NUCLEON RECOIL POLARIZATION IN QUASI-ELASTIC ELECTRON SCATTERING WITH TWO-BODY CURRENTS

[illegible]. Boffi, C. Giusti, F.D. Pacati and M. R.

Polarization experiments

$\Downarrow$

spin degrees of freedom of the particles involved in the reaction are put in evidence and exploited

$\Downarrow$

1] New observables $\longrightarrow$ new structure functions

2] Complete determination of scattering amplitudes

Hard task! (at least one measurement of recoil nucleus polarization)

$\Downarrow$

Selection of the structure functions more sensitive to the various effects to be explored — F.S.I.

M.E.C. + I.C.

1] General Formalism $\longrightarrow$ polarization observables
structure functions

Details of the model

2] Definition of the kinematics

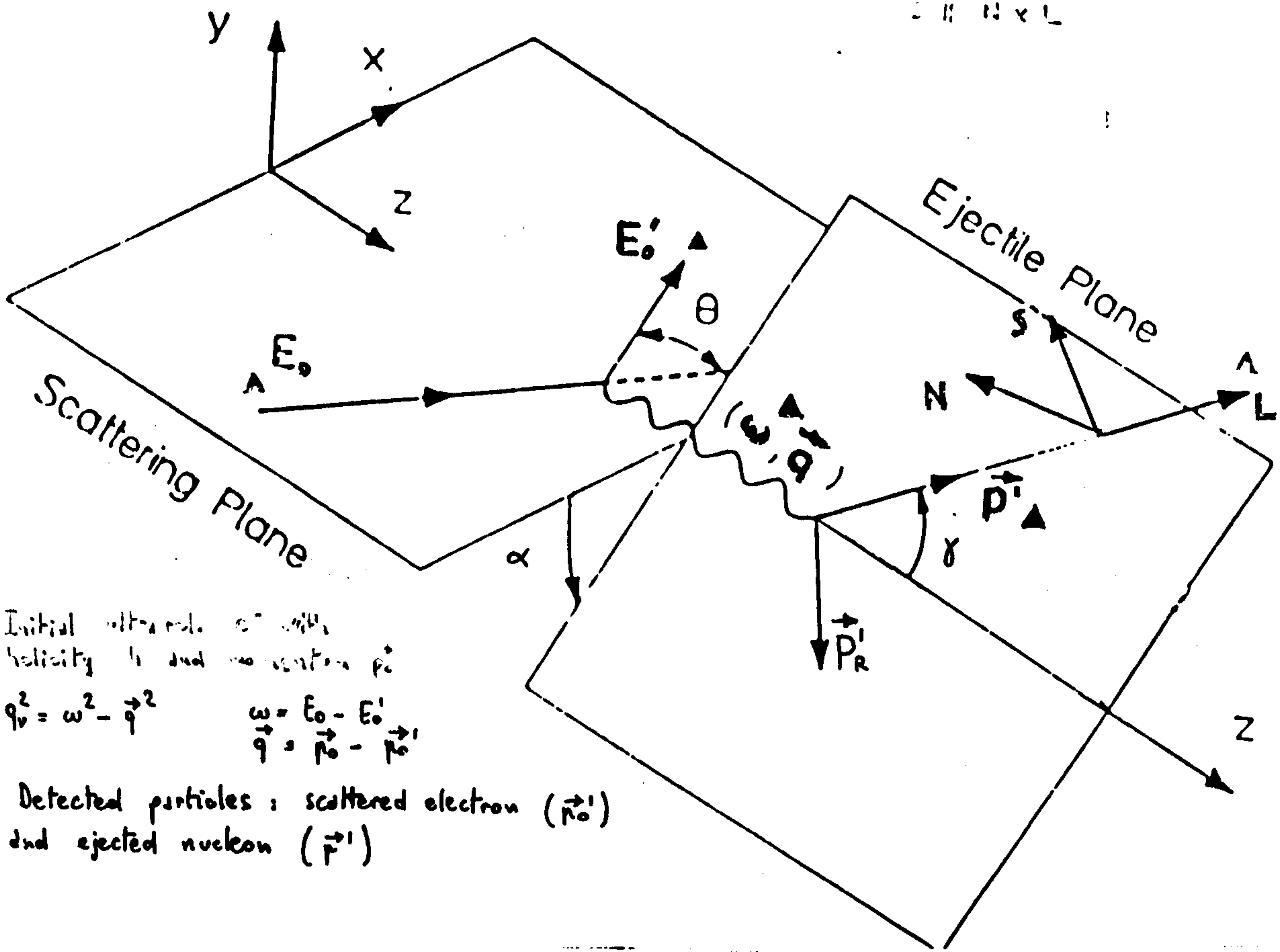
3] Discussion of results for the $(\vec{e}, e'\vec{p})$, $(\vec{e}, e'\vec{n})$ reactions

4] Conclusions and outlooks

$\hat{L} \parallel \vec{p}\,'$

$\hat{N} \parallel \vec{q} \times \vec{p}\,'$

$\hat{S} \parallel \hat{N} \times \hat{L}$



- ▲ Initial ultra-rel. e^- with helicity h and momentum $\vec{p}_0$
- ▲ $q_\mu^2 = \omega^2 - \vec{q}^{\,2}$ $\omega = E_0 - E_0'$, $\vec{q} = \vec{p}_0 - \vec{p}_0\,'$
- ▲ Detected particles : scattered electron $(\vec{p}_0\,')$ and ejected nucleon $(\vec{p}\,')$

$e^-;\ h,\ \vec{p}_e \qquad e^{-\prime};\ \vec{p}_0^{\,\prime} \qquad \vec{N};\ \vec{p}^{\,\prime}, s'$

DWIA + Born Approximation

$$\frac{d\sigma^{h,s'}}{d\vec{p}_0^{\,\prime}\, d\vec{p}^{\,\prime}} = \frac{1}{2}\sigma_0 \left[1 + \vec{P}\cdot\vec{\sigma} + h\left(A + \vec{P}'\cdot\vec{\sigma}\right)\right]$$

unpolarized cross section

$$\sigma_0 = K\left[2\varepsilon_L h^u_{00} + h^u_{11} + \sqrt{\varepsilon_L(1+\varepsilon)}\, h^u_{01}\cos\alpha - \varepsilon h^u_{1-1}\cos 2\alpha\right]$$

$$K = \frac{e^4}{8\pi^2 q_\nu^2\, p_0'\, p_e\, (\varepsilon-1)}$$

$$\varepsilon_L = -\frac{q_\nu^2}{\vec{q}^{\,2}}\,\varepsilon$$

$$\varepsilon = \left[1 - 2\frac{\vec{q}^{\,2}}{q_\nu^2}\, tg^2\frac{\theta}{2}\right]^{-1}$$

Electron analyzing power

$$A = \frac{K}{\sigma_0}\sqrt{\varepsilon_L(1-\varepsilon)}\; h'^u_{01}\sin\alpha$$

Vector polarization

$$P^N = \frac{K}{\sigma_0}\left[2\varepsilon_L h^N_{00} + h^N_{11} + \sqrt{\varepsilon_L(1+\varepsilon)}\, h^N_{01}\cos\alpha - \varepsilon h^N_{1-1}\cos 2\alpha\right]$$

$$P^{L,S} = \frac{K}{\sigma_0}\left[\sqrt{\varepsilon_L(1+\varepsilon)}\, h^{L,S}_{01}\sin\alpha - \varepsilon h^{L,S}_{1-1}\sin 2\alpha\right]$$

Polarization transfer coefficient

$$P'^N = \frac{K}{\sigma_0}\sqrt{\varepsilon_L(1-\varepsilon)}\, h'^N_{01}\sin\alpha$$

$$P'^{L,S} = \frac{K}{\sigma_0}\left[\sqrt{1-\varepsilon^2}\, h'^{L,S}_{11} + \sqrt{\varepsilon_L(1-\varepsilon)}\, h'^{L,S}_{01}\cos\alpha\right]$$

