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Towards a Faddeev Description of (d,p) Reactions: Separabilizaton of Optical Potentials

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TORUS collaboration

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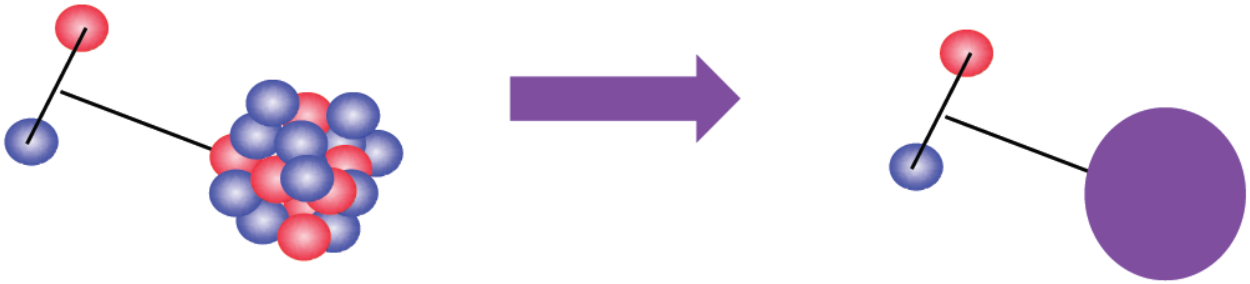
Exploring Nuclear Matter - Quarks to Stars

Reactions of Interest:

^{3}He (d,p) ^{4}He ⇒ ^{140}Sn (d,p)^{141}Sn … ?

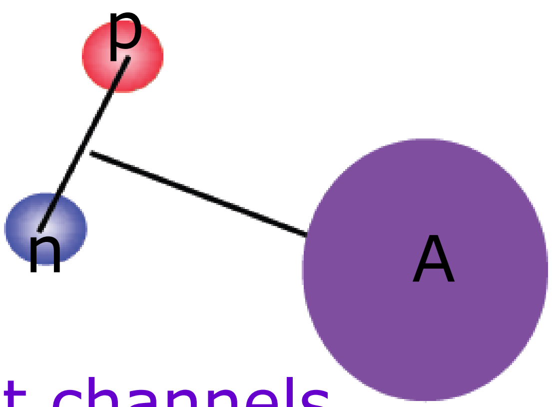
Ansatz:

Reduce many-body to few-body problem



- Isolate important degrees of freedom in a reaction
  - **Keeping track of all relevant channels**
- Connect back to the many-body problem
  - **Multiple scattering expansion d+A to be developed**

(d,p) Reaction as three-body problem:



Faddeev AGS

Elastic, breakup, rearrangement channels are included and fully coupled.

Deltuva and Fonseca, Phys. Rev. C**79**, 014606 (2009).

Hamiltonian: $\mathbf{H = H_0 + V_{np} + V_{nA} + V_{pA}}$

Issues:

- Traditional Faddeev eqs do not consider target exitations
- Coulomb force for heavy nuclei: current calculations to not converge for Z ≥ 20

Suggestion to extend Faddeev equations:

- Inclusion of target excitations
- Novel treatment of Coulomb in momentum space

A.M. Mukhamedzhanov, V.Eremenko and A.I. Sattarov,

arXiv:1206.3791 [nucl-th]

Including target excitations:

Formulation natural when transition amplitudes in sub-systems are separable.

Reminder:

t-matrices (= interactions summed up to all orders) from two-body subsystems are input to Faddeev amplitudes

Optical Potentials (phenomenological) for proton and neutron elastic scattering from nuclei:

Wood-Saxon functions in coordinate space

Example: Central part of CH89 optical potential

$$U_{\mathrm{nucl}}(r) = V(r) + i\,(W(r) + W_s(r)).$$

$$V(r) = \frac{-V_r}{1 + \exp\left(\frac{r - R_r}{a_r}\right)}$$

$$W(r) = \frac{-V_i}{1 + \exp\left(\frac{r - R_i}{a_i}\right)}$$

$$W_s(r) = \frac{-V_s \times 4 \times \exp\left(\frac{-(r - R_s)}{a_s}\right)}{\left(1 + \exp\left(\frac{-(r - R_s)}{a_s}\right)\right)^2}$$

Not a form that can be used in a Faddeev calculation in momentum space

Our test case:

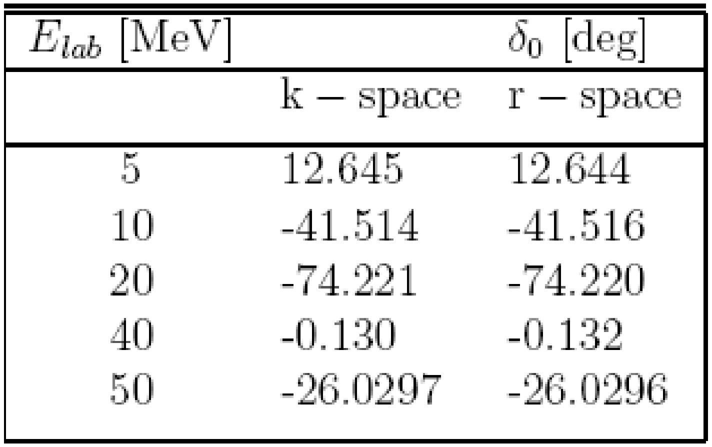
n+^{48}Ca CH89 cenral optical potential

Steps for creating a separable t-matrix:

1. Fourier Transform

Analytic in form of a series

– lowest terms sufficient.



