An Analytical Study of Total Cross-section of Proton – Proton And Proton – Antiproton Interactions

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Introduction

Hadron-Hadron scattering cross sections are often used as standards in hadron-nucleus and nucleus-nucleus collisions and in the same time comparisons with theoretical models provide information on the nucleon-nucleon nuclear potential. The existing data especially for angular differential cross-section are scarce for incident hadron energies above 40 (MeV) [l-4]. The imaginary part of the amplitude is obtained from the total cross-section, using the optical theorem [5] while the phase is determined experimentally by measuring the interference with the known Coulomb amplitude [6]. At the CERN SPS Collider, the proton-antiproton total cross-section was measured at $\sqrt{s}$ = 546 (GeV). The experimental result agrees with the prediction of dispersion relations.

To explain and to predict the experimental data, different models and parameterizations have been proposed, which are discussed in the previous work. The present work is devoted to calculate the total cross-sections $\sigma_{tot}(pp)$ and $\sigma_{tot}(p\bar{p})$, the difference between these two cross-sections, $\Delta\sigma$, and the ratio ρ of the real part to the imaginary part of the scattering amplitude. A new approach of geometrical fitting of the data is introduced in the present work to parameterize the total cross-section of hadron-hadron interactions. The modified form of the fitting of the total cross-section is used for proton-proton and proton-antiproton interactions.

Parameterization of Total Cross-sections

The increasing behavior of the total cross-sections of proton-proton and proton-antiproton interactions has been analyzed and several fittings for the experimental data have been proposed by different authors. Some data have been fitted by a linear increase with ln(s) where (s) is the square of center of mass (c.m.) energy, while some other fittings have predicted the $\ln^2(s)$ behavior of σ_{tot}. The commonly used fittings [6,7] are,

$$\sigma_{tot}(pp) = 38.4 + 0.49 \ln^2 (s/122) \quad (l)$$

$$\sigma_{tot}(p\bar{p}) = 4.91 \ln [p+541)/0.3] + (11.1/p^{0.58} \quad (2)$$

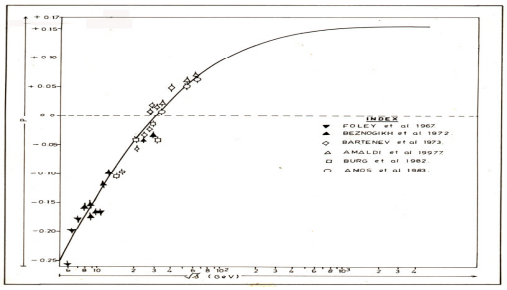
where's' is the squared c.m. energy (GeV) and 'p' is the laboratory momentum (GeV/c). The total cross-section is expressed in milibarns. In the similar manner $\sigma_{tot}(p\bar{p})$ for proton-antiproton interaction might be fitted. With the consideration of $\ln^2$s behavior, the variation of σ_{tot} should have the same form for proton-proton and proton-antiproton interactions, which is not consistent with experimental data (It is seen from Fig.1) also the fittings, given by Eq.1 and Eq.2 are not in agreement with experimental data at high energies above about 200 (GeV). There is, therefore, a need of a new or a modified form of the parameterization of σ_{tot} for proton-proton and proton-antiproton interactions, which might predict the entire experimental data.

Present Parameterization

The present parameterization is done to calculate the total cross-sections σ_{tot} (pp) and σ_{tot} $(p\bar{p})$, the total cross-section difference [$\Delta\sigma_{tot}$ = σ_{tot} $(p\bar{p})$ - σ_{tot} (pp)] the ratio 'ρ' of the real part to the imaginary part of the scattering amplitude. For these calculations we have proposed a new

geometrical approach to parameterize the experimental data.

FIG.1 The Total Cross-Section σ_{tot} at different c.m. energies for pp and $p\bar{p}$ interactions. The data are taken form ref. [2, 5-7]. The curves represent the present parameterization



Total Cross-sections

We find that the variation of the data of σ_{tot} for both the pp and $p\bar{p}$ has parabolic shape (Fig.1). The axis of the parabola, in both the cases, is found inclined towards the axis of c.m. energy. The angles of inclination, in the two cases turn out to be different. In the case of the $p\bar{p}$ interaction, this angle is found to be 82.9° while in the case of pp interaction its value is 80.8°. In other words the entire symmetry of the parabola is rotated by 7.1° in the case of pp and 9.2° in the case of $p\bar{p}$, from the axis representing the σ_{tot} and the c.m. energy,

With these findings we have tried to give a new parameterization of σ_{tot} for pp and $p\bar{p}$ interactions;

(i) **For pp interaction,**

$$\sigma_{tot}(pp) = A\,[\ln s - B\,(\ln s + C)^{1/2} + D\,] \qquad (3)$$

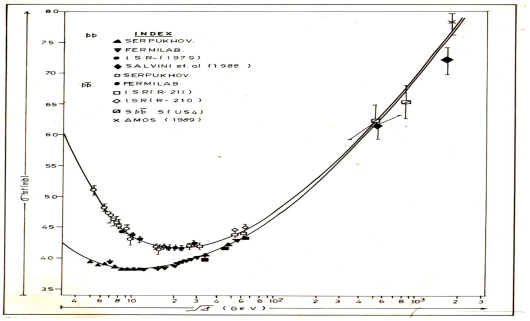
Where A, B, C and D are parameters having values 20.86, 6.22, 4.92 and 16.43 respectively.

(ii) **For $p\bar{p}$ interactions**,

$$\sigma_{tot}(p\bar{p}) = A'\,[\ln s - B'\,(\ln s - C')^{1/2} + D'] \qquad (4)$$

with parameters A', B', C' and D' having values 15.936, 4.47, 1.13 and 6.47 respectively. Eq. 3 and Eq.4 are simply, the equations of parabola and the values of parameters A, B, C, D, A', B', C' and D' are obtained from the two parabola passing through the experimental data of σ_{tot} (pp) and σ_{tot} ($p\bar{p}$). The parabolic shape is considered from the Ref. [6].

FIG.2 Total Cross-section Difference $\Delta\sigma = \sigma_{tot}(p\bar{p}) - \sigma_{tot}(pp)$ (mb) as a function of c.m. energy. The data are extracted from Ref. [6, 8]. The Curve represents the present fit.



Conclusions

1. A new parameterization for the total cross-sections of proton-proton and proton-antiproton interactions is proposed. This proposed parameterization is found in fair agreement with the experimental data.

2. The parameterization of σ_{tot} (pp), σ_{tot} ($p\bar{p}$) is used to find the values of the difference $\Delta\sigma$ between σ_{tot} (pp) and σ_{tot} ($p\bar{p}$) .The new approach of the parameterization of $\Delta\sigma$ is obtained, which is found to be capable of predicting the experimental data.

3. A new fitting for the ratio ρ of the real to the imaginary part of the scattering-amplitude is also obtained from the proposed parameterization of σ_{tot} (pp) and σ_{tot} ($p\bar{p}$). This fitting is also in well consistence with the experimental data.

4. The results of the calculations of σ_{tot} (pp) and σ_{tot} ($p\bar{p}$), $\Delta\sigma$ and ρ approve the concepts of the proposed parameterizations.

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