$\alpha = 0^\circ, \pi$

$$A = 0$$
$$P^{L,S} = 0$$
$$P'^N = 0$$

The structure functions $h_{\mu\nu}$ are suitable linear combinations of the hadronic tensor

$$W^{\mu\nu}_{s s'} = \overline{\sum_{if}} \langle \psi_f^s | J^\mu | \psi_i \rangle \left(\langle \psi_f^{s'} | J^\nu | \psi_i \rangle \right)^* \delta(E_i - E_f)$$

hadronic matrix elements of electromagnetic current

$$\langle \psi_f^s | J^\mu | \psi_i \rangle = \int d\vec{r} \; e^{i\vec{q}\cdot\vec{r}} \langle \psi_f | J_\mu | \psi_i \rangle \, e^\mu_s$$

$$\downarrow$$

helicity amplitudes

$$\vec{e}_0 = (1, 0, 0, 0) \qquad \text{longitudinal}$$

$$\vec{e}_{\pm 1} = \left(0, \mp \frac{1}{\sqrt{2}}, \frac{-i}{\sqrt{2}}, 0\right) \qquad \text{transverse}$$

respect to the virtual photon exchanged

Following S. Boffi et al., Nucl. Phys. A379 (1982) 509

helicity amplitudes

$$\langle \psi_f | J^\mu | \psi_i \rangle = \int d\vec{p}\, d\vec{p}\,'\, \delta(\vec{p}\,' - \vec{p} - \vec{q})\, \chi^{(-)*}_{E\alpha}(\vec{p}\,')\, J_\mu(\vec{p}, \vec{p}\,')\, \epsilon^{\mu}_{\lambda} \;\cdot$$

$$\cdot\; \varphi_{E\alpha}(\vec{p})\, \left[S_\alpha(E) \right]^{1/2}$$

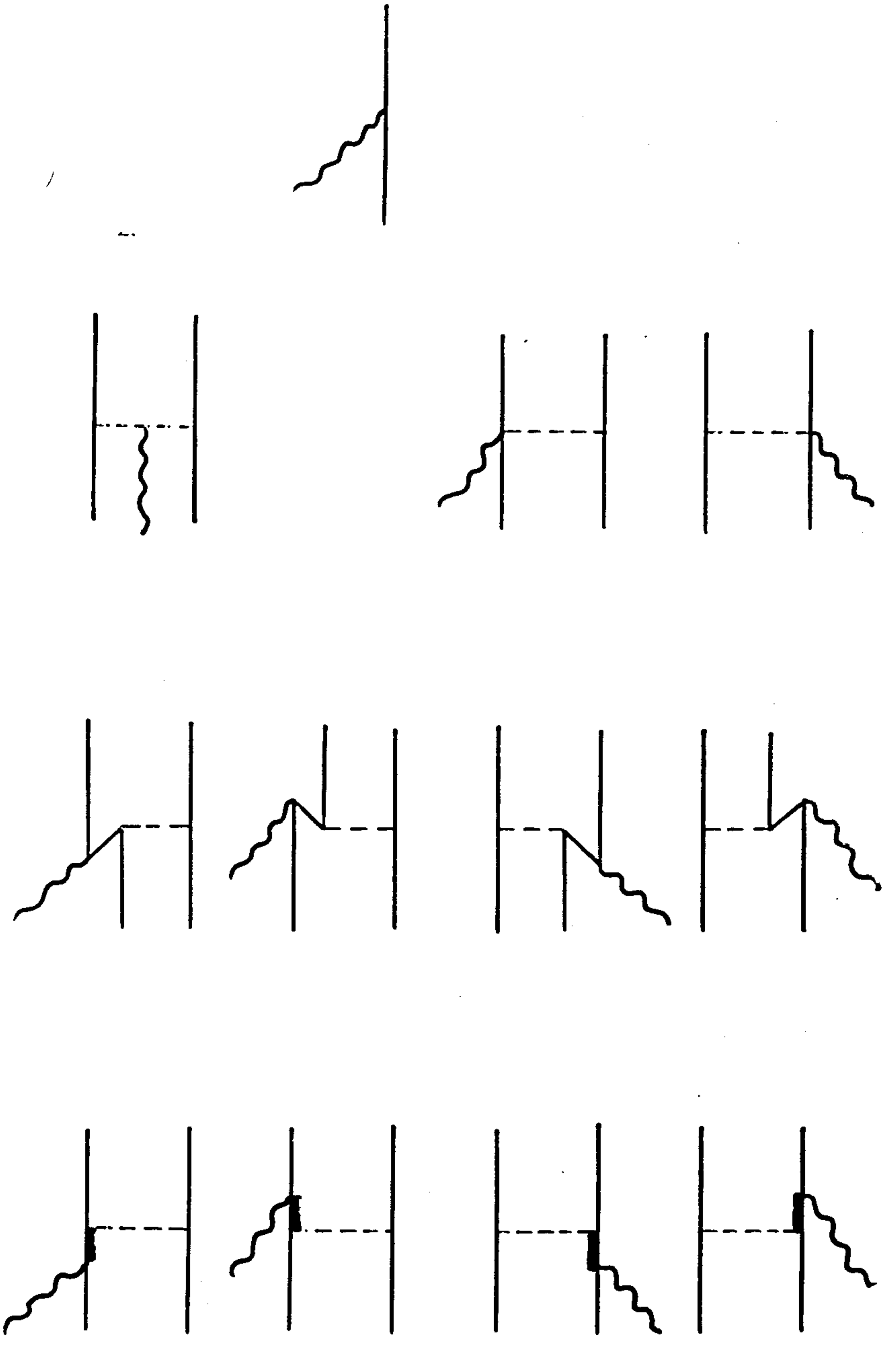
$S_\alpha(E)$ spectroscopic factor for the residual nucleus in $|E\alpha\rangle$

$\varphi_{E\alpha}(\vec{r})$ solution of Feshbach optical potential $\mathcal{H}(E)$ referred to residual nucleus state

$\chi^{(-)}_{E\alpha}(\vec{r}\,')$ solution of Feshbach optical potential $\mathcal{H}^{+}(E+\omega)$ referred to distorted ejectile particle state

$$\chi^{(-)}_{E\alpha}(\vec{r}) \not\perp \varphi_{E\alpha}(\vec{r}) \implies J_\mu^{\text{eff.}}(\vec{r}, \vec{r}\,')$$

$$J_\mu(\vec{p}, \vec{p}\,') = j^{(1)}_\mu(\vec{p}, \vec{p}\,') - \int d\vec{k}\; j^{(2)}_\mu(\vec{p}\,' - \vec{k}, \vec{k} - \vec{p})\, n(\vec{k})\, \delta^\mu_i$$



Kinematics

$(\vec{q}, \omega)$ constant :

p' q fixed $\longrightarrow$ p variable
γ variable

p-dependence of $J_{\mu}(\vec{p}, \vec{p}')$

parallel :

