Analysis of production of forward-angle fragments in the $^{22}Ne + ^{9}Be/^{181}Ta$(42 MeV/nucleon) nuclear reactions.

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Abstract

Up to date analysis of velocity and isotope distributions of light fragments obtained in the projectile fragmentation reactions of ^{22}Ne at 42 MeV/nucleon on ^{9}Be and ^{181}Ta targets measured at COMBAS fragment separator at the U400M Research Facility in JINR [1] are presented. The results of velocity spectra analytical parameterization 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

- 14-mg/cm^2 9Be and 181Ta target foil was irradiated with a 42A-MeV ^{22}Ne beam 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 mass number A and atomic number Z with a (ΔE, E) telescope placed at 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 3 ≤ 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 by combining two methods: magnetic rigidity and (ΔE, E):
- E = (Bρ)2 × Z2/A, (1)
- ΔE ≈ A × Z2/E.   (2)
- 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.

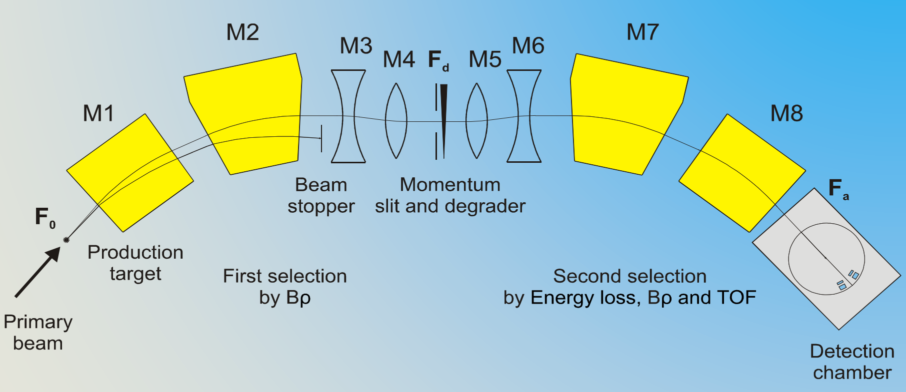


Fig.1. Magneto-optical scheme of the separator COMBAS

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.2 . Particle identification in the *dE*–E plane at *Bρ* = 1.78 Tm with the Be target

