Mapping the densities of exotic nuclei

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Introduction

Much information on the neutron density of neutron-rich nuclei is known:

- Halos
- Skins
- Nucleus-nucleus collisions
- Proton scattering in inverse kinematics

Not much is known of the proton density; reactions tend to concentrate on probing the neutron density only.

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Mapping the density

Usually, we rely on more than one reaction to obtain information on the overall structures of nuclei:

- Proton scattering pn part of interaction dominates, probes neutron density
- Electron scattering Purely electromagnetic interaction. Longitudinal form factors probe directly the charge (proton) density.

Utilising both, self-consistently, provides a complete mapping of the matter density of the nucleus.

This requires, *a priori*, a self-consistent approach to both electron and proton (nucleon) scattering.

Requirements of both scatterings necessitates use of microscopic theories. The Shell Model is utilised to produce the underlying **one-body density matrix elements** (OBDME) which are used in both analyses of electron and nucleon scattering.

Electron scattering: de Forest and Walecka approach. (Adv. Phys. **15**, 1 (1966)); SK, *et al.* (PRC **51**, 2494 (1995)).

Nucleon scattering: Melbourne *g*-folding model. (K. Amos, *et al.*, Adv. Nucl. Phys. **25**, 275 (2000)).

Other predictions…

- Antonov *et al.* [PRC **72**, 044307 (2005)]: Form factors of He isotopes as obtained from densities calculated using large space shell model. Did not consider directly the effect of the halo in ^{6}He;
- Bertulani [JPG **34**, 315 (2007)]: Form factors of ^{6}He and ^{11}Li using densities obtained from a potential model. Did not find any effect of the halo on the elastic scattering charge form factors. Did find a significant effect of the proton halo on the charge form factor for ^{8}B.

Current work:

- Elastic scattering form factors of He and Li isotopes to investigate whether charge density changes with addition of neutrons and introduction of the halo;
- Inelastic scattering form factors of ^{6}He to see whether the halo has an effect therein.

