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[1]E. L. Miller *et al.*, Phys. Rev. Lett. 26, 984 (1971); J. Engler *et al.*, Phys. Lett. 34B, 528 (1971); M. N. Kreisler *et al.*, Nucl. Phys. B84, 3 (1975); V. Böhmer *et al.*, Nucl. Phys. B110, 205 (1976); A. Babaev *et al.*, Nucl. Phys. B110, 189 (1976).

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Some Features of *n-p* Charge-Exchange Scattering between 60 and 300 GeV/*c**

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We examine the dependence of the n-p charge-exchange cross section on the squared four-momentum transfer and on the incident momentum, and include some comparisons with data from lower energies. Implications for the difference between n-p and p-p total cross sections are presented.

In the previous Letter we presented the results of a new measurement of the n-p charge exchange differential cross section covering incident momenta from 60 to 300 GeV/c and squared four-momentum transfers (t) from 0.002 to 0.8 (GeV/c)^2.[1] We present here an analysis of the data in which we examine the energy dependence of this reaction, and use the $t=0$ differential cross-section points to set bounds on the difference of the n-p and p-p total cross sections.

All n-p charge-exchange cross sections[1-5] above 3 GeV/c may be fitted acceptably for $|t|$ less than 0.07 (GeV/c)^2 by the form

$$\frac{d\sigma}{dt}=A\left(\frac{m_\pi^4}{(|t|+m_\pi^2)^2}\right)+B. \qquad (1)$$

The phenomenological expression is motivated by models incorporating pion exchange with absorption[6] and is useful in displaying the energy dependence of the size of the "pion" peak relative to the background. At $t=0$, the differential cross section is the sum of the "pion" contribution whose coefficient is A and the sum of all other contributions given by B. The ratio A/B is a measure of the relative size of the forward peak independent of normalization. We have fitted our data and those of others to expression (1) over a range of $|t|$ in the forward direction. The fits appear to be stable within errors for starting points ranging from 0.002 to 0.008 (GeV/c)^2 and end points from 0.05 to 0.07 (GeV/c)^2. In Fig. 1 are plotted the results of fits to our data for the region $0.002<|t|<0.06$ (GeV/c)^2, and in Table I we summarize our data as well as those of others.

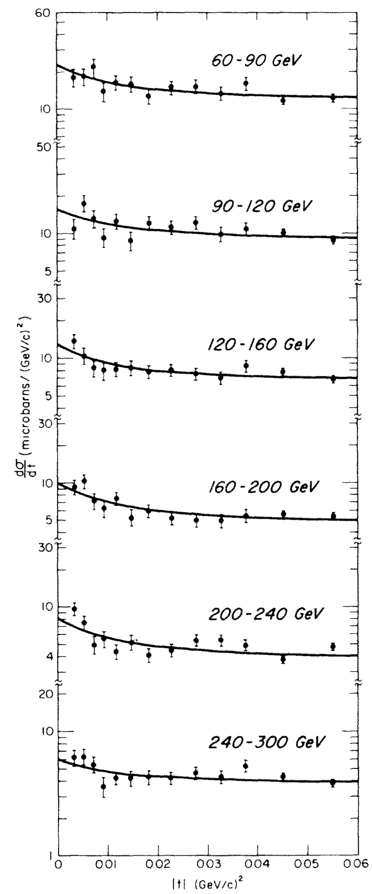

FIG. 1. Fits to the highest energy data using pion exchange plus background. The data are from Ref. 1, the solid curve is the best least-squares fit of formula (1).

It is evident that the ratio A/B fluctuates considerably between different energy bins and that there are large discrepancies between the data of some of the experiments. For instance, the experiments of Böhmer *et al.*[4] and Babaev *et al.*[5] display systematically larger forward peaks than ours measured at higher energies and also larger ones than those of Kreisler *et al.*[3] measured at lower and overlapping energies. The differential cross section depends directly on correctly weighting detected events by the probability of their detection. These weights include the efficiencies of the neutron counters, the probability of the neutron escaping from the target, and the subtraction of inelastic backgrounds beneath the elastic peaks. Although we estimate that the systematic effects resulting from a poor understanding of the above corrections are no more than 20% in our data, it is only fair to surmise that the systematic discrepancies observed among the several experiments may represent the true level of uncertainty involving these corrections. To avoid these difficulties, we choose to compare our current data with those of Refs. 1 and 3, which use similar correction techniques and agree within regions of overlap. We note that the ratio A/B has shrunk by approximately a factor of 2 in going from 3–27 GeV/c to our present measurement, but that the pion peak is still statistically significant up to our highest energies.

