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THE ANGULAR DISTRIBUTIONS OF Λ's FROM CENTRAL COLLISIONS OF LIGHT NUCLEI IN CASCADE MODEL APPROACH

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Recently there have been definite progress in measuring the production rates of lambda hyperons in relativistic heavy ion collisions [1-12] and in their theoretical analysis in the framework of the elaborated three-dimensional cascade model CASIMIR [13-16]. This model has been used to investigate a variety of reactions with strageness production. The emerging results do not contradict the idea that the strange particles are produced in binary collisions. Further, the rescattering of strange particles by the surrounding nuclear matter, as well as the influence of competing strageness producing channels, was noted to be very important for explaining the final characteristics.

Different experimental facilities have been recently used to study the lambda production at the Dubna synchrophasotron. One of these arrangements, the streamer chamber spectrometer SM-200, was used to take data at a 3.66 A GeV projectile energy [5,11] from inelastic He Li as well as from central (multinucleon) C + C, C + Ne - and O + Ne -collisions, i.e. those selected events in which all protons (and neutrons in some runs) of the projectile nucleus were involved in the reaction. A propane bubble chamber was used to obtain data from untriggered C + C -collisions at 3.36 A GeV in another experiment [9]. The angular distributions of the produced lambdas as well as of their energies were analysed among other kinematic characteristics in more detail [10,11]. This was performed in the N - N frame of reference corresponding to the centre of mass of colliding nuclei with nearly equal masses. The behaviour of the data appeared to be rather strange and unexpected. It is a challenge to analyse them to find out to what extent they can be understood within the framework of a microscopic approach as the intranuclear cascade (INC) model CASIMIR [14]. Up to now there exists no theoretical analysis of the above characteristics in detail apart from an attempt [17] in the framework of the Dubna cascade model, in which the strangeness production was realized on the basis of weighted probabilities. Using this method, it is difficult to get information concerning one of the important properties of the system, namely the ability to rescatter. Moreover, the comparison is based on some preliminary (unpublished) experimental data with very poor statistics.

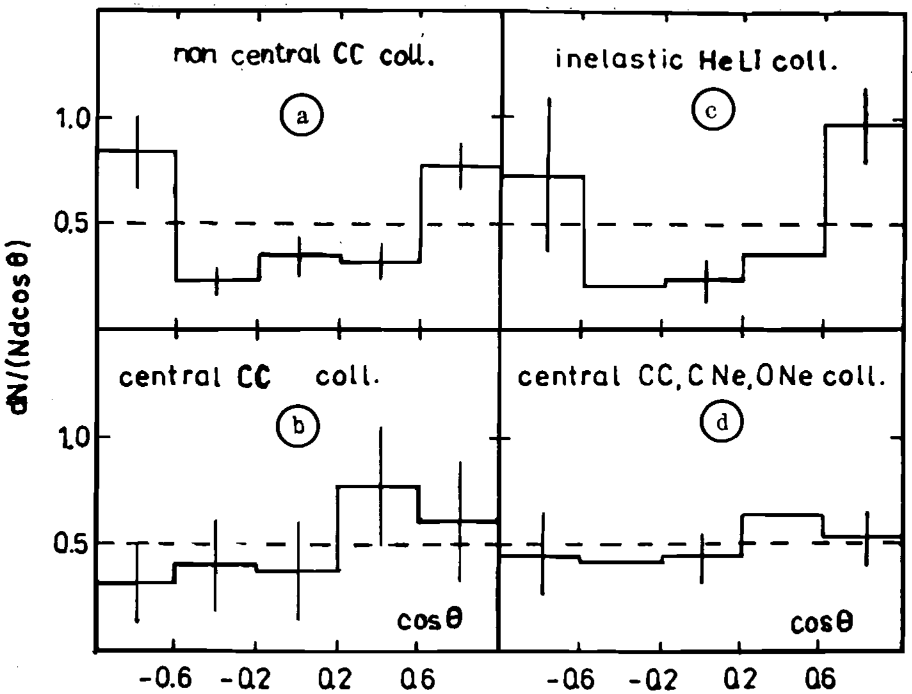

Fig. 1. Experimental angular distributions $dN/d\cos\theta^*$ *of lambda particles (*θ^* *is the emission angle in the N-N system) stemming from the bubble chamber* [9] *at 3.36 A GeV (fig. 1a,b) and from the streamer chamber* [5] *at 3.66 A GeV (Fig. 1c,d). The distributions in Fig. 1b and d follow from trigger measurements selecting only central collisions.*

