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COLLISIONS ON RELATIVISTIC NUCLEI: SHOCK WAVES?

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In the last years the generation of shock waves in high energy heavy ion collisions is of great interest that is caused by new available possibilities to investigate the behaviour of superdence and hot nuclear matter [1-5]. One gets encouraged by recent experiment [6] where a peak was observed in the angular distribution of secondaries. The peak position θ_s and its dependence on the velocity v_0 of an incident nucleus follow surprisingly well predictions of the shock wave hydrodynamics

$$\cos\theta_s = v_s / v_0 \tag{1}$$

(v_s is the velocity of the shock wave front). This agreement, however, seems illusory as theoretical estimates concern very idealized case while rather a specific group of events was selected out in experiment. Besides, the correction of systematic errors in ref. [6] changes essentially the results of first measurements *.

Our analysis of experimental data on observation of signs of shock waves proceeds from kinetic rather than hydrodynamic ideas. Each of colliding nuclei in its own reference frame is treated as a Fermi gas of nucleons in the Saxon-Woods potential well. Any of the nuclear nucleons can produce a shower (cascade) of particles in another nucleus. On completing the fast cascade stage the remaining nuclei are excited and a subsequent deexcitation is described in the framework of the equilibrium statistical theory. All calculations are performed by the Monte-Carlo method. The model fits well enough average characteristics of inelastic collisions of two nuclei [8].

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* We are grateful to Prof. S.Shopper for discussion and kind information about new results [7]. Below we shall use these new corrected data.

The considered mechanism of nucleus-nucleus interaction corresponds to the relaxation of the system due to particle-particle collisions only. Such a mechanism, of course, should occur but, on the other hand, it is clear that it is not the only possible one and any collective mode of excitation (including also shock waves) should be singled out of this "collisional backgrounds".

It should be noted especially that, unlike all other theoretical approaches in this work we simulate exactly the experimental conditions: we select "stars" with the number of "visible" tracks $n_h \geq 13$, where "track" means the hydrogen isotope with kinetic energy $T < 28$ *MeV/nucl.* or helium isotope with $T < 200$ *MeV/nucl.*

The calculation results are given in *Fig. 1*. The effect of formation of a shock wave can be found as the difference between experimental and theoretical histograms. It is seen that, in spite of clearly unsufficient statistics of measurement *, there are some points in excess of the calculated curves in the expected range of angles $\theta \sim \theta_s$ and this is more noticeable with decreasing kinetic energy T_0 of a bombarding nucleus. This result is in qualitative agreement with the conclusions of ref. /2/ that the energy region $T_0 \lesssim 1$ *GeV/nucl.* is apparently most favourable for generation of shock waves.

However, it is not yet possible to identify the observed deviations from the "background" with the effect of shock waves. It is necessary to essentially increase the statistics of measurements, to identify the type of detected particles, and to know their energy spectra. Besides, that seems to us to be most important, an alternative may be pointed out: the observed in *Fig. 1* discrepancy between theory and experiment can be attributed to the processes of preequilibrium particle emission. At present the preequilibrium approach to nuclear reactions is widely used in the region of intermediate excitations to explain the high-energy component in spectra of emitted nucleons and

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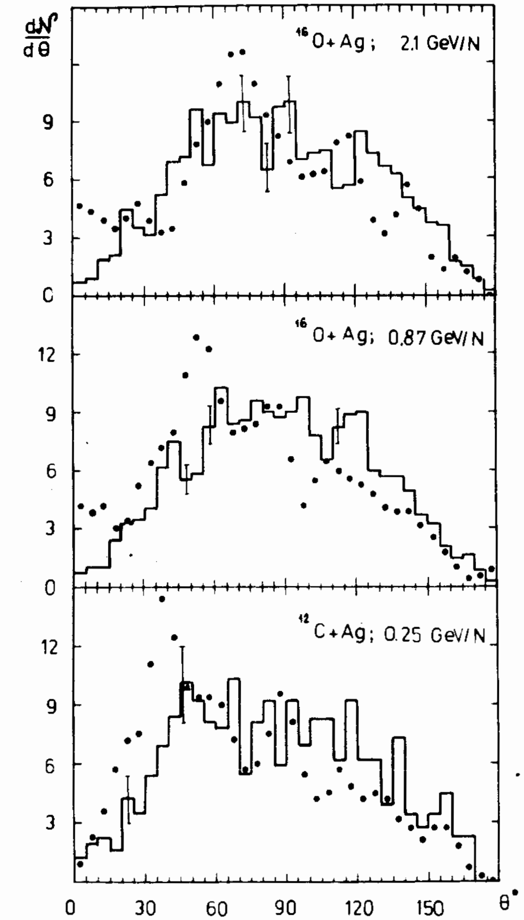
* In the figure we picture the statistical errors of the calculation. The total number of stars detected in experiment /6,7/ is two-three times lower than the calculated one.



The angular distribution of tracks in stars with $n_h \geq 13$. *The type of colliding nuclei and energy of the bombarding nucleus are shown. Points are experiment* /7/, *histograms - calculation results.*

complex particles (see reviews [9,10]). As follows from the analysis [6], it is just the fast α-particles, the observed maximum is associated to. The above assumption is favoured also by the shape of spectra of nuclei ^3He and ^4He measured in the same reactions as is shown in *Fig. 1* [11]. And finally, one may suggest some experiments which allow one, in principle, to make choice between these alternatives:

i. To carry out experiments of type [6] in the energy range $T_0 \simeq (1 \div 2)$ *GeV/nucl.* with a small step in T_0. The fact is that when θ_s is extracted from the corrected data in *Fig. 1* and v_s is estimated according to (1) it appears that passing from $T_0 = 0.87$ to 2.1 *GeV/nucl.* the velocity of the shock wave front does not increase but decreases from $v_s/c \simeq 0.51$ to 0.38. This hydrodynamically unexpected behaviour may be explained keeping the hudrodynamic approach if one assumes the existence of the density isomer [12,13] but than in the interval $T_0 \simeq (1 \div 2)$ *GeV/nucl.* there should be the region where $v_s \to 0$. The preequilibrium processes should not manifest such a dramatic behaviour; the expected agreement of cascade calculations with experiment should be of the same nature as at the top of *Fig. 1*.

ii. To perform analogous experiments on light $(A \sim 40)$ targets. In this case the conditions of applicability of the hydrodynamical approach are worse if ever satisfied but the preequilibrium decay should occur.

iii. To repeat experiments by the technique of [6] on beams of fast hadrons. It is unlikely that, e.g., pion with $T_0 \simeq 1 \div 2$ *GeV* is able to produce the shock wave, however, the preequilibrium particle emission takes place in this case, as well. Therefore the observation of maximum in the angular distribution of secondaries in hadron-nucleus reactions under the conditions identical with [6,7] would favour the preequilibrium hypothesis.

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