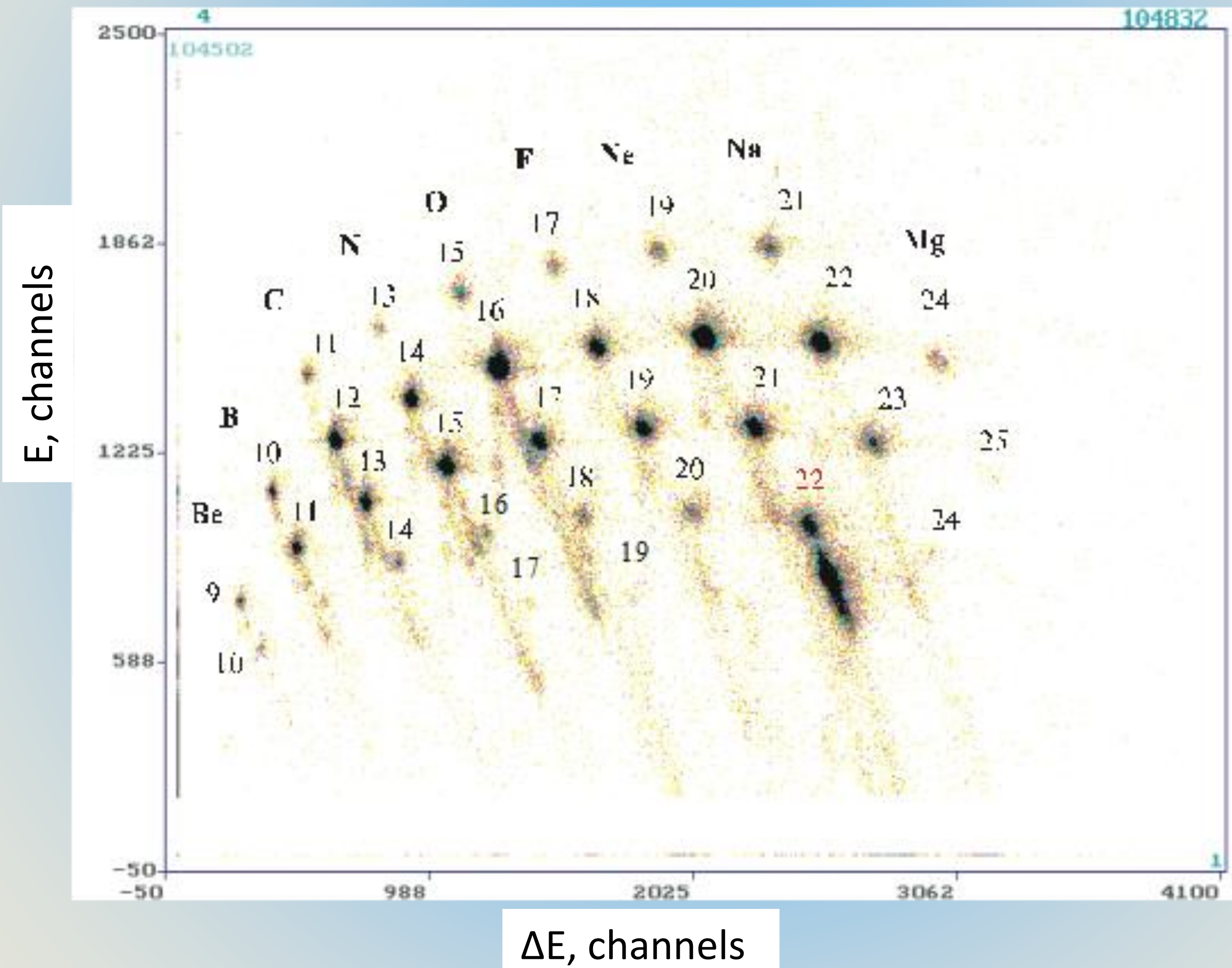
