From $\bar{K}$ bound states to $\bar{K}$ condensation?

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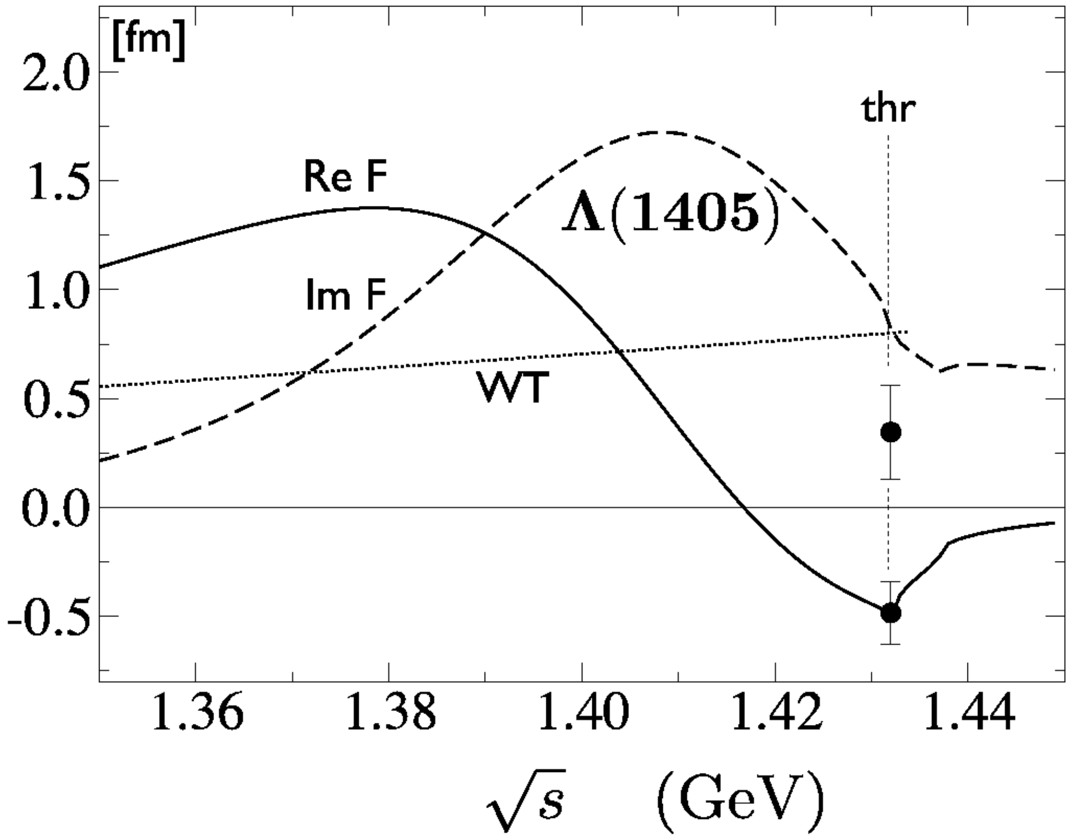
Based on D. Gazda, E. Friedman, A. Gal, J. Mareš :

$\bar{K}$ and multi-$\bar{K}$ nuclei, PRC **76**, 055204 (2007)

Multi-$\bar{K}$ nuclei and kaon condensation, arXiv:0801.3335

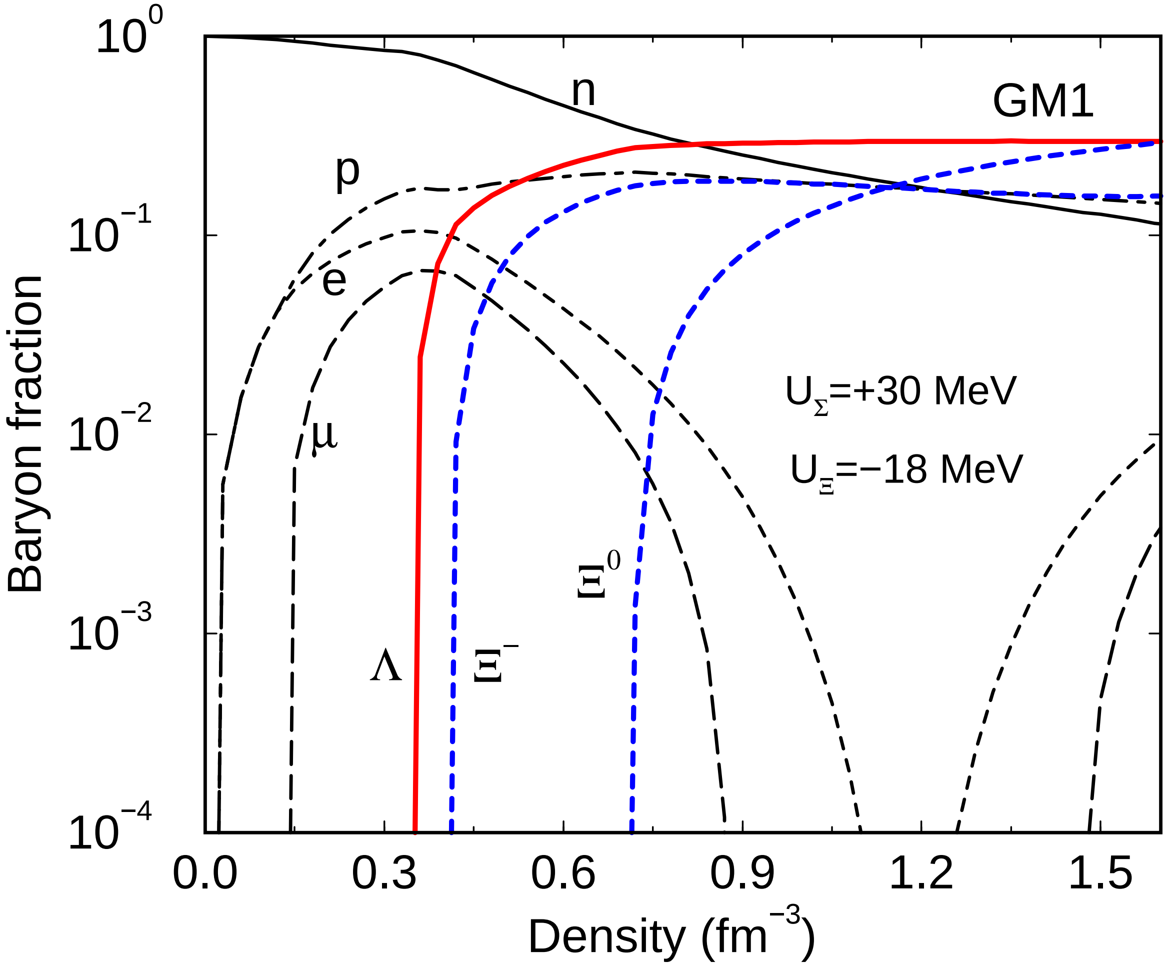
- no accepted $\bar{K}$ bound states at present (KEK, Frascati)
- chance for narrow states with $B_{\bar{K}} \sim 100 - 200$ MeV?
- is $\bar{K}$ condensation limiting case of $\bar{K}$ bound states?
- $\bar{K}$ cond on Earth (lab) or in Heaven (neutron stars)?



W. Weise, R. Hartle, arXiv:0801.1467, NPA (in press)

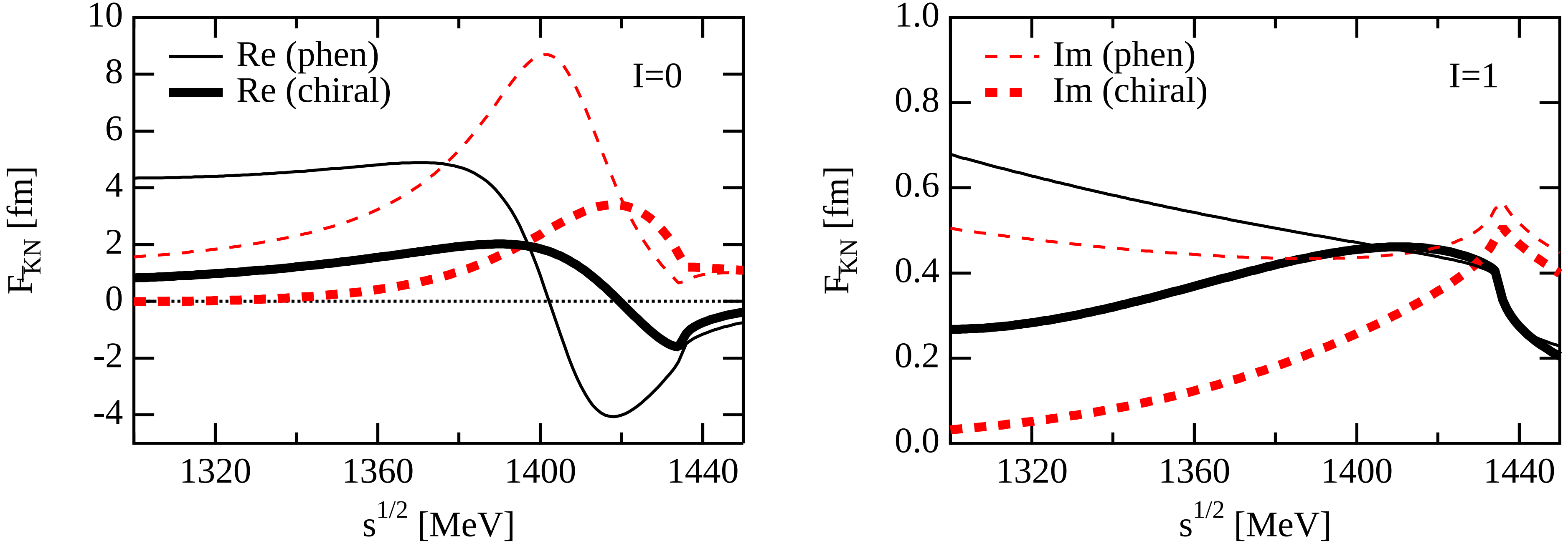
Forward F_{K^-p} in SU(3) chiral $\bar{K}N - \pi Y$ model from

