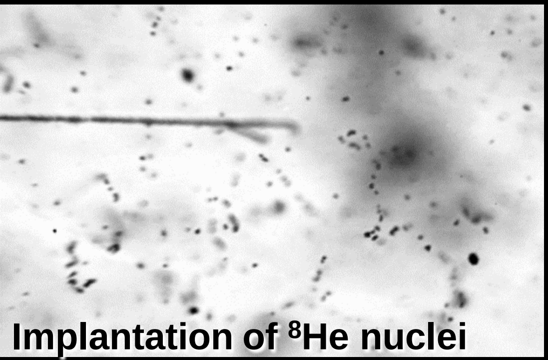
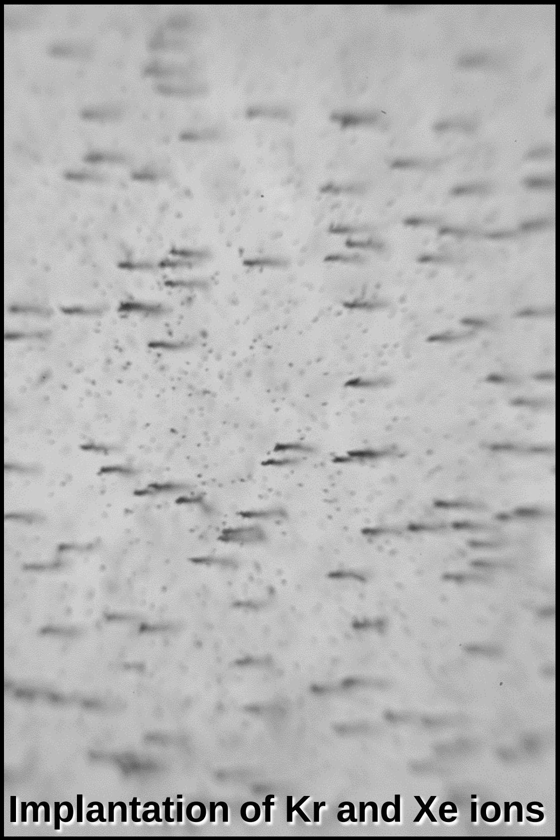
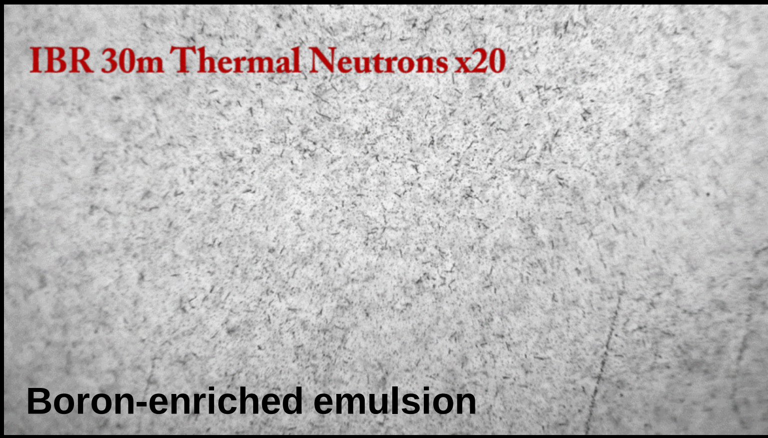
Irina Zarubina "Recent applications of nuclear track emulsion "


Implantation of ^{8}He nuclei


Splittings of $^{12}C \rightarrow 3\alpha$, induced by 14.1 MeV neutrons

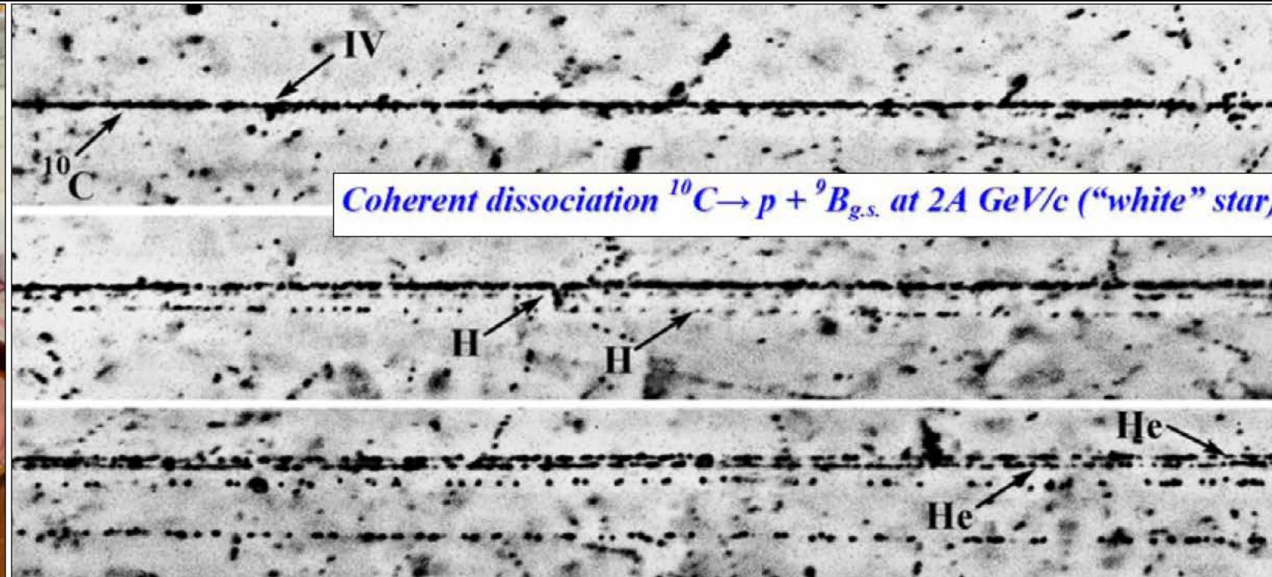

Implantation of Kr and Xe ions



Boron-enriched emulsion

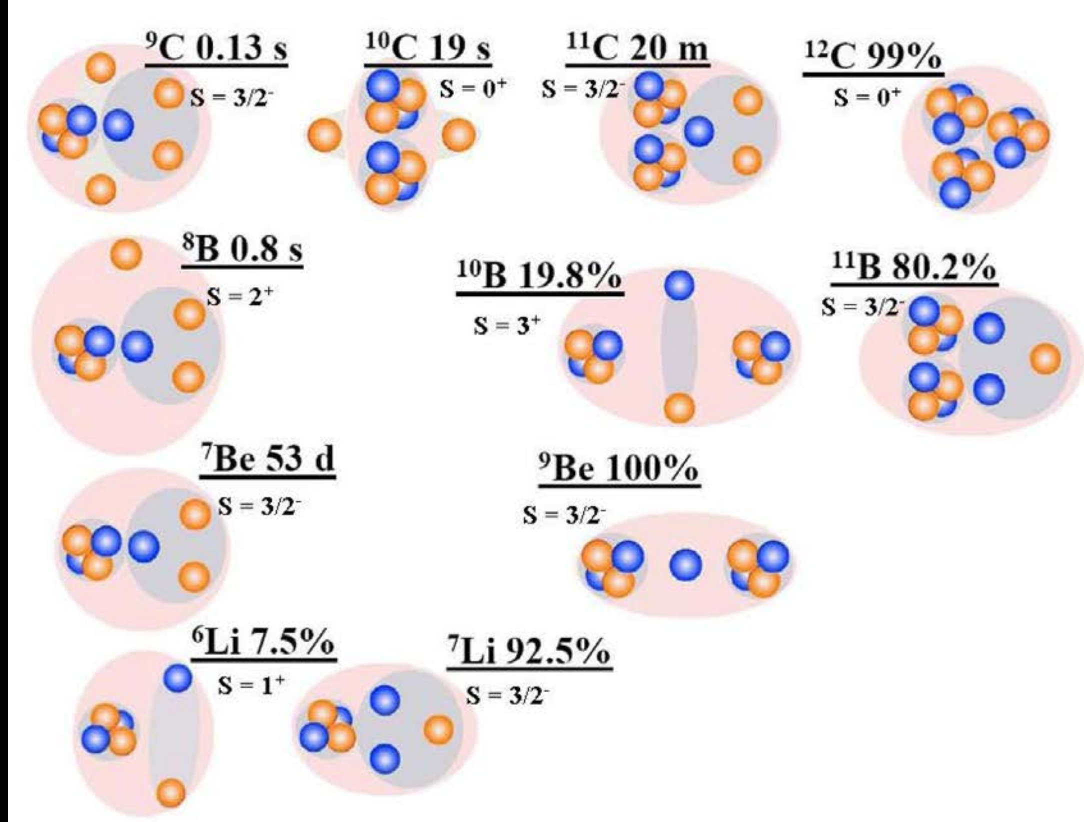
Surface exposure to a ^{252}Cf source

Veksler & Baldin Laboratory of High Energy Physics, JINR, Dubna, Russia



Layers of thickness of 50 to 200 μm on a glass base

Nuclear track emulsion: 0.5 μm resolution



Exposure of Nuclear Track Emulsion to ^{8}He Nuclei at the ACCULINNA Separator

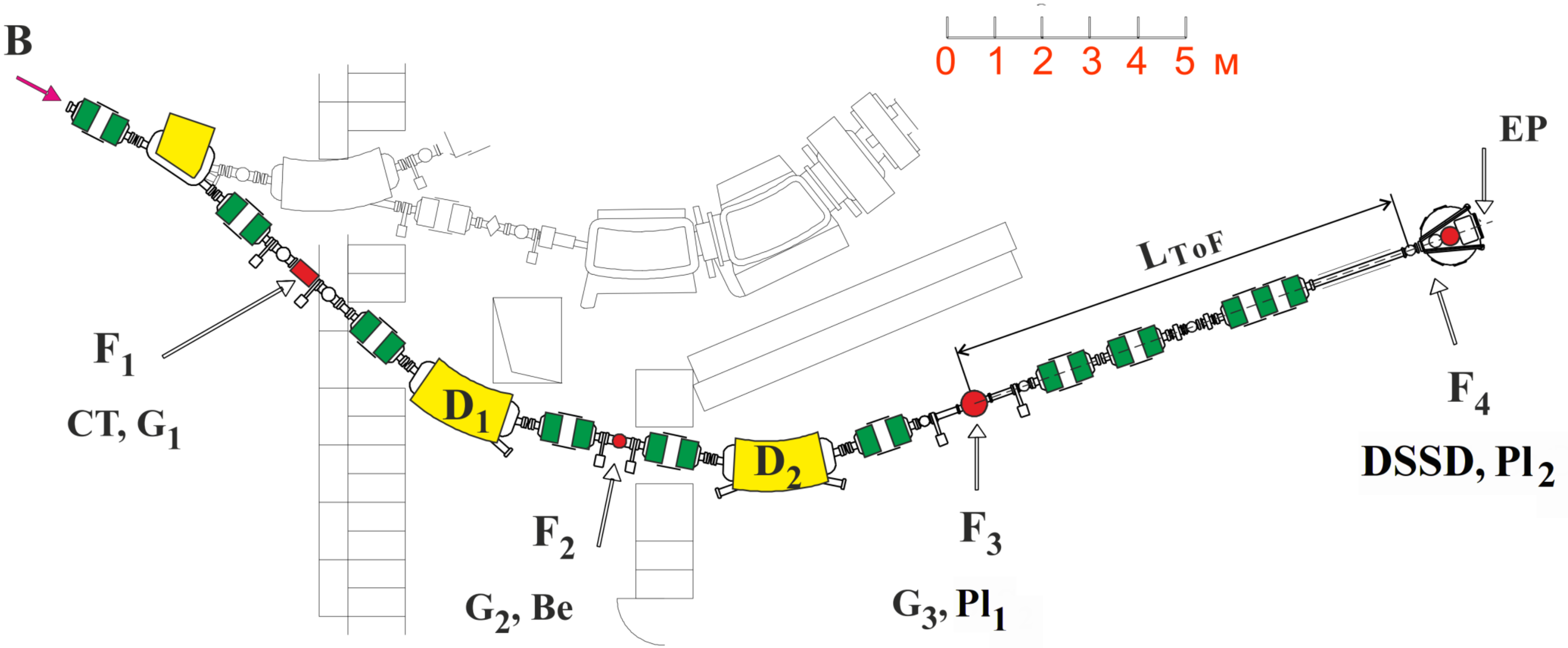
D. A. Artemenkov[a], A. A. Bezbakh[a], V. Bradnova[a], M. S. Golovkov[a], A. V. Gorshkov[a], P. I. Zarubin[a], I. G. Zarubina[a], G. Kaminski[a, b], N. K. Kornegrutsa[a], S. A. Krupko[a], K. Z. Mamatkulov[a], R. R. Kattabekov[a], V. V. Rusakova[a], R. S. Slepnev[a], R. Stanoeva[c], S. V. Stepantsov[a], A. S. Fomichev[a], and V. Chudoba[a, d]

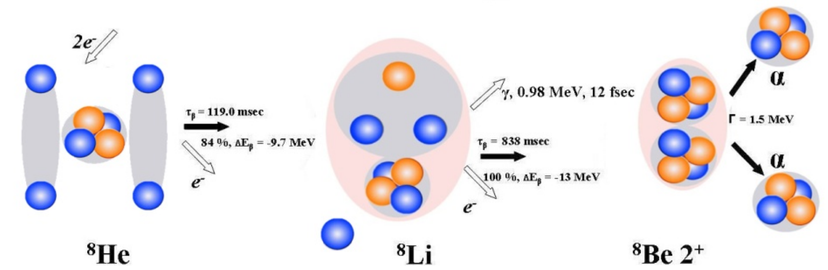
[a]*Joint Institute for Nuclear Research, Dubna, Russia*

[b]*Institute of Nuclear Physics, Polish Academy of Sciences, Krakow, Poland*

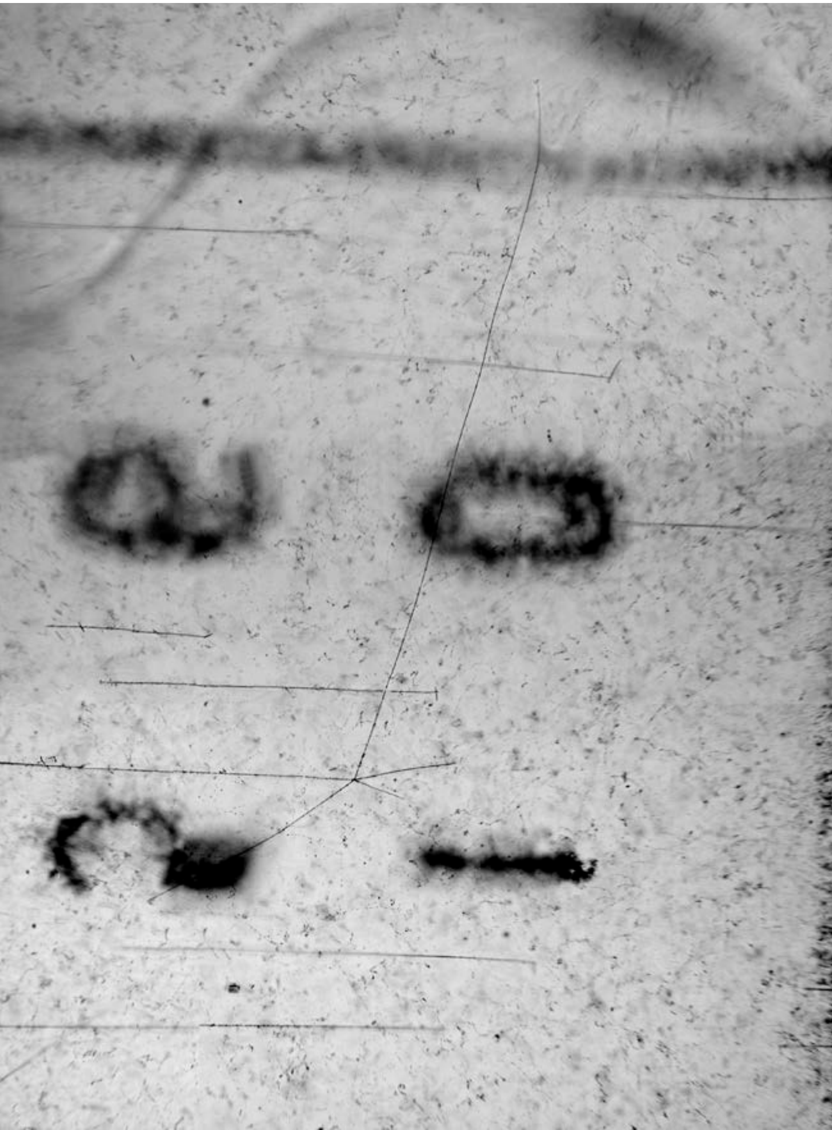
[c]*South-West University, Blagoevgrad, Bulgaria*

