PRL 114 (5) (2015), PRC 92 (5) (2015), PLB 772 (2017)

Heavy π's and light nuclei.

Johannes Kirscher with N. Barnea, D. Gazit, U. v. Kolck

The City College of New York

יוהנס קירשר

Suppose a copy of QCD exists parallel to the one we *experience*, which differs only in the numerical values of the quark masses. Further assume the existence of a portal between that and our QCD sector which allows for "communication".

What can *we* learn from the study of *their* peculiar nuclei?

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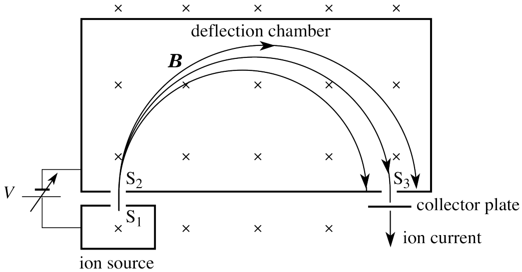

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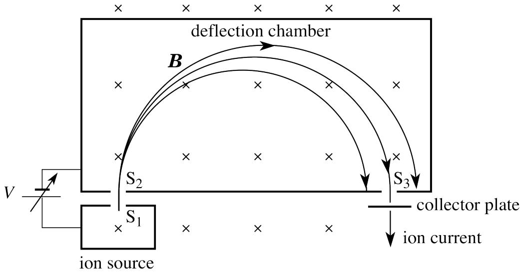

A hadron prepared at the source

$$\overline{N}^{\alpha}_{\text{source}}(\mathbf{0},t_0)=\epsilon_{abc}(u^{a,T}C\gamma_5 d^b)u^{c,\alpha}(\mathbf{0},t_0)$$

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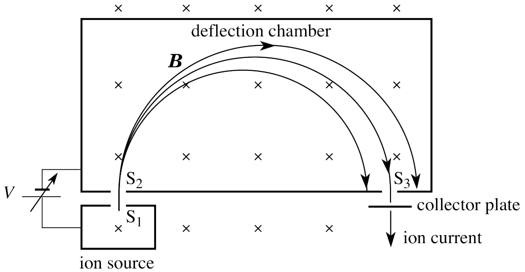

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is detected at the sink.

$$N^{\alpha}_{\text{sink}}(\boldsymbol{x}, t) = \epsilon_{abc}(u^{a,T} C\gamma_5 d^b) u^{c,\alpha}(\boldsymbol{x}, t)$$

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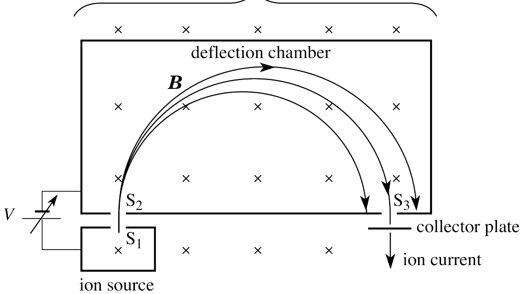
Systematic finite-volume error $\propto e^{-m_\pi L}$



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Statistical monte-carlo-sampling error

Nuclear scales from the *lattice apparatus*

i) Non-relativistic theory

ii) for protons and neutrons

iii) with contact interactions.

