# Covariances from Nuclear Theory for Light Nuclei

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# Contents

- Theory yields unique output, no error bands
- R-matrix analysis as standard procedure for light nuclei
- Nuclear potentials allow for parameters
- The very light nuclei
- Nuclei above A = 6
- Combine theory with R-matrix analyses?

# Theory yields no error bands

For given input theory yields a unique answer
via a soluble model
Results might agree with data or not

Different models might yield different answers
No combination of different models possible

$\Rightarrow$ no fitting to data possible
$\Rightarrow$ no covariances

End of theory?

# R-matrix primer

Partial wave expansion

Scattering observable $O_{a,b} = \sum_{J^\pi,J^{\pi\prime}} C_{a,b}^{J^\pi,J^{\pi\prime}} * S_{a,b}^{J^\pi} * S{*}_{a,b}^{J^{\pi\prime}}$

Pole expansion of $S_{a,b}^{J^\pi}$(E) via R-matrix

fit R-matrix parameters, energies and residues, to data

tedious procedure, but guaranteed to work in the end

Advantages relative to purely statistical methods:

Energy dependence already from known external functions

Sensitive, differential data can be included in analysis

Unitarity yields constraints from other reaction channels

Charge symmetry arguments allow input from charged particle channels, reduce no. of free parameters

# R-matrix primer

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Problems

Large number of parameters

Quality of data

Finite range of data

Extrapolation in energy

# Nuclear Theory for Light Nuclei

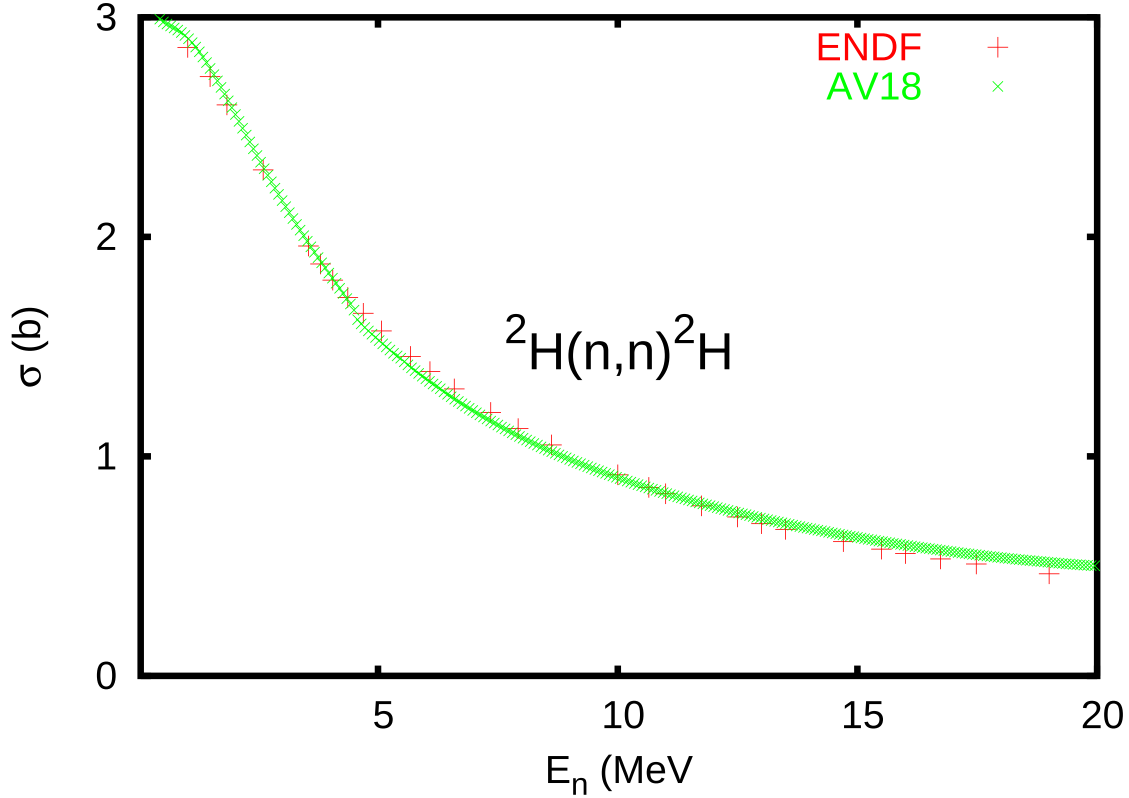
No QCD solutions known for nuclear binding energies

