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The Legacy of Adelchi Fabrocini

Short-range correlations and Double-Beta Decay

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Short-range correlation effects on the nuclear matrix element of neutrinoless double-β decay

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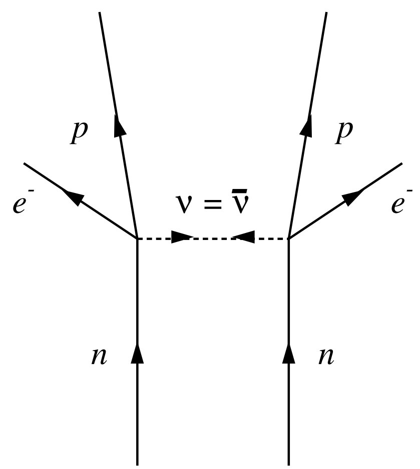
TABLE I. Ratio between the $0\nu\beta\beta$ NME of Eq. (4), computed including central and central plus spin-dependent correlations and the corresponding quantity obtained setting $f(r_{12}) = 1$ and $g(r_{12}) = 0$.

	$f(r_{12})$	$f(r_{12}) + g(r_{12})(\boldsymbol{\sigma}_1 \cdot \boldsymbol{\sigma}_2)$
M/M_{SM}	0.77	0.79

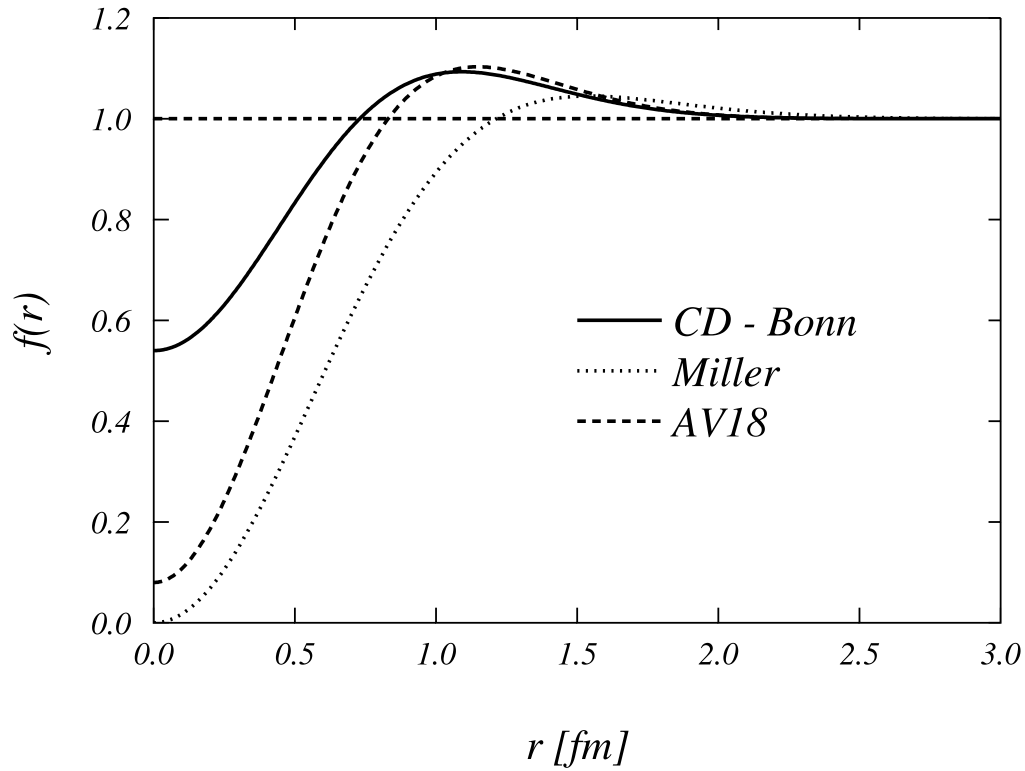


$$\frac{1}{\tau} = G\,|M|^2$$

$$\begin{aligned} M &= \langle A, Z+2| \int d^3 q e^{i\mathbf{q}\cdot(\mathbf{r}_1-\mathbf{r}_2)} \mathcal{O}(1) \sum_i |i\rangle \frac{1}{|\mathbf{q}|(|\mathbf{q}| + \omega_i/\hbar)} \langle i|\mathcal{O}(2)|A, Z\rangle \\ &\simeq \langle A, Z+2| \int d^3 q \frac{e^{i\mathbf{q}\cdot(\mathbf{r}_1-\mathbf{r}_2)}}{|\mathbf{q}|(|\mathbf{q}| + < \omega_i/\hbar >)} \mathcal{O}(1)\mathcal{O}(2)|A, Z\rangle \\ &= \langle A, Z+2|H(\mathbf{r}_{12})\mathcal{O}(1)\mathcal{O}(2)|A, Z\rangle = \langle A, Z+2|\mathcal{T}(1,2)|A, Z\rangle \end{aligned}$$

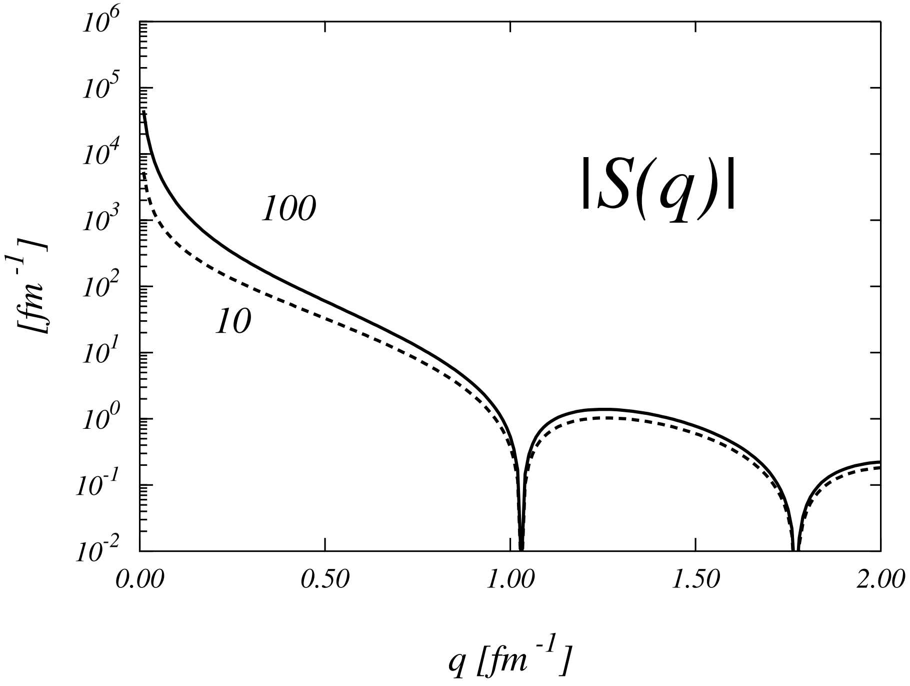
$$\langle A, Z+2|\mathcal{T}(1,2)|A, Z\rangle \longrightarrow \langle A, Z+2|f(r_{12})\mathcal{T}(1,2)f(r_{12})|A, Z\rangle$$