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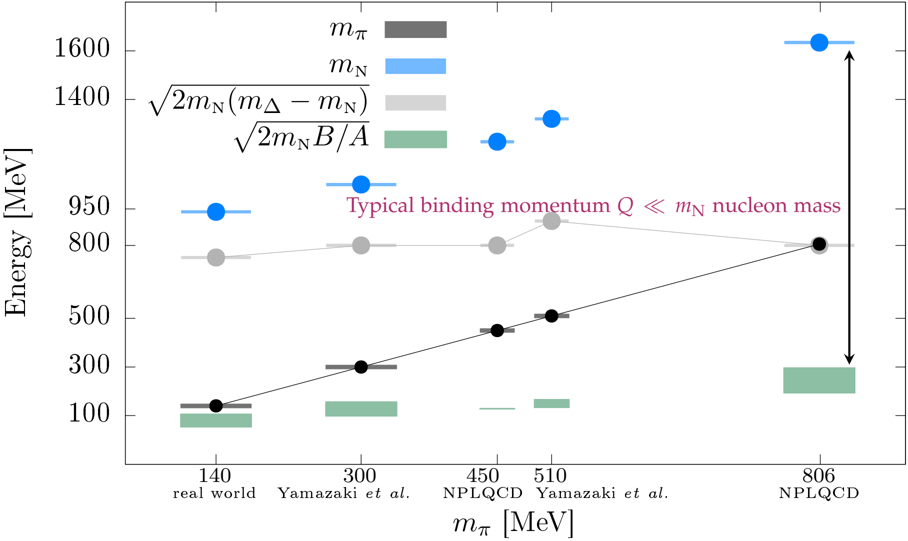

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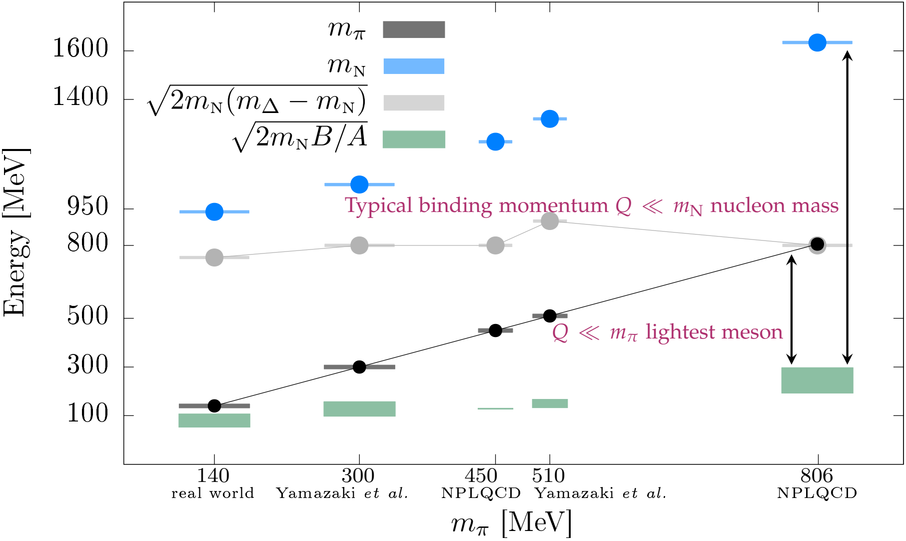

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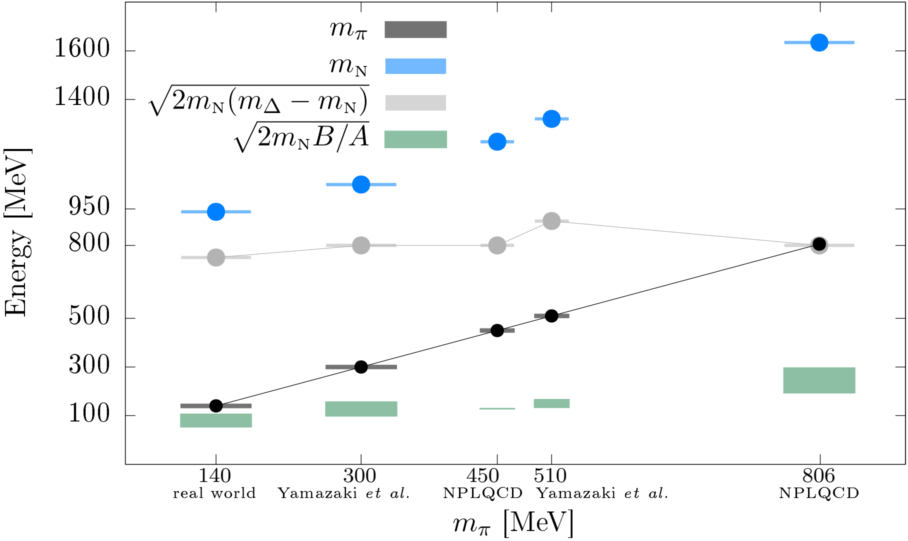

