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ABSTRACT

The neutron-proton charge-exchange polarization has provided new information to test various theoretical models and exchange degeneracy of ρ and A_2 trajectories. The small polarization which is consistently negative and independent of energy at most points is changing our belief that particles like ρ and A_2 are exchange degenerate. We are considering here a theoretical model which is capable of reproducing the desired np-pn polarization that has been found experimentally. This model for which the polarization has given reasonable qualitative and quantitative agreement with experimental data is consistent when we study simultaneously the polarizations and differential cross sections for the processes $np \rightarrow pn$ and $p\bar{p} \rightarrow n\bar{n}$.

INTRODUCTION

The idea of exchange degeneracy has been popular until recently since reactions[1] like $K^+n \to K^0n$ and $K^-p \to \bar{K}^0n$ over a wide range of momentum provided some evidence for the strong form of exchange degeneracy for ρ and A_2. Not only is a large number of parameters like residues and trajectories reduced thereby and formulations much simplified, but a good test of duality principle is provided. The recent polarization measurement[2] on $np \to pn$ scattering has shaken our faith that ρ and A_2 obey the strong form of exchange degneracy, since this model predicts zero polarization. The two particles obey the strong form of exchange degeneracy when their residues and trajectories are equal. The weak-form exchange degeneracy between two particles means that their trajectories should be equal but not their residues. Nobody has found any resonance of usual quantum numbers in the reactions $K^+n \to K^0p$. When ρ and A_2 are exchanged in the t channel, because of the strong form of exchange degeneracy, the complex parts of their contributions are mutually canceled. This indicates that there is no resonance in the s channel. The fact that contributions due to the complex part of the ρ and A_2 exchanges in the t channel for the reaction $K^-p \to \bar{K}^0n$ are added together provides the evidence for the existence of s-channel resonance. This property of the strong form of exchange degeneracy was applied recently[3] on $np \to pn$ and $p\bar{p} \to n\bar{n}$ differential cross sections. The $np \to pn$ polarization provides a test of the strong form of exchange degeneracy for the ρ and A_2 trajectories. However, one would like to use a weaker form of exchange degeneracy for ρ and A_2 without much ambiguity. Recently the differential cross sections for $np \to pn$

and $p\bar{p} \to n\bar{n}$ scatterings,[3] ρ and A_2 were assumed to obey the stronger form of exchange degeneracy. Small polarization and the expression for polarization[4] indicate that lower-lying trajectories π and β and their opposite parity partners that are supposed to play an important part in determining sharp forward peak are not expected to contribute for the $np \to pn$ polarization whether the above-mentioned particles are exchange degenerate or not. Also, these trajectories are approximately zero near $t = 0$. The Veneziano[3,5] forms for the exchange of π and β and their opposite parity partners considered as strongly exchange degenerate are retained in this model. But it is essential to break the strong form of exchange degeneracy for ρ and A_2 so that amplitudes become complex in order to predict the $np \to pn$ polarization. We make this model compatible with other well-studied reactions such as $\pi^- p \to \eta n$ and $\pi^- p \to \pi^0 n$ where only A_2 and ρ are exchange respectively. Because of the even signature of A_2 trajectory, one has to choose the Gell-Mann mechanism here to kill the ghost when $\alpha_{A_2}(t) = 0$. This ghost-killing mechanism is consistent with $\pi^- p \to \eta n$ and $K^+ p \to K^0 \Delta^{++}$ where no dip[6] is found. Also our parametrization is consistent by factorization with the dip[7] seen in $\pi^- p \to \pi^0 n$ at the point where $\alpha_\rho(t) = 0$. Not only has our model been able to produce a sharp forward peak in the differential cross sections for $np \to pn$ and $p\bar{p} \to n\bar{n}$ scattering, but it also explains the consistenly negative and independent-of-energy polarization at most points. Arnold and Logan,[8] who used a weaker form of exchange degeneracy for ρ and A_2, predict that polarizations should be zero when $\alpha_\rho(t) = 0$. This is inconsistent with experimental data which show that the polarization is monotonically increasing and has no indication of passing through zero in the range studied.