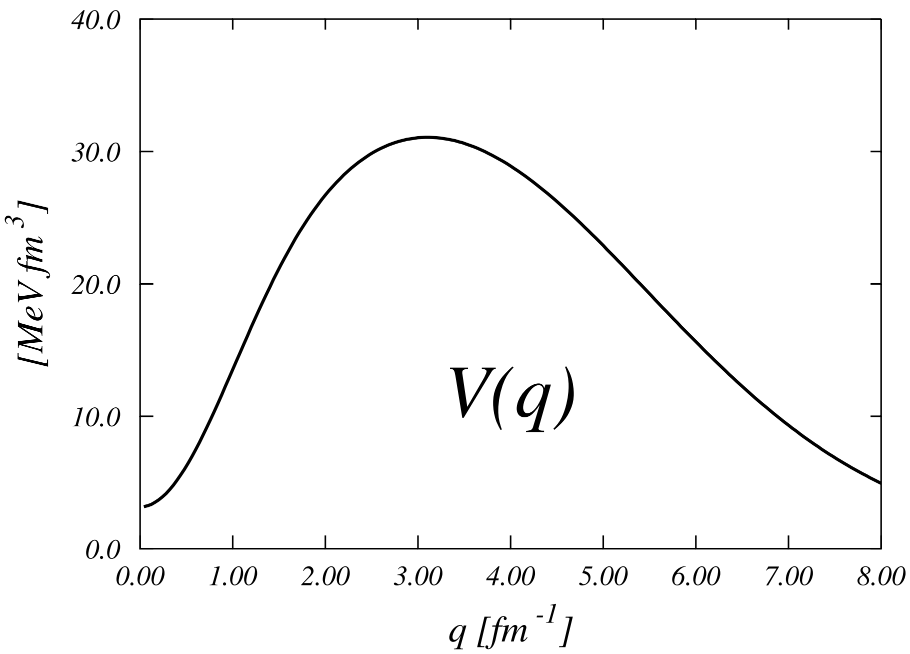
$$\mathcal{T}(1,2) \longrightarrow \mathcal{T}^{\text{eff}}(1,2) = f(r_{12})\mathcal{T}(1,2)f(r_{12})$$



$f(r) = 1 - e^{-ar}(1 - br^2)$ Miller and Spencer, Ann.Phys. 100(1976)562.

Authors	Method	Ref.	M/M_{MF}
M. Kortelainen *et al.*	SM	PLB 647 (2007) 128	0.7
E. Caurier *et al.*	SM	EPJA 36 (2008) 195	0.59
F. Šimkovic *et al.*	QRPA	PRC 77(2008) 045503	~ 0.8
F. Šimkovic *et al.*	QRPA	PRC 79(2009) 055501	$0.7, 0.5$
M. Horoi S. Stoica	QRPA	PRC 81 (2010) 024321	0.8,1.2,1.1



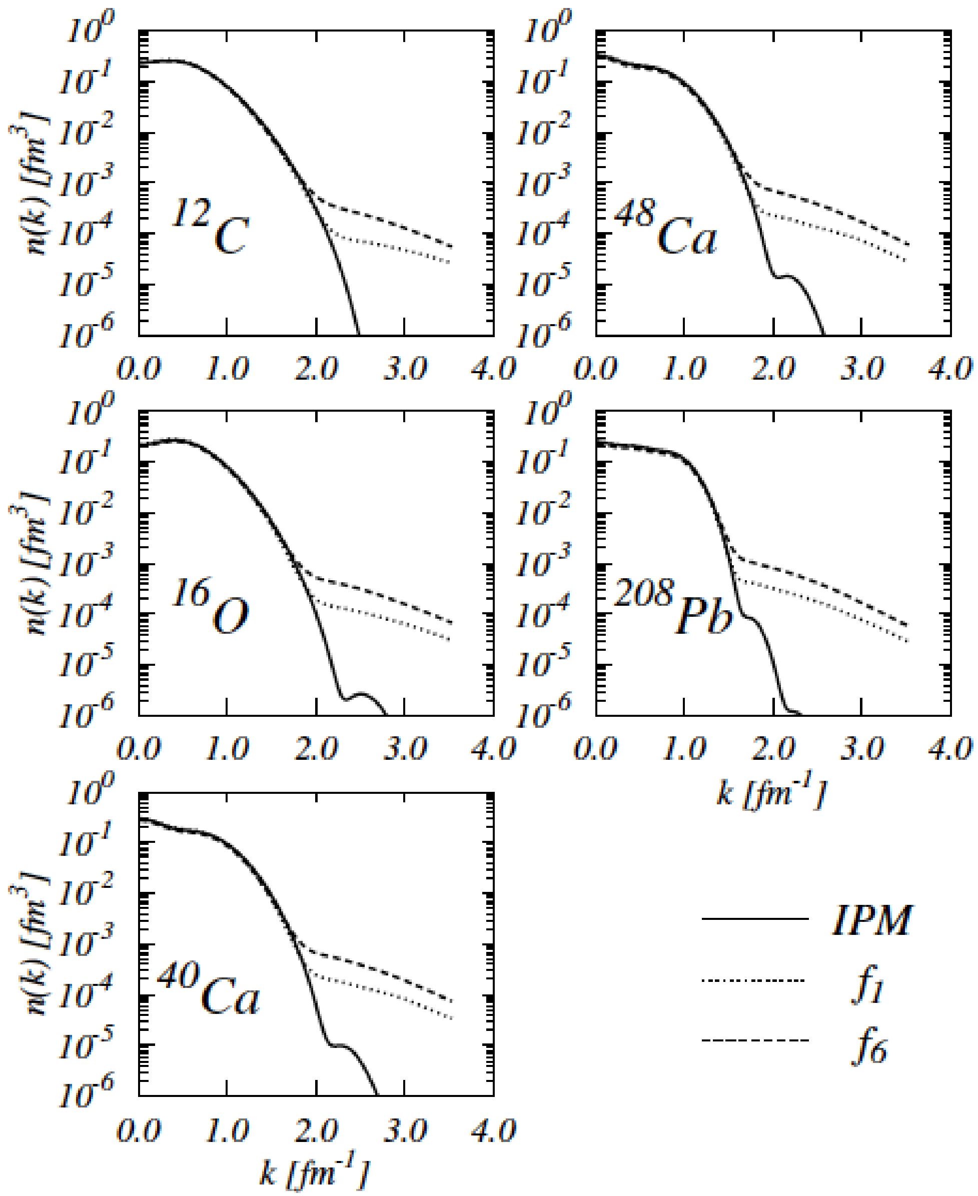


Neutrino potential

$$S(q) = \int drr^2 \frac{j_0(qr)}{q(q+<\omega>)}$$

Argonne V18 potential

$$\tilde{V}(q) = \int drr^2 j_0(qr) V(r)$$



Momentum distribution

F. Arias de Saavedra, C. Bisconti,
G. Co', A. Fabrocini ,
Phys. Rep. 450 (2007) 1-95.

$$\Delta x \Delta p\, c \simeq \hbar c \simeq 2.0\text{fm}^{-1}\, 0.5\text{fm}$$

$$\rho^{\mathrm{II}}(\mathbf{r}_1,\mathbf{r}_2) = \frac{1}{\langle\Psi|\Psi\rangle}\int d^3 r_3 \cdots d^3 r_A \Psi^*(\mathbf{r}_1,\mathbf{r}_2,\cdots\mathbf{r}_A)\Psi(\mathbf{r}_1,\mathbf{r}_2,\cdots\mathbf{r}_A)$$

$$\rho^{\mathrm{II,MF}}(\mathbf{r}_1,\mathbf{r}_2) = \rho^{\mathrm{I,MF}}(\mathbf{r}_1,\mathbf{r}_1)\rho^{\mathrm{I,MF}}(\mathbf{r}_2,\mathbf{r}_2) - \rho^{\mathrm{I,MF}}(\mathbf{r}_1,\mathbf{r}_2)\rho^{\mathrm{I,MF}}(\mathbf{r}_2,\mathbf{r}_1)$$

$$\rho^{\mathrm{I,MF}}(\mathbf{r}_1,\mathbf{r}_2) = \sum_{i<\epsilon_F}\phi_i^*(\mathbf{r}_1)\phi_i(\mathbf{r}_2)$$

