Wrocław, Dec. 7-10, 2005

20th Max Born Symposium

Random Phase Approximation
and
neutrino-nucleus cross sections

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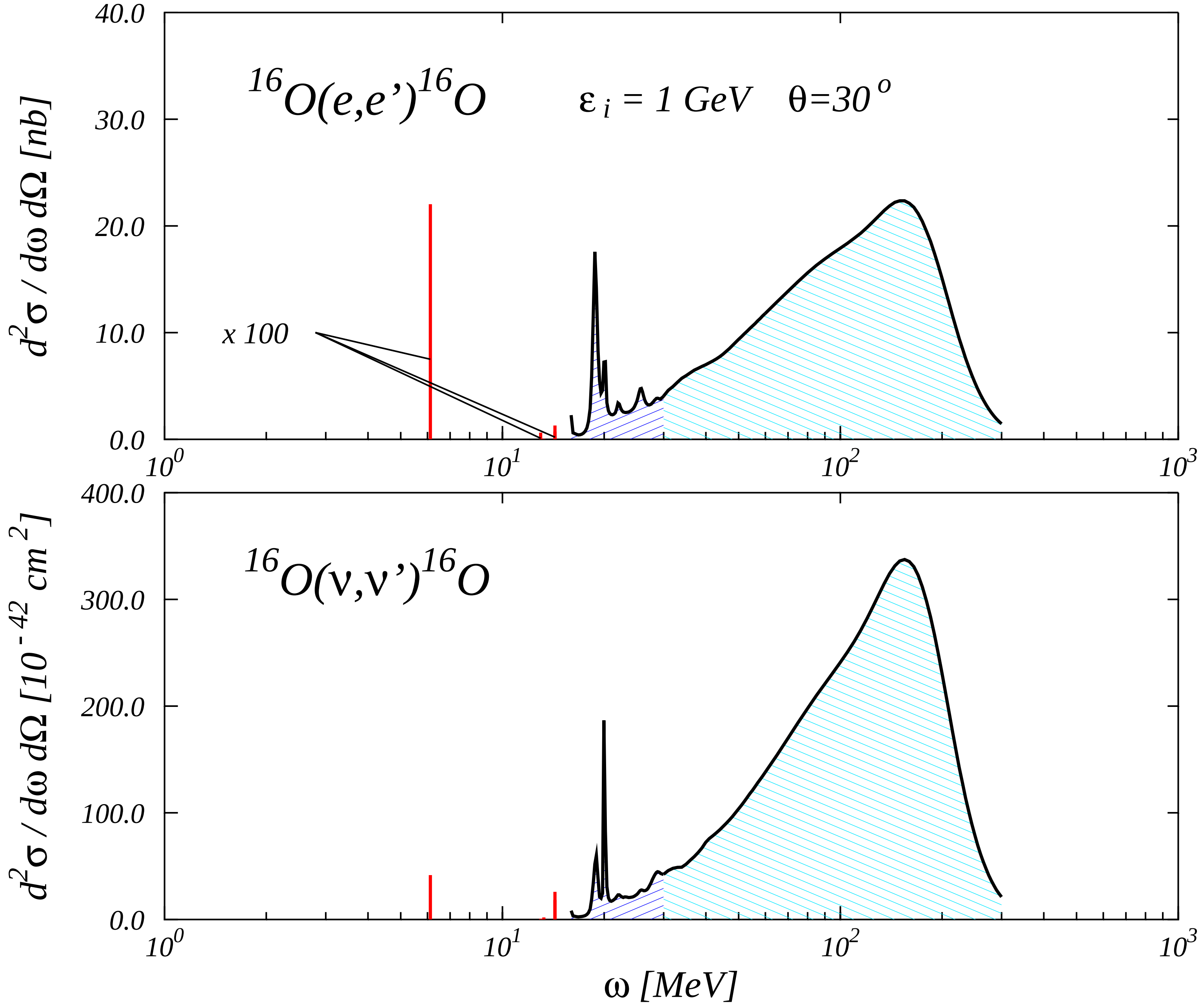


$^{16}O(e,e')^{16}O$
ε_i = 1 GeV θ=30^o
x 100
$d^2\sigma$ / dω dΩ [nb]
40.0
30.0
20.0
10.0
0.0
10^0
10^1
10^2
10^3
$^{16}O(\nu,\nu')^{16}O$
$d^2\sigma$ / dω dΩ [10^{-42} cm^2]
400.0
300.0
200.0
100.0
0.0
ω [MeV]

Random Phase Approximation (RPA)

$$|\Psi_n> = Q_n^+ |\Psi_o> \qquad Q_n|\Psi_o> = 0$$

$$Q_n^+ = \sum_{ph} X_{ph}^n \, a_p^+ a_h + \sum_{ph} Y_{ph}^n \, a_h^+ a_p$$

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

$$< \Psi_n|W|\Psi_o> = \sum_{ph} X_{ph}^n < p|w|h > - \sum_{ph} Y_{ph}^n < h|w|p >$$

Equations of motion

$$< \Psi_o| \left[\delta Q_n^+, \left[H^{eff}, Q_n^+,\right]\right] |\Psi_o >$$
$$= (E_n - E_o) < \Psi_o| \left[\delta Q_n^+, Q_n^+\right] |\Psi_o >$$