BNW, EPJA 25 (2005) 79 $\rightarrow V_{\bar{K}}(\rho_0) \sim -100$ MeV



J. Schaffner-Bielich, NPA (in press) updated arXiv:astro-ph/0703113

Neutron-star composition with density, disregarding $\bar{K}$ condensation

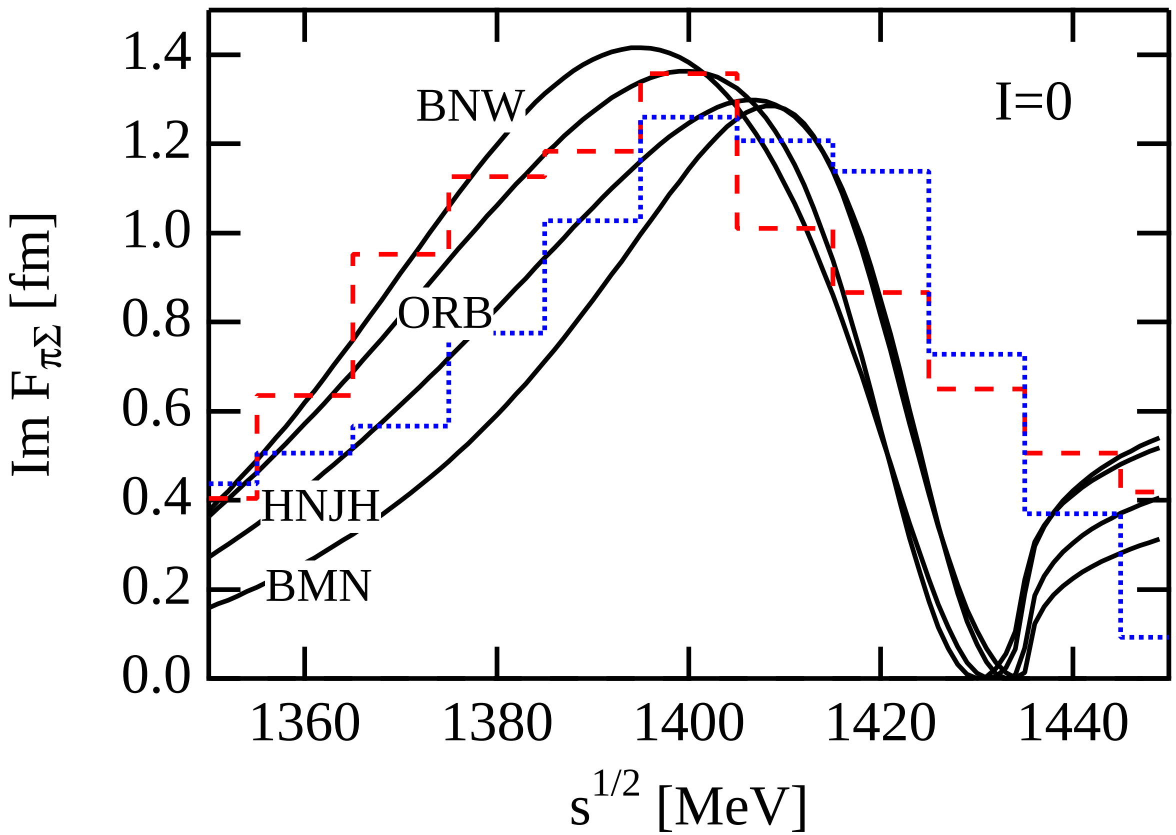


T. Hyodo, W. Weise, arXiv:0712.1613

Critique of phenomenological K^- potential

phen: T. Yamazaki, Y. Akaishi, PRC 76 (2007) 045201

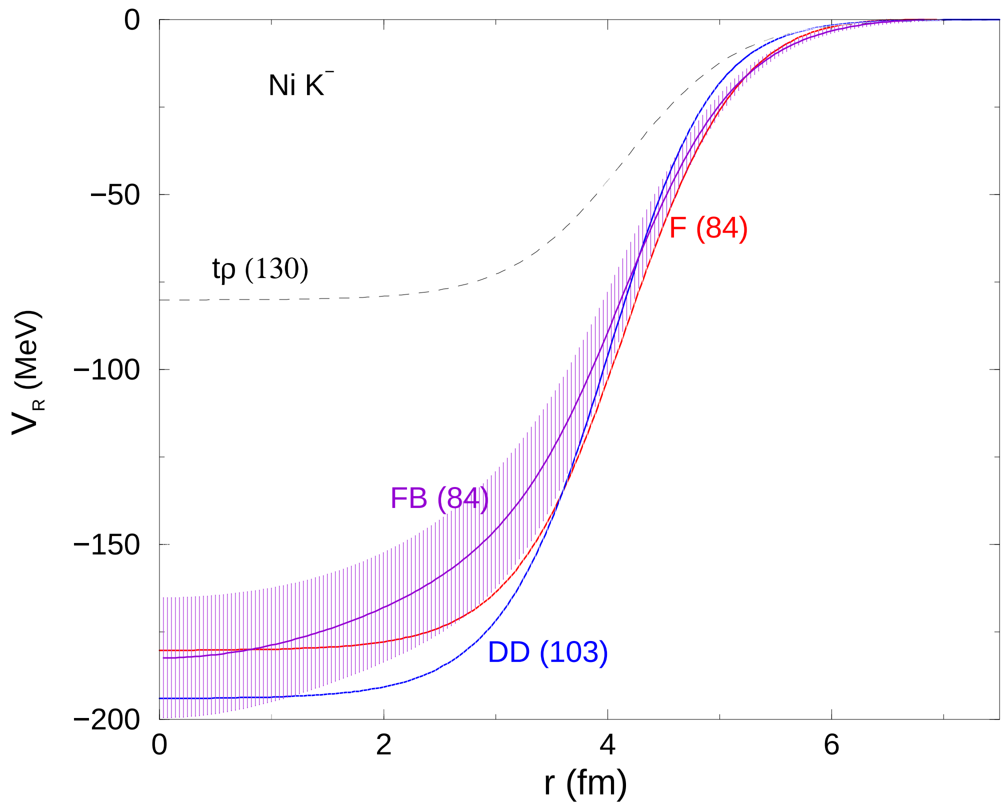
Quasibound $\bar{K}N$ state: at 1405 MeV (phen) or at 1420 MeV (chiral)?



T. Hyodo, W. Weise, arXiv:0712.1613

$\Lambda(1405)$ shape in $\pi - \Sigma$ spectrum, calculated in chiral models

Do chiral models work well?

