A Novel Approach for the Calculation of Few-body Response Functions

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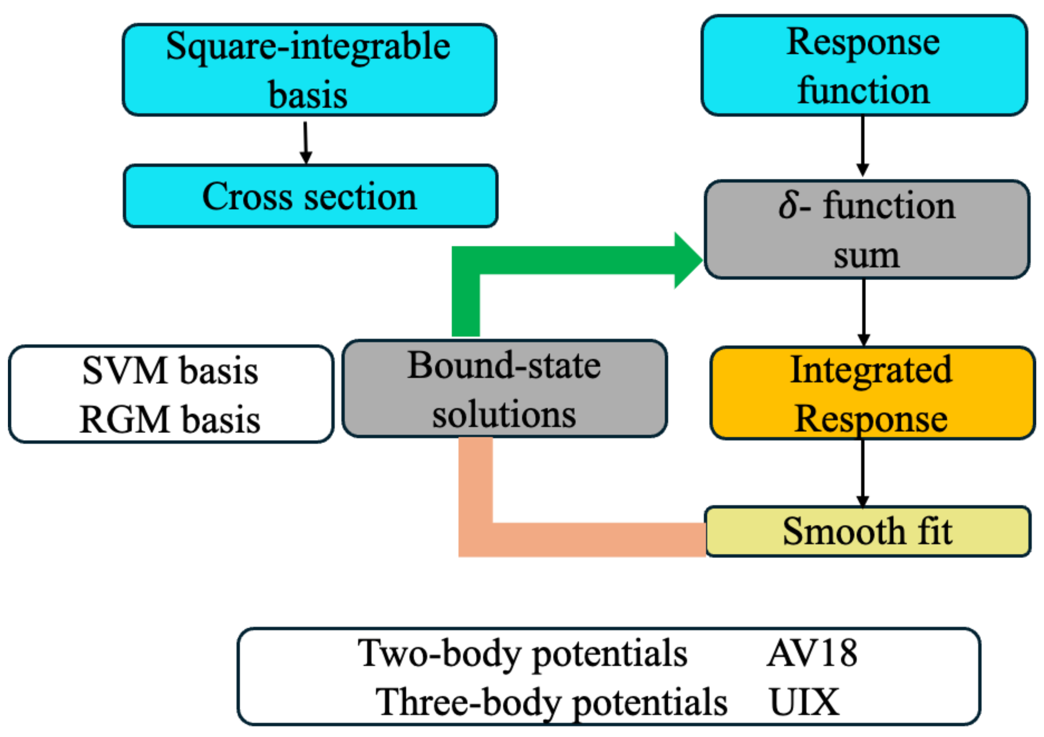
Background/Aims

- We want to understand neutron properties through electromagnetic response from experimental studies of light nuclei.
- Requires to club one- and many-body computational techniques to perform the computations.
- Experiments from light nuclei at $E\gamma$ of 50-150 MeV are an exploration of nucleon and of nuclear structure.
- Proton: the principal effect at low energy are the polarisabilities.
- For light nuclei, the deviations from Thomson scattering important; by 50 MeV the response involves an interplay of both nucleonic and nuclear excitations.
- Description of such experiments validates the underlying theory and allows for extraction of neutron polarisabilities.
- By comparing results from more than one nucleus, the efficacy of the few-body description can also be tested.
- Three parts: (i) nuclear rescattering, arising from intermediate excited states involving only nucleons, (ii) the effect of irreducible one- and (iii) two-nucleon current operators. **This work is about nuclear rescattering only.**

