Neutrino-matter interactions from chiral EFT

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TRIUMF

CANADA'S NATIONAL LABORATORY FOR PARTICLE AND NUCLEAR PHYSICS

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with S. Bacca, K. Hally, G. Lykasov and C.J. Pethick

PRC 78, 045803 (2008) and arXiv:0812.0102.

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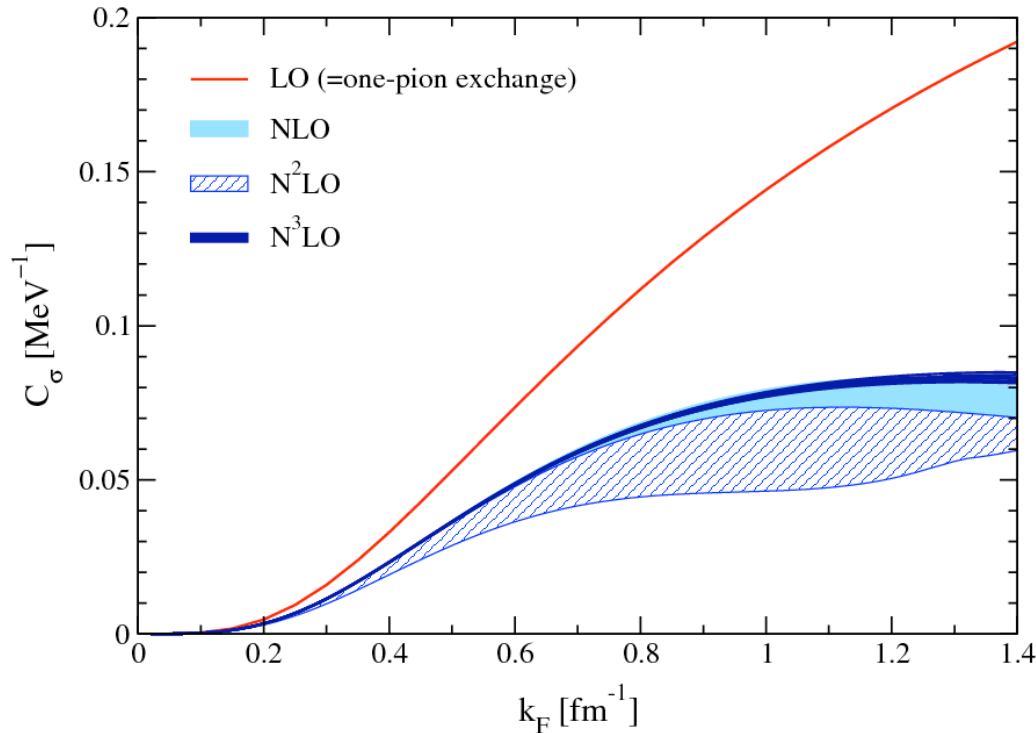
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Spin relaxation rate in neutron matter from chiral EFT

$$\frac{1}{\tau_\sigma} = C_\sigma \left[T^2 + (\omega/2\pi)^2 \right]$$

bremsstrahlung rate ~ C_σ
when $|\omega| \gg 1/\tau_\sigma$
at low frequencies suppressed
by LPM effect

chiral EFT interactions to N^{3}LO
Epelbaum et al. (2005) Entem, Machleidt (2003)
used in Born approximation
(will justify next)

