An Analytical Study of Jet Cross-Section in Proton-Proton Interactions

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Introduction

The concept of jets of a pair of jets of approximately equal and opposite large transverse momenta, produced by some dynamical mechanism[1]. The jets than fragment into the syatem of hadrons and thus multiparticle production takes place. This is the consequence of the character of the strong interaction between quarks and gluons.

The data from [2] and FERMILAB [3] indicate that the jets, observed in large p_T hadron-hadron collisions, similar to those processes, initiated by leptons(i.e. e^+e^-, ep and υp processes) fragment or cascade into a collection of hadrons, moving roughly, in the direction of the original quarks [4]. At higher energies, it was expected that jets, produced in hadronic collisions, would be distinctive, since the transverse momentum of the scattered parton, would be large enough to make jet.

In the present work, an attempt is made to discuss the mechanism of jet production in ptoton-proton interactions and also to calculate the jet production cross-section in different sub processes [5].

Jet Cross-Section

The jet production in hadronic collisions is interpreted in the frame work of the parton model [6] as hard scattering among the constituents of the incident hadrons since the initial state contains quarks, antiquarks and gluons, there are several elementary sub processes that can contribute to jet production. For each sub process the scattering cross-section calculated to first order in the strong running coupling constant α_s, is given by the following expression [7].

$$\frac{d\sigma}{d\cos\theta} = \frac{\pi\alpha_s^2}{2s}|M|^2 \qquad \text{-------------} (1)$$

where θ is the scattering angle, s is the square of centre of mass energy of the two partons, $|M|^2$ is expressed by different expressions, depending upon the various sub processes [8] and π = 3.14 . These sub processes are given in the table 1. In QCD, the running coupling constant $\alpha_{s,}$ is calculated from the relation $C = 4\ \alpha_s /3\pi$ [9] where C is a energy dependent parameter. It may also related to α, as $\alpha_s = (1- \alpha)$, where α is well known fine structure constant [10]. In the case of proton-proton interactions, since the proton consists of quarks and gluons only, the possible sub processes are only four viz. qq'→ qq', qq→ qq, qg→ qg and gg→ gg. The jet cross-section is calculated, in this work, for these sub processes, using equation (1).

Tables and Figure

Table 1: Formulae and Magnitudes of various sub processes.

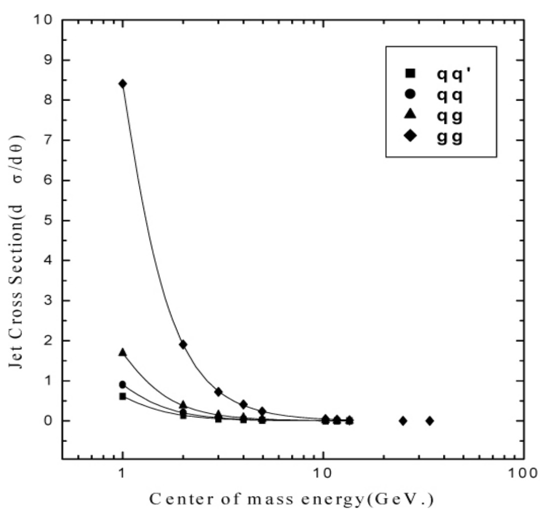
Sub Processes	$\|M\|^2$	$\|M\|^2$ at $\theta=90^0$
qq'→ qq' $q\bar q \to q\bar q$	$\frac{4}{9}\left(\frac{s^2+u^2}{t^2}\right)$	2.22
qq→ qq	$\frac{4}{9}\left(\frac{s^2+u^2}{t^2}+\frac{s^2+t^2}{u^2}\right)-\frac{8}{27}\frac{s^2}{ut}$	3.26
$q\bar q \to q'\bar q'$	$\frac{4}{9}\left(\frac{t^2+u^2}{s^2}\right)$	0.22
$q\bar q \to q\bar q$	$\frac{4}{9}\left(\frac{s^2+u^2}{t^2}+\frac{t^2+u^2}{s^2}\right)-\frac{8}{27}\frac{u^2}{st}$	2.59
$q\bar q \to gg$	$\frac{32}{27}\frac{u^2+t^2}{ut}-\frac{8}{3}\frac{u^2+t^2}{s^2}$	1.04
$gg \to q\bar q$	$\frac{1}{6}\frac{u^2+t^2}{ut}-\frac{3}{8}\frac{u^2+t^2}{s^2}$	0.15
qg→ qg	$-\frac{4}{9}\frac{u^2+s^2}{us}+\frac{u^2+s^2}{t^2}$	6.11
gg→ gg	$\frac{9}{2}\left(3-\frac{ut}{s^2}-\frac{us}{t^2}-\frac{st}{u^2}\right)$	30.38

In the table-1, here s represents the square of centre of mass energy of interacting partons. The parameters u and t are related to s as,
u = s (1+ cosθ)/ 2 and t = - s (1 – cosθ)/ 2

Table 2: Jet cross-section at different centre of mass energies for the different sub processes, used in the case of proton-proton interactions.

$\sqrt{s}$ (Gev.)	α_s	$\left(\frac{d\sigma}{d\theta}\right)_{qq'}$	$\left(\frac{d\sigma}{d\theta}\right)_{qq}$	$\left(\frac{d\sigma}{d\theta}\right)_{qg}$	$\left(\frac{d\sigma}{d\theta}\right)_{gg}$
1	0.42	0.614	0.902	1.692	8.413
2	0.40	0.139	0.204	0.383	1.907
3	0.37	0.053	0.077	0.145	0.725
4	0.37	0.029	0.043	0.082	0.408
4.95	0.35	0.017	0.025	0.047	0.238
10.25	0.32	0.003	0.004	0.009	0.046
11.7	0.30	0.002	0.003	0.006	0.031
13.5	0.25	0.001	0.001	0.003	0.016
25	0.18	--	--	--	0.002
33.95	0.16	--	--	--	0.001

Fig. 1 Variation of jet cross-section in the case of proton-proton interactions as a centre of mass energy. The curves represent the present work for the different sub processes.



Result and Discussions

The results of the present work are presented in table-2 and the variation of jet cross-section, in different sub processes, with centre of mass energy is plotted in the Figure-1. The range of centre of mass energy is considered from 1 Gev. to 33.95 Gev. In all sub processes, the values of jet cross-section decreases on increasing the centre of mass energy. In the three sub process viz. qq'→ qq', qq→ qq, qg→ qg, the gets are found to appear up to only 13.5 Gev. But in the case of gg→ gg jets may found to be appearing up to 33.95 Gev.

Since the value of $|M|^2$ for gg→ gg is largest (i.e. 30.38), the jet cross-section for this sub process is expected to be dominated which is found to be consistent with our present work. Also found to be consistent with our present work. Also the running coupling constant α_s decreases on increasing the centre of mass energy, and hence the probability of jet production decreases with increase in centre of mass energy.

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