Strangeness and Spin in hadronic and e.m. interaction

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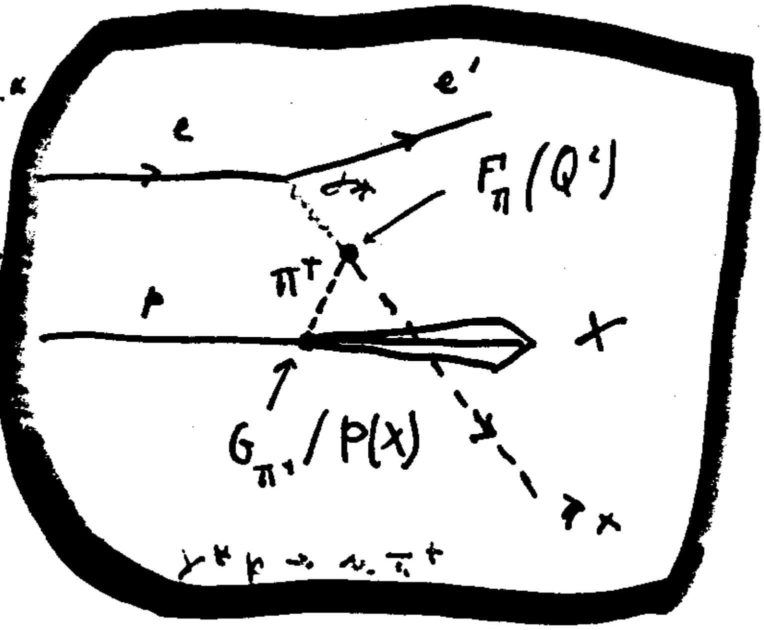
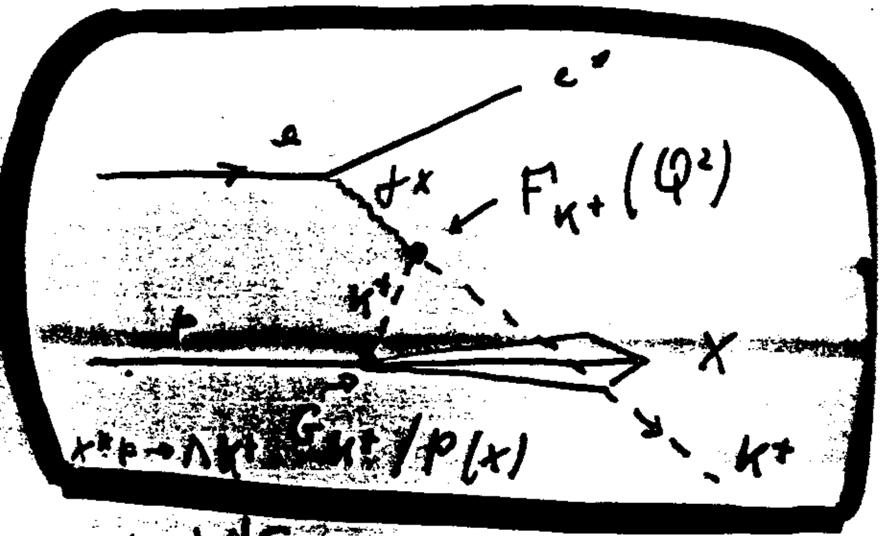
1) Strangeness content of the nucleon
2) hypernuclear states { potential
decay
Y-N int.
3) Strange resonances
4) Hyperon polarization

Quasi-elastic scattering on virtual
π K

$\gamma^{*2} = (e - e')^2 = -Q^2$ = s.q. mass γ^*
$\nu = E - E'$ = en. loss of e
$s = (\gamma^* + p)^2 = W^2$ = s.q. mass $\gamma^* N$
$t = (\gamma^* - \pi)^2$ = s.q. mom. onto N



$Q^2 \leq 1$ GeV
$\nu \geqslant 2.2$ GeV
$W \geqslant 2.1$ GeV



$$2\pi \frac{d^2\sigma}{dt\, d\varphi} = \frac{d\sigma_T}{dt} + \varepsilon \frac{d\sigma_L}{dt} + \varepsilon \cos(2\varphi) \frac{d\sigma_P}{dt} + \sqrt{2\varepsilon(\varepsilon+1)} \cos\varphi \frac{d\sigma_I}{dE}$$

σ_T → unpolarized transverse photons $\frac{1}{2}(\sigma_{11} + \sigma_{-1-1})$
σ_L → longitudinal polarized photons σ_{00} $\lambda = 0$
σ_P transverse linearly polarized photons $\frac{1}{2}(\sigma_{11} - \sigma_{-1-1})$ $\lambda =$
σ_I interference transverse - longitudinal polar. phot. σ_{11}

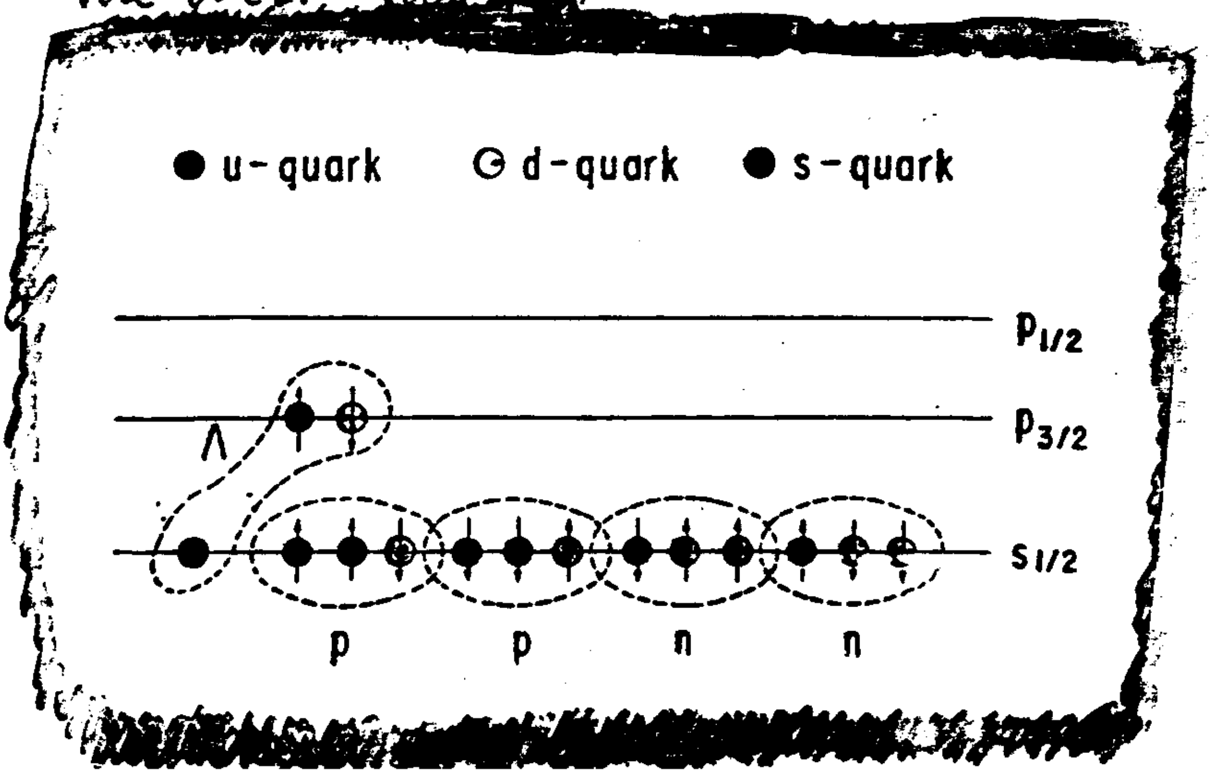
$$\frac{d^2\sigma_L(ep \to e'\pi X)}{dx\, dQ^2} = G_{\pi^*}/p(x) \; 2\pi \frac{d\sigma_{el}(e\pi^* \to e'\pi)}{dQ^2}$$

$$\frac{d\sigma}{d\Omega}_{\text{Hyp-state}} \sim N_{eff} \frac{d\sigma}{d\Omega}_{el.} |F(q)|^2$$

$$\Downarrow$$

Hypernuclei

1) Test nuclear model
2) hyperon nucleon interaction at low momenta
3) Different behaviour of a baryon when free or embedded in nuclear matter



$p + {}^{Z}A \rightarrow K^+ + {}^{Z}_{Hyp}(A+1)$

$p + {}^{Z}A \rightarrow K^+ + p + {}^{(Z-1)}_{Hyp}A$

associated production

$A + p \rightarrow {}^{Z}_{Hyp}(A+1) + K^+$

${}^{(Z-1)}_{Hyp}A + p + K^+$

${}^{Z}_{Hyp}A + n + K^+$

$p + p \rightarrow p + \Lambda + K^+$

$T_p = 2.85$ GeV $\sigma_t = 51 \pm 12$ μb

$\pi^+ + {}^{Z}A \rightarrow {}^{Z}_{\Lambda}A + K^+$

$\pi^+ + n \rightarrow \Lambda + K^+$

$e^- + {}^{Z}A \rightarrow {}^{Z-1}A + e^{-\prime} + K^+$

$\gamma + A \rightarrow \Lambda\,{}^{Z}_{\Lambda}A + K^+$

$e^- + p \rightarrow e^{-\prime} + K^+ + \Lambda$

$\gamma + p \rightarrow \Lambda + K^+$

$K^- + {}^{Z}A \rightarrow \pi^- + {}^{Z}_{\substack{\Lambda \\ \Sigma^0}}A$

$\pi^- + {}^{(Z-1)}_{\Sigma^+}A$

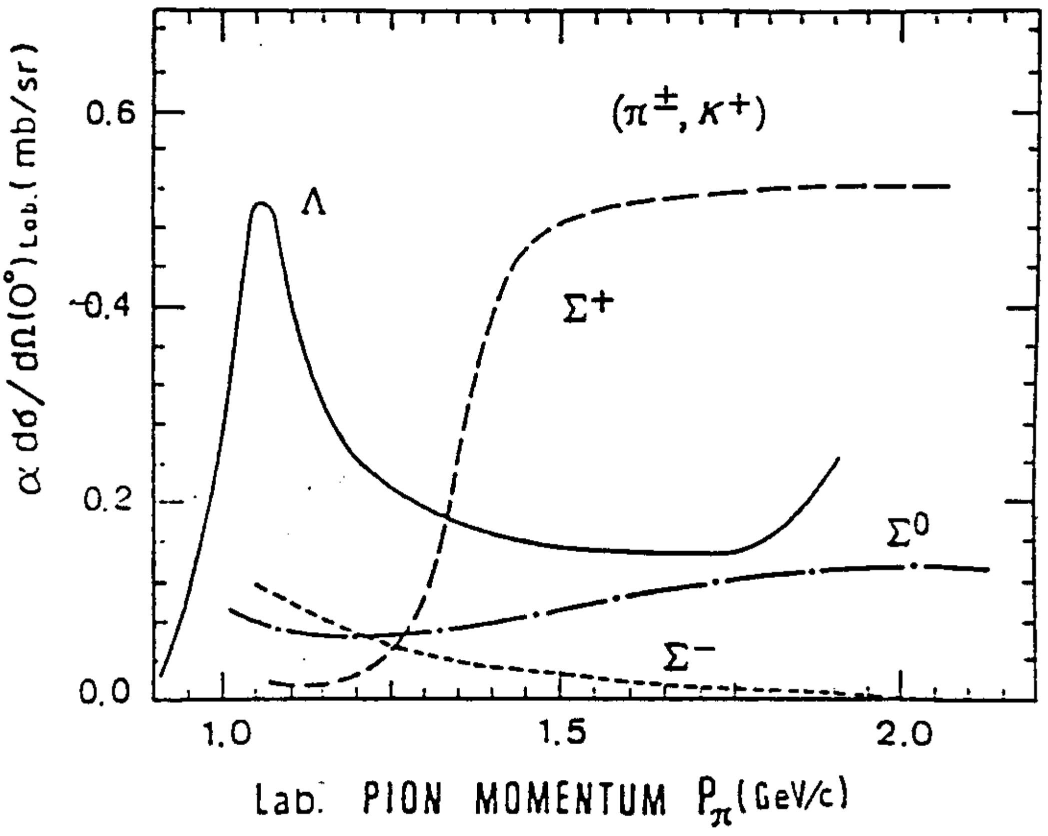
$\pi^+ + {}^{(Z-1)}_{\Sigma^-}A$

strangeness exchange

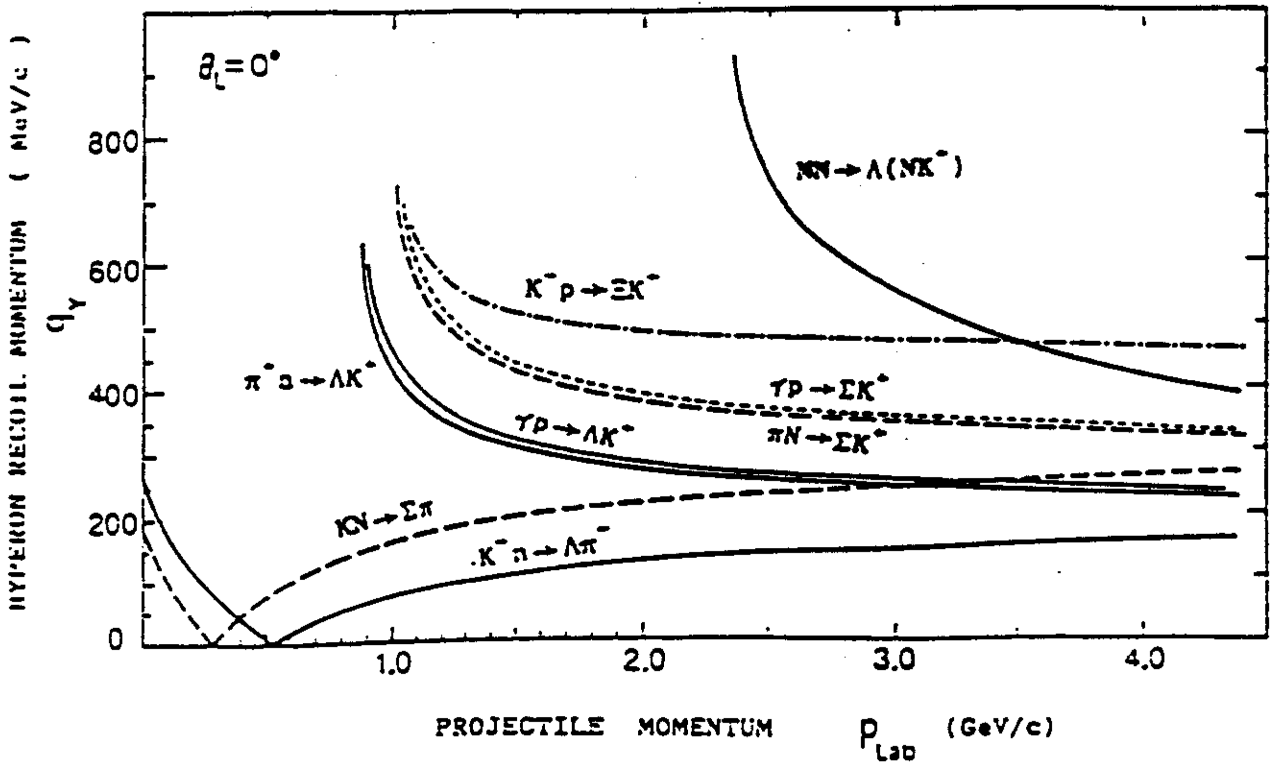
$K^- + n \rightarrow \pi^- + \substack{\Lambda \\ \Sigma_0}$

$p \qquad \Sigma^+$

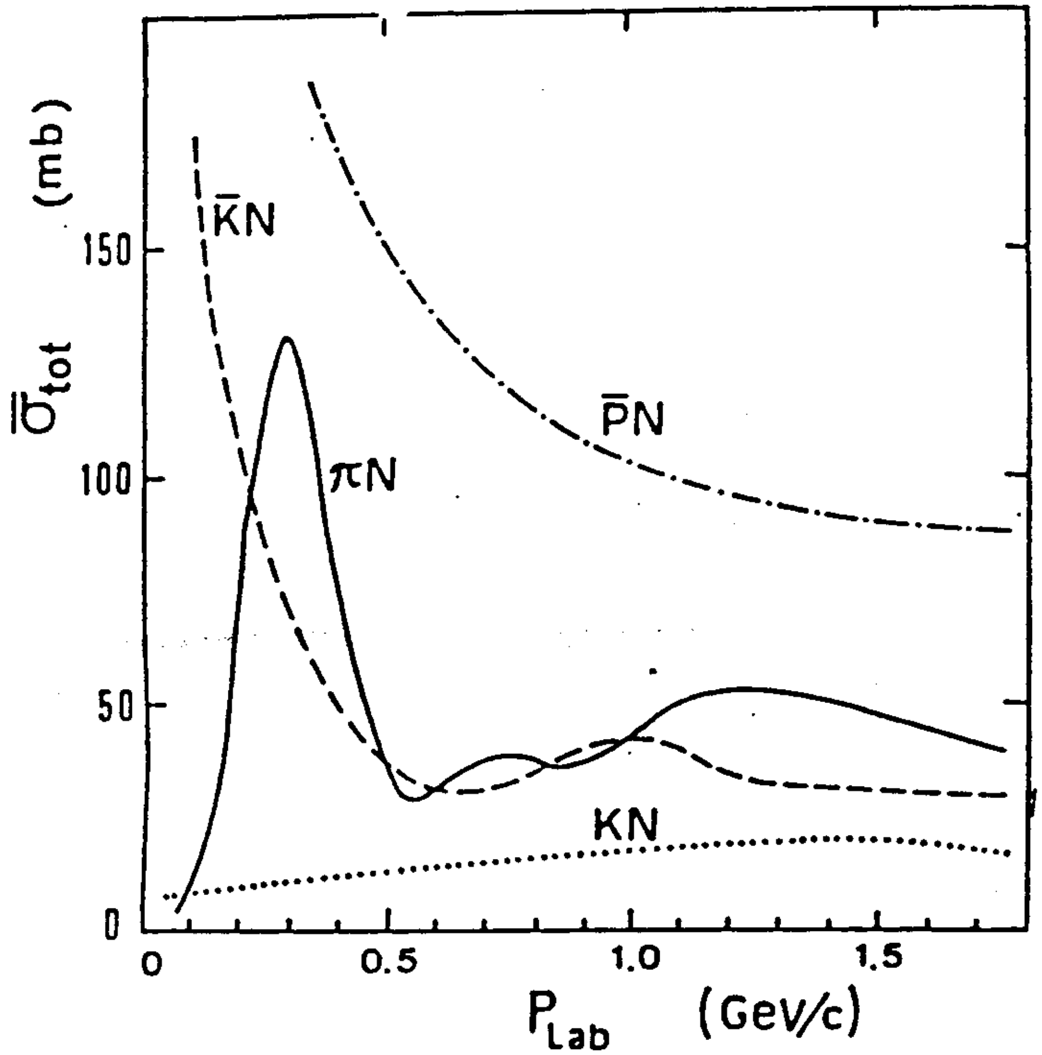
$+ p \rightarrow \pi^+ + \Sigma^-$

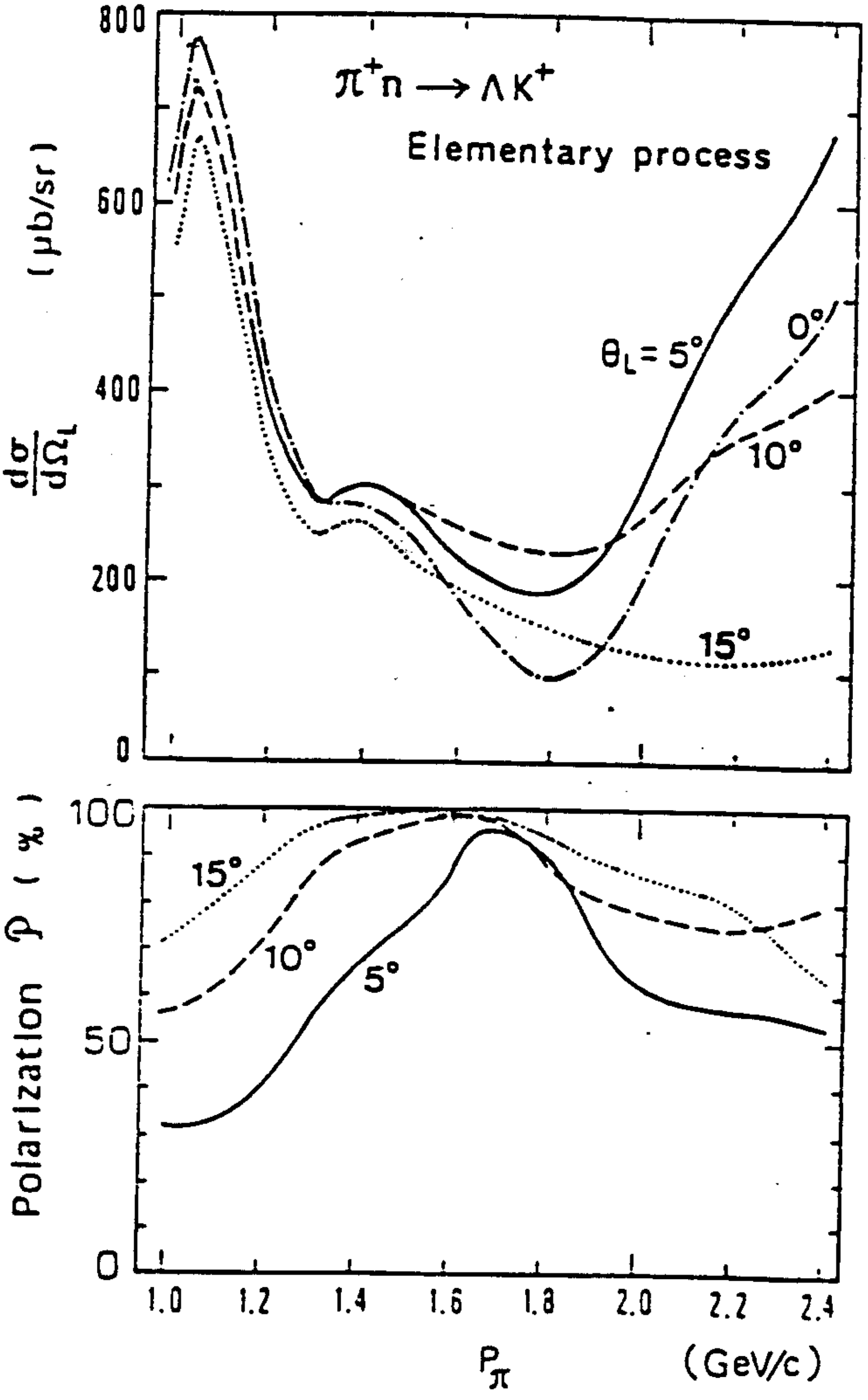


$(\pi^{\pm}, K^{+})$
Λ
Σ^{+}
Σ^{0}
Σ^{-}
$\alpha\, d\sigma/d\Omega(0^{\circ})_{Lab.}$ (mb/sr)
0.6
0.4
0.2
0.0
1.0
1.5
2.0
Lab. PION MOMENTUM P_{π} (GeV/c)

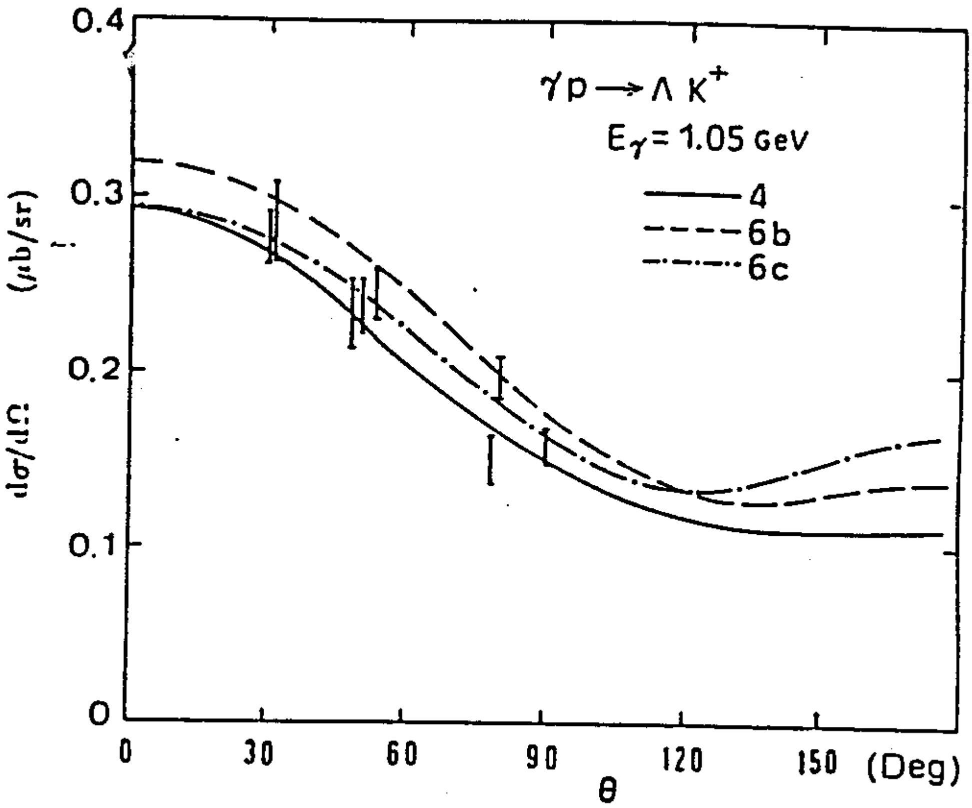


$\theta_L = 0^{\circ}$
$\bar{K}N \rightarrow \Lambda(NK^{-})$
$K^{-}p \rightarrow \Xi K^{+}$
$\pi^{+}n \rightarrow \Lambda K^{+}$
$\gamma p \rightarrow \Sigma K^{+}$
$\gamma p \rightarrow \Lambda K^{+}$
$\pi N \rightarrow \Sigma K^{+}$
$\bar{K}N \rightarrow \Sigma\pi$
$K^{-}n \rightarrow \Lambda\pi^{-}$
HYPERON RECOIL MOMENTUM q_Y (MeV/c)
800
600
400
200
0
1.0
2.0
3.0
4.0
PROJECTILE MOMENTUM p_{Lab} (GeV/c)

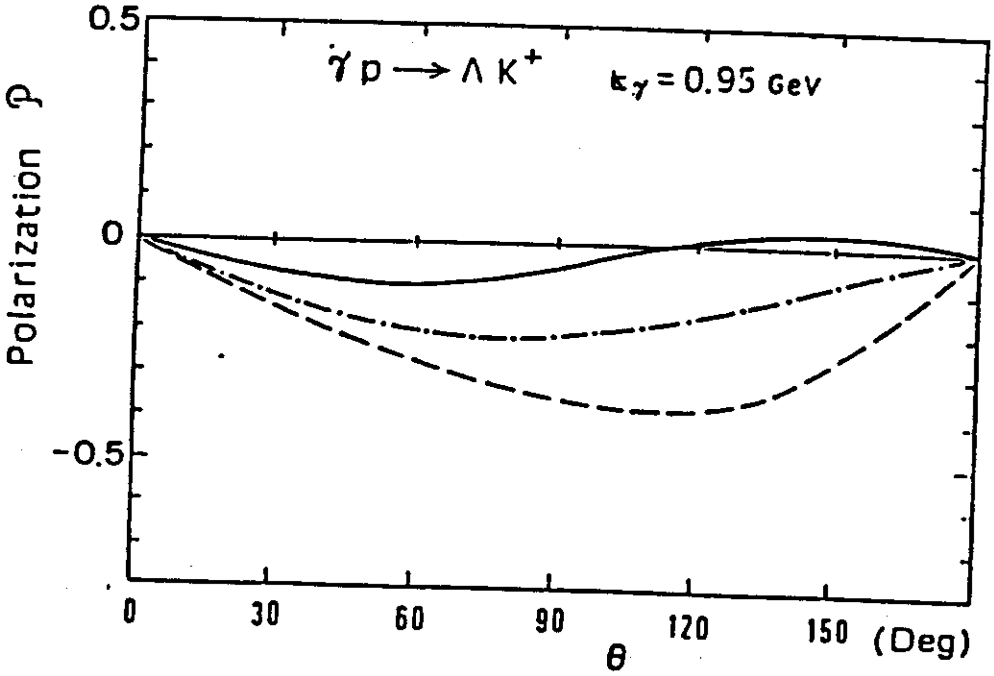

$\overline{\sigma}_{tot}$ (mb)
150
100
50
0
$\bar{K}N$
$\bar{P}N$
πN
KN
0
0.5
1.0
1.5
P_{Lab} (GeV/c)


800
600
400
200
0
$\frac{d\sigma}{d\Omega_L}$ (μb/sr)
$\pi^+ n \longrightarrow \Lambda K^+$
Elementary process
$\theta_L = 5°$
0°
10°
15°
Polarization $\mathcal{P}$ (%)
100
50
0
15°
10°
5°
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
P_π (GeV/c)

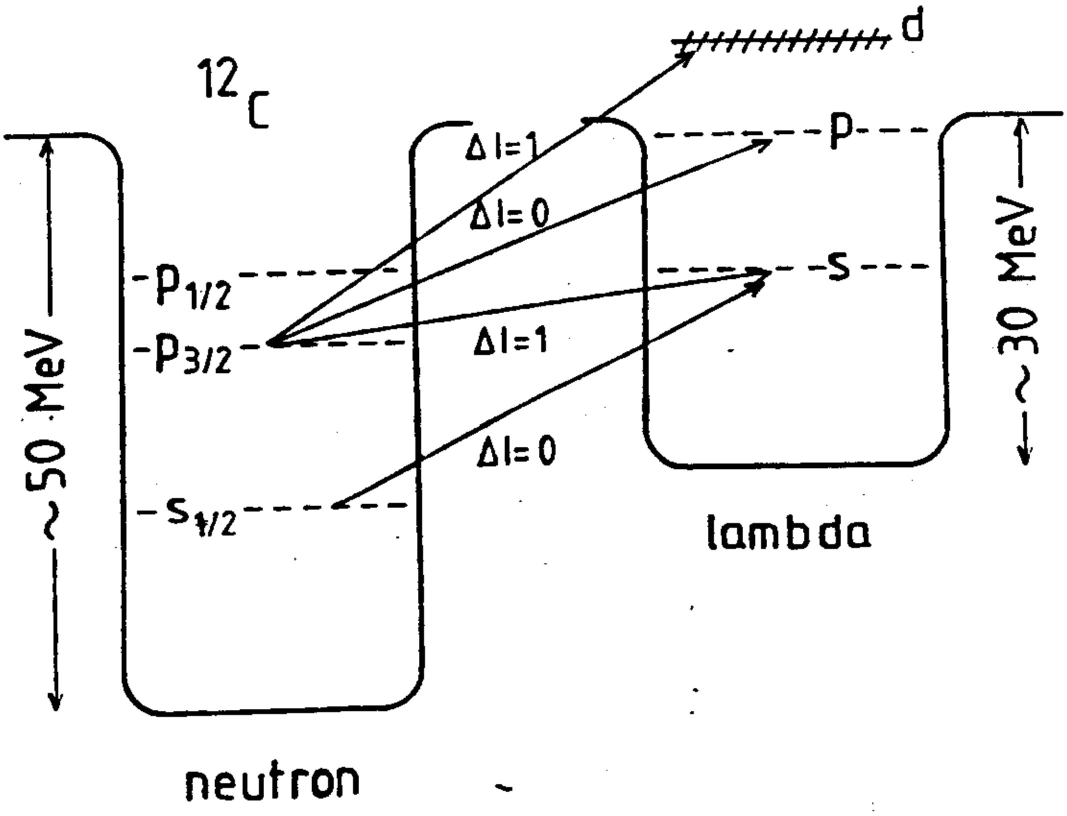
exp. data γ, K^+ J. Cohen Int. Rev. Mod. Phys. A 4 (89) 1



