Analysis of electron scattering data to constrain neutrino scattering

Graham Chambers-Wall,[1] Afroditi Papadopoulou,[2] Steve Dytman,[3] and Minerba Betancourt,[4]
[1]William Jewell College, [2]Massachusetts Institute of Technology, [3]University of Pittsburgh, [4]Fermilab

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Introduction

- Accelerator-based neutrino oscillation experiments require a precise understanding of neutrino-nucleus interactions to extract fundamental parameters [1].
- Electron and neutrino scattering modes are similar in the quasi-elastic (QE) regime, so monoenergetic electron beams can be used to constrain nuclear models [2].
- We used data from CLAS at Jefferson Lab and the Monte Carlo (MC) event generator GENIE to calculate transparencies for protons emitted in QE scattering.

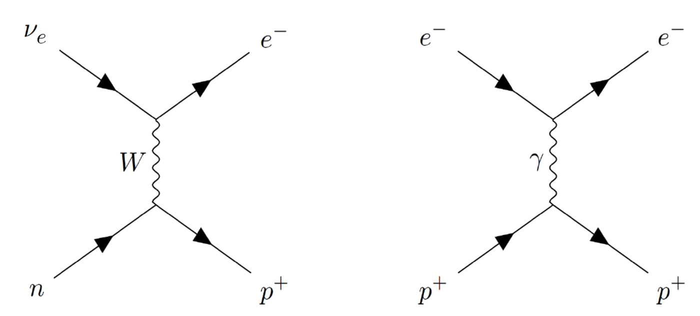


Fig. 1: Feynman diagrams for neutrino (left) and electron (right) QE scattering.

CEBAF Large Acceptance Spectrometer

- CLAS detects scattered particles from high-energy electron-nucleus collisions.
- The large acceptance of the detector allows measurements of momentum and angles of most particles produced in the collisions.

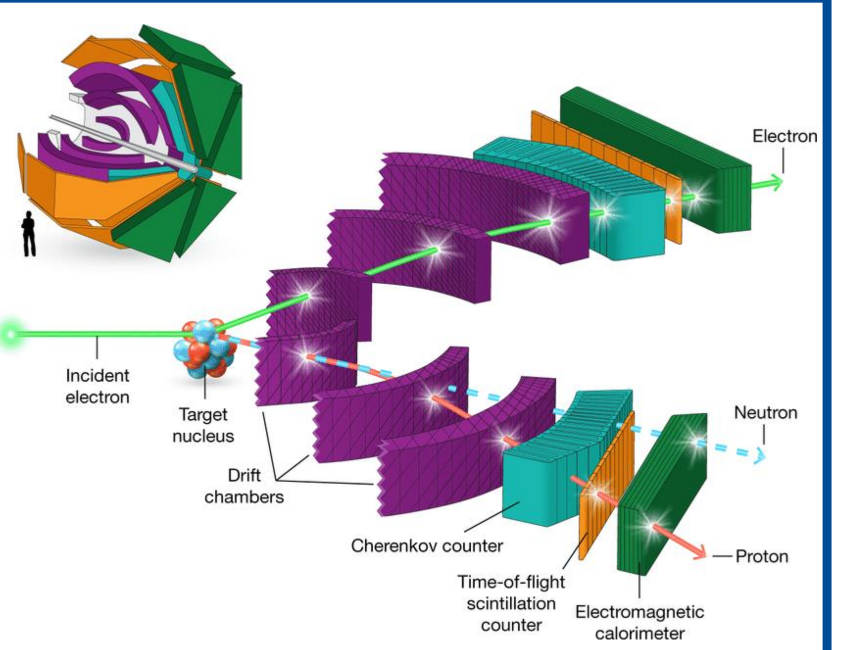
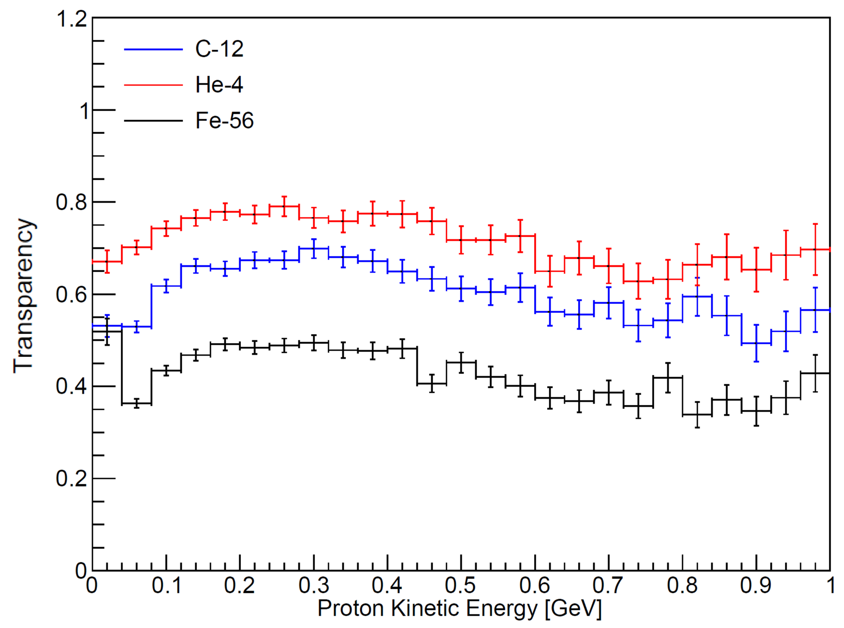


