Marciana Marina, June 21-25 2004

Weak response of nuclei

Antonio Botrugno

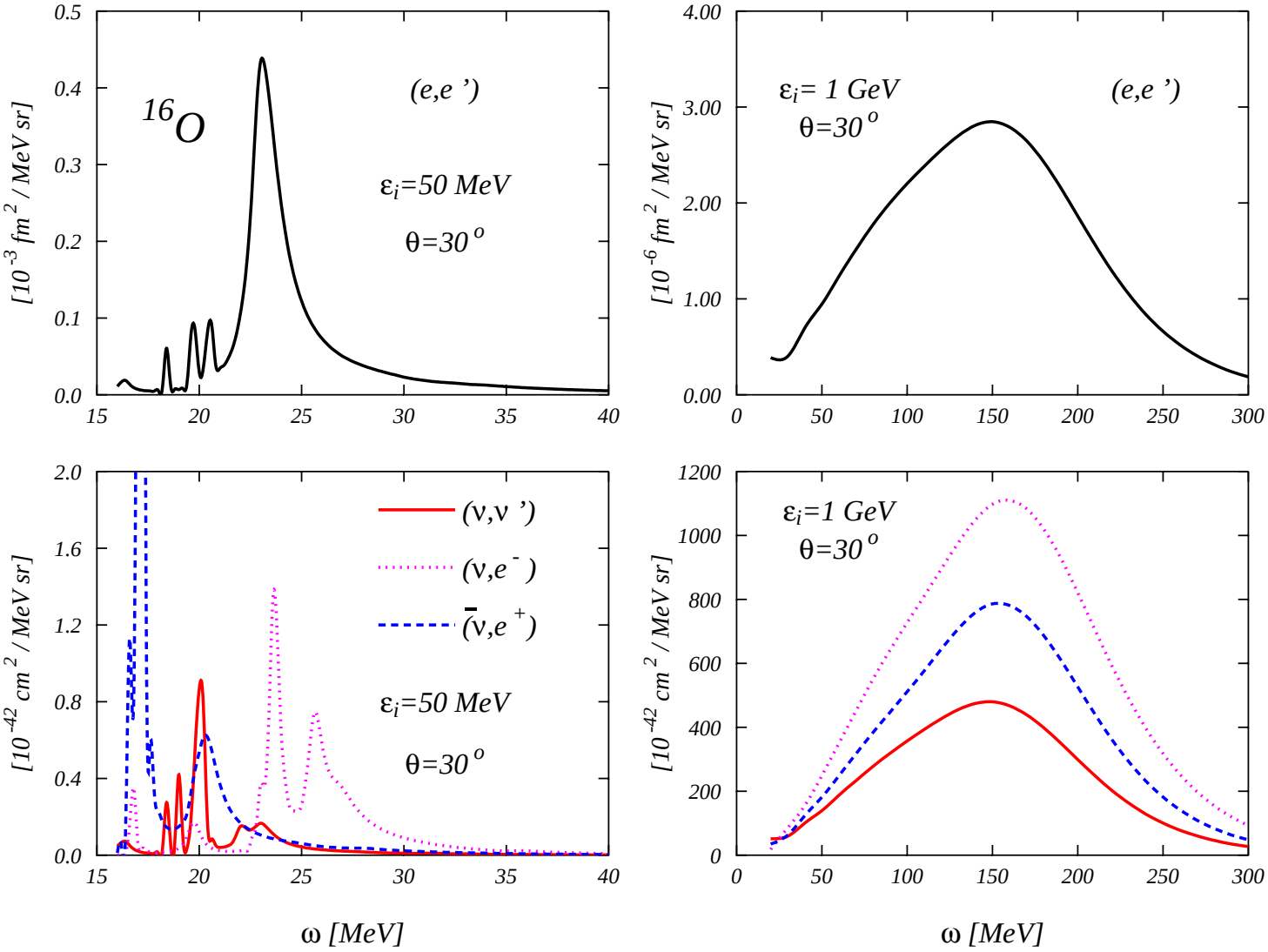
Giampaolo Co'

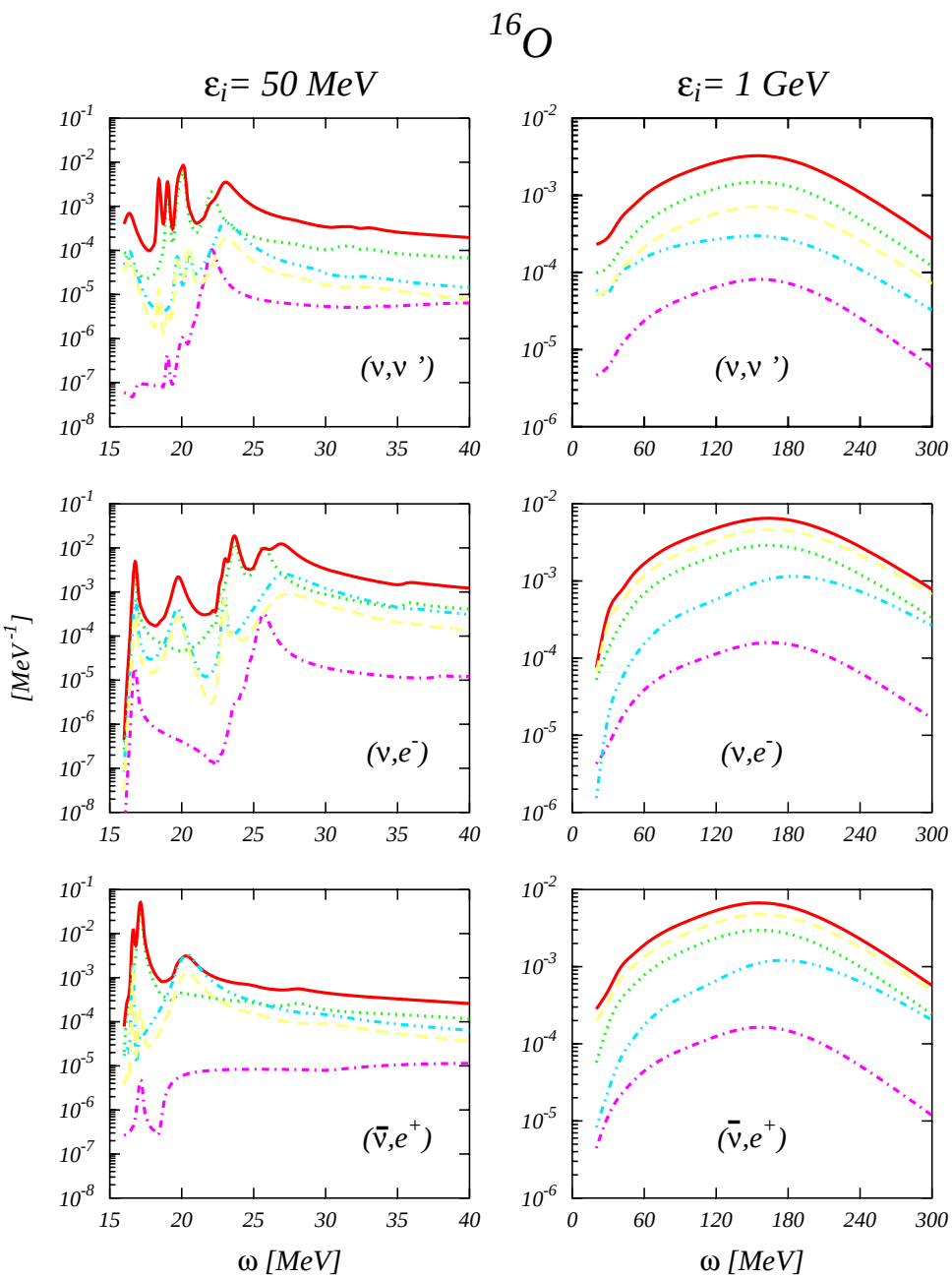
Dipartimento di Fisica e Sezione INFN, Università di Lecce, ITALY

