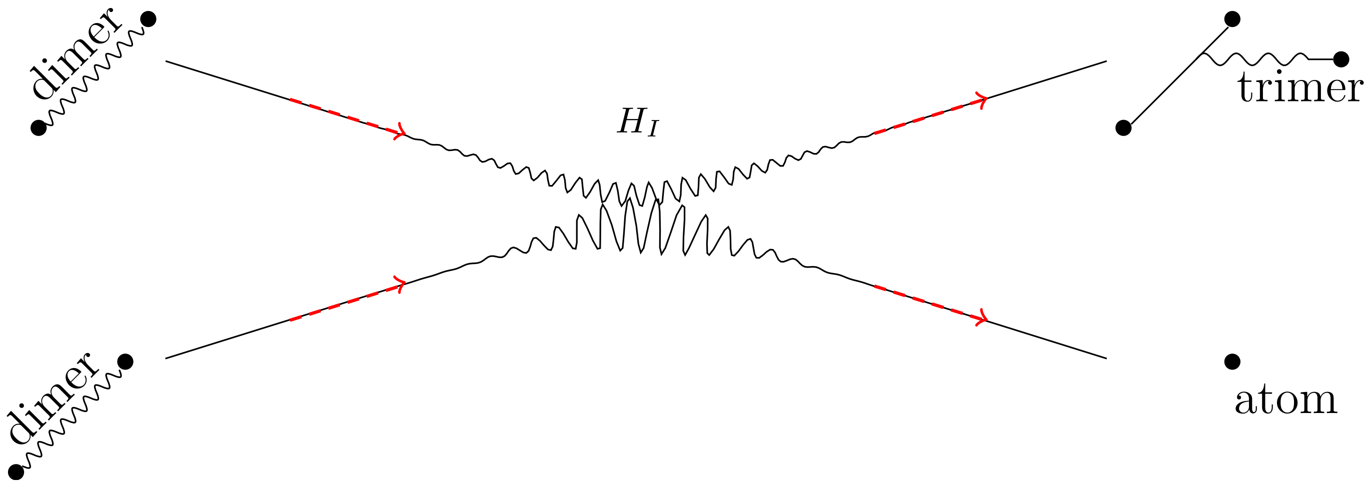
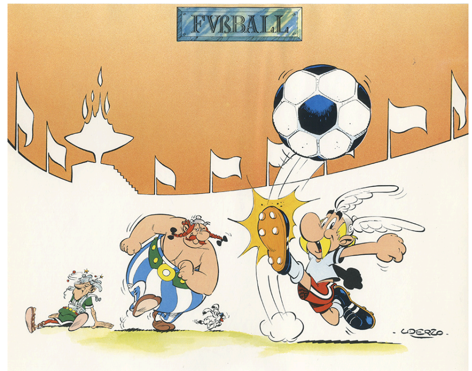
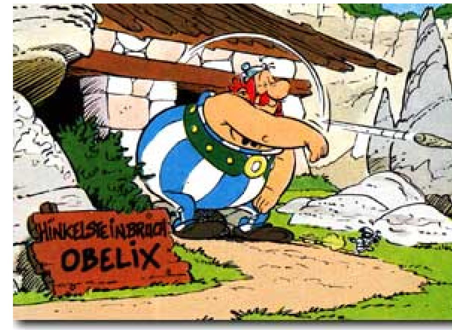
4-body reaction features universally correlated with dimer & trimer subsystems

October 9, 2024



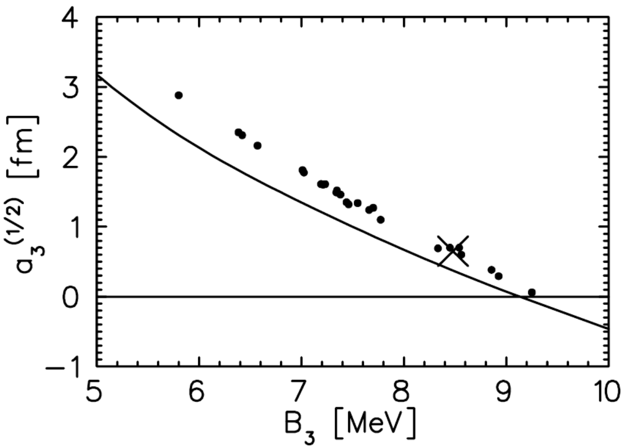
Sourav Mondal, Rakshanda Goswami, Udit Raha -- IIT Guwahati
J. Kirscher -- SRM University AP



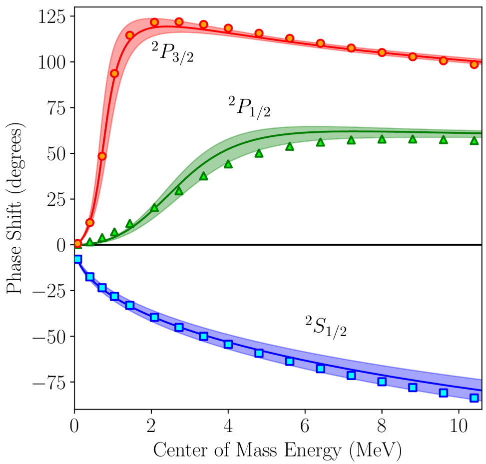


Øtd's (NFL '13) ≈ 2.8 — Øgoals (UK '13) ≈ 2.8 — Øtries (AUS '13) ≈ 5.7

$\approx 410(15)$g — $\approx 430(20)$g — $\approx 430(25)$g



P.F. Bedaque, H.-W. Hammer, U. van Kolck (2000)