$\gamma = 0 \quad p' \parallel q$

p' fixed $\longrightarrow$ p variable
q variable

q-dependence of MEC + IC in J_{μ}
at fixed FSI

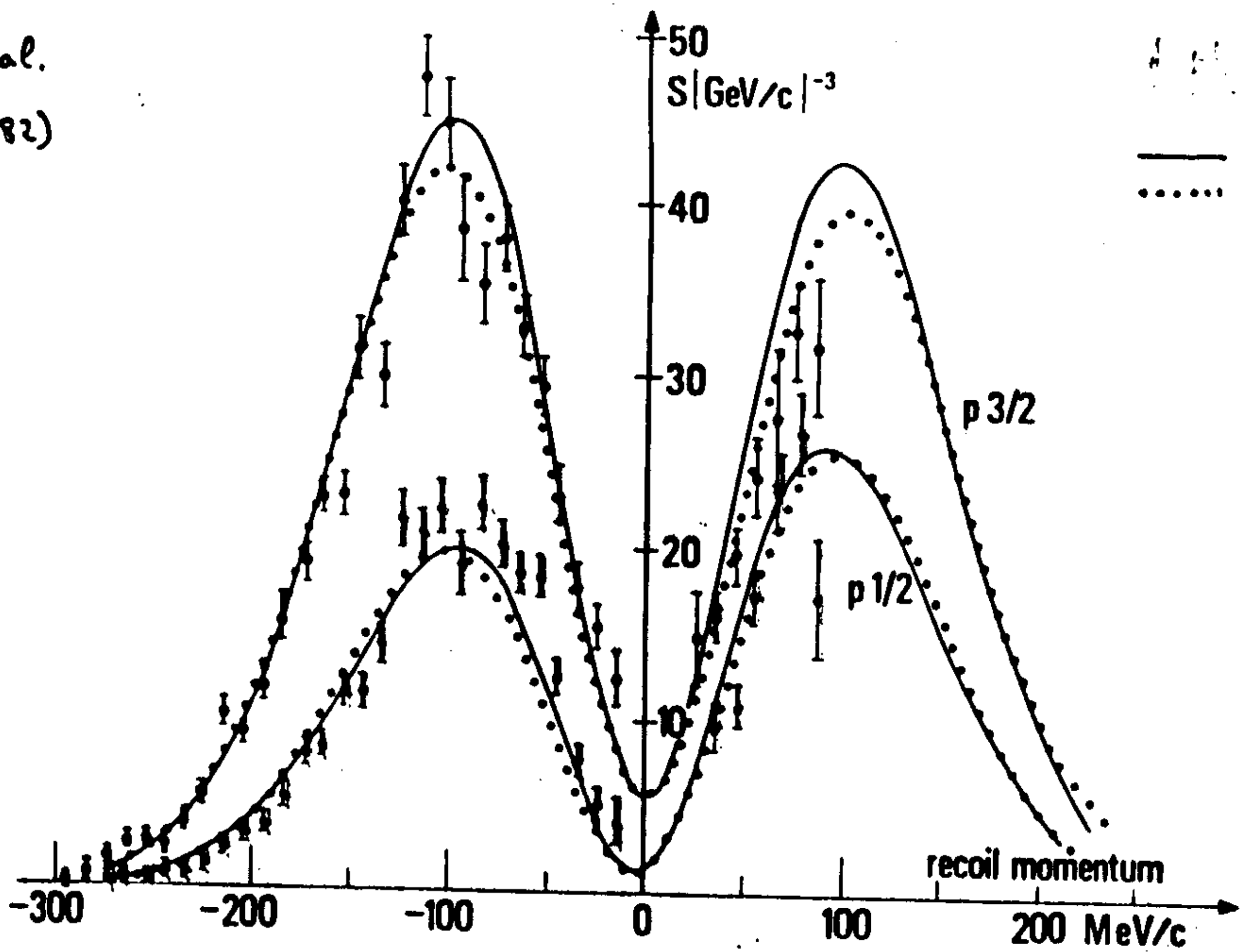
Target nucleus ^{16}O knockout from shells with $j = \frac{1}{2}$, $j = \frac{3}{2}$

$$\left.\begin{array}{lll} E_0 = 700 \text{ MeV} & & \text{initial electron energy} \\ T_{p'} = 150 \text{ MeV} & & \text{ejected nucleon kinetic energy} \\ q = 550 \text{ MeV/c} & & \text{in } (\vec{q}, \omega) \text{ constant kinematics} \end{array}\right\} \text{If not otherwise specified}$$

M. Bernheim et al.

N.P. A375, 381 (1982)

$^{16}O(e,e'p)$



$p\,3/2$

—— Elton-S. + Jackson-A.

······ Gogny + Jackson-A.