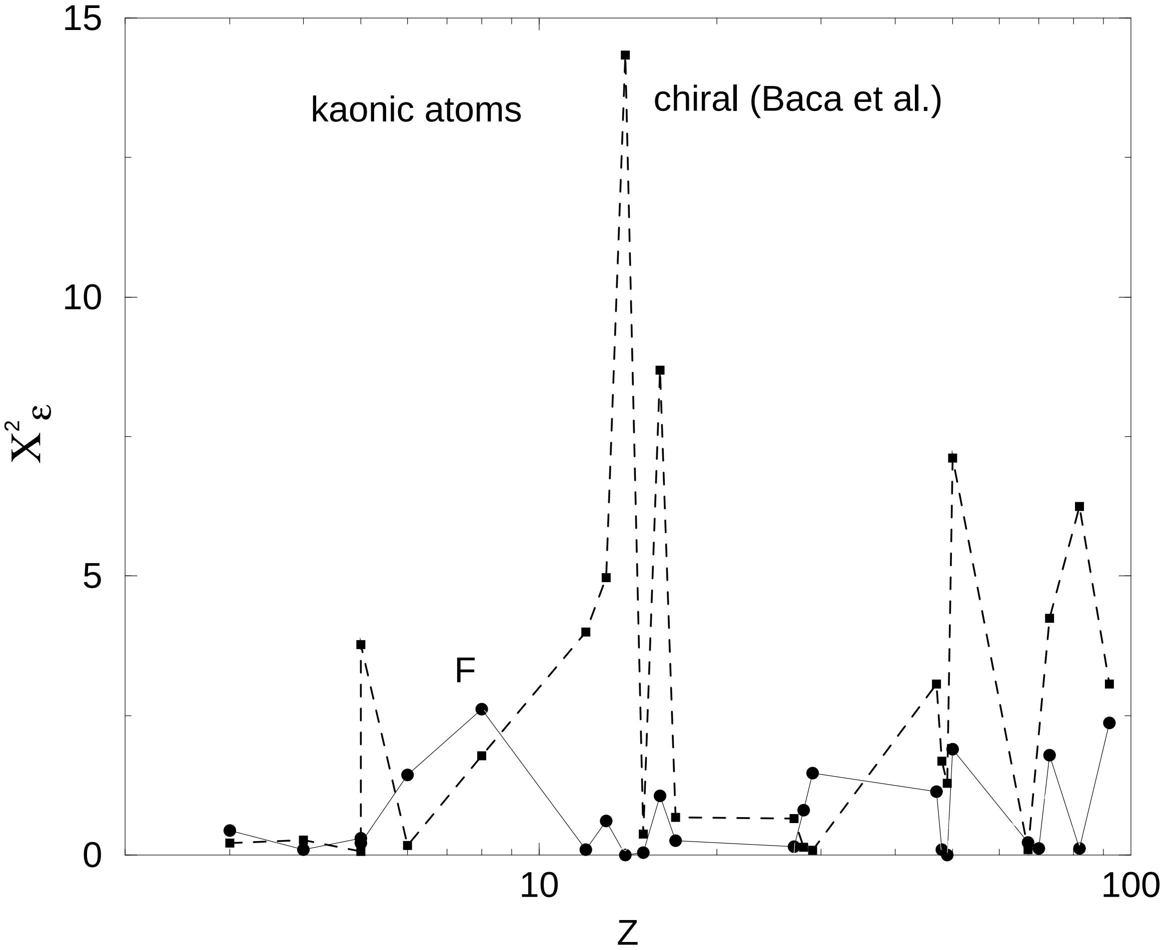


N. Barnea, E. Friedman, Phys. Rev. C 75 (2007) 022202

Example of K^--Ni (real) potentials in different atomic data fits

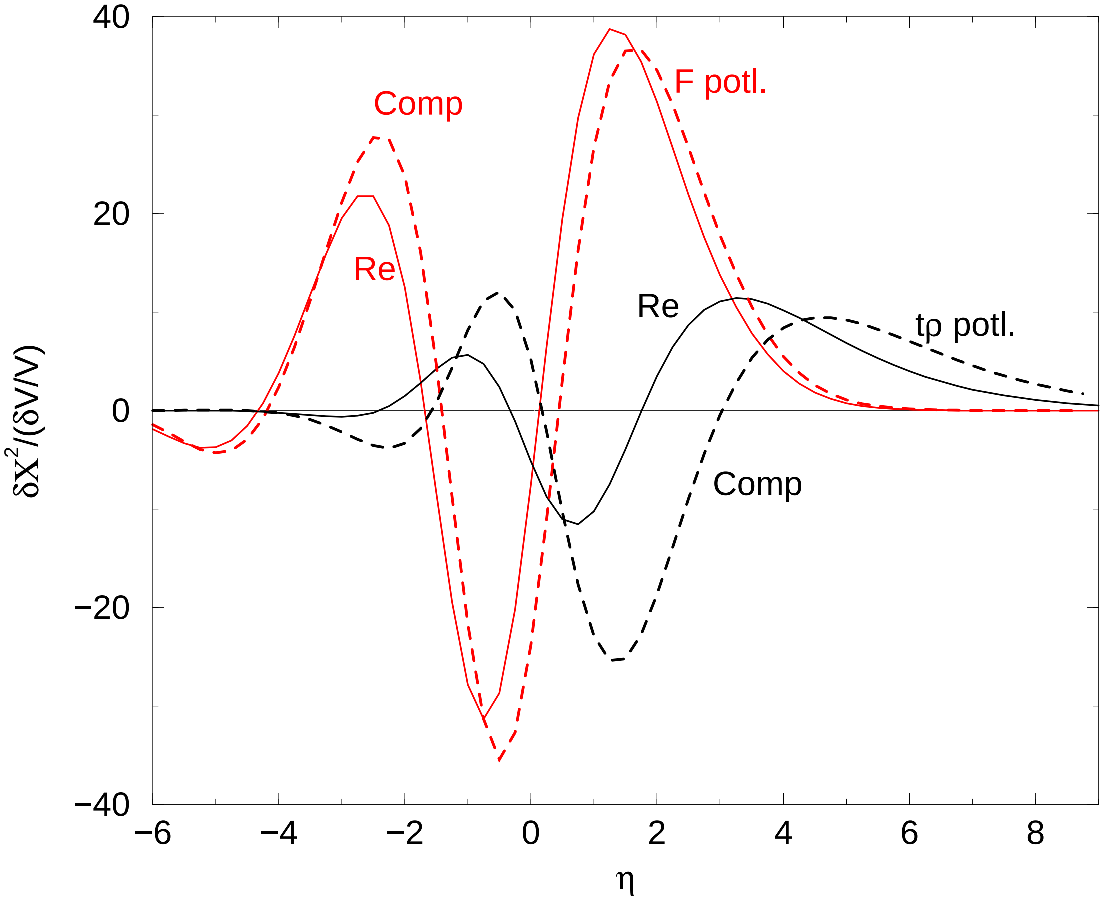
χ^2 with respect to 65 data points across the periodic table

K^- atom review: E. Friedman, A. Gal, Phys. Rep. 452 (2007) 89



E. Friedman, A. Gal, Phys. Rep. 452 (2007) 89

Deep potential (F) favored over shallow chiral potential



N. Barnea, E. Friedman, Phys. Rev. C 75 (2007) 022202

Functional Derivative analysis $[\eta = (r - R)/a]$

Deep potential (F) is determined inside the nucleus

RMF for nucleons and $\bar{K}$ mesons

$$\mathcal{L}_K = (\mathcal{D}_\mu K)^\dagger (\mathcal{D}^\mu K) - m_K^2 K^\dagger K + g_{\sigma K} m_K K^\dagger K \, \sigma$$

$$\mathcal{D}_\mu \equiv \partial_\mu + \mathrm{i}\, g_{\omega K}\, \omega_\mu + \mathrm{i}\, g_{\rho K}\, \vec{\tau} \cdot \vec{\rho}_\mu + \mathrm{i}\, g_{\phi K}\, \phi_\mu + \mathrm{i}\, e\, \tfrac{1}{2}(1+\tau_3) A_\mu$$

$$(-\nabla^2 - E_{K^-}^2 + m_K^2 + \Pi_{K^-})K^- = 0$$

$$\mathrm{Re}\, \Pi_{K^-} = -g_{\sigma K} m_K \sigma_0 - 2E_{K^-}(g_{\omega K}\omega_0 + g_{\rho K}\rho_0 + g_{\phi K}\phi_0 + eA_0) - (\cdots)^2$$

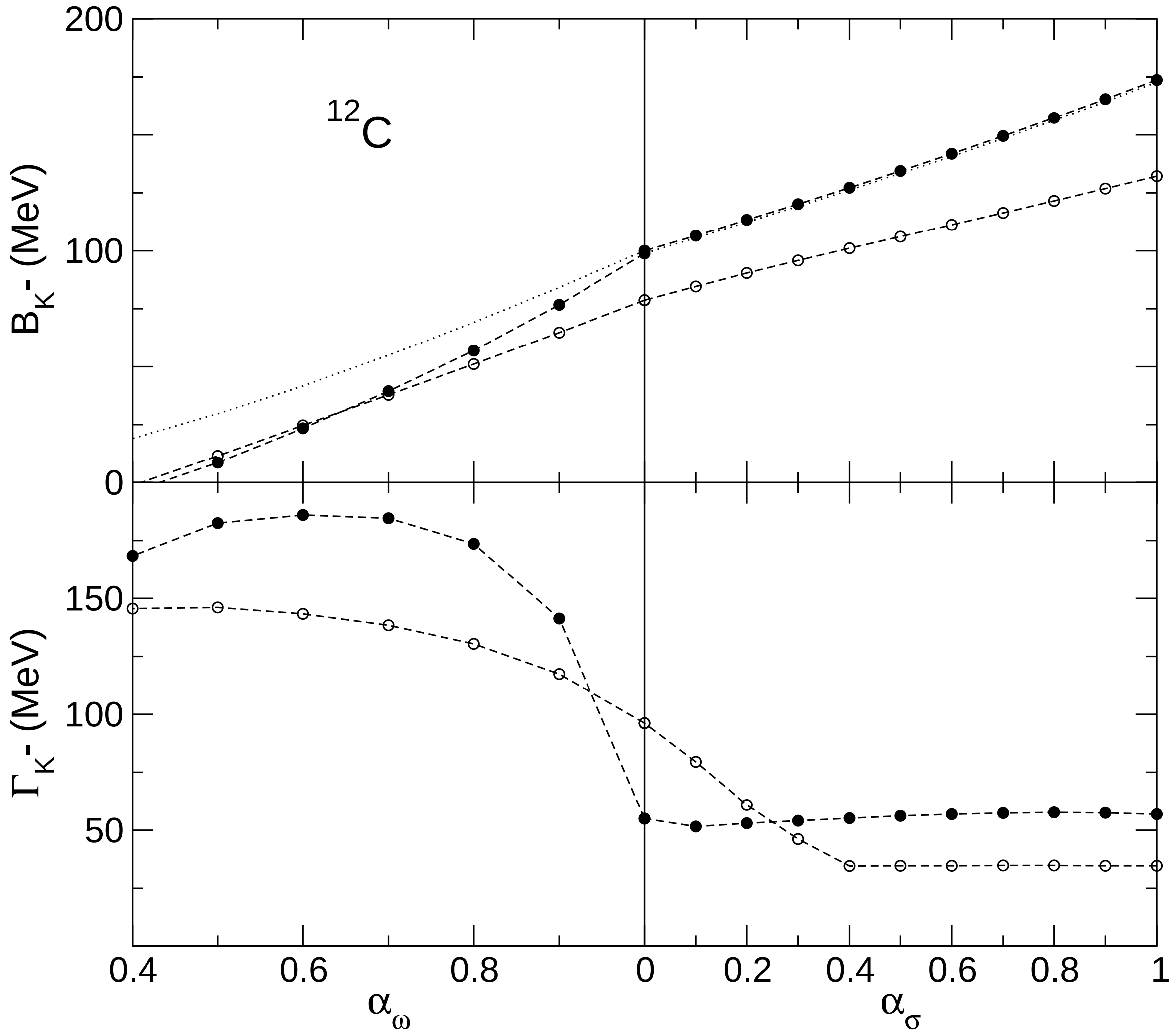
$\mathrm{Im}\, \Pi_{K^-}$ from K^- atom fit, considering decay phase space

$$(-\nabla^2 + m_\sigma^2)\sigma_0 = +g_{\sigma N}\rho_s + g_2\sigma_0^2 - g_3\sigma_0^3 + g_{\sigma K} m_K K^- K^+$$

$$(-\nabla^2 + m_\omega^2)\omega_0 = +g_{\omega N}\rho_v - g_{\omega K}\rho_{K^-}$$

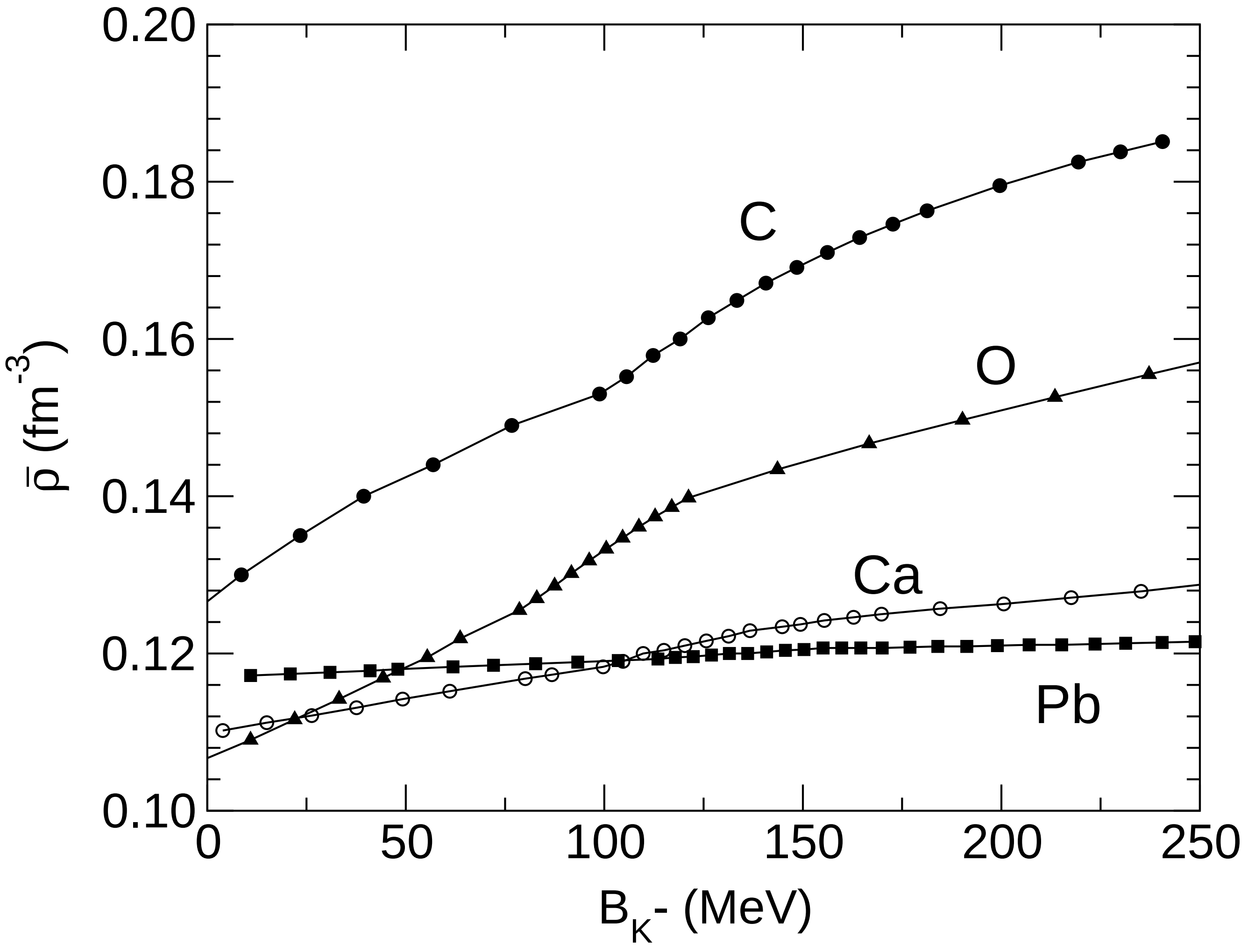
$$(-\nabla^2 + m_\rho^2)\rho_0 = +g_{\rho N}\rho_3 - g_{\rho K}\rho_{K^-} \qquad (-\nabla^2 + m_\phi^2)\phi_0 = -g_{\phi K}\rho_{K^-}$$