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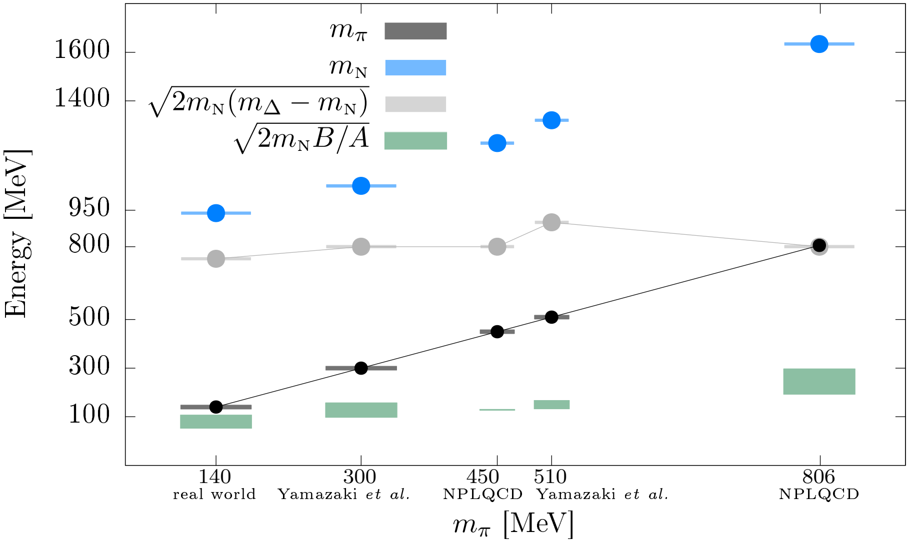
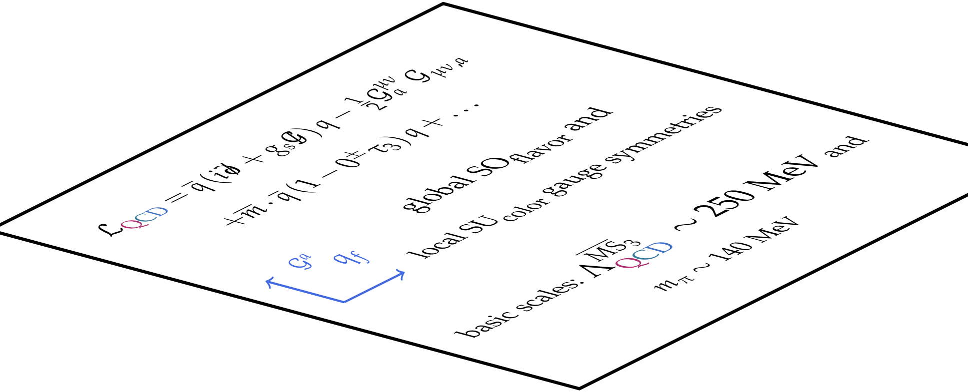


A sequence of effective (field) theories
to relate nuclear properties to QCD parameters,
to assess "How much more it takes, to be different".



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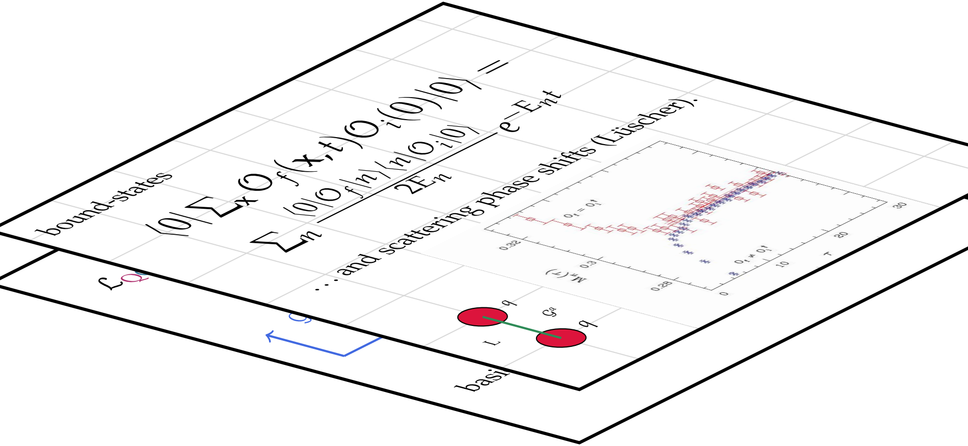

