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The Chou-Yang model, lattice quantum chromodynamics and hyperon-proton elastic scattering

MOHAMMAD SALEEM, MUHAMMAD RAFIQUE,* HARIS RASHID and FAZAL-E-ALEEM†

Centre for High Energy Physics, *Department of Mathematics, University of Punjab, Lahore 20, Pakistan

† Department of Physics and Astronomy, University of Maryland, College Park, Maryland, USA

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Abstract. The hyperon form factors obtained by using lattice quantum chromodynamics have been used in the Chou-Yang model in conjunction with the proton form factor obtained by parametrization of the experimental data including the most recent results to obtain differential cross-sections of hyperon-proton elastic reactions. The agreement with available experimental data verifies lattice QCD results at low momentum transfers.

Keywords. Chou-Yang model; lattice quantum chromodynamics; hyperon-proton scattering; hyperon form factors; proton form factor.

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1. Introduction

The high energy hyperon-proton elastic scattering has been studied at Brookhaven, Fermilab and CERN and measurements of total and elastic differential cross-section σ_T and $d\sigma/dt$, the slope parameter B and the ratio of integrated and total cross-section, σ_{el}/σ_T, have been made (Bourquin and Repellin 1984 and Pondrom 1985). A number of papers based on various models have been written to give piecemeal explanations of different characteristics of hyperon-proton elastic reactions at high energies (Kamran and Qureshi 1987; Lach and Pondrom 1979 and Saleem *et al* 1982), but a thorough explanation has always been elusive. The advent of quantum chromodynamics (QCD) came as a ray of hope for a comprehensive solution of the problem (Lepage and Brodsky 1979a,b).

Quantum chromodynamics is now recognized as the accepted theory of strong interactions. It is formulated in close analogy to quantum electrodynamics (QED), the highly successful theory of the interaction of photons with electrons. The coupling constant for QED is the fine structure constant α which is 1/137. The perturbative calculations can therefore always be performed as the higher order terms become smaller and smaller at a rapid pace and the expansion series in QED converges at an early stage. On the other hand, the effective coupling constant for QCD, which unlike QED, is a non-Abelian gauge theory and whose quanta, gluons, carry colours, is given by

$$\alpha_s(Q^2)=(g^2/4\pi)/[1+\beta g^2/4\pi)\ln(-Q^2/\Lambda^2)],$$

where $g^2/4\pi$ is the physical coupling constant and β depends upon the group structure. For SU(3):

$$\beta = (33 - 2N_f)/12\pi.$$

Q^2, Λ and N_f denote, respectively, $-t$, the scaling parameter and the number of quark flavours. The effective coupling constant $\alpha_s(Q^2)$ varies with the momentum which a quark transfers to the gluon it emits. At small momentum transfer squared $-t$ it is about unity. The perturbation expansion techniques therefore break down because higher order terms cannot be ignored; the series does not converge. However, for $-t \to \infty$, the coupling constant goes to zero. Therefore for large values of $-t$, the perturbation techniques may be used even in QCD. It will therefore be interesting to find out the limits of applicability of perturbative QCD.

In exclusive reactions, the perturbative hard scattering mechanism and the nonperturbative confinement component compete with each other. QCD tells us that, with increasing momentum transfer, the nonperturbative component falls faster than the perturbative component at least by a factor of $-t$. Then for large $-t$, the perturbative component will dominate and the process is calculable. Conventionally, this dominance occurs when $-t$ is larger than a few $(\mathrm{GeV/c})^2$. However, every large $-t$ gluon exchange, required by the perturbative mechanism of a given exclusive reaction, suppresses the perturbative amplitude by a factor of $\alpha_s(Q^2)$ (Isgur and Llewellyn Smith 1984). On the other hand, in the nonperturbative component, $\alpha_s(Q^2)$ is of order unity and therefore no such suppression is produced. Thus, in an exclusive reaction requiring the exchange of n hard gluons, the requirement for perturbative dominance becomes: $(\alpha_s)^n Q^2$, or equivalently $10^{-n} Q^2$ must be larger than a few $(\mathrm{GeV/c})^2$. This means that asymptopia is simply out of reach in any present accessible momentum transfers; the nonperturbative confinement components will remain dominant.

Although some physicists do not agree with this interpretation, they do admit (Brodsky and Lepage 1981 and Brodsky and Ji 1985) that owing to the technical difficulty of summation over a very large number of Feynman diagrams involved, it is not practicable to make calculations for all $-t$ using QCD-based analysis of two-body exclusive reactions.

As mathematical tools are not available to obtain a QCD-based comprehensive solution of elastic scattering, attempts have to be made for the construction of heuristic models which can explain the experimental data for elastic processes. In this paper, in order to explain the available experimental data on proton-hyperon elastic scattering, we shall employ the Chou-Yang model in conjunction with the form factors of proton and hyperons consistent with experimental data and obtained from lattice-QCD-based computations, respectively.

2. Experimental measurements

The production of hyperon beams at CERN, Fermilab and Brookhaven has opened a new era in particle physics. These beams, which are emanated when a proton beam produced in an accelerator is made to strike a metal or refractory target, have a sufficiently high flux to permit measurements of various hyperon interaction cross-sections in a more or less conventional fashion.