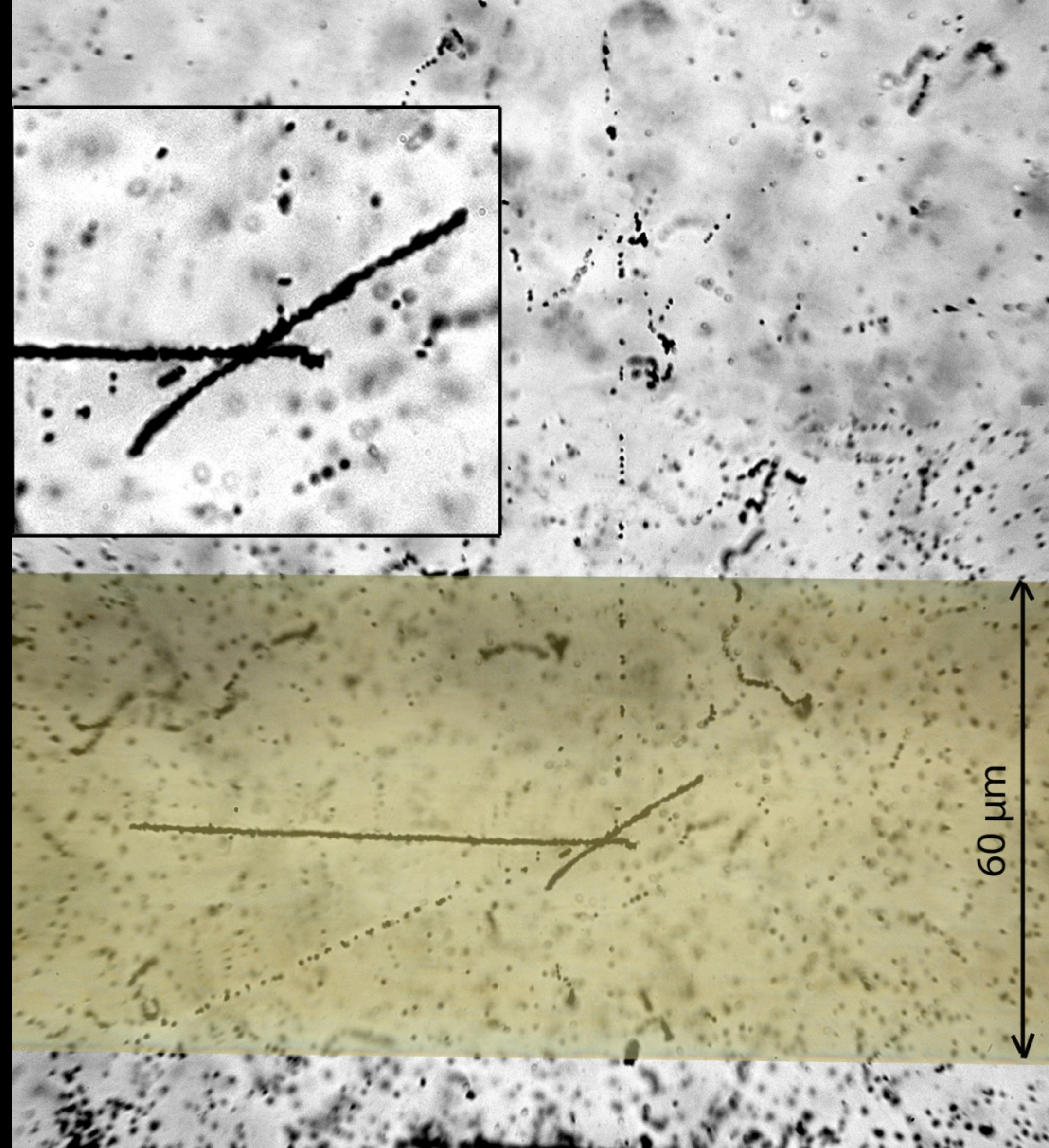
[d]*Institute of Physics, Silesian University in Opava, Czech Republic*



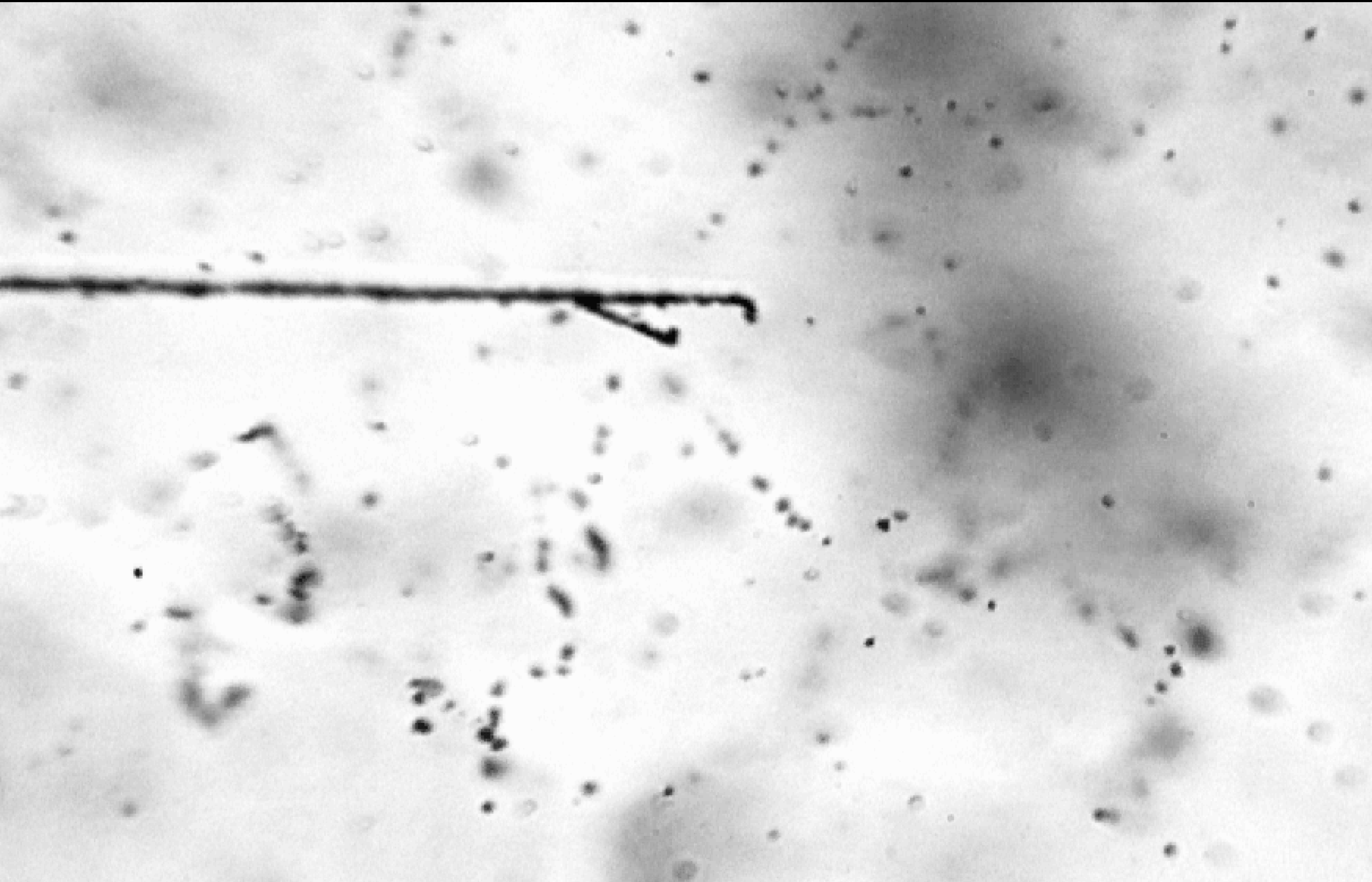


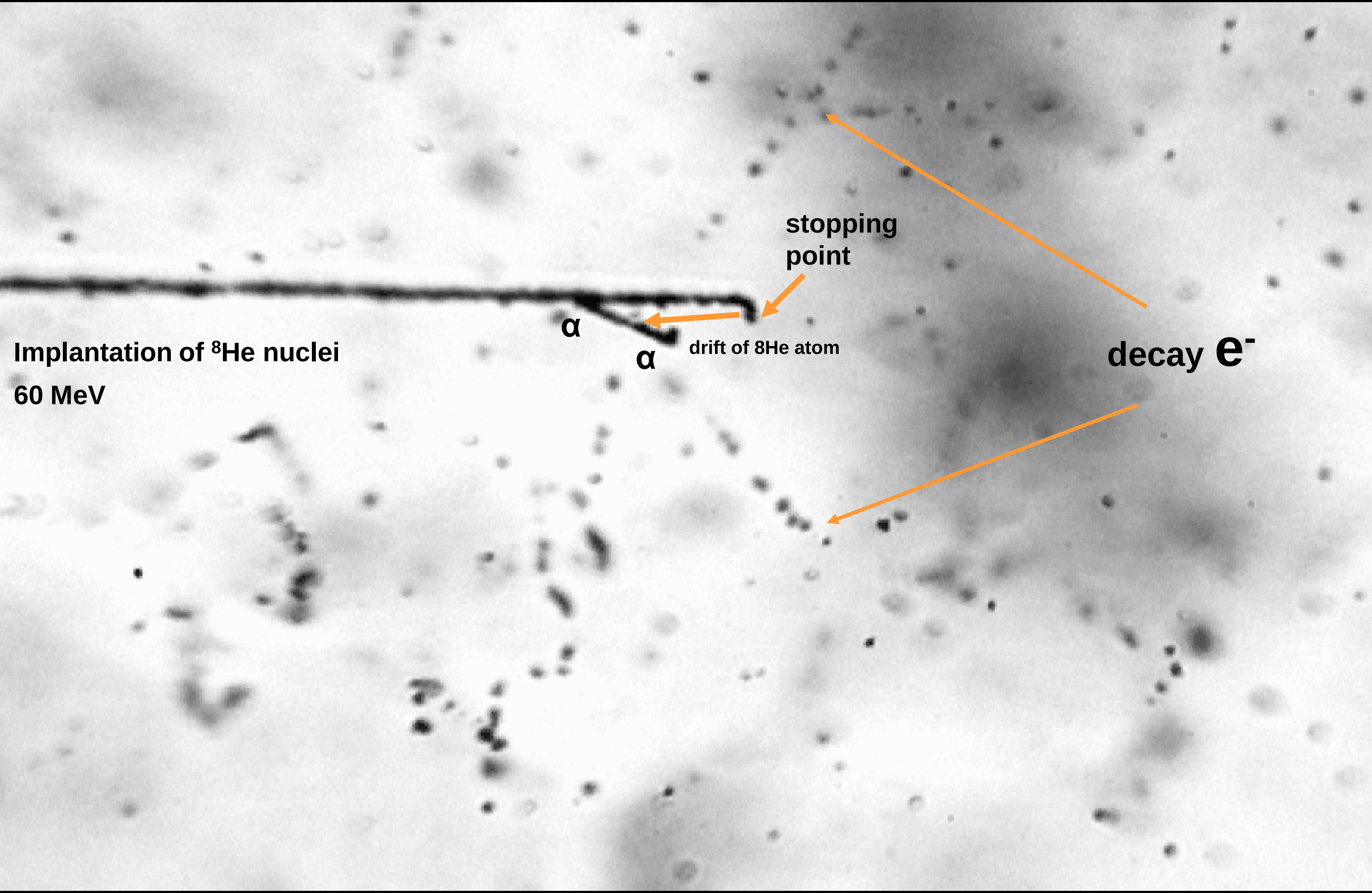
Scheme of a major channel of the cascade decay of ^{8}He isotope:



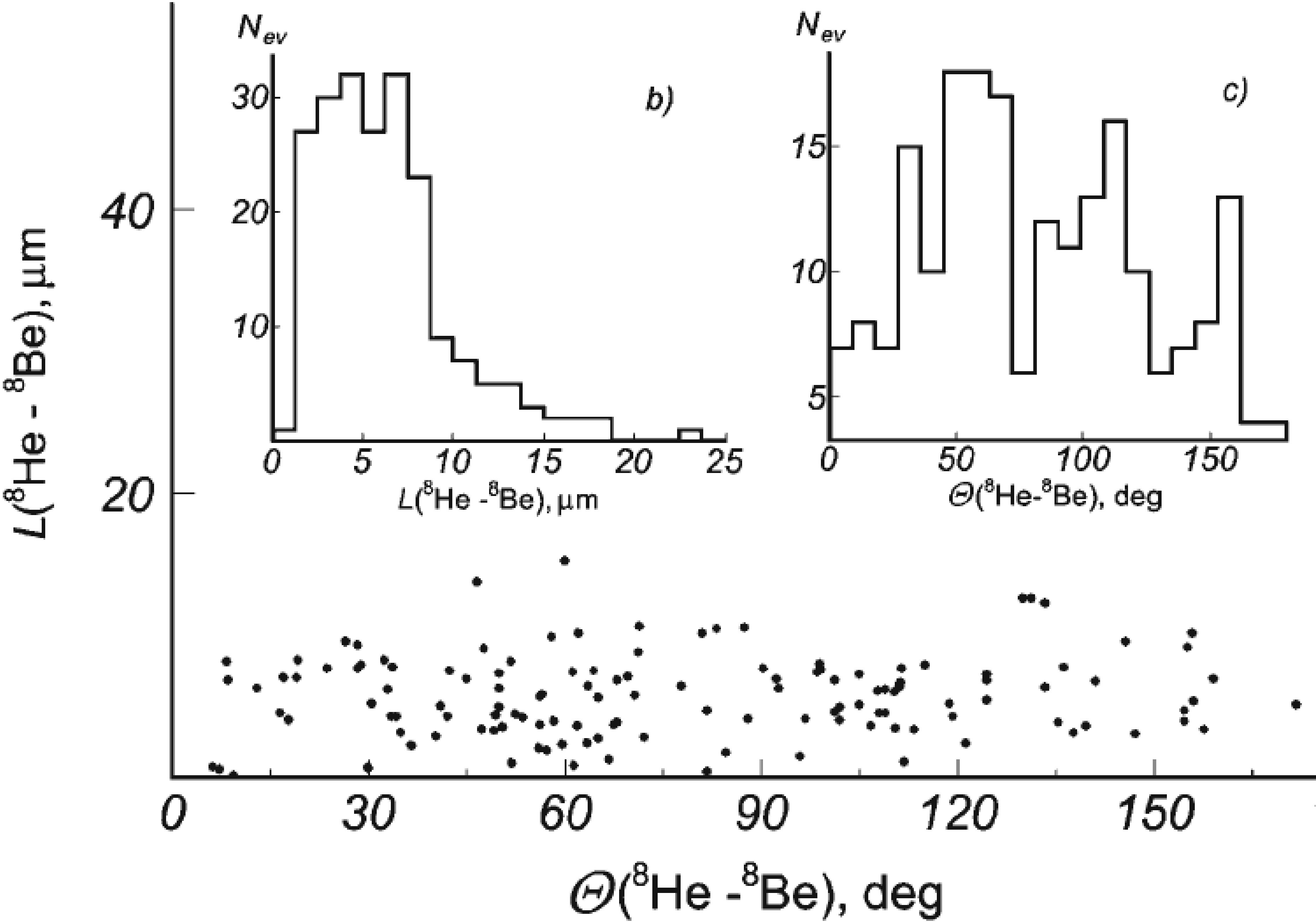


Mosaic macrophotography of a hammer-like decay of ^{8}He nucleus (horizontal track) stopped in nucle track emulsion. Pair of electrons (point-like tracks) and pair of α-particles (short opposite tracks). On insertio (top): enlarged decay vertex. To illustrate special resolution the image of the decay is superimposed t macrophotography of a human hair of thickness of 60 μm.



