Pion-mass dependence of light nuclei.

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Proper references in arXiv:1509.07697 [nucl-th]

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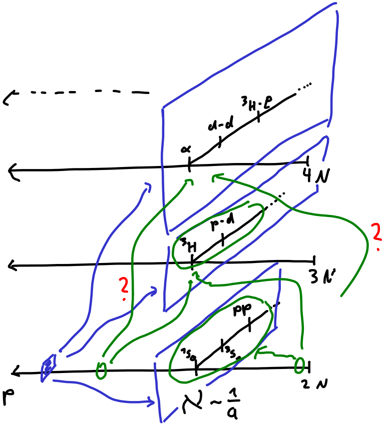
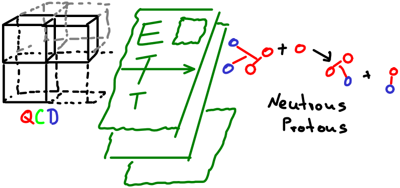
"Science does not serve an external purpose; like every strive for perfection it has its innate purpose." (H. Hesse)

THE PROBLEM.

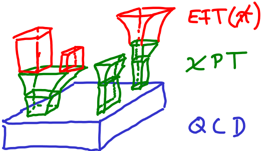




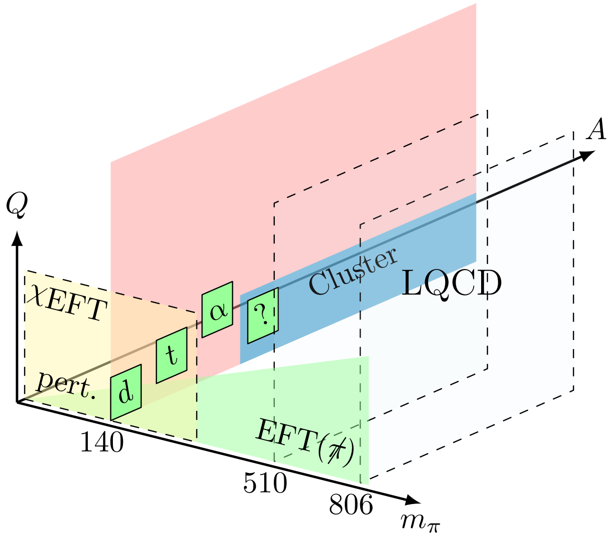
If we would like to simulate a universe, would it include a burning sun with its beauty reflected in the images of bubble chambers?

i, emergence of complexity.

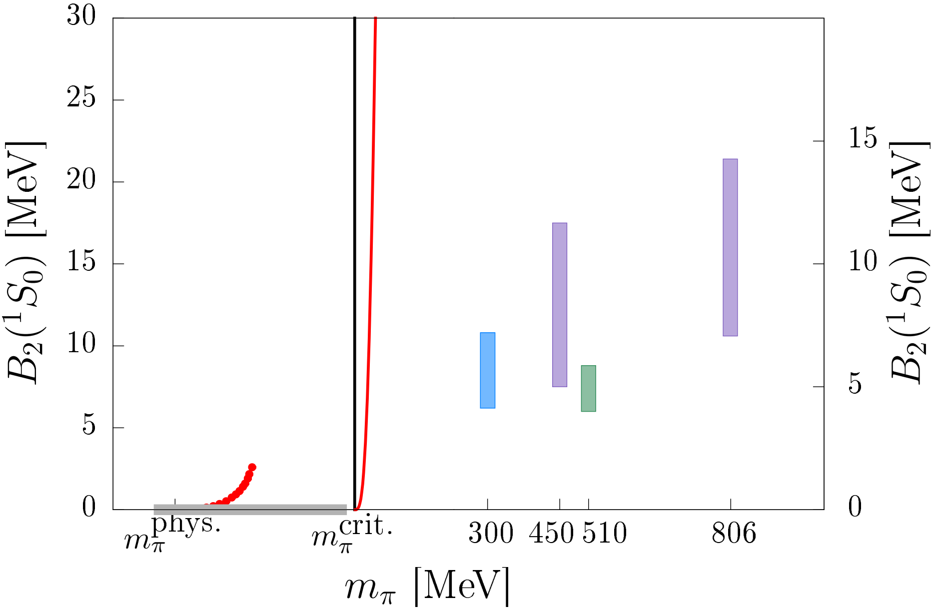
ii, exploration.



