Effective nuclear theories and lattice QCD

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Goal:

A derivation of nuclear physics from the Standard Model.

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- Consistent understanding of nature;

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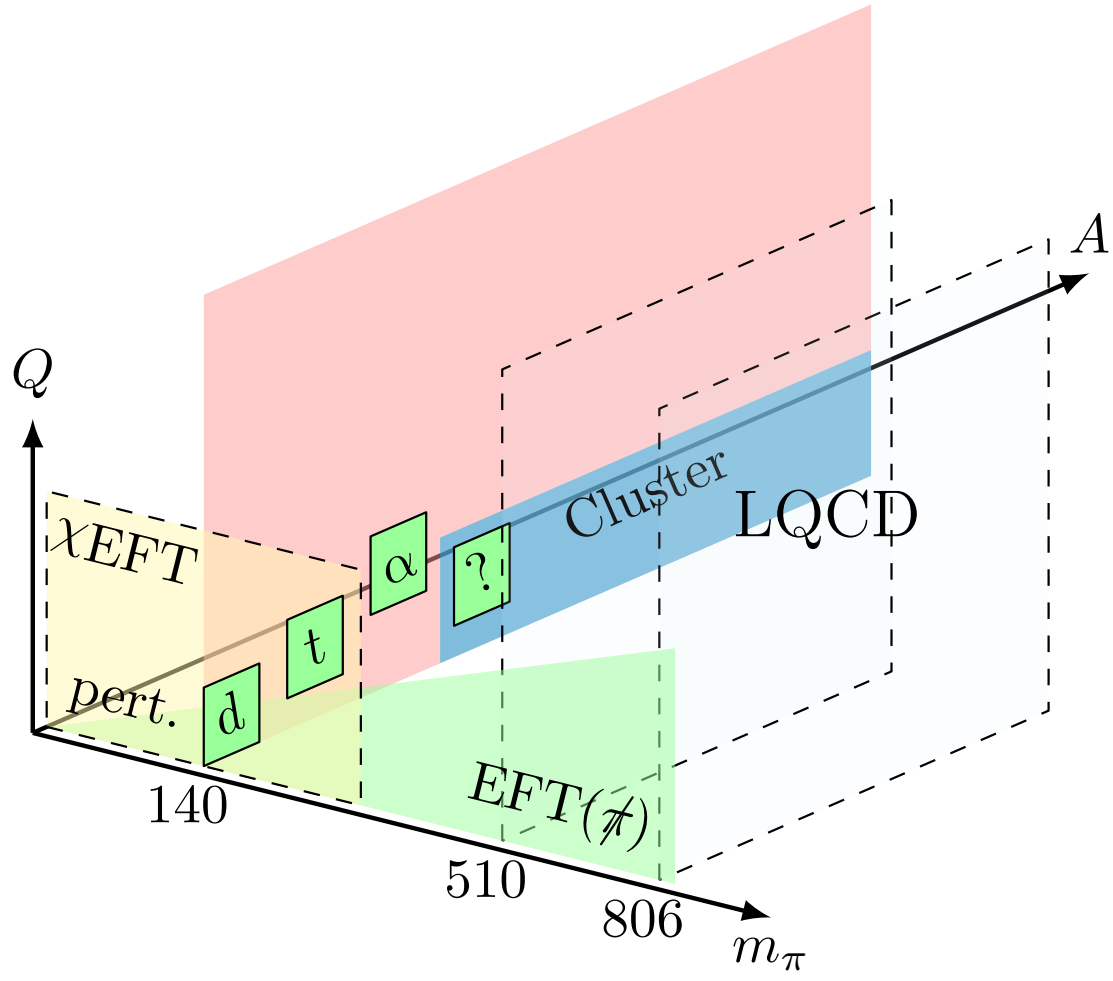
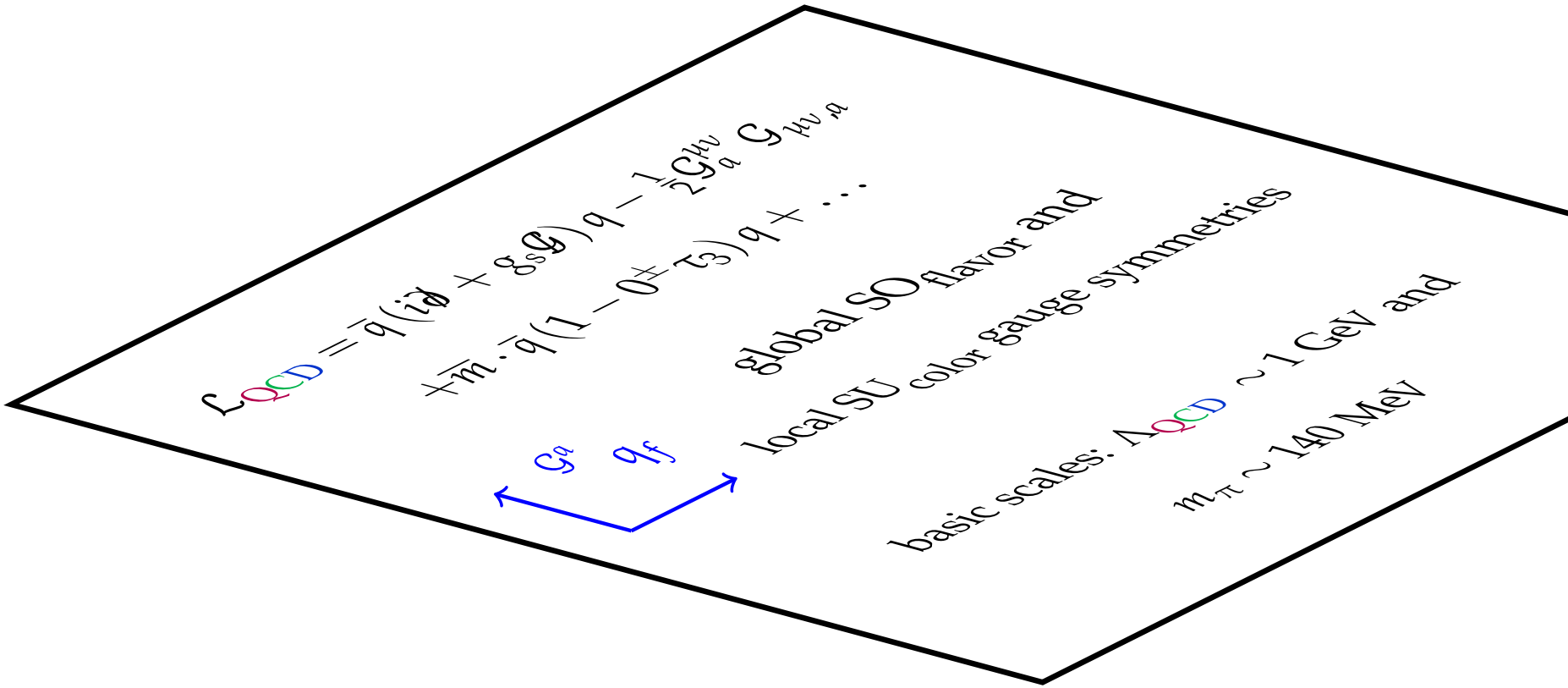
Motivation:

- Consistent understanding of nature;
- Analysis/exploration/discovery of new phenomena;
- Stability of the universe with respect to variations in fundamental constants.