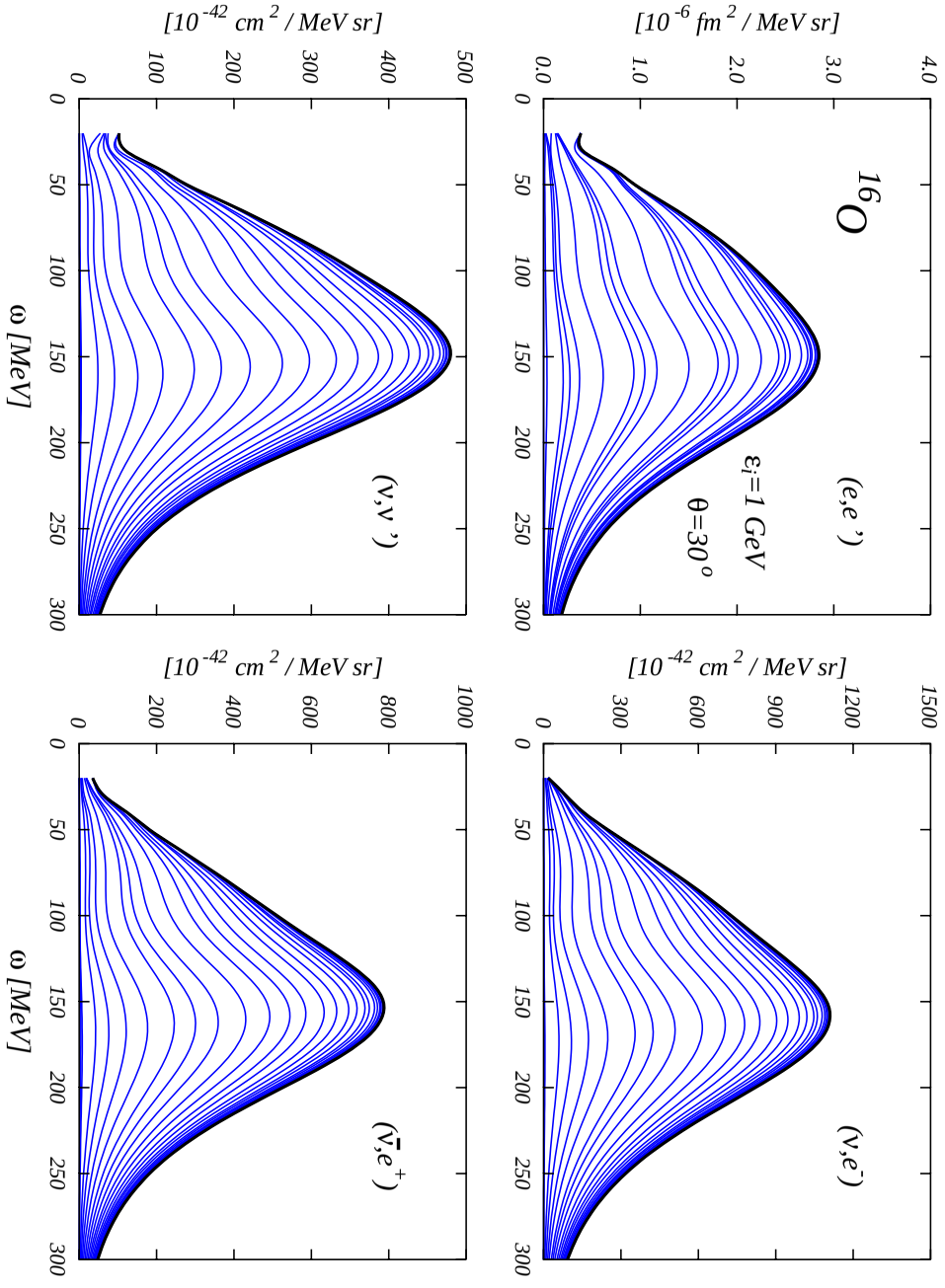
$$\left(\frac{d^2\sigma}{d\Omega\, d\omega}\right)^{J_i\to J_f}_{\nu,\overline{\nu}} = \frac{G^2}{2J_i+1}\frac{|\mathbf{k}_f|}{\epsilon_i}\left[\sigma_L+\sigma_T\right]$$

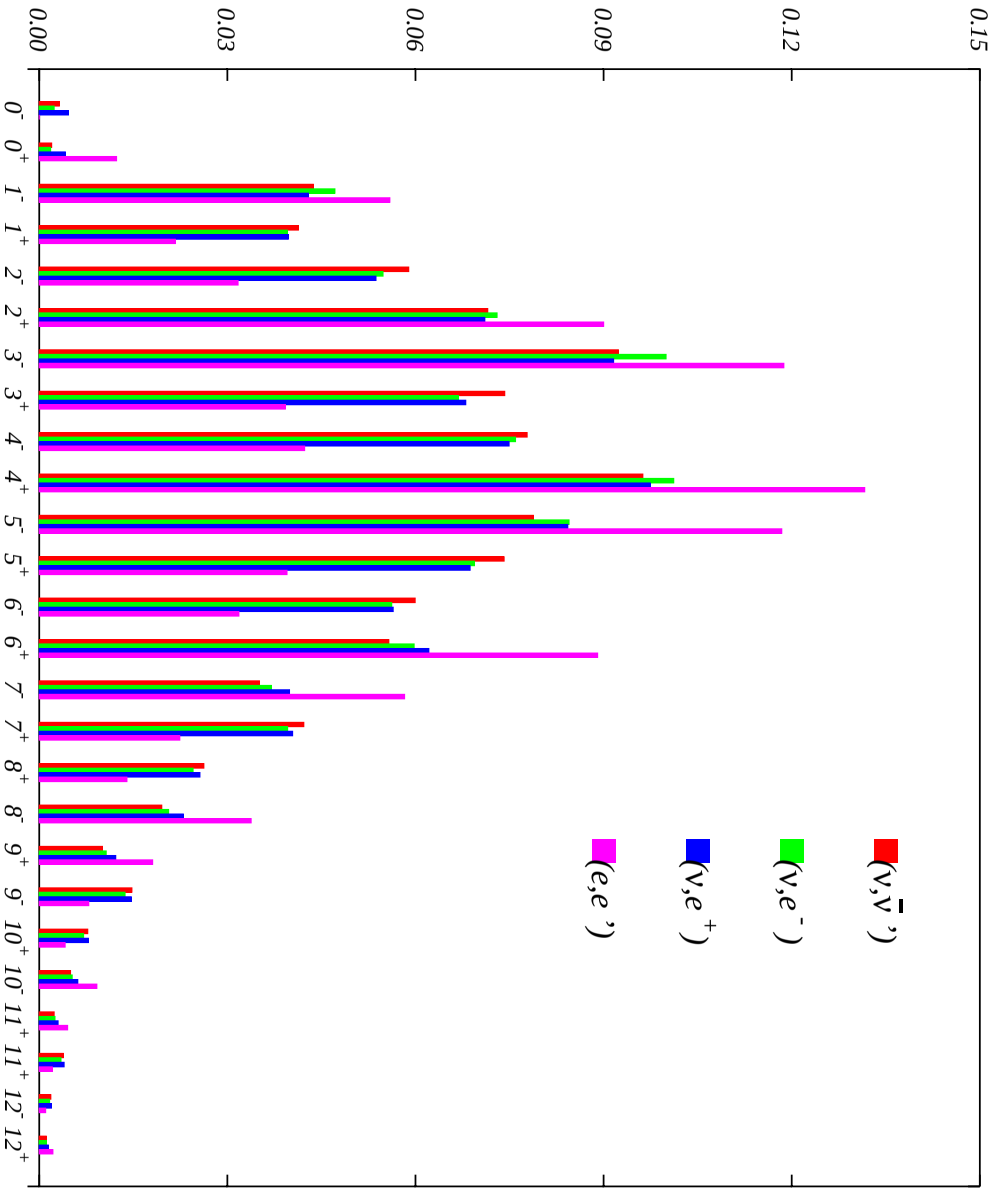
$$\begin{aligned}
\sigma_L = {} & l_v \sum_J |<J_f||\mathcal{M}^V_J||J_i>|^2 \\
& + l_{00}\sum_J |<J_f||\mathcal{M}^A_J||J_i>|^2 \\
& - l_{33}\sum_J |<J_f||\mathcal{L}^A_J||J_i>|^2 \\
& + l_{03}\sum_J 2Re<J_f||\mathcal{M}^A_J||J_i><J_f||\mathcal{L}^A_J||J_i>^*
\end{aligned}$$

