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Short Range Correlations in finite nuclear systems

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$$\delta E[\Psi_0] \equiv \delta \left[\frac{< \Psi_0 | H | \Psi_0 >}{< \Psi_0 | \Psi_0 >} \right] = 0$$

$$|\Psi_0 >= F \ |\Phi_0 >$$

$$F = \mathcal{S} \prod_{i<j} \left(\sum_{p=1}^{n} f^p(r_{ij}) \ O^p(i,j) \right)$$

$$O^{p=1,8}(i,j) = [1, \boldsymbol{\sigma}(i) \cdot \boldsymbol{\sigma}(j), S(i,j), \mathbf{L}(i,j) \cdot \mathbf{S}(i,j)] \otimes [\boldsymbol{\tau}(i) \cdot \boldsymbol{\tau}(j)]$$

$$H = \frac{-\hbar^2}{2\,m} \sum_i \nabla_i^2 + \sum_{i<j} v_{ij} + \sum_{i<j<k} v_{ijk}$$

FHNC-1

SOC

$p = n$

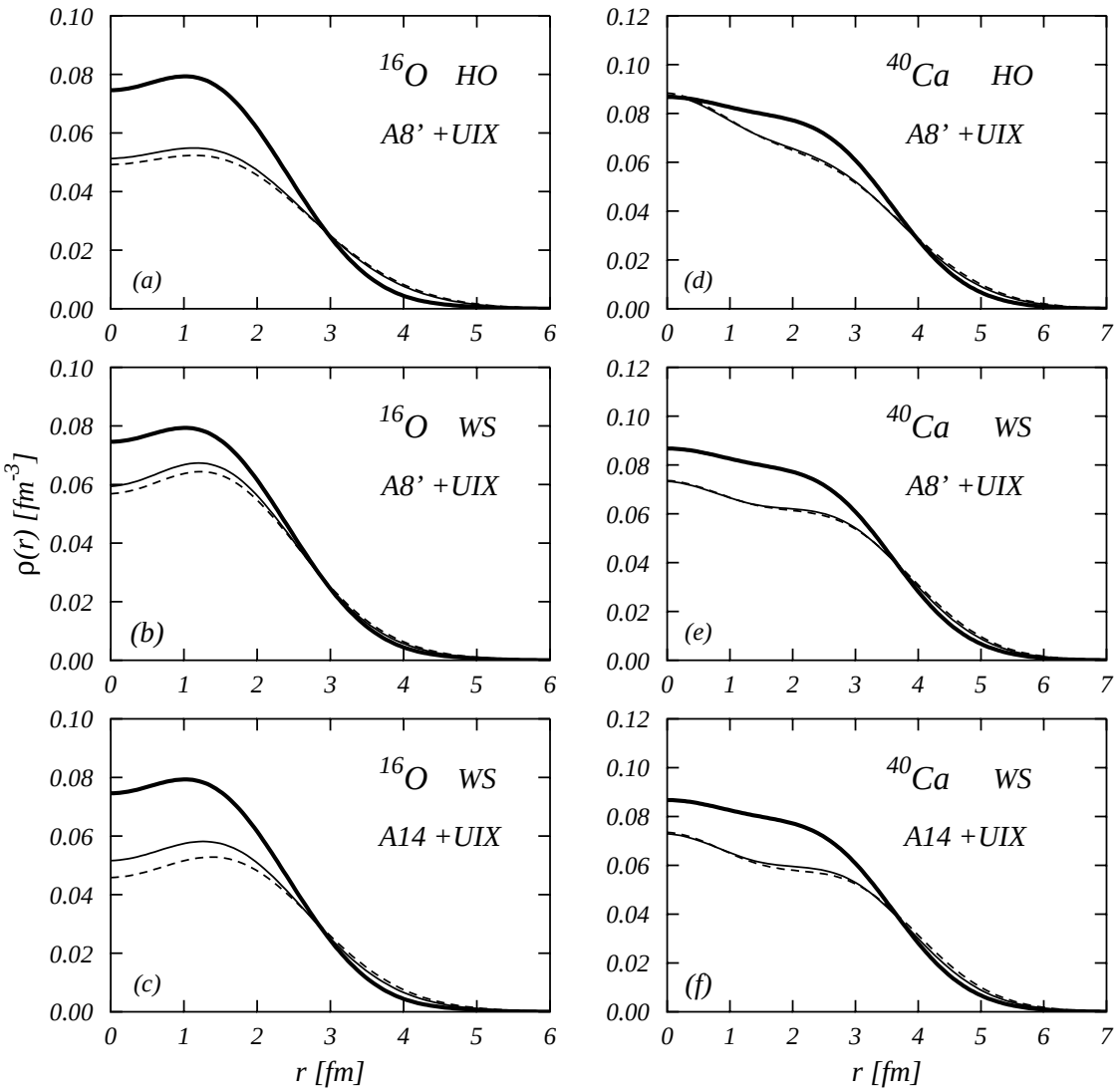
$l - s$ **coupling**

v_{ij} Argonne V8' v_{ijk} Urbana IX

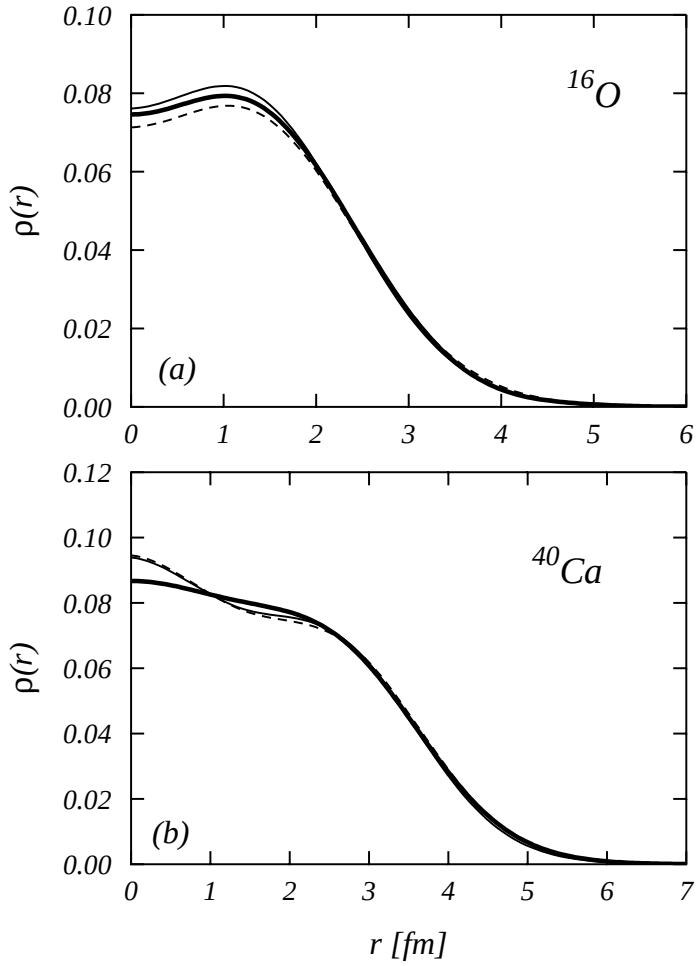
NUCLEAR MATTER - FHNC/0

ρ_{nm}	$E/A(A18)$	$E/A(A8')$	$E/A(A14)$
0.04	-4.11	-5.50	-5.25
0.08	-7.46	-8.45	-8.43
0.12	-9.42	-10.31	-10.63
0.16	-10.05	-10.87	-11.99
0.20	-8.74	-10.06	-12.37
0.24	-5.66	-7.75	-11.74

	^{16}O(WS)$_{A8'}$	^{16}O(WS)$_{A14}$	^{40}Ca(WS)$_{A8'}$	^{40}Ca(WS)$_{A14}$
V_0	-42.00	-36.00	-50.00	-41.50
R_0	3.60	3.80	5.30	5.00
a_0	0.55	0.55	0.53	0.55
$\langle T \rangle$	27.34	25.91	30.58	30.90
$\langle v_{8,ij} \rangle$	-32.48	-31.05	-38.68	-39.08
$\langle v_{ijk}^{2\pi} \rangle$	-1.66	-1.35	-1.94	-1.74
$\langle v_{ijk}^{R} \rangle$	1.98	1.56	2.37	2.11
E_{cm}	0.58	0.52	0.20	0.19
$\langle v_{Coul} \rangle$	0.86	0.84	1.85	1.87
ΔE	-0.94	-0.50	-0.96	-0.70
E_{gs}	-5.48	-5.11	-6.97	-6.50
rms	2.83	2.93	3.66	3.66


^{16}O HO
A8' +UIX
(a)
^{40}Ca HO
A8' +UIX
(d)
^{16}O WS
A8' +UIX
(b)
^{40}Ca WS
A8' +UIX
(e)
^{16}O WS
A14 +UIX
(c)
^{40}Ca WS
A14 +UIX
(f)
ρ(r) [fm^{-3}]
r [fm]
r [fm]

	$^{16}O(WS)_{A8'}$	$^{40}Ca(WS)_{A8'}$
V_0	-53.00	-50.00
R_0	3.45	4.60
a_0	0.7	0.5
$\langle T \rangle$	32.64	38.15
$\langle v_{8,ij} \rangle$	-37.79	-46.34
$\langle v^{2\pi}_{ijk} \rangle$	-2.36	-2.98
$\langle v^{R}_{ijk} \rangle$	3.00	3.94
E_{cm}	0.64	0.23
$\langle v_{Coul} \rangle$	0.94	2.10
ΔE	-1.21	-1.28
E_{gs}	-5.41	-6.64
rms	2.67	3.39

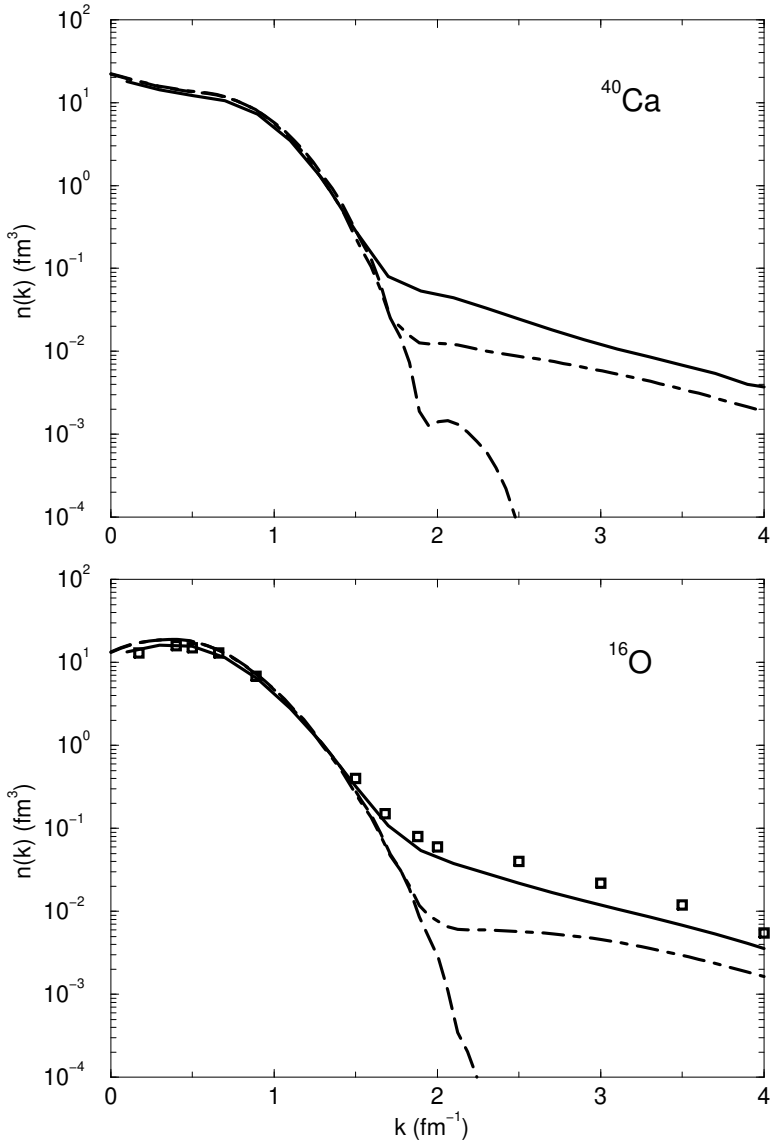

0.10
0.08
0.06
0.04
0.02
0.00
ρ(r)
^{16}O
(a)
0
1
2
3
4
5
6
0.12
0.10
0.08
0.06
0.04
0.02
0.00
ρ(r)
^{40}Ca
(b)
0
1
2
3
4
5
6
7
r [fm]