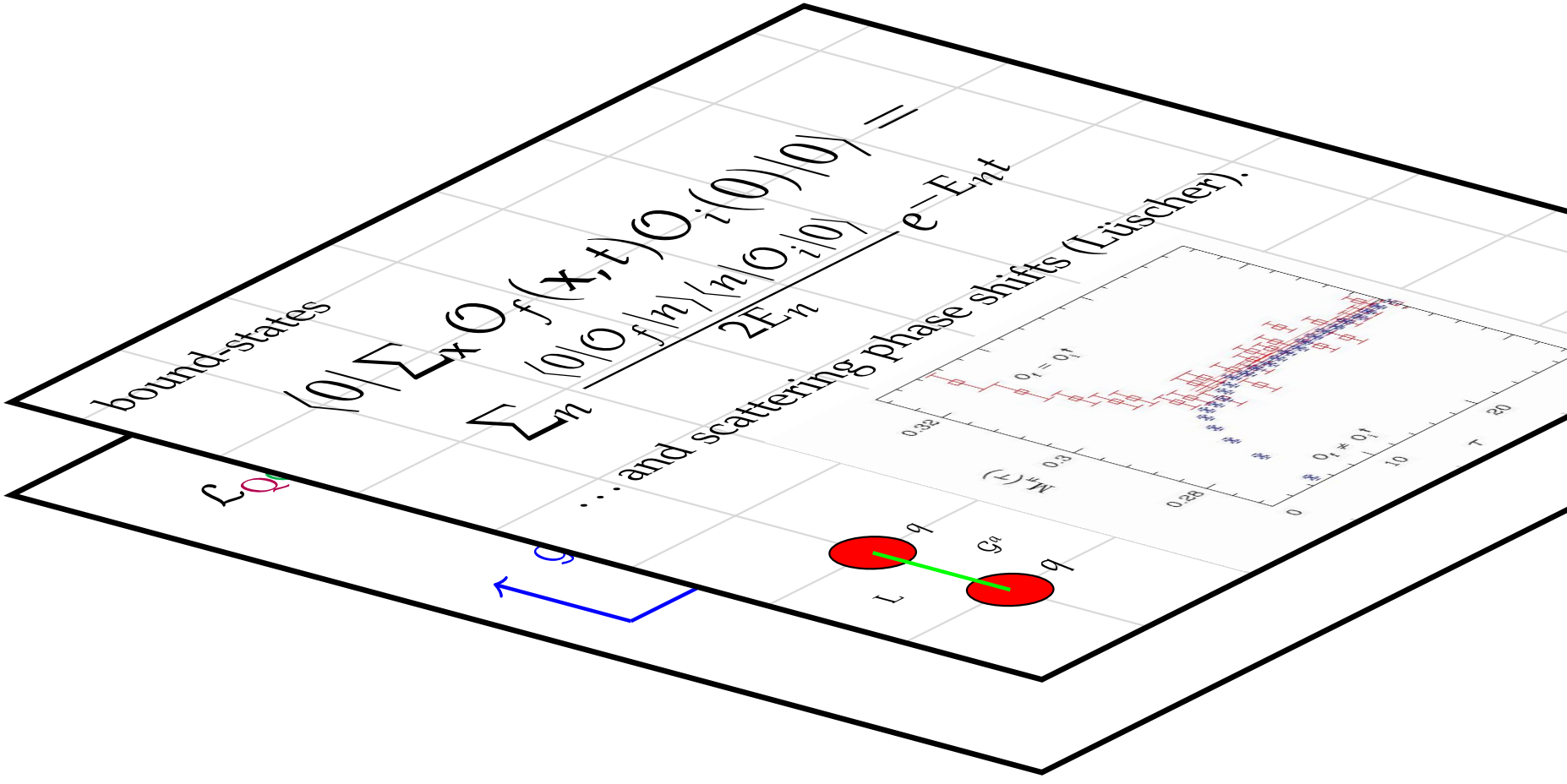
Nuclear theory as a combination of EFTs.



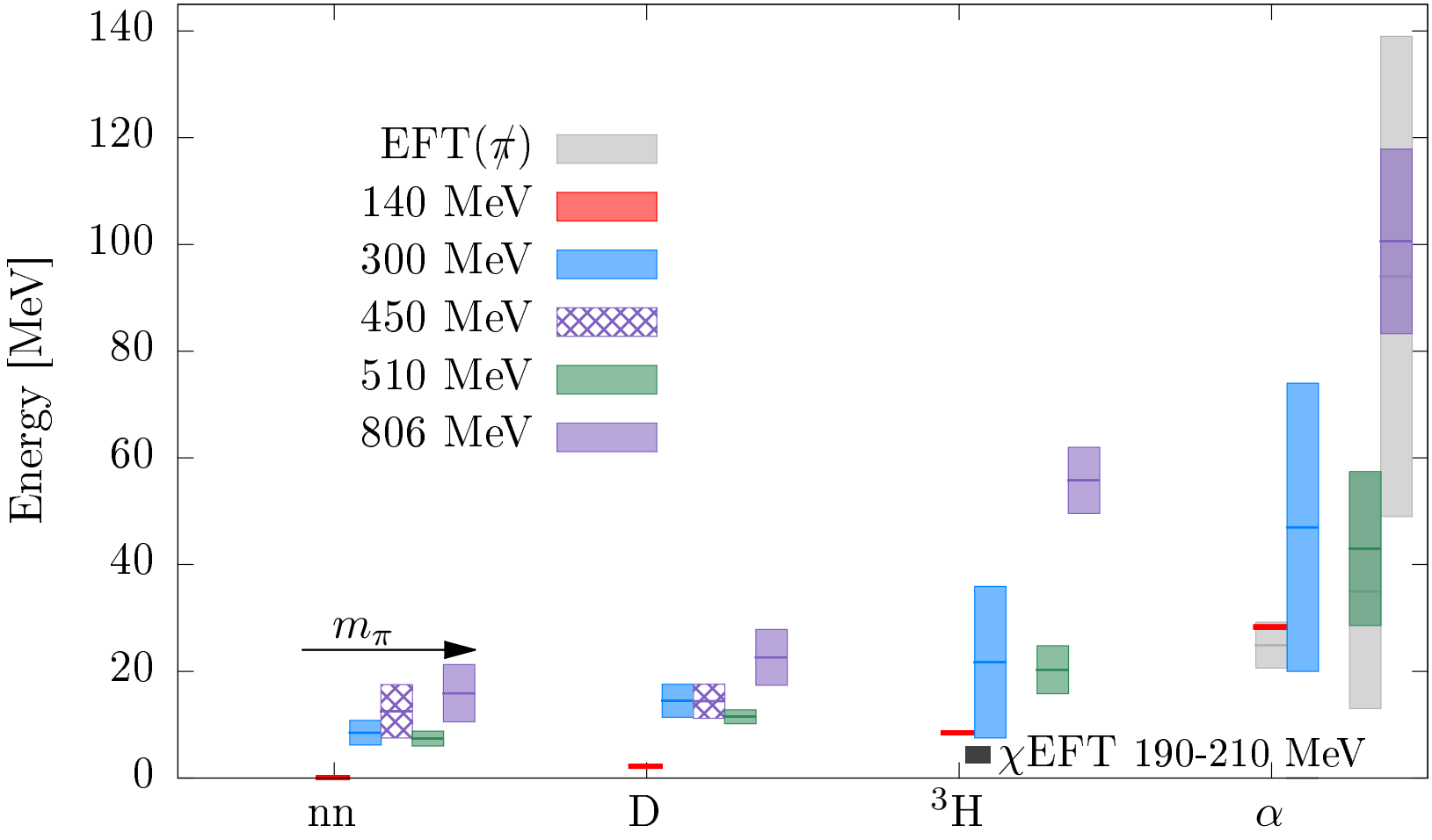
The theory of strong interactions, QCD.



