Electron scattering off $^4\text{He}$ with Three-Nucleon forces

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Outline:

• Brief summary of formalism for inclusive electron scattering

• Ingredients/methods of the performed *ab initio* calculation with realistic nuclear forces

• Results
Ab initio electron scattering

Inclusive process $A(e,e')X$

$$\frac{d^2\sigma}{d\Omega d\omega} = \sigma_M \left[ \frac{Q^4}{q^4} R_L(\omega, q) + \left( \frac{Q^2}{2q^2} + \tan^2 \frac{\theta}{2} \right) R_T(\omega, q) \right]$$

$$R_L(\omega, q) = \sum_f |\langle \Psi_f | \rho(q) | \Psi_0 \rangle|^2 \delta \left( E_f - E_0 - \omega + \frac{q^2}{2M} \right)$$

$$\rho(q) = \sum_k e^{i q \cdot r'_k} \frac{1 + \tau^3_k}{2}$$

Purpose: Investigate the effect of three-nucleon forces on $R_L(\omega, q)$

Nuclear forces employed: NN $\rightarrow$ AV18
NNN $\rightarrow$ U1X

Results with LIT + EIHH

W. Leidemann - Panic08
Calculation of ground state and of LIT \( L(\sigma, \Gamma) \) via expansions in Hyperspherical Harmonics (HH).

HH expansions have a very slow convergence rate for nuclear physics problems. Strong acceleration of convergence is obtained by the so-called Effective Interaction HH (EIHH).

**EIHH:** unitary transformation of bare interaction in a given model space leads to an effective interaction for model space; steady increase of model space up to the point that convergent ground-state/LIT results are obtained (similar to NCSM). Barnea, W.L., Orlandini, PRC 61, 054001 (2000)
Precision of obtained results

- Convergence check of HH expansion
- Check of inversion

\[ q = 250 \text{ MeV/c} \]
\( R_L(\omega, q) \) of \(^4\text{He}\)

- AV18
- AV18 + UIX
- PWIA

- **Large FSI effects**
- **10% reduction due to 3BF**
- **rather good agreement with data**

At \( q=500 \text{ MeV/c} \) relativistic effects could become more important (see my poster on \( R_{LT}(\omega, q) \) of \(^3\text{He}\))
$R_L(\omega,q)$ of $^4\text{He}$ at lower $q$

AV18

AV18 +UIX

Large 3BF effects
3BF effects on peak position and peak height

<table>
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<tr>
<th>q [MeV/c]</th>
<th>$\omega_p$ [MeV]</th>
<th>$\omega_p$ [MeV]</th>
<th>$R_L$ [10^{-3}MeV^{-1}]</th>
<th>$R_L$ [10^{-3}MeV^{-1}]</th>
<th>$\Delta R$ [%]</th>
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Experiments at low q would be needed!
Summary

• We have performed an *ab initio* calculation of $R_L(\omega, q)$ of $^4$He with a realistic nuclear force (AV18+UIX)

• Rather strong FSI effects are found, even in peak region

• Important 3BF contribution, in particular at low $q$

Outlook

We are presently carrying out calculations with nuclear force AV18+TM' in order to find out if 3BF effect changes