RPA secular equations

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

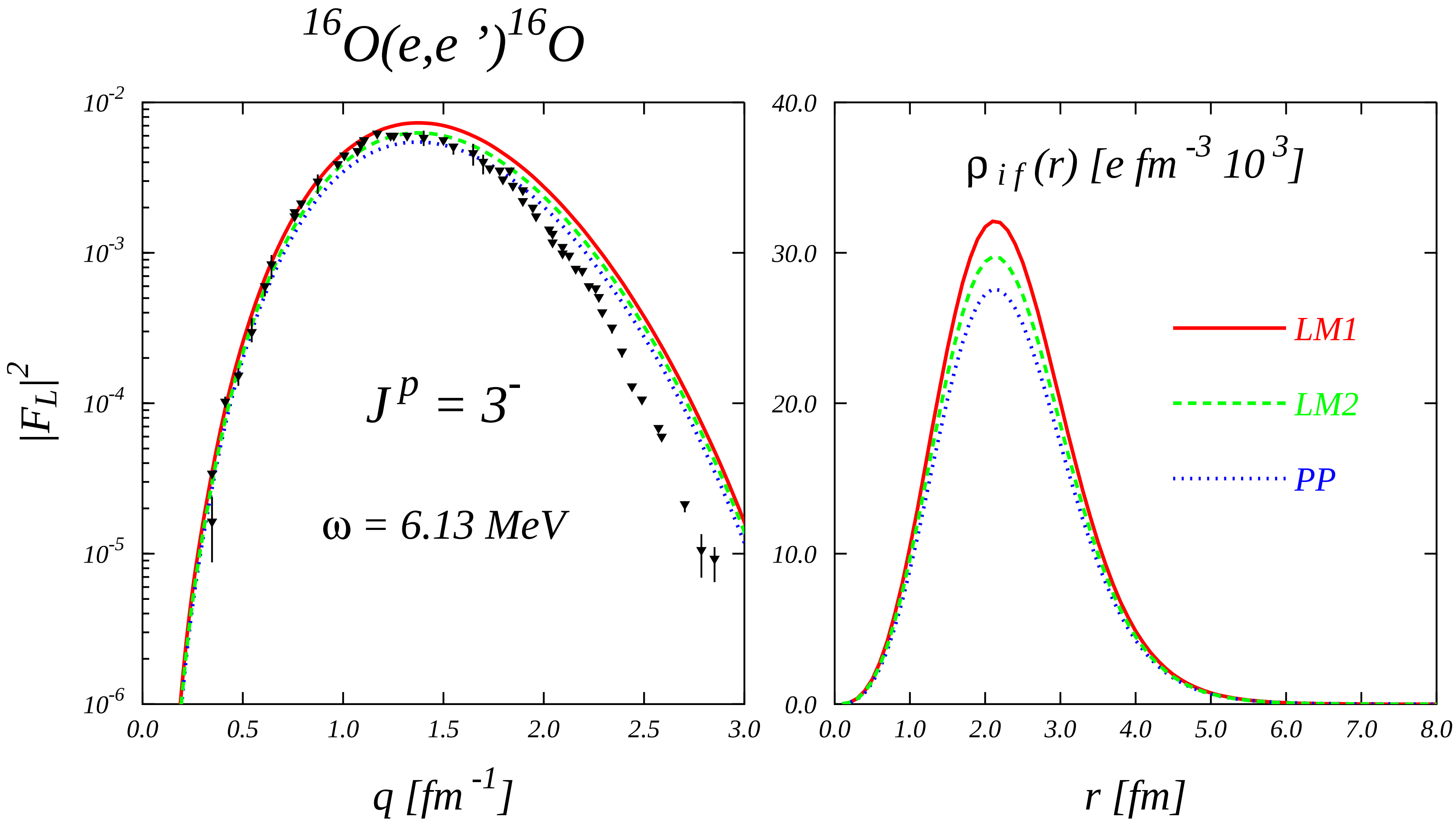
$$A_{ph,p'h'} = (\epsilon_p - \epsilon_h)\delta_{ph,p'h'} + < ph'|V^{eff}|hp' > - < ph'|V^{eff}|p'h >$$

$$B_{ph,p'h'} = < pp'|V^{eff}|hh' > - < pp'|V^{eff}|h'h >$$

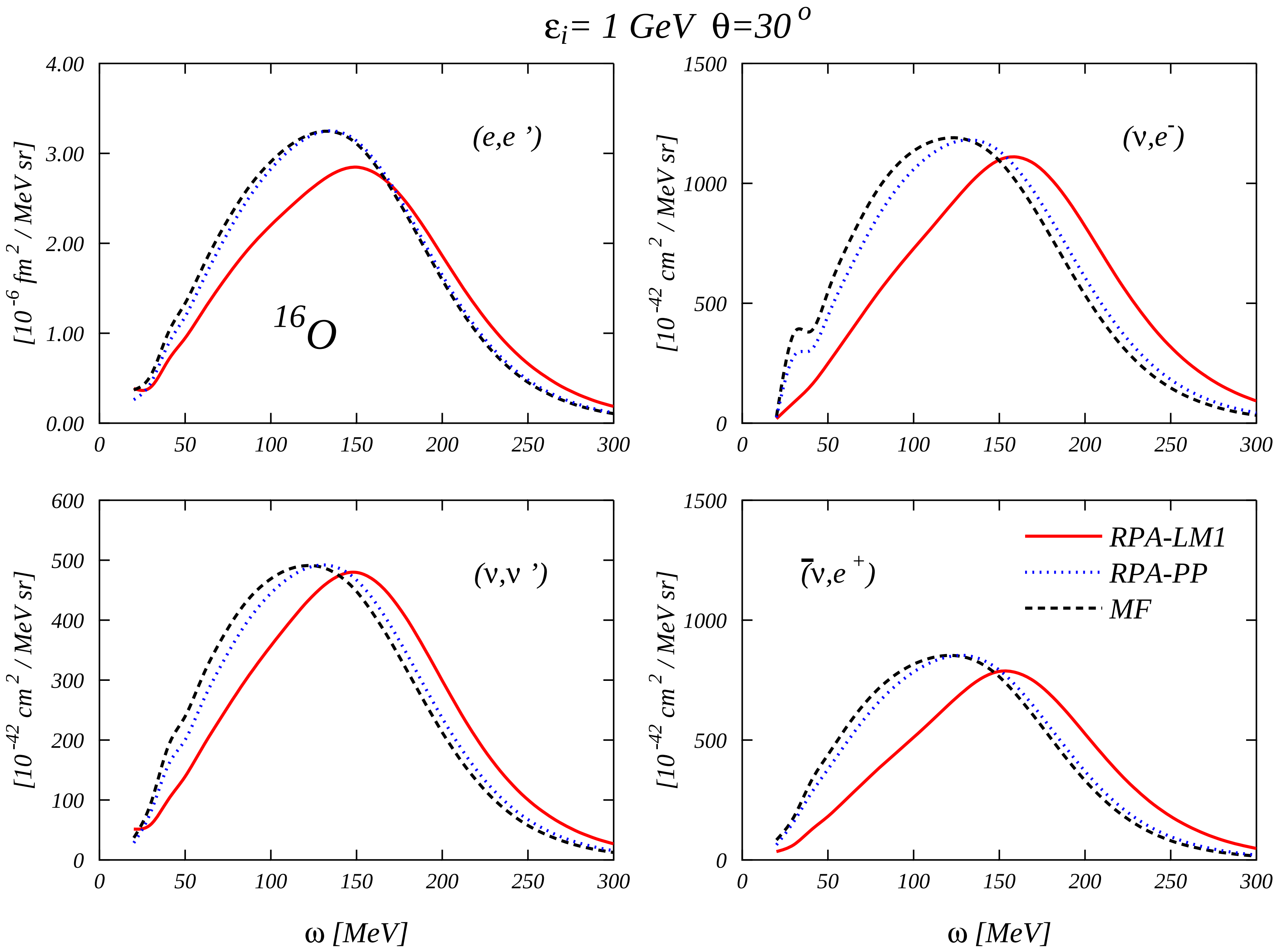
$$V^{eff}(k,\rho) = \mathcal{K}\,[\,F(k,\rho) + F'(k,\rho)\,\vec{\tau}(1)\cdot\vec{\tau}(2)$$
$$+\ G(k)\,\vec{\sigma}(1)\cdot\vec{\sigma}(2)$$
$$+\ G'(k)\,\vec{\sigma}(1)\cdot\vec{\sigma}(2)\,\vec{\tau}(1)\cdot\vec{\tau}(2)\,]$$