K. Kravvaris et al. (2020)

Phillips *line*:

low-energy deuteron-neutron amplitude $= f(B_3)$

neutron-α:

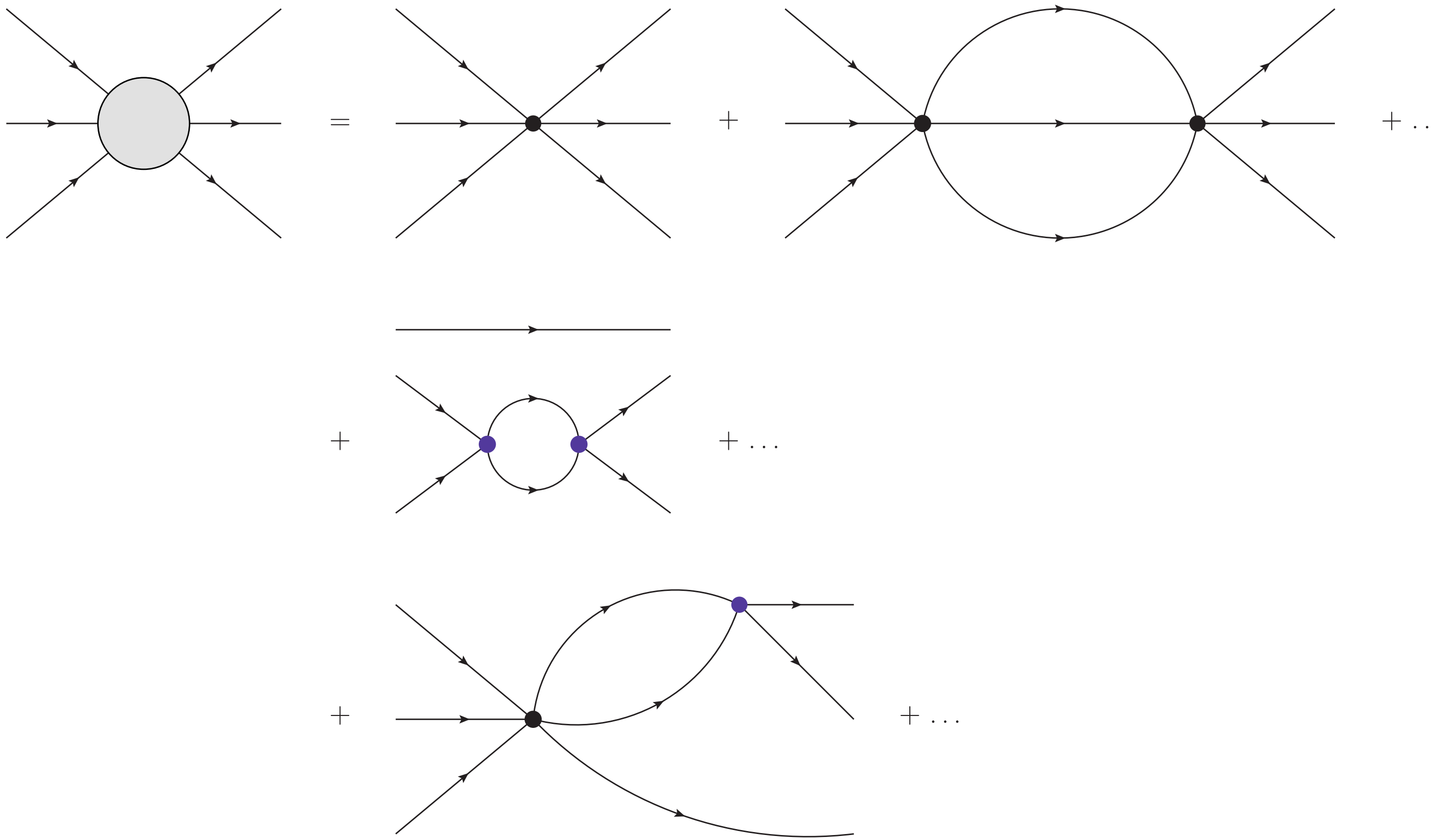
resonance poles$= f(?)$

$$a_{\text{dimer-dimer}} / a_{\text{atom-atom}} \approx 0.6$$

D.S. Petrov, C. Salomon, and G.V. Shlyapnikov (2003)