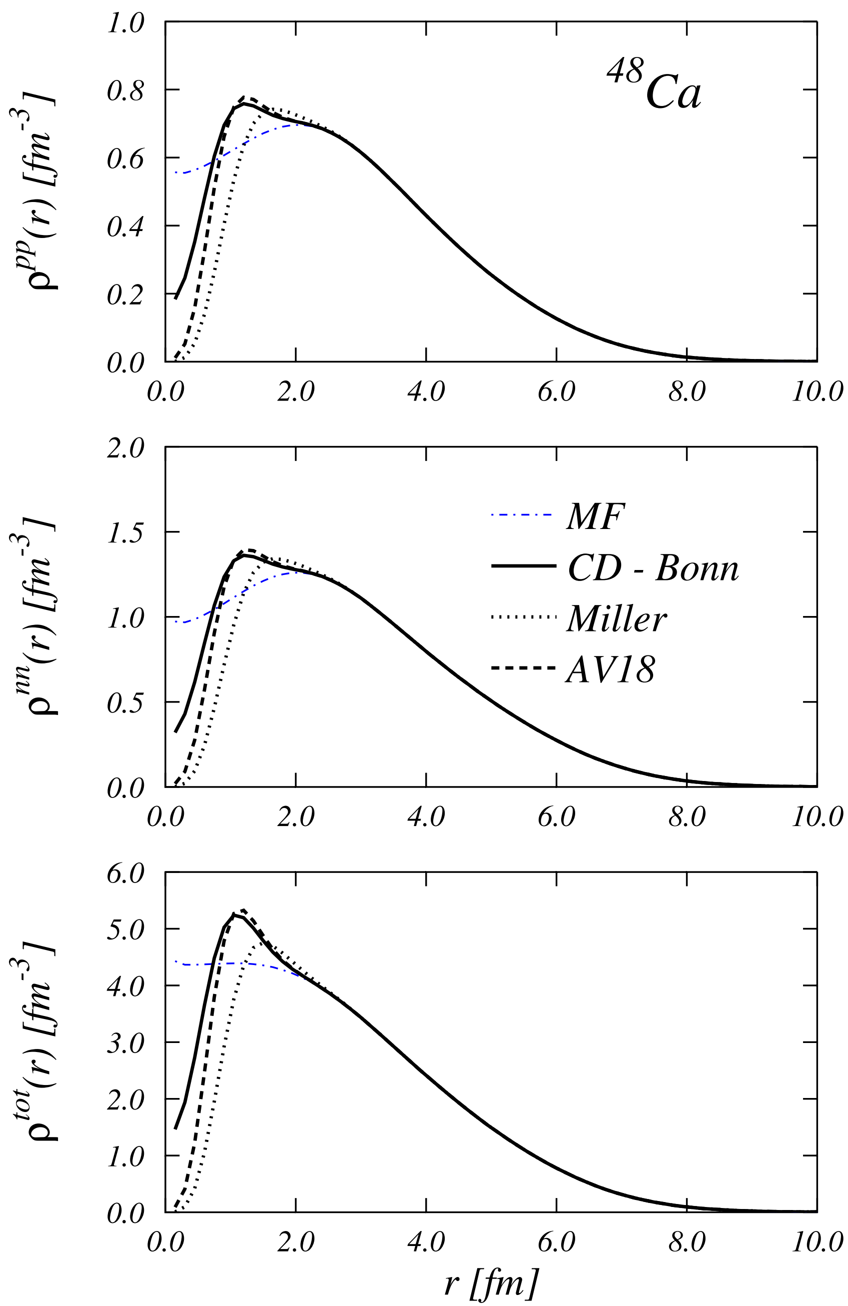
$$\int d^3 r_1 \rho^{\mathrm{I,MF}}(\mathbf{r}_1,\mathbf{r}_1) = A \ ; \ \int d^3 r_3 \rho^{\mathrm{I,MF}}(\mathbf{r}_1,\mathbf{r}_3)\rho^{\mathrm{I,MF}}(\mathbf{r}_3,\mathbf{r}_2) = \rho^{\mathrm{I,MF}}(\mathbf{r}_1,\mathbf{r}_2)$$

$$\int d^3 r_1 \int d^3 r_2 \rho^{\mathrm{II,MF}}(\mathbf{r}_1,\mathbf{r}_2) = A(A-1)$$

$$\mathbf{r} = \mathbf{r}_1 - \mathbf{r}_2 \ ; \ \mathbf{R} = \frac{1}{2}(\mathbf{r}_1 + \mathbf{r}_2) \ ; \ \rho^{\mathrm{II,MF}}(\mathbf{r}_1,\mathbf{r}_2) \to \rho^{\mathrm{II,MF}}(\mathbf{r},\mathbf{R})$$

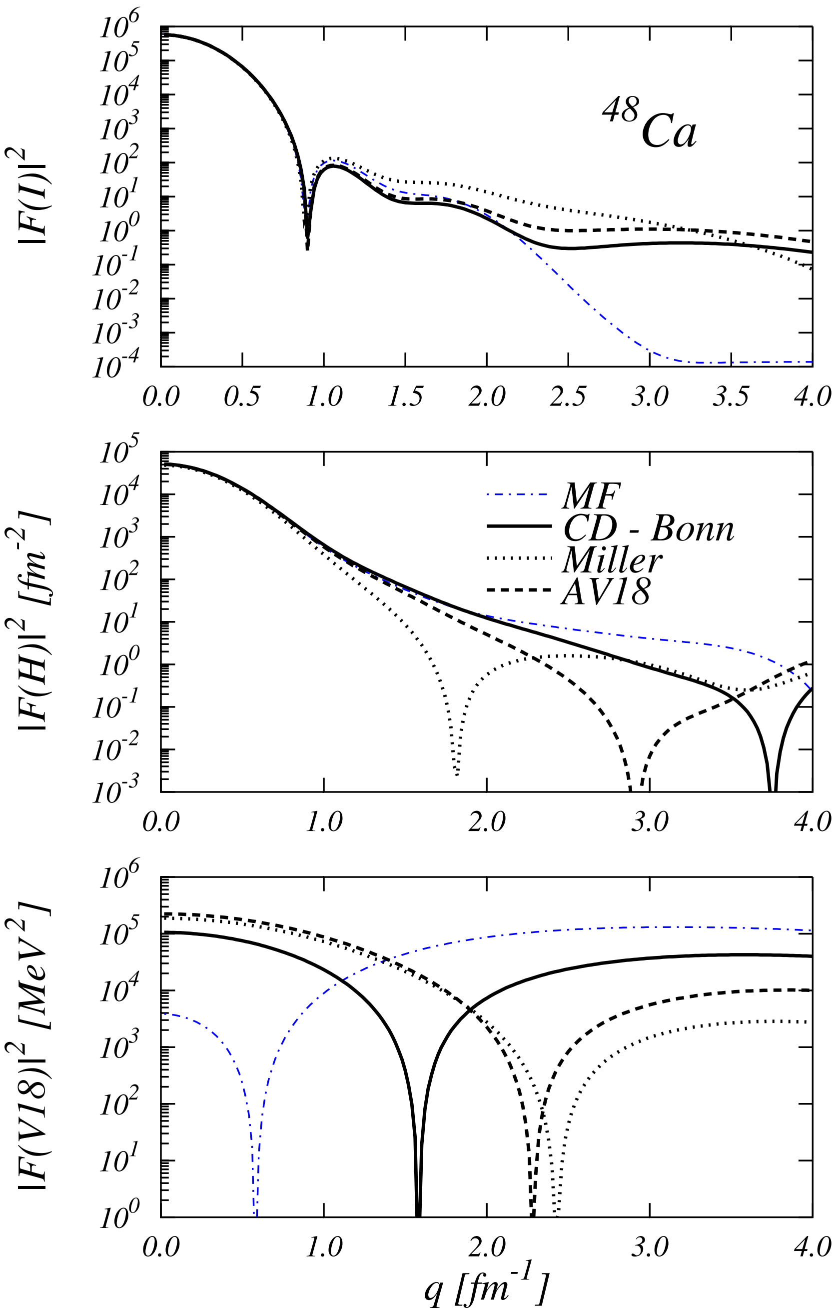
$$\tilde{\rho}^{\mathrm{II,MF}}(r) = \int d(\cos(\theta_{rR}))\int dR R^2 \rho^{\mathrm{II,MF}}(r,R,\cos(\theta_{rR}))$$