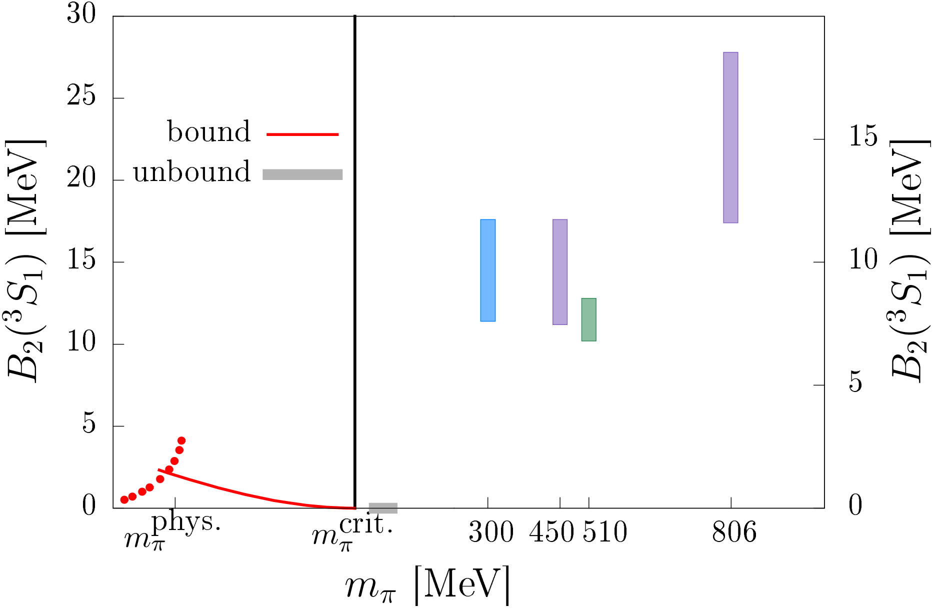
Theoretical patchwork.



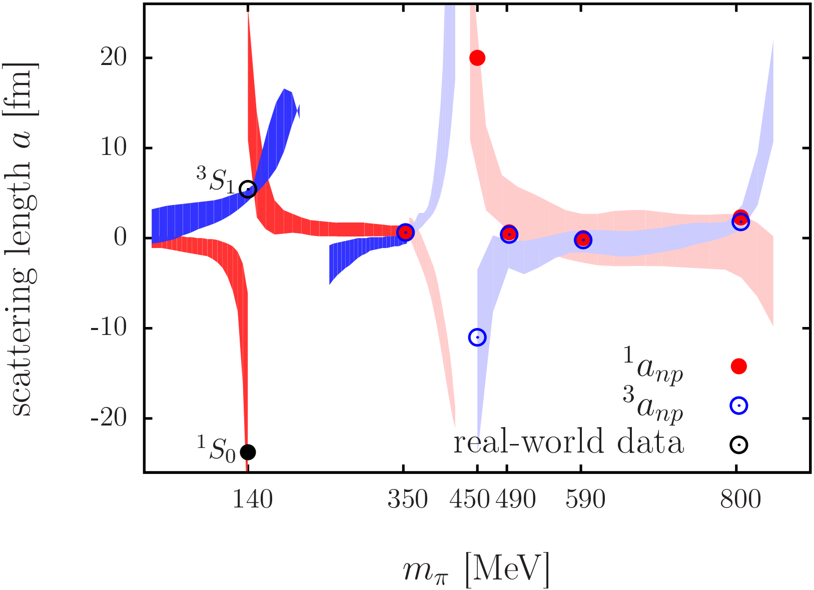
2 Nucleons ($^1S_0$).



