1. Introduction

○ Reactiom mechanism of the Photoreaction

$$40 \text{ MeV} < E_\gamma < 100 \text{ MeV}$$

○ Non-relativistic approach

- J. Ryckebusch et al. Nucl. Phys. A476 (1988) 237.

  Shell model (Hartree-Fock)

  Correlation (RPA)

  Meson exchange currents (MEC) …large

  (γ, p) and (γ, n) reactions

- D.G. Ireland and G. van der Steenhoven, Phys. Rev. C49 (1994) 2182.

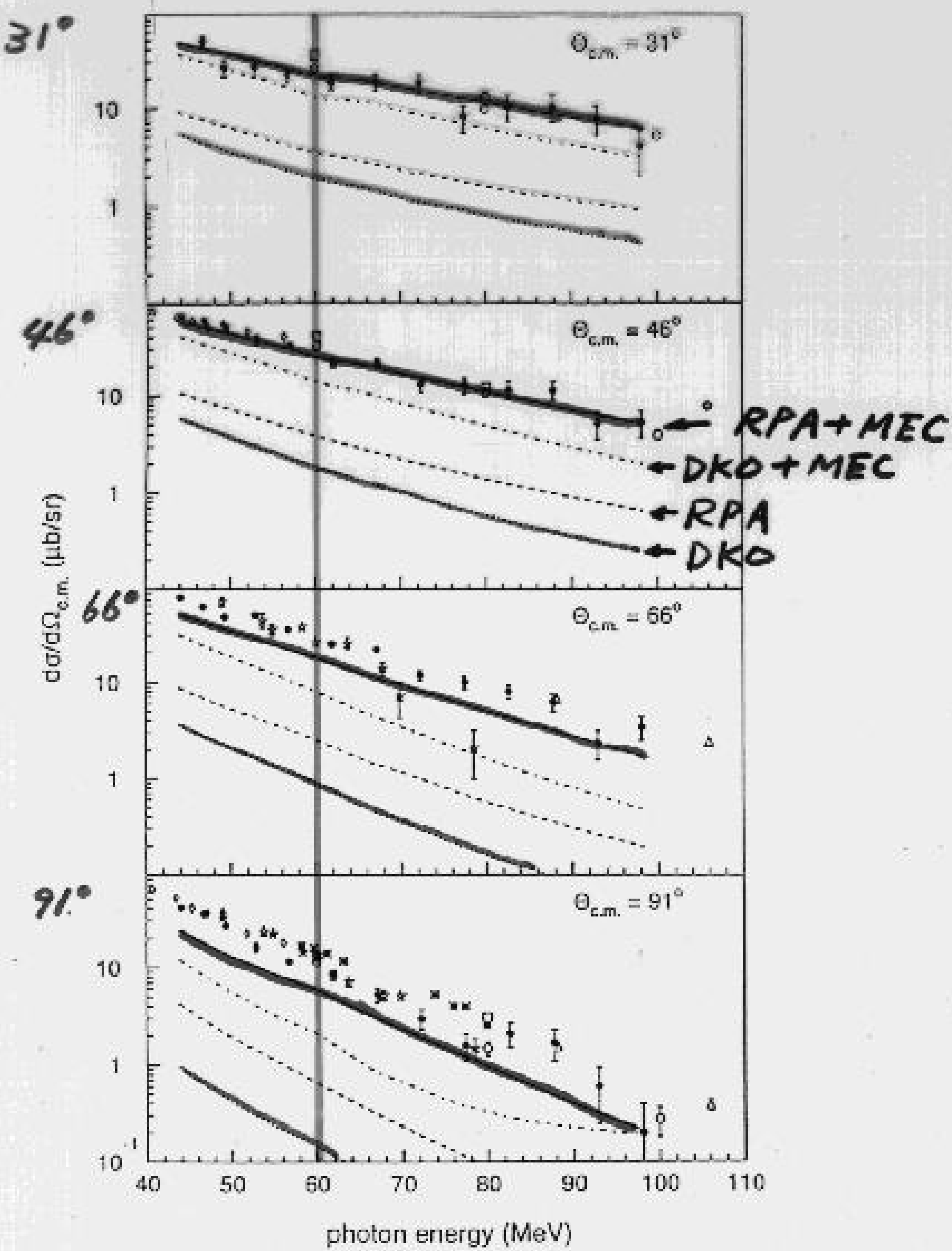
  Direct knock-out (DWIA)