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

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	-



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

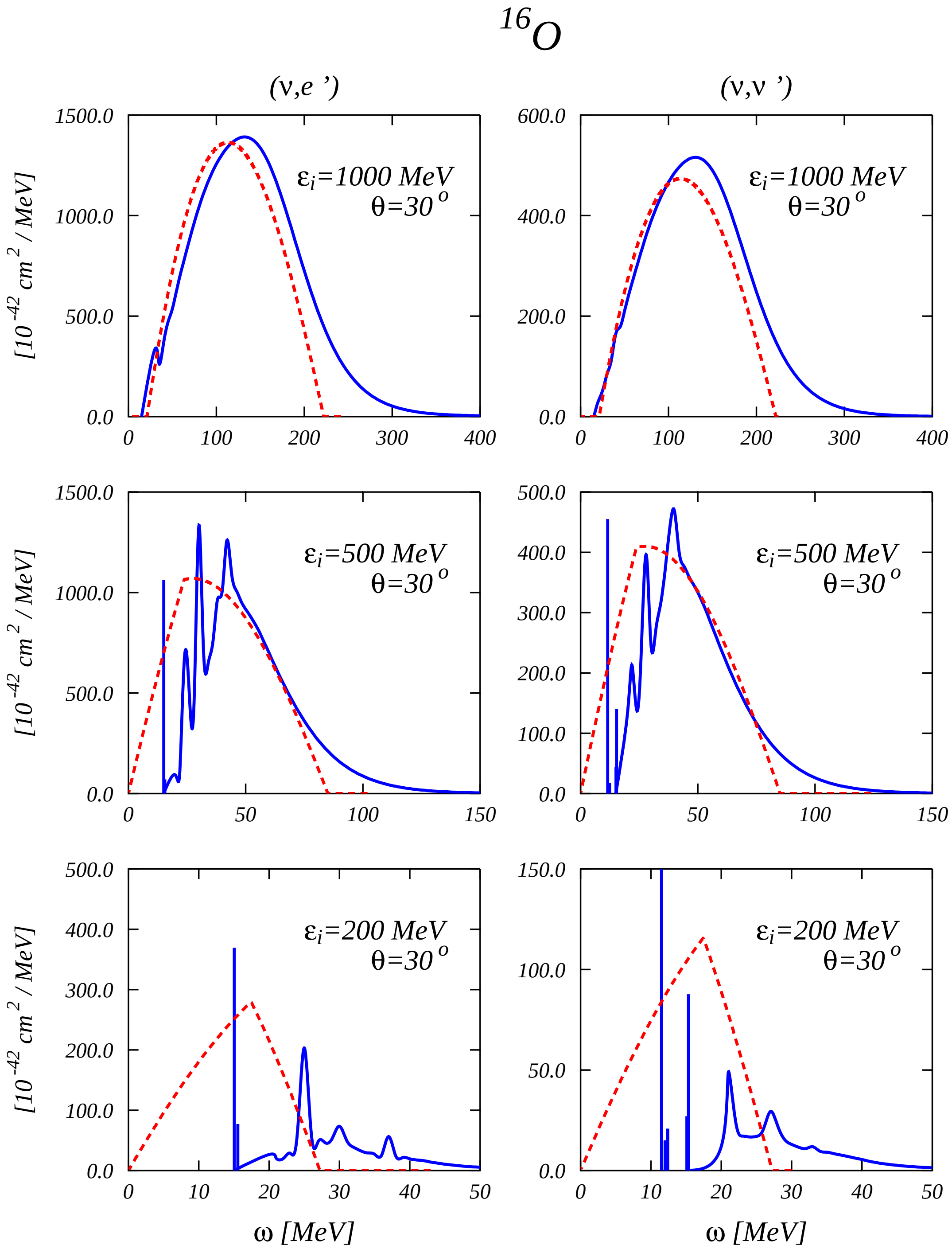


εi= 1 GeV θ=30 o
(e,e ')
16O
[10 -6 fm 2 / MeV sr]
(ν,e-)
[10 -42 cm 2 / MeV sr]
(ν,ν ')
(ν̄,e +)
RPA-LM1
RPA-PP
MF
ω [MeV]

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

$k_F = 216$ MeV/c

$\epsilon_B = 0$



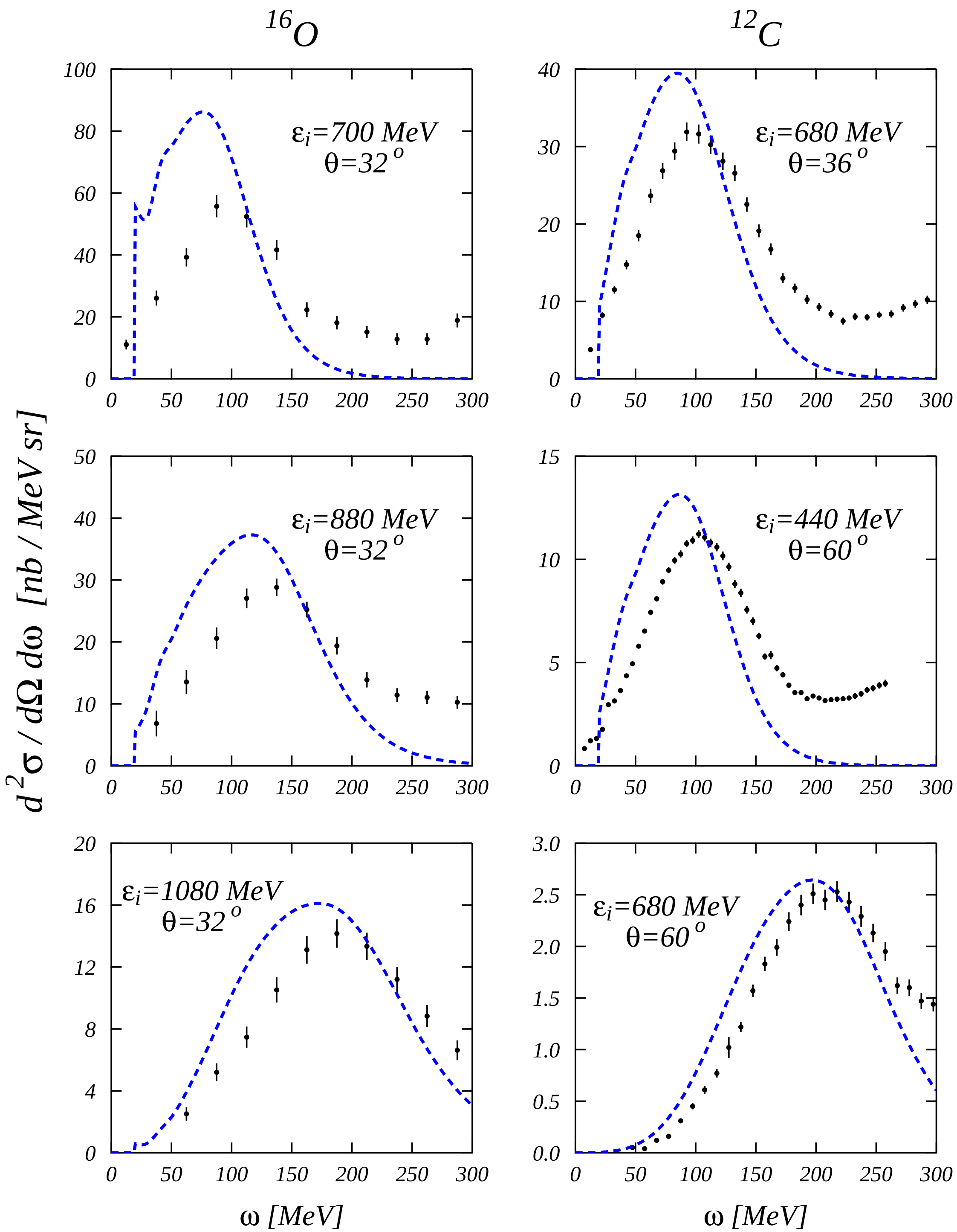
DATA:

M.Anghinolfi *et al.*,

Nucl. Phys. A 602 (1996) 405.