The first measurement of total cross-section for $\Sigma^- p$ was made in 1972 by Badier *et al* (1972) and was restricted to a single result at 18·7 GeV/c with a momentum spread of $\pm 10\%$. The experimental value of $\sigma_T(\Sigma^- p)$ was found as $34{\cdot}0 \pm 1{\cdot}1$ mb. The subsequent measurements of $\Sigma^- p$ total cross-section made by using the hyperon beam at the SPS were published in 1981 by Biagi *et al* (1981). The cross-sections were determined at five momenta from 74·5 to 136·9 GeV/c. A statistical accuracy up to $\pm 10\%$ was obtained for the $\Sigma^- p$ measurements while the systematic uncertainty for each data point is estimated to be of the order of $\pm 0{\cdot}5\%$. As an experimental check these authors also measured the $\bar{p}p$ and $\bar{p}d$ total cross-sections at 101·5 GeV/c, and found good agreement with the results of Carroll *et al* (1976, 1979) obtained at Fermilab. The $\sigma_T(\Sigma^- p)$ measurements of Biagi *et al* (1981) indicate a rising trend with increase in momentum.

The $\Xi^- p$ total cross-section has also been measured (Biagi *et al* 1981) to the same statistical accuracy and with the same systematic uncertainty at 101·5 and 133·8 GeV/c.

The differential cross-section for $\Sigma^- p$ elastic scattering was measured at CERN by Blaising *et al* (1975) and at Brookhaven by Majka *et al* (1976). The CERN experiment covered the range $0{\cdot}12 < -t < 0{\cdot}38$ (GeV/c)^2 at 17·2 GeV/c incident Σ^-, and collected 2826 $\Sigma^- p$ elastic events. The Brookhaven experiment covered the range $0{\cdot}1 < -t < 0{\cdot}23$ (GeV/c)^2 at 23 GeV/c incident Σ^-, and collected 6200 $\Sigma^- p$ elastic events. The CERN group normalized their $\Sigma^- p$ relative to $\pi^- p$ while the Brookhaven group normalized $\Sigma^- p$ cross-section absolutely. The results of the two experiments are shown in figure 1. They show that in the range under consideration, the $d\sigma/dt$ falls exponentially.

Biagi *et al* (1983) published the results of $\Xi^- p$ differential cross-section measurements in the SPS hyperon beam at 102 and 135 GeV/c. The $-t$ range was $0{\cdot}01 < -t < 0{\cdot}6$ (GeV/c)^2 and the corrected number of elastic events was 2280 at 102 GeV/c and 987 at 135 GeV/c. The $d\sigma/dt$ results at these momenta are shown in figures 2 and 3. The values of integrated cross-section are shown in table 1. The values of the slope parameter $B(s, t)$ for $\Xi^- p$ and $\Sigma^- p$ elastic scattering at different momenta are also shown in table 1.

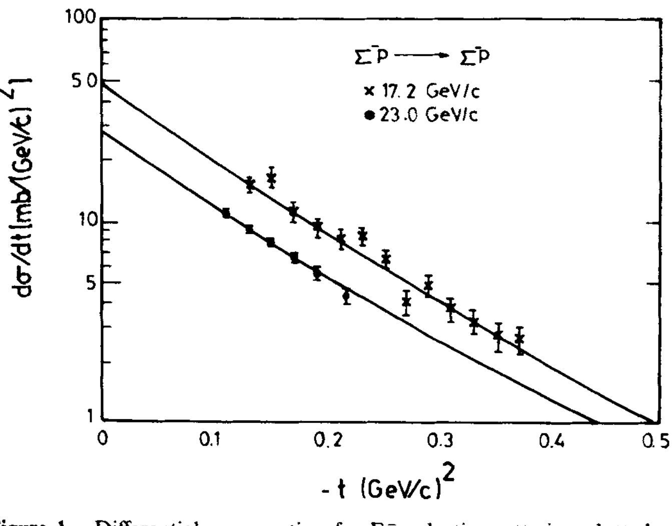

Figure 1. Differential cross-section for $\Sigma^- p$ elastic scattering plotted vs $-t$, at 17·2 and 23 GeV/c. The experimental points have been taken from Blaising *et al* (1975) and Majka *et al* (1976). The solid curves represent the predictions of the model described in the text.

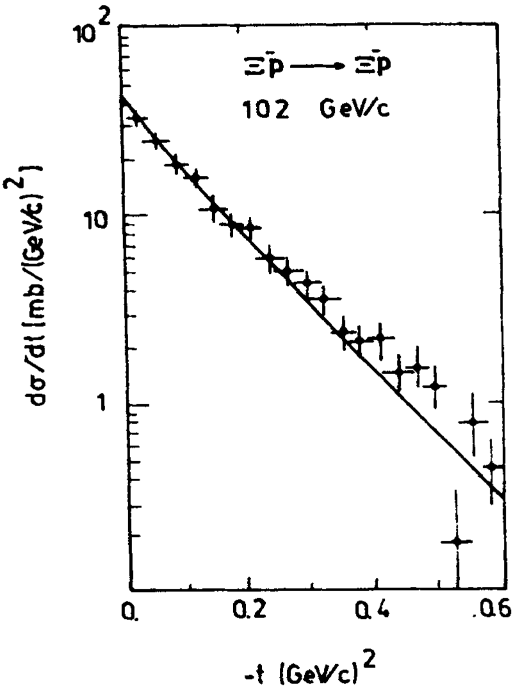

Figure 2. Differential cross-section for $\Xi^- p$ elastic scattering plotted vs $-t$ at 102 GeV/c. The experimental points have been taken from Biagi *et al* (1983). The solid curve represents the prediction of the Chou-Yang model.

