Toward a new parameterization of the Gogny force

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I)

From D1S to D1N:
the fit of Neutron Matter Equation Of State (EOS)

The Gogny force

Analytical form:

$$V(|\vec{r}_1 - \vec{r}_2|) =$$

central term

$$\sum_{j=1,2} \exp^{\left\{-\frac{(\vec{r}_1-\vec{r}_2)^2}{\mu_j^2}\right\}} .(W_j + B_j P_\sigma - H_j P_\tau - M_j P_\sigma P_\tau)$$

$$+ t_0 (1 + x_0 P_\sigma) \delta(\vec{r}_1 - \vec{r}_2) \left[\rho\left(\frac{\vec{r}_1 + \vec{r}_2}{2}\right)\right]^\alpha$$

density dependence

$$+ i.W_{ls} \overleftarrow{\nabla}_{12} . \delta(\vec{r}_1 - \vec{r}_2) \times \vec{\nabla}_{12} . (\vec{\sigma}_1 + \vec{\sigma}_2)$$

spin-orbit

$$+ \text{Coulomb}$$

14 parameters

(W_i, B_i, H_i, M_i, μ_i) for i=1,2; t_0, x_0, α, W_{ls}

Present set of parameters: D1S

- Nuclear matter properties:

  ρ_0 , E_0/A, K, E_{surf}, m_{eff}, E_{sym}….

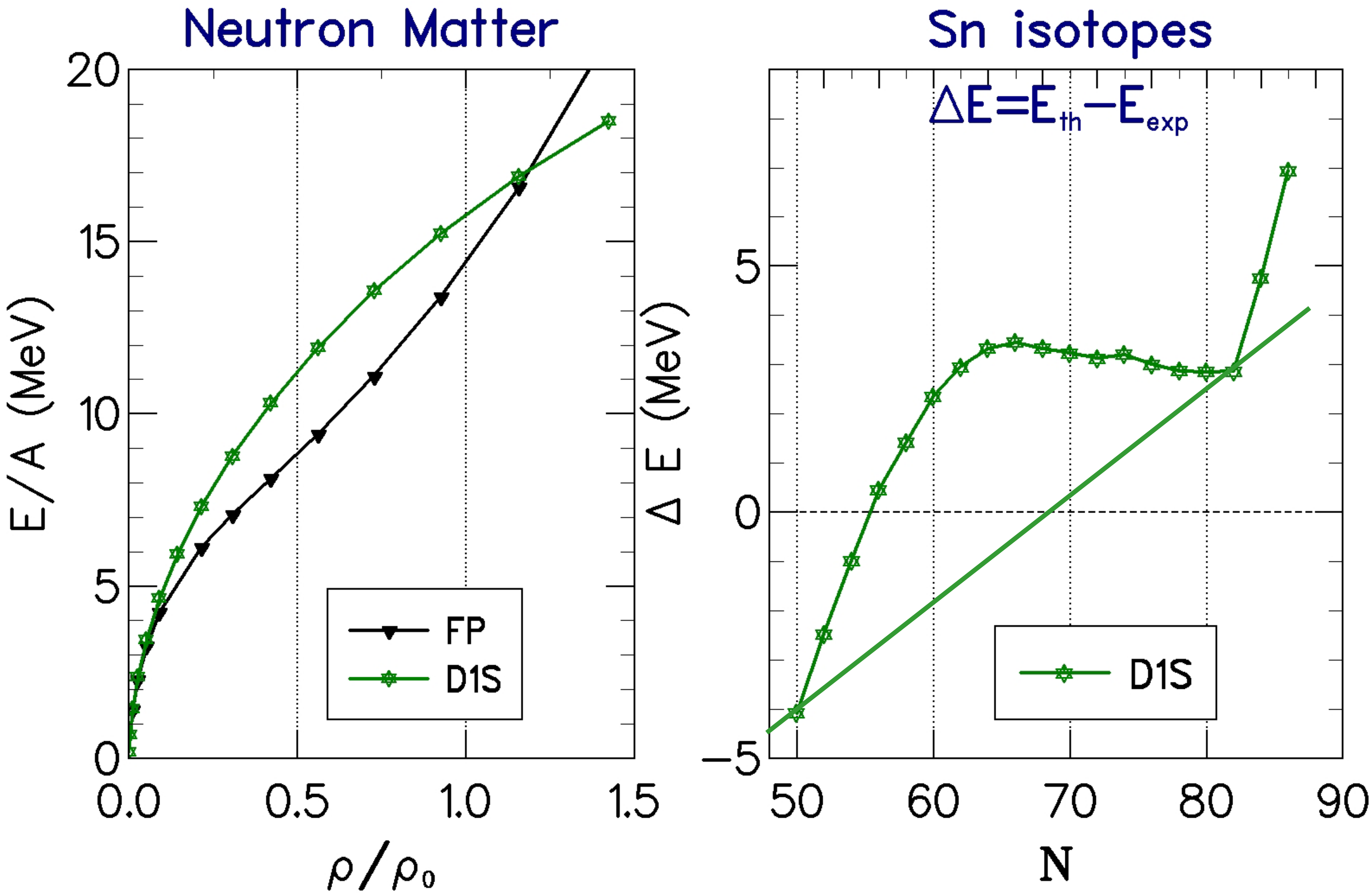
- Pairing properties:

Odd-Even mass differences, Moments of Inertia

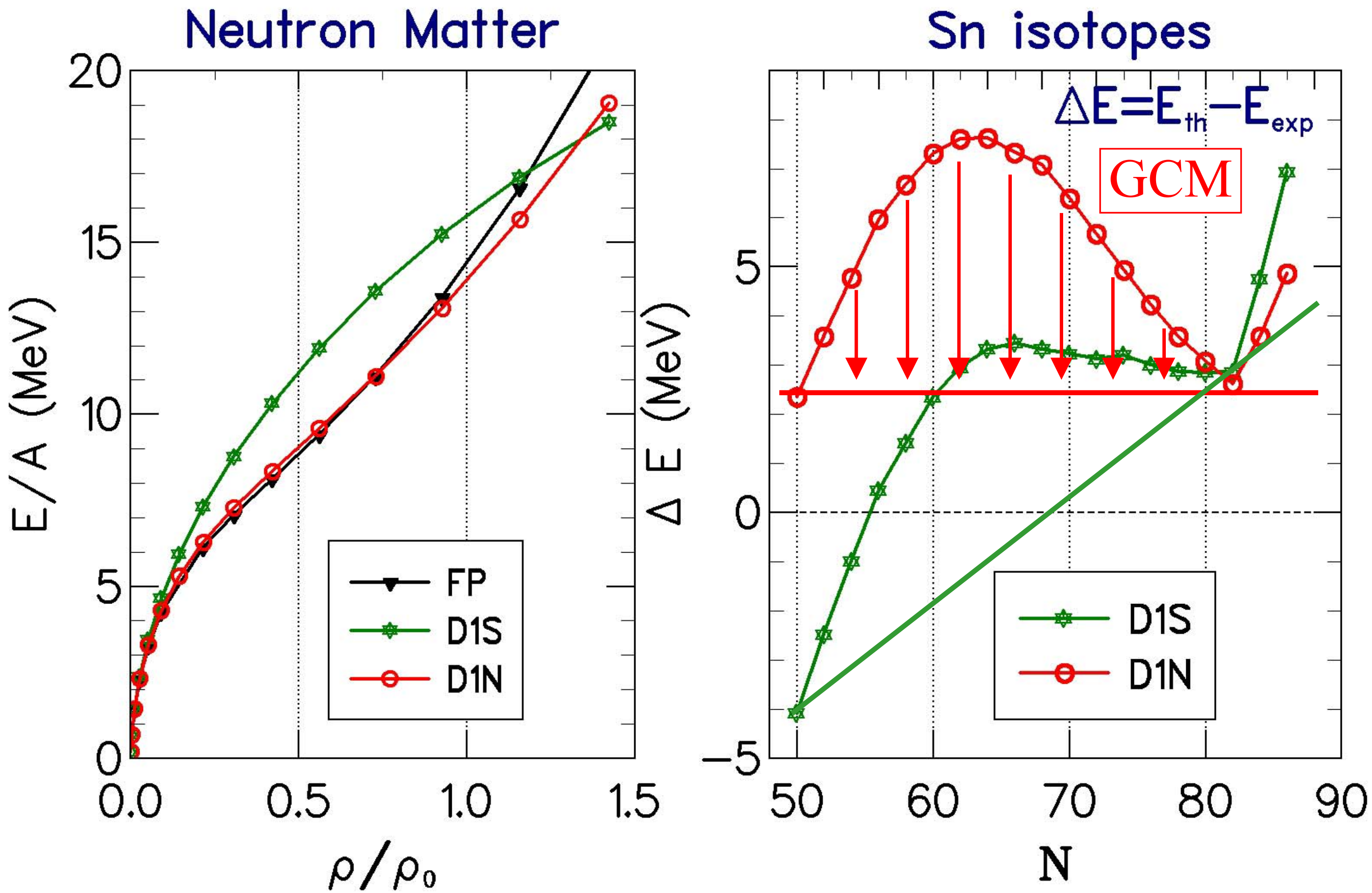
BUT still some deficiencies:

