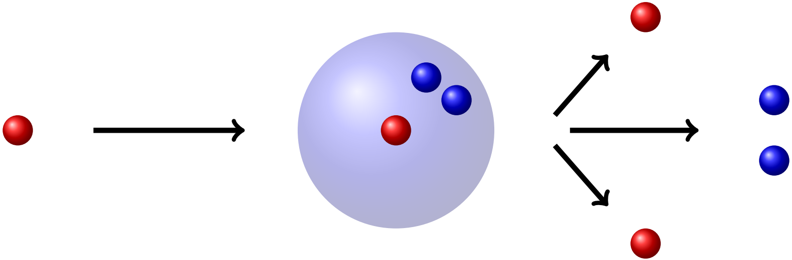
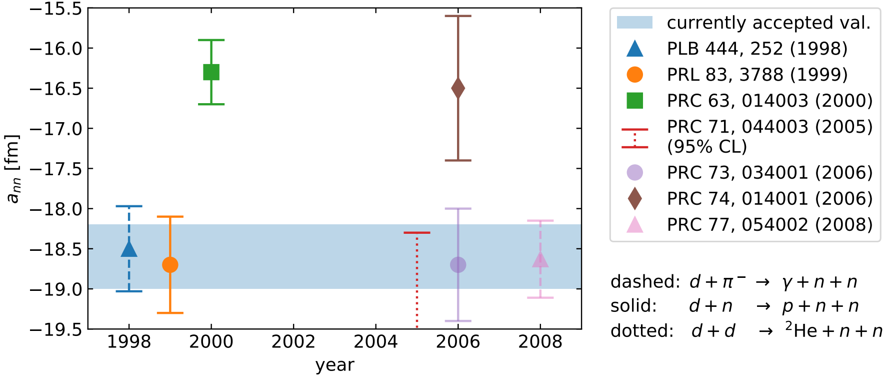
Two neutron distribution in the triton



[T. Kirchner, M. Göbel, HW. Hammer, Phys. Rev. C 111, 044002 (2025)]

Motivation for determining a_{nn}

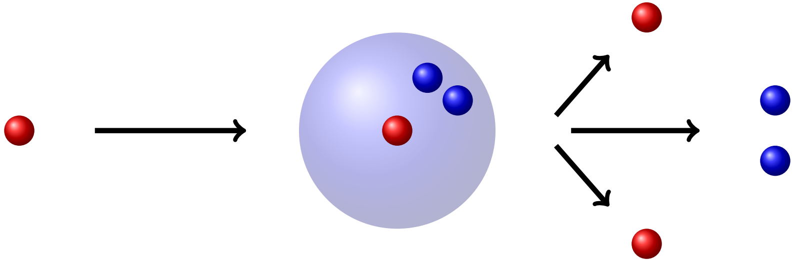


dashed: $d + \pi^- \rightarrow \gamma + n + n$
solid: $d + n \rightarrow p + n + n$
dotted: $d + d \rightarrow {}^2\mathrm{He} + n + n$

[Göbel et al., Phys.Rev.C 104 (2021) 2, 024001]

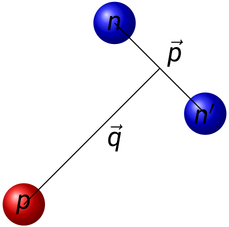
Hard knockout reaction

- goal: obtain *nn* scattering length a_{nn} with
  $^6\text{He}(p, p\alpha)nn$
  $t(p, 2p)nn$

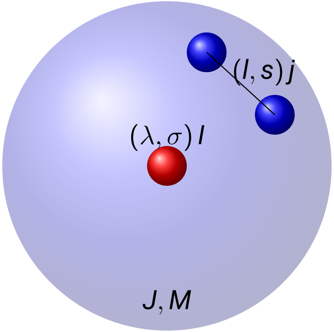


- assumptions:
  - sudden knockout -> strong separation of proton and two neutrons in momentum space
  - *nn* final-state interactions dominate