$$\tilde{\rho}^{\mathrm{II,c1}}(r) = f(r)\tilde{\rho}^{\mathrm{II,MF}}(r)f(r)$$



Normalisations

	pp	nn	tot
expct.	380.00	756.00	2256.00
MF	380.44	756.74	2258.40
Bonn	382.10	759.73	2269.14
Miller	380.70	757.27	2258.19
AV18	382.00	760.00	2268.08



$$F(\mathrm{I}) = \int d^3r e^{i\mathbf{q}\cdot\mathbf{r}} \tilde{\rho}^{\mathrm{nn}}(r)$$

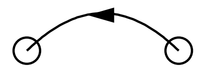
$$F(\mathrm{H}) = \int d^3r e^{i\mathbf{q}\cdot\mathbf{r}} H(r) \tilde{\rho}^{\mathrm{nn}}(r)$$

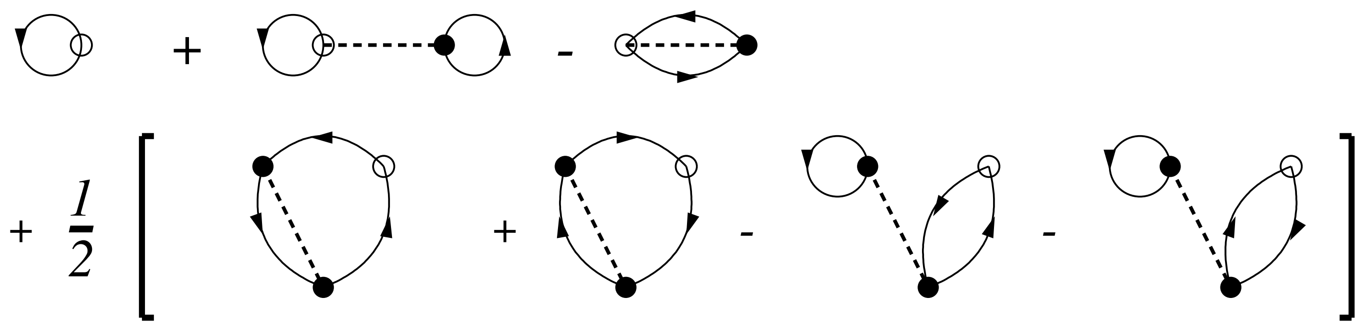
$$F(\mathrm{V18}) = \int d^3r e^{i\mathbf{q}\cdot\mathbf{r}} V_{18}(r) \tilde{\rho}^{\mathrm{nn}}(r)$$

$$
\begin{aligned}
\rho^{\mathrm{I}}(\mathbf{r}_1, \mathbf{r}_1) &= \frac{1}{\langle \Psi | \Psi \rangle} \int d^3 r_2\, d^3 r_3 \cdots d^3 r_A \Psi^*(\mathbf{r}_1, \mathbf{r}_2, \cdots \mathbf{r}_A) \Psi(\mathbf{r}_1, \mathbf{r}_2, \cdots \mathbf{r}_A) \\
&= \frac{1}{\langle \Psi | \Psi \rangle} \int d^3 r_2\, d^3 r_3 \cdots d^3 r_A \Phi^*(\mathbf{r}_1, \mathbf{r}_2, \cdots \mathbf{r}_A) F^\dagger F \Phi(\mathbf{r}_1, \mathbf{r}_2, \cdots \mathbf{r}_A)
\end{aligned}
$$

$$
F^\dagger F = \prod_{ij} f^2(r_{ij}) = \prod_{ij} [1 + h(r_{ij})]
$$

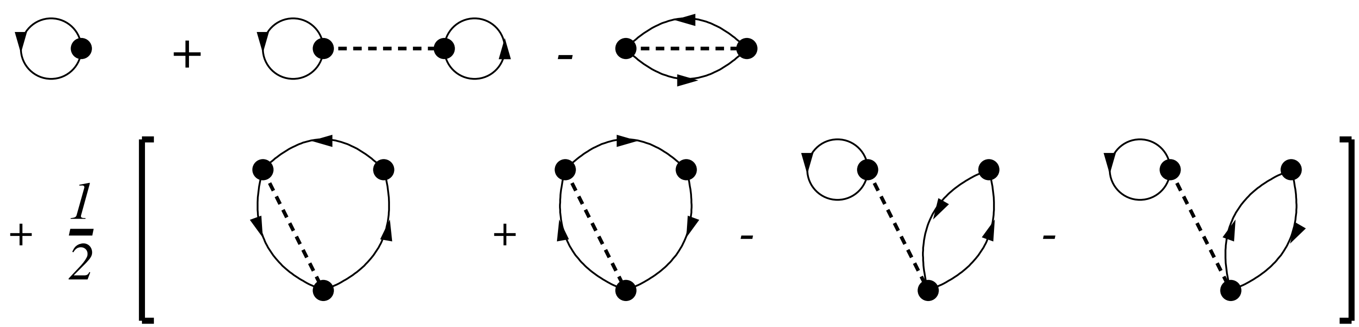
$h(r_{12}) \rightarrow$ 

$$\rho^{\mathrm{I,MF}}(\mathbf{r}_1, \mathbf{r}_2) = \sum_{\alpha < \epsilon_{\mathrm{F}}} \phi_\alpha^*(\mathbf{r}_1)\phi_\alpha(\mathbf{r}_2) \rightarrow$$ 



$$\int d^3 r_3 \, \rho^{\mathrm{I}}(\mathbf{r}_1, \mathbf{r}_3)\rho^{\mathrm{I}}(\mathbf{r}_3, \mathbf{r}_2) = \rho^{\mathrm{I}}(\mathbf{r}_1, \mathbf{r}_2)$$

$$\int d^3 r_1 \, \rho^{\mathrm{I}}(\mathbf{r}_1, \mathbf{r}_1) = \int d^3 r_1 \, \rho(\mathbf{r}_1) =$$



$$= A$$

$$\int d^3 r_1 \, \rho^{\mathsf{MF}}(\mathbf{r}_1) = \int d^3 r_1 \sum_{\alpha} |\phi_\alpha(\mathbf{r}_1)|^2 = A$$

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Nucl. Phys. A 473 (1987), 234.