P.Barreau *et al.*,

Nucl. Phys. A 402 (1983) 515.



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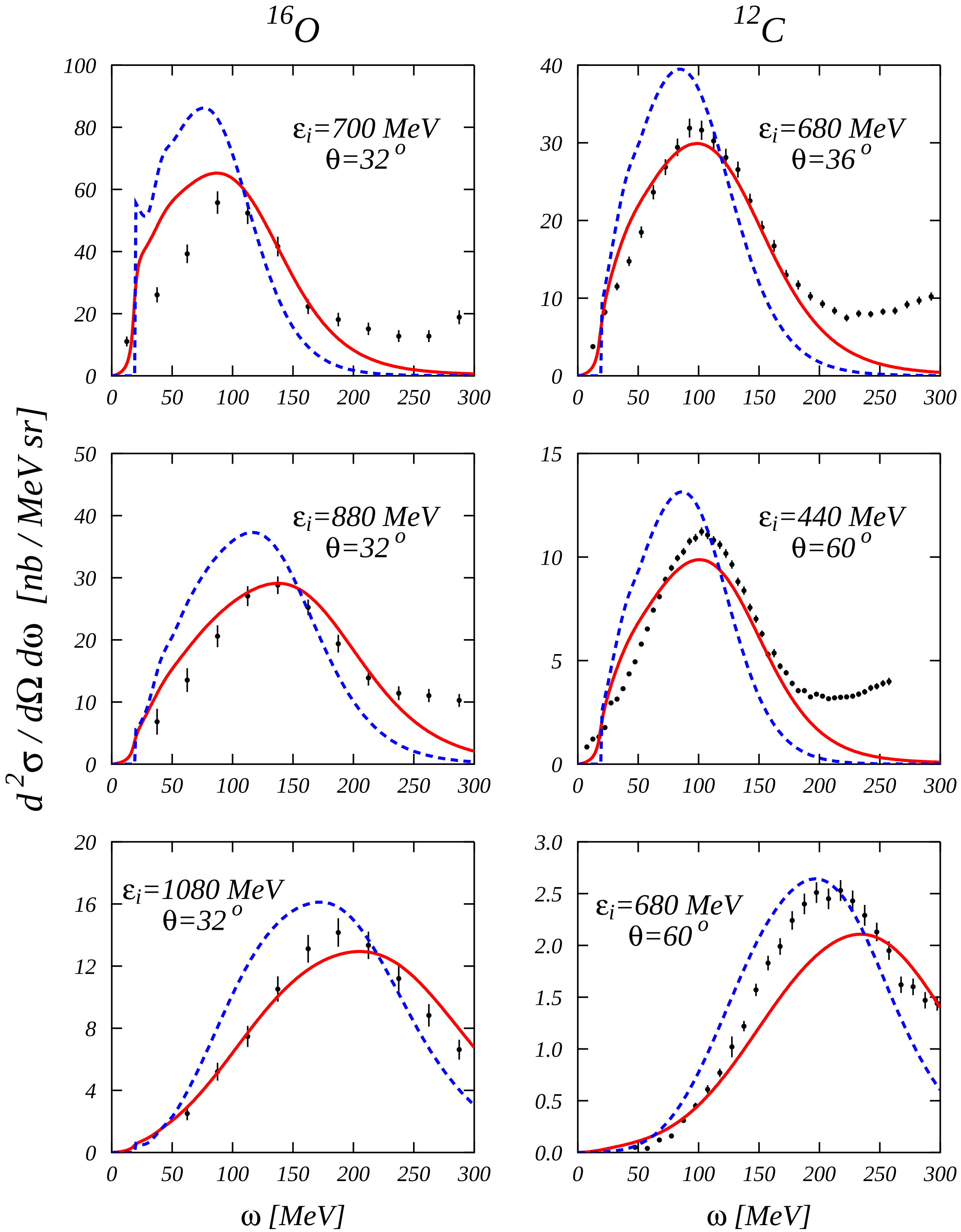
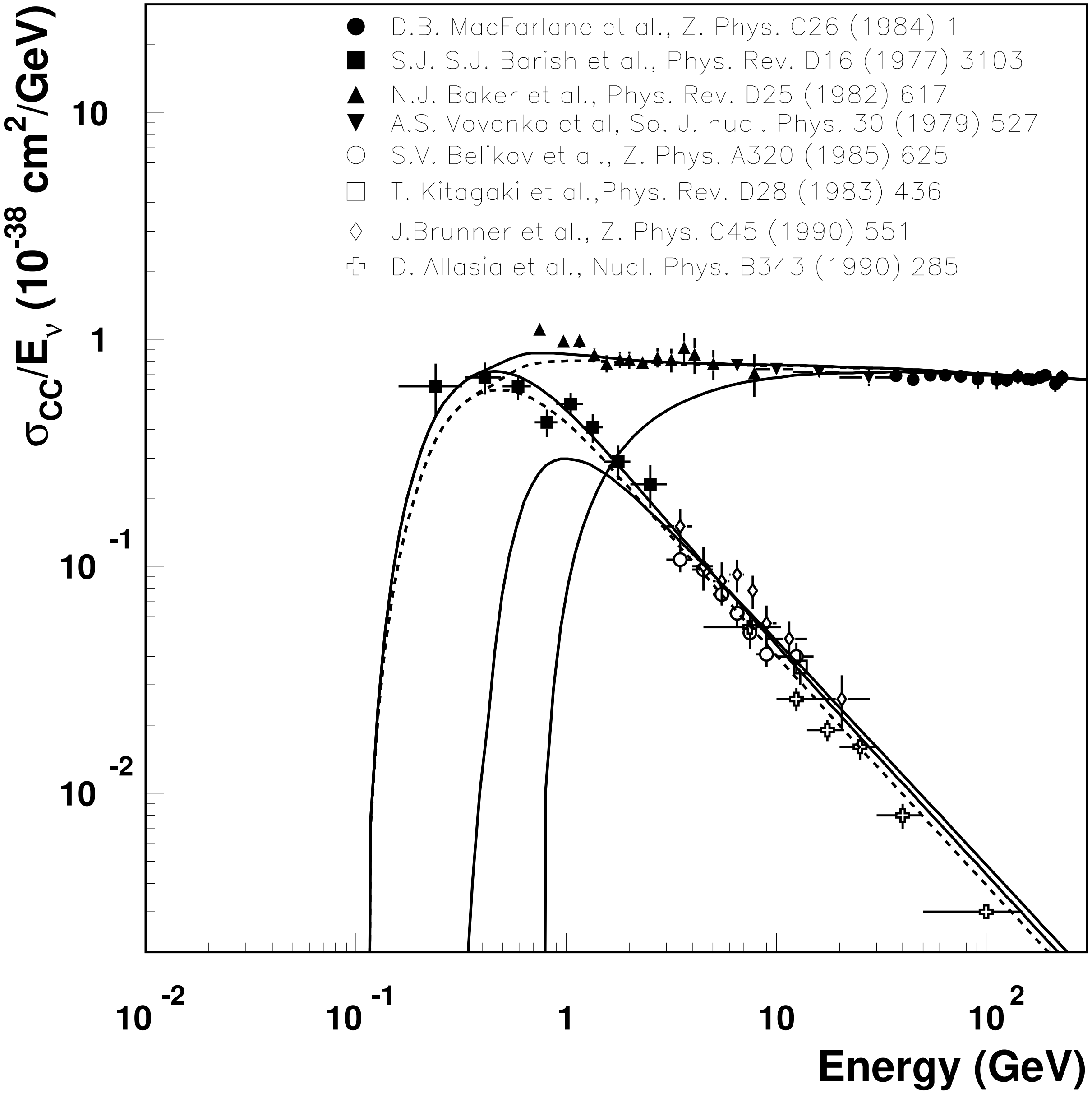