  Meson exchange currents (MEC)

  (γ, p) and (e,e'p) reaction

$$\sigma(\gamma, p)^{\exp} \sim 5 \times \sigma(\gamma, p)^{\mathrm{DWIA}}$$

$^{12}C(\gamma,p)$



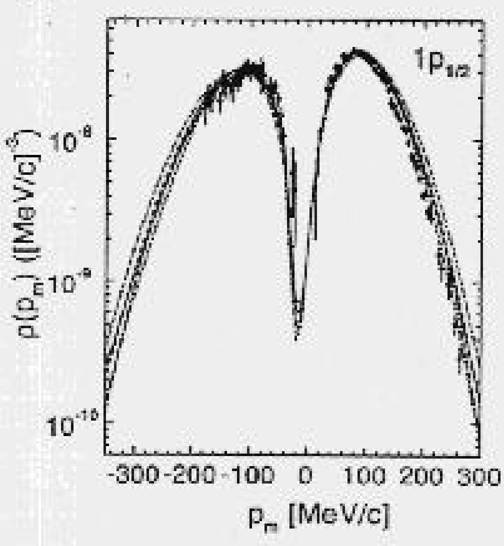
K. Mori et al.
Phys. Rev. C51 (1995) 2611.

- M. K. Gaidarov et al, (Bulgarian Academy)
  Phys. Rev. C61 (1999) 014306 + C. Giusti
  - DWIA using overlap functions
    with no free parameters
  - DWIA + MEC

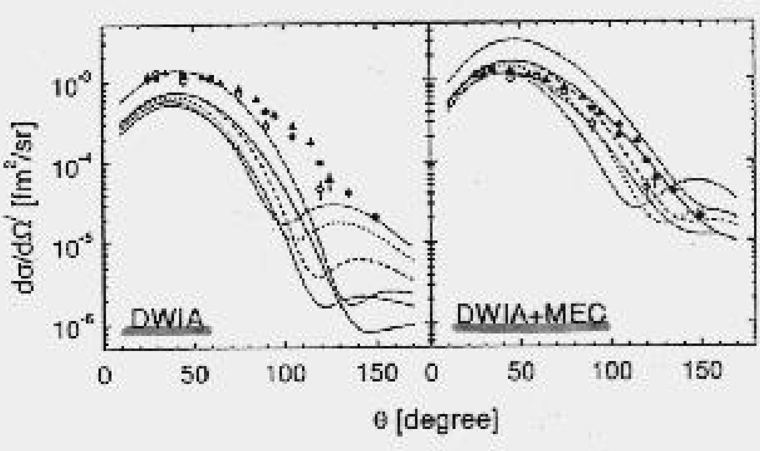
^{16}O (g.s. 1/2$^-$, 6.3 MeV 3/2$^-$)

Quasi-elastic (e, e'p)

(γ, p) Eγ = 60, 72 MeV



^{16}O (γ, p_0) 1P½



Eγ = 60 MeV

○ Relativistic approach

- J.Johansson et al. Nucl. Phys. A605 (1996) 517.
  (Alberta)
  Wave functions…Solutions of Dirac equation.
  Relativistic Hartree potentials for bound states.
  Complex phenomenological optical potentials
  for continuum protons

