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ANALYZING POWERS OF QUASI-ELASTIC C(p,2p) AND Cu(p,2p) SCATTERING AT 3.5GeV AND RELATIVISTIC EFFECTS

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Analyzing powers have been measured for the quasi-elastic $(\vec{p},2p)$ reaction on C and Cu at 3.5GeV over an angular range of $3.5° - 8.8°$. The results on C show larger values compared with those measured at SATURNE II up to 2.8GeV, and are reproduced well by the Relativistic Impulse Approximation (RIA) Model using the nucleon effective mass.

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We have measured analyzing powers for quasi-elastic C(p,2p) and Cu(p,2p) processes at 3.5GeV over the laboratory angular range of $3.5° - 8.8°$, in parallel with the measurement of the analyzing power for elastic pd scattering at 3.5GeV [1] using the KEK polarized proton beam and two detection systems. One system was an external beam polarimeter[2] and another system was the detection system for pd scattering(the pd Detector) [1].

The polarimeter consists of two sets of double arm counter systems, each of which consists of four-fold scintillation counters and one-veto counter as shown in Fig.1. The forward counters (F1 and F2) and the backward telescope counters (B1, B2 and B3) were set at pp elastic scattering kinematics. For the forward scattered particles, a C-type magnet selected the elastically scattered protons by rejecting magnetically the inelastically produced particles. Between B2 and B3 in the backward arm, a copper plate absorber was set to stop the elastically recoiled protons. Therefore, a quasi-elastic event was selected by the logic of $F1 \times F2 \times B1 \times B2 \times \overline{B3}$. Details of the polarimeter are reported in ref. [2].

The pd Detector (Fig. 1) consists of three scintillation counters (F1,F2 and F3) for the forward scattered proton detection and five scintillation counters (B1,...B5) for the backward recoiled proton detection. These counters were set at pp elastic scattering kinematics. The measuring conditions such as counter size, the thickness of absorber and trigger logic etc. were adjusted carefully corresponding to the measuring angles. Carbon and copper plates were used as a target. The target thickness was also changed depending on the scattering angle to avoid the absorption of the low energy recoiled proton. Recoiled protons were identified by two kinds of 2-dimensional information formed by a combination of the time of flight (TOF) and energy loss, that is, (i) the TOF(between B1 and B3) and the energy loss ΔE(in B3) and (ii) the TOF(between B1 and B3) and the whole energy loss E(in B4), corresponding to the recoiled proton energy. The beam

intensity was monitored by two detectors, a secondary emission chamber and a two fold counter telescope set in the vertical plane to look at a thin target plate.

Results obtained by the two detection systems are shown in Table 1 and Fig.2, where only the statistical errors are indicated. The averaged values for C(p,2p) are 0.135 ± 0.010(by Polarimeter), 0.115 ± 0.017(by the pd Detector) and one for Cu($\vec{p}$,2p) is 0.112 ± 0.018, where analyzing power for pp scattering is nearly 0.19. These analyzing powers are not so small compared with elastic pp scattering. The ratios of the ($\vec{p}$, 2p) analyzing powers to elastic pp scattering ($A_{(p,2p)}/A_{pp}$) are 0.717 ± 0.048(by the Polarimeter), 0.611 ± 0.090(by the pd Detector) for C($\vec{p}$,2p) and 0.596 ± 0.096 (by the pd Detector) for Cu($\vec{p}$,2p).

To explain analyzing powers of quasi-elastic scattering, the RIA calculation [3] has been applied by C.J.Holowitz and M.J.Iqbal[4]. In their approach, nucleon-nucleon (NN) interactions in nuclei are considered to differ from the free NN interactions and the differences are characterized by one parameter, that is, an effective nucleon mass m^*. We compared present data with the calculation based on this approach using the scattering amplitude K given by two parts, that is, spin non-flip (a and b) and spin flip (e), for pp scattering. The spin non-flip and the spin flip amplitudes of NN scattering have been parametrized as[4,5]

$$K = \frac{1}{2}[(a+b) + (a-b)\sigma_{1n}\sigma_{2n} + (c+d)\sigma_{1m}\sigma_{2m} + (c-d)\sigma_{1l}\sigma_{2l} + e(\sigma_{1n} + \sigma_{2n})] \qquad (1)$$

$$a = b = (i+\alpha)(4\pi)^{-1}\exp(-\mathrm{b}\cdot \mathrm{q}^2)\sigma_{\mathrm{total}} \qquad (2)$$

$$c = d = 0 \qquad (3)$$

$$\text{and } e = q \cdot (i + \alpha_{flip})(4\pi)^{-1}\exp(-b_{flip}\cdot q^2)\cdot \lambda\ . \qquad (4)$$

The values of the parameters in the above expression used in the present calculation were determined from the free NN scattering data [6,7,8,9,10,11], which are tabulated in Table 2.

