

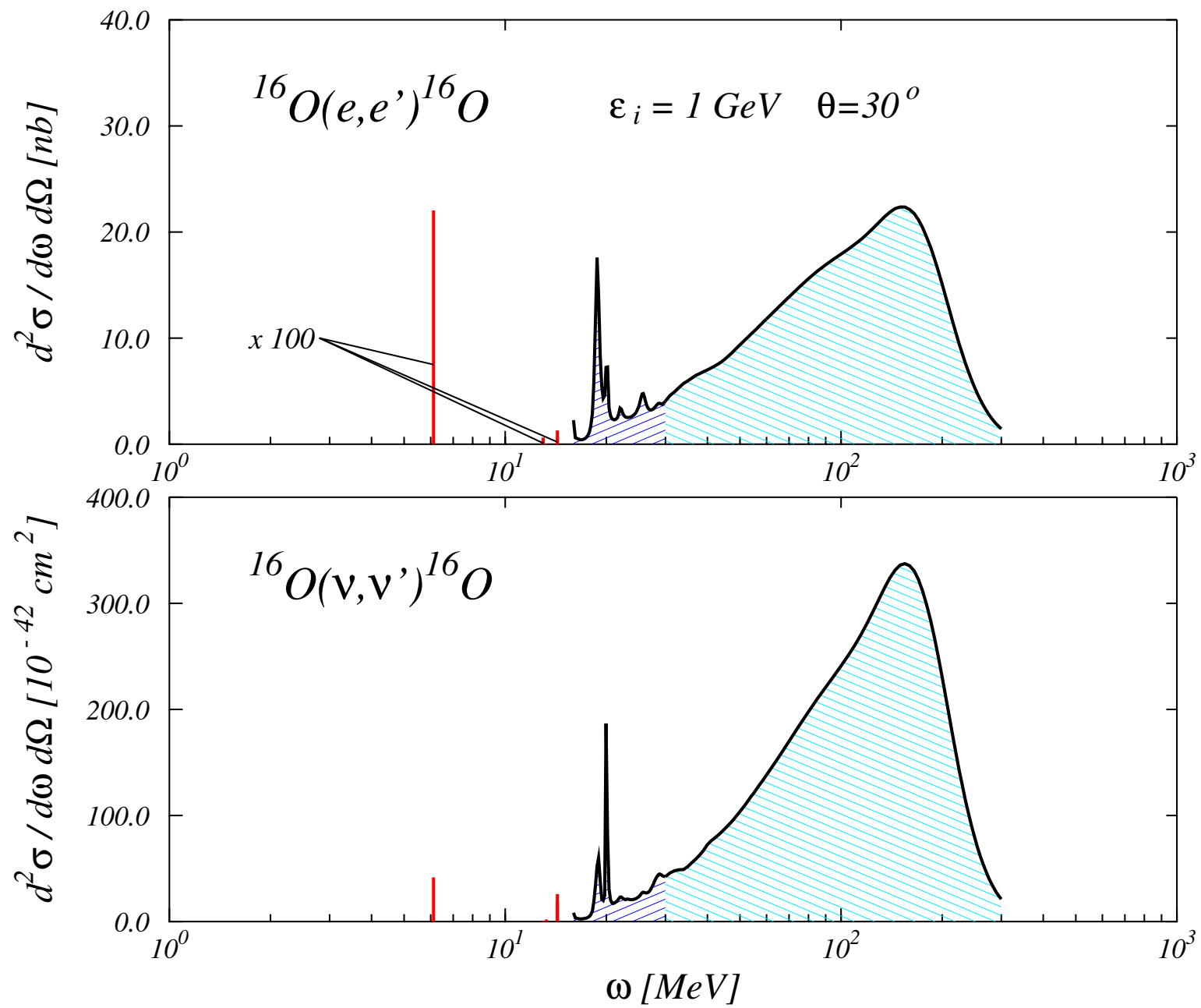
Wrocław, Dec. 7-10, 2005

20th Max Born Symposium

**Random Phase Approximation
and
neutrino-nucleus cross sections**

Giampaolo Co'

University and INFN, Lecce, ITALY



Random Phase Approximation (RPA)

$$|\Psi_n\rangle = Q_n^\dagger |\Psi_o\rangle \quad Q_n |\Psi_o\rangle = 0$$

$$Q_n^\dagger = \sum_{ph} \textcolor{red}{X}_{ph}^n a_p^\dagger a_h + \sum_{ph} \textcolor{red}{Y}_{ph}^n a_h^\dagger a_p$$

$$W = \sum_{\alpha\beta} w a_\alpha^\dagger a_\beta$$

$$\langle \Psi_n | W | \Psi_o \rangle = \sum_{ph} \textcolor{red}{X}_{ph}^n \langle p | w | h \rangle - \sum_{ph} \textcolor{red}{Y}_{ph}^n \langle h | w | p \rangle$$

Equations of motion

$$\begin{aligned} & \langle \Psi_o | [\delta Q_n^+, [H^{eff}, Q_n^+]] | \Psi_o \rangle \\ &= (E_n - E_o) \langle \Psi_o | [\delta Q_n^+, Q_n^+] | \Psi_o \rangle \end{aligned}$$

RPA secular equations

$$\begin{pmatrix} A & B \\ B^* & A^* \end{pmatrix} \begin{pmatrix} X \\ Y \end{pmatrix} = (E_n - E_o) \begin{pmatrix} X \\ -Y \end{pmatrix}$$

$$A_{ph,p'h'} = (\epsilon_p - \epsilon_h) \delta_{ph,p'h'} + \langle ph' | V^{eff} | hp' \rangle - \langle ph' | V^{eff} | p'h \rangle$$

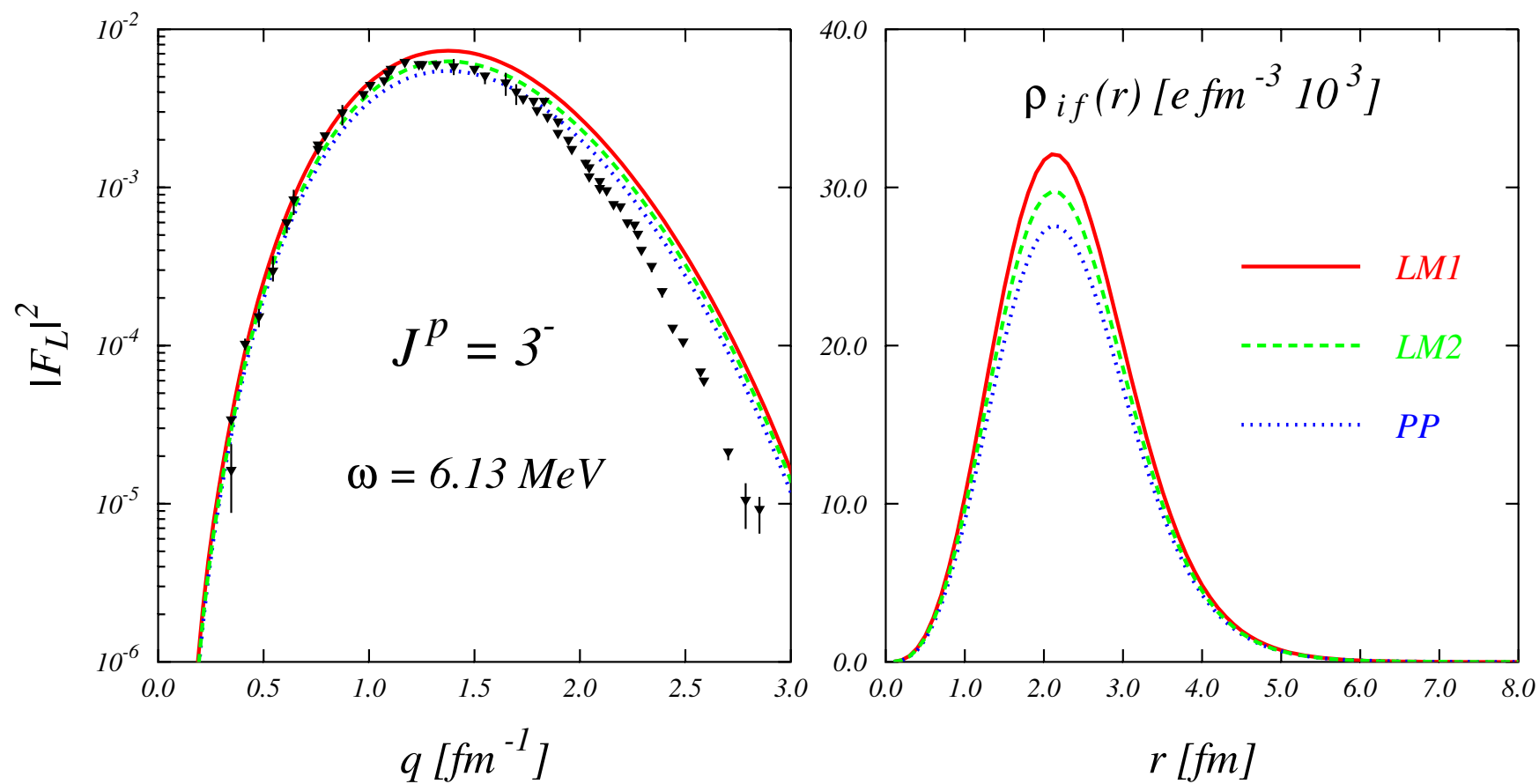
$$B_{ph,p'h'} = \langle pp' | V^{eff} | hh' \rangle - \langle pp' | V^{eff} | h'h \rangle$$