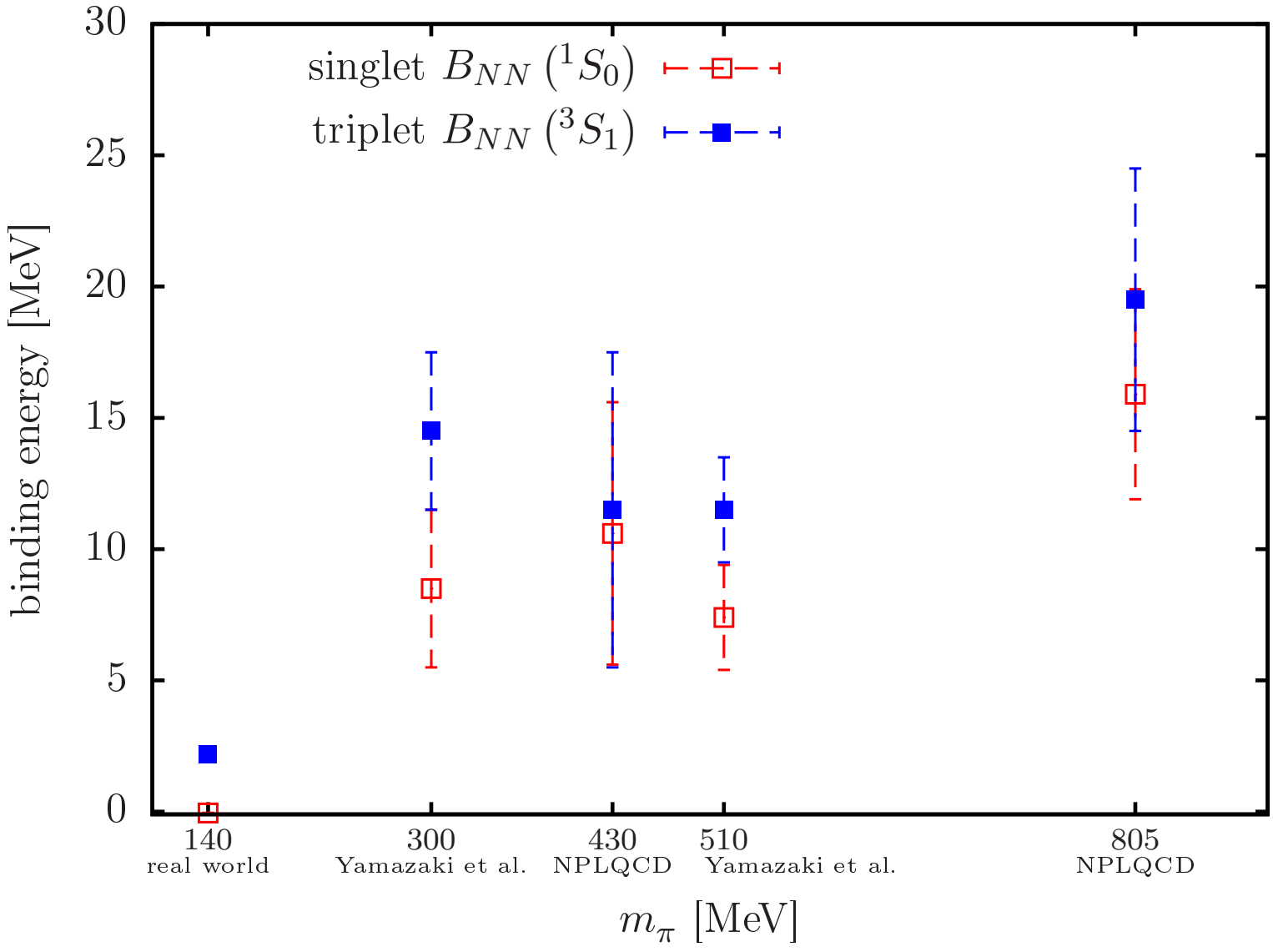
QCD solution in discretized space time.



Lattice nuclei for various pion masses.



m_π DEPENDENCE OF TWO NUCLEONS (I).