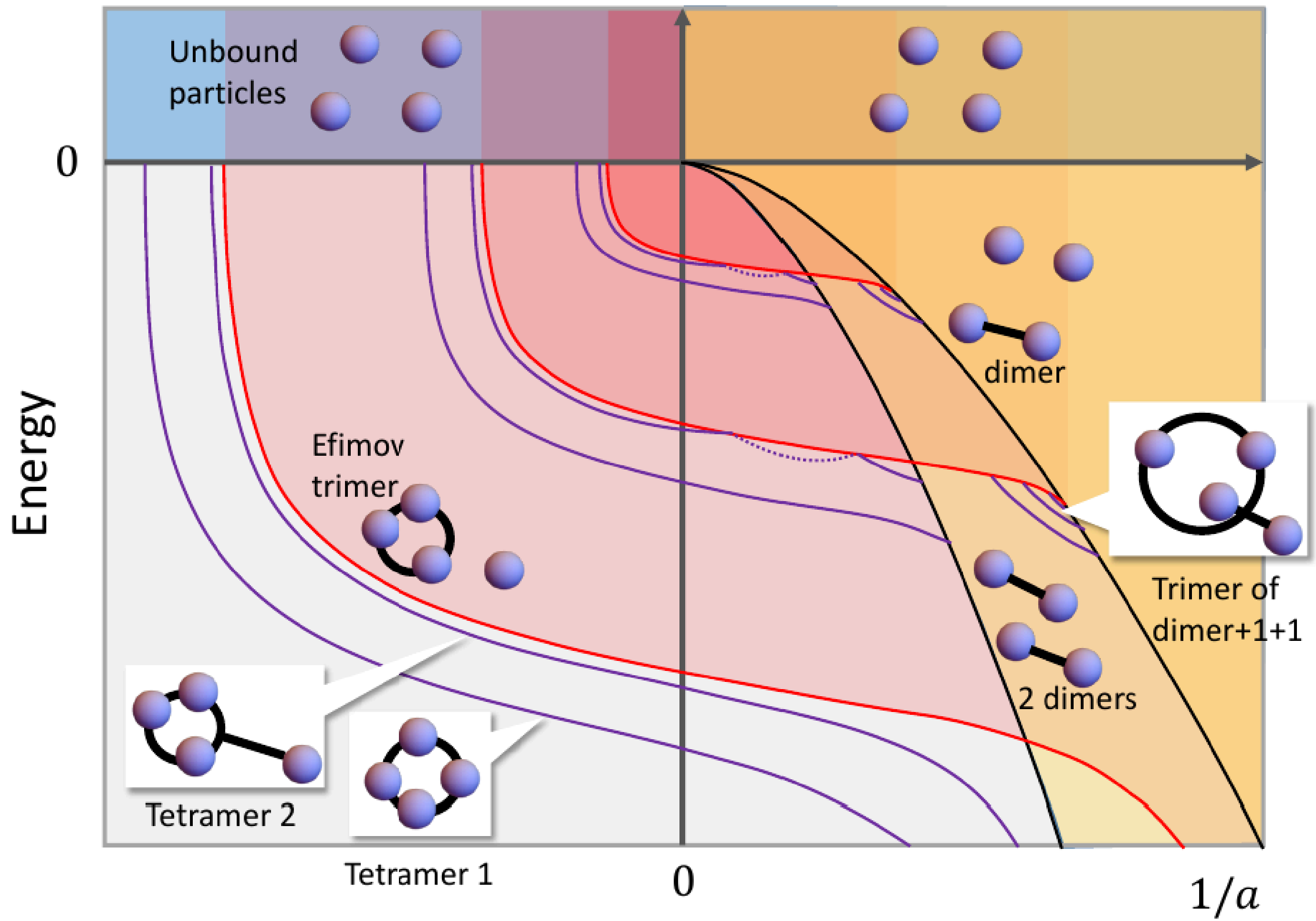
The universal minimum $\hat{V}$: structure and input

$$
\begin{aligned}
\Psi(E) &= C + C^2 \cdot L_1(E) + C^3 \cdot L_2(E) + \ldots \\
&= C(\lambda) + C(\lambda)^2 \cdot L_{1,\lambda}(E) + C^3 \cdot L_{2,\lambda}(E) + \ldots \\
&\text{"}\overset{!}{=}\text{"}\ B_{\text{exp}} = \frac{\langle \Psi | \hat{H} | \Psi \rangle}{\langle \Psi | \Psi \rangle}
\end{aligned}
$$



What do we know about universal phenomena in the 4-boson system?

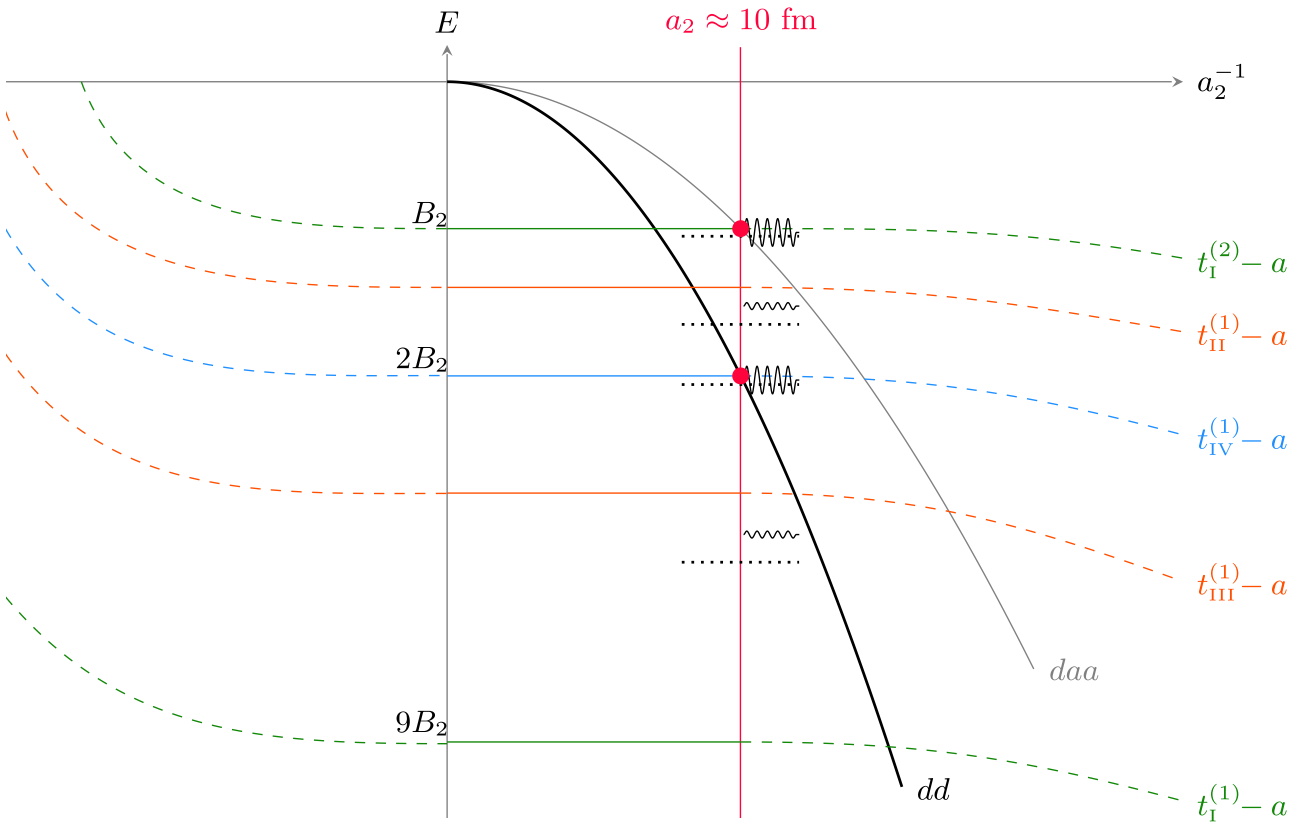
$a_2 \to \infty$ i.e. **no** 2-body scale



