Nuclear Structure Physics in Coherent Elastic Neutrino-Nucleus Scattering

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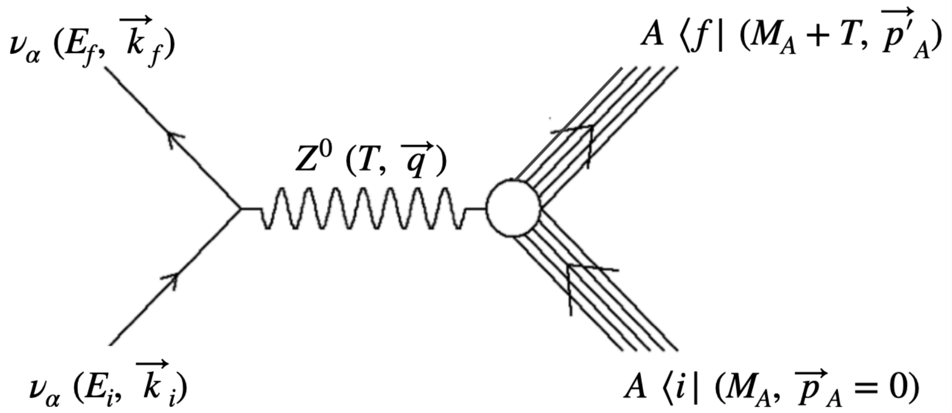
I. Introduction

- The primary source of uncertainty in the evaluation of the coherent elastic neutrino-nucleus scattering (CEvNS) cross section comes from the underlying nuclear dynamics embedded in the nucleon form factors.
- Proton density distributions are relatively well constrained through elastic electron scattering experiments while the neutron density distributions are poorly known.
- An accurate estimation of form factors is vital to the CEvNS program, since any experimentally measured deviation from the expected CEvNS event rate can either be attributed to new physics or to unconstrained nuclear physics.

II. Formalism

- A neutrino scatters off a nucleus, initially at rest, exchanging a single Z^0 boson. The nucleus remains in its ground state and receives a small recoil energy T. The differential cross section is expressed as:



$$\frac{d\sigma}{dT} = \frac{G_F^2}{\pi} M_A \left(1 - \frac{T}{E_i} - \frac{M_A T}{2E_i^2}\right) \frac{Q_W^2}{4}\ F_W^2(Q^2)$$

where Q_W is weak nuclear charge, and $F_W(Q^2)$ is weak form factor written as:

$$F_W(q^2) = \frac{1}{Q_W}\left[(1 - 4\sin^2\theta_W)\, f_p(q)\ F_p(q^2) - f_n(q)\ F_n(q^2)\right]$$

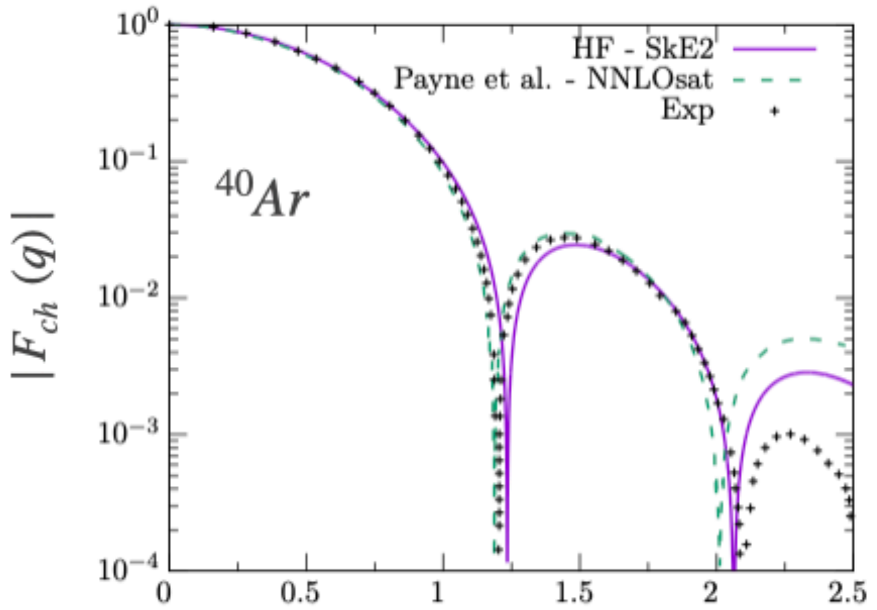
$$f_n(q) = \frac{4\pi}{N}\int dr\ r^2\ \frac{\sin(qr)}{qr}\ \rho_n(r), \qquad f_p(q) = \frac{4\pi}{Z}\int dr\ r^2\ \frac{\sin(qr)}{qr}\ \rho_p(r)$$