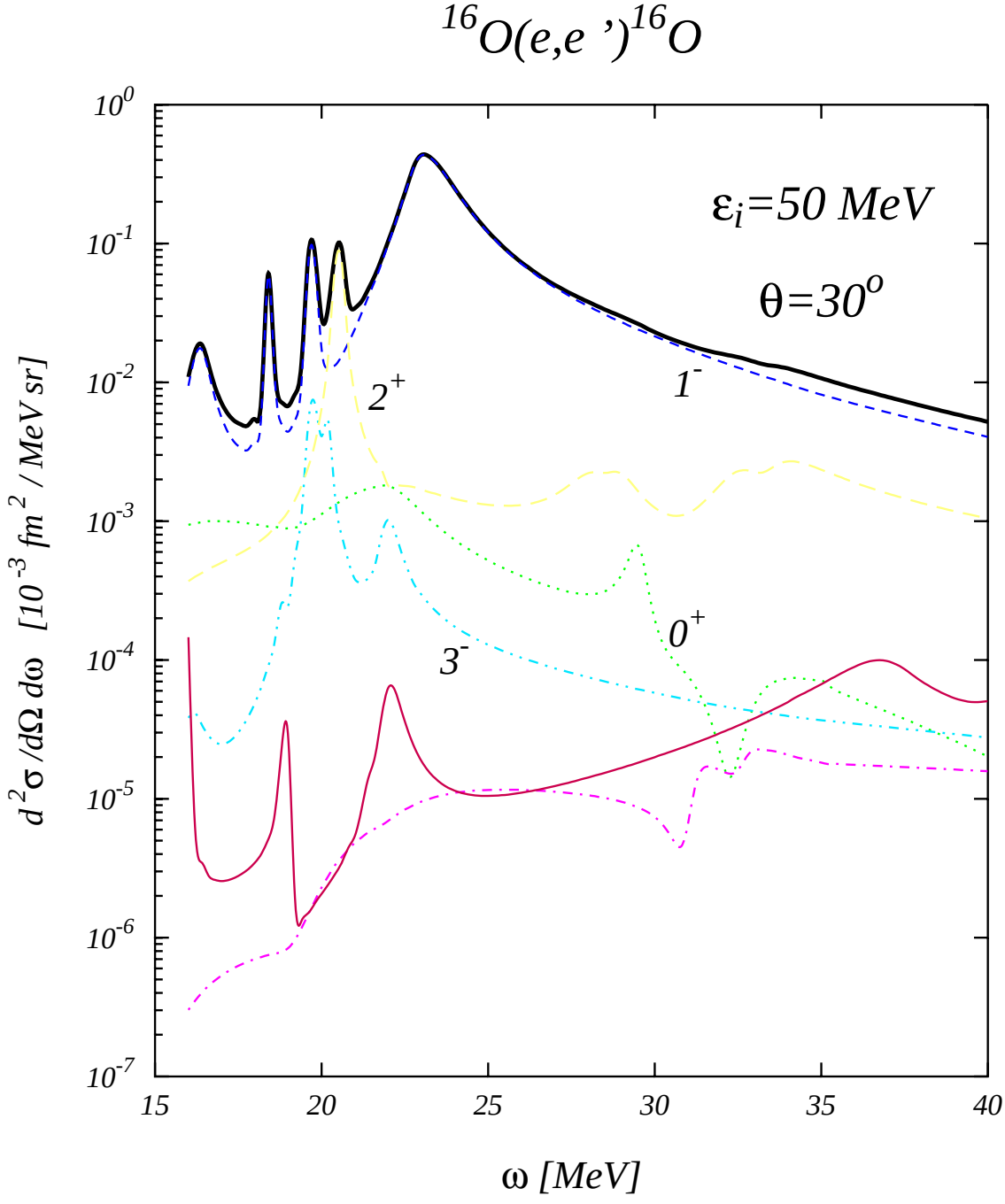
$$\begin{aligned}
\sigma^J_T = {} & l_+ \left[\sum_J |<J_f||\mathcal{J}^V_J||J_i>|^2 \right. \\
& \left. + \sum_J |<J_f||\mathcal{J}^A_J||J_i>|^2\right] \\
\mp {} & l_- \sum_J 2Re<J_f||\mathcal{J}^A_J||J_i><J_f||\mathcal{J}^V_J||J_i>^*
\end{aligned}$$

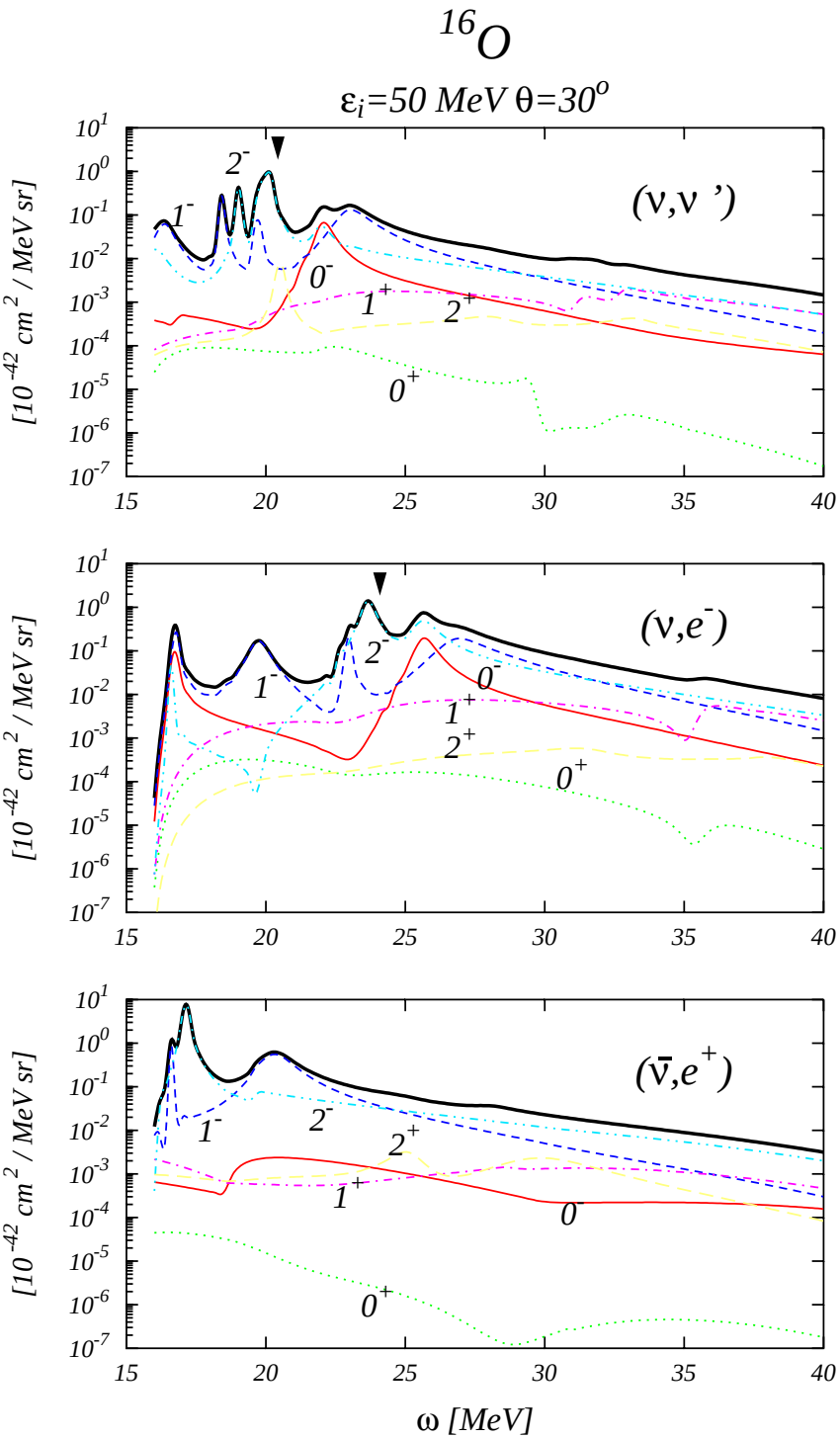

^{16}O
(e,e ')
ε_i=50 MeV
θ=30 o
[10-3 fm 2 / MeV sr]
ε_i= 1 GeV
θ=30 o
(e,e ')
[10-6 fm 2 / MeV sr]
(ν,ν ')
(ν,e -)
(ν,e +)
ε_i=50 MeV
θ=30 o
[10-42 cm 2 / MeV sr]
ε_i=1 GeV
θ=30 o
[10-42 cm 2 / MeV sr]
ω [MeV]
ω [MeV]