Nuclear potential(s) determined by fitting 2N and 3N data

$\Rightarrow$ Complicated operator structure $\Rightarrow$ realistic forces

Scattering calculations for A$\leq$5 feasible

RRGM calculations describe X-sections for A=3,4,(5) well



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Idea

Data are well reproduced
Consider operator strength parameters as free parameters
Get sensitivity matrices
fit strength parameters to data
$\Rightarrow$ fitting procedure analogous to R-matrix analysis

but for $A > 5$?

# Effective NN-Interactions for Light Nuclei

Realistic forces for $A > 5$ no more feasible
Too complicated wave functions
Too many channels, resonances

Reduce repulsive core of central potential for easier binding
Get rid of the tensor force neccessary for binding
Bind deuteron, triton, $\alpha$ with S-waves only
$\Rightarrow$ Much simpler wave functions
e.g. realistic $\alpha$ 500 - 1500 terms, S-wave $\alpha$ one Gaussian
$\Rightarrow$ RRGM calculation till $A \approx 16$ feasible

Existing effective forces do not yet describe data well

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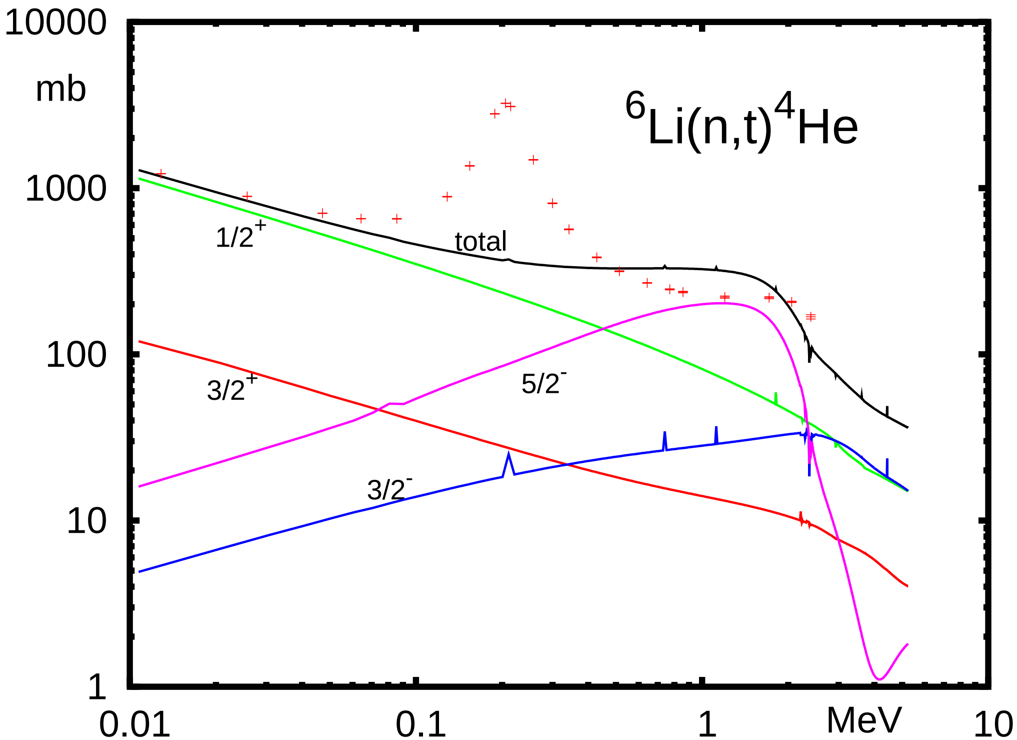

