hep-ph/0205197
IISc/CTS/04-02

Total Cross-sections[a]

R.M. Godbole[1], A. Grau[2], and G. Pancheri[3]

1. Centre for Theoretical Studies, Indian Institute of Science, Bangalore, 560012, India. E-mail: rohini@cts.iisc.ernet.in

2. Centro Andaluz de Física de Partículas Elementales and Departamento de Física Teórica y del Cosmos, Universidad de Granada, Spain. E-mail igrau@ugr.es

3. INFN Frascati National Laboratories, Via E. Fermi 40, I00044 Frascati, Italy. E-mail:pancheri@lnf.infn.it

Abstract

We examine the energy dependence of total cross-sections for photon processes and discuss the QCD contribution to the rising behaviour.

[a]Talk given by G.Pancheri at Photon2001,Ascona, Switzerland

TOTAL CROSS-SECTIONS

ROHINI M. GODBOLE
Centre for Theoretical Studies, Indian Institute of Science, Bangalore,India

AGNES GRAU
Department of Theoretical Physics, University of Granada, Granada, Spain

GIULIA PANCHERI
INFN Frascati National Laboratories, Frascati, Italy

We examine the energy dependence of total cross-sections for photon processes and discuss the QCD contribution to the rising behaviour.

A look at total cross-sections[1] for the processes $pp, p\bar{p}, \gamma p, \gamma\gamma \to hadrons$ immediately raises a number of questions, like: what gives the energy dependence of total cross-sections? Are photon data properly normalized? Are the predictions from factorization[2], quark counting and VMD, consistent with the complete set of data available in the same energy range?

In this talk we describe work in progress towards a QCD Description of the energy dependence of total cross-sections[1,3]. The issue has both a theoretical and a practical interest, as it is necessary to have a reliable model to predict total hadronic cross-sections from $\gamma\gamma$ collisions, which form a bulk of the hadronic backgrounds at the Linear Colliders, in order that these are properly evaluated. Indeed, convoluting the photon spectrum with various predictions for $\gamma\gamma \to hadrons$[4], one finds that those for $e^+e^- \to e^+e^-\ hadrons$ differ by 30−40%. In order to reduce this uncertainty, it is necessary to drastically reduce the range of variability present in $\gamma\gamma$ collisions, where models can differ by more than a factor two in their predictions for the total cross-section. These differences are due to those in the absolute normalization and the slope with which the total cross-section rises in these models, all being consistent with the current data.

In general the task of describing the energy behaviour of total cross-sections can be broken down into three parts: i) the rise, ii) the initial decrease, iii) the normalization. The rise alone can be obtained

- in the Regge-Pomeron model[5], with $\sigma_{total} = Xs^{\epsilon} + Ys^{-\eta}$, through s^{ϵ}, although it does not seem that the same power ϵ fits protons and photons[6]: one finds $\epsilon_{pp} = 0.08, \epsilon_{\gamma\gamma} = 0.1 - 0.2$. To overcome this problem, it has been suggested to add more power terms, thus increasing the number of free parameters.

- from factorization[2], but there remain the problem of getting the proton-proton cross-section from first principles
- using the QCD calculable contribution from the parton-parton cross-section, whose total yield increases with energy[7]
- a combination of the above two

In the Minijet Model[1], the rise is driven by the LO QCD contribution to the integrated jet cross-section

$$\sigma_{jet} = \int_{p_t min} \frac{d^2\sigma_{jet}}{d^2\vec{p}_t} d^2\vec{p}_t = \sum_{partons} \int_{p_{tmin}} d^2\vec{p}_t \int f(x_1)dx_1 \int f(x_2)dx_2 \frac{d^2\sigma^{partons}}{d^2\vec{p}_t}$$

which depends on the densities and very dramatically on p_{tmin}, the minimum transverse momentum cut-off. To ensure unitarity, the mini-jet cross-sections are embedded into the eikonal formulation, which gives the Eikonal Minijet Model in LO QCD (EMM)

$$\sigma^{\text{inel}}_{pp(\bar{p})} = 2\int d^2\vec{b}[1 - e^{-n(b,s)}], \qquad \sigma^{\text{tot}}_{pp(\bar{p})} = 2\int d^2\vec{b}[1 - e^{-n(b,s)/2} cos(\chi_R)]$$

In the EMM, one puts $\chi_R = 0$. To proceed further, one can separate the non perturbative from the perturbative behaviour, with $n(b,s) = n_{NP}(b,s) + n_P(b,s)$, and then factorize b vs. s behaviour. The simplest model has $n(b,s) = A(b)[\sigma_{soft} + \sigma_{jet}]$.

Taking the matter distribution A(b) to be the convolution of the Fourier transform of the form factors of the colliding particles, the s-dependence is then entirely contained in σ_{soft}, parametrized so as to reproduce the low-energy data, and σ_{jet}, which is given by the LO QCD jet cross-sections.