$$\begin{aligned}
V^{eff}(k, \rho) = & \mathcal{K} [F(k, \rho) + F'(k, \rho) \vec{\tau}(1) \cdot \vec{\tau}(2) \\
& + G(k) \vec{\sigma}(1) \cdot \vec{\sigma}(2) \\
& + G'(k) \vec{\sigma}(1) \cdot \vec{\sigma}(2) \vec{\tau}(1) \cdot \vec{\tau}(2)]
\end{aligned}$$

$$F(k, \rho) = F^{ext}(k, \rho) + \left[F^{int}(k, \rho) - F^{ext}(k, \rho) \right] \frac{\rho(r)}{\rho(0)}$$

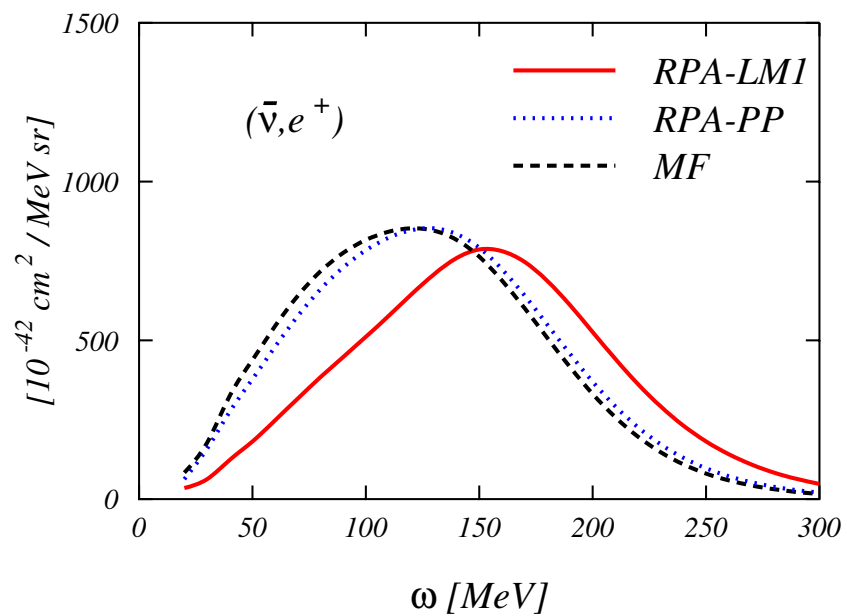
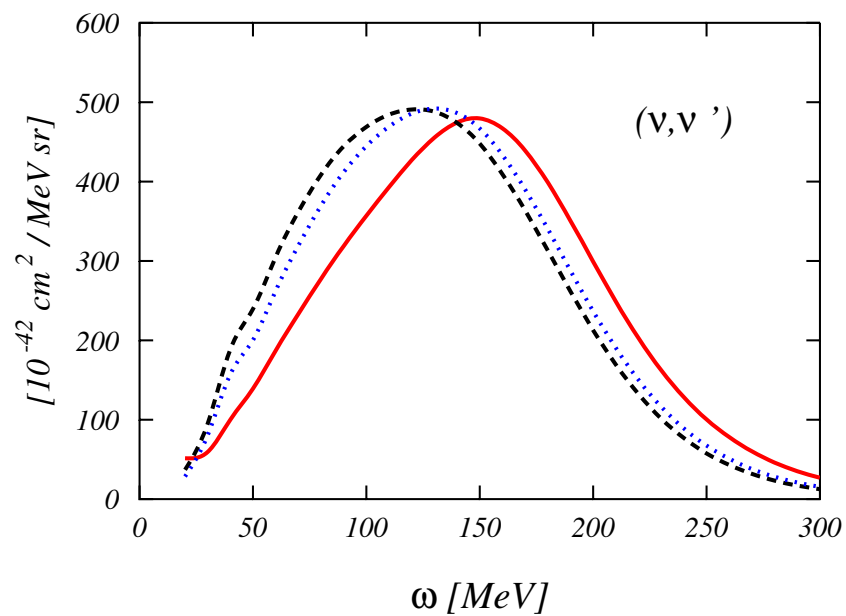
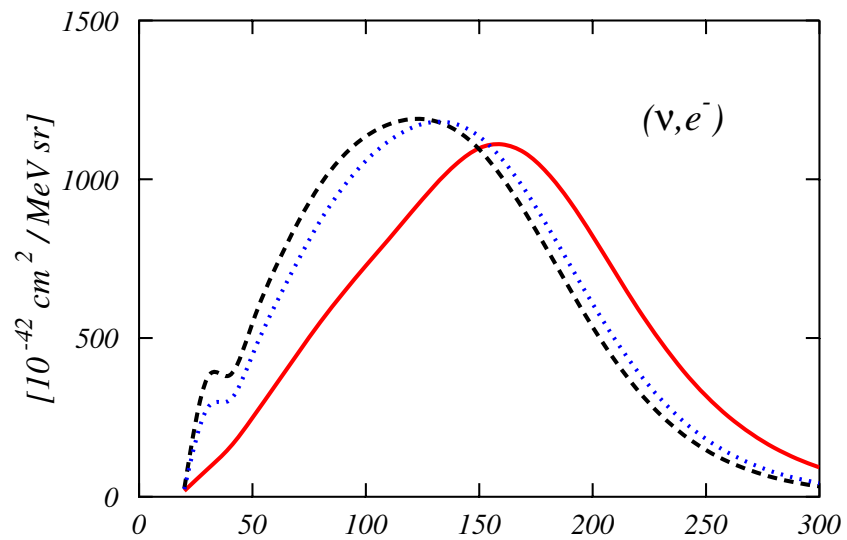
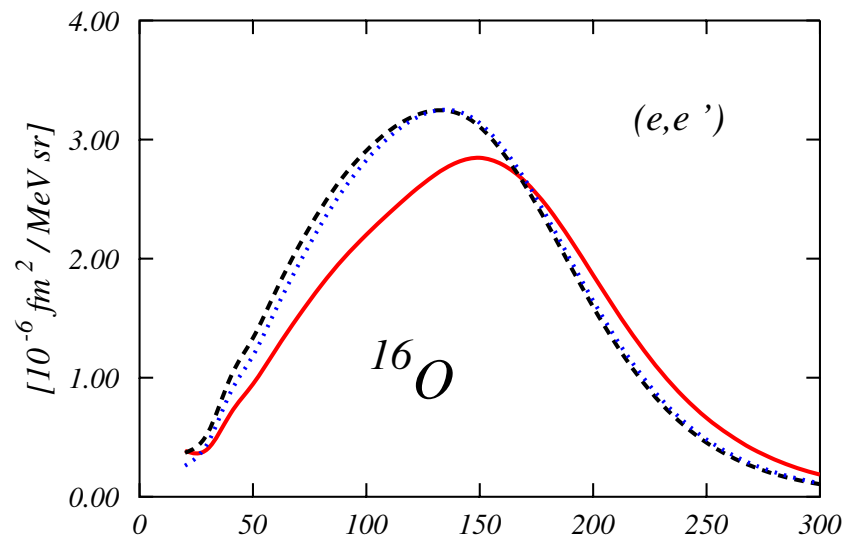
MeV fm ³	F^{ext}	F^{int}	F'^{ext}	F'^{int}	G	G'	$\mathcal{K}$ (¹² C)	$\mathcal{K}$ (¹⁶ O)
LM1	-740.0	60.4	453.0	453.0	166.1	211.4	0.8	0.865
LM2	-630.0	0.0	450.0	195.0	0.0	300.0	1.0	0.865
PP	-1007.0	-54.7	677.8	201.3	60.0	241.0	1.2	1.030
NuInt05	-740.0	60.4	453.0	302.0	-30.2	51.34	1.0	-

$$^{16}\text{O}(e,e')^{16}\text{O}$$



Data: T.N. Buti et al. , Phys. Rev. C 33 (1986) 755.