H. Bando et al. Int. J. Mod. Phys.
to be publ.



$$^{12}C\,(K^-,\pi^-)\,^{12}_{\Lambda}C$$



$$\Gamma_{ph} = \Gamma_p * \Gamma_h$$

$$E_K - E_\pi = M_{HY} - M_A + \cancel{T}_{HY} \qquad T_{HY} \simeq \frac{q^2}{2M_{H}}$$

$$= M_C + M_{\substack{\Lambda\\ \Sigma}} - B_{\substack{\Lambda\\ \Sigma}} - M_A$$

$$= \cancel{M_C} + M_{\substack{\Lambda\\ \Sigma}} - B_{\substack{\Lambda\\ \Sigma}} - \left(\cancel{M_C} + M_{\substack{n\\ p}} - B_{\substack{n\\ p}}\right)$$

$$= M_{\substack{\Lambda\\ \Sigma}} - M_{\substack{n\\ p}} - \left(B_{\substack{\Lambda\\ \Sigma}} - B_{\substack{n\\ p}}\right)$$

$$\downarrow$$

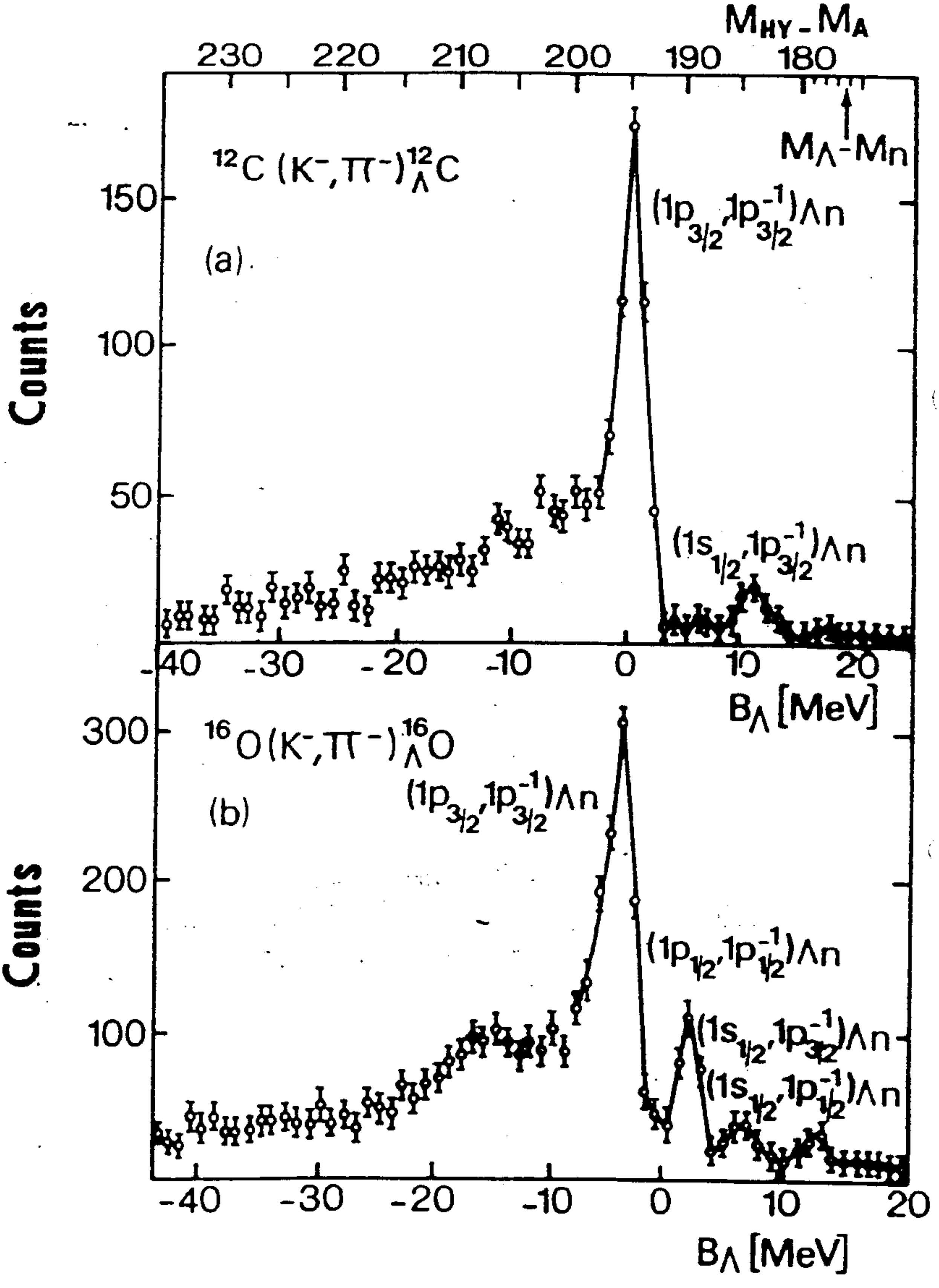
$$- \Delta B_{\substack{n\\ p}\,\substack{\Lambda\\ \Sigma}}$$

$$\Delta B_{\substack{n\\ p}\,\substack{\Lambda\\ \Sigma}} = M_{HY} - M_A - \left(M_{\substack{\Lambda\\ \Sigma}} - M_{\substack{n\\ p}}\right)$$

$$\downarrow$$

$$E_K - E_\pi$$

$p_K = 720$ MeV/c



W. Brückner et al. P. L. 79 B (1978) 157

Potential $V(r)$

Central

$$V(r) = -V_0\, f(r)$$

$f(r) = (1 + \exp(r-R)/a)$

$R = r_0 A^{1/3}$ $r_0 = 1.1$ fm

$a = .6$ fm.

Spin orbit term

$$+ \; V_{LS}\, \vec{\ell} \cdot \vec{\sigma} \left(\frac{\hbar}{m_\pi c} \right)^2 \frac{1}{r} \frac{df(r)}{dr}$$

$+$ Lane term

$$(V_1 / A)\, \vec{t} \cdot \vec{T}_{A-1}$$

but

$$\boxed{\text{residual}} \; V_{YN} \; \boxed{\text{residual}}$$

interaction

Quasi free

No momentum limitation due to Pauli principl

$$\boxed{-K_F \le K \le +K_F}$$

$$\omega = M_\Lambda - U_\Lambda + (K+q)^2/2M_\Lambda - [M_N - U_N + K^2/2M_N] = E_K - E_\pi$$

$$\omega = M_\Lambda - U_\Lambda + (U_N - M_N) + \frac{q^2}{2M_\Lambda} + \frac{K_z q}{M_\Lambda} + \frac{K^2}{2M_\Lambda M_N}(M_N - M_\Lambda)$$

but $\bar{K}^2 \simeq \frac{K_F^2}{2}$

$$\omega = M_\Lambda - M_N + (U_N - U_\Lambda) + \frac{q^2}{2M_\Lambda} + [illegible] \frac{K_F^2}{M_\Lambda M_N}(M_N - M_\Lambda)$$

if $K_z =$ [illegible]

$$\frac{dN}{dK_z} = \frac{3}{4K_F}\left([illegible] K_z / K_F\right) [illegible]$$

$$\frac{dN}{d\omega} = \frac{dN}{dK_z}\frac{dK_z}{d\omega} = \frac{dN}{dK_z}\frac{M_\Lambda}{q} = \frac{M_\Lambda}{q} [illegible] \left(1 - K_z^2/K_F^2\right)$$

but $\omega - \bar{\omega} = \frac{K_z q}{M_\Lambda} \rightarrow K_z = (\omega - \bar{\omega})\frac{M_\Lambda}{q}$

$$\frac{dN}{d\omega} = \frac{3}{4}\frac{M_\Lambda}{q K_F}\left(1 - \frac{M_\Lambda^2}{q K_z^2}(\omega - \bar{\omega})^2\right)$$

H. Dalitz and A. Gal Phys. Lett. 64 B (1976) 154

$p_K \simeq 900$ MeV/c

W. Brückner et al.
Phys. Lett. 62B (1976) 481

R. H. Dalitz and
A. Gal
Phys. Lett. 64B (1976)
154

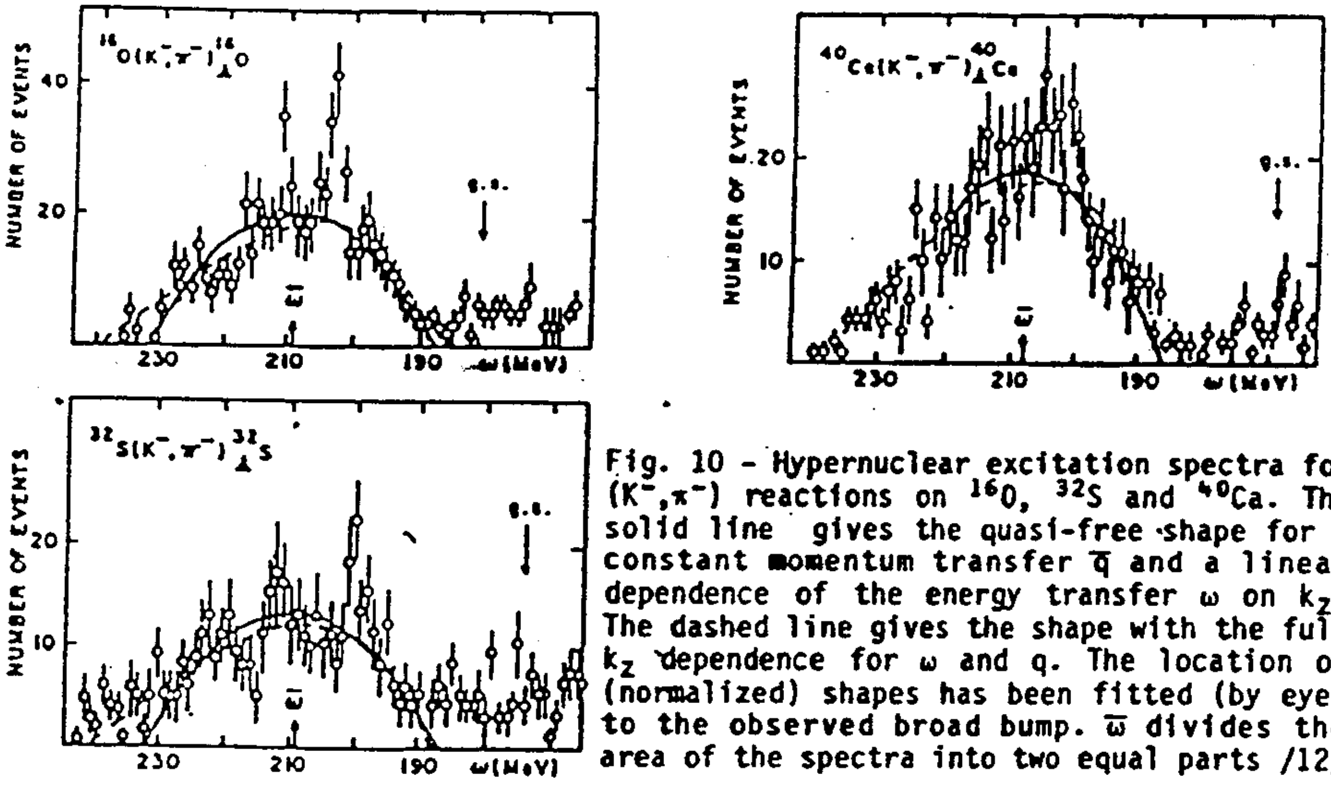


Fig. 10 - Hypernuclear excitation spectra for (K^-,π^-) reactions on ^{16}O, ^{32}S and ^{40}Ca. The solid line gives the quasi-free shape for a constant momentum transfer $\bar{q}$ and a linear dependence of the energy transfer ω on k_z. The dashed line gives the shape with the full k_z dependence for ω and q. The location of (normalized) shapes has been fitted (by eye) to the observed broad bump. $\bar{\omega}$ divides the area of the spectra into two equal parts /12/

↓

$V_0^\Lambda \simeq 30$ MeV

$$V_{\Lambda N}(r_\Lambda - r_N) = V(r_\Lambda - r_N)\left(1 - \varepsilon' + \varepsilon' P_x\right)$$

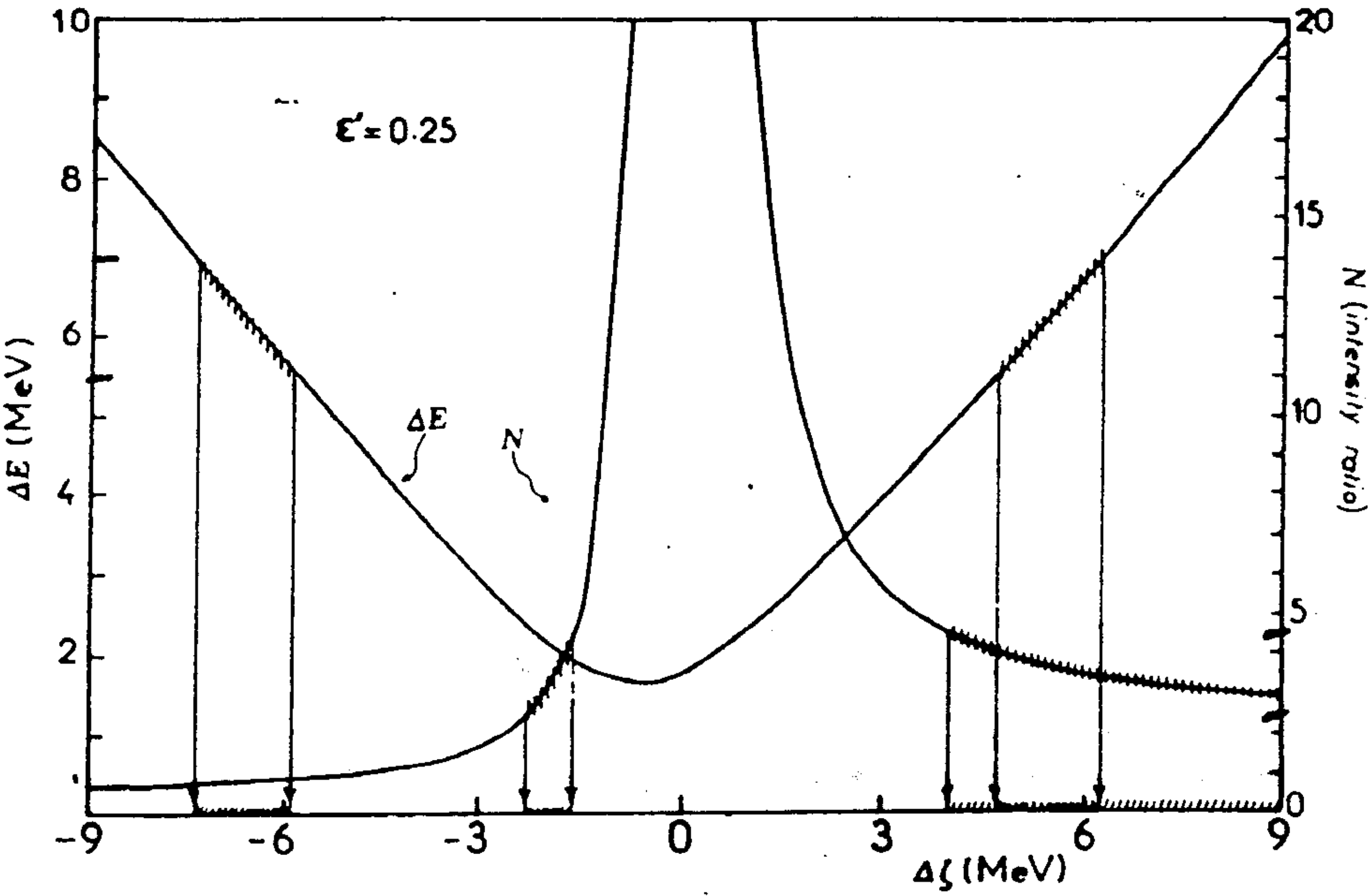
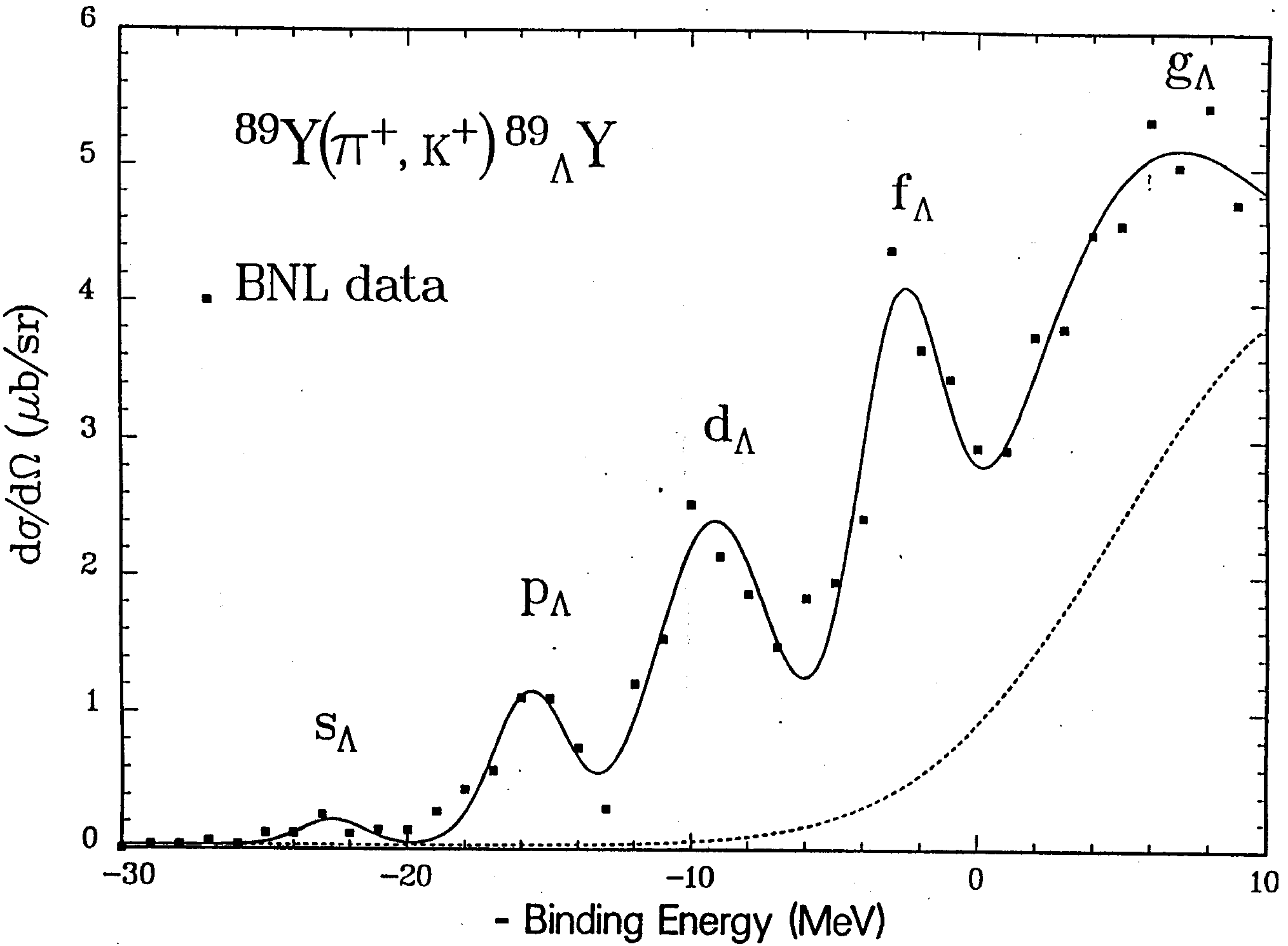


Fig. 1. Separation energy (on the left scale) and intensity ratio (on the right scale) as functions of the spin–orbit difference. The solid line corresponds to the gaussian interaction with a range $\mu = 1.04$ fm. The experimental and theoretical uncertainties on ΔE $(5.5 < \Delta E < 7)$ and on N $(2.5 < N < 4.5)$ impose constraints on $\Delta\zeta$ (indicated by slashes). The overlap (if any) gives the value of the spin–orbit difference. A value $\epsilon' = 0.25$ has been taken for the exchange mixture parameter.

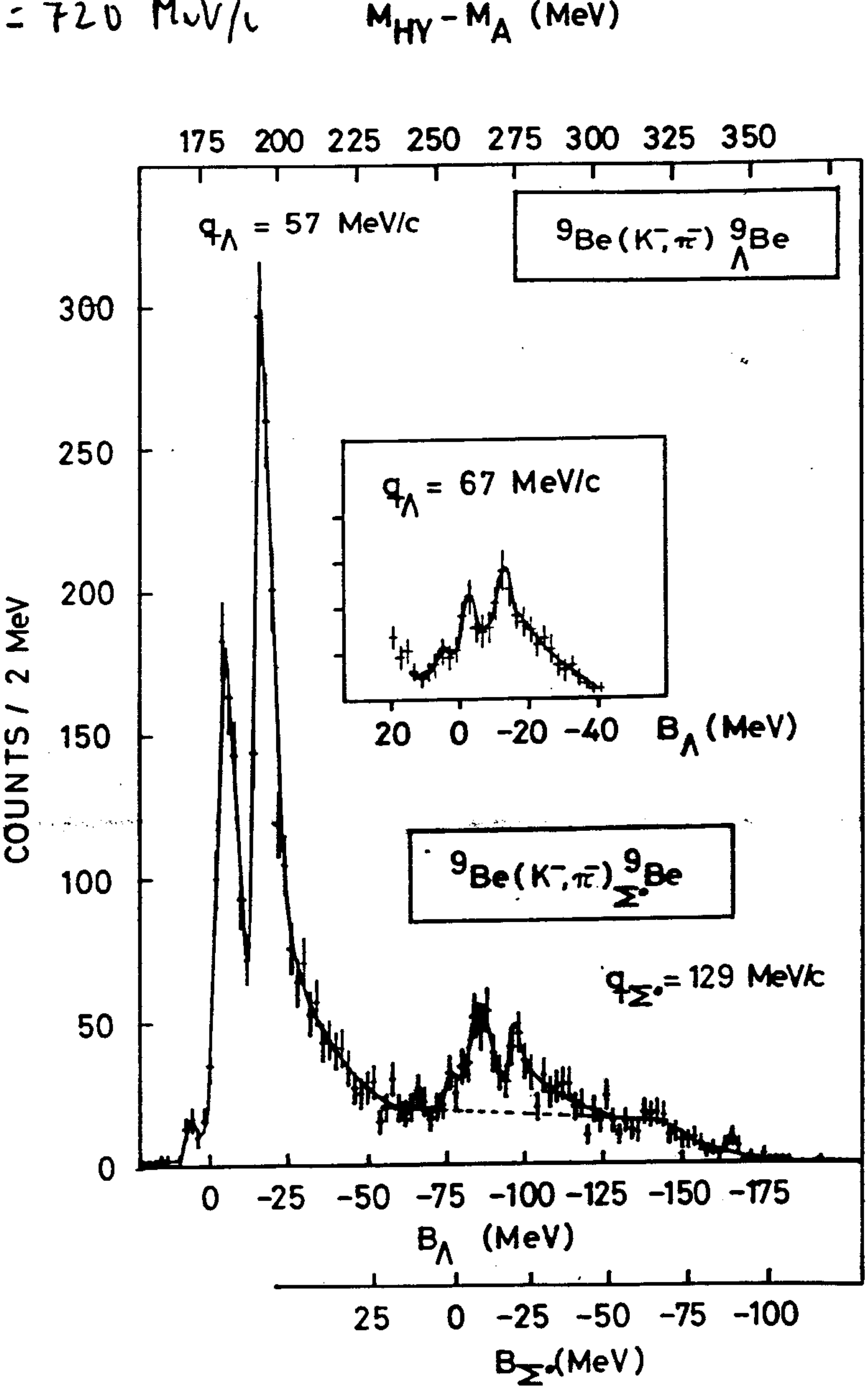
A. Bouyssy P.L. 91 B (1980) 15

R. Chrien private comm. (1994)



#3

p_K = 720 MeV/c



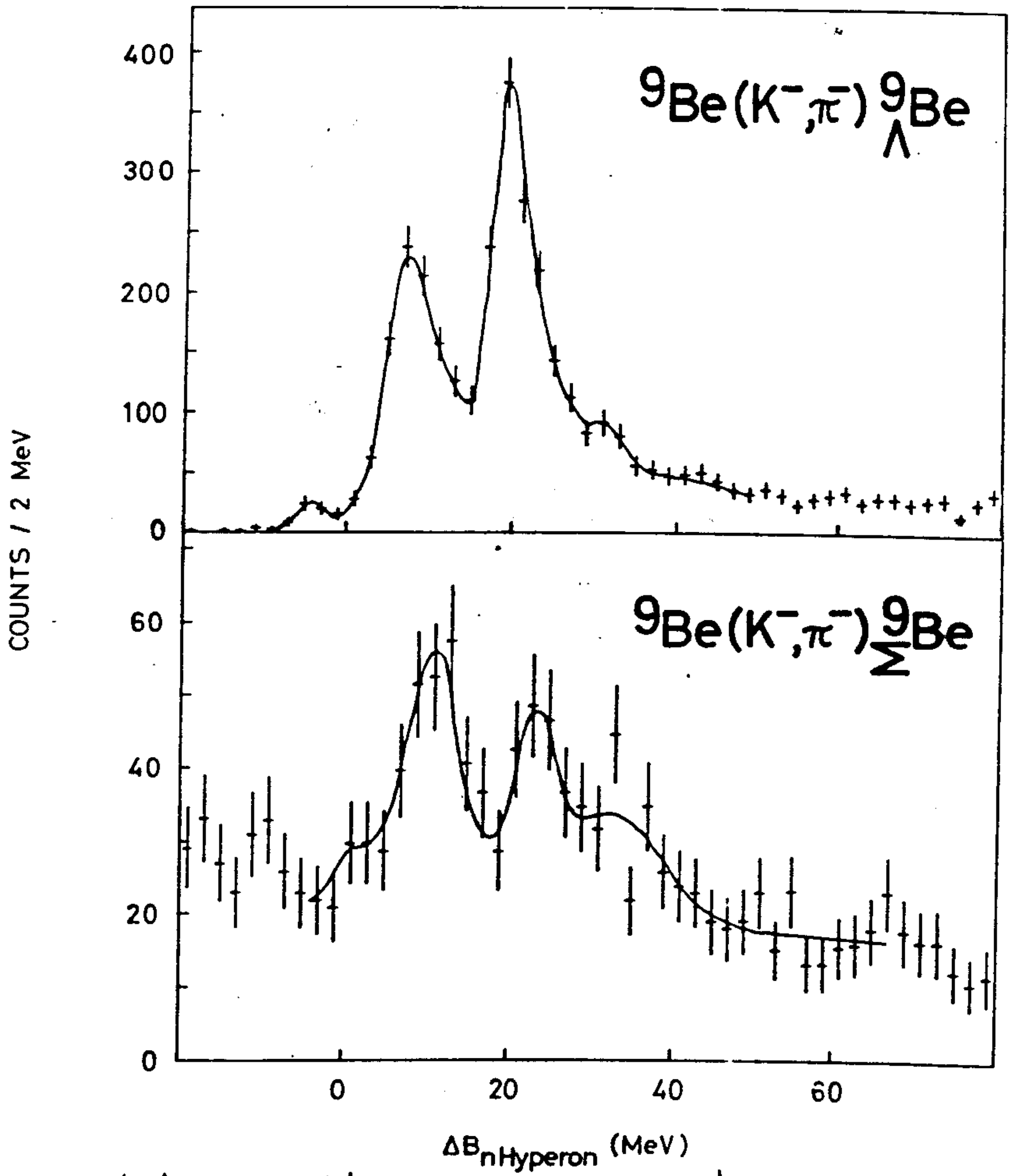
R. Bertini et al.
Phys. Lett. 90 B (1980) 375

Hyp (S = -1)	Mass (MeV)	I	J^P	τ (sec.) / Γ (MeV)	Mode	%
Λ	1115.6	0	$1/2^+$	$2.6 \cdot 10^{-10}$ $4.1 \cdot 10^{-12}$	$p\pi^-$ $n\pi^0$	64. 36.
Σ^+	1189.4	1	$1/2^+$	$.8 \cdot 10^{-10}$ $8.2 \cdot 10^{-12}$	$p\pi^0$ $n\pi^+$	52. 48.
Σ^0	1192.5	1	$1/2^+$	$7.4 \cdot 10^{-20}$ $8.9 \cdot 10^{-3}$	$\Lambda\gamma$	100.
Σ^-	1197.4	1	$1/2^+$	$1.5 \cdot 10^{-10}$ $4.4 \cdot 10^{-12}$	$n\pi^-$	100.

but in the nuclear matter

$\Lambda + N \rightarrow N + N$ weak int.

