path for the diffraction generation of particles in emulsion at average energies near 200 GeV (in cosmic rays). It is essential in this connection to set up an accelerator experiment similar to that described above at particle (proton and pion) energies 60 - 70 GeV, at which the production threshold will be exceeded for the more prevalent nucleon isobars with both three-particle and five-particle decay.

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INTERFERENCE EFFECTS IN COLLISIONS OF COMPLEX NUCLEI

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It is common knowledge that if the formation of a system in the final state following scattering is described by a pair* of divergent waves that are coherent and have comparable amplitudes, then an interference term appears in the differential cross section. The angular-distribution singularities due this term are of greatest interest when the interference waves correspond to a reversal of the sign of the relative momentum of the colliding particles, and the scattering process is strongly influenced by the Coulomb repulsion potential acting between them. This situation is typical of the physics of multiply-charged ions, or more accurately for collisions between complex nuclei having equal or near-equal masses. Namely, for example, if identical nuclei collide (or are produced), then the interfering waves are due to their quantum-mechanical indistinguishability; this case is considered in detail in [1, 2], in which it is predicted that the angular distributions will contain considerable oscillations, with properties determined by a number of the most important characteristics of the states taking part in the process. Another class of examples is associated with the fact that the large number of open channels leading to the formation of a given final state frequently include a pair satisfying the conditions formulated above. In this note we consider, by way of a very simple example of this kind, the elastic subbarrier scattering of nuclei of a beam A by a target of nuclei B, which can be effectively represented as a bound system of a certain nuclear particle α ($_0h^1$, $_1H^1$, $_1D^2$, $_2He^4$) and a core A_2 which is identical to the beam nuclei. In this case a coherent contribution to the elastic-scattering amplitude will be made by the amplitude of the Rutherford Coulomb scattering through an angle θ and the amplitude of the resonant transfer of the particle α from the nucleus of the target A_2 to the nucleus of the beam A_1, with scattering of the beam nuclei through an angle π - θ. As is well known [3], the probability of such a transfer is determined, first, by the value of the reduced width γ of the cluster state under consideration, and second by the ratio of the interaction time

$$t \sim 2a/v$$

($a = z_1 z_2 E^2/E$ is closest-approach distance between the nuclei in the case of head-on collision and v is the relative-motion velocity) and the time of the resonant transition of the particle α

$$\tau \sim \frac{\hbar}{\Delta E},$$

where ΔE is the energy splitting of the ground level of the system B under the influence of the nucleus A_1 moving nearby. On the whole, this process is the nuclear analog of the well known resonant charge exchange of ions [4]. As shown earlier [1,2], under semiclassical conditions and at subbarrier energies, the inelastic-scattering amplitude can be factored into

$$f_{res}(\theta) = b_{res}(\theta)\, f_Q(\theta) = b_{res}(\theta)\, \frac{a}{\sin^2\theta/2}\, e^{-i\eta \ln \sin^2\theta/2},$$

where $f_Q(\theta)$ is the Coulomb amplitude of scattering through an angle θ, and $b_{res}(\theta)$ is the probability that this will be accompanied by resonant transfer of the particle α. Then,

$$\frac{d\sigma}{d\Omega} = a^2[\sin^{-4}\theta/2 + |b_{res}(\pi-\theta)|^2\cos^{-4}\theta/2 + 2|b(\pi-\theta)|\sin^{-2}\theta/2\cos^{-2}\theta/2 \times$$
$$\times \cos(\eta \ln \mathrm{tg}^2\theta/2 + \arg b^*(\pi-\theta))] .$$

The first term gives the "classical" correction to the Rutherford cross section, due to the transfer, and the third term, due to the interference, predicts the appearance of intense angle oscillations, the swing of which is largest when $t \sim \tau$, $\gamma \sim 1$, and $\theta \sim 90°$ (cms), thus determining the most favorable conditions for their experimental observation. We note that a reliable attribute that facilitates their identification may be the characteristic Coulomb value of the period ($\Delta\theta \sim (\pi/\eta)$ near 90° cms). Let us determine more concretely the experimental conditions for the simplest example of elastic subbarier scattering of neighboring isotopes of one element

$${}_zx^A + {}_zx^{A+1} \rightarrow {}_zx^A + {}_zx^{A+1}$$

and let us use for the estimates, following Temmer [3], the model of two one-dimensional potential wells of width $2R_0 \sim 3A^{1/3}$ F and of depth $V_0 \sim 40$ MeV, spaced by a distance a. The particle spins are neglected. Then

$$\tau \simeq 2\pi m_n \frac{(a-2R_0)}{\sqrt{2m_n(v_0-\epsilon_0)}} \exp\left[-\frac{(a-2R_0)}{\hbar}\sqrt{2m_n\epsilon_0}\right] \qquad (1)$$

$$t \simeq z^2 e^2 \sqrt{M}/\sqrt{E},$$

where m_n is the neutron mass and ϵ_0 is its binding energy with A_2.

It follows from (1) and (2) that in the case of a weakly-bound neutron, for sufficiently heavy nuclei, the value of τ becomes of the same order as t when $E < E_B \sim z^2e^2/2R_0$.

The table lists the relative-motion energy most suitable for the measurements and also some of the other quantities used above, for a number of nuclei.

	C^{12}	O^{16}	Ne^{26}
t/τ	0.97	0.81	0.62
E_{cms}, MeV	6.0	10.0	15.0
η	6.1	9.3	12
$\Delta\theta$	30°	11°	9°

The experimental observation of the predicted oscillations and their further investigation are of considerable interest. First, this would make it possible to measure times $t \sim 10^{-21}$ sec in some nuclear reactions [3]. Second, it would be possible to estimate directly from the swing of the oscillations the the probability of existence of the target nucleus B in the form of the proposed nucleon cluster (B = A + a). Third, this would uncover a new method for investigating the rather complicated mechanism of nucleon (or cluster) transfer.

It must also be noted that a perfectly analogous situation can occur also in inelastic-scattering processes (for example, in the case of Coulomb excitation of single-particle states, a coherent contribution will be made by single-nucleon transfer at a given level), and also in scattering with nucleon redistribution, of the type**

$$A + B \rightarrow C + D.$$

The possibility of directly comparing, in one experiment, of the probabilities of different inelastic processes is in our opinion the most attractive feature of investigations of this kind.

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*Their number can in principle be also larger.

** This case was called to our attention by Ya. B. Zel'dovich.

GAS LASER USING MULTIPLY CHARGED IONS

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Let us consider the operating conditions of a gas laser with multiply charged ions. Such a laser takes the form of a gas-filled tube with a current of multiply charged ions flowing along its axis. These ions have had time to cover a sufficiently long path from the source, so that they are in either the ground or a metastable state. The multiply-charged ions exchange charges with the atoms (molecules) of the gas, producing ions with smaller charge. The mechanism of partial charge exchange of a multiply charged ion, $x^{n+} + y \rightarrow x^{*(n-1)+} + y^{*+}$, is treated quite fully in the literature [1-8] and reduces to the following: When the distance between nuclei changes, the terms of the quasimolecule $(xy)^{n+}$, which correspond to the state $x^{n+} + y$, vary relatively little with the distance, owing to the weak polarization