The calculated analyzing powers also shown in Fig.2 can reproduce the present experimental results for C($\vec{p}$,2p) and Cu($\vec{p}$,2p), well. In this calculation, we used $m^* = 0.8m$ and $m^* = 0.72m$ for C($\vec{p}$,2p) and Cu($\vec{p}$,2p), respectively, which had been obtained by C.J.Horowitz and M.J.Iqbal for quasielastic electron scattering.

Finally, we discuss about the energy dependence of the analyzing power ratio ($A_{C(p,2p)}/A_{pp}$) of C($\vec{p}$,2p) to elastic pp scattering. The ratios have been measured up to 2.8GeV at SATURNE II [12] as shown in Fig.3, in which present data at 3.5GeV is also shown. The SATURNE II results show the tendency that the ratio decreases with energy up to 2.8GeV, with which the present data at 3.5GeV are considerably different.

One has to be careful in interpreting this tendency, because analyzing powers are changed remarkably by the contamination of inelastically produced pions. In order to estimate these effects of pion contamination, we calculated analyzing power for both cases, that is, for selected proton events and for the events contaminated by pions. The analyzing power for the latter case showed a small value as shown in Fig. 3. The degree of the reduction of analyzing power for the event contaminated by pions corresponds to the ratio 1.6-2.0 of the events with pions and without pions (selected proton events). Therefore, it seems to be reasonable to consider that the decrease of analyzing powers at lower energy than 2.8GeV at SATURNE might be caused by the inclusion of pions. The detection system of SATURNE II polarimeter might not be enough to identify pions and protons completely [14]. We could select protons well using the particle identification systems mentioned before. Of course, the final conclusion should be checked by the further detailed and careful measurements in this energy region.

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References

[1] C.Ohmori et. al., Phys. Lett. B, to be published.

[2] C.Ohmori et. al., Nucl. Instr. and Meth., A278(1989)705.

[3] J.A.McNeil,J.Shepard and S.J.Wallace,Phys.Rev.Lett.50(1983) 1439

[4] C.J.Holowitz and M.J.Iqbal, Phys.Rev.C 33(1986)2059

[5] J.Bystricky, F.Lehar and P.Winternitz, J.Phys.(Paris)39,1(1978)

[6] R.Diebold et. al., Phys. Rev. Lett. 35(1975)632.

[7] J.H.Parry et. al., Phys. Rev. D8(1973)45.

[8] D.V.Bugg et. al., Phys.Rev. 146(1966)980.

[9] S.Coletti et al., NC 49A(1967)479.

[10] M.N.Kreisler et al., Phys.Rev.Lett. 16(1966)1217.

[11] P.Jenni et. al., Nucl.Phys. B129(1977)232.

[12] J.Bystricky et.al., Lett. al Nuovo Cimento 40(1984)466.

[13] J.A.McGill et. al., Phys. Lett. B 134(1984)157.

[14] J.Bystricky et.al., Nucl. Instr. and Meth., A239(1985)131

Table 1. Results at 3.5 GeV

Detectors	targets	-t[(GeV/c)^2]	θ_{Lab}[deg]	Analyzing Powers
Polarimeter	carbon	0.15	4.2-5.9	0.130 ± 0.014
		0.20	5.2-6.7	0.139 ± 0.014
		0.100	3.5-4.7	0.123 ± 0.033
pd	carbon	0.175	5.3-5.8	0.126 ± 0.031
Detector		0.285	7.0-7.7	0.103 ± 0.031
		0.395	8.3-8.8	0.100 ± 0.039
		0.115	3.5-5.3	0.085 ± 0.032
pd	copper	0.230	5.8-7.0	0.134 ± 0.029
Detector		0.370	7.7-8.8	0.112 ± 0.036

Table 2. The values of parameters used in the calculation at 3.5 GeV

Parameters	*The Values*
σ_{Total}	40mb
b	8[$(GeV/c)^{-2}$]
α	-0.39
λ	12.3mb/(GeV/c)
b_{flip}	12.6[$(GeV/c)^{-2}$]
α_{flip}	-0.39