$$\varepsilon_i = 1 \text{ GeV } \theta = 30^\circ$$

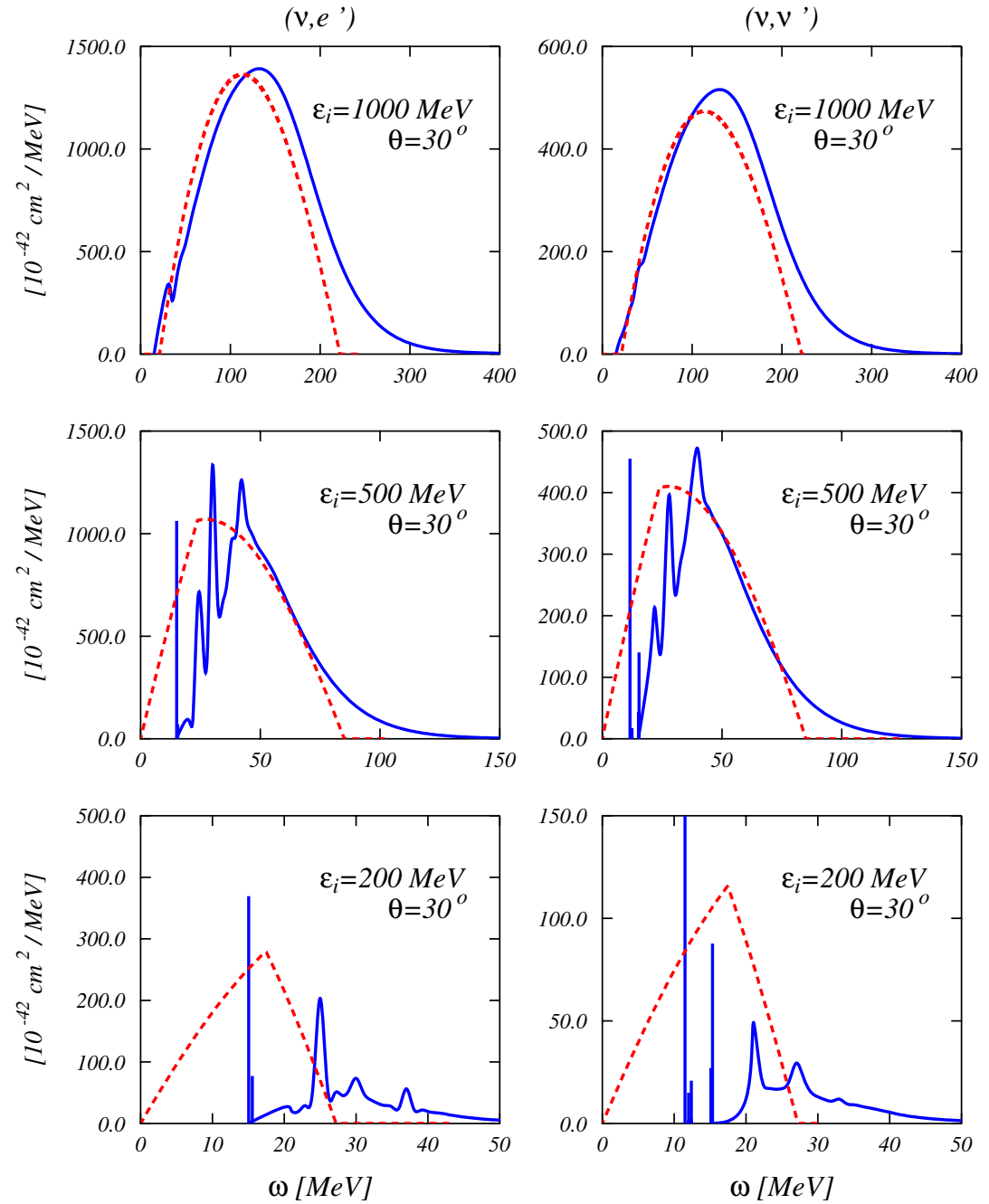


FG calculations by
M.B. Barbaro and
C. Maieron

$$k_F = 216 \text{ MeV}/c$$

$$\epsilon_B = 0$$

^{16}O



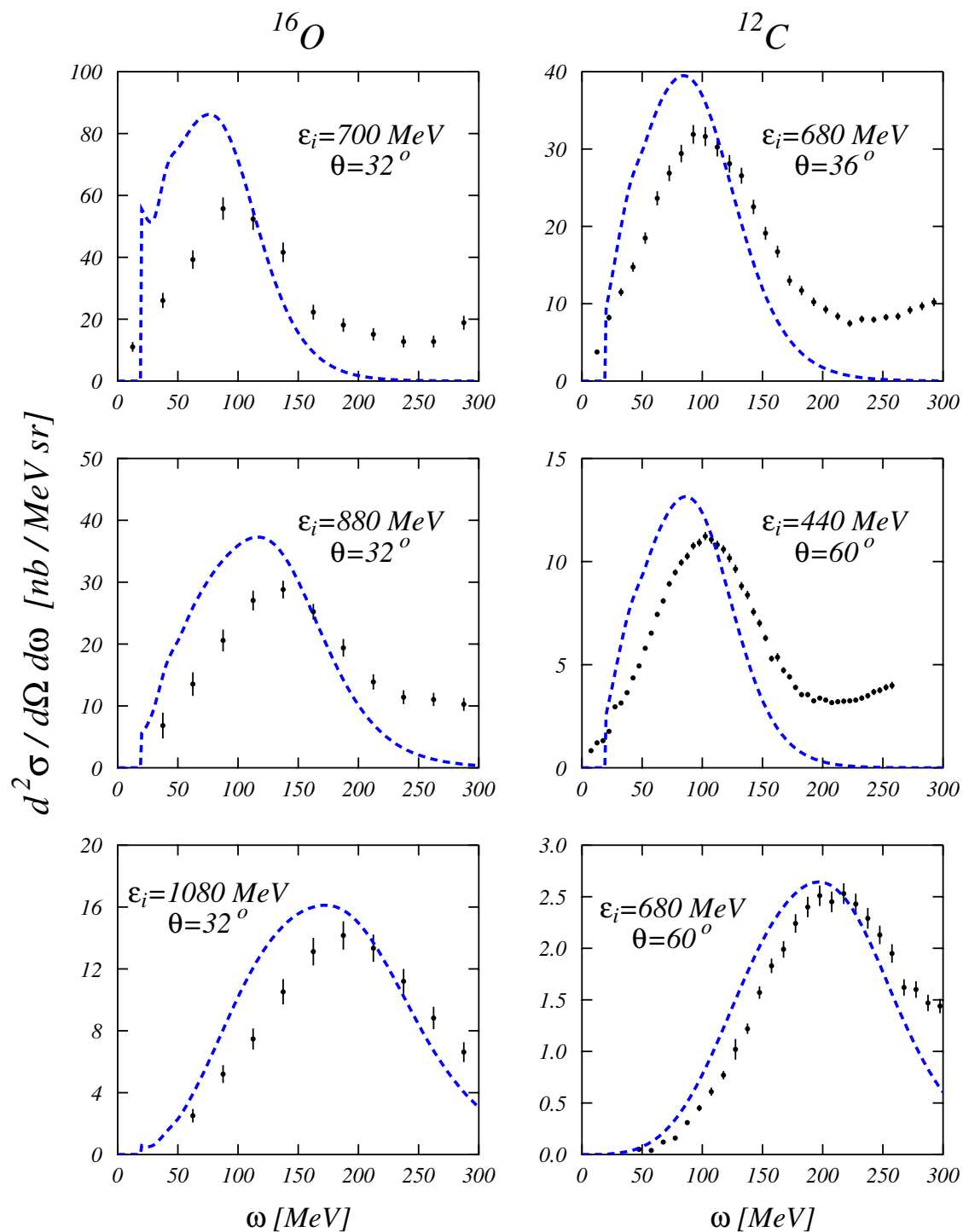
DATA:

M.Anghinolfi *et al.*,

Nucl. Phys. A 602 (1996) 405.

