Transparency in Central Xe+Sn Collisions

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The formation of longitudinally elongated composite systems is a general feature of central heavy-ion collisions [1]. It can be the result of a transparency, i.e. of an incomplete stopping of the incoming projectile by the target, as, e.g., observed by the FOPI collaboration for Zr+Ru collisions at 400 A.MeV [2]. Here, we report new data, measured with INDRA at GSI, for the Xe+Sn collisions at 100 A.MeV, obtained by cross-bombarding isotopically separated ^{112,124}Sn targets with ^{124,129}Xe projectiles. The total transverse energy of light charged particles (Z=1,2) has been used to select central collisions.

We present in Fig. 1, left panel, the yield ratios obtained with various light isotopes emitted at sideward angles in the center-of-mass ($80^o \leq \theta_{cm} \leq 100^o$) as a function of the total N/Z of the system. We see in all cases a remarkable exponential dependence which reflects, as expected at mid-rapidity, a full mixing of the target and the projectile [3]. Slope parameters of the exponential fits are proportional to the difference in N between the isotopes forming the ratios (Fig. 2), suggesting a statistical type of emission in the grand-canonical description [4].

Ratios obtained at forward angles ($\theta_{cm} \leq 34^o$), presented in Fig. 1, right panel, deviate from the exponential law and exhibit a characteristic step pattern common to all the ratios. The difference in yield ratio is larger if the projectile is changed and smaller if the target is changed, indicating an incomplete isospin equilibration for the reaction products at forward angles.

One can derive from these deviations a transparency coefficient τ, with regard to a given isotope ratio, using the following relation:

$$\tau = \frac{\tau_P - \tau_T}{\tau_P + \tau_T}$$

where τ_P and τ_T are the proportions of N/Z transfer at forward angles, from the projectile and the target, respectively. For example, τ_P is obtained by comparing the measured ratios from two reactions with different projectiles on the same target with the expectation for pure projectile matter according to:

$$\tau_P = \frac{log(R_1/R_2)}{\alpha \Delta(N/Z)}$$

where R_i are the forward yield ratios, $\Delta(N/Z)$ is the difference in N/Z between the two projectiles, and α is the slope of the exponential fit obtained at sideward angles (Figs. 1 and 2). Similarly, τ_T is obtained by comparing systems where the target is changed (and the projectile unchanged). Full isospin equilibration would be indicated by $\tau = 0$. The measured values, obtained from averaging over all four reactions, are all positive (see Table 1). For hydrogen isotopes, transparency is moderate ($\tau \approx 20-30\%$), while nearly complete transparency is observed for heavier products.

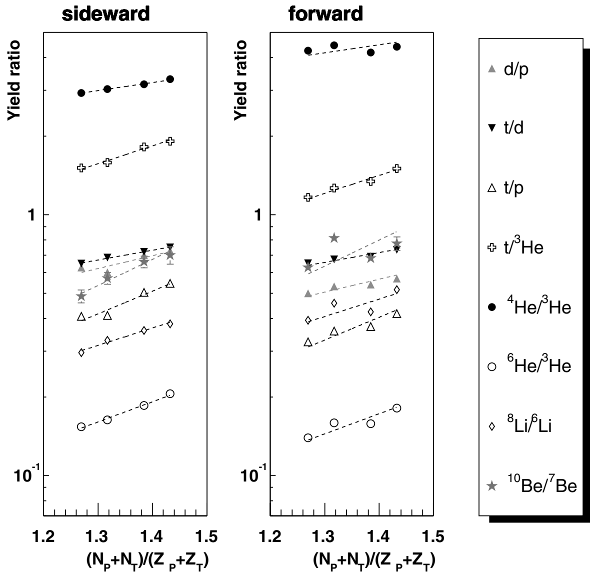

Figure 1: Isotope yield ratios as a function of the total N/Z of the system in central $^{124,129}Xe +^{112,124} Sn$ at 100 A.MeV, for sideward angles (left panel, $80^o \leq \theta_{cm} \leq 100^o$) and forward angles (right panel, $\theta_{cm} \leq 34^o$). The line are exponential fits.

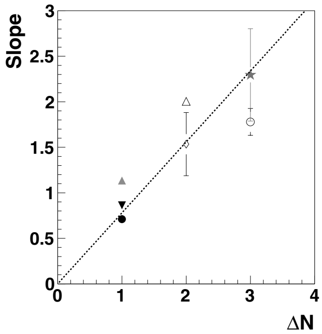

Figure 2: Slopes of exponential fits extracted from Fig. 1, left panel, as a function of the difference ΔN in neutron number of the isotope pair. The symbols are chosen as in Fig. 1.

	d/p	t/d	t/p	$t/^3He$
$\tau(\%)$	34 ± 2	26 ± 2	30 ± 2	22 ± 2
	$^4He/^3He$	$^6He/^3He$	$^8Li/^6Li$	$^{10}Be/^7Be$
$\tau(\%)$	124 ± 4	46 ± 6	64 ± 10	92 ± 10

Table 1: Transparency τ (in percent) as derived from forward emissions ($\theta_{cm} \leq 34^o$). Only statistical errors are given.

References

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