(γ, p) and (e,e'p) reactions

Meson-exchange contributions….. small

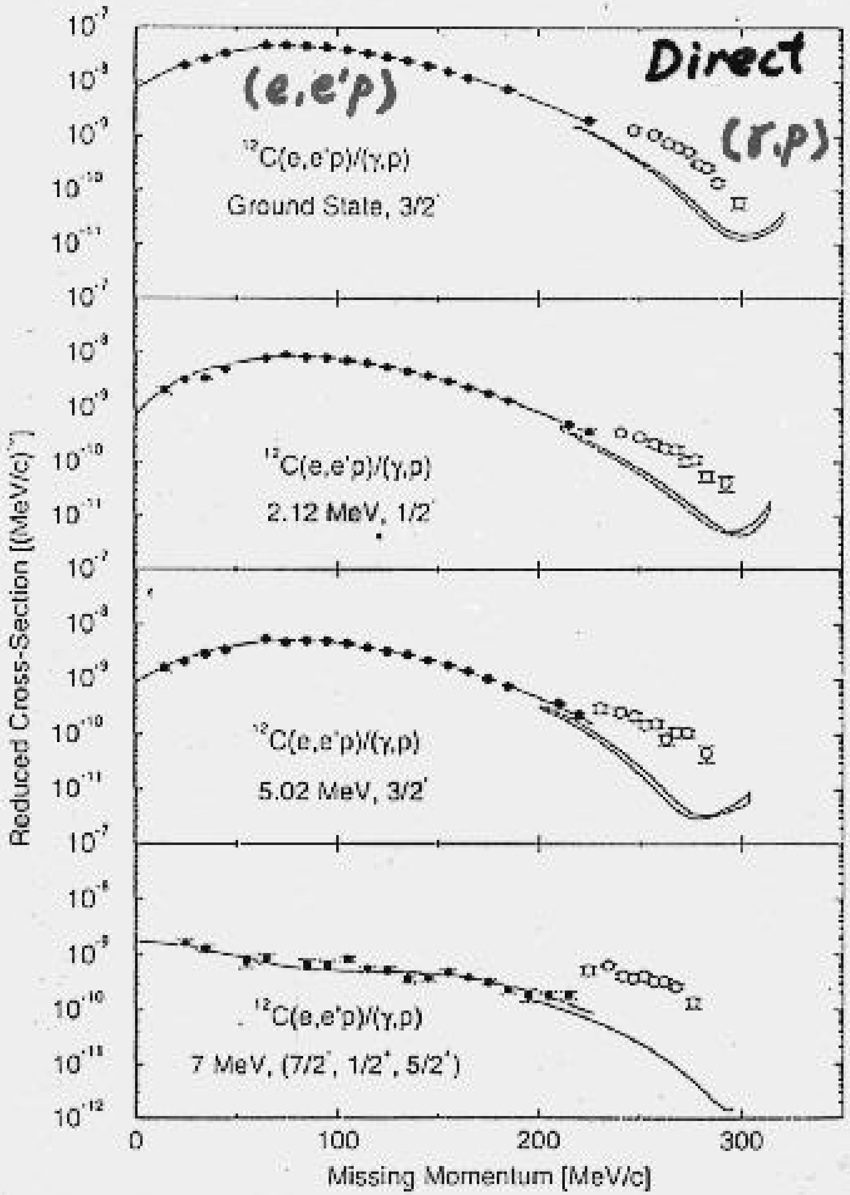
Direct

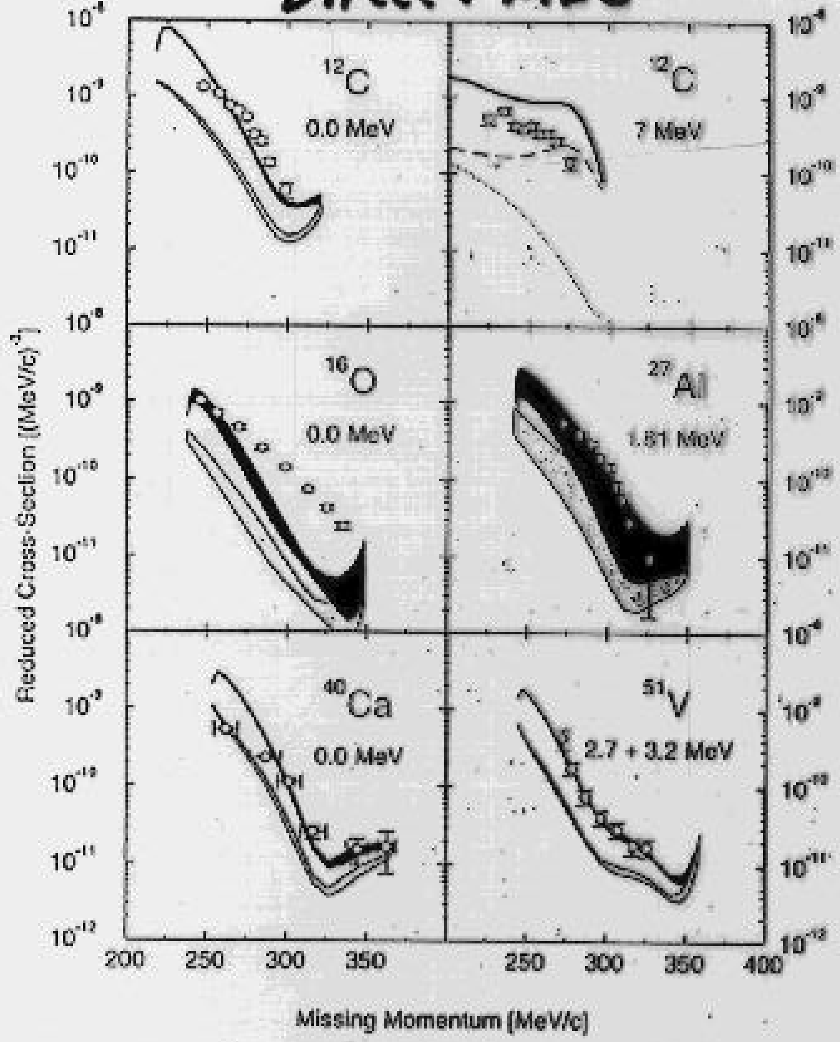
$$\sigma(\gamma, p)^{\text{relativistic}} \sim 10 \times \sigma(\gamma, p)^{\text{DWIA}}$$