Fig. 2: Schematic of CEBAF Large Acceptance Spectrometer (CLAS) [3].

- We analyzed data for runs with ^{4}He, ^{12}C, and ^{56}Fe targets at an electron beam energy 2.261 GeV.

MC Transparencies for ν_e Beam



Transparency represents the probability that a hardon produced in a nucleus escapes.

Fig. 3: MC transparency as a function of proton kinetic energy for three targets with a 2.261 GeV ν_e beam. Transparency calculated as the proton kinetic energy distribution with final-state interactions (FSI) divided by the proton kinetic energy distribution without FSI.

Data and MC Transparencies for e⁻ Beam

- Transparency is the ratio of (e,e′p) events to (e,e′) events.
- We applied angular and momentum cuts on electrons to select for a QE-dominated sample for (e,e′) events.
- We applied additional cuts on proton angle to select for elastic kinematics for the (e,e′p) sample.

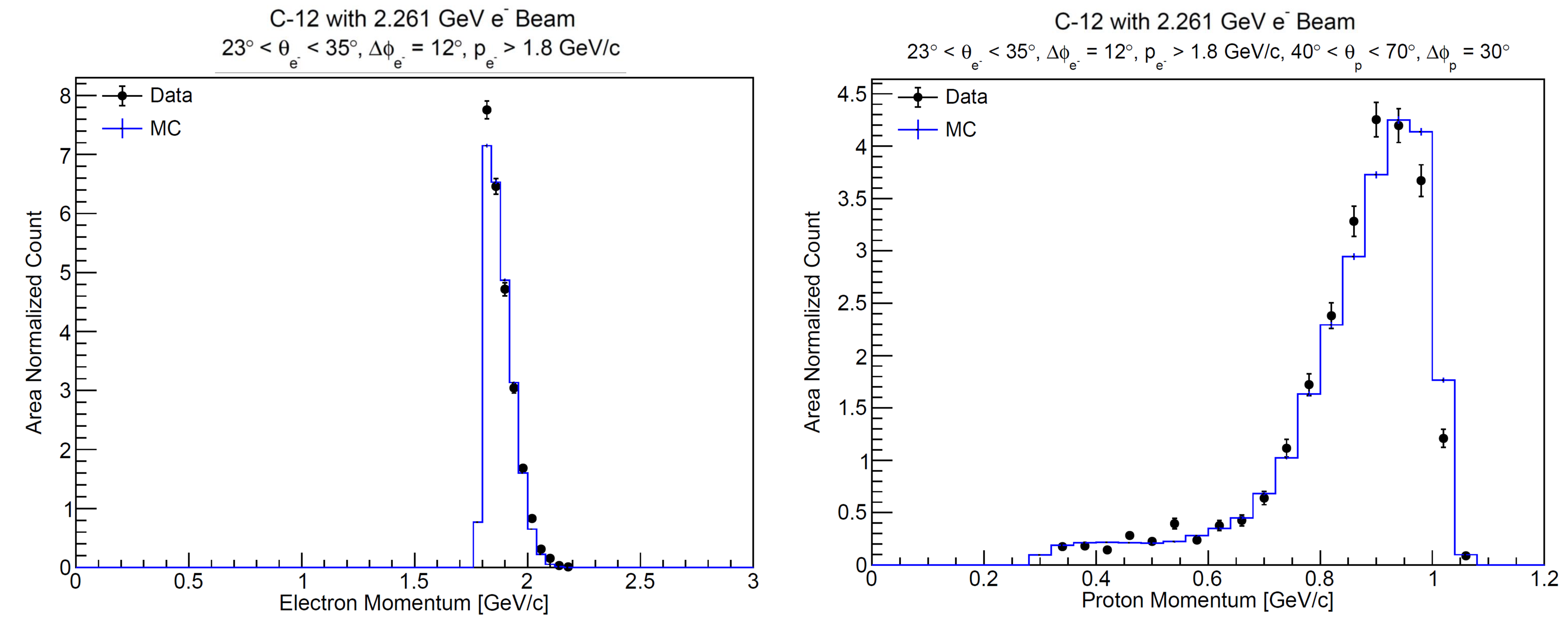


Fig. 4: Electron and proton momentum for the (e,e′) (left) and (e,e′p) (right) samples for ^{12}C with a 2.261 GeV e⁻ beam for MC and data (area normalized).

Cuts for (e,e′) sample:

- $23° < \theta_e < 35°$
- $\Delta\phi_e = 12°$
- e⁻ in CLAS sectors 1 or 6
- $p_e > 1.8$ GeV/c

Additional cuts for (e,e′p) sample:

- $40° < \theta_p < 70°$
- $\Delta\phi_p = 30°$
- p⁺ in CLAS sectors 1 or 6

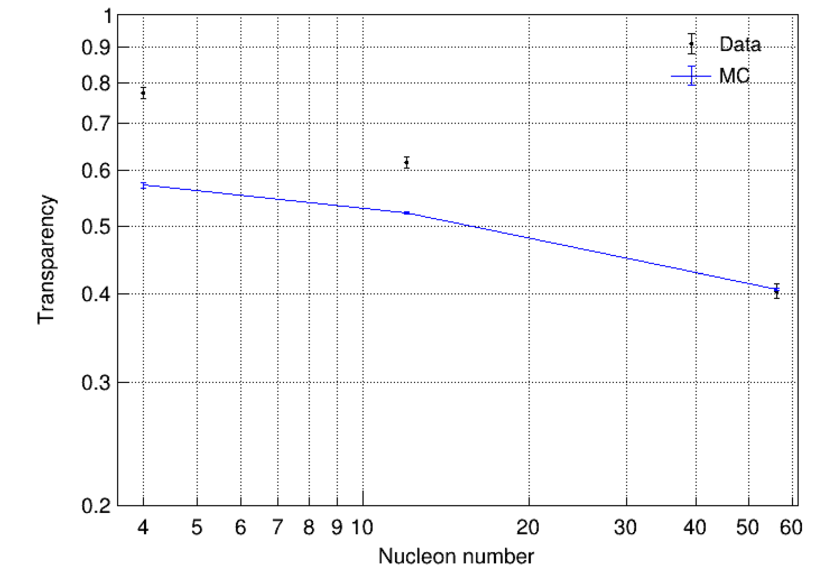


Fig. 5: Transparency vs nucleon number for ^{4}He, ^{12}C, and ^{56}Fe for MC and data.