P.Barreau *et al.*,

Nucl. Phys. A 402 (1983) 515.



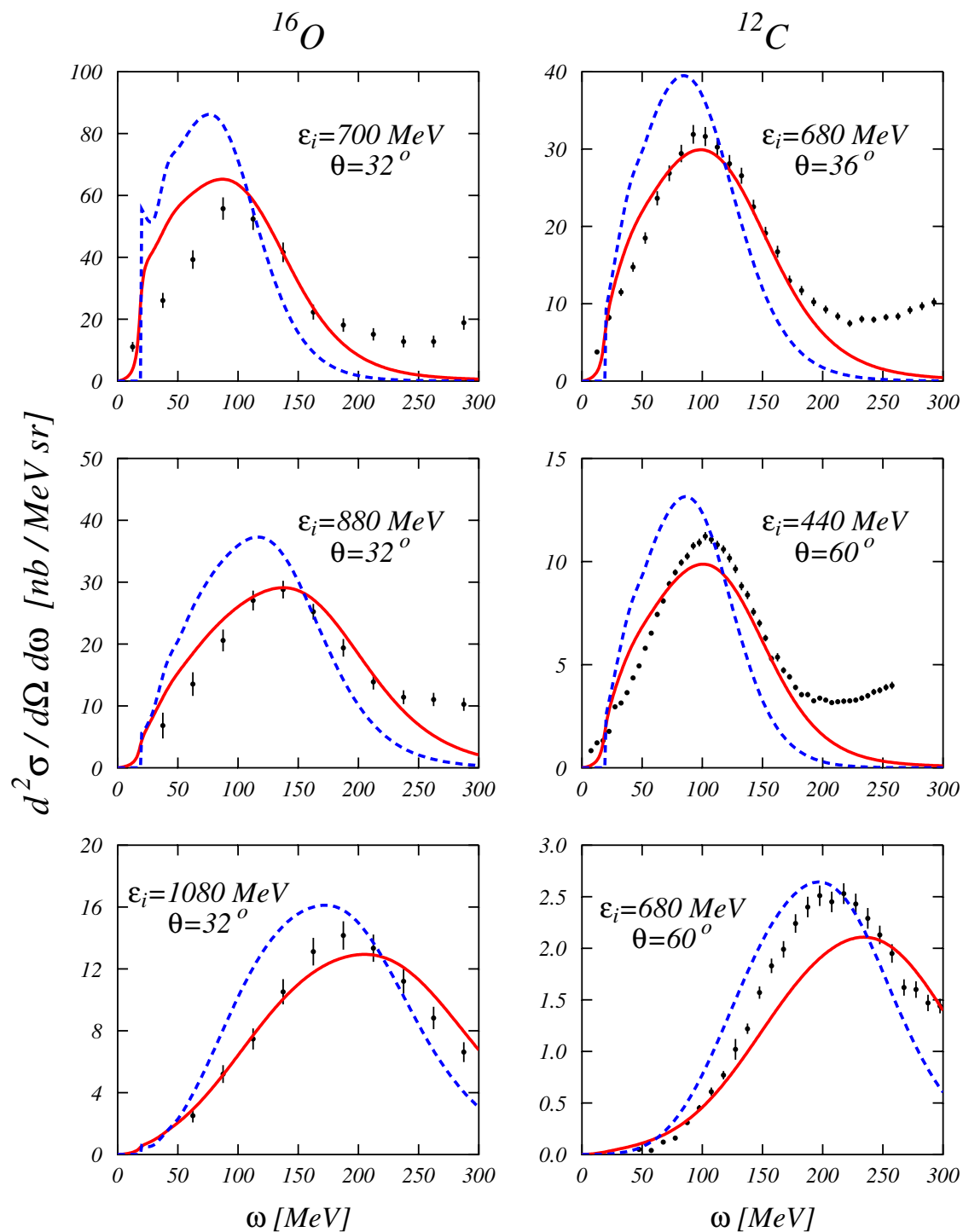
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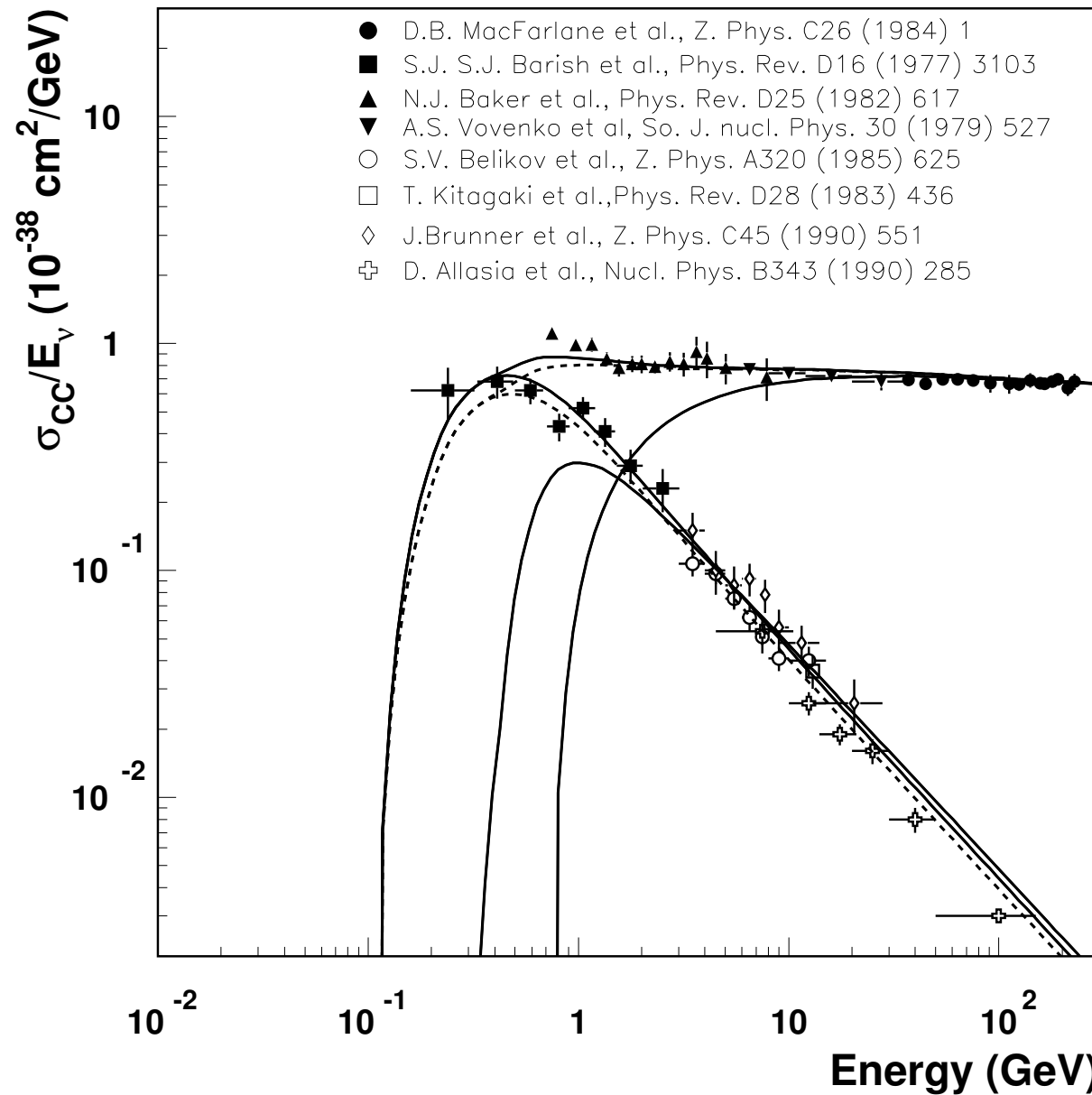
M.Anghinolfi *et al.*,

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P.Barreau *et al.*,

Nucl. Phys. A 402 (1983) 515.