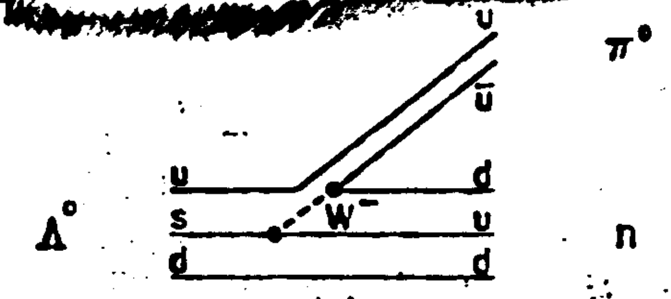
$\Sigma + N \rightarrow \Lambda + N$ strong int.



$$\Delta B_{NY} = M_{YA} - M_{A} - (M_Y - M_N) = B_N - B_Y$$

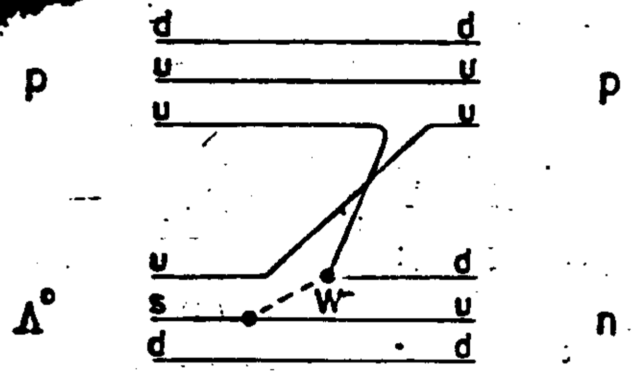
NONLEPTONIC WEAK INTERACTIONS

MESONIC $\Lambda^\circ \longrightarrow n + \pi^\circ$



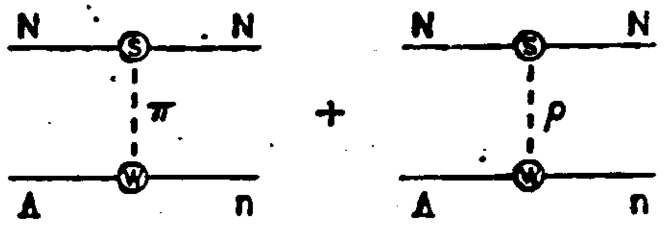
(a)

NONMESONIC $\Lambda + p \longrightarrow n + p$



(b)

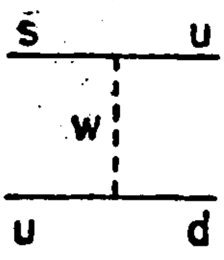
MESON Exchange Calculations



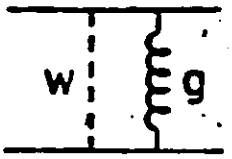
$$H_{VA} = \frac{G_F}{\sqrt{2}} \sin\vartheta_c \cos\vartheta_c \, Q_{VA} + c.c.$$

"$\Delta I = \frac{1}{2}$ rule"

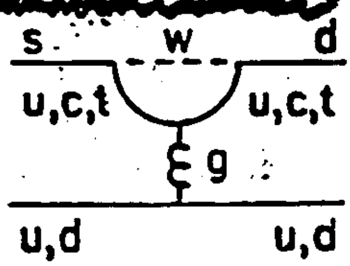
Strong interaction corrections



V-A
interaction



gluon radiative
correction



Penguin
diagram

Non leptonic decay rates

Mesonic decay — Energy release

Γ_{π^0} — $\Lambda \to n + \pi^0$

Γ_{π^-} $\Lambda \to p + \pi^-$ — $+37$ MeV $- (B_\Lambda$

Non mesonic decay

Γ_n $\Lambda + n \to n + n$ — $+176$ MeV $- (B_\Lambda + B_N$

Γ_p $\Lambda + p \to n + p$

$\Gamma_p = .49^{+.3}_{-.2}\ )\ \Gamma_\Lambda$

$\Gamma_n = .65^{+.2}_{-.3}\ )\ \Gamma_\Lambda$ — Γ_Λ = free Λ decay rate

$\Gamma_{\pi^-} = .05^{+.06}_{-.03}\ )\ \Gamma_\Lambda$

$\Gamma_{\pi^0} = .06^{+.08}_{-.05}\ )\ \Gamma_\Lambda$ — [illegible] $\pm .02$

${}^{12}C_\Lambda$ $\tau = 211 \pm 31$ ps — $\Gamma/\Gamma_\Lambda = 1.25 \pm .16$

$$1/\tau = \Gamma = \Gamma_{\pi^0} + \Gamma_{\pi^-} + \Gamma_n + \Gamma_p$$

R. Grace et al P. R. L. 55 (1985) 1055

A Sakaguchi et al [illegible]

$^{11}_{\Lambda\Lambda}\mathrm{Be}$ $B_{\Lambda\Lambda} = 17.7 \pm .4$ MeV

$^{6}_{\Lambda\Lambda}\mathrm{He}$ $B_{\Lambda\Lambda} = 11.4 \pm .6$ MeV

$$\Downarrow$$

H particle

K^-, K^+ reaction

S = 0 Resonances

$I = 1/2$ nucleon resonances N^*

$I = 3/2$ Δ resonances

$\Gamma \simeq 100 - 200$ MeV

S = -1 Resonances

$I = 0$ Λ resonances

$I = 1$ Σ resonances

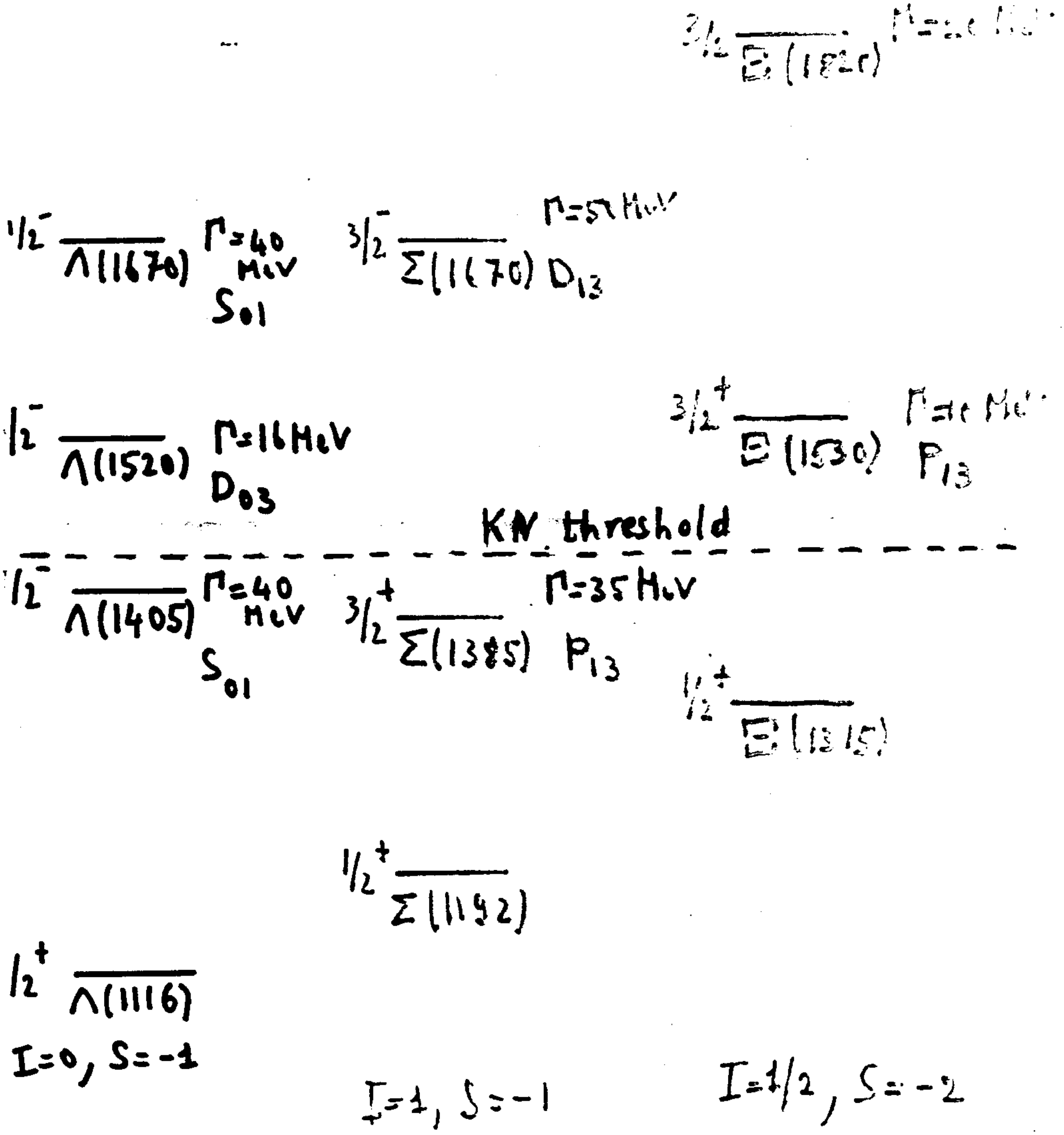
$\Gamma \simeq 15 - 60$ MeV

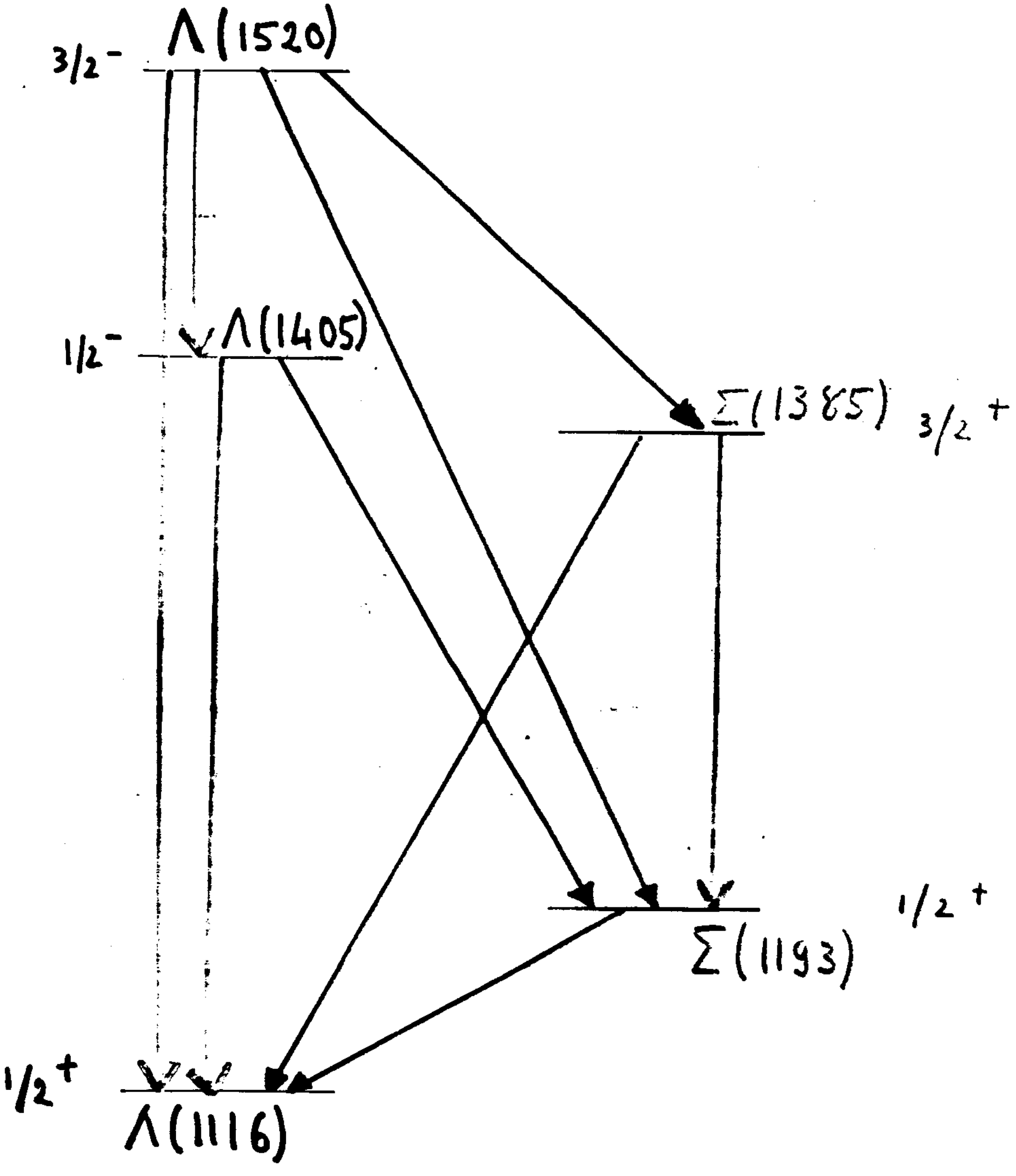
S = -2 Resonances

$I = 1/2$ Ξ resonances

$\Gamma \simeq 10 - 20$ MeV

Hyperon Level Scheme

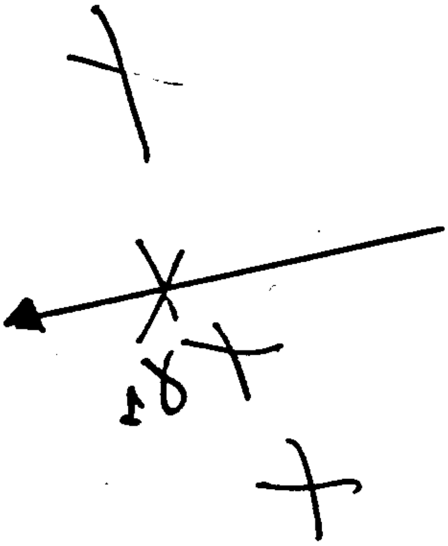



3/2⁻
Λ(1520)
1/2⁻
Λ(1405)
Σ(1385)
3/2 +
1/2 +
Σ(1193)
1/2⁺
Λ(1116)

$\mu\uparrow$
$l\uparrow$
$s\uparrow$

$$s^2p_{3/2} = \left[((\uparrow\downarrow))\downarrow_{s=0,I=0}\right]$$

$$s^3 = \left[((\downarrow\uparrow))\downarrow_{s=1,I=1}\right]$$



$$s^2p_{1/2} = \left[((\uparrow\downarrow\downarrow_{s=0,I=0}\right.$$

$(E_f + M_f) = 1314 \pm 30$ KeV

E1

$$s^2 = \sqrt{\frac{1}{3}}\left[((\uparrow\downarrow))\downarrow_{s=0,I=1}\right] + \sqrt{\frac{2}{3}}\left[((\downarrow\uparrow))\uparrow_{s=1,I=1}\right]$$

M1 $\Gamma_\gamma = 11.3$ KeV ± 2.6

$$s^3 = \left(\left[((\uparrow\downarrow))\right]\downarrow_{s=0,I=0}\right)$$

E. Kaxiras et al Phys. Rev. D 32 (1985) 695

$$\underline{.86\Lambda\left\{1,\tfrac{3}{2}^-\right\}} + .35\Lambda\left\{8,\tfrac{3}{2}^-\right\}_{S=0} - .35\Lambda\left\{8,\tfrac{3}{2}^-\right\}_{S=1} - .14\Lambda\left\{1,\tfrac{1}{2}^-\right\}$$

$$- .91\Lambda_1\,{}^2P_M + .40\Lambda_8\,{}^2P_M + .01\Lambda_8\,{}^4P_M$$

γ_0 27 KeV

48 KeV

96 KeV

γ_1 102 KeV

17 KeV

74 KeV

$$.97\Sigma_8\,{}^2S_S + .18\Sigma_8\,{}^2S_S - .10\Sigma_8\,{}^2S_S - .02\Sigma\,{}^2S_M$$

$$.93\Lambda_8\,{}^2S_S - .30\Lambda_8\,{}^2S_S - .20\Lambda_8\,{}^2S_M - .05\Lambda_1\,{}^2S_M$$

J.W. Darewych et al,
Phys. Rev. D 28 (83) 1125

$$X_{Am}^{2S+1}L_\sigma$$

$$\sigma_{tot} = 4\pi \lambda\!\!\!^{-2} \left(J + 1/2 \right) x_e$$

$$x_e = \frac{\Gamma_{el}}{\Gamma} = .45$$

$$\sigma_\gamma = 4\pi \lambda\!\!\!^{-2} \cdot x_e \cdot \left(J + \frac{1}{2} \right) \frac{\Gamma_\gamma}{\Gamma} = 74 \cdot \frac{\Gamma_\gamma}{\Gamma}$$

F.W. correction = .5 $\rightarrow \sigma_{eff} = 37$ mb.

$$\frac{d\sigma}{d\Omega}_{eff} = \frac{37}{4\pi} = 2.94 \text{ mb/sr.}$$

$$V_\gamma^c = N_k \times D_{Time} \times \Delta\Omega_\gamma \times \varepsilon_{NaI} \times \sigma_{eff} \times \frac{\Gamma_\gamma}{\Gamma} \times N_{Targ.} \times \varepsilon_{Rec} \times \Delta\Omega_{R}$$

$$= 3.5 \cdot 10^8 \times .9 \times 5.8 \cdot 10^{-2} \times .70 \times 2.9 \cdot 10^{-27} \times \frac{\Gamma_\gamma}{\Gamma} \times 7.7 \cdot 10^{23} \times 1 \times 1$$

$$= 3.0 \cdot 10^4 \frac{\Gamma_\gamma}{\Gamma}$$

$V_{\gamma_0}^c = 63 \pm 20$ $\qquad$ $N_{\gamma_1}^c = 90 \pm 32$

$\downarrow$ $\qquad\qquad$ $\downarrow$

$\Gamma_{\gamma_0} = 33 \pm 11$ KeV $\qquad$ $\Gamma_{\gamma_1} = 47 \pm 17$ KeV

$$\boxed{\frac{\Gamma_{\gamma_1}}{\Gamma_{\gamma_0}} = 1.4 \pm .7} \longleftrightarrow \frac{\Gamma_{\gamma_1}}{\Gamma_{\gamma_t}} = 3.8$$

$\uparrow$

exp. Value

$$\frac{\Gamma_{\gamma_1}}{\Gamma_{\gamma_0}} = .37$$

$$\frac{\Gamma_{\gamma_1}}{\Gamma_{..}} = .8$$

Resonance propagation in nuclei

Free space no Fermi motion !

$$d_{\Delta} = vt \simeq \frac{p_{\pi}}{m_{\Delta}\Gamma_{\Delta}} \simeq .5\ fm$$

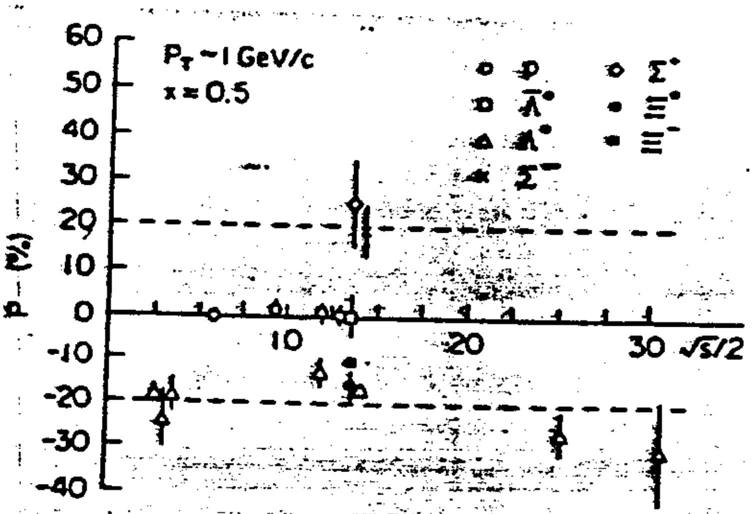
$$d_{\Lambda(1520)} = vt \simeq \frac{p_K}{m_{\Lambda^*}\Gamma_{\Lambda^*}} \sim 6\ fm.$$

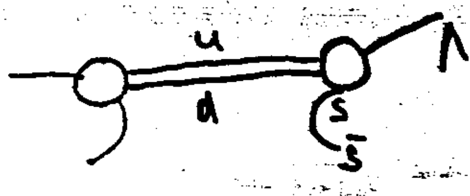
Decay modes :

$$\Lambda(1520) \longrightarrow \left\{ \begin{array}{lll} \bar{K} N & 45\% & \pm 1 \\ \pi \Sigma & 42\% & \pm 1 \\ \Lambda \pi\pi & 10\% & \pm 1 \\ \Sigma \pi\pi & .9\% & \pm .1 \end{array} \right.$$

Hyperon polarization

Reaction $p + A \to \vec{Y}$





Λ (↑↓↑)
$(s_{1/2})^3$
$I = 0$

Regularities:

a) Λ, Σ and Ξ are polarized for $p_T >$

b) P_Λ has opposite sign to P_Σ

c) $P_{\bar{\Lambda}}$ always $= 0$ but $P_{\bar{\Lambda}} \neq 0$ for the reaction $\bar{p} + A \to \vec{\bar{\Lambda}}$

$\Downarrow$

When 1 or 2 squarks are picked up from the quark sea $P_Y \neq 0$ when 3 $P_Y = 0$

$\Downarrow$

Questions: why $P_Y \neq 0$ if 3 quark picked up from sea

$\Downarrow$

Models ad hoc: QFRC
VVS

Ex. $p \to \vec{\Lambda}$
uud → uds

For p_T large $p_T \simeq \boxed{q_T} + \boxed{k_T}$
diquark squark

In this framework: there should not be a correlation between the spin direction of the incoming proton and the spin of the Λ

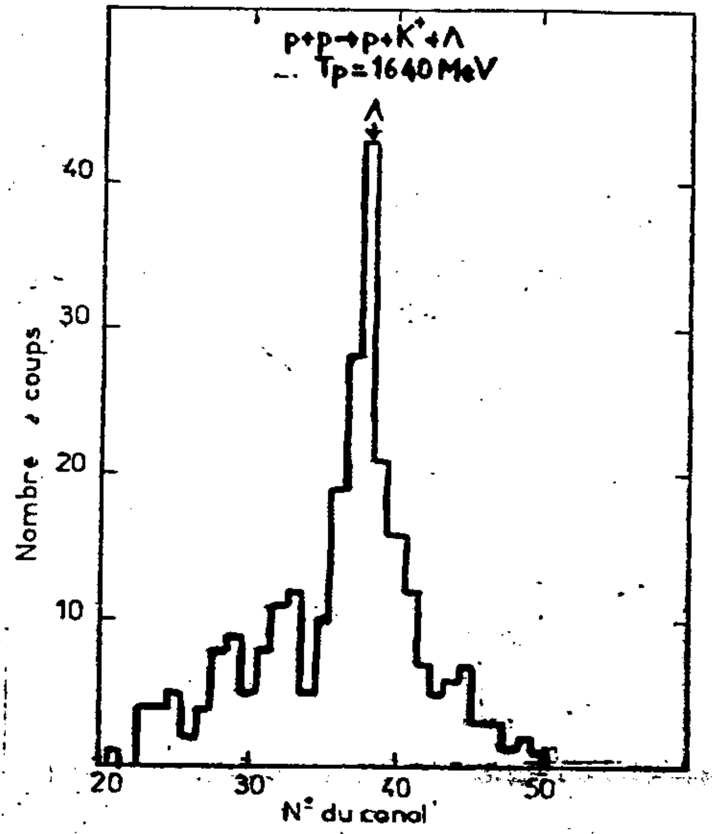
there should be a correlation between the spin direction of the incoming proton. and the spin of the

Σ (↑↑↓) $(s_{1/2})^3$ $I = 1$

With the inclusive reaction $p + A \to \Lambda$ problems:

1) $p \to \vec{\Lambda}$ directely
but also
$p \to \Sigma^0 \hookrightarrow \gamma\ \Lambda$

2) measurements performed at forward angles only
$\vartheta_\Lambda \leq 10°$ overall



Measurement of spin correlation parameters

At Saturne

$pp \to p K^+ \Lambda$ exclusive
$\hookrightarrow p\pi^-$ $\alpha = .64$
choose the right angle ϑ_Λ for same p_T

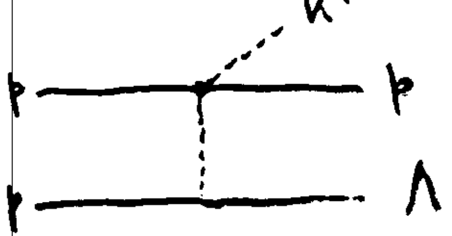
Also possible:

$pp \to p K^+ \Sigma^0 \hookrightarrow \gamma\ \Lambda$

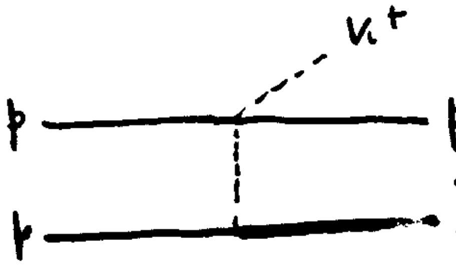
$pp \to K^+ n\ \Sigma^+$
$\quad\ \ K^0 p \hookrightarrow p\pi^0$ $\alpha = -.98$

$pn \to p K^+ \Sigma^- \hookrightarrow n\pi^-$ $\alpha = -.$[illegible]

Comparison with OBEM



$\frac{G_\Lambda^2}{4\pi} \sim 1?$



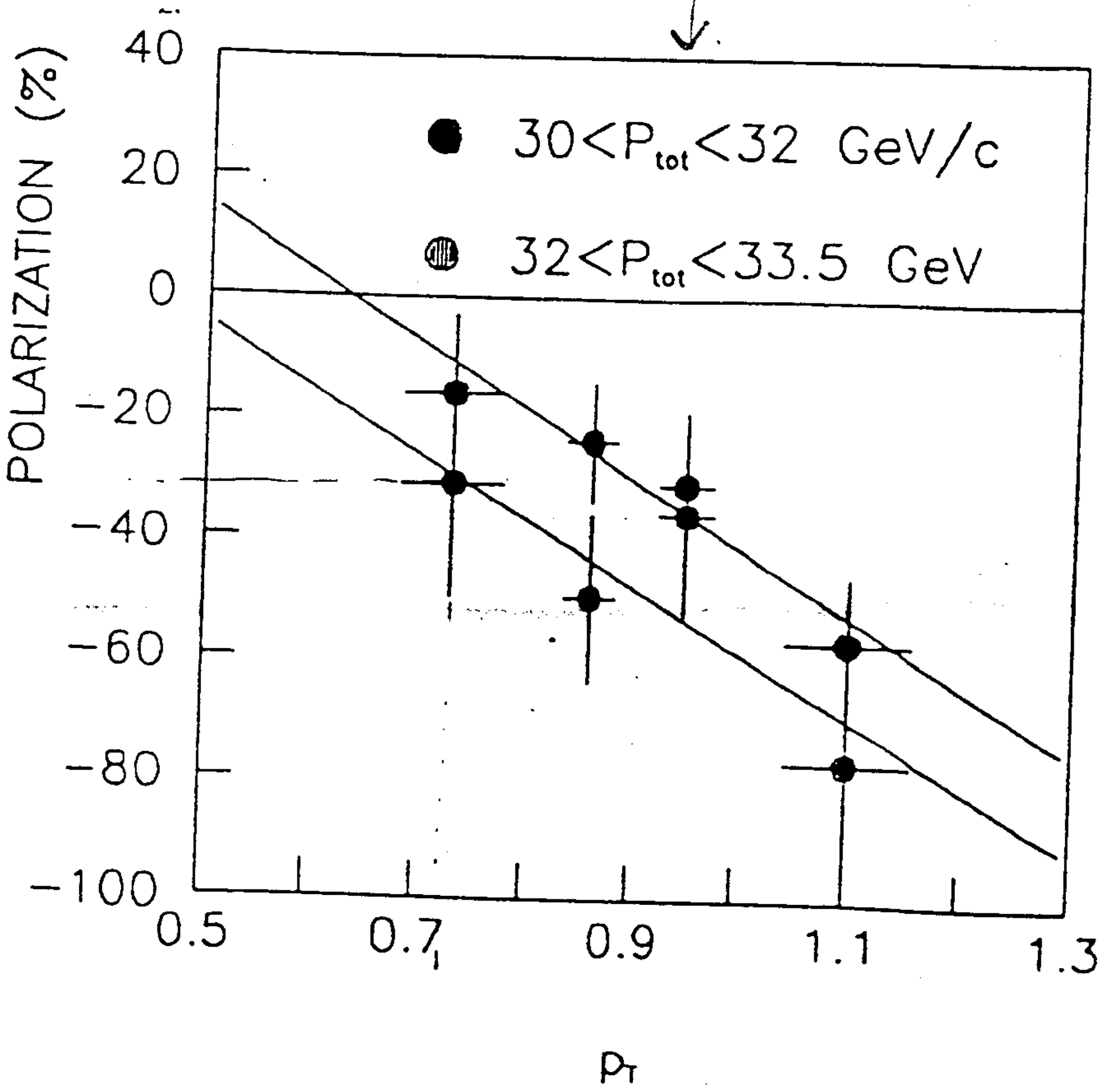
$\Sigma^0 (\Sigma^+)$

$\frac{G_\Sigma^2}{4\pi} \sim 5$

Layet calculations

$pp \to p \; (\Lambda K^+)$

$2.1 \leq M_{\Lambda K} \leq$



[PRELIMINARY RESULTS]

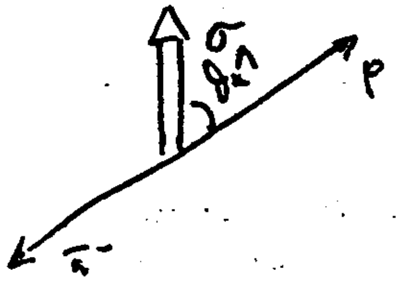
CERN ISR $\to \sqrt{s} = 63$ GeV
(R608)

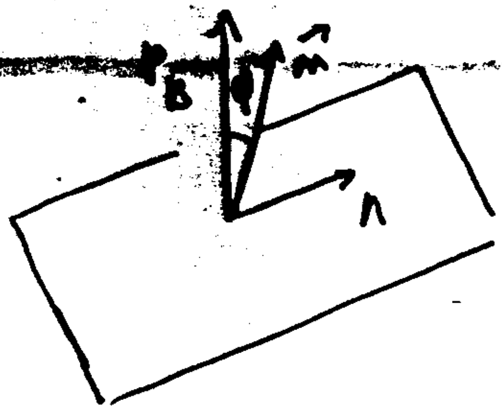
$pp \to p(\Lambda K^+)$

$$A_N = \frac{1}{P_B \cos\psi} \frac{N\uparrow(\psi) - N\downarrow(\psi)}{N\uparrow(\psi) + N\downarrow(\psi)}$$

$$D_{NN} = \frac{1}{P_B \cos\psi} \left[P_\Lambda^{\uparrow} - P_\Lambda^{\downarrow} \right]$$

$$\frac{dN}{d\cos\theta^*} = N_0 \left(1 + \alpha P_\Lambda \cos\theta^* \right)$$





$pp \to p(K^+ \Lambda)$

$\hookrightarrow p\pi^-$

$pp \to p\left(K^+ \Sigma^0\right)_{N^*}$

$\hookrightarrow \gamma\Lambda$

$\hookrightarrow p\pi^-$

$pp \to pK^+\Lambda^*$

$pp \to pK^+\Sigma^*$

$pp \to pK^+\Lambda^*$

$\hookrightarrow \gamma\Lambda$

$\hookrightarrow \gamma\Sigma$

Nuclei

$pA \to pK^+\Lambda^* X$

$\hookrightarrow pK^-$

$\hookrightarrow \gamma\Lambda$

$\hookrightarrow \gamma\Sigma$

$pA \to pK^+\Sigma^0 X$

$V(r) = V_0(r) + \text{s.o.} + \text{L.T.} + \text{r.i}$

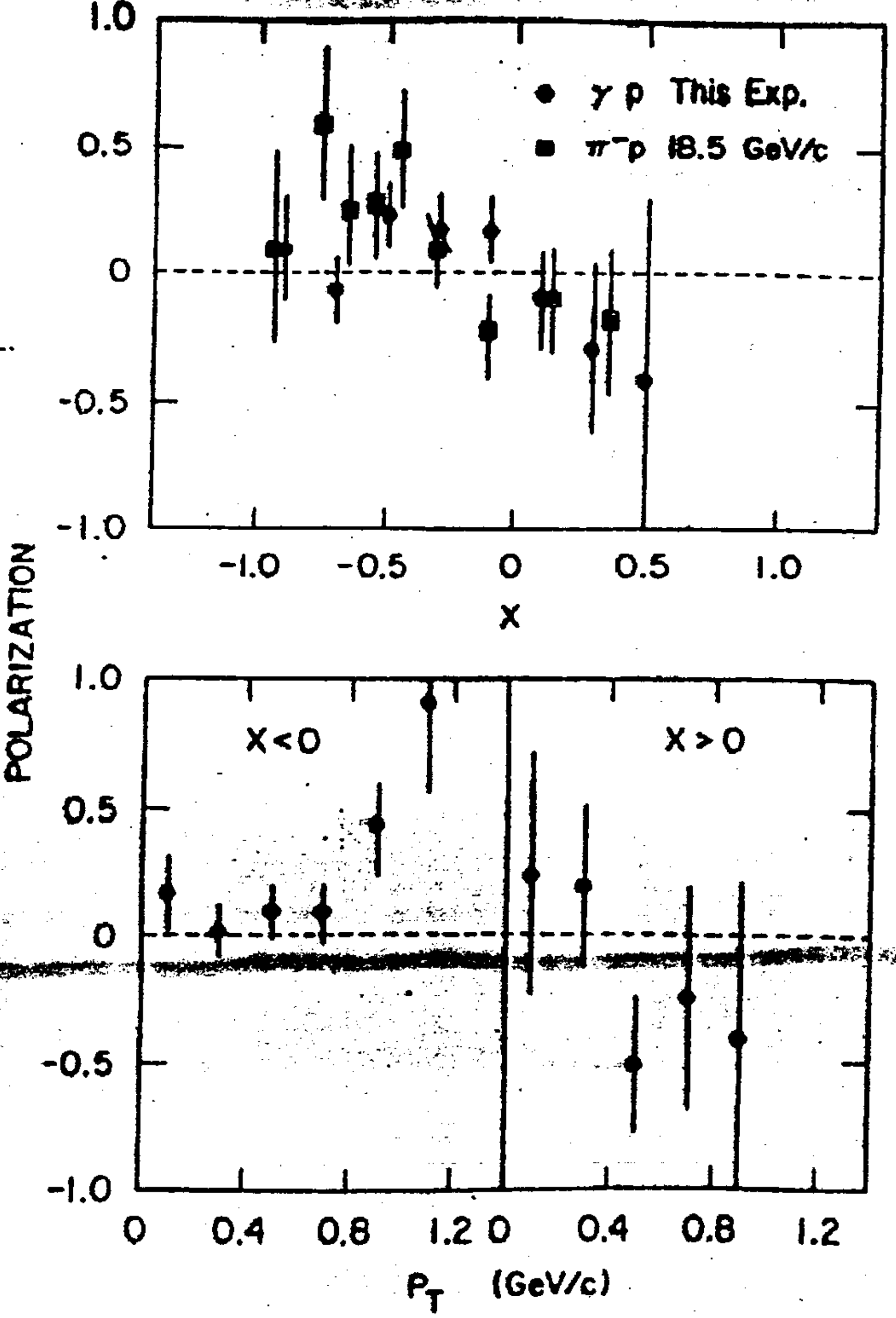


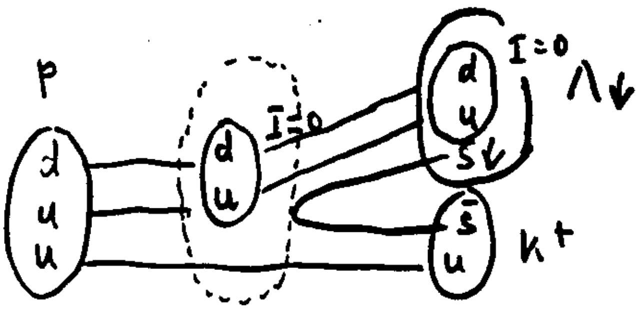
FIG. 8. Average polarization of Λ's as a function of x and p_T. The open square points are from Ref. 1.

