Isospin dependence of the mean field from DBHF

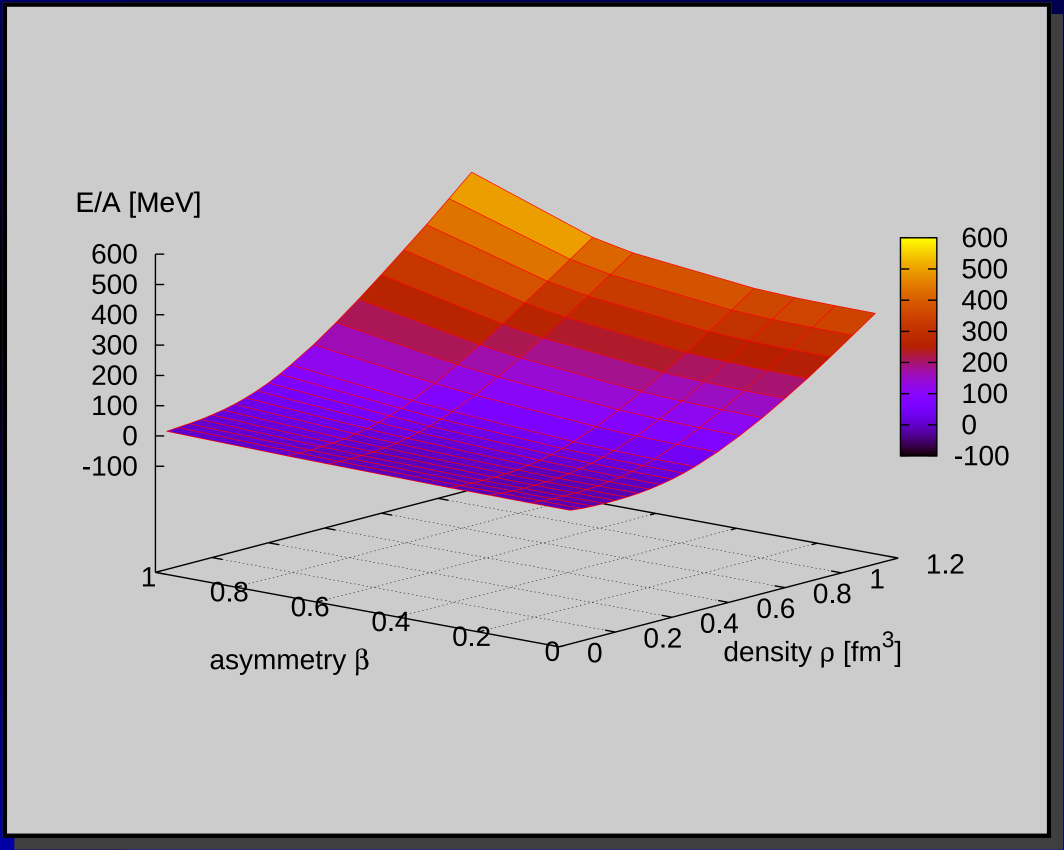
Christian Fuchs

University of Tübingen

Germany

EBERHARD KARLS UNIVERSITÄT TÜBINGEN

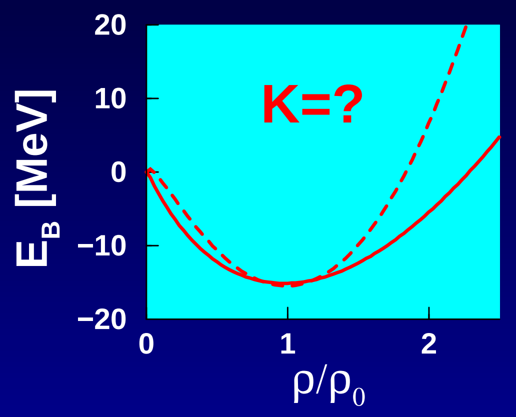
Outline

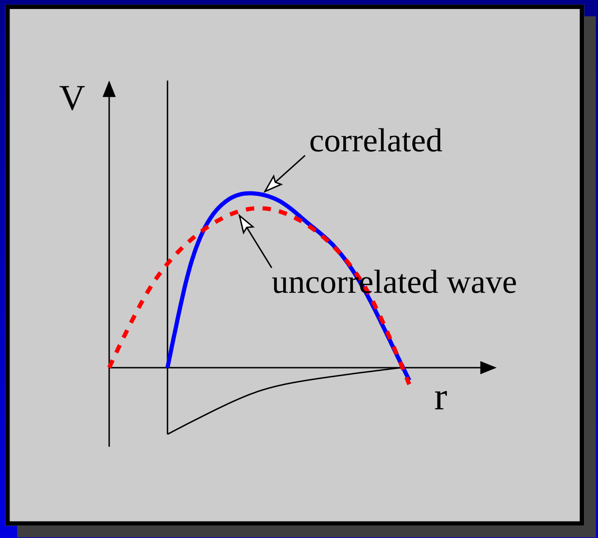


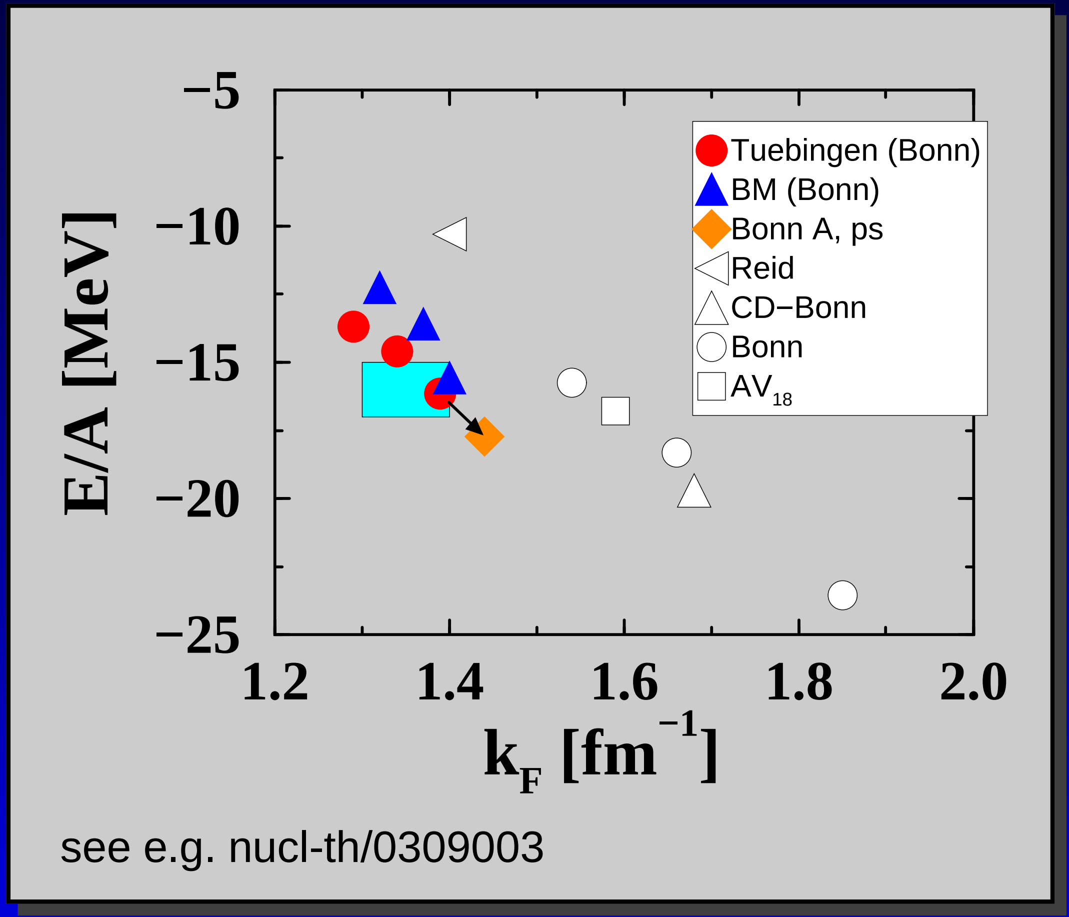
- review DBHF
- nuclear/neutron matter
- effective masses
- optical potentials

Saturation of Nuclear Matter

DBHF: realistic NN force, no parameter







Coester line $\Longrightarrow$ relativistic!

Hadronic many-body theory

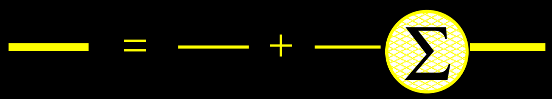
Relativistic Brueckner: N+OBEP ($V = \sigma, \omega, \pi, \rho, \eta, \delta$)

$\Longrightarrow$ 2-N correlations in hole-line expansion

$\Longrightarrow$ self-consistent sum of ladder diagrams

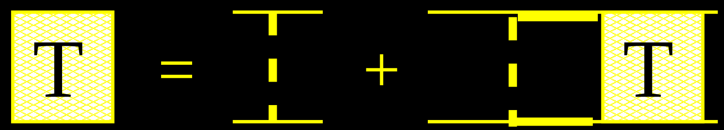
Dyson-Equation:

$$G = G_0 + G_0 \Sigma G$$



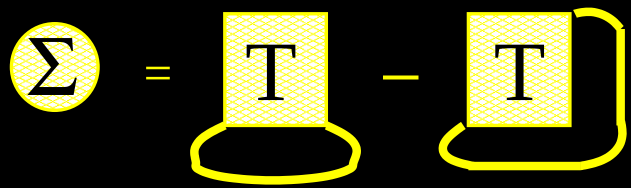
Bethe-Salpeter-Equation:

$$T = V + i \int VGGQT$$



