Gesellschaft für Schwerionenforschung, Darmstadt,

Theory Division

^{4}He photodisintegration with realistic nuclear forces

S. Bacca

in collaboration with:

W. Leidemann and G. Orlandini

Dipartimento di Fisica, Università di Trento and INFN

D. Gazit and N. Barnea

The Racah Institute of Physics, The Hebrew University, Jerusalem

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Outline

- Motivation

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- Theoretical Tools

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- Realistic Photoabsorption

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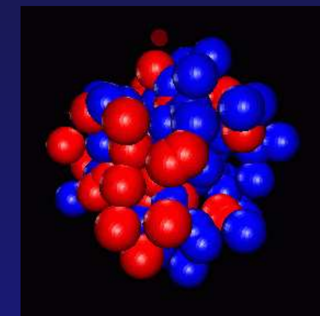
- Motivation
- Theoretical Tools
- Realistic Photoabsorption
- Conclusions

Motivation

Low energy QCD

→ **Nuclear interaction** →

“bridging”



Properties of nuclei

Motivation

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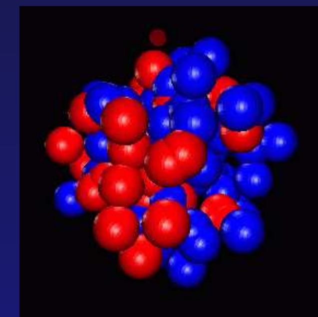

Low energy QCD

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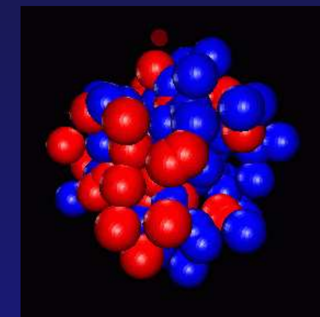
Properties of nuclei

Probing Few Nucleon Systems with Photons

Motivation

Nuclear interaction



Low energy QCD "bridging" Properties of nuclei

Probing Few Nucleon Systems with Photons

- Exact description of the wave function
- Perturbative approach + consistent current operator
- Study structure of light nuclei and reactions

Motivation

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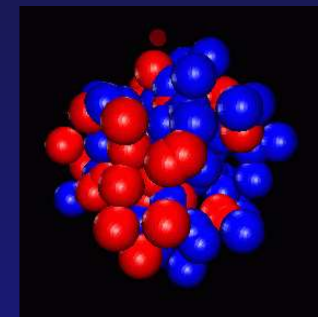

Low energy QCD — "bridging" — Properties of nuclei

Probing Few Nucleon Systems with Photons

- Exact description of the wave function
- Perturbative approach + consistent current operator
- Study structure of light nuclei and reactions

→ "Theoretical laboratory" to test nuclear force models:

two-body and three-body interactions

Theoretical Tools

Response Function $$R(\omega) = \sum_f \left| \langle \Psi_f | \hat{O} | \Psi_0 \rangle \right|^2 \delta(E_f - E_0 - \omega)$$

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$\mathcal{L}(\sigma) \xrightarrow{\text{Inversion}} R(\omega)$ with full FSI

Efros, Leidemann and Orlandini

PL B338 (1994) 130-133

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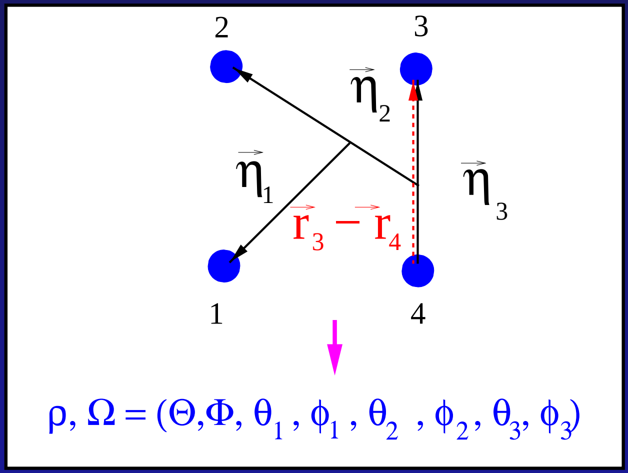
Good bound state techniques are needed!

Theoretical Tools

The Hyperspherical Harmonics Expansion

$$\Phi(\vec{r}_1, \vec{r}_2, \vec{r}_3, \vec{r}_4) = \Phi(\vec{R}_{CM})\Psi(\vec{\eta}_1, \vec{\eta}_2, \vec{\eta}_3)$$



Center of mass removed form the beginning

$$H = \frac{1}{2m}\frac{\hat{K}^2}{\rho^2} + \sum_{i<j} V_{i,j}$$

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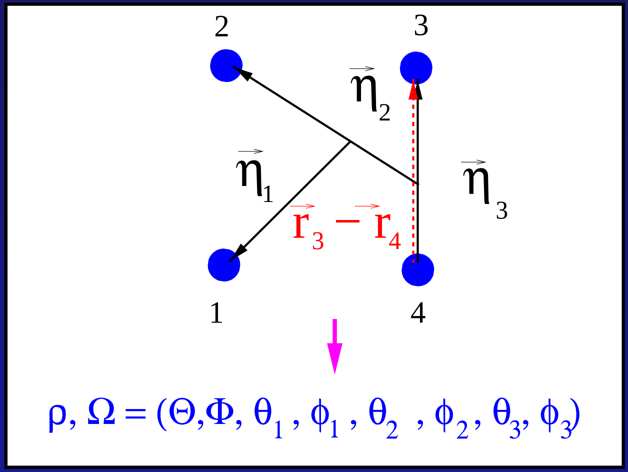

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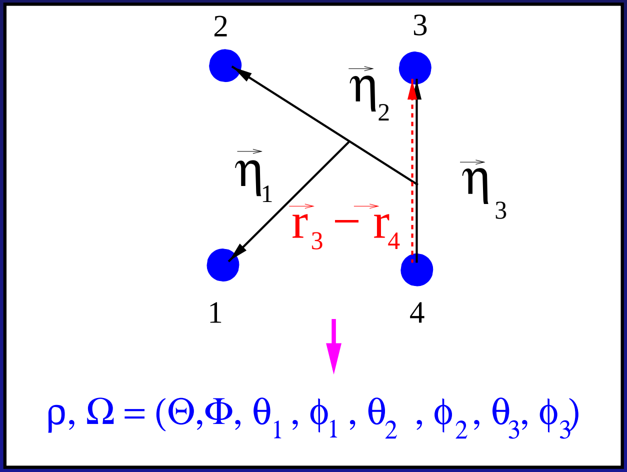