$2\mathrm{g}_{\omega K} = \sqrt{2}\, g_{\phi K} = 2\, g_{\rho K} = g_{\rho\pi} = 6.04$ F-type SU(3) (TW)

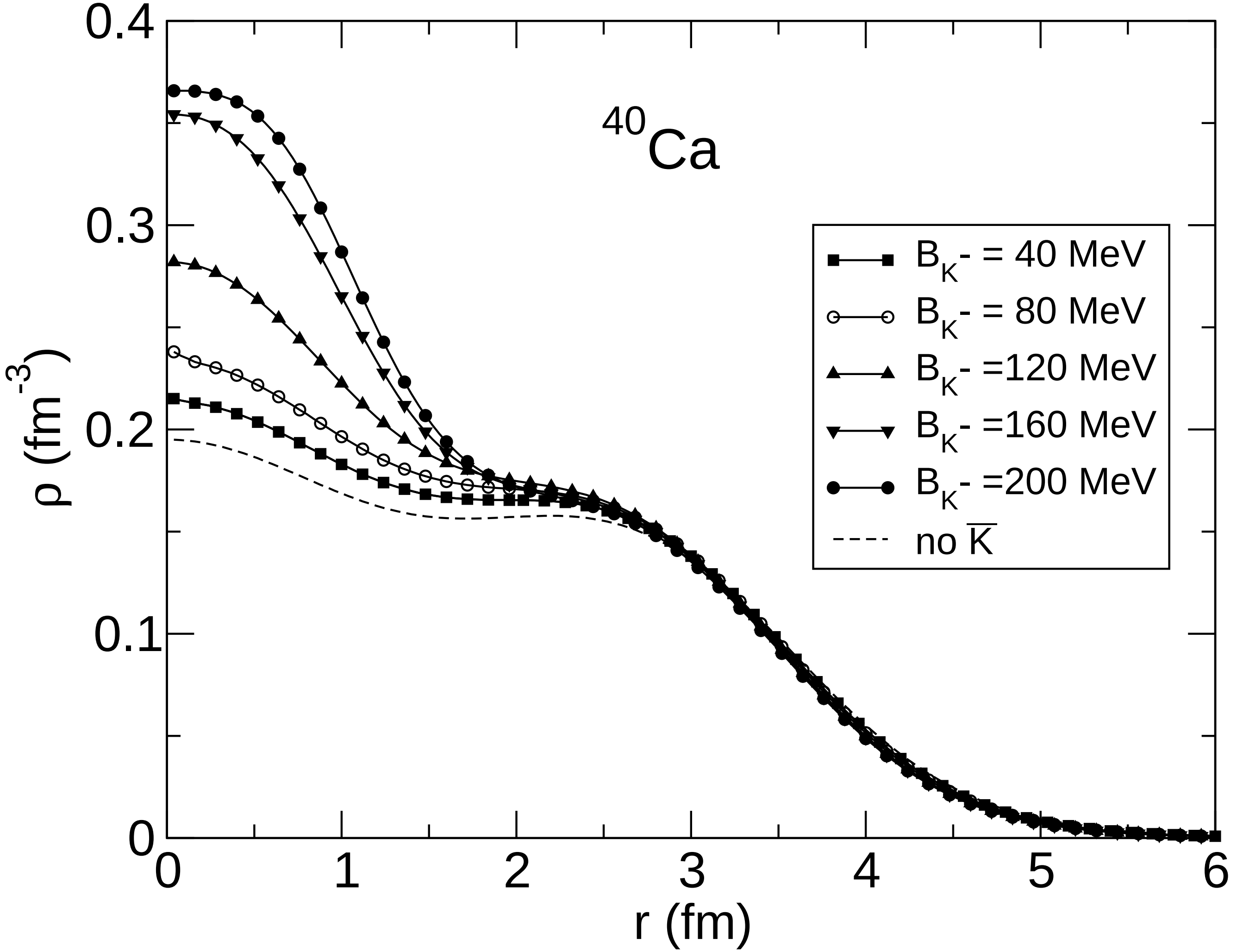


J. Mareš, E. Friedman, A. Gal, NPA 770 (2006) 84

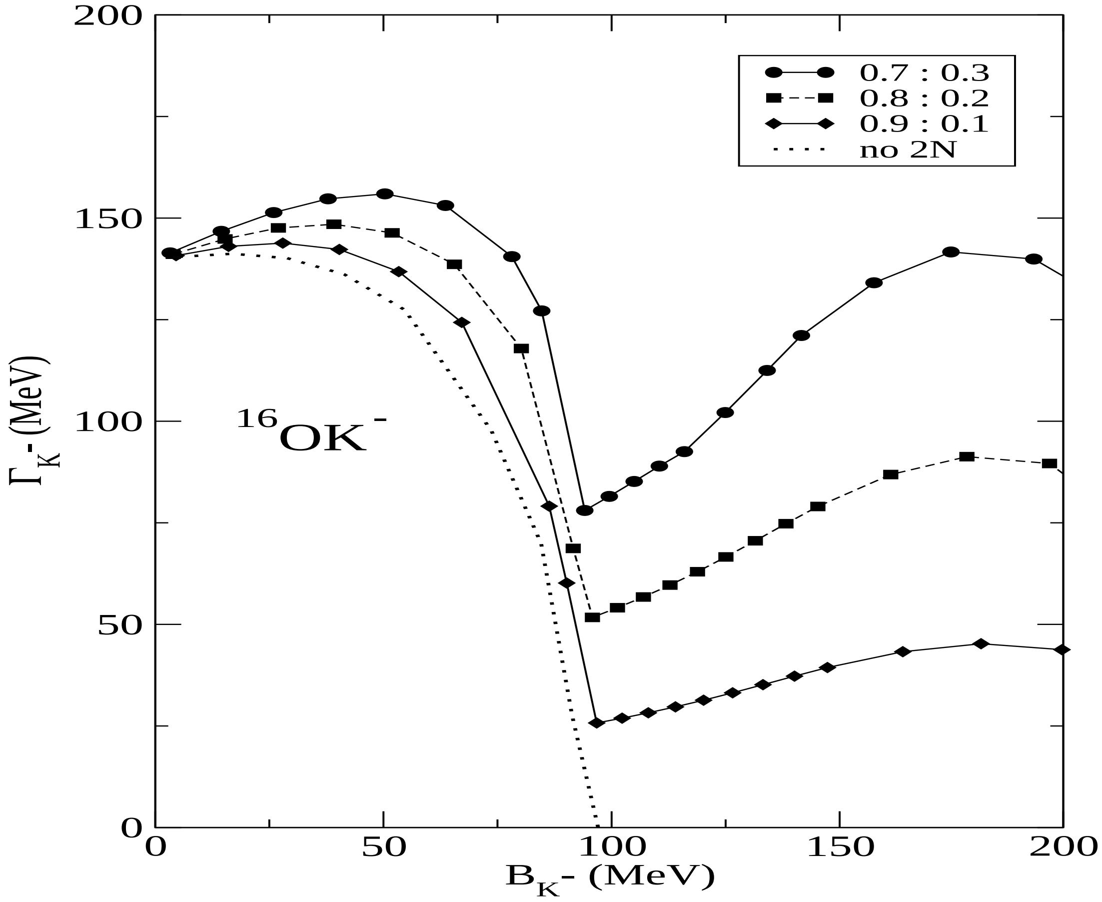
B_{K^-} and Γ_{K^-} in RMF calculations: static - empty, dynamical - solid



Average nuclear density $\overline{\rho}$ for a $1s$ K^- bound state



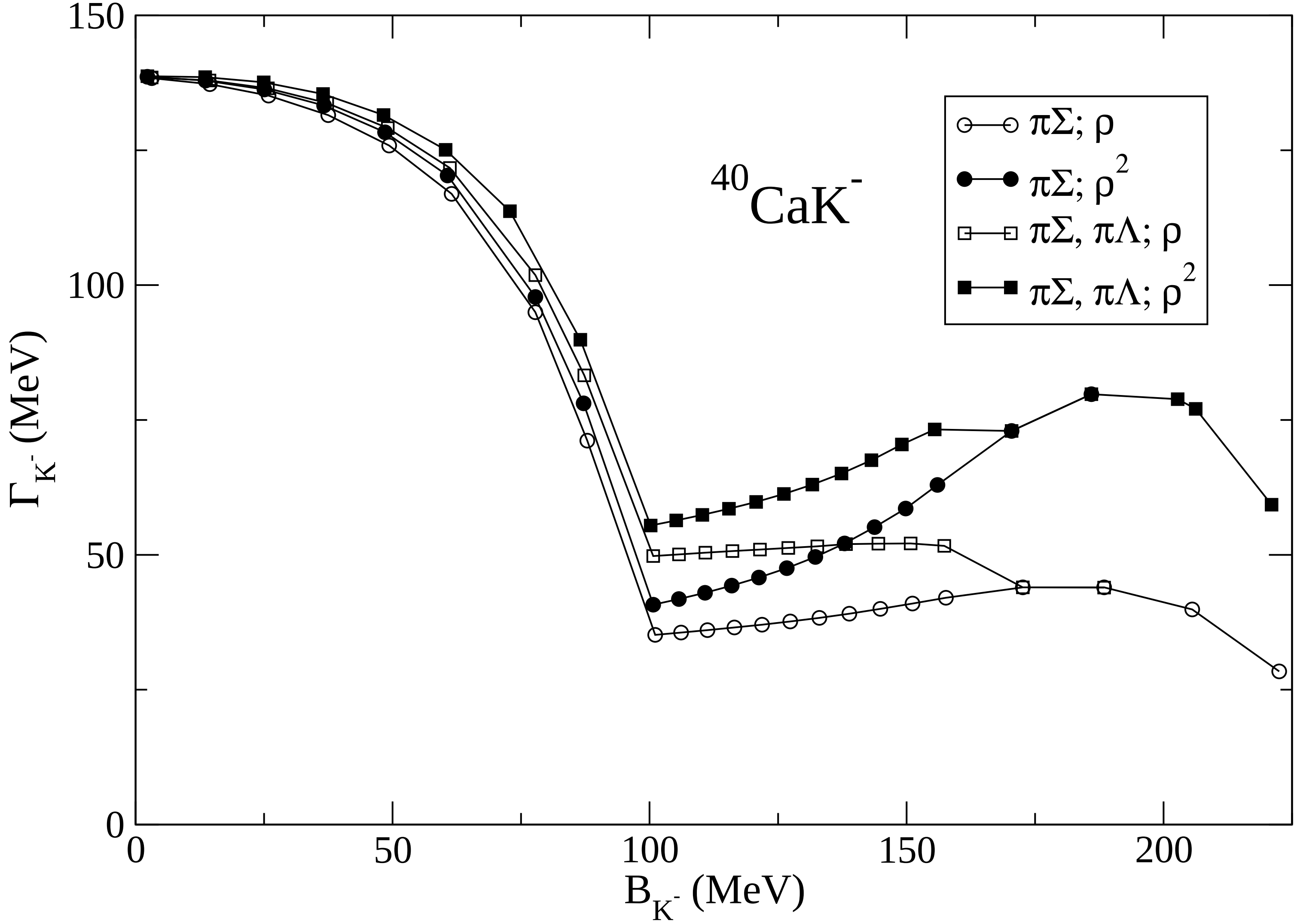
Localized effect of a $1s$ K^- deeply bound state