- Neutron Matter Equation Of State
- Drift of Binding Energies along isotopic chains

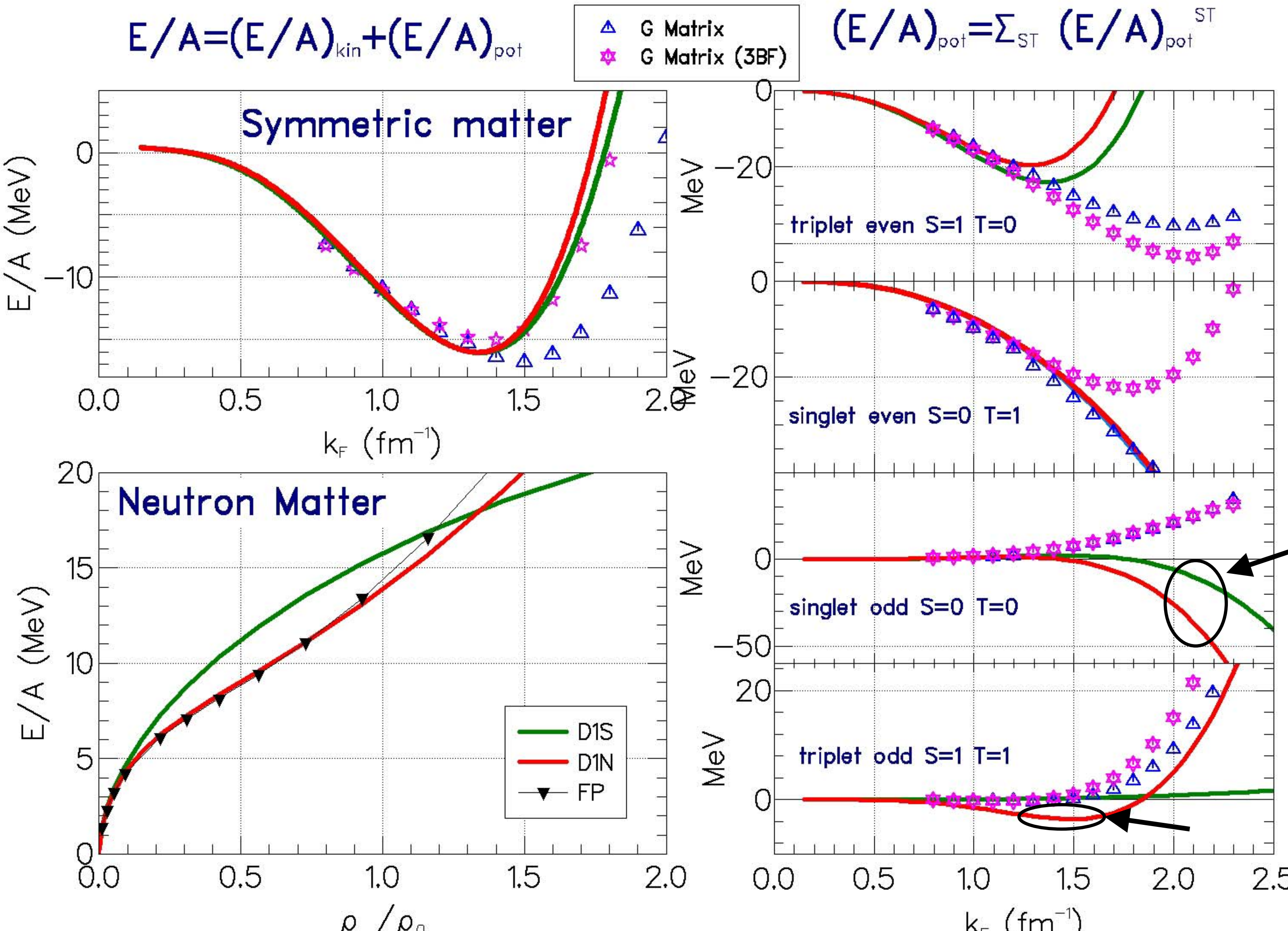
D1S: What can be improved?



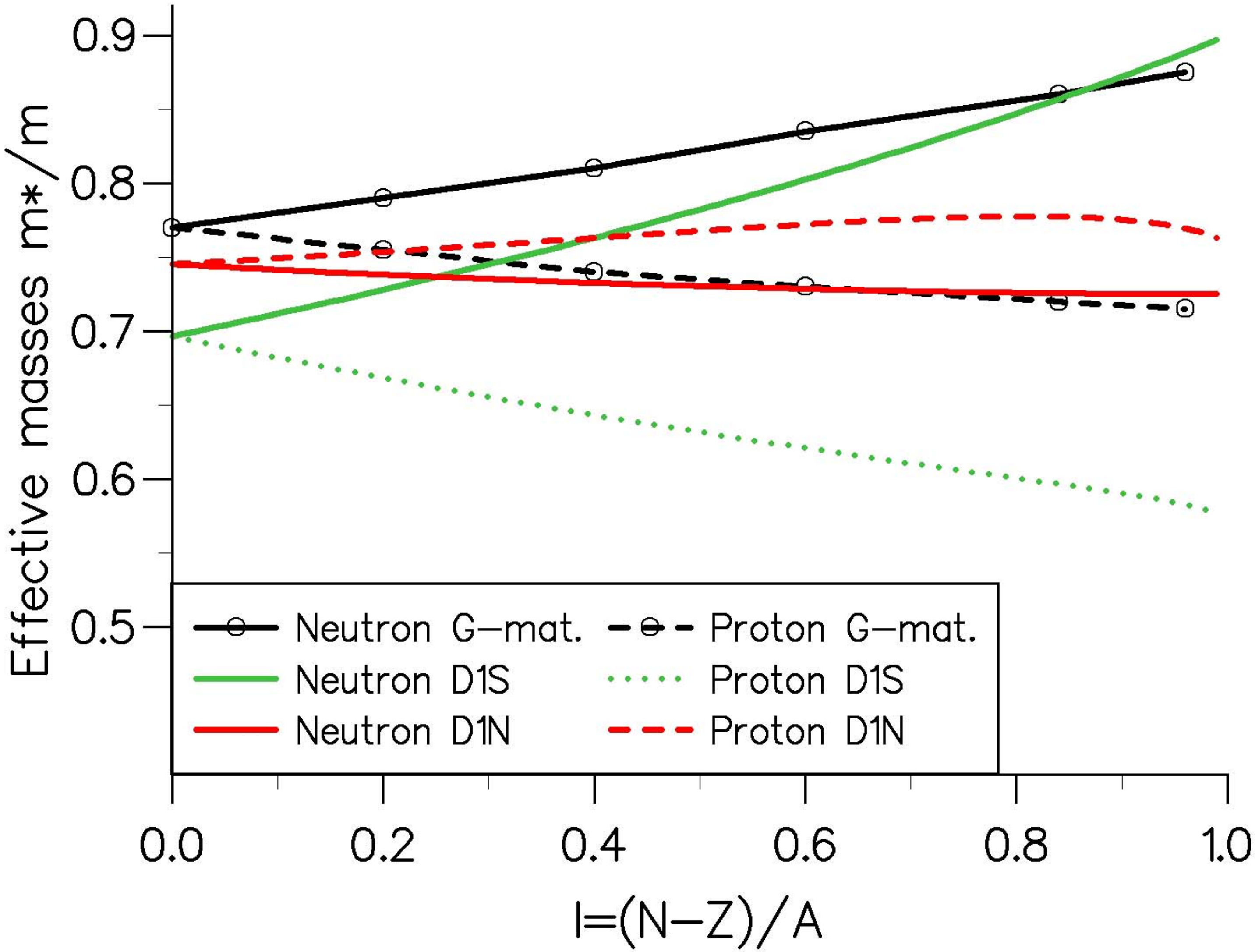
From D1S to D1N: the fit of Neutron Matter EOS



