Emission of large-$p_T$ particles in $p$-nucleus and nucleus-nucleus collisions

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Abstract. The observed dependence of the yield of high $p_T$ particles on the atomic number $A$ of the target and the incident energy, in $p$-$a$, $a$-$a$ and $p$-nucleus collisions, is explained in a coherent tube model.

Keywords. High $p_T$ particles; proton-nucleus; nucleus-nucleus collision.

1. Introduction

Large $p_T$ reactions have been studied extensively (Jacob and Landschoff 1978; Antreasyn et al 1979; Cronin et al 1975; Bromberg et al 1979) using both nucleons and heavy nuclei as targets. The latter, however, have been used until quite recently more for convenience rather than for any particular merit in their use to yield new physics of intrinsic value. Now there has come a shift in our understanding of the importance of $p$-nucleus and nucleus-nucleus collisions due to two factors. Firstly, the few existing results in such collisions have shown rather anomalous features (Bromberg et al 1979). Secondly there have been several speculations (Domokos and Goldman 1981; Anishetty et al 1980) about the production of exotic forms of nuclear matter or dense quark-gluon plasmas in heavy ion collisions at highly relativistic energies and a possible similarity of these states with conditions that existed during the first few seconds after the 'big bang' which created the universe.

The purpose of this paper is to present a model for large $p_T$ reactions involving heavy nuclei and to explain the data on $p$-nucleus collisions at Fermilab (Antreasyn et al 1979; Cronin et al 1975) and the recent isr data (Karabarbounis et al 1981; Bell et al 1982; Angelis et al 1982) on $p$-$a$ and $a$-$a$ collisions. A gratifying feature of the model is that experimental results which look anomalous or mutually conflicting are seen to be, in fact, consistent with the model and that the differences are due to different kinematical situations.

2. Description of the model

The model discussed here is an elaboration of the model, proposed by Fredriksson (1976) to explain the data of Chicago-Princeton collaboration (CP) (Antreasyn et al
1979) on p-nucleus collisions. The essential idea of the model is that in a p-nucleus collision, a large fraction of the target nucleons, lying in a tube along the straight line path of the projectile through the target nucleus, acts collectively and coherently in the interaction. An immediate consequence of this assumption is that the N-N C. M. energy $\sqrt{s}$ gets enhanced to an effective value $(s_{\text{eff}})^{1\over 3} = (v(A) s)^{1\over 3}$, where $v(A)$ is the average number of nucleons in the tube which interact collectively. The model is often referred to as a coherent tube model (CTM) (Bergstrom et al 1983). Narayan and Sarma (1964) had invoked the model several years ago to explain the features of deuteron production in 25 GeV P-A collisions.

All the struck nucleons in the tube presumably form a localized hot-dense quark-gluon composite which interacts with the projectile. It is assumed that the composite remains in the environment of the residual nucleus (nucleons outside the tube) during hadronization. A consequence of this assumption is that the particles, emitted at large angles and hence with large $p_T$, can undergo secondary collisions in traversing nuclear matter and suffer an attenuation in the yield of particles at higher $p_T$ values. This consideration is particularly important in the CP experiments where the targets are relatively heavy nuclei and the particles are detected at 90° in the C. M. system. In ISR experiments, the internuclear cascade would be negligible as the nuclei are light $\alpha$-particles.

3. p-nucleus collisions

To implement the CTM for p-nucleus collisions, we need to make two changes in relation to p-p collisions. One expects that p-nucleus cross-section would be larger than the p-p cross-section by a factor like $A^{1\over 3}$, with a 'geometrical' value of $\delta \sim 2/3$. So we first multiply the p-p cross-section by a factor $A^{1\over 3}$. Secondly the $N-N$ C. M. energy $\sqrt{s}$ is replaced, as mentioned earlier, by $(s_{\text{eff}})^{1\over 3}$. These changes can be made in the conventional formulation of any model for large $p_T$ reactions. In the present work, we merely use a parametrized form of the inclusive large $p_T$ cross-sections and make the necessary changes, as was done by Fredriksson (1976).

The large $p_T$ inclusive cross-sections for $p + N \rightarrow \pi^- + X$ have been parametrized (Busser et al 1973) as

$$\Sigma (pp) = E (d \sigma (pp)/d^3 p) = (K/p_T^2) \exp (-Bp_T/\sqrt{s}); \ B = 26. \quad (1)$$

In the light of our remarks, one can parametrize the inclusive p-nucleus collisions as

$$\Sigma (PA) = E (d \sigma (PA)/d^3 p) = (K/p_T^2) A^{1\over 3} \exp \left[-Bp_T/(s_{\text{eff}})^{1\over 3}\right] \quad (2)$$

From (1) and (2), we have

$$R (PA) = \Sigma (PA)/\Sigma (pp) = \exp \left\{ \log A [\delta + B (p_T/\sqrt{s}) f_1 (A)] \right\}, \quad (3)$$

$$\Sigma (PA)/\Sigma (PA_0) = \exp \left\{ \alpha_{-\pi^-} (s, p_T) \log A \right\}, \quad (4)$$