Self Energy (Hartree-Fock):

$$\Sigma(\rho, k) = \sum_{q \epsilon F} < q | T(q,k) | q > = \Sigma_S - \gamma_0 \Sigma_0 + \vec{\gamma} \cdot \vec{k} \Sigma_V$$



Determination of Σ

- Fit to single-particle potential: $\Sigma_{S,0}(k_F)$

  Brockmann/Machleidt 90, Envik et al., Sammarunca et al.,...

$$
\begin{aligned}
U(k) &= \frac{m^*}{E^*} < k|\Sigma|k > = \frac{m^*}{E^*} \sum_{q \epsilon F} < kq|T(q,k)|kq > \\
&= \frac{m^* \Sigma_S}{\sqrt{\mathbf{k}^2 + (M + \Sigma_S)^2}} - \Sigma_0
\end{aligned}
$$

- Projection on covariant amplitudes:

  $\Sigma_{S,0,V}(k_F, k)$

  Horowitz/Serot 87, Malfliet et. al., DeJong/Lenske, T¨ubingen

- Include negative energy states

  Weigel et al., DeJong/Lenske

Isospin dependent self-energy

$$\Sigma_n = -i \int_{F_n} (Tr[G_n T_{nn}] - G_n T_{nn}) - i \int_{F_p} (Tr[G_p T_{np}] - G_p T_{np})$$

$$\Sigma_p = -i \int_{F_p} (Tr[G_p T_{pp}] - G_p T_{pp}) - i \int_{F_n} (Tr[G_n T_{np}] - G_n T_{np})$$