Q.E.

$$\sigma(e,e'p)^{\text{relativistic}} \sim \sigma(e,e'p)^{\text{DWIA}}$$

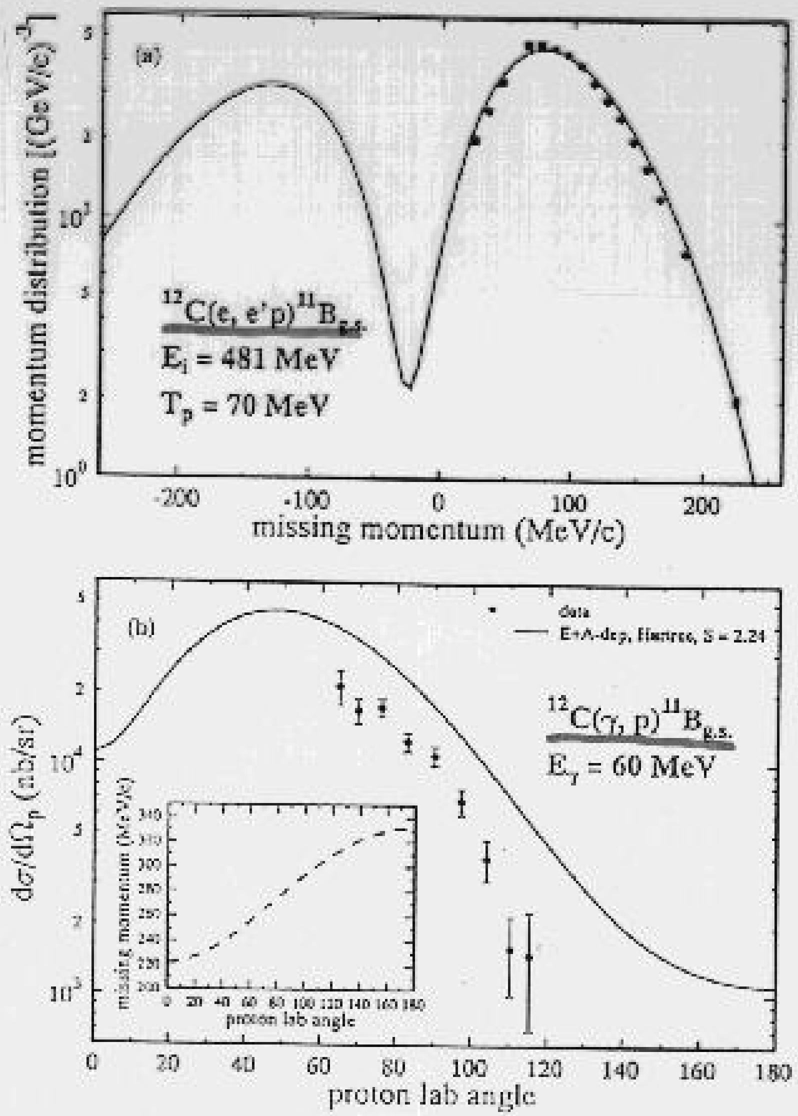
$^{12}C(e,e'p)$ $^{12}C(\gamma,p)$





Ireland et al.