E_{lab} [MeV]	δ_0 [deg]	
	k − space	r − space
5	12.645	12.644
10	-41.514	-41.516
20	-74.221	-74.220
40	-0.130	-0.132
50	-26.0297	-26.0296

2. Separabilization via EST scheme

D. J. Ernst, C. M. Shakin and R. M. Thaler, Phys. Rev. C 8, 46 (1973).

Use in momentum space

Use half-shell t-matrices as form factors at EST support points

EST Scheme:

$$\hat{t}(p,p',E) = \sum_{ij} \langle p|v_l|\psi_i\rangle \tau_{ij}(E) \langle\psi_j|v_l|p'\rangle$$

i,j give the rank

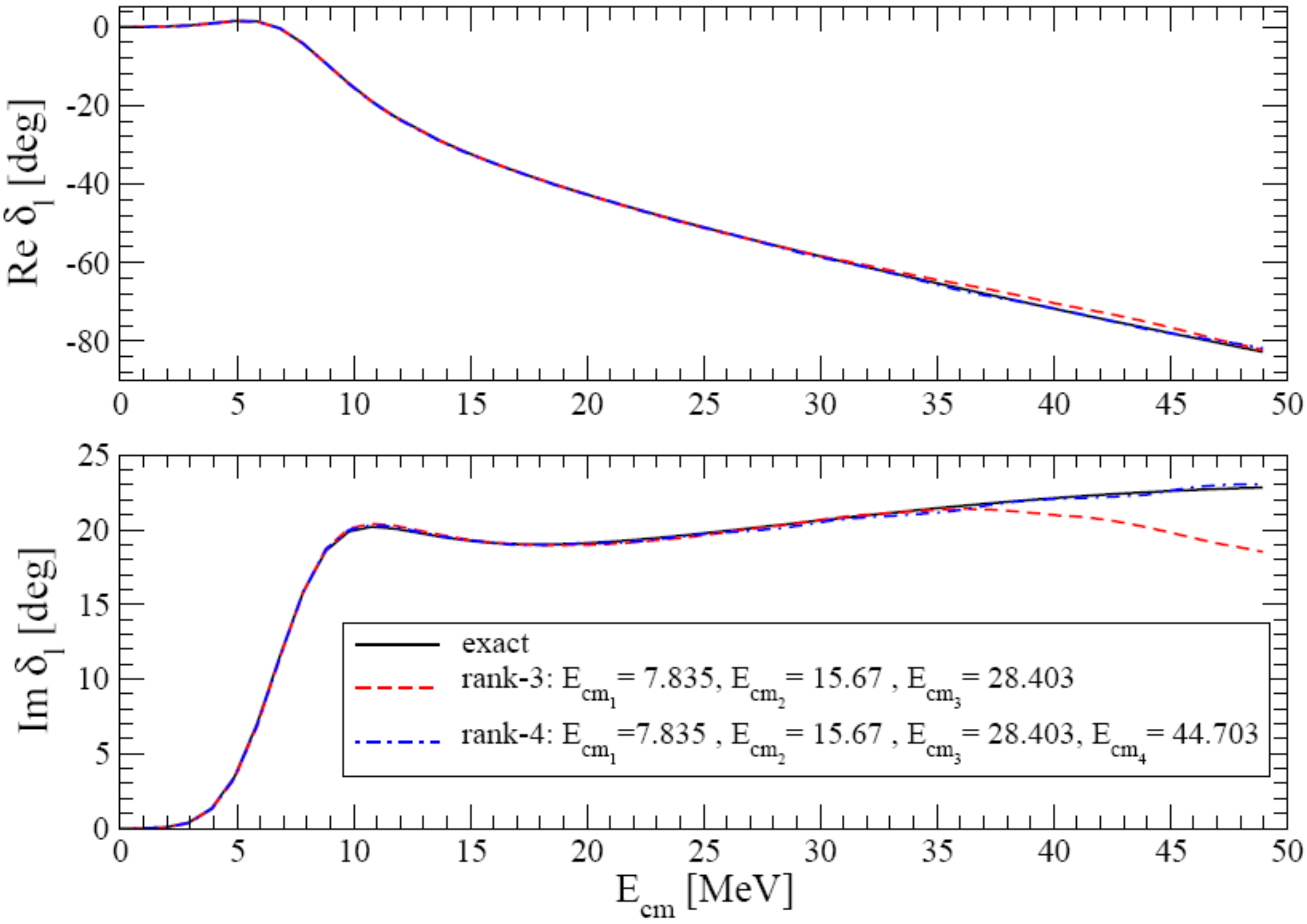
$$\sum_j \tau_{ij}(E)\ \underbrace{\langle\Psi_j|v - v g_0(E) v|\Psi_k\rangle} = \delta_{ik}$$