FORMULAS AND PARAMETRIZATION

Both π and β and their opposite parity partners c and β_c are strongly exchange degenerate. The contributions due to exchange of all these particles to the helicity amplitudes are expressed as ϕ_i^x, where x denotes symbolically all the particles together. The $\phi_i^x(s,t)$ for large s and fixed t are given by[3]

$$\phi_1^x(s,t)_{np\to pn} \sim -\beta_t\left(\frac{m^2}{s}\right)\frac{s^{\frac{1}{2}}(bs)^{\alpha_c(t)-1}}{\sin\pi\alpha_c(t)\ \alpha_c(0)\ \Gamma[\alpha_c(t)]}$$

$$-\ \beta\frac{s^{\frac{1}{2}}(bs)^{\alpha_c(t)-1}}{\sin\pi\alpha_c(t)\ \alpha_c(0)\ \Gamma[\alpha_c(t)]} \sim \phi_3^x(s,t)_{np\to pn}$$

$$\phi_2^x(s,t)_{np\to pn} \sim -\beta_t\frac{s^{\frac{1}{2}}(bs)^{\alpha_\pi(t)-1}}{\sin\pi\alpha_\pi(t)\ \Gamma[\alpha_\pi(t)+1]}$$

$$-\ \beta_t\frac{s^{\frac{1}{2}}(bs)^{\alpha_c(t)-1}}{\sin\pi\alpha_c(t)\ \alpha_c(0)\ \Gamma[\alpha_c(t)]} \qquad (1)$$

$$\phi_4^x(s,t)_{np\to pn} \sim -\beta_t\frac{s^{\frac{1}{2}}(bs)^{\alpha_\pi(t)-1}}{\sin\pi\alpha_\pi(t)\ \Gamma[\alpha_\pi(t)+1]}$$

$$+\ \beta_t\frac{s^{\frac{1}{2}}(bs)^{\alpha_c(t)-1}}{\sin\pi\alpha_c(t)\ \alpha_c(0)\ \Gamma[\alpha_c(t)]}$$

$$\phi_5^x(s,t)_{np\to pn} \sim \beta_t\left(1+\frac{s}{m^2}\right)^{\frac{1}{2}}\frac{m(bs)^{\alpha_c(t)-1}}{\sin\pi\alpha_c(t)\ \alpha_c(0)\ \Gamma[\alpha_c(t)]}\ ,$$

A_2 contributions to $\phi_i(np\to pn)$ are obtained by multiplying the usual residue for A_2 exchange from Ref. 9 by $\alpha_{A_2}(t)$. The experimental data show that the polarization is consistently negative and that it increases in that direction with $-t$. The theoretical prediction for the polarization is inconsistent with experimental data since it decreases with $-t$. In order that the residue and, therefore, the polarizations should not decrease with $-t$, one has to multiply the above residue by another factor $(a - bt)$, where positive constants a and b are chosen in such a way that one can predict that the polarization and its slope with $-t$ will agree fairly well with experimental data. Consistent with these facts, A_2 contributions for large s and fixed t are given by

$$\phi_1^R(s,t)_{np\to pn} = \phi_3^R(s,t)_{np\to pn}$$

$$\sim -\left(b_{1R} + \tau\,\alpha_\rho(t)\, b_{2R}\right)^2 \frac{\alpha_\rho(t)(a - bt)\, s^{\frac{1}{2}}(bs)^{\alpha_\rho(t)-1}}{\sin \pi\alpha_\rho(t)} \left(1 + e^{-i\pi\alpha_\rho(t)}\right)$$

$$\phi_2^R(s,t)_{np\to pn} = -\,\phi_4^R(s,t)_{np\to pn}$$

$$\sim \tau\left(b_{1R} - \alpha_\rho(t)\, b_{2R}\right)^2 \frac{\alpha_\rho(t)(a - bt) s^{\frac{1}{2}}(bs)^{\alpha_\rho(t)-1}}{\sin \pi\alpha_\rho(t)} \left(1 + e^{-i\pi\alpha_\rho(t)}\right) \qquad (2)$$

$$\phi_5^R(s,t)_{np\to pn} \sim \tau^{\frac{1}{2}}(b_{1R} + \tau\alpha_\rho(t)\, b_{2R})(b_{1R} - \alpha_\rho(t)\, b_{2R})$$

$$\times\ \alpha_\rho(t)(a - bt)\, \frac{s^{\frac{1}{2}}(bs)^{\alpha_\rho(t)-1}}{\sin \pi\alpha_\rho(t)} \left(1 + e^{-i\pi\alpha_\rho(t)}\right) .$$

Here τ denotes $-t/4m_N^2$.