Figures 1a and c present the $dN/d\cos\theta^*$ distributions of lambda particles (θ^* is the emission angle in the N-N system) measured in the untriggered reactions C + C , He + Li → Λ + X .

As can be seen from Fig. 2a, the lambdas in the elementary reaction p + p → Λ + X have a forward-background peaked distribution. This figure contains the only known angular distributions close to the studied energy range, namely at ~5 GeV [18] and 2.85 GeV [19] projectile energies. The observed structure

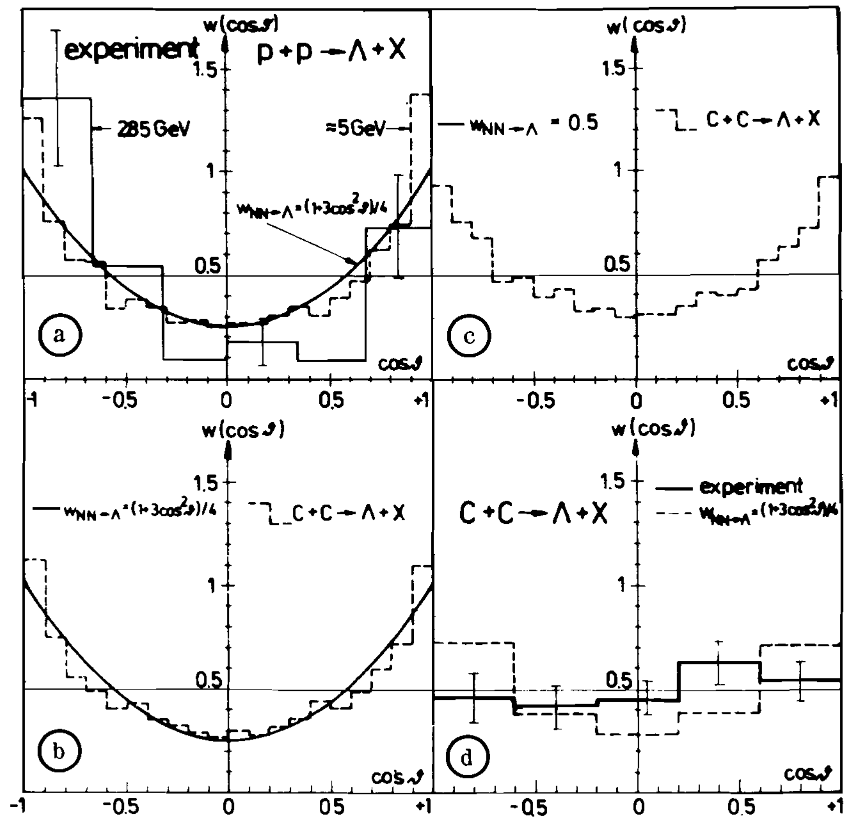

Fig. 2. Angular distributions $dN/d\cos\theta^*$ *of lambda particles in the N-N system. Fig. a) shows two experiments* [18, 19] p + p → Λ + X *together with the fit (full curve in Fig. b) used in CASIMIR. The dashed line in Fig. b represents the calculation of* C + C → Λ + X *using the fit of the experimental lambda distribution given in Fig. a. Fig. c shows the same, but the lambda distribution is taken to be isotopic. The experiment* C + C → Λ + X *(full lines in Fig. 1d are the average ones of Fig. 1b and d) is compared with the CASIMIR calculations.*

in the distribution is most likely to manifest the well-known baryonic diquark leading effect illustrated in Fig. 3a. In each case two quarks in the nucleons play a role of spectators that keep their momenta unchanged and give rise to small angle