‘

$$\psi_h(x) = \sqrt{A}\frac{\langle \Psi_h(A-1)|\delta(x-x_A)|\Psi_0(A)\rangle}{\langle \Psi_h(A-1)|\Psi_h(A-1)\rangle^{1/2}\langle \Psi_0(A)|\Psi_0(A)\rangle^{1/2}}$$

$$\mathcal{N}_h = \frac{\langle \Psi_h(A-1)|\Psi_h(A-1)\rangle}{\langle \Psi_0(A)|\Psi_0(A)\rangle}$$

	corr.	$1s$	$1p$	$1d$	$2s$
^{16}O	f_1	1.00	0.98		
	f_4	0.79	0.96		
	f_6	0.70	0.90		
^{40}Ca	f_1	0.98	0.99	0.97	0.98
	f_4	0.71	0.76	0.96	0.97
	f_6	0.55	0.58	0.87	0.86


^{40}Ca
^{16}O
n(k) (fm^3)
k (fm^{-1})

$$S(\mathbf{q},\omega) \;=\; -\frac{1}{\pi}\,\mathrm{Im}\,\mathrm{D}(\mathbf{q},\omega)$$

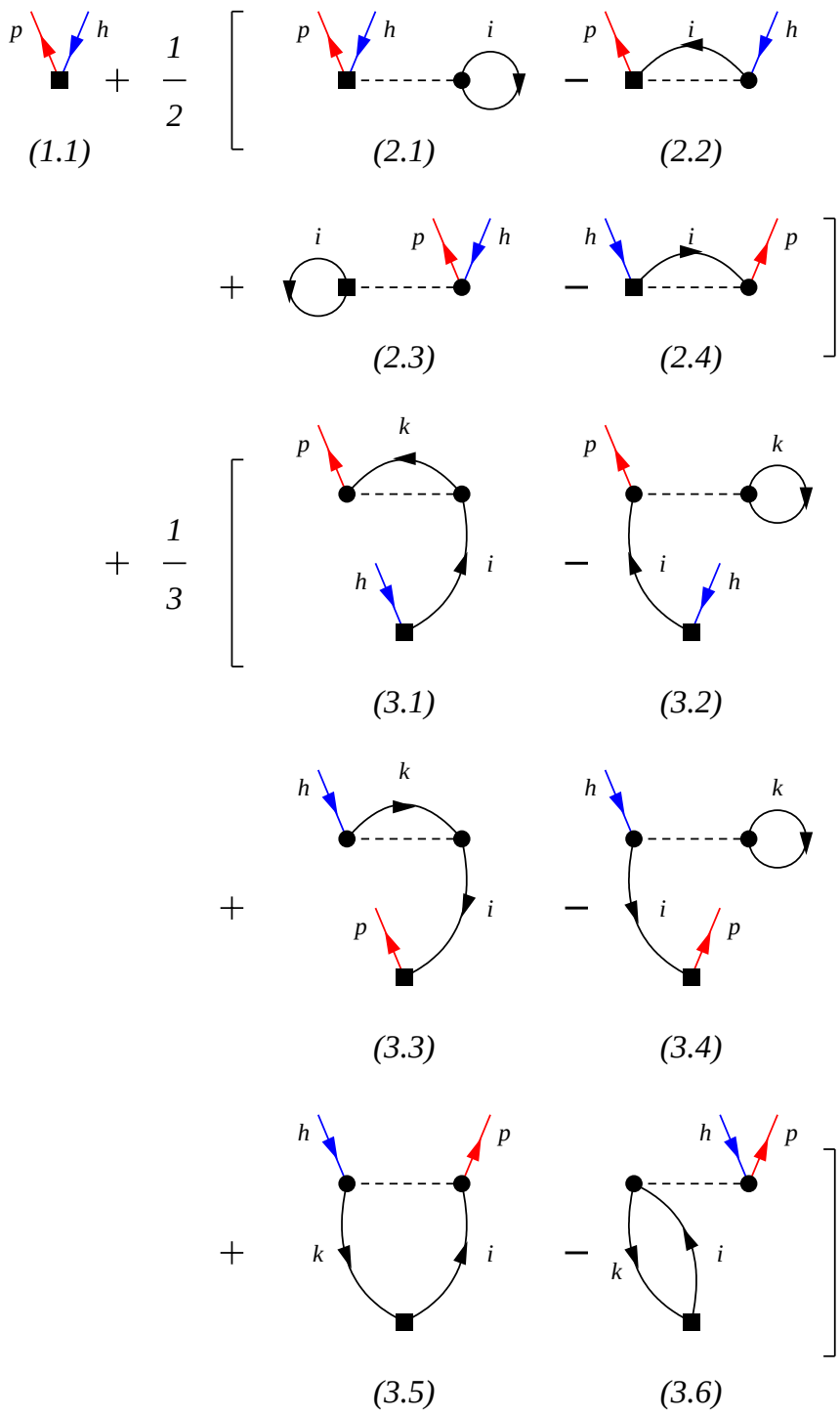
$$D(\mathbf{q},\omega) \;=\; \langle\widetilde{\Psi}_0\,|\,O^{+}(\mathbf{q})\,(H-E_0-\omega+i\eta)^{-1}\,O(\mathbf{q})\,|\,\widetilde{\Psi}_0\rangle$$

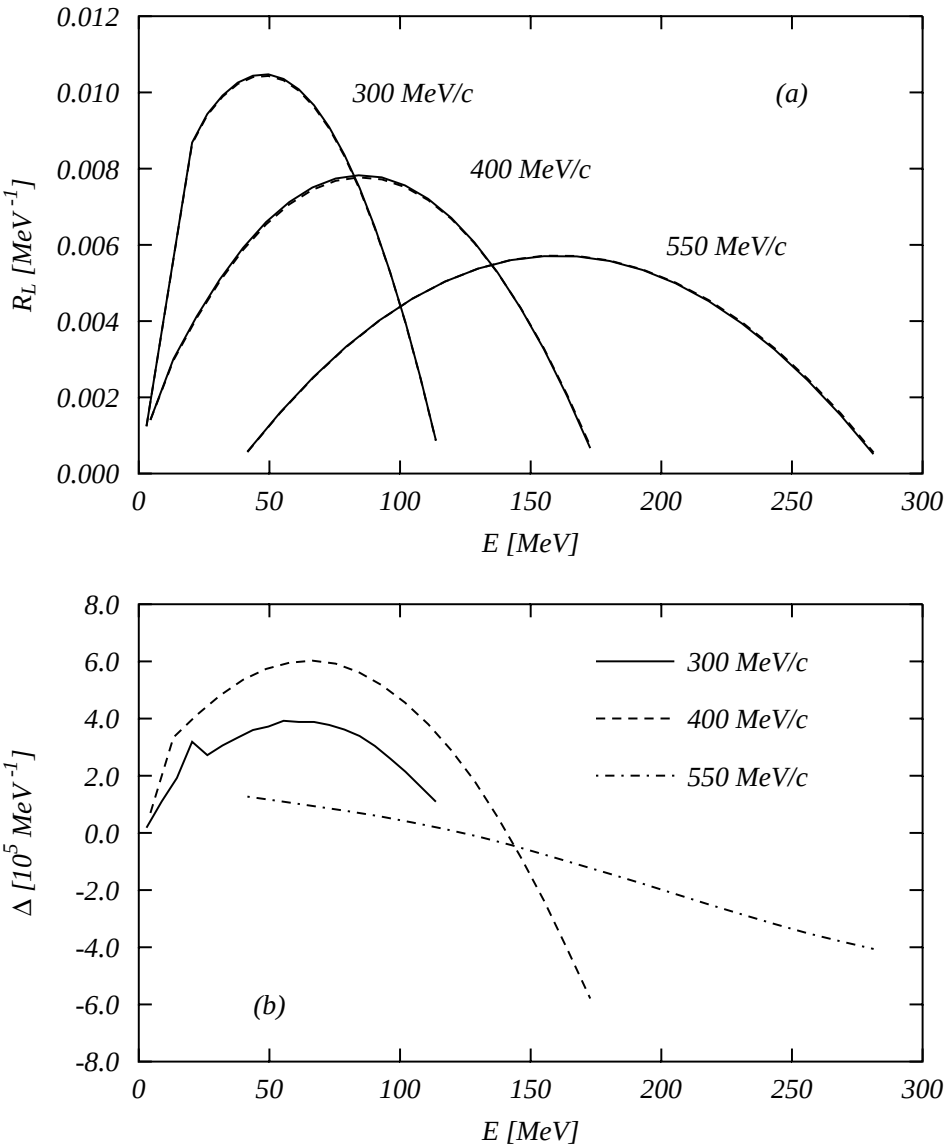
$$|\,\widetilde{\Psi}_n\rangle \;=\; \frac{|\Psi_n\rangle}{\langle\Psi_n|\Psi_n\rangle^{\frac{1}{2}}}$$