C. Bleve et al. Astroparticle Phys. 16 (2001) 145

- Kinematics definition of the quasi-elastic regime
- Finite size effects
- RPA effects
- Final State Interactions
- Relativity
- Short-range correlations effects
- Superscaling

Neutrino working group

Barbaro

Torino

Benhar, Farina

Roma I

Co'

Lecce

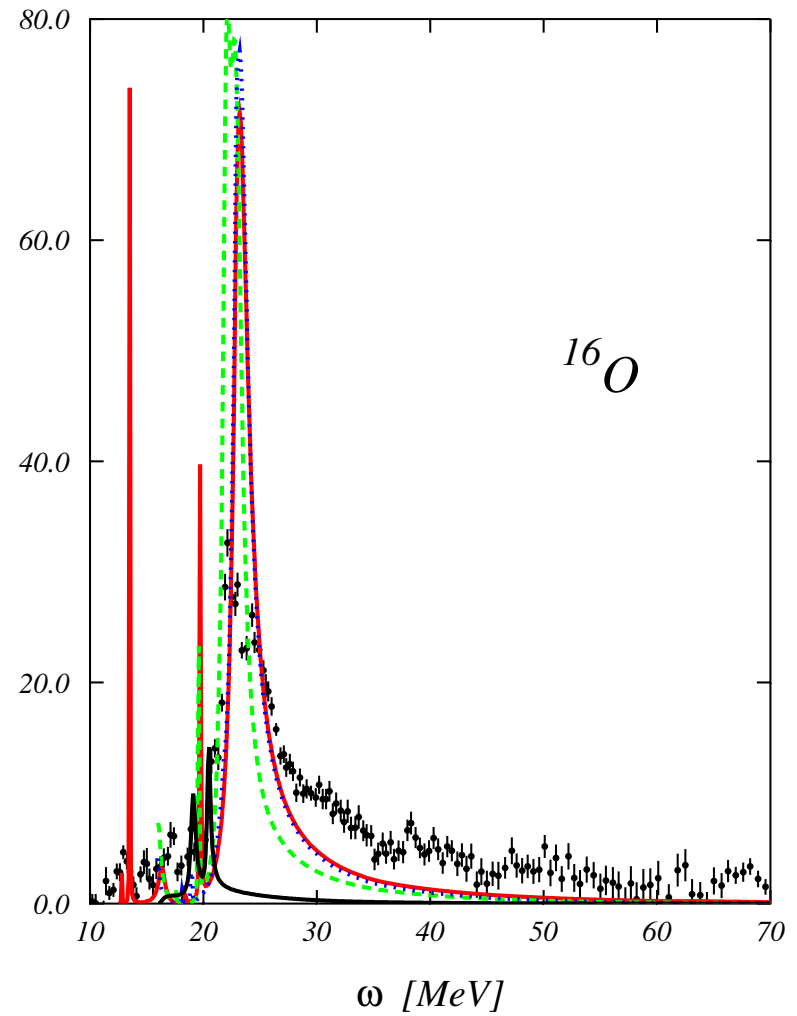
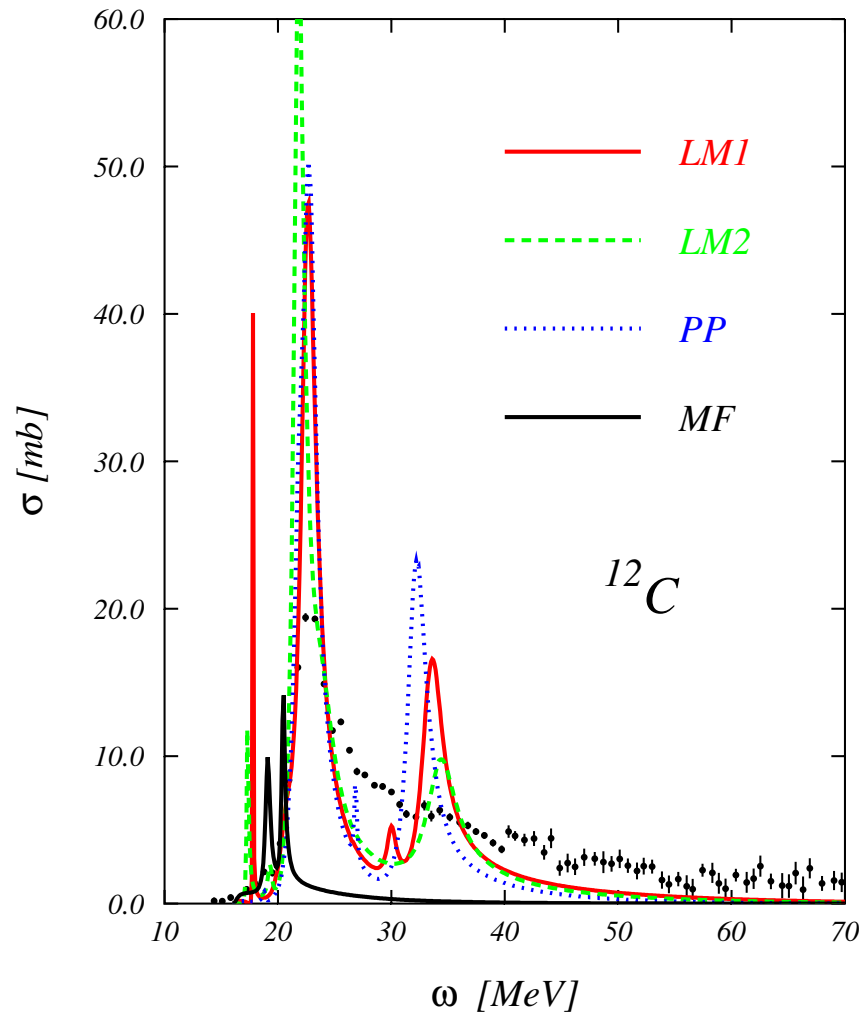
Giusti, Meucci, Pacati