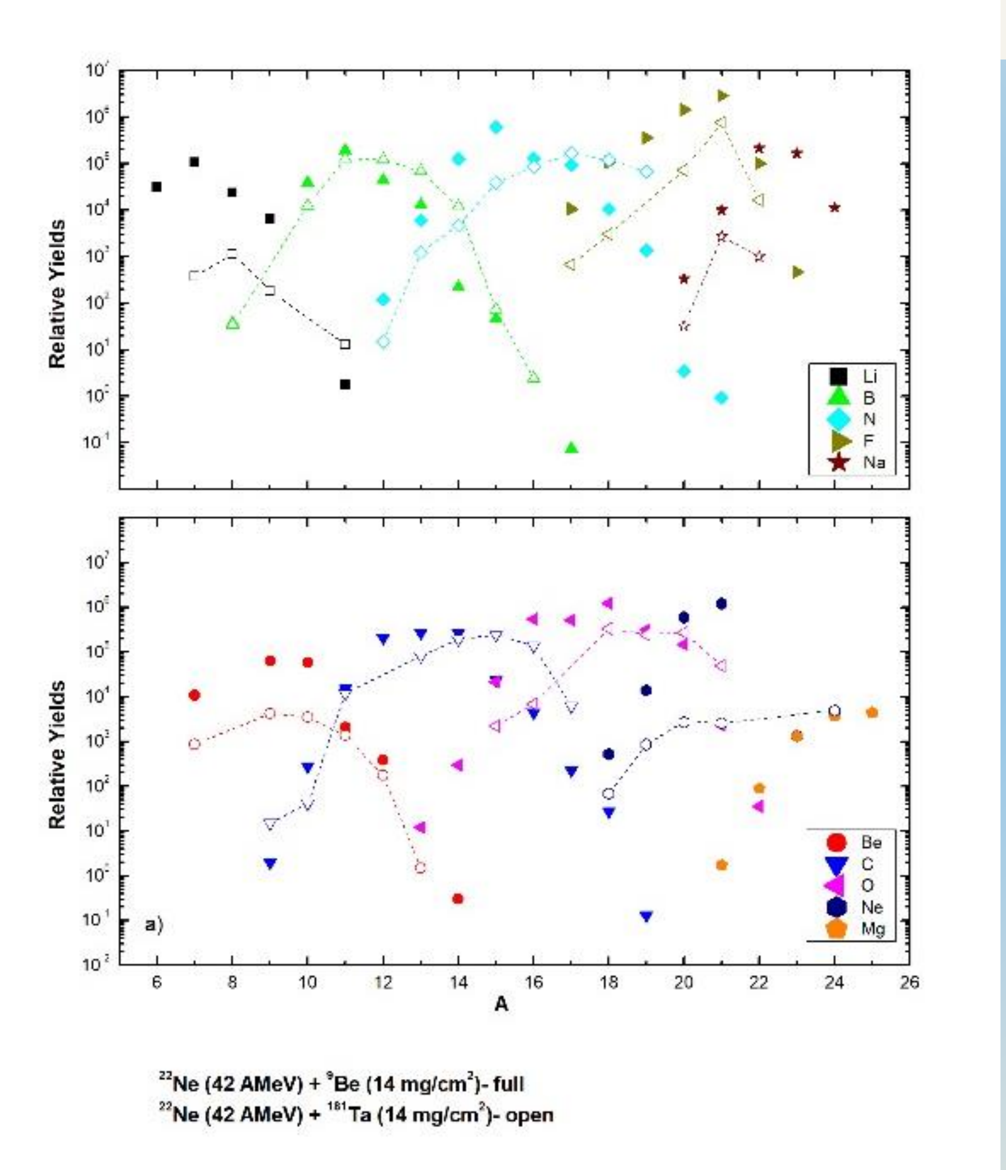