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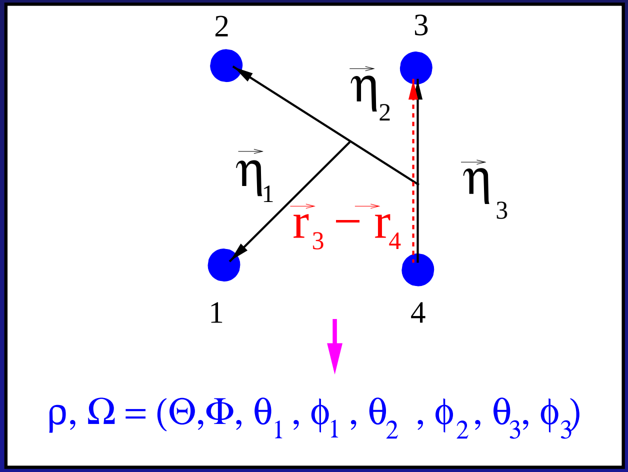

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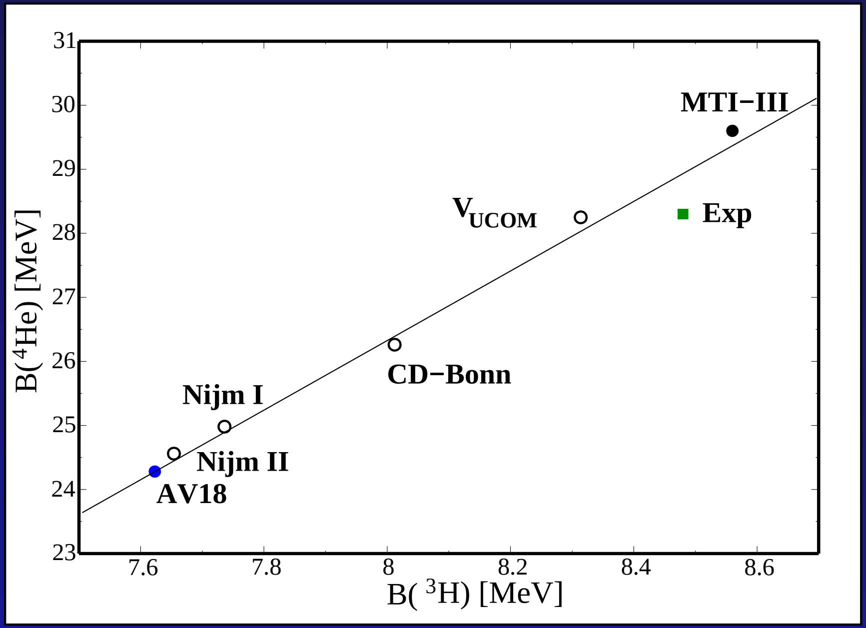
To accelerate the convergence of the expansion in an effective interaction is constructed via the Lee-Suzuki method, similarly as in the NCSM

$\longrightarrow$ Effective Interaction with the Hyperspherical Harmonics: EIHH

Barnea, Leidemann, Orlandini, PRC **61***, 054001 (2000)*

Modern Potential Models

two-body forces



Modern Potential Models

two-body forces

+

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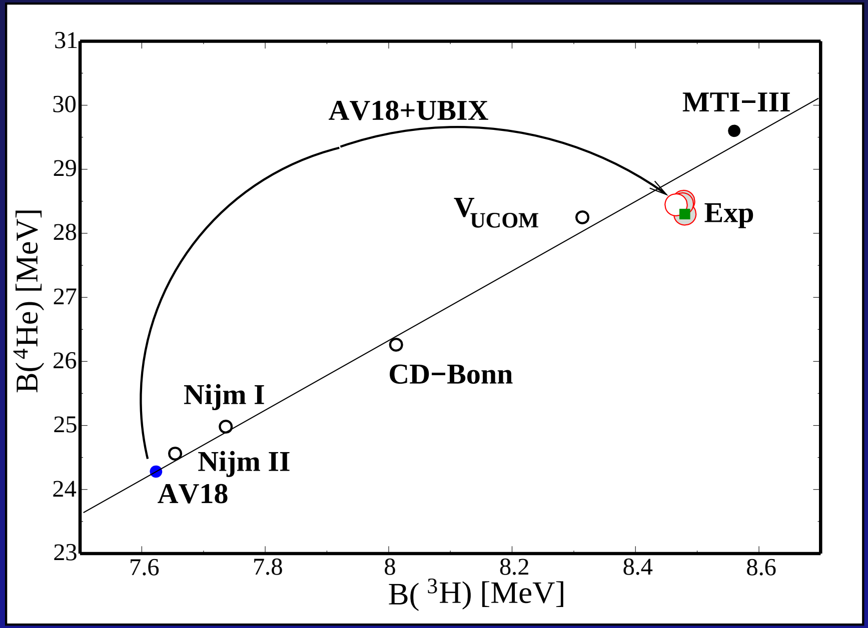

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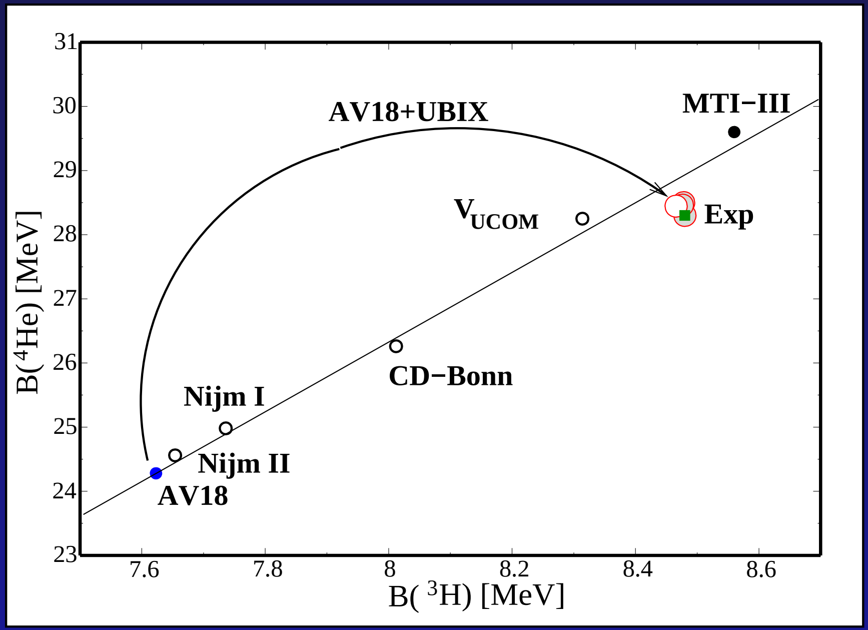

What is the effect of three-body forces in a scattering observable?