New Samples for Transparencies

We implemented a more detailed sample selection by applying different cuts for different ranges of θ_e. These cuts reduce background from meson-exchange currents (MEC) and rescattered protons. For ^{4}He, we apply new cuts:

- $20-25°$: $p_e > 1.9$ GeV/c and $45° < \theta_p < 75°$
- $30-35°$: $p_e > 1.65$ GeV/c and $40° < \theta_p < 60°$
- $40-45°$: $p_e > 1.4$ GeV/c and $35° < \theta_p < 50°$

New Samples for Transparencies

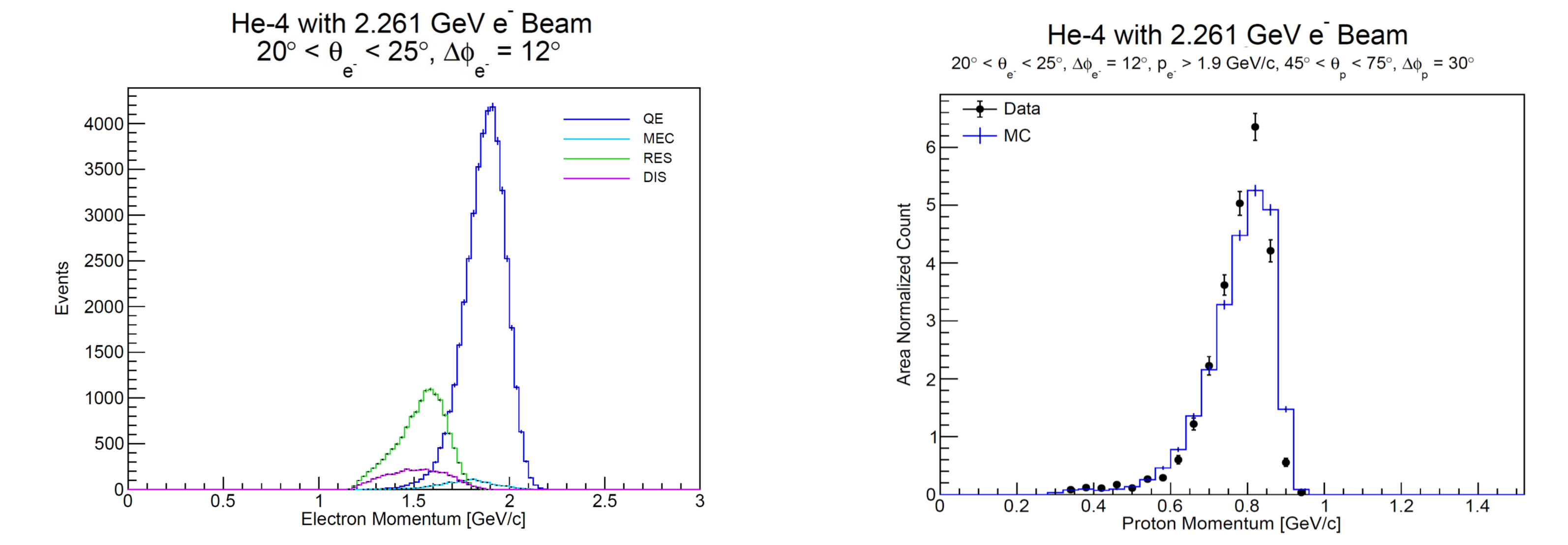


Fig. 6: For $20° < \theta_e < 25°$, we apply a cut on electron momentum (left) at a minimum of 1.9 GeV/c. The right plot shows the final proton momentum distribution with cuts on electron angle and momentum and proton angle.

Conclusions

- We compared total transparencies for ^{4}He, ^{12}C, and ^{56}Fe for a 2.261 GeV e⁻ beam for MC and data.
- ^{56}Fe has good agreement between MC and data, but ^{4}He and ^{12}C data are larger than the MC predictions.
- Applying a cut on electron momentum and proton angle for different ranges of θ_e provides a better sample with less MEC background and less rescattered protons.
- Next steps include applying these more detailed cuts on all targets for e⁻ beam energies 1.161 and 4.461 GeV/c to compare MC with data.

References

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