Potential Energies in ST-channels



Splitting of Effective Masses in asymmetric matter



Conclusion 1

Fit of the Neutron Matter EOS: D1S → D1N

→ drift of Binding Energies along isotopic chains has disappeared

BUT:

Potential Energies in odd ST channels (ST=00,11)

→ disagree with microscopic predictions (G-matrix)

Splitting of Neutron and Proton effective masses

→

Zero range terms: $\delta(\mathbf{r}_1 - \mathbf{r}_2)$

→
- density dependence
- spin-orbit

II) Extension of the Gogny force: finite range density dependence

II.1) Improvements over D1N

II.2) Pairing properties

II) Extension of the Gogny force

II.1) Present analytical form: D1, D1S, D1N

$$V\left(\left|\vec{r}_1 - \vec{r}_2\right|\right) =$$

$$\sum_{j=1,2} \exp^{\left\{-\frac{(\vec{r}_1-\vec{r}_2)^2}{\mu_j^{\,2}}\right\}} .\left(W_j + B_j P_\sigma - H_j P_\tau - M_j P_\sigma P_\tau\right)$$

$$+ t_0\left(1 + x_0 P_\sigma\right)\delta\left(\vec{r}_1 - \vec{r}_2\right)\left[\rho\left(\frac{\vec{r}_1 + \vec{r}_2}{2}\right)\right]^\alpha$$

density dependence

$$+ i.W_{ls}\overleftarrow{\nabla}_{12}.\delta\left(\vec{r}_1 - \vec{r}_2\right)\times\overrightarrow{\nabla}_{12}.\left(\vec{\sigma}_1 + \vec{\sigma}_2\right)$$

$$+ \text{Coulomb}$$

II) Extension of the Gogny force

II.2) Finite range density dependent term

D1_ :

$$t_0\left(1+x_0P_\sigma\right)\delta\left(\vec{r}_1-\vec{r}_2\right)\left[\rho\left(\frac{\vec{r}_1+\vec{r}_2}{2}\right)\right]^\alpha$$

$$\left(W_3+B_3P_\sigma-H_3P_\tau-M_3P_\sigma P_\tau\right)\exp\left\{-\frac{\left(\vec{r}_1-\vec{r}_2\right)^2}{\mu_3^{\,2}}\right\}\frac{\left[\rho\left(\vec{r}_1\right)\right]^\alpha+\left[\rho\left(\vec{r}_2\right)\right]^\alpha}{2}$$

D2

II) Extension of the Gogny force

II.1) New analytical form: D2

$$V(|\vec{r}_1-\vec{r}_2|)=$$

$$\sum_{j=1,2}(W_j+B_jP_\sigma-H_jP_\tau-M_jP_\sigma P_\tau)\exp\left\{-\frac{(\vec{r}_1-\vec{r}_2)^2}{\mu_j^2}\right\}$$

central

$$+(W_3+B_3P_\sigma-H_3P_\tau-M_3P_\sigma P_\tau)\exp\left\{-\frac{(\vec{r}_1-\vec{r}_2)^2}{\mu_3^2}\right\}\left[\frac{\rho^\alpha(\vec{r}_1)+\rho^\alpha(\vec{r}_2)}{2}\right]$$

density

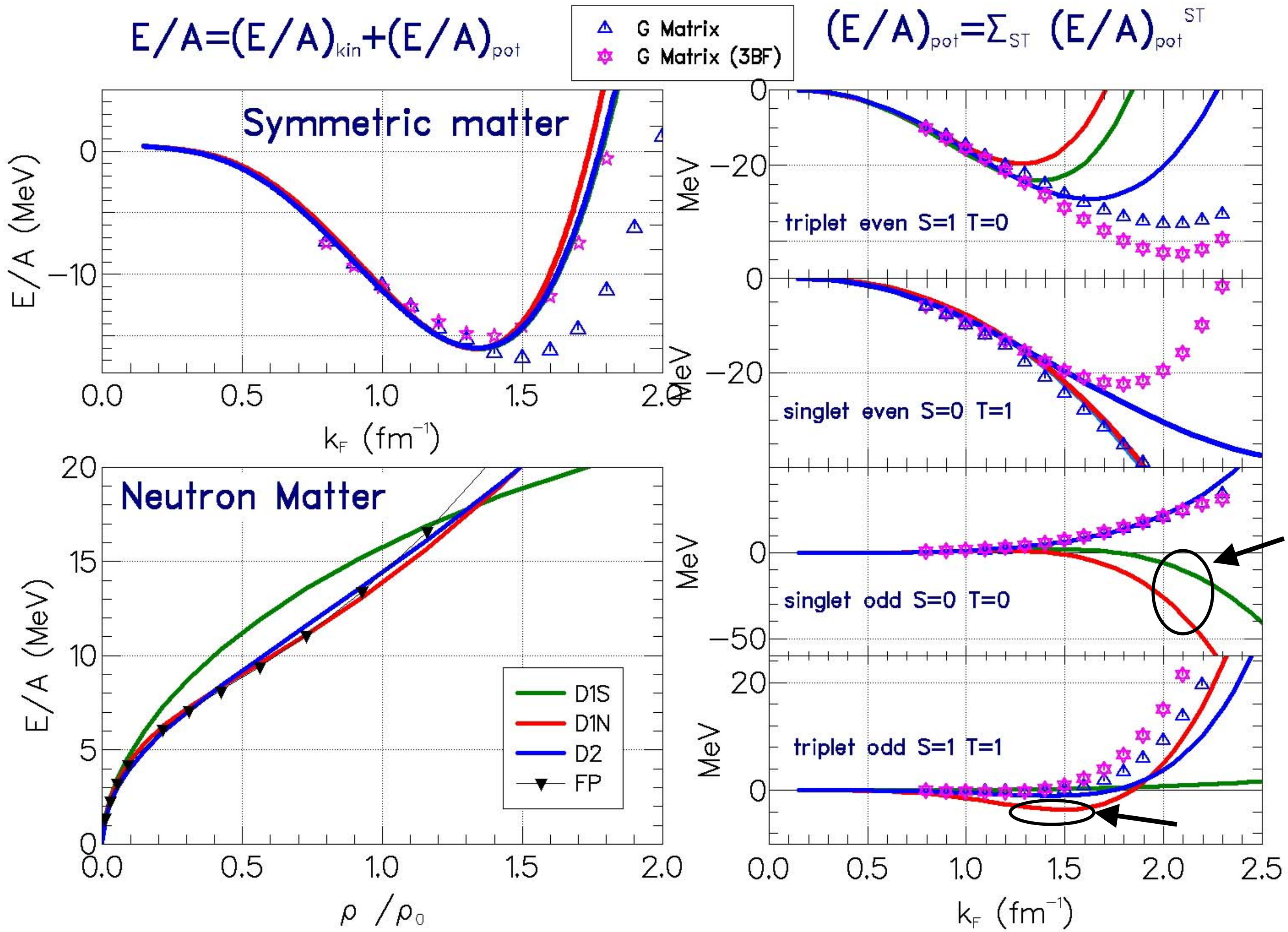
$$+i.W_{ls}\overleftarrow{\nabla}_{12}.\delta(\vec{r}_1-\vec{r}_2)\times\vec{\nabla}_{12}.(\vec{\sigma}_1+\vec{\sigma}_2)$$