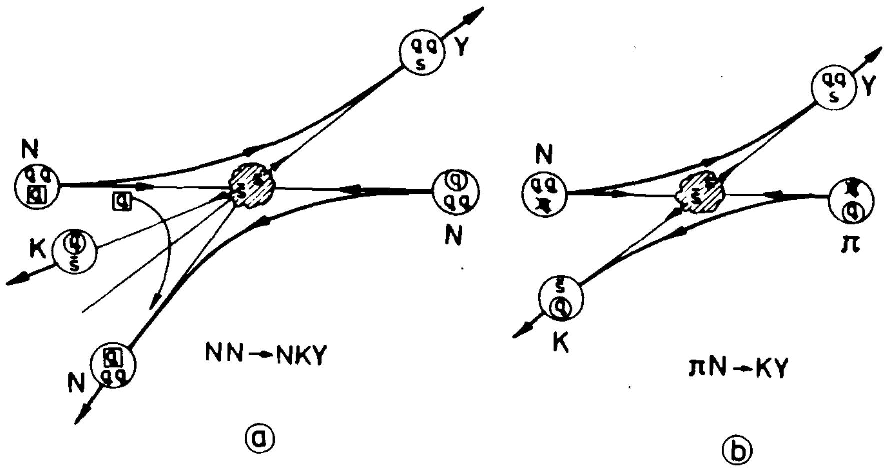

Fig.3. Schematic pictures of strangeness producing elementary reactions at the quark level demonstrating the forward-backward peaked small angle scattering.

scattering. It is seen that the angular distributions following from an elementary reaction (Fig.2a) and from inelastic He + Li and C + C reactions (see Fig. 1c presented on the basis of about 250 lambdas) are consistent with each other. This indicates that the Fermi motion of nucleons has no significant influence on the lambda angular distributions. To a good approximation, the reaction can be understood to be due to the sum of independent N - N collisions averaged over the charge of nucleons and their Fermi momenta.

In contrast to these forward-backward peaked angular distributions, the $\cos\theta^*$ distributions of lambdas produced in central collisions of the type C + C , C + Ne and O + Ne (at 3.66 A GeV) exhibit an amazing isotropy (within the error bars). The flattening of the distribution is clearly correlated with the degree of collision centrality, i.e. the number of protons involved in the reaction. The more rigid triggering of central collisions leads to the more flattening of the lambda angular distribution [11] . This behaviour has been observed in independent bubble chamber measurements [9] for the same reaction (Figs. 1a,b). The forward-backward peaks are observed without some selection criteria (Fig. 1a). It disappears when the adjusted trigger conditions similar to those in the streamer chamber experiment are on. Although the distribution in Fig. 1b is presented on the basis of not much statistics, its shape is consistent with that of Fig. 1d within the errors. Such an isotropic behaviour is further confirmed by preliminary results concerning lambda production (about 100 Λ's) in central Ca + Ca collisions at 2.07 A GeV [8] . Within its poor statistics, the angular distribution also reveals nearly isotropic features with no forward-backward peaking. In spite of the poor statistics, we can thus state with some confidence that the experiment seems to favour the isotropic angular distribution of the lambdas (in the NN-system). For further discussions the statistics can be improved by amalgamating the two distributions of Figs. 1b and d to obtain Fig. 2d.

We would like to apply the elaborated INC model CASIMIR developed for analysing nucleus-nucleus reactions with strangeness production to the above reactions. A detailed description of CASIMIR can be found elsewhere [16] . Only some main characteristics are recalled here. The code simulates the interaction process of heavy ions in terms of a sequence of binary collisions of free-moving hadrons. Neglecting the mean field, the particles move along the straight lines. Two particles collide if the closest distance between them is within the area of their cross section. Hence, CASIMIR accounts properly for the rescattering of particles by the surrounding nuclear matter. Further, the model takes into account an essential ability of the system to produce strange particles from different competing elementary processes. Actually, these two properties of the system are of great importance, and their immediate influence on the final characteristics has been already demonstrated in Ref. [15,16].