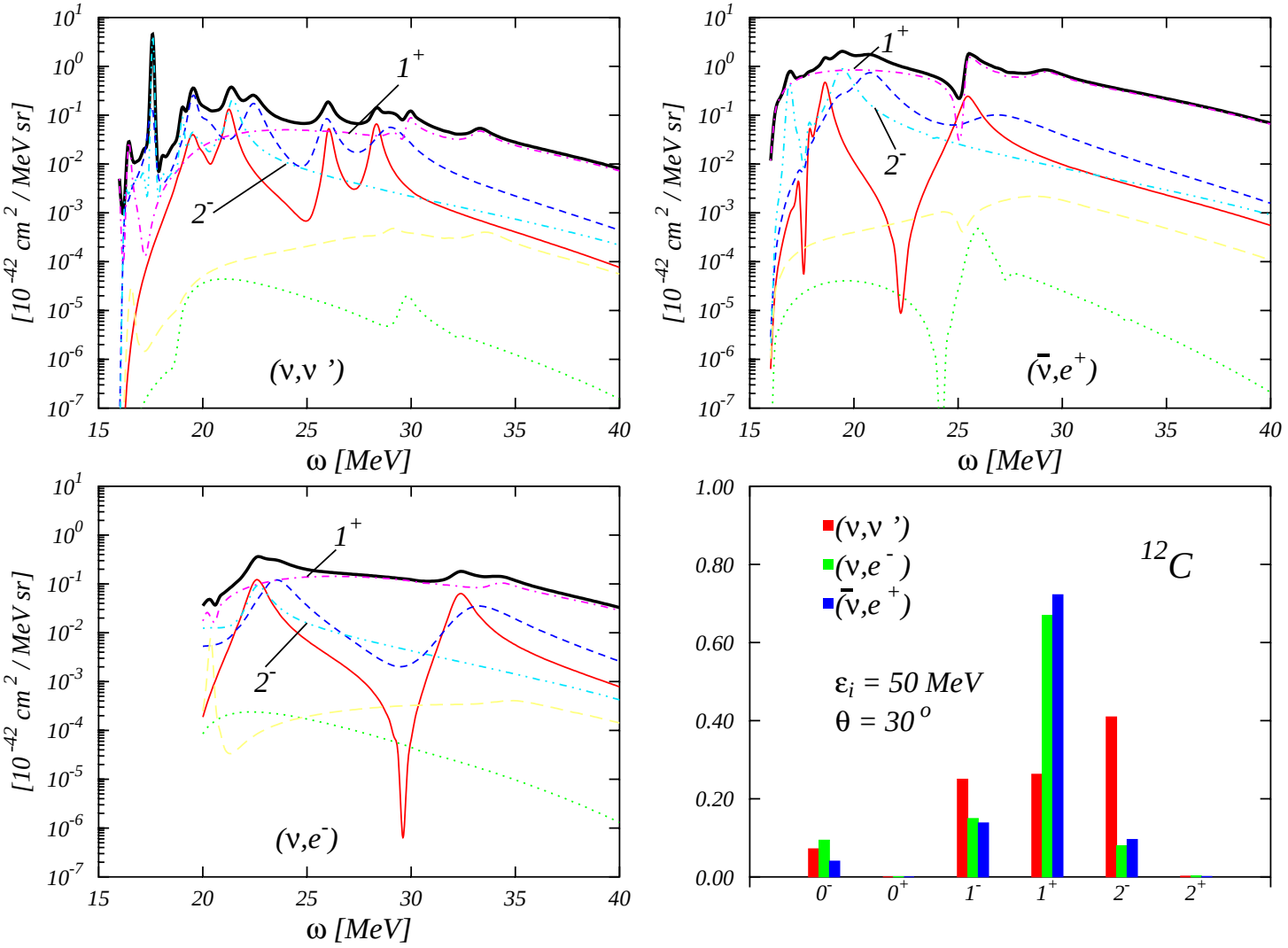

^{16}O
ε_i= 50 MeV
ε_i= 1 GeV
(ν,ν ')
(ν,e⁻)
($\bar{\nu}$,e⁺)
[MeV⁻¹]
ω [MeV]

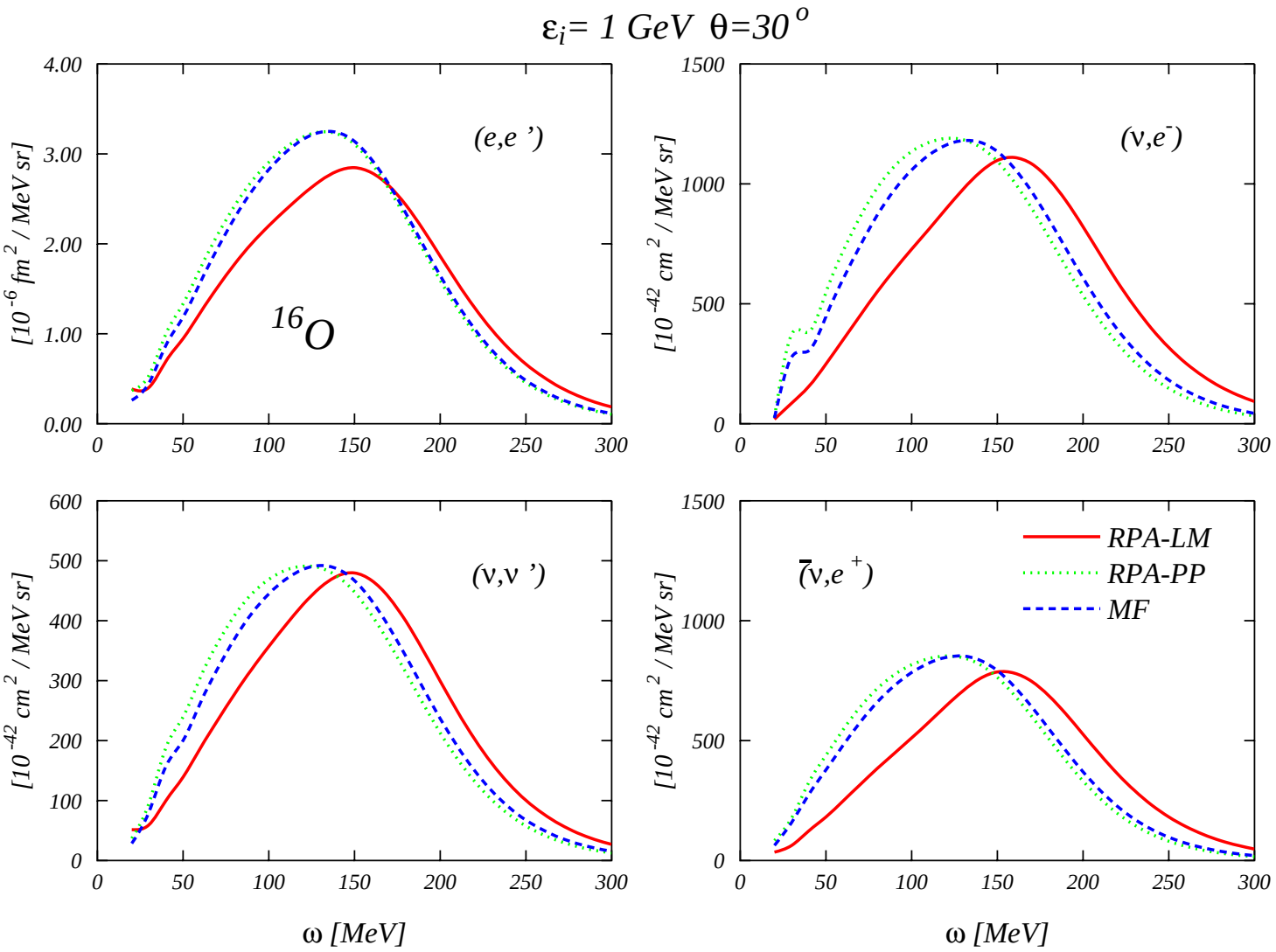

^{16}O
ε_i=1 GeV
θ=30°
(e,e')
(ν,ν')
(ν,e⁻)
($\bar{\nu}$,e⁺)
[10⁻⁶ fm² / MeV sr]
[10⁻⁴² cm² / MeV sr]
ω [MeV]