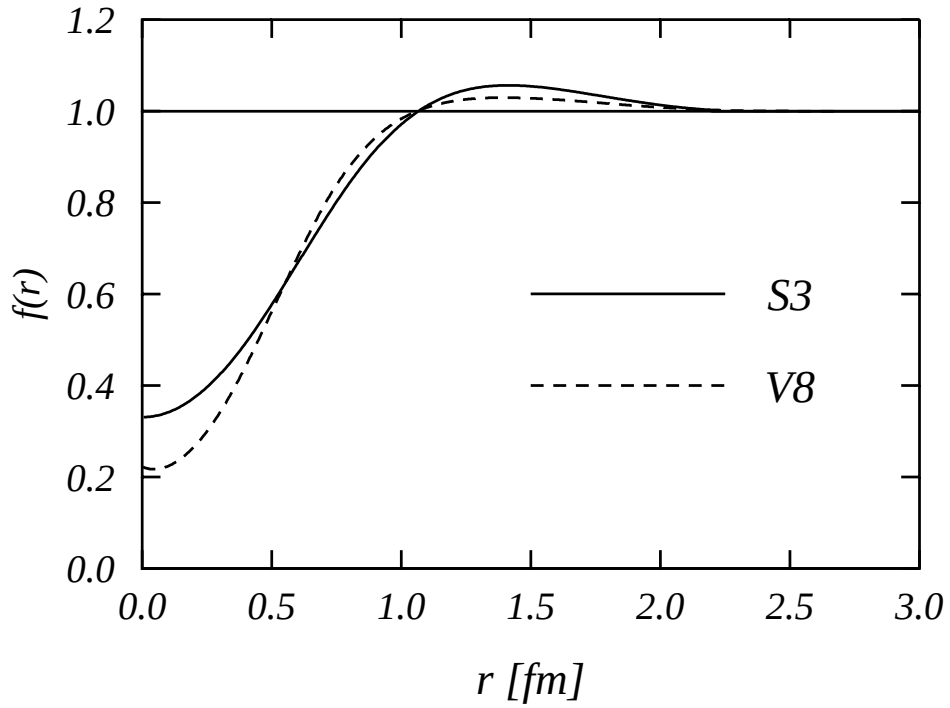
$$\begin{aligned} D(\mathbf{q},\omega) \;&=\; \sum_n \frac{|\langle\widetilde{\Psi}_n\,|\,O(\mathbf{q})\,|\,\widetilde{\Psi}_0\rangle|^2}{E_n-E_0-\omega+i\eta} \\ &=\; \sum_n \xi_n^{+}(\mathbf{q})\,(E_n-E_0-\omega+i\eta)^{-1}\,\xi_n(\mathbf{q}) \end{aligned}$$

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

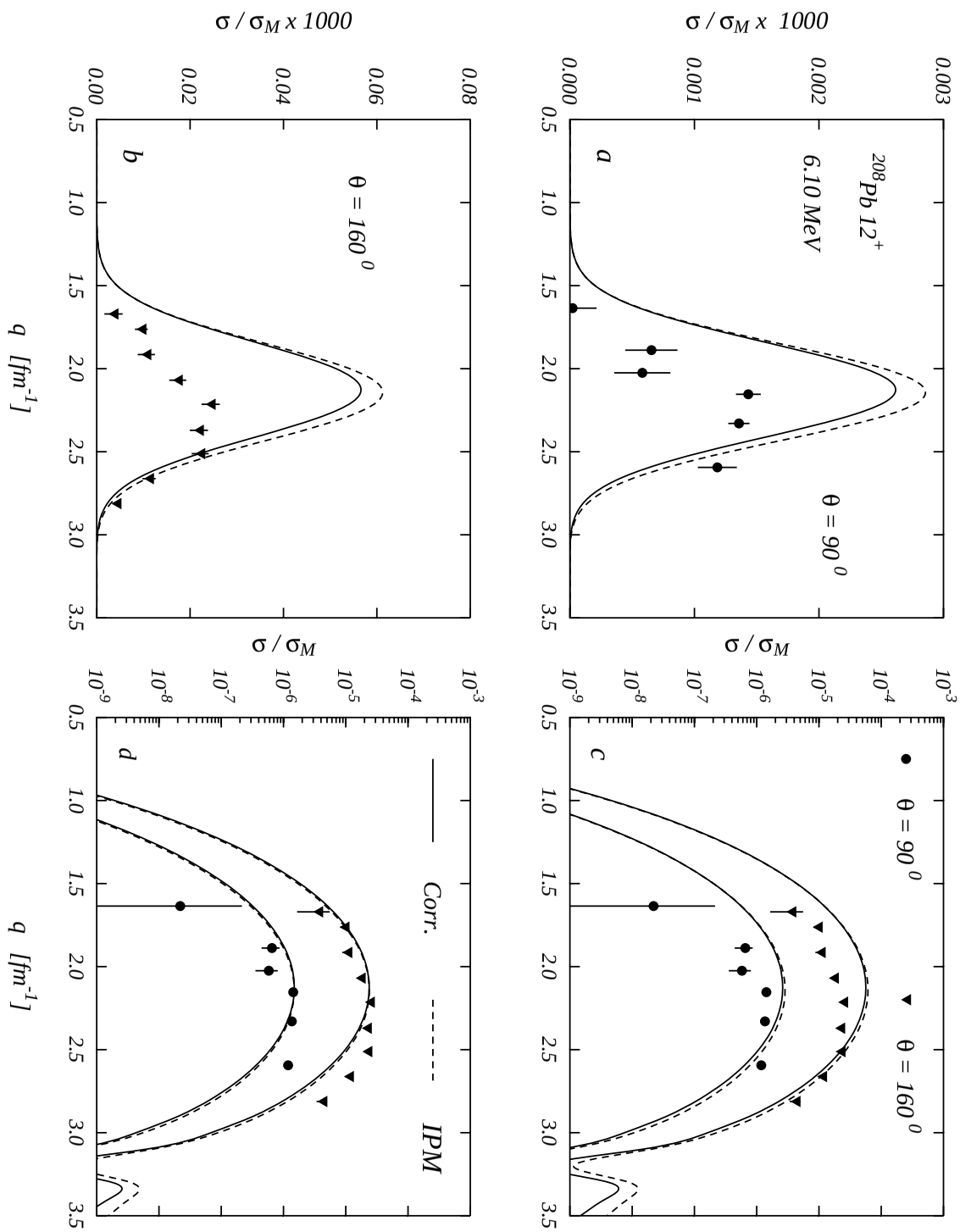
$$|\Psi_0\rangle \;=F\,|\Phi_0\rangle \qquad |\Psi_n\rangle \;=F\,|\Phi_n\rangle$$

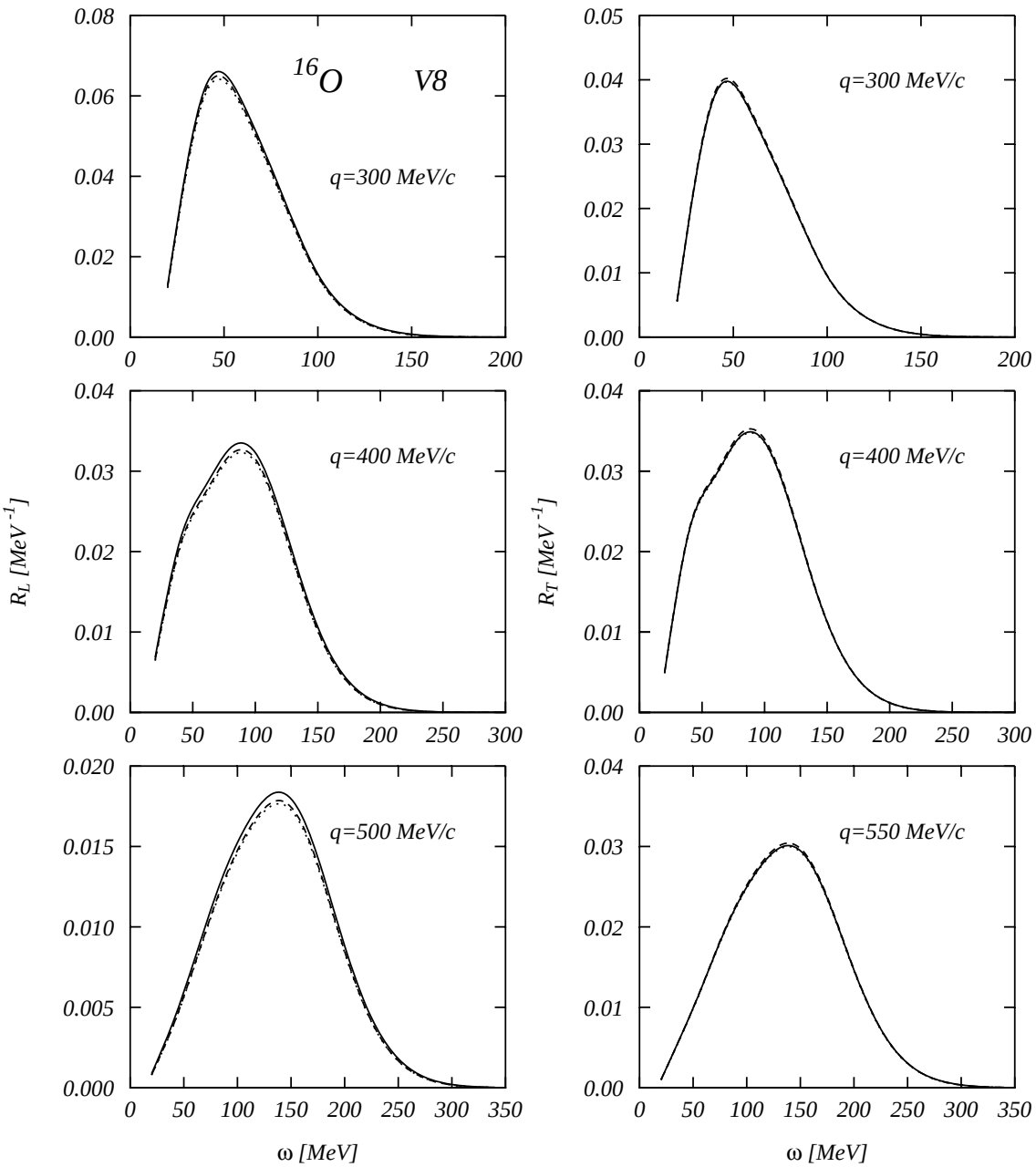

p h
+ 1/2 [
p h i
p i h
(1.1)
(2.1)
(2.2)
+ i p h
h i p]
(2.3)
(2.4)
+ 1/3 [
p k h i
p k i h
(3.1)
(3.2)
+ h k p i
h k i p
(3.3)
(3.4)
+ h p k i
h p k i]
(3.5)
(3.6)


0.012
0.010
0.008
0.006
0.004
0.002
0.000
R_L [MeV^{-1}]
300 MeV/c
400 MeV/c
550 MeV/c
(a)
0
50
100
150
200
250
300
E [MeV]
8.0
6.0
4.0
2.0
0.0
-2.0
-4.0
-6.0
-8.0
Δ [10^5 MeV^{-1}]
300 MeV/c
400 MeV/c
550 MeV/c
(b)
0
50
100
150
200
250
300
E [MeV]