The consistency between $\gamma\, p$ and $\gamma\gamma$ can be studied by applying the EMM model with same set of parameters to the relevant data. The total cross-section predictions for photon processes in the EMM model include the probability P_{had} for the photon to behave like a hadron, a probability expressed through a parameter obtained using VMD, $P_{had} \approx 1/240$. With the EMM for the $\gamma\, p$ total cross-sections, using for A(b) the convolution of proton (dipole) and pion-like (monopole with scale k_0) formfactor, one obtains a band of values symmetrically encompassing all the data. We then apply the same formalism and the same parameters to the $\gamma\gamma$ case, and find the band shown in Fig.(1), which spans all the data, but with the lower bound slighly below the data, especially at low energies. We also see that the Aspen model

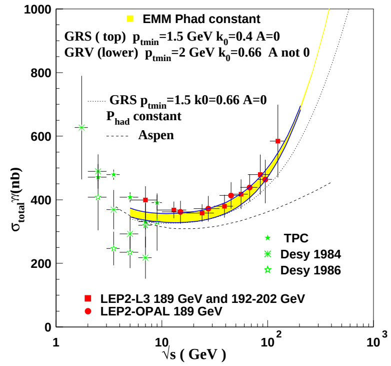

Figure 1. Predictions and data on total $\gamma\gamma$ cross-sections.

prediction[2], obtained using factorization, is clearly lower than the data. The comparison between $\gamma\ p$ and $\gamma\gamma$ indicates the existence of a problem in the normalization of $\gamma\gamma$ data, first noticed in[2]. Indeed one can see that using VMD and Quark Counting to put proton and photon data on same scale, $\gamma\ p$ falls in place, $\gamma\gamma$ data remain higher than the rest, basically the same result suggested by the EMM model. From these considerations, it would appear that data for $\gamma\gamma$ total x-section are overestimated by about 10%. We also notice that the normalization problem can confuse the issue of the rise.

Further refinements of the minijet model are possible, using soft gluon summation to include initial state acollinearity among partons. The model proposed[3] to do this introduced an energy dependence in the impact parameter distribution, namely

$$n(b,s) = A_{soft}(b)\sigma_{soft} + A_{PQCD}(b,s)\sigma_{jet}^{LO}$$

with $A_{PQCD}(b,s)$ given by the Fourier transform of the transverse momentum distribution of the initial parton pair, due to initial state soft gluon radiation. Using the QCD resummation techniques, this leads to

$$A_{PQCD}(b,s) \equiv \frac{e^{-h(b,s)}}{\int d^2\vec{b}e^{-h(b,s)}},\ with\ h(b,s) = \int_{k_{min}}^{k_{max}} d^3 n_{gluons}(k)[1 - e^{i\vec{k}_t\cdot\vec{b}}]$$

k_{max}, which is energy dependent, can be taken to be the kinematic limit, averaged over the parton densities, while $k_{min} = 0$. The difficulty in using $k_{min} = 0$ stems from our ignorance on $\alpha_s(k_t)$ as $k_t \to 0$. To proceed further one needs to make models for this behaviour. Our model uses a singular but integrable parametrization for α_s in the infrared limit. This introduces a strong energy dependence in the impact parameter distribution, physically understandable as follows. As the energy increases, one probes smaller and smaller k_t values. The more singular α_s is, the more is the emission of soft gluons making the initial partons more acollinear resulting in loss of parton luminosity and a decrease in the jet cross-section. This effect is what one might call the *taming of the rise*. We show in Fig.(2) a preliminary result with GRV densities and $p_{tmin} = 2\ GeV$.

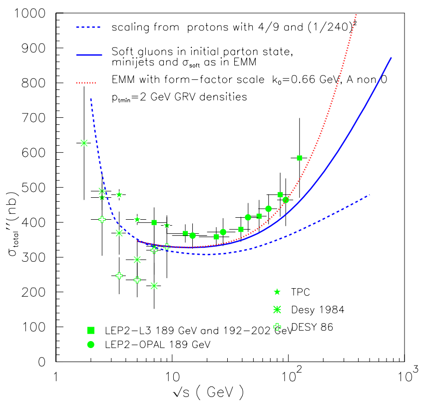

Figure 2. Effect of resummation on total cross-sections.

References

1. R. M. Godbole and G. Pancheri, Phys. Lett. **B435** (1998) 441, Eur.Phys.J.C19:129-136,2001.
2. M. Block, E. Gregores, F. Halzen and G. Pancheri, Phys.Rev.**D60** (1999) 054024.
3. A. Grau, G. Pancheri and Y. N. Srivastava, Phys. Rev. **D60** (1999) 114020.
4. A. de Roeck, R.M. Godbole and G. Pancheri, LC-TH-2001-030.
5. A. Donnachie, and P.V. Landshoff, P.V., Phys. Lett. **B296**, 227 (1992), **hep-ph/9209205**.
6. A. de Roeck, hep-ph/0101076.
7. T.Gaisser and F.Halzen, *Phys. Rev. Lett.* **54**, 1754 (1985)