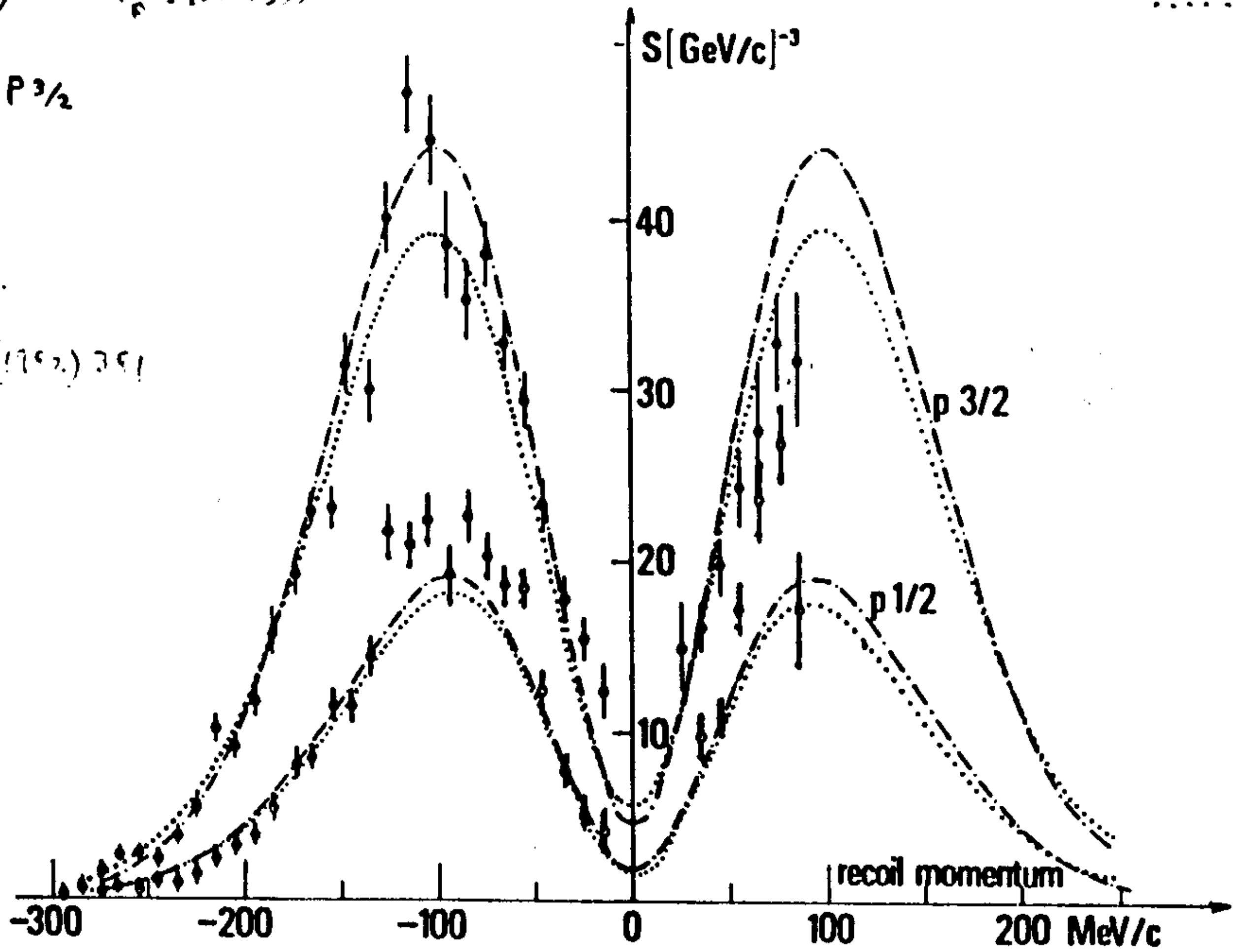
T_F = 100 MeV

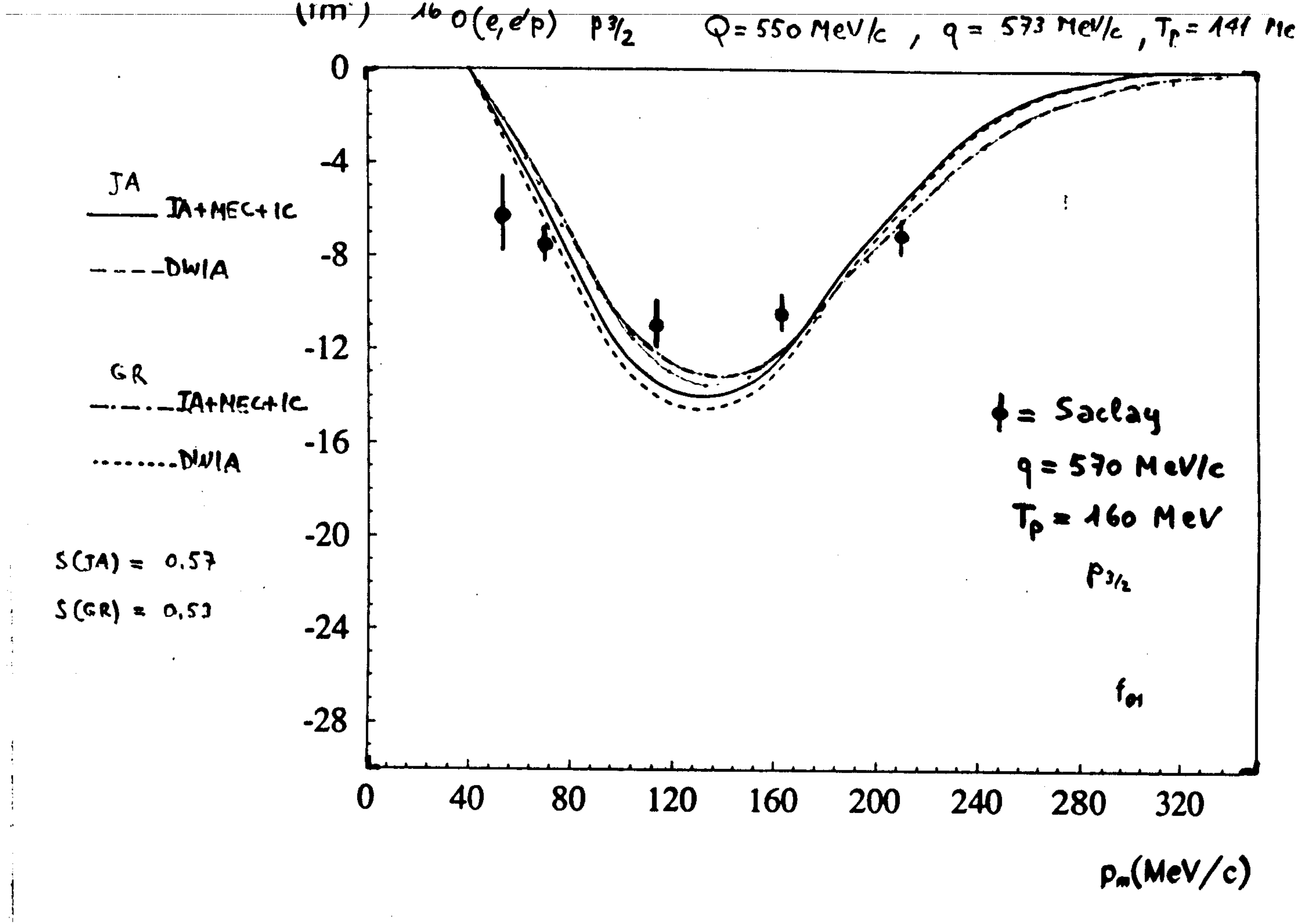
$^{16}O(e,e'p)$ T_p = 100 MeV

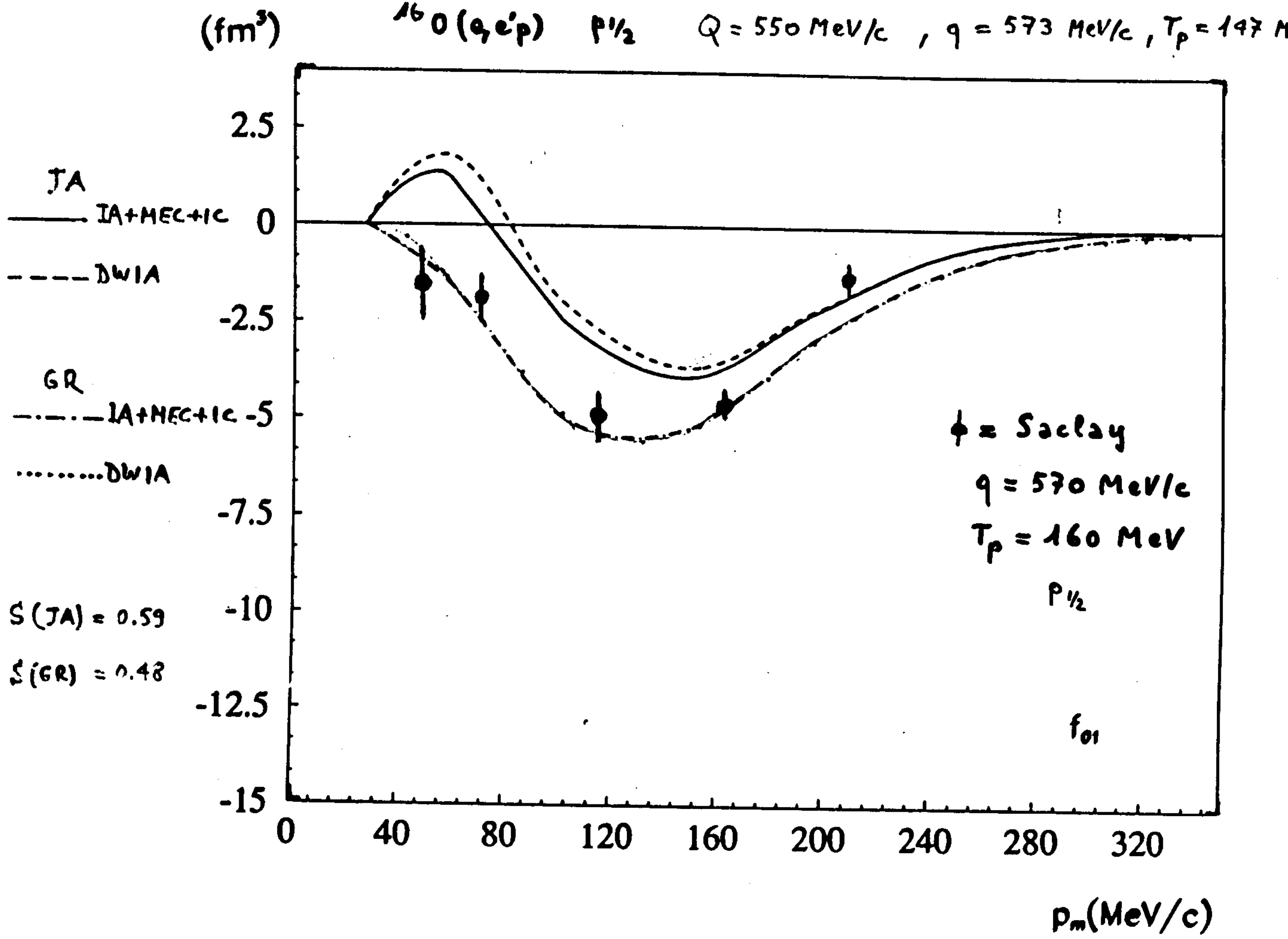
$p_{1/2}$ $p_{3/2}$

M. Bernheim et al.

Nucl. Phys. A375 (1982) 381

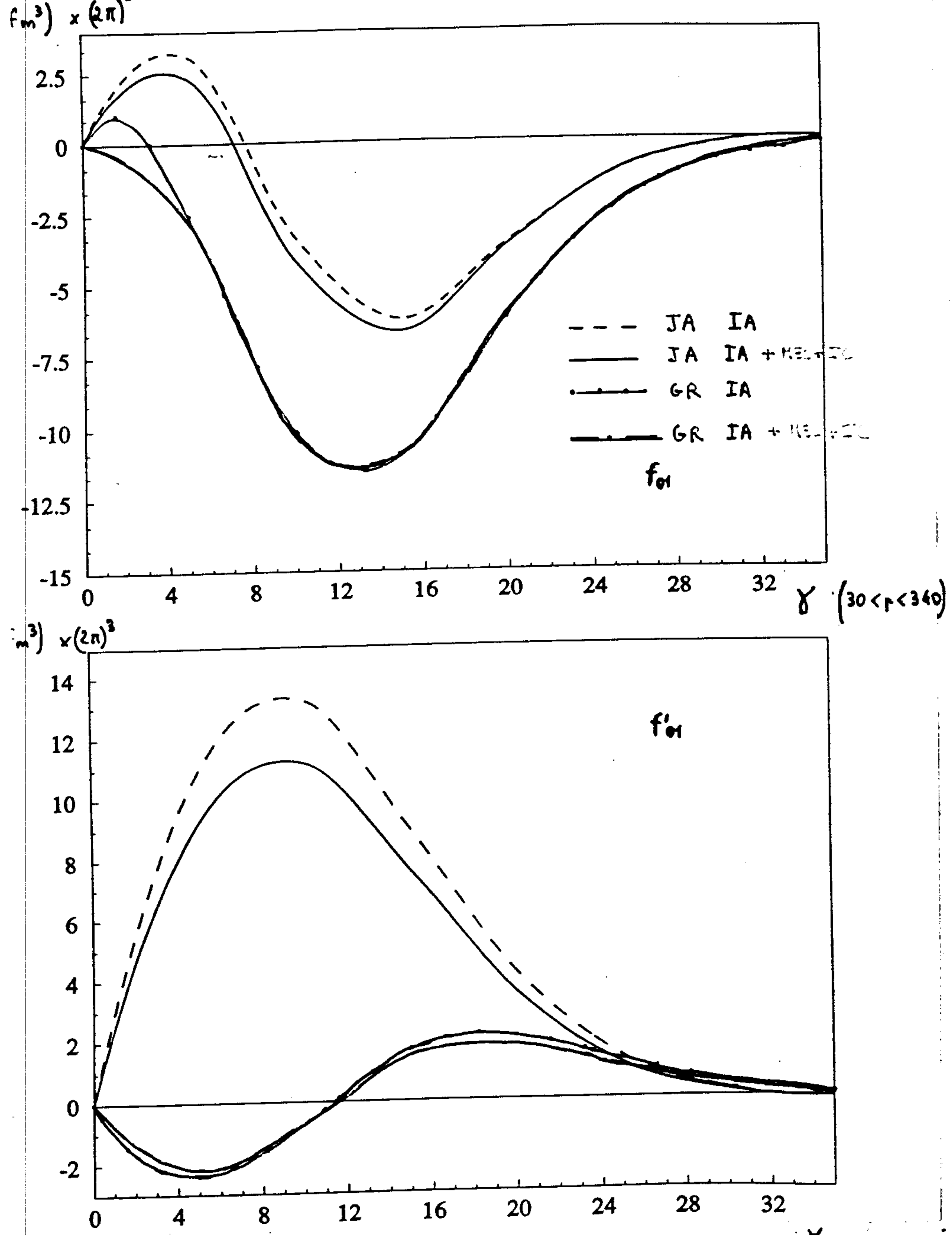



(fm) $^{16}O(e,e'p)$ $p_{3/2}$ Q = 550 MeV/c , q = 573 MeV/c , T_p = 141 Me
JA
IA+MEC+IC
DWIA
GR
IA+MEC+IC
DWIA
S(JA) = 0.57
S(GR) = 0.53