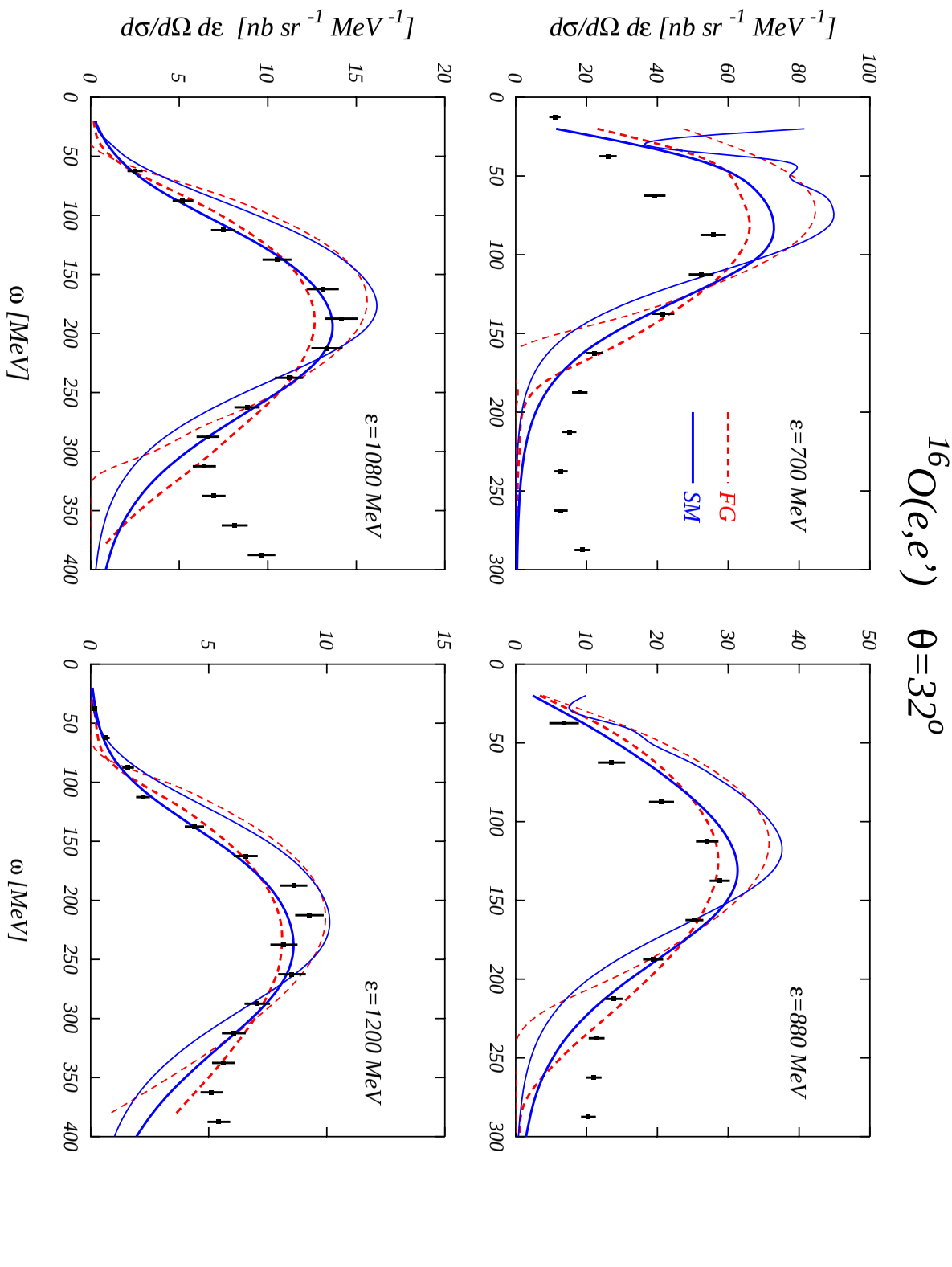

1.2
1.0
0.8
0.6
0.4
0.2
0.0
f(r)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
r [fm]
S3
V8

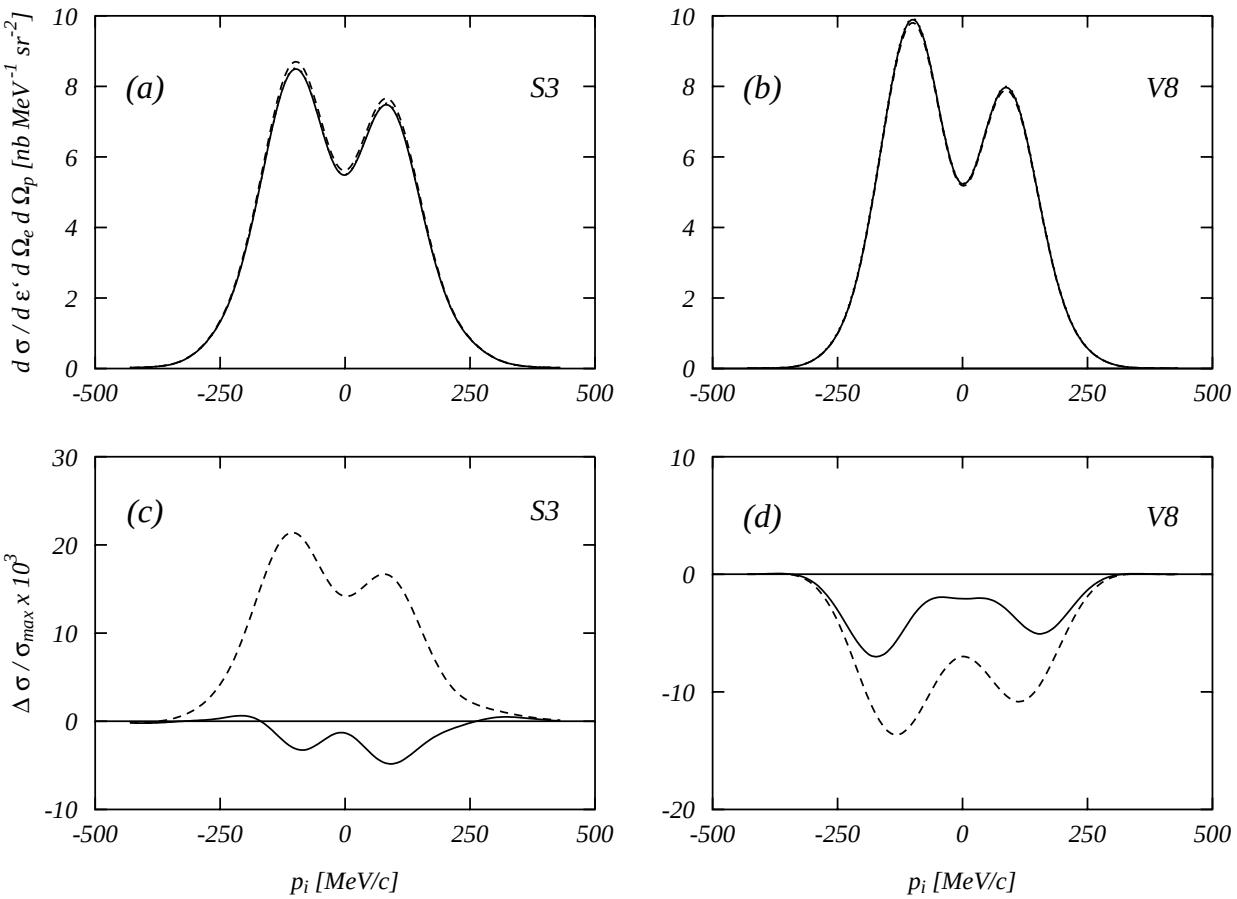
Data: J. Lichtenstadt *et al.* P.R. C20 (1979) 497.

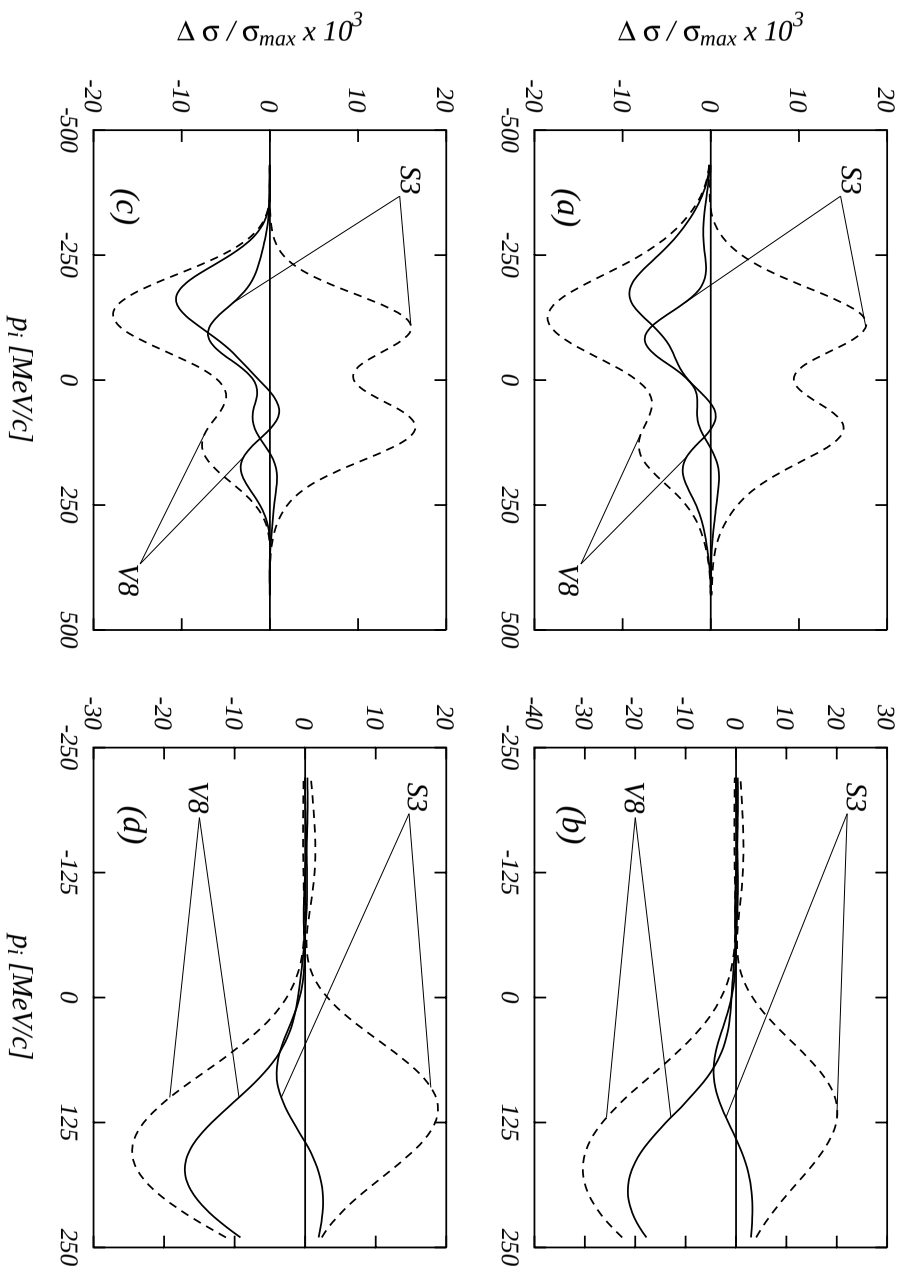



^{16}O V8
q=300 MeV/c
q=300 MeV/c
q=400 MeV/c
q=400 MeV/c
q=500 MeV/c
q=550 MeV/c
R_L [MeV^{-1}]
R_T [MeV^{-1}]
ω [MeV]
ω [MeV]