$$+\text{Coulomb}$$

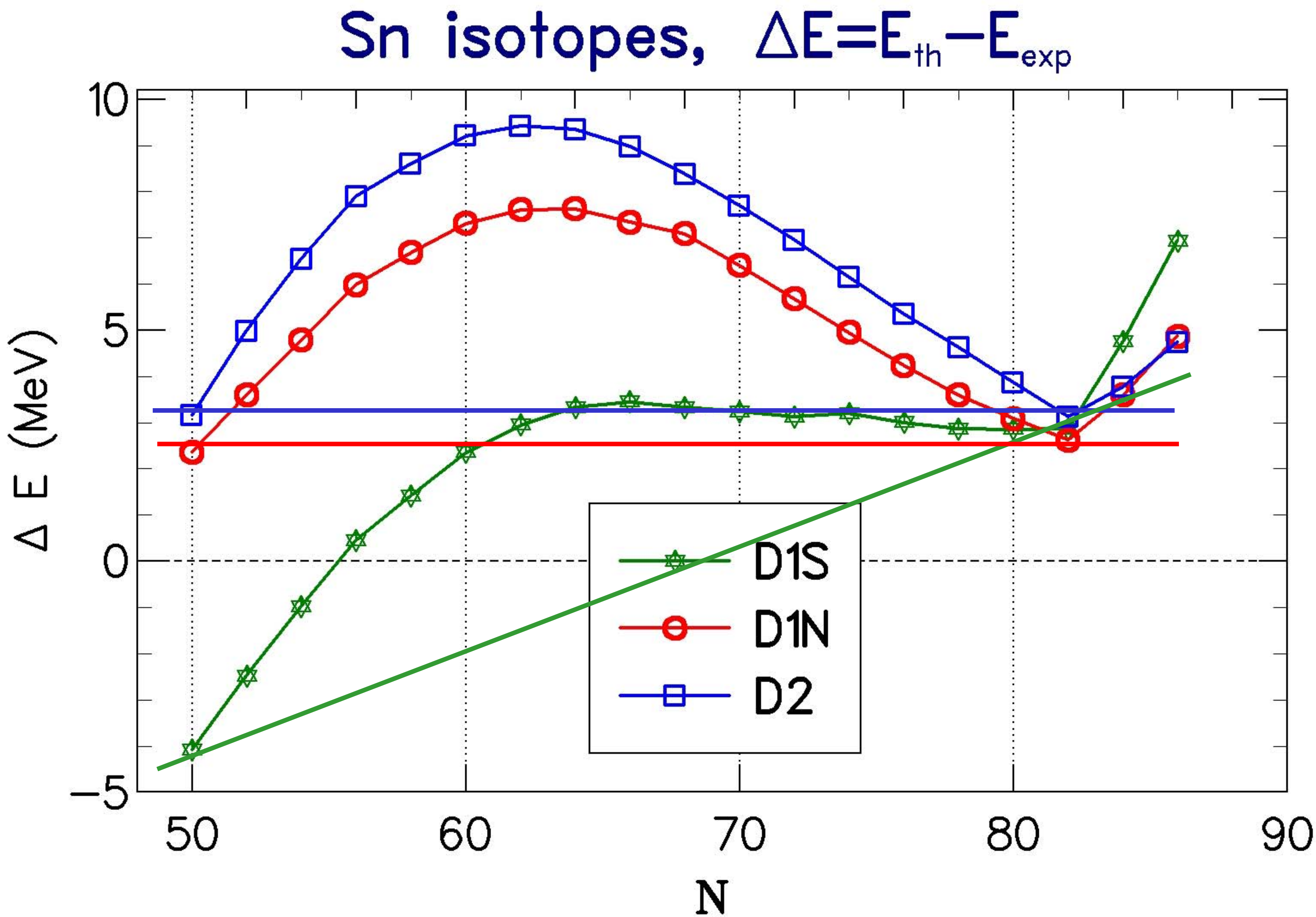
II) D2: Extension of the Gogny force

II.1) Improvements over D1N

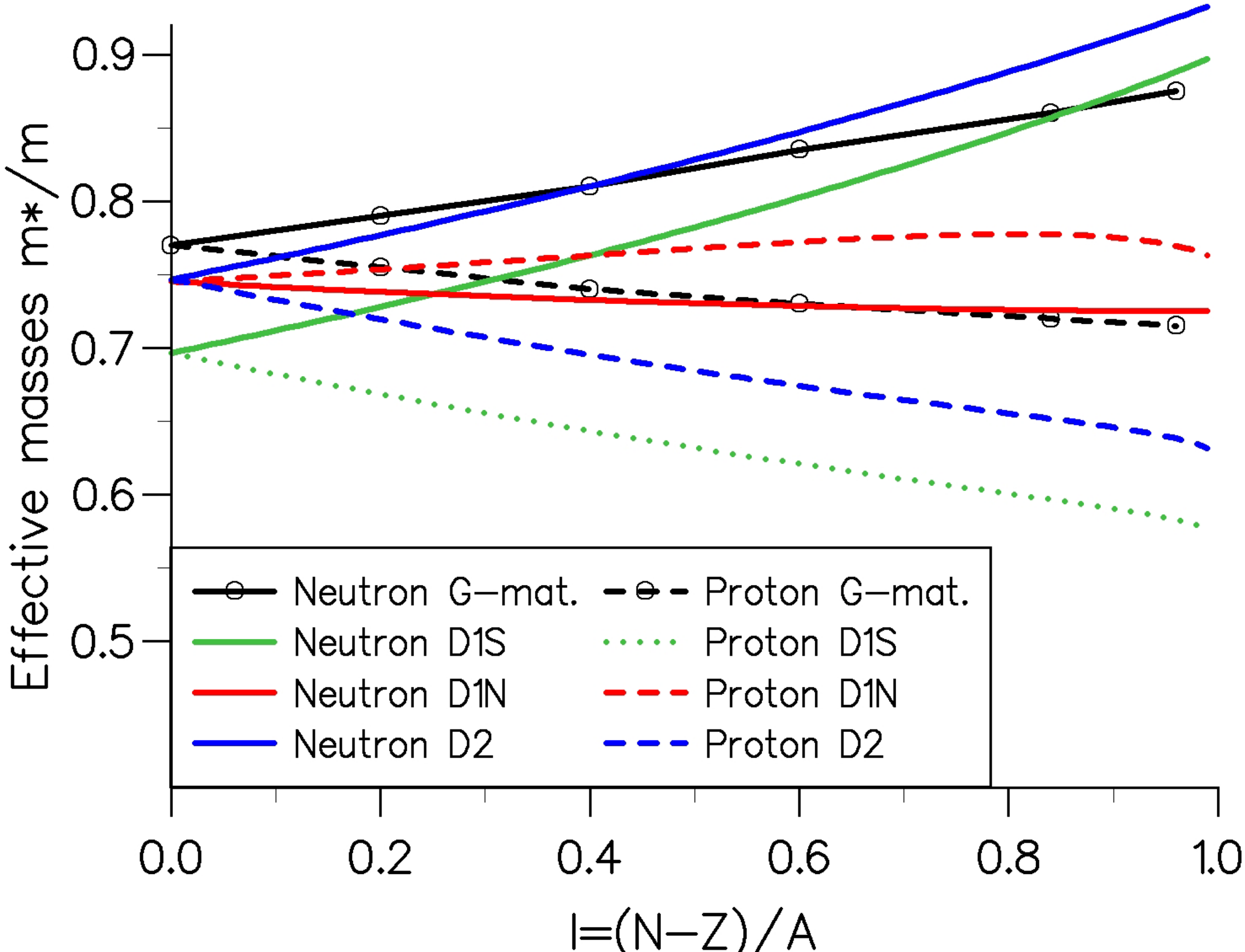