Pavia

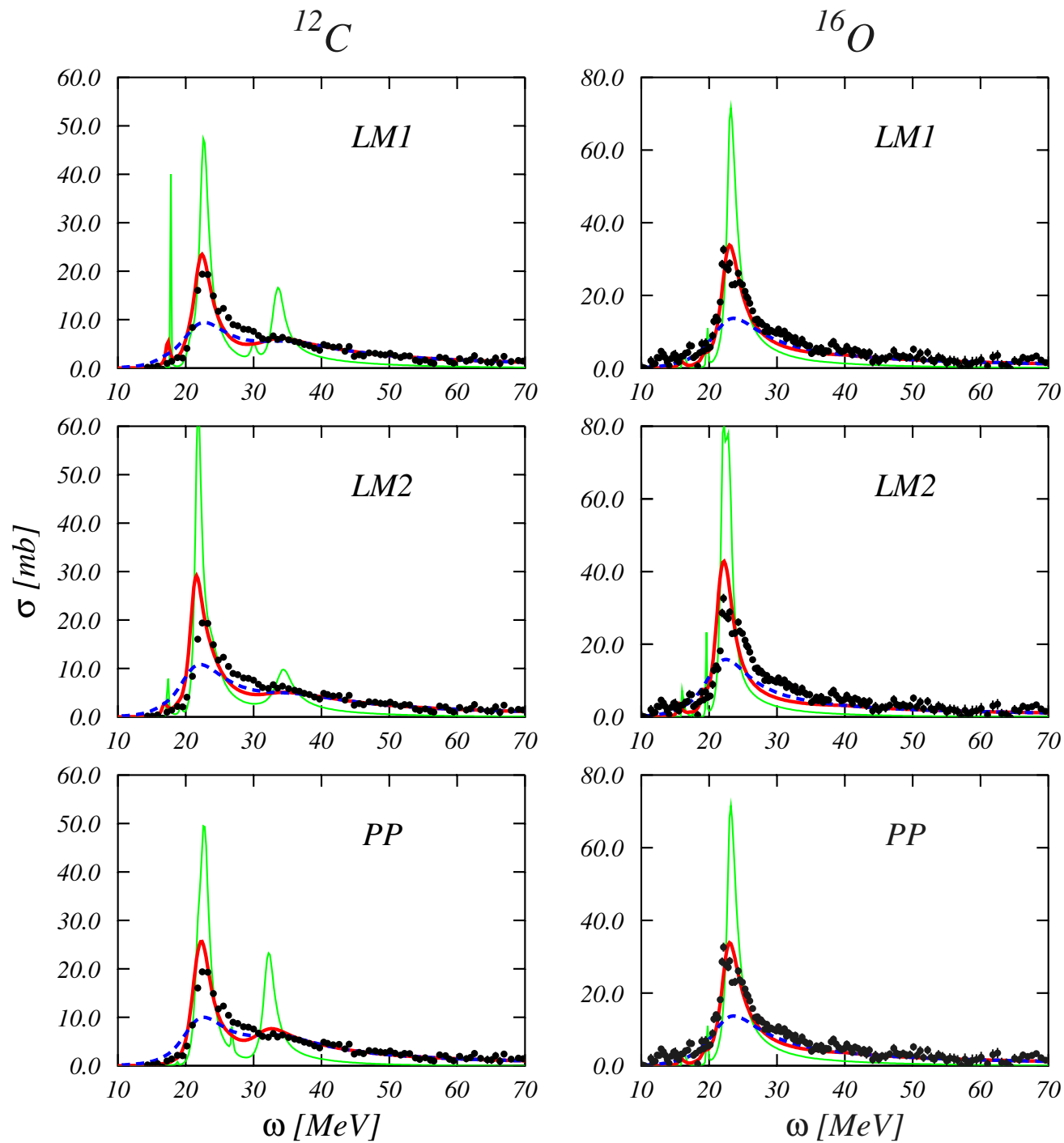
Maieron

Catania

PHOTOABSORPTION



DATA: J. Ahrens et al., Nucl. Phys. A 251 (1975) 479.



$$^{12}\text{C}(e,e')^{12}\text{C}$$

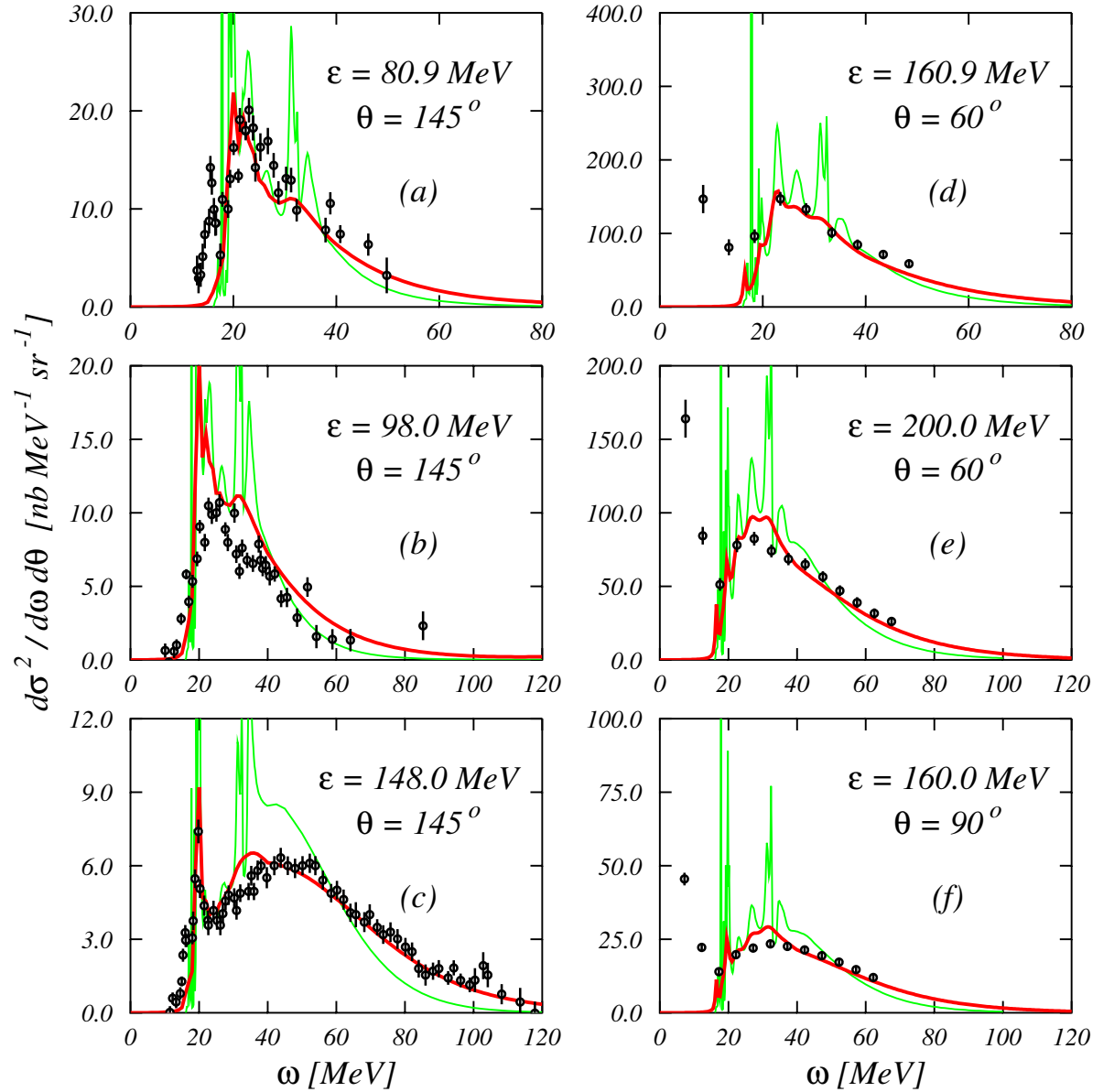
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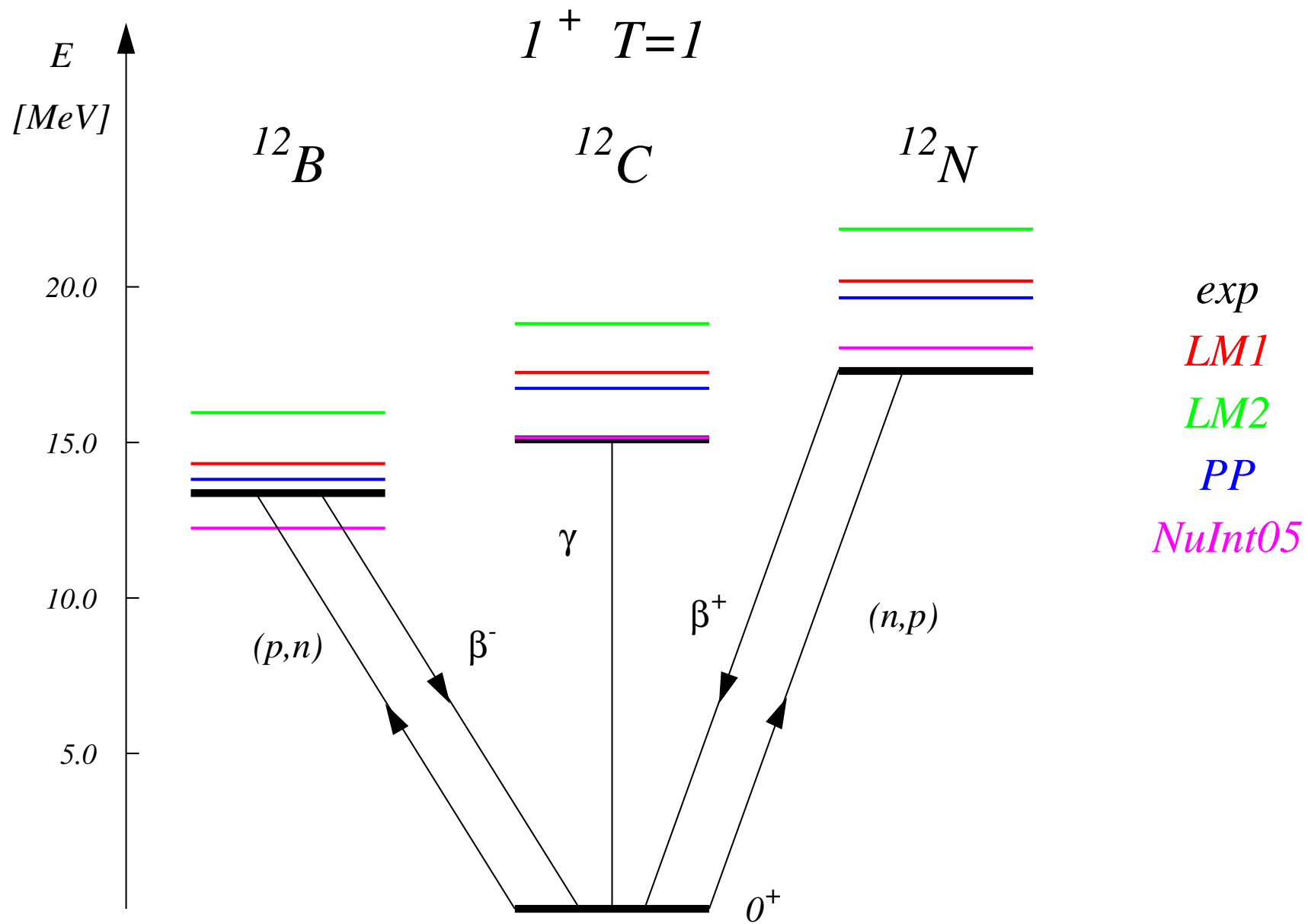
(a,b,c) quoted in E. Kolbe