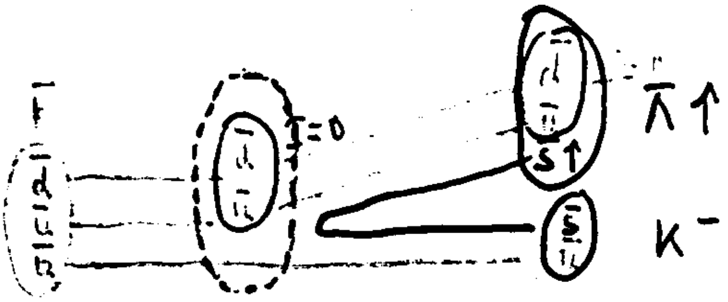
K. Abe et al.
Phys. Rev. D 29 (1984) 1877

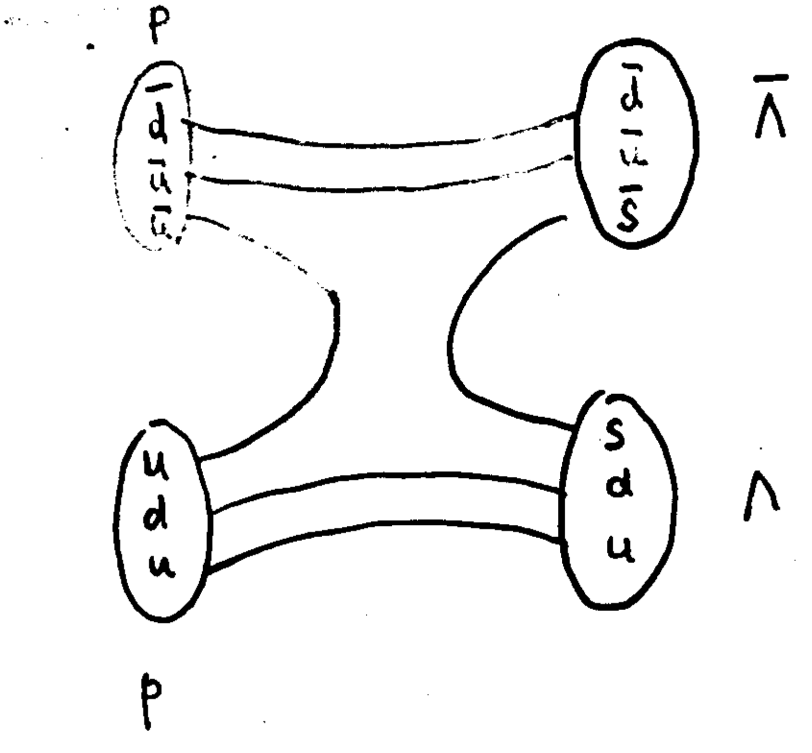
Strangeness

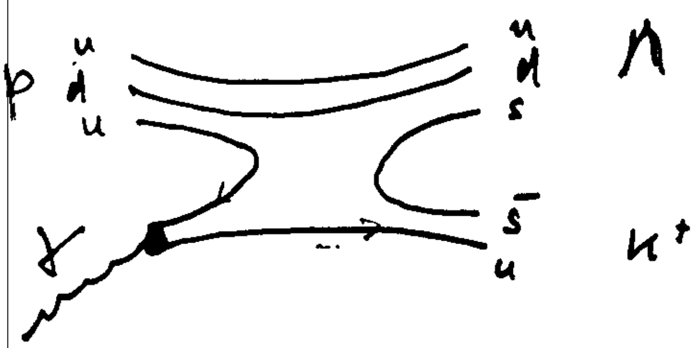
$N \; N$

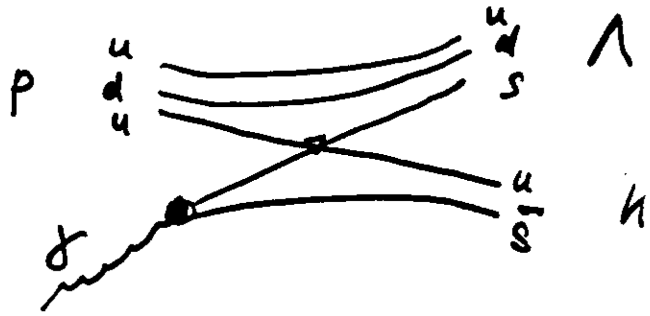
$\bar{N} \; N$

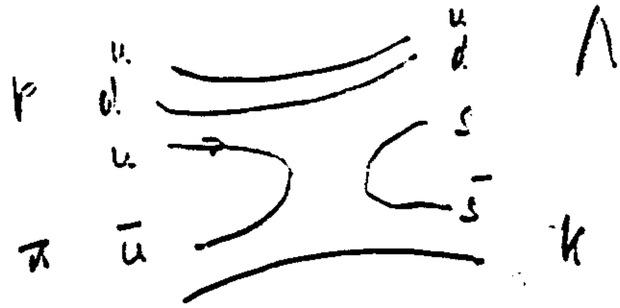







p
u
d
u
γ
u
d
s
$\bar{s}$
u
Λ
K+


p
u
d
u
γ
u
d
s
u
$\bar{s}$
Λ
K


p
u
d
u
π
$\bar{u}$
u
d
s
$\bar{s}$
Λ
K


u
d
u
$\bar{u}$
K⁻
s
Λ
φ

* M. Bernheim, J.F. Danel, J.E. Ducret, J.M. Le Goff,
L. Lakehal-Ayat, A. Magnon, C. Marchand, J. Mougey
J. Morgenstern, S. Turck-chieze, P. Vernin, A. Zghiche
SACLAY, DPHN, FRANCE

* S. Frullani, F. Garibaldi, F. Ghio, M. Iodice
SANITA, INFN, ITALY

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LNF, FRASCATI, INFN, ITALY

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U. ILLINOIS, U.S.A.

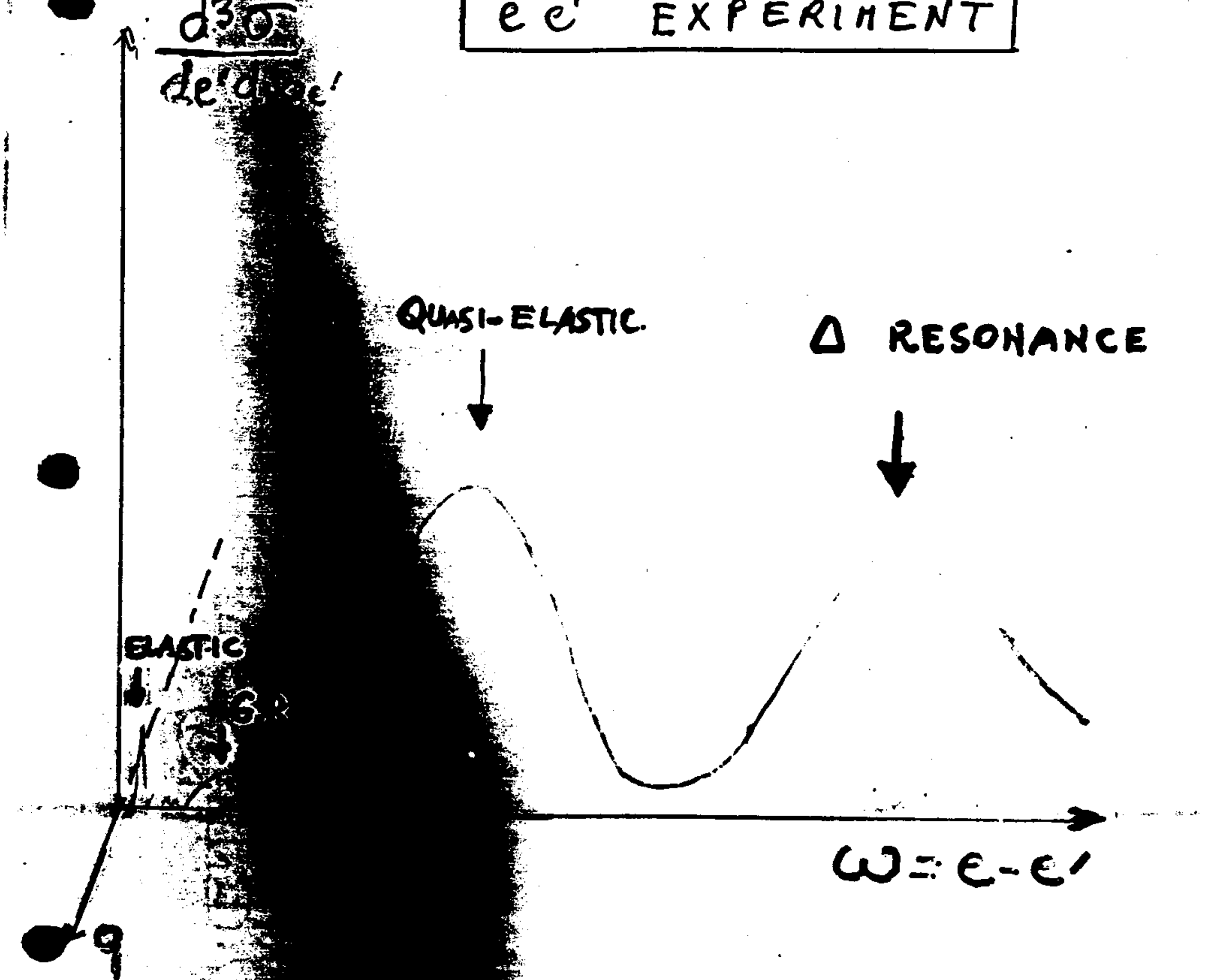
* H.E Jackson
ANL, ARGONNE, U.S.A.

* Z.E. Meziani
U STANFORD, U.S.A.

* J. Le Rose, J. Mougey, S. Nanda, A. Saha, P. Ulmer
CEBAF, U.S.A.

* C. Perdrisat, V. Punjabi
WILLIAM and MARY, U.S.A.

ee' EXPERIMENT



[illegible] e' ELECTRON ENERGY TRANSFER

$\vec{q}$ [illegible] $\vec{e}'$ ELECTRON MOMENTUM TRANSFER

QUASI-ELASTIC SCATTERING AND MEDIUM EFFEC

QUASI ELECTRON SCATTERING IS DOMINATED BY ONE SINGLE NUCLEON KNOCK-OUT.

THIS REACTION IS SUITABLE TO STUDY PROPERTIES OF THE NUCLEON INSIDE THE NUCLEAR MEDIUM.

FOR THAT PURPOSE WE HAVE MEASURED THE LONGITUDINAL AND THE TRANSVERSE RESPONSES IN COINCIDENCE $ee'p$ AND IN INCLUSIVE ee' EXPERIMENTS

THESE RESULTS WERE OBTAINED FOR NUCLEON MOMENTA $p < 200$ MeV CORRESPONDING TO THE MEAN FIELD REGIME

WE HAVE FOUND FOR THE TRANSVERSE RESPONSE A RESULT VERY SIMILAR FOR THE PROTON INSIDE AND OUTSIDE THE NUCLEAR MEDIUM FOR ELECTRON MOMENTUM TRANSFER q UP TO [illegible] MeV/c

FOR THE LONGITUDINAL RESPONSE WE OBSERVE A q DEPENDENCE WITH A SLOPE WHICH IS COMPATIBLE WITH THE FREE NUCEON BUT WITH A SMALLER STRENGTH. THIS LACK IN STRENGTH INCREASE WITH THE MASS NUMBER.

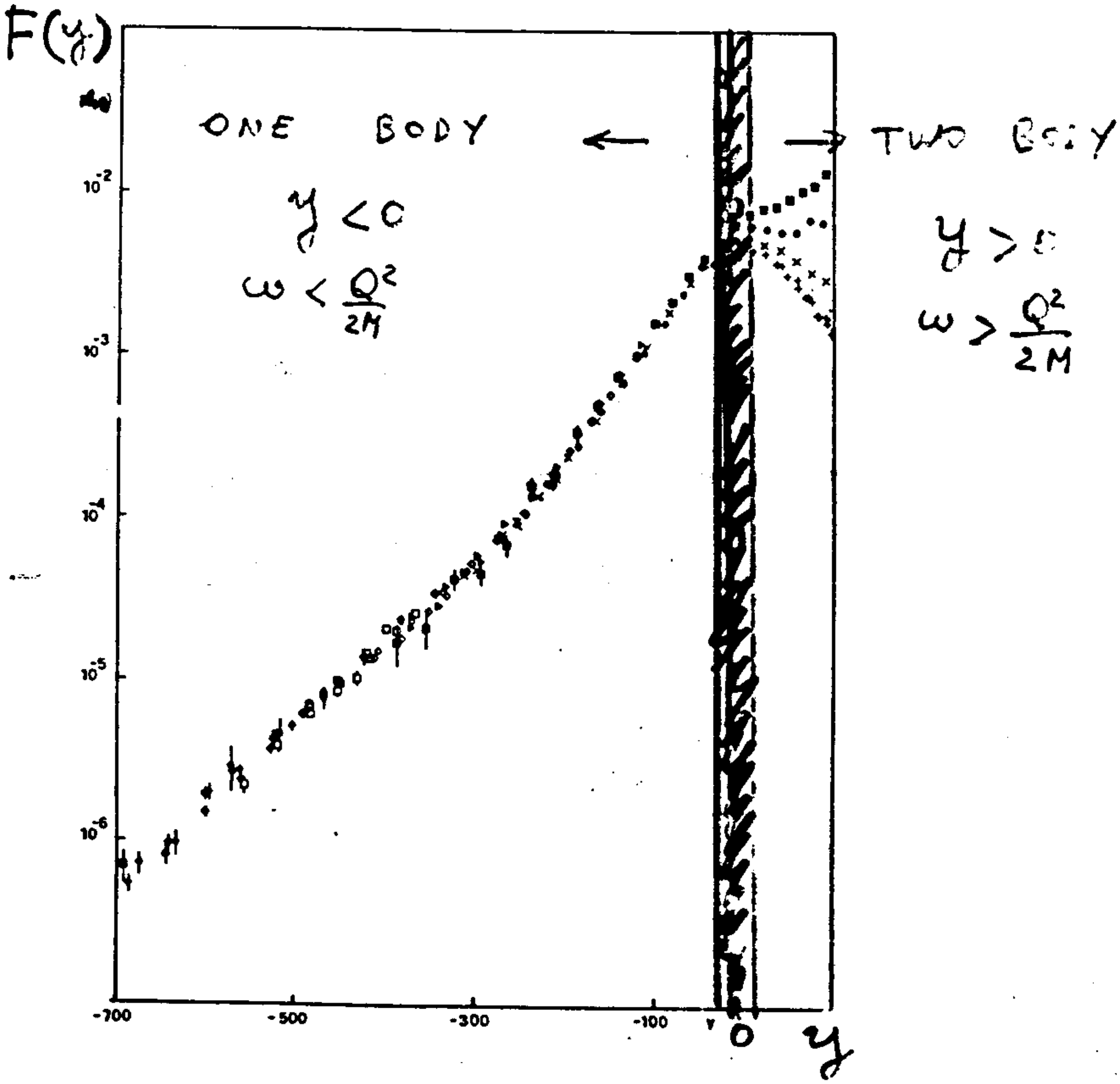
- IN ADDITION TO NUCLEONIC DEGREES OF FREEDOM, WE CAN HAVE:
- VIRTUAL PION DEGREES OF FREEDOM: EXCHANGE CURRENTS
- REAL PION DEGREES OF FREEDOM ONLY ABOVE PION ELECTROPRODUCTION THRESHOLD.
- THESE NEW DEGREES OF FREEDOM ARE ESSENTIALLY TRANSVERSE.

THE LONGITUDINAL RESPONSE FUNCTION SEEMS MORE SUITABLE FOR STUDYING THE NUCLEONIC DEGREES OF FREEDOM

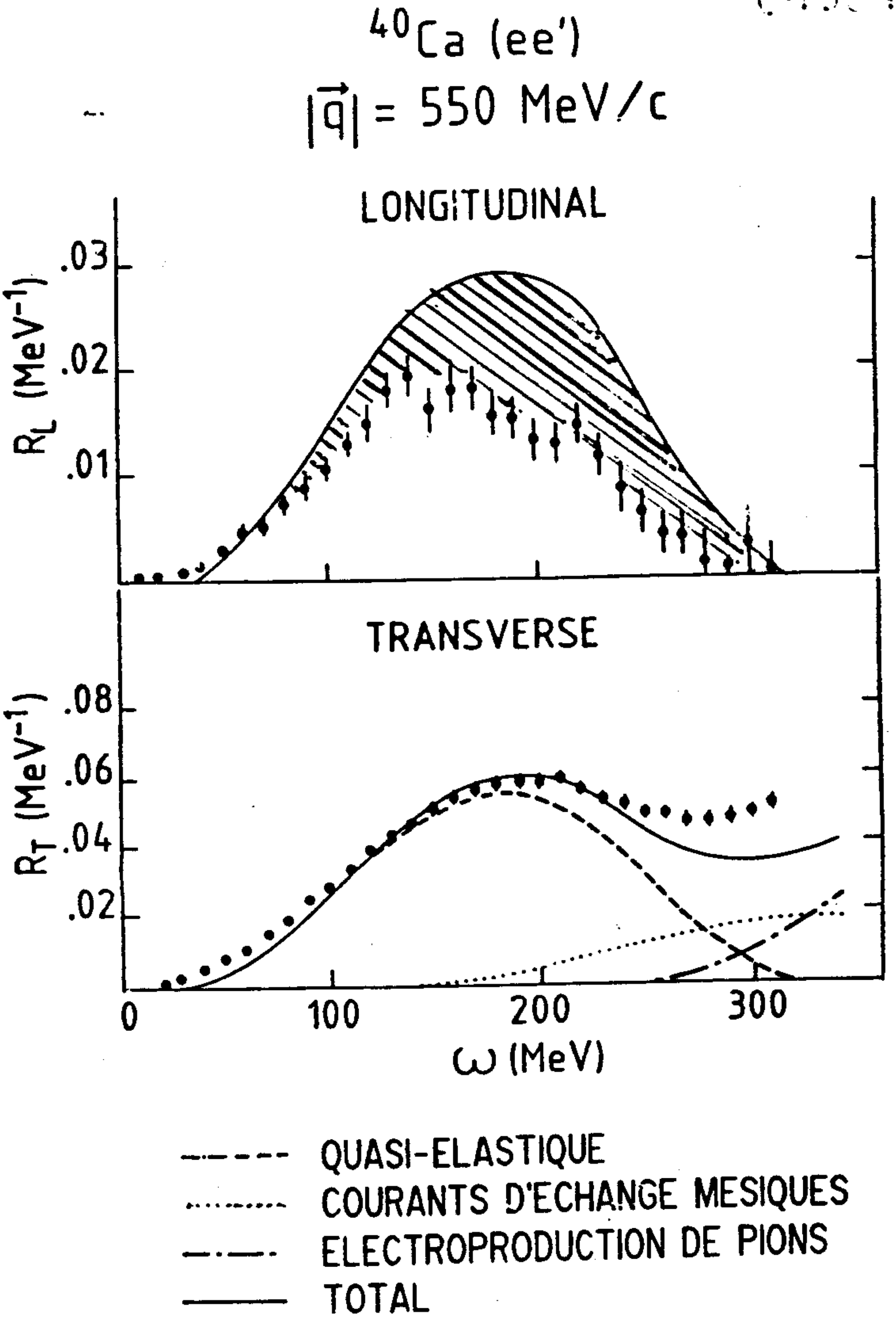
$^3He\ (ee')$

S.L.A.C.   D. DAY & al.

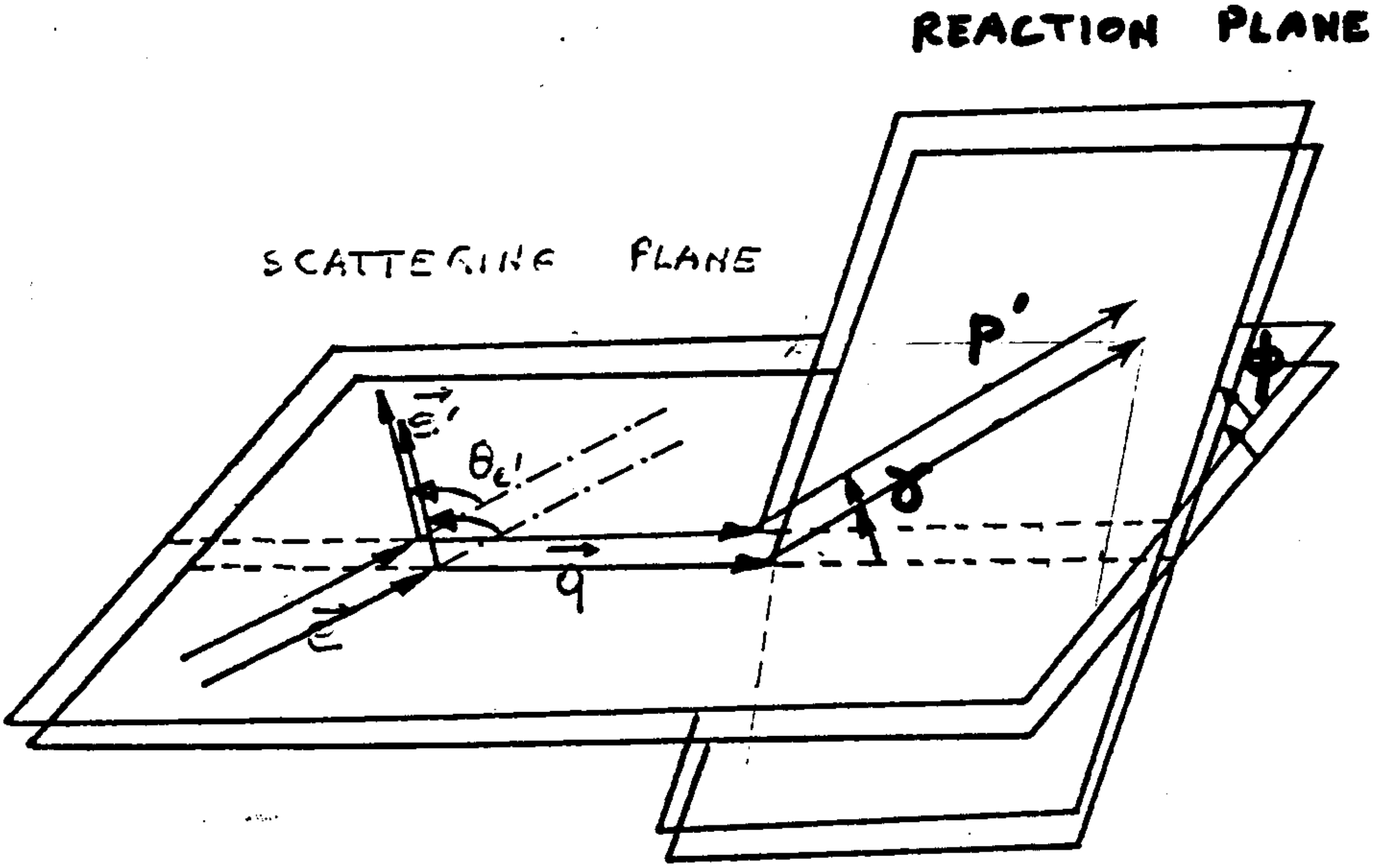
PHYS. REV. LETT 45, 871 (1980)



SACLAY
(1984)


^{40}Ca (ee')
$|\vec{q}|$ = 550 MeV/c
LONGITUDINAL
R_L (MeV^{-1})
.03
.02
.01
TRANSVERSE
R_T (MeV^{-1})
.08
.06
.04
.02
0
100
200
300
ω (MeV)
QUASI-ELASTIQUE
COURANTS D'ECHANGE MESIQUES
ELECTROPRODUCTION DE PIONS
TOTAL

ee'p EXPERIMENT



ee'p EXPERIMENT

DEFINITIONS

$\theta_{e'}$ → ELECTRON SCATTERING ANGLE

$\vec{q}$ → 3-MOMENTUM TRANSFER

ω → ENERGY TRANSFER

$\vec{p}$ → PROTON INITIAL MOMENTUM

$\vec{p}'$ → PROTON FINAL MOMENTUM

$\vec{p}_R = \vec{q} - \vec{p}'$ → RECOIL MOMENTUM

γ → ANGLE BETWEEN $\vec{p}'$ AND $\vec{q}$

ϕ → ANGLE BETWEEN THE ELECTRON SCATTERING PLANE AND THE REACTION PLANE

$$E_m = M^*_{A-1} + m - M_A = \omega - T_{p'} - T_R$$

IS THE MISSING ENERGY
OR REMOVAL, OR SEPARATION ENERGY

$\vec{q}, \omega, \vec{p}_R, E_m$

ARE COMPLETELY DETERMINED

BY THE EXPERIMENT

ee'p CROSS-SECTION
1st BORN APPROXIMATION

NO ELECTRON DISTORTION

$$\frac{d^6\sigma}{de'\, d\Omega_{e'}\, dT_{p'}\, d\Omega_{p'}} = \Gamma\, \sigma_\gamma$$

Γ : VIRTUAL PHOTON FLUX

$$\boxed{\sigma_\gamma = \sigma_T + \varepsilon\, \sigma_L + \varepsilon \cos 2\phi\, \sigma_{TT} + [\varepsilon(\varepsilon+1)] \cos\phi\, \sigma_{TL}}$$

TRANSVERSE LONGITUDINAL INTERFERENCE

$\varepsilon(\theta)$: ELECTRON POLARIZATION PARAMETER

$\varepsilon \to 1$ for $\theta \to 0°$ $\varepsilon \to 0$ for $\theta \to 180°$

σ_T, σ_L, σ_{TT}, σ_{TL} ARE FUNCTIONS OF ω, q, p', P_R,

IF THE PROTON IS EMITTED IN THE DIRECTION OF THE ELECTRON MOMENTUM TRANSFER

$$\sigma_{TT} = \sigma_{TL} = 0$$

$$\boxed{\sigma_\gamma = \sigma_T + \varepsilon(\theta)\sigma_L}$$

INCLUSIVE EXPERIMENT

WE DETECT ONLY THE SCATTERED ELECTRO

$$S_L = \int \sigma_L \, d\vec{p}' \, dE_m$$

$$S_T = \int \sigma_T \, d\vec{p}' \, dE_m$$

$$\int \cos\phi = \int \cos 2\phi = 0$$

NO MORE INTERFERENCE TERMS

$$\frac{d^3\sigma}{d\epsilon' \, d\Omega_{e'}} = \Gamma \left(S_T + \varepsilon(\epsilon) S_L \right)$$

INSTEAD OF S_L AND S_T
IT IS OFTEN USED :

$$R_L = \frac{q^3}{4\pi^2 \alpha q_\mu^2} S_L$$

$$R_T = \frac{q}{2\pi^2 \alpha} S_T$$

WE CAN DEFINE REDUCED RESPONSES

$$\tilde{R}_L = \frac{1}{Z} \frac{q_\nu^4}{q^4} R_L \qquad \tilde{R}_T = \frac{2M^2}{q^2} \frac{1}{Z\mu_p^2 + N\mu_N^2}$$

