ANALYSIS OF VELOCITY AND ISOTOPE DISTRIBUTIONS IN PROJECTILE FRAGMENTATION REACTIONS OF ^{18}O AT 35 MEV/NUCLEON ON ^{9}BE AND ^{181}TA TARGETS

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Abstract

Up to date analysis of velocity and isotope distributions of light fragments obtained in the projectile fragmentation reactions of 18O at 35 MeV/nucleon on 9Be and 181Ta targets measured at COMBAS fragment separator at the U400M Research Facility in JINR [1] are presented. The results of velocity spectra analytical parametrization and isotopic ratios are compared with the ones obtained in the experiments presented in the literature [2,3]. The discussion of the different mechanisms involved in these types of the reactions is given.

The experimental details

HA 14-mg/cm2 9Be and 181Ta target foil was irradiated with a 35A-MeV 18Obeam of (electric) intensity up to 2 µA from the U-400M cyclotron installed at the Flerov Laboratory of Nuclear Reactions, Joint Institute for Nuclear Research (JINR, Dubna). The target was placed at the entrance focus of the COMBAS separator (Fig. 1). The diameter of the beam spot on the target did not exceed 3 mm. Nuclear products emitted at forward angles within a COMBAS solid angle (6.4 msr) were separated from the intense beam of bombarding particles by magnetic rigidity and identified by the nuclear charge and by the mass number by combining two methods: magnetic rigidity and (ΔE, E): E = (Bρ)2 × Z2/A, (1)

ΔE ≈ A × Z2/E. (2)

the exit achromatic focus of the COMBAS separator. The yields of isotopes were measured by scanning the range of magnetic rigidities covering the velocity distributions of the 2 ≤ Z ≤ 11 light element isotopes studied here. The products were detected in the achromatic focus Fa by a telescope consisting of silicon detectors—ΔE1(0.38 mm, 60 × 60 mm2), ΔE2 (3.5 mm, Ø60 mm), and E (7.5 mm, Ø60 mm)—and were identified by the nuclear charge and by the mass number A and atomic number Z with a (ΔE, E) telescope placed at

Here, A, Z, and E are, respectively, the mass number, the atomic number, and the energy of the detected product. The yields of all of the isotopes are presented in relative units after the normalization of the recorded isotopic events to the monitor detector counting.

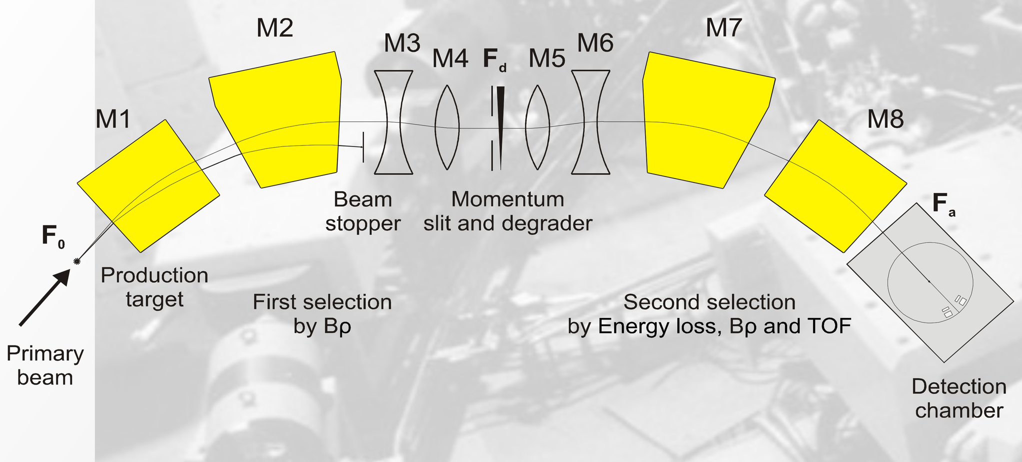

Fig.1. Magneto-optical scheme of the separator COMBAS

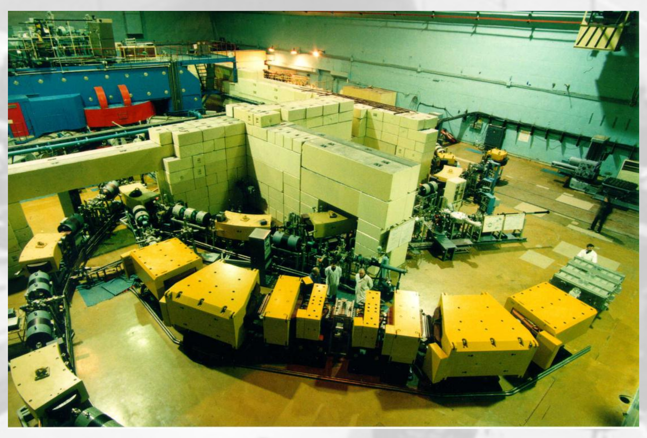

Fig.2. View of the separator COMBAS in the experimental hall of the cyclotron U-400M (beam direction from the left to the right)