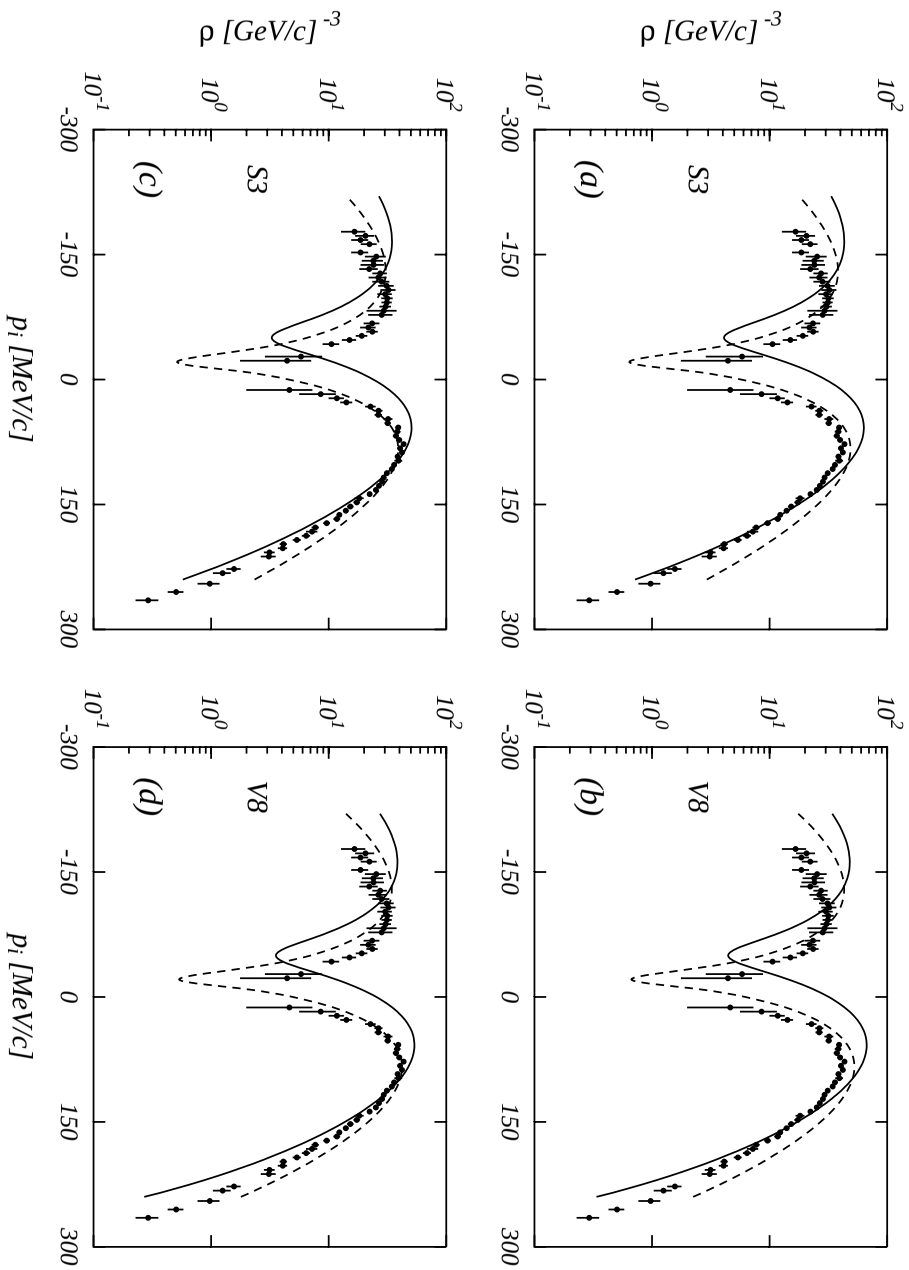
Data: M. Anghinolfi *et al.* N.P. A602 (1996) 405.

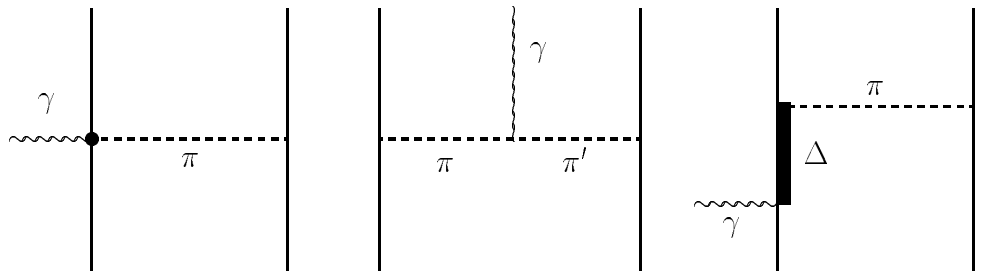


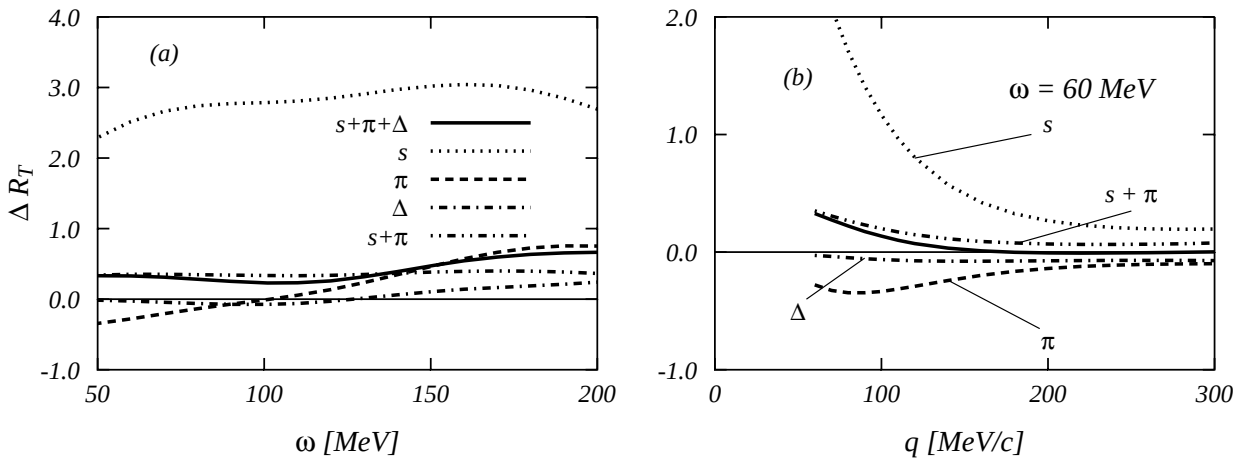

(a)
S3
(b)
V8
(c)
S3
(d)
V8
$d\sigma / d\varepsilon' d\Omega_e d\Omega_p$ [nb MeV^{-1} sr^{-2}]
$\Delta\sigma / \sigma_{max} \times 10^3$
p_i [MeV/c]
p_i [MeV/c]

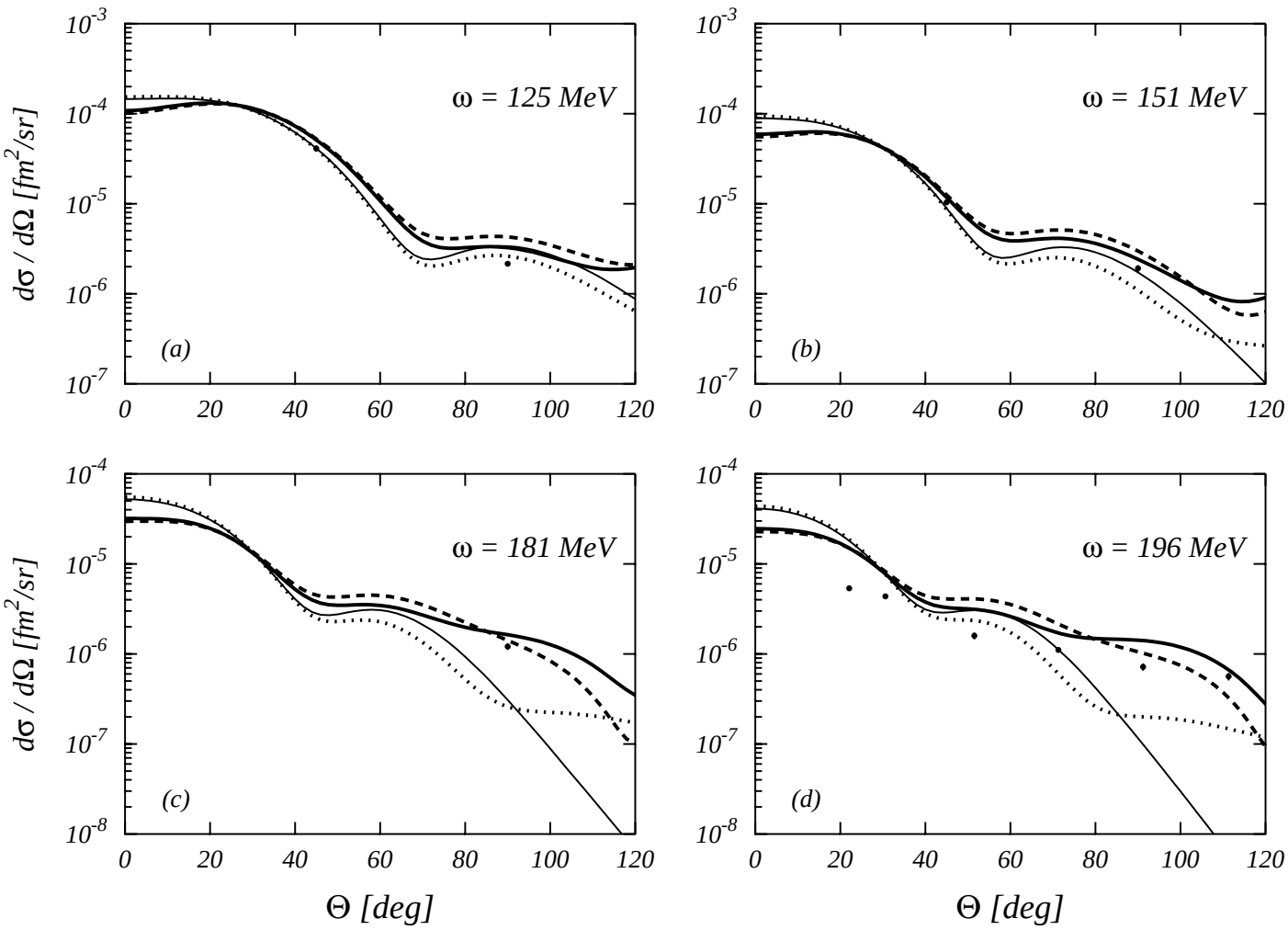

Δ σ / σmax x 10^3
(a)
S3
V8
(b)
(c)
(d)
pi [MeV/c]