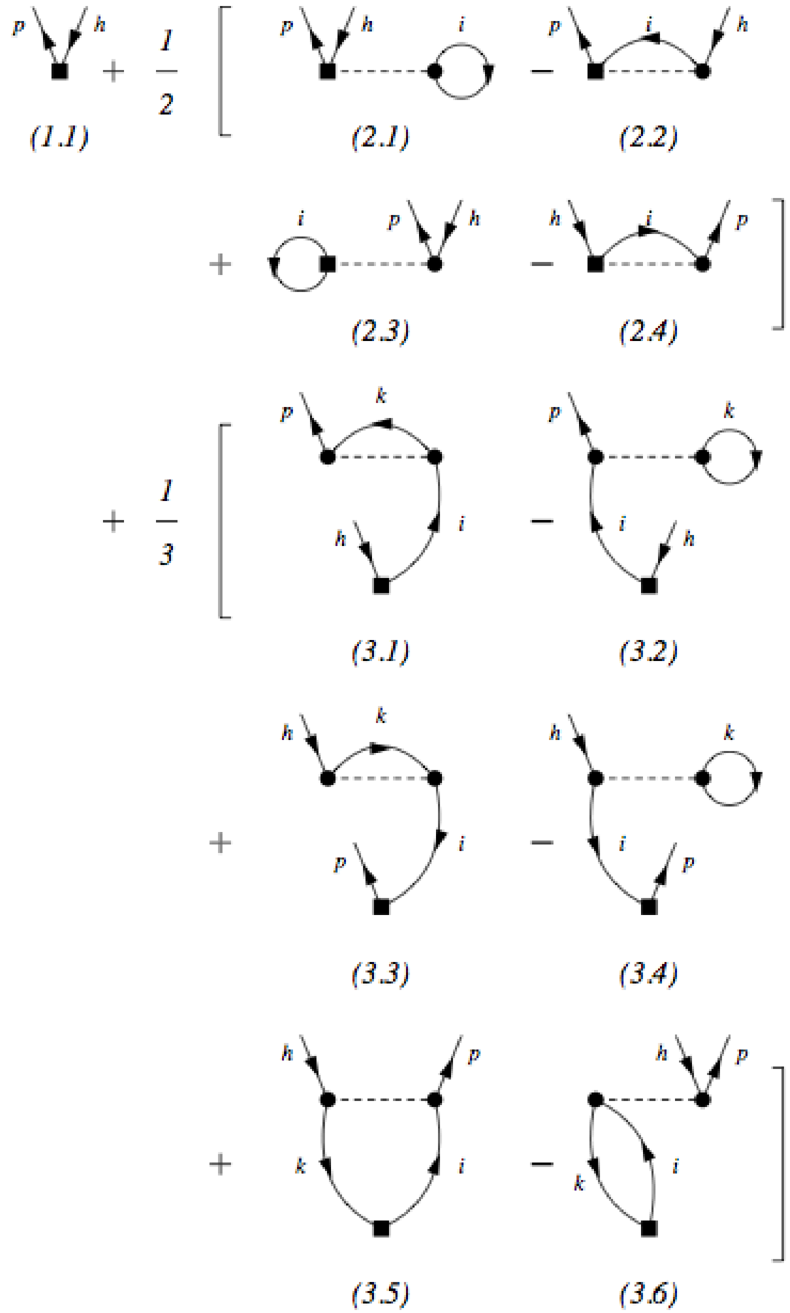
$$D(\mathbf{q},\omega) = \sum_n \frac{|\langle \widetilde{\Psi}_n \,| O(\mathbf{q}) \,|\, \widetilde{\Psi}_0\rangle|^2}{E_n - E_0 - \omega + i\eta} = \sum_n \xi_n^+(\mathbf{q})\,(E_n - E_0 - \omega + i\eta)^{-1}\,\xi_n(\mathbf{q}),$$

$$\xi_n(\mathbf{q}) = \frac{\langle \Psi_n | O(\mathbf{q}) | \Psi_0\rangle}{\langle \Psi_n|\Psi_n\rangle^{\frac{1}{2}}\,\langle \Psi_0|\Psi_0\rangle^{\frac{1}{2}}}.$$

$$\begin{aligned}\xi_n(\mathbf{q}) &= \frac{\langle \Phi_n| \prod_{i<j} f_{ij}^+ O(\mathbf{q}) \prod_{i<j} f_{ij} |\Phi_0\rangle}{\langle \Phi_0| \prod_{i<j} f_{ij}^+ \prod_{i<j} f_{ij} |\Phi_0\rangle} \left[\frac{\langle \Phi_0| \prod_{i<j} f_{ij}^+ \prod_{i<j} f_{ij} |\Phi_0\rangle}{\langle \Phi_n| \prod_{i<j} f_{ij}^+ \prod_{i<j} f_{ij} |\Phi_n\rangle}\right]^{\frac{1}{2}} \\ &= \frac{\langle \Phi_n| O(\mathbf{q}) \prod_{i<j} (1+h_{ij}) |\Phi_0\rangle}{\langle \Phi_0| \prod_{i<j} (1+h_{ij}) |\Phi_0\rangle} \left[\frac{\langle \Phi_0| \prod_{i<j} (1+h_{ij}) |\Phi_0\rangle}{\langle \Phi_n| \prod_{i<j} (1+h_{ij}) |\Phi_n\rangle}\right]^{\frac{1}{2}},\end{aligned}$$

our ansatz

$$\xi_n(\mathbf{q}) \to \xi_n^1(\mathbf{q}) = \langle \Phi_n | O(\mathbf{q}) \sum_{i<j} (1+h_{ij}) |\Phi_0\rangle_L\,,$$