P. Naidon, S. Endo (2016 review)

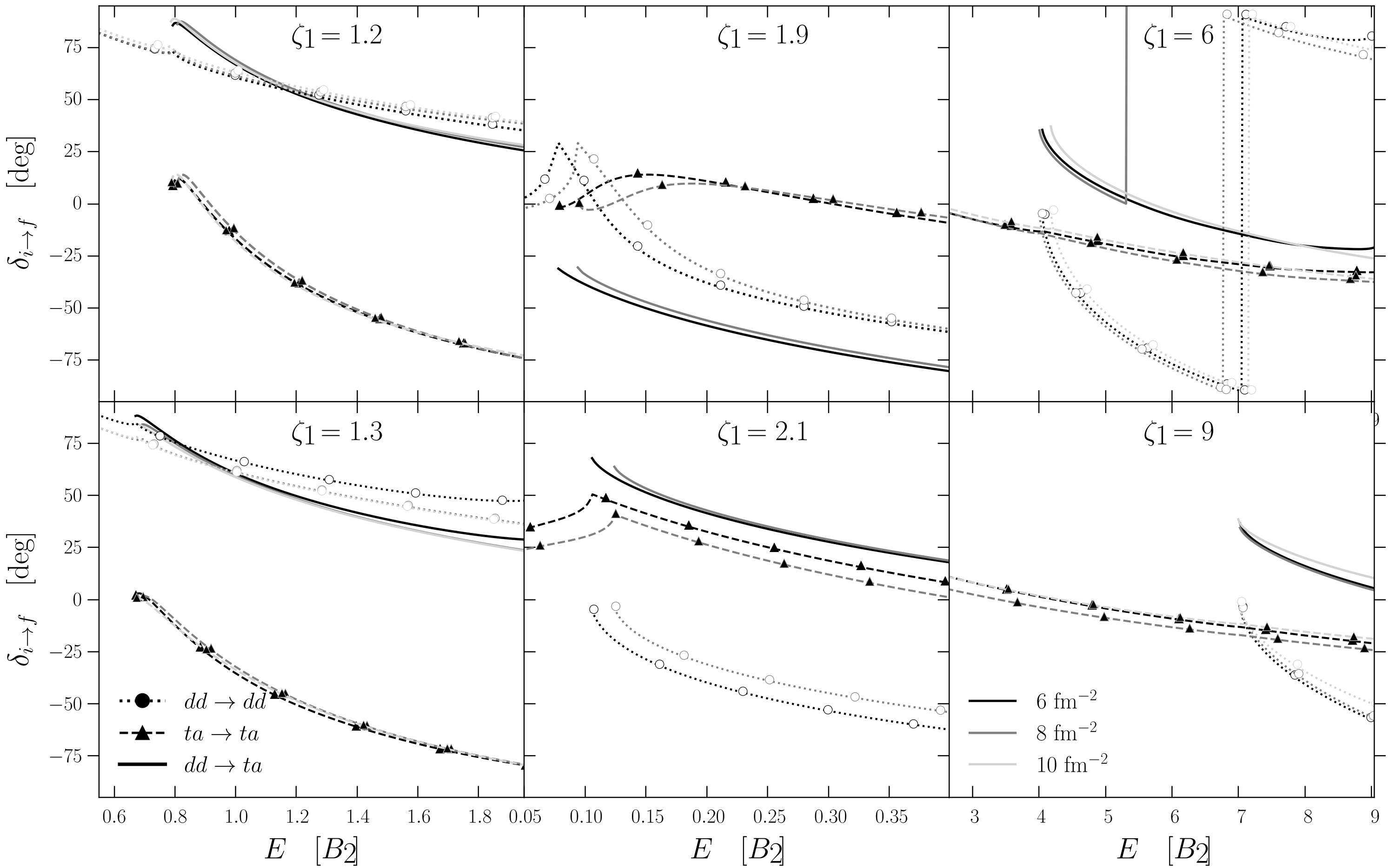
How does the minimal theory describe 4-component-fermion reactions?