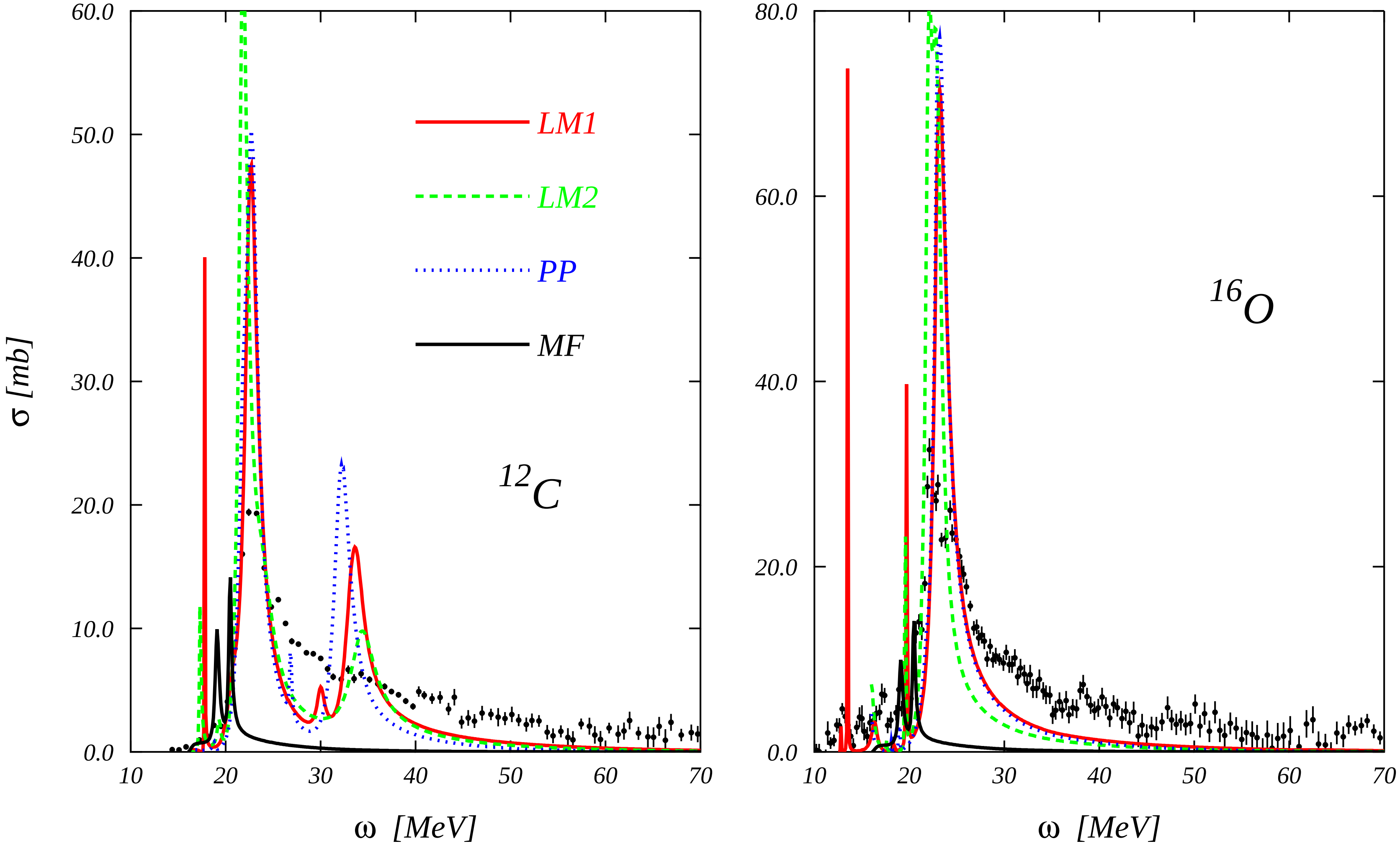
C. Bleve et al. Astroparticle Phys. 16 (2001) 145