Potential Energies in ST-channels



Drift of B.E. with D2



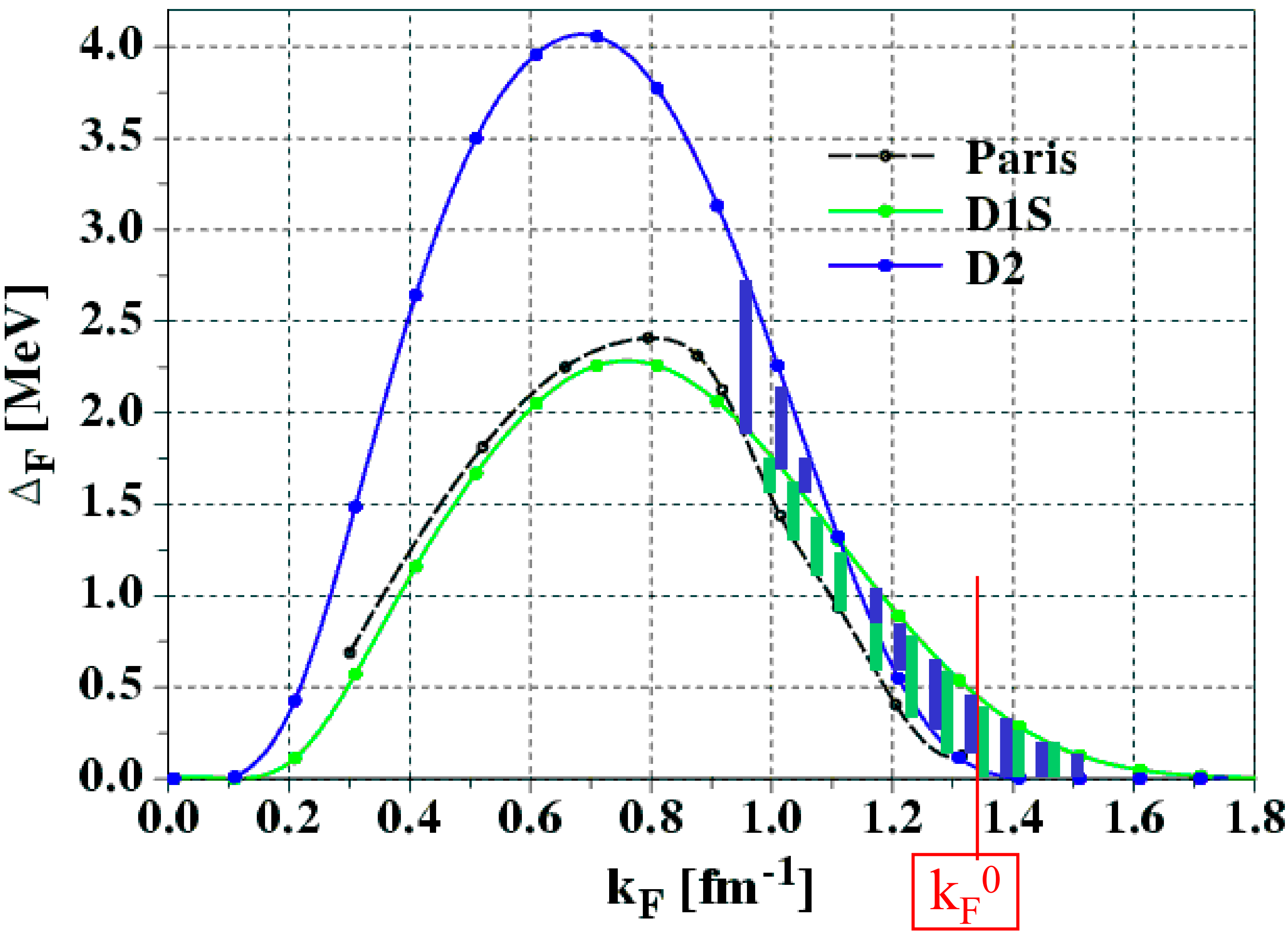
Splitting of Effective Masses in asymmetric matter