convergence with successively higher orders, bands estimate uncertainty

OPE significantly overestimates C_σ for all relevant densities

at NLO: shorter-range noncentral interactions, constrained by NN data

at N^{3}LO (accurately reproduces NN scattering): interaction independent

Comparison of interactions and to NN phase shifts
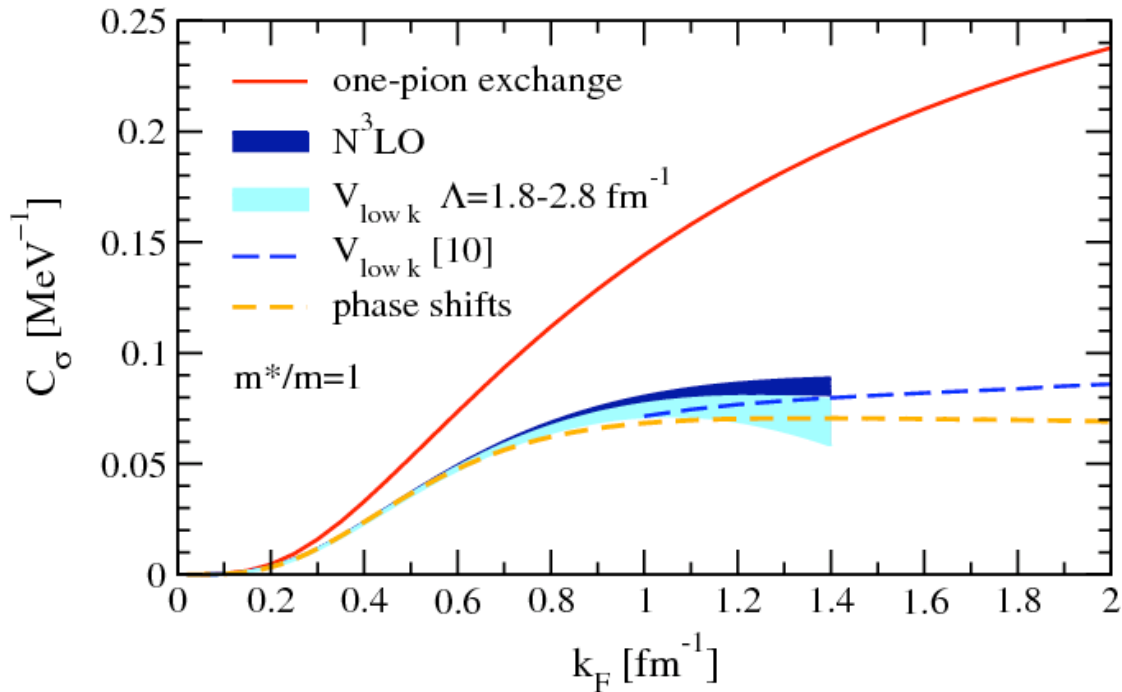
at subnuclear densities
$\rho < 10^{14} \, \text{g cm}^{-3}$

spin relaxation rate is well
constrained at NN level

low-density limit: two-nucleon collisions dominate, model-independent
rate based on NN phase shifts, K-matrix for near-degenerate conditions
see Hanhart, Phillips, Reddy (2001) for T matrix

in general unclear if expansion in terms of K or T matrix is reliable
for these conditions (Pauli blocking, strong interactions,…)

Born rates from chiral N^3LO interactions close to rates from phase shifts

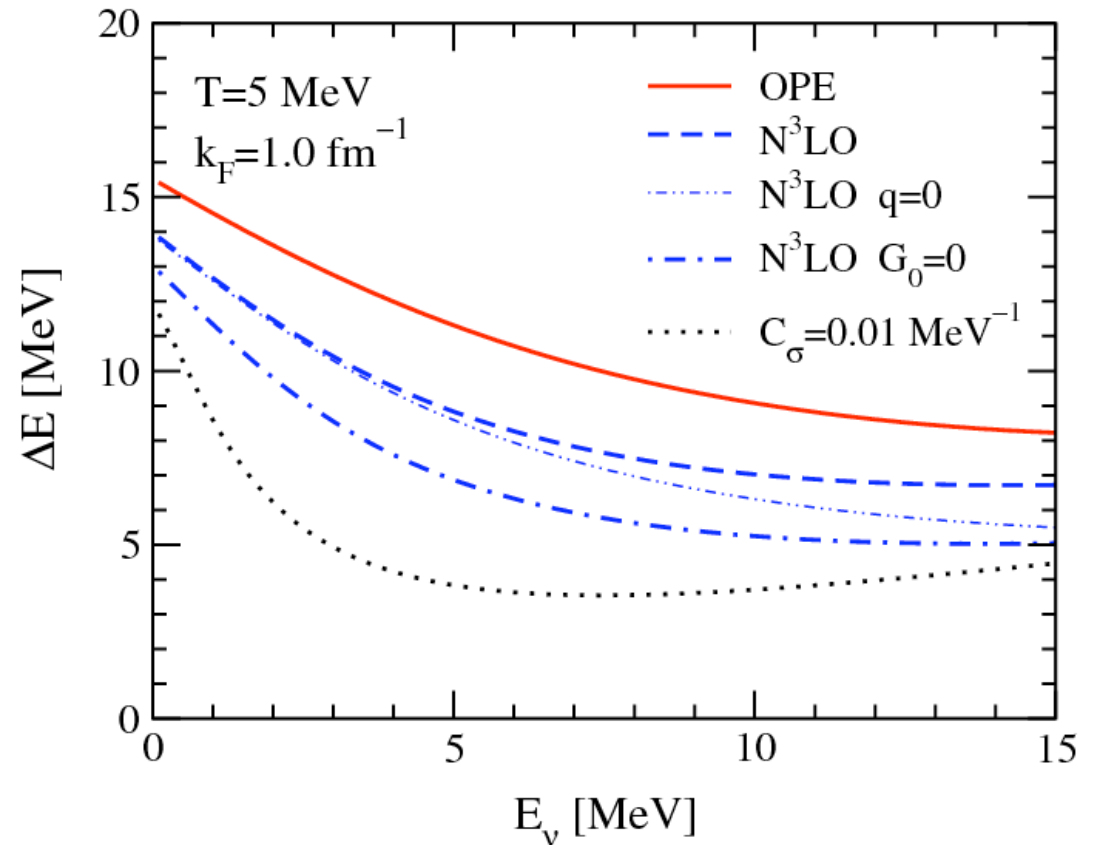noncentral part of the strong neutron-neutron amplitude is perturbative