Isospin dependent self-energy

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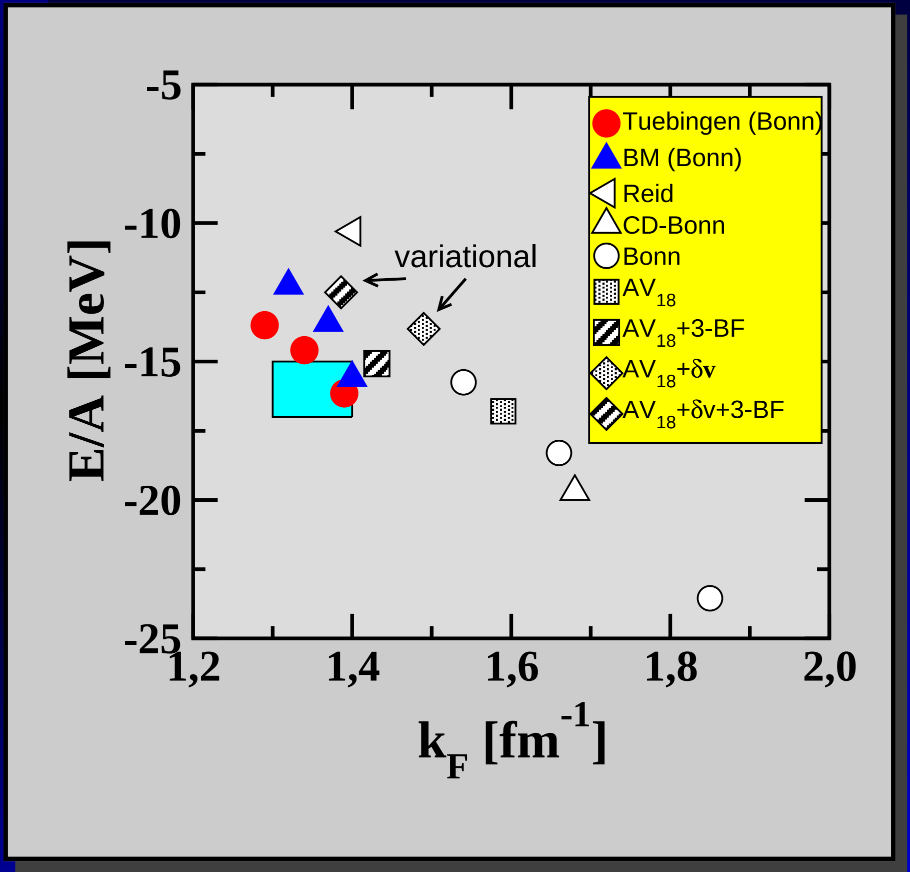
$$\Sigma_p = -i \int_{F_p} (Tr[G_p T_{pp}] - G_p T_{pp}) - i \int_{F_n} (Tr[G_n T_{np}] - G_n T_{np})$$

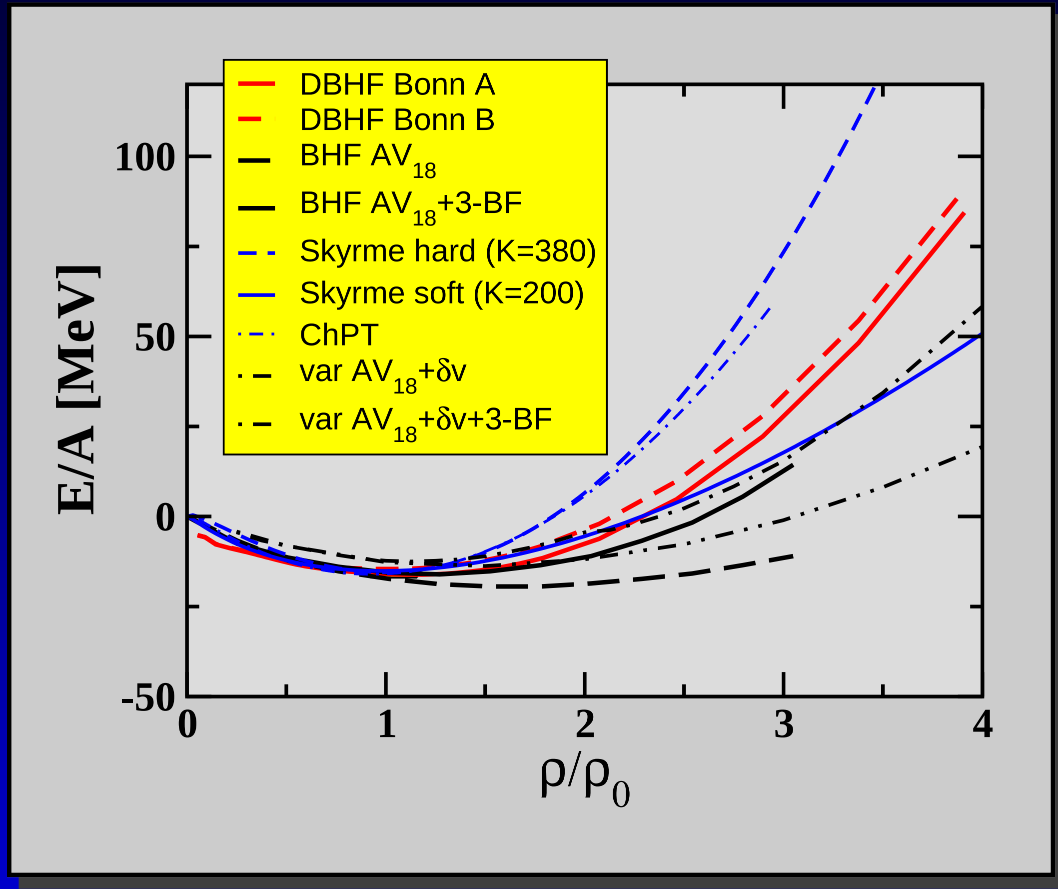
- projection method on covariant amplitudes
- averaged mass in n/p channel
- relativistic n/p Pauli operator

van Dalen, C.F., Faessler, NPA 744 (2004) 227.