II) D2: Extension of the Gogny force

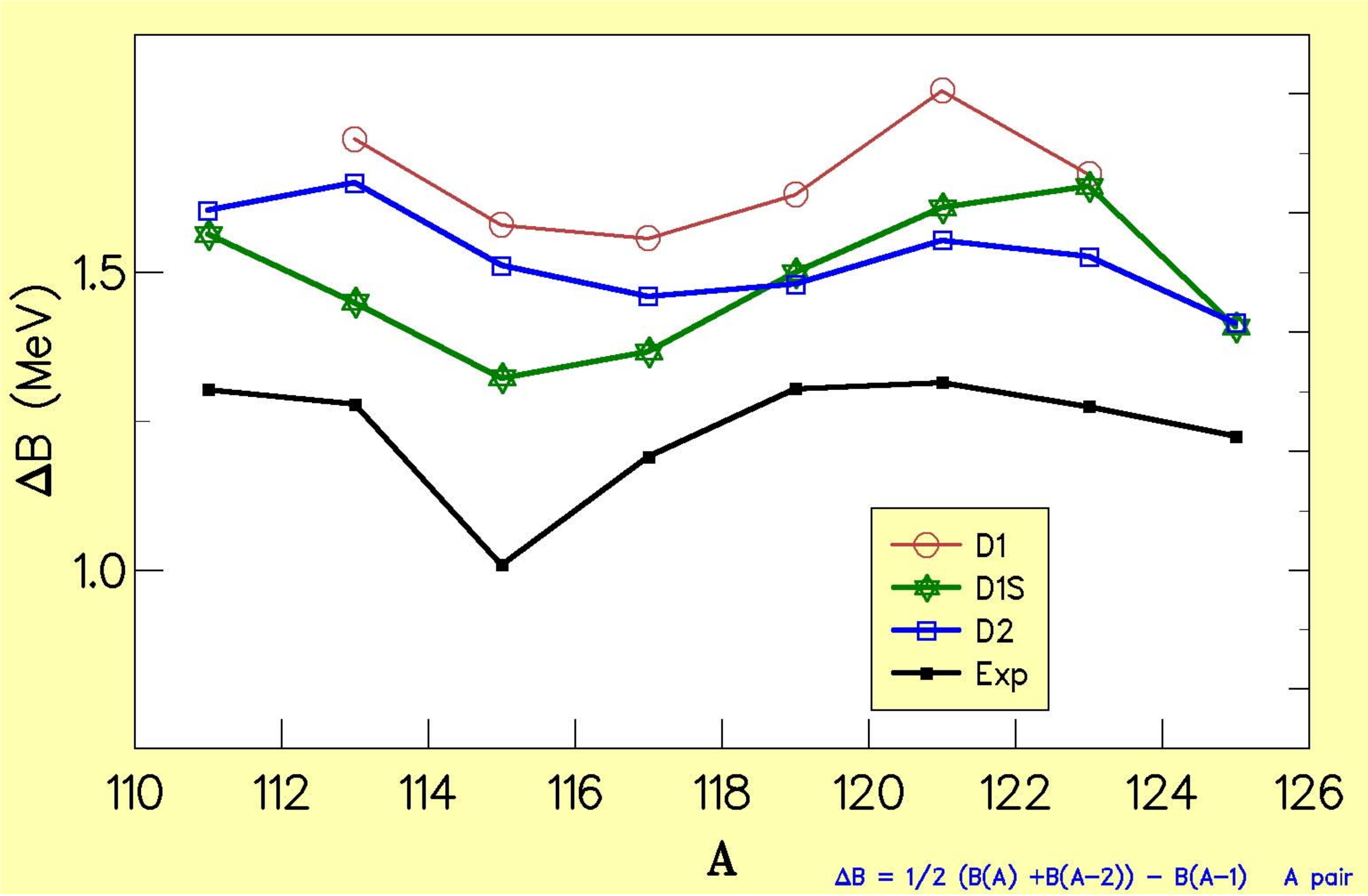
II.2) Pairing properties

Gap in Nuclear Matter



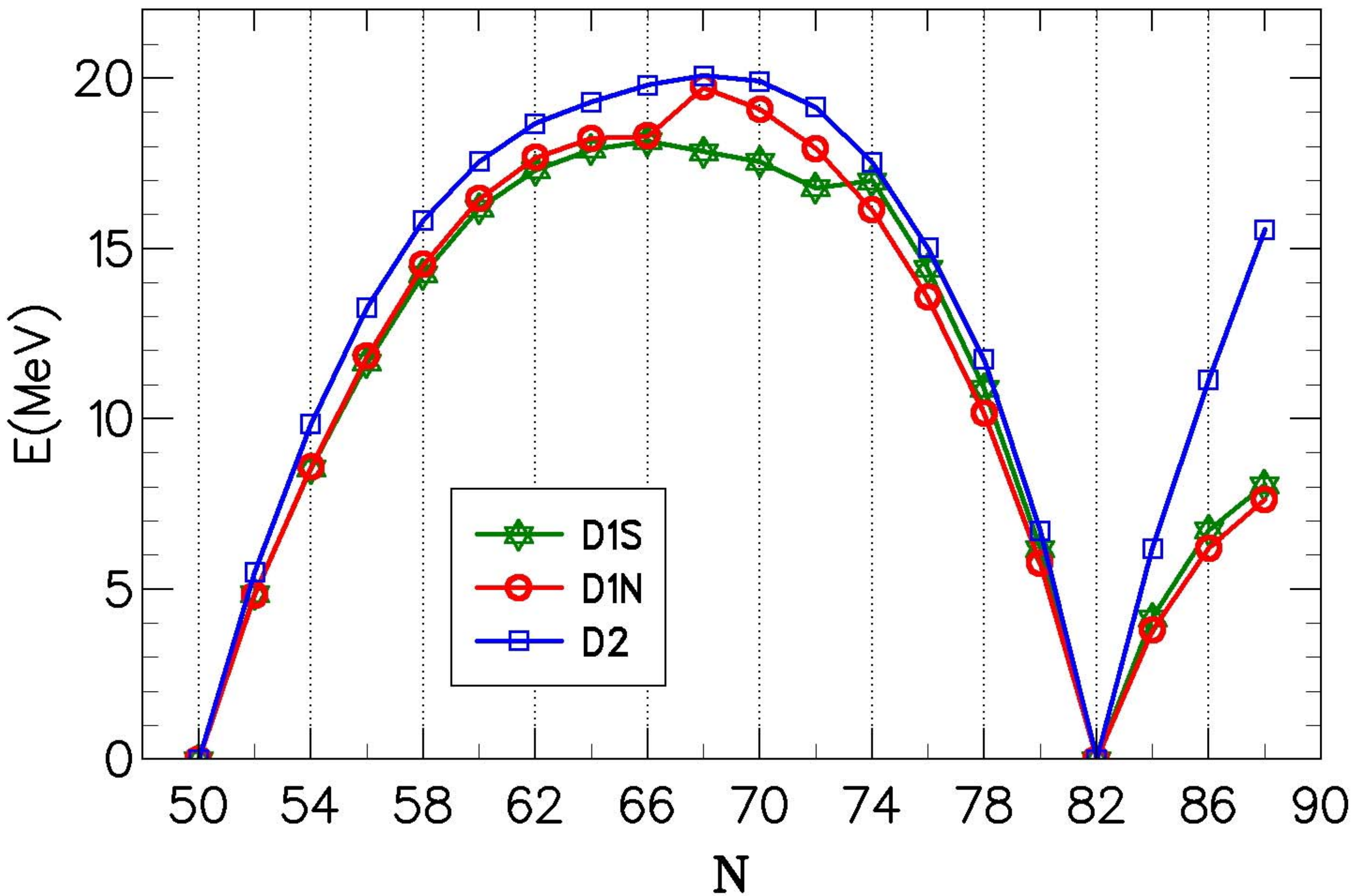
Pairing in Sn isotopes

$$\Delta B = \frac{B_{A-1} + B_{A+1}}{2} - B_A \text{ , A odd}$$

