDs contain the correlation between quarks' positions and their longitudinal momenta ("3D" picture)



Each slice represent quarks' positions for a different momentum => tomography of the nucleon

- GPDs are measured in "hard" exclusive reactions (all products are known), at an energy scale accessing quarks. We study one of them: DDVCS

Double Deeply Virtual Compton Scattering (DDVCS): e- P -> e- P μ- μ+

- We need to detect an electron a proton and a muon pair
- There is no muon detector at JLab: we are developing it There are 2 **main challenges**: they don't deposit much energy on detectors, and they are difficult to identify from background of another particle called "pion"

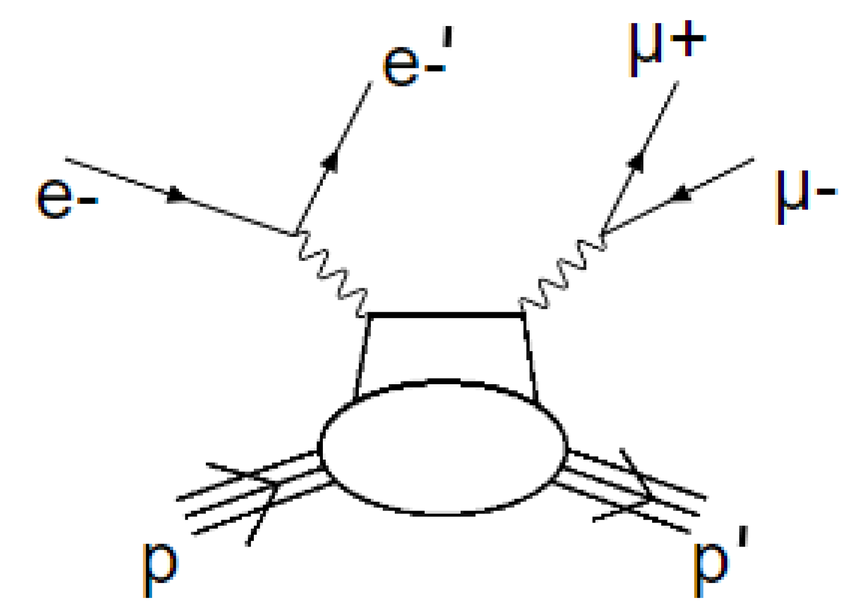


Figure 3. Double Deeply Virtual Compton Scattering.

Muon detector Simulations

We use **Geant4** software package for simulating the passage of particles through matter and to have a mock-up of our proposed detector design, for muon detector R&D

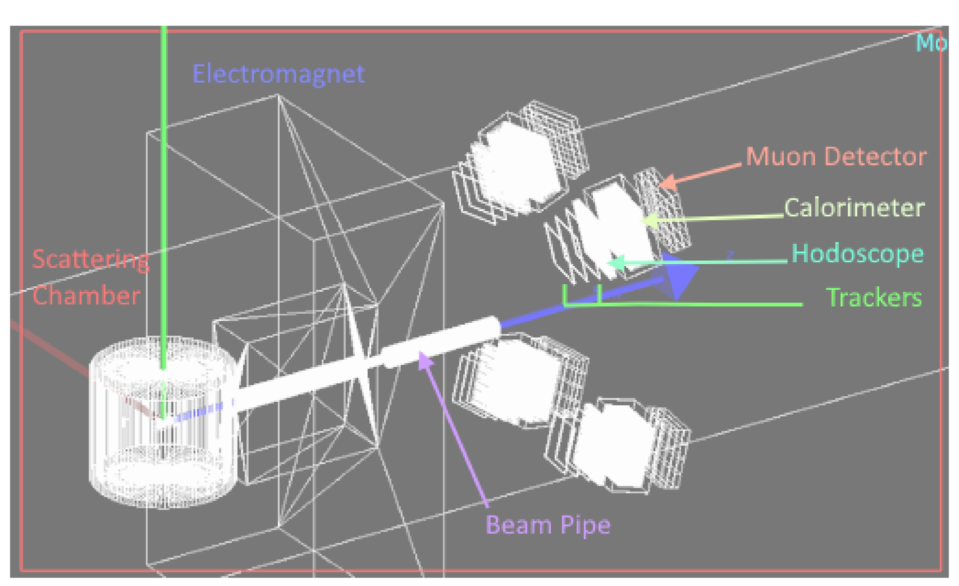


Figure 4. Preliminary design of the experiment setup for DDVCS at Jefferson Lab in Hall C.