$a_2 < \infty$



Phase-shift parameters of the 2-channel S-matrix

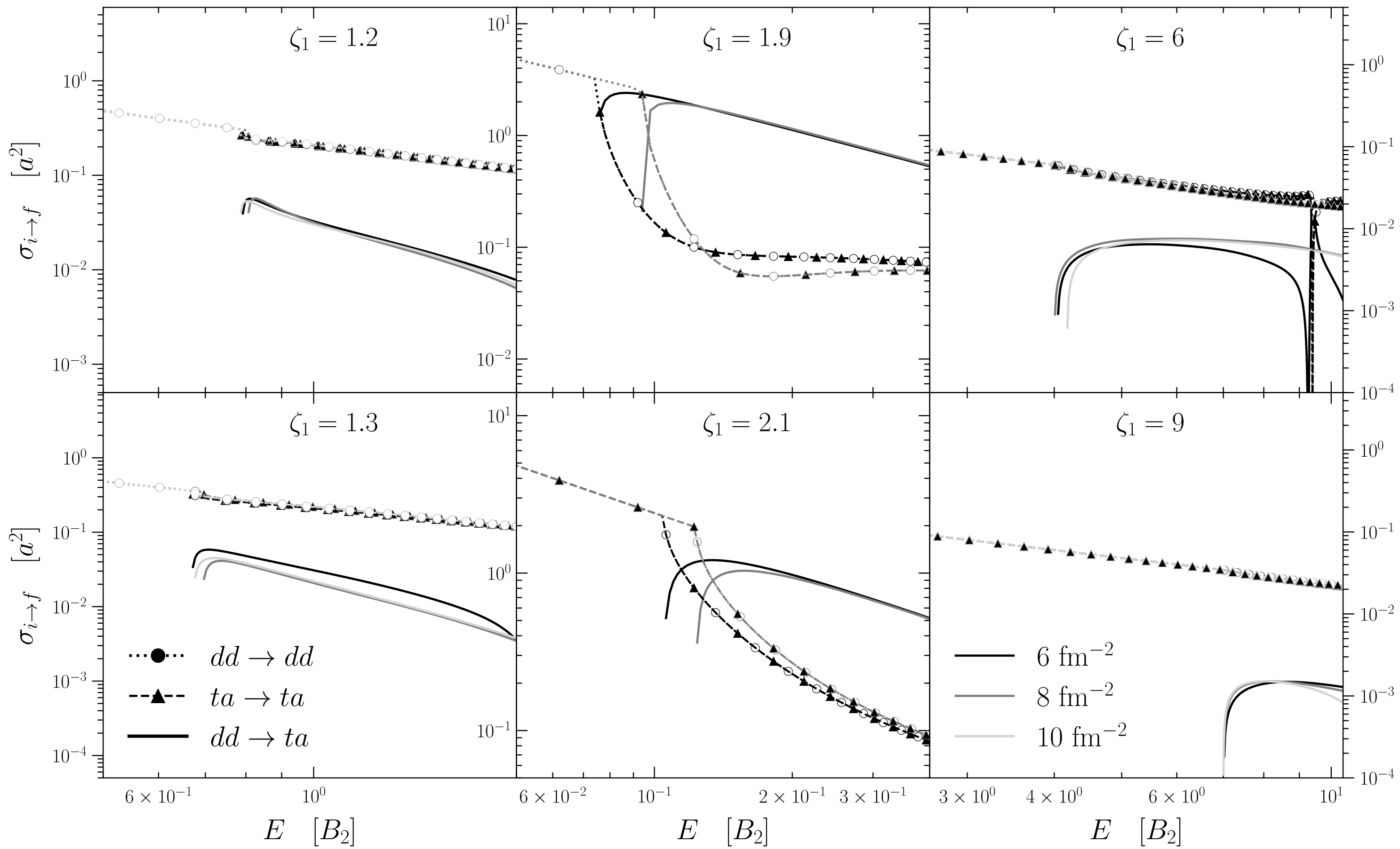
$$S_{if} = \eta_{if}\, e^{2i\delta_{if}}$$



