BECQUEREL PROJECT
Проект БЕККЕРЕЛЬ
Beryllium (Boron) Clustering Quest in Relativistic Multifragmentation
http://becquerel.jinr.ru

Analysis of nuclear track emulsion exposed by relativistic hadrons

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(BECQUEREL Experiment)

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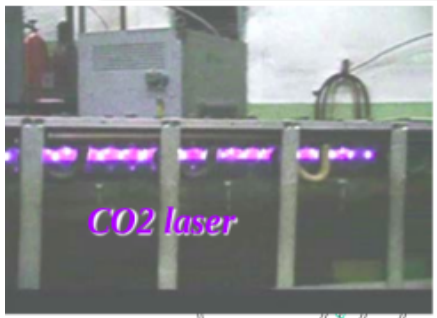
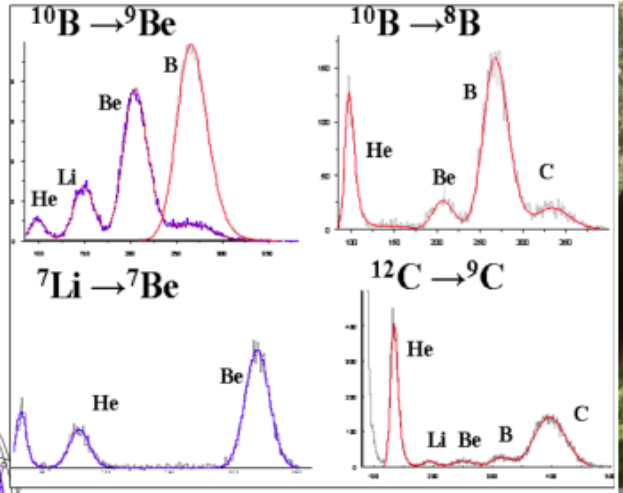
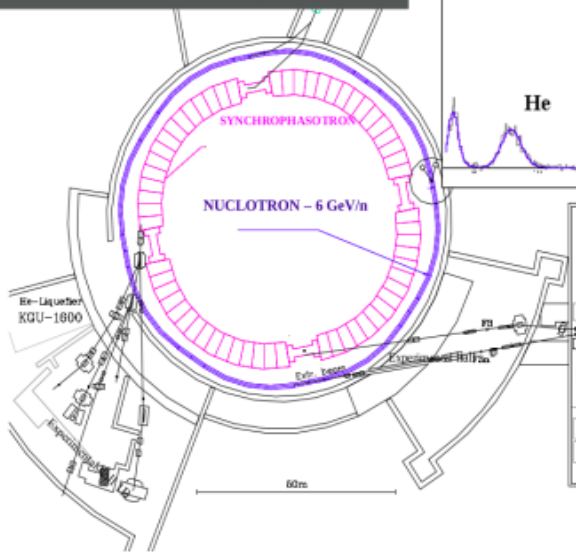
Outline

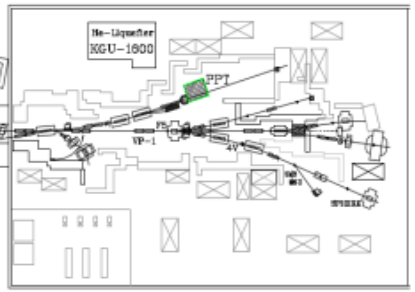
BECQUEREL Experiment

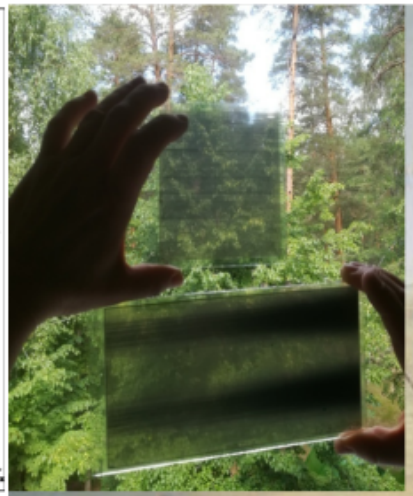
- The BECQUEREL experiment at the JINR Nuclotron-NICA focuses on the systematic investigation of clustering phenomena in light stable and radioactive nuclei.
- The fragmentation of a diverse range of light nuclei was studied using emulsions exposed to a few A GeV nuclear beams at the JINR Nuclotron. Nuclear track emulsions were employed to investigate the fragmentation of relativistic nuclei.