Modern Potential Models

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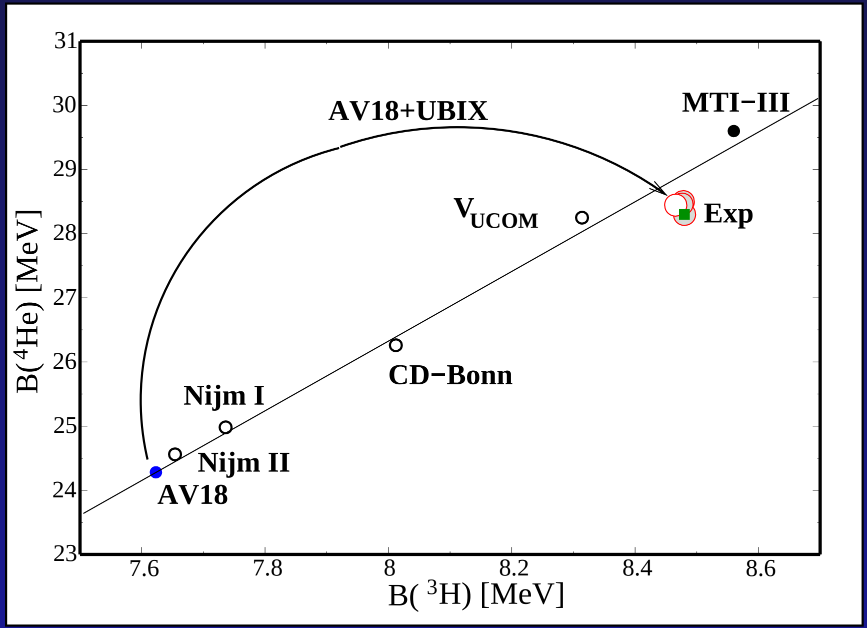

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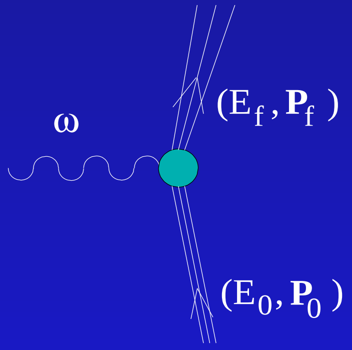
Total photodisintegration cross section as interesting observable



$$\sigma(\omega) = 4\pi^2 \alpha \omega R(\omega)$$

$$R(\omega) = \sum\!\!\!\!\!\!\int_f \left|\langle \Psi_f | O | \Psi_0 \rangle\right|^2 \delta(E_f - E_0 - \omega)$$