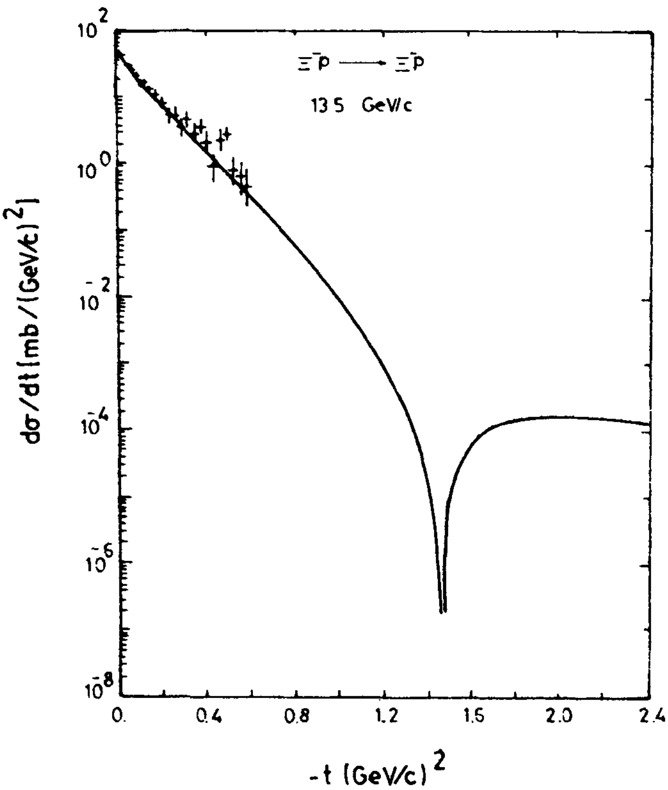

Figure 3. Differential cross-section for $\Xi^- p$ elastic scattering plotted vs $-t$, at 135 GeV/c. The experimental points have been taken from Biagi *et al* (1983). The solid curve represents the prediction of the Chou-Yang model.

Table 1. Theoretical values of σ_{el} and B for charged hyperon-proton elastic reactions for various momenta or total cross-sections. Experimental values wherever available are shown for comparison.

Reaction	Total cross-section σ_T (mb)	Momentum (GeV/c)	σ_{el} (mb)		B (GeV/c)$^{-2}$	
			Expt.	Theor.	Expt.	Theor.
$\Xi^- p \to \Xi^- p$	29·19	102	$4{\cdot}9 \pm 0{\cdot}7$[a]	5·31	$7{\cdot}7 \pm 0{\cdot}4$[a] (0·01–0·42)	8·19, $0{\cdot}01 \leqslant -t \leqslant 0{\cdot}42$
	29·34	135	$5{\cdot}6 \pm 0{\cdot}9$[a]	5·35	$8{\cdot}2 \pm 0{\cdot}5$[a] (0·01–0·42)	8·20, $0{\cdot}01 \leqslant -t \leqslant 0{\cdot}42$
$\Sigma^- p \to \Sigma^- p$	30·37	17·2	—	5·87	$8{\cdot}12 \pm 0{\cdot}35$[b] (0·12–0·38)	8·01, $0{\cdot}12 \leqslant -t \leqslant 0{\cdot}38$
	22·29	23·0	—	3·36	$8{\cdot}99 \pm 0.31$[c] (0·10–0·23)	7·53, $0{\cdot}10 \leqslant -t \leqslant 0{\cdot}23$
	34·14	—	—	7·20	—	8·24, $0 \leqslant -t \leqslant 0{\cdot}1$
$\Omega^- p \to \Omega^- p$	29·88	—	—	4·67	—	9·98, $0 \leqslant -t \leqslant 0{\cdot}1$
$\Sigma^+ p \to \Sigma^+ p$	30·71	—	—	5·65	—	8·48, $0 \leqslant -t \leqslant 0{\cdot}05$

[a] Biagi *et al* 1983; [b] Blaising *et al* 1975; [c] Majka *et al* 1976.

3. The Chou-Yang Model

Chou and Yang (1968) proposed a preliminary version of the eikonal model for proton-proton elastic scattering: this is now known as the Chou-Yang model. They employed an eikonal (or opacity) which was related to the distribution of matter inside the colliding particles. The colliding protons were considered as clusters of particles which pass through each other with attenuation. Elastic scattering then results from the propagation of the attenuated wave function. By assuming that at high energies spins of the interacting particles can be neglected and that the hadronic matter distribution is proportional to the charge distribution on protons, the single scattering amplitude in this model can be written as

$$T = i \int b\,db[1 - \exp(-\Omega(b))]J_0(b\sqrt{-t}),$$

where b denotes the impact-parameter variable and $\Omega(b)$ is called the opaqueness or blackness. The central assumption of the model consists in expressing $\Omega(b)$ as:

$$\Omega(b) = K \int \sqrt{-t}\, d\sqrt{-t}\, G_p^2(t) J_0(b\sqrt{-t}),$$

where $G_p(t)$ is the charge form factor of the proton and serves as an input in the Chou-Yang model. The normalization of T is such that the differential and total cross-sections are given by

$$d\sigma/dt = \pi |T|^2$$

$$\sigma_T = 4\pi \mathrm{Im}\, T(t=0).$$

The parameter K was originally treated as a constant since, when this model was proposed, experimental results gave the impression that the total cross-section for pp was tending to a constant asymptotic value and the assumption that the energy independent eikonal was proportional to the Fourier-Bessel transform of the proton form factor appeared to be justified. The calculated differential cross-section exhibited two dips: one near $-t=1{\cdot}4$ (GeV/c)^2 and the other in the vicinity of $-t=6$ (GeV/c)^2. The dip near $-t=1{\cdot}4$ (GeV/c)^2 has been observed since but the second diffraction minimum has not been seen up to $-t\approx 14$ (GeV/c)^2. However, it was later discovered experimentally that the total cross-section rises with energy (Amaldi 1973 and Amendolia 1973a, b). The continuous growth of the total cross-section through the FNAL-ISR energy range makes it imperative to introduce energy dependence in opacity even at available high energies. Hayot and Sukhatme (1974) suggested that the only way to generalize the model without destroying the underlying physical picture is to make K energy dependent. Then at a particular energy, the value of K is obtained by adjusting it so as to give the experimental value of the total cross-section at that energy. Once K is known, the differential cross-section and other characteristics of the process can be calculated. Throughout this paper the units of K are (GeV/c)$^{-2}$.