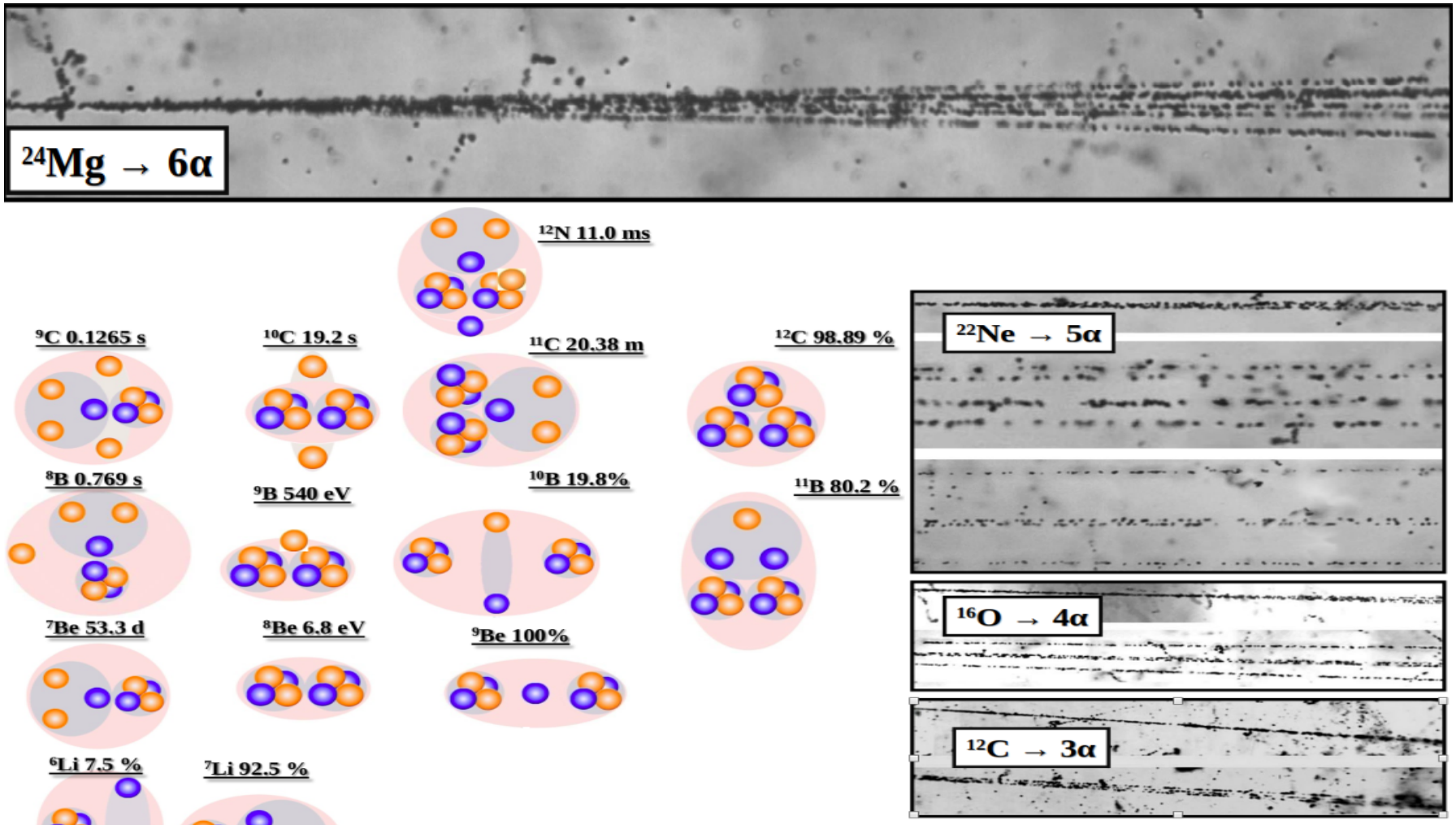






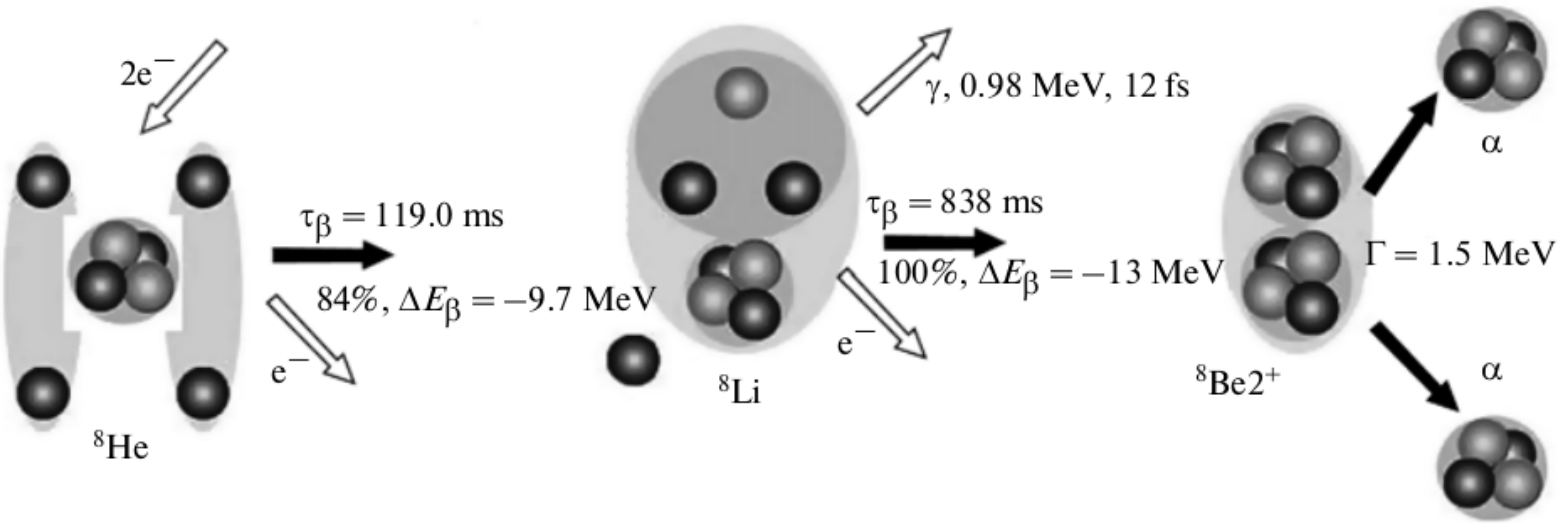




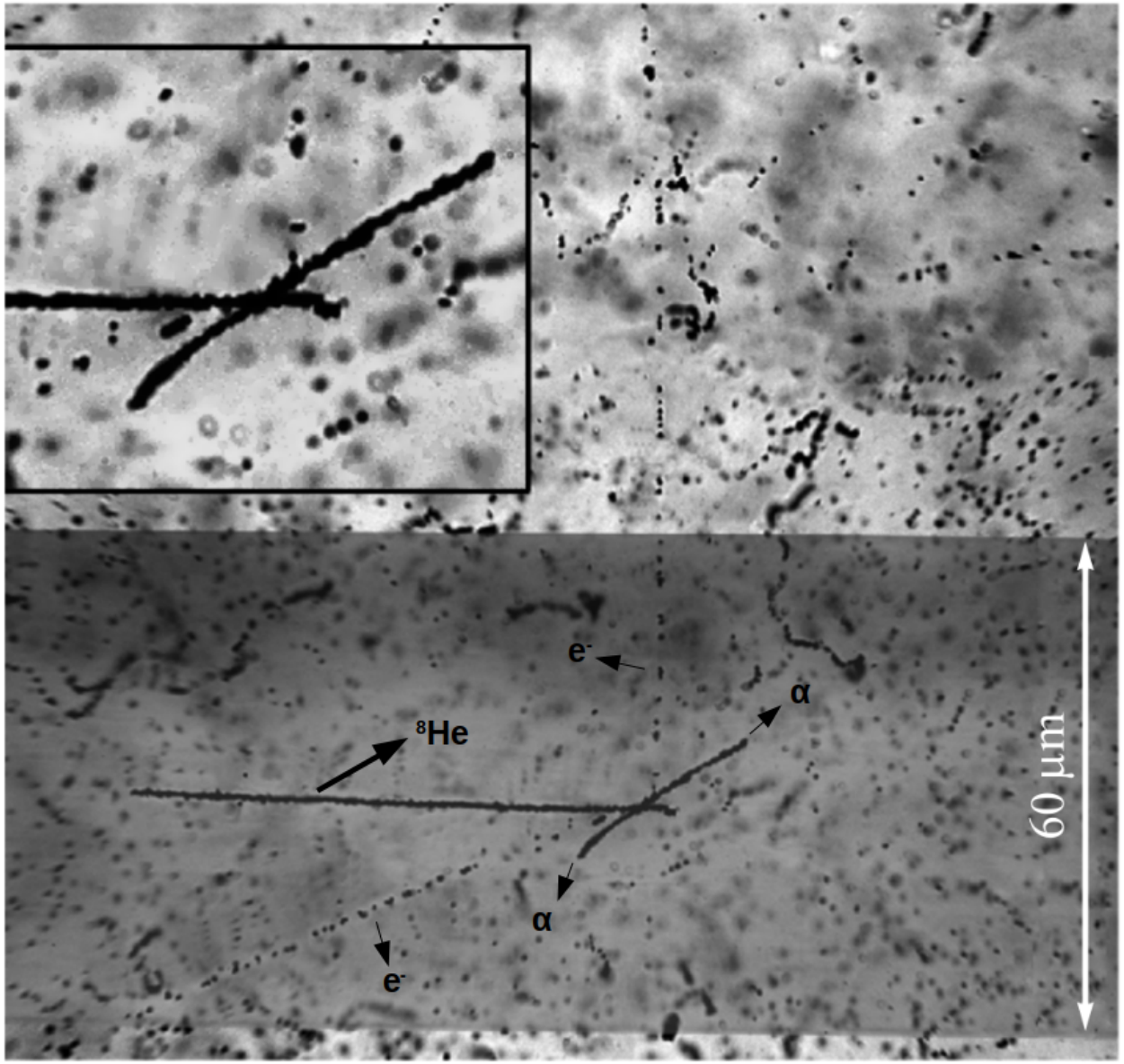


Based on the invariant mass ($Q = M^{*}- M$) of relativistic pairs and triplets of helium (He) and hydrogen (H), the unstable nuclei ^{8}Be and ^{9}B are identified during the dissociation of the isotopes ^{9}Be, ^{10}B and ^{10,11}C, Additionally, the Hoyle state is identified during the dissociation of ^{12}C and ^{16}O.