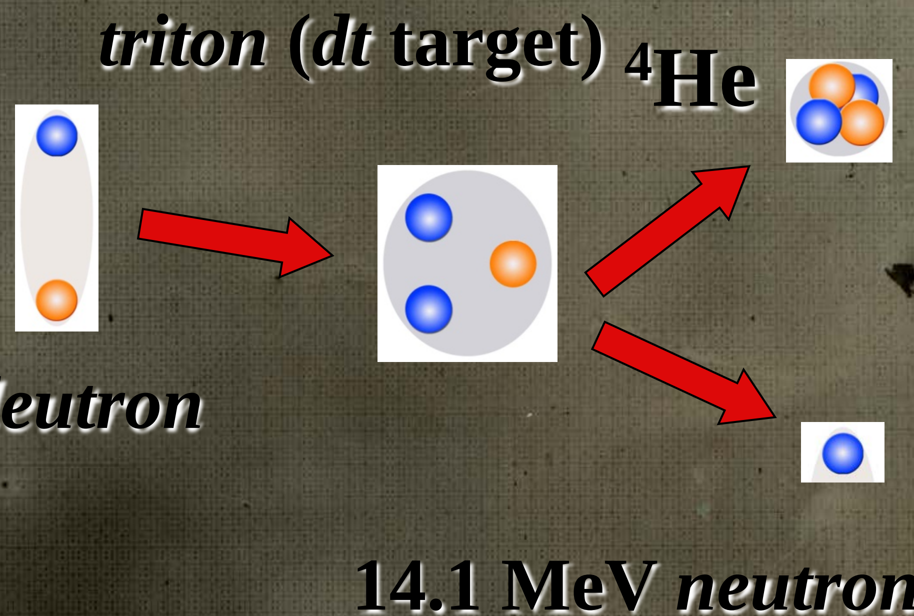

stopping point
α
α
drift of 8He atom
Implantation of ⁸He nuclei
60 MeV
decay e⁻

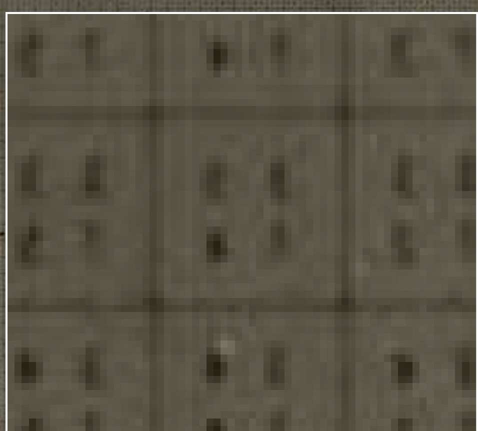
http://becquerel.jinr.ru/miscellanea/8He

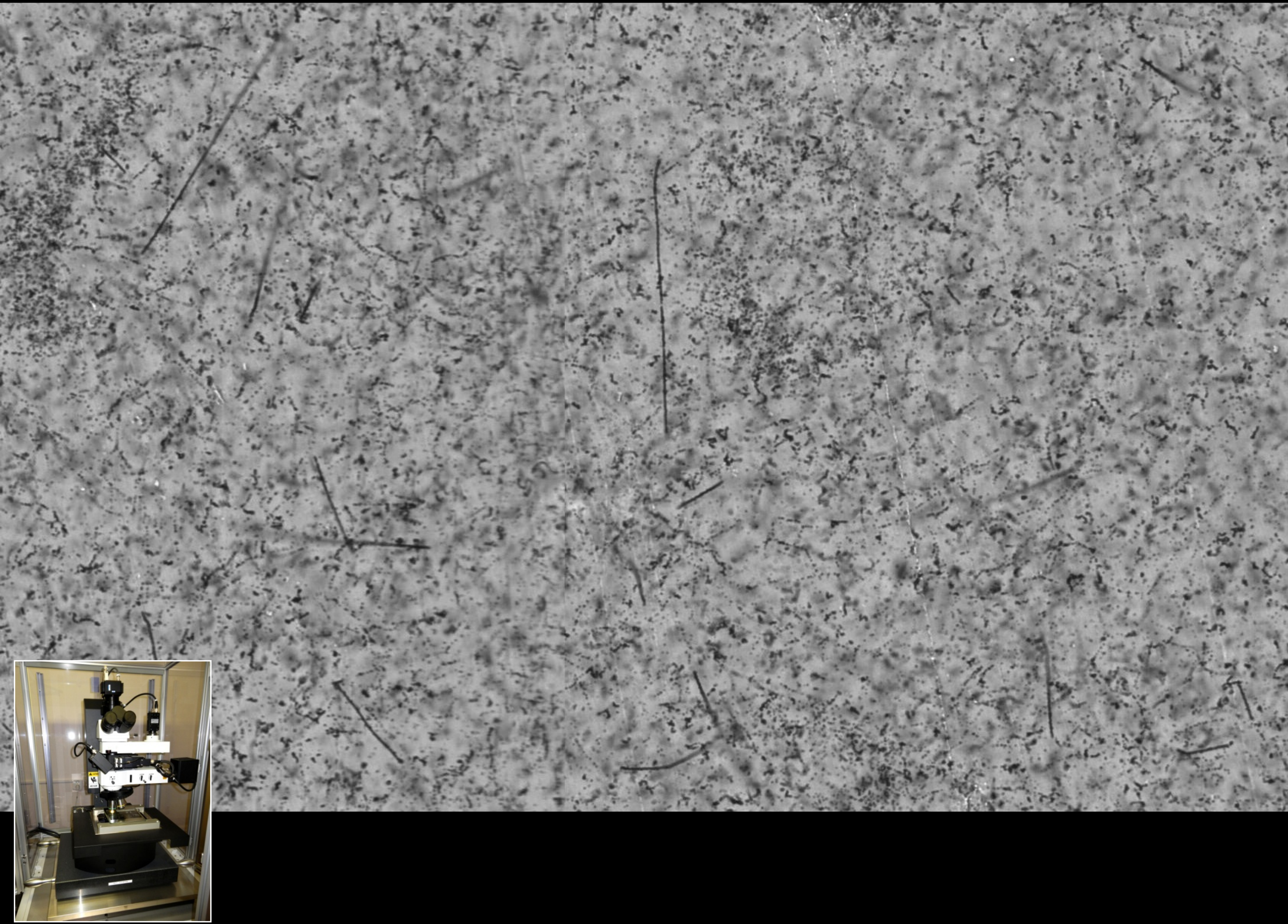


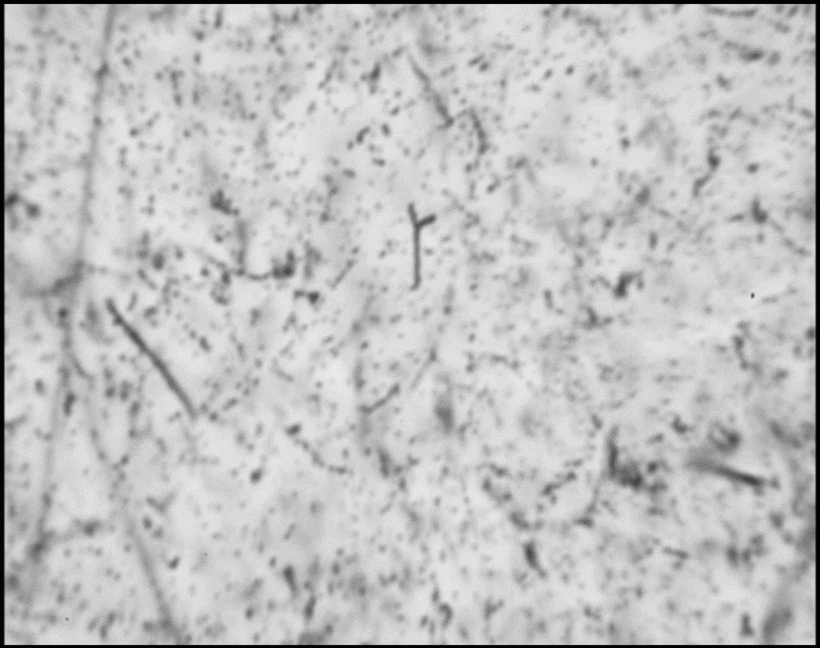
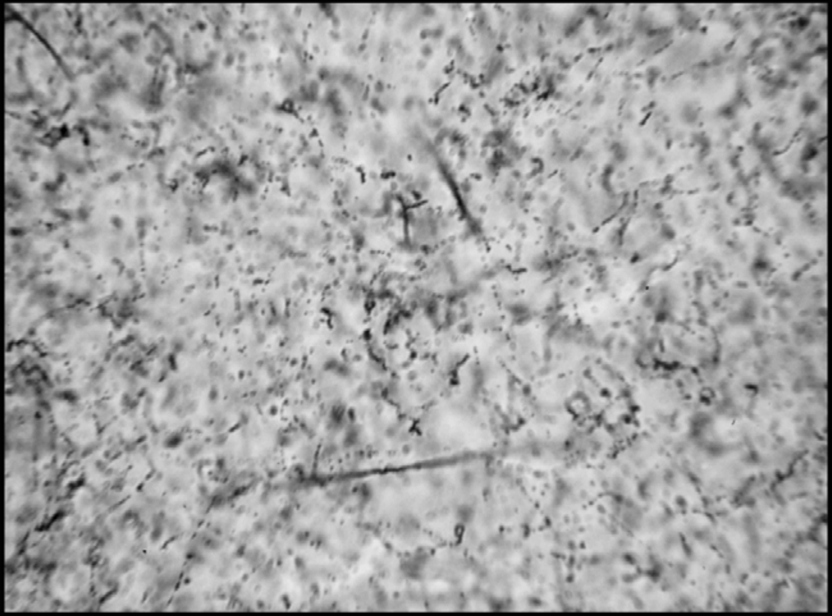
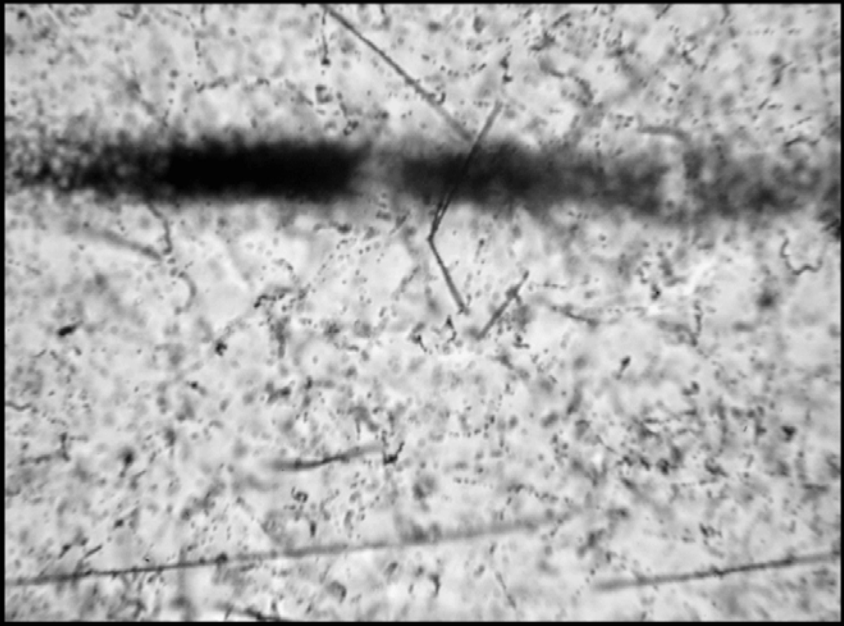
N_ev
b)
30
20
10
0 5 10 15 20 25
L(8He -8Be), μm
N_ev
c)
15
10
5
0 50 100 150
Θ(8He-8Be), deg
40
20
L(8He - 8Be), μm
0 30 60 90 120 150
Θ(8He -8Be), deg

Correlation of α-particle triples in disintegrations of carbon nuclei by 14.1 MeV neutrons