DESCRIPTION OF THE FIT

The np charge exchange polarization is consistently negative and independent of energy.[2] It increases monotonically with uniform slope with $-t$. In order to predict the polarization so that it agrees reasonably well with the experimental data, the residues of the ρ and A_2 trajectories are multiplied by a factor $(a - bt)$. The best values for a and b consistent with experimental data on $np \to pn$ polarization and differential cross sections for $np \to pn$ and $p\bar{p} \to n\bar{n}$ obtained by the trial and error method are $a = 0.3$ and $b = 3.0\ (\mathrm{GeV}/c)^{-2}$. Altogether there are 32 data for $np \to pn$ differential cross sections[10] at an incident laboratory momentum of 8 GeV/c. There is a systematic uncertainty of ±30% common to all values, and an additional systematic uncertainty of ±15% for $-t > 0.143\ \mathrm{GeV}/c^2$. All these, apart from statistical errors, are taken into consideration for the minimum value of χ^2. Twelve points[11] of experimental data at each incident laboratory momentum 5, 6, 7, and 9 GeV/c for $p\bar{p} \to n\bar{n}$ differential cross sections are considered in this investigation. The errors for $p\bar{p} \to n\bar{n}$ differential cross sections were obtained by multiplying statistical errors by a factor of 2.2. This rather arbitrary factor was a crude compromise between not including any systematic error at all and multiplying the statistical error by a factor of 4.78. The best fit was obtained with $\chi^2 = 162$ for 94 points (without 7- and 9-GeV/c $p\bar{p} \to n\bar{n}$ data). In this fit, the agreement with experiment decreases with increasing laboratory momentum from 5 to 9 GeV/c for $p\bar{p} \to n\bar{n}$ data. It was found impossible to fit 7- and 9-GeV/c points with $p\bar{p} \to n\bar{n}$ at 5- and 6-GeV/c

$np \to pn$ differential cross section and polarization data. The lower curves at 7- and 9-GeV/c $p\bar{p} \to n\bar{n}$ are predicted ones obtained from the outputs of the best fit with $\chi^2 = 162$ for 96 points. The best fit for 7- and 9-GeV/c $p\bar{p} \to n\bar{n}$ data was obtained with $\chi^2 = 10$ for 24 points. The two fits of curves for 7- and 9-GeV/c $p\bar{p} \to n\bar{n}$ data are plotted in Fig. 4 for comparison. The residue parameters β_t, β, b_{1R}, b_{2R}, $b_{1\rho}$, and $b_{2\rho}$ from the best fit with $\chi^2 = 162$ for 96 points are given by

$$\begin{aligned}
\beta_t &\approx 0.63 \text{ mb}(\text{GeV}/c)^{-2} \\
\beta &\approx 0.38 \text{ mb } (\text{GeV}/c)^{-2} \\
b_{1R} &\approx 0.099 \ (\text{mb})^{\frac{1}{2}} \ (\text{GeV}/c)^{-1} \\
b_{2R} &\approx 0.36 \ (\text{mb})^{\frac{1}{2}} \ (\text{GeV}/c)^{-1} \qquad (8) \\
b_{1\rho} &\approx 1.57 \ (\text{mb})^{\frac{1}{2}} \ (\text{GeV}/c)^{-1} \\
b_{2\rho} &\approx 0.44 \ (\text{mb})^{\frac{1}{2}} \ (\text{GeV}/c)^{-1} \quad .
\end{aligned}$$

Also the above residue parameters from the best fit with $\chi^2 = 10$ at 7- and 9-GeV/c $p\bar{p} \to n\bar{n}$ for 24 points are given by

$$\begin{aligned}
\beta_t &\approx 0.84 \text{ mb } (\text{GeV}/c)^{-2} \\
\beta &\approx 0.39 \text{ mb } (\text{GeV}/c)^{-2} \\
b_{1R} &\approx 0.099 \text{ (mb)}^{\frac{1}{2}} (\text{GeV}/c)^{-1} \\
b_{2R} &\approx 0.36 \text{ (mb)}^{\frac{1}{2}} (\text{GeV}/c)^{-1} \qquad (9) \\
b_{1\rho} &\approx 3.6 \text{ (mb)}^{\frac{1}{2}} (\text{GeV}/c)^{-1} \\
b_{2\rho} &\approx 0.44 \text{ (mb)}^{\frac{1}{2}} (\text{GeV}/c)^{-1} \ .
\end{aligned}$$