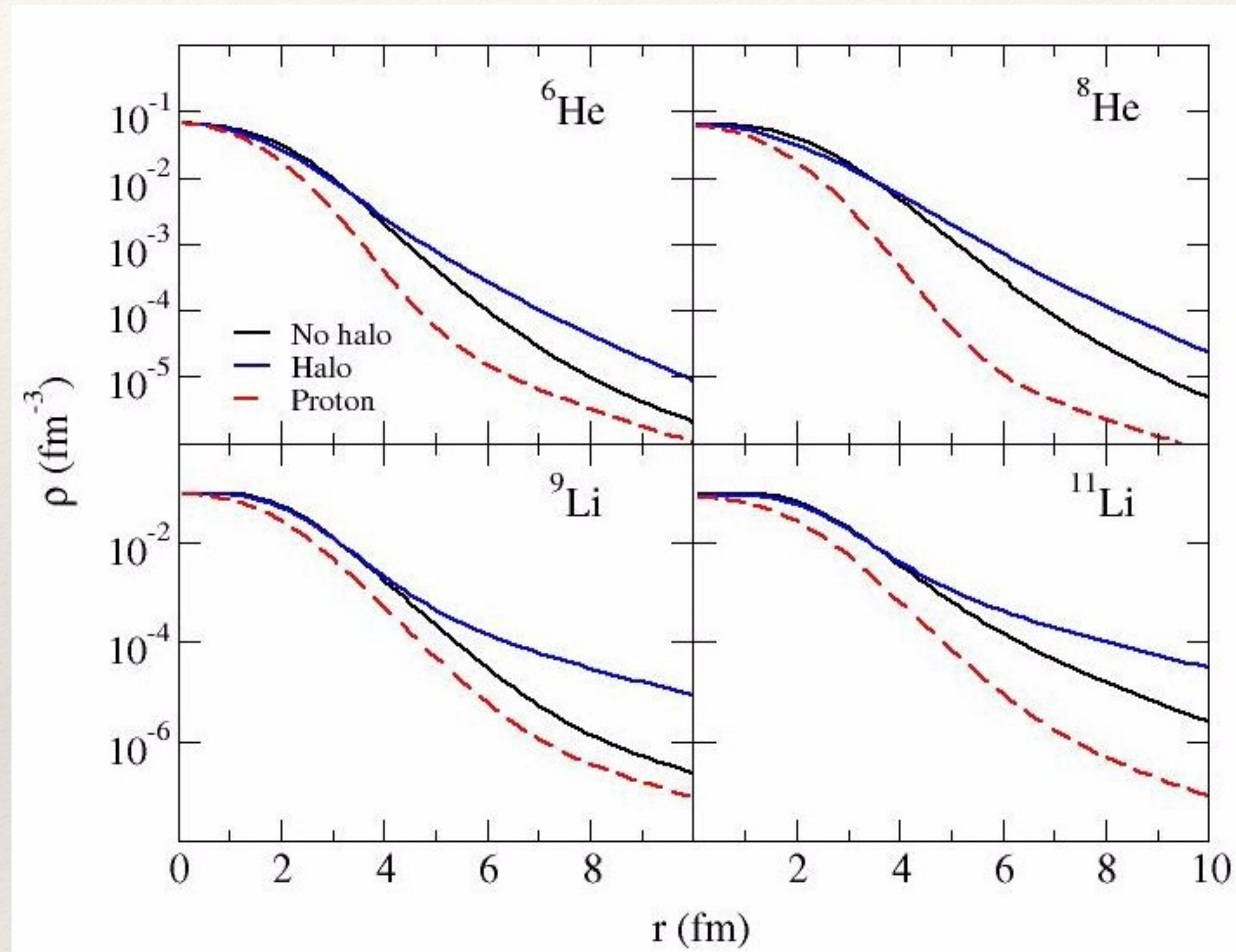
Densities, exotic nuclei

$4\hbar\omega$ shell model, Zheng interaction (SK., *et al.*, PRC **61**, 024319 (2000)).

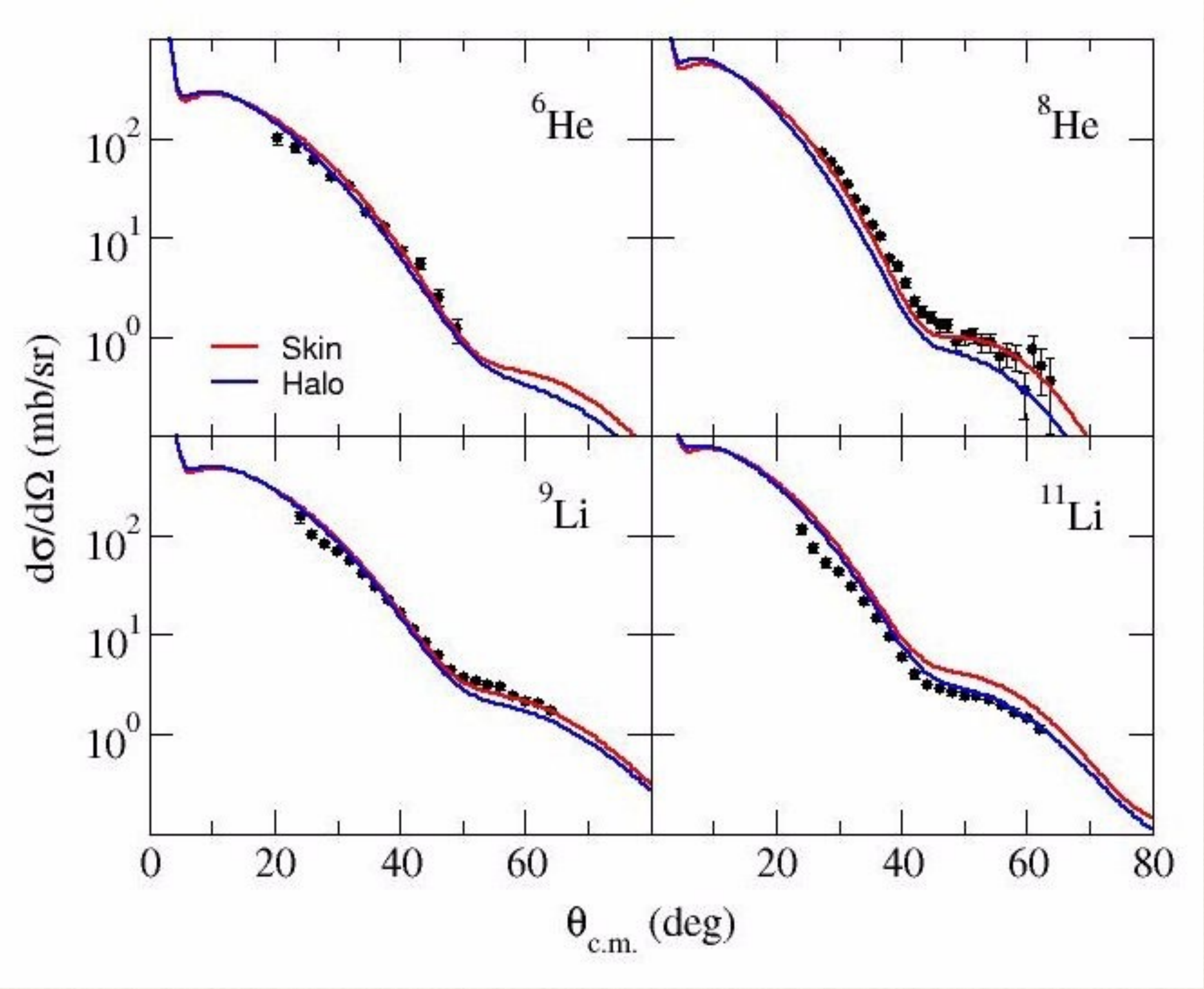
TABLE I. Root-mean-square (rms) radii in fm for ^{6}He, ^{8}He, ^{9}Li, and ^{11}Li. The results of our shell model calculations are compared to those obtained from a Glauber model analysis of the reaction cross sections [26,25], and also from a few-body model analysis of scattering data from hydrogen [2].

