ESNT 2026 — Discussion Blackboards

Few-Body Nuclear Physics: Open Questions & Working Groups

Day 2 — Open questions

- Use improved actions? Pro's / Obstacles? · How to bind A-nucleon system at LO?
- Resum eff. range at LO?
- Strong cancellations between 2N / 3N / 4N interactions for $\lim_{\lambda\to\infty} \Rightarrow$ oscillations of numerically evaluated integrals

  $\rightsquigarrow$ soften interactions, e.g. by "improved action"?
- Cutoff numerically limited (see above) $\Rightarrow$ Alternative RG-invariance assessments?
- Numerically stable approach to strict perturbation? $\Rightarrow$ alternatives to "multipliers"
- What observable is important for fit / exp.? · Identify a key reaction!
- Which parametrisation is <u>efficient</u> in $A > 3$ systems?
- How to assess order-by-order convergence?

Day 2/5 — Perturbative expansion of the T-matrix

Idea (top): $V_{\rm LO} + \epsilon\, V_{\rm NLO} \;\Rightarrow\; {\rm Res}(\epsilon) \;\Rightarrow\; \dfrac{{\rm Res}(\epsilon\neq 0) - {\rm Res}(\epsilon = 0)}{\epsilon} = {\rm Res}_{\rm NLO}.$

$$T = \frac{V}{[\,1 - VG\,]}, \qquad \boxed{T = V + VGT} \;= V[\,1 + GT\,], \qquad V = V_{\rm LO} + V_{\rm NLO} + V_{\rm N^2LO} + \ldots, \qquad T = T_{\rm LO} + T_{\rm NLO} + T_{\rm N^2LO} + \ldots$$

Order by order:

$$T_{\rm LO} = V_{\rm LO} + V_{\rm LO}\, G\, T_{\rm LO} \qquad \Rightarrow\; T_{\rm LO} = [\,1 - V_{\rm LO} G\,]^{-1}\, V_{\rm LO}$$

$$T_{\rm NLO} = V_{\rm NLO} + V_{\rm NLO}\, G\, T_{\rm LO} + V_{\rm LO}\, G\, T_{\rm NLO} \qquad \Rightarrow\; T_{\rm NLO} = \frac{V_{\rm NLO}(1 + G\, T_{\rm LO})}{[\,1 - V_{\rm LO} G\,]}$$

$$T_{\rm N^2LO} = V_{\rm N^2LO} + V_{\rm N^2LO}\, G\, T_{\rm LO} + V_{\rm NLO}\, G\, T_{\rm NLO} + V_{\rm LO}\, G\, T_{\rm N^2LO} \qquad \Rightarrow\; T_{\rm N^2LO} = \frac{V_{\rm N^2LO}(1 + G\, T_{\rm LO}) + V_{\rm NLO}\, T_{\rm NLO}}{[\,1 - V_{\rm LO} G\,]}$$

Day 3 — Board 1: Topics

i) Excited states with the same J^π.

ii) CDCC:

- $A > 2$ charged-particle continuum
- non-local
- few-nucleon systems

iii) GEM & perturbative calc. ("quality" of the wave function?).

iv) Branching ratios

v) neural networks $\cup$ ab-initio wave functions for $\lim_{\lambda \to \infty}$.

Day 4 — Board: Numbered questions

1. Relevance of the "B" parameter (spurious states, R-matrix).
2. Generalization to $A > 2$ (technical issues, R-matrix).
6. (d, p) DWBA $\longleftrightarrow$ (n capture).
7. Which loss functions should we optimize in "NN" (neural networks)?
3. ^{8}Be as an asymptotic channel in R-matrix. $V_{cc} = \langle\psi|V|\psi\rangle$
8. Does adiabatic training of NQS mitigate numerical instabilities of short-range potentials?
4. Distortion channel in R-matrix.

   (v) Definition of a distortion channel.

Day 5 — Board 1: Perturbation theory (LS & Schrödinger)

Lippmann–Schwinger, order n:

$$T_n = [\,1 - V_0 G\,]^{-1} \left[V_n\,(1 + G\,T_0) + \sum_{m=1}^{n-1} V_{n-m}\,G\,T_m \right].$$

Schrödinger:

$$|n\rangle = [\,E_0 - H_0\,]^{-1} \left[(E_n - V_n)\,|0\rangle + \sum_{m=1}^{n-1} (E_m - V_m)\,|n-m\rangle \right],$$

with $\langle 0|\,E_n - H_0\,|n\rangle = 0$ determining E_n, and

$$|1\rangle = (E_0 - H_0)^{-1}(E_1 - V_1)\,|0\rangle.$$

Coupling / matrix element (schematic):

$$\big\langle\, \ell_1\ell_2 ss \,\big|\, [\tfrac{q_1 q_5}{|r_1 - r_2|}\,\hat{P}?]\,\big[\,[\ell_1 \otimes \ell_2] \otimes [s \circ s_2]\,\big]\,\big\rangle, \qquad |0\rangle = |\phi_1\rangle + |\phi_c\rangle + \cdots + |\phi_3\rangle.$$

Convergence table (which order binds which system):

	^{2}H	^{3}H	^{3}He	^{4}He
LO	✓	✓	×	×
NLO	✓	✓	✓	✓
N^{2}LO	✓	✓	✓	✓

Day 5 — Board 2: Coulomb / AGS

1. Coulomb at low E (AGS + perturbation).

   ↪ 3B doable (depends on the 3B force), 4B ?

   $$\langle p\,q\,|\,W_3\,|\,p\,q\rangle = f\big(p^2 + \tfrac{3}{4}q^2,\; p^2 + \tfrac{3}{4}q^2\big) \qquad \text{— optimal numerics}$$

2. Most costly / complicated part: $\vec{q} \longrightarrow \vec{q}\,'$, i.e., transformations to different Jacobi sets due to the action of permutation operators.

3. n–d / $[\,d$–$d\,]^{S=5/2}$ SVM — AGS [↑NLO?] benchmark.

Day 5 — Board 3: Working groups

GROUP 1 ($A \geq 2$)

1) R-matrix (2+1) (or alternative method)
2) extraction of perturbative corrections
3) practical code implementation
4) benchmark

GROUP 2 ($A \leq 3$)

1) implementation of formal perturbative expansion with AGS/FY approach for the easiest channels
2) Interaction (EFT)
   - ↪ parameter selection
   - ↪ fitting in pert.
3) Perturbative methods (2B, 3B)
4) Benchmarks

GROUP 3

Lattice EFT $\oplus$ contact, perturbative EFT implementation of a proof of principle and design of a challenge.