Chou and Yang (1979) repeated the Hayot-Sukhatme calculation using the dipole fit for $G_p(t)$. They have conceded that quantitatively agreement between calculated values and experimental data is not particularly impressive. In fact, they did not make any attempt to exhibit comparison of theoretical results and experimental data for differential cross-sections at ISR energies which were the highest available energies at that time. However, it was predicted that with an increase of σ_T from 42·5 mb to 60 mb, the ratio σ_{el}/σ_T should increase from 0·177 to 0·226. This is in qualitative agreement with the now available measurements at ISR and Collider energies. As shown in figure 4, which has been drawn for $\sigma_T=60$ mb, the model predicts a very sharp dip around $-t=1$ (GeV/c)^2 in contrast with the recently measured $d\sigma/dt$ data for $\bar{p}p$ at $\sqrt{s}=546$ GeV ($\sigma_T=61{\cdot}9$ mb) which exhibits a shoulder. The slope parameter was also found to be inconsistent with experiment.

The appearance of the predicted dip in pp elastic scattering at $-t\approx 1{\cdot}4$ (GeV/c)^2 gave a boost to the Chou-Yang model and attempts (Orear 1982; Chou and Yang 1980; Kamran and Qureshi 1986) were made to apply it also to $\pi^- p$ elastic scattering at 200 GeV/c.

It may be pointed out that some serious shortcomings of the model have been exposed from the pp data at ISR energies (Amaldi and Schubert 1980) and $\bar{p}p$ data at collider energies (Fearnley 1985). For small $|t|$, the Chou-Yang model fails to account for the observed slope break near $|t|\approx 0{\cdot}1$ (GeV/c)^2 in pp scattering, and the dip structure in $\bar{p}p$ scattering is very poorly reproduced at collider energies. Chou and Yang, themselves, have realized the shortcomings of their model for $\bar{p}p$, in that they have proposed a new form of eikonal (Chou and Yang 1983). The scope of the model has been critically examined in a recent paper by Patel and Parida (1987). The same type of limitations are expected in hyperon-proton elastic scattering.

No attempt has been made to explain the available experimental data on hyperon-proton elastic scattering at high energies on the Chou-Yang model. This has been due to the reason that the electric form factors for hyperons which would serve as input, were not available experimentally. However, very recently, Samuel and Moriarty (1986) have made theoretical calculations based on lattice QCD to determine electric form factors of hyperons. In fact they used lattice QCD to understand how the strong

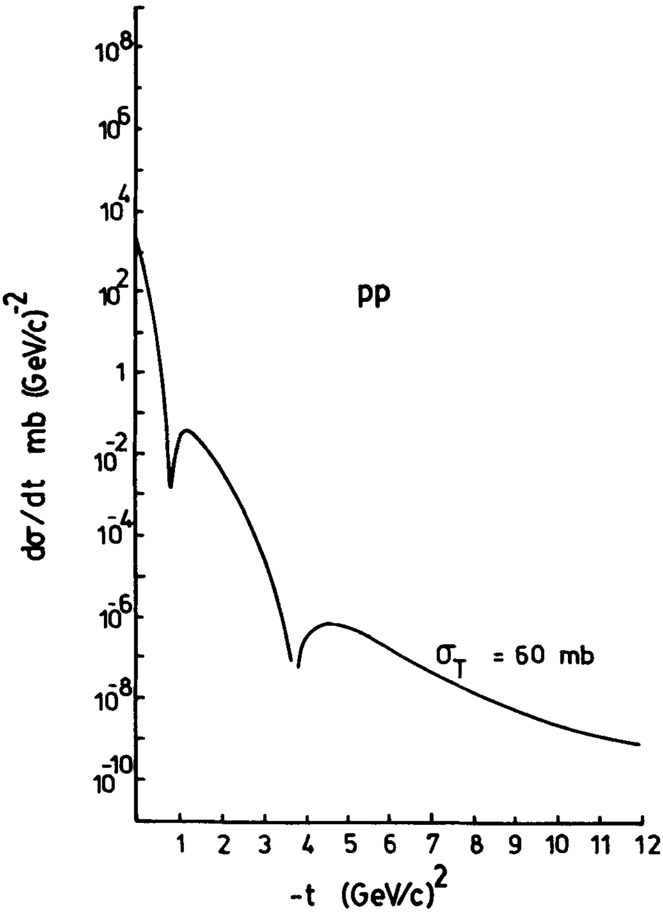

Figure 4. The dip predicted by the Chou-Yang model in the $\bar{p}p$ elastic scattering at $\sqrt{s} = 546$ corresponding to $\sigma_T = 60$ mb around $-t = 1$ (GeV/c)^2.

force binds matter into bound states both for mesons and hyperons. In particular, they have obtained quark-antiquark wave functions which describe the quark probability distributions. By multiplying these by quark charges, charge distributions were obtained from which electromagnetic form factors were computed. Their theoretical computations are in good agreement with the experimental data where such data are available.