(1.1)
(2.1)
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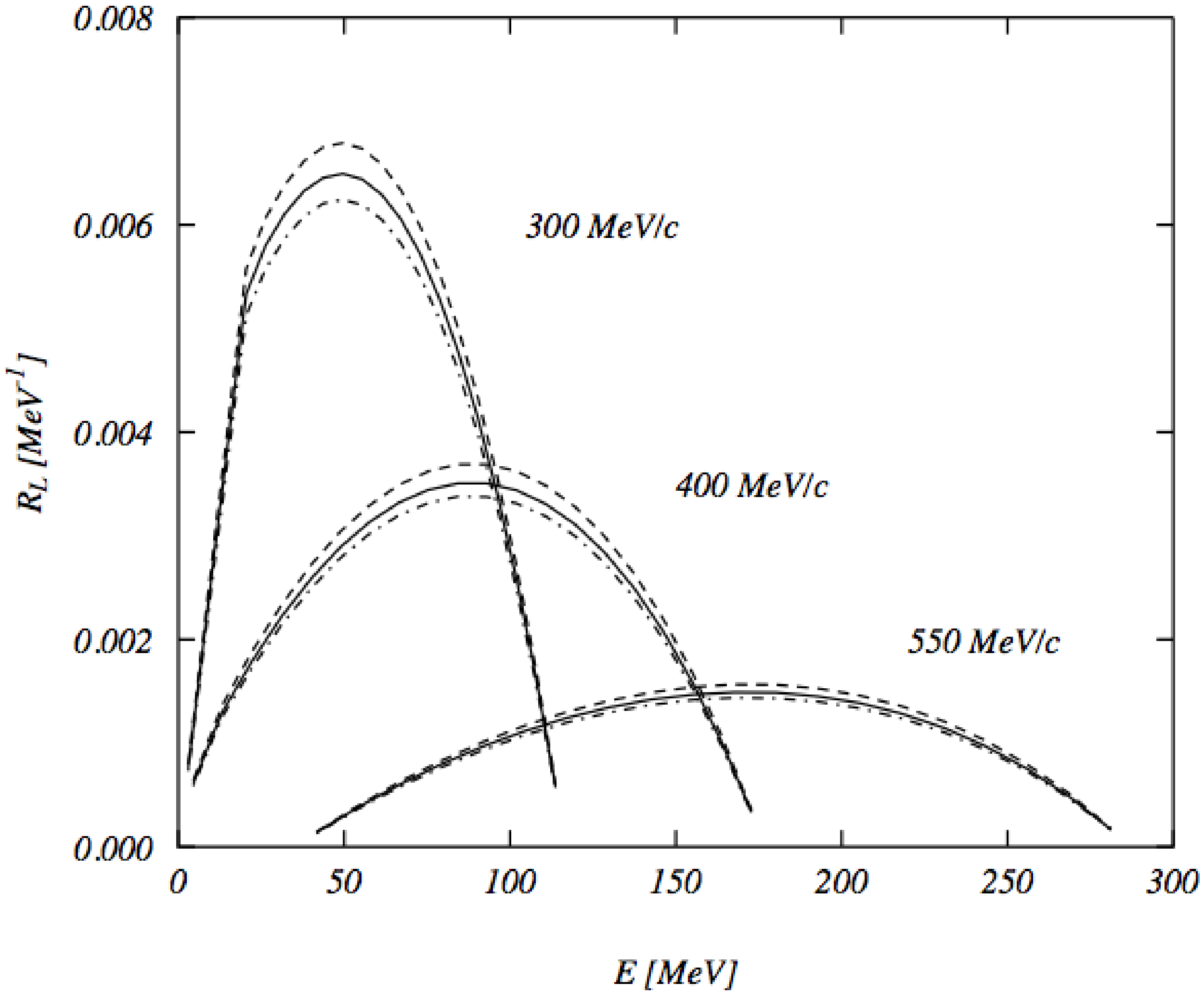
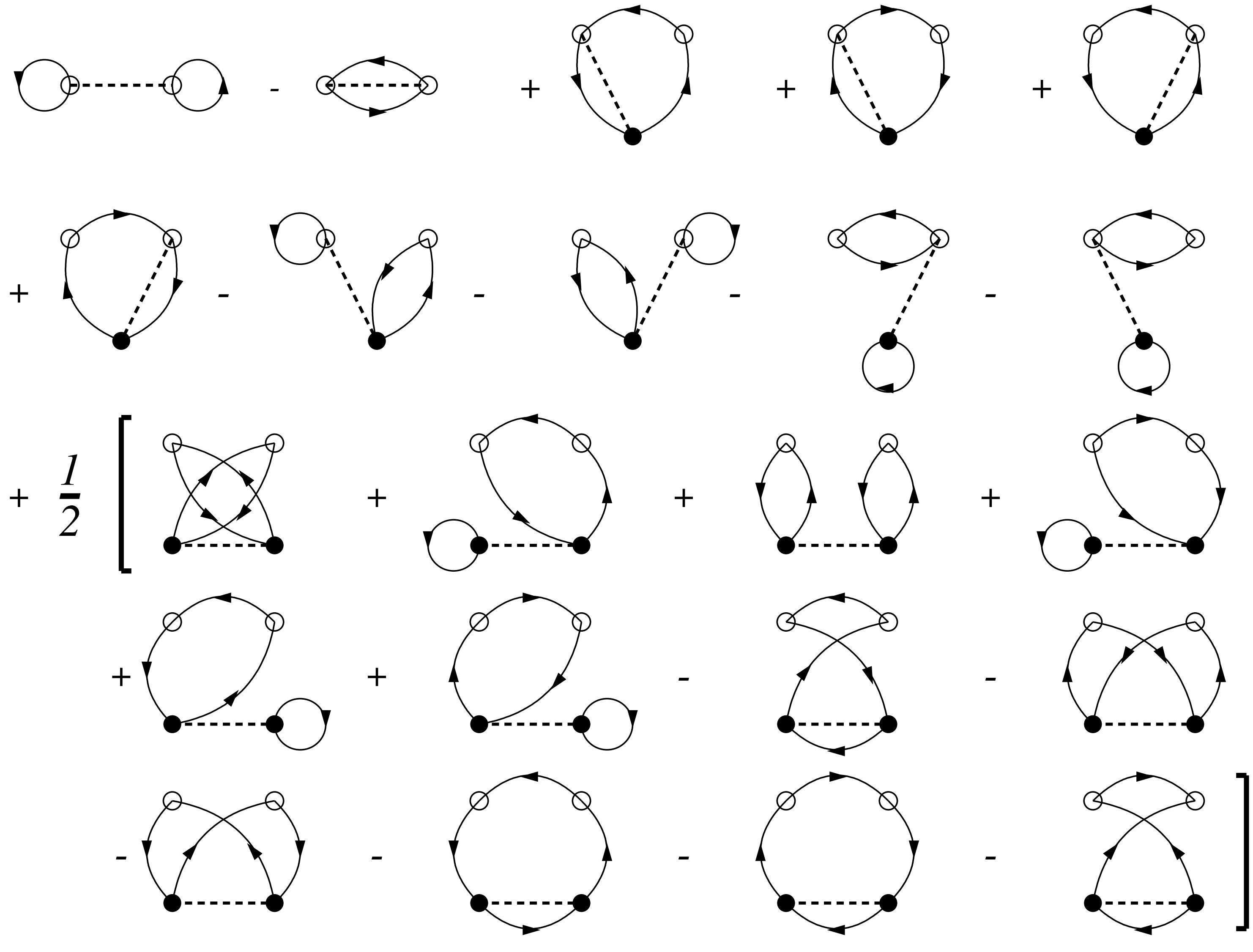
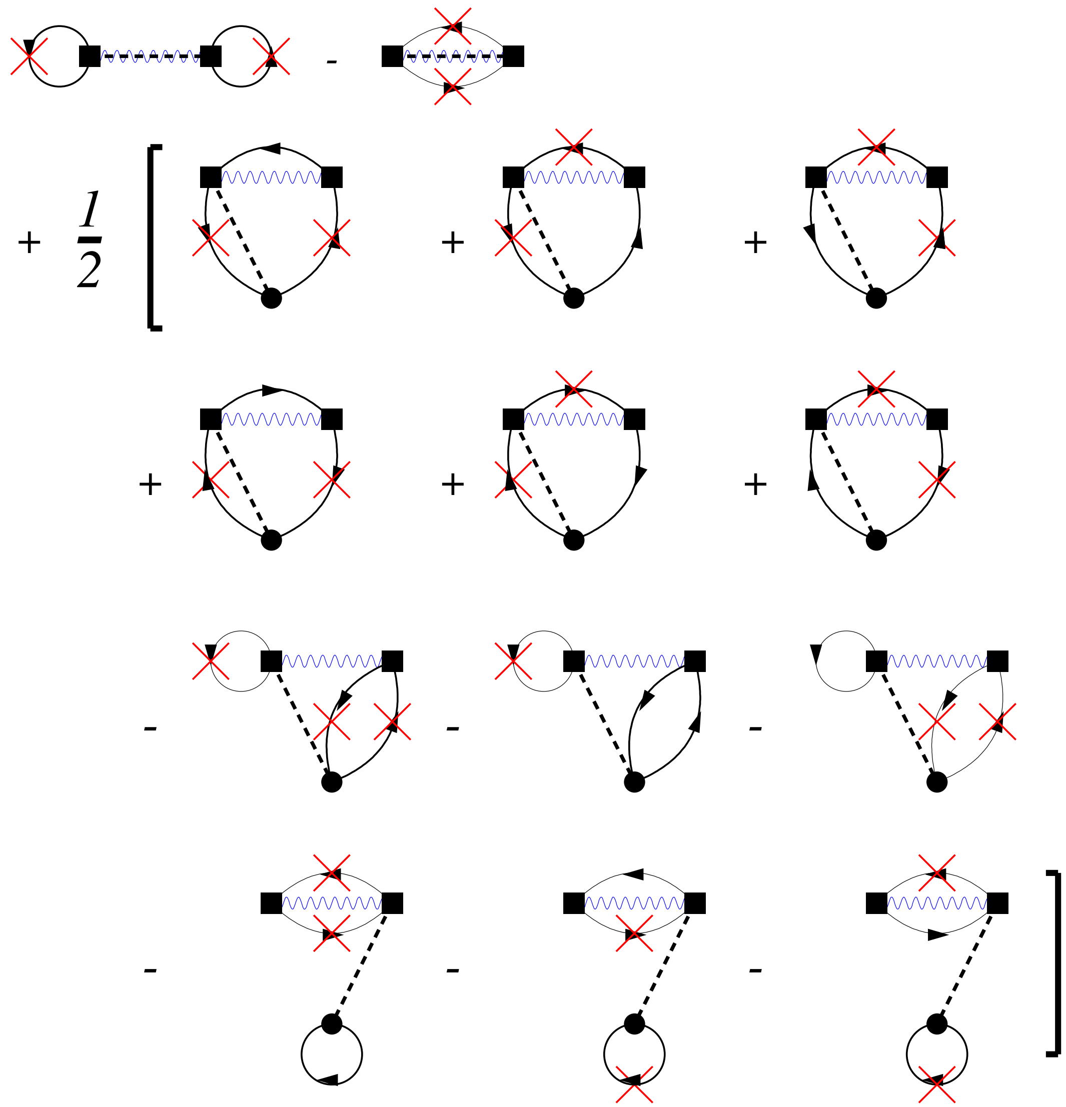