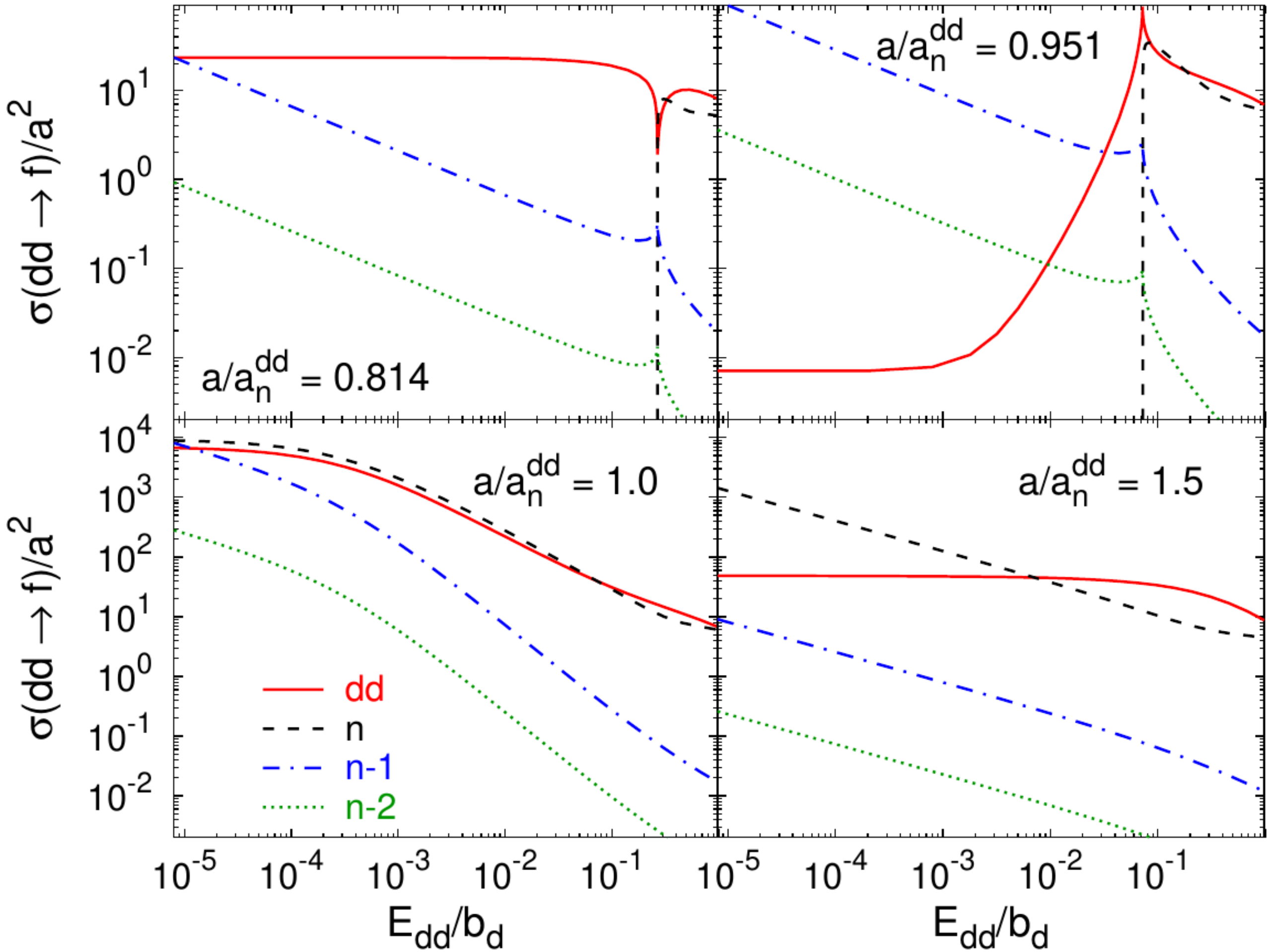
S. Mondal, R. Goswami, U. Raha, JK (2024)

Diagonal- and mixing-strength parameters of the 2-channel S-matrix

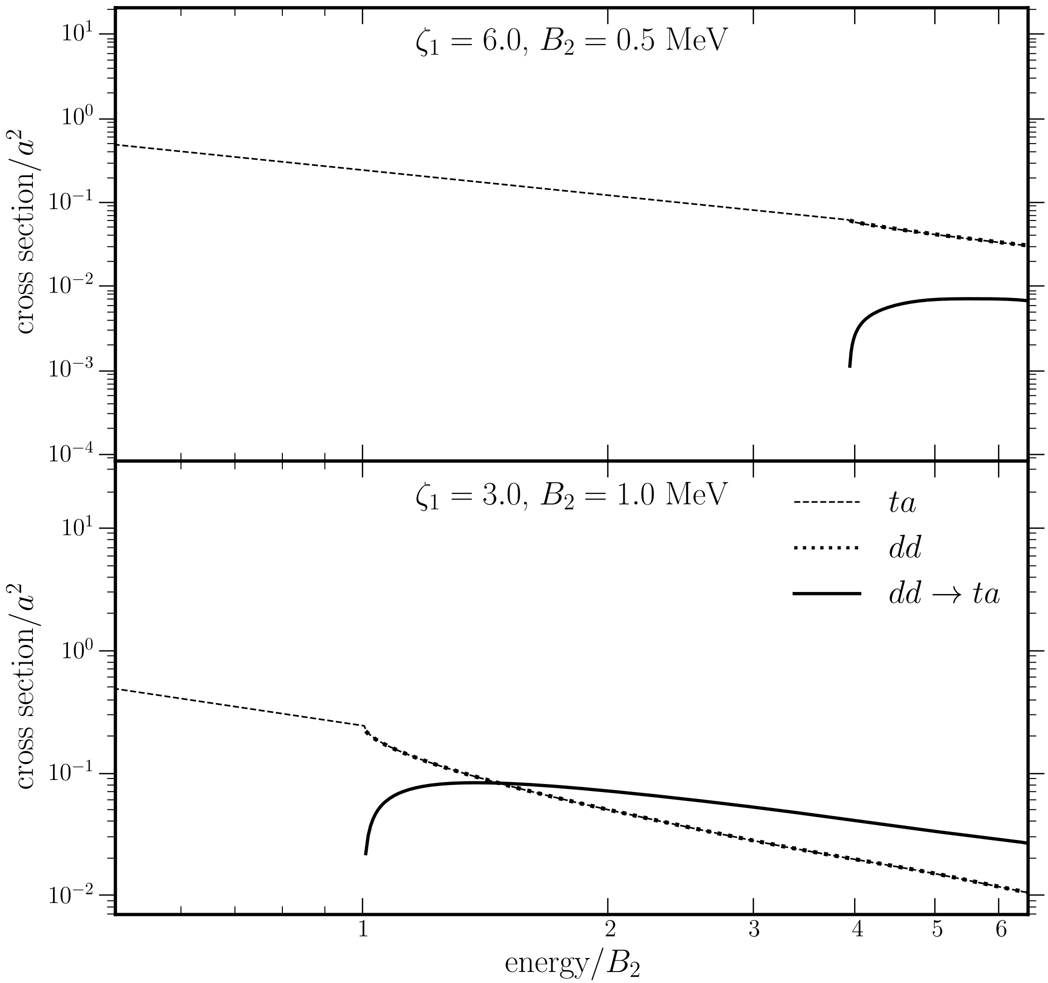
$S_{if} = \eta_{if}\, e^{2i\delta_{if}}$