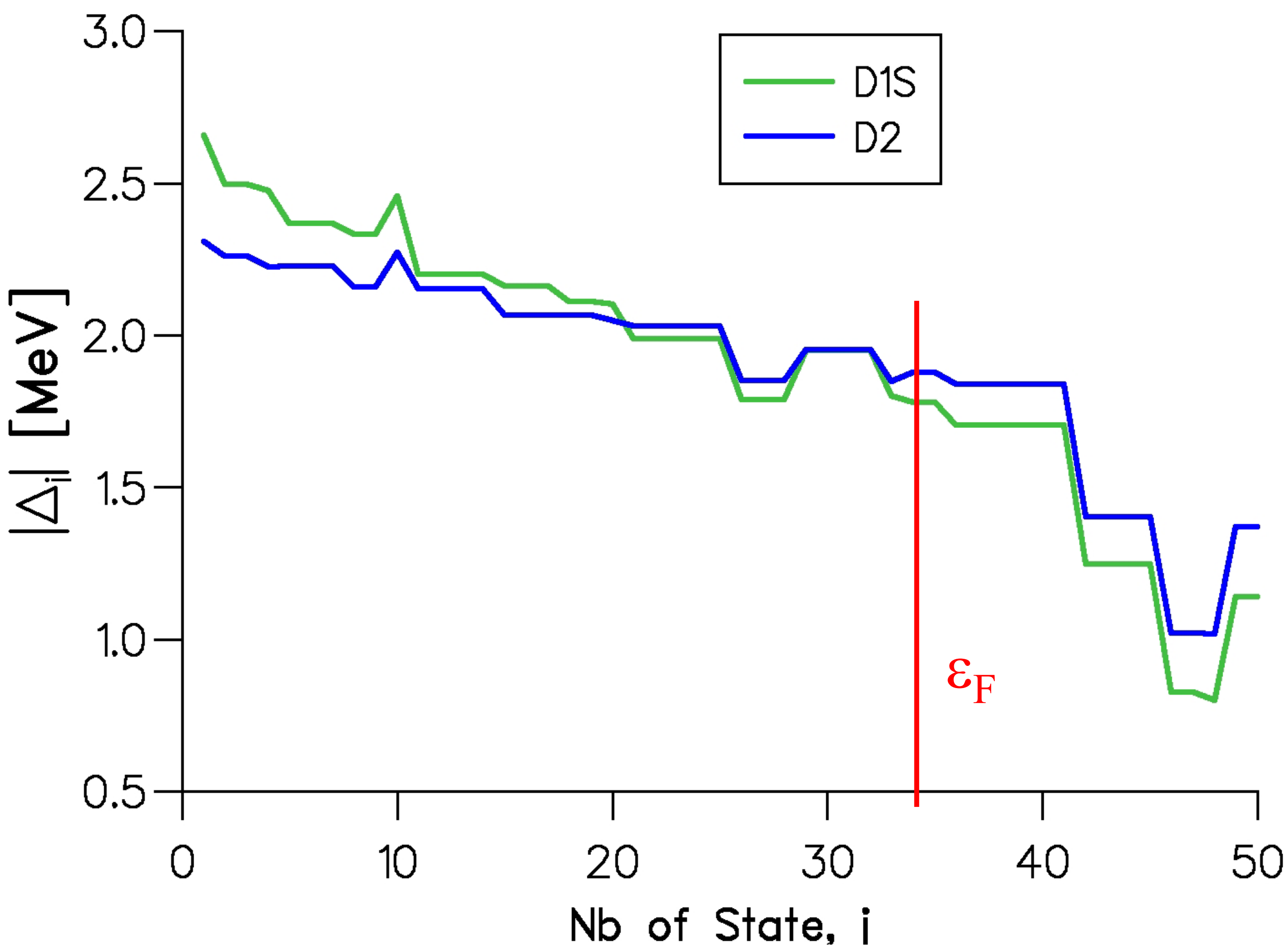


Pairing energy in Sn isotopes

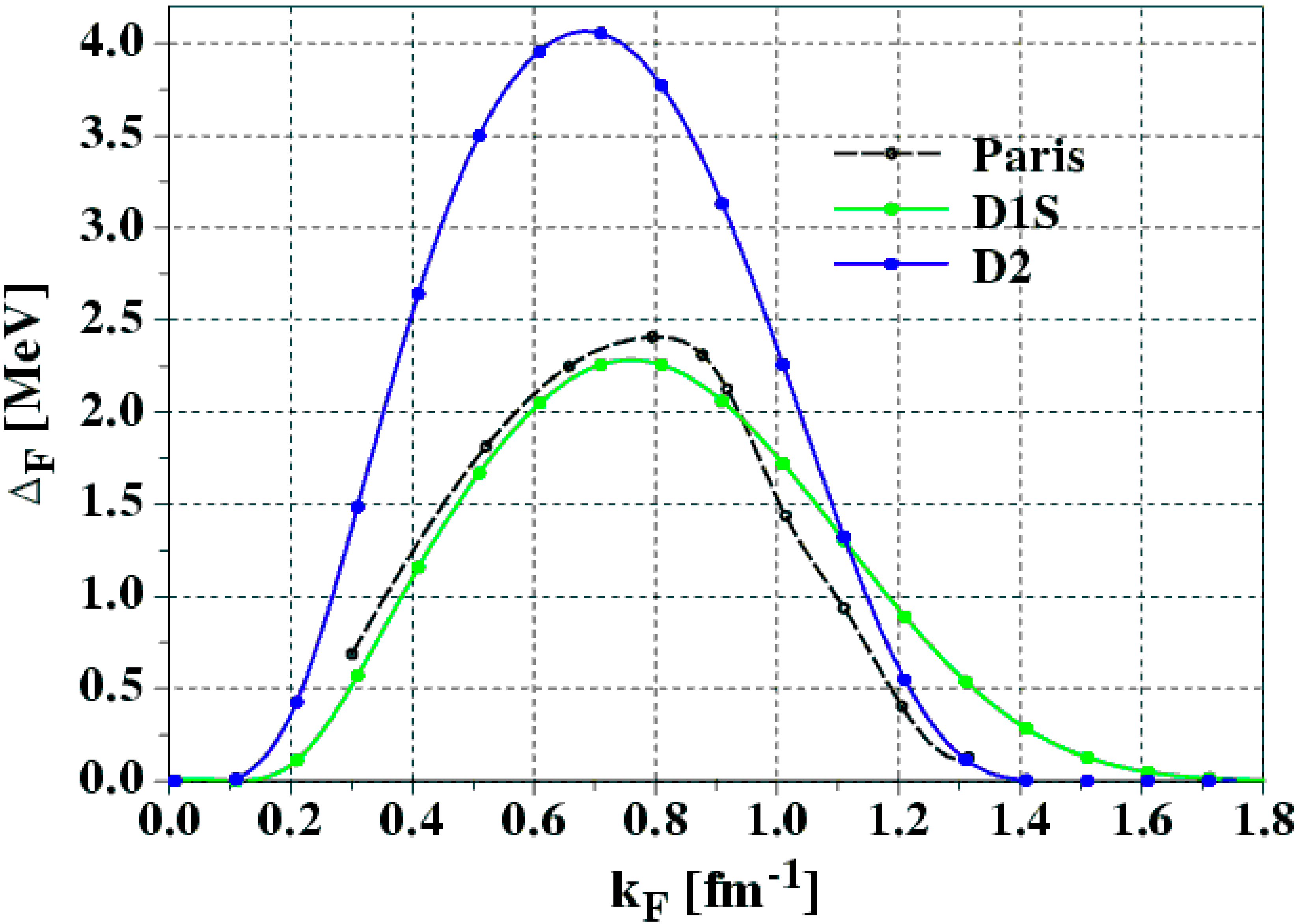
$$E^{HFB}_{pair} = \frac{1}{2}\sum_{\alpha\beta}\Delta_{\alpha\beta}K_{\beta\alpha}$$