Recently, we have used (Saleem *et al* 1986) the Chou-Yang model to explain/predict the experimental data on proton-hyperon elastic scattering by using the dipole form factor for proton. The analysis of proton form factor reveals that the dipole form factor of proton agrees with the experimental data and lattice QCD calculations for small $-t$ but differs drastically from the perturbative QCD calculations. In this paper we shall use a new parametrization for the proton form factor which is consistent with the experimental data and with the large $-t$ behaviour of the proton form factor determined by Lepage and Brodsky (1979a, 1980) on the basis of perturbative QCD, to obtain the various characteristics of hyperon-proton elastic scattering.

Since form factors of the colliding particles are used as input in the Chou-Yang model we now discuss the form factors of proton and hyperons. In this paper, we shall use the Chou-Yang model to obtain various characteristics of hyperon-proton elastic processes.

4. Proton form factor

Unfortunately, at present there is no known theoretical expression which may give values for the electric form factor for proton for all $Q^2 = -t$ to serve as input in the Chou-Yang model. The experimental data therefore has to be parametrized for this purpose. A number of experiments have been performed in the last two decades which yield charge form factor of proton. The experimental progress in the recent past has been particularly significant because high current electron beams in the GeV energy range have become available for nuclear scattering experiments. The specimen data from the earlier measurements (Chen *et al* 1966; Janssens *et al* 1966; Bartel *et al* 1966 and Albrecht *et al* 1966) are shown in figure 5. Recently, Arnold *et al* (1986) have

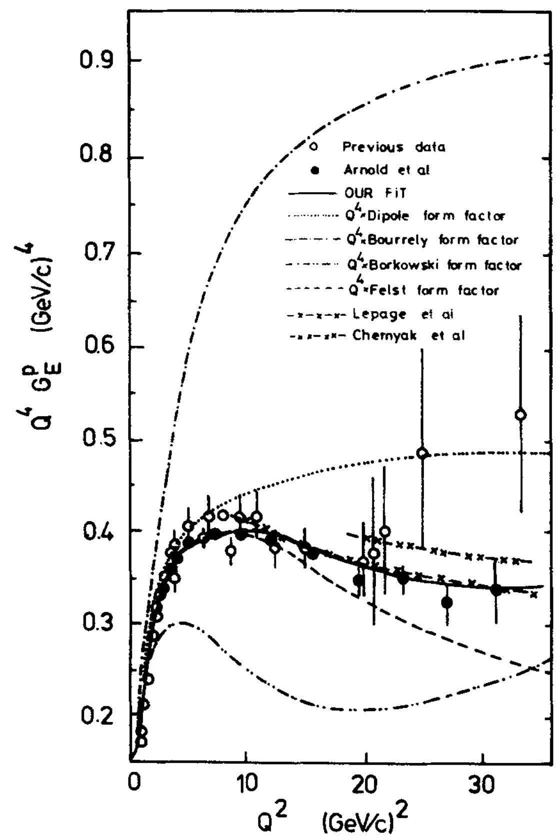

Figure 5. Different parametrizations of proton form factor plotted against Q^2 after multiplying each one of them with Q^4. The experimental data have been taken from Chen *et al* (1986), Janssens *et al* (1966), Bartel *et al* (1966), Albrecht *et al* (1966) and Arnold *et al* (1986).

reported new measurements of elastic electron scattering from protons which significantly increase the precision of the data at large values of the square of the four momentum transfer (Q^2). The data which are in agreement with previous measurements at low Q^2 extend to $Q^2=31{\cdot}3$ (GeV/c)^2. With some modest assumptions, these cross-section measurements can be used to extract the proton magnetic form factor G_p^M, and consequently charge form factor G_p^E by virtue of the scaling relation $G_p^E = G_p^M/\mu_p$, where μ_p is the magnetic moment of the proton. The results have sufficient precision to allow a significant comparison with recent predictions of perturbative quantum chromodynamics (Lepage and Brodsky 1979a, 1980; Lepage *et al* 1983 and Brodsky *et al* 1983). The experimental results obtained by Arnold *et al* (1986) are shown in figure 5 where $Q^4G_p^E$ $(=Q^4G_p^M/\mu_p)$ has been plotted vs Q^2. Since all the parametrizations claim to represent the experimental data for $G_p(t)$, we expect them to yield the same pattern of values for all Q^2. This is not found to be the case. In figure 5, we have also plotted the results obtained from the expression for the dipole form factor (Chou and Yang 1968 and Durand and Lipes 1968), and from the parametrizations of the form factors due to Felst (1973), Borkowski *et al* (1975) and Bourrely *et al* (1984). It is seen that the parametrization of Bourrely *et al* (1984) is far from the experimental data for large Q^2. It agrees with experimental results only up to $Q^2\approx 2{\cdot}5$ (GeV/c)^2, then starts deviating from it and becomes more than twice as $Q^2=31{\cdot}3$ (GeV/c)^2 is approached. The Borkowski form factor (Borkowski *et al* 1975) also agrees with experiment only up to $Q^2\approx 2{\cdot}5$ (GeV/c)^2 and then starts deviating from the measured values, always remaining substantially below them up to $Q^2=31{\cdot}3$ (GeV/c)^2. The Felst form factor (Felst 1973) for proton agrees with experimental values up to $Q^2=15$ (GeV/c)^2. Beyond this value, it lies below the experimental data including the recently measured values by Arnold *et al* (1986). The dipole form factor gives good results, except for the region $10<Q^2<20$ (GeV/c)^2, only if old data for G_p for large Q^2 were taken into consideration. If these data are discarded in favour of the more precise results obtained recently (Arnold *et al* 1986), the dipole form factor does not agree with experiment beyond $Q^2=10$ (GeV/c)^2. It is interesting to note that all the parametrizations described above differ substantially from the large Q^2 results of Lepage and Brodsky (1979a, 1980) and of Chernyak and Zhitnitskii (1984a, 1984b) which are both based on quantum chromodynamics and are also shown in figure 5.