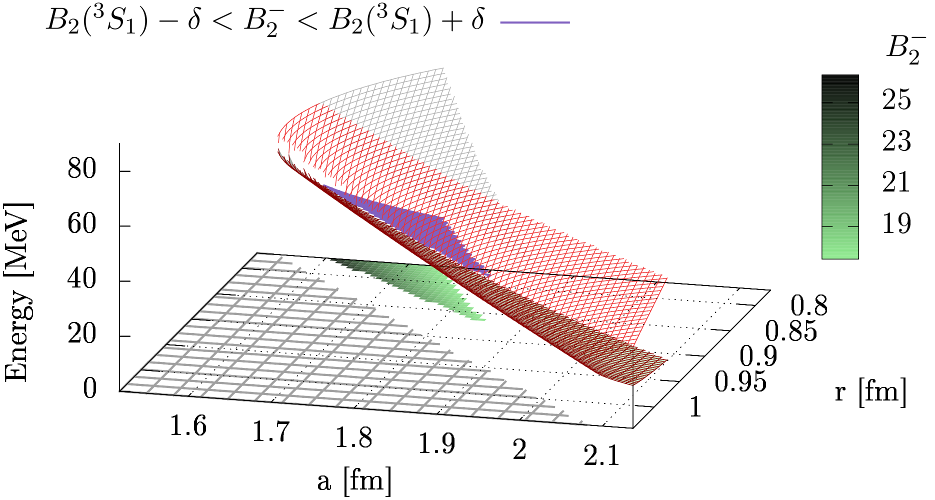
2 Nucleons ($^3S_1$).



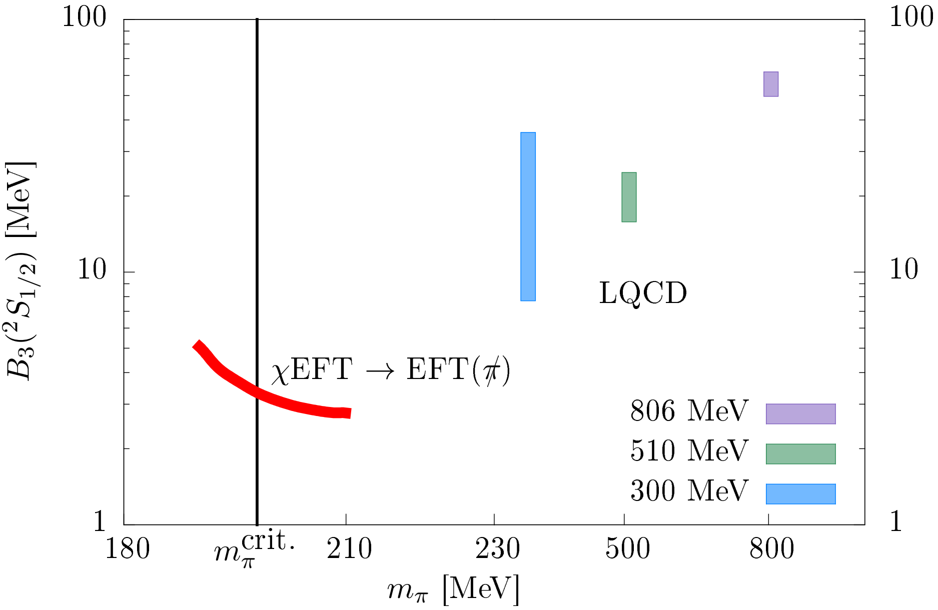
Scattering 2 Nucleons (I).



Scattering 2 Nucleons (II).