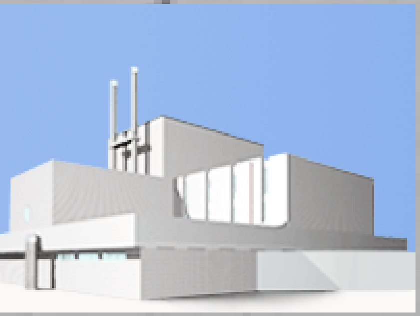


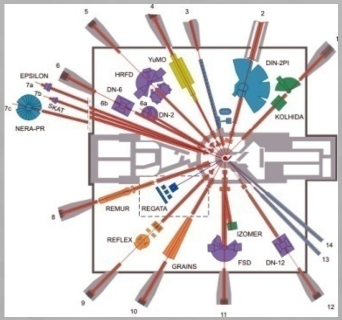


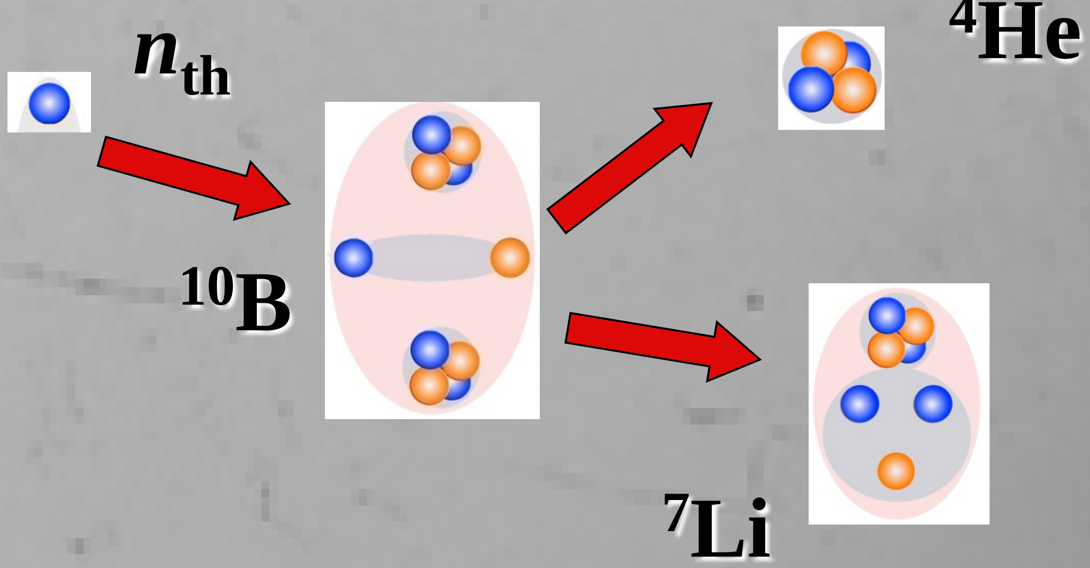


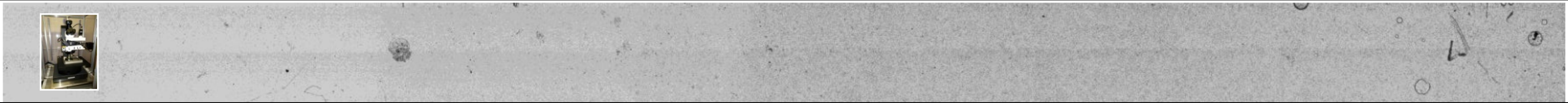





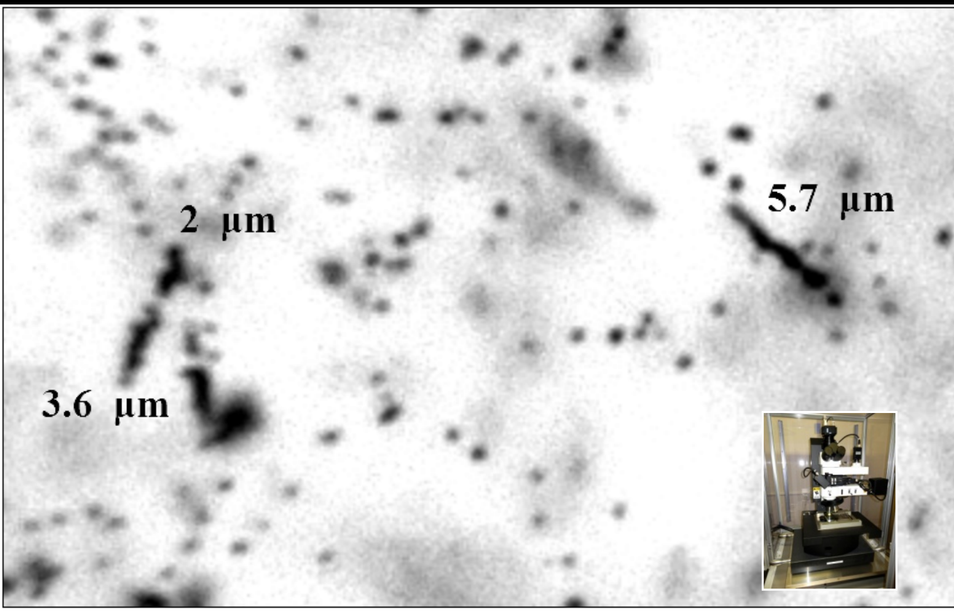
JINR IBR-2 Pulsed Reactor

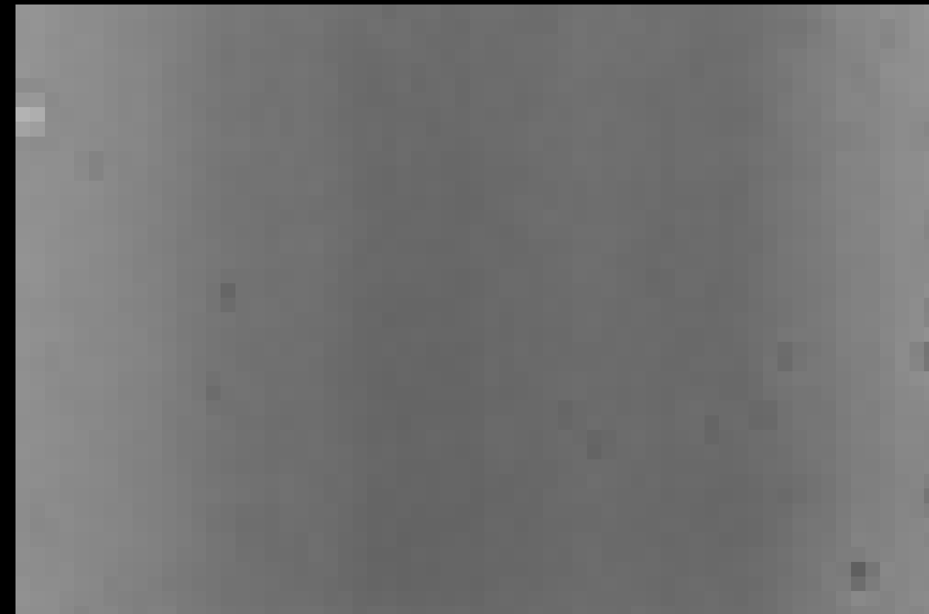












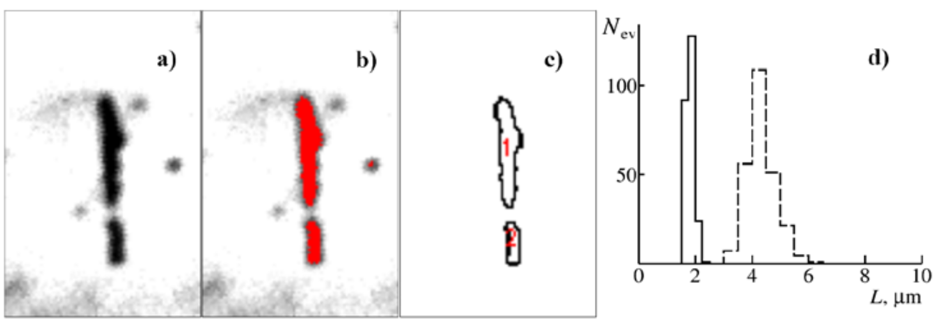
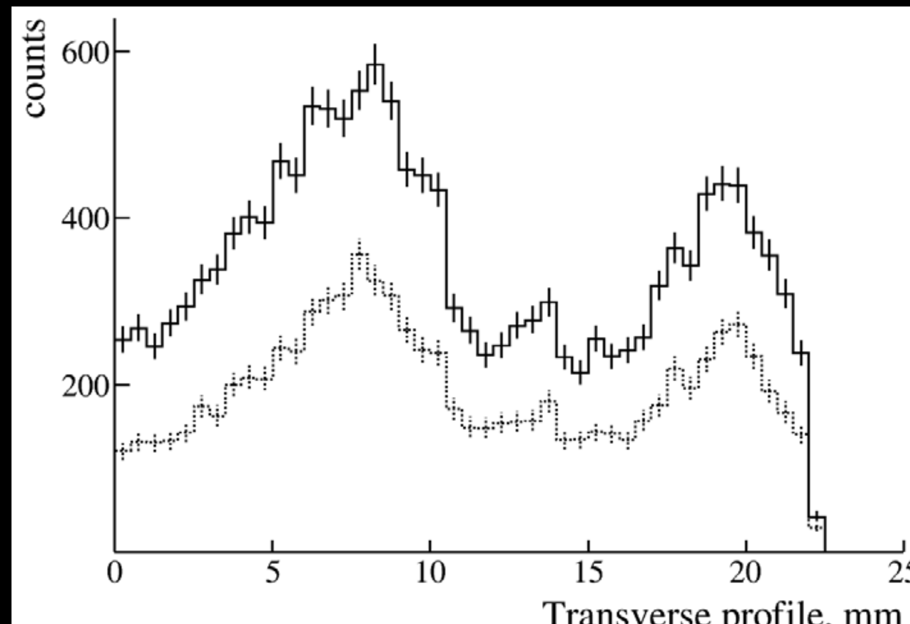
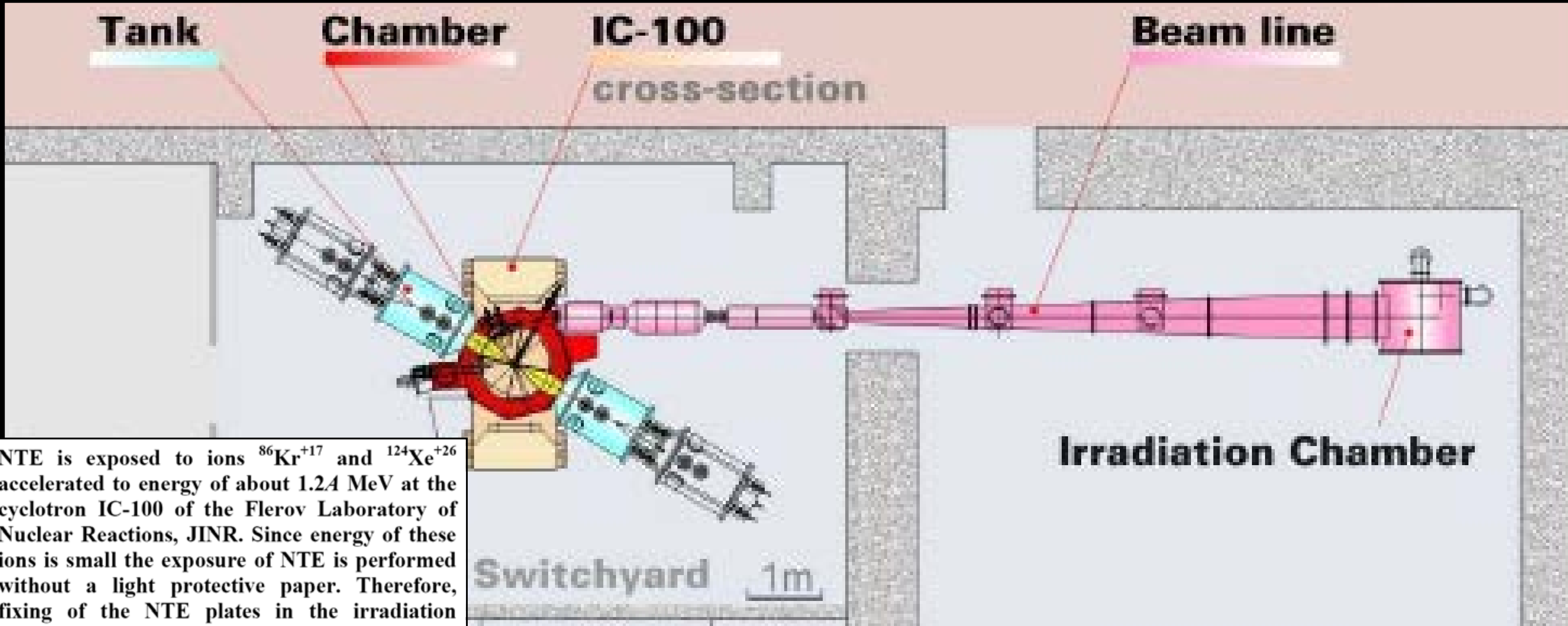
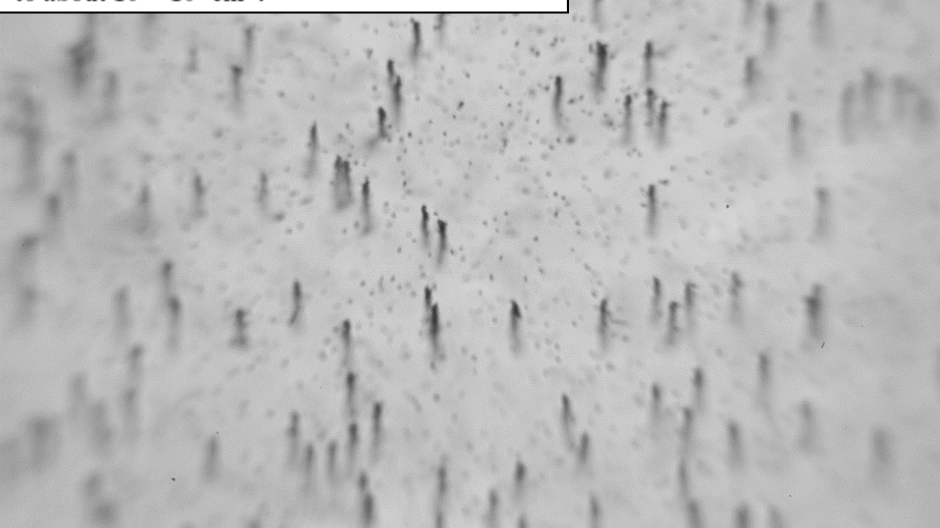


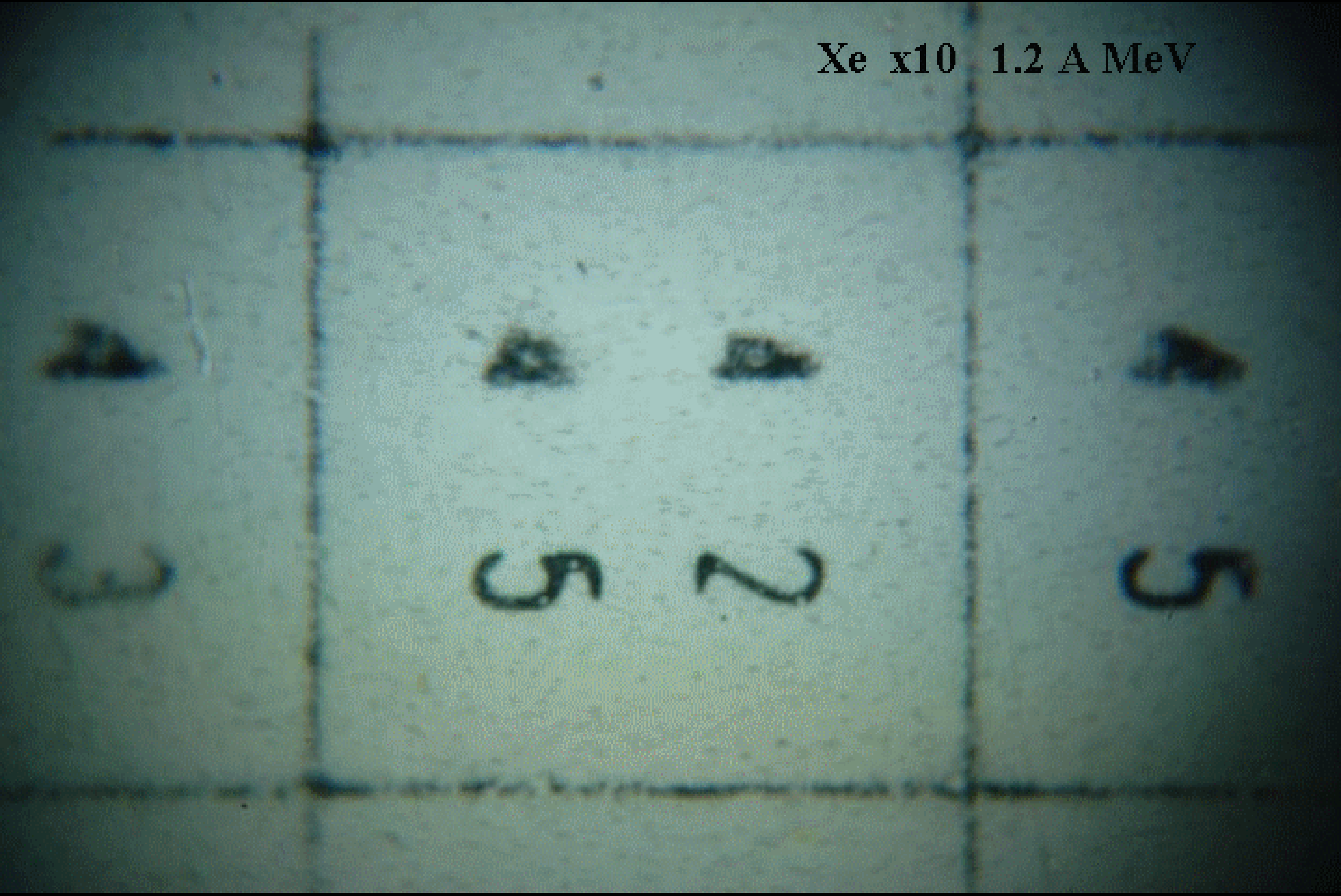
Figure 3. Example of disintegration of boron nucleus by thermal neutron to the Li and He n_{th} (a) and steps of image recognition via the ImageJ program (a-c). Distribution of mean range of Li (solid line) and He (dotted line) (d).