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

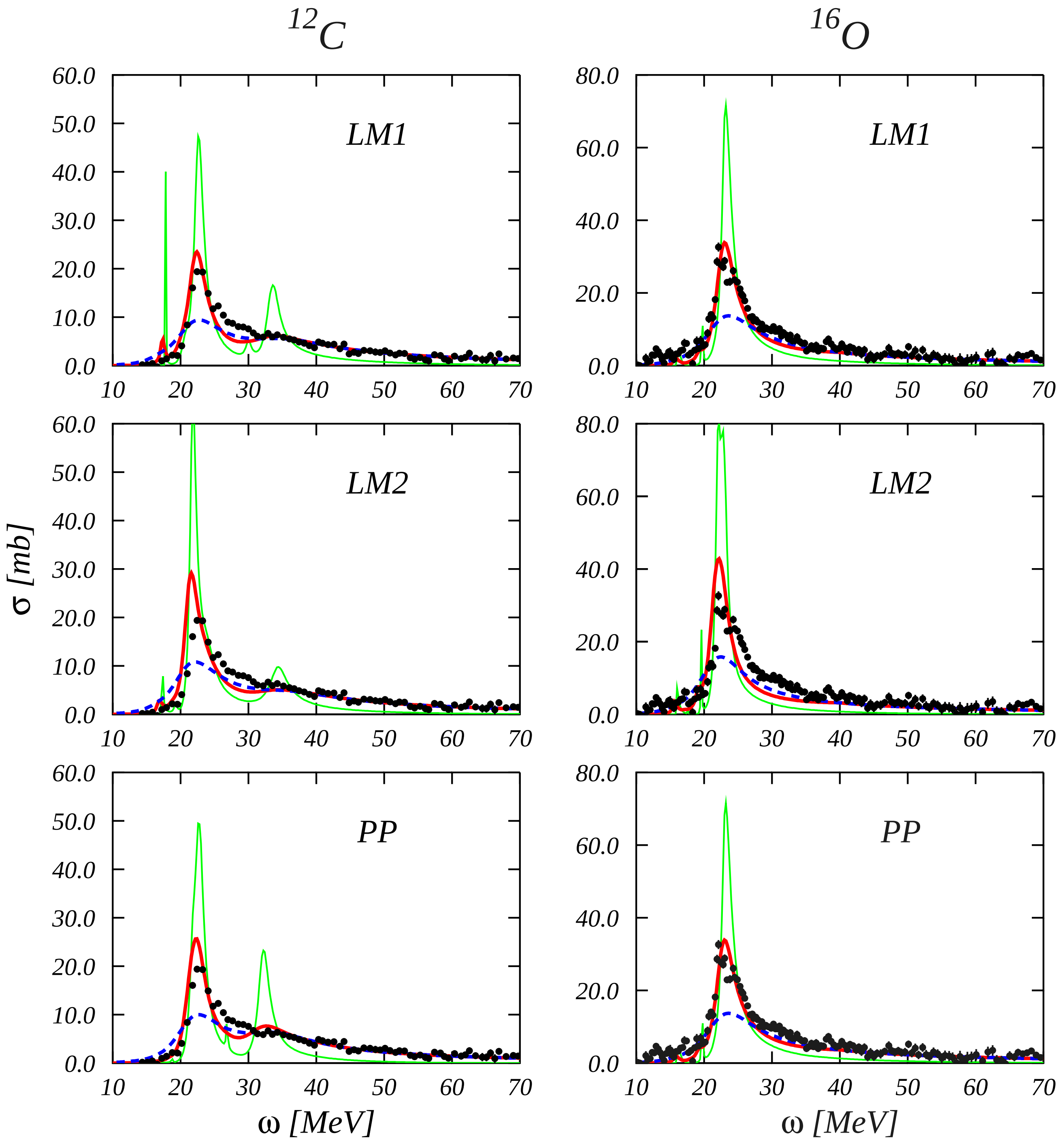
Neutrino working group

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}C
^{16}O
LM1
LM2
PP
σ [mb]
ω [MeV]
0.0
10.0
20.0
30.0
40.0
50.0
60.0
80.0
10
20
30
40
50
60
70

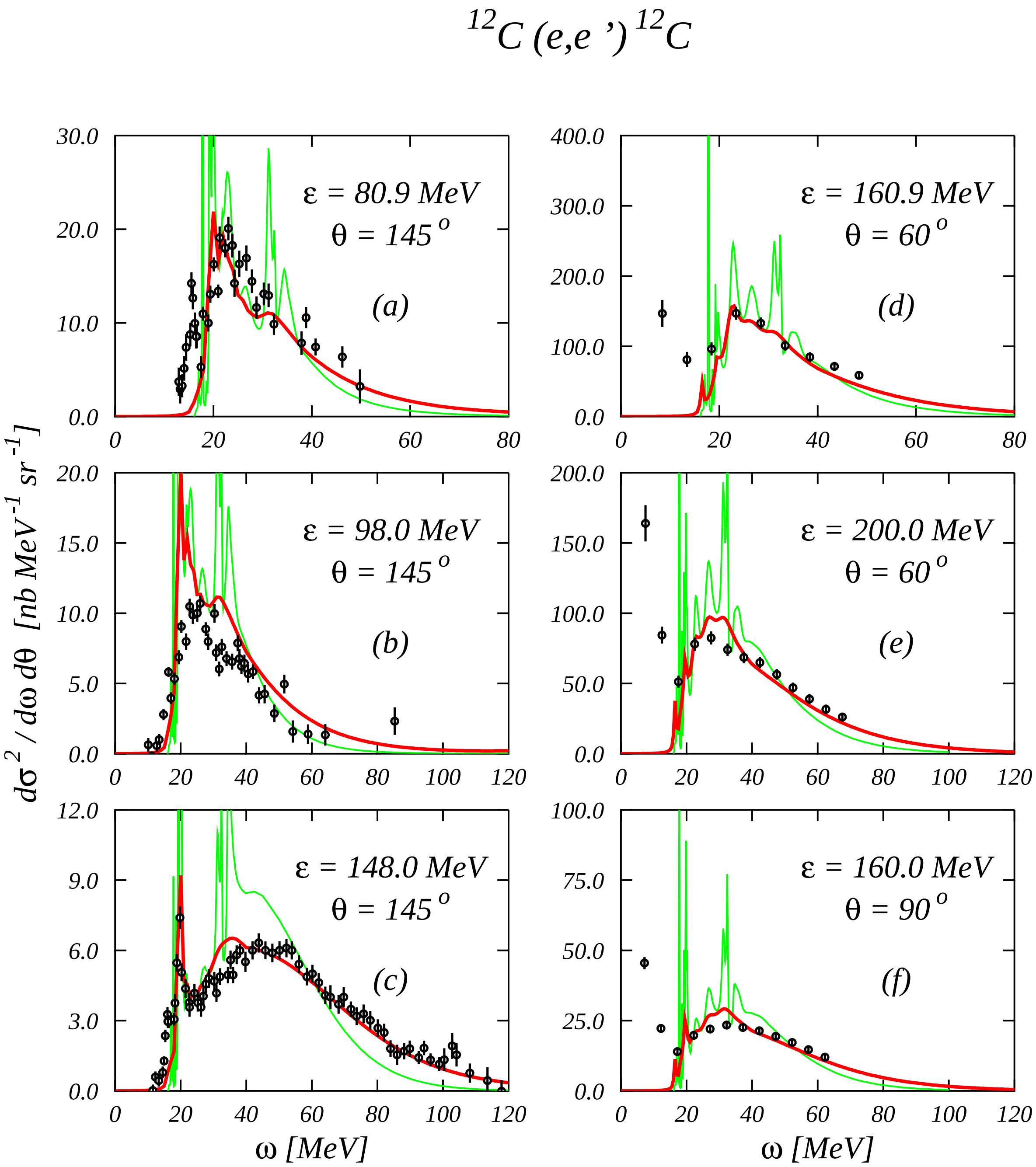
DATA:

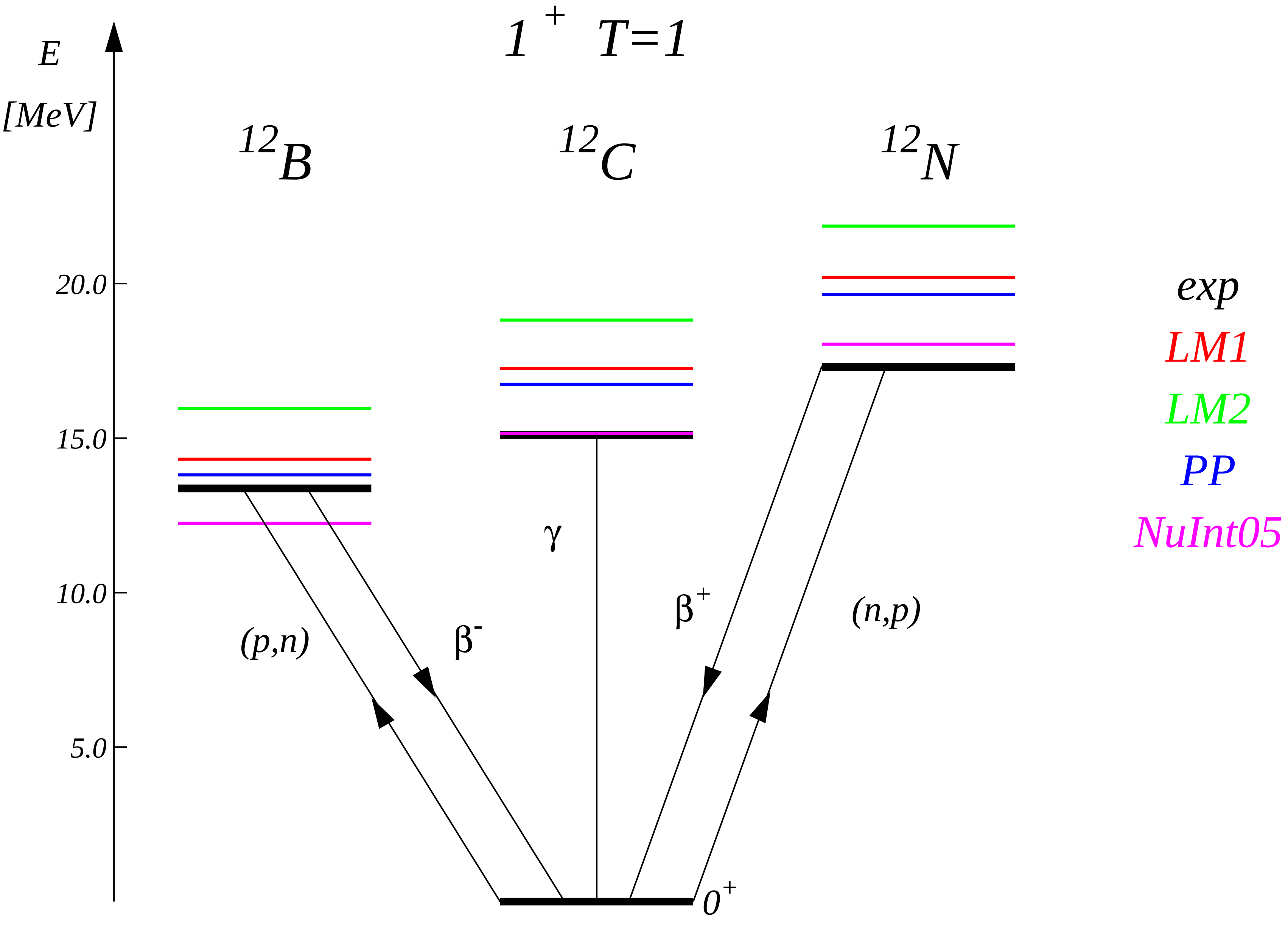
(a,b,c) quoted in E. Kolbe

Nucl. Phys. A 602 (1996) 405.

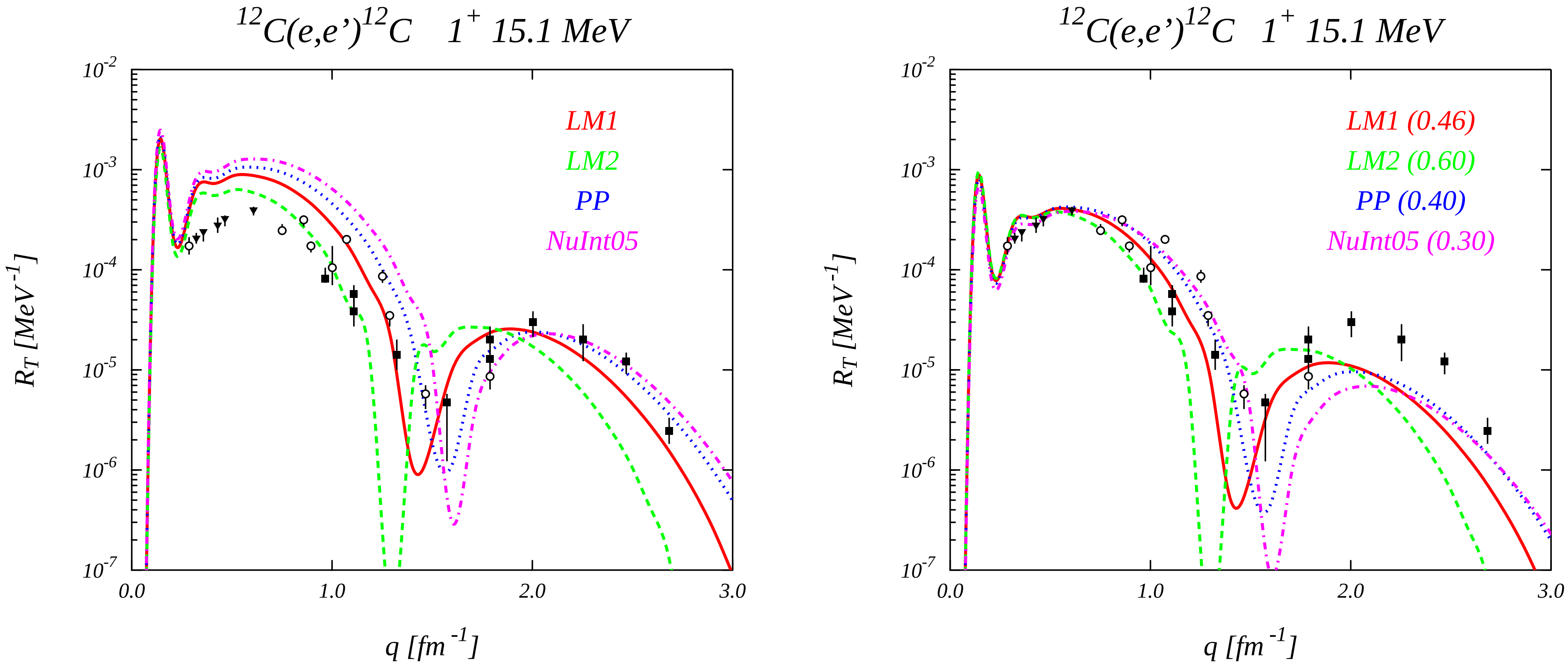
(d,e,f) P.Barreau *et al.*,

Nucl. Phys. A 402 (1983) 515.