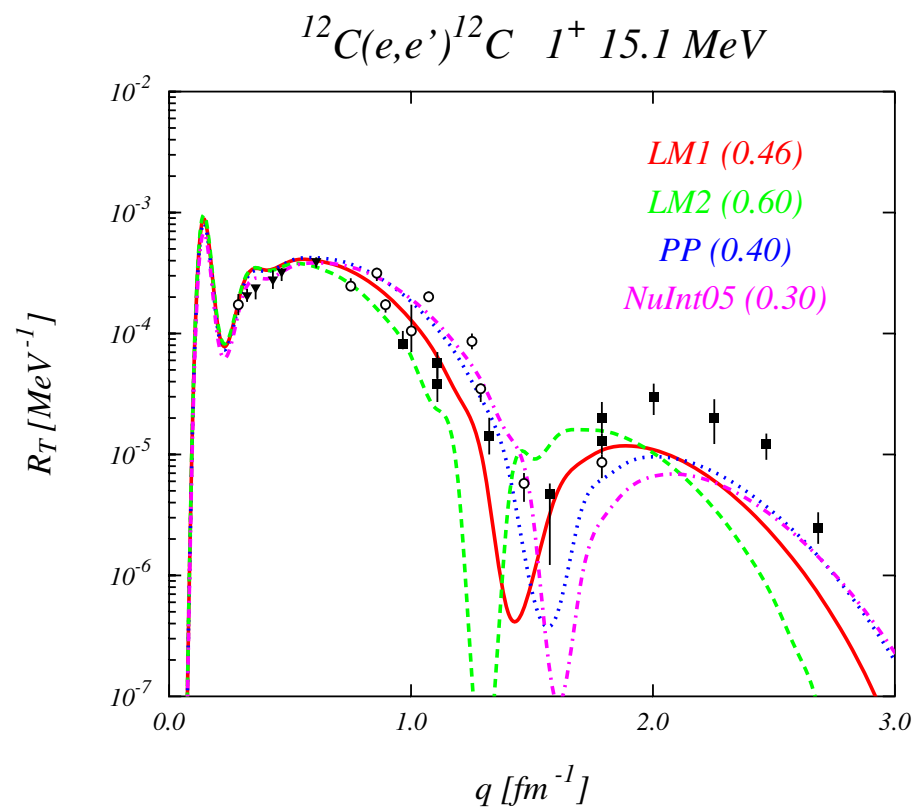
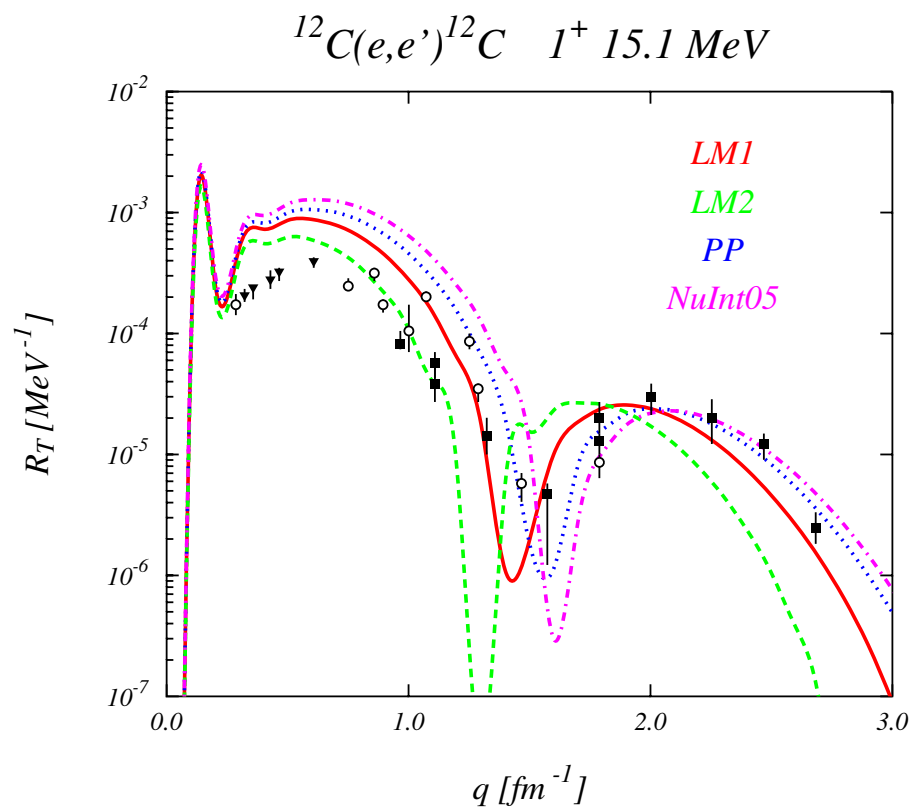
Nucl. Phys. A 602 (1996) 405.

(d,e,f) P.Barreau *et al.*,

Nucl. Phys. A 402 (1983) 515.



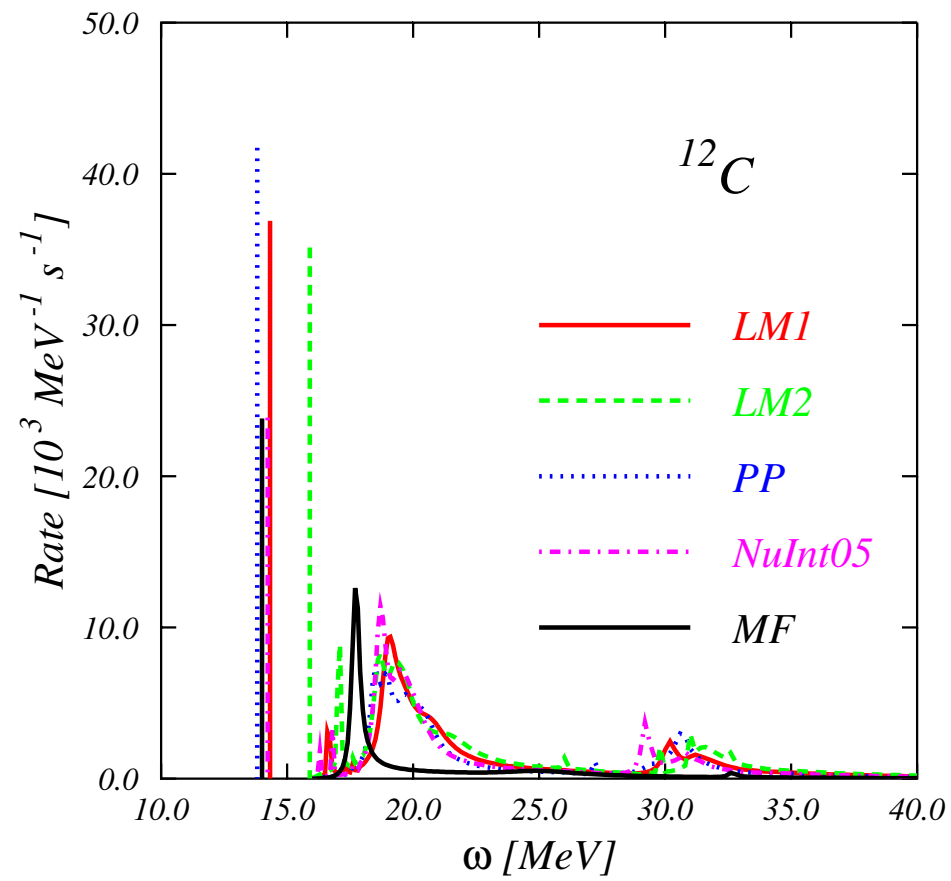


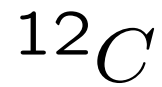


DATA from T.W. Donnelly, J.D. Walecka, I Sick, E.B. Hughes

Phys. Rev. Lett. 21 (1968) 1197.