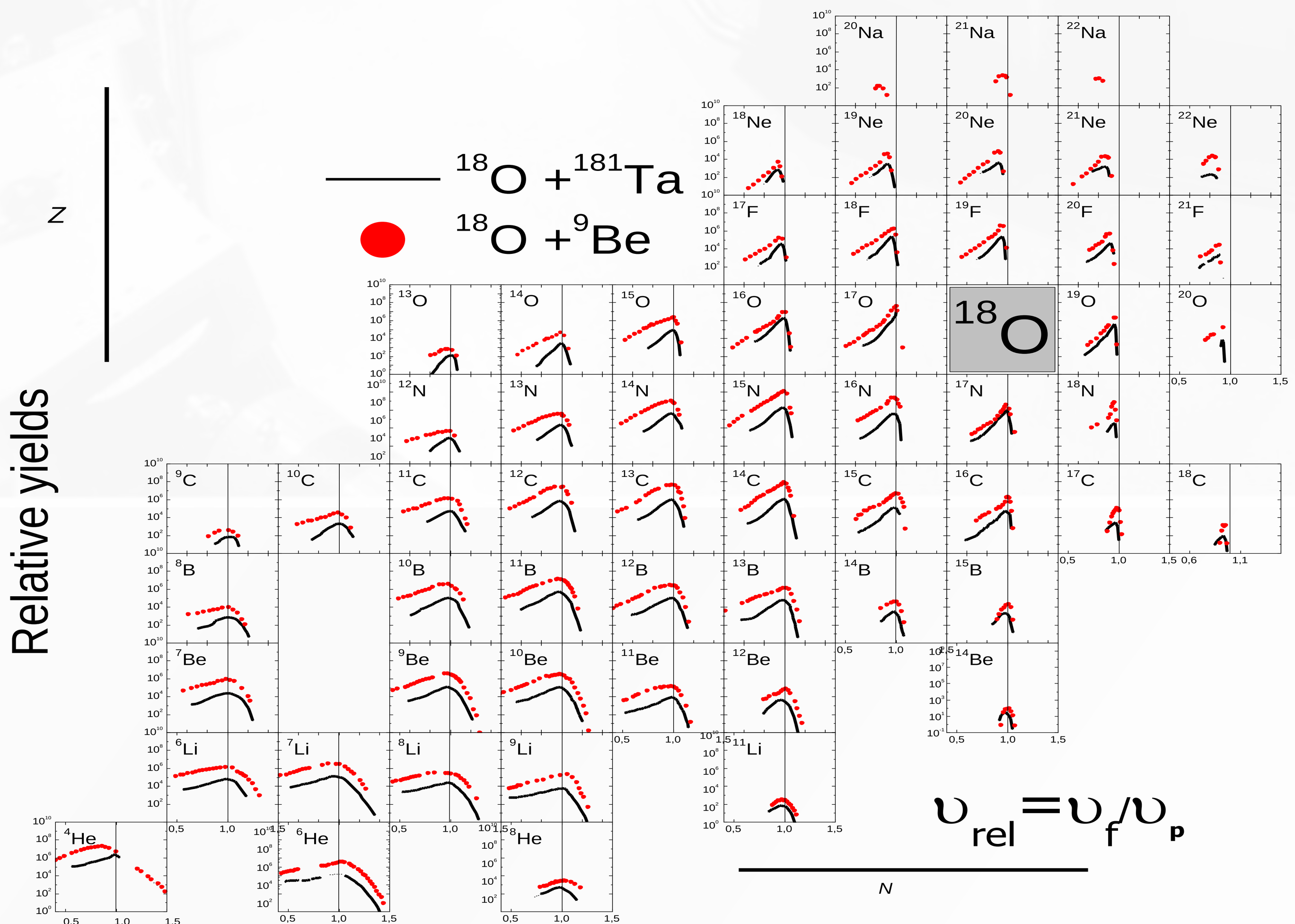

Fig.3. Forward-angle inclusive velocity distributions (relative yields) of isotopes producd in (red) ^{18}O(35Mev/nucleon)+^{9}Be reactions and (black) ^{18}O(35Mev/nucleon)+^{181}Ta reactions [1].