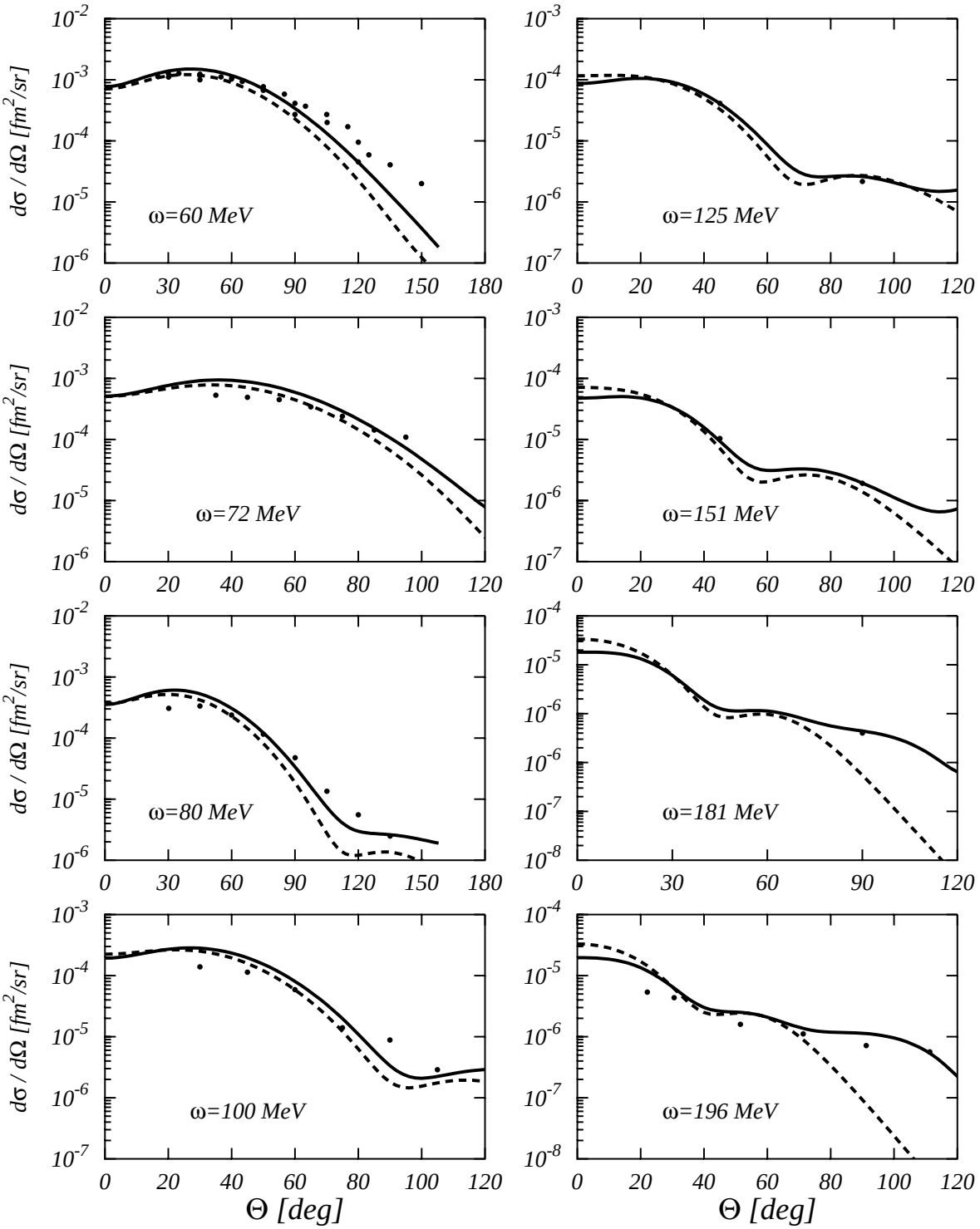
Data: M. Leuschner *et al.* P.R. C49 (1994) 955.

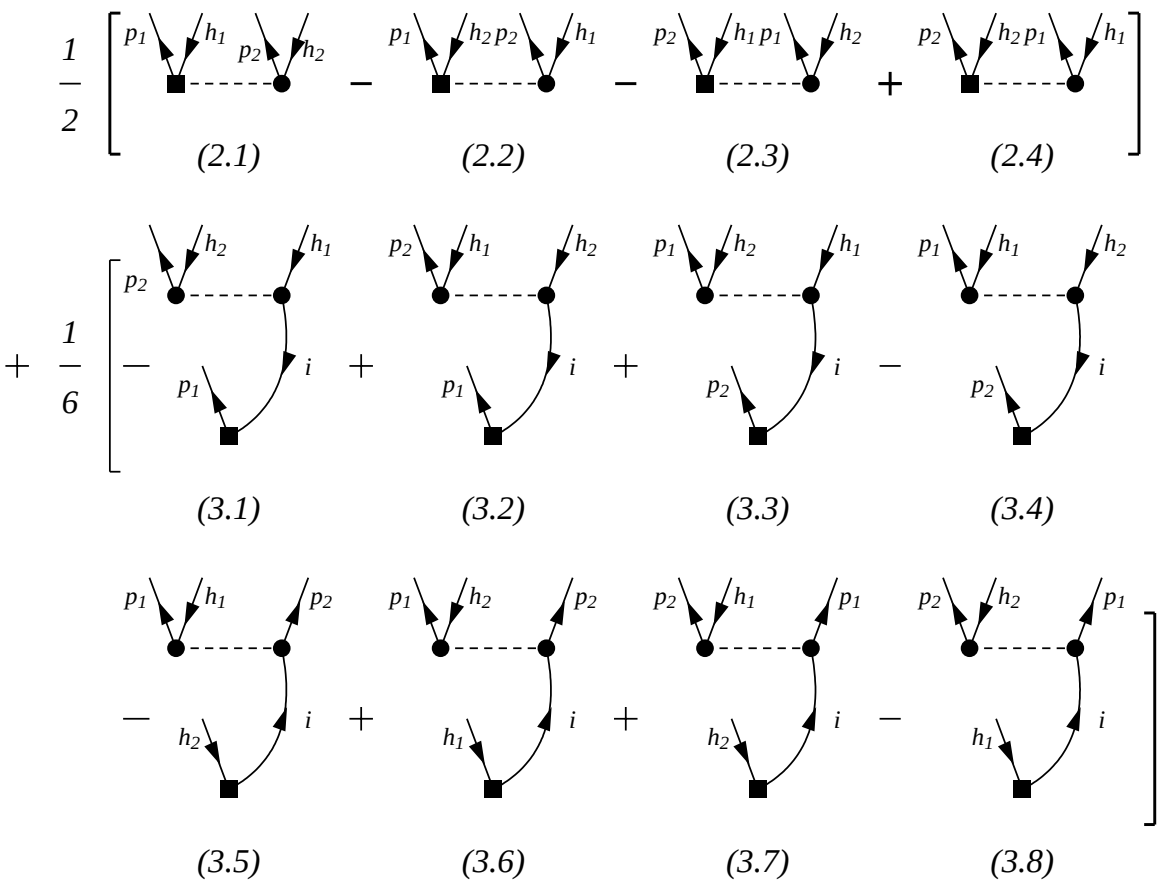


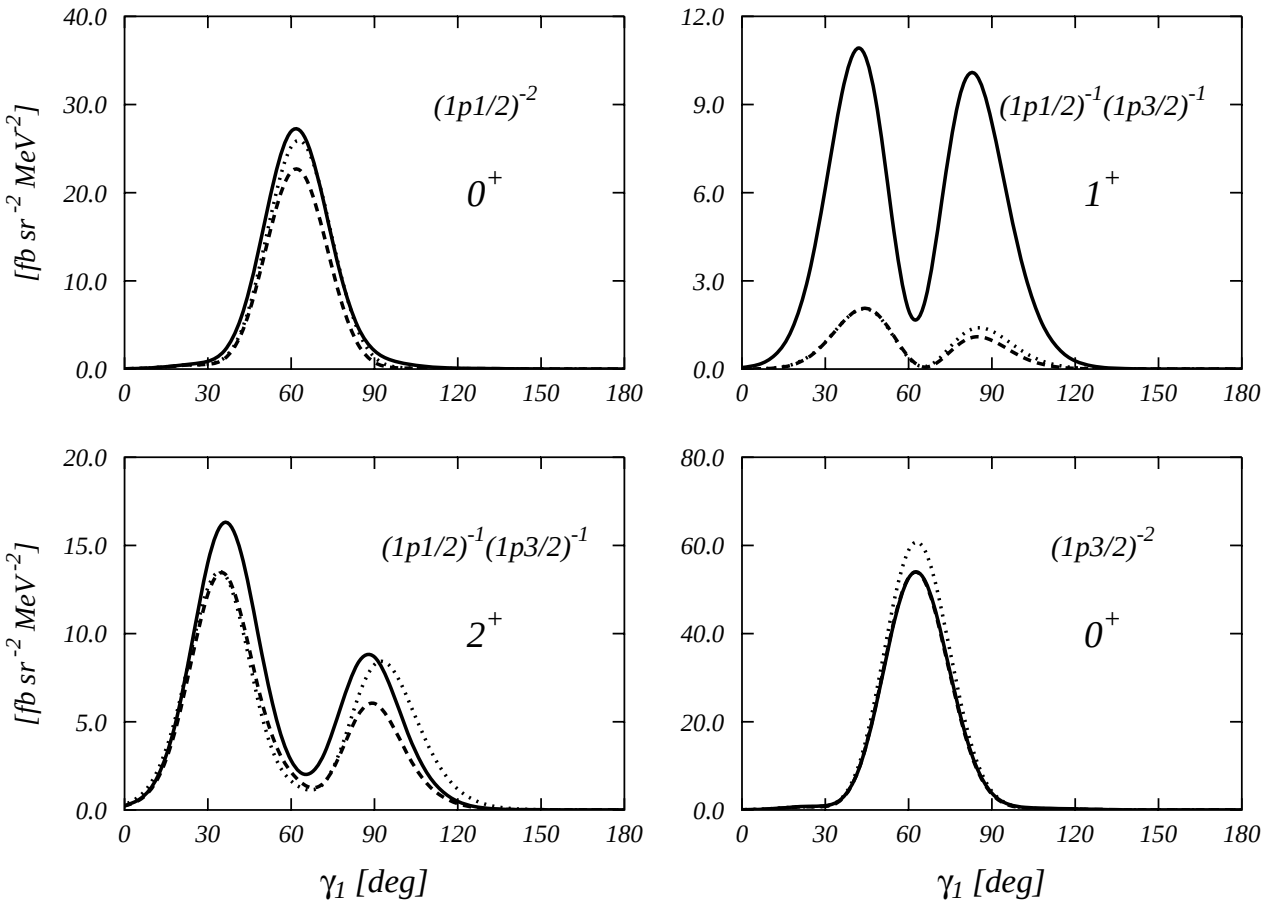

γ
π
(a)
γ
π
π′
(b)
π
Δ
γ
(c)


(a)
s+π+Δ
s
π
Δ
s+π
Δ R_T
ω [MeV]
(b)
ω = 60 MeV
s
s + π
Δ
π
q [MeV/c]


dσ / dΩ [fm²/sr]
ω = 125 MeV
(a)
ω = 151 MeV
(b)
ω = 181 MeV
(c)
ω = 196 MeV
(d)
Θ [deg]
Θ [deg]


dσ / dΩ [fm²/sr]
ω=60 MeV
ω=125 MeV
ω=72 MeV
ω=151 MeV
ω=80 MeV
ω=181 MeV
ω=100 MeV
ω=196 MeV
Θ [deg]
Θ [deg]


1/2
p1 h1 p2 h2
h2 p2
h1 p1
p2 h2 p1
(2.1)
(2.2)
(2.3)
(2.4)
+ 1/6
p2 h2 h1 i p1
p2 h1 h2 i p1
p1 h2 h1 i p2
p1 h1 h2 i p2
(3.1)
(3.2)
(3.3)
(3.4)
p1 h1 p2 h2 i
p1 h2 p2 h1 i
p2 h1 p1 h2 i
p2 h2 p1 h1 i
(3.5)
(3.6)
(3.7)
(3.8)


