An Analytical Study of Jets and Multiparticle Production in Hadron – Hadron and Hadron – Nucleus Interactions

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Introduction

During last three decades or so, the jets and multiparticle production in hadron – hadron and hadron – nucleus collisions have been the study of great interest [1-3]. The data from ISR [4-6] and FERMILAB [7-9] indicate that the jets observed in large four momentum transfer hadron – hadron collisions are similar to those initiated by leptons. The jets observed in both the cases are thought to arise from quarks and fragment into a collection of hadrons, moving roughly in the direction of the original quarks. The study of hadron – hadron and hadron – nucleus collisions throws light on deconfining phase transition from hadronic jet to Quark – Gluon Plasma (QGP). The nuclear targets allow to analyses the hadron – nucleon or hadron – hadron system by a second scattering, shortly after the primary one. The average shower particle multiplicity thus, plays an important role in the production mechanism.

For the explanation of jet formation many theoretical models have been suggested and many attempts were made to parameterize the jet cross – section. In the beginning the studies of high energy physics were mainly confined to proton – proton interactions only, due to the complex dynamics of multiparticle production. But during recent years, a considerable interest in the study of multiparticle production, in hadron – hadron and hadron – nucleus interactions at high energies has grown up. The main reasons of the interest in this field are as following,

(a) The phenomenal success of Gluber theory of multiparticle scattering to account for the nuclear effects in hadron – nucleus collisions.

(b) The possibility of measuring hadron – nucleon cross – section for the hadrons, which decay, through electromagnetic and weak interaction processes.

(c) The investigation of multiparticle production in hadron – nucleus collisions may provide information's about the mechanism of hadron – hadron collisions. It offers a possibility of studying the space - time development of particle production processes.

In the jet formation, a pair of jets of approximately equal and opposite large transverse momentum is produced by some dynamical mechanism. The jets, then, fragment into systems of hadrons and thus, multiparticle production takes place. The quarks, constituents of hadrons, materialize as jets, showing kinematical features, which are typical of reactions involving hadron constituents, acting to a large extent independently of one another. Since the initial state contains quarks, anti-quarks and gluons, there are several elementary subprocesses, which can contribute to jet production. For each sub process, the scattering cross – section may be given as

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

where θ → scattering angle and s is the square of total c.m. energy. $|M|^2$ is square of the matrix element, has explicit expressions e.g. $qq' \to qq'$,

$$|M|^2 = \frac{4}{9}\left[\frac{s^2+u^2}{t^2}\right]$$

The experimental studies of hadron – hadron and hadron – nucleus collisions, have generally been carried out either by employing Counters or Emulsion Technique and Hydrogen Bubble Chamber. The characteristics of secondary particles are expected to reveal information regarding the process as taking place during the interaction. Various models have been proposed for the description of multiparticle production in high energy collisions of elementary particles. There are two basic ingredients, which form thev basis of the models of particle production in hadron – hadron and hadron- nucleus collisions,

(a) A model for the multiparticle production in hadron – hadron collisions.
(b) Its projection to the case of nuclear collisions, taking into account of the nuclear effects.

Several physicists [9-12] proposed different parameterizations regarding the mechanism of multiparticle production. The mean charged multiplicity $(\langle n_{ch}\rangle_{hh})$ is an important parameter for such studies. The number of charged particles produced in an interaction for a given sample, with velocity $\beta \geq 0.7$ is the multiplicity of relativistic charged particles. The study at high energy reveals that the number of relativistic charged particles produced in any collisions, increases on increasing the beam energy. A slow increment in this number with target mass number (A_T) has also been observed.

Present Parameterization

In the present work, an effort is made to analyse the experimental data on jet cross – section, multiparticle production and on mean normalized multiplicity (R_A) in hadron – hadron and hadron – nucleus collisions. The mechanisms of jet production and multiparticle production have been included in our study and the different models of such events have been discussed. The various fitting and parameterizations of mean charged multiplicity in hadron – hadron and hadron – nucleus interaction processes are analysed and a new modified form of such parameterizations have been proposed in the proposed work. The modified form of mean charged multiplicity in hadron – hadron interactions has the following form [13],

$$\langle n_{ch}\rangle_{hh} = A + B\,(\ln\sqrt{s_A}) + C\,(\ln\sqrt{s_A})^2 \text{ --------- (2)}$$

here $\sqrt{s_A}$ represent the available c.m. energy i.e. $\left(\sqrt{s_A} = \sqrt{s} - m_p - m_t\right)$, $\sqrt{s}$ the centre of mass energy, m_p the mass of projectile and m_t the mass of target hadron. The values of the parameters A, B and C are considered on the basis of interaction processes. Here we have introduced a new parameter D, called Cascade parameter. The modified form of mean charged multiplicity in hadron – nucleus interactions has the following form [14],

$$\langle n_{ch}\rangle_{hA} = \upsilon\left[A + B\ln\left(\frac{\sqrt{s_A}}{\upsilon}\right) + C\left\{\ln\left(\frac{\sqrt{s_A}}{\upsilon}\right)\right\}^2 + D\left\{\ln\left(\frac{\sqrt{s_A}}{\upsilon}\right)\right\}^3\right] \text{ -- (3)}$$

where υ is the number of nucleons lying in a tube of the target nucleus, participating in the interacting process.

One of the most important uses of the mean charged multiplicity of relativistic charged particles is in estimating the mean normalized multiplicity 'R_A' which is defined as the ratio of the mean numbers of relativistic charged particles produced in hadron – hadron and hadron – nucleus interactions respectively, at the same incident energy i.e.

$$R_A = \langle n_s\rangle_{hA} / \langle n_{ch}\rangle_{hh} \text{ ------------- (4)}$$

where $\langle n_s\rangle_{hA}$ represents the mean charged multiplicity in hadron – nucleus interactions and $\langle n_{ch}\rangle_{hh}$ represents the mean charged multiplicity in hadron – hadron interactions.

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References

[1] The ALEPHI Collaboration, CERN-PPE/90-196 (1990)
[2] V. D. Rusov and I. V. Sherf Nucl. Phy.A 764 (2006)460
[3] S. J. Brodsky, *etal*; Preprint SLAC-PUB 5711(Dec.1991)
[4] F. Abe, *etal*; FERMILAB Preprint FNAL-PUB 91/181 (1991)
[5] C.Stewart, *etal*; FERMILAB Preprint FNAL-PUB 90/22E (1990)
[6] R. J. Glaubar, 'Lect. In Theo. Phys.' W. E. Brittin and L.G.Dunham V-1 (N.Y.1959)315
[7] C.S.Lam, *etal*; Int J. Mod. Phys.AVol.5 No.12 (1990) 2411
[8] L.Frankfurt, *etal*; Phys.Lett. B 616(2005) 59
[9] E. Albini, *etal*; Nucl. Phys. B 84(1975)269
[10] M. Shyam, *etal*; Phys. Lett. B 164(1985)189
[11] N. Amos, *etal*;Phys.Lett.120B 460-64(1983)
[12] L. DiLella, Ann. Rev. Nul. Part. Sci. 35 (1985)107
[13] A. Kumar,*etal*;Proc. DAE-BRNS Symp.on Nucl. Phys.Vol.50(2005)406
[14] Anil Kumar,*etal*;Proc. DAE-BRNS Symp.on Nucl. Phys.Vol.51(2006)515