How fast is the growth of Total Cross Section at High Energies?

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Abstract

Relativistic Heavy Ion Collider and Large Hadron Colliders have special agenda for the measurements of the total cross sections at high energies giving us an opportunity to touch cosmic ray energies. Recent analyses of the cosmic ray data together with earlier experimental measurements at ISR and SPS gives us an insight about the behaviour of this important parameter at asymptotic energies. We will study the growth of total cross section at high energies in the light of various theoretical approaches with special reference to measurements at RHIC and LHC.

1. Introduction

One of the most fundamental parameters, in the realm of hadronic scattering is the total cross section, σ_{T}. It is a common belief that the dynamics of strong interactions, explaining the hadronic scattering processes, would become understandable and simple at high energies. In order to develop a theory, information about the rise of total cross section at cosmic energies would be very important [12]. Experimental information on the behavior of hadronic total cross sections at ultrahigh energies can be obtained from cosmic ray experiments. In this respect, analyses of extensive air showers observations provide an important source of information. The primary cosmic ray data for total cross sections has been observed in the Utah "Fly's Eye" detector [7]. A recent analysis of the same data [4–6] further enhances the need for a comprehensive study at ultrahigh energies. In our study we would briefly give an overall picture of the total cross section with special reference to existence or otherwise of Odderon at very high energies.

2. Theoretical studies

A large amount of work has been carried out using various approaches [18, 19]. In almost all the models attempts have been made to fit the world data for the total cross section. The models give a fit at ISR energies. As we move to

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higher energies of SPS and Fermilab-Tevatron [3], there is a difference of predicted values. This difference becomes visible at LHC/Cosimc Ray energies. The same is symbolically depicted in Fig.1. We will discuss this phenomenon in more detail in the following discussion.

A typical dispersion relation result as done by Augier et al [2] gives total cross section, which is shown in Fig.1. Here data over a wide range of $5 \leq \sqrt{\mathrm{s}} \leq 546$ GeV has been used to fit the parameters. The resulting asymptotic dependence found for the total cross section is.$\sigma_{\mathrm{T}} \approx [\log\,(\mathrm{s}/\mathrm{s}_0)]^{2.2\,\pm\,0.3}$. This analysis favours $\log^2 s$ dependence of σ_T as compared to log s. This kind of behaviour corresponds to the maximum rate of rise of energy allowed by the analyticity and unitarity and is close to the Froissart bound. The extrapolated values for 10 TeV and 14 TeV are 103 ± 7 mb and 112 ± 10 mb respectively. Using dispersion relations, Avila et al [4] have recently presented the results of several parameterizations to two different ensembles of data on pp total cross sections at the highest center-of-mass energies including cosmic-ray information. The results are statistically consistent with two distinct scenarios at high energies. From one ensemble the prediction for σ_T at LHC ($\sqrt{s} = 14$ TeV) is 113 ± 5 mb and from the other ensamble 140 ± 7 mb. In both cases good description of the experimental data is obtained mainly due to large error bars of the cosmic ray measurements. This therefore reiterates the need for precise measurements at RHIC and LHC.

In Regge models [14], increase in the total cross section is approximated by the intercept of the Pomeron trajectory. High energy data is fitted well by this approximation although at ISR contributions from mesonic trajectories are needed [17]. The predicted cross section at 1.8 and 14 TeV is 75 and 95 mb respectively and is consistent with *log*s behaviour. The σ_{T} value is predicted to be significantly higher when Odderon is taken in to account [10–11] within the

Regge framework A comparison of the theoretical results with [11] and without [8] Odderon contribution is shown in Fig.2. It is evident that predictions differ in the RHIC and LHC regions. However, the simple Regge pole picture does not satisfy unitarity. Due to this violation, predictions of this model can only be taken as an upper bound to the predicted cross sections of the future accelerators. Donnachie and Landshoff also obtained a good fit to the data using the exchange of soft Pomeron and the f_2, ω, ρ, and A_2 families of particles [9].

Hufner and Povh [13] gave an elegant account of this parameter in the geometrical picture. Here, total cross section is described by the shape of the colliding hadrons, which varies with energy. The geometrical picture thus gives a good fit to the experimental data for $\sqrt{s} > 20$ GeV. Real part of the radius (which has been taken as energy dependent) increases linearly with logs, which makes predictions to higher energy straightforward. The model predicts $\sigma_{\mathrm{T}} = 73$ and 95 mb respectively for 1.8 and 14 TeV respectively. Other geometrical models make similar predictions. Measurements of RHIC will therefore give us a good

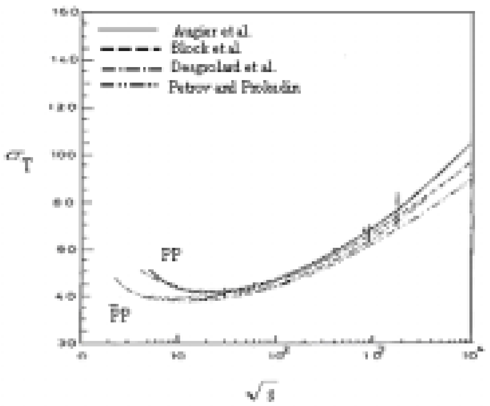

Fig. 1. Predicted of different models- for total cross section for pp and $\overline{\text{p}}$p [1,16].

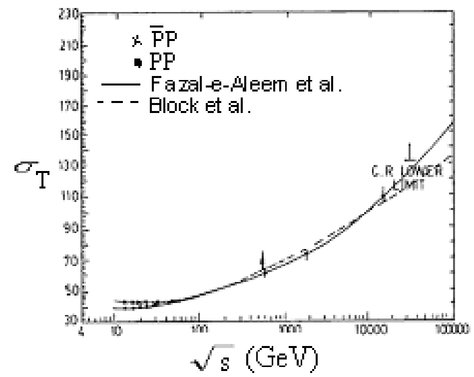

Fig. 2. Total cross section measurements compared with the predictions of models with [11] and without [8] Odderon contribution at current and future energies.

indication of the trend for the total cross section. However, measurements in the near forward direction would be of significant importance at LHC as it would unambiguously establish or definitely contradict $\log^2 s$ behaviour which emerges as a consequence of Odderon. QCD based models generally predict total cross section between 100 and 110 mb at LHC. This is significantly different from the predictions of Odderon-based models. COMPETE collaboration in their most recent work [15] have reported on fits of a large class of analytic amplitude models for forward scattering against the comprehensive data for all available reactions. Their work is based on the results of studies on the fits of the comprehensive analytic amplitude models for the high energy forward scattering amplitude against all available data of the cross sections and real part of the hadronic amplitudes. In order to differentiate the goodness of the fits of many possible parameterizations to a large sample of data, they developed and used a set of quantitative indicators measuring statistical quality of the fits over and beyond the typical criterion of the χ^2/dof. They conclude that these indicators favour models with a universal log^2s Pomeron term.

3. Conclusions

From the above discussion we find that at LHC predictions of different approaches are significantly different (Fig.1). A comparison of these models thus reveals that total cross section values will begin to differ from the RHIC energies. More important would be the difference in the total cross section values for proton-proton and proton-antiproton scattering. This difference will become very prominent at the LHC energies in case of the Odderon contribution. We also observe that the value of total cross section for different models varies from about 95 to about 145 mb. Although cosmic ray data due to large error bars accommodate these values, accurate measurements at LHC will be very important.

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