From (8) and (9) it is obvious that only β_t and $b_{1\rho}$ differ to a great extent from the two best fits. Although the predicted curves at 7 and 9 GeV/c for $p\bar{p} \to n\bar{n}$ differential cross sections are not in fair agreement with experimental data, the sharp forward peaks and slopes are in fair agreement with data. One has, therefore, to multiply the 7- and 9-GeV/c $p\bar{p} \to n\bar{n}$ calculated points by a factor of 2 in order to get reasonable agreement with experimental points. Figures 1 through 4 summarize the work of this investigation.

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FOOTNOTES AND REFERENCES

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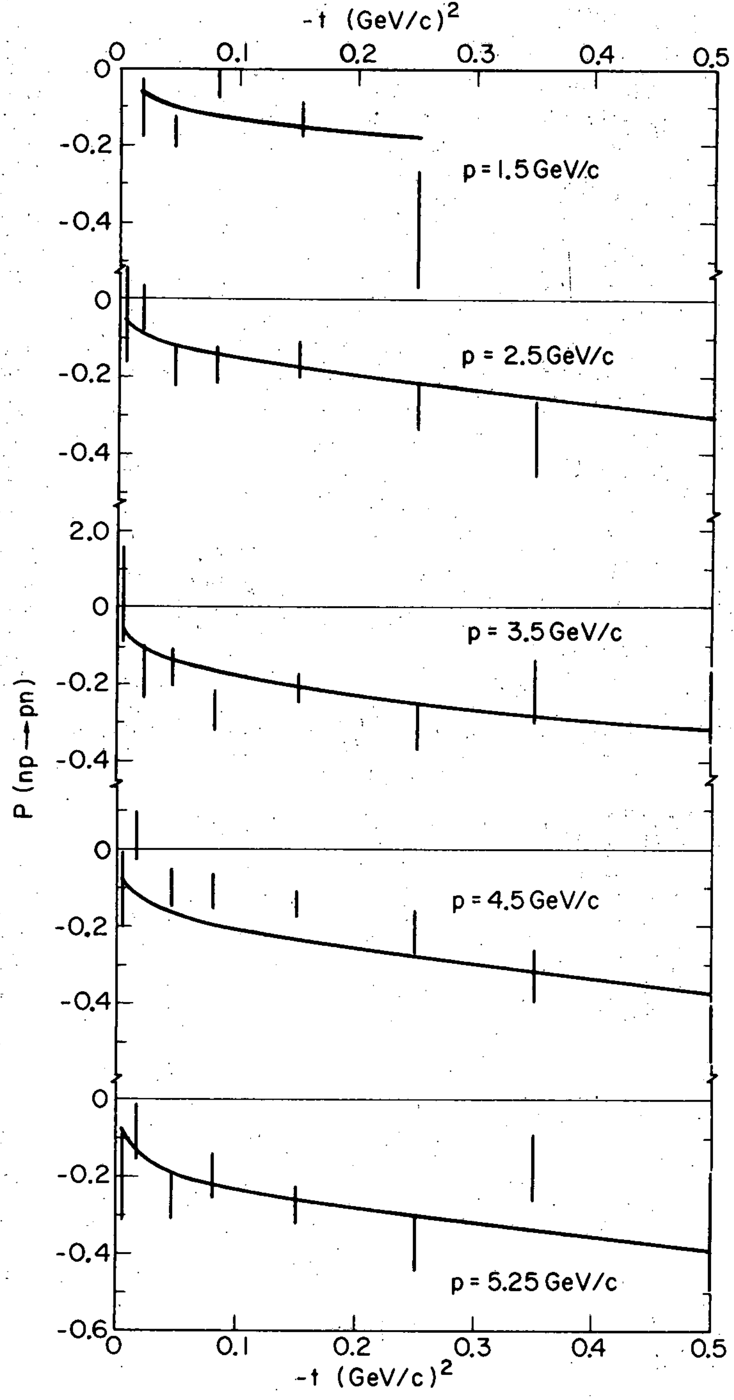
FIGURE CAPTIONS

Fig. 1. Polarization P for np charge-exchange scattering at laboratory momentum 1.5, 2.5, 3.5, 4.5, and 5.25 GeV/c. Data points are taken from Ref. 2.