Method Details



Formulation Basic Ideas

- Parametrise cross section as $\frac{d^2\sigma}{d\epsilon d\Omega} = g^2 \sum_i f_i(\epsilon, q, \Omega) F_i(\epsilon, \mathbf{q})$, [1-3]
- For a single channel
  $$F(\epsilon, \mathbf{q}) = \int d\mathbf{k} \langle \psi_0 | O^\dagger(\mathbf{q}) | \psi_\mathbf{k} \rangle \langle \psi_\mathbf{k} | O(\mathbf{q}) | \psi_0 \rangle \delta(E_\mathbf{k} - E_0 - \epsilon)$$
- Assuming $|\psi_0\rangle$ is normalised, we we can approximate this as
  $$F(\epsilon, \mathbf{q}) = \sum_i |\gamma_i(\mathbf{q})|^2 \delta(E_i - E_0 - \epsilon)$$
  with $\gamma_i(\mathbf{q}) = \langle \phi_i | O(\mathbf{q}) | \psi_0 \rangle$
- Will look at $T(\epsilon, \mathbf{q}) = \int_{E_0}^{\epsilon} d\epsilon' F(\epsilon', \mathbf{q})$

Direct approach:

We can look at the integrated strength distribution

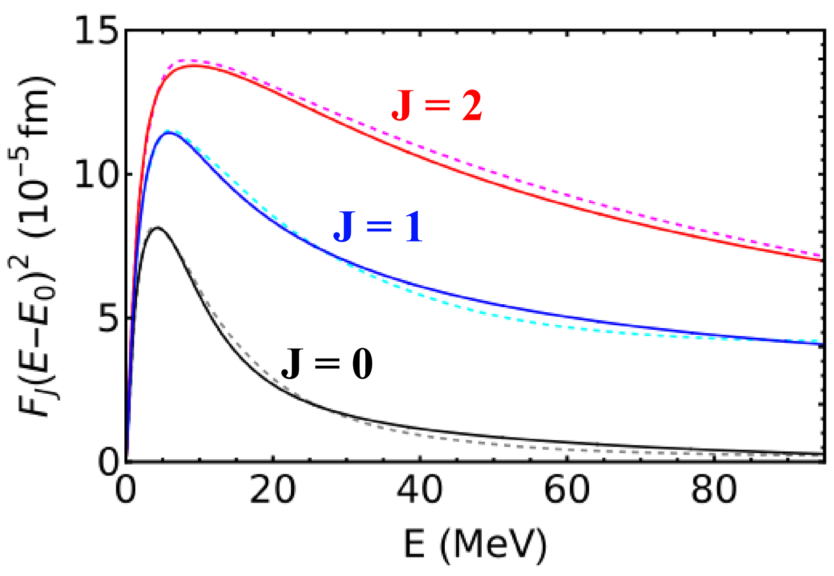
$$T(E) = \int_{E_0}^{E} d\epsilon \; F(E) = \int_{E_0}^{E} d\epsilon \; \gamma_i(q)^2 :$$

sum of delta functions→step function.

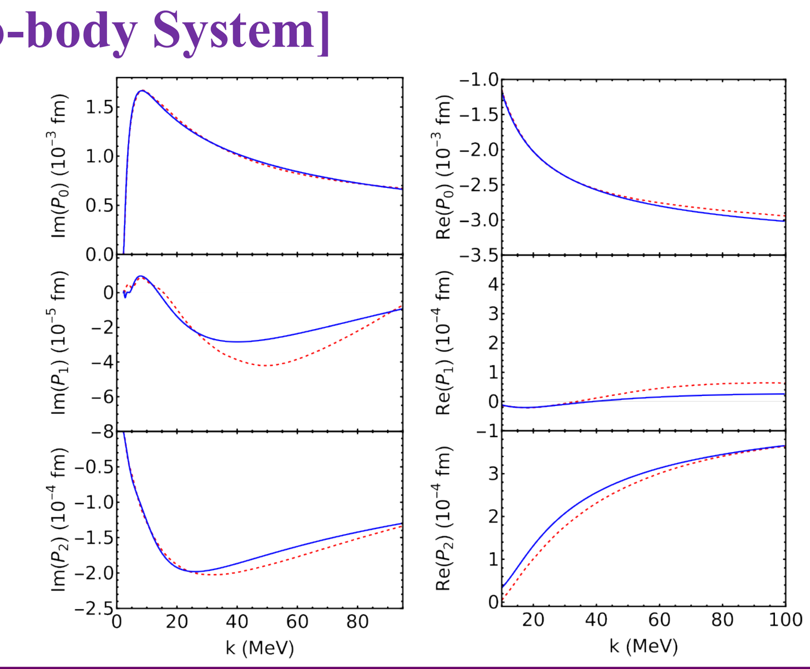
- Fit this function to a know smooth function (or class of): differentiate and get $F(E)$.
- Then from $F(E)$ the polarisabilities and total cross section is calculated.