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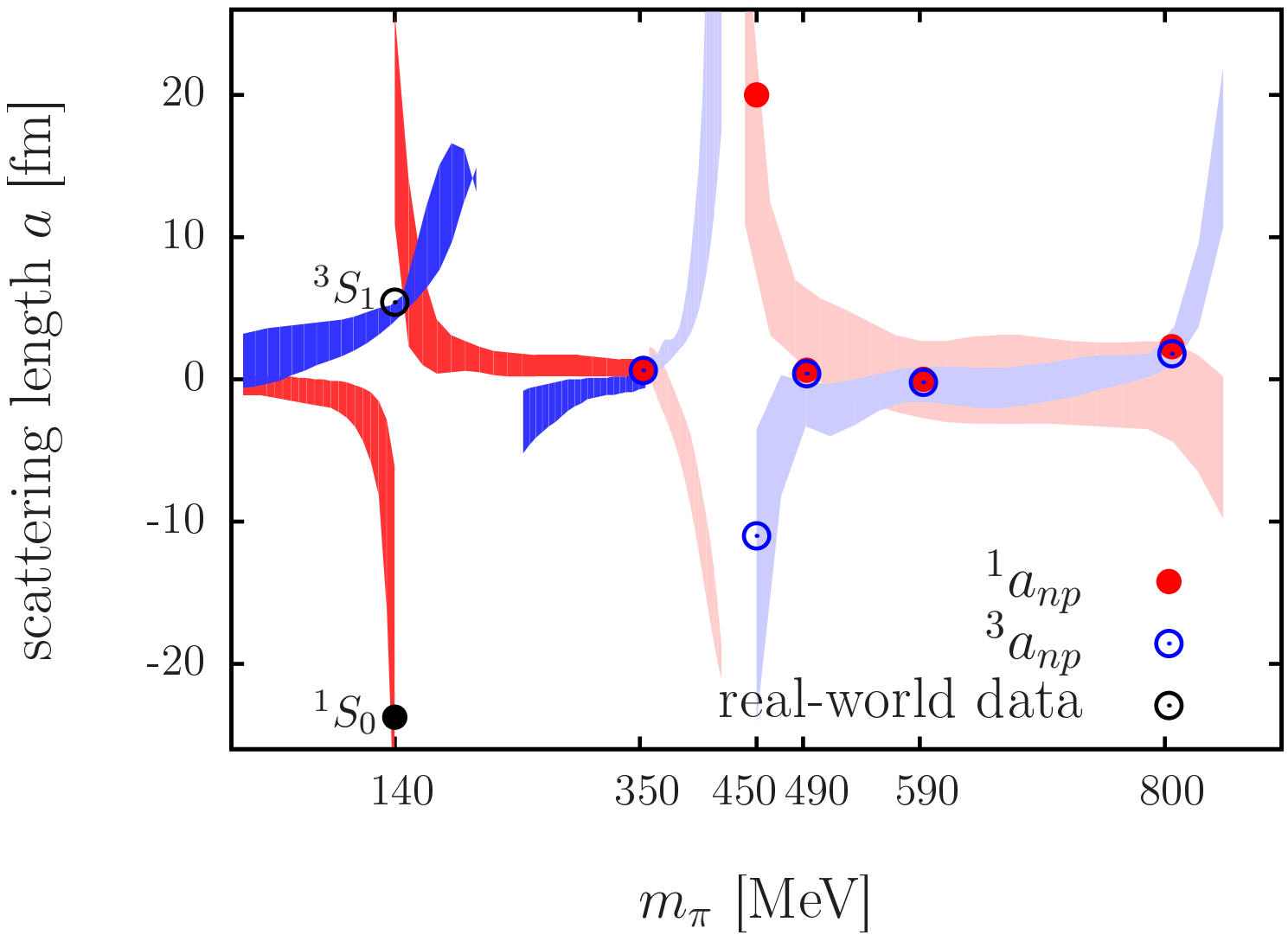
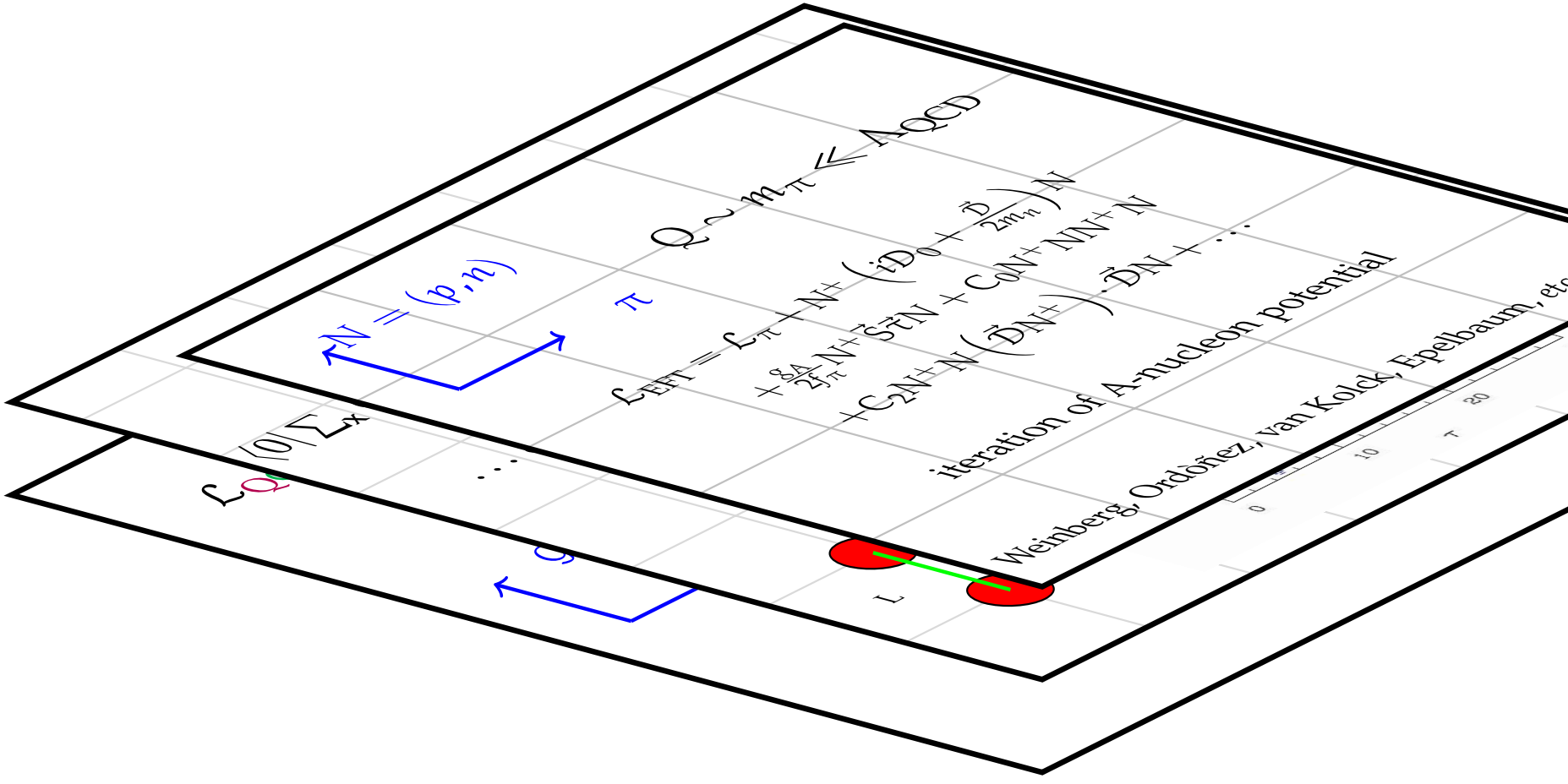
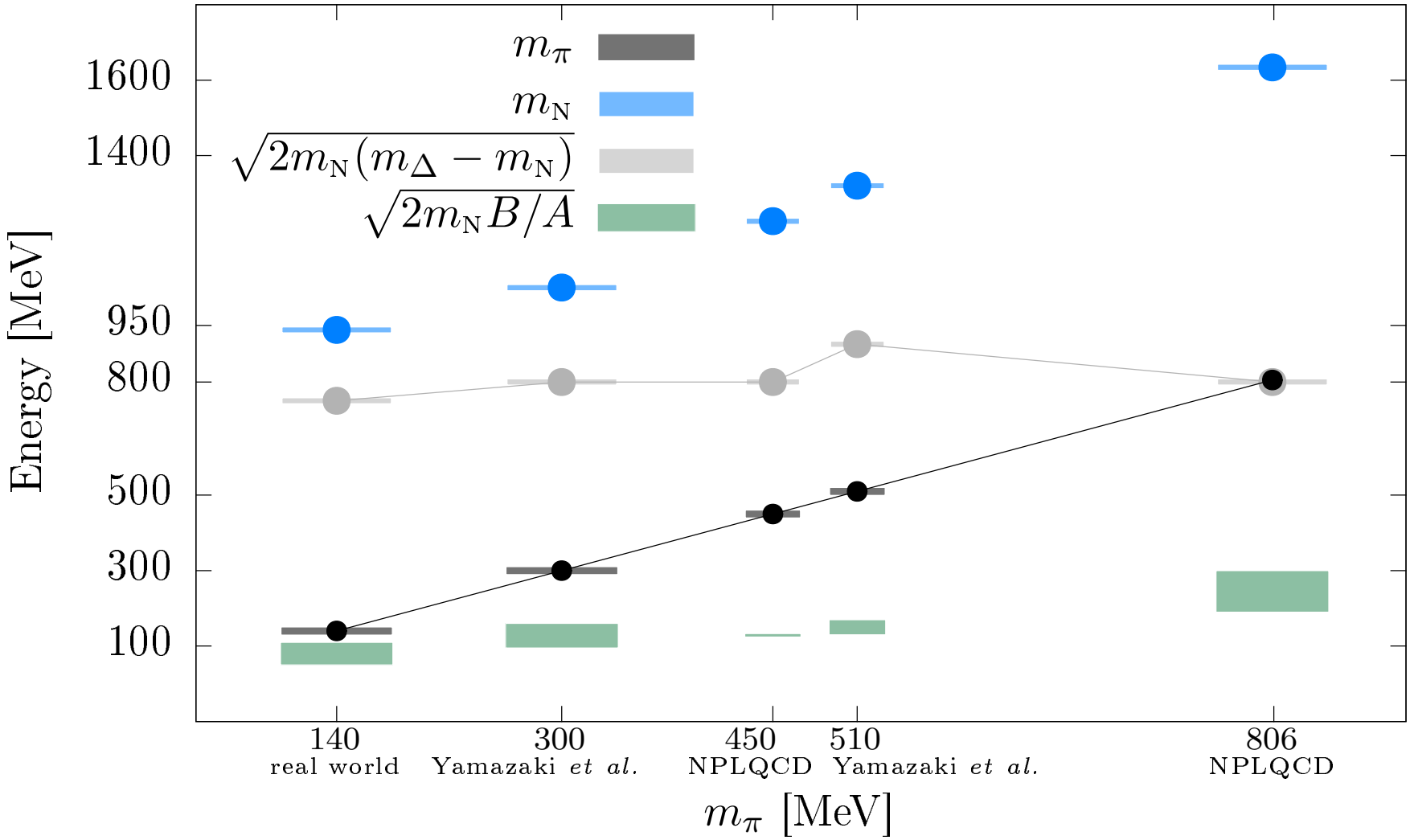