O = E1 via Siegert Theorem

Dominant part of

Meson Exchange Currents is included

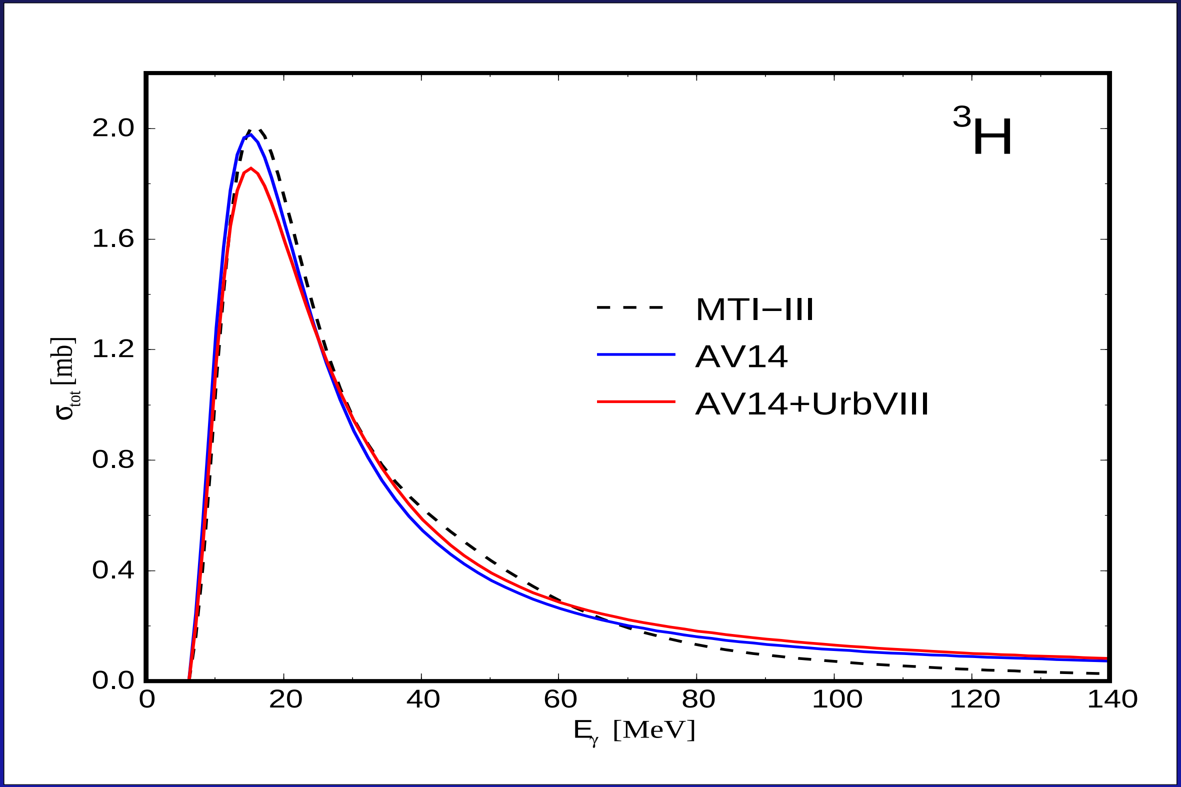
Total photodisintegration of ^{3}H

Semirealistic vs Realistic Potential

Efros, Leidemann,

Orlandini, Tomusiak

PLB 484 (2000) 223



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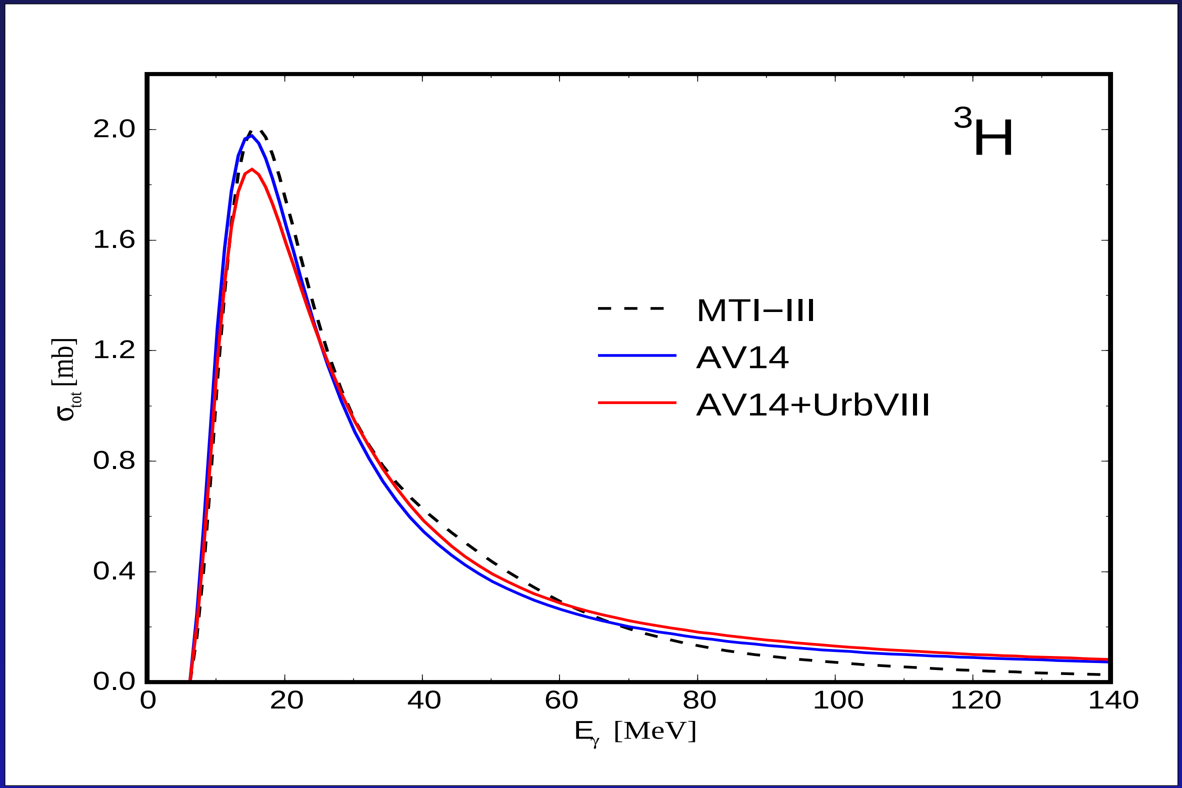
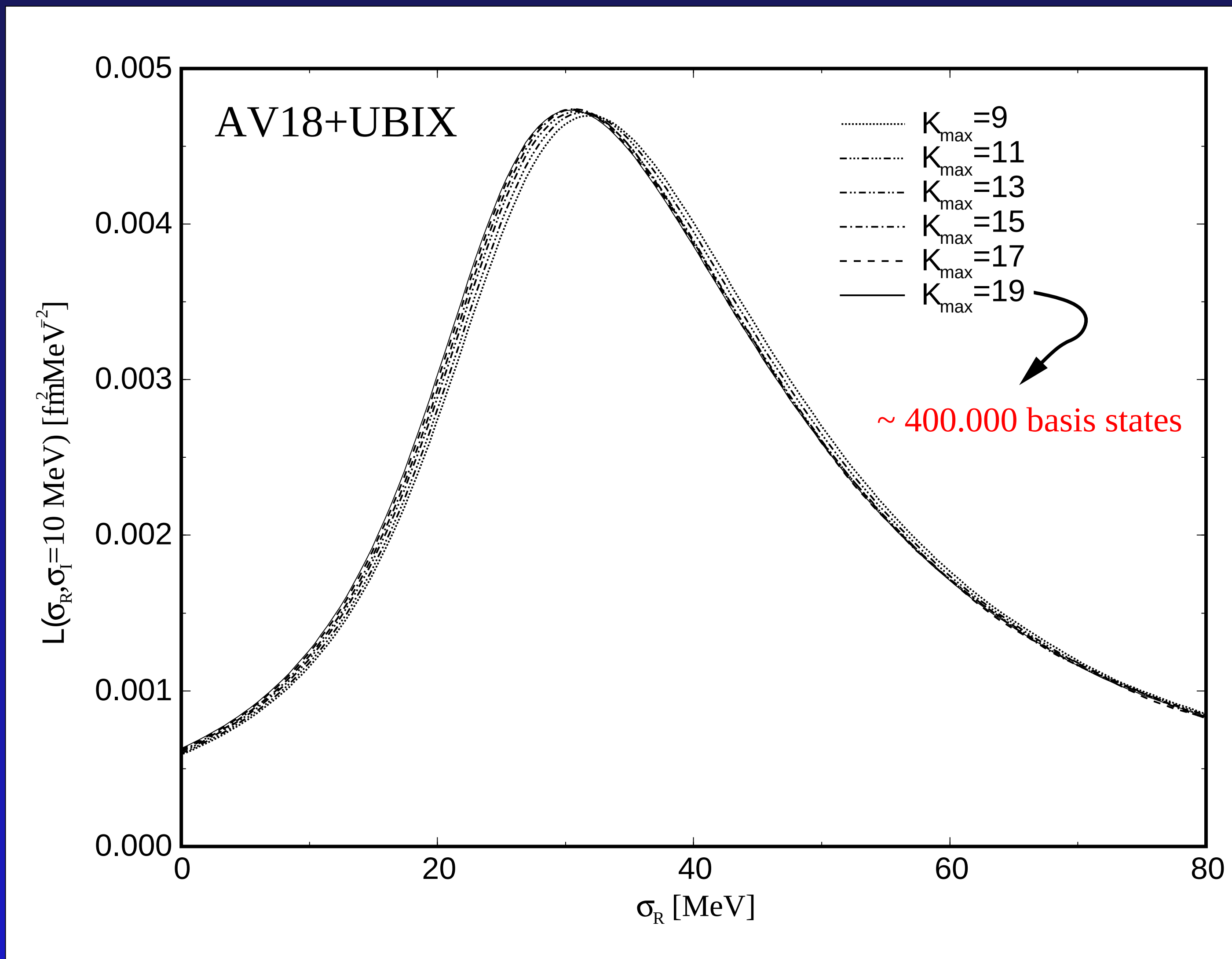


- Semirelistic → peak overestimation $< 10\%$ + strong tail underestimation
- Three-body forces → peak damping 10% + tail enhancing 15%