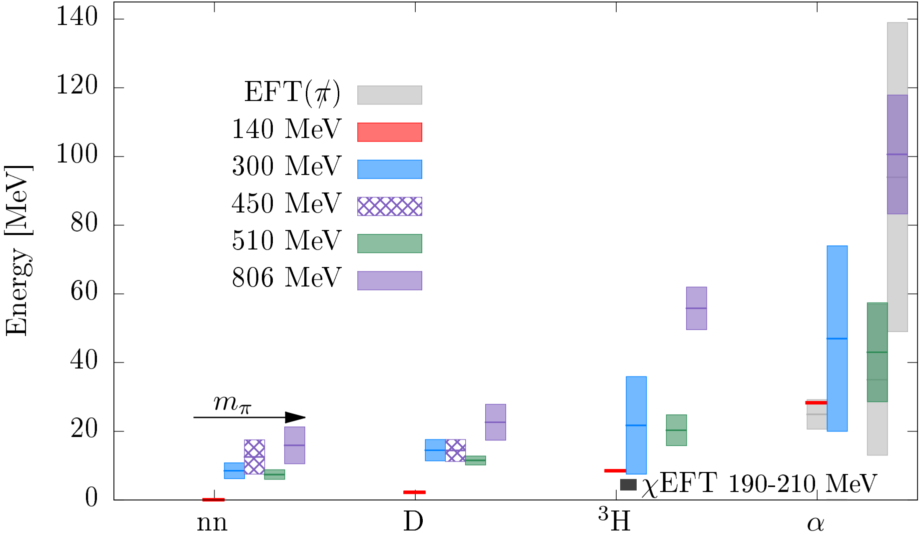


3 Nucleons.

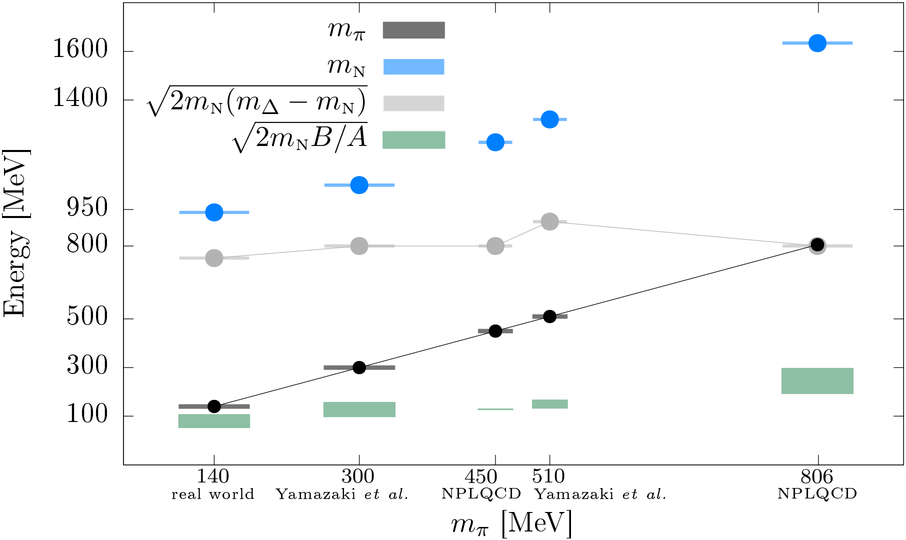


100
10
1
180
$m_\pi^{\text{crit.}}$
210
230
500
800
m_π [MeV]
$B_3(^2S_{1/2})$ [MeV]
LQCD
χEFT $\to$ EFT($\not\pi$)
806 MeV
510 MeV
300 MeV

Nuclear $A \leq 4$ spectrum.

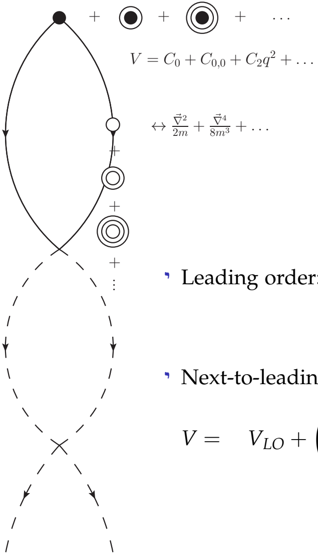


Scales.



m_π
m_N
$\sqrt{2m_N(m_\Delta - m_N)}$
$\sqrt{2m_N B/A}$
Energy [MeV]
1600
1400
950
800
500
300
100
140
real world
300
Yamazaki *et al.*
450
NPLQCD
510
Yamazaki *et al.*
806
NPLQCD
m_π [MeV]

NLO EFT($\not{\pi}$) WITH SINGLE NUCLEONS.