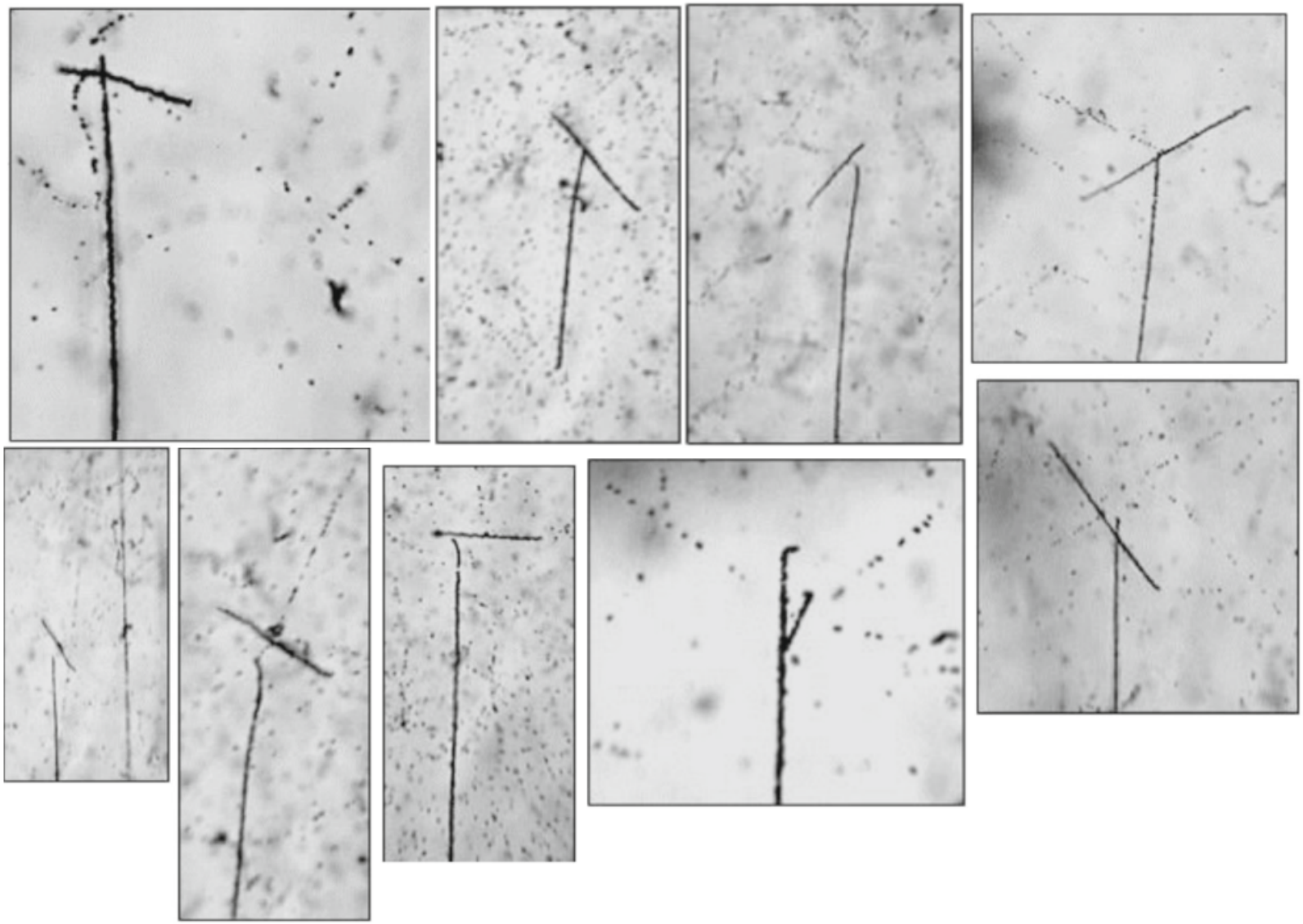
Exposure of NTE to ^{8}He Nuclei at the ACCULINNA Separator



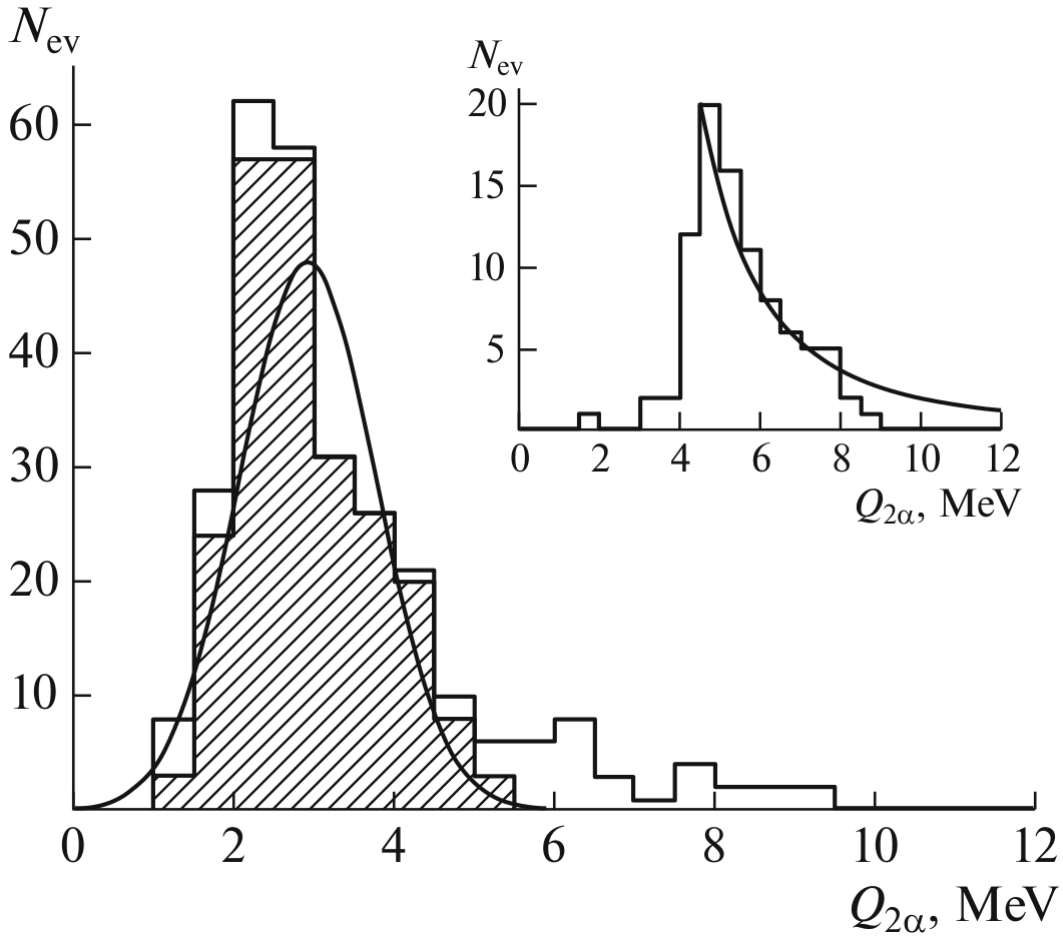
Scheme of the main cascade decay channel for the ^{8}He isotope. Circles are protons (light) and neutrons (dark). Darker background indicates clusters.



Mosaic macrophotograph of the "hammerlike" decay of the ^{8}He nucleus stopped in the nuclear track emulsion.

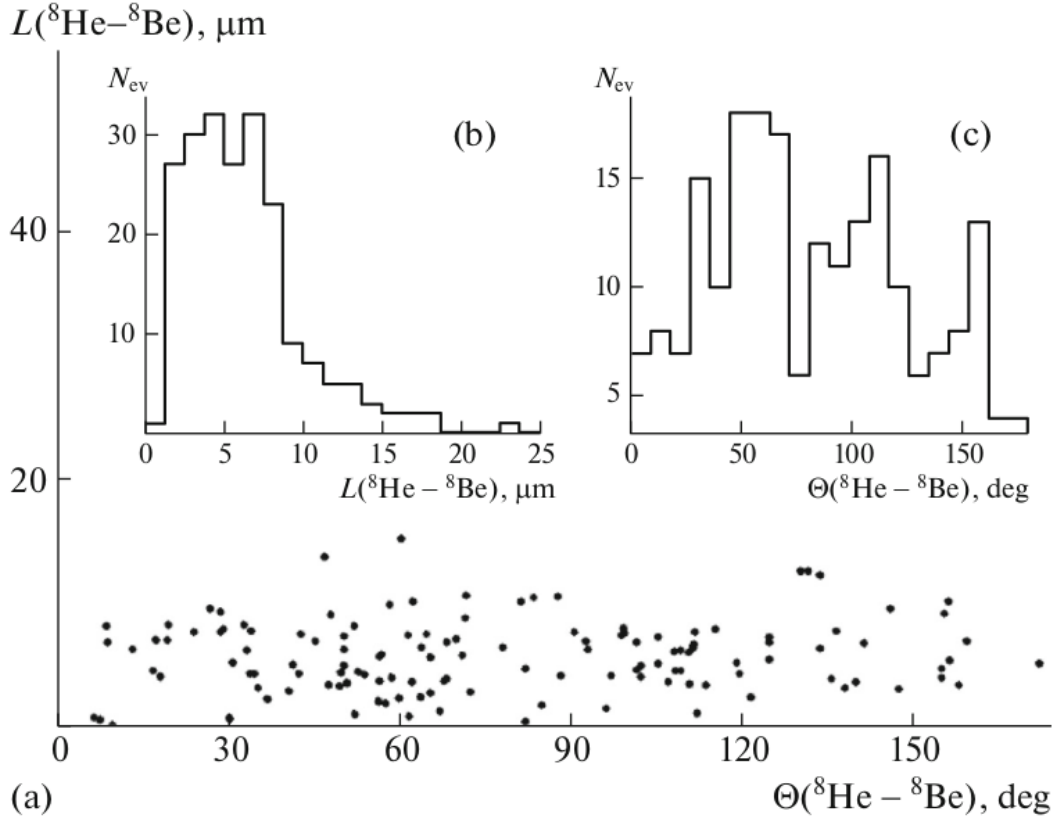


Macrophotos of "hammer-like" decays of ^{8}He nuclei stopped in NTE.