Nucleus	r_{rms} non-halo	r_{rms} halo	Glauber model
^{6}He	2.301	2.586	2.54±0.04
^{8}He	2.627	2.946	2.60 [a]
^{9}Li	2.238	2.579	2.30±0.02
^{11}Li	2.447	2.964	3.53±0.10

[a] Taken from Ref. [2]



Elastic scattering



71*A* MeV

62*A* MeV

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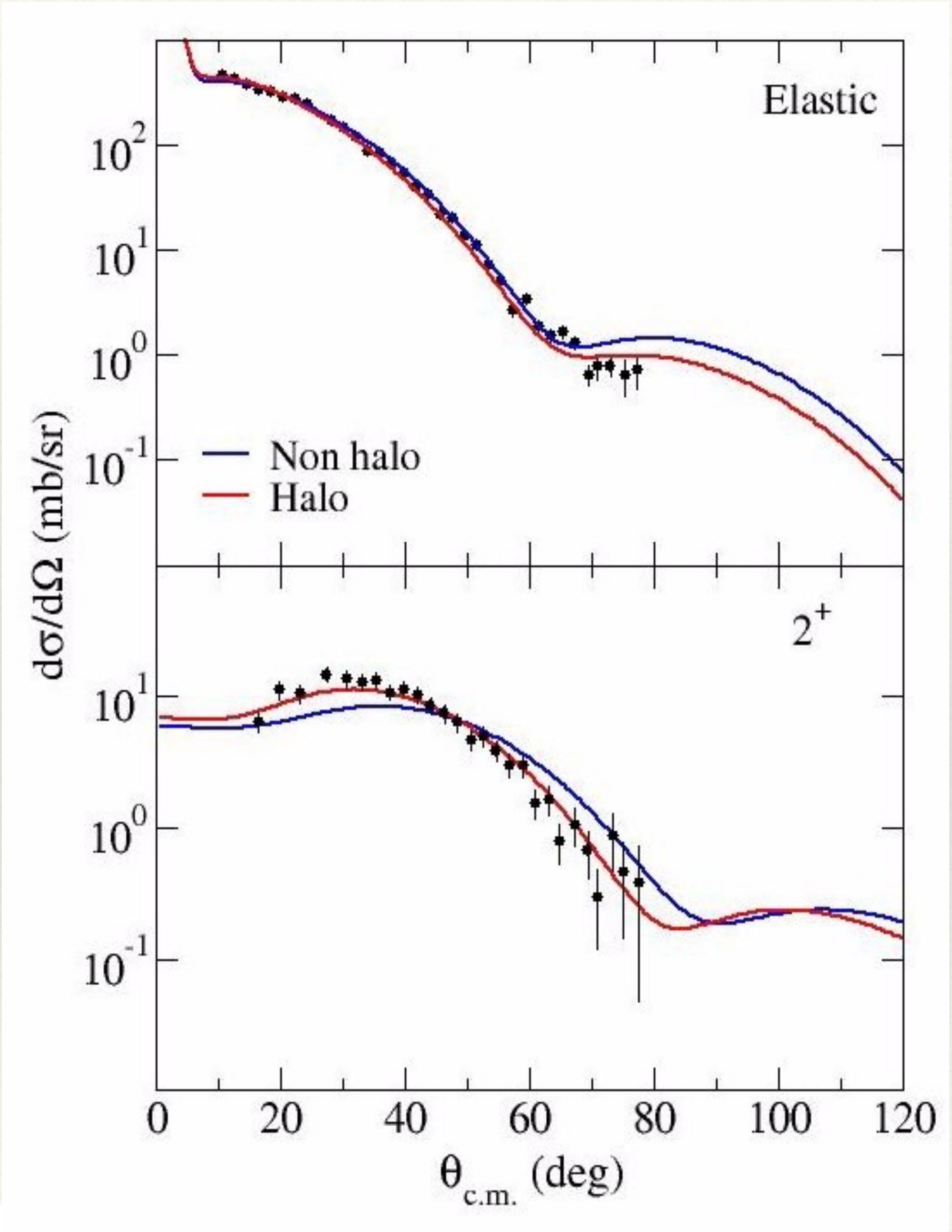
p-^{6}He scattering