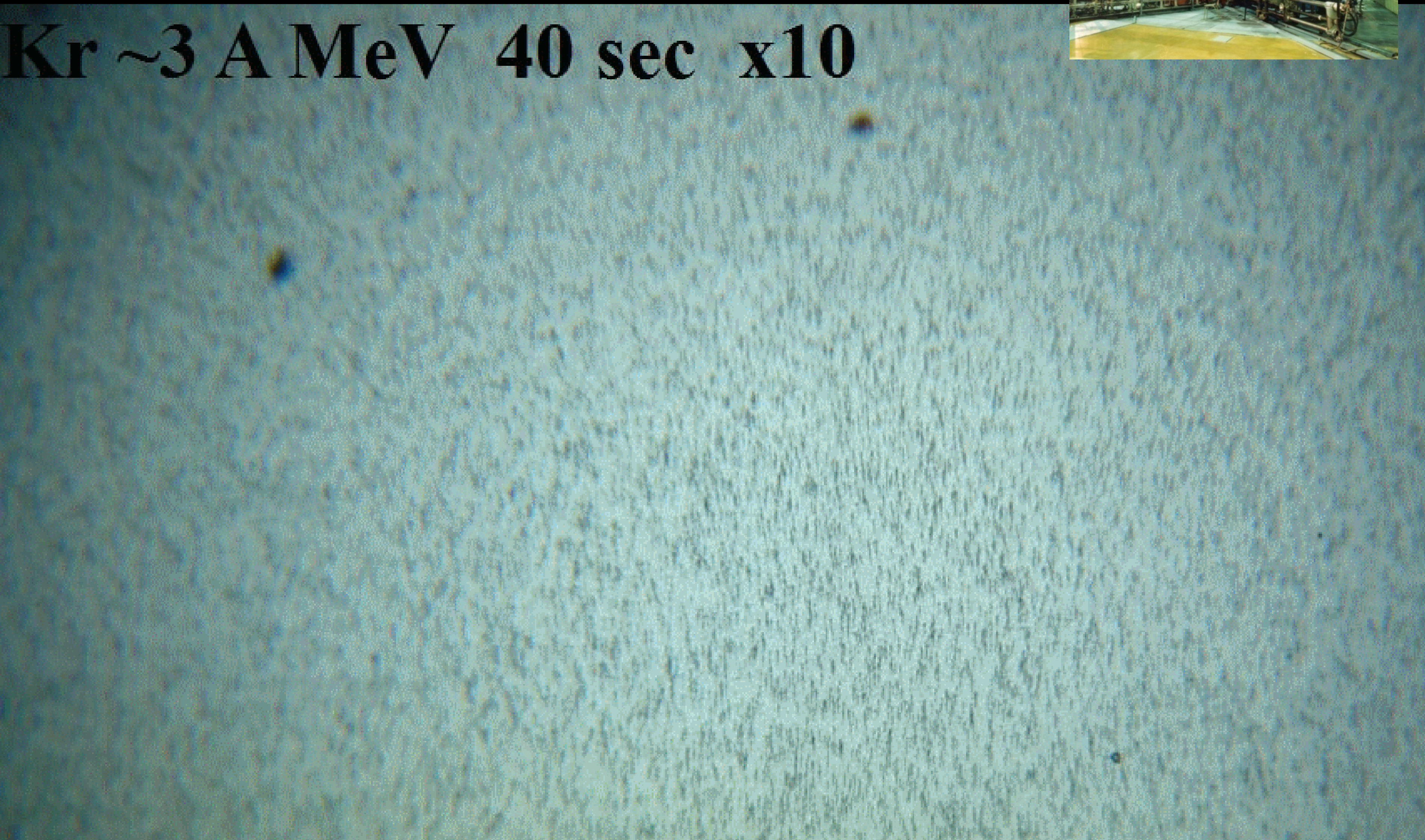


NTE is exposed to ions $^{86}Kr^{+17}$ and $^{124}Xe^{+26}$ accelerated to energy of about 1.2*A* MeV at the cyclotron IC-100 of the Flerov Laboratory of Nuclear Reactions, JINR. Since energy of these ions is small the exposure of NTE is performed without a light protective paper. Therefore, fixing of the NTE plates in the irradiation chamber was performed at lighting which is ordinary for a photographic laboratory. For 5 seconds of exposure the track density amounted to about 10^5 - 10^6 cm^{-2}.




Xe x10 1.2 A MeV

Flerov Laboratory



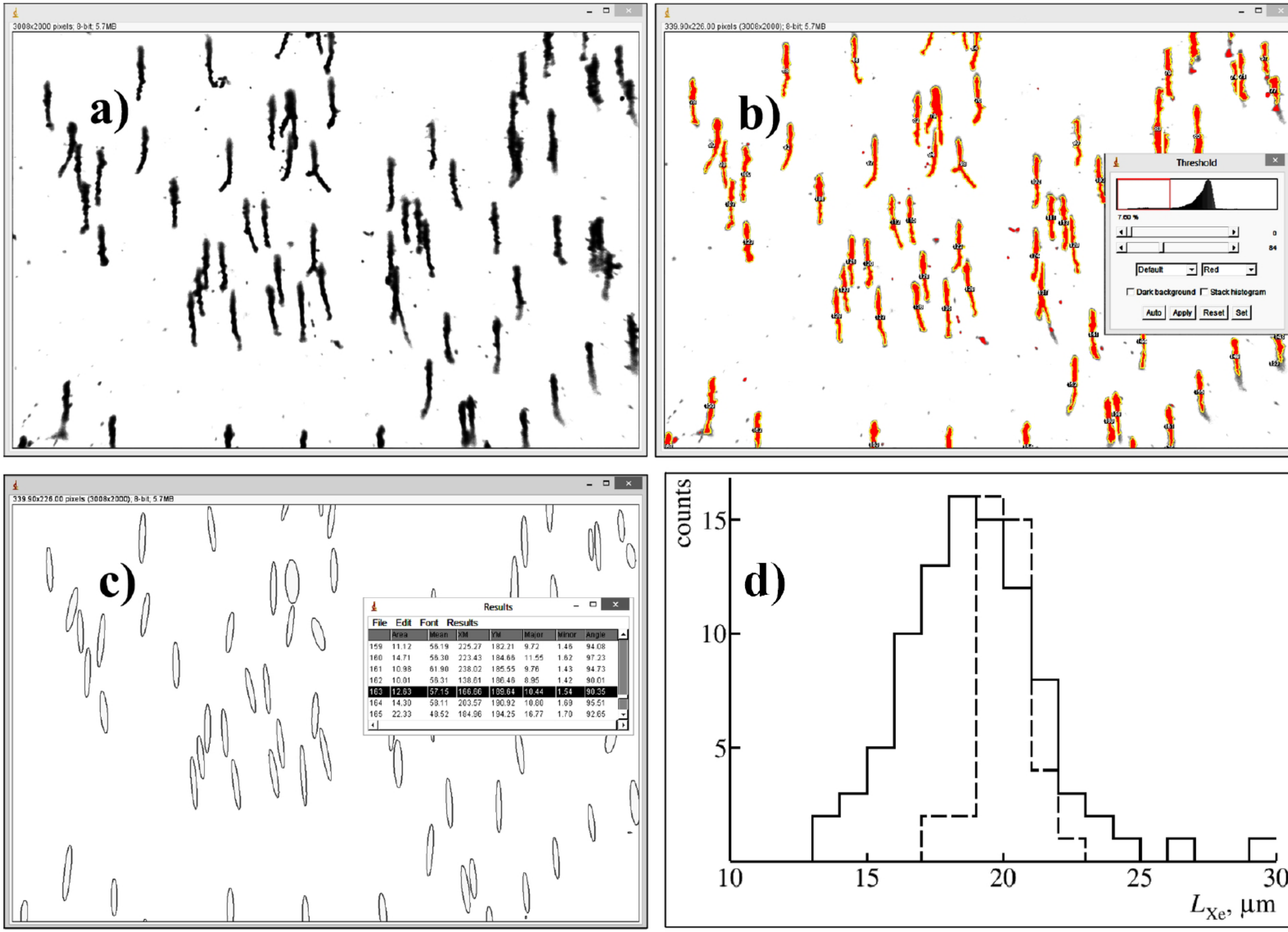
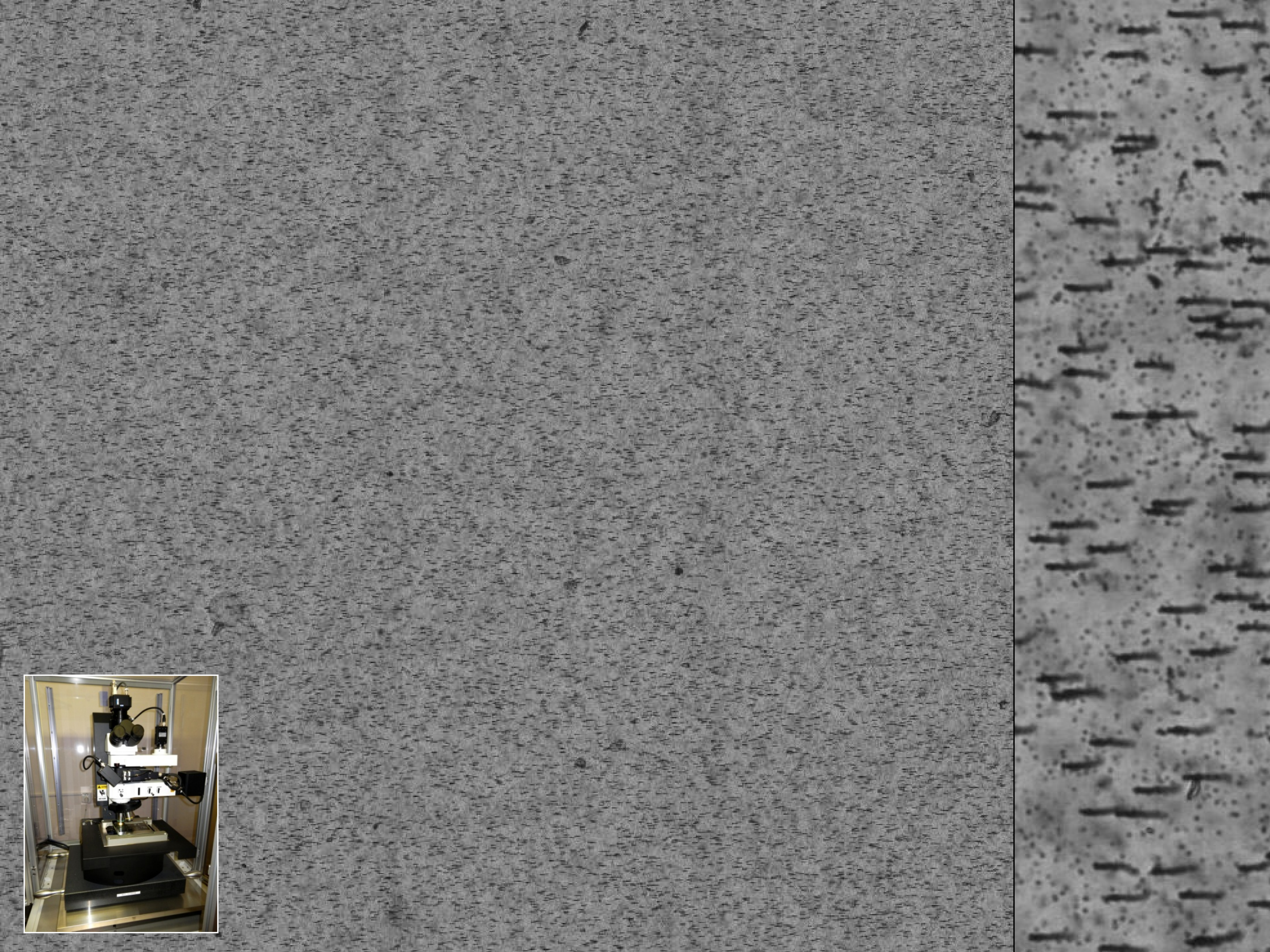
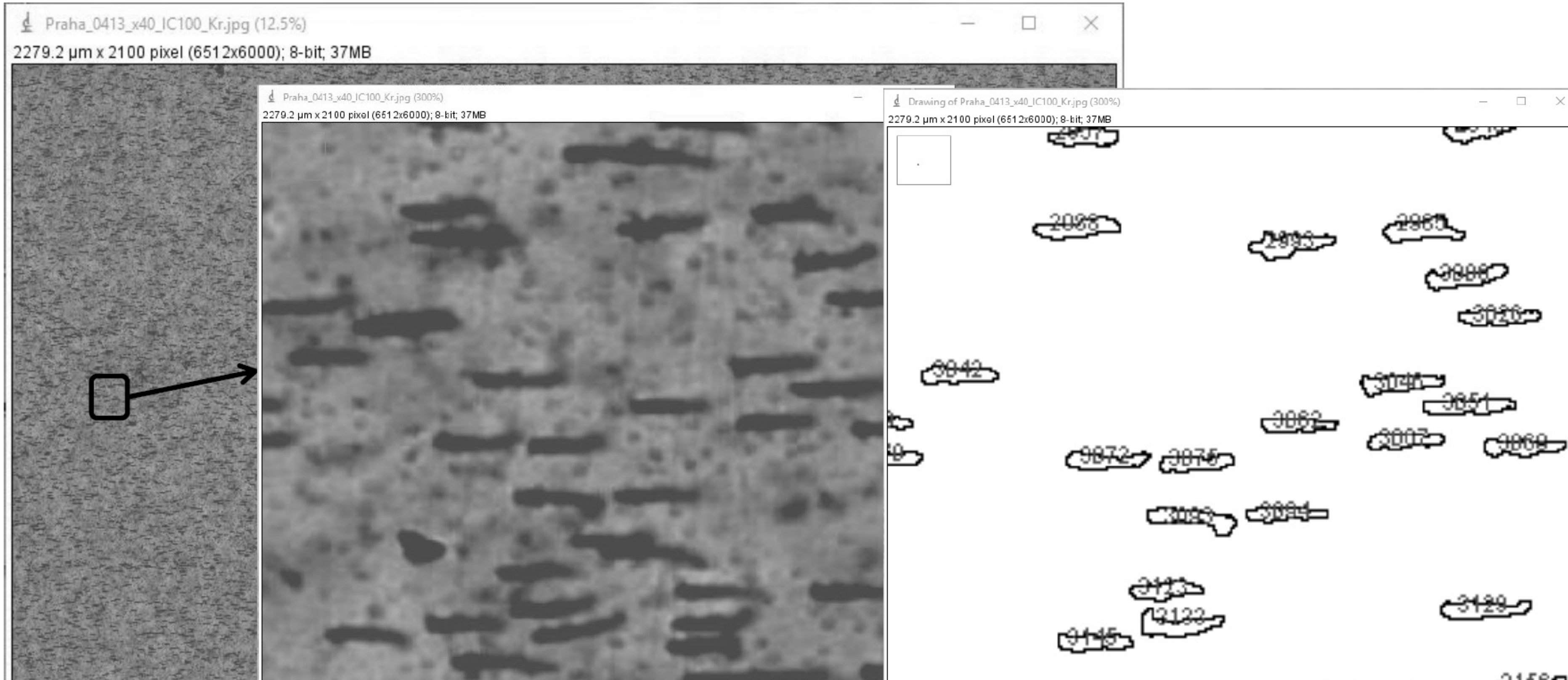


Fig. 5. Stages of computer analysis: (a) initial close-up, (b) finding of track images, (c) description of them as ellipses and (d) ion range distribution in computer (solid line) and manual (dashed line) analysis.