Energy $Q_{2\alpha}$ distribution for 278 pairs of α particles

The $Q_{2\alpha}$ distribution on the whole corresponds to the decay from the first excited state of $^{8}Be_{2+}$. For events in which the ranges of both α particles are shorter than 12.5 μm and the opening angles are larger than 145°, the average value of $Q_{2\alpha}$ is equal to (2.9 $\pm$ 0.1) MeV with the RMS equal to 0.85 MeV, which corresponds to $^{8}Be_{2+}$.

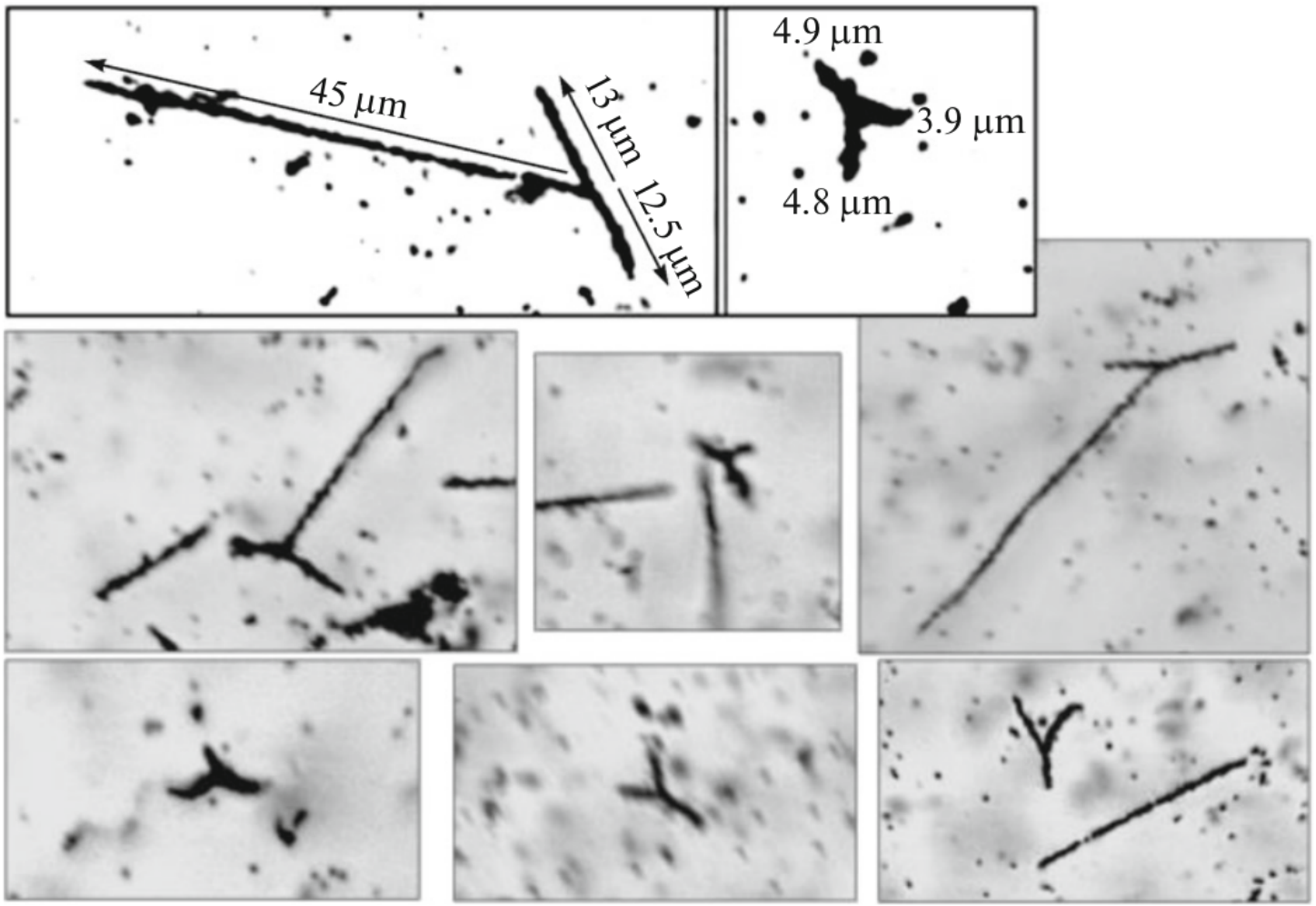


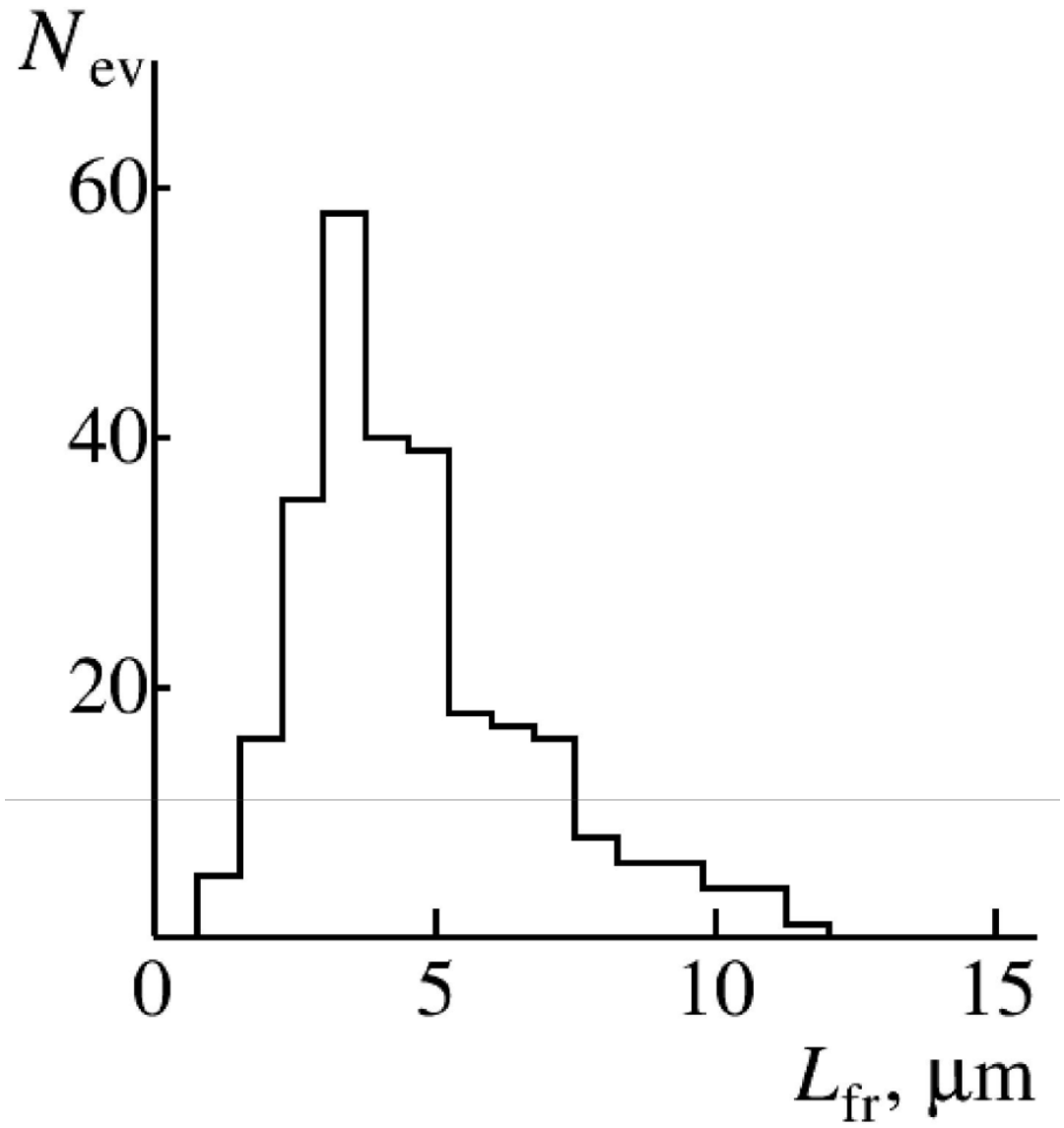
(a) Event distribution with respect to the distances L(^{8}He-^{8}Be) and angles Θ (^{8}He-^{8}Be); the insets show projections (b) L(^{8}He-^{8}Be) and (c) Θ (^{8}He-^{8}Be).