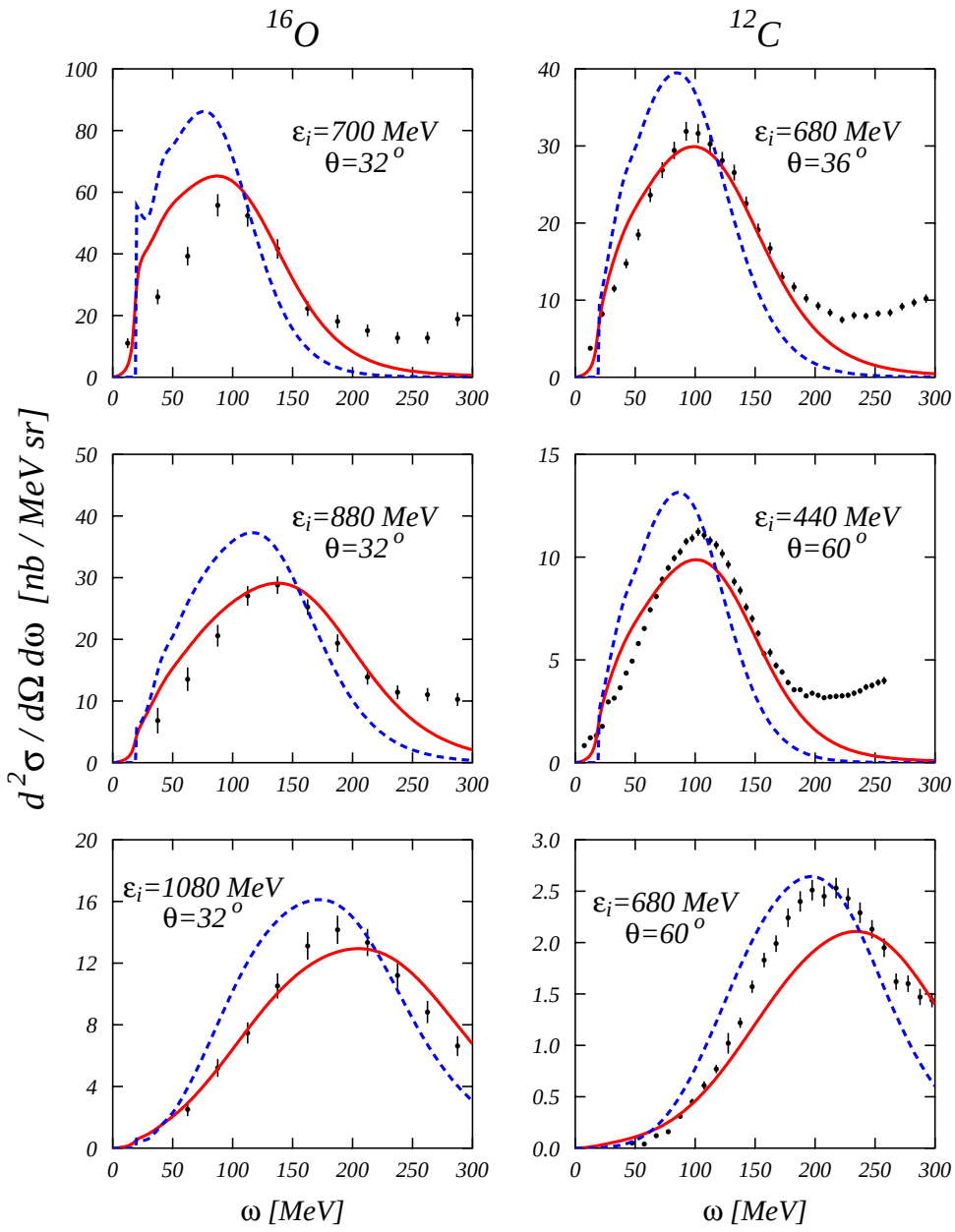

0.00
0.03
0.06
0.09
0.12
0.15
0⁻ 0⁺ 1⁻ 1⁺ 2⁻ 2⁺ 3⁻ 3⁺ 4⁻ 4⁺ 5⁻ 5⁺ 6⁻ 6⁺ 7⁻ 7⁺ 8⁺ 8⁻ 9⁺ 9⁻ 10⁺ 10⁻ 11⁺ 11⁺ 12⁻ 12⁺
(ν,ν̄ ')
(ν,e⁻)
(ν,e⁺)
(e,e ')


$^{16}O(e,e')^{16}O$
ε_i=50 MeV
θ=30°
2^+
1^-
0^+
3^-
$d^2\sigma/d\Omega\, d\omega$ [10^{-3} fm^2 / MeV sr]
ω [MeV]
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
15
20
25
30
35
40


^{16}O
ε_i=50 MeV θ=30°
(ν,ν ')
(ν,e⁻)
(ν̄,e⁺)
[10⁻⁴² cm² / MeV sr]
ω [MeV]
1⁻
2⁻
0⁻
1⁺
2⁺
0⁺


[10^-42 cm^2 / MeV sr]
ω [MeV]
1^+
2^-
(ν,ν ')
(ν̄,e^+)
(ν,e^-)
(ν,ν ')
(ν,e^-)
(ν̄,e^+)
ε_i = 50 MeV
θ = 30^o
^12C
0^-
0^+
1^-
1^+
2^-
2^+


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



^{16}O DATA: M. Anghinolfi *et al.*, Nucl. Phys. A 602 (1996) 405.

^{12}C DATA: P. Barreau *et al.*, Nucl. Phys. A 402 (1983) 515.

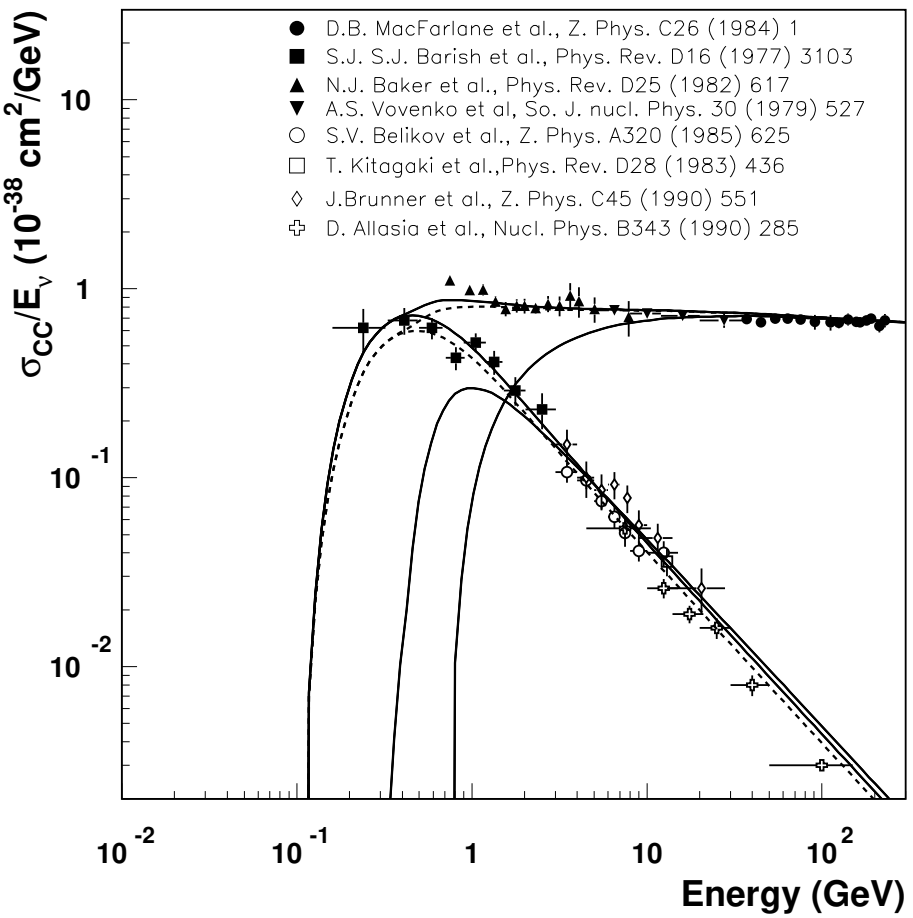
$$S(|\mathbf{q}|,\omega) = \int_0^\infty dE \;\; S^0(|\mathbf{q}|,E)\,[\rho(E,\omega)+\rho(E,-\omega)]$$

$$\rho(E,\omega) = \frac{1}{2\pi}\frac{\Gamma(\omega)}{[E-\omega-\Delta(\omega)]^2+[\Gamma(\omega)/2]^2}$$