Results

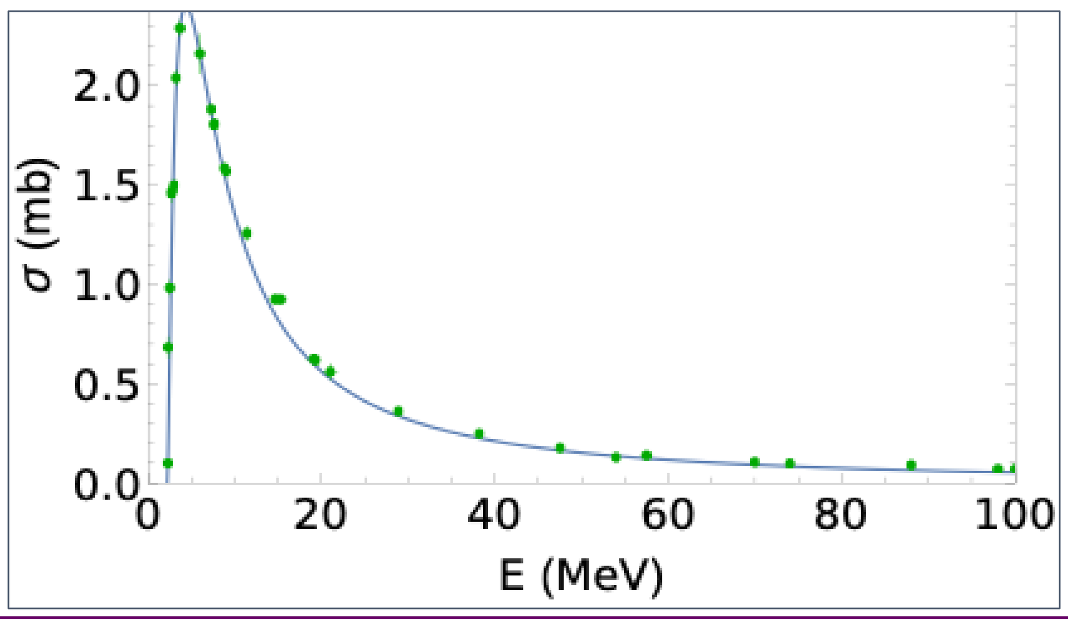
Deuteron Photo-Disintegration [Two-body System]



A comparison of the strength function multiplied with energy-transfer squared, The dashed lines are the results from Ref. [4], solid lines are our results [5].