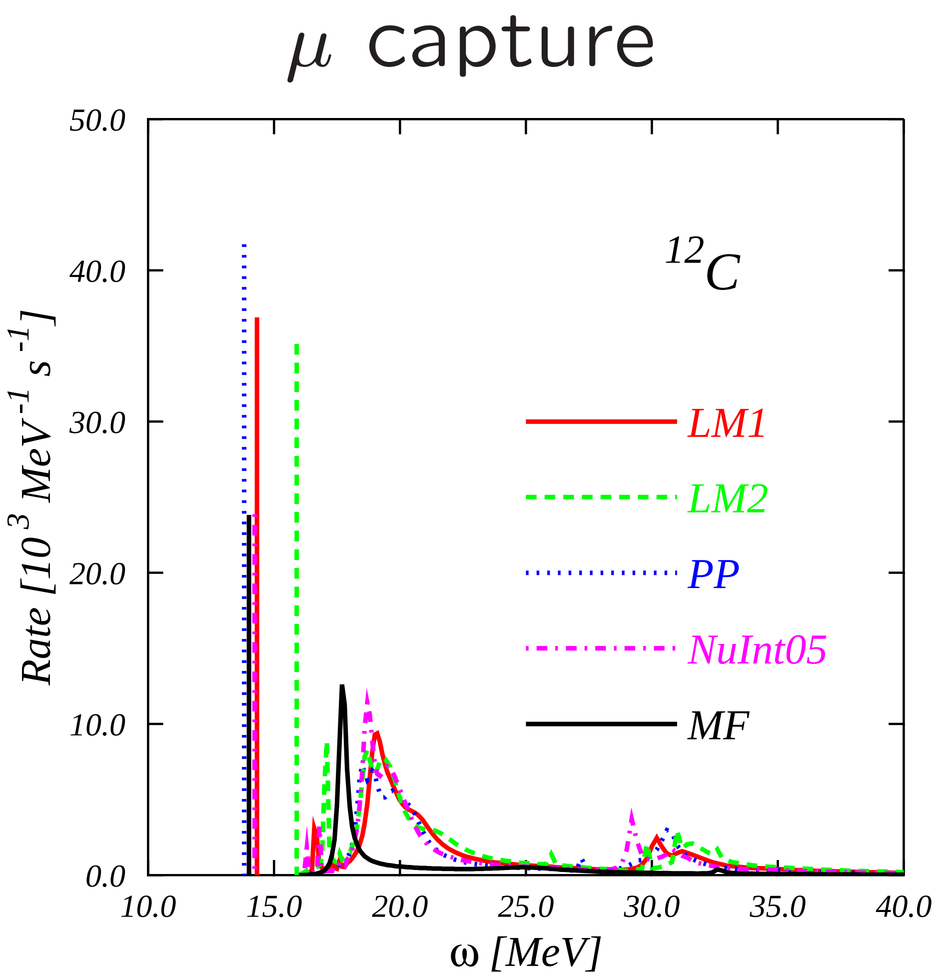


1 + T=1
E
[MeV]
12B
12C
12N
20.0
15.0
10.0
5.0
exp
LM1
LM2
PP
NuInt05
γ
(p,n)
β-
β+
(n,p)
0+



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

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

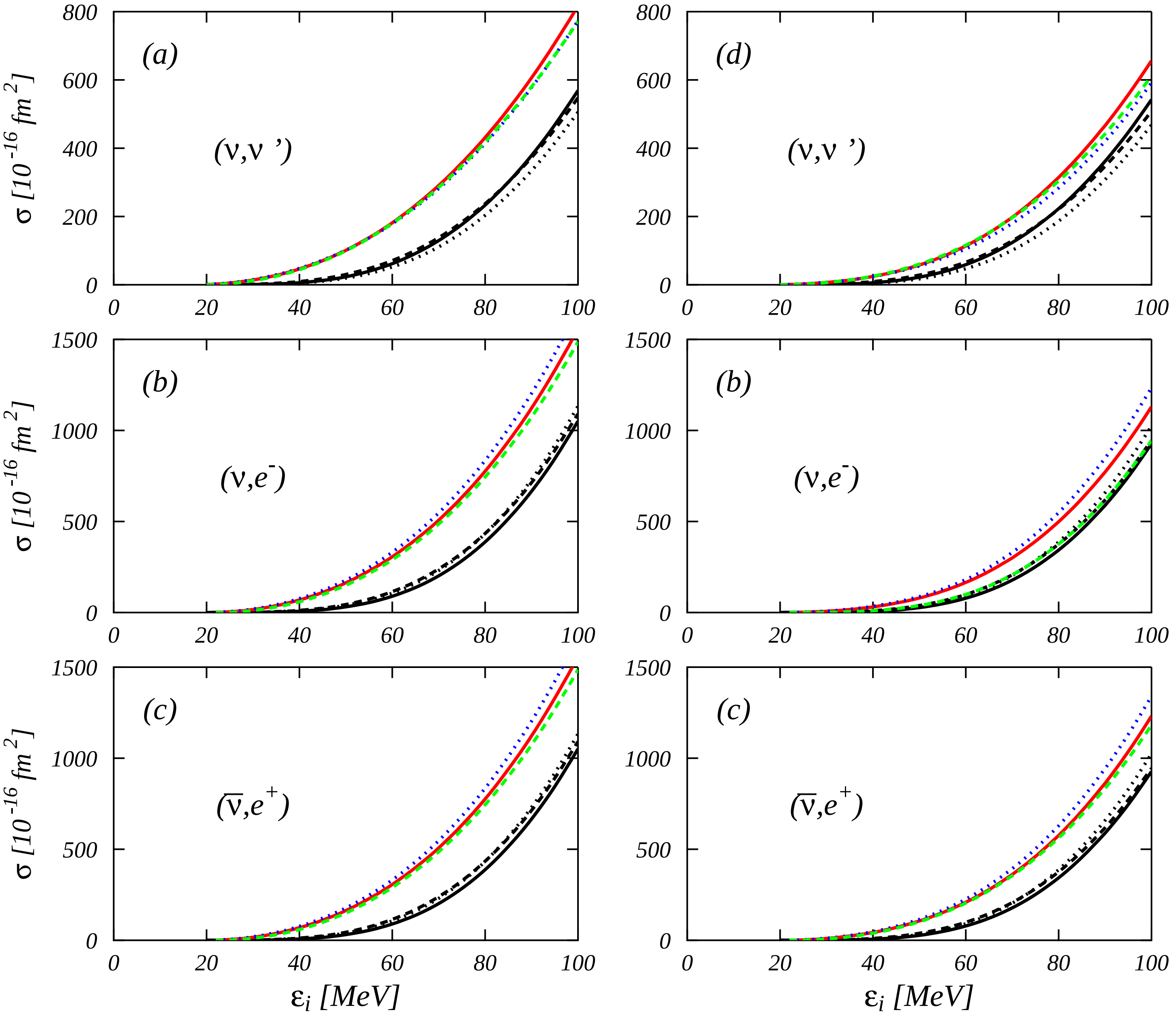

μ capture
^{12}C
LM1
LM2
PP
NuInt05
MF
Rate [10^3 MeV^{-1} s^{-1}]
ω [MeV]
0.0
10.0
20.0
30.0
40.0
50.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0

^{12}C

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


(a)
(ν,ν ')
(d)
(ν,ν ')
(b)
(ν,e⁻)
(b)
(ν,e⁻)
(c)
(ν̄,e⁺)
(c)
(ν̄,e⁺)
σ [10⁻¹⁶ fm²]
ε_i [MeV]
0
20
40
60
80
100
200
400
600
800
500
1000
1500

$$\mu^+ \to \overline{\nu}_\mu + \nu_e + e^+$$

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

$$\exp = 14.0 \pm 1.2$$

	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.