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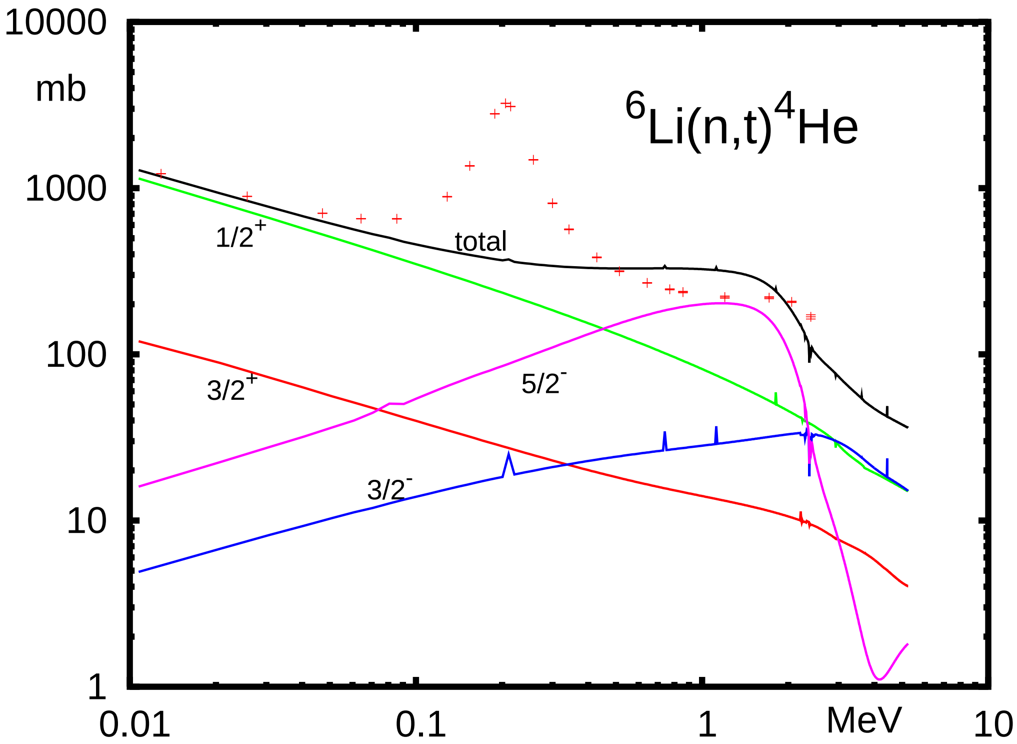


$5/2^-$ - peak too high

spin orbit force too weak

# How to Choose an Effective NN-Interaction

Properties wanted (in energy range of interest)
Reproduce x-section data
Reproduce relative thresholds of relevant channels
Yield $J^{\pi}$-resonances in correct order
Keep interaction and wave functions simple

Common wisdom
Every channel can support at most one resonance
$\Rightarrow$many resonances need many coupled channels
Interaction is model space dependent
$\Rightarrow$interaction changes from A to A + 1
Hopefully minor changes!

Heavier nuclei have more resonances, more difficult to treat
Search for $V_{eff}$, start with smallest A of interest

# Combine Theory with R-matrix Analyses?

Till now for $A \geq 6$

Use (some) standard $V_{eff}$
Compare gross structure
Compare number and order of resonances
Draw general conclusions

Aim

Find an understanding of gross structure
Explain main features
No detailed description of data required
No detailed energy dependence sought

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Till now for $A \geq 6$

Use (some) standard $V_{eff}$
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Future

Search for specific $V_{eff}$ to reproduce relevant channels well
Allow $V_{eff}$ $J^{\pi}$ dependent?
Above resonance region use theoretical estimate as input into R-matrix?