Fig. 2. $\frac{d\sigma}{dt}$ for np charge-exchange scattering at laboratory momentum 8 GeV/c. Data points are taken from Ref. 10.

Fig. 3. $\frac{d\sigma}{dt}$ for $p\bar{p}$ charge-exchange scattering at laboratory momentum 5 and 6 GeV/c. Data points are taken from Ref. 11.

Fig. 4. $\frac{d\sigma}{dt}$ for $p\bar{p}$ charge-exchange scattering at laboratory momentum 7 and 9 GeV/c. Data points are taken from Ref. 11.



XBL705-3011

Fig. 1.

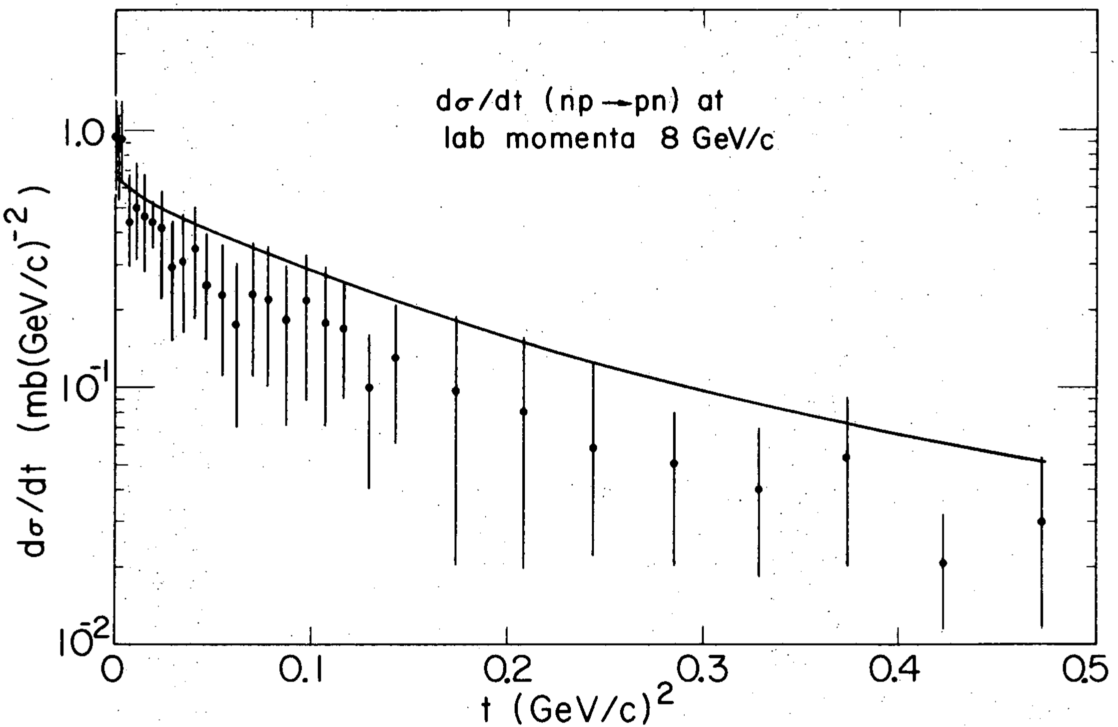


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Fig. 2.