Total photodisintegration of ^{4}He

Convergence of the Lorentz Integral Transform



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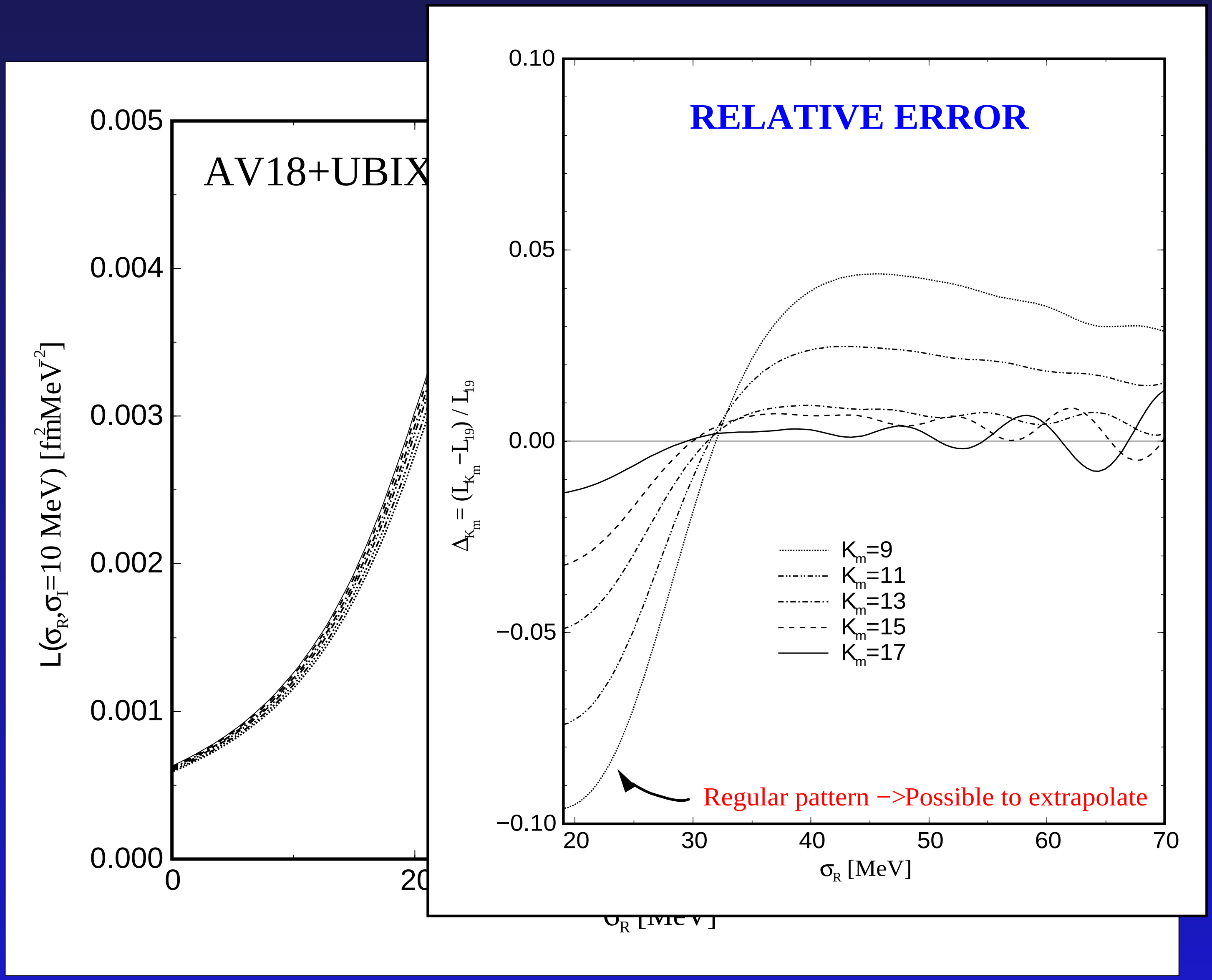

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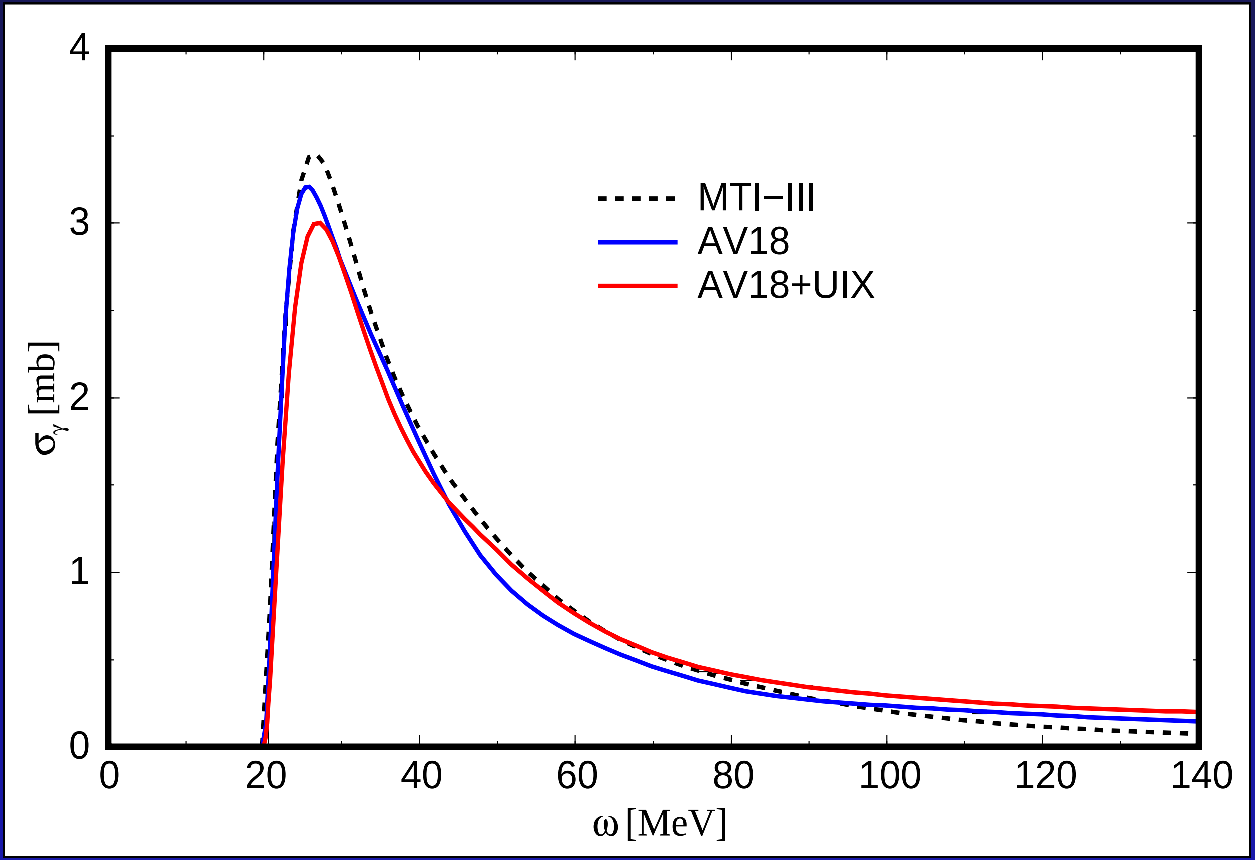
Latest Results

for AV18, AV18+UIX

Gazit, Bacca, Barnea

Leidemann, Orlandini

PRL 96, 112301 (2006)