FOR INDEPENDENT PARTICLE MODE
LIKE FERMI GAS MODEL AND
NUCLEONIC DEGREES OF FREEDOM

$$\tilde{R}_L \equiv \tilde{R}_T$$

LONGITUDINAL SUM RULE

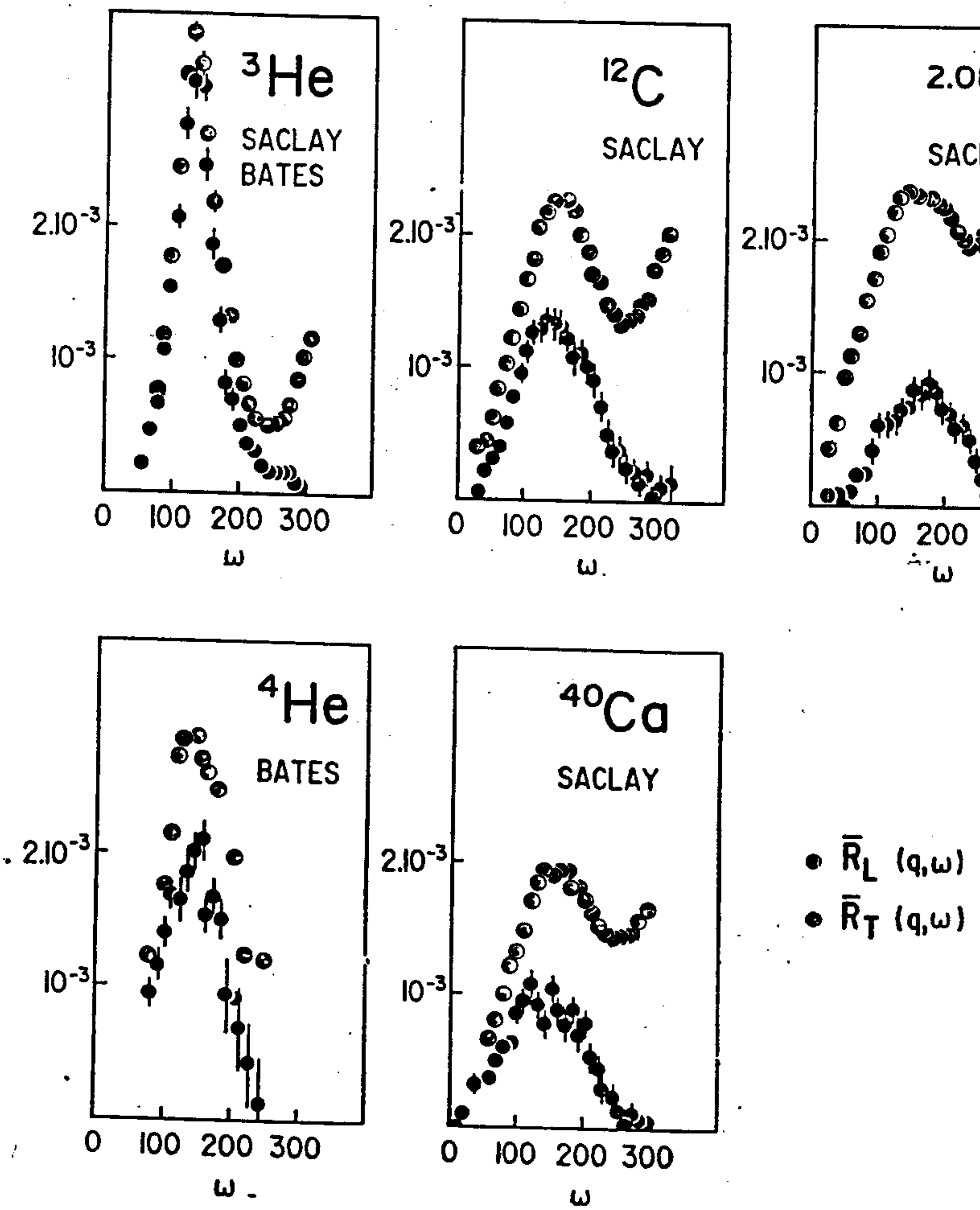
$$S_L(q) = \frac{1}{Z}\int \frac{R_L(q,\omega)}{G_E^2}\, d\omega$$

$$S_L(q) = 1 - \underset{\nearrow}{C}(q)$$

TWO BODY CORRELATIONS

REDUCED RESPONSE FUNCTIONS

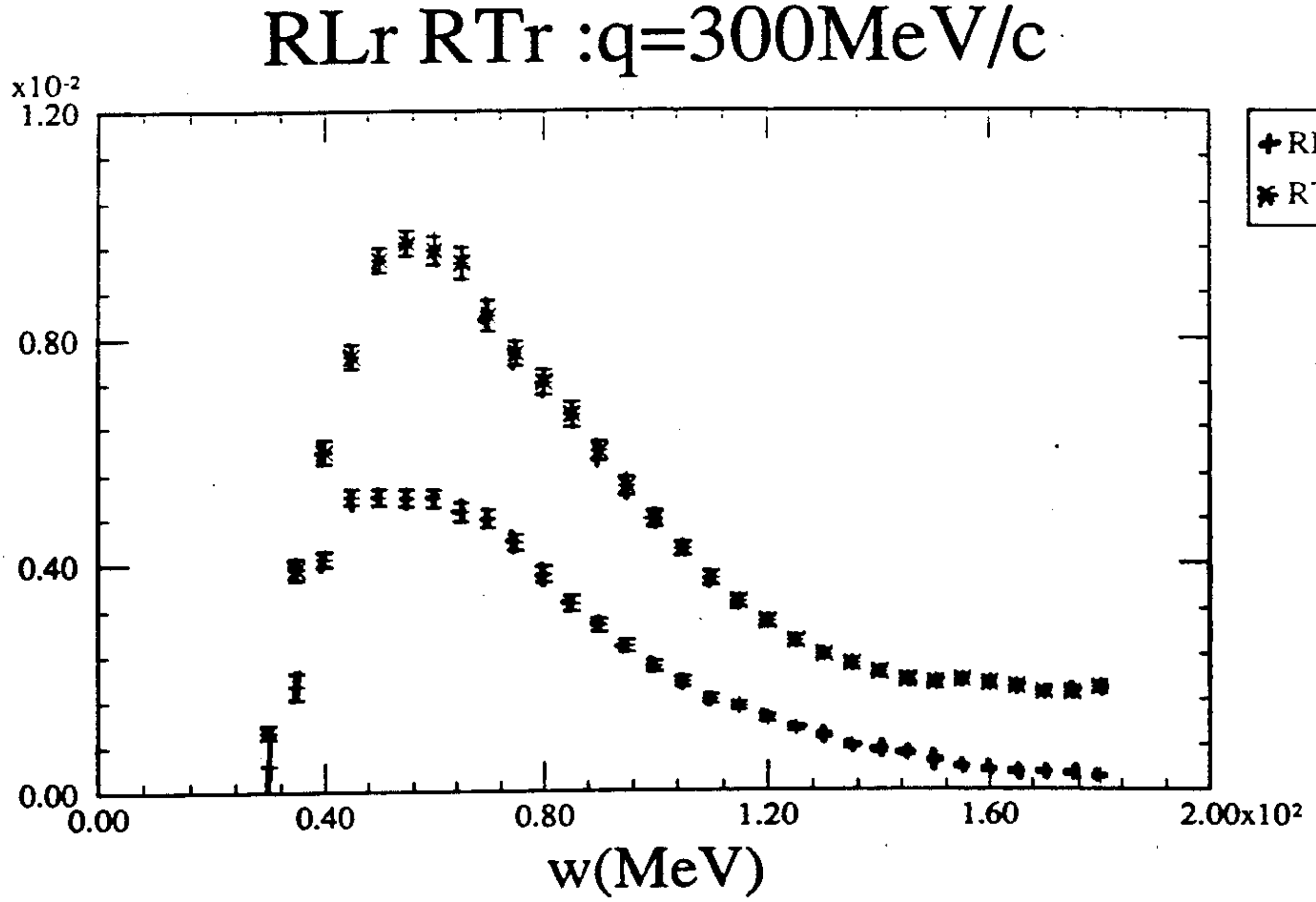
q=500MeV/c



^{4}He (ee')

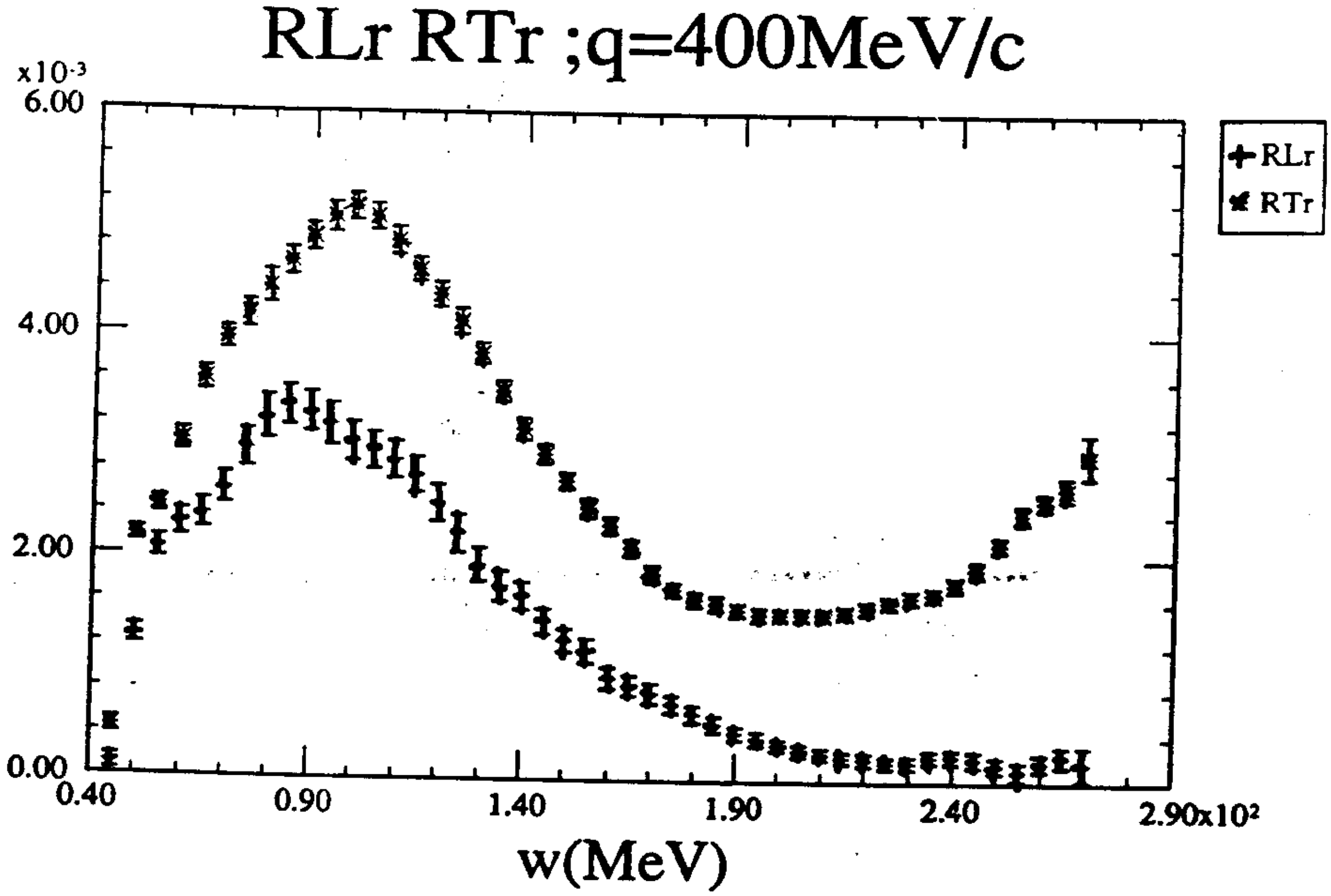
SACLAY

J.F. DANEL et



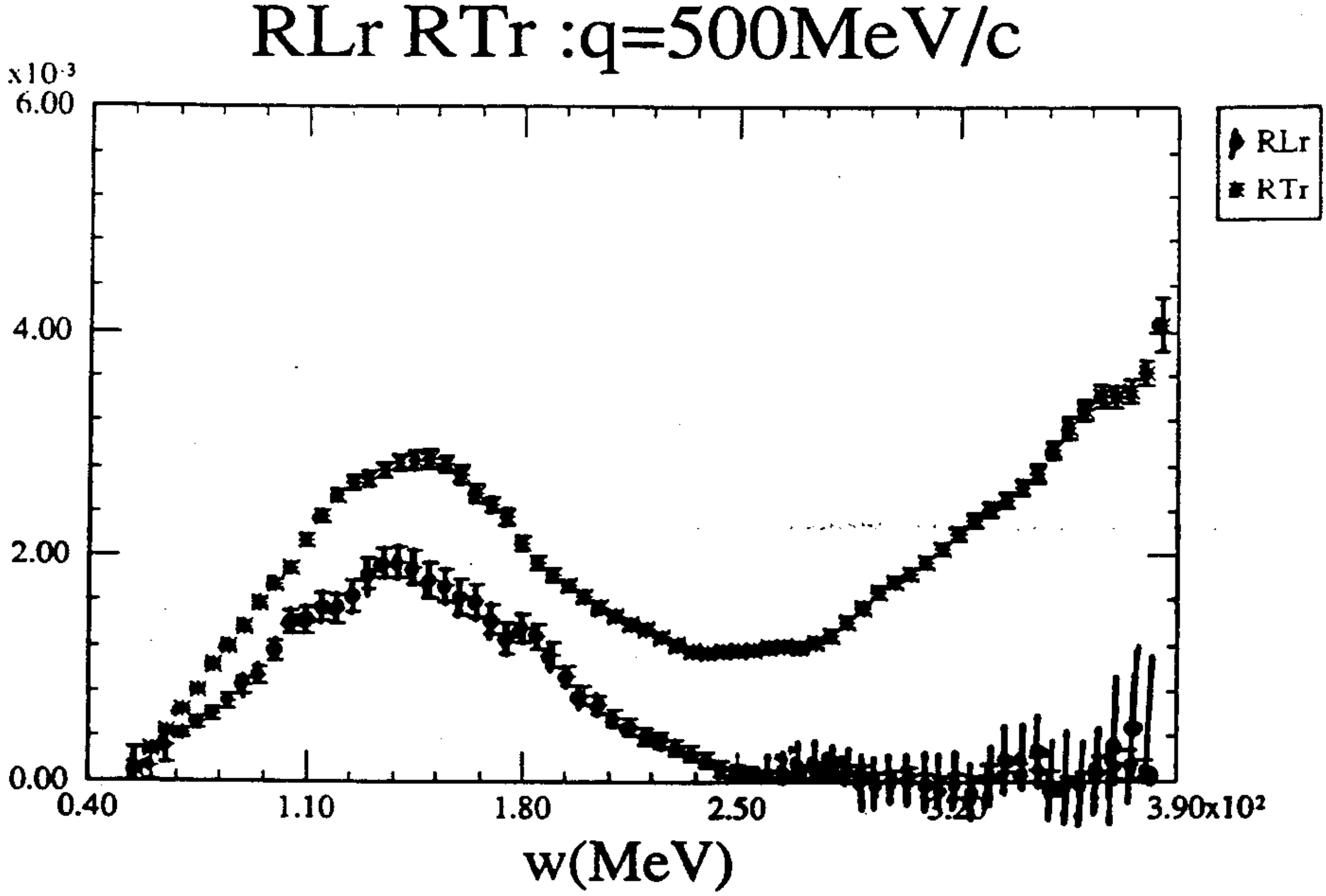
^{4}He (ee')

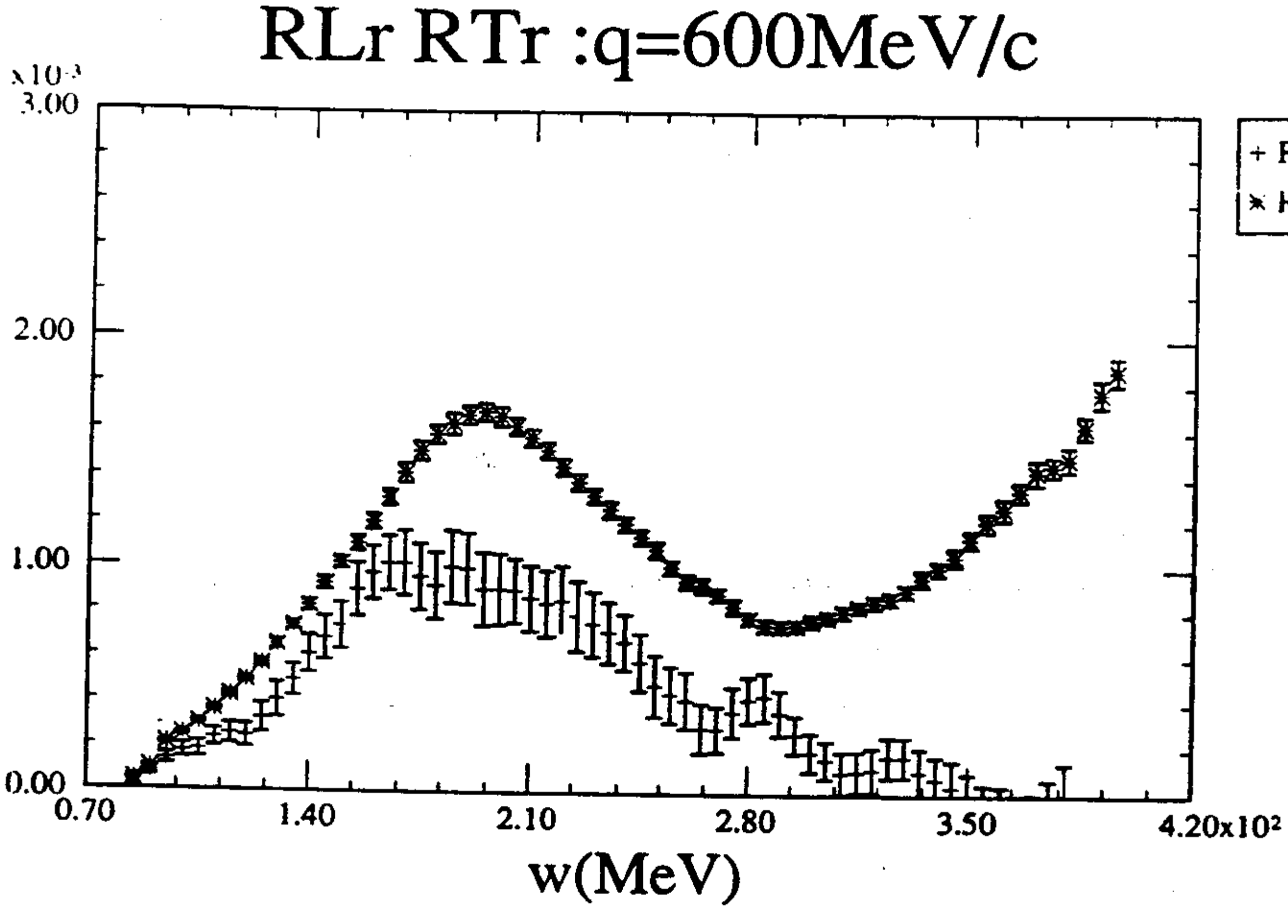
SACLAY
J.F. DANEL et al.

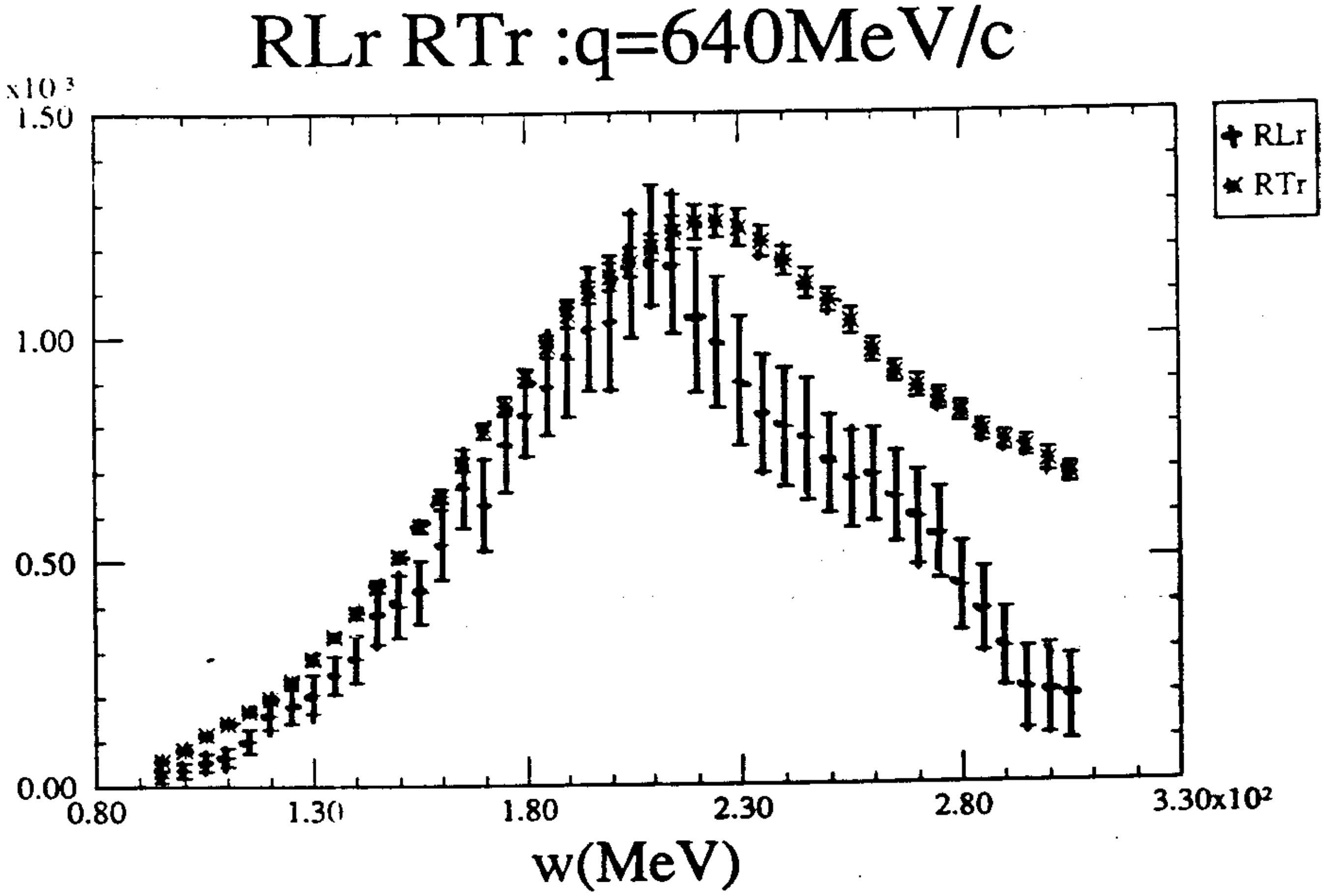


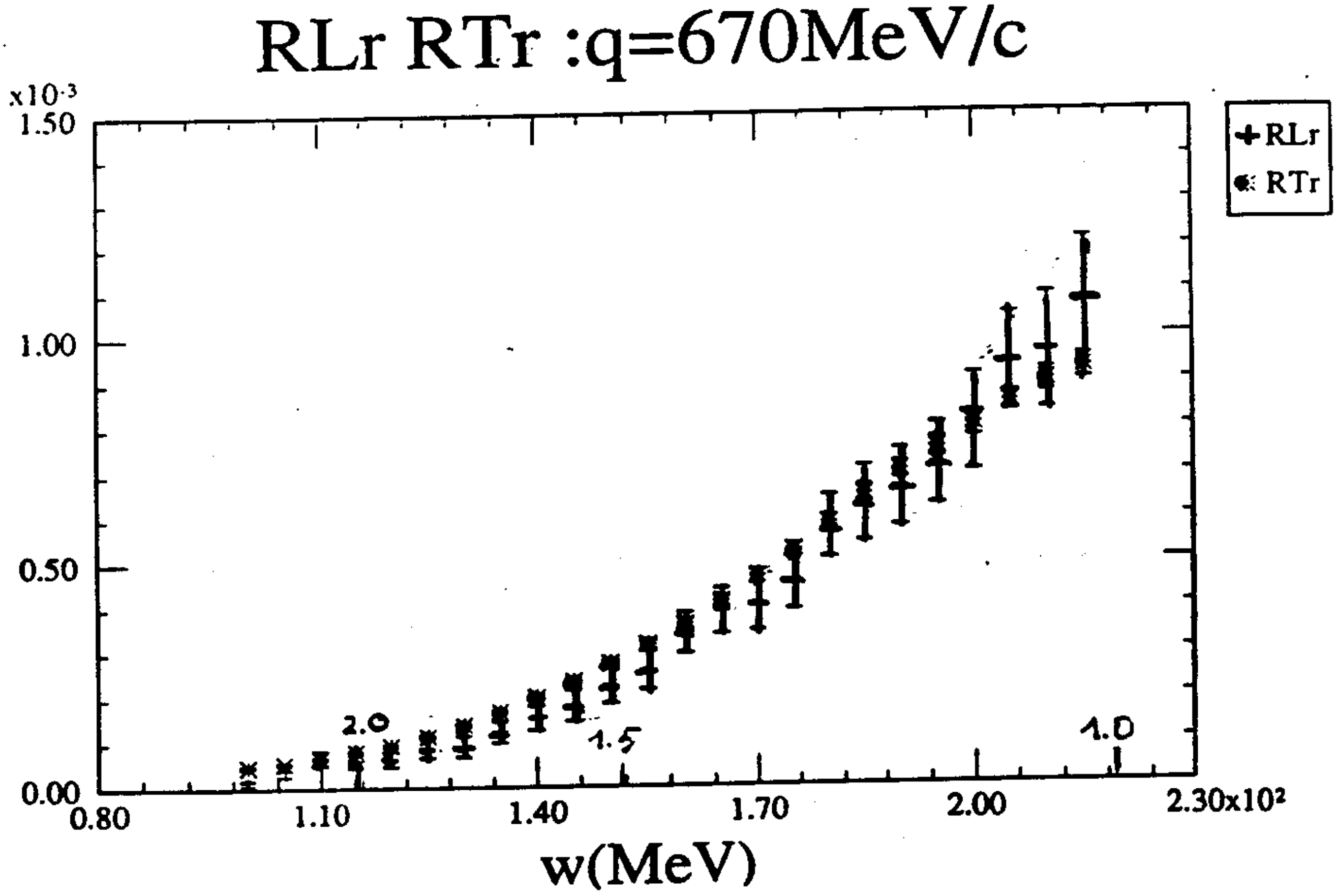
^{4}He (ee')

SACLAY
J.-F. DANEL et al.

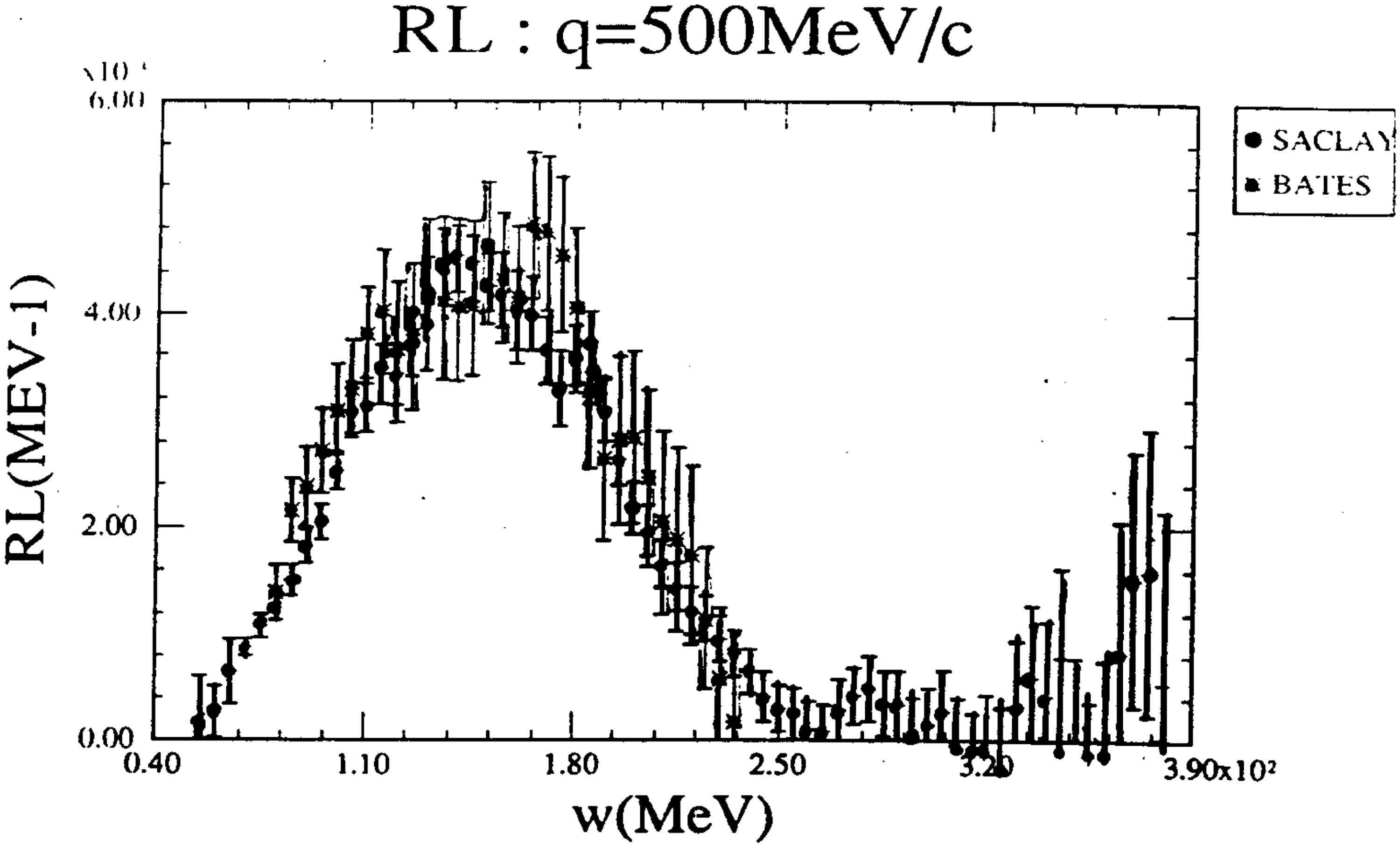



RLr RTr :q=600MeV/c
x10⁻³
3.00
2.00
1.00
0.00
0.70
1.40
2.10
2.80
3.50
4.20x10²
w(MeV)
+ RLr
⁎ RTr


RLr RTr :q=640MeV/c
x10³
1.50
1.00
0.50
0.00
0.80
1.30
1.80
2.30
2.80
3.30x10²
w(MeV)
RLr
RTr


RLr RTr :q=670MeV/c
x10⁻³
1.50
1.00
0.50
0.00
0.80
1.10
1.40
1.70
2.00
2.30x10²
w(MeV)
RLr
RTr
2.0
1.5
1.0