Fig.3. Forward-angle inclusive isotope distributions (relative yields) of isotopes produced in (full) ^{22}Ne(42Mev/nucleon)+^{9}Be reactions and (open) ^{22}Ne(42Mev/nucleon)+^{181}Ta reactions. Isotopic distributions that were obtained by integration of velocity distributions versus the detected mass A.



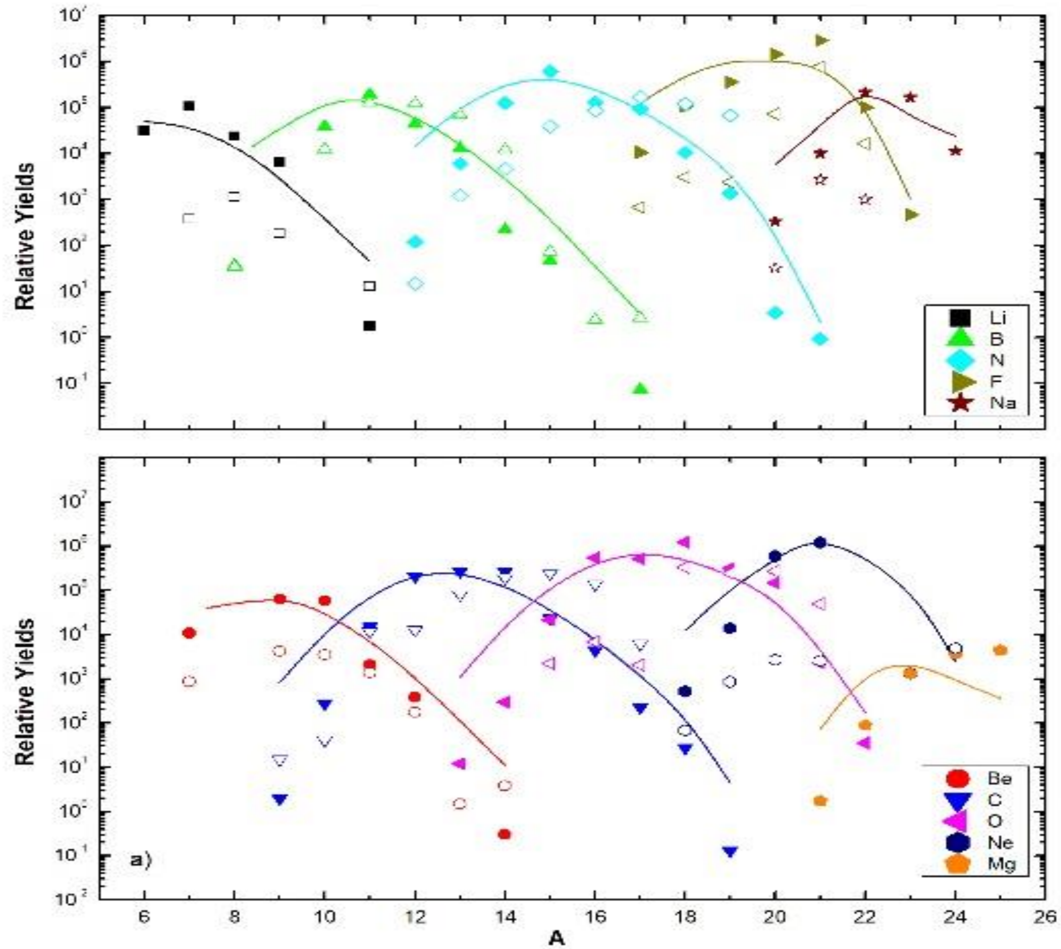
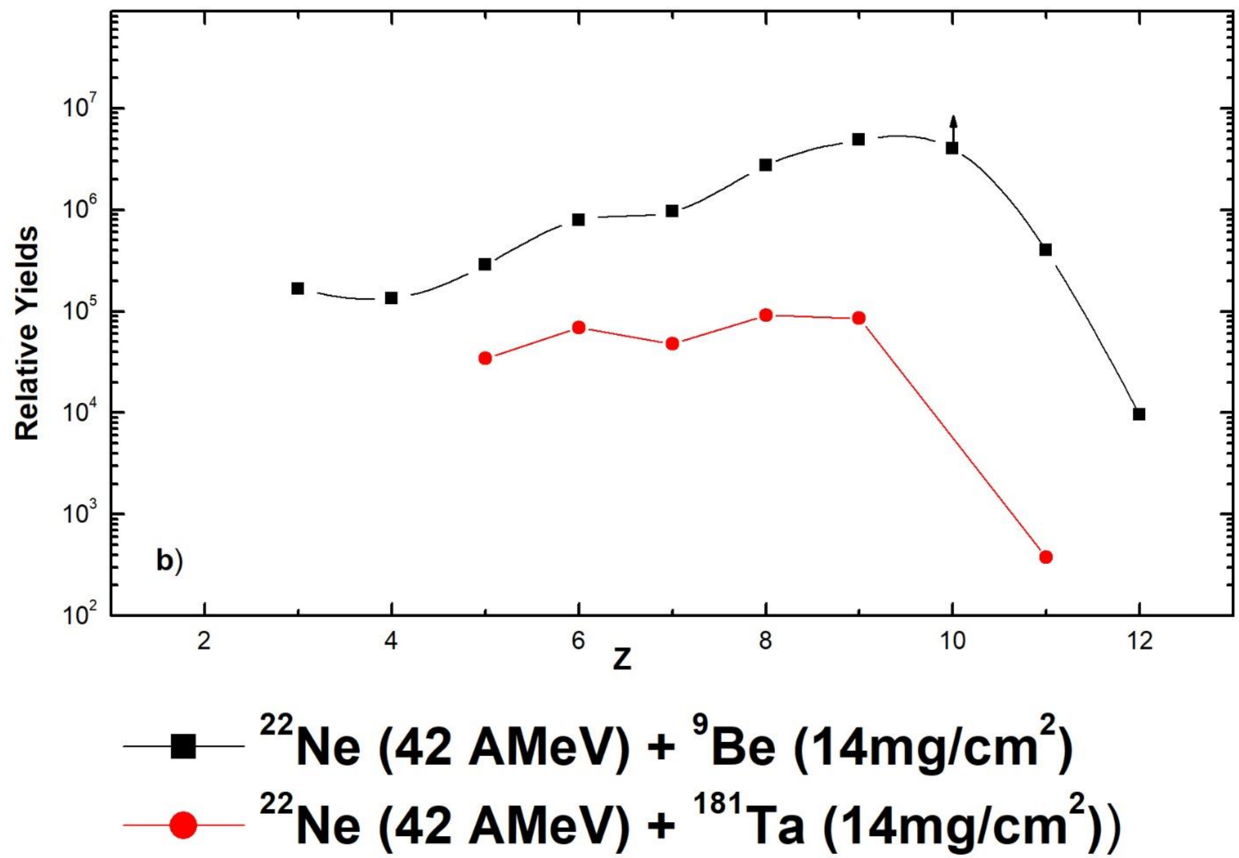
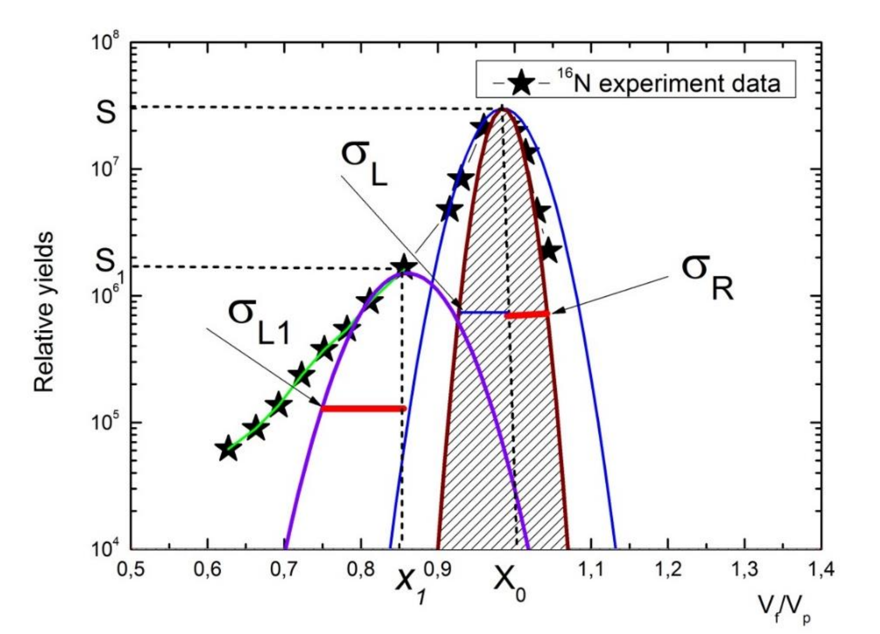