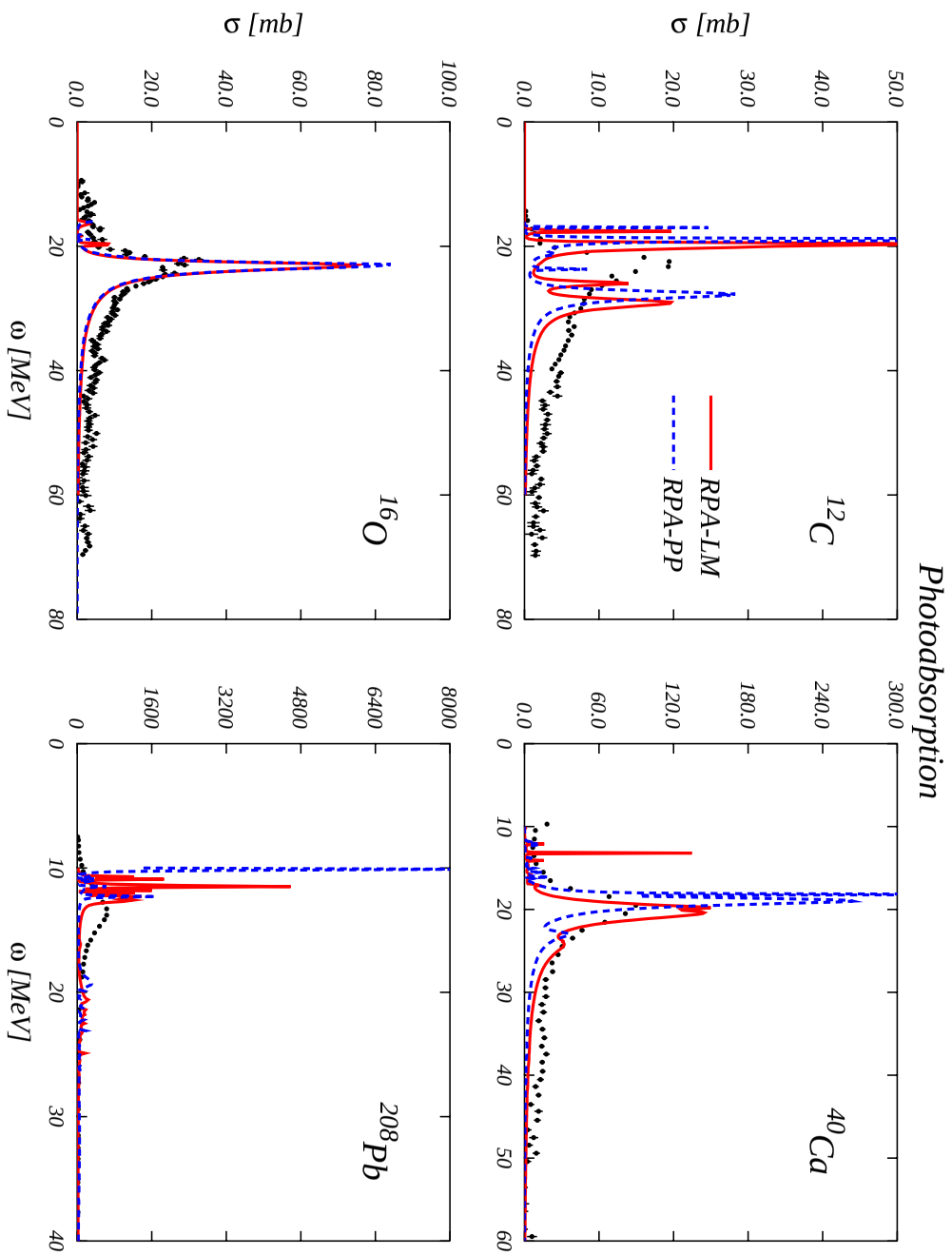
$$\Delta(\omega) = \frac{1}{2\pi}P\int_0^\infty d\omega' \;\; \frac{\Gamma(\omega')}{\omega'-\omega}$$

$$\Gamma(\omega) \sim \frac{1}{\omega}\int_0^\omega d\epsilon\,[\gamma(\epsilon_F+\epsilon+\omega)+\gamma(\epsilon_F+\epsilon-\omega)]$$

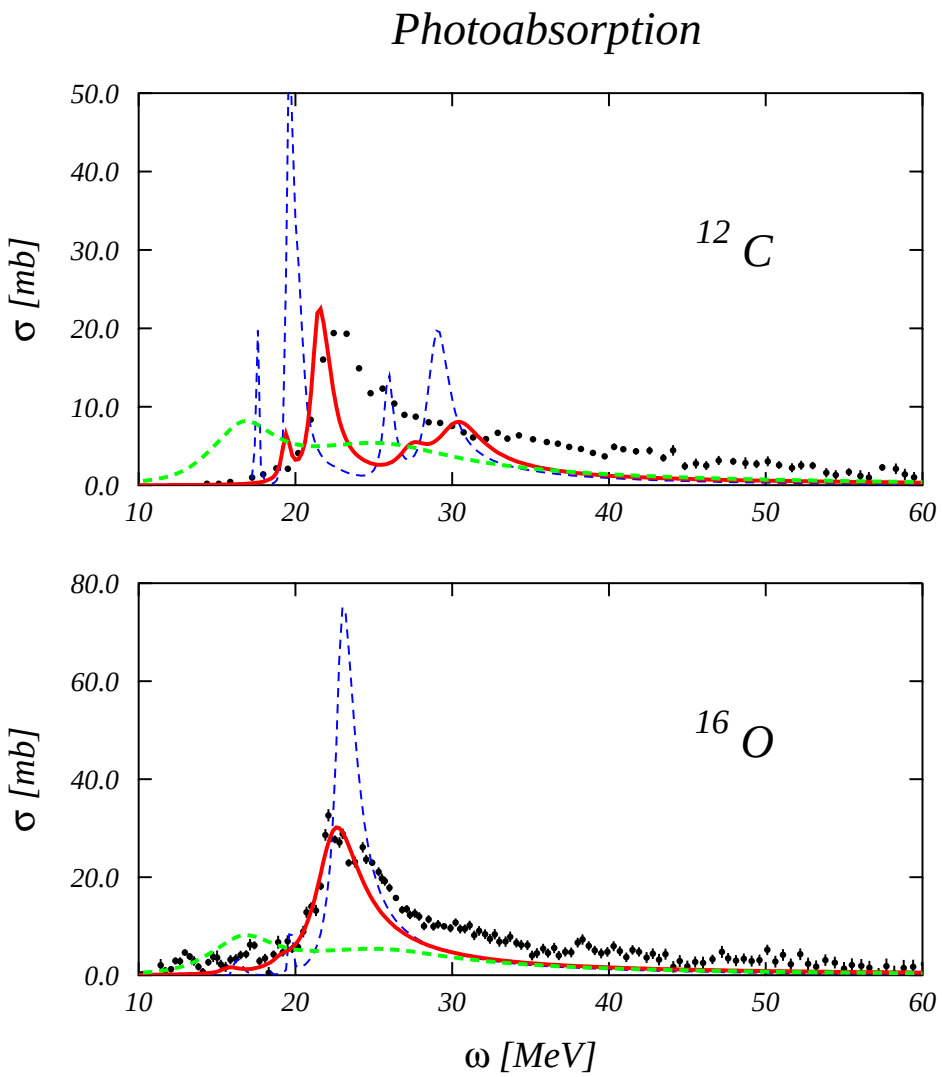
$$\gamma(\epsilon) = A_\Gamma\left(\frac{\epsilon^2}{\epsilon^2+{B_\Gamma}^2}\right)\left(\frac{{C_\Gamma}^2}{\epsilon^2+{C_\Gamma}^2}\right)$$