Description of the three-body state



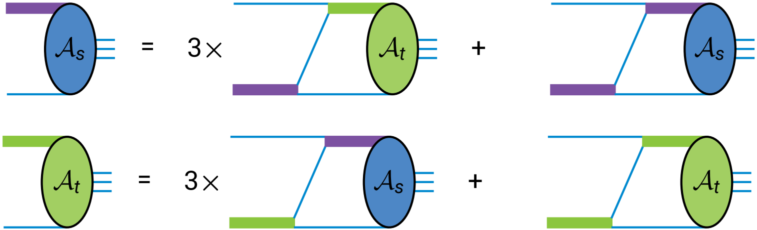
- $|\vec{p}, \vec{q}\rangle_i$, here $|\vec{p}, \vec{q}\rangle_p$
- use absolute momenta: $|p, q; \Omega\rangle_p$



- $^1S_0(nn) + p$ nn singlet
- $^1S_0(np) + n$ np singlet
- $^3S_1(np) + n$ np triplet: deuteron

Faddeev formalism

- $|\Psi\rangle = \sum_i |\psi_i\rangle$ with $i \in \{{}^{(0)}_{nn'}, \; {}^{(0)}_{np}, \; {}^{(1)}_{np}\}$
- Faddeev amplitudes $G_0 t_i \, |F_i\rangle = |\psi_i\rangle = G_0 V_i \, |\Psi\rangle$
- coupled equations $|F_i\rangle = \sum_{j \neq i} G_0 t_j \, |F_j\rangle$ for the interaction channels $\rightarrow t^{(0)}_{nn'} \quad t^{(0)}_{np} \quad t^{(1)}_{np}$



- 3-body force $h(\Lambda)$ fixed to triton binding energy $B = 8.48$ MeV

Parameterizing the t-matrix

<u>effective range expansion</u>

$$\tau_i(p) = \frac{1}{2\pi^2 M} \frac{1}{-1/a_i + r_i p^2/2 - \mathrm{i}p}$$

<u>mod. effective range expansion around pole</u>

$$\tau_d(p) = \frac{1}{2\pi^2 M} \frac{1}{-\gamma_d + \rho_d({\gamma_d}^2 + p^2)/2 - \mathrm{i}p}$$

Parameterizing the t-matrix

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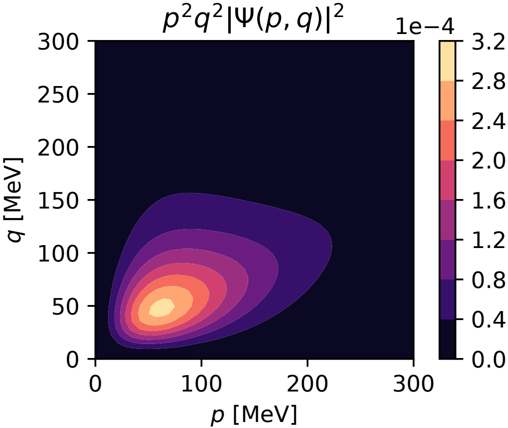
unphysical poles around momenta of $p \approx 150\,\mathrm{MeV}$:

$$\frac{1}{-1/a_i + r_i p^2/2 - ip} = \underbrace{\frac{1}{-1/a_i - ip}}_{\text{LO t-matrix}} \left(1 - \frac{r_i p^2/2}{-1/a_i - ip} + \dots\right)$$

SFB 1245

Obtaining the density distribution

- $|\Omega\rangle_i = |(l,s)j,(\lambda,\sigma)l;J,M\rangle_i$
- wave function in partial wave Ω:
  $\Psi_{p;\Omega}(p,q) = {}_p\langle p,q;\Omega|\Psi\rangle_p$



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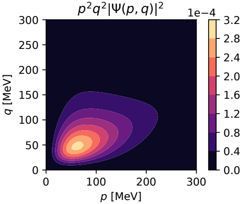
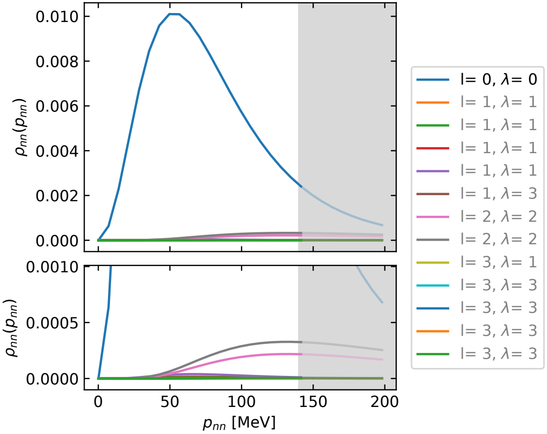