"Natural", renormalized LECs:

$$C_{2n} = \frac{4\pi\mathcal{O}(1)}{m\aleph(M\aleph)^n} \qquad C'_{2n} = \frac{4\pi\mathcal{O}(1)}{mM^{2n+1}}$$

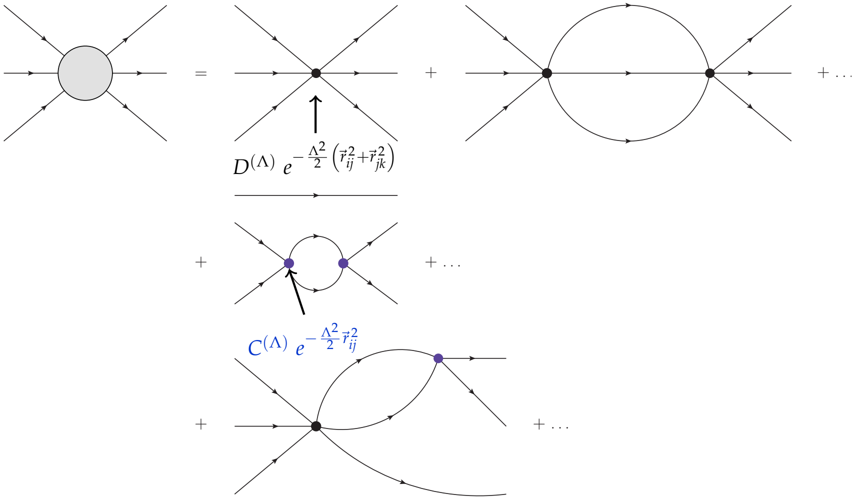
- Leading order:

$$V = \overset{\circ\circ\circ}{C}_{0,s}\,\hat{P}^{(^1S_0)} + \overset{\circ\circ\circ}{C}_{0,t}\,\hat{P}^{(^3S_1)} + \overset{\circ\circ\circ}{D}_{(*)}\,\hat{P}^{(S)}$$

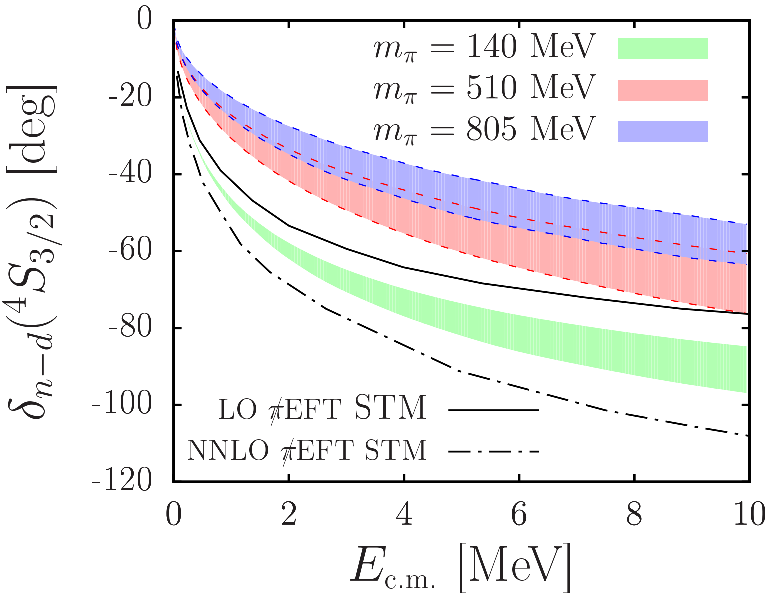
- Next-to-leading order:

