Cluster Effective Field Theory calculation of electromagnetic breakup reactions with the Lorentz Integral Transform method

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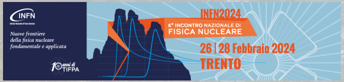
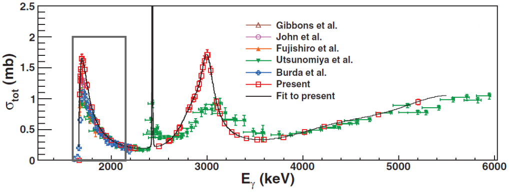


$$\gamma + {}^9\text{Be} \rightarrow \alpha + \alpha + n$$

Study of the reaction of *astrophysical interest* in the **low-energy regime**:

- ^{9}Be 3-body ($\alpha\alpha n$) binding energy
- Cross section



[Arnold *et al.* (2012)]

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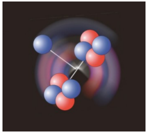
MODEL



P. Mueller/Argonne National Lab

- Effective particles: **nucleons** and **α-particles**
- Interaction: potential models from **Effective Field Theory** (EFT)
  (2-body and 3-body potentials) [Hammer *et al.* (2017)]

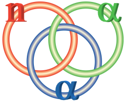
Cluster-EFT approach: why?

^{9}Be binding $B_3 \approx 1.573$ MeV $<< \alpha$ binding (≈ 20 MeV) $\leftarrow$ SEPARATION OF SCALES

$\uparrow$ shallow binding

$\Rightarrow$ ^{9}Be is a 3-body *effective* clustering system in the low energy regime

$\Rightarrow$ EFT approach



Two-Body Effective Potentials

Effective potential defined in momentum space and in the partial wave ℓ:

$$\mathcal{V}_\ell(p,p') = \left[\lambda_0 + \lambda_1 (p^2 + p'^2) \right] p^\ell p'^\ell \, g(p) g(p')$$

Regulator function:

$$g(p) = e^{-\left(\frac{p}{\Lambda}\right)^{2m}} \qquad m = 1, 2$$

- We calculate the T-matrix by solving the Lippmann-Schwinger equation
- We compare the calculated low-energy T-matrix with its ERE

The LECs are fixed on the experimental values of the scattering length and the effective range

$$\lambda_i = \lambda_i(a_\ell^{\text{exp}}, r_\ell^{\text{exp}}, \Lambda)$$

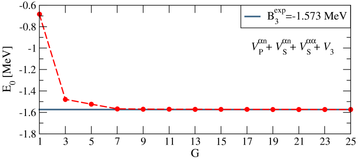
The effective potentials $\mathcal{V}_\ell^{\alpha n}(p,p')$ and $\mathcal{V}_\ell^{\alpha\alpha}(p,p')$

reproduce the correct low-energy αn and $\alpha\alpha$ phase-shifts

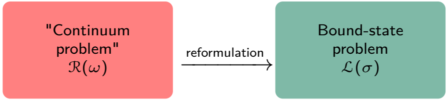
$$\gamma + {}^9\text{Be} \rightarrow \alpha + \alpha + n$$

METHOD

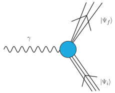
- Bound-state problem:
  the variational method with a **Non-Symmetrized Hyperspherical Harmonics** (NSHH) basis
  [Gattobigio *et al.* (2011), Deflorian *et al.* (2013)]



- Continuum problem:
  the **Lorentz Integral Transform** (LIT) method
  [Efros *et al.* (2007)]



$$\gamma + {}^9\text{Be} \to \alpha + \alpha + n \qquad \gamma : \hat{\epsilon}_{\boldsymbol{q},\lambda},\ \omega = |\boldsymbol{q}|$$



Bacca *et al* (2014)

RESULTS

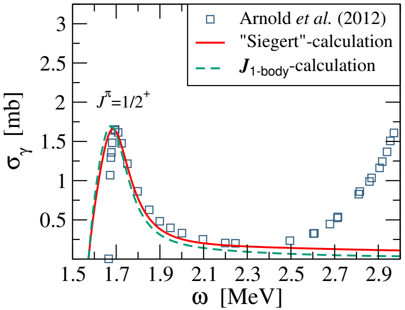
$$\sigma_\gamma \propto \mathcal{R}_\gamma(\omega) \sim \langle \Psi_f | \hat{\epsilon}_{\boldsymbol{q},\lambda} \cdot \boldsymbol{J}(\boldsymbol{q}) | \Psi_0 \rangle \leftarrow \text{Nuclear Current m.e.}$$

$$\boldsymbol{J} = \boldsymbol{J}_{\text{1-body}} + \boldsymbol{J}_{\text{2-body}} + \dots$$

We make two types of calculations (E1 contribution):

1. we use the **one-body current** $\boldsymbol{J}_{\text{1-body}}$ [Filandri (2022)]
2. we calculate the **dipole operator m.e.** $\langle \Psi_f | \hat{\epsilon}_{\boldsymbol{q},\lambda} \cdot \boldsymbol{D} | \Psi_0 \rangle$

Why? The ***Siegert theorem***, at low energy, ensures that the dipole operator contains the contribution of the 1-body current and beyond $\Rightarrow$ inclusion of $\boldsymbol{J}_{\text{2-body}}$ and $\boldsymbol{J}_{\text{3-body}}$ contribution to σ_γ



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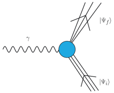

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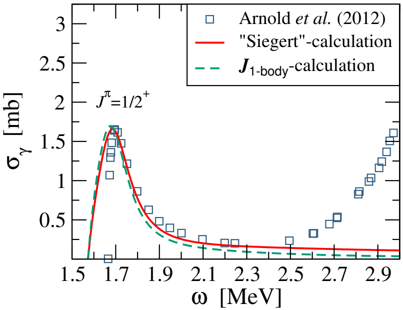

Thank You!