Reaction cross section

Predicted

$$\sigma_R = 356 \text{ mb (nonhalo)}$$
$$= 409 \text{ mb (halo)}$$

Measured

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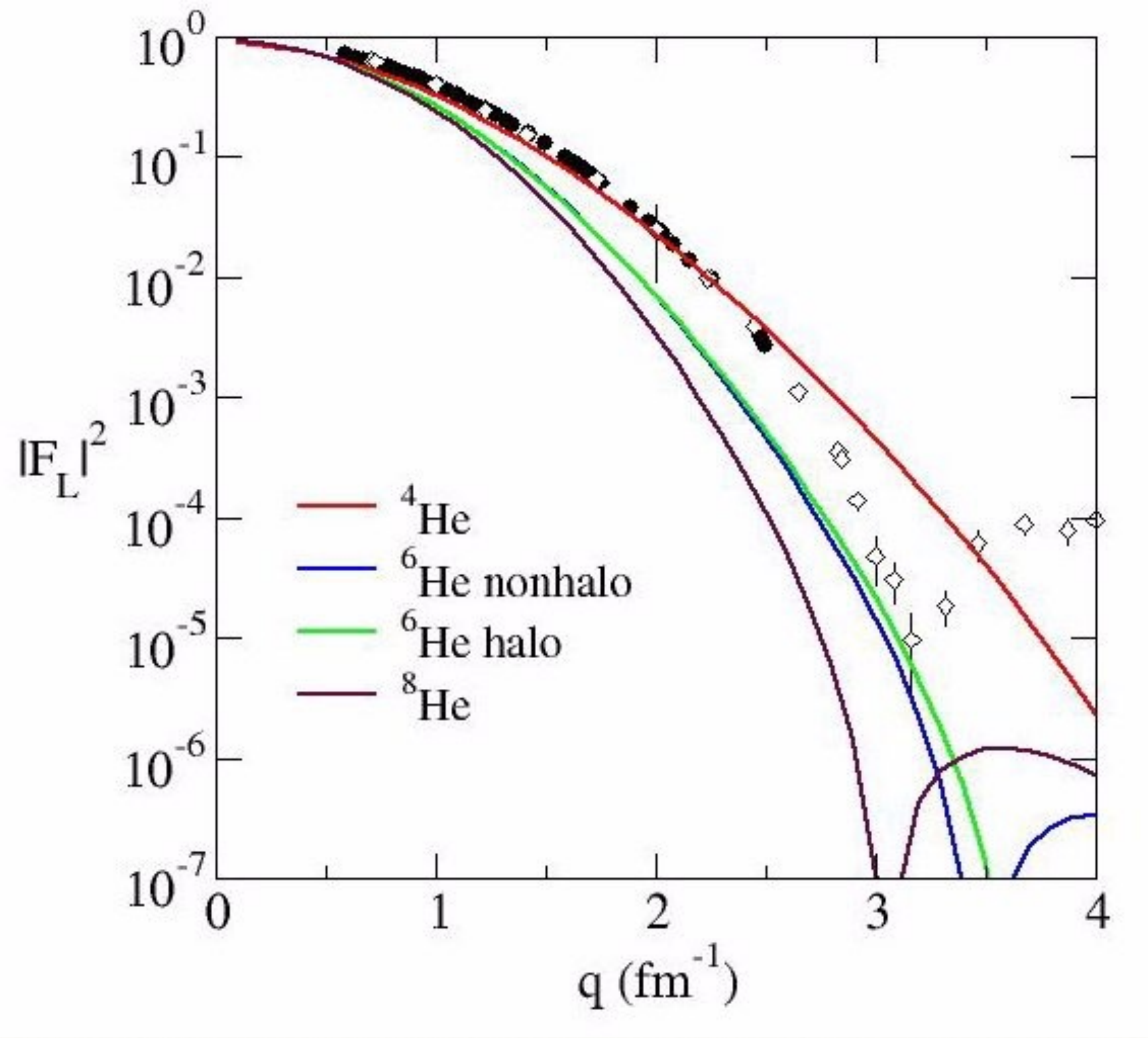
Electron scattering, He isotopes