The distances L(^{8}He-^{8}Be) between the stopping points of ^{8}He ions and the decay vertices and the angles Θ (^{8}He-^{8}Be) between the ion incidence and the line connecting the stopping points and the decay vertices were determined in "broken" events. The distribution homogeneity for these parameters and the absence of pronounced correlations point to thermal drift of ^{8}He atoms. The average value of L(^{8}He-^{8}Be) equal to (5.8 ± 0.3) μm with the RMS of 3.1 μm can be associated with the average range of ^{8}He atoms.

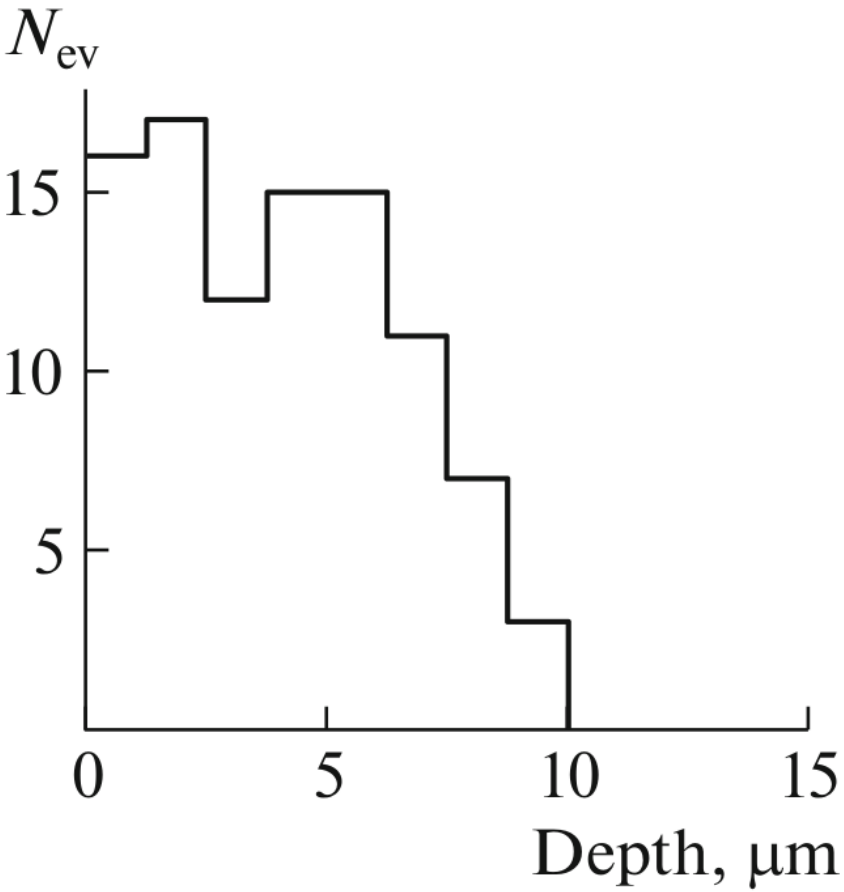
Irradiations of NTE by ^{252}Cf Source

This ^{252}Cf isotope can also undergo spontaneous fission into two or even three fragments with a probability of 3% and 0.1%, respectively. For comparison, the NTE sample was irradiated by a ^{241}Am source emitting α particles in the same energy range.





The mean value of L_{fr} is 4.6±0.13 (RMS 2.1) μm, and a rough estimate of the average energy is 400 A keV.



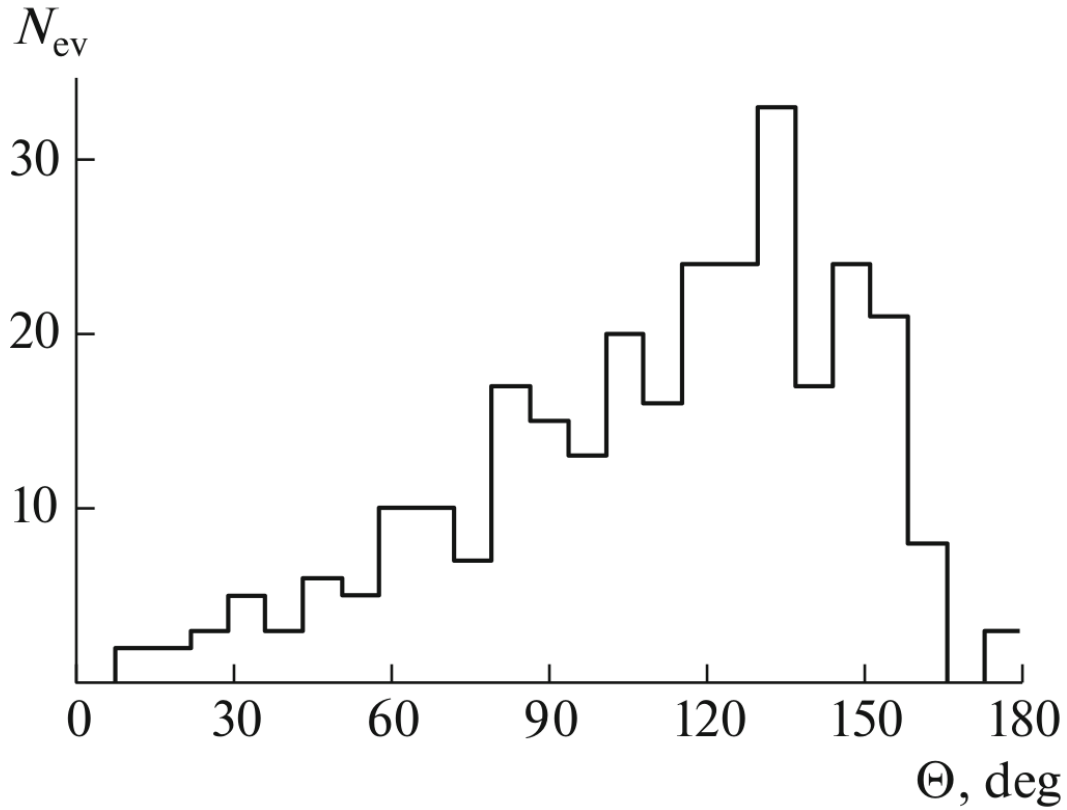
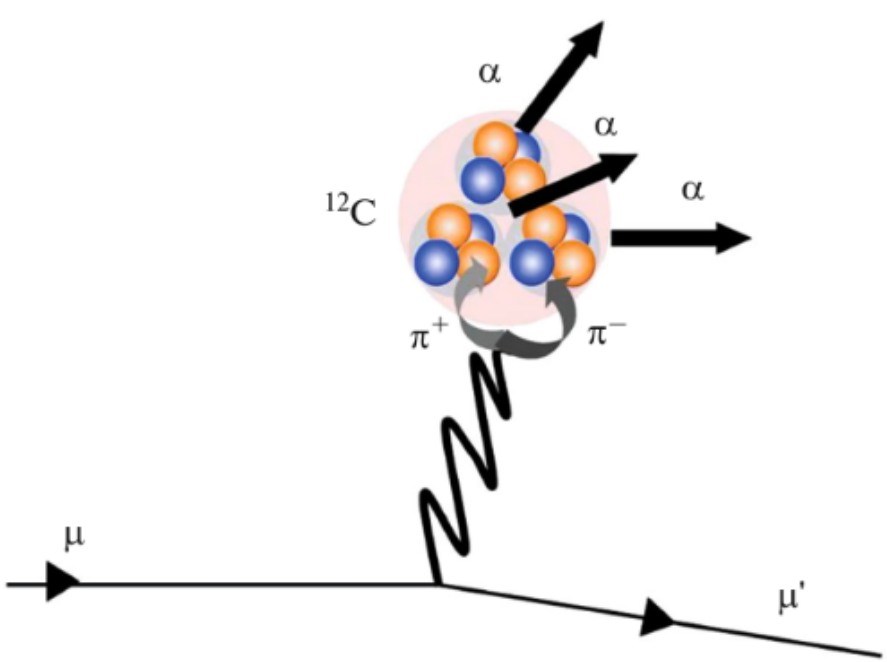
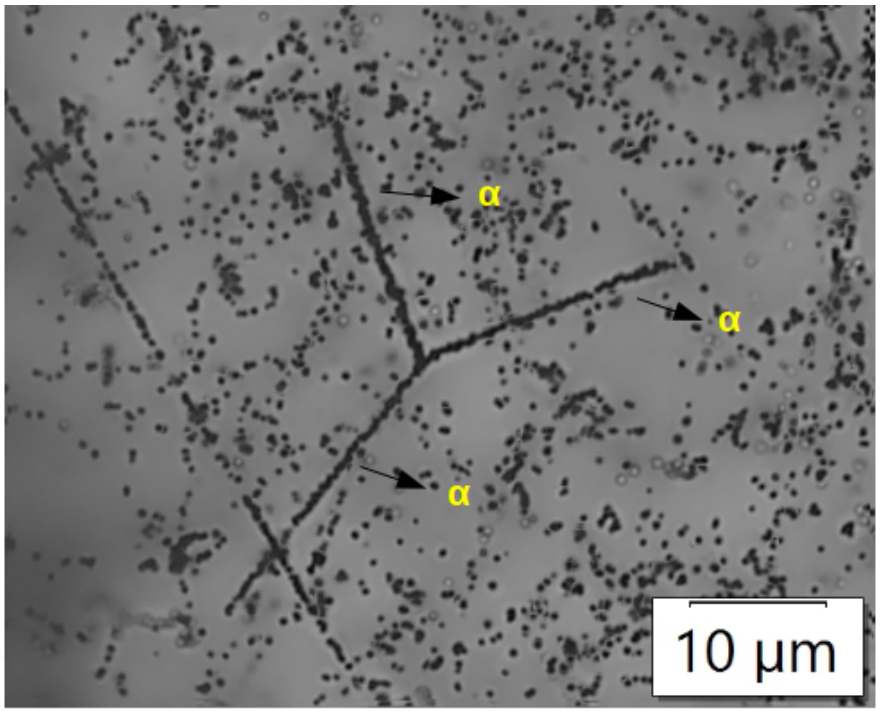