Momentum distributions

The reactions of fragmentations at energies close to Fermi energy are the powerful tool in producing new isotopes. This can be helpful in producing radioactive ion-beams to study the laws of physics and also in medicine an technik.

These reactions shows an unexpected feature: the pick of velocity distributions for projectile-like fragments are very close to the velocity of the beam as shoud be expected at relativistic energies. Their right slopes can be described by a gaussian with a width compatibles with Goldhaber model [G], while the left slope has a long showlder.

In papers [2,3] the shape of velocity distributions of fragments close to the projectile are described as

$$\frac{d\sigma}{dp}=\begin{cases}\cdots s\exp\left[-(p-p_0)^2/(2\sigma_L^2)\right]\ldots(p\le p_o)\\ s\exp\left[-(p-p_0)^2/(2\sigma_R^2)\right]\ldots(p>p_o)\end{cases}$$

The experiments presented in [2,3] were performed at somewhat higher energies (57 and 140 A MeV). Our data shows additional peak at the left of the maximum of velocity distribution. Here we present the parametrization of velocity distribution for the reactions O+Be/Ta at 35 A MeV. Where S_0,X_0,σ_l and σ_r are the height, the position, the width of left and right slopes, S_1,X_1,$\sigma_{l,1}$ the same for left peak (see fig.4)

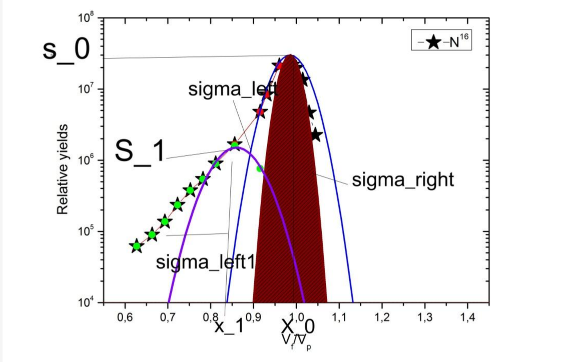

Fig.4 . Velocity distributions for ^{16}N (scatered stars) produced in fragmentation of ^{18}O primary beam on Be target. The brown curve is a Gaussian fit to the right side of the velocity distribution The left side solid curves Blue and Violet represents a sum of two gaussian and to show the asymmetry of the experimental distributions.

Momentum distributions, continuation

The momentum distributions of projectile-like fragments provide valuable information about the reaction mechanism. To study this, only the isotopes with fully measured momentum distributions have been used in the analysis.

In the nuclear fragmentation process at low energies, the velocity of the fragment is smaller than that of the projectile, for part of the projectile kinetic energy has been converted into excitation energy of the fragment. This energy loss is called "momentum peak shift," , it follows the solid curves in fig the predictions of the Borrel model, which suggests that the momentum peak shift can be simply explained by the amount of binding energy (8 MeV/nucleon in average) of the removed nucleons will be subtracted from the kinetic energy of the remaining part of the projectile (solid brown line in Fig.5). As we can see the velocity distributions in the case of fragmentation reactions at Fermi energy has maximum close to the beam energy that means that the more mechanisms are involved.

We also compare the experimental data [1] with the transport calculations [5]. In fig.5 the results for the positions of velocity distribution maxima are showen for hot (excited) fragments. One can see that they would predict the process to be much more dissipative.

The results for the width of gaussian distributions are shown in figs 6 and 7. The right slope widths show dependence on mass number of fragments similar to the one predicted by Goldhaber for the reactions at relativistic energies[6] but with the smaller normalization constant (s = 58 MeV/c instead of 90 Mev/c) .

In accordance with the results of [2,3] left-slope widths are higher than the right-hand side ones.

In fig. 8 the heights of main gaussains and the left hand-side gaussians are shown. The nature of the left-hand side peak should be investigated more thoroughly. We hope it could cast the light on competion between direct in dissipative processes in these type of reactions.