Phys. Rev. C49 (1994) 2182



J. Johansson et al.

Nucl. Phys. A605 (1996) 517

○ Kinematics

parallel

- Quasi-elastic (e, e'p) reaction; mainly longitudinal

  T_p ~70 MeV for $p_m > 0$

  High q: $q = 358$ MeV/c for $p_m = 102$ MeV/c

  $q = 155$ MeV/c for $p_m = 203$ MeV/c

- (γ, p) reaction; fully transverse

  $\theta_p \gtrsim 30°$
  angular distribution

  T_p ~46 MeV for $E_\gamma = 60$ MeV ;

  $q = 60$ MeV/c $p_m = 240$~300 MeV/c

Question; Does the DWIA work at $E_\gamma = 60$ MeV?

Low-q region

- (e, e'p) experiment at low momentum transfer;

  mainly longitudinal: $\sigma_T / \sigma_L = 0.04$ (PWIA)

  T_p ~46 MeV at $\omega = 60$ MeV,

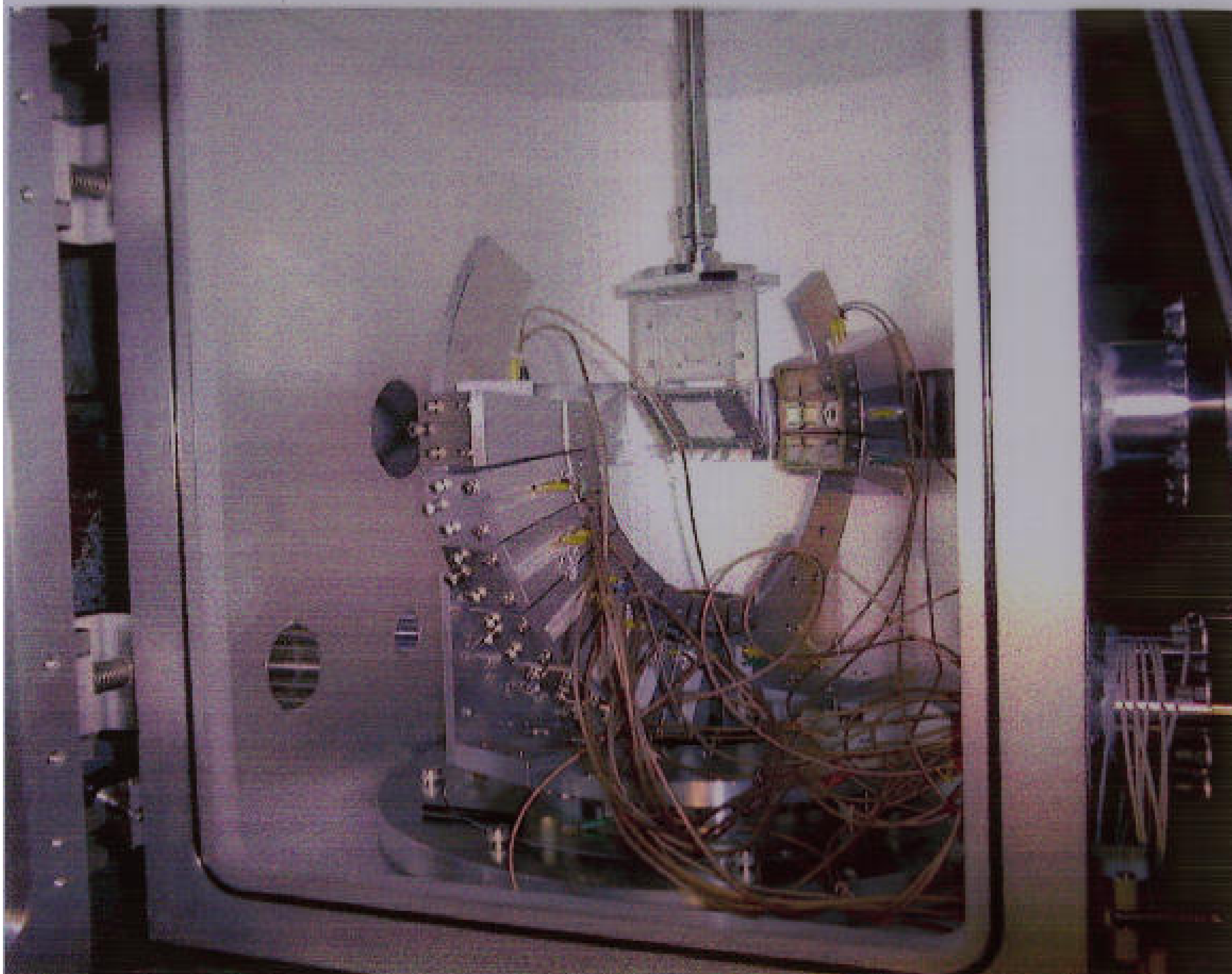
  $q = 104$ MeV/c $p_m = 181$~321 MeV/c

p angular distribution

2. Experiment

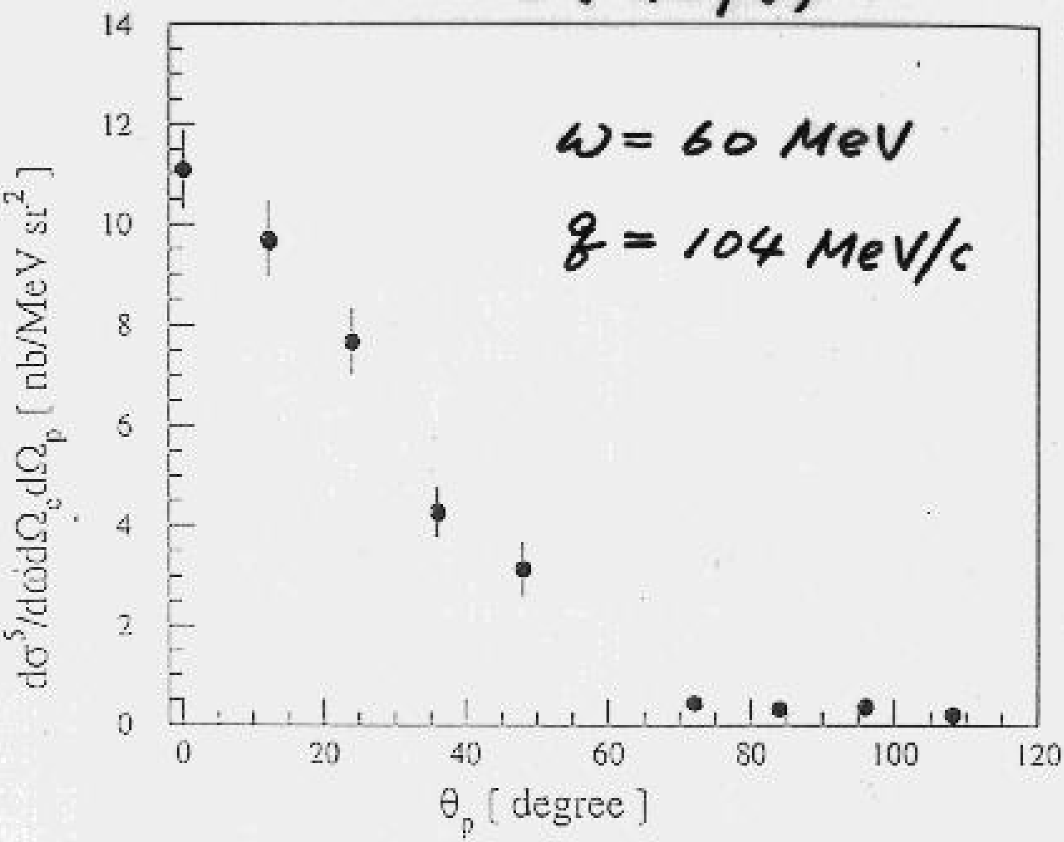
- Electron energy 197 MeV
- Electron scattering angle 30°
- Transferred Energy 60 ± 4 MeV
- Transferred Momentum 104.1 MeV/c
- Reaction plane $\phi = 90^\circ$
- Proton angle (θ_p) 0°, 12°, 24°, 36°, 48°
  72°, 84°, 96°, 108°

$$\frac{d^3\sigma}{d\omega d\Omega_e d\Omega_p} = \frac{d^3}{d\omega d\Omega_e d\Omega_p}\left(\sigma_L + \sigma_T + \sigma_{LT}\cos\phi + \sigma_{TT}\cos 2\phi\right)$$