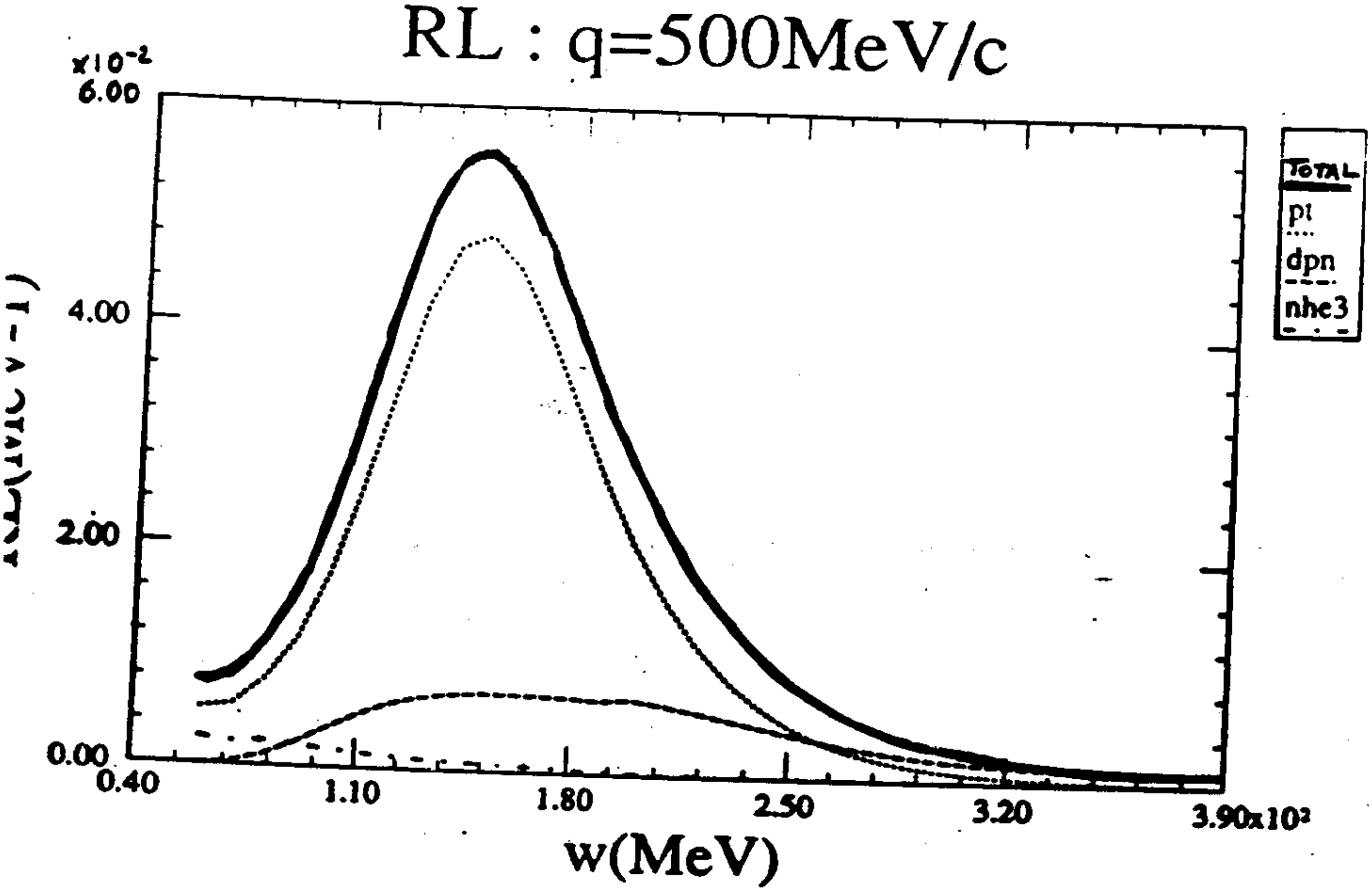
$^4He(ee')$



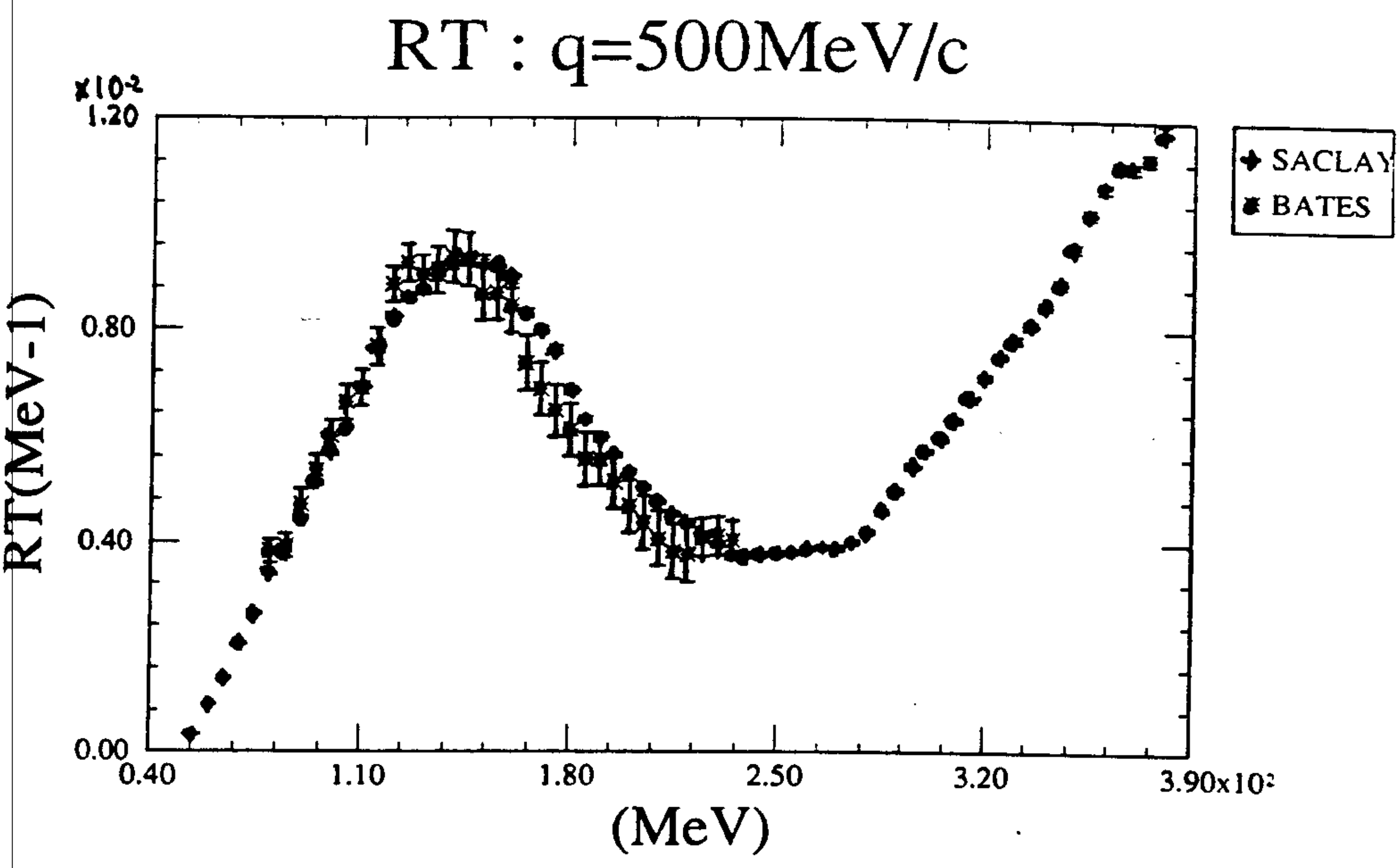
RL : q=500MeV/c
x10⁻³
6.00
4.00
2.00
0.00
RL(MEV-1)
0.40
1.10
1.80
2.50
3.20
3.90x10²
w(MeV)
● SACLAY
* BATES

^{4}He (ee')

J.M. LAGET CALCULATIONS

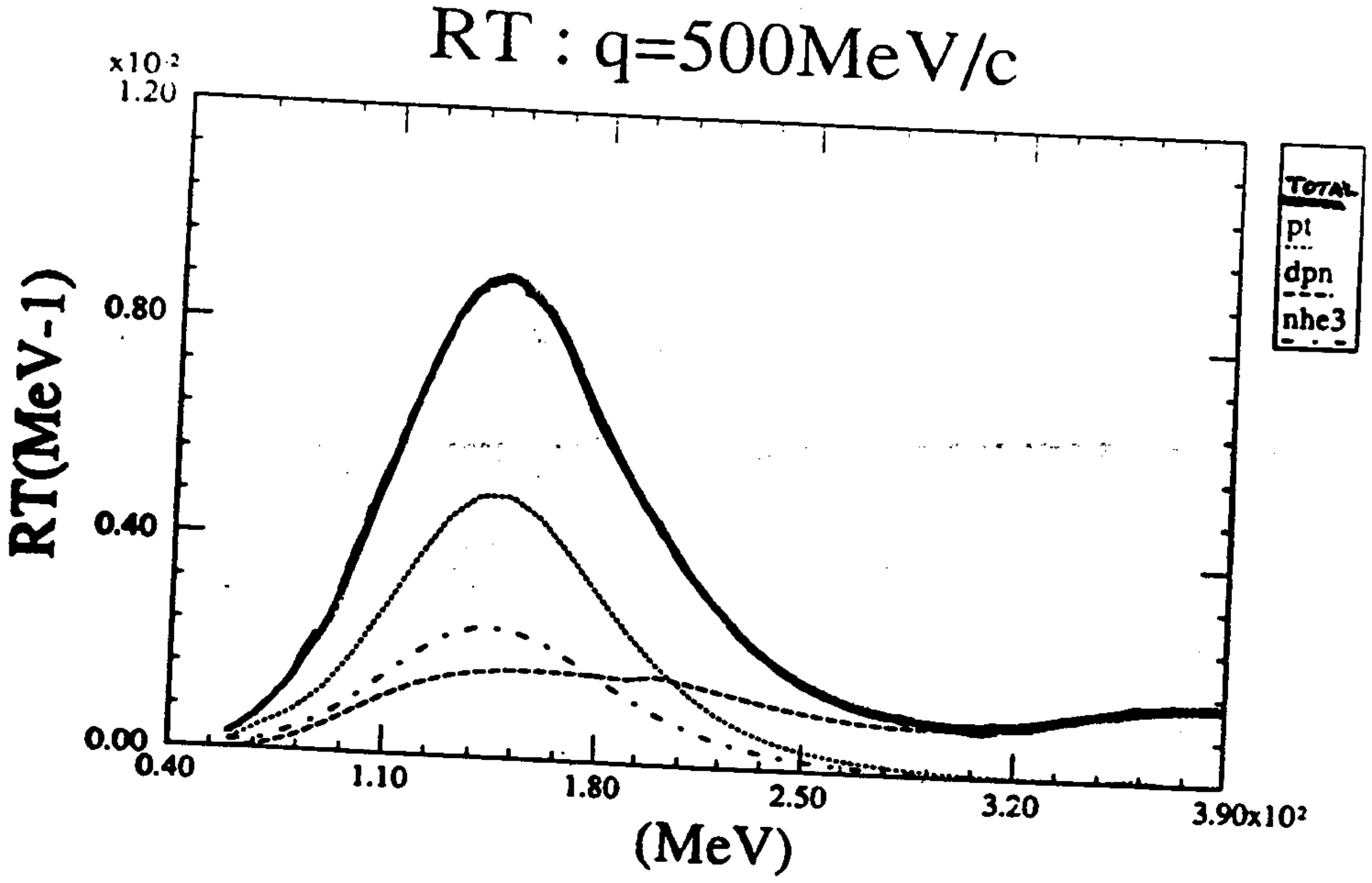


^{4}He (ee')


RT : q=500MeV/c
x10-2
1.20
0.80
0.40
0.00
RT(MeV-1)
0.40
1.10
1.80
2.50
3.20
3.90x10²
(MeV)
✦ SACLAY
✱ BATES

^{4}He (ee')

J.M. LAGET CALCULATIONS



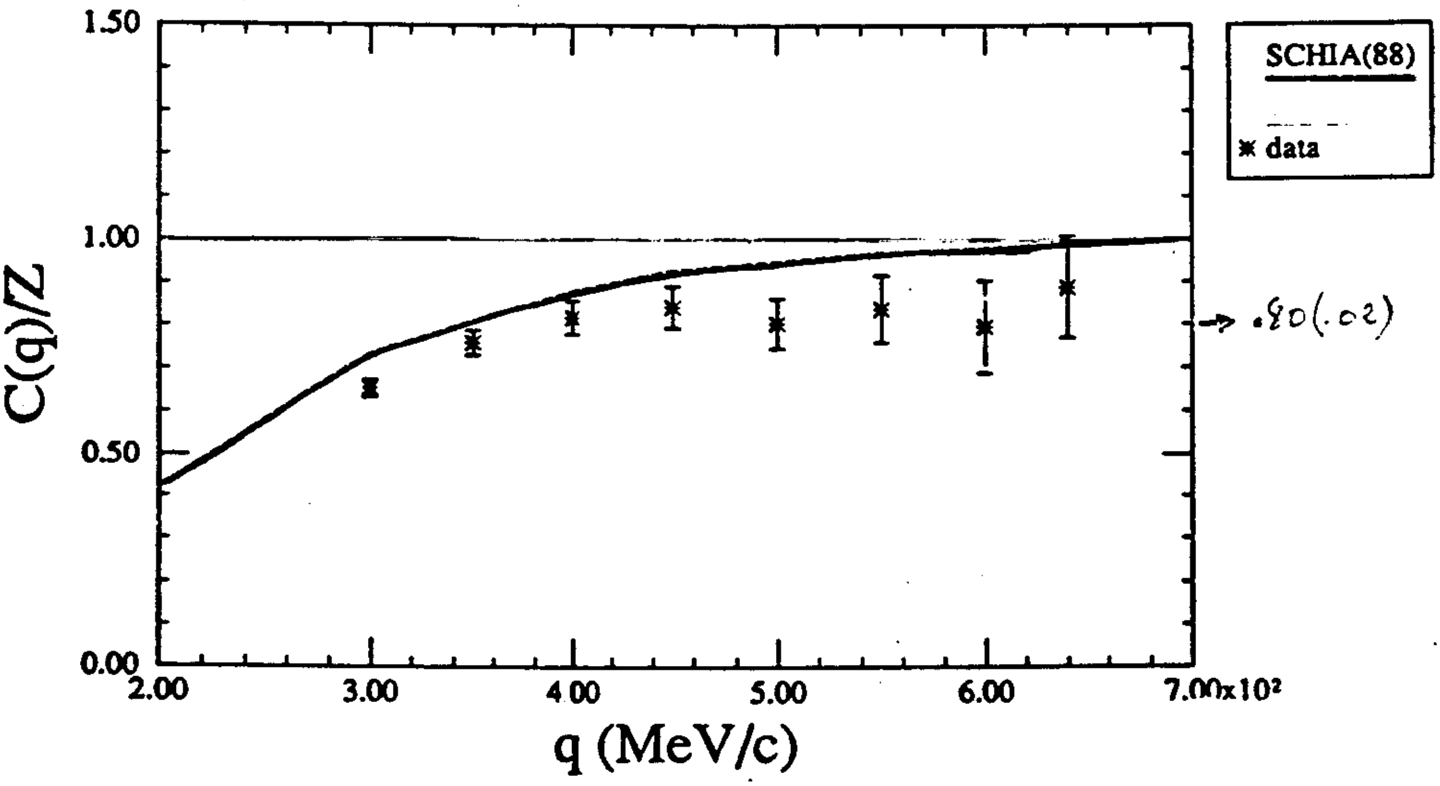
REGLE DE SOMME

COULOMBIENNE

$$C(|\vec{q}|) = \int_{\omega > \omega_{elas}} d\omega \; \frac{R_L(|\vec{q}|, \omega)}{\tilde{G}_E^2}$$

$\tilde{G}_E^2 = G_E^2$ [illegible] q^2 [illegible] / $(1 + q^2$ [illegible]$)$

G_E : facteur de forme électrique du nucléon libre
(Simon et al)



→ .80(.02)

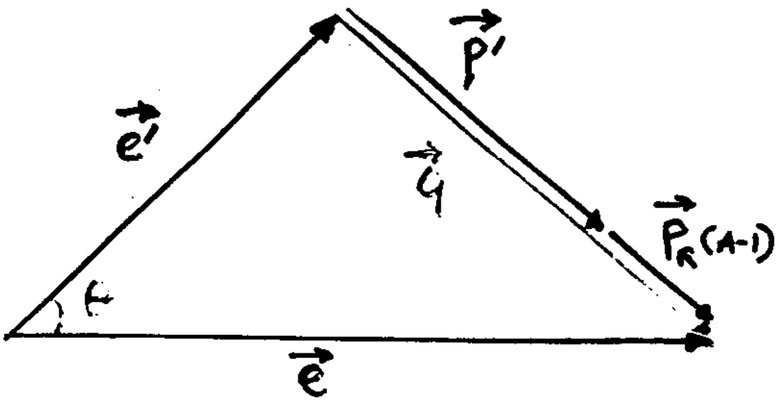
IN INCLUSIVE EXPERIMENTS,
WE AVERAGE OVER THE
MOMENTUM AND THE SEPARATION ENERGY
OF THE NUCLEON.

ON THE OTHER HAND, EVEN IF
THE SINGLE NUCLEON KNOCK-OUT
MINATES, WE ARE MIXING OTHER CHANNELS.

TO BE MORE SPECIFIC
WE HAVE DONE EE'P EXPERIMENTS
WITH SEPARATION OF THE
DIFFERENT STRUCTURE FUNCTIONS
TO SELECT THE ONE
SINGLE PROTON KNOCK-OUT.

IN SUCH EXPERIMENT, WE
MAKE THIS SEPARATION FOR
A GIVEN REMOVAL ENERGY
AND A GIVEN MOMENTUM
OF THE PROTON.

IN THIS EXPERIMENT, WE DETECT THE PROTON IN THE DIRECTION OF THE ELECTRON MOMENTUM TRANSFER



THE CROSS-SECTION IS GIVEN BY :
(1st BORN APPROXIMATION).

$$\frac{d^6\sigma}{d\epsilon' \, d\Omega_{e'} \, dT_{p'} \, d\Omega_{p'}} = \Gamma \left[\sigma_T(q,\omega;p',p_R) + \epsilon(\theta) \, \sigma_L(q,\omega;p',p_R) \right]$$

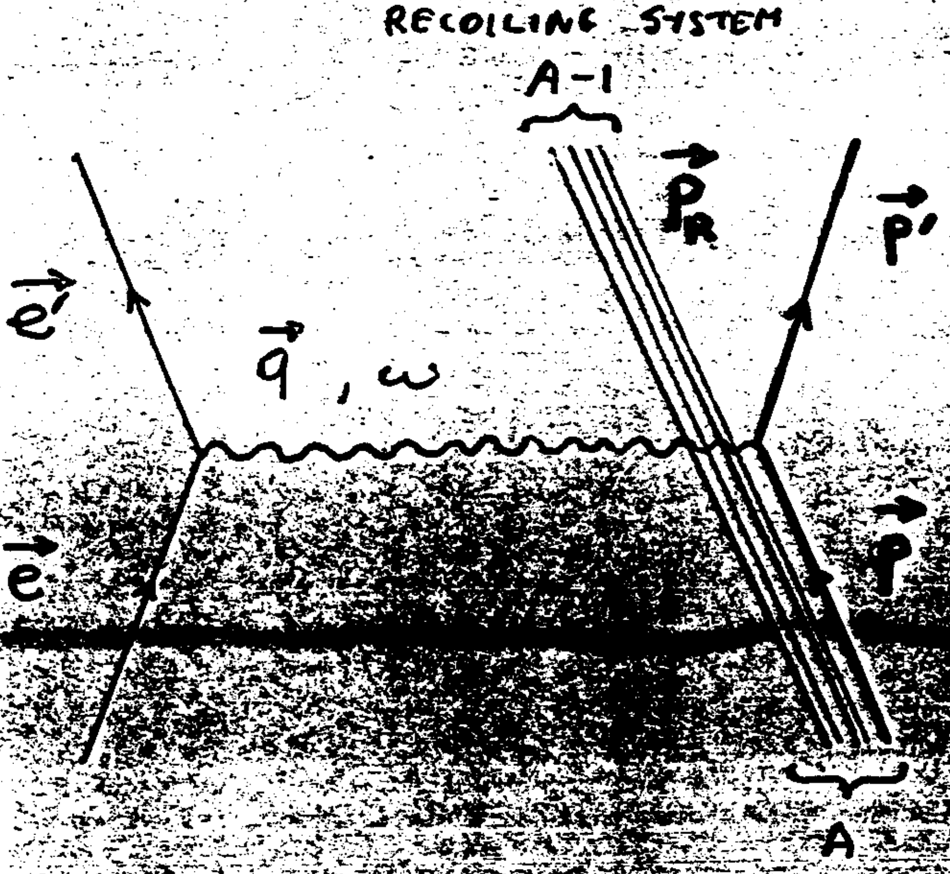
TRANSVERSE RESPONSE

LONGITUDINAL (COULOMB RESPONSE

Γ : VIRTUAL PHOTON FLUX

$\epsilon(\theta)$: ELECTRON POLARIZATION PARAMETER

PLANE WAVE IMPULSE APPROXIMATION P.W.I.A.



THE VIRTUAL PHOTON IS ABSORBED BY A SINGLE NUCLEON IN A NUCLEUS WITH MASS A. THE REMAINING SYSTEM WITH MASS A-1 IS SPECTATOR AND RECOILS WITH A MOMENTUM

$$\vec{P}_R = -\vec{p}$$

P. W. I. A.

WE CAN EXPRESS THE ELECTRON – NUCLEON CROSS SECTION BY AN EXPRESSION SIMILAR TO THE ELECTRON – NUCLEUS CROSS SECTION

$$\sigma^{ep} = \Gamma \left[\sigma_T^{ep} + \varepsilon \, \sigma_L^{ep} \right]$$

IN P.W.I.A. THE ELECTRON – NUCLEU CROSS – SECTION FACTORIZES:

$$\frac{d^6\sigma}{d\epsilon' \, d\Omega_{e'} \, dT_{p'} \, d\Omega_{p'}} = \sigma^{ep} \times S(E_m, \vec{p})$$

WHERE $S(E_m, \vec{p})$ IS THE SPECTRAL FUNCTI WHICH GIVES THE PROBABILITY TO FIN A PROTON WITH A MOMENTUM $\vec{p}$ AND A SEPARATION ENERGY E_m IN THE INITIAL NUCLEUS

P. W. I A. IMPLIES :

$$\frac{\sigma_L}{\sigma_L^{ep}} = S_L^{Exp} = \frac{\sigma_T}{\sigma_T^{ep}} = S_T^{Exp} = S(E_m, p)$$

CORRECTIONS TO P.W.I.A.

FOR LIGHT NUCLEI : D, T, ^{3}He, ^{4}He

F.S.I. AND E.C. CAN BE

CALCULATED MICROSCOPICALLY

SEE : LAGET, ARENHÖVEL, CIOFI, SCHIAVILLA,
TJON ...

FOR MEDIUM AND HAVY NUCLEI,

F.S.I. ARE TAKEN INTO ACCOUNT

BY OPTICAL MODEL

SEE : BOFFI, GIUSTI, PACATI

ONE CAN DEFINE AN EXPERIMENTAL

SPECTRAL FUNCTION :

$$S^{exp} = \frac{\sigma^{exp}}{\sigma^{ep}}$$

FROM THEORETICAL CALCULATIONS

WITHOUT AND WITH F.S.I. AND E.C., WE GET

σ^{PWIA} AND σ^{th}

WE OBTAIN THE CORRECTED

SPECTRAL FUNCTION :

$$S^{CORR} = S^{EXP} \times \frac{\sigma^{PWIA}}{\sigma^{FULL}}$$

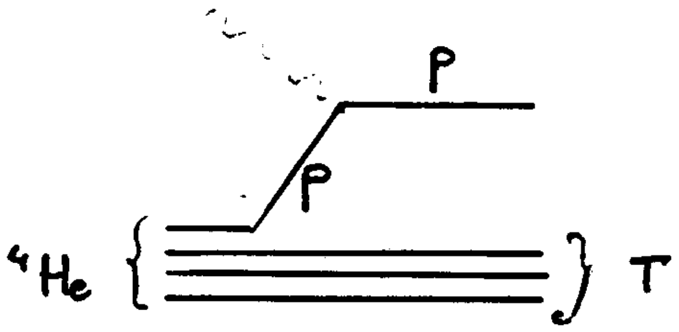
FOR EXPERIMENTS WHERE THE RESPONSE FUNCTIONS ARE SEPARATED, WE DEFINE $S_\alpha^{\widetilde{exp}}$, S_α^{CORR} WHERE $\alpha = L, T, LT, TT$ AND WE HAVE

$$S_\alpha^{CORR} = S_\alpha^{EXP} \times \frac{\sigma_\alpha^{PWIA}}{\sigma_\alpha^{FULL}}$$