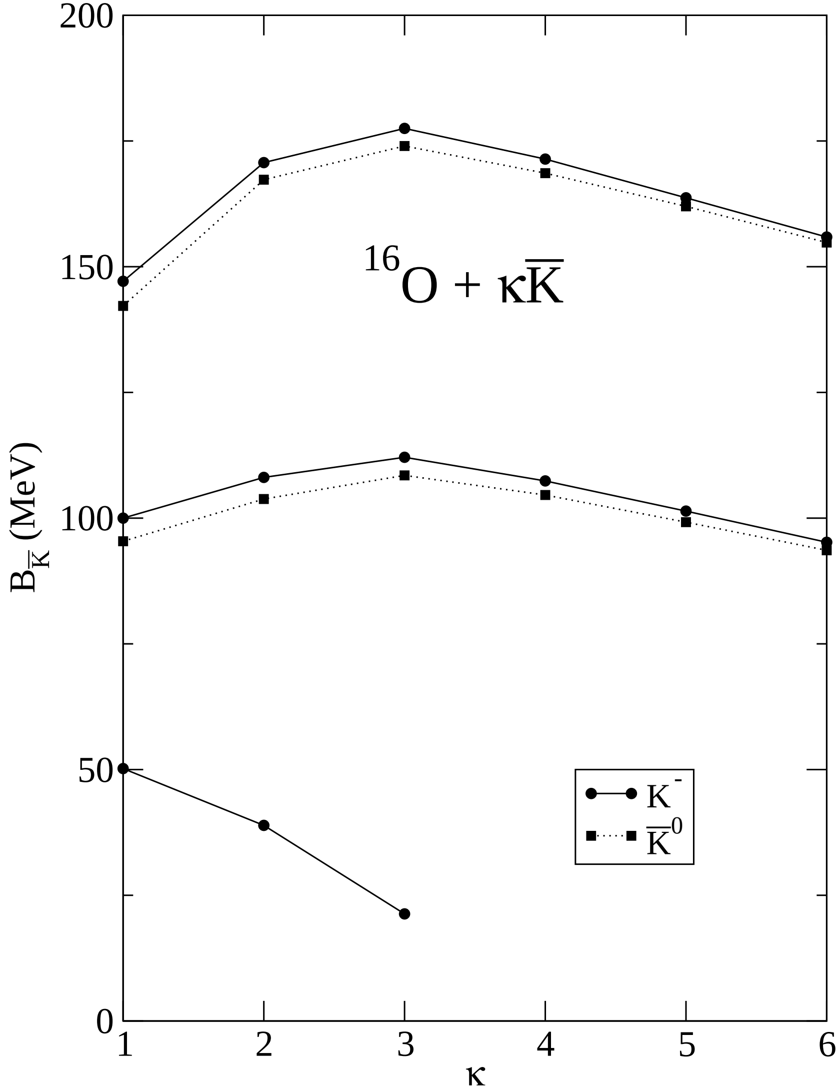
D. Gazda, E. Friedman, A. Gal, J. Mareš, PRC 76 (2007) 055204

Dependence on $(\bar{K}N \to \pi\Sigma) : (\bar{K}NN \to \Sigma N)$

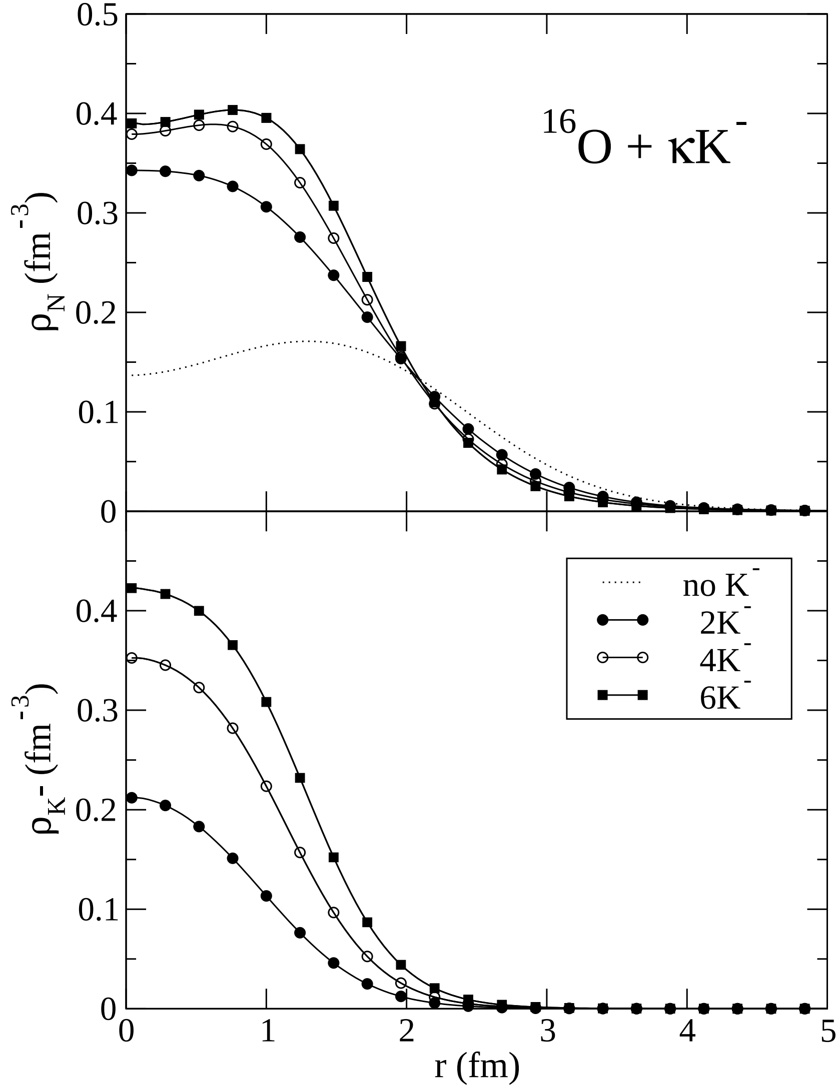
Ratio 0.8 : 0.2 is observed in capture at rest



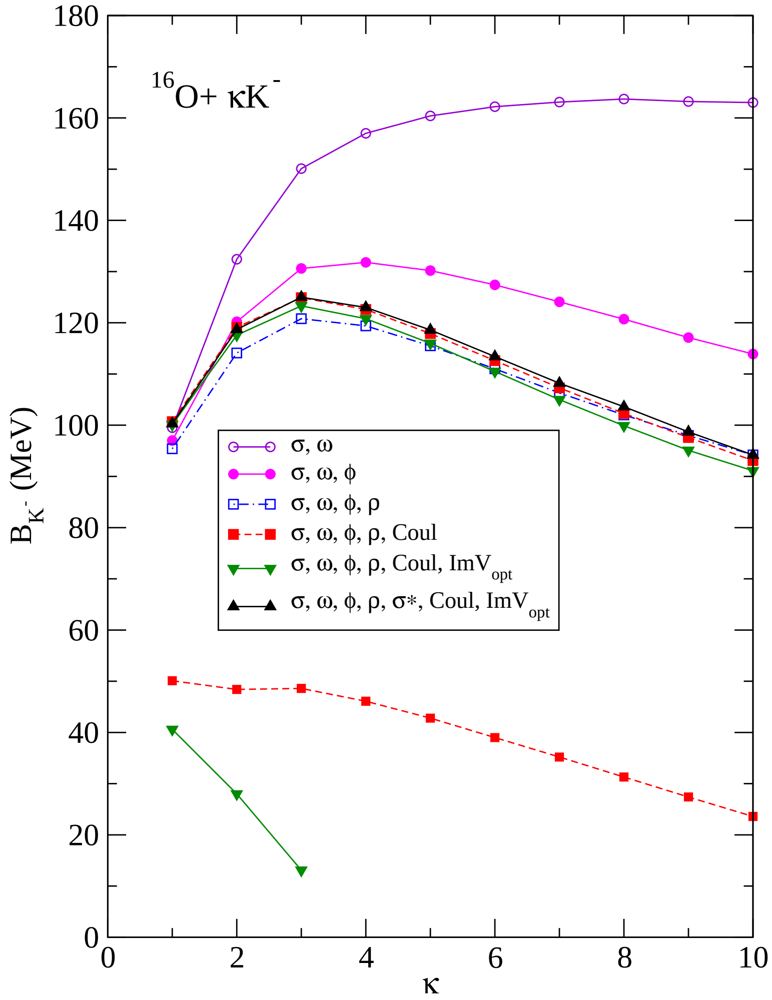
Conclusion: $\Gamma_{\bar{K}} > 50$ MeV for deeply bound states



Saturation of $B_{\bar{K}}$ in ^{16}O with number of $\bar{K}$ mesons (κ)