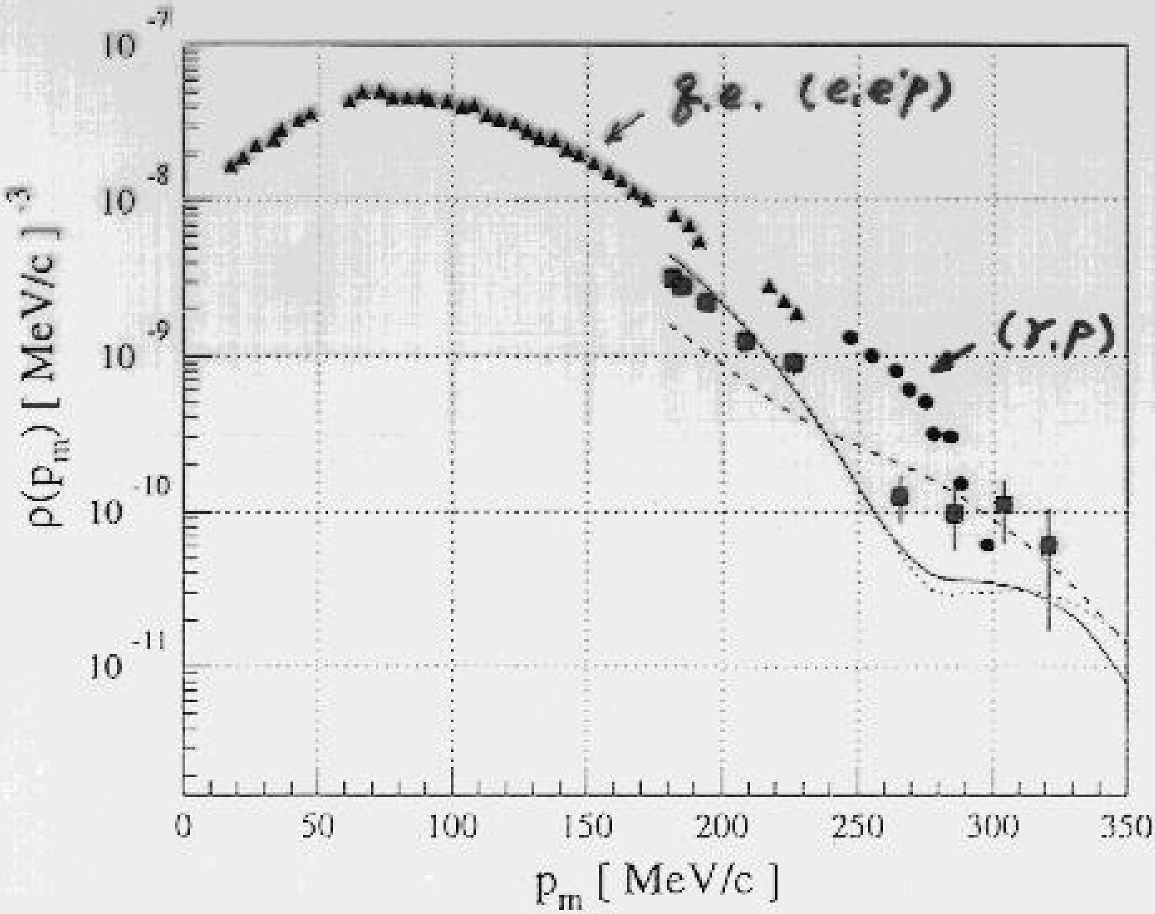


Angular Distribution

$^{12}C(e,e'p_0)$



Reduced Cross Section



■ present data
(e,e'p) ω~ 60 MeV

— DWIA (DWEEPY)

4. Conclusions.

- Our results agree with the DWIA calculation within a factor of 2.

Non-relativistic

- The DWIA calculation
  ...accounts for the (e,e'p) reaction at low momentum transfer. (Longitudinal)

  ... is reliable at $\omega = 60$ MeV.

  ...underestimates the (γ, p) reaction. (Transverse)

- The MEC contribution is large in the (γ, p) reaction

non-relativistic

- A relativistic calculation at our kinematics is necessary.

relativistic effects

R_{LT} A(e,e'p)
D(γ,p)
D(e,e'p)

○ Theories should simultaneously describe
  - quasi-elastic (e,e'p),
  - (e,e'p) at low momentum transfer,
  - (γ, p)
  - (γ, n) reactions.