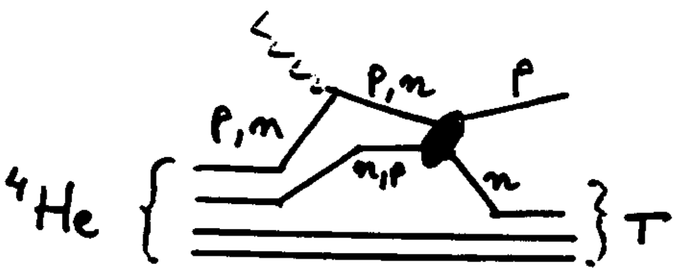
$^4He\ (ee'p)\ ^3H$

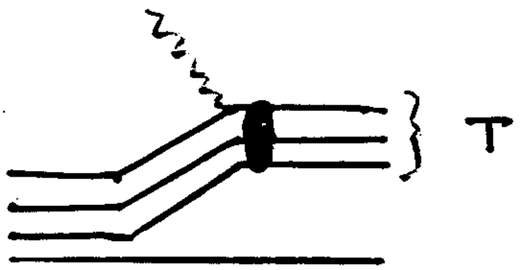
LAGET CALCULATIONS

IMPULSE APPROXIMATION

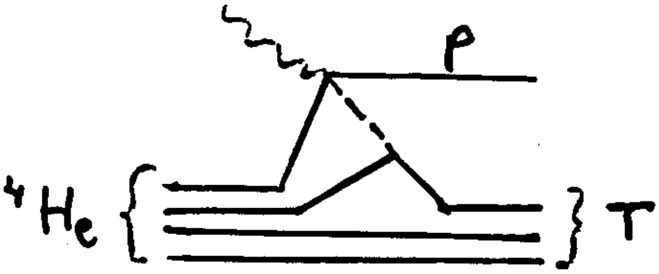


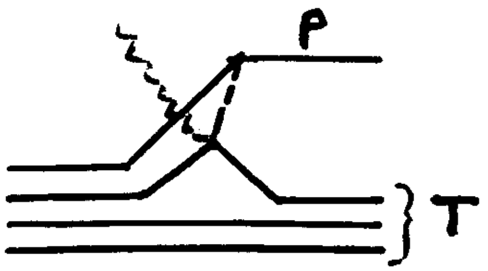
RESCATTERING





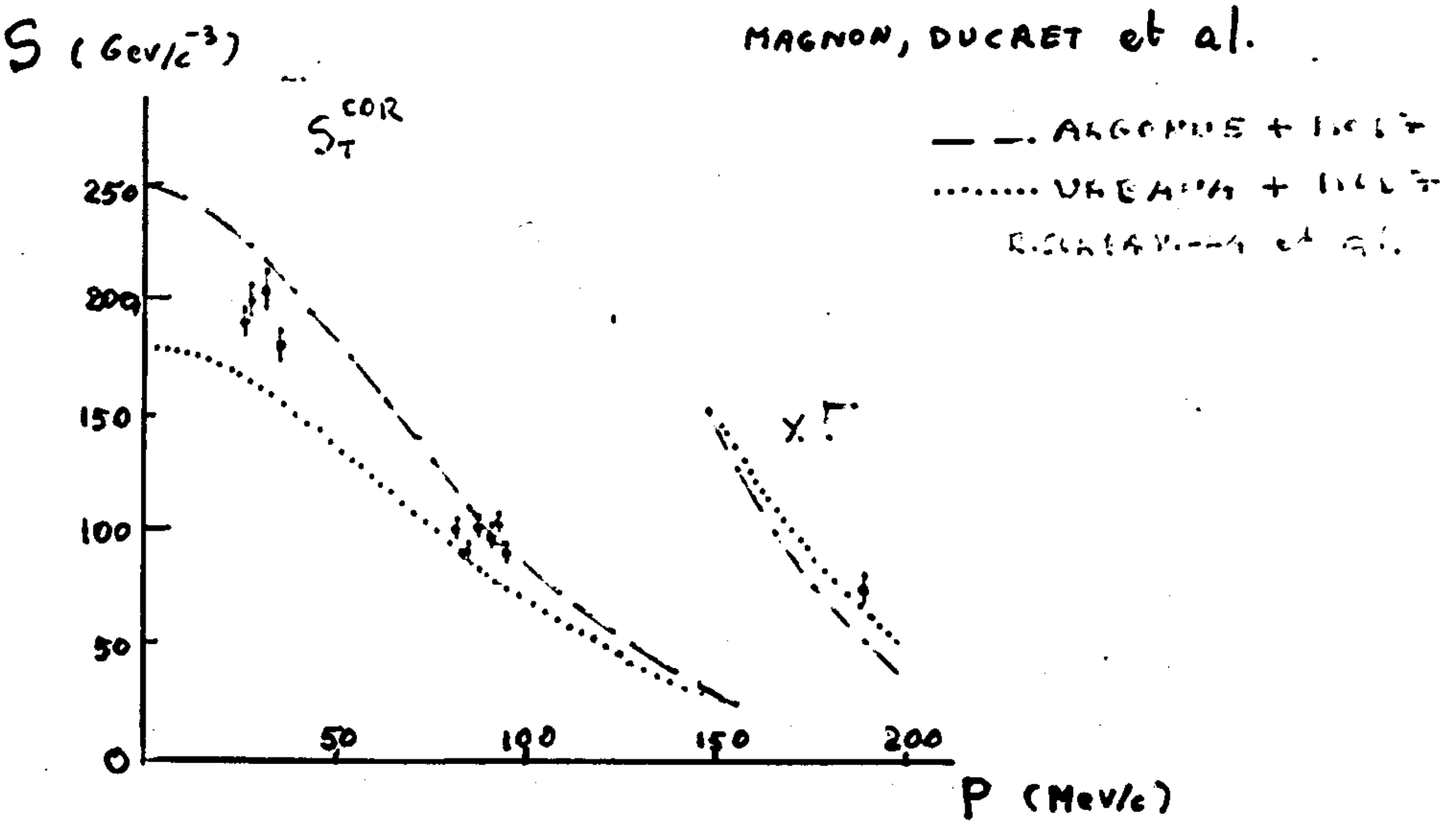
MESON EXCHANGE

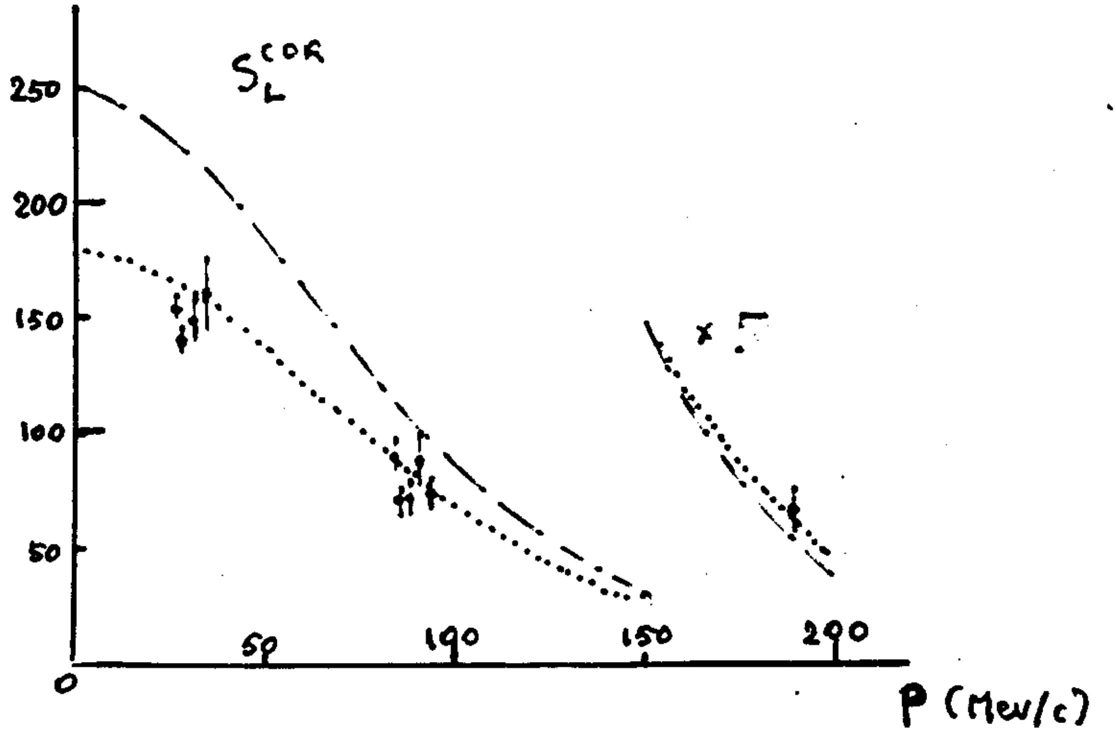


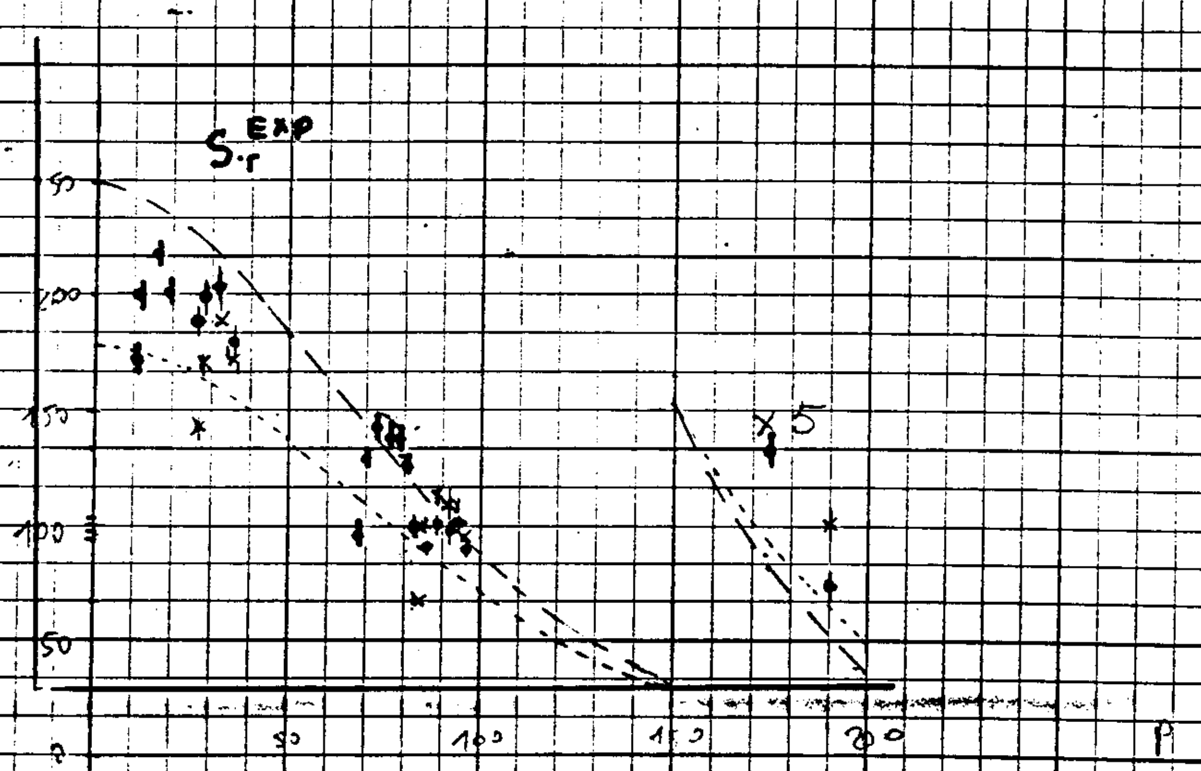


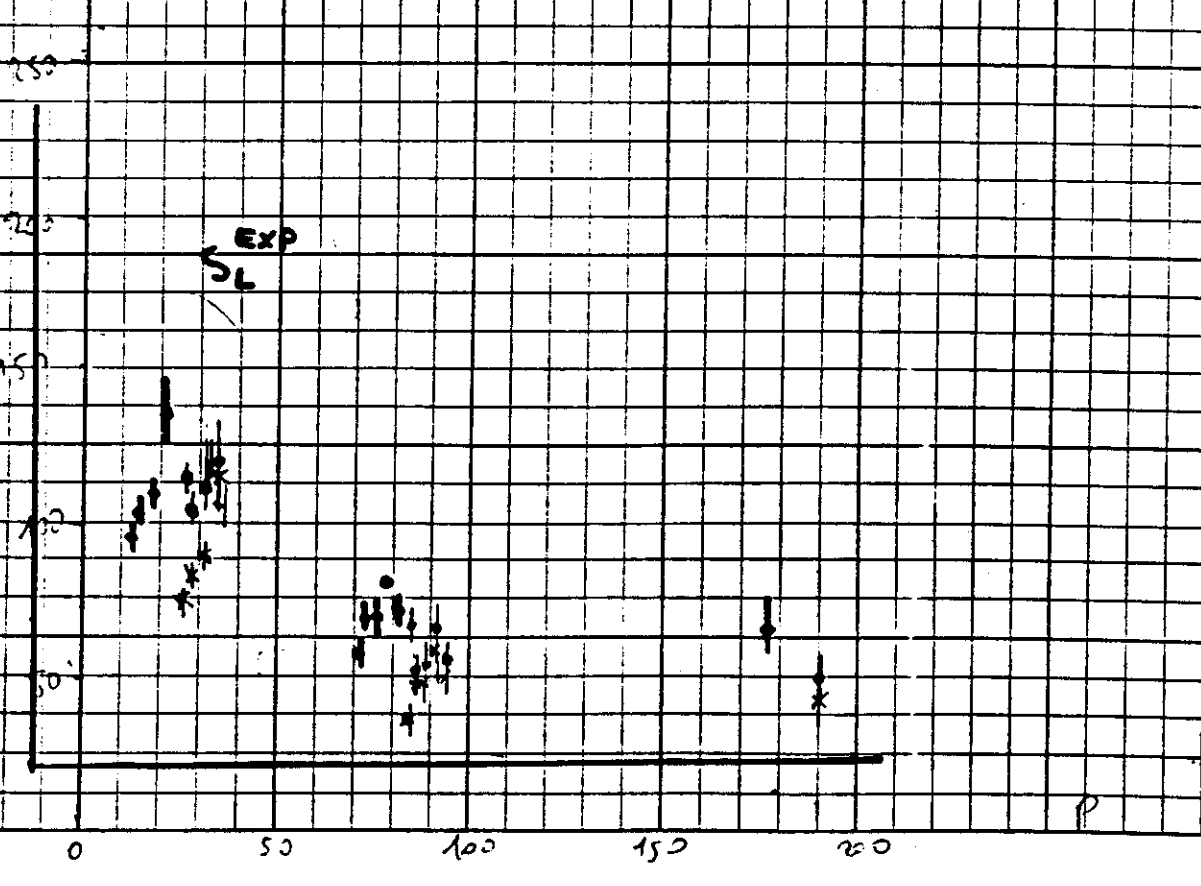
$^4He(ee'p)^3H$

SACLAY 1990
MAGNON, DUCRET et al.






S_T^{EXP}
250
200
150
100
50
×5
0
50
100
150
200
P

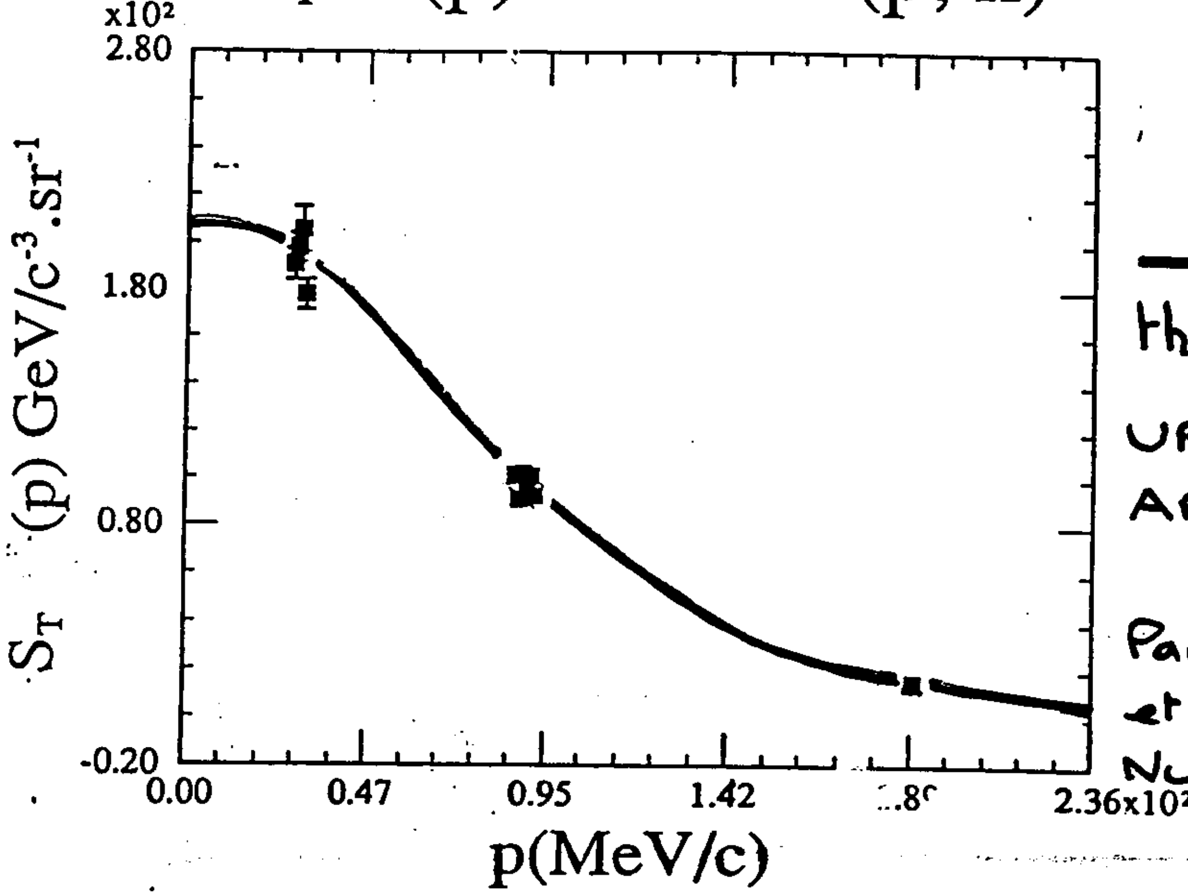

S_L^{EXP}
250
200
150
100
50
0
50
100
150
200
P

^{4}He RADIUS

URBANA + MOD 7	1.62 fm
ARGONNE + MOD 7	1.71 fm
EXPERIMENTAL VALUE	1.67 fm

A. Magnon et al PHYS LETT B222 (1989)
J.E Ducret

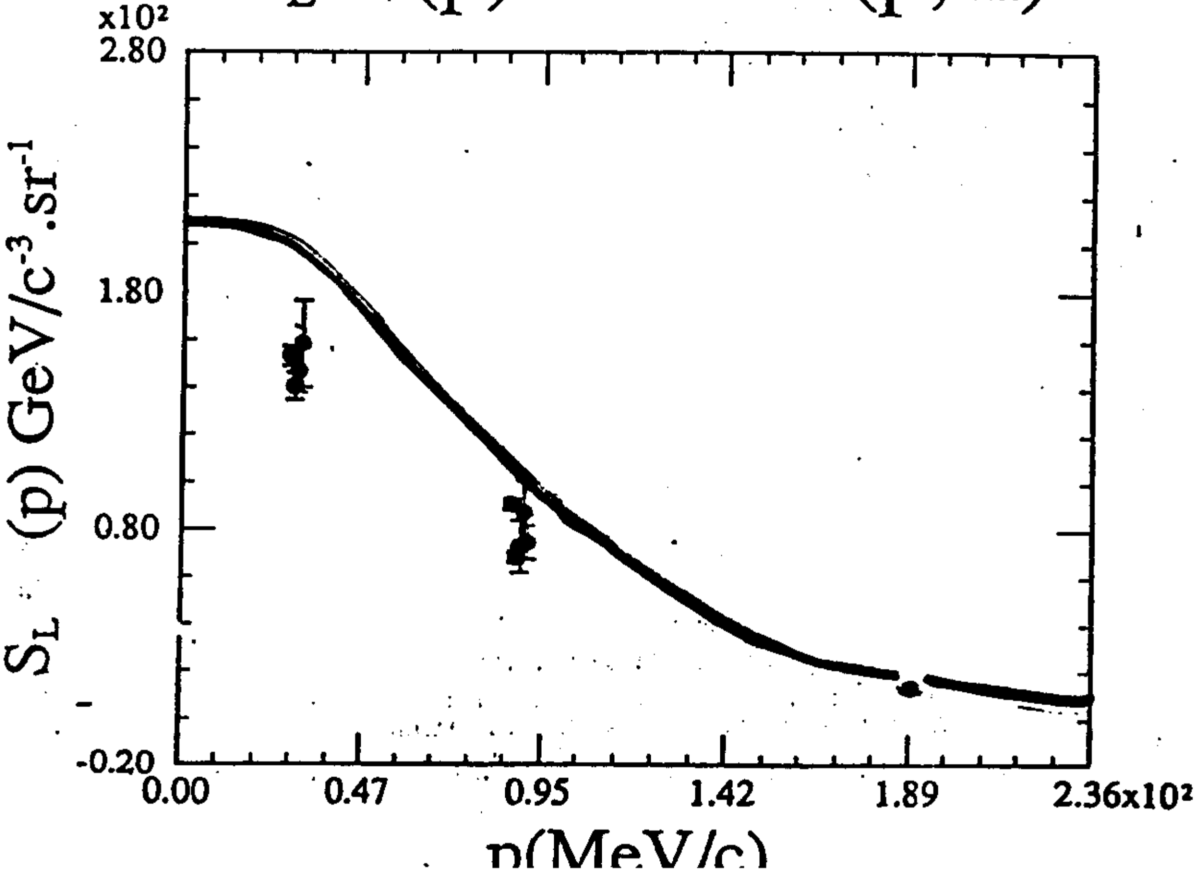
S_T (p) -> ^{4}he->(p,^{3}h)

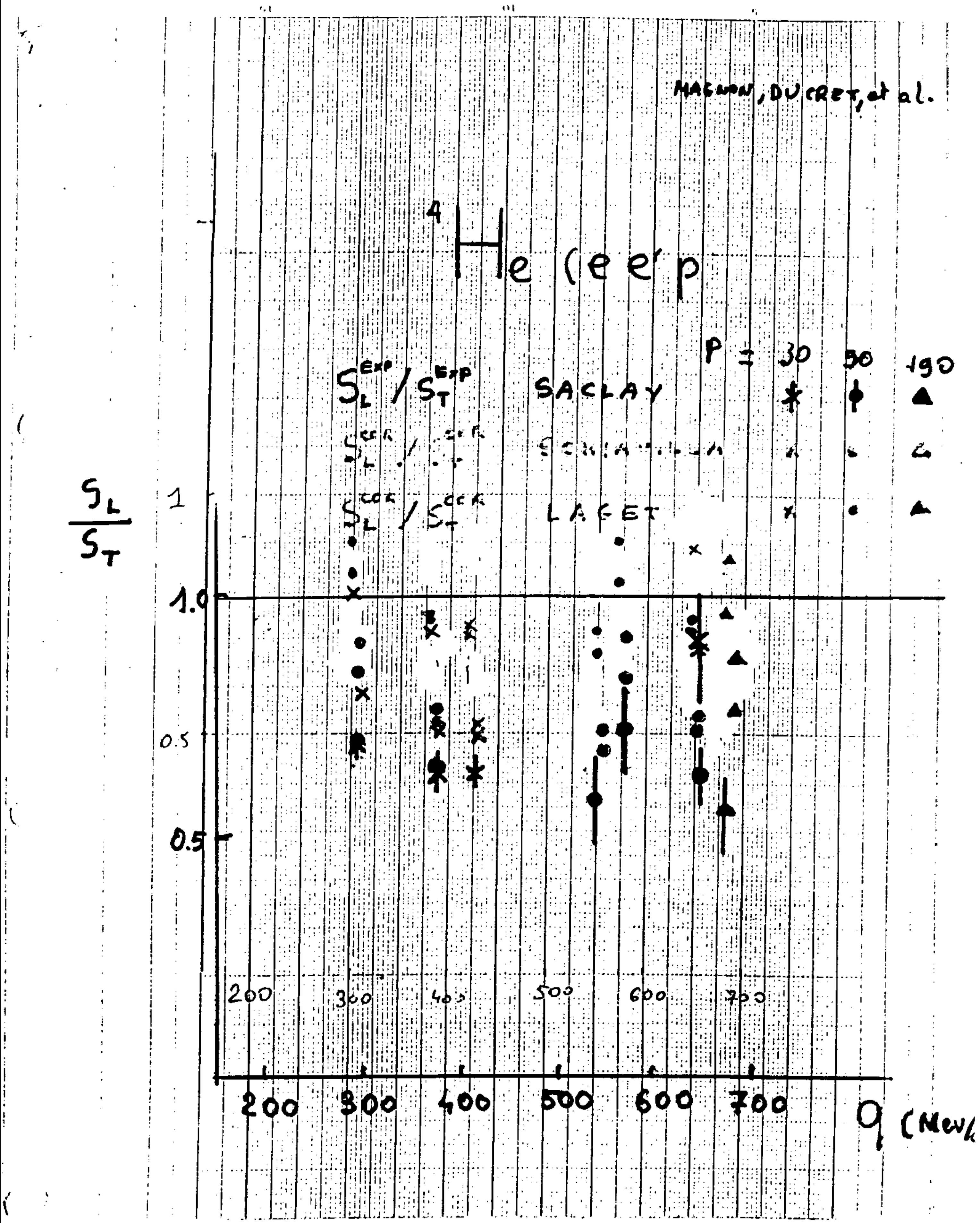


théorie
URBANA/
ARGONNE

Pandharipande
et al.
Nucl φ A449
(1986)

S_L (p) -> ^{4}he->(p,^{3}h)



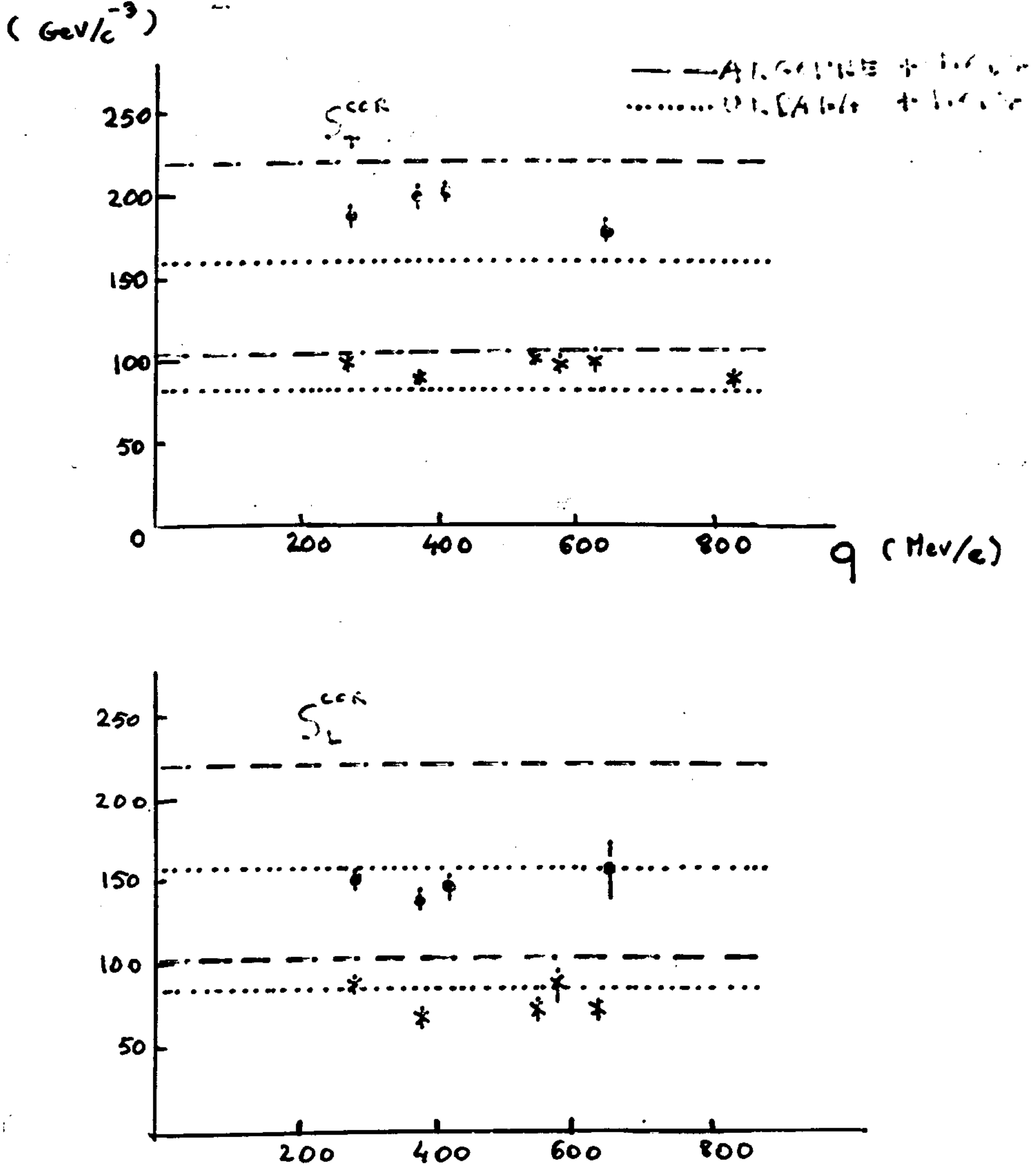

MAGNON, DUCRET, et al.
⁴He (e e'p
P = 30 50 190
S_L^EXP / S_T^EXP SACLAY
S_L^COR / S_T^COR SCHIAVILLA
S_L^COR / S_T^COR LAGET
S_L / S_T
1
1.0
0.5
0.5
200 300 400 500 600
200 300 400 500 600 700
q (MeV

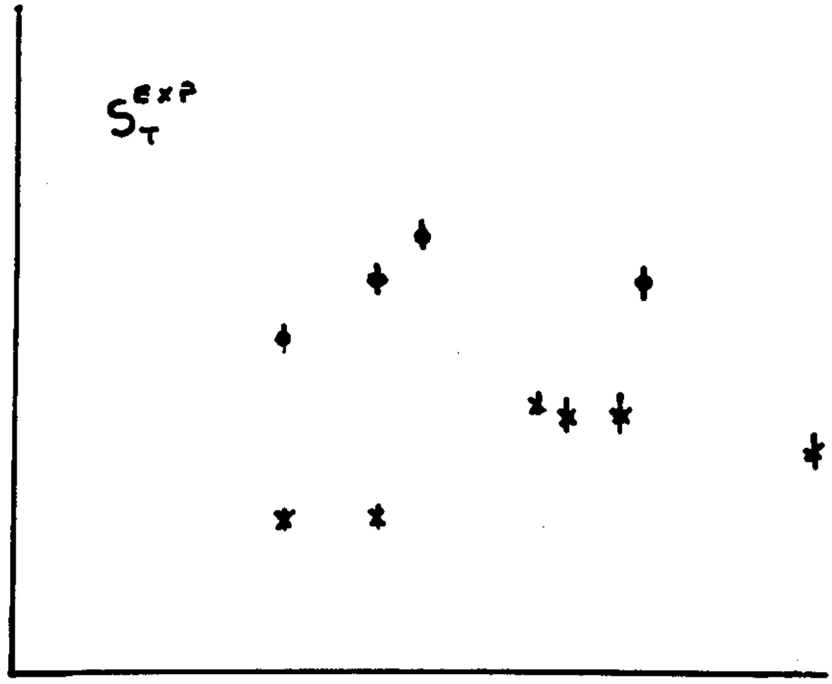
SACLAY 1990
MAGNON, DUCRET et al.