BHF versus DBHF

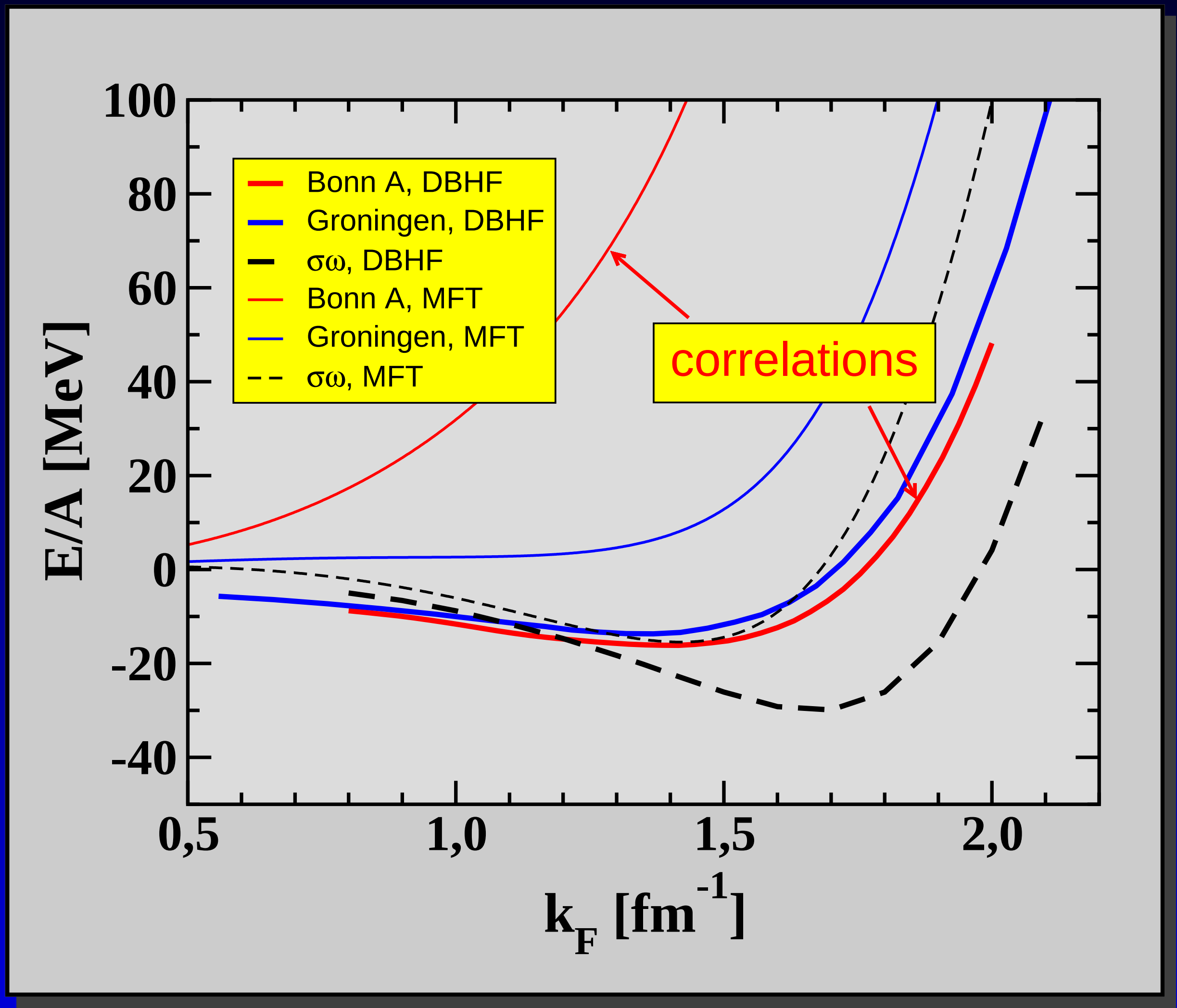
BHF: 3-body forces necessary (Zuo et al., NPA 706 (2002) 418)





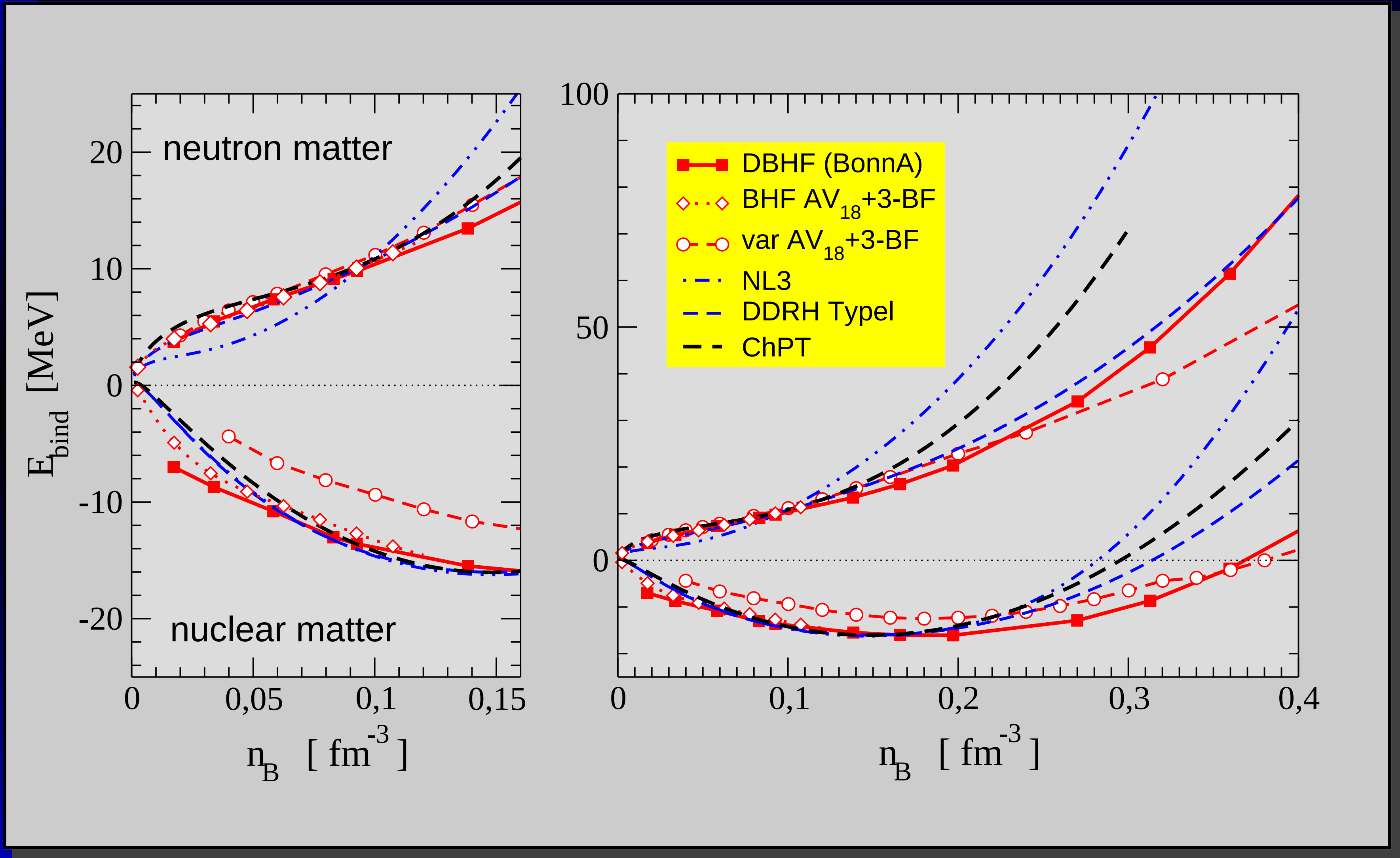
All microscopic EOS are soft !