= Saclay
q = 570 MeV/c
T_p = 160 MeV
$p_{3/2}$
f_{01}
0
-4
-8
-12
-16
-20
-24
-28
0
40
80
120
160
200
240
280
320
p_m(MeV/c)

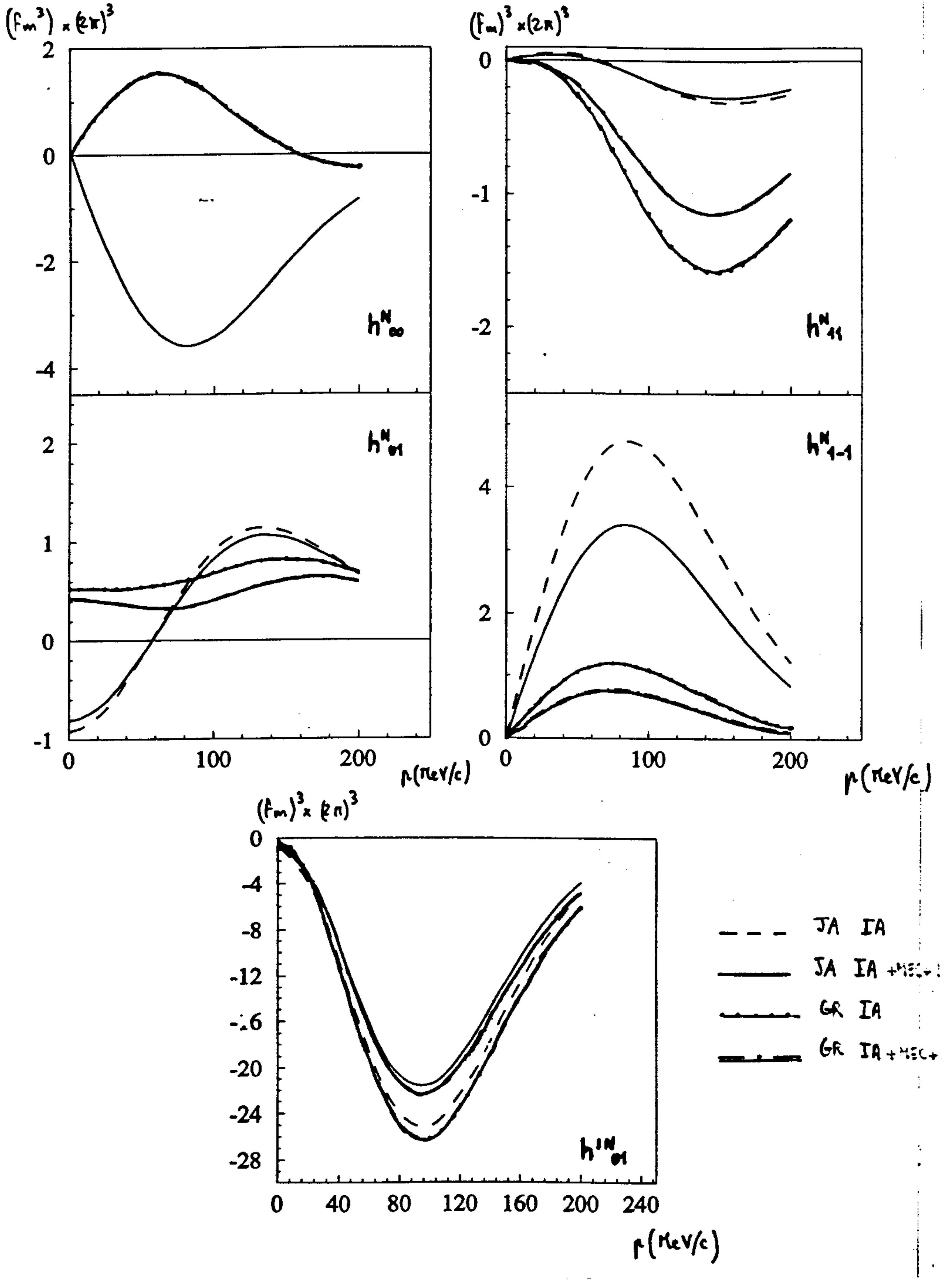


(fm³)
¹⁶O (e,e'p) p1/2 Q = 550 MeV/c , q = 573 MeV/c , Tp = 147 M
JA
IA+MEC+IC
DWIA
GR
IA+MEC+IC
DWIA
S (JA) = 0.59
S (GR) = 0.48
2.5
0
-2.5
-5
-7.5
-10
-12.5
-15
0
40
80
120
160
200
240
280
320
= Saclay
q = 570 MeV/c
Tp = 160 MeV
p1/2
f01
pm(MeV/c)