Nuclear matter
charge response
Dashed lines - MF
D-d lines - 2 points
Full lines 2+3 point.

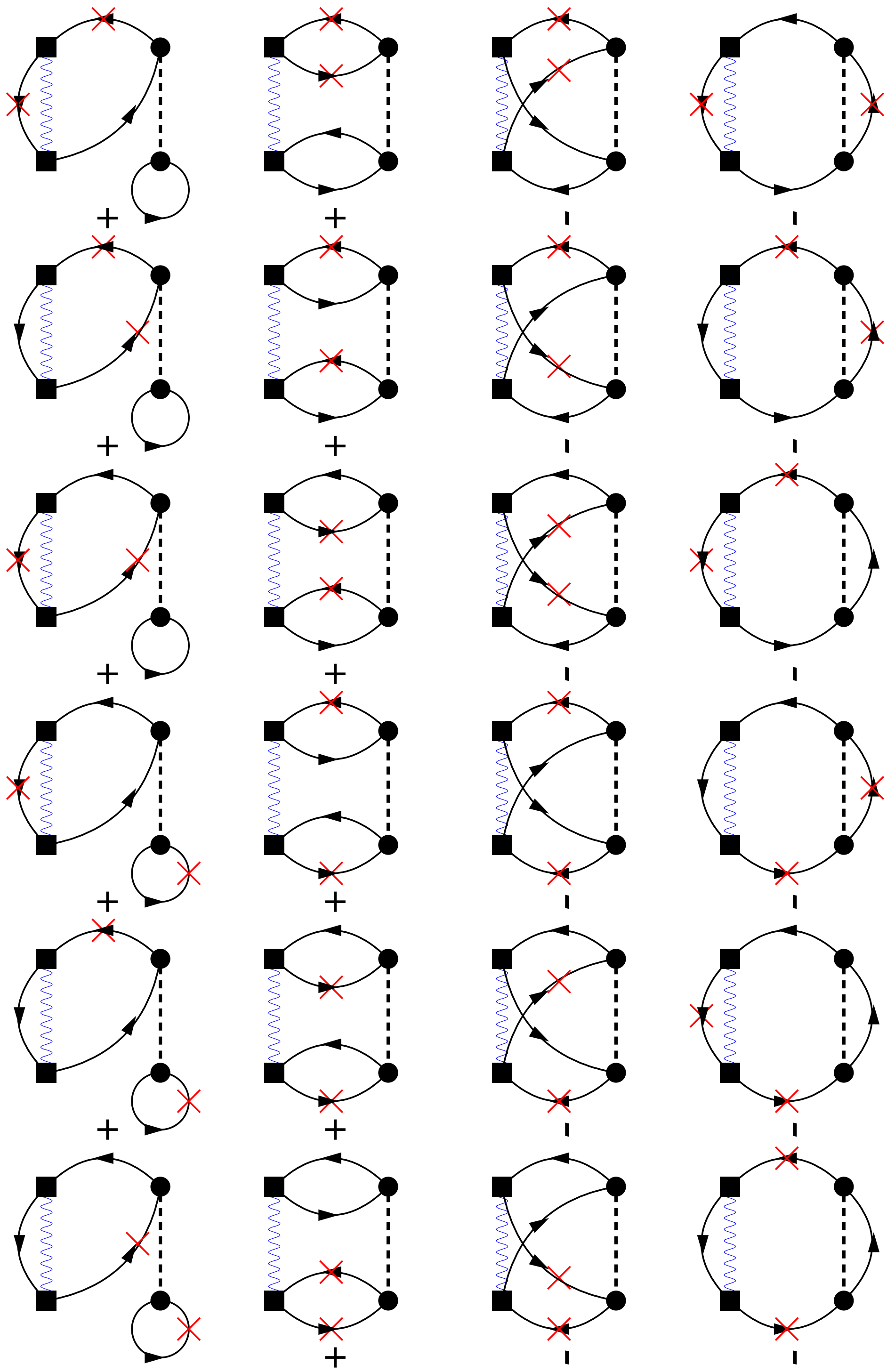
J.E.Amaro,
A.M.Lallena,
G. Co' and A.Fabrocini
Phys. Rev. C 57
(1998) 3473;