Role of correlations



Lect. Notes Phys. 641 (2004)119 [nucl-th/0309003]

Nuclear/neutron matter EOS



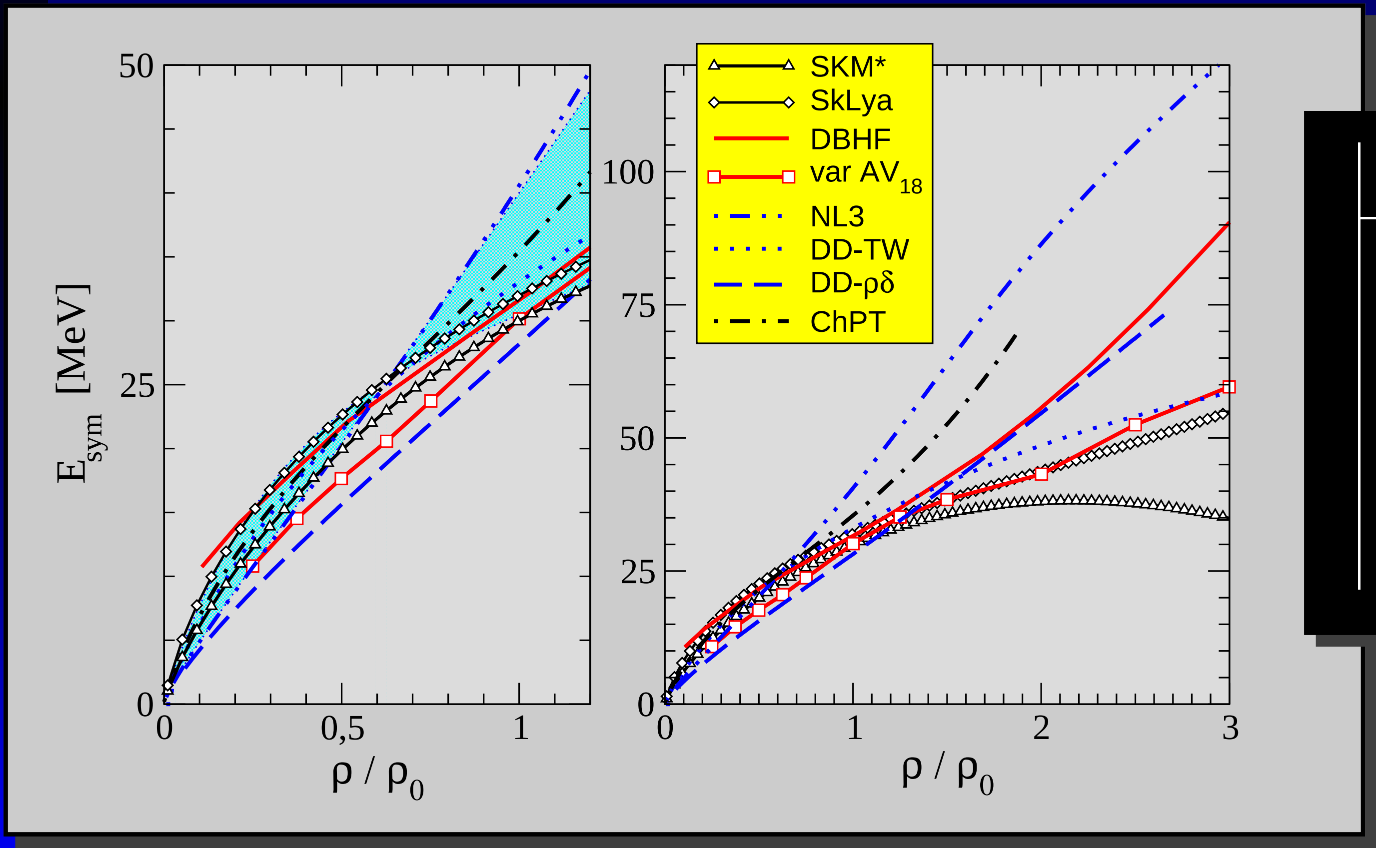
neutron matter better controlled.

