FERMILAB-POSTER-20-062-T

A Novel Approach for the Intranuclear Cascade

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This manuscript has been authored by Fermi Research Alliance, LLC under Contract No. DE-AC02-07CH11359 with the U.S. Department of Energy, Office of Science, Office of High Energy Physics.

Abstract

- Traditional Intranuclear Cascades assume point like interactions → neglects interaction range
- Propose new algorithm using:
  - Nuclear configurations
  - Model for wavefunction overlap
- Compare approach to traditional Mean Free Path Algorithm in:
  - pC cross-sections
  - Nuclear transparency

Introduction

- Intranuclear cascades describe transition from a hard interaction to the final state
- Comprises propagation of nucleons from the inside to the outside of the nucleus
- Essential for understanding:
  - Electron-nucleus scattering experiments
  - Neutrino oscillation experiments
  - Dark Matter searches
- Intranuclear cascades need proper modelling of:
  - Hadron-nucleon scattering cross-sections
  - Fermi statistics via Pauli Blocking
  - Nuclear potential
- Here we propose a new algorithm using:
  - Pre-determined nucleon positions
  - Pauli blocking effects
  - Geometric interpretation of the nucleon-nucleon cross-sections

Theory: Configurations

Generate nuclear configurations according to:

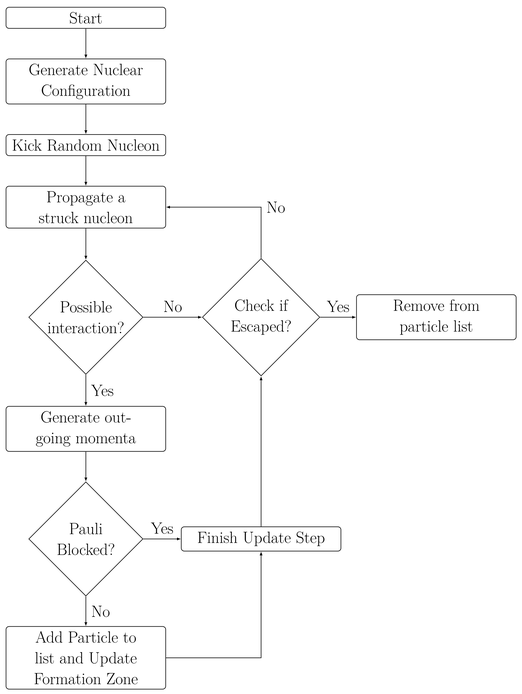
1. Nuclear density
2. Nuclear correlations (optional)

This can be done using Quantum Monte Carlo [1], or Mean Field approaches

Theory: Geometric Method for Cross-Sections

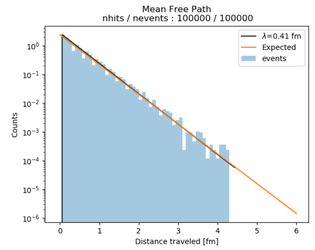
- Interpret cross-sections as a probability of interacting via wavefunction overlap
- Require: $P(b=0)=1$, b is the impact parameter
- Require: $\int_0^{2\pi}\int_0^{\infty} bP(b)d\phi db = \sigma$
- Model wavefunction overlap modeled with:
  1. Cylinder:
  $$P_{\rm cyl}(b) = \Theta\left(\sigma/\pi - b^2\right)$$
  2. Gaussian:
  $$P_{Gau} = \exp\left(-\frac{\pi b^2}{\sigma}\right)$$

Algorithm



Mean Free Path Validation

Fix density and nucleon cross-sections:

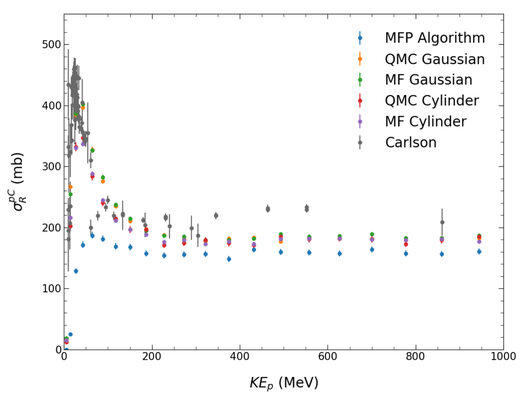


Calculation Set-Up

- Use elastic pp and pn cross-sections [2]
- Calculations considered:
  1. Mean Free Path(MFP) Algorithm [3]
  2. Configuration based Algorithm using:
     1. Quantum Monte Carlo (QMC) or Mean Field (MF) configurations
     2. Gaussian or Cylinder interaction probabilities

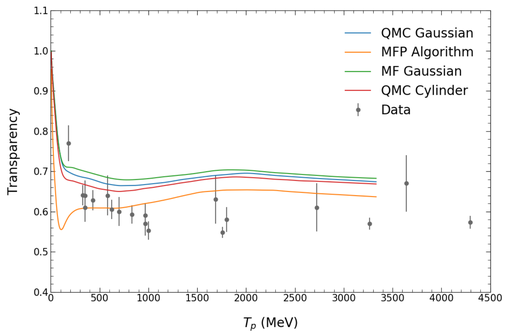
Cross-Section Results

- p-Nucleus scattering used to test cascade models
- Two Pieces: $\sigma_{\rm tot} = \sigma_r + \sigma_{el}$
- Below: Comparison of σ_r data [4] to different cascade models for $p + C \to X$



Transparency Results

$$\text{Transparency} = \frac{N_{no\ FSI}}{N_{total}},$$



Data is from: [5, 6]

Conclusion & Future Work

- Proposed new algorithm based on configurations for cascades
- Include the effects of inelastic scattering (pion cascade), which is important at high energy

References

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