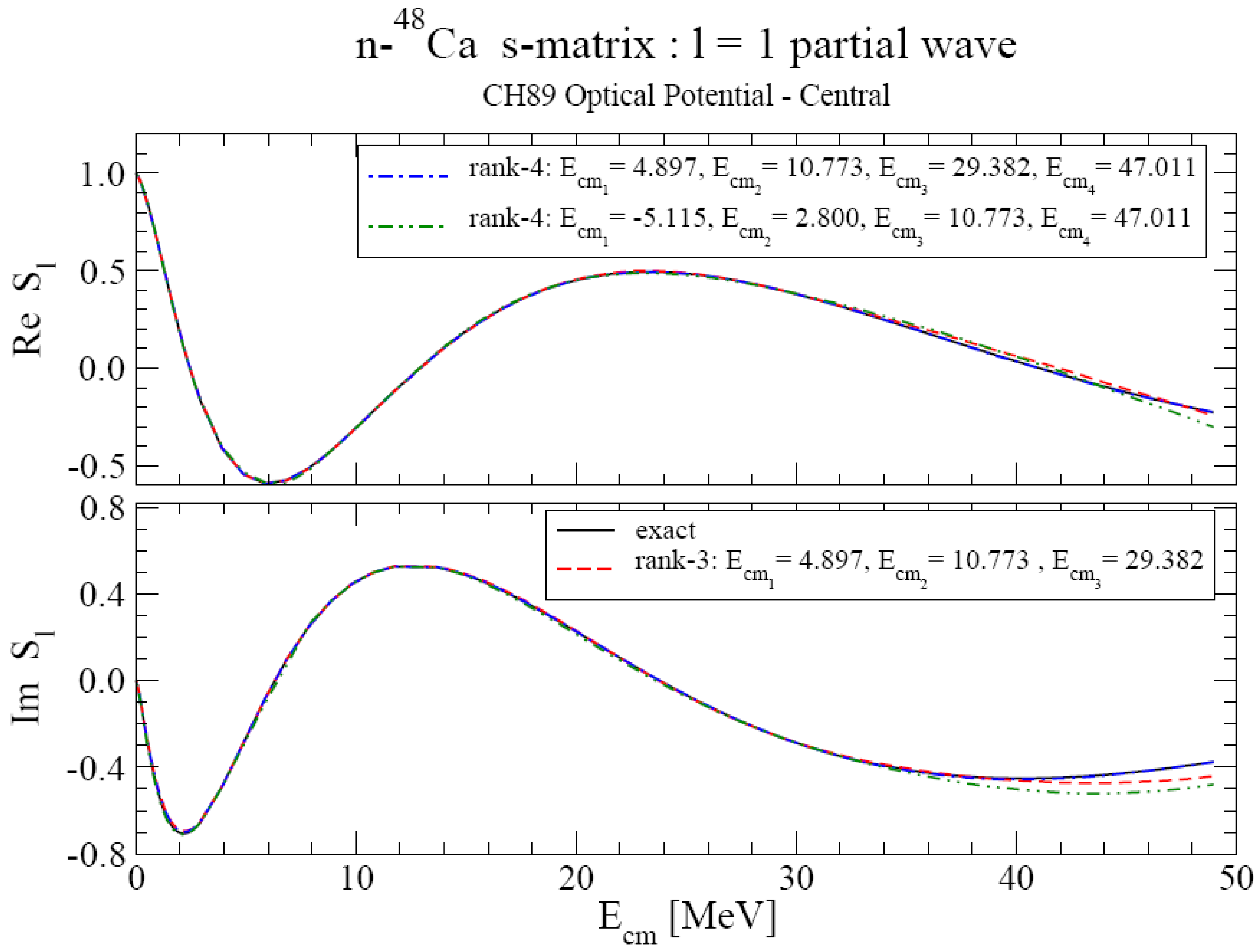
Calculate matrix for given j,k
and solve algebraic system of eqs.

- $v|\Psi_j\rangle$:= half-shell t-matrices at fixed energies E_k
- t-matrix exact those E_k =: EST support points
- EST separable t-matrix interpolates between the support points

n-^{48}Ca phase shifts : l = 4 partial wave

CH89 Optical Potential - Central





Next: spin-orbit … straightforward …