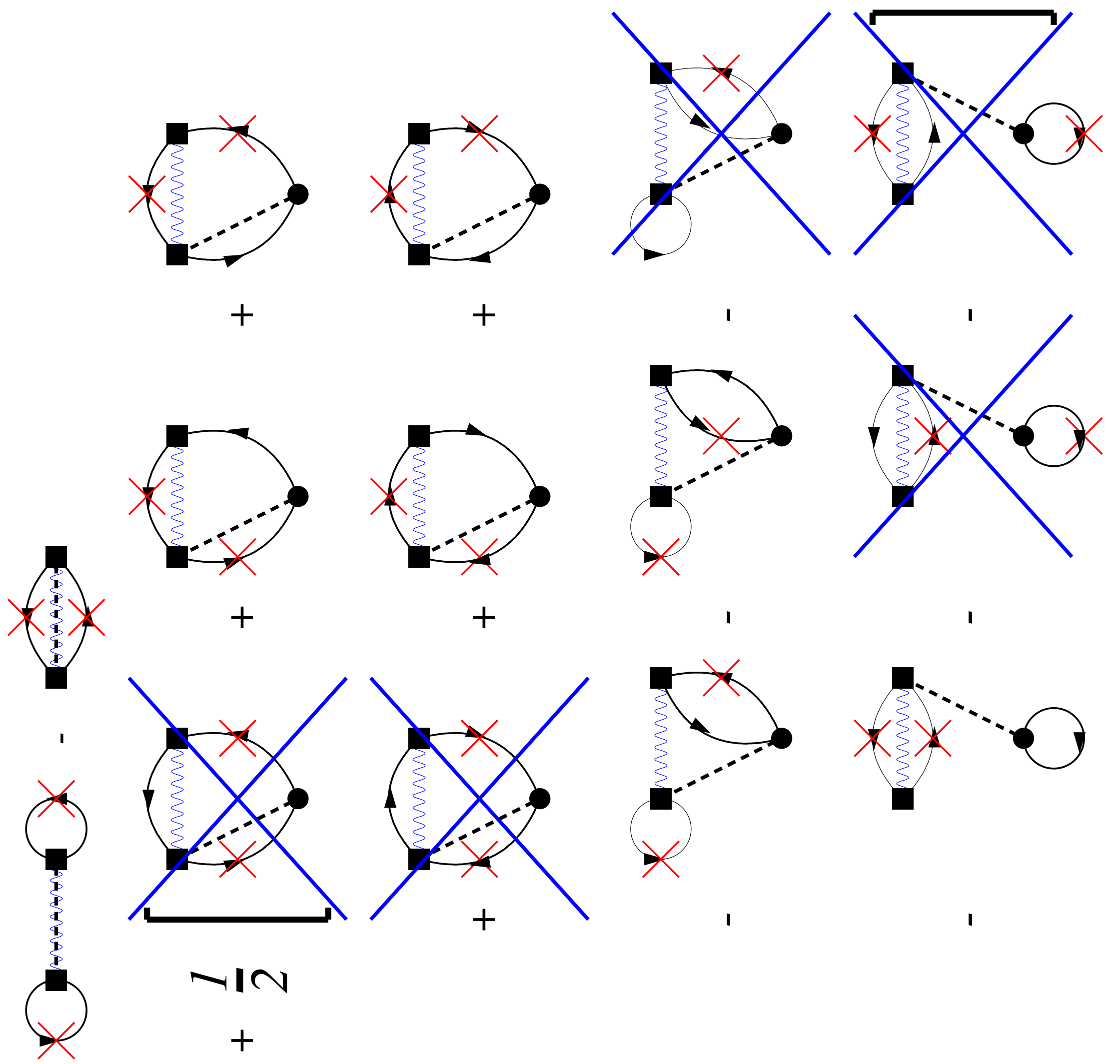
$$\rho^{\mathrm{II}}(\mathbf{r}_1, \mathbf{r}_2) = \rho^{\mathrm{II,MF}}(\mathbf{r}_1, \mathbf{r}_2) +$$

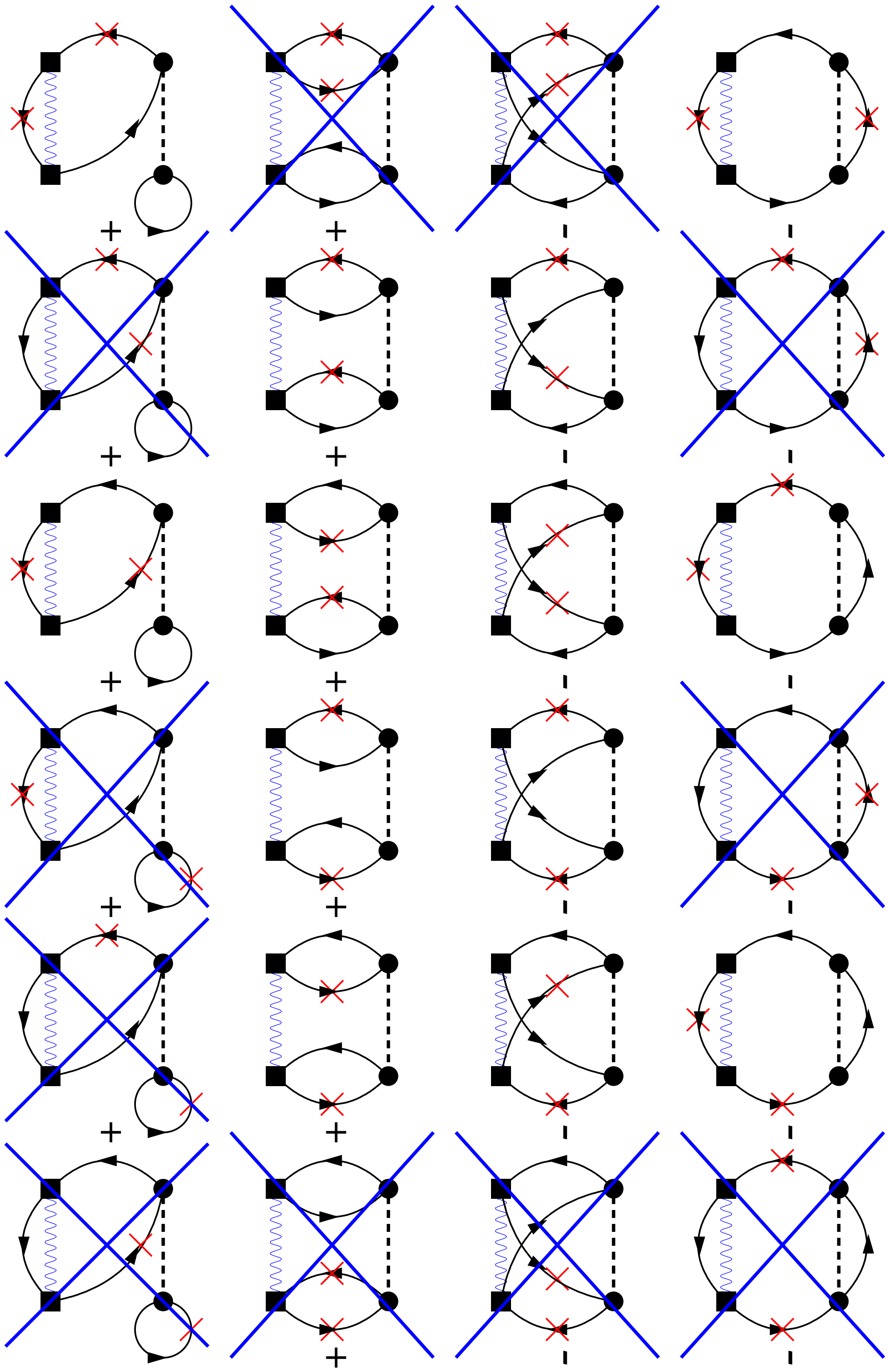




-
+
1
2







Adelchi Fabrocini 1951 - 2006