

Interpretation of “anomalous effects” in α -particle interactions at $\sqrt{s} = 125$ GeV

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The differences between such characteristics of $\alpha\alpha$ collisions and pp collisions as the invariant inclusive cross sections and the transverse-energy distributions stem to a significant extent from “soft” collisions of the nucleons of the α particles.

The well-known difficulties in a relativistically invariant description of bound systems in quantum field theory have unavoidably resulted in a proliferation of models in the theoretical analysis of hadron-nucleus, nucleus-nucleus, and lepton-nucleus interactions. For example, the appearance of data (Ref. 1; see also Ref. 2) on the dependence of the yield of secondary particles with large transverse momenta (P_T) on the mass of the target nucleus (the A dependence) was followed by the proposal of a variety of models (see the citations in Ref. 3). In particular, a model⁴ of a rescattering of “hard” partons of the incident hadron was proposed. That model was used to explain the anomalously strong A dependence of the inclusive spectra of particles produced in high-energy proton-nucleus interactions. That model has a completely definite mechanism for the interaction of complex systems (hadrons) with nuclei (no less complex), which leads to the production of particles with large values of P_T .

According to this model (Ref. 5, for example) the cross for the scattering of hard partons in inelastic collisions of nuclei with mass numbers A and B should be proportional to $A \times B$. Experimental data^{3,6} on $\alpha\alpha$ interactions would seem to be consistent with this assertion (Fig. 1), but there is the confusing point that even for particles which are clearly “soft,” with small values of P_T , the ratio of invariant cross sections is significantly greater than unity. To reach an understanding of this behavior, let us assume that the spectra in $\alpha\alpha$ collisions are similar to those in pp interactions, aside from a normalization: The spectra in pp interactions are normalized to $\langle n \rangle_{pp} \sigma_{pp}^{\text{in}}$, and those in $\alpha\alpha$ interactions to $\langle n \rangle_{\alpha\alpha} \sigma_{\alpha\alpha}^{\text{in}}$. Here $\langle n \rangle$ is the average number of particles of one species or another. Since we have $\langle \sigma_{\alpha\alpha}^{\text{in}} / \sigma_{pp}^{\text{in}} \rangle \simeq 7.7$ and $\langle n \rangle_{\alpha\alpha} / \langle n \rangle_{pp} \simeq 1.76$, the ratio of inclusive cross sections [$R(P_T)$] cannot be less than 13.6 under our assumptions. This quantity is not greatly different from 16, so that if $R(P_T)$ exceeds the value of $A \times B$ that fact would still not indicate that rescattering of hard partons plays a significant role in nucleus-nucleus interactions. For a more rigorous test of this conclusion, we have calculated the inclusive spectra of particles in $\alpha\alpha$ collisions in the model of a cascade of leading baryons, proposed in Refs. 7 and 8. As can be seen from Fig. 1, a model which ignores hard rescattering predicts a value $R(P_T) > 16$ at $P_T \gtrsim 1.5$ GeV/c.

It is a more complicated matter to explain the spectra of the total transverse energy¹⁾ (E_T) or that of the total energy of neutral particles (E_{tot}^0) produced in the

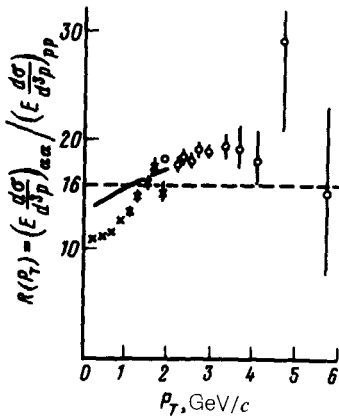


FIG. 1. Ratio of the invariant cross sections for $\alpha\alpha$ and pp interactions at $\sqrt{s_{NN}} = 31.2$ GeV for charged particles produced in the central region ($|y^*| \leq 0.6$). The circles and crosses are experimental data⁶; the solid line is the calculation of the present paper.

central region of $\alpha\alpha$ interactions. Angelis *et al.*⁹ have mentioned that the nature of the fluctuations in the value of E_{tot}^0 in $\alpha\alpha$ collisions is quite different from that of the fluctuations in four “parallel” (simultaneous) nucleon-nucleon interactions. This is not a surprising result, since the idea of making such a comparison had been rejected as groundless a long time ago in the analysis of inelastic and elastic nucleus-nucleus reactions. The model of “wounded” nucleons, which also lacked a solid theoretical foundation, turned out to be just as groundless (see Ref. 10 for predictions of this model regarding the E_{tot}^0 spectrum, in comparison with experimental data⁹). The model of a cascade of leading baryons, on the other hand, which is a possible generalization of the Glauber theory of hadron-nucleus and nucleus-nucleus interactions, describes the experimental data¹¹ on the total transverse energy of charged particles (E_T^{ch}) but does not describe the distribution in the total transverse energy of neutral particles (E_T^0) (Fig. 2). The first of these facts is not surprising in light of Ref. 11,