40.0
30.0
20.0
10.0
0.0
[fb sr^{-2} MeV^{-2}]
(1p1/2)$^{-2}$
0^{+}
0 30 60 90 120 150 180
12.0
9.0
6.0
3.0
0.0
(1p1/2)$^{-1}$(1p3/2)$^{-1}$
1^{+}
0 30 60 90 120 150 180
20.0
15.0
10.0
5.0
0.0
[fb sr^{-2} MeV^{-2}]
(1p1/2)$^{-1}$(1p3/2)$^{-1}$
2^{+}
0 30 60 90 120 150 180
γ$_1$ [deg]
80.0
60.0
40.0
20.0
0.0
(1p3/2)$^{-2}$
0^{+}
0 30 60 90 120 150 180
γ$_1$ [deg]

Josè Enrique Amaro (Granada, Spain)

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Adelchi Fabrocini (Pisa, Italy)

Stefano Fantoni (Trieste, Italy)

Paolo Folgarait (Pisa, Italy)

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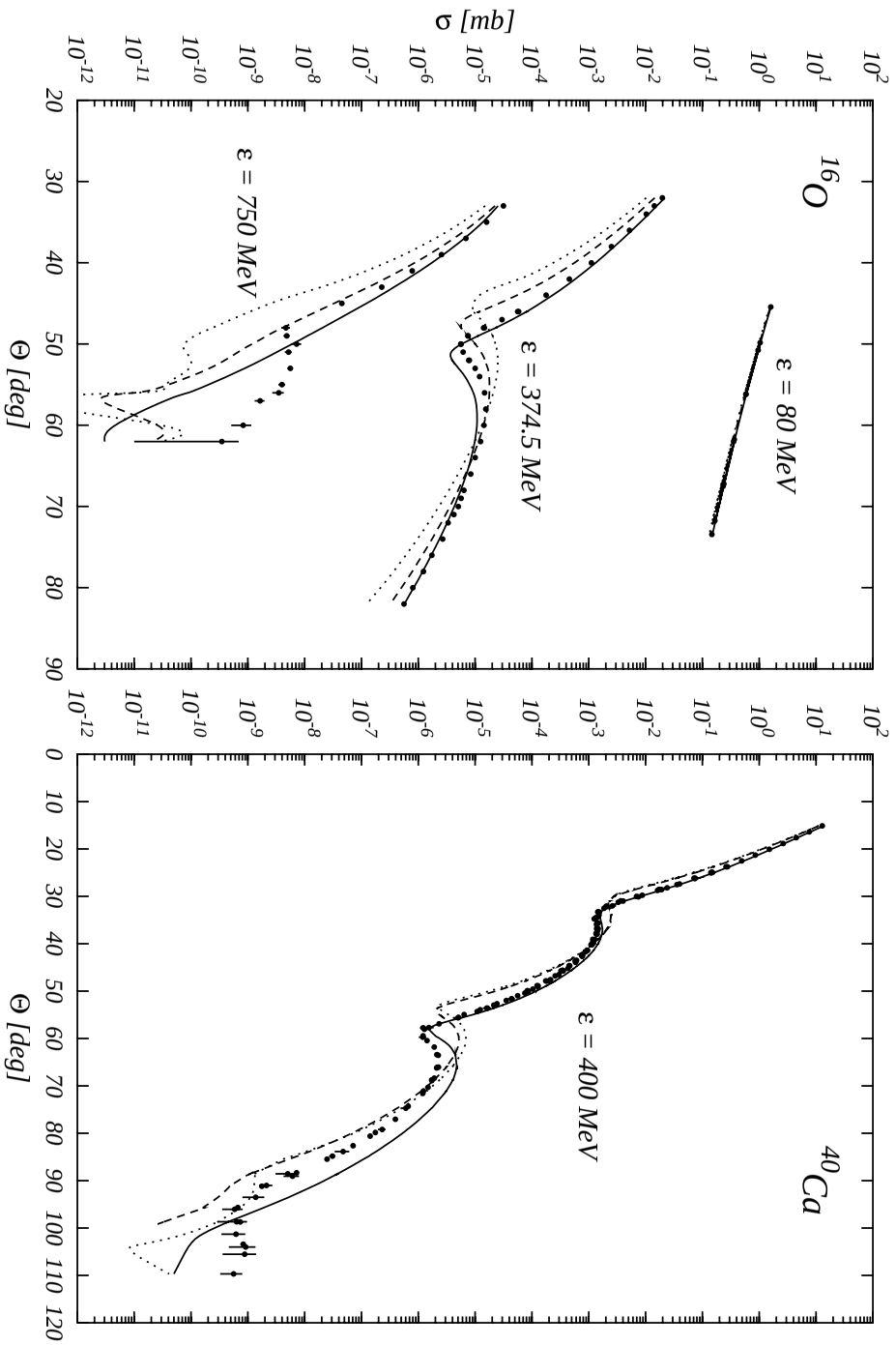
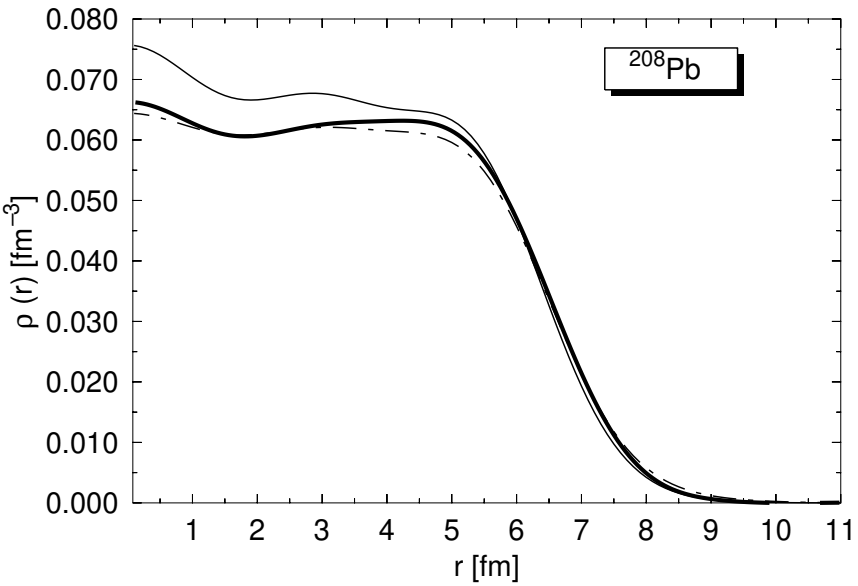
Antonio Miguel Lallena (Granada, Spain)

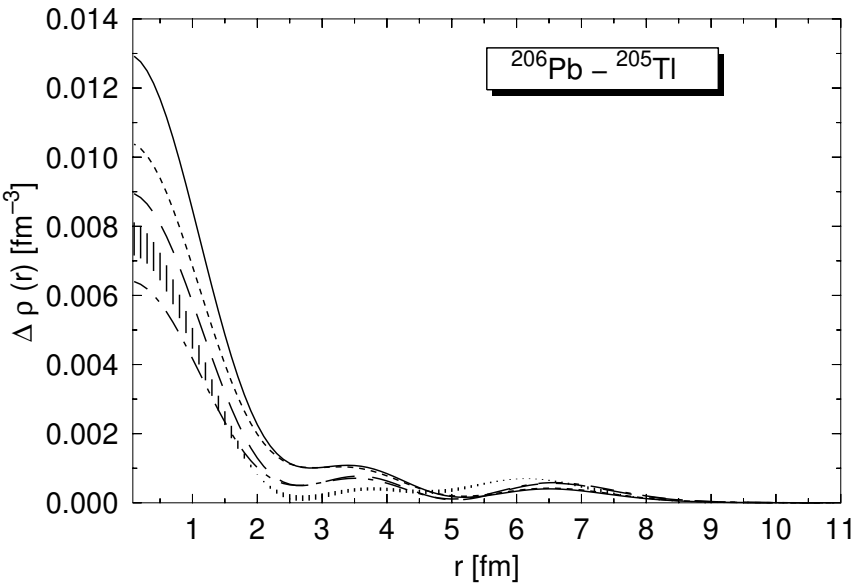
Sherif Rashad Mokhtar (Assiut, Egypt)

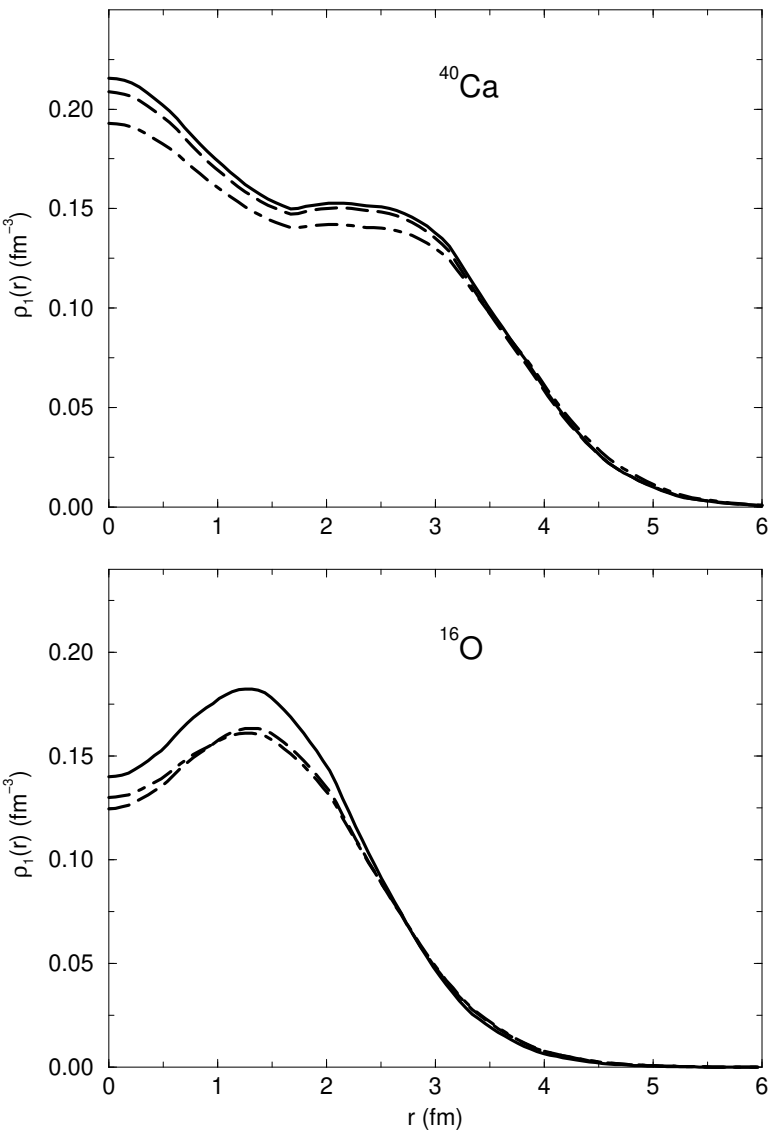
Maria Milena Renis (Lecce, Italy)