S. Mondal, R. Goswami, U. Raha, JK (2024)



A. Deltuva (2011)



S. Mondal, R. Goswami, U. Raha, JK (2024)

- Expand in *realistic* DoF's

$$\Psi = \hat{\mathcal{A}}\left\{\sum_i \phi(A_i)\phi(B_i)F_i(\mathbf{R}_i) + \sum_j \phi(A_j)\phi(B_j)\phi(C_j)F_j(\mathbf{R}_{1j},\mathbf{R}_{2j}) + \ldots + \sum_m c_m\chi_m\right\} Z(\mathbf{R}_{\text{c.m.}})$$

- Obtain these states explicitly within "your" theory

$$\hat{H}\phi_A^{(n)} = e_A^{(n)}\phi_A^{(n)}$$

- "Freeze" the asymptotic states

$$\delta\Psi \stackrel{!}{=} \delta F_i$$

- Integrate-out/average-over internal DoF's

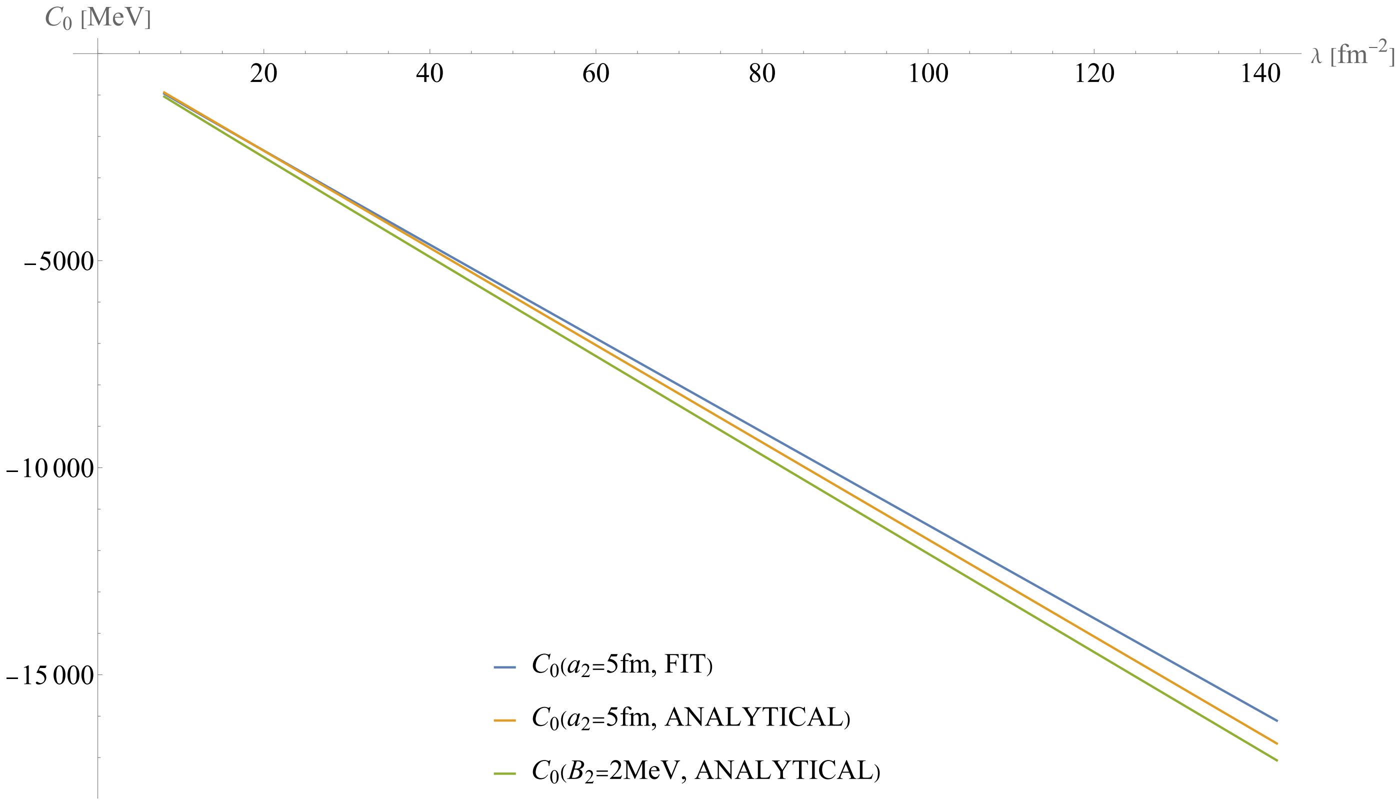
$$\left(\hat{T}_{\mathbf{R}} - E_{\text{rel}} + \mathbb{N}^{-1}\langle\phi_A\phi_B|\hat{V}|\phi_A\phi_B\rangle\right)\chi(\mathbf{R}) - \mathbb{N}^{-1}\int d\mathbf{R}'\left[\langle\phi_A\phi_B|\left(\hat{T}_{\mathbf{R}} - E_{\text{rel}} + \hat{V}\right)\hat{\mathcal{A}}\left\{|\phi_A\phi_B\rangle\delta(\mathbf{R}-\mathbf{R}')\right\}\right]\chi(\mathbf{R}') = 0$$