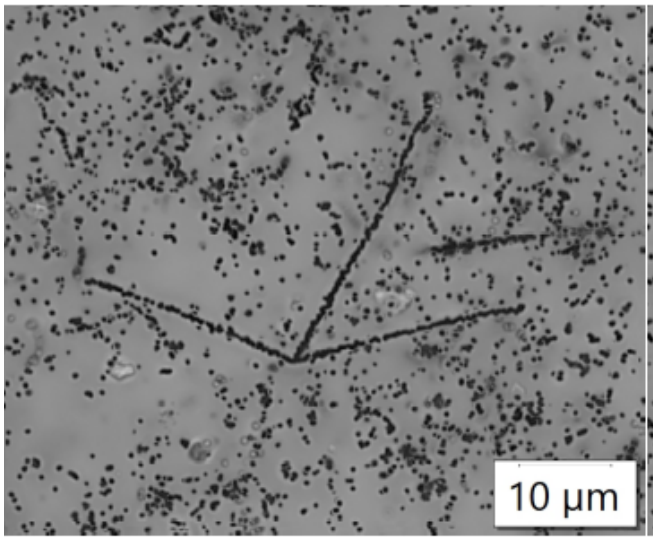
Figure shows the distribution of 96 Cf fission vertices into three fragments along the NTE layer depth, with an average of 4.1±0.2 μm and RMS of 2.5 μm, likely due to the binding and drift of Cf atoms in AgBr microcrystals.

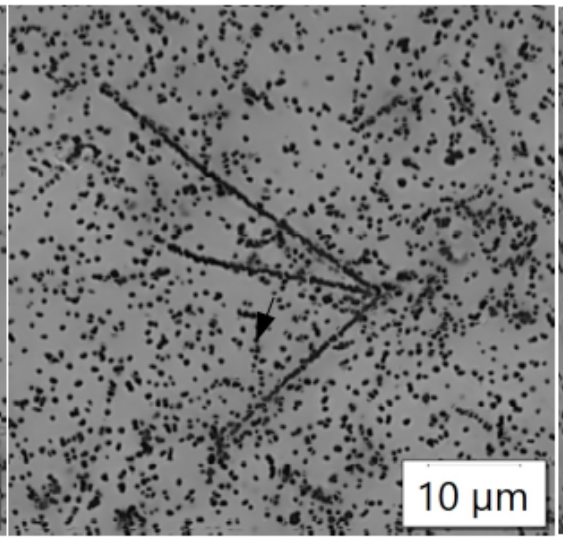
The fragment opening angles were also measured in these events. Their distribution is characterized by an average value of (111 ± 2)°and an RMS of 36°.