NPLQCD "data" and EFT extrapolation;

χEFT as an effective theory of QCD for mesons and nuclei.



EFT($\not\pi$) = EFT($\not\pi$) FOR $m_\pi > 140$ MEV.



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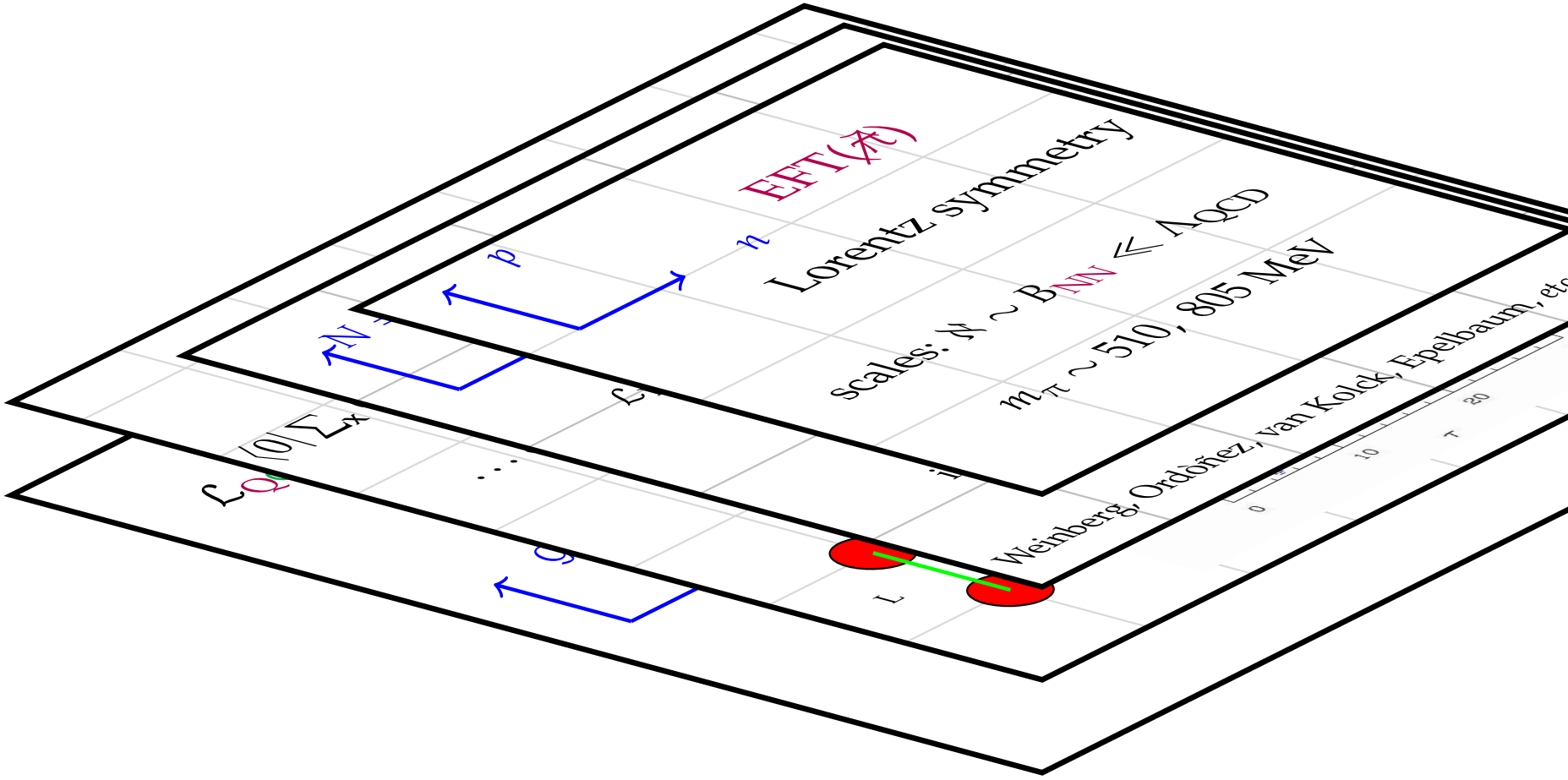
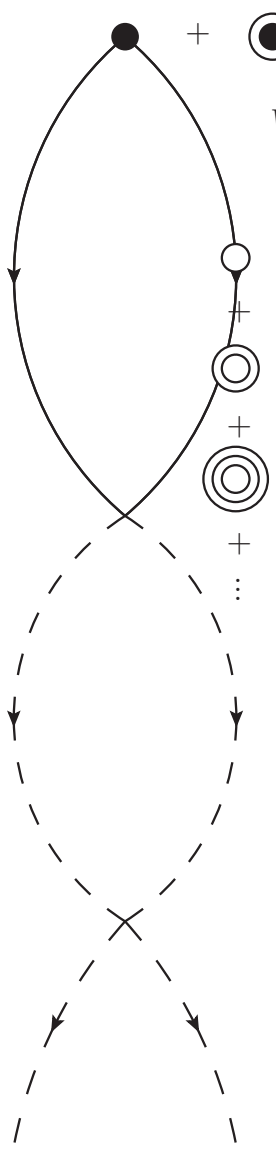


EFT = LOOP AND VERTEX EXPANSION.