The rescattering of the lambdas in the collision process is considerable. On the average, they suffer 2.0 elastic collisions before excaping the system ($\sigma_{\Lambda N}$ is taken to be 35 mb). This "free" cross section might be modified during the collision process. To feel the consequences of this, the value of $\sigma_{\Lambda N}$ is supposed to be 70 mb. This would cause 3.1 elastic interactions, however, without effecting the characteristics discussed below.

There are mainly two channels that contribute to the production of lambdas. The most important one includes all the baryon encounters leading to lambdas. The second channel concerns pion-induced lambdas. In the final state, 65% of all lambdas are produced from the baryon-baryon channel with 45% from the direct NN channel. In the CC-system the lambda production induced by pions amounts to about 35%. In the πN system these lambdas exhibit a clear forward-backward peaking (see Fig. 3b). In our N-N frame of reference the peaks become pronounced. The lambdas emerging from baryon-baryon encounters are assumed to obey the angular distribution deduced from the $pp \to \Lambda X$ experiment. The function

$$w_{NN \to \Lambda}(\cos\theta^*) = (1 + 3\cos^2\theta^*)/4$$

represents a nice fit to the data as shown in Fig.2a. The final state lambda angular distribution for the reaction C+C is calculated taking into account the experimental trigger conditions. It differs only slightly from the anisotropic input distribution $w_{NN \to \Lambda}$ (Fig. 2b). A light tendency towards isotropy is noticeable. On the other hand, starting from isotropic lambda production in all elementary processes ($w_{NN \to \Lambda} = 1/2$), one obtains forward-backward peaked lambdas due to rescattering and secondary processes (Fig. 2c). To compare these results with the experimental data, the calculated distributions of Fig. 2b and c have to be averaged over the intervals corresponding to the experimental ones (Fig. 2d). The statistical error of the theoretical curves is about 3%. Finally, an anisotropic distribution is obtained. Its inner and side points lie clearly outside the experimental errors. In comparison with the experiment the CASIMIR-INC calculations show lambda emission in the forward-backward direction to be favoured. It is compatible with the lambda emission following from noncentral collisions. However, it deviates remarkably from that leading in the experiment to a rather flat distribution of central-produced lambdas.

In conclusion we can state the following. On the basis of a sequence of binary collisions it is difficult to understand the isotropic feature of lambda production in central C+C collisions. On the other hand, the Boltzmann type spectra with a slope parameter of 150 MeV [11] revealed in the same experiment under the same trigger conditions indicate a reached stopping and randomization. However, how it could happen in such a small system remains an open question. In this connection it cannot be excluded that a new reaction mechanism has to be considered.

Because of rather poor statistics (about 200 Λ's) only five-bin distributions are presented. Actually, due to the error bars, the bins are just within the limits still allowing one to visualize the distribution as an isotropic one. Speaking of the significance of the experimental data, one has to keep in mind that their isotropy interpretation is based on the results of three different experiments [5,8,9]. Two of them [5,9] which our paper concentrates on allow one to study the angular distributions quantitatively via their dispersions [10]. Here $D_{\cos\theta^*}$ changes with increasing the degree of centrality in nucleus-nucleus collisions. It varies from $D = 0.72 \pm 0.02$ for the peaked distribution to $D = 0.58 \pm 0.04$ for the flat one which should be compared with $D = 0.577$ characterizing complete isotropy.

Nevertheless, it would be desirable to carry out experiments with better statistics.

In any case in this energy region the collision system exhibits a behaviour that is not easily understood. Thus, it stimulates further experimental and theoretical research into this fascinating subject.

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