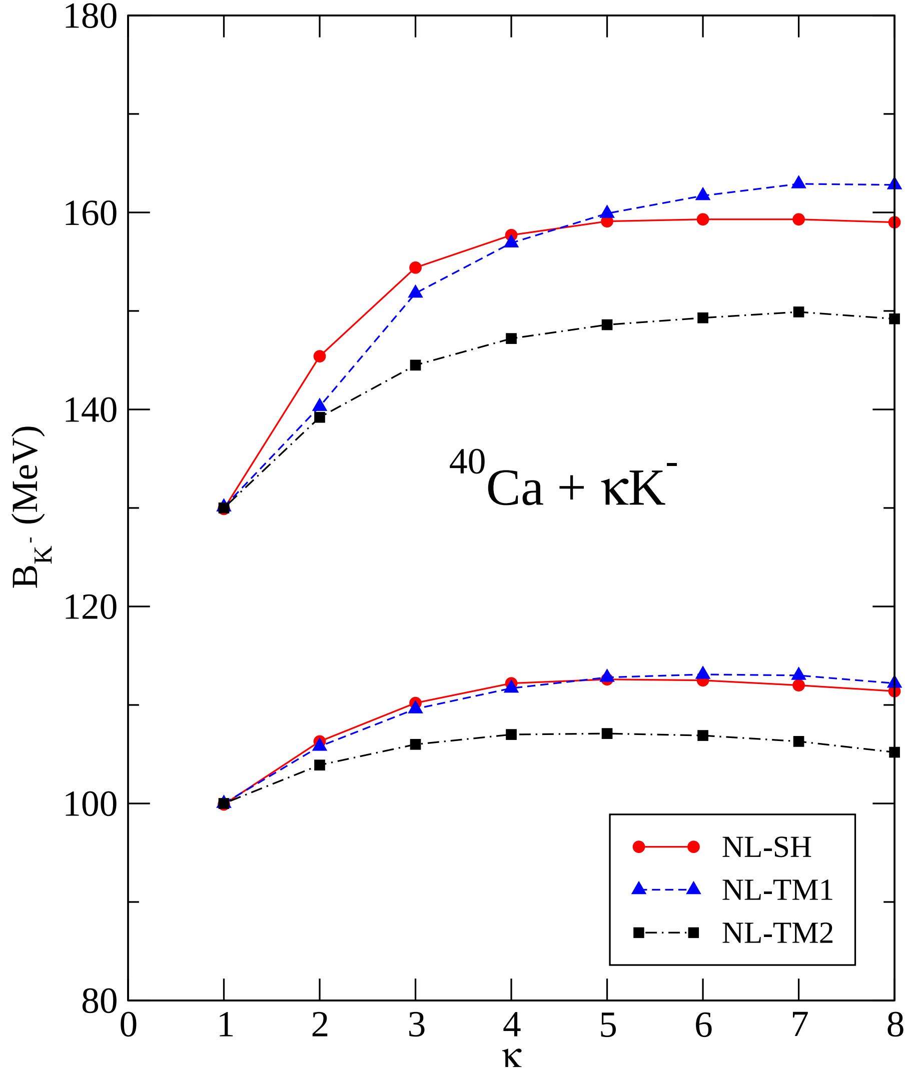


Saturation of ^{16}O nuclear density with κ, for $B_{1\bar{K}} = 100$ MeV

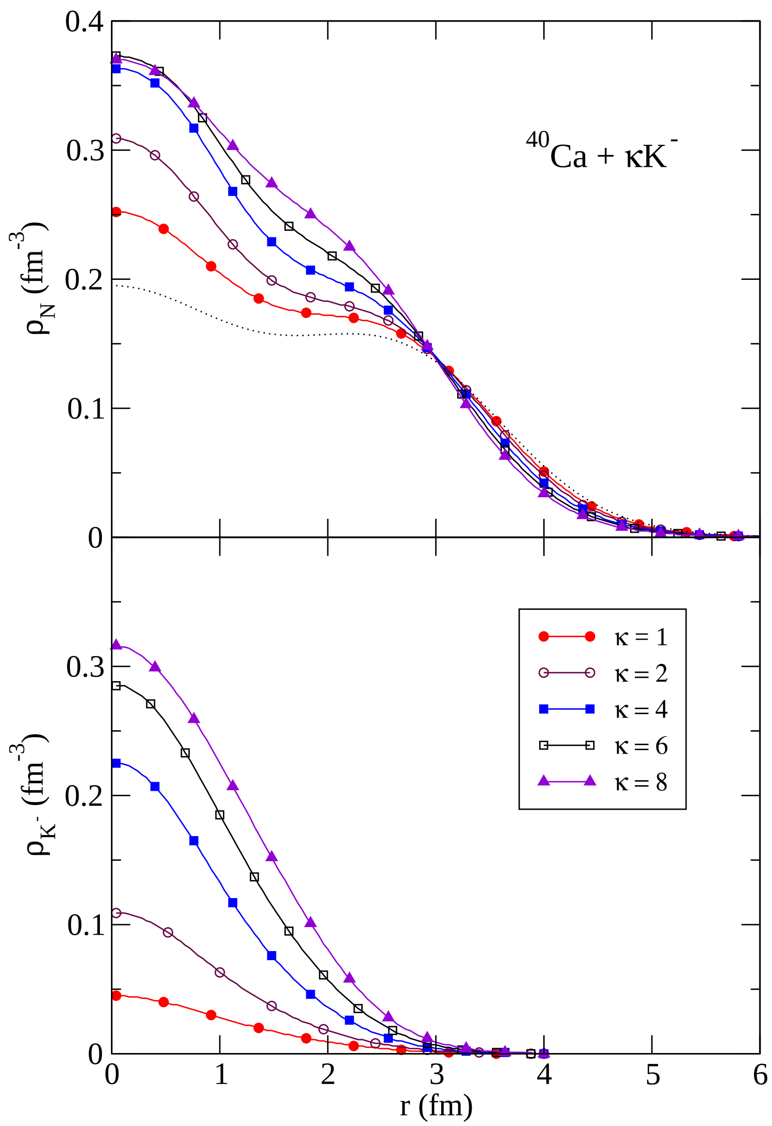


D. Gazda, E. Friedman, A. Gal, J. Mareš, arXiv:0801.3335

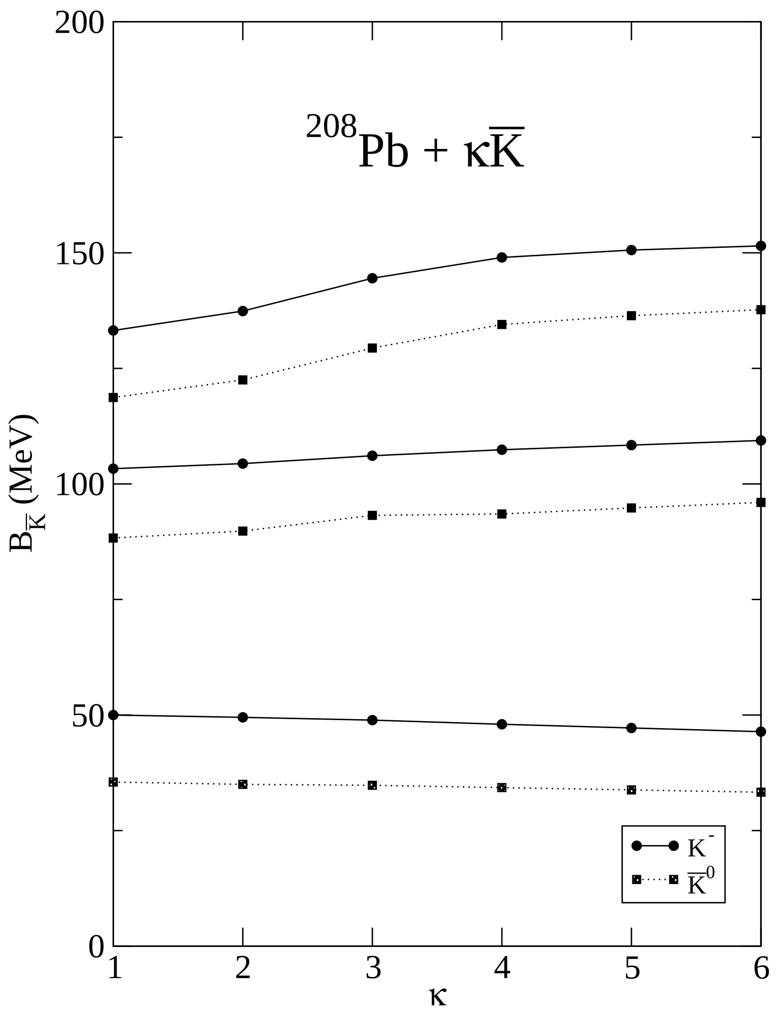
$B_{\bar{K}}$ contributions in ^{16}O: substantial ρ and ϕ repulsion for $\bar{K}\bar{K}$ pairs