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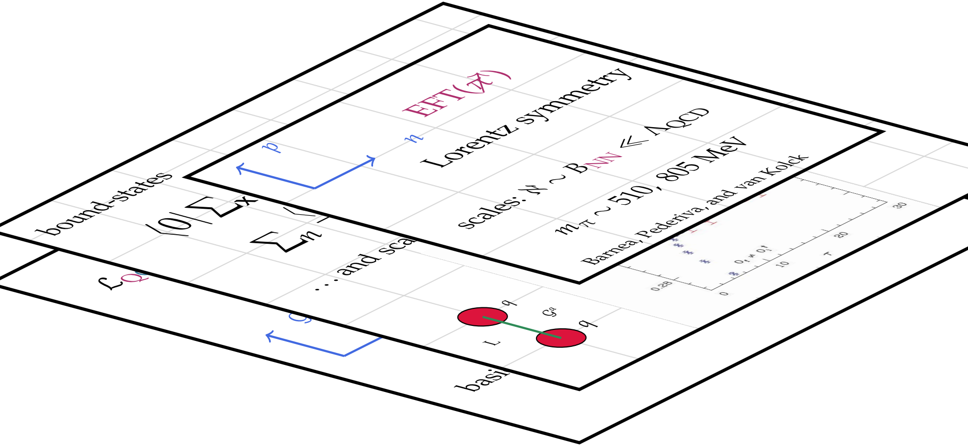

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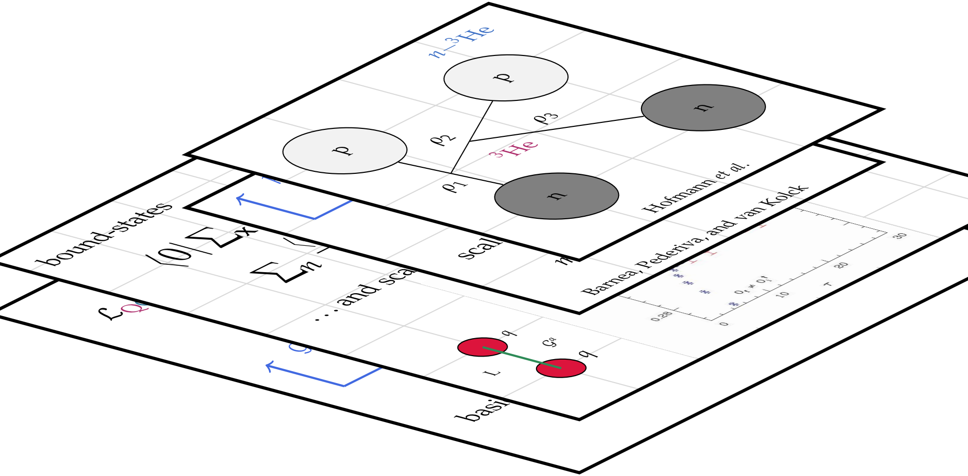

Effect of detuned scales on nuclear characteristics?