Energy transfer in neutrino scattering from nucleons

mean-square neutrino energy transfer in $\nu nn \leftrightarrow \nu nn$

$$(\Delta E)^2 = \frac{\int d\mathbf{p}'_\nu \, (E_\nu - E'_\nu)^2 \, \Gamma(E_\nu - E'_\nu, p_\nu - p'_\nu)}{\int d\mathbf{p}'_\nu \, \Gamma(E_\nu - E'_\nu, p_\nu - p'_\nu)}$$

NN analogue of inelastic
excitations of nuclei
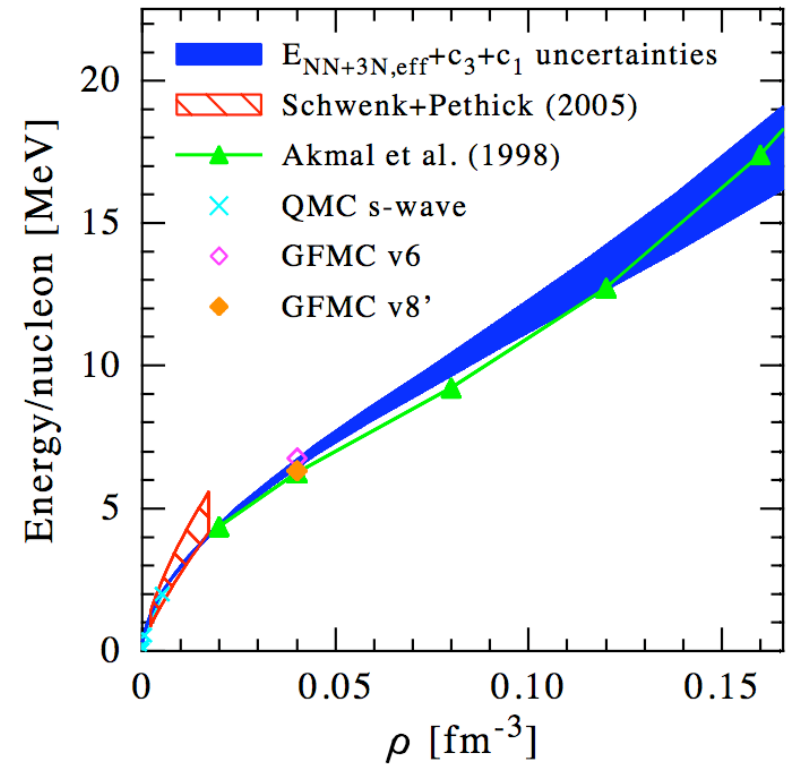
significant dependence on
spin relaxation rate