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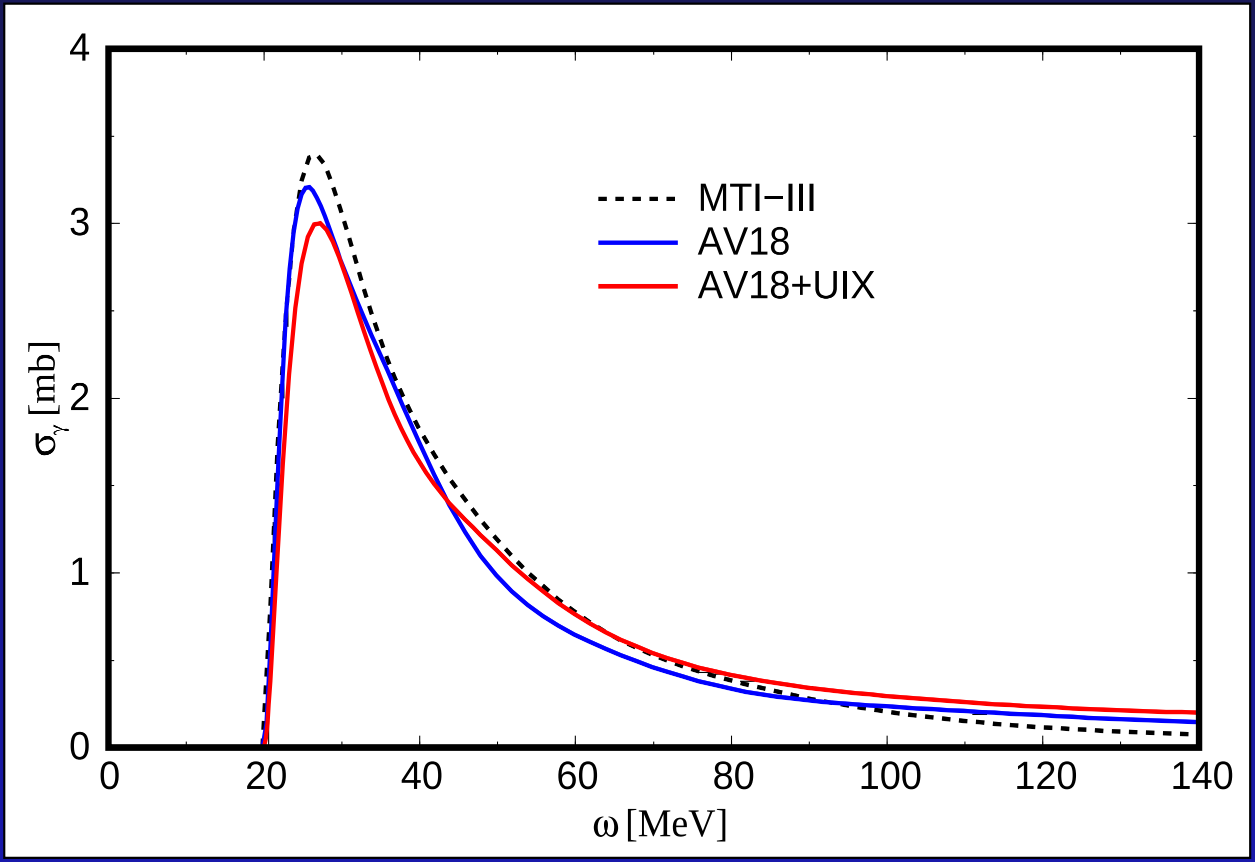
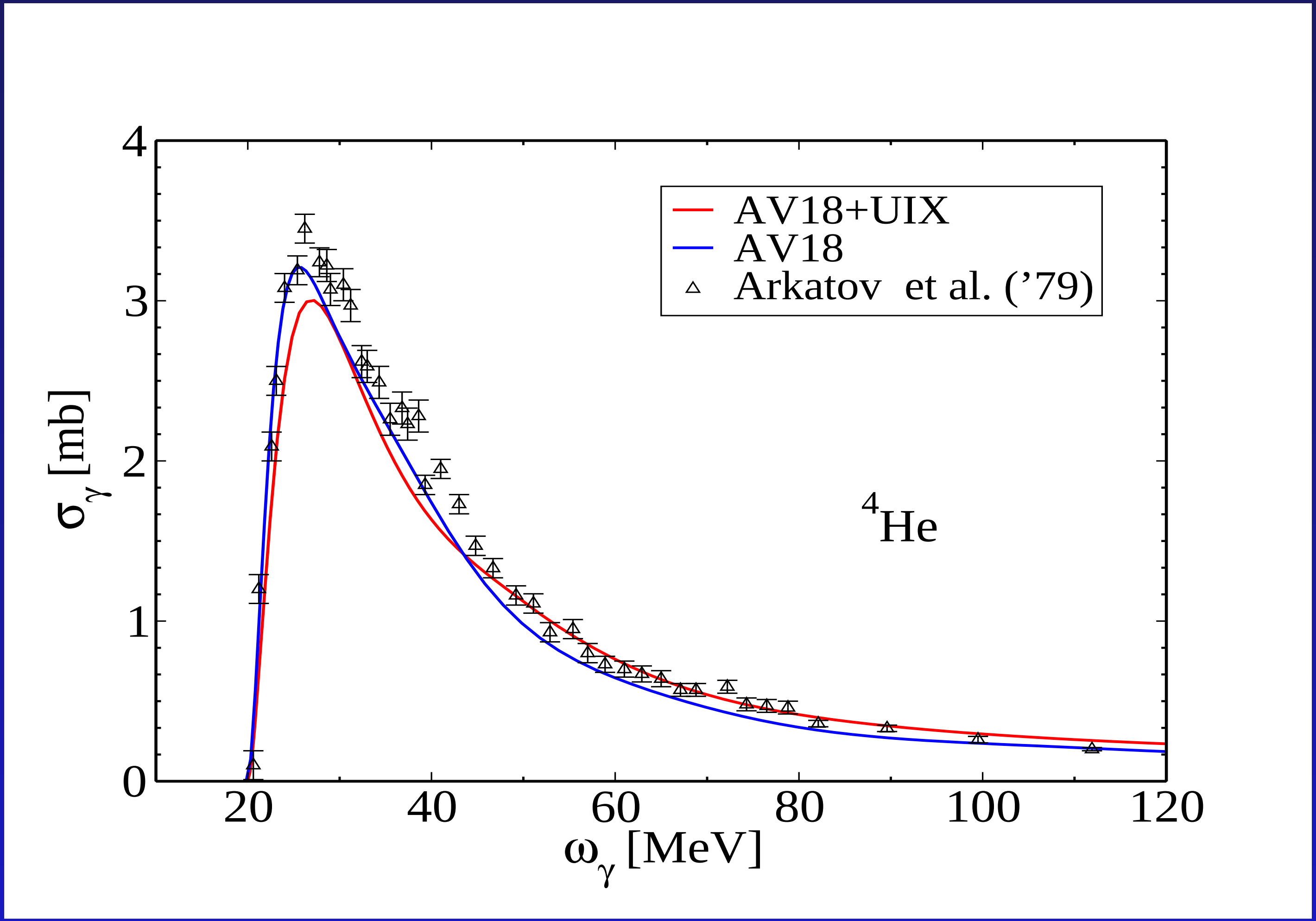