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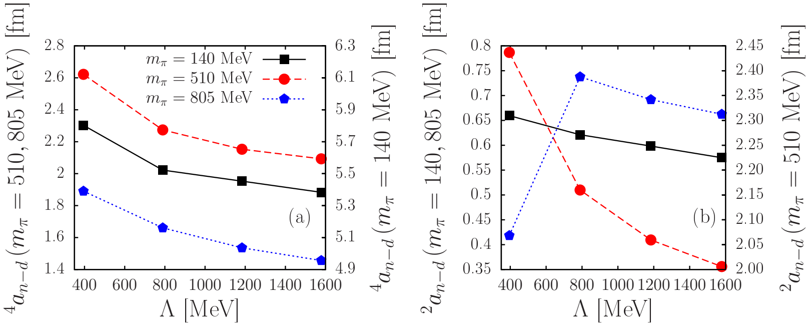

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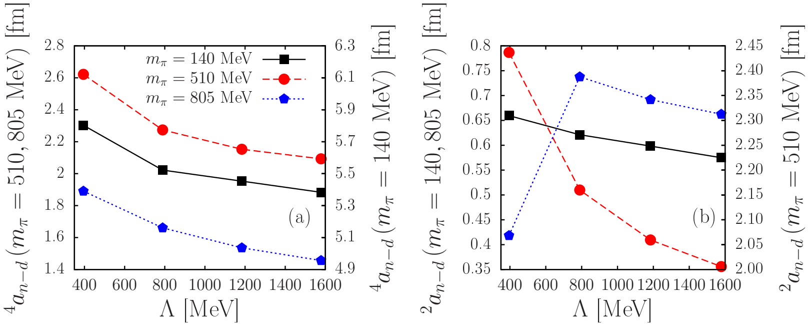
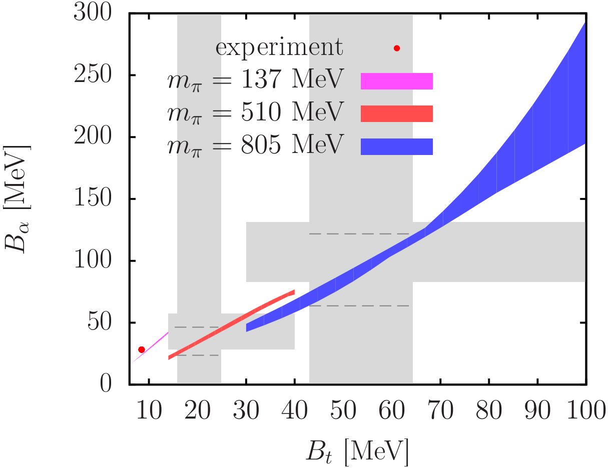


Observations:

i) No bound $^4S_{\frac{3}{2}}$ 3-nucleon state.

ii) Scattering lengths run non monotonous with m_π.

Effect of detuned scales on nuclear characteristics?



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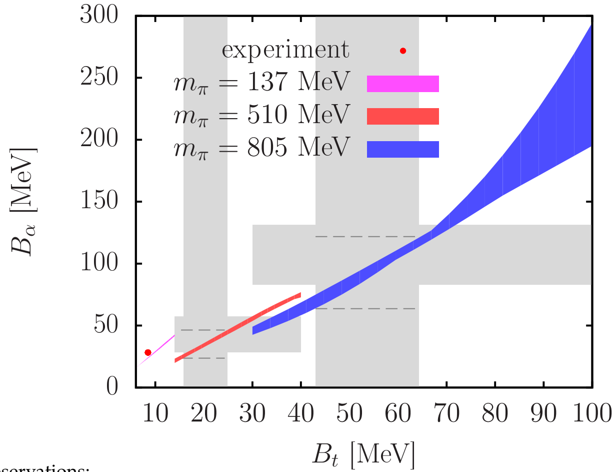


Observations:

i) At physical m_π, the 3- and 4-nucleon ground states are correlated.

ii) This correlation is preserved at higher m_π.

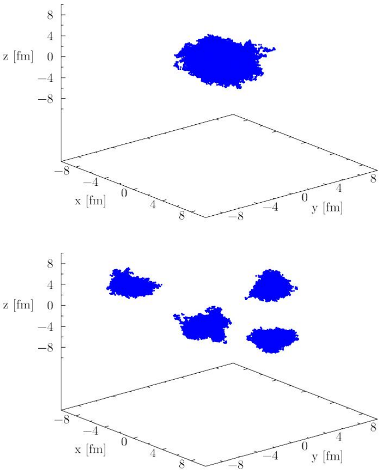
Effect of detuned scales on nuclear characteristics?