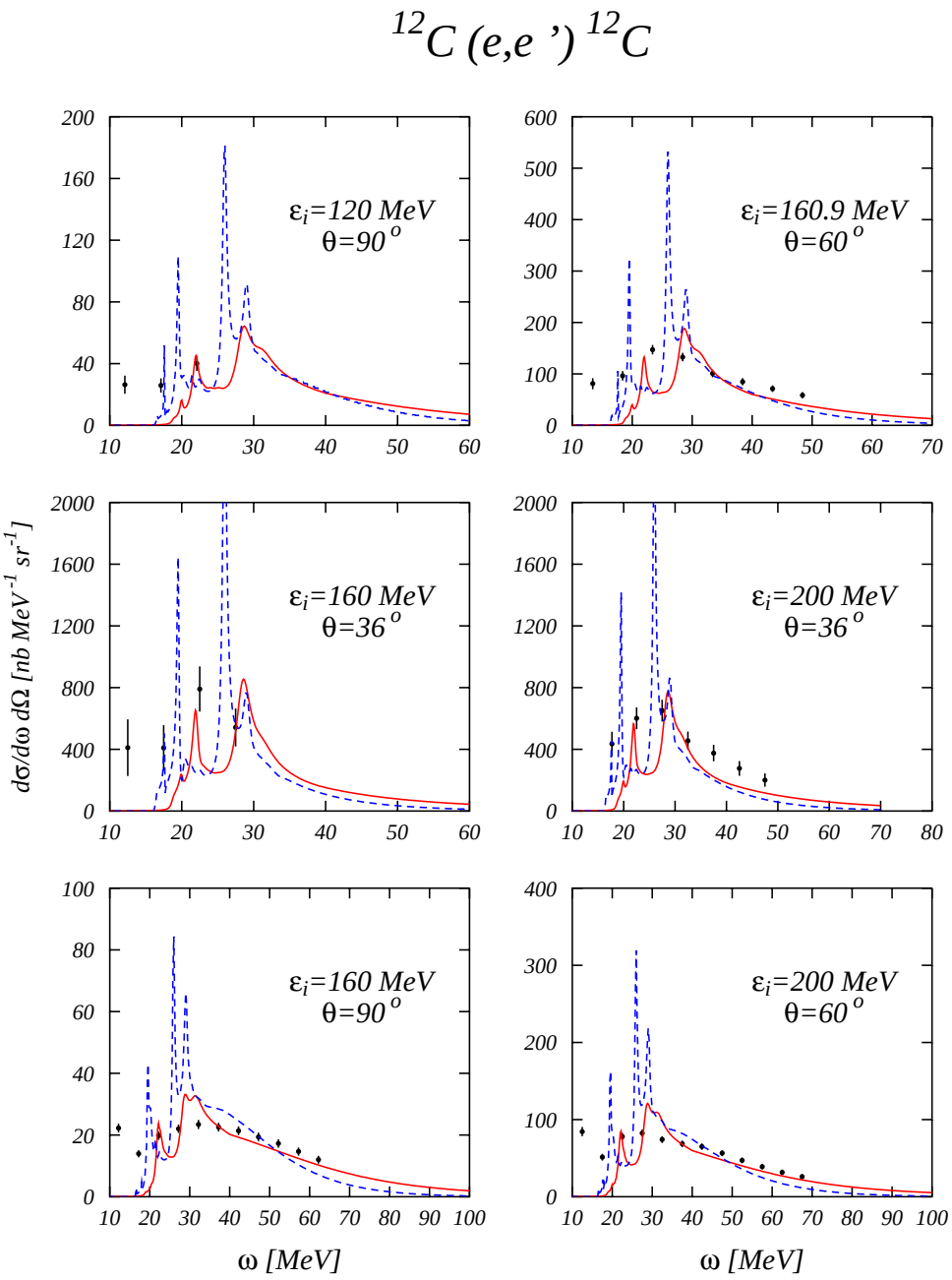


C. Bleve *et al.*, Astroparticle Phys. 16 (2001) 145.

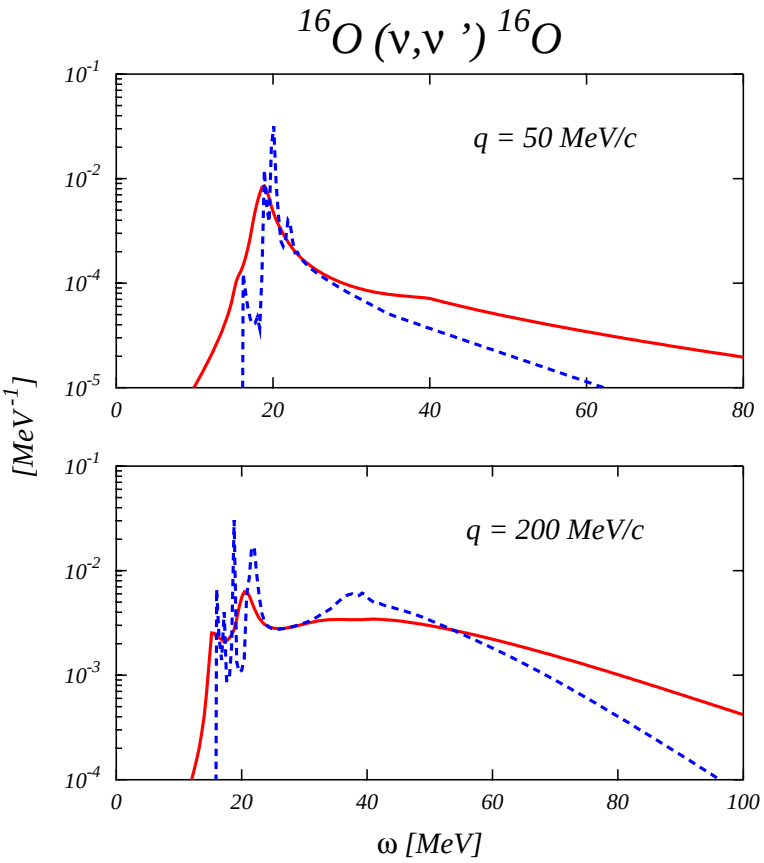


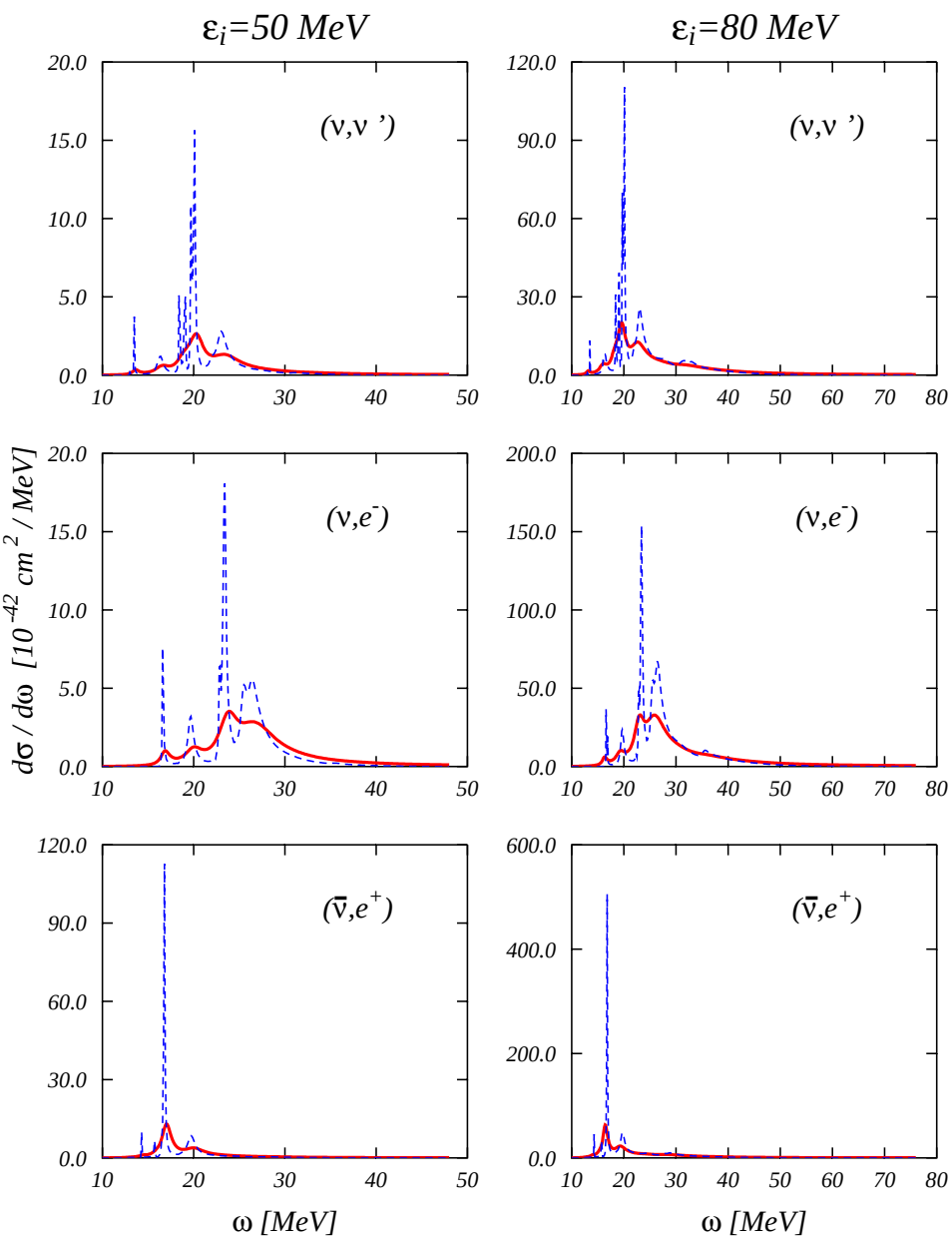
DATA: J. Ahrens *et al.*, Nucl. Phys. A 251 (1975) 479.