Saturation of $B_{\bar{K}}$ in ^{40}Ca for various RMF nuclear models

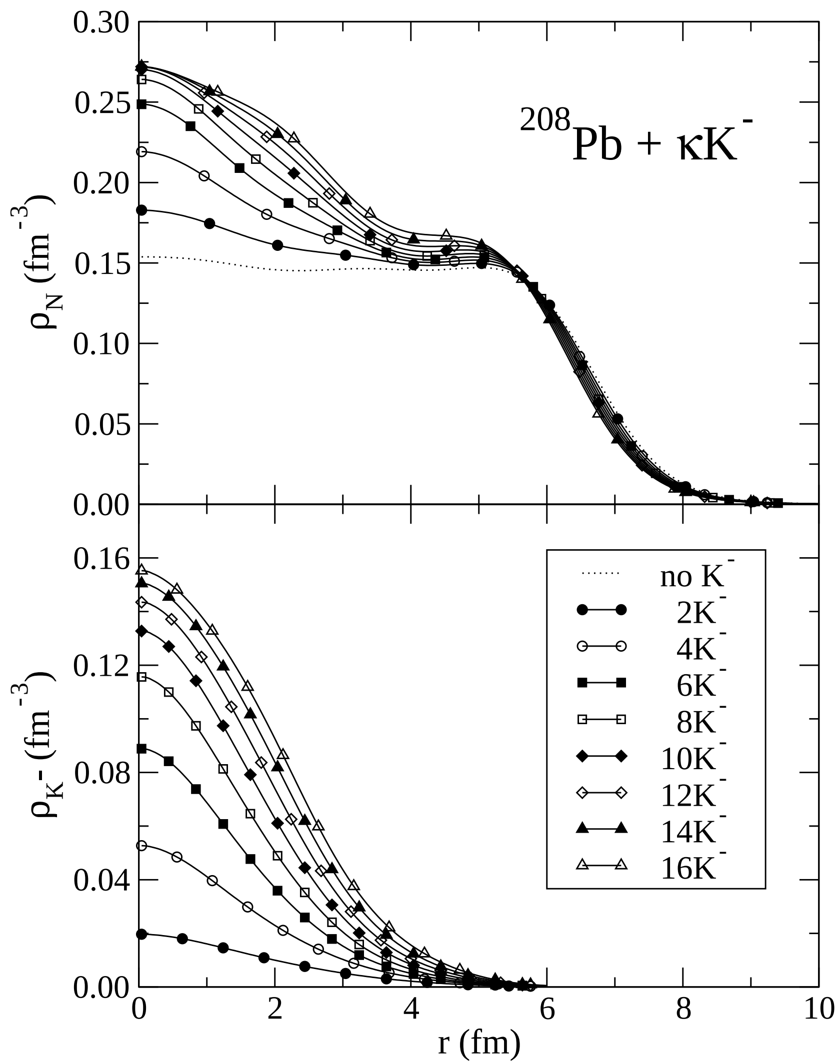


Saturation of ^{40}Ca nuclear density with κ, for $B_{1\bar{K}} = 100$ MeV

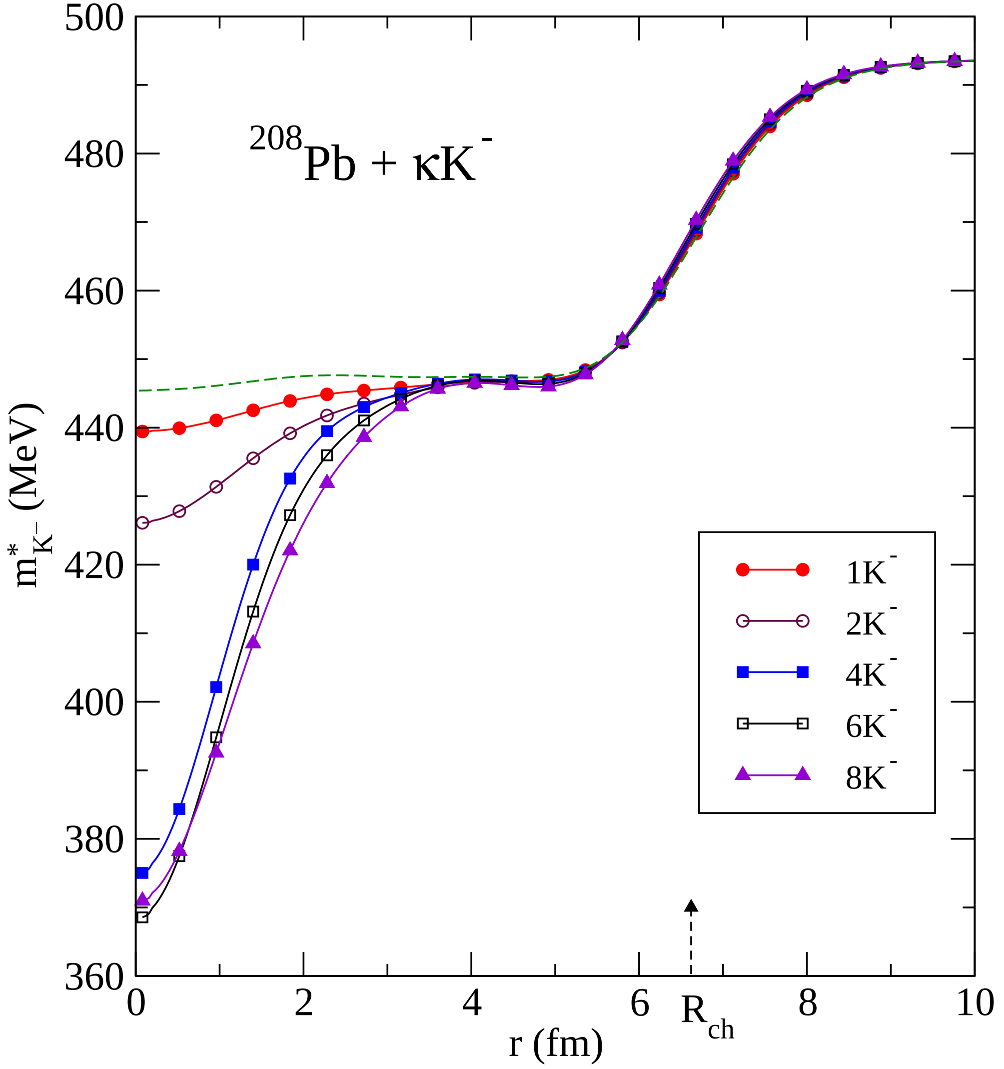


Saturation of $B_{\bar{K}}$ in ^{208}Pb with κ, far away from $\bar{K}$ condensation

$B_{\bar{K}}(\kappa \rightarrow \infty) << (m_K + M_N - M_\Lambda) \approx 320$ MeV



Saturation of ^{208}Pb nuclear density with κ, for $B_{1\bar{K}} = 100$ MeV



$1s$ K^- effective mass in $^{208}\mathrm{Pb} + \kappa K^-$, for $B_{1\bar{K}} = 100$ MeV

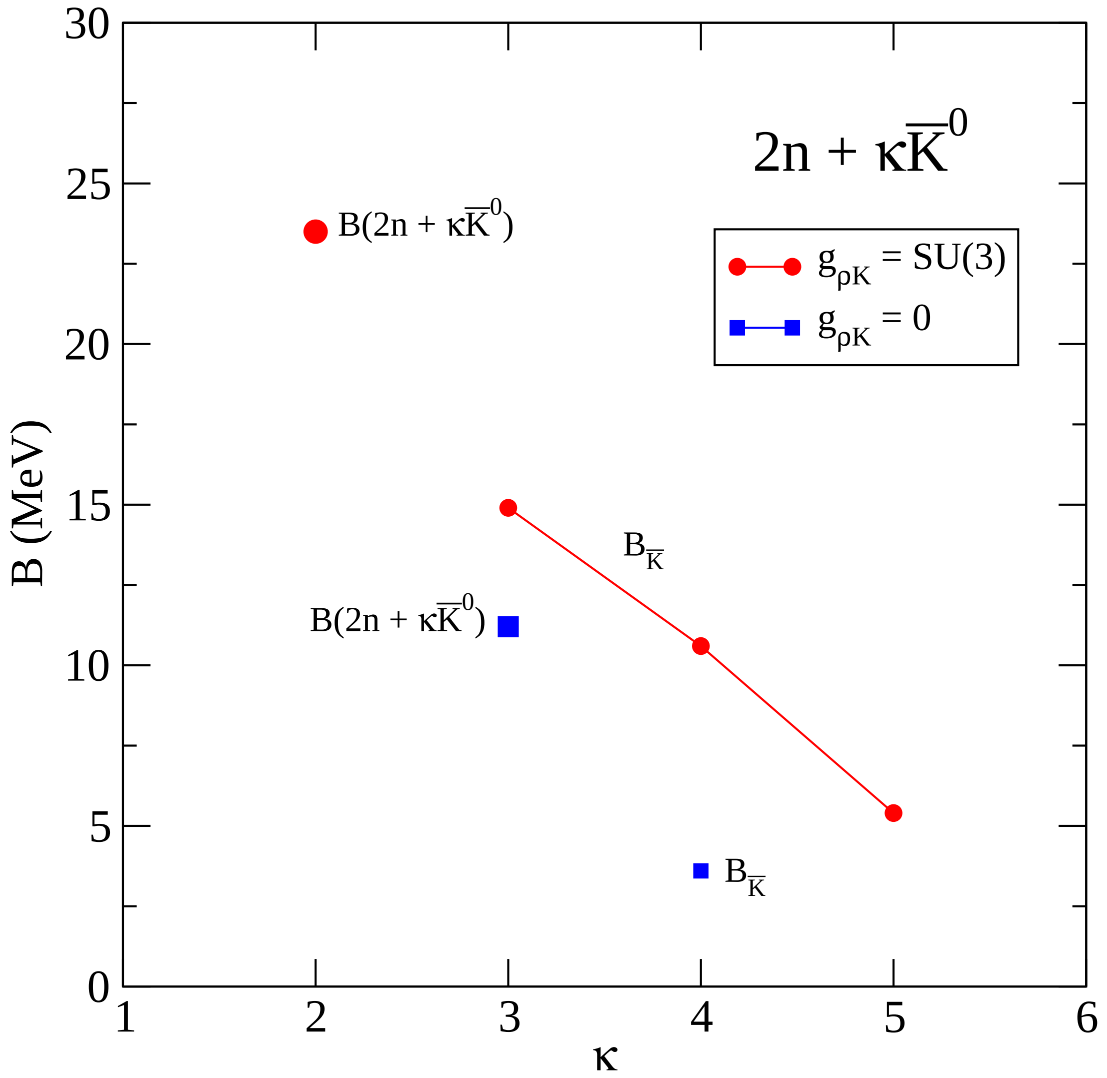
Exotic $\bar{K}$ structures, with unbound nuclear cores

onset of binding: K^-pp and $\overline{K}^0 nn$

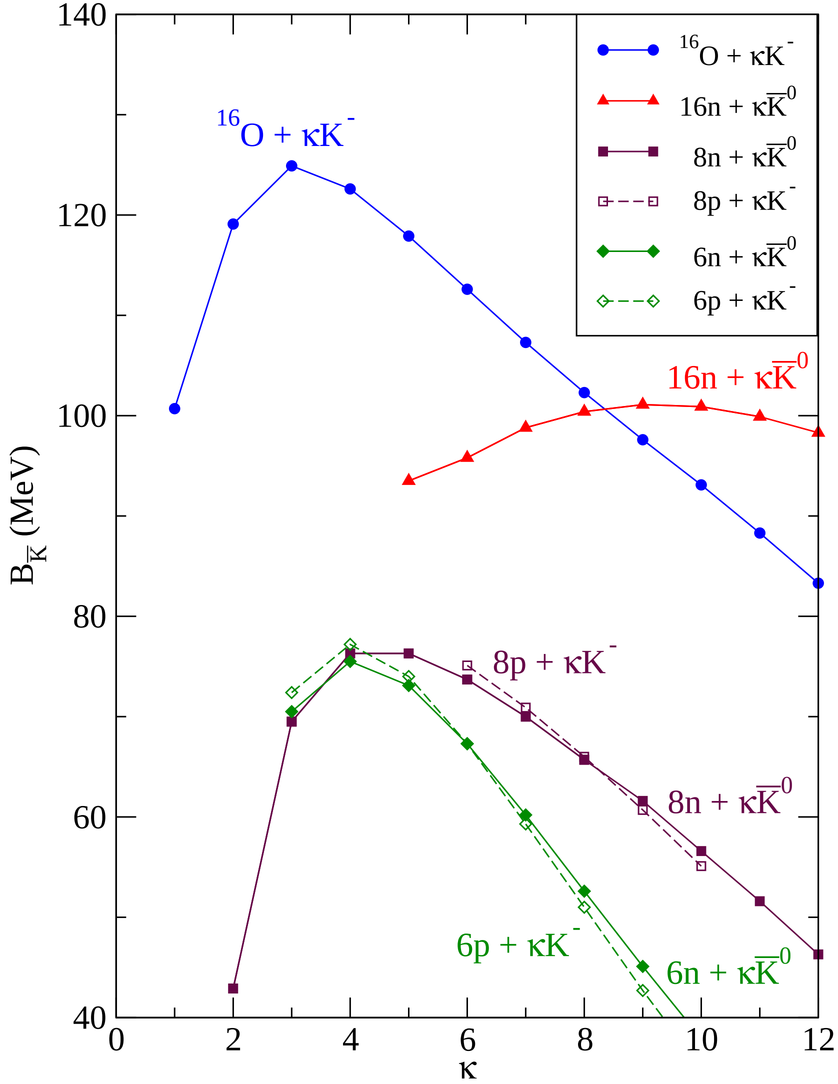
Table 1: Binding energies (B) and widths (Γ) calculated for K^-pp (in MeV) exclusive of $\bar{K}NN \to YN$ contributions

	single channel		coupled channels		experiment
	ATMS [1]	AMD [2]	Faddeev [3]	Faddeev [4]	FINUDA [5]
B	48	16–22	50–70	60–95	$115 \pm 6 \pm 4$
Γ	61	40–70	90–110	45–80	$67 \pm 14 \pm 3$