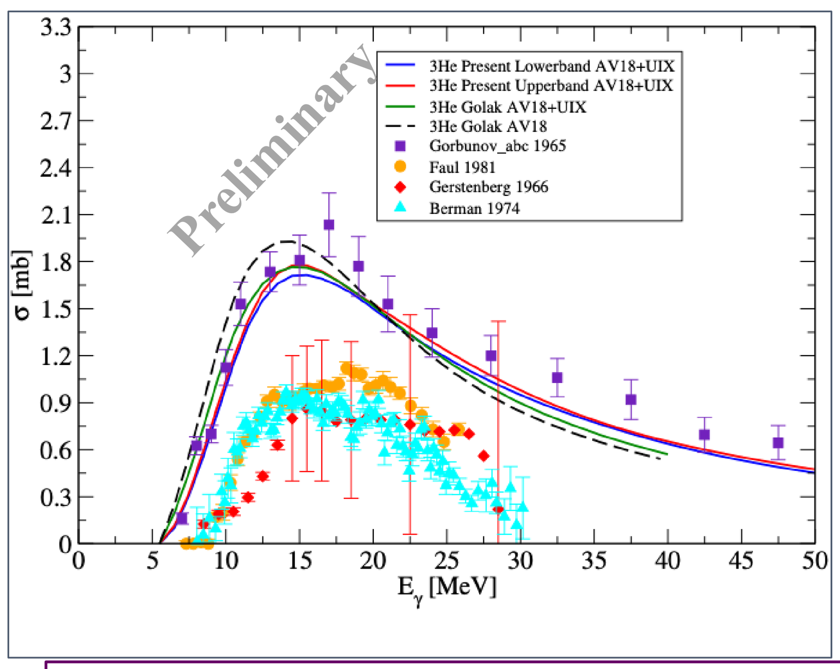
A comparison of the polarisabilities that enter the calculation of the cross section. Red dashed lines are results from Ref. [4], and solid blue lines are our results [5].

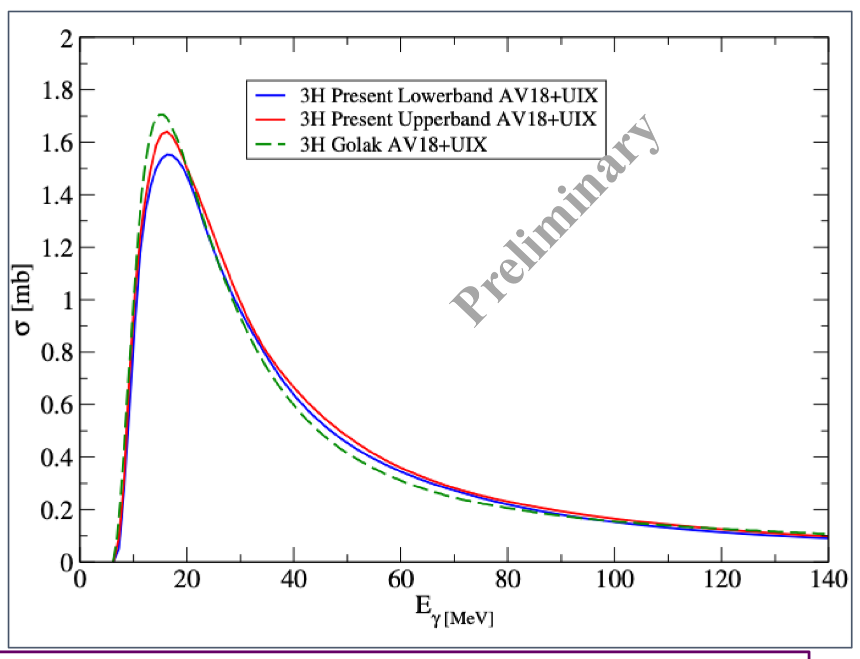


A comparison of the deuteron cross section as extracted from our method (using the imaginary part of the responses) versus the data from the EXFOR database (green dots).

^{3}He and ^{3}H Photo-Disintegration [Three-body Systems]

- We initially struggled with three-body (3He or 3H)
- The issue is the presence of two thresholds; pure three-body is "easy"





A comparison of the 3He (on left) and 3H (on right) cross section as extracted from our method, results from Ref. [6] versus the experimental data from the EXFOR database.

Future Perspectives

- We have successfully described total cross-section of 2- and 3-body systems with our new method.
- In future it would be interesting to disentangle 2-body channel cross-sections from total 3-body cross-sections. . [Work in Progress]
- The study "heavier" systems" ^{4}He and its low-lying resonances would be interesting. [Work in Progress]
- We are also working on M1 response. . [Work in Progress]
- We may look at other external probes as well. Anything but hadronic.
- The future looks interesting!

References

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