- density distribution
  $\rho_{nn}(p) = \sum_\Omega \int \mathrm{d}q\, p^2 q^2\, |\Psi_{p;\Omega}(p,q)|^2$



Results for the groundstate

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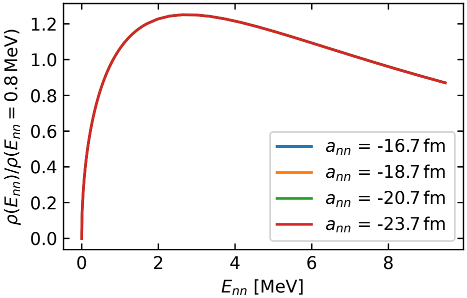
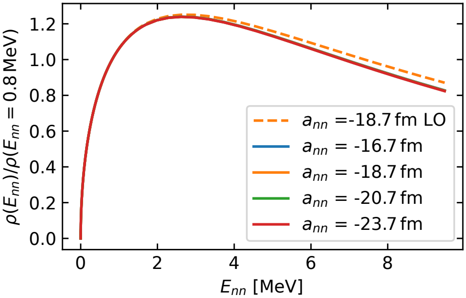
LO groundstate



a_{np} [fm]	γ_d [MeV]
-23.736	45.7021

NLO groundstate



r_{nn} [fm]	r_{np} [fm]	ρ_d [fm]
2.84	2.704	1.752

Including final-state interactions

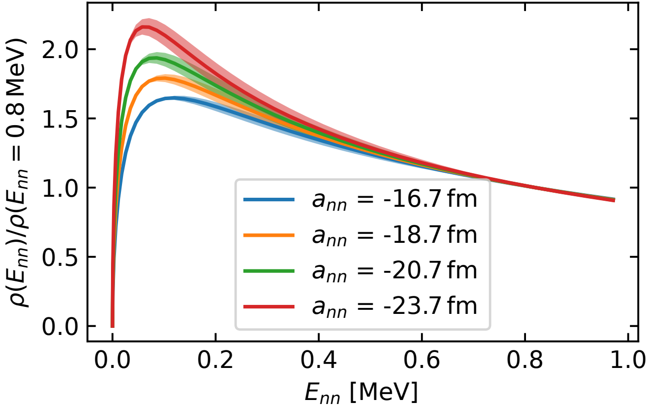
nn-final-state interactions included via the t-matrix

$$\Psi_p^{(wFSI)}(p,q) = \Psi_p(p,q) + \frac{2}{\pi} \underbrace{\frac{1}{a_{nn}^{-1} - \frac{r_{nn}}{2}p^2 + ip}}_{\text{nn t-matrix}}$$

$$\times \left[\int_0^\Lambda dp' \, \frac{p'^2 \Psi_p(p',q) - p^2 \Psi_p(p,q)}{p^2 - p'^2} - \left(\frac{i\pi}{2} - \frac{1}{2} \ln\left(\frac{\Lambda + p}{\Lambda - p} \right) \right) p \Psi_p(p,q) \right]$$

FSI results with uncertainties

- NLO groundstate curve with *nn* FSI applied
- conservative error band given by the difference to the LO curve
- all curves normed at $E_{nn} = 0.8\,\text{MeV}$

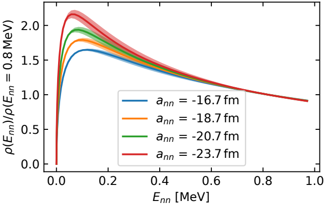


possible to distinguish a_{nn} within 2 fm

[T. Kirchner, M. Göbel, HW. Hammer, Phys. Rev. C 111, 044002 (2025)]

Summary & Outlook

- calculate NLO groundstate curve for the triton
- include nn-FSI
- distinguish peaks for different a_{nn} within the uncertainties



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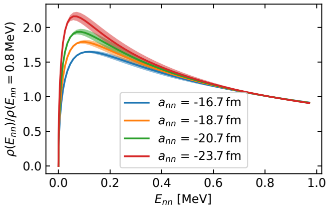

- Going to NNLO: include another three-body force (e.g. determine from radius)

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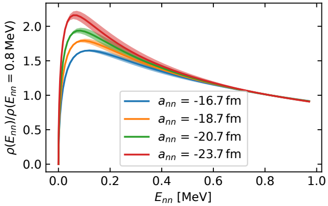

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Thank you for your attention!