μ capture

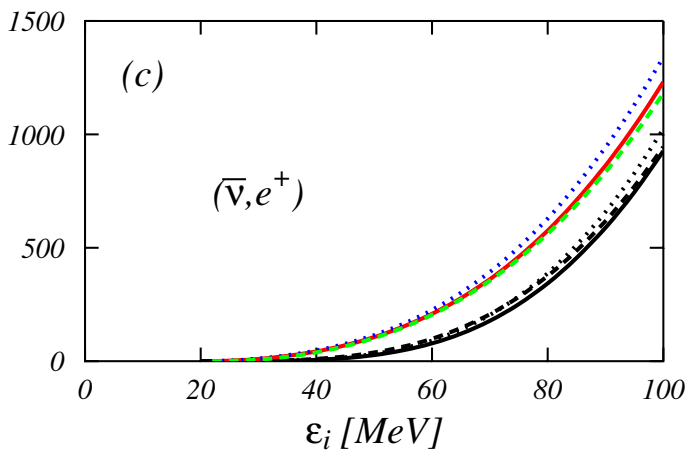
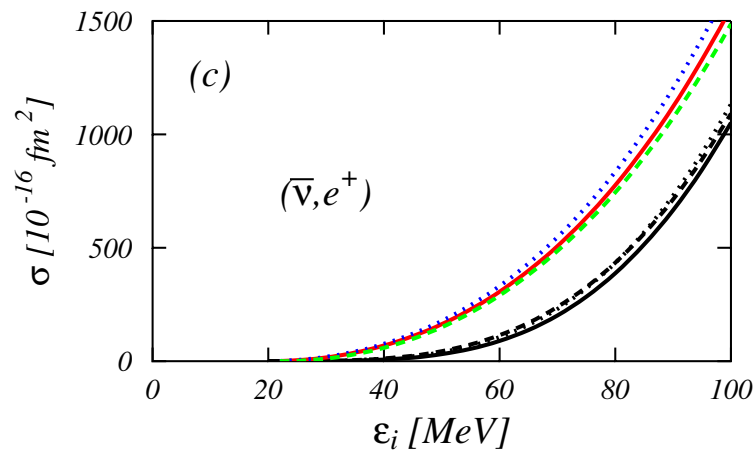
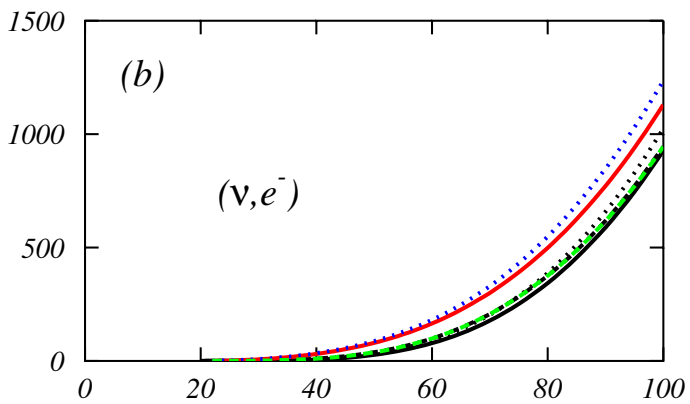
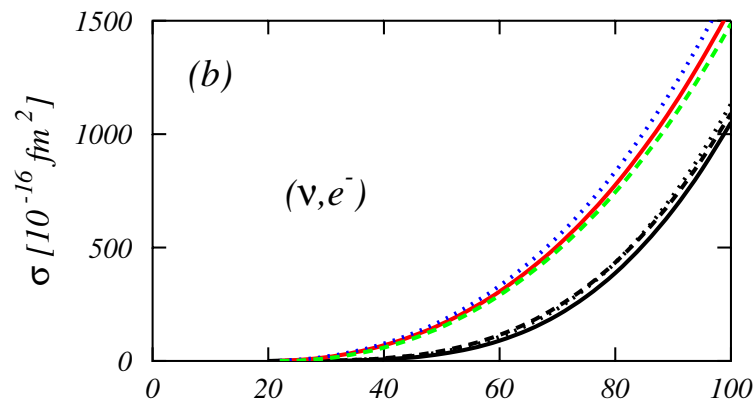
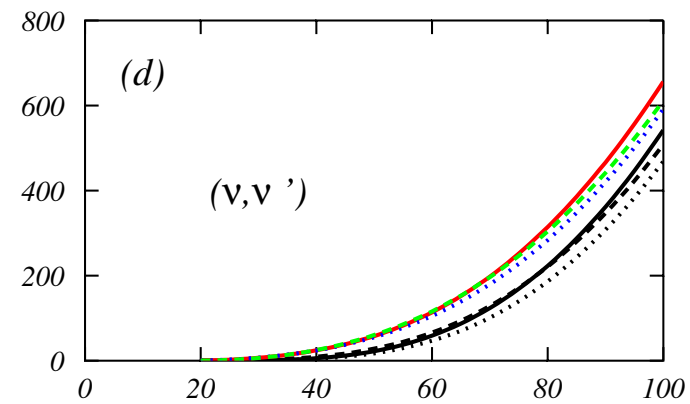
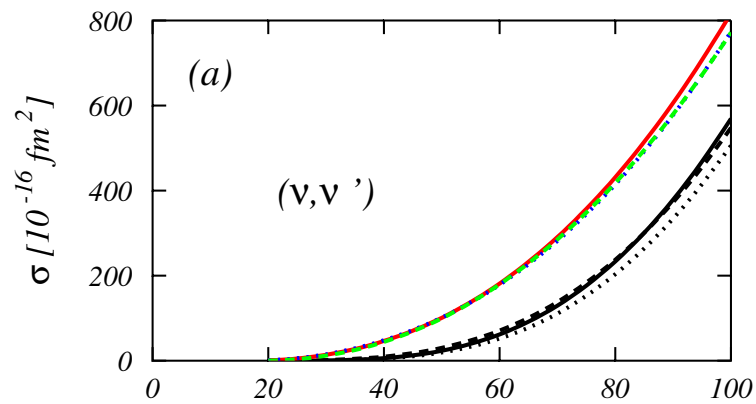




Total Rates 10^3 s^{-1}

	LM1	LM2	PP	NuInt05	MF	exp
1^+	34.93	33.86	34.56	31.57	23.83	6.04
2^+	0.26	0.20	0.35	0.39	0.46	0.21
2^-	1.40	0.79	0.52	8.09	9.04	0.18
1^-	0.32	0.29	6.31	0.98	1.13	0.62
dis	36.90	35.13	41.73	41.03	34.46	7.05
con	31.35	37.09	28.28	31.16	12.48	30.04
tot	68.25	72.22	70.53	72.19	46.94	37.09

Exp: D.F. Measday, Phys. Rep. 354 (2001) 243



$$\mu^+ \rightarrow \bar{\nu}_\mu + \nu_e + e^+$$

$$\sigma[10^{-16} fm^2]$$

$$\text{exp} = 14.0 \pm 1.2$$

	RPA	RPA FSI
LM1	42.0	19.2
LM2	36.0	7.0
PP	46.6	21.3

Exp: B.E. Bodmann et al.

Phys. Lett. B 332 (1994) 251.