collision processes and spin-dependent mean-field effects (G_0)
dominate over energy transfer due to recoil, nonzero momentum transfers
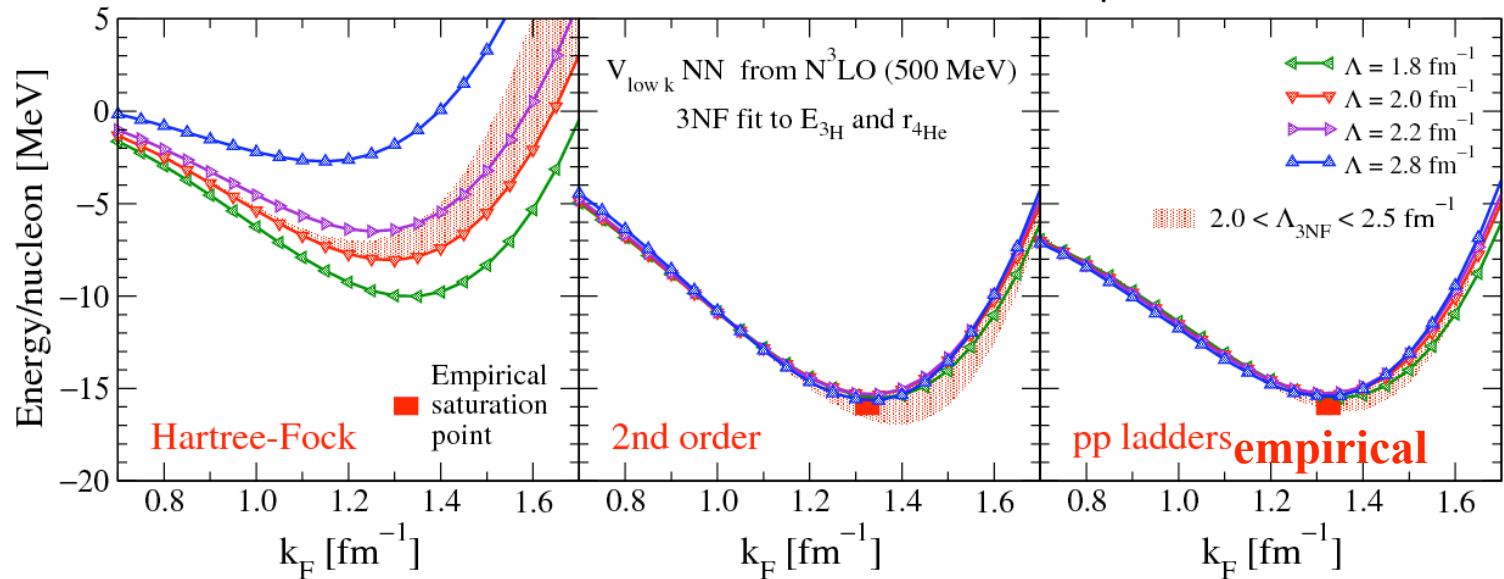
Chiral EFT interactions and nuclear matter

neutron matter

Tolos, Friman, AS (2007); Hebeler, AS, in prep.

nuclear matter saturation
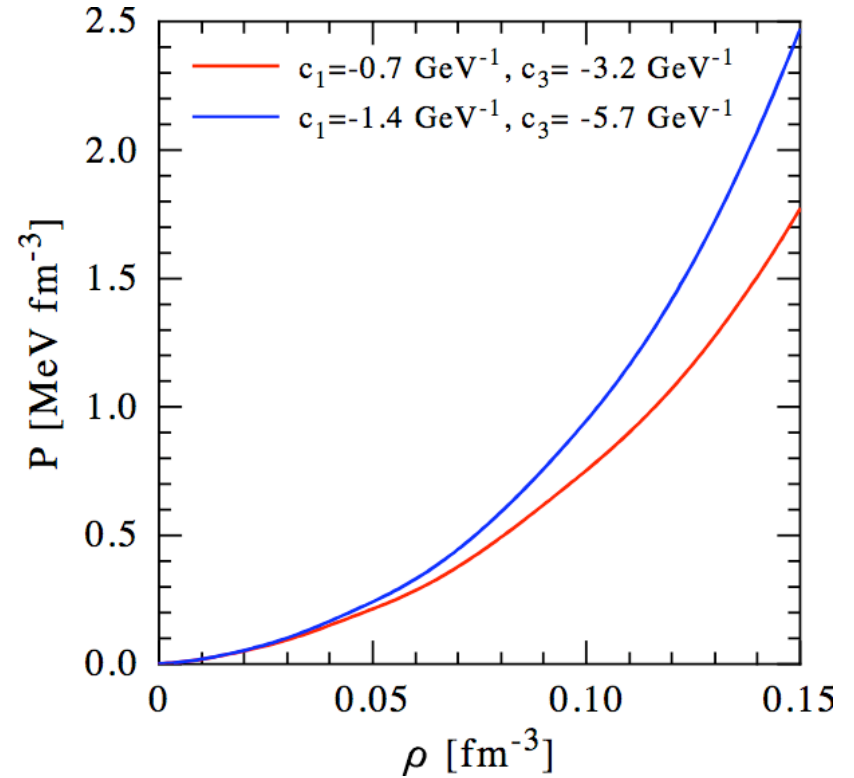## with theoretical uncertainties

Bogner, Furnstahl, Nogga, AS, arXiv:0903.3366.

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