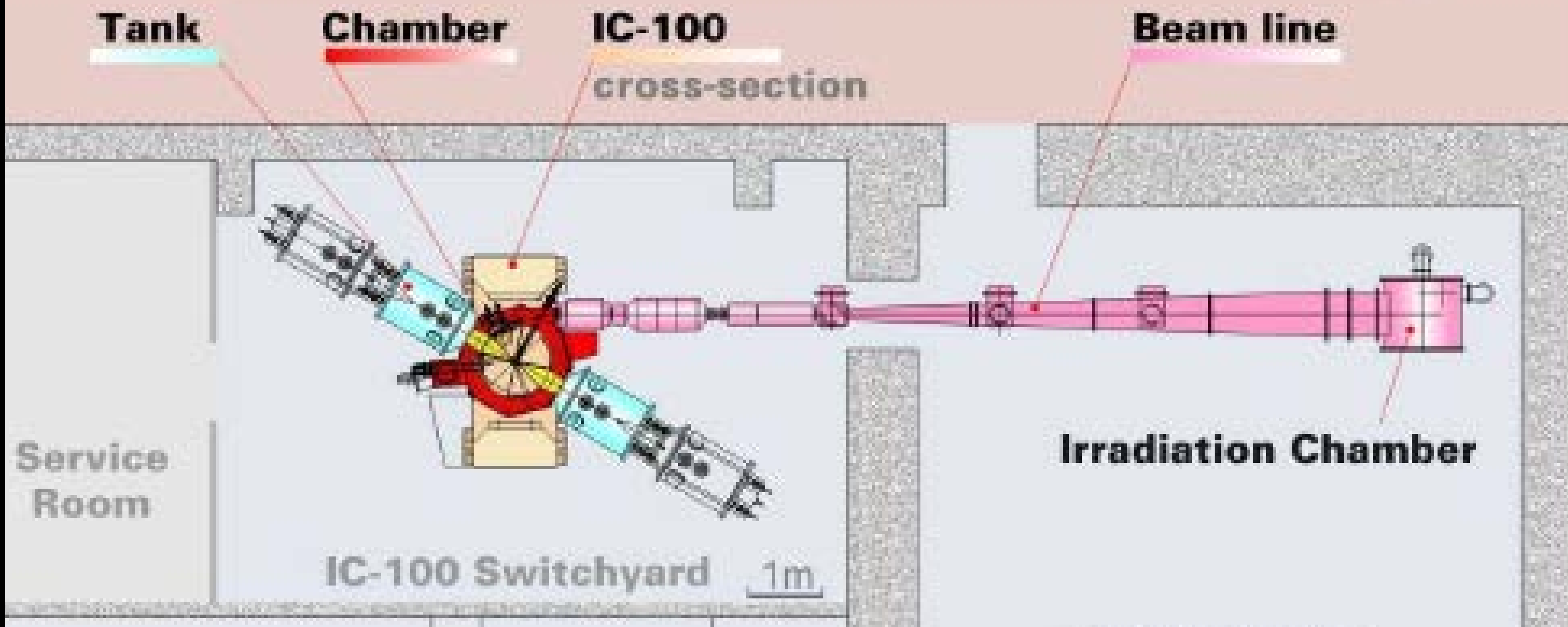


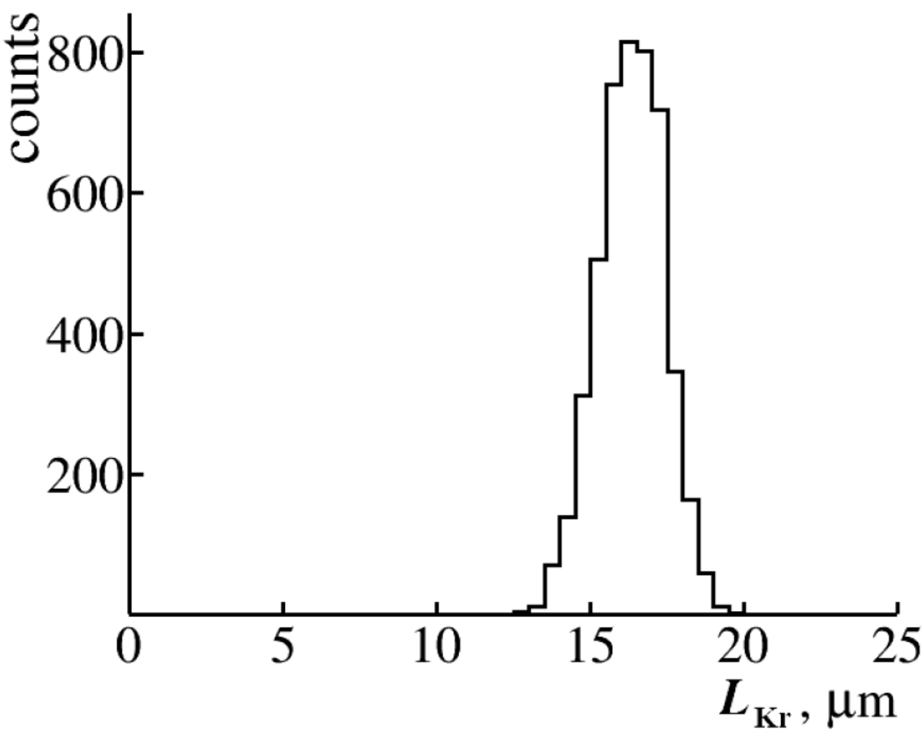


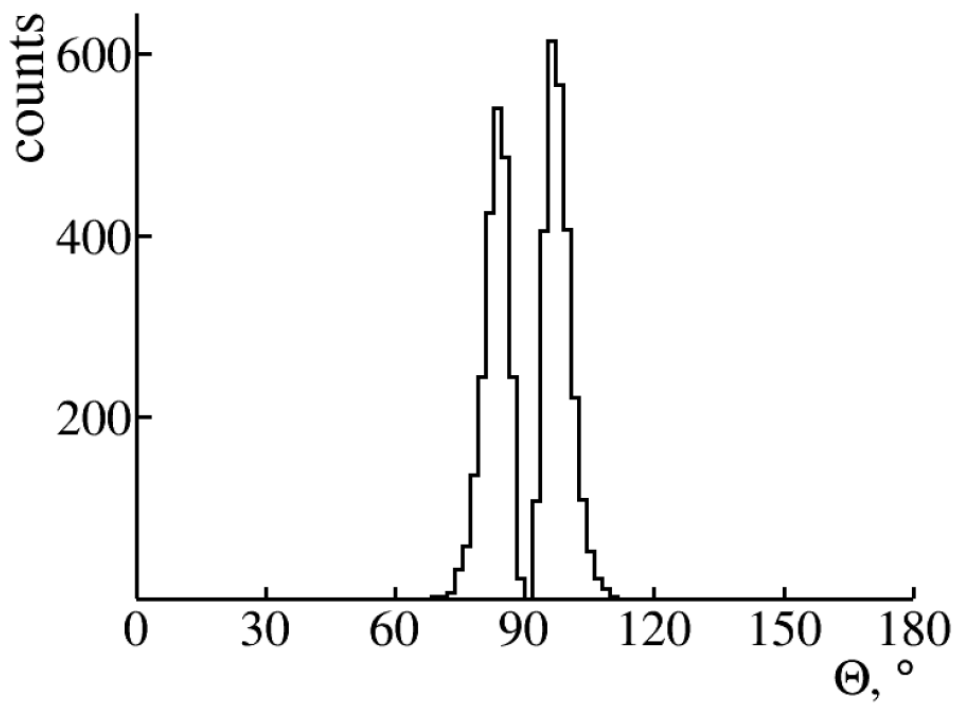
Results

File Edit Font Results

	Area	X	Y	Perim.	Major	Minor	Angle	Circ.	Feret	FeretX	FeretY	FeretAngle	MinFeret	AR	Round
3182	15.312	548.773	1314.083	23.730	11.515	1.693	4.694	0.342	10.990	543.550	1314.950	9.162	1.907	6.801	0.147
3183	25.602	208.164	1315.026	30.044	10.302	3.164	2.184	0.356	11.336	202.650	1315.650	8.881	4.729	3.256	0.307
3184	22.662	748.806	1314.813	27.364	11.655	2.476	176.318	0.380	11.465	743.400	1313.550	167.661	3.121	4.708	0.212
3185	16.292	623.072	1314.512	23.730	11.391	1.821	0.947	0.364	10.901	617.750	1314.950	5.528	2.098	6.255	0.160
3186	16.905	1175.295	1315.224	23.984	10.918	1.971	4.026	0.369	10.523	1170.050	1314.950	176.186	2.591	5.538	0.181
3187	21.560	1502.451	1315.145	22.584	9.231	2.974	0.784	0.531	9.267	1498.000	1314.600	169.114	3.500	3.104	0.322
3188	23.397	943.595	1315.473	25.420	11.721	2.542	3.319	0.455	11.336	938.000	1316.350	8.881	2.800	4.612	0.217
3189	22.417	2158.895	1315.555	25.589	10.935	2.610	2.810	0.430	10.365	2153.550	1316.000	11.689	3.150	4.189	0.239

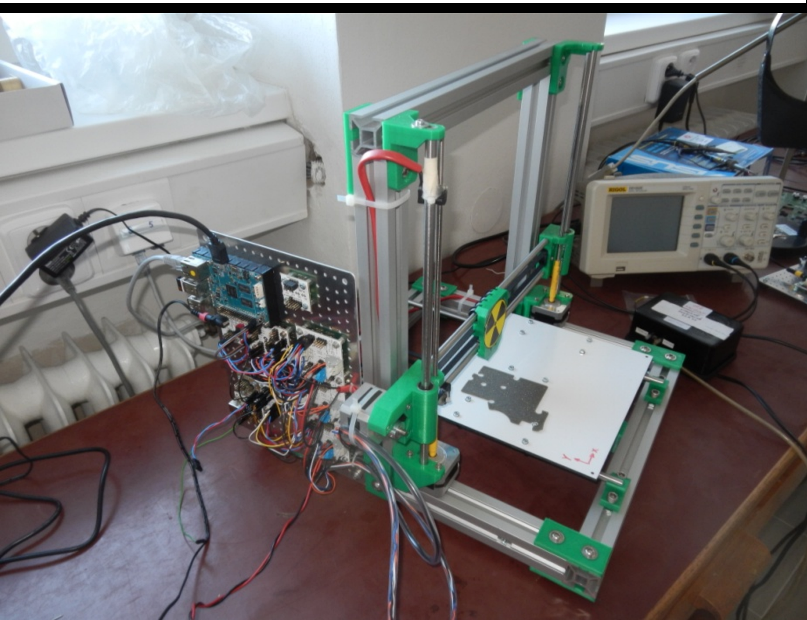

Tank
Chamber
IC-100
cross-section
Beam line
Service
Room
IC-100 Switchyard
1m
Irradiation Chamber