$+ \quad + \quad + \quad \ldots$

$V = C_0 + C_{0,0} + C_2 q^2 + \ldots$

$\leftrightarrow \frac{\vec{\nabla}^2}{2m} + \frac{\vec{\nabla}^4}{8m^3} + \ldots$

- Leading order:

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

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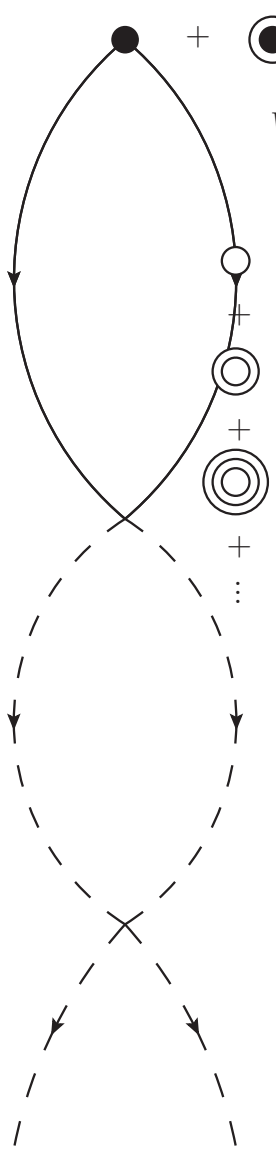

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$$C_{2n} = \frac{4\pi\mathcal{O}(1)}{m\aleph(M\aleph)^n} \qquad C'_{2n} = \frac{4\pi\mathcal{O}(1)}{mM^{2n+1}}$$

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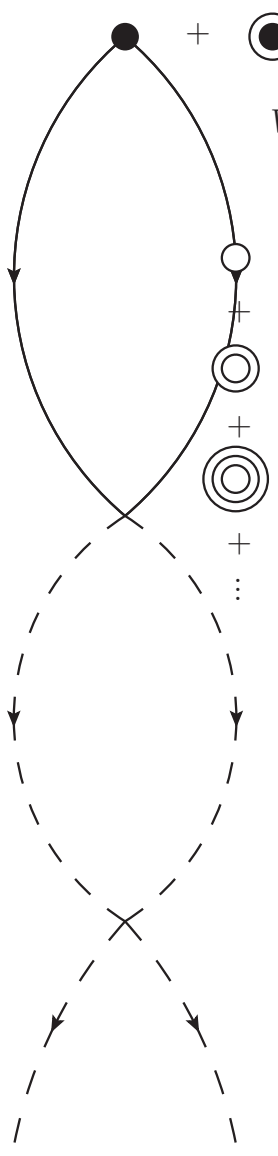

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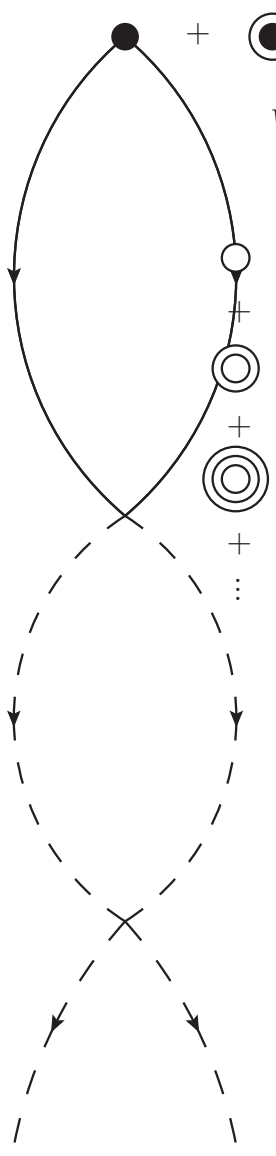

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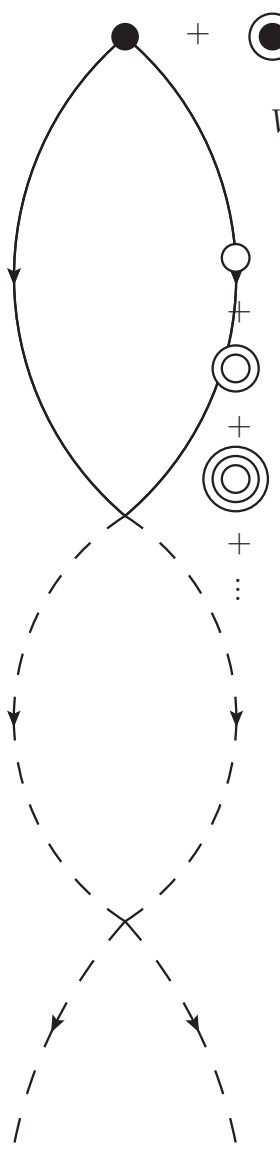