The current idea for separating muon events from pion events is to have multiple layers of an absorber, like Iron, and scintillators. Pion and muon are stopped at different rates.

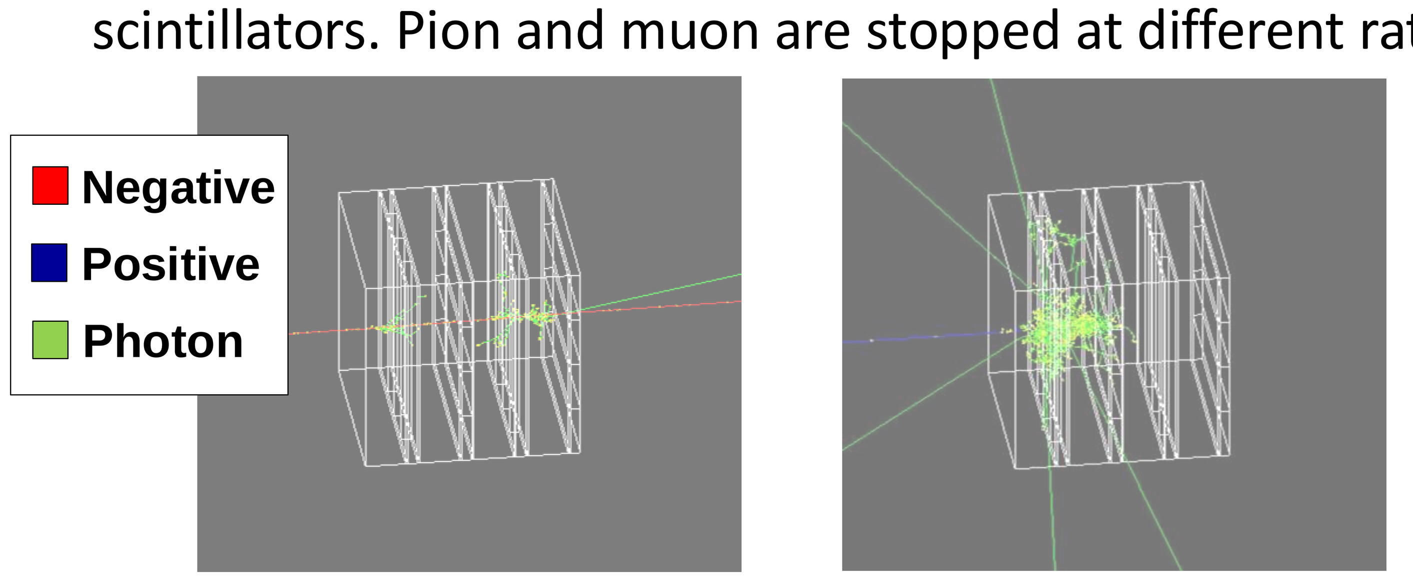


Figure 5. Example simulation of the muon detector component from the full experiment setup

Results

Muons deposit overall less energy in the detector than pions. We can block the pions with a thick layer of Iron, while the muons will mostly pass through. The energy range of incoming pions is expected to be around 0.2 GeV to 6 GeV. To stop 90% of 4-GeV pions from reaching the scintillator, roughly one meter thick of Iron is required.