TABLE I. The ratio of pion peak to background (A/B) is shown as a function of incident neutron momentum for five different experiments. The erros shown are generally those given by least squares, but have been increased when necessary to cover dependence of A/B on the range of momentum transfers used in the fitting.

P (GeV/c)	A/B	Authors
60-90	0.85 ± 0.23	Barton, et al
90-120	0.70 ± 0.22	
120-160	0.92 ± 0.21	(1)
160-200	1.13 ± 0.23	
200-240	0.98 ± 0.22	
240-300	0.52 ± 0.19	
4	1.50 ± 0.13	Miller, et al
5	1.56 ± 0.13	
6	1.82 ± 0.15	(2)
7	1.51 ± 0.20	
8	1.68 ± 0.24	
9	1.78 ± 0.16	
10	1.81 ± 0.15	
11	1.86 ± 0.20	
11.75	3.03 ± 0.35	
8-11	1.39 ± 0.39	Kreisler, et al
11-14	2.29 ± 0.42	
14-16	2.10 ± 0.47	(3)
16-18	1.56 ± 0.41	
18-20	2.99 ± 0.54	
20-22	2.06 ± 0.42	
22-24	1.31 ± 0.32	
24-26	1.76 ± 0.39	
26-29	1.28 ± 0.32	
9-12	2.31 ± 0.20	Böhmer, et al
12-15	2.68 ± 0.29	
15-17	3.03 ± 0.45	(4)
17-19	3.04 ± 0.42	
19-21	2.92 ± 0.32	
21-23	3.23 ± 0.39	
23.5	1.33 ± 0.69	Babaev, et al
27.5	3.27 ± 0.42	
32.5	3.98 ± 0.51	(5)
37.5	3.17 ± 0.37	
42.5	4.12 ± 0.57	
47.5	5.00 ± 0.59	
52.5	3.66 ± 0.41	
57.5	2.99 ± 0.34	
62.5	2.36 ± 0.28	

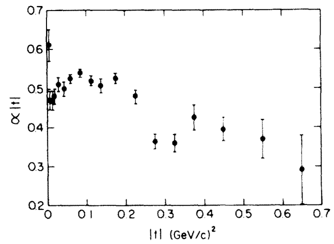

FIG. 2. The best least-squares fit of $\alpha(t)$ from formula (2) to the data of Ref. 1. Please note that the zero of α has been suppressed, and that an overall normalization error of $\pm 1\frac{1}{2}\%$ due uncertainties in the neutron beam shape has not been included.

We next examine the energy dependence of the differential cross section by fitting the data with a Regge form:

$$d\sigma/dt = \eta(t) S^{2\alpha(t)-2}, \quad (2)$$

where S is the square of the center-of-mass energy.[7] In Fig. 2 we plot the resulting $\alpha(t)$ for our data and in Fig. 3 we show the relative dependence of data from the cited experiments spanning the incident neutron momentum range from 3 to 300 GeV/c. Not included in Fig. 2 is the overall normalization error of $\pm 1.5\%$ due to uncertainties in the momentum dependence of the neutron-beam spectrum. For $|t|$ less than 0.25 (GeV/c)^2 the value of $\alpha(t)$ is approximately 0.5 for incident momenta 60 to 300 GeV/c. This value should be compared with $\alpha \cong 0.0$ for 3 to 11 GeV/c, $\alpha \cong 0.1$ for 9 to 27 GeV/c, and $\alpha \cong 0.25$ for 23 to 62 GeV/c. It is evident both from the increasing value of

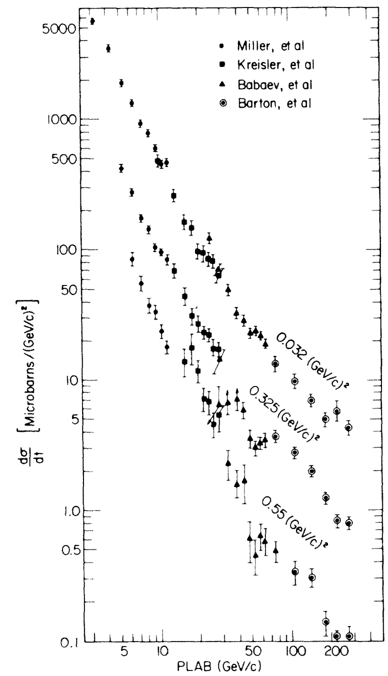

FIG. 3. Dated from several experiments are presented within three fixed bins in momentum transfer. Though the normalization from the experiments is not always compatible, there is a strong indication that the energy dependence decreases as the energy increases.