Fig.3. Forward-angle inclusive isotope distributions (relative yields) of isotopes produced in (full) ^{22}Ne(42Mev/nucleon)+^{9}Be reactions and (open) ^{22}Ne(42Mev/nucleon)+^{181}Ta reactions. Isotopic distributions that were obtained by integration of velocity distributions versus the detected mass A. The solid curves present the LISE code fit for ^{22}Ne(42Mev/nucleon)+^{9}Be reactions.

Element distributions (Z distributions) versus the atomic number.



Momentum distributions



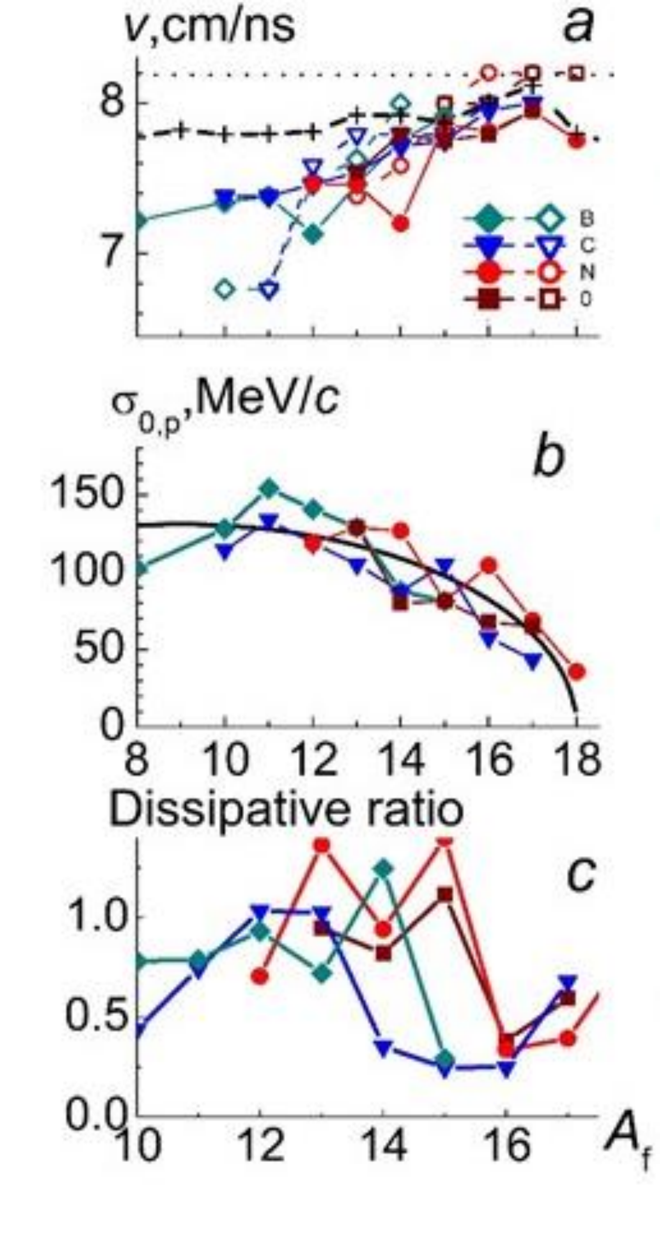
The reactions of fragmentations at energies close to Fermi energy are the powerful tool in producing new isotopes. These reactions shows an unexpected feature: the pick of velocity distributions for projectile-like fragments are very close to the velocity of the beam as should be expected at relativistic 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 shoulder.

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

$$\frac{d\sigma}{dv} = s_0 \exp[-(v - v_0)^2 / 2\sigma_0^2] + s_1 \exp[-(v - v_1)^2 / 2\sigma_1^2]$$

Fig.4 . Velocity distributions for ^{16}N (scattered stars) produced in fragmentation of ^{22}Ne 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.

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 parameterization of velocity distribution for the reactions Ne+Be/Ta at 42 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)



The comparison with predictions by transport calculations and empirical fragmentation models.

Characteristics of the two-component fit of the velocity distributions of ^{22}Ne+Be as a function of the fragment mass A_f. The elements are denoted by symbols and colour as indicated in the legend in the figure. Upper row (panel a): position of the dissipative peak v_1: full symbols-solid line for the fit, open symbols-dashed lines for the BNV-SMM calculations. Black solid line with crosses - mean velocities v_{mean}. The brown solid line is the prediction of the Borell formula . Dotted line – position of beam velocity. Middle row (panel b): width of the direct peak from the fit. The brown line here represents the prediction of the Goldhaber model . Lower row (panel c) dissipative ratio, i.e. the ratio of the integrated dissipative to direct contributions, from the fit.

Conclusions

- 1. The velocity, isotopic and element distributions of projectile like fragments for reactions ^{22}Ne+Be/Ta are studied.
- 2. The parameterization of velocity distributions obtained in the projectile fragmentation reactions of ^{22}Ne beam on 9Be and 181Ta targets at 42 A MeV beam energy with a modified asymmetric Gaussian expression was completed.
- 3. The results show that the mechanism of these types of reactions is complicated; the data show competition between direct and dissipative components. The direct component is prevailing forming the larger part of the cross-section of the reaction.
- 4. The direct component follows the Goldhaber predictions, however the normalization parameter is smaller than that predicted by Goldhaber for the collisions at larger energies.
- 5. The nature of the left-hand side peak and its connection with dissipative mode of the reaction has to be investigated in more details.
- 6. Transport model calculations are a tool to describe dissipative component of fragmentation reactions.