$$V = \quad V_{LO} + \left(\mathring{C}_{2,s} + \mathring{C}^{\,q^2}_{2,s}\right)\hat{P}^{(^1S_0)} + \left(\mathring{C}_{2,t} + \mathring{C}^{\,q^2}_{2,t}\right)\hat{P}^{(^3S_1)} + \mathring{D}_{(*)}\,\hat{P}^{(S)}$$
$$+\mathring{C}_{pp}\hat{P}^{(^1S_0)}_{pp} + \frac{e^2}{4|r|}$$

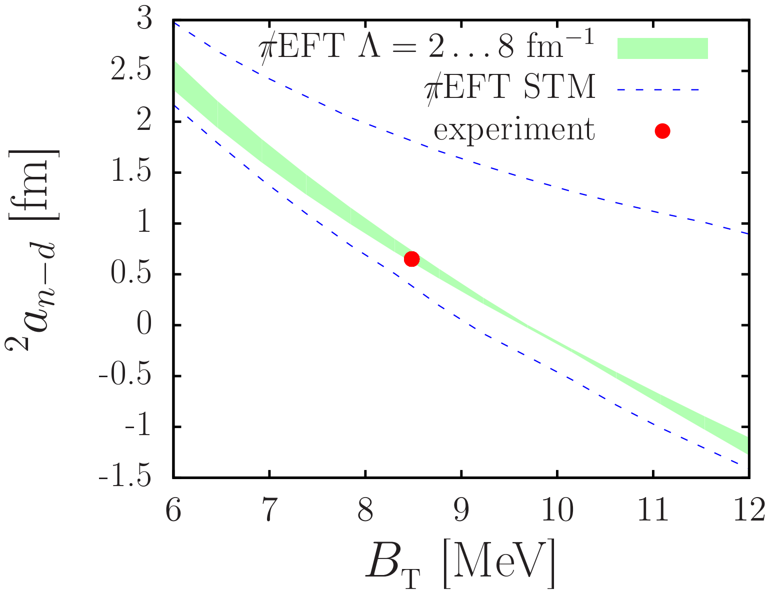
Regularization & Projection.



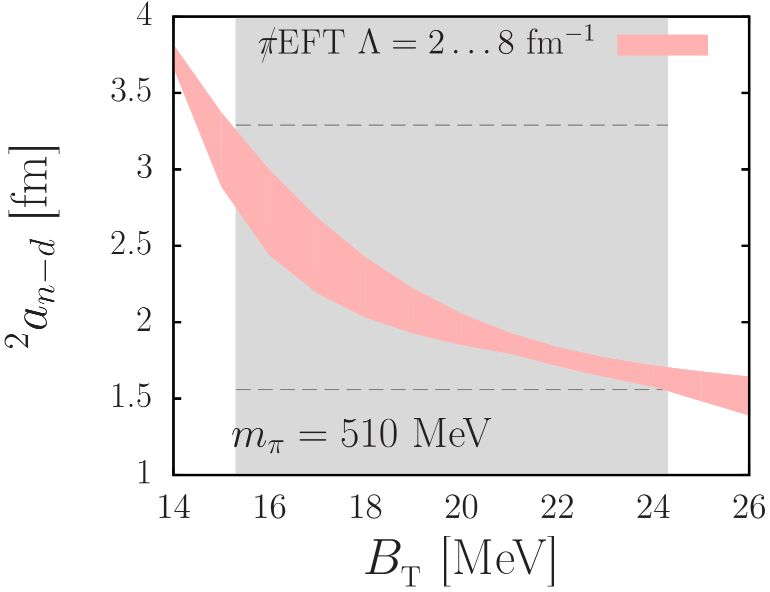
3-Nucleon scattering EFT($\not\pi$).