Λ	$m_\pi = 140$ MeV	$m_\pi = 510$ MeV	$m_\pi = 805$ MeV
2 fm^{-1}	-97.19 ± 0.06	-116.59 ± 0.08	-350.69 ± 0.05
4 fm^{-1}	-92.23 ± 0.14	-137.15 ± 0.15	-362.92 ± 0.07
6 fm^{-1}	-97.51 ± 0.14	-143.84 ± 0.17	-382.17 ± 0.25
8 fm^{-1}	-100.97 ± 0.20	-146.37 ± 0.27	-402.24 ± 0.39
$\to \infty$	$-115^{\pm 1\,(\text{sys})}_{\pm 8\,(\text{stat})}$	$-151^{\pm 2\,(\text{sys})}_{\pm 10\,(\text{stat})}$	$-504^{\pm 20\,(\text{sys})}_{\pm 12\,(\text{stat})}$
Exp.	-127.62	–	–

Table 3: ^{16}O energy for different values of the pion mass m_π and the cutoff Λ, compared with experiment. (No LQCD data exist for this nucleus.) See main text and appendix for details on errors and extrapolations.

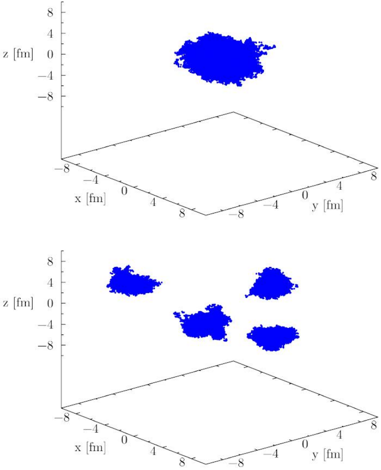
Effect of detuned scales on nuclear characteristics?

Contessi *et al.*



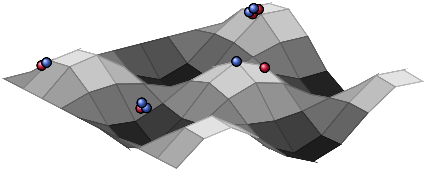
EFFECT OF DETUNED SCALES ON NUCLEAR CHARACTERISTICS?

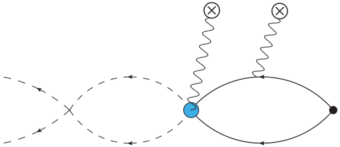
CONTESSI *et al.*

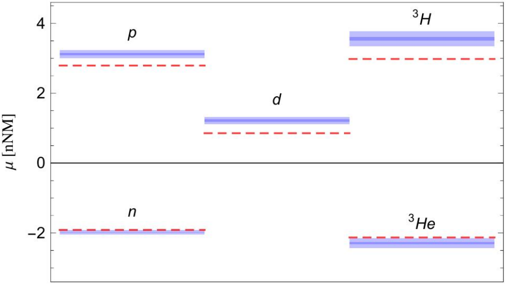


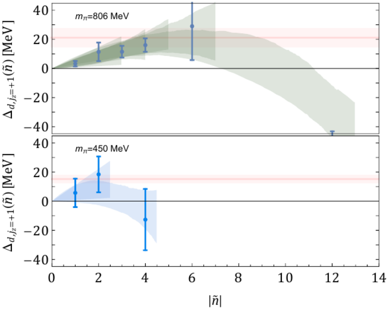
^{16}O stability sensitive to structural features (m_{π}, Λ).