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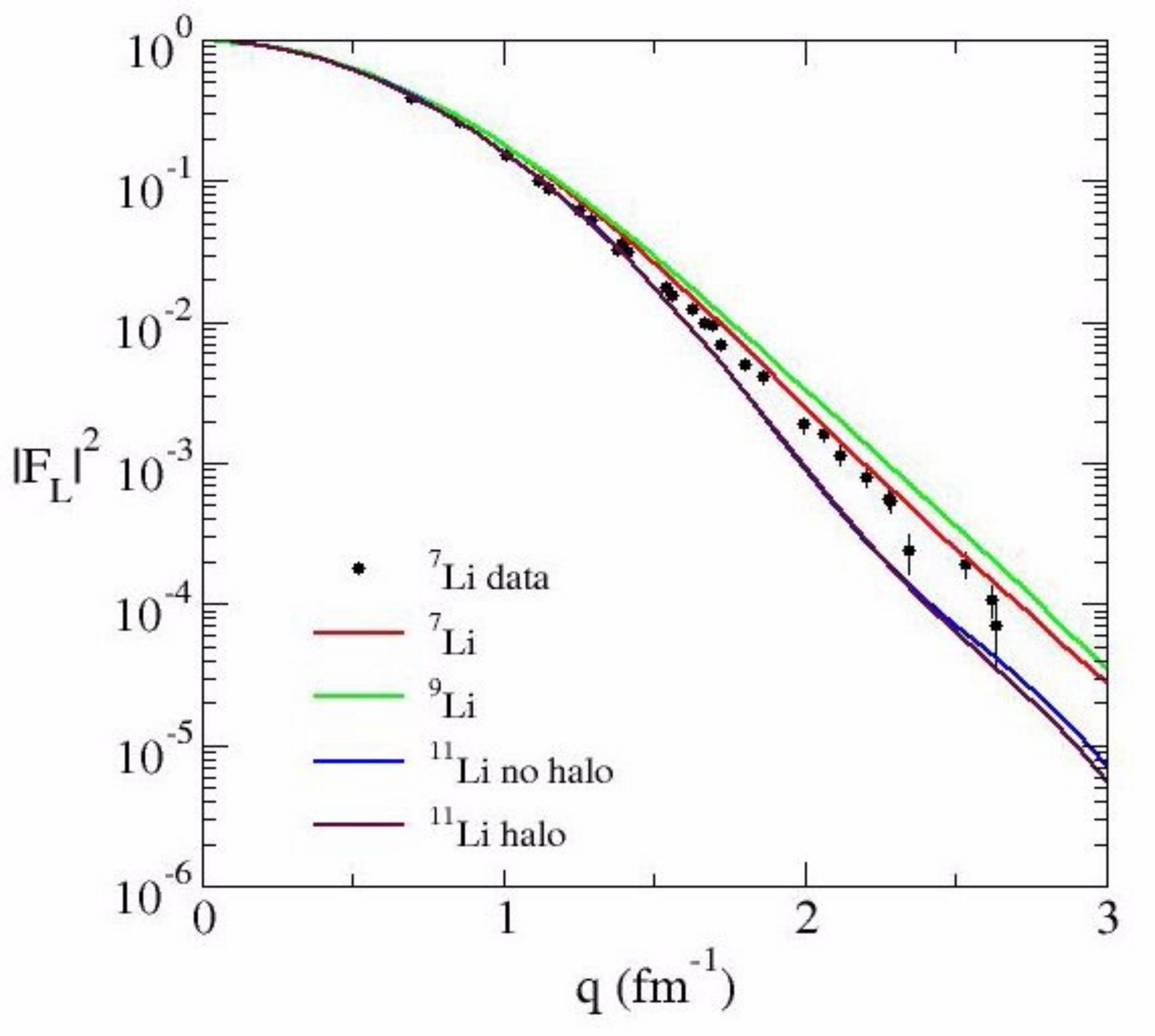
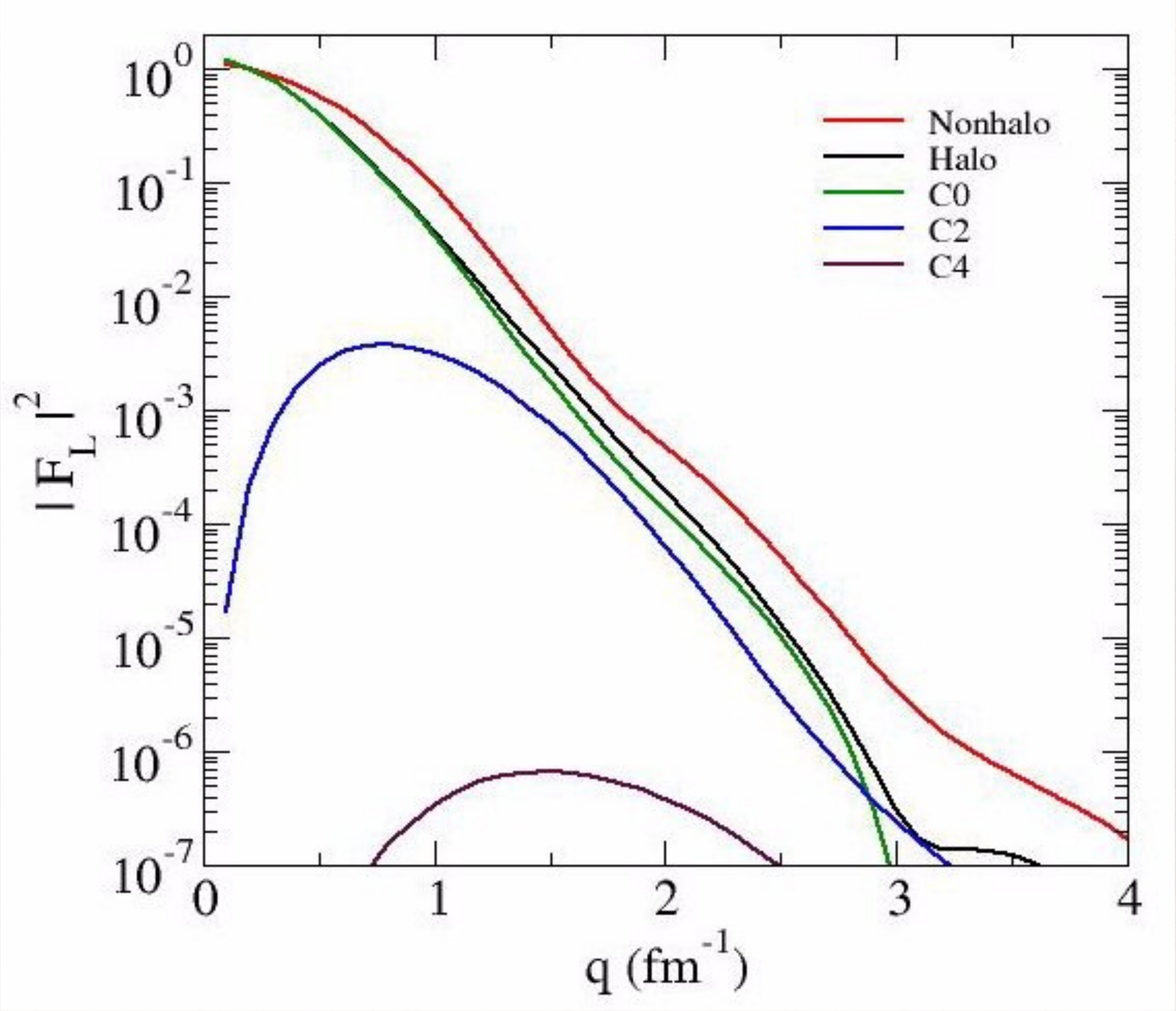
Electron scattering, Li isotopes