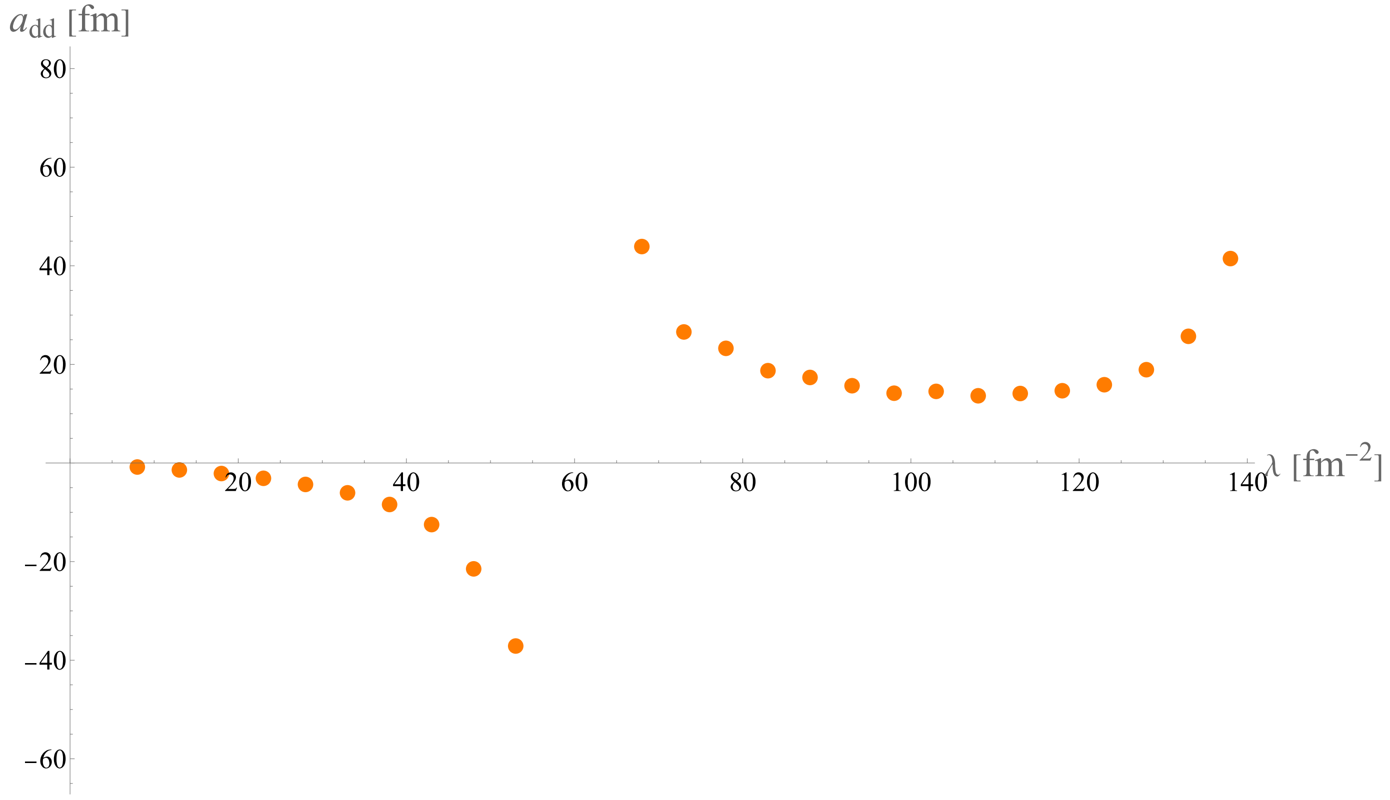
- Obtain inter-cluster dynamics with a potential matrix parametrized with "microscopic" observables

$$\sum_{n=1}^{N_{\text{loc}}}\hat{\eta}_n\, e^{-w_n\mathbf{R}^2}\chi(\mathbf{R}) - \sum_{n=1}^{N_{\text{n-loc}}}\int\left\{\hat{\zeta}_n\, e^{-a_n\mathbf{R}^2 - b_n\mathbf{R}\cdot\mathbf{R}' - c_n\mathbf{R}'^2}\right\}\chi(\mathbf{R}')d\mathbf{R}' = 0$$

with $\hat{\eta}_n,\hat{\zeta}_n,w_n,a_n,b_n,c_n$ dependent upon $C_{nn}(\lambda),C_{nnn}(\lambda),\alpha(\lambda),E_{\text{rel}},A,B$

2-body contact-interaction strength's regulator dependence




a_{dd} [fm]
80
60
40
20
−20
−40
−60
20
40
60
80
100
120
140
λ [fm^{-2}]