Magnetic background fields:
Experimentally unreachable strengths. (NPLQCD)



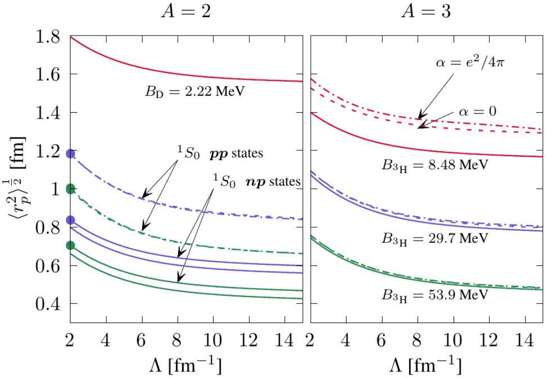






Magnetic background fields:

Barnea, Pazy, JK



Observations:

i) Diproton radius ≈ insensitive to Coulomb repulsion (ecce: large m_π and $B(pp)$)
$\Rightarrow$ dynamical QED effect small at $\not\pi$.

ii) $B(2) < B(3) \Rightarrow r(2) > r(3)$ at $m_\pi = 137$ MeV

iii) $B(2) < B(3)$ but $r(2) < r(3)$ at $m_\pi = 806$ MeV

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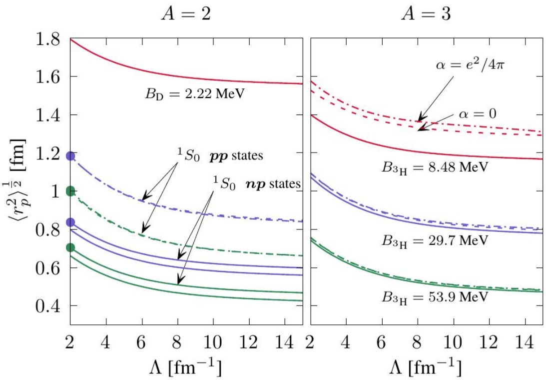

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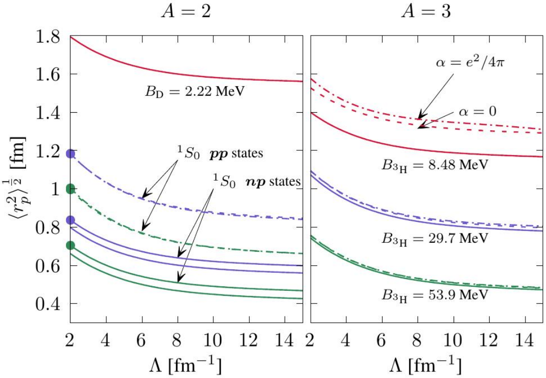

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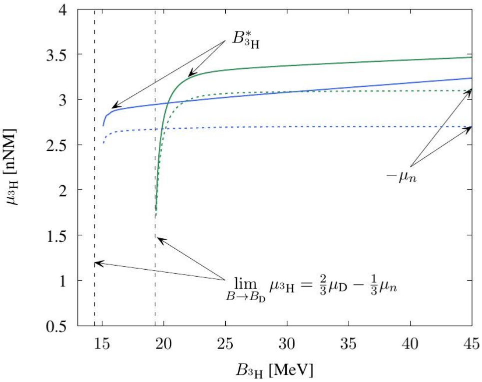

Observations:

i) EFT($\not\pi$) $\Rightarrow$ $\mu_{^3H}\,(B_{^3H})$.

ii) $\lim_{B(3)\to B(2)} \mu(3)$ = free deuteron+neutron

iii) $\lim_{B(3)\to\infty} \mu(3)$ = shell model

iv) zero-range/$\Lambda \to \infty$ limit $\Rightarrow$ discontinuous transition between free- and shell-model behavior

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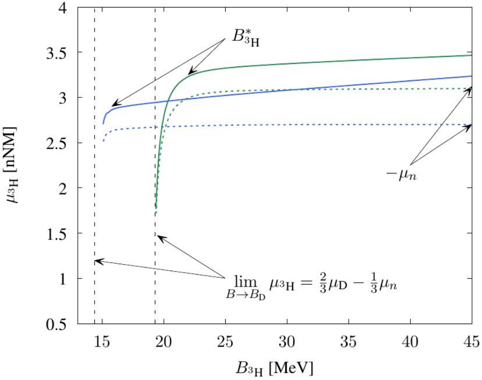