$\alpha(t)$ and from a cursory examination of Fig. 3 that the momentum dependence of the data is a monotonic decrease with increasing momentum. Simple theoretical models predict that the pion-exchange contribution falls with $\alpha(0) = 0$, and that

TABLE II. $|\sigma_{pp} - \sigma_{np}|$ derived from differences of total cross sections and inferred from the np charge-exchange cross section extrapolated to zero degrees.

P (average) (GeV/c)	σ_{pn} [a] (mb)	σ_{pp} [b] (mb)	From total cross-section differences[c] $\lvert\sigma_{pp} - \sigma_{np}\rvert$ (mb)	Bound from charge exchange (formula 3) (mb)
75	38.63 ± 0.40	38.26 ± 0.06	0.37 ± 0.40	0.66 ± 0.06
105	38.95 ± 0.26	38.43 ± 0.06	0.52 ± 0.27	0.54 ± 0.06
140	39.28 ± 0.19	38.61 ± 0.06	0.67 ± 0.20	0.49 ± 0.05
180	39.61 ± 0.20	38.79 ± 0.06	0.82 ± 0.21	0.44 ± 0.05
220	39.90 ± 0.24	38.95 ± (?)	0.95 ± (?)	0.39 ± 0.04
265	40.19 ± 0.24	39.11 ± (?)	1.08 ± (?)	0.34 ± 0.04

[a]Taken from the fit $\sigma = 38.4 + 0.85\,[\ln(S/95)]^{1.47}$ given in Ref. 7. The errors are interpolated from neighboring data points.

[b]The data from Ref. 8 are fitted by the similar form $\sigma = 38.14 + 0.46[\ln(S/95)]^{1.47}$. Errors are not stated above the 200-GeV/c end point of the data.

[c]We could have used the np cross sections derived from the proton-deuteron cross sections of Ref. 8, but would have incurred an error of ± 0.6 mb. For example, the point at 180 GeV would have been 0.33 ± 0.6 mb. Thus, we preferred to use the directly measured np cross section given in Ref. 7.

$\rho - A_2$ exchange falls as $\alpha(0) = 0.5$. Within the context of these simple models, it is difficult to reconcile a value for α compatible with ρ-A_2 exchange with the presistence of the forward peak mentioned previously.

It is worth noting that the differential cross section at higher momentum transfers shows a shoulder developing at $|t| \cong 0.1$ (GeV/c)^2 as the incident momentum is increased, while beyond a $|t|$ of 0.25 the falloff appears to be exponential. As indicated by the decreasing values of $\alpha(t)$, there is some evidence for shrinkage in this exponential region.

With use of the $|t| = 0$ cross section derived from formula (1), bounds on the total cross-section difference may be estimated from the optical theorem and the assumption of charge symmetry[8]:

$$[4\sqrt{\pi}\hbar(A+B)^{1/2}] \geq |\sigma_{pp} - \sigma_{np}|. \qquad (3)$$

These limits are presented in Table II, together with limits from the separate measurements of the total cross sections.[9,10] It is evident the limits from this experiment at the highest energies are comparable to those found from subtraction of the total cross sections.

Finally, formula (3) neglects both the real part of the amplitude and the double-flip zero net helicity-flip amplitude. Thus, any theoretical model which estimates these large contributions should be able to establish significantly stronger bounds on the cross-section difference than those presented in this paper.

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One-Loop Renormalizability of Pure Supergravity and of Maxwell-Einstein Theory in Extended Supergravity

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It is shown that the four-particle S matrix of pure supergravity and of the recently constructed theory of extended supergravity with O(2) internal symmetry is one-loop finite. An explicit calculation of photon-photon scattering confirms this latter result.

Whereas the one-loop quantum corrections to the S matrix of pure Einstein gravitation are known to be finite,[1] all endeavors to couple matter fields to gravitons (scalars,[1] photons,[2] fermions,[2] Yang-Mills bosons,[2] or quantum electrodynamics[3]) have led so far to divergent quantum field theories. Because of the dimensional character of the gravitational constant, proper renormalizability can never be obtained and instead one should look for theories where all divergences cancel in a miraculous way. The prime candidate for such a theory is supergravity[4-6] which connects intimately Fermi-Bose supersymmetry with gravitation by means of a local gauge theo-