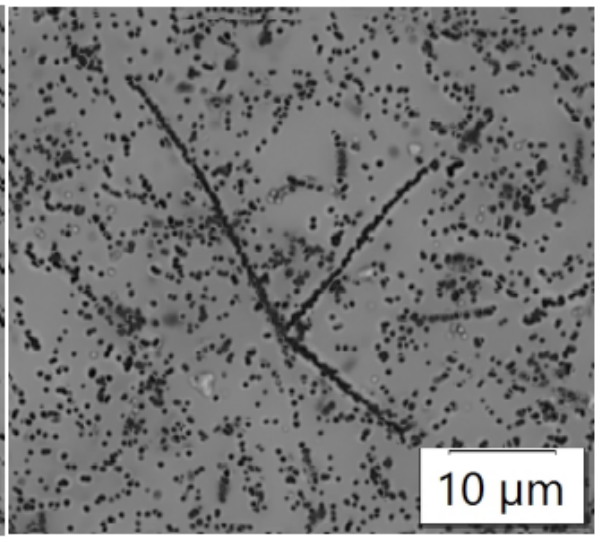
Exposure of NTE by muons

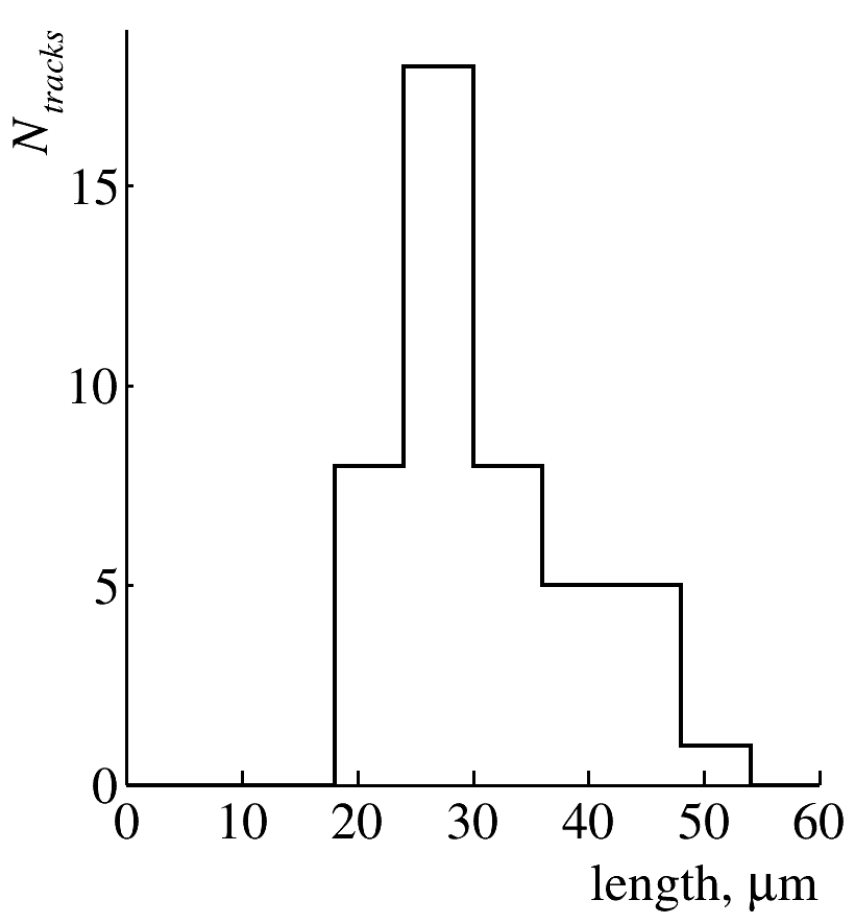


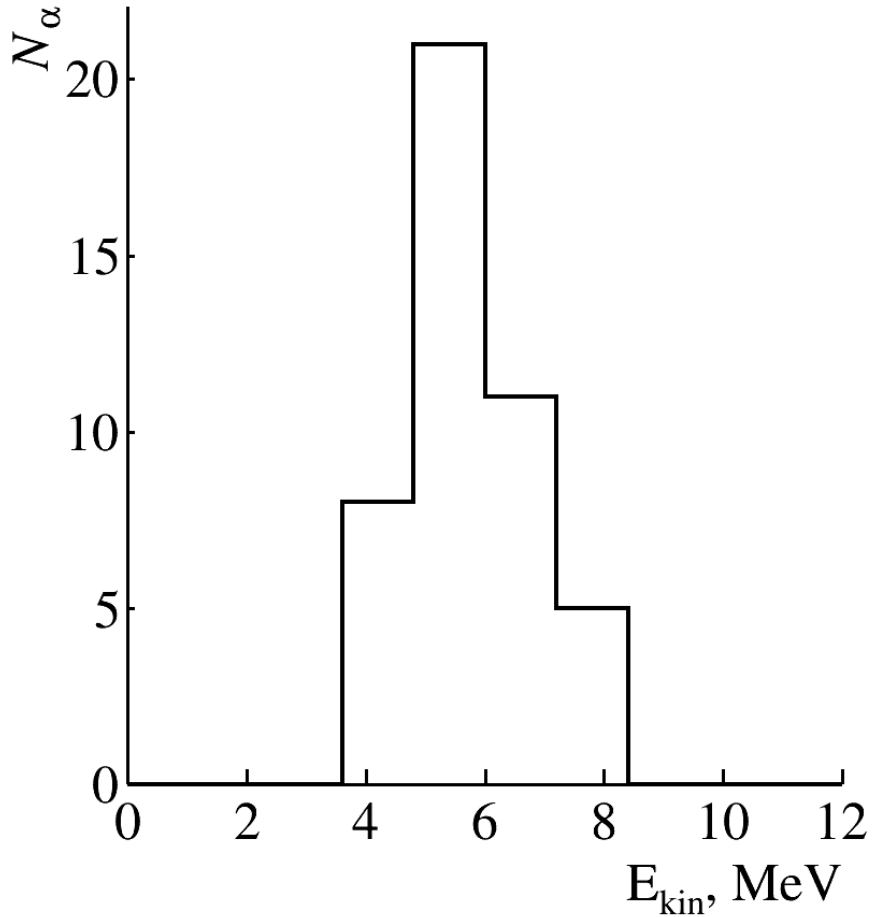




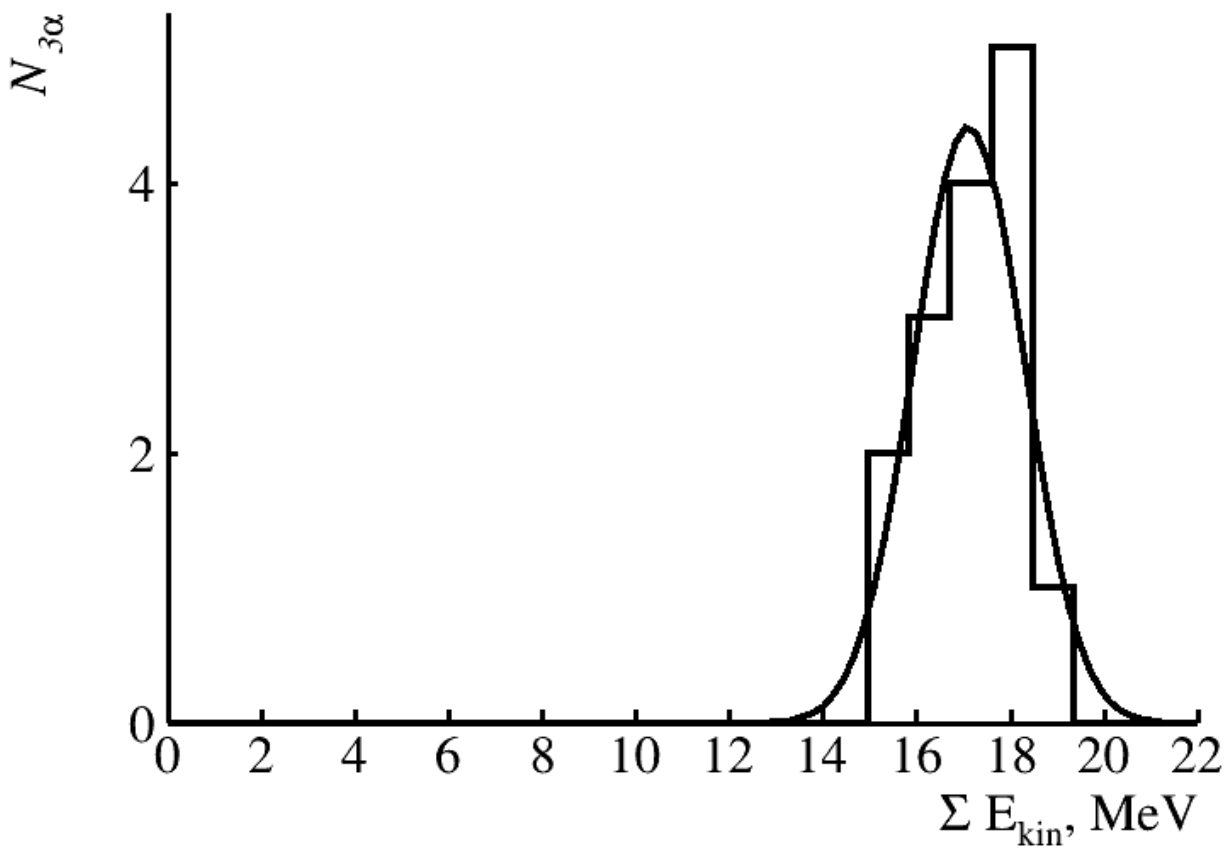




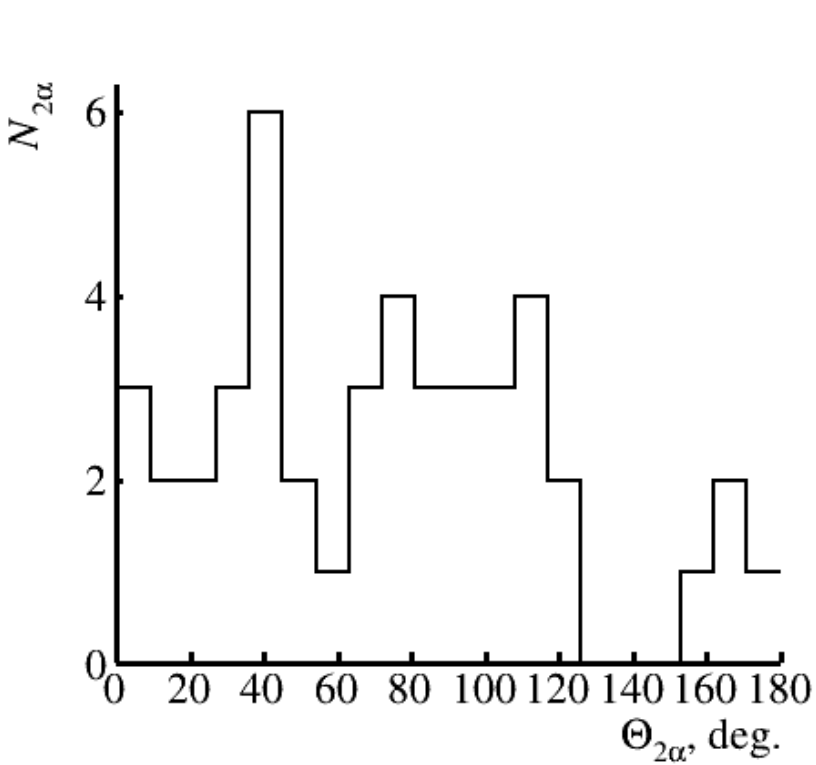


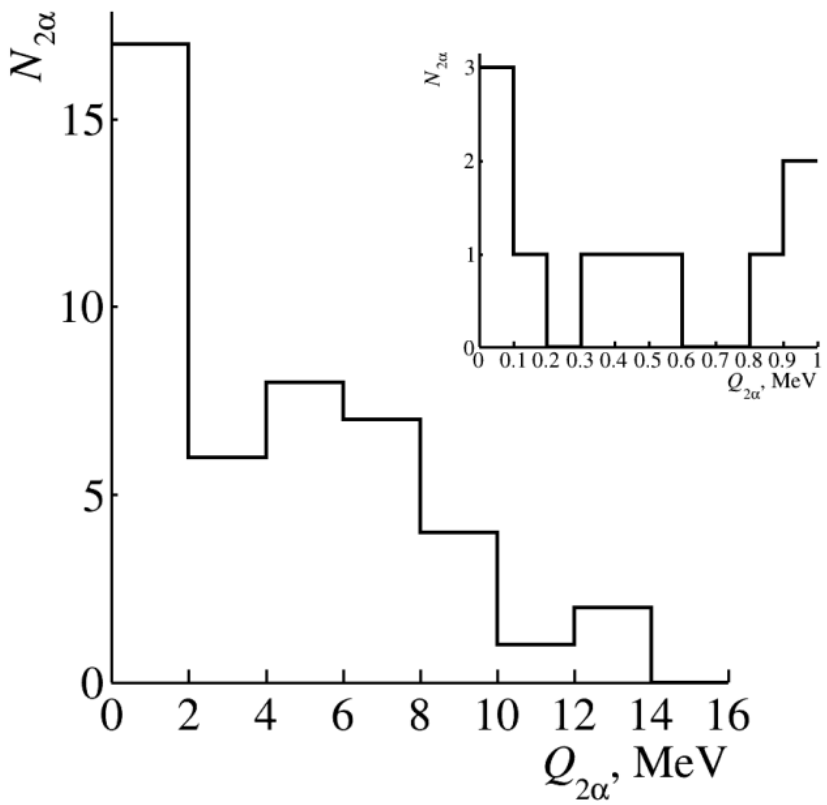


The α-particle ranges and spatial emission angles were determined on the basis of coordinate measurements for tracks. The mean α-particle range was 27.2 ± 3.2 μm (RMS = 7.7 μm). The α-particle energy was estimated on the basis of the SRIM model. Its mean value proved to be 5.6 ± 0.1 MeV (RMS = 1 MeV).

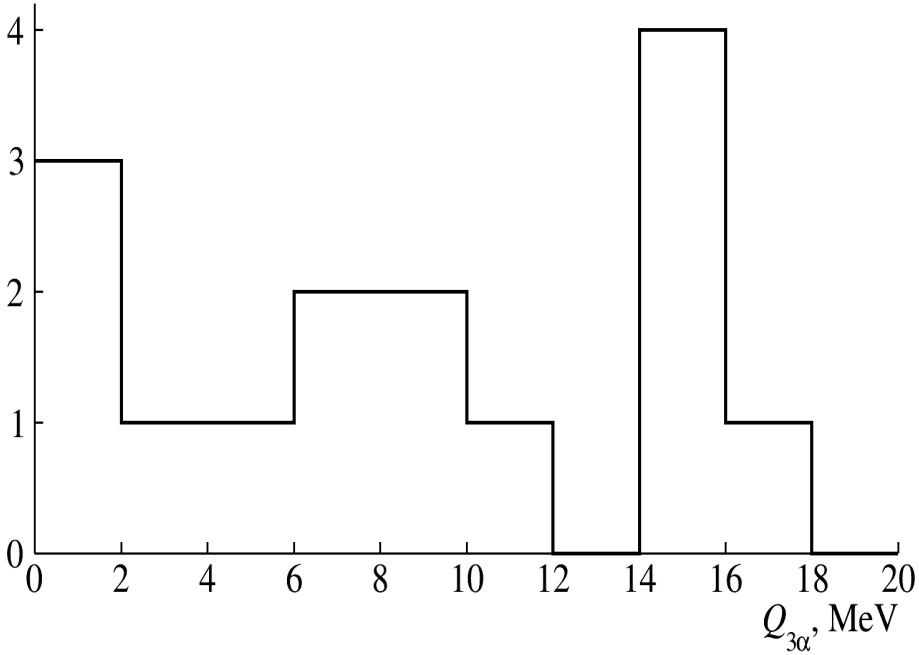


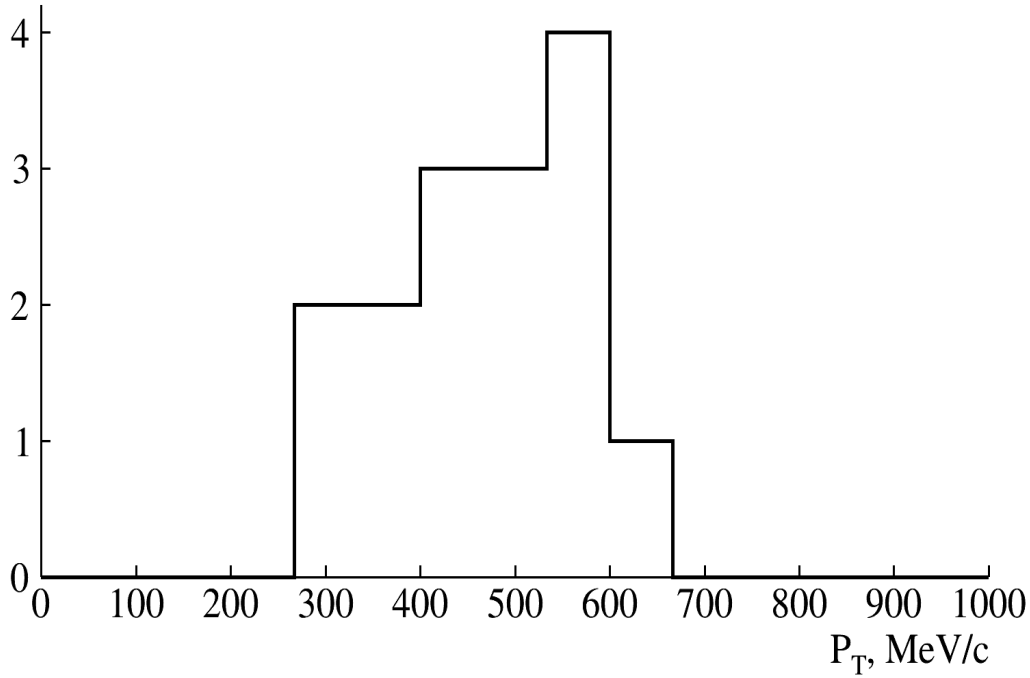
The total energy of the α triplets was fitted by a Gaussian function with a mean value of 17.1 $\pm$ 0.4 MeV and a standard deviation of 1.1 $\pm$ 0.3 MeV.





The α particle angle distribution is characterized by a mean value of (73 $\pm$ 7)° and an RMS of 45°.





The distribution of P_T is characterized by the mean value of 465±26 MeV/c(RMS = 100 MeV/c).

Summary

- The integration of modern radioactive sources, proven metrology (NTE), and advanced microscopy appears to be a reliable prospect for α-radioactivity and nuclear fission research.
- The emulsion technique's exceptional spatial resolution makes it particularly effective for studying light nuclei, especially those that are neutron-deficient. This study emphasizes the practical application of NTE in nuclear experiments, serving as a prototype for addressing a wide range of challenges.
- This report provides preliminary findings from a study on the multifragmentation of ^{12}C nuclei subjected to ultra-relativistic muons. Macro photographs illustrating the discussed exposures and corresponding videos can be accessed through the BECQUEREL project website.
- The BECQUEREL experiment will continue to investigate the interactions between ultra-relativistic muons and carbon nuclei.

Thank you for your kind attention !