- Semirelistic $\rightarrow$ peak overestimation 10-15% + strong tail underestimation
- Three-body forces $\rightarrow$ peak damping 6% + tail enhancing 35%

Total photodisintegration of ^{4}He

Comparison with experiments



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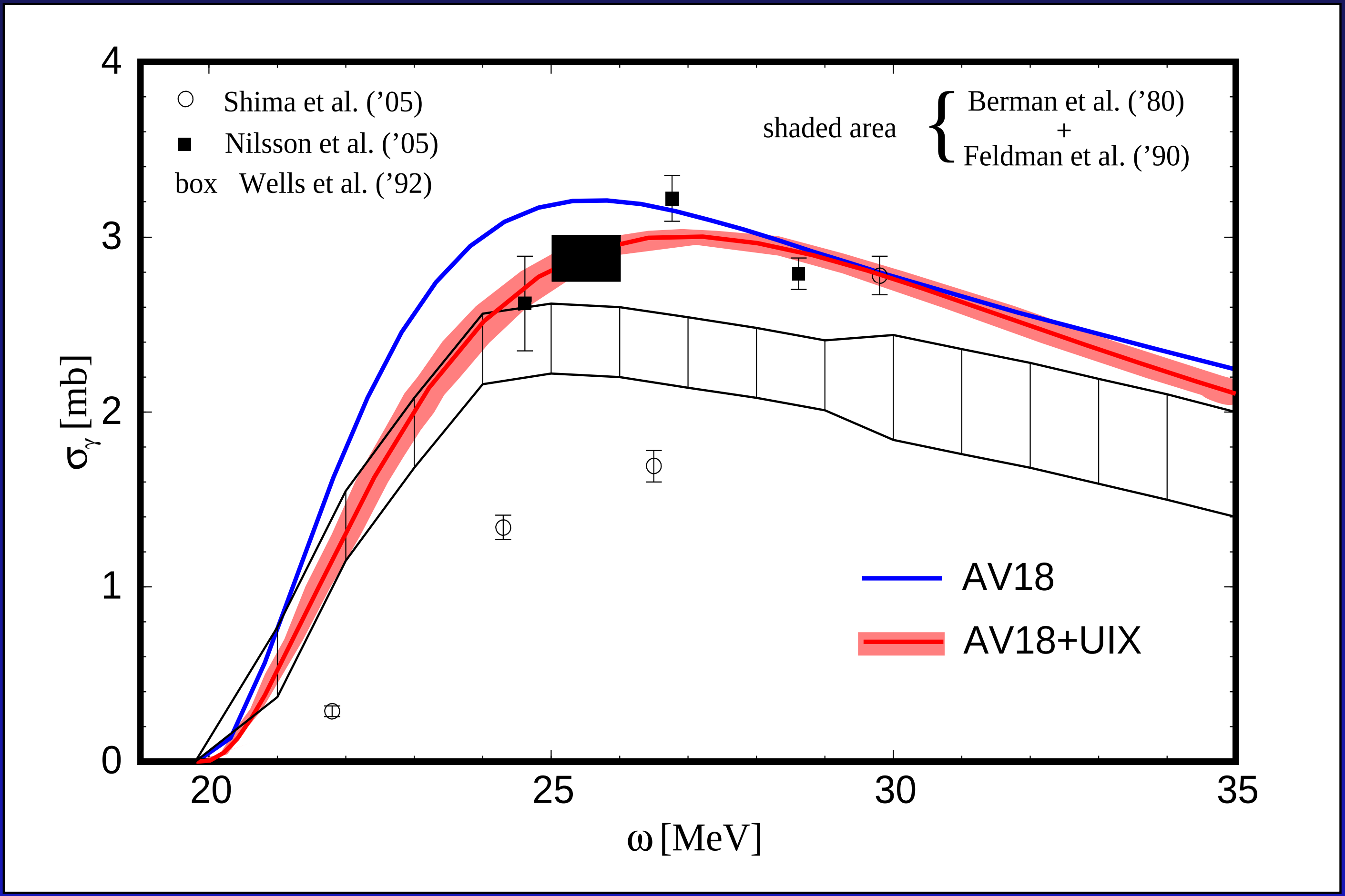