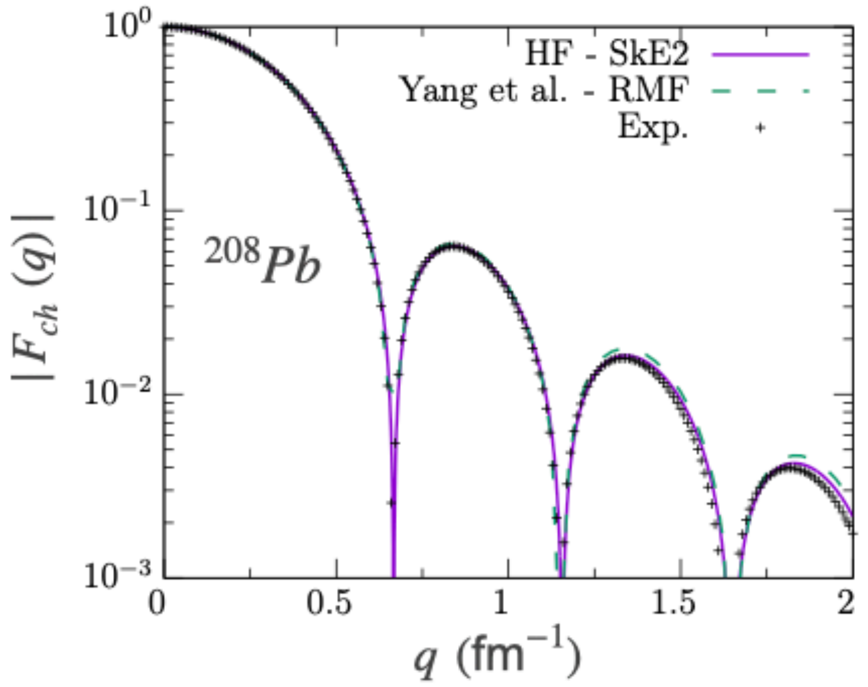
with f_n (f_p) as neutron (proton) form factors, and ρ_n (ρ_p) as density distributions.

- We obtain proton and neutron densities, and charge and weak form factors, in a microscopic many-body nuclear theory model where the nuclear ground state is described in a Hartree-Fock (HF) approach with a Skyrme (SkE2) nuclear potential [1].

III. Results

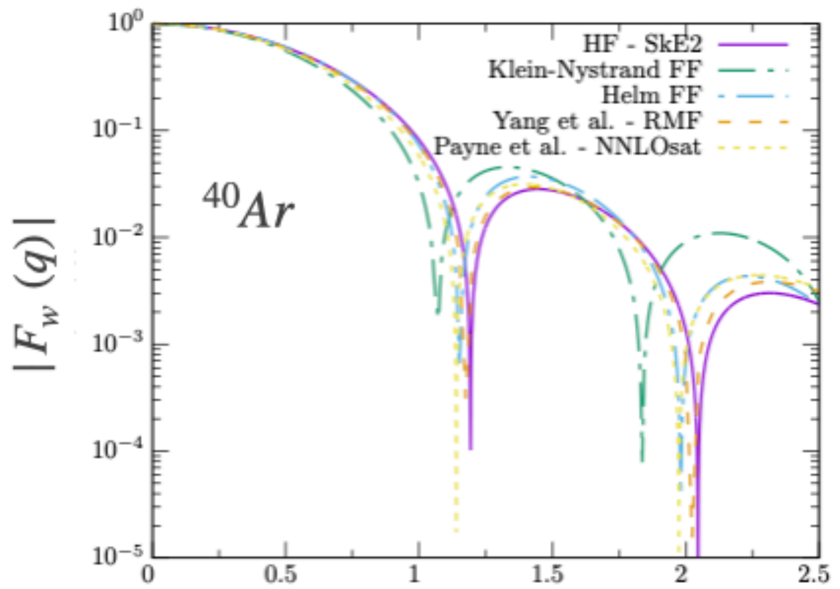
Charge Form Factor

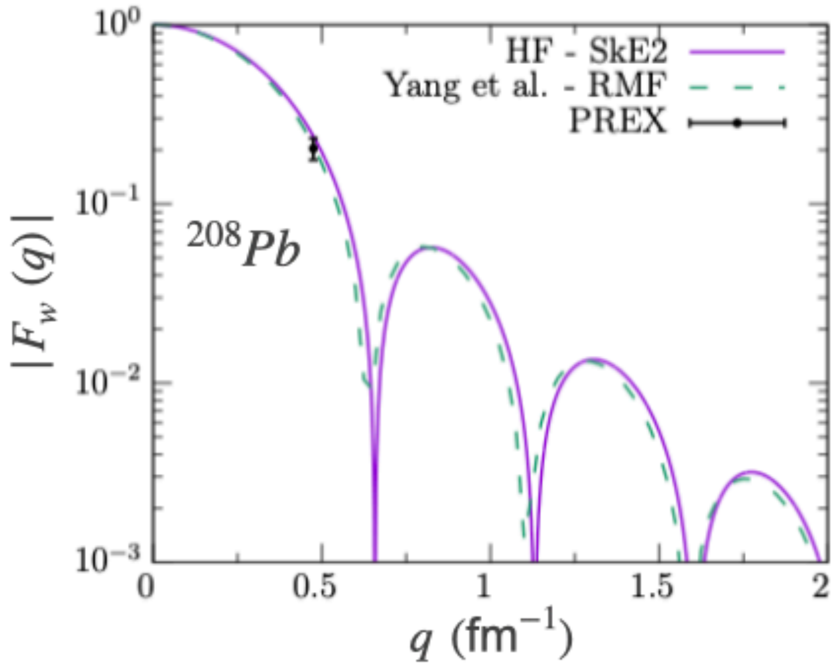




- HF-SkE2 charge form factor predictions of ^{40}Ar and ^{208}Pb compared with elastic electron scattering data of Ref. [2] and [3], and theoretical predictions of Ref. [4] and [5].
- Our approach describes $F_{ch}(q)$ data remarkably well.