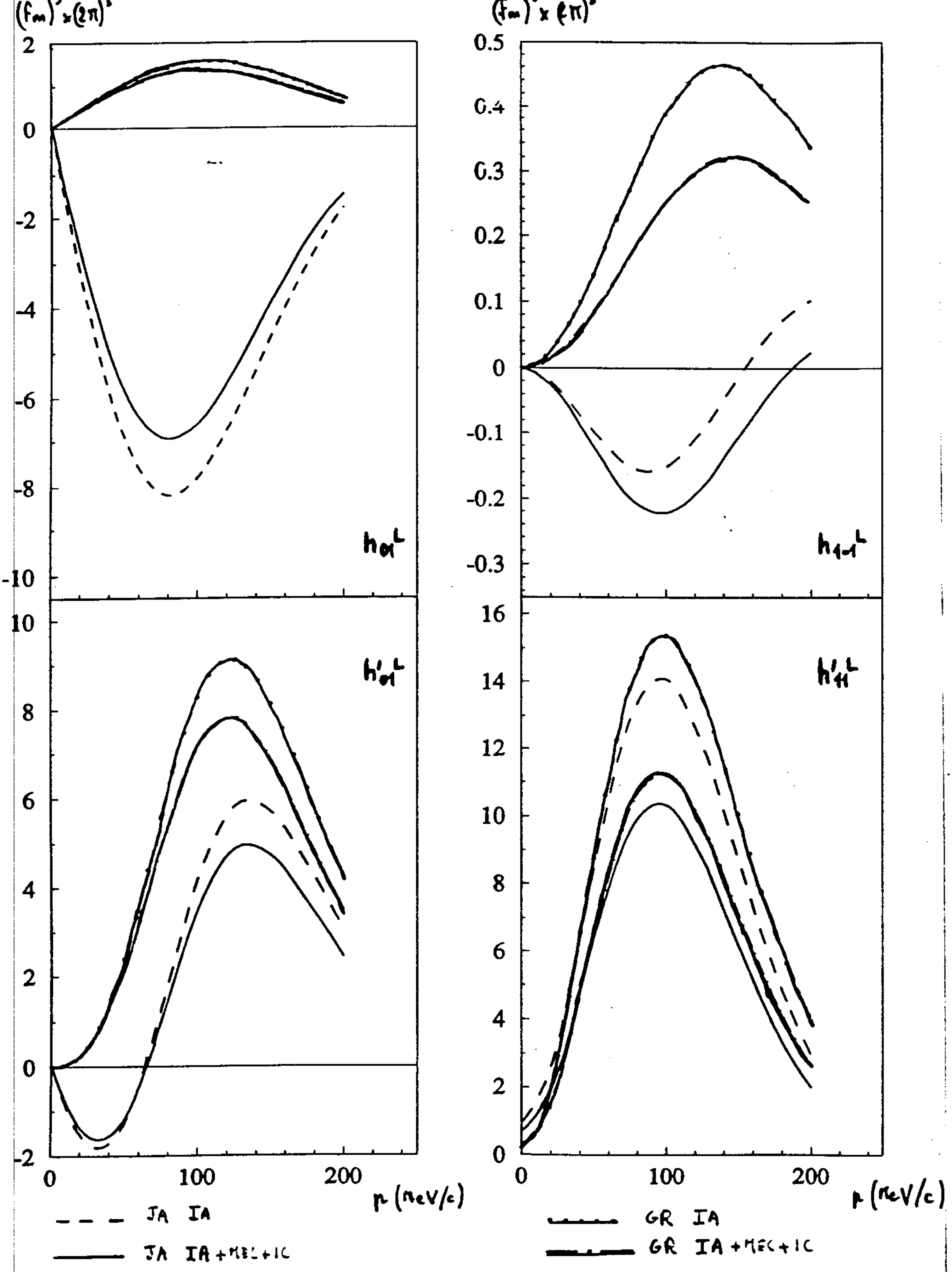
$^{16}O\ (\vec{e}, e'p)$ $j=\frac{1}{2}$ $Q = 550$ MeV/c $T_{p'} = 147$ MeV