Symmetry energy

$$E(\rho,\beta) = E(\rho) + E_{\rm sym}(\rho)\beta^2 + \mathcal{O}(\beta^4) + \cdots$$

$$E_{\rm sym}(\rho) = \frac{1}{2}\frac{\partial^2 E(\rho,\beta)}{\partial\beta^2}|_{\beta=0} = a_4 + \frac{p_0}{\rho_0^2}(\rho-\rho_0) + \cdots$$

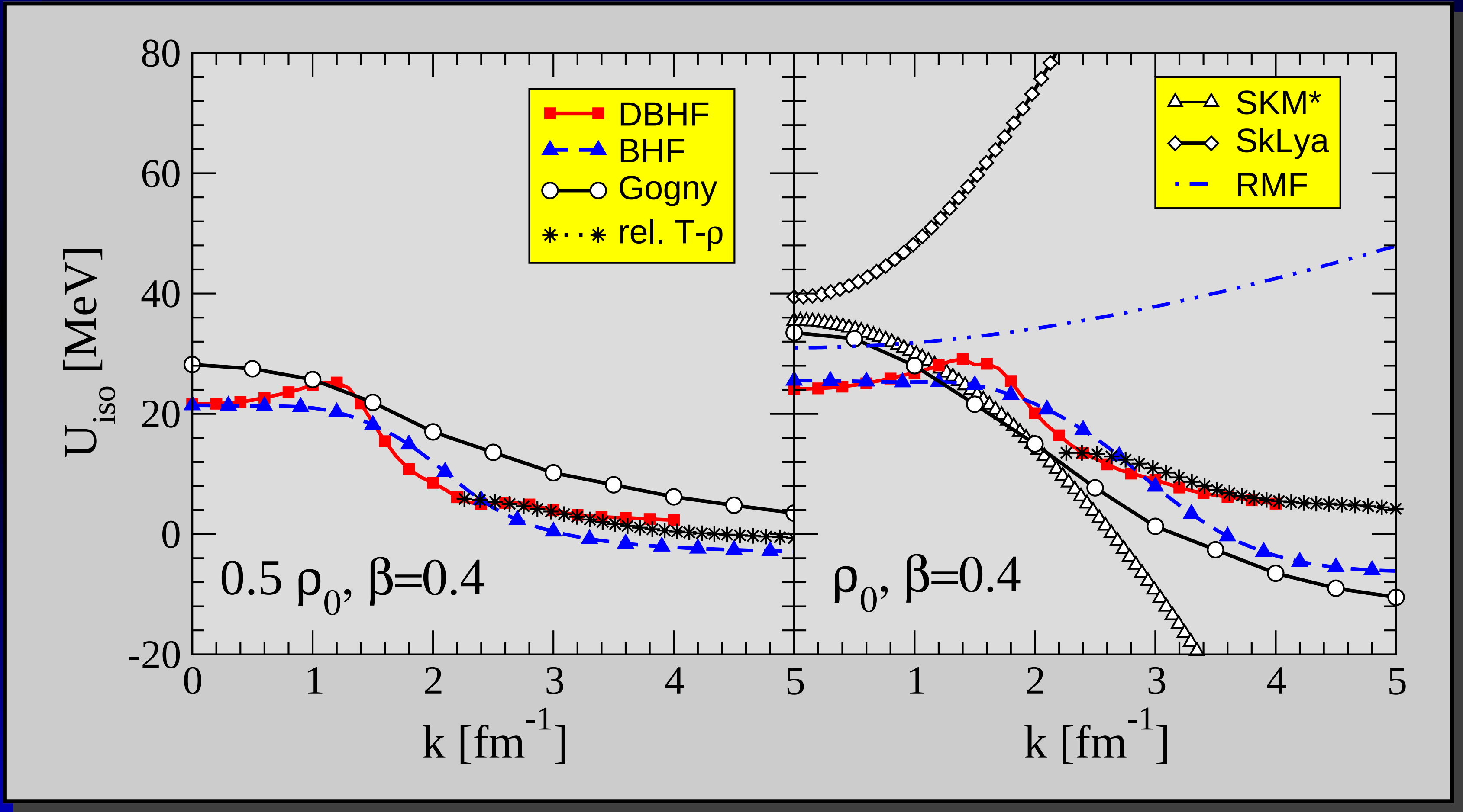
asymmetry parameter : $\beta = Y_n - Y_p$



model	a_4 [MeV]
Skyrme	<30
SkLy	32
RMF	32-36
DBHF	34.4
ChPT	34

Isovector potential

$$U_{\text{iso}}(n_B, \mathbf{k}) = (U_n - U_p)/2\beta$$



BHF: Zuo et al. PRC 72 (2005) 014005

RIA: Chen, Ko, Li, nucl-th/0509009, amplitudes from: McNeil, Shepard, Wallace.

Effective nucleon mass

Comparison of different approaches $\Longrightarrow$ careful !
Many different defnitions of effective masses are used!

Non-relativistic mass:

$$m^*_{NR} = \left[M + \frac{1}{k}\frac{d}{dk}U_{s.p.}\right]^{-1}$$
$$= |\mathbf{k}|[dE/d|\mathbf{k}|]^{-1}$$

Dirac mass:

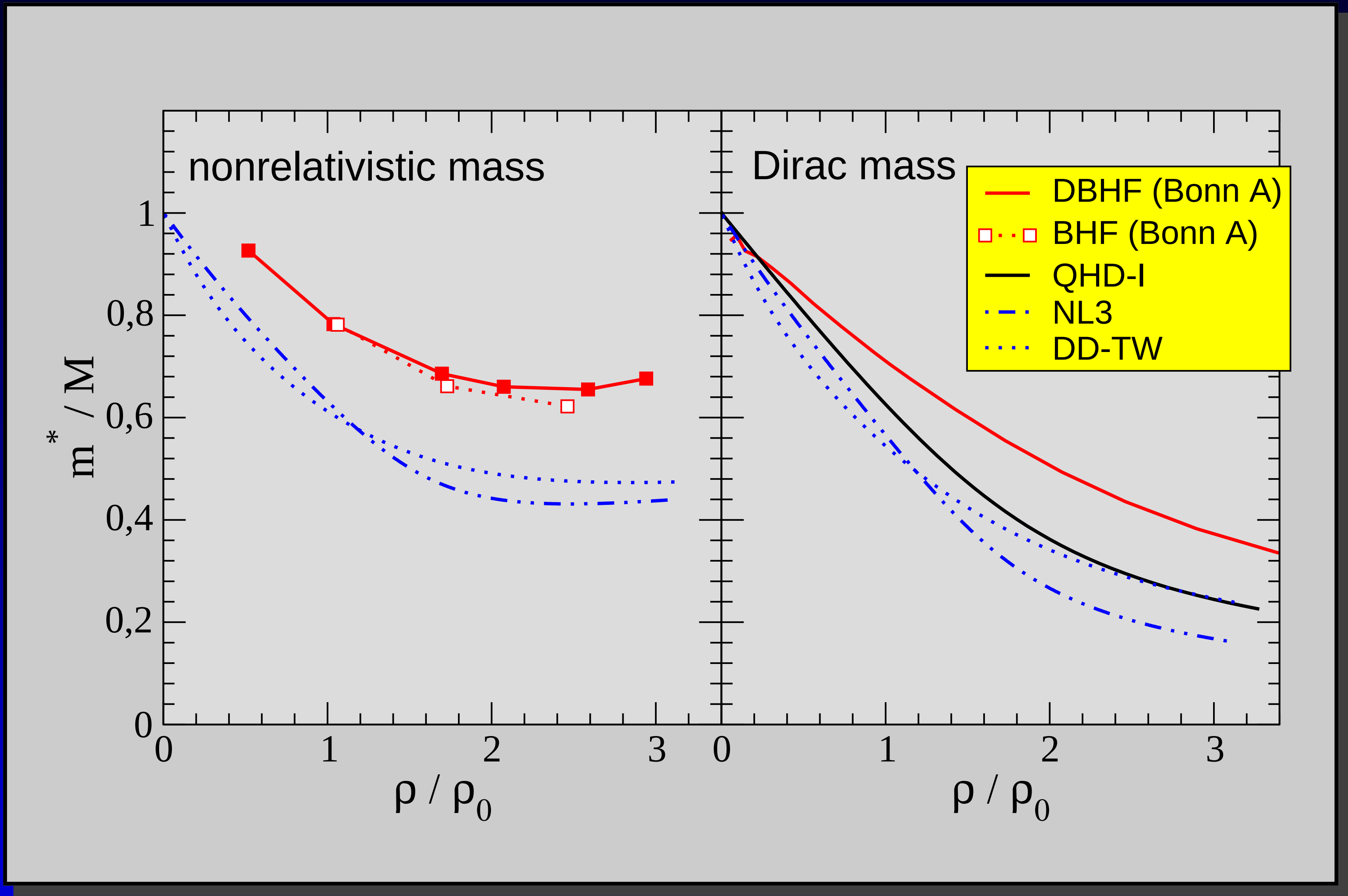
$$m^*_D = M + \Sigma_S$$

Relativistic:
$U_{s.p.} \simeq \frac{m^*_D}{E^*}\Sigma_S + \Sigma_0$

parameterizes non-locality in space (k-mass) and time (e-mass)

Mahaux et al., Müther, Frick,..

Symmetric nuclear matter



DBHF/BHF: larger $m^*_{NR} \Longrightarrow$ less repulsive

Neutron-proton mass splitting

- BHF: $m^*_{NR,n} > m^*_{NR,p}$
- RMF: $m^*_{D,n} < m^*_{D,p}$; $m^*_{NR,n} < m^*_{NR,p}$ $(\rho + \delta)$

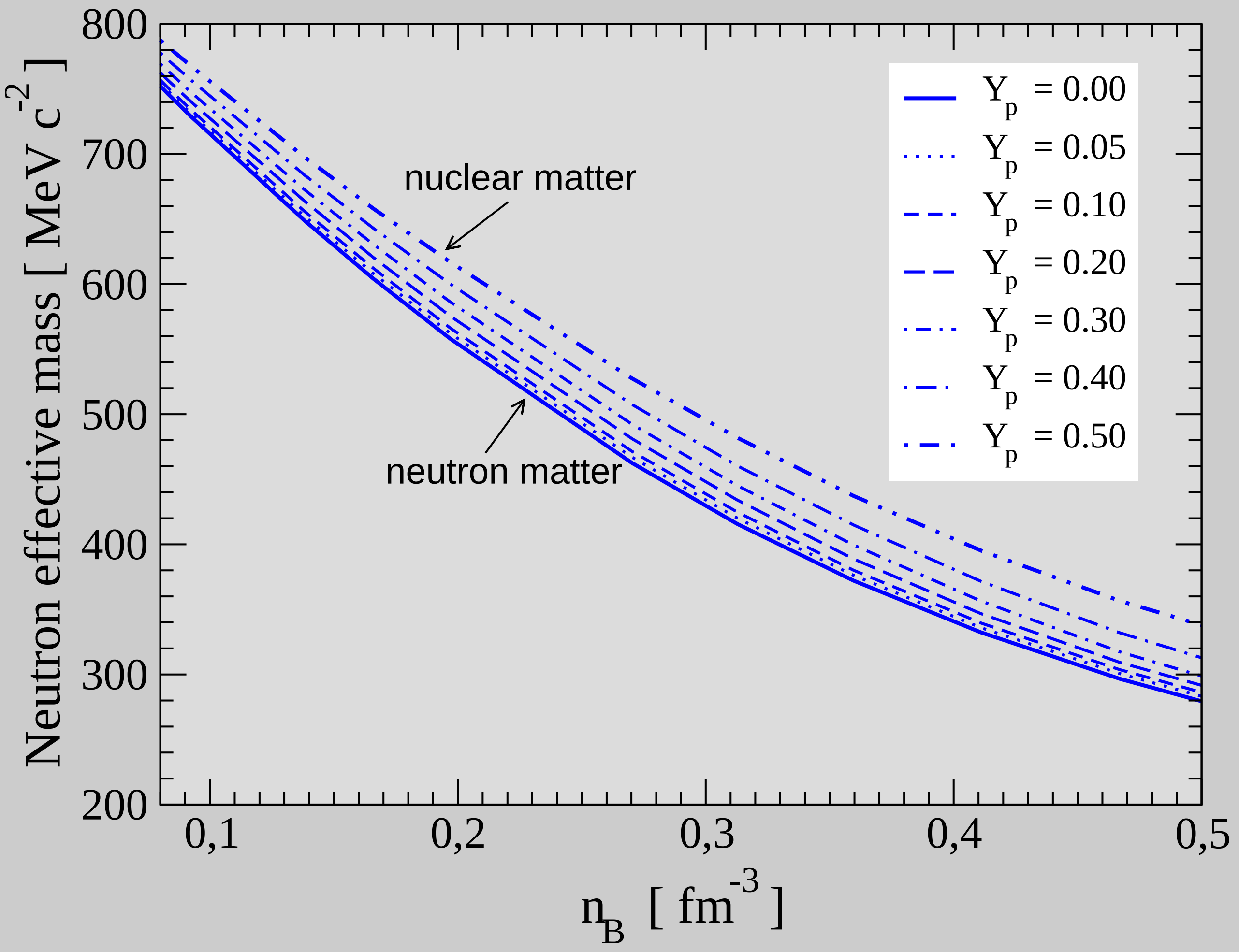
  Baran, Di Toro et al., Phys. Rep. 410 ('05) 335
- DBHF with Σ extracted by fit method: $m^*_{D,n} > m^*_{D,p}$