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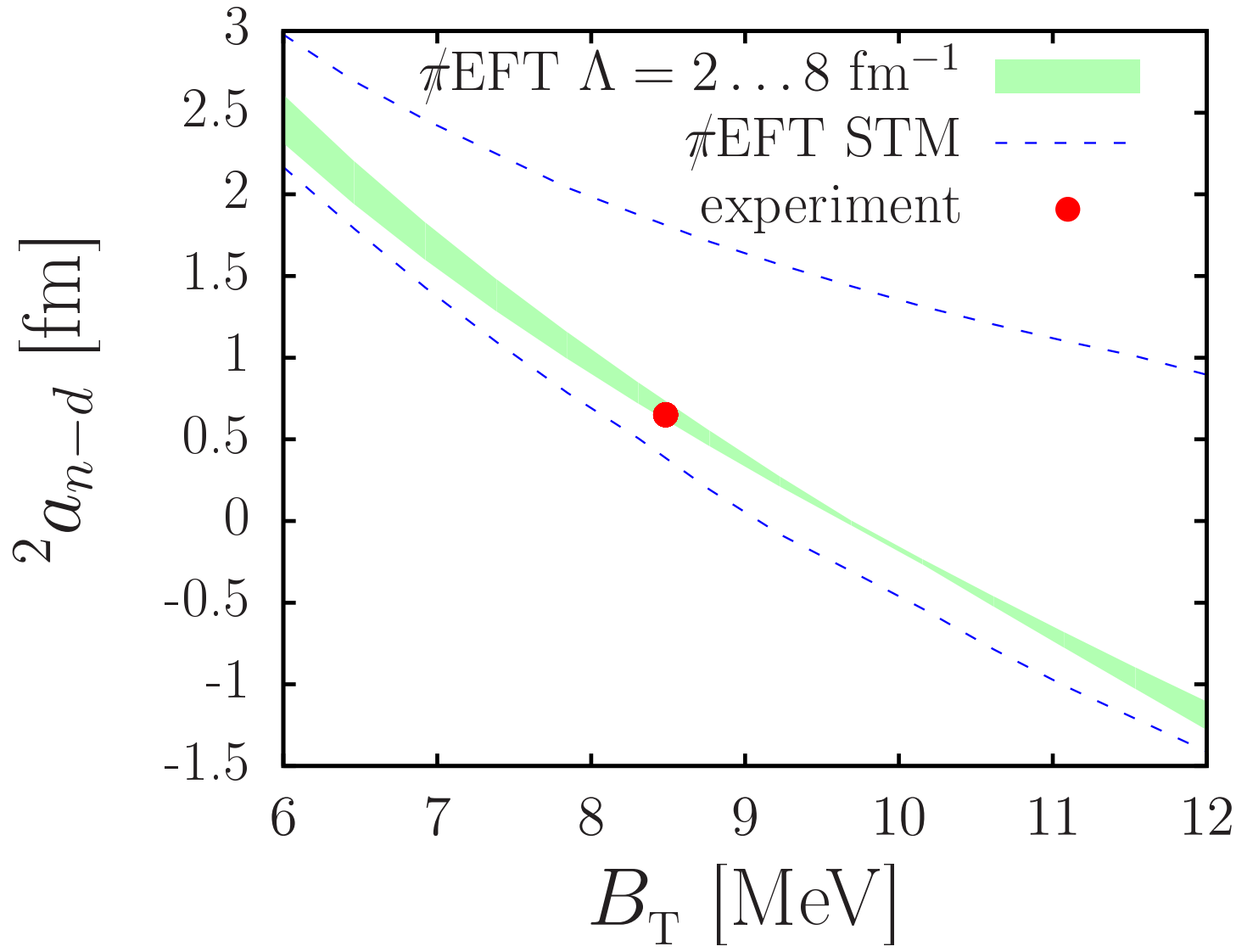
This program is incomplete for $A > 2$ (even physical m_π)!

The Phillips 3-nucleon characteristicum.



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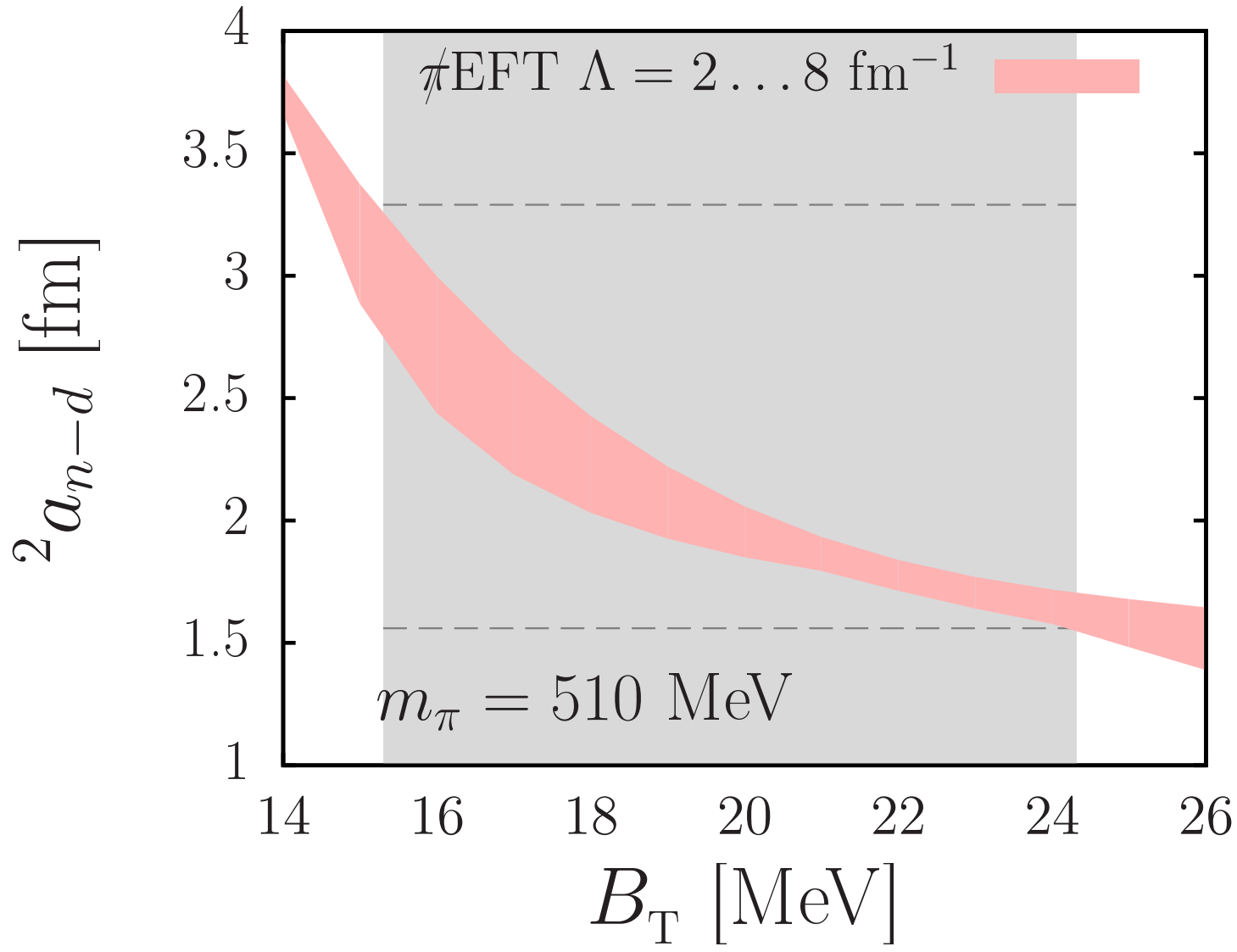