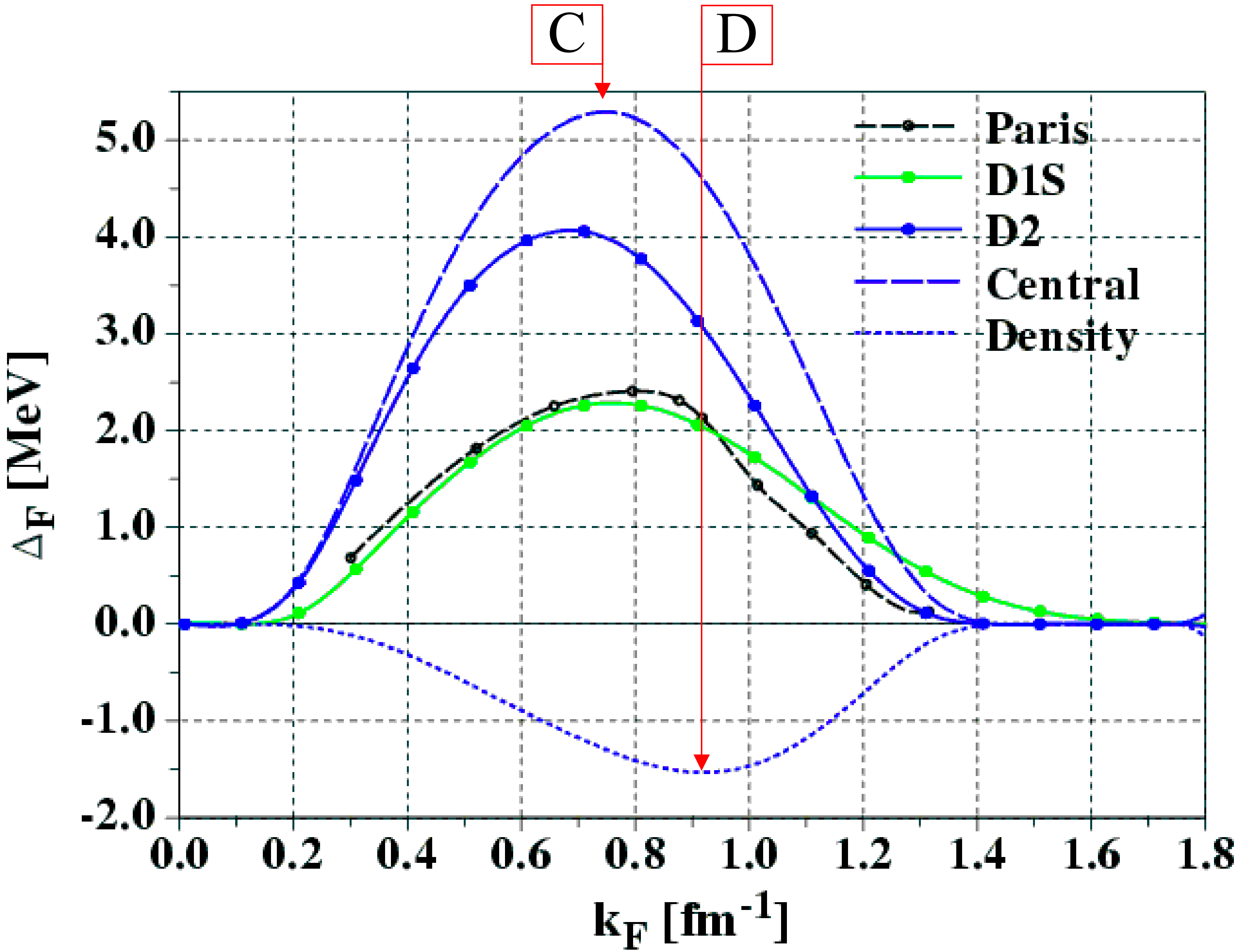
Gaps in ^{116}Sn



Gap in Nuclear Matter



Gap in Nuclear Matter



How to correct this?

W_1-B_1-H_1+M_1 W_2-B_2-H_2+M_2 W_3-B_3-H_3+M_3

W_3-B_3-H_3+M_3 [ρ^α] is given a prescribed value

$$\left\langle \mathbf{1S,1S} \middle| \mathbf{V_{12}} \middle| \mathbf{1S,1S} \right\rangle_{\mathbf{S=0,T=1}} = -\mathbf{V_{1S}}$$

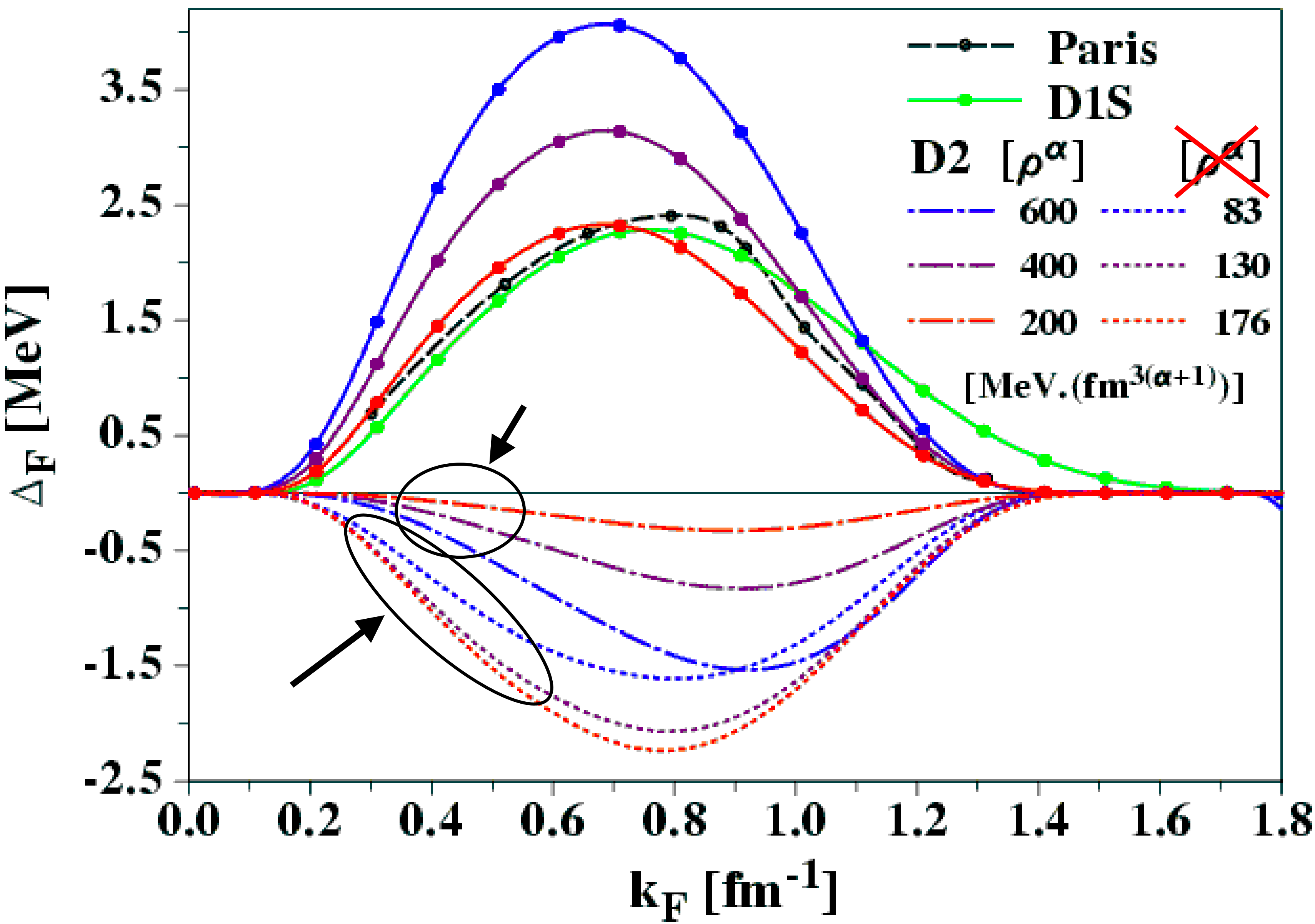
$$\left\langle \mathbf{2S,2S} \middle| \mathbf{V_{12}} \middle| \mathbf{2S,2S} \right\rangle_{\mathbf{S=0,T=1}} = -\mathbf{V_{2S}}$$

$\mathbf{(W_1 - B_1 - H_1 + M_1)}$

$\mathbf{(W_2 - B_2 - H_2 + M_2)}$

	D1S	D2	D2	D2
W_3-B_3-H_3+M_3[ρ^α] (MeV.fm$^{3(\alpha+1)}$)	0	600	400	200
W_1-B_1-H_1+M_1 (MeV)	193	83	130	176
W_2-B_2-H_2+M_2 (MeV)	-119	-141	-143	-146

Gap in Nuclear Matter



Conclusion 2

D2: Finite range density dependence

- More realistic potential energies in odd ST channels
- Correct splitting of effective masses: $m_n^* > m_p^*$

- Role of the density dependence for pairing?
  - → Gap in nuclear matter $\Delta_F(k_F)$
  - → Effects on nuclei properties?

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