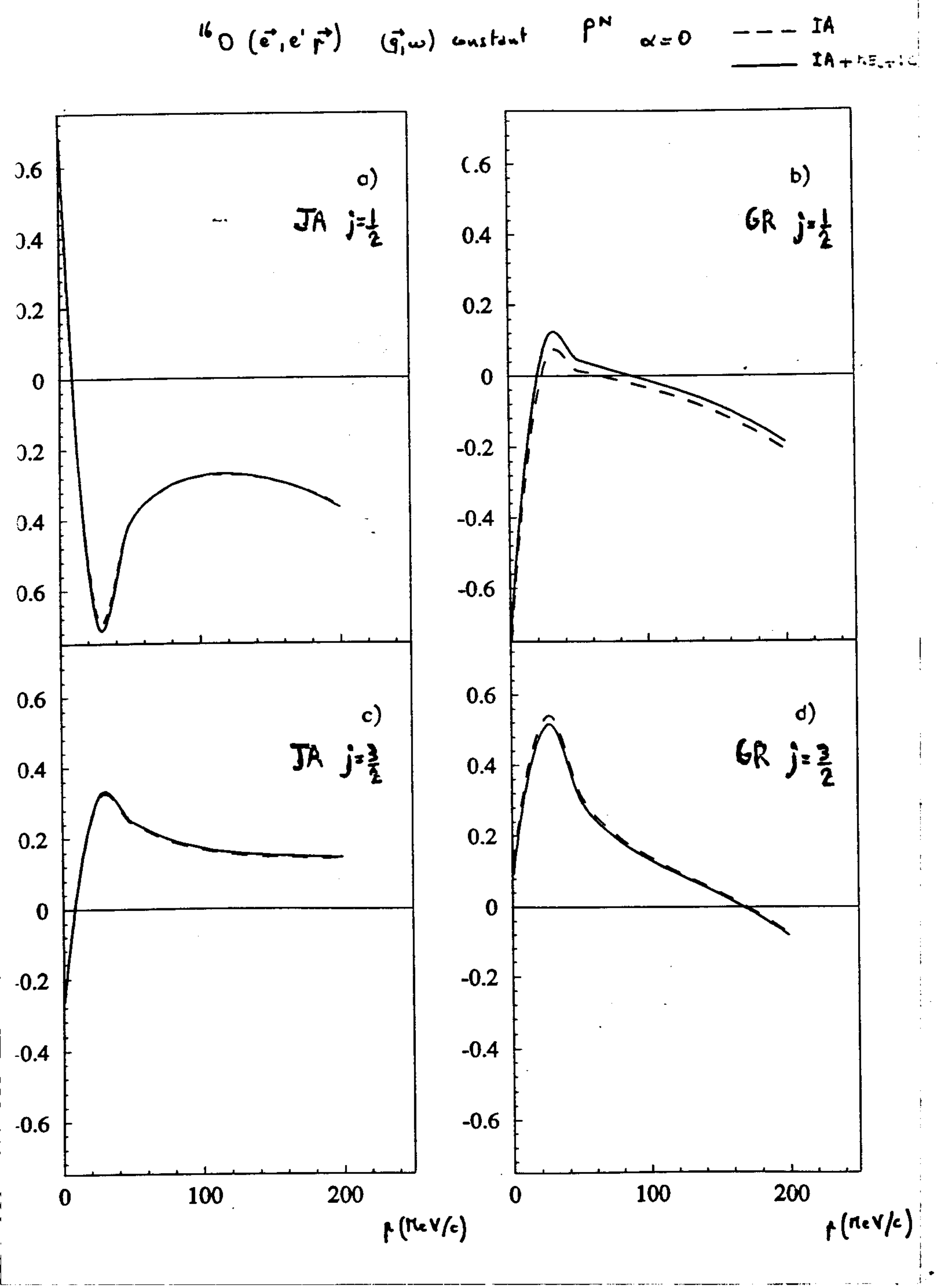


O (e,e'p) j=½ (g,ω) constant



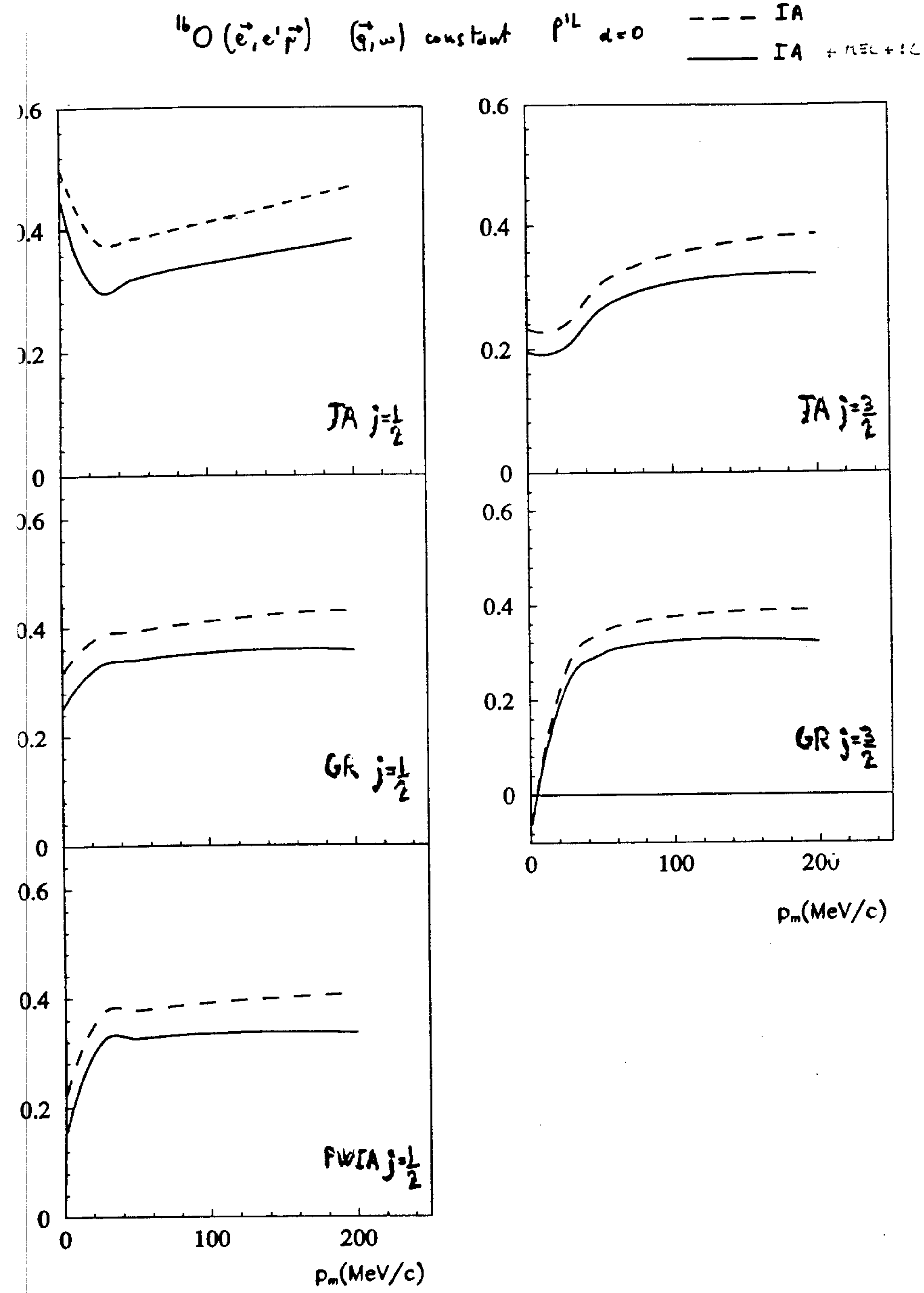
$^{16}O\ (\vec{e}, e'\ \vec{p})$ $j=\frac{1}{2}$ $(\vec{q}, \omega)$ constant



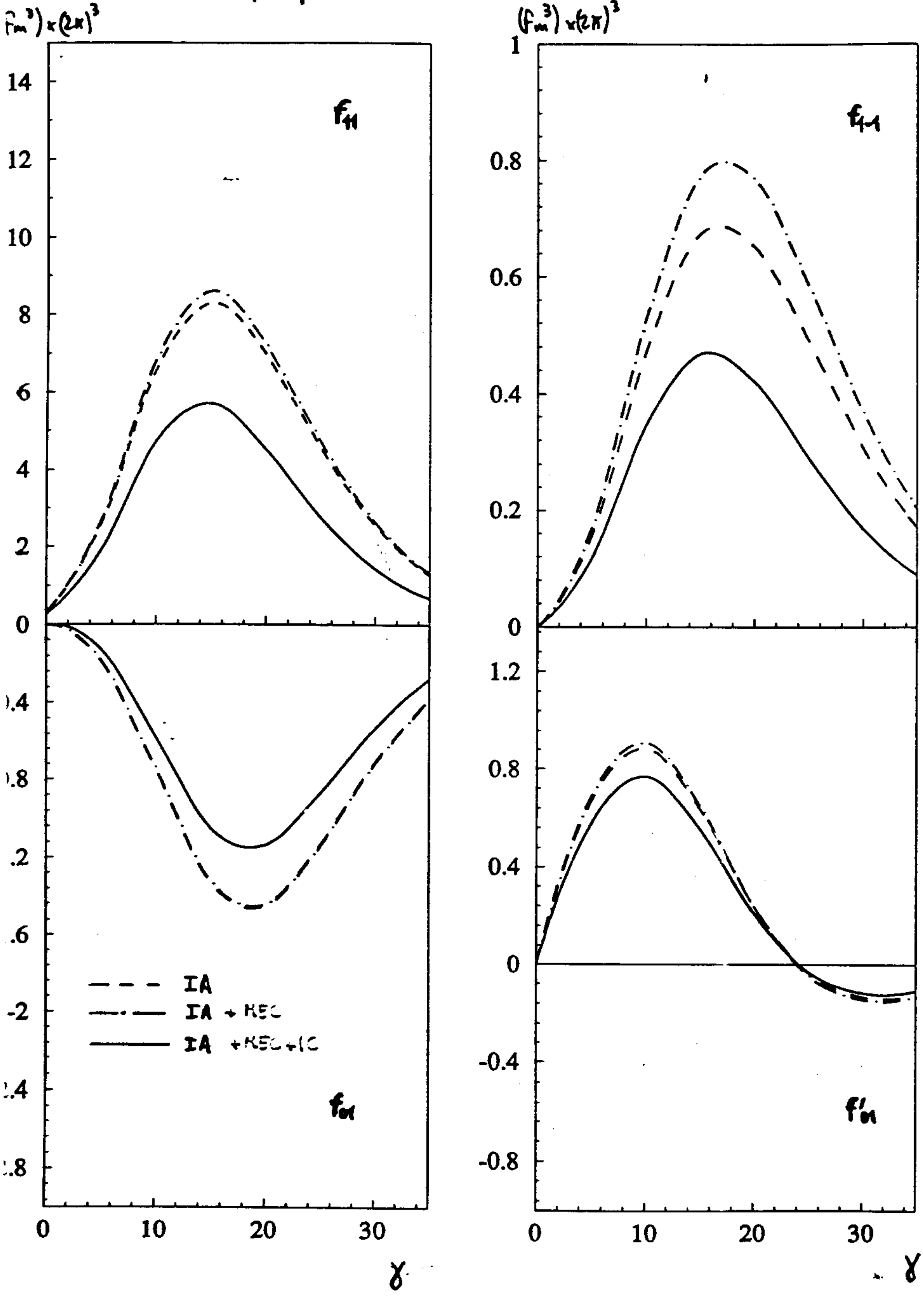


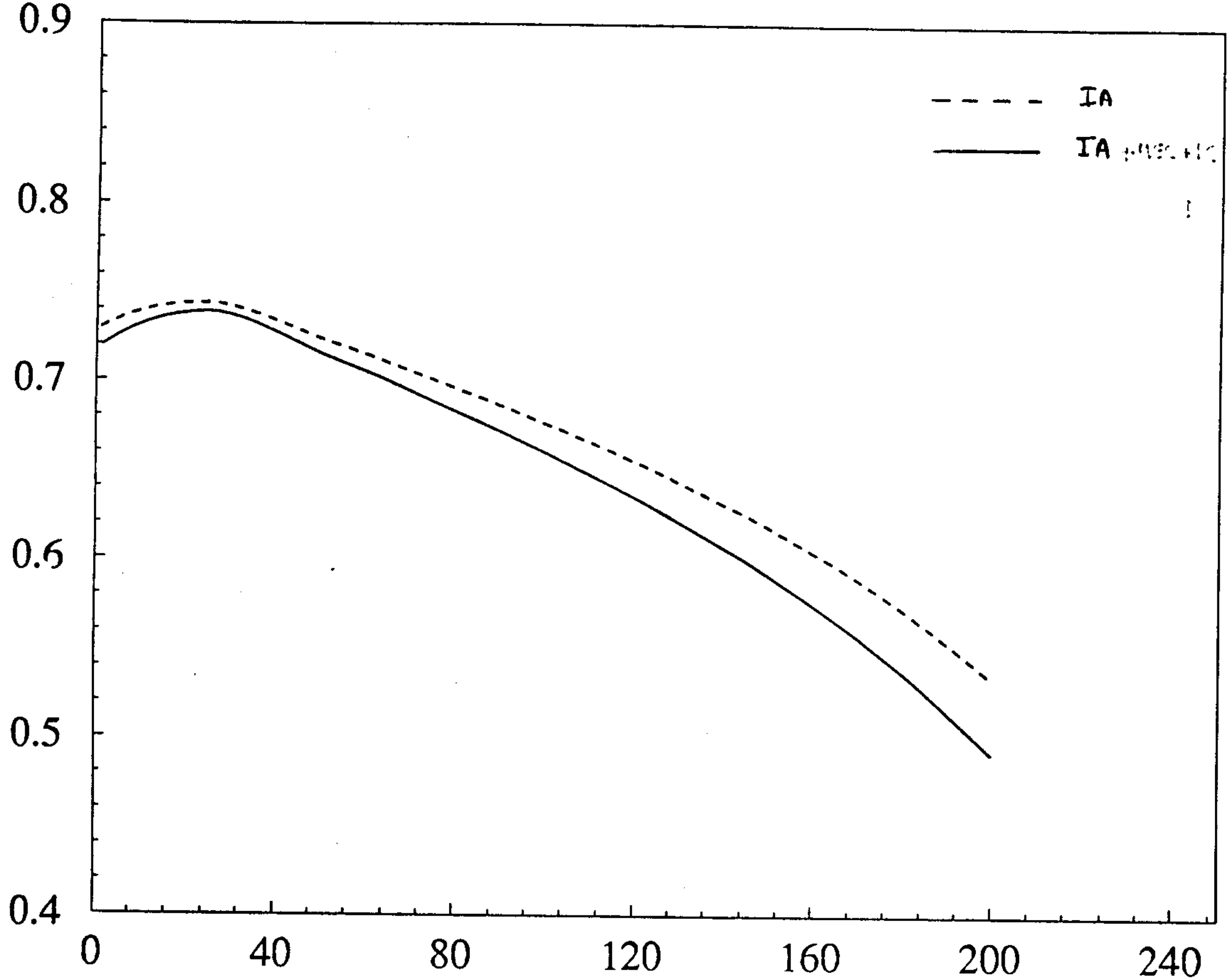
$^{16}O(\vec{e},e'\vec{p})$ $(\vec{q},\omega)$ constant P^N $\alpha=0$
IA
a)
JA $j=\frac{1}{2}$
b)
GR $j=\frac{1}{2}$
c)
JA $j=\frac{3}{2}$
d)
GR $j=\frac{3}{2}$
p (MeV/c)
p (MeV/c)