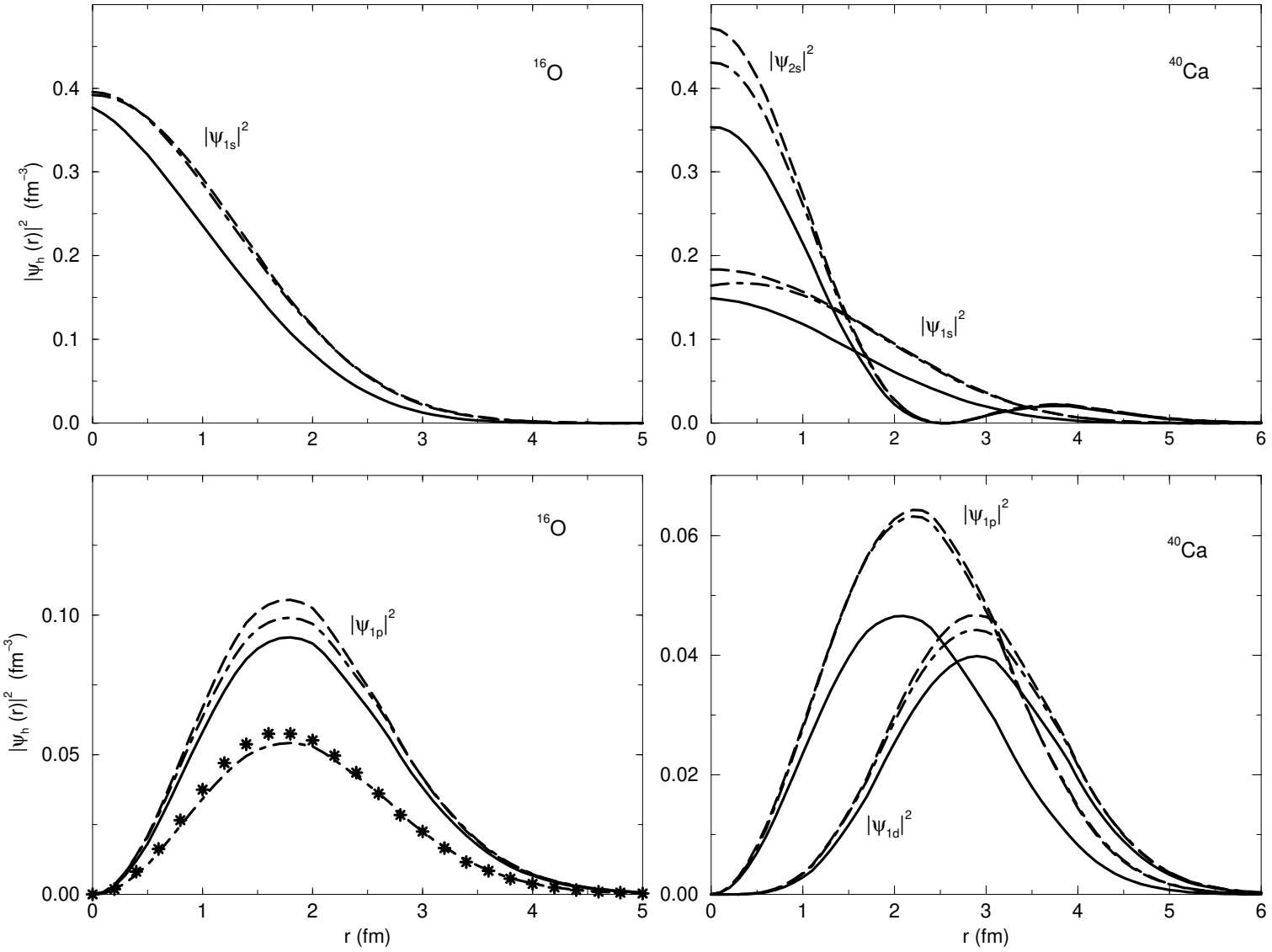
Data: I. Sick *(priv. comm.)*

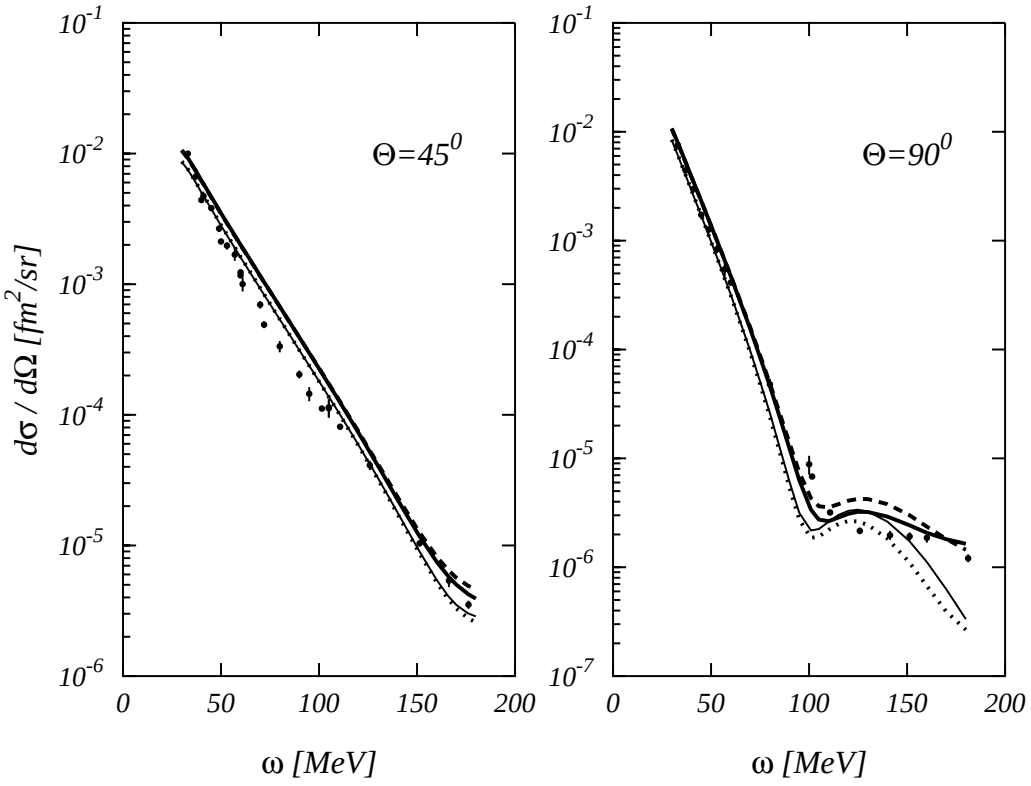


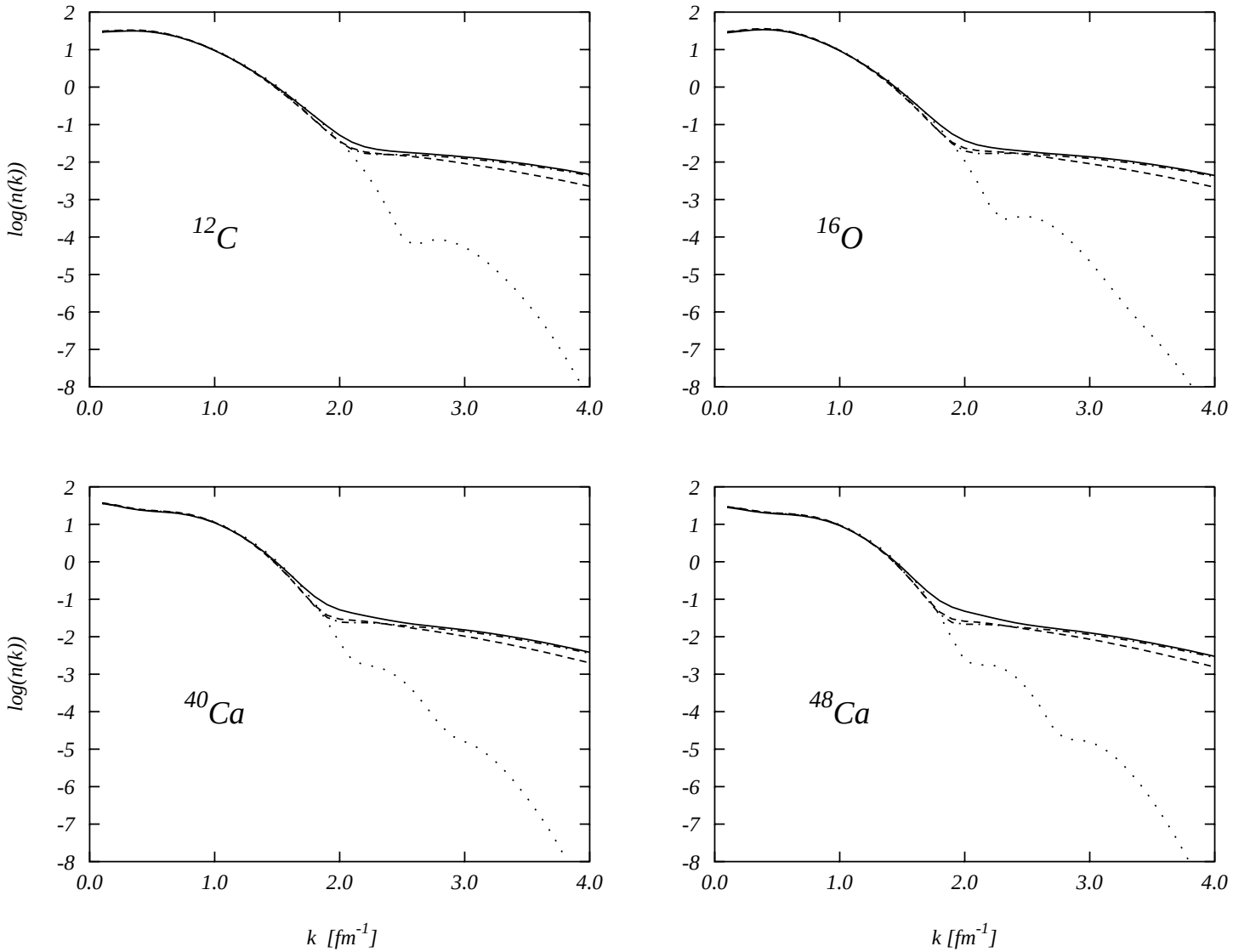

0.080
0.070
0.060
0.050
0.040
0.030
0.020
0.010
0.000
ρ (r) [fm^{-3}]
^{208}Pb
1 2 3 4 5 6 7 8 9 10 11
r [fm]


0.014
0.012
0.010
0.008
0.006
0.004
0.002
0.000
Δ ρ (r) [fm^{-3}]
^{206}Pb – ^{205}Tl
1 2 3 4 5 6 7 8 9 10 11
r [fm]


^{40}Ca
^{16}O
$\rho_1(r)$ (fm^{-3})
r (fm)
0.00
0.05
0.10
0.15
0.20
0
1
2
3
4
5
6


^{16}O
$|\psi_{1s}|^2$
^{40}Ca
$|\psi_{2s}|^2$
$|\psi_{1s}|^2$
^{16}O
$|\psi_{1p}|^2$
^{40}Ca
$|\psi_{1p}|^2$
$|\psi_{1d}|^2$
$|\psi_h(r)|^2$ (fm^{-3})
r (fm)


Θ=45^0
Θ=90^0
dσ / dΩ [fm^2/sr]
ω [MeV]
ω [MeV]
10^-1
10^-2
10^-3
10^-4
10^-5
10^-6
10^-7
0
50
100
150
200


log(n(k))
^{12}C
^{16}O
^{40}Ca
^{48}Ca
k [fm^{-1}]
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
0.0
1.0
2.0
3.0
4.0