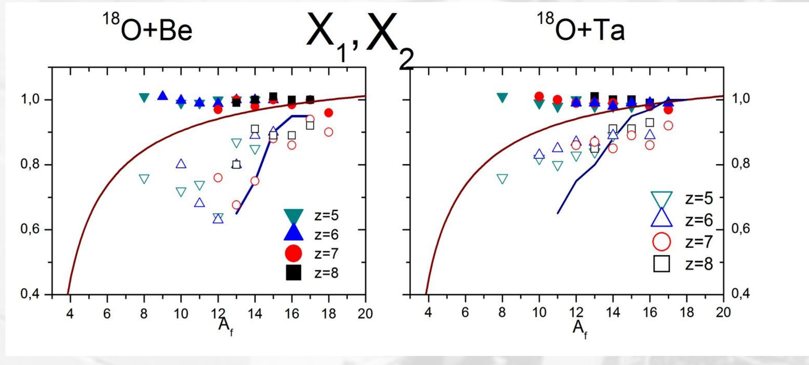

Fig 5 Momentum peak shifts of fragments produced in the 18O+9Be (a) and 18O+181Ta (b) reactions. Solid symbols-the main peak, open symbols left-hand side peak.The solid curves are the predictions of Borrel and transport models.

The momentum distribution of a fragment can be fitted with a function:

$$\frac{d\sigma}{dp}=\begin{cases}s\exp\left[-(p-p_0)^2/(2\sigma_L^2)\right]+s_1\exp\left[-(p_1-p_{01})^2/(2\sigma_{L1}^2)\right](p\le p_o)\\ s\exp\left[-(p-p_0)^2/(2\sigma_R^2)\right](p>p_o)\end{cases}$$

where S is the normalization factor, p_0 is the peak position of the distribution, σ_L and σ_R are widths of "left" and "right" halfes of two Gaussian distributions used to fit the momentum distributions.

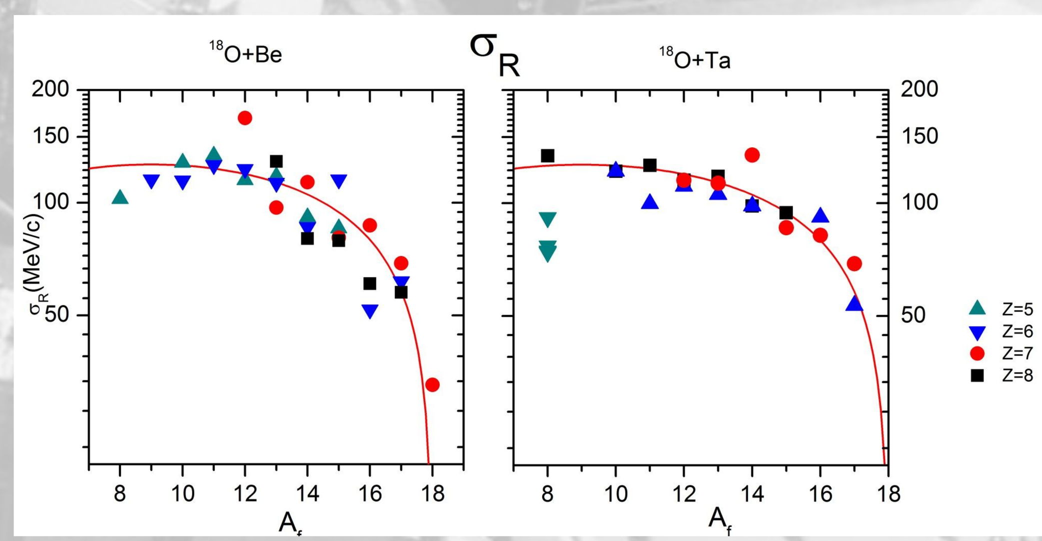

Fig 6 High-momentum-side widths of fragments produced in 18O+9Be (a) and 18O+181Ta (b) reactions. The solid curves are the predictions of Goldhaber model with σ_0=58 MeV/ c [6]