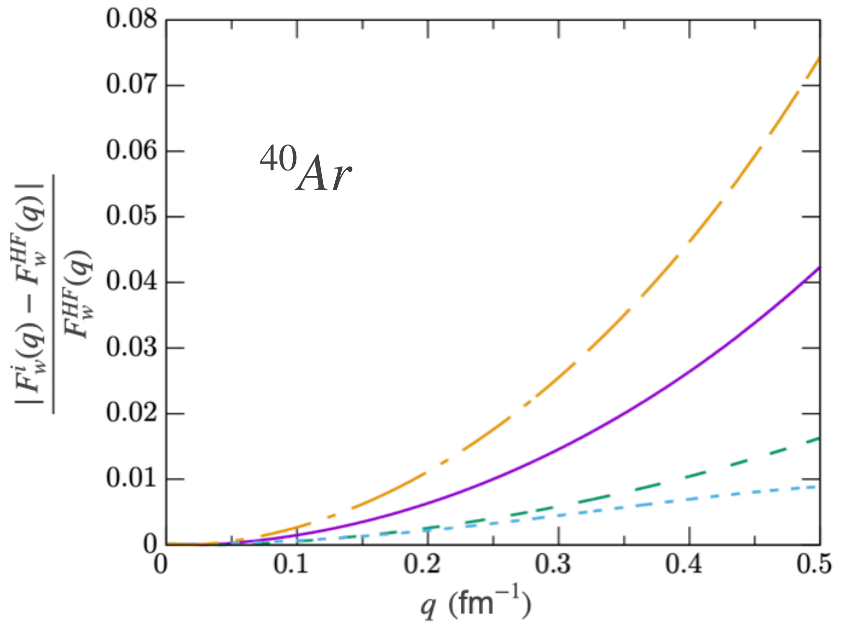
Weak Form Factor





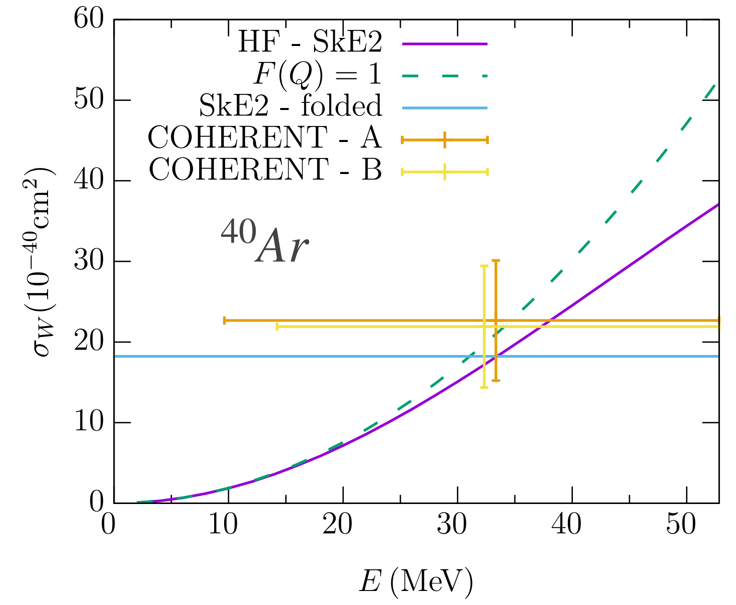
- HF-SkE2 weak form factor predictions of ^{40}Ar compared with theoretical predictions of Ref. [4] and [5] and with Klein-Nystrand and Helm calculations.
- ^{208}Pb predictions compared with Ref. [5] and with the single point measured by the PREX collaboration [6].

Relative differences in $F_w(q)$



- Relative differences between theoretical predictions of ^{40}Ar weak form factor.

CEvNS Cross Section



- CEvNS cross section on ^{40}Ar along with the recent flux-averaged measurements performed by COHERENT [7].

IV. Summary

- HF-SkE2 predictions of ^{40}Ar and ^{208}Pb charge form factor describe elastic electron scattering data remarkably well, successfully validating the approach.
- We make predictions for ^{40}Ar and ^{208}Pb weak form factor and CEvNS cross section off ^{40}Ar. Thereby, we attempt to gauge the level of theoretical uncertainty pertaining the description of ^{40}Ar form factor by evaluating relative differences between various theory predictions.

References

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