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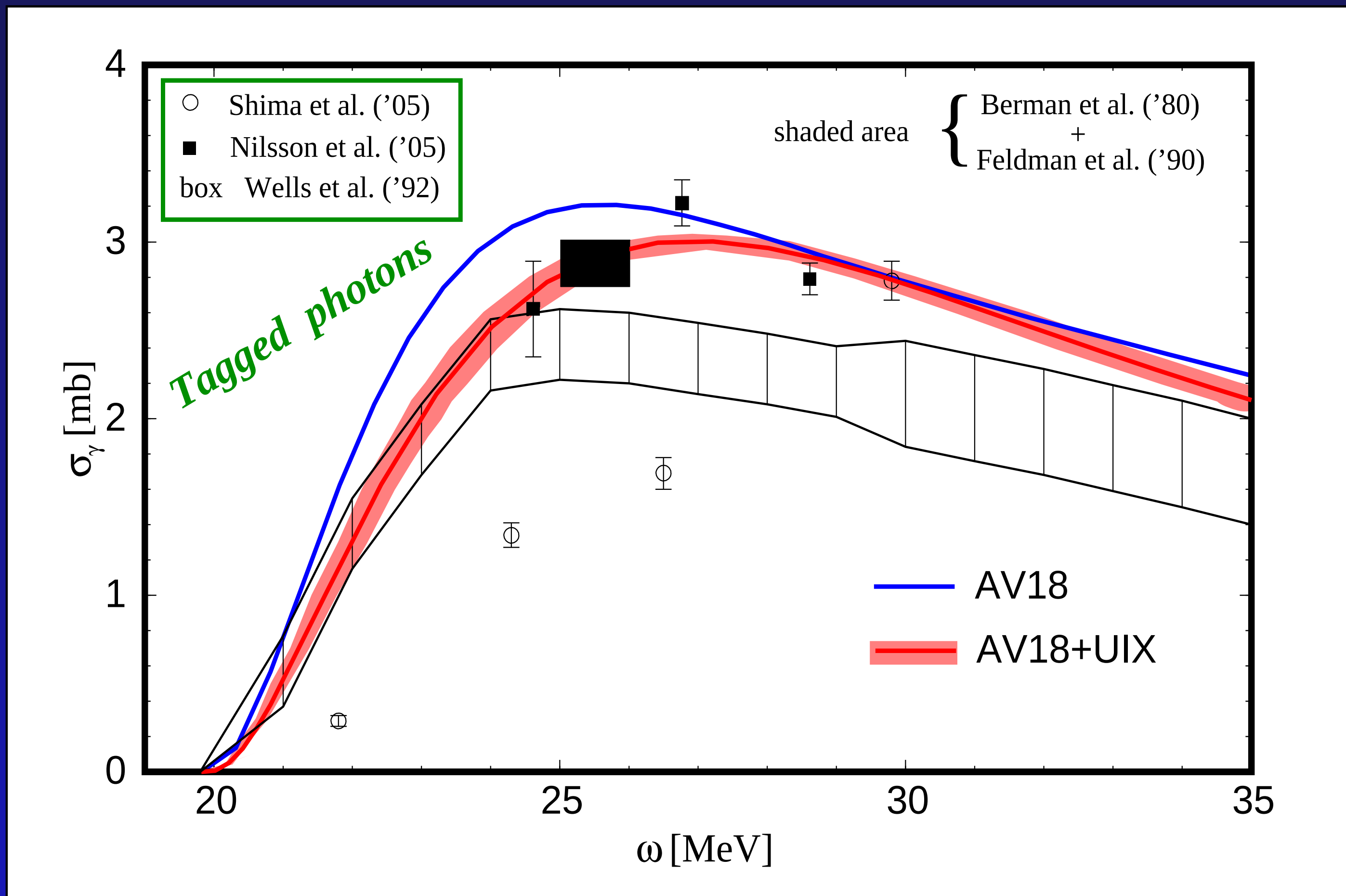

Conclusions

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  we can treat simultaneously the different four-body disintegration channels with exact treatment of initial and final state interaction using modern potentials

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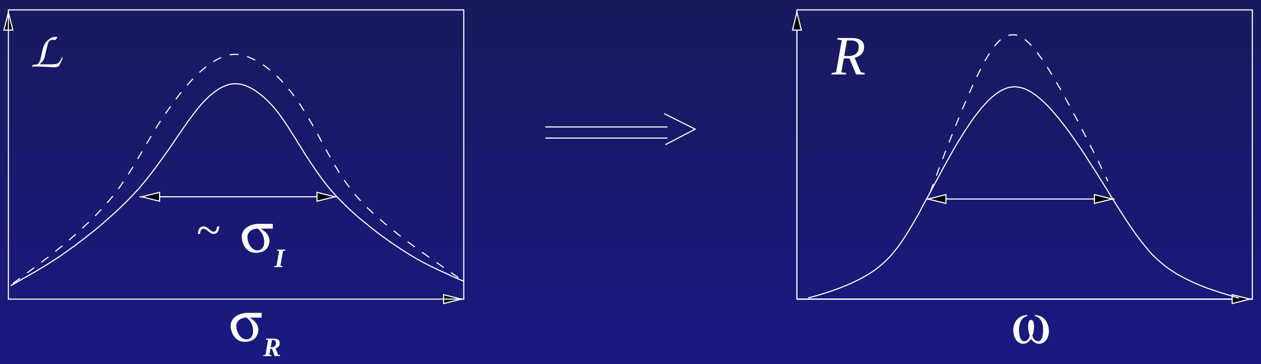
- The experimental situation is not settled and does not allow for a conclusive judgment on the reliability of modern two and three-body forces in the description of photodisintegration of ^{4}He

Inversion of the LIT

$$\mathcal{L}(\mathbf{q}, \sigma_R, \sigma_I) \Rightarrow \text{Inversion} \Rightarrow R(\mathbf{q}, \omega)$$



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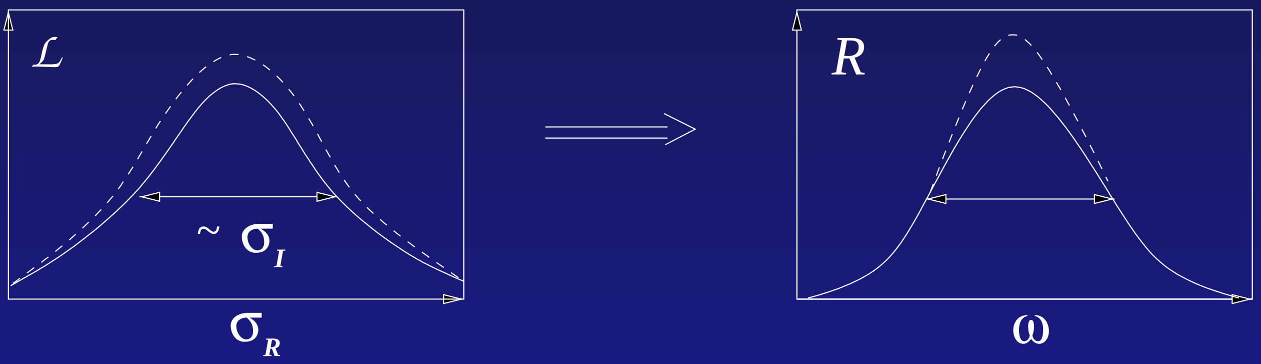

- Fix σ_I to a reasonable value:
  $\sigma_I \sim$ of the order of width of Response

- Calculate $\mathcal{L}(\mathbf{q}, \sigma_R)$ for a grid of M values of σ_R

Inversion of the LIT

- Expand the response over a set of functions whose LIT is well known

$$R(\mathbf{q},\omega) = \sum_{n=1}^{N} c_n \chi_n(\mathbf{q},\omega) \text{ with } \chi_n(\mathbf{q},\omega) \xrightarrow{\text{LIT}} \tilde{\chi}_n(\mathbf{q},\sigma)$$

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- Make best fit to calculate c_n with $M > N$

$$\sum_{k=1}^{M} \left| \mathcal{L}\left(\sigma_R^k, \sigma_I, \mathbf{q}\right) - \sum_{n=1}^{N} c_n \mathcal{L}_n\left(\sigma_R^k, \sigma_I, \mathbf{q}, \alpha\right) \right|^2 = \min,$$

- Check stability by increasing N to $N+i$ with $(N+i < M)$