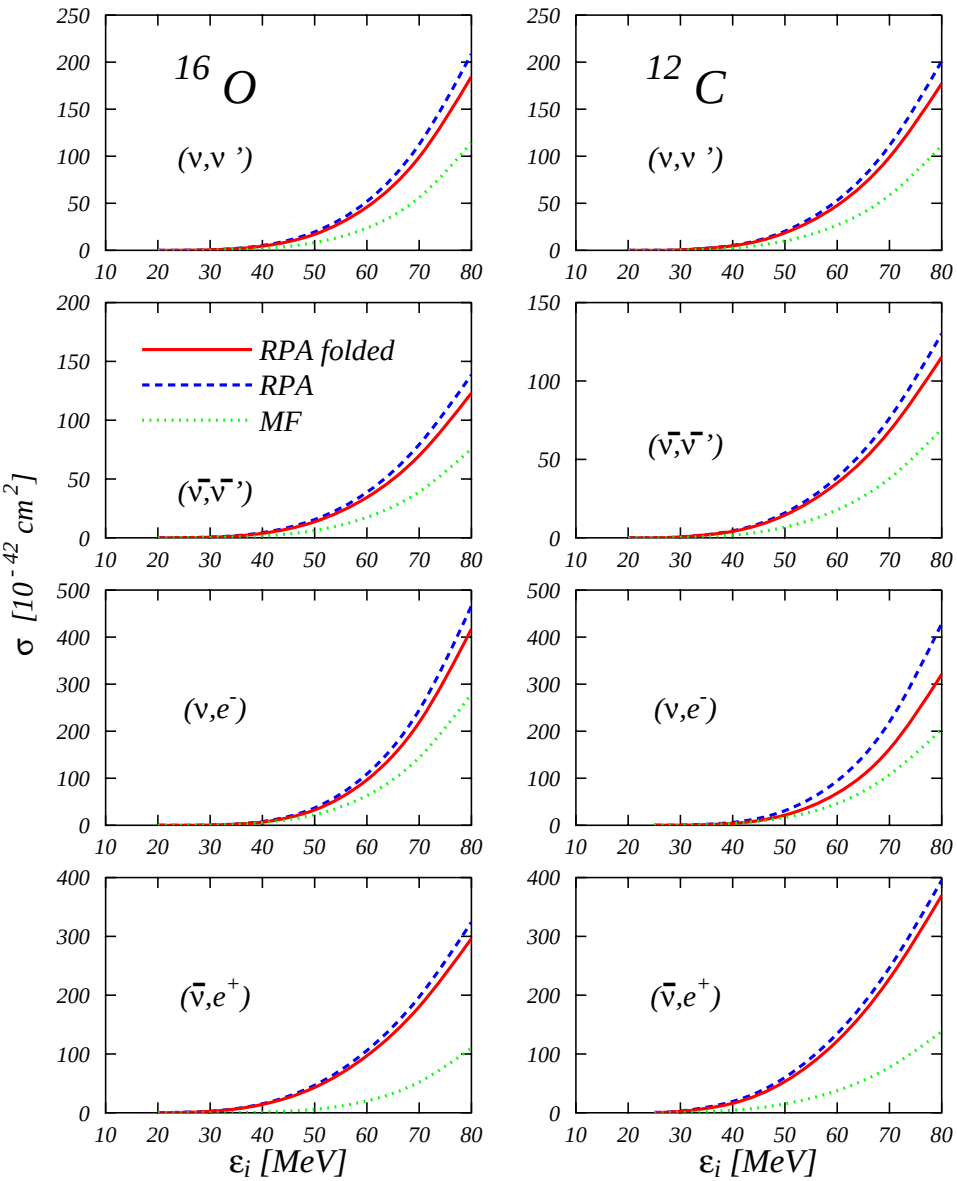

Photoabsorption
σ [mb]
50.0
40.0
30.0
20.0
10.0
0.0
10
20
30
40
50
60
12 C
σ [mb]
80.0
60.0
40.0
20.0
0.0
16 O
ω [MeV]



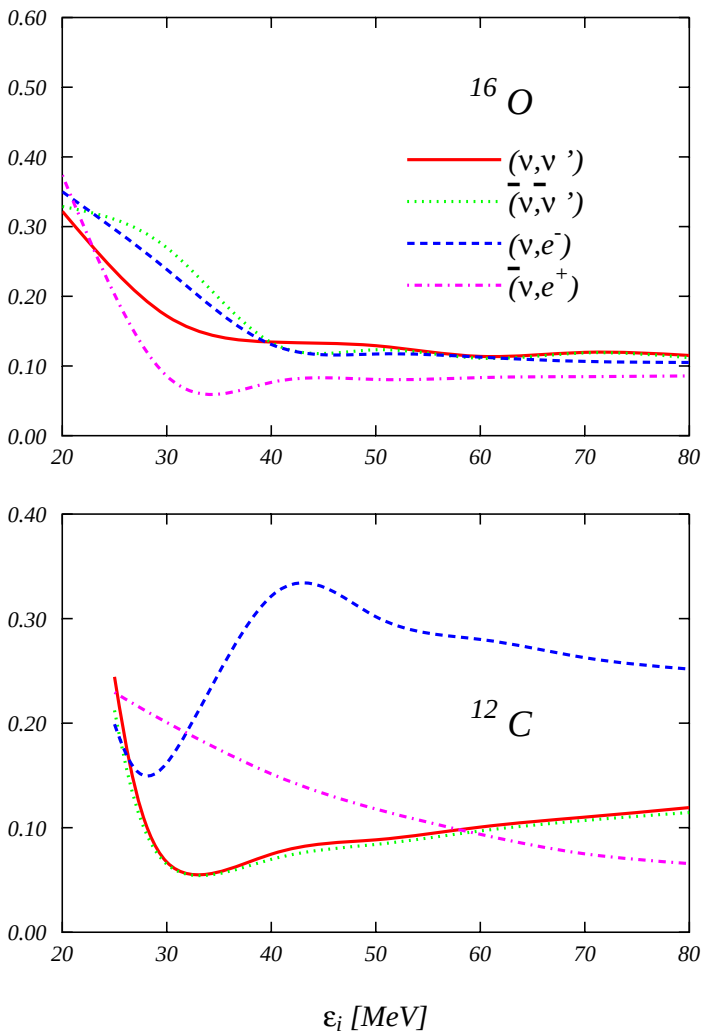
DATA: P. Barreau *et al.*, Nucl. Phys. A 402 (1983) 515.


16O (ν,ν ’) 16O
q = 50 MeV/c
q = 200 MeV/c
[MeV-1]
ω [MeV]


εi=50 MeV
εi=80 MeV
(ν,ν ')
(ν,e-)
(ν̄,e+)
dσ / dω [10-42 cm2 / MeV]
ω [MeV]


16 O
12 C
(ν,ν ')
(ν̄,ν̄ ')
(ν,e⁻)
(ν̄,e⁺)
RPA folded
RPA
MF
σ [10⁻⁴² cm²]
εi [MeV]

$$\left(\sigma^{RPA} - \sigma^{fold}\right)/\sigma^{RPA}$$



Conclusions

- e and ν are very different probes
- Need of improving the description of nuclear responses (more GR than QE)
- DATA are required