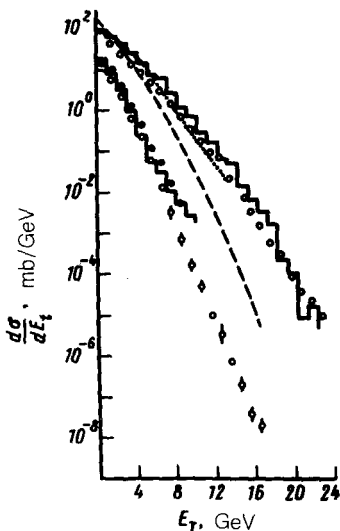


FIG. 2. Distribution in the transverse energy in $\alpha\alpha$ and pp interactions. The dotted line and the filled circles show data from Ref. 11 on charged particles produced in the region $|y^*| \leq 0.8$ in $\alpha\alpha$ and pp collisions, respectively. The open points are the corresponding data of Ref. 9 on neutral particles ($|y^*| \leq 0.9$). The histograms are calculations of the charged-particle spectra carried out in the present study. The dashed line is a calculation of the E_T^0 spectra in $\alpha\alpha$ interactions.

since we are reproducing⁸ the distribution in the multiplicity of charged particles produced in the central region, and we are reproducing the inclusive spectrum of π mesons at $y^* \sim 0$ up to $P_T \lesssim 2.5$ GeV/c. The procedure is sufficient¹¹ for describing the E_T^{ch} spectrum. The second fact is a direct consequence of the isotopic symmetry which is "built into" the model.

Comparison of the data of Refs. 9 and 11 indicates that either there is a contradiction between the data of these groups or there is a violation of the isotopic relations in $\alpha\alpha$ interactions at $\sqrt{s} = 125$ GeV.

Returning to the calculations by the model of a cascade of leading baryons, we can conclude that soft nucleon-nucleon collisions are responsible to a significant extent for the formation of the basic characteristics of the nucleus-nucleus interactions discussed above.²⁾

Many effects of bound systems are taken into account effectively in the Glauber-Sitenko approximation. Consequently, it is not at all surprising to see the success of models which are genetically related to the Glauber theory in the description of experimental data on nucleus-nucleus interactions.

¹⁾The total transverse energy is defined as $\sum_i \sqrt{m_i^2 + p_{iT}^2}$, where m_i is the mass of particle i , and the summation is over all the particles which are produced in the given angular or rapidity interval.

²⁾A similar conclusion can be reached on the basis of a fragmentation or additive quark model.

¹⁾J. W. Cronin *et al.*, Phys. Rev. Lett. **31**, 1426 (1973); J. W. Cronin *et al.*, Phys. Rev. D **11**, 3105 (1975).

²⁾V. L. Kluberg *et al.*, Phys. Rev. Lett. **38**, 670 (1977); V. D. Antreasyan *et al.*, Phys. Rev. D **19**, 764 (1979).

³⁾M. A. Faessler, Phys. Rep. **115**, 1 (1984).

⁴⁾G. Farrar, Phys. Lett. **56D**, 185 (1975); J. Pumplin and E. Yen, Phys. Rev. D **11**, 1812 (1975); P. V. Landshoff *et al.*, Phys. Rev. D **12**, 3738 (1975).

⁵⁾U. P. Sukhatme and G. Wilk, Phys. Rev. D **25** (1982); M. Staszal and G. Wilk, Z. Phys. **C19**, 57 (1983); M. Lev and B. Petersson, Z. Phys. **C21**, 155 (1984).

⁶⁾T. Akesson *et al.*, Nucl. Phys. **B209**, 309 (1982).

⁷⁾V. V. Uzhinskiĭ, Preprint R2-81-780, Joint Institute for Nuclear Research, Dubna, 1981; V. V. Uzhinskiĭ and Z. Omboo, Preprint JINR, E-2-83-254, Dubna, 1983.

⁸⁾A. M. Zadorozhyĭ *et al.*, Preprint R2-86-361, Joint Institute for Nuclear Research, Dubna, 1986.

⁹⁾A. L. Angelis *et al.*, Phys. Lett. **141B**, 140 (1984).

¹⁰⁾I. Otterlund, Lund Report, LUIP 8606, 1982; LUNFD6/(NFFK-7072 1-31/1986).

¹¹⁾H. Gordon *et al.*, Phys. Rev. D **28**, 2736 (1983).

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