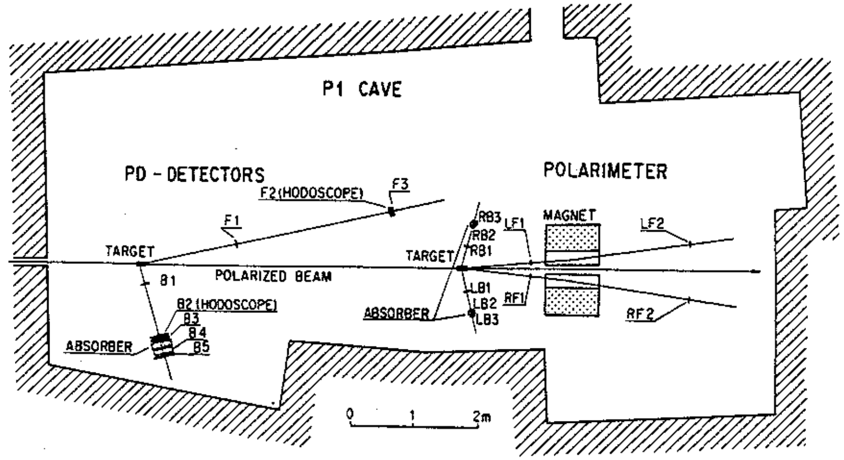

Fig.1

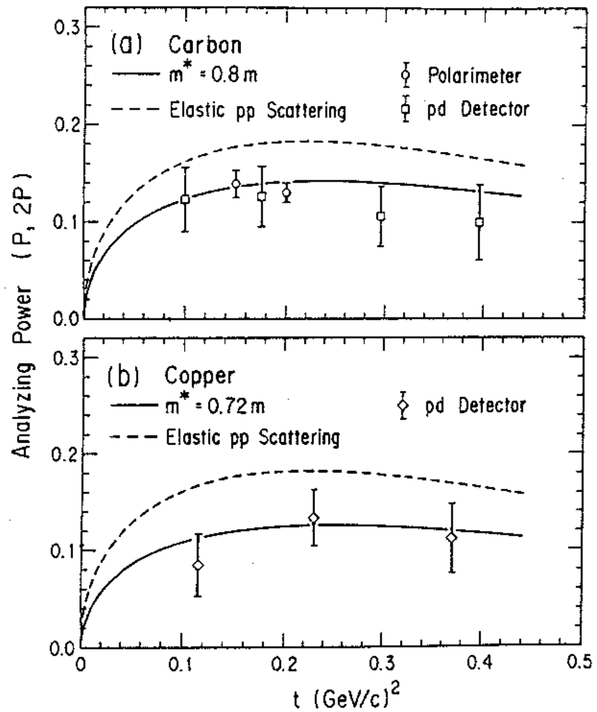

Fig.2

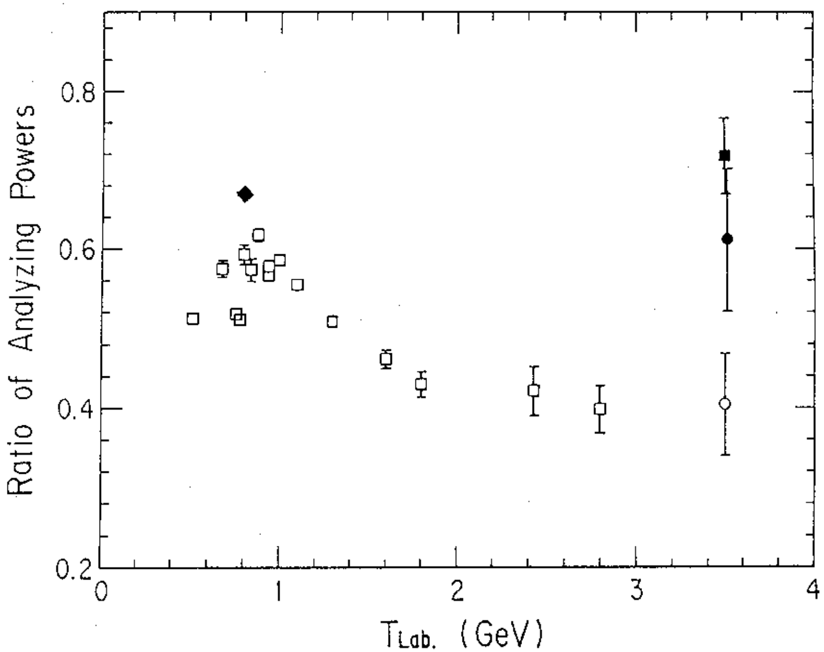

Fig.3

FIGURE CAPTIONS

Fig.1, The experimental lay out. Elements labeled F1,F2,F3 and B1,..B5 of the pd detector are scintillation counters. The angular position of each arm is remotely controlled. Elements labeled LF1,..LB3,RF1,..RB3 of the external polarimeter are scintillation counters. The magnet was placed between LF1(RF1) and LF2(RF2).

Fig.2, Experimental results for ^{12}C (Fig.2-a) and Cu at 3.5GeV (Fig.2-b). The horizontal axis is the momentum transfer and the vertical axis is the analyzing power. The solid line and the dashed line in the figures are analyzing powers for elastic proton scattering and those calculated by the RIA model with $m^* = 0.8m$ for carbon and with $m^* = 0.72m$ for copper.

Fig.3, Energy dependence of analyzing power ratio ($A_{C(p,2p)}/A_{pp}$) for ^{12}C. The horizontal axis is the proton incident energy. The vertical axis is the analyzing power ratio. The closed square is the result from the polarimeter. The open and closed circle are the results including the inelastic pions and rejecting the inelastic pions, respectively. The open squares are the results at SATURNE II. The closed diamond is the result from LAMPF [13]