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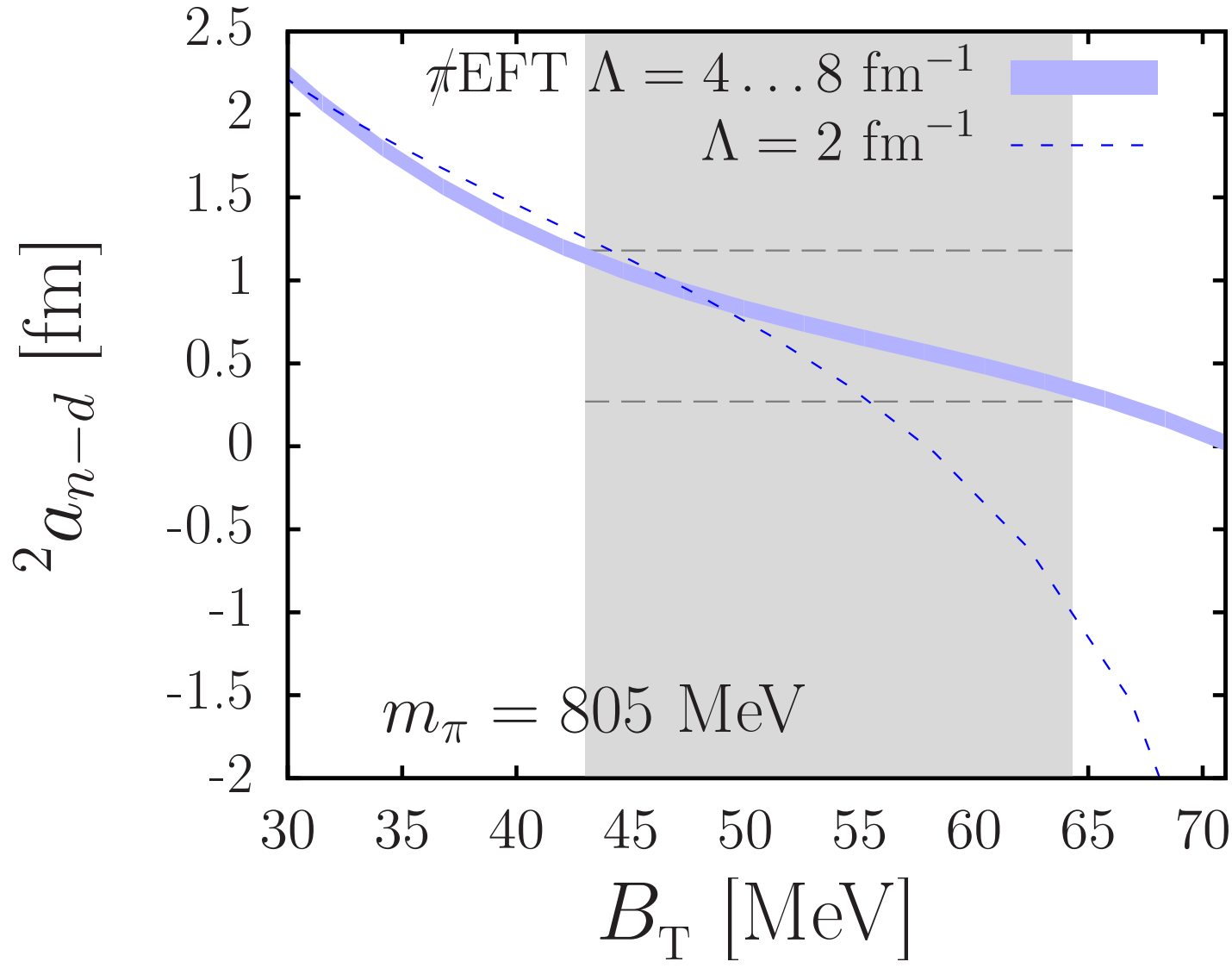
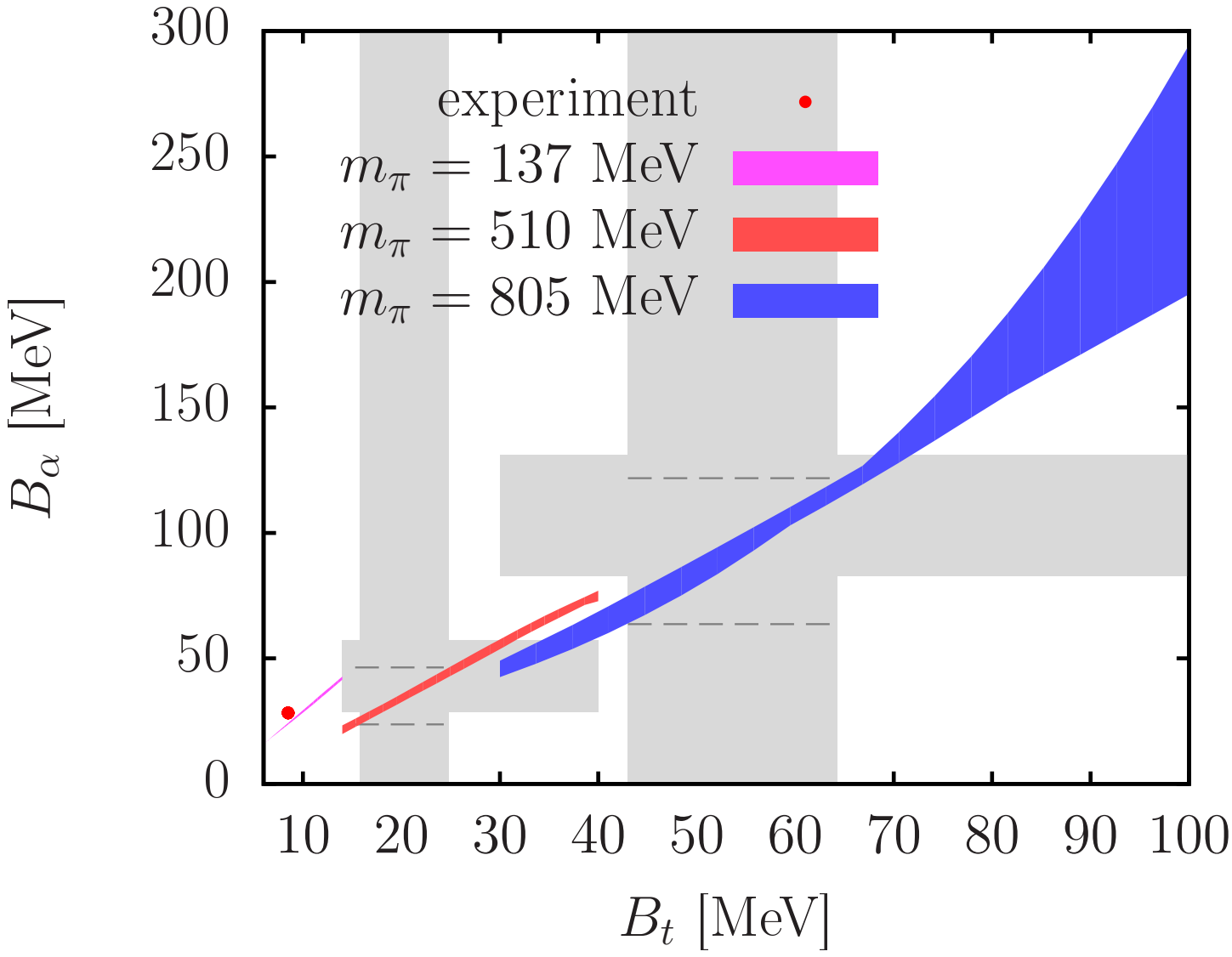


The Tjon 4-nucleon characteristicum.



The future.

- m_π dependence of other nuclear characteristics:
  - 5 and 6 nucleons and reactions;
  - Electro-weak interactions (moments and decays);
  - Emergence of *strange* nuclei.
- Nuclei under extreme conditions
  (magnetic and gravitational fields close to neutron stars).
- Refinement of multi-nucleon EFTs for physical and large pion masses.

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