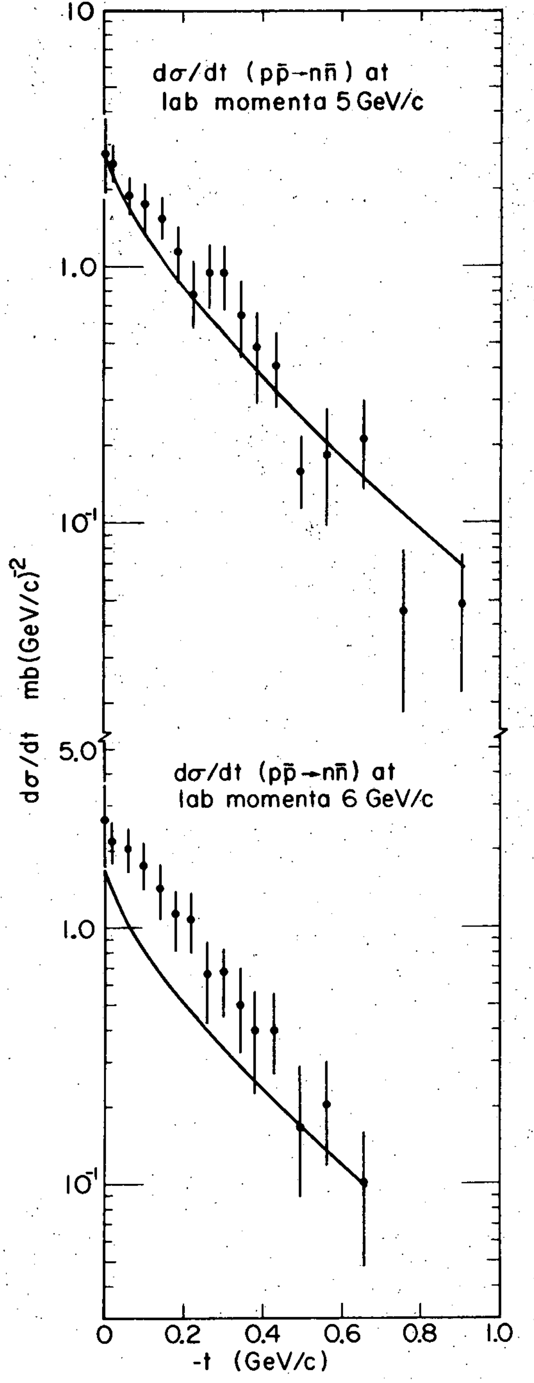

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Fig. 3.

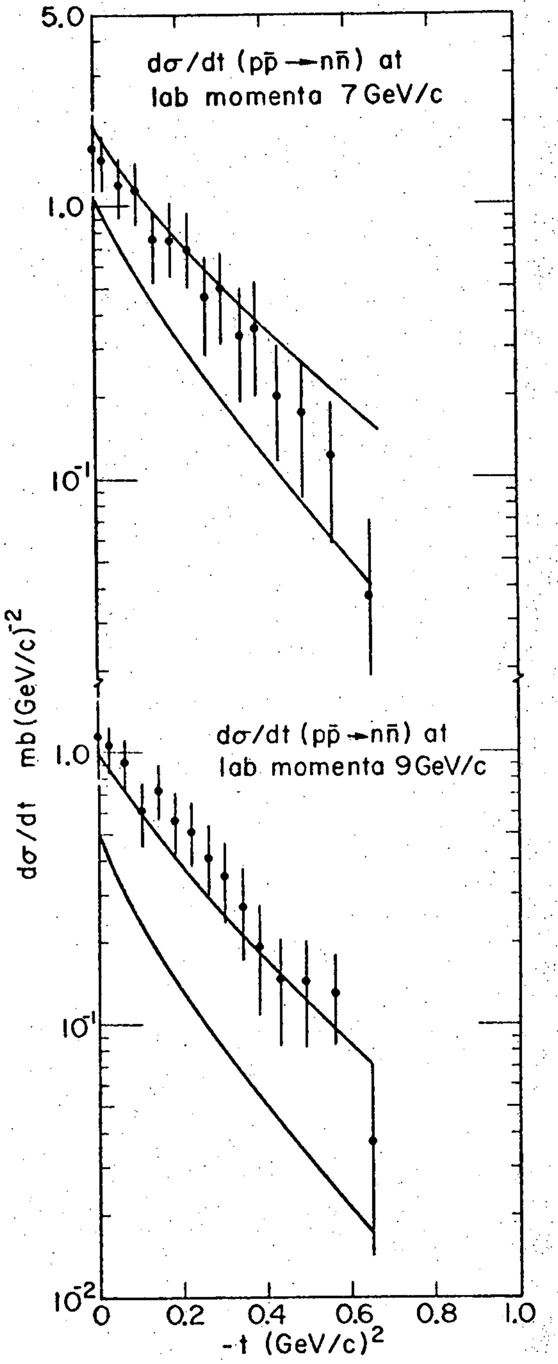

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Fig. 4.

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