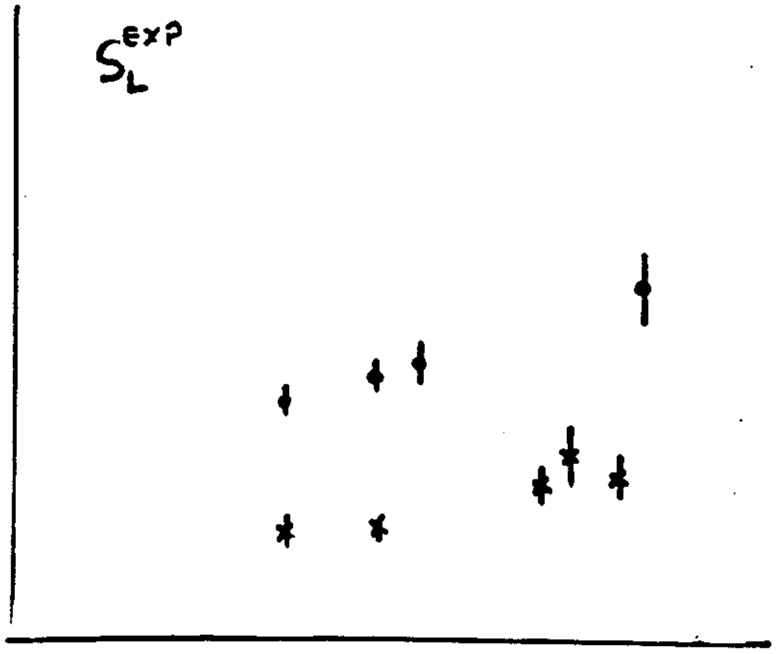
^{4}He (ee'p) ^{3}H

q DEPENDENCE

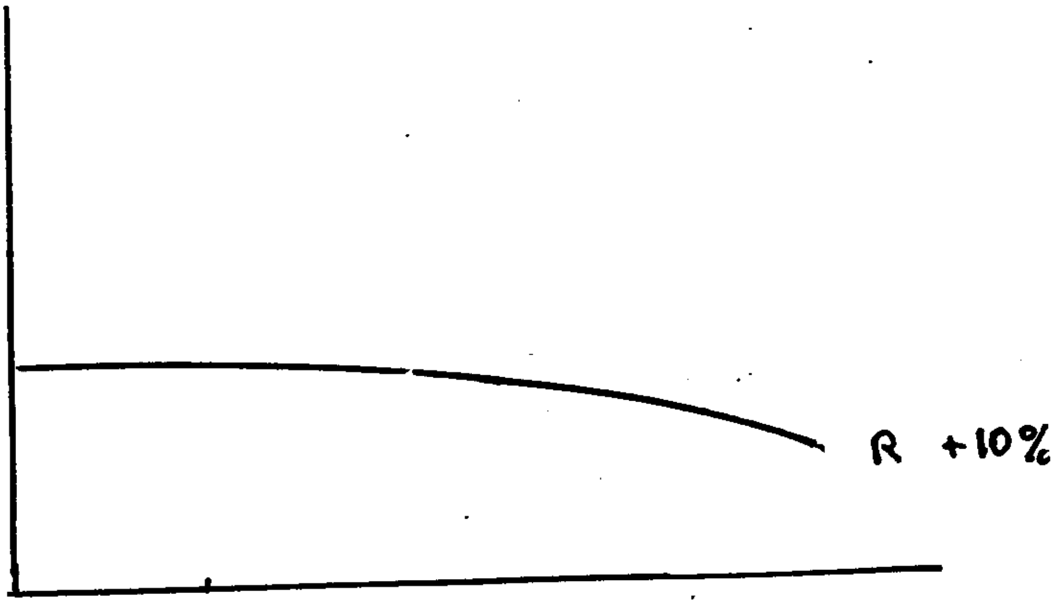
• P = 30 MeV/c
x. P = 90 MeV/c




S_T^{exp}

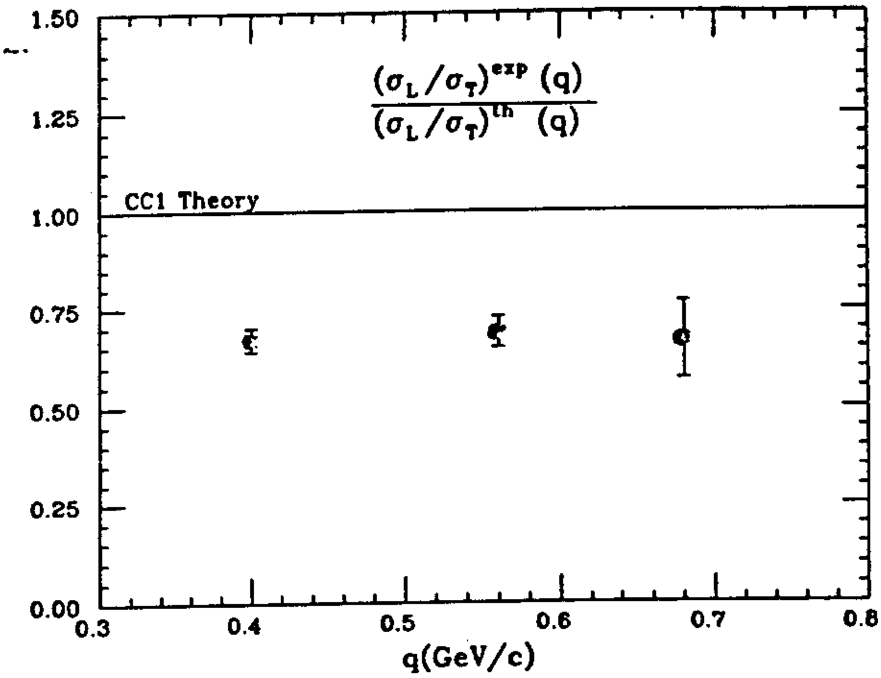

S_L^{exp}


R +10%

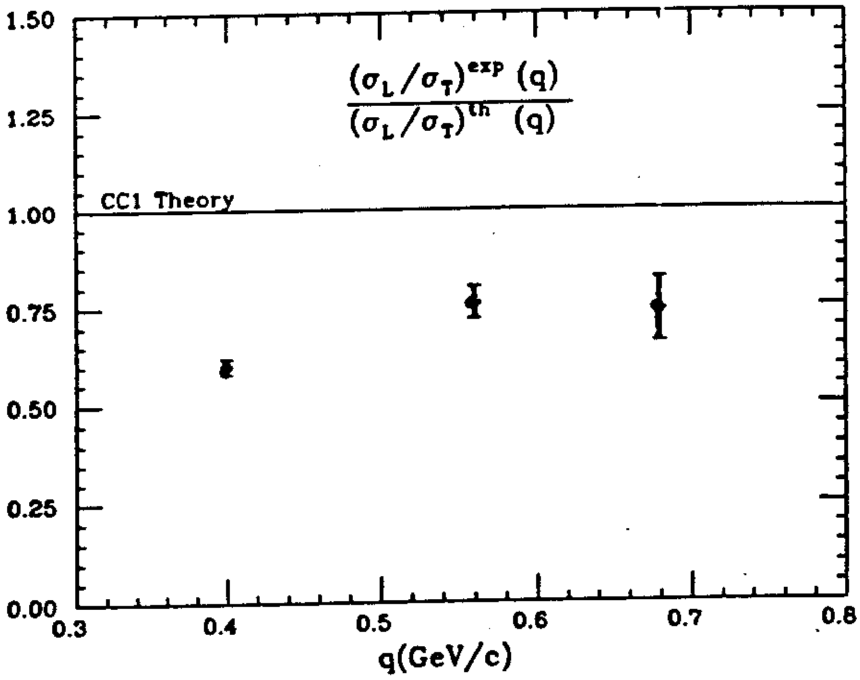

R +10%

SACLAY EXPERIMENT

F. GHIO et al.



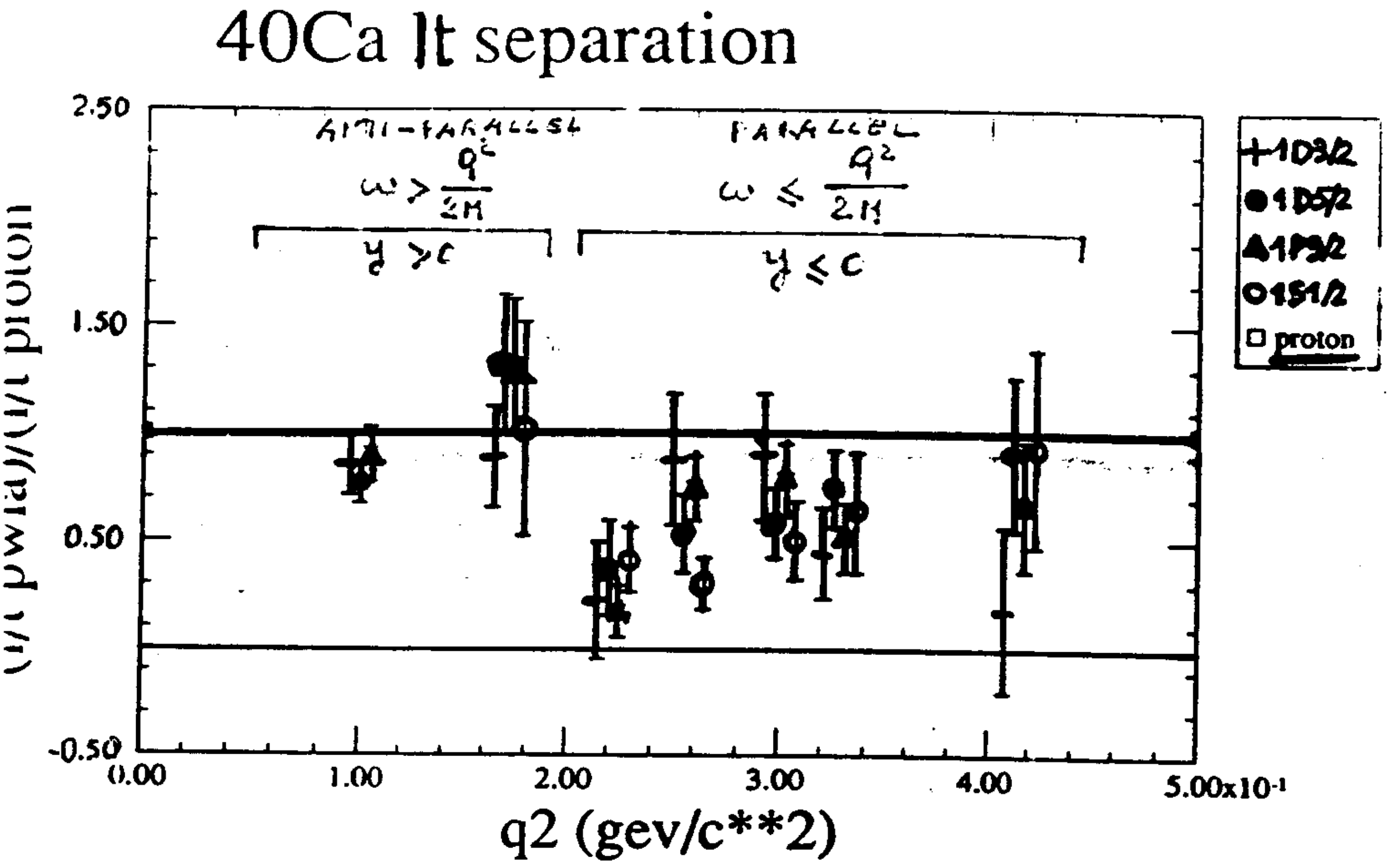
^{6}Li(e,e'p) – 1p Knockout



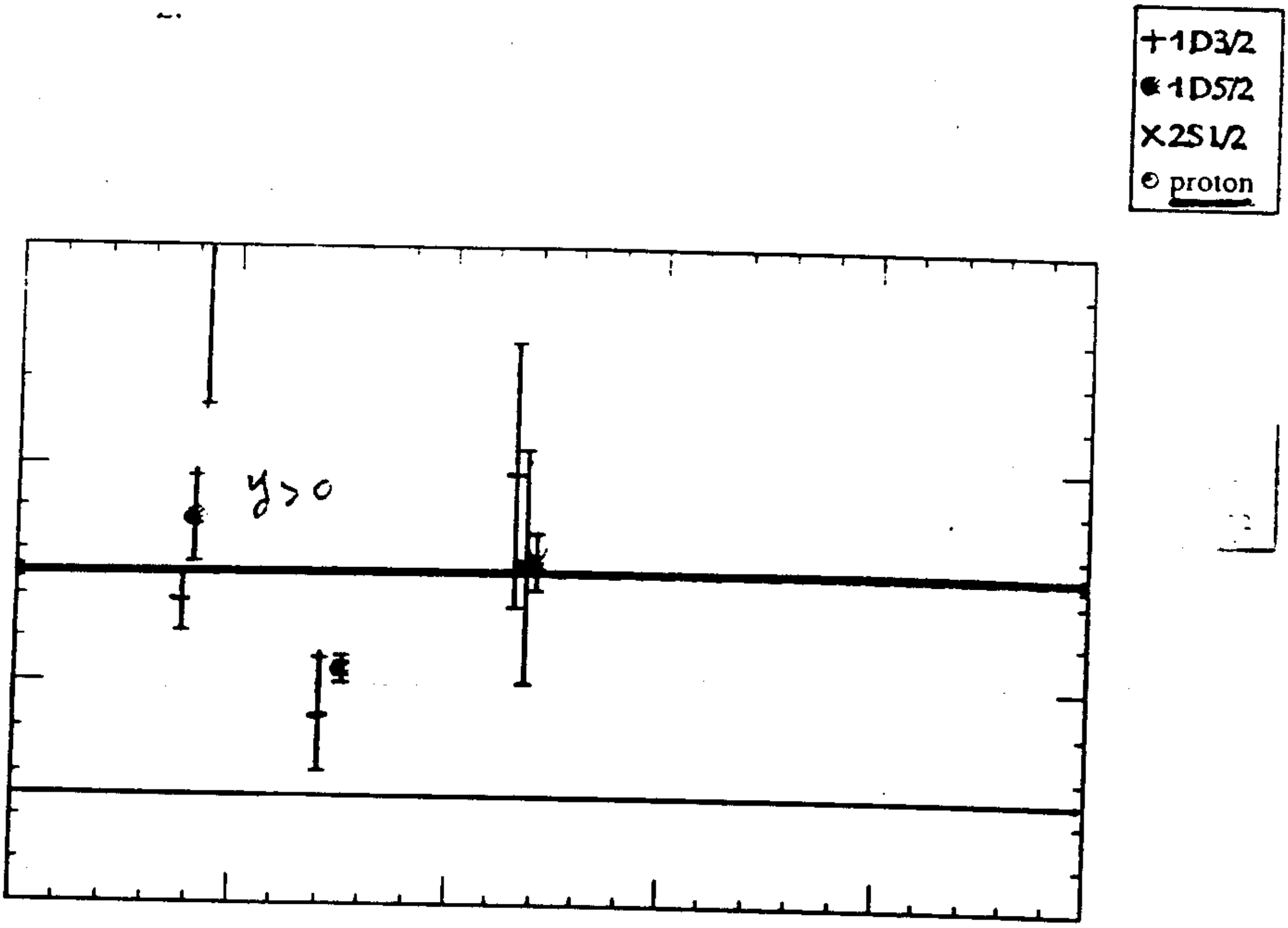
^{6}Li(e,e'p) – 1s Knockout

● SACLAY

D. REFFAY-PIKEROEN et al.

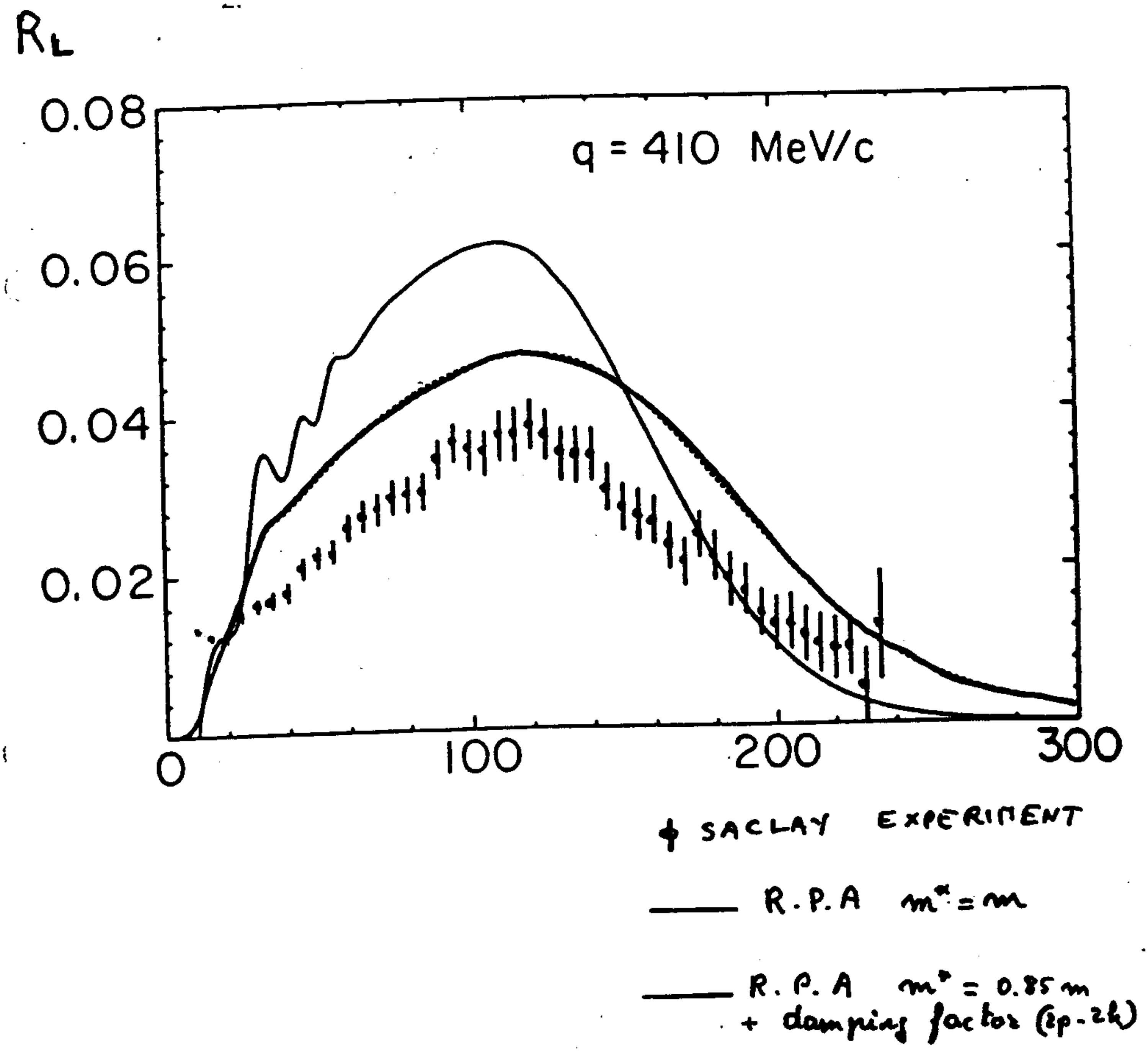


ϕ NIKHEF
H.J. BULTEN et al.



^{40}Ca (ee')

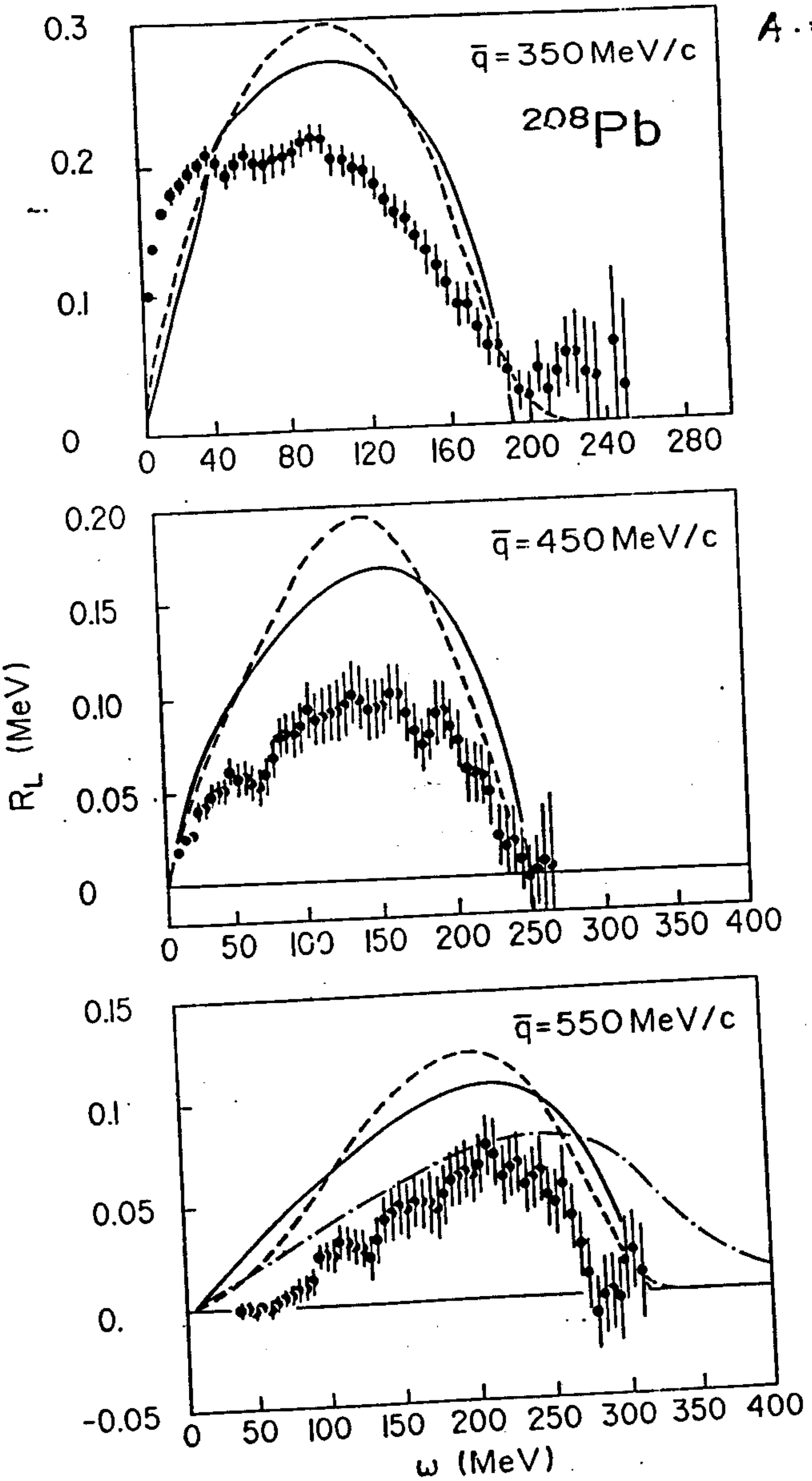
LONGITUDINAL RESPONSE



G. Cò & al.

Pb (ee') L/T SEPARATION

SACLAY
A. ZGHICHE et al.

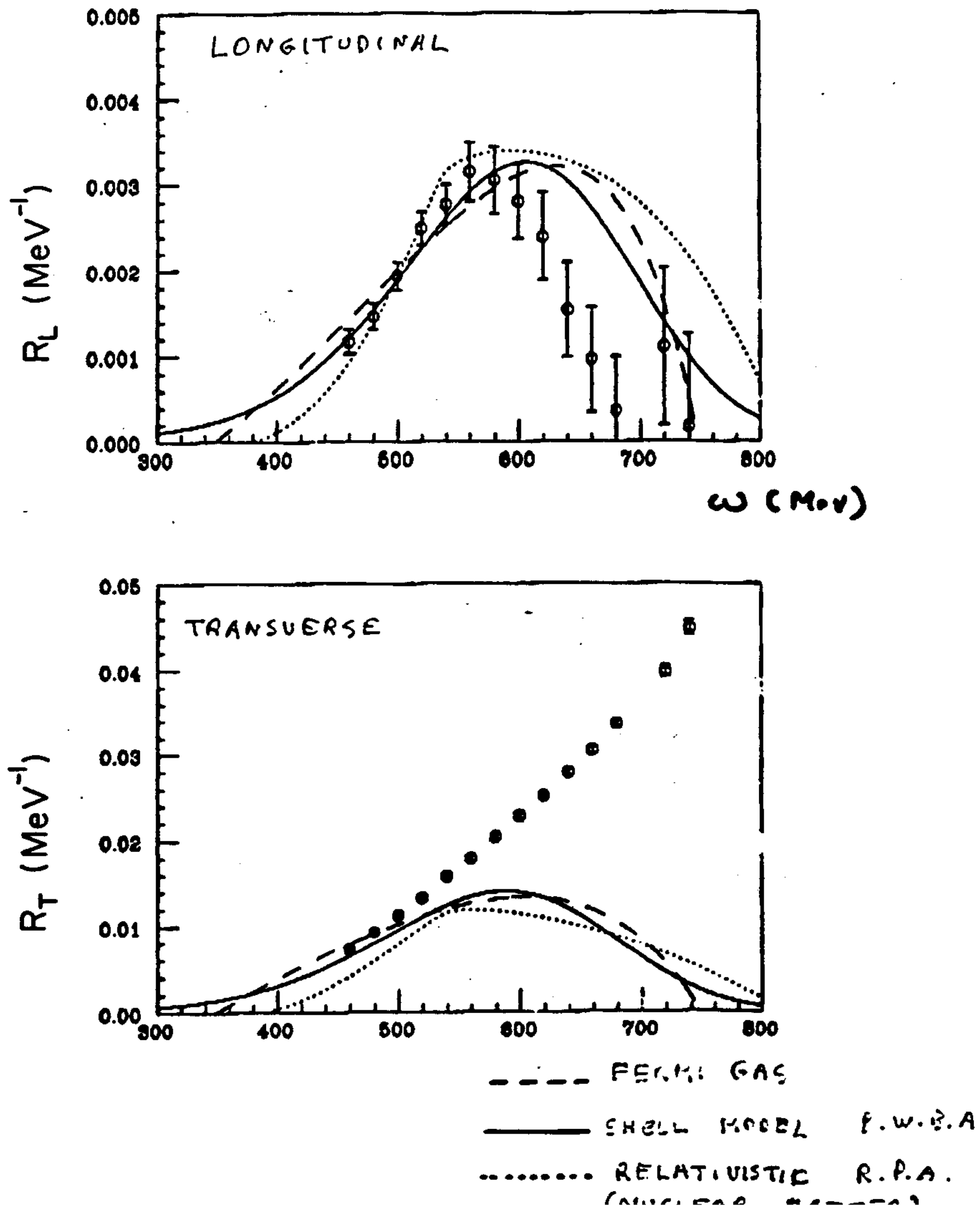


——— RELATIVISTIC FERMI GAS M. TRAINI
- - - - HARTREE - FOCK M. TRAINI
—·— WITH CORRELATIONS S. FANTONI et al.

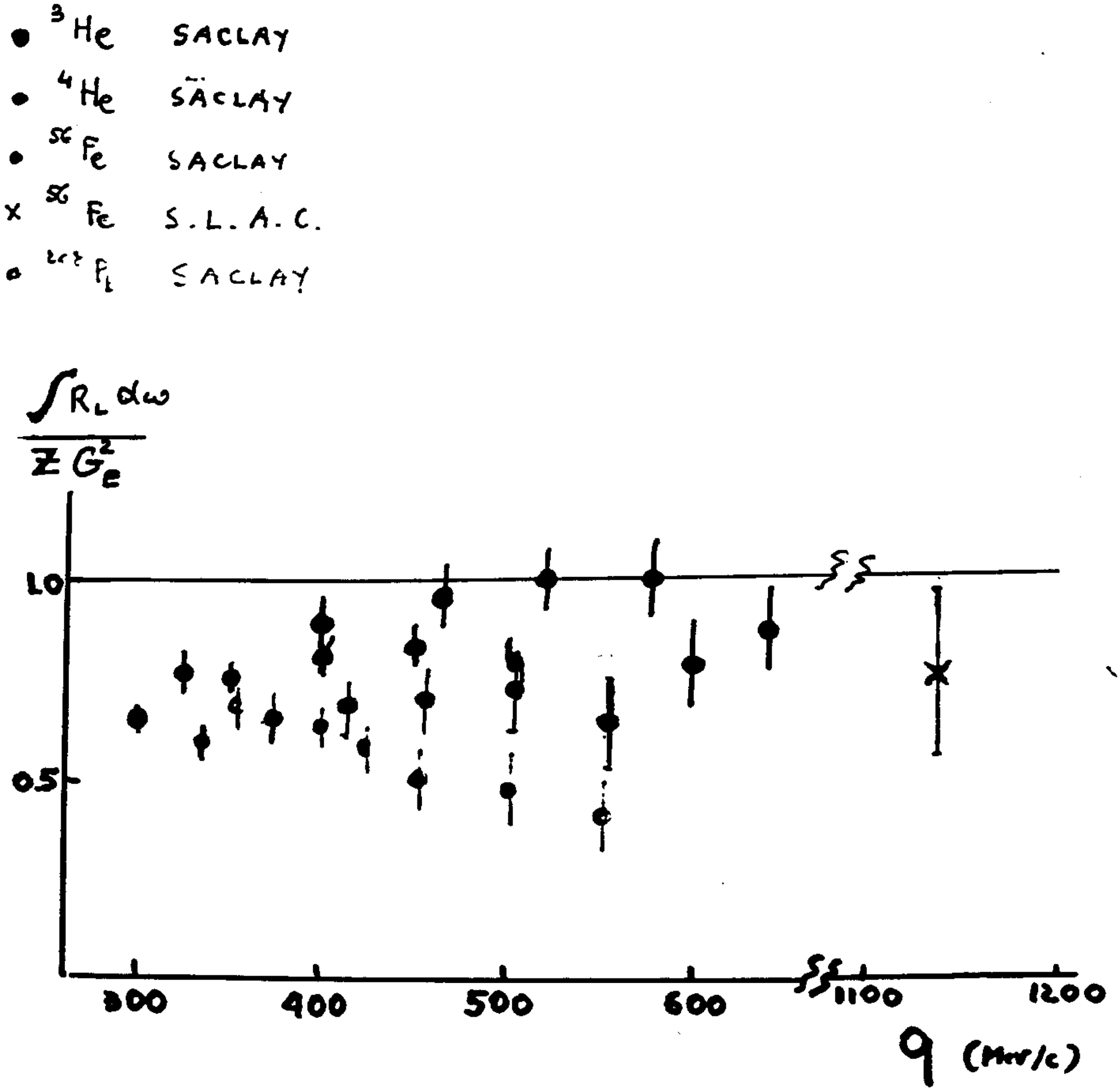
^{56}Fe (ee')

S.L.A.C EXPERIMENT
J.P. CHEN et al.
Z.E. MEZIANI

$q = 1140$ MeV



LONGITUDINAL SUM RULE



SUMMARY

* SINGLE NUCLEON KNOCK-OUT DOMINATES QUASI-ELASTIC ELECTRON SCATTERING

* CORRELATIONS ARE IMPORTANT OR SIGNIFICATIVE UNTIL $\approx$ 500 MeV/c

* RELATIVISTIC EFFECTS ARE NOT VERY IMPORTANT IN HARTREE-FOCK CALCULATIONS. RELATIVISTIC RPA CALCULATIONS ARE IN PROGRESS

* CONCERNING THE ELECTRON-PROTO INTERACTION INSIDE THE NUCLEUS

- THE TRANSVERSE COMPONENT VARIES WITH q THE FREE ONE

- THERE IS A LACK OF STRENGTH IN THE LONGITUDINAL RESPONSE WHICH INCREASES WITH A
THE SLOPE OF THE VARIATION WITH q IS COMPATIBLE WITH THAT OF THE FREE PROTON

NUCLEAR AND MOMENTUM TRANSFER DEPENDENCE OF QUASI-ELASTIC ee'p REACTION AT LARGE MOMENTUM TRANSFER

S.L.A.C NE 18 PROPOSAL

R. Mc KEOWN , R. MILNER SPOKESMEN

STUDY OF Q^2 AND A DEPENDANCE OF THE ee'p CROSS-SECTION ON ^{12}C , ^{56}Fe , ^{197}Au AND COMPARE TO DIFFERENT MODELS FOR FINAL STATE INTERACTION.

$$1 \ GeV/c^2 < Q^2 < 7 \ GeV/c^2$$

FINAL STATE INTERACTION MODELS:

$\sigma^{eH} \approx 40$ nb GLAUBER TYPE CALCULATIONS

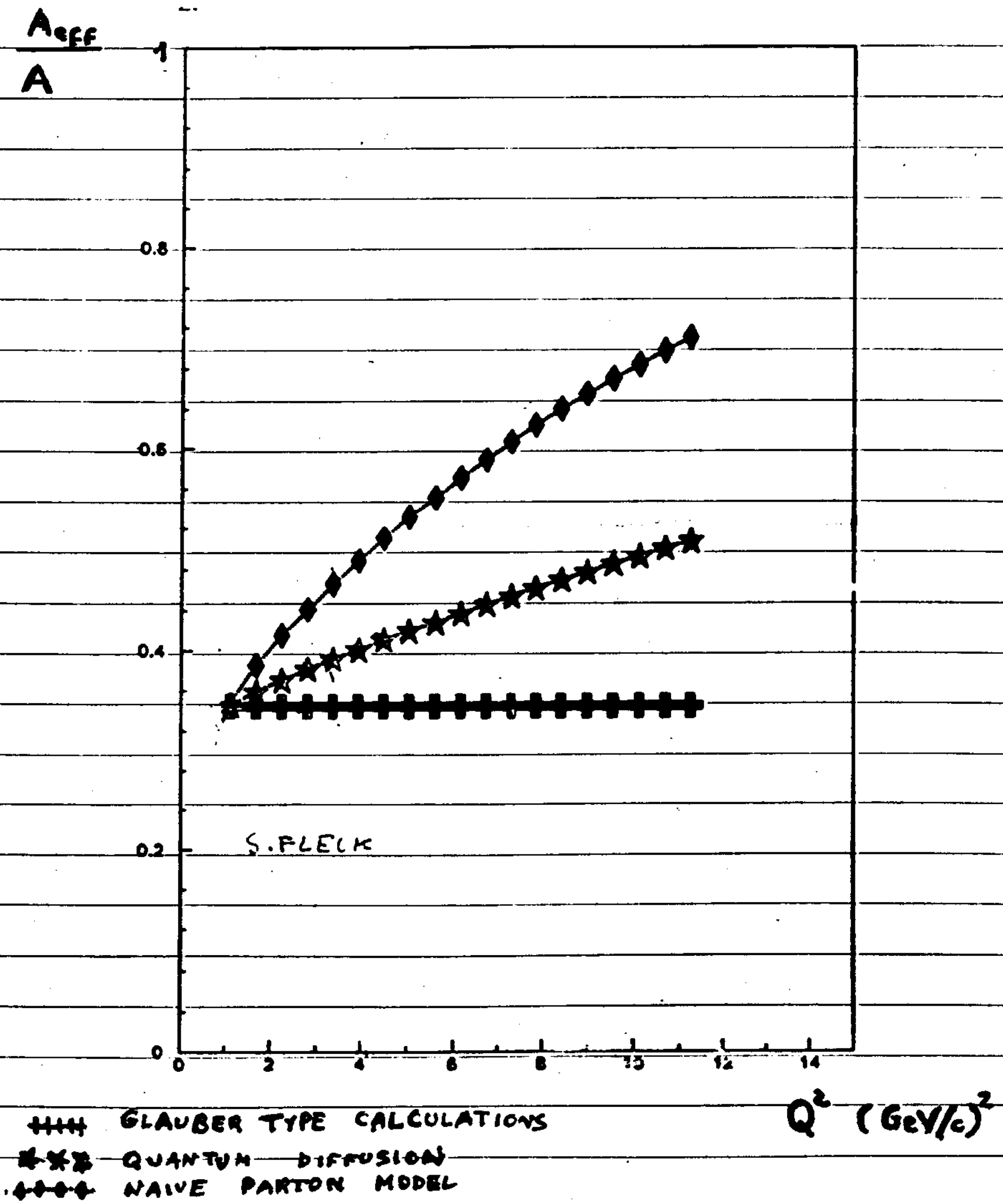
$\sigma^{eH} \propto z^2$ PARTON MODEL

$\sigma^{eH} \propto z$ QUANTUM DIFFUSION Perturbative Q

z is the distance from the point where the hard interaction occurs

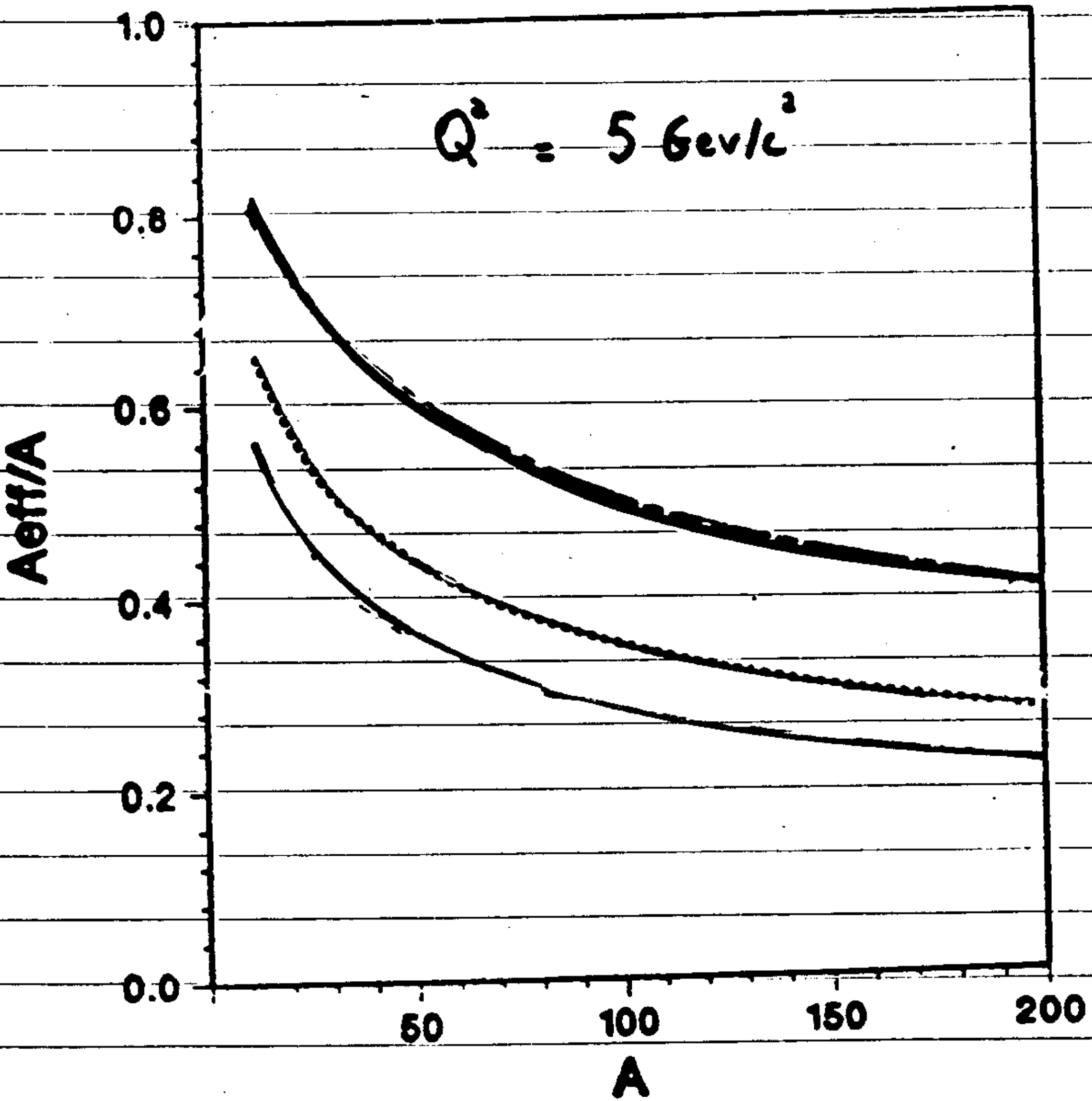
COLOUR TRANSPARENCY

^{56}Fe (ee'p)



SEE FARRAR et al. P.R.L. 61, 686 (1988)

COLOUR TRANSPARENCY



—— GLAUBER TYPE CALCULATIONS

—— QUANTUM DIFFUSION

—— NAIVE PARTON MODEL

FARRAR et al. PRL 61, 686 (1988)