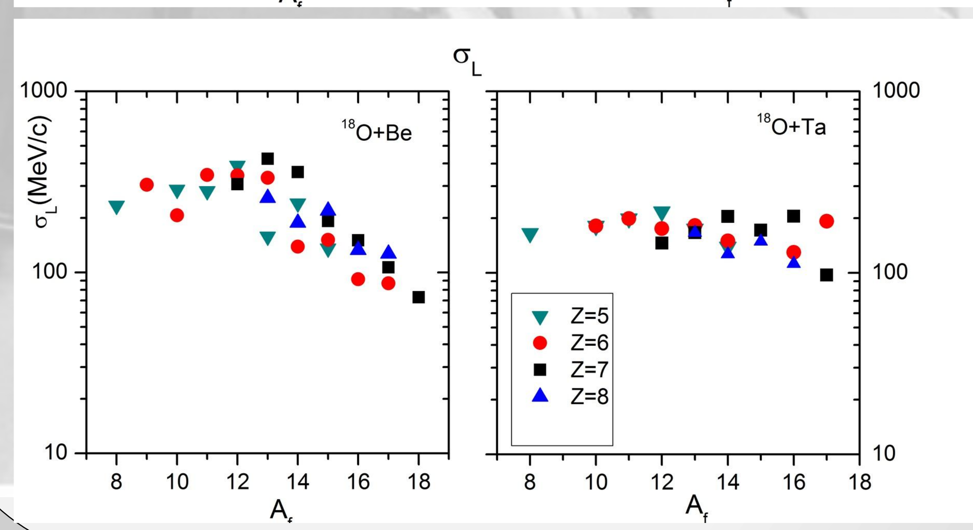

Fig 7 low-momentum-side widths of fragments produced in 18O+9Be (a) and 18O+181Ta (b) reactions.

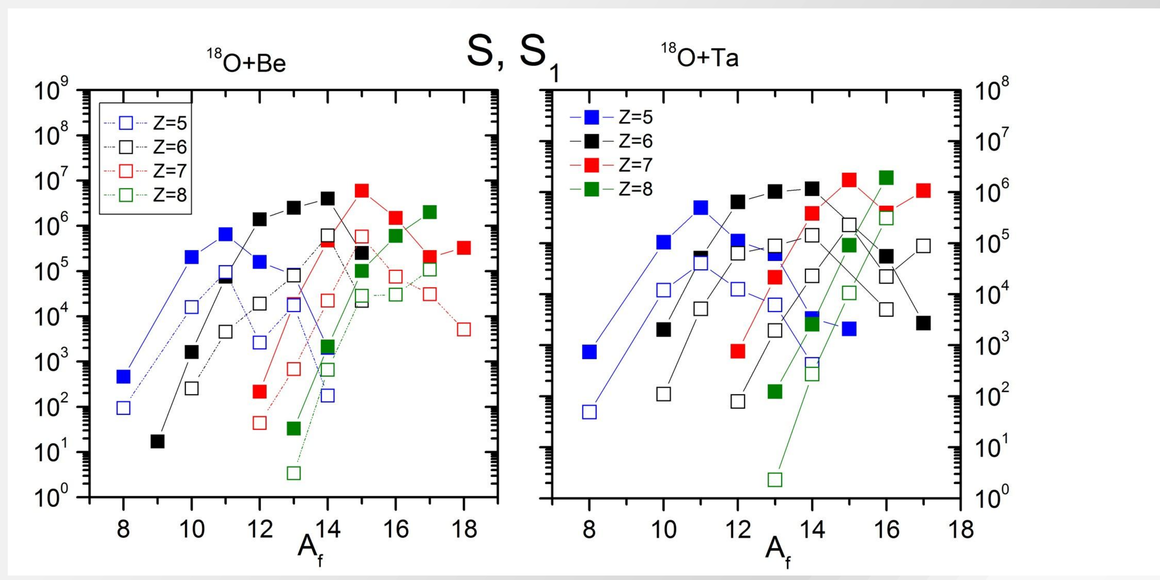

Fig 8 The heights of relative yields dependences S and S_1 (see fig.4) for the reactions ^{18}O at 35 MeV/nucleon on the ^{9}Be and ^{181}Ta targets.

Conclusions

1. The projectile fragmentation reactions of a 35 MeV/nucleon ^{18}O beam on ^{9}Be and ^{181}Ta targets have been studied by COMBAS fragment seperator at the U400M.
2. By measuring the velocity distribution of the fragments, we have seen clearly the competition between dissipative and direct reaction
3. The high-momentum-side widths of the fragments are in good agreement with the Goldhaber model, which shows that the direct reaction mechanism is dominant.
4. The low-momentum-side widths are much broader and was represented as a sum of two Gaussians.
5) We hope that our results will help to better understand the competition of dissipative and direct process in transfer reactions at Fermi energies

References

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