  Alonso & Sammarunca, PRC 67 ('03) 054301
- DBHF with projection method: $m^*_{D,n} < m^*_{D,p}$

  de Jong & Lenske, PRC 58 ('98) 890, van Dalen, C.F., Faessler, NPA 744 ('04) 227
- non-rel. mass in DBHF: $m^*_{NR,n} > m^*_{NR,p}$

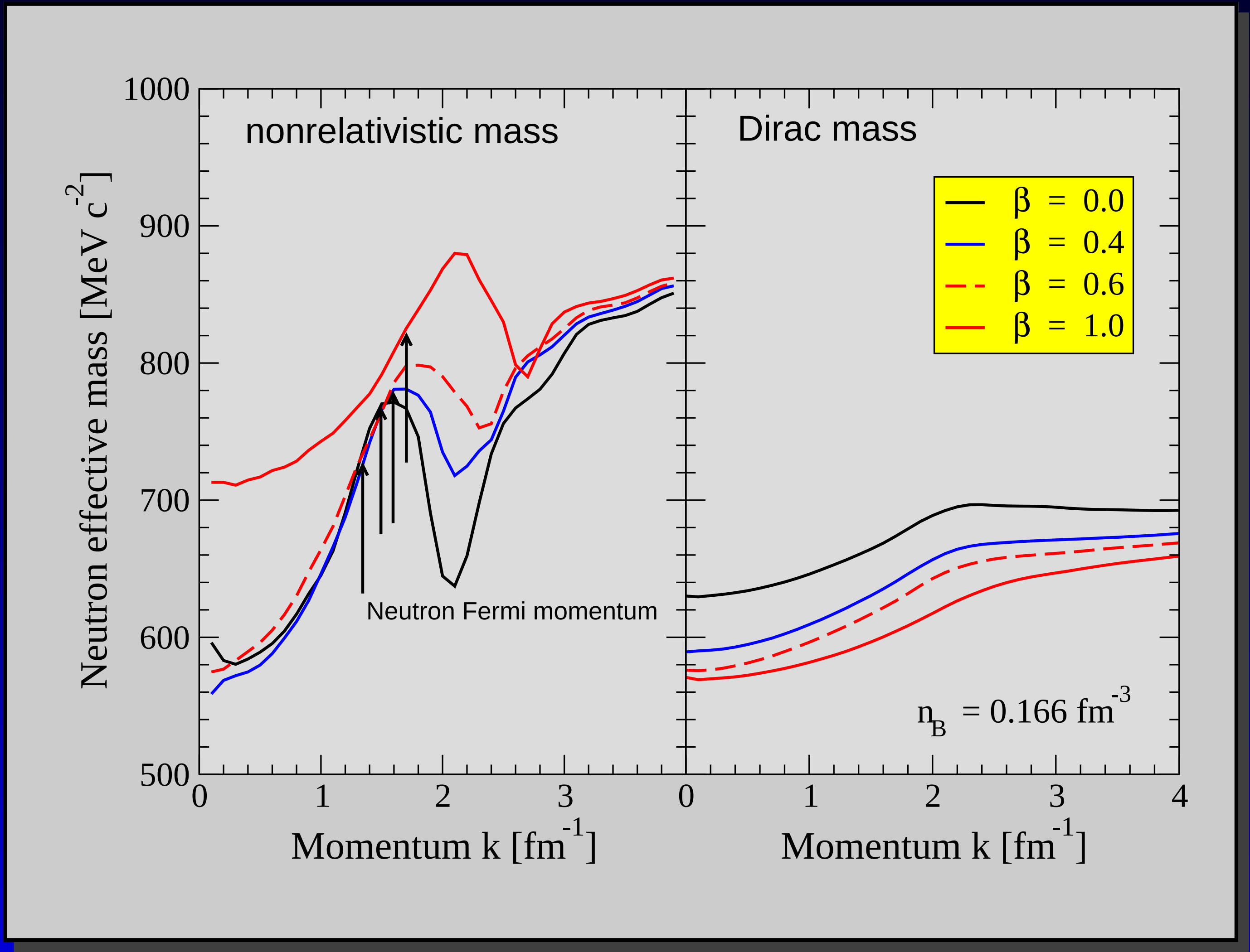
  van Dalen, C.F, Faessler, PRL 95 (2005) 022302

Dirac mass in asym. matter



np-mass splitting: $m^*_{D,n} < m^*_{D,p}$

Neutron-proton mass splitting



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Summary

- Ab initio calculations $\Longrightarrow$ guidance for high density / extreme isospin regime
- Predictions: symmetry energy, n/p mass splitting, optical potentials, ...
- DBHF: consistent with sum rules, $T\rho$ for $U_{\rm iso}$, heavy ion reactions
- Outlook: large scalar/vector fields already generated at tree level $\Longrightarrow$ nucl-th/0509049