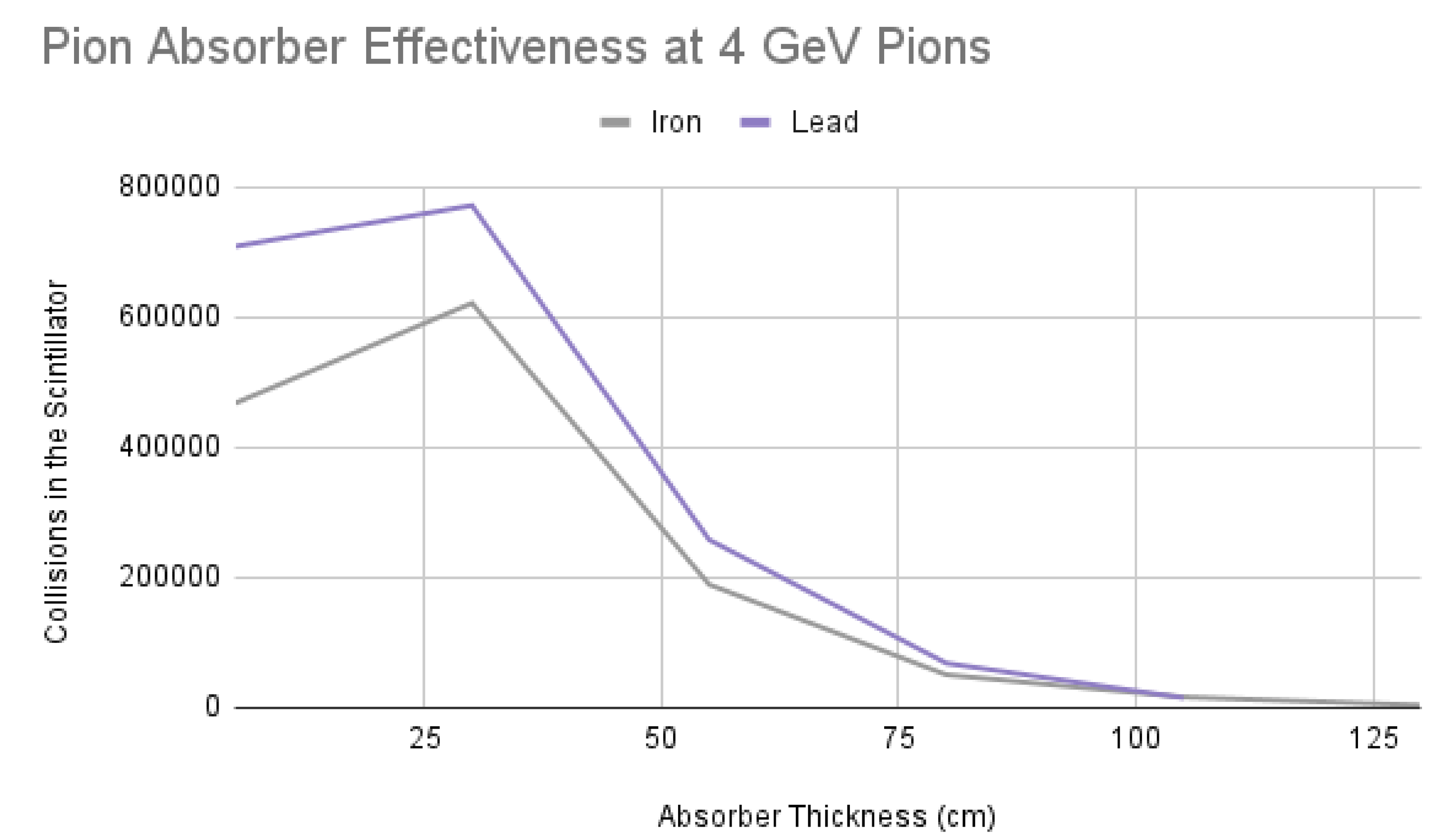


Figure 6. The number of particle collisions in the scint-illator decreases as we increase the absorber thickness

Summary

Studying Double Deeply Virtual Compton Scattering DDVCS (among other interactions) would provide excellent insight on the internal structure of protons. To study DDVCS, the detection of muons is necessary. The main challenge to detecting muons in an experiment is the background of pions that are produced from other interactions. Pions make more interactions in matter which enables the separation of muons and pions in detectors. As we proceed, we will work to optimize the detector geometry and detector placement within the hall. DDVCS has never been measured and JLab Hall C doesn't have a muon detector: this project is challenging but will bring unique information about the proton.

Acknowledgments

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References

[1] M. Guidal, M. Vanderhaeghen, Phys. Rev. Lett. 90, 012001 (2003).