Electron scattering, ^{8}B



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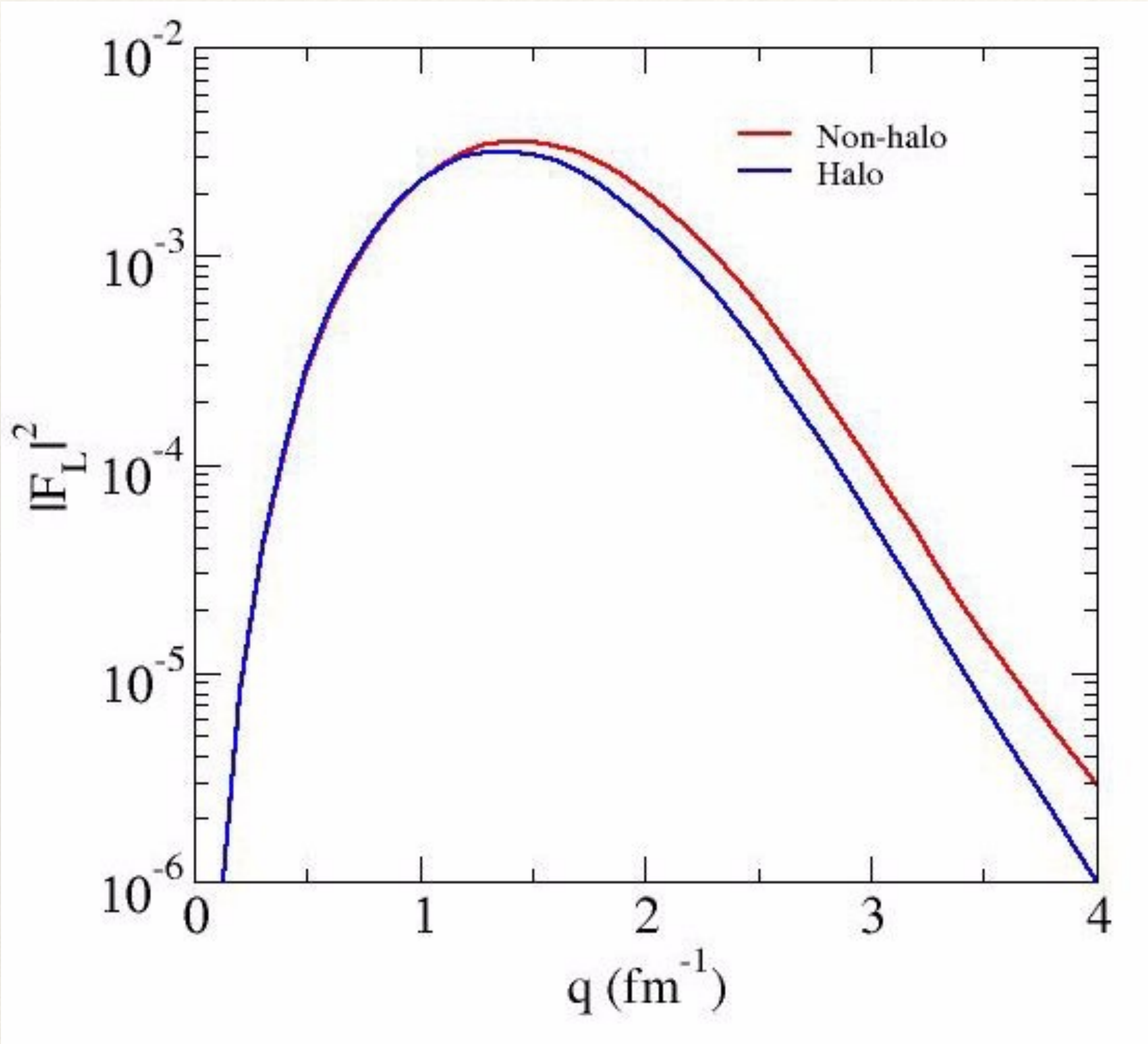
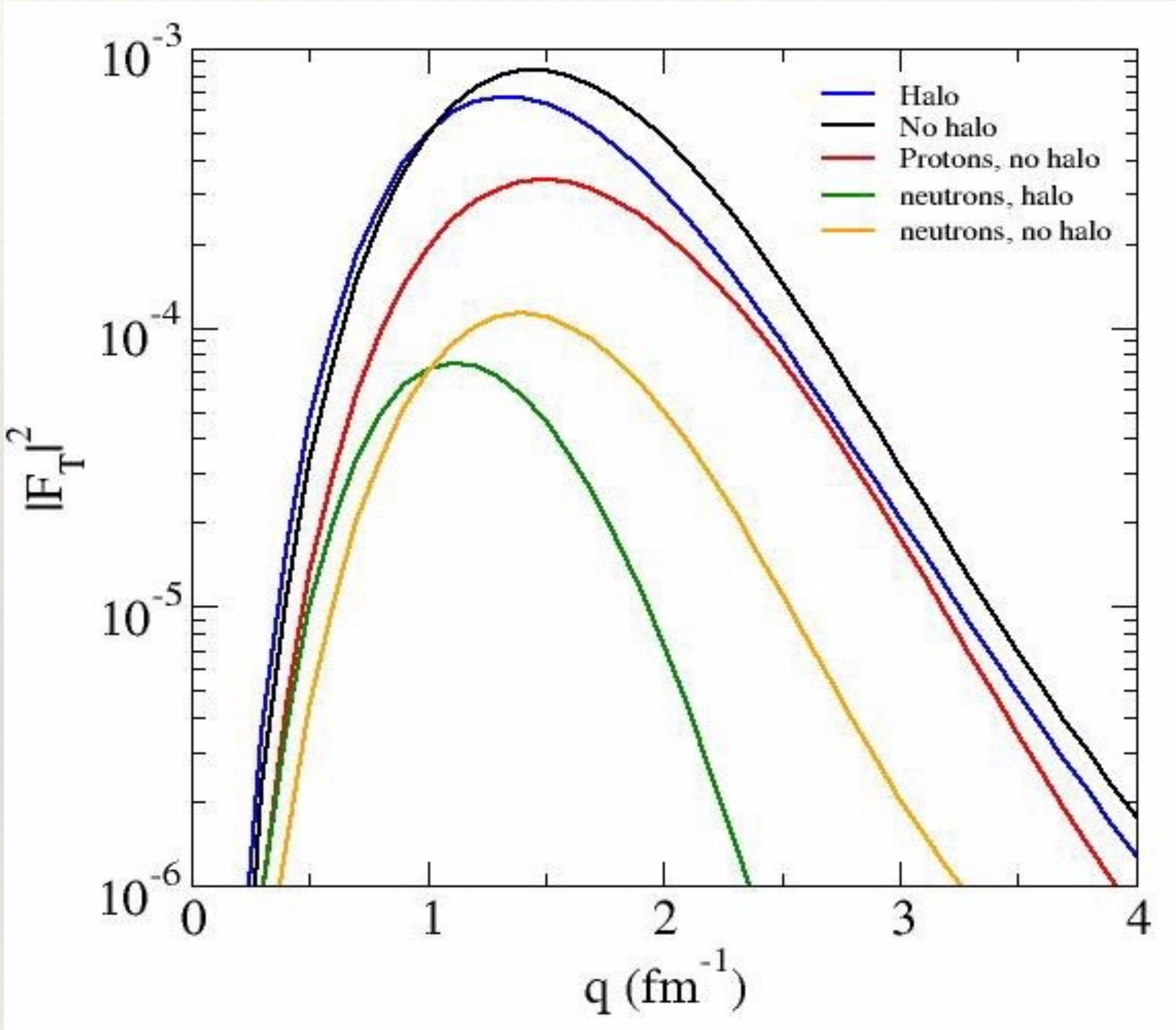
Inelastic electron scattering, ^{6}He





Conclusions

- The work presented illustrated what may be achieved with SCRIT.
- For the He isotopes, the results of the calculations for the elastic longitudinal form factors follow a natural mass dependence.
- For the Li isotopes, the results of the calculations also follow a natural mass dependence.
- For ^{8}B, the proton halo **does** significantly change the prediction of the form factor.
- The inelastic scattering form factor for ^{6}He does show some effect due to the neutron halo, as consistent with the results of proton scattering.

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