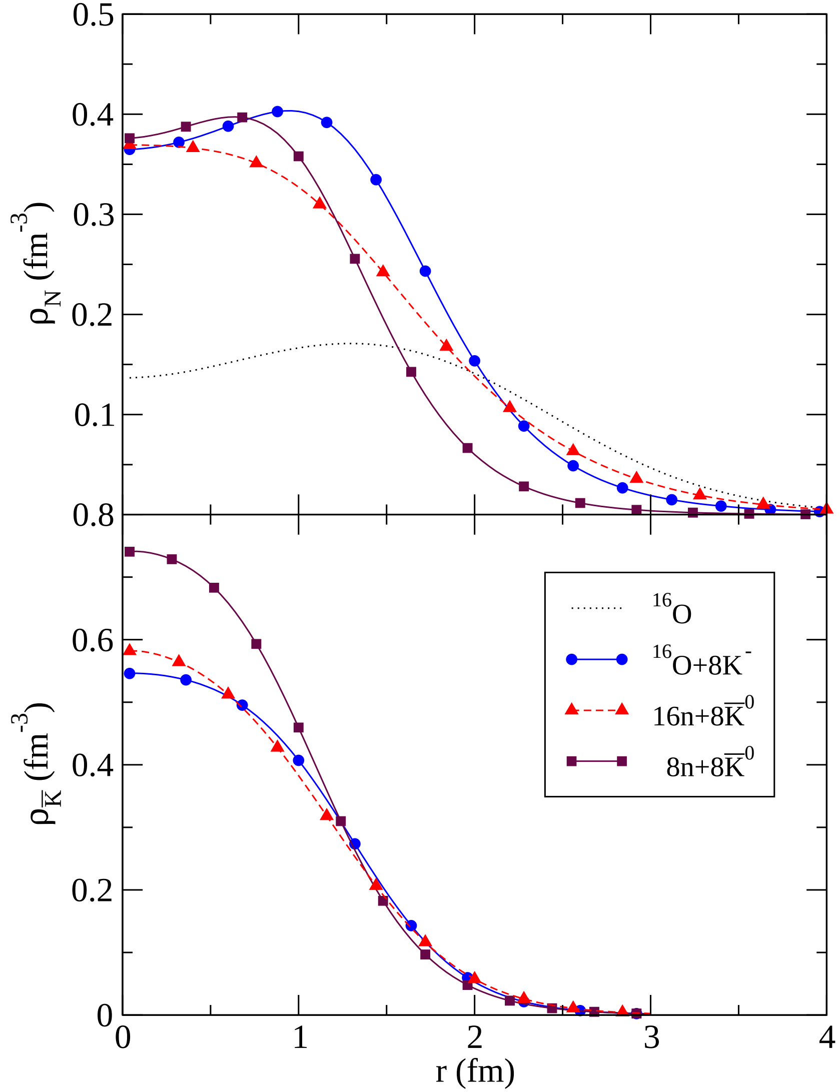
1. T. Yamazaki, Y. Akaishi, PLB **535** (2002) 70
2. A. Doté, T. Hyodo, W. Weise, NPA (in press) arXiv:0802.0238
3. N.V. Shevchenko, A. Gal, J. Mareš, PRL **98** (2007) 082301; PRC **76** (2007) 044004
4. Y. Ikeda, T. Sato, PRC **76** (2007) 035203
5. M. Agnello *et al.*, PRL **94** (2005) 212303



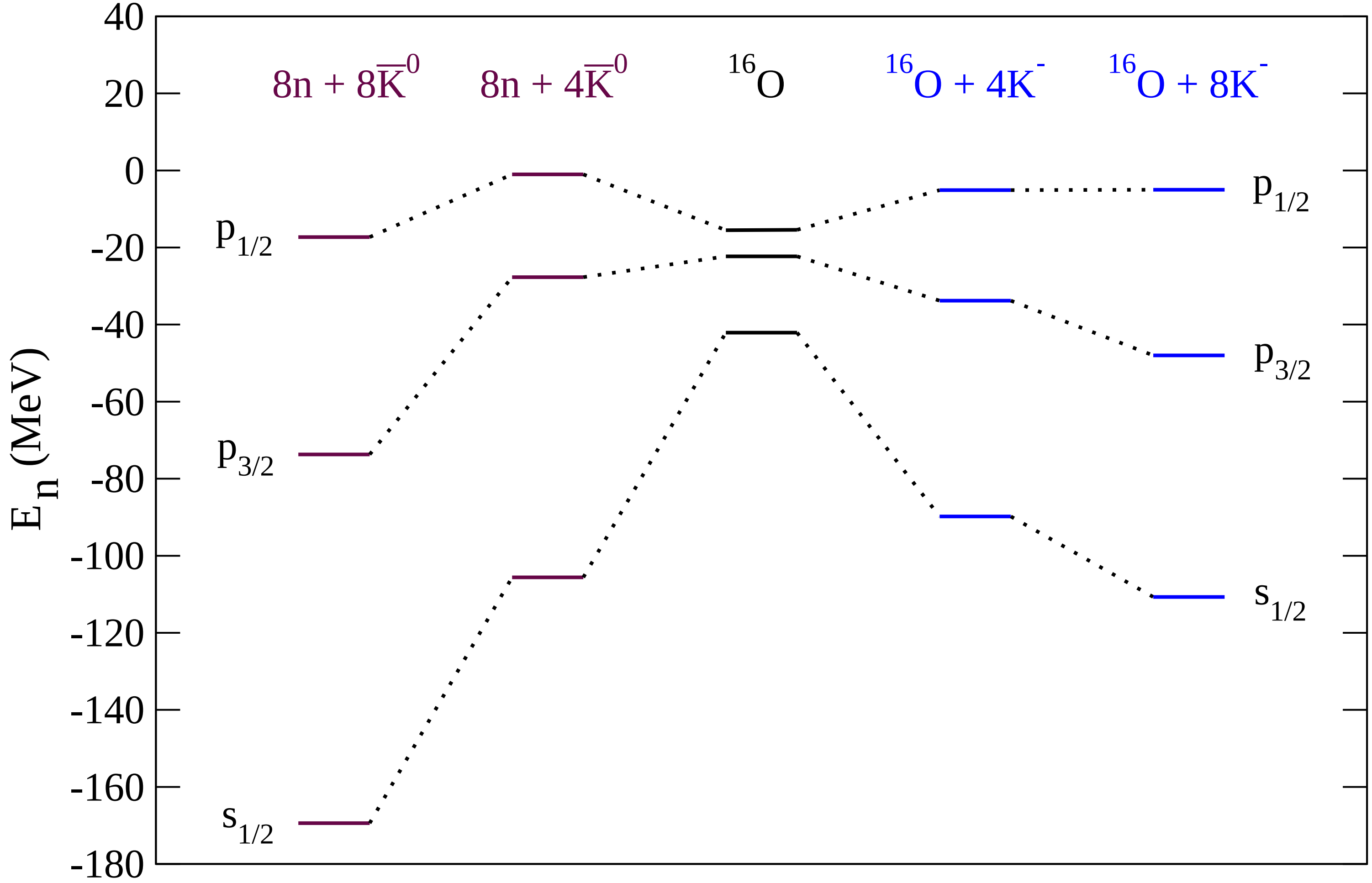
RMF extension of K^-pp calculations



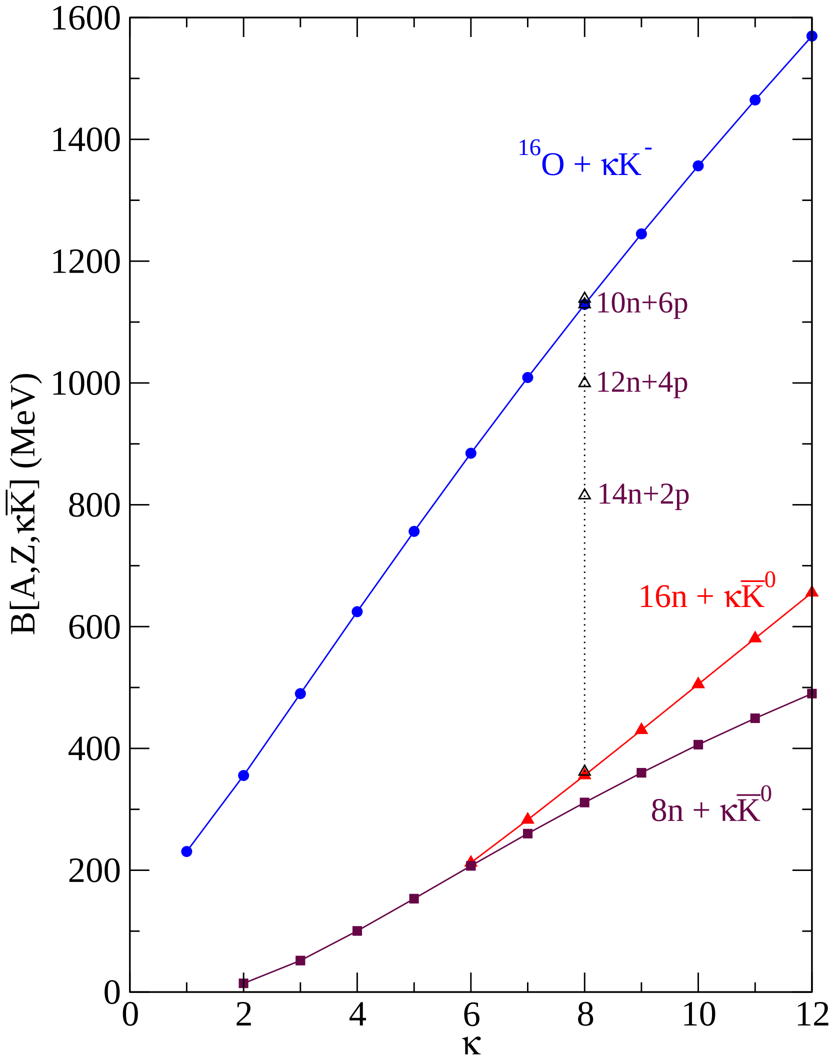
Exotic neutrons-only nuclei stabilized by $\overline{K}^0$ mesons



Saturation of nuclear density in exotic multi-$\bar{K}$ states



Polarization of nuclear cores: neutron single-particle energies



Metastability of exotic neutrons-only multi-$\overline{K}^0$ states

Summary

- Large widths, $\Gamma_{\overline{K}} > 50$ MeV, obscure search for single-$\overline{K}$ quasibound nuclear states. Focus searches in light systems

- $\overline{K}$ separation energy saturates in multi-$\overline{K}$ nuclei, and probably also in multi-$\overline{K}$ hypernuclei. $\overline{K}$ condensation unlikely in self-bound matter on Earth

- $\overline{K}$ condensation in neutron stars is uncertain