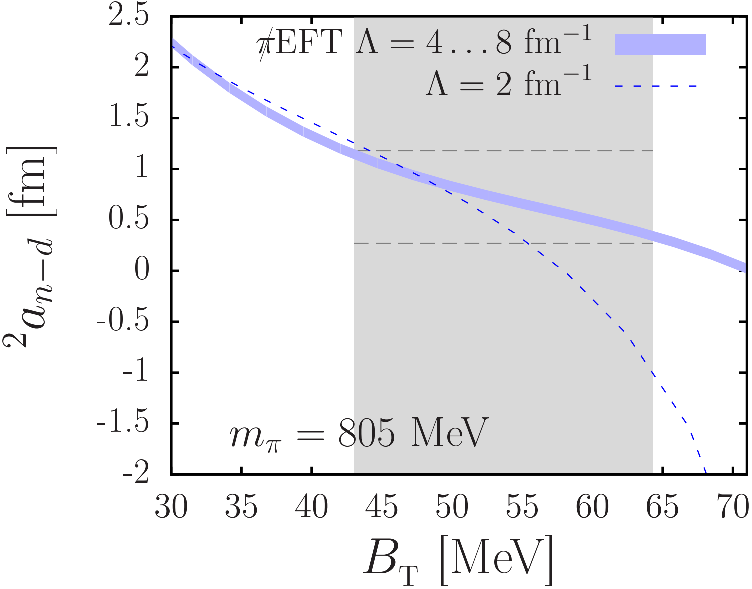
3-Nucleon correlation EFT($\not\pi$).



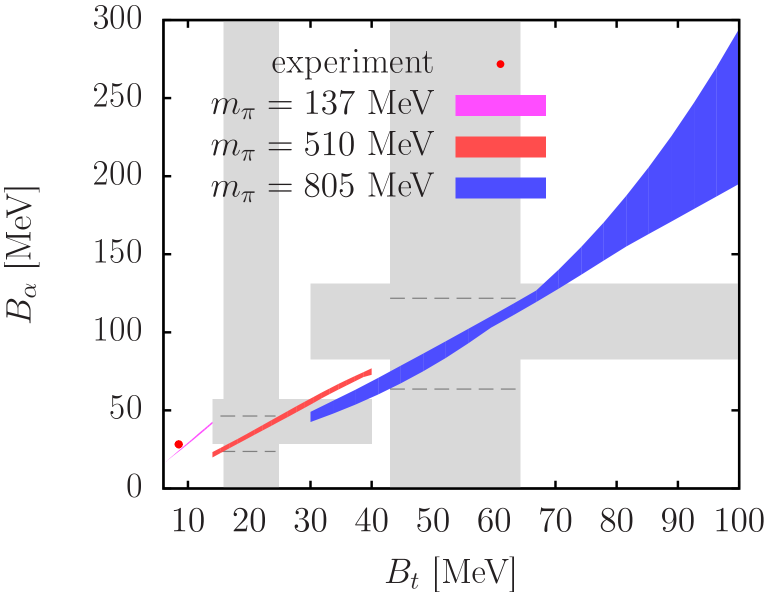
3-Nucleon correlation EFT($\not\pi$).



3-Nucleon correlation EFT($\not\pi$).



4-Nucleon correlation EFT($\not{\pi}$).

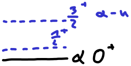


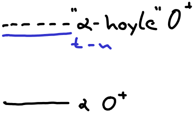
What's next?

Nuclear characteristics beyond "something is bound":

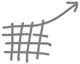
i) E&M properties. (NPLQCD, Barnea et al.)

ii) Next order in the EFT($\not{\pi}$) expansion. (B. Bazak's talk?)

iii) 

iv) 

Intuitive improvements:



i) $\left.\frac{\Delta B(2)}{\Delta m_\pi}\right|_{m_\pi \simeq 806\,\mathrm{MeV}}$.

ii) axial background.

iii) SU(3) vs. SU(2) @ fixed m_π.

Few-body & EFT problems:

i) role/effect of seemingly equivalent regulators in f-b calculations.

ii) correlations for $A \geq 4$.