$^{16}O(\vec{e},e'\vec{p})$ $(\vec{q},\omega)$ constant P'^L $\alpha=0$



45 MeV/c < p < 236 MeV/c





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

$j=\frac{1}{2}$ IA

P'_L (p (MeV/c))

$\alpha=0$

$(\vec{q},\omega)$ constant

Parallel kinematics

$$\gamma = 0 \longrightarrow \vec{p}' \parallel \vec{q}$$

$$\sigma_0 = K \left(2 \varepsilon_L h^u_{00} + h^u_{11} \right)$$

$$P^N = \frac{K}{\sigma_0} \sqrt{\varepsilon_L (1+\varepsilon)}\, h^N_{01}$$

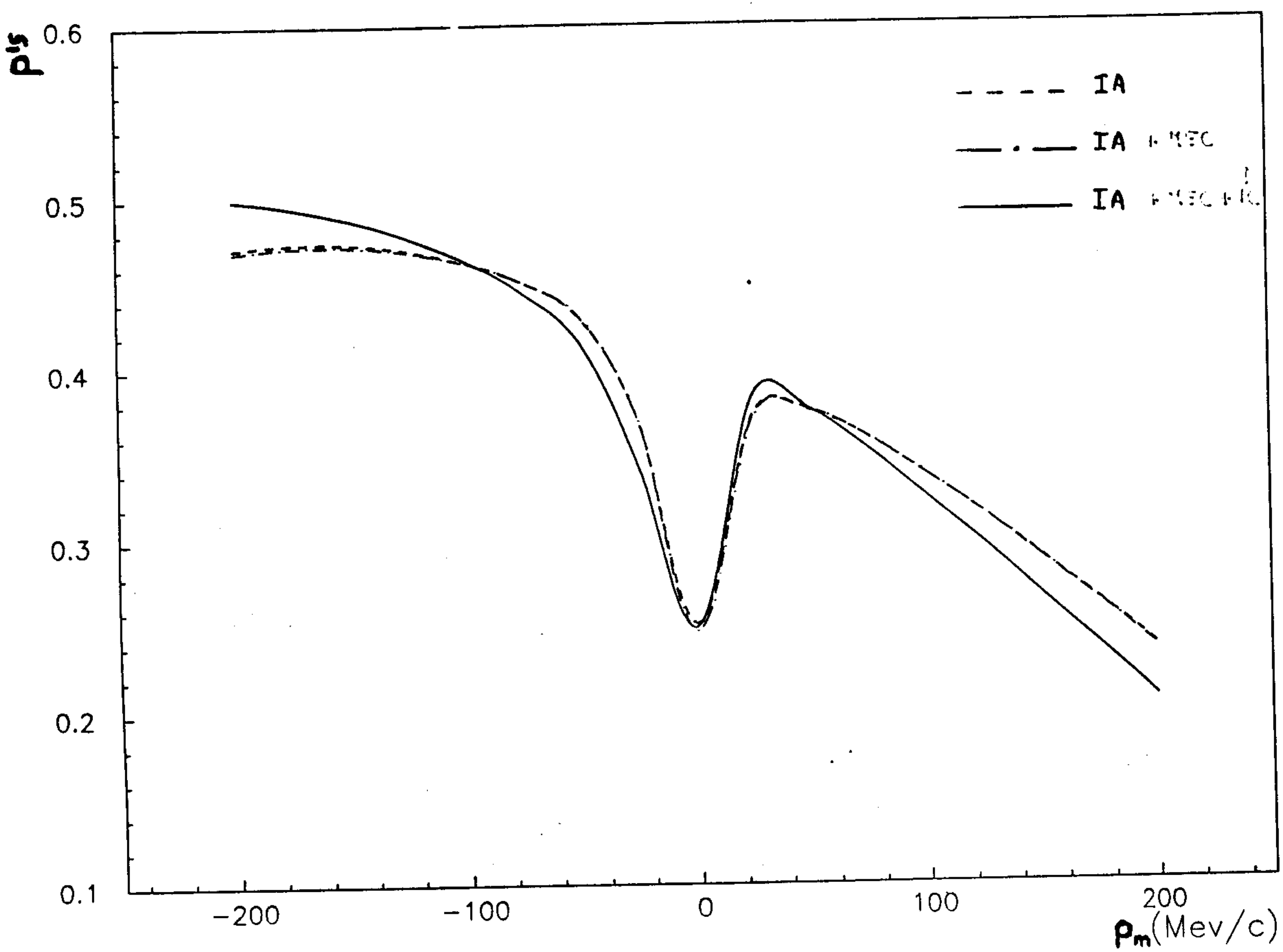
$$P'^L = \frac{K}{\sigma_0} \sqrt{1-\varepsilon^2}\, h'^L_{11} \qquad j=\tfrac{1}{2} \longrightarrow h'^L_{11} \equiv h^u_{11}$$

$$P'^S = \frac{K}{\sigma_0} \sqrt{\varepsilon_L (1-\varepsilon)}\, h'^S_{01}$$

1] Two polarization measurements (P^N, P'^S) only

2] Direct access to structure functions

$^{16}O(\vec{e},e'\vec{p})$ $J=\frac{1}{2}$ parallel 350 MeV/c < q < 750 MeV/c JA



Conclusions

PWIA $\qquad$ DWIA

$A, \vec{P} = 0 \longrightarrow A, h^{1L}_{01}$ $\quad$ sensitive to FSI

$\vec{P}, h^{1,\ldots}_{\mu\nu}$ $\quad$ to IC but effect overwhelmed by FSI

not to MEC (in this model and energy domain)

$(\vec{q},\omega)$ constant kinematics prefereable, because quantities are more sizeable

PWIA $\qquad$ DWIA

$\vec{P}' \neq 0 \longrightarrow \vec{P}', h^{1N,\ldots}_{\mu\nu}$ $\quad$ sensitive to IC

not to FSI

not to MEC (In this model and energy domain)

P^{1L} is prefereable, because very sensitive to IC and sizeable in both kinematics [$(\vec{q},\omega)$ constant and parallel] and both knockout reactions [$(\vec{e},e'\vec{p})$; $(\vec{e},e'\vec{n})$]

Non-relativ. DWIA in Born-approximation basically confirmed in quasi-elastic energy region

MEC, IC (small) corrections

Measurement of P^N in coplanar $(\alpha=0,\pi)$ $(\vec{q},\omega)$ constant kinematics $\longrightarrow$ Additional informations on FSI

Measurement of P^{1L} in coplanar $(\vec{q},\omega)$ constant or in parallel kinematics $\longrightarrow$ Test of "Two-body currents model"