We have ourselves parametrized (Saleem *et al* 1987) the experimental data for proton electric form factor by taking into account the recent precise data for large values of Q^2. The expression obtained is

$$G_p=0{\cdot}73665e^{3{\cdot}1t}+0{\cdot}235e^{0{\cdot}772t}+0{\cdot}267e^{0{\cdot}22t}+0{\cdot}00165e^{0{\cdot}052t}.$$

As shown in figure 5, our parametrization of the form factor is in very good agreement with the experimental data for all $-t$ and is also consistent with the theoretical curve obtained by Lepage and Brodsky (1979a, 1980) using perturbative QCD for large $-t$.

It may be mentioned that Samuel and Moriarty (1986) have recently made use of lattice QCD to calculate, inter alia, the electric form factor for proton for small $-t$. Their results are consistent with various parametrizations and fit the experimental data well although they are slightly above the experimental data in the $Q\approx 0{\cdot}6$ GeV/c range. This indicates the validity of lattice QCD based calculations of proton form factor for small $-t$. This fact has been made use (Saleem *et al* 1986) of in applying the Chou-Yang model to hyperon-proton elastic scattering.

5. Hyperon form factors and lattice QCD

The Chou-Yang model has not been used to explain/predict the various characteristics of hyperon-proton elastic scattering. This is due to the fact that electromagnetic form factors for hyperons were not available. The experimental measurements of these form factors have not yet been made. But, as already pointed out, very recently, Samuel and Moriarty (1986) have used the lattice quantum chromodynamics to compute the electromagnetic form factors. Their theoretical computations are in good agreement with experimental data wherever available. The predictions in the lattice QCD for charged hyperons may be used as good representations of the form factors until experimental determinations become available.

The lattice QCD based computed values of the electromagnetic form factors of hyperons can be well represented by the following expressions:

For Ξ^-: $F(t) = -\exp(1{\cdot}12t + 0{\cdot}035t^2)$

For Σ^-: $F(t) = -\exp(0{\cdot}98t + 0{\cdot}04t^2)$

For Σ^+: $F(t) = 0{\cdot}8\exp(1{\cdot}55t) + 0{\cdot}23\exp(-t^2) - 0{\cdot}03$

For Ω^-: $F(t) = -\exp(0{\cdot}93t + 0{\cdot}045t^2)$

where $-t = Q^2$.

6. Calculations and discussion

Since the total cross-sections at high energies for $\Xi^- p$ and $\Sigma^- p$ scattering have been measured experimentally (Biagi *et al* 1981), we are now in a position to calculate $d\sigma/dt$ and other characteristics of these reactions by using the Chou-Yang model. For other reactions, for given σ_T, predictions can be made for differential cross-sections, etc. Recently, we (Saleem *et al* 1986) have explained/predicted the differential cross-section measurements of hyperon-proton elastic scattering by using the dipole form factor for proton in conjunction with the hyperon form factors as input in the Chou-Yang model. It is found that values of the proton form factor for large values of $-t$ have an insignificant effect on the values of the differential cross-section for small values of $-t$ but they have an appreciable effect on the values of the differential cross-section for large $-t$. Thus for small $-t$ region any parametrization of the form factor which agrees with the experimental values for small $-t$ can lead to good results. Since the dipole form factor for the proton agrees with the experimental data for small $-t$, we were able to obtain good results for elastic hyperon-proton scattering for small $-t$.

It is seen that our parametrization of the proton form factor agrees with the experimental data, with the small $-t$ calculations of Samuel and Moriarty (1986) based on lattice QCD and with the large $-t$ behaviour of the form factor determined by Brodsky and Lepage (1979, 1980) on the basis of perturbative QCD. In view of this, we shall use this parametrization of the proton form factor throughout this work.

For $\Xi^- p$, by adjusting $K = -7{\cdot}65$ so as to yield the total cross-section consistent with the measured value of $29{\cdot}35 \pm 0{\cdot}31$ mb, we obtain the differential cross-section curve which alongwith the experimental data (Biagi *et al* 1983) at 135 GeV/c is shown in figure 3. This is in very good agreement with experiment endorsing the validity of the