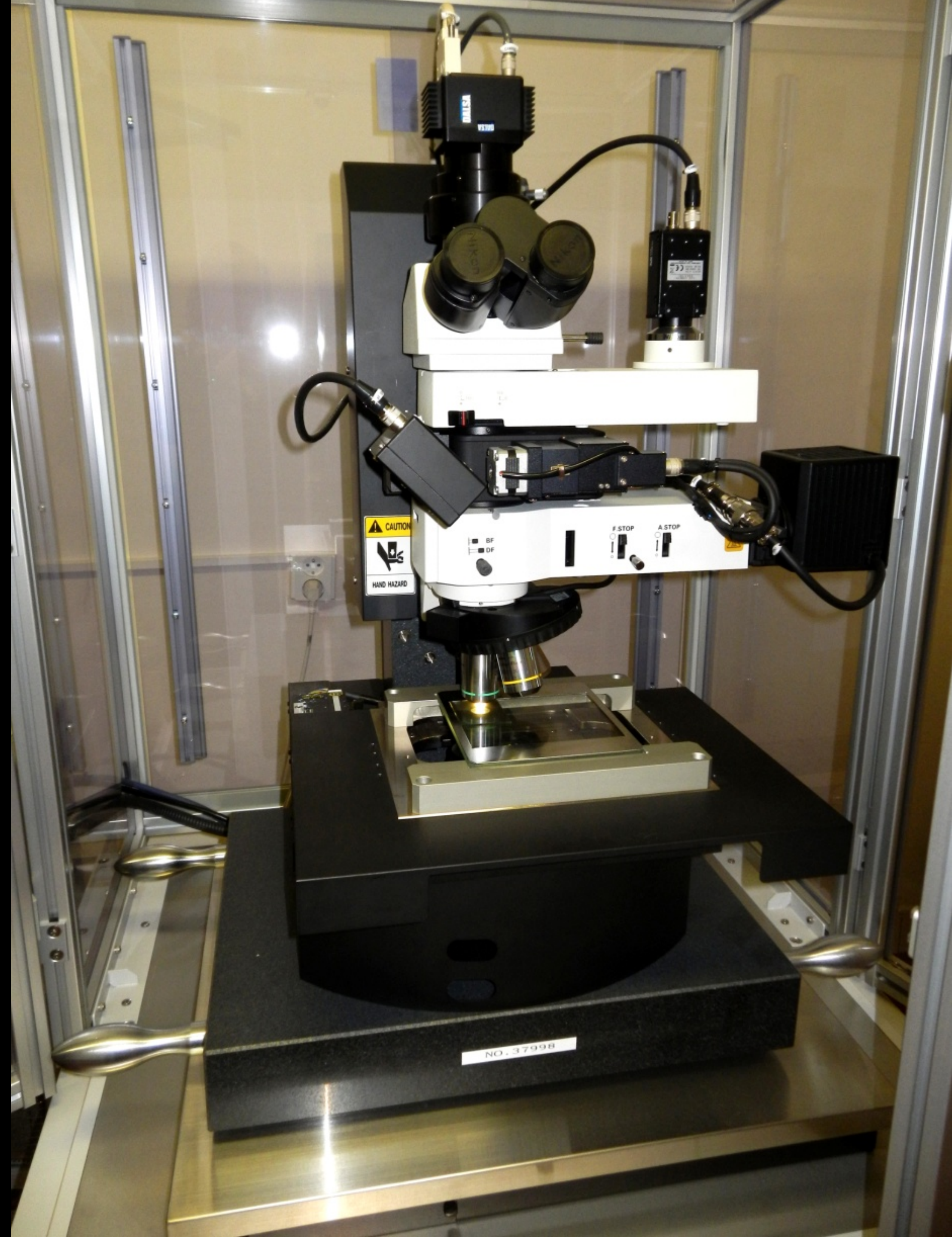

counts
800
600
400
200
0
5
10
15
20
25
L_{Kr}, μm

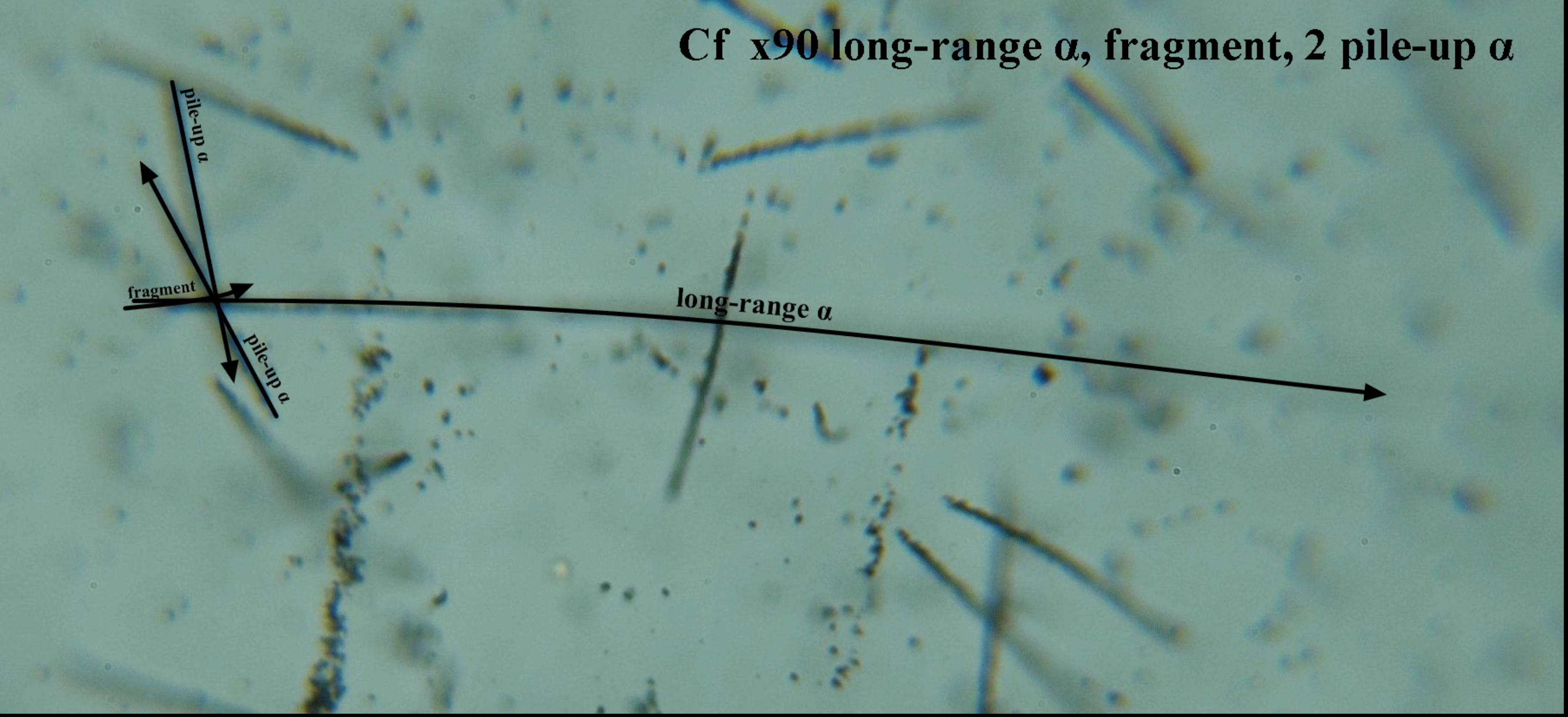

counts
600
400
200
0
30
60
90
120
150
180
Θ, °

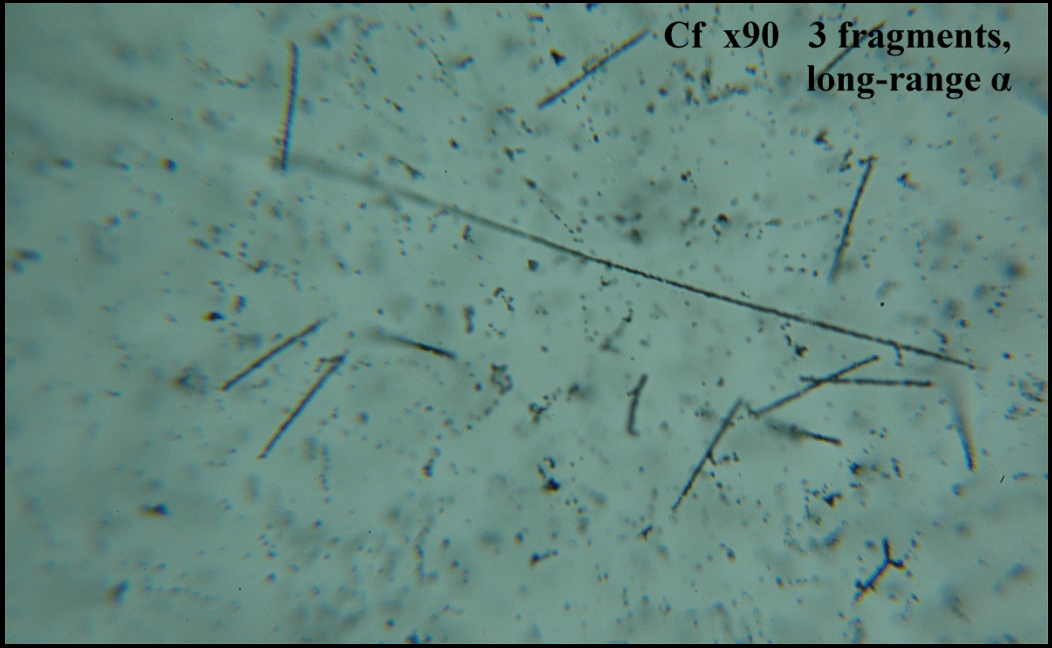
www.odz.ujf.cas.cz

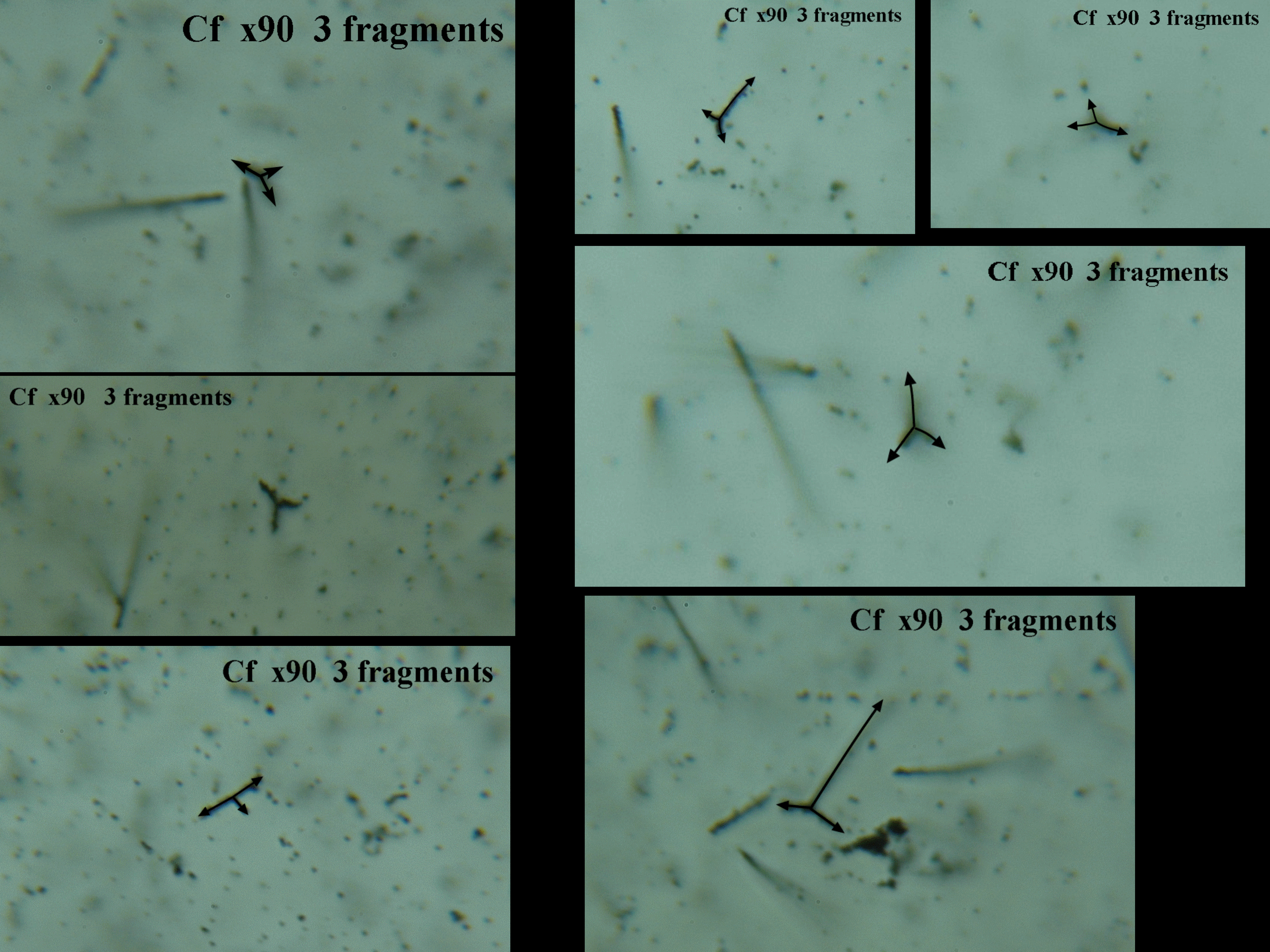
A large-scale NTE scanning is suggested to be performed on the microscope HSP-1000 of the Department of radiation dosimetry (DRD) of Nuclear Physics Institute of the Academy of Czech Republic. The use of the NTE resolution will be full if the microscope will be adapted to operate with lenses of the highest magnification. Development of algorithms for automatic search and analysis of short tracks of heavy ions in NTE will be required. On the experimental side, ion ranges in NTE must be calibrated in the α-decay and fission energy scale. Progress of the preparatory phase of the proposed study is summarized below.