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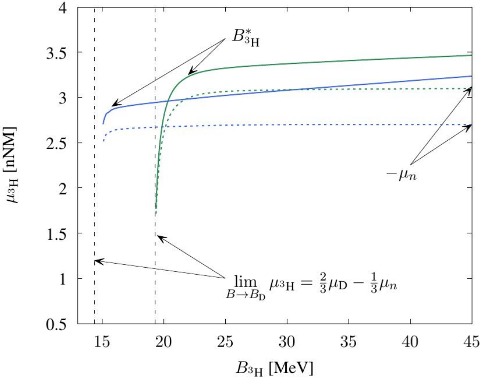

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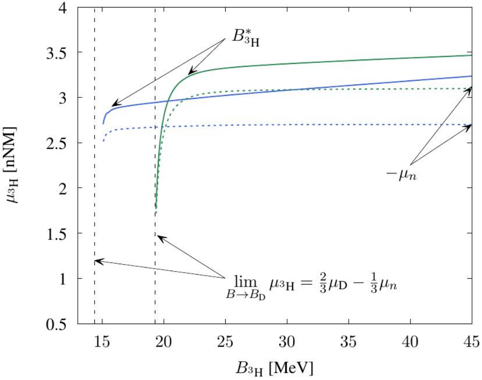

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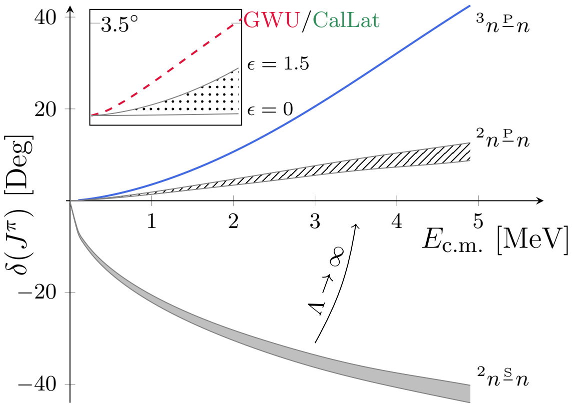
Pure neutron cluster.

JK (under rev.)



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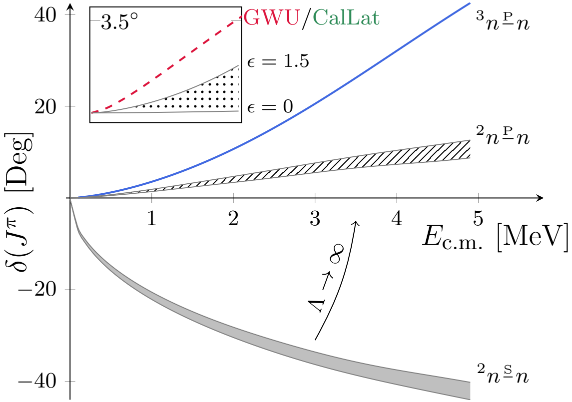

Observations:

i) Negative-parity 3-neutron ground state $\leftrightarrow$ π(tetraneutron)=positive.

ii) Enhancement target-neutron interaction with target's neutron number.

$\Downarrow$ (?)

particle-stable A-neutron cluster

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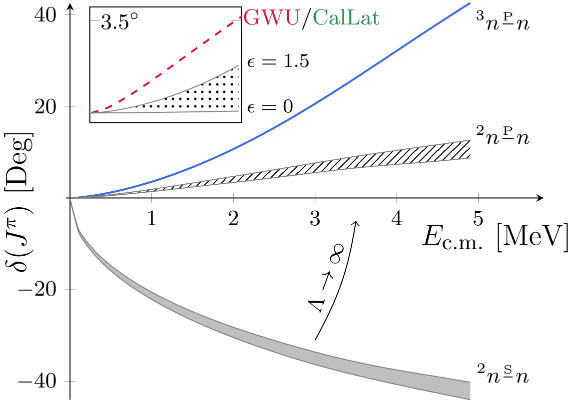

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