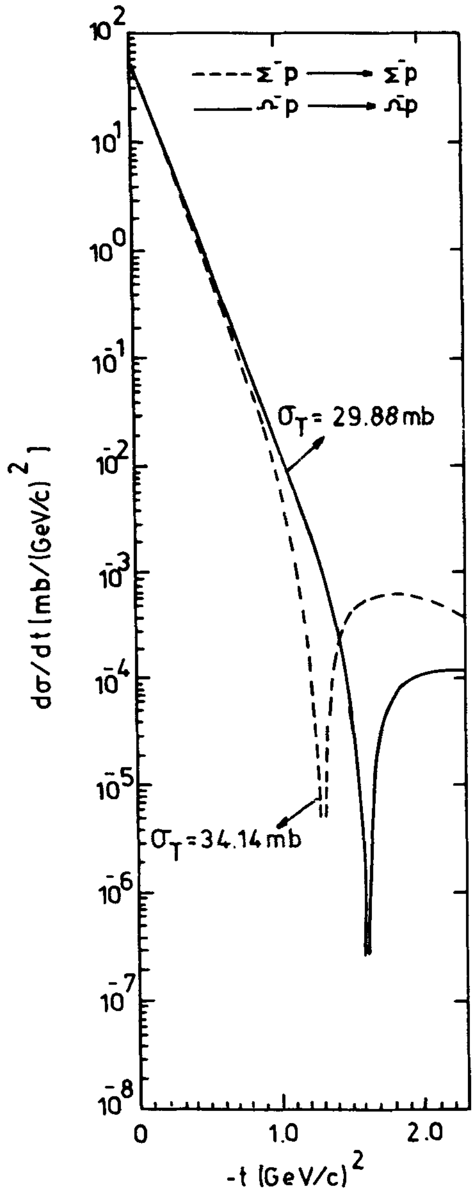

Figure 6. Predictions of the Chou-Yang model for the differential cross-section for $\Sigma^- p$ and $\Omega^- p$ elastic scattering at $\sigma_T = 34{\cdot}14$ and $29{\cdot}88$ mb respectively.

electromagnetic form factor for Ξ^- obtained by using lattice QCD. We also notice that the differential cross-section shows a zero near $-t = 1{\cdot}46$ $(\text{GeV/c})^2$, rises up to $-t \approx 2{\cdot}01$ $(\text{GeV/c})^2$ and then starts falling again. The values up to $-t = 2{\cdot}4$ $(\text{GeV/c})^2$ are shown in figure. In fact, we have not considered the real part of the scattering amplitude. We expect that this real part of the scattering amplitude would partially fill this zero so as to form a dip.

Figure 2 shows the fit of the experimental data (Biagi *et al* 1983) for $\Xi^- p \to \Xi^- p$ with the prediction of the Chou-Yang model at 102 GeV/c, corresponding to $\sigma_T = 29{\cdot}19 \pm 0{\cdot}29$ mb. The value of K is $-7{\cdot}6$.

The differential cross-section for $\Sigma^- p \to \Sigma^- p$ has been measured at 17·2 and 23·0 GeV/c (Blaising *et al* 1975 and Majka *et al* 1976). We have adjusted the values of $K = -8{\cdot}1$ and $-5{\cdot}5$ so as to give the values of σ_T as 30·37 and 22·29 mb respectively. The differential cross-section results obtained by using the Chou-Yang model agree very well with the experimental data. This is shown in figure 1. The σ_T results show that these measurements have been made in the range where total cross-section is falling with energy. The total cross-sections for this reaction are available at various high momenta ranging from 74·5 to 136·9 GeV/c (Biagi *et al* 1981). Therefore the Chou-Yang model can be used to predict differential cross-section and other characteristics of this reaction. We have calculated the differential cross-section at 136·9 GeV/c corresponding to $\sigma_T = 34{\cdot}14$ mb which is obtained by adjusting $K = -9{\cdot}59$. The theoretical curve is drawn in figure 6. The curve exhibits a behaviour similar to that of $\Xi^- p$ elastic scattering. The dip in this case occurs near $-t = 1{\cdot}28$ $(\mathrm{GeV/c})^2$ while bump occurs at $-t \approx 1{\cdot}80$ $(\mathrm{GeV/c})^2$. The $d\sigma/dt$ measurements corresponding to this value of σ_T would further endorse the validity of the Σ^- form factor computed by Samuel and Moriarty (1986).

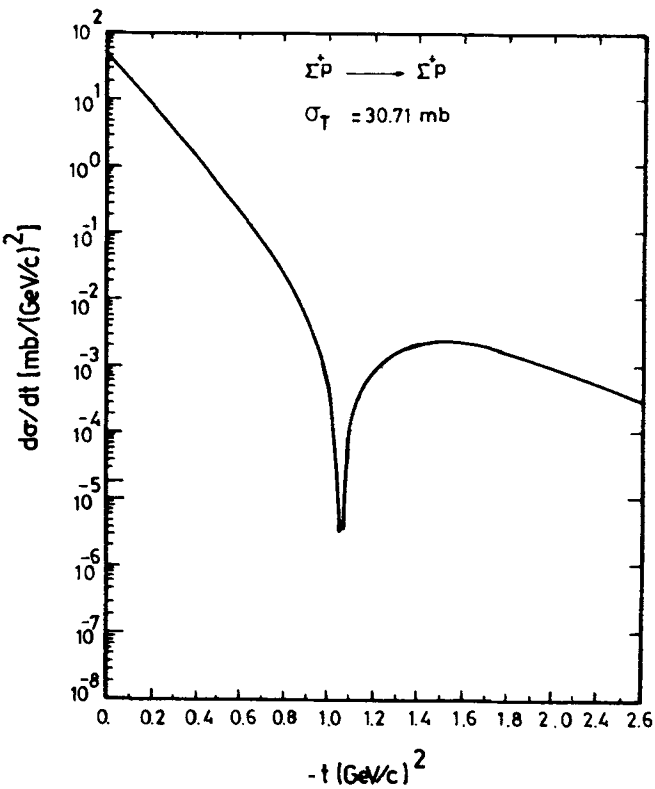

Figure 7. Differential cross-section predictions of the Chou-Yang model for the reaction $\Sigma^+ p$ elastic scattering at $\sigma_T = 30{\cdot}71$ mb.