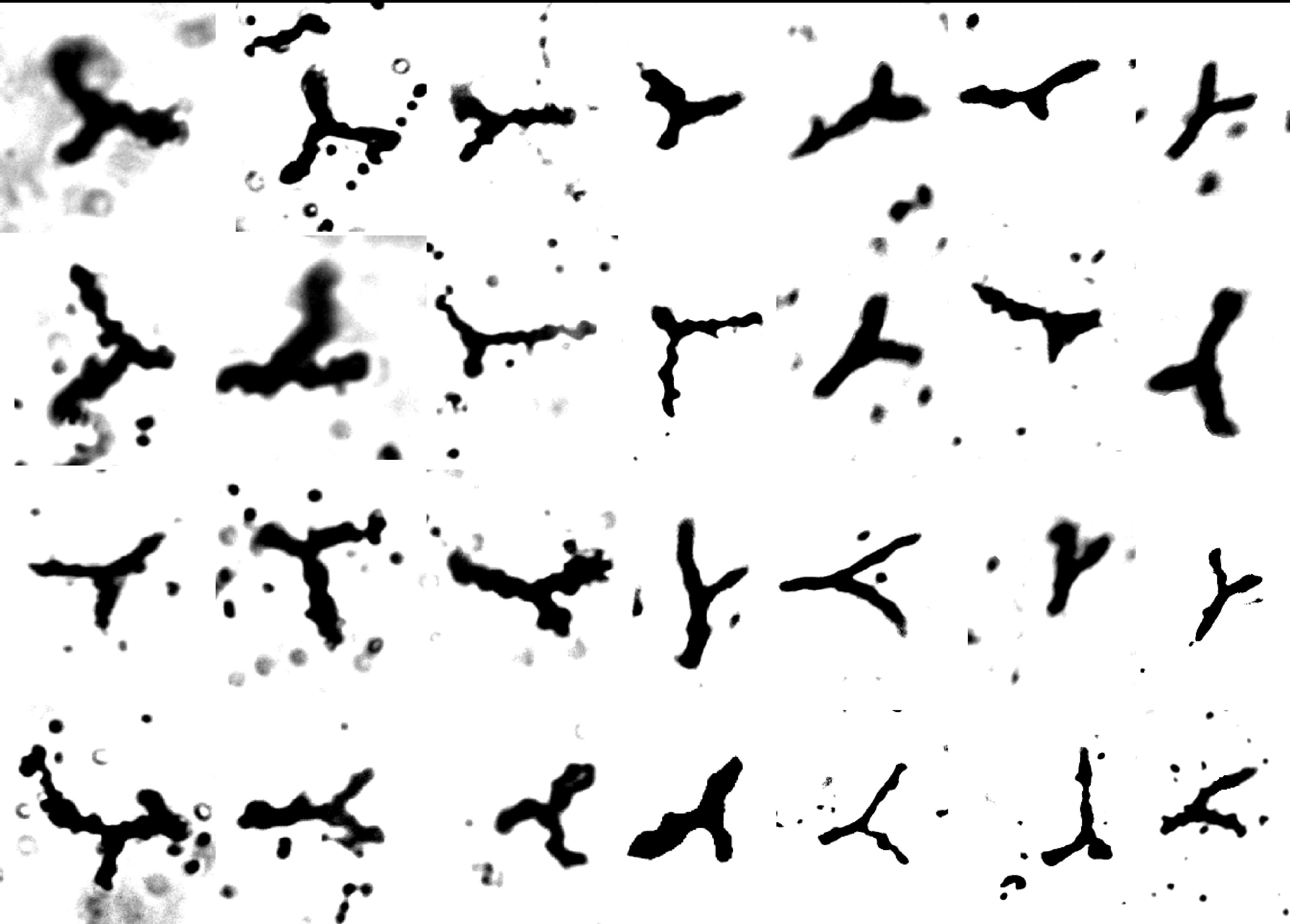


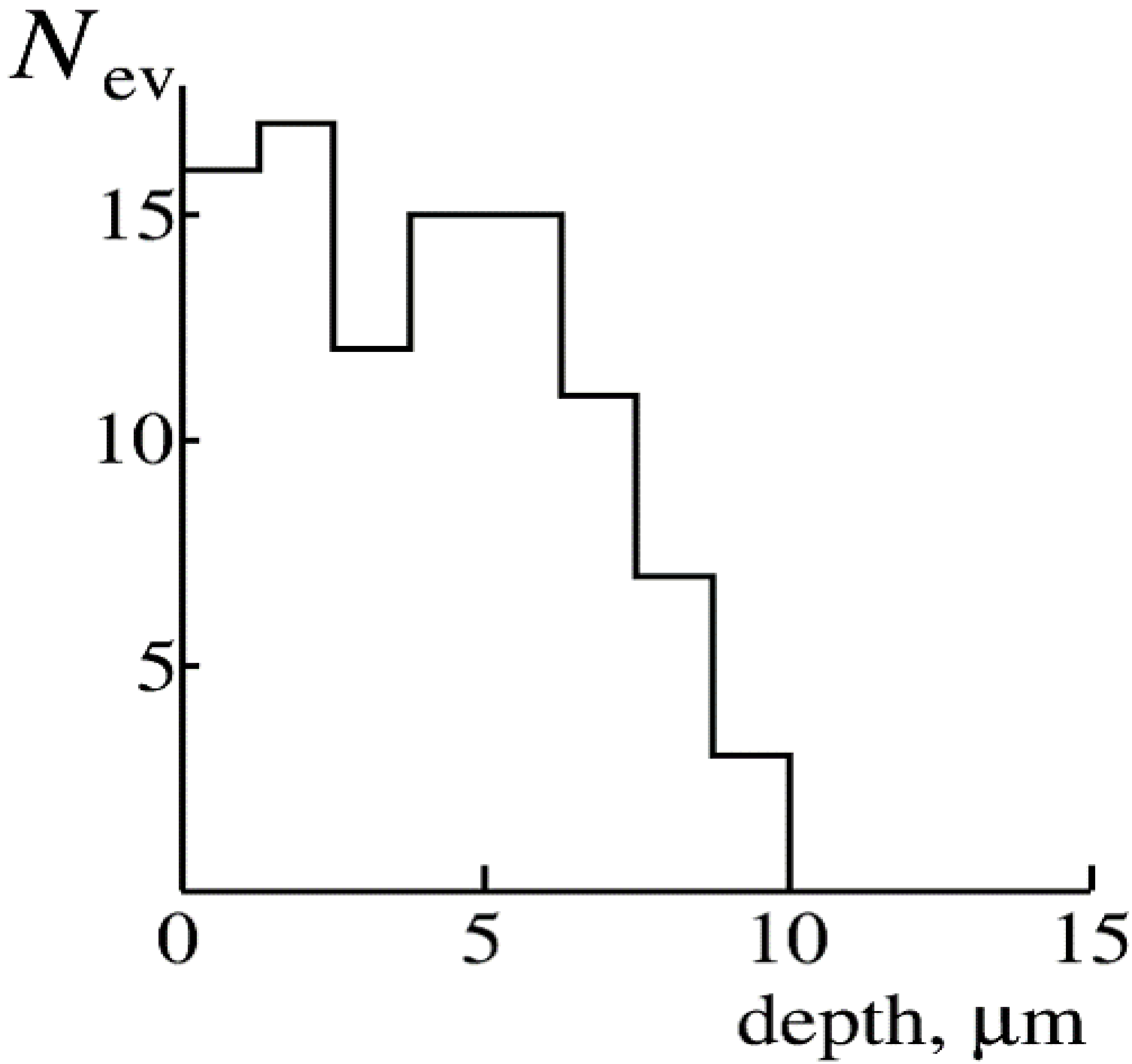



Cf x90 long-range α, fragment, 2 pile-up α
pile-up α
fragment
long-range α
pile-up α


Cf x90 3 fragments,
long-range α

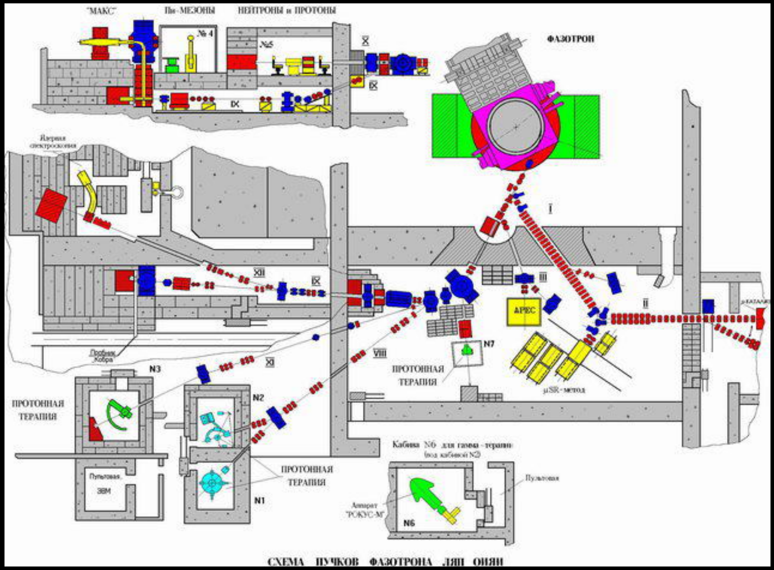

Cf x90 3 fragments
Cf x90 3 fragments
Cf x90 3 fragments
Cf x90 3 fragments
Cf x90 3 fragments
Cf x90 3 fragments
Cf x90 3 fragments

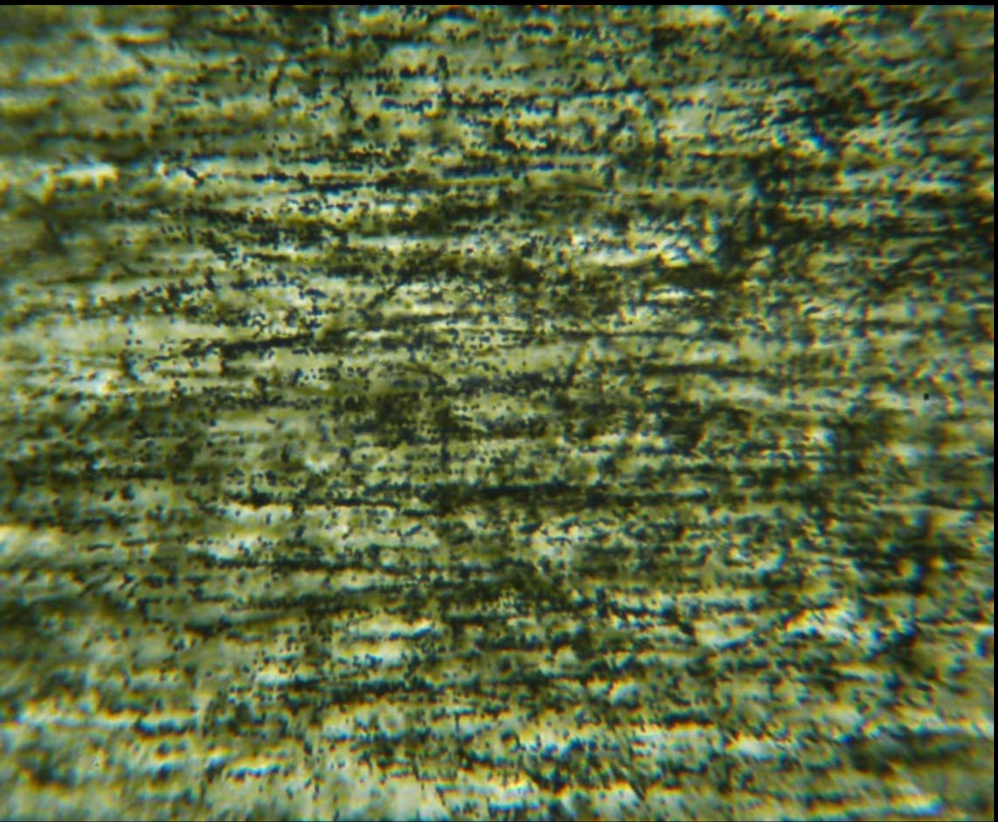


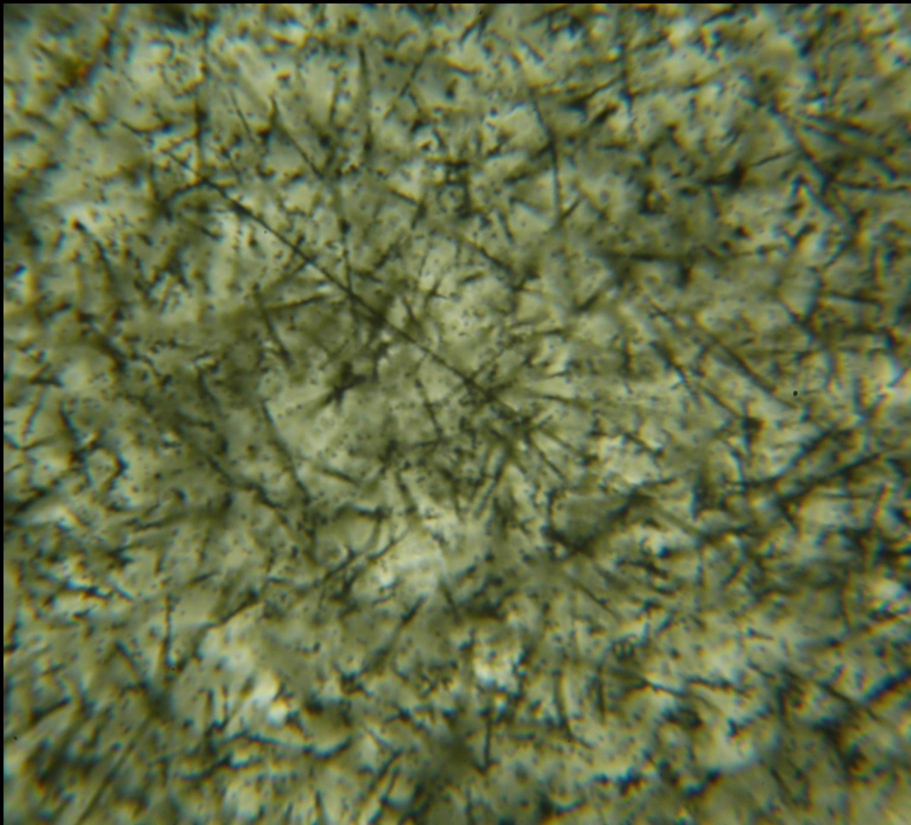


N_{ev}
15
10
5
0
5
10
15
depth, μm

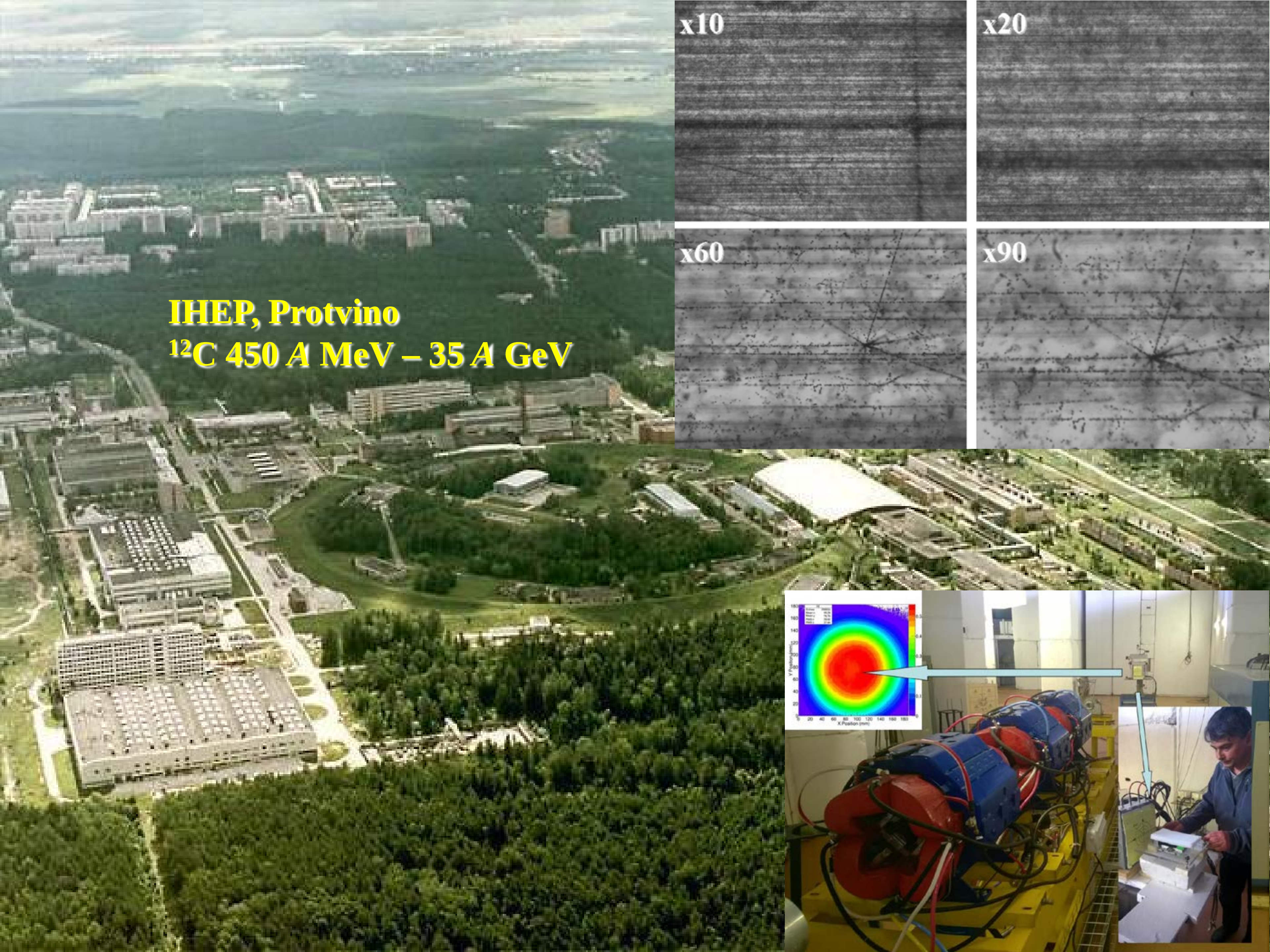

"Электросила"
им. С.М.Кирова


"МАКС"
Пи-МЕЗОНЫ
НЕЙТРОНЫ и ПРОТОНЫ
№ 4
№5
ФАЗОТРОН
Ядерная спектроскопия
Пробник Кобра
N3
N2
N1
N7
N6
ПРОТОННАЯ ТЕРАПИЯ
ПРОТОННАЯ ТЕРАПИЯ
ПРОТОННАЯ ТЕРАПИЯ
АРЕС
μSR-метод
Пультовая ЭВМ
Кабина N6 для гамма-терапии (под кабиной N2)
Пультовая
Аппарат "РОКУС-М"
СХЕМА ПУЧКОВ ФАЗОТРОНА ЛЯП ОИЯИ





IHEP, Protvino
^{12}C 450 *A* MeV – 35 *A* GeV



Nuclear education with nuclear track emulsion

Conclusions

In spite of the fact that half a century passed since its development nuclear track emulsion retains the status of a universal and inexpensive detector. With a record spatial resolution this technique provides complete observation of tracks starting from fission fragments and down to relativistic particles. Nuclear emulsion method deserves further applications in fundamental and applied research in modern accelerators and reactors , and sources of radioactivity, including natural ones. Application of NTE is especially justified in those pioneering experiments in which nuclear particle tracks cannot be reconstructed with the help of electronic detectors.

Conclusions

The NTE technique continues to be based on intelligence, vision and performance of researchers using traditional microscopes.

Despite wide interest, its labor consumption causes limited samplings of hundreds of measured tracks which present as a rule only tiny fractions of the available statistics.

Application of computerized and fully automated microscopes in the NTE analysis allows one to bridge this gap.

These are complicated and expensive devices of collective or even remote use allow one to describe a record statistics of short nuclear tracks.

To make such a development purposeful it is necessary to focus on such topical issues of nuclear physics the solution of which can be reduced to simple tasks of recognition and measurement of tracks in NTE to be solved with the aid of already developed programs.