Pion Interactions with Proton and Carbon Targets using PYTHIA8

Isidora Carreño Salinas and Roberto Martínez Naranjo
Andrés Bello University

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Abstract

In this project, we simulate π− collisions at 40.8 GeV and 48 GeV with a proton and carbon at rest using Pythia8.3.13 and Angantyr, HardQCD, and SoftQCD physics scenarios. These configurations were chosen for direct comparison with experimental data, ensuring a robust validation of our simulations. We analyze the π0 production. Detail description of the models used for the π0 is presented.

Introduction

Pion charge-exchange reactions are a crucial experimental approach for investigating strong interactions. These reactions, characterized by processes such as

$$\pi^- + A(Z) \rightarrow \pi^0 + A(Z-1)$$

That process allow us to explore both perturbative (HardQCD) and non-perturbative (SoftQCD) regimes of QCD. By studying these interactions, we gain valuable insights into the dynamics of hadronic and nuclear systems.

Using PYTHIA8, HardQCD and SoftQCD

PYTHIA8 employs HardQCD to model high-momentum transfer processes, such as hard scattering and jet production, and SoftQCD for low-momentum transfer interactions, including hadron formation and fragmentation. Together, these regimes provide a comprehensive description of hadronic collisions, from initial particle production to the final-state fragmentation dynamics.

Using PYTHIA8 and its module Angantyr

With the Angantyr module, PYTHIA8 extends its capabilities to simulate hadronic collisions involving nuclei, such as π^- + ^{12}C and π^- + p. This module models pion production (π^0, π^+, π^-) and fragmentation dynamics, enabling the analysis of cross sections, decay channels, and energy-momentum transfer in complex nuclear systems.

Aspect	$\pi^- + p^+$	$\pi^- +^{12} C$
Main interaction	Single-proton collision	Collision with multiple nucleons
Cross section	Fixed hadron-hadron cross-section	Core-fitted cross-section
Production mechanism	HardQCD describes the partonic interaction	Angantyr models the interaction with the whole kernel
Fragmentation and hadronization	Fewer particles produced	More particles due to multiple interactions
Nuclear effects	No absorption or scattering in a nuclear medium	Absorption, scattering and nucleon ejection are included

Table 1. Comparison between the collision $\pi^- + p^+$ and the collision $\pi^- +^{12} C$.

Results

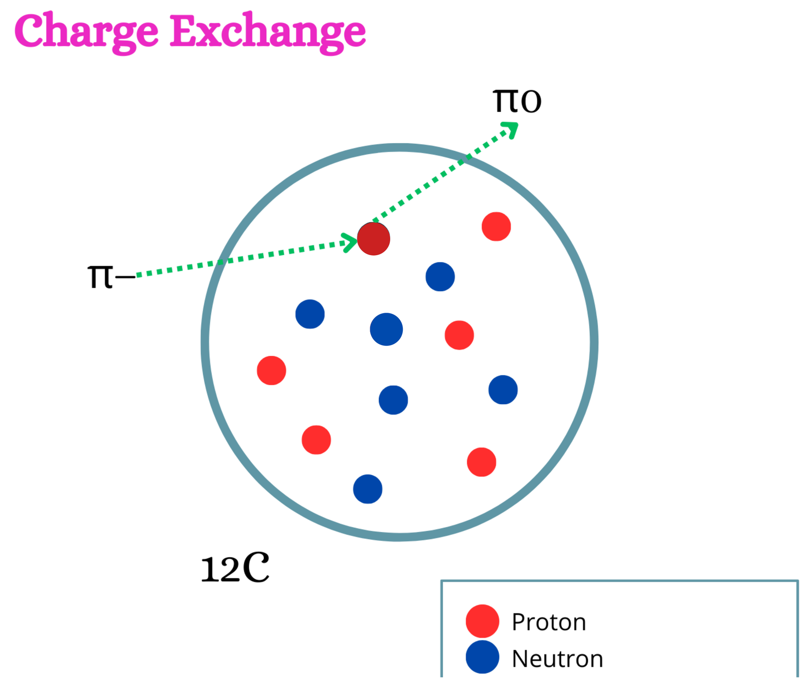
The chosen configurations allow future comparison with experimental data [1,2]. The selected channels consider final state interactions (FSI) with pions. Future analysis will involve estimating the differential cross section.

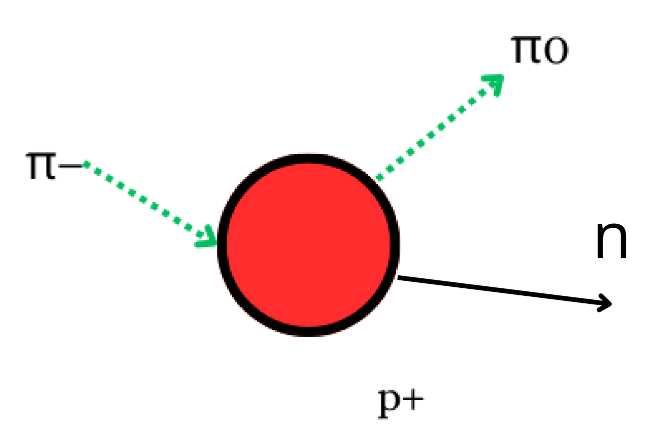
Table 2. Comparison between the collision $\pi^- + p^+$ and $\pi^- +^{12} C$ using SoftQCD

Variable	**40.8 GeV** $\pi^- p^+$	**40.8 GeV** $\pi^- +^{12} C$	**48 GeV** $\pi^- p^+$	**48 GeV** $\pi^- +^{12} C$
Average number of particles per event	≈ 208	≈ 309	≈ 236	≈ 207
Percentage of π^0 (%)	≈ 28.71%	≈ 28.62%	≈ 41.51%	≈ 29.46%
Percentage of π^+ (%)	≈ 24.44%	≈ 25.33%	≈ 26.66%	≈ 12.88%
Percentage of π^- (%)	≈ 22.76%	≈ 20.66%	≈ 13.34%	≈ 14.37%

Table 3. Comparison between the collision $\pi^- p^+$ and $\pi^- +^{12} C$ using Hard QCD

Variable	**40.8 GeV** $\pi^- p^+$	**40.8 GeV** $\pi^- +^{12} C$	**48 GeV** $\pi^- p^+$	**48 GeV** $\pi^- +^{12} C$
Average number of particles per event	≈ 106	≈ 237	≈ 102	≈ 279
Percentage of π^0 (%)	≈ 54.49%	≈ 35.48%	≈ 54.48%	≈ 36.45%
Percentage of π^+ (%)	≈ 26.74%	≈ 27.29%	≈ 17.74%	≈ 9.33%
Percentage of π^- (%)	≈ 23.26%	≈ 22.71%	≈ 20.21%	≈ 10.40%





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