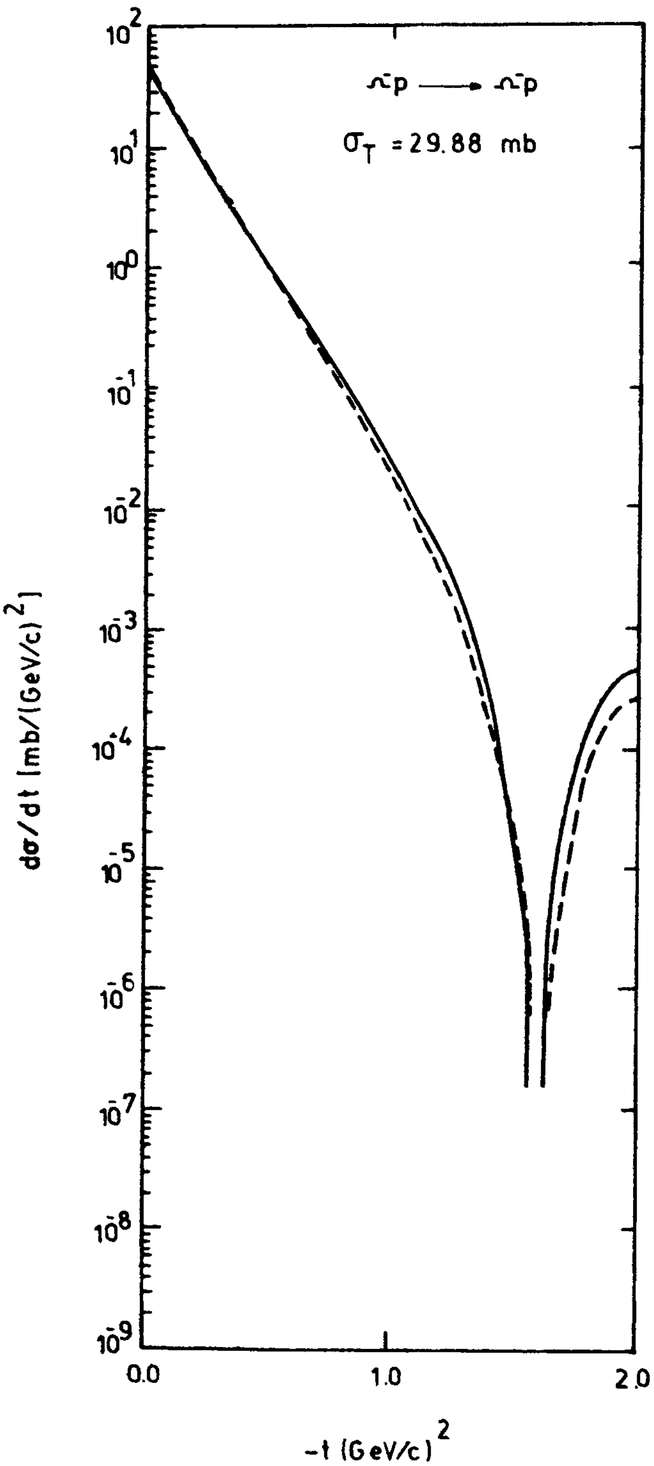

Figure 8. Comparison of $d\sigma/dt$ for Ω^-p elastic reaction obtained by using the dipole parameterization (broken curve) and the one described in this paper (solid curve) for the proton form factor.

Figure 6 also shows the predicted values of the differential cross-section for $\Omega^- p$ elastic scattering corresponding to $\sigma_T = 29{\cdot}88$ mb which is obtained for $K = -8{\cdot}046$. The experimental data are not available for this reaction but we expect a dip (when the real part is included) in the vicinity of $-t = 1{\cdot}65$ (GeV/c)^2.

The experimental data for $\Sigma^+ p$ elastic scattering are also not available. We can however predict differential cross-sections for this reaction at any given total cross-section. Figure 7 shows theoretical prediction corresponding to $\sigma_T = 30{\cdot}71$ mb which is obtained for $K = 8{\cdot}0$. The zero in the differential cross-section curve occurs at $-t \approx 1{\cdot}06$ (GeV/c)^2.

It is well-known that in pp and $\pi^- p$ scattering the predicted results on $d\sigma/dt$ in the model are sensitive to the precise nature of the form factor parametrization. Even though the dipole fit used earlier (Saleem *et al* 1986) and the new fit yield very similar values for $d\sigma/dt$ for small $|t|$, they are found to have different $d\sigma/dt$ for relatively large $|t|$ values. This is shown for $\Omega^- p$ elastic scattering in figure 8. Similar situation prevails in other hyperon-proton reactions. The future measurements in hyperon-nucleon scattering would be able to discriminate one form of parametrization from the other.

The predicted values of σ_{el} and B at momenta corresponding to various total cross-sections and for different reactions alongwith the experimental data wherever available are shown in table 1. The agreement is quite satisfactory.

7. Conclusions

The above analysis shows that for large $-t$ the dipole form factor for the proton is not consistent with the experimental data. Since for small $-t$ the differential cross-section of hyperon-proton elastic reactions is not affected significantly by the large $-t$ behaviour of the proton form factor, good results were obtained for elastic hyperon-proton scattering for small $-t$. However, in this paper our own parametrization of the form factor, which is consistent with the experimental data as well as the QCD based calculation of Lepage and Brodsky (1979a, 1980) for large $-t$, has been used in conjunction with the hyperon form factors obtained by using lattice QCD. The results are again in good agreement with experimental data which are available only for small $-t$.

The agreement between the experimental data for $d\sigma/dt$ and the corresponding results obtained from the Chou-Yang model for small $-t$ endorses the validity of lattice QCD calculations of hyperon form factors. It would be interesting to see what happens at higher momentum transfers.

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